CDO User Guide

Climate Data Operator
Version 2.5.0
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1. Introduction

The Climate Data Operator (**CDO**) software is a collection of many operators for standard processing of climate and forecast model data. The operators include simple statistical and arithmetic functions, data selection and subsampling tools, and spatial interpolation. **CDO** was developed to have the same set of processing functions for GRIB [GRIB] and NetCDF [NetCDF] datasets in one package.

The Climate Data Interface [CDI] is used for the fast and file format independent access to GRIB and NetCDF datasets. The local MPI-MET data formats SERVICE, EXTRA and IEG are also supported.

There are some limitations for GRIB and NetCDF datasets:

GRIB datasets have to be consistent, similar to NetCDF. That means all time steps need to have the same variables, and within a time step each variable may occur only once. Multiple fields in single GRIB2 messages are not supported!

NetCDF datasets are only supported for the classic data model and arrays up to 4 dimensions. These dimensions should only be used by the horizontal and vertical grid and the time. The NetCDF attributes should follow the GDT, COARDS or CF Conventions.

The main **CDO** features are:

- More than 700 operators available
- Modular design and easily extendable with new operators
- Very simple UNIX command line interface
- A dataset can be processed by several operators, without storing the interim results in files
- Most operators handle datasets with missing values
- Fast processing of large datasets
- Support of many different grid types
- Tested on many UNIX/Linux systems, Cygwin, and MacOS-X

Latest pdf documentation be found here.

1.1. Installation

CDO is supported in different operative systems such as Unix, macOS and Windows. This section describes how to install **CDO** in those platforms. More examples are found on the main website (`https://code.mpimet.mpg.de/projects/cdo/wiki`)

1.1.1. Unix

1.1.1.1. Prebuilt CDO packages

Prebuilt **CDO** versions are available in online Unix repositories, and you can install them by typing on the Unix terminal

```
apt-get install cdo
```

Note that prebuilt libraries do not offer the most recent version, and their version might vary with the Unix system (see table below). It is recommended to build from the source or Conda environment for an updated version or a customised setting.

Unix OS		**CDO** Version
Debian	11 (Bullseye)	1.9.10-1
	10 (Buster)	1.9.6-1
	Sid	2.0.6-2
FreeBSD	13	2.0.6
	12	2.0.6
openSUSE	Leap 15.3	2.0.6
	Tumbleweed	2.0.6-1
Ubuntu	18.04 LTS	1.9.3
	20.04 LTS	1.9.9
	22.04 LTS	2.0.4-1

1.1.1.2. Building from sources

CDO uses the GNU configure and build system for compilation. The only requirement is a working ISO C++17 and C11 compiler.

First go to the download page (`https://code.mpimet.mpg.de/projects/cdo`) to get the latest distribution, if you do not have it yet.

To take full advantage of **CDO** features the following additional libraries should be installed:

- Unidata NetCDF library (`https://www.unidata.ucar.edu/software/netcdf`) version 3 or higher. This library is needed to process NetCDF [NetCDF] files with **CDO**.
- ECMWF ecCodes library (`https://software.ecmwf.int/wiki/display/ECC/ecCodes+Home`) version 2.3.0 or higher. This library is needed to process GRIB2 files with **CDO**.
- HDF5 szip library (`https://www.hdfgroup.org/doc_resource/SZIP`) version 2.1 or higher. This library is needed to process szip compressed GRIB [GRIB] files with **CDO**.
- HDF5 library (`https://www.hdfgroup.org`) version 1.6 or higher. This library is needed to import CM-SAF [CM-SAF] HDF5 files with the **CDO** operator **import_cmsaf**.
- PROJ library (`https://proj.org`) version 5.0 or higher. This library is needed to convert Sinusoidal and Lambert Azimuthal Equal Area coordinates to geographic coordinates, for e.g. remapping.
- Magics library (`https://software.ecmwf.int/wiki/display/MAGP/Magics`) version 2.18 or higher. This library is needed to create contour, vector and graph plots with **CDO**.

Compilation

Compilation is done by performing the following steps:

1. Unpack the archive, if you haven't done that yet:

```
gunzip cdo-$VERSION.tar.gz    # uncompress the archive
tar xf cdo-$VERSION.tar       # unpack it
cd cdo-$VERSION
```

2. Run the configure script:

```
./configure
```

   - Optionaly with NetCDF [NetCDF] support:

```
./configure --with-netcdf=<NetCDF root directory>
```

   - and with ecCodes:

```
./configure --with-eccodes=<ecCodes root directory>
```

For an overview of other configuration options use

```
./configure --help
```

3. Compile the program by running make:

```
make
```

The program should compile without problems and the binary (`cdo`) should be available in the `src` directory of the distribution.

Installation

After the compilation of the source code do a `make install`, possibly as root if the destination permissions require that.

```
make install
```

The binary is installed into the directory `<prefix>/bin`. `<prefix>` defaults to `/usr/local` but can be changed with the *--prefix* option of the configure script.

Alternatively, you can also copy the binary from the `src` directory manually to some `bin` directory in your search path.

1.1.1.3. Conda

Conda is an open-source package manager and environment management system for various languages (Python, R, etc.). Conda is installed via Anaconda or Miniconda. Unlike Anaconda, miniconda is a lightweight conda distribution. They can be dowloaded from the main conda Website (https://conda.io/projects/conda/en/latest/user-guide/install/linux.html) or on the terminal

```
wget https://repo.anaconda.com/archive/Anaconda3-2021.11-Linux-x86_64.sh
bash Anaconda3-2021.11-Linux-x86_64.sh
source ~/.bashrc
```

and

```
wget https://repo.continuum.io/miniconda/Miniconda3-latest-Linux-x86_64.sh
sh Miniconda3-latest-Linux-x86_64.sh
```

Upon setting your conda environment, you can install **CDO** using conda

```
conda install cdo
conda install python-cdo
```

1.1.2. MacOS

Among the MacOS package managers, **CDO** can be installed from Homebrew and Macports. The installation via Homebrew is straight forward process on the terminal

```
brew install cdo
```

Similarly, Macports

```
port install cdo
```

In contrast to Homebrew, Macport allows you to enable GRIB2, szip compression and Magics++ graphic in **CDO** installation.

```
port install cdo +grib_api +magicspp +szip
```

In addition, you could also set **CDO** via Conda as Unix. You can follow this tutorial to install anaconda or miniconda in your computer (https://conda.io/projects/conda/en/latest/user-guide/install/macos.html). Then, you can install cdo by

```
conda install -c conda-forge cdo
```

1.1.3. Windows

Currently, **CDO** is not supported in Windows system and the binary is not available in the windows conda repository. Therefore, **CDO** needs to be set in a virtual environment. Here, it covers the installation of **CDO** using Windows Subsystem Linux (WSL) and virtual machines.

1.1.3.1. WSL

WSL emulates Unix in your Windows system. Then, you can install Unix libraries and software such as **CDO** or the linux conda distribution in your computer. Also, it allows you to directly share your files between your Windows and the WSL environment. However, more complex functions that require a graphic interface are not allowed.

In Windows 10 or newer, WSL can be readily set in your cmd by typing

```
wsl --install
```

This command will install, by default, Ubuntu 20.04 in WSL2. You could also choose a different system from this list.

```
wsl -l -o
```

Then, you can install your WSL environment as

```
wsl --install -d NAME
```

1.1.3.2. Virtual machine

Virtual machines can emulate different operative systems in your computer. Virtual machines are guest computers mounted inside your host computer. You can set a Linux distribution in your Windows device in this particular case. The advantages of Virtual machines to WSL are the graphical interface and the fully operational Linux system. You can follow any tutorial on the internet such as this one

https://ubuntu.com/tutorials/how-to-run-ubuntu-desktop-on-a-virtual-machine-using-virtualbox#1-overview

Finally, you can install **CDO** following any method listed in the section 1.1.1.

1.2. Usage

This section descibes how to use **CDO**. The syntax is:

```
cdo  [ Options ] Operator1 [ -Operator2 [ -OperatorN ] ]
```

1.2.1. Options

All options have to be placed before the first operator. The following options are available for all operators:

-a Generate an absolute time axis.

-b <nbits> Set the number of bits for the output precision. The valid precisions depend on the file format:

<format>	*<nbits>*
`grb1, grb2`	`P1 - P24`
`nc1, nc2, nc4, nc4c, nc5`	`I8/I16/I32/F32/F64`
`nc4, nc4c, nc5`	`U8/U16/U32`
`grb2, srv, ext, ieg`	`F32/F64`

For `srv`, `ext` and `ieg` format the letter `L` or `B` can be added to set the byteorder to Little or Big endian.

--cmor CMOR conform NetCDF output.

-C, --color Colorized output messages.

--double Using double precision floats for data in memory.

--eccodes Use ecCodes to decode/encode GRIB1 messages.

--filter <filterspec>
NetCDF4 filter specification.

-f <format> Set the output file format. The valid file formats are:

File format	*<format>*
GRIB version 1	`grb1/grb`
GRIB version 2	`grb2`
NetCDF	`nc1`
NetCDF version 2 (64-bit offset)	`nc2/nc`
NetCDF-4 (HDF5)	`nc4`
NetCDF-4 classic	`nc4c`
NetCDF version 5 (64-bit data)	`nc5`
SERVICE	`srv`
EXTRA	`ext`
IEG	`ieg`

GRIB2 is only available if **CDO** was compiled with ecCodes support and all NetCDF file types are only available if **CDO** was compiled with NetCDF support!

-g <grid> Define the default grid description by name or from file (see chapter 1.3 on page 17). Available grid names are: `global_<DXY>`, `zonal_<DY>`, `r<NX>x<NY>`, `lon=<LON>/lat=<LAT>`, `F<XXX>`, `gme<NI>`, `hpz<ZOOM>`

-h, --help Help information for the operators.

--no_history Do not append to NetCDF *history* global attribute.

--netcdf_hdr_pad, --hdr_pad, --header_pad <nbr>
Pad NetCDF output header with *nbr* bytes.

-k <chunktype> NetCDF4 chunk type: auto, grid or lines.

-L Lock I/O (sequential access).

-m <missval> Set the missing value of non NetCDF files (default: `-9e+33`).

-O Overwrite existing output file, if checked.
Existing output file is checked only for: `ens<STAT>`, `merge`, `mergetime`

--operators List of all operators.

-P <nthreads> Set number of OpenMP threads (Only available if OpenMP support was compiled in).

--pedantic Warnings count as errors.

--percentile <method>
Methods: `nrank`, `nist`, `rtype8`, `<NumPy method (linear|lower|higher|nearest|...)>`

--reduce_dim Reduce NetCDF dimensions.

-R, --regular Convert GRIB1 data from global reduced to regular Gaussian grid (only with cgribex lib).

-r Generate a relative time axis.

-S Create an extra output stream for the module TIMSTAT. This stream contains

	the number of non missing values for each output period.
-s, --silent	Silent mode.
--shuffle	Specify shuffling of variable data bytes before compression (NetCDF).
--single	Using single precision floats for data in memory.
--sortname	Alphanumeric sorting of NetCDF parameter names.
-t <partab>	Set the GRIB1 (cgribex) default parameter table name or file (see chapter 1.6 on page 23). Predefined tables are: `echam4 echam5 echam6 mpiom1 ecmwf remo`
--timestat_date <srcdate>	Target timestamp (temporal statistics): `first, middle, midhigh` or `last` source timestep.
-V, --version	Print the version number.
-v, --verbose	Print extra details for some operators.
-w	Disable warning messages.
--worker <num>	Number of worker to decode/decompress GRIB records.
-z aec	AEC compression of GRIB1 records.
jpeg	JPEG compression of GRIB2 records.
zip[_1-9]	Deflate compression of NetCDF4 variables.
zstd[_1-19]	Zstandard compression of NetCDF4 variables.

1.2.2. Environment variables

There are some environment variables which influence the behavior of **CDO**. An incomplete list can be found in Appendix A.

Here is an example to set the envrionment variable CDO_RESET_HISTORY for different shells:

Bourne shell (sh):	CDO_RESET_HISTORY=1 ; export CDO_RESET_HISTORY
Korn shell (ksh):	export CDO_RESET_HISTORY=1
C shell (csh):	setenv CDO_RESET_HISTORY 1

1.2.3. Operators

There are more than 700 operators available. A detailed description of all operators can be found in the **Reference Manual** section.

1.2.4. Parallelized operators

Some of the **CDO** operators are shared memory parallelized with OpenMP. An OpenMP-enabled C compiler is needed to use this feature. Users may request a specific number of OpenMP threads `nthreads` with the ' `-P`' switch.

Here is an example to distribute the bilinear interpolation on 8 OpenMP threads:

```
cdo -P 8 remapbil,targetgrid infile outfile
```

Many **CDO** operators are I/O-bound. This means most of the time is spend in reading and writing the data. Only compute intensive **CDO** operators are parallelized. An incomplete list of OpenMP parallelized operators can be found in Appendix B.

1.2.5. Operator parameter

Some operators need one or more parameter. A list of parameter is indicated by the seperator ','.

- STRING

  String parameters require quotes if the string contains blanks or other characters interpreted by the shell. The following command select variables with the name `pressure` and `tsurf`:

```
cdo selvar,pressure,tsurf infile outfile
```

- FLOAT

  Floating point number in any representation. The following command sets the range between `0` and `273.15` of all fields to missing value:

  ```
  cdo setrtomiss,0,273.15 infile outfile
  ```

- BOOL

  Boolean parameter in the following representation TRUE/FALSE, T/F or 0/1. To disable the weighting by grid cell area in the calculation of a field mean, use:

  ```
  cdo fldmean,weights=FALSE infile outfile
  ```

- INTEGER

  A range of integer parameter can be specified by *first*/*last*[/*inc*]. To select the days 5, 6, 7, 8 and 9 use:

  ```
  cdo selday,5/9 infile outfile
  ```

  The result is the same as:

  ```
  cdo selday,5,6,7,8,9 infile outfile
  ```

1.2.6. Operator chaining

Operator chaining allows to combine two or more operators on the command line into a single **CDO** call. This allows the creation of complex operations out of more simple ones: reductions over several dimensions, file merges and all kinds of analysis processes. All operators with a fixed number of input streams and one output stream can pass the result directly to an other operator. For differentiation between files and operators all operators must be written with a prepended "–" when chaining.

```
cdo -monmean -add -mulc,2.0 infile1 -daymean infile2 outfile        (CDO example call)
```

Here `monmean` will have the output of `add` while `add` takes the output of `mulc,2.0` and `daymean`. `infile1` and `infile2` are inputs for their predecessor. When mixing operators with an arbitrary number of input streams extra care needs to be taken. The following examples illustrates why.

1. `cdo info -timavg infile1 infile2`
2. `cdo info -timavg infile?`
3. ```
   cdo timavg infile1 tmpfile
   cdo info tmpfile infile2
   rm tmpfile
   ```

All three examples produce identical results. The time average will be computed only on the first input file.

Note(1): In section 1.3.2 we introduce argument groups which will make this a lot easier and less error prone.

Note(2): Operator chaining is implemented over POSIX Threads (pthreads). Therefore this **CDO** feature is not available on operating systems without POSIX Threads support!

1.2.7. Chaining Benefits

Combining operators can have several benefits. The most obvious is a performance increase through reducing disk I/O:

```
cdo sub -dayavg infile2 -timavg infile1 outfile
```
```

instead of

```
cdo timavg infile1 tmp1
cdo dayavg infile2 tmp2
cdo sub tmp2 tmp1 outfile
rm tmp1 tmp2
```

Especially with large input files the reading and writing of intermediate files can have a big influence on the overall performance.
A second aspect is the execution of operators: Limited by the algorythms potentially all operators of a chain can run in parallel.

1.3. Advanced Usage

In this section we will introduce advanced features of **CDO**. These include operator grouping which allows to write more complex **CDO** calls and the apply keyword which allows to shorten calls that need an operator to be executed on multiple files as well as wildcards which allow to search paths for file signatures. These features have several restrictions and follow rules that depend on the input/output properties. These required properties of operators can be investigated with the following commands which will output a list of operators that have selected properties:

```
cdo --attribs [arbitrary/filesOnly/onlyFirst/noOutput/obase]
```

- *arbitrary* describes all operators where the number of inputs is not defined.
- *filesOnly* are operators that can have other operators as input.
- *onlyFirst* shows which operators can only be at the most left position of the polish notation argument chain.
- *noOutput* are all operators that do not print to any file (e.g info)
- *obase* Here obase describes an operator that does not use the output argument as file but e.g as a file name base (output base). This is almost exclusivly used for operators the split input files.

  ```
  cdo -splithour baseName_
  could result in: baseName_1 baseName_2 ... baseName_N
  ```

For checking a single or multiple operator directly the following usage of --attribs can be used:

```
cdo --attribs operatorName
```

1.3.1. Wildcards

Wildcards are a standard feature of command line interpreters (shells) on many operating systems. They are placeholder characters used in file paths that are expanded by the interpreter into file lists. For further information the Advance Bash Scripting Guide is a valuable source of information. Handling of input is a central issue for **CDO** and in some circumstances it is not enough to use the wildcards from the shell. That's why **CDO** can handle them on its own.

all files	2020-2-01.txt 2020-2-11.txt 2020-2-15.txt 2020-3-01.txt 2020-3-02.txt 2020-3-12.txt 2020-3-13.txt 2020-3-15.txt 2021.grb 2022.grb

wildcard	**filelist results**
2020-3* and 2020-3-??.txt	2020-3-01.txt 2020-3-02.txt 2020-3-12.txt 2020-3-13.txt 2020-3-15.txt
2020-3-?1.txt	2020-3-01.txt
*.grb	2021.grb 2020.grb

Use single quotes if the input stream names matched to a single wildcard expression. In this case **CDO** will do the pattern matching and the output can be combined with other operators. Here is an example for this feature:

```
cdo timavg -select,name=temperature 'infile?' outfile
```

In earlier versions of **CDO** this was necessary to have the right files parsed to the right operator. Newer version support this with the argument grouping feature (see 1.3.2). We advice the use of the grouping mechanism instead of the single quoted wildcards since this feature could be deprecated in future versions.

Note: Wildcard expansion is not available on operating systems without the *glob()* function!

1.3.2. Argument Groups

In section 1.2.6 we described that it is not possible to chain operators with an arbitrary number of inputs. In this section we want to show how this can be achieved through the use of *operator grouping* with angled brackets `[]`. Using these brackets **CDO** can assigned the inputs to their corresponding operators during the execution of the command line. The ability to write operator combination in a parenthis-free way is partly given up in favor of allowing operators with arbitrary number of inputs. This allows a much more compact way to handle large number of input files.
The following example shows an example which we will transform from a non-working solution to a working one.

```
cdo -infon -div -fldmean -cat infileA -mulc,2.0 infileB -fldmax infileC
```

This example will throw the following error:

```
cdo (Warning): Did you forget to use '[' and/or ']' for multiple variable input operators?
cdo (Warning): use option --variableInput, for description

cdo (Abort): Too few streams specified! Operator div needs 2 input streams and 1 output stream!
```

The error is raised by the operator *div*. This operator needs two input streams and one output stream, but the *cat* operator has claimed all possible streams on its right hand side as input because it accepts an arbitrary number of inputs. Hence it didn't leave anything for the remaining input or output streams of *div*. For this we can declare a group which will be passed to the operator left of the group.

```
cdo -infon -div -fldmean -cat [ infileA -mulc,2.0 infileB ] -fldmax infileC
```

For full flexibility it is possible to have groups inside groups:

```
cdo -infon -div -fldmean -cat [ infileA infileB -merge [ infileC1 infileC2 ] ] -fldmax infileD
```

1.3.3. Apply Keyword

When working with medium or large number of similar files there is a common problem of a processing step (often a reduction) which needs to be performed on all of them before a more specific analysis can be applied. Ususally this can be done in two ways: One option is to use `merge` to glue everything together and chain the reduction step after it. The second option is to write a for-loop over all inputs which perform the basic processing on each of the files separately and call `merge` one the results. Unfortunately both options have side-effects: The first one needs a lot of memory because all files are read in completely and reduced afterwards while the latter one creates a lot of temporary files. Both memory and disk IO can be bottlenecks and should be avoided.
The *apply* keyword was introduced for that purpose. It can be used as an operator, but it needs at least one operator as a parameter, which is applied in parallel to all related input streams in a parallel way before all streams are passed to operator next in the chain.
The following is an example with three input files:

```
cdo -merge -apply,-daymean [ infile1 infile2 infile3 ] outfile
```

would result in:

```
cdo -merge -daymean infile1 -daymean infile2 -daymean infile3 outfile
```

Figure 1.1.: Usage and result of apply keyword

Apply is especially useful when combined with wildcards. The previous example can be shortened further.

```
cdo -merge -apply,-daymean [ infile? ] outfile
```

As shown this feature allows to simplify commands with medium amount of files and to move reductions further back. This can also have a positive impact on the performance.

An example where performance can take a hit.

```
cdo -yearmean -daymean -merge [ f1 ... f40 ]
```

An improved but ugly to write example.

```
cdo -yearmean -merge [ -daymean f1 -daymean f2 ... -daymean f40 ]
```

Apply saves the day. And creates the call above with much less typing.

```
cdo -yearmean -merge [ -apply,-daymean [ f1 ... f40 ] ]
```

Figure 1.2.: Apply keyword simplifies command and execution

In the example in figure 1.2 the resulting call will dramatically save process interaction as well as execution times since the reduction (daymean) is applied on the files first. That means that the merge operator will receive the reduced files and the operations for merging the whole data is saved. For other **CDO** calls further improvements can be made by adding more arguments to apply (1.3)

A less performant example.

```
cdo -aReduction -anotherReduction -daymean -merge [ f1 ... f40 ]
```

```
cdo  -merge -apply,"-aReduction -anotherReduction -daymean" [ f1 ... f40 ]
```

Figure 1.3.: Multi argument apply

Restrictions: While the apply keyword can be extremely helpful it has several restrictions (for now!).

- Apply inputs can only be files, wildcards and operators that have 0 inputs and 1 output.
- Apply can not be used as the first **CDO** operator.
- Apply arguments can only be operators with 1 input and 1 output.
- Grouping inside the Apply argument or input is not allowed.

1.4. Memory Requirements

This section roughly describes the memory requirements of **CDO**. **CDO** tries to use as little memory as possible. The smallest unit that is read by all operators is a horizontal field. The required memory depends mainly on the used operators, the data format, the data type and the size of the fields.

The operators have partly very different memory requirements. Many **CDO** modules like FLDSTAT process one horizontal field at a time. Memory-intensive modules such as ENSSTAT and TIMSTAT require all fields of a time step to be held in memory. Of course, the memory requirements of each operator add up when they are combined. Some operators are parallelized with OpenMP. In multi-threaded mode (see option *-P*) the memory requirement can increase for these operators. This increase grows with the number of threads used.

The data type determines the number of bytes per value. Single precision floating point data occupies 4 bytes per value. All other data types are read as double precision floats and thus occupy 8 bytes per value. With the **CDO** option *--single* all data is read as single precision floats. This can reduce the memory requirement by a factor of 2.

1.5. Horizontal grids

Physical quantities of climate models are typically stored on a horizonal grid. **CDO** supports structured grids like regular lon/lat or curvilinear grids and also unstructured grids.

1.5.1. Grid area weights

One single point of a horizontal grid represents the mean of a grid cell. These grid cells are typically of different sizes, because the grid points are of varying distance.

Area weights are individual weights for each grid cell. They are needed to compute the area weighted mean or variance of a set of grid cells (e.g. fldmean - the mean value of all grid cells). In **CDO** the area weights are derived from the grid cell area. If the cell area is not available then it will be computed from the geographical coordinates via spherical triangles. This is only possible if the geographical coordinates of the grid cell corners are available or derivable. Otherwise **CDO** gives a warning message and uses constant area weights for all grid cells.

The cell area is read automatically from a NetCDF input file if a variable has the corresponding "cell_measures" attribute, e.g.:

```
var:cell_measures = "area: cell_area" ;
```

If the computed cell area is not desired then the **CDO** operator setgridarea can be used to set or overwrite the grid cell area.

1.5.2. Grid description

In the following situations it is necessary to give a description of a horizontal grid:

- Changing the grid description (operator: setgrid)
- Horizontal interpolation (all remapping operators)
- Generating of variables (operator: const, random)

As now described, there are several possibilities to define a horizontal grid.

1.5.2.1. Predefined grids

Predefined grids are available for global regular, gaussian, HEALPix or icosahedral-hexagonal GME grids.

Global regular grid: `global_<DXY>`

`global_<DXY>` defines a global regular lon/lat grid. The grid increment `<DXY>` can be chosen arbitrarily. The longitudes start at `<DXY>`/2 - 180° and the latitudes start at `<DXY>`/2 - 90°.

Regional regular grid: `dcw:<CountryCode>[_<DXY>]`

`dcw:<CountryCode>[_<DXY>]` defines a regional regular lon/lat grid from the country code. The default value of the optional grid increment `<DXY>` is 0.1 degree. The ISO two-letter country codes can be found on https://en.wikipedia.org/wiki/ISO_3166-1_alpha-2. To define a state, append the state code to the country code, e.g. USAK for Alaska. For the coordinates of a country **CDO** uses the DCW (Digital Chart of the World) dataset from GMT. This dataset must be installed on the system and the environment variable `DIR_DCW` must point to it.

Zonal latitudes: `zonal_<DY>`

`zonal_<DY>` defines a grid with zonal latitudes only. The latitude increment `<DY>` can be chosen arbitrarily. The latitudes start at `<DY>`/2 - 90°. The boundaries of each latitude are also generated. The number of longitudes is 1. A grid description of this type is needed to calculate the zonal mean (zonmean) for data on an unstructured grid.

Global regular grid: `r<NX>x<NY>`

`r<NX>x<NY>` defines a global regular lon/lat grid. The number of the longitudes `<NX>` and the latitudes `<NY>` can be chosen arbitrarily. The longitudes start at 0° with an increment of (360/`<NX>`)°. The latitudes go from south to north with an increment of (180/`<NY>`)°.

One grid point: `lon=<LON>/lat=<LAT>`

`lon=<LON>/lat=<LAT>` defines a lon/lat grid with only one grid point.

Full regular Gaussian grid: `F<XXX>`

`F<XXX>` defines a global regular Gaussian grid. `XXX` specifies the number of latitudes lines between the Pole and the Equator. The longitudes start at 0° with an increment of (360/nlon)°. The gaussian latitudes go from north to south.

Global icosahedral-hexagonal GME grid: `gme<NI>`

`gme<NI>` defines a global icosahedral-hexagonal GME grid. `NI` specifies the number of intervals on a main triangle side.

HEALPix grid: `hp<NSIDE>[_<ORDER>]`

HEALPix is an acronym for Hierarchical Equal Area isoLatitude Pixelization of a sphere.
`hp<NSIDE>[_<ORDER>]` defines the parameter of a global HEALPix grid. The `NSIDE` parameter controls the resolution of the pixellization. It is the number of pixels on the side of each of the 12 top-level HEALPix pixels. The total number of grid pixels is `12*NSIDE*NSIDE`. `NSIDE=1` generates the 12 (H=4, K=3) equal sized top-level HEALPix pixels. `ORDER` sets the index ordering convention of the pixels, available are `nested` (default) or `ring` ordering. A shortcut for `hp<NSIDE>_nested` is `hpz<ZOOM>`. `ZOOM` is the zoom level and the relation to `NSIDE` is $zoom = log_2(nside)$.

If the geographical coordinates are required in **CDO**, they are calculated from the HEALPix parameters. For this calculation the `astropy-healpix` C library is used.

1.5.2.2. Grids from data files

You can use the grid description from an other datafile. The format of the datafile and the grid of the data field must be supported by **CDO**. Use the operator 'sinfo' to get short informations about your variables and the grids. If there are more then one grid in the datafile the grid description of the first variable will be used. Add the extension :N to the name of the datafile to select grid number N.

1.5.2.3. SCRIP grids

SCRIP (Spherical Coordinate Remapping and Interpolation Package) uses a common grid description for curvilinear and unstructured grids. For more information about the convention see [SCRIP]. This grid description is stored in NetCDF. Therefor it is only available if **CDO** was compiled with NetCDF support!

SCRIP grid description example of a curvilinear MPIOM [MPIOM] GROB3 grid (only the NetCDF header):

```
netcdf grob3s {
dimensions:
        grid_size = 12120 ;
        grid_corners = 4 ;
        grid_rank = 2 ;
variables:
        int grid_dims(grid_rank) ;
        double grid_center_lat(grid_size) ;
                grid_center_lat:units = "degrees" ;
                grid_center_lat:bounds = "grid_corner_lat" ;
        double grid_center_lon(grid_size) ;
                grid_center_lon:units = "degrees" ;
                grid_center_lon:bounds = "grid_corner_lon" ;
        int grid_imask(grid_size) ;
                grid_imask:units = "unitless" ;
                grid_imask:coordinates = "grid_center_lon grid_center_lat" ;
        double grid_corner_lat(grid_size, grid_corners) ;
                grid_corner_lat:units = "degrees" ;
        double grid_corner_lon(grid_size, grid_corners) ;
                grid_corner_lon:units = "degrees" ;

// global attributes:
                :title = "grob3s" ;
}
```

1.5.2.4. CDO grids

All supported grids can also be described with the **CDO** grid description. The following keywords can be used to describe a grid:

Keyword	Datatype	Description
gridtype	STRING	Type of the grid (gaussian, lonlat, curvilinear, unstructured).
gridsize	INTEGER	Size of the grid.
xsize	INTEGER	Size in x direction (number of longitudes).
ysize	INTEGER	Size in y direction (number of latitudes).
xvals	FLOAT ARRAY	X values of the grid cell center.
yvals	FLOAT ARRAY	Y values of the grid cell center.
nvertex	INTEGER	Number of the vertices for all grid cells.
xbounds	FLOAT ARRAY	X bounds of each gridbox.
ybounds	FLOAT ARRAY	Y bounds of each gridbox.
xfirst, xinc	FLOAT, FLOAT	Macros to define xvals with a constant increment, xfirst is the x value of the first grid cell center.
yfirst, yinc	FLOAT, FLOAT	Macros to define yvals with a constant increment, yfirst is the y value of the first grid cell center.
xunits	STRING	units of the x axis
yunits	STRING	units of the y axis

Which keywords are necessary depends on the gridtype. The following table gives an overview of the default values or the size with respect to the different grid types.

gridtype	lonlat	gaussian	projection	curvilinear	unstructured
gridsize	xsize*ysize	xsize*ysize	xsize*ysize	xsize*ysize	**ncell**
xsize	**nlon**	**nlon**	**nx**	**nlon**	gridsize
ysize	**nlat**	**nlat**	**ny**	**nlat**	gridsize
xvals	xsize	xsize	xsize	gridsize	gridsize
yvals	ysize	ysize	ysize	gridsize	gridsize
nvertex	2	2	2	4	**nv**
xbounds	2*xsize	2*xsize	2*xsize	4*gridsize	nv*gridsize
ybounds	2*ysize	2*ysize	2*xsize	4*gridsize	nv*gridsize
xunits	degrees	degrees	m	degrees	degrees
yunits	degrees	degrees	m	degrees	degrees

The keywords nvertex, xbounds and ybounds are optional if area weights are not needed. The grid cell corners xbounds and ybounds have to rotate counterclockwise.

CDO grid description example of a T21 gaussian grid:

```
gridtype = gaussian
xsize    = 64
ysize    = 32
xfirst   =  0
xinc     = 5.625
yvals    = 85.76  80.27  74.75  69.21  63.68  58.14  52.61  47.07
           41.53  36.00  30.46  24.92  19.38  13.84   8.31   2.77
           -2.77  -8.31 -13.84 -19.38 -24.92 -30.46 -36.00 -41.53
          -47.07 -52.61 -58.14 -63.68 -69.21 -74.75 -80.27 -85.76
```

CDO grid description example of a global regular grid with 60x30 points:

```
gridtype = lonlat
xsize    =   60
ysize    =   30
xfirst   = -177
xinc     =    6
yfirst   =  -87
yinc     =    6
```

The description for a projection is somewhat more complicated. Use the first section to describe the coordinates of the projection with the above keywords. Add the keyword **grid_mapping_name** to descibe the mapping between the given coordinates and the true latitude and longitude coordinates. **grid_mapping_name** takes a string value that contains the name of the projection. A list of attributes can be added to define the mapping. The name of the attributes depend on the projection. The valid names of the projection and there attributes follow the NetCDF CF-Convention.

CDO supports the special grid mapping attribute **proj_params**. These parameter will be passed directly to the PROJ library to generate the geographic coordinates if needed.

The geographic coordinates of the following projections can be generated without the attribute **proj_params**, if all other attributes are available:

- **rotated_latitude_longitude**
- **lambert_conformal_conic**
- **lambert_azimuthal_equal_area**
- **sinusoidal**
- **polar_stereographic**

It is recommend to set the attribute **proj_params** also for the above projections to make sure all PROJ parameter are set correctly.

Here is an example of a **CDO** grid description using the attribute **proj_params** to define the PROJ parameter of a polar stereographic projection:

```
gridtype = projection
xsize     = 11
ysize     = 11
xunits    = "meter"
yunits    = "meter"
xfirst    = -638000
xinc      = 150
yfirst    = -3349350
yinc      = 150
grid_mapping = crs
grid_mapping_name = polar_stereographic
proj_params = "+proj=stere +lon_0=-45 +lat_ts=70 +lat_0=90 +x_0=0 +y_0=0"
```

The result is the same as using the CF conform Grid Mapping Attributes:

```
gridtype = projection
xsize     = 11
ysize     = 11
xunits    = "meter"
yunits    = "meter"
xfirst    = -638000
xinc      = 150
yfirst    = -3349350
yinc      = 150
grid_mapping = crs
grid_mapping_name = polar_stereographic
straight_vertical_longitude_from_pole = -45.
standard_parallel = 70.
latitude_of_projection_origin = 90.
false_easting = 0.
false_northing = 0.
```

CDO grid description example of a regional rotated lon/lat grid:

```
gridtype = projection
xsize    = 81
ysize    = 91
xunits   = "degrees"
yunits   = "degrees"
xfirst   =  -19.5
xinc     =    0.5
yfirst   =  -25.0
yinc     =    0.5
grid_mapping_name = rotated_latitude_longitude
grid_north_pole_longitude = -170
grid_north_pole_latitude = 32.5
```

Example **CDO** descriptions of a curvilinear and an unstructured grid can be found in Appendix D.

1.5.3. ICON - Grid File Server

The geographic coordinates of the ICON model are located on an unstructured grid. This grid is stored in a separate grid file independent of the model data. The grid files are made available to the general public via a file server. Furthermore, these grid files are located at DKRZ under `/pool/data/ICON/grids`.

With the **CDO** function `setgrid,<gridfile>` this grid information can be added to the data if needed. Here is an example:

```
cdo sellonlatbox,-20,60,10,70 -setgrid,<path_to_gridfile> icondatafile result
```

ICON model data in NetCDF format contains the global attribute `grid_file_uri`. This attribute contains a link to the appropriate grid file on the ICON grid file server. If the global attribute `grid_file_uri` is present and valid, the grid information can be added automatically. The `setgrid` function is then no longer required. The environment variable `CDO_DOWNLOAD_PATH` can be used to select a directory for storing the grid file. If this environment variable is set, the grid file will be automatically downloaded from the grid file server to this directory if needed. If the grid file already exists in the current directory, the environment variable does not need to be set.

If the grid files are available locally, like at DKRZ, they do not need to be fetched from the grid file server. Use the environment variable `CDO_ICON_GRIDS` to set the root directory of the ICON grids. Here is an example for the ICON grids at DKRZ:

```
CDO_ICON_GRIDS=/pool/data/ICON
```

1.6. Z-axis description

Sometimes it is necessary to change the description of a z-axis. This can be done with the operator setzaxis. This operator needs an ASCII formatted file with the description of the z-axis. The following keywords can be used to describe a z-axis:

Keyword	Datatype	Description
zaxistype	STRING	type of the z-axis
size	INTEGER	number of levels
levels	FLOAT ARRAY	values of the levels
lbounds	FLOAT ARRAY	lower level bounds
ubounds	FLOAT ARRAY	upper level bounds
vctsize	INTEGER	number of vertical coordinate parameters
vct	FLOAT ARRAY	vertical coordinate table

The keywords **lbounds** and **ubounds** are optional. **vctsize** and **vct** are only necessary to define hybrid model levels.

Available z-axis types:

Z-axis type	Description	Units
surface	Surface	
pressure	Pressure level	pascal
hybrid	Hybrid model level	
height	Height above ground	meter
depth_below_sea	Depth below sea level	meter
depth_below_land	Depth below land surface	centimeter
isentropic	Isentropic (theta) level	kelvin

Z-axis description example for pressure levels 100, 200, 500, 850 and 1000 hPa:

```
zaxistype = pressure
size      = 5
levels    = 10000 20000 50000 85000 100000
```

Z-axis description example for ECHAM5 L19 hybrid model levels:

```
zaxistype = hybrid
size      = 19
levels    = 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
vctsize   = 40
vct       = 0 2000 4000 6046.10938 8267.92578 10609.5117 12851.1016 14698.5
            15861.125 16116.2383 15356.9258 13621.4609 11101.5625 8127.14453
```

```
                5125.14062 2549.96875 783.195068 0 0 0
                0 0 0 0.000338993268 0.00335718691 0.0130700432 0.0340771675
                0.0706498027 0.12591666 0.201195419 0.295519829 0.405408859
                0.524931908 0.646107674 0.759697914 0.856437683 0.928747177
                0.972985268 0.992281914 1
```

Note that the vctsize is twice the number of levels plus two and the vertical coordinate table must be specified for the level interfaces.

1.7. Time axis

A time axis describes the time for every timestep. Two time axis types are available: absolute time and relative time axis. **CDO** tries to maintain the actual type of the time axis for all operators.

1.7.1. Absolute time

An absolute time axis has the current time to each time step. It can be used without knowledge of the calendar. This is preferably used by climate models. In NetCDF files the absolute time axis is represented by the unit of the time: `"day as %Y%m%d.%f"`.

1.7.2. Relative time

A relative time is the time relative to a fixed reference time. The current time results from the reference time and the elapsed interval. The result depends on the calendar used. **CDO** supports the standard Gregorian, proleptic Gregorian, 360 days, 365 days and 366 days calendars. The relative time axis is preferably used by numerical weather prediction models. In NetCDF files the relative time axis is represented by the unit of the time: "*time-units* `since` *reference-time*", e.g `"days since 1989-6-15 12:00"`.

1.7.3. Conversion of the time

Some programs which work with NetCDF data can only process relative time axes. Therefore it may be necessary to convert from an absolute into a relative time axis. This conversion can be done for each operator with the **CDO** option '-r'. To convert a relative into an absolute time axis use the **CDO** option '-a'.

1.8. Parameter table

A parameter table is an ASCII formated file to convert code numbers to variable names. Each variable has one line with its code number, name and a description with optional units in a blank separated list. It can only be used for GRIB, SERVICE, EXTRA and IEG formated files. The **CDO** option '-t <partab>' sets the default parameter table for all input files. Use the operator 'setpartab' to set the parameter table for a specific file.

Example of a **CDO** parameter table:

```
  134  aps      surface pressure [Pa]
  141  sn       snow depth [m]
  147  ahfl     latent heat flux [W/m**2]
  172  slm      land sea mask
  175  albedo   surface albedo
  211  siced    ice depth [m]
```

1.9. Missing values

Missing values are data points that are missing or invalid. Such data points are treated in a different way than valid data. Most **CDO** operators can handle missing values in a smart way. But if the missing value is within the range of valid data, it can lead to incorrect results. This applies to all arithmetic operations, but especially to logical operations when the missing value is 0 or 1.

The default missing value for GRIB, SERVICE, EXTRA and IEG files is $-9.e^{33}$. The **CDO** option '-m <missval>' overwrites the default missing value. In NetCDF files the variable attribute '_FillValue' is used as a missing value. The operator 'setmissval' can be used to set a new missing value.

The **CDO** use of the missing value is shown in the following tables, where one table is printed for each operation. The operations are applied to arbitrary numbers a, b, the special case 0, and the missing value $miss$. For example the table named "addition" shows that the sum of an arbitrary number a and the missing value is the missing value, and the table named "multiplication" shows that 0 multiplied by missing value results in 0.

addition	b		miss
a	$a+b$		$miss$
miss	$miss$		$miss$

subtraction	b		miss
a	$a-b$		$miss$
miss	$miss$		$miss$

multiplication	b	0	miss
a	$a*b$	0	$miss$
0	0	0	0
miss	$miss$	0	$miss$

division	b	0	miss
a	a/b	$miss$	$miss$
0	0	$miss$	$miss$
miss	$miss$	$miss$	$miss$

maximum	b		miss
a	$max(a,b)$		a
miss	b		$miss$

minimum	b		miss
a	$min(a,b)$		a
miss	b		$miss$

sum	b		miss
a	$a+b$		a
miss	b		$miss$

The handling of missing values by the operations "minimum" and "maximum" may be surprising, but the definition given here is more consistent with that expected in practice. Mathematical functions (e.g. *log*, *sqrt*, etc.) return the missing value if an argument is the missing value or an argument is out of range.

All statistical functions ignore missing values, treading them as not belonging to the sample, with the side-effect of a reduced sample size.

1.9.1. Mean and average

An artificial distinction is made between the notions mean and average. The mean is regarded as a statistical function, whereas the average is found simply by adding the sample members and dividing the result by the sample size. For example, the mean of 1, 2, $miss$ and 3 is $(1+2+3)/3 = 2$, whereas the average is $(1+2+miss+3)/4 = miss/4 = miss$. If there are no missing values in the sample, the average and mean are identical.

1.10. Percentile

There is no standard definition of percentile. All definitions yield to similar results when the number of values is very large. The following percentile methods are available in **CDO**:

Percentile method	Description
nrank	Nearest Rank method [default in **CDO**]
nist	The primary method recommended by NIST
rtype8	R's type=8 method
inverted_cdf	NumPy with percentile method='inverted_cdf' (R type=1)
averaged_inverted_cdf	NumPy with percentile method='averaged_inverted_cdf' (R type=2)
closest_observation	NumPy with percentile method='closest_observation' (R type=3)
interpolated_inverted_cdf	NumPy with percentile method='interpolated_inverted_cdf' (R type=4)
hazen	NumPy with percentile method='hazen' (R type=5)
weibull	NumPy with percentile method='weibull' (R type=6)
linear	NumPy with percentile method='linear' (R type=7) [default in NumPy and R]
median_unbiased	NumPy with percentile method='median_unbiased' (R type=8)
normal_unbiased	NumPy with percentile method='normal_unbiased' (R type=9)
lower	NumPy with percentile method='lower'
higher	NumPy with percentile method='higher'
midpoint	NumPy with percentile method='midpoint'
nearest	NumPy with percentile method='nearest'

The percentile method can be selected with the **CDO** option `--percentile`. The Nearest Rank method is the default percentile method in **CDO**.

The different percentile methods can lead to different results, especially for small number of data values. Consider the ordered list {15, 20, 35, 40, 50, 55}, which contains six data values. Here is the result for the 30th, 40th, 50th, 75th and 100th percentiles of this list using the different percentile methods:

Percentile P	nrank	nist	rtype8	NumPy linear	NumPy lower	NumPy higher	NumPy nearest
30th	20	21.5	23.5	27.5	20	35	35
40th	35	32	33	35	35	35	35
50th	35	37.5	37.5	37.5	35	40	40
75th	50	51.25	50.42	47.5	40	50	50
100th	55	55	55	55	55	55	55

1.10.1. Percentile over timesteps

The amount of data for time series can be very large. All data values need to held in memory to calculate the percentile. The percentile over timesteps uses a histogram algorithm, to limit the amount of required memory. The default number of histogram bins is 101. That means the histogram algorithm is used, when the dataset has more than 101 time steps. The default can be overridden by setting the environment variable `CDO_PCTL_NBINS` to a different value. The histogram algorithm is implemented only for the Nearest Rank method.

1.11. Regions

The **CDO** operators maskregion and selregion can be used to mask and select regions. For this purpose, the region needs to be defined by the user. In **CDO** there are two possibilities to define regions.

One possibility is to define the regions with an ASCII file. Each region is defined by a polygon. Each line of the polygon contains the longitude and latitude coordinates of a point. A description file for regions can contain several polygons, these must be separated by a line with the character &.

Here is a simple example of a polygon for a box with longitudes from 120W to 90E and latitudes from 20N to 20S:

```
120   20
120 −20
270 −20
270   20
```

With the second option, predefined regions can be used via country codes. A country is specified with `dcw:<CountryCode>`. Country codes can be combined with the plus sign.

Here is an example to select the region Spain and Portugal:

```
cdo  selregion,dcw:ES+PT infile outfile
```

The ISO two-letter country codes can be found on https://en.wikipedia.org/wiki/ISO_3166-1_alpha-2. To define a state, append the state code to the country code, e.g. USAK for Alaska. For the coordinates of a country **CDO** uses the DCW (Digital Chart of the World) dataset from GMT. This dataset must be installed on the system and the environment variable `DIR_DCW` must point to it.

2. Reference manual

This section gives a description of all operators. Related operators are grouped to modules. For easier description all single input files are named `infile` or `infile1`, `infile2`, etc., and an arbitrary number of input files are named `infiles`. All output files are named `outfile` or `outfile1`, `outfile2`, etc. Further the following notion is introduced:

$i(t)$ Timestep t of `infile`

$i(t, x)$ Element number x of the field at timestep t of `infile`

$o(t)$ Timestep t of `outfile`

$o(t, x)$ Element number x of the field at timestep t of `outfile`

2.1. Information

This section contains modules to print information about datasets. All operators print there results to standard output.

Here is a short overview of all operators in this section:

info	Dataset information listed by parameter identifier
infon	Dataset information listed by parameter name
cinfo	Compact information listed by parameter name
map	Dataset information and simple map
sinfo	Short information listed by parameter identifier
sinfon	Short information listed by parameter name
xsinfo	Extra short information listed by parameter name
xsinfop	Extra short information listed by parameter identifier
diff	Compare two datasets listed by parameter id
diffn	Compare two datasets listed by parameter name
npar	Number of parameters
nlevel	Number of levels
nyear	Number of years
nmon	Number of months
ndate	Number of dates
ntime	Number of timesteps
ngridpoints	Number of gridpoints
ngrids	Number of horizontal grids
showformat	Show file format
showcode	Show code numbers
showname	Show variable names
showstdname	Show standard names
showlevel	Show levels
showltype	Show GRIB level types
showyear	Show years
showmon	Show months
showdate	Show date information
showtime	Show time information
showtimestamp	Show timestamp
showchunkspec	Show chunk specification
showfilter	Show filter specification
showattribute	Show a global attribute or a variable attribute
partab	Parameter table
codetab	Parameter code table
griddes	Grid description
zaxisdes	Z-axis description
vct	Vertical coordinate table

2.1.1. INFO - Information and simple statistics

Synopsis

<operator> `infiles`

Description

This module writes information about the structure and contents for each field of all input files to standard output. A field is a horizontal layer of a data variable. All input files need to have the same structure with the same variables on different timesteps. The information displayed depends on the chosen operator.

Operators

info Dataset information listed by parameter identifier
Prints information and simple statistics for each field of all input datasets. For each field the operator prints one line with the following elements:

- Date and Time
- Level, Gridsize and number of Missing values
- Minimum, Mean and Maximum
  The mean value is computed without the use of area weights!
- Parameter identifier

infon Dataset information listed by parameter name
The same as operator info but using the name instead of the identifier to label the parameter.

cinfo Compact information listed by parameter name
cinfo is a compact version of infon. It prints the minimum, mean and maximum value for each variable across all layers and time steps.

map Dataset information and simple map
Prints information, simple statistics and a map for each field of all input datasets. The map will be printed only for fields on a regular lon/lat grid.

Example

To print information and simple statistics for each field of a dataset use:

```
cdo infon infile
```

This is an example result of a dataset with one 2D parameter over 12 timesteps:

```
   -1 :       Date     Time Level   Size   Miss :    Minimum     Mean  Maximum : Name
    1 : 1987-01-31 12:00:00     0   2048   1361 :     232.77   266.65   305.31 : SST
    2 : 1987-02-28 12:00:00     0   2048   1361 :     233.64   267.11   307.15 : SST
    3 : 1987-03-31 12:00:00     0   2048   1361 :     225.31   267.52   307.67 : SST
    4 : 1987-04-30 12:00:00     0   2048   1361 :     215.68   268.65   310.47 : SST
    5 : 1987-05-31 12:00:00     0   2048   1361 :     215.78   271.53   312.49 : SST
    6 : 1987-06-30 12:00:00     0   2048   1361 :     212.89   272.80   314.18 : SST
    7 : 1987-07-31 12:00:00     0   2048   1361 :     209.52   274.29   316.34 : SST
    8 : 1987-08-31 12:00:00     0   2048   1361 :     210.48   274.41   315.83 : SST
    9 : 1987-09-30 12:00:00     0   2048   1361 :     210.48   272.37   312.86 : SST
   10 : 1987-10-31 12:00:00     0   2048   1361 :     219.46   270.53   309.51 : SST
   11 : 1987-11-30 12:00:00     0   2048   1361 :     230.98   269.85   308.61 : SST
   12 : 1987-12-31 12:00:00     0   2048   1361 :     241.25   269.94   309.27 : SST
```

2.1.2. SINFO - Short information

Synopsis

<operator> `infiles`

Description

This module writes information about the structure of `infiles` to standard output. `infiles` is an arbitrary number of input files. All input files need to have the same structure with the same variables on different timesteps. The information displayed depends on the chosen operator.

Operators

sinfo Short information listed by parameter identifier
Prints short information of a dataset. The information is divided into 4 sections. Section 1 prints one line per parameter with the following information:

- institute and source
- time c=constant v=varying
- type of statistical processing
- number of levels and z-axis number
- horizontal grid size and number
- data type
- parameter identifier

Section 2 and 3 gives a short overview of all grid and vertical coordinates. And the last section contains short information of the time coordinate.

sinfon Short information listed by parameter name
The same as operator sinfo but using the name instead of the identifier to label the parameter.

Example

To print short information of a dataset use:

```
cdo sinfon infile
```

This is the result of an ECHAM5 dataset with 3 parameter over 12 timesteps:

```
    -1 : Institut Source  T Steptype Levels Num    Points Num Dtype : Name
     1 : MPIMET   ECHAM5  c instant       1   1      2048   1  F32   : GEOSP
     2 : MPIMET   ECHAM5  v instant       4   2      2048   1  F32   : T
     3 : MPIMET   ECHAM5  v instant       1   1      2048   1  F32   : TSURF
   Grid coordinates :
     1 : gaussian              : points=2048 (64x32)  F16
                   longitude : 0 to 354.375 by 5.625 degrees_east  circular
                    latitude : 85.7606 to -85.7606 degrees_north
   Vertical coordinates :
     1 : surface               : levels=1
     2 : pressure              : levels=4
                         level : 92500 to 20000 Pa
   Time coordinate :
                          time : 12 steps
YYYY-MM-DD hh:mm:ss YYYY-MM-DD hh:mm:ss YYYY-MM-DD hh:mm:ss YYYY-MM-DD hh:mm:ss
1987-01-31 12:00:00 1987-02-28 12:00:00 1987-03-31 12:00:00 1987-04-30 12:00:00
1987-05-31 12:00:00 1987-06-30 12:00:00 1987-07-31 12:00:00 1987-08-31 12:00:00
1987-09-30 12:00:00 1987-10-31 12:00:00 1987-11-30 12:00:00 1987-12-31 12:00:00
```

2.1.3. XSINFO - Extra short information

Synopsis

<operator> `infiles`

Description

This module writes information about the structure of `infiles` to standard output. `infiles` is an arbitrary number of input files. All input files need to have the same structure with the same variables on different timesteps. The information displayed depends on the chosen operator.

Operators

xsinfo Extra short information listed by parameter name
Prints short information of a dataset. The information is divided into 4 sections. Section 1 prints one line per parameter with the following information:

- institute and source
- time c=constant v=varying
- type of statistical processing
- number of levels and z-axis number
- horizontal grid size and number
- data type
- memory type (float or double)
- parameter name

Section 2 to 4 gives a short overview of all grid, vertical and time coordinates.

xsinfop Extra short information listed by parameter identifier
The same as operator xsinfo but using the identifier instead of the name to label the parameter.

Example

To print extra short information of a dataset use:

```
cdo xsinfo infile
```

This is the result of an ECHAM5 dataset with 3 parameter over 12 timesteps:

```
 -1 : Institut Source  T Steptype Levels Num   Points Num Dtype Mtype : Name
  1 : MPIMET   ECHAM5  c instant       1   1     2048   1  F32    F32 : GEOSP
  2 : MPIMET   ECHAM5  v instant       4   2     2048   1  F32    F32 : T
  3 : MPIMET   ECHAM5  v instant       1   1     2048   1  F32    F32 : TSURF
Grid coordinates :
  1 : gaussian          : points=2048 (64x32)  F16
              longitude: 0 to 354.375 by 5.625 degrees_east  circular
               latitude: 85.7606 to -85.7606 degrees_north
Vertical coordinates :
  1 : surface           : levels=1
  2 : pressure          : levels=4
                  level: 92500 to 20000 Pa
Time coordinate :
                  steps: 12
                   time: 1987-01-31T18:00:00 to 1987-12-31T18:00:00 by 1 month
                  units: days since  1987-01-01T00:00:00
               calendar: proleptic_gregorian
```

2.1.4. DIFF - Compare two datasets field by field

Synopsis

<operator>[,parameter] `infile1 infile2`

Description

Compares the contents of two datasets field by field. The input datasets need to have the same structure and its fields need to have the dimensions. Try the option *names* if the number of variables differ. Exit status is 0 if inputs are the same and 1 if they differ.

Operators

diff Compare two datasets listed by parameter id
Provides statistics on differences between two datasets. For each pair of fields the operator prints one line with the following information:

- Date and Time
- Level, Gridsize and number of Missing values
- Number of different values
- Occurrence of coefficient pairs with different signs (S)
- Occurrence of zero values (Z)
- Maxima of absolute difference of coefficient pairs
- Maxima of relative difference of non-zero coefficient pairs with equal signs
- Parameter identifier

$$Absdiff(t,x) = |i_1(t,x) - i_2(t,x)|$$

$$Reldiff(t,x) = \frac{|i_1(t,x) - i_2(t,x)|}{\max(|i_1(t,x)|, |i_2(t,x)|)}$$

diffn Compare two datasets listed by parameter name
The same as operator diff. Using the name instead of the identifier to label the parameter.

Parameter

maxcount	INTEGER	Stop after maxcount different fields
abslim	FLOAT	Limit of the maximum absolute difference (default: 0)
rellim	FLOAT	Limit of the maximum relative difference (default: 1)
names	STRING	Consideration of the variable names of only one input file (left/right) or the intersection of both (intersect).

Example

To print the difference for each field of two datasets use:

```
cdo diffn infile1 infile2
```

This is an example result of two datasets with one 2D parameter over 12 timesteps:

```
          Date    Time Level Size Miss Diff : S Z Max_Absdiff Max_Reldiff : Name
 1 : 1987-01-31 12:00:00    0 2048 1361  273 : F F  0.00010681  4.1660e-07 : SST
 2 : 1987-02-28 12:00:00    0 2048 1361  309 : F F  6.1035e-05  2.3742e-07 : SST
 3 : 1987-03-31 12:00:00    0 2048 1361  292 : F F  7.6294e-05  3.3784e-07 : SST
 4 : 1987-04-30 12:00:00    0 2048 1361  183 : F F  7.6294e-05  3.5117e-07 : SST
 5 : 1987-05-31 12:00:00    0 2048 1361  207 : F F  0.00010681  4.0307e-07 : SST
 7 : 1987-07-31 12:00:00    0 2048 1361  317 : F F  9.1553e-05  3.5634e-07 : SST
 8 : 1987-08-31 12:00:00    0 2048 1361  219 : F F  7.6294e-05  2.8849e-07 : SST
 9 : 1987-09-30 12:00:00    0 2048 1361  188 : F F  7.6294e-05  3.6168e-07 : SST
10 : 1987-10-31 12:00:00    0 2048 1361  297 : F F  9.1553e-05  3.5001e-07 : SST
11 : 1987-11-30 12:00:00    0 2048 1361  234 : F F  6.1035e-05  2.3839e-07 : SST
12 : 1987-12-31 12:00:00    0 2048 1361  267 : F F  9.3553e-05  3.7624e-07 : SST
11 of 12 fields differ
```

2.1.5. NINFO - Print the number of parameters, levels or times

Synopsis

<*operator*> `infile`

Description

This module prints the number of variables, levels or times of the input dataset.

Operators

npar Number of parameters
Prints the number of parameters (variables).

nlevel Number of levels
Prints the number of levels for each variable.

nyear Number of years
Prints the number of different years.

nmon Number of months
Prints the number of different combinations of years and months.

ndate Number of dates
Prints the number of different dates.

ntime Number of timesteps
Prints the number of timesteps.

ngridpoints Number of gridpoints
Prints the number of gridpoints for each variable.

ngrids Number of horizontal grids
Prints the number of horizontal grids.

Example

To print the number of parameters (variables) in a dataset use:

```
cdo npar infile
```

To print the number of months in a dataset use:

```
cdo nmon infile
```

2.1.6. SHOWINFO - Show variable information

Synopsis

<*operator*> `infile`

Description

This module prints meta-data information of all input variables. Depending on the chosen operator the name, level, date, time and other information is printed.

Operators

showformat Show file format
Prints the file format of the input dataset.

showcode Show code numbers
Prints the code number of all variables.

showname Show variable names
Prints the name of all variables.

showstdname Show standard names
Prints the standard name of all variables.

showlevel Show levels
Prints all levels for each variable.

showltype Show GRIB level types
Prints the GRIB level type for all z-axes.

showyear Show years
Prints all years.

showmon Show months
Prints all months.

showdate Show date information
Prints date information of all timesteps (format YYYY-MM-DD).

showtime Show time information
Prints time information of all timesteps (format hh:mm:ss).

showtimestamp Show timestamp
Prints timestamp of all timesteps (format YYYY-MM-DDThh:mm:ss).

showchunkspec Show chunk specification
Prints NetCDF4 chunk specification of all variables.

showfilter Show filter specification
Prints NetCDF4 filter specification of all variables.

Example

To print the code number of all variables in a dataset use:

```
cdo showcode infile
```

This is an example result of a dataset with three variables:

```
129 130 139
```

To print all months in a dataset use:

```
cdo showmon infile
```

This is an examples result of a dataset with an annual cycle:

```
 1  2  3  4  5  6  7  8  9  10  11  12
```

2.1.7. SHOWATTRIBUTE - Show attributes

Synopsis

showattribute*[,attributes]* `infile`

Description

This operator prints the attributes of the data variables of a dataset.

Each attribute has the following structure:

[**var_nm**@][**att_nm**]

var_nm Variable name (optional). Example: pressure

att_nm Attribute name (optional). Example: units

The value of **var_nm** is the name of the variable containing the attribute (named **att_nm**) that you want to print. Use wildcards to print the attribute **att_nm** of more than one variable. A value of **var_nm** of '*****' will print the attribute **att_nm** of all data variables. If **var_nm** is missing then **att_nm** refers to a global attribute.

The value of **att_nm** is the name of the attribute you want to print. Use wildcards to print more than one attribute. A value of **att_nm** of '*****' will print all attributes.

Parameter

attributes STRING Comma-separated list of attributes.

2.1.8. FILEDES - Dataset description

Synopsis

<*operator*> `infile`

Description

This module provides operators to print meta information about a dataset. The printed meta-data depends on the chosen operator.

Operators

partab Parameter table
Prints all available meta information of the variables.

codetab Parameter code table
Prints a code table with a description of all variables. For each variable the operator prints one line listing the code, name, description and units.

griddes Grid description
Prints the description of all grids.

zaxisdes Z-axis description
Prints the description of all z-axes.

vct Vertical coordinate table
Prints the vertical coordinate table.

Example

Assume all variables of the dataset are on a Gausssian N16 grid. To print the grid description of this dataset use:

```
cdo griddes infile
```

Result:

```
gridtype  : gaussian
gridsize  : 2048
xname     : lon
xlongname : longitude
xunits    : degrees_east
yname     : lat
ylongname : latitude
yunits    : degrees_north
xsize     : 64
ysize     : 32
xfirst    : 0
xinc      : 5.625
yvals     : 85.76058 80.26877 74.74454 69.21297 63.67863 58.1429 52.6065
            47.06964 41.53246 35.99507 30.4575 24.91992 19.38223 13.84448
            8.306702 2.768903 -2.768903 -8.306702 -13.84448 -19.38223
            -24.91992 -30.4575 -35.99507 -41.53246 -47.06964 -52.6065
            -58.1429 -63.67863 -69.21297 -74.74454 -80.26877 -85.76058
```

2.2. File operations

This section contains modules to perform operations on files.

Here is a short overview of all operators in this section:

apply	Apply operators on each input file.
copy	Copy datasets
clone	Clone datasets
cat	Concatenate datasets
tee	Duplicate a data stream
pack	Pack data
unpack	Unpack data
setchunkspec	Specify chunking
setfilter	Specify filter
bitrounding	Bit rounding
replace	Replace variables
duplicate	Duplicates a dataset
mergegrid	Merge grid
merge	Merge datasets with different fields
mergetime	Merge datasets sorted by date and time
splitcode	Split code numbers
splitparam	Split parameter identifiers
splitname	Split variable names
splitlevel	Split levels
splitgrid	Split grids
splitzaxis	Split z-axes
splittabnum	Split parameter table numbers
splithour	Split hours
splitday	Split days
splitseas	Split seasons
splityear	Split years
splityearmon	Split in years and months
splitmon	Split months
splitsel	Split time selection
splitdate	Splits a file into dates
distgrid	Distribute horizontal grid
collgrid	Collect horizontal grid

2.2.1. APPLY - Apply operators

Synopsis

apply,*operators* infiles

Description

The apply utility runs the named operators on each input file. The input files must be enclosed in square brackets. This utility can only be used on a series of input files. These are all operators with more than one input file (infiles). Here is an incomplete list of these operators: copy, cat, merge, mergetime, select, ENSSTAT. The parameter operators is a blank-separated list of **CDO** operators. Use quotation marks if more than one operator is needed. Each operator may have only one input and output stream.

Parameter

operators	STRING	Blank-separated list of CDO operators.

Example

Suppose we have multiple input files with multiple variables on different time steps. The input files contain the variables U and V, among others. We are only interested in the absolute windspeed on all time steps. Here is the standard **CDO** solution for this task:

```
cdo expr,wind="sqrt(u*u+v*v)" -mergetime infile1 infile2 infile3 outfile
```

This first joins all the time steps together and then calculates the wind speed. If there are many variables in the input files, this procedure is ineffective. In this case it is better to first calculate the wind speed:

```
cdo mergetime -expr,wind="sqrt(u*u+v*v)" infile1 \
              -expr,wind="sqrt(u*u+v*v)" infile2 \
              -expr,wind="sqrt(u*u+v*v)" infile3 outfile
```

However, this can quickly become very confusing with more than 3 input files. The apply operator solves this problem:

```
cdo mergetime -apply,-expr,wind="sqrt(u*u+v*v)" [ infile1 infile2 infile3 ] outfile
```

Another example is the calculation of the mean value over several input files with ensmean. The input files contain several variables, but we are only interested in the variable named XXX:

```
cdo ensmean -apply,-selname,XXX [ infile1 infile2 infile3 ] outfile
```

2.2.2. COPY - Copy datasets

Synopsis

<operator> `infiles outfile`

Description

This module contains operators to copy, clone or concatenate datasets. `infiles` is an arbitrary number of input files. All input files need to have the same structure with the same variables on different timesteps.

Operators

copy Copy datasets
Copies all input datasets to `outfile`.

clone Clone datasets
Copies all input datasets to `outfile`. In contrast to the copy operator, clone tries not to change the input data. GRIB records are neither decoded nor decompressed.

cat Concatenate datasets
Concatenates all input datasets and appends the result to the end of `outfile`. If `outfile` does not exist it will be created.

Example

To change the format of a dataset to NetCDF use:

```
cdo -f nc copy infile outfile.nc
```

Add the option '-r' to create a relative time axis, as is required for proper recognition by GrADS or Ferret:

```
cdo -r -f nc copy infile outfile.nc
```

To concatenate 3 datasets with different timesteps of the same variables use:

```
cdo copy infile1 infile2 infile3 outfile
```

If the output dataset already exists and you wish to extend it with more timesteps use:

```
cdo cat infile1 infile2 infile3 outfile
```

2.2.3. TEE - Duplicate a data stream and write it to file

Synopsis

tee,*outfile2* `infile outfile1`

Description

This operator copies the input dataset to `outfile1` and `outfile2`. The first output stream in `outfile1` can be further processesd with other cdo operators. The second output `outfile2` is written to disk. It can be used to store intermediate results to a file.

Parameter

outfile2	STRING	Destination filename for the copy of the input file

Example

To compute the daily and monthy average of a dataset use:

```
cdo monavg -tee,outfile_dayavg dayavg infile outfile_monavg
```

2.2.4. PACK - Pack data

Synopsis

pack[,*parameter*] `infile outfile`

Description

Packing reduces the data volume by reducing the precision of the stored numbers. It is implemented using the NetCDF attributes `add_offset` and `scale_factor`. The operator pack calculates the attributes `add_offset` and `scale_factor` for all variables. The default data type for all variables is automatically changed to 16-bit integer. Use the **CDO** option -b to change the data type to a different integer precision, if needed. Missing values are automatically transformed to the current data type.

Alternatively, the pack parameters `add_offset` and `scale_factor` can be read from a file for each variable.

Parameter

printparam	BOOL	Print pack parameters to stdout for each variable
filename	STRING	Read pack parameters from file for each variable[format: name=<> add_offset=<> scale_factor=<>]

2.2.5. UNPACK - Unpack data

Synopsis

unpack `infile outfile`

Description

Packing reduces the data volume by reducing the precision of the stored numbers. It is implemented using the NetCDF attributes `add_offset` and `scale_factor`. The operator unpack unpack all packed variables. The default data type for all variables is automatically changed to 32-bit floats. Use the **CDO** option -b F64 to change the data type to 64-bit floats, if needed.

2.2.6. SETCHUNKSPEC - Specify chunking

Synopsis

setchunkspec,*parameter* `infile outfile`

Description

Specify chunking for selected variables in the output. Chunking is available for NetCDF4 and useful to specify the units of disk access and compression. The filename parameter is used to specify the file which contains the chunk specification for each variable. The chunkspec argument is a comma-separated string with the chunk size for the dimensions x,y,z,t. A chunkspec must name at least one dimension, e.g. t=<chunksize> to set the chunk size of the time dimension to <chunksize>.

Use the **CDO** option --chunkspec instead of setchunkspec if all variables require the same chunks.

Parameter

filename STRING Name of the file containing the chunk specification per variable [format: varname="<chunkspec>"]

2.2.7. SETFILTER - Specify filter

Synopsis

setfilter,*parameter* `infile outfile`

Description

Specify filter for selected variables in the output. Filters are available for NetCDF4 and mainly used to compress/decompress data. NetCDF4 uses the HDF5 plugins for filter support. To find the HDF5 plugins, the environment variable HDF5_PLUGIN_PATH must point to the directory with the installed plugins. The program may terminate unexpectedly if filters are used whose plugins are not found.

The filename parameter is used to specify the file which contains the filter specification for each variable. A filter specification consists of the filterId and the filter parameters. **CDO** supports multiple filters connected with '|'. Here is a filter specification for bzip2 (filterId: 307) combined with szip (filterId:4): "307,9|4,32,32".

Use the **CDO** option --filter instead of setfilter if all variables require the same filter. More information about NetCDF4 filters can be found in https://docs.unidata.ucar.edu/netcdf-c/current/filters.html.

Parameter

filename STRING Name of the file containing the filter specification per variable [format: varname="<filterspec>"]

2.2.8. BITROUNDING - Bit rounding

Synopsis

bitrounding[,*parameter*] `infile outfile`

Description

This operator calculates for each field the number of necessary mantissa bits to get a certain information level in the data. With this number of significant bits (**numbits**) a rounding of the data is performed. This allows the data to be compressed to a higher level.

The default value of the information level is 0.9999 and can be adjusted with the parameter **inflevel**. That means 99.99% of the information in the mantissa bits is preserved.

Alternatively, the number of significant bits can be set for all variables with the **numbits** parameter. Furthermore, **numbits** can be assigned for each variable via the filename parameter. In this case, **numbits** is still calculated for all variables if they are not present in the file.

The analysis of the bit information is based on the Julia library BitInformation.jl. The procedure to derive the number of significant mantissa bits was adapted from the Python library xbitinfo. Quantize to the number of mantissa bits is done with IEEE rounding using code from NetCDF 4.9.0.

Currently only 32-bit float data is rounded. Data with missing values are not yet supported for the calculation of significant bits.

Parameter

inflevel	FLOAT	Information level (0 - 1) [default: 0.9999]
addbits	INTEGER	Add bits to the number of significant bits [default: 0]
minbits	INTEGER	Minimum value of the number of bits [default: 1]
maxbits	INTEGER	Maximum value of the number of bits [default: 23]
numsteps	INTEGER	Set to 1 to run the calculation only in the first time step
numbits	INTEGER	Set number of significant bits
printbits	BOOL	Print max. numbits per variable of 1st timestep to stdout [format: name=numbits]
filename	STRING	Read number of significant bits per variable from file [format: name=numbits]

Example

Apply bit rounding to all 32-bit float fields, preserving 99.9% of the information, followed by compression and storage to NetCDF4:

```
cdo -f nc4 -z zip bitrounding,inflevel=0.999 infile outfile
```

Add the option '-v' to view used number of mantissa bits for each field:

```
cdo -v -f nc4 -z zip bitrounding,inflevel=0.999 infile outfile
```

2.2.9. REPLACE - Replace variables

Synopsis

replace `infile1 infile2 outfile`

Description

This operator replaces variables in `infile1` by variables from `infile2` and write the result to `outfile`. Both input datasets need to have the same number of timesteps. All variable names may only occur once!

Example

Assume the first input dataset `infile1` has three variables with the names geosp, t and tslm1 and the second input dataset `infile2` has only the variable tslm1. To replace the variable tslm1 in `infile1` by tslm1 from `infile2` use:

```
cdo replace infile1 infile2 outfile
```

2.2.10. DUPLICATE - Duplicates a dataset

Synopsis

duplicate*[,ndup]* `infile outfile`

Description

This operator duplicates the contents of `infile` and writes the result to `outfile`. The optional parameter sets the number of duplicates, the default is 2.

Parameter

ndup INTEGER Number of duplicates, default is 2.

2.2.11. MERGEGRID - Merge grid

Synopsis

mergegrid `infile1 infile2 outfile`

Description

Merges grid points of all variables from `infile2` to `infile1` and write the result to `outfile`. Only the non missing values of `infile2` will be used. The horizontal grid of `infile2` should be smaller or equal to the grid of `infile1` and the resolution must be the same. Only rectilinear grids are supported. Both input files need to have the same variables and the same number of timesteps.

2.2.12. MERGE - Merge datasets

Synopsis

merge `infiles outfile`

mergetime*[,options]* `infiles outfile`

Description

This module reads datasets from several input files, merges them and writes the resulting dataset to `outfile`.

Operators

merge Merge datasets with different fields
Merges time series of different fields from several input datasets. The number of fields per timestep written to `outfile` is the sum of the field numbers per timestep in all input datasets. The time series on all input datasets are required to have different fields and the same number of timesteps. The fields in each different input file either have to be different variables or different levels of the same variable. A mixture of different variables on different levels in different input files is not allowed.

mergetime Merge datasets sorted by date and time
Merges all timesteps of all input files sorted by date and time. All input files need to have the same structure with the same variables on different timesteps. After this operation every input timestep is in `outfile` and all timesteps are sorted by date and time.

Parameter

skip_same_time BOOL Skips all consecutive timesteps with a double entry of the same timestamp.

names STRING Fill missing variable names with missing values (union) or use the intersection (intersect).

Note

Operators of this module need to open all input files simultaneously. The maximum number of open files depends on the operating system!

Example

Assume three datasets with the same number of timesteps and different variables in each dataset. To merge these datasets to a new dataset use:

```
cdo merge infile1 infile2 infile3 outfile
```

Assume you split a 6 hourly dataset with splithour. This produces four datasets, one for each hour. The following command merges them together:

```
cdo mergetime infile1 infile2 infile3 infile4 outfile
```

2.2.13. SPLIT - Split a dataset

Synopsis

<operator>[,parameter] `infile obase`

Description

This module splits `infile` into pieces. The output files will be named <obase><xxx><suffix> where `suffix` is the filename extension derived from the file format. `xxx` and the contents of the output files depends on the chosen operator. params is a comma-separated list of processing parameters.

Operators

splitcode Split code numbers
Splits a dataset into pieces, one for each different code number. `xxx` will have three digits with the code number.

splitparam Split parameter identifiers
Splits a dataset into pieces, one for each different parameter identifier. `xxx` will be a string with the parameter identifier.

splitname Split variable names
Splits a dataset into pieces, one for each variable name. `xxx` will be a string with the variable name.

splitlevel Split levels
Splits a dataset into pieces, one for each different level. `xxx` will have six digits with the level.

splitgrid Split grids
Splits a dataset into pieces, one for each different grid. `xxx` will have two digits with the grid number.

splitzaxis Split z-axes
Splits a dataset into pieces, one for each different z-axis. `xxx` will have two digits with the z-axis number.

splittabnum Split parameter table numbers
Splits a dataset into pieces, one for each GRIB1 parameter table number. `xxx` will have three digits with the GRIB1 parameter table number.

Parameter

swap	STRING	Swap the position of obase and xxx in the output filename
uuid=<attname>	STRING	Add a UUID as global attribute <attname> to each output file

Environment

`CDO_FILE_SUFFIX` Set the default file suffix. This suffix will be added to the output file names instead of the filename extension derived from the file format. Set this variable to NULL to disable the adding of a file suffix.

Note

Operators of this module need to open all output files simultaneously. The maximum number of open files depends on the operating system!

Example

Assume an input GRIB1 dataset with three variables, e.g. code number 129, 130 and 139. To split this dataset into three pieces, one for each code number use:

```
cdo splitcode infile code
```

Result of 'dir code*':

```
code129.grb code130.grb code139.grb
```

2.2.14. SPLITTIME - Split timesteps of a dataset

Synopsis

<operator> `infile obase`

splitmon*[,format]* `infile obase`

Description

This module splits `infile` into timesteps pieces. The output files will be named <obase><xxx><suffix> where `suffix` is the filename extension derived from the file format. `xxx` and the contents of the output files depends on the chosen operator.

Operators

splithour Split hours
Splits a file into pieces, one for each different hour. `xxx` will have two digits with the hour.

splitday Split days
Splits a file into pieces, one for each different day. `xxx` will have two digits with the day.

splitseas Split seasons
Splits a file into pieces, one for each different season. `xxx` will have three characters with the season.

splityear Split years
Splits a file into pieces, one for each different year. `xxx` will have four digits with the year (YYYY).

splityearmon Split in years and months
Splits a file into pieces, one for each different year and month. `xxx` will have six digits with the year and month (YYYYMM).

splitmon Split months
Splits a file into pieces, one for each different month. `xxx` will have two digits with the month.

Parameter

format STRING C-style format for strftime() (e.g. %B for the full month name)

Environment

`CDO_FILE_SUFFIX` Set the default file suffix. This suffix will be added to the output file names instead of the filename extension derived from the file format. Set this variable to NULL to disable the adding of a file suffix.

Note

Operators of this module need to open all output files simultaneously. The maximum number of open files depends on the operating system!

Example

Assume the input GRIB1 dataset has timesteps from January to December. To split each month with all variables into one separate file use:

```
cdo splitmon infile mon
```

Result of 'dir mon*':

```
mon01.grb  mon02.grb  mon03.grb  mon04.grb  mon05.grb  mon06.grb
mon07.grb  mon08.grb  mon09.grb  mon10.grb  mon11.grb  mon12.grb
```

2.2.15. SPLITSEL - Split selected timesteps

Synopsis

splitsel,*nsets[,noffset[,nskip]]* `infile obase`

Description

This operator splits `infile` into pieces, one for each adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same selected time range. The output files will be named <obase><nnnnnn><suffix> where nnnnnn is the sequence number and `suffix` is the filename extension derived from the file format.

Parameter

nsets	INTEGER	Number of input timesteps for each output file
noffset	INTEGER	Number of input timesteps skipped before the first timestep range (optional)
nskip	INTEGER	Number of input timesteps skipped between timestep ranges (optional)

Environment

`CDO_FILE_SUFFIX`	Set the default file suffix. This suffix will be added to the output file names instead of the filename extension derived from the file format. Set this variable to NULL to disable the adding of a file suffix.

2.2.16. SPLITDATE - Splits a file into dates

Synopsis

splitdate `infile obase`

Description

This operator splits `infile` into pieces, one for each different date. The output files will be named <obase><YYYY-MM-DD><suffix> where YYYY-MM-DD is the date and `suffix` is the filename extension derived from the file format.

Environment

`CDO_FILE_SUFFIX`	Set the default file suffix. This suffix will be added to the output file names instead of the filename extension derived from the file format. Set this variable to NULL to disable the adding of a file suffix.

2.2.17. DISTGRID - Distribute horizontal grid

Synopsis

distgrid,*nx[,ny]* `infile obase`

Description

This operator distributes a dataset into smaller pieces. Each output file contains a different region of the horizontal source grid. 2D Lon/Lat grids can be split into *nx***ny* pieces, where a target grid region contains a structured longitude/latitude box of the source grid. Data on an unstructured grid is split into *nx* pieces. The output files will be named <obase><xxx><suffix> where suffix is the filename extension derived from the file format. xxx will have five digits with the number of the target region.

Parameter

nx	INTEGER	Number of regions in x direction, or number of pieces for unstructured grids
ny	INTEGER	Number of regions in y direction [default: 1]

Note

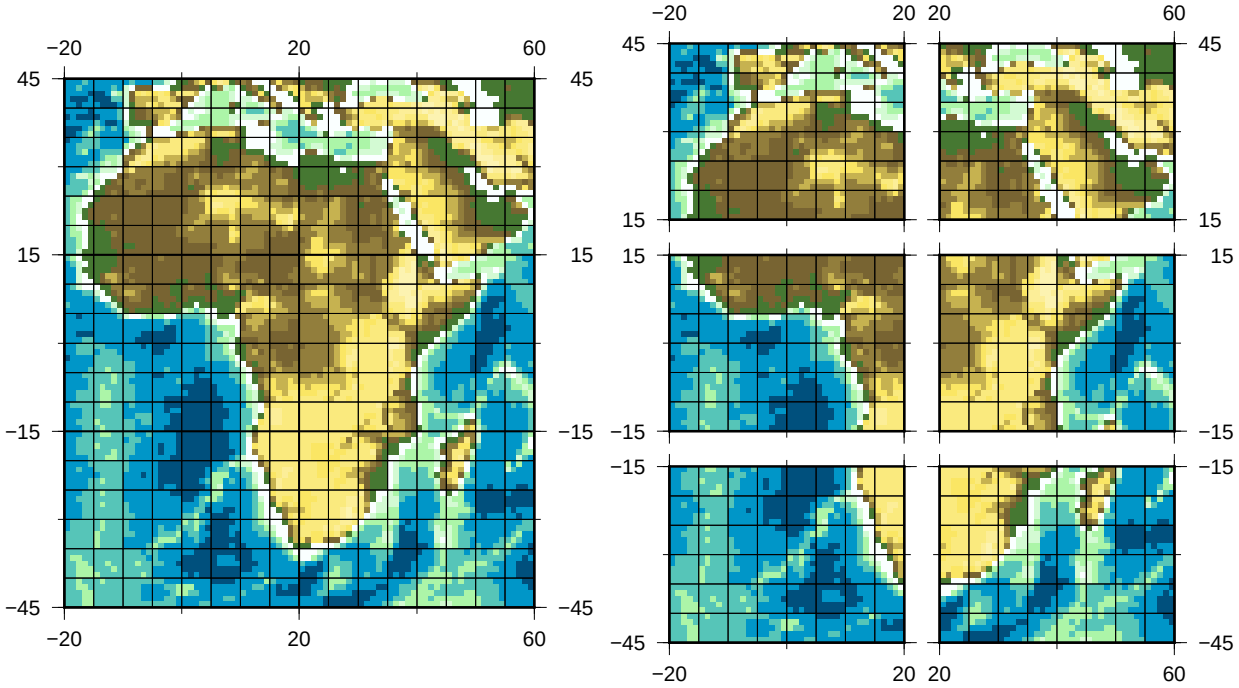
This operator needs to open all output files simultaneously. The maximum number of open files depends on the operating system!

Example

Distribute data on a 2D Lon/Lat grid into 6 smaller files, each output file receives one half of x and a third of y of the source grid:

```
cdo distgrid,2,3 infile.nc obase
```

Below is a schematic illustration of this example:



On the left side is the data of the input file and on the right side is the data of the six output files.

2.2.18. COLLGRID - Collect horizontal grid

Synopsis

collgrid[,*parameter*] `infiles outfile`

Description

This operator collects the data of the input files to one output file. All input files need to have the same variables and the same number of timesteps on a different horizonal grid region. If the source regions are on a structured lon/lat grid, all regions together must result in a new structured lat/long grid box. Data on an unstructured grid are concatenated in the order of the input files. For ICON restart data, the array global_cell_indices is used for indexing if it is available. The parameter *nx* needs to be specified only for curvilinear grids.

Parameter

nx	INTEGER	Number of regions in x direction [default: number of input files]
name	STRING	Comma-separated list of variable names.
levidx	INTEGER	Comma-separated list or first/last[/inc] range of index of levels.
gridtype	STRING	For unstructured grids, set to unstructured.

Note

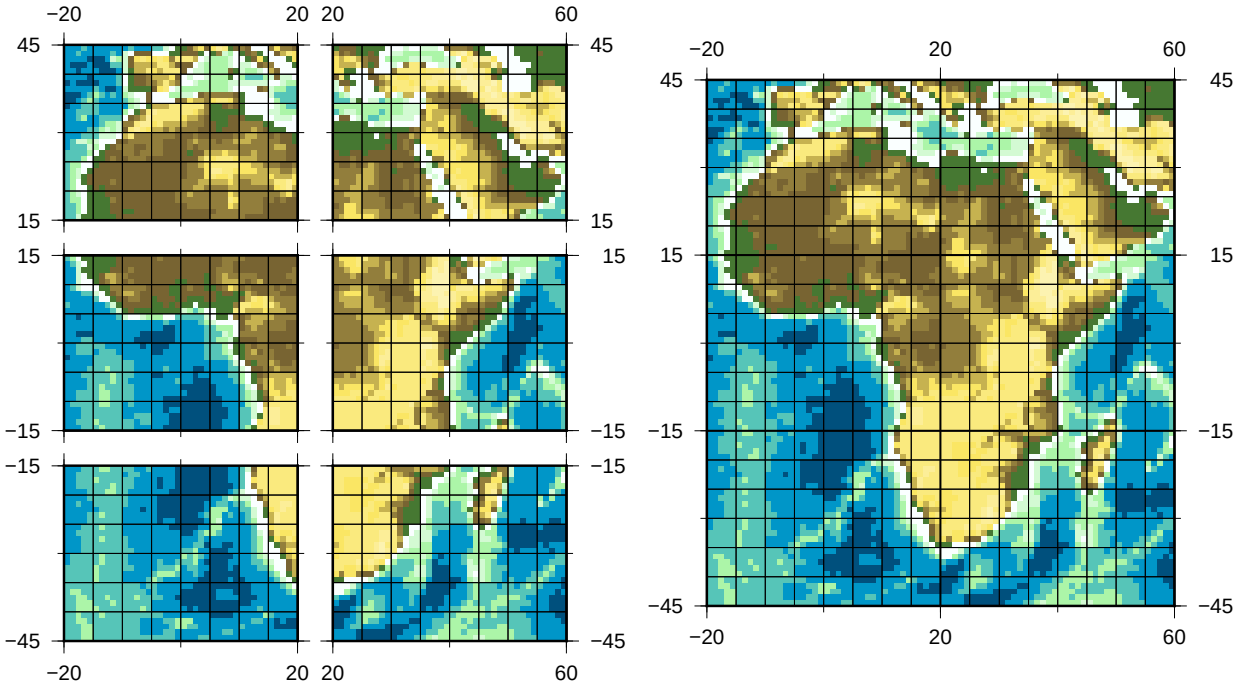
This operator needs to open all input files simultaneously. The maximum number of open files depends on the operating system!

Example

Collect the horizonal grid of 6 input files. Each input file contains a lon/lat region of the target grid:

```
cdo collgrid infile[1-6] outfile
```

Below is a schematic illustration of this example:



On the left side is the data of the six input files and on the right side is the collected data of the output file.

2.3. Selection

This section contains modules to select time steps, fields or a part of a field from a dataset.

Here is a short overview of all operators in this section:

select	Select fields
delete	Delete fields
selmulti	Select multiple fields
delmulti	Delete multiple fields
changemulti	Change identication of multiple fields
selparam	Select parameters by identifier
delparam	Delete parameters by identifier
selcode	Select parameters by code number
delcode	Delete parameters by code number
selname	Select parameters by name
delname	Delete parameters by name
selstdname	Select parameters by standard name
sellevel	Select levels
sellevidx	Select levels by index
selgrid	Select grids
selzaxis	Select z-axes
selzaxisname	Select z-axes by name
selltype	Select GRIB level types
seltabnum	Select parameter table numbers
seltimestep	Select timesteps
seltime	Select times
selhour	Select hours
selday	Select days
selmonth	Select months
selyear	Select years
selseason	Select seasons
seldate	Select dates
selsmon	Select single month
sellonlatbox	Select a longitude/latitude box
selindexbox	Select an index box
selregion	Select cells inside regions
selcircle	Select cells inside a circle
selgridcell	Select grid cells
delgridcell	Delete grid cells
samplegrid	Resample grid
selyearidx	Select year by index
seltimeidx	Select timestep by index
bottomvalue	Extract bottom level
topvalue	Extract top level
isosurface	Extract isosurface

2.3.1. SELECT - Select fields

Synopsis

<operator>,parameter `infiles outfile`

Description

This module selects some fields from `infiles` and writes them to `outfile`. `infiles` is an arbitrary number of input files. All input files need to have the same structure with the same variables on different timesteps. The fields selected depends on the chosen parameters. Parameter is a comma-separated list of "key=value" pairs. A range of integer values can be specified by first/last[/inc]. Wildcards are supported for string values.

Operators

select Select fields
Selects all fields with parameters in a user given list.

delete Delete fields
Deletes all fields with parameters in a user given list.

Parameter

name	STRING	Comma-separated list of variable names.
param	STRING	Comma-separated list of parameter identifiers.
code	INTEGER	Comma-separated list or first/last[/inc] range of code numbers.
level	FLOAT	Comma-separated list of vertical levels.
levrange	FLOAT	First and last value of the level range.
levidx	INTEGER	Comma-separated list or first/last[/inc] range of index of levels.
zaxisname	STRING	Comma-separated list of zaxis names.
zaxisnum	INTEGER	Comma-separated list or first/last[/inc] range of zaxis numbers.
ltype	INTEGER	Comma-separated list or first/last[/inc] range of GRIB level types.
gridname	STRING	Comma-separated list of grid names.
gridnum	INTEGER	Comma-separated list or first/last[/inc] range of grid numbers.
steptype	STRING	Comma-separated list of timestep types (constant|avg|accum|min|max|range|diff|su
date	STRING	Comma-separated list of dates (format: YYYY-MM-DDThh:mm:ss).
startdate	STRING	Start date (format: YYYY-MM-DDThh:mm:ss).
enddate	STRING	End date (format: YYYY-MM-DDThh:mm:ss).
minute	INTEGER	Comma-separated list or first/last[/inc] range of minutes.
hour	INTEGER	Comma-separated list or first/last[/inc] range of hours.
day	INTEGER	Comma-separated list or first/last[/inc] range of days.
month	INTEGER	Comma-separated list or first/last[/inc] range of months.
season	STRING	Comma-separated list of seasons (substring of DJFMAMJJASOND or ANN).
year	INTEGER	Comma-separated list or first/last[/inc] range of years.

dom	STRING	Comma-separated list of the day of month (e.g. 29feb).
timestep	INTEGER	Comma-separated list or first/last[/inc] range of timesteps. Negative values select timesteps from the end (NetCDF only).
timestep_of_year	INTEGER	Comma-separated list or first/last[/inc] range of timesteps of year.
timestepmask	STRING	Read timesteps from a mask file.

Example

Assume you have 3 inputfiles. Each inputfile contains the same variables for a different time period. To select the variable T,U and V on the levels 200, 500 and 850 from all 3 input files, use:

```
cdo select,name=T,U,V,level=200,500,850 infile1 infile2 infile3 outfile
```

To remove the February 29th use:

```
cdo delete,dom=29feb infile outfile
```

2.3.2. SELMULTI - Select multiple fields via GRIB1 parameters

Synopsis

<operator>,selection-specification `infile outfile`

Description

This module selects multiple fields from `infile` and writes them to `outfile`. selection-specification is a filename or in-place string with the selection specification. Each selection-specification has the following compact notation format:

```
<type>(parameters; leveltype(s); levels)
```

type	sel for select or del for delete (optional)
parameters	GRIB1 parameter code number
leveltype	GRIB1 level type
levels	value of each level

Examples:

```
(1; 103; 0)
(33,34; 105; 10)
(11,17; 105; 2)
(71,73,74,75,61,62,65,117,67,122,121,11,131,66,84,111,112; 105; 0)
```

The following descriptive notation can also be used for selection specification from a file:

```
SELECT/DELETE, PARAMETER=parameters, LEVTYPE=leveltye(s), LEVEL=levels
```

Examples:

```
SELECT, PARAMETER=1, LEVTYPE=103, LEVEL=0
SELECT, PARAMETER=33/34, LEVTYPE=105, LEVEL=10
SELECT, PARAMETER=11/17, LEVTYPE=105, LEVEL=2
SELECT, PARAMETER=71/73/74/75/61/62/65/117/67/122, LEVTYPE=105, LEVEL=0
DELETE, PARAMETER=128, LEVTYPE=109, LEVEL=*
```

The following will convert Pressure from Pa into hPa; Temp from Kelvin to Celsius:

```
SELECT, PARAMETER=1, LEVTYPE= 103, LEVEL=0, SCALE=0.01
SELECT, PARAMETER=11, LEVTYPE=105, LEVEL=2, OFFSET=273.15
```

If SCALE and/or OFFSET are defined, then the data values are scaled as SCALE*(VALUE-OFFSET).

Operators

selmulti Select multiple fields

delmulti Delete multiple fields

changemulti Change identication of multiple fields

Example

Change ECMWF GRIB code of surface pressure to Hirlam notation:

```
cdo changemulti,'{(134;1;*|1;105;*)}' infile outfile
```

2.3.3. SELVAR - Select fields

Synopsis

<operator>,parameter `infile outfile`

selcode,*codes* `infile outfile`

delcode,*codes* `infile outfile`

selname,*names* `infile outfile`

delname,*names* `infile outfile`

selstdname,*stdnames* `infile outfile`

sellevel,*levels* `infile outfile`

sellevidx,*levidx* `infile outfile`

selgrid,*grids* `infile outfile`

selzaxis,*zaxes* `infile outfile`

selzaxisname,*zaxisnames* `infile outfile`

selltype,*ltypes* `infile outfile`

seltabnum,*tabnums* `infile outfile`

Description

This module selects some fields from `infile` and writes them to `outfile`. The fields selected depends on the chosen operator and the parameters. A range of integer values can be specified by first/last[/inc].

Operators

selparam	Select parameters by identifier Selects all fields with parameter identifiers in a user given list.
delparam	Delete parameters by identifier Deletes all fields with parameter identifiers in a user given list.
selcode	Select parameters by code number Selects all fields with code numbers in a user given list or range.
delcode	Delete parameters by code number Deletes all fields with code numbers in a user given list or range.
selname	Select parameters by name Selects all fields with parameter names in a user given list.
delname	Delete parameters by name Deletes all fields with parameter names in a user given list.
selstdname	Select parameters by standard name Selects all fields with standard names in a user given list.
sellevel	Select levels Selects all fields with levels in a user given list.
sellevidx	Select levels by index Selects all fields with index of levels in a user given list or range.
selgrid	Select grids Selects all fields with grids in a user given list.

selzaxis Select z-axes
Selects all fields with z-axes in a user given list.

selzaxisname Select z-axes by name
Selects all fields with z-axis names in a user given list.

selltype Select GRIB level types
Selects all fields with GRIB level type in a user given list or range.

seltabnum Select parameter table numbers
Selects all fields with parameter table numbers in a user given list or range.

Parameter

parameter	STRING	Comma-separated list of parameter identifiers.
codes	INTEGER	Comma-separated list or first/last[/inc] range of code numbers.
names	STRING	Comma-separated list of variable names.
stdnames	STRING	Comma-separated list of standard names.
levels	FLOAT	Comma-separated list of vertical levels.
levidx	INTEGER	Comma-separated list or first/last[/inc] range of index of levels.
ltypes	INTEGER	Comma-separated list or first/last[/inc] range of GRIB level types.
grids	STRING	Comma-separated list of grid names or numbers.
zaxes	STRING	Comma-separated list of z-axis types or numbers.
zaxisnames	STRING	Comma-separated list of z-axis names.
tabnums	INTEGER	Comma-separated list or range of parameter table numbers.

Example

Assume an input dataset has three variables with the code numbers 129, 130 and 139. To select the variables with the code number 129 and 139 use:

```
cdo selcode,129,139 infile outfile
```

You can also select the code number 129 and 139 by deleting the code number 130 with:

```
cdo delcode,130 infile outfile
```

2.3.4. SELTIME - Select timesteps

Synopsis

seltimestep,*timesteps* `infile outfile`

seltime,*times* `infile outfile`

selhour,*hours* `infile outfile`

selday,*days* `infile outfile`

selmonth,*months* `infile outfile`

selyear,*years* `infile outfile`

selseason,*seasons* `infile outfile`

seldate,*startdate[,enddate]* `infile outfile`

selsmon,*month[,nts1[,nts2]]* `infile outfile`

Description

This module selects user specified timesteps from `infile` and writes them to `outfile`. The timesteps selected depends on the chosen operator and the parameters. A range of integer values can be specified by first/last[/inc].

Operators

seltimestep Select timesteps
Selects all timesteps with a timestep in a user given list or range.

seltime Select times
Selects all timesteps with a time in a user given list or range.

selhour Select hours
Selects all timesteps with a hour in a user given list or range.

selday Select days
Selects all timesteps with a day in a user given list or range.

selmonth Select months
Selects all timesteps with a month in a user given list or range.

selyear Select years
Selects all timesteps with a year in a user given list or range.

selseason Select seasons
Selects all timesteps with a month of a season in a user given list.

seldate Select dates
Selects all timesteps with a date in a user given range.

selsmon Select single month
Selects a month and optional an arbitrary number of timesteps before and after this month.

Parameter

timesteps	INTEGER	Comma-separated list or first/last[/inc] range of timesteps. Negative values select timesteps from the end (NetCDF only).
times	STRING	Comma-separated list of times (format hh:mm:ss).
hours	INTEGER	Comma-separated list or first/last[/inc] range of hours.
days	INTEGER	Comma-separated list or first/last[/inc] range of days.
months	INTEGER	Comma-separated list or first/last[/inc] range of months.
years	INTEGER	Comma-separated list or first/last[/inc] range of years.
seasons	STRING	Comma-separated list of seasons (substring of DJFMAMJJASOND or ANN).
startdate	STRING	Start date (format: YYYY-MM-DDThh:mm:ss).
enddate	STRING	End date (format: YYYY-MM-DDThh:mm:ss) [default: startdate].
nts1	INTEGER	Number of timesteps before the selected month [default: 0].
nts2	INTEGER	Number of timesteps after the selected month [default: nts1].

2.3.5. SELBOX - Select a box

Synopsis

sellonlatbox,*lon1*,*lon2*,*lat1*,*lat2* `infile outfile`

selindexbox,*idx1*,*idx2*,*idy1*,*idy2* `infile outfile`

Description

Selects grid cells inside a lon/lat or index box.

Operators

sellonlatbox Select a longitude/latitude box
Selects grid cells inside a lon/lat box. The user must specify the longitude and latitude of the edges of the box. Only those grid cells are considered whose grid center lies within the lon/lat box. For rotated lon/lat grids the parameters must be specified in rotated coordinates.

selindexbox Select an index box
Selects grid cells within an index box. The user must specify the indices of the edges of the box. The index of the left edge can be greater then the one of the right edge. Use negative indexing to start from the end. The input grid must be a regular lon/lat or a 2D curvilinear grid.

Parameter

lon1	FLOAT	Western longitude in degrees
lon2	FLOAT	Eastern longitude in degrees
lat1	FLOAT	Southern or northern latitude in degrees
lat2	FLOAT	Northern or southern latitude in degrees
idx1	INTEGER	Index of first longitude (1 - nlon)
idx2	INTEGER	Index of last longitude (1 - nlon)
idy1	INTEGER	Index of first latitude (1 - nlat)
idy2	INTEGER	Index of last latitude (1 - nlat)

Example

To select the region with the longitudes from 30W to 60E and latitudes from 30N to 80N from all input fields use:

```
cdo sellonlatbox,-30,60,30,80 infile outfile
```

If the input dataset has fields on a Gaussian N16 grid, the same box can be selected with selindexbox by:

```
cdo selindexbox,60,11,3,11 infile outfile
```

2.3.6. SELREGION - Select horizontal regions

Synopsis

selregion,*regions* `infile outfile`

selcircle[,*parameter*] `infile outfile`

Description

Selects all grid cells with the center point inside user defined regions or a circle. The resulting grid is unstructured.

Operators

selregion Select cells inside regions
Selects all grid cells with the center point inside the regions. Regions can be defined by the user via an ASCII file. Each region consists of the geographic coordinates of a polygon. Each line of a polygon description file contains the longitude and latitude of one point. Each polygon description file can contain one or more polygons separated by a line with the character &.

Predefined regions of countries can be specified via the country codes. A country is specified with dcw:<CountryCode>. Country codes can be combined with the plus sign.

selcircle Select cells inside a circle
Selects all grid cells with the center point inside a circle. The circle is described by geographic coordinates of the center and the radius of the circle.

Parameter

regions	STRING	Comma-separated list of ASCII formatted files with different regions
lon	FLOAT	Longitude of the center of the circle in degrees, default lon=0.0
lat	FLOAT	Latitude of the center of the circle in degrees, default lat=0.0
radius	STRING	Radius of the circle, default radius=1deg (units: deg, rad, km, m)

Example

To select all grid cells of a country use the country code with data from the Digital Chart of the World. Here is an example for Spain with the country code ES:

```
cdo selregion,dcw:ES infile outfile
```

2.3.7. SELGRIDCELL - Select grid cells

Synopsis

<operator>,indices `infile outfile`

Description

The operator selects grid cells of all fields from `infile`. The user must specify the index of each grid cell. The resulting grid in `outfile` is unstructured.

Operators

selgridcell Select grid cells

delgridcell Delete grid cells

Parameter

indices INTEGER Comma-separated list or first/last[/inc] range of indices

2.3.8. SAMPLEGRID - Resample grid

Synopsis

samplegrid,*factor* `infile outfile`

Description

This is a special operator for resampling the horizontal grid. No interpolation takes place. Resample factor=2 means every second grid point is removed. Only rectilinear and curvilinear source grids are supported by this operator.

Parameter

factor INTEGER Resample factor, typically 2, which will half the resolution

2.3.9. SELYEARIDX - Select year by index

Synopsis

selyearidx `infile1 infile2 outfile`

Description

Selects field elements from `infile2` according to a year index from `infile1`. The index of the year in `infile1` should be the result of corresponding yearminidx or yearmaxidx operations, respectively.

2.3.10. SELTIMEIDX - Select timestep by index

Synopsis

seltimeidx `infile1 infile2 outfile`

Description

Selects field elements from `infile2` according to a timestep index from `infile1`. The index of the timestep in `infile1` should be the result of corresponding timminidx or timmaxidx operations, respectively.

2.3.11. SELSURFACE - Extract surface

Synopsis

<operator> `infile outfile`

isosurface,*isovalue* `infile outfile`

Description

This module computes a surface from all 3D variables. The result is a horizonal 2D field.

Operators

bottomvalue Extract bottom level
This operator selects the valid values at the bottom level. The NetCDF CF compliant attribute positive is used to determine where top and bottom are. If this attribute is missing, low values are bottom and high values are top.

topvalue Extract top level
This operator selects the valid values at the top level. The NetCDF CF compliant attribute positive is used to determine where top and bottom are. If this attribute is missing, low values are bottom and high values are top.

isosurface Extract isosurface
This operator computes an isosurface. The value of the isosurfce is specified by the parameter isovalue. The isosurface is calculated by linear interpolation between two layers.

Parameter

isovalue FLOAT Isosurface value

2.4. Conditional selection

This section contains modules to conditional select field elements. The fields in the first input file are handled as a mask. A value not equal to zero is treated as "true", zero is treated as "false".

Here is a short overview of all operators in this section:

ifthen	If then
ifnotthen	If not then
ifthenelse	If then else
ifthenc	If then constant
ifnotthenc	If not then constant
reducegrid	Reduce input file variables to locations, where mask is non-zero.

2.4.1. COND - Conditional select one field

Synopsis

<operator> `infile1 infile2 outfile`

Description

This module selects field elements from `infile2` with respect to `infile1` and writes them to `outfile`. The fields in `infile1` are handled as a mask. A value not equal to zero is treated as "true", zero is treated as "false". The number of fields in `infile1` has either to be the same as in `infile2` or the same as in one timestep of `infile2` or only one. The fields in `outfile` inherit the meta data from `infile2`.

Operators

ifthen If then

$$o(t,x) = \begin{cases} i_2(t,x) & \text{if } i_1(t,x) \neq 0 \quad \wedge \; i_1(t,x) \neq \text{miss} \\ \text{miss} & \text{if } i_1(t,x) = 0 \quad \vee \; i_1(t,x) = \text{miss} \end{cases}$$

ifnotthen If not then

$$o(t,x) = \begin{cases} i_2(t,x) & \text{if } i_1(t,x) = 0 \quad \wedge \; i_1(t,x) \neq \text{miss} \\ \text{miss} & \text{if } i_1[t,x) \neq 0 \quad \vee \; i_1(t,x) = \text{miss} \end{cases}$$

Example

To select all field elements of `infile2` if the corresponding field element of `infile1` is greater than 0 use:

```
cdo ifthen infile1 infile2 outfile
```

2.4.2. COND2 - Conditional select two fields

Synopsis

ifthenelse `infile1 infile2 infile3 outfile`

Description

This operator selects field elements from `infile2` or `infile3` with respect to `infile1` and writes them to `outfile`. The fields in `infile1` are handled as a mask. A value not equal to zero is treated as "true", zero is treated as "false". The number of fields in `infile1` has either to be the same as in `infile2` or the same as in one timestep of `infile2` or only one. `infile2` and `infile3` need to have the same number of fields. The fields in `outfile` inherit the meta data from `infile2`.

$$o(t,x) = \begin{cases} i_2(t,x) & \text{if } i_1(t,x) \neq 0 \quad \wedge \; i_1(t,x) \neq \text{miss} \\ i_3(t,x) & \text{if } i_1(t,x) = 0 \quad \wedge \; i_1(t,x) \neq \text{miss} \\ \text{miss} & \text{if } i_1(t,x) = \text{miss} \end{cases}$$

Example

To select all field elements of `infile2` if the corresponding field element of `infile1` is greater than 0 and from `infile3` otherwise use:

```
cdo ifthenelse infile1 infile2 infile3 outfile
```

2.4.3. CONDC - Conditional select a constant

Synopsis

<operator>,*c* `infile outfile`

Description

This module creates fields with a constant value or missing value. The fields in `infile` are handled as a mask. A value not equal to zero is treated as "true", zero is treated as "false".

Operators

ifthenc If then constant

$$o(t,x) = \begin{cases} \text{c} & \text{if } i(t,x) \neq 0 \quad \wedge \; i(t,x) \neq \text{miss} \\ \text{miss} & \text{if } i(t,x) = 0 \quad \vee \; i(t,x) = \text{miss} \end{cases}$$

ifnotthenc If not then constant

$$o(t,x) = \begin{cases} \text{c} & \text{if } i(t,x) = 0 \quad \wedge \; i(t,x) \neq \text{miss} \\ \text{miss} & \text{if } i(t,x) \neq 0 \quad \vee \; i(t,x) = \text{miss} \end{cases}$$

Parameter

c FLOAT Constant

Example

To create fields with the constant value 7 if the corresponding field element of `infile` is greater than 0 use:

```
cdo ifthenc,7 infile outfile
```

2.4.4. MAPREDUCE - Reduce fields to user-defined mask

Synopsis

reducegrid,*mask[,limitCoordsOutput]* `infile outfile`

Description

This module holds an operator for data reduction based on a user defined mask. The output grid is unstructured and includes coordinate bounds. Bounds can be avoided by using the additional 'nobounds' keyword. With 'nocoords' given, coordinates a completely suppressed.

Parameter

mask	STRING	file which holds the mask field
limitCoordsOutput	STRING	optional parameter to limit coordinates output: 'nobounds' disables coordinate bounds, 'nocoords' avoids all coordinate information

Example

To limit data fields to land values, a mask has to be created first with

```
cdo -gtc,0 -topo,ni96 lsm_gme96.grb
```

Here a GME grid is used. Say `temp_gme96.grb` contains a global temperture field. The following command limits the global grid to landpoints.

```
cdo -f nc reduce,lsm_gme96.grb temp_gme96.grb tempOnLand_gme96.nc
```

Note that output file type is NetCDF, because unstructured grids cannot be stored in GRIB format.

2.5. Comparison

This section contains modules to compare datasets. The resulting field is a mask containing 1 if the comparison is true and 0 if not.

Here is a short overview of all operators in this section:

eq	Equal
ne	Not equal
le	Less equal
lt	Less than
ge	Greater equal
gt	Greater than
eqc	Equal constant
nec	Not equal constant
lec	Less equal constant
ltc	Less than constant
gec	Greater equal constant
gtc	Greater than constant
ymoneq	Compare time series with Equal
ymonne	Compare time series with NotEqual
ymonle	Compare time series with LessEqual
ymonlt	Compares if time series with LessThan
ymonge	Compares if time series with GreaterEqual
ymongt	Compares if time series with GreaterThan
yseaseq	Compare time series with Equal
yseasne	Compare time series with NotEqual
yseasle	Compare time series with LessEqual
yseaslt	Compares if time series with LessThan
yseasge	Compares if time series with GreaterEqual
yseasgt	Compares if time series with GreaterThan

2.5.1. COMP - Comparison of two fields

Synopsis

<operator> `infile1 infile2 outfile`

Description

This module compares two datasets field by field. The resulting field is a mask containing 1 if the comparison is true and 0 if not. The number of fields in `infile1` should be the same as in `infile2`. One of the input files can contain only one timestep or one field. The fields in `outfile` inherit the meta data from `infile1` or `infile2`. The type of comparison depends on the chosen operator.

Operators

eq Equal

$$o(t,x) = \begin{cases} 1 & \text{if } i_1(t,x) = i_2(t,x) \quad \wedge\ i_1(t,x), i_2(t,x) \neq \text{miss} \\ 0 & \text{if } i_1(t,x) \neq i_2(t,x) \quad \wedge\ i_1(t,x), i_2(t,x) \neq \text{miss} \\ \text{miss} & \text{if } i_1(t,x) = \text{miss} \quad \vee\ i_2(t,x) = \text{miss} \end{cases}$$

ne Not equal

$$o(t,x) = \begin{cases} 1 & \text{if } i_1(t,x) \neq i_2(t,x) \quad \wedge\ i_1(t,x), i_2(t,x) \neq \text{miss} \\ 0 & \text{if } i_1(t,x) = i_2(t,x) \quad \wedge\ i_1(t,x), i_2(t,x) \neq \text{miss} \\ \text{miss} & \text{if } i_1(t,x) = \text{miss} \quad \vee\ i_2(t,x) = \text{miss} \end{cases}$$

le Less equal

$$o(t,x) = \begin{cases} 1 & \text{if } i_1(t,x) \leq i_2(t,x) \quad \wedge\ i_1(t,x), i_2(t,x) \neq \text{miss} \\ 0 & \text{if } i_1(t,x) > i_2(t,x) \quad \wedge\ i_1(t,x), i_2(t,x) \neq \text{miss} \\ \text{miss} & \text{if } i_1(t,x) = \text{miss} \quad \vee\ i_2(t,x) = \text{miss} \end{cases}$$

lt Less than

$$o(t,x) = \begin{cases} 1 & \text{if } i_1(t,x) < i_2(t,x) \quad \wedge\ i_1(t,x), i_2(t,x) \neq \text{miss} \\ 0 & \text{if } i_1(t,x) \geq i_2(t,x) \quad \wedge\ i_1(t,x), i_2(t,x) \neq \text{miss} \\ \text{miss} & \text{if } i_1(t,x) = \text{miss} \quad \vee\ i_2(t,x) = \text{miss} \end{cases}$$

ge Greater equal

$$o(t,x) = \begin{cases} 1 & \text{if } i_1(t,x) \geq i_2(t,x) \quad \wedge\ i_1(t,x), i_2(t,x) \neq \text{miss} \\ 0 & \text{if } i_1(t,x) < i_2(t,x) \quad \wedge\ i_1(t,x), i_2(t,x) \neq \text{miss} \\ \text{miss} & \text{if } i_1(t,x) = \text{miss} \quad \vee\ i_2(t,x) = \text{miss} \end{cases}$$

gt Greater than

$$o(t,x) = \begin{cases} 1 & \text{if } i_1(t,x) > i_2(t,x) \quad \wedge\ i_1(t,x), i_2(t,x) \neq \text{miss} \\ 0 & \text{if } i_1(t,x) \leq i_2(t,x) \quad \wedge\ i_1(t,x), i_2(t,x) \neq \text{miss} \\ \text{miss} & \text{if } i_1(t,x) = \text{miss} \quad \vee\ i_2(t,x) = \text{miss} \end{cases}$$

Example

To create a mask containing 1 if the elements of two fields are the same and 0 if the elements are different use:

```
cdo eq infile1 infile2 outfile
```

2.5.2. COMPC - Comparison of a field with a constant

Synopsis

<operator>,*c* `infile outfile`

Description

This module compares all fields of a dataset with a constant. The resulting field is a mask containing 1 if the comparison is true and 0 if not. The type of comparison depends on the chosen operator.

Operators

eqc Equal constant

$$o(t,x) = \begin{cases} 1 & \text{if } i(t,x) = \text{c} \quad \wedge\ i(t,x), c \neq \text{miss} \\ 0 & \text{if } i(t,x) \neq c \quad \wedge\ i(t,x), c \neq \text{miss} \\ \text{miss} & \text{if } i(t,x) = \text{miss} \quad \vee\ c = \text{miss} \end{cases}$$

nec Not equal constant

$$o(t,x) = \begin{cases} 1 & \text{if } i(t,x) \neq c \quad \wedge\ i(t,x), c \neq \text{miss} \\ 0 & \text{if } i(t,x) = c \quad \wedge\ i(t,x), c \neq \text{miss} \\ \text{miss} & \text{if } i(t,x) = \text{miss} \quad \vee\ c = \text{miss} \end{cases}$$

lec Less equal constant

$$o(t,x) = \begin{cases} 1 & \text{if } i(t,x) \leq c \quad \wedge\ i(t,x), c \neq \text{miss} \\ 0 & \text{if } i(t,x) > c \quad \wedge\ i(t,x), c \neq \text{miss} \\ \text{miss} & \text{if } i(t,x) = \text{miss} \quad \vee\ c = \text{miss} \end{cases}$$

ltc Less than constant

$$o(t,x) = \begin{cases} 1 & \text{if } i(t,x) < c \quad \wedge\ i(t,x), c \neq \text{miss} \\ 0 & \text{if } i(t,x) \geq c \quad \wedge\ i(t,x), c \neq \text{miss} \\ \text{miss} & \text{if } i(t,x) = \text{miss} \quad \vee\ c = \text{miss} \end{cases}$$

gec Greater equal constant

$$o(t,x) = \begin{cases} 1 & \text{if } i(t,x) \geq c \quad \wedge\ i(t,x), c \neq \text{miss} \\ 0 & \text{if } i(t,x) < c \quad \wedge\ i(t,x), c \neq \text{miss} \\ \text{miss} & \text{if } i(t,x) = \text{miss} \quad \vee\ c = \text{miss} \end{cases}$$

gtc Greater than constant

$$o(t,x) = \begin{cases} 1 & \text{if } i(t,x) > c \quad \wedge\ i(t,x), c \neq \text{miss} \\ 0 & \text{if } i(t,x) \leq c \quad \wedge\ i(t,x), c \neq \text{miss} \\ \text{miss} & \text{if } i(t,x) = \text{miss} \quad \vee\ c = \text{miss} \end{cases}$$

Parameter

c FLOAT Constant

Example

To create a mask containing 1 if the field element is greater than 273.15 and 0 if not use:

```
cdo gtc,273.15 infile outfile
```

2.5.3. YMONCOMP - Multi-year monthly comparison

Synopsis

<*operator*> `infile1 infile2 outfile`

Description

This module performs comparisons of a time series and one timestep with the same month of year. For each field in `infile1` the corresponding field of the timestep in `infile2` with the same month of year is used. The resulting field is a mask containing 1 if the comparison is true and 0 if not. The type of comparison depends on the chosen operator. The input files need to have the same structure with the same variables. Usually `infile2` is generated by an operator of the module YMONSTAT.

Operators

ymoneq Compare time series with Equal
Compares whether a time series is equal to a multi-year monthly time series.

ymonne Compare time series with NotEqual
Compares whether a time series is not equal to a multi-year monthly time series.

ymonle Compare time series with LessEqual
Compares whether a time series is less than or equal to a multi-year monthly time series.

ymonlt Compares if time series with LessThan
Compares whether a time series is less than a multi-year monthly time series.

ymonge Compares if time series with GreaterEqual
Compares whether a time series is greater than or equal to a multi-year monthly time series.

ymongt Compares if time series with GreaterThan
Compares whether a time series is greater than a multi-year monthly time series.

2.5.4. YSEASCOMP - Multi-year seasonal comparison

Synopsis

<operator> `infile1 infile2 outfile`

Description

This module performs comparisons of a time series and one timestep with the same season of year. For each field in `infile1` the corresponding field of the timestep in `infile2` with the same season of year is used. The resulting field is a mask containing 1 if the comparison is true and 0 if not. The type of comparison depends on the chosen operator. The input files need to have the same structure with the same variables. Usually `infile2` is generated by an operator of the module YseasSTAT.

Operators

yseaseq Compare time series with Equal
Compares whether a time series is equal to a multi-year seasonal time series.

yseasne Compare time series with NotEqual
Compares whether a time series is not equal to a multi-year seasonal time series.

yseasle Compare time series with LessEqual
Compares whether a time series is less than or equal to a multi-year seasonal time series.

yseaslt Compares if time series with LessThan
Compares whether a time series is less than a multi-year seasonal time series.

yseasge Compares if time series with GreaterEqual
Compares whether a time series is greater than or equal to a multi-year seasonal time series.

yseasgt Compares if time series with GreaterThan
Compares whether a time series is greater than a multi-year seasonal time series.

2.6. Modification

This section contains modules to modify the metadata, fields or part of a field in a dataset.

Here is a short overview of all operators in this section:

setattribute	Set attributes
delattribute	Delete attributes
setpartabp	Set parameter table
setpartabn	Set parameter table
setcodetab	Set parameter code table
setcode	Set code number
setparam	Set parameter identifier
setname	Set variable name
setunit	Set variable unit
setlevel	Set level
setltype	Set GRIB level type
setmaxsteps	Set max timesteps
setdate	Set date
settime	Set time of the day
setday	Set day
setmon	Set month
setyear	Set year
settunits	Set time units
settaxis	Set time axis
settbounds	Set time bounds
setreftime	Set reference time
setcalendar	Set calendar
shifttime	Shift timesteps
chcode	Change code number
chparam	Change parameter identifier
chname	Change variable or coordinate name
chunit	Change variable unit
chlevel	Change level
chlevelc	Change level of one code
chlevelv	Change level of one variable
setgrid	Set grid
setgridtype	Set grid type
setgridarea	Set grid cell area
setgridmask	Set grid mask
setprojparams	Set proj params
setzaxis	Set z-axis
genlevelbounds	Generate level bounds
invertlat	Invert latitudes
invertlev	Invert levels
shiftx	Shift x
shifty	Shift y

maskregion	Mask regions
masklonlatbox	Mask a longitude/latitude box
maskindexbox	Mask an index box
setclonlatbox	Set a longitude/latitude box to constant
setcindexbox	Set an index box to constant
enlarge	Enlarge fields
setmissval	Set a new missing value
setctomiss	Set constant to missing value
setmisstoc	Set missing value to constant
setrtomiss	Set range to missing value
setvrange	Set valid range
setmisstonn	Set missing value to nearest neighbor
setmisstodis	Set missing value to distance-weighted average
vertfillmiss	Vertical filling of missing values
timfillmiss	Temporal filling of missing values
setgridcell	Set the value of a grid cell

2.6.1. SETATTRIBUTE - Set attributes

Synopsis

<operator>,attributes `infile outfile`

Description

This operator sets or deletes attributes of a dataset and writes the result to `outfile`. The new attributes are only available in `outfile` if the file format supports attributes.

Each attribute has the following structure:

[**var_nm**@]**att_nm**[:s|d|i]=[**att_val**|{[**var_nm**@]**att_nm**}]

var_nm Variable name (optional). Example: pressure

att_nm Attribute name. Example: units

att_val Comma-separated list of attribute values. Example: pascal

The value of **var_nm** is the name of the variable containing the attribute (named **att_nm**) that you want to set. Use wildcards to set the attribute **att_nm** to more than one variable. A value of **var_nm** of '*****' will set the attribute **att_nm** to all data variables. If **var_nm** is missing then **att_nm** refers to a global attribute.

The value of **att_nm** is the name of the attribute you want to set. For each attribute a string (att_nm:s), a double (att_nm:d) or an integer (att_nm:i) type can be defined. By default the native type is set.

The value of **att_val** is the contents of the attribute **att_nm**. **att_val** may be a single value or one-dimensional array of elements. The type and the number of elements of an attribute will be detected automatically from the contents of the values. An already existing attribute **att_nm** will be overwritten or it will be removed if **att_val** is omitted. Alternatively, the values of an existing attribute can be copied. This attribute must then be enclosed in curly brackets.

A special meaning has the attribute name **FILE**. If this is the 1st attribute then all attributes are read from a file specified in the value of **att_val**.

Operators

setattribute Set attributes

delattribute Delete attributes

Parameter

attributes STRING Comma-separated list of attributes.

Note

Attributes are evaluated by **CDO** when opening `infile`. Therefor the result of this operator is not available for other operators when this operator is used in chaining operators.

Example

To set the units of the variable pressure to pascal use:

```
cdo setattribute,pressure@units=pascal infile outfile
```

To set the global text attribute "my_att" to "my contents", use:

```
cdo setattribute,my_att="my contents" infile outfile
```

Result of 'ncdump -h outfile':

```
netcdf outfile {
dimensions: ...

variables: ...

// global attributes:
                :my_att = "my contents" ;
}
```

2.6.2. SETPARTAB - Set parameter table

Synopsis

<operator>,table[,convert] `infile outfile`

Description

This module transforms data and metadata of `infile` via a parameter table and writes the result to `outfile`. A parameter table is an ASCII formatted file with a set of parameter entries for each variable. Each new set have to start with "&parameter" and to end with "/".

The following parameter table entries are supported:

Entry	Type	Description
name	WORD	Name of the variable
out_name	WORD	New name of the variable
param	WORD	Parameter identifier (GRIB1: code[.tabnum]; GRIB2: num[.cat[.dis]])
out_param	WORD	New parameter identifier
type	WORD	Data type (real or double)
standard_name	WORD	As defined in the CF standard name table
long_name	STRING	Describing the variable
units	STRING	Specifying the units for the variable
comment	STRING	Information concerning the variable
cell_methods	STRING	Information concerning calculation of means or climatologies
cell_measures	STRING	Indicates the names of the variables containing cell areas and volumes
filterspec	STRING	NetCDF4 filter specification
missing_value	FLOAT	Specifying how missing data will be identified
valid_min	FLOAT	Minimum valid value
valid_max	FLOAT	Maximum valid value
ok_min_mean_abs	FLOAT	Minimum absolute mean
ok_max_mean_abs	FLOAT	Maximum absolute mean
factor	FLOAT	Scale factor
delete	INTEGER	Set to 1 to delete variable
convert	INTEGER	Set to 1 to convert the unit if necessary

Unsupported parameter table entries are stored as variable attributes. The search key for the variable depends on the operator. Use setpartabn to search variables by the name. This is typically used for NetCDF datasets. The operator setpartabp searches variables by the parameter ID.

Operators

setpartabp Set parameter table
Search variables by the parameter identifier.

setpartabn Set parameter table
Search variables by name.

Parameter

table STRING Parameter table file or name

convert STRING Converts the units if necessary

Example

Here is an example of a parameter table for one variable:

```
prompt> cat mypartab
&parameter
  name          = t
  out_name      = ta
  standard_name = air_temperature
  units         = "K"
  missing_value = 1.0e+20
  valid_min     = 157.1
  valid_max     = 336.3
/
```

To apply this parameter table to a dataset use:

```
cdo setpartabn,mypartab,convert infile outfile
```

This command renames the variable **t** to **ta**. The standard name of this variable is set to **air_temperature** and the unit is set to [**K**] (converts the unit if necessary). The missing value will be set to **1.0e+20**. In addition it will be checked whether the values of the variable are in the range of **157.1** to **336.3**.

2.6.3. SET - Set field info

Synopsis

setcodetab,*table* `infile outfile`

setcode,*code* `infile outfile`

setparam,*param* `infile outfile`

setname,*name* `infile outfile`

setunit,*unit* `infile outfile`

setlevel,*level* `infile outfile`

setltype,*ltype* `infile outfile`

setmaxsteps,*maxsteps* `infile outfile`

Description

This module sets some field information. Depending on the chosen operator the parameter table, code number, parameter identifier, variable name or level is set.

Operators

setcodetab	Set parameter code table Sets the parameter code table for all variables.
setcode	Set code number Sets the code number for all variables to the same given value.
setparam	Set parameter identifier Sets the parameter identifier of the first variable.
setname	Set variable name Sets the name of the first variable.
setunit	Set variable unit Sets the unit of the first variable.
setlevel	Set level Sets the first level of all variables.
setltype	Set GRIB level type Sets the GRIB level type of all variables.
setmaxsteps	Set max timesteps Sets maximum number of timesteps

Parameter

table	STRING	Parameter table file or name
code	INTEGER	Code number
param	STRING	Parameter identifier (GRIB1: code[.tabnum]; GRIB2: num[.cat[.dis]])
name	STRING	Variable name
level	FLOAT	New level
ltype	INTEGER	GRIB level type
maxsteps	INTEGER	Maximum number of timesteps

2.6.4. SETTIME - Set time

Synopsis

setdate,*date* `infile outfile`

settime,*time* `infile outfile`

setday,*day* `infile outfile`

setmon,*month* `infile outfile`

setyear,*year* `infile outfile`

settunits,*units* `infile outfile`

settaxis,*date,time[,inc]* `infile outfile`

settbounds,*frequency* `infile outfile`

setreftime,*date,time[,units]* `infile outfile`

setcalendar,*calendar* `infile outfile`

shifttime,*shiftValue* `infile outfile`

Description

This module sets the time axis or part of the time axis. Which part of the time axis is overwritten/created depends on the chosen operator. The number of time steps does not change.

Operators

setdate Set date
Sets the date in every timestep to the same given value.

settime Set time of the day
Sets the time in every timestep to the same given value.

setday Set day
Sets the day in every timestep to the same given value.

setmon Set month
Sets the month in every timestep to the same given value.

setyear Set year
Sets the year in every timestep to the same given value.

settunits Set time units
Sets the base units of a relative time axis.

settaxis Set time axis
Sets the time axis.

settbounds Set time bounds
Sets the time bounds.

setreftime Set reference time
Sets the reference time of a relative time axis.

setcalendar Set calendar
Sets the calendar attribute of a relative time axis.

shifttime Shift timesteps
Shifts all timesteps by the parameter shiftValue.

Parameter

day	INTEGER	Value of the new day
month	INTEGER	Value of the new month
year	INTEGER	Value of the new year
units	STRING	Base units of the time axis (seconds|minutes|hours|days|months|years)
date	STRING	Date (format: YYYY-MM-DD)
time	STRING	Time (format: hh:mm:ss)
inc	STRING	Optional increment (seconds|minutes|hours|days|months|years) [default: 1hour]
frequency	STRING	Frequency of the time series (hour|day|month|year)
calendar	STRING	Calendar (standard|proleptic_gregorian|360_day|365_day|366_day)
shiftValue	STRING	Shift value (e.g. -3hour)

Example

To set the time axis to 1987-01-16 12:00:00 with an increment of one month for each timestep use:

```
cdo settaxis,1987-01-16,12:00:00,1mon infile outfile
```

Result of 'cdo showdate outfile' for a dataset with 12 timesteps:

```
1987-01-16 1987-02-16 1987-03-16 1987-04-16 1987-05-16 1987-06-16 \
1987-07-16 1987-08-16 1987-09-16 1987-10-16 1987-11-16 1987-12-16
```

To shift this time axis by -15 days use:

```
cdo shifttime,-15days infile outfile
```

Result of 'cdo showdate outfile':

```
1987-01-01 1987-02-01 1987-03-01 1987-04-01 1987-05-01 1987-06-01 \
1987-07-01 1987-08-01 1987-09-01 1987-10-01 1987-11-01 1987-12-01
```

2.6.5. CHANGE - Change field header

Synopsis

chcode,*oldcode,newcode[,...]* `infile outfile`

chparam,*oldparam,newparam,...* `infile outfile`

chname,*oldname,newname,...* `infile outfile`

chunit,*oldunit,newunit,...* `infile outfile`

chlevel,*oldlev,newlev,...* `infile outfile`

chlevelc,*code,oldlev,newlev* `infile outfile`

chlevelv,*name,oldlev,newlev* `infile outfile`

Description

This module reads fields from `infile`, changes some header values and writes the results to `outfile`. The kind of changes depends on the chosen operator.

Operators

chcode	Change code number Changes some user given code numbers to new user given values.
chparam	Change parameter identifier Changes some user given parameter identifiers to new user given values.
chname	Change variable or coordinate name Changes some user given variable or coordinate names to new user given names.
chunit	Change variable unit Changes some user given variable units to new user given units.
chlevel	Change level Changes some user given levels to new user given values.
chlevelc	Change level of one code Changes one level of a user given code number.
chlevelv	Change level of one variable Changes one level of a user given variable name.

Parameter

code	INTEGER	Code number
oldcode,newcode,...	INTEGER	Pairs of old and new code numbers
oldparam,newparam,...	STRING	Pairs of old and new parameter identifiers
name	STRING	Variable name
oldname,newname,...	STRING	Pairs of old and new variable names
oldlev	FLOAT	Old level
newlev	FLOAT	New level
oldlev,newlev,...	FLOAT	Pairs of old and new levels

Example

To change the code number 98 to 179 and 99 to 211 use:

```
cdo chcode,98,179,99,211 infile outfile
```

2.6.6. SETGRID - Set grid information

Synopsis

setgrid,*grid* `infile outfile`

setgridtype,*gridtype* `infile outfile`

setgridarea,*gridarea* `infile outfile`

setgridmask,*gridmask* `infile outfile`

setprojparams,*projparams* `infile outfile`

Description

This module modifies the metadata of the horizontal grid. Depending on the chosen operator a new grid description is set, the coordinates are converted or the grid cell area is added.

Operators

setgrid Set grid
Sets a new grid description. The input fields need to have the same grid size as the size of the target grid description.

setgridtype Set grid type
Sets the grid type of all input fields. The following grid types are available:

curvilinear	Converts a regular grid to a curvilinear grid
unstructured	Converts a regular or curvilinear grid to an unstructured grid
dereference	Dereference a reference to a grid
regular	Linear interpolation of a reduced Gaussian grid to a regular Gaussian grid
regularnn	Nearest neighbor interpolation of a reduced Gaussian grid to a regular Gaussian grid
lonlat	Converts a regular lonlat grid stored as a curvilinear grid back to a lonlat grid
projection	Removes the geographical coordinates if projection parameter available

setgridarea Set grid cell area
Sets the grid cell area. The parameter *gridarea* is the path to a data file, the first field is used as grid cell area. The input fields need to have the same grid size as the grid cell area. The grid cell area is used to compute the weights of each grid cell if needed by an operator, e.g. for fldmean.

setgridmask Set grid mask
Sets the grid mask. The parameter *gridmask* is the path to a data file, the first field is used as the grid mask. The input fields need to have the same grid size as the grid mask. The grid mask is used as the target grid mask for remapping, e.g. for remapbil.

setprojparams Set proj params
Sets the `proj_params` attribute of a projection. This attribute is used to compute geographic coordinates of a projecton with the proj library.

Parameter

grid	STRING	Grid description file or name
gridtype	STRING	Grid type (curvilinear, unstructured, regular, lonlat, projection or dereference)
gridarea	STRING	Data file, the first field is used as grid cell area
gridmask	STRING	Data file, the first field is used as grid mask
projparams	STRING	Proj library parameter (e.g.:+init=EPSG:3413)

Example

Assuming a dataset has fields on a grid with 2048 elements without or with wrong grid description. To set the grid description of all input fields to a Gaussian N32 grid (8192 gridpoints) use:

```
cdo setgrid,n32 infile outfile
```

2.6.7. SETZAXIS - Set z-axis information

Synopsis

setzaxis,*zaxis* `infile outfile`

genlevelbounds[,*zbot*[,*ztop*]] `infile outfile`

Description

This module modifies the metadata of the vertical grid.

Operators

setzaxis	Set z-axis This operator sets the z-axis description of all variables with the same number of level as the new z-axis.
genlevelbounds	Generate level bounds Generates the layer bounds of the z-axis.

Parameter

zaxis	STRING	Z-axis description file or name of the target z-axis
zbot	FLOAT	Specifying the bottom of the vertical column. Must have the same units as z-axis.
ztop	FLOAT	Specifying the top of the vertical column. Must have the same units as z-axis.

2.6.8. INVERT - Invert latitudes

Synopsis

invertlat `infile outfile`

Description

This operator inverts the latitudes of all fields on a rectilinear grid.

Example

To invert the latitudes of a 2D field from N->S to S->N use:

```
cdo invertlat infile outfile
```

2.6.9. INVERTLEV - Invert levels

Synopsis

invertlev `infile outfile`

Description

This operator inverts the levels of all 3D variables.

2.6.10. SHIFTXY - Shift field

Synopsis

<operator>,*<nshift>*,*<cyclic>*,*<coord>* `infile outfile`

Description

This module contains operators to shift all fields in x or y direction. All fields need to have the same horizontal rectilinear or curvilinear grid.

Operators

shiftx Shift x
Shifts all fields in x direction.

shifty Shift y
Shifts all fields in y direction.

Parameter

nshift	INTEGER	Number of grid cells to shift (default: 1)
cyclic	STRING	If set, cells are filled up cyclic (default: missing value)
coord	STRING	If set, coordinates are also shifted

Example

To shift all input fields in the x direction by +1 cells and fill the new cells with missing value, use:

```
cdo shiftx infile outfile
```

To shift all input fields in the x direction by +1 cells and fill the new cells cyclic, use:

```
cdo shiftx,1,cyclic infile outfile
```

2.6.11. MASKREGION - Mask regions

Synopsis

maskregion,*regions* `infile outfile`

Description

Masks different regions of the input fields. The grid cells inside a region are untouched, the cells outside are set to missing value. Considered are only those grid cells with the grid center inside the regions. All input fields must have the same horizontal grid.

Regions can be defined by the user via an ASCII file. Each region consists of the geographic coordinates of a polygon. Each line of a polygon description file contains the longitude and latitude of one point. Each polygon description file can contain one or more polygons separated by a line with the character &.

Predefined regions of countries can be specified via the country codes. A country is specified with dcw:<CountryCode>. Country codes can be combined with the plus sign.

Parameter

regions	STRING	Comma-separated list of ASCII formatted files with different regions

Example

To mask the region with the longitudes from 120E to 90W and latitudes from 20N to 20S on all input fields use:

```
cdo maskregion,myregion infile outfile
```

For this example the description file of the region `myregion` should contain one polygon with the following four coordinates:

```
120   20
120  −20
270  −20
270   20
```

To mask the region of a country use the country code with data from the Digital Chart of the World. Here is an example for Spain with the country code ES:

```
cdo maskregion,dcw:ES infile outfile
```

2.6.12. MASKBOX - Mask a box

Synopsis

masklonlatbox,*lon1*,*lon2*,*lat1*,*lat2* `infile outfile`

maskindexbox,*idx1*,*idx2*,*idy1*,*idy2* `infile outfile`

Description

Masks grid cells inside a lon/lat or index box. The elements inside the box are untouched, the elements outside are set to missing value. All input fields need to have the same horizontal grid. Use sellonlatbox or selindexbox if only the data inside the box are needed.

Operators

masklonlatbox Mask a longitude/latitude box
Masks grid cells inside a lon/lat box. The user must specify the longitude and latitude of the edges of the box. Only those grid cells are considered whose grid center lies within the lon/lat box. For rotated lon/lat grids the parameters must be specified in rotated coordinates.

maskindexbox Mask an index box
Masks grid cells within an index box. The user must specify the indices of the edges of the box. The index of the left edge can be greater then the one of the right edge. Use negative indexing to start from the end. The input grid must be a regular lon/lat or a 2D curvilinear grid.

Parameter

lon1	FLOAT	Western longitude
lon2	FLOAT	Eastern longitude
lat1	FLOAT	Southern or northern latitude
lat2	FLOAT	Northern or southern latitude
idx1	INTEGER	Index of first longitude
idx2	INTEGER	Index of last longitude
idy1	INTEGER	Index of first latitude
idy2	INTEGER	Index of last latitude

Example

To mask the region with the longitudes from 120E to 90W and latitudes from 20N to 20S on all input fields use:

```
cdo masklonlatbox,120,-90,20,-20 infile outfile
```

If the input dataset has fields on a Gaussian N16 grid, the same box can be masked with maskindexbox by:

```
cdo maskindexbox,23,48,13,20 infile outfile
```

2.6.13. SETBOX - Set a box to constant

Synopsis

setclonlatbox,*c*,*lon1*,*lon2*,*lat1*,*lat2* `infile outfile`

setcindexbox,*c*,*idx1*,*idx2*,*idy1*,*idy2* `infile outfile`

Description

Sets a box of the rectangularly understood field to a constant value. The elements outside the box are untouched, the elements inside are set to the given constant. All input fields need to have the same horizontal grid.

Operators

setclonlatbox Set a longitude/latitude box to constant
Sets the values of a longitude/latitude box to a constant value. The user has to give the longitudes and latitudes of the edges of the box.

setcindexbox Set an index box to constant
Sets the values of an index box to a constant value. The user has to give the indices of the edges of the box. The index of the left edge can be greater than the one of the right edge.

Parameter

c	FLOAT	Constant
lon1	FLOAT	Western longitude
lon2	FLOAT	Eastern longitude
lat1	FLOAT	Southern or northern latitude
lat2	FLOAT	Northern or southern latitude
idx1	INTEGER	Index of first longitude
idx2	INTEGER	Index of last longitude
idy1	INTEGER	Index of first latitude
idy2	INTEGER	Index of last latitude

Example

To set all values in the region with the longitudes from 120E to 90W and latitudes from 20N to 20S to the constant value -1.23 use:

```
cdo setclonlatbox,-1.23,120,-90,20,-20 infile outfile
```

If the input dataset has fields on a Gaussian N16 grid, the same box can be set with setcindexbox by:

```
cdo setcindexbox,-1.23,23,48,13,20 infile outfile
```

2.6.14. ENLARGE - Enlarge fields

Synopsis

enlarge,*grid* `infile outfile`

Description

Enlarge all fields of `infile` to a user given horizontal grid. Normally only the last field element is used for the enlargement. If however the input and output grid are regular lon/lat grids, a zonal or meridional enlargement is possible. Zonal enlargement takes place, if the xsize of the input field is 1 and the ysize of both grids are the same. For meridional enlargement the ysize have to be 1 and the xsize of both grids should have the same size.

Parameter

grid STRING Target grid description file or name

Example

Assumed you want to add two datasets. The first dataset is a field on a global grid (n field elements) and the second dataset is a global mean (1 field element). Before you can add these two datasets the second dataset have to be enlarged to the grid size of the first dataset:

```
cdo enlarge,infile1 infile2 tmpfile
cdo add infile1 tmpfile outfile
```

Or shorter using operator piping:

```
cdo add infile1 -enlarge,infile1 infile2 outfile
```

2.6.15. SETMISS - Set missing value

Synopsis

setmissval,*newmiss* `infile outfile`

setctomiss,*c* `infile outfile`

setmisstoc,*c* `infile outfile`

setrtomiss,*rmin*,*rmax* `infile outfile`

setvrange,*rmin*,*rmax* `infile outfile`

setmisstonn `infile outfile`

setmisstodis*[,neighbors]* `infile outfile`

Description

This module sets part of a field to missing value or missing values to a constant value. Which part of the field is set depends on the chosen operator.

Operators

setmissval Set a new missing value

$$o(t,x) = \begin{cases} \text{newmiss} & \text{if } i(t,x) = \mathit{miss} \\ i(t,x) & \text{if } i(t,x) \neq \mathit{miss} \end{cases}$$

setctomiss Set constant to missing value

$$o(t,x) = \begin{cases} \text{miss} & \text{if } i(t,x) = c \\ i(t,x) & \text{if } i(t,x) \neq c \end{cases}$$

setmisstoc Set missing value to constant

$$o(t,x) = \begin{cases} c & \text{if } i(t,x) = \text{miss} \\ i(t,x) & \text{if } i(t,x) \neq \text{miss} \end{cases}$$

setrtomiss Set range to missing value

$$o(t,x) = \begin{cases} \text{miss} & \text{if } i(t,x) \geq \mathit{rmin} \wedge i(t,x) \leq \mathit{rmax} \\ i(t,x) & \text{if } i(t,x) < \mathit{rmin} \vee i(t,x) > \mathit{rmax} \end{cases}$$

setvrange Set valid range

$$o(t,x) = \begin{cases} \text{miss} & \text{if } i(t,x) < \mathit{rmin} \vee i(t,x) > \mathit{rmax} \\ i(t,x) & \text{if } i(t,x) \geq \mathit{rmin} \wedge i(t,x) \leq \mathit{rmax} \end{cases}$$

setmisstonn Set missing value to nearest neighbor
Set all missing values to the nearest non missing value.

$$o(t,x) = \begin{cases} i(t,y) & \text{if } i(t,x) = \text{miss} \wedge i(t,y) \neq \text{miss} \\ i(t,x) & \text{if } i(t,x) \neq \text{miss} \end{cases}$$

setmisstodis Set missing value to distance-weighted average
Set all missing values to the distance-weighted average of the nearest non missing values. The default number of nearest neighbors is 4.

Parameter

neighbors	INTEGER	Number of nearest neighbors
newmiss	FLOAT	New missing value
c	FLOAT	Constant
rmin	FLOAT	Lower bound
rmax	FLOAT	Upper bound

Example

setrtomiss

Assume an input dataset has one field with temperatures in the range from 246 to 304 Kelvin. To set all values below 273.15 Kelvin to missing value use:

```
cdo setrtomiss,0,273.15 infile outfile
```

Result of 'cdo info infile':

```
   -1 :       Date   Time     Code Level   Size   Miss :    Minimum       Mean    Maximum
    1 : 1987-12-31 12:00:00 139      0   2048      0 :     246.27     276.75     303.71
```

Result of 'cdo info outfile':

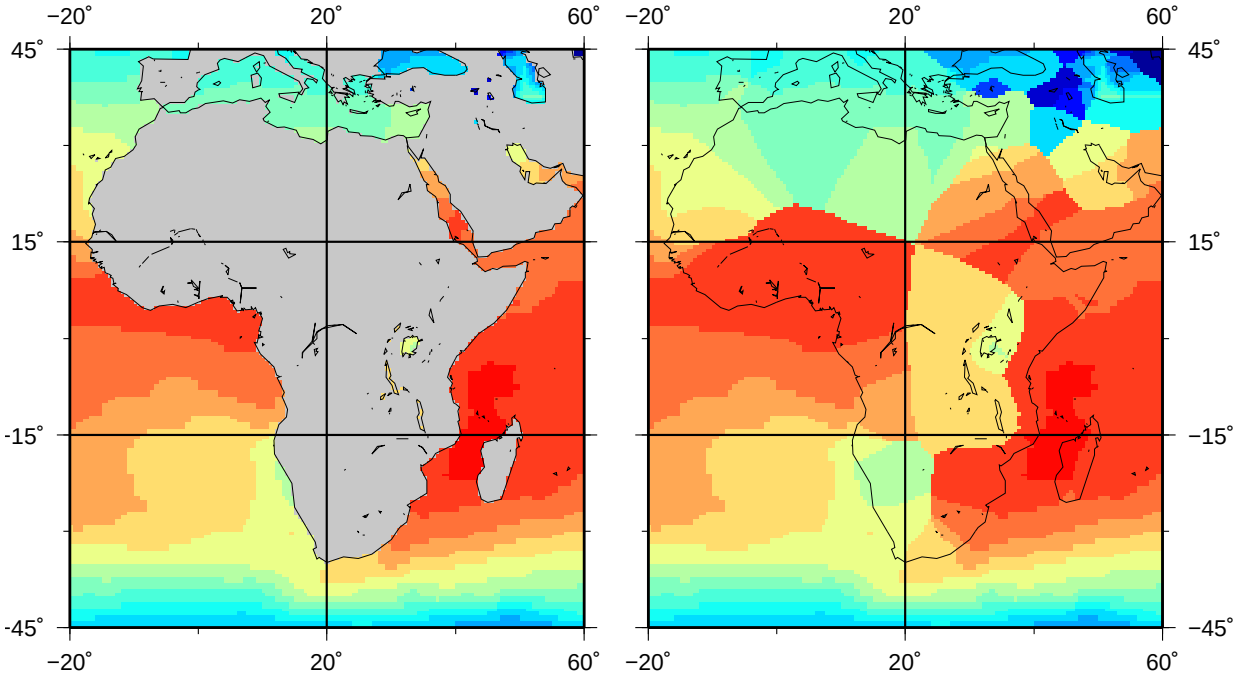
```
   -1 :       Date   Time     Code Level   Size   Miss :    Minimum       Mean    Maximum
    1 : 1987-12-31 12:00:00 139      0   2048    871 :     273.16     287.08     303.71
```

setmisstonn

Set all missing values to the nearest non missing value:

```
cdo setmisstonn infile outfile
```

Below is a schematic illustration of this example:



On the left side is input data with missing values in grey and on the right side the result with the filled missing values.

2.6.16. VERTFILLMISS - Vertical filling of missing values

Synopsis

vertfillmiss*[,parameter]* `infile outfile`

Description

This operator fills in vertical missing values. The *method* parameter can be used to select the filling method. The default *method=nearest* fills missing values with the nearest neighbor value. Other options are *forward* and *backward* to fill missing values by forward or backward propagation of values. Use the *limit* parameter to set the maximum number of consecutive missing values to fill and *max_gaps* to set the maximum number of gaps to fill.

Parameter

method	STRING	Fill method [nearest|linear|forward|backward] (default: nearest)
limit	INTEGER	The maximum number of consecutive missing values to fill (default: all)
max_gaps	INTEGER	The maximum number of gaps to fill (default: all)

2.6.17. TIMFILLMISS - Temporal filling of missing values

Synopsis

timfillmiss*[,parameter]* `infile outfile`

Description

This operator fills in temporally missing values. The *method* parameter can be used to select the filling method. The default *method=nearest* fills missing values with the nearest neighbor value. Other options are *forward* and *backward* to fill missing values by forward or backward propagation of values. Use the *limit* parameter to set the maximum number of consecutive missing values to fill and *max_gaps* to set the maximum number of gaps to fill.

Parameter

method	STRING	Fill method [nearest|linear|forward|backward] (default: nearest)
limit	INTEGER	The maximum number of consecutive missing values to fill (default: all)
max_gaps	INTEGER	The maximum number of gaps to fill (default: all)

2.6.18. SETGRIDCELL - Set the value of a grid cell

Synopsis

setgridcell,*parameter* `infile outfile`

Description

This operator sets the value of the selected grid cells. The grid cells can be selected by a comma-separated list of grid cell indices or a mask. The mask is read from a data file, which may contain only one field. If no grid cells are selected, all values are set.

Parameter

value	FLOAT	Value of the grid cell
cell	INTEGER	Comma-separated list of grid cell indices
mask	STRING	Name of the data file which contains the mask

2.7. Arithmetic

This section contains modules to arithmetically process datasets.

Here is a short overview of all operators in this section:

expr	Evaluate expressions
exprf	Evaluate expressions script
aexpr	Evaluate expressions and append results
aexprf	Evaluate expression script and append results
abs	Absolute value
int	Integer value
nint	Nearest integer value
pow	Power
sqr	Square
sqrt	Square root
exp	Exponential
ln	Natural logarithm
log10	Base 10 logarithm
sin	Sine
cos	Cosine
tan	Tangent
asin	Arc sine
acos	Arc cosine
atan	Arc tangent
reci	Reciprocal value
not	Logical NOT
addc	Add a constant
subc	Subtract a constant
mulc	Multiply with a constant
divc	Divide by a constant
minc	Minimum of a field and a constant
maxc	Maximum of a field and a constant
add	Add two fields
sub	Subtract two fields
mul	Multiply two fields
div	Divide two fields
min	Minimum of two fields
max	Maximum of two fields
atan2	Arc tangent of two fields
setmiss	Set missing values
dayadd	Add daily time series
daysub	Subtract daily time series
daymul	Multiply daily time series
daydiv	Divide daily time series
monadd	Add monthly time series
monsub	Subtract monthly time series
monmul	Multiply monthly time series
mondiv	Divide monthly time series

yearadd	Add yearly time series
yearsub	Subtract yearly time series
yearmul	Multiply yearly time series
yeardiv	Divide yearly time series
yhouradd	Add multi-year hourly time series
yhoursub	Subtract multi-year hourly time series
yhourmul	Multiply multi-year hourly time series
yhourdiv	Divide multi-year hourly time series
ydayadd	Add multi-year daily time series
ydaysub	Subtract multi-year daily time series
ydaymul	Multiply multi-year daily time series
ydaydiv	Divide multi-year daily time series
ymonadd	Add multi-year monthly time series
ymonsub	Subtract multi-year monthly time series
ymonmul	Multiply multi-year monthly time series
ymondiv	Divide multi-year monthly time series
yseasadd	Add multi-year seasonal time series
yseassub	Subtract multi-year seasonal time series
yseasmul	Multiply multi-year seasonal time series
yseasdiv	Divide multi-year seasonal time series
muldpm	Multiply with days per month
divdpm	Divide by days per month
muldpy	Multiply with days per year
divdpy	Divide by days per year
mulcoslat	Multiply with the cosine of the latitude
divcoslat	Divide by cosine of the latitude

2.7.1. EXPR - Evaluate expressions

Synopsis

expr,*instr* `infile outfile`

exprf,*filename* `infile outfile`

aexpr,*instr* `infile outfile`

aexprf,*filename* `infile outfile`

Description

This module arithmetically processes every timestep of the input dataset. Each individual assignment statement have to end with a semi-colon. The special key _ALL_ is used as a template. A statement with a template is replaced for all variable names. Unlike regular variables, temporary variables are never written to the output stream. To define a temporary variable simply prefix the variable name with an underscore (e.g. _varname) when the variable is declared.

The following operators are supported:

Operator	**Meaning**	**Example**	**Result**
=	assignment	x = y	Assigns y to x
+	addition	x + y	Sum of x and y
-	subtraction	x - y	Difference of x and y
*	multiplication	x * y	Product of x and y
/	division	x / y	Quotient of x and y
^	exponentiation	x ^ y	Exponentiates x with y
==	equal to	x == y	1, if x equal to y; else 0
!=	not equal to	x != y	1, if x not equal to y; else 0
>	greater than	x > y	1, if x greater than y; else 0
<	less than	x < y	1, if x less than y; else 0
>=	greater equal	x >= y	1, if x greater equal y; else 0
<=	less equal	x <= y	1, if x less equal y; else 0
<=>	less equal greater	x <=> y	-1, if x less y; 1, if x greater y; else 0
&&	logical AND	x && y	1, if x and y not equal 0; else 0
||	logical OR	x || y	1, if x or y not equal 0; else 0
!	logical NOT	!x	1, if x equal 0; else 0
?:	ternary conditional	x ? y : z	y, if x not equal 0, else z

The following functions are supported:

Math intrinsics:

abs(x)	Absolute value of x
floor(x)	Round to largest integral value not greater than x
ceil(x)	Round to smallest integral value not less than x
float(x)	32-bit float value of x
int(x)	Integer value of x
nint(x)	Nearest integer value of x
sqr(x)	Square of x
sqrt(x)	Square Root of x
exp(x)	Exponential of x

ln(x)	Natural logarithm of x
log10(x)	Base 10 logarithm of x
sin(x)	Sine of x, where x is specified in radians
cos(x)	Cosine of x, where x is specified in radians
tan(x)	Tangent of x, where x is specified in radians
asin(x)	Arc-sine of x, where x is specified in radians
acos(x)	Arc-cosine of x, where x is specified in radians
atan(x)	Arc-tangent of x, where x is specified in radians
sinh(x)	Hyperbolic sine of x, where x is specified in radians
cosh(x)	Hyperbolic cosine of x, where x is specified in radians
tanh(x)	Hyperbolic tangent of x, where x is specified in radians
asinh(x)	Inverse hyperbolic sine of x, where x is specified in radians
acosh(x)	Inverse hyperbolic cosine of x, where x is specified in radians
atanh(x)	Inverse hyperbolic tangent of x, where x is specified in radians
rad(x)	Convert x from degrees to radians
deg(x)	Convert x from radians to degrees
rand(x)	Replace x by pseudo-random numbers in the range of 0 to 1
isMissval(x)	Returns 1 where x is missing
mod(x,y)	Floating-point remainder of x/ y
min(x,y)	Minimum value of x and y
max(x,y)	Maximum value of x and y
pow(x,y)	Power function
hypot(x,y)	Euclidean distance function, sqrt(x*x + y*y)
atan2(x,y)	Arc tangent function of y/x, using signs to determine quadrants

Coordinates:

clon(x)	Longitude coordinate of x (available only if x has geographical coordinates)
clat(x)	Latitude coordinate of x (available only if x has geographical coordinates)
gridarea(x)	Grid cell area of x (available only if x has geographical coordinates)
gridindex(x)	Grid cell indices of x
clev(x)	Level coordinate of x (0, if x is a 2D surface variable)
clevidx(x)	Level index of x (0, if x is a 2D surface variable)
cthickness(x)	Layer thickness, upper minus lower level bound of x (1, if level bounds are missing)
ctimestep()	Timestep number (1 to N)
cdate()	Verification date as YYYYMMDD
ctime()	Verification time as HHMMSS.millisecond
cdeltat()	Difference between current and last timestep in seconds
cday()	Day as DD
cmonth()	Month as MM

cyear()	Year as YYYY
csecond()	Second as SS.millisecond
cminute()	Minute as MM
chour()	Hour as HH

Constants:

ngp(x)	Number of horizontal grid points
nlev(x)	Number of vertical levels
size(x)	Total number of elements (ngp(x)*nlev(x))
missval(x)	Returns the missing value of variable x

Statistics over a field:

fldmin(x), fldmax(x), fldrange(x), fldsum(x), fldmean(x), fldavg(x), fldstd(x), fldstd1(x), fldvar(x), fldvar1(x), fldskew(x), fldkurt(x), fldmedian(x)

Zonal statistics for regular 2D grids:

zonmin(x), zonmax(x), zonrange(x), zonsum(x), zonmean(x), zonavg(x), zonstd(x), zonstd1(x), zonvar(x), zonvar1(x), zonskew(x), zonkurt(x), zonmedian(x)

Vertical statistics:

vertmin(x), vertmax(x), vertrange(x), vertsum(x), vertmean(x), vertavg(x), vertstd(x), vertstd1(x), vertvar(x), vertvar1(x)

Miscellaneous:

sellevel(x,k)	Select level k of variable x
sellevidx(x,k)	Select level index k of variable x
sellevelrange(x,k1,k2)	Select all levels of variable x in the range k1 to k2
sellevidxrange(x,k1,k2)	Select all level indices of variable x in the range k1 to k2
remove(x)	Remove variable x from output stream

Operators

expr	Evaluate expressions The processing instructions are read from the parameter.
exprf	Evaluate expressions script Contrary to expr the processing instructions are read from a file.
aexpr	Evaluate expressions and append results Same as expr, but keep input variables and append results
aexprf	Evaluate expression script and append results Same as exprf, but keep input variables and append results

Parameter

instr	STRING	Processing instructions (need to be 'quoted' in most cases)
filename	STRING	File with processing instructions

Note

If the input stream contains duplicate entries of the same variable name then the last one is used.

Example

Assume an input dataset contains at least the variables 'aprl', 'aprc' and 'ts'. To create a new variable 'var1' with the sum of 'aprl' and 'aprc' and a variable 'var2' which convert the temperature 'ts' from Kelvin to Celsius use:

```
cdo expr,'var1=aprl+aprc;var2=ts-273.15;' infile outfile
```

The same example, but the instructions are read from a file:

```
cdo exprf,myexpr infile outfile
```

The file `myexpr` contains:

```
var1 = aprl + aprc;
var2 = ts - 273.15;
```

2.7.2. MATH - Mathematical functions

Synopsis

`<operator> infile outfile`

Description

This module contains some standard mathematical functions. All trigonometric functions calculate with radians.

Operators

abs Absolute value
$o(t,x) = \mathrm{abs}(i(t,x))$

int Integer value
$o(t,x) = \mathrm{int}(i(t,x))$

nint Nearest integer value
$o(t,x) = \mathrm{nint}(i(t,x))$

pow Power
$o(t,x) = i(t,x)^y$

sqr Square
$o(t,x) = i(t,x)^2$

sqrt Square root
$o(t,x) = \sqrt{i(t,x)}$

exp Exponential
$o(t,x) = \mathrm{e}^{i(t,x)}$

ln Natural logarithm
$o(t,x) = \ln(i(t,x))$

log10 Base 10 logarithm
$o(t,x) = \log_{10}(i(t,x))$

sin Sine
$o(t,x) = \sin(i(t,x))$

cos Cosine
$o(t,x) = \cos(i(t,x))$

tan Tangent
$o(t,x) = \tan(i(t,x))$

asin Arc sine
$o(t,x) = \arcsin(i(t,x))$

acos Arc cosine
$o(t,x) = \arccos(i(t,x))$

atan Arc tangent
$o(t,x) = \arctan(i(t,x))$

reci Reciprocal value
$o(t,x) = 1/i(t,x)$

not Logical NOT
$o(t,x) = 1, if xequal 0; else 0$

Example

To calculate the square root for all field elements use:

```
cdo sqrt infile outfile
```

2.7.3. ARITHC - Arithmetic with a constant

Synopsis

<operator>,*c* `infile outfile`

Description

This module performs simple arithmetic with all field elements of a dataset and a constant. The fields in `outfile` inherit the meta data from `infile`.

Operators

addc Add a constant
$o(t, x) = i(t, x) + c$

subc Subtract a constant
$o(t, x) = i(t, x) - c$

mulc Multiply with a constant
$o(t, x) = i(t, x) * c$

divc Divide by a constant
$o(t, x) = i(t, x)/c$

minc Minimum of a field and a constant
$o(t, x) = \min(i(t, x), c)$

maxc Maximum of a field and a constant
$o(t, x) = \max(i(t, x), c)$

Parameter

c FLOAT Constant

Example

To sum all input fields with the constant -273.15 use:

```
cdo addc,-273.15 infile outfile
```

2.7.4. ARITH - Arithmetic on two datasets

Synopsis

<operator> `infile1 infile2 outfile`

Description

This module performs simple arithmetic of two datasets. The number of fields in `infile1` should be the same as in `infile2`. The fields in `outfile` inherit the meta data from `infile1`. All operators in this module simply process one field after the other from the two input files. Neither the order of the variables nor the date is checked. One of the input files can contain only one timestep or one variable.

Operators

add Add two fields
$o(t,x) = i_1(t,x) + i_2(t,x)$

sub Subtract two fields
$o(t,x) = i_1(t,x) - i_2(t,x)$

mul Multiply two fields
$o(t,x) = i_1(t,x) * i_2(t,x)$

div Divide two fields
$o(t,x) = i_1(t,x)/i_2(t,x)$

min Minimum of two fields
$o(t,x) = \min(i_1(t,x), i_2(t,x))$

max Maximum of two fields
$o(t,x) = \max(i_1(t,x), i_2(t,x))$

atan2 Arc tangent of two fields
The *atan*2 operator calculates the arc tangent of two fields. The result is in radians, which is between -PI and PI (inclusive).

$o(t,x) = \text{atan2}(i_1(t,x), i_2(t,x))$

setmiss Set missing values
Sets missing values of `infile1` to values from `infile2`.

Example

To sum all fields of the first input file with the corresponding fields of the second input file use:

```
cdo add infile1 infile2 outfile
```

2.7.5. DAYARITH - Daily arithmetic

Synopsis

<operator> `infile1 infile2 outfile`

Description

This module performs simple arithmetic of a time series and one timestep with the same day, month and year. For each field in `infile1` the corresponding field of the timestep in `infile2` with the same day, month and year is used. The input files need to have the same structure with the same variables. Usually `infile2` is generated by an operator of the module DAYSTAT.

Operators

dayadd Add daily time series
Adds a time series and a daily time series.

daysub Subtract daily time series
Subtracts a time series and a daily time series.

daymul Multiply daily time series
Multiplies a time series and a daily time series.

daydiv Divide daily time series
Divides a time series and a daily time series.

Example

To subtract a daily time average from a time series use:

```
cdo daysub infile -dayavg infile outfile
```

2.7.6. MONARITH - Monthly arithmetic

Synopsis

<operator> `infile1 infile2 outfile`

Description

This module performs simple arithmetic of a time series and one timestep with the same month and year. For each field in `infile1` the corresponding field of the timestep in `infile2` with the same month and year is used. The input files need to have the same structure with the same variables. Usually `infile2` is generated by an operator of the module MONSTAT.

Operators

monadd Add monthly time series
Adds a time series and a monthly time series.

monsub Subtract monthly time series
Subtracts a time series and a monthly time series.

monmul Multiply monthly time series
Multiplies a time series and a monthly time series.

mondiv Divide monthly time series
Divides a time series and a monthly time series.

Example

To subtract a monthly time average from a time series use:

```
cdo monsub infile -monavg infile outfile
```

2.7.7. YEARARITH - Yearly arithmetic

Synopsis

<operator> `infile1 infile2 outfile`

Description

This module performs simple arithmetic of a time series and one timestep with the same year. For each field in `infile1` the corresponding field of the timestep in `infile2` with the same year is used. The header information in `infile1` have to be the same as in `infile2`. Usually `infile2` is generated by an operator of the module YEARSTAT.

Operators

yearadd Add yearly time series
Adds a time series and a yearly time series.

yearsub Subtract yearly time series
Subtracts a time series and a yearly time series.

yearmul Multiply yearly time series
Multiplies a time series and a yearly time series.

yeardiv Divide yearly time series
Divides a time series and a yearly time series.

Example

To subtract a yearly time average from a time series use:

```
cdo yearsub infile -yearavg infile outfile
```

2.7.8. YHOURARITH - Multi-year hourly arithmetic

Synopsis

<operator> `infile1 infile2 outfile`

Description

This module performs simple arithmetic of a time series and one timestep with the same hour and day of year. For each field in `infile1` the corresponding field of the timestep in `infile2` with the same hour and day of year is used. The input files need to have the same structure with the same variables. Usually `infile2` is generated by an operator of the module YHOURSTAT.

Operators

yhouradd Add multi-year hourly time series
Adds a time series and a multi-year hourly time series.

yhoursub Subtract multi-year hourly time series
Subtracts a time series and a multi-year hourly time series.

yhourmul Multiply multi-year hourly time series
Multiplies a time series and a multi-year hourly time series.

yhourdiv Divide multi-year hourly time series
Divides a time series and a multi-year hourly time series.

Example

To subtract a multi-year hourly time average from a time series use:

```
cdo yhoursub infile -yhouravg infile outfile
```

2.7.9. YDAYARITH - Multi-year daily arithmetic

Synopsis

<*operator*> `infile1 infile2 outfile`

Description

This module performs simple arithmetic of a time series and one timestep with the same day of year. For each field in `infile1` the corresponding field of the timestep in `infile2` with the same day of year is used. The input files need to have the same structure with the same variables. Usually `infile2` is generated by an operator of the module YDAYSTAT.

Operators

ydayadd Add multi-year daily time series
Adds a time series and a multi-year daily time series.

ydaysub Subtract multi-year daily time series
Subtracts a time series and a multi-year daily time series.

ydaymul Multiply multi-year daily time series
Multiplies a time series and a multi-year daily time series.

ydaydiv Divide multi-year daily time series
Divides a time series and a multi-year daily time series.

Example

To subtract a multi-year daily time average from a time series use:

```
cdo ydaysub infile -ydayavg infile outfile
```

2.7.10. YMONARITH - Multi-year monthly arithmetic

Synopsis

<operator> `infile1 infile2 outfile`

Description

This module performs simple arithmetic of a time series and one timestep with the same month of year. For each field in `infile1` the corresponding field of the timestep in `infile2` with the same month of year is used. The input files need to have the same structure with the same variables. Usually `infile2` is generated by an operator of the module YMONSTAT.

Operators

ymonadd Add multi-year monthly time series
Adds a time series and a multi-year monthly time series.

ymonsub Subtract multi-year monthly time series
Subtracts a time series and a multi-year monthly time series.

ymonmul Multiply multi-year monthly time series
Multiplies a time series with a multi-year monthly time series.

ymondiv Divide multi-year monthly time series
Divides a time series by a multi-year monthly time series.

Example

To subtract a multi-year monthly time average from a time series use:

```
cdo ymonsub infile -ymonavg infile outfile
```

2.7.11. YSEASARITH - Multi-year seasonal arithmetic

Synopsis

<*operator*> `infile1 infile2 outfile`

Description

This module performs simple arithmetic of a time series and one timestep with the same season. For each field in `infile1` the corresponding field of the timestep in `infile2` with the same season is used. The input files need to have the same structure with the same variables. Usually `infile2` is generated by an operator of the module YSEASSTAT.

Operators

yseasadd Add multi-year seasonal time series
Adds a time series and a multi-year seasonal time series.

yseassub Subtract multi-year seasonal time series
Subtracts a time series and a multi-year seasonal time series.

yseasmul Multiply multi-year seasonal time series
Multiplies a time series and a multi-year seasonal time series.

yseasdiv Divide multi-year seasonal time series
Divides a time series and a multi-year seasonal time series.

Example

To subtract a multi-year seasonal time average from a time series use:

```
cdo yseassub infile -yseasavg infile outfile
```

2.7.12. ARITHDAYS - Arithmetic with days

Synopsis

<operator> `infile outfile`

Description

This module multiplies or divides each timestep of a dataset with the corresponding days per month or days per year. The result of these functions depends on the used calendar of the input data.

Operators

muldpm Multiply with days per month
$o(t,x) = i(t,x) * days\_per\_month$

divdpm Divide by days per month
$o(t,x) = i(t,x)/days\_per\_month$

muldpy Multiply with days per year
$o(t,x) = i(t,x) * days\_per\_year$

divdpy Divide by days per year
$o(t,x) = i(t,x)/days\_per\_year$

2.7.13. ARITHLAT - Arithmetic with latitude

Synopsis

<operator> `infile outfile`

Description

This module multiplies or divides each field element with the cosine of the latitude.

Operators

mulcoslat Multiply with the cosine of the latitude
$o(t,x) = i(t,x) * cos(latitude(x))$

divcoslat Divide by cosine of the latitude
$o(t,x) = i(t,x)/cos(latitude(x))$

2.8. Statistical values

This section contains modules to compute statistical values of datasets. In this program there is the different notion of "mean" and "average" to distinguish two different kinds of treatment of missing values. While computing the mean, only the not missing values are considered to belong to the sample with the side effect of a probably reduced sample size. Computing the average is just adding the sample members and divide the result by the sample size. For example, the mean of 1, 2, miss and 3 is (1+2+3)/3 = 2, whereas the average is (1+2+miss+3)/4 = miss/4 = miss. If there are no missing values in the sample, the average and the mean are identical.
CDO is using the verification time to identify the time range for temporal statistics. The time bounds are never used!

In this section the abbreviations as in the following table are used:

sum	$\sum_{i=1}^{n} x_i$
mean resp. **avg** $\overline{x}$	$n^{-1} \sum_{i=1}^{n} x_i$
mean resp. **avg** weighted by $\{w_i, i = 1, ..., n\}$	$\left(\sum_{j=1}^{n} w_j \right)^{-1} \sum_{i=1}^{n} w_i \, x_i$
Variance **var**	$n^{-1} \sum_{i=1}^{n} (x_i - \overline{x})^2$
var1	$(n-1)^{-1} \sum_{i=1}^{n} (x_i - \overline{x})^2$
var weighted by $\{w_i, i = 1, ..., n\}$	$\left(\sum_{j=1}^{n} w_j \right)^{-1} \sum_{i=1}^{n} w_i \left(x_i - \left(\sum_{j=1}^{n} w_j \right)^{-1} \sum_{j=1}^{n} w_j \, x_j \right)^2$
Standard deviation **std** s	$\sqrt{n^{-1} \sum_{i=1}^{n} (x_i - \overline{x})^2}$
std1	$\sqrt{(n-1)^{-1} \sum_{i=1}^{n} (x_i - \overline{x})^2}$
std weighted by $\{w_i, i = 1, ..., n\}$	$\sqrt{\left(\sum_{j=1}^{n} w_j \right)^{-1} \sum_{i=1}^{n} w_i \left(x_i - \left(\sum_{j=1}^{n} w_j \right)^{-1} \sum_{j=1}^{n} w_j \, x_j \right)^2}$
median	$\begin{cases} x_{\frac{n+1}{2}} & \text{if } n \text{ is odd} \\ \frac{1}{2} \left(x_{\frac{n}{2}} + x_{\frac{n}{2}+1} \right) & \text{if } n \text{ is even} \end{cases}$

Skewness **skew**	$\frac{\sum_{i=1}^{n}(x_i - \overline{x})/n}{s^3}$
Kurtosis **kurt**	$\frac{\sum_{i=1}^{n}(x_i - \overline{x})^4/n}{s^4}$
Cumulative Ranked Probability Score **crps**	$\int_{-\infty}^{\infty} [H(x_1) - cdf(\{x_2 \dots x_n\})\|_r]^2 \, dr$

with $cdf(X)|_r$ being the cumulative distribution function of $\{x_i, i = 2 \dots n\}$ at r

and $H(x)$ the Heavyside function jumping at x.

Here is a short overview of all operators in this section:

timcumsum	Cumulative sum over all timesteps
consecsum	Consecutive Sum
consects	Consecutive Timesteps
varsmin	Variables minimum
varsmax	Variables maximum
varsrange	Variables range
varssum	Variables sum
varsmean	Variables mean
varsavg	Variables average
varsstd	Variables standard deviation
varsstd1	Variables standard deviation (n-1)
varsvar	Variables variance
varsvar1	Variables variance (n-1)
ensmin	Ensemble minimum
ensmax	Ensemble maximum
ensrange	Ensemble range
enssum	Ensemble sum
ensmean	Ensemble mean
ensavg	Ensemble average
ensstd	Ensemble standard deviation
ensstd1	Ensemble standard deviation (n-1)
ensvar	Ensemble variance
ensvar1	Ensemble variance (n-1)
ensskew	Ensemble skewness
enskurt	Ensemble kurtosis
ensmedian	Ensemble median
enspctl	Ensemble percentiles
ensrkhistspace	Ranked Histogram averaged over space
ensrkhisttime	Ranked Histogram averaged over time
ensroc	Ensemble Receiver Operating characteristics
enscrps	Ensemble CRPS and decomposition
ensbrs	Ensemble Brier score

fldmin	Field minimum
fldmax	Field maximum
fldrange	Field range
fldsum	Field sum
fldint	Field integral
fldmean	Field mean
fldavg	Field average
fldstd	Field standard deviation
fldstd1	Field standard deviation (n-1)
fldvar	Field variance
fldvar1	Field variance (n-1)
fldskew	Field skewness
fldkurt	Field kurtosis
fldmedian	Field median
fldcount	Field count
fldpctl	Field percentiles

zonmin	Zonal minimum
zonmax	Zonal maximum
zonrange	Zonal range
zonsum	Zonal sum
zonmean	Zonal mean
zonavg	Zonal average
zonstd	Zonal standard deviation
zonstd1	Zonal standard deviation (n-1)
zonvar	Zonal variance
zonvar1	Zonal variance (n-1)
zonskew	Zonal skewness
zonkurt	Zonal kurtosis
zonmedian	Zonal median
zonpctl	Zonal percentiles

mermin	Meridional minimum
mermax	Meridional maximum
merrange	Meridional range
mersum	Meridional sum
mermean	Meridional mean
meravg	Meridional average
merstd	Meridional standard deviation
merstd1	Meridional standard deviation (n-1)
mervar	Meridional variance
mervar1	Meridional variance (n-1)
merskew	Meridional skewness
merkurt	Meridional kurtosis
mermedian	Meridional median
merpctl	Meridional percentiles

gridboxmin	Gridbox minimum
gridboxmax	Gridbox maximum
gridboxrange	Gridbox range
gridboxsum	Gridbox sum
gridboxmean	Gridbox mean
gridboxavg	Gridbox average
gridboxstd	Gridbox standard deviation
gridboxstd1	Gridbox standard deviation (n-1)
gridboxvar	Gridbox variance
gridboxvar1	Gridbox variance (n-1)
gridboxskew	Gridbox skewness
gridboxkurt	Gridbox kurtosis
gridboxmedian	Gridbox median

remapmin	Remap minimum
remapmax	Remap maximum
remaprange	Remap range
remapsum	Remap sum
remapmean	Remap mean
remapavg	Remap average
remapstd	Remap standard deviation
remapstd1	Remap standard deviation (n-1)
remapvar	Remap variance
remapvar1	Remap variance (n-1)
remapskew	Remap skewness
remapkurt	Remap kurtosis
remapmedian	Remap median

vertmin	Vertical minimum
vertmax	Vertical maximum
vertrange	Vertical range
vertsum	Vertical sum
vertmean	Vertical mean
vertavg	Vertical average
vertstd	Vertical standard deviation
vertstd1	Vertical standard deviation (n-1)
vertvar	Vertical variance
vertvar1	Vertical variance (n-1)

timselmin	Time selection minimum
timselmax	Time selection maximum
timselrange	Time selection range
timselsum	Time selection sum
timselmean	Time selection mean
timselavg	Time selection average
timselstd	Time selection standard deviation
timselstd1	Time selection standard deviation (n-1)
timselvar	Time selection variance
timselvar1	Time selection variance (n-1)

timselpctl	Time range percentiles

runmin	Running minimum
runmax	Running maximum
runrange	Running range
runsum	Running sum
runmean	Running mean
runavg	Running average
runstd	Running standard deviation
runstd1	Running standard deviation (n-1)
runvar	Running variance
runvar1	Running variance (n-1)
runpctl	Running percentiles
timmin	Time minimum
timmax	Time maximum
timminidx	Index of time minimum
timmaxidx	Index of time maximum
timrange	Time range
timsum	Time sum
timmean	Time mean
timavg	Time average
timstd	Time standard deviation
timstd1	Time standard deviation (n-1)
timvar	Time variance
timvar1	Time variance (n-1)
timpctl	Time percentiles
hourmin	Hourly minimum
hourmax	Hourly maximum
hourrange	Hourly range
hoursum	Hourly sum
hourmean	Hourly mean
houravg	Hourly average
hourstd	Hourly standard deviation
hourstd1	Hourly standard deviation (n-1)
hourvar	Hourly variance
hourvar1	Hourly variance (n-1)
hourpctl	Hourly percentiles
daymin	Daily minimum
daymax	Daily maximum
dayrange	Daily range
daysum	Daily sum
daymean	Daily mean
dayavg	Daily average
daystd	Daily standard deviation
daystd1	Daily standard deviation (n-1)
dayvar	Daily variance
dayvar1	Daily variance (n-1)
daypctl	Daily percentiles

monmin	Monthly minimum
monmax	Monthly maximum
monrange	Monthly range
monsum	Monthly sum
monmean	Monthly mean
monavg	Monthly average
monstd	Monthly standard deviation
monstd1	Monthly standard deviation (n-1)
monvar	Monthly variance
monvar1	Monthly variance (n-1)
monpctl	Monthly percentiles
yearmonmean	Yearly mean from monthly data
yearmin	Yearly minimum
yearmax	Yearly maximum
yearminidx	Index of yearly minimum
yearmaxidx	Index of yearly maximum
yearrange	Yearly range
yearsum	Yearly sum
yearmean	Yearly mean
yearavg	Yearly average
yearstd	Yearly standard deviation
yearstd1	Yearly standard deviation (n-1)
yearvar	Yearly variance
yearvar1	Yearly variance (n-1)
yearpctl	Yearly percentiles
seasmin	Seasonal minimum
seasmax	Seasonal maximum
seasrange	Seasonal range
seassum	Seasonal sum
seasmean	Seasonal mean
seasavg	Seasonal average
seasstd	Seasonal standard deviation
seasstd1	Seasonal standard deviation (n-1)
seasvar	Seasonal variance
seasvar1	Seasonal variance (n-1)
seaspctl	Seasonal percentiles
yhourmin	Multi-year hourly minimum
yhourmax	Multi-year hourly maximum
yhourrange	Multi-year hourly range
yhoursum	Multi-year hourly sum
yhourmean	Multi-year hourly mean
yhouravg	Multi-year hourly average
yhourstd	Multi-year hourly standard deviation
yhourstd1	Multi-year hourly standard deviation (n-1)
yhourvar	Multi-year hourly variance
yhourvar1	Multi-year hourly variance (n-1)

dhourmin	Multi-day hourly minimum
dhourmax	Multi-day hourly maximum
dhourrange	Multi-day hourly range
dhoursum	Multi-day hourly sum
dhourmean	Multi-day hourly mean
dhouravg	Multi-day hourly average
dhourstd	Multi-day hourly standard deviation
dhourstd1	Multi-day hourly standard deviation (n-1)
dhourvar	Multi-day hourly variance
dhourvar1	Multi-day hourly variance (n-1)

dminutemin	Multi-day by the minute minimum
dminutemax	Multi-day by the minute maximum
dminuterange	Multi-day by the minute range
dminutesum	Multi-day by the minute sum
dminutemean	Multi-day by the minute mean
dminuteavg	Multi-day by the minute average
dminutestd	Multi-day by the minute standard deviation
dminutestd1	Multi-day by the minute standard deviation (n-1)
dminutevar	Multi-day by the minute variance
dminutevar1	Multi-day by the minute variance (n-1)

ydaymin	Multi-year daily minimum
ydaymax	Multi-year daily maximum
ydayrange	Multi-year daily range
ydaysum	Multi-year daily sum
ydaymean	Multi-year daily mean
ydayavg	Multi-year daily average
ydaystd	Multi-year daily standard deviation
ydaystd1	Multi-year daily standard deviation (n-1)
ydayvar	Multi-year daily variance
ydayvar1	Multi-year daily variance (n-1)

ydaypctl	Multi-year daily percentiles

ymonmin	Multi-year monthly minimum
ymonmax	Multi-year monthly maximum
ymonrange	Multi-year monthly range
ymonsum	Multi-year monthly sum
ymonmean	Multi-year monthly mean
ymonavg	Multi-year monthly average
ymonstd	Multi-year monthly standard deviation
ymonstd1	Multi-year monthly standard deviation (n-1)
ymonvar	Multi-year monthly variance
ymonvar1	Multi-year monthly variance (n-1)

ymonpctl	Multi-year monthly percentiles

yseasmin	Multi-year seasonal minimum
yseasmax	Multi-year seasonal maximum
yseasrange	Multi-year seasonal range
yseassum	Multi-year seasonal sum
yseasmean	Multi-year seasonal mean
yseasavg	Multi-year seasonal average
yseasstd	Multi-year seasonal standard deviation
yseasstd1	Multi-year seasonal standard deviation (n-1)
yseasvar	Multi-year seasonal variance
yseasvar1	Multi-year seasonal variance (n-1)
yseaspctl	Multi-year seasonal percentiles
ydrunmin	Multi-year daily running minimum
ydrunmax	Multi-year daily running maximum
ydrunsum	Multi-year daily running sum
ydrunmean	Multi-year daily running mean
ydrunavg	Multi-year daily running average
ydrunstd	Multi-year daily running standard deviation
ydrunstd1	Multi-year daily running standard deviation (n-1)
ydrunvar	Multi-year daily running variance
ydrunvar1	Multi-year daily running variance (n-1)
ydrunpctl	Multi-year daily running percentiles

2.8.1. TIMCUMSUM - Cumulative sum over all timesteps

Synopsis

timcumsum `infile outfile`

Description

The timcumsum operator calculates the cumulative sum over all timesteps. Missing values are treated as numeric zero when summing.

$o(t,x) = \mathbf{sum}\{i(t',x), 0 < t' \leq t\}$

2.8.2. CONSECSTAT - Consecute timestep periods

Synopsis

<operator> `infile outfile`

Description

This module computes periods over all timesteps in `infile` where a certain property is valid. The property can be chosen by creating a mask from the original data, which is the expected input format for operators of this module. Depending on the operator full information about each period or just its length and ending date are computed.

Operators

consecsum Consecutive Sum
This operator computes periods of consecutive timesteps similar to a runsum, but periods are finished, when the mask value is 0. That way multiple periods can be found. Timesteps from the input are preserved. Missing values are handled like 0, i.e. finish periods of consecutive timesteps.

consects Consecutive Timesteps
In contrast to the operator above consects only computes the length of each period together with its last timestep. To be able to perform statistical analysis like min, max or mean, everything else is set to missing value.

Example

For a given time series of daily temperatures, the periods of summer days can be calculated with inplace maskting the input field:

```
cdo consects -gtc,20.0 infile1 outfile
```

2.8.3. VARSSTAT - Statistical values over all variables

Synopsis

<operator> `infile outfile`

Description

This module computes statistical values over all variables for each timestep. Depending on the chosen operator the minimum, maximum, range, sum, average, variance or standard deviation is written to `outfile`. All input variables need to have the same gridsize and the same number of levels.

Operators

varsmin Variables minimum
For every timestep the minimum over all variables is computed.

varsmax Variables maximum
For every timestep the maximum over all variables is computed.

varsrange Variables range
For every timestep the range over all variables is computed.

varssum Variables sum
For every timestep the sum over all variables is computed.

varsmean Variables mean
For every timestep the mean over all variables is computed.

varsavg Variables average
For every timestep the average over all variables is computed.

varsstd Variables standard deviation
For every timestep the standard deviation over all variables is computed. Normalize by n.

varsstd1 Variables standard deviation (n-1)
For every timestep the standard deviation over all variables is computed. Normalize by (n-1).

varsvar Variables variance
For every timestep the variance over all variables is computed. Normalize by n.

varsvar1 Variables variance (n-1)
For every timestep the variance over all variables is computed. Normalize by (n-1).

2.8.4. ENSSTAT - Statistical values over an ensemble

Synopsis

<operator> `infiles outfile`

enspctl,*p* `infiles outfile`

Description

This module computes statistical values over an ensemble of input files. Depending on the chosen operator, the minimum, maximum, range, sum, average, standard deviation, variance, skewness, kurtosis, median or a certain percentile over all input files is written to `outfile`. All input files need to have the same structure with the same variables. The date information of a timestep in `outfile` is the date of the first input file.

Operators

ensmin Ensemble minimum
$o(t,x) = \mathbf{min}\{i_1(t,x), i_2(t,x), \cdots, i_n(t,x)\}$

ensmax Ensemble maximum
$o(t,x) = \mathbf{max}\{i_1(t,x), i_2(t,x), \cdots, i_n(t,x)\}$

ensrange Ensemble range
$o(t,x) = \mathbf{range}\{i_1(t,x), i_2(t,x), \cdots, i_n(t,x)\}$

enssum Ensemble sum
$o(t,x) = \mathbf{sum}\{i_1(t,x), i_2(t,x), \cdots, i_n(t,x)\}$

ensmean Ensemble mean
$o(t,x) = \mathbf{mean}\{i_1(t,x), i_2(t,x), \cdots, i_n(t,x)\}$

ensavg Ensemble average
$o(t,x) = \mathbf{avg}\{i_1(t,x), i_2(t,x), \cdots, i_n(t,x)\}$

ensstd Ensemble standard deviation
Normalize by n.

$o(t,x) = \mathbf{std}\{i_1(t,x), i_2(t,x), \cdots, i_n(t,x)\}$

ensstd1 Ensemble standard deviation (n-1)
Normalize by (n-1).

$o(t,x) = \mathbf{std1}\{i_1(t,x), i_2(t,x), \cdots, i_n(t,x)\}$

ensvar Ensemble variance
Normalize by n.

$o(t,x) = \mathbf{var}\{i_1(t,x), i_2(t,x), \cdots, i_n(t,x)\}$

ensvar1 Ensemble variance (n-1)
Normalize by (n-1).

$o(t,x) = \mathbf{var1}\{i_1(t,x), i_2(t,x), \cdots, i_n(t,x)\}$

ensskew Ensemble skewness
$o(t,x) = \mathbf{skew}\{i_1(t,x), i_2(t,x), \cdots, i_n(t,x)\}$

enskurt Ensemble kurtosis
$o(t,x) = \mathbf{kurt}\{i_1(t,x), i_2(t,x), \cdots, i_n(t,x)\}$

ensmedian Ensemble median
$o(t,x) = \mathbf{median}\{i_1(t,x), i_2(t,x), \cdots, i_n(t,x)\}$

enspctl Ensemble percentiles
$o(t,x) = \mathbf{pth\ percentile}\{i_1(t,x), i_2(t,x), \cdots, i_n(t,x)\}$

Parameter

p	FLOAT	Percentile number in 0, ..., 100

Note

Operators of this module need to open all input files simultaneously. The maximum number of open files depends on the operating system!

Example

To compute the ensemble mean over 6 input files use:

```
cdo ensmean infile1 infile2 infile3 infile4 infile5 infile6 outfile
```

Or shorter with filename substitution:

```
cdo ensmean infile[1-6] outfile
```

To compute the 50th percentile (median) over 6 input files use:

```
cdo enspctl,50 infile1 infile2 infile3 infile4 infile5 infile6 outfile
```

2.8.5. ENSSTAT2 - Statistical values over an ensemble

Synopsis

<operator> `obsfile ensfiles outfile`

Description

This module computes statistical values over the ensemble of `ensfiles` using `obsfile` as a reference. Depending on the operator a ranked Histogram or a roc-curve over all Ensembles `ensfiles` with reference to `obsfile` is written to `outfile`. The date and grid information of a timestep in `outfile` is the date of the first input file. Thus all input files are required to have the same structure in terms of the gridsize, variable definitions and number of timesteps.

All Operators in this module use `obsfile` as the reference (for instance an observation) whereas `ensfiles` are understood as an ensemble consisting of n (where n is the number of `ensfiles`) members.

The operators ensrkhistspace and ensrkhisttime compute Ranked Histograms. Therefor the vertical axis is utilized as the Histogram axis, which prohibits the use of files containing more than one level. The histogram axis has nensfiles+1 bins with level 0 containing for each grid point the number of observations being smaller as all ensembles and level nensfiles+1 indicating the number of observations being larger than all ensembles.

ensrkhisttime computes a ranked histogram at each timestep reducing each horizontal grid to a 1x1 grid and keeping the time axis as in `obsfile`. Contrary ensrkhistspace computes a histogram at each grid point keeping the horizontal grid for each variable and reducing the time-axis. The time information is that from the last timestep in `obsfile`.

Operators

ensrkhistspace Ranked Histogram averaged over space

ensrkhisttime Ranked Histogram averaged over time

ensroc Ensemble Receiver Operating characteristics

Example

To compute a rank histogram over 5 input files `ensfile1-ensfile5` given an observation in `obsfile` use:

```
cdo ensrkhisttime obsfile ensfile1 ensfile2 ensfile3 ensfile4 ensfile5 outfile
```

Or shorter with filename substitution:

```
cdo ensrkhisttime obsfile ensfile[1-5] outfile
```

2.8.6. ENSVAL - Ensemble validation tools

Synopsis

enscrps `rfile infiles outfilebase`

ensbrs,*x* `rfile infiles outfilebase`

Description

This module computes ensemble validation scores and their decomposition such as the Brier and cumulative ranked probability score (CRPS). The first file is used as a reference it can be a climatology, observation or reanalysis against which the skill of the ensembles given in infiles is measured. Depending on the operator a number of output files is generated each containing the skill score and its decomposition corresponding to the operator. The output is averaged over horizontal fields using appropriate weights for each level and timestep in rfile.

All input files need to have the same structure with the same variables. The date information of a timestep in `outfile` is the date of the first input file. The output files are named as <outfilebase>.<type>.<filesu where <type> depends on the operator and <filesuffix> is determined from the output file type. There are three output files for operator enscrps and four output files for operator ensbrs.

The CRPS and its decomposition into Reliability and the potential CRPS are calculated by an appropriate averaging over the field members (note, that the CRPS does *not* average linearly). In the three output files <type> has the following meaning: `crps` for the CRPS, `reli` for the reliability and `crpspot` for the potential crps. The relation $CRPS = CRPS_{pot} + RELI$

holds.

The Brier score of the Ensemble given by `infiles` with respect to the reference given in `rfile` and the threshold x is calculated. In the four output files <type> has the following meaning: `brs` for the Brier score wrt threshold x; `brsreli` for the Brier score reliability wrt threshold x; `brsreso` for the Brier score resolution wrt threshold x; `brsunct` for the Brier score uncertainty wrt threshold x. In analogy to the CRPS the following relation holds: $BRS(x) = RELI(x) - RESO(x) + UNCT(x)$.

The implementation of the decomposition of the CRPS and Brier Score follows Hans Hersbach (2000): Decomposition of the Continuous Ranked Probability Score for Ensemble Prediction Systems, in: Weather and Forecasting (15) pp. 559-570.

The CRPS code decomposition has been verified against the CRAN - ensemble validation package from R. Differences occur when grid-cell area is not uniform as the implementation in R does not account for that.

Operators

enscrps Ensemble CRPS and decomposition

ensbrs Ensemble Brier score
Ensemble Brier Score and Decomposition

Example

To compute the field averaged Brier score at x=5 over an ensemble with 5 members `ensfile1-5` w.r.t. the reference `rfile` and write the results to files `obase.brs.`<suff>, `obase.brsreli`<suff>, `obase.brsreso`<suff>, `obase.brsunct`<suff> where <suff> is determined from the output file type, use

```
cdo ensbrs,5 rfile ensfile1 ensfile2 ensfile3 ensfile4 ensfile5 obase
```

or shorter using file name substitution:

```
cdo ensbrs,5 rfile ensfile[1-5] obase
```

2.8.7. FLDSTAT - Statistical values over a field

Synopsis

<operator> `infile outfile`

fldint,*weights* `infile outfile`

fldmean,*weights* `infile outfile`

fldavg,*weights* `infile outfile`

fldstd,*weights* `infile outfile`

fldstd1,*weights* `infile outfile`

fldvar,*weights* `infile outfile`

fldvar1,*weights* `infile outfile`

fldpctl,*p* `infile outfile`

Description

This module computes statistical values of all input fields. A field is a horizontal layer of a data variable. Depending on the chosen operator, the minimum, maximum, range, sum, integral, average, standard deviation, variance, skewness, kurtosis, median or a certain percentile of the field is written to `outfile`.

Operators

fldmin Field minimum
For every gridpoint $x\_1, ..., x\_n$ of the same field it is:
$o(t,1) = \mathbf{min}\{i(t,x'), x_1 < x' \leq x_n\}$

fldmax Field maximum
For every gridpoint $x\_1, ..., x\_n$ of the same field it is:
$o(t,1) = \mathbf{max}\{i(t,x'), x_1 < x' \leq x_n\}$

fldrange Field range
For every gridpoint $x\_1, ..., x\_n$ of the same field it is:
$o(t,1) = \mathbf{range}\{i(t,x'), x_1 < x' \leq x_n\}$

fldsum Field sum
For every gridpoint $x\_1, ..., x\_n$ of the same field it is:
$o(t,1) = \mathbf{sum}\{i(t,x'), x_1 < x' \leq x_n\}$

fldint Field integral
For every gridpoint $x\_1, ..., x\_n$ of the same field it is:
$o(t,1) = \mathbf{sum}\{i(t,x') * cellarea(x'), x_1 < x' \leq x_n\}$

fldmean Field mean
For every gridpoint $x\_1, ..., x\_n$ of the same field it is:
$o(t,1) = \mathbf{mean}\{i(t,x'), x_1 < x' \leq x_n\}$

weighted by area weights obtained by the input field.

fldavg Field average
For every gridpoint $x\_1, ..., x\_n$ of the same field it is:
$o(t,1) = \mathbf{avg}\{i(t,x'), x_1 < x' \leq x_n\}$

weighted by area weights obtained by the input field.

fldstd Field standard deviation
Normalize by n. For every gridpoint $x\_1, ..., x\_n$ of the same field it is:
$o(t, 1) = \mathbf{std}\{i(t, x'), x_1 < x' \leq x_n\}$

weighted by area weights obtained by the input field.

fldstd1 Field standard deviation (n-1)
Normalize by (n-1). For every gridpoint $x\_1, ..., x\_n$ of the same field it is:
$o(t, 1) = \mathbf{std1}\{i(t, x'), x_1 < x' \leq x_n\}$

weighted by area weights obtained by the input field.

fldvar Field variance
Normalize by n. For every gridpoint $x\_1, ..., x\_n$ of the same field it is:
$o(t, 1) = \mathbf{var}\{i(t, x'), x_1 < x' \leq x_n\}$

weighted by area weights obtained by the input field.

fldvar1 Field variance (n-1)
Normalize by (n-1). For every gridpoint $x\_1, ..., x\_n$ of the same field it is:
$o(t, 1) = \mathbf{var1}\{i(t, x'), x_1 < x' \leq x_n\}$

weighted by area weights obtained by the input field.

fldskew Field skewness
For every gridpoint $x\_1, ..., x\_n$ of the same field it is:
$o(t, 1) = \mathbf{skew}\{i(t, x'), x_1 < x' \leq x_n\}$

fldkurt Field kurtosis
For every gridpoint $x\_1, ..., x\_n$ of the same field it is:
$o(t, 1) = \mathbf{kurt}\{i(t, x'), x_1 < x' \leq x_n\}$

fldmedian Field median
For every gridpoint $x\_1, ..., x\_n$ of the same field it is:
$o(t, 1) = \mathbf{median}\{i(t, x'), x_1 < x' \leq x_n\}$

fldcount Field count
Number of non-missing values of the field.

fldpctl Field percentiles
For every gridpoint $x\_1, ..., x\_n$ of the same field it is:
$o(t, 1) = \mathbf{pth\ percentile}\{i(t, x'), x_1 < x' \leq x_n\}$

Parameter

weights	BOOL	weights=FALSE disables weighting by grid cell area [default: weights=TRUE]
p	FLOAT	Percentile number in 0, ..., 100

Example

To compute the field mean of all input fields use:

```
cdo fldmean infile outfile
```

To compute the 90th percentile of all input fields use:

```
cdo fldpctl,90 infile outfile
```

2.8.8. ZONSTAT - Zonal statistics

Synopsis

<operator> `infile outfile`

zonmean*[,zonaldes]* `infile outfile`

zonpctl,*p* `infile outfile`

Description

This module computes zonal statistical values of the input fields. Depending on the chosen operator, the zonal minimum, maximum, range, sum, average, standard deviation, variance, skewness, kurtosis, median or a certain percentile of the field is written to `outfile`. Operators of this module require all variables on the same regular lon/lat grid. Only the zonal mean (zonmean) can be calculated for data on an unstructured grid if the latitude bins are defined with the optional parameter zonaldes.

Operators

zonmin Zonal minimum
For every latitude the minimum over all longitudes is computed.

zonmax Zonal maximum
For every latitude the maximum over all longitudes is computed.

zonrange Zonal range
For every latitude the range over all longitudes is computed.

zonsum Zonal sum
For every latitude the sum over all longitudes is computed.

zonmean Zonal mean
For every latitude the mean over all longitudes is computed. Use the optional parameter zonaldes for data on an unstructured grid.

zonavg Zonal average
For every latitude the average over all longitudes is computed.

zonstd Zonal standard deviation
For every latitude the standard deviation over all longitudes is computed. Normalize by n.

zonstd1 Zonal standard deviation (n-1)
For every latitude the standard deviation over all longitudes is computed. Normalize by (n-1).

zonvar Zonal variance
For every latitude the variance over all longitudes is computed. Normalize by n.

zonvar1 Zonal variance (n-1)
For every latitude the variance over all longitudes is computed. Normalize by (n-1).

zonskew Zonal skewness
For every latitude the skewness over all longitudes is computed.

zonkurt Zonal kurtosis
For every latitude the kurtosis over all longitudes is computed.

zonmedian Zonal median
For every latitude the median over all longitudes is computed.

zonpctl Zonal percentiles
For every latitude the pth percentile over all longitudes is computed.

Parameter

p	FLOAT	Percentile number in 0, ..., 100
zonaldes	STRING	Description of the zonal latitude bins needed for data on an unstructured grid. A predefined zonal description is zonal_<DY>. DY is the increment of the latitudes in degrees.

Example

To compute the zonal mean of all input fields use:

```
cdo zonmean infile outfile
```

To compute the 50th meridional percentile (median) of all input fields use:

```
cdo zonpctl,50 infile outfile
```

2.8.9. MERSTAT - Meridional statistics

Synopsis

<operator> `infile outfile`

merpctl,*p* `infile outfile`

Description

This module computes meridional statistical values of the input fields. Depending on the chosen operator, the meridional minimum, maximum, range, sum, average, standard deviation, variance, skewness, kurtosis, median or a certain percentile of the field is written to `outfile`. Operators of this module require all variables on the same regular lon/lat grid.

Operators

mermin Meridional minimum
For every longitude the minimum over all latitudes is computed.

mermax Meridional maximum
For every longitude the maximum over all latitudes is computed.

merrange Meridional range
For every longitude the range over all latitudes is computed.

mersum Meridional sum
For every longitude the sum over all latitudes is computed.

mermean Meridional mean
For every longitude the area weighted mean over all latitudes is computed.

meravg Meridional average
For every longitude the area weighted average over all latitudes is computed.

merstd Meridional standard deviation
For every longitude the standard deviation over all latitudes is computed. Normalize by n.

merstd1 Meridional standard deviation (n-1)
For every longitude the standard deviation over all latitudes is computed. Normalize by (n-1).

mervar Meridional variance
For every longitude the variance over all latitudes is computed. Normalize by n.

mervar1 Meridional variance (n-1)
For every longitude the variance over all latitudes is computed. Normalize by (n-1).

merskew Meridional skewness
For every longitude the skewness over all latitudes is computed.

merkurt Meridional kurtosis
For every longitude the kurtosis over all latitudes is computed.

mermedian Meridional median
For every longitude the median over all latitudes is computed.

merpctl Meridional percentiles
For every longitude the pth percentile over all latitudes is computed.

Parameter

p FLOAT Percentile number in 0, ..., 100

Example

To compute the meridional mean of all input fields use:

```
cdo mermean infile outfile
```

To compute the 50th meridional percentile (median) of all input fields use:

```
cdo merpctl,50 infile outfile
```

2.8.10. GRIDBOXSTAT - Statistical values over grid boxes

Synopsis

<operator>,nx,ny `infile outfile`

Description

This module computes statistical values over surrounding grid boxes. Depending on the chosen operator, the minimum, maximum, range, sum, average, standard deviation, variance, skewness, kurtosis or median of the neighboring grid boxes is written to `outfile`. All gridbox operators only work on quadrilateral curvilinear grids.

Operators

gridboxmin Gridbox minimum
Minimum value of the selected grid boxes.

gridboxmax Gridbox maximum
Maximum value of the selected grid boxes.

gridboxrange Gridbox range
Range (max-min value) of the selected grid boxes.

gridboxsum Gridbox sum
Sum of the selected grid boxes.

gridboxmean Gridbox mean
Mean of the selected grid boxes.

gridboxavg Gridbox average
Average of the selected grid boxes.

gridboxstd Gridbox standard deviation
Standard deviation of the selected grid boxes. Normalize by n.

gridboxstd1 Gridbox standard deviation (n-1)
Standard deviation of the selected grid boxes. Normalize by (n-1).

gridboxvar Gridbox variance
Variance of the selected grid boxes. Normalize by n.

gridboxvar1 Gridbox variance (n-1)
Variance of the selected grid boxes. Normalize by (n-1).

gridboxskew Gridbox skewness
Skewness of the selected grid boxes.

gridboxkurt Gridbox kurtosis
Kurtosis of the selected grid boxes.

gridboxmedian Gridbox median
Median of the selected grid boxes.

Parameter

nx	INTEGER	Number of grid boxes in x direction
ny	INTEGER	Number of grid boxes in y direction

Example

To compute the mean over 10x10 grid boxes of the input field use:

```
cdo gridboxmean,10,10 infile outfile
```

2.8.11. REMAPSTAT - Remaps source points to target cells

Synopsis

<operator>,grid `infile outfile`

Description

This module maps source points to target cells by calculating a statistical value from the source points. Each target cell contains the statistical value from all source points within that target cell. If there are no source points within a target cell, it gets a missing value. Depending on the chosen operator the minimum, maximum, range, sum, average, variance, standard deviation, skewness, kurtosis or median of source points is computed.

Operators

remapmin Remap minimum
Minimum value of the source points.

remapmax Remap maximum
Maximum value of the source points.

remaprange Remap range
Range (max-min value) of the source points.

remapsum Remap sum
Sum of the source points.

remapmean Remap mean
Mean of the source points.

remapavg Remap average
Average of the source points.

remapstd Remap standard deviation
Standard deviation of the source points. Normalize by n.

remapstd1 Remap standard deviation (n-1)
Standard deviation of the source points. Normalize by (n-1).

remapvar Remap variance
Variance of the source points. Normalize by n.

remapvar1 Remap variance (n-1)
Variance of the source points. Normalize by (n-1).

remapskew Remap skewness
Skewness of the source points.

remapkurt Remap kurtosis
Kurtosis of the source points.

remapmedian Remap median
Median of the source points.

Parameter

grid STRING Target grid description file or name

Example

To compute the mean over source points within the taget cells, use:

```
cdo remapmean,<targetgrid> infile outfile
```

If some of the target cells contain missing values, use the Operator setmisstonn to fill these missing values with the nearest neighbor cell:

```
cdo setmisstonn -remapmean,<targetgrid> infile outfile
```

2.8.12. VERTSTAT - Vertical statistics

Synopsis

<operator>,weights `infile outfile`

Description

This module computes statistical values over all levels of the input variables. According to chosen operator the vertical minimum, maximum, range, sum, average, variance or standard deviation is written to `outfile`.

Operators

vertmin Vertical minimum
For every gridpoint the minimum over all levels is computed.

vertmax Vertical maximum
For every gridpoint the maximum over all levels is computed.

vertrange Vertical range
For every gridpoint the range over all levels is computed.

vertsum Vertical sum
For every gridpoint the sum over all levels is computed.

vertmean Vertical mean
For every gridpoint the layer weighted mean over all levels is computed.

vertavg Vertical average
For every gridpoint the layer weighted average over all levels is computed.

vertstd Vertical standard deviation
For every gridpoint the standard deviation over all levels is computed. Normalize by n.

vertstd1 Vertical standard deviation (n-1)
For every gridpoint the standard deviation over all levels is computed. Normalize by (n-1).

vertvar Vertical variance
For every gridpoint the variance over all levels is computed. Normalize by n.

vertvar1 Vertical variance (n-1)
For every gridpoint the variance over all levels is computed. Normalize by (n-1).

Parameter

weights BOOL weights=FALSE disables weighting by layer thickness [default: weights=TRUE]

Example

To compute the vertical sum of all input variables use:

```
cdo vertsum infile outfile
```

2.8.13. TIMSELSTAT - Time range statistics

Synopsis

<operator>,nsets[,noffset[,nskip]] `infile outfile`

Description

This module computes statistical values for a selected number of timesteps. According to the chosen operator the minimum, maximum, range, sum, average, variance or standard deviation of the selected timesteps is written to `outfile`. The time of `outfile` is determined by the time in the middle of all contributing timesteps of `infile`. This can be change with the **CDO** option --timestat_date <first|middle|last>.

Operators

timselmin Time selection minimum
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same selected time range it is:
$o(t, x) = \mathbf{min}\{i(t', x), t_1 < t' \leq t_n\}$

timselmax Time selection maximum
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same selected time range it is:
$o(t, x) = \mathbf{max}\{i(t', x), t_1 < t' \leq t_n\}$

timselrange Time selection range
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same selected time range it is:
$o(t, x) = \mathbf{range}\{i(t', x), t_1 < t' \leq t_n\}$

timselsum Time selection sum
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same selected time range it is:
$o(t, x) = \mathbf{sum}\{i(t', x), t_1 < t' \leq t_n\}$

timselmean Time selection mean
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same selected time range it is:
$o(t, x) = \mathbf{mean}\{i(t', x), t_1 < t' \leq t_n\}$

timselavg Time selection average
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same selected time range it is:
$o(t, x) = \mathbf{avg}\{i(t', x), t_1 < t' \leq t_n\}$

timselstd Time selection standard deviation
Normalize by n. For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same selected time range it is:
$o(t, x) = \mathbf{std}\{i(t', x), t_1 < t' \leq t_n\}$

timselstd1 Time selection standard deviation (n-1)
Normalize by (n-1). For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same selected time range it is:
$o(t, x) = \mathbf{std1}\{i(t', x), t_1 < t' \leq t_n\}$

timselvar Time selection variance
Normalize by n. For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same selected time range it is:
$o(t, x) = \mathbf{var}\{i(t', x), t_1 < t' \leq t_n\}$

timselvar1 Time selection variance (n-1)
Normalize by (n-1). For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same selected time range it is:
$o(t, x) = \mathbf{var1}\{i(t', x), t_1 < t' \leq t_n\}$

Parameter

nsets	INTEGER	Number of input timesteps for each output timestep
noffset	INTEGER	Number of input timesteps skipped before the first timestep range (optional)
nskip	INTEGER	Number of input timesteps skipped between timestep ranges (optional)

Example

Assume an input dataset has monthly means over several years. To compute seasonal means from monthly means the first two month have to be skipped:

```
cdo timselmean,3,2 infile outfile
```

2.8.14. TIMSELPCTL - Time range percentile values

Synopsis

timselpctl,*p*,*nsets*[,*noffset*[,*nskip*]] `infile1 infile2 infile3 outfile`

Description

This operator computes percentile values over a selected number of timesteps in `infile1`. The algorithm uses histograms with minimum and maximum bounds given in `infile2` and `infile3`, respectively. The default number of histogram bins is 101. The default can be overridden by setting the environment variable `CDO_PCTL_NBINS` to a different value. The files `infile2` and `infile3` should be the result of corresponding timselmin and timselmax operations, respectively. The time of `outfile` is determined by the time in the middle of all contributing timesteps of `infile1`. This can be change with the **CDO** option --timestat_date <first|middle|last>.

For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same selected time range it is:

$o(t, x) = \mathbf{pth\ percentile}\{i(t', x), t_1 < t' \leq t_n\}$

Parameter

p	FLOAT	Percentile number in 0, ..., 100
nsets	INTEGER	Number of input timesteps for each output timestep
noffset	INTEGER	Number of input timesteps skipped before the first timestep range (optional)
nskip	INTEGER	Number of input timesteps skipped between timestep ranges (optional)

Environment

`CDO_PCTL_NBINS`	Sets the number of histogram bins. The default number is 101.

2.8.15. RUNSTAT - Running statistics

Synopsis

<operator>,nts `infile outfile`

Description

This module computes running statistical values over a selected number of timesteps. Depending on the chosen operator the minimum, maximum, range, sum, average, variance or standard deviation of a selected number of consecutive timesteps read from `infile` is written to `outfile`. The time of `outfile` is determined by the time in the middle of all contributing timesteps of `infile`. This can be change with the **CDO** option --timestat_date <first|middle|last>.

Operators

runmin Running minimum
$o(t + (nts - 1)/2, x) = \mathbf{min}\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x)\}$

runmax Running maximum
$o(t + (nts - 1)/2, x) = \mathbf{max}\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x)\}$

runrange Running range
$o(t + (nts - 1)/2, x) = \mathbf{range}\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x)\}$

runsum Running sum
$o(t + (nts - 1)/2, x) = \mathbf{sum}\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x)\}$

runmean Running mean
$o(t + (nts - 1)/2, x) = \mathbf{mean}\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x)\}$

runavg Running average
$o(t + (nts - 1)/2, x) = \mathbf{avg}\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x)\}$

runstd Running standard deviation
Normalize by n.

$o(t + (nts - 1)/2, x) = \mathbf{std}\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x)\}$

runstd1 Running standard deviation (n-1)
Normalize by (n-1).

$o(t + (nts - 1)/2, x) = \mathbf{std1}\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x)\}$

runvar Running variance
Normalize by n.

$o(t + (nts - 1)/2, x) = \mathbf{var}\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x)\}$

runvar1 Running variance (n-1)
Normalize by (n-1).

$o(t + (nts - 1)/2, x) = \mathbf{var1}\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x)\}$

Parameter

nts INTEGER Number of timesteps

Environment

`CDO_TIMESTAT_DATE` Sets the time stamp in outfile to the "first", "middle" or "last" contributing timestep of infile.

Example

To compute the running mean over 9 timesteps use:

```
cdo runmean,9 infile outfile
```

2.8.16. RUNPCTL - Running percentile values

Synopsis

runpctl,*p*,*nts* `infile outfile`

Description

This module computes running percentiles over a selected number of timesteps in `infile`. The time of `outfile` is determined by the time in the middle of all contributing timesteps of `infile`. This can be change with the **CDO** option --timestat_date <first|middle|last>.

$o(t + (nts - 1)/2, x) = \textbf{pth percentile}\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x)\}$

Parameter

p	FLOAT	Percentile number in 0, ..., 100
nts	INTEGER	Number of timesteps

Example

To compute the running 50th percentile (median) over 9 timesteps use:

```
cdo runpctl,50,9 infile outfile
```

2.8.17. TIMSTAT - Statistical values over all timesteps

Synopsis

<operator> `infile outfile`

Description

This module computes statistical values over all timesteps in `infile`. Depending on the chosen operator the minimum, maximum, range, sum, average, variance or standard deviation of all timesteps read from `infile` is written to `outfile`. The time of `outfile` is determined by the time in the middle of all contributing timesteps of `infile`. This can be change with the **CDO** option --timestat_date <first|middle|last>.

Operators

timmin Time minimum
$o(1,x) = \mathbf{min}\{i(t',x), t_1 < t' \leq t_n\}$

timmax Time maximum
$o(1,x) = \mathbf{max}\{i(t',x), t_1 < t' \leq t_n\}$

timminidx Index of time minimum
$o(1,x) = \mathbf{minidx}\{i(t',x), t_1 < t' \leq t_n\}$

timmaxidx Index of time maximum
$o(1,x) = \mathbf{maxidx}\{i(t',x), t_1 < t' \leq t_n\}$

timrange Time range
$o(1,x) = \mathbf{range}\{i(t',x), t_1 < t' \leq t_n\}$

timsum Time sum
$o(1,x) = \mathbf{sum}\{i(t',x), t_1 < t' \leq t_n\}$

timmean Time mean
$o(1,x) = \mathbf{mean}\{i(t',x), t_1 < t' \leq t_n\}$

timavg Time average
$o(1,x) = \mathbf{avg}\{i(t',x), t_1 < t' \leq t_n\}$

timstd Time standard deviation
Normalize by n.
$o(1,x) = \mathbf{std}\{i(t',x), t_1 < t' \leq t_n\}$

timstd1 Time standard deviation (n-1)
Normalize by (n-1).
$o(1,x) = \mathbf{std1}\{i(t',x), t_1 < t' \leq t_n\}$

timvar Time variance
Normalize by n.
$o(1,x) = \mathbf{var}\{i(t',x), t_1 < t' \leq t_n\}$

timvar1 Time variance (n-1)
Normalize by (n-1).
$o(1,x) = \mathbf{var1}\{i(t',x), t_1 < t' \leq t_n\}$

Example

To compute the mean over all input timesteps use:

```
cdo timmean infile outfile
```

2.8.18. TIMPCTL - Percentile values over all timesteps

Synopsis

timpctl,p `infile1 infile2 infile3 outfile`

Description

This operator computes percentiles over all timesteps in `infile1`. The algorithm uses histograms with minimum and maximum bounds given in `infile2` and `infile3`, respectively. The default number of histogram bins is 101. The default can be overridden by defining the environment variable `CDO_PCTL_NBINS`. The files `infile2` and `infile3` should be the result of corresponding timmin and timmax operations, respectively. The time of `outfile` is determined by the time in the middle of all contributing timesteps of `infile1`. This can be change with the **CDO** option --timestat_date <first|middle|last>.

$o(1, x) = \textbf{pth percentile}\{i(t', x), t_1 < t' \leq t_n\}$

Parameter

p	FLOAT	Percentile number in 0, ..., 100

Environment

`CDO_PCTL_NBINS`	Sets the number of histogram bins. The default number is 101.

Example

To compute the 90th percentile over all input timesteps use:

```
cdo timmin infile minfile
cdo timmax infile maxfile
cdo timpctl,90 infile minfile maxfile outfile
```

Or shorter using operator piping:

```
cdo timpctl,90 infile -timmin infile -timmax infile outfile
```

2.8.19. HOURSTAT - Hourly statistics

Synopsis

<*operator*> `infile outfile`

Description

This module computes statistical values over timesteps of the same hour. Depending on the chosen operator the minimum, maximum, range, sum, average, variance or standard deviation of timesteps of the same hour is written to `outfile`. The time of `outfile` is determined by the time in the middle of all contributing timesteps of `infile`. This can be change with the **CDO** option --timestat_date <first|middle|last>.

Operators

hourmin Hourly minimum
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same hour it is:
$o(t, x) = \mathbf{min}\{i(t', x), t_1 < t' \leq t_n\}$

hourmax Hourly maximum
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same hour it is:
$o(t, x) = \mathbf{max}\{i(t', x), t_1 < t' \leq t_n\}$

hourrange Hourly range
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same hour it is:
$o(t, x) = \mathbf{range}\{i(t', x), t_1 < t' \leq t_n\}$

hoursum Hourly sum
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same hour it is:
$o(t, x) = \mathbf{sum}\{i(t', x), t_1 < t' \leq t_n\}$

hourmean Hourly mean
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same hour it is:
$o(t, x) = \mathbf{mean}\{i(t', x), t_1 < t' \leq t_n\}$

houravg Hourly average
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same hour it is:
$o(t, x) = \mathbf{avg}\{i(t', x), t_1 < t' \leq t_n\}$

hourstd Hourly standard deviation
Normalize by n. For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same hour it is:
$o(t, x) = \mathbf{std}\{i(t', x), t_1 < t' \leq t_n\}$

hourstd1 Hourly standard deviation (n-1)
Normalize by (n-1). For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same hour it is:
$o(t, x) = \mathbf{std1}\{i(t', x), t_1 < t' \leq t_n\}$

hourvar Hourly variance
Normalize by n. For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same hour it is:
$o(t, x) = \mathbf{var}\{i(t', x), t_1 < t' \leq t_n\}$

hourvar1 Hourly variance (n-1)
Normalize by (n-1). For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same hour it is:
$o(t, x) = \mathbf{var1}\{i(t', x), t_1 < t' \leq t_n\}$

Example

To compute the hourly mean of a time series use:

```
cdo hourmean infile outfile
```

2.8.20. HOURPCTL - Hourly percentile values

Synopsis

hourpctl,p `infile1 infile2 infile3 outfile`

Description

This operator computes percentiles over all timesteps of the same hour in `infile1`. The algorithm uses histograms with minimum and maximum bounds given in `infile2` and `infile3`, respectively. The default number of histogram bins is 101. The default can be overridden by defining the environment variable `CDO_PCTL_NBINS`. The files `infile2` and `infile3` should be the result of corresponding hourmin and hourmax operations, respectively. The time of `outfile` is determined by the time in the middle of all contributing timesteps of `infile1`. This can be change with the **CDO** option --timestat_date <first|middle|last>.

For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same hour it is:

$$o(t, x) = \textbf{pth percentile}\{i(t', x), t_1 < t' \leq t_n\}$$

Parameter

p	FLOAT	Percentile number in 0, ..., 100

Environment

`CDO_PCTL_NBINS`	Sets the number of histogram bins. The default number is 101.

Example

To compute the hourly 90th percentile of a time series use:

```
cdo hourmin infile minfile
cdo hourmax infile maxfile
cdo hourpctl,90 infile minfile maxfile outfile
```

Or shorter using operator piping:

```
cdo hourpctl,90 infile -hourmin infile -hourmax infile outfile
```

2.8.21. DAYSTAT - Daily statistics

Synopsis

<operator>[,parameter] `infile outfile`

Description

This module computes statistical values over timesteps of the same day. Depending on the chosen operator the minimum, maximum, range, sum, average, variance or standard deviation of timesteps of the same day is written to `outfile`. The time of `outfile` is determined by the time in the middle of all contributing timesteps of `infile`. This can be change with the **CDO** option --timestat_date <first|middle|last>.

Operators

daymin Daily minimum
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same day it is:
$o(t, x) = \mathbf{min}\{i(t', x), t_1 < t' \leq t_n\}$

daymax Daily maximum
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same day it is:
$o(t, x) = \mathbf{max}\{i(t', x), t_1 < t' \leq t_n\}$

dayrange Daily range
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same day it is:
$o(t, x) = \mathbf{range}\{i(t', x), t_1 < t' \leq t_n\}$

daysum Daily sum
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same day it is:
$o(t, x) = \mathbf{sum}\{i(t', x), t_1 < t' \leq t_n\}$

daymean Daily mean
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same day it is:
$o(t, x) = \mathbf{mean}\{i(t', x), t_1 < t' \leq t_n\}$

dayavg Daily average
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same day it is:
$o(t, x) = \mathbf{avg}\{i(t', x), t_1 < t' \leq t_n\}$

daystd Daily standard deviation
Normalize by n. For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same day it is:
$o(t, x) = \mathbf{std}\{i(t', x), t_1 < t' \leq t_n\}$

daystd1 Daily standard deviation (n-1)
Normalize by (n-1). For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same day it is:
$o(t, x) = \mathbf{std1}\{i(t', x), t_1 < t' \leq t_n\}$

dayvar Daily variance
Normalize by n. For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same day it is:
$o(t, x) = \mathbf{var}\{i(t', x), t_1 < t' \leq t_n\}$

dayvar1 Daily variance (n-1)
Normalize by (n-1). For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same day it is:
$o(t, x) = \mathbf{var1}\{i(t', x), t_1 < t' \leq t_n\}$

Parameter

complete_only	BOOL	Process the last day only if it is complete

Example

To compute the daily mean of a time series use:

```
cdo daymean infile outfile
```

2.8.22. DAYPCTL - Daily percentile values

Synopsis

daypctl,*p* `infile1 infile2 infile3 outfile`

Description

This operator computes percentiles over all timesteps of the same day in `infile1`. The algorithm uses histograms with minimum and maximum bounds given in `infile2` and `infile3`, respectively. The default number of histogram bins is 101. The default can be overridden by defining the environment variable `CDO_PCTL_NBINS`. The files `infile2` and `infile3` should be the result of corresponding daymin and daymax operations, respectively. The time of `outfile` is determined by the time in the middle of all contributing timesteps of `infile1`. This can be change with the **CDO** option --timestat_date <first|middle|last>.

For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same day it is:

$$o(t,x) = \textbf{pth percentile}\{i(t',x), t_1 < t' \leq t_n\}$$

Parameter

p	FLOAT	Percentile number in 0, ..., 100

Environment

`CDO_PCTL_NBINS`	Sets the number of histogram bins. The default number is 101.

Example

To compute the daily 90th percentile of a time series use:

```
cdo daymin infile minfile
cdo daymax infile maxfile
cdo daypctl,90 infile minfile maxfile outfile
```

Or shorter using operator piping:

```
cdo daypctl,90 infile -daymin infile -daymax infile outfile
```

2.8.23. MONSTAT - Monthly statistics

Synopsis

<operator>[,parameter] `infile outfile`

Description

This module computes statistical values over timesteps of the same month. Depending on the chosen operator the minimum, maximum, range, sum, average, variance or standard deviation of timesteps of the same month is written to `outfile`. The time of `outfile` is determined by the time in the middle of all contributing timesteps of `infile`. This can be change with the **CDO** option --timestat_date <first|middle|last>.

Operators

monmin Monthly minimum
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same month it is:
$o(t, x) = \mathbf{min}\{i(t', x), t_1 < t' \leq t_n\}$

monmax Monthly maximum
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same month it is:
$o(t, x) = \mathbf{max}\{i(t', x), t_1 < t' \leq t_n\}$

monrange Monthly range
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same month it is:
$o(t, x) = \mathbf{range}\{i(t', x), t_1 < t' \leq t_n\}$

monsum Monthly sum
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same month it is:
$o(t, x) = \mathbf{sum}\{i(t', x), t_1 < t' \leq t_n\}$

monmean Monthly mean
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same month it is:
$o(t, x) = \mathbf{mean}\{i(t', x), t_1 < t' \leq t_n\}$

monavg Monthly average
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same month it is:
$o(t, x) = \mathbf{avg}\{i(t', x), t_1 < t' \leq t_n\}$

monstd Monthly standard deviation
Normalize by n. For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same month it is:
$o(t, x) = \mathbf{std}\{i(t', x), t_1 < t' \leq t_n\}$

monstd1 Monthly standard deviation (n-1)
Normalize by (n-1). For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same month it is:
$o(t, x) = \mathbf{std1}\{i(t', x), t_1 < t' \leq t_n\}$

monvar Monthly variance
Normalize by n. For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same month it is:
$o(t, x) = \mathbf{var}\{i(t', x), t_1 < t' \leq t_n\}$

monvar1 Monthly variance (n-1)
Normalize by (n-1). For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same month it is:
$o(t, x) = \mathbf{var1}\{i(t', x), t_1 < t' \leq t_n\}$

Parameter

complete_only	BOOL	Process the last month only if it is complete

Example

To compute the monthly mean of a time series use:

```
cdo monmean infile outfile
```

2.8.24. MONPCTL - Monthly percentile values

Synopsis

monpctl,*p* `infile1 infile2 infile3 outfile`

Description

This operator computes percentiles over all timesteps of the same month in `infile1`. The algorithm uses histograms with minimum and maximum bounds given in `infile2` and `infile3`, respectively. The default number of histogram bins is 101. The default can be overridden by defining the environment variable `CDO_PCTL_NBINS`. The files `infile2` and `infile3` should be the result of corresponding monmin and monmax operations, respectively. The time of `outfile` is determined by the time in the middle of all contributing timesteps of `infile1`. This can be change with the **CDO** option --timestat_date <first|middle|last>.

For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same month it is:

$$o(t, x) = \textbf{pth percentile}\{i(t', x), t_1 < t' \leq t_n\}$$

Parameter

p	FLOAT	Percentile number in 0, ..., 100

Environment

`CDO_PCTL_NBINS`	Sets the number of histogram bins. The default number is 101.

Example

To compute the monthly 90th percentile of a time series use:

```
cdo monmin infile minfile
cdo monmax infile maxfile
cdo monpctl,90 infile minfile maxfile outfile
```

Or shorter using operator piping:

```
cdo monpctl,90 infile -monmin infile -monmax infile outfile
```

2.8.25. YEARMONSTAT - Yearly mean from monthly data

Synopsis

yearmonmean `infile outfile`

Description

This operator computes the yearly mean of a monthly time series. Each month is weighted with the number of days per month. The time of `outfile` is determined by the time in the middle of all contributing timesteps of `infile`.

For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same year it is:
$o(t, x) = \mathbf{mean}\{i(t', x), t_1 < t' \leq t_n\}$

Environment

`CDO_TIMESTAT_DATE` Sets the date information in outfile to the "first", "middle" or "last" contributing timestep of infile.

Example

To compute the yearly mean of a monthly time series use:

```
cdo yearmonmean infile outfile
```

2.8.26. YEARSTAT - Yearly statistics

Synopsis

<operator>[,parameter] `infile outfile`

Description

This module computes statistical values over timesteps of the same year. Depending on the chosen operator the minimum, maximum, range, sum, average, variance or standard deviation of timesteps of the same year is written to `outfile`. The time of `outfile` is determined by the time in the middle of all contributing timesteps of `infile`. This can be change with the **CDO** option --timestat_date <first|middle|last>.

Operators

yearmin Yearly minimum
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same year it is:
$o(t, x) = \mathbf{min}\{i(t', x), t_1 < t' \leq t_n\}$

yearmax Yearly maximum
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same year it is:
$o(t, x) = \mathbf{max}\{i(t', x), t_1 < t' \leq t_n\}$

yearminidx Index of yearly minimum
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same year it is:
$o(t, x) = \mathbf{minidx}\{i(t', x), t_1 < t' \leq t_n\}$

yearmaxidx Index of yearly maximum
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same year it is:
$o(t, x) = \mathbf{maxidx}\{i(t', x), t_1 < t' \leq t_n\}$

yearrange Yearly range
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same year it is:
$o(t, x) = \mathbf{range}\{i(t', x), t_1 < t' \leq t_n\}$

yearsum Yearly sum
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same year it is:
$o(t, x) = \mathbf{sum}\{i(t', x), t_1 < t' \leq t_n\}$

yearmean Yearly mean
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same year it is:
$o(t, x) = \mathbf{mean}\{i(t', x), t_1 < t' \leq t_n\}$

yearavg Yearly average
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same year it is:
$o(t, x) = \mathbf{avg}\{i(t', x), t_1 < t' \leq t_n\}$

yearstd Yearly standard deviation
Normalize by n. For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same year it is:
$o(t, x) = \mathbf{std}\{i(t', x), t_1 < t' \leq t_n\}$

yearstd1 Yearly standard deviation (n-1)
Normalize by (n-1). For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same year it is:
$o(t, x) = \mathbf{std1}\{i(t', x), t_1 < t' \leq t_n\}$

yearvar Yearly variance
Normalize by n. For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same year it is:
$o(t, x) = \mathbf{var}\{i(t', x), t_1 < t' \leq t_n\}$

yearvar1 Yearly variance (n-1)
Normalize by (n-1). For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same year it is:
$o(t, x) = \mathbf{var1}\{i(t', x), t_1 < t' \leq t_n\}$

Parameter

complete_only	BOOL	Process the last year only if it is complete

Note

The operators yearmean and yearavg compute only arithmetical means!

Example

To compute the yearly mean of a time series use:

```
cdo yearmean infile outfile
```

To compute the yearly mean from the correct weighted monthly mean use:

```
cdo yearmonmean infile outfile
```

2.8.27. YEARPCTL - Yearly percentile values

Synopsis

yearpctl,p `infile1 infile2 infile3 outfile`

Description

This operator computes percentiles over all timesteps of the same year in `infile1`. The algorithm uses histograms with minimum and maximum bounds given in `infile2` and `infile3`, respectively. The default number of histogram bins is 101. The default can be overridden by defining the environment variable `CDO_PCTL_NBINS`. The files `infile2` and `infile3` should be the result of corresponding yearmin and yearmax operations, respectively. The time of `outfile` is determined by the time in the middle of all contributing timesteps of `infile1`. This can be change with the **CDO** option --timestat_date <first|middle|last>.

For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same year it is:

$$o(t, x) = \textbf{pth percentile}\{i(t', x), t_1 < t' \leq t_n\}$$

Parameter

p	FLOAT	Percentile number in 0, ..., 100

Environment

`CDO_PCTL_NBINS`	Sets the number of histogram bins. The default number is 101.

Example

To compute the yearly 90th percentile of a time series use:

```
cdo yearmin infile minfile
cdo yearmax infile maxfile
cdo yearpctl,90 infile minfile maxfile outfile
```

Or shorter using operator piping:

```
cdo yearpctl,90 infile -yearmin infile -yearmax infile outfile
```

2.8.28. SEASSTAT - Seasonal statistics

Synopsis

<operator> `infile outfile`

Description

This module computes statistical values over timesteps of the same meteorological season. Depending on the chosen operator the minimum, maximum, range, sum, average, variance or standard deviation of timesteps of the same season is written to `outfile`. The time of `outfile` is determined by the time in the middle of all contributing timesteps of `infile`. This can be change with the **CDO** option --timestat_date <first|middle|last>. Be careful about the first and the last output timestep, they may be incorrect values if the seasons have incomplete timesteps.

Operators

seasmin Seasonal minimum
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same season it is:
$o(t,x) = \mathbf{min}\{i(t',x), t_1 < t' \leq t_n\}$

seasmax Seasonal maximum
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same season it is:
$o(t,x) = \mathbf{max}\{i(t',x), t_1 < t' \leq t_n\}$

seasrange Seasonal range
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same season it is:
$o(t,x) = \mathbf{range}\{i(t',x), t_1 < t' \leq t_n\}$

seassum Seasonal sum
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same season it is:
$o(t,x) = \mathbf{sum}\{i(t',x), t_1 < t' \leq t_n\}$

seasmean Seasonal mean
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same season it is:
$o(t,x) = \mathbf{mean}\{i(t',x), t_1 < t' \leq t_n\}$

seasavg Seasonal average
For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same season it is:
$o(t,x) = \mathbf{avg}\{i(t',x), t_1 < t' \leq t_n\}$

seasstd Seasonal standard deviation
Normalize by n. For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same season it is:
$o(t,x) = \mathbf{std}\{i(t',x), t_1 < t' \leq t_n\}$

seasstd1 Seasonal standard deviation (n-1)
Normalize by (n-1). For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same season it is:
$o(t,x) = \mathbf{std1}\{i(t',x), t_1 < t' \leq t_n\}$

seasvar Seasonal variance
Normalize by n. For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same season it is:
$o(t,x) = \mathbf{var}\{i(t',x), t_1 < t' \leq t_n\}$

seasvar1 Seasonal variance (n-1)
Normalize by (n-1). For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same season it is:
$o(t,x) = \mathbf{var1}\{i(t',x), t_1 < t' \leq t_n\}$

Example

To compute the seasonal mean of a time series use:

```
cdo seasmean infile outfile
```

2.8.29. SEASPCTL - Seasonal percentile values

Synopsis

seaspctl,*p* `infile1 infile2 infile3 outfile`

Description

This operator computes percentiles over all timesteps in `infile1` of the same season. The algorithm uses histograms with minimum and maximum bounds given in `infile2` and `infile3`, respectively. The default number of histogram bins is 101. The default can be overridden by defining the environment variable `CDO_PCTL_NBINS`. The files `infile2` and `infile3` should be the result of corresponding seasmin and seasmax operations, respectively. The time of `outfile` is determined by the time in the middle of all contributing timesteps of `infile1`. This can be change with the **CDO** option --timestat_date <first|middle|last>. Be careful about the first and the last output timestep, they may be incorrect values if the seasons have incomplete timesteps.

For every adjacent sequence $t\_1, ..., t\_n$ of timesteps of the same season it is:

$$o(t, x) = \textbf{pth percentile}\{i(t', x), t_1 < t' \leq t_n\}$$

Parameter

p	FLOAT	Percentile number in 0, ..., 100

Environment

`CDO_PCTL_NBINS`	Sets the number of histogram bins. The default number is 101.

Example

To compute the seasonal 90th percentile of a time series use:

```
cdo seasmin infile minfile
cdo seasmax infile maxfile
cdo seaspctl,90 infile minfile maxfile outfile
```

Or shorter using operator piping:

```
cdo seaspctl,90 infile -seasmin infile -seasmax infile outfile
```

2.8.30. YHOURSTAT - Multi-year hourly statistics

Synopsis

<operator> `infile outfile`

Description

This module computes statistical values of each hour and day of year. Depending on the chosen operator the minimum, maximum, range, sum, average, variance or standard deviation of each hour and day of year in `infile` is written to `outfile`. The date information in an output field is the date of the last contributing input field.

Operators

yhourmin Multi-year hourly minimum

$$o(0001, x) = \mathbf{min}\{i(t, x), \mathrm{day}(i(t)) = 0001\}$$
$$\vdots$$
$$o(8784, x) = \mathbf{min}\{i(t, x), \mathrm{day}(i(t)) = 8784\}$$

yhourmax Multi-year hourly maximum

$$o(0001, x) = \mathbf{max}\{i(t, x), \mathrm{day}(i(t)) = 0001\}$$
$$\vdots$$
$$o(8784, x) = \mathbf{max}\{i(t, x), \mathrm{day}(i(t)) = 8784\}$$

yhourrange Multi-year hourly range

$$o(0001, x) = \mathbf{range}\{i(t, x), \mathrm{day}(i(t)) = 0001\}$$
$$\vdots$$
$$o(8784, x) = \mathbf{range}\{i(t, x), \mathrm{day}(i(t)) = 8784\}$$

yhoursum Multi-year hourly sum

$$o(0001, x) = \mathbf{sum}\{i(t, x), \mathrm{day}(i(t)) = 0001\}$$
$$\vdots$$
$$o(8784, x) = \mathbf{sum}\{i(t, x), \mathrm{day}(i(t)) = 8784\}$$

yhourmean Multi-year hourly mean

$$o(0001, x) = \mathbf{mean}\{i(t, x), \mathrm{day}(i(t)) = 0001\}$$
$$\vdots$$
$$o(8784, x) = \mathbf{mean}\{i(t, x), \mathrm{day}(i(t)) = 8784\}$$

yhouravg Multi-year hourly average

$$o(0001, x) = \mathbf{avg}\{i(t, x), \mathrm{day}(i(t)) = 0001\}$$
$$\vdots$$
$$o(8784, x) = \mathbf{avg}\{i(t, x), \mathrm{day}(i(t)) = 8784\}$$

yhourstd Multi-year hourly standard deviation
Normalize by n.

$$o(0001, x) = \mathbf{std}\{i(t, x), \mathrm{day}(i(t)) = 0001\}$$
$$\vdots$$
$$o(8784, x) = \mathbf{std}\{i(t, x), \mathrm{day}(i(t)) = 8784\}$$

yhourstd1 Multi-year hourly standard deviation (n-1)
Normalize by (n-1).

$$o(0001, x) = \textbf{std1}\{i(t, x), \text{day}(i(t)) = 0001\}$$
$$\vdots$$
$$o(8784, x) = \textbf{std1}\{i(t, x), \text{day}(i(t)) = 8784\}$$

yhourvar Multi-year hourly variance
Normalize by n.

$$o(0001, x) = \textbf{var}\{i(t, x), \text{day}(i(t)) = 0001\}$$
$$\vdots$$
$$o(8784, x) = \textbf{var}\{i(t, x), \text{day}(i(t)) = 8784\}$$

yhourvar1 Multi-year hourly variance (n-1)
Normalize by (n-1).

$$o(0001, x) = \textbf{var1}\{i(t, x), \text{day}(i(t)) = 0001\}$$
$$\vdots$$
$$o(8784, x) = \textbf{var1}\{i(t, x), \text{day}(i(t)) = 8784\}$$

2.8.31. DHOURSTAT - Multi-day hourly statistics

Synopsis

<operator> `infile outfile`

Description

This module computes statistical values of each hour of day. Depending on the chosen operator the minimum, maximum, range, sum, average, variance or standard deviation of each hour of day in `infile` is written to `outfile`. The date information in an output field is the date of the last contributing input field.

Operators

dhourmin Multi-day hourly minimum

$$o(01,x) = \mathbf{min}\{i(t,x), \mathrm{day}(i(t)) = 01\}$$
$$\vdots$$
$$o(24,x) = \mathbf{min}\{i(t,x), \mathrm{day}(i(t)) = 24\}$$

dhourmax Multi-day hourly maximum

$$o(01,x) = \mathbf{max}\{i(t,x), \mathrm{day}(i(t)) = 01\}$$
$$\vdots$$
$$o(24,x) = \mathbf{max}\{i(t,x), \mathrm{day}(i(t)) = 24\}$$

dhourrange Multi-day hourly range

$$o(01,x) = \mathbf{range}\{i(t,x), \mathrm{day}(i(t)) = 01\}$$
$$\vdots$$
$$o(24,x) = \mathbf{range}\{i(t,x), \mathrm{day}(i(t)) = 24\}$$

dhoursum Multi-day hourly sum

$$o(01,x) = \mathbf{sum}\{i(t,x), \mathrm{day}(i(t)) = 01\}$$
$$\vdots$$
$$o(24,x) = \mathbf{sum}\{i(t,x), \mathrm{day}(i(t)) = 24\}$$

dhourmean Multi-day hourly mean

$$o(01,x) = \mathbf{mean}\{i(t,x), \mathrm{day}(i(t)) = 01\}$$
$$\vdots$$
$$o(24,x) = \mathbf{mean}\{i(t,x), \mathrm{day}(i(t)) = 24\}$$

dhouravg Multi-day hourly average

$$o(01,x) = \mathbf{avg}\{i(t,x), \mathrm{day}(i(t)) = 01\}$$
$$\vdots$$
$$o(24,x) = \mathbf{avg}\{i(t,x), \mathrm{day}(i(t)) = 24\}$$

dhourstd Multi-day hourly standard deviation
Normalize by n.

$$o(01,x) = \mathbf{std}\{i(t,x), \mathrm{day}(i(t)) = 01\}$$
$$\vdots$$
$$o(24,x) = \mathbf{std}\{i(t,x), \mathrm{day}(i(t)) = 24\}$$

dhourstd1 Multi-day hourly standard deviation (n-1)
Normalize by (n-1).

$$o(01, x) = \textbf{std1}\{i(t, x), \text{day}(i(t)) = 01\}$$
$$\vdots$$
$$o(24, x) = \textbf{std1}\{i(t, x), \text{day}(i(t)) = 24\}$$

dhourvar Multi-day hourly variance
Normalize by n.

$$o(01, x) = \textbf{var}\{i(t, x), \text{day}(i(t)) = 01\}$$
$$\vdots$$
$$o(24, x) = \textbf{var}\{i(t, x), \text{day}(i(t)) = 24\}$$

dhourvar1 Multi-day hourly variance (n-1)
Normalize by (n-1).

$$o(01, x) = \textbf{var1}\{i(t, x), \text{day}(i(t)) = 01\}$$
$$\vdots$$
$$o(24, x) = \textbf{var1}\{i(t, x), \text{day}(i(t)) = 24\}$$

2.8.32. DMINUTESTAT - Multi-day by the minute statistics

Synopsis

<operator> `infile outfile`

Description

This module computes statistical values of each minute of day. Depending on the chosen operator the minimum, maximum, range, sum, average, variance or standard deviation of each minute of day in `infile` is written to `outfile`. The date information in an output field is the date of the last contributing input field.

Operators

dminutemin Multi-day by the minute minimum

$$o(01,x) = \mathbf{min}\{i(t,x), \mathrm{day}(i(t)) = 01\}$$
$$\vdots$$
$$o(1440,x) = \mathbf{min}\{i(t,x), \mathrm{day}(i(t)) = 1440\}$$

dminutemax Multi-day by the minute maximum

$$o(01,x) = \mathbf{max}\{i(t,x), \mathrm{day}(i(t)) = 01\}$$
$$\vdots$$
$$o(1440,x) = \mathbf{max}\{i(t,x), \mathrm{day}(i(t)) = 1440\}$$

dminuterange Multi-day by the minute range

$$o(01,x) = \mathbf{range}\{i(t,x), \mathrm{day}(i(t)) = 01\}$$
$$\vdots$$
$$o(1440,x) = \mathbf{range}\{i(t,x), \mathrm{day}(i(t)) = 1440\}$$

dminutesum Multi-day by the minute sum

$$o(01,x) = \mathbf{sum}\{i(t,x), \mathrm{day}(i(t)) = 01\}$$
$$\vdots$$
$$o(1440,x) = \mathbf{sum}\{i(t,x), \mathrm{day}(i(t)) = 1440\}$$

dminutemean Multi-day by the minute mean

$$o(01,x) = \mathbf{mean}\{i(t,x), \mathrm{day}(i(t)) = 01\}$$
$$\vdots$$
$$o(1440,x) = \mathbf{mean}\{i(t,x), \mathrm{day}(i(t)) = 1440\}$$

dminuteavg Multi-day by the minute average

$$o(01,x) = \mathbf{avg}\{i(t,x), \mathrm{day}(i(t)) = 01\}$$
$$\vdots$$
$$o(1440,x) = \mathbf{avg}\{i(t,x), \mathrm{day}(i(t)) = 1440\}$$

dminutestd Multi-day by the minute standard deviation
Normalize by n.

$$o(01,x) = \mathbf{std}\{i(t,x), \mathrm{day}(i(t)) = 01\}$$
$$\vdots$$
$$o(1440,x) = \mathbf{std}\{i(t,x), \mathrm{day}(i(t)) = 1440\}$$

dminutestd1 Multi-day by the minute standard deviation (n-1)
Normalize by (n-1).

$$o(01, x) = \textbf{std1}\{i(t, x), \text{day}(i(t)) = 01\}$$
$$\vdots$$
$$o(1440, x) = \textbf{std1}\{i(t, x), \text{day}(i(t)) = 1440\}$$

dminutevar Multi-day by the minute variance
Normalize by n.

$$o(01, x) = \textbf{var}\{i(t, x), \text{day}(i(t)) = 01\}$$
$$\vdots$$
$$o(1440, x) = \textbf{var}\{i(t, x), \text{day}(i(t)) = 1440\}$$

dminutevar1 Multi-day by the minute variance (n-1)
Normalize by (n-1).

$$o(01, x) = \textbf{var1}\{i(t, x), \text{day}(i(t)) = 01\}$$
$$\vdots$$
$$o(1440, x) = \textbf{var1}\{i(t, x), \text{day}(i(t)) = 1440\}$$

2.8.33. YDAYSTAT - Multi-year daily statistics

Synopsis

<operator> `infile outfile`

Description

This module computes statistical values of each day of year. Depending on the chosen operator the minimum, maximum, range, sum, average, variance or standard deviation of each day of year in `infile` is written to `outfile`. The date information in an output field is the date of the last contributing input field.

Operators

ydaymin Multi-year daily minimum

$$o(001, x) = \mathbf{min}\{i(t, x), \mathrm{day}(i(t)) = 001\}$$
$$\vdots$$
$$o(366, x) = \mathbf{min}\{i(t, x), \mathrm{day}(i(t)) = 366\}$$

ydaymax Multi-year daily maximum

$$o(001, x) = \mathbf{max}\{i(t, x), \mathrm{day}(i(t)) = 001\}$$
$$\vdots$$
$$o(366, x) = \mathbf{max}\{i(t, x), \mathrm{day}(i(t)) = 366\}$$

ydayrange Multi-year daily range

$$o(001, x) = \mathbf{range}\{i(t, x), \mathrm{day}(i(t)) = 001\}$$
$$\vdots$$
$$o(366, x) = \mathbf{range}\{i(t, x), \mathrm{day}(i(t)) = 366\}$$

ydaysum Multi-year daily sum

$$o(001, x) = \mathbf{sum}\{i(t, x), \mathrm{day}(i(t)) = 001\}$$
$$\vdots$$
$$o(366, x) = \mathbf{sum}\{i(t, x), \mathrm{day}(i(t)) = 366\}$$

ydaymean Multi-year daily mean

$$o(001, x) = \mathbf{mean}\{i(t, x), \mathrm{day}(i(t)) = 001\}$$
$$\vdots$$
$$o(366, x) = \mathbf{mean}\{i(t, x), \mathrm{day}(i(t)) = 366\}$$

ydayavg Multi-year daily average

$$o(001, x) = \mathbf{avg}\{i(t, x), \mathrm{day}(i(t)) = 001\}$$
$$\vdots$$
$$o(366, x) = \mathbf{avg}\{i(t, x), \mathrm{day}(i(t)) = 366\}$$

ydaystd Multi-year daily standard deviation
Normalize by n.

$$o(001, x) = \mathbf{std}\{i(t, x), \mathrm{day}(i(t)) = 001\}$$
$$\vdots$$
$$o(366, x) = \mathbf{std}\{i(t, x), \mathrm{day}(i(t)) = 366\}$$

ydaystd1 Multi-year daily standard deviation (n-1)
Normalize by (n-1).

$$o(001, x) = \textbf{std1}\{i(t, x), \text{day}(i(t)) = 001\}$$
$$\vdots$$
$$o(366, x) = \textbf{std1}\{i(t, x), \text{day}(i(t)) = 366\}$$

ydayvar Multi-year daily variance
Normalize by n.

$$o(001, x) = \textbf{var}\{i(t, x), \text{day}(i(t)) = 001\}$$
$$\vdots$$
$$o(366, x) = \textbf{var}\{i(t, x), \text{day}(i(t)) = 366\}$$

ydayvar1 Multi-year daily variance (n-1)
Normalize by (n-1).

$$o(001, x) = \textbf{var1}\{i(t, x), \text{day}(i(t)) = 001\}$$
$$\vdots$$
$$o(366, x) = \textbf{var1}\{i(t, x), \text{day}(i(t)) = 366\}$$

Example

To compute the daily mean over all input years use:

```
cdo ydaymean infile outfile
```

2.8.34. YDAYPCTL - Multi-year daily percentile values

Synopsis

ydaypctl,p `infile1 infile2 infile3 outfile`

Description

This operator writes a certain percentile of each day of year in `infile1` to `outfile`. The algorithm uses histograms with minimum and maximum bounds given in `infile2` and `infile3`, respectively. The default number of histogram bins is 101. The default can be overridden by setting the environment variable `CDO_PCTL_NBINS` to a different value. The files `infile2` and `infile3` should be the result of corresponding ydaymin and ydaymax operations, respectively. The date information in an output field is the date of the last contributing input field.

$$o(001, x) = \textbf{pth percentile}\{i(t, x), \text{day}(i(t)) = 001\}$$
$$\vdots$$
$$o(366, x) = \textbf{pth percentile}\{i(t, x), \text{day}(i(t)) = 366\}$$

Parameter

p	FLOAT	Percentile number in 0, ..., 100

Environment

`CDO_PCTL_NBINS`	Sets the number of histogram bins. The default number is 101.

Example

To compute the daily 90th percentile over all input years use:

```
cdo ydaymin infile minfile
cdo ydaymax infile maxfile
cdo ydaypctl,90 infile minfile maxfile outfile
```

Or shorter using operator piping:

```
cdo ydaypctl,90 infile -ydaymin infile -ydaymax infile outfile
```

2.8.35. YMONSTAT - Multi-year monthly statistics

Synopsis

<operator> `infile outfile`

Description

This module computes statistical values of each month of year. Depending on the chosen operator the minimum, maximum, range, sum, average, variance or standard deviation of each month of year in `infile` is written to `outfile`. The date information in an output field is the date of the last contributing input field. This can be change with the **CDO** option --timestat_date <first|middle|last>.

Operators

ymonmin Multi-year monthly minimum

$$o(01,x) = \mathbf{min}\{i(t,x), \text{month}(i(t)) = 01\}$$
$$\vdots$$
$$o(12,x) = \mathbf{min}\{i(t,x), \text{month}(i(t)) = 12\}$$

ymonmax Multi-year monthly maximum

$$o(01,x) = \mathbf{max}\{i(t,x), \text{month}(i(t)) = 01\}$$
$$\vdots$$
$$o(12,x) = \mathbf{max}\{i(t,x), \text{month}(i(t)) = 12\}$$

ymonrange Multi-year monthly range

$$o(01,x) = \mathbf{range}\{i(t,x), \text{month}(i(t)) = 01\}$$
$$\vdots$$
$$o(12,x) = \mathbf{range}\{i(t,x), \text{month}(i(t)) = 12\}$$

ymonsum Multi-year monthly sum

$$o(01,x) = \mathbf{sum}\{i(t,x), \text{month}(i(t)) = 01\}$$
$$\vdots$$
$$o(12,x) = \mathbf{sum}\{i(t,x), \text{month}(i(t)) = 12\}$$

ymonmean Multi-year monthly mean

$$o(01,x) = \mathbf{mean}\{i(t,x), \text{month}(i(t)) = 01\}$$
$$\vdots$$
$$o(12,x) = \mathbf{mean}\{i(t,x), \text{month}(i(t)) = 12\}$$

ymonavg Multi-year monthly average

$$o(01,x) = \mathbf{avg}\{i(t,x), \text{month}(i(t)) = 01\}$$
$$\vdots$$
$$o(12,x) = \mathbf{avg}\{i(t,x), \text{month}(i(t)) = 12\}$$

ymonstd Multi-year monthly standard deviation
Normalize by n.

$$o(01,x) = \mathbf{std}\{i(t,x), \text{month}(i(t)) = 01\}$$
$$\vdots$$
$$o(12,x) = \mathbf{std}\{i(t,x), \text{month}(i(t)) = 12\}$$

ymonstd1 Multi-year monthly standard deviation (n-1)
Normalize by (n-1).

$$o(01,x) = \mathbf{std1}\{i(t,x), \text{month}(i(t)) = 01\}$$
$$\vdots$$
$$o(12,x) = \mathbf{std1}\{i(t,x), \text{month}(i(t)) = 12\}$$

ymonvar Multi-year monthly variance
Normalize by n.

$$o(01,x) = \mathbf{var}\{i(t,x), \text{month}(i(t)) = 01\}$$
$$\vdots$$
$$o(12,x) = \mathbf{var}\{i(t,x), \text{month}(i(t)) = 12\}$$

ymonvar1 Multi-year monthly variance (n-1)
Normalize by (n-1).

$$o(01,x) = \mathbf{var1}\{i(t,x), \text{month}(i(t)) = 01\}$$
$$\vdots$$
$$o(12,x) = \mathbf{var1}\{i(t,x), \text{month}(i(t)) = 12\}$$

Example

To compute the monthly mean over all input years use:

```
cdo ymonmean infile outfile
```

2.8.36. YMONPCTL - Multi-year monthly percentile values

Synopsis

ymonpctl,p `infile1 infile2 infile3 outfile`

Description

This operator writes a certain percentile of each month of year in `infile1` to `outfile`. The algorithm uses histograms with minimum and maximum bounds given in `infile2` and `infile3`, respectively. The default number of histogram bins is 101. The default can be overridden by setting the environment variable `CDO_PCTL_NBINS` to a different value. The files `infile2` and `infile3` should be the result of corresponding ymonmin and ymonmax operations, respectively. The date information in an output field is the date of the last contributing input field.

$$o(01,x) = \textbf{pth percentile}\{i(t,x), \text{month}(i(t)) = 01\}$$
$$\vdots$$
$$o(12,x) = \textbf{pth percentile}\{i(t,x), \text{month}(i(t)) = 12\}$$

Parameter

p	FLOAT	Percentile number in 0, ..., 100

Environment

`CDO_PCTL_NBINS`	Sets the number of histogram bins. The default number is 101.

Example

To compute the monthly 90th percentile over all input years use:

```
cdo ymonmin infile minfile
cdo ymonmax infile maxfile
cdo ymonpctl,90 infile minfile maxfile outfile
```

Or shorter using operator piping:

```
cdo ymonpctl,90 infile -ymonmin infile -ymonmax infile outfile
```

2.8.37. YSEASSTAT - Multi-year seasonal statistics

Synopsis

<operator> `infile outfile`

Description

This module computes statistical values of each season. Depending on the chosen operator the minimum, maximum, range, sum, average, variance or standard deviation of each season in `infile` is written to `outfile`. The date information in an output field is the date of the last contributing input field.

Operators

yseasmin Multi-year seasonal minimum

$o(1,x) = \mathbf{min}\{i(t,x), \mathrm{month}(i(t)) = 12, 01, 02\}$
$o(2,x) = \mathbf{min}\{i(t,x), \mathrm{month}(i(t)) = 03, 04, 05\}$
$o(3,x) = \mathbf{min}\{i(t,x), \mathrm{month}(i(t)) = 06, 07, 08\}$
$o(4,x) = \mathbf{min}\{i(t,x), \mathrm{month}(i(t)) = 09, 10, 11\}$

yseasmax Multi-year seasonal maximum

$o(1,x) = \mathbf{max}\{i(t,x), \mathrm{month}(i(t)) = 12, 01, 02\}$
$o(2,x) = \mathbf{max}\{i(t,x), \mathrm{month}(i(t)) = 03, 04, 05\}$
$o(3,x) = \mathbf{max}\{i(t,x), \mathrm{month}(i(t)) = 06, 07, 08\}$
$o(4,x) = \mathbf{max}\{i(t,x), \mathrm{month}(i(t)) = 09, 10, 11\}$

yseasrange Multi-year seasonal range

$o(1,x) = \mathbf{range}\{i(t,x), \mathrm{month}(i(t)) = 12, 01, 02\}$
$o(2,x) = \mathbf{range}\{i(t,x), \mathrm{month}(i(t)) = 03, 04, 05\}$
$o(3,x) = \mathbf{range}\{i(t,x), \mathrm{month}(i(t)) = 06, 07, 08\}$
$o(4,x) = \mathbf{range}\{i(t,x), \mathrm{month}(i(t)) = 09, 10, 11\}$

yseassum Multi-year seasonal sum

$o(1,x) = \mathbf{sum}\{i(t,x), \mathrm{month}(i(t)) = 12, 01, 02\}$
$o(2,x) = \mathbf{sum}\{i(t,x), \mathrm{month}(i(t)) = 03, 04, 05\}$
$o(3,x) = \mathbf{sum}\{i(t,x), \mathrm{month}(i(t)) = 06, 07, 08\}$
$o(4,x) = \mathbf{sum}\{i(t,x), \mathrm{month}(i(t)) = 09, 10, 11\}$

yseasmean Multi-year seasonal mean

$o(1,x) = \mathbf{mean}\{i(t,x), \mathrm{month}(i(t)) = 12, 01, 02\}$
$o(2,x) = \mathbf{mean}\{i(t,x), \mathrm{month}(i(t)) = 03, 04, 05\}$
$o(3,x) = \mathbf{mean}\{i(t,x), \mathrm{month}(i(t)) = 06, 07, 08\}$
$o(4,x) = \mathbf{mean}\{i(t,x), \mathrm{month}(i(t)) = 09, 10, 11\}$

yseasavg Multi-year seasonal average

$o(1,x) = \mathbf{avg}\{i(t,x), \mathrm{month}(i(t)) = 12, 01, 02\}$
$o(2,x) = \mathbf{avg}\{i(t,x), \mathrm{month}(i(t)) = 03, 04, 05\}$
$o(3,x) = \mathbf{avg}\{i(t,x), \mathrm{month}(i(t)) = 06, 07, 08\}$
$o(4,x) = \mathbf{avg}\{i(t,x), \mathrm{month}(i(t)) = 09, 10, 11\}$

yseasstd Multi-year seasonal standard deviation

$o(1,x) = \mathbf{std}\{i(t,x), \mathrm{month}(i(t)) = 12, 01, 02\}$
$o(2,x) = \mathbf{std}\{i(t,x), \mathrm{month}(i(t)) = 03, 04, 05\}$
$o(3,x) = \mathbf{std}\{i(t,x), \mathrm{month}(i(t)) = 06, 07, 08\}$
$o(4,x) = \mathbf{std}\{i(t,x), \mathrm{month}(i(t)) = 09, 10, 11\}$

yseasstd1 Multi-year seasonal standard deviation (n-1)

$o(1,x) = \mathbf{std1}\{i(t,x), \text{month}(i(t)) = 12,\ 01,\ 02\}$
$o(2,x) = \mathbf{std1}\{i(t,x), \text{month}(i(t)) = 03,\ 04,\ 05\}$
$o(3,x) = \mathbf{std1}\{i(t,x), \text{month}(i(t)) = 06,\ 07,\ 08\}$
$o(4,x) = \mathbf{std1}\{i(t,x), \text{month}(i(t)) = 09,\ 10,\ 11\}$

yseasvar Multi-year seasonal variance

$o(1,x) = \mathbf{var}\{i(t,x), \text{month}(i(t)) = 12,\ 01,\ 02\}$
$o(2,x) = \mathbf{var}\{i(t,x), \text{month}(i(t)) = 03,\ 04,\ 05\}$
$o(3,x) = \mathbf{var}\{i(t,x), \text{month}(i(t)) = 06,\ 07,\ 08\}$
$o(4,x) = \mathbf{var}\{i(t,x), \text{month}(i(t)) = 09,\ 10,\ 11\}$

yseasvar1 Multi-year seasonal variance (n-1)

$o(1,x) = \mathbf{var1}\{i(t,x), \text{month}(i(t)) = 12,\ 01,\ 02\}$
$o(2,x) = \mathbf{var1}\{i(t,x), \text{month}(i(t)) = 03,\ 04,\ 05\}$
$o(3,x) = \mathbf{var1}\{i(t,x), \text{month}(i(t)) = 06,\ 07,\ 08\}$
$o(4,x) = \mathbf{var1}\{i(t,x), \text{month}(i(t)) = 09,\ 10,\ 11\}$

Example

To compute the seasonal mean over all input years use:

```
cdo yseasmean infile outfile
```

2.8.38. YSEASPCTL - Multi-year seasonal percentile values

Synopsis

yseaspctl,*p* `infile1 infile2 infile3 outfile`

Description

This operator writes a certain percentile of each season in `infile1` to `outfile`. The algorithm uses histograms with minimum and maximum bounds given in `infile2` and `infile3`, respectively. The default number of histogram bins is 101. The default can be overridden by setting the environment variable `CDO_PCTL_NBINS` to a different value. The files `infile2` and `infile3` should be the result of corresponding yseasmin and yseasmax operations, respectively. The date information in an output field is the date of the last contributing input field.

$o(1,x) = \textbf{pth percentile}\{i(t,x), \text{month}(i(t)) = 12,\ 01,\ 02\}$
$o(2,x) = \textbf{pth percentile}\{i(t,x), \text{month}(i(t)) = 03,\ 04,\ 05\}$
$o(3,x) = \textbf{pth percentile}\{i(t,x), \text{month}(i(t)) = 06,\ 07,\ 08\}$
$o(4,x) = \textbf{pth percentile}\{i(t,x), \text{month}(i(t)) = 09,\ 10,\ 11\}$

Parameter

p	FLOAT	Percentile number in 0, ..., 100

Environment

`CDO_PCTL_NBINS`	Sets the number of histogram bins. The default number is 101.

Example

To compute the seasonal 90th percentile over all input years use:

```
cdo yseasmin infile minfile
cdo yseasmax infile maxfile
cdo yseaspctl,90 infile minfile maxfile outfile
```

Or shorter using operator piping:

```
cdo yseaspctl,90 infile -yseasmin infile -yseasmax infile outfile
```

2.8.39. YDRUNSTAT - Multi-year daily running statistics

Synopsis

<operator>,nts[,rm=c] `infile outfile`

Description

This module writes running statistical values for each day of year in `infile` to `outfile`. Depending on the chosen operator, the minimum, maximum, sum, average, variance or standard deviation of all timesteps in running windows of which the medium timestep corresponds to a certain day of year is computed. The date information in an output field is the date of the timestep in the middle of the last contributing running window. Note that the operator have to be applied to a continuous time series of daily measurements in order to yield physically meaningful results. Also note that the output time series begins (nts-1)/2 timesteps after the first timestep of the input time series and ends (nts-1)/2 timesteps before the last one. For input data which are complete but not continuous, such as time series of daily measurements for the same month or season within different years, the operator yields physically meaningful results only if the input time series does include the (nts-1)/2 days before and after each period of interest.

Operators

ydrunmin Multi-year daily running minimum

$$o(001,x) = \mathbf{min}\{i(t,x), i(t+1,x), ..., i(t+nts-1,x); \mathrm{day}[(i(t+(nts-1)/2)] = 001\}$$
$$\vdots$$
$$o(366,x) = \mathbf{min}\{i(t,x), i(t+1,x), ..., i(t+nts-1,x); \mathrm{day}[(i(t+(nts-1)/2)] = 366\}$$

ydrunmax Multi-year daily running maximum

$$o(001,x) = \mathbf{max}\{i(t,x), i(t+1,x), ..., i(t+nts-1,x); \mathrm{day}[(i(t+(nts-1)/2)] = 001\}$$
$$\vdots$$
$$o(366,x) = \mathbf{max}\{i(t,x), i(t+1,x), ..., i(t+nts-1,x); \mathrm{day}[(i(t+(nts-1)/2)] = 366\}$$

ydrunsum Multi-year daily running sum

$$o(001,x) = \mathbf{sum}\{i(t,x), i(t+1,x), ..., i(t+nts-1,x); \mathrm{day}[(i(t+(nts-1)/2)] = 001\}$$
$$\vdots$$
$$o(366,x) = \mathbf{sum}\{i(t,x), i(t+1,x), ..., i(t+nts-1,x); \mathrm{day}[(i(t+(nts-1)/2)] = 366\}$$

ydrunmean Multi-year daily running mean

$$o(001,x) = \mathbf{mean}\{i(t,x), i(t+1,x), ..., i(t+nts-1,x); \mathrm{day}[(i(t+(nts-1)/2)] = 001\}$$
$$\vdots$$
$$o(366,x) = \mathbf{mean}\{i(t,x), i(t+1,x), ..., i(t+nts-1,x); \mathrm{day}[(i(t+(nts-1)/2)] = 366\}$$

ydrunavg Multi-year daily running average

$$o(001,x) = \mathbf{avg}\{i(t,x), i(t+1,x), ..., i(t+nts-1,x); \mathrm{day}[(i(t+(nts-1)/2)] = 001\}$$
$$\vdots$$
$$o(366,x) = \mathbf{avg}\{i(t,x), i(t+1,x), ..., i(t+nts-1,x); \mathrm{day}[(i(t+(nts-1)/2)] = 366\}$$

ydrunstd Multi-year daily running standard deviation
Normalize by n.

$$o(001,x) = \mathbf{std}\{i(t,x), i(t+1,x), ..., i(t+nts-1,x); \mathrm{day}[(i(t+(nts-1)/2)] = 001\}$$
$$\vdots$$
$$o(366,x) = \mathbf{std}\{i(t,x), i(t+1,x), ..., i(t+nts-1,x); \mathrm{day}[(i(t+(nts-1)/2)] = 366\}$$

ydrunstd1 Multi-year daily running standard deviation (n-1)
Normalize by (n-1).

$$o(001,x) = \mathbf{std1}\{i(t,x), i(t+1,x), ..., i(t+nts-1,x); \text{day}[(i(t+(nts-1)/2)] = 001\}$$
$$\vdots$$
$$o(366,x) = \mathbf{std1}\{i(t,x), i(t+1,x), ..., i(t+nts-1,x); \text{day}[(i(t+(nts-1)/2)] = 366\}$$

ydrunvar Multi-year daily running variance
Normalize by n.

$$o(001,x) = \mathbf{var}\{i(t,x), i(t+1,x), ..., i(t+nts-1,x); \text{day}[(i(t+(nts-1)/2)] = 001\}$$
$$\vdots$$
$$o(366,x) = \mathbf{var}\{i(t,x), i(t+1,x), ..., i(t+nts-1,x); \text{day}[(i(t+(nts-1)/2)] = 366\}$$

ydrunvar1 Multi-year daily running variance (n-1)
Normalize by (n-1).

$$o(001,x) = \mathbf{var1}\{i(t,x), i(t+1,x), ..., i(t+nts-1,x); \text{day}[(i(t+(nts-1)/2)] = 001\}$$
$$\vdots$$
$$o(366,x) = \mathbf{var1}\{i(t,x), i(t+1,x), ..., i(t+nts-1,x); \text{day}[(i(t+(nts-1)/2)] = 366\}$$

Parameter

nts	INTEGER	Number of timesteps
rm=c	STRING	Read method circular

Example

Assume the input data provide a continuous time series of daily measurements. To compute the running multi-year daily mean over all input timesteps for a running window of five days use:

```
cdo ydrunmean,5 infile outfile
```

Note that except for the standard deviation the results of the operators in this module are equivalent to a composition of corresponding operators from the YDAYSTAT and RUNSTAT modules. For instance, the above command yields the same result as:

```
cdo ydaymean -runmean,5 infile outfile
```

2.8.40. YDRUNPCTL - Multi-year daily running percentile values

Synopsis

ydrunpctl,*p*,*nts*[,*rm*=*c*[,*pm*=*r8*]] `infile1 infile2 infile3 outfile`

Description

This operator writes running percentile values for each day of year in `infile1` to `outfile`. A certain percentile is computed for all timesteps in running windows of which the medium timestep corresponds to a certain day of year. The algorithm uses histograms with minimum and maximum bounds given in `infile2` and `infile3`, respectively. The default number of histogram bins is 101. The default can be overridden by setting the environment variable `CDO_PCTL_NBINS` to a different value. The files `infile2` and `infile3` should be the result of corresponding ydrunmin and ydrunmax operations, respectively. The date information in an output field is the date of the timestep in the middle of the last contributing running window. Note that the operator have to be applied to a continuous time series of daily measurements in order to yield physically meaningful results. Also note that the output time series begins (nts-1)/2 timesteps after the first timestep of the input time series and ends (nts-1)/2 timesteps before the last. For input data which are complete but not continuous, such as time series of daily measurements for the same month or season within different years, the operator only yields physically meaningful results if the input time series does include the (nts-1)/2 days before and after each period of interest.

$$o(001,x) = \textbf{pth percentile}\{i(t,x), i(t+1,x), ..., i(t+nts-1,x); \text{day}[(i(t+(nts-1)/2)] = 001\}$$
$$\vdots$$
$$o(366,x) = \textbf{pth percentile}\{i(t,x), i(t+1,x), ..., i(t+nts-1,x); \text{day}[(i(t+(nts-1)/2)] = 366\}$$

Parameter

p	FLOAT	Percentile number in 0, ..., 100
nts	INTEGER	Number of timesteps
rm=c	STRING	Read method circular
pm=r8	STRING	Percentile method rtype8

Environment

`CDO_PCTL_NBINS` Sets the number of histogram bins. The default number is 101.

Example

Assume the input data provide a continuous time series of daily measurements. To compute the running multi-year daily 90th percentile over all input timesteps for a running window of five days use:

```
cdo ydrunmin,5 infile minfile
cdo ydrunmax,5 infile maxfile
cdo ydrunpctl,90,5 infile minfile maxfile outfile
```

Or shorter using operator piping:

```
cdo ydrunpctl,90,5 infile -ydrunmin infile -ydrunmax infile outfile
```

2.9. Correlation and co.

This sections contains modules for correlation and co. in grid space and over time.
In this section the abbreviations as in the following table are used:

Covariance **covar**	$n^{-1}\sum_{i=1}^{n}(x_i-\overline{x})(y_i-\overline{y})$
covar weighted by $\{w_i, i=1,...,n\}$	$\left(\sum_{j=1}^{n} w_j\right)^{-1}\sum_{i=1}^{n} w_i \left(x_i-\left(\sum_{j=1}^{n} w_j\right)^{-1}\sum_{j=1}^{n} w_j\, x_j\right)\left(y_i-\left(\sum_{j=1}^{n} w_j\right)^{-1}\sum_{j=1}^{n} w_j\, y_j\right)$

Here is a short overview of all operators in this section:

fldcor	Correlation in grid space
timcor	Correlation over time
fldcovar	Covariance in grid space
timcovar	Covariance over time

2.9.1. FLDCOR - Correlation in grid space

Synopsis

fldcor `infile1 infile2 outfile`

Description

The correlation coefficient is a quantity that gives the quality of a least squares fitting to the original data. This operator correlates all gridpoints of two fields for each timestep. With

$$S(t) = \{x, i_1(t,x) \neq missval \wedge i_2(t,x) \neq missval\}$$

it is

$$o(t,1) = \frac{\sum\limits_{x \in S(t)} i_1(t,x) i_2(t,x) w(x) - \overline{i_1(t,x)}\ \overline{i_2(t,x)} \sum\limits_{x \in S(t)} w(x)}{\sqrt{\left(\sum\limits_{x \in S(t)} i_1(t,x)^2 w(x) - \overline{i_1(t,x)}^2 \sum\limits_{x \in S(t)} w(x)\right)\left(\sum\limits_{x \in S(t)} i_2(t,x)^2 w(x) - \overline{i_2(t,x)}^2 \sum\limits_{x \in S(t)} w(x)\right)}}$$

where $w(x)$ are the area weights obtained by the input streams. For every timestep t only those field elements x belong to the sample, which have $i_1(t,x) \neq missval$ and $i_2(t,x) \neq missval$.

2.9.2. TIMCOR - Correlation over time

Synopsis

timcor `infile1 infile2 outfile`

Description

The correlation coefficient is a quantity that gives the quality of a least squares fitting to the original data. This operator correlates each gridpoint of two fields over all timesteps. If there is only one input field, the p-value (probability value) is also written out. With

$$S(x) = \{t, i_1(t,x) \neq missval \wedge i_2(t,x) \neq missval\}$$

it is

$$o(1,x) = \frac{\sum\limits_{t \in S(x)} i_1(t,x) i_2(t,x) - n\ \overline{i_1(t,x)}\ \overline{i_2(t,x)}}{\sqrt{\left(\sum\limits_{t \in S(x)} i_1(t,x)^2 - n\ \overline{i_1(t,x)}^2\right)\left(\sum\limits_{t \in S(x)} i_2(t,x)^2 - n\ \overline{i_2(t,x)}^2\right)}}$$

For every gridpoint x only those timesteps t belong to the sample, which have $i_1(t,x) \neq missval$ and $i_2(t,x) \neq missval$.

2.9.3. FLDCOVAR - Covariance in grid space

Synopsis

fldcovar `infile1 infile2 outfile`

Description

This operator calculates the covariance of two fields over all gridpoints for each timestep. With

$$S(t) = \{x, i_1(t,x) \neq missval \wedge i_2(t,x) \neq missval\}$$

it is

$$o(t,1) = \left(\sum_{x \in S(t)} w(x) \right)^{-1} \sum_{x \in S(t)} w(x) \left(i_1(t,x) - \frac{\sum\limits_{x \in S(t)} w(x)\, i_1(t,x)}{\sum\limits_{x \in S(t)} w(x)} \right) \left(i_2(t,x) - \frac{\sum\limits_{x \in S(t)} w(x)\, i_2(t,x)}{\sum\limits_{x \in S(t)} w(x)} \right)$$

where $w(x)$ are the area weights obtained by the input streams. For every timestep t only those field elements x belong to the sample, which have $i_1(t,x) \neq missval$ and $i_2(t,x) \neq missval$.

2.9.4. TIMCOVAR - Covariance over time

Synopsis

timcovar `infile1 infile2 outfile`

Description

This operator calculates the covariance of two fields at each gridpoint over all timesteps. With

$$S(x) = \{t, i_1(t,x) \neq missval \wedge i_2(t,x) \neq missval\}$$

it is

$$o(1,x) = n^{-1} \sum_{t \in S(x)} \left(i_1(t,x) - \overline{i_1(t,x)} \right) \left(i_2(t,x) - \overline{i_2(t,x)} \right)$$

For every gridpoint x only those timesteps t belong to the sample, which have $i_1(t,x) \neq missval$ and $i_2(t,x) \neq missval$.

2.10. Regression

This sections contains modules for linear regression of time series.

Here is a short overview of all operators in this section:

regres	Regression
detrend	Detrend
trend	Trend
addtrend	Add trend
subtrend	Subtract trend

2.10.1. REGRES - Regression

Synopsis

regres*[,equal]* `infile outfile`

Description

The values of the input file `infile` are assumed to be distributed as $N(a+bt, \sigma^2)$ with unknown a, b and σ^2. This operator estimates the parameter b. For every field element x only those timesteps t belong to the sample $S(x)$, which have $i(t,x) \neq$ miss. It is

$$o(1,x) = \frac{\sum\limits_{t \in S(x)} \left(i(t,x) - \frac{1}{\#S(x)} \sum\limits_{t' \in S(x)} i(t',x) \right) \left(t - \frac{1}{\#S(x)} \sum\limits_{t' \in S(x)} t' \right)}{\sum\limits_{t \in S(x)} \left(t - \frac{1}{\#S(x)} \sum\limits_{t' \in S(x)} t' \right)^2}$$

It is assumed that all timesteps are equidistant, if this is not the case set the parameter equal=false.

Parameter

equal BOOL Set to false for unequal distributed timesteps (default: true)

2.10.2. DETREND - Detrend time series

Synopsis

detrend*[,equal]* `infile outfile`

Description

Every time series in `infile` is linearly detrended. For every field element x only those timesteps t belong to the sample $S(x)$, which have $i(t,x) \neq$ miss. It is assumed that all timesteps are equidistant, if this is not the case set the parameter equal=false. With

$$a(x) = \frac{1}{\#S(x)} \sum_{t \in S(x)} i(t,x) - b(x) \left(\frac{1}{\#S(x)} \sum_{t \in S(x)} t \right)$$

and

$$b(x) = \frac{\sum\limits_{t \in S(x)} \left(i(t,x) - \frac{1}{\#S(x)} \sum\limits_{t' \in S(x)} i(t',x) \right) \left(t - \frac{1}{\#S(x)} \sum\limits_{t' \in S(x)} t' \right)}{\sum\limits_{t \in S(x)} \left(t - \frac{1}{\#S(x)} \sum\limits_{t' \in S(x)} t' \right)^2}$$

it is

$$o(t,x) = i(t,x) - (a(x) + b(x)t)$$

Parameter

equal BOOL Set to false for unequal distributed timesteps (default: true)

Note

This operator has to keep the fields of all timesteps concurrently in the memory. If not enough memory is available use the operators trend and subtrend.

Example

To detrend the data in `infile` and to store the detrended data in `outfile` use:

```
cdo detrend infile outfile
```

2.10.3. TREND - Trend of time series

Synopsis

trend*[,equal]* `infile outfile1 outfile2`

Description

The values of the input file `infile` are assumed to be distributed as $N(a + bt, \sigma^2)$ with unknown a, b and σ^2. This operator estimates the parameter a and b. For every field element x only those timesteps t belong to the sample $S(x)$, which have $i(t, x) \neq$ miss. It is

$$o_1(1,x) = \frac{1}{\#S(x)} \sum_{t \in S(x)} i(t,x) - b(x) \left(\frac{1}{\#S(x)} \sum_{t \in S(x)} t \right)$$

and

$$o_2(1,x) = \frac{\sum_{t \in S(x)} \left(i(t,x) - \frac{1}{\#S(x)} \sum_{t' \in S(x)} i(t',x) \right) \left(t - \frac{1}{\#S(x)} \sum_{t' \in S(x)} t' \right)}{\sum_{t \in S(x)} \left(t - \frac{1}{\#S(x)} \sum_{t' \in S(x)} t' \right)^2}$$

Thus the estimation for a is stored in `outfile1` and that for b is stored in `outfile2`. To subtract the trend from the data see operator subtrend. It is assumed that all timesteps are equidistant, if this is not the case set the parameter equal=false.

Parameter

equal	BOOL	Set to false for unequal distributed timesteps (default: true)

2.10.4. TRENDARITH - Add or subtract a trend

Synopsis

<operator>[,equal] `infile1 infile2 infile3 outfile`

Description

This module is for adding or subtracting a trend computed by the operator trend.

Operators

addtrend Add trend
It is

$$o(t,x) = i_1(t,x) + (i_2(1,x) + i_3(1,x) \cdot t)$$

where t is the timesteps.

subtrend Subtract trend
It is

$$o(t,x) = i_1(t,x) - (i_2(1,x) + i_3(1,x) \cdot t)$$

where t is the timesteps.

Parameter

equal	BOOL	Set to false for unequal distributed timesteps (default: true)

Example

The typical call for detrending the data in `infile` and storing the detrended data in `outfile` is:

```
cdo trend infile afile bfile
cdo subtrend infile afile bfile outfile
```

The result is identical to a call of the operator detrend:

```
cdo detrend infile outfile
```

2.11. EOFs

This section contains modules to compute Empirical Orthogonal Functions and - once they are computed - their principal coefficients.
An introduction to the theory of principal component analysis as applied here can be found in:

Principal Component Analysis in Meteorology and Oceanography [Preisendorfer]

Details about calculation in the time- and spatial spaces are found in:

Statistical Analysis in Climate Research [vonStorch]

EOFs are defined as the eigen values of the scatter matrix (covariance matrix) of the data. For the sake of simplicity, samples are regarded as **time series of anomalies**

$$(z(t)), t \in \{1, \ldots, n\}$$

of (column-) vectors $z(t)$ with p entries (where p is the gridsize). Thus, using the fact, that $z_j(t)$ are anomalies, i.e.

$$\langle z_j \rangle = n^{-1} \sum_{i=1}^{n} z_j(i) = 0 \; \forall \; 1 \leq j \leq p$$

the scatter matrix $\mathbf{S}$ can be written as

$$\mathbf{S} = \sum_{t=1}^{n} \left[\sqrt{\mathbf{W}} z(t)\right] \left[\sqrt{\mathbf{W}} z(t)\right]^T$$

where $\mathbf{W}$ is the diagonal matrix containing the area weight of cell p_0 in z at $\mathbf{W}(x, x)$.

The matrix $\mathbf{S}$ has a set of orthonormal eigenvectors $e_j, j = 1, \ldots p$, which are called *empirical orthogonal functions (EOFs) of the sample* z. (Please note, that e_j is the eigenvector of $\mathbf{S}$ and not the weighted eigen-vector which would be $\mathbf{W}e_j$.) Let the corresponding eigenvalues be denoted λ_j. The vectors e_j are spatial patterns which explain a certain amount of variance of the time series $z(t)$ that is related linearly to λ_j. Thus, the spatial pattern defined by the first eigenvector (the one with the largest eigenvalue) is the pattern which explains a maximum possible amount of variance of the sample $z(t)$. The orthonormality of eigenvectors reads as

$$\sum_{x=1}^{p} \left[\sqrt{\mathbf{W}(x,x)} e_j(x)\right] \left[\sqrt{\mathbf{W}(x,x)} e_k(x)\right] = \sum_{x=1}^{p} \mathbf{W}(x,x) e_j(x) e_k(x) = \begin{cases} 0 \; if \; j \neq k \\ 1 \; if \; j = k \end{cases}$$

If all EOFs e_j with $\lambda_j \neq 0$ are calculated, the data can be reconstructed from

$$z(t, x) = \sum_{j=1}^{p} \mathbf{W}(x, x) a_j(t) e_j(x)$$

where a_j are called the *principal components* or *principal coefficients* or *EOF coefficients* of z. These coefficients - as readily seen from above - are calculated as the projection of an EOF e_j onto a time step of the data sample $z(t_0)$ as

$$a_j(t_0) = \sum_{x=1}^{p} \left[\sqrt{\mathbf{W}(x,x)} e_j(x)\right] \left[\sqrt{\mathbf{W}(x,x)} z(t_0, x)\right] = \left[\sqrt{\mathbf{W}} z(t_0)\right]^T \left[\sqrt{\mathbf{W}} e_j\right].$$

Here is a short overview of all operators in this section:

eof	Calculate EOFs in spatial or time space
eoftime	Calculate EOFs in time space
eofspatial	Calculate EOFs in spatial space
eof3d	Calculate 3-Dimensional EOFs in time space
eofcoeff	Calculate principal coefficients of EOFs

2.11.1. EOFS - Empirical Orthogonal Functions

Synopsis

<operator>,neof `infile outfile1 outfile2`

Description

This module calculates empirical orthogonal functions of the data in `infile` as the eigen values of the scatter matrix (covariance matrix) S of the data sample $z(t)$. A more detailed description can be found above.

Please note, that the input data are assumed to be anomalies.

If operator eof is chosen, the EOFs are computed in either time or spatial space, whichever is the fastest. If the user already knows, which computation is faster, the module can be forced to perform a computation in time- or gridspace by using the operators eoftime or eofspatial, respectively. This can enhance performance, especially for very long time series, where the number of timesteps is larger than the number of grid-points. Data in `infile` are assumed to be anomalies. If they are not, the behavior of this module is **not well defined**. After execution `outfile1` will contain all eigen-values and `outfile2` the eigenvectors *e_j*. All EOFs and eigen-values are computed. However, only the first *neof* EOFs are written to `outfile2`. Nonetheless, `outfile1` contains all eigen-values.

Missing values are not fully supported. Support is only checked for non-changing masks of missing values in time. Although there still will be results, they are not trustworthy, and a warning will occur. In the latter case we suggest to replace missing values by 0 in `infile`.

Operators

eof	Calculate EOFs in spatial or time space
eoftime	Calculate EOFs in time space
eofspatial	Calculate EOFs in spatial space
eof3d	Calculate 3-Dimensional EOFs in time space

Parameter

neof	INTEGER	Number of eigen functions

Environment

`CDO_SVD_MODE`	Is used to choose the algorithm for eigenvalue calculation. Options are 'jacobi' for a one-sided parallel jacobi-algorithm (only executed in parallel if -P flag is set) and 'danielson_lanczos' for a non-parallel d/l algorithm. The default setting is 'jacobi'.
`CDO_WEIGHT_MODE`	It is used to set the weight mode. The default is 'off'. Set it to 'on' for a weighted version.
`MAX_JACOBI_ITER`	Is the maximum integer number of annihilation sweeps that is executed if the jacobi-algorithm is used to compute the eigen values. The default value is 12.
`FNORM_PRECISION`	Is the Frobenius norm of the matrix consisting of an annihilation pair of eigenvectors that is used to determine if the eigenvectors have reached a sufficient level of convergence. If all annihilation-pairs of vectors have a norm below this value, the computation is considered to have converged properly. Otherwise, a warning will occur. The default value 1e-12.

Example

To calculate the first 40 EOFs of a data-set containing anomalies use:

```
cdo eof,40 infile outfile1 outfile2
```

If the dataset does not containt anomalies, process them first, and use:

```
cdo sub infile1 -timmean infile1 anom_file
cdo eof,40 anom_file outfile1 outfile2
```

2.11.2. EOFCOEFF - Principal coefficients of EOFs

Synopsis

eofcoeff `infile1 infile2 obase`

Description

This module calculates the time series of the principal coefficients for given EOF (empirical orthogonal functions) and data. Time steps in `infile1` are assumed to be the EOFs, time steps in `infile2` are assumed to be the time series. Note, that this operator calculates a non weighted dot product of the fields in `infile1` and `infile2`. For consistency set the environment variable `CDO_WEIGHT_MODE=off` when using eof or eof3d. Given a set of EOFs e_j and a time series of data $z(t)$ with p entries for each timestep from which e_j have been calculated, this operator calculates the time series of the projections of data onto each EOF

$$o_j(t) = \sum_{x=1}^{p} z(t,x) e_j(x)$$

There will be a seperate file o_j for the principal coefficients of each EOF.

As the EOFs e_j are uncorrelated, so are their principal coefficients, i.e.

$$\sum_{t=1}^{n} o_j(t) o_k(t) = \begin{cases} 0 \; if \; j \neq k \\ \lambda_j \; if \; j = k \end{cases} \quad with \sum_{t=1}^{n} o_j(t) = 0 \forall j \in \{1, \ldots, p\}.$$

There will be a separate file containing a time series of principal coefficients with time information from `infile2` for each EOF in `infile1`. Output files will be numbered as <obase><neof><suffix> where `neof+1` is the number of the EOF (timestep) in `infile1` and `suffix` is the filename extension derived from the file format.

Environment

`CDO_FILE_SUFFIX` Set the default file suffix. This suffix will be added to the output file names instead of the filename extension derived from the file format. Set this variable to NULL to disable the adding of a file suffix.

Example

To calculate principal coefficients of the first 40 EOFs of `anom_file`, and write them to files beginning with obase, use:

```
export CDO_WEIGHT_MODE=off
cdo eof,40 anom_file eval_file eof_file
cdo eofcoeff eof_file anom_file obase
```

The principal coefficients of the first EOF will be in the file `obase000000.nc` (and so forth for higher EOFs, nth EOF will be in `obase<n-1>`).

If the dataset `infile` does not containt anomalies, process them first, and use:

```
export CDO_WEIGHT_MODE=off
cdo sub infile -timmean infile anom_file
cdo eof,40 anom_file eval_file eof_file
cdo eofcoeff eof_file anom_file obase
```

2.12. Interpolation

This section contains modules to interpolate datasets. There are several operators to interpolate horizontal fields to a new grid. Some of those operators can handle only 2D fields on a regular rectangular grid. Vertical interpolation of 3D variables is possible from hybrid model levels to height or pressure levels. Interpolation in time is possible between time steps and years.

Here is a short overview of all operators in this section:

remapbil	Bilinear interpolation
genbil	Generate bilinear interpolation weights
remapbic	Bicubic interpolation
genbic	Generate bicubic interpolation weights
remapnn	Nearest neighbor remapping
gennn	Generate nearest neighbor remap weights
remapdis	Distance weighted average remapping
gendis	Generate distance weighted average remap weights
remapcon	First order conservative remapping
gencon	Generate 1st order conservative remap weights
remaplaf	Largest area fraction remapping
genlaf	Generate largest area fraction remap weights
remap	Grid remapping
remapeta	Remap vertical hybrid level
ml2pl	Model to pressure level interpolation
ml2hl	Model to height level interpolation
ap2pl	Air pressure to pressure level interpolation
gh2hl	Geometric height to height level interpolation
intlevel	Linear level interpolation
intlevel3d	Linear level interpolation onto a 3D vertical coordinate
intlevelx3d	like intlevel3d but with extrapolation
inttime	Interpolation between timesteps
intntime	Interpolation between timesteps
intyear	Interpolation between two years

2.12.1. REMAPBIL - Bilinear interpolation

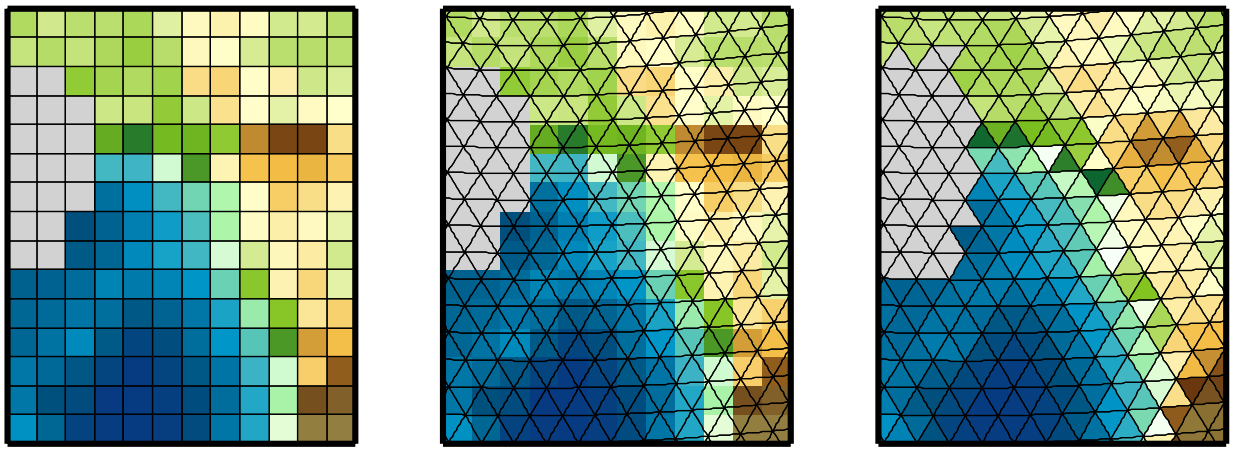
Synopsis

remapbil,*grid* `infile outfile`

genbil,*grid[,map3d]* `infile outfile`

Description

This module contains operators for a bilinear remapping of fields between grids in spherical coordinates. The interpolation is based on an adapted SCRIP library version. For a detailed description of the interpolation method see [SCRIP]. This interpolation method only works on quadrilateral curvilinear source grids. Below is a schematic illustration of the bilinear remapping:



The figure on the left side shows the input data on a regular lon/lat source grid and on the right side the remapped result on an unstructured triangular target grid. The figure in the middle shows the input data with the target grid. Grid cells with missing value are grey colored.

Operators

remapbil Bilinear interpolation
Performs a bilinear interpolation on all input fields.

genbil Generate bilinear interpolation weights
Generates bilinear interpolation weights for the first input field and writes the result to a file. The format of this file is NetCDF following the SCRIP convention. Use the operator remap to apply this remapping weights to a data file with the same source grid. Set the parameter `map3d=true` to generate all mapfiles of the first 3D field with varying masks. In this case the mapfiles will be named <outfile><xxx>.nc. xxx will have five digits with the number of the mapfile.

Parameter

grid	STRING	Target grid description file or name
map3d	BOOL	Generate all mapfiles of the first 3D field

Environment

`REMAP_EXTRAPOLATE`	This variable is used to switch the extrapolation feature 'on' or 'off'. By default the extrapolation is enabled for circular grids.

Example

Say `infile` contains fields on a quadrilateral curvilinear grid. To remap all fields bilinear to a Gaussian N32 grid, type:

```
cdo remapbil,n32 infile outfile
```

2.12.2. REMAPBIC - Bicubic interpolation

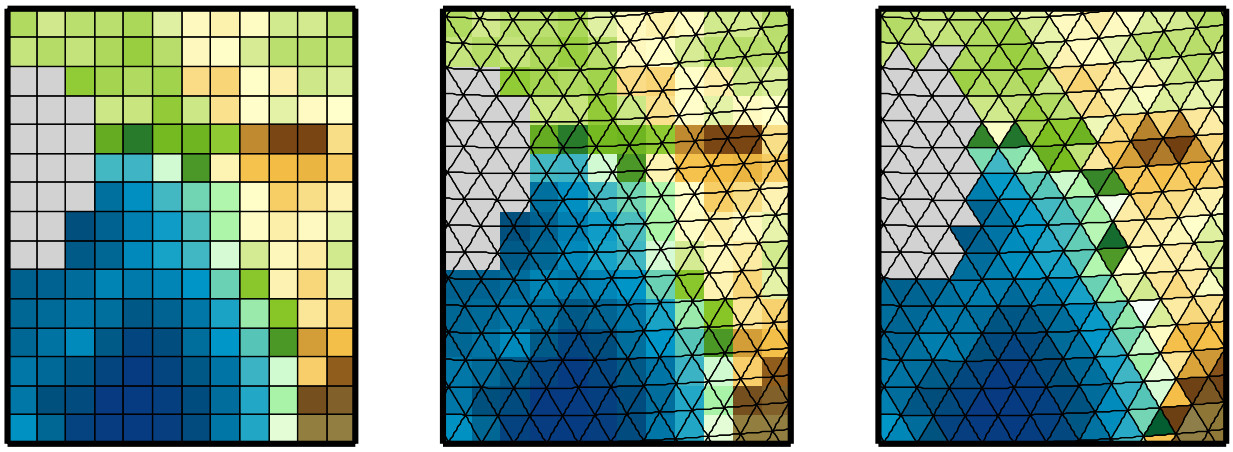
Synopsis

remapbic,*grid* `infile outfile`

genbic,*grid[,map3d]* `infile outfile`

Description

This module contains operators for a bicubic remapping of fields between grids in spherical coordinates. The interpolation is based on an adapted SCRIP library version. For a detailed description of the interpolation method see [SCRIP]. This interpolation method only works on quadrilateral curvilinear source grids. Below is a schematic illustration of the bicubic remapping:



The figure on the left side shows the input data on a regular lon/lat source grid and on the right side the remapped result on an unstructured triangular target grid. The figure in the middle shows the input data with the target grid. Grid cells with missing value are grey colored.

Operators

remapbic Bicubic interpolation
Performs a bicubic interpolation on all input fields.

genbic Generate bicubic interpolation weights
Generates bicubic interpolation weights for the first input field and writes the result to a file. The format of this file is NetCDF following the SCRIP convention. Use the operator remap to apply this remapping weights to a data file with the same source grid. Set the parameter `map3d=true` to generate all mapfiles of the first 3D field with varying masks. In this case the mapfiles will be named <outfile><xxx>.nc. xxx will have five digits with the number of the mapfile.

Parameter

grid	STRING	Target grid description file or name
map3d	BOOL	Generate all mapfiles of the first 3D field

Environment

`REMAP_EXTRAPOLATE`	This variable is used to switch the extrapolation feature 'on' or 'off'. By default the extrapolation is enabled for circular grids.

Example

Say `infile` contains fields on a quadrilateral curvilinear grid. To remap all fields bicubic to a Gaussian N32 grid, type:

```
cdo remapbic,n32 infile outfile
```

2.12.3. REMAPNN - Nearest neighbor remapping

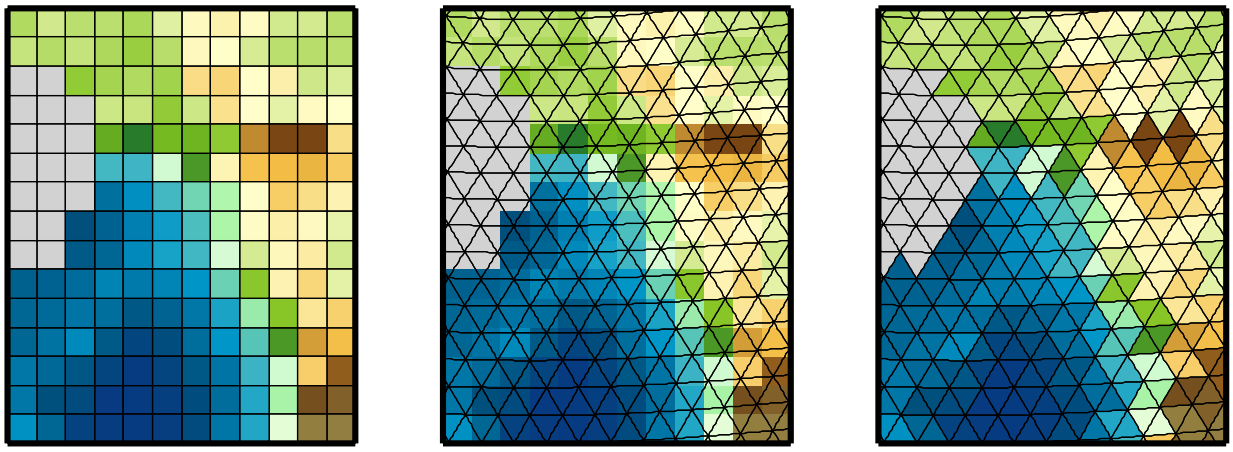
Synopsis

remapnn,*grid* `infile outfile`

gennn,*grid[,map3d]* `infile outfile`

Description

This module contains operators for a nearest neighbor remapping of fields between grids in spherical coordinates. Below is a schematic illustration of the nearest neighbor remapping:



The figure on the left side shows the input data on a regular lon/lat source grid and on the right side the remapped result on an unstructured triangular target grid. The figure in the middle shows the input data with the target grid. Grid cells with missing value are grey colored.

Operators

remapnn Nearest neighbor remapping
Performs a nearest neighbor remapping on all input fields.

gennn Generate nearest neighbor remap weights
Generates nearest neighbor remapping weights for the first input field and writes the result to a file. The format of this file is NetCDF following the SCRIP convention. Use the operator remap to apply this remapping weights to a data file with the same source grid. Set the parameter `map3d=true` to generate all mapfiles of the first 3D field with varying masks. In this case the mapfiles will be named <outfile><xxx>.nc. xxx will have five digits with the number of the mapfile.

Parameter

grid	STRING	Target grid description file or name
map3d	BOOL	Generate all mapfiles of the first 3D field

Environment

`REMAP_EXTRAPOLATE`	This variable is used to switch the extrapolation feature 'on' or 'off'. By default the extrapolation is enabled for this remapping method.
`CDO_GRIDSEARCH_RADIUS`	Grid search radius in degree, default 180 degree.

2.12.4. REMAPDIS - Distance weighted average remapping

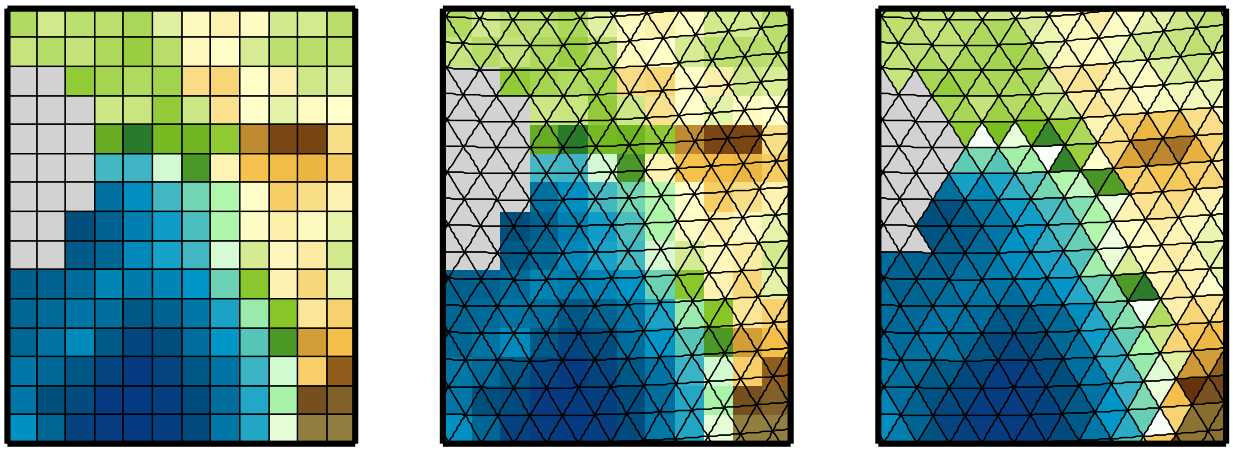
Synopsis

remapdis,*grid[,neighbors]* `infile outfile`

gendis,*grid[,neighbors[,map3d]]* `infile outfile`

Description

This module contains operators for an inverse distance weighted average remapping of the four nearest neighbor values of fields between grids in spherical coordinates. The default number of 4 neighbors can be changed with the *neighbors* parameter. Below is a schematic illustration of the distance weighted average remapping:



The figure on the left side shows the input data on a regular lon/lat source grid and on the right side the remapped result on an unstructured triangular target grid. The figure in the middle shows the input data with the target grid. Grid cells with missing value are grey colored.

Operators

remapdis Distance weighted average remapping
Performs an inverse distance weighted averaged remapping of the nearest neighbor values on all input fields.

gendis Generate distance weighted average remap weights
Generates distance weighted averaged remapping weights of the nearest neighbor values for the first input field and writes the result to a file. The format of this file is NetCDF following the SCRIP convention. Use the operator remap to apply this remapping weights to a data file with the same source grid. Set the parameter `map3d=true` to generate all mapfiles of the first 3D field with varying masks. In this case the mapfiles will be named <outfile><xxx>.nc. xxx will have five digits with the number of the mapfile.

Parameter

grid	STRING	Target grid description file or name
neighbors	INTEGER	Number of nearest neighbors [default: 4]
map3d	BOOL	Generate all mapfiles of the first 3D field

Environment

`REMAP_EXTRAPOLATE`	This variable is used to switch the extrapolation feature 'on' or 'off'. By default the extrapolation is enabled for this remapping method.
`CDO_GRIDSEARCH_RADIUS`	Grid search radius in degree, default 180 degree.

2.12.5. REMAPCON - First order conservative remapping

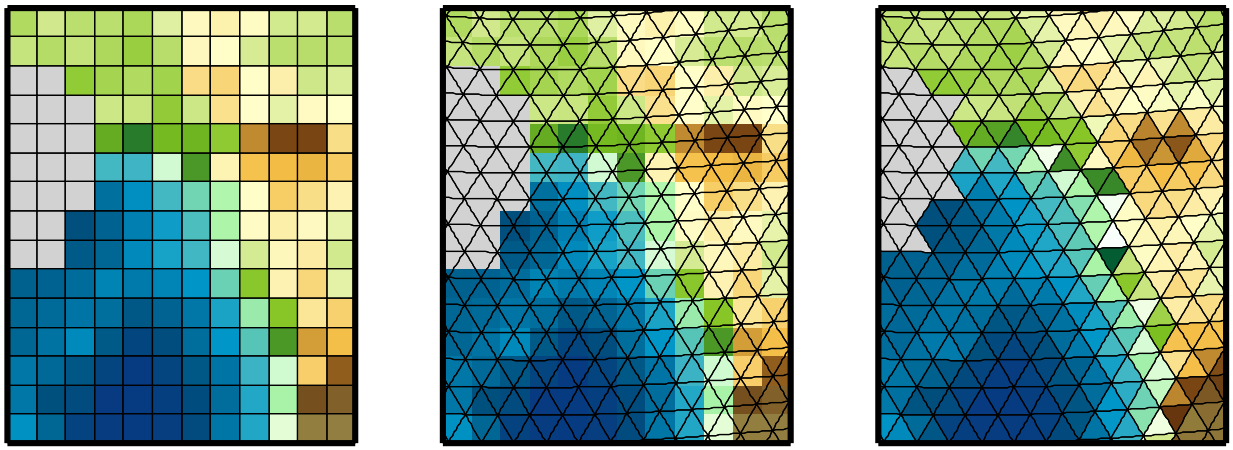
Synopsis

remapcon,*grid* `infile outfile`

gencon,*grid[,map3d]* `infile outfile`

Description

This module contains operators for a first order conservative remapping of fields between grids in spherical coordinates. The operators in this module uses code from the YAC software package to compute the conservative remapping weights. For a detailed description of the interpolation method see [YAC]. The interpolation method is completely general and can be used for any grid on a sphere. The search algorithm for the conservative remapping requires that no grid cell occurs more than once. Below is a schematic illustration of the 1st order conservative remapping:



The figure on the left side shows the input data on a regular lon/lat source grid and on the right side the remapped result on an unstructured triangular target grid. The figure in the middle shows the input data with the target grid. Grid cells with missing value are grey colored.

Operators

remapcon First order conservative remapping
Performs a first order conservative remapping on all input fields.

gencon Generate 1st order conservative remap weights
Generates first order conservative remapping weights for the first input field and writes the result to a file. The format of this file is NetCDF following the SCRIP convention. Use the operator remap to apply this remapping weights to a data file with the same source grid. Set the parameter `map3d=true` to generate all mapfiles of the first 3D field with varying masks. In this case the mapfiles will be named <outfile><xxx>.nc. xxx will have five digits with the number of the mapfile.

Parameter

grid	STRING	Target grid description file or name
map3d	BOOL	Generate all mapfiles of the first 3D field

Environment

`CDO_REMAP_NORM` This variable is used to choose the normalization of the conservative interpolation. By default `CDO_REMAP_NORM` is set to 'fracarea'. 'fracarea' uses the sum of the non-masked source cell intersected areas to normalize each target cell field value. This results in a reasonable flux value but the flux is not locally conserved. The option 'destarea' uses the total target cell area to normalize each target cell field value. Local flux conservation is ensured, but unreasonable flux values may result.

`REMAP_AREA_MIN` This variable is used to set the minimum destination area fraction. The default of this variable is 0.0.

Example

Say `infile` contains fields on a quadrilateral curvilinear grid. To remap all fields conservative to a Gaussian N32 grid, type:

```
cdo remapcon,n32 infile outfile
```

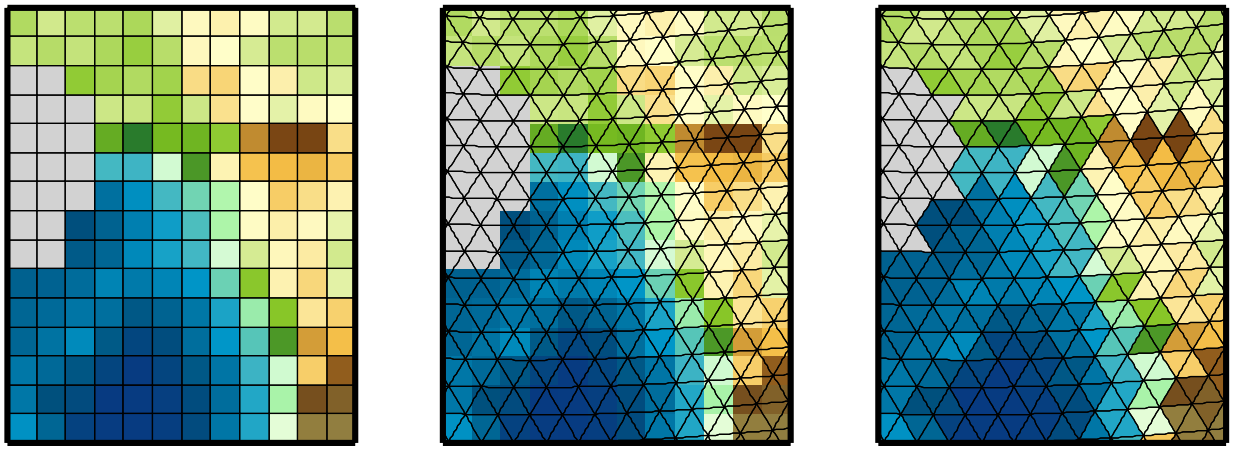
2.12.6. REMAPLAF - Largest area fraction remapping

Synopsis

<operator>,grid `infile outfile`

Description

This module contains operators for a largest area fraction remapping of fields between grids in spherical coordinates. The operators in this module uses code from the YAC software package to compute the largest area fraction. For a detailed description of the interpolation method see [YAC]. The interpolation method is completely general and can be used for any grid on a sphere. The search algorithm for this remapping method requires that no grid cell occurs more than once. Below is a schematic illustration of the largest area fraction conservative remapping:



The figure on the left side shows the input data on a regular lon/lat source grid and on the right side the remapped result on an unstructured triangular target grid. The figure in the middle shows the input data with the target grid. Grid cells with missing value are grey colored.

Operators

remaplaf Largest area fraction remapping
Performs a largest area fraction remapping on all input fields.

genlaf Generate largest area fraction remap weights
Generates largest area fraction remapping weights for the first input field and writes the result to a file. The format of this file is NetCDF following the SCRIP convention. Use the operator remap to apply this remapping weights to a data file with the same source grid.

Parameter

grid STRING Target grid description file or name

Environment

`REMAP_AREA_MIN` This variable is used to set the minimum destination area fraction. The default of this variable is 0.0.

2.12.7. REMAP - Grid remapping

Synopsis

remap,*grid*,*weights* `infile outfile`

Description

Interpolation between different horizontal grids can be a very time-consuming process. Especially if the data are on an unstructured and/or a large grid. In this case the interpolation process can be split into two parts. Firstly the generation of the interpolation weights, which is the most time-consuming part. These interpolation weights can be reused for every remapping process with the operator remap. This operator remaps all input fields to a new horizontal grid. The remap type and the interpolation weights of one input grid are read from a NetCDF file. More weights are computed if the input fields are on different grids. The NetCDF file with the weights should follow the [SCRIP] convention. Normally these weights come from a previous call to one of the genXXX operators (e.g. genbil) or were created by the original SCRIP package.

Parameter

grid	STRING	Target grid description file or name
weights	STRING	Interpolation weights (SCRIP NetCDF file)

Environment

`CDO_REMAP_NORM`	This variable is used to choose the normalization of the conservative interpolation. By default `CDO_REMAP_NORM` is set to 'fracarea'. 'fracarea' uses the sum of the non-masked source cell intersected areas to normalize each target cell field value. This results in a reasonable flux value but the flux is not locally conserved. The option 'destarea' uses the total target cell area to normalize each target cell field value. Local flux conservation is ensured, but unreasonable flux values may result.
`REMAP_EXTRAPOLATE`	This variable is used to switch the extrapolation feature 'on' or 'off'. By default the extrapolation is enabled for remapdis, remapnn and for circular grids.
`REMAP_AREA_MIN`	This variable is used to set the minimum destination area fraction. The default of this variable is 0.0.
`CDO_GRIDSEARCH_RADIUS`	Grid search radius in degree, default 180 degree.

Example

Say `infile` contains fields on a quadrilateral curvilinear grid. To remap all fields bilinear to a Gaussian N32 grid use:

```
cdo genbil,n32 infile remapweights.nc
cdo remap,n32,remapweights.nc infile outfile
```

The result will be the same as:

```
cdo remapbil,n32 infile outfile
```

2.12.8. REMAPETA - Remap vertical hybrid level

Synopsis

remapeta,*vct[,oro]* `infile outfile`

Description

This operator interpolates between different vertical hybrid levels. This include the preparation of consistent data for the free atmosphere. The procedure for the vertical interpolation is based on the HIRLAM scheme and was adapted from [INTERA]. The vertical interpolation is based on the vertical integration of the hydrostatic equation with few adjustments. The basic tasks are the following one:

- at first integration of hydrostatic equation
- extrapolation of surface pressure
- Planetary Boundary-Layer (PBL) proutfile interpolation
- interpolation in free atmosphere
- merging of both proutfiles
- final surface pressure correction

The vertical interpolation corrects the surface pressure. This is simply a cut-off or an addition of air mass. This mass correction should not influence the geostrophic velocity field in the middle troposhere. Therefore the total mass above a given reference level is conserved. As reference level the geopotential height of the 400 hPa level is used. Near the surface the correction can affect the vertical structure of the PBL. Therefore the interpolation is done using the potential temperature. But in the free atmosphere above a certain n (n=0.8 defining the top of the PBL) the interpolation is done linearly. After the interpolation both proutfiles are merged. With the resulting temperature/pressure correction the hydrostatic equation is integrated again and adjusted to the reference level finding the final surface pressure correction. A more detailed description of the interpolation can be found in [INTERA]. This operator requires all variables on the same horizontal grid.

Parameter

vct	STRING	File name of an ASCII dataset with the vertical coordinate table
oro	STRING	File name with the orography (surf. geopotential) of the target dataset (optional)

Environment

`REMAPETA_PTOP`	Sets the minimum pressure level for condensation. Above this level the humidity is set to the constant 1.E-6. The default value is 0 Pa.

Note

The code numbers or the variable names of the required parameter have to follow the [ECHAM] convention.

Use the sinfo command to test if your vertical coordinate system is recognized as hybrid system.

In case remapeta complains about not finding any data on hybrid model levels you may wish to use the setzaxis command to generate a zaxis description which conforms to the ECHAM convention. See section "1.4 Z-axis description" for an example how to define a hybrid Z-axis.

Example

To remap between different hybrid model level data use:

```
cdo remapeta,vct infile outfile
```

Here is an example vct file with 19 hybrid model level:

```
 0        0.00000000000000000        0.00000000000000000
 1     2000.00000000000000000        0.00000000000000000
 2     4000.00000000000000000        0.00000000000000000
 3     6046.10937500000000000        0.00033899326808751
 4     8267.92968750000000000        0.00335718691349030
 5    10609.51171875000000000        0.01307003945112228
 6    12851.10156250000000000        0.03407714888453484
 7    14698.50000000000000000        0.07064980268478394
 8    15861.12890625000000000        0.12591671943664551
 9    16116.23828125000000000        0.20119541883468628
10    15356.92187500000000000        0.29551959037780762
11    13621.46093750000000000        0.40540921688079834
12    11101.55859375000000000        0.52493220567703247
13     8127.14453125000000000        0.64610791206359863
14     5125.14062500000000000        0.75969839096069336
15     2549.96899414062500000        0.85643762350082397
16      783.19506835937500000        0.92874687910079956
17        0.00000000000000000        0.97298520803451538
18        0.00000000000000000        0.99228149652481079
19        0.00000000000000000        1.00000000000000000
```

2.12.9. VERTINTML - Vertical interpolation

Synopsis

ml2pl,*plevels* `infile outfile`

ml2hl,*hlevels* `infile outfile`

Description

Interpolates 3D variables on hybrid sigma pressure level to pressure or height levels. To calculate the pressure on model levels, the a and b coefficients defining the model levels and the surface pressure are required. The a and b coefficients are normally part of the model level data. If not available, the surface pressure can be derived from the logarithm of the surface pressure. To extrapolate the temperature, the surface geopotential is also needed. The geopotential height must be present at the hybrid layer interfaces (model half-layers)! All needed variables are identified by their GRIB1 code number or NetCDF CF standard name. Supported parameter tables are: WMO standard table number 2 and ECMWF local table number 128.

Name	Units	GRIB1 code	CF standard name
log surface pressure	Pa	152	
surface pressure	Pa	134	surface_air_pressure
air temperature	K	130	air_temperature
surface geopotential	m2 s-2	129	surface_geopotential
geopotential height	m	156	geopotential_height

Use the alias **ml2plx/ml2hlx** or the environment variable `EXTRAPOLATE` to extrapolate missing values. This operator requires all variables on the same horizontal grid. Missing values in the input data are not supported.

Operators

ml2pl Model to pressure level interpolation
Interpolates 3D variables on hybrid sigma pressure level to pressure level.

ml2hl Model to height level interpolation
Interpolates 3D variables on hybrid sigma pressure level to height level. The procedure is the same as for the operator ml2pl except for the pressure levels being calculated from the heights by: $plevel = 101325 * exp(hlevel/-7000)$

Parameter

plevels FLOAT Pressure levels in pascal

hlevels FLOAT Height levels in meter

Environment

`EXTRAPOLATE` If set to 1 extrapolate missing values.

Note

The components of the hybrid coordinate must always be avaiable at the hybrid layer interfaces even if the data is defined at the hybrid layer midpoints.

Example

To interpolate hybrid model level data to pressure levels of 925, 850, 500 and 200 hPa use:

```
cdo ml2pl,92500,85000,50000,20000 infile outfile
```

2.12.10. VERTINTAP - Vertical pressure interpolation

Synopsis

ap2pl,*plevels* `infile outfile`

Description

Interpolate 3D variables on hybrid sigma height coordinates to pressure levels. The input file must contain the 3D air pressure in pascal. The air pressure is identified by the NetCDF CF standard name **`air_pressure`**. Use the alias **ap2plx** or the environment variable `EXTRAPOLATE` to extrapolate missing values. This operator requires all variables on the same horizontal grid.

Parameter

plevels FLOAT Comma-separated list of pressure levels in pascal

Environment

`EXTRAPOLATE` If set to 1 extrapolate missing values.

Note

This is a specific implementation for NetCDF files from the ICON model, it may not work with data from other sources.

Example

To interpolate 3D variables on hybrid sigma height level to pressure levels of 925, 850, 500 and 200 hPa use:

```
cdo ap2pl,92500,85000,50000,20000 infile outfile
```

2.12.11. VERTINTGH - Vertical height interpolation

Synopsis

gh2hl,*hlevels* `infile outfile`

Description

Interpolate 3D variables on hybrid sigma height coordinates to height levels. The input file must contain the 3D geometric height in meter. The geometric height is identified by the NetCDF CF standard name **`geometric_height_at_full_level_center`**. Use the alias **gh2hlx** or the environment variable `EXTRAPOLATE` to extrapolate missing values. This operator requires all variables on the same horizontal grid.

Parameter

hlevels FLOAT Comma-separated list of height levels in meter

Environment

`EXTRAPOLATE` If set to 1 extrapolate missing values.

Note

This is a specific implementation for NetCDF files from the ICON model, it may not work with data from other sources.

Example

To interpolate 3D variables on hybrid sigma height level to height levels of 20, 100, 500, 1000, 5000, 10000 and 20000 meter use:

```
cdo gh2hl,20,100,500,1000,5000,10000,20000 infile outfile
```

2.12.12. INTLEVEL - Linear level interpolation

Synopsis

intlevel,*parameter* `infile outfile`

Description

This operator performs a linear vertical interpolation of 3D variables. The 1D target levels can be specified with the level parameter or read in via a Z-axis description file.

Parameter

level	FLOAT	Comma-separated list of target levels
zdescription	STRING	Path to a file containing a description of the Z-axis
zvarname	STRING	Use zvarname as the vertical 3D source coordinate instead of the 1D coordinate variable
extrapolate	BOOL	Fill target layers out of the source layer range with the nearest source layer

Example

To interpolate 3D variables on height levels to a new set of height levels use:

```
cdo intlevel,level=10,50,100,500,1000 infile outfile
```

2.12.13. INTLEVEL3D - Linear level interpolation from/to 3D vertical coordinates

Synopsis

<*operator*>,*tgtcoordinate* `infile1 infile2 outfile`

Description

This operator performs a linear vertical interpolation of 3D variables fields with given 3D vertical coordinates. `infile1` contains the 3D data variables and `infile2` the 3D vertical source coordinate. The parameter `tgtcoordinate` is a datafile with the 3D vertical target coordinate.

Operators

intlevel3d Linear level interpolation onto a 3D vertical coordinate

intlevelx3d like intlevel3d but with extrapolation

Parameter

tgtcoordinate	STRING	filename for 3D vertical target coordinates

Example

To interpolate 3D variables from one set of 3D height levels into another one where

- `infile2` contains a single 3D variable, which represents the source 3D vertical coordinate
- `infile1` contains the source data, which the vertical coordinate from `infile2` belongs to
- `tgtcoordinate` only contains the target 3D height levels

```
cdo intlevel3d,tgtcoordinate infile1 infile2 outfile
```

2.12.14. INTTIME - Time interpolation

Synopsis

inttime,*date*,*time*[,*inc*] `infile outfile`

intntime,*n* `infile outfile`

Description

This module performs linear interpolation between timesteps. Interpolation is only performed if both values exist. If both values are missing values, the result is also a missing value. If only one value exists, it is taken if the time weighting is greater than or equal to 0.5. So no new value will be created at existing time steps, if the value is missing there.

Operators

inttime Interpolation between timesteps
This operator creates a new dataset by linear interpolation between timesteps. The user has to define the start date/time with an optional increment.

intntime Interpolation between timesteps
This operator performs linear interpolation between timesteps. The user has to define the number of timesteps from one timestep to the next.

Parameter

date	STRING	Start date (format YYYY-MM-DD)
time	STRING	Start time (format hh:mm:ss)
inc	STRING	Optional increment (seconds, minutes, hours, days, months, years) [default: 0hour]
n	INTEGER	Number of timesteps from one timestep to the next

Example

Assumed a 6 hourly dataset starts at 1987-01-01 12:00:00. To interpolate this time series to a one hourly dataset use:

```
cdo inttime,1987-01-01,12:00:00,1hour infile outfile
```

2.12.15. INTYEAR - Year interpolation

Synopsis

intyear,*years* `infile1 infile2 obase`

Description

This operator performs linear interpolation between two years, timestep by timestep. The input files need to have the same structure with the same variables. The output files will be named `<obase><yyyy><suffix>` where `yyyy` will be the year and `suffix` is the filename extension derived from the file format.

Parameter

years INTEGER Comma-separated list or first/last[/inc] range of years

Environment

`CDO_FILE_SUFFIX` Set the default file suffix. This suffix will be added to the output file names instead of the filename extension derived from the file format. Set this variable to NULL to disable the adding of a file suffix.

Note

This operator needs to open all output files simultaneously. The maximum number of open files depends on the operating system!

Example

Assume there are two monthly mean datasets over a year. The first dataset has 12 timesteps for the year 1985 and the second one for the year 1990. To interpolate the years between 1985 and 1990 month by month use:

```
cdo intyear,1986,1987,1988,1989 infile1 infile2 year
```

Example result of 'dir year*' for NetCDF datasets:

```
year1986.nc year1987.nc year1988.nc year1989.nc
```

2.13. Transformation

This section contains modules to perform spectral transformations.

Here is a short overview of all operators in this section:

sp2gp	Spectral to gridpoint
gp2sp	Gridpoint to spectral
sp2sp	Spectral to spectral
dv2ps	D and V to velocity potential and stream function
dv2uv	Divergence and vorticity to U and V wind
uv2dv	U and V wind to divergence and vorticity
fourier	Fourier transformation

2.13.1. SPECTRAL - Spectral transformation

Synopsis

<operator>[,type|trunc] `infile outfile`

Description

This module transforms fields on a global regular Gaussian grid to spectral coefficients and vice versa. The transformation is achieved by applying Fast Fourier Transformation (FFT) first and direct Legendre Transformation afterwards in gp2sp. In sp2gp the inverse Legendre Transformation and inverse FFT are used. Missing values are not supported.

The relationship between the spectral resolution, governed by the truncation number T, and the grid resolution depends on the number of grid points at which the shortest wavelength field is represented. For a grid with 2N points between the poles (so 4N grid points in total around the globe) the relationship is:

linear grid: the shortest wavelength is represented by 2 grid points $\rightarrow$ 4N $\simeq$ 2(TL + 1)

quadratic grid: the shortest wavelength is represented by 3 grid points $\rightarrow$ 4N $\simeq$ 3(TQ + 1)

cubic grid: the shortest wavelength is represented by 4 grid points $\rightarrow$ 4N $\simeq$ 4(TC + 1)

The quadratic grid is used by ECHAM and ERA15. ERA40 is using a linear Gaussian grid reflected by the TL notation.

The following table shows the calculation of the number of latitudes and the triangular truncation for the different grid types:

Gridtype	**Number of latitudes:** nlat	**Triangular truncation:** ntr
linear	NINT((ntr*2 + 1)/2)	(nlat*2 - 1) / 2
quadratic	NINT((ntr*3 + 1)/2)	(nlat*2 - 1) / 3
cubic	NINT((ntr*4 + 1)/2)	(nlat*2 - 1) / 4

Operators

sp2gp Spectral to gridpoint
Convert all spectral fields to a global regular Gaussian grid. The optional parameter ***trunc*** must be greater than the input truncation.

gp2sp Gridpoint to spectral
Convert all Gaussian gridpoint fields to spectral fields. The optional parameter ***trunc*** must be lower than the input truncation.

Parameter

type STRING Type of the grid: quadratic, linear, cubic (default: type=quadratic)

trunc STRING Triangular truncation

Note

To speed up the calculations, the Legendre polynoms are kept in memory. This requires a relatively large amount of memory. This is for example 12GB for T1279 data.

Example

To transform spectral coefficients from T106 to N80 Gaussian grid use:

```
cdo sp2gp infile outfile
```

To transform spectral coefficients from TL159 to N80 Gaussian grid use:

```
cdo sp2gp,type=linear infile outfile
```

2.13.2. SPECCONV - Spectral conversion

Synopsis

sp2sp,*trunc* `infile outfile`

Description

Changed the triangular truncation of all spectral fields. This operator performs downward conversion by cutting the resolution. Upward conversions are achieved by filling in zeros.

Parameter

trunc INTEGER New spectral resolution

2.13.3. WIND2 - D and V to velocity potential and stream function

Synopsis

dv2ps `infile outfile`

Description

Calculate spherical harmonic coefficients of velocity potential and stream function from spherical harmonic coefficients of relative divergence and vorticity. The divergence and vorticity need to have the names sd and svo or code numbers 155 and 138.

2.13.4. WIND - Wind transformation

Synopsis

<operator>[,gridtype] `infile outfile`

Description

This module converts relative divergence and vorticity to U and V wind and vice versa. Divergence and vorticity are spherical harmonic coefficients in spectral space and U and V are on a global regular Gaussian grid. The Gaussian latitudes need to be ordered from north to south. Missing values are not supported.

The relationship between the spectral resolution, governed by the truncation number T, and the grid resolution depends on the number of grid points at which the shortest wavelength field is represented. For a grid with 2N points between the poles (so 4N grid points in total around the globe) the relationship is:

linear grid: the shortest wavelength is represented by 2 grid points $\rightarrow 4N \simeq 2(TL + 1)$

quadratic grid: the shortest wavelength is represented by 3 grid points $\rightarrow 4N \simeq 3(TQ + 1)$

cubic grid: the shortest wavelength is represented by 4 grid points $\rightarrow 4N \simeq 4(TC + 1)$

The quadratic grid is used by ECHAM and ERA15. ERA40 is using a linear Gaussian grid reflected by the TL notation.

The following table shows the calculation of the number of latitudes and the triangular truncation for the different grid types:

Gridtype	**Number of latitudes:** nlat	**Triangular truncation:** ntr
linear	NINT((ntr*2 + 1)/2)	(nlat*2 - 1) / 2
quadratic	NINT((ntr*3 + 1)/2)	(nlat*2 - 1) / 3
cubic	NINT((ntr*4 + 1)/2)	(nlat*2 - 1) / 4

Operators

dv2uv Divergence and vorticity to U and V wind
Calculate U and V wind on a Gaussian grid from spherical harmonic coefficients of relative divergence and vorticity. The divergence and vorticity need to have the names sd and svo or code numbers 155 and 138.

uv2dv U and V wind to divergence and vorticity
Calculate spherical harmonic coefficients of relative divergence and vorticity from U and V wind. The U and V wind need to be on a Gaussian grid and need to have the names u and v or the code numbers 131 and 132.

Parameter

gridtype STRING Type of the grid: quadratic, linear, cubic (default: quadratic)

Note

To speed up the calculations, the Legendre polynoms are kept in memory. This requires a relatively large amount of memory. This is for example 12GB for T1279 data.

Example

Assume a dataset has at least spherical harmonic coefficients of divergence and vorticity. To transform the spectral divergence and vorticity to U and V wind on a Gaussian grid use:

```
cdo dv2uv infile outfile
```

2.13.5. FOURIER - Fourier transformation

Synopsis

fourier,*epsilon* `infile outfile`

Description

The fourier operator performs the fourier transformation or the inverse fourier transformation of all input fields. If the number of timesteps is a power of 2 then the algorithm of the Fast Fourier Transformation (FFT) is used.

It is

$$o(t,x) = \frac{1}{\sqrt{n}} \sum_{j=0}^{n-1} i(t,x) e^{\epsilon 2\pi ij}$$

where a user given $epsilon = -1$ leads to the forward transformation and a user given $epsilon = 1$ leads to the backward transformation.

If the input stream `infile` consists only of complex fields, then the fields of `outfile`, computed by

```
cdo -f ext fourier,1 -fourier,-1 infile outfile
```

are the same than that of `infile`. For real input files see function retocomplex.

Parameter

epsilon	INTEGER	-1: forward transformation; 1: backward transformation

Note

Complex numbers can only be stored in NetCDF4 and EXTRA format.

2.14. Import/Export

This section contains modules to import and export data files which can not read or write directly with CDO.

Here is a short overview of all operators in this section:

import_binary	Import binary data sets
import_cmsaf	Import CM-SAF HDF5 files
import_amsr	Import AMSR binary files
input	ASCII input
inputsrv	SERVICE ASCII input
inputext	EXTRA ASCII input
output	ASCII output
outputf	Formatted output
outputint	Integer output
outputsrv	SERVICE ASCII output
outputext	EXTRA ASCII output
outputtab	Table output
gmtxyz	GMT xyz format
gmtcells	GMT multiple segment format

2.14.1. IMPORTBINARY - Import binary data sets

Synopsis

import_binary `infile outfile`

Description

This operator imports gridded binary data sets via a GrADS data descriptor file. The GrADS data descriptor file contains a complete description of the binary data as well as instructions on where to find the data and how to read it. The descriptor file is an ASCII file that can be created easily with a text editor. The general contents of a gridded data descriptor file are as follows:

- Filename for the binary data
- Missing or undefined data value
- Mapping between grid coordinates and world coordinates
- Description of variables in the binary data set

A detailed description of the components of a GrADS data descriptor file can be found in [GrADS]. Here is a list of the supported components: BYTESWAPPED, CHSUB, DSET, ENDVARS, FILEHEADER, HEADERBYTES, OPTIONS, TDEF, TITLE, TRAILERBYTES, UNDEF, VARS, XDEF, XYHEADER, YDEF, ZDEF

Note

Only 32-bit IEEE floats are supported for standard binary files!

Example

To convert a binary data file to NetCDF use:

```
cdo -f nc import_binary infile.ctl outfile.nc
```

Here is an example of a GrADS data descriptor file:

```
DSET ^infile.bin
OPTIONS sequential
UNDEF -9e+33
XDEF 360 LINEAR -179.5 1
YDEF 180 LINEAR -89.5 1
ZDEF 1 LINEAR 1 1
TDEF 1 LINEAR 00:00Z15jun1989 12hr
VARS 1
param 1 99 description of the variable
ENDVARS
```

The binary data file infile.bin contains one parameter on a global 1 degree lon/lat grid written with FORTRAN record length headers (sequential).

2.14.2. IMPORTCMSAF - Import CM-SAF HDF5 files

Synopsis

import_cmsaf `infile outfile`

Description

This operator imports gridded CM-SAF (Satellite Application Facility on Climate Monitoring) HDF5 files. CM-SAF exploits data from polar-orbiting and geostationary satellites in order to provide climate monitoring products of the following parameters:

Cloud parameters: cloud fraction (CFC), cloud type (CTY), cloud phase (CPH), cloud top height, pressure and temperature (CTH,CTP,CTT), cloud optical thickness (COT), cloud water path (CWP).

Surface radiation components: Surface albedo (SAL); surface incoming (SIS) and net (SNS) shortwave radiation; surface downward (SDL) and outgoing (SOL) longwave radiation, surface net longwave radiation (SNL) and surface radiation budget (SRB).

Top-of-atmosphere radiation components: Incoming (TIS) and reflected (TRS) solar radiative flux at top-of-atmosphere. Emitted thermal radiative flux at top-of-atmosphere (TET).

Water vapour: Vertically integrated water vapour (HTW), layered vertically integrated water vapour and layer mean temperature and relative humidity for 5 layers (HLW), temperature and mixing ratio at 6 pressure levels.

Daily and monthly mean products can be ordered via the CM-SAF web page (www.cmsaf.eu). Products with higher spatial and temporal resolution, i.e. instantaneous swath-based products, are available on request (contact.cmsaf@dwd.de). All products are distributed free-of-charge. More information on the data is available on the CM-SAF homepage (www.cmsaf.eu).

Daily and monthly mean products are provided in equal-area projections. **CDO** reads the projection parameters from the metadata in the HDF5-headers in order to allow spatial operations like remapping. For spatial operations with instantaneous products on original satellite projection, additional files with arrays of latitudes and longitudes are needed. These can be obtained from CM-SAF together with the data.

Note

To use this operator, it is necessary to build **CDO** with HDF5 support (version 1.6 or higher). The PROJ library (version 5.0 or higher) is needed for full support of the remapping functionality.

Example

A typical sequence of commands with this operator could look like this:

```
cdo -f nc remapbil,r360x180 -import_cmsaf cmsaf_product.hdf output.nc
```

(bilinear remapping to a predefined global grid with 1 deg resolution and conversion to NetCDF).

If you work with CM-SAF data on original satellite project, an additional file with information on geolocation is required, to perform such spatial operations:

```
cdo -f nc remapbil,r720x360 -setgrid,cmsaf_latlon.h5 -import_cmsaf cmsaf.hdf out.nc
```

Some CM-SAF data are stored as scaled integer values. For some operations, it could be desirable (or necessary) to increase the accuracy of the converted products:

```
cdo -b f32 -f nc fldmean -sellonlatbox,0,10,0,10 -remapbil,r720x360 \
              -import_cmsaf cmsaf_product.hdf output.nc
```

2.14.3. IMPORTAMSR - Import AMSR binary files

Synopsis

import_amsr `infile outfile`

Description

This operator imports gridded binary AMSR (Advanced Microwave Scanning Radiometer) data. The binary data files are available from the AMSR ftp site (ftp://ftp.ssmi.com/amsre). Each file consists of twelve (daily) or five (averaged) 0.25 x 0.25 degree grid (1440,720) byte maps. For daily files, six daytime maps in the following order, Time (UTC), Sea Surface Temperature (SST), 10 meter Surface Wind Speed (WSPD), Atmospheric Water Vapor (VAPOR), Cloud Liquid Water (CLOUD), and Rain Rate (RAIN), are followed by six nighttime maps in the same order. Time-Averaged files contain just the geophysical layers in the same order [SST, WSPD, VAPOR, CLOUD, RAIN]. More information to the data is available on the AMSR homepage http://www.remss.com/amsr.

Example

To convert monthly binary AMSR files to NetCDF use:

```
cdo -f nc amsre_yyyymmv5 amsre_yyyymmv5.nc
```

2.14.4. INPUT - Formatted input

Synopsis

input,*grid[,zaxis]* `outfile`

inputsrv `outfile`

inputext `outfile`

Description

This module reads time series of one 2D variable from standard input. All input fields need to have the same horizontal grid. The format of the input depends on the chosen operator.

Operators

input ASCII input
Reads fields with ASCII numbers from standard input and stores them in `outfile`. The numbers read are exactly that ones which are written out by the output operator.

inputsrv SERVICE ASCII input
Reads fields with ASCII numbers from standard input and stores them in `outfile`. Each field should have a header of 8 integers (SERVICE likely). The numbers that are read are exactly that ones which are written out by the outputsrv operator.

inputext EXTRA ASCII input
Read fields with ASCII numbers from standard input and stores them in `outfile`. Each field should have header of 4 integers (EXTRA likely). The numbers read are exactly that ones which are written out by the outputext operator.

Parameter

grid	STRING	Grid description file or name
zaxis	STRING	Z-axis description file

Example

Assume an ASCII dataset contains a field on a global regular grid with 32 longitudes and 16 latitudes (512 elements). To create a GRIB1 dataset from the ASCII dataset use:

```
cdo -f grb input,r32x16 outfile.grb < my_ascii_data
```

2.14.5. OUTPUT - Formatted output

Synopsis

output infiles

outputf,*format*[,*nelem*] infiles

outputint infiles

outputsrv infiles

outputext infiles

Description

This module prints all values of all input datasets to standard output. All input fields need to have the same horizontal grid. All input files need to have the same structure with the same variables. The format of the output depends on the chosen operator.

Operators

output ASCII output
Prints all values to standard output. Each row has 6 elements with the C-style format "%13.6g".

outputf Formatted output
Prints all values to standard output. The format and number of elements for each row have to be specified by the parameters *format* and *nelem*. The default for *nelem* is 1.

outputint Integer output
Prints all values rounded to the nearest integer to standard output.

outputsrv SERVICE ASCII output
Prints all values to standard output. Each field with a header of 8 integers (SERVICE likely).

outputext EXTRA ASCII output
Prints all values to standard output. Each field with a header of 4 integers (EXTRA likely).

Parameter

format	STRING	C-style format for one element (e.g. %13.6g)
nelem	INTEGER	Number of elements for each row (default: nelem = 1)

Example

To print all field elements of a dataset formatted with "%8.4g" and 8 values per line use:

```
cdo outputf,%8.4g,8 infile
```

Example result of a dataset with one field on 64 grid points:

```
  261.7     262   257.8   252.5   248.8   247.7   246.3   246.1
  250.6   252.6   253.9   254.8     252   246.6   249.7   257.9
  273.4   266.2   259.8   261.6   257.2   253.4     251   263.7
  267.5   267.4   272.2   266.7   259.6   255.2   272.9   277.1
  275.3   275.5   276.4   278.4     282   269.6   278.7   279.5
  282.3   284.5   280.3   280.3     280   281.5   284.7   283.6
  292.9   290.5   293.9   292.6   292.7   292.8   294.1   293.6
  293.8   292.6   291.2   292.6   293.2   292.8     291   291.2
```

2.14.6. OUTPUTTAB - Table output

Synopsis

outputtab,*parameter* `infiles outfile`

Description

This operator prints a table of all input datasets to standard output. `infiles` is an arbitrary number of input files. All input files need to have the same structure with the same variables on different timesteps. All input fields need to have the same horizontal grid.

The contents of the table depends on the chosen parameters. The format of each table parameter is keyname[:len]. len is the optional length of a table entry. The number of significant digits of floating point parameters can be set with the **CDO** option --precision, the default is 7. Here is a list of all valid keynames:

Keyname	Type	Description
value	FLOAT	Value of the variable [len:8]
name	STRING	Name of the variable [len:8]
param	STRING	Parameter ID (GRIB1: code[.tabnum]; GRIB2: num[.cat[.dis]]) [len:11]
code	INTEGER	Code number [len:4]
x	FLOAT	X coordinate of the original grid [len:6]
y	FLOAT	Y coordinate of the original grid [len:6]
lon	FLOAT	Longitude coordinate in degrees [len:6]
lat	FLOAT	Latitude coordinate in degrees [len:6]
lev	FLOAT	Vertical level [len:6]
xind	INTEGER	Grid x index [len:4]
yind	INTEGER	Grid y index [len:4]
timestep	INTEGER	Timestep number [len:6]
date	STRING	Date (format YYYY-MM-DD) [len:10]
time	STRING	Time (format hh:mm:ss) [len:8]
year	INTEGER	Year [len:5]
month	INTEGER	Month [len:2]
day	INTEGER	Day [len:2]
nohead	INTEGER	Disable output of header line

Parameter

parameter STRING Comma-separated list of keynames, one for each column of the table

Example

To print a table with name, date, lon, lat and value information use:

```
cdo  outputtab,name,date,lon,lat,value infile
```

Here is an example output of a time series with the yearly mean temperatur at lon=10/lat=53.5:

```
#   name        date     lon     lat     value
    tsurf   1991-12-31     10    53.5   8.83903
    tsurf   1992-12-31     10    53.5   8.17439
    tsurf   1993-12-31     10    53.5   7.90489
    tsurf   1994-12-31     10    53.5   10.0216
    tsurf   1995-12-31     10    53.5   9.07798
```

2.14.7. OUTPUTGMT - GMT output

Synopsis

<operator> `infile`

Description

This module prints the first field of the input dataset to standard output. The output can be used to generate 2D Lon/Lat plots with [GMT]. The format of the output depends on the chosen operator.

Operators

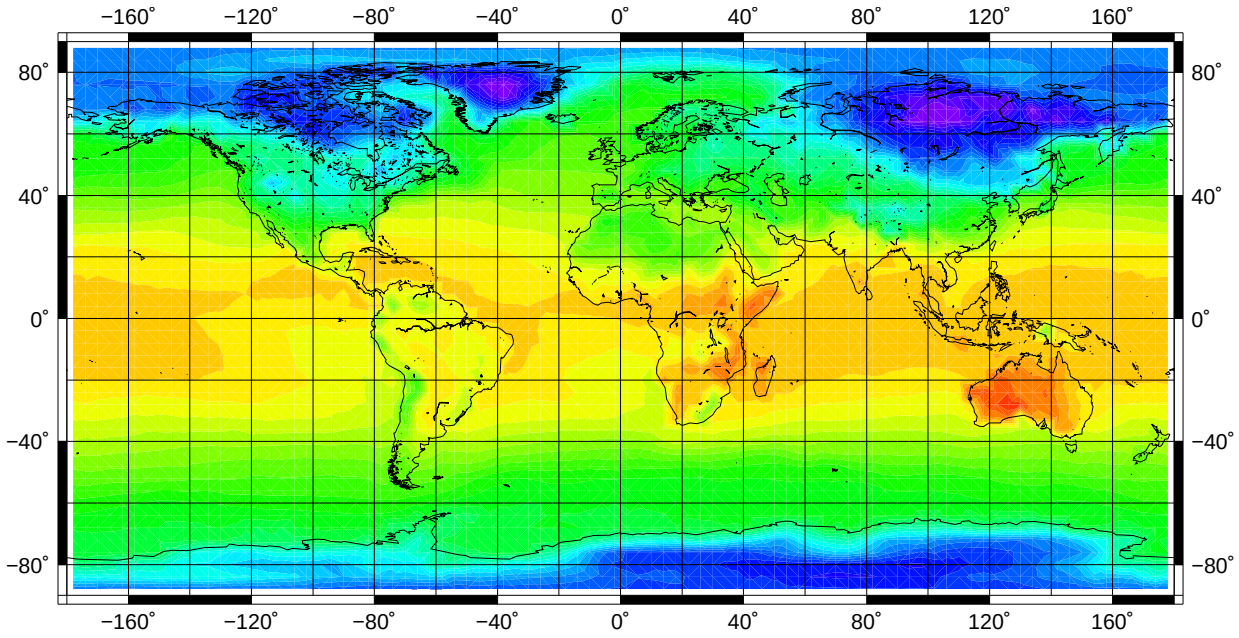
gmtxyz GMT xyz format
The operator exports the first field to the GMT xyz ASCII format. The output can be used to create contour plots with the GMT module pscontour.

gmtcells GMT multiple segment format
The operator exports the first field to the GMT multiple segment ASCII format. The output can be used to create shaded gridfill plots with the GMT module psxy.

Example

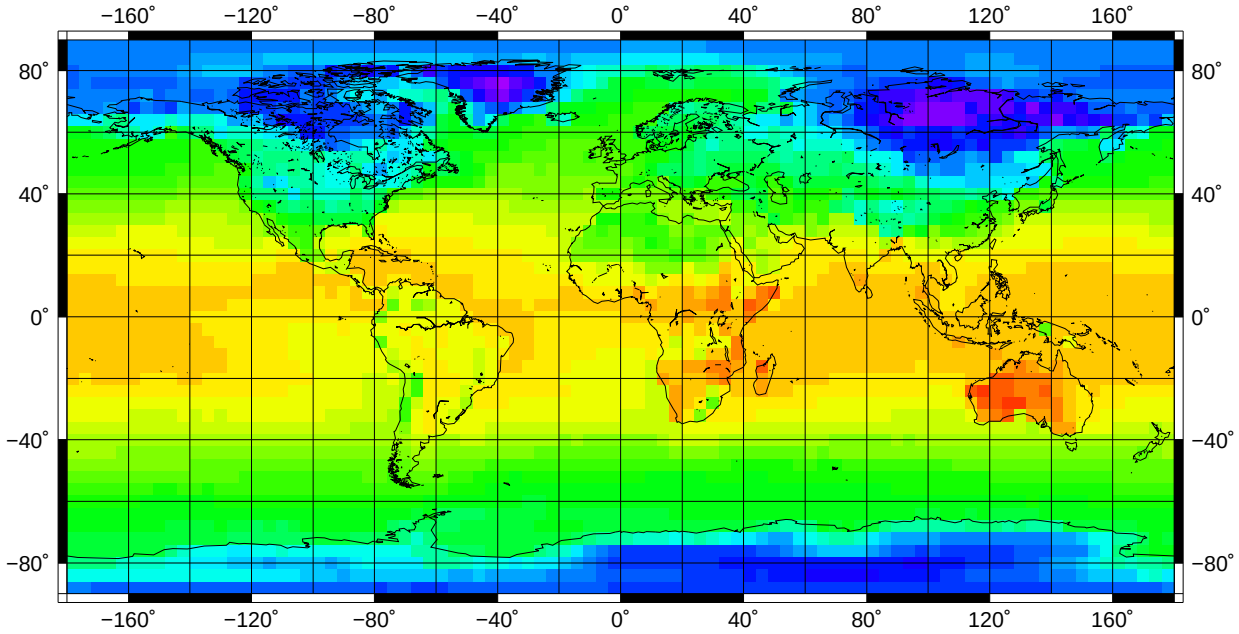
1) GMT shaded contour plot of a global temperature field with a resolution of 4 degree. The contour interval is 3 with a rainbow color table.

```
cdo gmtxyz temp > data.gmt
makecpt -T213/318/3 -Crainbow > gmt.cpt
pscontour -K -JQ0/10i -Rd -I -Cgmt.cpt data.gmt > gmtplot.ps
pscoast -O -J -R -Dc -W -B40g20 >> gmtplot.ps
```



2) GMT shaded gridfill plot of a global temperature field with a resolution of 4 degree. The contour interval is 3 with a rainbow color table.

```
cdo gmtcells temp > data.gmt
makecpt -T213/318/3 -Crainbow > gmt.cpt
psxy -K -JQ0/10i -Rd -L -Cgmt.cpt -m data.gmt > gmtplot.ps
pscoast -O -J -R -Dc -W -B40g20 >> gmtplot.ps
```



2.15. Miscellaneous

This section contains miscellaneous modules which do not fit to the other sections before.

Here is a short overview of all operators in this section:

gradsdes	GrADS data descriptor file
after	ECHAM standard post processor
bandpass	Bandpass filtering
lowpass	Lowpass filtering
highpass	Highpass filtering
gridarea	Grid cell area
gridweights	Grid cell weights
smooth	Smooth grid points
smooth9	9 point smoothing
setvals	Set list of old values to new values
setrtoc	Set range to constant
setrtoc2	Set range to constant others to constant2
gridcellindex	Get grid cell index from lon/lat point
const	Create a constant field
random	Create a field with random numbers
topo	Create a field with topography
seq	Create a time series
stdatm	Create values for pressure and temperature for hydrostatic atmosphere
timsort	Sort over the time
uvDestag	Destaggering of u/v wind components
rotuvNorth	Rotate u/v wind to North pole.
projuvLatLon	Cylindrical Equidistant projection
rotuvb	Backward rotation
mrotuvb	Backward rotation of MPIOM data
mastrfu	Mass stream function
pressure_half	Pressure on half-levels
pressure	Pressure on full-levels
delta_pressure	Pressure difference of half-levels
sealevelpressure	Sea level pressure
gheight	Geopotential height on full-levels
gheight_half	Geopotential height on half-levels
air_density	Air density
adisit	Potential temperature to in-situ temperature
adipot	In-situ temperature to potential temperature

rhopot	Calculates potential density
histcount	Histogram count
histsum	Histogram sum
histmean	Histogram mean
histfreq	Histogram frequency
sethalo	Set the bounds of a field
wct	Windchill temperature
fdns	Frost days where no snow index per time period
strwin	Strong wind days index per time period
strbre	Strong breeze days index per time period
strgal	Strong gale days index per time period
hurr	Hurricane days index per time period
cmorlite	CMOR lite
verifygrid	Verify grid coordinates
hpdegrade	Degrade healpix
hpupgrade	Upgrade healpix

2.15.1. GRADSDES - GrADS data descriptor file

Synopsis

gradsdes[,*mapversion*] `infile`

Description

Creates a [GrADS] data descriptor file. Supported file formats are GRIB1, NetCDF, SERVICE, EXTRA and IEG. For GRIB1 files the GrADS map file is also generated. For SERVICE and EXTRA files the grid have to be specified with the **CDO** option '-g <grid>'. This module takes `infile` in order to create filenames for the descriptor (`infile.ctl`) and the map (`infile.gmp`) file.

Parameter

mapversion INTEGER Format version of the GrADS map file for GRIB1 datasets. Use 1 for a machine specific version 1 GrADS map file, 2 for a machine independent version 2 GrADS map file and 4 to support GRIB files >2GB. A version 2 map file can be used only with GrADS version 1.8 or newer. A version 4 map file can be used only with GrADS version 2.0 or newer. The default is 4 for files >2GB, otherwise 2.

Example

To create a GrADS data descriptor file from a GRIB1 dataset use:

```
cdo gradsdes infile.grb
```

This will create a descriptor file with the name `infile.ctl` and the map file `infile.gmp`.

Assumed the input GRIB1 dataset has 3 variables over 12 timesteps on a Gaussian N16 grid. The contents of the resulting GrADS data description file is approximately:

```
DSET ^infile.grb
DTYPE GRIB
INDEX ^infile.gmp
XDEF 64 LINEAR 0.000000 5.625000
YDEF 32 LEVELS -85.761 -80.269 -74.745 -69.213 -63.679 -58.143
               -52.607 -47.070 -41.532 -35.995 -30.458 -24.920
               -19.382 -13.844  -8.307  -2.769   2.769   8.307
                13.844  19.382  24.920  30.458  35.995  41.532
                47.070  52.607  58.143  63.679  69.213  74.745
                80.269  85.761
ZDEF 4 LEVELS 925 850 500 200
TDEF 12 LINEAR 12:00Z1jan1987 1mo
TITLE infile.grb T21 grid
OPTIONS yrev
UNDEF -9e+33
VARS 3
geosp    0  129,1,0  surface geopotential (orography)  [m^2/s^2]
t        4  130,99,0  temperature  [K]
tslm1    0  139,1,0  surface temperature of land  [K]
ENDVARS
```

2.15.2. AFTERBURNER - ECHAM standard post processor

Synopsis

after*[,vct]* `infiles outfile`

Description

The "afterburner" is the standard post processor for [ECHAM] GRIB and NetCDF data which provides the following operations:

- Extract specified variables and levels
- Compute derived variables
- Transform spectral data to Gaussian grid representation
- Vertical interpolation to pressure levels
- Compute temporal means

This operator reads selection parameters as namelist from stdin. Use the UNIX redirection "<namelistfile" to read the namelist from file.

The input files can't be combined with other **CDO** operators because of an optimized reader for this operator.

Namelist

Namelist parameter and there defaults:

```
TYPE=0, CODE=-1, LEVEL=-1, INTERVAL=0, MEAN=0, EXTRAPOLATE=1
```

TYPE controls the transformation and vertical interpolation. Transforming spectral data to Gaussian grid representation and vertical interpolation to pressure levels are performed in a chain of steps. The **TYPE** parameter may be used to stop the chain at a certain step. Valid values are:

```
TYPE =  0 : Hybrid   level spectral coefficients
TYPE = 10 : Hybrid   level fourier  coefficients
TYPE = 11 : Hybrid   level zonal mean sections
TYPE = 20 : Hybrid   level gauss grids
TYPE = 30 : Pressure level gauss grids
TYPE = 40 : Pressure level fourier  coefficients
TYPE = 41 : Pressure level zonal mean sections
TYPE = 50 : Pressure level spectral coefficients
TYPE = 60 : Pressure level fourier  coefficients
TYPE = 61 : Pressure level zonal mean sections
TYPE = 70 : Pressure level gauss grids
```

Vorticity, divergence, streamfunction and velocity potential need special treatment in the vertical transformation. They are not available as types 30, 40 and 41. If you select one of these combinations, type is automatically switched to the equivalent types 70, 60 and 61. The type of all other variables will be switched too, because the type is a global parameter.

CODE selects the variables by the ECHAM GRIB1 code number (1-255). The default value **-1** processes all detected codes. Derived variables computed by the afterburner:

Code	Name	Longname	Units	Level	Needed Codes
34	low_cld	low cloud		single	223 on modellevel
35	mid_cld	mid cloud		single	223 on modellevel
36	hih_cld	high cloud		single	223 on modellevel
131	u	u-velocity	m/s	atm (ml+pl)	138, 155
132	v	v-velocity	m/s	atm (ml+pl)	138, 155
135	omega	vertical velocity	Pa/s	atm (ml+pl)	138, 152, 155
148	stream	streamfunction	mˆ 2/s	atm (ml+pl)	131, 132
149	velopot	velocity potential	mˆ 2/s	atm (ml+pl)	131, 132
151	slp	mean sea level pressure	Pa	surface	129, 130, 152
156	geopoth	geopotential height	m	atm (ml+pl)	129, 130, 133, 152
157	rhumidity	relative humidity		atm (ml+pl)	130, 133, 152
189	sclfs	surface solar cloud forcing		surface	176-185
190	tclfs	surface thermal cloud forcing		surface	177-186
191	sclf0	top solar cloud forcing		surface	178-187
192	tclf0	top thermal cloud forcing		surface	179-188
259	windspeed	windspeed	m/s	atm (ml+pl)	sqrt(u*u+v*v)
260	precip	total precipitation		surface	142+143

LEVEL selects the hybrid or pressure levels. The allowed values depends on the parameter **TYPE**. The default value **-1** processes all detected levels.

INTERVAL selects the processing interval. The default value **0** process data on monthly intervals. **INTERVAL=1** sets the interval to daily.

MEAN=1 compute and write monthly or daily mean fields. The default value **0** writes out all timesteps.

EXTRAPOLATE=0 switch of the extrapolation of missing values during the interpolation from model to pressure level (only available with **MEAN=0** and **TYPE=30**). The default value **1** extrapolate missing values.

Possible combinations of TYPE, CODE and MEAN:

TYPE	CODE	MEAN
0/10/11	130 temperature	0
0/10/11	131 u-velocity	0
0/10/11	132 v-velocity	0
0/10/11	133 specific humidity	0
0/10/11	138 vorticity	0
0/10/11	148 streamfunction	0
0/10/11	149 velocity potential	0
0/10/11	152 LnPs	0
0/10/11	155 divergence	0
>11	all codes	0/1

Parameter

vct STRING File with VCT in ASCII format

Example

To interpolate ECHAM hybrid model level data to pressure levels of 925, 850, 500 and 200 hPa, use:

```
cdo after infile outfile << EON
   TYPE=30 LEVEL=92500,85000,50000,20000
EON
```

2.15.3. FILTER - Time series filtering

Synopsis

bandpass,*fmin*,*fmax* `infile outfile`

lowpass,*fmax* `infile outfile`

highpass,*fmin* `infile outfile`

Description

This module takes the time series for each gridpoint in `infile` and (fast fourier) transforms it into the frequency domain. According to the particular operator and its parameters certain frequencies are filtered (set to zero) in the frequency domain and the spectrum is (inverse fast fourier) transformed back into the time domain. To determine the frequency the time-axis of `infile` is used. (Data should have a constant time increment since this assumption applies for transformation. However, the time increment has to be different from zero.) All frequencies given as parameter are interpreted per year. This is done by the assumption of a 365-day calendar. Consequently if you want to perform multiyear-filtering accurately you have to delete the 29th of February. If your `infile` has a 360 year calendar the frequency parameters *fmin* respectively *fmax* should be multiplied with a factor of 360/365 in order to obtain accurate results. For the set up of a frequency filter the frequency parameters have to be adjusted to a frequency in the data. Here *fmin* is rounded down and *fmax* is always rounded up. Consequently it is possible to use bandpass with *fmin*=*fmax* without getting a zero-field for `outfile`. Hints for efficient usage:

- to get reliable results the time-series has to be detrended (cdo detrend)
- the lowest frequency greater zero that can be contained in infile is 1/(N*dT),
- the greatest frequency is 1/(2dT) (Nyquist frequency),

with N the number of timesteps and dT the time increment of `infile` in years.

Missing value support for operators in this module is not implemented, yet!

Operators

bandpass Bandpass filtering
Bandpass filtering (pass for frequencies between *fmin* and *fmax*). Suppresses all variability outside the frequency range specified by [*fmin*,*fmax*].

lowpass Lowpass filtering
Lowpass filtering (pass for frequencies lower than *fmax*). Suppresses all variability with frequencies greater than *fmax*.

highpass Highpass filtering
Highpass filtering (pass for frequencies greater than *fmin*). Suppresses all variabilty with frequencies lower than *fmin*.

Parameter

fmin	FLOAT	Minimum frequency per year that passes the filter.
fmax	FLOAT	Maximum frequency per year that passes the filter.

Note

For better performace of these operators use the **CDO** configure option --with-fftw3.

Example

Now assume your data are still hourly for a time period of 5 years but with a 365/366-day- calendar and you want to suppress the variability on timescales greater or equal to one year (we suggest here to use a number x bigger than one (e.g. x=1.5) since there will be dominant frequencies around the peak (if there is one) as well due to the issue that the time series is not of infinite length). Therefor you can use the following:

```
cdo highpass,x -del29feb infile outfile
```

Accordingly you might use the following to suppress variability on timescales shorter than one year:

```
cdo lowpass,1 -del29feb infile outfile
```

Finally you might be interested in 2-year variability. If you want to suppress the seasonal cycle as well as say the longer cycles in climate system you might use

```
cdo bandpass,x,y -del29feb infile outfile
```

with x<=0.5 and y >=0.5.

2.15.4. GRIDCELL - Grid cell quantities

Synopsis

gridarea*[,radius]* `infile outfile`

gridweights `infile outfile`

Description

This module reads the grid cell area of the first grid from the input stream. If the grid cell area is missing it will be computed from the grid coordinates. The area of a grid cell is calculated using spherical triangles from the coordinates of the center and the vertices. The base is a unit sphere which is scaled with the radius of the planet. The default planet radius is 6371000 meter. The parameter *radius* or the environment variable `PLANET_RADIUS` can be used to change the default. Depending on the chosen operator the grid cell area or weights are written to the output stream.

Operators

gridarea Grid cell area
Writes the grid cell area to the output stream. If the grid cell area have to be computed it is scaled with the planet radius to square meters.

gridweights Grid cell weights
Writes the grid cell area weights to the output stream.

Parameter

radius FLOAT Planet radius in meter

Environment

`PLANET_RADIUS` This variable is used to scale the computed grid cell areas to square meters. By default PLANET_RADIUS is set to an earth radius of 6371000 meter.

2.15.5. SMOOTH - Smooth grid points

Synopsis

smooth*[,options]* `infile outfile`

smooth9 `infile outfile`

Description

Smooth all grid points of a horizontal grid. Options is a comma-separated list of "key=value" pairs with optional parameters.

Operators

smooth Smooth grid points
Performs a N point smoothing on all input fields. The number of points used depend on the search radius (radius) and the maximum number of points (maxpoints). Per default all points within the search radius of 1degree are used. The weights for the points depend on the weighting method and the distance. The implemented weighting method is linear with constant default weights of 0.25 at distance 0 (weight0) and at the search radius (weightR).

smooth9 9 point smoothing
Performs a 9 point smoothing on all fields with a quadrilateral curvilinear grid. The result at each grid point is a weighted average of the grid point plus the 8 surrounding points. The center point receives a weight of 1.0, the points at each side and above and below receive a weight of 0.5, and corner points receive a weight of 0.3. All 9 points are multiplied by their weights and summed, then divided by the total weight to obtain the smoothed value. Any missing data points are not included in the sum; points beyond the grid boundary are considered to be missing. Thus the final result may be the result of an averaging with less than 9 points.

Parameter

nsmooth	INTEGER	Number of times to smooth, default nsmooth=1
radius	STRING	Search radius, default radius=1deg (units: deg, rad, km, m)
maxpoints	INTEGER	Maximum number of points, default maxpoints=<gridsize>
weighted	STRING	Weighting method, default weighted=linear
weight0	FLOAT	Weight at distance 0, default weight0=0.25
weightR	FLOAT	Weight at the search radius, default weightR=0.25

2.15.6. DELTAT - Difference between timesteps

Synopsis

deltat `infile outfile`

Description

This operator computes the difference between each timestep.

2.15.7. REPLACEVALUES - Replace variable values

Synopsis

setvals,*oldval,newval[,...]* `infile outfile`

setrtoc,*rmin,rmax,c* `infile outfile`

setrtoc2,*rmin,rmax,c,c2* `infile outfile`

Description

This module replaces old variable values with new values, depending on the operator.

Operators

setvals Set list of old values to new values
Supply a list of n pairs of old and new values.

setrtoc Set range to constant

$$o(t,x) = \begin{cases} \text{c} & \text{if } i(t,x) \geq rmin \wedge i(t,x) \leq rmax \\ i(t,x) & \text{if } i(t,x) < rmin \vee i(t,x) > rmax \end{cases}$$

setrtoc2 Set range to constant others to constant2

$$o(t,x) = \begin{cases} \text{c} & \text{if } i(t,x) \geq rmin \wedge i(t,x) \leq rmax \\ \text{c2} & \text{if } i(t,x) < rmin \vee i(t,x) > rmax \end{cases}$$

Parameter

oldval,newval,...	FLOAT	Pairs of old and new values
rmin	FLOAT	Lower bound
rmax	FLOAT	Upper bound
c	FLOAT	New value - inside range
c2	FLOAT	New value - outside range

2.15.8. GETGRIDCELL - Get grid cell index

Synopsis

gridcellindex[,*parameter*] `infile`

Description

Get the grid cell index of one grid point selected by the parameter lon and lat.

Parameter

lon	INTEGER	Longitude of the grid cell in degree
lat	INTEGER	Latitude of the grid cell in degree

2.15.9. VARGEN - Generate a field

Synopsis

const,*const*,*grid* `outfile`

random,*grid[,seed]* `outfile`

topo*[,grid]* `outfile`

seq,*start*,*end[,inc]* `outfile`

stdatm,*levels* `outfile`

Description

Generates a dataset with one or more fields

Operators

const Create a constant field
Creates a constant field. All field elements of the grid have the same value.

random Create a field with random numbers
Creates a field with rectangularly distrubuted random numbers in the interval [0,1].

topo Create a field with topography
Creates a field with topography data, per default on a global half degree grid.

seq Create a time series
Creates a time series with field size 1 and field elements beginning with a start value in time step 1 which is increased from one time step to the next.

stdatm Create values for pressure and temperature for hydrostatic atmosphere
Creates pressure and temperature values for the given list of vertical levels. The formulas are:

$$P(z) = P_0 \exp\left(-\frac{g}{R}\frac{H}{T_0}\log\left(\frac{\exp\left(\frac{z}{H}\right)T_0+\Delta T}{T_0+\Delta T}\right)\right)$$

$$T(z) = T_0 + \Delta T \exp\left(-\frac{z}{H}\right)$$

with the following constants

$$\begin{aligned} T_0 &= 213\text{K} && : \text{offset to get a surface temperature of 288K} \\ \Delta T &= 75\text{K} && : \text{Temperature lapse rate for 10Km} \\ P_0 &= 1013.25\text{hPa} && : \text{surface pressure} \\ H &= 10000.0\text{m} && : \text{scale height} \\ g &= 9.80665\frac{\text{m}}{\text{S}^2} && : \text{earth gravity} \\ R &= 287.05\frac{\text{J}}{\text{kgK}} && : \text{gas constant for air} \end{aligned}$$

This is the solution for the hydrostatic equations and is only valid for the troposphere (constant positive lapse rate). The temperature increase in the stratosphere and other effects of the upper atmosphere are not taken into account.

Parameter

const	FLOAT	Constant
seed	INTEGER	The seed for a new sequence of pseudo-random numbers [default: 1]
grid	STRING	Target grid description file or name
start	FLOAT	Start value of the loop
end	FLOAT	End value of the loop
inc	FLOAT	Increment of the loop [default: 1]
levels	FLOAT	Target levels in metre above surface

Example

To create a standard atmosphere dataset on a given horizontal grid:

```
cdo enlarge,gridfile -stdatm,10000,8000,5000,3000,2000,1000,500,200,0 outfile
```

2.15.10. TIMSORT - Timsort

Synopsis

timsort `infile outfile`

Description

Sorts the elements in ascending order over all timesteps for every field position. After sorting it is:

$o(t_1, x) <= o(t_2, x) \qquad \forall (t_1 < t_2), x$

Example

To sort all field elements of a dataset over all timesteps use:

```
cdo timsort infile outfile
```

2.15.11. WINDTRANS - Wind Transformation

Synopsis

uvDestag,*u,v[,-/+0.5[,-/+0.5]]* `infile outfile`

rotuvNorth,*u,v* `infile outfile`

projuvLatLon,*u,v* `infile outfile`

Description

This module contains special operators for datsets with wind components on a rotated lon/lat grid, e.g. data from the regional model HIRLAM or REMO.

Operators

uvDestag Destaggering of u/v wind components
This is a special operator for destaggering of wind components. If the file contains a grid with temperature (name='t' or code=11) then grid_temp will be used for destaggered wind.

rotuvNorth Rotate u/v wind to North pole.
This is an operator for transformation of wind-vectors from grid-relative to north-pole relative for the whole file. (FAST implementation with JACOBIANS)

projuvLatLon Cylindrical Equidistant projection
Thus is an operator for transformation of wind-vectors from the globe-spherical coordinate system into a flat Cylindrical Equidistant (lat-lon) projection. (FAST JACOBIAN implementation)

Parameter

u,v	STRING	Pair of u,v wind components (use variable names or code numbers)
-/+0.5,-/+0.5	STRING	Destaggered grid offsets are optional (default -0.5,-0.5)

Example

Typical operator sequence on HIRLAM NWP model output (LAMH_D11 files):

```
cdo uvDestag,33,34 inputfile inputfile_destag
cdo rotuvNorth,33,34 inputfile_destag inputfile_rotuvN
```

2.15.12. ROTUVB - Rotation

Synopsis

rotuvb,*u,v,...* `infile outfile`

Description

This is a special operator for datsets with wind components on a rotated grid, e.g. data from the regional model REMO. It performs a backward transformation of velocity components U and V from a rotated spherical system to a geographical system.

Parameter

u,v,... STRING Pairs of zonal and meridional velocity components (use variable names or code numbers)

Note

This is a specific implementation for data from the REMO model, it may not work with data from other sources.

Example

To transform the u and v velocity of a dataset from a rotated spherical system to a geographical system use:

```
cdo rotuvb,u,v infile outfile
```

2.15.13. MROTUVB - Backward rotation of MPIOM data

Synopsis

mrotuvb `infile1 infile2 outfile`

Description

MPIOM data are on a rotated Arakawa C grid. The velocity components U and V are located on the edges of the cells and point in the direction of the grid lines and rows. With mrotuvb the velocity vector is rotated in latitudinal and longitudinal direction. Before the rotation, U and V are interpolated to the scalar points (cell center). U is located with the coordinates for U in infile1 and V in infile2. mrotuvb assumes a positive meridional flow for a flow from grid point(i,j) to grid point(i,j+1) and positive zonal flow for a flow from grid point(i+1,j) to point(i,j).

Note

This is a specific implementation for data from the MPIOM model, it may not work with data from other sources.

2.15.14. MASTRFU - Mass stream function

Synopsis

mastrfu `infile outfile`

Description

This is a special operator for the post processing of the atmospheric general circulation model [ECHAM]. It computes the mass stream function (code=272). The input dataset have to be a zonal mean of v-velocity [m/s] (code=132) on pressure levels.

Example

To compute the mass stream function from a zonal mean v-velocity dataset use:

```
cdo mastrfu infile outfile
```

2.15.15. PRESSURE - Pressure on model levels

Synopsis

```
<operator> infile outfile
```

Description

This module contains operators to calculate the pressure on model levels. To calculate the pressure on model levels, the a and b coefficients defining the model levels and the surface pressure are required. The a and b coefficients are normally part of the model level data. If not available, the surface pressure can be derived from the logarithm of the surface pressure. The surface pressure is identified by the GRIB1 code number or NetCDF CF standard name.

Name	Units	GRIB1 code	CF standard name
log surface pressure	Pa	152	
surface pressure	Pa	134	surface_air_pressure

Operators

pressure_half Pressure on half-levels
This operator computes the pressure on model half-levels in pascal. The model half-level pressure (p_half) is given by:

$$p\_half = a + b * sp$$

with
a, b: coefficients defining the model levels
sp: surface pressure

pressure Pressure on full-levels
This operator computes the pressure on model full-levels in pascal. The pressure on model full-levels (p_full) is in the middle of the layers defined by the model half-levels:

$$p\_full = \frac{p\_half\_above + p\_half\_below}{2}$$

delta_pressure Pressure difference of half-levels
This operator computes the pressure difference between to model half-levels.

$$delta\_p = p\_half\_below - p\_half\_above$$

2.15.16. DERIVEPAR - Derived model parameters

Synopsis

```
<operator> infile outfile
```

Description

This module contains operators that calculate derived model parameters. All necessary input variables are identified by their GRIB1 code number or the NetCDF CF standard name. Supported GRIB1 parameter tables are: WMO standard table number 2 and ECMWF local table number 128.

CF standard name	Units	GRIB 1 code
surface_air_pressure	Pa	134
air_temperature	K	130
specific_humidity	kg/kg	133
surface_geopotential	m2 s-2	129
geopotential_height	m	156

Operators

sealevelpressure Sea level pressure
This operator computes the sea level pressure (air_pressure_at_sea_level). Required input fields are surface_air_pressure, surface_geopotential and air_temperature on full hybrid sigma pressure levels.

gheight Geopotential height on full-levels
This operator computes the geopotential height (geopotential_height) on model full-levels in metres. Required input fields are surface_air_pressure, surface_geopotential, specific_humidity and air_temperature on full hybrid sigma pressure levels. Note, this procedure is an approximation, which doesn't take into account the effects of e.g. cloud ice and water, rain and snow.

gheight_half Geopotential height on half-levels
This operator computes the geopotential height (geopotential_height) on model half-levels in metres. Required input fields are surface_air_pressure, surface_geopotential, specific_humidity and air_temperature on full hybrid sigma pressure levels. Note, this procedure is an approximation, which doesn't take into account the effects of e.g. cloud ice and water, rain and snow.

air_density Air density
This operator computes the air density, it depends on pressure, humidity and temperature. Required input fields are surface_air_pressure, specific_humidity and air_temperature on full hybrid sigma pressure levels. The air density (rho) is calculated with the following formula:

$$rho = P/Rs * Tv$$

P: air pressure in Pascal
Tv: virtual temperature in Kelvin
Rs: specific gas constant for try air; 287.085 J/(kg*K)

$$Tv = T * [1 + a * q]$$

T: air temperature in Kelvin
q: specific humidity
a: gas constants of air and water vapor; 0.6078

2.15.17. ADISIT - Potential temperature to in-situ temperature and vice versa

Synopsis

<operator>[,pressure] `infile outfile`

Description

Operators

adisit Potential temperature to in-situ temperature
This is a special operator for the post processing of the ocean and sea ice model [MPIOM]. It converts potential temperature adiabatically to in-situ temperature to(t, s, p). Required input fields are sea water potential temperature (name=tho; code=2) and sea water salinity (name=sao; code=5). Pressure is calculated from the level information or can be specified by the optional parameter. Output fields are sea water temperature (name=to; code=20) and sea water salinity (name=s; code=5).

adipot In-situ temperature to potential temperature
This is a special operator for the post processing of the ocean and sea ice model [MPIOM]. It converts in-situ temperature to potential temperature tho(to, s, p). Required input fields are sea water in-situ temperature (name=t; code=2) and sea water salinity (name=sao,s; code=5). Pressure is calculated from the level information or can be specified by the optional parameter. Output fields are sea water temperature (name=tho; code=2) and sea water salinity (name=s; code=5).

Parameter

pressure FLOAT Pressure in bar (constant value assigned to all levels)

2.15.18. RHOPOT - Calculates potential density

Synopsis

rhopot*[,pressure]* `infile outfile`

Description

This is a special operator for the post processing of the ocean and sea ice model [MPIOM]. It calculates the sea water potential density (name=rhopoto; code=18). Required input fields are sea water in-situ temperature (name=to; code=20) and sea water salinity (name=sao; code=5). Pressure is calculated from the level information or can be specified by the optional parameter.

Parameter

pressure FLOAT Pressure in bar (constant value assigned to all levels)

Example

To compute the sea water potential density from the potential temperature use this operator in combination with adisit:

```
cdo rhopot -adisit infile outfile
```

2.15.19. HISTOGRAM - Histogram

Synopsis

<operator>,bounds `infile outfile`

Description

This module creates bins for a histogram of the input data. The bins have to be adjacent and have non-overlapping intervals. The user has to define the bounds of the bins. The first value is the lower bound and the second value the upper bound of the first bin. The bounds of the second bin are defined by the second and third value, aso. Only 2-dimensional input fields are allowed. The output file contains one vertical level for each of the bins requested.

Operators

histcount Histogram count
Number of elements in the bin range.

histsum Histogram sum
Sum of elements in the bin range.

histmean Histogram mean
Mean of elements in the bin range.

histfreq Histogram frequency
Relative frequency of elements in the bin range.

Parameter

bounds FLOAT Comma-separated list of the bin bounds (-inf and inf valid)

2.15.20. SETHALO - Set the bounds of a field

Synopsis

sethalo*[,parameter]* `infile outfile`

Description

This operator sets the boundary in the east, west, south and north of the rectangular understood fields. Positive values of the parameters increase the boundary in the selected direction. Negative values decrease the field at the selected boundary. The new rows and columns are filled with the missing value. With the optional parameter value a different fill value can be used. Global cyclic fields are filled cyclically at the east and west borders, if the fill value is not set by the user. All input fields need to have the same horizontal grid.

Parameter

east INTEGER East halo

west INTEGER West halo

south INTEGER South halo

north INTEGER North halo

value FLOAT Fill value (default is the missing value)

2.15.21. WCT - Windchill temperature

Synopsis

wct `infile1 infile2 outfile`

Description

Let `infile1` and `infile2` be time series of temperature and wind speed fields, then a corresponding time series of resulting windchill temperatures is written to `outfile`. The wind chill temperature calculation is only valid for a temperature of T <= 33 °C and a wind speed of v >= 1.39 m/s. Whenever these conditions are not satisfied, a missing value is written to `outfile`. Note that temperature and wind speed fields have to be given in units of °C and m/s, respectively.

2.15.22. FDNS - Frost days where no snow index per time period

Synopsis

fdns `infile1 infile2 outfile`

Description

Let `infile1` be a time series of the daily minimum temperature TN and `infile2` be a corresponding series of daily surface snow amounts. Then the number of days where TN < 0 °C and the surface snow amount is less than 1 cm is counted. The temperature TN have to be given in units of Kelvin. The date information of a timestep in `outfile` is the date of the last contributing timestep in `infile`.

2.15.23. STRWIN - Strong wind days index per time period

Synopsis

strwin*[,v]* `infile outfile`

Description

Let `infile` be a time series of the daily maximum horizontal wind speed VX, then the number of days where VX > v is counted. The horizontal wind speed v is an optional parameter with default v = 10.5 m/s. A further output variable is the maximum number of consecutive days with maximum wind speed greater than or equal to v. Note that both VX and v have to be given in units of m/s. Also note that the horizontal wind speed is defined as the square root of the sum of squares of the zonal and meridional wind speeds. The date information of a timestep in `outfile` is the date of the last contributing timestep in `infile`.

Parameter

v FLOAT Horizontal wind speed threshold (m/s, default v = 10.5 m/s)

2.15.24. STRBRE - Strong breeze days index per time period

Synopsis

strbre `infile outfile`

Description

Let `infile` be a time series of the daily maximum horizontal wind speed VX, then the number of days where VX is greater than or equal to 10.5 m/s is counted. A further output variable is the maximum number of consecutive days with maximum wind speed greater than or equal to 10.5 m/s. Note that VX is defined as the square root of the sum of squares of the zonal and meridional wind speeds and have to be given in units of m/s. The date information of a timestep in `outfile` is the date of the last contributing timestep in `infile`.

2.15.25. STRGAL - Strong gale days index per time period

Synopsis

strgal `infile outfile`

Description

Let `infile` be a time series of the daily maximum horizontal wind speed VX, then the number of days where VX is greater than or equal to 20.5 m/s is counted. A further output variable is the maximum number of consecutive days with maximum wind speed greater than or equal to 20.5 m/s. Note that VX is defined as the square root of the sum of square of the zonal and meridional wind speeds and have to be given in units of m/s. The date information of a timestep in `outfile` is the date of the last contributing timestep in `infile`.

2.15.26. HURR - Hurricane days index per time period

Synopsis

hurr `infile outfile`

Description

Let `infile` be a time series of the daily maximum horizontal wind speed VX, then the number of days where VX is greater than or equal to 32.5 m/s is counted. A further output variable is the maximum number of consecutive days with maximum wind speed greater than or equal to 32.5 m/s. Note that VX is defined as the square root of the sum of squares of the zonal and meridional wind speeds and have to be given in units of m/s. The date information of a timestep in `outfile` is the date of the last contributing timestep in `infile`.

2.15.27. CMORLITE - CMOR lite

Synopsis

cmorlite,*table*[,*convert*] `infile outfile`

Description

The [CMOR] (Climate Model Output Rewriter) library comprises a set of functions, that can be used to produce CF-compliant NetCDF files that fulfill the requirements of many of the climate community's standard model experiments. These experiments are collectively referred to as MIP's. Much of the metadata written to the output files is defined in MIP-specific tables, typically made available from each MIP's web site.

The **CDO** operator cmorlite process the header and variable section of such MIP tables and writes the result with the internal IO library [CDI]. In addition to the CMOR 2 and 3 table format, the **CDO** parameter table format is also supported. The following parameter table entries are available:

Entry	Type	Description
`name`	WORD	Name of the variable
`out_name`	WORD	New name of the variable
`type`	WORD	Data type (real or double)
`standard_name`	WORD	As defined in the CF standard name table
`long_name`	STRING	Describing the variable
`units`	STRING	Specifying the units for the variable
`comment`	STRING	Information concerning the variable
`cell_methods`	STRING	Information concerning calculation of means or climatologies
`cell_measures`	STRING	Indicates the names of the variables containing cell areas and volumes
`missing_value`	FLOAT	Specifying how missing data will be identified
`valid_min`	FLOAT	Minimum valid value
`valid_max`	FLOAT	Maximum valid value
`ok_min_mean_abs`	FLOAT	Minimum absolute mean
`ok_max_mean_abs`	FLOAT	Maximum absolute mean
`factor`	FLOAT	Scale factor
`delete`	INTEGER	Set to 1 to delete variable
`convert`	INTEGER	Set to 1 to convert the unit if necessary

Most of the above entries are stored as variables attributes, some of them are handled differently. The variable `name` is used as a search key for the parameter table. `valid_min`, `valid_max`, `ok_min_mean_abs` and `ok_max_mean_abs` are used to check the range of the data.

Parameter

table	STRING	Name of the CMOR table as specified from PCMDI
convert	STRING	Converts the units if necessary

Example

Here is an example of a parameter table for one variable:

```
prompt> cat mypartab
&parameter
  name          = t
```

```
  out_name      = ta
  standard_name = air_temperature
  units         = "K"
  missing_value = 1.0e+20
  valid_min     = 157.1
  valid_max     = 336.3
/
```

To apply this parameter table to a dataset use:

```
cdo -f nc cmorlite,mypartab,convert infile outfile
```

This command renames the variable **t** to **ta**. The standard name of this variable is set to **air_temperature** and the unit is set to [K] (converts the unit if necessary). The missing value will be set to **1.0e+20**. In addition it will be checked whether the values of the variable are in the range of **157.1** to **336.3**. The result will be stored in NetCDF.

2.15.28. VERIFYGRID - Verify grid coordinates

Synopsis

verifygrid infile

Description

This operator verifies the coordinates of all horizontal grids found in infile. Among other things, it searches for duplicate cells, non-convex cells, and whether the center is located outside the cell bounds. Use the **CDO** option -v to output the position of these cells. This information can be useful to avoid problems when interpolating the data.

2.15.29. HEALPIX - Change healpix resolution

Synopsis

<operator>,parameter `infile outfile`

Description

Degrade or upgrade the resolution of a healpix grid.

Operators

hpdegrade Degrade healpix
Degrade the resolution of a healpix grid. The value of the target pixel is the mean of the source pixels.

hpupgrade Upgrade healpix
Upgrade the resolution of a healpix grid. The values of the target pixels is the value of the source pixel.

Parameter

nside INTEGER The nside of the target healpix, must be a power of two [default: same as input].

order STRING Pixel ordering of the target healpix ('nested' or 'ring').

power FLOAT If non-zero, divide the result by (nside[in]/nside[out])**power. power=-2 keeps the sum of the map invariant.

3. Contributors

3.1. History

CDO was originally developed by Uwe Schulzweida at the Max Planck Institute for Meteorology (MPI-M). The first public release is available since 2003. The MPI-M, together with the DKRZ, has a long history in the development of tools for processing climate data. **CDO** was inspired by some of these tools, such as the PINGO package and the GRIB-Modules.

PINGO[1] was developed by Jürgen Waszkewitz, Peter Lenzen, and Nathan Gillet in 1995 at the DKRZ, Hamburg (Germany). **CDO** has a similar user interface and uses some of the PINGO routines.

The GRIB-Modules was developed by Heiko Borgert and Wolfgang Welke in 1991 at the MPI-M. **CDO** is using a similar module structure and also some of the routines.

3.2. External sources

CDO has incorporated code from several sources:

afterburner is a postprocessing application for ECHAM data and ECMWF analysis data, originally developed by Edilbert Kirk, Michael Ponater and Arno Hellbach. The afterburner code was modified for the **CDO** operators after, ml2pl, ml2hl, sp2gp, gp2sp.

SCRIP is a software package used to generate interpolation weights for remapping fields from one grid to another in spherical geometry [SCRIP]. It was developed at the Los Alamos National Laboratory by Philip W. Jones. The SCRIP library was converted from Fortran to ANSI C and is used as the base for the remapping operators in **CDO**.

YAC (Yet Another Coupler) was jointly developed by DKRZ and MPI-M by Moritz Hanke and Rene Redler [YAC]. **CDO** is using the clipping and cell search routines for the conservative remapping with remapcon.

libkdtree a C99 implementation of the kd-tree algorithm developed by Jörg Dietrich.

CDO uses tools from the GNU project, including automake, and libtool.

3.3. Contributors

The primary contributors to the **CDO** development have been:

Uwe Schulweida : Concept, design and implementation of **CDO**, project coordination, and releases.

Luis Kornblueh : He supports **CDO** from the beginning. His main contributions are GRIB performance and compression, GME and unstructured grid support. Luis also helps with design and planning.

Ralf Müller : He is working on **CDO** since 2009. His main contributions are the implementation of the User Portal, the ruby and python interface for all **CDO** operators, the building process and the Windows support. The **CDO** User Portal was funded by the European Commission infracstructure project IS-ENES. Ralf also helps a lot with the user support. Implemented operators: intlevel3d, consecsum, consects, ngrids, ngridpoints, reducegrid

[1] Procedural INterface for GRIB formatted Objects

Oliver Heidmann : He is working on **CDO** since 2015. His main contributions are refactoring to C++ and the new command line parser.

Karin Meier-Fleischer : She is working in the **CDO** user support since 2017.

Fabian Wachsmann : He is working on **CDO** for the CMIP6 project since 2016. His main task is the implementation and support of the cmor operator. He has also implemented the ETCCDI Indices of Daily Temperature and Precipitation Extremes.

Cedrick Ansorge : He worked on the software package **CDO** as a student assistant at MPI-M from 2007-2011. Implemented operators: eof, eof3d, enscrps, ensbrs, maskregion, bandpass, lowpass, highpass, smooth9

Ralf Quast : He worked on **CDO** on behalf of the Service Gruppe Anpassung (SGA), DKRZ in 2006. He implemented all ECA Indices of Daily Temperature and Precipitation Extremes, all percentile operators, module YDRUNSTAT and wct.

Kameswarrao Modali : He worked on **CDO** from 2012-2013.
Implemented operators: contour, shaded, grfill, vector, graph.

Michal Koutek : Implemented operators: selmulti delmulti, changemulti, samplegrid, uvDestag, rotuvNorth, projuvLatLon.

Etienne Tourigny : Implemented operators: setclonlatbox, setcindexbox, setvals, splitsel, histfreq, setrtoc, setrtoc2.

Karl-Hermann Wieners : Implemented operators: aexpr, aexprf, selzaxisname.

Asela Rajapakse : He worked on **CDO** from 2016-2017 as part of the EUDAT project.
Implemented operator: verifygrid

Estanislao Gavilan : Improved the **CDO** documentation for the installation section.

Many users have contributed to **CDO** by sending bug reports, patches and suggestions over time. Very helpful is also the active participation in the user forum of some users. Here is an incomplete list:

Jaison-Thomas Ambadan, Harald Anlauf, Andy Aschwanden, Stefan Bauer, Simon Blessing, Renate Brokopf, Michael Boettinger, Tim Brücher, Reinhard Budich, Martin Claus, Traute Crüger, Brendan de Tracey, Irene Fischer-Bruns, Chris Fletscher, Helmut Frank, Kristina Fröhlich, Oliver Fuhrer, Monika Esch, Pier Giuseppe Fogli, Beate Gayer, Veronika Gayler, Marco Giorgetta, David Gobbett, Holger Goettel, Helmut Haak, Stefan Hagemann, Angelika Heil, Barbara Hennemuth, Daniel Hernandez, Nathanael Huebbe, Thomas Jahns, Frank Kaspar, Daniel Klocke, Edi Kirk, Yvonne Küstermann, Stefanie Legutke, Leonidas Linardakis, Stephan Lorenz, Frank Lunkeit, Uwe Mikolajewicz, Laura Niederdrenk, Dirk Notz, Hans-Jürgen Panitz, Ronny Petrik, Swantje Preuschmann, Florian Prill, Asela Rajapakse, Daniel Reinert, Hannes Reuter, Mathis Rosenhauer, Reiner Schnur, Martin Schultz, Dennis Shea, Kevin Sieck, Martin Stendel, Bjorn Stevens, Martina Stockhaus, Claas Teichmann, Adrian Tompkins, Jörg Trentmann, Álvaro M. Valdebenito, Geert Jan van Oldenborgh, Jin-Song von Storch, David Wang, Joerg Wegner, Heiner Widmann, Claudia Wunram, Klaus Wyser

Please let me know if your name was omitted!

Bibliography

[BitInformation.jl]
M Klöwer, M Razinger, JJ Dominguez, PD Düben and TN Palmer, 2021. Compressing atmospheric data into its real information content. Nature Computational Science 1, 713–724. 10.1038/s43588-021-00156-2

[CDI]
Climate Data Interface, from the Max Planck Institute for Meteorologie

[CM-SAF]
Satellite Application Facility on Climate Monitoring, from the German Weather Service (Deutscher Wetterdienst, DWD)

[CMOR]
Climate Model Output Rewriter, from the Program For Climate Model Diagnosis and Intercomparison (PCMDI)

[ecCodes]
API for GRIB decoding/encoding, from the European Centre for Medium-Range Weather Forecasts (ECMWF)

[ECHAM]
The atmospheric general circulation model ECHAM5, from the Max Planck Institute for Meteorologie

[GMT]
The Generic Mapping Tool, from the School of Ocean and Earth Science and Technology (SOEST)

[GrADS]
Grid Analysis and Display System, from the Center for Ocean-Land-Atmosphere Studies (COLA)

[GRIB]
GRIB version 1, from the World Meteorological Organisation (WMO)

[HDF5]
HDF version 5, from the HDF Group

[INTERA]
INTERA Software Package, from the Max Planck Institute for Meteorologie

[Magics]
Magics Software Package, from the European Centre for Medium-Range Weather Forecasts (ECMWF)

[MPIOM]
Ocean and sea ice model, from the Max Planck Institute for Meteorologie

[NetCDF]
NetCDF Software Package, from the UNIDATA Program Center of the University Corporation for Atmospheric Research

[PINGO]
The PINGO package, from the Model & Data group at the Max Planck Institute for Meteorologie

[REMO]
Regional Model, from the Max Planck Institute for Meteorologie

[Preisendorfer]
Rudolph W. Preisendorfer: Principal Component Analysis in Meteorology and Oceanography, Elsevier (1988)

[PROJ]
Cartographic Projections Library, originally written by Gerald Evenden then of the USGS.

[SCRIP]
SCRIP Software Package, from the Los Alamos National Laboratory

[szip]
Szip compression software, developed at University of New Mexico.

[vonStorch]
Hans von Storch, Walter Zwiers: Statistical Analysis in Climate Research, Cambridge University Press (1999)

[YAC]
YAC - Yet Another Coupler Software Package, from DKRZ and MPI for Meteorologie

A. Environment Variables

The following table describes the environment variables that affect **CDO**.

Variable name	Default	Description
CDO_DOWNLOAD_PATH	None	Path where **CDO** can store downloads.
CDO_FILE_SUFFIX	None	Default filename suffix. This suffix will be added to the output file name instead of the filename extension derived from the file format. NULL will disable the adding of a file suffix.
CDO_GRIDSEARCH_RADIUS	180	Grid search radius in degree. Used by the operators setmisstonn, remapdis and remapnn.
CDO_HISTORY_INFO	true	'false' don't write information to the global *history* attribute.
CDO_ICON_GRIDS	None	Root directory of the installed ICON grids (e.g. /pool/data/ICON).
CDO_PCTL_NBINS	101	Number of histogram bins.
CDO_RESET_HISTORY	false	'true' resets the global *history* attribute.
CDO_REMAP_NORM	fracarea	Choose the normalization for the conservative interpolation
CDO_TIMESTAT_DATE	None	Set target timestamp of a temporal statistic operator to the "first", "middle", "midhigh" or "last" contributing source timestep.
CDO_USE_FFTW	1	Set to 0 to switch off usage of FFTW. Used in the Filter module.
CDO_VERSION_INFO	true	'false' disables the global NetCDF attribute CDO.

B. Parallelized operators

Some of the **CDO** operators are parallelized with OpenMP. To use **CDO** with multiple OpenMP threads, you have to set the number of threads with the option '-P'. Here is an example to distribute the bilinear interpolation on 8 OpenMP threads:

```
cdo -P 8 remapbil,targetgrid infile outfile
```

The following **CDO** operators are parallelized with OpenMP:

Module	Operator	Description
Afterburner	after	ECHAM standard post processor
Detrend	detrend	Detrend
EcaEtccdi	etccdi_tx90p	% of days when daily max temperature is > the 90th percentile
EcaEtccdi	etccdi_tx10p	% of days when daily max temperature is < the 10th percentile
EcaEtccdi	etccdi_tn90p	% of days when daily min temperature is > the 90th percentile
EcaEtccdi	etccdi_tn10p	% of days when daily min temperature is < the 10th percentile
EcaEtccdi	etccdi_r95p	Annual tot precip when daily precip exceeds the 95th percentile of ...
EcaEtccdi	etccdi_r99p	Annual tot precip when daily precip exceeds the 99th percentile of ...
Ensstat	ens<STAT>	Statistical values over an ensemble
EOF	eof	Empirical Orthogonal Functions
Fillmiss	setmisstonn	Set missing value to nearest neighbor
Fillmiss	setmisstodis	Set missing value to distance-weighted average
Filter	bandpass	Bandpass filtering
Filter	lowpass	Lowpass filtering
Filter	highpass	Highpass filtering
Fourier	fourier	Fourier transformation
Genweights	genbil	Generate bilinear interpolation weights
Genweights	genbic	Generate bicubic interpolation weights
Genweights	gendis	Generate distance-weighted average remap weights
Genweights	gennn	Generate nearest neighbor remap weights
Genweights	gencon	Generate 1st order conservative remap weights
Genweights	gencon2	Generate 2nd order conservative remap weights
Genweights	genlaf	Generate largest area fraction remap weights
Gridboxstat	gridbox<STAT>	Statistical values over grid boxes
Intlevel	intlevel	Linear level interpolation
Intlevel3d	intlevel3d	Linear level interpolation from/to 3D vertical coordinates
Remapeta	remapeta	Remap vertical hybrid level
Remap	remapbil	Bilinear interpolation
Remap	remapbic	Bicubic interpolation
Remap	remapdis	Distance-weighted average remapping
Remap	remapnn	Nearest neighbor remapping
Remap	remapcon	First order conservative remapping
Remap	remapcon2	Second order conservative remapping
Remap	remaplaf	Largest area fraction remapping
Smooth	smooth	Smooth grid points
Spectral	sp2gp, gp2sp	Spectral transformation

Module	Operator	Description
Vertintap	ap2pl, ap2hl	Vertical interpolation on hybrid sigma height coordinates
Vertintgh	gh2hl	Vertical height interpolation
Vertintml	ml2pl, ml2hl	Vertical interpolation on hybrid sigma pressure coordinates

C. Standard name table

The following CF standard names are supported by **CDO**.

CF standard name	Units	GRIB 1 code	variable name
surface_geopotential	m2 s-2	129	geosp
air_temperature	K	130	ta
specific_humidity	1	133	hus
surface_air_pressure	Pa	134	aps
air_pressure_at_sea_level	Pa	151	psl
geopotential_height	m	156	zg

D. Grid description examples

D.1. Example of a curvilinear grid description

Here is an example for the **CDO** description of a curvilinear grid. xvals/yvals describe the positions of the 6x5 quadrilateral grid cells. The first 4 values of xbounds/ybounds are the corners of the first grid cell.

```
gridtype  = curvilinear
gridsize  = 30
xsize     = 6
ysize     = 5
xvals     = -21  -11    0   11   21   30  -25  -13    0   13
             25   36  -31  -16    0   16   31   43  -38  -21
              0   21   38   52  -51  -30    0   30   51   64
xbounds   = -23  -14  -17  -28       -14   -5   -6  -17        -5    5    6   -6
              5   14   17    6        14   23   28   17        23   32   38   28
            -28  -17  -21  -34       -17   -6   -7  -21        -6    6    7   -7
              6   17   21    7        17   28   34   21        28   38   44   34
            -34  -21  -27  -41       -21   -7   -9  -27        -7    7    9   -9
              7   21   27    9        21   34   41   27        34   44   52   41
            -41  -27  -35  -51       -27   -9  -13  -35        -9    9   13  -13
              9   27   35   13        27   41   51   35        41   52   63   51
            -51  -35  -51  -67       -35  -13  -21  -51       -13   13   21  -21
             13   35   51   21        35   51   67   51        51   63   77   67
yvals     =  29   32   32   32   29   26   39   42   42   42
             39   35   48   51   52   51   48   43   57   61
             62   61   57   51   65   70   72   70   65   58
ybounds   =  23   26   36   32       26   27   37   36        27   27   37   37
             27   26   36   37       26   23   32   36        23   19   28   32
             32   36   45   41       36   37   47   45        37   37   47   47
             37   36   45   47       36   32   41   45        32   28   36   41
             41   45   55   50       45   47   57   55        47   47   57   57
             47   45   55   57       45   41   50   55        41   36   44   50
             50   55   64   58       55   57   67   64        57   57   67   67
             57   55   64   67       55   50   58   64        50   44   51   58
             58   64   72   64       64   67   77   72        67   67   77   77
             67   64   72   77       64   58   64   72        58   51   56   64
```

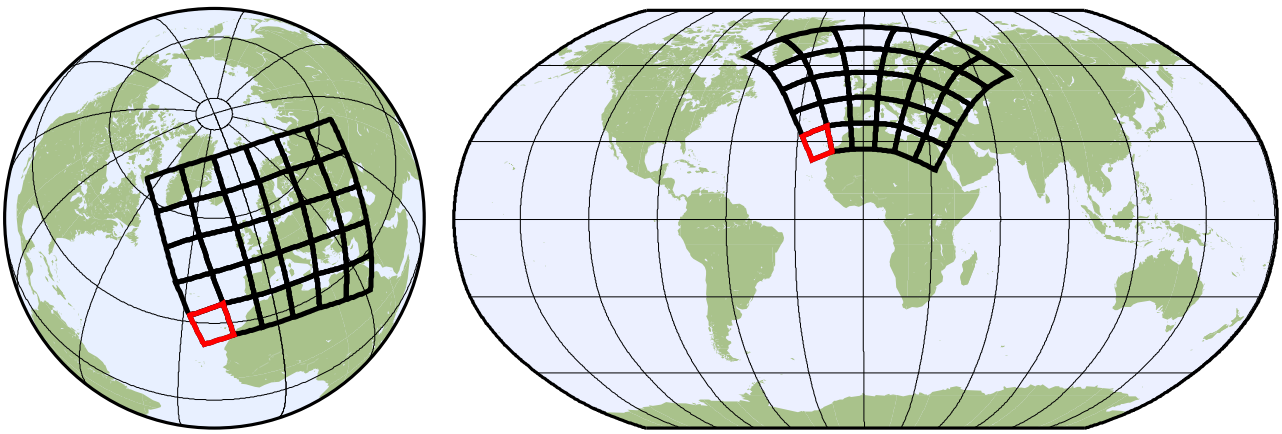


Figure D.1.: Orthographic and Robinson projection of the curvilinear grid, the first grid cell is colored red

D.2. Example description for an unstructured grid

Here is an example of the **CDO** description for an unstructured grid. xvals/yvals describe the positions of 30 independent hexagonal grid cells. The first 6 values of xbounds/ybounds are the corners of the first grid cell. The grid cell corners have to rotate counterclockwise. The first grid cell is colored red.

```
gridtype  = unstructured
gridsize  = 30
nvertex   = 6
xvals     =  -36   36    0  -18   18  108   72   54   90  180  144  126  162 -108 -144
             -162 -126  -72  -90  -54    0   72   36  144  108 -144  180  -72 -108  -36
xbounds   =  339    0    0  288  288  309        21   51   72   72    0    0
               0   16   21    0  339  344       340    0   -0  344  324  324
              20   36   36   16    0    0        93  123  144  144   72   72
              72   88   93   72   51   56        52   72   72   56   36   36
              92  108  108   88   72   72       165  195  216  216  144  144
             144  160  165  144  123  128       124  144  144  128  108  108
             164  180  180  160  144  144       237  267  288  288  216  216
             216  232  237  216  195  200       196  216  216  200  180  180
             236  252  252  232  216  216       288  304  309  288  267  272
             268  288  288  272  252  252       308  324  324  304  288  288
             345  324  324   36   36   15        36   36  108  108   87   57
              20   15   36   57   52   36       108  108  180  180  159  129
              92   87  108  129  124  108       180  180  252  252  231  201
             164  159  180  201  196  180       252  252  324  324  303  273
             236  231  252  273  268  252       308  303  324  345  340  324
yvals     =   58   58   32    0    0   58   32    0    0   58   32    0    0   58   32
               0    0   32    0    0  -58  -58  -32  -58  -32  -58  -32  -58  -32  -32
ybounds   =   41   53   71   71   53   41        41   41   53   71   71   53
              11   19   41   53   41   19       -19   -7   11   19    7  -11
             -19  -11    7   19   11   -7        41   41   53   71   71   53
              11   19   41   53   41   19       -19   -7   11   19    7  -11
             -19  -11    7   19   11   -7        41   41   53   71   71   53
              11   19   41   53   41   19       -19   -7   11   19    7  -11
             -19  -11    7   19   11   -7        41   41   53   71   71   53
              11   19   41   53   41   19       -19   -7   11   19    7  -11
             -19  -11    7   19   11   -7        11   19   41   53   41   19
             -19   -7   11   19    7  -11       -19  -11    7   19   11   -7
             -41  -53  -71  -71  -53  -41       -53  -71  -71  -53  -41  -41
             -19  -41  -53  -41  -19  -11       -53  -71  -71  -53  -41  -41
             -19  -41  -53  -41  -19  -11       -53  -71  -71  -53  -41  -41
             -19  -41  -53  -41  -19  -11       -53  -71  -71  -53  -41  -41
             -19  -41  -53  -41  -19  -11       -19  -41  -53  -41  -19  -11
```

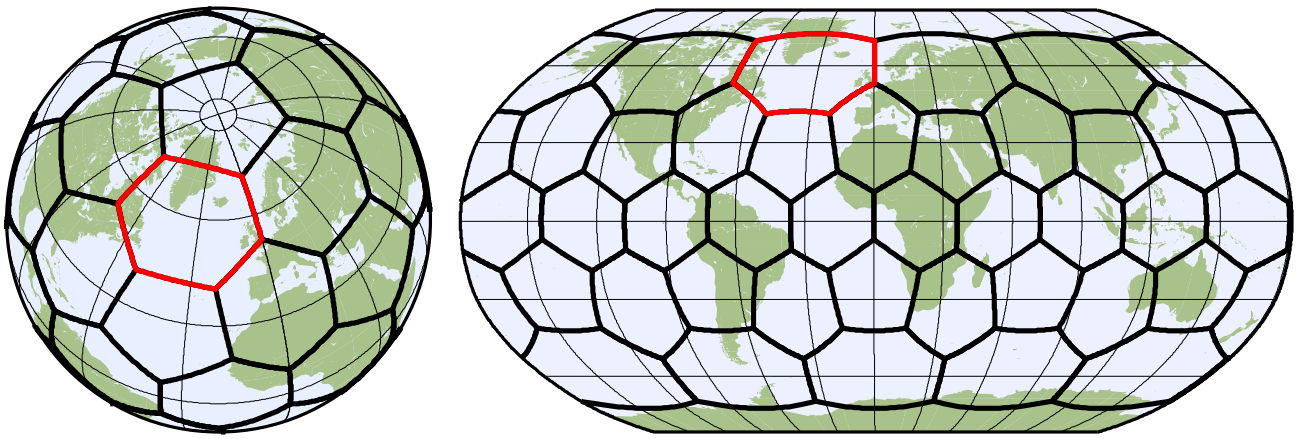


Figure D.2.: Orthographic and Robinson projection of the unstructured grid

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