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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. A GRIB dataset has 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. 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 user interface and some operators are similar to the PINGO [PINGO] package.

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

1.1. Building from sources

This section describes how to build CDO from the sources on a UNIX system. CDO uses the GNU configure and build system for compilation. The only requirement is a working ISO C++11 and ANSI C99 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 (http://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 (http://www.hdfgroup.org/HDF5) version 1.6 or higher. This library is needed to import CM-SAF [CM-SAF] HDF5 files with the CDO operator import_cmsaf.
• **PROJ.4** library ([http://trac.osgeo.org/proj](http://trac.osgeo.org/proj)) version 4.6 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](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**.

**CDO** is a multi-threaded application. Therefore all the above libraries should be compiled thread safe. Using non-threadsafe libraries could cause unexpected errors!

### 1.1.1. 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
   ```

   • Optionally 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.

### 1.1.2. 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.

### 1.2. Usage

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

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:

<table>
<thead>
<tr>
<th>File format</th>
<th>&lt;nbits&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>grb1, grb2</td>
<td>P1 - P24</td>
</tr>
<tr>
<td>nc1, nc2, nc4, nc4c</td>
<td>I8/I16/I32/F32/F64</td>
</tr>
<tr>
<td>grb2, srv, ext, ieg</td>
<td>F32/F64</td>
</tr>
</tbody>
</table>

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

- `-c` CMOR conform NetCDF output.
- `-C` Colorized output messages.
- `--eccodes` Use ecCodes to decode/encode GRIB1 messages.
- `-f <format>` Set the output file format. The valid file formats are:

<table>
<thead>
<tr>
<th>File format</th>
<th>&lt;format&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRIB version 1</td>
<td>grb1/grb</td>
</tr>
<tr>
<td>GRIB version 2</td>
<td>grb2</td>
</tr>
<tr>
<td>NetCDF</td>
<td>nc1</td>
</tr>
<tr>
<td>NetCDF version 2 (64-bit offset)</td>
<td>nc2/nc</td>
</tr>
<tr>
<td>NetCDF-4 (HDF5)</td>
<td>nc4</td>
</tr>
<tr>
<td>NetCDF-4 classic</td>
<td>nc4c</td>
</tr>
<tr>
<td>NetCDF version 5 (64-bit data)</td>
<td>nc5</td>
</tr>
<tr>
<td>SERVICE</td>
<td>srv</td>
</tr>
<tr>
<td>EXTRA</td>
<td>ext</td>
</tr>
<tr>
<td>IEG</td>
<td>ieg</td>
</tr>
</tbody>
</table>

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 11).

Available grid names are: `r<NX>x<NY>`, `lon=<LON>/lat=<LAT>`, `n<N>`, `gme<NI>`

- `-h` 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` Switch to indicate that the I/O streams have missing values.
- `-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).
- `--percentile <method>` Percentile method: `nrank nist numpy numpy_lower numpy_higher numpy_nearest`

- `--reduce_dim` Reduce NetCDF dimensions.
- `--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 mode.
- `--sortname` Alphanumerical sorting of NetCDF parameter names.
- `-t <partab>` Set the GRIB1 (cgribex) default parameter table name or file (see chapter 1.6 on page 16).

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
  Print extra warning messages.

-z szip
  SZIP compression of GRIB1 records.

jpeg
  JPEG compression of GRIB2 records.

zip[0-9]
  Deflate 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 environment 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. Operator chaining

All operators with a fixed number of input streams and one output stream can pipe the result directly to an other operator. The operator must begin with "--", in order to combine it with others. This can improve the performance by:

• reducing unnecessary disk I/O
• parallel processing

Use

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

All operators with one input stream will process only one input stream! You need to take care when mixing those operators with an operator with an arbitrary number of input streams. The following examples illustrate this problem.

1. cdo info -timavg infile?
2. cdo info -timavg infile1 infile2
3. cdo timavg infile1 tmpfile
cdo info tmpfile infile2
All three examples produce identical results. The time average will be computed only on the first input file.

All operators with an arbitrary number of input streams (infiles) can’t be combined with other operators if these operators are used with more than one input stream. Here is an incomplete list of these operators: `copy`, `cat`, `merge`, `mergetime`, `select`, `ens<STAT>`.

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
```

The CDO internal wildcard expansion is using the `glob()` function. Therefore internal wildcard expansion is not available on operating systems without the `glob()` function! The following wildcards are supported: `*`, `?`, `[]`

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

### 1.2.5. 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.

### 1.2.6. Operator parameter

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

- **STRING**
  
  Unquoted characters without blanks and tabs. The following command select variables with the `name pressure` and `t_surf`:
  
  ```
cdo selvar,pressure,t_surf 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
  ```
1.3. Horizontal grids

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

1.3.1. 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.

1.3.2. 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.

1.3.2.1. Predefined grids

Predefined grids are available for global regular, gaussian 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 selected at will. The longitudes start at <DXY>/2 - 180° and the latitudes start at <DXY>/2 - 90°.

**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 selected at will. 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.
Global Gaussian grid: $n<\mathbb{N}>$

$n<\mathbb{N}>$ defines a global Gaussian grid. $\mathbb{N}$ specifies the number of latitudes lines between the Pole and the Equator. The longitudes start at $0^\circ$ with an increment of $(360/nlon)^\circ$. The gaussian latitudes go from north to south.

Global icosahedral-hexagonal GME grid: $\text{gme}<\mathbb{N}>$

$\text{gme}<\mathbb{N}>$ defines a global icosahedral-hexagonal GME grid. $\mathbb{N}$ specifies the number of intervals on a main triangle side.

### 1.3.2.2. Grids from data files

You can use the grid description from another 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 than 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 $N$.

### 1.3.2.3. 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. Therefore 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):

```plaintext
netcdf grob3s {
    dimensions:
        grid_size = 12120 ;
        grid_xsize = 120 ;
        grid_ysize = 101 ;
        grid_corners = 4 ;
        grid_rank = 2 ;
    variables:
        int grid_dims(grid_rank) ;
        float grid_center_lat(grid_ysize, grid_xsize) ;
            grid_center_lat:units = "degrees" ;
            grid_center_lat:bounds = "grid_corner_lat" ;
        float grid_center_lon(grid_ysize, grid_xsize) ;
            grid_center_lon:units = "degrees" ;
            grid_center_lon:bounds = "grid_corner_lon" ;
        int grid_imask(grid_ysize, grid_xsize) ;
            grid_imask:units = "unitless" ;
            grid_imask:coordinates = "grid_center_lon grid_center_lat" ;
        float grid_corner_lat(grid_ysize, grid_xsize, grid_corners) ;
            grid_corner_lat:units = "degrees" ;
        float grid_corner_lon(grid_ysize, grid_xsize, grid_corners) ;
            grid_corner_lon:units = "degrees" ;
    // global attributes:
        :title = "grob3s" ;
}
```

### 1.3.2.4. 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.
xsizex | INTEGER | Size in x direction (number of longitudes).
ysizey | 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.
vertices | INTEGER | Number of 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.

<table>
<thead>
<tr>
<th>gridtype</th>
<th>lonlat</th>
<th>gaussian</th>
<th>projection</th>
<th>curvilinear</th>
<th>unstructured</th>
</tr>
</thead>
</table>
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 |
vertices | 2 | 2 | 2 | 4 | nv |
xbounds | 2*xsize | 2*xsize | 2*xsize | 4*gridsize | nv*gridsize |
ybounds | 2*ysize | 2*ysize | 2*ysize | 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
xsizex = 64
ysizey = 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
xsizex = 60
ysizey = 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 describe 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 `proj4_params`. These parameter will be passed directly to the proj4 library to generate the geographic coordinates if needed.

The geographic coordinates of the following projections can be generated without the attribute `proj4_params`, if all other attributes are available:

- `rotated_latitude_longitude`
- `lambert_conformal_conic`
- `lambert_azimuthal_equal_area`
- `sinusoidal`
- `polar_stereographic`

**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.

### 1.4. 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:

<table>
<thead>
<tr>
<th>Keyword</th>
<th>Datatype</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>zaxistype</td>
<td>STRING</td>
<td>type of the z-axis</td>
</tr>
<tr>
<td>size</td>
<td>INTEGER</td>
<td>number of levels</td>
</tr>
<tr>
<td>levels</td>
<td>FLOAT ARRAY</td>
<td>values of the levels</td>
</tr>
<tr>
<td>lbounds</td>
<td>FLOAT ARRAY</td>
<td>lower level bounds</td>
</tr>
<tr>
<td>ubounds</td>
<td>FLOAT ARRAY</td>
<td>upper level bounds</td>
</tr>
<tr>
<td>vctsize</td>
<td>INTEGER</td>
<td>number of vertical coordinate parameters</td>
</tr>
<tr>
<td>vct</td>
<td>FLOAT ARRAY</td>
<td>vertical coordinate table</td>
</tr>
</tbody>
</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:

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

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

```
zaxis = 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 15861.75 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 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.

### 1.5. 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.

#### 1.5.1. 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'*.  

#### 1.5.2. 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'*.  

#### 1.5.3. 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`.  

15
1.6. Parameter table

A parameter table is an ASCII formatted 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 formatted 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:

<table>
<thead>
<tr>
<th>Code</th>
<th>Name</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>134</td>
<td>aps</td>
<td>surface pressure</td>
<td>[Pa]</td>
</tr>
<tr>
<td>141</td>
<td>sn</td>
<td>snow depth</td>
<td>[m]</td>
</tr>
<tr>
<td>147</td>
<td>ahfl</td>
<td>latent heat flux</td>
<td>[W/m²]</td>
</tr>
<tr>
<td>172</td>
<td>slm</td>
<td>land sea mask</td>
<td></td>
</tr>
<tr>
<td>175</td>
<td>albedo</td>
<td>surface albedo</td>
<td></td>
</tr>
<tr>
<td>211</td>
<td>siced</td>
<td>ice depth</td>
<td>[m]</td>
</tr>
</tbody>
</table>

1.7. Missing values

Most operators can handle missing values. The default missing value for GRIB, SERVICE, EXTRA and IEG files is $-9.33 \times 10^9$. 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 $\text{miss}$. 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.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>addition</td>
<td>$a + b$</td>
<td>$\text{miss}$</td>
<td>$\text{miss}$</td>
</tr>
<tr>
<td>subtraction</td>
<td>$a - b$</td>
<td>$\text{miss}$</td>
<td>$\text{miss}$</td>
</tr>
<tr>
<td>multiplication</td>
<td>$a \times b$</td>
<td>$0$</td>
<td>$\text{miss}$</td>
</tr>
<tr>
<td>division</td>
<td>$a/b$</td>
<td>$\text{miss}$</td>
<td>$\text{miss}$</td>
</tr>
<tr>
<td>maximum</td>
<td>$\max(a,b)$</td>
<td>$a$</td>
<td>$\text{miss}$</td>
</tr>
<tr>
<td>minimum</td>
<td>$\min(a,b)$</td>
<td>$b$</td>
<td>$\text{miss}$</td>
</tr>
<tr>
<td>sum</td>
<td>$a + b$</td>
<td>$a$</td>
<td>$\text{miss}$</td>
</tr>
</tbody>
</table>
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. \(\log\),
\(\sqrt{x}\), 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.

1.7.1. 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, \(\text{miss}\) and 3 is \((1 + 2 + 3)/3 = 2\), whereas the
average is \((1 + 2 + \text{miss} + 3)/4 = \text{miss}/4 = \text{miss}\). If there are no missing values in the sample, the average
and mean are identical.

1.8. 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:

<table>
<thead>
<tr>
<th>Percentile method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>nrank</td>
<td>Nearest Rank method, the default method used in CDO</td>
</tr>
<tr>
<td>nist</td>
<td>The primary method recommended by NIST</td>
</tr>
<tr>
<td>numpy</td>
<td>numpy.percentile with the option interpolation set to 'linear'</td>
</tr>
<tr>
<td>numpy_lower</td>
<td>numpy.percentile with the option interpolation set to 'lower'</td>
</tr>
<tr>
<td>numpy_higher</td>
<td>numpy.percentile with the option interpolation set to 'higher'</td>
</tr>
<tr>
<td>numpy_nearest</td>
<td>numpy.percentile with the option interpolation set to 'nearest'</td>
</tr>
</tbody>
</table>

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:

<table>
<thead>
<tr>
<th>Percentile</th>
<th>nrank</th>
<th>nist</th>
<th>numpy</th>
<th>numpy_lower</th>
<th>numpy_higher</th>
<th>numpy_nearest</th>
</tr>
</thead>
<tbody>
<tr>
<td>30th</td>
<td>20</td>
<td>21.5</td>
<td>27.5</td>
<td>20</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>40th</td>
<td>35</td>
<td>32</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>50th</td>
<td>35</td>
<td>37.5</td>
<td>37.5</td>
<td>35</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>75th</td>
<td>50</td>
<td>51.25</td>
<td>47.5</td>
<td>40</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>100th</td>
<td>55</td>
<td>55</td>
<td>55</td>
<td>55</td>
<td>55</td>
<td>55</td>
</tr>
</tbody>
</table>

1.8.1. 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.
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:

\[ i(t) \text{ Timestep } t \text{ of infile} \]
\[ i(t, x) \text{ Element number } x \text{ of the field at timestep } t \text{ of infile} \]
\[ o(t) \text{ Timestep } t \text{ of outfile} \]
\[ o(t, x) \text{ Element number } x \text{ of the field at timestep } t \text{ of outfile} \]
2.1. Information

This section contains modules to print information about datasets. All operators print their 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
- **map**: Dataset information and simple map
- **sinfo**: Short information listed by parameter identifier
- **sinfon**: Short information listed by parameter name
- **diff**: Compare two datasets listed by parameter id
- **diffn**: Compare two datasets listed by parameter name
- **npars**: 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
- **showatts**: Show all attributes
- **showattsglob**: Show all global attributes
- **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
- **showattribute**: Show a global attribute or a variable attribute
- **showattsvar**: Show all variable attributes.
- **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 of all input files to standard output. 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 param-
eter.

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:

<table>
<thead>
<tr>
<th>-1</th>
<th>Date</th>
<th>Time</th>
<th>Level</th>
<th>Size</th>
<th>Miss</th>
<th>Minimum</th>
<th>Mean</th>
<th>Maximum</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1987-01-31</td>
<td>12:00:00</td>
<td>0</td>
<td>2048</td>
<td>1361</td>
<td>232.77</td>
<td>266.65</td>
<td>305.31</td>
<td>SST</td>
</tr>
<tr>
<td>2</td>
<td>1987-02-28</td>
<td>12:00:00</td>
<td>0</td>
<td>2048</td>
<td>1361</td>
<td>233.64</td>
<td>267.11</td>
<td>307.15</td>
<td>SST</td>
</tr>
<tr>
<td>3</td>
<td>1987-03-31</td>
<td>12:00:00</td>
<td>0</td>
<td>2048</td>
<td>1361</td>
<td>225.31</td>
<td>268.52</td>
<td>307.67</td>
<td>SST</td>
</tr>
<tr>
<td>4</td>
<td>1987-04-30</td>
<td>12:00:00</td>
<td>0</td>
<td>2048</td>
<td>1361</td>
<td>215.68</td>
<td>268.65</td>
<td>310.47</td>
<td>SST</td>
</tr>
<tr>
<td>5</td>
<td>1987-05-31</td>
<td>12:00:00</td>
<td>0</td>
<td>2048</td>
<td>1361</td>
<td>215.78</td>
<td>271.53</td>
<td>312.49</td>
<td>SST</td>
</tr>
<tr>
<td>6</td>
<td>1987-06-30</td>
<td>12:00:00</td>
<td>0</td>
<td>2048</td>
<td>1361</td>
<td>212.89</td>
<td>272.80</td>
<td>314.18</td>
<td>SST</td>
</tr>
<tr>
<td>7</td>
<td>1987-07-31</td>
<td>12:00:00</td>
<td>0</td>
<td>2048</td>
<td>1361</td>
<td>209.52</td>
<td>274.29</td>
<td>316.34</td>
<td>SST</td>
</tr>
<tr>
<td>8</td>
<td>1987-08-31</td>
<td>12:00:00</td>
<td>0</td>
<td>2048</td>
<td>1361</td>
<td>210.48</td>
<td>274.41</td>
<td>315.83</td>
<td>SST</td>
</tr>
<tr>
<td>9</td>
<td>1987-09-30</td>
<td>12:00:00</td>
<td>0</td>
<td>2048</td>
<td>1361</td>
<td>210.48</td>
<td>272.37</td>
<td>312.86</td>
<td>SST</td>
</tr>
<tr>
<td>10</td>
<td>1987-10-31</td>
<td>12:00:00</td>
<td>0</td>
<td>2048</td>
<td>1361</td>
<td>219.46</td>
<td>270.53</td>
<td>309.51</td>
<td>SST</td>
</tr>
<tr>
<td>11</td>
<td>1987-11-30</td>
<td>12:00:00</td>
<td>0</td>
<td>2048</td>
<td>1361</td>
<td>230.98</td>
<td>269.85</td>
<td>308.61</td>
<td>SST</td>
</tr>
<tr>
<td>12</td>
<td>1987-12-31</td>
<td>12:00:00</td>
<td>0</td>
<td>2048</td>
<td>1361</td>
<td>241.25</td>
<td>269.94</td>
<td>309.27</td>
<td>SST</td>
</tr>
</tbody>
</table>
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 : Institute Source T Steptype Levels Num Points Num Dtype : Name |
| 1 : MPI/MPET ECHAM5 c instant 1 1 2048 1 F32 : GEOSP |
| 2 : MPI/MPET ECHAM5 v instant 4 2 2048 1 F32 : T |
| 3 : MPI/MPET ECHAM5 v instant 1 1 2048 1 F32 : TSURF |

Grid coordinates:

| 1 : gaussian      | points=2048 (64x32) np=16  |
| longitude: 0 to 354.375 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: 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. DIFF - Compare two datasets field by field

Synopsis

\(<\text{operator}>[\text{options}]\ \text{infile1} \ \text{infile2}\)

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 same header information and dimensions. Try the option \textit{names} if the number of variables differ. Exit status is 0 if inputs are the same and 1 if they differ.

Operators

\textbf{diff} \quad \text{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

\[
\text{Absdiff}(t,x) = |i_1(t,x) - i_2(t,x)|
\]

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

\textbf{diffn} \quad \text{Compare two datasets listed by parameter name}

The same as operator \texttt{diff}. Using the name instead of the identifier to label the parameter.

Parameter

- \textit{abslim} \quad \texttt{FLOAT} \quad \text{Limit of the maximum absolute difference (default: 0)}
- \textit{rellim} \quad \texttt{FLOAT} \quad \text{Limit of the maximum relative difference (default: 1)}
- \textit{names} \quad \texttt{STRING} \quad \text{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:

\begin{verbatim}
cdo diffn infile1 infile2
\end{verbatim}

This is an example result of two datasets with one 2D parameter over 12 timesteps:
### 2.1.4. 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
```
2.1.5. SHOWINFO - Show variables, levels or times

Synopsis

\(<\text{operator}>\) infile

Description

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

Operators

<table>
<thead>
<tr>
<th>Operator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>showformat</td>
<td>Show file format. Prints the file format of the input dataset.</td>
</tr>
<tr>
<td>showcode</td>
<td>Show code numbers. Prints the code number of all variables.</td>
</tr>
<tr>
<td>showname</td>
<td>Show variable names. Prints the name of all variables.</td>
</tr>
<tr>
<td>showstdname</td>
<td>Show standard names. Prints the standard name of all variables.</td>
</tr>
<tr>
<td>showatts</td>
<td>Show all attributes. Prints all variable and global attributes.</td>
</tr>
<tr>
<td>showattglob</td>
<td>Show all global attributes. Prints all global attributes.</td>
</tr>
<tr>
<td>showlevel</td>
<td>Show levels. Prints all levels for each variable.</td>
</tr>
<tr>
<td>showltype</td>
<td>Show GRIB level types. Prints the GRIB level type for all z-axes.</td>
</tr>
<tr>
<td>showyear</td>
<td>Show years. Prints all years.</td>
</tr>
<tr>
<td>showmon</td>
<td>Show months. Prints all months.</td>
</tr>
<tr>
<td>showdate</td>
<td>Show date information. Prints date information of all timesteps (format YYYY-MM-DD).</td>
</tr>
<tr>
<td>showtime</td>
<td>Show time information. Prints time information of all timesteps (format hh:mm:ss).</td>
</tr>
<tr>
<td>showtimestamp</td>
<td>Show timestamp. Prints timestamp of all timesteps (format YYYY-MM-DDThh:mm:ss).</td>
</tr>
</tbody>
</table>

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

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

### 2.1.6. SHOWATTRIBUTE - Show attributes

**Synopsis**

```
showattribute,attribute  infile
showattsvar[,var_nm]  infile
```

**Description**

This operator prints attributes of a dataset. If a global attribute should be printed, the attribute name can be specified as a parameter directly. If a variable attribute should be printed, the following format is requested:

```
var_nm@att_nm
```

- **var_nm** Variable name. Example: pressure
- **att_nm** Attribute name. Example: units

**Operators**

- **showattribute** Show a global attribute or a variable attribute
- **showattsvar** Show all variable attributes.
  - If var_nm is specified, only for a subset of variables.

**Parameter**

- **attribute** STRING Attribute in the format [var_nm@]att_nm
- **var_nm** STRING Variable name
2.1.7. 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

<table>
<thead>
<tr>
<th>Operator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>partab</td>
<td>Parameter table</td>
</tr>
<tr>
<td>codetab</td>
<td>Parameter code table</td>
</tr>
<tr>
<td>griddles</td>
<td>Grid description</td>
</tr>
<tr>
<td>zaxisdes</td>
<td>Z-axis description</td>
</tr>
<tr>
<td>vct</td>
<td>Vertical coordinate table</td>
</tr>
</tbody>
</table>

partab
Prints all available meta information of the variables.

codetab
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.

griddles
Prints the description of all grids.

zaxisdes
Prints the description of all z-axes.

vct
Prints the vertical coordinate table.

Example

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

```
cdo griddles 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
```
## 2.2. File operations

This section contains modules to perform operations on files.

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

<table>
<thead>
<tr>
<th>Operator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>copy</td>
<td>Copy datasets</td>
</tr>
<tr>
<td>cat</td>
<td>Concatenate datasets</td>
</tr>
<tr>
<td>tee</td>
<td>Duplicate a data stream</td>
</tr>
<tr>
<td>replace</td>
<td>Replace variables</td>
</tr>
<tr>
<td>duplicate</td>
<td>Duplicates a dataset</td>
</tr>
<tr>
<td>mergegrid</td>
<td>Merge grid</td>
</tr>
<tr>
<td>merge</td>
<td>Merge datasets with different fields</td>
</tr>
<tr>
<td>mergetime</td>
<td>Merge datasets sorted by date and time</td>
</tr>
<tr>
<td>splitcode</td>
<td>Split code numbers</td>
</tr>
<tr>
<td>splitparam</td>
<td>Split parameter identifiers</td>
</tr>
<tr>
<td>splitname</td>
<td>Split variable names</td>
</tr>
<tr>
<td>splitlevel</td>
<td>Split levels</td>
</tr>
<tr>
<td>splitgrid</td>
<td>Split grids</td>
</tr>
<tr>
<td>splitzaxis</td>
<td>Split z-axes</td>
</tr>
<tr>
<td>splittabnum</td>
<td>Split parameter table numbers</td>
</tr>
<tr>
<td>splithour</td>
<td>Split hours</td>
</tr>
<tr>
<td>splitday</td>
<td>Split days</td>
</tr>
<tr>
<td>splitseas</td>
<td>Split seasons</td>
</tr>
<tr>
<td>splityear</td>
<td>Split years</td>
</tr>
<tr>
<td>splityearmon</td>
<td>Split in years and months</td>
</tr>
<tr>
<td>splitmon</td>
<td>Split months</td>
</tr>
<tr>
<td>splitsel</td>
<td>Split time selection</td>
</tr>
<tr>
<td>distgrid</td>
<td>Distribute horizontal grid</td>
</tr>
<tr>
<td>collgrid</td>
<td>Collect horizontal grid</td>
</tr>
</tbody>
</table>
2.2.1. COPY - Copy datasets

Synopsis

\[ \text{<operator>} \text{ infiles outfile} \]

Description

This module contains operators to copy 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.

- **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
```

2.2.2. TEE - Duplicate a data stream

Synopsis

\[ \text{tee} \text{ infile outfile1 outfile2} \]

Description

This operator copies the input datasets to outfile1 and outfile2. It can be used to store intermediate results to a file.

Example

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

```
cdo monavg -tee dayavg infile outfile_dayavg outfile_monavg
```
2.2.3. REPLACE - Replace variables

Synopsis

\[ \text{replace} \ \text{infile1} \ \text{infile2} \ \text{outfile} \]

Description

The replace operator replaces variables in \text{infile1} by variables from \text{infile2} and write the result to \text{outfile}. Both input datasets need to have the same number of timesteps.

Example

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

\[ \text{cdo replace infile1 infile2 outfile} \]

2.2.4. DUPLICATE - Duplicates a dataset

Synopsis

\[ \text{duplicate}\[\text{ndup}\] \ \text{infile} \ \text{outfile} \]

Description

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

Parameter

\[ \text{ndup} \quad \text{INTEGER} \quad \text{Number of duplicates, default is 2.} \]

2.2.5. MERGEGRID - Merge grid

Synopsis

\[ \text{mergegrid} \ \text{infile1} \ \text{infile2} \ \text{outfile} \]

Description

Merges grid points of all variables from \text{infile2} to \text{infile1} and write the result to \text{outfile}. Only the non missing values of \text{infile2} will be used. The horizontal grid of \text{infile2} should be smaller or equal to the grid of \text{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.
2.2.6. MERGE - Merge datasets

Synopsis

<operator> 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.

Environment

SKIP_SAME_TIME
If set to 1, skips all consecutive timesteps with a double entry of the same timestamp.

Note

The operators in 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
```
2.2.7. SPLIT - Split a dataset

Synopsis

<operator>[,params] 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

The operators in 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
```
2.2.8. 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 (YYMMYY).

- **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

The operators in 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
```

2.2.9. 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.
2.2.10. 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. A target grid region contains a structured longitude/latitude box of the source grid. Only rectilinear and curvilinear source grids are supported by this operator. The number of different regions can be specified with the parameter $nx$ and $ny$. 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
- $ny$ 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 a file 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.
2.2.11. COLLGRID - Collect horizontal grid

Synopsis

    collgrid[,nx[,names]] 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 horizontal grid region. A source region must be a structured longitude/latitude grid box. And all regions together must give a new structured longitude/latitude grid box. The parameter nx needs to be specified only for non regular lon/lat grids.

Parameter

    nx    INTEGER    Number of regions in x direction [default: number of input files]
    names STRING    Comma separated list of variable names [default: all variables]

Note

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

Example

Collect the horizontal 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 identification 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
- **selgridcell** Select grid cells
- **delgridcell** Delete grid cells
- **samplegrid** Resample grid
2.3.1. SELECT - Select fields

Synopsis

<operator>,params 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. Wildcards can be used for string parameter.

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 of code numbers.
- **level**: FLOAT
  - Comma separated list of vertical levels.
- **levidx**: INTEGER
  - Comma separated list of index of levels.
- **zaxisname**: STRING
  - Comma separated list of zaxis names.
- **zaxisnum**: INTEGER
  - Comma separated list of zaxis numbers.
- **ltype**: INTEGER
  - Comma separated list of GRIB level types.
- **gridname**: STRING
  - Comma separated list of grid names.
- **gridnum**: INTEGER
  - Comma separated list of grid numbers.
- **steptype**: STRING
  - Comma separated list of timestep types.
- **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 of minutes.
- **hour**: INTEGER
  - Comma separated list of hours.
- **day**: INTEGER
  - Comma separated list of days.
- **month**: INTEGER
  - Comma separated list of months.
- **season**: STRING
  - Comma separated list of seasons (substring of DJFMAMJJA-SOND or ANN).
- **year**: INTEGER
  - Comma separated list of years.
- **timestep**: INTEGER
  - Comma separated list of timesteps. Negative values selects timesteps from the end (NetCDF only).
- **timestep_of_year**: INTEGER
  - Comma separated list of timesteps of year.
- **timestepmask**: STRING
  - Read timesteps from a mask file.
Example

Assume you have 3 input files. Each input file 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
```
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:

\[
\langle\text{type}\rangle(\text{parameters}; \text{leveltype(s)}; \text{levels})
\]

type \quad\text{sel for select or del for delete (optional)}
parameters \quad\text{GRIB1 parameter code number}
leveltype \quad\text{GRIB1 level type}
levels \quad\text{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=leveltype(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 \quad\text{Select multiple fields}

delmulti \quad\text{Delete multiple fields}

changemulti \quad\text{Change identification 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

\texttt{<operator>,params infile outfile} \\
\texttt{selcode,codes infile outfile} \\
\texttt{delcode,codes infile outfile} \\
\texttt{selname,names infile outfile} \\
\texttt{delname,names infile outfile} \\
\texttt{selstdname,stdnames infile outfile} \\
\texttt{sellevel,levels infile outfile} \\
\texttt{sellevidx,levidx infile outfile} \\
\texttt{selgrid,grids infile outfile} \\
\texttt{selzaxis,zaxes infile outfile} \\
\texttt{selzaxisname,zaxisnames infile outfile} \\
\texttt{selltype,htypes infile outfile} \\
\texttt{seltabnum,tabnums infile outfile}

Description

This module selects some fields from \texttt{infile} and writes them to \texttt{outfile}. The fields selected depends on the chosen operator and the parameters.

Operators

- \texttt{selparam} Select parameters by identifier
  Selects all fields with parameter identifiers in a user given list.

- \texttt{delparam} Delete parameters by identifier
  Deletes all fields with parameter identifiers in a user given list.

- \texttt{selcode} Select parameters by code number
  Selects all fields with code numbers in a user given list.

- \texttt{delcode} Delete parameters by code number
  Deletes all fields with code numbers in a user given list.

- \texttt{selname} Select parameters by name
  Selects all fields with parameter names in a user given list.

- \texttt{delname} Delete parameters by name
  Deletes all fields with parameter names in a user given list.

- \texttt{selstdname} Select parameters by standard name
  Selects all fields with standard names in a user given list.

- \texttt{sellevel} Select levels
  Selects all fields with levels in a user given list.

- \texttt{sellevidx} Select levels by index
  Selects all fields with index of levels in a user given list.

- \texttt{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.

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

### Parameter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>params</td>
<td>INTEGER</td>
<td>Comma separated list of parameter identifiers</td>
</tr>
<tr>
<td>codes</td>
<td>INTEGER</td>
<td>Comma separated list of code numbers</td>
</tr>
<tr>
<td>names</td>
<td>STRING</td>
<td>Comma separated list of variable names</td>
</tr>
<tr>
<td>stdnames</td>
<td>STRING</td>
<td>Comma separated list of standard names</td>
</tr>
<tr>
<td>levels</td>
<td>FLOAT</td>
<td>Comma separated list of vertical levels</td>
</tr>
<tr>
<td>levidx</td>
<td>INTEGER</td>
<td>Comma separated list of index of levels</td>
</tr>
<tr>
<td>ltypes</td>
<td>INTEGER</td>
<td>Comma separated list of GRIB level types</td>
</tr>
<tr>
<td>grids</td>
<td>STRING</td>
<td>Comma separated list of grid names or numbers</td>
</tr>
<tr>
<td>zaxes</td>
<td>STRING</td>
<td>Comma separated list of z-axis types or numbers</td>
</tr>
<tr>
<td>zaxisnames</td>
<td>STRING</td>
<td>Comma separated list of z-axis names</td>
</tr>
<tr>
<td>tabnums</td>
<td>INTEGER</td>
<td>Comma separated list of parameter table numbers</td>
</tr>
</tbody>
</table>

### 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.

 Operators

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

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

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

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

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

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

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 of timesteps. Negative values selects timesteps from the end (NetCDF only).
times  STRING  Comma separated list of times (format hh:mm:ss).
hours  INTEGER  Comma separated list of hours.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>days</td>
<td>INTEGER</td>
<td>Comma separated list of days.</td>
</tr>
<tr>
<td>months</td>
<td>INTEGER</td>
<td>Comma separated list of months.</td>
</tr>
<tr>
<td>years</td>
<td>INTEGER</td>
<td>Comma separated list of years.</td>
</tr>
<tr>
<td>seasons</td>
<td>STRING</td>
<td>Comma separated list of seasons (substring of DJFMAMJJASOND or ANN).</td>
</tr>
<tr>
<td>startdate</td>
<td>STRING</td>
<td>Start date (format YYYY-MM-DDThh:mm:ss).</td>
</tr>
<tr>
<td>enddate</td>
<td>STRING</td>
<td>End date (format YYYY-MM-DDThh:mm:ss) [default: startdate].</td>
</tr>
<tr>
<td>nts1</td>
<td>INTEGER</td>
<td>Number of timesteps before the selected month [default: 0].</td>
</tr>
<tr>
<td>nts2</td>
<td>INTEGER</td>
<td>Number of timesteps after the selected month [default: nts1].</td>
</tr>
</tbody>
</table>
2.3.5. SELBOX - Select a box of a field

Synopsis

sellonlatbox,lon1,lon2,lat1,lat2  infile outfile
selindexbox,idx1,idx2,idxy1,idxy2  infile outfile

Description

Selects a box of the rectangularly understood field.

Operators

sellonlatbox  Select a longitude/latitude box
Selects a regular longitude/latitude box. The user has to give the longitudes and latitudes of the edges of the box. Considered are only those grid cells with the grid center inside the lon/lat box. For rotated lon/lat grids the parameter needs to be rotated coordinates.

selindexbox  Select an index box
Selects an index box. The user has to give the indexes of the edges of the box. The index of the left edge may be greater then that of the right edge.

Parameter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>lon1</td>
<td>FLOAT</td>
<td>Western longitude</td>
</tr>
<tr>
<td>lon2</td>
<td>FLOAT</td>
<td>Eastern longitude</td>
</tr>
<tr>
<td>lat1</td>
<td>FLOAT</td>
<td>Southern or northern latitude</td>
</tr>
<tr>
<td>lat2</td>
<td>FLOAT</td>
<td>Northern or southern latitude</td>
</tr>
<tr>
<td>idx1</td>
<td>INTEGER</td>
<td>Index of first longitude (1 - nlon)</td>
</tr>
<tr>
<td>idx2</td>
<td>INTEGER</td>
<td>Index of last longitude (1 - nlon)</td>
</tr>
<tr>
<td>idxy1</td>
<td>INTEGER</td>
<td>Index of first latitude (1 - nlat)</td>
</tr>
<tr>
<td>idxy2</td>
<td>INTEGER</td>
<td>Index of last latitude (1 - nlat)</td>
</tr>
</tbody>
</table>

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. SELGRIDCELL - Select grid cells

Synopsis

<operator>, indexes infile outfile

Description

Selects grid cells of all fields from infile. The user has to give the indexes of each grid cell. The resulting grid in outfile is unstructured.

Operators

selgridcell  Select grid cells

delgridcell  Delete grid cells

Parameter

indexes  INTEGER  Comma separated list of indexes

2.3.7. 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
2.4. 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

\[ o(t,x) = \begin{cases} 
    i_2(t,x) & \text{if } i_1([t,x]) \neq 0 \land i_1([t,x]) \neq \text{miss} \\
    \text{miss} & \text{if } i_1([t,x]) = 0 \lor i_1([t,x]) = \text{miss} 
\end{cases} \]

ifnotthen

\[ o(t,x) = \begin{cases} 
    i_2(t,x) & \text{if } i_1([t,x]) = 0 \land i_1([t,x]) \neq \text{miss} \\
    \text{miss} & \text{if } i_1([t,x]) \neq 0 \lor i_1([t,x]) = \text{miss} 
\end{cases} \]

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.

\[ o(t,x) = \begin{cases} 
    i_2(t,x) & \text{if } i_1([t,x]) \neq 0 \land i_1([t,x]) \neq \text{miss} \\
    i_3(t,x) & \text{if } i_1([t,x]) = 0 \land i_1([t,x]) \neq \text{miss} \\
    \text{miss} & \text{if } i_1([t,x]) = \text{miss} 
\end{cases} \]

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
  
  \[ o(t,x) = \begin{cases} 
  c & \text{if } i(t,x) \neq 0 \land i(t,x) \neq \text{miss} \\
  \text{miss} & \text{if } i(t,x) = 0 \lor i(t,x) = \text{miss} 
  \end{cases} \]

- **ifnotthenc** If not then constant
  
  \[ o(t,x) = \begin{cases} 
  c & \text{if } i(t,x) = 0 \land i(t,x) \neq \text{miss} \\
  \text{miss} & \text{if } i(t,x) \neq 0 \lor i(t,x) = \text{miss} 
  \end{cases} \]

**Parameter**

\[ c \quad \text{FLOAT} \quad \text{Constant} \]

**Example**

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

\[ \text{cd}o \text{ ifthenc,7 infile outfile} \]
2.4.4. MAPREDUCE - Reduce fields to user-defined mask

Synopsis

\texttt{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

- \texttt{mask} STRING file which holds the mask field
- \texttt{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

\begin{verbatim}
cdo -gtc,0 -topo,ni96 lsm_gme96.grb
\end{verbatim}

Here a GME grid is used. Say \texttt{temp_gme96.grb} contains a global temperature field. The following command limits the global grid to landpoints.

\begin{verbatim}
cdo -f nc reduce, lsm_gme96.grb temp_gme96.grb tempOnLand_gme96.nc
\end{verbatim}

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:

<table>
<thead>
<tr>
<th>Operator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>eq</td>
<td>Equal</td>
</tr>
<tr>
<td>ne</td>
<td>Not equal</td>
</tr>
<tr>
<td>le</td>
<td>Less equal</td>
</tr>
<tr>
<td>lt</td>
<td>Less than</td>
</tr>
<tr>
<td>ge</td>
<td>Greater equal</td>
</tr>
<tr>
<td>gt</td>
<td>Greater than</td>
</tr>
<tr>
<td>eqc</td>
<td>Equal constant</td>
</tr>
<tr>
<td>nec</td>
<td>Not equal constant</td>
</tr>
<tr>
<td>lec</td>
<td>Less equal constant</td>
</tr>
<tr>
<td>ltc</td>
<td>Less than constant</td>
</tr>
<tr>
<td>gec</td>
<td>Greater equal constant</td>
</tr>
<tr>
<td>gtc</td>
<td>Greater than constant</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Operator</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>eq</td>
<td>Equal</td>
<td><code>cdo eq infile1 infile2 outfile</code></td>
</tr>
<tr>
<td>o</td>
<td>Not equal</td>
<td><code>cdo ne infile1 infile2 outfile</code></td>
</tr>
<tr>
<td>le</td>
<td>Less equal</td>
<td><code>cdo le infile1 infile2 outfile</code></td>
</tr>
<tr>
<td>lt</td>
<td>Less than</td>
<td><code>cdo lt infile1 infile2 outfile</code></td>
</tr>
<tr>
<td>ge</td>
<td>Greater equal</td>
<td><code>cdo ge infile1 infile2 outfile</code></td>
</tr>
<tr>
<td>gt</td>
<td>Greater than</td>
<td><code>cdo gt infile1 infile2 outfile</code></td>
</tr>
</tbody>
</table>

Example

To create a mask containing 1 if the elements of two fields are the same and 0 if the elements are different use:
2.5.2. COMPC - Comparison of a field with a constant

Synopsis

\[ <\text{operator}>,c \text{ infile outfile} \]

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
  \[ o(t,x) = \begin{cases} 
  1 & \text{if } i(t,x) = c \land i(t,x), c \neq \text{miss} \\
  0 & \text{if } i(t,x) \neq c \land i(t,x), c \neq \text{miss} \\
  \text{miss} & \text{if } i(t,x) = \text{miss} \lor c = \text{miss} 
\end{cases} \]

- **nec** Not equal constant
  \[ o(t,x) = \begin{cases} 
  1 & \text{if } i(t,x) \neq c \land i(t,x), c \neq \text{miss} \\
  0 & \text{if } i(t,x) = c \land i(t,x), c \neq \text{miss} \\
  \text{miss} & \text{if } i(t,x) = \text{miss} \lor c = \text{miss} 
\end{cases} \]

- **lec** Less equal constant
  \[ o(t,x) = \begin{cases} 
  1 & \text{if } i(t,x) \leq c \land i(t,x), c \neq \text{miss} \\
  0 & \text{if } i(t,x) > c \land i(t,x), c \neq \text{miss} \\
  \text{miss} & \text{if } i(t,x) = \text{miss} \lor c = \text{miss} 
\end{cases} \]

- **ltc** Less than constant
  \[ o(t,x) = \begin{cases} 
  1 & \text{if } i(t,x) < c \land i(t,x), c \neq \text{miss} \\
  0 & \text{if } i(t,x) \geq c \land i(t,x), c \neq \text{miss} \\
  \text{miss} & \text{if } i(t,x) = \text{miss} \lor c = \text{miss} 
\end{cases} \]

- **gec** Greater equal constant
  \[ o(t,x) = \begin{cases} 
  1 & \text{if } i(t,x) \geq c \land i(t,x), c \neq \text{miss} \\
  0 & \text{if } i(t,x) < c \land i(t,x), c \neq \text{miss} \\
  \text{miss} & \text{if } i(t,x) = \text{miss} \lor c = \text{miss} 
\end{cases} \]

- **gtc** Greater than constant
  \[ o(t,x) = \begin{cases} 
  1 & \text{if } i(t,x) > c \land i(t,x), c \neq \text{miss} \\
  0 & \text{if } i(t,x) \leq c \land i(t,x), c \neq \text{miss} \\
  \text{miss} & \text{if } i(t,x) = \text{miss} \lor c = \text{miss} 
\end{cases} \]

Parameter

- \( c \rightarrow \text{FLOAT} \) Constant

Example

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

\[ \text{cdo gtc,273.15 infile outfile} \]
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
- **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
- **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
- **setRetime**: Set reference time
- **setCalendar**: Set calendar
- **shiftTtime**: 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
- **setZaxis**: Set z-axis
- **genLevelBounds**: Generate level bounds
- **invertLat**: Invert latitudes
- **invertLev**: Invert levels
- **shiftX**: Shift x
- **shiftY**: Shift y
- **maskRegion**: Mask regions
<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>masklonlatbox</td>
<td>Mask a longitude/latitude box</td>
</tr>
<tr>
<td>maskindexbox</td>
<td>Mask an index box</td>
</tr>
<tr>
<td>setclonlatbox</td>
<td>Set a longitude/latitude box to constant</td>
</tr>
<tr>
<td>setcindexbox</td>
<td>Set an index box to constant</td>
</tr>
<tr>
<td>enlarge</td>
<td>Enlarge fields</td>
</tr>
<tr>
<td>setmissval</td>
<td>Set a new missing value</td>
</tr>
<tr>
<td>setctomiss</td>
<td>Set constant to missing value</td>
</tr>
<tr>
<td>setmisstoc</td>
<td>Set missing value to constant</td>
</tr>
<tr>
<td>setrtonss</td>
<td>Set range to missing value</td>
</tr>
<tr>
<td>setvrange</td>
<td>Set valid range</td>
</tr>
<tr>
<td>setmisstonn</td>
<td>Set missing value to nearest neighbor</td>
</tr>
<tr>
<td>setmisstodis</td>
<td>Set missing value to distance-weighted average</td>
</tr>
</tbody>
</table>
### 2.6.1. SETATTRIBUTE - Set attributes

**Synopsis**

```
setattribute,attributes infile outfile
```

**Description**

This operator sets 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=att_VAL
```

- **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.

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.

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**.

**Parameter**

- **attributes** STRING Comma separated list of attributes.

**Note**

Attributes are evaluated by CDO when opening infile. Therefore 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:

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

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:

```plaintext
prompt> cat mypartab
&parameter
   name = t
   out_name = ta
   standard_name = air_temperature
   units = "K"
   missing_value = 1e+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 1e+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

```c
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
```

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.

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
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, sval 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.

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 of a relative time axis.
- **shifttime** Shift timesteps
  Shifts all timesteps by the parameter sval.
**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)
- **sval** 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:

```
```

To shift this time axis by -15 days use:

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

Result of `cdo showdate outfile`:

```
```
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

\texttt{setgrid.grid \ infile \ outfile}
\texttt{setgridtype.gridtype \ infile \ outfile}
\texttt{setgridarea.gridarea \ infile \ outfile}
\texttt{setgridmask.gridmask \ 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

\begin{itemize}
\item \texttt{setgrid} \hspace{1cm} 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.
\item \texttt{setgridtype} \hspace{1cm} Set grid type
Sets the grid type of all input fields. The following grid types are available:
\begin{itemize}
\item \texttt{curvilinear} \hspace{1cm} Converts a regular grid to a curvilinear grid
\item \texttt{unstructured} \hspace{1cm} Converts a regular or curvilinear grid to an unstructured grid
\item \texttt{dereference} \hspace{1cm} Dereference a reference to a grid
\item \texttt{regular} \hspace{1cm} Linear interpolation of a reduced Gaussian grid to a regular Gaussian grid
\item \texttt{regularnn} \hspace{1cm} Nearest neighbor interpolation of a reduced Gaussian grid to a regular Gaussian grid
\item \texttt{lonlat} \hspace{1cm} Converts a regular lonlat grid stored as a curvilinear grid back to a lonlat grid
\end{itemize}
\item \texttt{setgridarea} \hspace{1cm} Set grid cell area
Sets the grid cell area. The parameter \texttt{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 \texttt{fldmean}.
\item \texttt{setgridmask} \hspace{1cm} Set grid mask
Sets the grid mask. The parameter \texttt{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 \texttt{remapbil}.
\end{itemize}

Parameter

\begin{itemize}
\item \texttt{grid} \hspace{1cm} STRING \hspace{0.5cm} Grid description file or name
\item \texttt{gridtype} \hspace{1cm} STRING \hspace{0.5cm} Grid type (curvilinear, unstructured, regular, lonlat or dereference)
\item \texttt{gridarea} \hspace{1cm} STRING \hspace{0.5cm} Data file, the first field is used as grid cell area
\item \texttt{gridmask} \hspace{1cm} STRING \hspace{0.5cm} Data file, the first field is used as grid mask
\end{itemize}
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

\texttt{\texttt{<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

<table>
<thead>
<tr>
<th>Operator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>\texttt{shiftx}</td>
<td>Shift x</td>
</tr>
<tr>
<td>\texttt{shifty}</td>
<td>Shift y</td>
</tr>
</tbody>
</table>

Parameter

- \texttt{nshift} \hspace{1em} \texttt{INTEGER} \hspace{1em} Number of grid cells to shift (default: 1)
- \texttt{cyclic} \hspace{1em} \texttt{STRING} \hspace{1em} If set, cells are filled up cyclic (default: missing value)
- \texttt{coord} \hspace{1em} \texttt{STRING} \hspace{1em} 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:

\begin{verbatim}
cdo shiftx infile outfile
\end{verbatim}

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

\begin{verbatim}
cdo shiftx,1,cyclic infile outfile
\end{verbatim}
2.6.11. MASKREGION - Mask regions

Synopsis

```bash
maskregion,regions infile outfile
```

Description

Masks different regions of fields with a regular lon/lat grid. The elements inside a region are un-
touched, the elements 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. The user has to
give ASCII formatted files with different regions. A region is defined by 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 &.

Parameter

```plaintext
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:

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

For this example the polygon description file `myregion` should contain the following four coordinates:

```
120   20
120  -20
270   20
270  -20
```
2.6.12. MASKBOX - Mask a box

Synopsis

masklonlatbox,lon1,lon2,lat1,lat2 infile outfile
maskindexbox,idx1,idx2,idx1,idx2 infile outfile

Description

Masked a box of the rectangularly understood field. 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
Masked a regular longitude/latitude box. The user has to give the longitudes and latitudes of the edges of the box. Considered are only those grid cells with the grid center inside the lon/lat box.

maskindexbox Mask an index box
Masked an index box. The user has to give the indexes of the edges of the box. The index of the left edge can be greater then the one of the right edge.

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 indexes 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:

```plaintext
    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:

```plaintext
    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:

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

Or shorter using operator piping:

```bash
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
\[ o(t,x) = \begin{cases} 
\text{newmiss} & \text{if } i(t,x) = \text{miss} \\
i(t,x) & \text{if } i(t,x) \neq \text{miss} 
\end{cases} \]

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
\[ o(t,x) = \begin{cases} 
\text{miss} & \text{if } i(t,x) \geq rmin \land i(t,x) \leq rmax \\
i(t,x) & \text{if } i(t,x) < rmin \lor i(t,x) > rmax 
\end{cases} \]

setvrange
Set valid range
\[ o(t,x) = \begin{cases} 
\text{miss} & \text{if } i(t,x) < rmin \lor i(t,x) > rmax \\
i(t,x) & \text{if } i(t,x) \geq rmin \land i(t,x) \leq rmax 
\end{cases} \]

setmisstonn
Set missing value to nearest neighbor
Set all missing values to the nearest non missing value.
\[ o(t,x) = \begin{cases} 
i(t,y) & \text{if } i(t,x) = \text{miss} \land i(t,y) \neq \text{miss} \\
i(t,x) & \text{if } i(t,x) \neq \text{miss} 
\end{cases} \]

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

- \texttt{neighbors} INTEGER Number of nearest neighbors
- \texttt{newmiss} FLOAT New missing value
- \texttt{c} FLOAT Constant
- \texttt{rmin} FLOAT Lower bound
- \texttt{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.
2.7. 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
- **monadd**: Add monthly time series
- **monsunb**: Subtract monthly time series
- **monmul**: Multiply monthly time series
- **mondiv**: Divide monthly 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
<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ydayadd</td>
<td>Add multi-year daily time series</td>
</tr>
<tr>
<td>ydaysub</td>
<td>Subtract multi-year daily time series</td>
</tr>
<tr>
<td>ydaymul</td>
<td>Multiply multi-year daily time series</td>
</tr>
<tr>
<td>ydaydiv</td>
<td>Divide multi-year daily time series</td>
</tr>
<tr>
<td>ymonadd</td>
<td>Add multi-year monthly time series</td>
</tr>
<tr>
<td>ymonsub</td>
<td>Subtract multi-year monthly time series</td>
</tr>
<tr>
<td>ymonmul</td>
<td>Multiply multi-year monthly time series</td>
</tr>
<tr>
<td>ymondiv</td>
<td>Divide multi-year monthly time series</td>
</tr>
<tr>
<td>yseasadd</td>
<td>Add multi-year seasonal time series</td>
</tr>
<tr>
<td>yseassub</td>
<td>Subtract multi-year seasonal time series</td>
</tr>
<tr>
<td>yseasmul</td>
<td>Multiply multi-year seasonal time series</td>
</tr>
<tr>
<td>yseasdiv</td>
<td>Divide multi-year seasonal time series</td>
</tr>
<tr>
<td>muldpm</td>
<td>Multiply with days per month</td>
</tr>
<tr>
<td>divdpm</td>
<td>Divide by days per month</td>
</tr>
<tr>
<td>muldpy</td>
<td>Multiply with days per year</td>
</tr>
<tr>
<td>divdpy</td>
<td>Divide by days per year</td>
</tr>
</tbody>
</table>
2.7.1. EXPR - Evaluate expressions

Synopsis

\texttt{expr.instr} infile outfile
\texttt{expr.filename} infile outfile
\texttt{aexpr.instr} infile outfile
\texttt{aexpr.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. 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:

<table>
<thead>
<tr>
<th>Operator</th>
<th>Meaning</th>
<th>Example</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>=</td>
<td>assignment</td>
<td>( x = y )</td>
<td>Assigns y to x</td>
</tr>
<tr>
<td>+</td>
<td>addition</td>
<td>( x + y )</td>
<td>Sum of ( x ) and ( y )</td>
</tr>
<tr>
<td>-</td>
<td>subtraction</td>
<td>( x - y )</td>
<td>Difference of ( x ) and ( y )</td>
</tr>
<tr>
<td>*</td>
<td>multiplication</td>
<td>( x \times y )</td>
<td>Product of ( x ) and ( y )</td>
</tr>
<tr>
<td>/</td>
<td>division</td>
<td>( x \div y )</td>
<td>Quotient of ( x ) and ( y )</td>
</tr>
<tr>
<td>^</td>
<td>exponentiation</td>
<td>( x \wedge y )</td>
<td>Exponentiates ( x ) with ( y )</td>
</tr>
<tr>
<td>==</td>
<td>equal to</td>
<td>( x == y )</td>
<td>1, if ( x ) equal to ( y ); else 0</td>
</tr>
<tr>
<td>!=</td>
<td>not equal to</td>
<td>( x != y )</td>
<td>1, if ( x ) not equal to ( y ); else 0</td>
</tr>
<tr>
<td>&gt;</td>
<td>greater than</td>
<td>( x &gt; y )</td>
<td>1, if ( x ) greater than ( y ); else 0</td>
</tr>
<tr>
<td>&lt;</td>
<td>less than</td>
<td>( x &lt; y )</td>
<td>1, if ( x ) less than ( y ); else 0</td>
</tr>
<tr>
<td>&gt;=</td>
<td>greater equal</td>
<td>( x &gt;= y )</td>
<td>1, if ( x ) greater equal ( y ); else 0</td>
</tr>
<tr>
<td>&lt;=</td>
<td>less equal</td>
<td>( x &lt;= y )</td>
<td>1, if ( x ) less equal ( y ); else 0</td>
</tr>
<tr>
<td>&lt;==</td>
<td>less equal greater</td>
<td>( x &lt;== y )</td>
<td>-1, if ( x ) less ( y ); 1, if ( x ) greater ( y ); else 0</td>
</tr>
<tr>
<td>&amp;&amp;</td>
<td>logical AND</td>
<td>( x &amp;&amp; y )</td>
<td>1, if ( x ) and ( y ) not equal 0; else 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>logical OR</td>
</tr>
<tr>
<td>!</td>
<td>logical NOT</td>
<td>!x</td>
<td>1, if ( x ) equal 0; else 0</td>
</tr>
<tr>
<td>?:</td>
<td>ternary conditional</td>
<td>( x ? y : z )</td>
<td>( y ), if ( x ) not equal 0, else ( z )</td>
</tr>
</tbody>
</table>

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
rad(x)  Convert x from degrees to radians
deg(x)  Convert x from radians to degrees

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)
clev(x)  Level coordinate of x (0, if x is a 2D surface variable)
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

Statistical values over a field:
fldmin(x), fldmax(x), fldsum(x), fldmean(x), fldavg(x), fldstd(x), fldstd1(x), fldvar(x), fldvar1(x)

Zonal statistical values for regular 2D grids:
zonmin(x), zonmax(x), zonsum(x), zonmean(x), zonavg(x), zonstd(x), zonstd1(x), zonvar(x), zonvar1(x)

Vertical statistical values:
vertmin(x), vertmax(x), vertsum(x), vertmean(x), vertavg(x), vertstd(x), vertstd1(x), vertvar(x), vertvar1(x)

Miscellaneous:
Arithmetic Reference manual

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

The expr commands sellevel(x,k) and sellevidx(x,k) are only available with exprf/aexprf. 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

<table>
<thead>
<tr>
<th>Operator</th>
<th>Description</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>abs</td>
<td>Absolute value</td>
<td>( o(t, x) = \text{abs}(i(t, x)) )</td>
</tr>
<tr>
<td>int</td>
<td>Integer value</td>
<td>( o(t, x) = \text{int}(i(t, x)) )</td>
</tr>
<tr>
<td>nint</td>
<td>Nearest integer value</td>
<td>( o(t, x) = \text{nint}(i(t, x)) )</td>
</tr>
<tr>
<td>pow</td>
<td>Power</td>
<td>( o(t, x) = i(t, x)^y )</td>
</tr>
<tr>
<td>sqr</td>
<td>Square</td>
<td>( o(t, x) = i(t, x)^2 )</td>
</tr>
<tr>
<td>sqrt</td>
<td>Square root</td>
<td>( o(t, x) = \sqrt{i(t, x)} )</td>
</tr>
<tr>
<td>exp</td>
<td>Exponential</td>
<td>( o(t, x) = e^{i(t, x)} )</td>
</tr>
<tr>
<td>ln</td>
<td>Natural logarithm</td>
<td>( o(t, x) = \ln(i(t, x)) )</td>
</tr>
<tr>
<td>log10</td>
<td>Base 10 logarithm</td>
<td>( o(t, x) = \log_{10}(i(t, x)) )</td>
</tr>
<tr>
<td>sin</td>
<td>Sine</td>
<td>( o(t, x) = \sin(i(t, x)) )</td>
</tr>
<tr>
<td>cos</td>
<td>Cosine</td>
<td>( o(t, x) = \cos(i(t, x)) )</td>
</tr>
<tr>
<td>tan</td>
<td>Tangent</td>
<td>( o(t, x) = \tan(i(t, x)) )</td>
</tr>
<tr>
<td>asin</td>
<td>Arc sine</td>
<td>( o(t, x) = \arcsin(i(t, x)) )</td>
</tr>
<tr>
<td>acos</td>
<td>Arc cosine</td>
<td>( o(t, x) = \arccos(i(t, x)) )</td>
</tr>
<tr>
<td>atan</td>
<td>Arc tangent</td>
<td>( o(t, x) = \arctan(i(t, x)) )</td>
</tr>
<tr>
<td>reci</td>
<td>Reciprocal value</td>
<td>( o(t, x) = \frac{1}{i(t, x)} )</td>
</tr>
<tr>
<td>not</td>
<td>Logical NOT</td>
<td>( o(t, x) = 1, \text{if } x \text{equal} 0; \text{else} 0 )</td>
</tr>
</tbody>
</table>
Example

To calculate the square root for all field elements use:

```bash
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
  
  \[ o(t, x) = i(t, x) \times c \]

- **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

Example

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

```bash
  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. One of the input files can contain only one timestep or one variable.

Operators

<table>
<thead>
<tr>
<th>Operator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>add</td>
<td>Add two fields</td>
</tr>
<tr>
<td></td>
<td>$o(t,x) = i_1(t,x) + i_2(t,x)$</td>
</tr>
<tr>
<td>sub</td>
<td>Subtract two fields</td>
</tr>
<tr>
<td></td>
<td>$o(t,x) = i_1(t,x) - i_2(t,x)$</td>
</tr>
<tr>
<td>mul</td>
<td>Multiply two fields</td>
</tr>
<tr>
<td></td>
<td>$o(t,x) = i_1(t,x) * i_2(t,x)$</td>
</tr>
<tr>
<td>div</td>
<td>Divide two fields</td>
</tr>
<tr>
<td></td>
<td>$o(t,x) = i_1(t,x)/i_2(t,x)$</td>
</tr>
<tr>
<td>min</td>
<td>Minimum of two fields</td>
</tr>
<tr>
<td></td>
<td>$o(t,x) = \min(i_1(t,x), i_2(t,x))$</td>
</tr>
<tr>
<td>max</td>
<td>Maximum of two fields</td>
</tr>
<tr>
<td></td>
<td>$o(t,x) = \max(i_1(t,x), i_2(t,x))$</td>
</tr>
<tr>
<td>atan2</td>
<td>Arc tangent of two fields</td>
</tr>
<tr>
<td></td>
<td>The atan2 operator calculates the arc tangent of two fields. The result is in radians, which is between -PI and PI (inclusive).</td>
</tr>
<tr>
<td></td>
<td>$o(t,x) = \text{atan2}(i_1(t,x), i_2(t,x))$</td>
</tr>
</tbody>
</table>

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. 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 header information in infile1 have to be the same as in infile2. Usually infile2 is generated by an operator of the module MONSTAT.

Operators

<table>
<thead>
<tr>
<th>Operator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>monadd</td>
<td>Add monthly time series</td>
</tr>
<tr>
<td></td>
<td>Adds a time series and a monthly time series.</td>
</tr>
<tr>
<td>monsub</td>
<td>Subtract monthly time series</td>
</tr>
<tr>
<td></td>
<td>Subtracts a time series and a monthly time series.</td>
</tr>
<tr>
<td>monmul</td>
<td>Multiply monthly time series</td>
</tr>
<tr>
<td></td>
<td>Multiplies a time series and a monthly time series.</td>
</tr>
<tr>
<td>mondiv</td>
<td>Divide monthly time series</td>
</tr>
<tr>
<td></td>
<td>Divides a time series and a monthly time series.</td>
</tr>
</tbody>
</table>

Example

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

```
cdo monsub infile -monavg infile outfile
```
2.7.6. YHOURARITH - Multi-year hourly arithmetic

Synopsis

\[ <operator> \text{infile1 infile2 outfile} \]

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 \text{infile1} the corresponding field of the timestep in \text{infile2} with the same hour and day of year is used. The header information in \text{infile1} have to be the same as in \text{infile2}. Usually \text{infile2} is generated by an operator of the module \text{YHOURSTAT}.

Operators

- \text{yhouradd} Add multi-year hourly time series
- \text{yhoursub} Subtract multi-year hourly time series
- \text{yhourmul} Multiply multi-year hourly time series
- \text{yhourdiv} Divide multi-year hourly time series

Example

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

\begin{verbatim}
cdo yhoursub infile -yhouravg infile outfile
\end{verbatim}
2.7.7. **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 header information in `infile1` have to be the same as in `infile2`. 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
```

---

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2.7.8. 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 header information in infile1 have to be the same as in infile2. 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 and a multi-year monthly time series.
ymondiv  Divide multi-year monthly time series
         Divides a time series and 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
```
2.7.9. 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 header information in infile1 have to be the same as in infile2. 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
```

2.7.10. 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
  \[ o(t,x) = i(t,x) \times \text{days\_per\_month} \]
- **divdpm**: Divide by days per month
  \[ o(t,x) = i(t,x) / \text{days\_per\_month} \]
- **muldpy**: Multiply with days per year
  \[ o(t,x) = i(t,x) \times \text{days\_per\_year} \]
- **divdpy**: Divide by days per year
  \[ o(t,x) = i(t,x) / \text{days\_per\_year} \]
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:

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>sum</td>
<td>(\sum_{i=1}^{n} x_i)</td>
</tr>
<tr>
<td>mean resp. avg</td>
<td>(n^{-1} \sum_{i=1}^{n} x_i)</td>
</tr>
<tr>
<td>mean resp. avg weighted by ({w_i, i = 1, ..., n})</td>
<td>(\left(\sum_{j=1}^{n} w_j\right)^{-1} \sum_{i=1}^{n} w_i x_i)</td>
</tr>
<tr>
<td>Variance var</td>
<td>(n^{-1} \sum_{i=1}^{n} (x_i - \bar{x})^2)</td>
</tr>
<tr>
<td>var1</td>
<td>((n - 1)^{-1} \sum_{i=1}^{n} (x_i - \bar{x})^2)</td>
</tr>
<tr>
<td>var weighted by ({w_i, i = 1, ..., n})</td>
<td>(\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)</td>
</tr>
<tr>
<td>Standard deviation std</td>
<td>(\sqrt{n^{-1} \sum_{i=1}^{n} (x_i - \bar{x})^2})</td>
</tr>
<tr>
<td>std1</td>
<td>((n - 1)^{-1} \sum_{i=1}^{n} (x_i - \bar{x})^2)</td>
</tr>
<tr>
<td>std weighted by ({w_i, i = 1, ..., n})</td>
<td>(\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)</td>
</tr>
<tr>
<td>Cumulative Ranked Probability Score crps</td>
<td>(\int_{-\infty}^{\infty} \left[H(x_1) - cdf([x_2 ... x_n])\right] r , dr)</td>
</tr>
</tbody>
</table>

with \(cdf(X)\) being the cumulative distribution function of \(\{x_i, i = 2 ... n\}\) at \(r\) and \(H(x)\) the Heavyside function jumping at \(x\).

Here is a short overview of all operators in this section:
<table>
<thead>
<tr>
<th><strong>timcumsum</strong></th>
<th>Cumulative sum over all timesteps</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>consecsum</strong></td>
<td>Consecutive Sum</td>
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<td>Consecutive Timesteps</td>
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<td>Variables standard deviation (n-1)</td>
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<td>Variables variance</td>
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<td>Ranked Histogram averaged over time</td>
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<td><strong>ensrkhisttime</strong></td>
<td>Ranked Histogram averaged over space</td>
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<td><strong>ensroc</strong></td>
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| **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) |
| **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) |

| **vertmin** | Vertical minimum |
| **vermax** | Vertical maximum |
| **verrange** | Vertical range |
| **vertsun** | 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) |
### Statistical values

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</table>
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.

\[ o(t, x) = \sum \{ i(t', x), 0 < t' \leq t \} \]

2.8.2. CONSECSTAT - Consecutive 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 masking the input field:

```
cdo consects -gtc,20.0 infile1 outfile
```
2.8.3. VARSSTAT - Statistical values over all variables

Synopsis

\(<\text{operator}>\) \text{ 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, variance, standard deviation 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  
  \( o(t, x) = \min\{i_1(t, x), i_2(t, x), \ldots, i_n(t, x)\} \)

- **ensmax**  
  Ensemble maximum  
  \( o(t, x) = \max\{i_1(t, x), i_2(t, x), \ldots, i_n(t, x)\} \)

- **ensrange**  
  Ensemble range  
  \( o(t, x) = \text{range}\{i_1(t, x), i_2(t, x), \ldots, i_n(t, x)\} \)

- **enssum**  
  Ensemble sum  
  \( o(t, x) = \sum\{i_1(t, x), i_2(t, x), \ldots, i_n(t, x)\} \)

- **ensmean**  
  Ensemble mean  
  \( o(t, x) = \text{mean}\{i_1(t, x), i_2(t, x), \ldots, i_n(t, x)\} \)

- **ensavg**  
  Ensemble average  
  \( o(t, x) = \text{avg}\{i_1(t, x), i_2(t, x), \ldots, i_n(t, x)\} \)

- **ensstd**  
  Ensemble standard deviation  
  Normalize by \( n \).  
  \( o(t, x) = \text{std}\{i_1(t, x), i_2(t, x), \ldots, i_n(t, x)\} \)

- **ensstd1**  
  Ensemble standard deviation \((n-1)\)  
  Normalize by \((n-1)\).  
  \( o(t, x) = \text{std1}\{i_1(t, x), i_2(t, x), \ldots, i_n(t, x)\} \)

- **ensvar**  
  Ensemble variance  
  Normalize by \( n \).  
  \( o(t, x) = \text{var}\{i_1(t, x), i_2(t, x), \ldots, i_n(t, x)\} \)

- **ensvar1**  
  Ensemble variance \((n-1)\)  
  Normalize by \((n-1)\).  
  \( o(t, x) = \text{var1}\{i_1(t, x), i_2(t, x), \ldots, i_n(t, x)\} \)

- **enspctl**  
  Ensemble percentiles  
  \( o(t, x) = \text{p}\text{th percentile}\{i_1(t, x), i_2(t, x), \ldots, i_n(t, x)\} \)

Parameter

- **p**  
  FLOAT  
  Percentile number in 0, ..., 100
Note

This operator needs 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.

ensrkhistspace computes a ranked histogram at each timestep reducing each horizontal grid to a 1x1 grid and keeping the time axis as in obsfile. Contrary ensrkhisttime 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 time
ensrkhisttime  Ranked Histogram averaged over space
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,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>.<filesuffix> 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 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>,weights infile outfile
fldpctl,p infile outfile

Description

This module computes statistical values of the input fields. According to the chosen operator the field minimum, maximum, range, sum, average, variance, standard deviation or a certain percentile is written to outfile.

Operators

fldmin  Field minimum
For every gridpoint $x_1,...,x_n$ of the same field it is:
$$o(t,1) = \min\{i(t,x'), x_1 < x' \leq x_n\}$$

fldmax  Field maximum
For every gridpoint $x_1,...,x_n$ of the same field it is:
$$o(t,1) = \max\{i(t,x'), x_1 < x' \leq x_n\}$$

fldrange  Field range
For every gridpoint $x_1,...,x_n$ of the same field it is:
$$o(t,1) = \text{range}\{i(t,x'), x_1 < x' \leq x_n\}$$

fldsum  Field sum
For every gridpoint $x_1,...,x_n$ of the same field it is:
$$o(t,1) = \sum\{i(t,x'), x_1 < x' \leq x_n\}$$
weighted by area weights obtained by the input field.

fldmean  Field mean
For every gridpoint $x_1,...,x_n$ of the same field it is:
$$o(t,1) = \text{mean}\{i(t,x'), x_1 < x' \leq x_n\}$$
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:
$$o(t,1) = \text{avg}\{i(t,x'), x_1 < x' \leq x_n\}$$
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:
$$o(t,1) = \text{std}\{i(t,x'), x_1 < x' \leq x_n\}$$
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:
$$o(t,1) = \text{std1}\{i(t,x'), x_1 < x' \leq x_n\}$$
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:
$$o(t,1) = \text{var}\{i(t,x'), x_1 < x' \leq x_n\}$$
weighted by area weights obtained by the input field.
**fldvar1**  
Field variance (n-1)  
Normalize by (n-1). For every gridpoint \( x_1, \ldots, x_n \) of the same field it is:  
\[ o(t,1) = \text{var1}\{i(t,x'), x_1 < x' \leq x_n\} \]
weighted by area weights obtained by the input field.

**fldpctl**  
Field percentiles  
For every gridpoint \( x_1, \ldots, x_n \) of the same field it is:  
\[ o(t,1) = \text{pth percentile}\{i(t,x'), x_1 < x' \leq x_n\} \]

**Parameter**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>weights</td>
<td>BOOL</td>
<td>weights=FALSE disables weighting by grid cell area [default: weights=TRUE]</td>
</tr>
<tr>
<td>p</td>
<td>FLOAT</td>
<td>Percentile number in 0, ..., 100</td>
</tr>
</tbody>
</table>

**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 statistical values

Synopsis

\[ <\text{operator}> \text{ infile outfile} \]
\[ \text{zonpctl, } p \text{ infile outfile} \]

Description

This module computes zonal statistical values of the input fields. According to the chosen operator the zonal minimum, maximum, range, sum, average, variance, standard deviation or a certain percentile is written to outfile. This operator requires all variables on the same regular lon/lat grid.

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.
- **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).
- **zonpctl**: Zonal percentiles
  For every latitude the pth percentile over all longitudes is computed.

Parameter

- **p** FLOAT Percentile number in 0, ..., 100

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 statistical values

Synopsis

\(<operator>\> \text{ infile outfile}

\text{merpctl}, p \text{ infile outfile}

Description

This module computes meridional statistical values of the input fields. According to the chosen operator the meridional minimum, maximum, range, sum, average, variance, standard deviation or a certain percentile is written to outfile. This operator requires all variables on the same regular lon/lat grid.

Operators

- \text{mermin} \quad \text{Meridional minimum}
  For every longitude the minimum over all latitudes is computed.
- \text{mermax} \quad \text{Meridional maximum}
  For every longitude the maximum over all latitudes is computed.
- \text{merrange} \quad \text{Meridional range}
  For every longitude the range over all latitudes is computed.
- \text{mersum} \quad \text{Meridional sum}
  For every longitude the sum over all latitudes is computed.
- \text{mermean} \quad \text{Meridional mean}
  For every longitude the area weighted mean over all latitudes is computed.
- \text{meravg} \quad \text{Meridional average}
  For every longitude the area weighted average over all latitudes is computed.
- \text{merstd} \quad \text{Meridional standard deviation}
  For every longitude the standard deviation over all latitudes is computed. Normalize by n.
- \text{merstd1} \quad \text{Meridional standard deviation (n-1)}
  For every longitude the standard deviation over all latitudes is computed. Normalize by (n-1).
- \text{mervar} \quad \text{Meridional variance}
  For every longitude the variance over all latitudes is computed. Normalize by n.
- \text{mervar1} \quad \text{Meridional variance (n-1)}
  For every longitude the variance over all latitudes is computed. Normalize by (n-1).
- \text{merpctl} \quad \text{Meridional percentiles}
  For every longitude the pth percentile over all latitudes is computed.

Parameter

\( p \quad \text{FLOAT} \quad \text{Percentile number in} \ 0, \ ..., \ 100 \)
Example

To compute the meridional mean of all input fields use:

```shell
CDO MEREAN INFILE OUTFILE
```

To compute the 50th meridional percentile (median) of all input fields use:

```shell
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. According to the chosen operator the minimum, maximum, range, sum, average, variance, or standard deviation of the neighboring grid boxes is written to outfile. All gridbox operators only works 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).

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. VERTSTAT - Vertical statistical values

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
2.8.12. TIMSELSTAT - Time range statistical values

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.

Operators

**timselmin**  Time selection minimum

For every adjacent sequence \( t_1, \ldots, t_n \) of timesteps of the same selected time range it is:

\[
o(t, x) = \min \{i(t', x), t_1 < t' \leq t_n\}
\]

**timselmax**  Time selection maximum

For every adjacent sequence \( t_1, \ldots, t_n \) of timesteps of the same selected time range it is:

\[
o(t, x) = \max \{i(t', x), t_1 < t' \leq t_n\}
\]

**timselrange**  Time selection range

For every adjacent sequence \( t_1, \ldots, t_n \) of timesteps of the same selected time range it is:

\[
o(t, x) = \text{range}\{i(t', x), t_1 < t' \leq t_n\}
\]

**timselsum**  Time selection sum

For every adjacent sequence \( t_1, \ldots, t_n \) of timesteps of the same selected time range it is:

\[
o(t, x) = \text{sum}\{i(t', x), t_1 < t' \leq t_n\}
\]

**timselmean**  Time selection mean

For every adjacent sequence \( t_1, \ldots, t_n \) of timesteps of the same selected time range it is:

\[
o(t, x) = \text{mean}\{i(t', x), t_1 < t' \leq t_n\}
\]

**timselavg**  Time selection average

For every adjacent sequence \( t_1, \ldots, t_n \) of timesteps of the same selected time range it is:

\[
o(t, x) = \text{avg}\{i(t', x), t_1 < t' \leq t_n\}
\]

**timselstd**  Time selection standard deviation

Normalize by \( n \). For every adjacent sequence \( t_1, \ldots, t_n \) of timesteps of the same selected time range it is:

\[
o(t, x) = \text{std}\{i(t', x), t_1 < t' \leq t_n\}
\]

**timselstd1**  Time selection standard deviation (n-1)

Normalize by \( (n-1) \). For every adjacent sequence \( t_1, \ldots, t_n \) of timesteps of the same selected time range it is:

\[
o(t, x) = \text{std1}\{i(t', x), t_1 < t' \leq t_n\}
\]

**timselvar**  Time selection variance

Normalize by \( n \). For every adjacent sequence \( t_1, \ldots, t_n \) of timesteps of the same selected time range it is:

\[
o(t, x) = \text{var}\{i(t', x), t_1 < t' \leq t_n\}
\]

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timselvar1  Time selection variance (n-1)
Normalize by (n-1). For every adjacent sequence \( t_1, \ldots, t_n \) of timesteps of the same selected time range it is:
\[
o(t, x) = \text{var1}\{i(t', x), t_1 < t' \leq t_n\}
\]

Parameter

- \textit{nsets} INTEGER  Number of input timesteps for each output timestep
- \textit{noffset} INTEGER  Number of input timesteps skipped before the first timestep range (optional)
- \textit{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 months have to be skipped:

```
cdo timselmean,3,2 infile outfile
```

### 2.8.13. 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 \( \text{infile1} \). The algorithm uses histograms with minimum and maximum bounds given in \( \text{infile2} \) and \( \text{infile3} \), respectively. The default number of histogram bins is 101. The default can be overridden by setting the environment variable \text{CDO\_PCTL\_NBINS} to a different value. The files \( \text{infile2} \) and \( \text{infile3} \) should be the result of corresponding \text{timselmin} and \text{timselmax} operations, respectively. The time of \( \text{outfile} \) is determined by the time in the middle of all contributing timesteps of \( \text{infile1} \). For every adjacent sequence \( t_1, \ldots, t_n \) of timesteps of the same selected time range it is:

\[
o(t, x) = \text{p}\text{th percentile}\{i(t', x), t_1 < t' \leq t_n\}
\]

Parameter

- \textit{p} FLOAT  Percentile number in 0, ..., 100
- \textit{nsets} INTEGER  Number of input timesteps for each output timestep
- \textit{noffset} INTEGER  Number of input timesteps skipped before the first timestep range (optional)
- \textit{nskip} INTEGER  Number of input timesteps skipped between timestep ranges (optional)

Environment

- \text{CDO\_PCTL\_NBINS}  Sets the number of histogram bins. The default number is 101.
2.8.14. RUNSTAT - Running statistical values

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.

Operators

- runmin: Running minimum
  \[ o(t + (nts - 1)/2, x) = \min\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x)\} \]

- runmax: Running maximum
  \[ o(t + (nts - 1)/2, x) = \max\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x)\} \]

- runrange: Running range
  \[ o(t + (nts - 1)/2, x) = \text{range}\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x)\} \]

- runsum: Running sum
  \[ o(t + (nts - 1)/2, x) = \text{sum}\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x)\} \]

- runmean: Running mean
  \[ o(t + (nts - 1)/2, x) = \text{mean}\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x)\} \]

- runavg: Running average
  \[ o(t + (nts - 1)/2, x) = \text{avg}\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x)\} \]

- runstd: Running standard deviation
  Normalize by n.
  \[ o(t + (nts - 1)/2, x) = \text{std}\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x)\} \]

- runstd1: Running standard deviation (n-1)
  Normalize by (n-1).
  \[ o(t + (nts - 1)/2, x) = \text{std1}\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x)\} \]

- runvar: Running variance
  Normalize by n.
  \[ o(t + (nts - 1)/2, x) = \text{var}\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x)\} \]

- runvar1: Running variance (n-1)
  Normalize by (n-1).
  \[ o(t + (nts - 1)/2, x) = \text{var1}\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x)\} \]

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
```

2.8.15. 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`.

\[
o(t + (nts - 1)/2, x) = \text{pth percentile}\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x)\}
\]

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
```
2.8.16. 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.

Operators

- **timmin**: Time minimum
  
  \[ o(1,x) = \min\{i(t', x), t_1 < t' \leq t_n \} \]

- **timmax**: Time maximum
  
  \[ o(1,x) = \max\{i(t', x), t_1 < t' \leq t_n \} \]

- **timrange**: Time range
  
  \[ o(1,x) = \text{range}\{i(t', x), t_1 < t' \leq t_n \} \]

- **timsum**: Time sum
  
  \[ o(1,x) = \text{sum}\{i(t', x), t_1 < t' \leq t_n \} \]

- **timmean**: Time mean
  
  \[ o(1,x) = \text{mean}\{i(t', x), t_1 < t' \leq t_n \} \]

- **timavg**: Time average
  
  \[ o(1,x) = \text{avg}\{i(t', x), t_1 < t' \leq t_n \} \]

- **timpl**: Time standard deviation
  
  Normalize by \( n \).
  
  \[ o(1,x) = \text{std}\{i(t', x), t_1 < t' \leq t_n \} \]

- **timpl1**: Time standard deviation \((n-1)\)
  
  Normalize by \((n-1)\).
  
  \[ o(1,x) = \text{std1}\{i(t', x), t_1 < t' \leq t_n \} \]

- **timvar**: Time variance
  
  Normalize by \( n \).
  
  \[ o(1,x) = \text{var}\{i(t', x), t_1 < t' \leq t_n \} \]

- **timvar1**: Time variance \((n-1)\)
  
  Normalize by \((n-1)\).
  
  \[ o(1,x) = \text{var1}\{i(t', x), t_1 < t' \leq t_n \} \]

Example

To compute the mean over all input timesteps use:

```
cdo timmean infile outfile
```
2.8.17. 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`.

\[ o(1, x) = \text{pth percentile}\{i(t', x), t_1 < t' \leq t_n\} \]

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
```
2.8.18. HOURSTAT - Hourly statistical values

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.

Operators

- **hourmin**  
  Hourly minimum  
  For every adjacent sequence \( t_1, ..., t_n \) of timesteps of the same hour it is:  
  \[ o(t, x) = \min\{ i(t', x), t_1 < t' \leq t_n \} \]

- **hourmax**  
  Hourly maximum  
  For every adjacent sequence \( t_1, ..., t_n \) of timesteps of the same hour it is:  
  \[ o(t, x) = \max\{ i(t', x), t_1 < t' \leq t_n \} \]

- **hourrange**  
  Hourly range  
  For every adjacent sequence \( t_1, ..., t_n \) of timesteps of the same hour it is:  
  \[ o(t, x) = \text{range}\{ i(t', x), t_1 < t' \leq t_n \} \]

- **hoursum**  
  Hourly sum  
  For every adjacent sequence \( t_1, ..., t_n \) of timesteps of the same hour it is:  
  \[ o(t, x) = \text{sum}\{ i(t', x), t_1 < t' \leq t_n \} \]

- **hourmean**  
  Hourly mean  
  For every adjacent sequence \( t_1, ..., t_n \) of timesteps of the same hour it is:  
  \[ o(t, x) = \text{mean}\{ i(t', x), t_1 < t' \leq t_n \} \]

- **houravg**  
  Hourly average  
  For every adjacent sequence \( t_1, ..., t_n \) of timesteps of the same hour it is:  
  \[ o(t, x) = \text{avg}\{ i(t', x), t_1 < t' \leq t_n \} \]

- **hourstd**  
  Hourly standard deviation  
  Normalize by \( n \). For every adjacent sequence \( t_1, ..., t_n \) of timesteps of the same hour it is:  
  \[ o(t, x) = \text{std}\{ i(t', x), t_1 < t' \leq t_n \} \]

- **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:  
  \[ o(t, x) = \text{std1}\{ i(t', x), t_1 < t' \leq t_n \} \]

- **hourvar**  
  Hourly variance  
  Normalize by \( n \). For every adjacent sequence \( t_1, ..., t_n \) of timesteps of the same hour it is:  
  \[ o(t, x) = \text{var}\{ i(t', x), t_1 < t' \leq t_n \} \]

- **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:  
  \[ o(t, x) = \text{var1}\{ i(t', x), t_1 < t' \leq t_n \} \]
Example

To compute the hourly mean of a time series use:

```
cdo hourmean infile outfile
```

2.8.19. 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`.

For every adjacent sequence `t_1,...,t_n` of timesteps of the same hour it is:

```
o(t,x) = 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
```
2.8.20. DAYSTAT - Daily statistical values

Synopsis

\(<\text{operator}>\) 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.

Operators

daymin  Daily minimum
For every adjacent sequence \(t_1, ..., t_n\) of timesteps of the same day it is:
\[
o(t, x) = \min\{i(t', x), t_1 < t' \leq t_n\}
\]

daymax  Daily maximum
For every adjacent sequence \(t_1, ..., t_n\) of timesteps of the same day it is:
\[
o(t, x) = \max\{i(t', x), t_1 < t' \leq t_n\}
\]

dayrange  Daily range
For every adjacent sequence \(t_1, ..., t_n\) of timesteps of the same day it is:
\[
o(t, x) = \text{range}\{i(t', x), t_1 < t' \leq t_n\}
\]

daysum  Daily sum
For every adjacent sequence \(t_1, ..., t_n\) of timesteps of the same day it is:
\[
o(t, x) = \text{sum}\{i(t', x), t_1 < t' \leq t_n\}
\]

daymean  Daily mean
For every adjacent sequence \(t_1, ..., t_n\) of timesteps of the same day it is:
\[
o(t, x) = \text{mean}\{i(t', x), t_1 < t' \leq t_n\}
\]

dayavg  Daily average
For every adjacent sequence \(t_1, ..., t_n\) of timesteps of the same day it is:
\[
o(t, x) = \text{avg}\{i(t', x), t_1 < t' \leq t_n\}
\]

daystd  Daily standard deviation
Normalize by \(n\). For every adjacent sequence \(t_1, ..., t_n\) of timesteps of the same day it is:
\[
o(t, x) = \text{std}\{i(t', x), t_1 < t' \leq t_n\}
\]

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:
\[
o(t, x) = \text{std1}\{i(t', x), t_1 < t' \leq t_n\}
\]

dayvar  Daily variance
Normalize by \(n\). For every adjacent sequence \(t_1, ..., t_n\) of timesteps of the same day it is:
\[
o(t, x) = \text{var}\{i(t', x), t_1 < t' \leq t_n\}
\]

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:
\[
o(t, x) = \text{var1}\{i(t', x), t_1 < t' \leq t_n\}
\]
Example

To compute the daily mean of a time series use:

```
cdo daymean infile outfile
```

2.8.21. 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`.

For every adjacent sequence `t_1,...,t_n` of timesteps of the same day it is:

\[ o(t, x) = \text{pth percentile}\{i(t', x), t_1 < t' \leq t_n\} \]

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
```
2.8.22. MONSTAT - Monthly statistical values

Synopsis

`<operator>` 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.

Operators

- **monmin** Monthly minimum
  For every adjacent sequence \( t_1, ..., t_n \) of timesteps of the same month it is:
  \[
  o(t, x) = \min\{i(t', x), t_1 < t' \leq t_n\}
  \]

- **monmax** Monthly maximum
  For every adjacent sequence \( t_1, ..., t_n \) of timesteps of the same month it is:
  \[
  o(t, x) = \max\{i(t', x), t_1 < t' \leq t_n\}
  \]

- **monrange** Monthly range
  For every adjacent sequence \( t_1, ..., t_n \) of timesteps of the same month it is:
  \[
  o(t, x) = \text{range}\{i(t', x), t_1 < t' \leq t_n\}
  \]

- **monsum** Monthly sum
  For every adjacent sequence \( t_1, ..., t_n \) of timesteps of the same month it is:
  \[
  o(t, x) = \sum\{i(t', x), t_1 < t' \leq t_n\}
  \]

- **monmean** Monthly mean
  For every adjacent sequence \( t_1, ..., t_n \) of timesteps of the same month it is:
  \[
  o(t, x) = \text{mean}\{i(t', x), t_1 < t' \leq t_n\}
  \]

- **monavg** Monthly average
  For every adjacent sequence \( t_1, ..., t_n \) of timesteps of the same month it is:
  \[
  o(t, x) = \text{avg}\{i(t', x), t_1 < t' \leq t_n\}
  \]

- **monstd** Monthly standard deviation
  Normalize by \( n \). For every adjacent sequence \( t_1, ..., t_n \) of timesteps of the same month it is:
  \[
  o(t, x) = \text{std}\{i(t', x), t_1 < t' \leq t_n\}
  \]

- **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:
  \[
  o(t, x) = \text{std1}\{i(t', x), t_1 < t' \leq t_n\}
  \]

- **monvar** Monthly variance
  Normalize by \( n \). For every adjacent sequence \( t_1, ..., t_n \) of timesteps of the same month it is:
  \[
  o(t, x) = \text{var}\{i(t', x), t_1 < t' \leq t_n\}
  \]

- **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:
  \[
  o(t, x) = \text{var1}\{i(t', x), t_1 < t' \leq t_n\}
  \]
Example

To compute the monthly mean of a time series use:

```
cdo monmean infile outfile
```

2.8.23. 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`.

For every adjacent sequence $t_1, \ldots, t_n$ of timesteps of the same month it is:

$$o(t, x) = \text{pth percentile}\{i(t', x), t_1 < t' \leq t_n\}$$

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
```
2.8.24. YEARMONSTAT - Yearly mean from monthly data

Synopsis

\[ \text{yearmonmean infile outfile} \]

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:

\[ o(t, x) = \text{mean}\{i(t', x), t_1 < t' \leq t_n\} \]

Environment

\text{CDO\_TIMESTAT\_DATE} \quad \text{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:

\begin{verbatim}
cdo yearmonmean infile outfile
\end{verbatim}
2.8.25. YEARSTAT - Yearly statistical values

Synopsis

<operator> 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.

Operators

**yearmin**  
Yearly minimum  
For every adjacent sequence \( t_1, \ldots, t_n \) of timesteps of the same year it is:  
\[
o(t, x) = \min\{i(t', x), t_1 < t' \leq t_n\}
\]

**yearmax**  
Yearly maximum  
For every adjacent sequence \( t_1, \ldots, t_n \) of timesteps of the same year it is:  
\[
o(t, x) = \max\{i(t', x), t_1 < t' \leq t_n\}
\]

**yearrange**  
Yearly range  
For every adjacent sequence \( t_1, \ldots, t_n \) of timesteps of the same year it is:  
\[
o(t, x) = \text{range}\{i(t', x), t_1 < t' \leq t_n\}
\]

**yearsum**  
Yearly sum  
For every adjacent sequence \( t_1, \ldots, t_n \) of timesteps of the same year it is:  
\[
o(t, x) = \text{sum}\{i(t', x), t_1 < t' \leq t_n\}
\]

**yearmean**  
Yearly mean  
For every adjacent sequence \( t_1, \ldots, t_n \) of timesteps of the same year it is:  
\[
o(t, x) = \text{mean}\{i(t', x), t_1 < t' \leq t_n\}
\]

**yearavg**  
Yearly average  
For every adjacent sequence \( t_1, \ldots, t_n \) of timesteps of the same year it is:  
\[
o(t, x) = \text{avg}\{i(t', x), t_1 < t' \leq t_n\}
\]

**yearstd**  
Yearly standard deviation  
Normalize by \( n \). For every adjacent sequence \( t_1, \ldots, t_n \) of timesteps of the same year it is:  
\[
o(t, x) = \text{std}\{i(t', x), t_1 < t' \leq t_n\}
\]

**yearstd1**  
Yearly standard deviation \((n-1)\)  
Normalize by \((n-1)\). For every adjacent sequence \( t_1, \ldots, t_n \) of timesteps of the same year it is:  
\[
o(t, x) = \text{std1}\{i(t', x), t_1 < t' \leq t_n\}
\]

**yearvar**  
Yearly variance  
Normalize by \( n \). For every adjacent sequence \( t_1, \ldots, t_n \) of timesteps of the same year it is:  
\[
o(t, x) = \text{var}\{i(t', x), t_1 < t' \leq t_n\}
\]

**yearvar1**  
Yearly variance \((n-1)\)  
Normalize by \((n-1)\). For every adjacent sequence \( t_1, \ldots, t_n \) of timesteps of the same year it is:  
\[
o(t, x) = \text{var1}\{i(t', x), t_1 < t' \leq t_n\}
\]

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
```

2.8.26. 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`.

For every adjacent sequence \( t_1, \ldots, t_n \) of timesteps of the same year it is:

\[
o(t, x) = pth \text{ percentile}\{i(t', x), t_1 < t' \leq t_n\}
\]

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
```
2.8.27. SEASSTAT - Seasonal statistical values

Synopsis

<operator> infile outfile

Description

This module computes statistical values over timesteps of the same 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. 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:
\[
o(t, x) = \min \{ i(t', x), t_1 < t' \leq t_n \}
\]

seasmax  Seasonal maximum
For every adjacent sequence \( t_1, ..., t_n \) of timesteps of the same season it is:
\[
o(t, x) = \max \{ i(t', x), t_1 < t' \leq t_n \}
\]

seasrange  Seasonal range
For every adjacent sequence \( t_1, ..., t_n \) of timesteps of the same season it is:
\[
o(t, x) = \text{range} \{ i(t', x), t_1 < t' \leq t_n \}
\]

seassum  Seasonal sum
For every adjacent sequence \( t_1, ..., t_n \) of timesteps of the same season it is:
\[
o(t, x) = \text{sum} \{ i(t', x), t_1 < t' \leq t_n \}
\]

seasmean  Seasonal mean
For every adjacent sequence \( t_1, ..., t_n \) of timesteps of the same season it is:
\[
o(t, x) = \text{mean} \{ i(t', x), t_1 < t' \leq t_n \}
\]

seasavg  Seasonal average
For every adjacent sequence \( t_1, ..., t_n \) of timesteps of the same season it is:
\[
o(t, x) = \text{avg} \{ i(t', x), t_1 < t' \leq t_n \}
\]

seasstd  Seasonal standard deviation
Normalize by \( n \). For every adjacent sequence \( t_1, ..., t_n \) of timesteps of the same season it is:
\[
o(t, x) = \text{std} \{ i(t', x), t_1 < t' \leq t_n \}
\]

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:
\[
o(t, x) = \text{std1} \{ i(t', x), t_1 < t' \leq t_n \}
\]

seasvar  Seasonal variance
Normalize by \( n \). For every adjacent sequence \( t_1, ..., t_n \) of timesteps of the same season it is:
\[
o(t, x) = \text{var} \{ i(t', x), t_1 < t' \leq t_n \}
\]

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:
\[
o(t, x) = \text{var1} \{ i(t', x), t_1 < t' \leq t_n \}
\]
Example

To compute the seasonal mean of a time series use:

\[
\text{cdo seasmean infile outfile}
\]

2.8.28. SEASPCTL - Seasonal percentile values

Synopsis

\[
\text{seaspctl},p\text{ infile1 infile2 infile3 outfile}
\]

Description

This operator computes percentiles over all timesteps in \texttt{infile1} of the same season. The algorithm uses histograms with minimum and maximum bounds given in \texttt{infile2} and \texttt{infile3}, respectively. The default number of histogram bins is 101. The default can be overridden by defining the environment variable \texttt{CDO\_PCTL\_NBINS}. The files \texttt{infile2} and \texttt{infile3} should be the result of corresponding \texttt{seasmin} and \texttt{seasmax} operations, respectively. The time of \texttt{outfile} is determined by the time in the middle of all contributing timesteps of \texttt{infile1}. 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:

\[
o(t, x) = p\text{th percentile}\{i(t', x), t_1 < t' \leq t_n\}
\]

Parameter

\[p\text{ FLOAT}\]
Percentile number in 0, ..., 100

Environment

\texttt{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:

\[
\text{cdo seasmin infile minfile} \\
\text{cdo seasmax infile maxfile} \\
\text{cdo seaspctl,90 infile minfile maxfile outfile}
\]

Or shorter using operator piping:

\[
\text{cdo seaspctl,90 infile -seasmin infile -seasmax infile outfile}
\]
2.8.29. YHOURSTAT - Multi-year hourly statistical values

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

<table>
<thead>
<tr>
<th>Operator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>yhourmin</td>
<td>Multi-year hourly minimum</td>
</tr>
<tr>
<td></td>
<td>( o(0001, x) = \min {i(t, x), day(i(t)) = 0001} )</td>
</tr>
<tr>
<td></td>
<td>\vdots</td>
</tr>
<tr>
<td></td>
<td>( o(8784, x) = \min {i(t, x), day(i(t)) = 8784} )</td>
</tr>
<tr>
<td>yhourmax</td>
<td>Multi-year hourly maximum</td>
</tr>
<tr>
<td></td>
<td>( o(0001, x) = \max {i(t, x), day(i(t)) = 0001} )</td>
</tr>
<tr>
<td></td>
<td>\vdots</td>
</tr>
<tr>
<td></td>
<td>( o(8784, x) = \max {i(t, x), day(i(t)) = 8784} )</td>
</tr>
<tr>
<td>yhourrange</td>
<td>Multi-year hourly range</td>
</tr>
<tr>
<td></td>
<td>( o(0001, x) = \text{range} {i(t, x), day(i(t)) = 0001} )</td>
</tr>
<tr>
<td></td>
<td>\vdots</td>
</tr>
<tr>
<td></td>
<td>( o(8784, x) = \text{range} {i(t, x), day(i(t)) = 8784} )</td>
</tr>
<tr>
<td>yhoursum</td>
<td>Multi-year hourly sum</td>
</tr>
<tr>
<td></td>
<td>( o(0001, x) = \text{sum} {i(t, x), day(i(t)) = 0001} )</td>
</tr>
<tr>
<td></td>
<td>\vdots</td>
</tr>
<tr>
<td></td>
<td>( o(8784, x) = \text{sum} {i(t, x), day(i(t)) = 8784} )</td>
</tr>
<tr>
<td>yhourmean</td>
<td>Multi-year hourly mean</td>
</tr>
<tr>
<td></td>
<td>( o(0001, x) = \text{mean} {i(t, x), day(i(t)) = 0001} )</td>
</tr>
<tr>
<td></td>
<td>\vdots</td>
</tr>
<tr>
<td></td>
<td>( o(8784, x) = \text{mean} {i(t, x), day(i(t)) = 8784} )</td>
</tr>
<tr>
<td>yhouravg</td>
<td>Multi-year hourly average</td>
</tr>
<tr>
<td></td>
<td>( o(0001, x) = \text{avg} {i(t, x), day(i(t)) = 0001} )</td>
</tr>
<tr>
<td></td>
<td>\vdots</td>
</tr>
<tr>
<td></td>
<td>( o(8784, x) = \text{avg} {i(t, x), day(i(t)) = 8784} )</td>
</tr>
<tr>
<td>yhourstd</td>
<td>Multi-year hourly standard deviation</td>
</tr>
<tr>
<td></td>
<td>Normalize by ( n ).</td>
</tr>
<tr>
<td></td>
<td>( o(0001, x) = \text{std} {i(t, x), day(i(t)) = 0001} )</td>
</tr>
<tr>
<td></td>
<td>\vdots</td>
</tr>
<tr>
<td></td>
<td>( o(8784, x) = \text{std} {i(t, x), day(i(t)) = 8784} )</td>
</tr>
<tr>
<td>yhourstd1</td>
<td>Multi-year hourly standard deviation (n-1)</td>
</tr>
<tr>
<td></td>
<td>Normalize by (n-1).</td>
</tr>
</tbody>
</table>
\[ o(0001, x) = \text{std1}\{i(t, x), \text{day}(i(t)) = 0001\} \]
\[ \vdots \]
\[ o(8784, x) = \text{std1}\{i(t, x), \text{day}(i(t)) = 8784\} \]

**yhourvar**
Multi-year hourly variance
Normalize by n.
\[ o(0001, x) = \text{var}\{i(t, x), \text{day}(i(t)) = 0001\} \]
\[ \vdots \]
\[ o(8784, x) = \text{var}\{i(t, x), \text{day}(i(t)) = 8784\} \]

**yhourvar1**
Multi-year hourly variance (n-1)
Normalize by (n-1).
\[ o(0001, x) = \text{var1}\{i(t, x), \text{day}(i(t)) = 0001\} \]
\[ \vdots \]
\[ o(8784, x) = \text{var1}\{i(t, x), \text{day}(i(t)) = 8784\} \]
2.8.30. YDAYSTAT - Multi-year daily statistical values

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

<table>
<thead>
<tr>
<th>Operator</th>
<th>Description</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>ydaymin</td>
<td>Multi-year daily minimum</td>
<td>( o(001, x) = \min{i(t, x), \text{day}(i(t)) = 001} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( o(366, x) = \min{i(t, x), \text{day}(i(t)) = 366} )</td>
</tr>
<tr>
<td>ydaymax</td>
<td>Multi-year daily maximum</td>
<td>( o(001, x) = \max{i(t, x), \text{day}(i(t)) = 001} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( o(366, x) = \max{i(t, x), \text{day}(i(t)) = 366} )</td>
</tr>
<tr>
<td>ydayrange</td>
<td>Multi-year daily range</td>
<td>( o(001, x) = \text{range}{i(t, x), \text{day}(i(t)) = 001} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( o(366, x) = \text{range}{i(t, x), \text{day}(i(t)) = 366} )</td>
</tr>
<tr>
<td>ydaysum</td>
<td>Multi-year daily sum</td>
<td>( o(001, x) = \text{sum}{i(t, x), \text{day}(i(t)) = 001} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( o(366, x) = \text{sum}{i(t, x), \text{day}(i(t)) = 366} )</td>
</tr>
<tr>
<td>ydaymean</td>
<td>Multi-year daily mean</td>
<td>( o(001, x) = \text{mean}{i(t, x), \text{day}(i(t)) = 001} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( o(366, x) = \text{mean}{i(t, x), \text{day}(i(t)) = 366} )</td>
</tr>
<tr>
<td>ydayavg</td>
<td>Multi-year daily average</td>
<td>( o(001, x) = \text{avg}{i(t, x), \text{day}(i(t)) = 001} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( o(366, x) = \text{avg}{i(t, x), \text{day}(i(t)) = 366} )</td>
</tr>
<tr>
<td>ydaystd</td>
<td>Multi-year daily standard deviation</td>
<td>Normalize by n.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( o(001, x) = \text{std}{i(t, x), \text{day}(i(t)) = 001} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( o(366, x) = \text{std}{i(t, x), \text{day}(i(t)) = 366} )</td>
</tr>
<tr>
<td>ydaystd1</td>
<td>Multi-year daily standard deviation (n-1)</td>
<td>Normalize by (n-1).</td>
</tr>
</tbody>
</table>
\[o(001, x) = \text{std1}\{i(t, x), \text{day}(i(t))\} = 001\]
\[\vdots\]
\[o(366, x) = \text{std1}\{i(t, x), \text{day}(i(t))\} = 366\]

**ydayvar**  
Multi-year daily variance  
Normalize by n.
\[o(001, x) = \text{var}\{i(t, x), \text{day}(i(t))\} = 001\]
\[\vdots\]
\[o(366, x) = \text{var}\{i(t, x), \text{day}(i(t))\} = 366\]

**ydayvar1**  
Multi-year daily variance (n-1)  
Normalize by (n-1).
\[o(001, x) = \text{var1}\{i(t, x), \text{day}(i(t))\} = 001\]
\[\vdots\]
\[o(366, x) = \text{var1}\{i(t, x), \text{day}(i(t))\} = 366\]

**Example**

To compute the daily mean over all input years use:

```
cdo ydaymean infile outfile
```
2.8.31. **YDAYPCTL - Multi-year daily percentile values**

**Synopsis**

```plaintext
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.

\[ o(001, x) = \text{pth percentile}\{i(t, x), \text{day}(i(t)) = 001\} \]

\[ \vdots \]

\[ o(366, x) = \text{pth percentile}\{i(t, x), \text{day}(i(t)) = 366\} \]

**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:

```plaintext
  cdo ydaymin infile minfile
  cdo ydaymax infile maxfile
  cdo ydaypctl,90 infile minfile maxfile outfile
```

Or shorter using operator piping:

```plaintext
  cdo ydaypctl,90 infile -ydaymin infile -ydaymax infile outfile
```
2.8.32. YMONSTAT - Multi-year monthly statistical values

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.

Operators

ymonmin Multi-year monthly minimum
\[ o(01, x) = \min\{i(t, x), \text{month}(i(t)) = 01\} \]
\[ \vdots \]
\[ o(12, x) = \min\{i(t, x), \text{month}(i(t)) = 12\} \]

ymonmax Multi-year monthly maximum
\[ o(01, x) = \max\{i(t, x), \text{month}(i(t)) = 01\} \]
\[ \vdots \]
\[ o(12, x) = \max\{i(t, x), \text{month}(i(t)) = 12\} \]

ymonrange Multi-year monthly range
\[ o(01, x) = \text{range}\{i(t, x), \text{month}(i(t)) = 01\} \]
\[ \vdots \]
\[ o(12, x) = \text{range}\{i(t, x), \text{month}(i(t)) = 12\} \]

ymonsum Multi-year monthly sum
\[ o(01, x) = \sum\{i(t, x), \text{month}(i(t)) = 01\} \]
\[ \vdots \]
\[ o(12, x) = \sum\{i(t, x), \text{month}(i(t)) = 12\} \]

ymonmean Multi-year monthly mean
\[ o(01, x) = \text{mean}\{i(t, x), \text{month}(i(t)) = 01\} \]
\[ \vdots \]
\[ o(12, x) = \text{mean}\{i(t, x), \text{month}(i(t)) = 12\} \]

ymonavg Multi-year monthly average
\[ o(01, x) = \text{avg}\{i(t, x), \text{month}(i(t)) = 01\} \]
\[ \vdots \]
\[ o(12, x) = \text{avg}\{i(t, x), \text{month}(i(t)) = 12\} \]

ymonstd Multi-year monthly standard deviation
Normalize by n.
\[ o(01, x) = \text{std}\{i(t, x), \text{month}(i(t)) = 01\} \]
\[ \vdots \]
\[ o(12, x) = \text{std}\{i(t, x), \text{month}(i(t)) = 12\} \]

ymonstd1 Multi-year monthly standard deviation (n-1)
Normalize by (n-1).
\[ o(01, x) = \text{std1}\{i(t, x), \text{month}(i(t)) = 01\} \]
\[ \vdots \]
\[ o(12, x) = \text{std1}\{i(t, x), \text{month}(i(t)) = 12\} \]

**ymonvar**  
Multi-year monthly variance  
Normalize by \( n \).
\[ o(01, x) = \text{var}\{i(t, x), \text{month}(i(t)) = 01\} \]
\[ \vdots \]
\[ o(12, x) = \text{var}\{i(t, x), \text{month}(i(t)) = 12\} \]

**ymonvar1**  
Multi-year monthly variance (n-1)  
Normalize by (n-1).
\[ o(01, x) = \text{var1}\{i(t, x), \text{month}(i(t)) = 01\} \]
\[ \vdots \]
\[ o(12, x) = \text{var1}\{i(t, x), \text{month}(i(t)) = 12\} \]

**Example**

To compute the monthly mean over all input years use:

```
cdo ymonmean infile outfile
```
2.8.33. 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.

\[ o(01,x) = \text{pth percentile}\{i(t,x),\text{month}(i(t)) = 01}\]  
\[ o(12,x) = \text{pth percentile}\{i(t,x),\text{month}(i(t)) = 12}\]

Parameter

\( p \quad \text{FLOAT} \quad \text{Percentile number in } 0, ..., 100 \)

Environment

CDO_PCTL_NBINS \quad \text{Sets the number of histogram bins. The default number is 101.}

Example

To compute the monthly 90th percentile over all input years use:

\[
\begin{align*}
cdo & \text{ ymonmin infile minfile} \\
cdo & \text{ ymonmax infile maxfile} \\
cdo & \text{ ymonpctl,90 infile minfile maxfile outfile}
\end{align*}
\]

Or shorter using operator piping:

\[
\begin{align*}
cdo & \text{ ymonpctl,90 infile -ymonmin infile -ymonmax infile outfile}
\end{align*}
\]
2.8.34. **YSEASSTAT - Multi-year seasonal statistical values**

**Synopsis**

\[ <\text{operator}> \text{infi} \text{outfile} \]

**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 `infi` is written to `outfile`. The date information in an output field is the date of the last contributing input field.

**Operators**

<table>
<thead>
<tr>
<th>Operator</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>yseasmin</td>
<td>Multi-year seasonal minimum</td>
<td><code>o(1, x) = \text{min}\{i(t, x), \text{month}(i(t))\} = 12, 01, 02</code></td>
</tr>
<tr>
<td>yseasmax</td>
<td>Multi-year seasonal maximum</td>
<td><code>o(1, x) = \text{max}\{i(t, x), \text{month}(i(t))\} = 12, 01, 02</code></td>
</tr>
<tr>
<td>yseasrange</td>
<td>Multi-year seasonal range</td>
<td><code>o(1, x) = \text{range}\{i(t, x), \text{month}(i(t))\} = 12, 01, 02</code></td>
</tr>
<tr>
<td>yseasmean</td>
<td>Multi-year seasonal mean</td>
<td><code>o(1, x) = \text{mean}\{i(t, x), \text{month}(i(t))\} = 12, 01, 02</code></td>
</tr>
<tr>
<td>yseasavg</td>
<td>Multi-year seasonal average</td>
<td><code>o(1, x) = \text{avg}\{i(t, x), \text{month}(i(t))\} = 12, 01, 02</code></td>
</tr>
<tr>
<td>yseasstd</td>
<td>Multi-year seasonal standard deviation</td>
<td><code>o(1, x) = \text{std}\{i(t, x), \text{month}(i(t))\} = 12, 01, 02</code></td>
</tr>
</tbody>
</table>
yseas\textsubscript{std1} Multi-year seasonal standard deviation (n-1)
\begin{align*}
o(1, x) &= \text{std1}\{i(t, x), \text{month}(i(t)) = 12, 01, 02\} \\
o(2, x) &= \text{std1}\{i(t, x), \text{month}(i(t)) = 03, 04, 05\} \\
o(3, x) &= \text{std1}\{i(t, x), \text{month}(i(t)) = 06, 07, 08\} \\
o(4, x) &= \text{std1}\{i(t, x), \text{month}(i(t)) = 09, 10, 11\}
\end{align*}

yseas\textsubscript{var} Multi-year seasonal variance
\begin{align*}
o(1, x) &= \text{var}\{i(t, x), \text{month}(i(t)) = 12, 01, 02\} \\
o(2, x) &= \text{var}\{i(t, x), \text{month}(i(t)) = 03, 04, 05\} \\
o(3, x) &= \text{var}\{i(t, x), \text{month}(i(t)) = 06, 07, 08\} \\
o(4, x) &= \text{var}\{i(t, x), \text{month}(i(t)) = 09, 10, 11\}
\end{align*}

yseas\textsubscript{var1} Multi-year seasonal variance (n-1)
\begin{align*}
o(1, x) &= \text{var1}\{i(t, x), \text{month}(i(t)) = 12, 01, 02\} \\
o(2, x) &= \text{var1}\{i(t, x), \text{month}(i(t)) = 03, 04, 05\} \\
o(3, x) &= \text{var1}\{i(t, x), \text{month}(i(t)) = 06, 07, 08\} \\
o(4, x) &= \text{var1}\{i(t, x), \text{month}(i(t)) = 09, 10, 11\}
\end{align*}

Example

To compute the seasonal mean over all input years use:

\begin{verbatim}
cdo yseasmean infile outfile
\end{verbatim}
2.8.35. **YSEASPCTL - Multi-year seasonal percentile values**

**Synopsis**

\texttt{yseaspctl, p infile1 infile2 infile3 outfile}

**Description**

This operator writes a certain percentile of each season in \texttt{infile1} to \texttt{outfile}. The algorithm uses histograms with minimum and maximum bounds given in \texttt{infile2} and \texttt{infile3}, respectively. The default number of histogram bins is 101. The default can be overridden by setting the environment variable \texttt{CDO\_PCTL\_NBINS} to a different value. The files \texttt{infile2} and \texttt{infile3} should be the result of corresponding \texttt{yseasmin} and \texttt{yseasmax} operations, respectively. The date information in an output field is the date of the last contributing input field.

\begin{align*}
o(1, x) &= \text{pth percentile}\{i(t, x), \text{month}(i(t)) = 12, 01, 02\} \\
o(2, x) &= \text{pth percentile}\{i(t, x), \text{month}(i(t)) = 03, 04, 05\} \\
o(3, x) &= \text{pth percentile}\{i(t, x), \text{month}(i(t)) = 06, 07, 08\} \\
o(4, x) &= \text{pth percentile}\{i(t, x), \text{month}(i(t)) = 09, 10, 11\}
\end{align*}

**Parameter**

\begin{itemize}
  \item \texttt{p} FLOT \hspace{1cm} Percentile number in 0, ..., 100
\end{itemize}

**Environment**

\begin{itemize}
  \item \texttt{CDO\_PCTL\_NBINS} \hspace{1cm} Sets the number of histogram bins. The default number is 101.
\end{itemize}

**Example**

To compute the seasonal 90th percentile over all input years use:

\begin{verbatim}
cdo yseasmin infile minfile
cdo yseasmax infile maxfile
cdo yseaspctl,90 infile minfile maxfile outfile
\end{verbatim}

Or shorter using operator piping:

\begin{verbatim}
cdo yseaspctl,90 infile -yseasmin infile -yseasmax infile outfile
\end{verbatim}
2.8.36. YDRUNSTAT - Multi-year daily running statistical values

Synopsis

\[ <\text{operator}>.nts\ \text{infile}\ \text{outfile} \]

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

\text{ydrunmin} \quad \text{Multi-year daily running minimum}

\[
a(001, x) = \min\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x); \text{day}[(i(t + (nts - 1)/2)] = 001\}
\]

\[
\vdots
\]

\[
a(366, x) = \min\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x); \text{day}[(i(t + (nts - 1)/2)] = 366\}
\]

\text{ydrunmax} \quad \text{Multi-year daily running maximum}

\[
a(001, x) = \max\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x); \text{day}[(i(t + (nts - 1)/2)] = 001\}
\]

\[
\vdots
\]

\[
a(366, x) = \max\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x); \text{day}[(i(t + (nts - 1)/2)] = 366\}
\]

\text{ydrunsum} \quad \text{Multi-year daily running sum}

\[
a(001, x) = \sum\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x); \text{day}[(i(t + (nts - 1)/2)] = 001\}
\]

\[
\vdots
\]

\[
a(366, x) = \sum\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x); \text{day}[(i(t + (nts - 1)/2)] = 366\}
\]

\text{ydrunmean} \quad \text{Multi-year daily running mean}

\[
a(001, x) = \text{mean}\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x); \text{day}[(i(t + (nts - 1)/2)] = 001\}
\]

\[
\vdots
\]

\[
a(366, x) = \text{mean}\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x); \text{day}[(i(t + (nts - 1)/2)] = 366\}
\]

\text{ydrunavg} \quad \text{Multi-year daily running average}

\[
a(001, x) = \text{avg}\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x); \text{day}[(i(t + (nts - 1)/2)] = 001\}
\]

\[
\vdots
\]

\[
a(366, x) = \text{avg}\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x); \text{day}[(i(t + (nts - 1)/2)] = 366\}
\]

\text{ydrunstd} \quad \text{Multi-year daily running standard deviation}

Normalize by \(n\).

\[
a(001, x) = \text{std}\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x); \text{day}[(i(t + (nts - 1)/2)] = 001\}
\]

\[
\vdots
\]

\[
a(366, x) = \text{std}\{i(t, x), i(t + 1, x), ..., i(t + nts - 1, x); \text{day}[(i(t + (nts - 1)/2)] = 366\}
\]
**ydrunstd1** Multi-year daily running standard deviation (n-1)
Normalized by (n-1).

\[
o(001, x) = \text{std1}\{i(t, x), i(t + 1, x), \ldots, i(t + nts - 1, x); \text{day}[i(t + (nts - 1)/2)] = 001\}
\]

\[
\vdots
\]

\[
o(366, x) = \text{std1}\{i(t, x), i(t + 1, x), \ldots, i(t + nts - 1, x); \text{day}[i(t + (nts - 1)/2)] = 366\}
\]

**ydrunvar** Multi-year daily running variance
Normalized by n.

\[
o(001, x) = \text{var}\{i(t, x), i(t + 1, x), \ldots, i(t + nts - 1, x); \text{day}[i(t + (nts - 1)/2)] = 001\}
\]

\[
\vdots
\]

\[
o(366, x) = \text{var}\{i(t, x), i(t + 1, x), \ldots, i(t + nts - 1, x); \text{day}[i(t + (nts - 1)/2)] = 366\}
\]

**ydrunvar1** Multi-year daily running variance (n-1)
Normalized by (n-1).

\[
o(001, x) = \text{var1}\{i(t, x), i(t + 1, x), \ldots, i(t + nts - 1, x); \text{day}[i(t + (nts - 1)/2)] = 001\}
\]

\[
\vdots
\]

\[
o(366, x) = \text{var1}\{i(t, x), i(t + 1, x), \ldots, i(t + nts - 1, x); \text{day}[i(t + (nts - 1)/2)] = 366\}
\]

### Parameter

nts INTEGER Number of timesteps

### 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
```
2.8.37. YDRUNPCTL - Multi-year daily running percentile values

Synopsis

ydrunpctl p,nts 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.

\[ o(001, x) = \text{p}^{\text{th}} \text{percentile} \{i(t, x), i(t + 1, x), \ldots, i(t + nts - 1, x); \text{day}[i(t + (nts - 1)/2)] = 001\} \]

\[ o(366, x) = \text{p}^{\text{th}} \text{percentile} \{i(t, x), i(t + 1, x), \ldots, i(t + nts - 1, x); \text{day}[i(t + (nts - 1)/2)] = 366\} \]

Parameter

- **p** FLOAT Percentile number in 0, ..., 100
- **nts** INTEGER Number of timesteps

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 section contains modules for correlation and co. in grid space and over time. In this section the abbreviations as in the following table are used:

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariance</td>
<td>[ n^{-1} \sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y}) ]</td>
</tr>
<tr>
<td>covar weighted by {w_i, i = 1, ..., n}</td>
<td>[ \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) ]</td>
</tr>
</tbody>
</table>

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

\[ S(t) = \{ x, i_1(t, x) \neq \text{missval} \land i_2(t, x) \neq \text{missval} \} \]

it is

\[ o(t, 1) = \frac{\sum_{x \in S(t)} i_1(t, x)i_2(t, x)w(x) - \overline{i_1(t, x)}\overline{i_2(t, x)} \sum_{x \in S(t)} w(x)}{\left( \sum_{x \in S(t)} i_1(t, x)^2w(x) - \overline{i_1(t, x)}^2 \sum_{x \in S(t)} w(x) \right) \left( \sum_{x \in S(t)} i_2(t, x)^2w(x) - \overline{i_2(t, x)}^2 \sum_{x \in S(t)} w(x) \right)} \]

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 \( i_1(t, x) \neq \text{missval} \) and \( i_2(t, x) \neq \text{missval} \).

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. With

\[ S(x) = \{ t, i_1(t, x) \neq \text{missval} \land i_2(t, x) \neq \text{missval} \} \]

it is

\[ o(1, x) = \frac{\sum_{t \in S(x)} i_1(t, x)i_2(t, x) - n \overline{i_1(t, x)}\overline{i_2(t, x)}}{\left( \sum_{t \in S(x)} i_1(t, x)^2 - n \overline{i_1(t, x)}^2 \right) \left( \sum_{t \in S(x)} i_2(t, x)^2 - n \overline{i_2(t, x)}^2 \right)} \]

For every gridpoint \( x \) only those timesteps \( t \) belong to the sample, which have \( i_1(t, x) \neq \text{missval} \) and \( i_2(t, x) \neq \text{missval} \).
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

\[ S(t) = \{ x, i_1(t, x) \neq missval \land i_2(t, x) \neq missval \} \]

it is

\[
o(t, 1) = \left( \sum_{x \in S(t)} w(x) \right)^{-1} \sum_{x \in S(t)} w(x) \left( i_1(t, x) - \frac{\sum_{x \in S(t)} w(x) i_1(t, x)}{\sum_{x \in S(t)} w(x)} \right) \left( i_2(t, x) - \frac{\sum_{x \in S(t)} w(x) i_2(t, x)}{\sum_{x \in S(t)} w(x)} \right)
\]

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

\[ S(x) = \{ t, i_1(t, x) \neq missval \land i_2(t, x) \neq missval \} \]

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 section contains modules for linear regression of time series.

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

<table>
<thead>
<tr>
<th>Operator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>regres</td>
<td>Regression</td>
</tr>
<tr>
<td>detrend</td>
<td>Detrend</td>
</tr>
<tr>
<td>trend</td>
<td>Trend</td>
</tr>
<tr>
<td>subtrend</td>
<td>Subtract trend</td>
</tr>
</tbody>
</table>
2.10.1. REGRES - Regression

Synopsis

regres infile outfile

Description

The values of the input file \texttt{infile} are assumed to be distributed as \( N(a + bt, \sigma^2) \) with unknown \( a, b \) and \( \sigma^2 \). This operator estimates the parameter \( b \). For every field element \( x \) only those timesteps \( t \) belong to the sample \( S(x) \), which have \( i(t, x) \neq \text{miss} \). It is

\[
o(1, x) = \frac{\sum_{t \in S(x)} \left( i(t, x) - \frac{1}{\#S(x)} \sum_{t' \in S(x)} i(t', x) \right) \left( t - \frac{1}{\#S(x)} \sum_{t' \in S(x)} t' \right)}{\sum_{t \in S(x)} \left( t - \frac{1}{\#S(x)} \sum_{t' \in S(x)} t' \right)^2}
\]

2.10.2. DETREND - Detrend time series

Synopsis

detrend infile outfile

Description

Every time series in \texttt{infile} is linearly detrended. For every field element \( x \) only those timesteps \( t \) belong to the sample \( S(x) \), which have \( i(t, x) \neq \text{miss} \). 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

\[
b(x) = \frac{\sum_{t \in S(x)} \left( i(t, x) - \frac{1}{\#S(x)} \sum_{t' \in S(x)} i(t', x) \right) \left( t - \frac{1}{\#S(x)} \sum_{t' \in S(x)} t' \right)}{\sum_{t \in S(x)} \left( t - \frac{1}{\#S(x)} \sum_{t' \in S(x)} t' \right)^2}
\]

it is

\[
o(t, x) = i(t, x) - (a(x) + b(x)t)
\]

Note

This operator has to keep the fields of all timesteps concurrently in the memory. If not enough memory is available use the operators \texttt{trend} and \texttt{subtrend}.

Example

To detrend the data in \texttt{infile} and to store the detrended data in \texttt{outfile} use:

\[
\texttt{cdo detrend infile outfile}
\]
2.10.3. TREND - Trend of time series

Synopsis

\texttt{trend infile outfile1 outfile2}

Description

The values of the input file \texttt{infile} are assumed to be distributed as $N(a + bt, \sigma^2)$ with unknown $a$, $b$ and $\sigma^2$. 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 $i(t, x) \neq \text{miss}$. 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 \texttt{outfile1} and that for $b$ is stored in \texttt{outfile2}. To subtract the trend from the data see operator \texttt{subtrend}.

2.10.4. SUBTREND - Subtract a trend

Synopsis

\texttt{subtrend infile1 infile2 infile3 outfile}

Description

This operator is for subtracting a trend computed by the operator \texttt{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.

Example

The typical call for detrending the data in \texttt{infile} and storing the detrended data in \texttt{outfile} is:

\begin{verbatim}
cdo trend infile afile bfile
cdo subtrend infile afile bfile outfile
\end{verbatim}

The result is identical to a call of the operator \texttt{detrend}:

\begin{verbatim}
cdo detrend infile outfile
\end{verbatim}
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 [Peisendorfer]

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 $S$ can be written as

$$S = \sum_{t=1}^{n} \left[\sqrt{W}z(t)\right] \left[\sqrt{W}z(t)\right]^T$$

where $W$ is the diagonal matrix containing the area weight of cell $p_0$ in $z$ at $W(x, x)$. The matrix $S$ has a set of orthonormal eigenvectors $e_j, j = 1, \ldots, p$, which are called empirical orthogonal functions (EOFs) of the sample $z$.

(EOFs) of the sample $z$. (Please note, that $e_j$ is the eigenvector of $S$ and not the weighted eigenvector which would be $We_j$.) Let the corresponding eigenvalues be denoted $\lambda_j$. 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 $\lambda_j$. 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

$$\sum_{x=1}^{p} \left[\sqrt{W(x, x)}e_j(x)\right] \left[\sqrt{W(x, x)}e_k(x)\right] = \sum_{x=1}^{p} W(x, x)e_j(x)e_k(x) = \begin{cases} 0 & \text{if } j \neq k \\ 1 & \text{if } j = k \end{cases}$$

If all EOFs $e_j$ with $\lambda_j \neq 0$ are calculated, the data can be reconstructed from

$$z(t, x) = \sum_{j=1}^{p} W(x, x)a_j(t)e_j(x)$$

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

$$a_j(t_0) = \sum_{x=1}^{p} \left[\sqrt{W(x, x)}e_j(x)\right] \left[\sqrt{W(x, x)}z(t_0, x)\right] = \left[\sqrt{Wz(t_0)}\right]^T \left[\sqrt{We}_j\right].$$

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
- `coefcoef` 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 grid-space 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 contain 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 separate file $o_.j$ for the principal coefficients of each EOF.

As the EOFs $e_.j$ are uncorrelated, so are their principal coefficients, i.e.

$$\sum_{t=1}^{n} o_j(t)o_k(t) = \begin{cases} 0 & \text{if } j \neq k \\ \lambda_j & \text{if } j = k \end{cases} \text{ with } \sum_{t=1}^{n} o_j(t) = 0 \forall j \in \{1, \ldots, p\}.$$

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:

```bash
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 contain anomalies, process them first, and use:

```bash
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
- **remapcon2**: Second order conservative remapping
- **gencon2**: Generate 2nd 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
- **ap2hl**: Air pressure 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

<operator>,grid 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.

Parameter

- **grid** STRING Target grid description file or name

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

\[ \text{<operator>}, \text{grid} \text{ infile outfile} \]

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.

Parameter

- **grid**  
  STRING  
  Target grid description file or name

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

<operator>.grid 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.

Parameter

- grid STRING Target grid description file or name

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

\texttt{remapdis,grid[,neighbors]} \ infile \ outfile
\texttt{gendis,grid} \ infile \ outfile

Description

This module contains operators for a distance-weighted average remapping of the four nearest neighbor values 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 \cite{SCRIP}. 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

\texttt{remapdis} \hspace{1em} Distance-weighted average remapping
Performs a distance-weighted average remapping of the nearest neighbors value on all input fields. The default number of nearest neighbors is 4.

\texttt{gendis} \hspace{1em} Generate distance-weighted average remap weights
Generates distance-weighted average remapping weights of the four 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 \texttt{remap} to apply this remapping weights to a data file with the same source grid.

Parameter

\begin{itemize}
  \item \texttt{grid} \hspace{1em} STRING \hspace{1em} Target grid description file or name
  \item \texttt{neighbors} \hspace{1em} INTEGER \hspace{1em} Number of nearest neighbors
\end{itemize}

Environment

\begin{itemize}
  \item \texttt{REMAP_EXTRAPOLATE} \hspace{1em} This variable is used to switch the extrapolation feature \textquote{on} or \textquote{off}. By default the extrapolation is enabled for this remapping method.
  \item \texttt{CDO_GRIDSEARCH_RADIUS} \hspace{1em} Grid search radius in degree, default 180 degree.
\end{itemize}
2.12.5. REMAPCON - First order conservative remapping

Synopsis

<operator>,grid 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 use 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.

Parameter

grid STRING Target grid description or name

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. REMAPCON2 - Second order conservative remapping

Synopsis

\[ \texttt{<operator>.grid infile outfile} \]

Description

This module contains operators for a second order conservative 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]. 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 2nd 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

- **remapcon2** Second order conservative remapping
  Performs a second order conservative remapping on all input fields.
- **gencon2** Generate 2nd order conservative remap weights
  Generates second 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.

Parameter

- **grid** STRING Target grid description file or name

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.

**Note**

The SCRIP conservative remapping method doesn’t work correctly for some grid combinations.

**Example**

Say `infile` contains fields on a quadrilateral curvilinear grid. To remap all fields conservative (2nd order) to a Gaussian N32 grid, type:

```
cdo remapcon2,n32 infile outfile
```
2.12.7. 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:

![Schematic illustration of the largest area fraction remapping](image)

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.
2.12.8. 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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>grid</td>
<td>STRING</td>
<td>Target grid description file or name</td>
</tr>
<tr>
<td>weights</td>
<td>STRING</td>
<td>Interpolation weights (SCRIP NetCDF file)</td>
</tr>
</tbody>
</table>

Environment

<table>
<thead>
<tr>
<th>Environment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDO_REMAP_NORM</td>
<td>This variable is used to choose the normalization of the conservative interpolation. By default <code>CDO_REMAP_NORM</code> 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.</td>
</tr>
<tr>
<td>REMAP_EXTRAPOLATE</td>
<td>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.</td>
</tr>
<tr>
<td>REMAP_AREA_MIN</td>
<td>This variable is used to set the minimum destination area fraction. The default of this variable is 0.0.</td>
</tr>
<tr>
<td>CDO_GRIDSEARCH_RADIUS</td>
<td>Grid search radius in degree, default 180 degree.</td>
</tr>
</tbody>
</table>

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
```
2.12.9. REMAPETA - Remap vertical hybrid level

Synopsis

\texttt{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 troposphere. 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

\begin{itemize}
  \item \texttt{vct} STRING File name of an ASCII dataset with the vertical coordinate table
  \item \texttt{oro} STRING File name with the orography (surf. geopotential) of the target dataset (optional)
\end{itemize}

Environment

\texttt{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 \texttt{sinfo} command to test if your vertical coordinate system is recognized as hybrid system.

In case \texttt{remapeta} complains about not finding any data on hybrid model levels you may wish to use the \texttt{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:

<table>
<thead>
<tr>
<th>0</th>
<th>0.00000000000000000000000000000000</th>
<th>0.00000000000000000000000000000000</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2000.00000000000000000000000000</td>
<td>0.00000000000000000000000000000000</td>
</tr>
<tr>
<td>2</td>
<td>4000.00000000000000000000000000</td>
<td>0.00000000000000000000000000000000</td>
</tr>
<tr>
<td>3</td>
<td>6046.109375000000000000000000</td>
<td>0.00033899326808751</td>
</tr>
<tr>
<td>4</td>
<td>8267.929687500000000000000000</td>
<td>0.0035718691349030</td>
</tr>
<tr>
<td>5</td>
<td>10609.511718750000000000000000</td>
<td>0.0130700394511228</td>
</tr>
<tr>
<td>6</td>
<td>12851.101562500000000000000000</td>
<td>0.0340771488845348</td>
</tr>
<tr>
<td>7</td>
<td>14698.500000000000000000000000</td>
<td>0.0706498026847839</td>
</tr>
<tr>
<td>8</td>
<td>15861.128906250000000000000000</td>
<td>0.1259167194366455</td>
</tr>
<tr>
<td>9</td>
<td>16116.238812500000000000000000</td>
<td>0.2011954188346862</td>
</tr>
<tr>
<td>10</td>
<td>15356.921875000000000000000000</td>
<td>0.2955195937780762</td>
</tr>
<tr>
<td>11</td>
<td>13621.460937500000000000000000</td>
<td>0.4054092168807983</td>
</tr>
<tr>
<td>12</td>
<td>11101.558593750000000000000000</td>
<td>0.5249322056770324</td>
</tr>
<tr>
<td>13</td>
<td>8127.144531250000000000000000</td>
<td>0.6461079120635986</td>
</tr>
<tr>
<td>14</td>
<td>5125.140625000000000000000000</td>
<td>0.7596983909606933</td>
</tr>
<tr>
<td>15</td>
<td>2549.968994140625000000000000</td>
<td>0.8564376235008239</td>
</tr>
<tr>
<td>16</td>
<td>783.195068359375000000000000</td>
<td>0.9287468791007995</td>
</tr>
<tr>
<td>17</td>
<td>0.00000000000000000000000000000000</td>
<td>0.9729852080345153</td>
</tr>
<tr>
<td>18</td>
<td>0.00000000000000000000000000000000</td>
<td>0.9922814965248107</td>
</tr>
<tr>
<td>19</td>
<td>0.00000000000000000000000000000000</td>
<td>1.0000000000000000</td>
</tr>
</tbody>
</table>
2.12.10. VERTINTML - Vertical interpolation

Synopsis

\texttt{ml2pl,plevel} infile outfile
\texttt{ml2hl,hlevels} infile outfile

Description

Interpolate 3D variables on hybrid sigma pressure level to pressure or height levels. The input file should contain the log. surface pressure or the surface pressure. To extrapolate the temperature, the surface geopotential is also needed. The pressure, temperature, and surface geopotential 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. Use the alias \texttt{ml2plx/ml2hlx} or the environment variable \texttt{EXTRAPOLATE} to extrapolate missing values. This operator requires all variables on the same horizontal grid.

Operators

\texttt{ml2pl} Model to pressure level interpolation
Interpolates 3D variables on hybrid sigma pressure level to pressure level.

\texttt{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 \texttt{ml2pl} except for the pressure levels being calculated from the heights by: \texttt{plevel = 101325 \ast exp(hlevel/ - 7000)}

Parameter

<table>
<thead>
<tr>
<th>plevels</th>
<th>FLOAT</th>
<th>Pressure levels in pascal</th>
</tr>
</thead>
<tbody>
<tr>
<td>hlevels</td>
<td>FLOAT</td>
<td>Height levels in meter (max level: 65535 m)</td>
</tr>
</tbody>
</table>

Environment

\texttt{EXTRAPOLATE} If set to 1 extrapolate missing values.

Example

To interpolate hybrid model level data to pressure levels of 925, 850, 500 and 200 hPa use:

\texttt{cdo ml2pl,92500,85000,50000,20000 infile outfile}

2.12.11. VERTINTAP - Vertical interpolation

Synopsis

\texttt{ap2pl,plevels} infile outfile
\texttt{ap2hl,hlevels} infile outfile
Description

Interpolate 3D variables on hybrid sigma height coordinates to pressure or height levels. The input file must contain the 3D air pressure. The air pressure is identified by the NetCDF CF standard name air_pressure. Use the alias ap2plx/ap2hlx or the environment variable EXTRAPOLATE to extrapolate missing values. This operator requires all variables on the same horizontal grid.

Operators

- **ap2pl**  Air pressure to pressure level interpolation
  Interpolates 3D variables on hybrid sigma height coordinates to pressure level.

- **ap2hl**  Air pressure to height level interpolation
  Interpolates 3D variables on hybrid sigma height coordinates to height level. The procedure is the same as for the operator ap2pl except for the pressure levels being calculated from the heights by: \( plevel = 101325 \times e^{(hlevel/7000)} \)

Parameter

- **plevels**  FLOAT  Pressure levels in pascal
- **hlevels**  FLOAT  Height levels in meter (max level: 65535 m)

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:

```plaintext
cdo ap2pl,92500,85000,50000,20000 infile outfile
```

2.12.12. INTLEVEL - Linear level interpolation

Synopsis

```plaintext
intlevel,levels infile outfile
```

Description

This operator performs a linear vertical interpolation of non hybrid 3D variables.

Parameter

- **levels**  FLOAT  Target levels
Example

To interpolate 3D variables on height levels to a new set of height levels use:

```
cdo intlevel,10,50,100,500,1000 infile outfile
```
### 2.12.13. INTLEVEL3D - Linear level interpolation from/to 3d vertical coordinates

**Synopsis**

```
<operator>,icoordinate infile1 infile2 outfile
```

**Description**

This operator performs a linear vertical interpolation of 3D variables fields with given 3D vertical coordinates.

**Operators**

- **intlevel3d**: Linear level interpolation onto a 3d vertical coordinate
- **intlevelx3d**: like intlevel3d but with extrapolation

**Parameter**

- **icoordinate** STRING: filename for vertical source coordinates variable
- **infile2**: STRING: target vertical coordinate field (intlevel3d only)

**Example**

To interpolate 3D variables from one set of 3d height levels into another one where
- **icoordinate** contains a single 3d variable, which represents the input 3d vertical coordinate
- **infile1** contains the source data, which the vertical coordinate from **icoordinate** belongs to
- **infile2** only contains the target 3d height levels

```bash
cdo intlevel3d,icoordinate infile1 infile2 outfile
```
2.12.14. INTTIME - Time interpolation

Synopsis

\texttt{inttime},date,time[,inc] infile outfile
\texttt{intntime},n infile outfile

Description

This module performs linear interpolation between timesteps.

Operators

\texttt{inttime} \hspace{1cm} \text{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.

\texttt{intntime} \hspace{1cm} \text{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

\begin{itemize}
\item \textit{date} STRING \hspace{1cm} \text{Tstart date (format YYYY-MM-DD)}
\item \textit{time} STRING \hspace{1cm} \text{Tstart time (format hh:mm:ss)}
\item \textit{inc} STRING \hspace{1cm} \text{Optional increment (seconds, minutes, hours, days, months, years) [default: 0hour]}
\item \textit{n} INTEGER \hspace{1cm} \text{Number of timesteps from one timestep to the next}
\end{itemize}

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:

\begin{verbatim}
cdo inttime,1987-01-01,12:00:00,1hour infile outfile
\end{verbatim}
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 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:

```
```

Example result of `dir year*` for NetCDF datasets:

```
```
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

\[ \text{<operator>[gridtype]} \text{ infile outfile} \]

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 \( \rightarrow \) \( 4N \approx 2(TL + 1) \)

**quadratic grid:** the shortest wavelength is represented by 3 grid points \( \rightarrow \) \( 4N \approx 3(TQ + 1) \)

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:

<table>
<thead>
<tr>
<th>Gridtype</th>
<th>Number of latitudes: ( n_{lat} )</th>
<th>Triangular truncation: ( n_{tr} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>linear</td>
<td>( \text{NINT}((n_{tr}*2 + 1)/2) )</td>
<td>( (n_{lat}*2 - 1) / 2 )</td>
</tr>
<tr>
<td>quadratic</td>
<td>( \text{NINT}((n_{tr}*3 + 1)/2) )</td>
<td>( (n_{lat}*2 - 1) / 3 )</td>
</tr>
</tbody>
</table>

Operators

- **sp2gp**  Spectral to gridpoint
  Convert all spectral fields to a global regular Gaussian grid.

- **gp2sp**  Gridpoint to spectral
  Convert all Gaussian gridpoint fields to spectral fields.

Parameter

- **gridtype**  STRING
  Type of the grid: quadratic, linear (default: quadratic)

Example

To transform spectral coefficients from T106 to N80 Gaussian grid use:

\[ \text{cdo sp2gp infile outfile} \]

To transform spectral coefficients from TL159 to N80 Gaussian grid use:

\[ \text{cdo sp2gp,linear infile outfile} \]
2.13.2. SPECCONV - Spectral conversion

Synopsis

\texttt{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

\texttt{trunc}\quad\texttt{INTEGER}\quad\texttt{New spectral resolution}

2.13.3. WIND2 - D and V to velocity potential and stream function

Synopsis

\texttt{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 \texttt{sd} and \texttt{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 $\rightarrow 4N \simeq 3(TQ + 1)$

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:

<table>
<thead>
<tr>
<th>Gridtype</th>
<th>Number of latitudes: nlat</th>
<th>Triangular truncation: ntr</th>
</tr>
</thead>
<tbody>
<tr>
<td>linear</td>
<td>NINT((ntr*2 + 1)/2)</td>
<td>(nlat*2 - 1) / 2</td>
</tr>
<tr>
<td>quadratic</td>
<td>NINT((ntr*3 + 1)/2)</td>
<td>(nlat*2 - 1) / 3</td>
</tr>
</tbody>
</table>

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 (default: quadratic)

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

\texttt{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 grid cells is a power of 2 then the algorithm of the Fast Fourier Transformation (FFT) is used.

It is

\[ o(t,x) = \frac{1}{\sqrt{n}} \sum_{j=0}^{n-1} i(t,x)e^{i2\pi ij} \]

where a user given \texttt{epsilon} = -1 leads to the forward transformation and a user given \texttt{epsilon} = 1 leads to the backward transformation. If the input stream \texttt{infile} consists only of complex fields, then the fields of \texttt{outfile}, computed by

\begin{verbatim}
cdo -f ext fourier,1 -fourier,-1 infile outfile
\end{verbatim}

are the same than that of \texttt{infile}. For real input files see function retocomplex.

Parameter

\texttt{epsilon} INTEGER -1: forward transformation; 1: backward transformation

Note

Currently only the EXTRA format supports fields with complex numbers.

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
- **outputtext**: 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 00:00 Z15jun1989 12 hr
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.4** library (version 4.6 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 projection, 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:
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

\[ \text{input, grid, zaxis} \] \text{outfile} \\
\text{inputsrv outfile} \\
\text{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 the 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
  Reads 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:

\[ \text{cdo -f grb input,r32x16 outfile.grb < my_ascii_data} \]
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, params 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. Here is a list of all valid keynames:

<table>
<thead>
<tr>
<th>Keyname</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>value</td>
<td>FLOAT</td>
<td>Value of the variable [len:8]</td>
</tr>
<tr>
<td>name</td>
<td>STRING</td>
<td>Name of the variable [len:8]</td>
</tr>
<tr>
<td>param</td>
<td>STRING</td>
<td>Parameter ID (GRIB1: code[.tabnum]; GRIB2: num[.cat[.dis]]) [len:11]</td>
</tr>
<tr>
<td>code</td>
<td>INTEGER</td>
<td>Code number [len:4]</td>
</tr>
<tr>
<td>lon</td>
<td>FLOAT</td>
<td>Longitude coordinate [len:6]</td>
</tr>
<tr>
<td>lat</td>
<td>FLOAT</td>
<td>Latitude coordinate [len:6]</td>
</tr>
<tr>
<td>lev</td>
<td>FLOAT</td>
<td>Vertical level [len:6]</td>
</tr>
<tr>
<td>xind</td>
<td>INTEGER</td>
<td>Grid x index [len:4]</td>
</tr>
<tr>
<td>yind</td>
<td>INTEGER</td>
<td>Grid y index [len:4]</td>
</tr>
<tr>
<td>timestep</td>
<td>INTEGER</td>
<td>Timestep number [len:6]</td>
</tr>
<tr>
<td>date</td>
<td>STRING</td>
<td>Date (format YYYY-MM-DD) [len:10]</td>
</tr>
<tr>
<td>time</td>
<td>STRING</td>
<td>Time (format hh:mm:ss) [len:8]</td>
</tr>
<tr>
<td>year</td>
<td>INTEGER</td>
<td>Year [len:5]</td>
</tr>
<tr>
<td>month</td>
<td>INTEGER</td>
<td>Month [len:2]</td>
</tr>
<tr>
<td>day</td>
<td>INTEGER</td>
<td>Day [len:2]</td>
</tr>
<tr>
<td>nohead</td>
<td>INTEGER</td>
<td>Disable output of header line</td>
</tr>
</tbody>
</table>

Parameter

```
params 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 temperature 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
- `setrtof`: Set range to constant
- `setrtof2`: Set range to constant others to constant2
- `timsort`: Sort over the time
- `const`: Create a constant field
- `random`: Create a field with random numbers
- `topo`: Create a field with topography
- `for`: Create a time series
- `stdatm`: Create values for pressure and temperature for hydrostatic atmosphere
- `uvDestag`: Destaggering of u/v wind components
- `rotuvNorth`: Rotate u/v wind to North pole.
- `projuvLatLon`: Cylindrical Equidistant projection
- `rotuvb`: Backward rotation
- `mastrfu`: Mass stream function
- `sealevelpressure`: Sea level pressure
- `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 left and right bounds of a field
- `wct`: Windchill temperature
- `fdns`: Frost days where no snow index per time period
<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>strwin</td>
<td>Strong wind days index per time period</td>
</tr>
<tr>
<td>strbre</td>
<td>Strong breeze days index per time period</td>
</tr>
<tr>
<td>strgal</td>
<td>Strong gale days index per time period</td>
</tr>
<tr>
<td>hurr</td>
<td>Hurricane days index per time period</td>
</tr>
<tr>
<td>cmorlite</td>
<td>CMOR lite</td>
</tr>
</tbody>
</table>
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
       -85.761 -80.269 -74.745 -69.213 -63.679 -58.143
        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
YDEF 32 LEVELS -85.761 -80.269 -74.745 -69.213 -63.679 -58.143
       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 12:00 Z1jan1987 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]
ts1m1 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] 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 `&lt;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 their defaults:

```
TYPE=0, CODE=-1, LEVEL=-1, INTERVAL=0, MEAN=0, EXTRAPOLATE=0
```

`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:
<table>
<thead>
<tr>
<th>Code</th>
<th>Name</th>
<th>Longname</th>
<th>Units</th>
<th>Level</th>
<th>Needed Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td>low_cld</td>
<td>low cloud</td>
<td>single</td>
<td>223 on modellevel</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>mid_cld</td>
<td>mid cloud</td>
<td>single</td>
<td>223 on modellevel</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>hih_cld</td>
<td>high cloud</td>
<td>single</td>
<td>223 on modellevel</td>
<td></td>
</tr>
<tr>
<td>131</td>
<td>u</td>
<td>u-velocity</td>
<td>m/s</td>
<td>atm (ml+pl)</td>
<td>138, 155</td>
</tr>
<tr>
<td>132</td>
<td>v</td>
<td>v-velocity</td>
<td>m/s</td>
<td>atm (ml+pl)</td>
<td>138, 155</td>
</tr>
<tr>
<td>135</td>
<td>omega</td>
<td>vertical velocity</td>
<td>Pa/s</td>
<td>atm (ml+pl)</td>
<td>138, 152, 155</td>
</tr>
<tr>
<td>148</td>
<td>stream</td>
<td>streamfunction</td>
<td>m(^{-2})/s</td>
<td>atm (ml+pl)</td>
<td>131, 132</td>
</tr>
<tr>
<td>149</td>
<td>velopot</td>
<td>velocity potential</td>
<td>m(^{-2})/s</td>
<td>atm (ml+pl)</td>
<td>131, 132</td>
</tr>
<tr>
<td>151</td>
<td>slp</td>
<td>mean sea level pressure</td>
<td>Pa</td>
<td>surface</td>
<td>129, 130, 152</td>
</tr>
<tr>
<td>156</td>
<td>geophoth</td>
<td>geopotential height</td>
<td>m</td>
<td>atm (ml+pl)</td>
<td>129, 130, 133, 152</td>
</tr>
<tr>
<td>157</td>
<td>rhumidity</td>
<td>relative humidity</td>
<td>atm (ml+pl)</td>
<td>130, 133, 152</td>
<td></td>
</tr>
<tr>
<td>189</td>
<td>selves</td>
<td>surface solar cloud forcing</td>
<td>surface</td>
<td>176-185</td>
<td></td>
</tr>
<tr>
<td>190</td>
<td>tclfs</td>
<td>surface thermal cloud forcing</td>
<td>surface</td>
<td>177-186</td>
<td></td>
</tr>
<tr>
<td>191</td>
<td>sclf0</td>
<td>top solar cloud forcing</td>
<td>surface</td>
<td>178-187</td>
<td></td>
</tr>
<tr>
<td>192</td>
<td>tclf0</td>
<td>top thermal cloud forcing</td>
<td>surface</td>
<td>179-188</td>
<td></td>
</tr>
<tr>
<td>259</td>
<td>windspeed</td>
<td>windspeed</td>
<td>m/s</td>
<td>atm (ml+pl)</td>
<td>sqrt(u<em>u+v</em>v)</td>
</tr>
<tr>
<td>260</td>
<td>precip</td>
<td>total precipitation</td>
<td>surface</td>
<td>142+143</td>
<td></td>
</tr>
</tbody>
</table>

**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**:

<table>
<thead>
<tr>
<th>TYPE</th>
<th>CODE</th>
<th>MEAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>0/10/11</td>
<td>130 temperature</td>
<td>0</td>
</tr>
<tr>
<td>0/10/11</td>
<td>131 u-velocity</td>
<td>0</td>
</tr>
<tr>
<td>0/10/11</td>
<td>132 v-velocity</td>
<td>0</td>
</tr>
<tr>
<td>0/10/11</td>
<td>133 specific humidity</td>
<td>0</td>
</tr>
<tr>
<td>0/10/11</td>
<td>138 vorticity</td>
<td>0</td>
</tr>
<tr>
<td>0/10/11</td>
<td>148 streamfunction</td>
<td>0</td>
</tr>
<tr>
<td>0/10/11</td>
<td>149 velocity potential</td>
<td>0</td>
</tr>
<tr>
<td>0/10/11</td>
<td>152 LnPs</td>
<td>0</td>
</tr>
<tr>
<td>0/10/11</td>
<td>155 divergence</td>
<td>0</td>
</tr>
<tr>
<td>&gt;11</td>
<td>all codes</td>
<td>0/1</td>
</tr>
</tbody>
</table>

**Parameter**

- **vct** STRING File with VCT in ASCII format

**Example**

To interoplate 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 $in\text{file}$ 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 $in\text{file}$ 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 $in\text{file}$ 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 $out\text{file}$.

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 $in\text{file}$ is $1/(N*\text{dT})$,
- the greatest frequency is $1/(2\text{dT})$ (Nyquist frequency),

with $N$ the number of timesteps and $\text{dT}$ the time increment of $in\text{file}$ 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 variability 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 performance 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). Therefore you can use the following:

\[
\text{cdo highpass,x -del29feb infile outfile}
\]

Accordingly you might use the following to suppress variability on timescales shorter than one year:

\[
\text{cdo lowpass,1 -del29feb infile outfile}
\]

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

\[
\text{cdo bandpass,x,y -del29feb infile outfile}
\]

with x<=0.5 and y >0.5.

2.15.4. GRIDCELL - Grid cell quantities

Synopsis

<operator> 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 description. 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 earth radius to square meters.

gridweights Grid cell weights
Writes the grid cell area weights to the output stream.

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 form of the curve and the distance. The implemented form of the curve 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>
form STRING Form of the curve, default form=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. 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
\[ o(t, x) = \begin{cases} 
  c & \text{if } i(t, x) \geq rmin \land i(t, x) \leq rmax \\
  i(t, x) & \text{if } i(t, x) < rmin \lor i(t, x) > rmax 
\end{cases} \]

setrtoc2  Set range to constant others to constant2
\[ o(t, x) = \begin{cases} 
  c & \text{if } i(t, x) \geq rmin \land i(t, x) \leq rmax \\
  c2 & \text{if } i(t, x) < rmin \lor i(t, x) > rmax 
\end{cases} \]

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
2.15.7. TIMSORT - Timsort

Synopsis

timsort infile outfile

Description

Sorts the elements in ascending order over all timesteps for every field position. After sorting it is:

\[ o(t_1, x) \leq o(t_2, x) \quad \forall (t_1 < t_2), x \]

Example

To sort all field elements of a dataset over all timesteps use:

```
cdo timsort infile outfile
```

2.15.8. VARGEN - Generate a field

Synopsis

const, const, grid outfile
random, grid[, seed] outfile
topo[, grid] outfile
for, start, end[, inc] outfile
stdatm, levels outfile

Description

Generates a dataset with one or more fields

Operators

<table>
<thead>
<tr>
<th>Operator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>const</td>
<td>Create a constant field. All field elements of the grid have the same value.</td>
</tr>
<tr>
<td>random</td>
<td>Create a field with random numbers.</td>
</tr>
<tr>
<td>topo</td>
<td>Create a field with topography.</td>
</tr>
<tr>
<td>for</td>
<td>Create a time series.</td>
</tr>
<tr>
<td>stdatm</td>
<td>Create values for pressure and temperature for hydrostatic atmosphere.</td>
</tr>
</tbody>
</table>

stdatm

Create pressure and temperature values for the given list of vertical levels. The formulas are:

\[
P(z) = P_0 \exp \left( -\frac{9}{\pi} \frac{H}{T_0} \log \left( \frac{\exp(\frac{H}{T_0+\Delta T})}{T_0+\Delta T} \right) \right)
\]

\[
T(z) = T_0 + \Delta T \exp \left( -\frac{9}{\pi} \right)
\]
with the following constants

\[ T_0 = 213K \quad : \text{offset to get a surface temperature of 288K} \]
\[ \Delta T = 75K \quad : \text{Temperature lapse rate for 10Km} \]
\[ P_0 = 1013.25\text{hPa} \quad : \text{surface pressure} \]
\[ H = 10000.0\text{m} \quad : \text{scale height} \]
\[ g = 9.80665\frac{\text{m}}{\text{s}^2} \quad : \text{earth gravity} \]
\[ R = 287.05\frac{\text{J}}{\text{kgK}} \quad : \text{gas constant for air} \]

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
```
2.15.9. 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 datasets 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
```
2.15.10. ROTUVB - Rotation

Synopsis

\texttt{rotuvb,u,v,... infile outfile}

Description

This is a special operator for datasets 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

\texttt{u,v,... STRING} Pairs of zonal and meridional velocity components (use variable names or code numbers)

Example

To transform the u and v velocity of a dataset from a rotated spherical system to a geographical system use:

\texttt{cdo rotuvb,u,v infile outfile}

2.15.11. MASTRFU - Mass stream function

Synopsis

\texttt{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:

\texttt{cdo mastrfu infile outfile}

2.15.12. DERIVEPAR - Sea level pressure

Synopsis

\texttt{sealevelpressure infile outfile}

Description

This operator computes the sea level pressure (\texttt{air\_pressure\_at\_sea\_level}). Required input fields are \texttt{surface\_air\_pressure}, \texttt{surface\_geopotential} and \texttt{air\_temperature} on hybrid sigma pressure levels.
2.15.13. ADISIT - Potential temperature to in-situ temperature and vice versa

Synopsis

\[ \text{adisit[,pressure]} \text{ infile outfile} \]
\[ \text{adipot} \text{ infile outfile} \]

Description

Operators

\begin{itemize}
\item \textbf{adisit} \hspace{1cm} Potential temperature to in-situ temperature
This is a special operator for the post processing of the ocean and sea ice model output. It converts potential temperature adiabatically to in-situ temperature \( \text{t, s, p} \). Required input fields are sea water potential temperature (name=\( \text{tho}; \) code=2) and sea water salinity (name=\( \text{sao}; \) code=5). Pressure is calculated from the level information or can be specified by the optional parameter. Output fields are sea water temperature (name=\( \text{to}; \) code=20) and sea water salinity (name=\( \text{s}; \) code=5).
\item \textbf{adipot} \hspace{1cm} In-situ temperature to potential temperature
This is a special operator for the post processing of the ocean and sea ice model output. It converts in-situ temperature to potential temperature \( \text{tho(t, s, p)} \). Required input fields are sea water in-situ temperature (name=\( \text{t}; \) code=2) and sea water salinity (name=\( \text{sao,s}; \) code=5). Pressure is calculated from the level information or can be specified by the optional parameter. Output fields are sea water temperature (name=\( \text{tho}; \) code=2) and sea water salinity (name=\( \text{s}; \) code=5).
\end{itemize}

Parameter

\begin{itemize}
\item \textit{pressure} \hspace{1cm} FLOAT \hspace{1cm} Pressure in bar (constant value assigned to all levels)
\end{itemize}

2.15.14. RHOPOT - Calculates potential density

Synopsis

\[ \text{rhopot[,pressure]} \text{ infile outfile} \]

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=\( \text{rhopoto}; \) code=18). Required input fields are sea water in-situ temperature (name=\( \text{to}; \) code=20) and sea water salinity (name=\( \text{sao}; \) code=5). Pressure is calculated from the level information or can be specified by the optional parameter.

Parameter

\begin{itemize}
\item \textit{pressure} \hspace{1cm} FLOAT \hspace{1cm} Pressure in bar (constant value assigned to all levels)
\end{itemize}

Example

To compute the sea water potential density from the potential temperature use this operator in combination with \textbf{adisit}:

\begin{verbatim}
cdo rhopot -adisit infile outfile
\end{verbatim}
### 2.15.15. HISTOGRAM - Histogram

**Synopsis**

\[ \text{<operator>}, bounds \text{ infile outfile} \]

**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**

\[ \text{bounds} \quad \text{FLOAT} \quad \text{Comma separated list of the bin bounds (-inf and inf valid)} \]

### 2.15.16. SETHALO - Set the left and right bounds of a field

**Synopsis**

\[ \text{sethalo, lhalo, rhalo \text{ infile outfile}} \]

**Description**

This operator sets the left and right bounds of the rectangularly understood fields. Positive numbers of the parameter \textit{lhalo} enlarges the left bound by the given number of columns from the right bound. The parameter \textit{rhalo} does the similar for the right bound. Negative numbers of the parameter \textit{lhalo/rhalo} can be used to remove the given number of columns of the left and right bounds.

**Parameter**

- **lhalo**
  - INTEGER
  - Left halo

- **rhalo**
  - INTEGER
  - Right halo
2.15.17. WCT - Windchill temperature

Synopsis

\texttt{wct} infile1 infile2 outfile

Description

Let \texttt{infile1} and \texttt{infile2} be time series of temperature and wind speed records, then a corresponding time series of resulting windchill temperatures is written to \texttt{outfile}. The wind chill temperature calculation is only valid for a temperature of \( T < 33 \, ^\circ \text{C} \) and a wind speed of \( v \geq 1.39 \, \text{m/s} \). Whenever these conditions are not satisfied, a missing value is written to \texttt{outfile}. Note that temperature and wind speed records have to be given in units of \(^\circ\text{C}\) and m/s, respectively.

2.15.18. FDNS - Frost days where no snow index per time period

Synopsis

\texttt{fdns} infile1 infile2 outfile

Description

Let \texttt{infile1} be a time series of the daily minimum temperature \( T_N \) and \texttt{infile2} be a corresponding series of daily surface snow amounts. Then the number of days where \( T_N < 0 \, ^\circ \text{C} \) and the surface snow amount is less than 1 cm is counted. The temperature \( T_N \) have to be given in units of Kelvin. The date information of a timestep in \texttt{outfile} is the date of the last contributing timestep in \texttt{infile}.

2.15.19. STRWIN - Strong wind days index per time period

Synopsis

\texttt{strwin[,]v} infile outfile

Description

Let \texttt{infile} be a time series of the daily maximum horizontal wind speed \( V_X \), then the number of days where \( V_X > v \) is counted. The horizontal wind speed \( v \) is an optional parameter with default \( v = 10.5 \, \text{m/s} \). A further output variable is the maximum number of consecutive days with maximum wind speed greater than or equal to \( v \). Note that both \( V_X \) 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 \texttt{outfile} is the date of the last contributing timestep in \texttt{infile}.

Parameter

\begin{itemize}
  \item \texttt{v} FLOAT Horizontal wind speed threshold (m/s, default \( v = 10.5 \, \text{m/s} \))
\end{itemize}
2.15.20. STRBRE - Strong breeze days index per time period

Synopsis

\texttt{strbre infile outfile}

Description

Let \texttt{infile} be a time series of the daily maximum horizontal wind speed \(V_X\), then the number of days where \(V_X\) 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 \(V_X\) 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 \texttt{outfile} is the date of the last contributing timestep in \texttt{infile}.

2.15.21. STRGAL - Strong gale days index per time period

Synopsis

\texttt{strgal infile outfile}

Description

Let \texttt{infile} be a time series of the daily maximum horizontal wind speed \(V_X\), then the number of days where \(V_X\) 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 \(V_X\) 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 \texttt{outfile} is the date of the last contributing timestep in \texttt{infile}.

2.15.22. HURR - Hurricane days index per time period

Synopsis

\texttt{hurr infile outfile}

Description

Let \texttt{infile} be a time series of the daily maximum horizontal wind speed \(V_X\), then the number of days where \(V_X\) 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 \(V_X\) 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 \texttt{outfile} is the date of the last contributing timestep in \texttt{infile}.
2.15.23. CMORLITE - CMOR lite

Synopsis

```bash
  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:

<table>
<thead>
<tr>
<th>Entry</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>WORD</td>
<td>Name of the variable</td>
</tr>
<tr>
<td>out_name</td>
<td>WORD</td>
<td>New name of the variable</td>
</tr>
<tr>
<td>type</td>
<td>WORD</td>
<td>Data type (real or double)</td>
</tr>
<tr>
<td>standard_name</td>
<td>WORD</td>
<td>As defined in the CF standard name table</td>
</tr>
<tr>
<td>long_name</td>
<td>STRING</td>
<td>Describing the variable</td>
</tr>
<tr>
<td>units</td>
<td>STRING</td>
<td>Specifying the units for the variable</td>
</tr>
<tr>
<td>comment</td>
<td>STRING</td>
<td>Information concerning the variable</td>
</tr>
<tr>
<td>cell_methods</td>
<td>STRING</td>
<td>Information concerning calculation of means or climatologies</td>
</tr>
<tr>
<td>cell_measures</td>
<td>STRING</td>
<td>Indicates the names of the variables containing cell areas and volumes</td>
</tr>
<tr>
<td>missing_value</td>
<td>FLOAT</td>
<td>Specifying how missing data will be identified</td>
</tr>
<tr>
<td>valid_min</td>
<td>FLOAT</td>
<td>Minimum valid value</td>
</tr>
<tr>
<td>valid_max</td>
<td>FLOAT</td>
<td>Maximum valid value</td>
</tr>
<tr>
<td>ok_min_mean_abs</td>
<td>FLOAT</td>
<td>Minimum absolute mean</td>
</tr>
<tr>
<td>ok_max_mean_abs</td>
<td>FLOAT</td>
<td>Maximum absolute mean</td>
</tr>
<tr>
<td>factor</td>
<td>FLOAT</td>
<td>Scale factor</td>
</tr>
<tr>
<td>delete</td>
<td>INTEGER</td>
<td>Set to 1 to delete variable</td>
</tr>
<tr>
<td>convert</td>
<td>INTEGER</td>
<td>Set to 1 to convert the unit if necessary</td>
</tr>
</tbody>
</table>

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:

```bash
  prompt> cat mypartab
  &parameter
  name = t
```
out_name = ta
standard_name = air_temperature
units = "K"
missing_value = 1e+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 \texttt{t} to \texttt{ta}. The standard name of this variable is set to \texttt{air\_temperature} and the unit is set to \texttt{[K]} (converts the unit if necessary). The missing value will be set to \texttt{1e+20}. In addition it will be checked whether the values of the variable are in the range of \texttt{157.1} to \texttt{336.3}. The result will be stored in NetCDF.
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 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 program 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, 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 infrastructure project IS-ENES. Ralf also helps a lot with the user support. Implemented operators: showunit, stdatm, intlevel3d, consecsum, consects, ngrids, ngridpoints, reducegrid

1 Procedural INterface for GRIB formatted Objects
Contributors

Cedrick Ansorge : He worked on the CDO software package as a student assistant at MPI-M from 2007-2011. Implemented operators: eol, eol3d, enscrps, ensbrs, maskregion, bandpass, lowpass, highpass, smooth9

Oliver Heidmann : He worked on the CDO software package as a student assistant at MPI-M from 2015-2018.

Karin Meier-Fleischer : She is working in the CDO user support since 2017.

Fabian Wachsmann : He is working on CDO for the CMIP6 project and is responsible for the operator cmor.

Ralf Quast : He worked on CDO on behalf of the Service Gruppe Anpassung (SGA), DKRZ in 2006. Implemented all ECA Indices of Daily Temperature and Precipitation Extremes, all percentile operators, module YDRUNSTAT and wct.

Kameswarrao Modali : Implemented operators: contour, shaded, grfill, vector, graph.

Michal Koutek : Implemented operators: selmulti delmulti, changemulti, samplegrid, uvDestag, rotu-vNorth, projuvLatLon.

Etienne Tourigny : Implemented operators: setclonlatbox, setcindexbox, setvals, splitsel, histfreq, setrtoc, setrtoc2.


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:


Please let me know if your name was omitted!
Bibliography

[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)


[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


[PROJ.4] 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]

[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**.

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDO_FILE_SUFFIX</td>
<td>None</td>
<td>Default file 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.</td>
</tr>
<tr>
<td>CDO_HISTORY_INFO</td>
<td>1</td>
<td>Append NetCDF global attribute histroy</td>
</tr>
<tr>
<td>CDO_PCTL_NBINS</td>
<td>101</td>
<td>Number of histogram bins.</td>
</tr>
<tr>
<td>CDO_RESET_HISTORY</td>
<td>0</td>
<td>Set to 1 to reset the NetCDF <code>history</code> global attribute.</td>
</tr>
<tr>
<td>CDO_REMAP_NORM</td>
<td>fracarea</td>
<td>Choose the normalization for the conservative interpolation</td>
</tr>
<tr>
<td>CDO_GRIDSEARCH_RADIUS</td>
<td>180</td>
<td>Grid search radius in degree. Used by the operators setmisstonn, remapdis and remapnn.</td>
</tr>
<tr>
<td>CDO_TIMESTAT_DATE</td>
<td>None</td>
<td>Set target timestamp of a temporal statistic operator to the 'first', 'middle', 'midhigh' or 'last' contributing source timestep.</td>
</tr>
<tr>
<td>CDO_USE_FFTW</td>
<td>1</td>
<td>Set to 0 to switch off usage of FFTW. Used in the Filter module.</td>
</tr>
<tr>
<td>CDO_VERSION_INFO</td>
<td>1</td>
<td>Set to 0 to disable NetCDF global attribute CDO</td>
</tr>
</tbody>
</table>
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:

<table>
<thead>
<tr>
<th>Module</th>
<th>Operator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detrend</td>
<td>detrend</td>
<td>Detrend</td>
</tr>
<tr>
<td>Ensstat</td>
<td>ensmin</td>
<td>Ensemble minimum</td>
</tr>
<tr>
<td>Ensstat</td>
<td>ensmax</td>
<td>Ensemble maximum</td>
</tr>
<tr>
<td>Ensstat</td>
<td>enssum</td>
<td>Ensemble sum</td>
</tr>
<tr>
<td>Ensstat</td>
<td>ensmean</td>
<td>Ensemble mean</td>
</tr>
<tr>
<td>Ensstat</td>
<td>ensavg</td>
<td>Ensemble average</td>
</tr>
<tr>
<td>Ensstat</td>
<td>ensvvar</td>
<td>Ensemble variance</td>
</tr>
<tr>
<td>Ensstat</td>
<td>enststd</td>
<td>Ensemble standard deviation</td>
</tr>
<tr>
<td>Ensstat</td>
<td>enspctl</td>
<td>Ensemble percentiles</td>
</tr>
<tr>
<td>Filter</td>
<td>bandpass</td>
<td>Bandpass filtering</td>
</tr>
<tr>
<td>Filter</td>
<td>lowpass</td>
<td>Lowpass filtering</td>
</tr>
<tr>
<td>Filter</td>
<td>highpass</td>
<td>Highpass filtering</td>
</tr>
<tr>
<td>Fourier</td>
<td>fourier</td>
<td>Fourier transformation</td>
</tr>
<tr>
<td>Genweights</td>
<td>genbil</td>
<td>Generate bilinear interpolation weights</td>
</tr>
<tr>
<td>Genweights</td>
<td>genbic</td>
<td>Generate bicubic interpolation weights</td>
</tr>
<tr>
<td>Genweights</td>
<td>gendis</td>
<td>Generate distance-weighted average remap weights</td>
</tr>
<tr>
<td>Genweights</td>
<td>genmn</td>
<td>Generate nearest neighbor remap weights</td>
</tr>
<tr>
<td>Genweights</td>
<td>gencon</td>
<td>Generate 1st order conservative remap weights</td>
</tr>
<tr>
<td>Genweights</td>
<td>gencon2</td>
<td>Generate 2nd order conservative remap weights</td>
</tr>
<tr>
<td>Gridboxstat</td>
<td>gridboxmin</td>
<td>Gridbox minimum</td>
</tr>
<tr>
<td>Gridboxstat</td>
<td>gridboxmax</td>
<td>Gridbox maximum</td>
</tr>
<tr>
<td>Gridboxstat</td>
<td>gridboxsum</td>
<td>Gridbox sum</td>
</tr>
<tr>
<td>Gridboxstat</td>
<td>gridboxmean</td>
<td>Gridbox mean</td>
</tr>
<tr>
<td>Gridboxstat</td>
<td>gridboxavg</td>
<td>Gridbox average</td>
</tr>
<tr>
<td>Gridboxstat</td>
<td>gridboxvar</td>
<td>Gridbox variance</td>
</tr>
<tr>
<td>Gridboxstat</td>
<td>gridboxstd</td>
<td>Gridbox standard deviation</td>
</tr>
<tr>
<td>Remapeta</td>
<td>remapeta</td>
<td>Remap vertical hybrid level</td>
</tr>
<tr>
<td>Remap</td>
<td>remapbil</td>
<td>Bilinear interpolation</td>
</tr>
<tr>
<td>Remap</td>
<td>remapbic</td>
<td>Bicubic interpolation</td>
</tr>
<tr>
<td>Remap</td>
<td>remapdis</td>
<td>Distance-weighted average remapping</td>
</tr>
<tr>
<td>Remap</td>
<td>remapnn</td>
<td>Nearest neighbor remapping</td>
</tr>
<tr>
<td>Remap</td>
<td>remapcon</td>
<td>First order conservative remapping</td>
</tr>
<tr>
<td>Remap</td>
<td>remapcon2</td>
<td>Second order conservative remapping</td>
</tr>
<tr>
<td>Remap</td>
<td>remaplaf</td>
<td>Largest area fraction remapping</td>
</tr>
</tbody>
</table>
C. Standard name table

The following CF standard names are supported by CDO.

<table>
<thead>
<tr>
<th>CF standard name</th>
<th>Units</th>
<th>GRIB 1 code</th>
<th>variable name</th>
</tr>
</thead>
<tbody>
<tr>
<td>surface_geopotential</td>
<td>m² s⁻²</td>
<td>129</td>
<td>geosp</td>
</tr>
<tr>
<td>air_temperature</td>
<td>K</td>
<td>130</td>
<td>ta</td>
</tr>
<tr>
<td>specific_humidity</td>
<td>1</td>
<td>133</td>
<td>huss</td>
</tr>
<tr>
<td>surface_air_pressure</td>
<td>Pa</td>
<td>134</td>
<td>aps</td>
</tr>
<tr>
<td>air_pressure_at_sea_level</td>
<td>Pa</td>
<td>151</td>
<td>psl</td>
</tr>
<tr>
<td>geopotential_height</td>
<td>m</td>
<td>156</td>
<td>zg</td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>gridtype</th>
<th>curvilinear</th>
</tr>
</thead>
<tbody>
<tr>
<td>gridsize</td>
<td>30</td>
</tr>
<tr>
<td>xsize</td>
<td>6</td>
</tr>
<tr>
<td>ysize</td>
<td>5</td>
</tr>
<tr>
<td>xvals</td>
<td>-21 -11 0 11 21 30 -25 -13 0 13</td>
</tr>
<tr>
<td></td>
<td>25 36 -31 -16 0 16 31 43 -38 -21</td>
</tr>
<tr>
<td></td>
<td>0 21 38 52 -51 -30 0 30 51 64</td>
</tr>
<tr>
<td>xbounds</td>
<td>-23 -14 -17 -28 -14 -5 -6 -17 -5 5 6 -6</td>
</tr>
<tr>
<td></td>
<td>-5 14 17 6 14 23 28 17 23 32 38 28</td>
</tr>
<tr>
<td></td>
<td>-28 -17 -21 -34 -17 -6 -7 -21 -6 6 7 -7</td>
</tr>
<tr>
<td></td>
<td>6 17 21 7 17 28 34 21 28 38 44 34</td>
</tr>
<tr>
<td></td>
<td>-34 -21 -27 -41 -21 -7 -9 -27 -7 7 9 -9</td>
</tr>
<tr>
<td></td>
<td>7 21 27 9 21 34 41 27 34 44 52 41</td>
</tr>
<tr>
<td></td>
<td>9 27 35 13 27 41 51 35 41 52 63 51</td>
</tr>
<tr>
<td></td>
<td>13 35 51 21 35 51 67 51 51 63 77 67</td>
</tr>
<tr>
<td>yvals</td>
<td>29 32 32 32 29 26 39 42 42 42</td>
</tr>
<tr>
<td></td>
<td>39 35 48 51 52 51 48 43 57 61</td>
</tr>
<tr>
<td></td>
<td>62 61 57 65 70 72 70 65 58</td>
</tr>
<tr>
<td>ybounds</td>
<td>23 26 36 32 26 27 37 36 27 27 37 37</td>
</tr>
<tr>
<td></td>
<td>27 26 36 37 26 23 32 36 23 19 28 32</td>
</tr>
<tr>
<td></td>
<td>32 36 45 41 36 37 47 45 37 37 47 47</td>
</tr>
<tr>
<td></td>
<td>37 36 45 47 36 32 41 45 32 28 36 41</td>
</tr>
<tr>
<td></td>
<td>41 45 55 50 45 47 57 55 47 47 57 57</td>
</tr>
<tr>
<td></td>
<td>47 45 55 57 45 41 50 55 41 36 44 50</td>
</tr>
<tr>
<td></td>
<td>50 55 64 58 55 57 67 64 57 57 67 67</td>
</tr>
<tr>
<td></td>
<td>57 55 64 67 55 50 58 64 50 44 51 58</td>
</tr>
<tr>
<td></td>
<td>58 64 72 64 64 67 77 72 67 67 77 77</td>
</tr>
<tr>
<td></td>
<td>67 64 72 77 64 58 64 72 58 51 56 64</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>gridtype</th>
<th>unstructured</th>
</tr>
</thead>
<tbody>
<tr>
<td>gridsize</td>
<td>30</td>
</tr>
<tr>
<td>nvertex</td>
<td>6</td>
</tr>
<tr>
<td>xvals</td>
<td>−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</td>
</tr>
<tr>
<td>xbounds</td>
<td>0 16 21 0 339 344 340 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 72 108 108 72 54 90 180 144 126 162 −108 −144</td>
</tr>
<tr>
<td>yvals</td>
<td>58 58 32 0 0 58 32 0 0 58 32 0 0 58 32 0 0 58 32 0 0 58 32 0 0 58 32 0 0 58 32 0 0</td>
</tr>
<tr>
<td>ybounds</td>
<td>41 53 71 71 53 41 41 41 53 71 71 53 11 19 41 53 41 19 −19 −11 7 19 11 −7 41 41 53 71 71 53 11 19 41 53 41 19 −19 −11 7 19 11 −7 41 41 53 71 71 53 11 19 41 53 41 19 11 19 41 53 41 19 11 19 41 53 41 19 11 19 41 53 41 19</td>
</tr>
</tbody>
</table>

Figure D.2.: Orthographic and Robinson projection of the unstructured grid
## Operator index

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>abs</td>
<td>delcode</td>
<td>enlarge</td>
<td>fdns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>acos</td>
<td>delete</td>
<td>ensavg</td>
<td>fdavg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>add</td>
<td>delgridcell</td>
<td>ensbrs</td>
<td>fldavg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>adde</td>
<td>delmulti</td>
<td>enscrps</td>
<td>fldmax</td>
<td></td>
<td></td>
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<tr>
<td>adipot</td>
<td>delname</td>
<td>ensmax</td>
<td>fliq</td>
<td></td>
<td></td>
</tr>
<tr>
<td>adisit</td>
<td>delparam</td>
<td>enssav</td>
<td>fliq2d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>aexpr</td>
<td>detrend</td>
<td>ensmean</td>
<td>fliq3d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>aexprf</td>
<td>diff</td>
<td>ensmin</td>
<td>fliqspatial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>after</td>
<td>dinf</td>
<td>enspctl</td>
<td>fliqspatial3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ap2hl</td>
<td>distgrid</td>
<td>ensrange</td>
<td>fliqv</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ap2pl</td>
<td>div</td>
<td>ensrkhistspace</td>
<td>fliqv2d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>asin</td>
<td>divdpn</td>
<td>ensrkhisttime</td>
<td>fliqv3d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>atan</td>
<td>divdpv</td>
<td>eof</td>
<td>fliq4d</td>
<td></td>
<td></td>
</tr>
<tr>
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