247.21 244.83 242.70 240.88 239.51 238.76
238.52 238.58 238.68 238.82 238.99 239.18
239.17 238.95 238.78 238.42 238.04 237.71
237.43 237.33 237.53 238.16 239.29 240.95
243.37 245.92 248.69 251.52 252.06 257.99
260.38 262.42 263.97 265.29 265.51 266.06
265.64 264.20 263.74 263.20 262.42 261.77
261.32 260.99 260.78 260.71 260.72 261.14
261.53 261.57 263.04 263.72 264.30 265.09
265.23 264.64 264.52 263.75 261.33 259.16
257.07 255.06 252.64 249.88 245.79 244.97
244.23 243.53 242.89 242.34 241.87 241.45
241.12 240.87 240.69 240.56 240.47 240.42
240.41 240.45 240.55 240.71 240.96 241.32
241.75 242.28 242.88 243.58 244.34 245.15

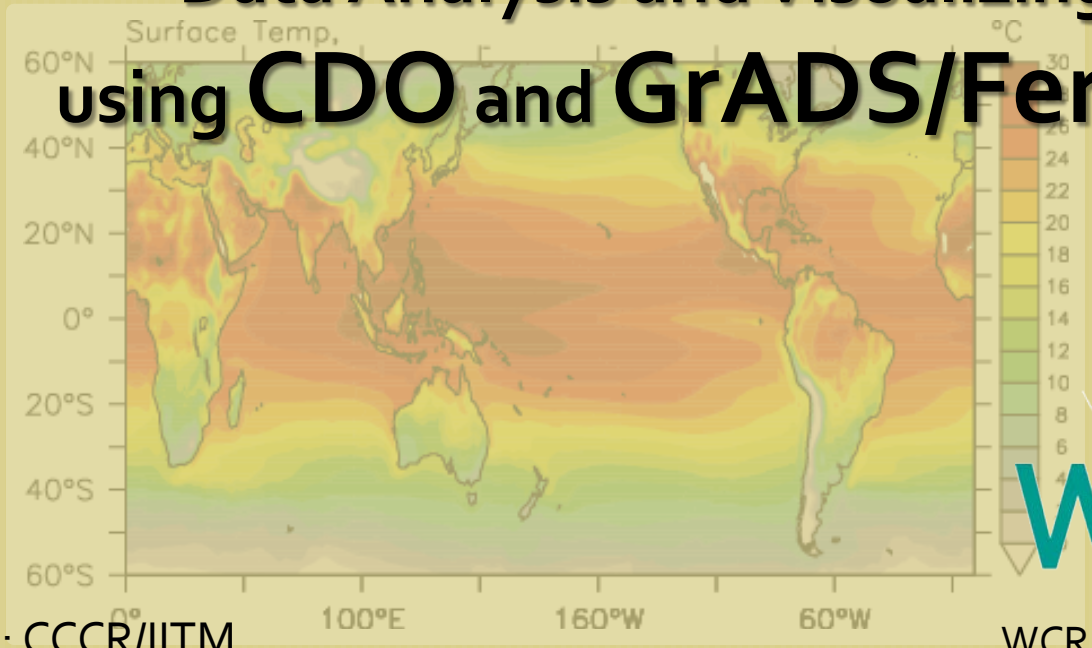
==== Analyze and Visualize ====

CDO

J >
243.53 242.89 242.34 241.87 241.45
J >
264.64 264.52 263.75 261.33 259.16
A >
264.20 263.74 263.20 262.42 261.77
S >
237.33 237.53 238.16 239.29 240.95

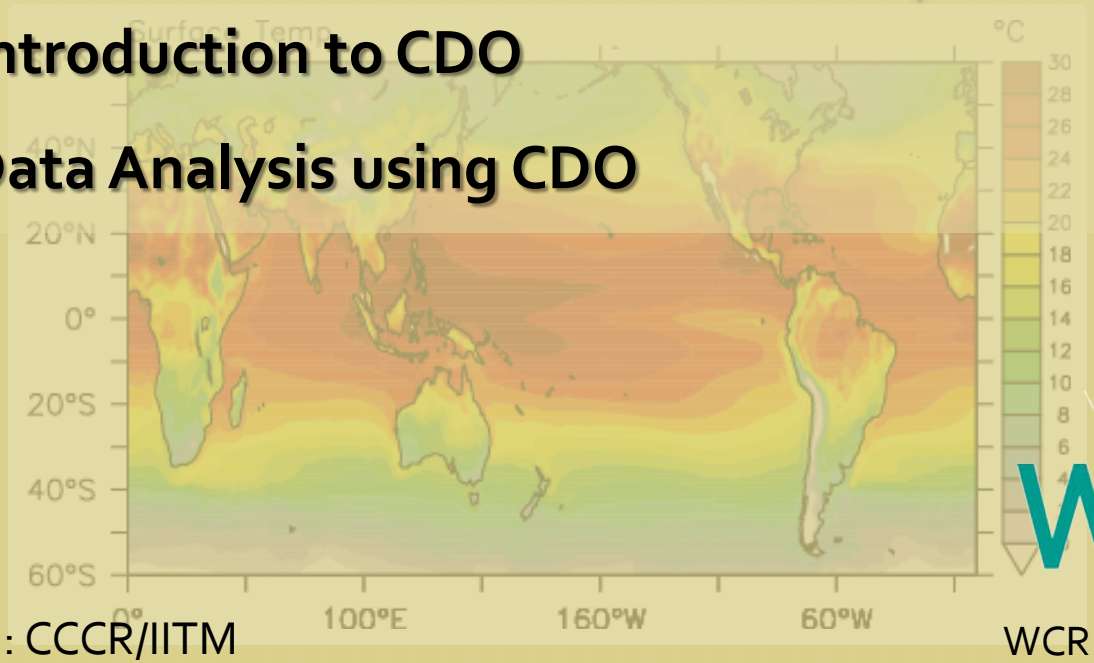
GraDs Ferret

Data Analysis and Visualizing using CDO and GrADS/Ferret



Roxy Mathew :: CCCR/IITM

1. Data Analysis and Visualization in Scientific Research
2. Data Attributes, Formats and netCDF
3. Common Tools for Data Analysis and Visualization
4. Introduction to CDO
5. Data Analysis using CDO

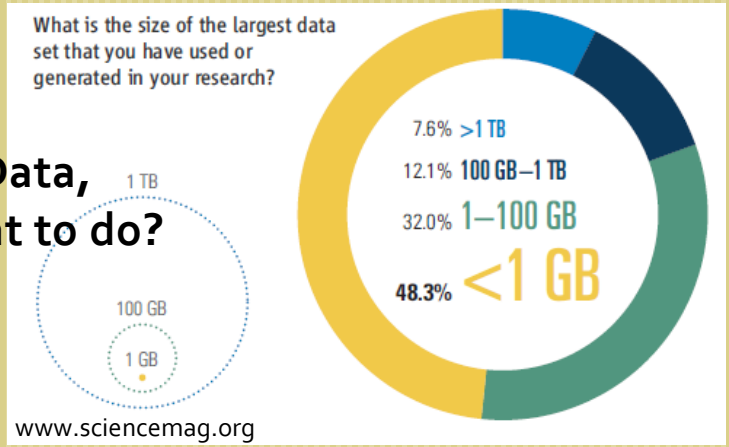


WCRP
World Climate Research Programme

Dealing with Data

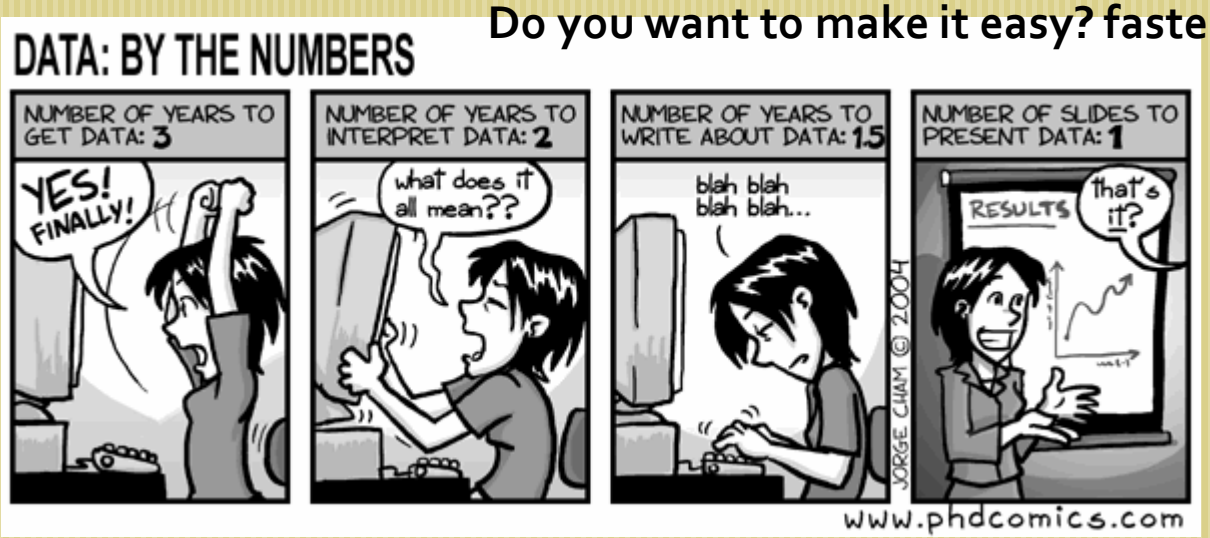
"If we can use and reuse scientific data better, the opportunities are myriad".

Lot of Data,
What to do?



How to do?
Who will do?!

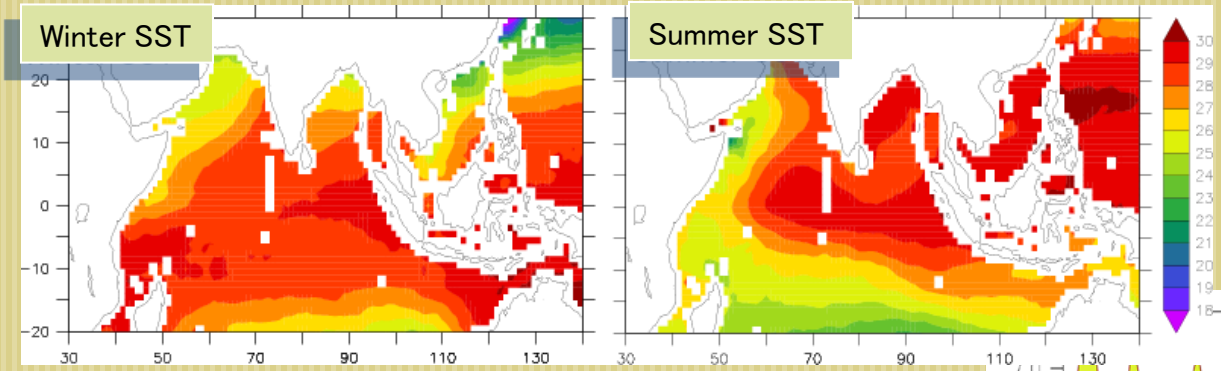
Do you want to make it easy? faster?



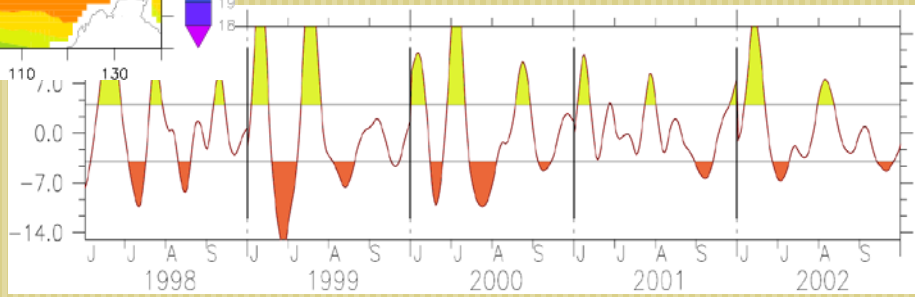
Dealing with Data

Data in Scientific Research

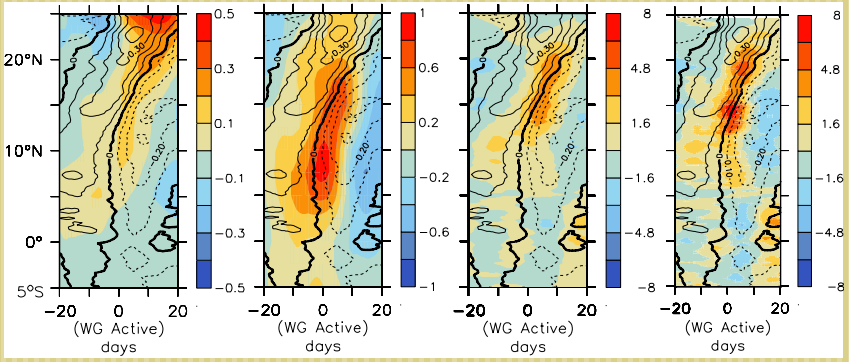
Climatological Analysis



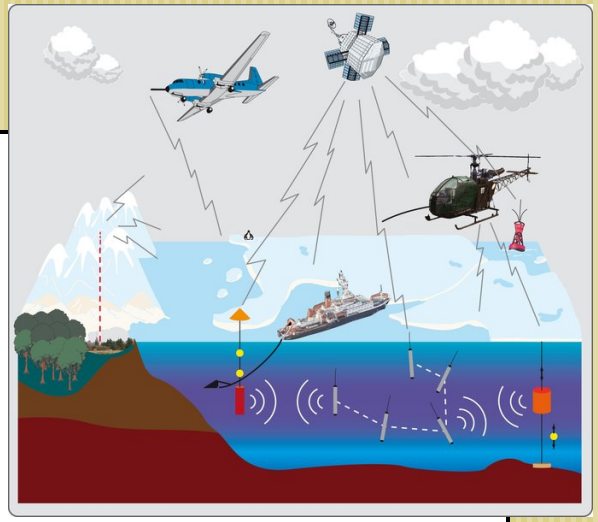
Time series Analysis



Extended Analysis:



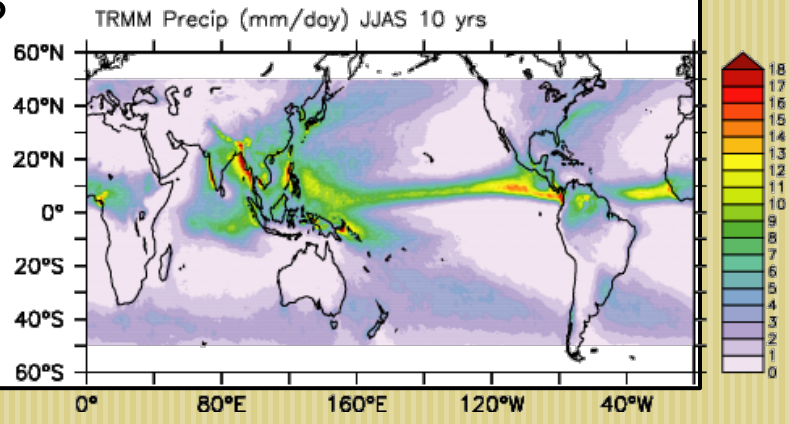
Eg. Ref: Roxy and Tanimoto 2011, Climate Dynamics



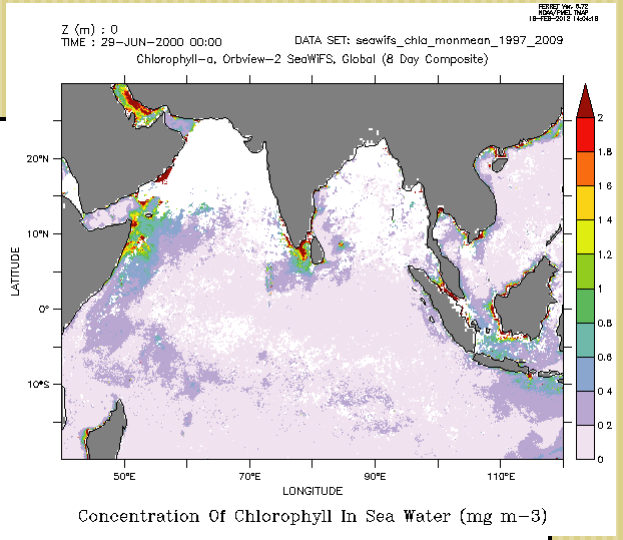
Attributes of the Data

Defines attributes of the data sets used,
e.g. resolution (x,y,t), coverage (spatial scale).

1. Where do the data come from?
    - direct sampling of atmos /ocean/ surface
    - derived from remote sensing
    - model
2. What geographic area does your data/model cover?
    - Eg: Indian Ocean? Monsoon region?
3. What time period does your data/model cover?
    - June-September? Which years?
4. What is the area your variable measured over (resolution of your grid boxes)?
    - Regional processes captured?



Attributes of the Data



Describes strengths / limitations
of data sets or models used.

1. Why was data set or model selected?
   - "It was available at the data server" ??
   - "My professor told me to use it" ??!

2. How accurate are the data?
   - Are they equally accurate in all parts of the world under all conditions?
   - What factors may impact confidence in the data?

3. What kind of analysis/techniques are you going to do?

Attributes of the Data

Basic netcdf utility, ncdump:

ncdump –h file.nc

```
netcdf file.nc {
dimensions:
          lon = 192 ;
          lat = 96 ;
          lev = 1 ;
          time = UNLIMITED ; // (10 currently)
variables:
     double lon(lon) ;
          lon:long_name = "longitude" ;
          lon:units = "degrees_east" ;
     double lat(lat) ;
          lat:long_name = "latitude" ;
          lat:units = "degrees_north" ;
     double lev(lev) ;
          lev:long_name = "pressure" ;
          lev:units = "Pa" ;
     double time(time) ;
          time:units = "day as %Y%m%d.%f" ;
     float q(time, lev, lat, lon) ;
          q:long_name = "specific humidity" ;
          q:units = "kg/kg" ;
          q:code = 133 ;
          q:table = 128 ;
          q:grid_type = "gaussian" ;
// global attributes:
     :CDO = "Climate Data Operators version 0.9.5 " ;
     :source = "ECHAM5.2" ;
     :institution = "Max-Planck-Institute for Meteorology" ;
}
```

```
247.21 244.83 242.70 240.88 239.51 238.76
238.52 238.58 238.68 238.82 238.99 239.18
239.17 238.95 238.78 238.42 238.04 237.71
237.43 237.33 237.53 238.16 239.29 240.95
243.37 245.92 248.69 251.52 252.06 257.99
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241.12 240.87 240.69 240.56 240.47 240.42
240.41 240.45 240.55 240.71 240.96 241.32
241.75 242.28 242.88 243.58 244.34 245.15
```

NCL

Matlab

CDO

Fortran

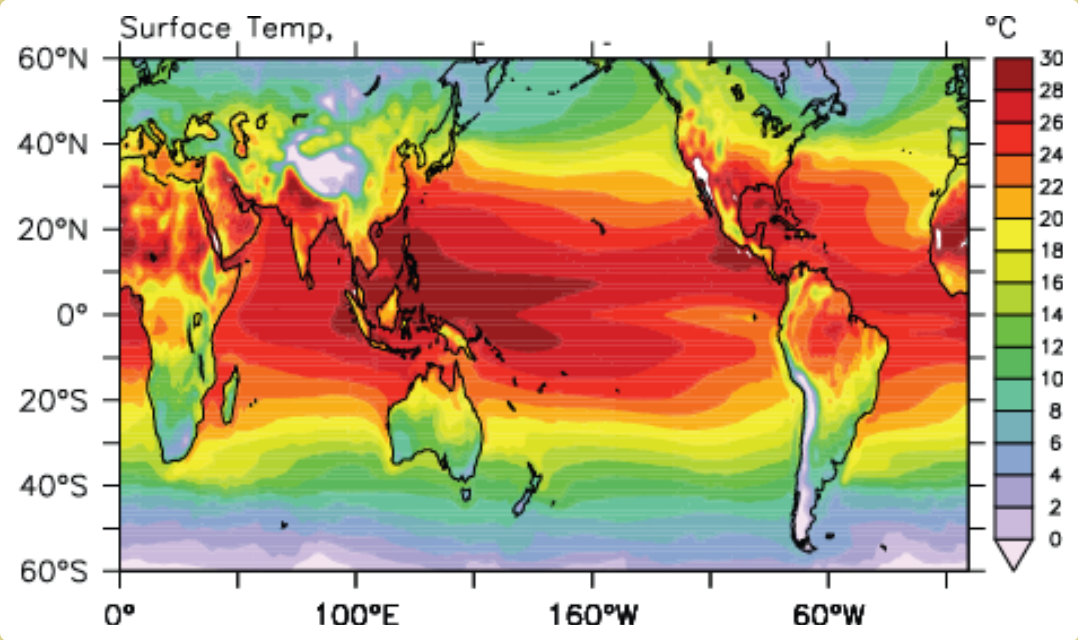
NCO

```
J >
  243.53 242.89 242.34 241.87 241.45
J >
  264.64 264.52 263.75 261.33 259.16
A >
  264.20 263.74 263.20 262.42 261.77
S >
  237.33 237.53 238.16 239.29 240.95
```

GraDs

Ferret

GMT



```
247.21 244.83 242.70 240.88 239.51 238.76
238.52 238.58 238.68 238.82 238.99 239.18
239.17 238.95 238.78 238.42 238.04 237.71
237.43 237.33 237.53 238.16 239.29 240.95
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```

CDO

```
J >
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  264.20 263.74 263.20 262.42 261.77
S >
  237.33 237.53 238.16 239.29 240.95
```
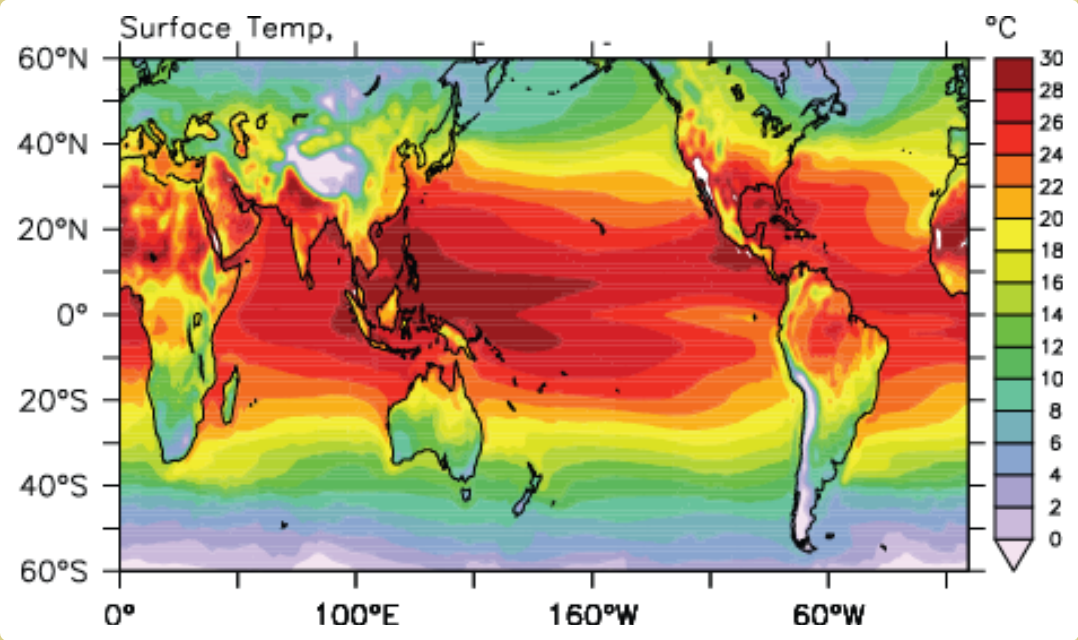

GraDs

Ferret



CDO – Climate Data Operators

CDO is a collection of operators to manipulate and analyze climate and forecast model data.

- Max-Planck-Institute for Meteorology

Current officially released version is cdo 1.5.6
https://code.zmaw.de/projects/cdo

Supported file formats: **GRIB** 1/2, **netCDF** 3/4, srv, ext, and ieg

Supported grid types: rectangular, curvilinear and unstructured

Installing CDO

```
bash$   tar -xvf cdo.tar

bash$   cd cdo

bash$   ./configure --with-netcdf=/usr/local/lib

bash$   make install
```

Magic Word*

* Usage: **cdo** , That's all!

```
bash$ cdo <options> <operator> input.nc out.nc
```

This is all you need to know about CDO

Operators

There are more than 600 operators available.

Categories	Description	Example
File information	Print information about datasets	`cdo sinfo file.nc`
File operations	Copy, split and merge datasets	`cdo mergetime f1995.nc f1996.nc out.nc`
Selection	Select parts of a dataset	`cdo seldate,1996-06-15 f1996.nc out.nc`
Comparison	Compare datasets	`cdo eq`
Modification	Modify datasets	
Arithmetic	Arithmeticly process datasets	`cdo add f1995.nc f1996.nc out.nc`
Statistical values	Ensemble, field, vertical and time statistic	`cdo monmean input.nc out.nc`
Regression	Detrend of time series	
Interpolation	Field, vertical and time interpolation	
Transformation	Spectral transformation	etc.

Global options for all operators:

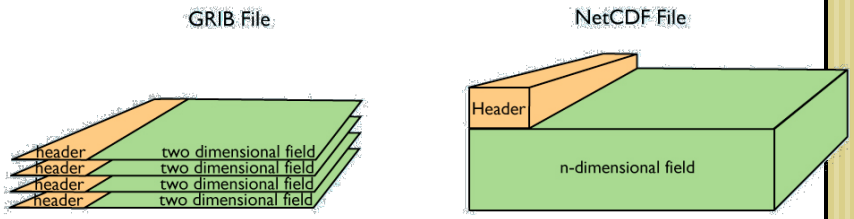
-h Help information for the operators

Eg: `cdo -h <operator>`

-f <format>

Format of the output file (grb, nc, srv, ext, ieg)

Eg: `cdo -f nc copy input.grb out.nc`



-m <missval>

Set the default missing value (default: -9e+33)

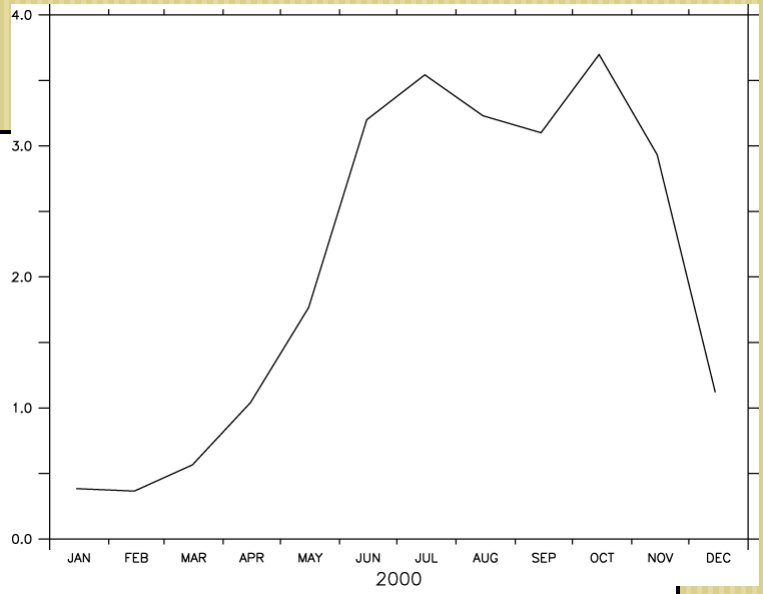
-a Converts from relative to absolute time axis

Eg: `cdo -a -f nc copy input.grb out.nc`

-r Converts from absolute to relative time axis

Eg: `cdo -r -f nc copy input.grb out.nc`

Eg: Annual Cycle of precipitation

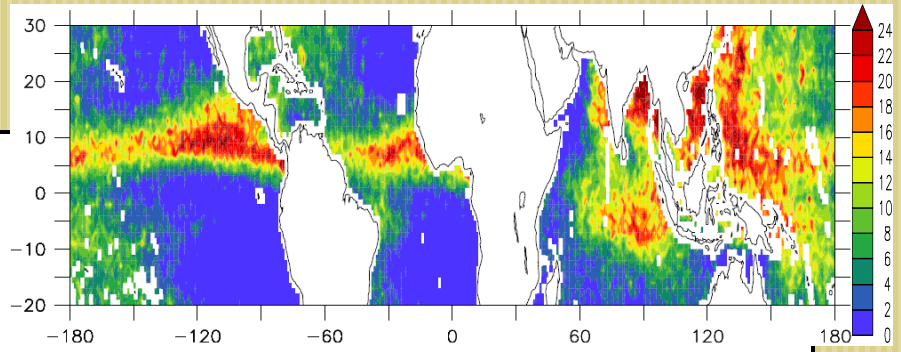


Step by Step:

```
bash$ cdo sellonlatbox,75,85,10,15 input.nc out_box.nc

bash$ cdo fldmean out_box.nc out_box_fldmean.nc

bash$ cdo ymonmean out_box_fldmean.nc out_box_ymonmean.nc
```

Piping:

```
bash$ cdo ymonmean –fldmean -sellonlatbox,75,85,10,15

                        input.nc out_box_ymonmean.nc
```



Piping

→ Reduces unnecessary disk I/O

→ Parallel processing

Eg: Standard deviation of JJAS precipitation anomalies

Step by Step:

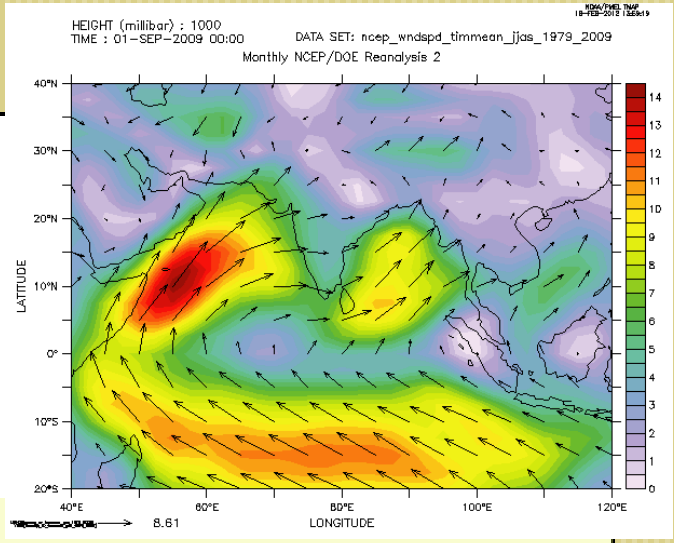
```
bash$ cdo selmon,6,7,8,9 input.nc out_jjas.nc

bash$ cdo timmean out_jjas.nc out_jjas_mean.nc

bash$ cdo sub out_jjas.nc out_jjas_mean.nc  out_jjas_anom.nc

bash$ cdo timstd out_jjas_anom.nc out_jjas_std.nc
```

Piping:

```
bash$ cdo –timstd -sub - selmon,6,7,8,9  input.nc
       -timmean –selmon,6,7,8,9 input.nc out_jjas_std.nc
```

Arithmetic example: sqr, sqrt

wind speed = $\sqrt{(u^2 + v^2)}$



Step by Step:

```
bash$ cdo sqr uwind.nc uwind_sqr.nc

bash$ cdo sqr vwind.nc vwind_sqr.nc

bash$ cdo add uwind_sqr.nc vwind_sqr.nc wind_add.nc

bash$ cdo sqrt wind_add.nc wind_spd.nc
```

Piping:

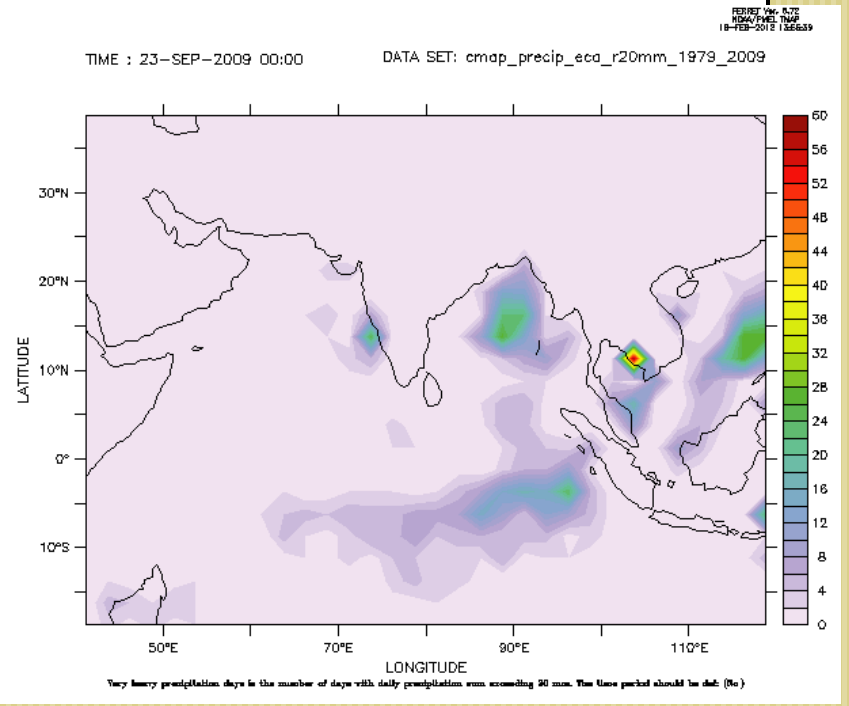
```
bash$ cdo sqrt -add -sqr uwind.nc -sqr vwind.nc wind_spd.nc
```

Indexes

Eg:
ECAR20MM

- Very heavy precipitation days index per time period

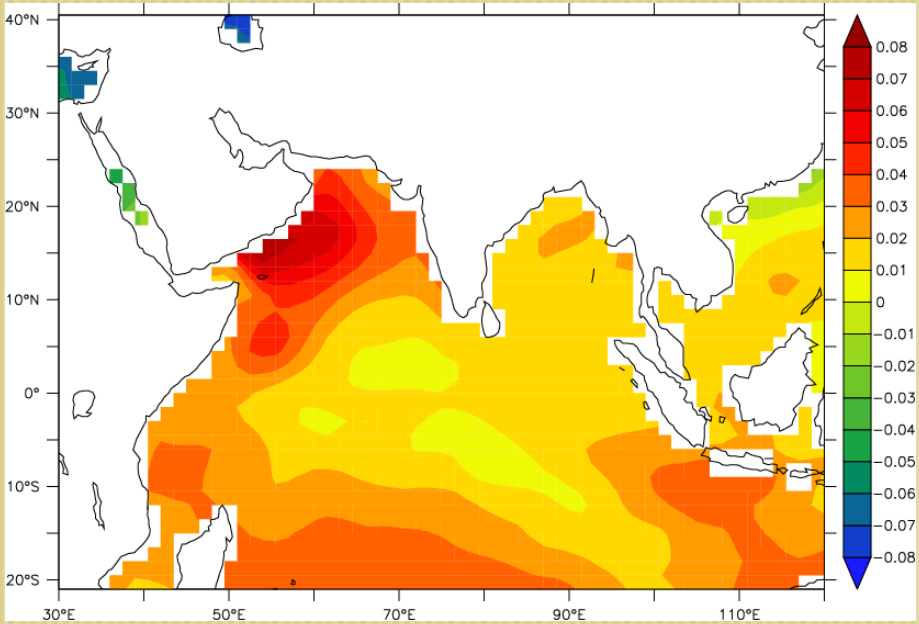
```
bash$ cdo eca_r10mm input.nc output.nc
```



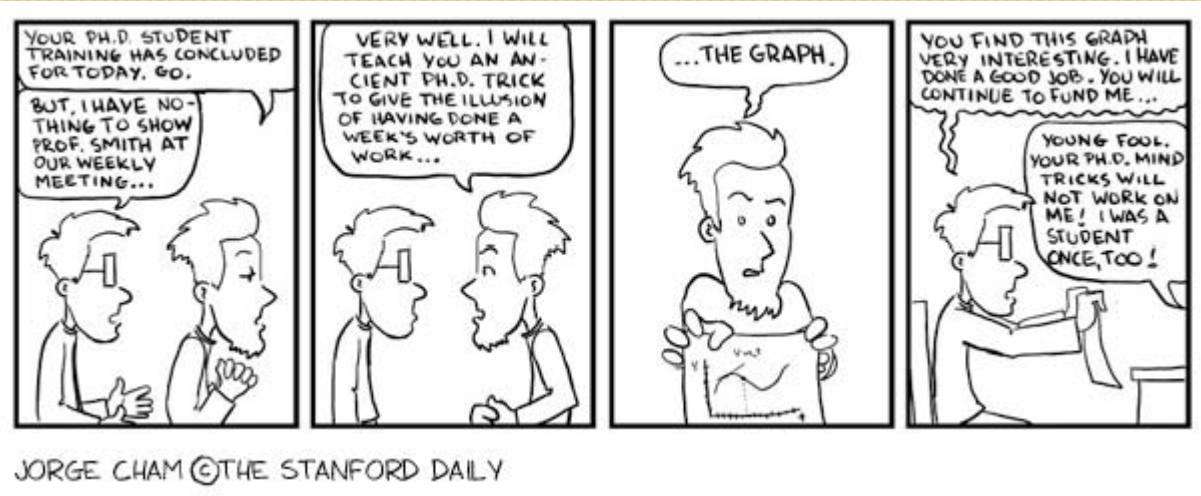
Extended analysis

Eg:
EOF analysis

```
bash$ cdo eof,4 input_anom.nc out1.nc out2.nc
```



Reference and Assignments



url: CDO