

# Worksheet 2a: Introduction to using CDO for analysis and NCL for visualisation



In this worksheet sample PRECIS output over Southeast Asia driven by HadCM3Q0 and ECHAM5 is compared with observations for validation purposes. Validation of model results by comparison with observed data is essential. It is the measure by which we can assess the quality of the model and it informs appropriate uses of the data.

Here, we use PRECIS output driven by two different GCMs. Using data from both experiments will give us two representations of present day climate and two possible climate scenarios. For more details on multimodel approaches see the PRECIS workshop lecture on climate model ensembles.

The following are examples of types of analyses undertaken as part of a model validation. The methods shown are not necessarily the only way to proceed and are intended to demonstrate the use of CDO tools in model validation, and provide a starting point for your own analyses. For further help on validating your PRECIS simulations, refer to the PRECIS workshop lecture notes.

The first worksheet uses xconv to visualise the data, whilst this is a useful tool to look quickly at results, it is not suitable for use in reports and papers. NCL visualisation software can produce high quality plots, this will be introduced in this worksheet.

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**Note:** The data used here has been processed in the same way as Worksheet 1. The 8 point-rim has been removed and it has been converted from PP to netCDF format.

## 2.1 Introduction to CDO

CDO stands for Climate Data Operators, it is a free open source tool set and like PP tools, it is used at the Linux command line. For further details and documentation see <https://code.zmaw.de/projects/cdo/wiki>.

The datasets used here are daily and monthly data from two PRECIS runs carried out over Southeast Asia, one driven by HadCM3Q0 and the other driven by ECHAM5. The observations used for comparison are APHRODITE and CRU.

1. ) Find out more information about the monthly precipitation file 1961-1990 of experiment **cahpa**.

**infov** writes information about the structure and content of the netCDF file to screen.

```
% DATA=/media/sf_kl2/ # change this for your computer if necessary
% cd $DATA/monthly
% ls
```

The runid of the HadCM3Q0 driven run is **cahpa** and the runid of the ECHAM5 driven run is **cahpb**.

```
% cd cahpa/05216
% cdo infov cahpaa.pm.6190.05216.rr8.nc
```

## 2.2 Climatological mean calculation

1 a. ) Calculate the 1960-1990 seasonal mean precipitation field for October-December (OND) from both the HadCM3Q0 (**cahpa**) and ECHAM5 (**cahpb**) driven PRECIS runs.

**timmean** calculates the mean over all timesteps in a file. We have combined **timmean** with **selmon** and **selyear** to be selective about the time period (e.g. selecting only OND - months 10,11 and 12.)

Firstly for **cahpa**

**Note:** sometimes commands are too long to fit on one line, if a line does not start with %, the command is continued on the next line and you should not press enter until it is complete.

```
% cd $DATA/monthly
% mkdir climatology # creates a new directory called climatology
% cdo timmean -selmon,10/12 -selyear,1961/1990 cahpa/05216
```

```
/cahpaa.pm.6190.05216.rr8.nc climatology/cahpaa.OND.mean.baseline.05216.nc
% xconv -i climatology/cahpaa.OND.mean.baseline.05216.nc
```

### Secondly for cahpb

```
% cdo timmean -selmon,10/12 -selyear,1961/1990 cahpb/05216
/cahpba.pm.6190.05216.rr8.nc climatology/cahpba.OND.mean.baseline.05216.nc
% xconv -i climatology/cahpba.OND.mean.baseline.05216.nc
```

**1 b. )** Convert the OND mean fields for both runs from kg/m<sup>2</sup>/s to mm/day (multiply by 86400.)

**mulc** multiplies the field by a constant. Similar operators exist for division, subtraction and addition.

```
% cdo mulc,86400 climatology/cahpaa.OND.mean.baseline.05216.nc
climatology/cahpaa.OND.mean.baseline.05216.mmday.nc
% cdo mulc,86400 climatology/cahpba.OND.mean.baseline.05216.nc
climatology/cahpba.OND.mean.baseline.05216.mmday.nc
```

**2. )** Calculate the 1961-1990 seasonal mean for OND from the APHRODITE observation data.

```
% cd $DATA/monthly/APHRODITE
% cdo timmean -selmon,10/12 -selyear,1961/1990 aphro.mon.6190.nc
../climatology/aphro.OND.mean.baseline.05216.nc
% xconv -i ../climatology/aphro.OND.mean.baseline.05216.nc
```

**Note:** APHRODITE is a daily high resolution (0.25 degree) rain gauge based precipitation data set over Asia 1950-2007. See <http://www.chikyu.ac.jp/precip/> for more information.

## 2.3 Mean annual cycle calculation

**1 a. )** Extract the area around Kuala Lumpur from the monthly PRECIS precipitation data for both the HadCM3Q0 and ECHAM5 driven runs by specifying lon and lat co-ordinates.

**sellonlatbox** allows you to extract an area from fields by choosing lon1,lon2,lat1,lat2.

```
% cd $DATA/monthly/cahpa/05216
% cdo sellonlatbox,101,101.7,2.5,3.5 cahpaa.pm.6190.05216.rr8.nc
cahpaa.pm.6190.05216.rr8.ext.nc

% cd $DATA/monthly/cahpb/05216
% cdo sellonlatbox,101,101.7,2.8,3.5 cahpba.pm.6190.05216.rr8.nc
cahpba.pm.6190.05216.rr8.ext.nc
```

**1 b. )** Calculate monthly mean fields for 1961-1990 for each of the twelve months for the KL area.

**ymonmean computes the mean of all the time steps of multiple years in each month.**

```
% cd - # returns you to the directory you were previously in
% cdo ymonmean -selyear,1961/1990 cahpaa.pm.6190.05216.rr8.ext.nc
$DATA/monthly/climatology/cahpaa.monmean.baseline.05216.rr8.ext.nc
% cd $DATA/monthly/cahpb/05216
% cdo ymonmean -selyear,1961/1990 cahpba.pm.6190.05216.rr8.ext.nc
$DATA/monthly/climatology/cahpba.monmean.baseline.05216.rr8.ext.nc
```

**Convert the monthly mean fields to mm/day**

```
% cd $DATA/monthly/climatology
% cdo mulc,86400 cahpaa.monmean.baseline.05216.rr8.ext.nc
cahpaa.monmean.baseline.05216.rr8.ext.mmday.nc
% cdo mulc,86400 cahpba.monmean.baseline.05216.rr8.ext.nc
cahpba.monmean.baseline.05216.rr8.ext.mmday.nc

% cdo infov cahpaa.monmean.baseline.05216.rr8.ext.mmday.nc
% cdo infov cahpba.monmean.baseline.05216.rr8.ext.mmday.nc
```

**What is the mean precipitation amount in mm/day for the HadCM3Q0 and ECHAM5 driven PRECIS runs?**

Month	cahpa (mm/day)	cahpb (mm/day)
1 - January		
2 - February		
3 - March		
4 - April		
5 - May		
6 - June		
7 - July		
8 - August		
9 - September		
10 - October		
11 - November		
12 - December		

**2. ) Now find monthly means 1961-1990 for observations.**

```
% cd $DATA/monthly/APHRODITE
% cdo sellonlatbox,101,101.7,2.8,3.5 -selyear,1961/1990 aphro.mon.6190.nc
aphro.mon.6190.ext.nc
% cdo ymonmean aphro.mon.6190.ext.nc ../climatology
/aphro.monmean.baseline.05216.ext.nc
```

**How do the observations compare to the models? In what months are there the greatest**

differences?

Month	APHRODITE observations (mm/day)
1 - January	
2 - February	
3 - March	
4 - April	
5 - May	
6 - June	
7 - July	
8 - August	
9 - September	
10 - October	
11 - November	
12 - December	

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## 2.4 Comparing models and observations

To fairly compare spatial model and observation fields they must firstly be on the same grid. We will regrid to the coarsest grid and then subtract the model field from the observations. In this case, the observations have the coarsest resolution so we will regrid the model data onto the observation grid.

1.) Regrid the multiannual OND mean model fields onto the observations grid.

**griddes** a command which prints a description of the input field(s) grid.

**remapbil** this operator remaps all input fields to a new horizontal grid using bilinear interpolation.

```
% cd $DATA/monthly/climatology
% cdo griddes aphro.OND.mean.baseline.05216.nc > mygrid
% cdo remapbil,mygrid cahpaa.OND.mean.baseline.05216.mmday.nc
```

```
cahpa.OND.mean.baseline.05216.mmday.rg.nc
% cdo remapbil,mygrid cahpba.OND.mean.baseline.05216.mmday.nc
cahpba.OND.mean.baseline.05216.mmday.rg.nc

% xconv -i cahpa.OND.mean.baseline.05216.mmday.rg.nc
```

**Note:** *mygrid is used as the target grid for remapping.*

**2 a. )** Find the difference between the model and observation OND multiannual mean fields.

**sub** this operator subtracts one field from another, similar operators exist for addition, multiplication and division.

```
% cdo sub cahpa.OND.mean.baseline.05216.mmday.rg.nc
aphro.OND.mean.baseline.05216.nc diff.cahpa_aphro.OND.baseline.nc
% cdo sub cahpba.OND.mean.baseline.05216.mmday.rg.nc
aphro.OND.mean.baseline.05216.nc diff.cahpb_aphro.OND.baseline.nc
% xconv -i diff.cahpb_aphro.OND.baseline.nc
```

**2 b. )** Extract the RCM domain from the difference fields (this improves plotting.)

```
% cdo sellonlatbox,90,137,-14,31 diff.cahpa_aphro.OND.baseline.nc
diff.cahpa_aphro.OND.baseline.ext.nc
% cdo sellonlatbox,90,137,-14,31 diff.cahpb_aphro.OND.baseline.nc
diff.cahpb_aphro.OND.baseline.ext.nc
% xconv -i diff.cahpb_aphro.OND.baseline.ext.nc
```

## 2.5 Climatological mean and annual cycle for an ensemble

So far data from two models downscaled with PRECIS have been used. In this section an ensemble of six models is used, five from the HadCMQ QUMP ensemble (discussed in the model ensemble lecture) and one ECHAM5 model. The five members of the QUMP ensemble are **HadCM3Q0** (cahpa), **HadCM3Q3** (cahpc), **HadCM3Q10** (cahpd), **HadCM3Q11** (cahpe) and **HadCM3Q13** (cahpf).

Taking an ensemble approach allows us to account for a range of uncertainty in the model projections. Typing the CDO commands into the command line for all six ensemble members would be very time consuming, so we use a script instead.

**1 . )** Calculate the OND seasonal mean and annual cycle (for the KL area) for 1.5m temperature for all six ensemble members and **CRU** observations. Also find the difference between model runs and observations.

The script **worksheet2.sh** contains all the CDO commands needed to calculate the OND mean, annual cycle and difference between models and observations for **cahpa**, **cahpb**, **cahpc**, **cahpd**, **cahpe**, and **cahpf**.

The top of the script needs to be edited to correct the location of `DATA` before running.

```
% cd $DATA
% emacs worksheet2.sh &
% ./worksheet2.sh
```

**Note:** CRU is a monthly global land only data set (1901-2002) at 0.5 degree resolution. Nine variables are available, including mean, min and max temperature and precipitation. For further details see [http://www.cru.uea.ac.uk/~timm/grid/CRU\\_TS\\_2\\_1.html](http://www.cru.uea.ac.uk/~timm/grid/CRU_TS_2_1.html).

2. ) Calculate the OND seasonal mean and annual cycle (for the KL area) for precipitation for all six ensemble members and **APHRODITE** observations. Also find the difference between model runs and observations.

Use the same script (**worksheet2.sh**) but change `stash` from 03236 to 05216 to change the script from calculating temperature to precipitation.

```
% emacs worksheet2.sh &
% ./worksheet2.sh
```

## 2.6 Introduction to NCL for visualisation

NCL is a powerful visualisation tool. It is easy to learn and can be scripted. Many examples of scripts and plots are available from <http://www.ncl.ucar.edu/>

To check if NCL is working simply type `ncl` on the command line. You should see something like:

```
Copyright (C) 1995-2011 - All Rights Reserved
University Corporation for Atmospheric Research
NCAR Command Language Version 6.0.0
The use of this software is governed by a License Agreement.
See http://www.ncl.ucar.edu/ for more details.
ncl 0>
```

Now type `exit`

1. ) Run an NCL script to plot the annual cycle of precipitation and temperature for the model and observations.

The script **annualcycle.ncl** uses the fields generated in section 2.5 to plot the annual cycle of precipitation and temperature. It reads in the NetCDF fields and finds the area mean for each month before plotting. It outputs a .png plot called **annualcycle.png**. Open the script for editing.

```
% cd $DATA/ncl_scripts
% emacs annualcycle.ncl & # you can use which ever text editor you prefer
```

Before running this script two changes need to be made. At the top of the script, change `data_dir` to be the location of the `climatology` directory which contains the data to be plotted. Also change `plot_location` to the location of the `ncl_scripts` directory.

```
% ncl annualcycle.ncl
% display annualcycle.png
```

**How does the annual cycle of the six ensemble members compare to observations and each other, what are the differences?**

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**2. ) Run an NCL script to plot mean OND precipitation fields for both PRECIS experiments and APHRODITE observations.**

The script **precip\_OND\_mean.ncl** uses the fields generated in section 2.2 to plot OND mean precip fields. It outputs a .png plot called **precip\_OND\_mean.png**, open the script for editing.

```
% emacs precip_OND_mean.ncl & # you can use which ever text editor you prefer
```

Before running this script two changes need to be made. At the top of the script, change `data_dir` to be the location of the `climatology` directory which contains the data to be plotted. Also change `plot_location` to the location of the `ncl_scripts` directory.

```
% ncl precip_OND_mean.ncl  
% display precip_OND_mean.png
```

**How do the two PRECIS runs compare to each other and observations?**

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**3. ) Run an NCL script to plot OND model minus observation fields for all six ensemble members. Do this for both precipitation and temperature**

The script **OND\_diff.ncl** uses the fields generated in section 2.5 to plot two difference fields. It outputs a .png plot called **OND\_diff.png**, open the script for editing.

```
% emacs OND_diff.ncl & # you can use which ever text editor you prefer
```

Before running this script two changes need to be made. At the top of the script, change `data_dir`



to be the location of the `climatology` directory which contains the data to be plotted. Also change `plot_location` to the location of the `ncl_scripts` directory.

```
% ncl OND_diff.ncl  
% display OND_diff.png
```

**How do the six ensemble members compare to observations, where are the biggest temperature/precipitation differences?**

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**2.7 Optional question**

If you have time, repeat the analysis of the above worksheet for the season June, July and August e.g. JJA.

- (1) How do the seasons compare to each other?
- (2) Are the model biases with respect to the observation the same in both seasons?

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