Earth System Dynamics and Modelling: Parameterization lab class 1

Adrian Tompkins, ICTP, Trieste, Italy

Email: tompkins@ictp.it

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1 Introduction

We are going to use an ECMWF output field in *netcdf* format.

The contains variables on model levels for one day for:

- T : Temperature
- r : Relative Humidity (calculated as in the model)
- q : specific humidity
- $clwc$: Specific cloud liquid water content
- $ciwc$: Specific ice liquid water content
- cc : Cloud Cover

The last 3 cloud variables are produced by the ECMWF prognostic cloud scheme described in Tiedtke (1993) and Tompkins et al. (2007).

The aim of this exercise is to code up some simple DIAGNOSTIC RH-based cloud cover parameterizations and compare how they do relative to the prognostic scheme.

We are going to do this using three tools:

- `ncview` : to quicklook view netcdf files
- `ncdump` : To examine netcdf file headers and contents
- `cdo` : climate data operators, a programme to manipulate netcdf files (`https://code.zmaw.de/projects/cdo`)

2 Exercise 1: coding up the Sundqvist scheme

We will work together through exercise 1, while the subsequent exercises you will perform in your groups.

1. code up the Sundqvist scheme (SS) to diagnose CC as a function of RH
2. examine maps of the bias between ECMWF CC and Sundqvist CC
3. show a vertical profile of the RMS error (difference) between ECMWF and Sundqvist CC (a) globally (b) Tropics (lat < 20) (c) NH extra tropics (lat> 30 deg).

Reminder: Subgrid-scale fluctuations allow cloud to form when $\overline{RH} < 1$. RH schemes formulize this by setting a critical RH (denoted RH_{crit}) at which cloud is assumed to form, and then increase C according to a monotonically increasing function of RH, with C=1 identically when RH=1.

One commonly used function was given by Sundqvist et al. (1989):

$$C = 1 - \sqrt{\frac{1 - RH}{1 - RH_{crit}}} \qquad (1)$$

In this first exercise we will assume RH_{crit}=0.6

Get the datafile `ecmwf_data.nc` here:
`http://clima-dods.ictp.it/Users/tompkins/diploma/`

Examine the file :
```
ncdump -h ecmwf_data.nc
```

View the file
```
ncview ecmwf_data.nc
```

Using `cdo` - Download the manual from the clima-dods page, or the cdo page. The general form of cdo is
```
cdo command input output
```

e.g. Extract the fields we need:
`cdo selvar,r ecmwf_data.nc rh.nc`
`cdo selvar,cc ecmwf_data.nc cc.nc`

The RH field has units of percent - we change it to a fraction first: `cdo divc,100 rh.nc rhf.nc`

Let's form the equation. We can do this from the command line or by putting the commands in a bash script.

How to calculate $1 - RH$?
`cdo mulc,-1 rhf.nc rhm.nc`
`cdo addc,1 rhm.nc 1-rh.nc`

`cdo` also allows you to *pipe* commands:
`cdo addc,1 -mulc,-1 rhf.nc 1-rh.nc`

Now we divide by $1 - RH_{crit}$:
`cdo divc,0.4 1-rh.nc 1-rh_d_1-rhc.nc`

Now, remember that RH can exceed 1.0, or be less than RH_{crit} and so we want to clip those negative values or values exceeding 1. To do this we need to define a mask - for negative values it is straightforward:
`cdo gec,0 1-rh_d_1-rhc.nc mask.nc`
`cdo mul 1-rh_d_1-rhc.nc mask.nc temp1.nc`

for max values is a little more tricky. This is one way, perhaps you can find a quicker one:
`cdo gtc,1 temp1.nc mask_high.nc`
`cdo lec,1 temp1.nc mask_low.nc`
`cdo mul temp1.nc mask_low.nc temp2.nc`
`cdo add temp2.nc mask_high.nc 1-rh_d_1-rhc_bnd.nc`

Clean some files: `rm -f temp?.nc`

Now we finish the equation by adding the 1-SQRT part:
`cdo addc,1 -mulc,-1 -sqrt 1-rh_d_1-rhc_bnd.nc sundqvistcc.nc`

check it out:
`ncview sundqvistcc.nc`

Calculate the difference map between Sundqvist CC and Tiedtke CC:
`cdo sub sundqvistcc.nc cc.nc ccdiff.nc`
`ncview ccdiff.nc`

3 NCO: more powerful metadata manipulation

While CDO can change some attributes of variables, it is quite limited in what it can do regarding the dimensions, variables, metadata, and global attributes in a netcdf file. For this task, a much more powerful set of functions are available collectively in NCO. NCO commands also allow you to directly modify the netcdf file, but it is better to test the function first!

As an example of NCO, we presently have a file sundqvist.nc that contains our diagnostic cloud cover, but the variable name still refers to relative humidity. This could be misleading if we pass the file to someone else, even if the CDO command history is stored in the global attributes.

To change the variable name to cloud cover (cc), we can thus use `ncrename` (`http://linux.die.net/man/1/ncrename`):
`ncrename -v r,cc -h sundqvistcc.nc`

This is fine but we may also want to change the variable metadate. For this we use `ncatted` (see `http://linux.die.net/man/1/ncatted`):
`ncatted -O -a units,cc,o,c,fraction`
`ncatted -O -a long_name,cc,o,c,''cloud fraction''`

Note the double quotes if the name has a space.

4 Exercise 2: Some summary statistics

Ex 2: For the following you will need the new CDO commands
```
sellonlatbox fldmean
```

1. Calculate the mean bias as a function of height (=model level)
2. Calculate the RMS error as a function of height
3. Repeat for the tropics (mod(lat)< 20 deg) and NH extratropics (lat> 30 deg).
4. Try to make a plot of the PDF of cloud cover - Describe and interpret what you find?

5 Exercise 3: Improving the self-consistency

Ex 3:The Tiedtke scheme has liquid and ice cloud water as prognostic variables. Basing the CC only on RH will likely lead to non-zero cloud cover being diagnosed where the cloud water (ice+liquid) is zero. In this exercise, use a mask to set the diagnosed Sundqvist cloud cover to zero in any grid box where the total cloud water (ice+liquid) is zero. Repeat the analysis of Exercise 2. Does the use of the self-consistent cloud water improve the match of the Sundqvist and Tiedtke cloud cover?

6 Exercise 4: Impact of subgrid variability

Ex 4: What parameter in the sundqvist scheme represents the amount of subgrid-scale variability? Does subgrid-scale variance of water increase or decrease when this parameter is increased? Investigate the impact of setting the threshold for cloud formation to 50, 70, 80 and 90%, does the cloud fraction respond as you would expect? Do you find that one value works best at all heights, or do you find that different thresholds are appropriate at different heights?

7 Exercise 5: The Xu and Randall scheme

Ex 5: Xu and Randall (1996) used a cloud resolving model (CRM) to derive an empirical relationship for cloud cover based on the two predictors of RH and cloud water content:

$$C = RH^p \left[1 - exp \left(\frac{-\alpha_0 \overline{q_l}}{(q_s - q_v)^\gamma} \right) \right], \tag{2}$$

where γ, α_0 and p are 'tunable' constants of the scheme, with values chosen using the CRM data.

For exercise 3, look up the paper online to get the constants and code up the scheme. Repeat the questions in exercise 2 with this new scheme. Which scheme is closer to ECMWF's Tiedtke scheme, the Xu or the Sundqvist scheme?

References

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