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Climate modelling and approaches to regional and local downscaling

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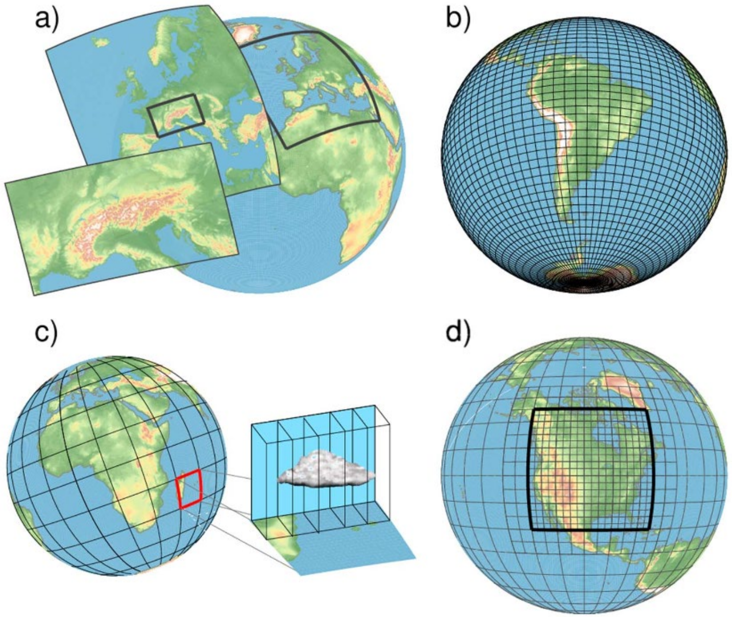
Regional climate change projections: Climate change analysis using CORDEX regional climate models over South Asia

13 October 2020 | Online via Microsoft Teams

Overview

- Discuss different ways of downscaling global climate models (GCMs) to obtain fine-scale climate information
- Explore the suitability of different several downscaling methods, and how they can add value
- Discuss different RCM evaluation techniques and aspects to consider



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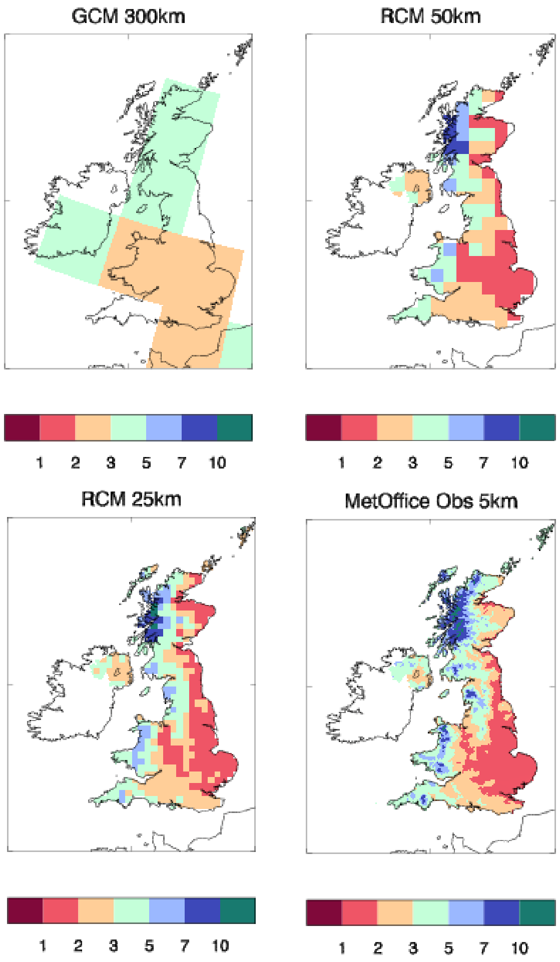
Why downscale?

- Impact assessors need regional detail to assess vulnerability and possible adaptation strategies
- However:
  - GCMs lack regional details due to coarse resolution
  - Smaller scale climate results from an interaction between global climate and local physiographic details and from unresolved motions and processes
  - There is an increasing need to better understand the processes that determine regional climate



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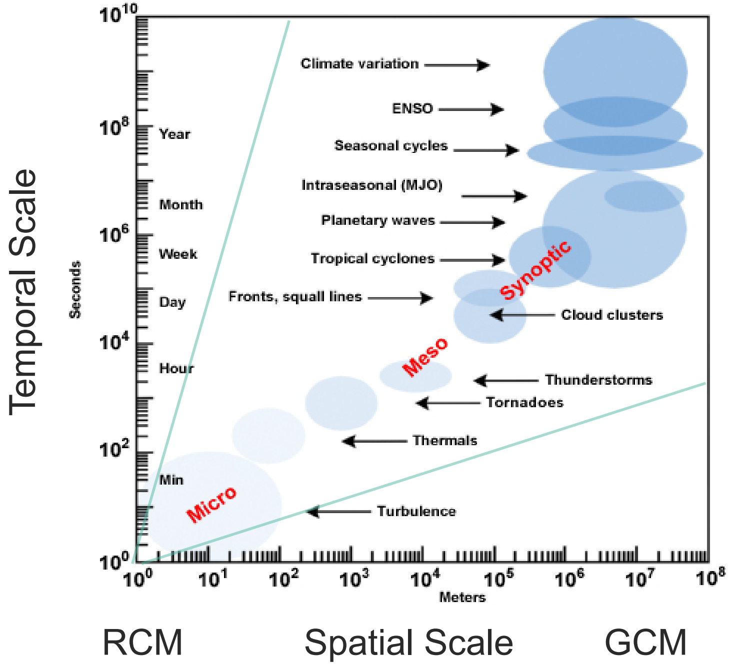
Coarse spatial resolution is not the only problem

- At typical resolutions, GCMs can skilfully resolve large weather systems – systems at the synoptic scale.
- These systems have a lifetime of several days.
- Shorter time scales and details of these systems requires higher horizontal resolutions – systems at the meso scale



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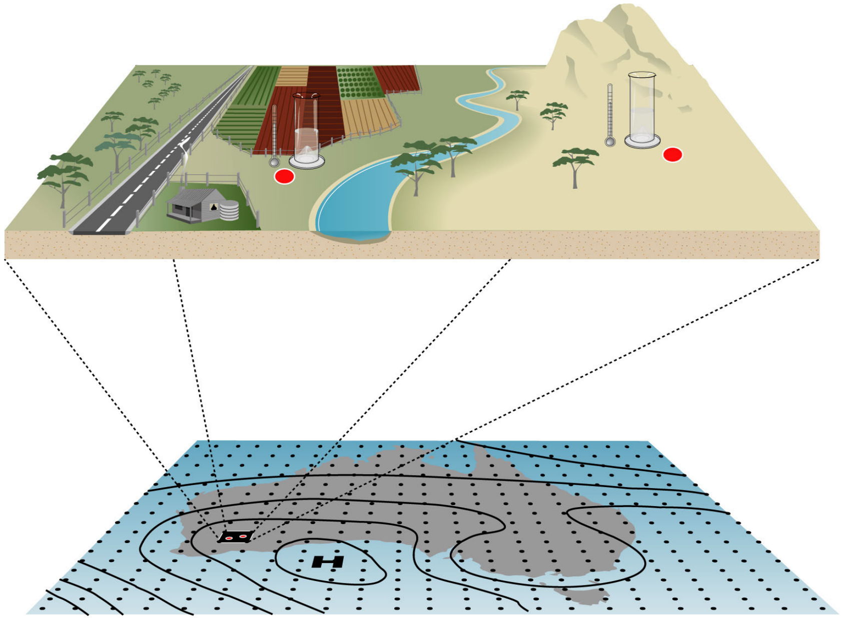
Multiple environments in a single grid box



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Downscaling techniques

100-300km

Coarse atmospheric data (T, Q, winds, pressure etc)

Statistical

Statistical relationship between large- and local- scale. Derived from present / historical climate.

$$fine\ scale\ value = \emptyset(large\ scale\ variable)$$

Dynamical

Numerical models at fine resolution over region of interest.

Fits output from GCM into a LAM or RCM.

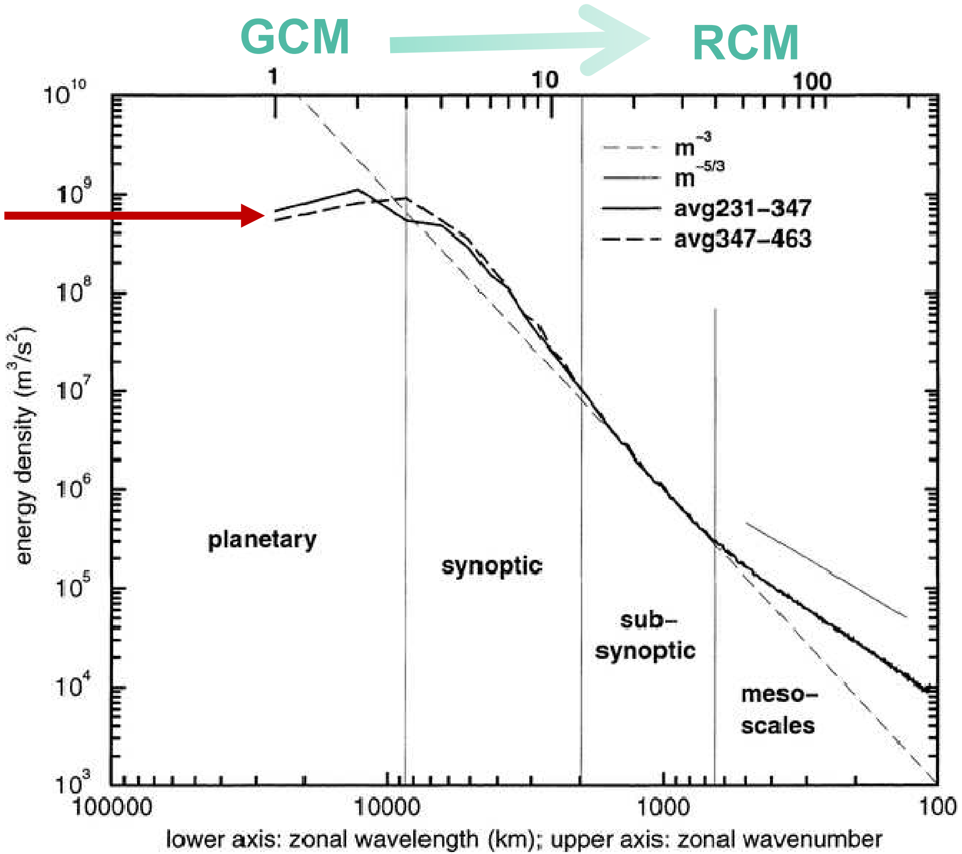
High resolution AOGCM

50km-1km

Local surface data (T, rainfall, winds, Q etc)

Why do these techniques work?

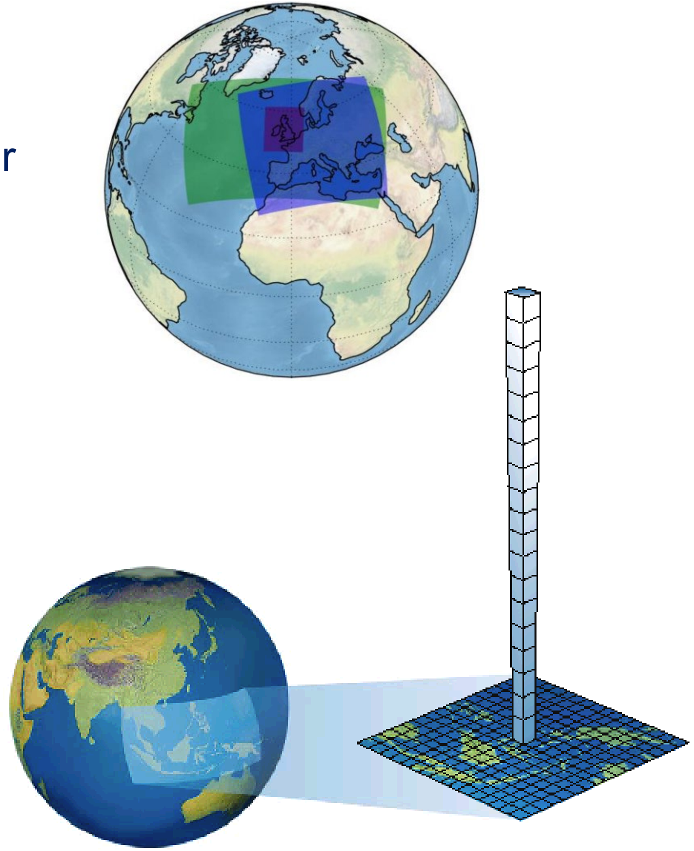
- The largest fraction of the energy of the atmospheric motion is due to very large scale systems.
- These systems are the main drivers of local scale weather.



Regional climate modelling

What is an RCM?

- An RCM is
  - an example of a **Limited Area Model (LAM);** similar to those used in Numerical Weather Prediction (NWP) i.e. short-term weather forecasting
  - a physically-based high resolution model
    - Includes atmosphere and land surface components
    - Contains representation of important processes
  - one-way nested: driven at boundaries by GCM or observed data
  - highly dependent on boundary conditions



Lateral Boundary Conditions (LBCs)

What are LBCs?

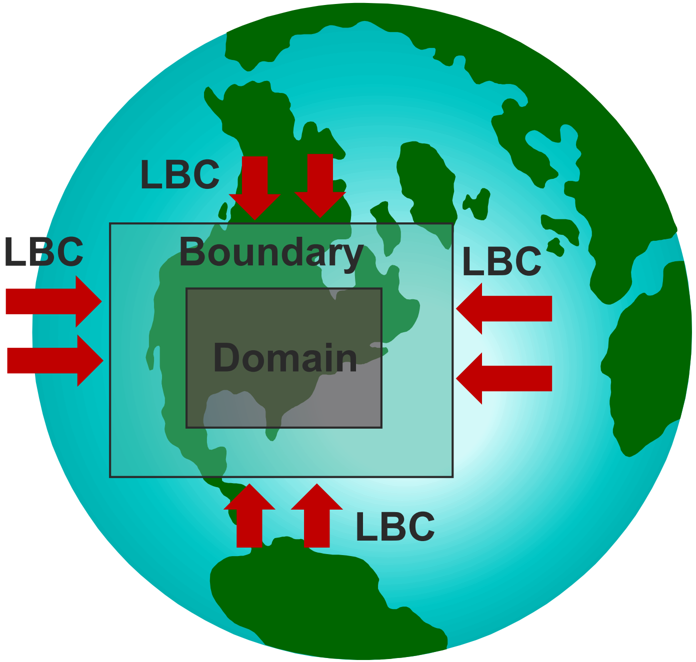
- Meteorological boundary conditions at the lateral (side) boundaries of the RCM domain (time dependent large scale data)
- E.g. Wind, Temperature, Water, Pressure, Aerosols

Why are LBCs important?

- Constrain the RCM throughout the simulations
- Provide the information the RCM needs from outside the domain

Where to LBCs come from?

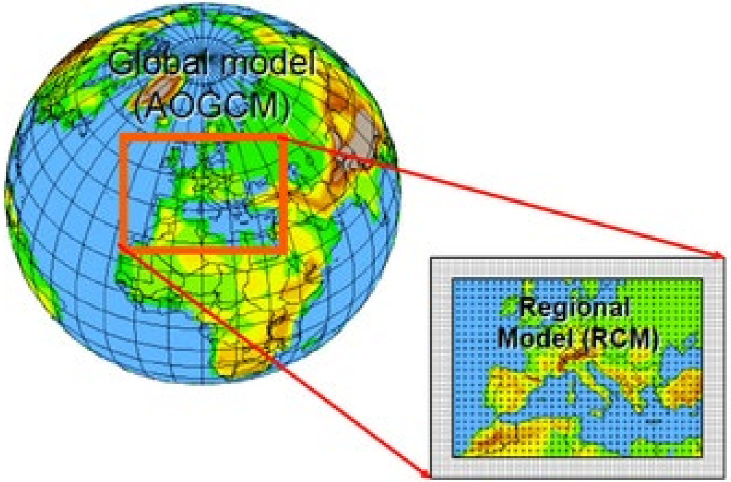
- GCMs
- reanalysis



Choice of domain and simulation length

Optimum domains:

- Are not too large or small.
    - Continental scale (5000km x 5000km)
        - Smaller domains: no mesoscale features
        - Larger domains: lose consistency with large scale atmospheric flow
- Will complete in a reasonable amount of time.
- Have the area of interest in the domain centre
- Encompass important climatological influences

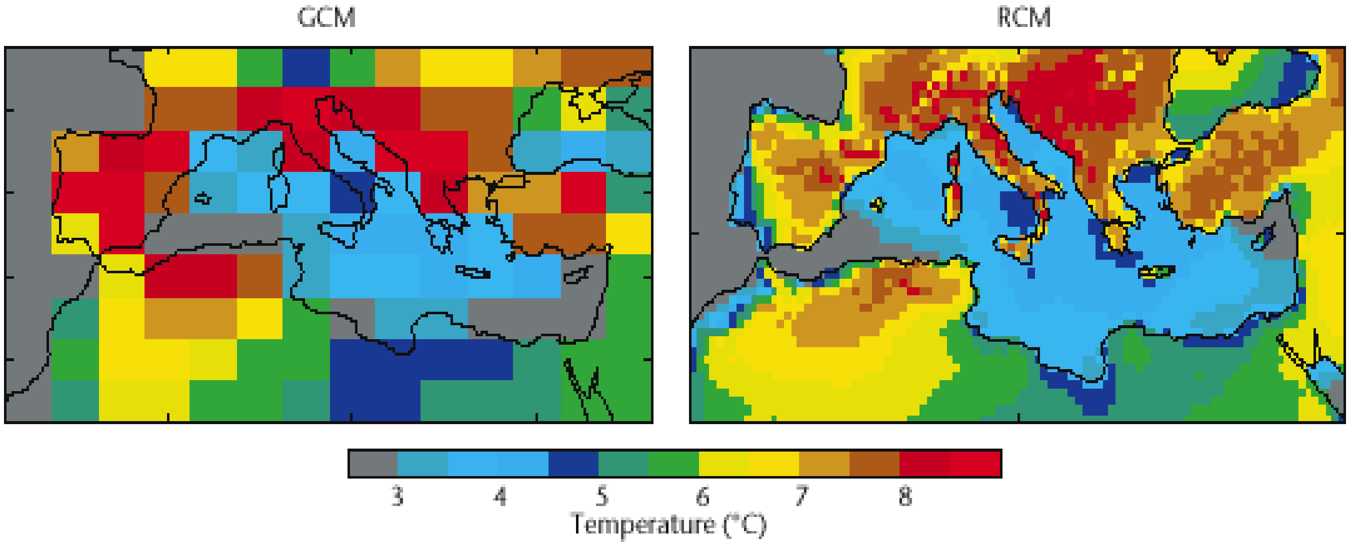


Optimum simulation length:

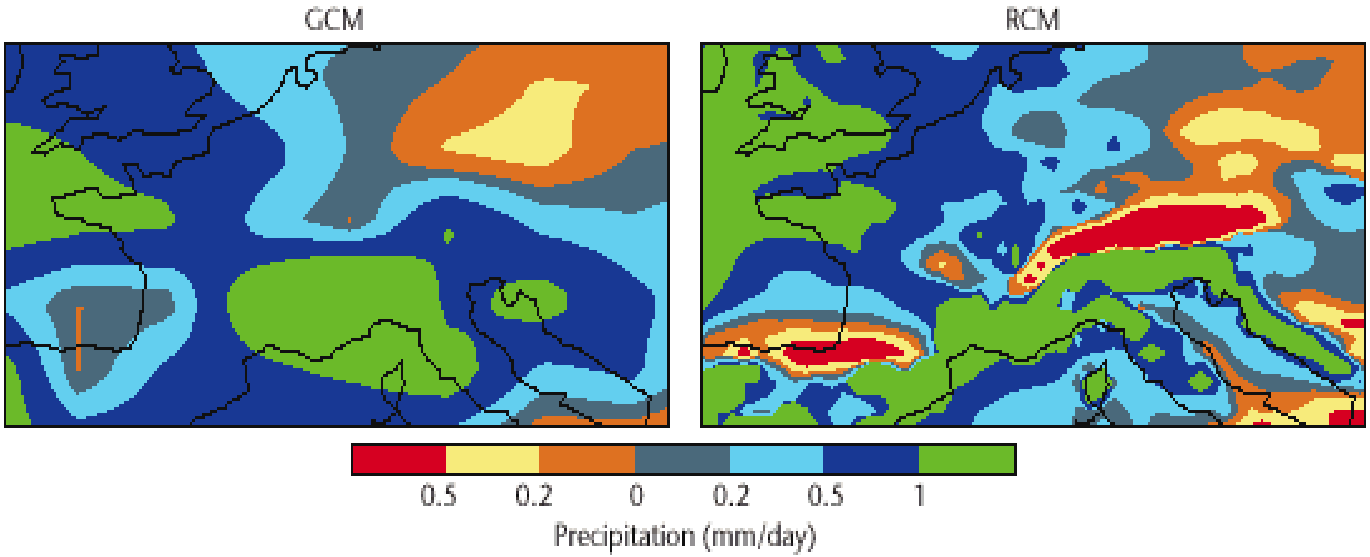
- Longer periods are better
- 30 years or more to study higher order statistics, climate variability, extremes, etc
- Multi-annual mode of variability (e.g ENSO) should also be considered

Added value of RCMs – some examples

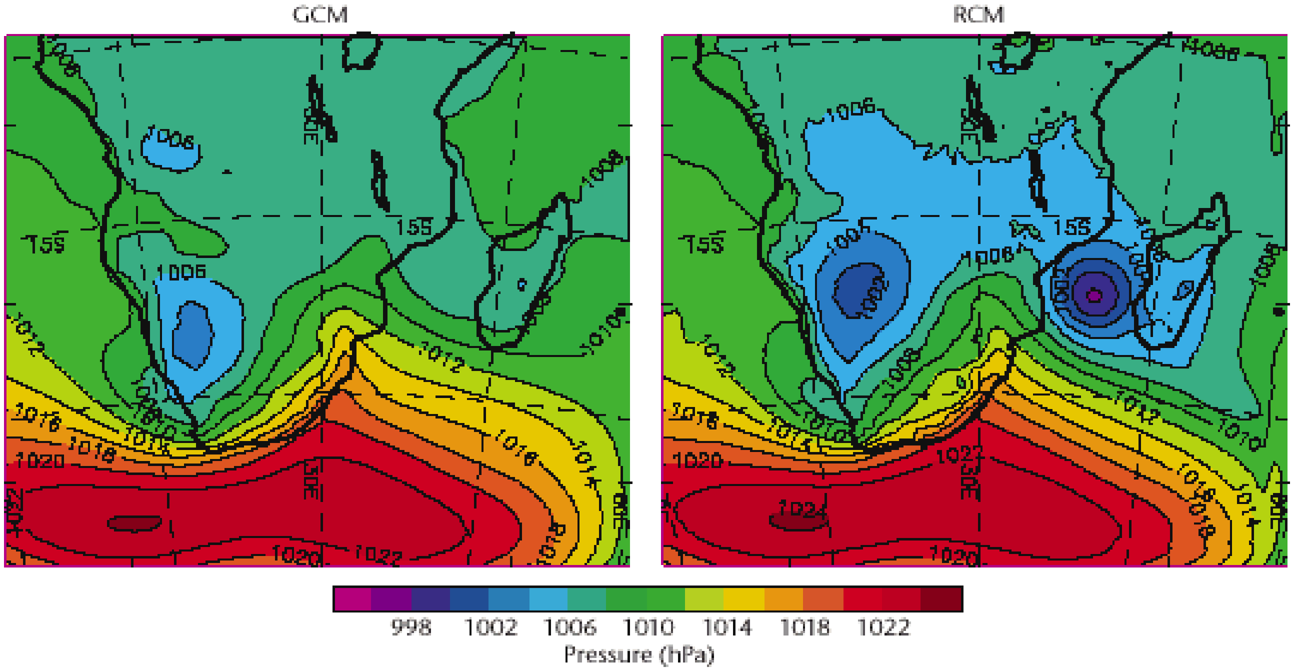
Projected changes in summer surface air temperature between present day and the end of the 21st century.



Projected changes in winter precipitation between 1970s and 2080s.



High and Low pressure systems



Model Evaluation

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What is a model evaluation?

An assessment of **how well** the model is able to **simulate the "present day**" climate

For a climate model, it is difficult to define an overall skill score for long-term projections. Each model tends to simulate some aspects of the climate system well and others not so well, and each model has its own set of strengths and weaknesses.

We do not need a perfect model, just one that serves the purpose

Why is it important?

- It enables you to gain **familiarity** with the model characteristics
- It indicates **which aspects** of the model simulation **are most credible**
- …and therefore indicates how to make the best, most credible**, use of the data** to answer relevant questions

The model evaluation process:

Stages of model evaluation:

1) Identify target and purpose
2) Obtain multiple sources of observed data
3) Assess errors and biases in the GCM
4) Evaluate RCM

1) Identify the target and **purpose of the evaluation**

2) **Obtain** multiple sources of **observed data** to evaluate model performance

3) Assess the **errors and biases in the GCMs** that provide the LBCs for the RCM

4) **Evaluate the RCM** acknowledging the multiple sources of uncertainty
   (splits into 4 types of model evaluation)

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Stages of model evaluation:

1) Identify target and purpose
2) Obtain multiple sources of observed data
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Which aspects of the climate system are of most interest?

- Which processes are key to understanding climate variability/change in the focus region?
- Which variables are of most interest?

Which time and space scales are of most interest?

- Extreme or rare events, or multi-year averages?
- Does the model need to provide accurate data at a specific spatial scale?

Choice of observed data

Stages of model evaluation:

1) Identify target and purpose
2) Obtain multiple sources of observed data
3) Assess errors and biases in the GCM
4) Evaluate RCM

- Use as many relevant observed datasets as possible.
- Ensure you're comparing 'like for like' data.

Gridded datasets

- Observed datasets – e.g. CRU (land surface), TRMM (satellite rainfall), GPCP (merged rain gauge and satellite rainfall)
- **Reanalysis data** – e.g. ERA-5

Station data

- It can be useful to compare directly to model output but be aware of differences in spatial scales; ultimately one would not expect the data to match.

Assess the GCM data that provides the LBCs

Stages of model evaluation:

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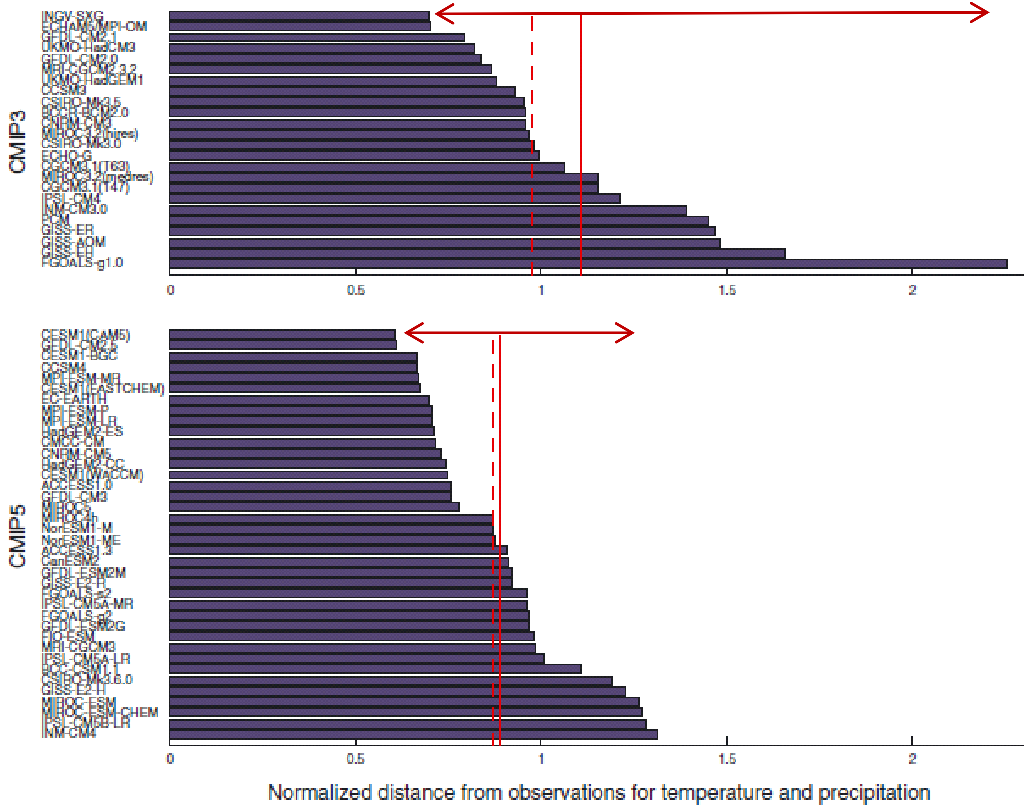

There is a general improvement in GCM/observations comparison over time

Evaluating RCM Output

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Potential for four separate validations:

Stages of model evaluation:

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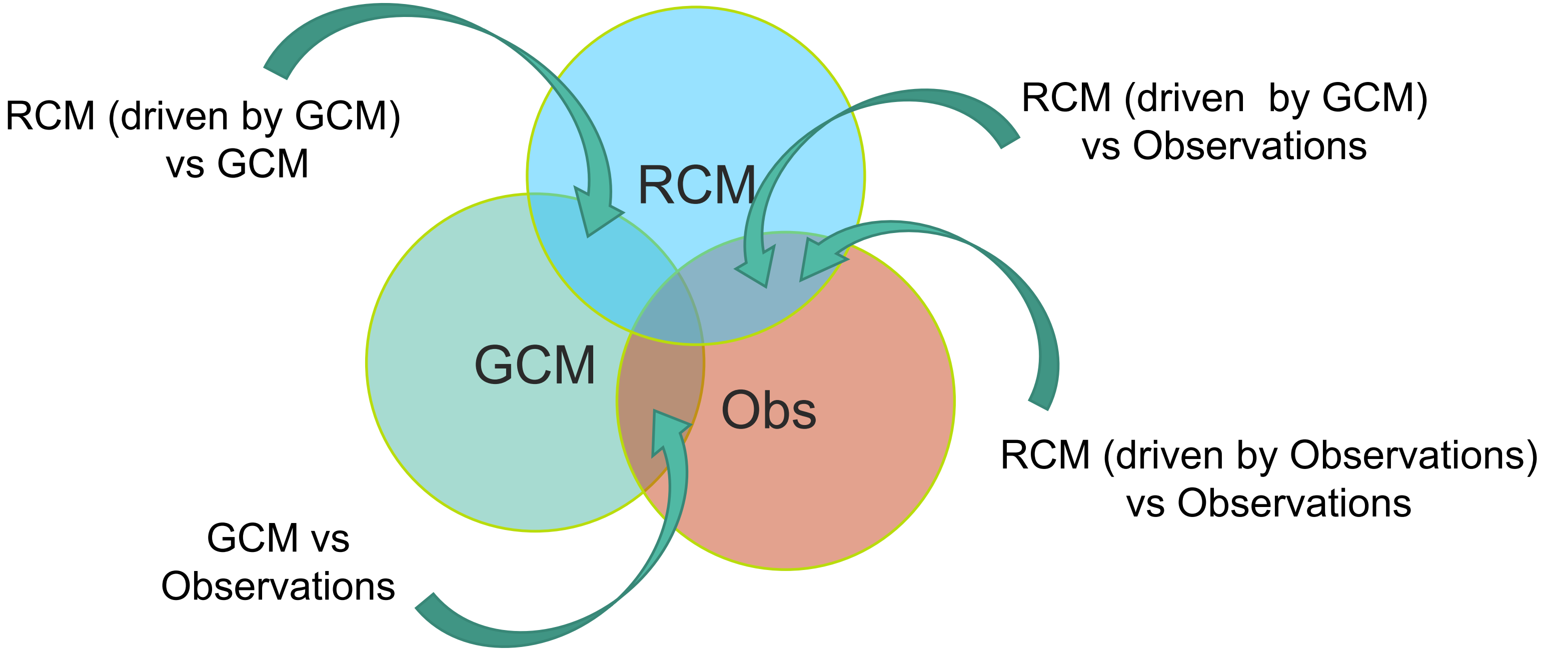

Use of the RCM output beyond evaluation

Having evaluated the RCM output…

- Is it appropriate to use the simulated future climate output?
- For what scales, variables and types of questions is the model output able to provide “useful” information?

Summary

Global climate models (GCMs) can be downscaled to obtain fine-scale climate information

- Statistical or dynamical downscaling
- RCMs can add more information about climate impacts

RCM evaluation is important because:

- It enables familiarisation with the model and its projected output.
- An evaluation provides a baseline for assessing the credibility of future projections from RCMs, which has implications for how the output can and should be used.

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Thank you for listening!

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