Regionalization Techniques and Regional Climate Modelling

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Objectives of this session

- To review the different methods of obtaining fine-scale climate information from global climate models (GCMs), with an emphasis on regional climate models (RCMs).

Contents

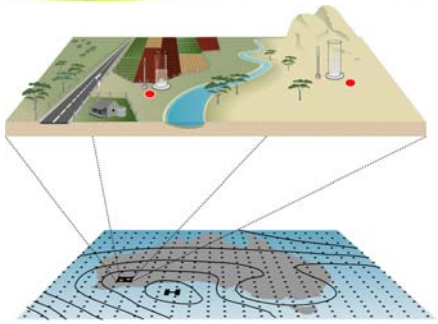
1. Regionalization techniques
   - Statistical
   - Dynamical
   - Statistical-dynamical
2. Suitability of regionalization techniques
3. Use of Regional Climate Models (RCMs)

What really are regionalization techniques?

Climate downscaling techniques

- These techniques allow fine scale information to be derived from GCM output.
- Smaller scale climate results from an interaction between global climate and local physiographic details
- Impact assessors need regional detail to assess vulnerability and possible adaptation strategies
- AOGCM projections lack that regional detail due to coarse spatial resolution
- Downscaling for climate change assessment differs from downscaling of seasonal climate prediction

From global to local climate …



… from a GCM grid to the point of interest.

Classification

- Statistical
  - Weather generators
  - Transfer functions
  - Weather typing
- Dynamical
  - High resolution and variable resolution AGCMs
  - Regional Climate Models
- Statistical/Dynamical

Statistical or empirical techniques

From historical data:

local variable = F (large scale variable(s))

Predicted local variable = F (AOGCM large scale variable)

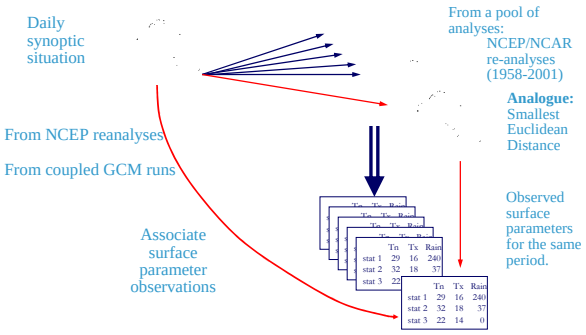
Categories of statistical techniques

- Transfer functions
  - linear regression, piecewise interpolation, artificial neural networks
- Weather generators
  - Markov chain, spell length
- Weather typing
  - Analogue methods, classification and tree analysis

Assumptions made for statistical downscaling

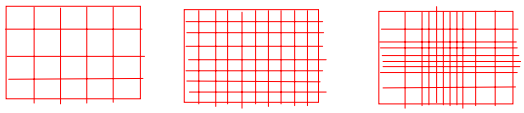
- Relies on large-scale predictors for which Climate System Models are most skilful:
  - Several grid lengths
  - Tropospheric variables (away from the surface)
  - Dynamic variables (geopotential, wind, temperature)
- The transfer function must remain valid in different climate conditions:
  - Hard to demonstrate
  - Can be evaluated by comparison with other approaches
- The predictors must encompass the entire climate change signal:
  - Importance of testing several predictors
  - Uncertainties related to the choice of predictors

Example: Technique of analogues



High resolution and variable resolution AGCMs

- Atmospheric GCMs can run with observed or AOGCM sea surface temperature as boundary conditions at the sea points.

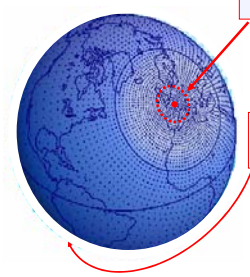


AOGCM O(300)km

High res. AGCM O(100) km

Variable res. AGCM 50 km to '100s' km

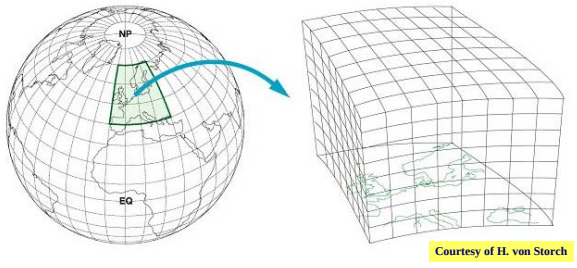
Features of Stretched Grid AGCM



The spatial resolution here is equivalent to a grid mesh of approximately 30 km.

The spatial resolution is progressively relaxed towards the antipode (near New-Zealand).

Regional Climate Models



Courtesy of H. von Storch

Regional atmospheric modelling: nesting into a global state

Suitability of regionalization techniques?

Criteria for suitability of downscaling techniques

- Consistency at regional level with global projections
- Physical plausibility and realism
- Appropriateness of information for impact assessment
- Representativeness of the potential range of future climate change
- Accessibility for use in impact assessments

Suitability of regionalisation techniques

Method	Strengths	Weaknesses
Statistical	• High resolution • Computationally cheap	• Dependent on empirical relationships derived for present-day climate • Few variables available • Not easily relocatable
High-res AGCMs	• High (very high) resolution • Can represent extremes • Physically based • Many variables • RCM: easily relocatable	• Dependent on surface boundary conditions from couple model • Computationally expensive • *(Have to parameterise across scales)*
Regional models		• Dependent on driving model & surface boundary conditions • Possible lack of two-way nesting • Computationally expensive • (*Have to parameterise across scales*)

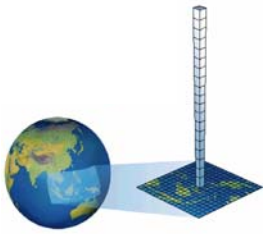
Regional Modeling vs. Statistical Downscaling

- The major theoretical weakness of statistical downscaling methods is that these empirically-based techniques cannot account for possible systematic changes in regional forcing conditions or feedback processes.
- The possibility of tailoring the statistical model to the requested regional or local information is a distinct advantage. However, it has the drawback that a systematic assessment of the uncertainty of this type of technique, as well as a comparison with other techniques, is difficult and may need to be carried out on a case-by-case basis.

Use of Regional Climate Models

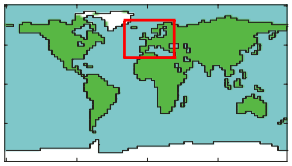
What is a Regional Climate Model?

- Comprehensive physical high resolution climate model that covers a limited area of the globe
- Includes the atmosphere and land surface components of the climate system (at least)
- Contains representations of the important processes within the climate system
  - e.g. clouds, radiation, precipitation



One way nesting methodology

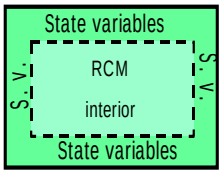
- A RCM is a limited area Model (LAM), similar to those used in NWP
- LAMs are driven at the boundaries by GCM or analysis data . . .



- Deviations between an RCM and its driving GCM tend to be bigger toward the surface and middle of the terrain

Lateral Boundary conditions

- Relaxation method (PRECIS)
  - Large scale forcing over a lateral buffer zone
- Spectral nesting
  - Large scale forcing of low wave number components
- Important issues
  - Spatial resolution of driving data
  - Updating frequency of driving data



Sea Surface Boundary conditions

Two methods of supplying SST and ice-extent and thickness:

- Using a coupled AOGCM
  - Need good quality simulation of SST and sea ice in model
- Using observed values
  - For the present-day simulation.
  - For future climate need add to the observed values the changes in SST and ice from a coupled GCM

Physical formulations

	Advantages	Disadvantages
Different physics	Optimal physics for each resolution	Difficult to interpret GCM and RCM differences
Same physics as driving GCM	Maximum compatibility	Consistency of behaviour over a range of resolutions

Sources of errors in RCMs

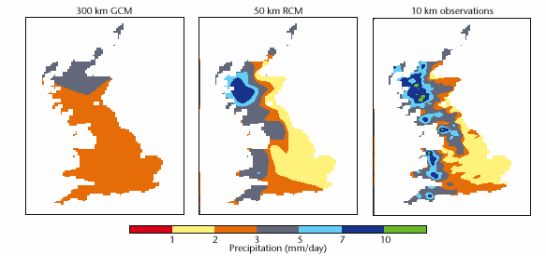
- The RCM adds fine detail to the large-scale and shouldn't deviate from it.
- Two sources of error:
  - Large scale driving fields (external)
  - Model physical formulation (internal).

Simulation length

- Minimum
  - 10 years to reasonably study the mean climate
- Preferably
  - 30 years to study higher order statistics, climate variability, extremes, etc

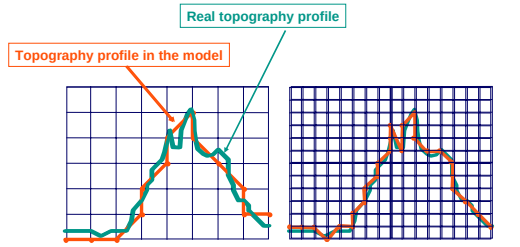
Added values of RCMs

RCMs simulate current climate more realistically



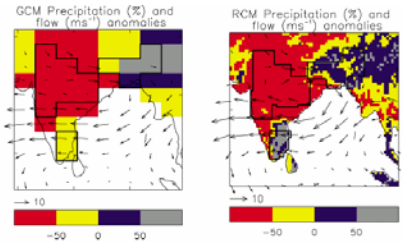
Patterns of present-day winter precipitation over Great Britain

Role of model topography

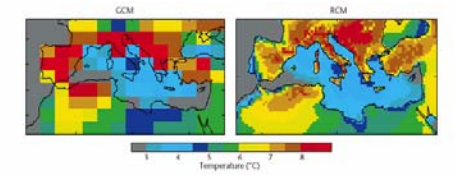


Standard resolution **Doubling of resolution**

RCMs simulate current climate more realistically

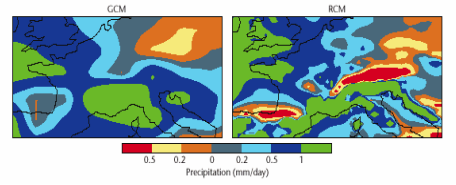


Represent smaller islands



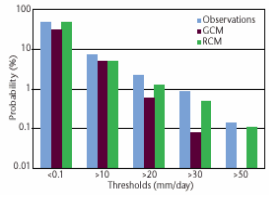
Projected changes in summer surface air temperature between present day and the end of the 21st century.

Predict climate change with more detail



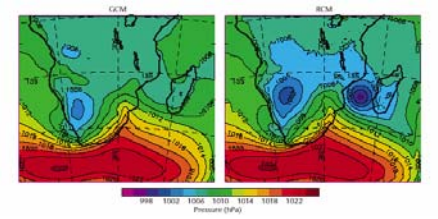
Projected changes in winter precipitation between now and 2080s.

Simulate and predict changes in extremes more realistically



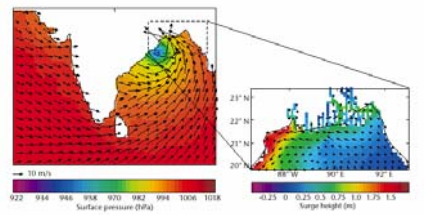
Frequency of winter days over the Alps with different daily rainfall thresholds.

Simulate cyclones and hurricanes



A tropical cyclone is evident in the RCM (right) but not in the GCM

RCM data can be used to drive other models



A cyclone in the Bay of Bengal simulated by an RCM and the resulting high water levels in the Bay simulated by a coastal shelf model.

Summary of regionalization techniques

- Used to add fine scale details to a GCM projection
- Several methods are available, with different strengths and weaknesses
- PRECIS is a physically-based and computationally accessible regional climate model

Questions & Answers