LIMITED AREA MODELLING

(Regional Modelling)

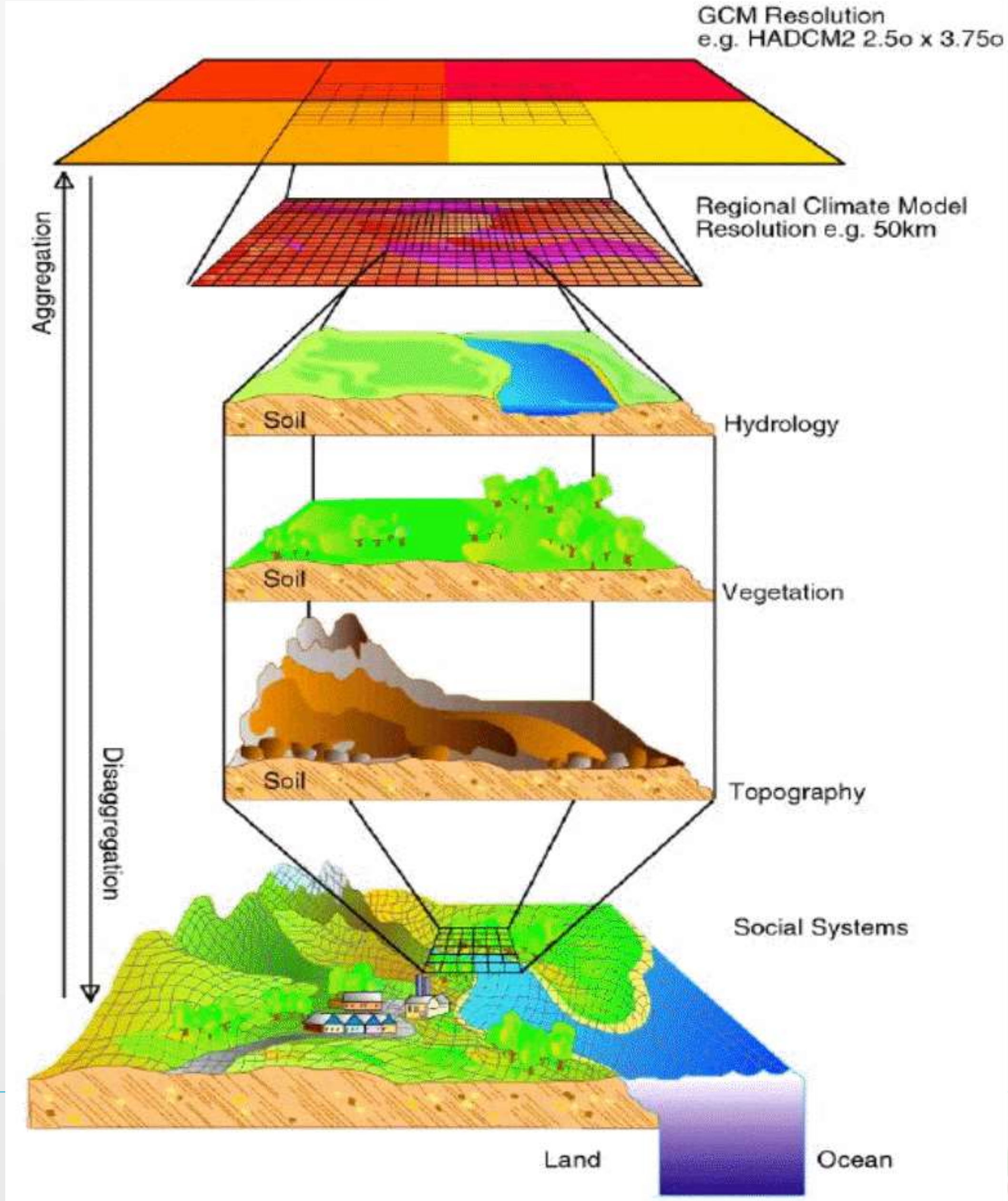
Regional Modelling : Purpose

- Detailed weather prediction
- Cover large areas
- Long period of time
- Surface forcings
  - Mountains, land-water contrasts, urban effects, islands
  - Orographic precipitation, sea breezes, lakes and urban heat islands

Regional Modelling : Constraints

- Computer resources
- Run-time quadruples with resolution increase
- Run-time increase with forecast lead-time
- THUS: downscale global models
- RESULT: detailed forecast over area of interest

Regional Modelling



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Downscaling

- Refining GCM output to local scale
- GCM simulate large scale atmospheric circulation better than surface climate elements
- Nowcasting through to multi-decadel climate change
- Two techniques:
  - Statistical
  - Dynamical

Downscaling Techniques

- Statistical:
  - Establish links between large-scale circulation and local features
  - Transfer functions > GCM output = predictor
    > local variables = predictand

Perfect Prognosis: link between predictand quantities and observed circulation fields (assume GCM is perfect)

Model Output Statistics: links GCM products directly to local conditions (model bias)

Downscaling Techniques

- Dynamical:
  - Local conditions are derived from parameters forecast by the GCM
  - Based explicitly on relevant physical processes (not relationships)
    - Regional model is nested within GCM which provides updates of atmospheric fields at boundaries

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Downscaling Techniques

Comparison of Statistical and Dynamical Downscaling Techniques

	Statistical	Dynamical
Current Skill	Comparable	Comparable
Future Skill	Limited to assoc between predictor & predictand	Improved model physics lead to greater skill
Computing Needs	Low, but requires extensive obs data	Intensive, grows to square of grid size
Implementation	Relatively easy, but is limited to one application	Complex, but can be used for several applications
Output	Specific to training procedure - static	Space and time resolution set by user - dynamic

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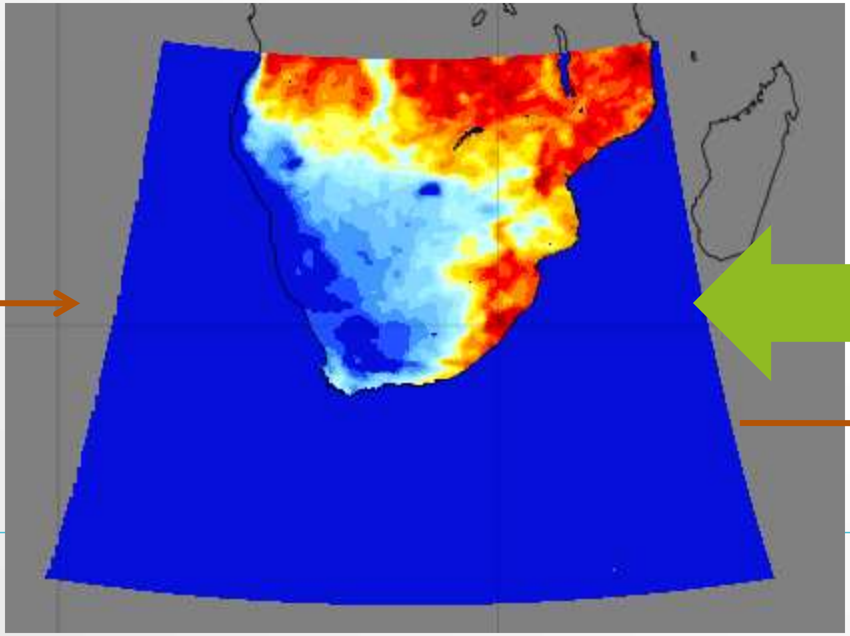
Setting Up a Regional Modelling System

- Global models runs at large institutions:
  - NCEP – USA
  - MetOffice – UK
  - ECMWF – Europe

- Regional models:
  - Any centre with computing capability and an internet link

Regional Model Domain

- Smaller domain size
- Dynamical equations and numerical techniques are equivalent to GCM
- Receives lateral boundary conditions from GCM



Air & Water

Air & Water

Considerations when choosing a system

- Types of simulation – choice of model and in/output data
    - Detailed climatology
    - Short-range forecasting
    - Month simulations (interannual variability)
    - Seasonally variability (full annual cycle) – complex system
    - Soil moisture & temperature
    - Vegetation models to simulate growth/ fires
- Nesting:
    - Nested in GCM output (most common)
    - Global fields interpolated to boundaries of RCM (buffer zone)
    - Multiple nesting to finer scale (physics and resolvable scales consistent)
    - One-way or two-way nesting (feedback to GCM or between RCM domains)

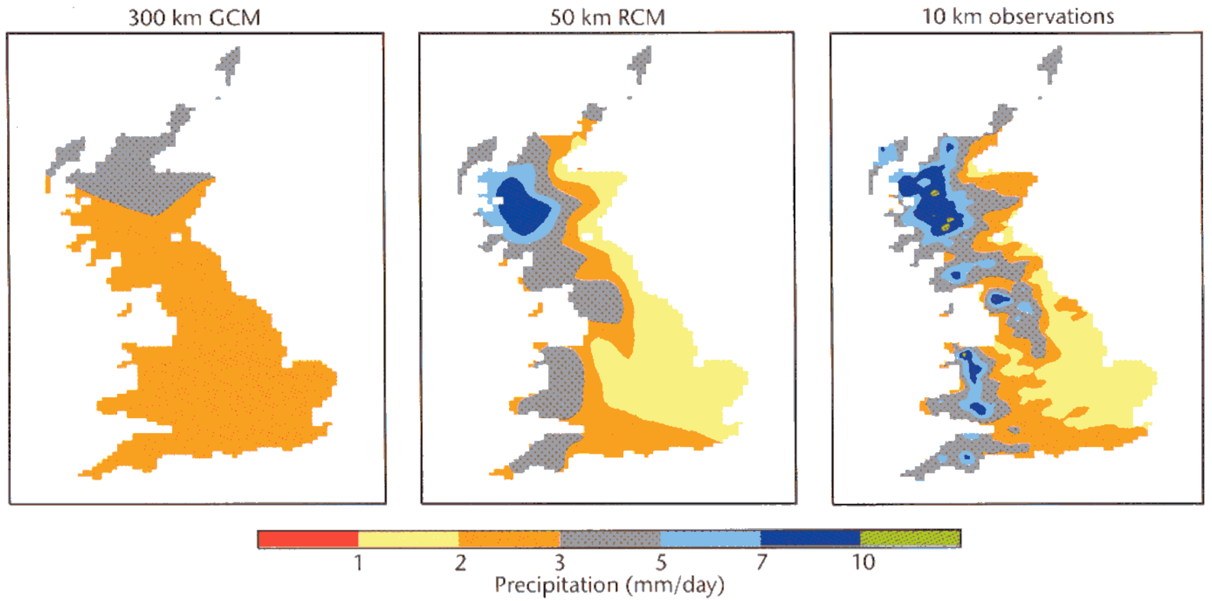
Considerations when choosing a system

- Initialization:
  - ALL models have physical parameterizations and the processes represented must be allowed to “spin-up” or initialised.
  - Careful treatment of surface, soil and vegetation interaction
  - Direct interpolation from GCM at land/sea boundaries and high gradients of topography, vegetation cover and soil types not adequate
- Domain size
  - Cover area of interest with buffer zone
  - Domain small enough in order for synoptic circulation not to depart from the driving GCM
  - Domain must be large enough to allow development of features in the RCM that have a scale too fine to be resolved by the GCM
  - Domain size can be constrained by resolution and computing resources

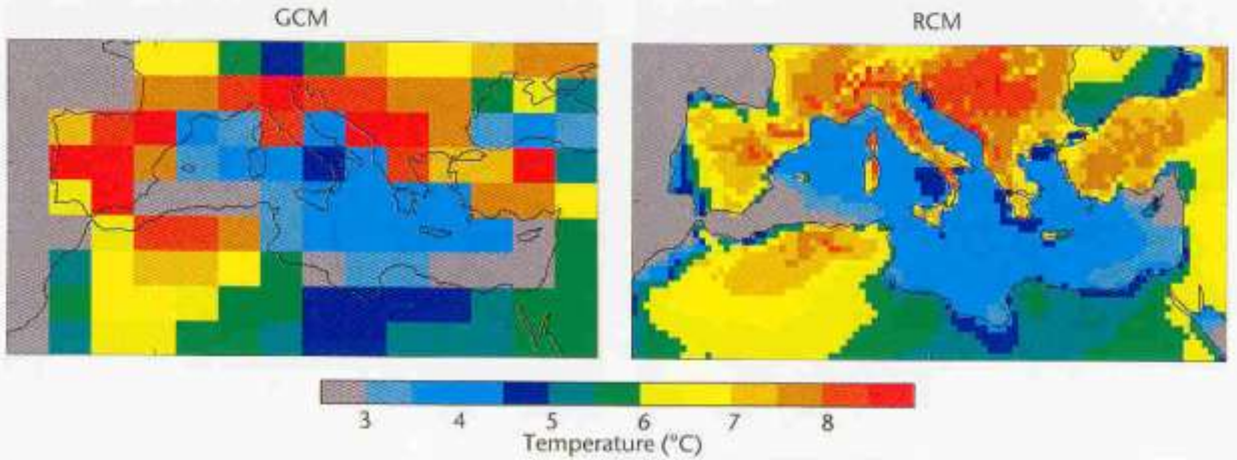
Performance of Regional Models

- ADVANTAGES:
  - Simulate climate better (resolves smaller scale features)
  - Represent smaller islands (effect of land in oceans)
  - Simulating extremes of weather better
  - Simulate tropical cyclones
  - Can run dispersion models, wave models

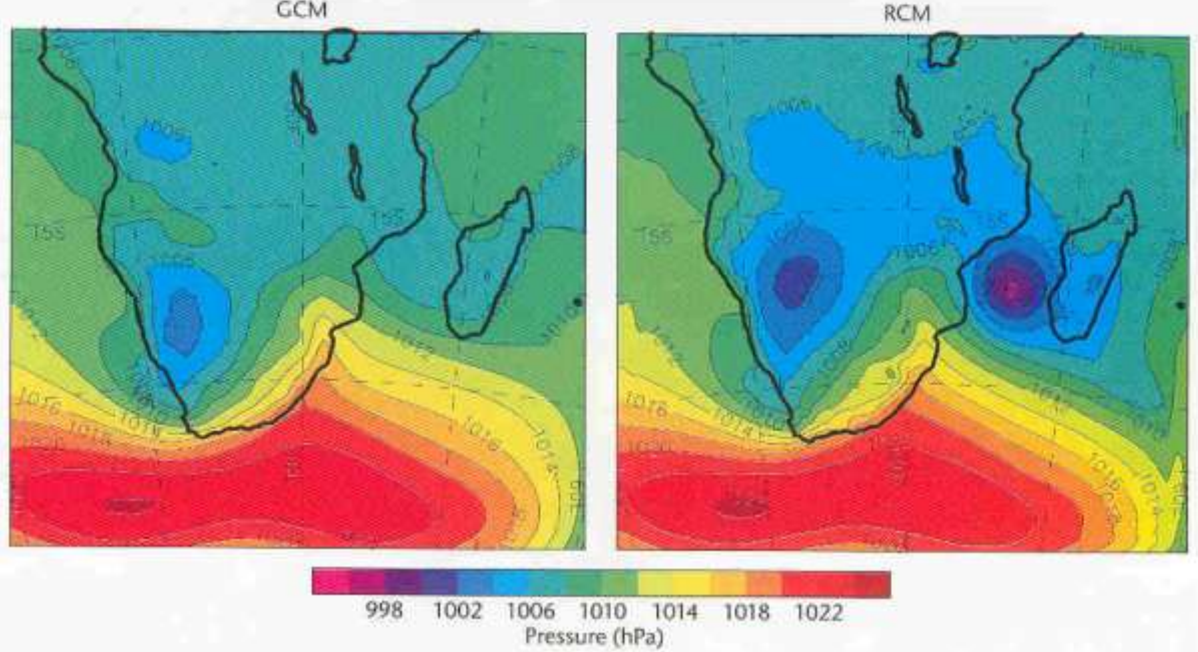
Performance of Regional Models



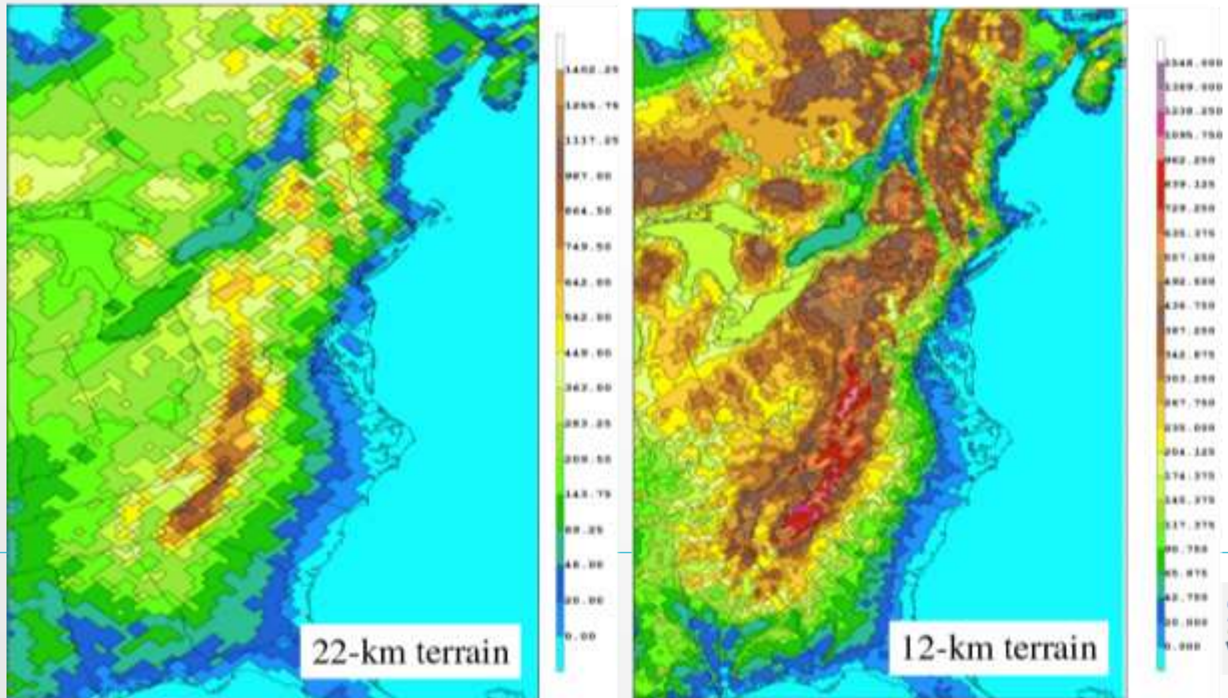
Patterns of present-day winter precipitation over Great Britain. Left, as simulated with the global model. Middle: as simulated with the 50 km regional model. Right, as observed.



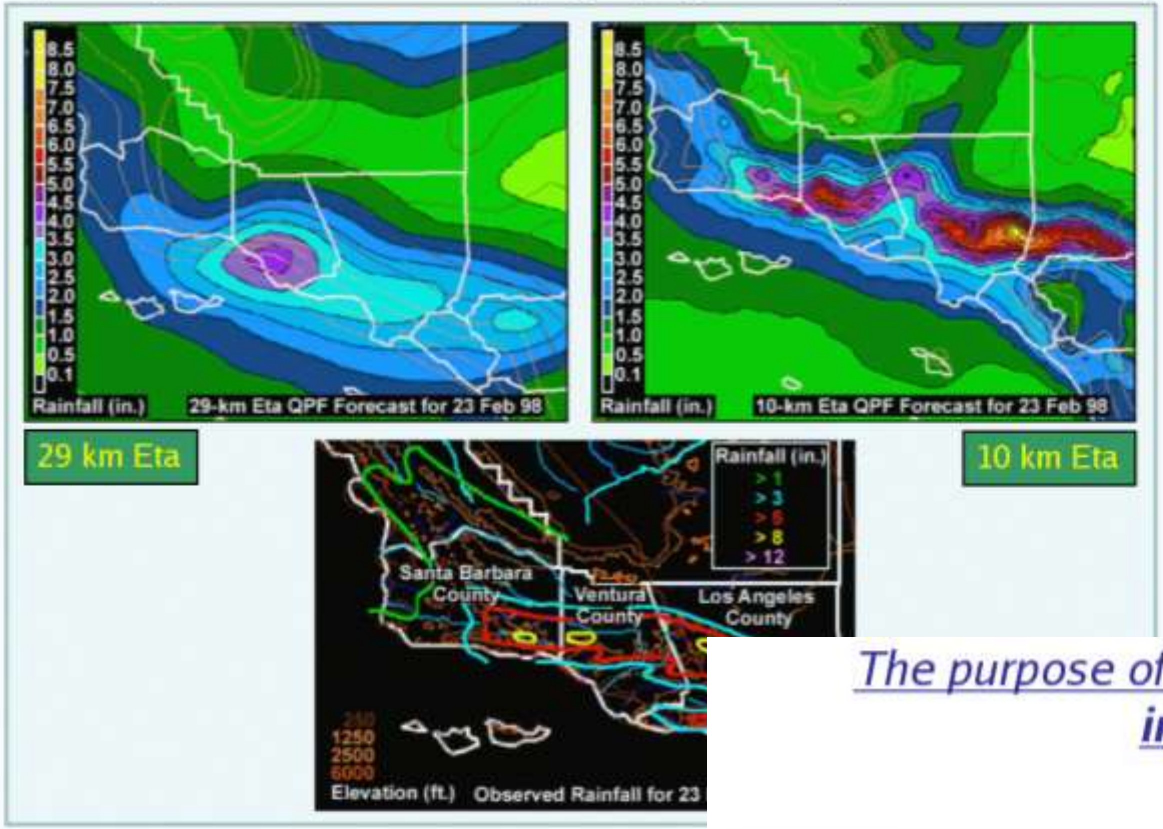
Predicted changes in summer surface air temperatures between the present day and the end of the 21st century. Left, from the global model. Right, from the regional model.



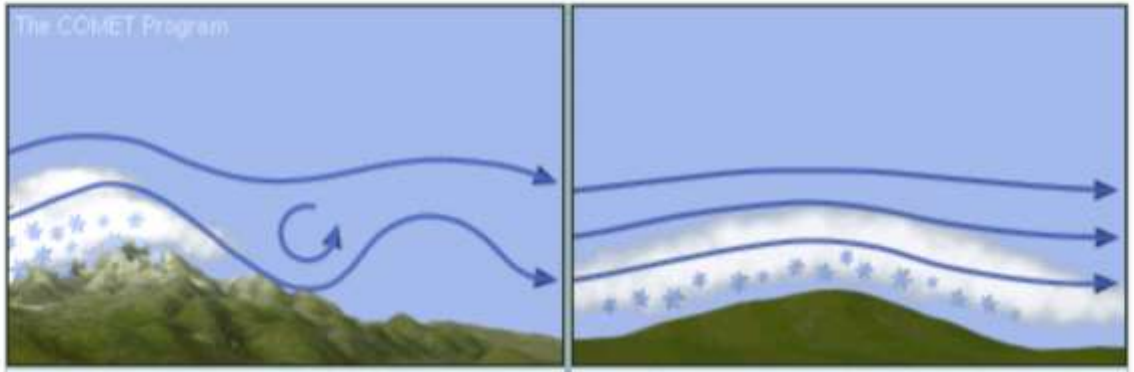
A tropical cyclone is evident in the mean sea-level pressure field from the RCM (right) but not in the driving GCM (left) for the corresponding day (from an RCM over southern Africa, developed by the Hadley Centre in collaboration with the University of Cape Town).



And allows some forecast parameters to be improved <u>markedly</u>
(especially those related to topography or land/sea boundaries)



The purpose of running models locally is to ***increase detail***



Actual terrain with terrain-induced downslope winds, mountain clouds, and precipitation.

Model terrain and model forecast terrain smoothing results in inability to depict physical processes associated with complex or steep terrain.

Constraints of Regional Modelling

- Orographic Effects
  - Less smooting of orography > steep slopes lead to excessive precipitation
  - Biases increase with resolution
- Topography
  - Tropics are most difficult for GCM
  - Weather patterns move slowly in tropics
  - Simulated precipitation patterns and corresponding heating rates are sensitive to choice of cumulus parameterization
  - Sensitive to vertical advection and radiation scheme

Constraints of Regional Modelling

- Conservation Properties:
  - GCM satisfy global conservation rules
  - RCM has net loss/gain of mass, moisture and heat from model domain
  - Lateral boundary flushing
  - Check for long-term biases accumulation over domain
- Nesting aspects
  - Precipitation forms near the boundaries
  - Problem is cosmetic – intermittend supply of data from the GCM as moisture reduction by precipitation at the boundary is overwritten by GCM input
  - THUS: parameters near boundaries are subject to error
  - Therefore: plot only uncontaminated interior part to forecasters

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Knowing your GCM

- GCM's have systematic biases
- Biases are geographical and seasonal dependent
- IT IS NOT A MAGIC BOX!

Poor GCM output = Poor RCM output

Knowing your GCM

- Non-hydrostatic Mesoscale Modelling
  - Mesocale defines processes in both spatial and temporal terms between large-scale (macro) and small-scale (micro) processes
    - Meso-alpha (200-2000km) – fronts and tropical cyclones
    - Meso-beta (20-200km) – low-level jets, internal waves, cloud clusters and orogrpahic disturbances
    - Meso-gamma (2-20km) – Cumulonimbus clouds, internal gravity waves and urban effects

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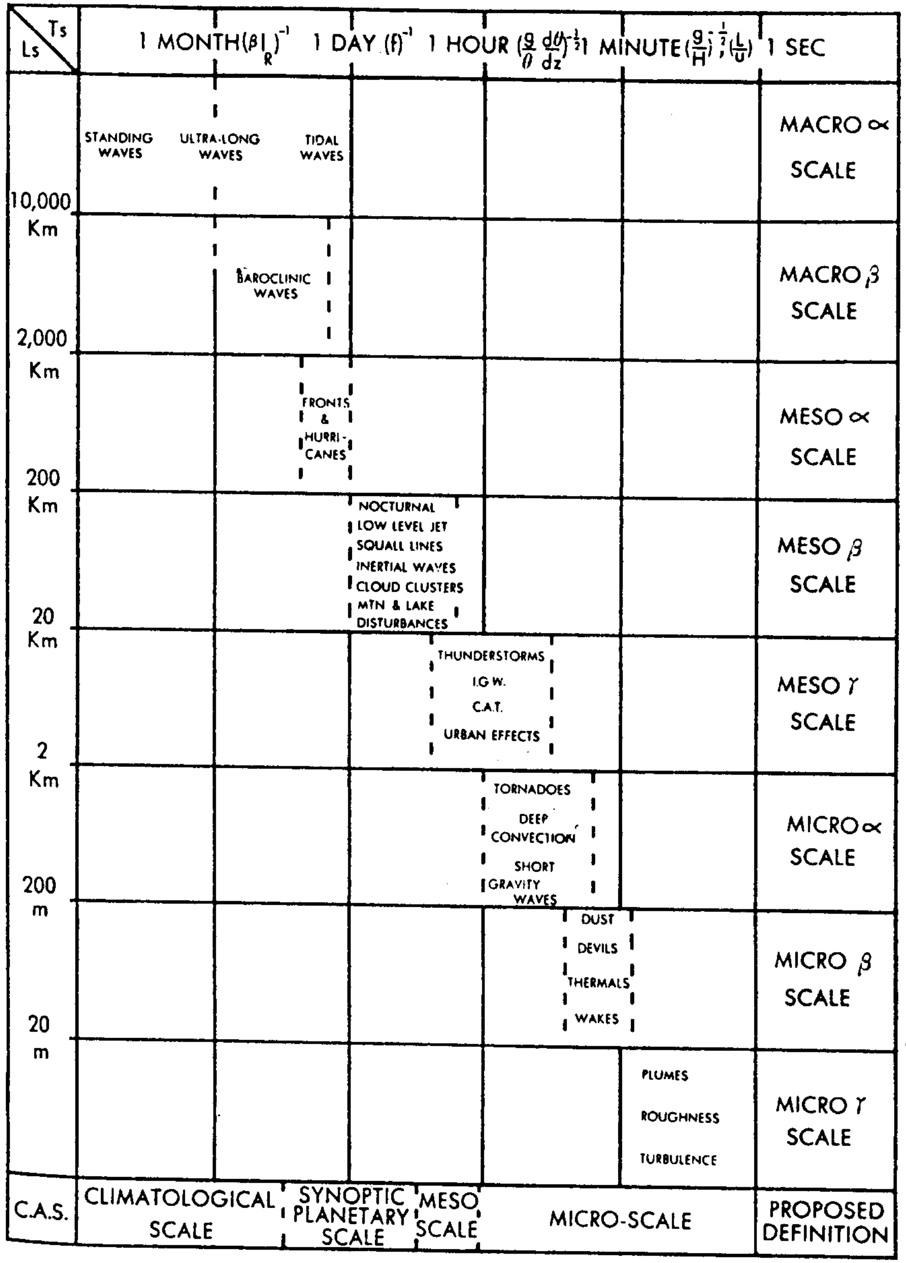

FIG. 6. Scale definitions and different processes with characteristic time and horizontal scales. (After Orlanski, 1975.)

Knowing your GCM

- Hydrostatic Approximation
  - Vertical forces of gravity (downwards) and pressure gradient force (upwards) are in balance
  - More than 10km (synoptic)
  - Simplifies governing equations, thereby decreasing computational power