Training activity on how to use/ interpret the GCM/RCM outputs

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Slides originally prepared by F. Giorgi

The protocol for a regional climate change simulation:

Step I: Perfect LBC experiments

- IC and LBC from analyses of observations
  - NCEP, ECMWF, ERAINTERIM, CFSR, JMA
- Simulation of actual periods
  - Validation of the model against observations for the simulated period
- Identification and possibly minimization of systematic errors in the model configuration, dynamics and physics
  - “Customization of the model”/”choice of parameterizations”

The protocol for a regional climate change simulation:

Step II: GCM-driven "Control" experiments

- IC and LBC from GCM simulations of present-day climate
- In-depth analysis of GCM forcing fields
  - Selection of best available forcing models
  - If errors in the GCM fields are too large, the value of the nested RCM experiment is doubtful
- Validation of model statistics against climatological observations
  - Need of long simulations to obtain robust statistics
- Identification of errors due to the GCM LBC vs. errors due to the model physics and configuration
- Assessment of added fine scale information provided by the RCM ("Added value")

The protocol for a regional climate change simulation:
Step III: GCM-driven experiments of "future" climate conditions

- IC and LBC from GCM simulations of present day and "future" climate conditions
  - Transient (e.g. 1960-2100)
  - Time slices (e.g. 1961-1990; 2071-2100)
- Comparison of "future" and present day "climate statistics" in order to identify the change signal
- Use in impact assessment
  - Direct use of model output
  - Post-processing of model output (e.g. bias correction)

RCM internal variability

<u>The internal variability of RCMs may be misinterpreted as a real signal</u>

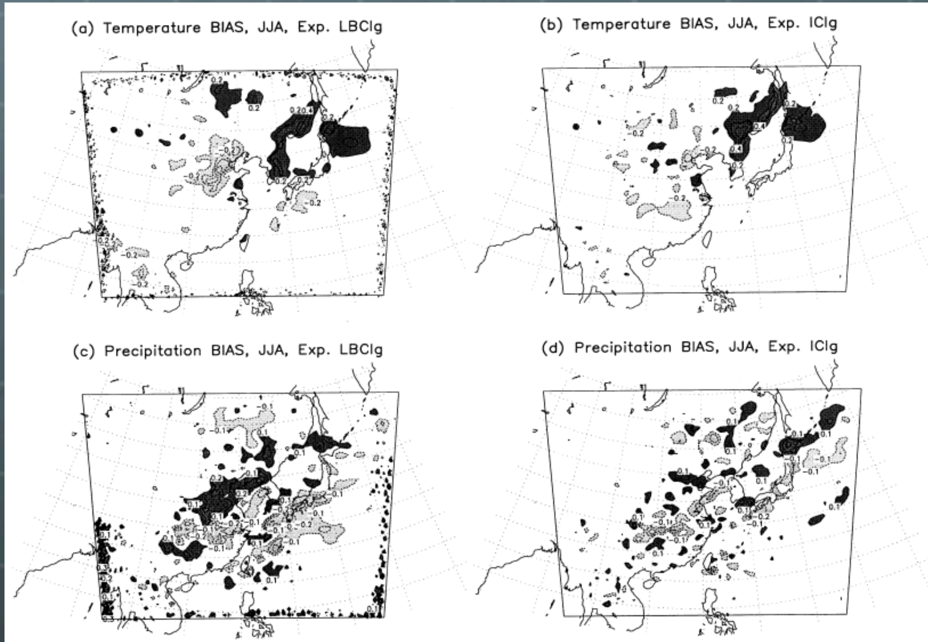


Figure 10. Bottom model level temperature (K) and precipitation (mm/day) BIAS for the LBC$_{lg}$ and IC$_{lg}$ perturbation experiments (not including the first 15 days of simulation). Season is JJA. (a) Temperature BIAS, Exp. LBC$_{lg}$; (b) temperature BIAS, Exp. IC$_{lg}$; (c) precipitation BIAS, Exp. LBC$_{lg}$; (d) precipitation BIAS, Exp. IC$_{lg}$. Light shading is for negative values and dark shading is for positive values.

Giorgi and Bi (2000)

<u>When doing sensitivity experiments, **either do a long run or an ensemble** (e.g. with perturbations in the IC)</u>

RCM internal variability

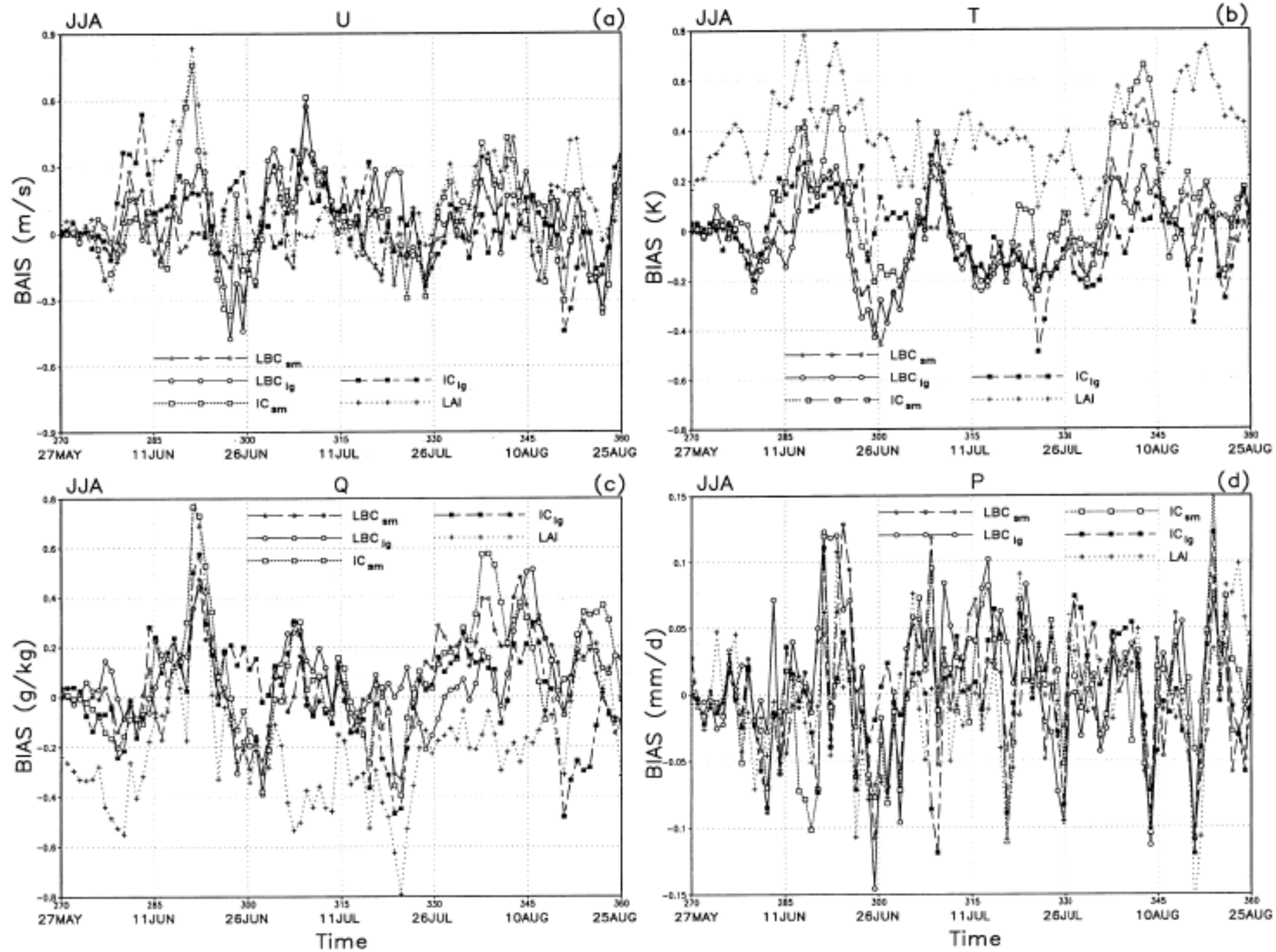
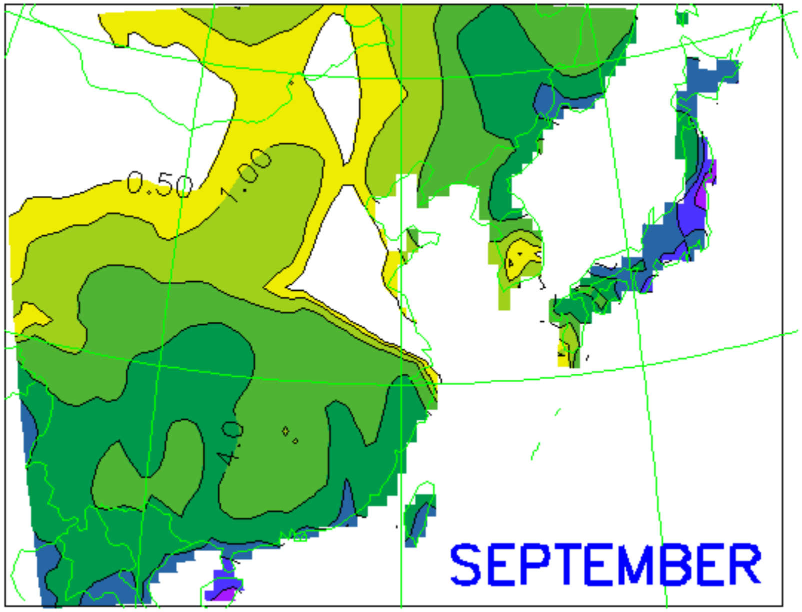


Figure 12. BIAS for precipitation (P) and wind speed (U), temperature (T), and water vapor mixing ratio (Q) at $\sigma = 0.995$ for different experiments. Only land points are used in the calculations. (a) U, (b) T, (c) Q, (d) P. Season is JJA.

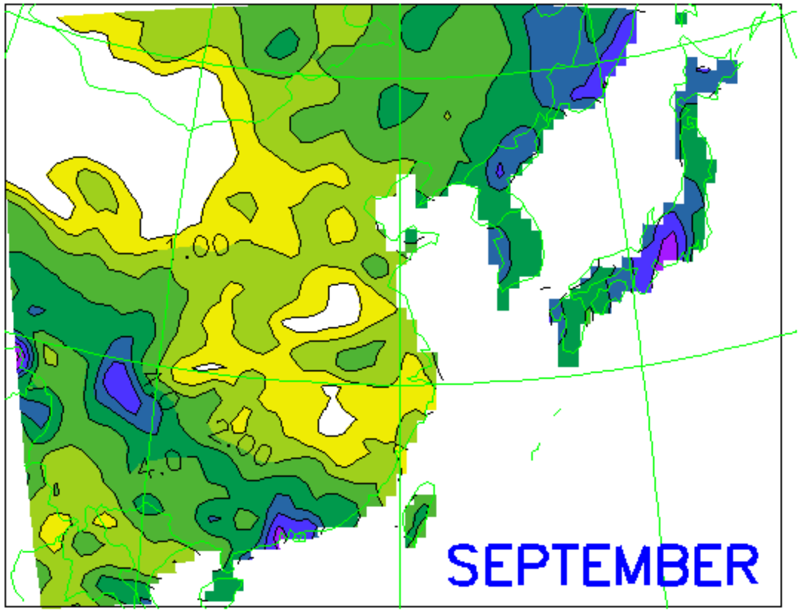
Domain Choice

<u>The choice of domain may affect your results so it needs to be done very carefully, possibly with testing of different domain sizes</u>

CRU Obs



RegCM



Domain choice

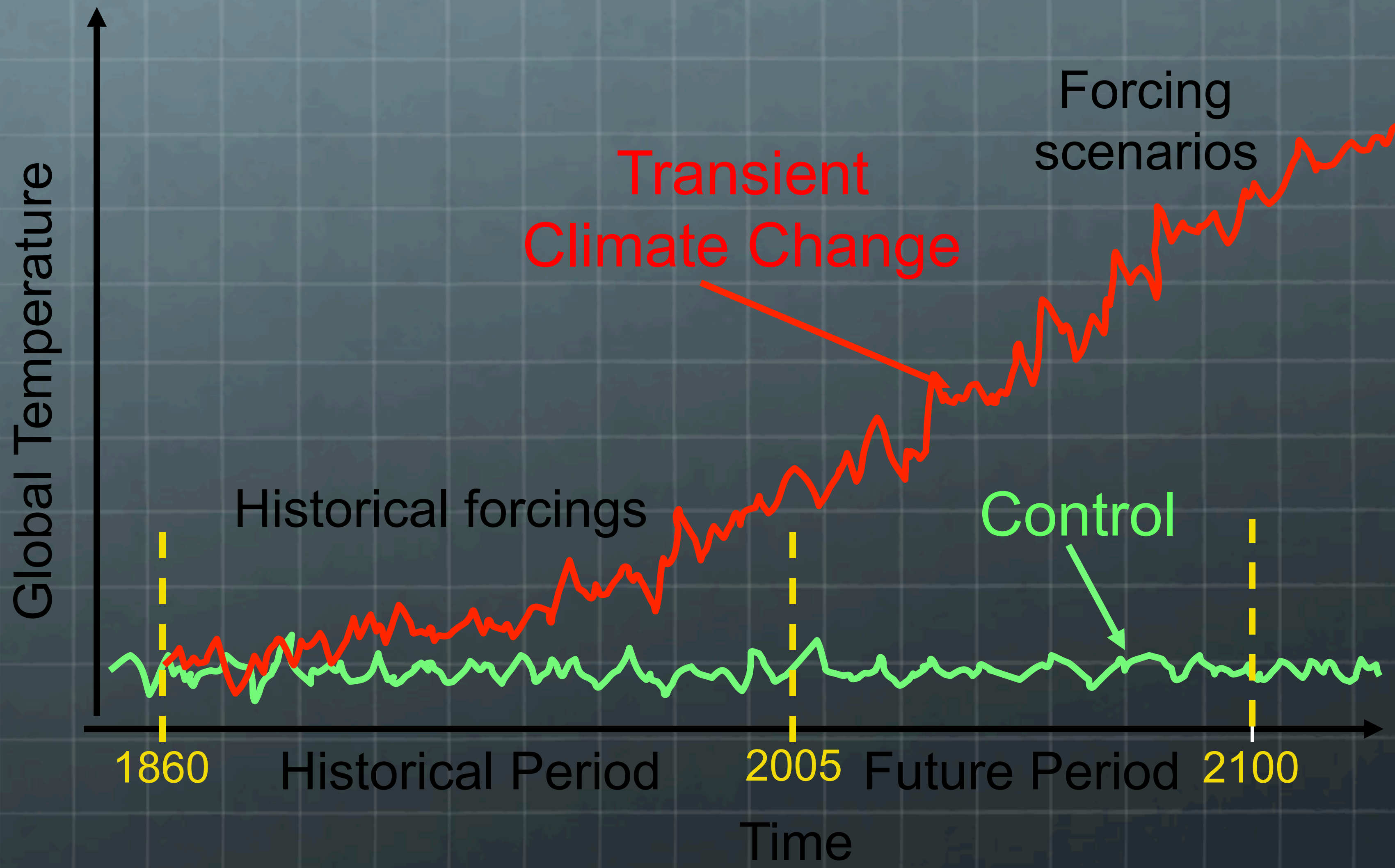
- In general the model results depend on the domain, at least up to a certain (large) size
  - If possible, test different domains
- Put your area of interest away from the boundaries as much as possible
  - Do not consider in the analysis areas close to the domain boundaries
- Include regions of key processes in your domain
- If possible, do not place the domain boundaries in areas of steep or complex topography

Check the length of your year

Different GCMs have different lengths of year
RCMs should thus have the same length

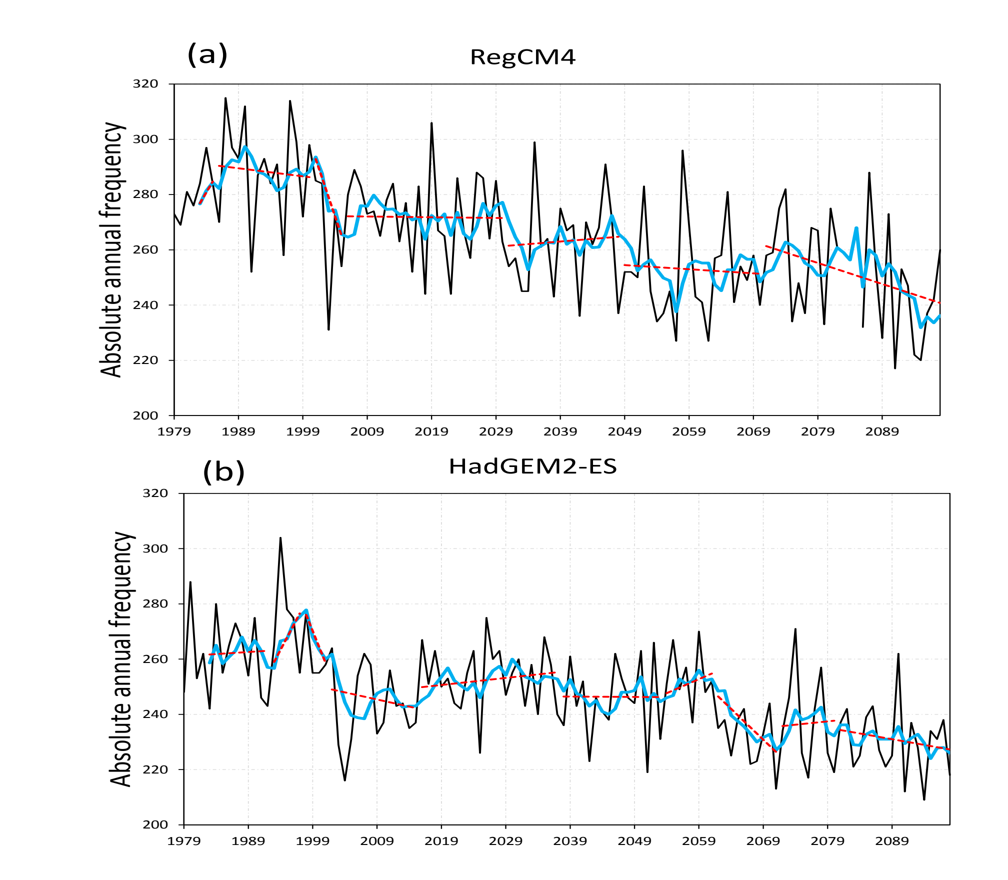
For example:
HadGEM – years with 360 days
MPI – standard calendary
GFDL – years with 365 days

Transient Climate Change "Projection"



Climate events on GCMs are not occurring at same time of the observations:

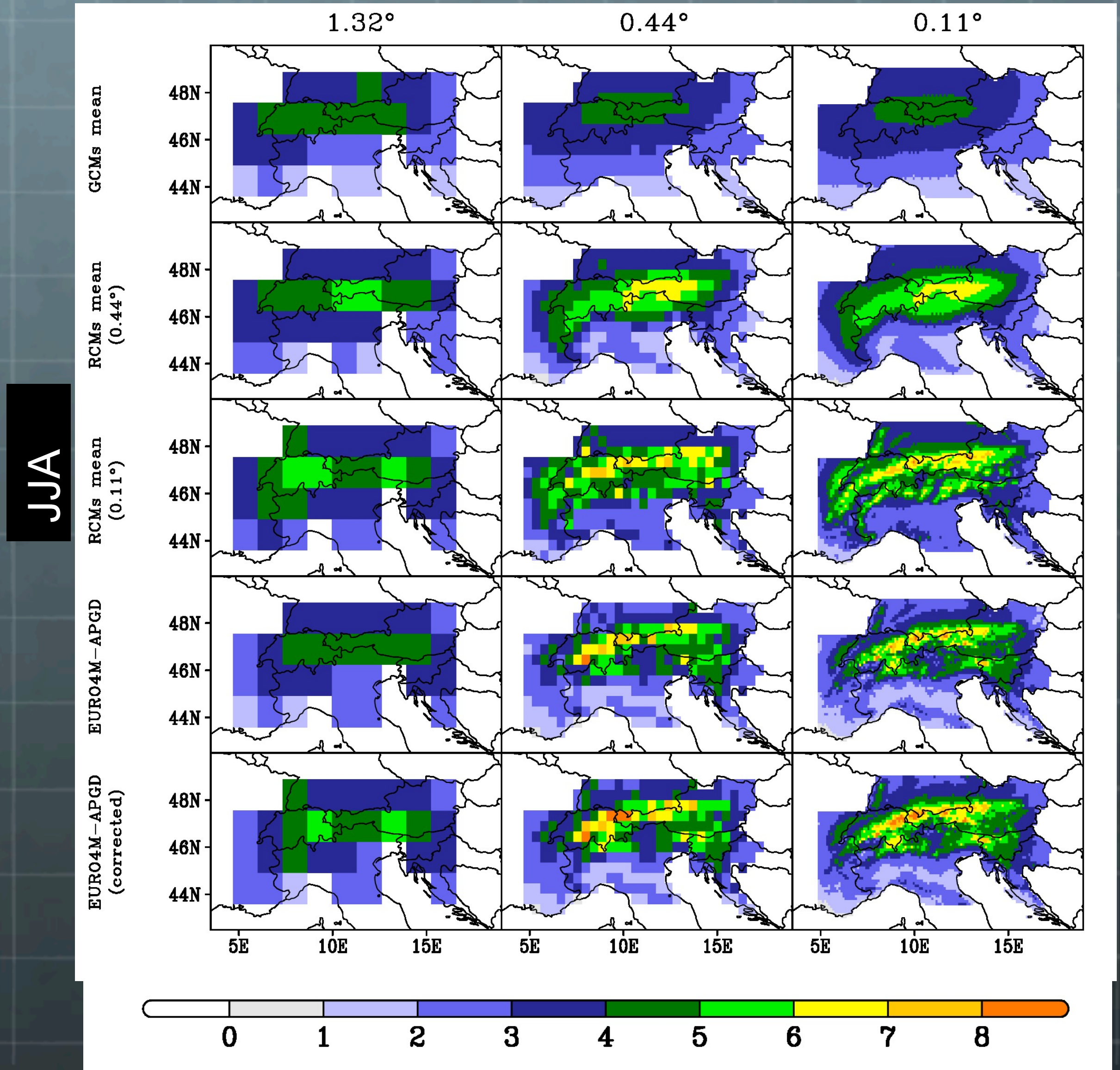
- we can look the general trends, the statistics of the different periods;
- We can not compare specific years or specificic events in a climate change projection



Time series of cyclogenetic density over Southh Atlantic

General negative trends, which is not stationary

Simulation of spatial patterns of precipitation - Summer



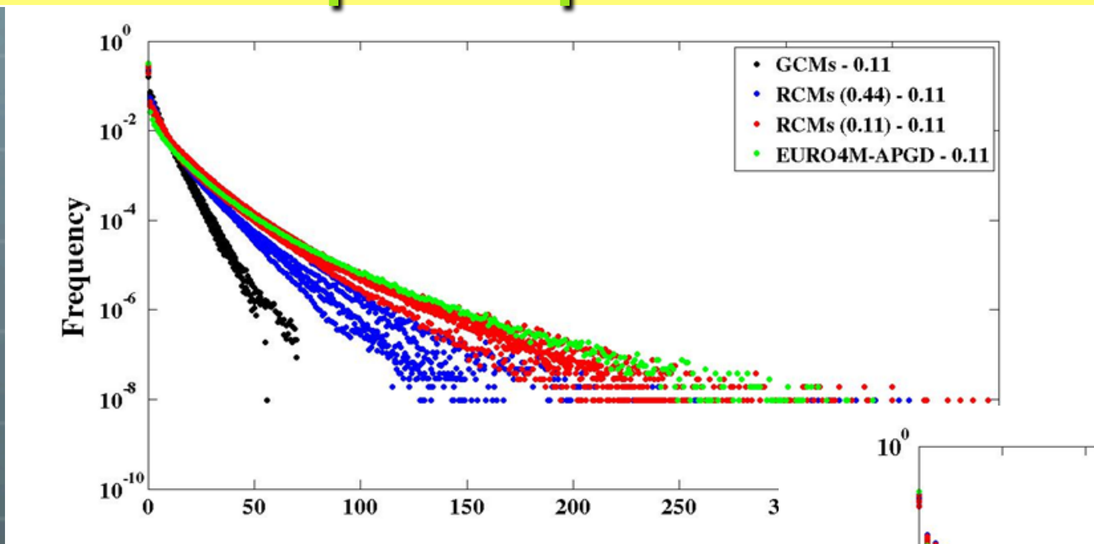
Higher resolution

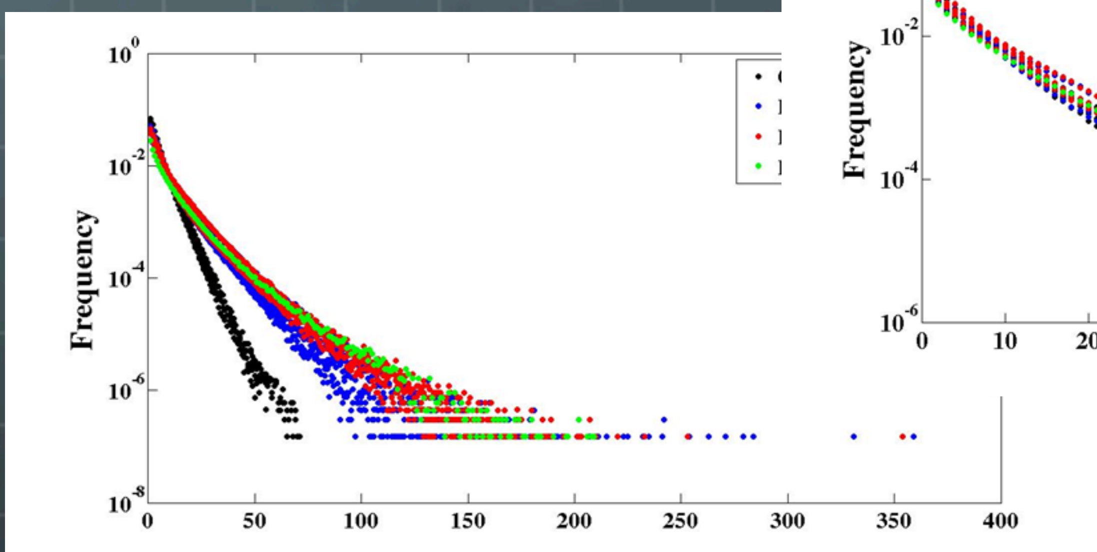
Increasing details in precipitation spatial distribution

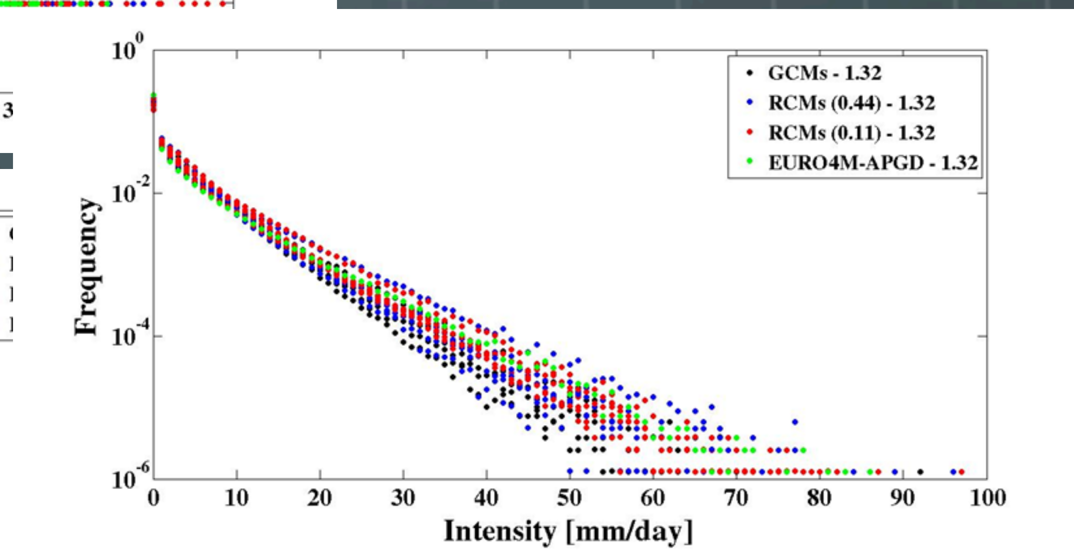
Fine scale AV

Torma et al. 2015

Added value: Simulation of daily precipitation intensity PDF







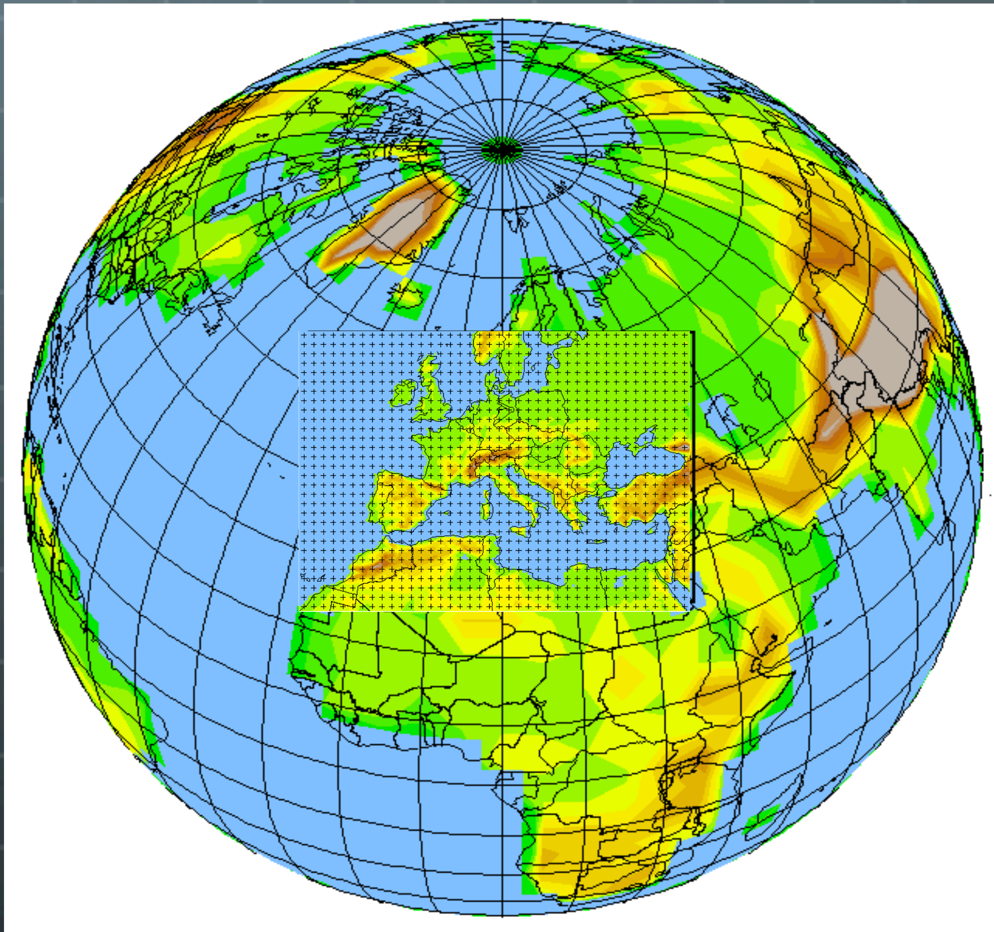
RCMs are always closer
to OBS (also when upscaled)

Tutorial

"Nested" Regional Climate Modeling: Technique and Strategy

- **Motivation:** The resolution of GCMs is still too coarse to capture regional and local climate processes

- **Technique:** A "Regional Climate Model" (RCM) is "nested" within a GCM in order to locally increase the model resolution.
  - Initial conditions (IC) and lateral boundary conditions (LBC) for the RCM are obtained from the GCM ("One-way Nesting") or analyses of observations (perfect LBC).



- **Strategy:** The GCM simulates the response of the general circulation to the large scale forcings, the RCM simulates the effect of sub-GCM-grid scale forcings and provides fine scale regional information
  - Technique borrowed from NWP

The equations of a climate model

$$\frac{\partial \overline{V}}{\partial t} + \overline{V} \cdot \nabla \overline{V} = -\frac{\nabla p}{\rho} - 2\overline{\Omega} \times \overline{V} + \overline{g} + \overline{F}_{\overline{V}}$$

Conservation of momentum

$$C_p\left(\frac{\partial T}{\partial t} + \overline{V} \cdot \nabla T\right) = \frac{1}{\rho}\frac{dp}{dt} + Q + F_T$$

Conservation of energy

$$\frac{\partial \rho}{\partial t} + \overline{V} \cdot \nabla \rho = -\rho \nabla \cdot \overline{V}$$

Conservation of mass

Physics

$$\frac{\partial q}{\partial t} + \overline{V} \cdot \nabla q = \frac{S_q}{\rho} + F_q$$

Conservation of water

$$p = \rho R T$$

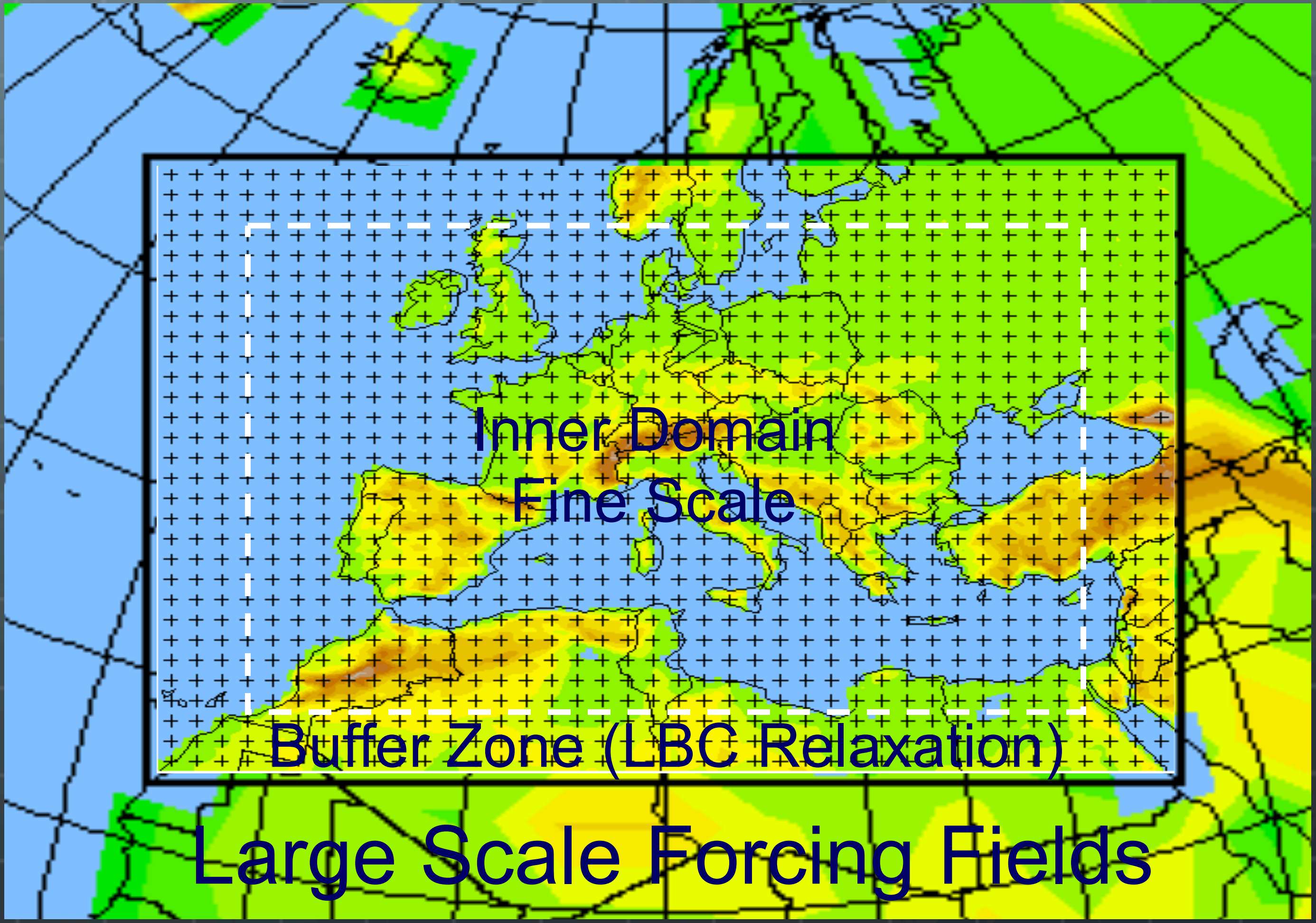
Equation of state

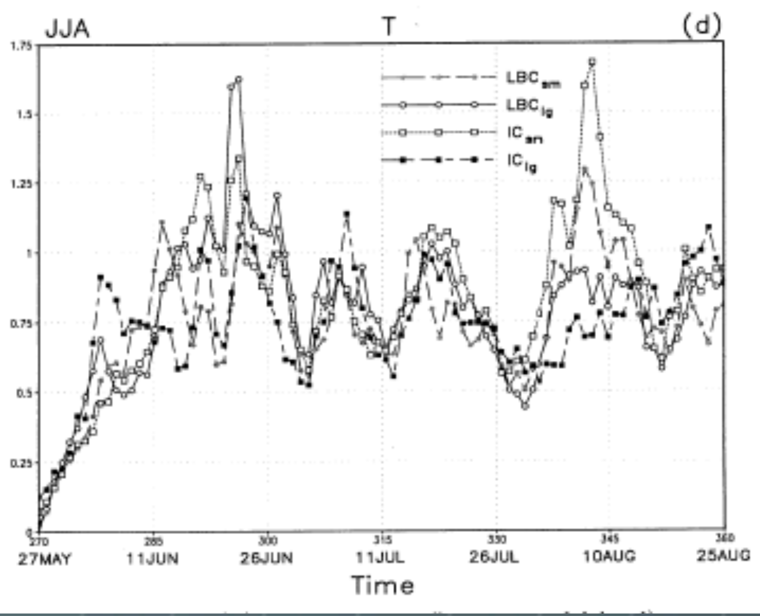
The components of a climate model

- **Dynamics**
  - Advection
  - Diffusion
  - Pressure gradient force
  - Coriolis force
  - Gravity
- **Physics (parameterizations)**
  - Radiative transfer
  - Planetary boundary layer
  - Resolvable scale clouds and precipitation
  - Convective clouds and precipitation
  - Land and ocean surface processes

RCM Nesting procedure

$$\frac{\partial \alpha}{\partial t} = F(n)F_1 \cdot (\alpha_{LBC} - \alpha_{mod}) - F(n)F_2 \cdot \Delta_2(\alpha_{LBC} - \alpha_{mod})$$





A dynamical equilibrium is reached in the interior domain between the information from the LBC and the model solution

900 hPa specific humidity (Courtesy of R. Laprise)