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2165-14

International MedCLIVAR-ICTP-ENEA Summer School on the Mediterranean Climate System and Regional Climate Change

13 - 22 September 2010

RCM: Physical parametrizations in RCMs

MONTAVEZ Juan Pedro
University of Murcia
Spain

Parameterizations in Regional Climate Models

Juan Pedro Montávez Gómez

Regional Atmospheric Modelling Group
Department of Physics
University of Murcia

International MedCLIVAR-ICTP-ENEA Summer School on the Mediterranean Climate System and Regional Climate Change
Trieste 2010

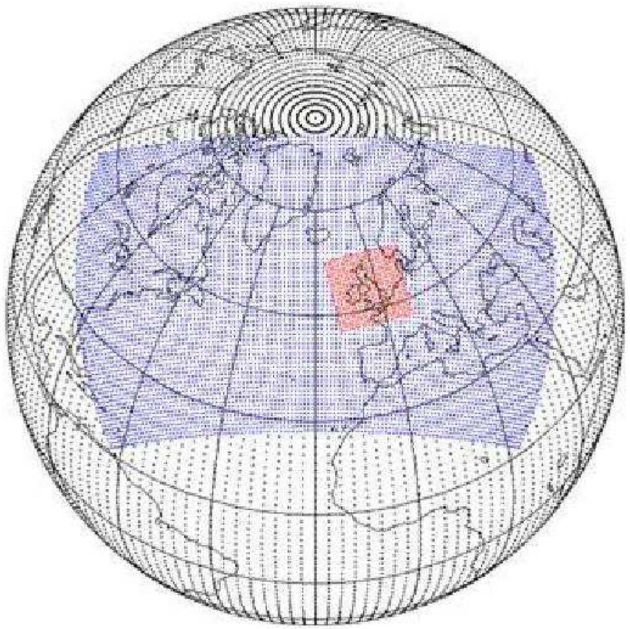
Outline

Models and downscaling

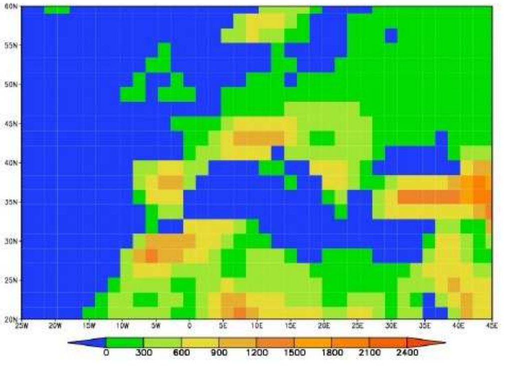
1. Introduction
   - RCM Structure
   - Need of parametrizations
   - Processes to be parametrized
2. Parametrizations
3. Uncertainties and Physics

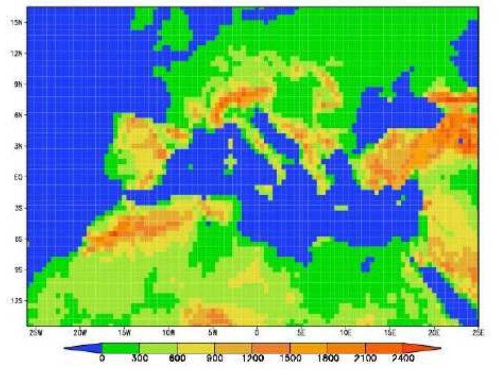
What is a RCM?

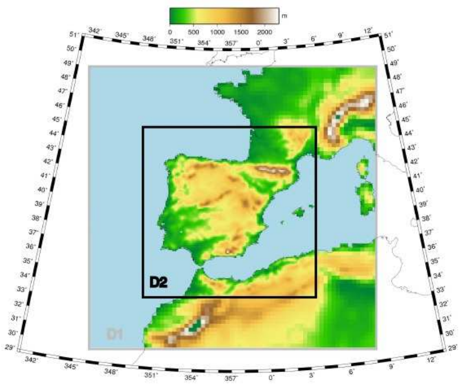
- Limited Area Model (or mesoscale model) designed for climate simulations
- Differences respect models for meteorology?
  - Regional Weather and Climate model tends to be the same. Most of RCM have born from a METEO model.
  - However, initial conditions are fundamental in Meteorology but not in RCM
- Also, soil treatment, radiation, and some others factor play an important role.
- Dynamical Downscaling



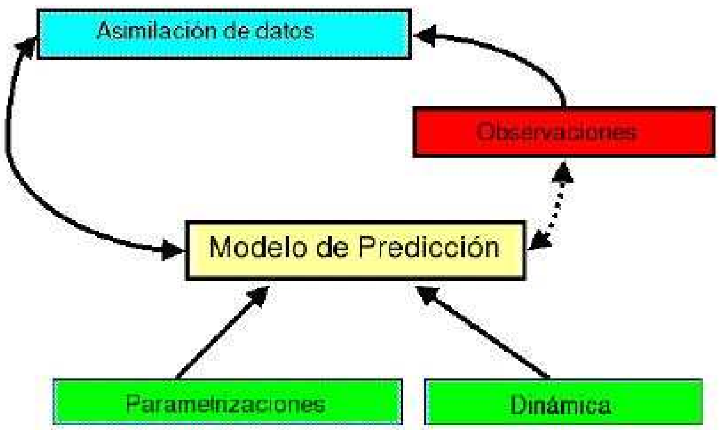
Dynamical Downscaling I

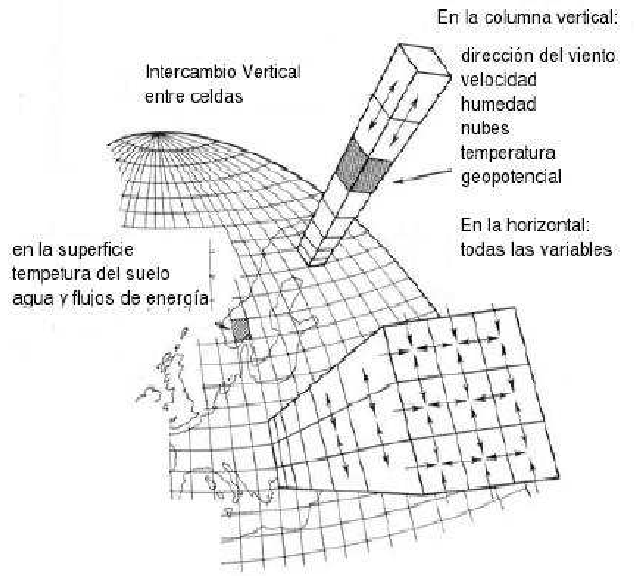






RCM Structure I



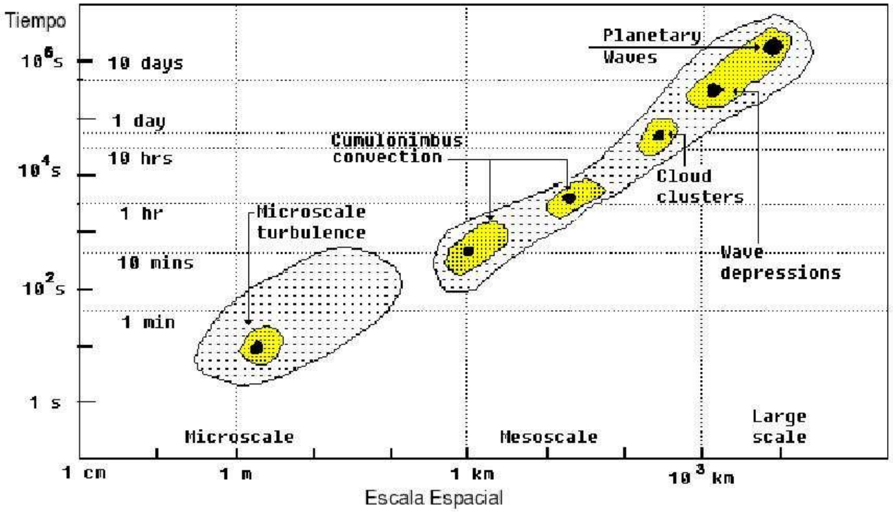


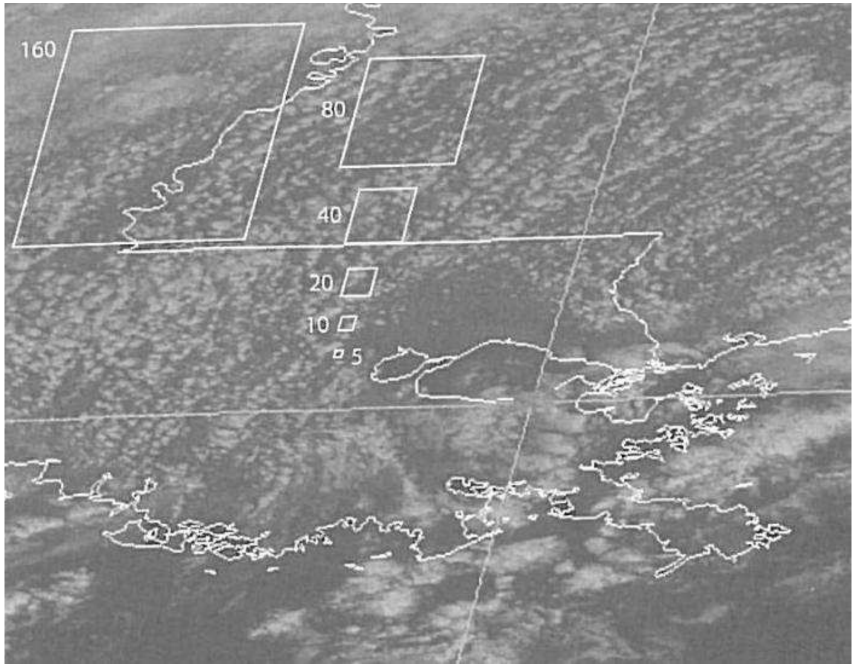
- Core
  - **Dynamics:** Resolution of Navier-Stokes equations for the atmosphere
  - **Physics:** More later ...
- Others:
  Preprocessing, post-processing

RCM Structure II

Arguably. the most important components of any numerical weather prediction model are the subgrid scale parameterizations. **D. Stensrud**

Some motivation





Why parametrizations are needed?

- A parametrization is an approximation to an unknow term by one or more known term of factors
- In general, need to parametrize processes at subgrid scale. Physical processes are known but too complicated or computationally unwieldy and simple parametrizations can be good enough.
- In some particular cases: some processes are not known enough to provide exact physical laws. However, net effects can be observed and parametrized.
- Then we can say:
  Parameterizations approximate the bulk effects of physical processes that are too small, too complex, or too poorly understood to be explicitly represented

Somethig about parameterization

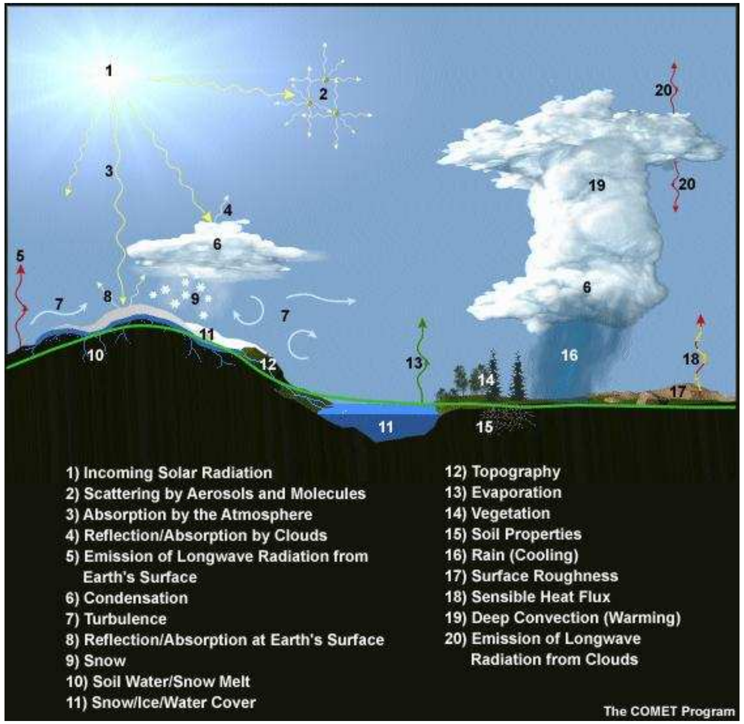
Parametrization = Approach. Need some factors, to be calculated empirically!!
Anybody can construct a parametrization scheme, however some rules:

1. be physically reasonable
2. dimensionally correct
3. same scalar or vector properties
4. have the same symmetries
5. be invariant uder coordinate transform
6. be invariant under inertial or newtonian transformations
7. sastify the same constrains and budget equations

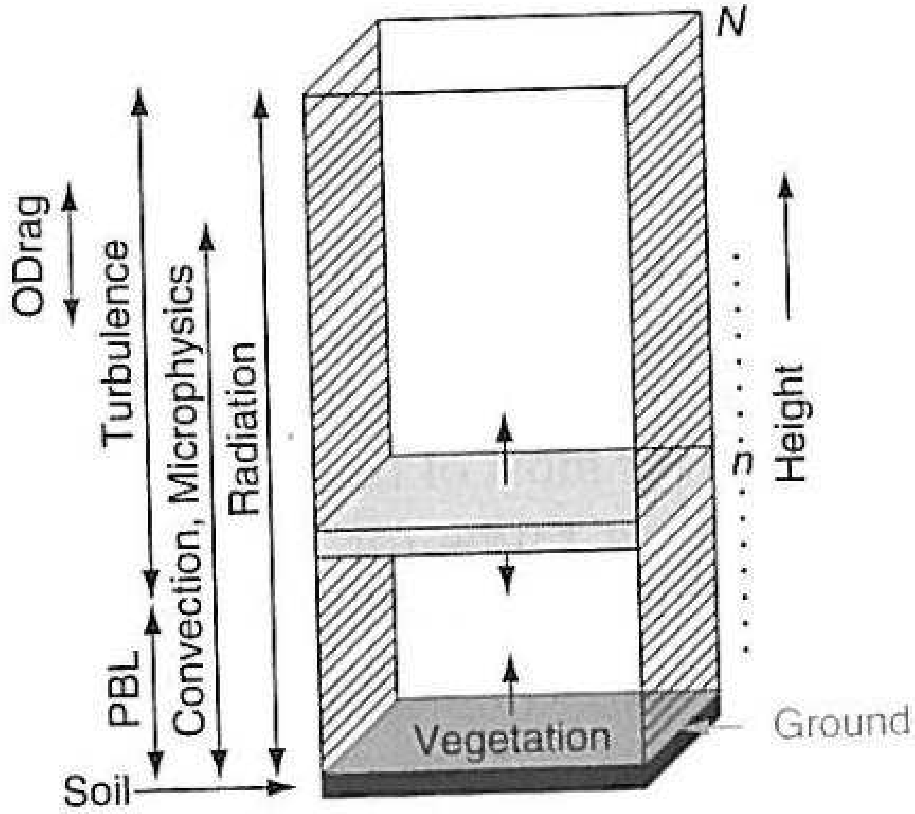
- Even satisfiying these rules, it can be succesfull only in some conditions.
- Parametrizations only approach nature
- They never will be perfect!!! But can be satisfactory!!

Processes to be parametrized I

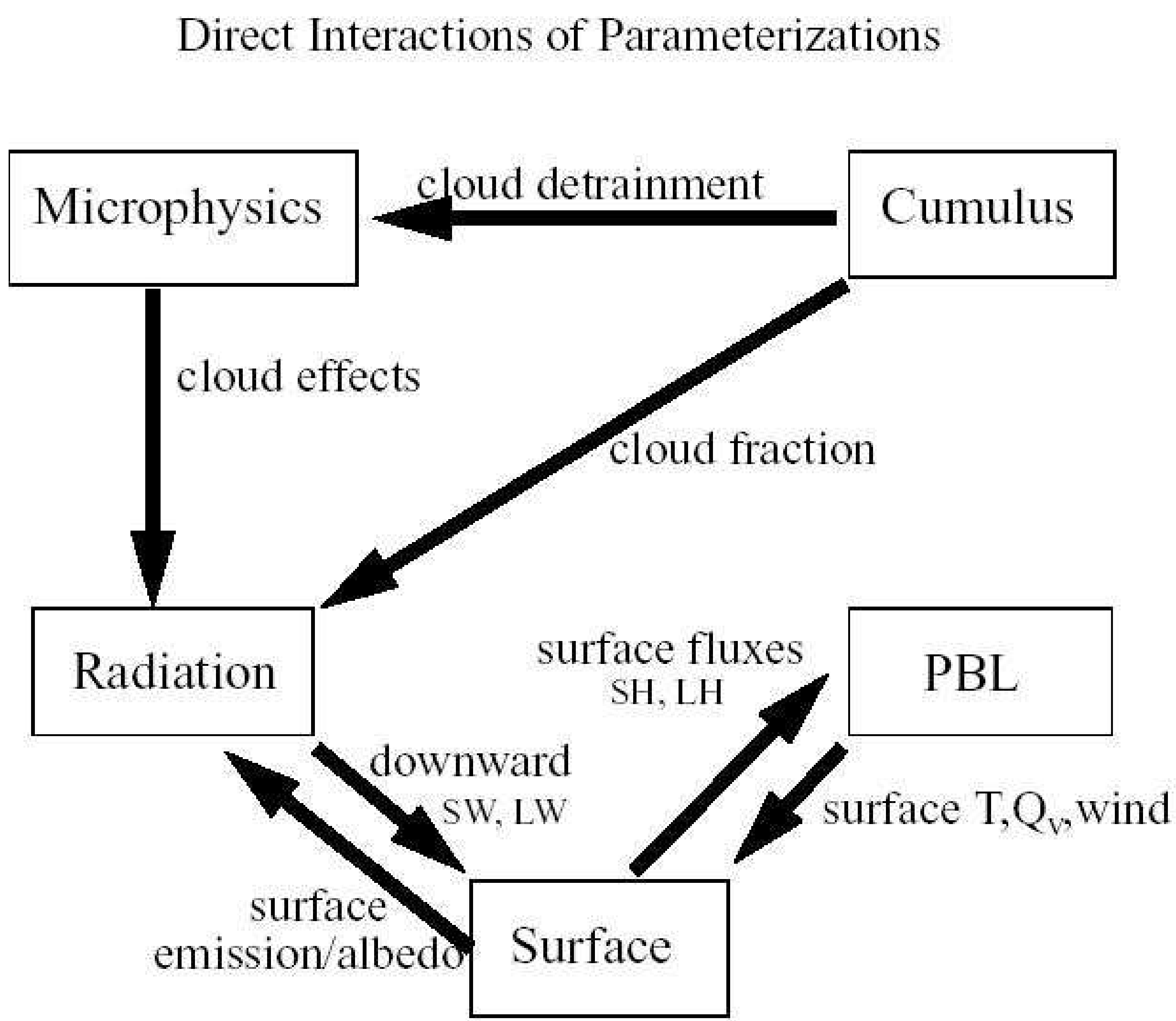
- Surface-atmosphere interactions
  - Land-atmosphere
  - Soil-atmosphere
  - Water-atmosphere
- Planetary boundary layer and turbulence
- Convective parameterizations (CUMULUS)
- Microphysics (moisture)
- Radiation
- Others
  - Cloud cover and cloudy-sky
  - Orographyc drag



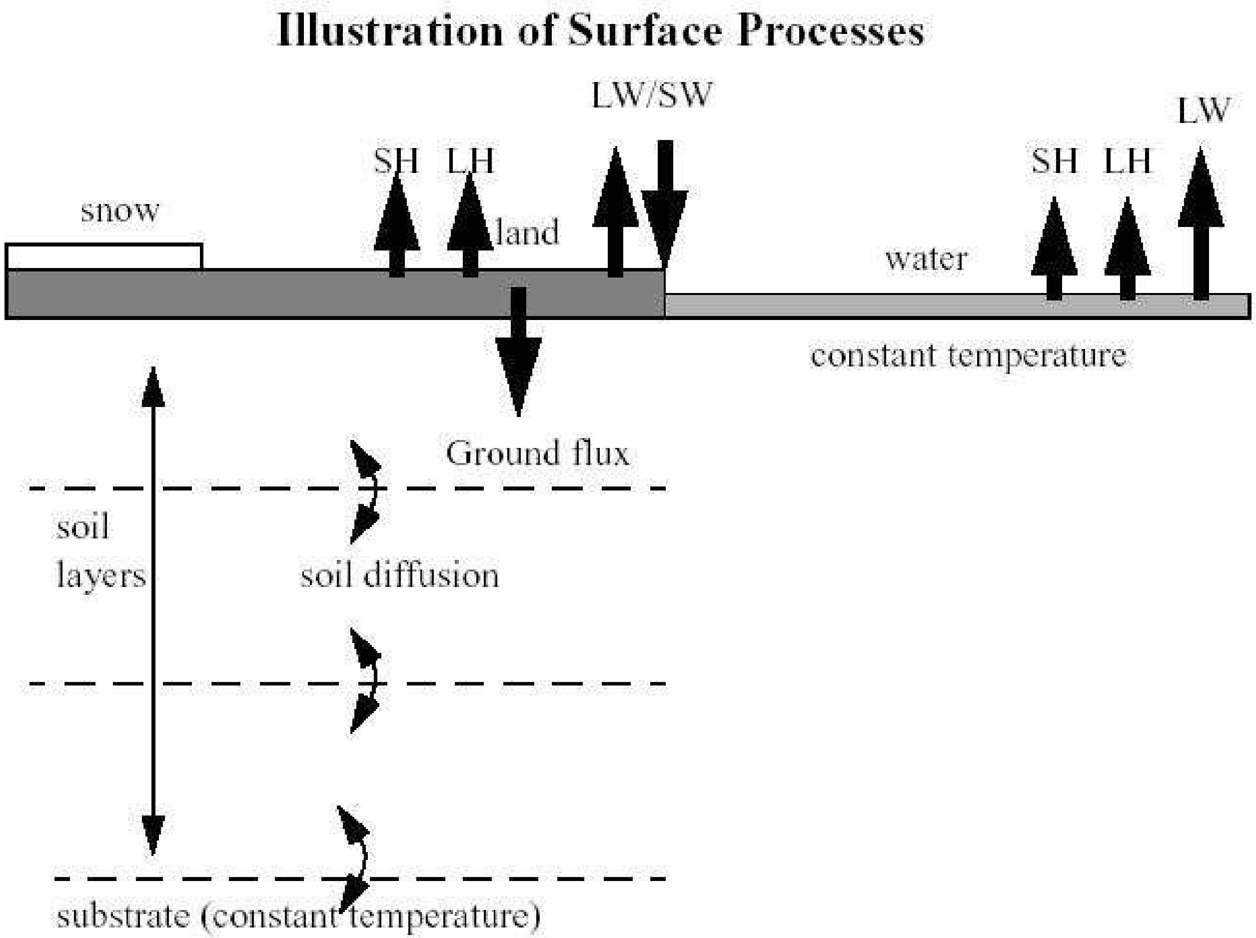
Unidirectional character of parameterizations



Interaction of parametrizations



Surface parametrizations: land-soil-water-atmosphere



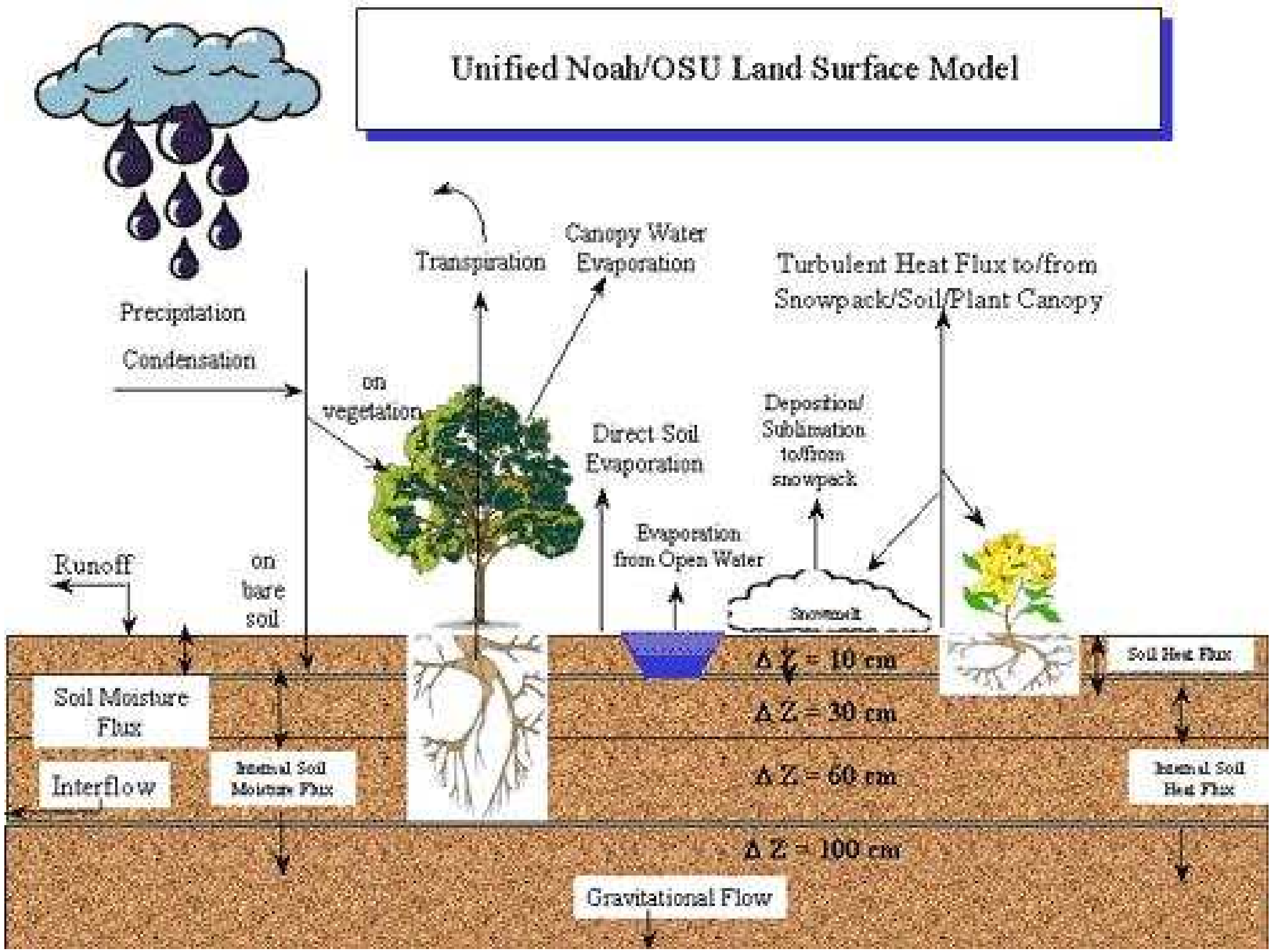
Provide Lower Boundary Conditions to the atmosphere

Land-surface Models I

Different levels of complexity as a function of modelled processes

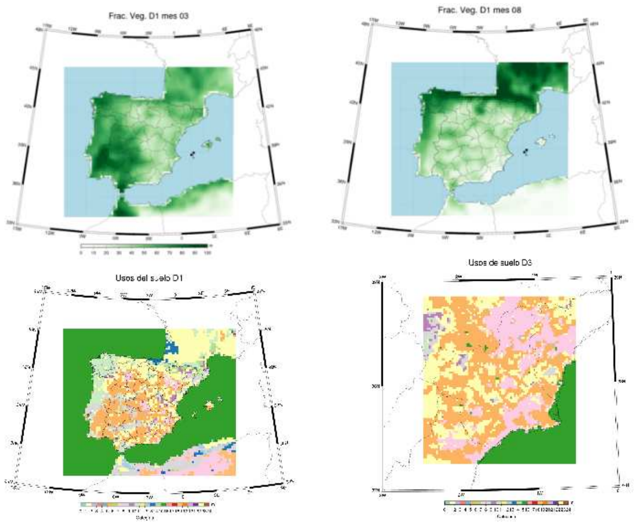
- Properties are just a function of Land use
- Use several soil layers or just two
- Include properties of soil (thermal and hidrology) and can be modified by precipitation
- Include fixed vegetation
- Permision of subgrid variety
- Include dynamic vegetation
- Include interaction of soil with atmosphere composition (biogeochemistry)
- Include full hidrology processes

One example of Land surface model (Typical)



Data base needed: also approachs!!!

- Land use clasification and physical properties associated.
- Vegetation fraction, Leaf area Index, vegetation clases
- Orography
- and more ....



Water atmosphere parametrizations

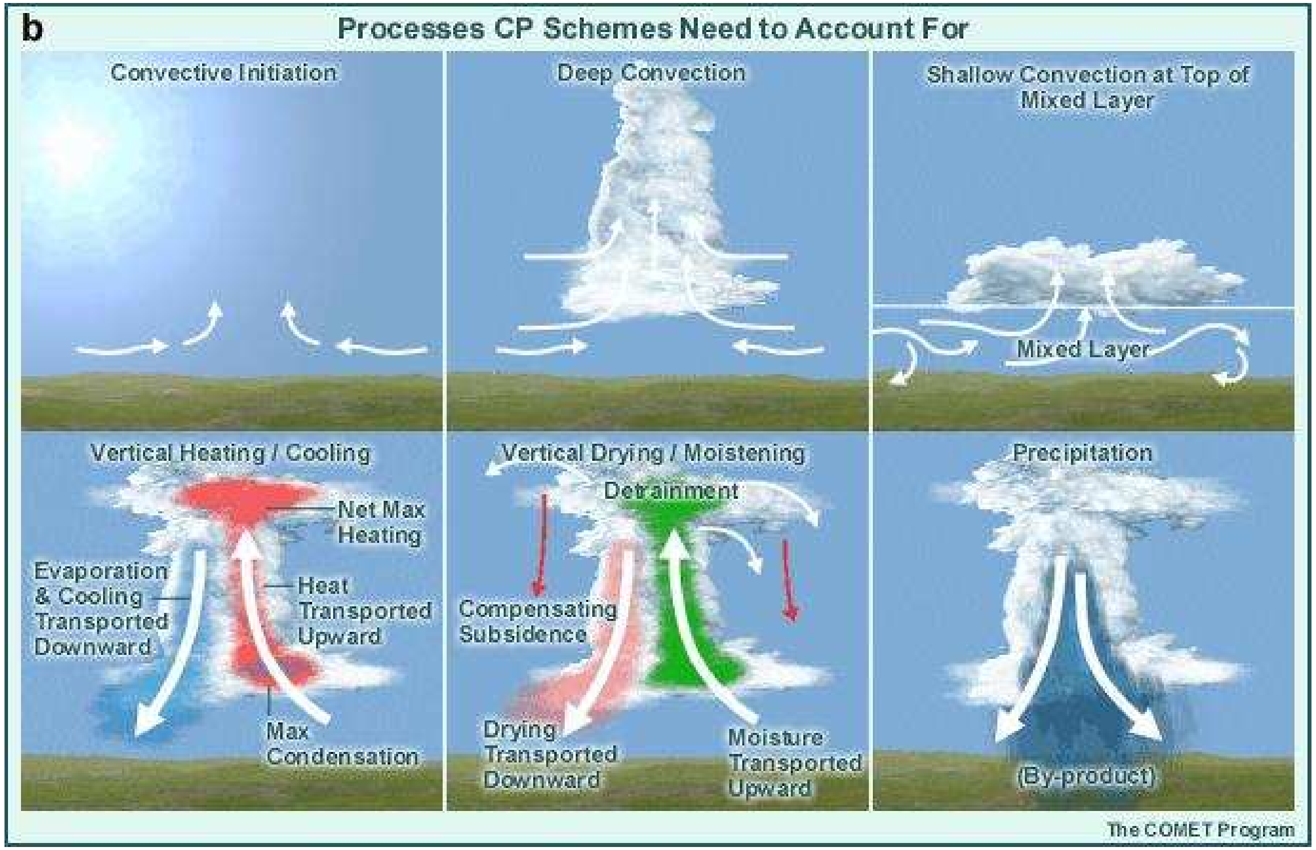
Different levels of complexity

- One way interaction: SST as low boundary conditions
- Simple two-way interaction with wave models
- Complex two-way interaction with Regional Ocean Models (and wave models)

Convective parameterization I

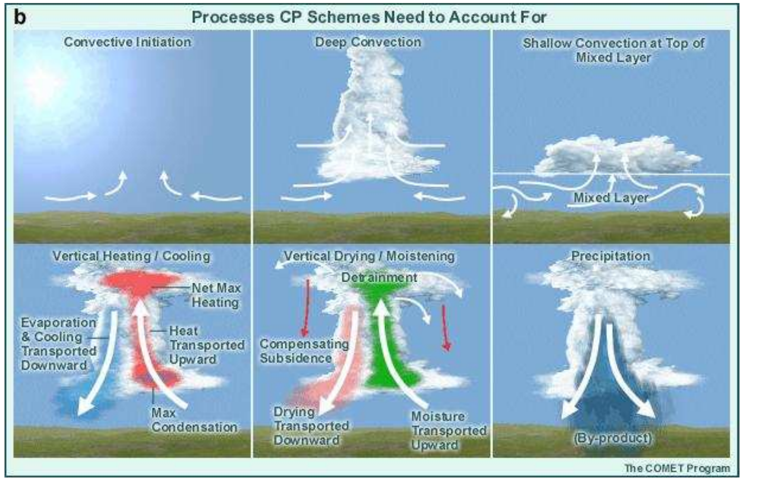
- **What is convective parameterization?**
  A technique used in NWP to predict the collective effects of (many) convective clouds that may exist within a single grid element as a function of larger-scale processes and/or conditions.
- **Why do we need to worry about it?**
  - Direct Concern: To Predict convective precipitation
  - Feedback to larger Scales:
    1. Deep convection overturns the atmosphere, strongly affecting mesoscale dynamics
    2. Changes vertical stability
    3. generates and redistributes heat
    4. removes and redistributes moisture
    5. makes clouds, strongly affecting surface heating and atmospheric radiation

Convective parameterization II



Types of convection to parametrize

- Deep convection
- Shallow convection
- CP can simulate both approximations, but ussually not.



- Most of schemes evaluate the Convective Available Potential Energy (CAPE). Also the convective inhibition
- some schemes gives a determinate end resutls, others stocastic approach to determine how convection influences the environment
- The closure assumptions:
  - place constraints on large sale states,moist convection processes or both
  - other–¿ deep layer control schemes and low level control schemes

Convective schemes I

- **Deep-layer control convective schemes**
  - Quasi-equilibrium or CAPE adjustement schemes
  - Arakawa-Schuber, Bets-Miller,Kuo

- **Low-level control advective schemes**
  - Activation control schemes $\longrightarrow$ deep convection is determined by Physical processes that control convective initiation
  - Some examples: Tiedke, Gregory-Rowntree, Kain-Fritsch, Emanuel (Mass flux schemes)

Convective schemes II

Clasificacion based upon how the environmental changes:

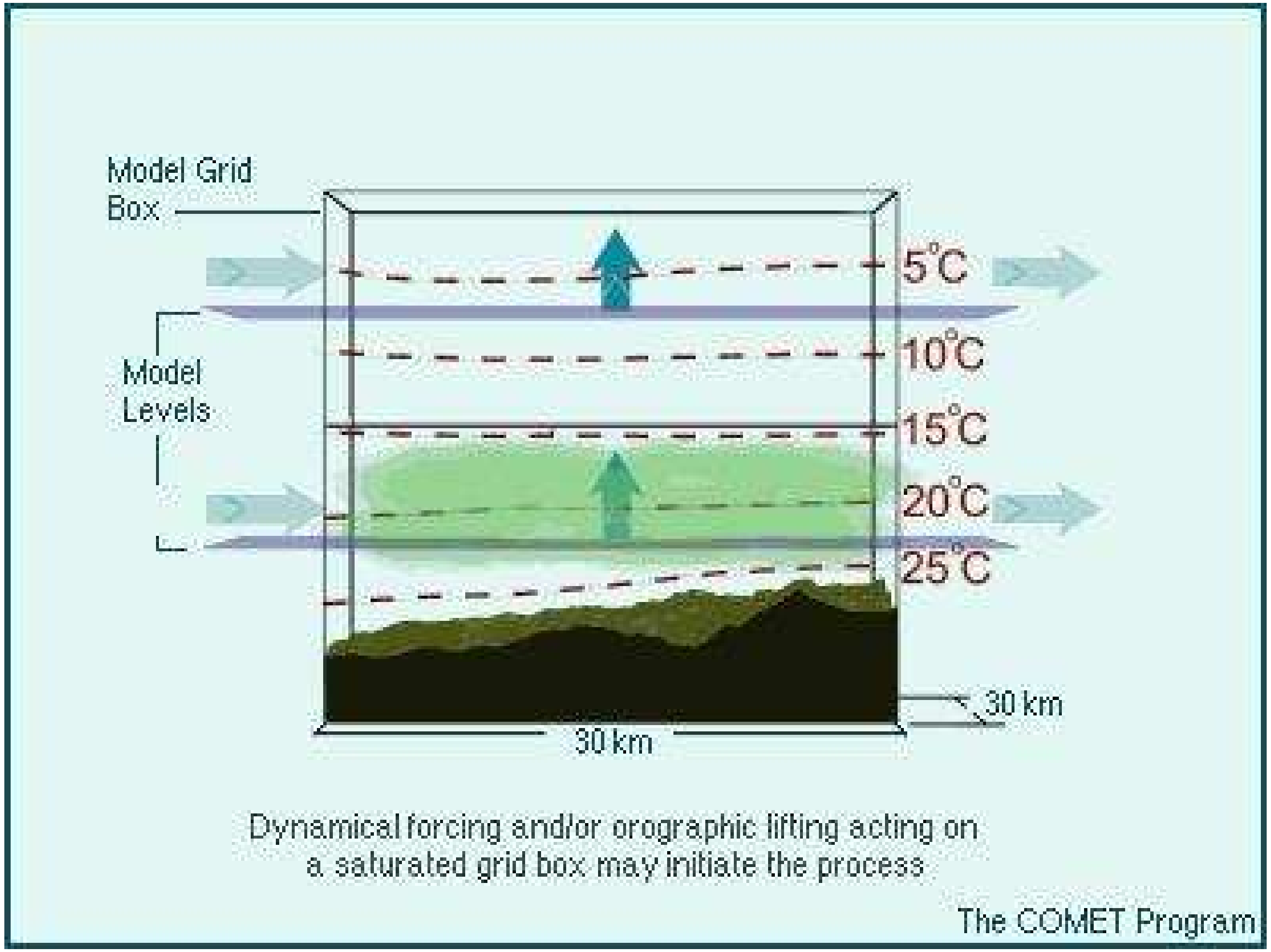
- **Static schemes** $\longrightarrow$ determines the final environment after convection is done and adjust the model fields towards this final state–only adjustement time period. The final state often is one that is neutral to convective overturning.
- **Dynamic schemes** $\longrightarrow$ physical processes are important ans should influence how the scheme functions. Some of the use entrainment plumes and calculate the transfer of mass in updrafs nd downdrafts

Convective schemes III

A convective parameterization must decide 3 things:

- **Activation** $\longrightarrow$Trigger Function (some times closure asumptions)
- **Intensity** $\longrightarrow$Closure Assumptions
- **Vertical distribution** $\longrightarrow$Cloud model or specified profile

Microphysics

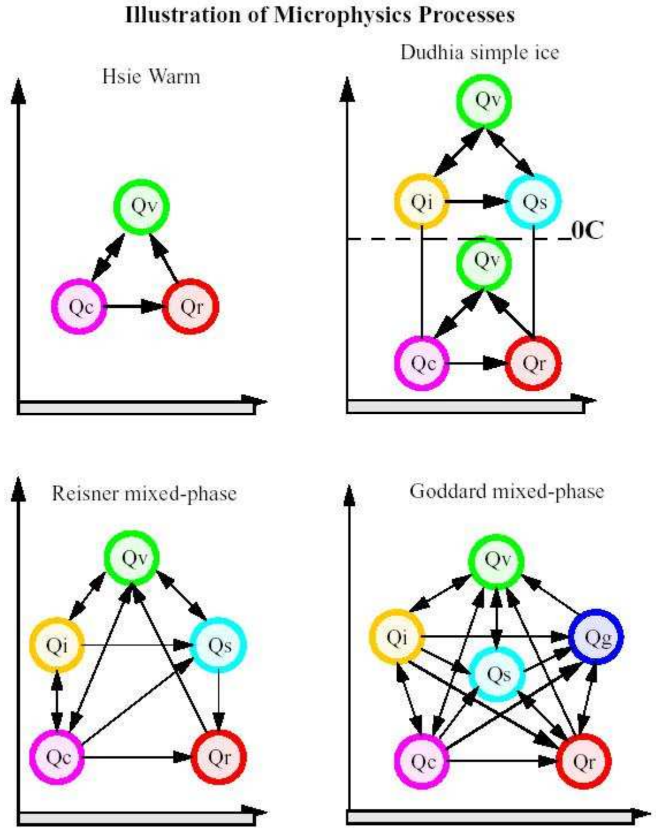


Microphyscis moisture approaches

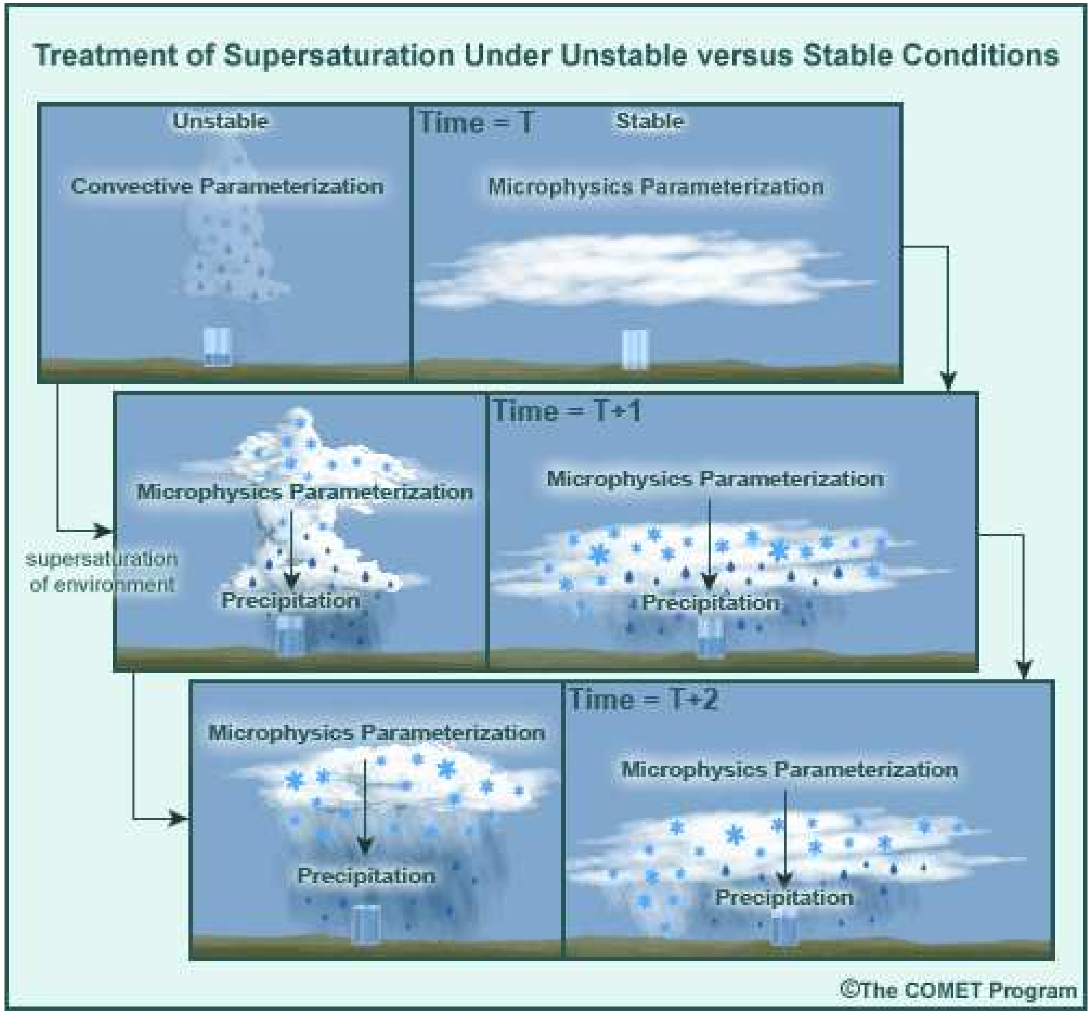
- **Bulk approach** :
  - Use specified functional form for the particle size distribution
  - Predicts:
    - Particle mixing ratio (single-moment)
    - and concentration (second-moment)
      Aplicable to a wider range of environments Less tuning
    - and third-moments approach
- **Bin approach**
  - Divide particle distribution into a number of mass (size) categories

Bulk approaches

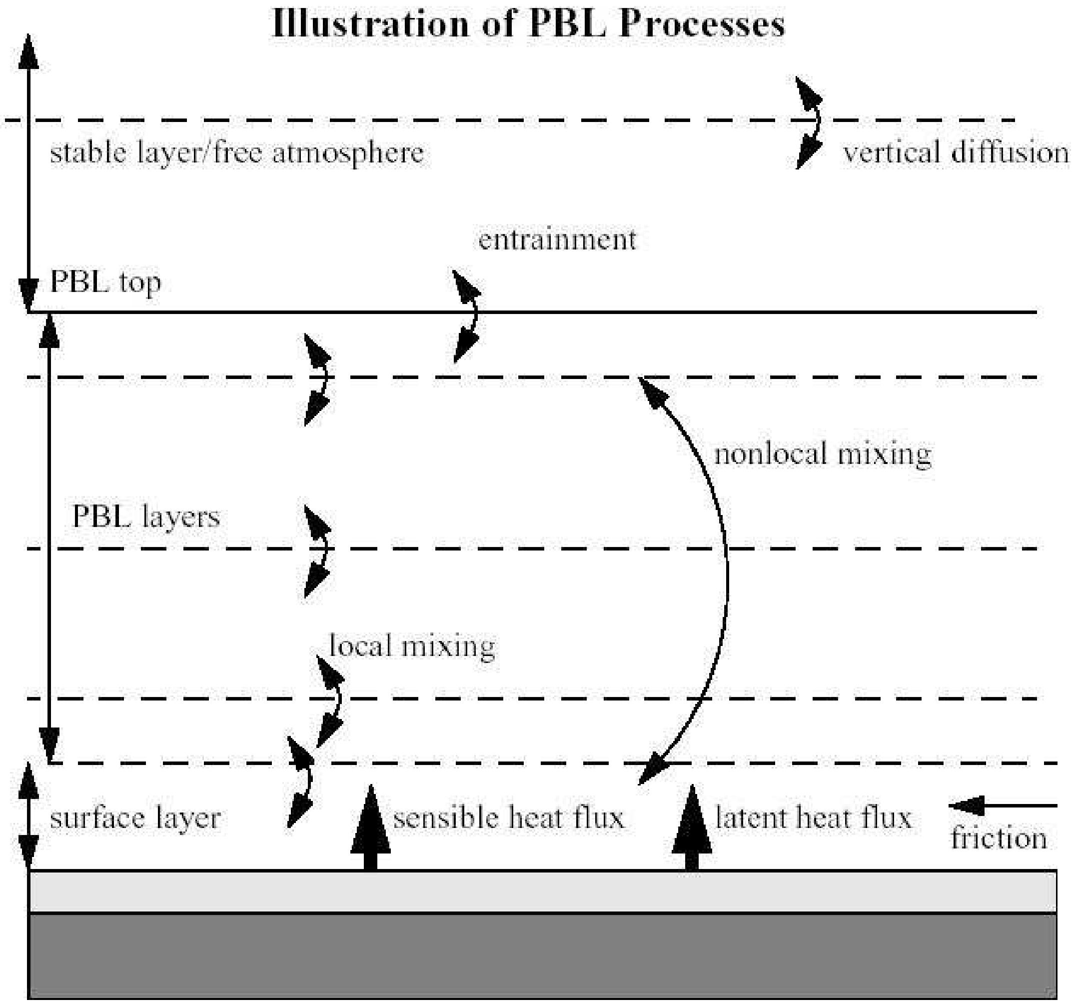
- Some aproximations
  - Cloud water and cloud ice: monodisperse and do not move, just advected (horizontal and vertical) while precipitating particles moves
  - Different functions for approximate the distribution of particles
- Differences in
  - Interplay between different interactions
  - and number of interactions



Precipitation produced by microphysics



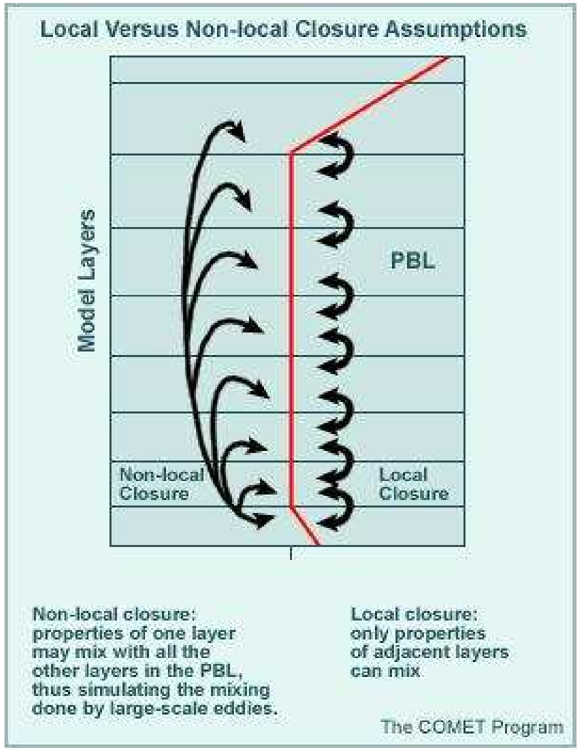
PBL and turbulence processes



Clasification of PBL schemes

In general, closure is what links the assumptions in a model parameterization to the forecast variables themselves. For the PBL, the forecast surface and near-surface winds, temperatures, and moisture are used to estimate the amount of buoyant and mechanical energy that will be available to create the model PBL. The resulting PBL transports are then used to further adjust the forecast variables.

- Local closure
- Non local closure



Some models used mix of local (night) and non-local (day) schemes

Non local closures

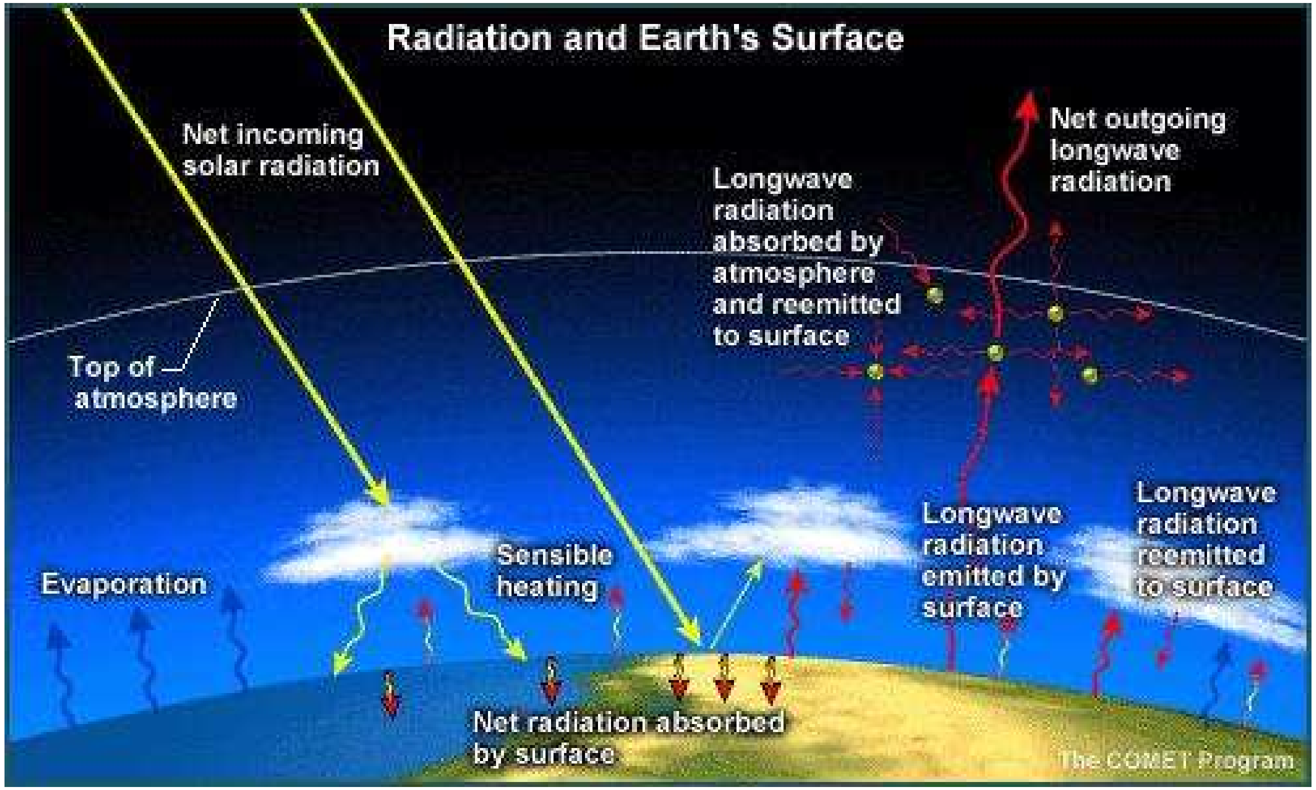
- Mixed layer schemes
- Penetrative convection schemes
  - Blackadar (In stable situations reverts to local closure)
  - Pleim and Chung
- Non local difussion scheme
  - Hong and Pang (MRF) $\longrightarrow$ Large eddy simulations
  - Transilient Turbulence (Stull) $\longrightarrow$ Discretization of several eddy sizes

Local closures

Closure accuracy partly depends upon the level of internal interactions included in the calculations (order of closure). For example, first order closure only estimates the effect of the turbulent eddies on PBL growth, while second order closure estimates both these effects and the effect of turbulent eddies on each other.

- First order $\longrightarrow$ K-theory.
  Covariance terms are parametrized. Good at night
- 1.5 order (Yamada, Mellor, Janjic)
  - Empirical length scale
  - Downgradient diffussion and Counter gradient flux
  - Gives TKE (important for pollution and turbulence)
- 2 order (Mellor and Yamada)
- Even larger!! 2.5 order

Radiation interactions



Longwave radiation

- **Empirical methods**
- **Two-stream methods** for clear skies
  - Paths
    - Simplication integrating all angles
    - Adjust of non-homogenious paths
    - Or previously paths that are interpolated (RRTM)
  - Frequency
    - Narrow bands models
    - Wide-band models (emissivity models)

Shortwave radiation

- **Empirical methods**
  Only predicts SWR on Earths surface, fitted from observations or more complex radiation models
- **Two-stream methods** in clear skies
  Treatment of direct and diffuse components
  - Eddintong aproximation
  - Delta-Eddington approach
  - Two.stream approach

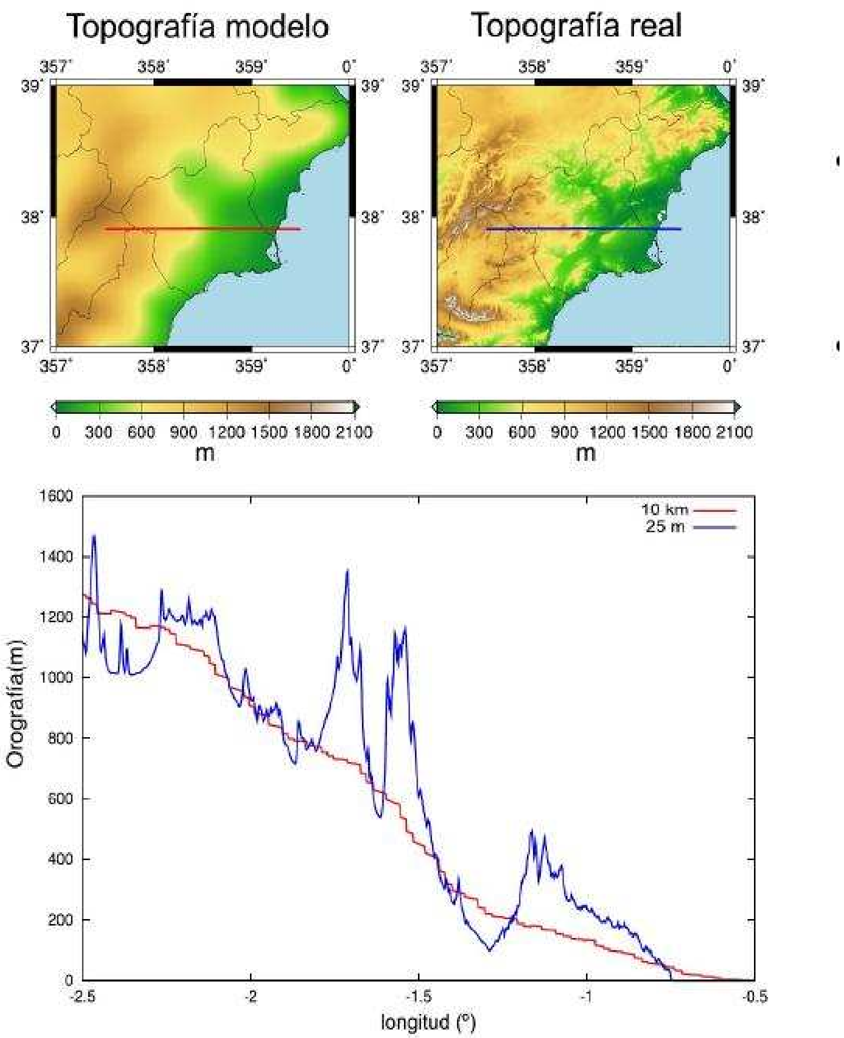
Some considerations

- Importance of data sets of aerosols, ozone, $C0_2$, etc
- One can find strong simplifications: constant values, modication of solar constant, etc ...
- Desirable to have chemistry models coupled to RCM to obtain two way interactions between physics and chemistry.

Cloud parametrizations

- When explicit microphysics (complex) is employed no subgrid clouds
  - Each grid cell has cloud o no cloud, no subgrid clouds!!
  - Less that 10km
- Diagnostic cover parametrization
  - Cloud cover is diagnosed after each time step
  - RH,convective activity,w, wind shear, and surface fluxes
  - Mainly 3 types of clouds (low, middle and high)
  - Subgrid clouds
- Prognostic cover parameterization
  - Add an additional predictive equation for cloud water
  - Cloud cover is a predicted model variable along with a second variable for cloud water

Orographic drag

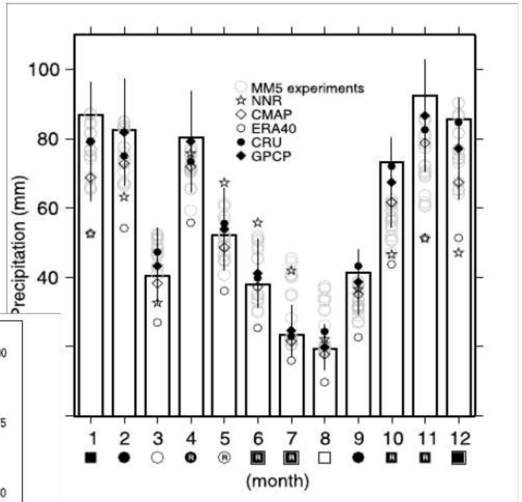


Physics ensemble present

Table 1. List of the Main MM5 V3.6 Physical Schemes and Parameterizations Numbered as Internally Identified by the MM5 in the Configuration File[a]

Explicit Moisture	Cumulus	PBL	Radiation
Dry	none	none	none
Stable precipitation	Anthes-Kuo	bulk PBL	simple cooling
Warm rain	**Grell**	**Blackadar**	**cloud**
Simple ice	Arakawa-Schubert	Burk-Thompson	CCM2
Mixed-phase	Fritsch-Chappell	Eta	**RRTM**
Goddard	**Kain-Fritsch**	**MRF**	
	Betts-Miller	Gayno-Seaman	
	Kain-Fritsch 2	Pleim-Chang	

[a]Those used in the sensitivity study are in bold face.



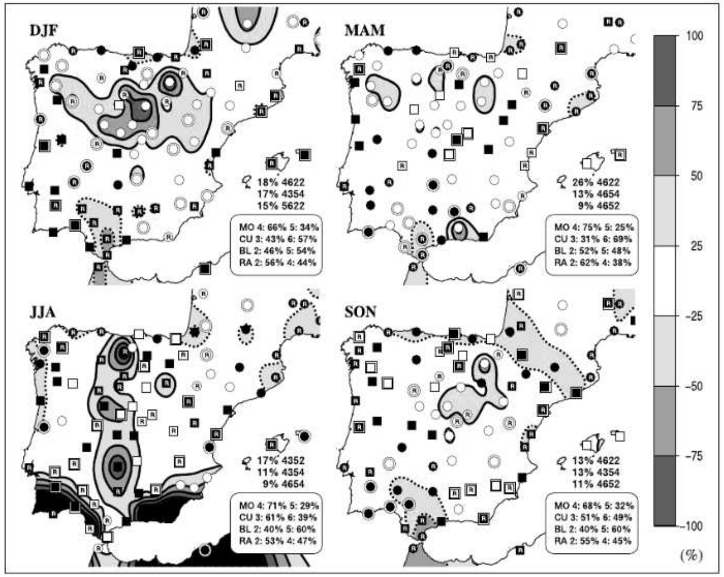


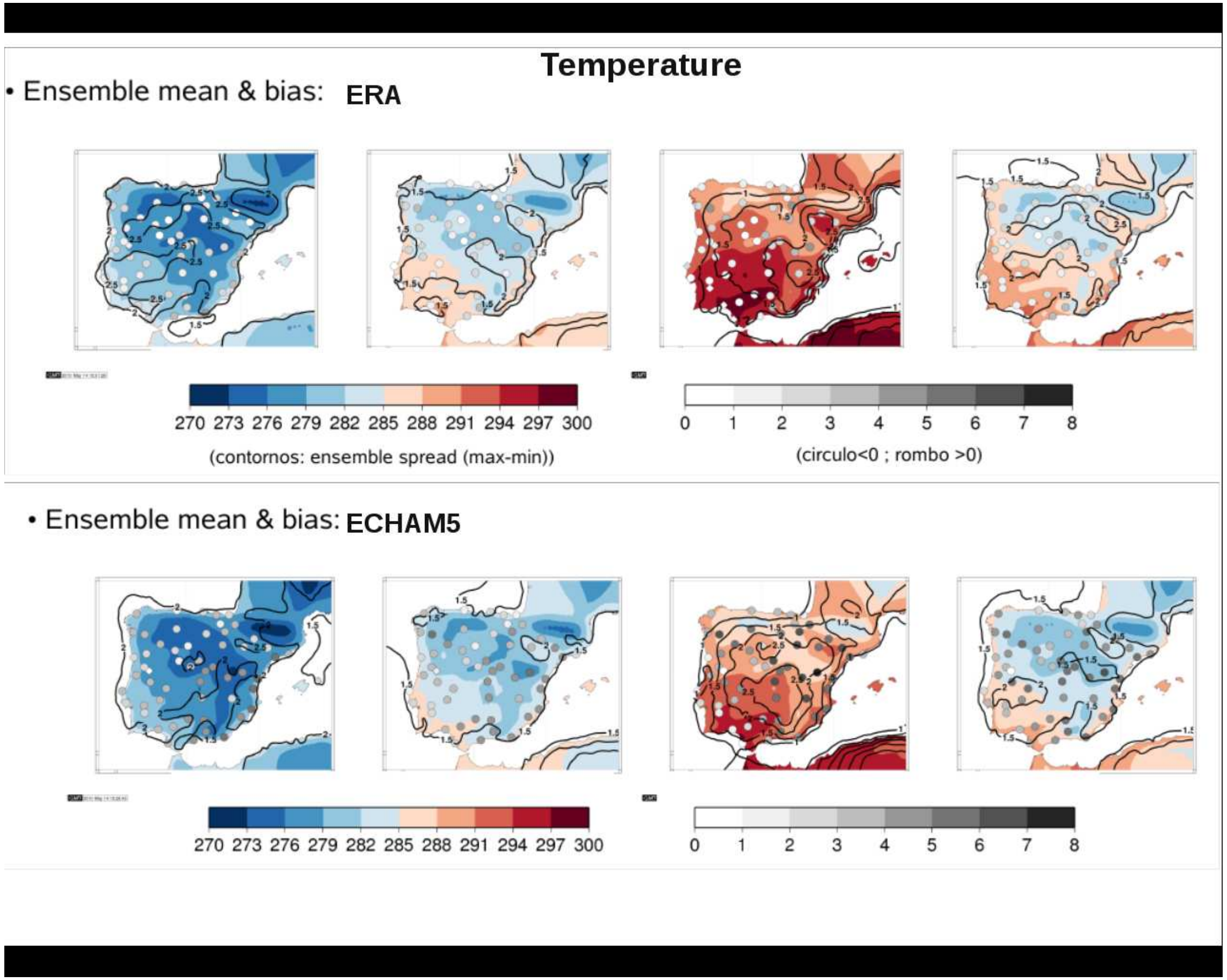
Figure 4. As in Figure 2 but using the relative error of the best experiment for each season. Dashed contours represent negative relative errors.

MM5 ensemble 16 members

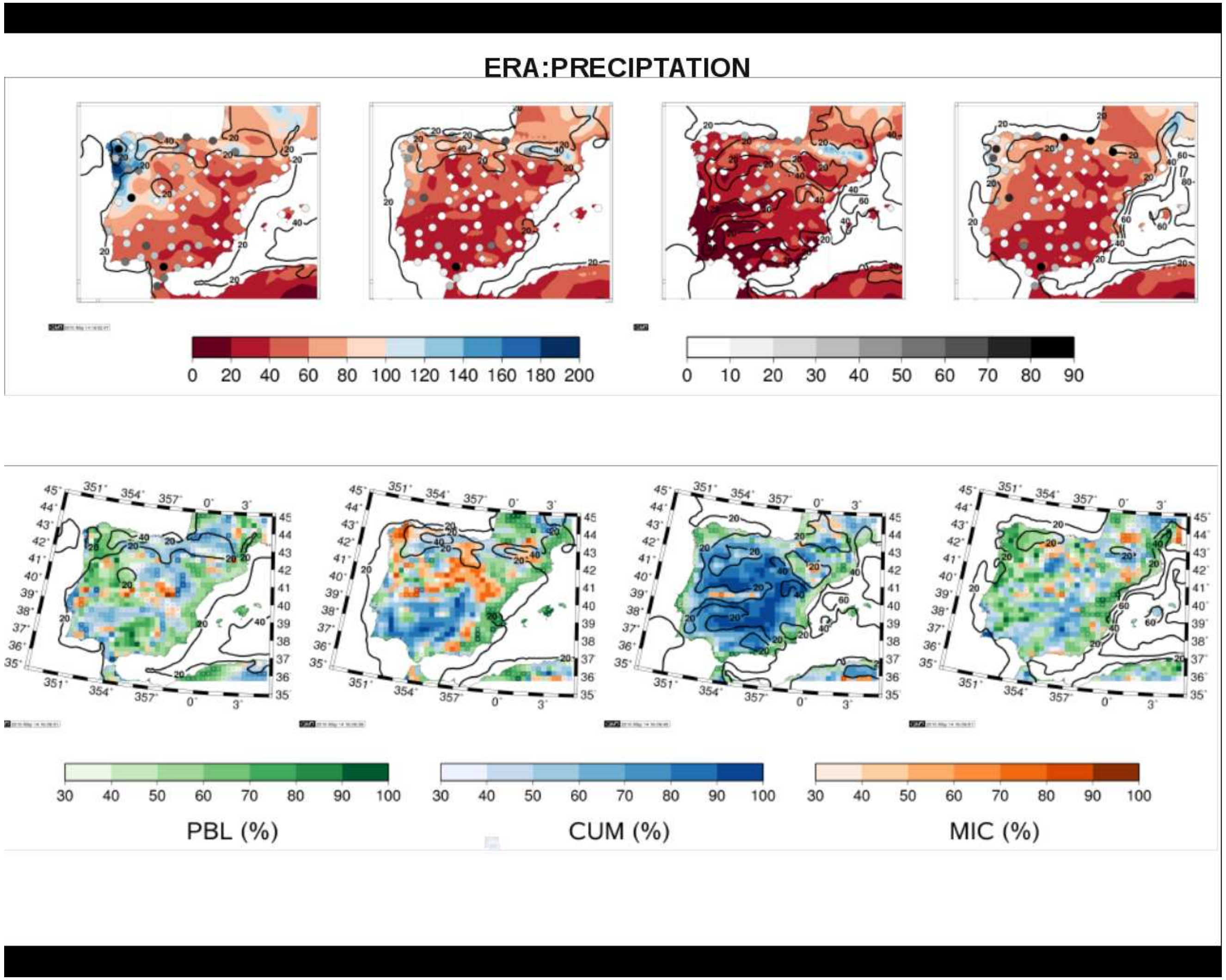
None of combination of PP
Is better

Spread is similar to
observations

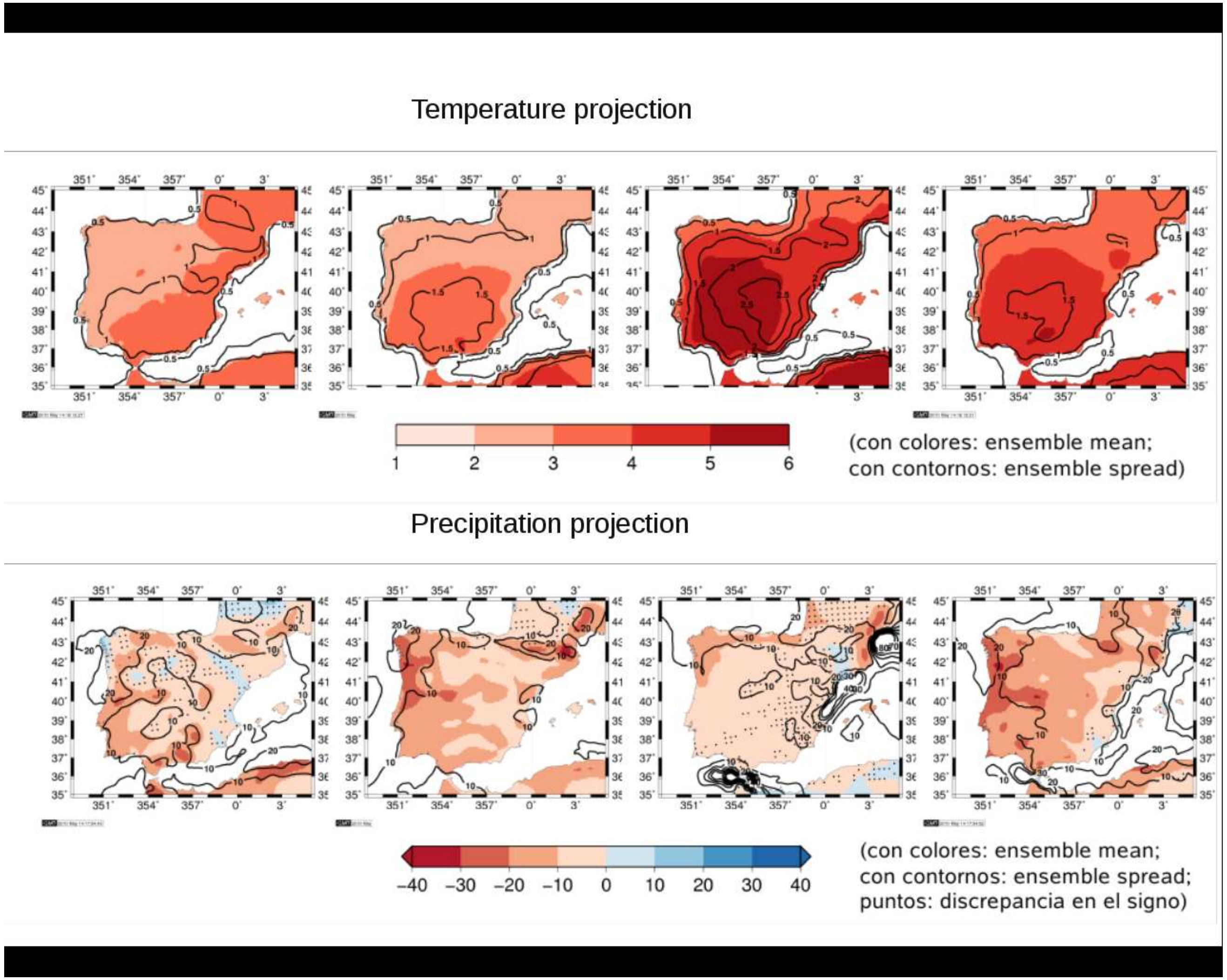
Physics ensemble present: temperature



Physics ensemble present: precipitation



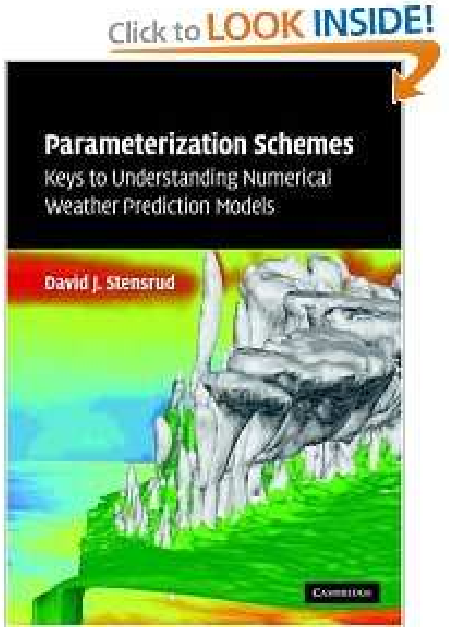
Physics ensemble future projection: precipitation



Good Bye

If you want to know much more about physics in RCM

- **David Stensrud** (2007) *Parameterization schemes*
- Also COMET has some nice documentation.



Nice to meet you!!!