# Climate Change and Future Scenarios. Simulations over the Iberian Peninsula

Pedro Jiménez-Guerrero

Regional Atmospheric Modelling
Physics of the Earth
University of Murcia

International Workshop ”Assessing Future Scenarios of Global Change, Impacts and Adaptation Measures in Water Resource Systems”
Granada, 25 Jun 2013

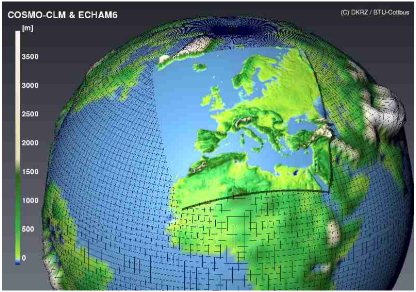
# Outline

1. Introduction
   - Need for RCMs
   - Structure of RCMs
2. Uncertainties in climate change projections
   - Sources of uncertainty
   - Present climate simulations over the Iberian Peninsula
   - Climate projections over the Iberian Peninsula
3. The CORDEX Initiative
   - Contribution to CORDEX: CORWES project

# Regional climate models

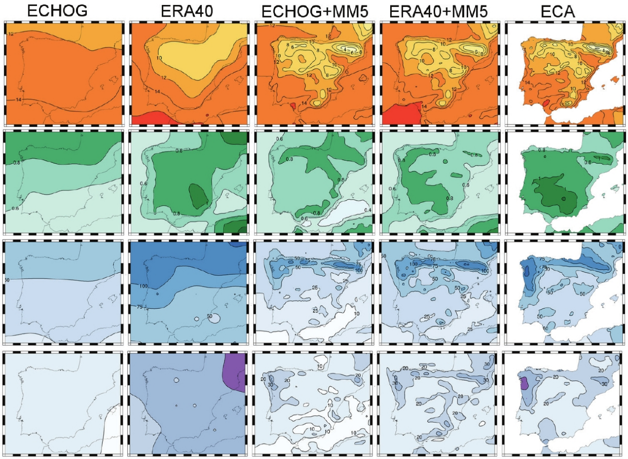
# What is a RCM?

- Limited Area Model (or mesoscale model) designed for climate simulations
- Differences with respect to meteorological models?
  - Regional Weather and Climate models tend to trust the same processes. Most of RCM were born from meteo models.
  - However, initial conditions are fundamental in meteorology but not in RCMs.
- Also, soil treatment, radiation, and some other factors play an important role.
- Dynamical downscaling.



# Added value of downscaling

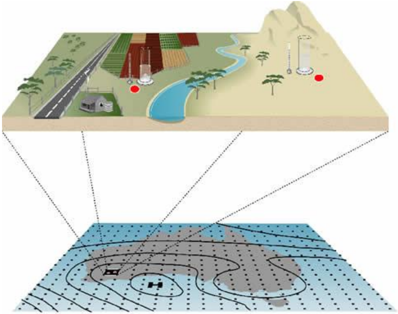
T, $\sigma(T)$, P y $\sigma(P)$, springtime



# Downscaling techniques

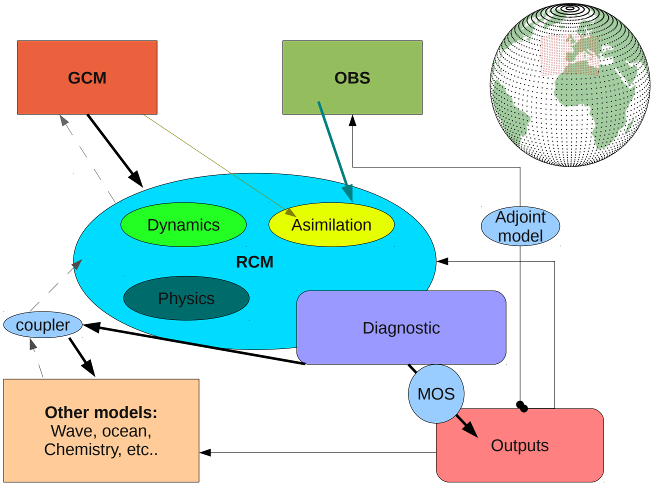
Two different ways of facing the same problem:

- **Statistical downscaling**. Looking for statistical relations between a larger scale circulation and local meteorological variables.
- **Dynamical downscaling**. Solving the equations determining the atmospheric behaviour (and other components of the climate system) at a higher resolution than GCMs in a limited area.

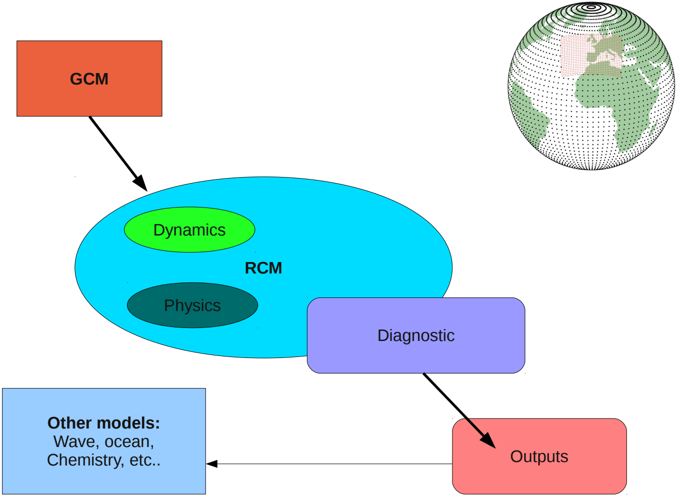


Important: What's going on in a perturbed climate? Probably dynamical downscaling has something to say.

# Regional modelling system



# Used regional modelling system for climate projections



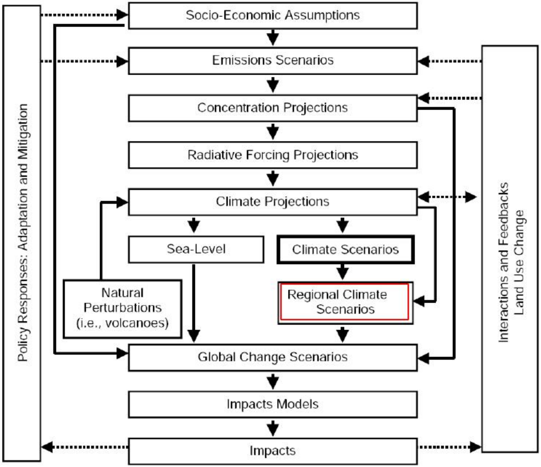
# Sources of uncertainty

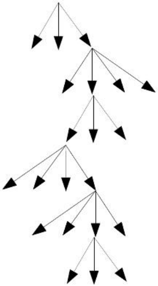
Any parameter modified in RCMs provokes changes in the final projections. Even assuming a perfect code, there are uncertainties related to:

- Initial conditions and forcing from global models.
- Size, position and resolution of the domains.
- Methods for numerical resolution.
- Physics of the model.
- Soil characterization, land use, vegetation fraction.
- Others: compilers, number of bits, etc.

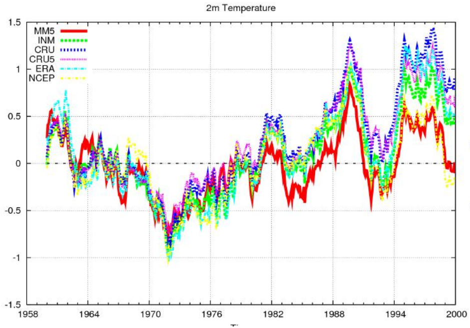
Not all of them have the same importance. They depend on the time scales.

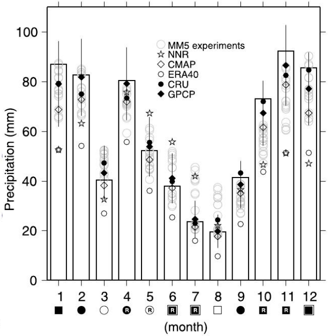
# Sources of uncertainty in climate projections



# Example of present uncertainty: Observations



# Why are parameterizations needed?

- A parametrization is an approximation to an unknown 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 parameterizations 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 parameterized.
- *Parameterizations approximate the bulk effects of physical processes that are too small, too complex, or too poorly understood to be explicitly represented.*

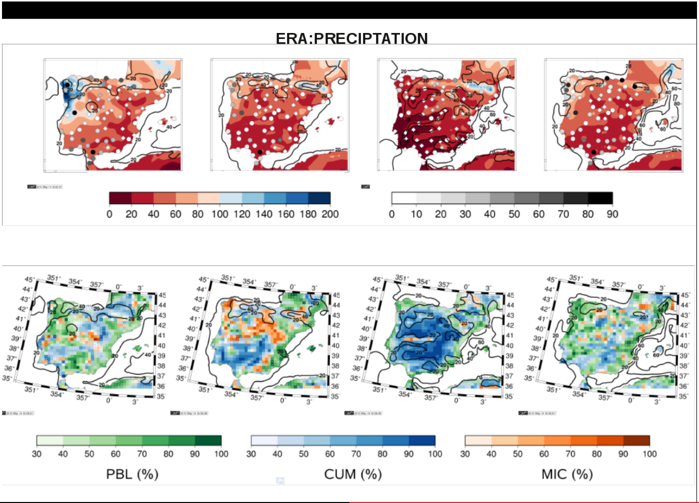
They will never be perfect. But can be satisfactory!!

# Processes to be parameterized

- 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
  - Orographic drag

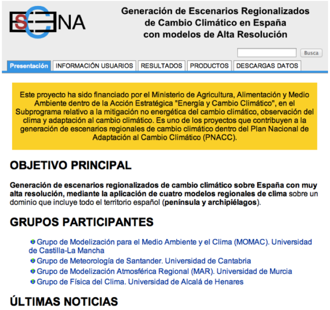
# Physics ensemble present: Precipitation

(Jerez et al., 2013; Clim. Dyn.)

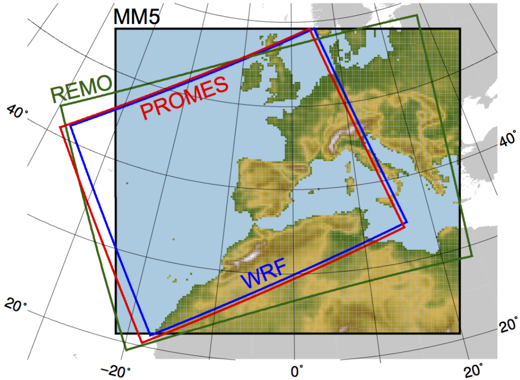


# Examples of multimodel uncertainty: ESCENA

- The objective of the project ESCENA (funded by the Spanish Ministry of the Environment) is to generate downscaled climate scenarios over Spain with a resolution of 25 km.
- Data is publicly available through `http://proyectoescena.uclm.es`

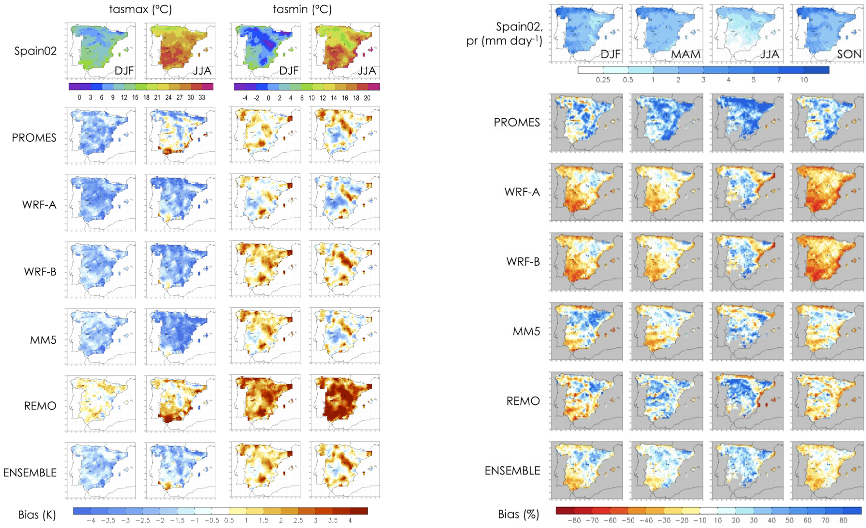


# ESCENA project



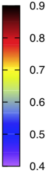

| | | GCMs | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ERAIN | EC5R2 | | | | ARPEG | | | HDQ03 | | HDQ16 | |
| | | Rean. | 20C3M | A1B | A2 | B1 | 20C3M | A1B | B1 | 20C3M | A1B | 20C3M | A1B |
| RCMs | PROMES | X | X | X | X | X | X | X | X | X | X | X | X |
| | MM5 | X | X | X | X | X | X | X | X | X | X | X | X |
| | REMO | X | X | X | | X | | | | | | | |
| | WRF-A | X | X | X | X | | | | | | | | |
| | WRF-B | X | X | X | | | | | | | | | |

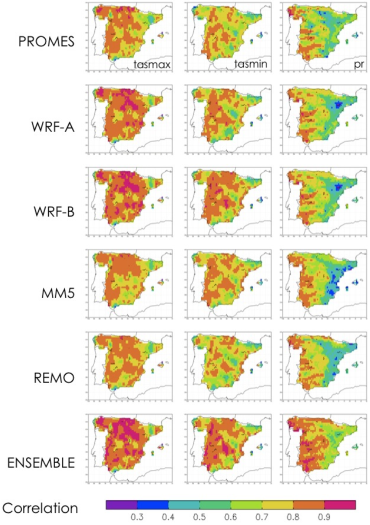
# Observed vs. modelled climatologies



# Skills of RCM over the IP

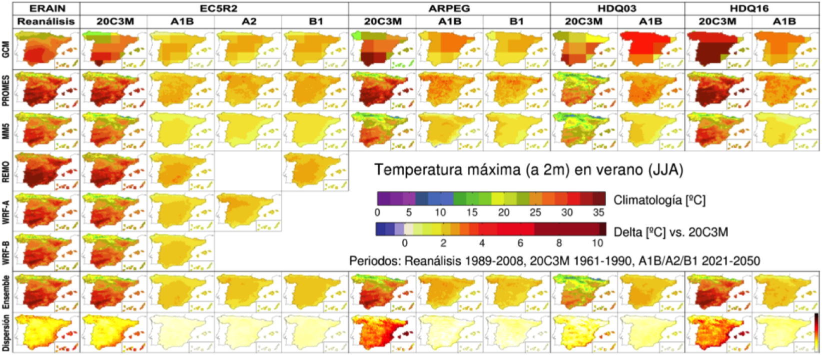
| | DJF | MAM | JJA | SON | ANNUAL |
|---|---|---|---|---|---|
| ENSEMBLE | 0.81 | 0.87 | 0.83 | 0.86 | 0.84 |
| REMO | 0.78 | 0.83 | 0.69 | 0.83 | 0.79 |
| MM5 | 0.77 | 0.83 | 0.74 | 0.80 | 0.78 |
| WRB | 0.80 | 0.86 | 0.83 | 0.84 | 0.84 |
| WRA | 0.78 | 0.85 | 0.83 | 0.84 | 0.83 |
| PROMES | 0.77 | 0.79 | 0.77 | 0.80 | 0.78 |
| ENSEMBLE | 0.82 | 0.74 | 0.77 | 0.83 | 0.79 |
| REMO | 0.78 | 0.66 | 0.68 | 0.78 | 0.72 |
| MM5 | 0.81 | 0.70 | 0.73 | 0.79 | 0.76 |
| WRB | 0.82 | 0.74 | 0.74 | 0.82 | 0.78 |
| WRA | 0.76 | 0.69 | 0.74 | 0.80 | 0.75 |
| PROMES | 0.67 | 0.74 | 0.77 | 0.76 | 0.73 |
| ENSEMBLE | 0.85 | 0.77 | 0.63 | 0.73 | 0.77 |
| REMO | 0.77 | 0.67 | 0.42 | 0.64 | 0.66 |
| MM5 | 0.77 | 0.64 | 0.44 | 0.62 | 0.66 |
| WRB | 0.80 | 0.69 | 0.53 | 0.63 | 0.69 |
| WRA | 0.78 | 0.68 | 0.52 | 0.62 | 0.68 |
| PROMES | 0.79 | 0.68 | 0.55 | 0.60 | 0.67 |



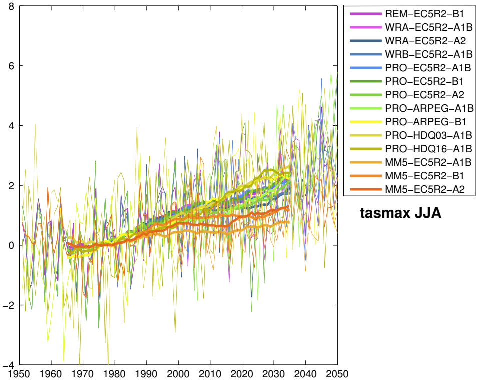
# Example of future uncertainty: Multimodel/Multiscenario

Results from the ESCENA project. Max summertime (JJA) 2-m temp (°C) (Future vs. present)



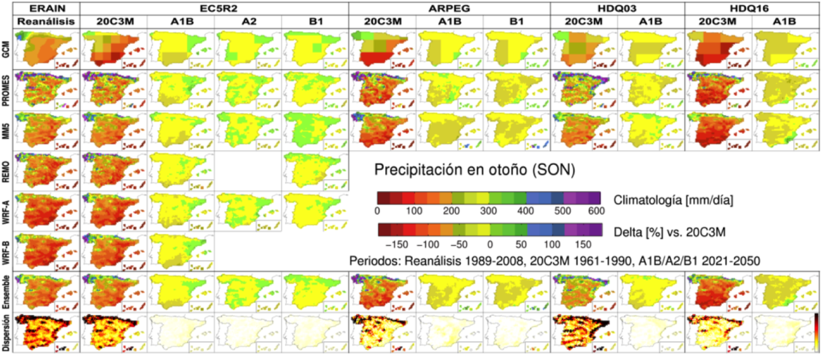
# Example of future uncertainty: Multimodel/Multiscenario

Results from the ESCENA project. Time series of the PC1 for 2-m temp anomalies under diverse scenarios (1951-2050)



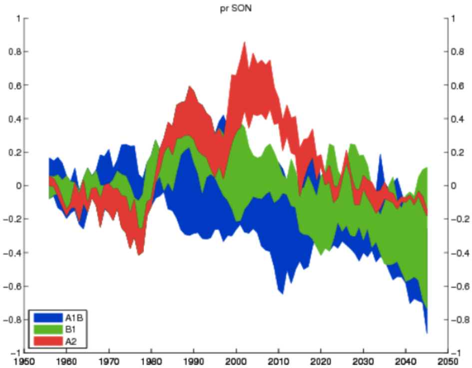
# Example of future uncertainty: Multimodel/Multiscenario

Results from the ESCENA project. Mean autumn (SON) precipitation (mm/day) (Future vs. present)



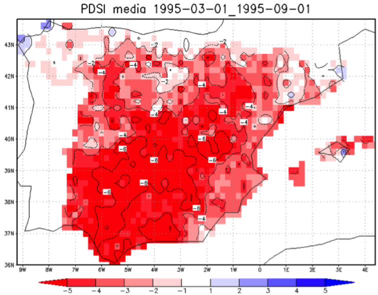
# Example of future uncertainty: Multimodel/Multiscenario

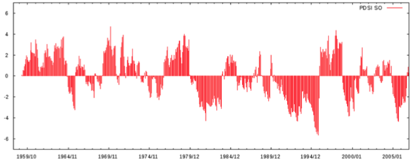
Results from the ESCENA project. Mean autumn (SON) precipitation anomalies under diverse scenarios (1951-2050)



# Applications from the ESCENA project

## Drought assessment in the Iberian Peninsula



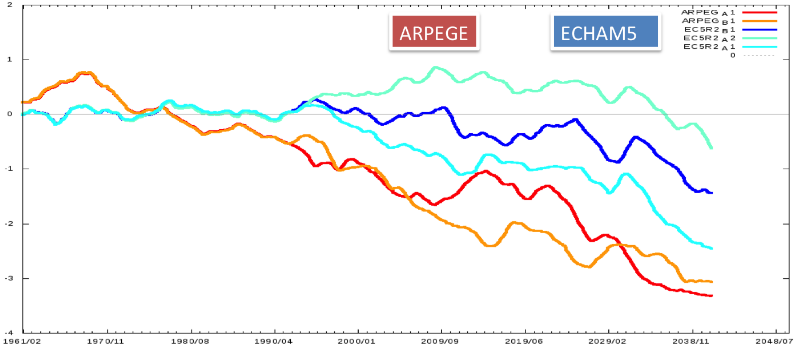





- Palmer Drought Severity Index (PDSI) for the period 1957-2007 in the SW domain from ESCENA project results.

# Applications from the ESCENA project

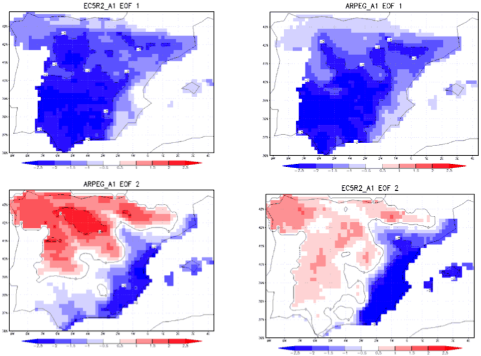
Projections of drought patterns under diverse climate change scenarios (1951-2050)




- 20-hr run-mean of the PDSI values projected averaged over the Iberian Peninsula

# Applications from the ESCENA project

## Spatial patterns of PDSI in climate change projections over the IP




Corr. coeff. between different simulations

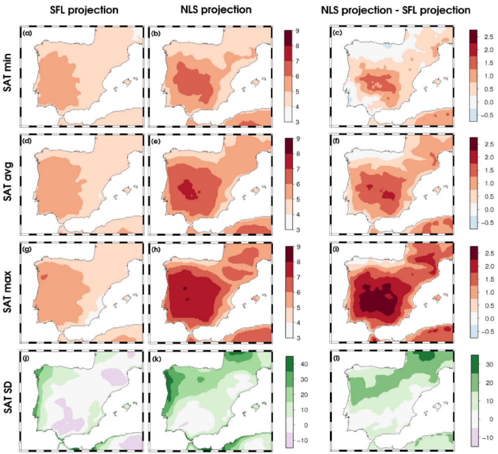
| | SPAIN02 -ARPEGE | SPAIN02 -EC5R2 | EC5R2-ARPEGE |
|---|---|---|---|
| EOF1 | 0,93 | 0,95 | 0,95 |
| EOF2 | 0,71 | 0,88 | 0,83 |
| EOF3 | 0,58 | 0,72 | 0,82 |
| EOF4 | 0,26 | 0,30 | 0,74 |

% of total variance explain by each EOF

| | SPAIN02 | EC5R2 | ARPEGE |
|---|---|---|---|
| EOF1 | 38 | 52 | 49 |
| EOF2 | 11 | 13 | 10 |
| EOF3 | 7 | 8 | 7 |
| EOF4 | 6 | 3 | 5 |
| ∑ | 62 | 76 | 71 |

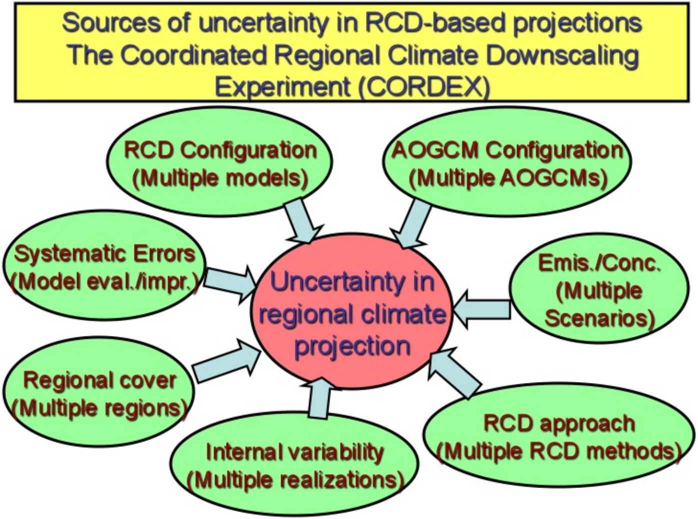
# Example of future uncertainty: Soil

(Jerez et al., 2010, Met. Zeit.)

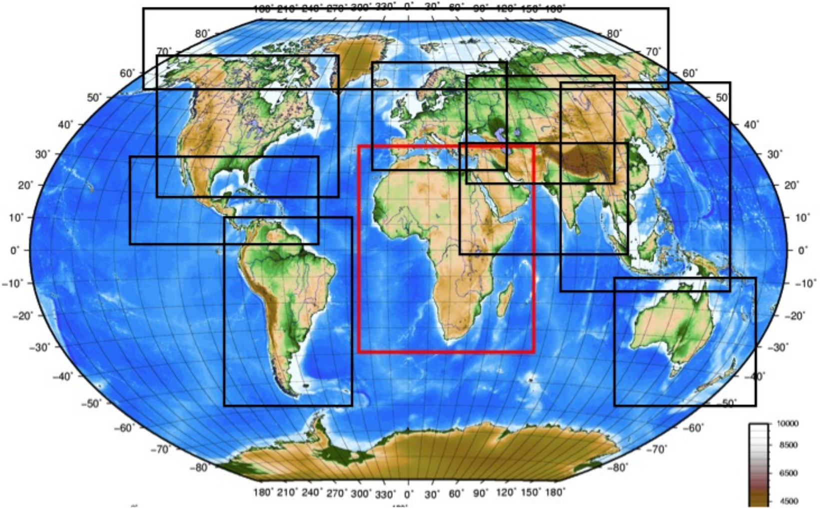


1. Introduction
2. Uncertainties in climate change projections
3. The CORDEX Initiative
   - Contribution to CORDEX: CORWES project

# The CORDEX initiative: structure



# The CORDEX initiative: domains

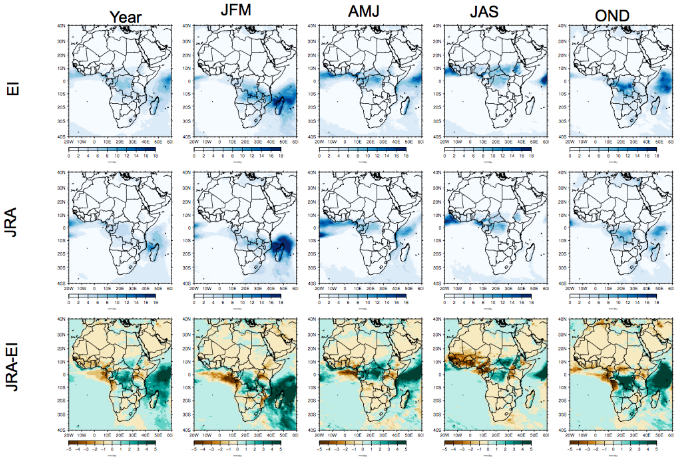


# The CORDEX initiative: CORWES

1. Contribute with basic CORDEX-compliant simulations for its key domains, through CORDEX-WRF and CORWES-UMU coordinated project.
2. Conduct research on the regional atmosphere-ocean coupling, assessing the role of the coupling on the climate change signal. The Regional Ocean Model System (ROMS) coupled to the WRF model will be used for this purpose.
3. Contribute to the analysis of the impacts in the climate change signal of atmosphere-ocean coupled models in such a complex area as the Canary Islands.
4. Maximize the number of basic CORDEX-compliant simulations. For that purpose, further research will be devoted to the optimization of the parallel performance of WRF-ROMS coupled system in a massive parallel infrastructure.
5. Transfer technology and knowledge among the groups, and to the rest of the scientific community, while developing diagnostic and formatting tools to be contributed as open source tools.

# The CORDEX initiative: CORWES

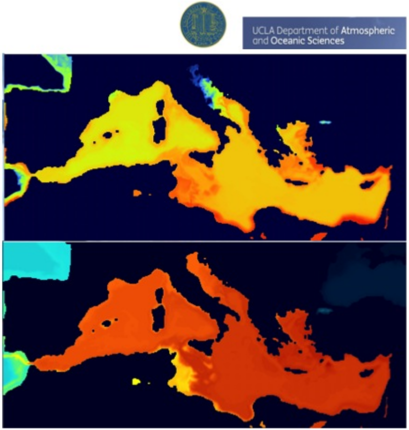
Precipitation climatologies over Africa: WRF-present climate simulations driven by ERA-Interim and JRA25 reanalyses.



# Atmosphere-Ocean Coupled Models

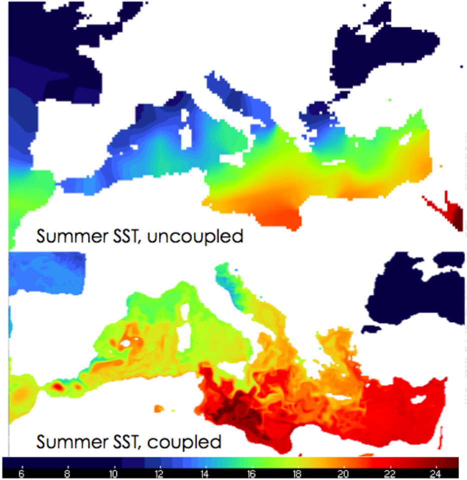
The atmosphere-ocean feedbacks play an important role in the amplification of regional warming:

- The coupling between WRF-ROMS for the Mediterranean allows reproducing accurately the variations in the climatology (1950-2000) with a modification in the precipitation patterns and a higher warming in coastal areas (between 0.05 and 0.2ºC).
- The salinity increased between 0.03 and 0.09 in that very period. This increase reflects the diminution of the precipitations in the Mediterranean, as well as the decrease in the rivers discharge.



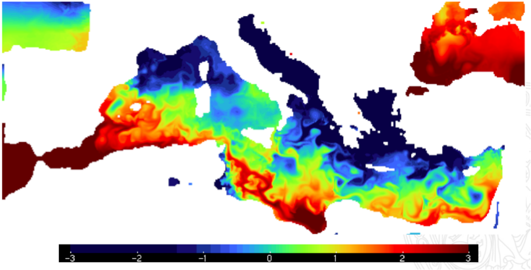
# Comparison of sea surface temperature (ºC)

Uncoupled vs. coupled simulations for the Mediterranean domain



# Summertime WRF-ROMS vs. ERA-Interim (ºC)

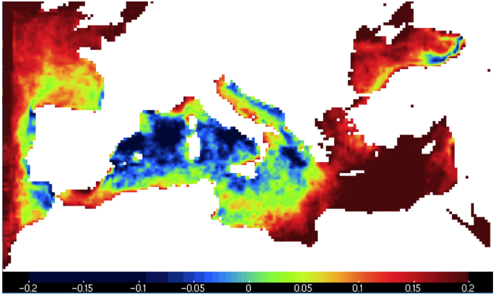
Bias of summertime SST




- During summer, WRF-ROMS provides higher temperatures in the southern Mediterranean (Alboran, Benghazi, Mersa Matrouh) and lower temperatures in the Adriatic and the north-eastern Levantine.
- According to Artale et al. (2010), this pattern corresponds to the prevaling anti-cyclonic oceanic structures along the southern coasts and to the cyclonic structures along the northern Mediterranean coasts.

# Difference in JJA convective precipitation (mm/day)

Coupled vs. uncoupled simulations




- In the WRF-ROMS simulation, mostly in the warm seasons, we find less convective rainfall over the Adriatic and the north-eastern Levantine basin (more convective rainfall over southern coasts and the eastern Mediterranean).
- **The differences in convective precipitation are associated to the differences found for SST in the coupled vs. uncoupled simulations.**

# Conclusions

- Large number of possible applications derived from RCMs.
- Large uncertainties, there is not such a "perfect model". The RCMs should be used bearing in mind their limitations and the applications we want them for.
- Uncertainty can characterized and reduced by using ensemble of simulations covering (1) different models; (2) different parameterizations; and (3) different scenarios.

Thank you for your attention