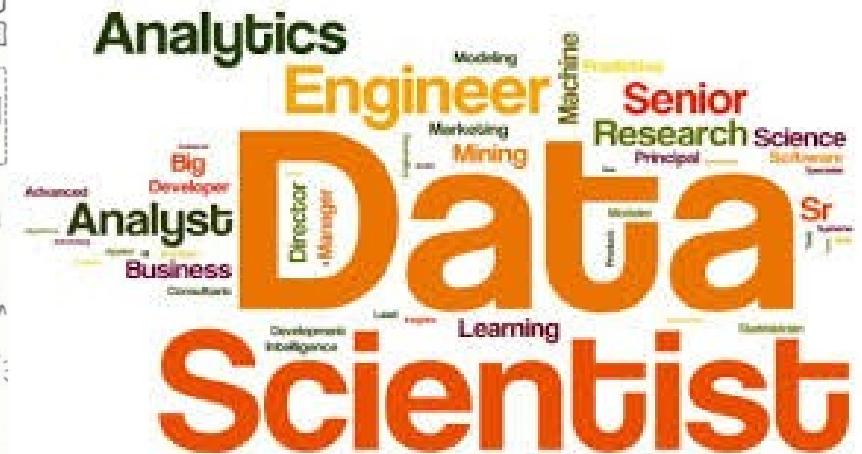
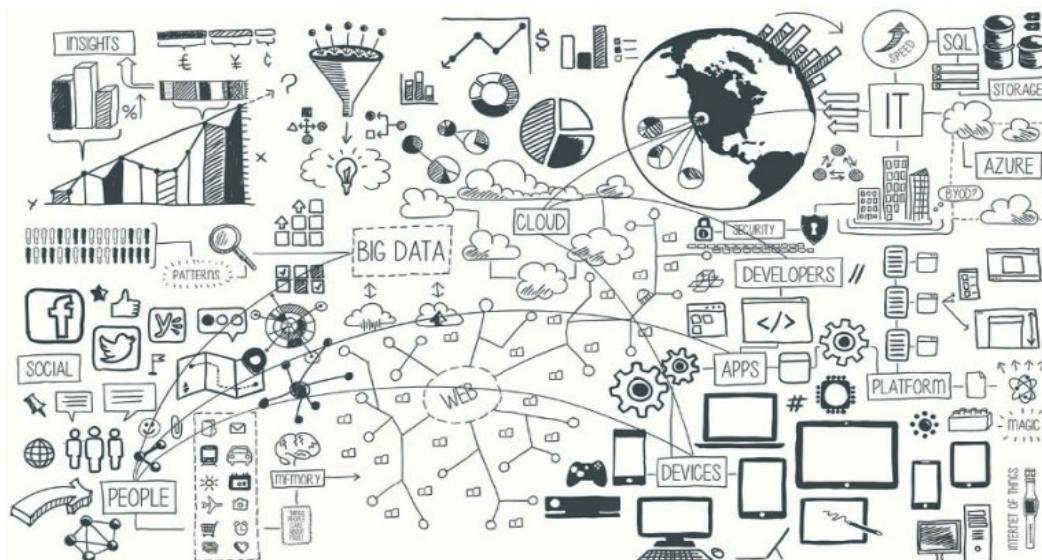


DataLab: Environment and Meteorology

Introduction



Sixto Herrera García

Grupo de Meteorología
Univ. de Cantabria – CSIC
MACC / IFCA



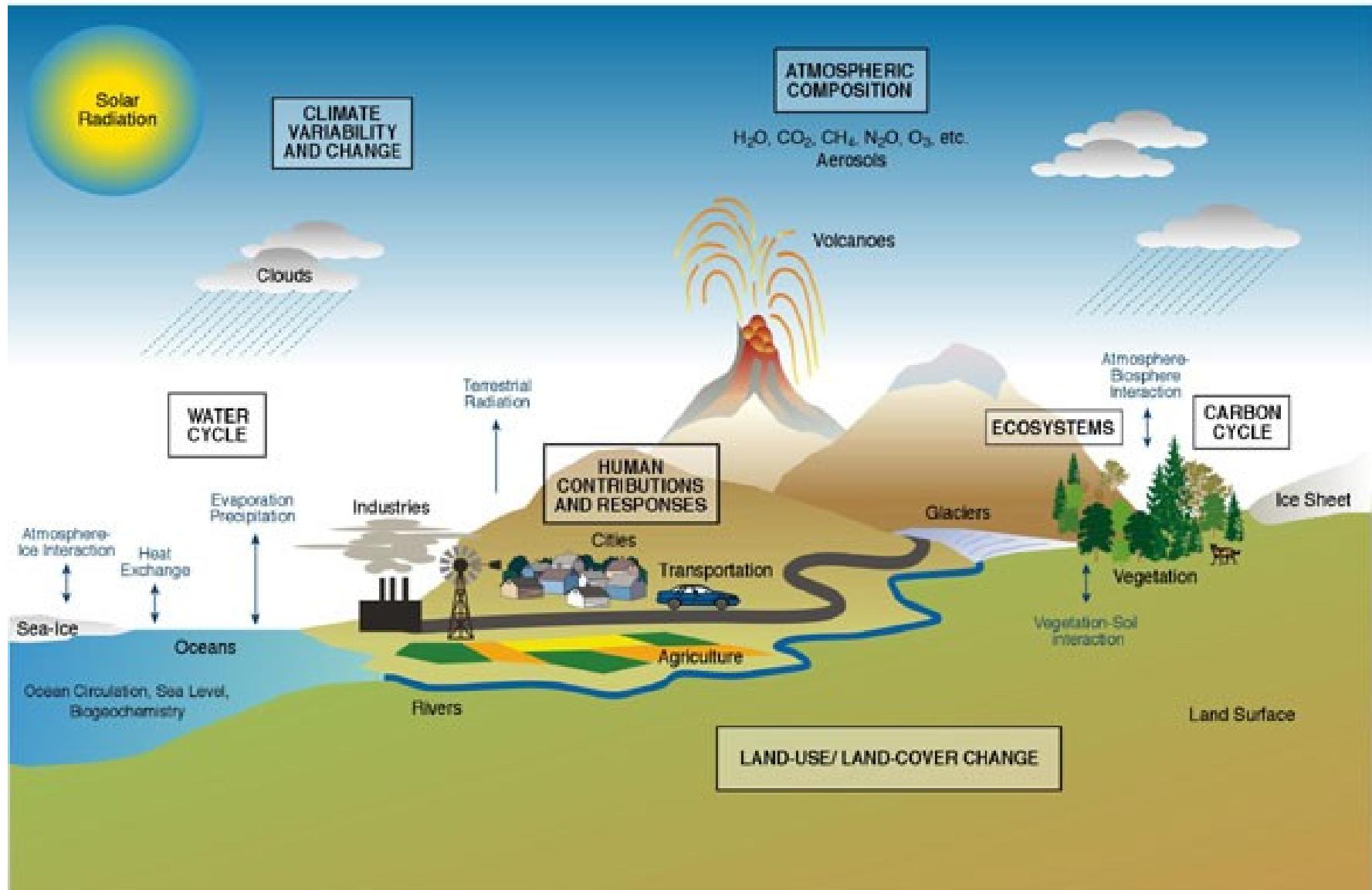
M1980 – Data Laboratory: Environment & Meteorology (16:00-18:00)

Virtual classroom: <https://meet.jit.si/M1980>

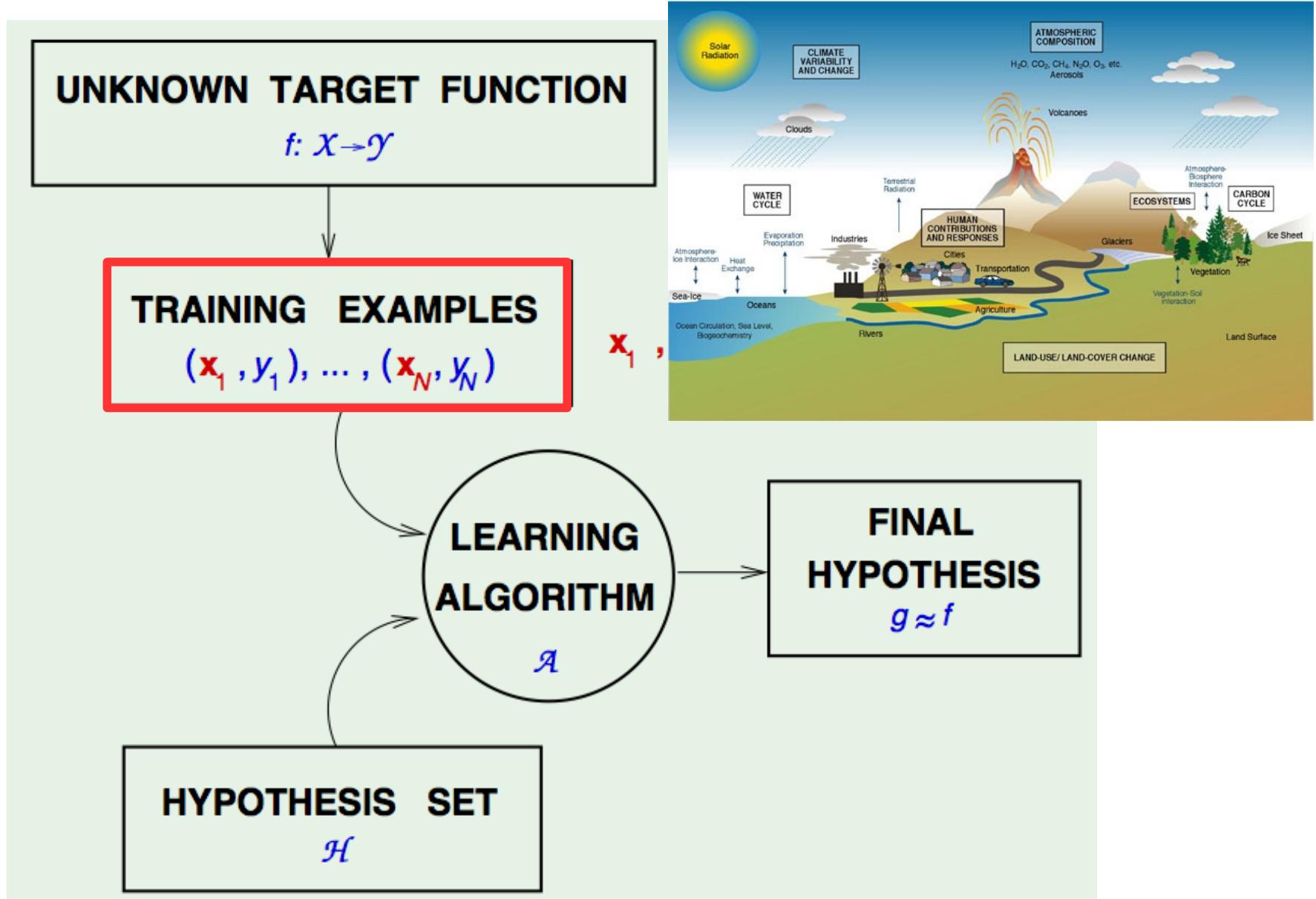
03/25	X	Introduction and Climate4R package	TL	JB
03/26	J	Climatic System & Models (DM & ML in Climate Science)	T	SH
03/27	V	Data Repositories: ESGF & MARS	TL	SH
03/30	L	Data Repositories: ESGF & MARS	TL	SH
03/31	M	Lab: Climate4R – Example 1	L	JB
04/01	X	Lab: Climate4R – Example 2	L	JB
04/02	J	Downscaling: Data Mining in Clime	T	SH
04/03	V	Lab: downscaleR	L	JB
04/06	L	Evaluation and Validation	T	SH
04/07	M	Lab: Evaluation and Validation	L	JB
04/08	X	Impacts	L	JB
04/13	L	Impacts	L	JB

SH - Sixto Herrera | **JB** - Joaquín Bedia

Atmosphere + Hydrosphere + Cryosphere + Lithosphere + Biosphere



Atmosphere + Hydrosphere + Cryosphere + Lithosphere + Biosphere



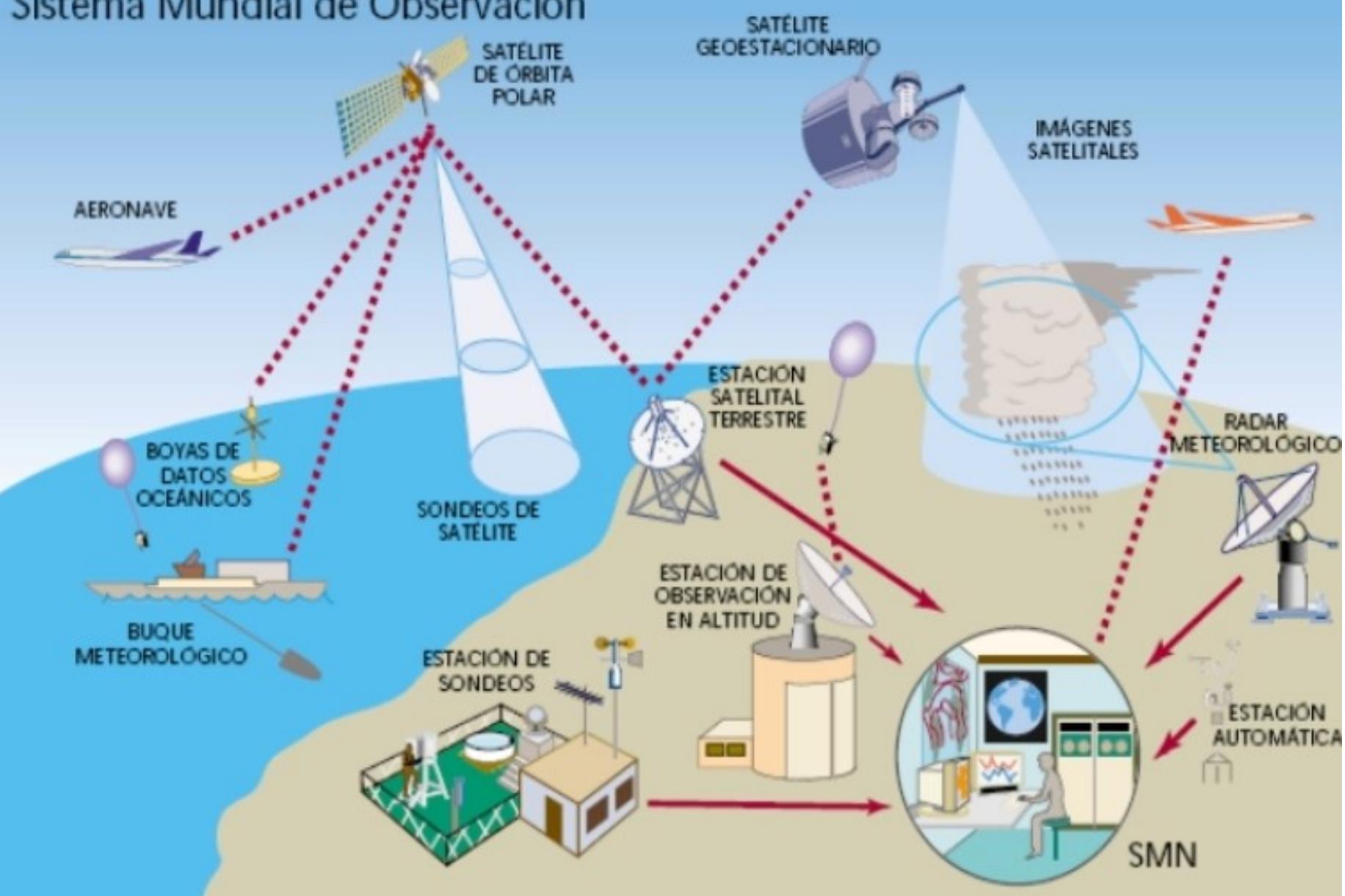
Atmosphere + Hydrosphere + Cryosphere + Lithosphere + Biosphere

What should be observed? → Essential Climate Variables (**ECVs**)

Atmosphere	Land	Ocean
Surface <ul style="list-style-type: none">• Precipitation• Pressure• Radiation budget• Temperature• Water vapour• Wind speed and direction	Hydrosphere <ul style="list-style-type: none">• Groundwater• Lakes• River discharge	Physical <ul style="list-style-type: none">• Ocean surface heat flux• Sea ice• Sea level• Sea state• Sea surface currents• Sea surface salinity• Sea surface stress• Sea surface temperature• Subsurface currents• Subsurface salinity• Subsurface temperature
Upper-air <ul style="list-style-type: none">• Earth radiation budget• Lightning• Temperature• Water vapor• Wind speed and direction	Cryosphere <ul style="list-style-type: none">• Glaciers• Ice sheets and ice shelves• Permafrost• Snow	Biogeochemical <ul style="list-style-type: none">• Inorganic carbon• Nitrous oxide• Nutrients• Ocean colour• Oxygen• Transient tracers
Atmospheric Composition <ul style="list-style-type: none">• Aerosol and ozone precursors• Aerosols properties• Carbon dioxide, methane and other greenhouse gases• Cloud properties• Ozone	Biosphere <ul style="list-style-type: none">• Above-ground biomass• Albedo• Evaporation from land• Fire• Fraction of absorbed photosynthetically active radiation (FAPAR)• Land cover• Land surface temperature• Leaf area index• Soil carbon• Soil moisture	Biological/ecosystems <ul style="list-style-type: none">• Marine habitat properties• Plankton
	Anthroposphere <ul style="list-style-type: none">• Anthropogenic Greenhouse gas fluxes• Anthropogenic water use	

Atmosphere + Hydrosphere + Cryosphere + Lithosphere + Biosphere

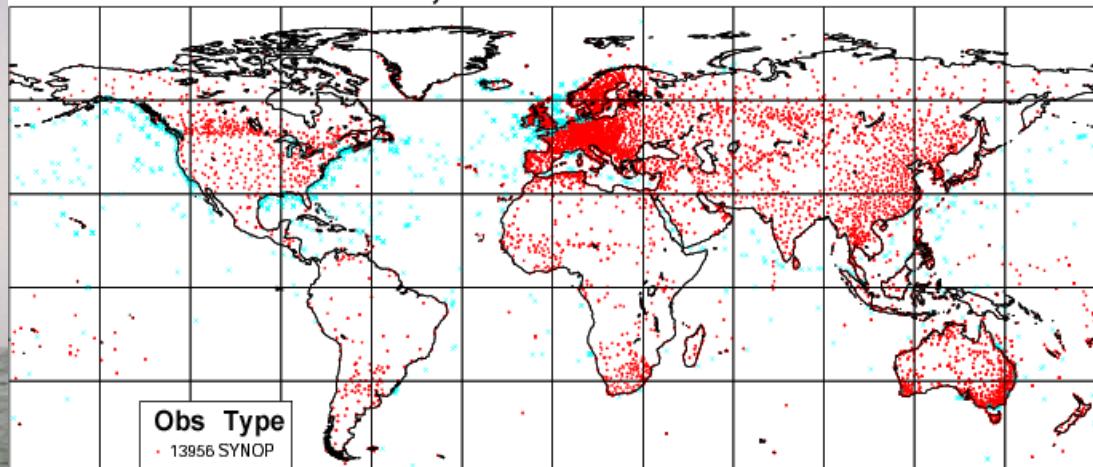
Sistema Mundial de Observación



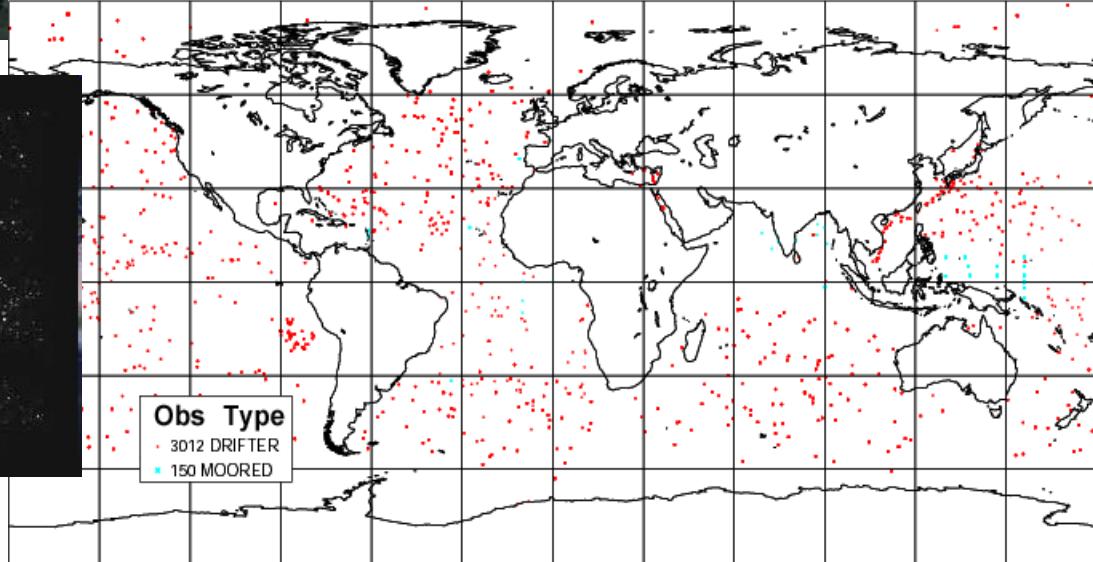
Atmosphere + Hydrosphere + Cryosphere + Lithosphere + Biosphere



ECMWF Data Coverage (All obs)-SYNOP/SHIP
29/DEC/2003; 12 UTC #obs = 15387



ECMWF Data Coverage (All obs)-BUOY
29/DEC/2003; 12 UTC #obs = 3162



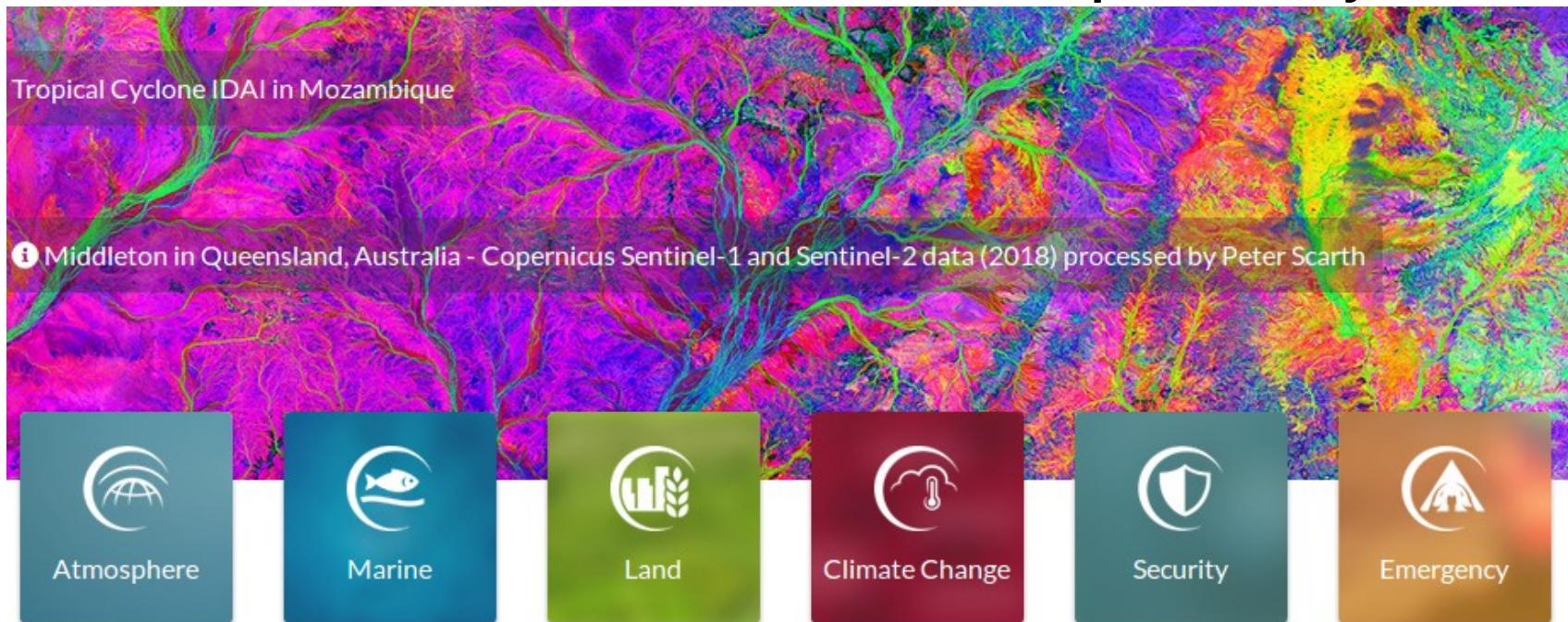
Atmosphere + Hydrosphere + Cryosphere + Lithosphere + Biosphere

Satellite: ~12 Sentinels in the following 10 years (**ESA, EUMETSAT 6**)

Local observations (*In situ*):

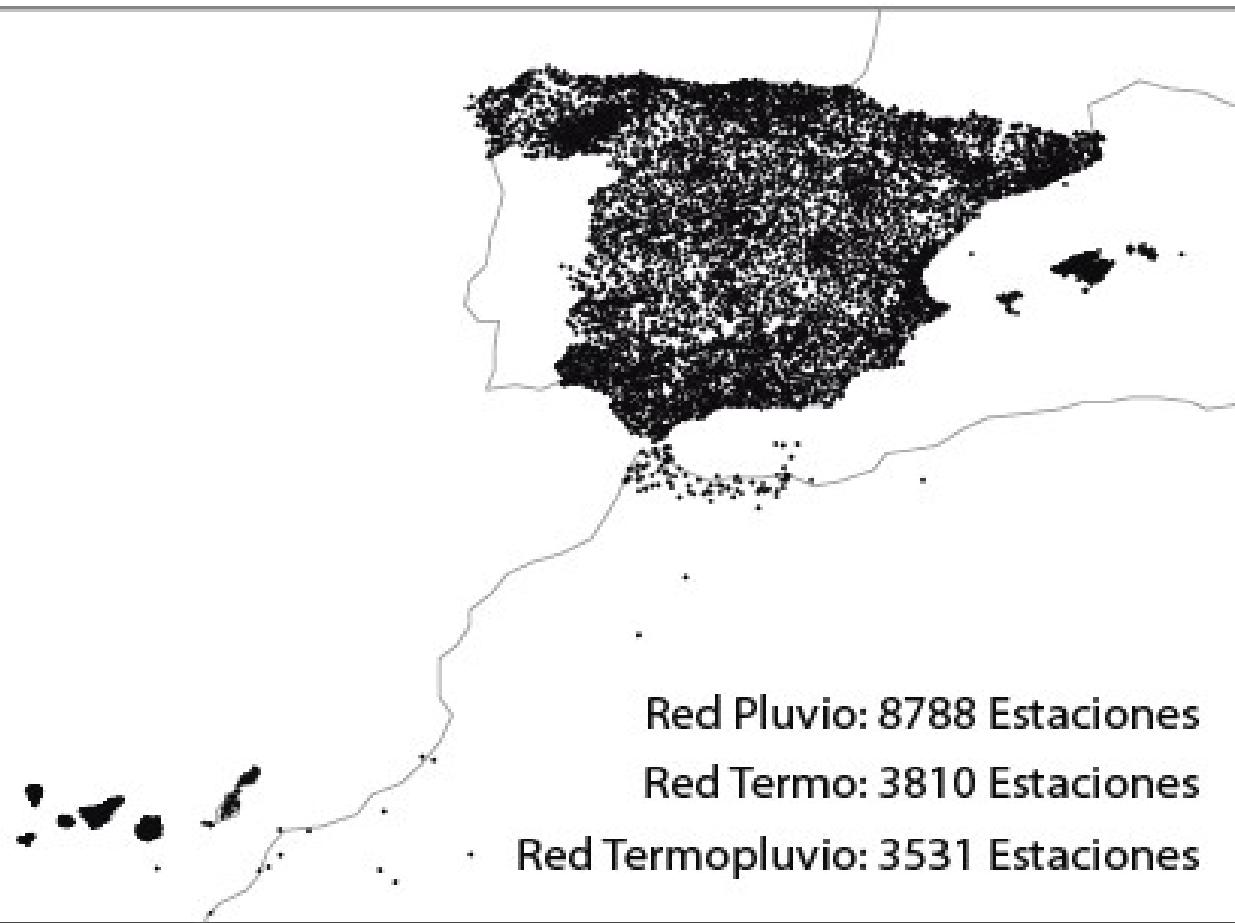
- Sensors in the shore of the rivers
- Ocean buoys
- Meteorological globes
- Non-static radars (ships, airplane, etc.)
-

Local observations are needed to calibrate the data provided by the satellite.



[https://www.copernicus.eu/
en](https://www.copernicus.eu/en)

Red Secundaria de AEMET: 11864 Estaciones

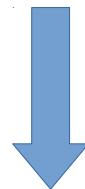


Daily data (1950-2019):

- ~25000 values

Variables:

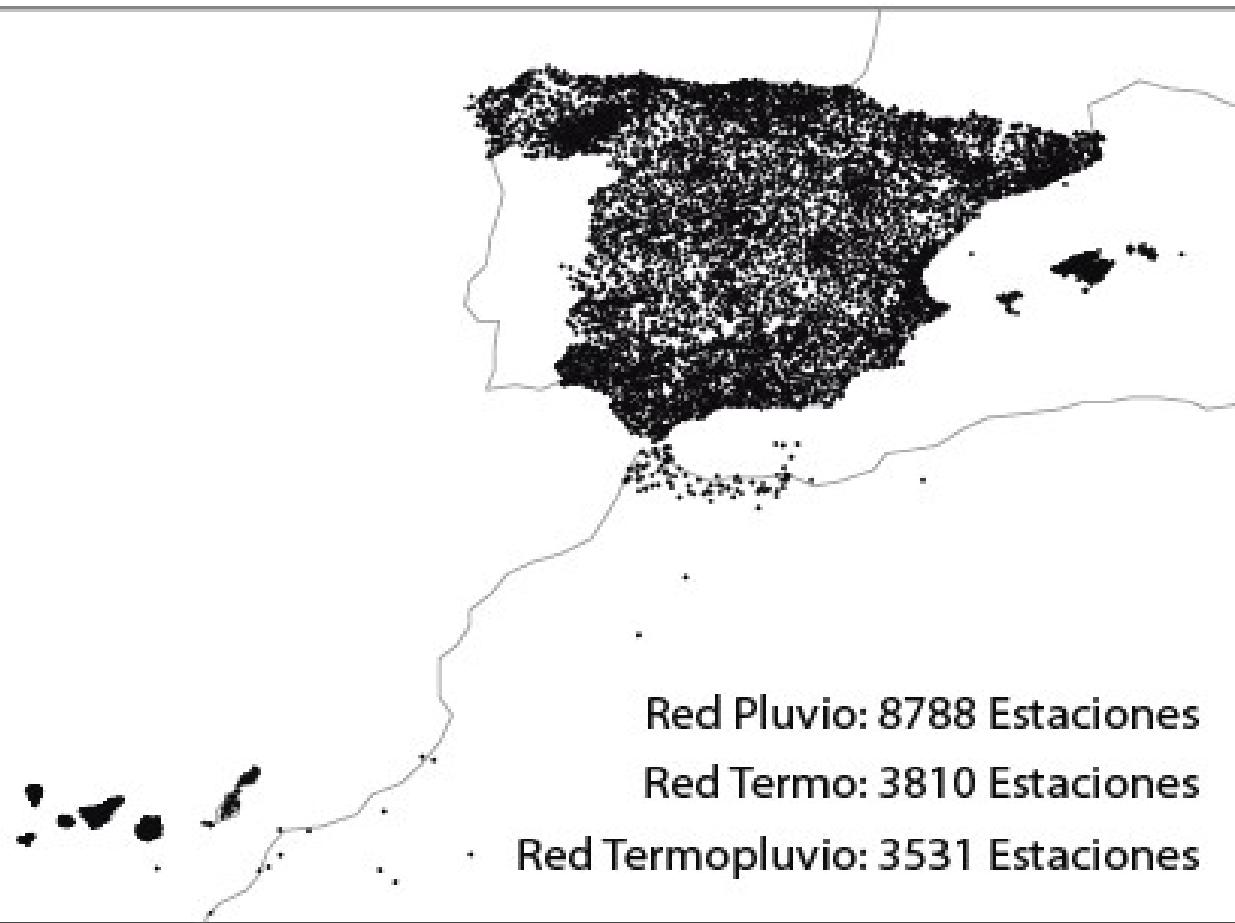
- Precipitation
- Temperatures
- Snow
- Wind
-



~25000 values
x ~3000 stations
x ~10 variables

~750000000 values

Red Secundaria de AEMET: 11864 Estaciones

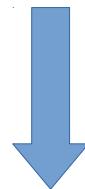


Daily data (1950-2019):

- ~25000 values

Variables:

- Precipitation
- Temperatures
- Snow
- Wind
-

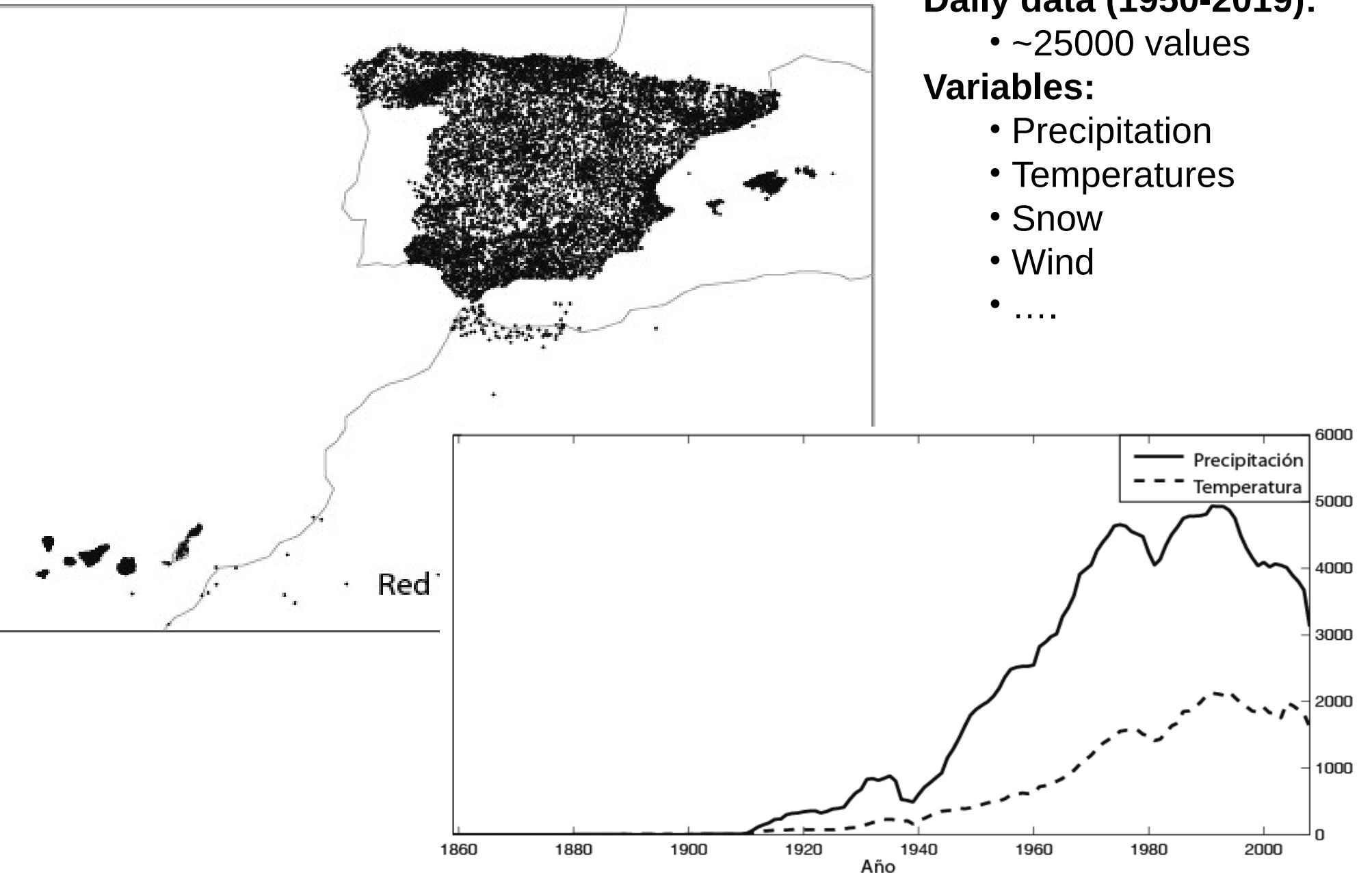


~25000 values
x ~3000 stations
x ~10 variables

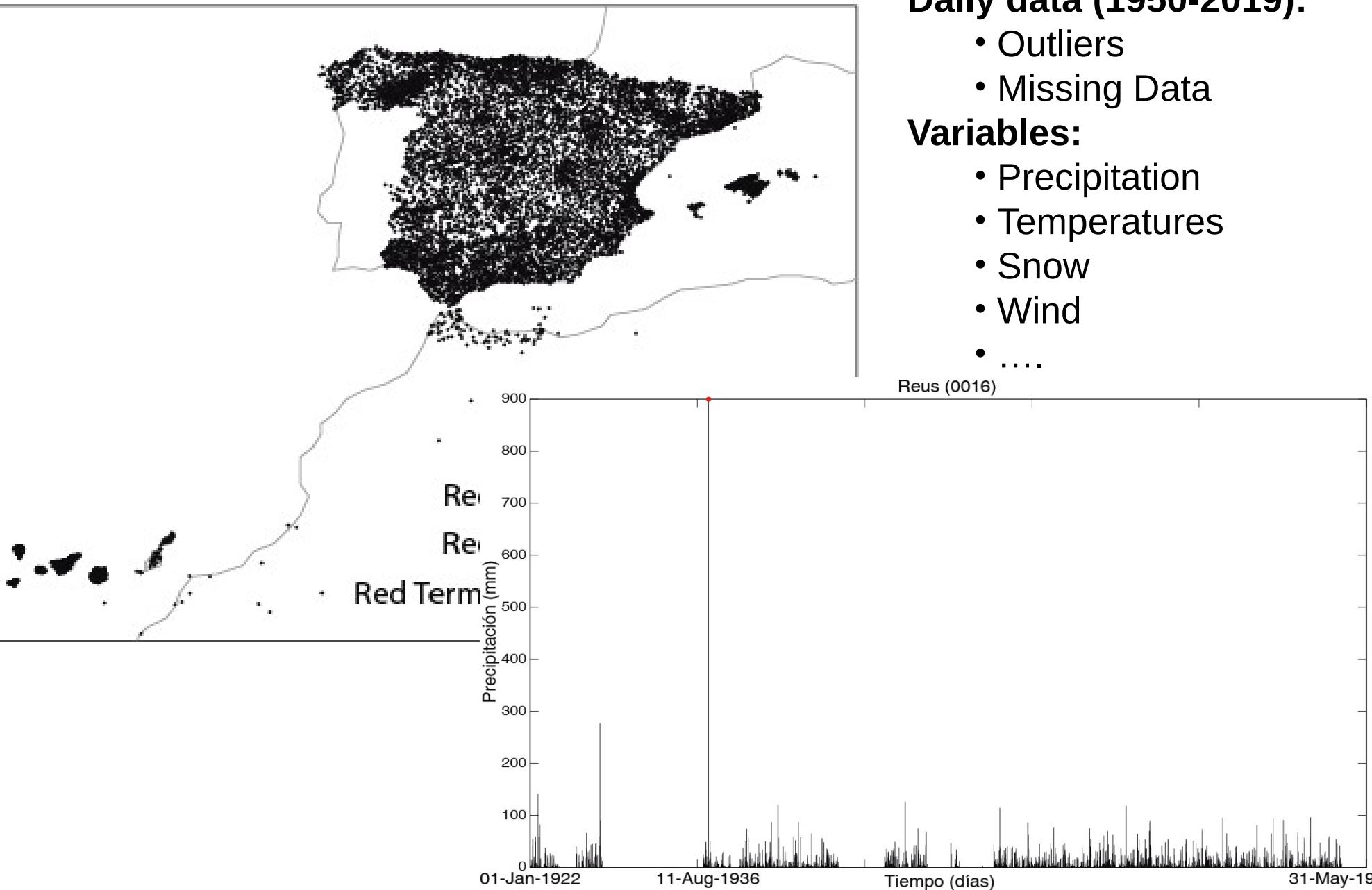
~750000000 values

We need efficient techniques to deal with this information → **Data Mining/Big Data**

Red Secundaria de AEMET: 11864 Estaciones



Red Secundaria de AEMET: 11864 Estaciones



Daily data (1950-2019):

- Outliers
- Missing Data

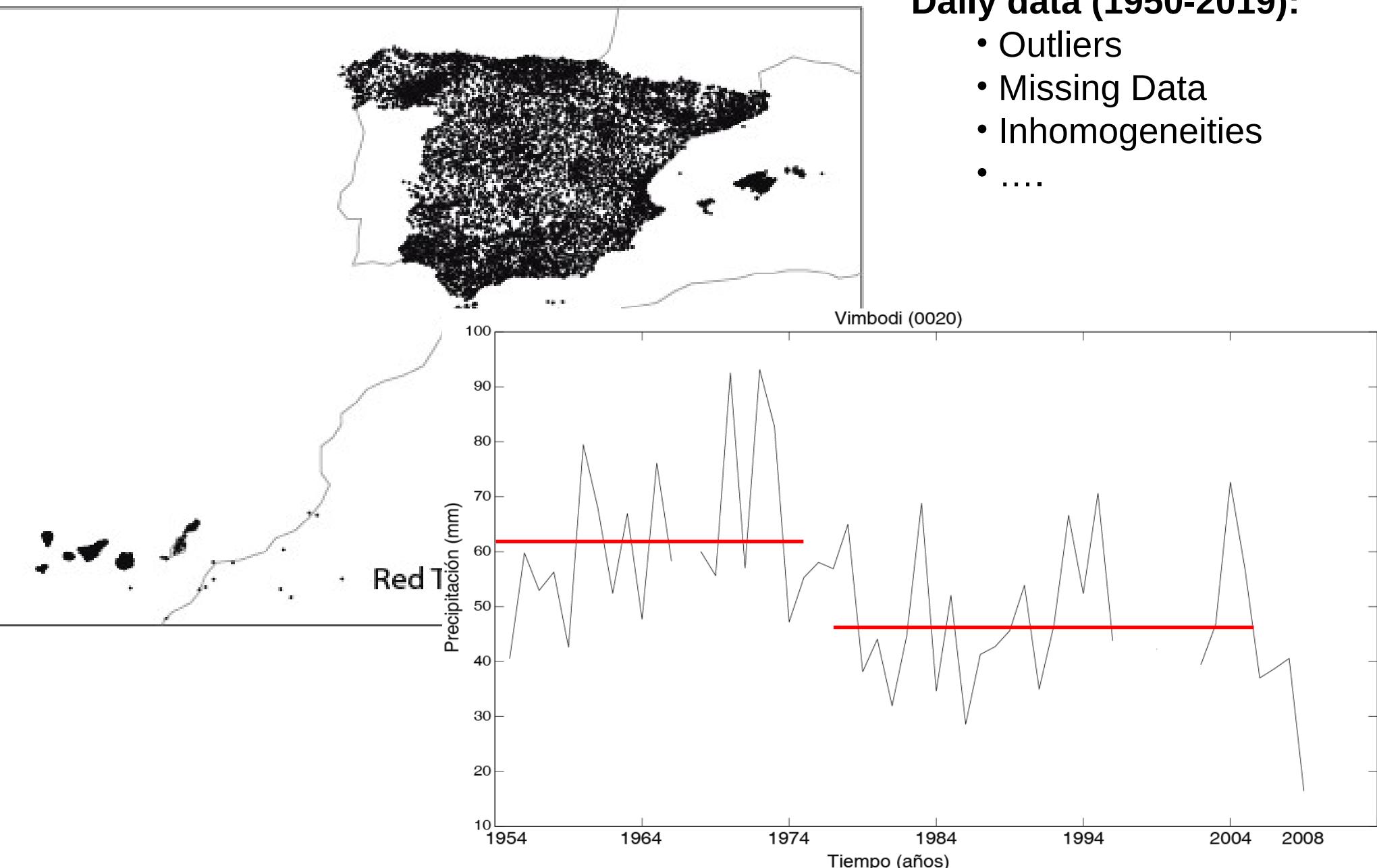
Variables:

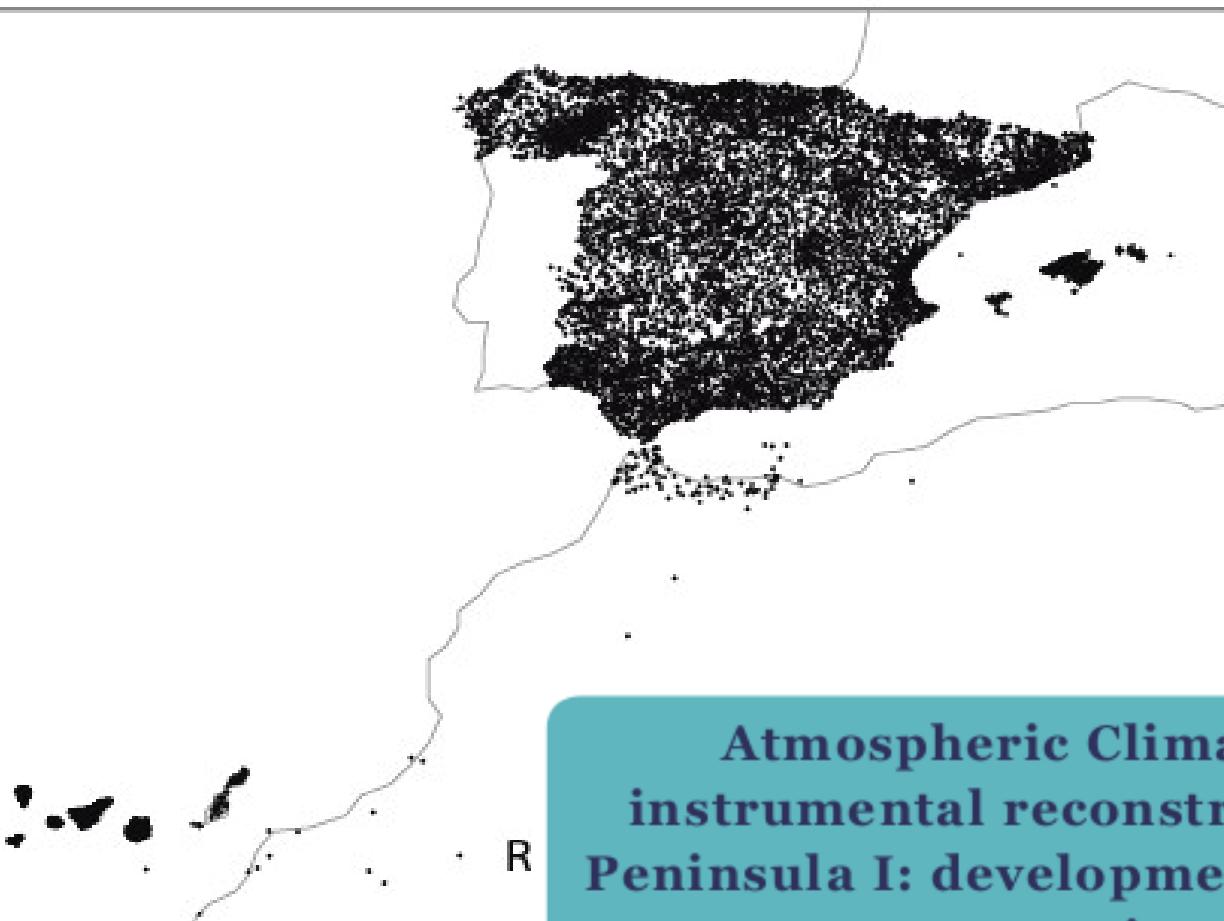
- Precipitation
- Temperatures
- Snow
- Wind
-

Red Secundaria de AEMET: 11864 Estaciones

Daily data (1950-2019):

- Outliers
- Missing Data
- Inhomogeneities
-





Daily data (1950-2019):

- Outliers
- Missing Data
- Inhomogeneities
-

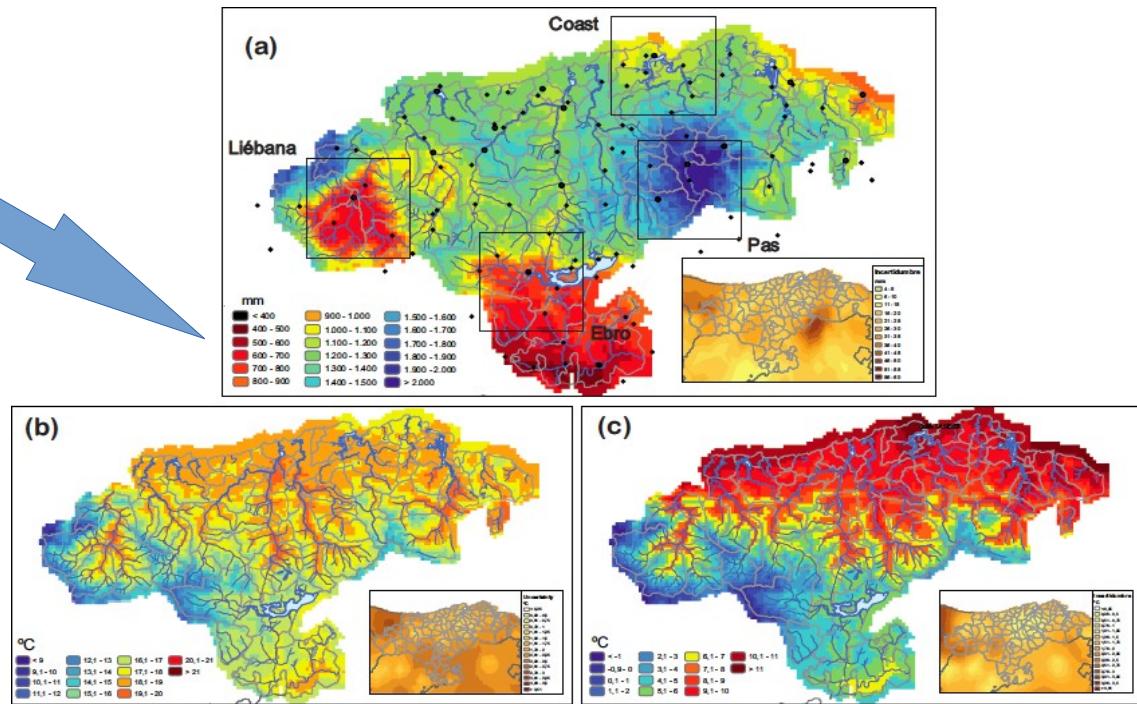
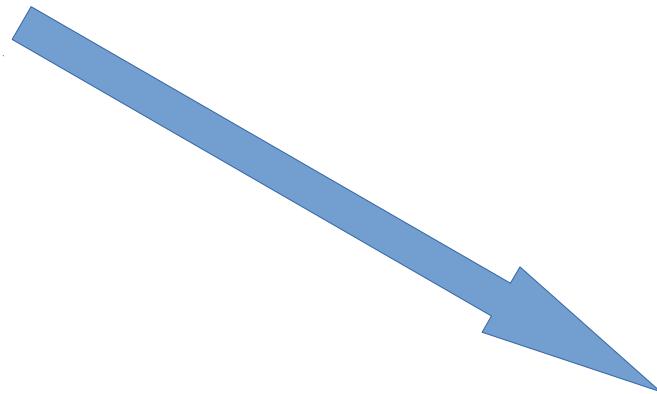
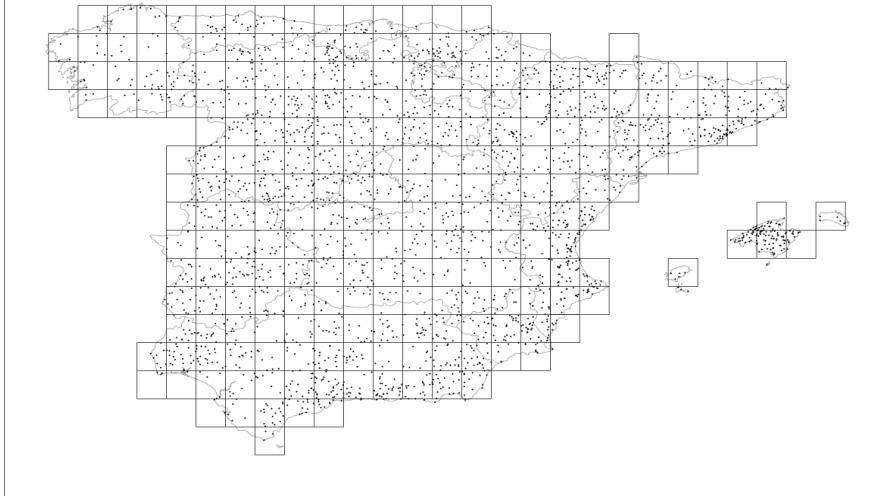


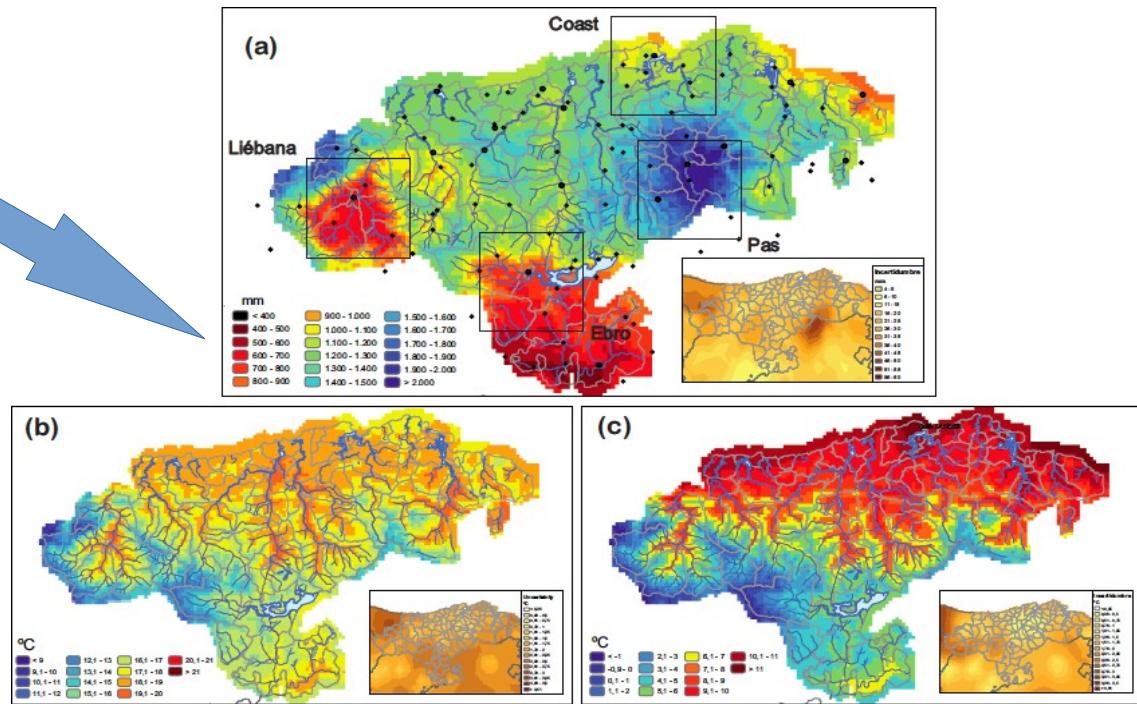
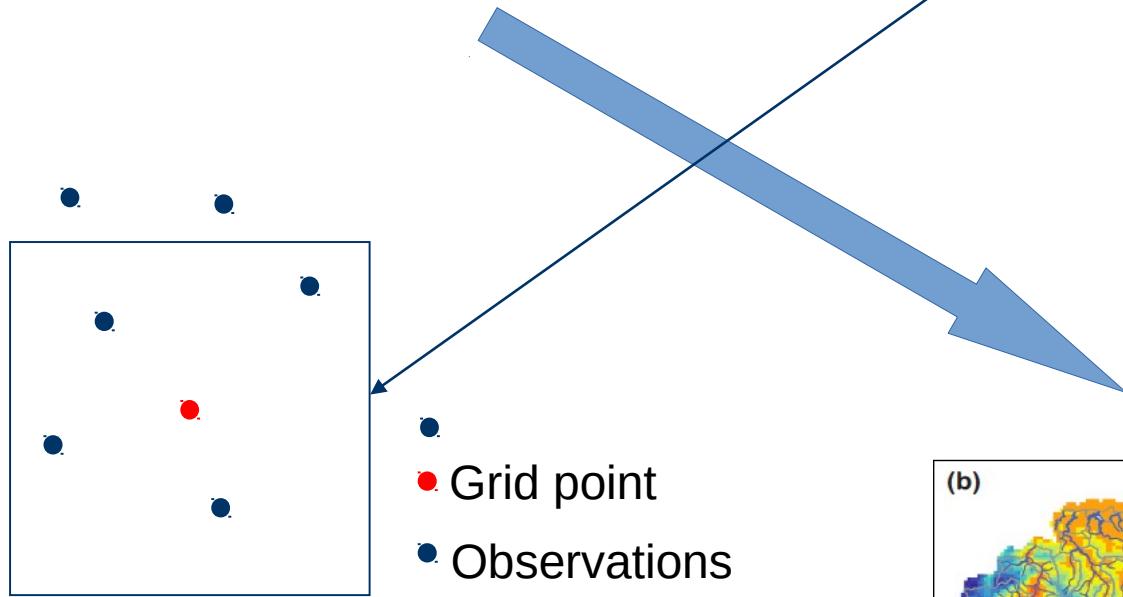
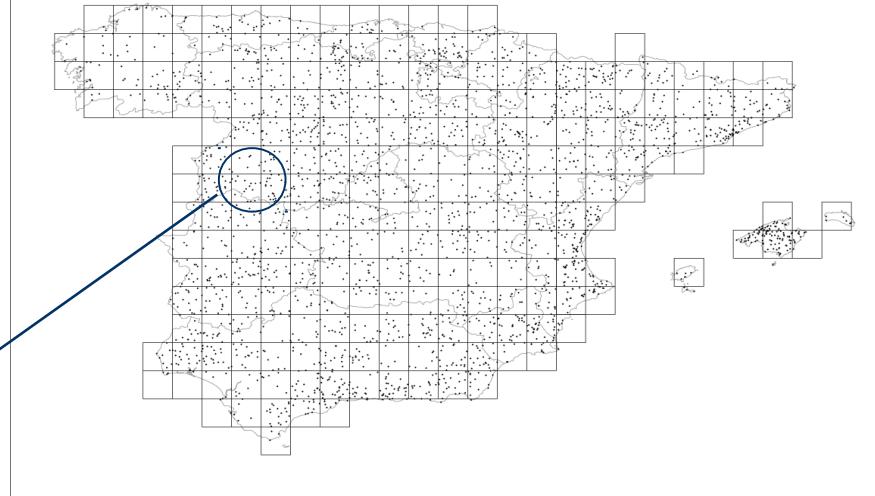
iii DATA CURATION
IS MANDATORY!!!

**Atmospheric Climatic observations and
instrumental reconstructions over the Iberian
Peninsula I: development of high-quality climatic
time series.**

José Antonio Guijarro¹, Cesar Azorin-Molina³, José Carlos González-Hidalgo⁴, Arturo Sanchez-Lorenzo⁵, Sixto Herrera², José Antonio López¹

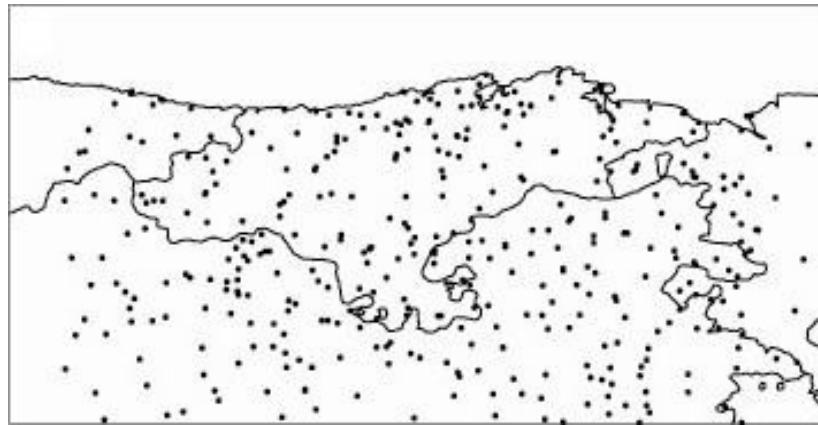
CLIVAR Exchanges, No. 73 September, 2017: Special Issue on climate over the Iberian Peninsula: an overview of CLIVAR-Spain coordinated science, **Editor:** Nico Caltabiano (ICPO), **Guest editors:** Enrique Sánchez (UCLM) and Belén Rodríguez (UCM-CSIC)



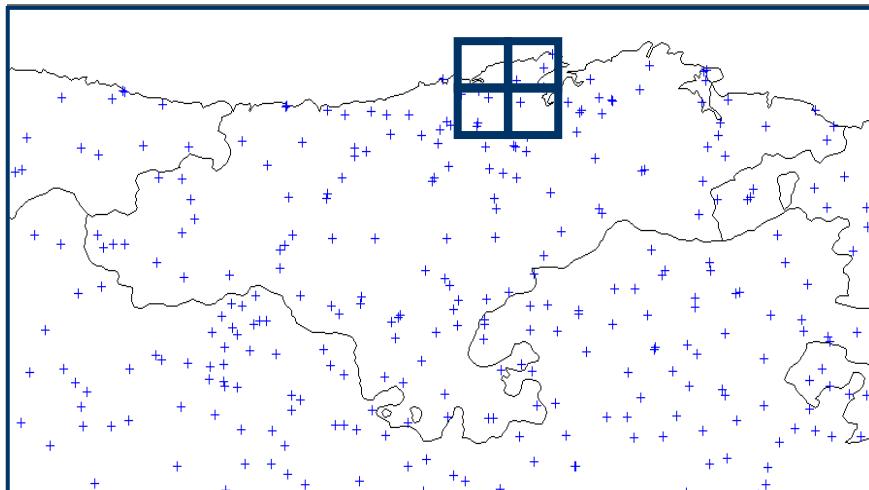


OBSERVACIONES

□
10km

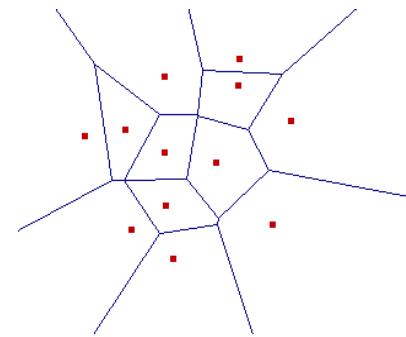


Interpolation Methods

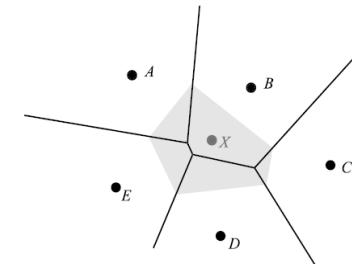


$$y_{interp}(x) = \sum_{i=1}^n w_i y_{obs}(x_i)$$

$$w_i = \frac{1}{d(x, x_i)^p}$$



Deterministic

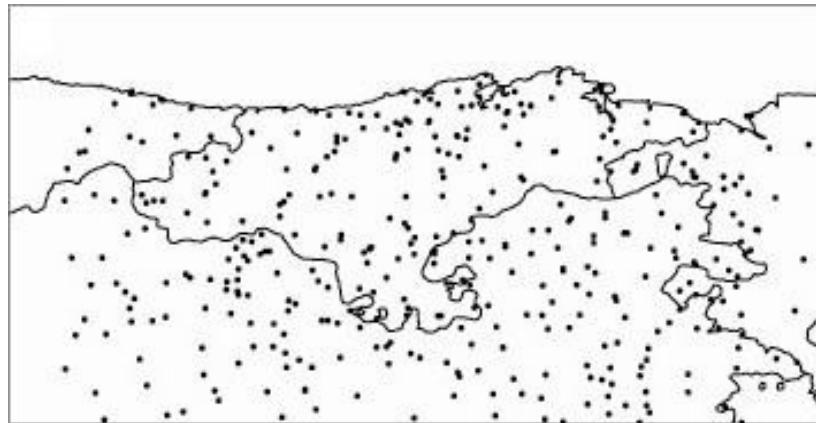


$$\begin{cases} \gamma^*(h) = \frac{1}{2N(h)} \sum_{\|x_i - x_j\|=h}^{N(h)} (y(x_i) - y(x_j))^2 \\ - \sum_{i=1}^k w_i \gamma(\|x_i - x_j\|) + \mu = -\gamma(\|x - x_j\|) \\ \sum_{i=1}^k w_i = 1 \end{cases}$$

Geoestatistic

$$y_{interp}(x) = \sum_{i=1}^n w_i y_{obs}(x_i) + f(x)$$

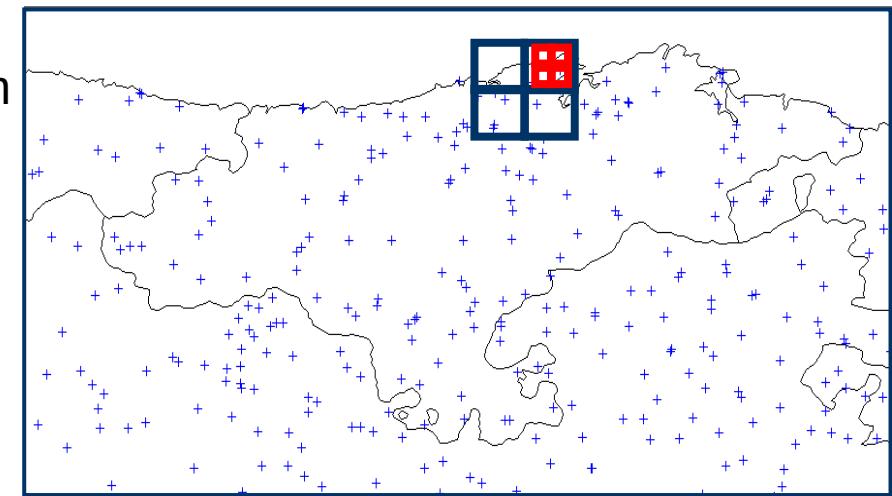
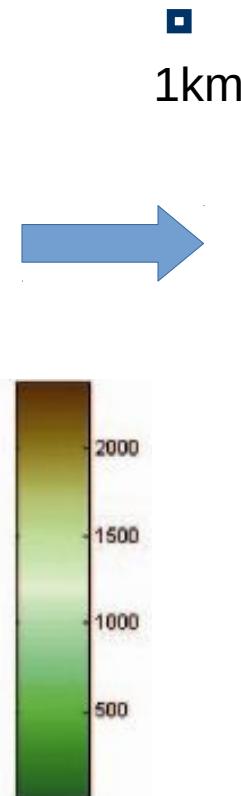
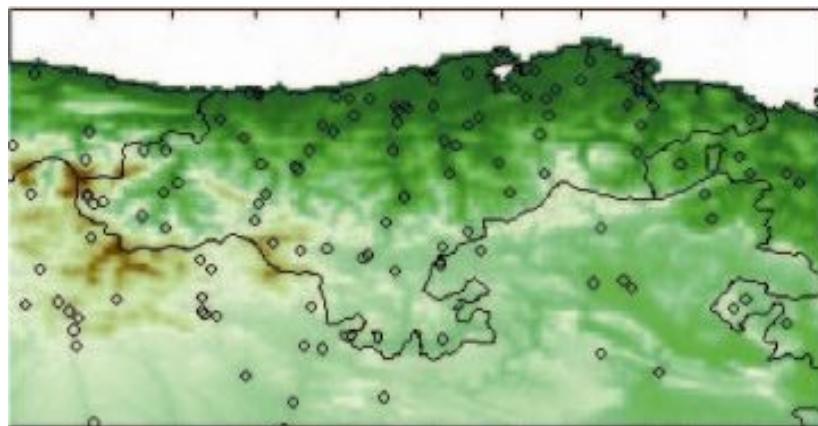
$$f(x) = a_0 + \sum_{k=1}^m a_k V_k(x)$$



Interpolation Methods + Regression

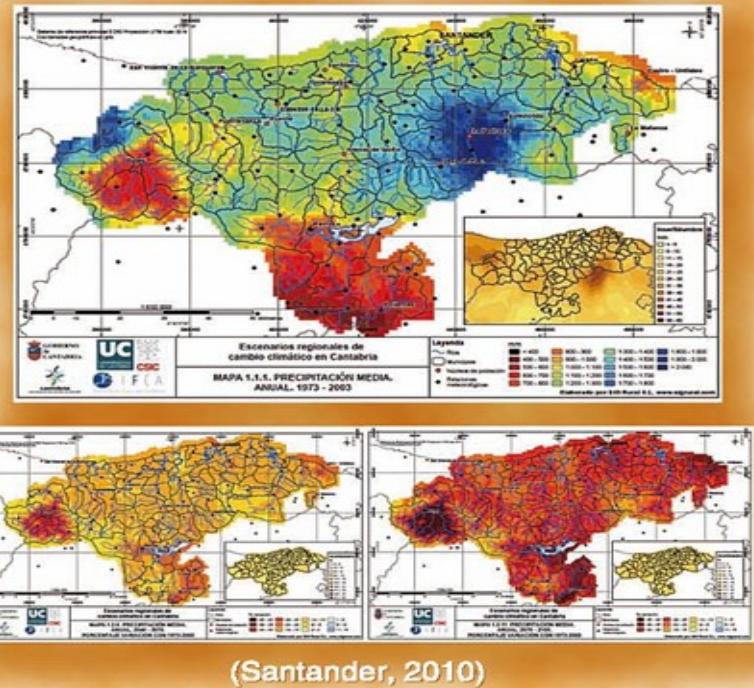
DIGITAL ELEVATION MODEL

Orography, blocking, continentality, etc..



Escenarios Regionales Probabilísticos de Cambio Climático en Cantabria: Termopluvíometría

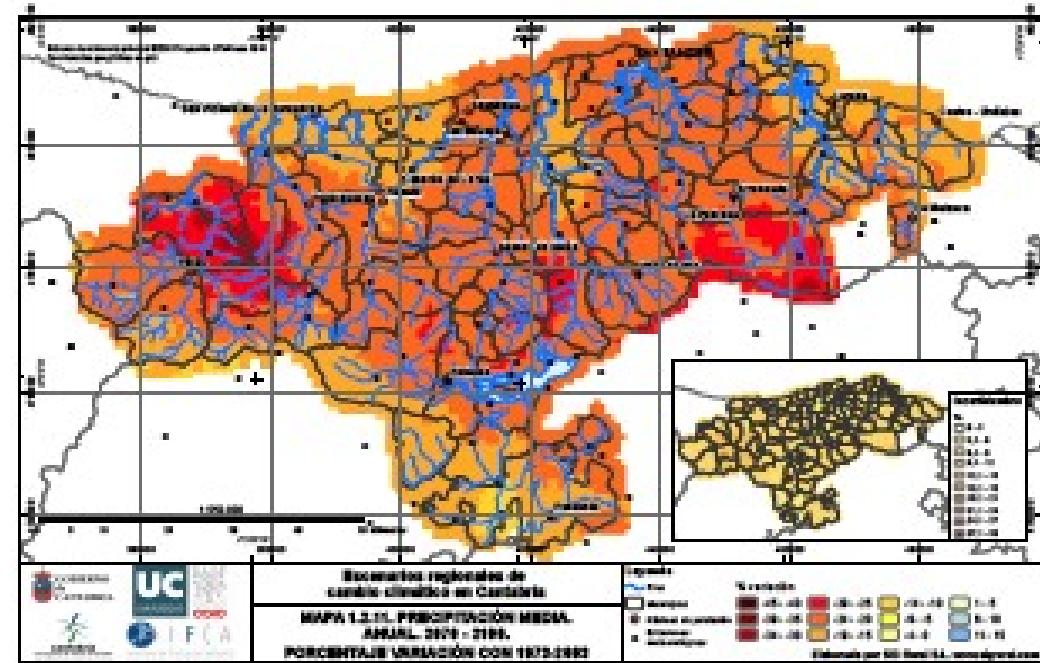
J.M. Gutiérrez, S. Herrera, D. San-Martín, C. Sordo,
J.J. Rodríguez, M. Frochoso, R. Ancell, J. Fernández,
A.S. Cofiño, M.R. Pons, M.A. Rodríguez



Annual, monthly and daily series of precipitation and temperatures. Present climate and future climate change projections.

Formats:

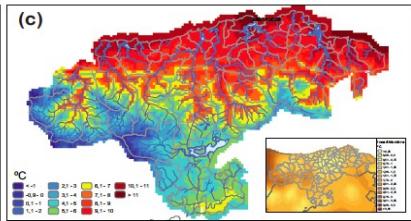
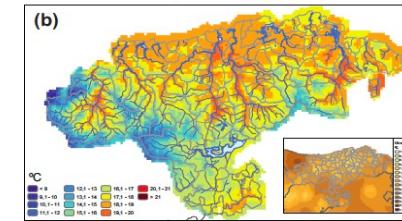
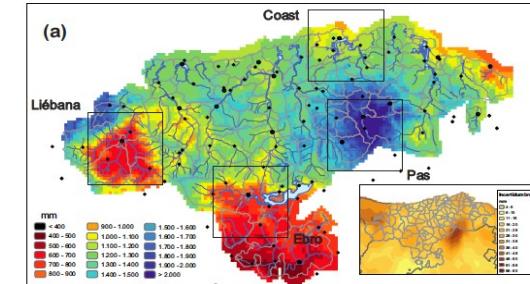
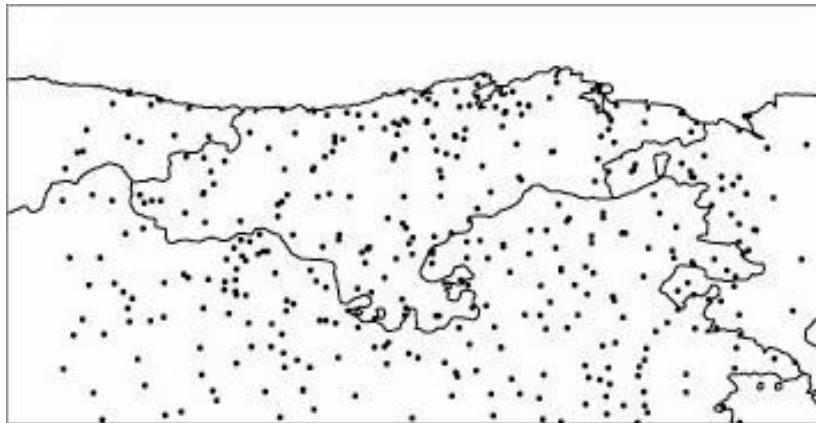
- GIS (ASCII-ESRII)
- NetCDF (binary)



<http://www.meteo.unican.es/escenariosCantabria>

$$y_{interp}(x) = \sum_{i=1}^n w_i y_{obs}(x_i) + f(x)$$

$$f(x) = a_0 + \sum_{k=1}^m a_k V_k(x)$$

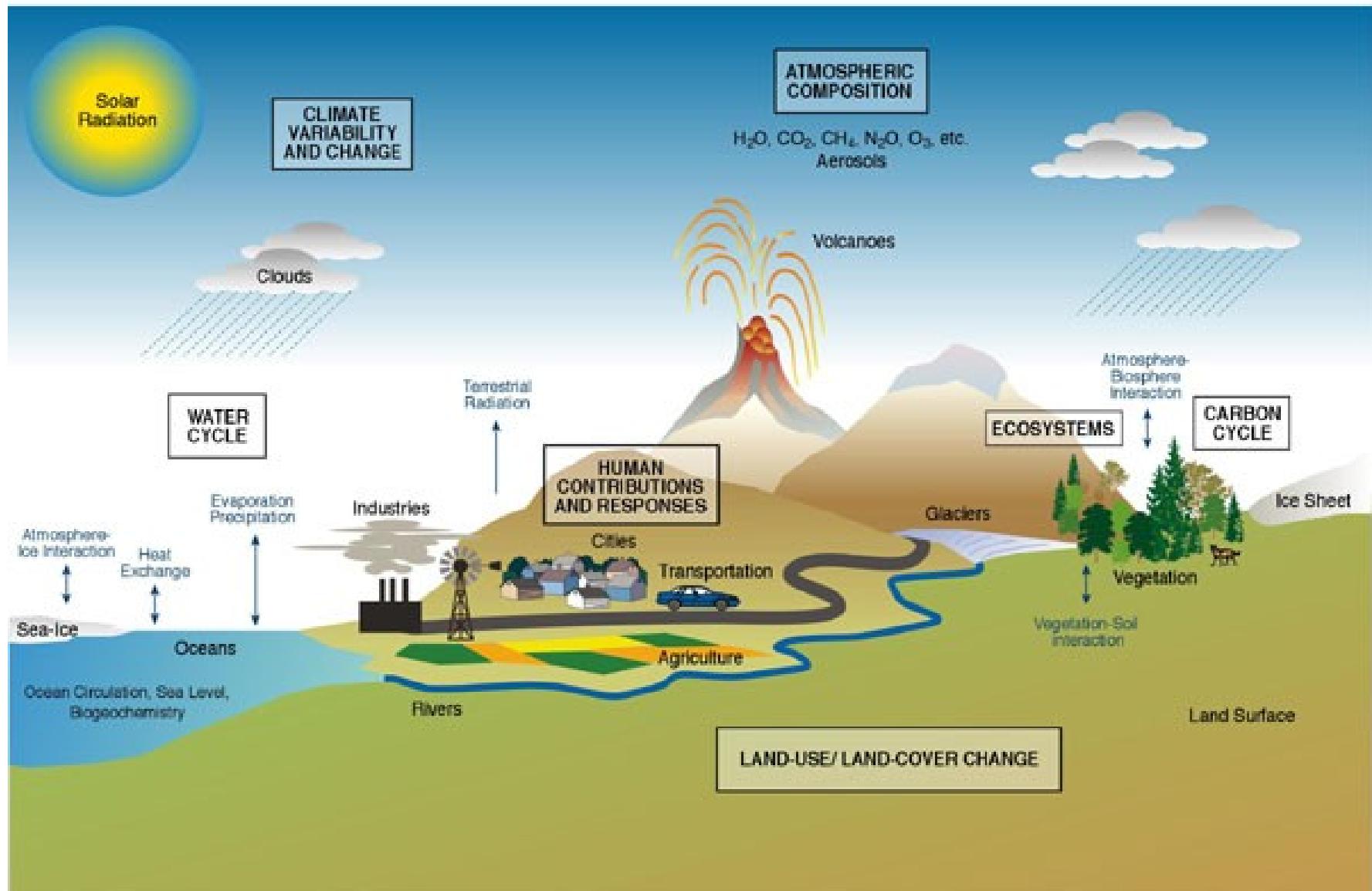


Climatic observations and instrumental reconstructions: development of high-quality climatic gridded products

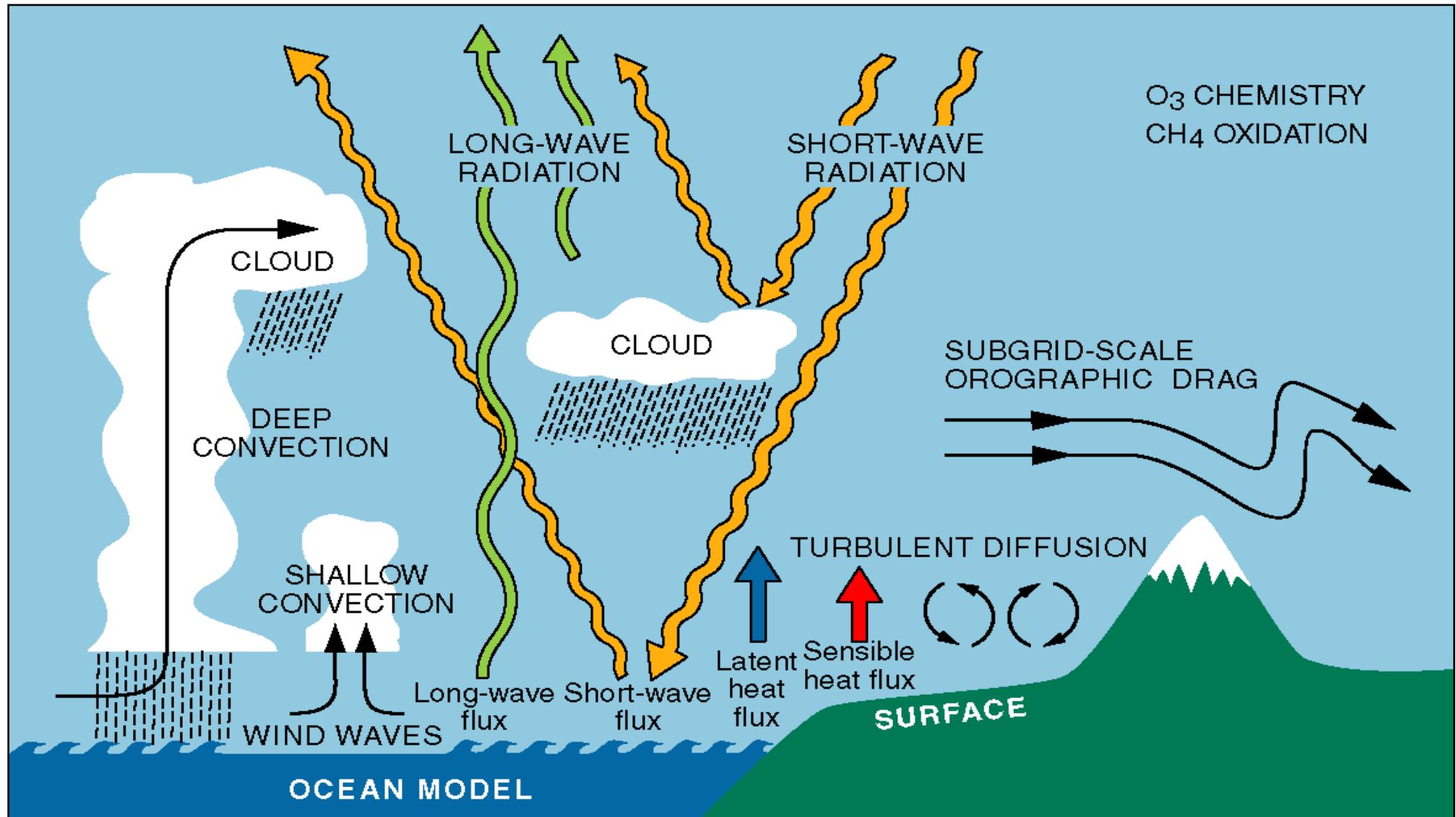
Sixto Herrera², Juan Javier Miró Pérez⁴, Pere Quintana-Seguí⁵, Julián Gonzalo⁶, José Antonio Ruiz-Arias⁷, Jose Carlos González-Hidalgo⁸, José Antonio Guijarro³, Jose Antonio López¹

CLIVAR Exchanges, No. 73 September, 2017: Special Issue on climate over the Iberian Peninsula: an overview of CLIVAR-Spain coordinated science, **Editor:** Nico Caltabiano (ICPO), **Guest editors:** Enrique Sánchez (UCLM) and Belén Rodríguez (UCM-CSIC)

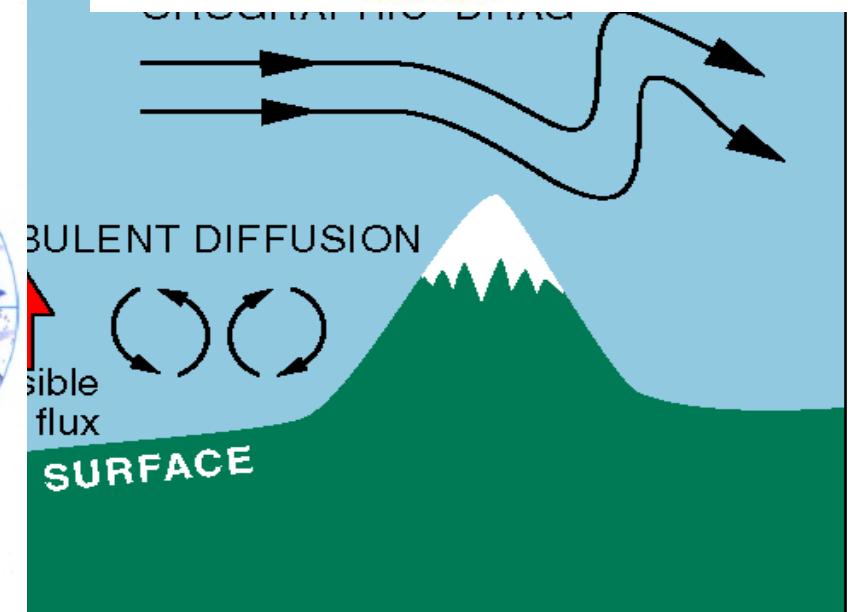
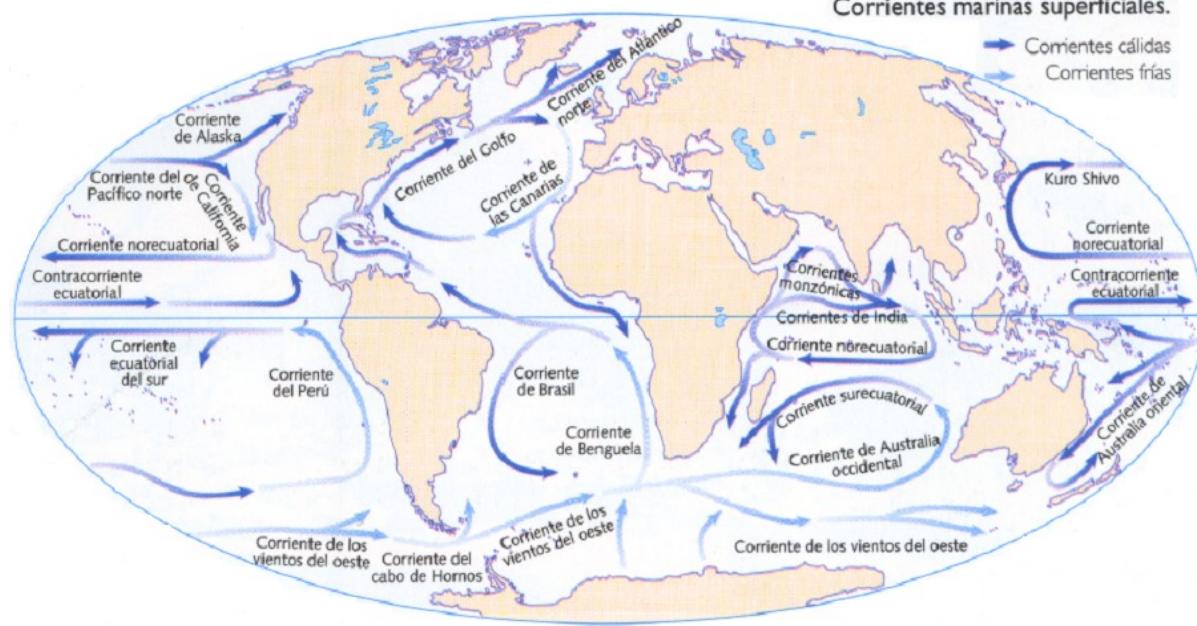
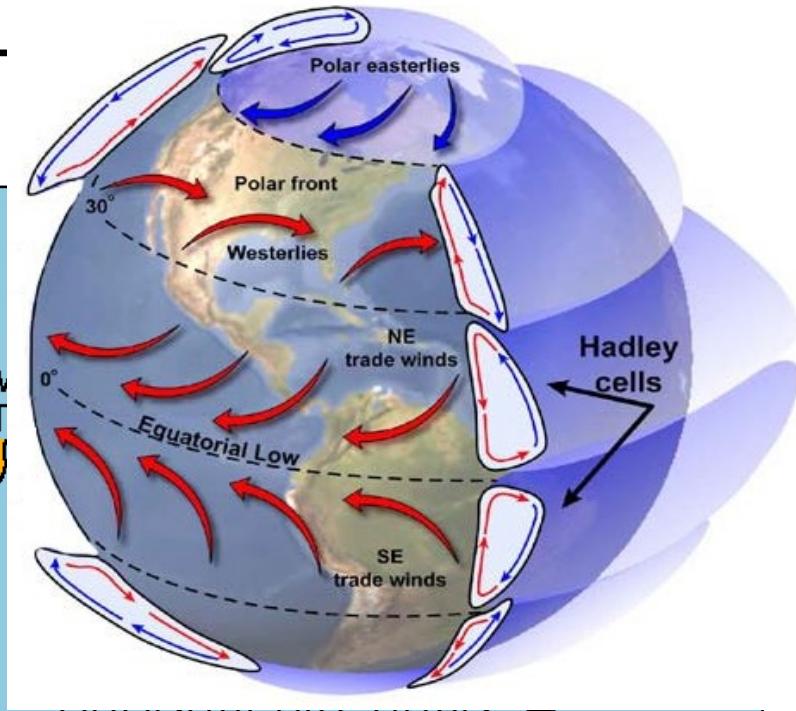
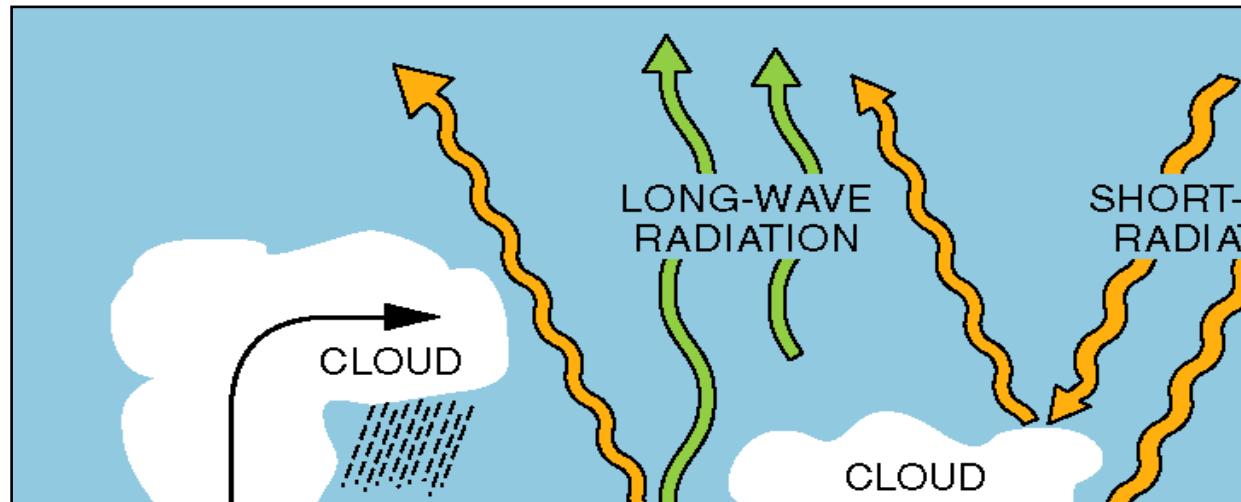
Atmosphere + Hydrosphere + Cryosphere + Lithosphere + Biosphere



Atmosphere + Hydrosphere + Cryosphere + Lithosphere + Biosphere

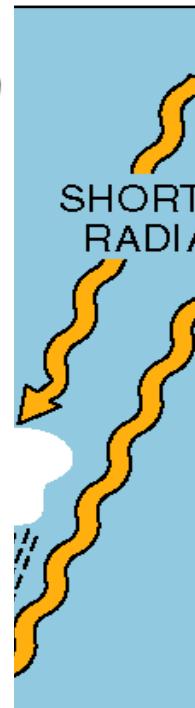
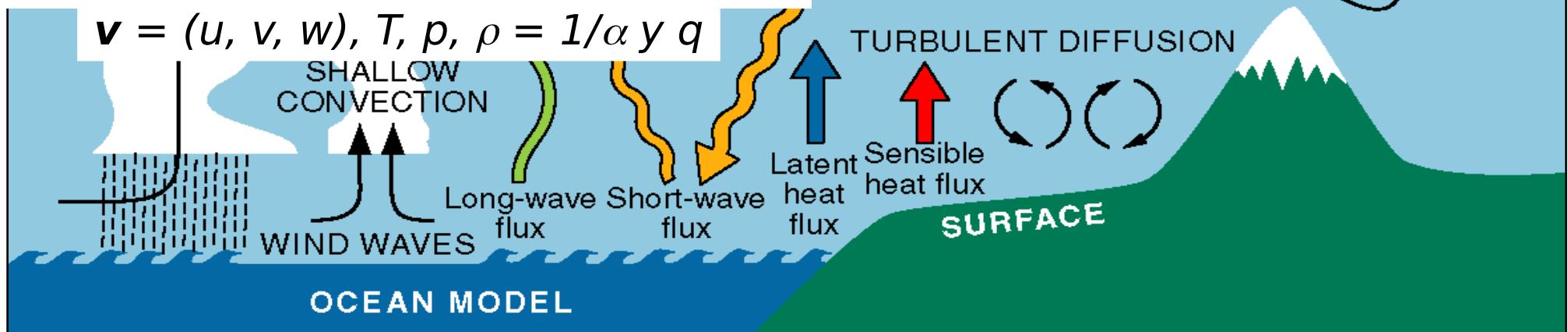


Atmosphere + Hydrosphere + Cryosphere



Atmosphere Equations: Conservation Laws (Energy, Mass, Momentum, etc..)

$$\left\{ \begin{array}{l} \frac{d\mathbf{v}}{dt} = -\alpha \nabla p - \nabla \phi + \mathbf{F} - 2\Omega \times \mathbf{v} \\ \frac{\partial \rho}{\partial t} = -\nabla \cdot (\rho \mathbf{v}) \\ p\alpha = RT \\ Q = C_p \frac{dT}{dt} - \alpha \frac{dp}{dt} \\ \frac{\partial \rho q}{\partial t} = -\nabla \cdot (\rho \mathbf{v} q) + \rho(E - C) \end{array} \right.$$

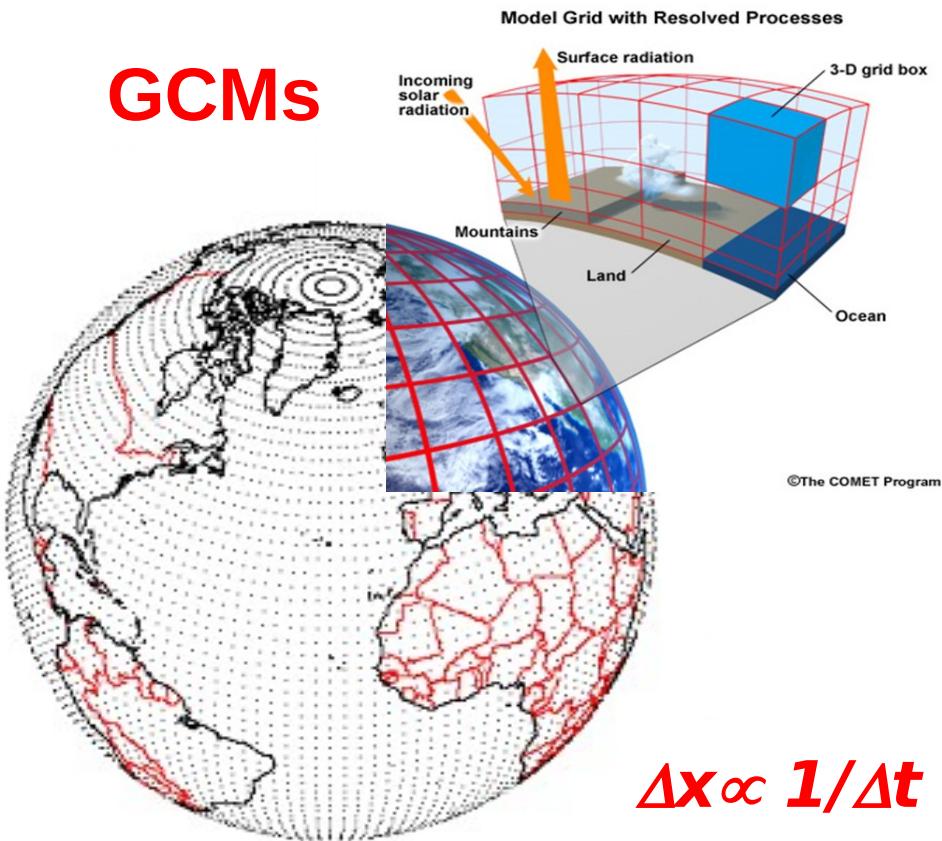


Atmosphere Equations

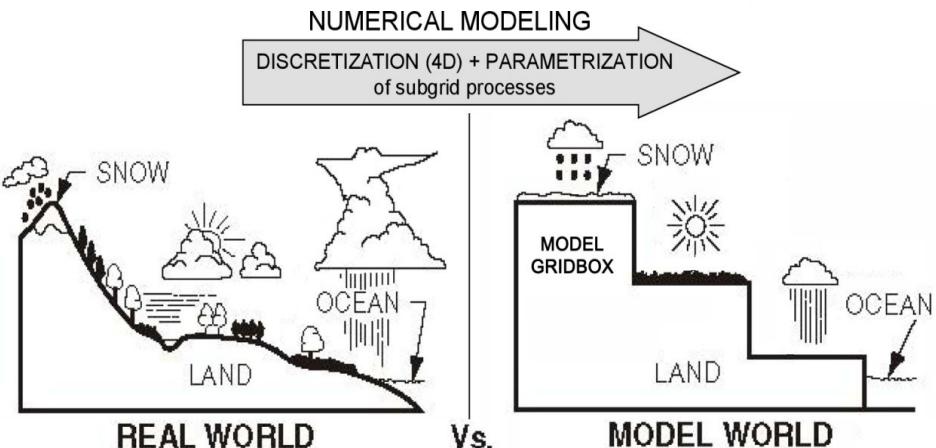
$$\left\{ \begin{array}{l} \frac{dv}{dt} = -\alpha \nabla p - \nabla \phi + F - 2\Omega \times v \\ \frac{\partial \rho}{\partial t} = -\nabla \cdot (\rho v) \\ p\alpha = RT \\ Q = C_p \frac{dT}{dt} - \alpha \frac{dp}{dt} \\ \frac{\partial \rho q}{\partial t} = -\nabla \cdot (\rho v q) + \rho(E - C) \end{array} \right.$$

$\mathbf{v} = (u, v, w), T, p, \rho = 1/\alpha \text{ y } q$

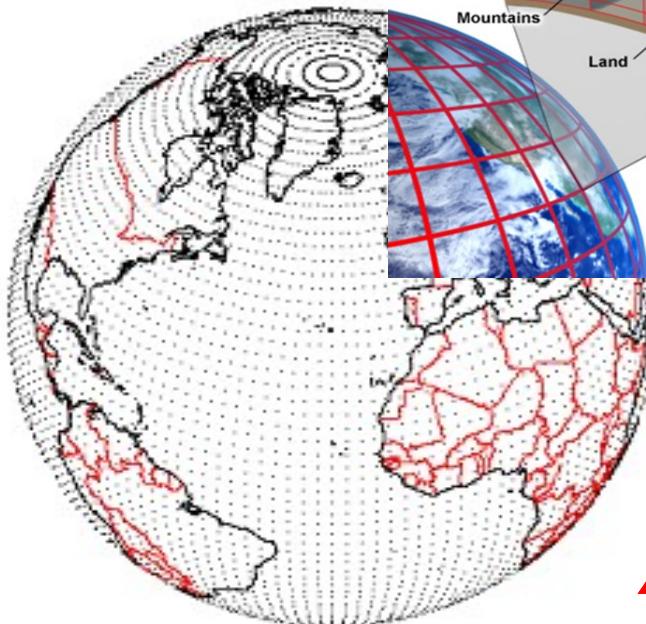
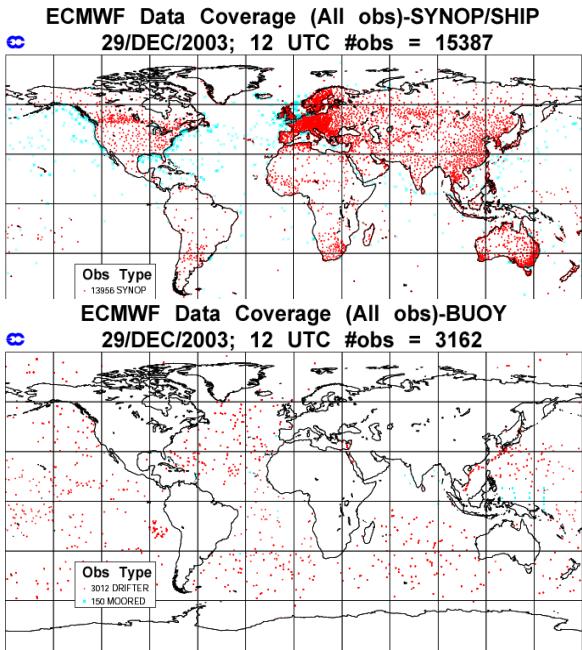
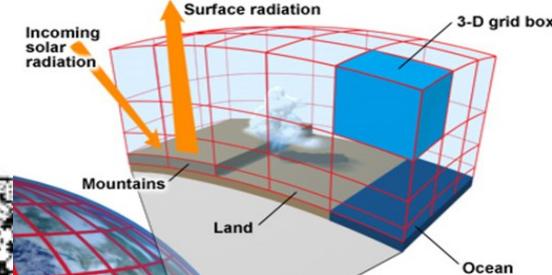
GCMS



$\Delta x \propto 1/\Delta t$

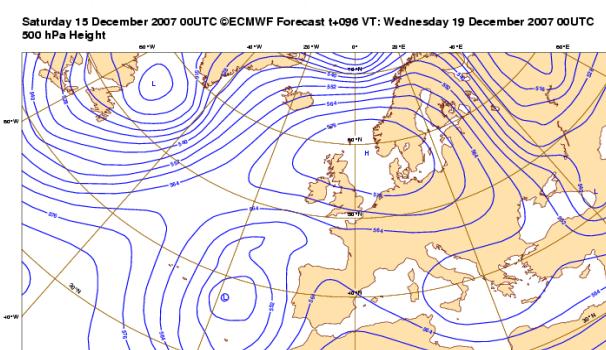
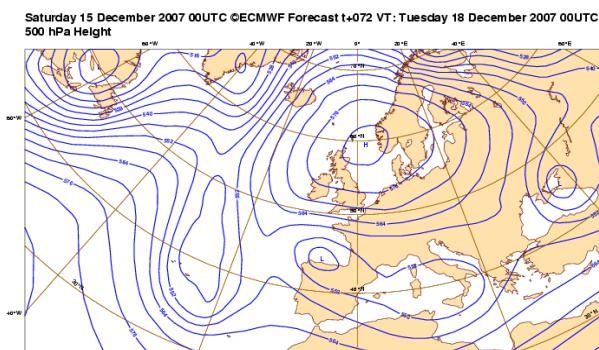
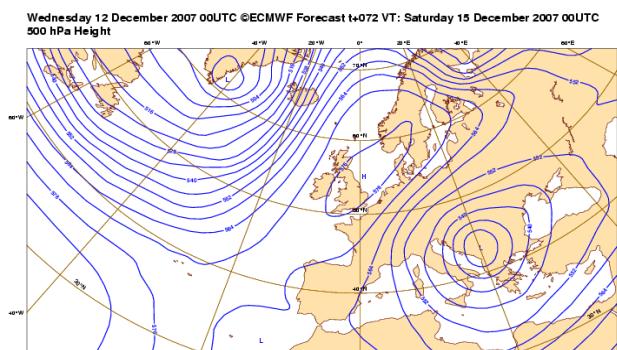


GCMS



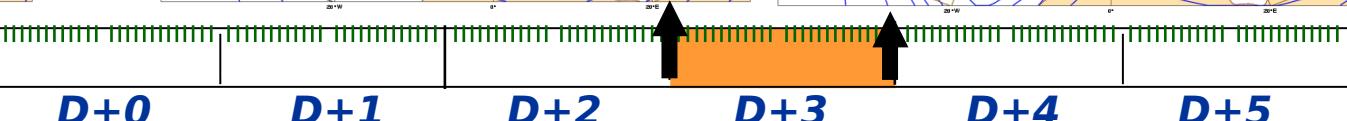
$$\Delta x \propto 1/\Delta t$$

Assimilation



Initial Condition

$H+0$



█ Initialization
█ Verification

Short-Medium Range Forecast

Days-Weeks



2020-03-26

Short-M Days-We

Predicción por municipios. Santander (Cantabria)

(i)

Predicción 7 días	Predicción por horas	El tiempo en tu web
Tabla	Gráfica	

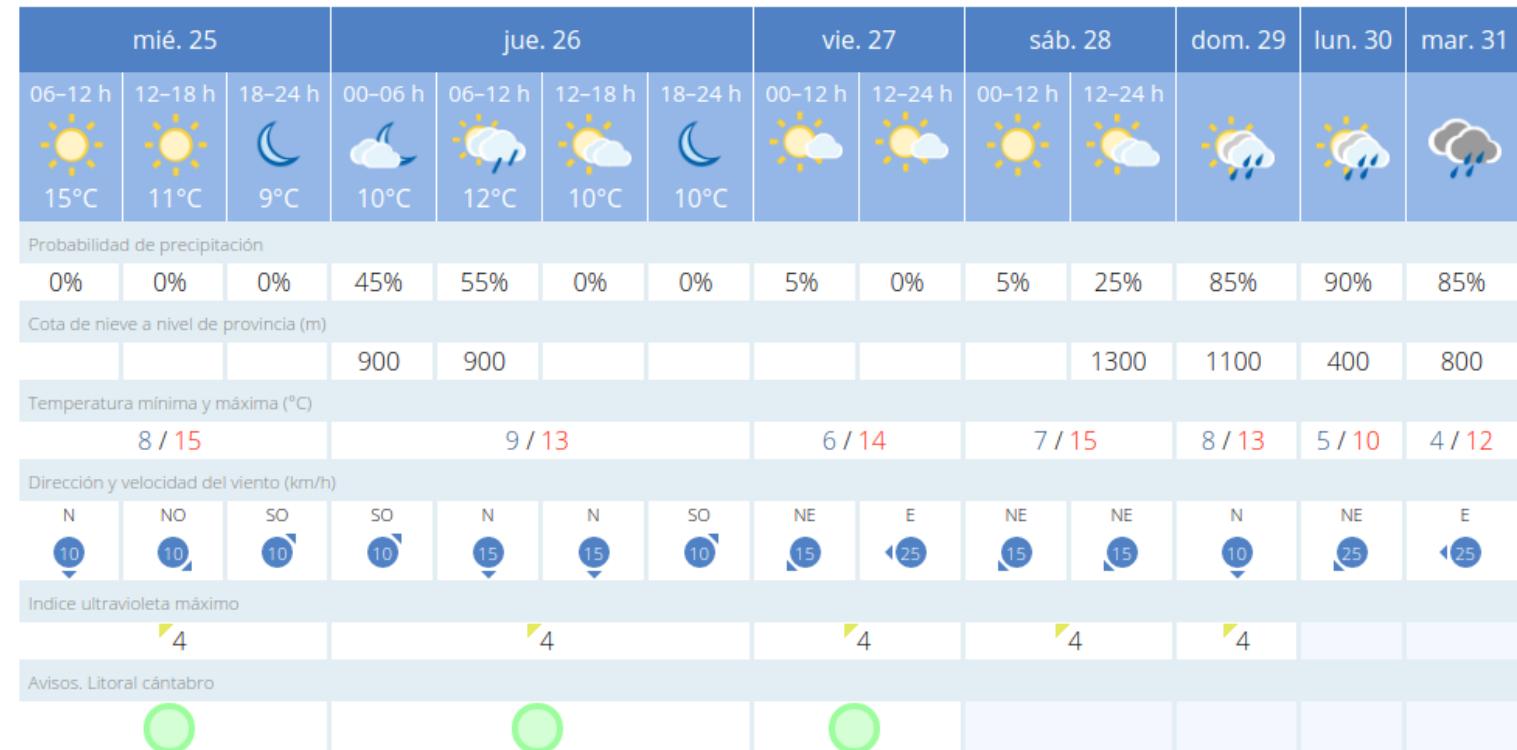
<http://www.aemet.es/es/portada>

Capital: Santander (altitud: 6 m)

Latitud: 43° 27' 43" N - **Longitud:** 3° 48' 34" O - **Posición:** Ver localización

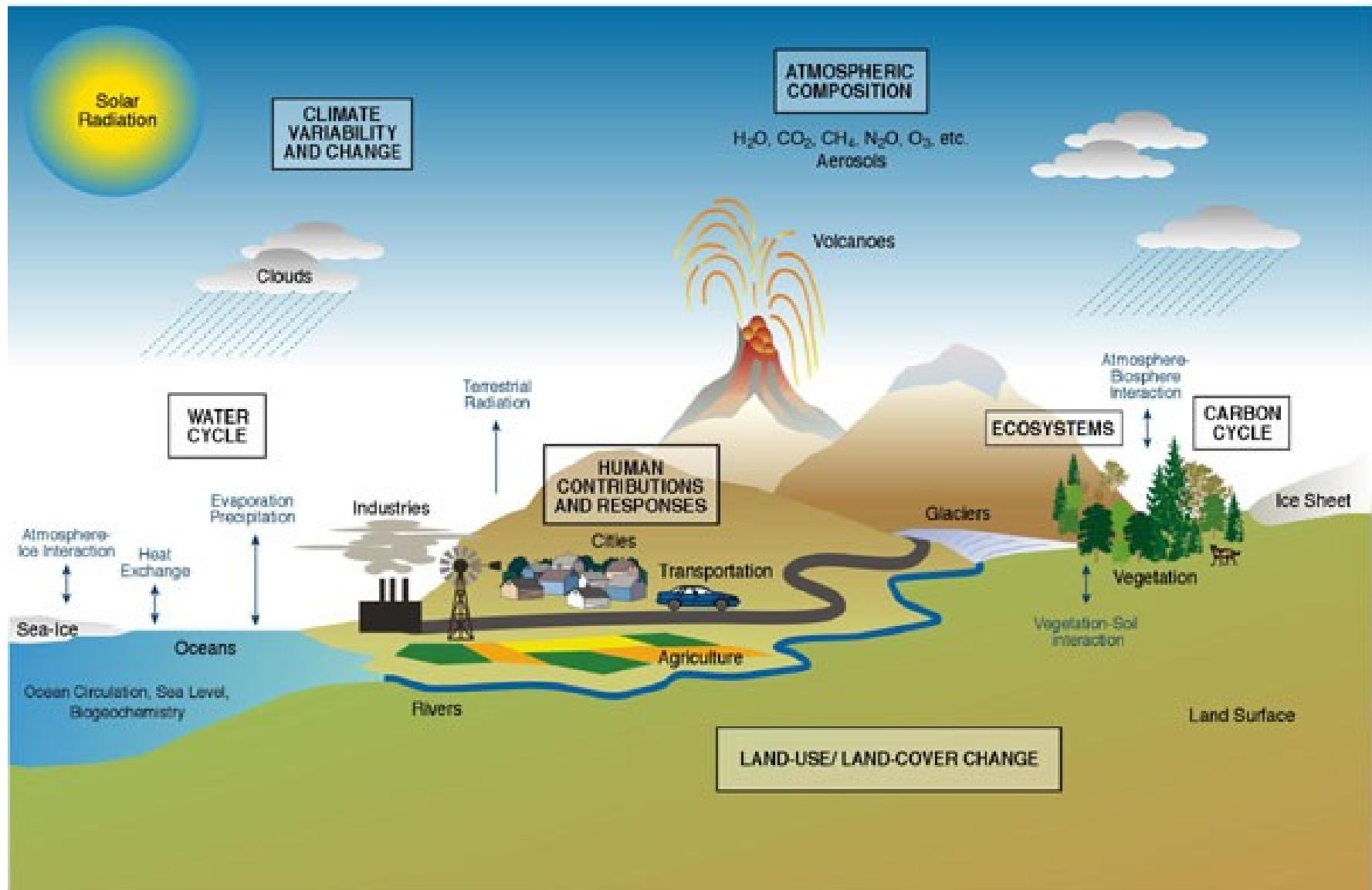
Zona de avisos: Litoral cántabro

[Descargar XML de la predicción detallada de Santander](#) [XML](#)



Atmosphere + Hydrosphere + Cryosphere + Lithosphere + Biosphere

1-7 days → Weather Forecast



predictable



**Non-Linear
Equations iii**

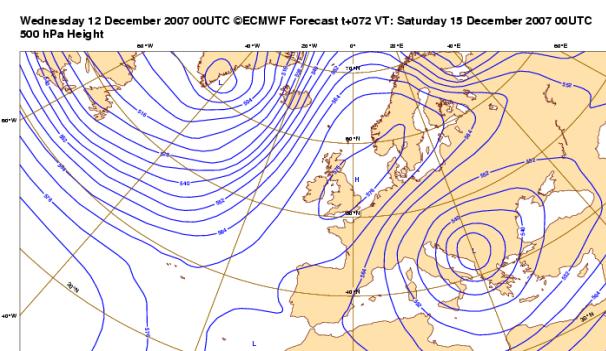
Semi-predictable



Unpredictable



$$\left\{ \begin{array}{l} \frac{dv}{dt} = -\alpha \nabla p - \nabla \phi + F - 2\Omega \times v \\ \frac{\partial \rho}{\partial t} = -\nabla \cdot (\rho v) \\ p\alpha = RT \\ Q = C_p \frac{dT}{dt} - \alpha \frac{dp}{dt} \\ \frac{\partial \rho q}{\partial t} = -\nabla \cdot (\rho v q) + \rho(E - C) \end{array} \right.$$



Initial Condition

$H+0$



D+0

D+1

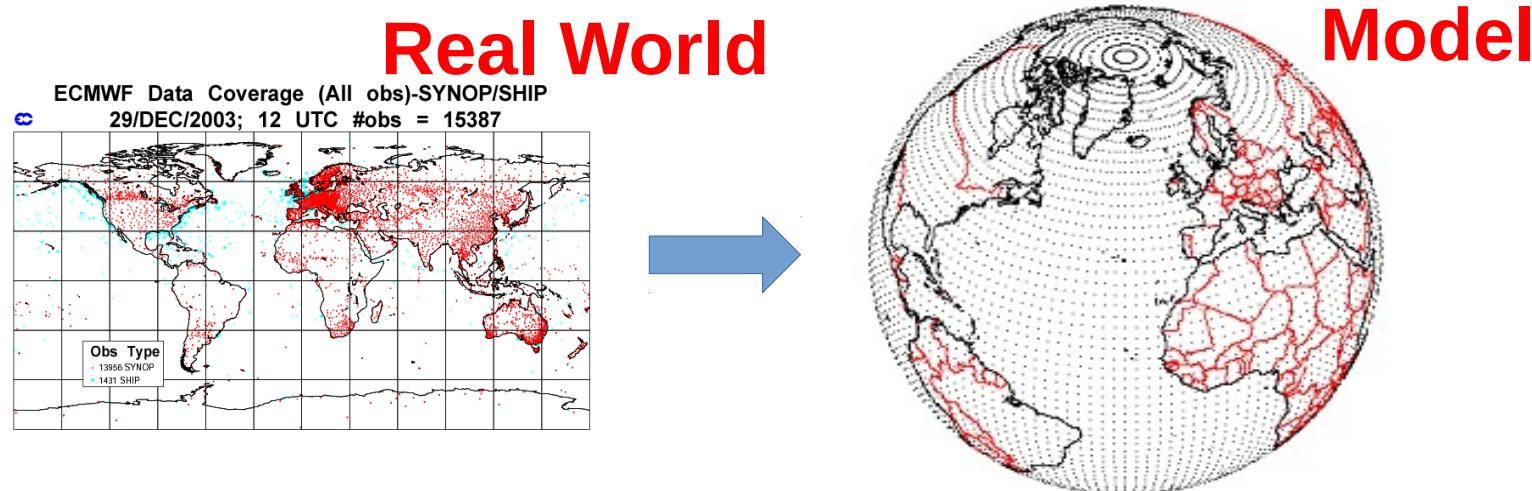
D+2

D+3

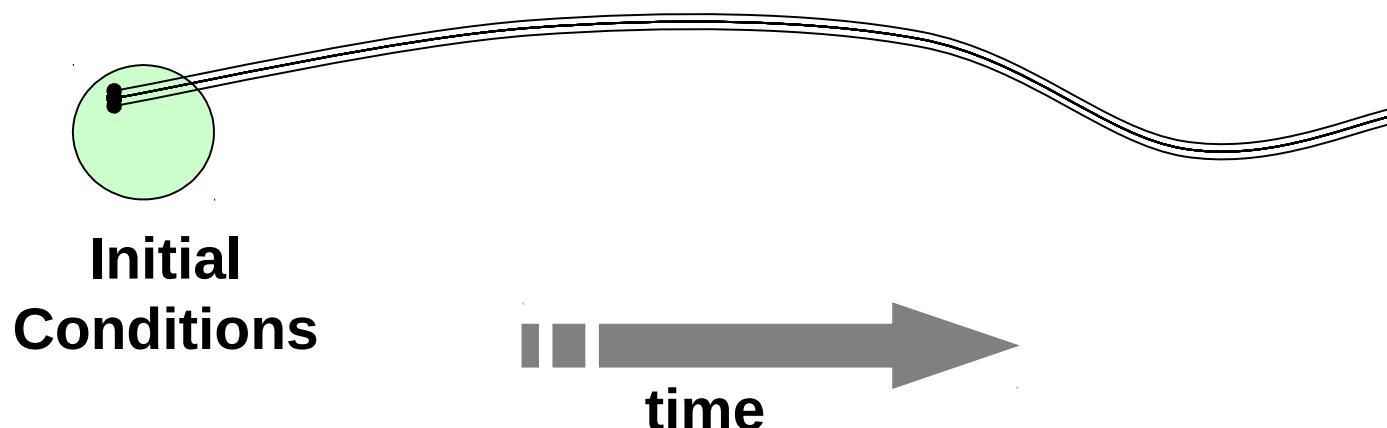
D+4

D+5

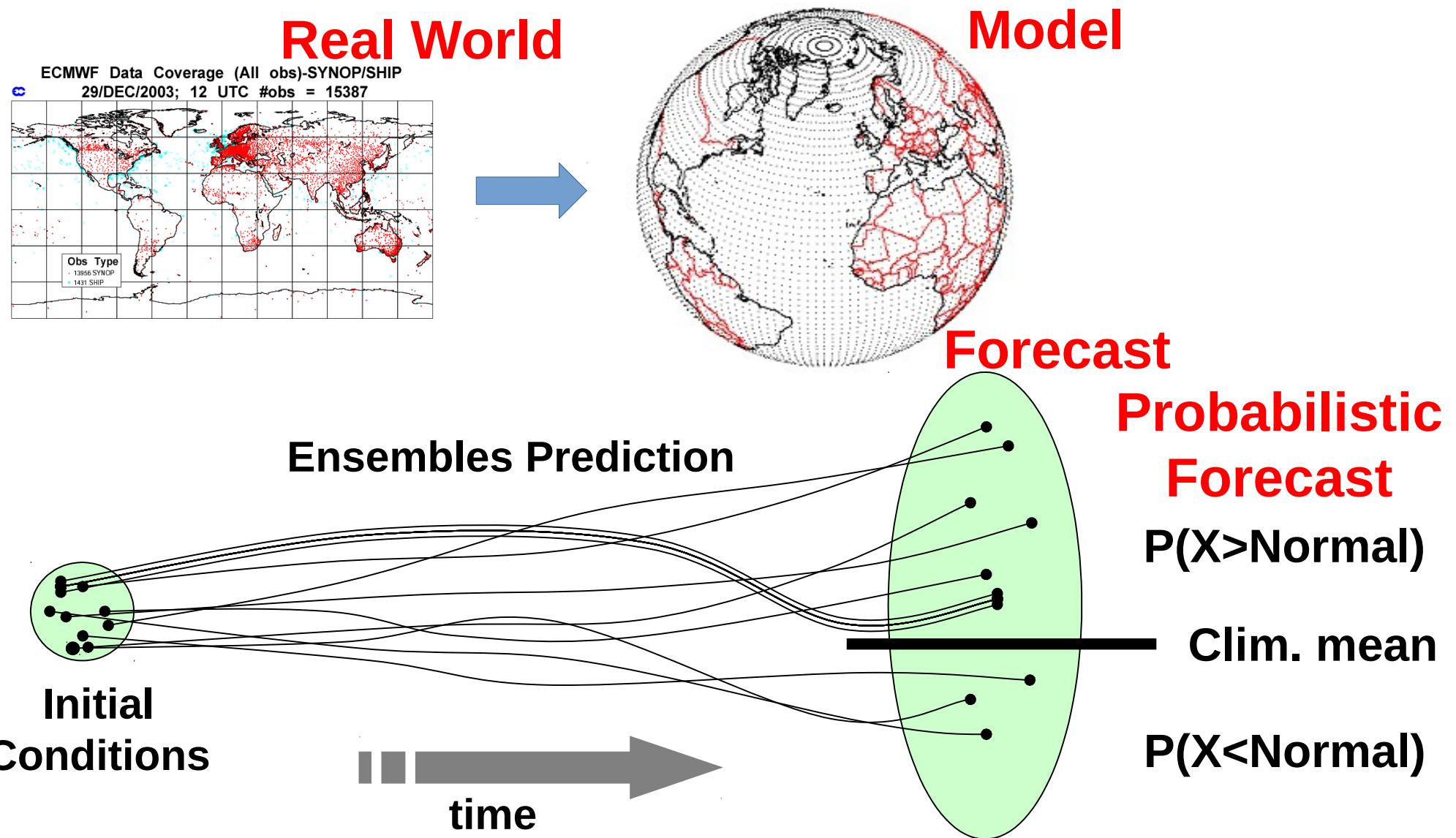
Uncertainty in the initial conditions: Perturbing the Initial Conditions of the atmosphere and ocean.



Deterministic Prediction

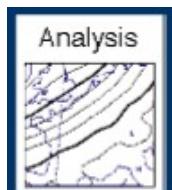
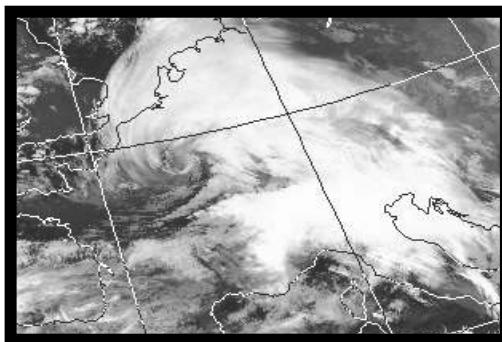


Uncertainty in the initial conditions: Perturbing the Initial Conditions of the atmosphere and ocean.



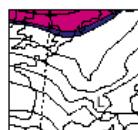
Uncertainty in the initial conditions: Perturbing the Initial Conditions of the atmosphere and ocean.

Borrasca Lothar: Francia/Alemania, 26/12/1999

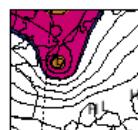


Ensemble forecast of the French / German storms (surface pressure)
Start date 24 December 1999 : Forecast time T+0 hours

Deterministic prediction



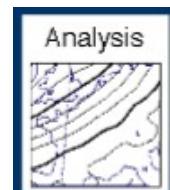
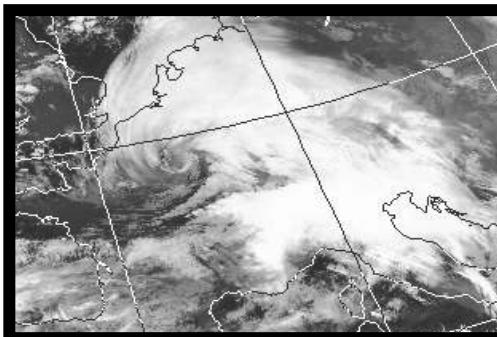
Verification



Ensemble forecast of the French / German storms (surface pressure)
Start date 24 December 1999 : Forecast time T+42 hours

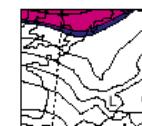
100 deaths and 3 million persons without services (e.g. water and electricity)

Borrasca Lothar: Francia/Alemania, 26/12/1999

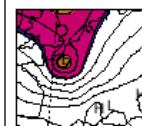


Ensemble forecast of the French / German storms (surface pressure)
Start date 24 December 1999 : Forecast time T+0 hours

Deterministic prediction



Verification

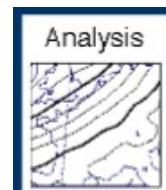
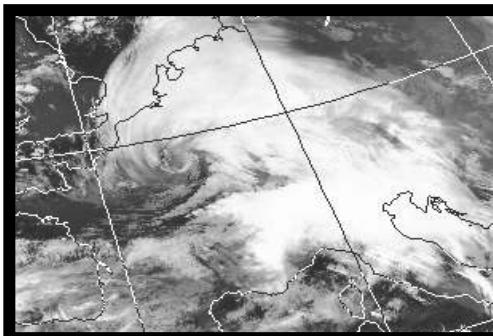


Ensemble forecast of the French / German storms (surface pressure)
Start date 24 December 1999 : Forecast time T+42 hours

100 deads y 3 millions
persons without
services (e.g. water
and electricity)



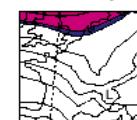
Borrasca Lothar: Francia/Alemania, 26/12/1999



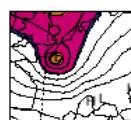
Ensemble forecast of the French / German storms (surface pressure)
Start date 24 December 1999 : Forecast time T+0 hours

100 deads y 3 millions
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Deterministic prediction

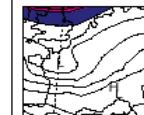


Verification



Ensemble forecast of the French / German storms (surface pressure)
Start date 24 December 1999 : Forecast time T+42 hours

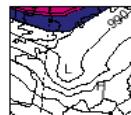
Forecast 1



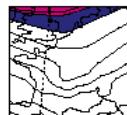
Forecast 2



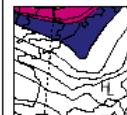
Forecast 3



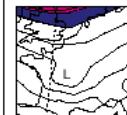
Forecast 4



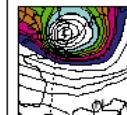
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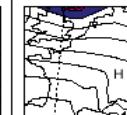
Forecast 6



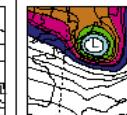
Forecast 7



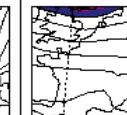
Forecast 8



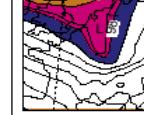
Forecast 9



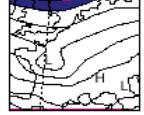
Forecast 10



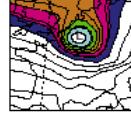
Forecast 11



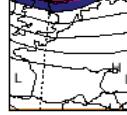
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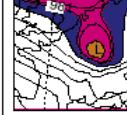
Forecast 13



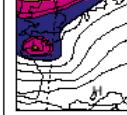
Forecast 14



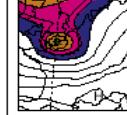
Forecast 15



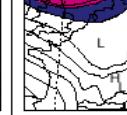
Forecast 16



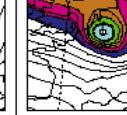
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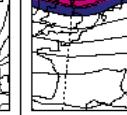
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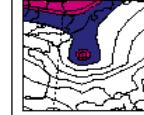
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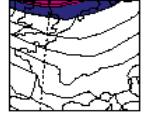
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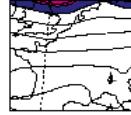
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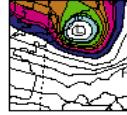
Forecast 22



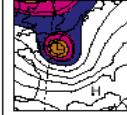
Forecast 23



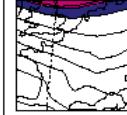
Forecast 24



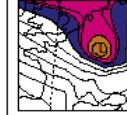
Forecast 25



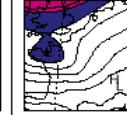
Forecast 26



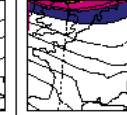
Forecast 27



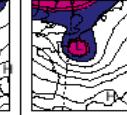
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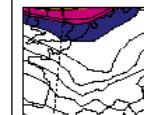
Forecast 29



Forecast 30



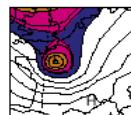
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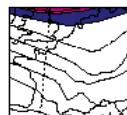
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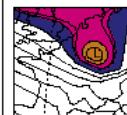
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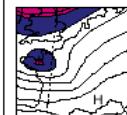
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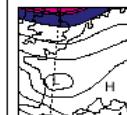
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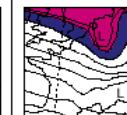
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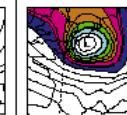
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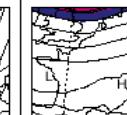
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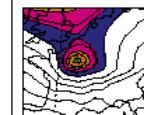
Forecast 39



Forecast 40



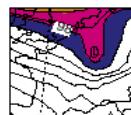
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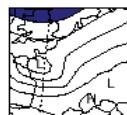
Forecast 42



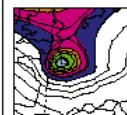
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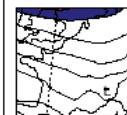
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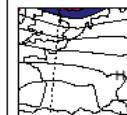
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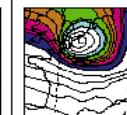
Forecast 46



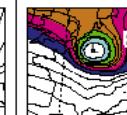
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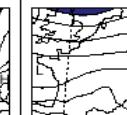
Forecast 48



Forecast 49



Forecast 50



█ Initialization
█ Verification

Weather Services

Short-Medium Range Forecast

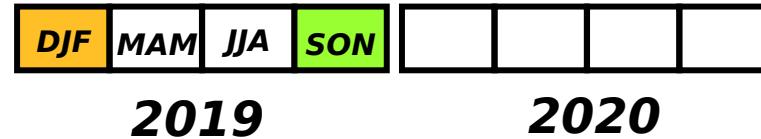
Days-Weeks



2019-04-01

Seasonal Forecast

Month-Season



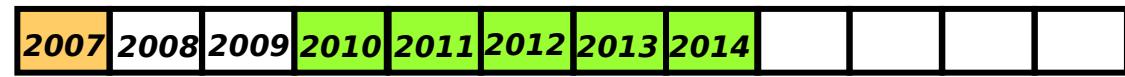
2019

2020

Climate Prediction

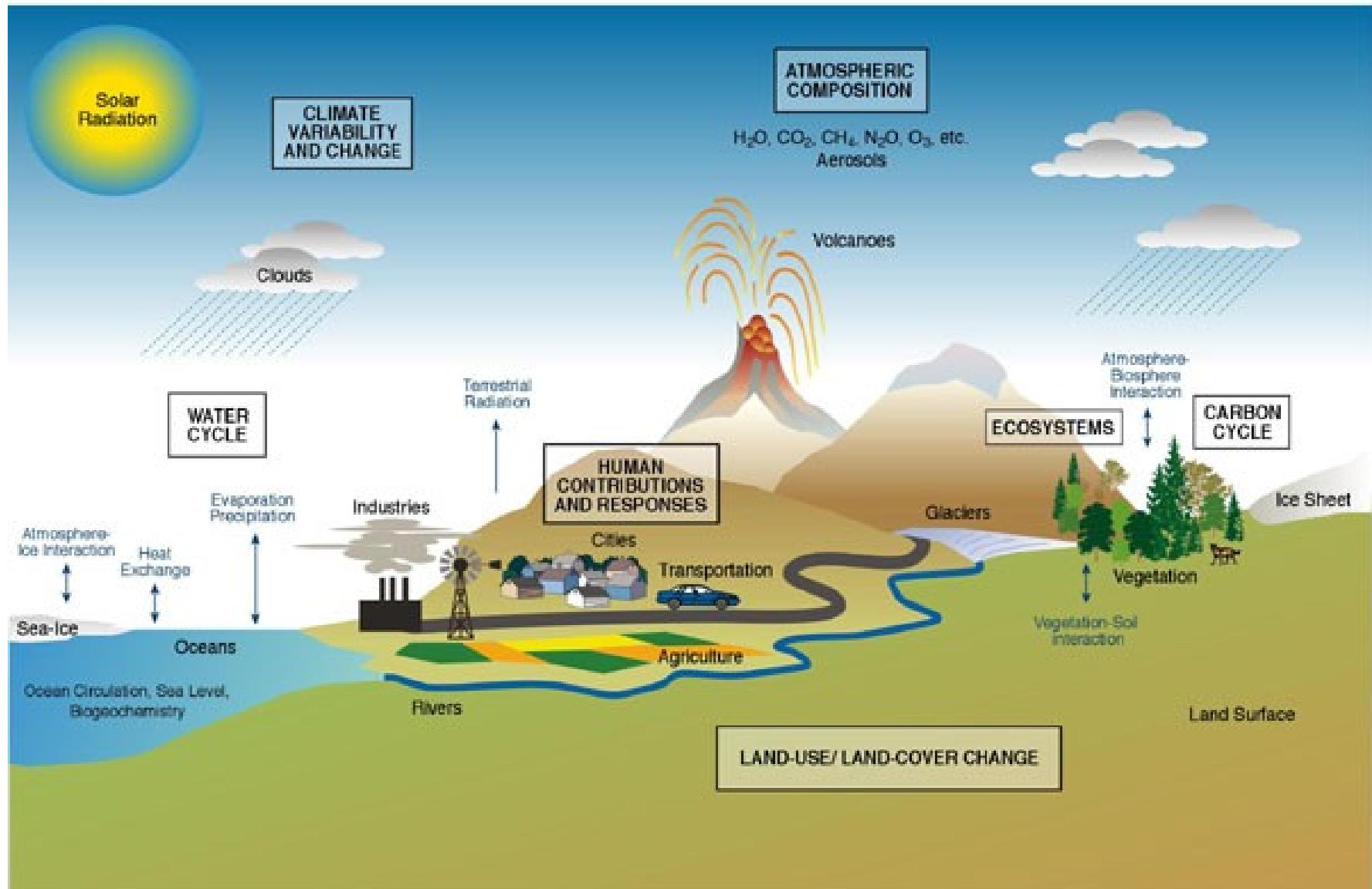
Decadal Prediction

Years-Decades



Atmosphere + Hydrosphere + Cryosphere + Lithosphere + Biosphere

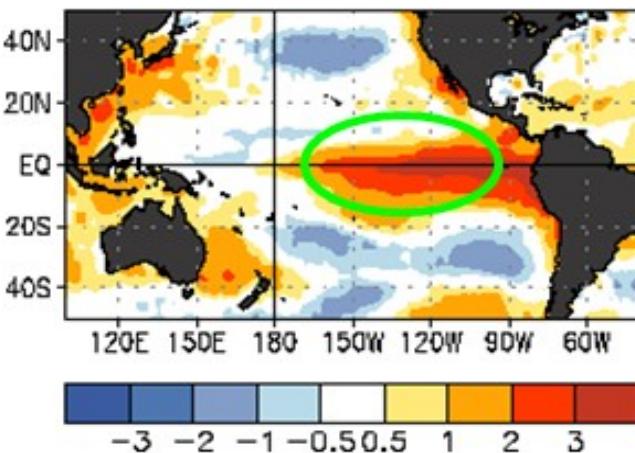
1-7 months → Seasonal Forecast



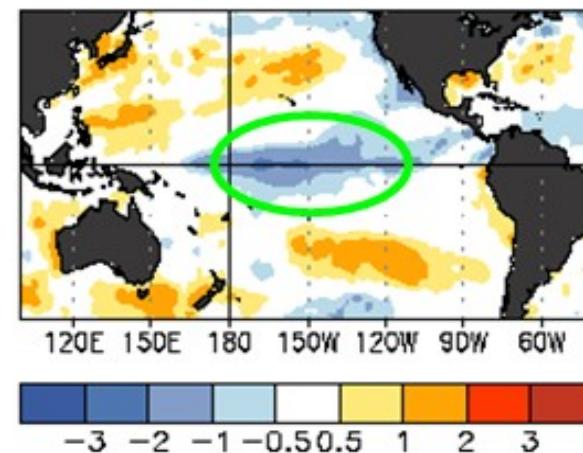
Atmosphere + Hydrosphere + Cryosphere + Lithosphere + Biosphere

At this time-scale the El Niño event is the main driver at global scale

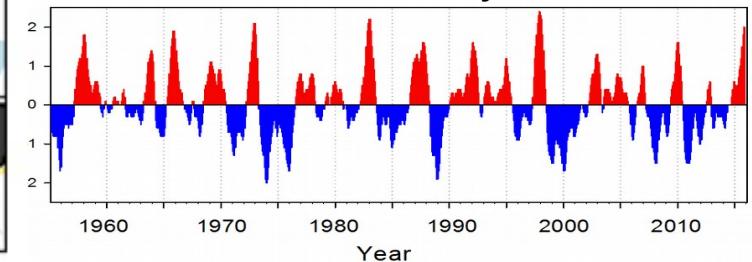
El Niño



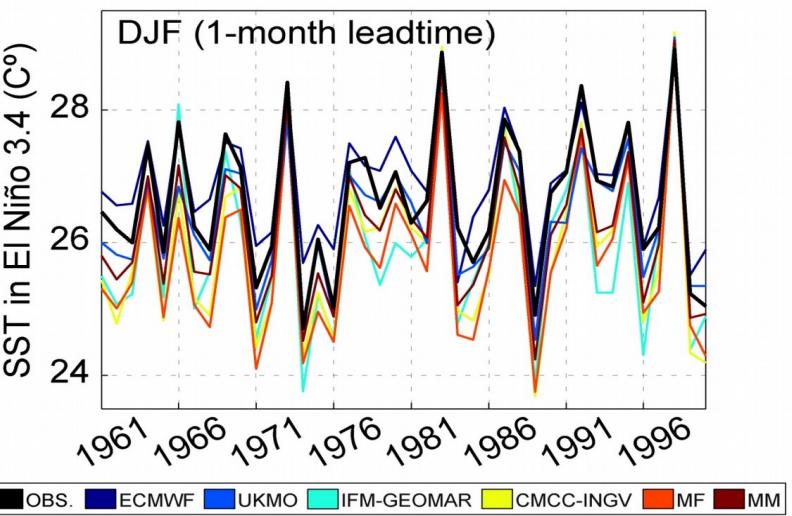
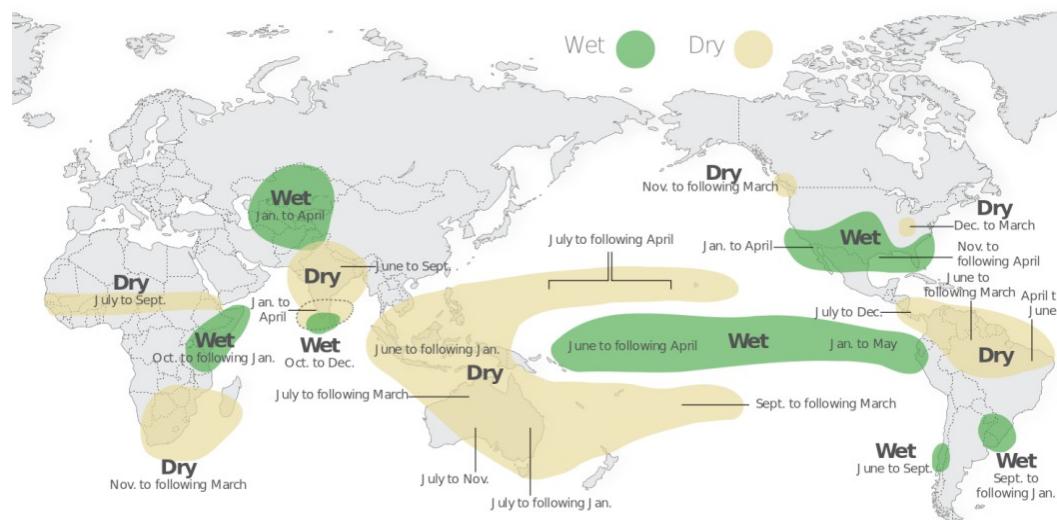
La Niña



Interannual variability of El Niño

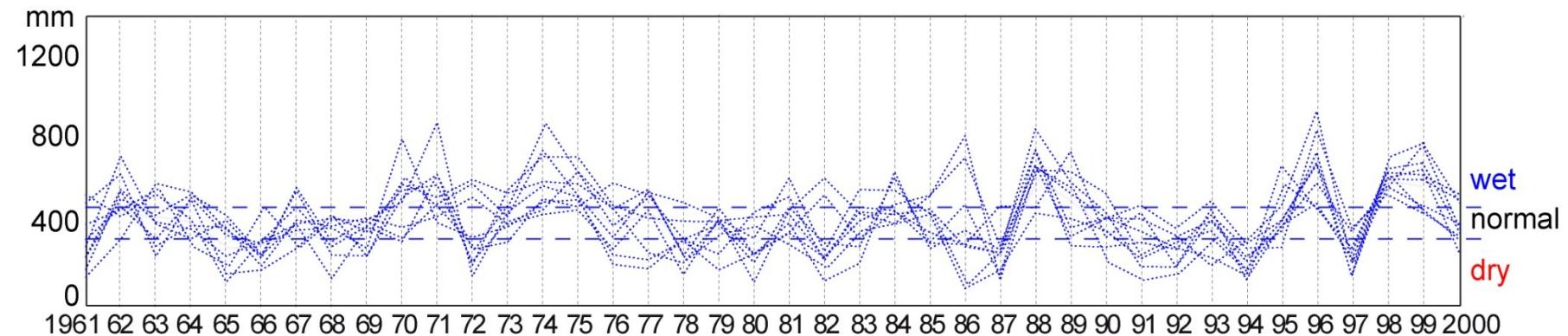


El Niño teleconnections



Atmosphere + Hydrosphere + Cryosphere + Lithosphere + Biosphere

The predictions are commonly expressed in terms of terciles:

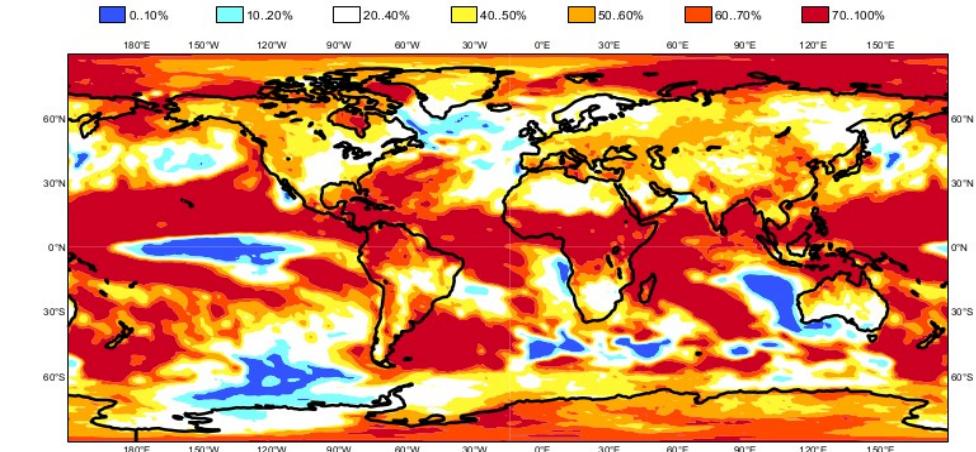
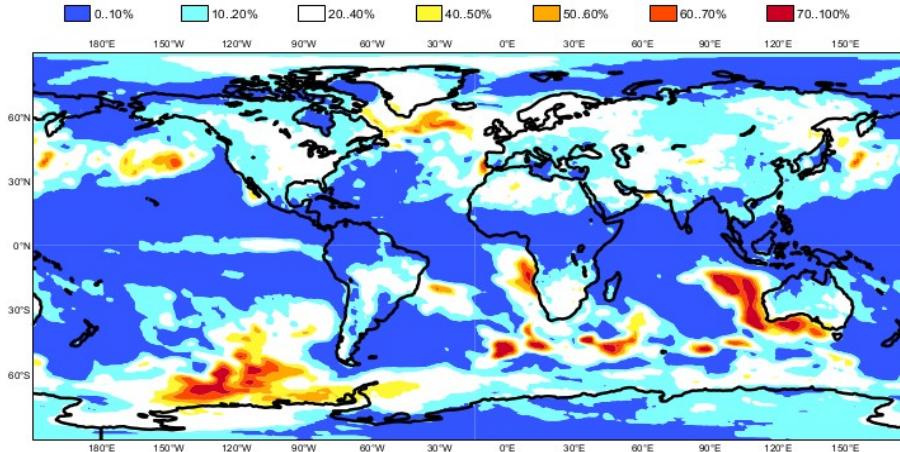


C3S: ECMWF contribution
Prob(2m temperature < lower tercile)
Nominal forecast start 01/08/17
Ensemble size = 51, climate size = 345

SON 2017

C3S: ECMWF contribution
Prob(2m temperature > upper tercile)
Nominal forecast start 01/08/17
Ensemble size = 51, climate size = 345

SON 2017



Atmosphere + Hydrosphere + Cryosphere + Lithosphere + Biosphere

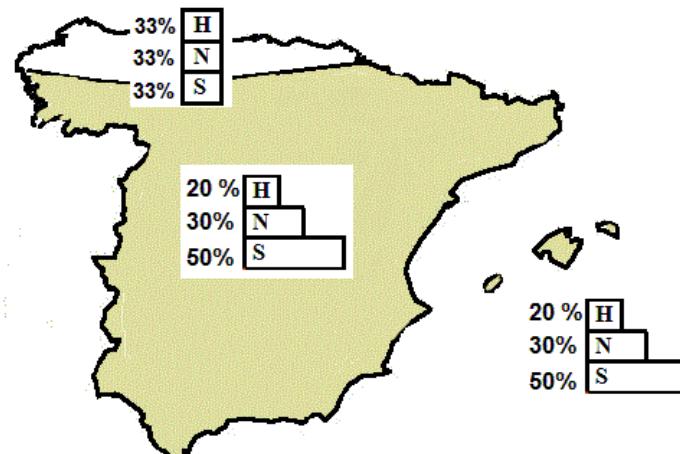
The predictions are commonly expressed in terms of terciles:

PROBABILIDAD DE LA CATEGORÍA MÁS PROBABLE DE PRECIPITACIÓN

MARZO - ABRIL - MAYO 2020

- [H] Probabilidad tercil superior
- [N] Probabilidad tercil central
- [S] Probabilidad tercil inferior

Los colores muestran la probabilidad de la categoría más probable.
El color blanco indica la climatología



Probabilidad categoría inferior

100% 70% 60 % 50% 40% 40% 50% 6

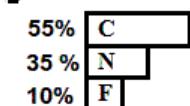
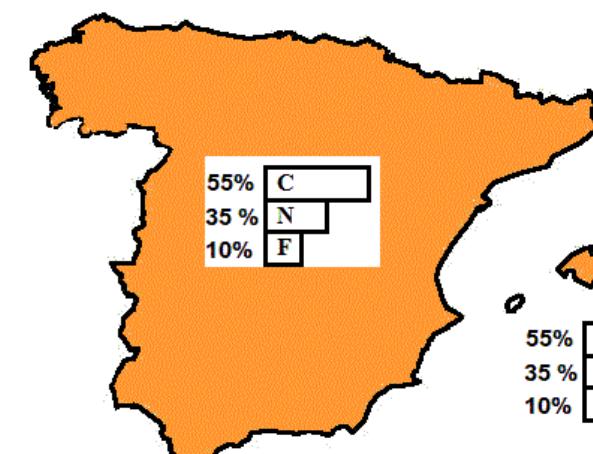
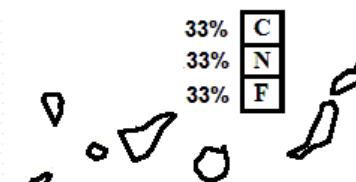
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PROBABILIDAD DE LA CATEGORÍA MÁS PROBABLE DE TEMPERATURA

MARZO - ABRIL - MAYO 2020

- [C] Probabilidad tercil superior
- [N] Probabilidad tercil central
- [F] Probabilidad tercil inferior

Los colores muestran la probabilidad de la categoría más probable.
El color blanco indica la climatología



Probabilidad categoría inferior

100% 70% 60 % 50% 40% 40% 50% 60% 70 % 100%

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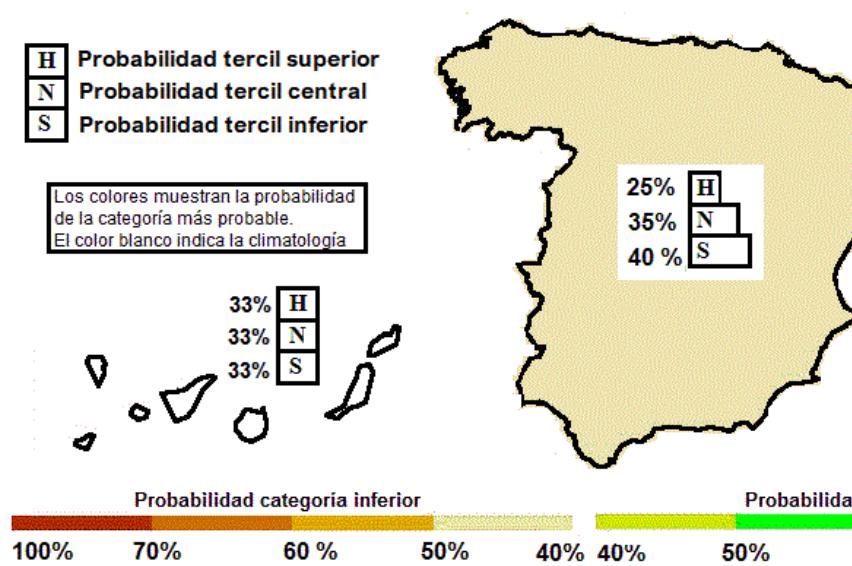
AE^{Met}
Agencia Estatal de Meteorología

Atmosphere + Hydrosphere + Cryosphere + Lithosphere + Biosphere

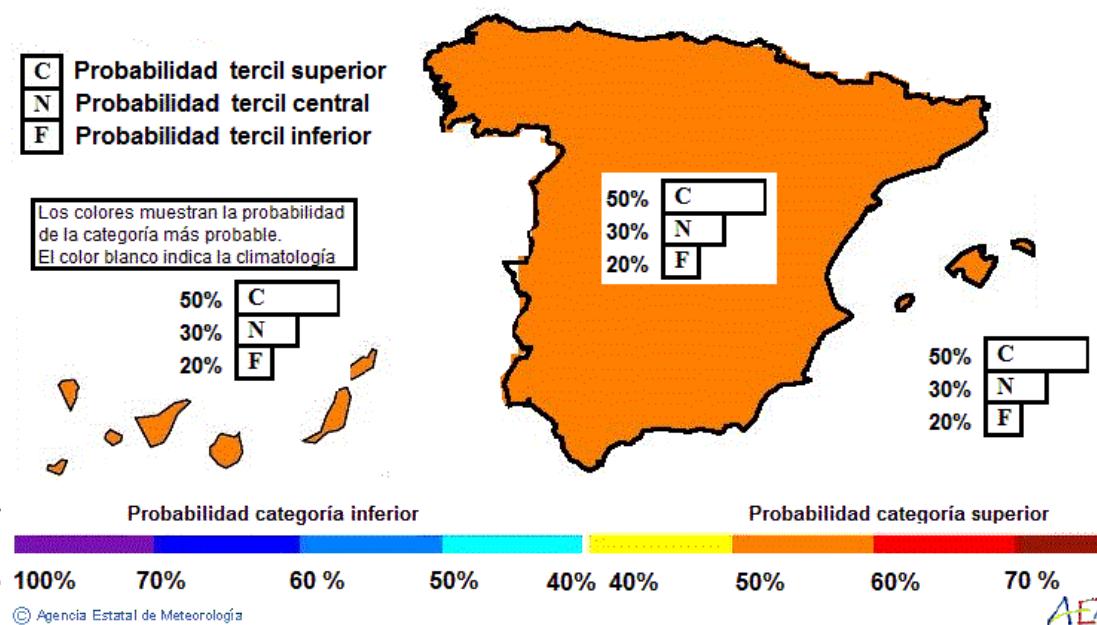
The predictions are commonly expressed in terms of terciles:

PROBABILIDAD DE LA CATEGORÍA MÁS PROBABLE DE PRECIPITACIÓN

ABRIL - MAYO - JUNIO 2019



PROBABILIDAD DE LA CATEGORÍA MÁS PROBABLE DE TEMPERATURA
ABRIL - MAYO - JUNIO 2019



Atmosphere + Hydrosphere + Cryosphere + Lithosphere + Biosphere

The predictions are commonly expressed in terms of terciles:

PROBABILIDAD DE LA CATEGORÍA MÁS PROBABLE DE PRECIPITACIÓN
ABRIL - MAYO - JUNIO 2019

- H** Probabilidad tercil superior
- N** Probabilidad tercil central
- S** Probabilidad tercil inferior

Los colores muestran la probabilidad de la categoría más probable.
El color blanco indica la climatología

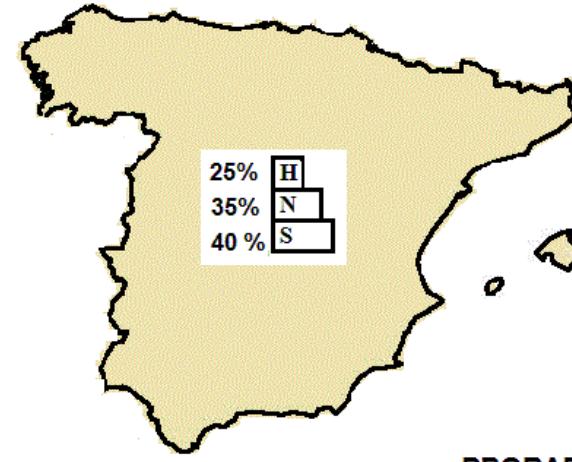
33% **H**
33% **N**
33% **S**

25% **H**
35% **N**
40% **S**

Probabilidad categoría inferior
100% 70% 60 % 50% 40% 40% 50%

Probabilidad categoría superior
50% 40% 40% 50%

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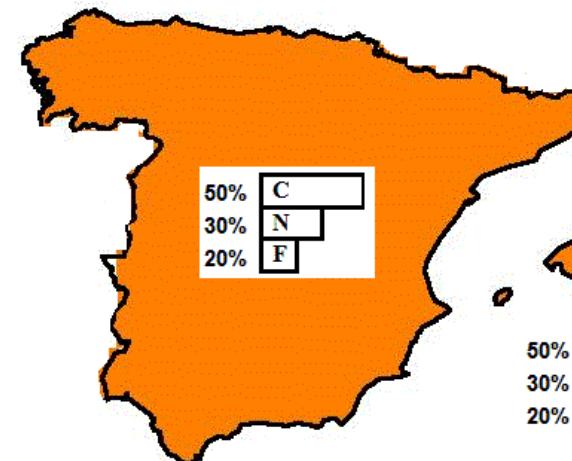


PROBABILIDAD DE LA CATEGORÍA MÁS PROBABLE DE TEMPERATURA
ABRIL - MAYO - JUNIO 2019

- C** Probabilidad tercil superior
- N** Probabilidad tercil central
- F** Probabilidad tercil inferior

Los colores muestran la probabilidad de la categoría más probable.
El color blanco indica la climatología

50% **C**
30% **N**
20% **F**



50% **C**
30% **N**
20% **F**

Probabilidad categoría inferior

100% 70% 60 % 50% 40% 40% 50%

Probabilidad categoría superior

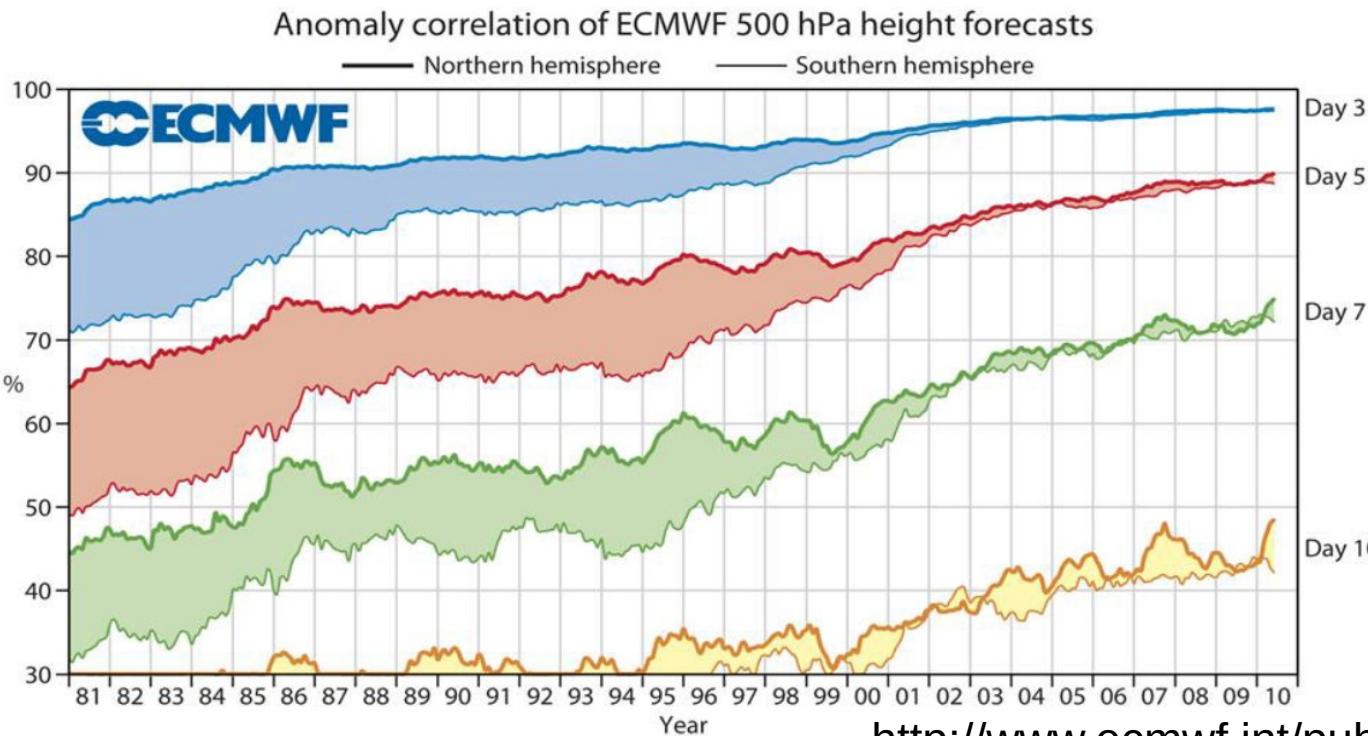
50% 60% 70 % 100%
AEMET
Agencia Estatal de Meteorología

There is not teleconnection
In Europe → Poor skill

Reanalysis a database of assimilated atmospheric states for a climatic period.

An **operational forecast** is a prediction for the future. Typically, only the recent past is stored.

A **reforecast (retrospective forecast)** is a database of historical forecasts performed with the same model for a long (climatic) period 1981-2010. In a **hindcast**, the initial conditions are taken from reanalysis.



<http://www.ecmwf.int/publications/newsletters/pdf/122.pdf>

█ Initialization
█ Verification

Weather Services

Short-Medium Range Forecast

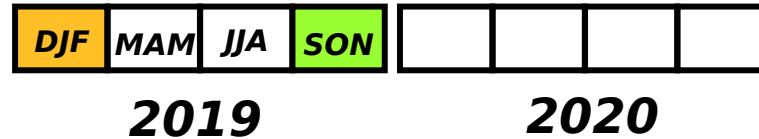
Days-Weeks



2019-04-01

Seasonal Forecast

Month-Season



2019

2020

Climate Services

Decadal Prediction

Years-Decades



Decadal prediction is currently experimental

Climate Prediction

█ Initialization
█ Verification

Weather Services

Short-Medium Range Forecast

Days-Weeks



2019-04-01

Seasonal Forecast

Month-Season

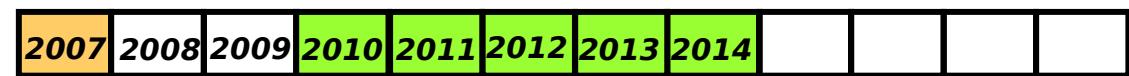


2019

2020

Decadal Prediction

Years-Decades



Anthropogenic Climate Change Projections

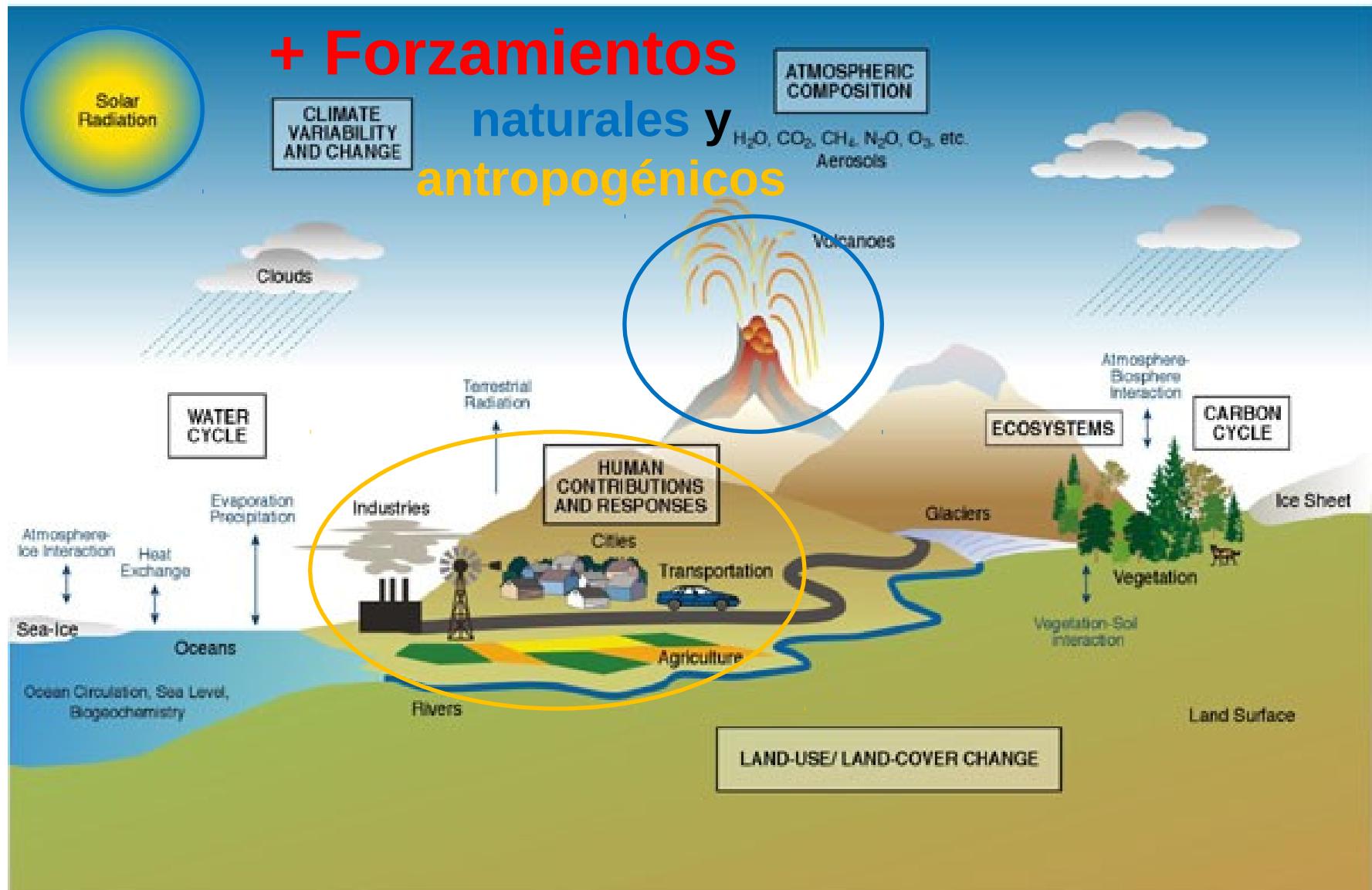
Decades-Century



Climate Services

Atmosphere + Hydrosphere + Cryosphere + Lithosphere + Biosphere

10-100 years → Decadal and Climate Change Projections

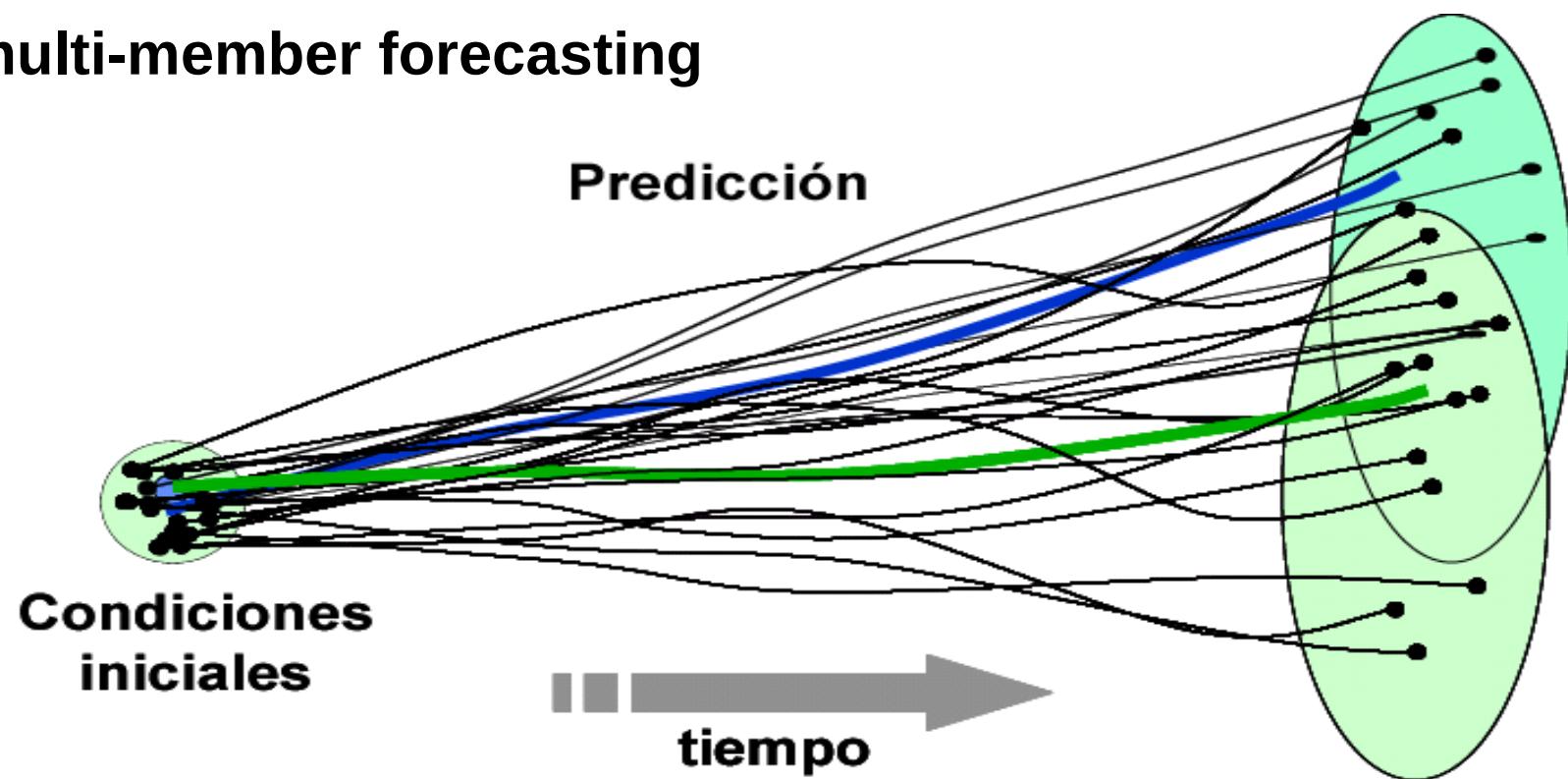


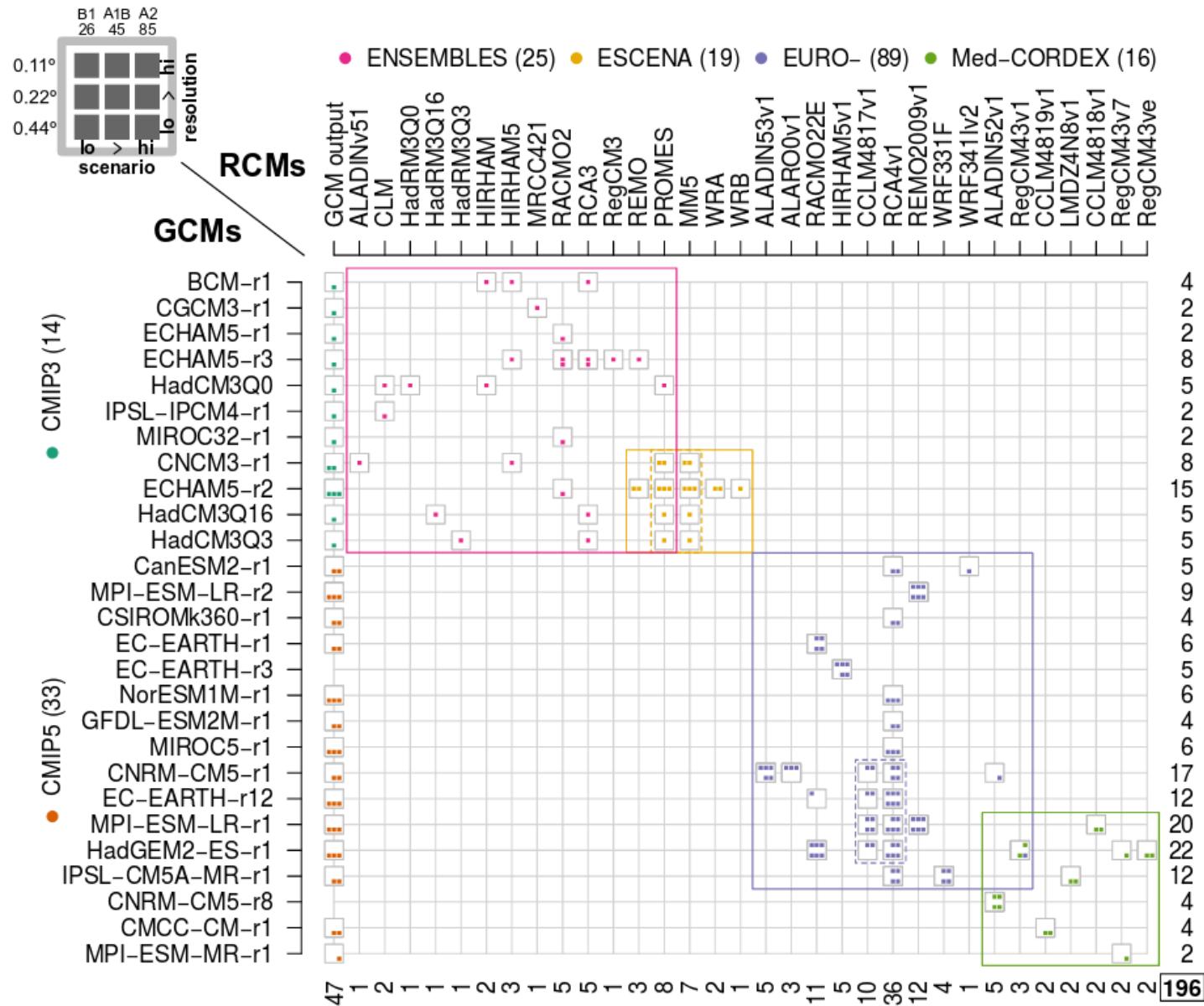
Uncertainty in the initial conditions: Perturbing the Initial Conditions of the atmosphere and ocean.

Other Uncertainties (model, scenario, etc.):

- Considering several models (**multi-model**)
- Stochastically perturbing the parameterizations of the model
- Considering several future scenarios.

Multi-model multi-member forecasting





Climate Change:
Global Models (**GCM**)
Regional Models (**RCM**)
Scenarios/Experiments
Runs
Parameterizations

...



Petabytes → Exabytes!!!

Source: Fernández, J. et al. 2018, Consistency of climate change projections from multiple global and regional model intercomparison projects. Climate Dynamics. Doi:10.1007/s00382-018-4181-8

Seasonal Forecast

seasons

DJF MAM JJA SON



2017

2018

2019

Seasonal Forecast has a great impact in several socio-economic fields:



- Agriculture
- Energy
- Transport
- Health
- Tourism
- Etc.



2010-2013



2011-2014



2012-2017



2016-

UC-IFCA (GMS)



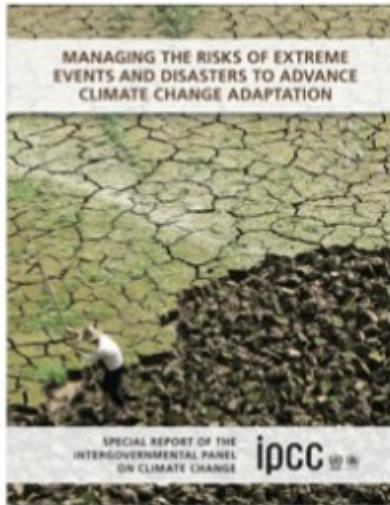
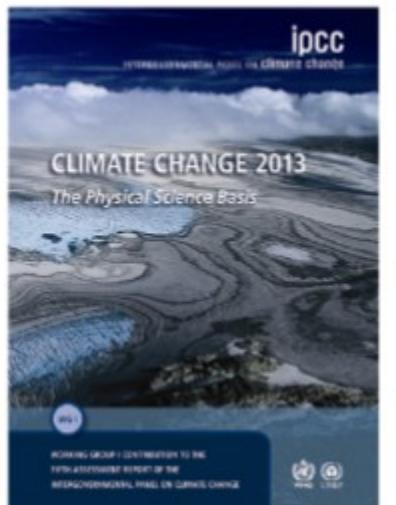
Anthropogenic Climate Change Projections

Decades-Century



United Nations created the Intergovernmental Panel on Climate Change (IPCC) in 1988 to improve the knowledge on climate change and to provide of authorized/contrast scientific information to the administrations. Three main branches were defined:

- I. Scientific information on climate change.
- II. Impact of and adaptation to the climate change.
- III. Political and economical aspects (mitigation).

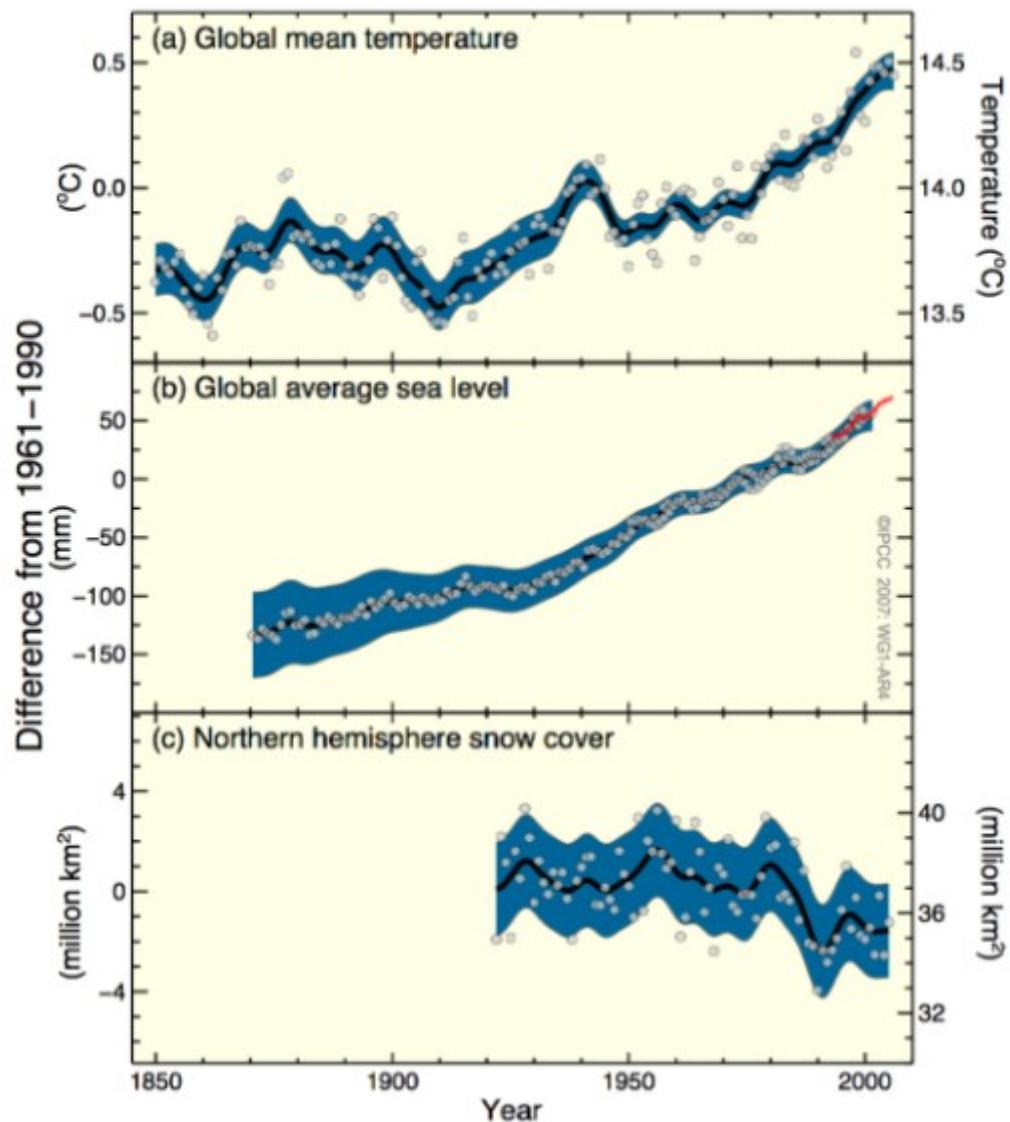


SRES Special Rep. (2012)

Five reports have been published since 1988, all of the available at <http://www.ipcc.ch>.

Recent Climate Change is evident:

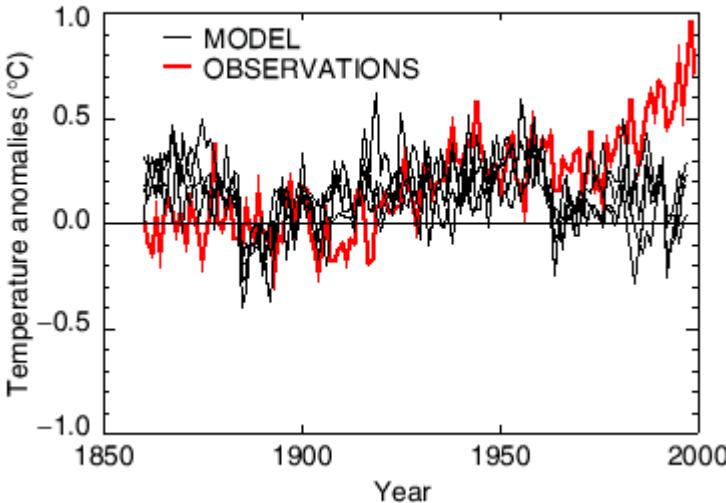
Changes in Temperature , Sea Level
and Northern Hemisphere Snow Cover



Recent Climate Change is evident → Attribution

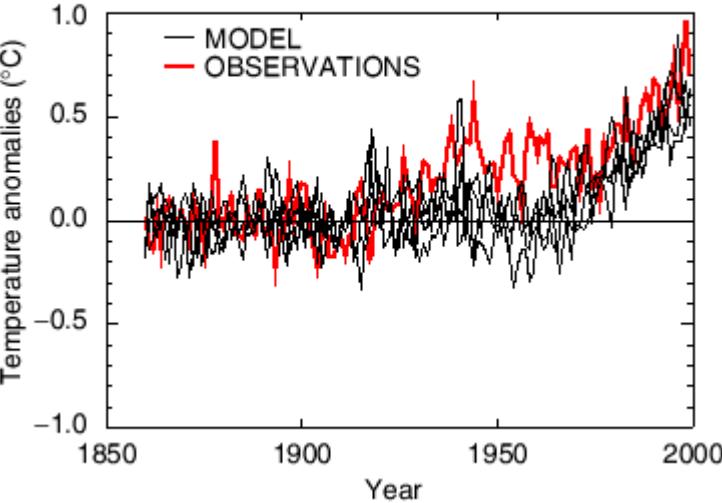
(a)

NATURAL : Annual global mean temperatures

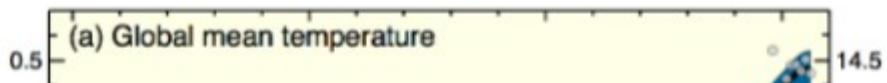


(b)

ANTHROPOGENIC : Annual global mean temperatures

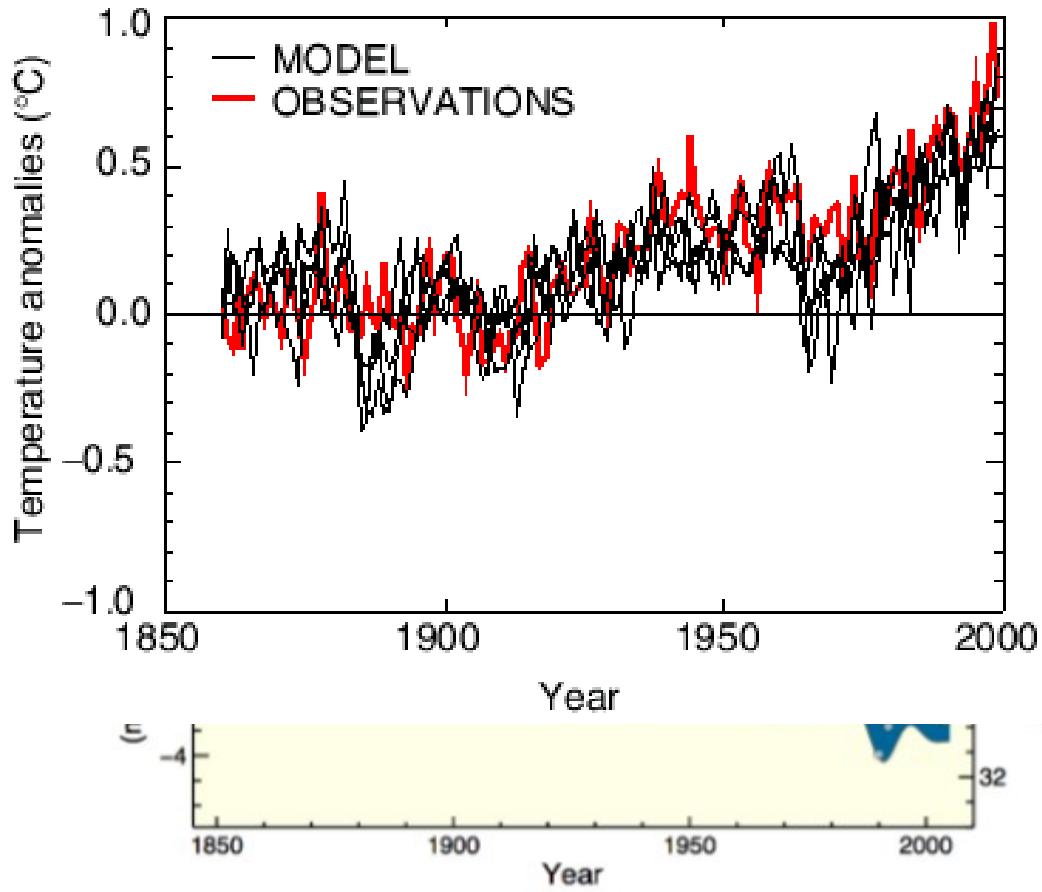


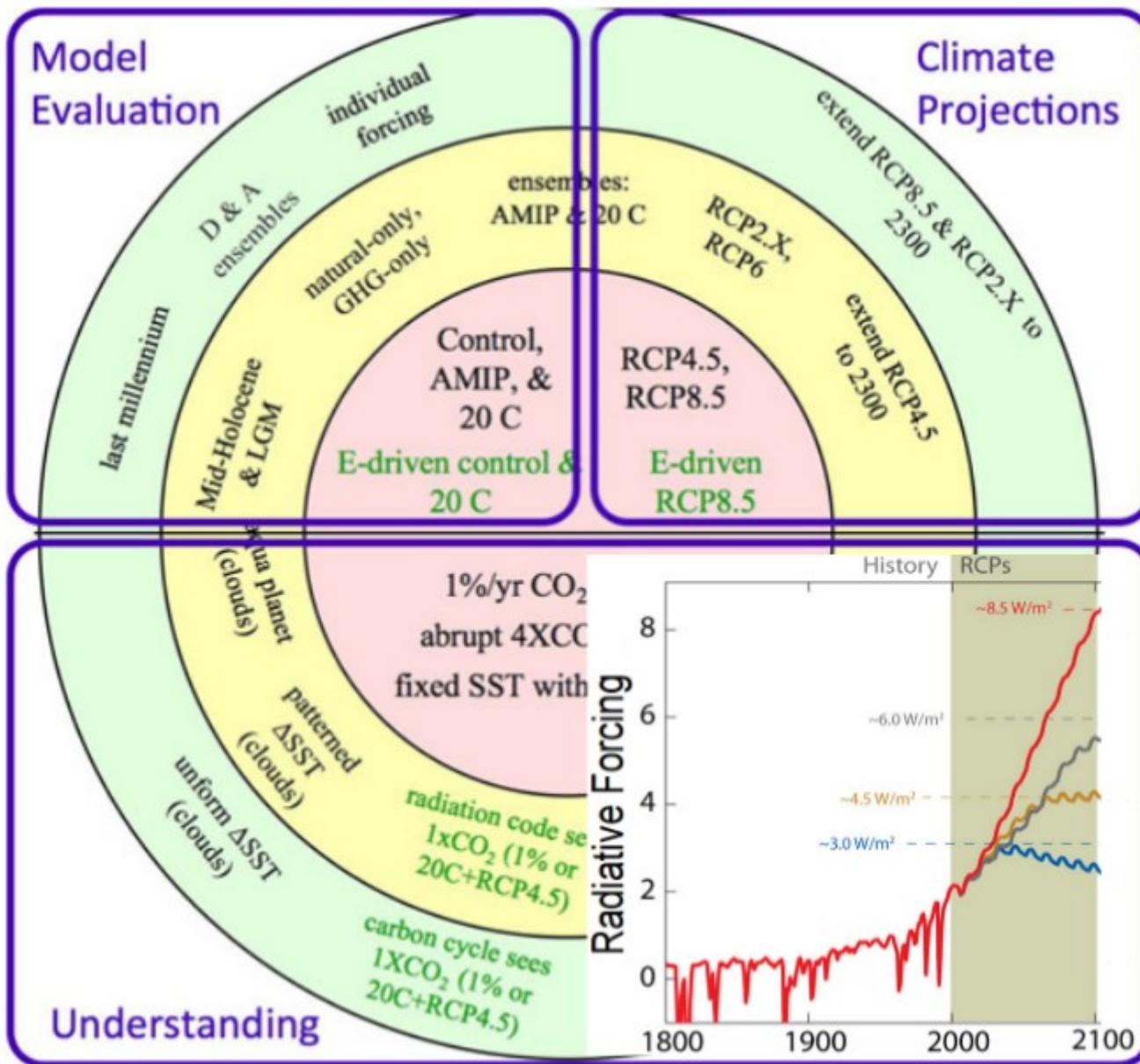
Changes in Temperature , Sea Level
and Northern Hemisphere Snow Cover



(c)

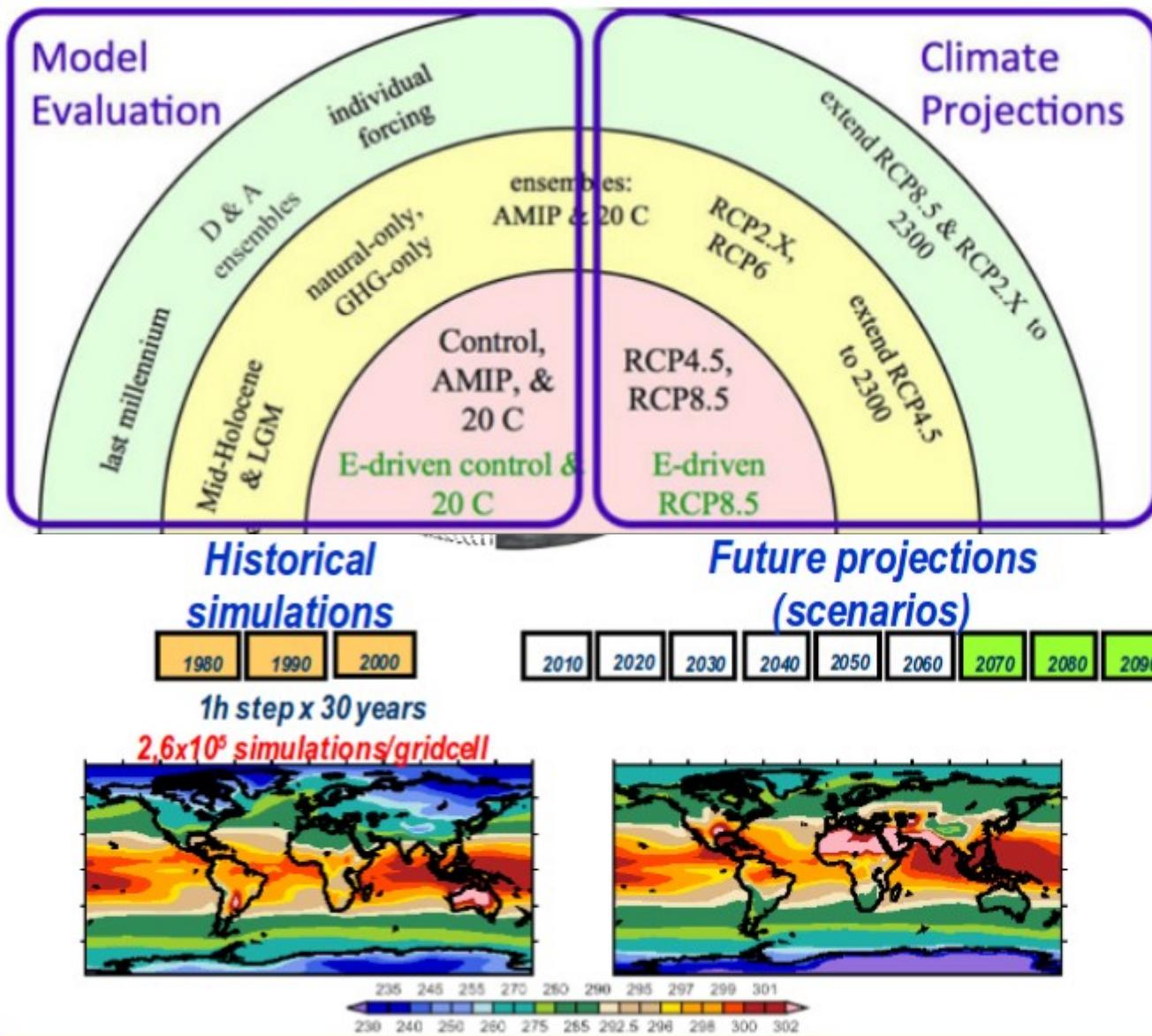
ALL FORCINGS : Annual global mean temperatures





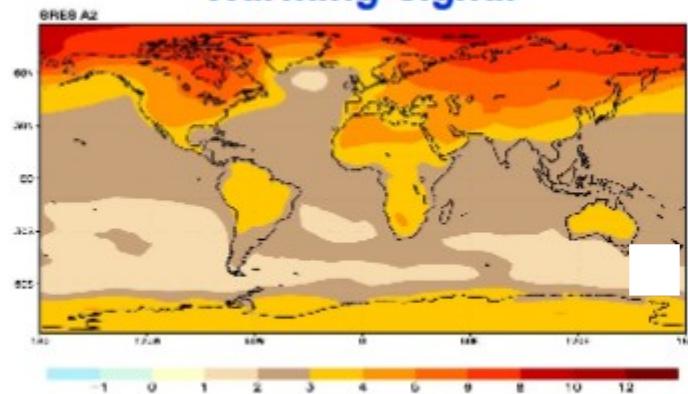
Multi-decadal forcing conditions are given for a number of historical and future scenarios for model validation and climate change attribution and projection.





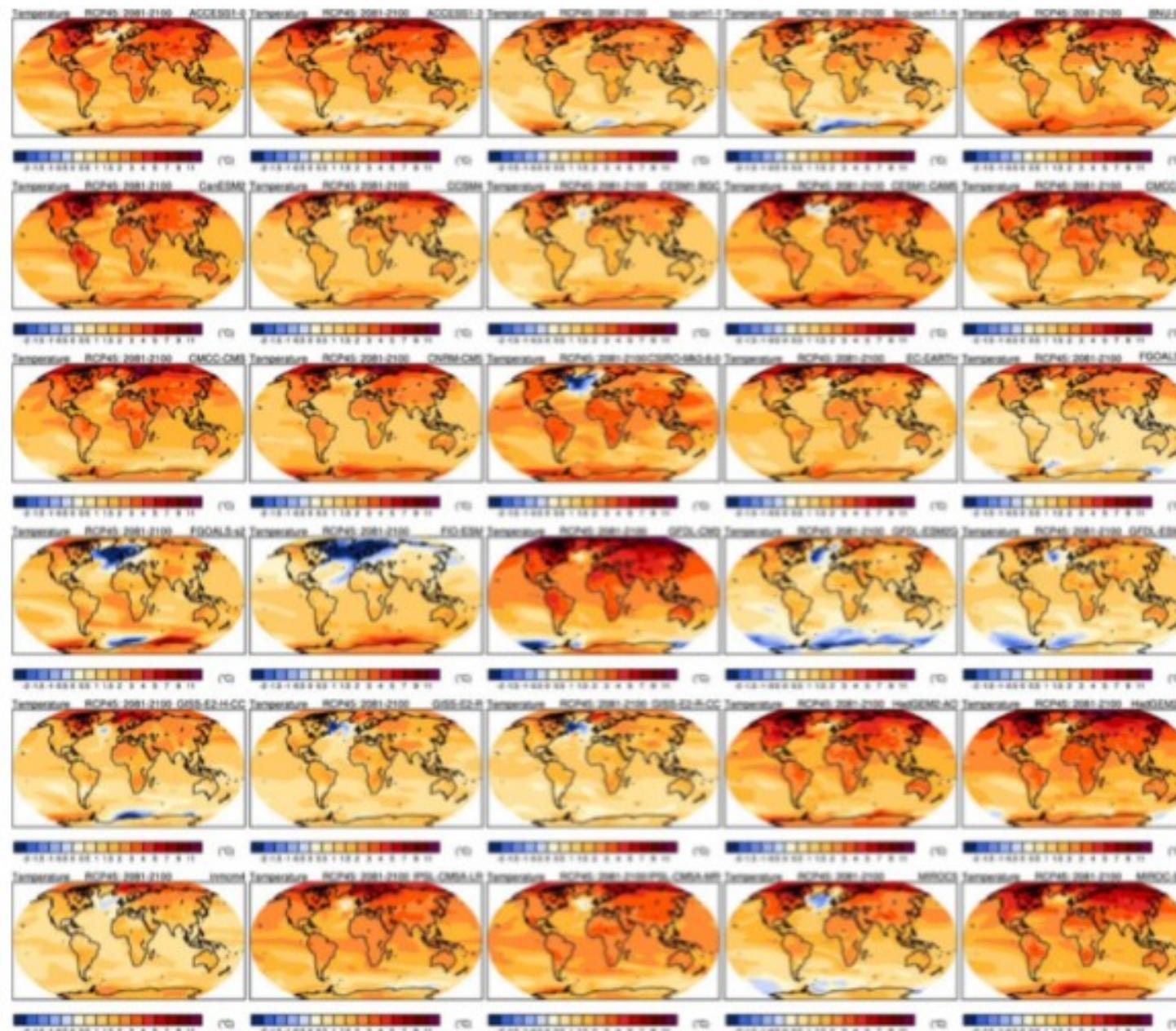
Multi-decadal forcing conditions are given for a number of historical and future scenarios for model validation and climate change attribution and projection.

"delta" method
Warming signal

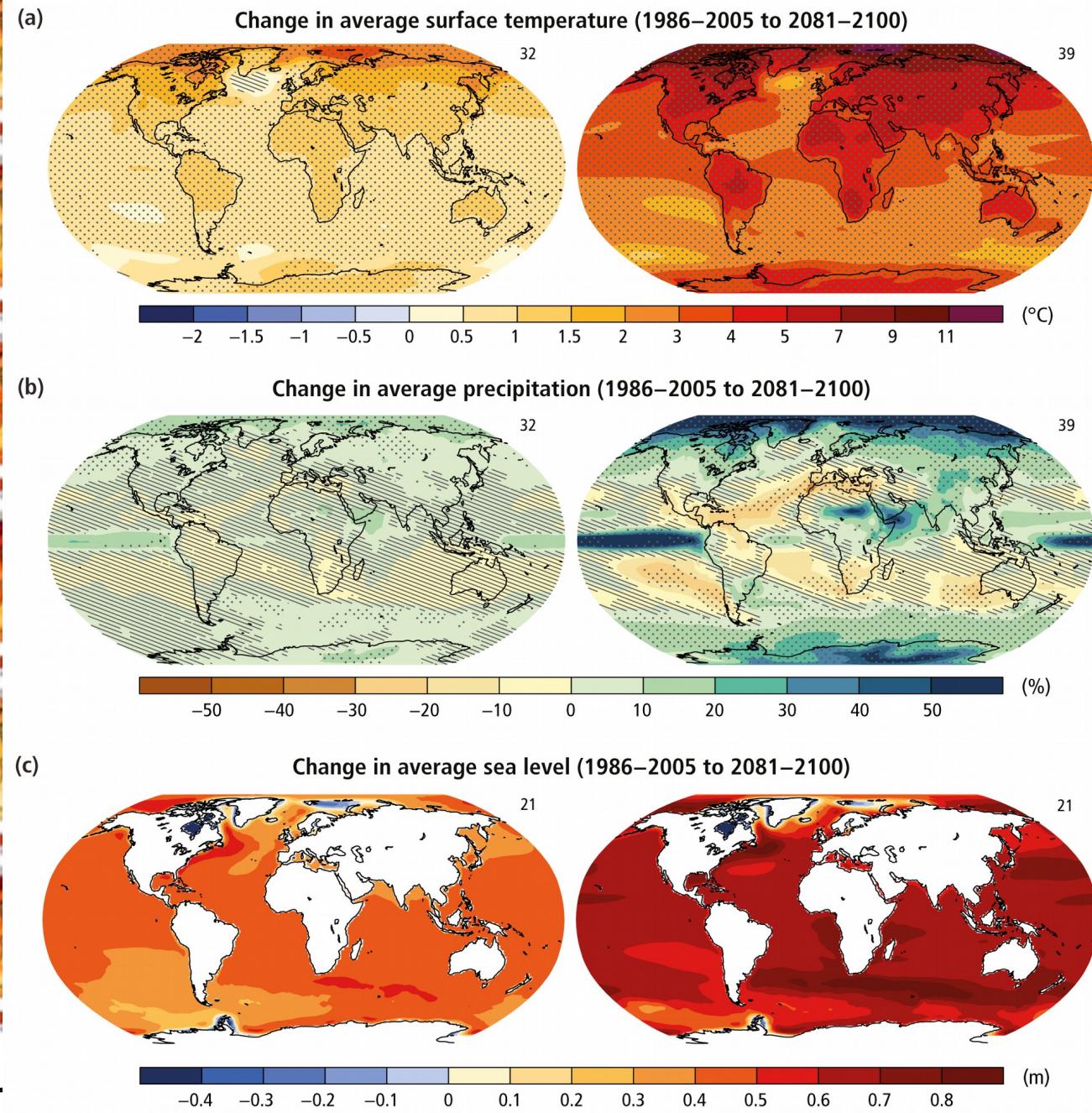
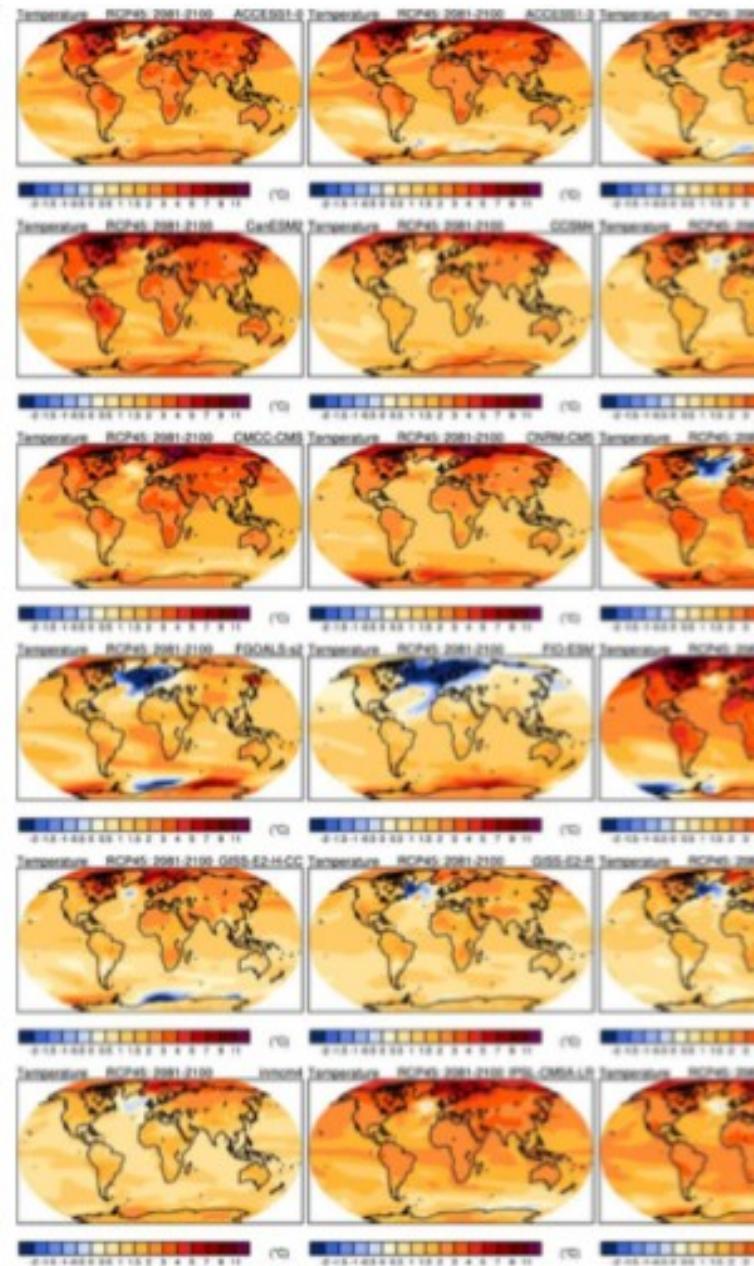


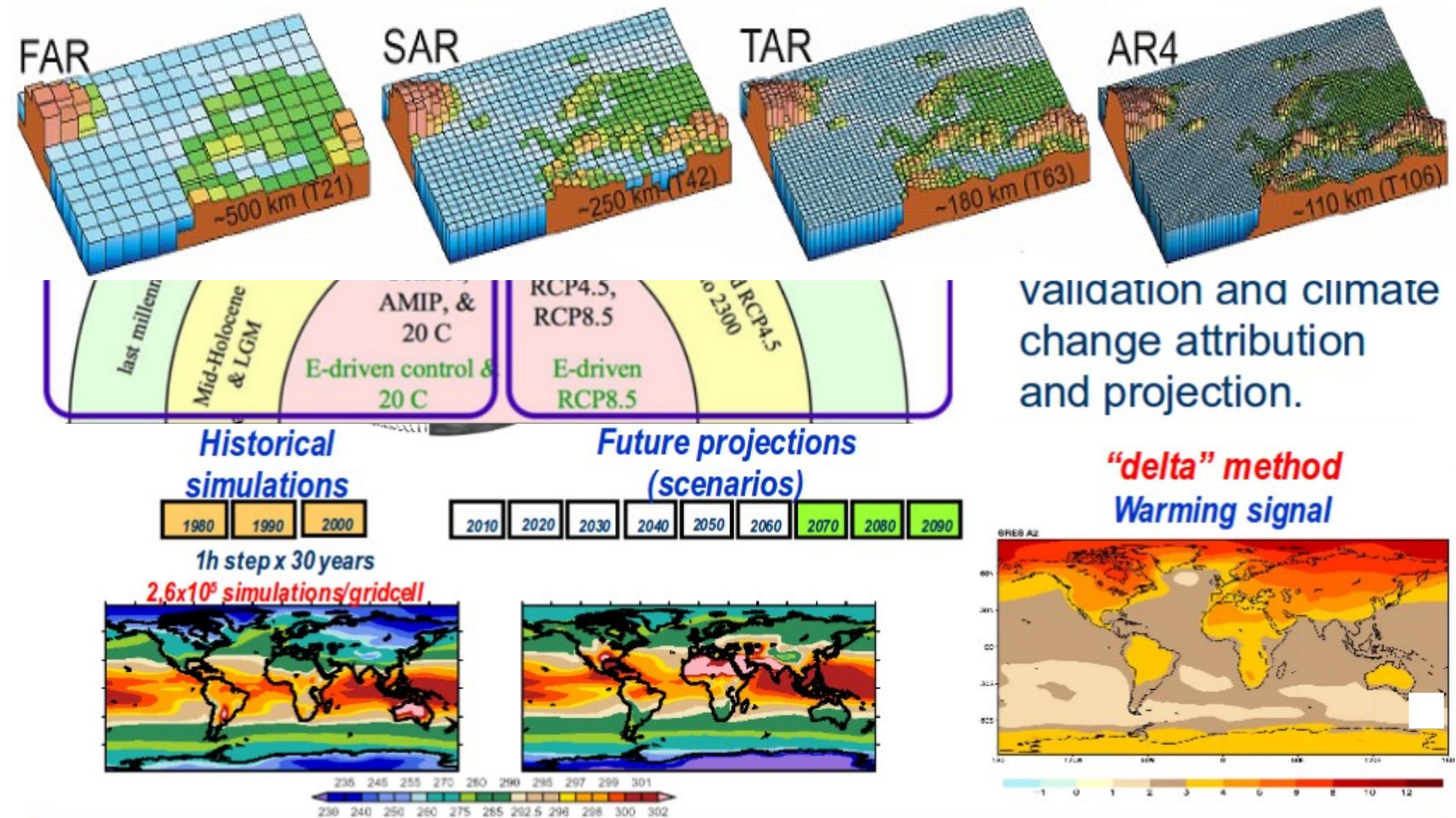
Computational (and physical) constraints limit the resolution (~100-200 Km)

Climate change projections are based on consensus multi-model information.

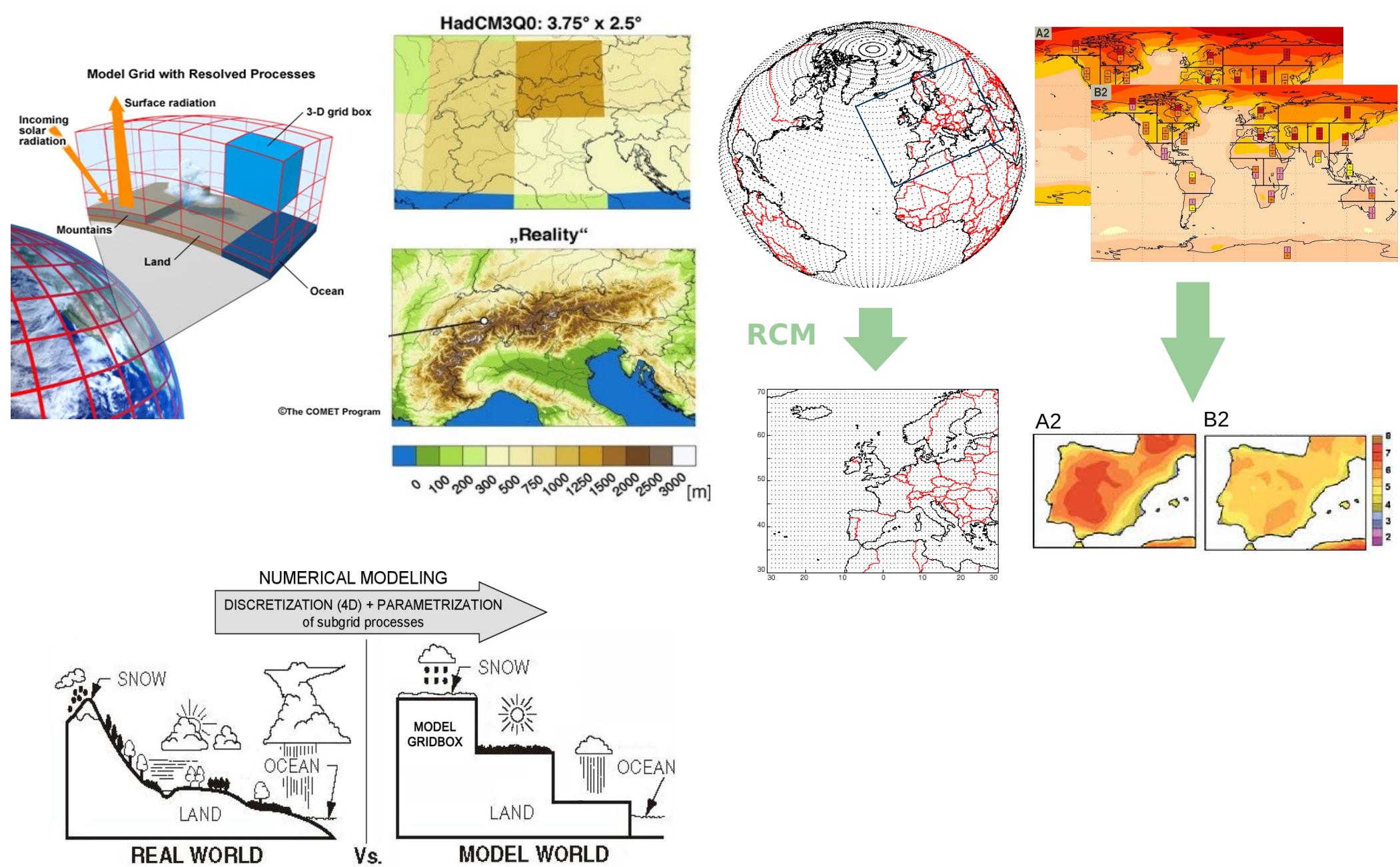


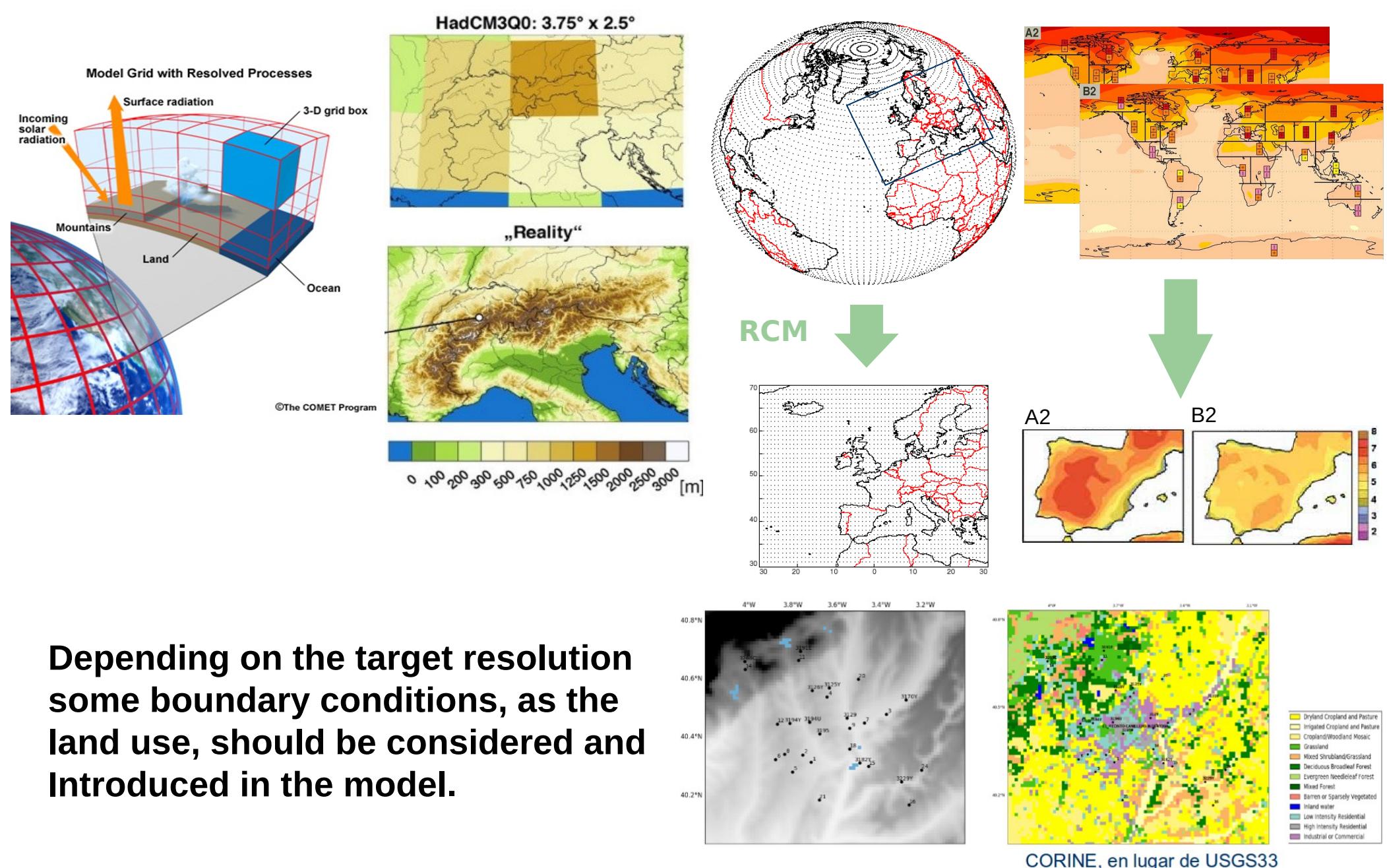
Climate change projections are based on consensus multi-model information.





Computational (and physical) constraints limit the resolution (~100-200 Km)



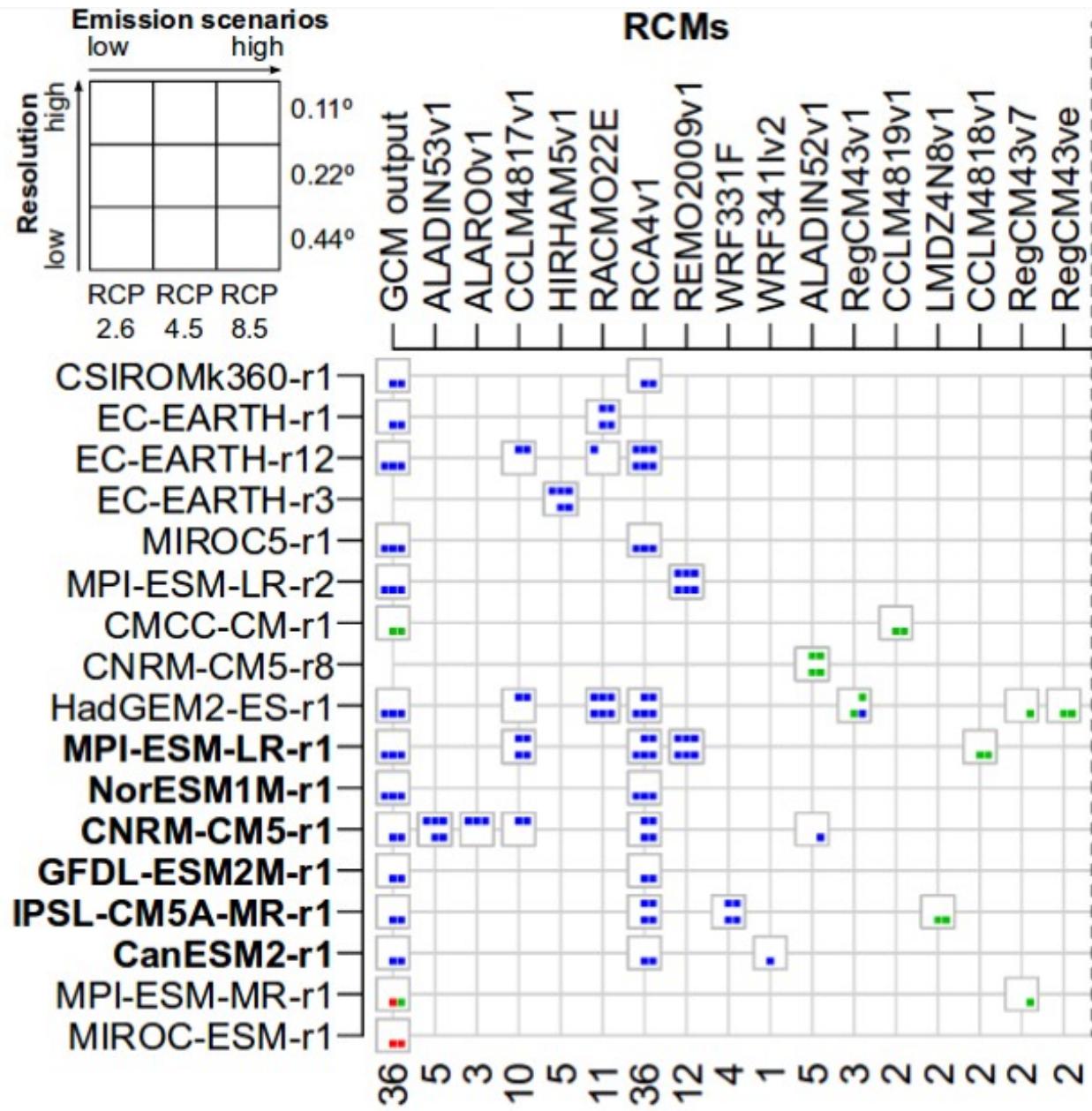


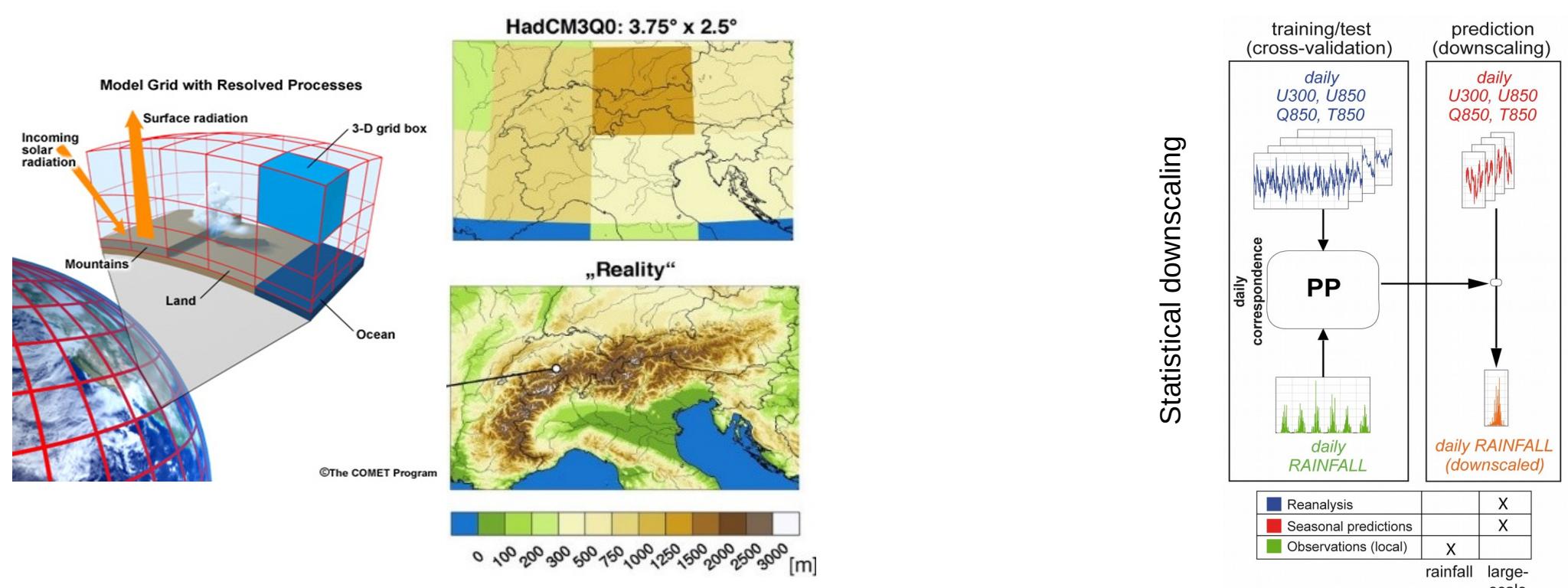
Depending on the target resolution
some boundary conditions, as the
land use, should be considered and
Introduced in the model.



Euro-CORDEX is the last of a series of international initiatives for regional climate change projection over Europe.

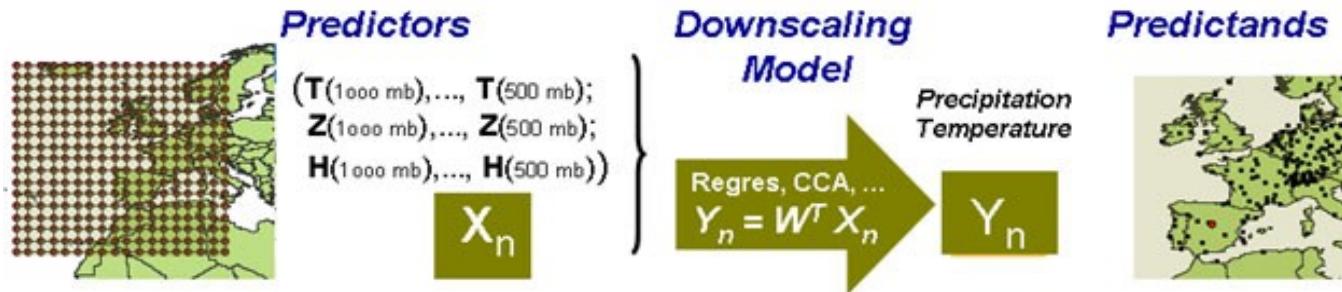
0.11° and **0.44°** resolution.





Statistical Downscaling

Statistical methods linking the local observed climate (**predictand Y**) with the global simulations given by the GCMs (**predictors X**), through some **function f** and/or **parameters θ** : $Y = f(X; \theta)$



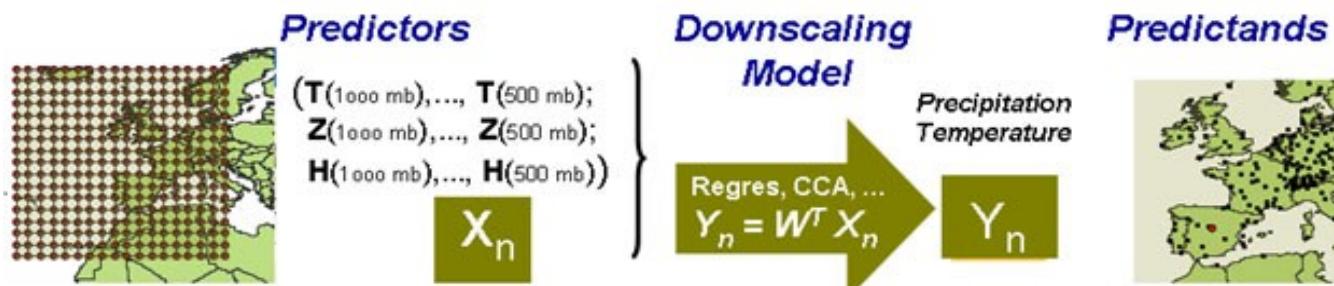
Appro.	Tech.	Generative		non-Generative	
		Deterministic	Stochastic	Deterministic	Stochastic
PP	Eventwise	Regression, Neural Nets.	GLMs	Analogs, weather types	Analog resampling
	Distribution	Regression on PDF parameters			
MOS	Eventwise	Regression, Neural Nets.	GLMs	Analogs	Analog resampling
	Distribution	Bias correction, parametric q-q map	Nonhomogeneous HMM	q-q map	

There is **day-to-day** correspondence.

There is **not day-to-day** correspondence.

Statistical Downscaling

Statistical methods linking the local observed climate (**predictand Y**) with the global simulations given by the GCMs (**predictors X**), through some **function f** and/or **parameters θ** : $Y = f(X; \theta)$





Cordex ESD

Experiment protocol – Empirical statistical downscaling

- ESD Overview
- ESD Background
- ESD Experiment1 protocols
- ESD Reference Document
- Register for CORDEX ESD Experiment 1

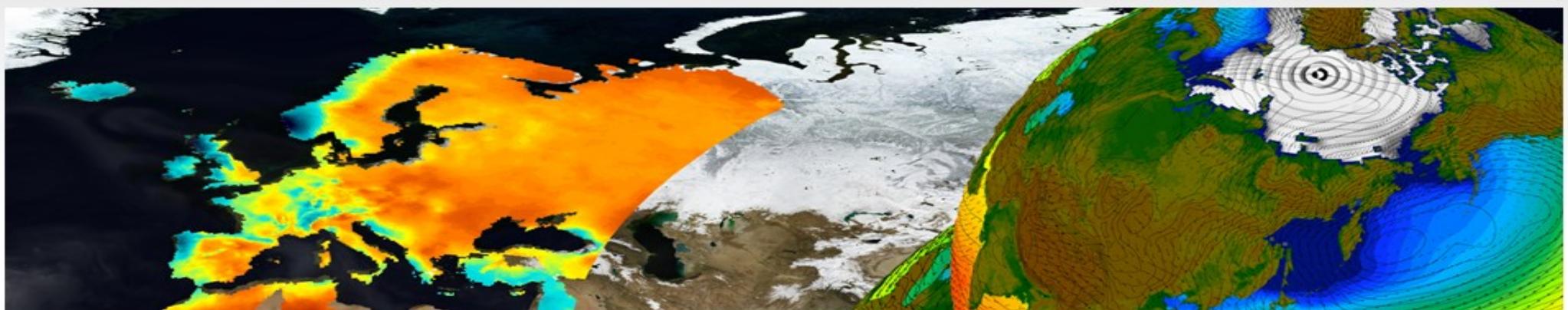
<http://www.value-cost.eu/>

VALUE: COST Action ES1102 (2012-2015)

CONTRIBUTE TO THE VALIDATION



Login



Validating and Integrating Downscaling Methods for Climate Change Research

Tech.		Generative		non-Generative	
Appro.		Deterministic	Stochastic	Deterministic	Stochastic
PP	Eventwise	Regression, Neural Nets.	GLMs	Analogs, weather types	Analog resampling
	Distribution	Regression on PDF parameters			
MOS	Eventwise	Regression, Neural Nets.	GLMs	Analogs	Analog resampling
	Distribution	Bias correction, parametric q-q map	Nonhomogeneous HMM	q-q map	

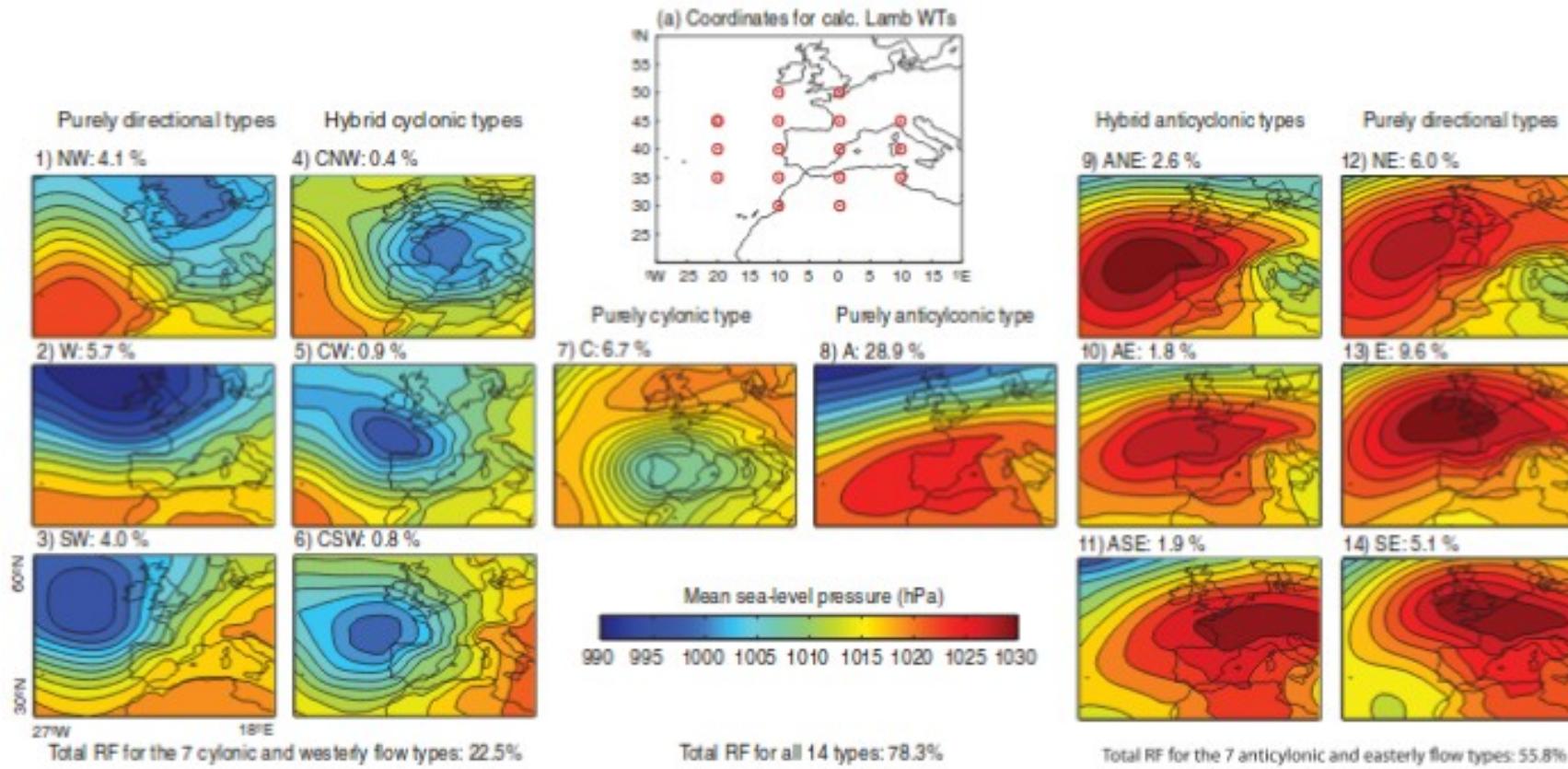
Weather Types:

The goal is obtaining a partitioning of the atmospheric space (using reanalysis data) in a predefined number of groups (weather types).

Weather Types:

The goal is obtaining a partitioning of the atmospheric space (using reanalysis data) in a predefined number of groups (weather types).

Lamb Weather Types (Expert Approach)



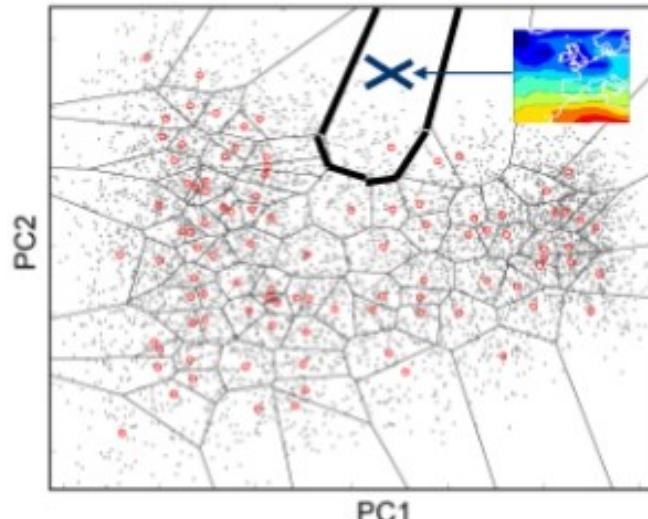
Source: Brands et al. 2014, <http://meteo.unican.es/en/node/73157>

Weather Types:

The goal is obtaining a partitioning of the atmospheric space (using reanalysis data) in a predefined number of groups (weather types).

Clustering algorithms:

OPT (optimization methods)					
48	CKMEANS09	9	MSLP	Y	Enke and Spekat (1997)
49	CKMEANS18	18	MSLP	Y	
50	CKMEANS27	27	MSLP	Y	
51	PCACA	4-5	MSLP	Y	Yamal (1993)
52	PCACAC09	9	MSLP	Y	
53	PCACAC18	18	MSLP	Y	
54	PCACAC27	27	MSLP	Y	
55	PETISCO	25-38	MSLP, Z500	Y	Petisco et al. (2005)
56	PETISCOC09	9	MSLP	Y	
57	PETISCOC18	18	MSLP	Y	
58	PETISCOC27	27	MSLP	Y	
59	PCA TRKM	11-17	MSLP	Y	Esteban et al. (2005, 2006)
60	PCA TRKMC09	9-10	MSLP	Y	
61	PCA TRKMC18	15-18	MSLP	Y	



Given a new pattern
(X), the group is
obtained C_k . Then, the
forecast is $P(y > u | C_k)$.

Weather Types:

The goal is obtaining a partitioning of the atmospheric space (using reanalysis data) in a predefined number of groups (weather types).

Clustering algorithms:

The SOM is made with an arbitrary number of centers/prototypes arranged in a 2D grid.

Each prototype $\mathbf{w}_i = (w_{i1}, \dots, w_{in})$,
 n is the dimension of the original space.

The training is made in cycles ($t=1, \dots, n$):

- 1) Compute the winner prototype (closest) $\mathbf{w}_{i(t)}$ for each pattern \mathbf{v}_k :

$$\|\mathbf{v}_k - \mathbf{w}_{i(t)}\| = \min_i \{\|\mathbf{v}_k - \mathbf{w}_i\|, i=1, \dots, m\}.$$

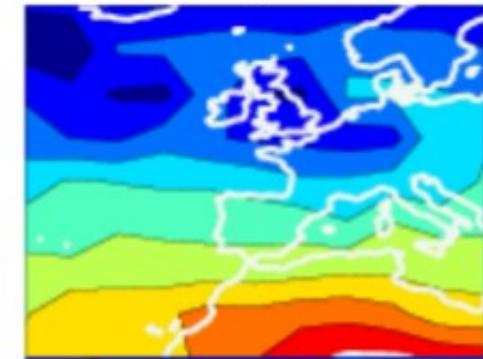
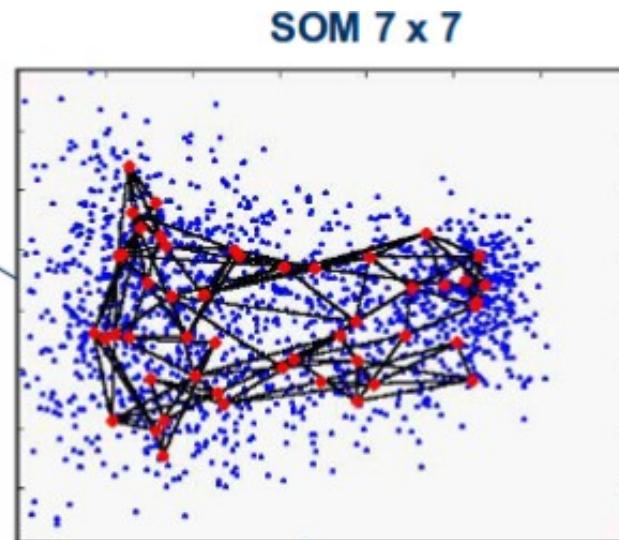
- 2) The winner prototype and the neighbors are moved towards the data point:

$$\mathbf{w}_i(t+1) = \mathbf{w}_i(t) + a(t) \mathbf{v}_k h(\|\mathbf{w}_i(t) - \mathbf{w}_{i(k)}(t)\|),$$

$a(t)$ learning rate (linear decreasing);

$h(x)$ neighborhood kernel (linear decreasing of the variance)

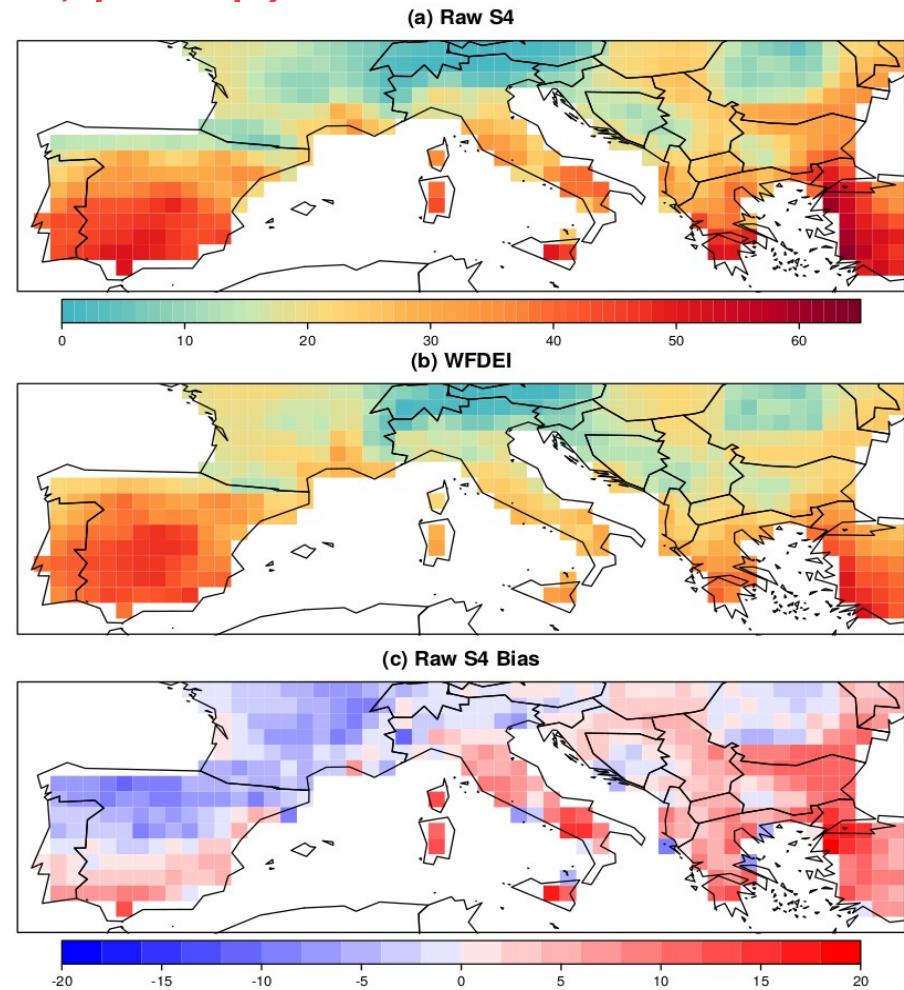
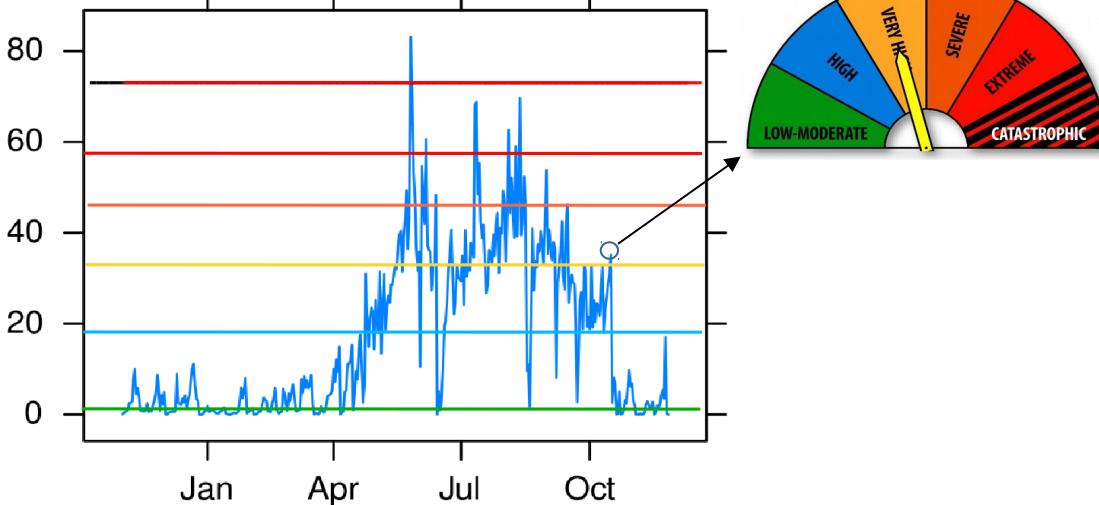
Oja E. And Kaski S., 1999: Kohonen Maps. Amsterdam, Elsevier



- FWI is a **daily-based, multivariable** CII rating the potential for fire ignition and spread given the atmospheric conditions

FWI: $f(hurs, tas, wss, precip)$

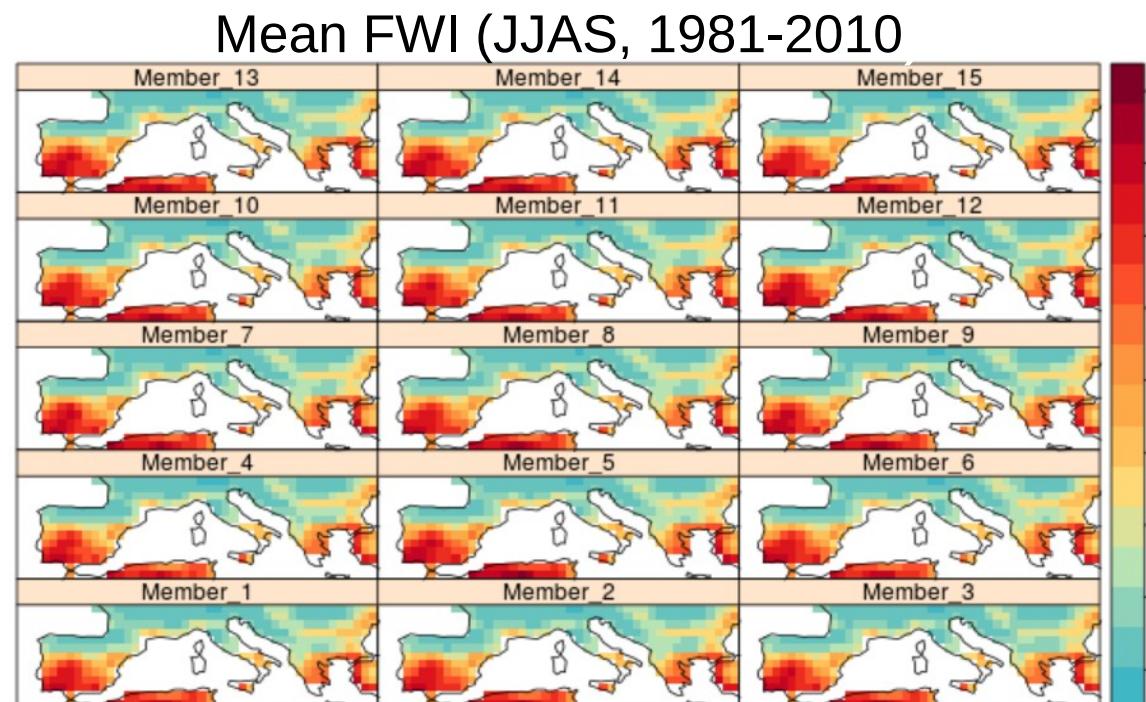
- Fire managers require **bias correction** for operational applicability
- Standard protocols and **user-friendly tools** are still lacking in a seasonal forecasting context



Bias correction (Empirical Quantile Mapping) of System4 JJAS FWI forecast over EU-MED region (May init., 15 members)

Worked example: [https://github.com/SantanderMetGroup/fireDanger/wiki/CS_Bedia-et-al-2016-\(submitted\)](https://github.com/SantanderMetGroup/fireDanger/wiki/CS_Bedia-et-al-2016-(submitted))

A relatively complex task usually involving many intermediate steps from data loading to FWI calculation and analysis of the results.



Climate Change Projections in Cantabria

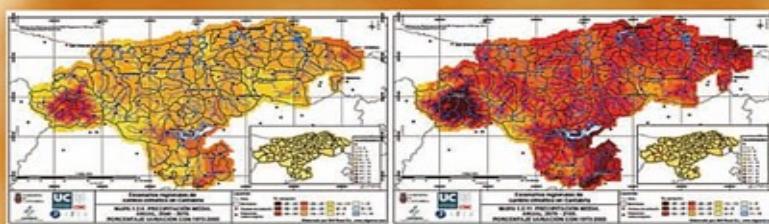
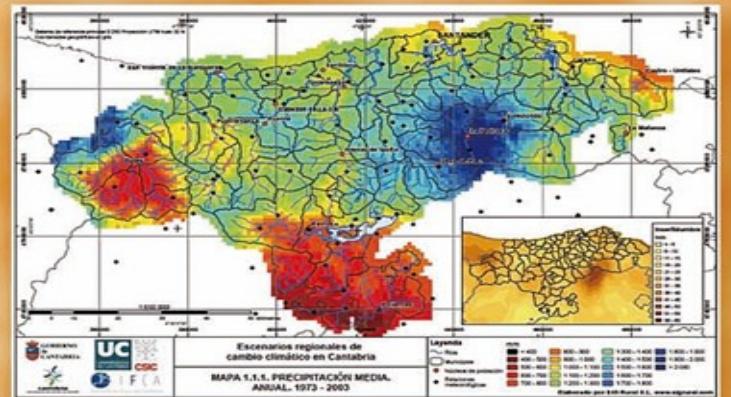


CONSEJERÍA DE MEDIO AMBIENTE



Escenarios Regionales Probabilísticos de Cambio Climático en Cantabria: Termopluviosidad

J.M. Gutiérrez, S. Herrera, D. San-Martín, C. Sordo,
J.J. Rodríguez, M. Frochoso, R. Ancell, J. Fernández,
A.S. Cofiño, M.R. Pons, M.A. Rodríguez



(Santander, 2010)

Master Universitario Oficial Data Science

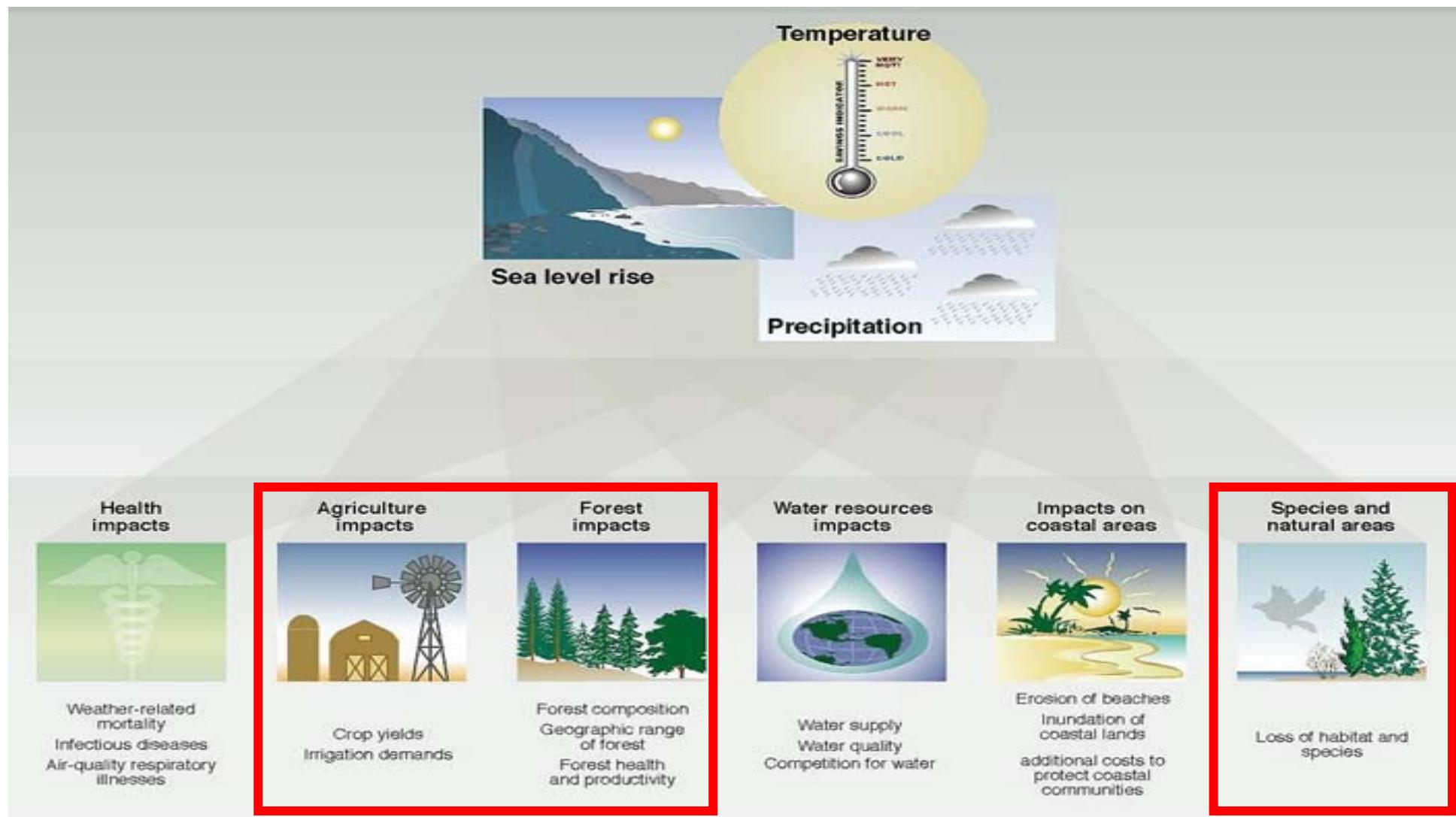


con el apoyo del

Introduction

Applications: Agriculture

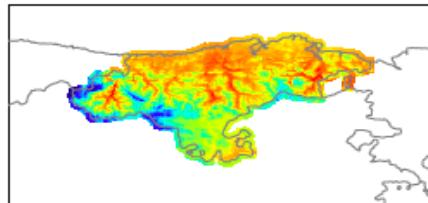
Climate Change Projections in Cantabria



Projections of Species Distribution (*fagus*) in Cantabria

temperature

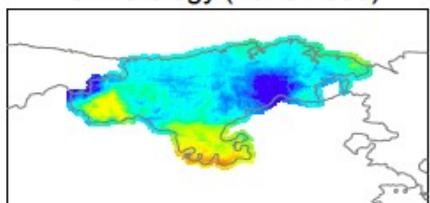
Climatology (1973-2003)



°C
22
20
18
16
14
12
10

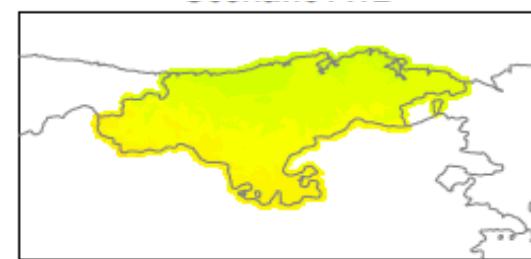
precipitation

Climatology (1973-2003)

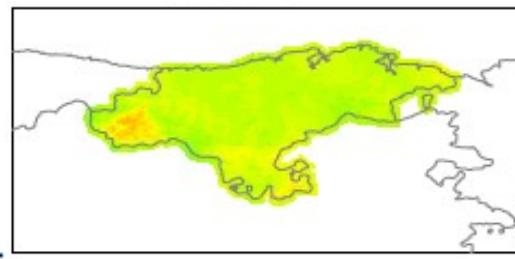
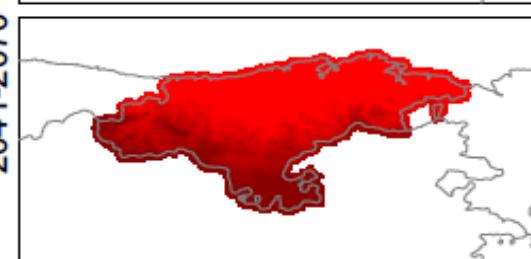
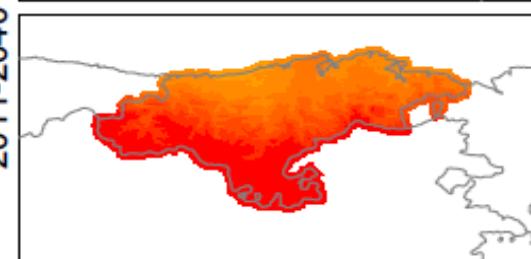


mm
2500
1600
900
400
100

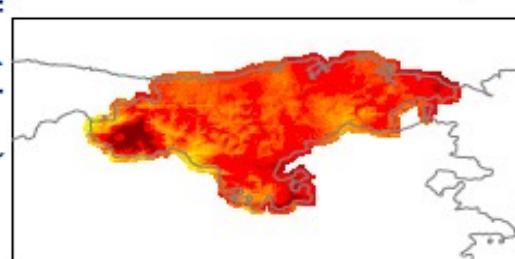
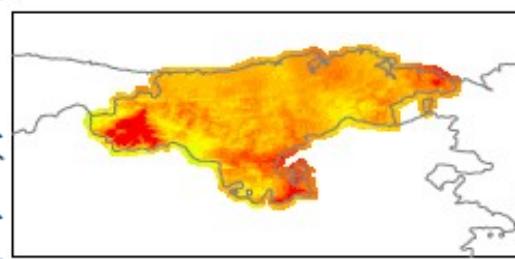
2011-2040
2041-2070
2071-2100



Increment (w.r.t. climatology)
°C
4
2
0
-2
-4



Increment (percentage w.r.t. climatology)
%
50
25
0
-25
-50



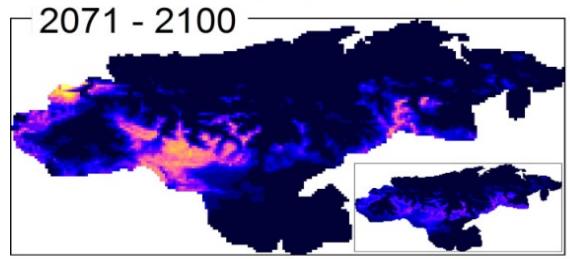
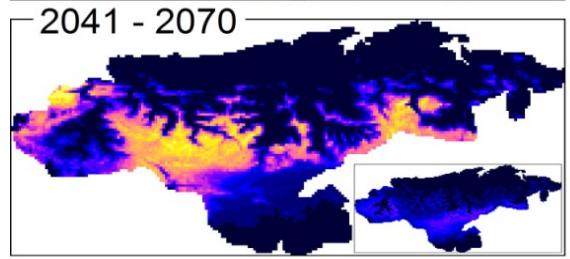
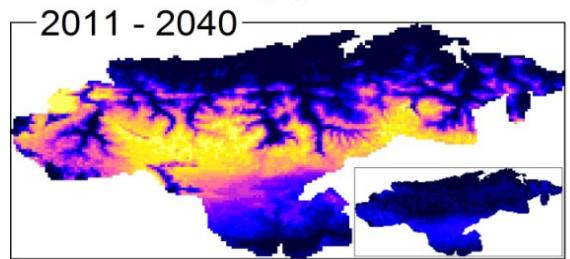
Presence/absence probability

2011 - 2040

2041 - 2070

2071 - 2100

1.0
0.8
0.6
0.4
0.2
0.0



Climate Change Projections in Cantabria

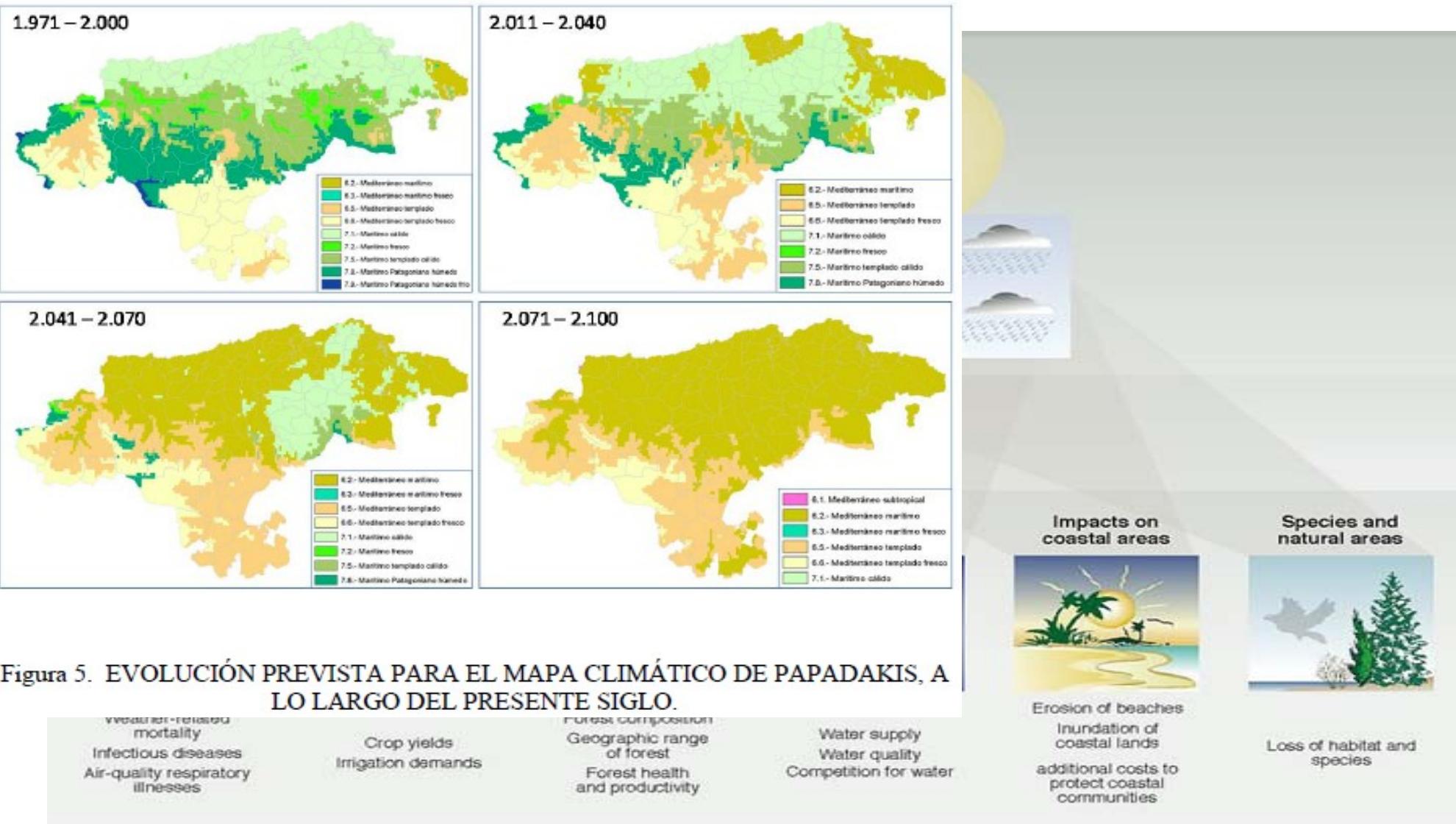


Figura 5. EVOLUCIÓN PREVISTA PARA EL MAPA CLIMÁTICO DE PAPADAKIS, A LO LARGO DEL PRESENTE SIGLO.



Climate Change Projections in Cantabria

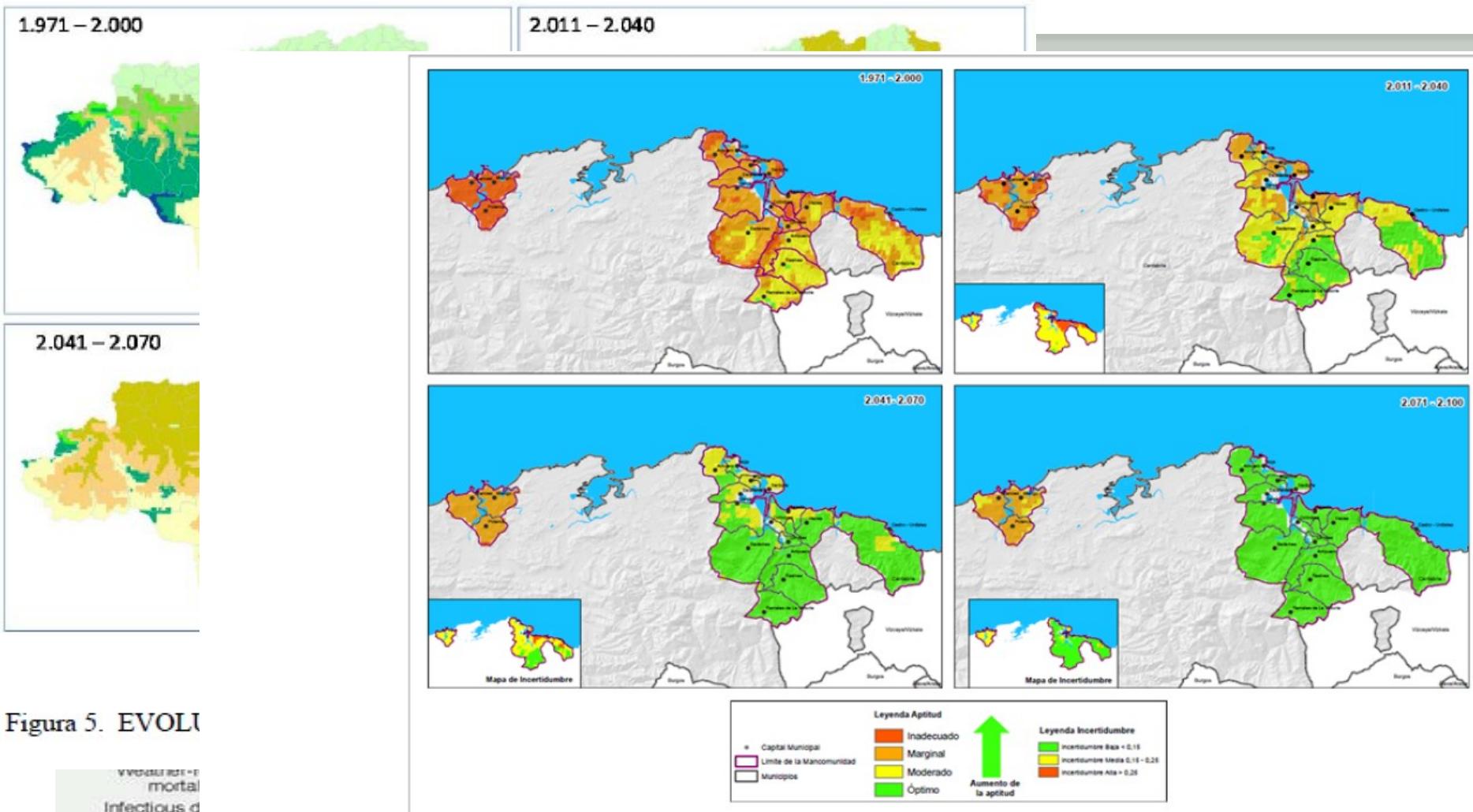


Figura 4. EVOLUCIÓN DE LA POTENCIALIDAD BIOCLIMÁTICA DE LA ENCINA.

Climate Change Projections in Cantabria

