http://www.meteo.unican.es

Global and regional ensemble projections for risk assessment: **The IPCC Interactive Atlas**

José M. Gutiérrez

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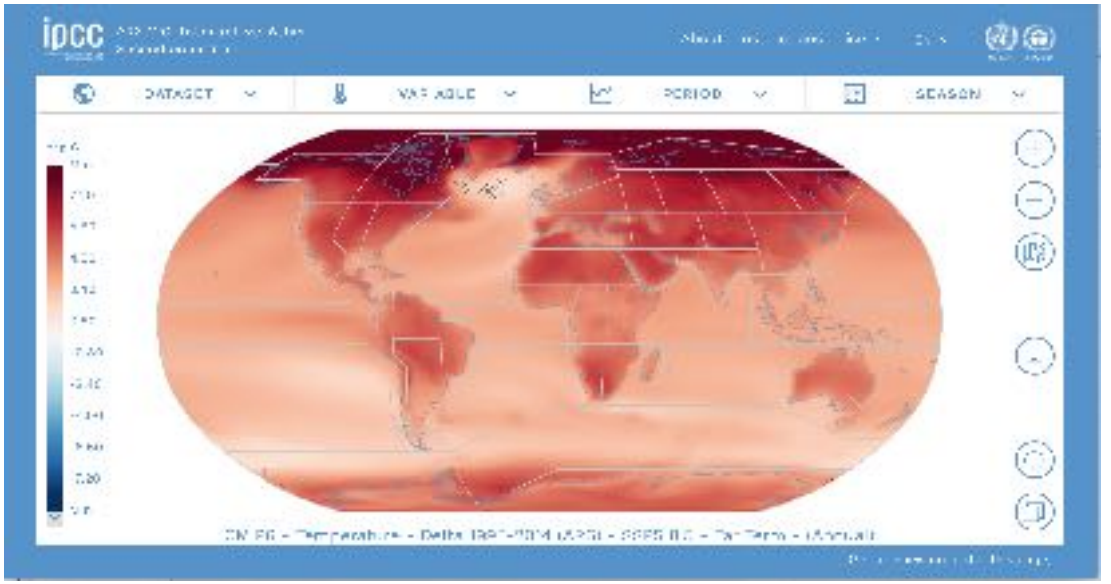
Instituto de Física de Cantabria



Next Generation Challenges in Energy and Climate Modelling. September 16, 2021

Contents

Motivation for the talk, illustrating the complexity of climate data for sectoral users.

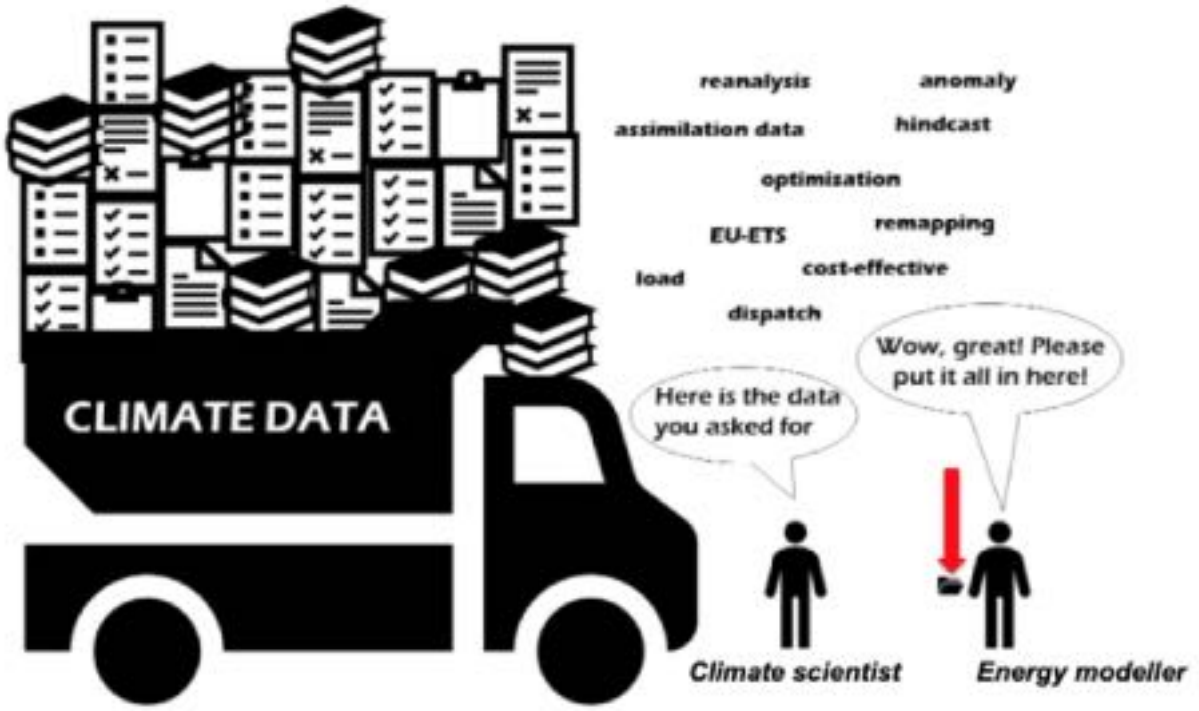


Fig. 3. The climate data truck analogy of the mismatch in data delivery (from climate scientists) to data requirements (from energy system modelers). Figure courtesy of Dr. Sofia Simões and the Clim2Power project (https://clim2power.com/).

https://doi.org/10.1175/BAMS-D-20-0256.1

Topics covered in this talk (focusing on climate change):

1. Climate data generation (projections) and standard postprocessing methodologies.

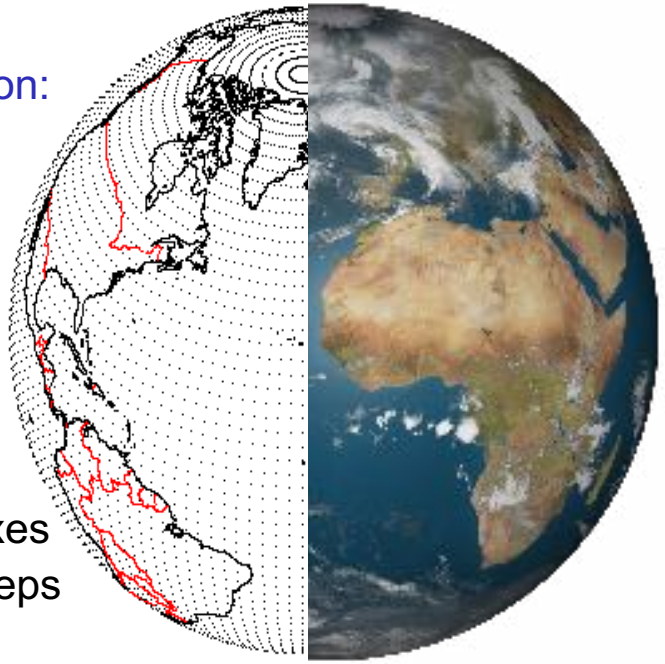
2. Integration (and availability) of climate data in the IPCC Interactive Atlas.

Global Climate Models (GCMs)

Discretization:

Gridbox operations (per day):

100 km
~ 10^9
10^7 gridboxes
100 timesteps



Conservation of mass,momentum, energy, water vapour and gas state

v = (u, v, w), T, p, $\rho = 1/\alpha$ and q

$$
\begin{aligned}
\frac{d\boldsymbol{v}}{dt} &= -\alpha\boldsymbol{\nabla}p - \boldsymbol{\nabla}\phi + \boldsymbol{F} - 2\boldsymbol{\Omega}\times\boldsymbol{v} \\
\frac{\partial\rho}{\partial t} &= -\boldsymbol{\nabla}\cdot(\rho\,\boldsymbol{v}) \\
p\alpha &= RT \\
Q &= C_p\frac{dT}{dt} - \alpha\frac{dp}{dt} \\
\frac{\partial\rho q}{\partial t} &= -\boldsymbol{\nabla}\cdot(\rho\,\boldsymbol{v}\,q) + \rho(E - C)
\end{aligned}
$$

Global Climate Models (GCMs) are the main tools to study the evolution of climate at different time-scales (inc. **subseasonal, sesonal, multi-decadal**). They numerically solve a set of equations describing the dynamics of the climate system using supercomputing infrastructures.

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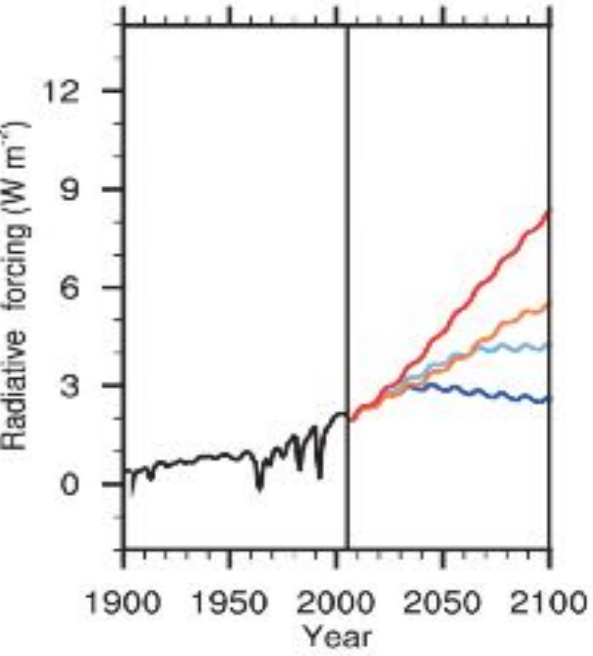
Global Climate Models (GCMs)



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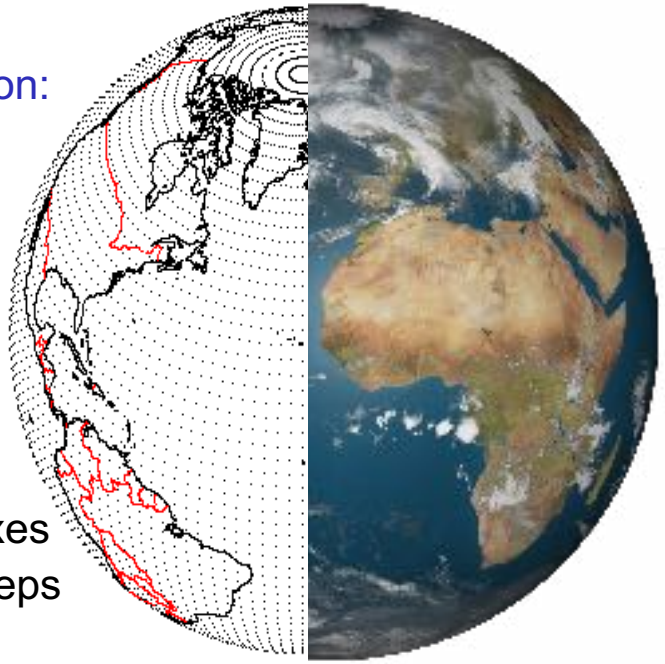

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Global Climate Models (GCMs) are the main tools to study the evolution of climate at different time-scales (inc. **subseasonal, sesonal, multi-decadal**). They numerically solve a set of equations describing the dynamics of the climate system using supercomputing infrastructures.

In **climate change modeling**, they are used to produce possible future projections of the climate system based on different natural and anthropogenic forcings as given by different scenarios (e.g. low-, medium- or high-emissions), thus informing risk assessment.

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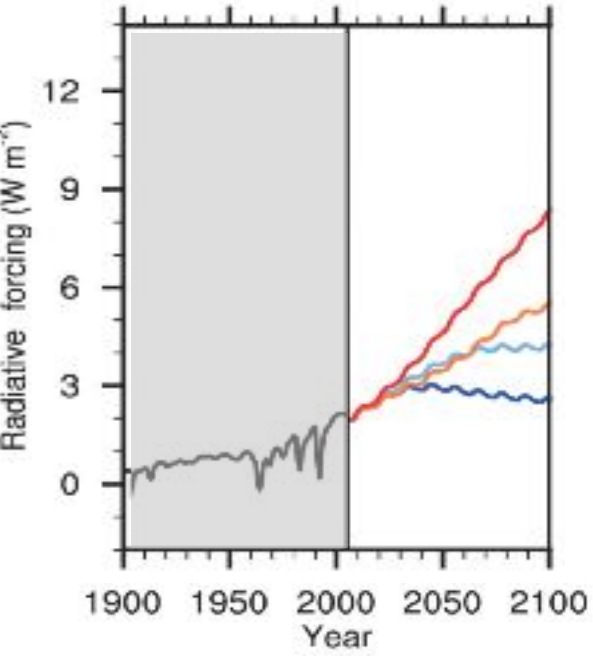
Global Climate Models (GCMs)



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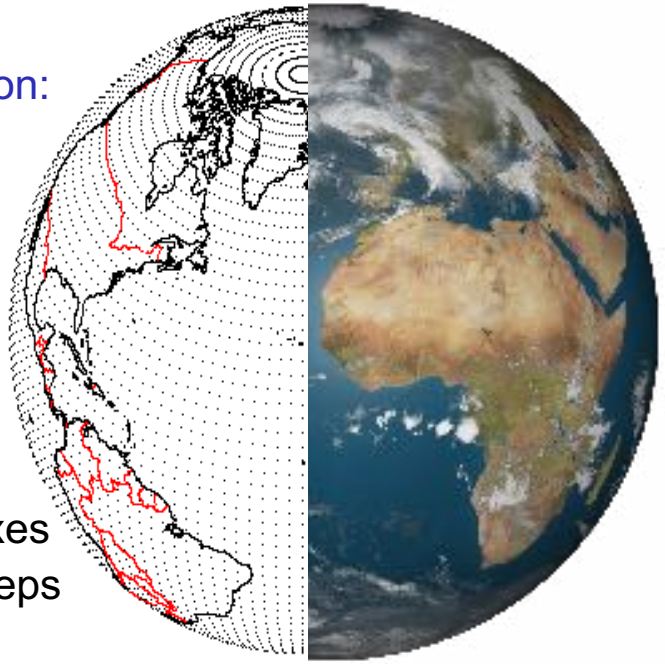

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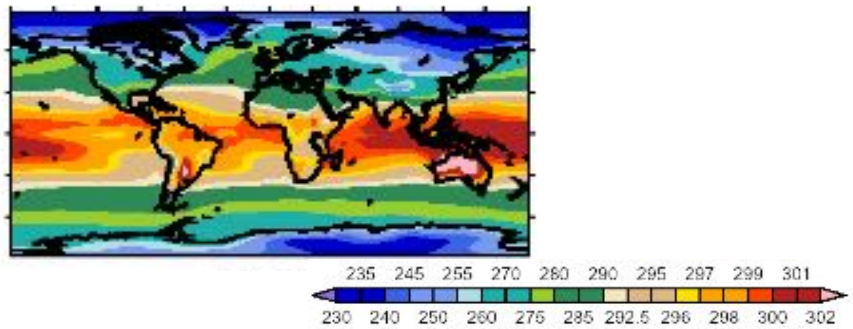
\end{aligned}
$$

Historical simulations

1980 ***1990*** ***2000***



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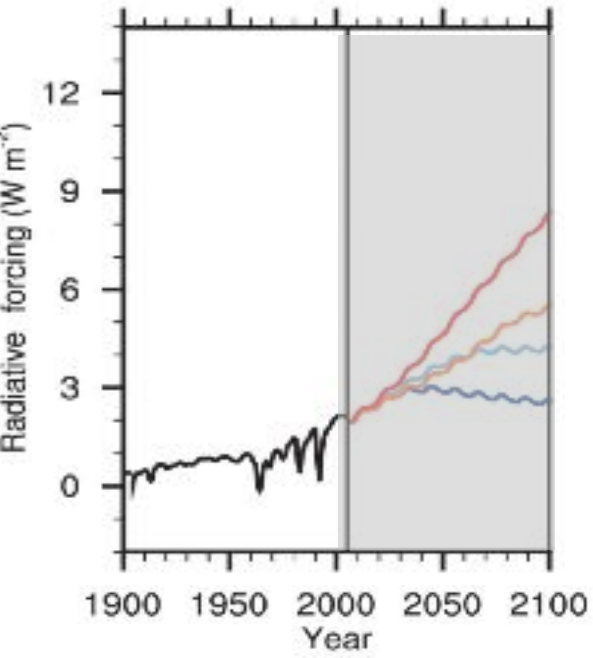
Global Climate Models (GCMs)



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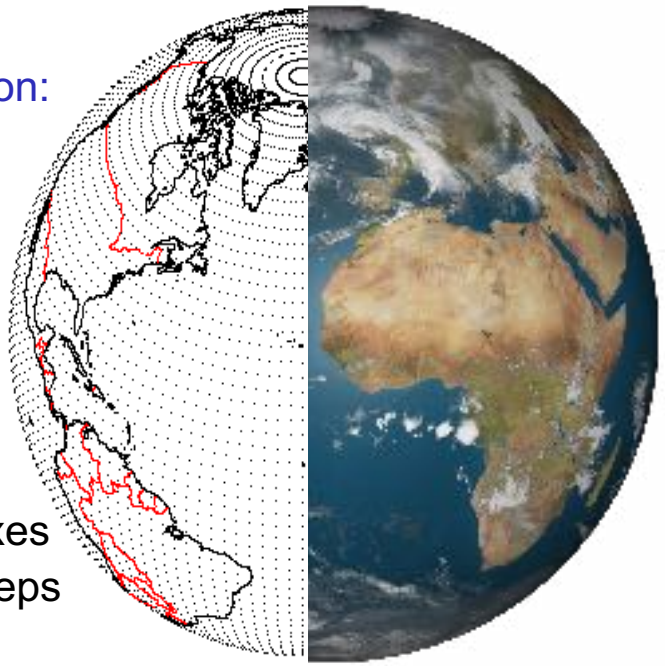

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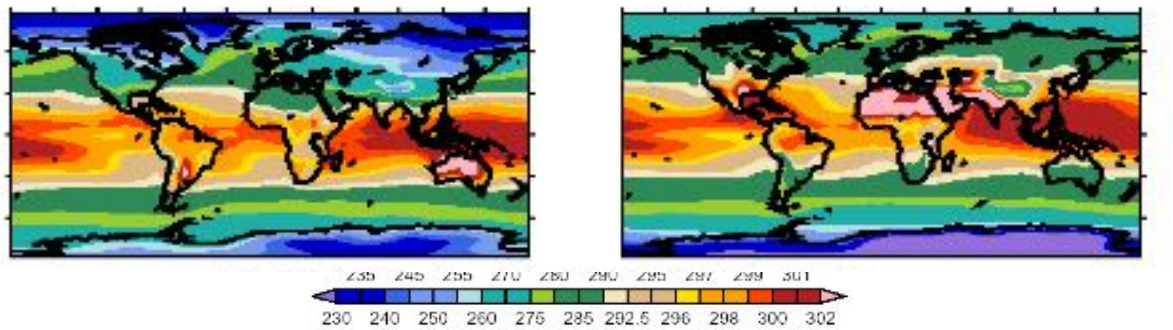
Historical simulations

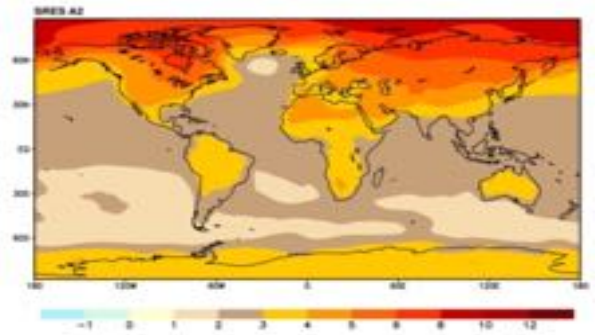
1980 | 1990 | 2000

Future projections (scenarios)

2010 | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 | 2080 | 2090

Difference:
climate change signal





https://www.carbonbrief.org/qa-how-do-climate-models-work

Global Projections (ensembles)

CMIP
The World Climate Research Programme's Coupled Model Intercomparison Project

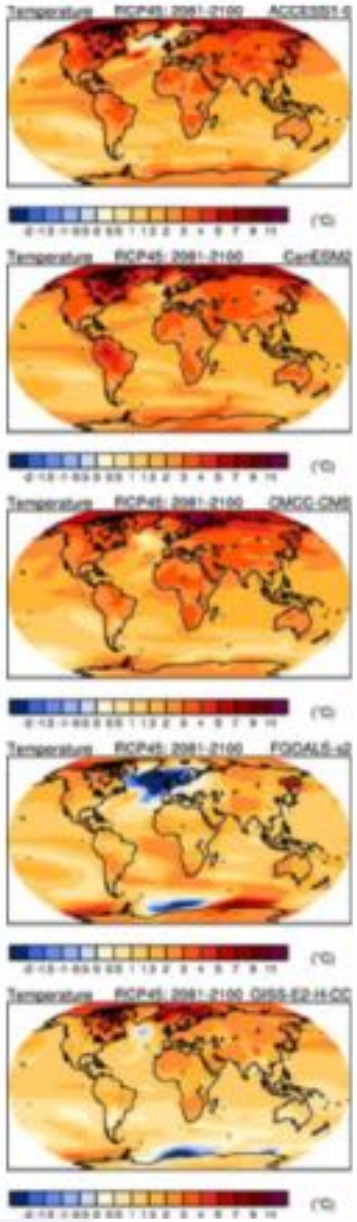
Multi-model intercomparison experiments, including climate change projections for different scenarios

CMIP5 (2013),
29 groups [~200 km]

CMIP6 (2021)
44 groups [~100km]

Climate Models

BCC-CSM1-1
CanESM2_esm
CanESM2
CCSM4
CESM1-BGC_esm
CESM1-CAM5
CESM1-WACCM
CNRM-CM5
CSIRO-ACCESS1-0
CSIRO-Mk3-6-0
FGOALS-g2
FGOALS-s2
GFDL-CM3
GFDL-ESM2G_esm
GFDL-ESM2M_esm
GFDL-ESM2M
GISS-E2-H
GISS-E2-R
HadGEM2-CC
HadGEM2-ES_esm
HadGEM2-ES
INMCM4_esm
IPSL-CM5A-LR_esm
IPSL-CM5A-LR
IPSL-CM5A-MR
IPSL-CM5B-LR
MIROC5
MIROC-ESM_esm
MIROC-ESM
MPI-ESM-LR_esm
MPI-ESM-P
MRI-CGCM3
MRI-ESM1_esm
NorESM1-M



Daily and sub-daily spatial information of relevant variables with physical consistency:

- **Wind**
- **Temperatures**
- **Radiation**

➔ **Derived indices**

e.g. heating degree days (HDD)

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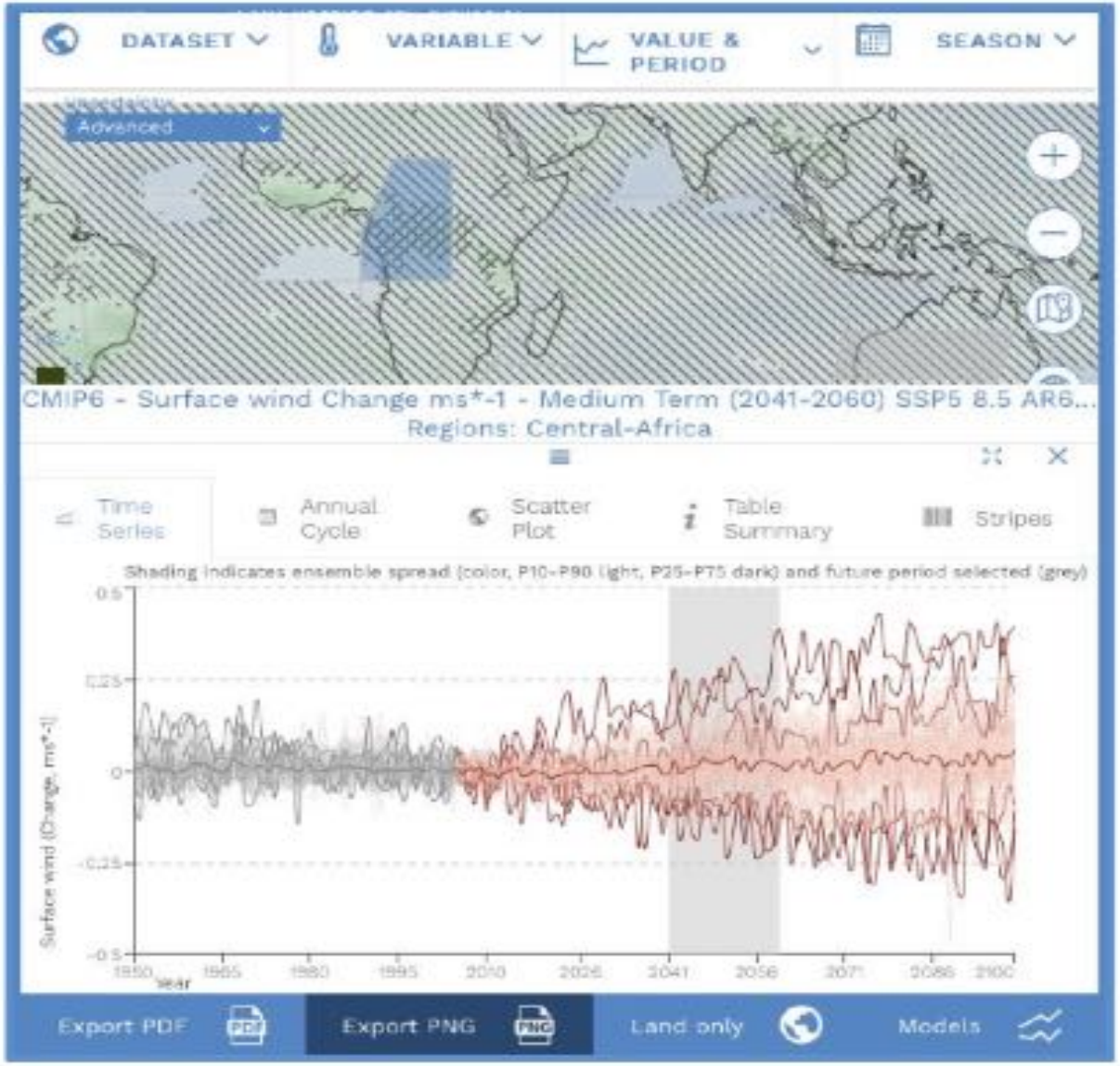
Ensembles of global projections

https://interactive-atlas.ipcc.ch/

Global projections provide an ensemble (~40 members in CMIP6) of projections for the variable of interest for historical and future periods.

Uncertainty is characterized by the spread using model agreement and robustness.



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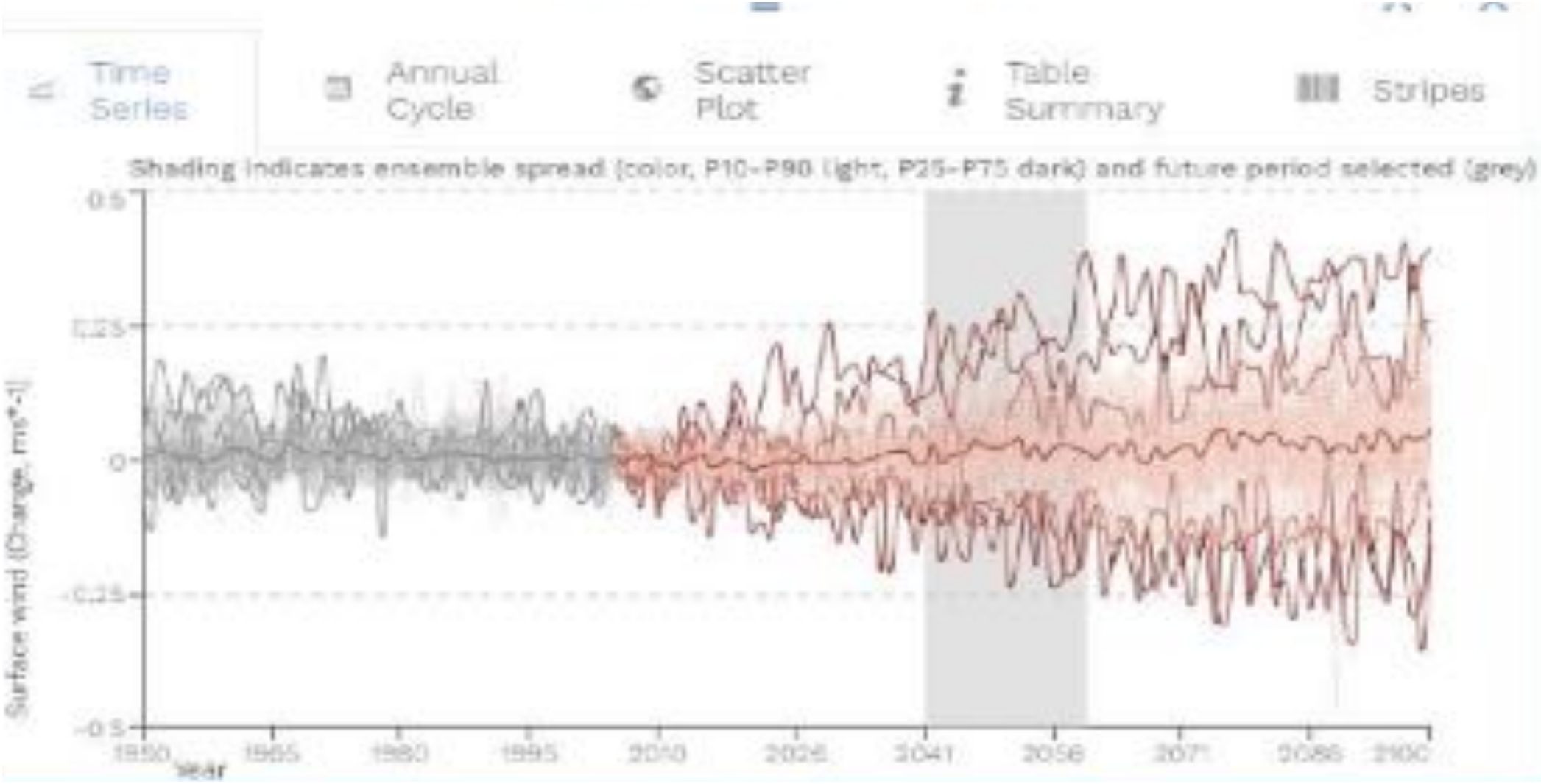
IPCC-AR6 Atlas

https://interactive-atlas.ipcc.ch/



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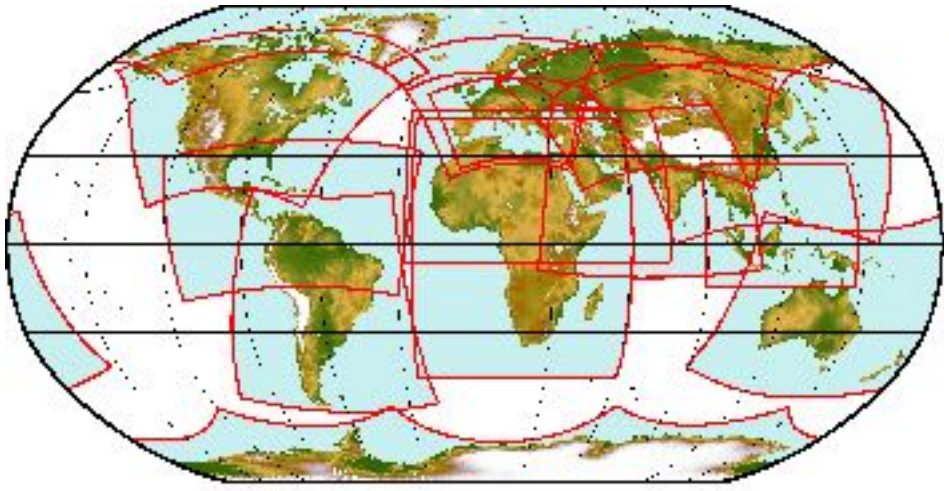
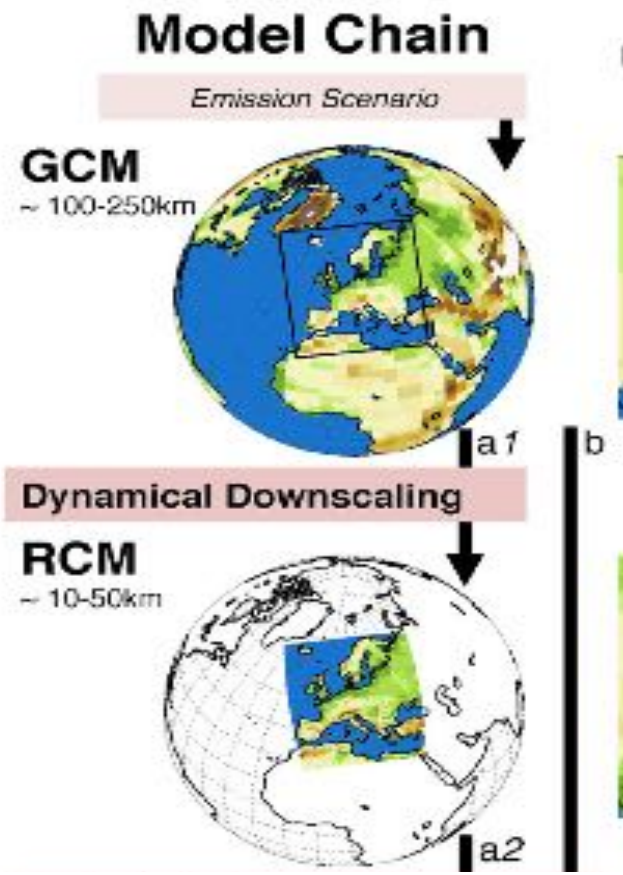
Dynamical Downscaling

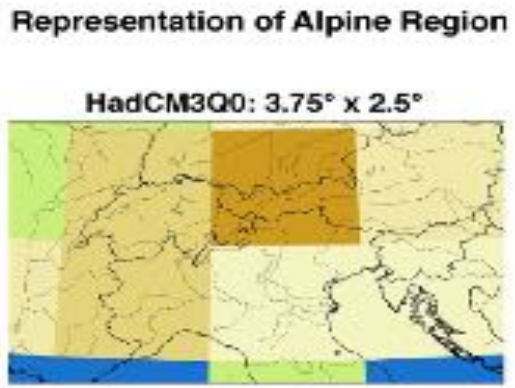
WCRP CORDEX

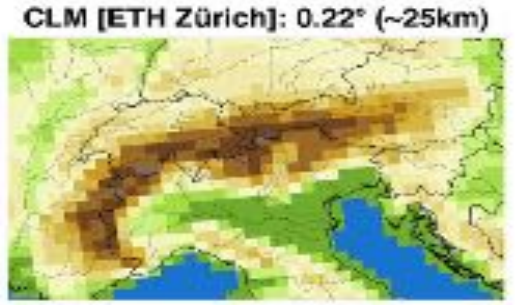
Downscaling methods work on smaller scales supporting more detailed impact and adaptation assessment.

14 domains cover the land regions with **10 - 40 km**

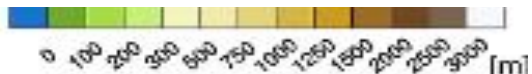








Dynamical downscaling is based on Regional Climate Models (RCMs) couple to the global ones.



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Statistical Downscaling

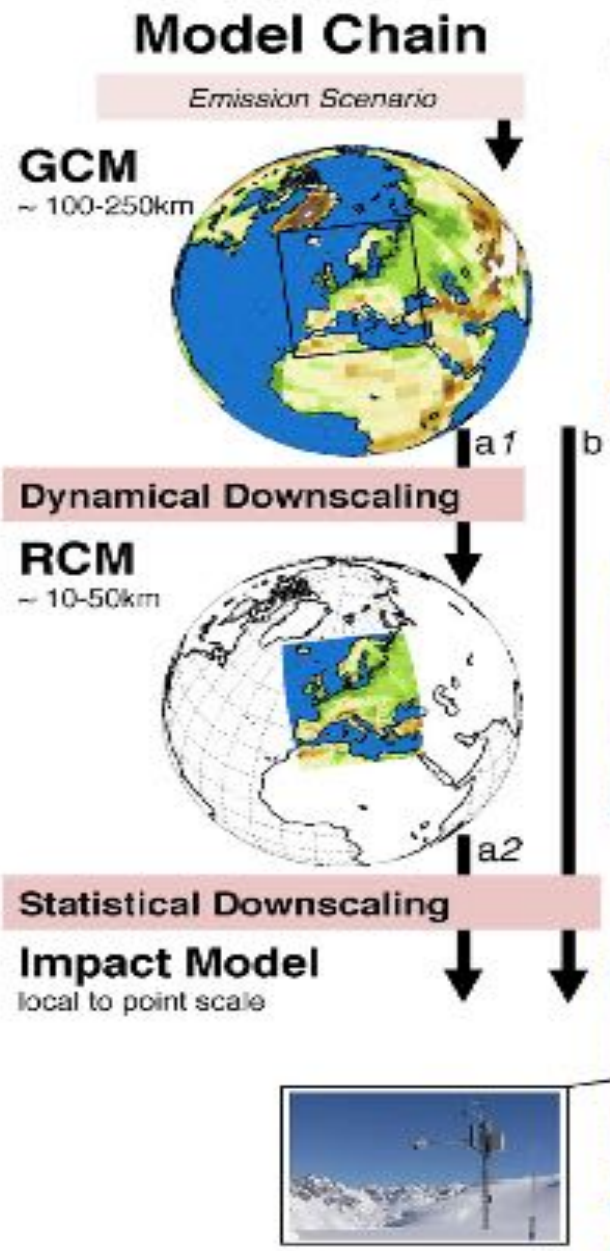
WCRP CORDEX

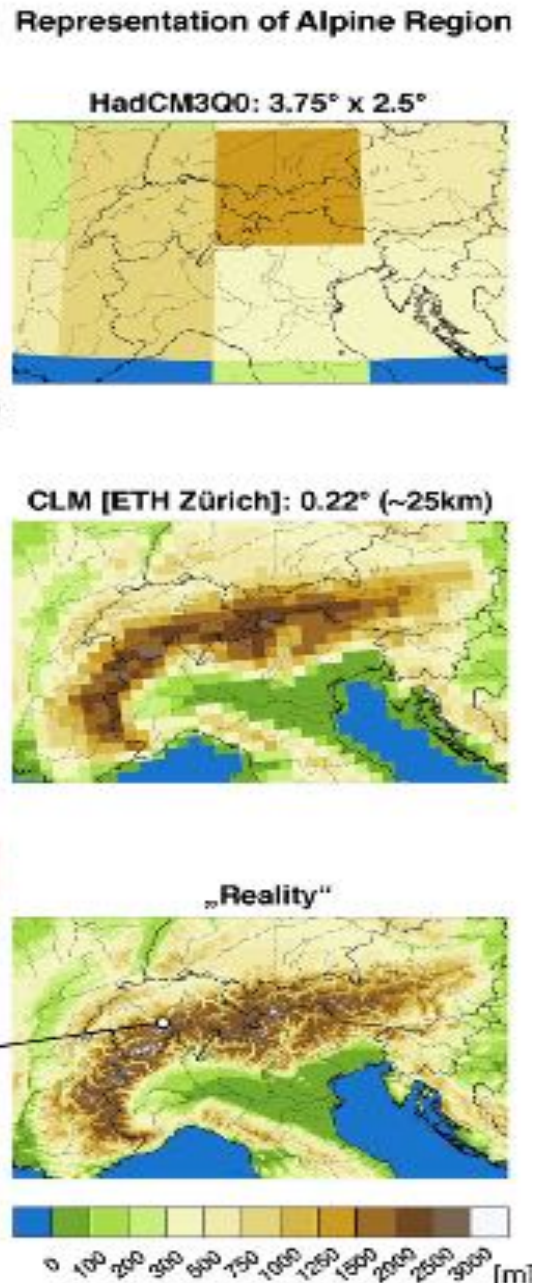
Downscaling methods work on smaller scales supporting more detailed impact and adaptation assessment.

14 domains cover the land regions with 10 - 40 km res.

Statistical methods link the large and **local** scale information and provide calibrated information (against observations)

➔ Bias adjustment (correction)





Climate Data

Climate Change Service

CORDEX regional climate model data on single levels

CORDEX regional climate model data on single levels

CMIP6 climate projections

CMIP6 climate projections

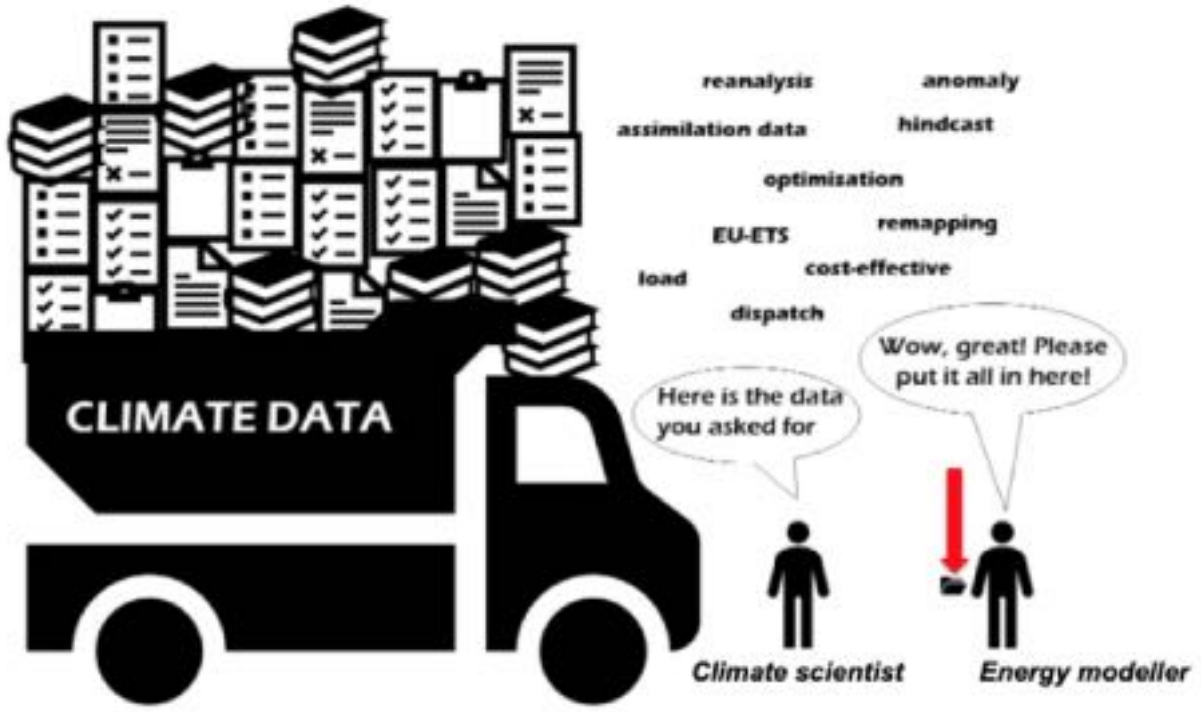


Fig. 3. The climate data truck analogy of the mismatch in data delivery (from climate scientists) to data requirements (from energy system modelers). Figure courtesy of Dr. Sofia Simões and the Clim2Power project (https://clim2power.com/).

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There is a need of distillation methods for data reduction providing actionable sectoral-relevant regional climate information.

More info: IPCC AR6 – Chapter 10

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Climate Data Services

Copernicus
Europe's eyes on Earth

Climate Change Service

CORDEX regional climate model data on single levels

CORDEX regional climate model data on single levels

CMIP6 climate projections

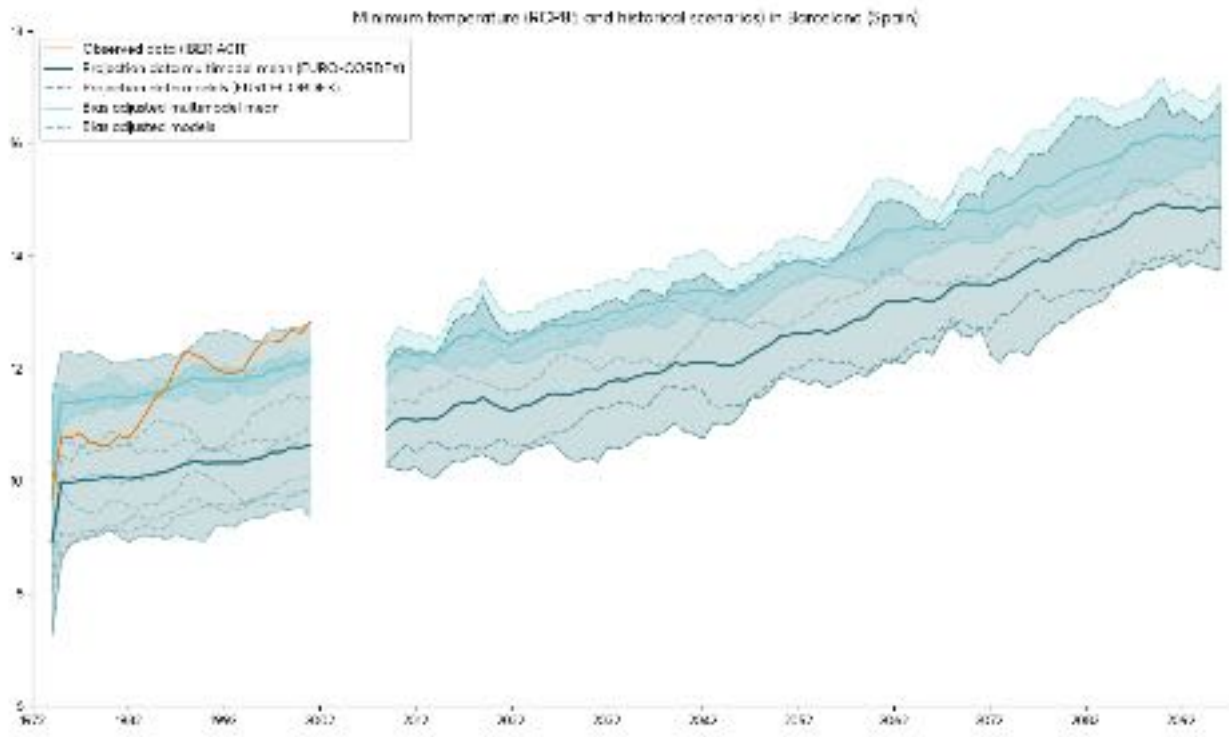
CMIP6 climate projections

Climadjust

A web service to apply Bias Adjustment techniques to your own climate data

https://climadjust.com

Example: Projections of average annual minimum temperature for Barcelona
(high-emission RCP8.5 scenario).
Observations: Spain01 (gridded, 11km resolution).



Observed data (IBERIA011)
Projection data multimodel mean (EURO-CORDEX)
Projection data models (EURO-CORDEX)
Bias adjusted multimodel mean
Bias adjusted models

MODEL DATA

USER REQUIREMENTS

DISTILLATION AND CO-PRODUCTION METHODOLOGIES

CUSTOMIZED SOLUTIONS

Climate Services

https://climate.copernicus.eu/energy

European Commission | Copernicus | IMPLEMENTED BY ECMWF

Home / What we do / Sectoral impacts / Sectoral specific challenges / Energy sector

SECTORAL INFORMATION

Energy

Climate change is expected to affect both the supply and demand of energy. As the energy sector is increasingly relying on renewable sources, the relevance of climate variability and change also increases. It is vital that energy providers and policy makers have the climate information they need to make informed choices on the future energy mix. We support the energy sector by providing information related to weather (wind, solar and hydro) and energy (capacity factors, demand, volatility) forecasts at a regional and national level in Europe.

DEMONSTRATOR PROJECTS | SHOWCASES

IPCC AR6

IPCC-AR6 (2021)

AR6 report (2021) builds on the **global and regional climate change projections** for different scenarios (and in the relevant literature published).

The Interactive Atlas allows for flexible spatial and temporal analysis:

- Variables and indices
- User-defined seasons
- Flexible regions, inc. updated reference

I. Physical Science Basis

➔ **Interactive *Atlas***

II. Impacts and Adaptation

➔ ***Atlas (static)***

III. Mitigation

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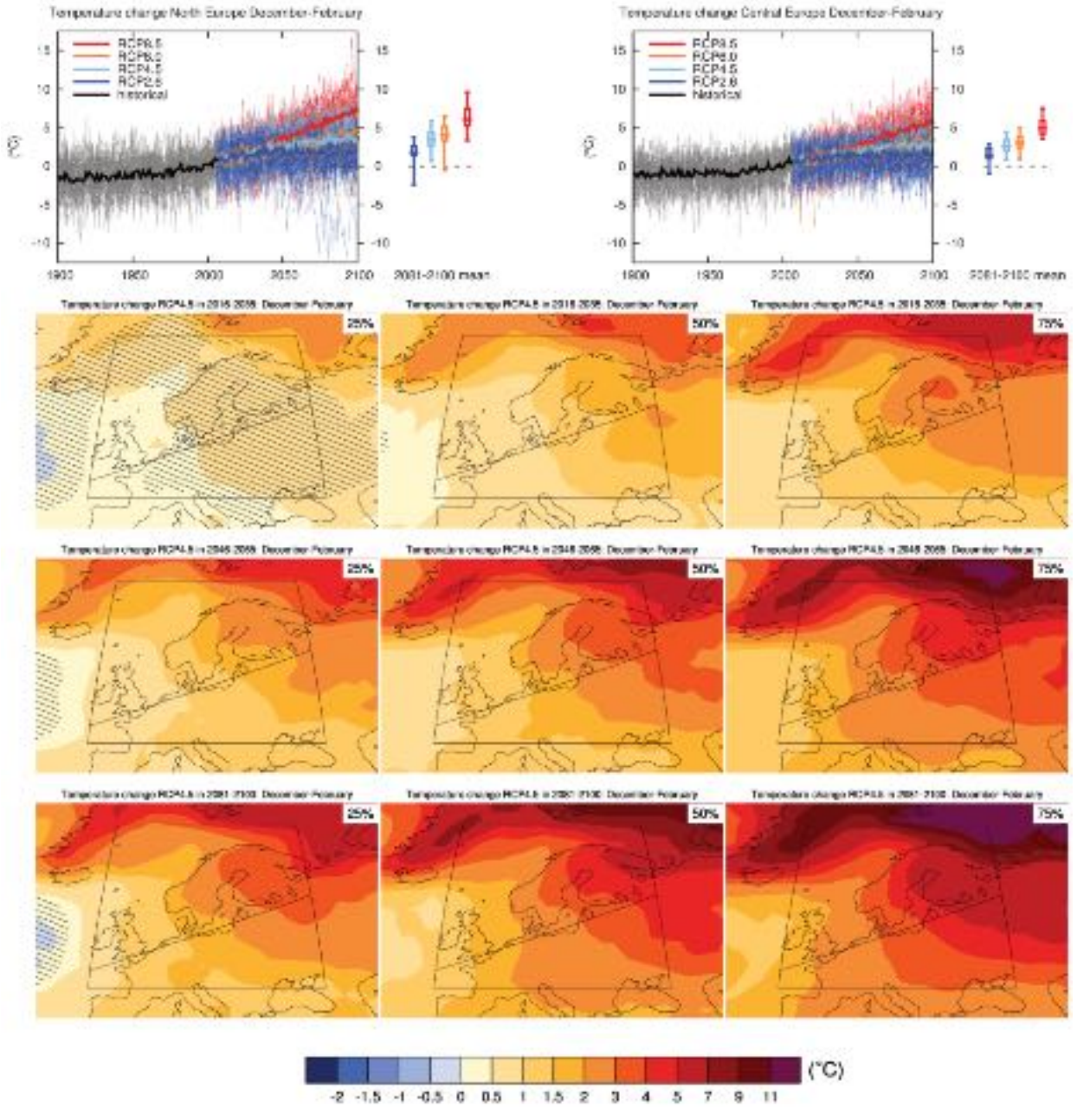
IPCC-AR5 Atlas

IPCC-AR5 (2013)

A limited collection of regional maps building on global projections:

- mean temp. and precip
- standard seasons
- reference regions



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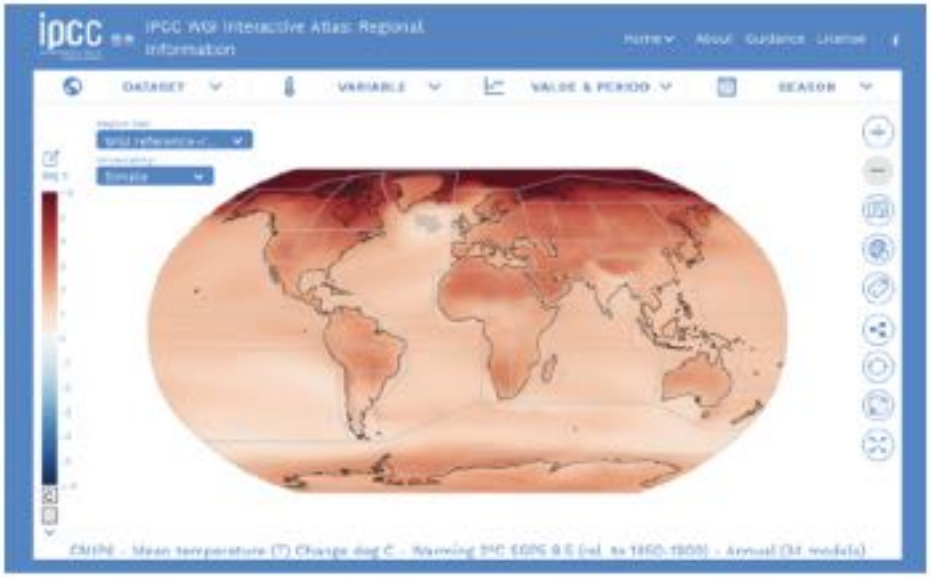
IPCC-AR6 Atlas

Regional information:



https://interactive-atlas.ipcc.ch/

- Global and regional observations
- Global and regional model simulations (CMIP5/6, CORDEX)
- Time slices and Global Warming levels.
- Scripts for downloads and processing

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IPCC-AR6 Atlas

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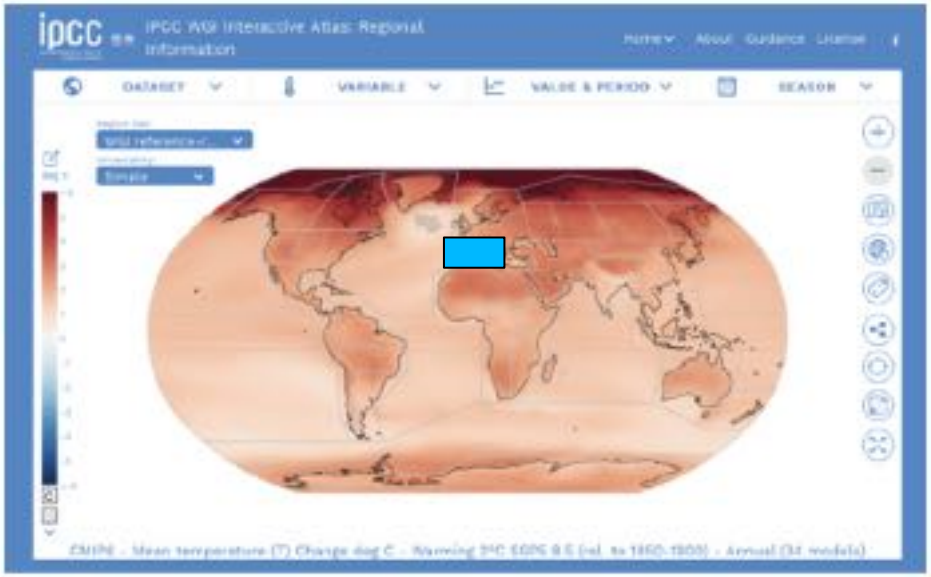

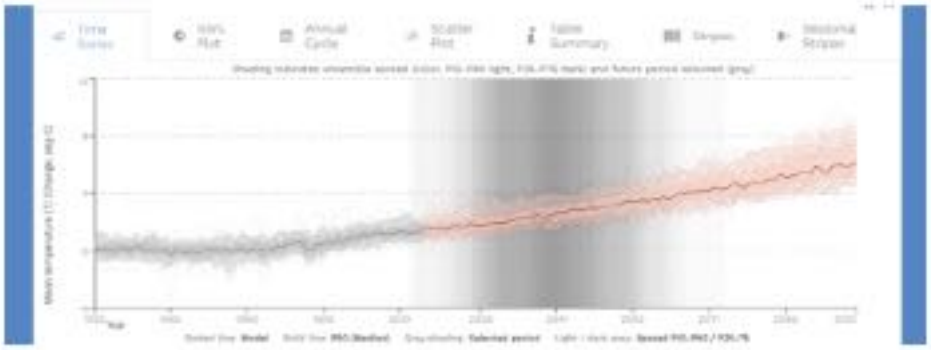

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Flexible global and regional analysis of climate information

ipcc AR6-WGI Interactive Atlas
First order draft

About Instructions

WMO UNEP

DATASET
CMIP5

VARIABLE
Mean temperature (MT)
(Anomaly)

SCENARIO
RCP 8.5: Medium term

SEASON
Annual

CMIP5 (2º)
CMIP6 (1º)
CORDEX (0.5º)
- EURO
- AFRICA
- ANTARCTICA, …

Observations

Precipitation, temperatures, wind
Extremes (CH11)
Hazards (CH12)

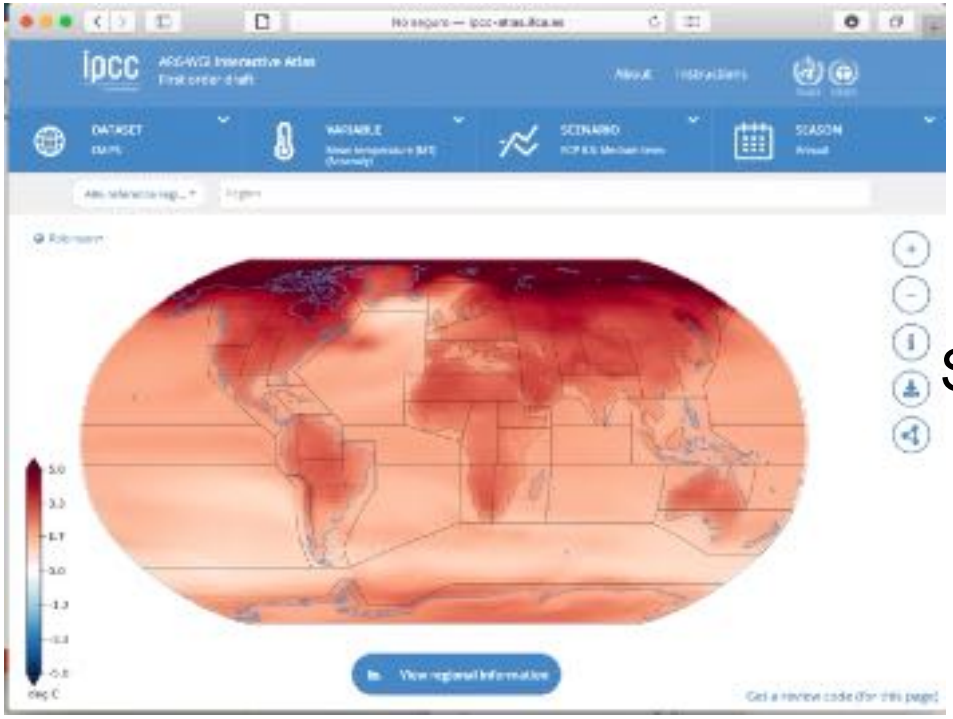
SST, pH, O_2

Bias adjust. (CH10)

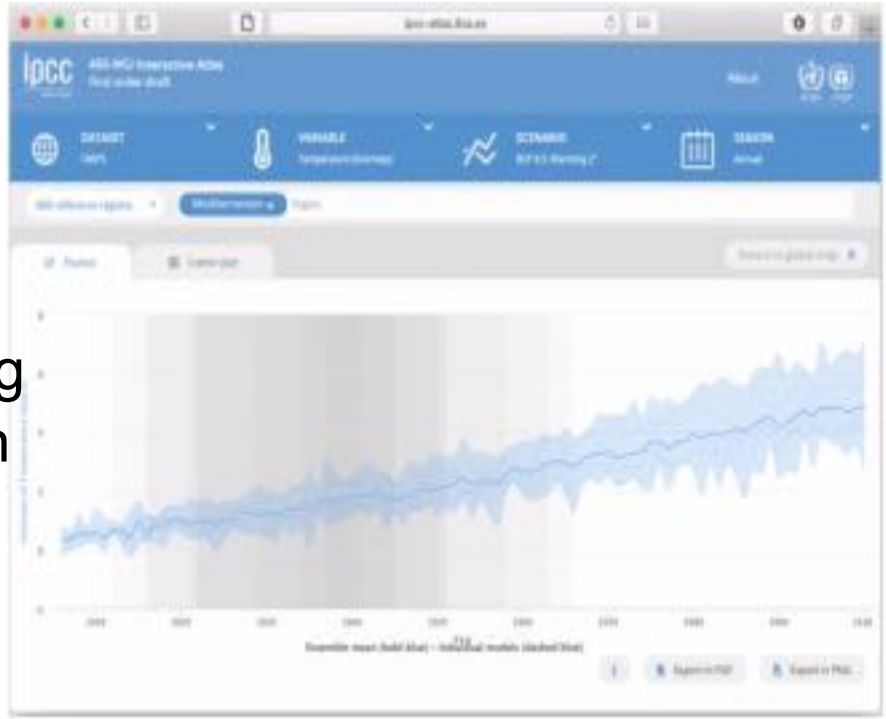
Multiple baselines (AR5, AR6, WMO)

Multiple scenarios
- **warming levels**
- time slices

Flexible



Selecting a region



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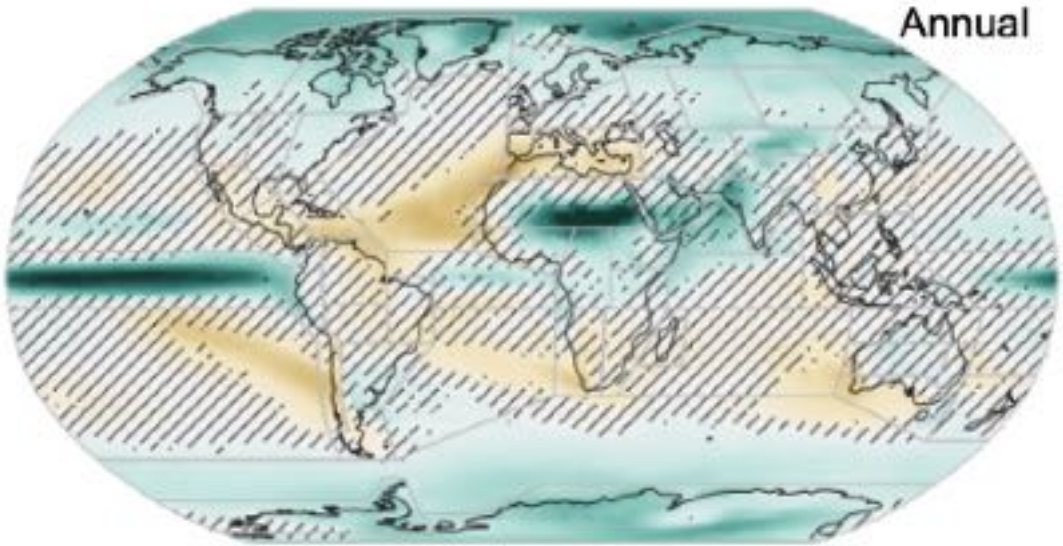

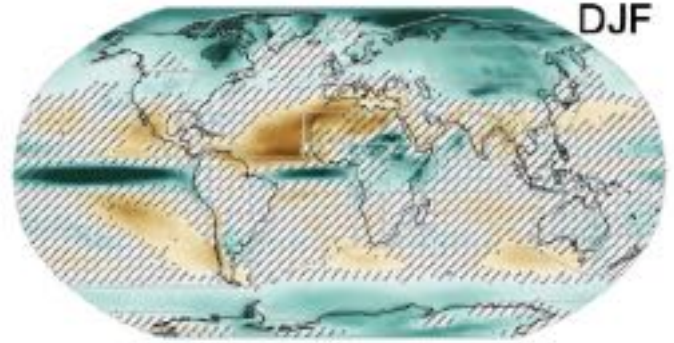

Maps represent the multi-model mean, but uncertainty is characterized considering **model agreement** (regions where less than 80% of the models agree on the sign are hatched).

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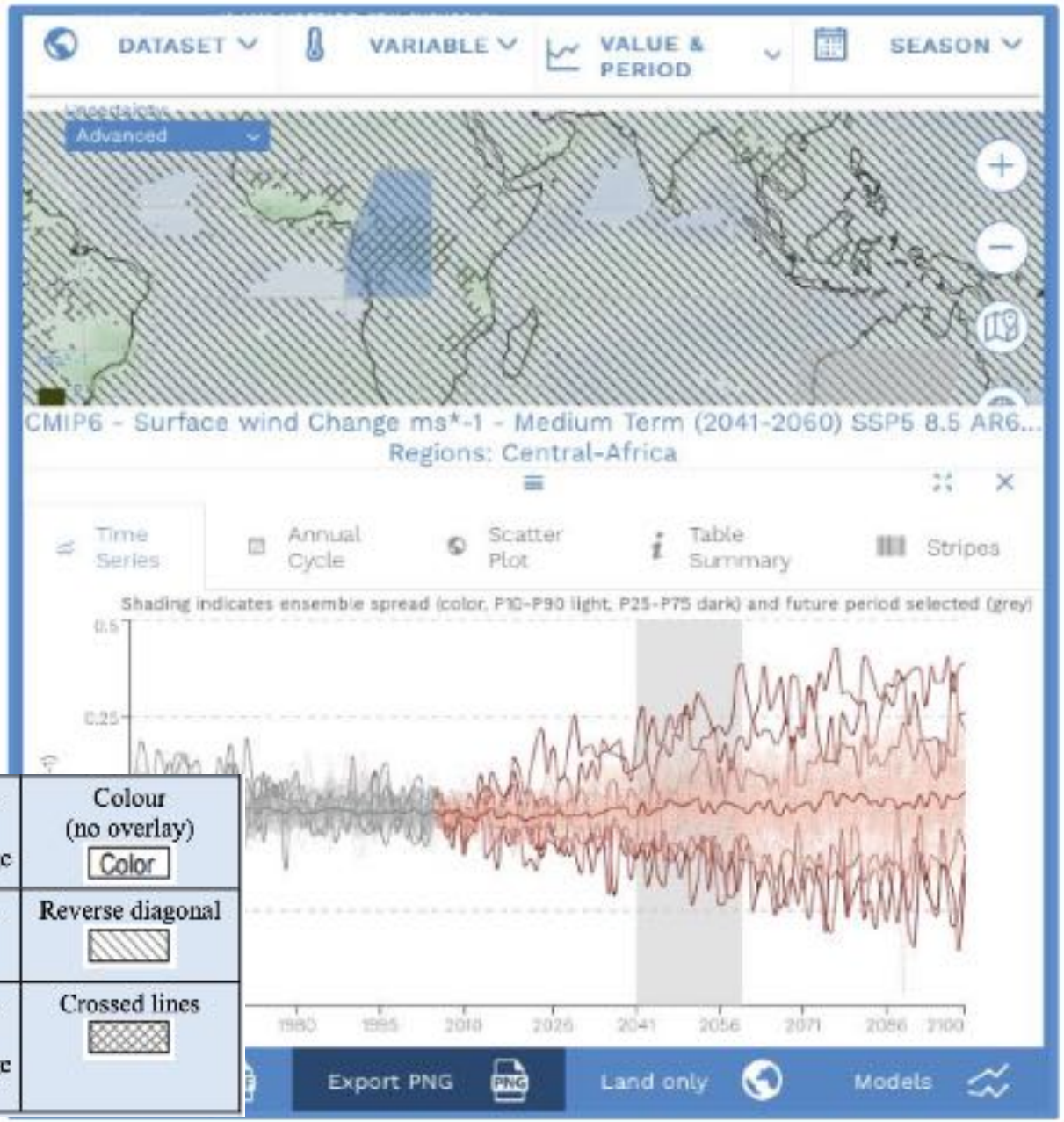
IPCC-AR6 Atlas

An innovation in AR6 is including an advanced method for representing uncertainty.

An extra category is included to indicate **conflicting information** (crossed lines).



C.1. Robust signal (significant change and high agreement)	≥66% of models show change greater than variability threshold γ and ≥80% of all models agree on sign of change	Colour (no overlay) Color
C.2. No change or no robust signal	<66% of models show change greater than variability threshold	Reverse diagonal
C.3. Conflicting signals (significant change but low agreement)	≥66% of models show change greater than variability threshold γ and <80% of all models agree on sign of change	Crossed lines

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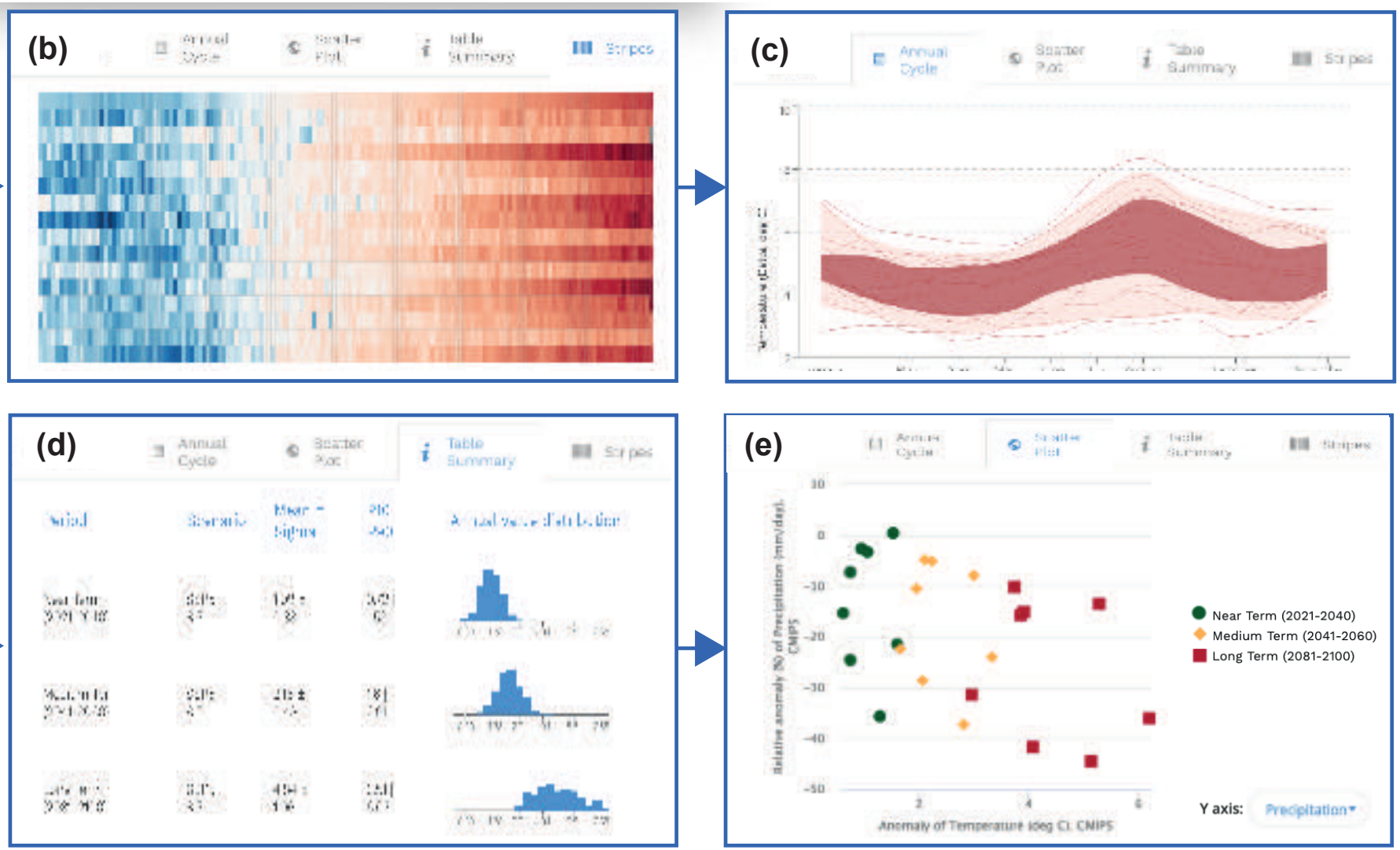

Thank you !

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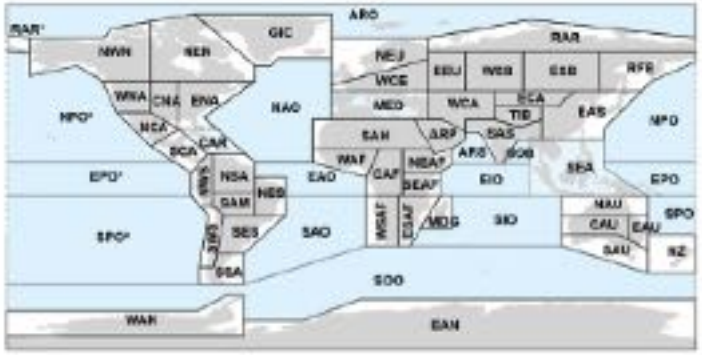
IPCC-AR6 Atlas

Seasons (user-defined)

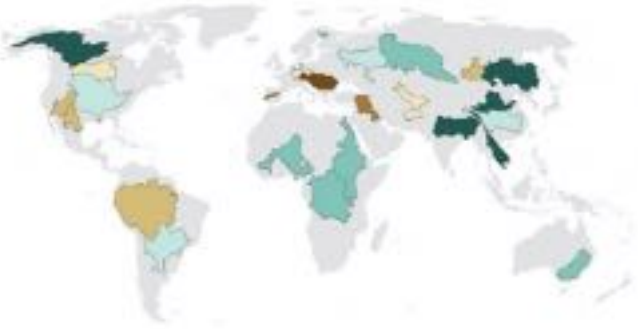
Regions (predefined):

WGI reference regions + thematic



WGII continental regions

Major river basins



Reusability:

Figures include full metadata and can be downloaded as **PNG → IPCC license.**

Underlying data can be downloaded as **NetCDF** or **GeoTiff.** → **CC-BY.**

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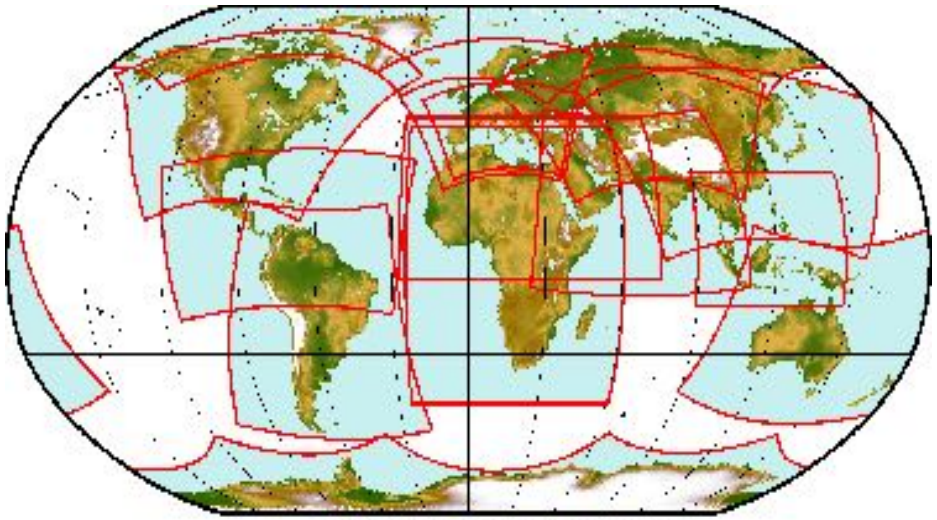

Domain	# RCMs	# GCMs	ERA Interim	RCP2.6	RCP4.5	RCP8.5	Total	ESGF	Local providers
1Africa (AFR)	12	15	13	12	36	37	98	64	98
Antarctica (ANT)	8	10	8	2	11	13	35	?	?
Arctic (ARC)	11	5	23	-	10	26	59	34	29
Australasia (AUS)	3	11	5	-	20	24	49	-	11
Central Asia (CAS)	1	3	1	-	3	3	10	-	10
East Asia (EAS)	2	5	2	-	5	6	13	-	13
SEACLID	8	12	3	-	15	15	48	?	?
South Asia (WAS)	6	12	4	6	27	24	61	45	16
EUR-44 EUR-11	11	11	28 23	20 18	31 24	34 40	113 105	61 49	52 56
MED-CORDEX (MED)	14	6	44	3	11	20	78	-	18
MENA (MNA)	6	7	8	2	12	12	34	15	19
North America (NAM)	10	5	16	1	7	24	52	9	36
Central America (CAM)	4	10	7	6	3	12	28	23	4
South America (SAM)	7	8	7	12	18	18	55	13	?

Climate Change Service

CORDEX4USERS - World-Wide CORDEX for Users through the C3S Climate Data Store

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Extend the evaluation of GCMs (CH3) to RCMs considering specific metrics (building on VALUE).