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

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

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) are the main tools to study the evolution of climate at different time-scales (inc. subseasonal, seasonal, multi-decadal). They numerically solve a set of equations describing the dynamics of the climate system using supercomputing infrastructures.
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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.
A multidisciplinary approach to weather & climate

Santander Meteorology Group

Global Climate Models (GCMs)

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

\[ \mathbf{v} = (u, v, w), T, p, \rho = 1/\alpha \text{ and } q \]

\[
\begin{align*}
\frac{d\mathbf{v}}{dt} &= -\alpha \nabla p - \nabla \phi + \mathbf{F} - 2\Omega \times \mathbf{v} \\
\frac{\partial p}{\partial t} &= -\nabla \cdot (\rho \mathbf{v}) \\
\rho \alpha &= RT \\
Q &= C_p \frac{dT}{dt} - \alpha \frac{\partial p}{\partial t} \\
\frac{\partial \rho q}{\partial t} &= -\nabla \cdot (\rho \mathbf{v} q) + \rho (E - C)
\end{align*}
\]

Discretization:

Gridbox operations (per day):

100 km
\(~ 10^9\)
10^7 gridboxes
100 timesteps

Historical simulations

1980 1990 2000
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Gridbox operations (per day):

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

Historical simulations
1980 1990 2000

Future projections (scenarios)
2010 2020 2030 2040 2050 2060 2070 2080 2090

Difference: climate change signal

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

\[
\begin{align*}
\frac{\partial \mathbf{v}}{\partial t} &= -\alpha \nabla p - \nabla \phi + \mathbf{F} - 2\Omega \times \mathbf{v} \\
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\rho \alpha &= RT \\
Q &= C_p \frac{dT}{dt} - \alpha \frac{dp}{dt} \\
\frac{\partial \rho q}{\partial t} &= -\nabla \cdot (\rho \mathbf{v} q) + \rho (E - C)
\end{align*}
\]

https://www.carbonbrief.org/qa-how-do-climate-models-work
Multi-model intercomparison experiments, including climate change projections for different scenarios:

**CMIP5 (2013)**
- 29 groups [~200 km]

**CMIP6 (2021)**
- 44 groups [~100 km]

**Daily and sub-daily spatial information of relevant variables with physical consistency:**
- Wind
- Temperatures
- Radiation

- Derived indices
  - e.g. heating degree days (HDD)
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.
https://interactive-atlas.ipcc.ch/

Shading indicates ensemble spread (color: P10-P90 light; P25-P75 dark) and future period selected (grey)
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.
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)
There is a need of distillation methods for data reduction providing actionable sectoral-relevant regional climate information.

More info: IPCC AR6 – Chapter 10
Example: Projections of average annual minimum temperature for Barcelona (high-emission RCP8.5 scenario). Observations: Spain01 (gridded, 11km resolution).
MODEL DATA

USER REQUIREMENTS

DISTILLATION AND CO-PRODUCTION METHODOLOGIES

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

**I. Physical Science Basis**
- **Interactive Atlas**

**II. Impacts and Adaptation**
- **Atlas (static)**

**III. Mitigation**

The Interactive Atlas allows for flexible spatial and temporal analysis:
- Variables and indices
- User-defined seasons
- Flexible regions, inc. updated reference
A limited collection of regional maps building on global projections:
- mean temp. and precip
- standard seasons
- reference regions
Regional information:

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

https://interactive-atlas.ipcc.ch/
<table>
<thead>
<tr>
<th>DATASET</th>
<th>CMIP5</th>
<th>Precipitation, temperatures, wind</th>
<th>Multiple baselines (AR5, AR6, WMO)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CMIP6</td>
<td>Extreme (CH11)</td>
<td>Multiple scenarios - warming levels</td>
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<tr>
<td></td>
<td></td>
<td>hazards (CH12)</td>
<td>- time slices</td>
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<tr>
<td></td>
<td>CORDEX</td>
<td>SST, pH, O₂</td>
<td>Flexible</td>
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<tr>
<td></td>
<td>(0.5°)</td>
<td>Bias adjust. (CH10)</td>
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Observations

Flexible

Selecting a region
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).
An innovation in AR6 is including an advanced method for representing uncertainty.

An extra category is included to indicate conflicting information (crossed lines).
The Interactive Atlas allows for flexible spatial and temporal analyses of essential variables, extreme indices (CH11) and climatic impact drivers (CH12) including multiple lines of evidence (global - CMIP5/6 at 2º/1º and regional - CORDEX at 0.5º).

Regional (aggregated) information for reference and typological regions:
(a) Time series.
(b) Stripes
(c) Annual cycle plots
(d) Summary tabular information.
(e) Scatter plots (e.g. precip. vs. temp.)

CORDEX regional information is available for multiple domains (North and South America, Europe, Africa, South Asia and Antarctica).

Uncertainty is communicated using different approaches (including model agreement and signal-to-nose ratio).

Regional analysis is displayed when clicking one or several subregions.
Thank you!
**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.**
A multidisciplinary approach for weather & climate

CORDEX4USERS - World-Wide CORDEX for Users through the C3S Climate Data Store
Extend the evaluation of GCMs (CH3) to RCMs considering specific metrics (building on VALUE).