Growing opportunities in climate change adaptation

EUFIWACC climate risk information day for consultants

Brussels - 2nd June 2015

How to interpret climate change projections

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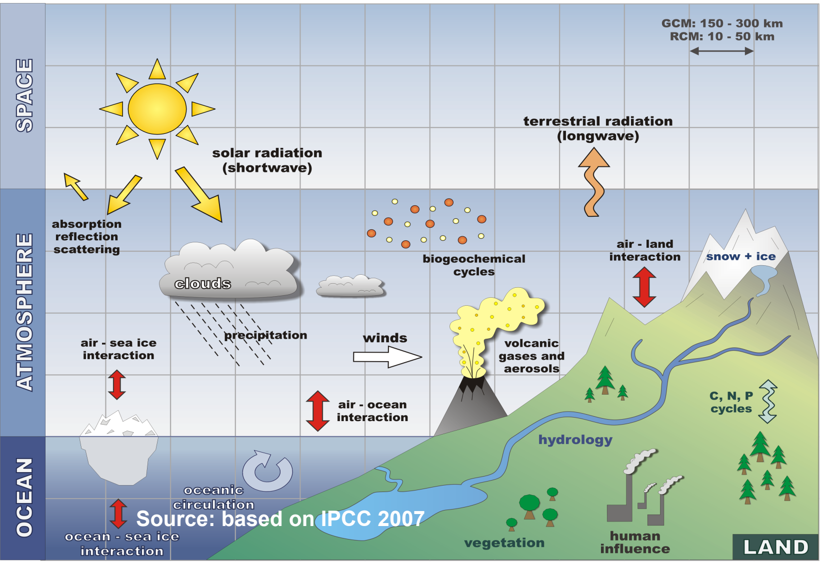
Structure

- 1. Motivation
- 2. Range of climate change projections
- 3. Model ensemble experiments
- 4. Relevance of uncertainties

Weather and Climate



Weather

- Physical state of atmosphere at a certain time and location
- can be characterised by measured meteorological parameters, e.g. air pressure, humidity, temperature

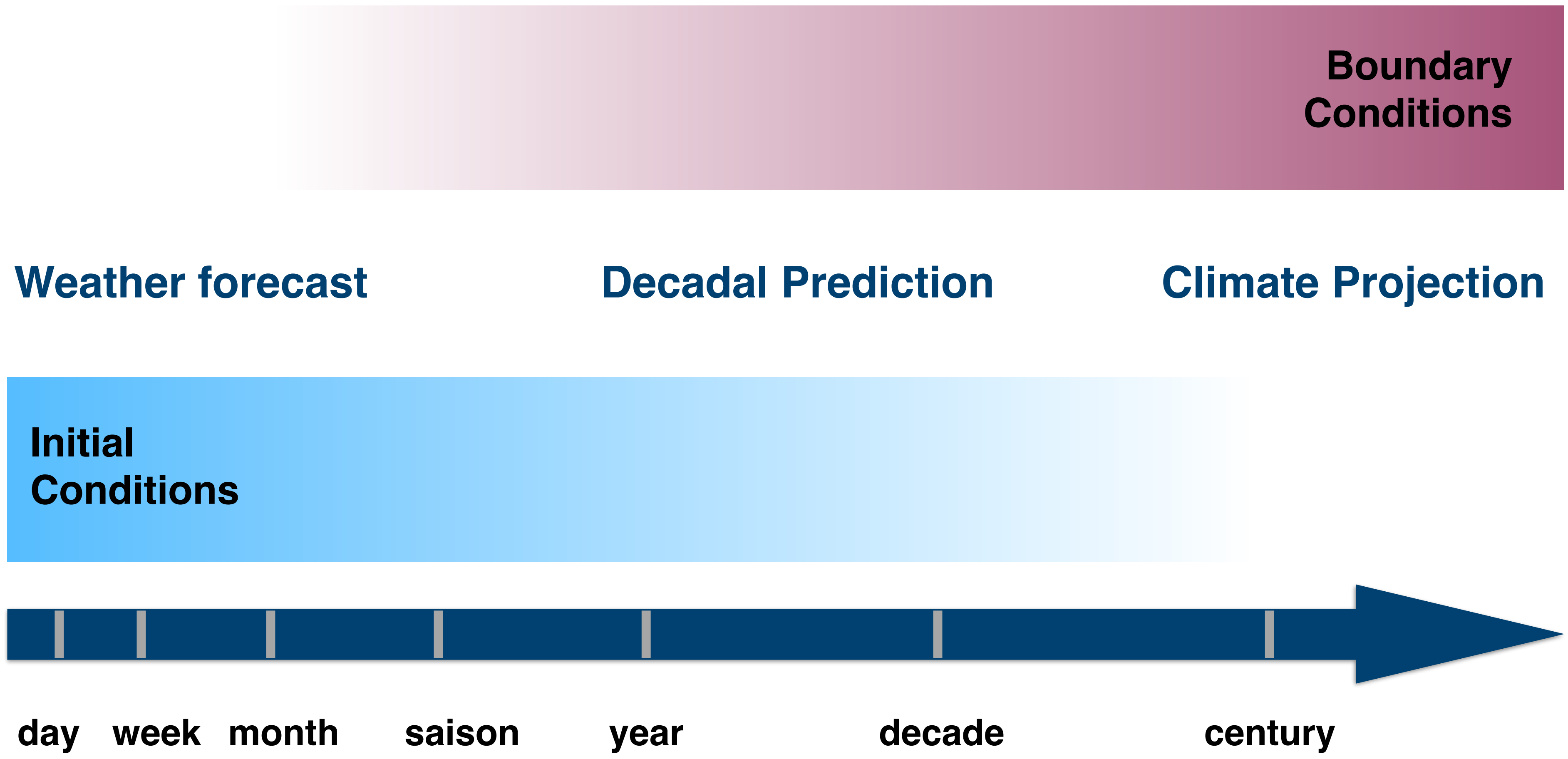
Weather is what you get

Climate

- Statistical distribution of weather characteristics over a long time period (WMO: 30 years)
- e.g. 30-year-mean of saisonal air temperature

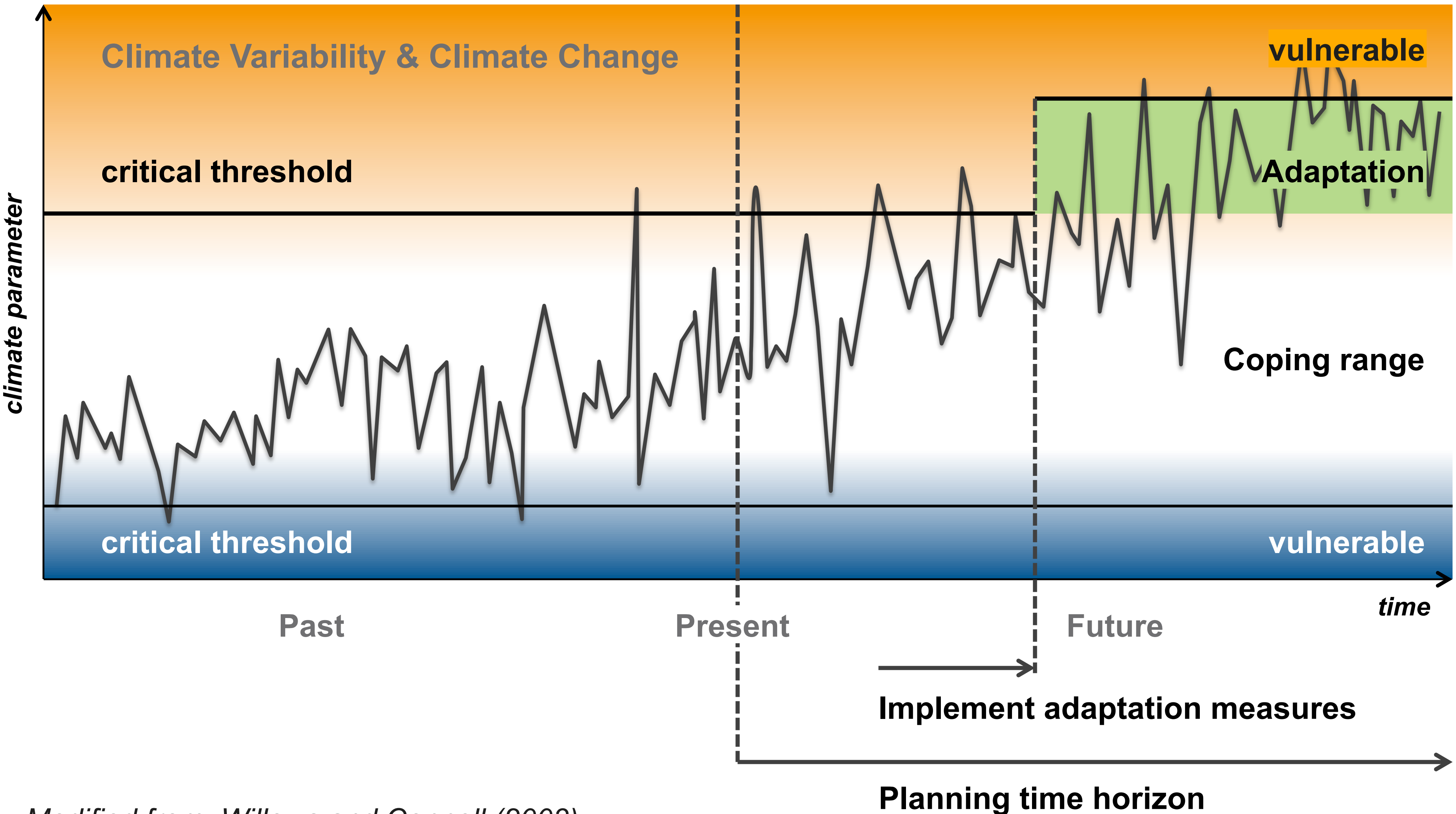
Climate is what you expect

Weather forecast and Climate projection



Modified from Meehl et al. (2009)

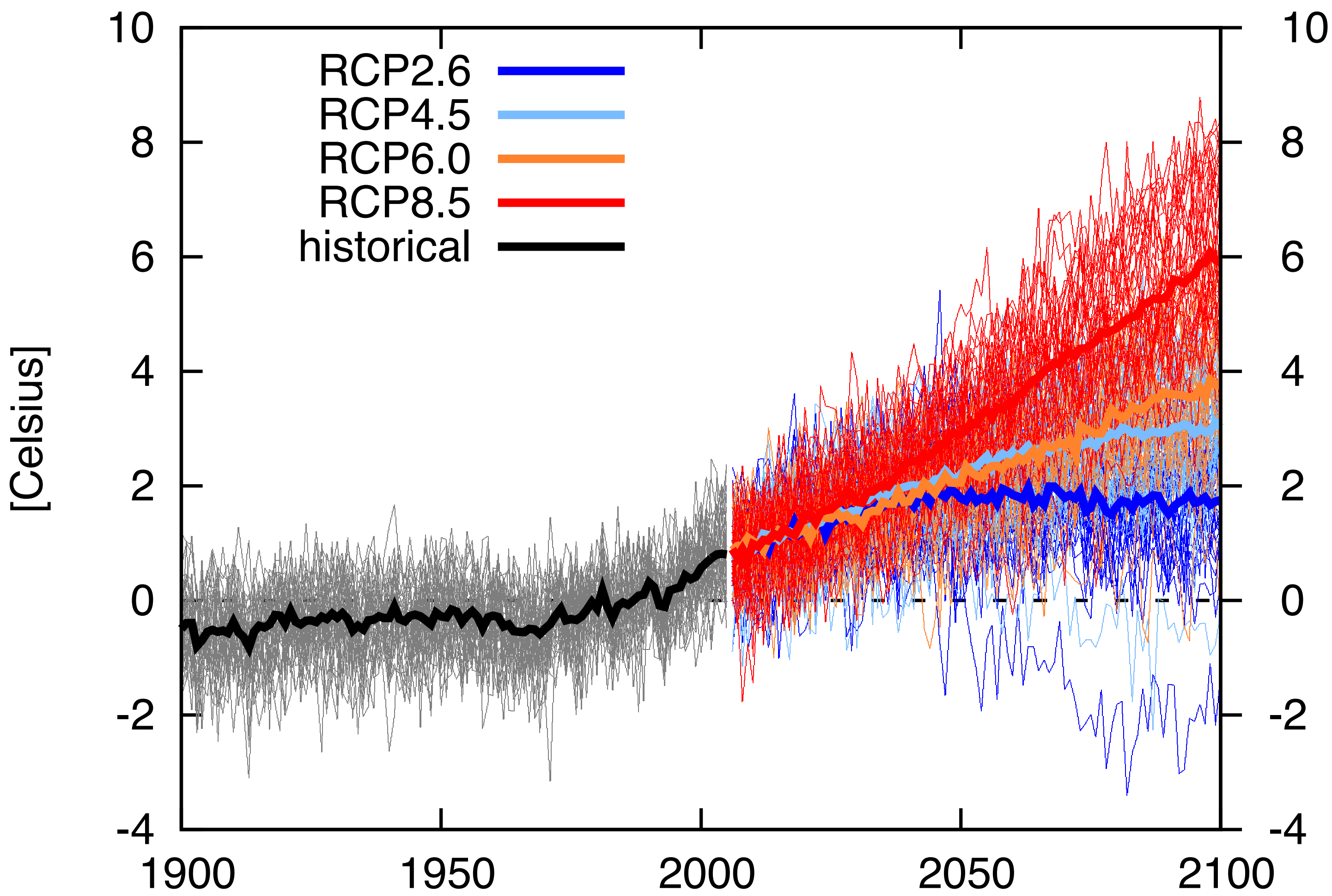
Coping range



Modified from: Willows and Connell (2003)

Climate Projections

CMIP5: Simulated annual temperature values in Europe relative to 1971-2000



?

Source: KNMI Climate Explorer

Challenge: Uncertainties of Climate Projections

Uncertainties are large does not mean that risks are small

- we need to understand uncertainties, so that they can be incorporated into the decision making process
- in order to avoid **under-adaptation** and **over-adaptation**

Each adaptation project has its own challenges

- many are related to uncertainties of potential future climate changes
- its relevance also depends on the importance of non-climate factors

Range of climate change projections

Future climate evolution depends on:

Natural external factors

Changing natural factors outside the climate system
e.g. solar variabilty, volcanic eruptions

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Human action

Anthropogenic emissions of radiatively active substancies to the atmosphere
Land use changes

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Internal climate variability

Variations of climate
due to natural processes inside the climate system

Climate projections: main sources of spread

Natural external factors

Changing natural factors outside the climate system
e.g. solar variabilty, volcanic eruptions

Human action

Anthropogenic emissions of radiatively active substancies to the atmosphere
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Internal climate variability

Variations of climate
due to natural processes inside the climate system

Modelling uncertainties

Models are a simplified image of the earth climate system

Model Ensemble Experiments

Climate projections: Ensemble experiments

Natural external factors

- *Prescribed or constant ("Unknowns")*

Human action

- **Emission scenario ensemble**

Internal climate variability

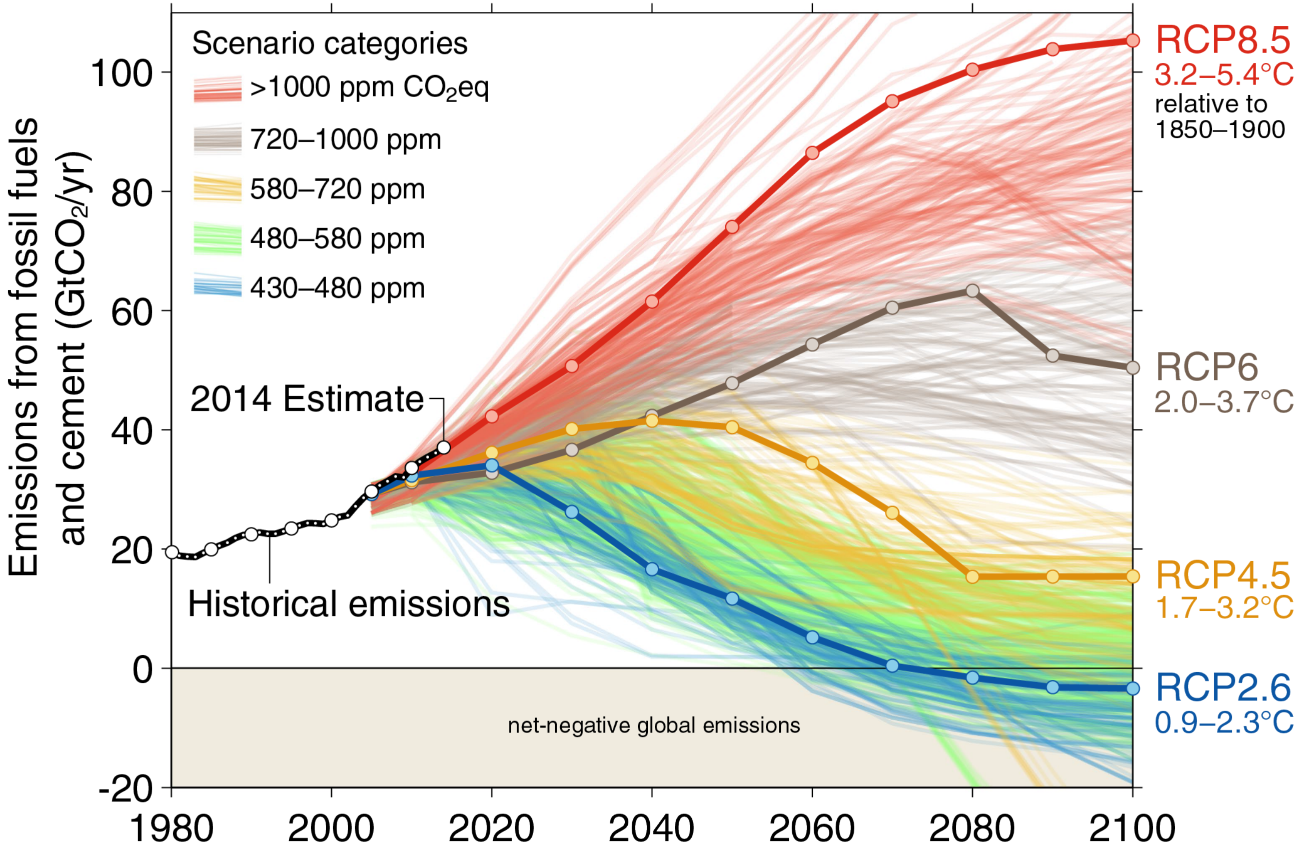
- **Initial condition ensemble**

Modelling uncertainties

- **Multi-model ensemble**

sample both modelling uncertainites and initial conditions
ensembles of (best available) opportunities

Emission scenarios: Representative Concentration Pathways RCPs



RCP8.5
> 1000 ppm CO_2-eq

RCP6.0
720-1000 ppm CO_2-eq

RCP4.5
580-720 ppm CO_2-eq

RCP2.6
430-480 ppm CO_2-eq
Large and sustained mitigation is required

Over 1000 scenarios from the IPCC Fifth Assessment Report are shown

Source: Fuss et al 2014; CDIAC; Global Carbon Budget 2014

GLOBAL CARBON PROJECT

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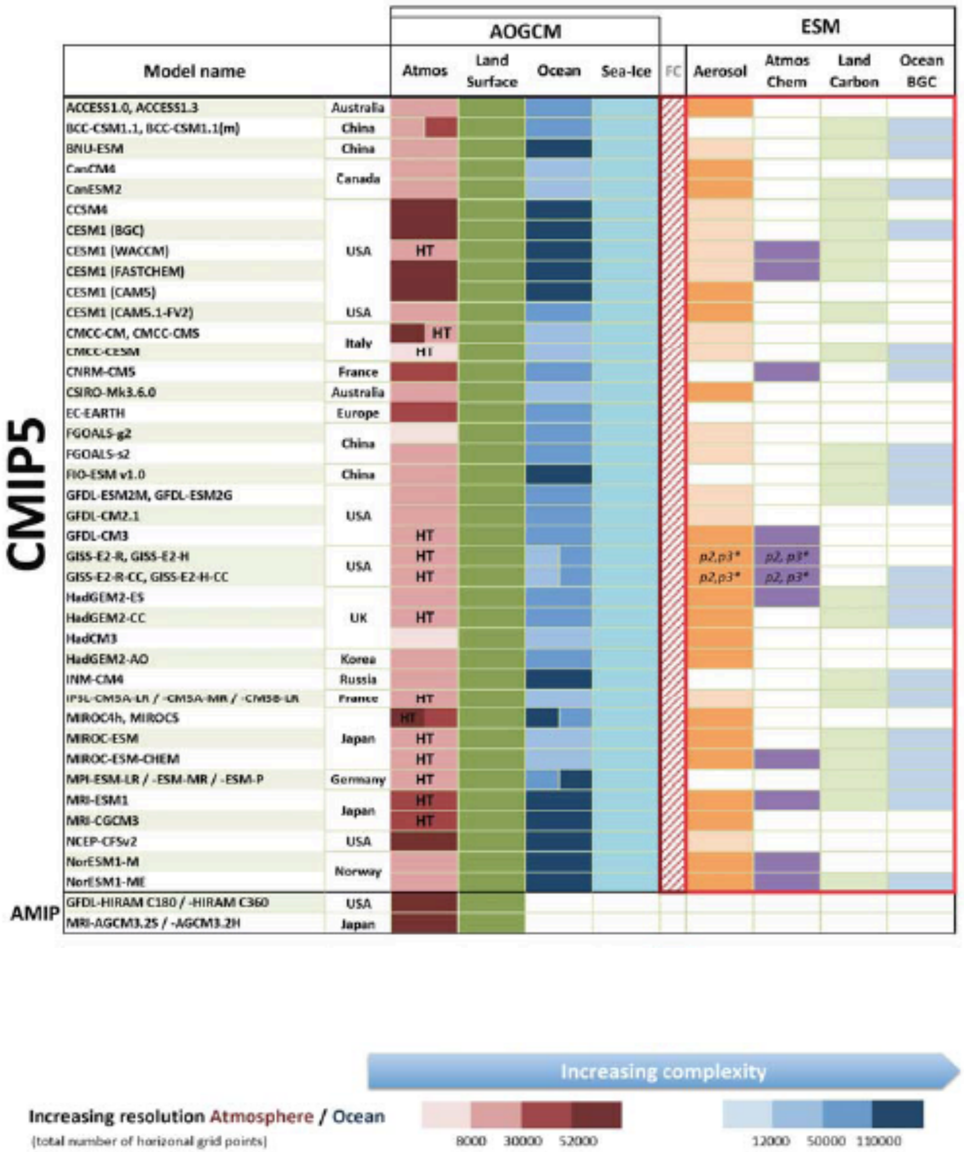
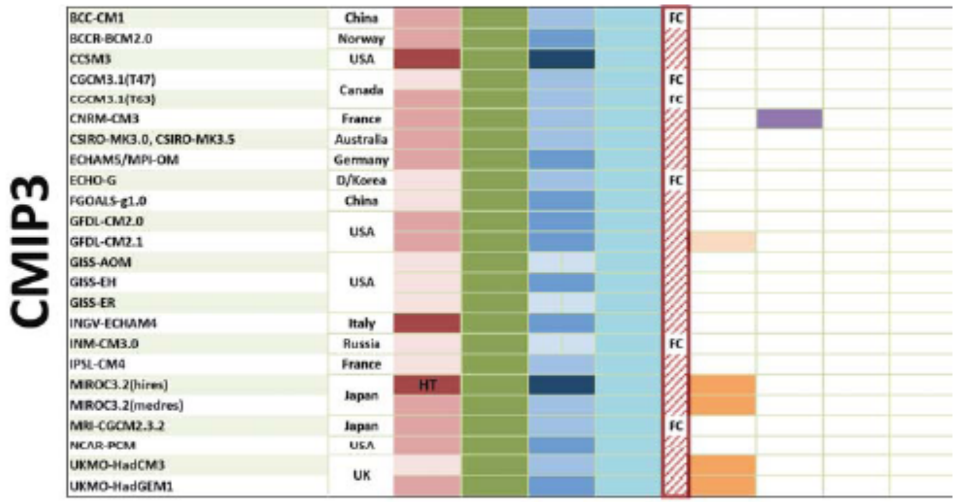
Multi-model ensemble CMIP5 and CMIP3





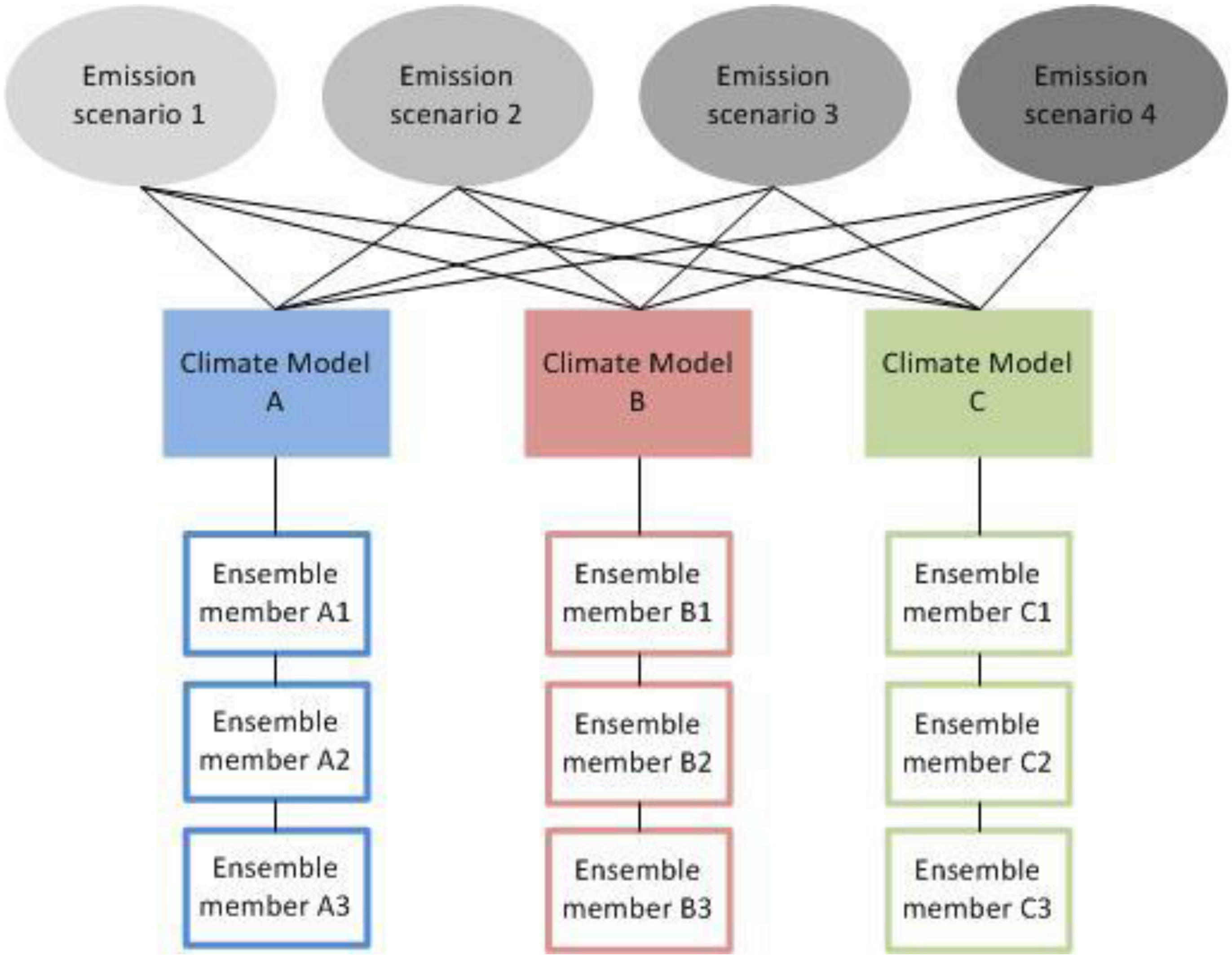
MIPs Model Intercompariso Projects (since 1990): standard experiment protocol and an world wide community-based infrastructure in support of model simulations, validation, intercomparison, documentation and data access.

CMIP3: coordinated climate projections, based on emission scenarios from SRES, global model basis for IPCC AR4

CMIP5: a new set of coordinated, based on the new RCPs, global model basis for IPCC AR5

Source: IPCC 2013 AR5 Chapter 9

Ensemble experiments: assessment of uncertainty



Scenario Uncertainty

Model uncertainty

Internal Variability

Source: Pelt and Ludwig, ECLISE user guide on uncertainties:
http://www.eclise-project.eu/content/mm_files/do_824/D%201.2-User%20guide%20on%20uncertainties.pdf

CMIP5: Projected global temperature range

relative to pre-industrial

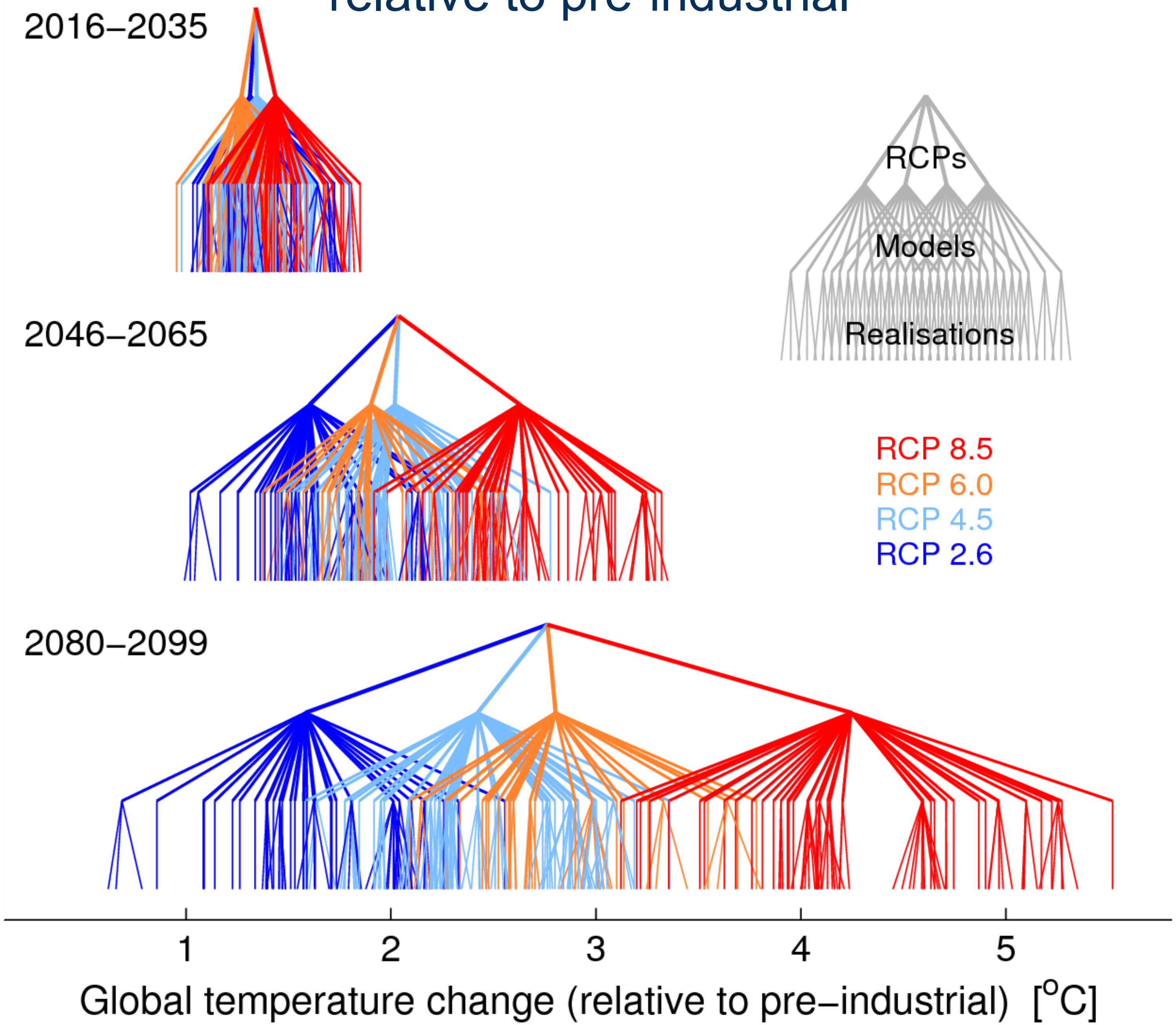
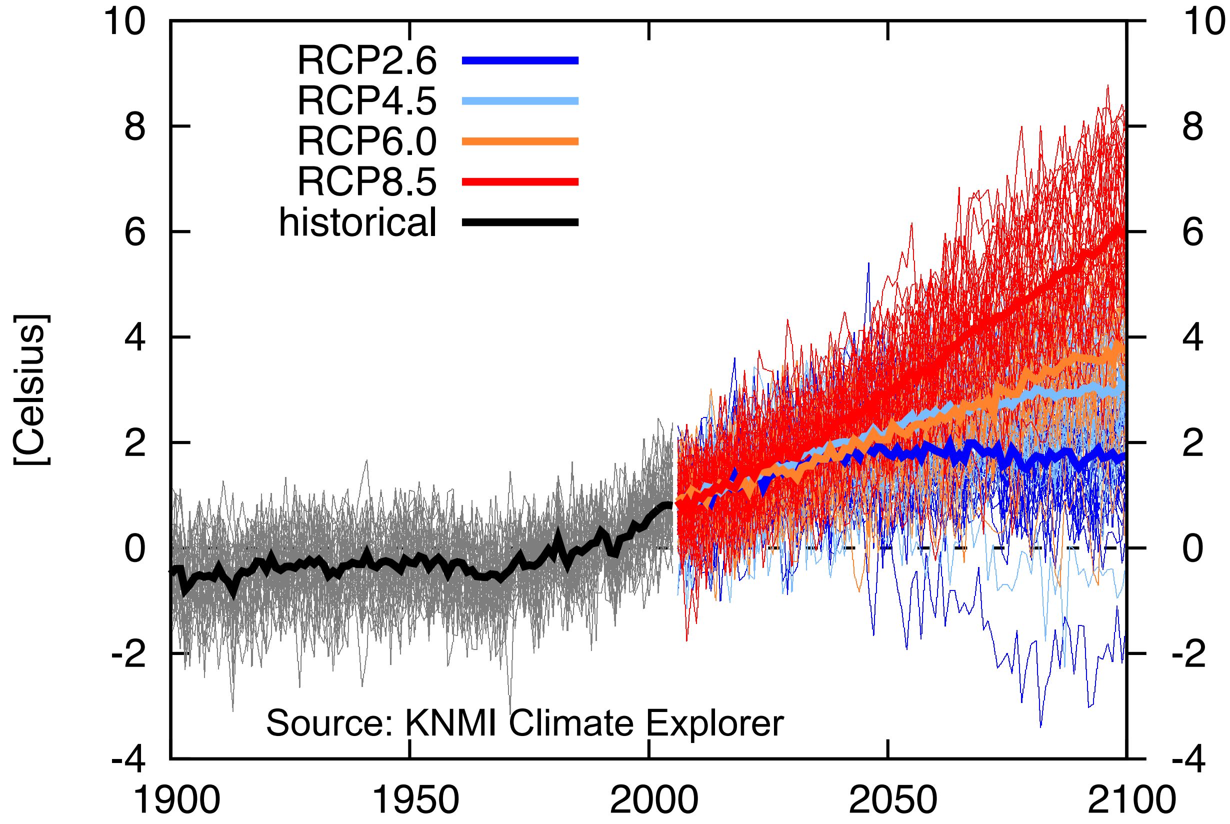


Figure created by Ed Hawkins 2014, source: http://www.climate-lab-book.ac.uk/2014/cascade-of-uncertainty/

CMIP5: Simulated annual temperature values in Europe

relative to 1971-2000



CMIP5 data available via **Earth System Grid Federation ESGF:**
http://esgf-data.dkrz.de/esgf-web-fe/

Monthly values can easily be accessed by **KNMI climate change atlas**:
http://climexp.knmi.nl/plot_atlas_form.py

- **learn more about KNMI climate explorer: presentation by Paul Bowyer**

CMIP5: Simulated annual temperature values in Europe

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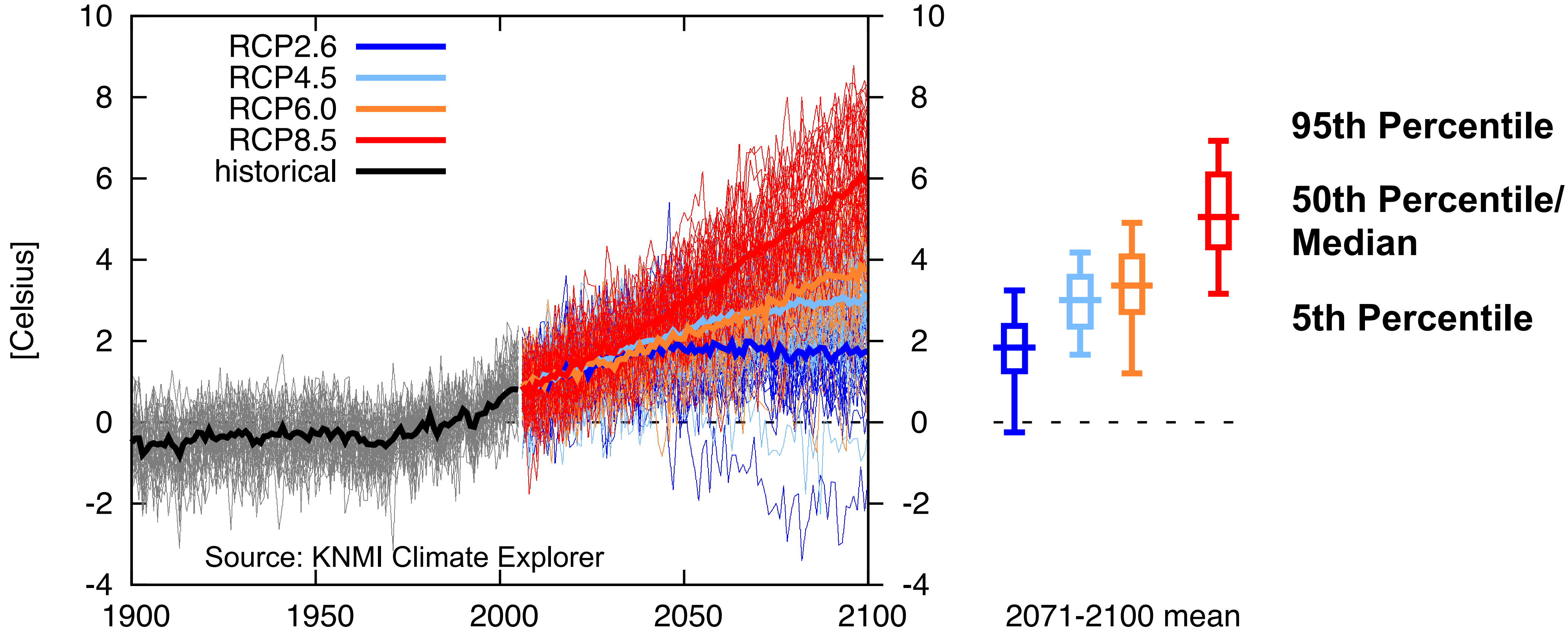

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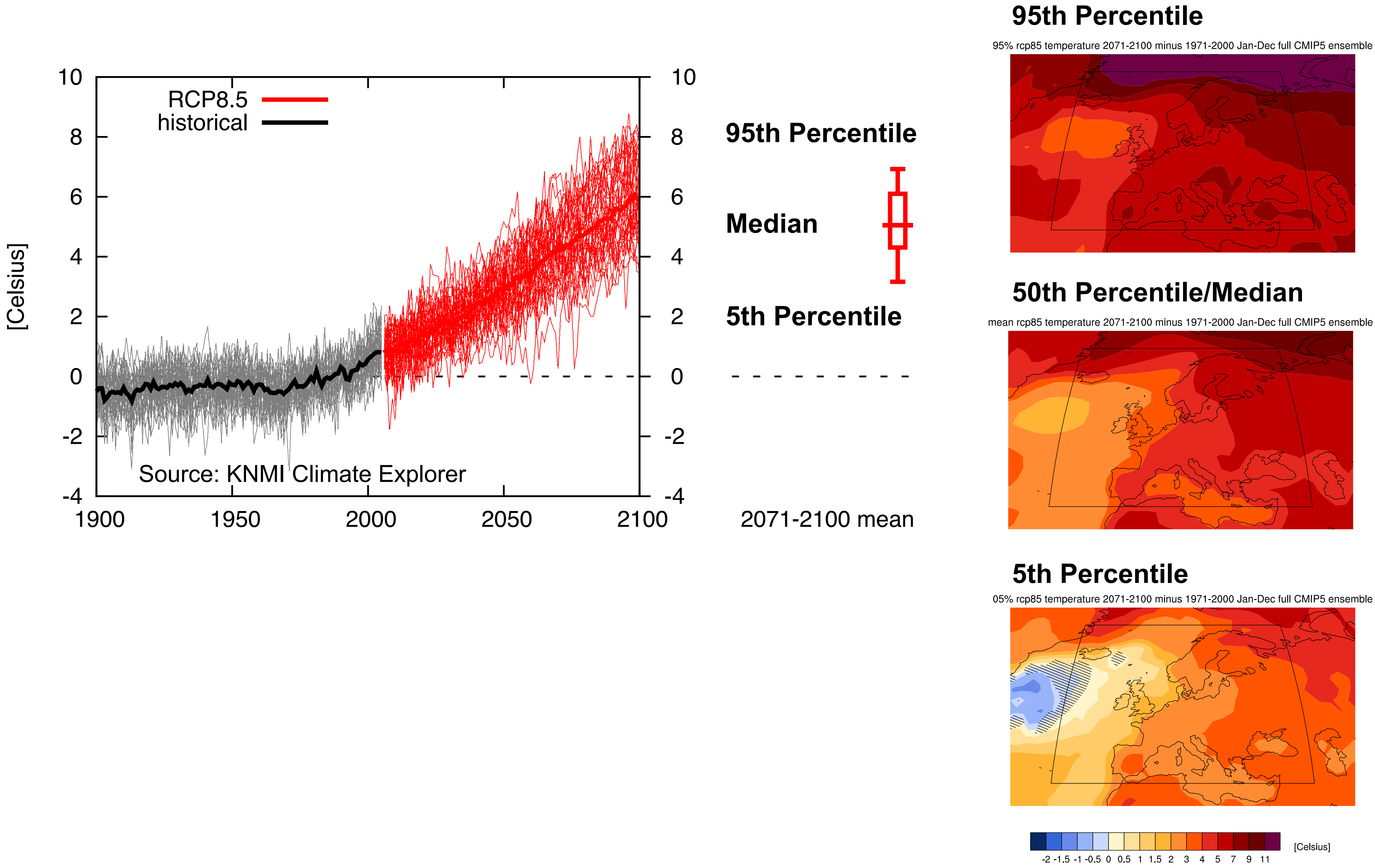

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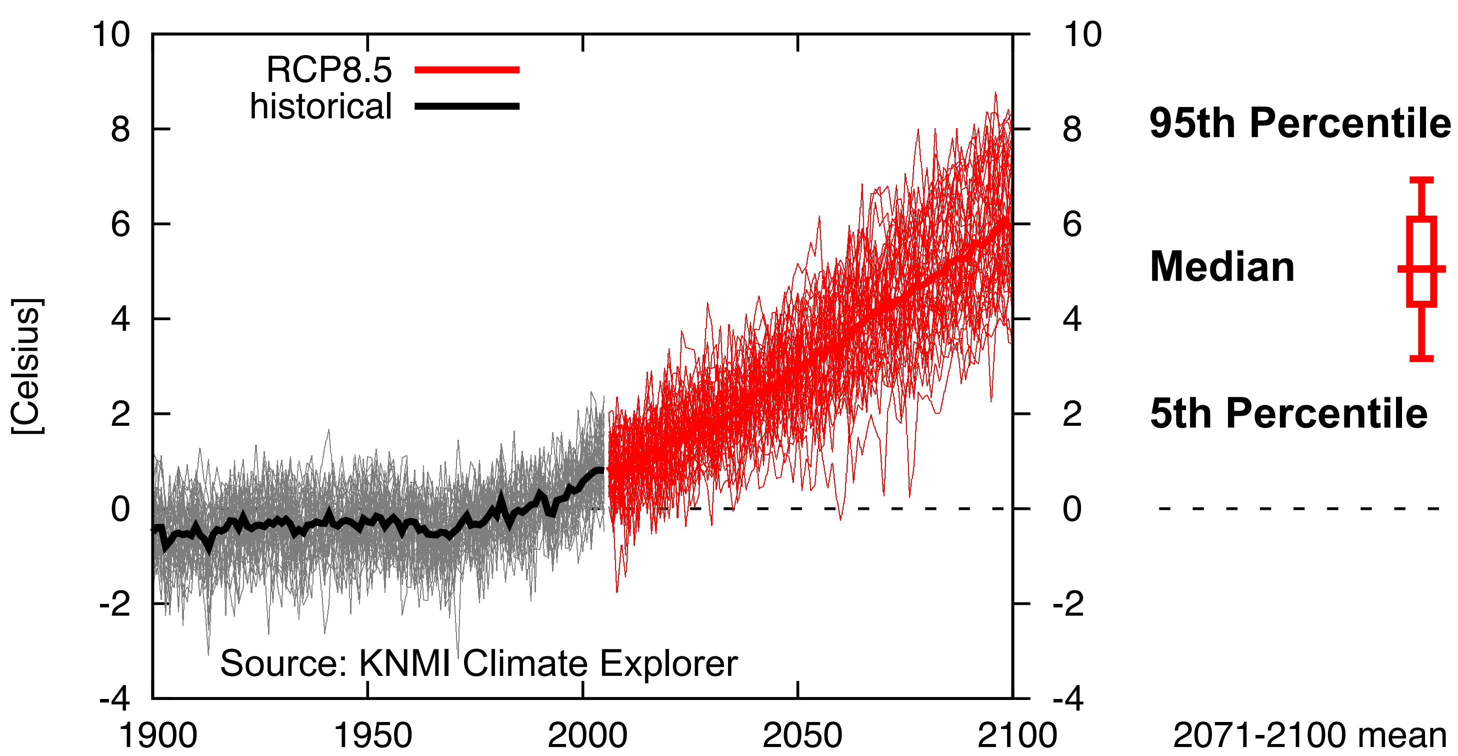
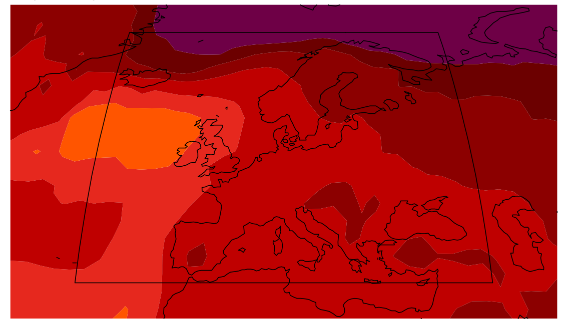


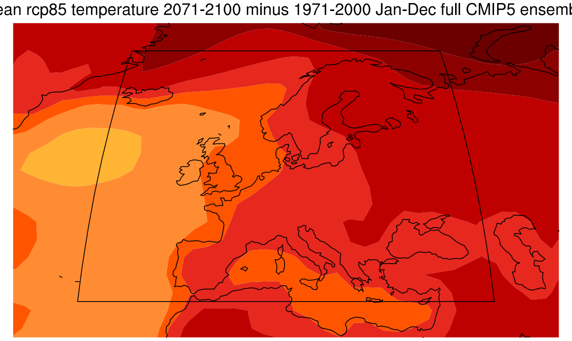
95th Percentile

95% rcp85 temperature 2071-2100 minus 1971-2000 Jan-Dec full CMIP5 ensemble



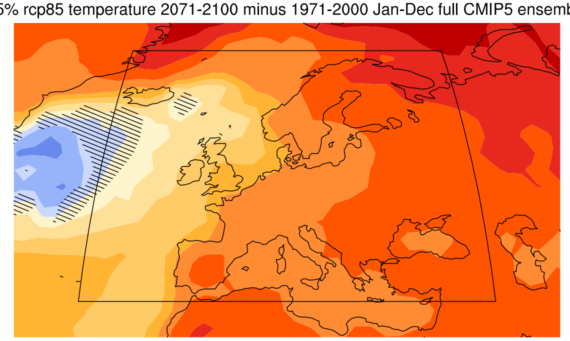
50th Percentile/Median

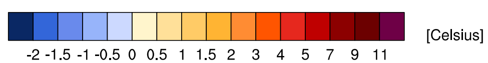
mean rcp85 temperature 2071-2100 minus 1971-2000 Jan-Dec full CMIP5 ensemble



5th Percentile

05% rcp85 temperature 2071-2100 minus 1971-2000 Jan-Dec full CMIP5 ensemble





Further evalutions on how robust are the simulated results:

- model agreement: e.g. how many models agree in the sign of the simulated change
- on the significance of change: e.g. if change is larger than 1 std of interannual variations

see also presentation by Andreas Hänsler

Relevance of Uncertainties

Uncertainties in climate projections

depend on:

- **climate parameters**
- **indices (mean or extremes)**
- **time scale**
- **spatial scale**

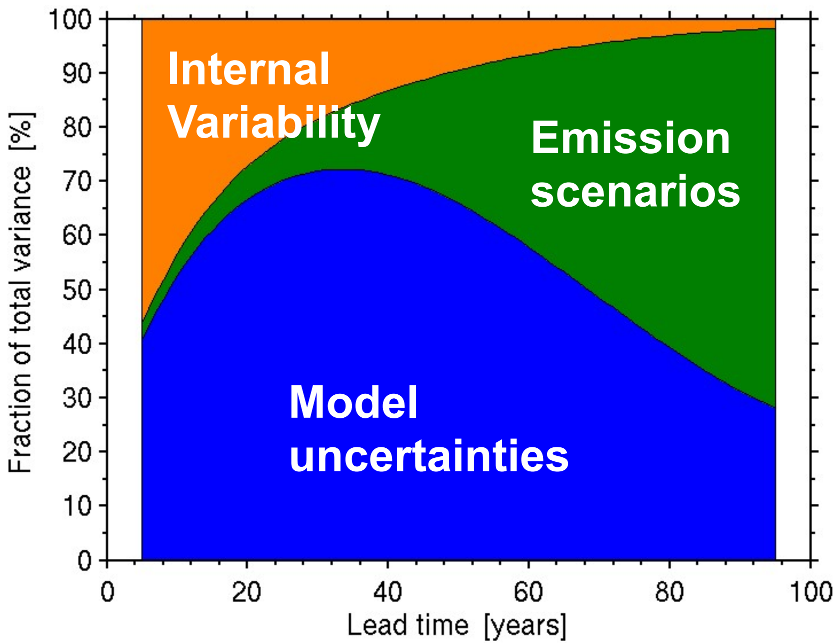
Internal Climate Variability is larger

- *for precipitation than temperature,*
- *for indices related to extremes than to mean climatic conditions,*
- *for smaller regions and*
- *on shorter time scales*

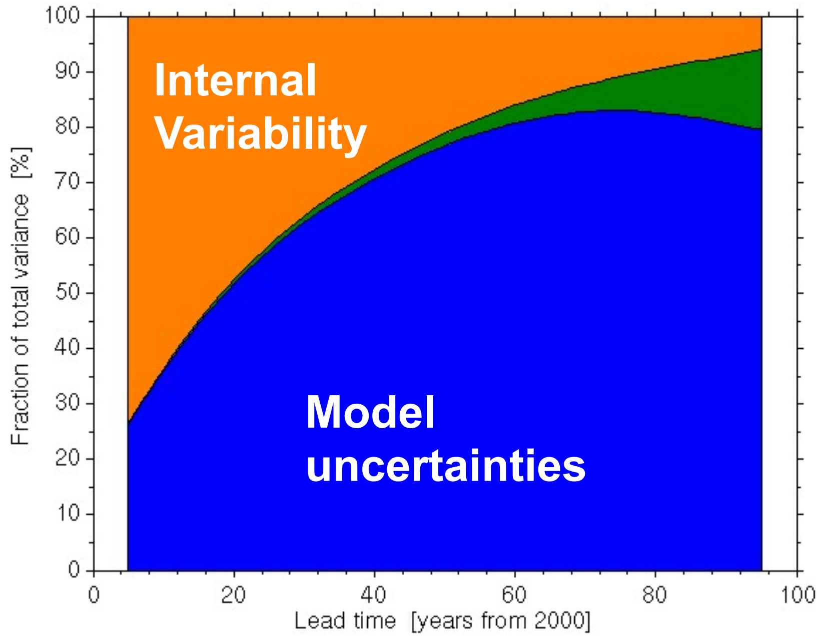
Relevance of uncertainties **on different time scales**

Relative contributions to the total projected range of decadal annual mean in Europe

Temperature



Precipitation



Figures: http://climate.ncas.ac.uk/research/uncertainty/plots.html, Source: Hawkins & Sutton 2009, 2010

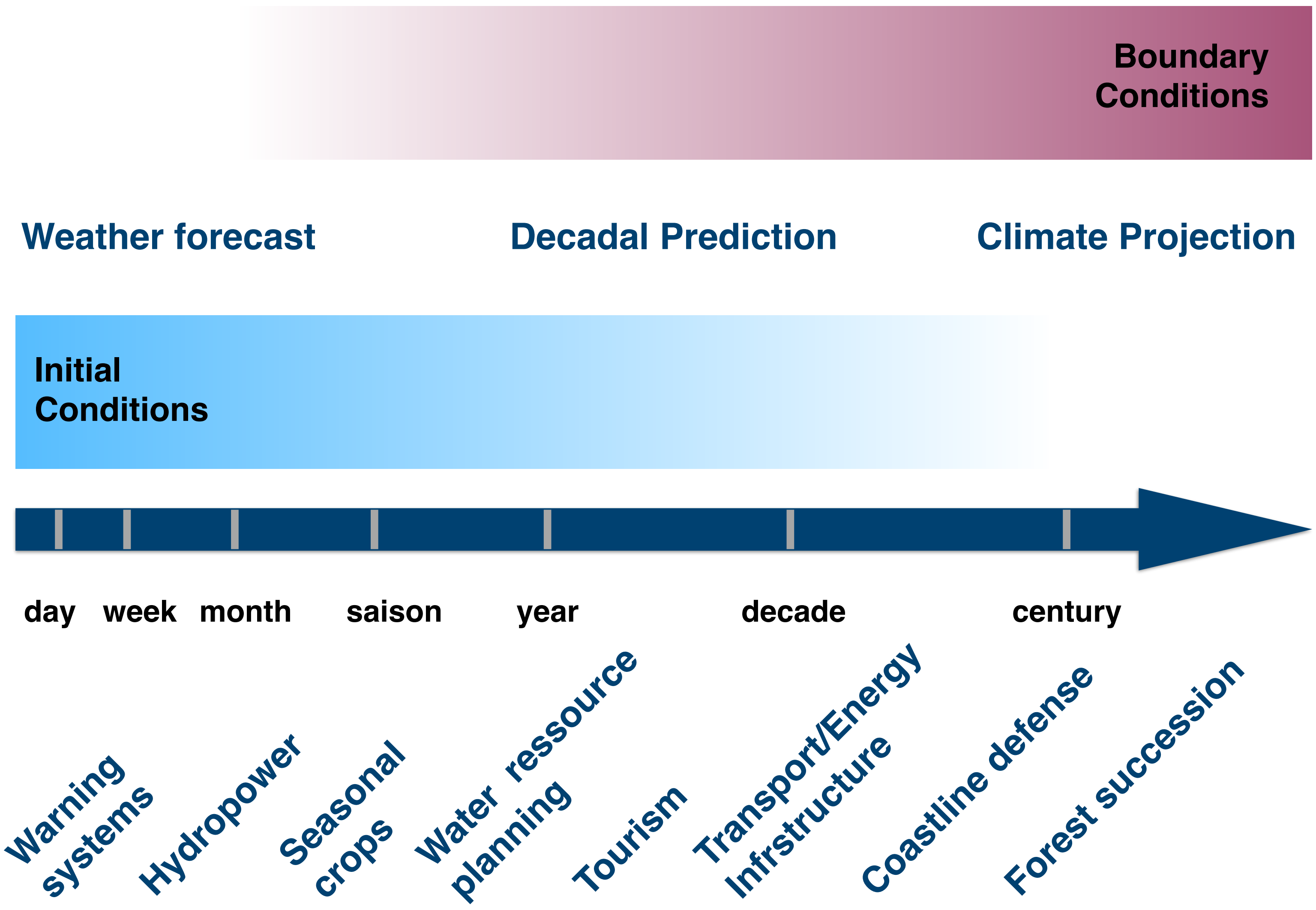
Temperature:

- internal variability dominates on shorter time scales,
- emission scenarios on longer time scales

Precipitation:

- internal variability dominates on shorter time scales
- modelling uncertainties on longer time scales

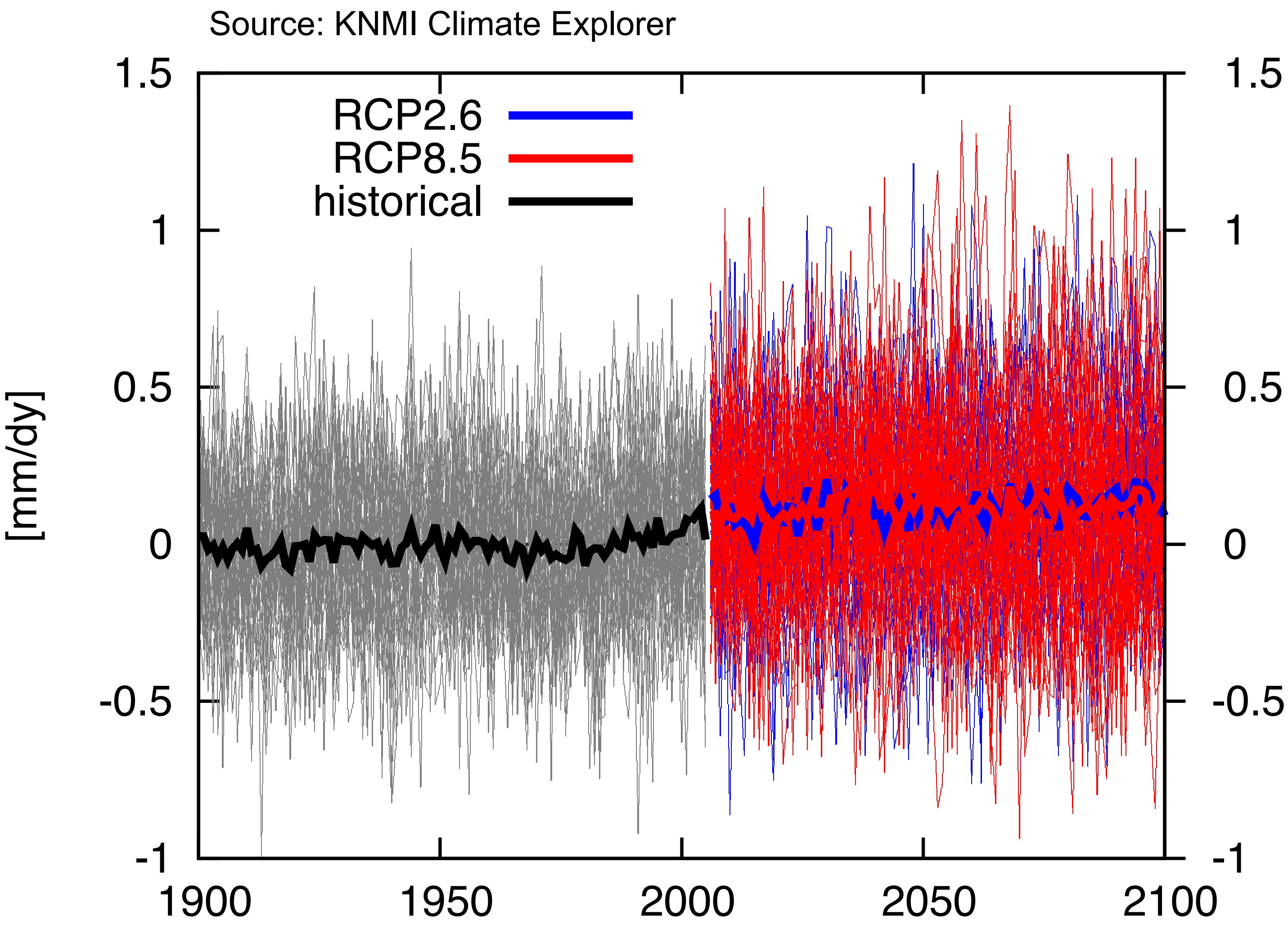
Climate information on different time scales and temporal context of the project



Modified from Meehl et al. (2009)

CMIP5: Simulated annual precipitation values (Germany)

relative to 1971-2000



no significant change in mean precipitation

but increase in inter-annual variability due to climate change

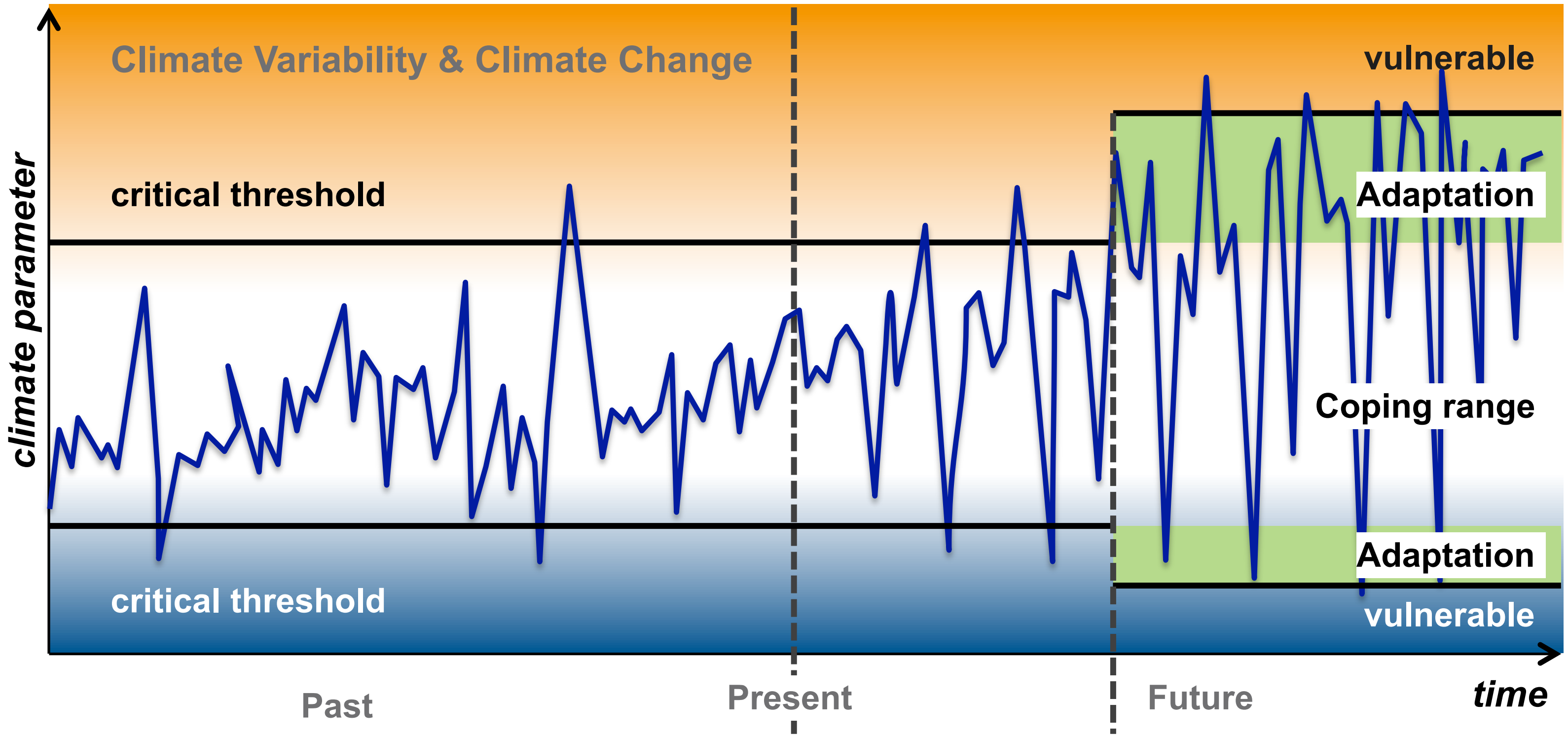
e.g. due to some years with more frequent dry conditions during summer

and some years with precipitation increase during winter dominating

Adaptation to increased precipitation variability

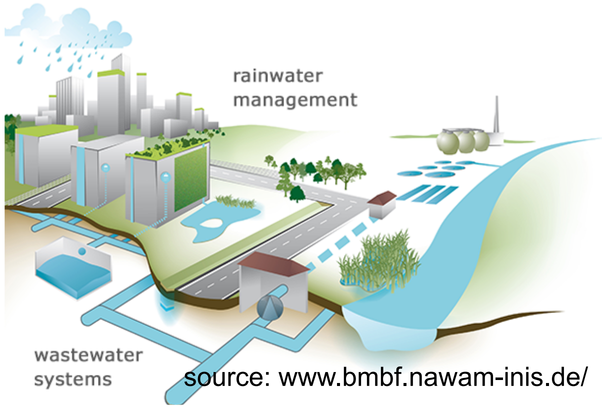
Example: Water management infrastructure

water sewage systems



policies: regulate water demand

water storage systems



Some key messages

- Climate models are not the real world and **we can not foresee the future**
- Climate projections show us **a whole range of possibilities** how future climate may evolve
- How this **range should be considered** in adaptation planning, depends on the specific project: climate parameters, temporal and spatial scales
- There is no standard recipe, but **understanding of climate data uncertainty is always an important step**
- There are some generic methods and tools how to deal with results of climate projections **and how to derive robust climate information: see presentations this afternoon**

Some generic climate data guidelines and good practise examples

European Climate Adaptation Platform (CLIMATE-ADAPT)
http://climate-adapt.eea.europa.eu/uncertainty-guidance/

ECLISE: Enabling CLimate Information Services for Europe
EU FP7 2011-2013
http://www.eclise-project.eu

www.wmo.int
e.g. *http://www.wmo.int/pages/prog/wcp/ccl/guide/documents/WMO_100_en.pdf*

World Meteorological Organization
Weather • Climate • Water

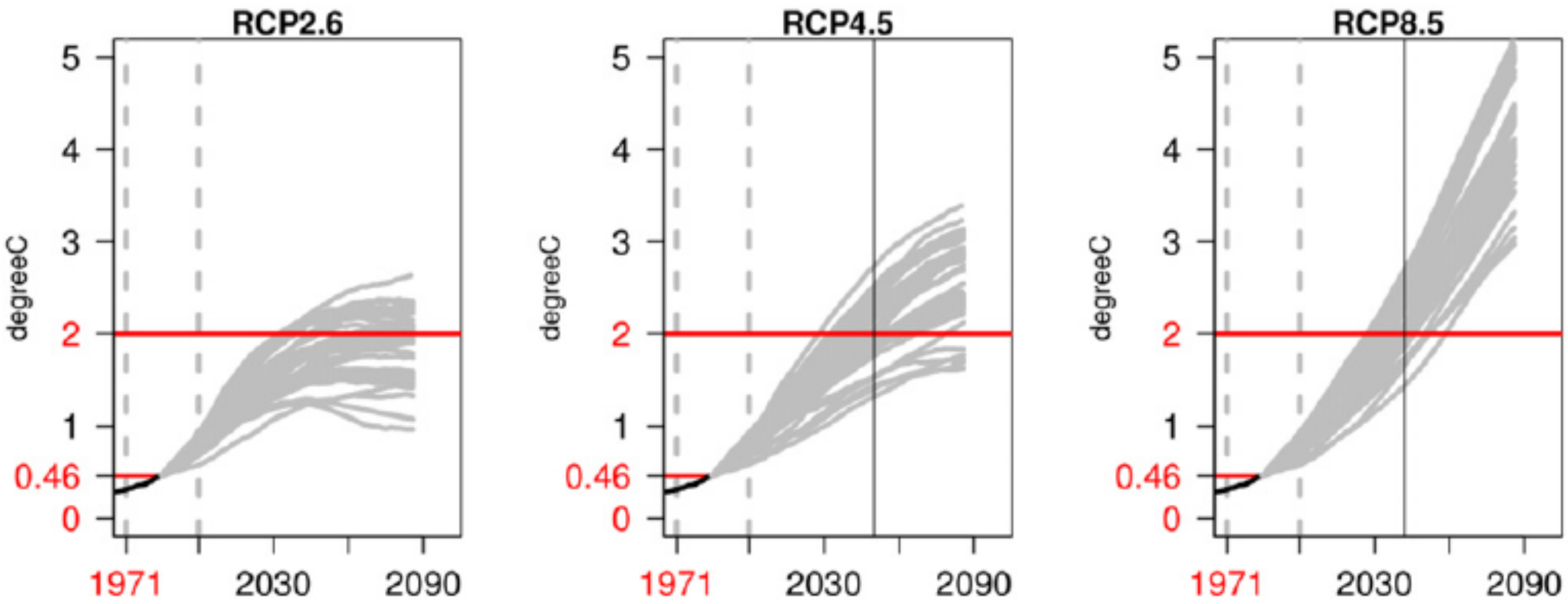
- **Reader on "Uncertainties of climate projections and how to derive robust climate change information", incl. good practise examples, will be provided: www.climate-service-center.de/eufiwacc**

Thank you for your attention.

When might we hit 2° C?

wrt pre-industrial

EU project **IMPACT2C** Quantifying projected impacts under 2°C warming
http://impact2c.hzg.de

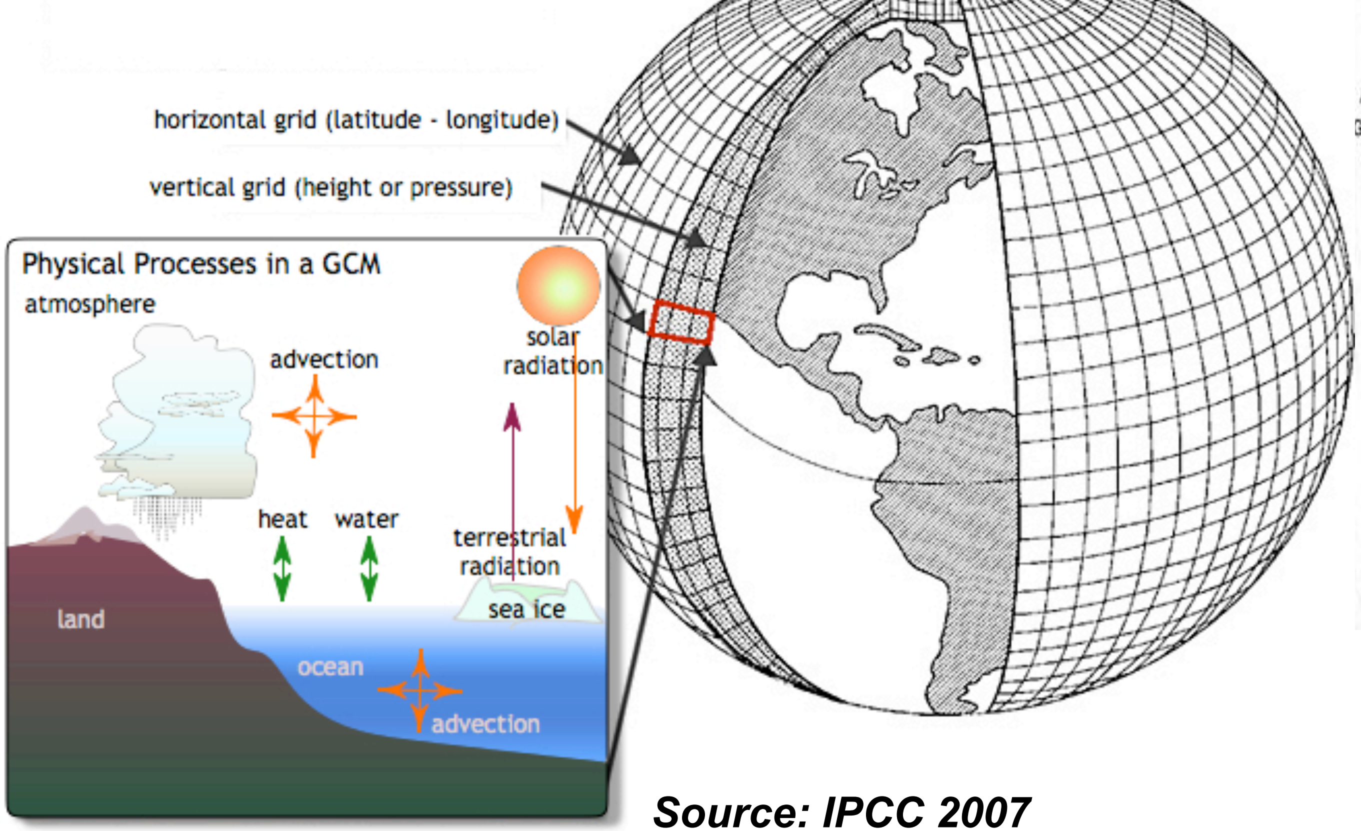


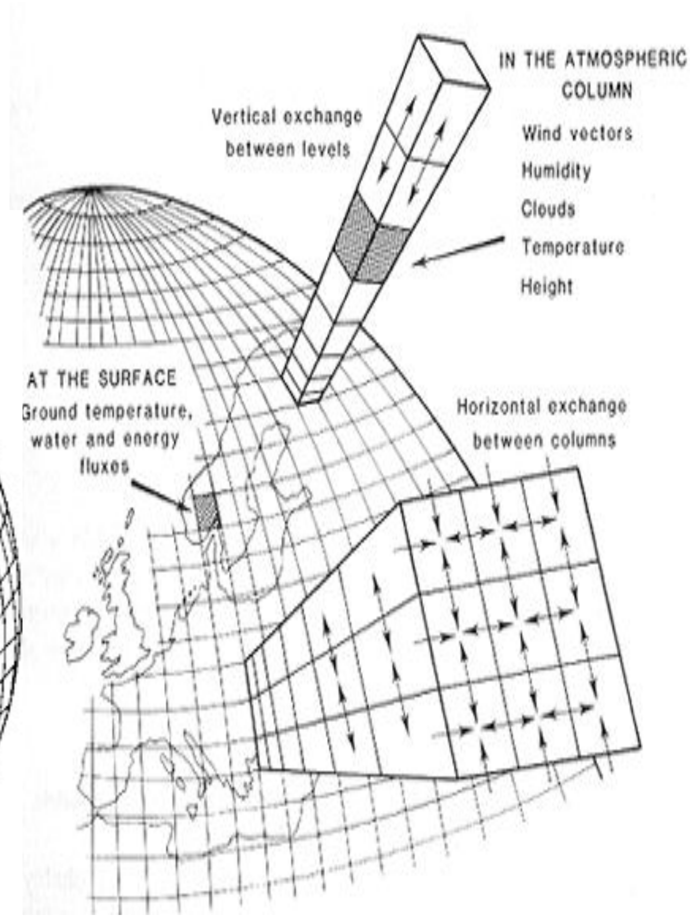
- Global mean warming of 2 °C will be reached by all simulations based on RCP8.5 between 2030 – 2060 - Apply model results at this threshold and study impact under 2°C

Vautard et al., 2014

Climate models

vertical: e.g. 90 atmospheric levels
horizontal: e.g. 200 x 400 cubes
time step: e.g. 20 minutes
e.g. 10 3D, 130 2D climate variables
integration for centuries ...

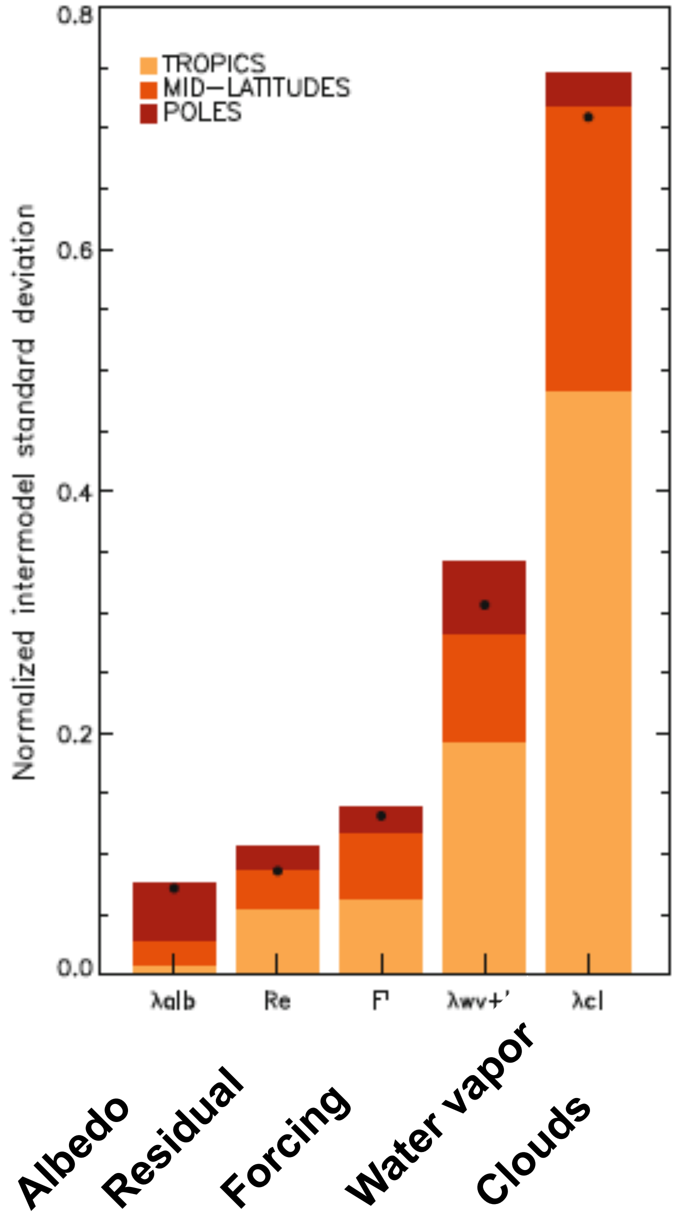




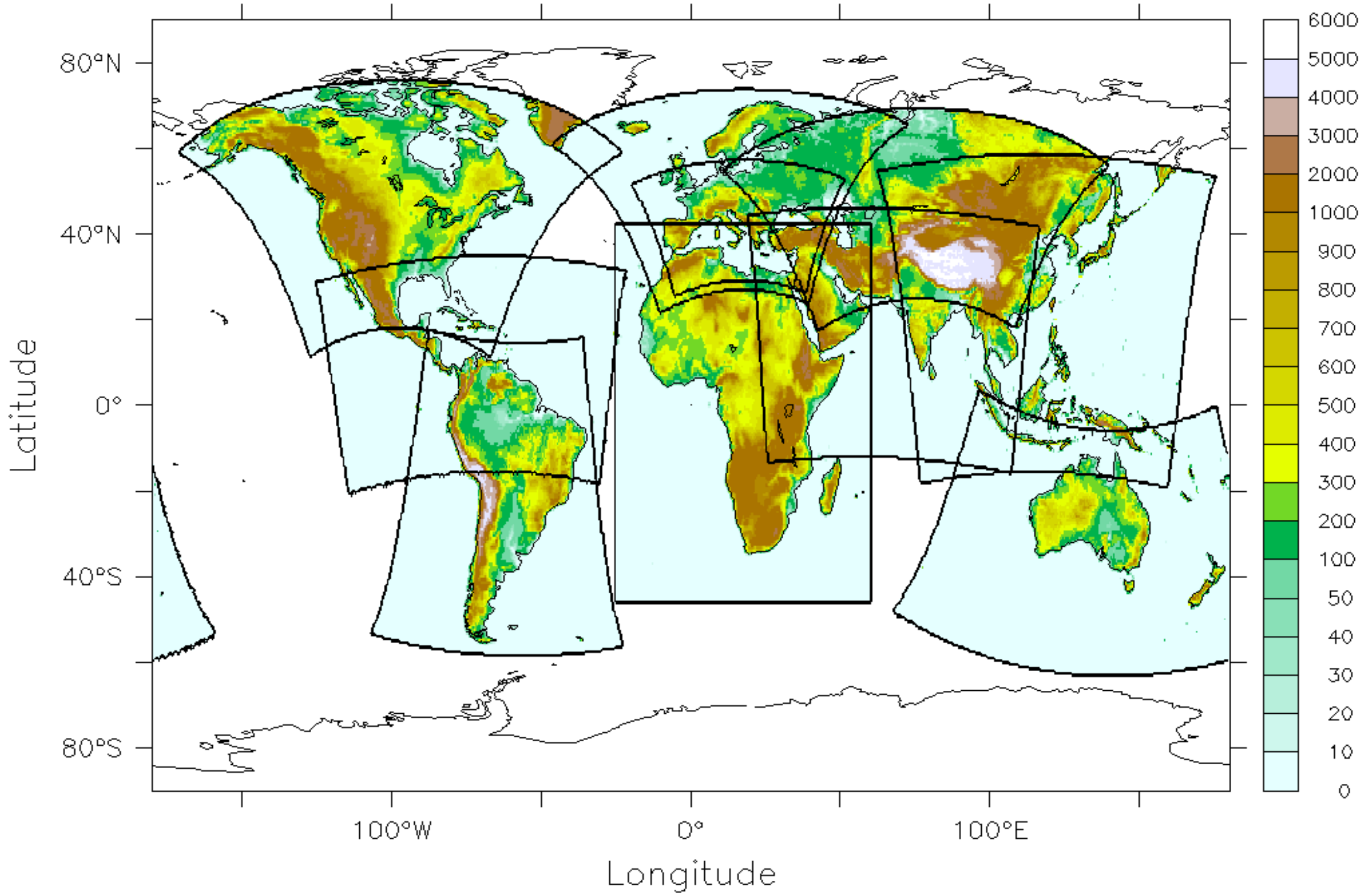
Source: IPCC 2007

Differential equations describing dynamics and physics in the climate system:
discretized on a 3-D grid, time dependent numerical solutions (Courant–Friedrichs–Lewy (CFL) condition necessary condition for stability)
and physical parameterisations for subscale processes

Contributions to inter-model spread in climate sensitivty



CORDEX
CORdinated Downscaling EXperiment



12 domains with a resolution of 0.44°x0.44° (approx. 50x50km²)

High resolution simulations with 0.11°x0.11° (approx. 12x12km²) for Europe

Orography of CORDEX model domains in [m] (except for the Arctic and Antarctica)
CORDEX data available via Earth System Grid Federation ESGF: http://esgf-data.dkrz.de/esgf-web-fe/

REMO @ MPI-M & CSC

WCRP CORDEX

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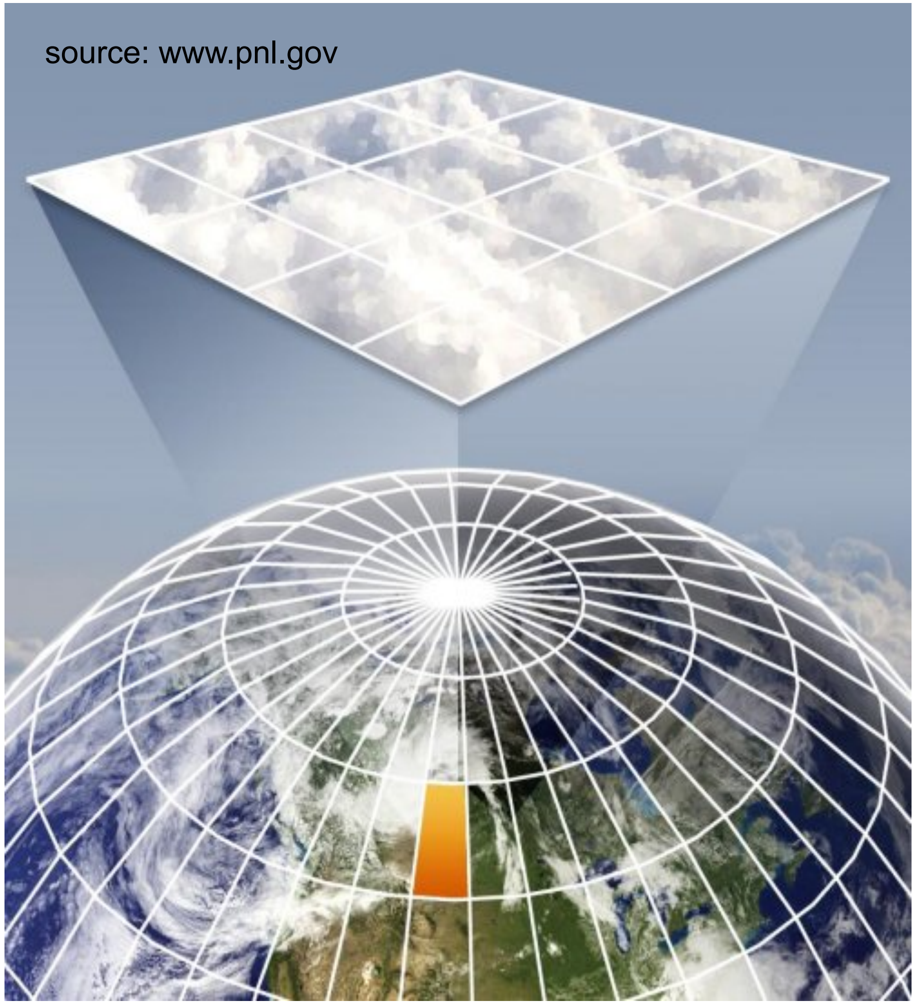
Relevance of high resolution modelling

Essential if coarse resolution simulations are a priori implausible:

- regions with small irregular land masses and complex coastlines
- areas of complex topography
- areas with heterogeneous landscapes
- areas where resolving meso-scale atmospheric phenomena is critical to reproducing important features of the climate (e.g. monsoon)



Type of needed information:

Some climate variables and indices are more sensitive to model resolution than others, e.g.

- temperature vs. precipiaton
- extremes vs means

See also: Mearns et al., 2003, Guidelines for Use of Climate Scenarios Developed from Regional Climate Model Experiments

Climate information on different spatial scales and spatial context of the project

1) Global integrated assessments:
Global General Circulation Models

2) National or continental scale assessments:
Global General Circulation Models
Regional Climate Models, on e.g. ~50 km

3) Regional (subcontinental) assessment:
Regional Climate Models, on ~50 km to ~10 km

4) Local assessment:
(Non-hydrostatic) Regional Climate Models on ~1 km to ~100 m
Statistical downscaling
Combined approaches of dynamic and statistical downscaling

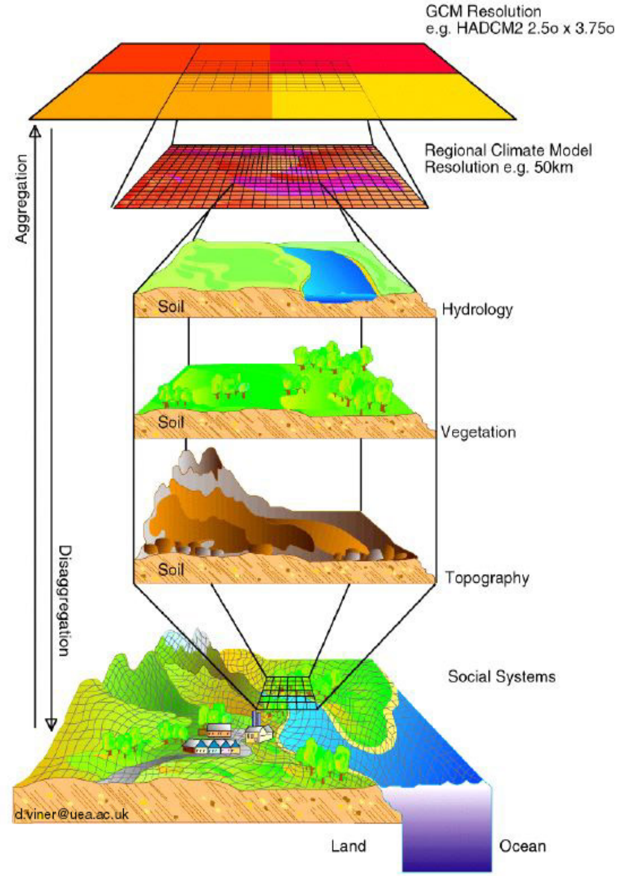


Figure source: David Viner, CRU, University of East Anglia, UK