IPCC Chapter 12: Long-term climate change: projections, commitments and irreversibility

- Introduction and Background *(from Chapter 10 and 11)*
- Climate Model Ensembles and Uncertainties *(Section 12.2)*
- Projected Climate Change over the 21st Century *(Section 12.4)*
- Executice Summary *(Ch. 12)*

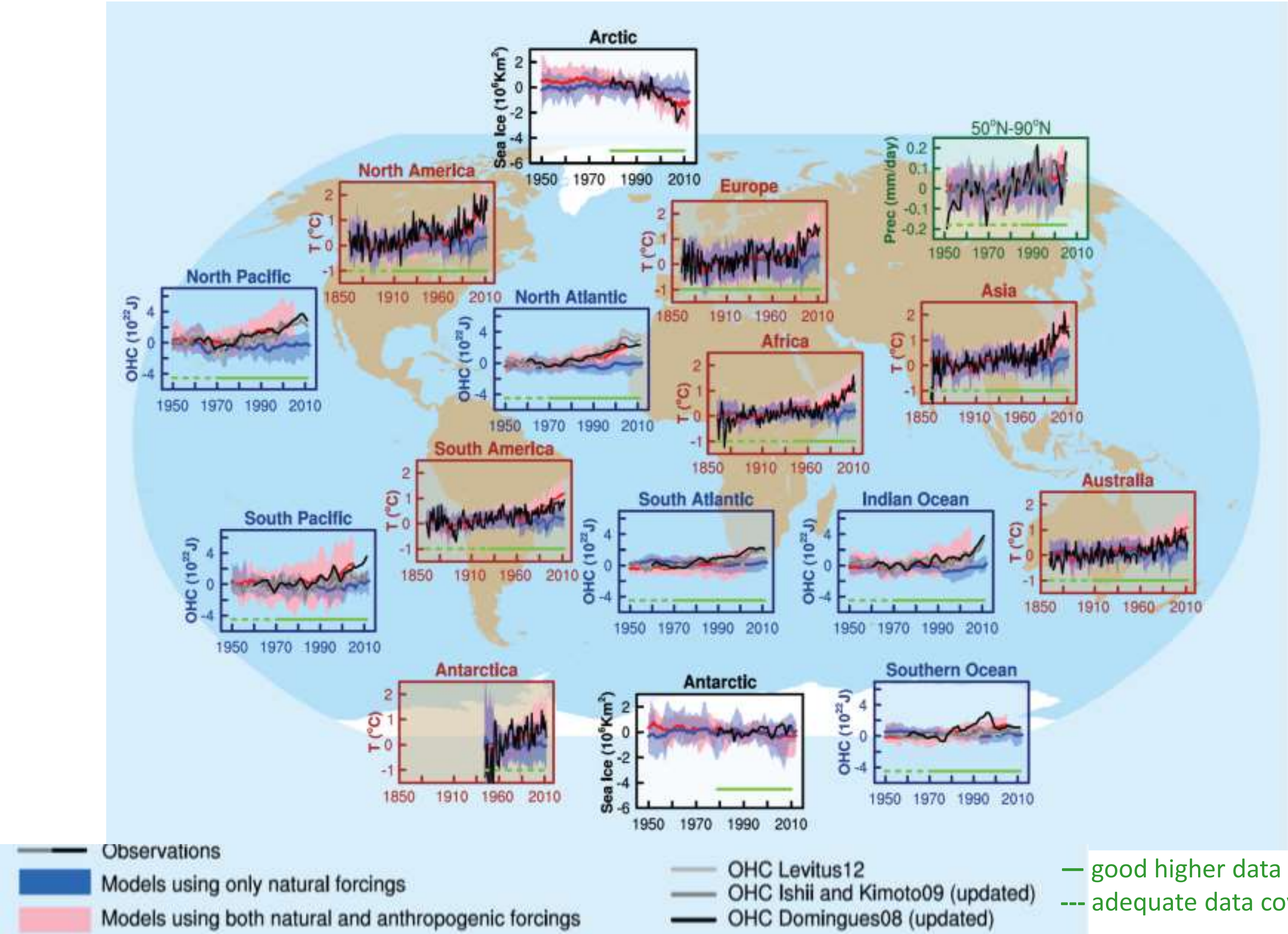
Collins, M.,et al., 2013: Long-term Climate Change: Projections, Commitments and Irreversibility. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press,.

Chapter 12: Long-term climate change …

This chapter assesses climate projections on time scales beyond those covered in Chapter 11, that is, beyond the mid-21st century.

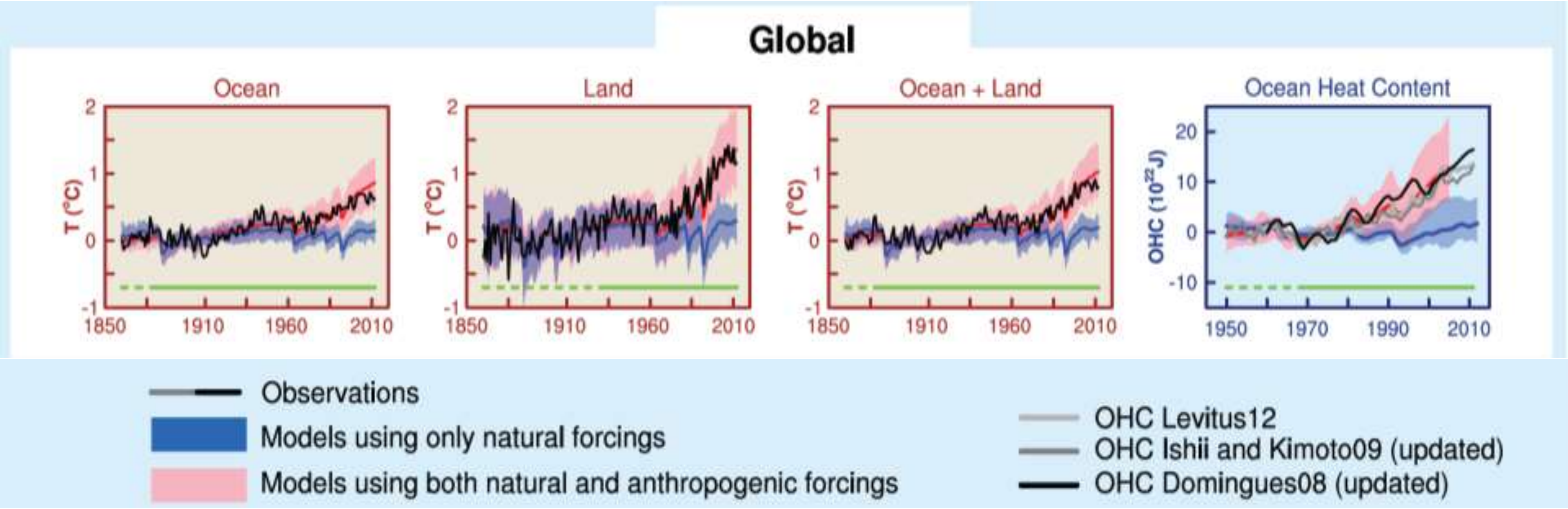
- **No** deterministic, definitive **prediction of** how **climate** will evolve over the next century and beyond **is possible** (in contrast to weather forecast).
- **Projections of climate change are uncertain**, because: 1) they depend on uncertain future forcing scenarios, 2) of incomplete understanding and imprecise models of the climate system, 3) the existence of internal climate variability **→term "climate projection"**.
- However, it is possible to **understand future climate change using models** and to **use models** to **characterize outcomes and uncertainties** under specific assumptions about future forcing scenarios.
- **New in contrast to AR4**: new RCP scenarios, new model developments, higher spatial resolution, new types of model experiments, baseline period now 1986-2005, climate change scenarios beyond 21 century.

Detection and Attribution Signals



— good higher data coverage
--- adequate data coverage

Detection and Attribution Signals



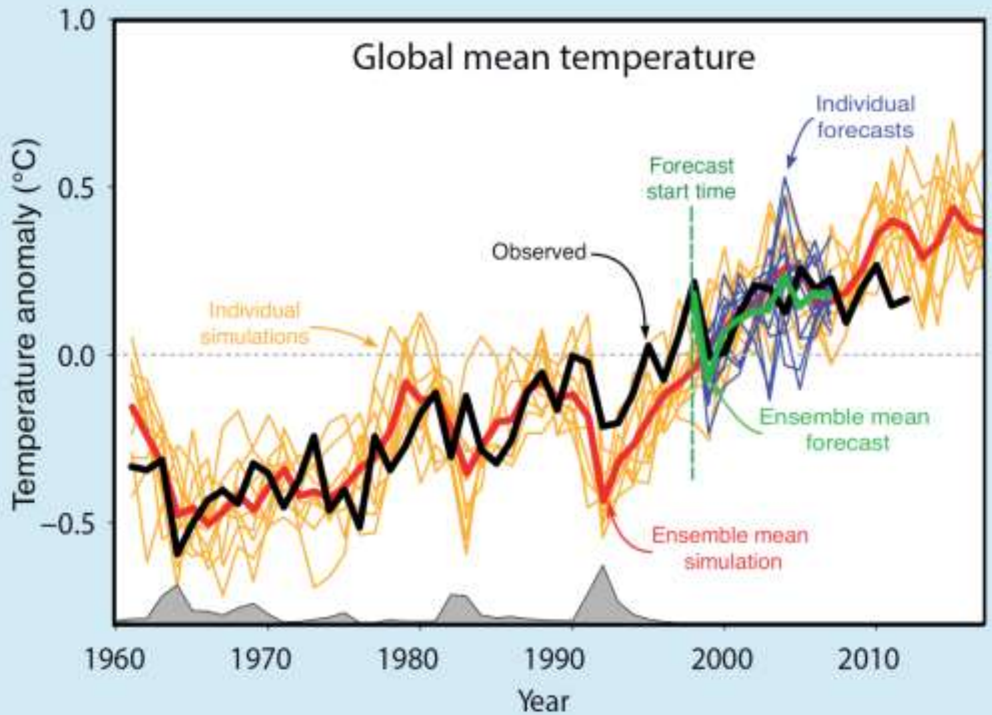
— >50% / good higher data coverage
--- <50% / adequate data coverage

Box 11.1 | Climate Simulation, Projection, Predictability and Prediction

This section outlines some of the ideas and the terminology used in this chapter.

Internally generated and externally forced climate variability

It is useful for purposes of analysis and description to consider the pre-industrial climate system as being in a state of climatic equilibrium with a fixed atmospheric composition and an unchanging Sun. In this idealized state, naturally occurring processes and interactions within the climate system give rise to 'internally generated' climate variability on many time scales (as discussed in Chapter 1). Variations in climate may also result due to features 'external' to this idealized system. Forcing factors, such as volcanic eruptions, solar variations, anthropogenic changes in the composition of the atmosphere, land use change etc., give rise to 'externally forced' climate variations. In this sense climate system variables such as annual mean temperatures (as in Box 11.1, Figure 1 for instance) may be characterized as a combination of externally forced and internally generated components with $T(t) = T_f(t) + T_i(t)$. This separation of T, and other climate variables, into components is useful when analysing climate behaviour but does not, of course, mean that the climate system is linear or that externally forced and internally generated components do not interact.



Climate simulation

A climate simulation is a model-based representation of the temporal behaviour of the climate system under specified external forcing and boundary conditions. The result is the modelled response to the imposed external forcing combined with internally generated variability. The thin yellow lines in Box 11.1, Figure 1 represent an ensemble of climate simulations begun from pre-industrial conditions with imposed historical external forcing. The imposed external conditions are the same for each ensemble member and differences among the simulations reflect differences in the evolutions of the internally generated component. Simulations are not intended to be forecasts of the observed evolution of the system (the black line in Box 11.1, Figure 1) but to be possible evolutions that are consistent with the external forcings.

In practice, and in Box 11.1, Figure 1, the forced component of the temperature variation is estimated by averaging over the different simulations of $T(t)$ with $T_f(t)$ the component that survives ensemble averaging (the red curve) while $T_i(t)$ averages to near zero for a large enough ensemble. The spread among individual ensemble members (from these or pre-industrial simulations) and their behaviour with time provides some information on the statistics of the internally generated variability. *(continued on next page)*

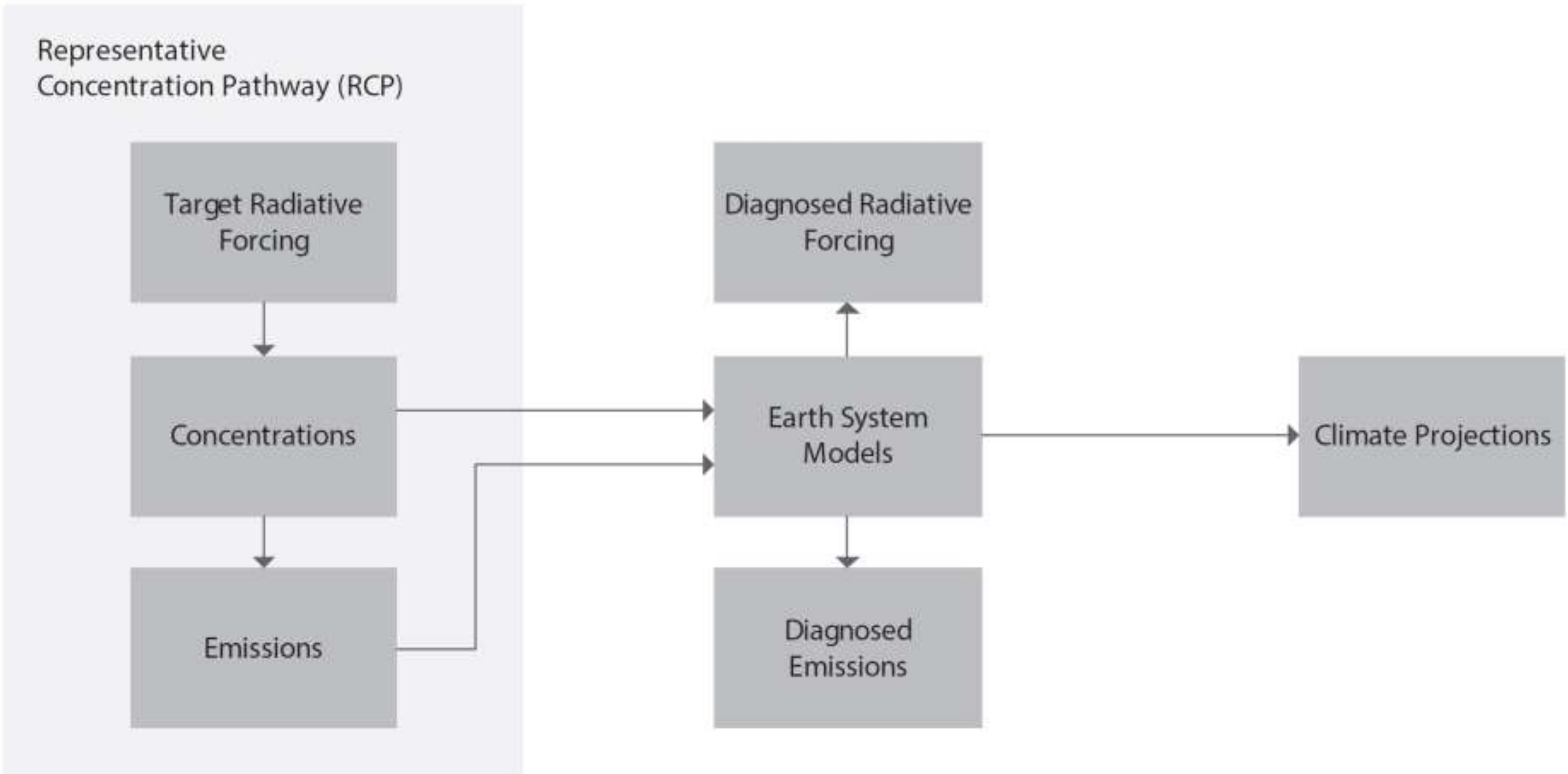
Climate projection

A climate projection is a climate simulation that extends into the future based on a scenario of future external forcing. The simulations in Box 11.1, Figure 1 become climate projections for the period beyond 2005 where the results are based on the RCP4.5 forcing scenario (see Chapters 1 and 8 for a discussion of forcing scenarios).

Climate prediction, climate forecast

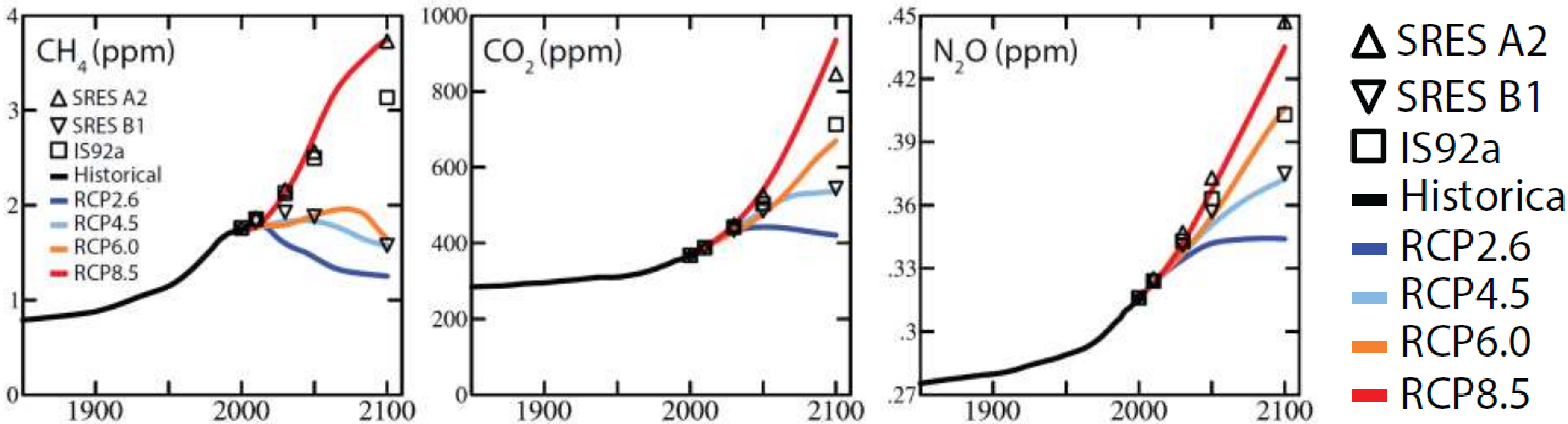
A climate prediction or climate forecast is a statement about the future evolution of some aspect of the climate system encompassing both forced and internally generated components. Climate predictions do not attempt to forecast the actual day-to-day progression of the system but instead the evolution of some climate statistic such as seasonal, annual or decadal averages or extremes, which may be for a particular location, or a regional or global average. Climate predictions are often made with models that are the same as, or similar to, those used to produce climate simulations and projections (assessed in Chapter 9). A climate prediction typically proceeds by integrating the governing equations forward in time from observation-based initial conditions. A decadal climate prediction combines aspects of both a forced and an initial condition problem as illustrated in Box 11.1, Figure 2. At short time scales the evolution is largely dominated by the initial state while at longer time scales the influence of the initial conditions decreases and the importance of the forcing increases as illustrated in Box 11.1, Figure 4. Climate predictions may also be made using statistical methods which relate current to future conditions using statistical relationships derived from past system behaviour.

Scenario-Model-Climate Projection Chain



Uncertainty propagates through the chain and results in a spread of ESM projections →spread is assessing projection uncertainty.

IPCC forcings for GHG

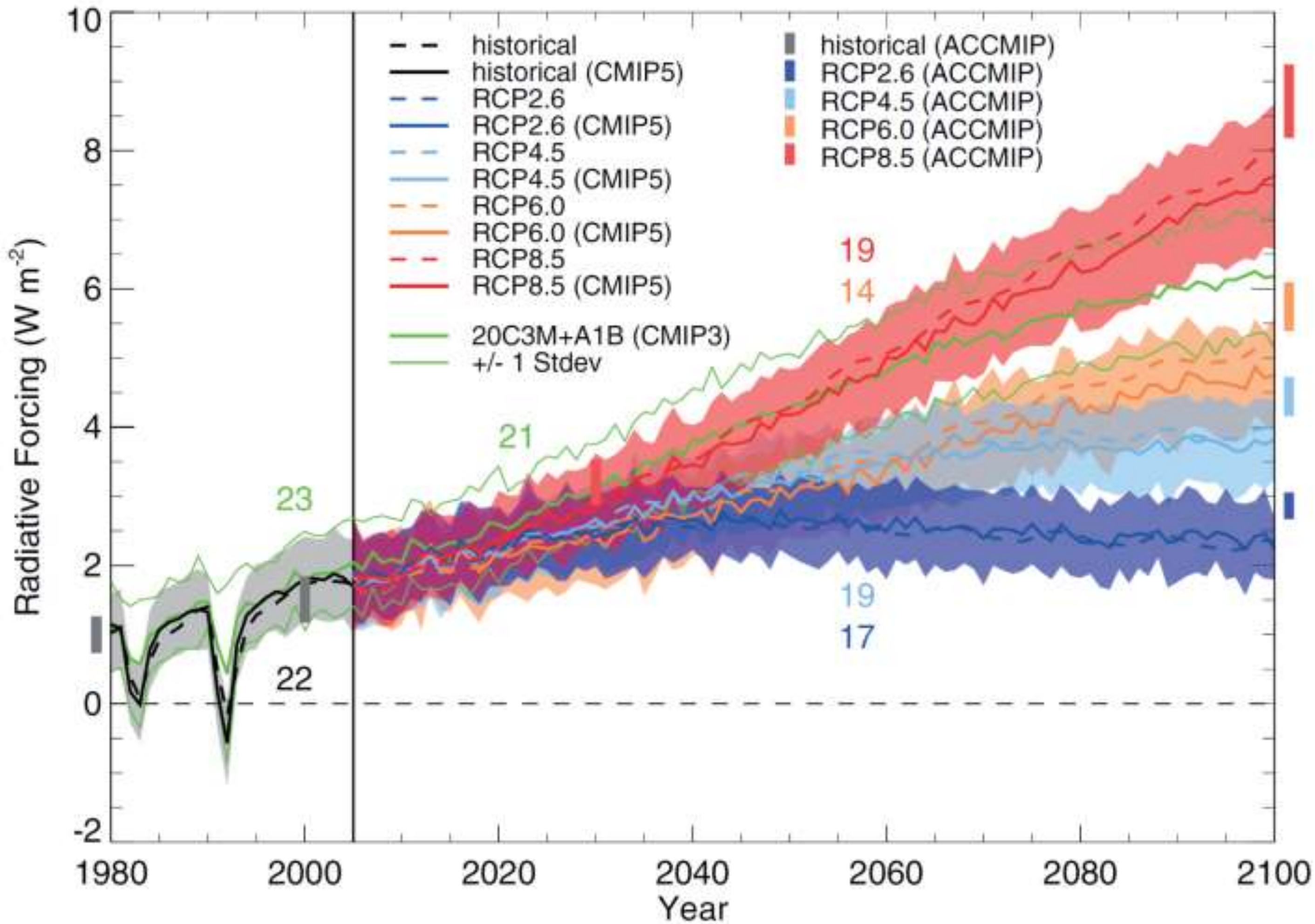


Meinshausen et al., 2011

Chapter 8 IPCC 2013 (www.climatechange2013.org)

SRES: Special Report on Emissions Scenarios (TAR, IPCC 2000)
RCP: Representative Concentration Pathway

Global Mean Radiative Forcing between 1980 and 2100



RCP: Representive Concentration Pathway, ACCMIP: Atmospheric Chemistry Climate Model Intercomparison Project

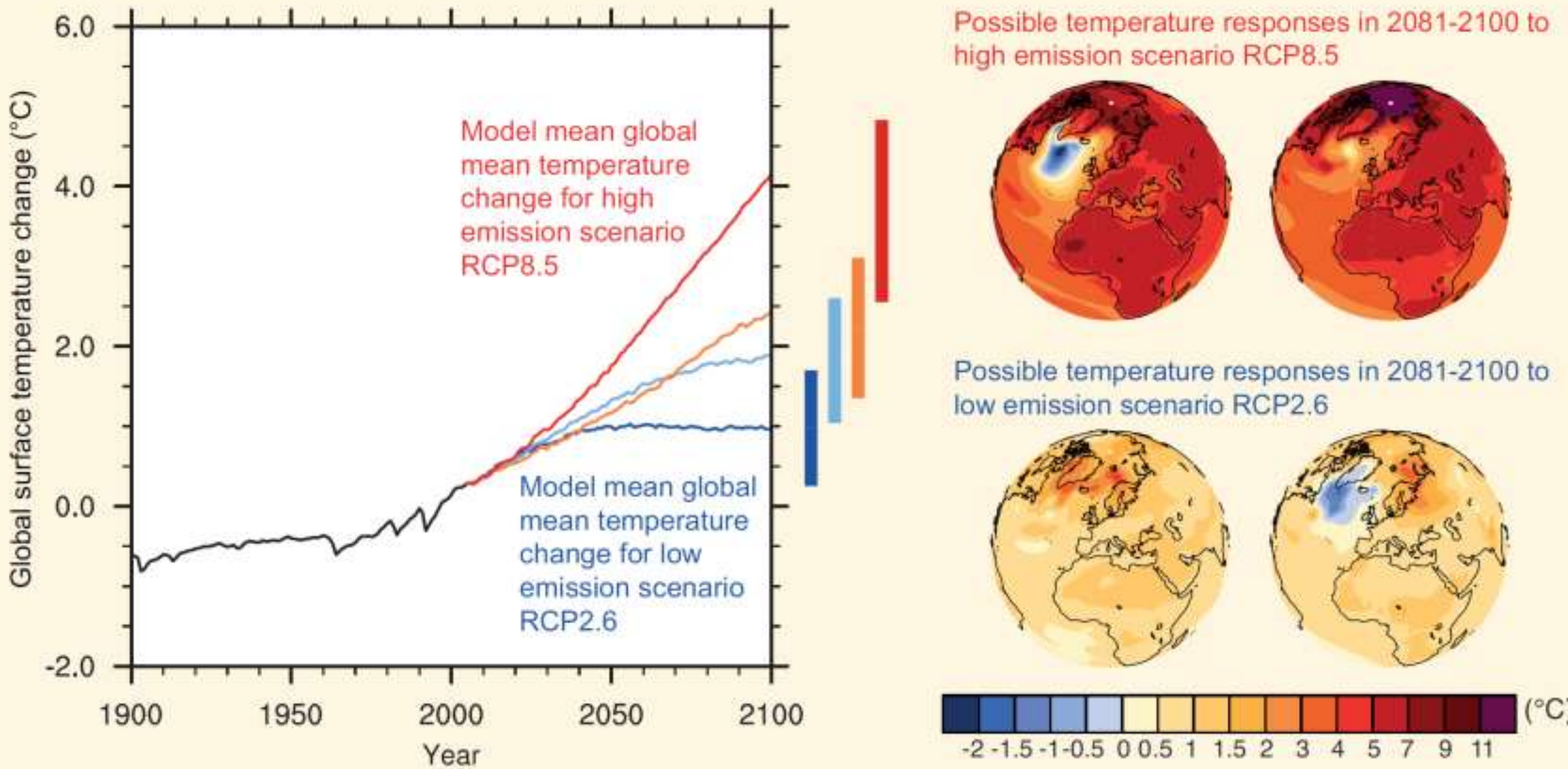
Frequently Asked Questions

FAQ 12.1 | Why Are So Many Models and Scenarios Used to Project Climate Change?

Future climate is partly determined by the magnitude of future emissions of greenhouse gases, aerosols and other natural and man-made forcings. These forcings are external to the climate system, but modify how it behaves. Future climate is shaped by the Earth's response to those forcings, along with internal variability inherent in the climate system. A range of assumptions about the magnitude and pace of future emissions helps scientists develop different emission scenarios, upon which climate model projections are based. Different climate models, meanwhile, provide alternative representations of the Earth's response to those forcings, and of natural climate variability. Together, ensembles of models, simulating the response to a range of different scenarios, map out a range of possible futures, and help us understand their uncertainties.

Frequently Asked Questions

FAQ 12.1 | Why Are So Many Models and Scenarios Used to Project Climate Change?



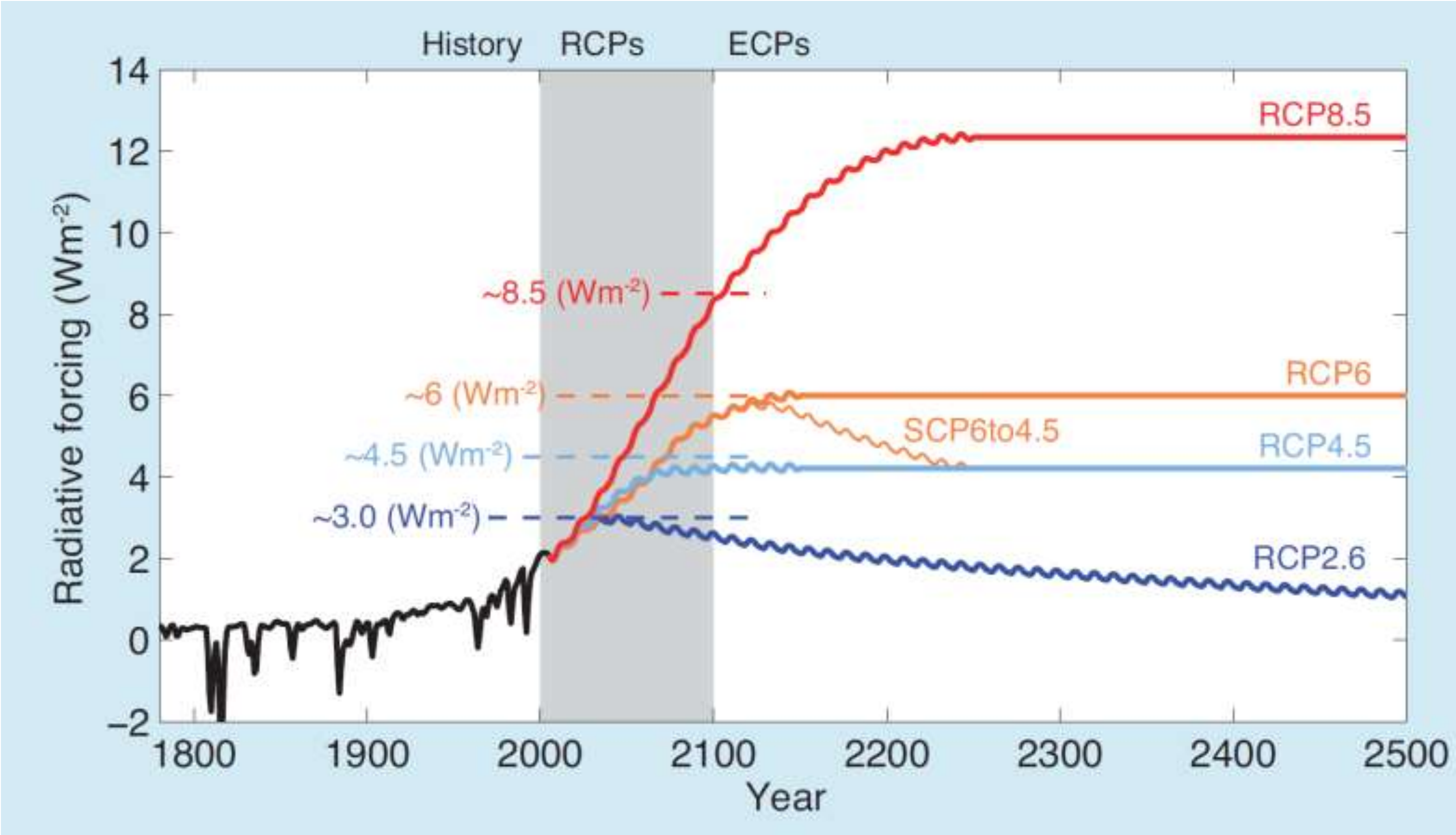
FAQ 12.1, Figure 1, right panels, shows the temperature response by the end of the 21st century for two illustrative models and the highest and lowest RCP scenarios. Models agree on large-scale patterns of warming at the surface, for example, that the land is going to warm faster than ocean, and the Arctic will warm faster than the tropics. But they differ both in the magnitude of their global response for the same scenario, and in small scale, regional aspects of their response. The magnitude of Arctic amplification, for instance, varies among different models, and a subset of models show a weaker warming or slight cooling in the North Atlantic as a result of the reduction in deepwater formation and shifts in ocean currents.

Chapter 12: Long-term climate change:
Projections, Commitments and Irreversibility

12.4 Projected Climate Change over the 21st Century

Atmosphere

RCP scenarios - RF

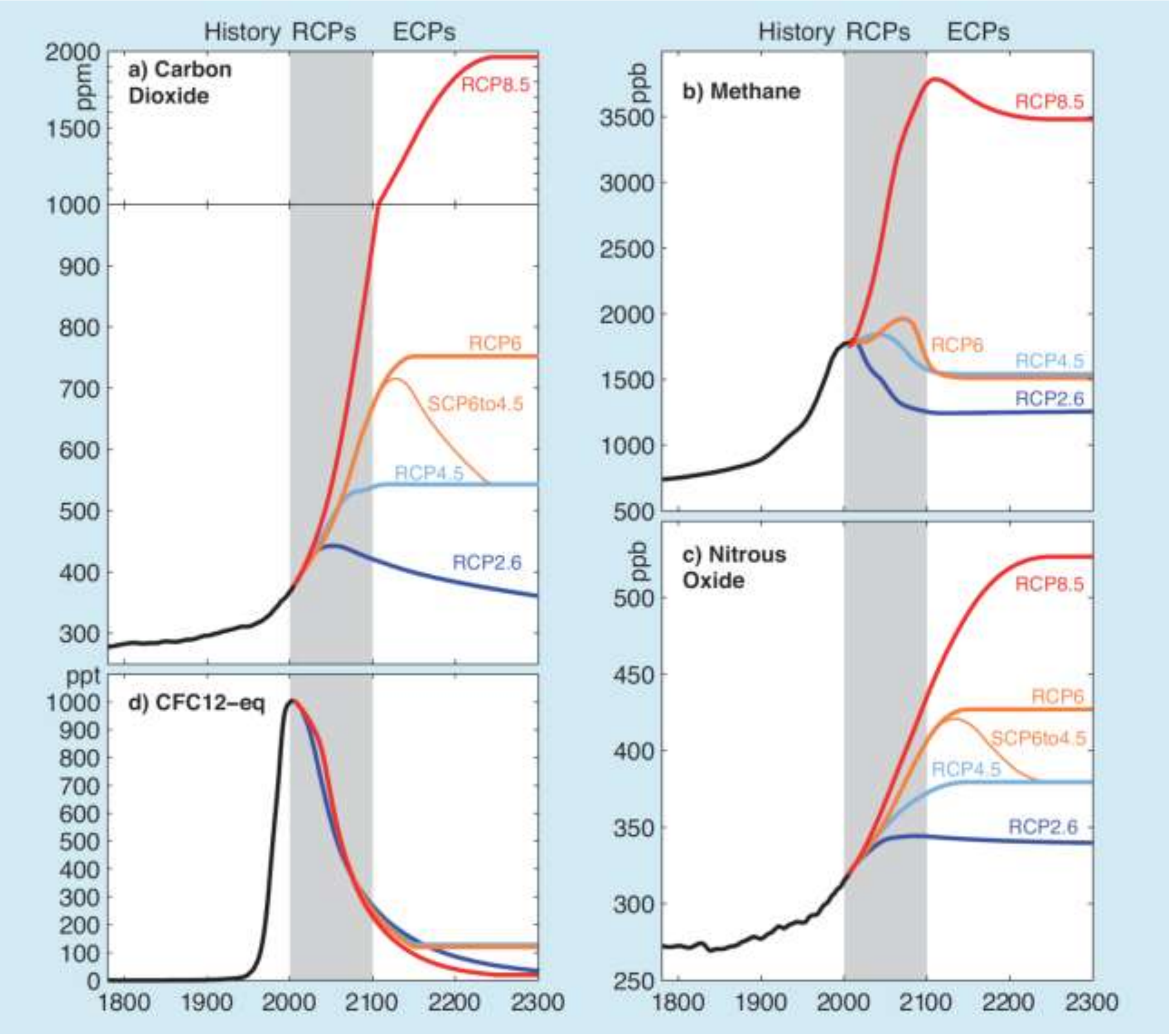


Chapter 1 IPCC 2013 (www.climatechange2013.org)

RCP: Representive Concentration Pathway, ECP: Extended Concentration Pathway

Recap

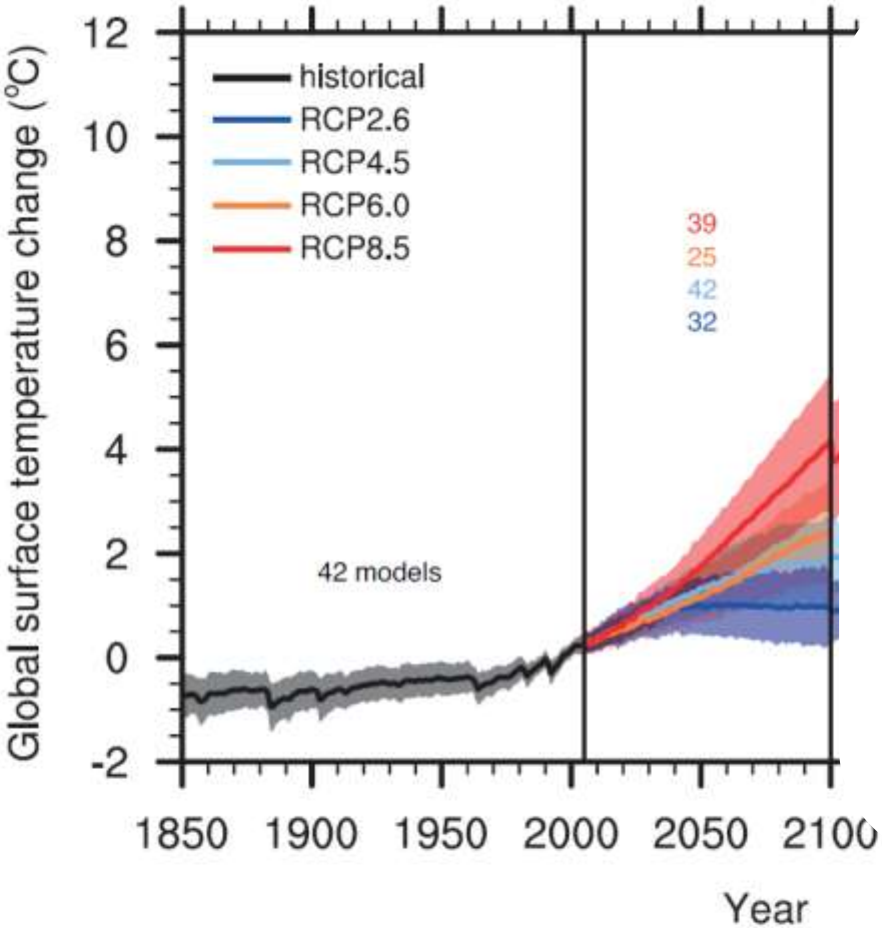
RCP scenarios - GHG



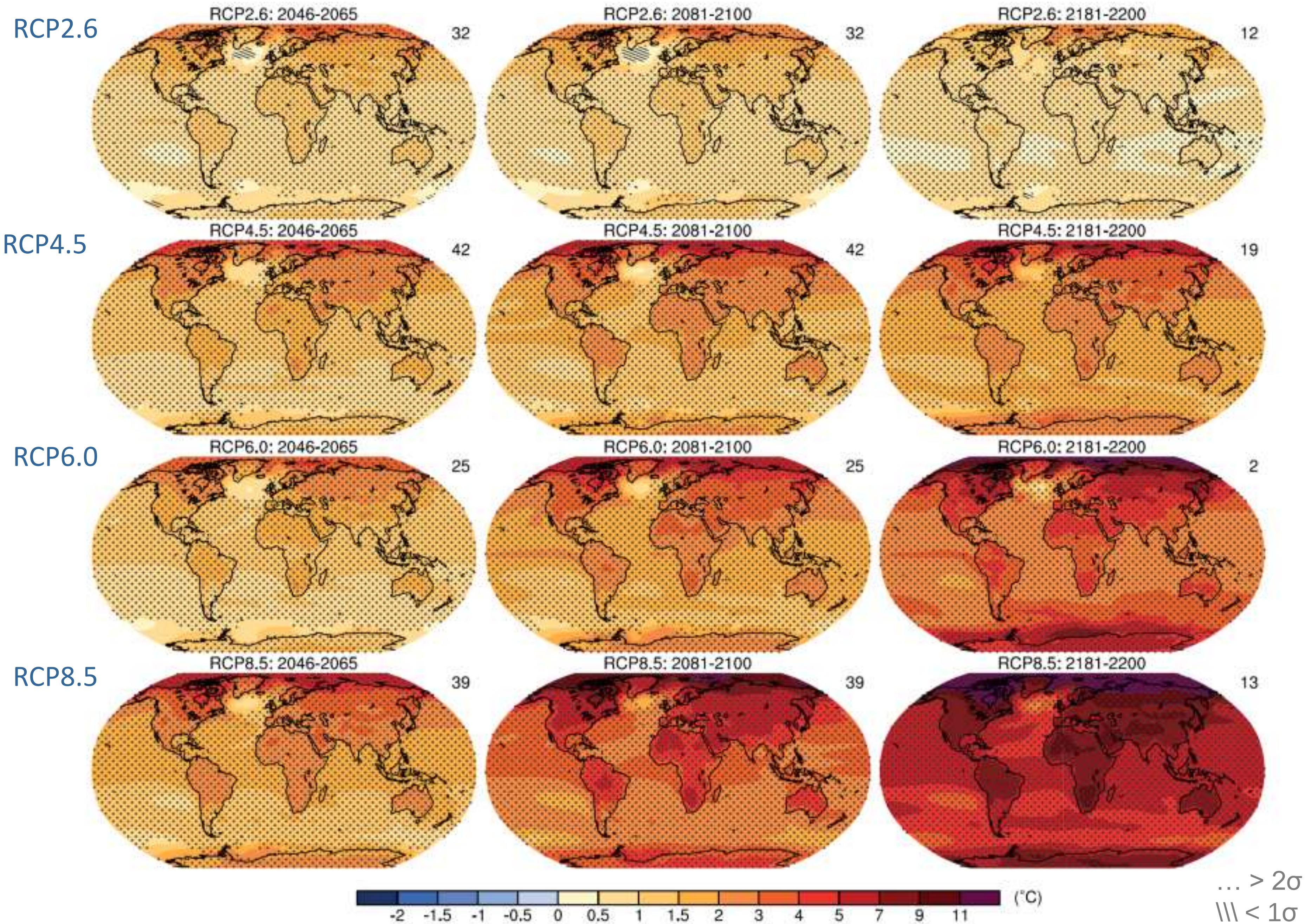
Chapter 1 IPCC 2013 (www.climatechange2013.org)

Projected climate change beyond the 21st century

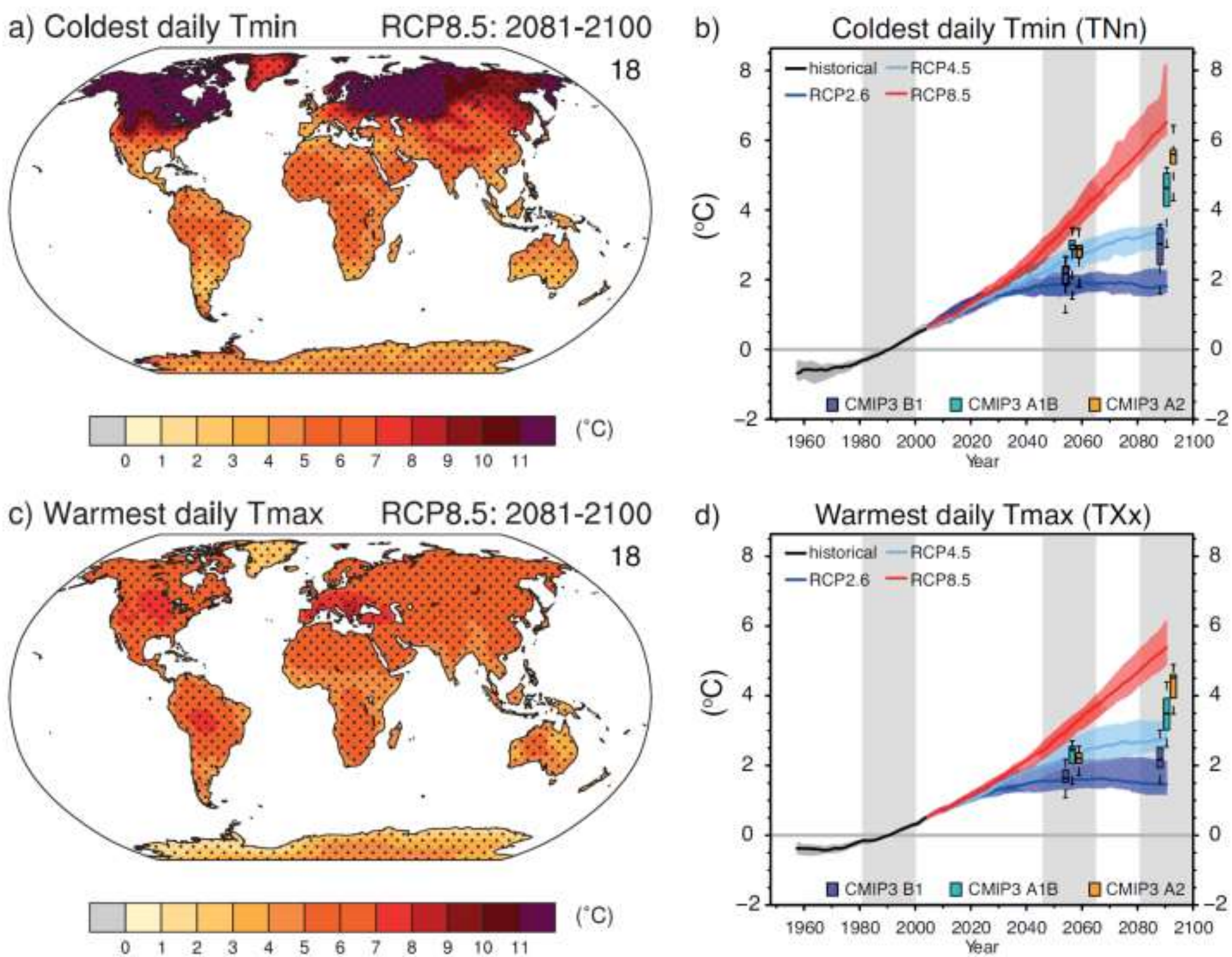
wrt 1986-2005, CMIP5 concentration-driven



Annual mean surface air temperature change



CMIP5 multi model mean changes
(wrt 1981-2000)



CMIP5 multi model mean changes
(wrt 1981-2000)

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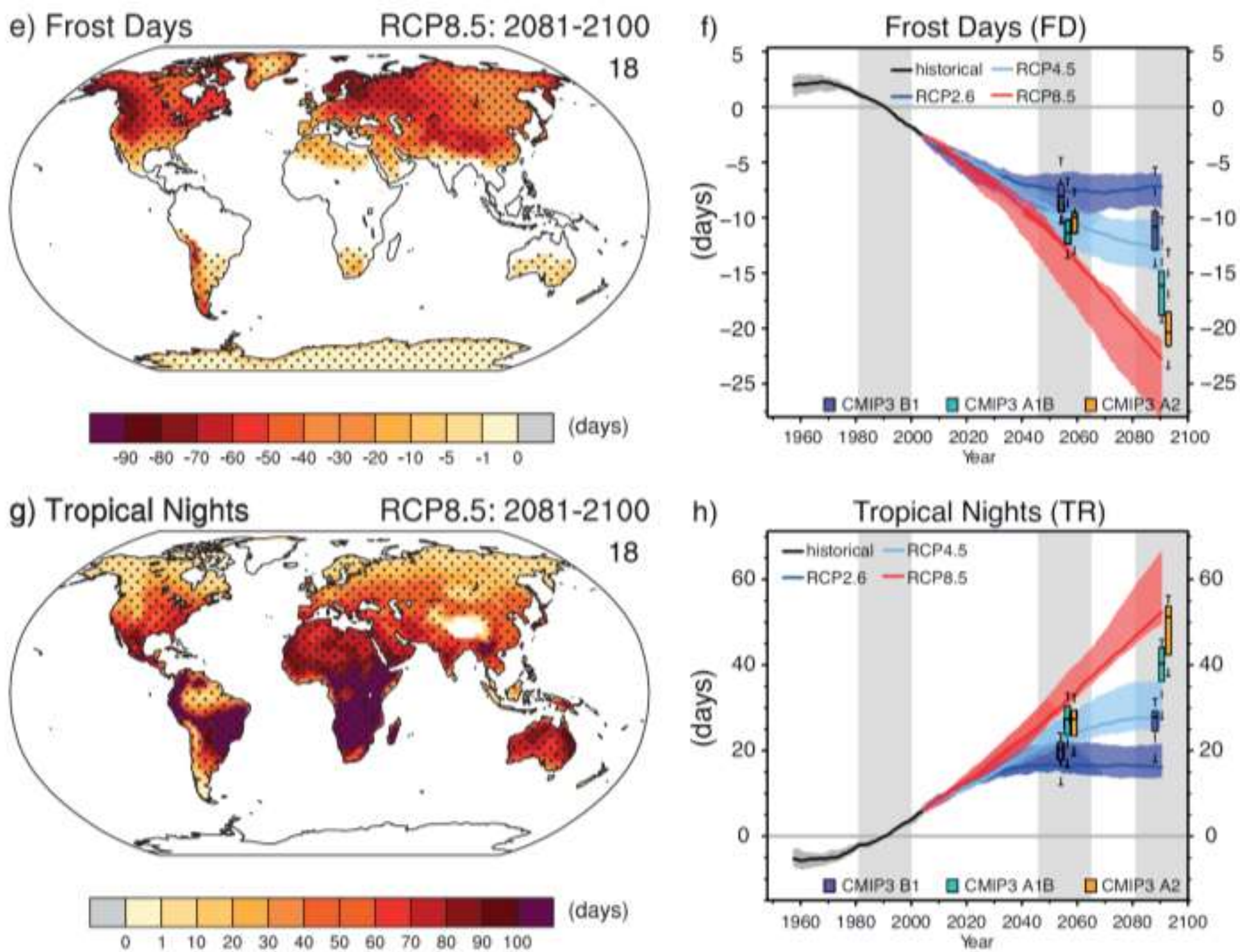
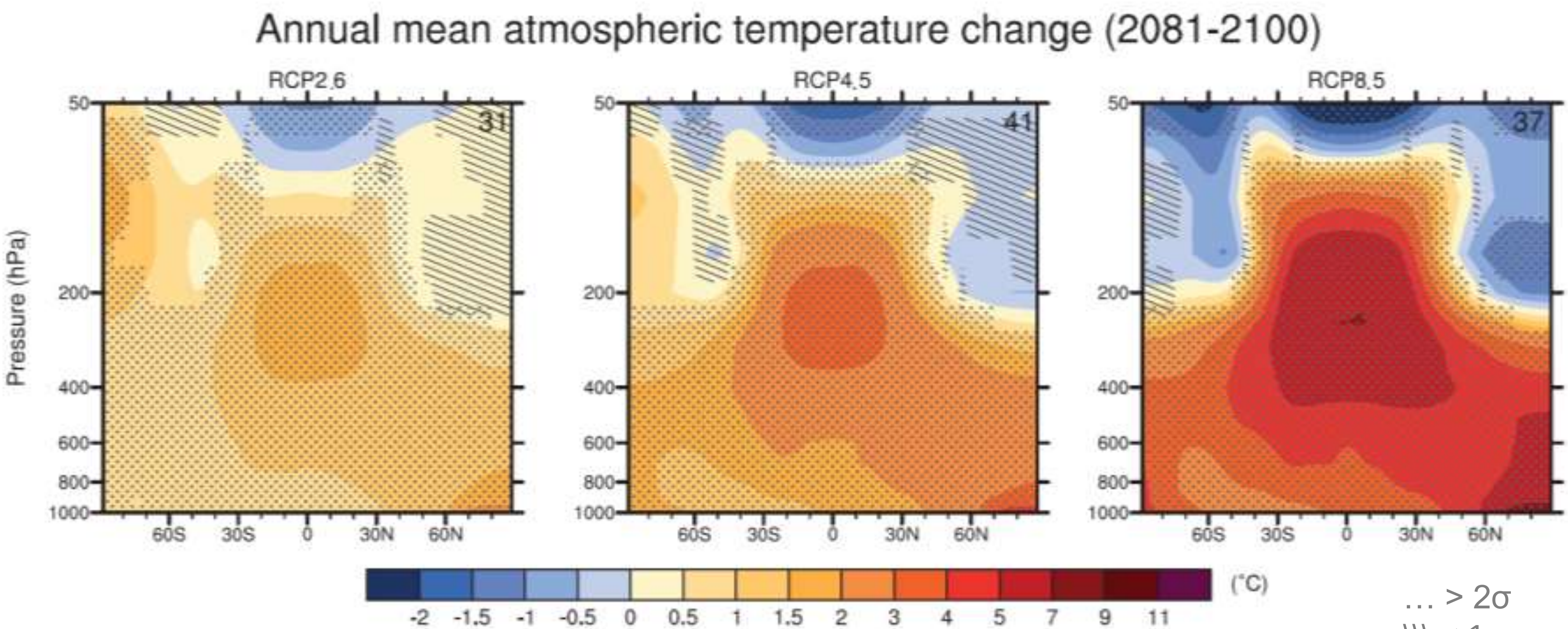
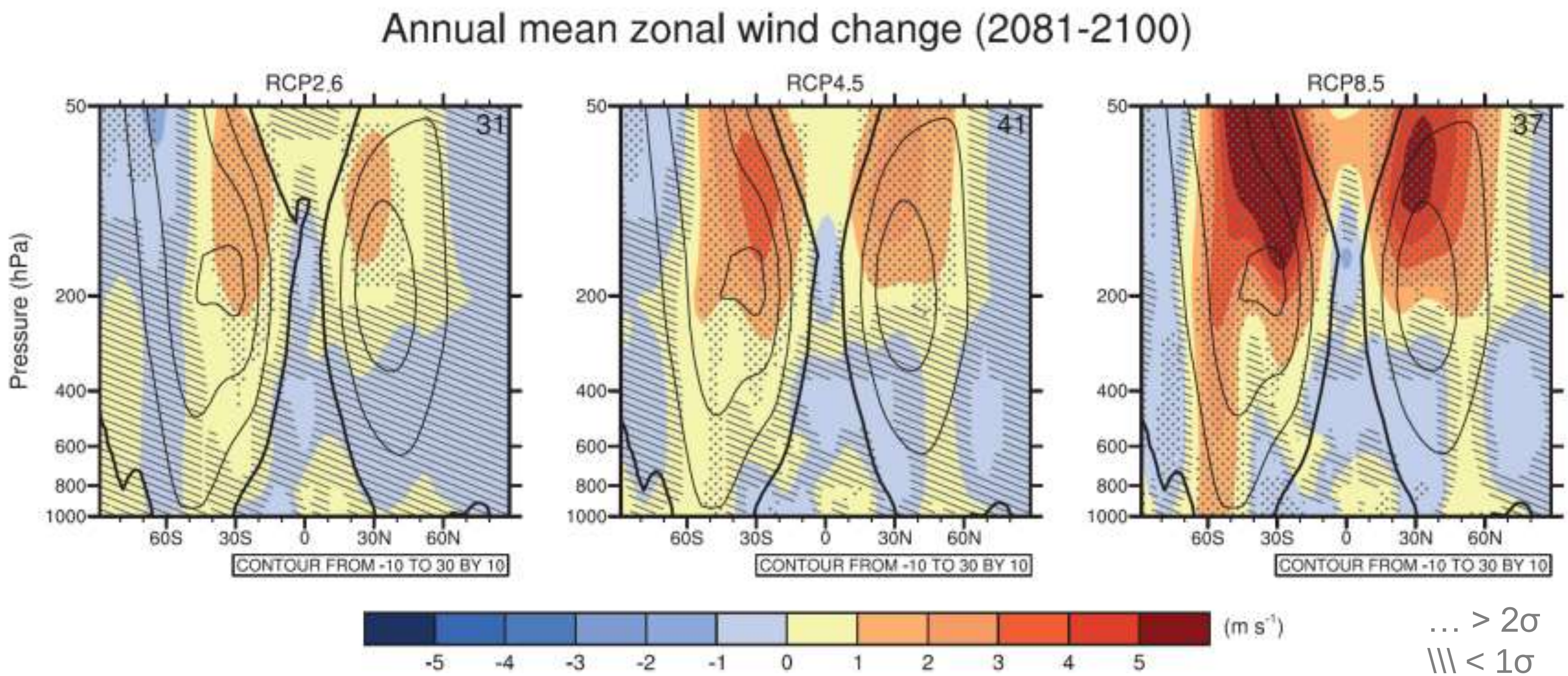


CMIP5 multi model mean changes
(wrt 1986-2005)



… > 2σ
\\\ < 1σ

CMIP5 multi model mean changes
(wrt 1986-2005)

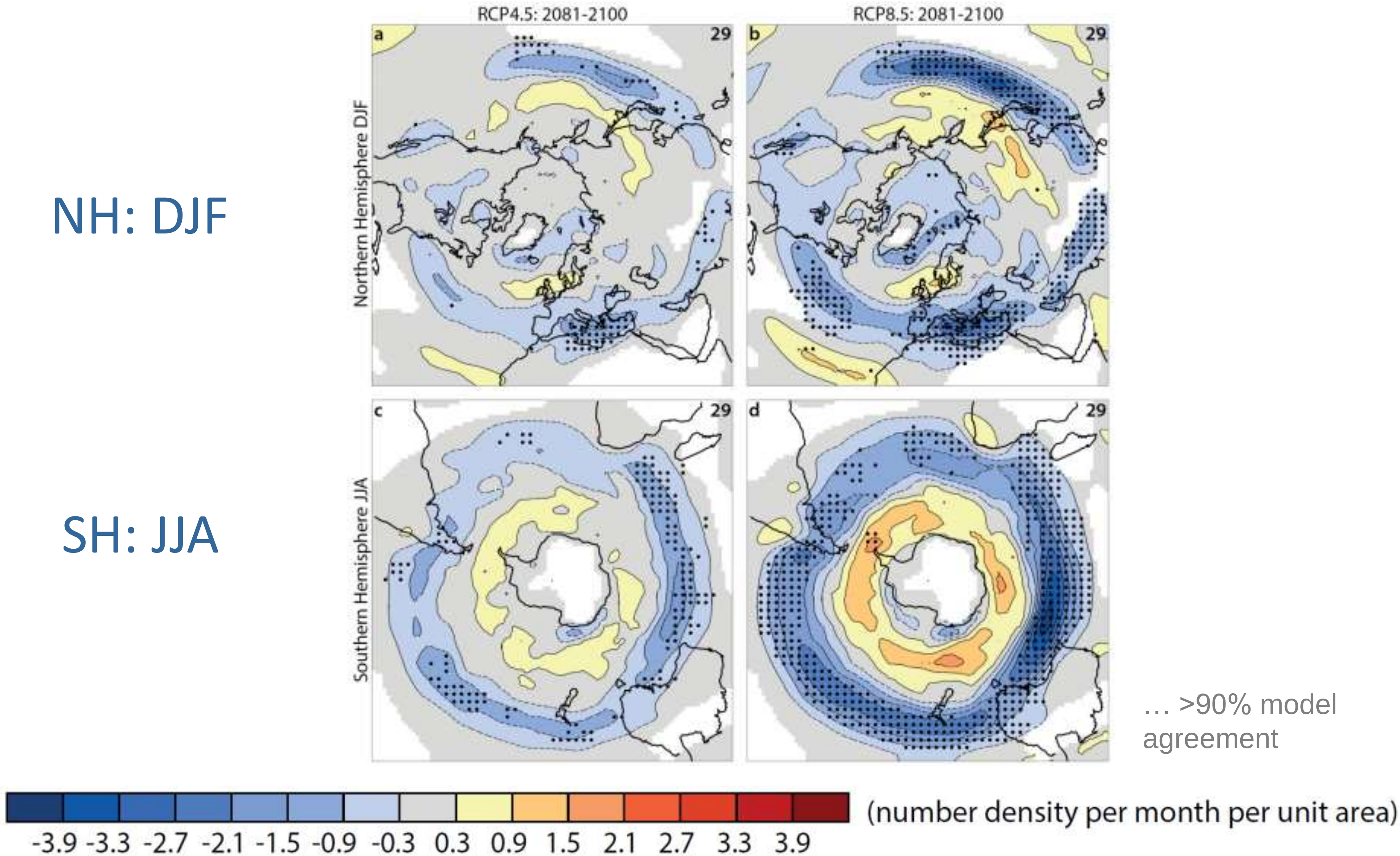


- Stronger changes in higher RCPs.
- Large increases in winds are evident in the tropical stratosphere.
- Poleward shift and intensification of SH tropospheric jet (RCP4.5/8.5) → increase in SH UT meridional temperature gradient.
- NH, the response of tropospheric jet is weaker and complicated due to additional thermal forcing of polar amplification.
- In RCP8.5 at the end of 2100: NH, the poleward shift is ~1°,;in the SH, poleward shift is by ~2°.
- A strengthening of the SH surface westerlies.

Change in winter, extratropical storm track density - CMIP5 MMM changes wrt 1986-2005

NH: DJF

SH: JJA

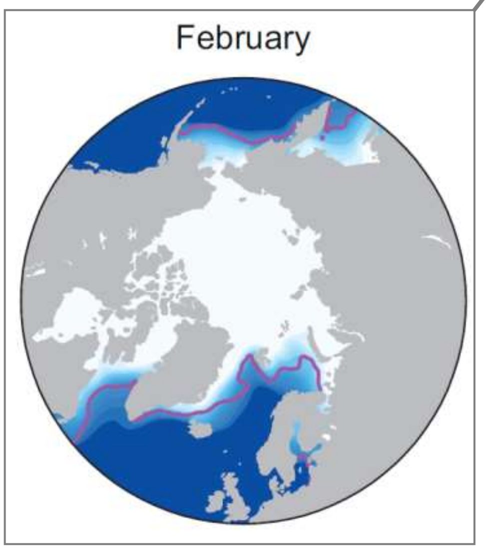


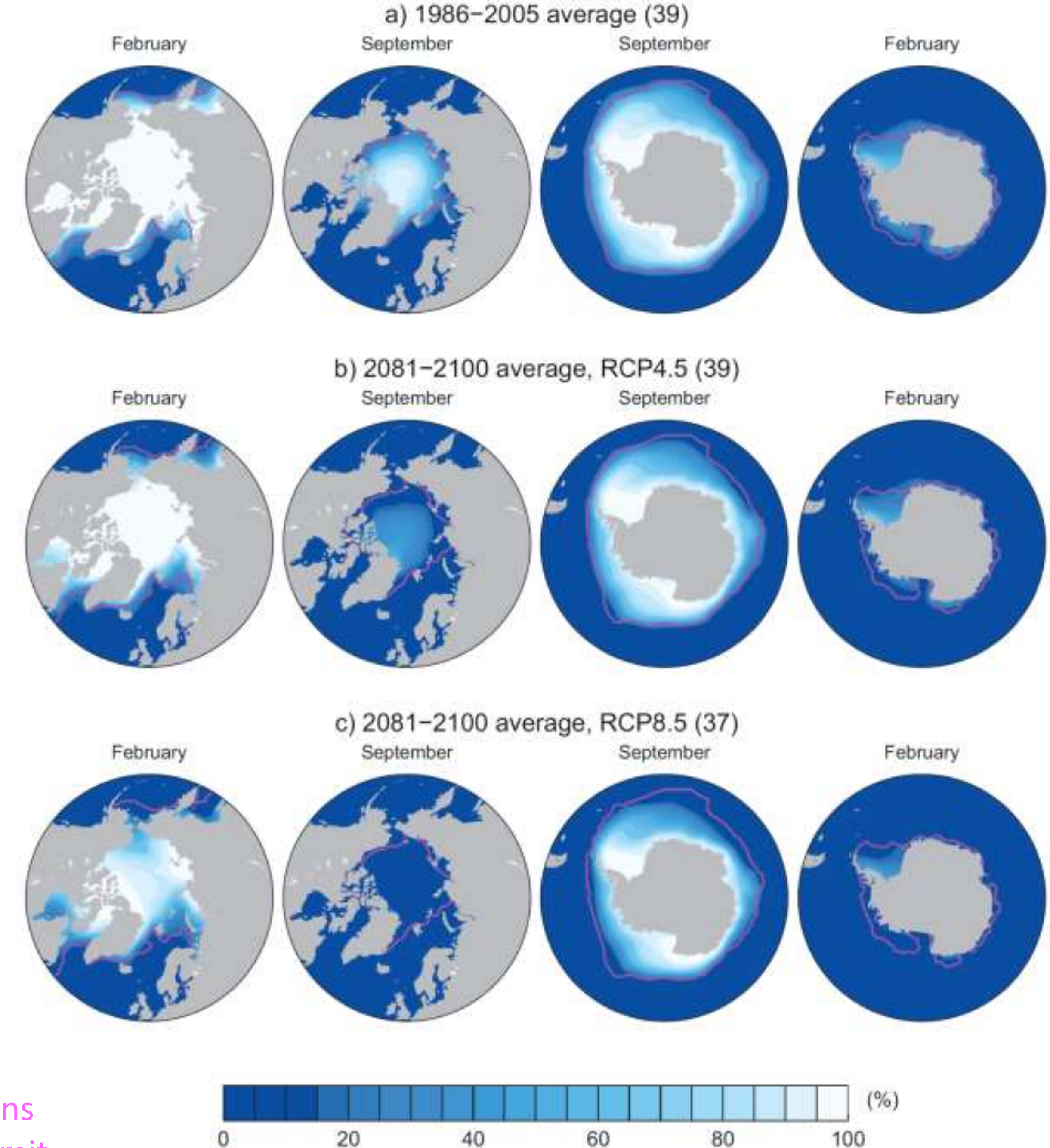
… >90% model agreement

Cryosphere

Sea ice concentration >15%

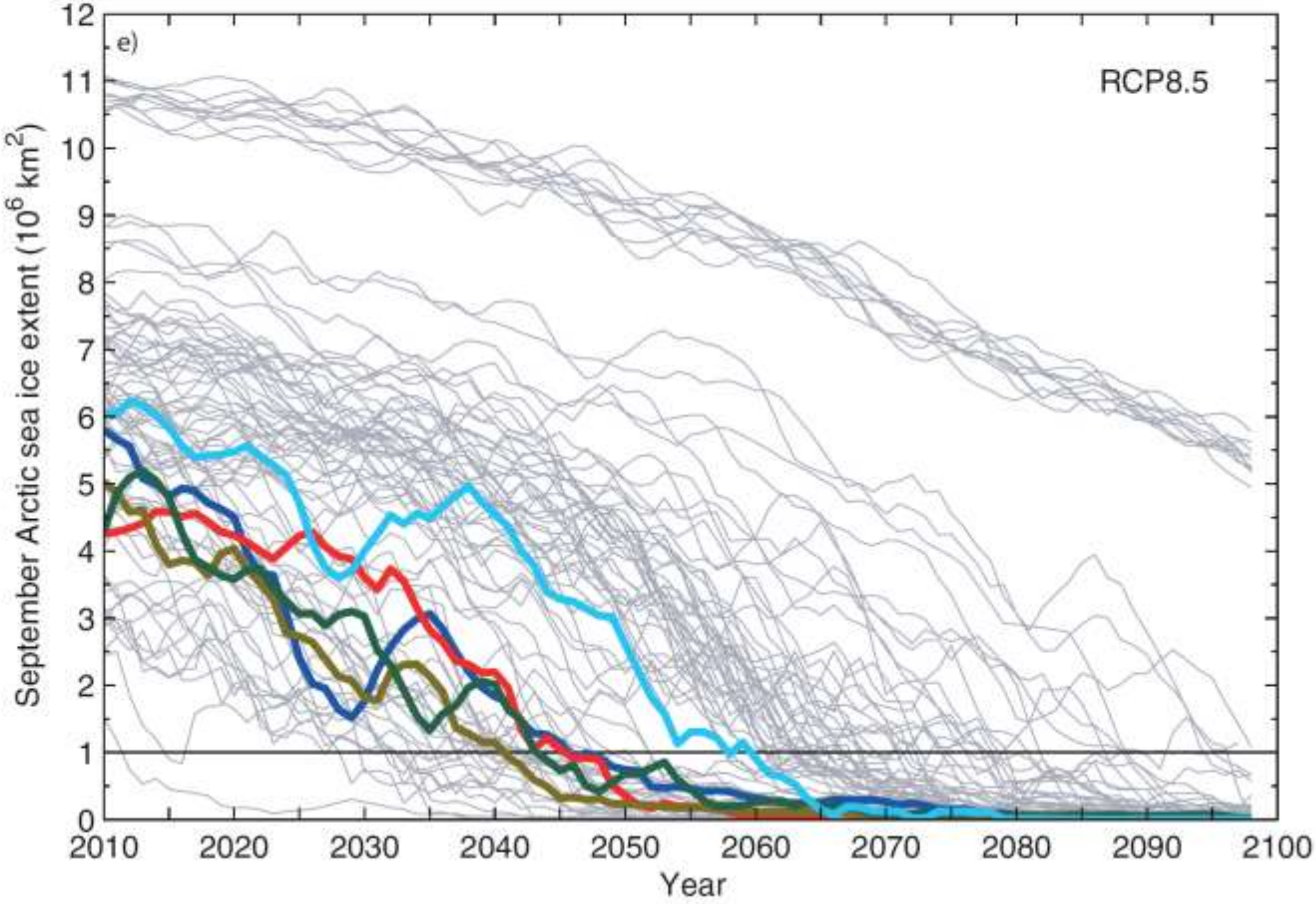
(in %) - CMIP5 MMM





—1986-2005 observations of 15% sea ice conc. limit

September Arctic sea ice extent-CMIP5 RCP8.5



Disappearance of the September Arctic sea ice remains wide: 2020–2100+ (2100+ = not before 2100) for the SRES A1B scenario and RCP4.5 (Stroeve et al., 2007, 2012; Boé et al., 2009b; Wang and Overland, 2009, 2012; Zhang, 2010b; Massonnet et al., 2012) and 2020–2060 for RCP8.5 (Massonnet et al., 2012; Wang and Overland, 2012).