Climate Change and Uncertainty

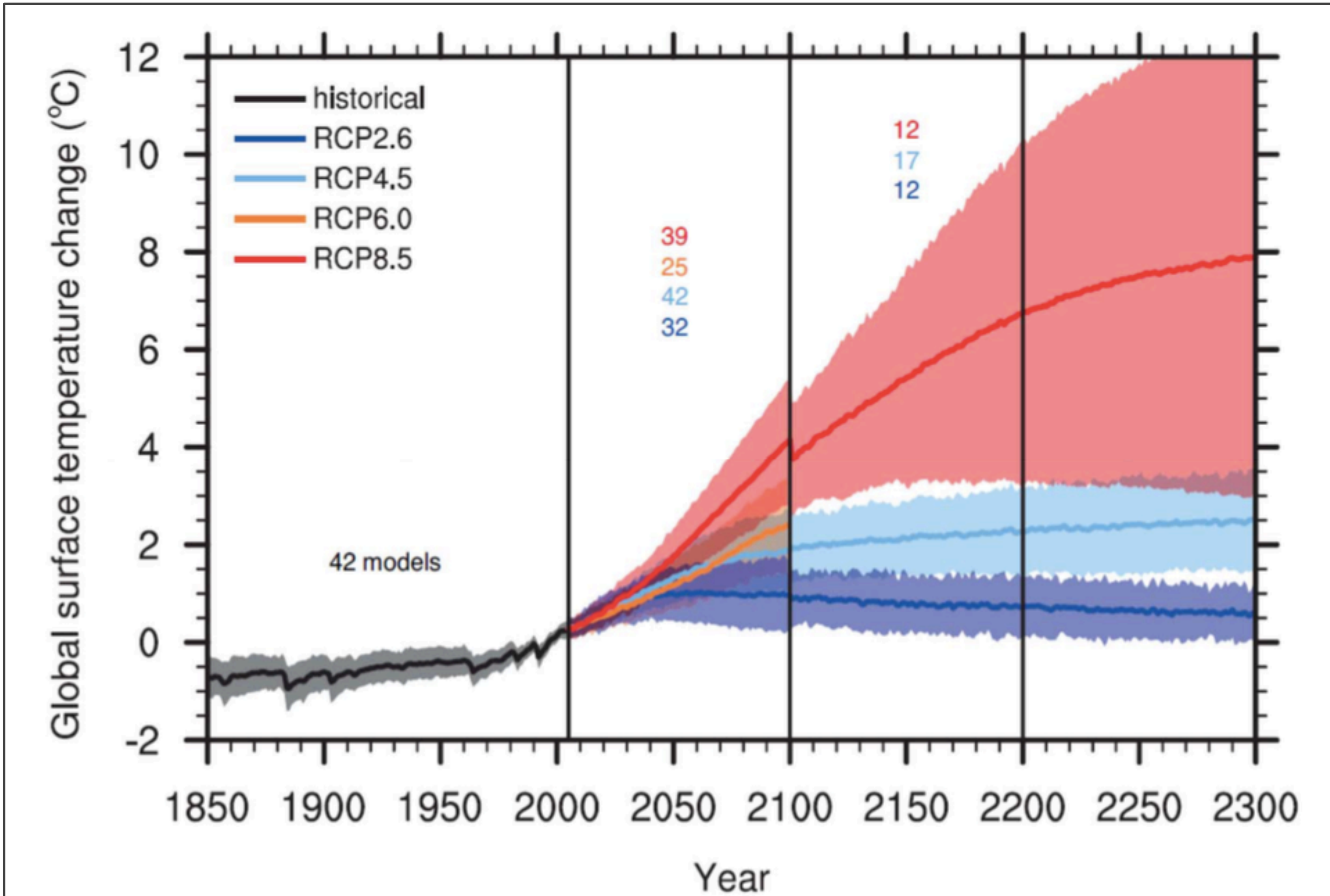


Photo credit: IPCC AR5

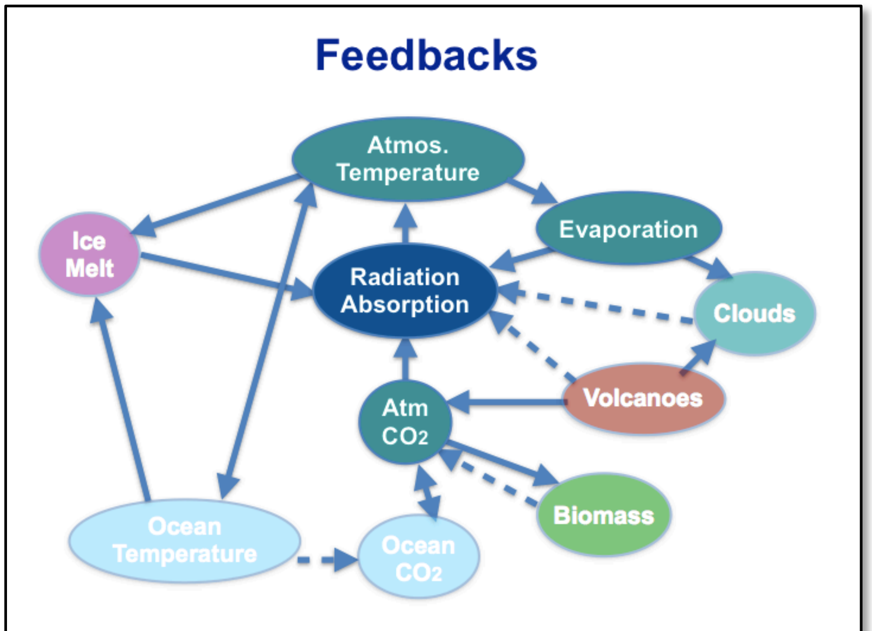
Update of the Goddard Institute of Space Studies

19 January 2016

"Global temperature in 2015 was +1.13 (~2.03°F) relative to the 1880-1920 mean. Accounting for interannual variability, it is fair to say that global warming has now reached ~1°C, almost ~2°F."

Hansen, Sato, Ruedy, Schmidt, Lo

Recap from yesterday



The climate system is complex

UNFCCC objectives stated in the Kyoto Protocol (1997): To stabilize greenhouse gas concentrations in the atmosphere that will prevent dangerous human interference with the climate system.

Paris update (2015): holding the increase in the global average temperature to well below 2 °C above preindustrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above preindustrial levels

Motivation

"This 2 °C warming target is perceived by the public as a universally accepted goal, identified by scientists as a safe limit that avoids dangerous climate change. This perception is incorrect: no scientific assessment has clearly justified or defended the 2 °C target as a safe level of warming, and indeed, this is not a problem that science alone can address."

Knutti, Rogelj, Sedlácek and Fischer, Nat Geo (Dec, 2015)

Motivating Questions

1. What emissions scenario achieves this 2^{o}C target?

2. What does a 2^{o}C world look like?

3. How certain can we be about 1. and 2. ?

4. How does uncertainty affect the decisions we make

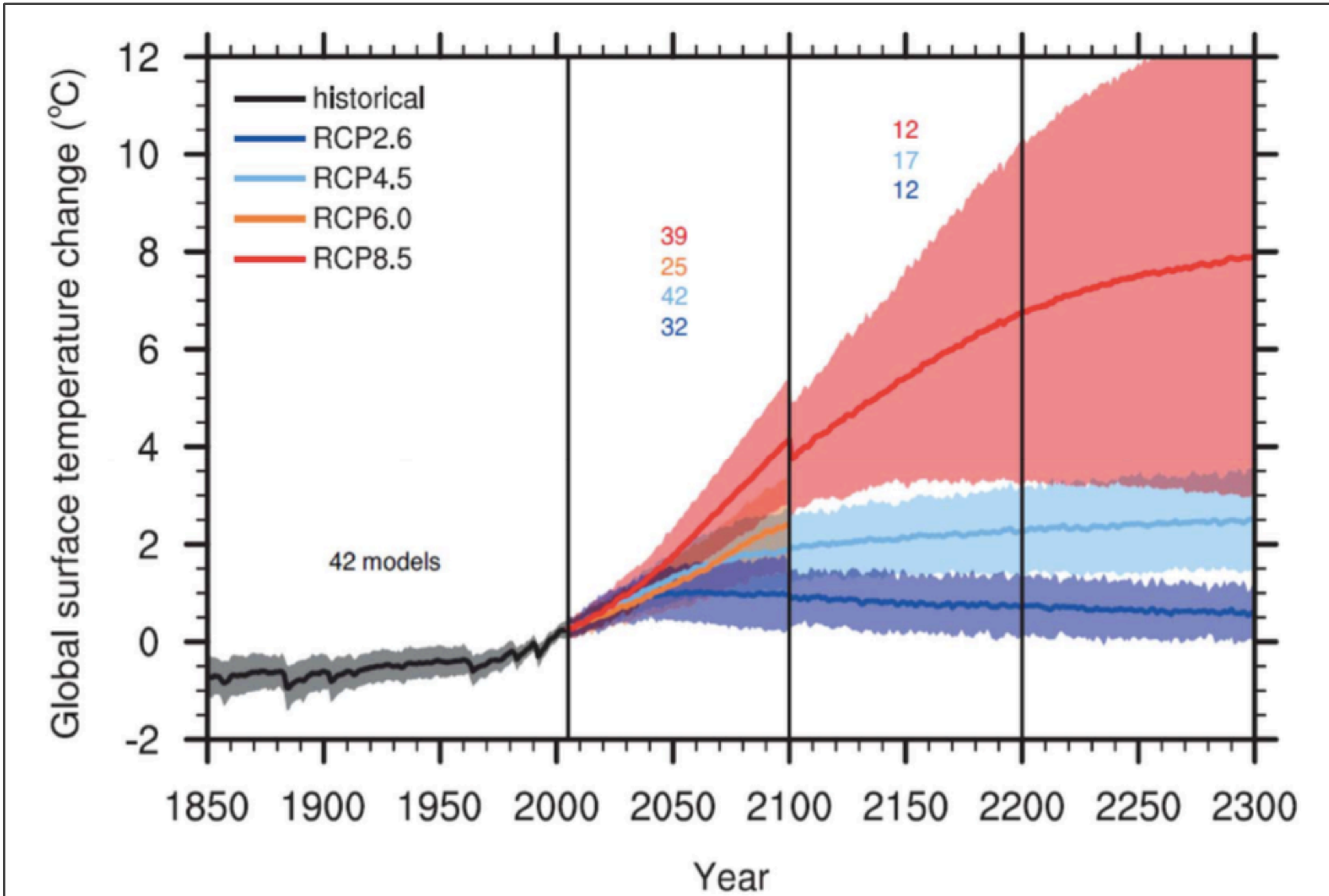


Photo credit: IPCC AR5

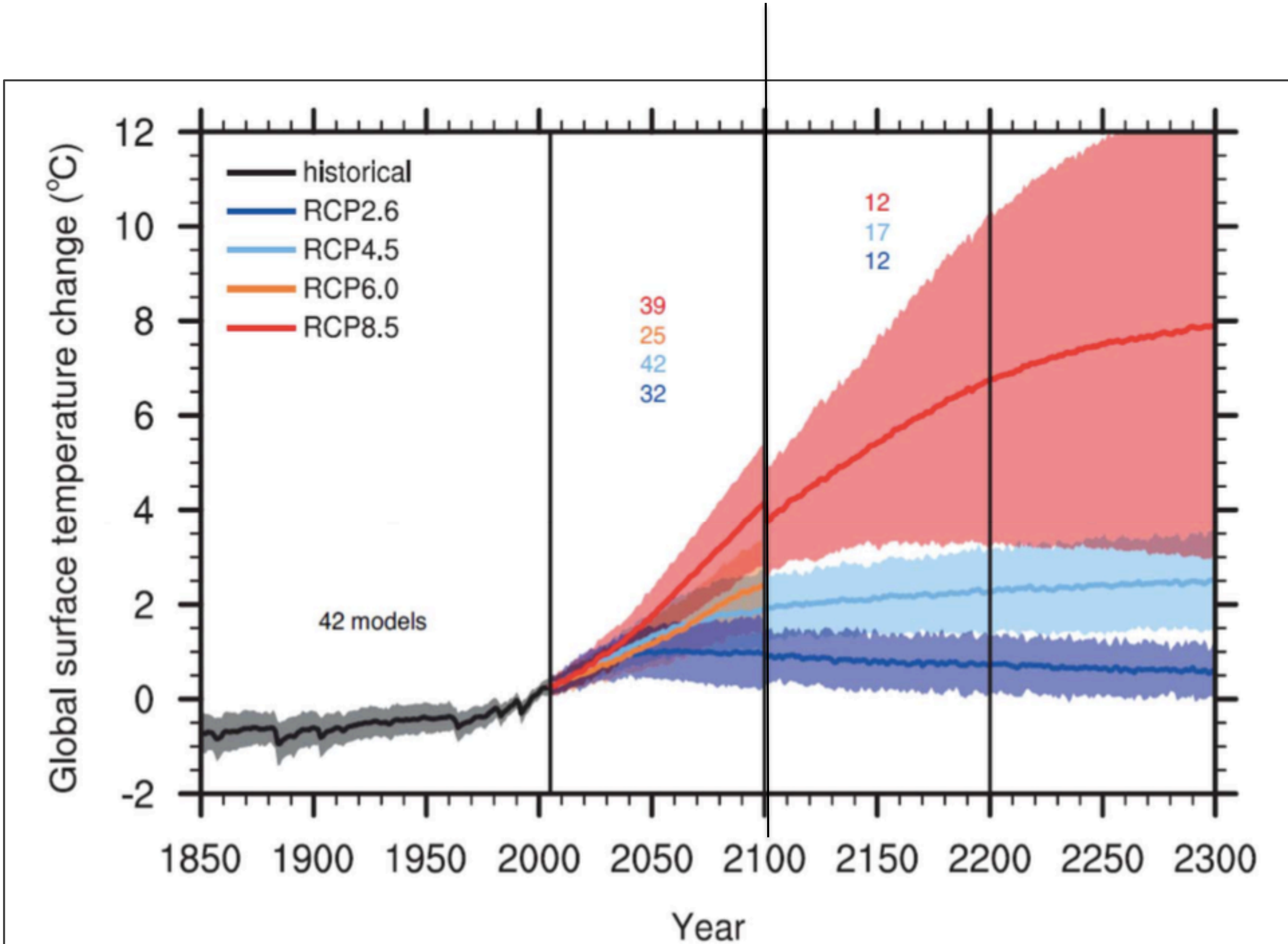


Photo credit: IPCC AR5

Representative **C**oncentration **P**athways

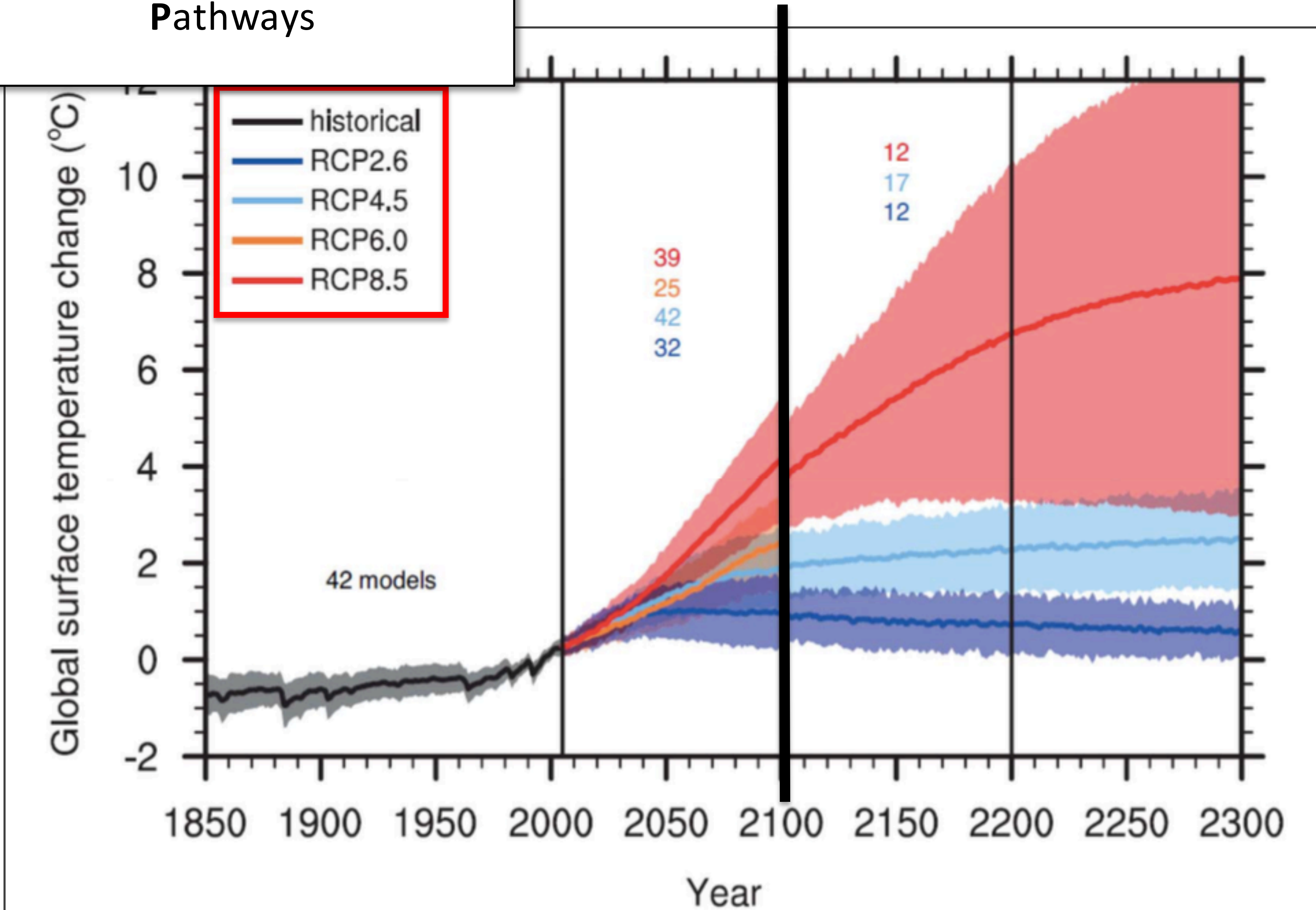


Photo credit: IPCC AR5

Representative **C**oncentration **P**athways

Greenhouse gas concentration pathways named after radiative forcing values in the year 2100 in W/m^2

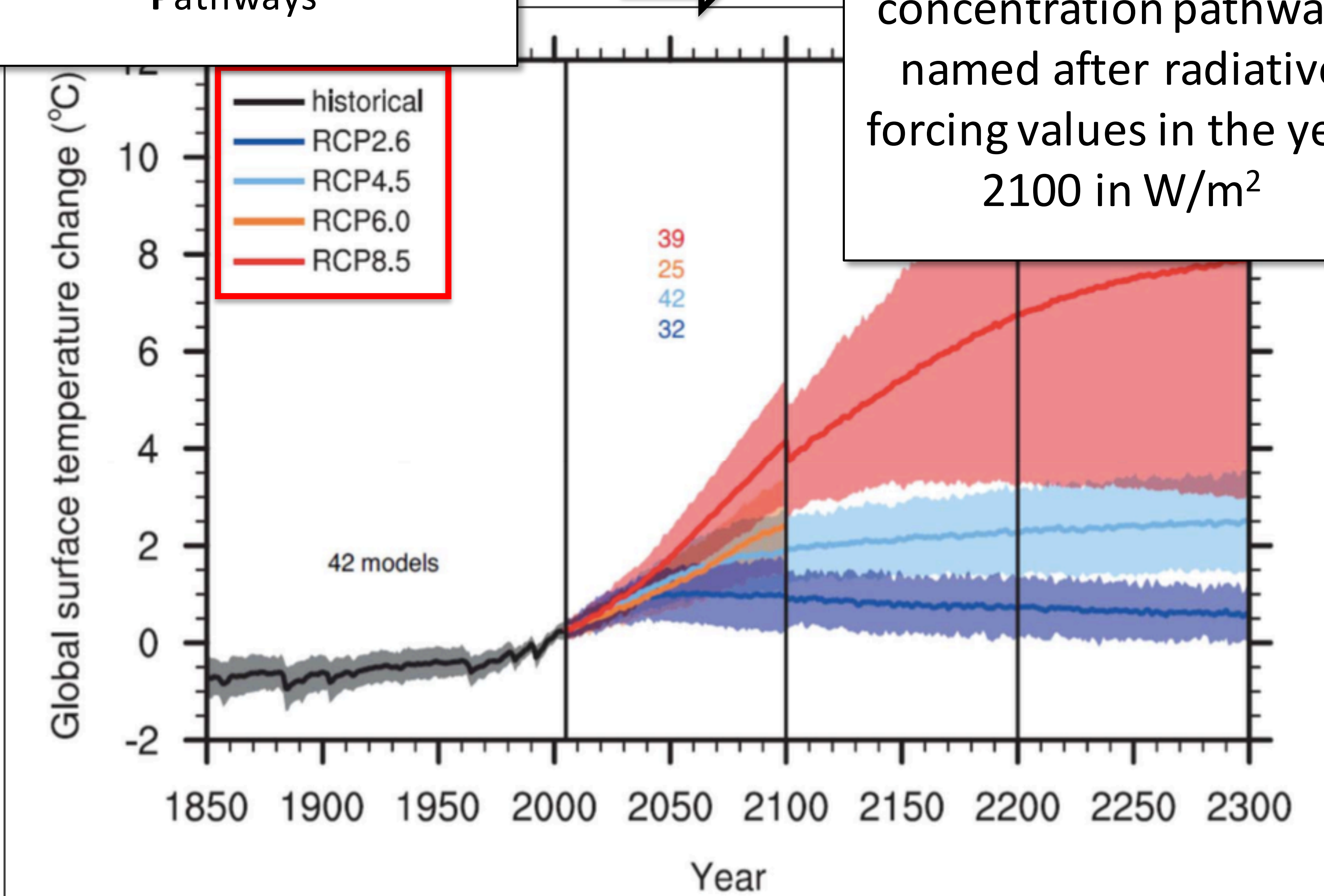


Photo credit: IPCC AR5

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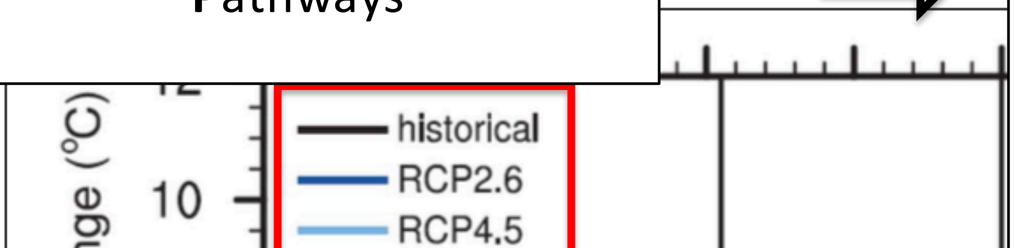
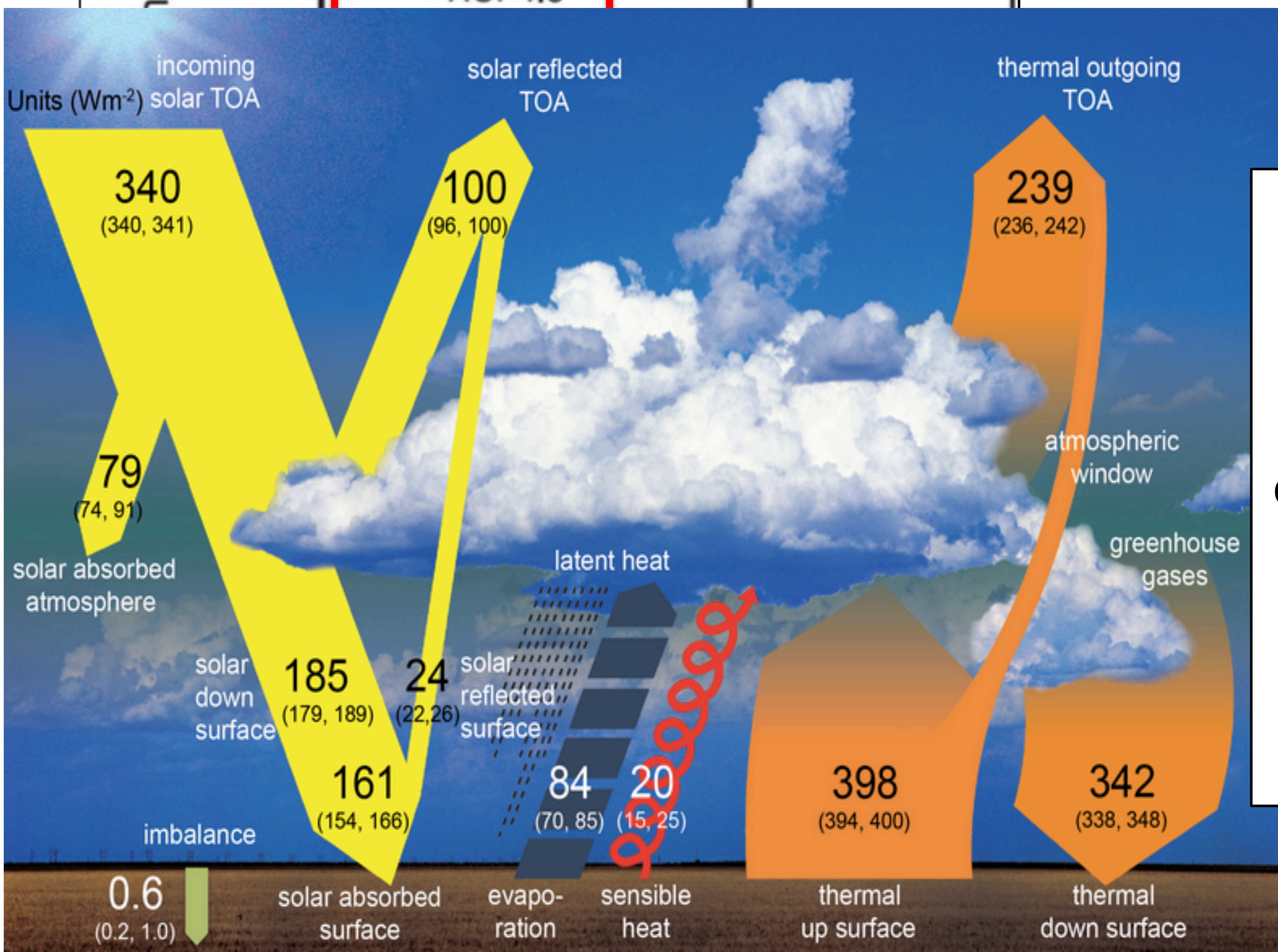
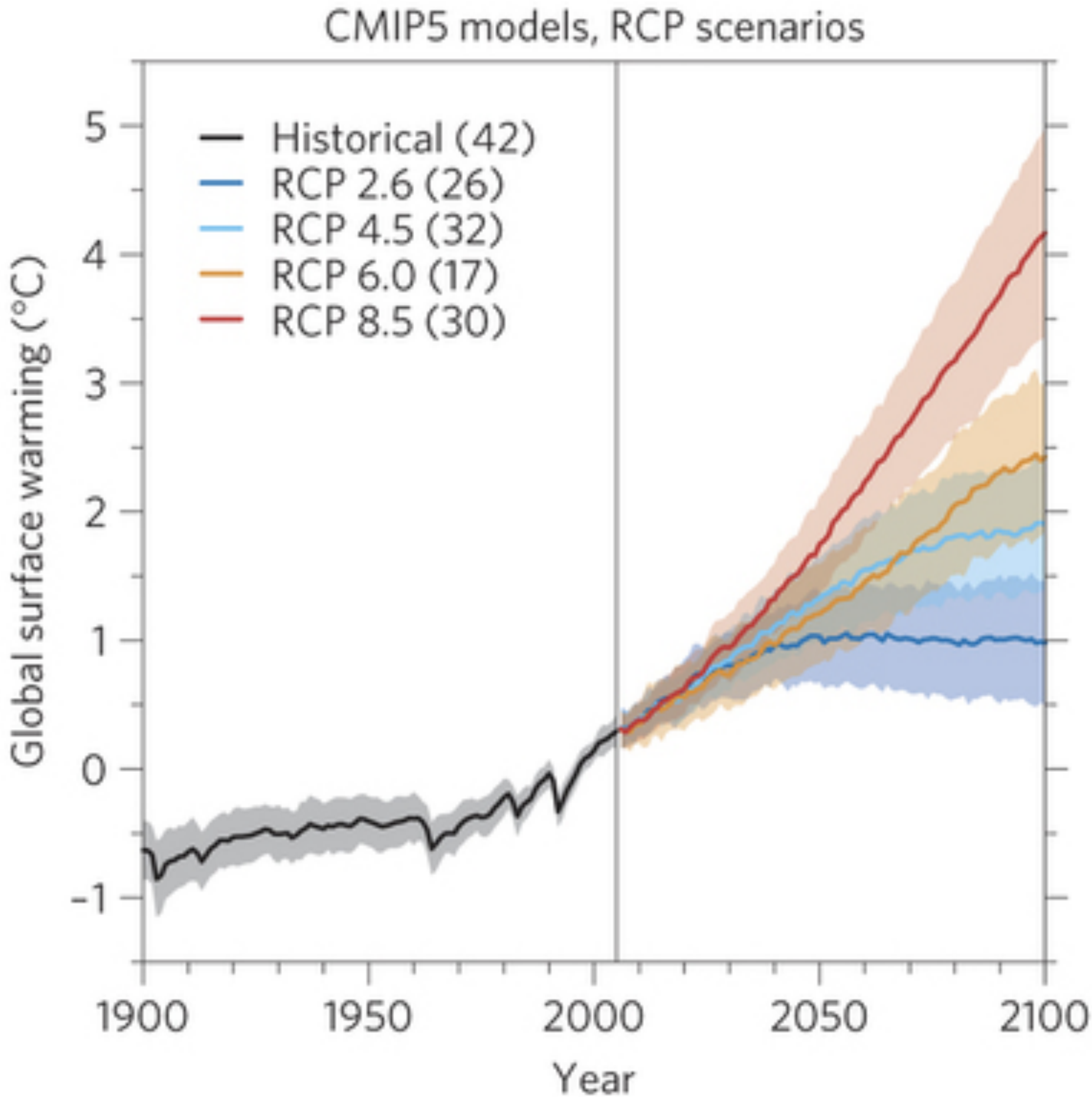


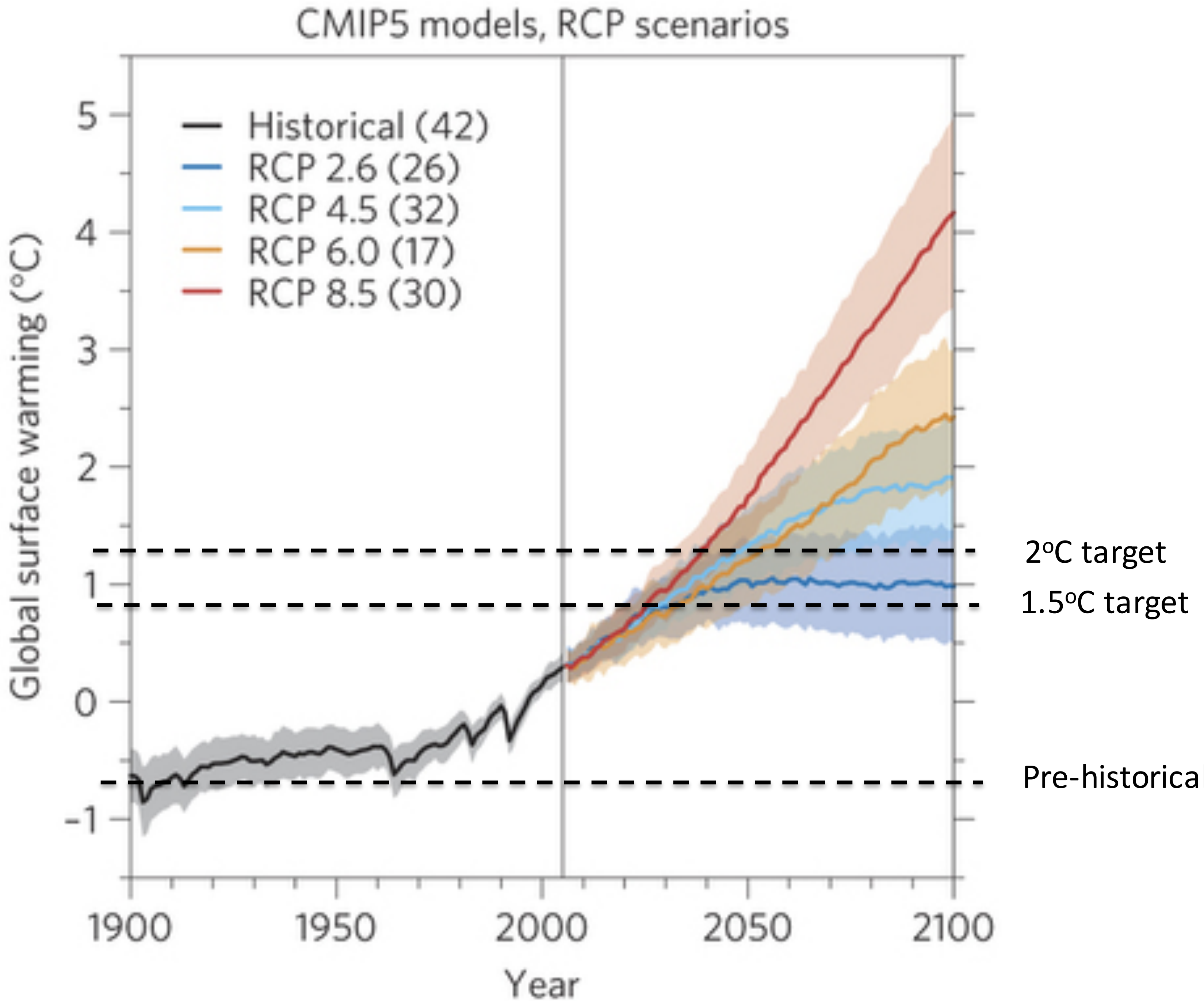


Recall: Radiative forcing is the difference between the amount of energy from the sun entering the earth system vs the amount reflected back.

Photo credit: IPCC AR5



CMIP5 models, RCP scenarios
Historical (42)
RCP 2.6 (26)
RCP 4.5 (32)
RCP 6.0 (17)
RCP 8.5 (30)
Global surface warming (°C)
5
4
3
2
1
0
-1
1900
1950
2000
2050
2100
Year



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5
4
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1900
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2000
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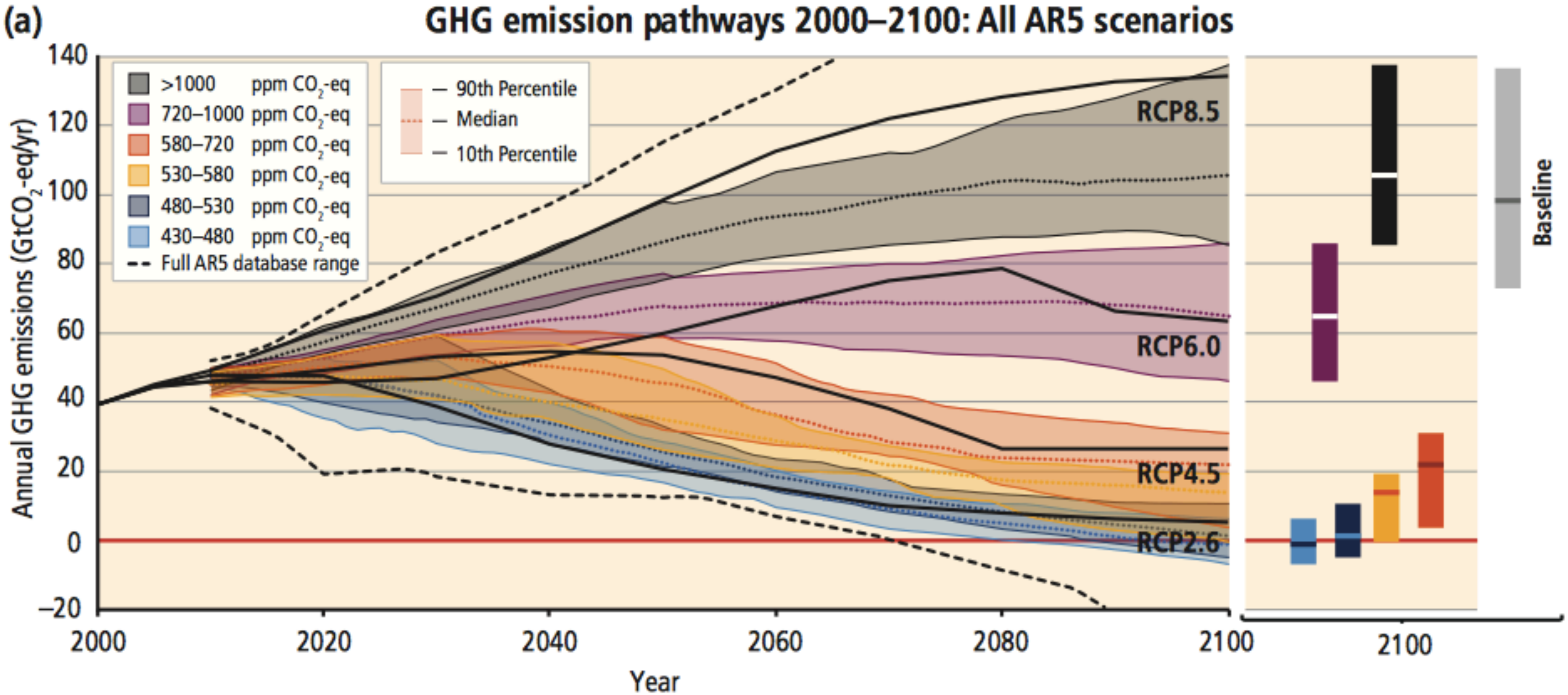
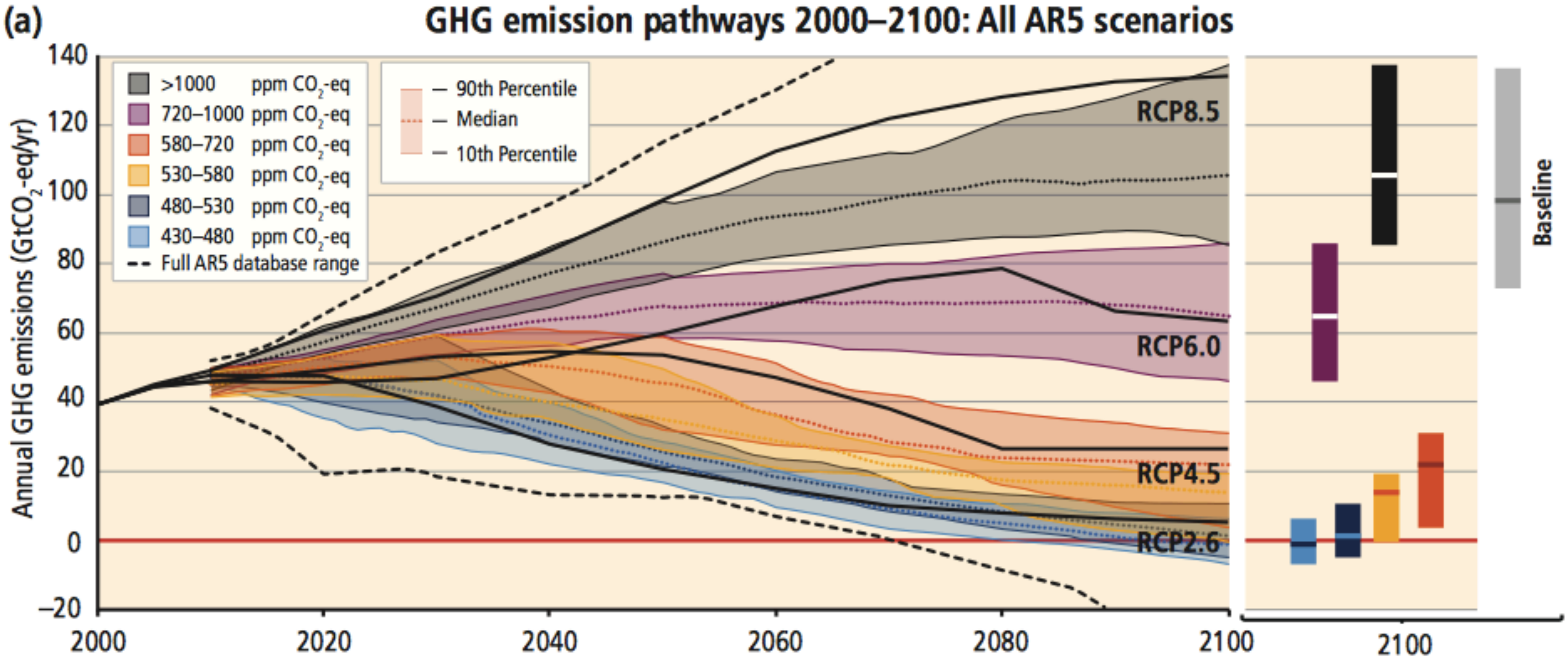
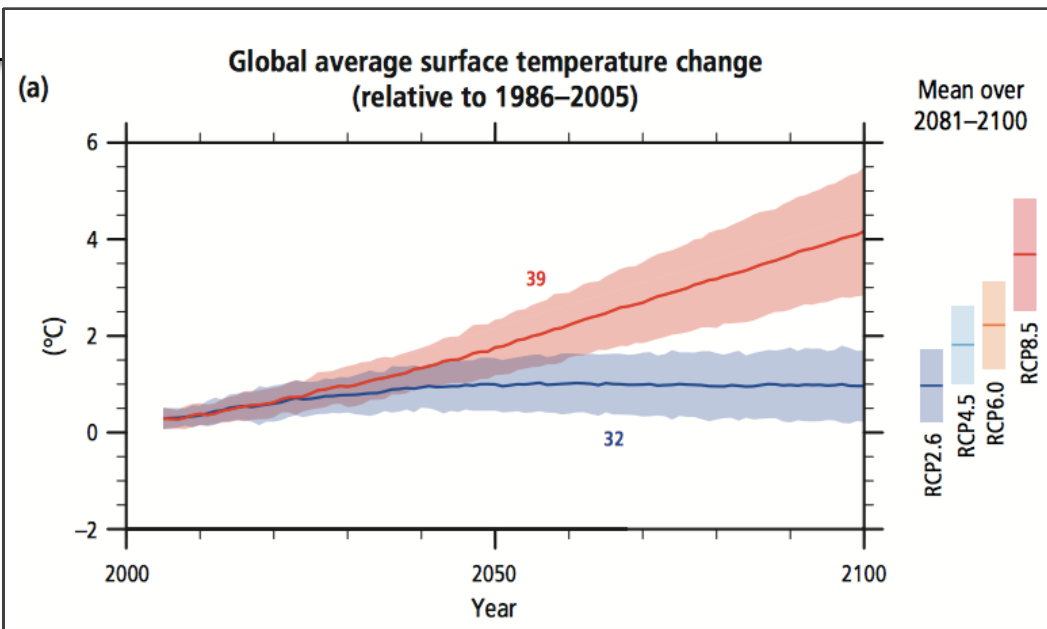
2100
Year
2°C target
1.5°C target
Pre-historical

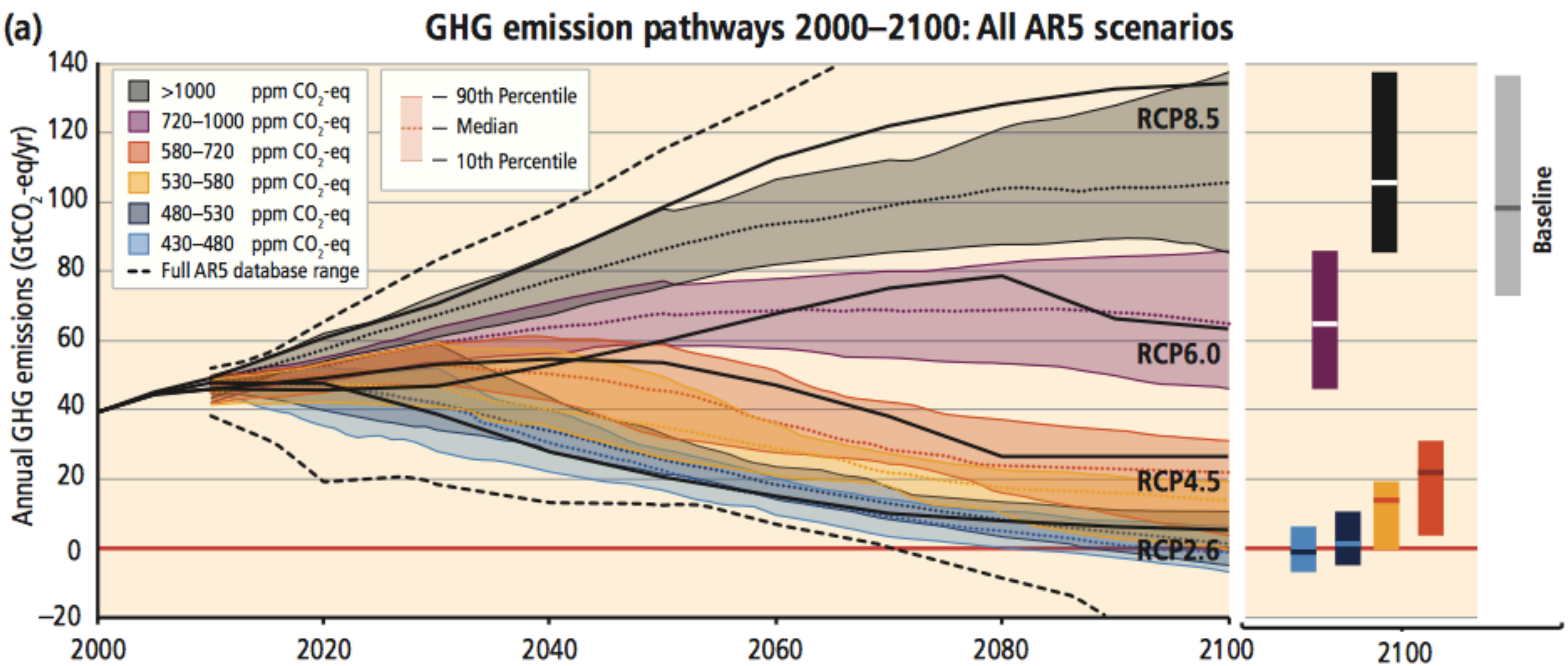


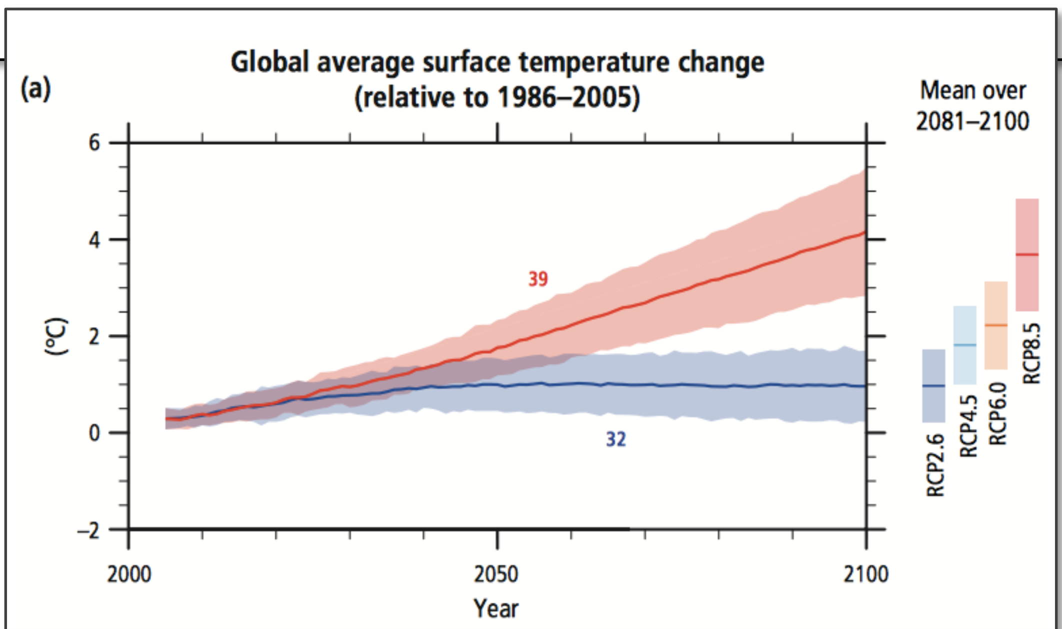
Figures: IPCC AR5 SPM, 2014





Figures: IPCC AR5 SPM, 2014





How do we get from RCP to temperature <u>projection</u>?

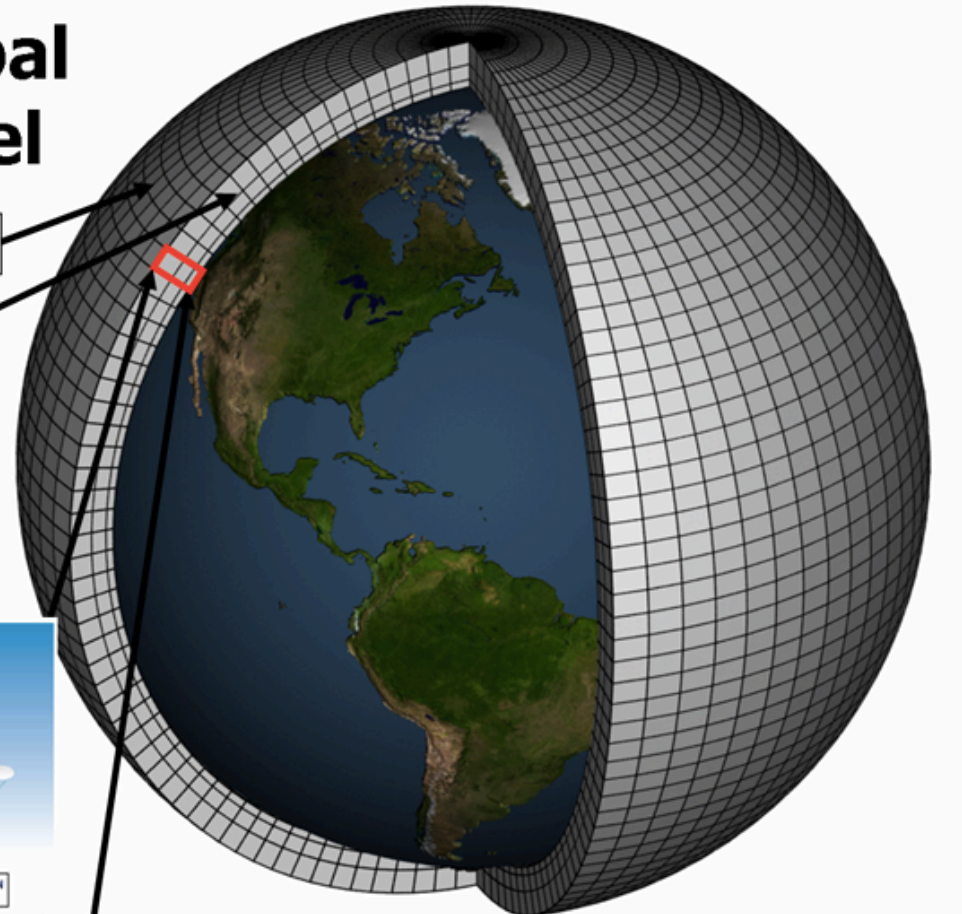
GCMs

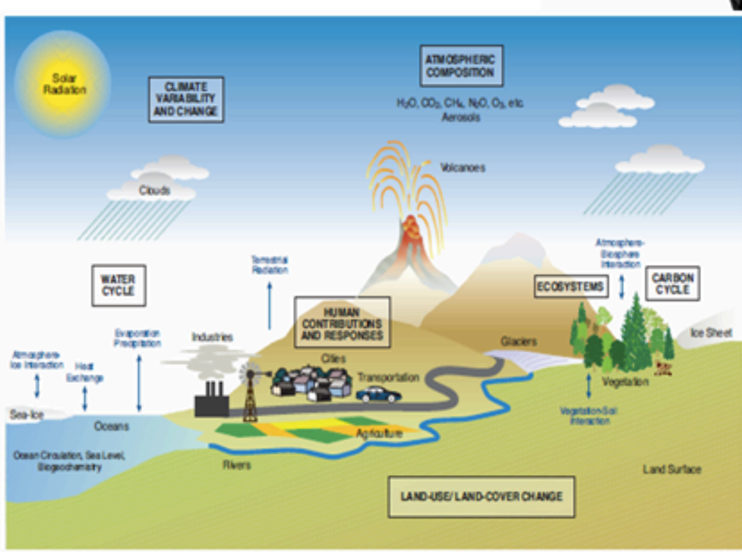
General Circulation Models

aka

Global Climate Models

Schematic for Global Atmospheric Model





- 3D physically based climate models
- Highly complex & computationally expensive
- Each climate model differs in resolution (spatial and temporal)

Figure credit: gfdl.noaa.gov

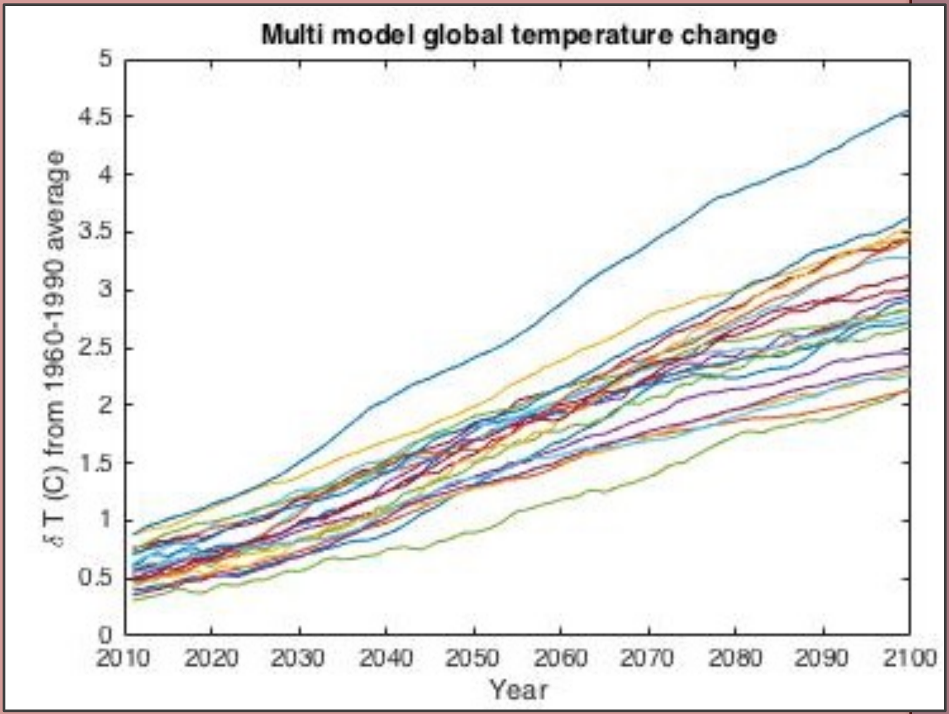
Projection vs Prediction

Projection: Possible Outcome

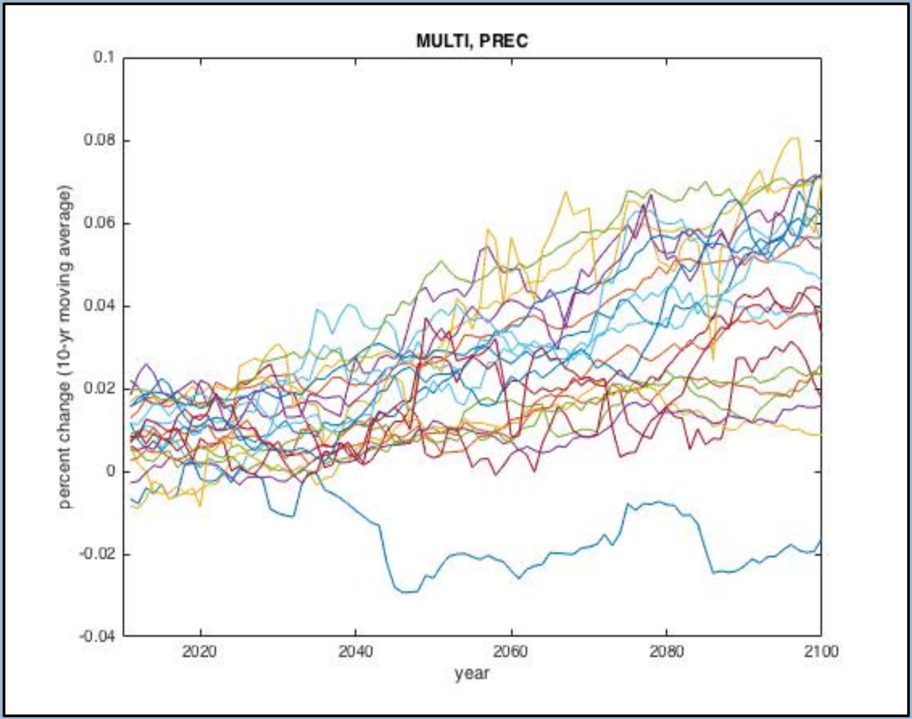
Prediction: Probable Outcome

Climate Model Projections

Temperature Change



Precipitation Change



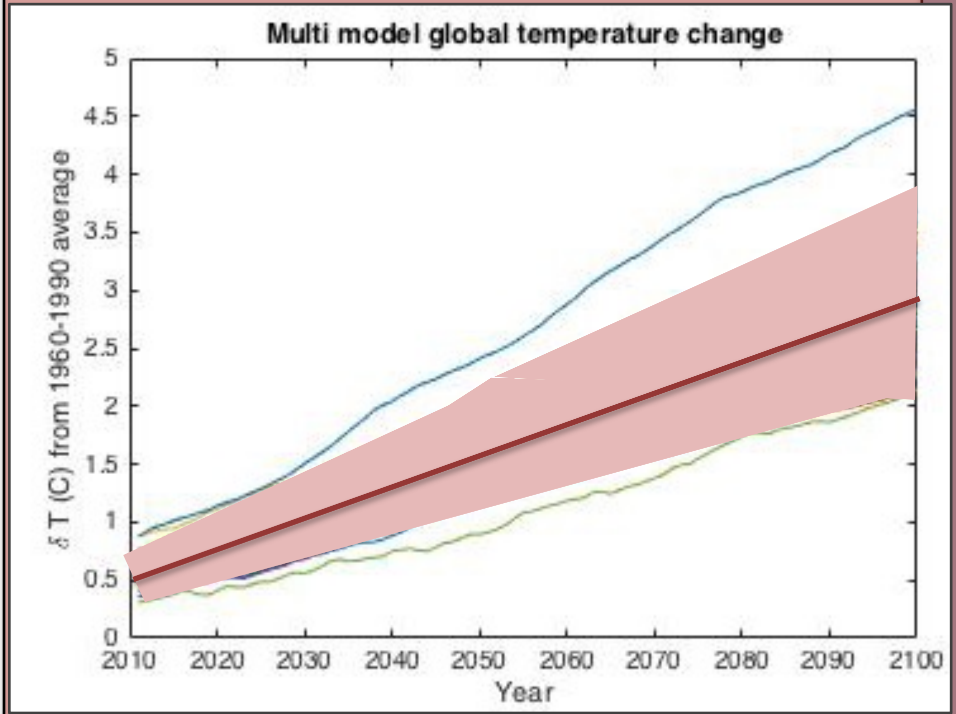
Multi Model Ensemble with 22 models run under one emissions scenario (RCP 4.5)

This does not provide a probability distribution, but rather a likely range of outcomes.

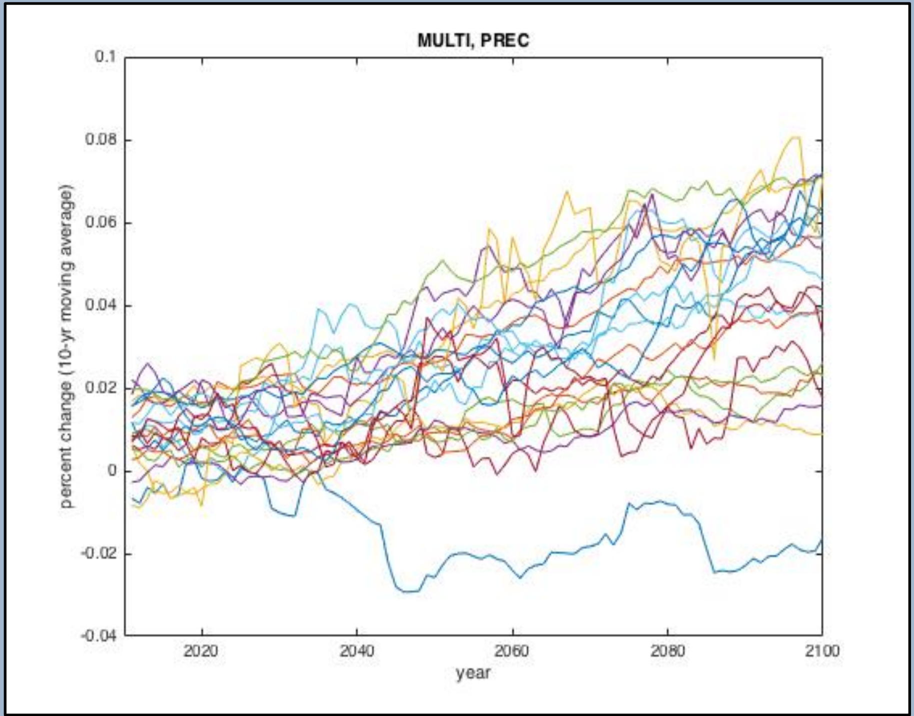
No model run is considered more likely than another.

Climate Model Projections

Temperature Change



Precipitation Change



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What might propagate uncertainty in climate models?

What might propagate uncertainty in climate models?

- Too coarse of a time step
- Too coarse of a spatial resolution
- Incomplete/inaccurate representation of feedbacks
- Incomplete database of current climate variables
- Unknown unknowns
- Known unknowns: (e.g. clouds and ice)

Largest source of uncertainties in Climate Models

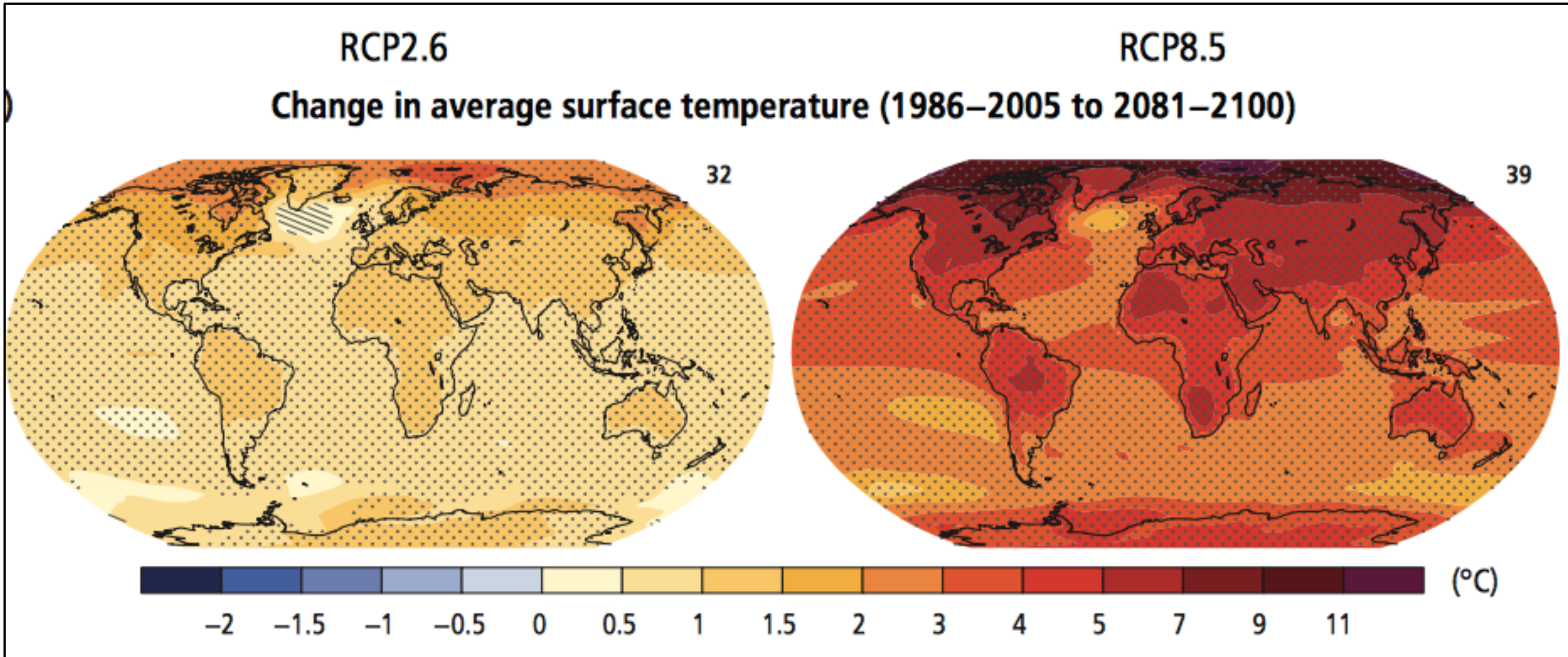
Photo credit: climate.nasa.gov

- Cloud temperature, height, `puffiness', and depth affect climate feedbacks
- Cloud size makes them difficult to model
- Life span of a cloud makes them difficult to model
- Incomplete understanding of cloud physics makes them difficult to model

All models are wrong, some are useful

- George Box, 1979

Multi model mean temperature projections



IPCC AR5, SPM, 2014

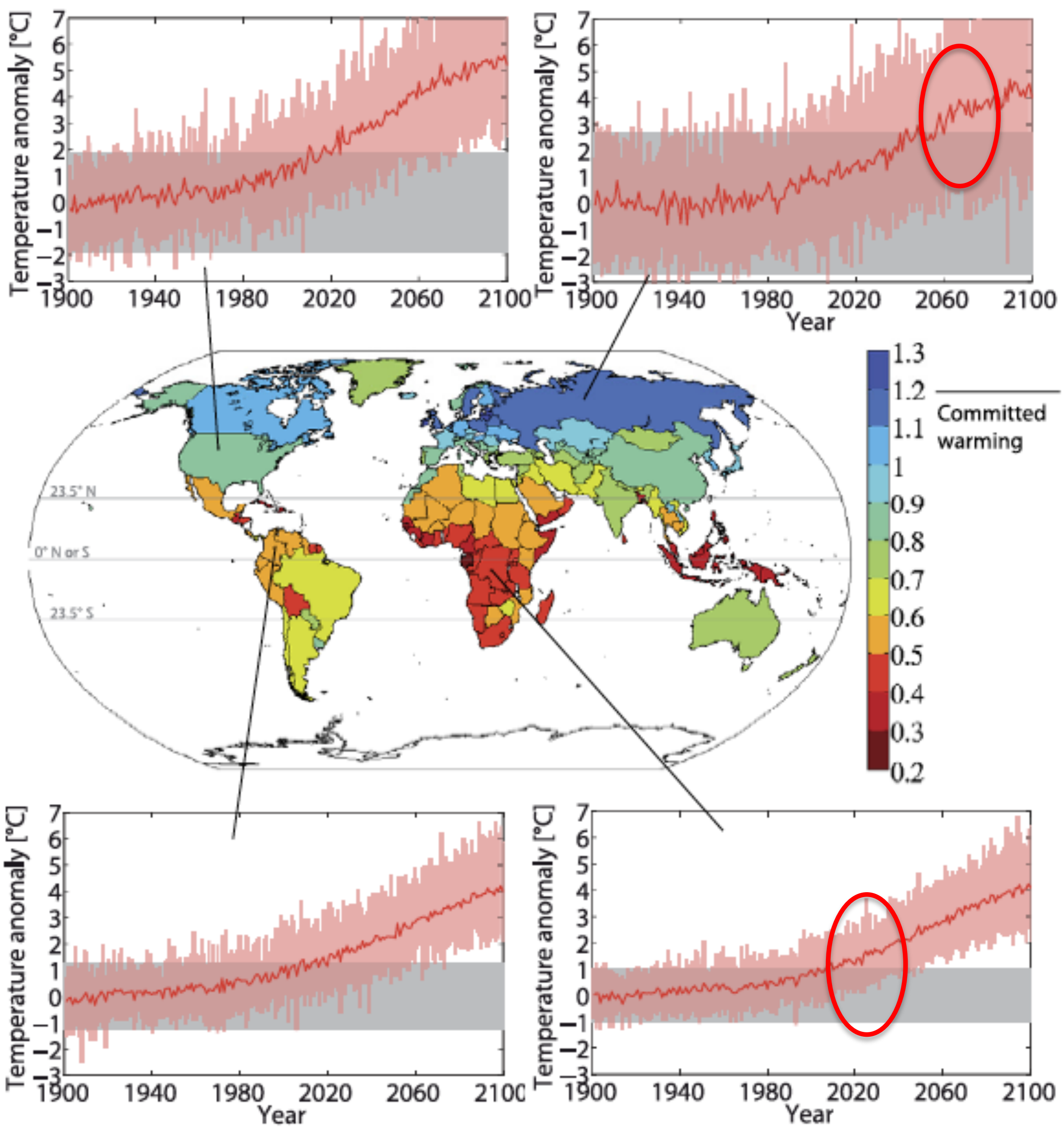
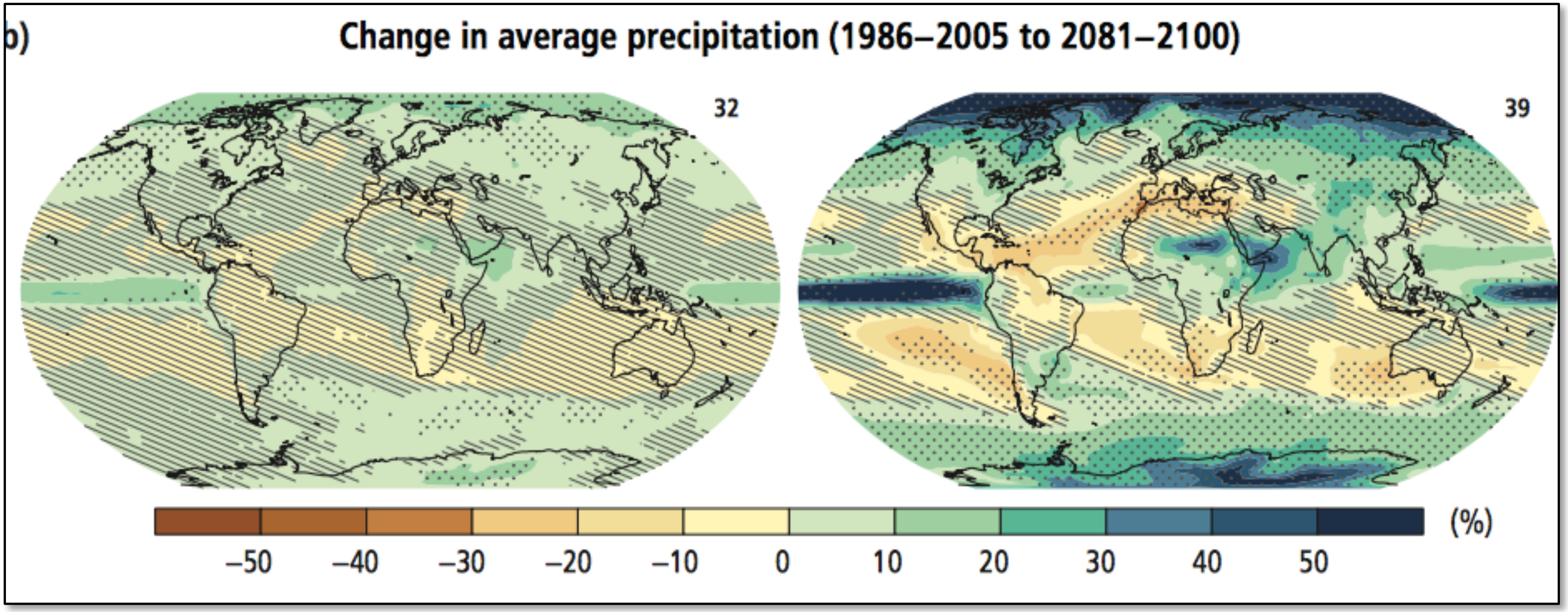


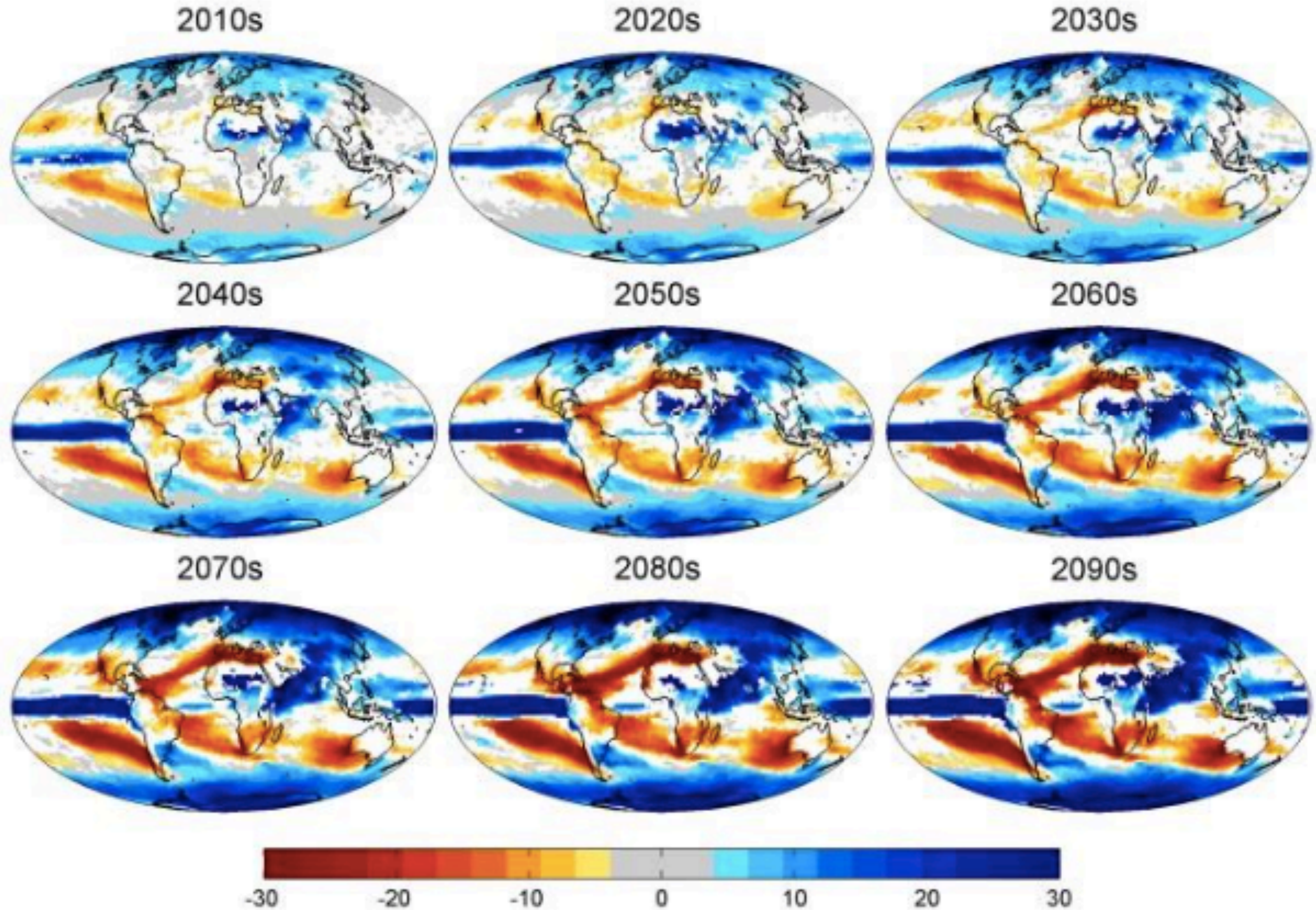
Figure: Mahlstein, Knutti, Portmann, Solomon, ERI 2011

Multi model mean precipitation projections



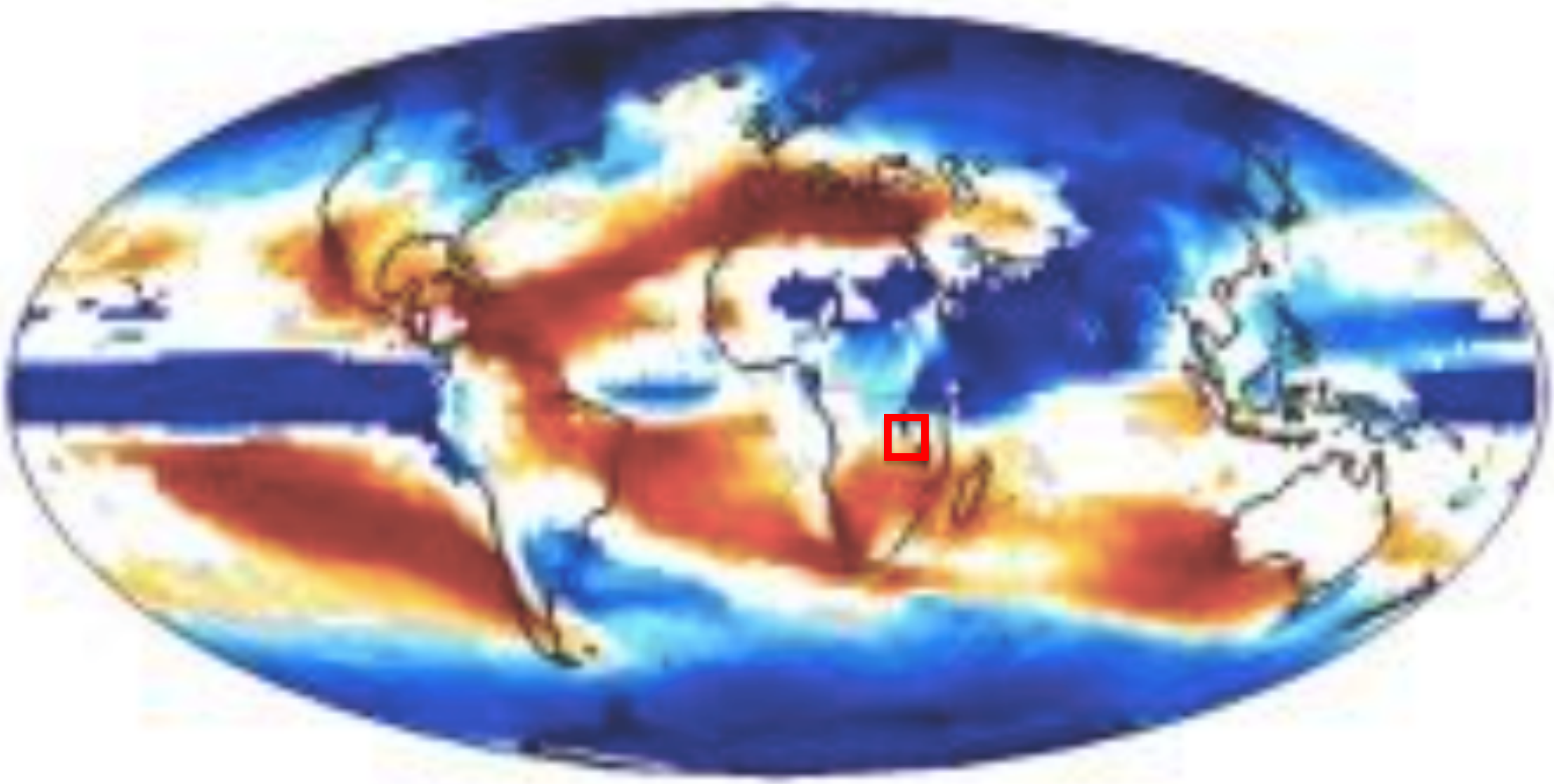
IPCC AR5, SPM, 2014

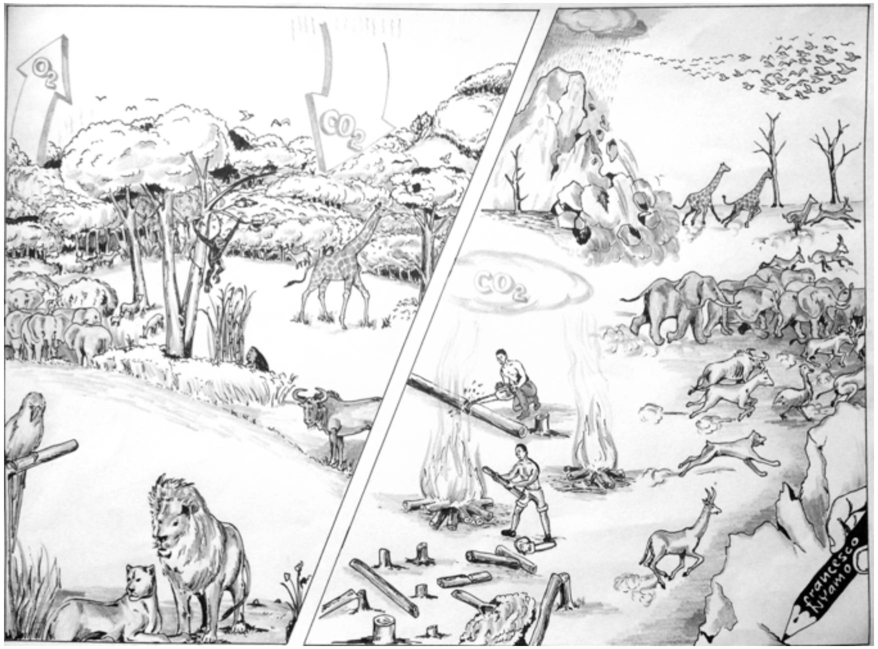
Percent Change in Precipitation By Decade

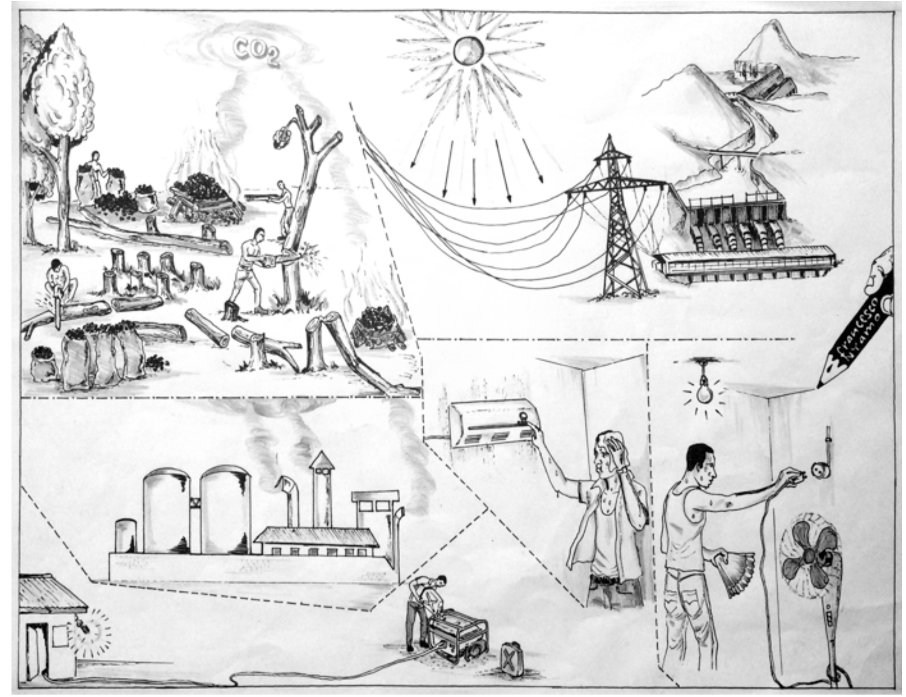


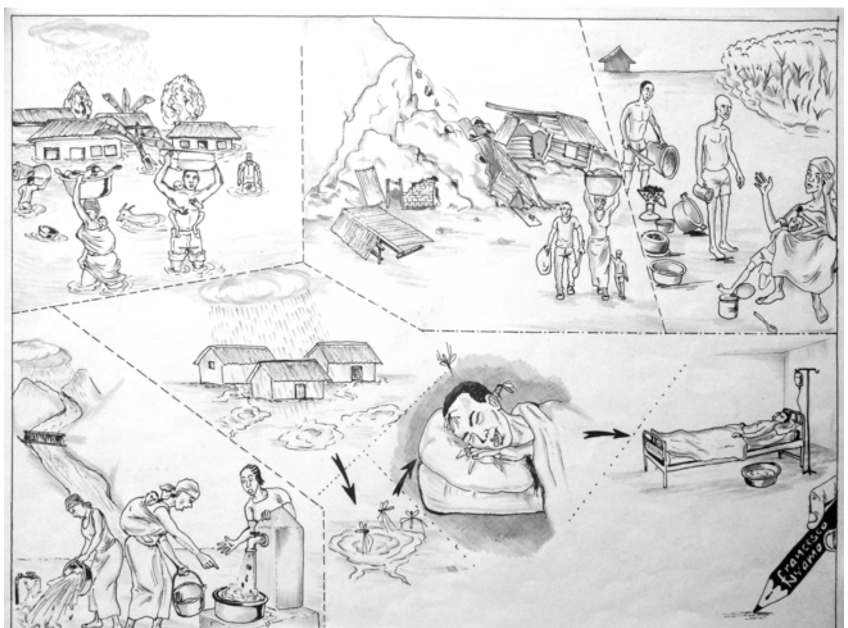
Boehlert, Solomon, Strzepek, 2015

Climate change at a local scale




O_2
CO_2
CO_2
francesco Nyamo


CO_2
francesco Nyamo


francesco Nyamo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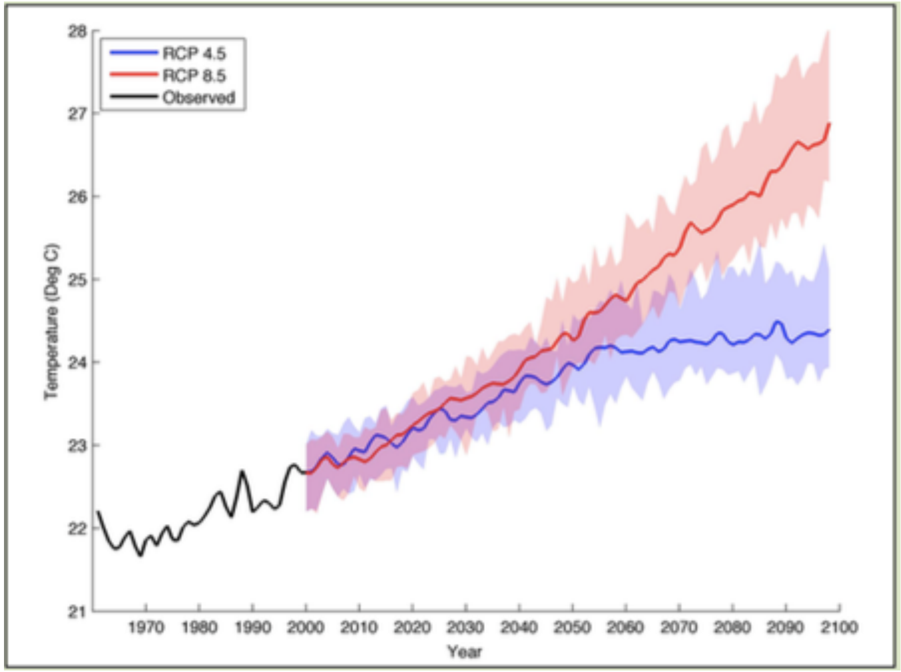
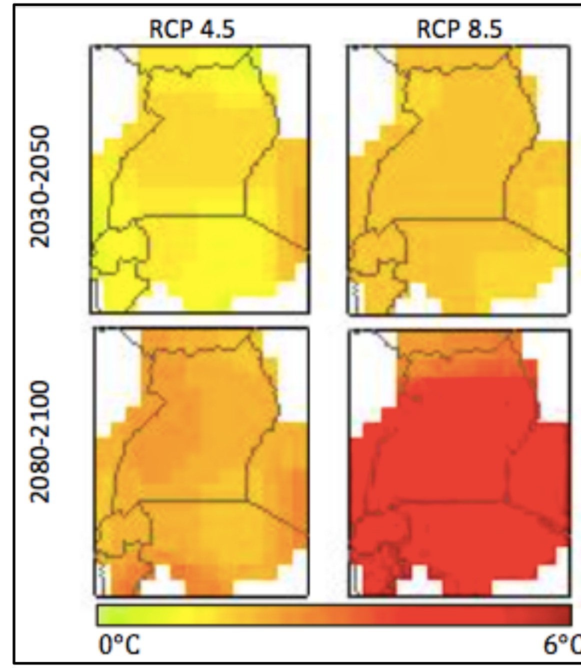
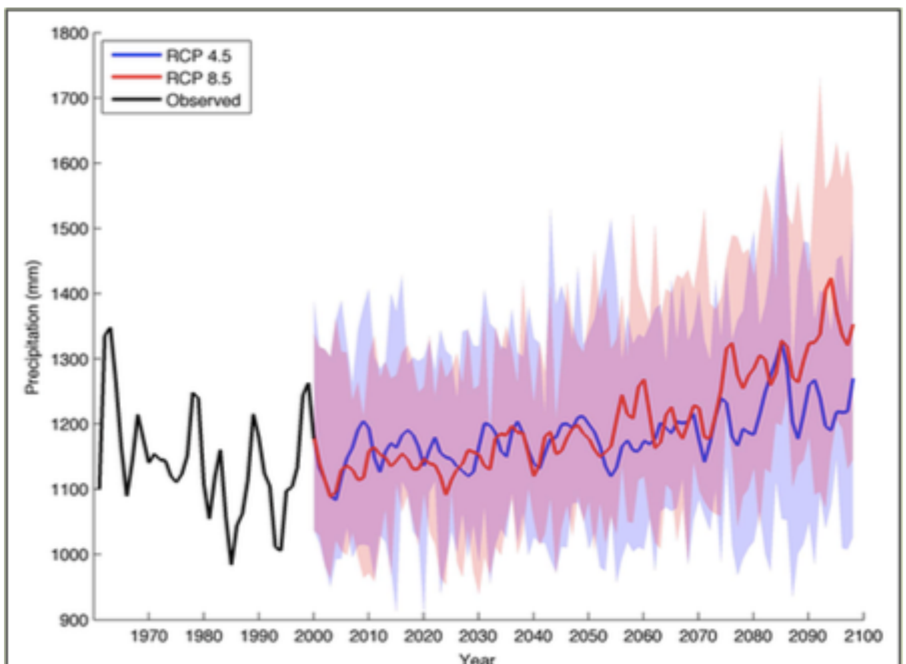
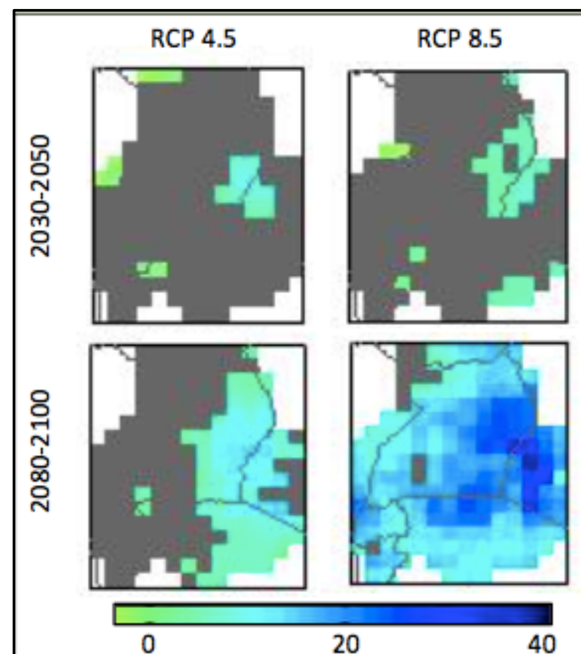

RCP 4.5
RCP 8.5
Observed
Temperature (Deg C)
28
27
26
25
24
23
22
21
1970 1980 1990 2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100
Year


RCP 4.5
RCP 8.5
2030-2050
2080-2100
0°C
6°C


RCP 4.5
RCP 8.5
Observed
Precipitation (mm)
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
1970 1980 1990 2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100
Year


RCP 4.5
RCP 8.5
2030-2050
2080-2100
0
20
40

Sea Level Rise

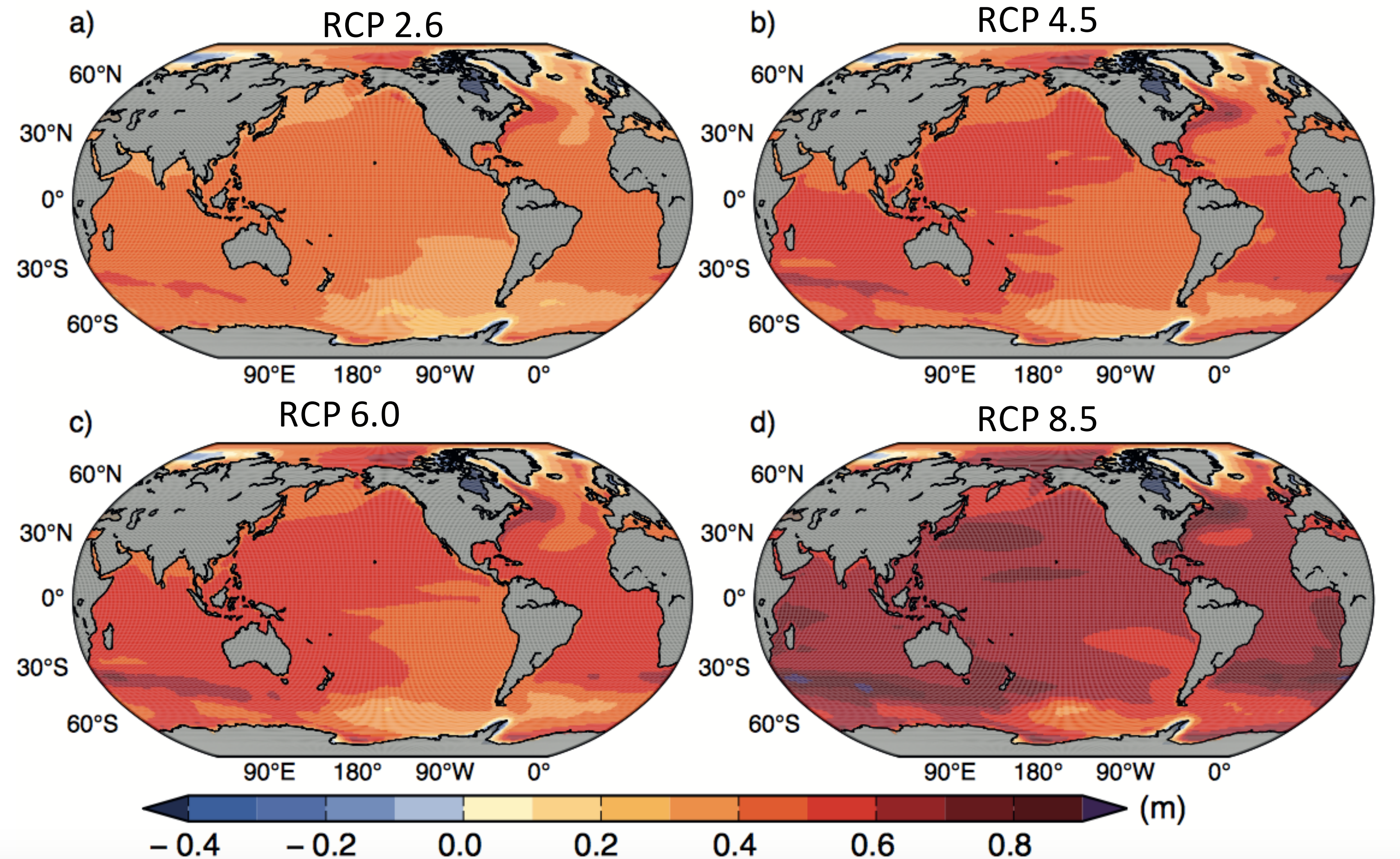
During the last interglacial period, sea level was at least 5m higher than today and temperatures were at least 2^{o}C greater than present.

Sea level has risen ~19 cm between 1901 an 2010

Thermal expansion and glacier melting explain about 75% of the rise in sea level since 1970

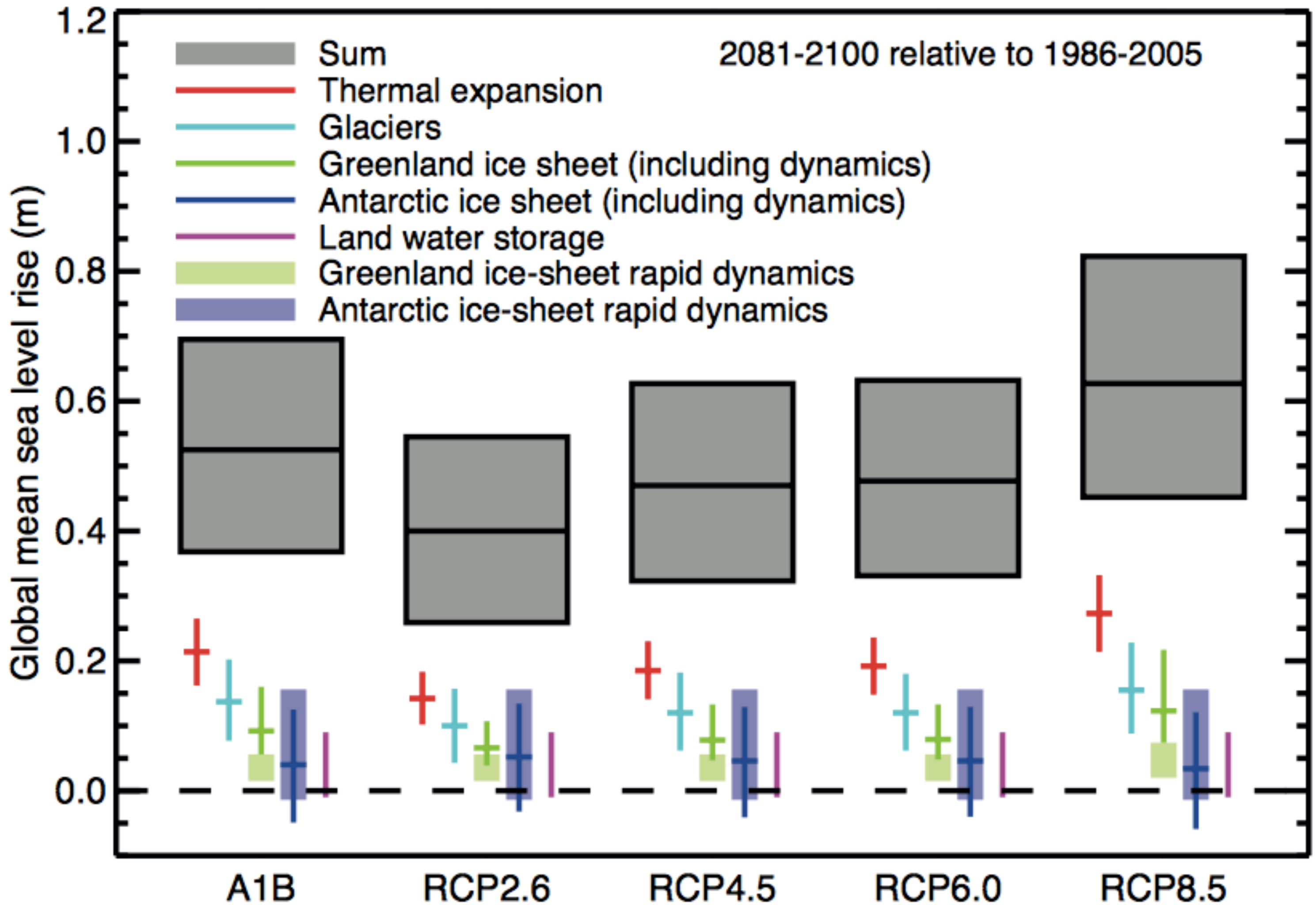
Contributions from Greenland and Antarctic Ice sheets has increased since the 1990s.

Sea Level Change



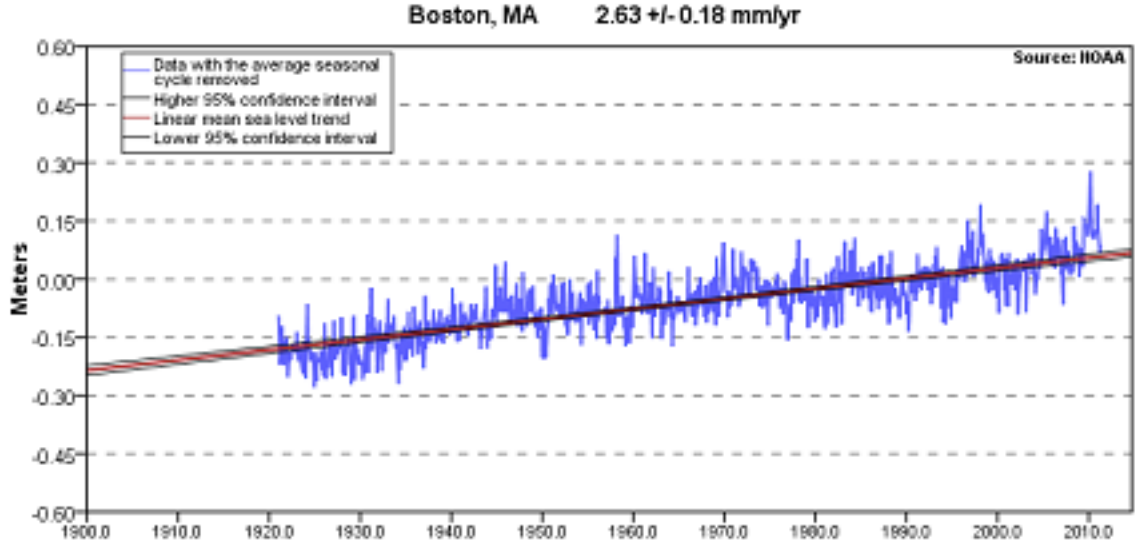
IPCC AR5,Chapter 13, 2014

Sea Level Change



IPCC AR5, chapter 13, 2014

Mean Sea Level Trend, Boston, Massachusetts



Sea-level rise projections for Boston

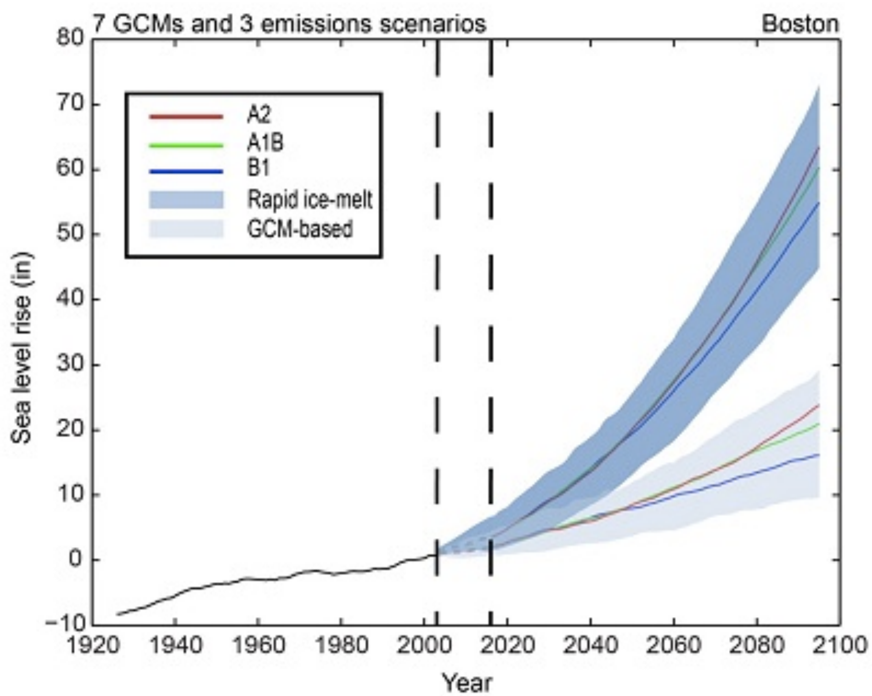
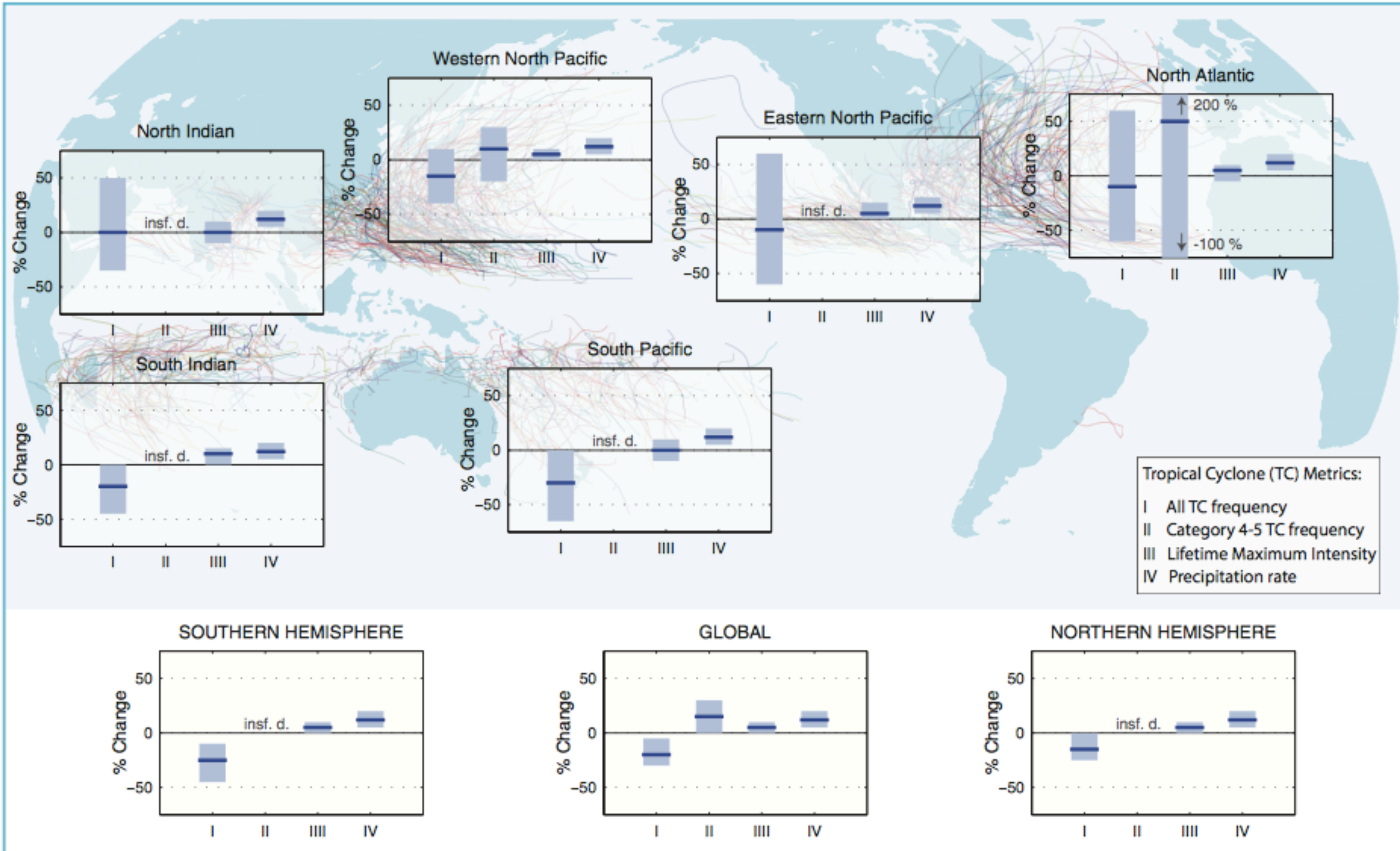


Figure credit: cityofboston.gov

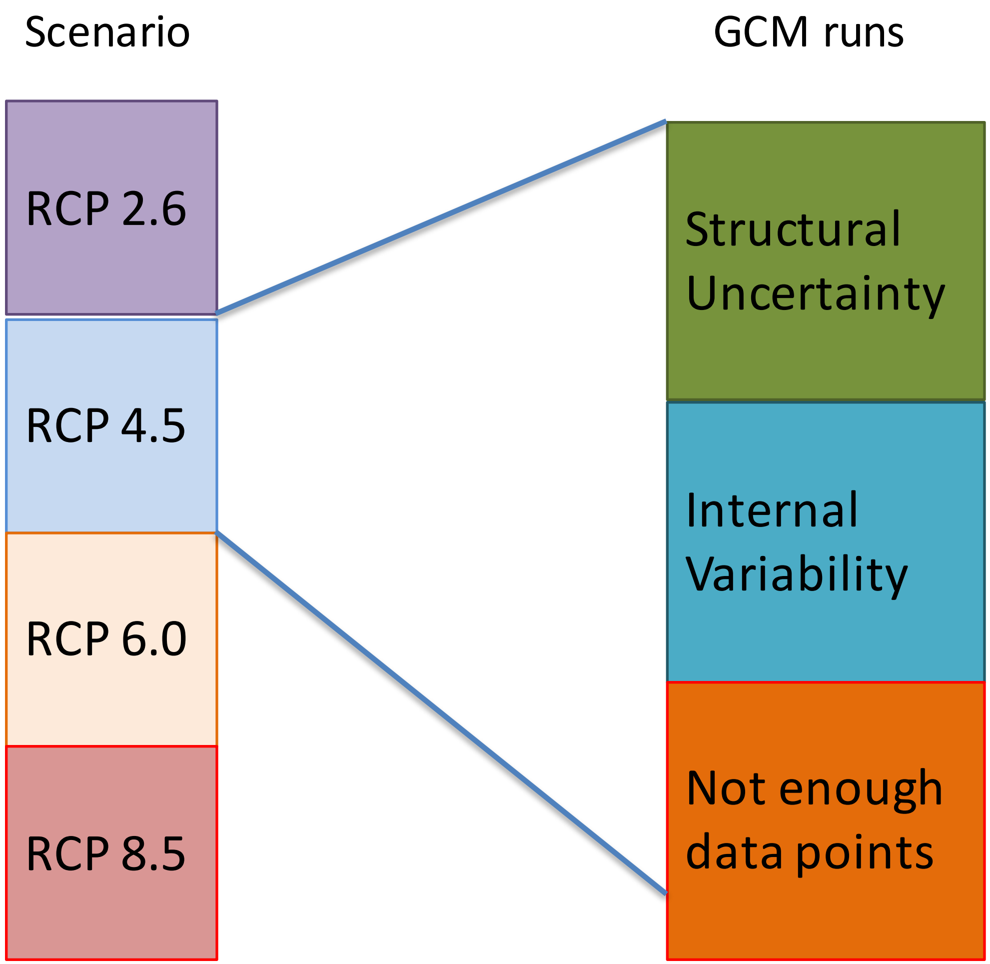
Storm Activity

RCP 4.5



IPCC AR5, Chapter 14, 2014

Summary of Uncertainty



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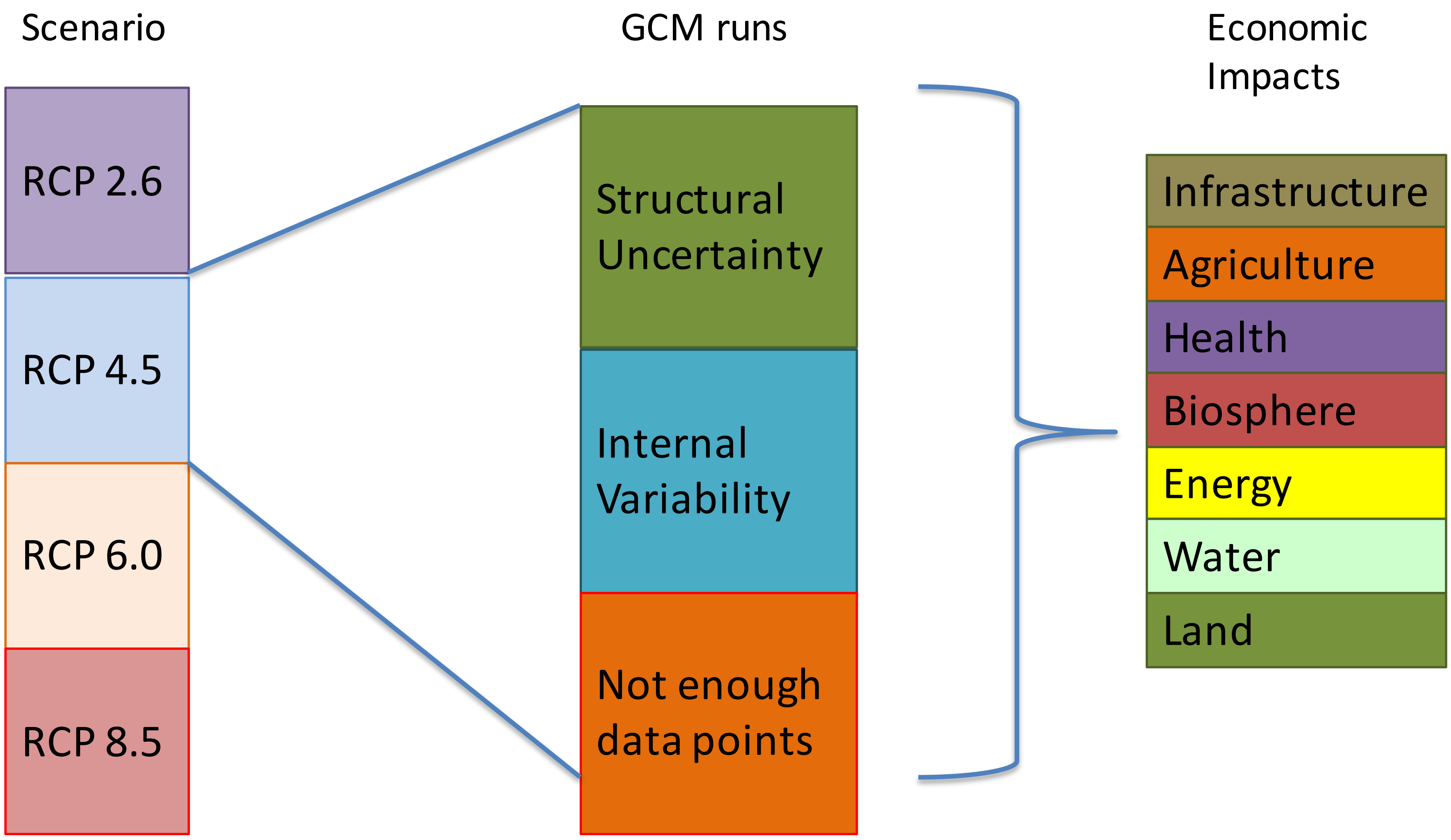

Upcoming Events

Sunday Jan 24, 6pm: Arlington St Church 351 Boylston St
Tu BiShvat Seder for Palestine, Climate, and Racial Justice

Monday Jan 25, 5:30pm: E51-315 (here!)
Dispatches from Paris: Reflecting on the Climate Talks with COP21 Attendees (RSVP to askmitei-ed@mit.edu)

Monday and Tuesday Jan 25-26, 10am-12pm: E51-085
From Turbines to Tariffs: Technical and Regulatory Issues for Scaling Up Wind Energy

Wednesday Jan 27, 8:30am-5:30pm: MIT 32-123
MIT on Climate = Science + Action

Friday Jan 29, 9am-5pm: MIT 3-415
Hackathon for Climate

Upcoming Events