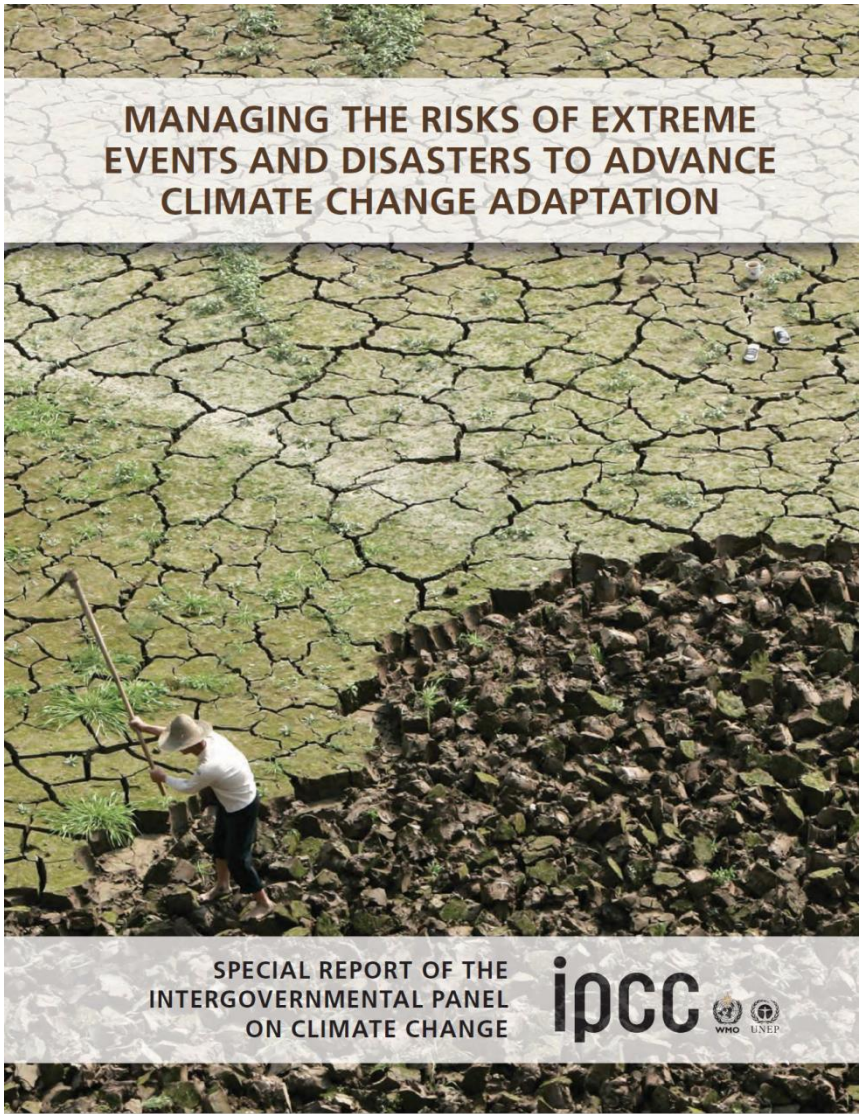
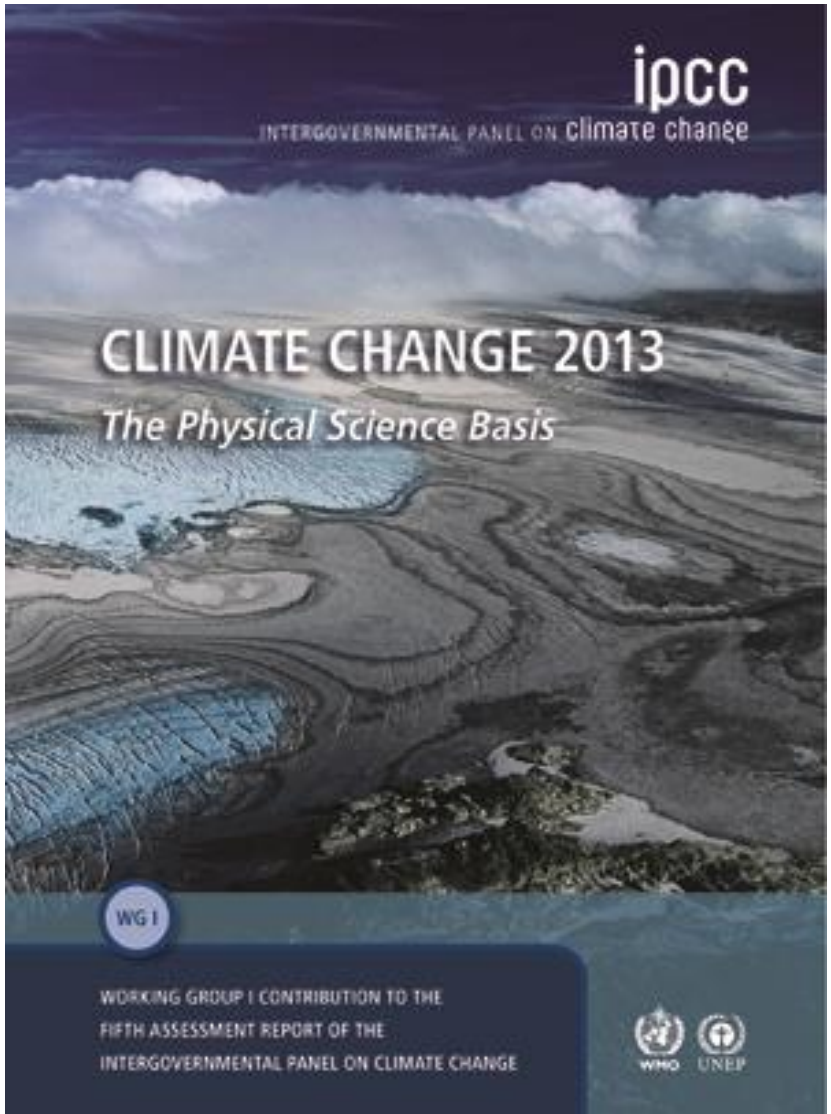
Current and future climate change

Frode Stordal, UiO

Most of the content from IPCC AR5[1] and IPCC SREX

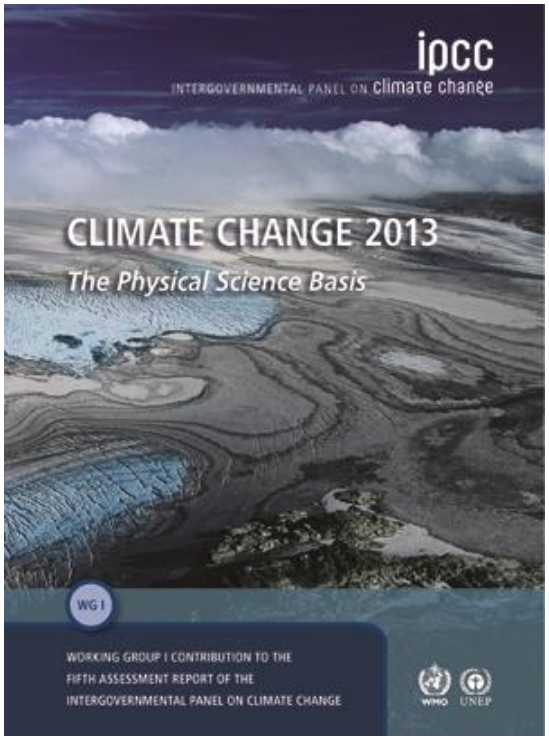
[1] Many slides from Gunnar Myhre, CICERO

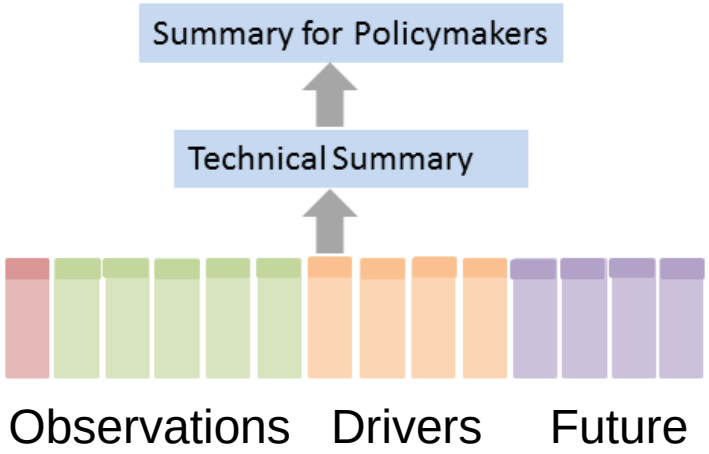




Facts About the WGI Contribution to IPCC AR5

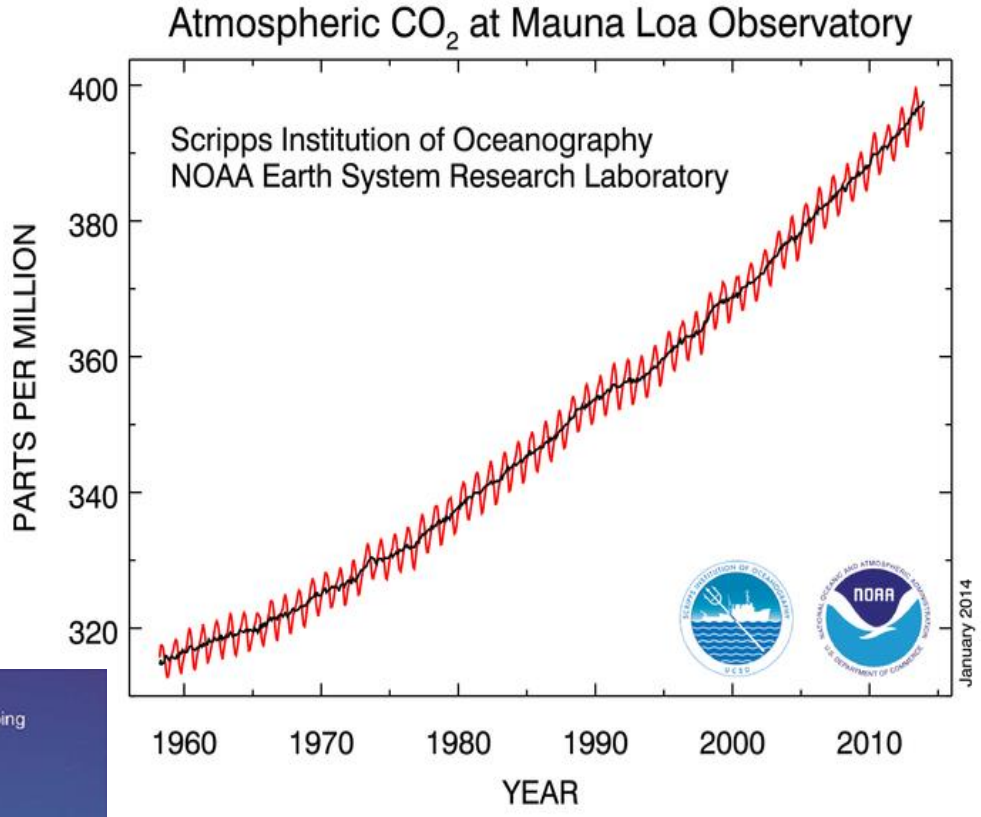
- **209 Lead Authors** and 50 Review Editors from 39 countries
- Over **600 Contributing Authors**
- More than **2 million gigabytes** of numerical data from climate models
- Over **9200 scientific publications** cited
- **1089 expert reviewers** from 55 countries and 38 governments
- **54,677 review comments**

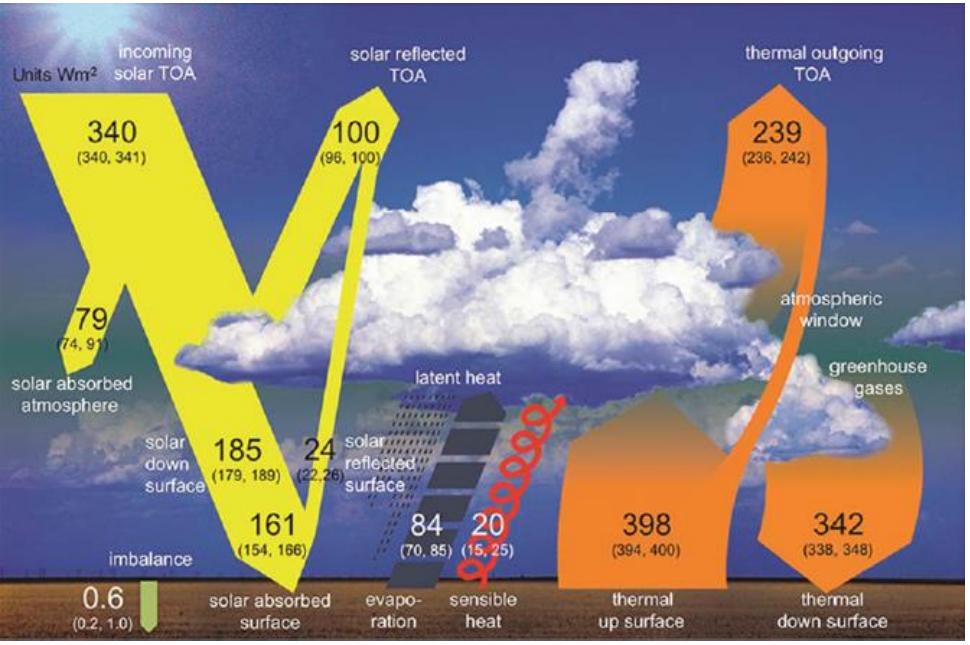




14 chapters

Increased greenhouse effect





ipcc
INTERGOVERNMENTAL PANEL ON climate change
WMO UNEP

The atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have increased to levels unprecedented in at least the last 800,000 years.

Global temperature change

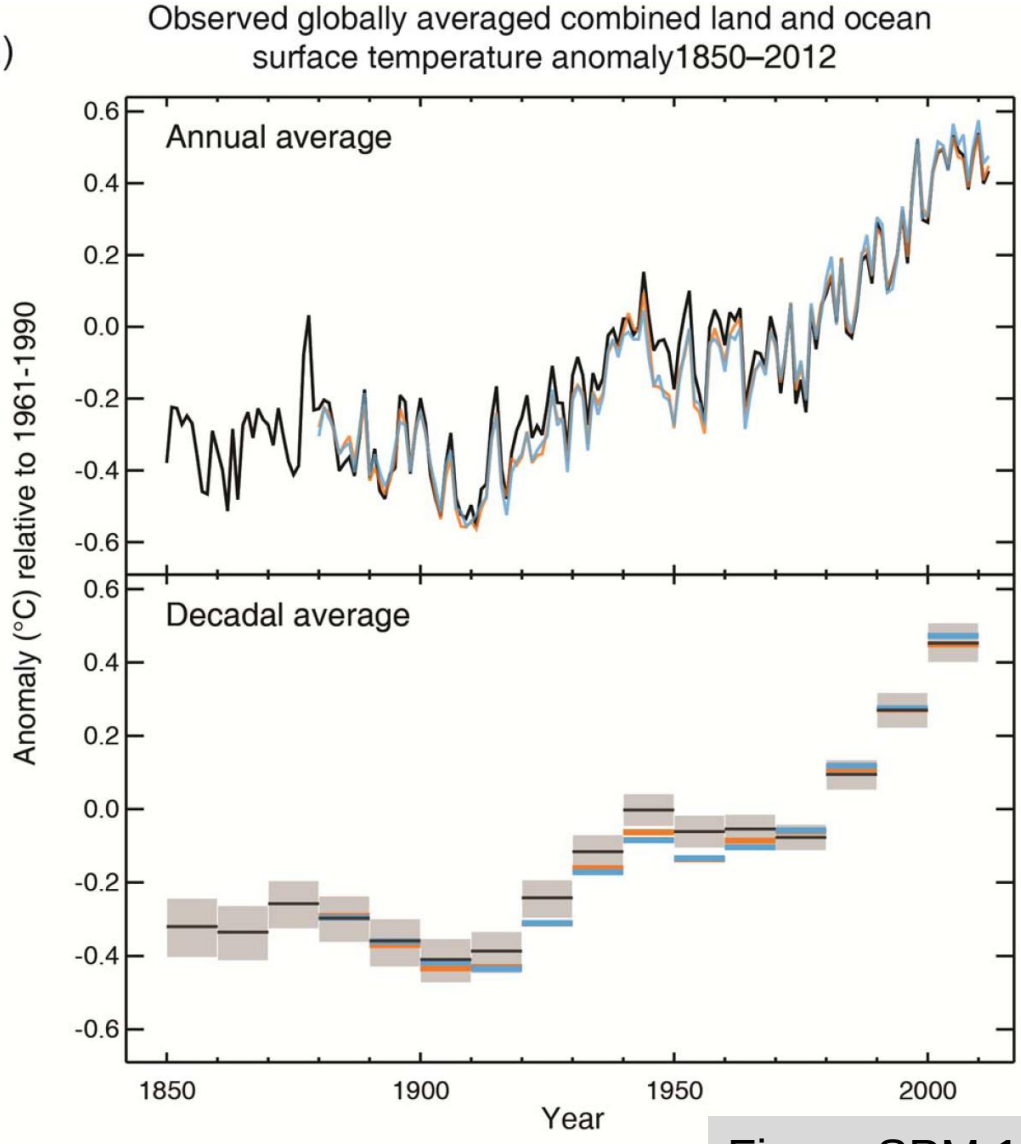
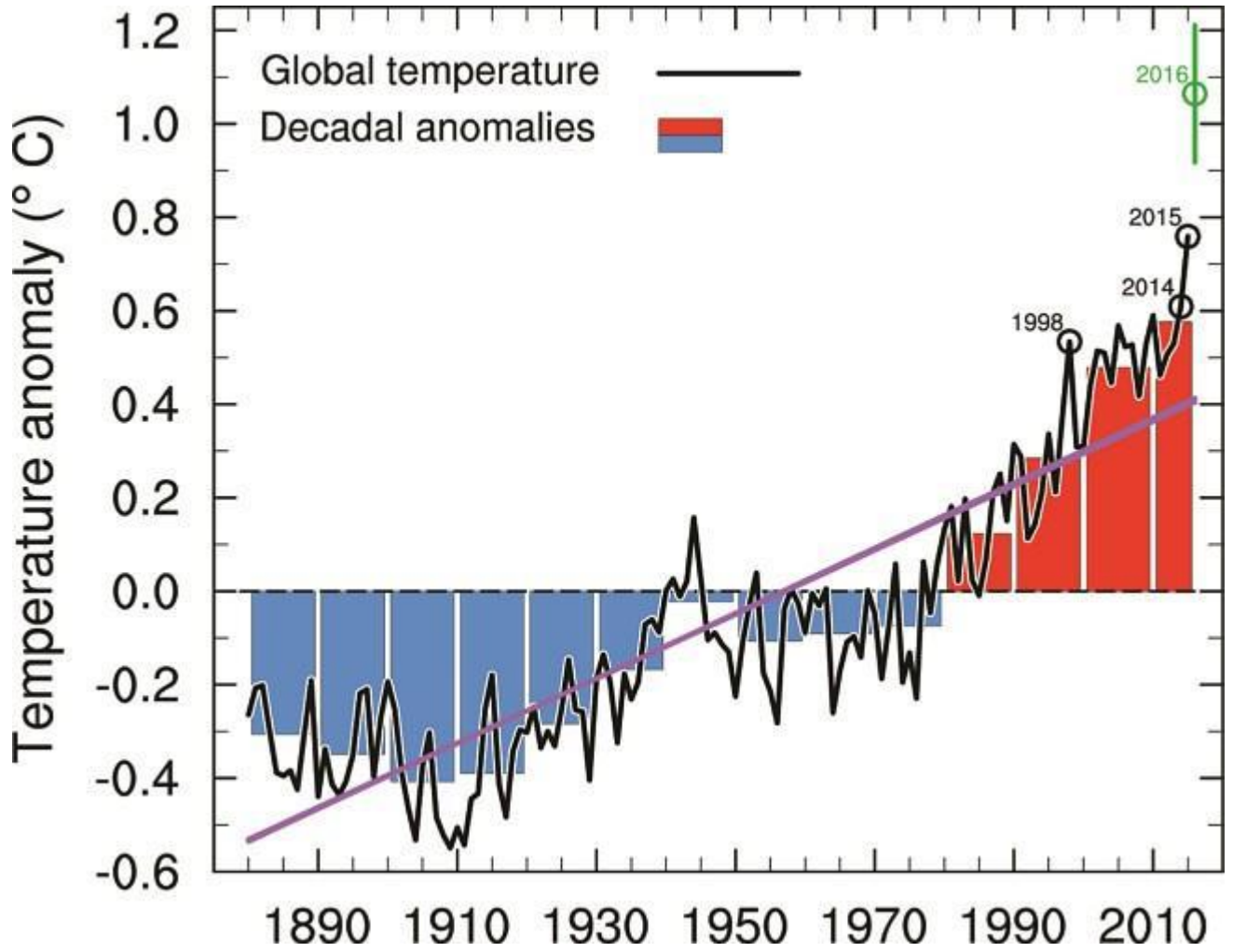


Figure SPM.1

Warming during the period 1880-2012 is 0.85 °C

The first decade this century is the warmest in the period of instrumental record

The last 30 year period is *likely* the warmest 30 year period in 1400 years


Global temperature
Decadal anomalies
2016
2015
2014
1998
Temperature anomaly (° C)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
1890
1910
1930
1950
1970
1990
2010

Global distribution of temperature changes

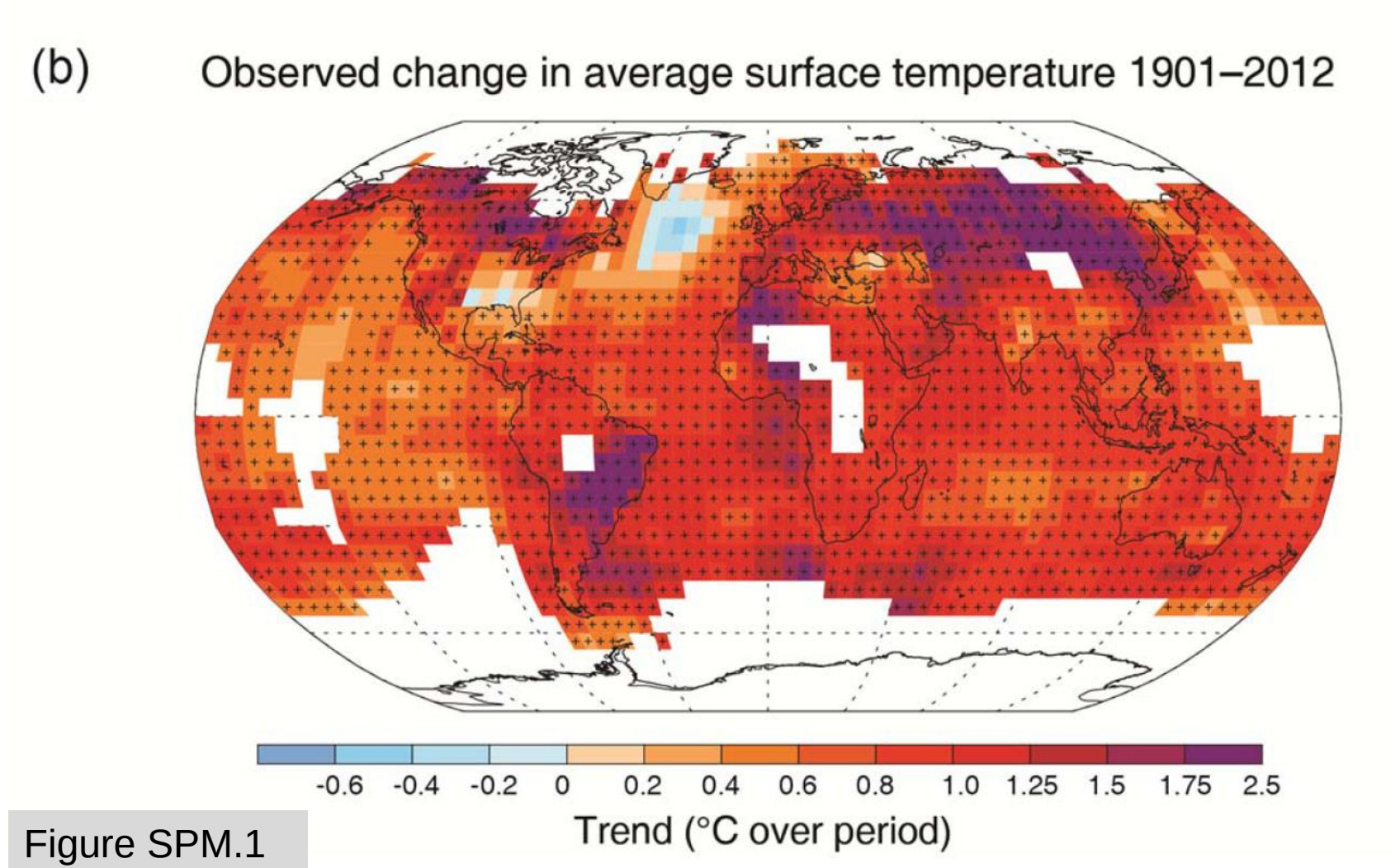
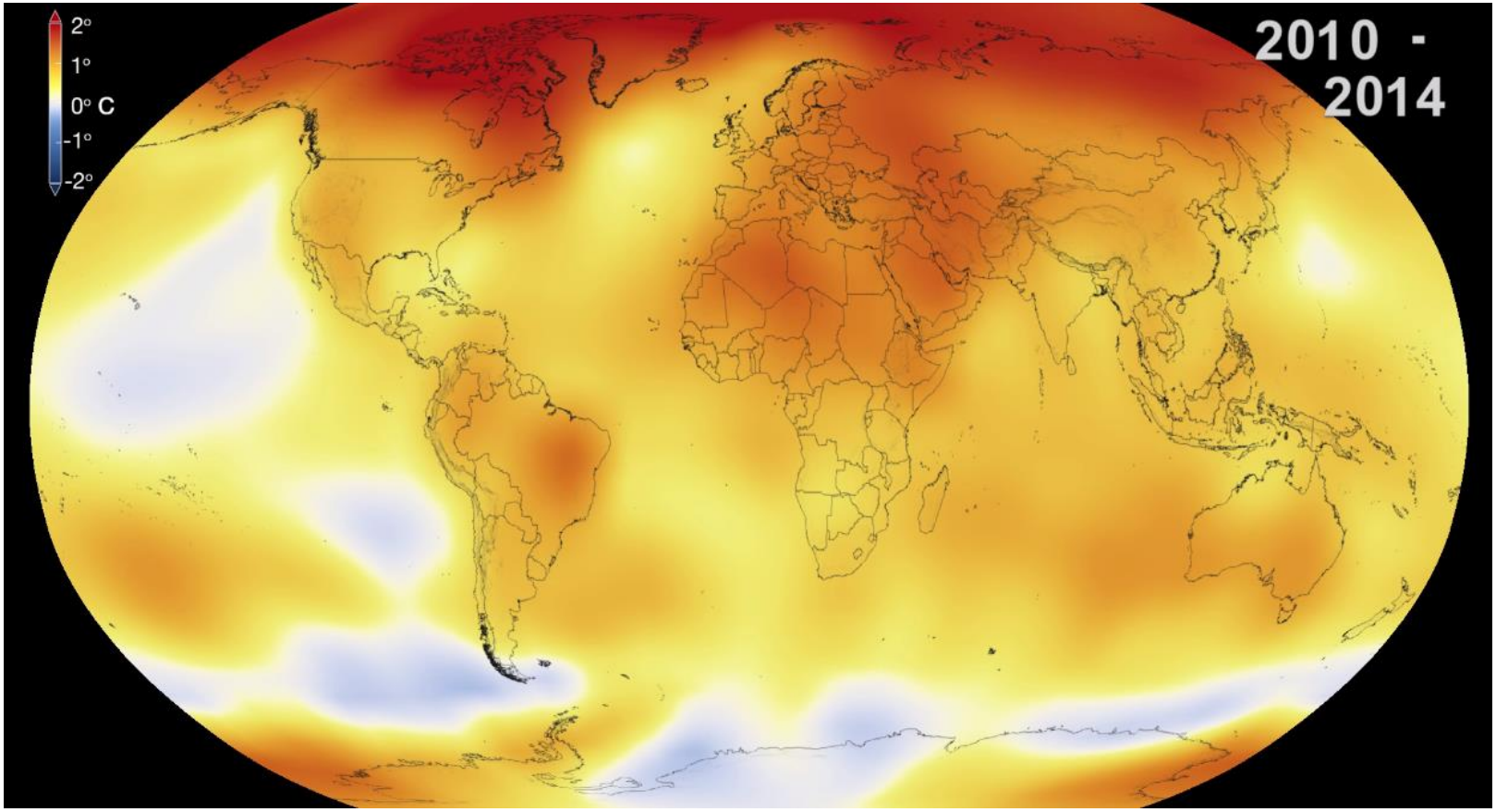
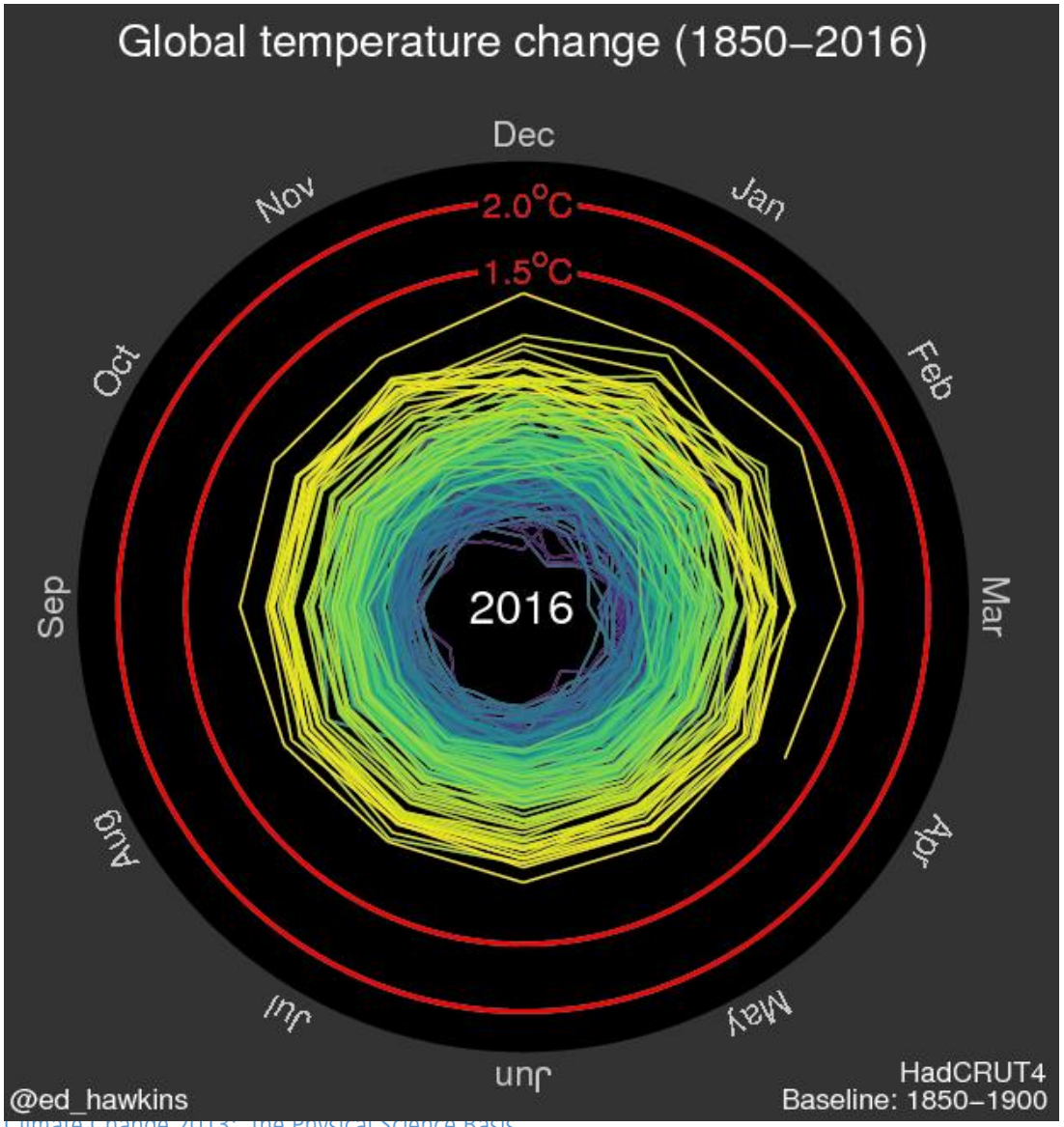


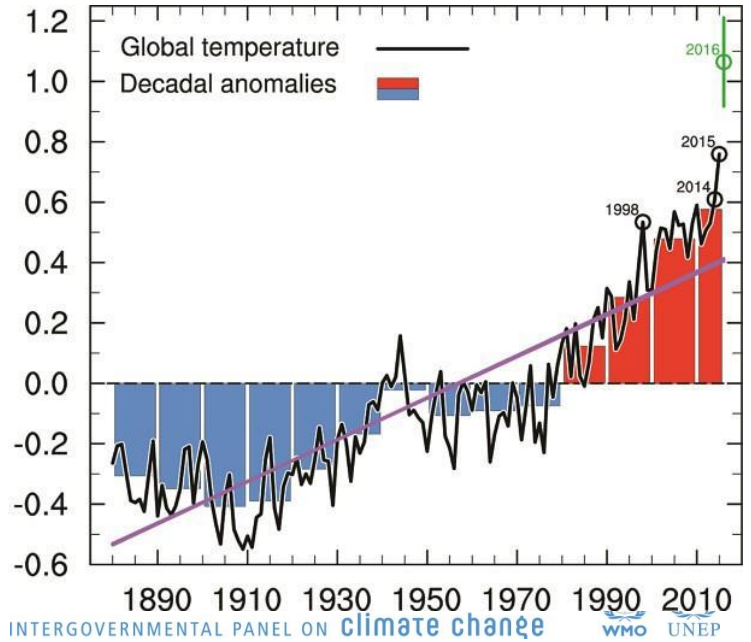
Figure SPM.1

Global warming



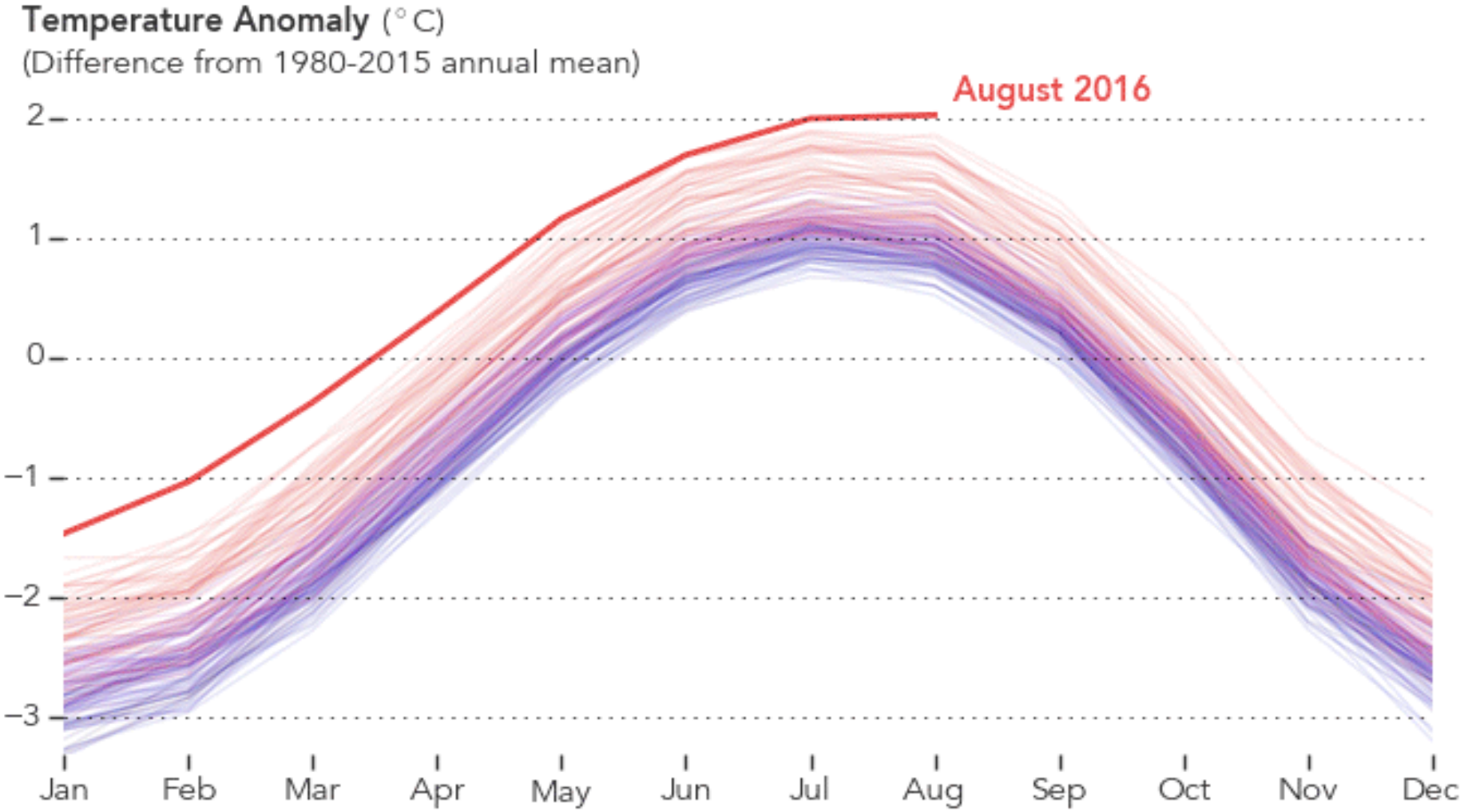
2014_update_robinson_composite.mp4





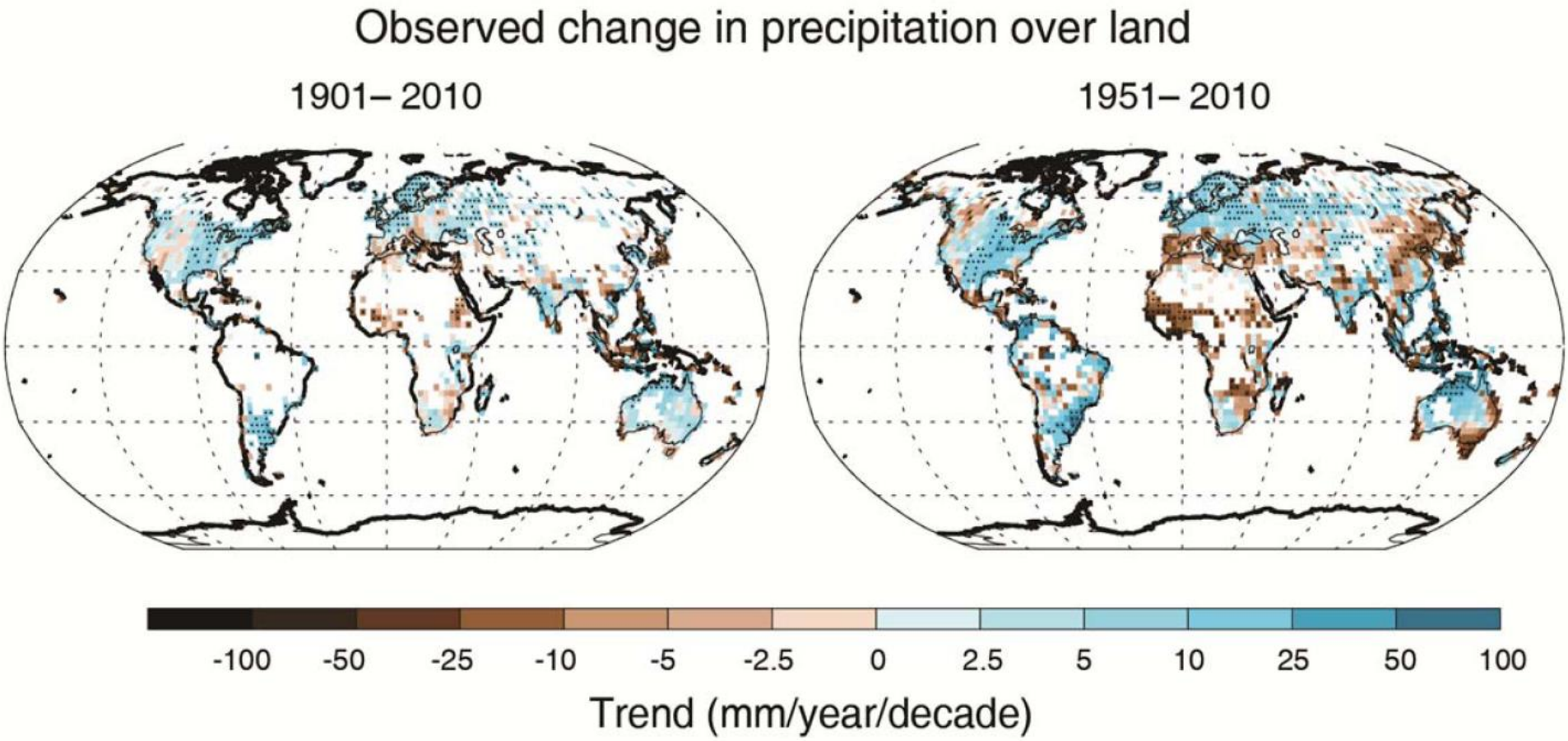
Climate Change 2013: The Physical Science Basis

http://www.climate-lab-book.ac.uk/spirals/



http://earthobservatory.nasa.gov/blogs/earthmatters/files/2016/09/tempanoms_gis_august2016.gif

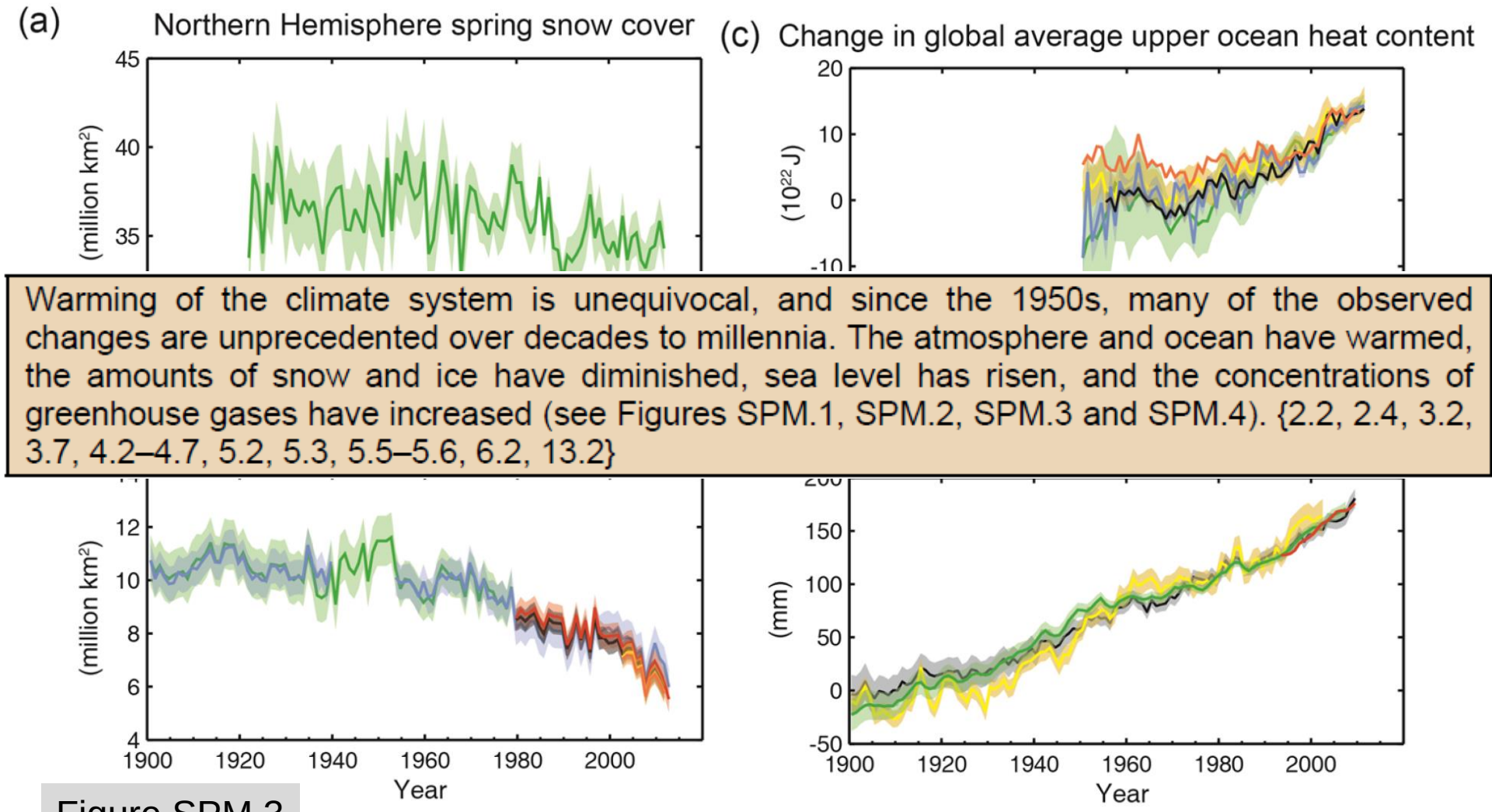
Global distribution of precipitation changes



White areas lack long time observations

Figure SPM.2

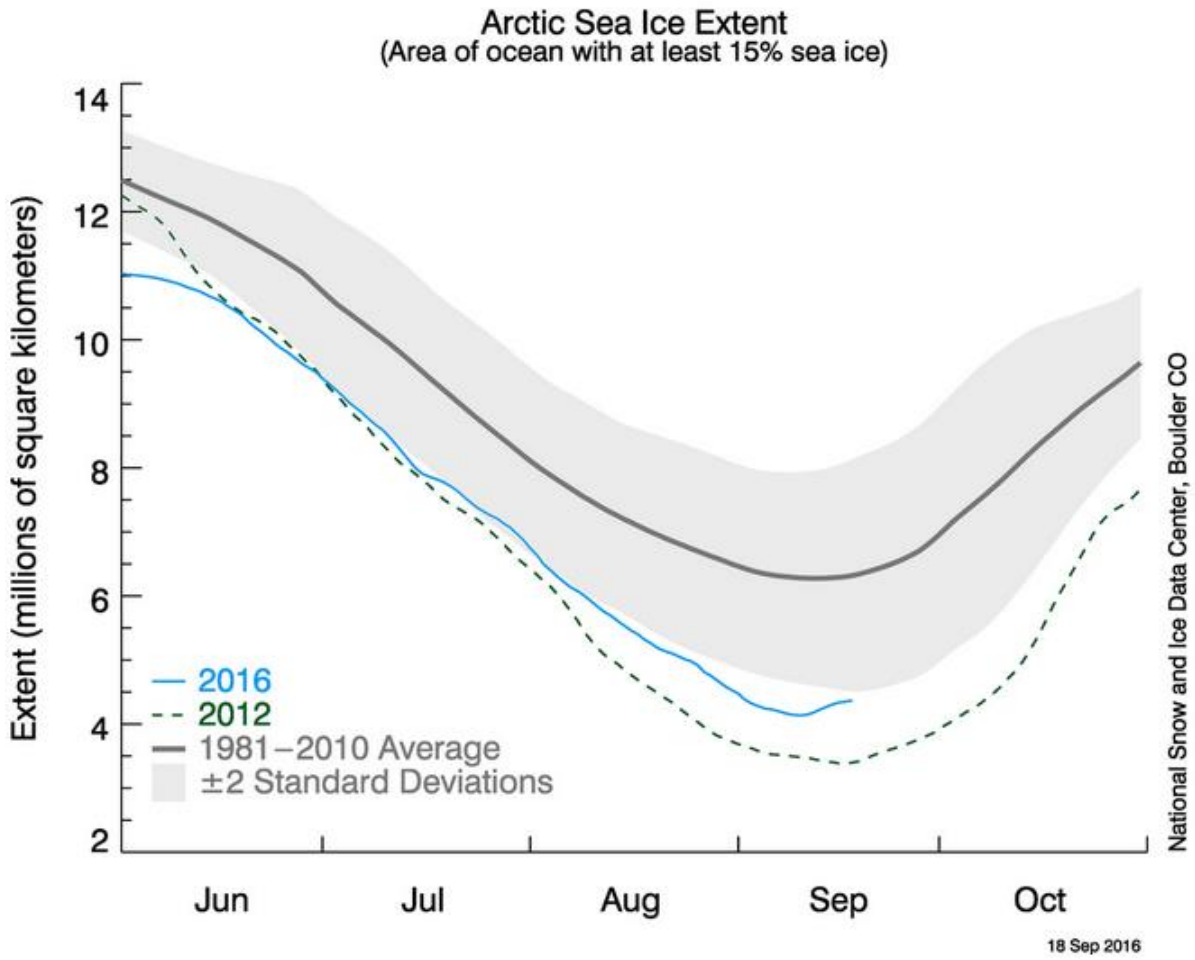
Warming of the entire climate system



Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased (see Figures SPM.1, SPM.2, SPM.3 and SPM.4). {2.2, 2.4, 3.2, 3.7, 4.2–4.7, 5.2, 5.3, 5.5–5.6, 6.2, 13.2}

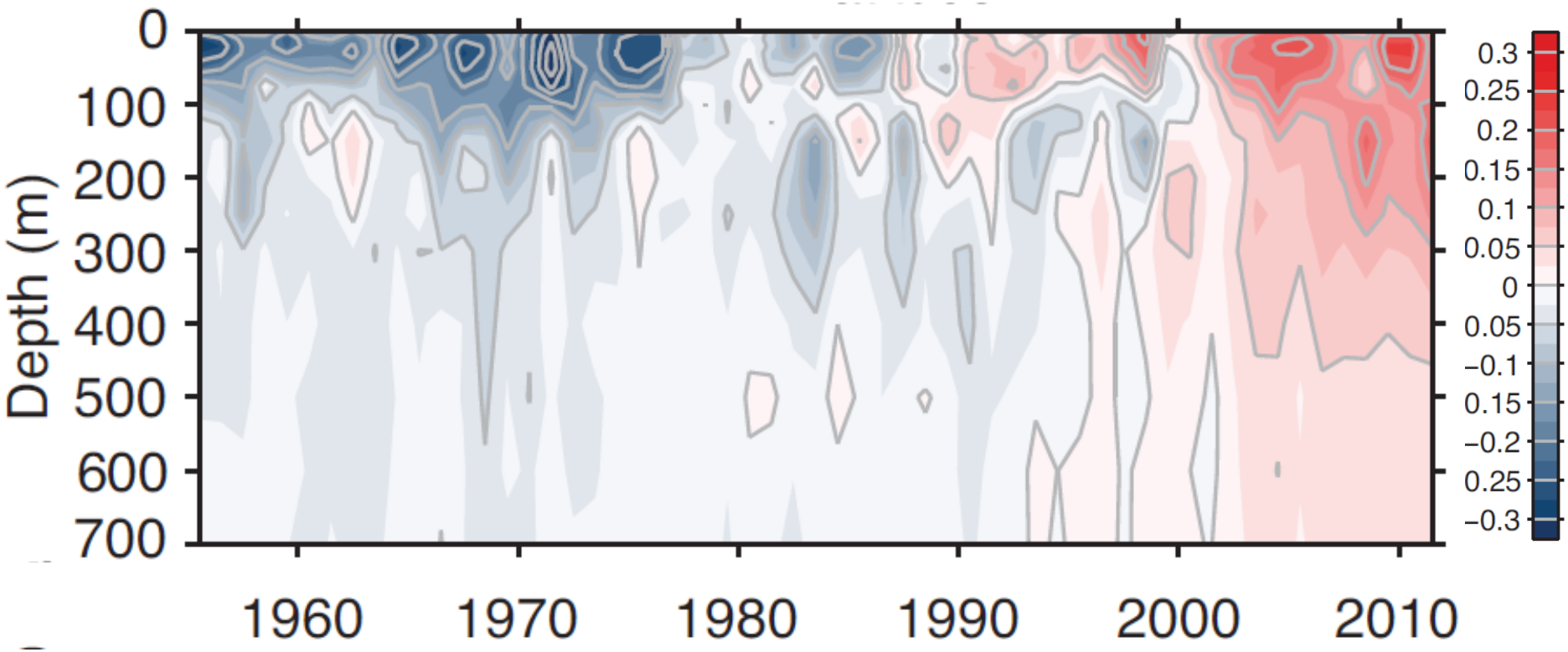
Figure SPM.3

Decline of Arctic sea ice



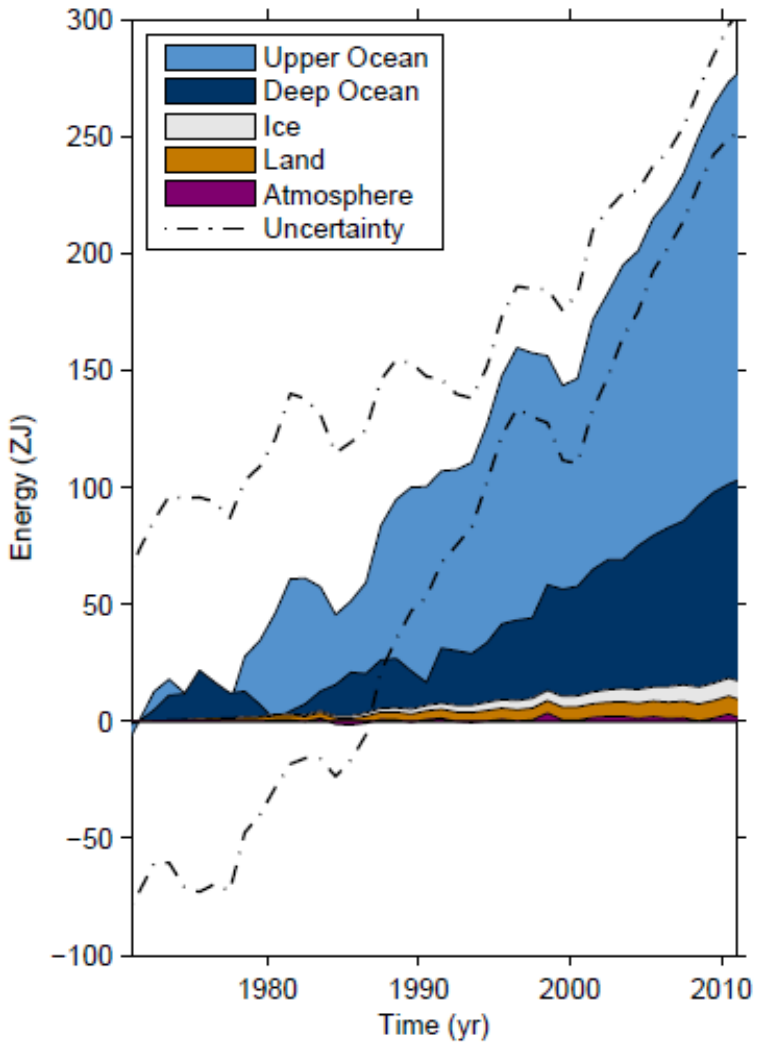
http://nsidc.org/arcticseaicenews/

Warming of the ocean



The warming of the oceans goes deeper during the last decade

The oceans absorb most of the energy



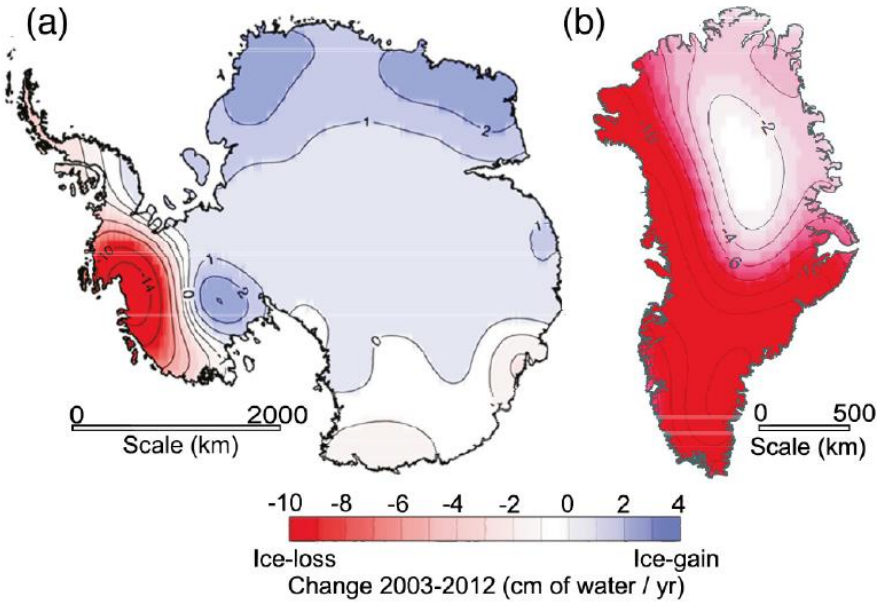
The warming of the oceans amounts to 93% of the energy accumulated in the climate system between1970 and 2010

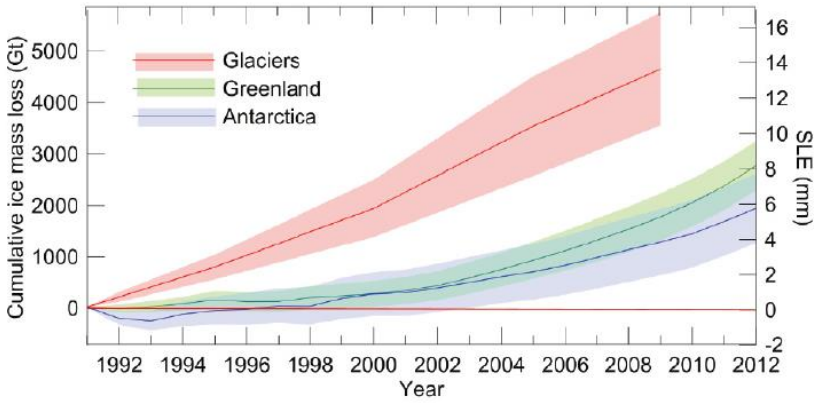
3% has heated land surfaces, 1% the atmosphere and 3% has melted glaciers

Warming of the ocean has contributed to a significant part of the sea level rise

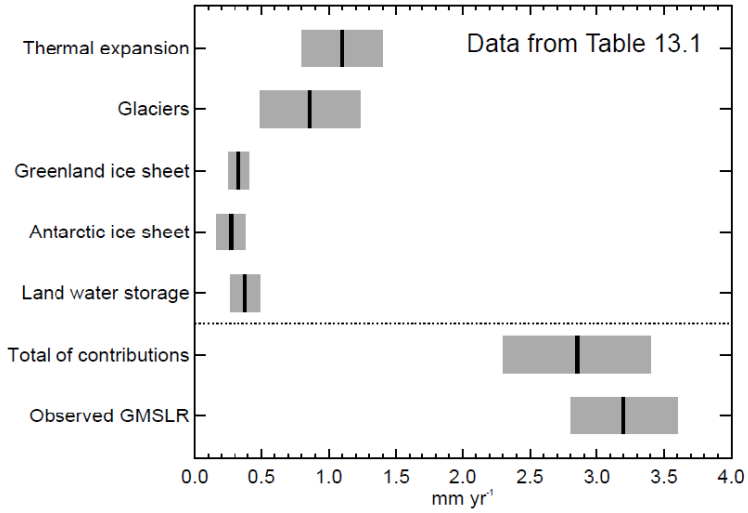
Greenland and Antarctica melting yields sea level rise

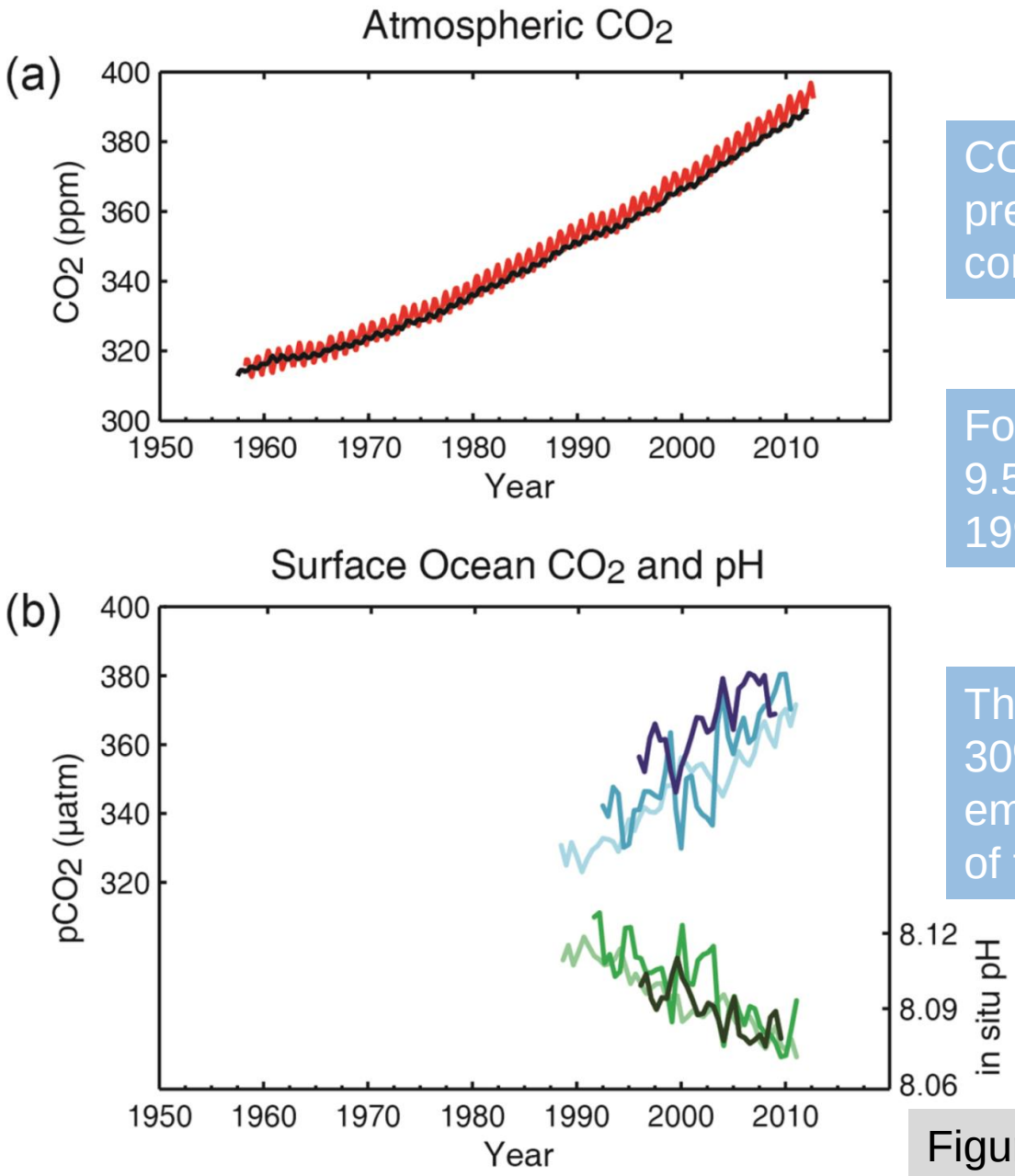
1.7 [1.5 to1.9] mm/yr 1901 – 2010
2.0 [1.7 to 2.3] mm/yr 1971 – 2010
3.2 [2.8 to 3.6] mm/yr 1993 – 2010





Observed contributions explain observed GMSLR 1993-2010



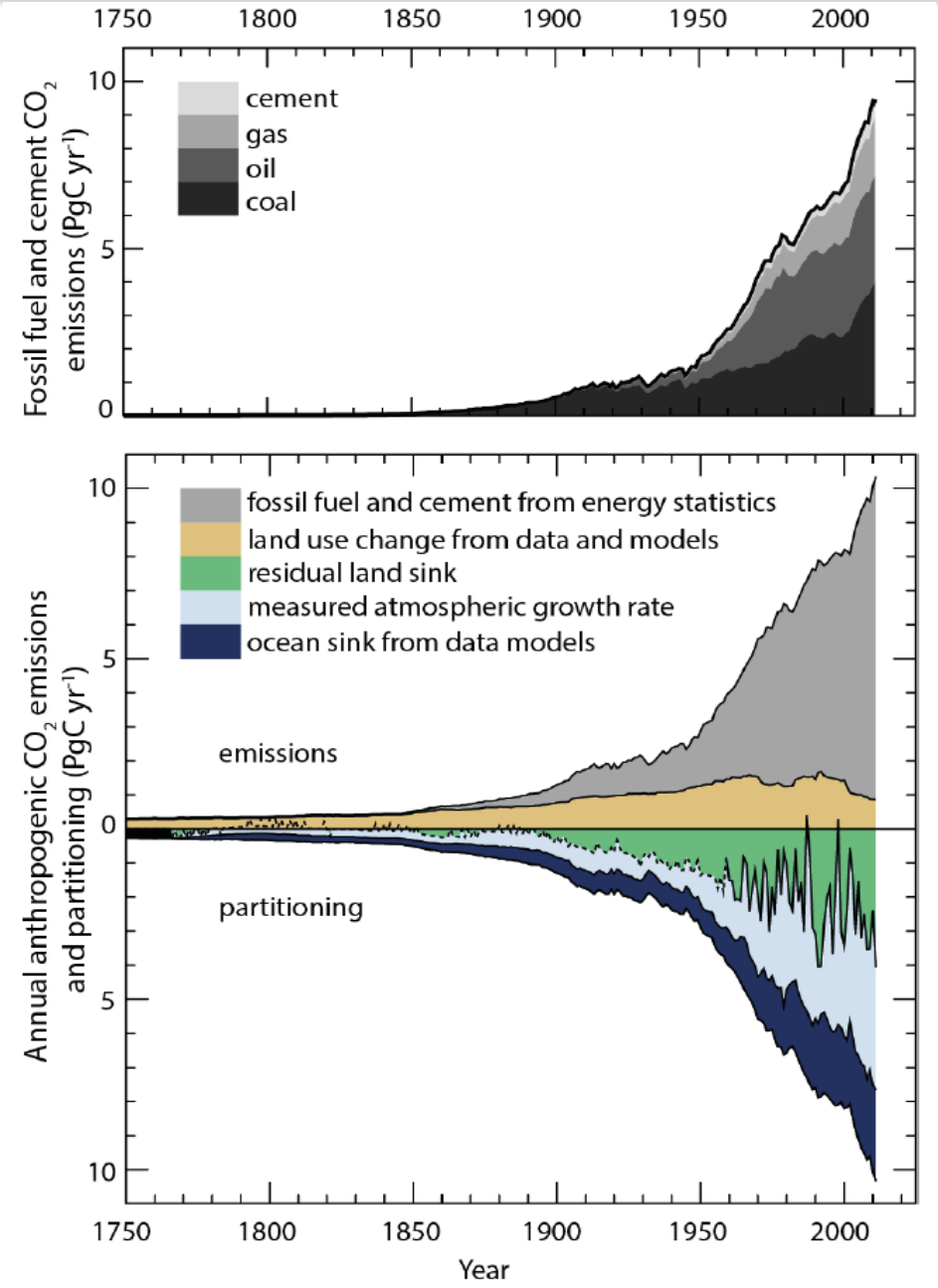


CO_2 has increased by 40% since pre-industrial time to a concentration of 391 ppm in 2011

Fossil fuel emissions in 2011 were 9.5 GtC/yr which is 54% above the 1990 level

The oceans have absorbed ca 30% of the anthropogenic CO_2 emissions resulting in acidification of the oceans

Figure SPM.4



Fossil fuel CO_2 emissions have increased by more than 50% since 1990

Emissions from coal have increased significantly over the last few years

CO_2 emissions from anthropogenic vegetation changes (land use change) have decreased lately

From emissions to climate change

Climate changes

⬆

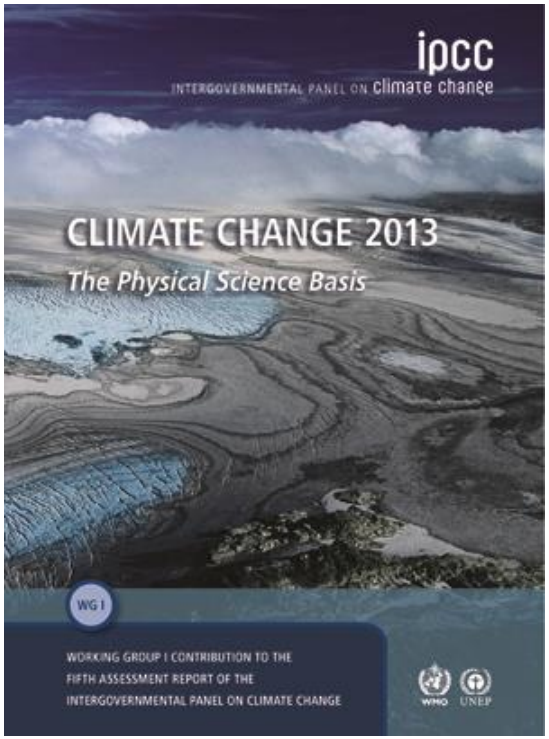
Climate (radiative) forcing

⬆

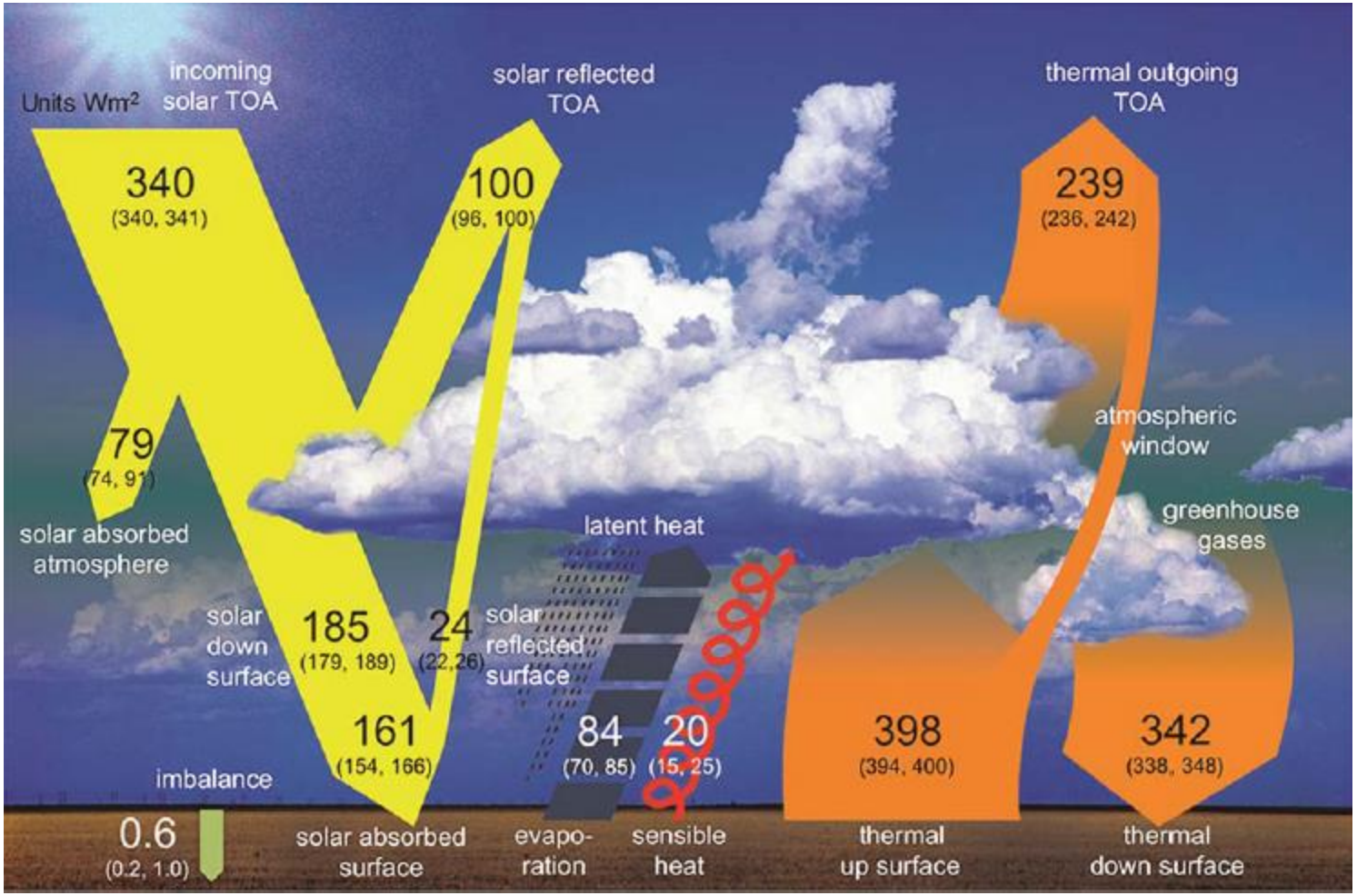
Atmospheric concentration changes

⬆

Emissions



Energy balance and greenhouse effect



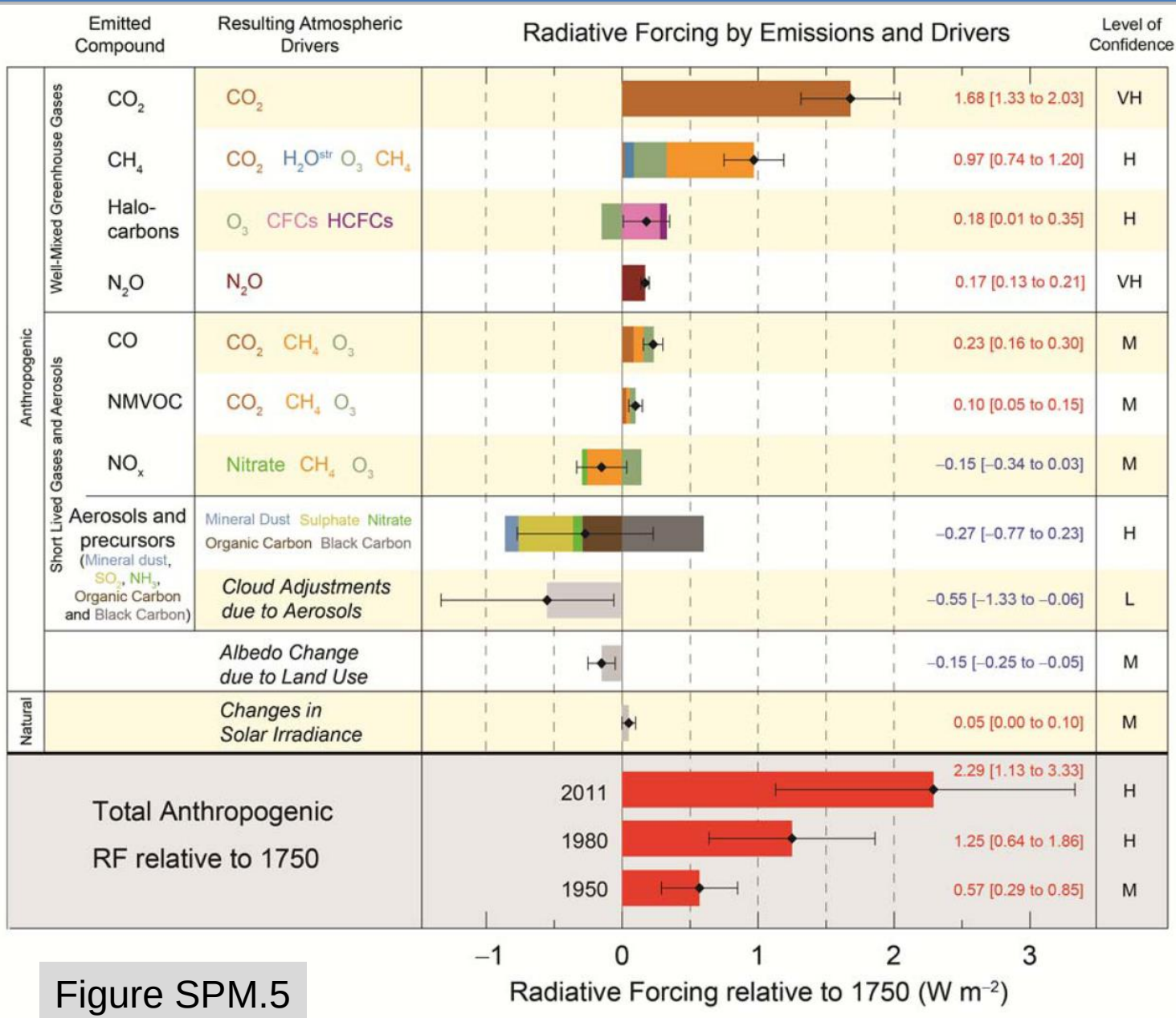
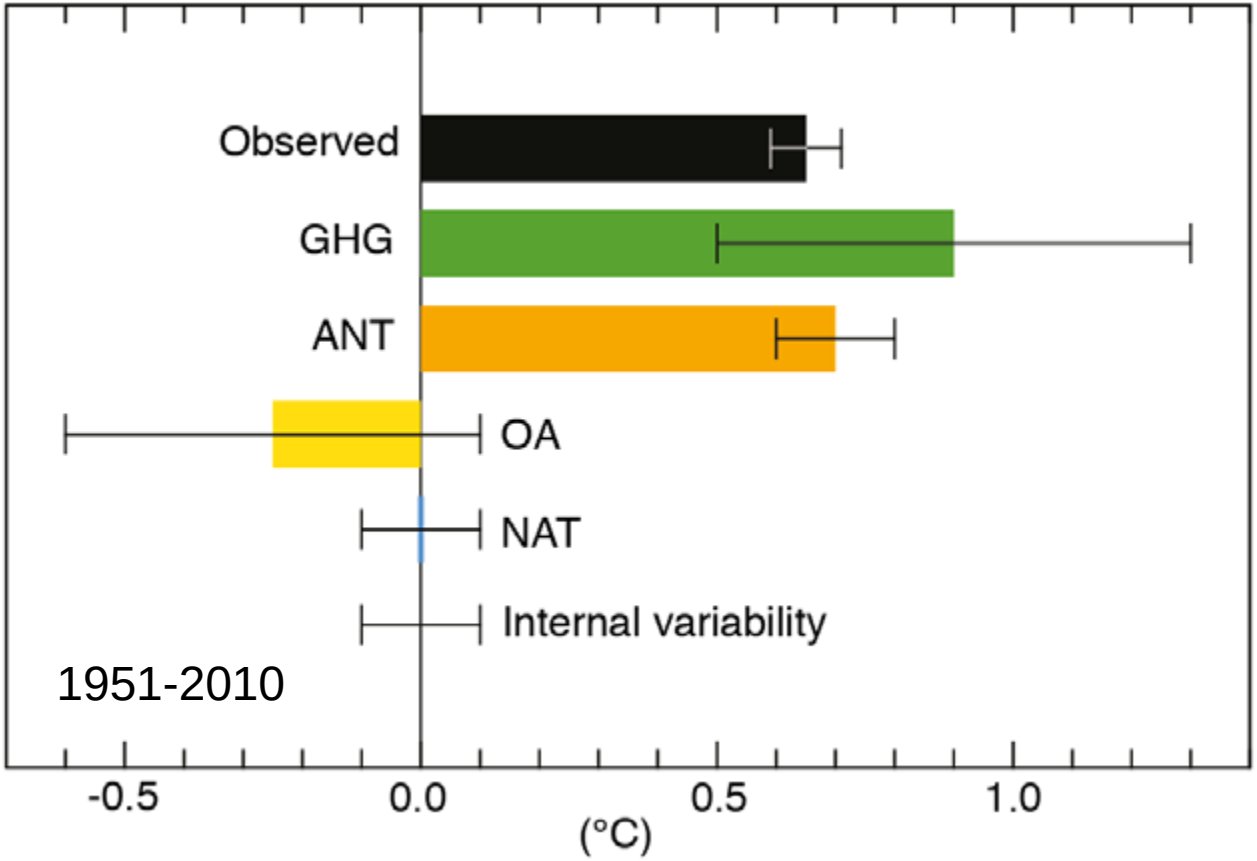


Figure SPM.5

Several components contribute to multiple drivers

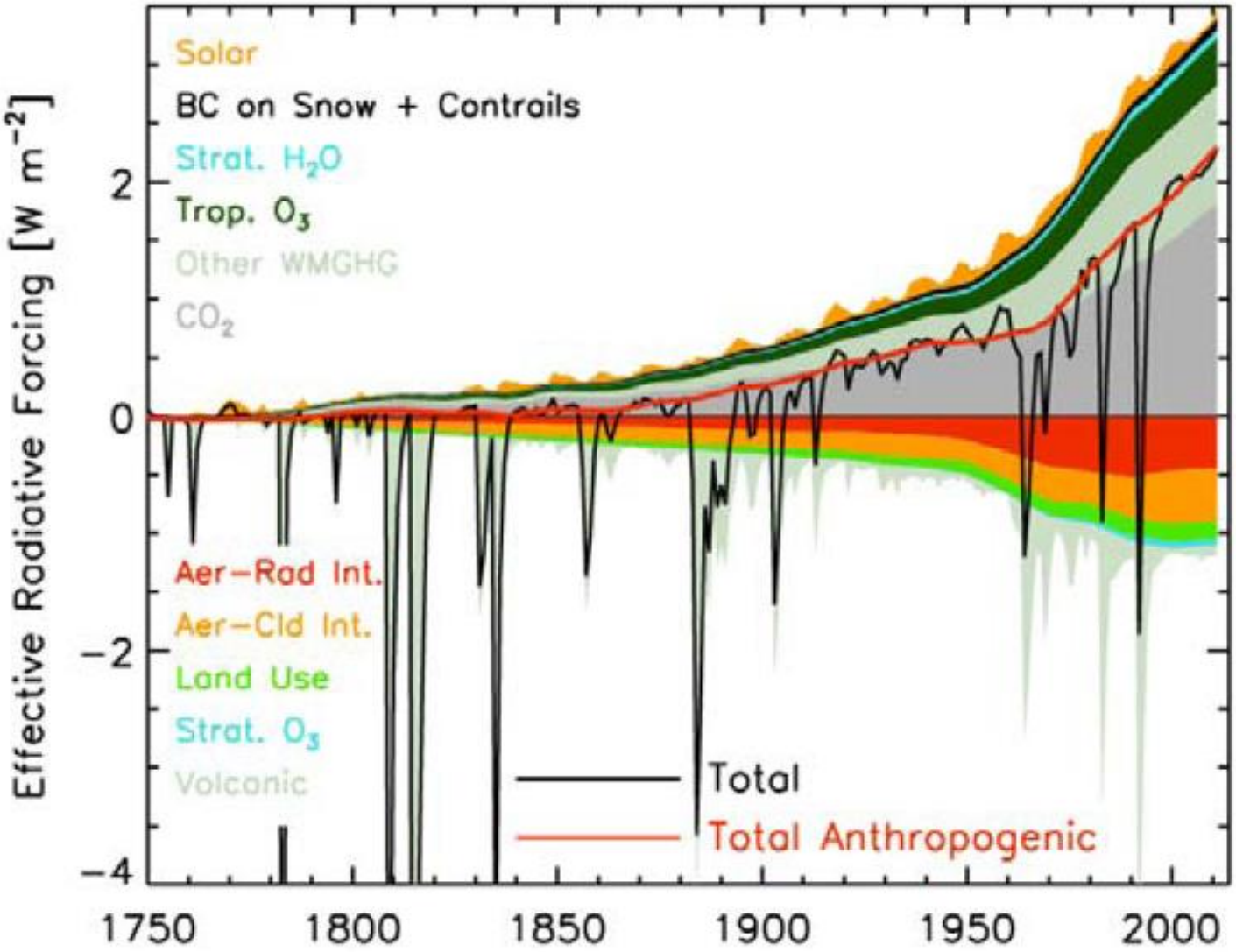
Greenhouse gases strongly positive Aerosols strongly negative



It is *extremely likely* that human influence has been the dominant cause of the observed warming since the mid-20th century.

* well-mixed greenhouse gases (GHG)
* other anthropogenic forcings (OA)
* natural forcings (NAT)
* combined anthropogenic forcings (ANT)
* internal variability

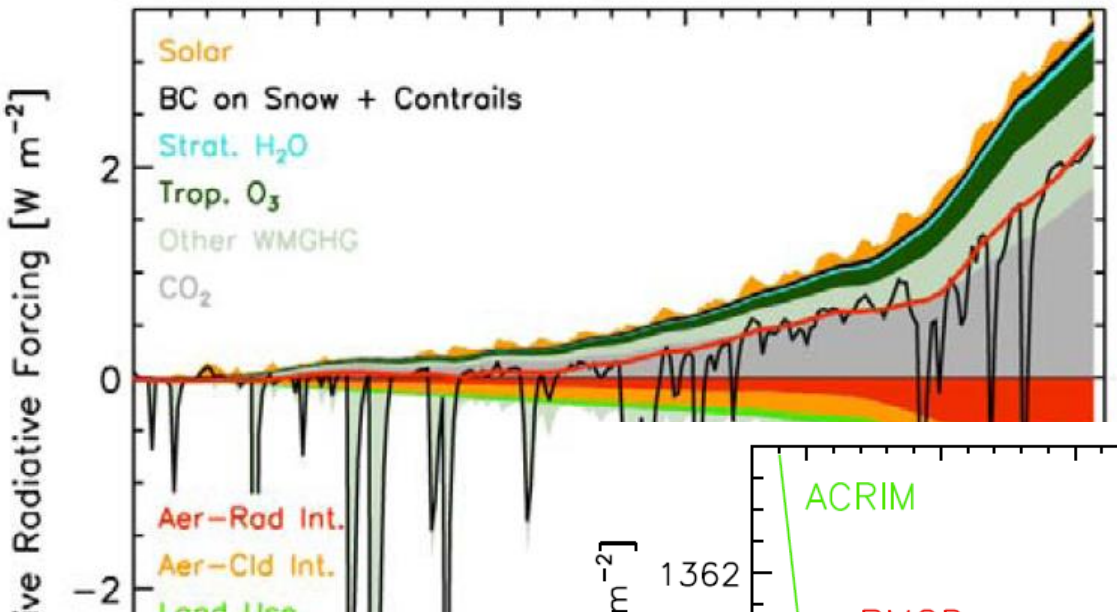
Figure 10.5



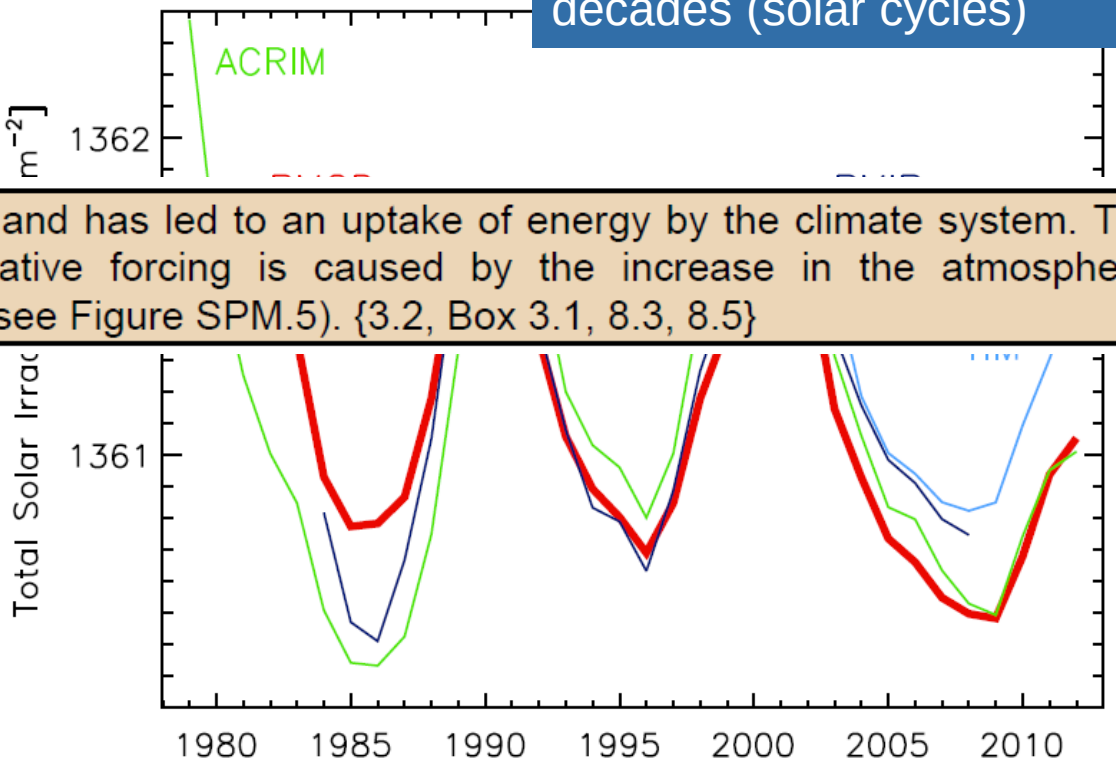
Steady increase for all drivers except volcanos

Strong increase in total anthropogenic forcing since 1970

CO_2 and other GHG clearly most important, but other contributions are significant



Solar radiation slightly weaker over the last few decades (solar cycles)



Total radiative forcing is positive, and has led to an uptake of energy by the climate system. The largest contribution to total radiative forcing is caused by the increase in the atmospheric concentration of CO_2 since 1750 (see Figure SPM.5). {3.2, Box 3.1, 8.3, 8.5}

From emissions to climate change

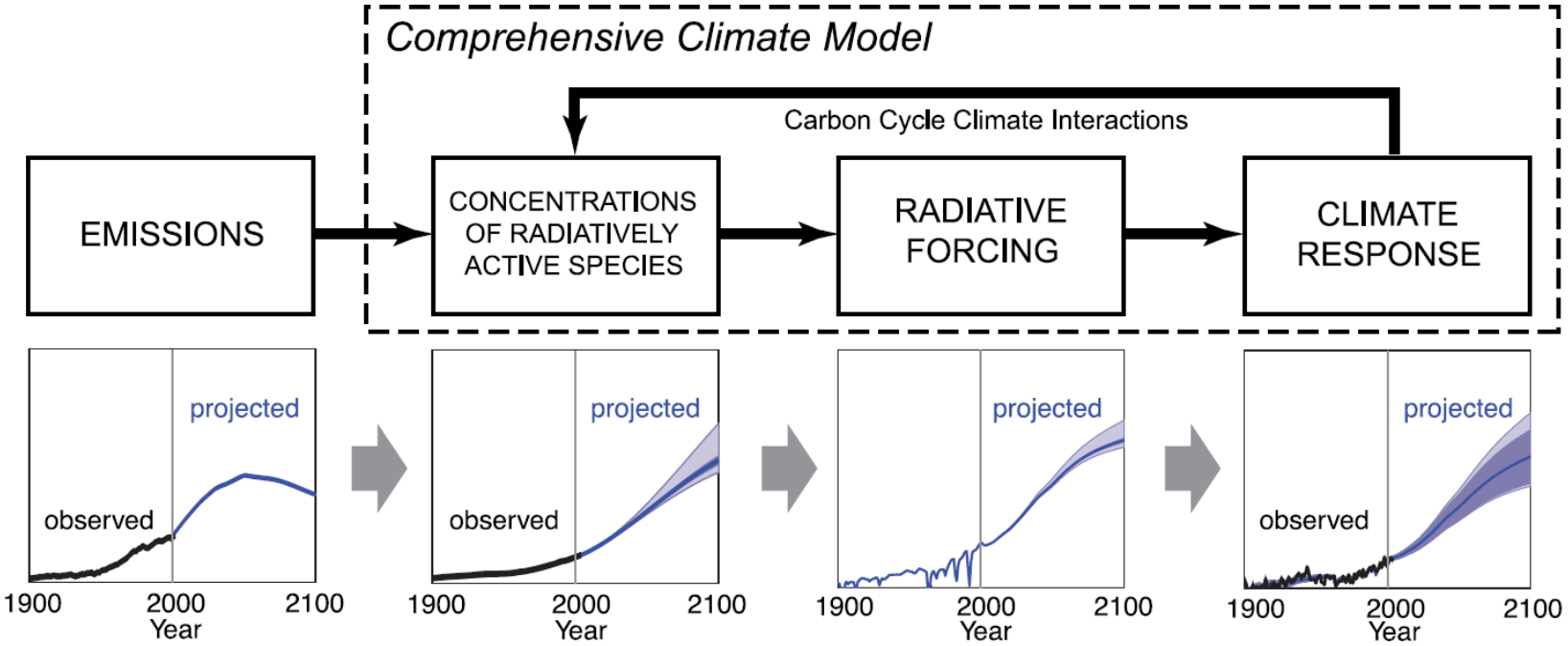
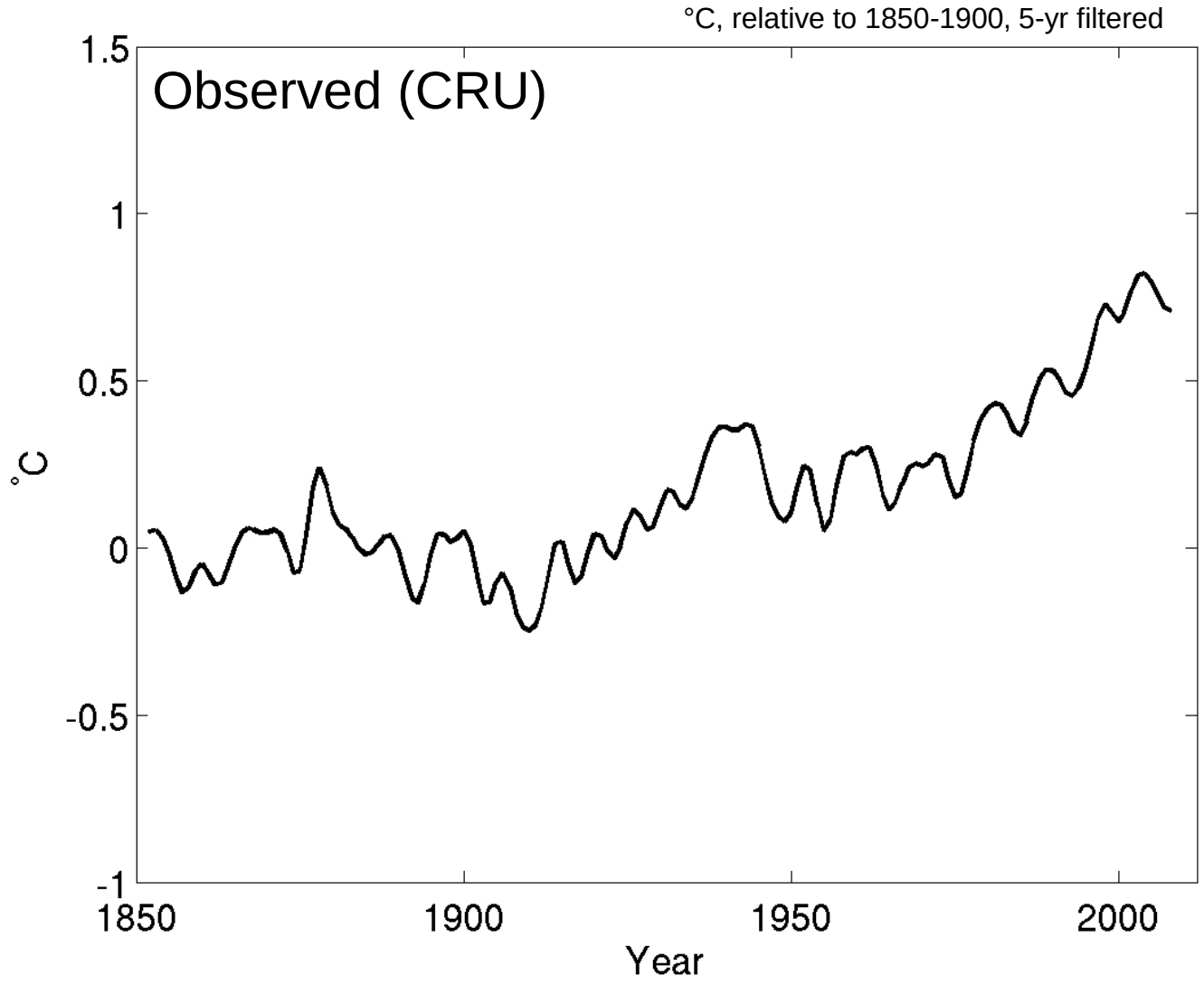


Figure 10.1. *Several steps from emissions to climate response contribute to the overall uncertainty of a climate model projection. These uncertainties can be quantified through a combined effort of observation, process understanding, a hierarchy of climate models, and ensemble simulations. In a comprehensive climate model, physical and chemical representations of processes permit a consistent quantification of uncertainty. Note that the uncertainty associated with the future emission path is of an entirely different nature and not addressed in Chapter 10. Bottom row adapted from Figure 10.26, A1B scenario, for illustration only.*

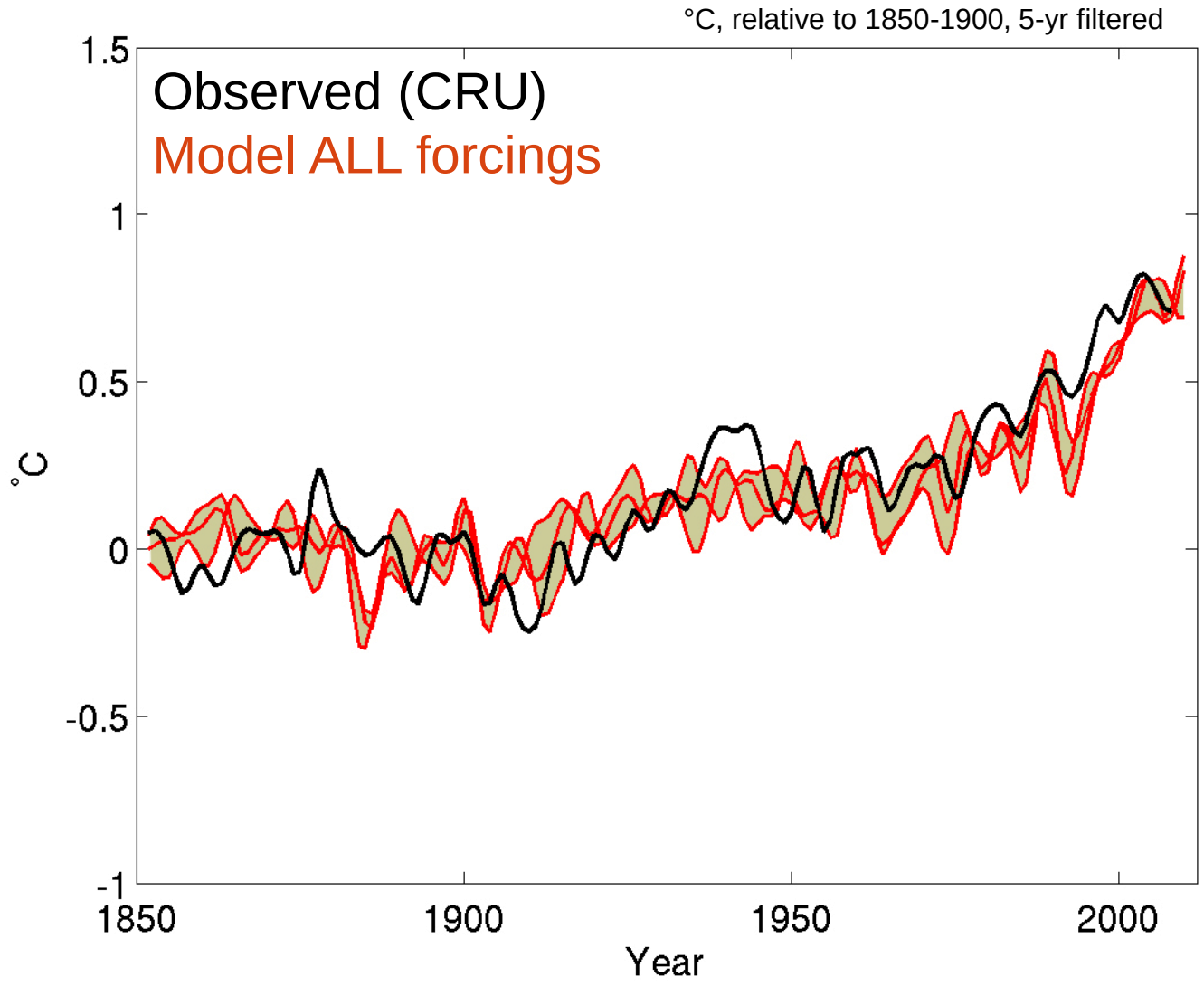
IPCC, 2007

Simulated vs observed global temperature



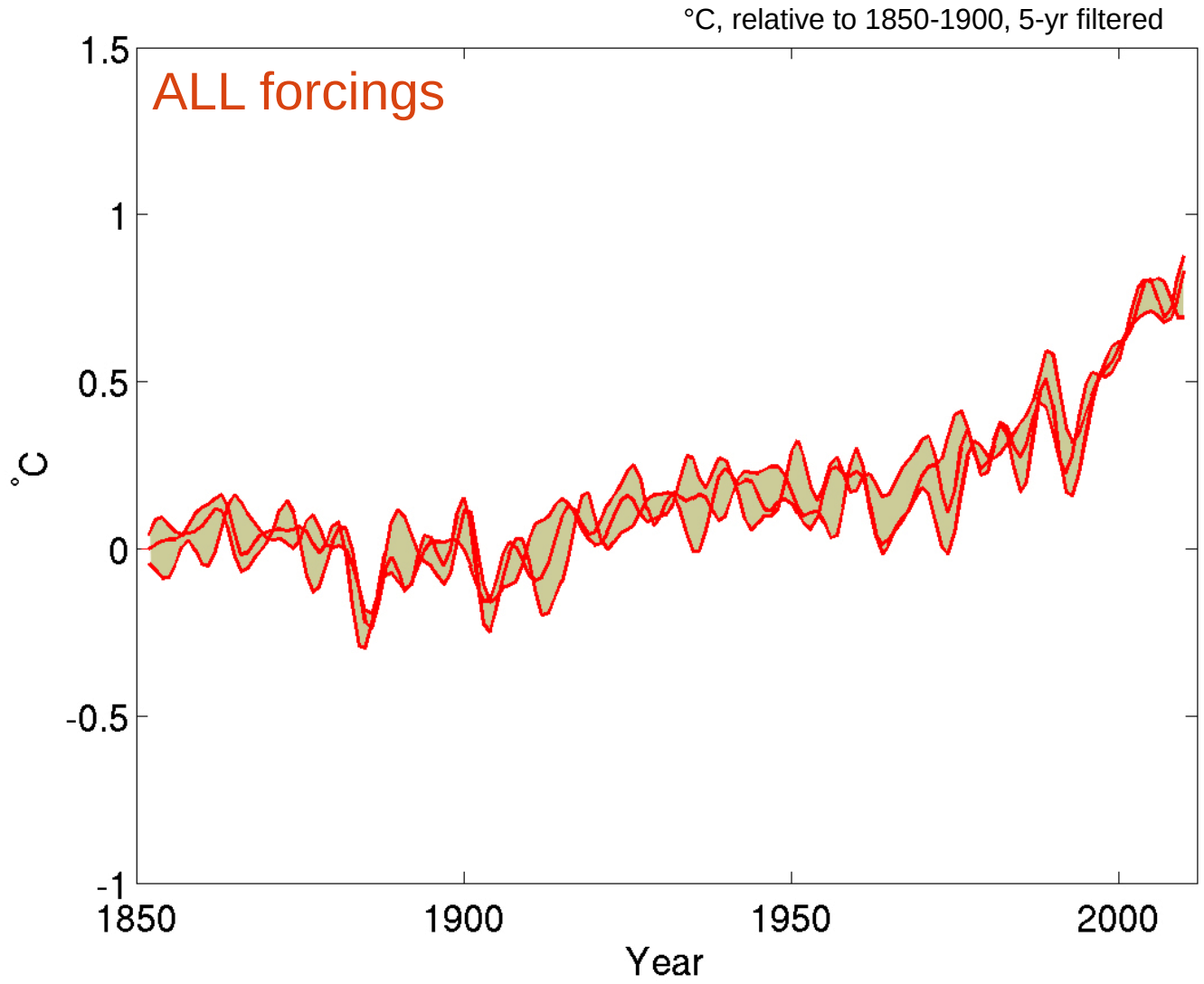
Courtesy of OH Otterå

Simulated vs observed global temperature



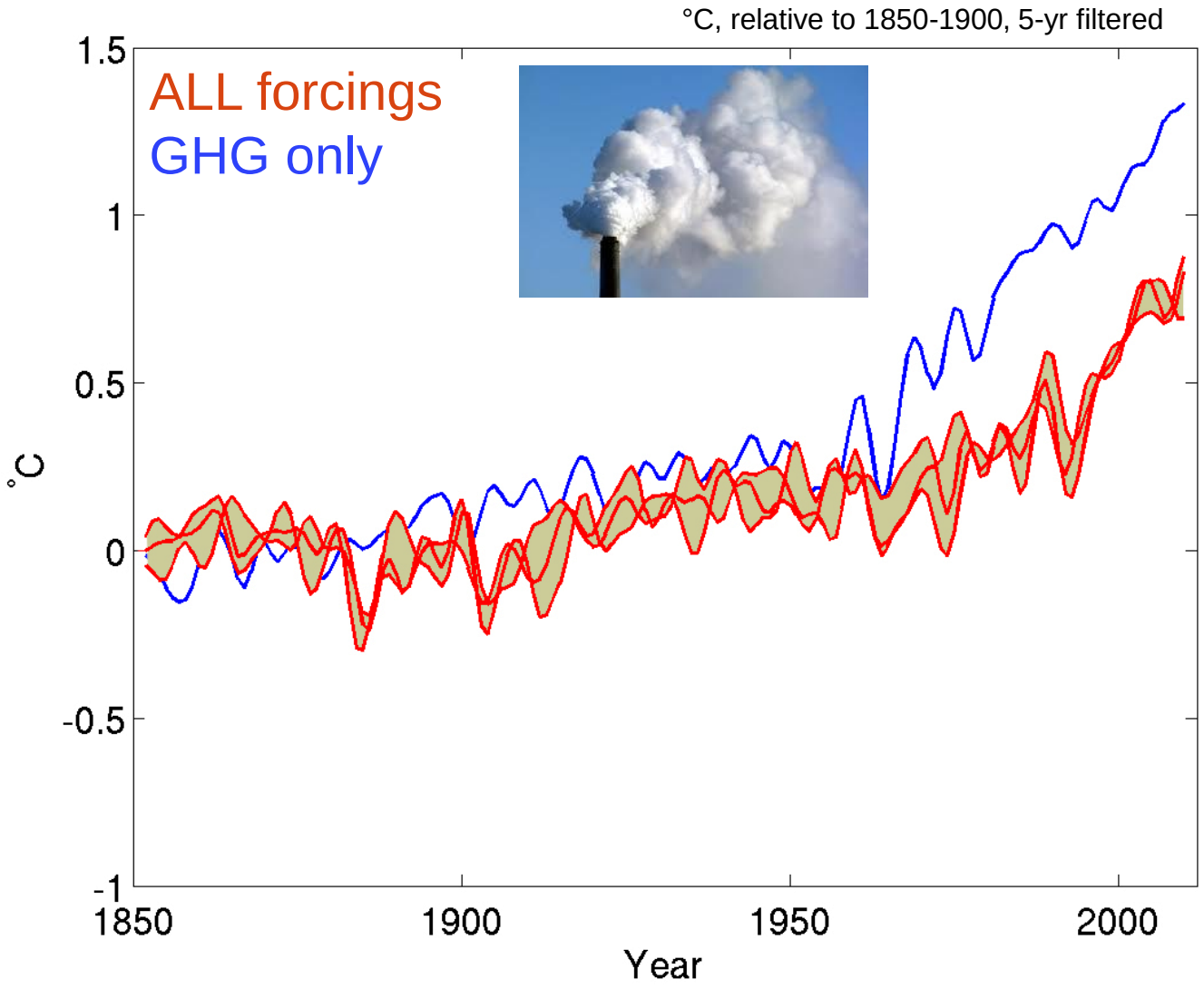
Courtesy of OH Otterå

Natural vs human-induced forcings



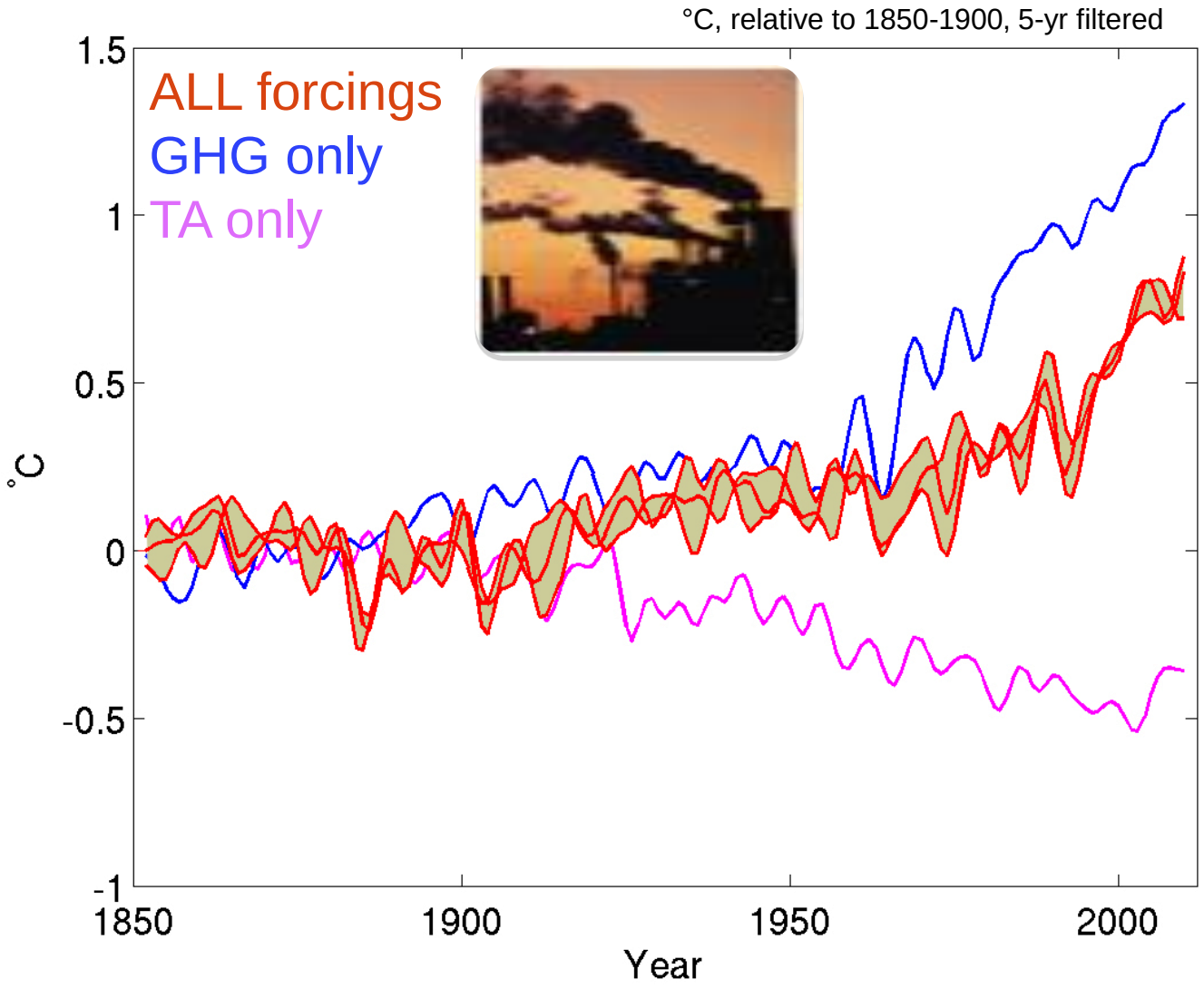
Courtesy of OH Otterå

Natural vs human-induced forcings



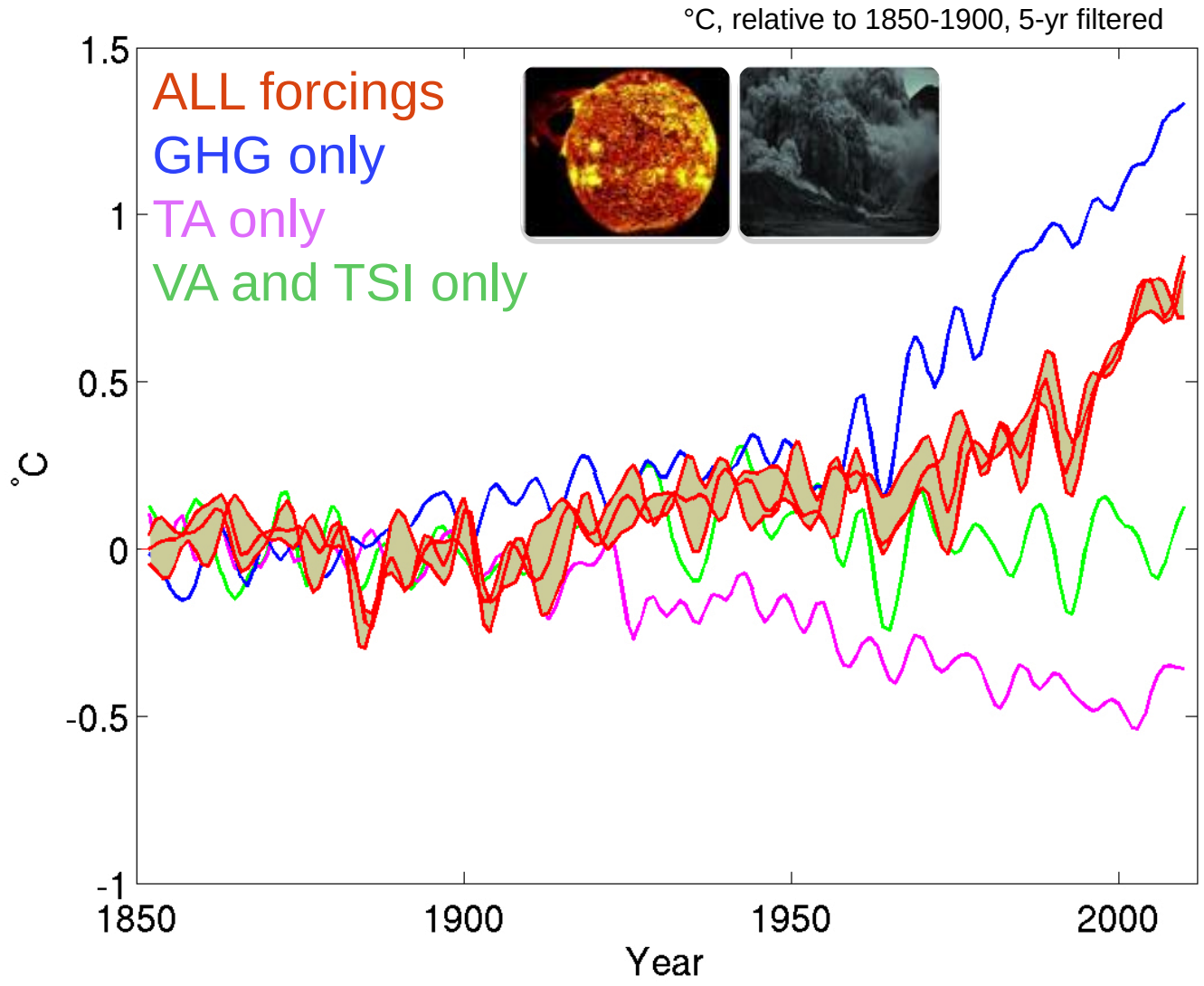
Courtesy of OH Otterå

Natural vs human-induced forcings



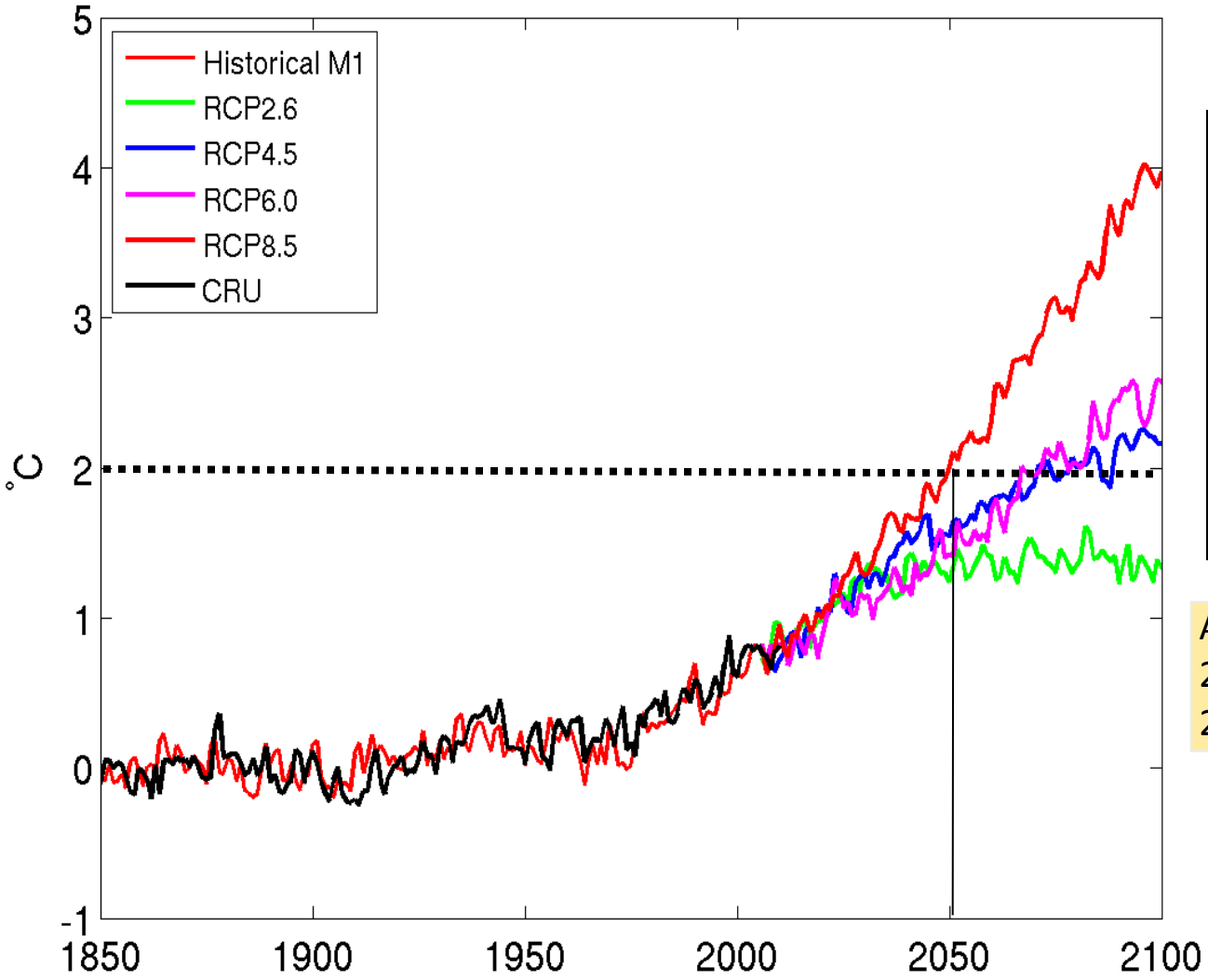
Courtesy of OH Otterå

Natural vs human-induced forcings



Courtesy of OH Otterå

Simulated future global temperature change

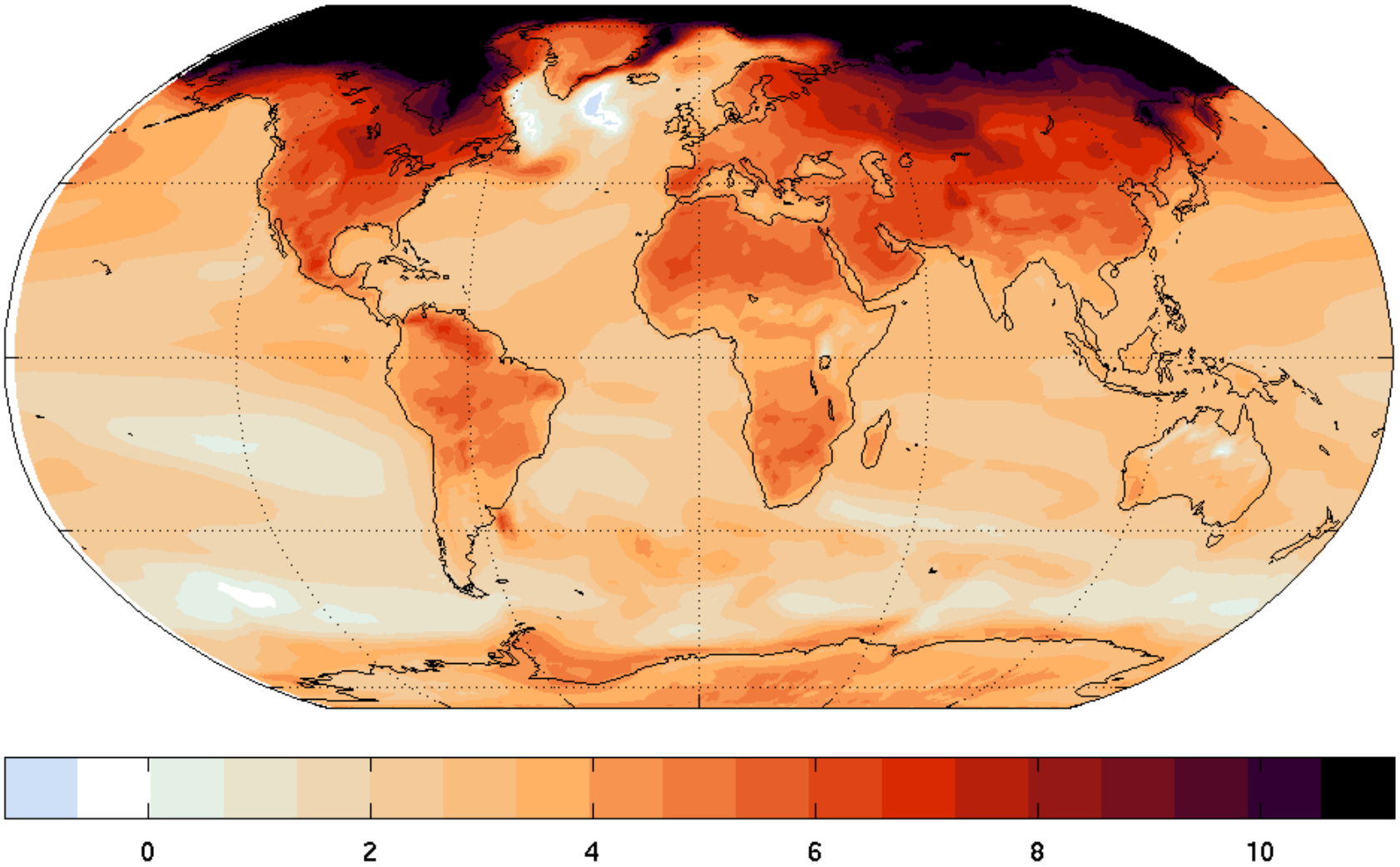


According to NorESM only RCP 2.6 pathway keeps us below 2°C global warming

Courtesy of OH Otterå

Simulated change in surface temperature, RCP8.5

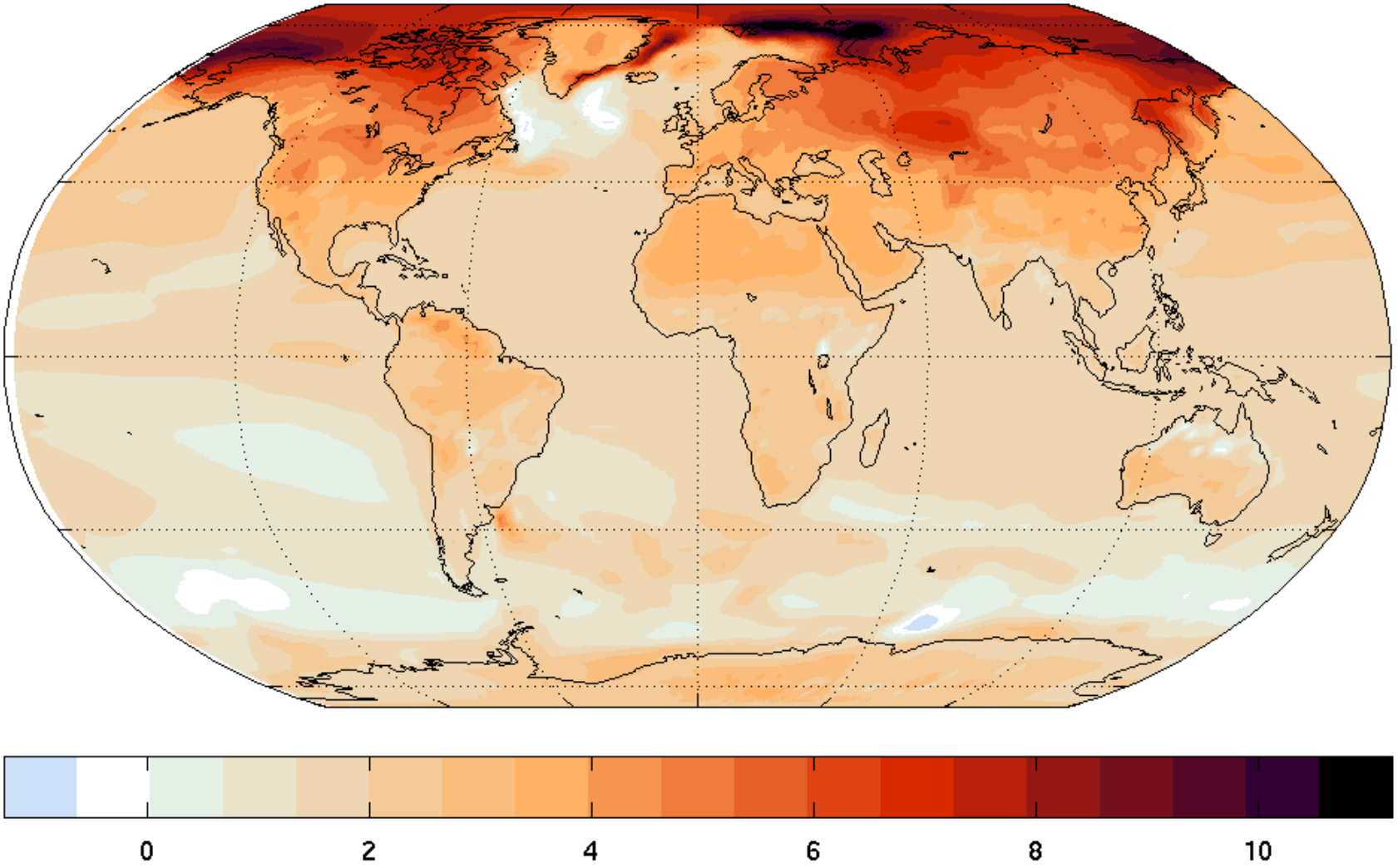
°C, 2090-2099 vs 1961-1990



Courtesy of OH Otterå

Simulated change in surface temperature, RCP6.0

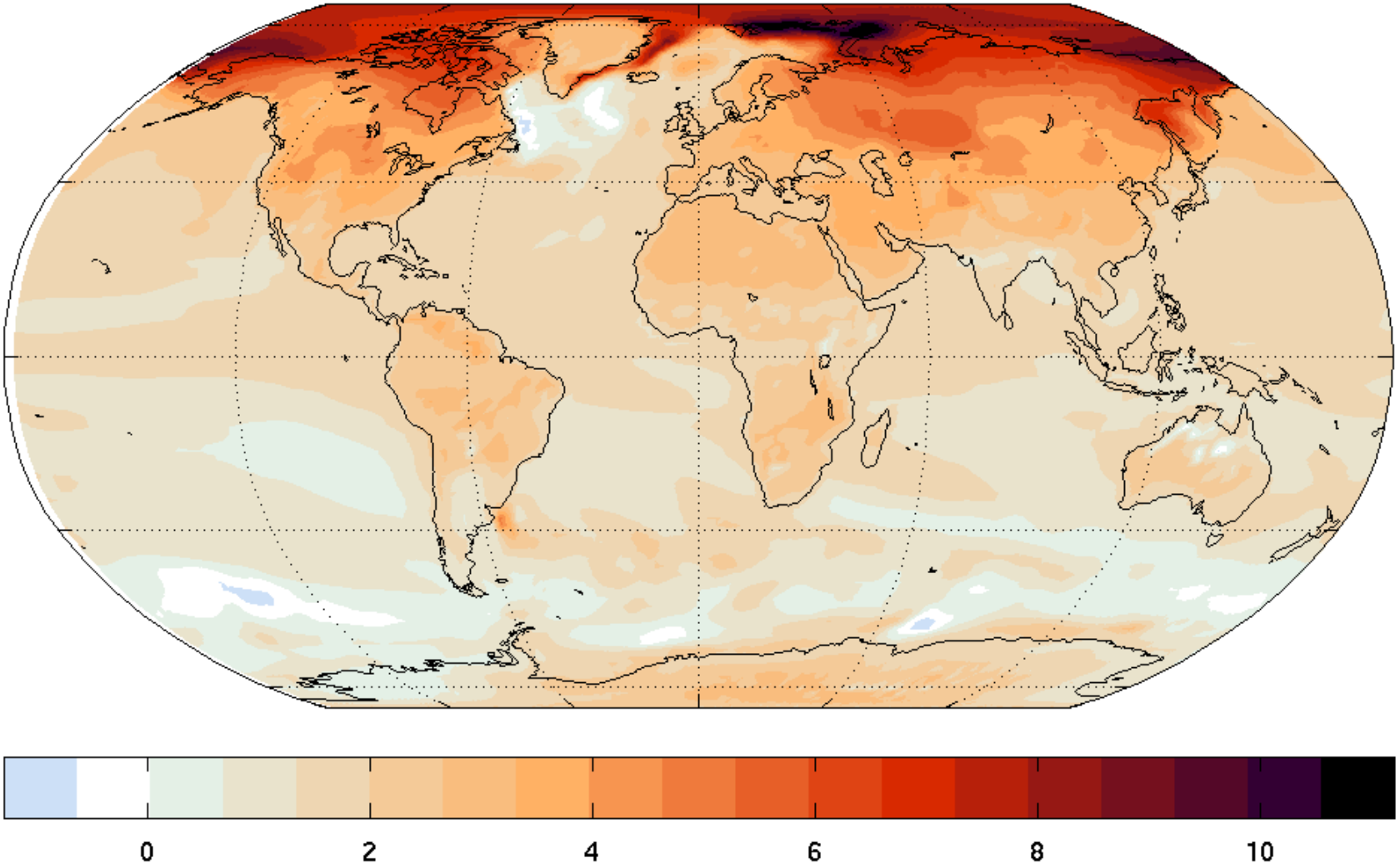
°C, 2090-2099 vs 1961-1990



Courtesy of OH Otterå

Simulated change in surface temperature, RCP4.5

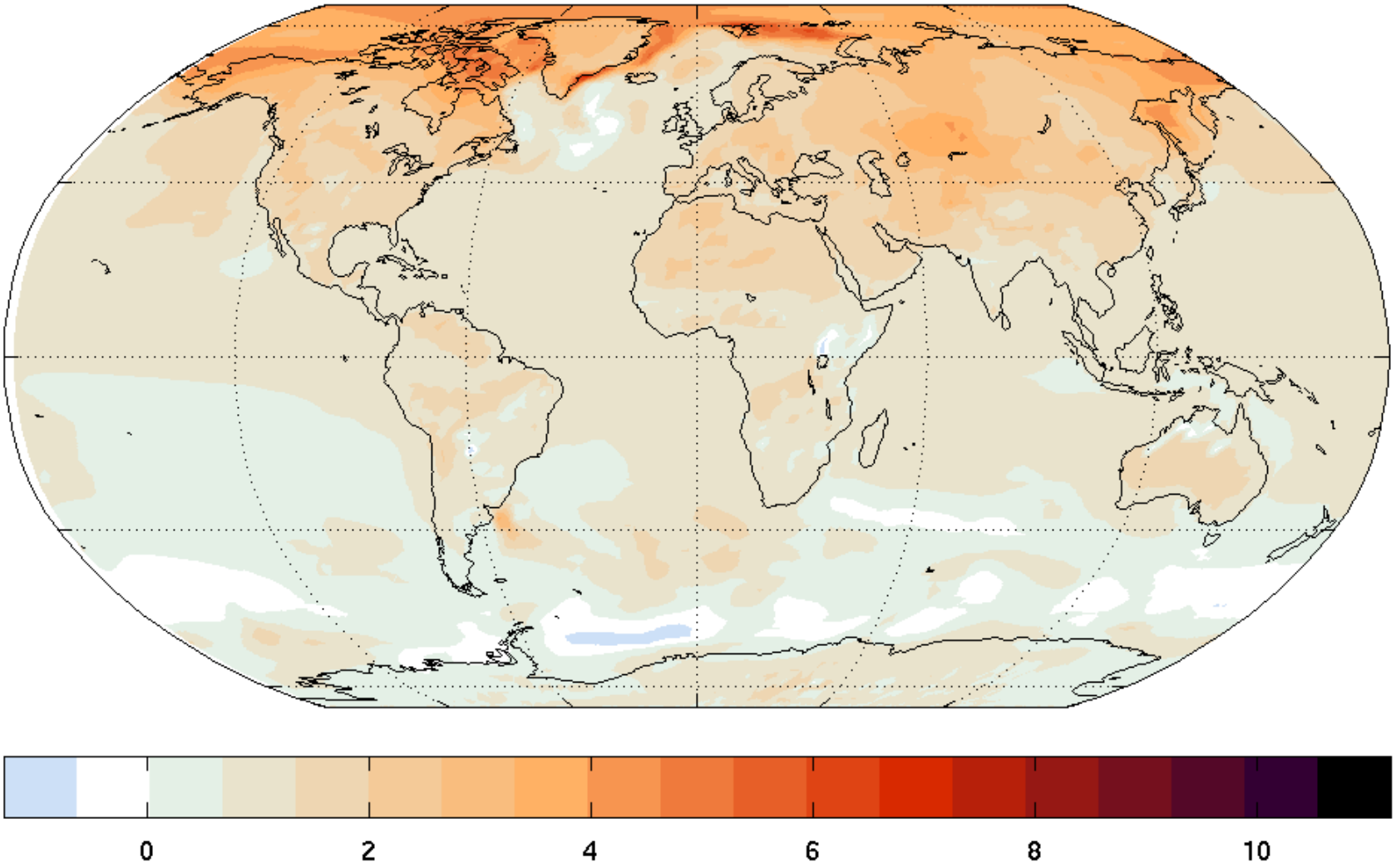
°C, 2090-2099 vs 1961-1990



Courtesy of OH Otterå

Simulated change in surface temperature, RCP2.6

°C, 2090-2099 vs 1961-1990



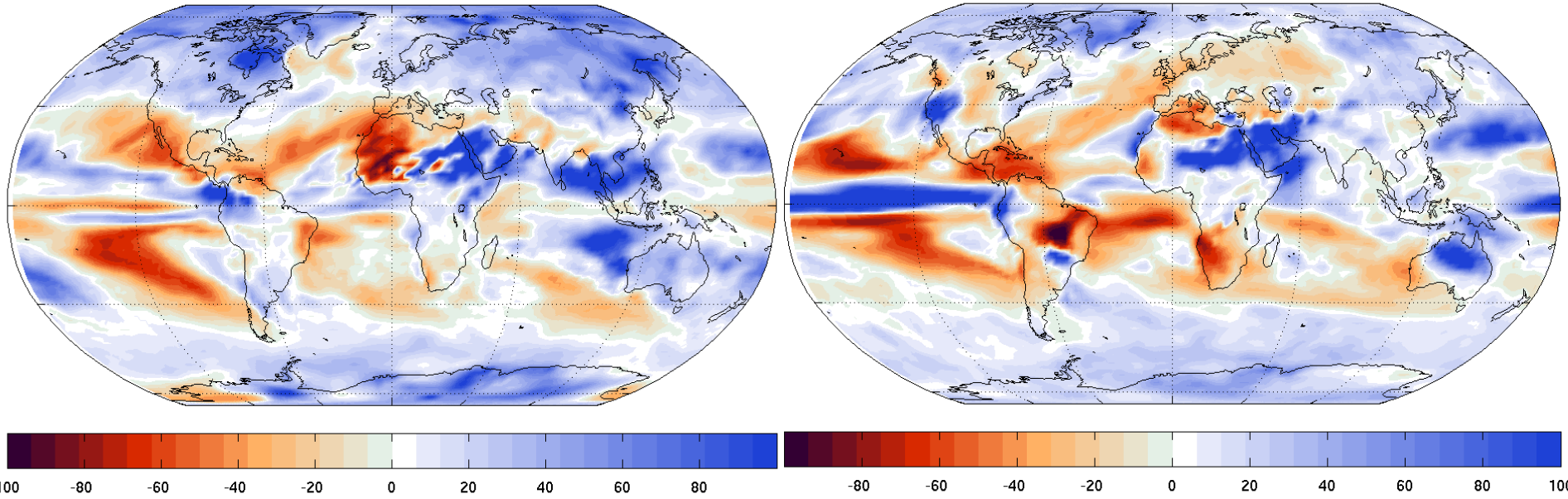
Courtesy of OH Otterå

Simulated change in precipitation, RCP8.5

%, 2080-99 vs 1961-1990

DJF

JJA



Increase: Mostly in the tropics and at mid/high latitudes

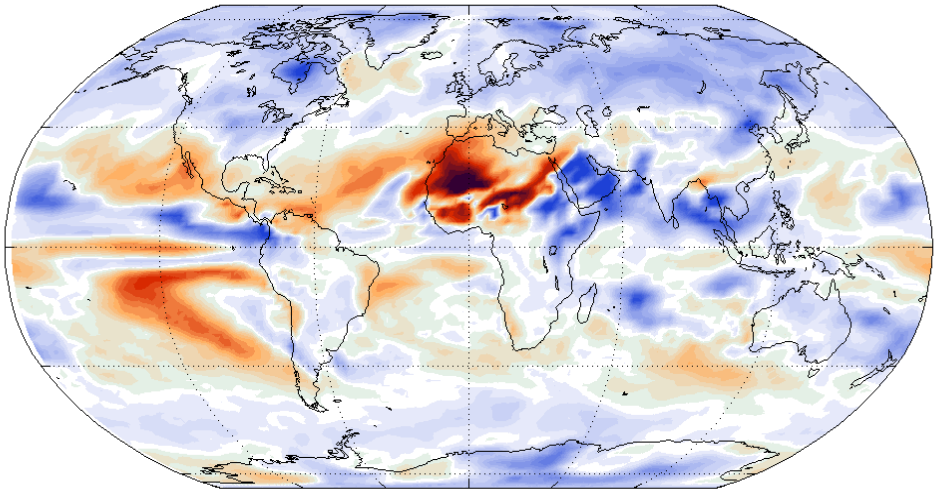
Decrease: Mostly in the sub-tropics (pushing sub-tropics towards mid latitides

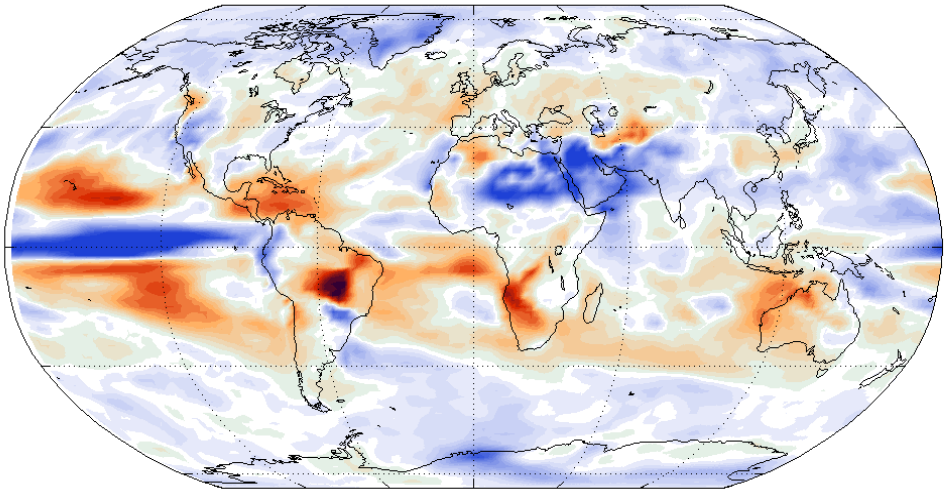
Courtesy of OH Otterå

Simulated change in precipitation, RCP6.0

%, 2080-99 vs 1961-1990

DJF **JJA**



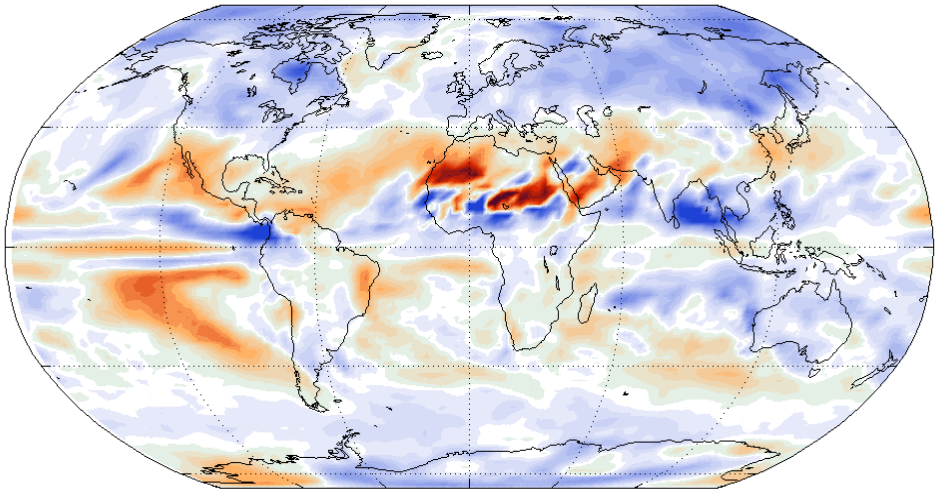


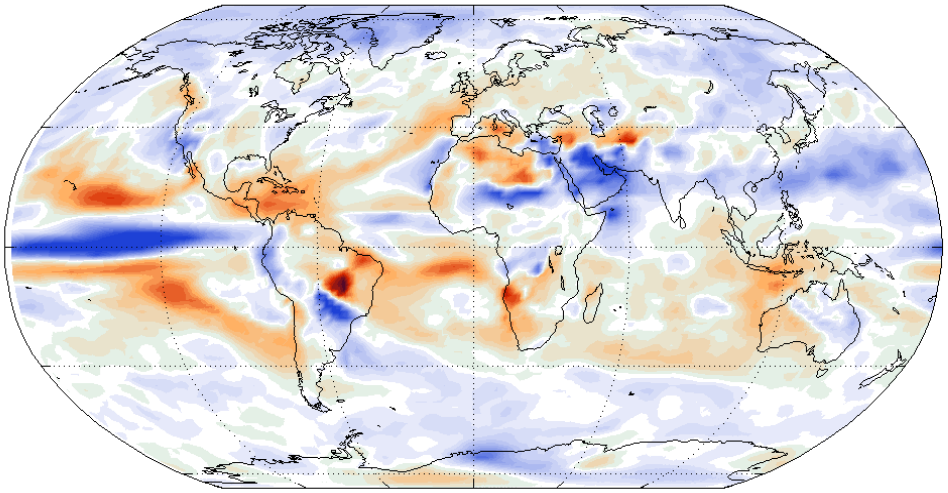
Courtesy of OH Otterå

Simulated change in precipitation, RCP4.5

%, 2080-99 vs 1961-1990

DJF **JJA**



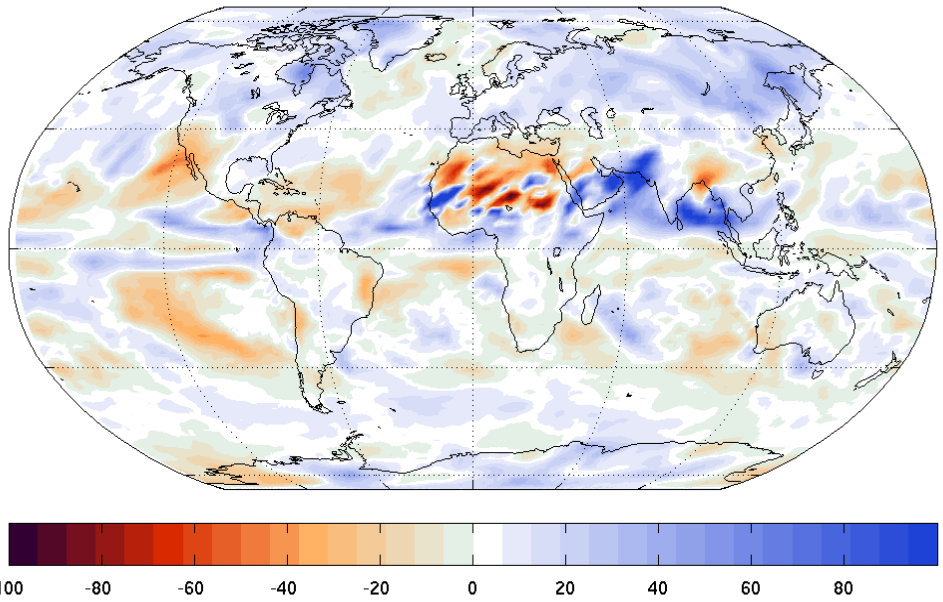


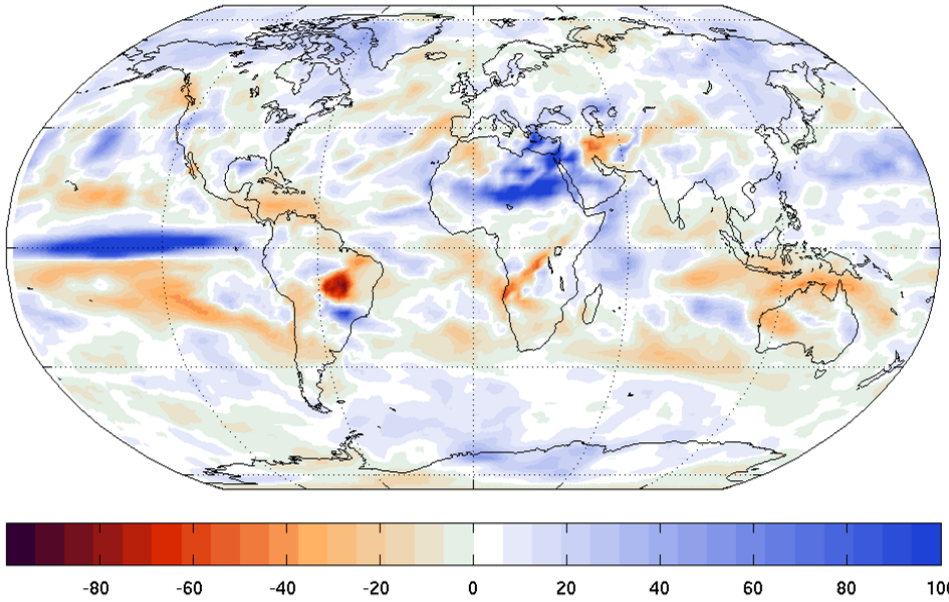
Courtesy of OH Otterå

Simulated change in precipitation, RCP2.6

%, 2080-99 vs 1961-1990

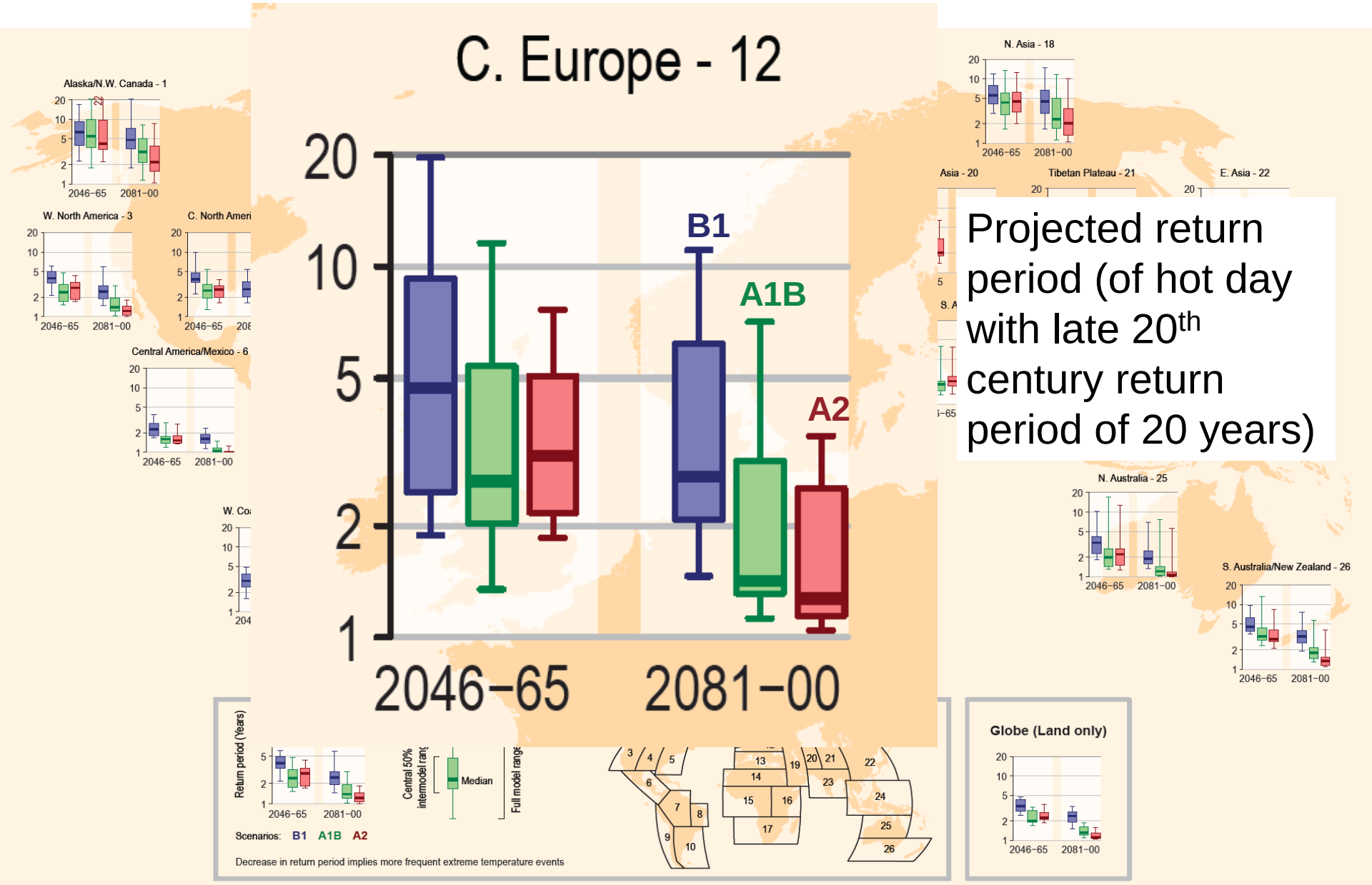
DJF **JJA**





Courtesy of OH Otterå

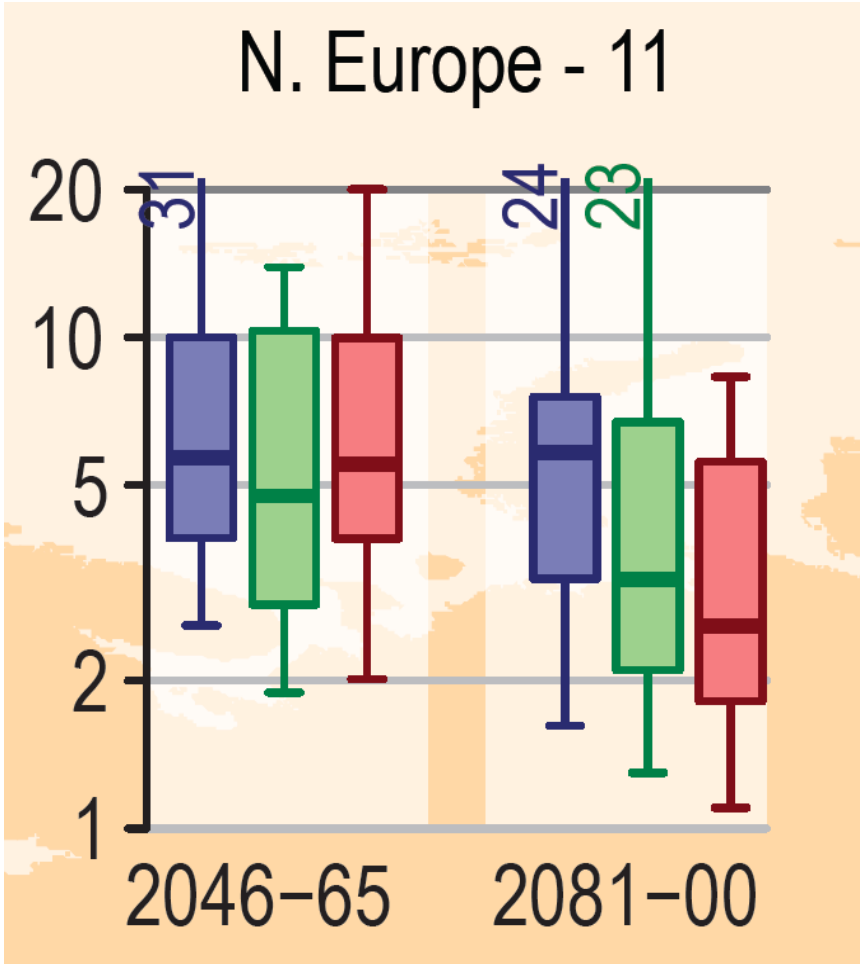
SREX: Temperature extremes

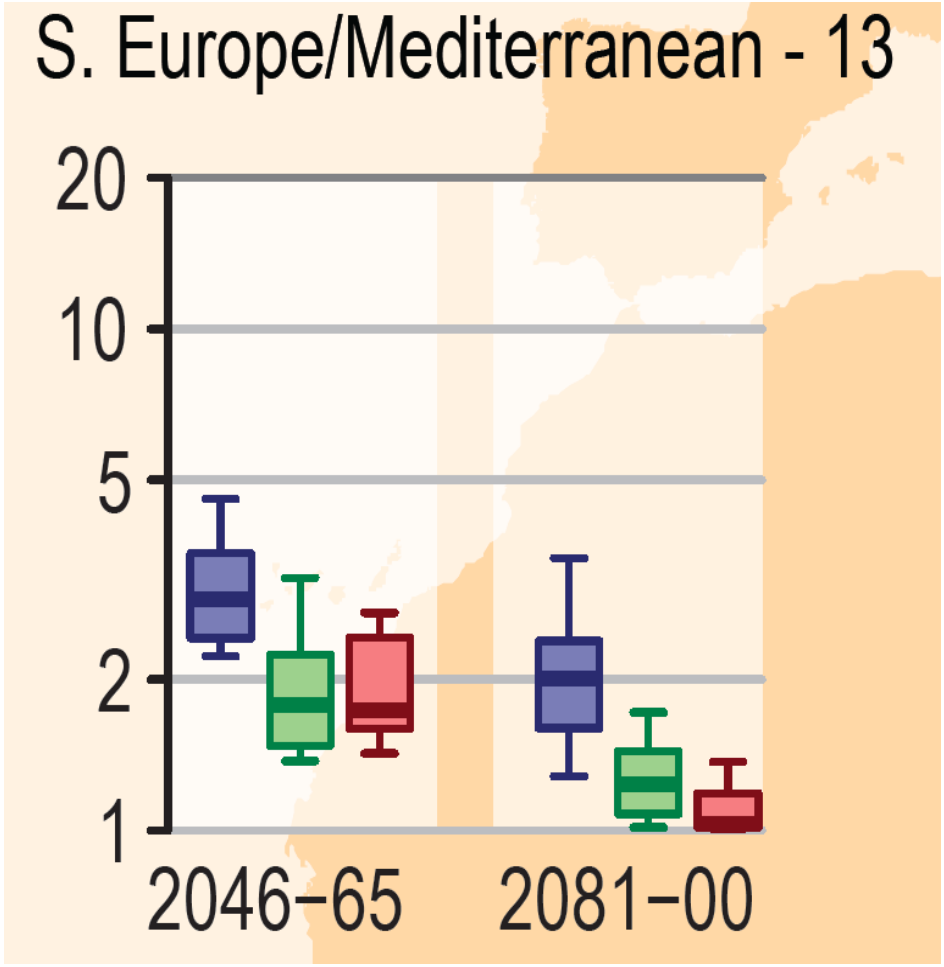


Projected return period (of hot day with late 20th century return period of 20 years)

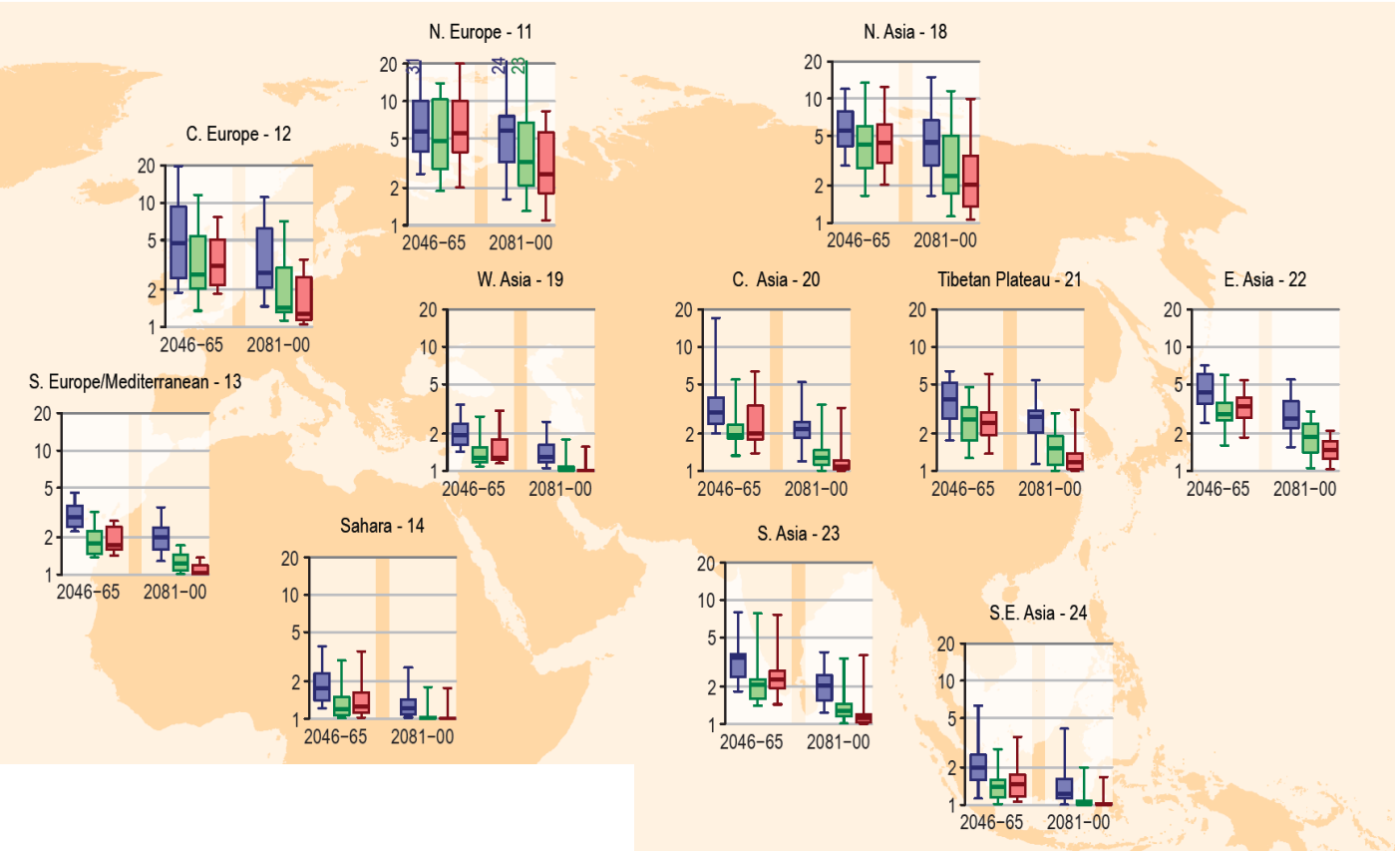
SREX: Temperature extremes

Strong regional variations





SREX: Temperature extremes

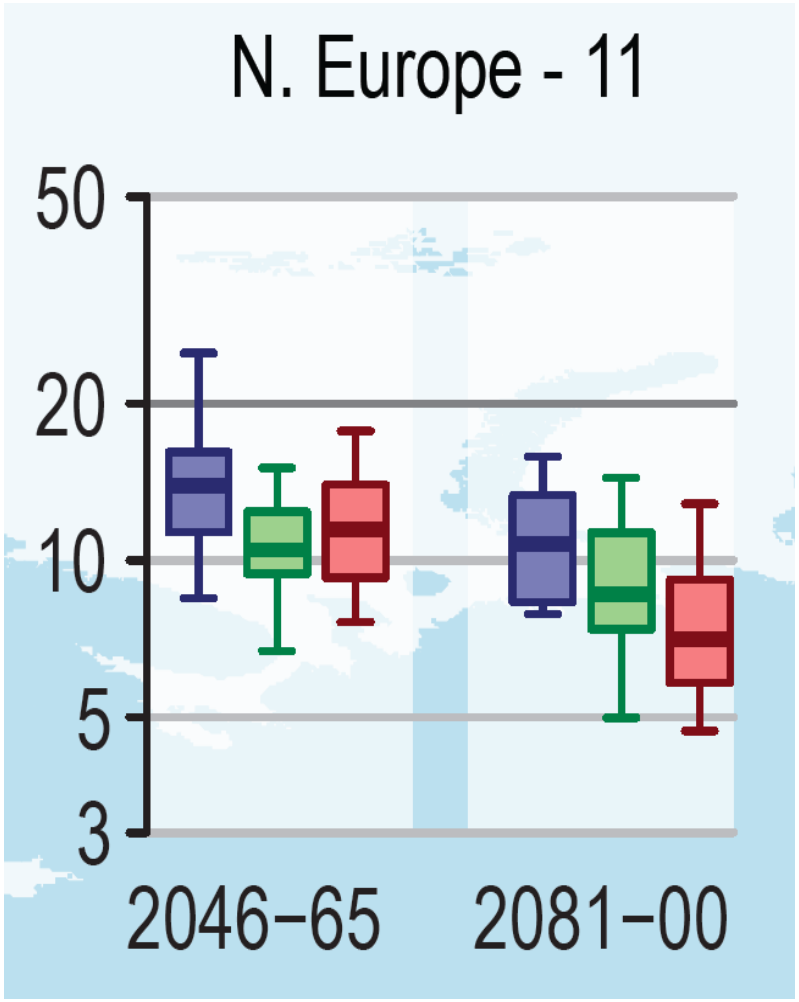


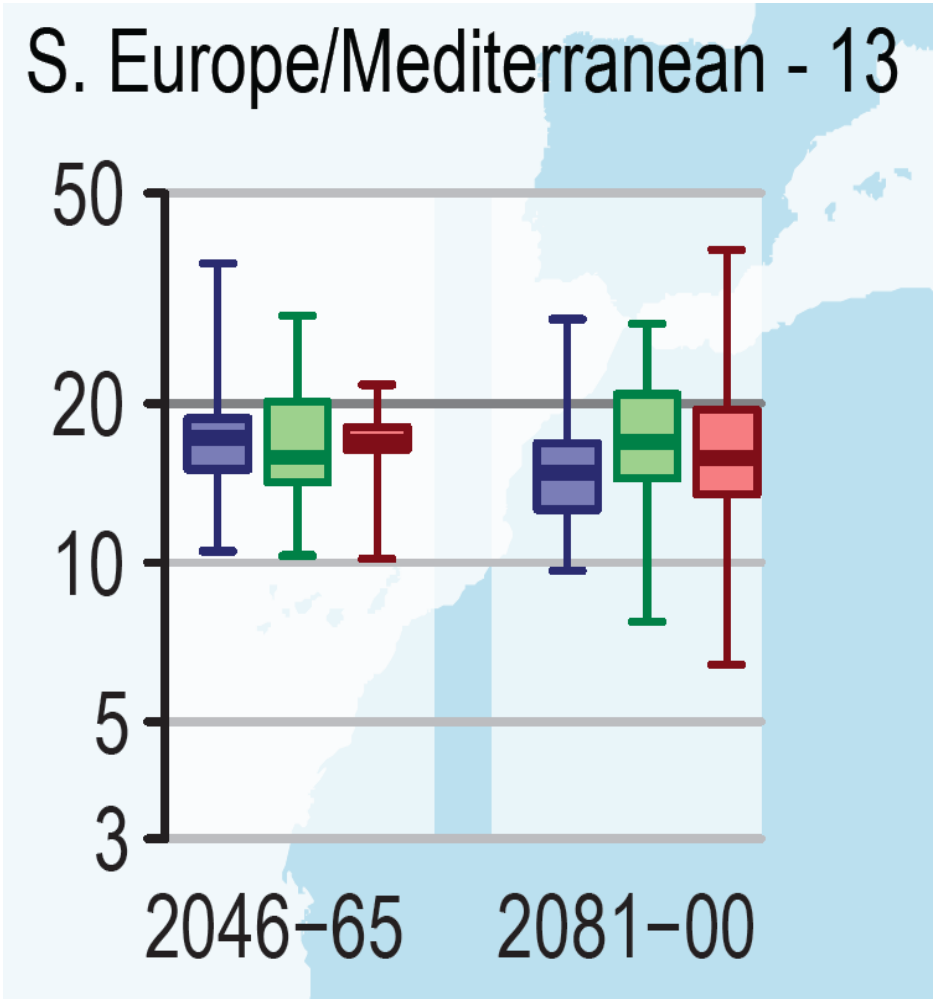
A1B, A2: A (late 20th-century) 1-in-20 year hottest day is *likely* to become a **1-in-2 year** event by the end of the 21st century in most regions, except in the high latitudes of the Northern Hemisphere, where it is *likely* to become a **1-in-5 year** event

B1: *likely* to become a **1-in-5 year** event (**1-in-10** in NH high latitudes)

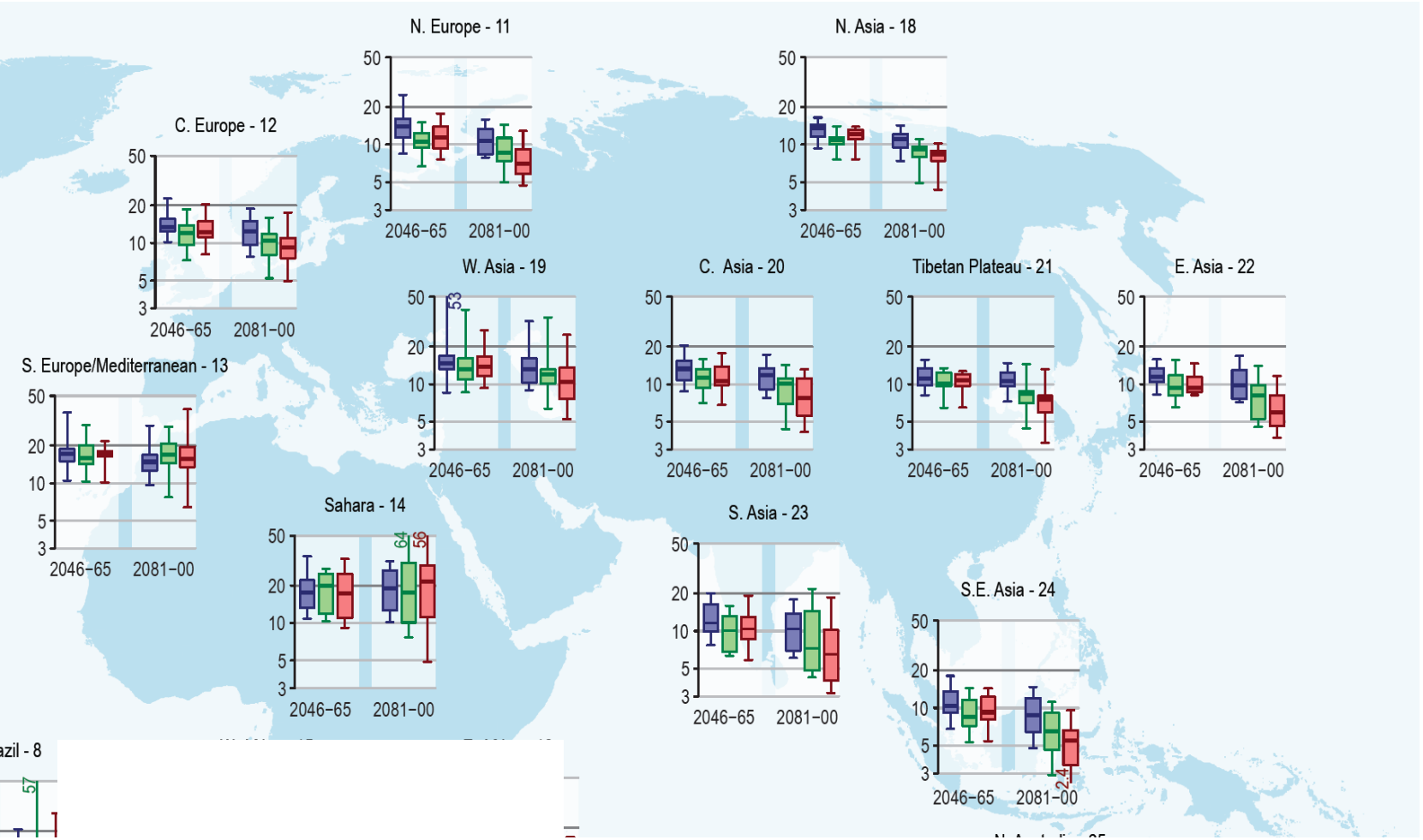
SREX: Precipitation extremes

Strong regional variations





SREX: Precipitation extremes



A1B and A2 A (late 20th-century) 1-in-20 year annual maximum daily precipitation amount is *likely to* become **a 1-in-5 to 1-in-15 year** event by the end of the 21st century in many regions, and in most regions the higher emissions scenarios lead to a stronger projected decrease in return period

Climate models with anthropogenic and natural climate forcings

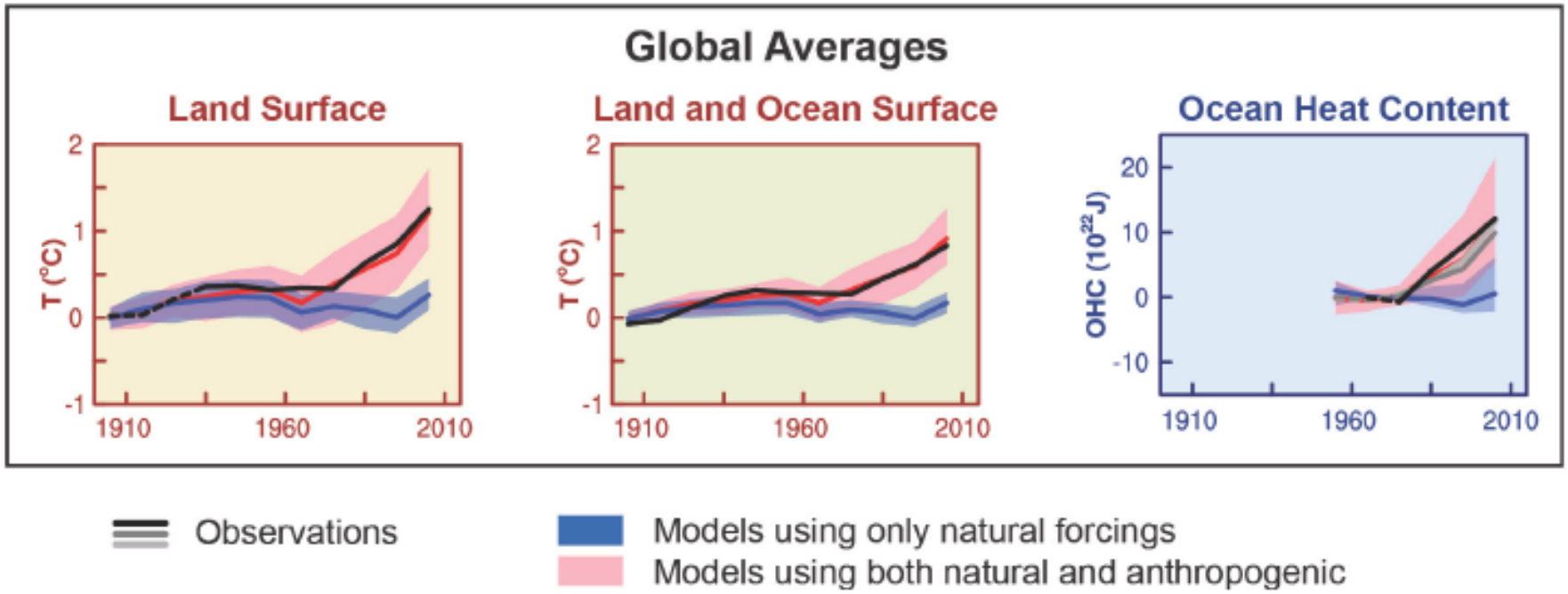


Figure SPM.6

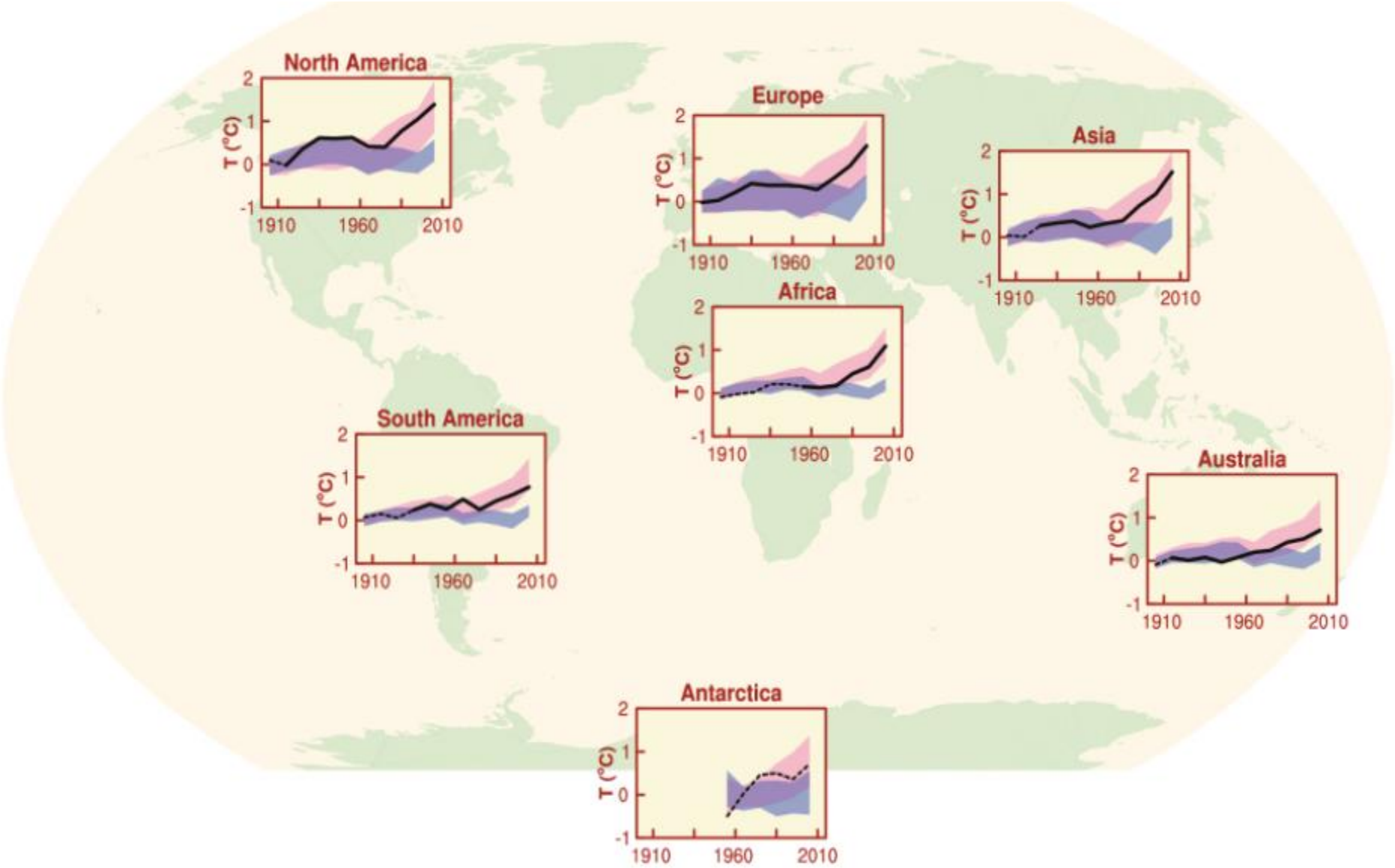
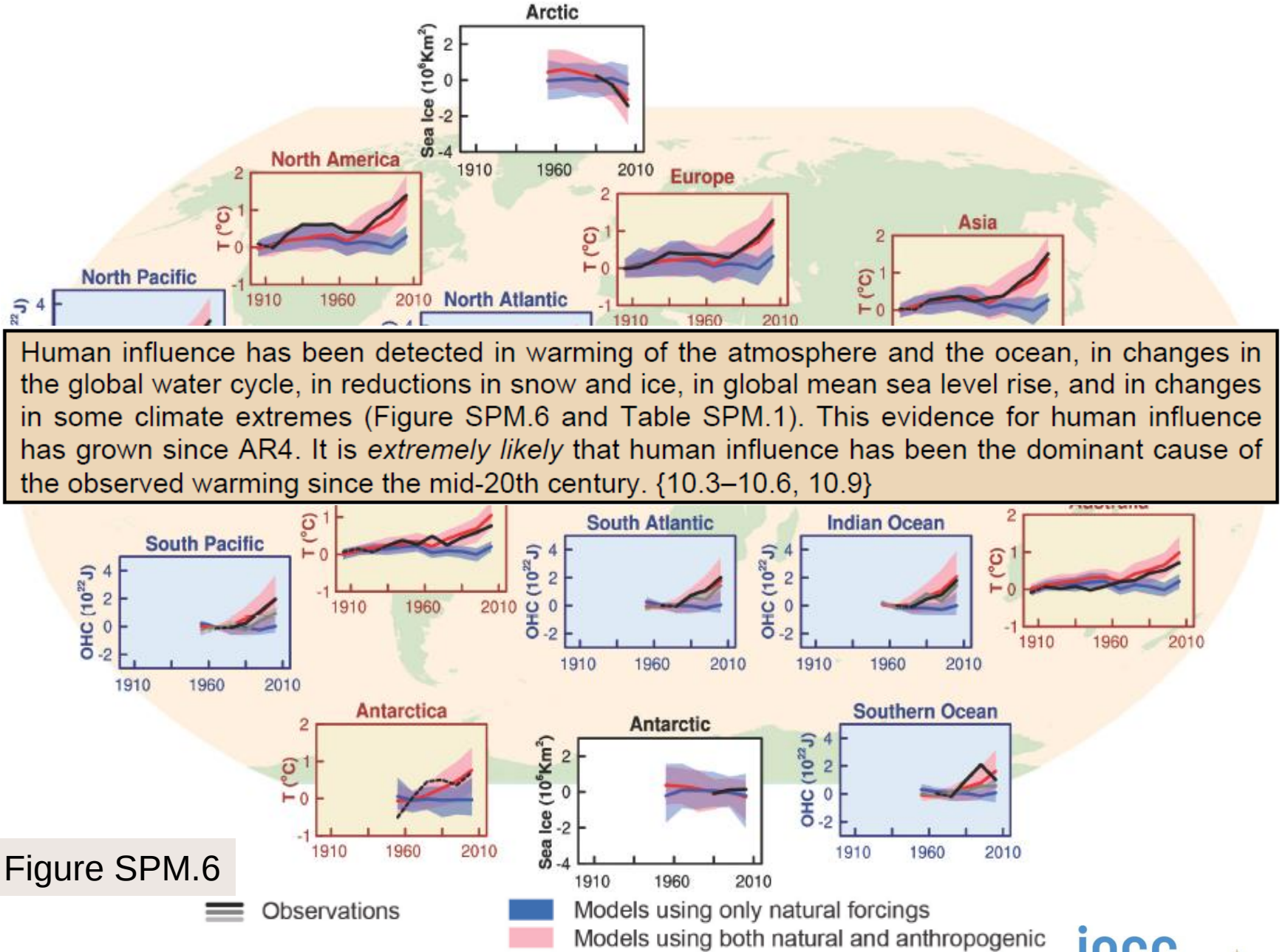

North America
Europe
Asia
Africa
South America
Australia
Antarctica
T (°C)
2
1
0
-1
1910
1960
2010
Observations
Models using only natural forcings
Models using both natural and anthropogenic

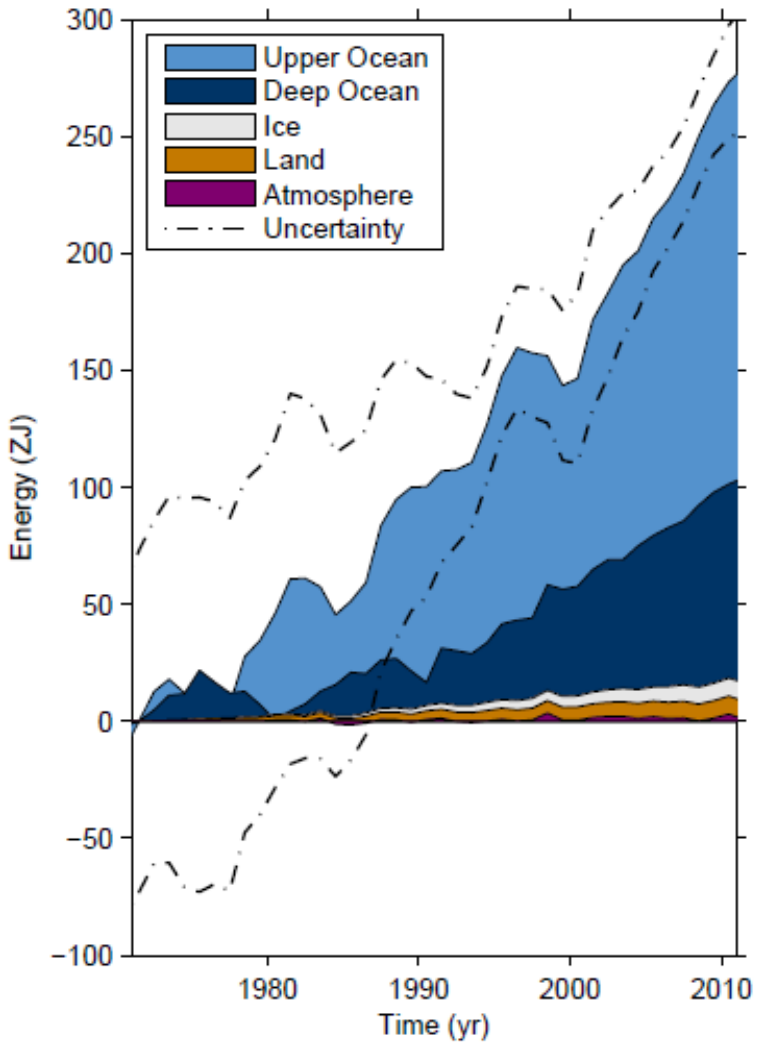
Figure SPM.6



Human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, in global mean sea level rise, and in changes in some climate extremes (Figure SPM.6 and Table SPM.1). This evidence for human influence has grown since AR4. It is *extremely likely* that human influence has been the dominant cause of the observed warming since the mid-20th century. {10.3–10.6, 10.9}

Figure SPM.6

The oceans absorb most of the energy

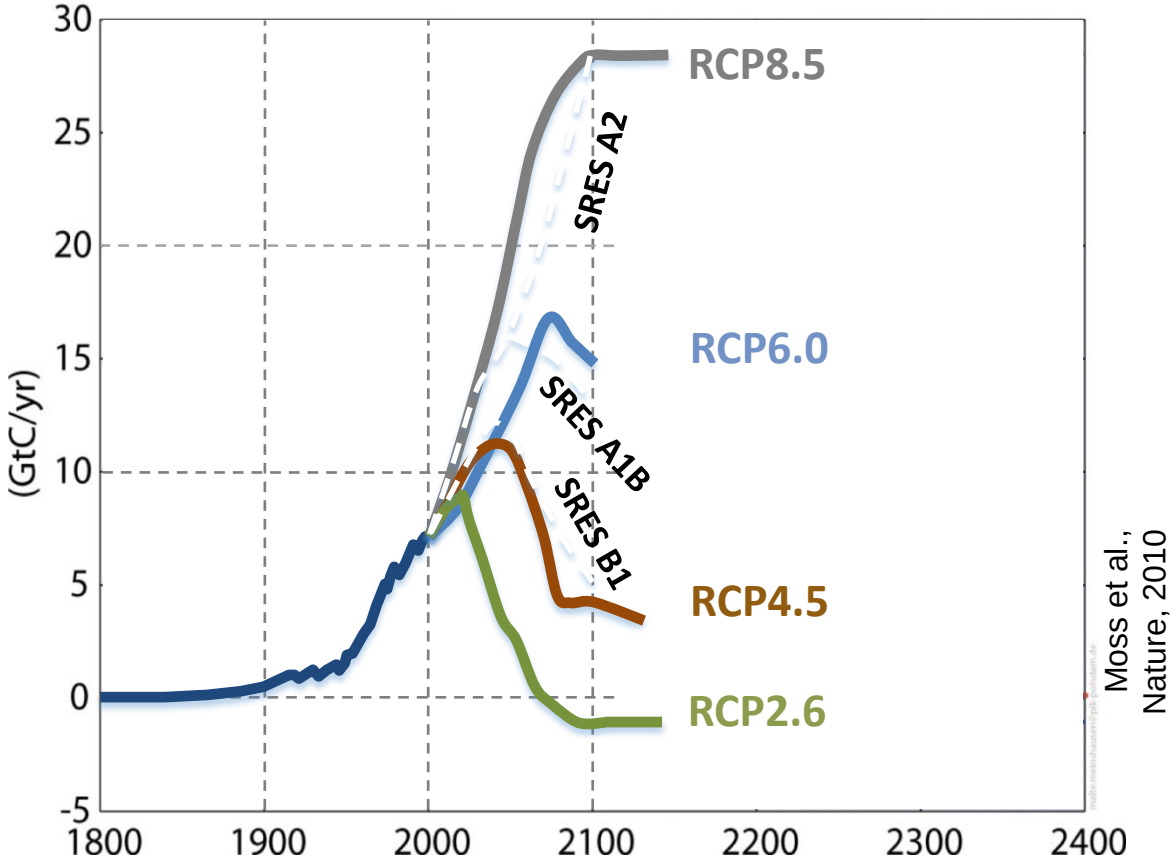


The warming of the oceans amounts to 93% of the energy accumulated in the climate system between1970 and 2010

3% has heated land surfaces, 1% the atmosphere and 3% has melted glaciers

Warming of the ocean has contributed to a significant part of the sea level rise

Future changes



Moss et al., Nature, 2010

Negative emissions:
CO_2 removal e.g. bio-energy with CCS, direct air capture, enhanced weathering
Needs to be implemented well before net negative emissions

CO_2 emissions

Future estimates based on 4 Representative Concentration Pathways (RCPs)

Likelihood are not given for any RCP

The development of CO_2 over the last decade is closest to RCP8.5

RCP2.6 particularly useful related to the 2 degree target

Future changes

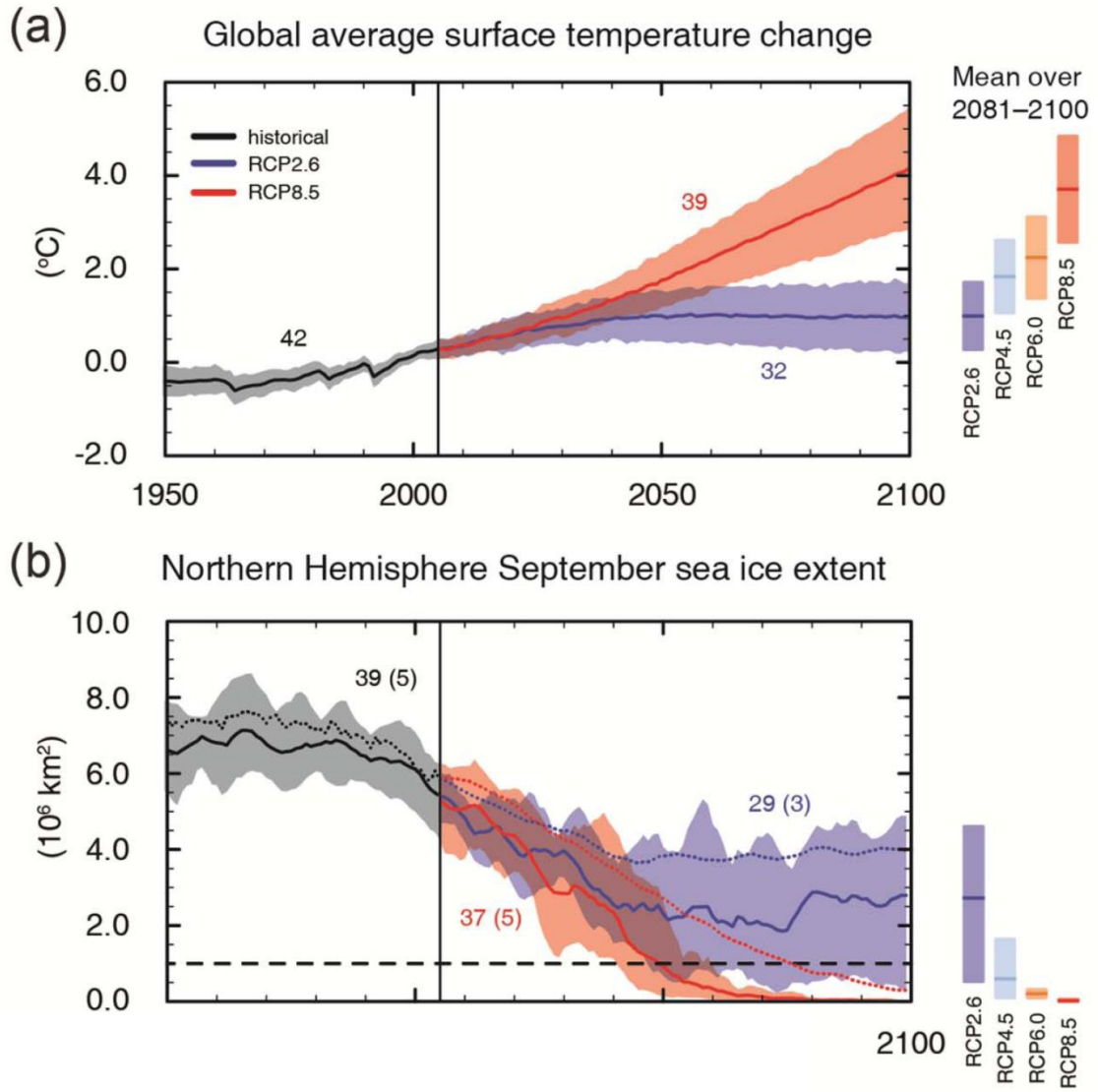


Figure SPM7

RCP 8.5 warming 2081-2100: 3.7 (2.6 to 4.8) °C relative to 1986-2005

RCP 2.6 warming 2081-2100: 1.0 (0.3 to 1.7) °C relative to 1986-2005

Observed warming 1986-2005: 0.61 (0.55 to 0.67) °C relative to1850-1900

Models that best reproduce trend 1979-2012 imply a near ice free Arctic ocean during summer is *likely* by middle of this century

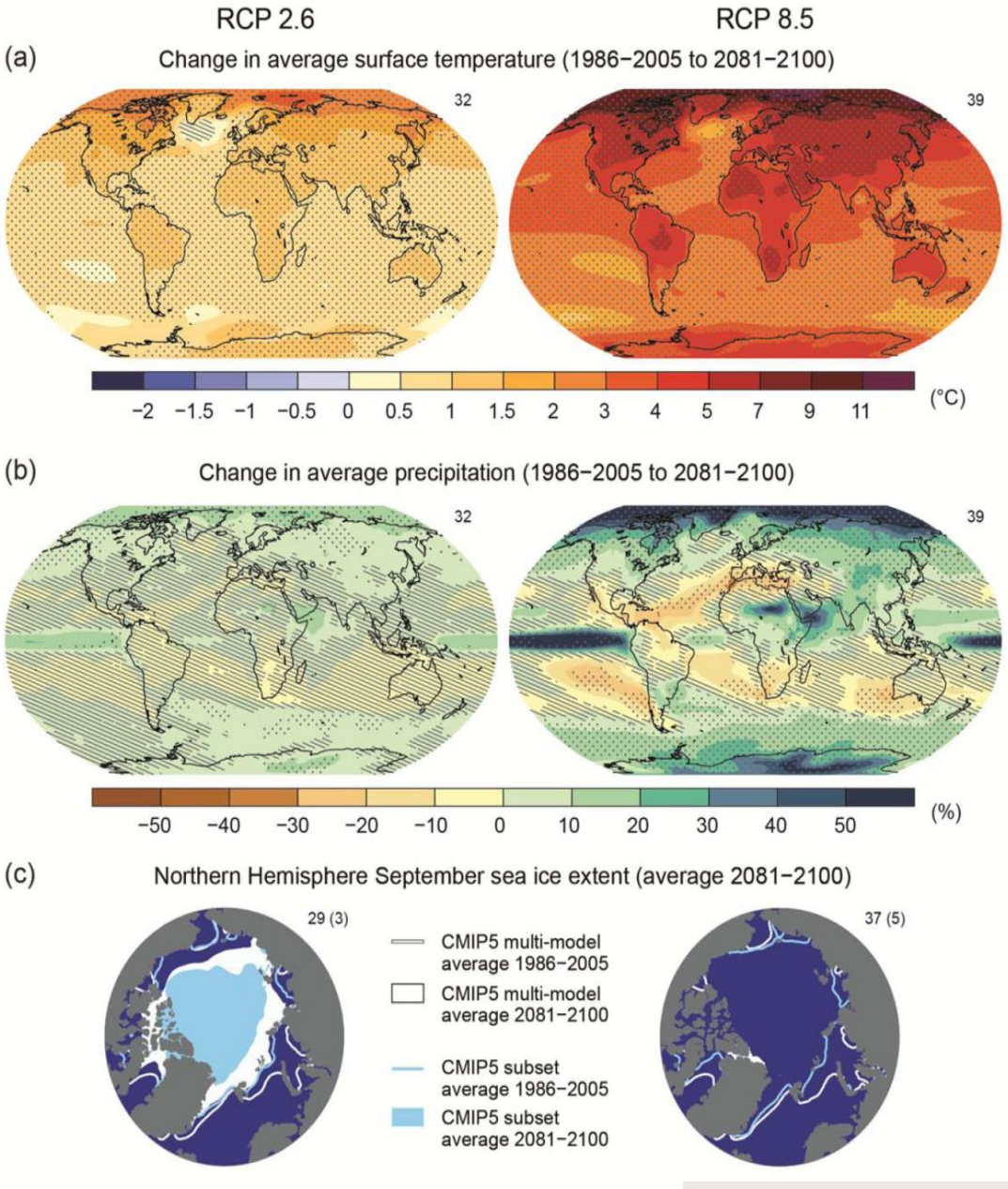


Figure SPM8

Temperature

Larger warming over land and in the Arctic than globally

Precipitation

Strengthening of patterns observed until now

Arctic Sea ice

Blue ocean in RCP8.5 in September