第八章:

全球增暖背景下的大气环流

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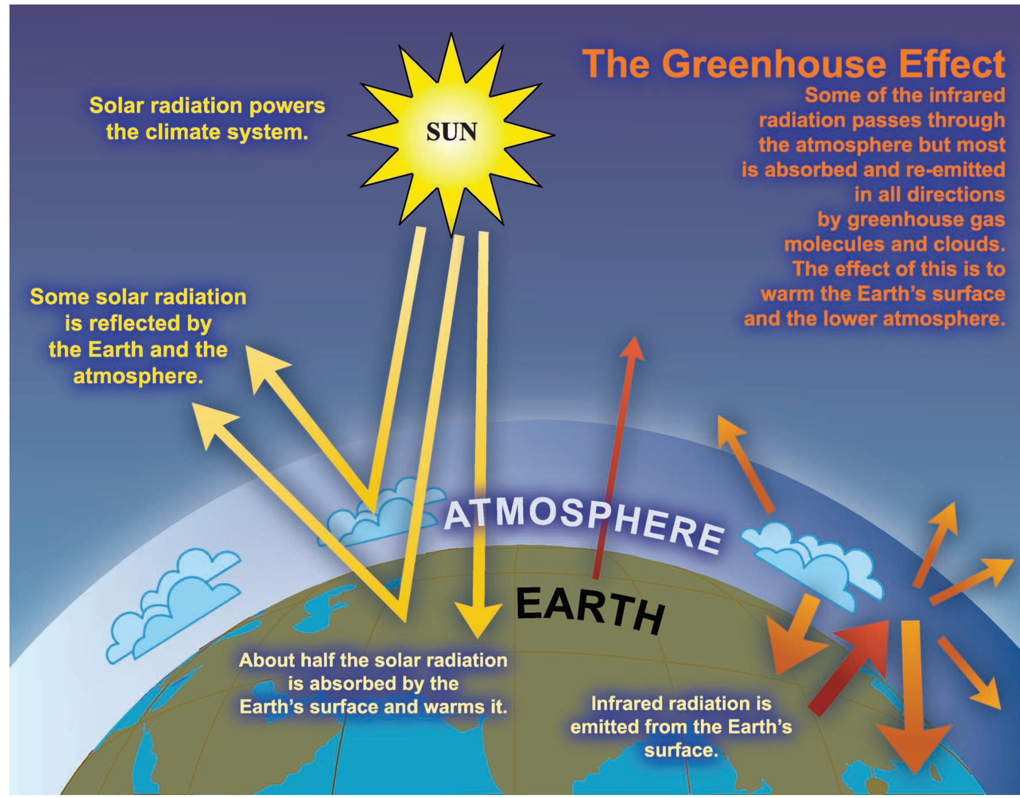
PART I:

An introduction of global warming

The green house effect

- Green house effect is a process by which *thermal radiation from a planetary surface is absorbed by atmospheric greenhouse gases, and re-radiated in all directions.* Since part of this re-radiation is back towards the surface, energy is transferred to the surface and the lower atmosphere. As a result, the temperature there is higher than it would be if direct heating by solar radiation were the only warming mechanism.



Earth's land and ocean surface warmed to an average of 14℃

Adapted from AR4

The green house effect

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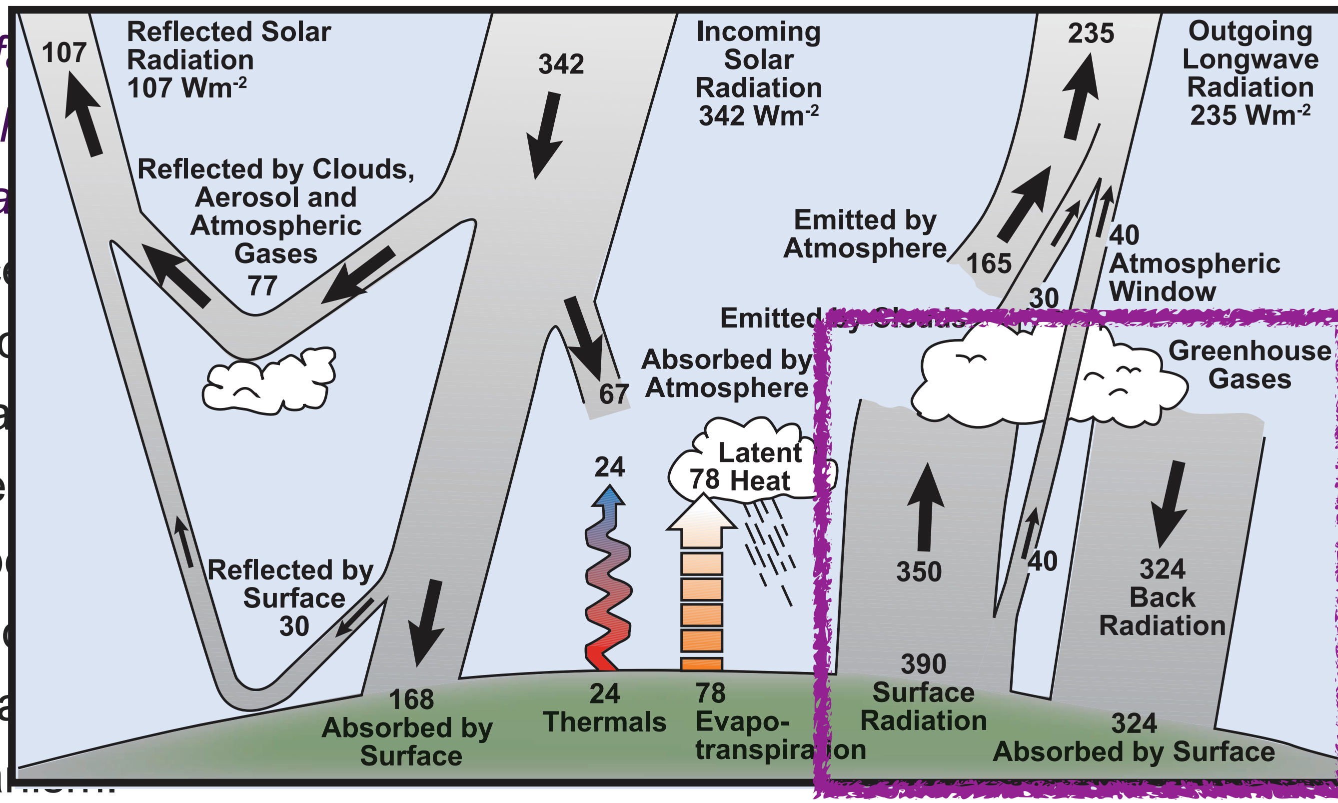


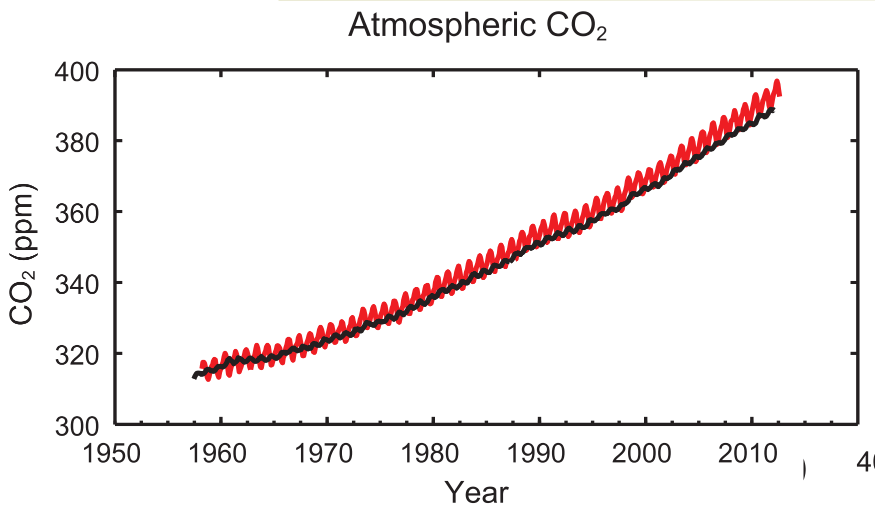
Adapted from AR4

The green house effect

- Green house gases, with their percentage contribution to the greenhouse effect on Earth:
    - water vapor (H_2O), 36–70%
    - carbon dioxide (CO_2), 9–26%
    - methane (CH_4), 4–9%
    - ozone (O_3), 3–7%

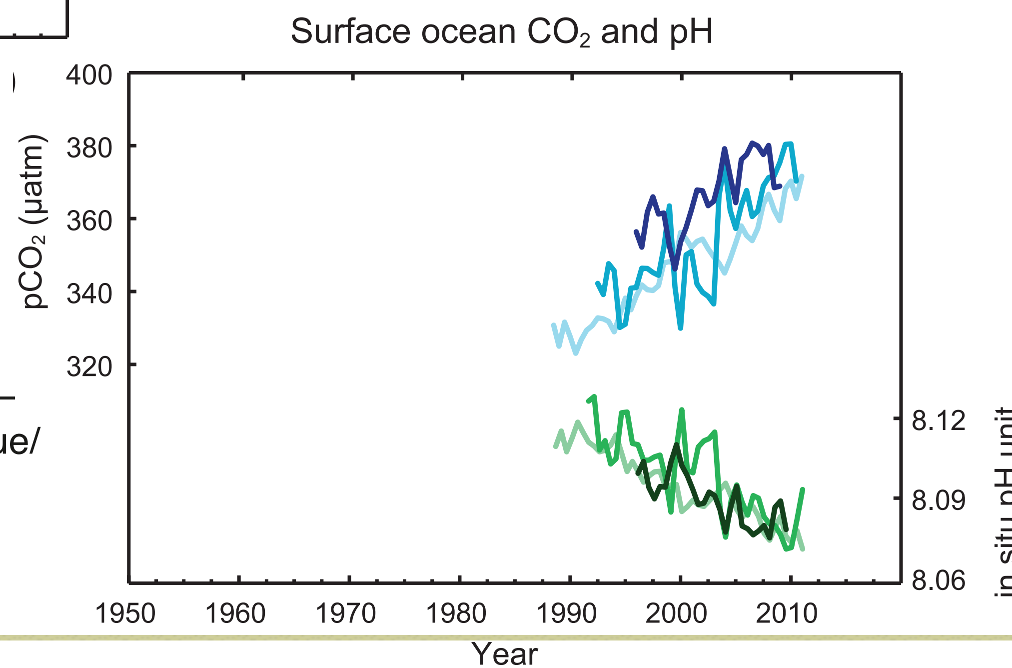
- The major non-gas contributor to the Earth's greenhouse effect, clouds

The observed increase of GHG



(a) atmospheric concentrations of carbon dioxide (CO_2) from Mauna Loa (19°32'N, 155°34'W – red) and South Pole (89°59'S, 24°48'W – black) since 1958;

b) partial pressure of dissolved CO_2 at the ocean surface (blue curves) and in situ pH (green curves), a measure of the acidity of ocean water. Measurements are from three stations from the Atlantic (29°10'N, 15°30'W – dark blue/dark green; 31°40'N, 64°10'W – blue/green) and the Pacific Oceans (22°45'N, 158°00'W – light blue/light green)



The observed global warming

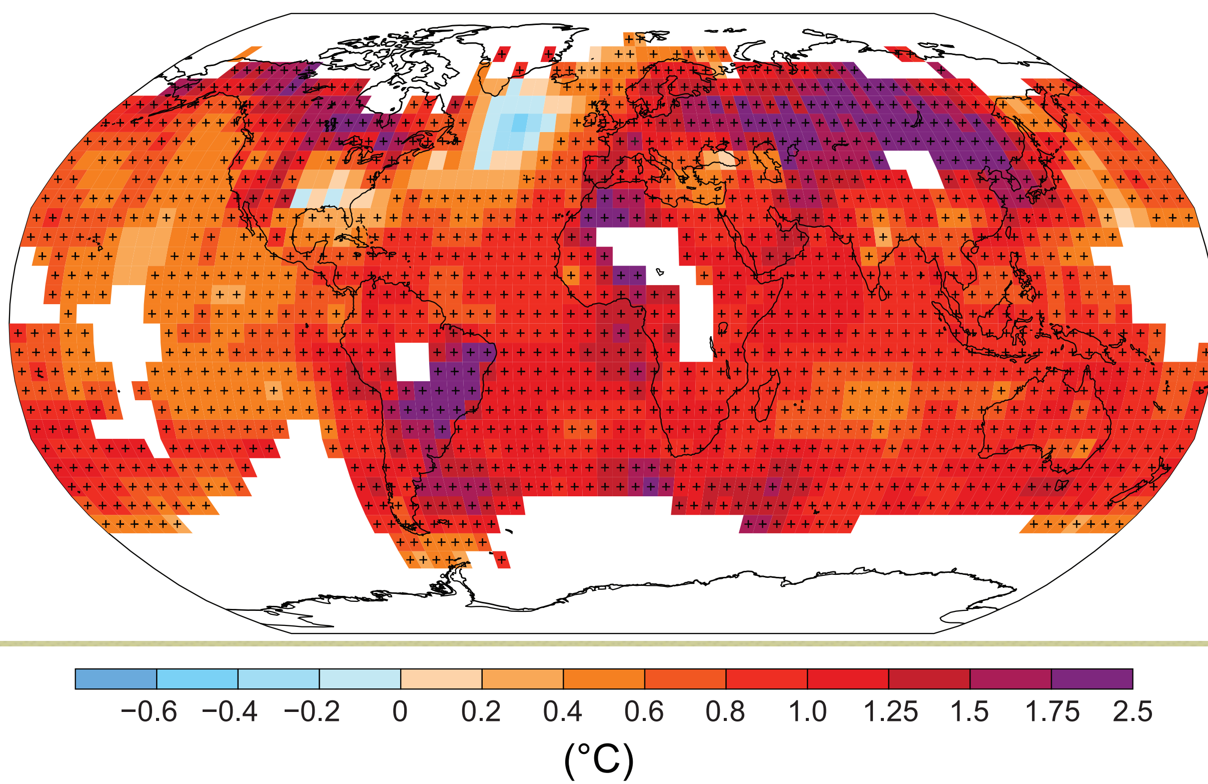
- The **Intergovernmental Panel on Climate Change** (**IPCC**) is a scientific intergovernmental body tasked with reviewing and assessing the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of climate change. It provides the world with a scientific view on the current state of climate change and its potential environmental and socio-economic consequences, notably the risk of climate change caused by human activity. The panel was established in 1988 by the **World Meteorological Organization (WMO)** and the **United Nations Environment Programme (UNEP)**, two organizations of the United Nations.

The **Fifth Assessment Report** (AR5) of IPCC, is the fifth in a series of reports intended to provide an update of knowledge on scientific, technical and socio-economic information concerning climate change. The first Working Group Report “The Physical Science Basis”was published in 2013 and the rest were completed in 2014.

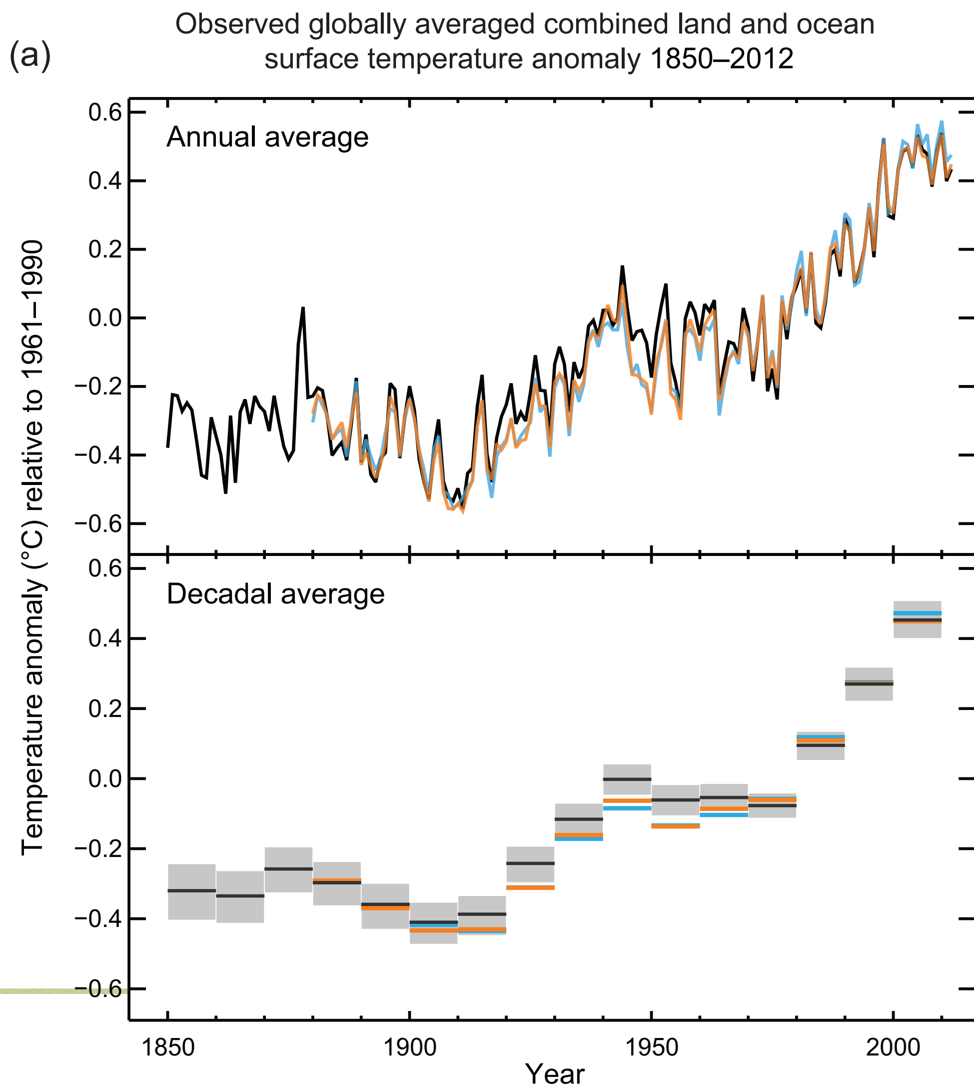
The observed global warming

- **Global warming** is the increase in the global average temperature of Earth near-surface air and oceans since the mid-20th century and its projected continuation. According to the 2013 Fifth Assessment Report (AR5) by the Intergovernmental Panel on Climate Change (IPCC), global surface temperature increased 0.85 [0.65 to 1.06] °C, over the period 1880-2012.

Observed change in surface temperature 1901–2012



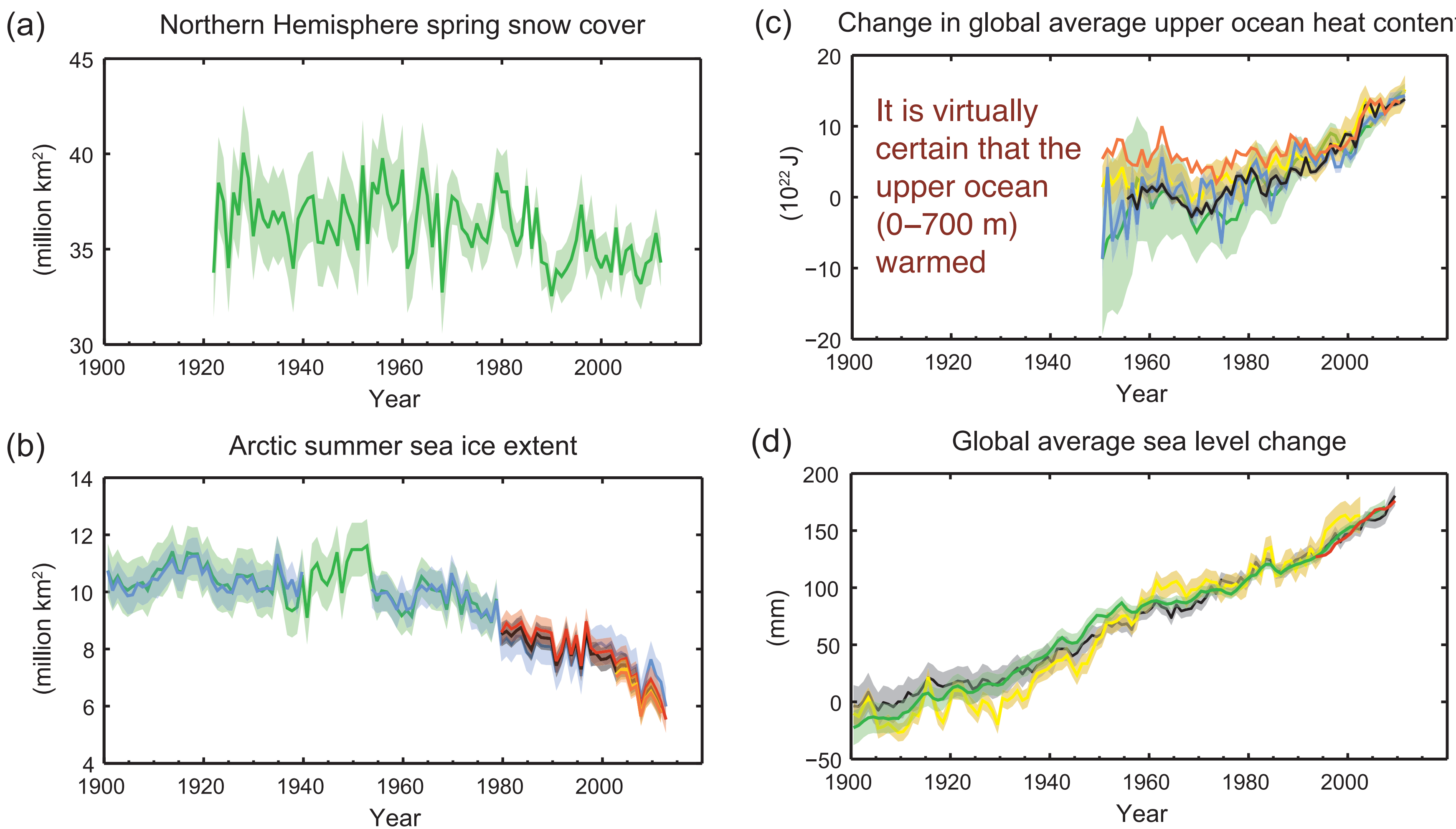
The observed global warming



Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850.

In the Northern Hemisphere, 1983–2012 was likely the warmest 30-year period of the last 1400 years (medium confidence)

The observed global warming



Attributing the global warming

- The **First Assessment Report** (FAR) published in 1990, global mean surface air temperature has increased by 0.3 to 0.6 ^{o}C over the last 100 years, which is also of the same magnitude as natural climate variability. Thus the observed increase ***could be largely due to this natural variability; alternatively***...

- The **Second Assessment Report** (SAR) published in 1995, "The balance of evidence ***suggests a discernible*** human influence on global climate"

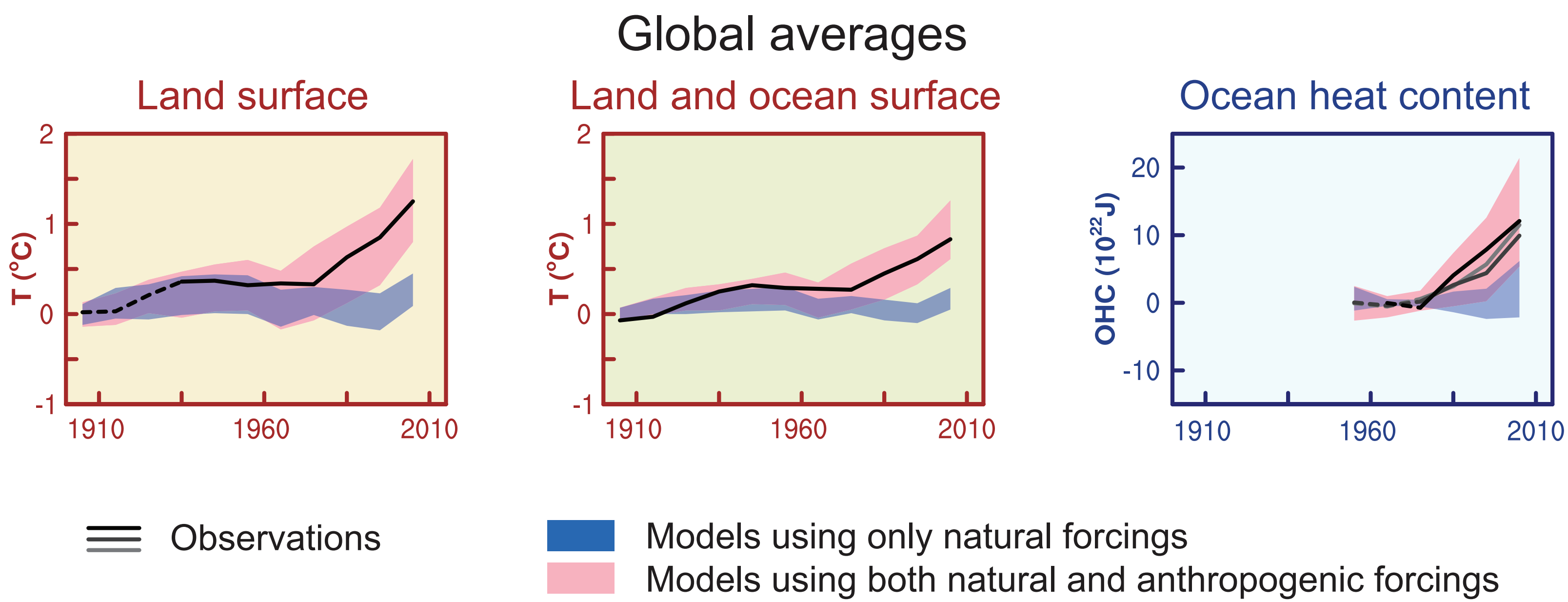
- The **Third Assessment Report** (TAR) published in 2001, "There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities"

- AR4 in 2007, "Most of the observed increase in global average temperatures since the mid-20th century is ***very likely*** due to the observed increase in anthropogenic greenhouse gas concentrations."

- AR5 in 2013, "It is ***extremely likely*** that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together. "

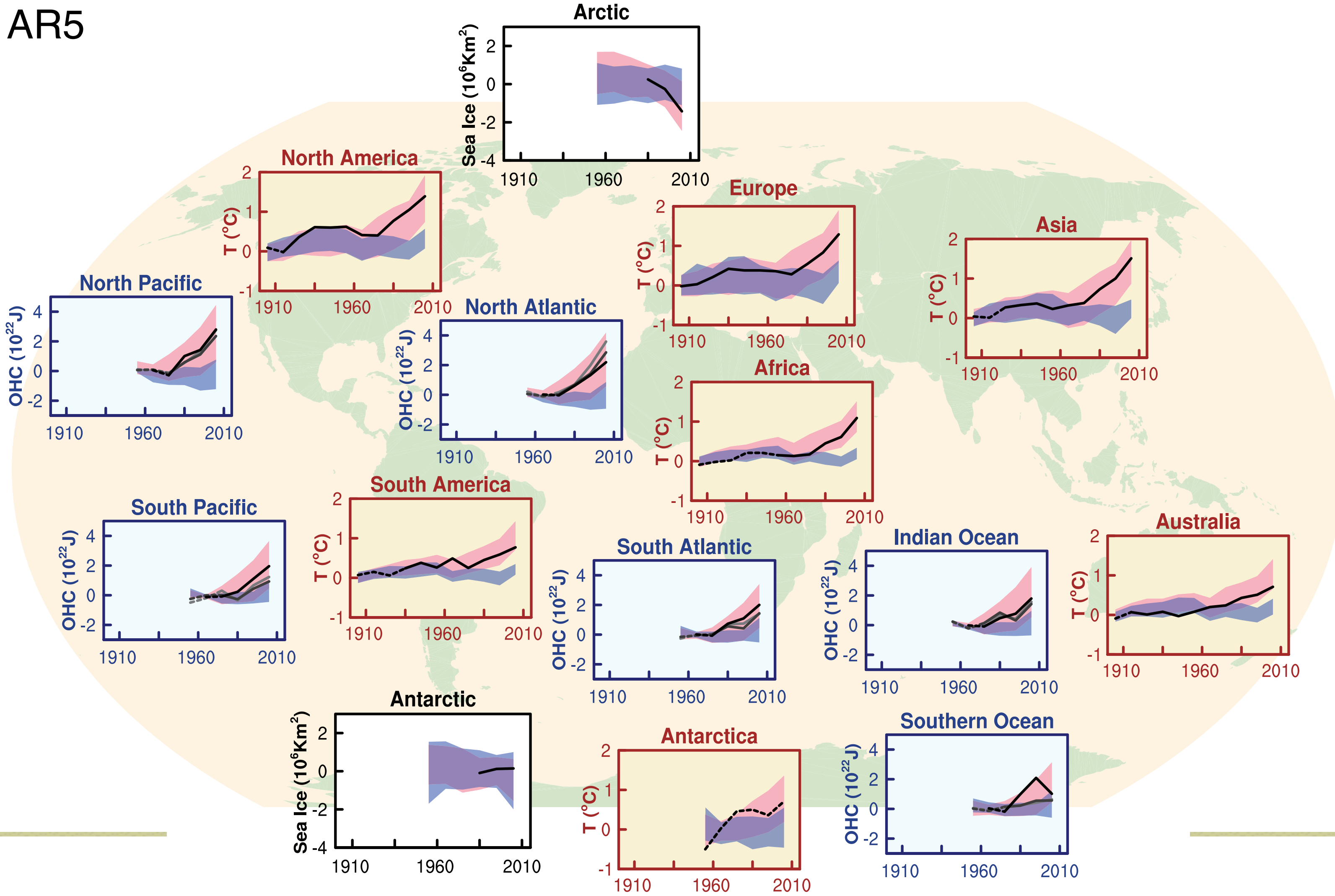
Attributing the global warming

- In AR5



Attributing the global warming

- In AR5



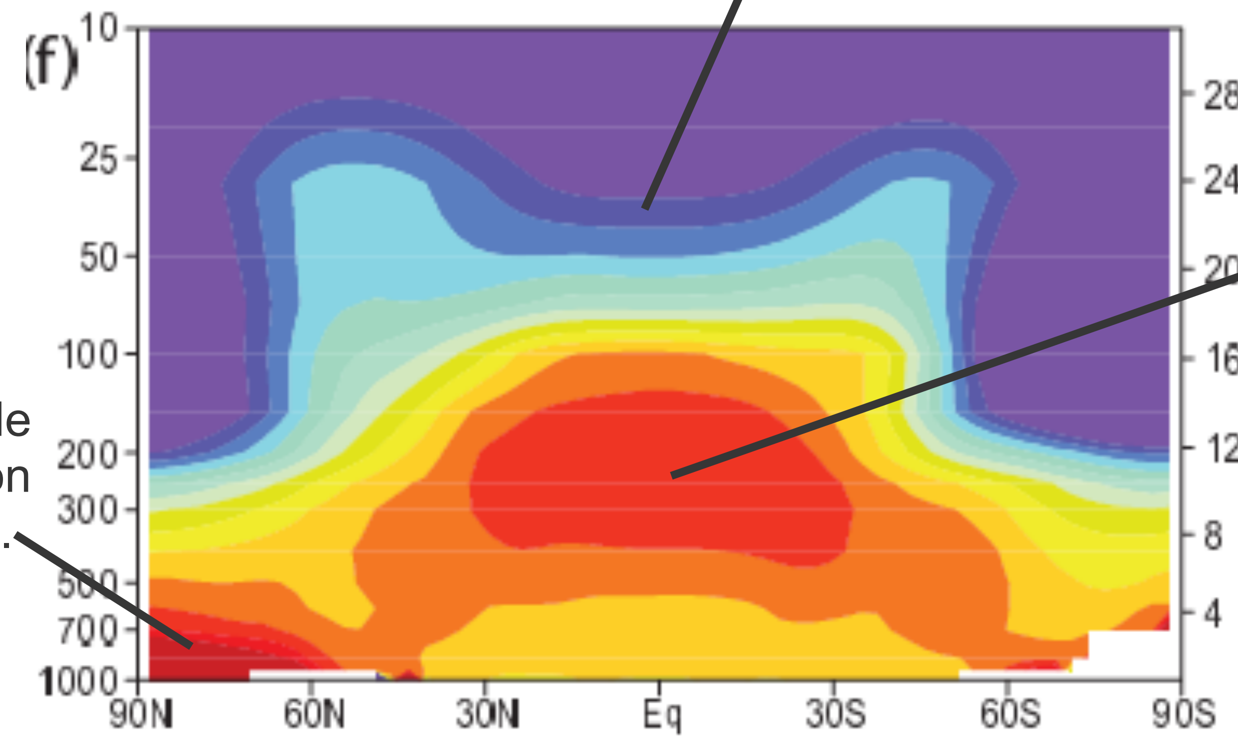
Attributing the global warming

- In AR4

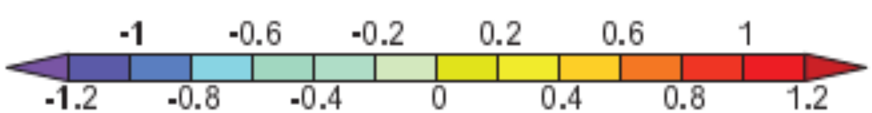
cooling in the stratosphere

warming in the troposphere

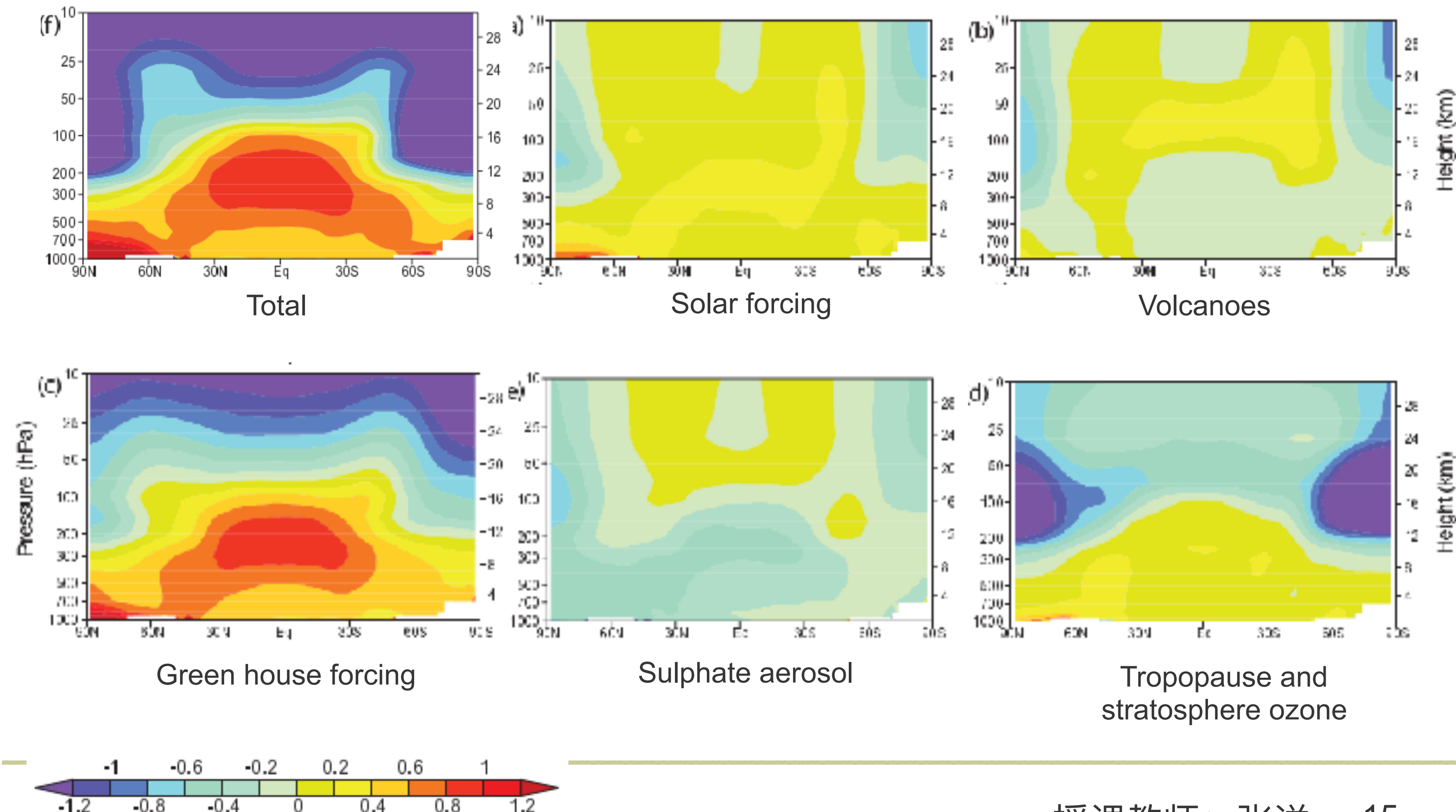
High latitude amplification in the N.H.



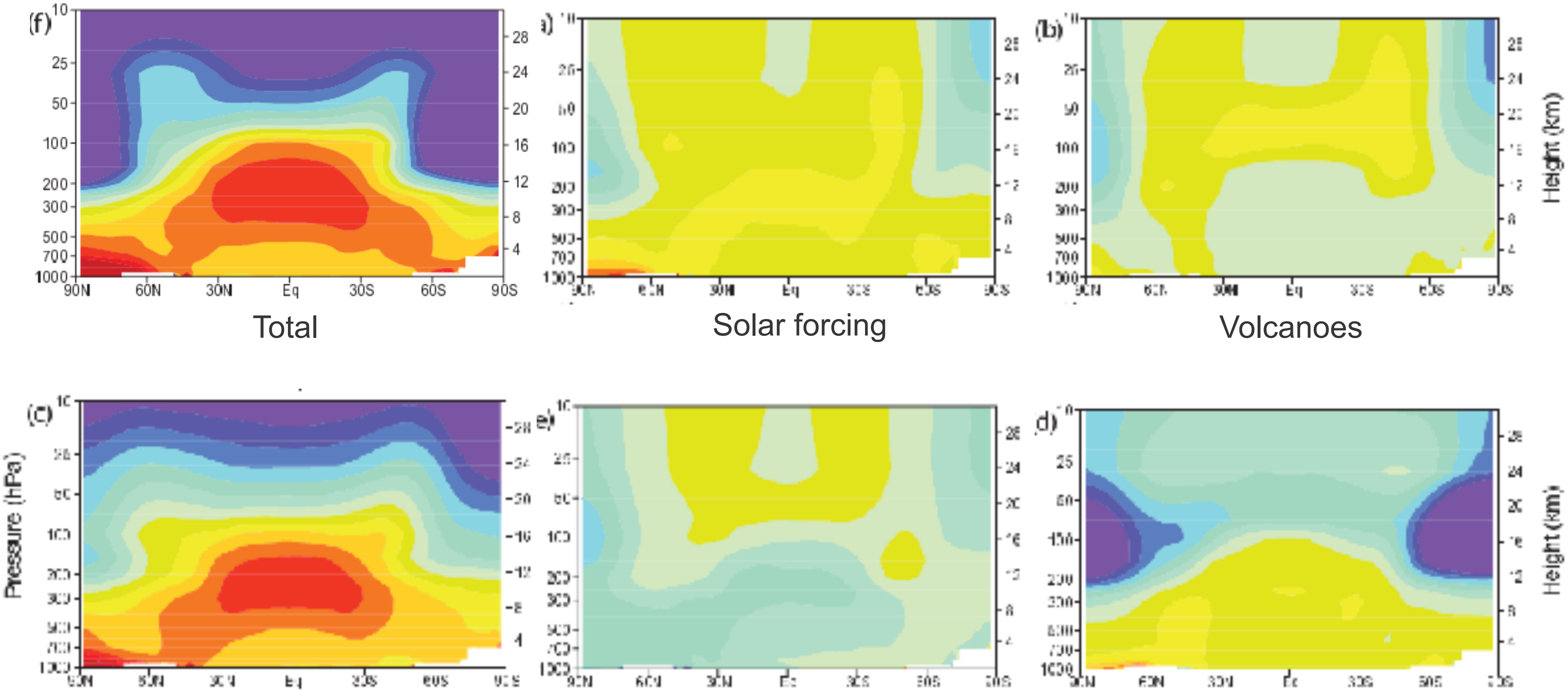
Zonal mean atmospheric temperature change from 1890 to 1999 (°C per century) as simulated by the PCM model



Attributing the global warming



Attributing the global warming



Total

Solar forcing

Volcanoes

Green house forcing

Sulfate aerosol

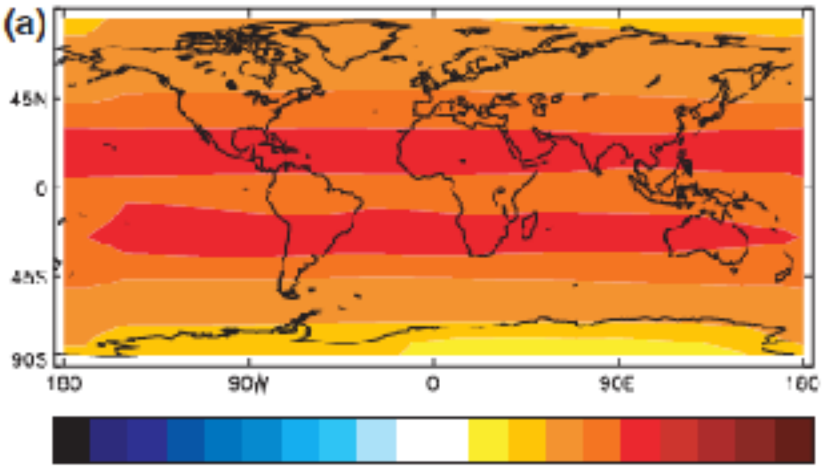
Tropopause and stratosphere ozone

"Most of the observed increase in global average temperatures since the mid-20th century is ***very likely*** due to the observed increase in anthropogenic greenhouse gas concentrations."

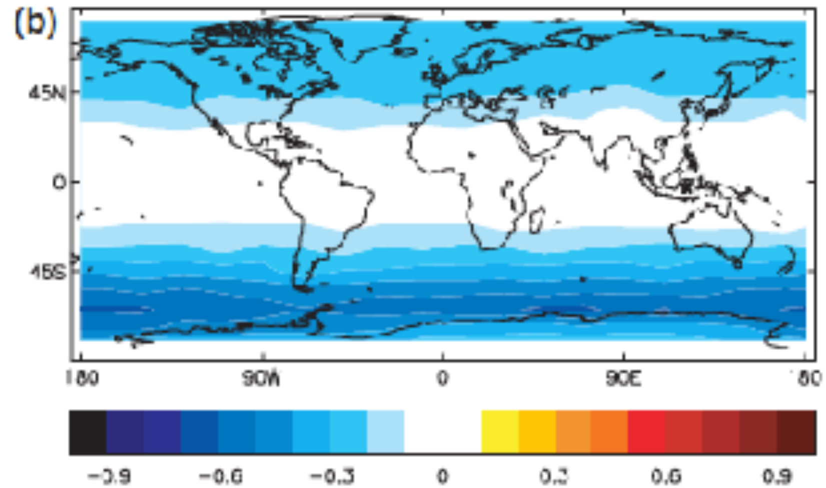
PART II:

An observed **variation of external forcing** in the global warming

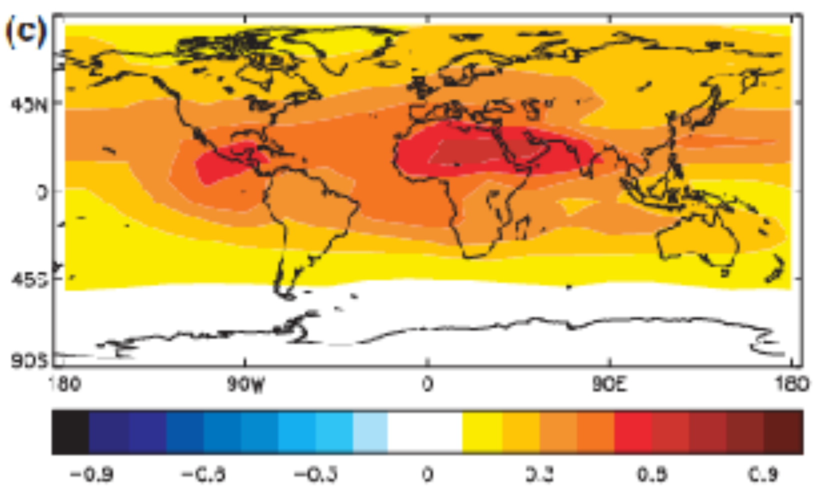
Variation of external forcing



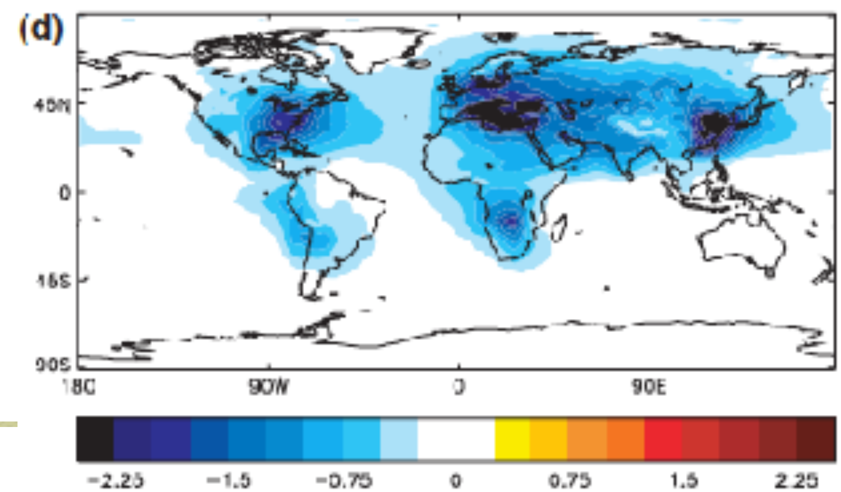
GHG, TAR6



Stratosphere Ozone depletion, TAR6

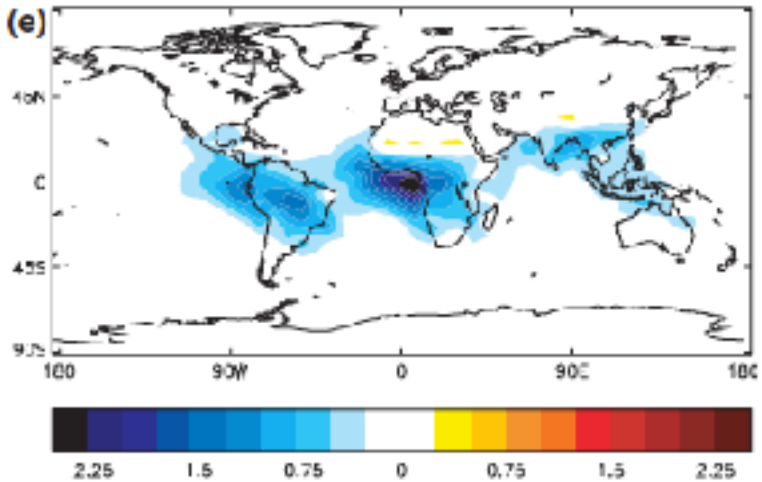


Troposphere Ozone, TAR6

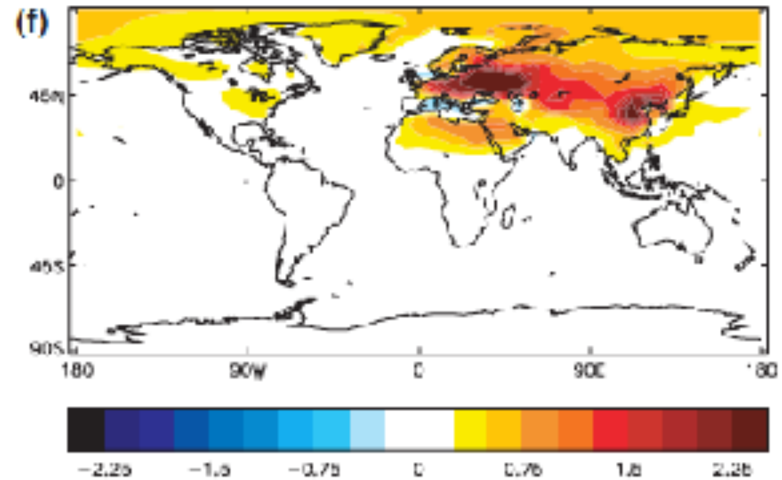


Direct effect sulfate aerosol, TAR6

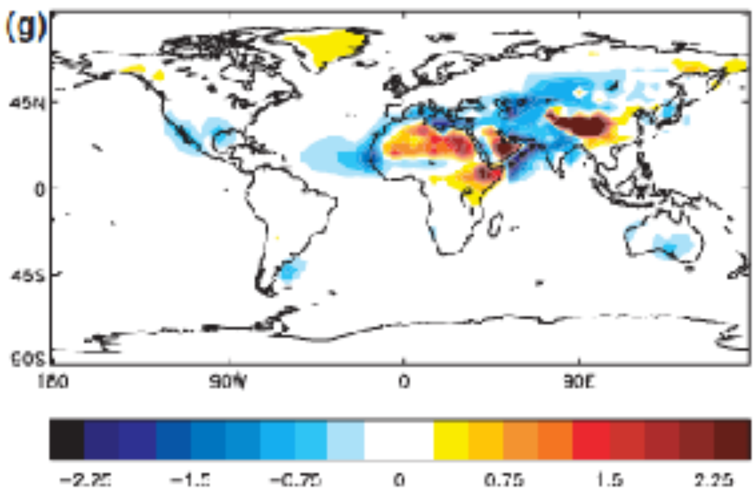
Variation of external forcing



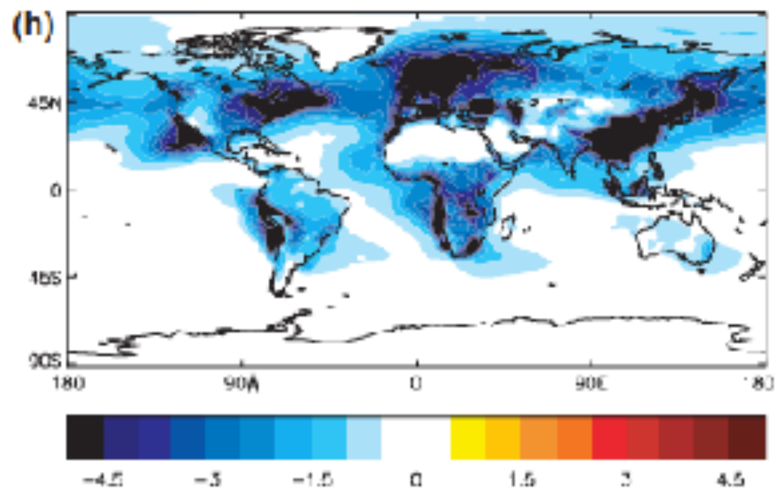
Direct black carbon from biomass



Direct black carbon from fossil fuel

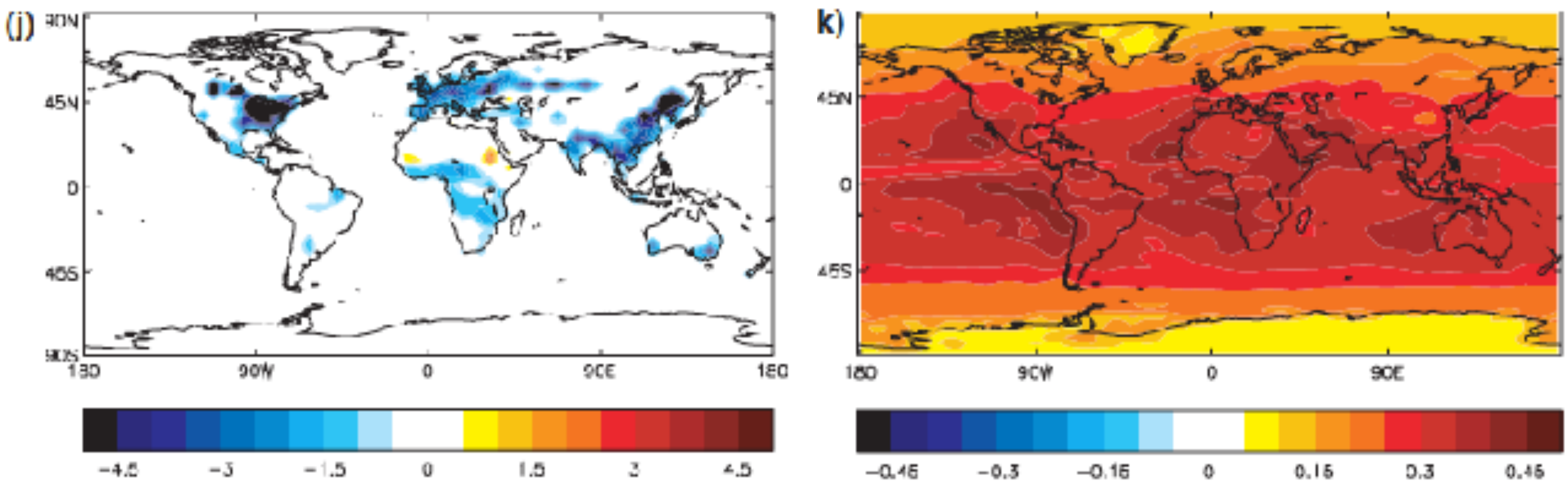


Emission of mineral dust



Indirect of sulphate aerosol

Variation of external forcing



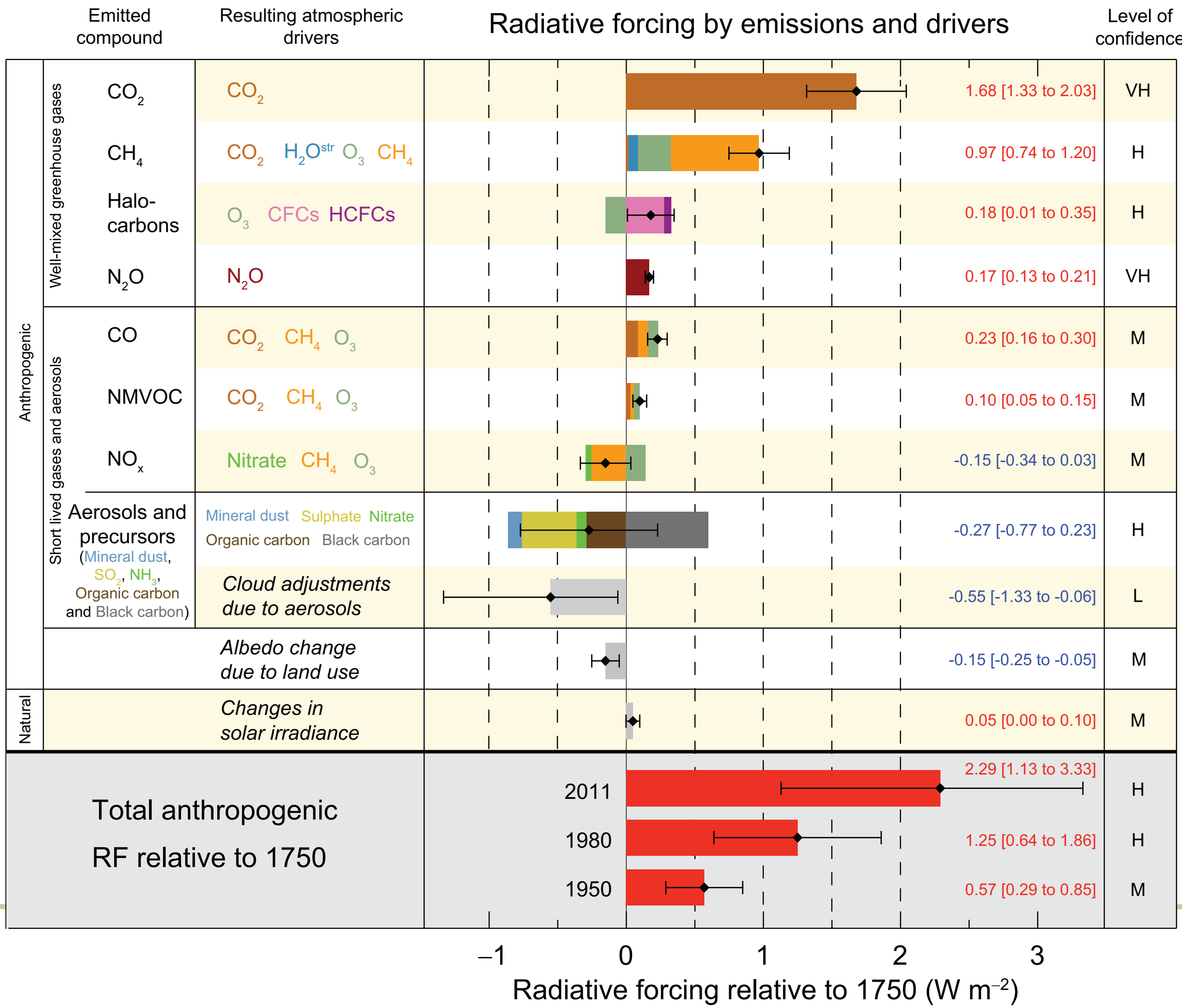
Surface albedo change (land use)

Solar forcing

Figure 6.7: Examples of the geographical distribution of present-day annual-average radiative forcing (1750 to 2000) due to (a) well-mixed greenhouse gases including CO2, CH4, N2O, CFC-11 and CFC-12 (Shine and Forster, 1999); (b) stratospheric ozone depletion over the period 1979 to 1994 given by WMO, 1995 (Shine and Forster, 1999); (c) increases in tropospheric O3 (Berntsen *et al*., 1997; Shine and Forster, 1999); (d) the direct effect of sulphate aerosol (Haywood *et al*., 1997a); (e) the direct effect of organic carbon and black carbon from biomass burning (Penner *et al*., 1998b; Grant *et al*., 1999); (f) the direct effect of organic carbon and black carbon from fossil fuel burning (Penner *et al*., 1998b; Grant *et al*., 1999), (g) the direct effect of anthropogenic emissions of mineral dust (Tegen *et al*., 1996); (h) the "first" indirect effect of sulphate aerosol calculated diagnostically in a similar way to Jones and Slingo (1997), but based on a more recent version of the Hadley Centre model (HadAM3; Pope *et al*., 2000), using sulphur emission scenarios for year 2000 from the SRES scenario (Johns *et al*., 2001) and including a simple parametrization of sea salt aerosol (Jones *et al*., 1999); (i) contrails (Minnis *et al*., 1999); (j) surface albedo change due to changes in land use (Hansen *et al*., 1998), (k) solar variability (Haigh, 1996). Note that the scale differs for the various panels. Different modelling studies may show considerably different spatial patterns as described in the text. (Units: Wm−2)

Variation of external forcing

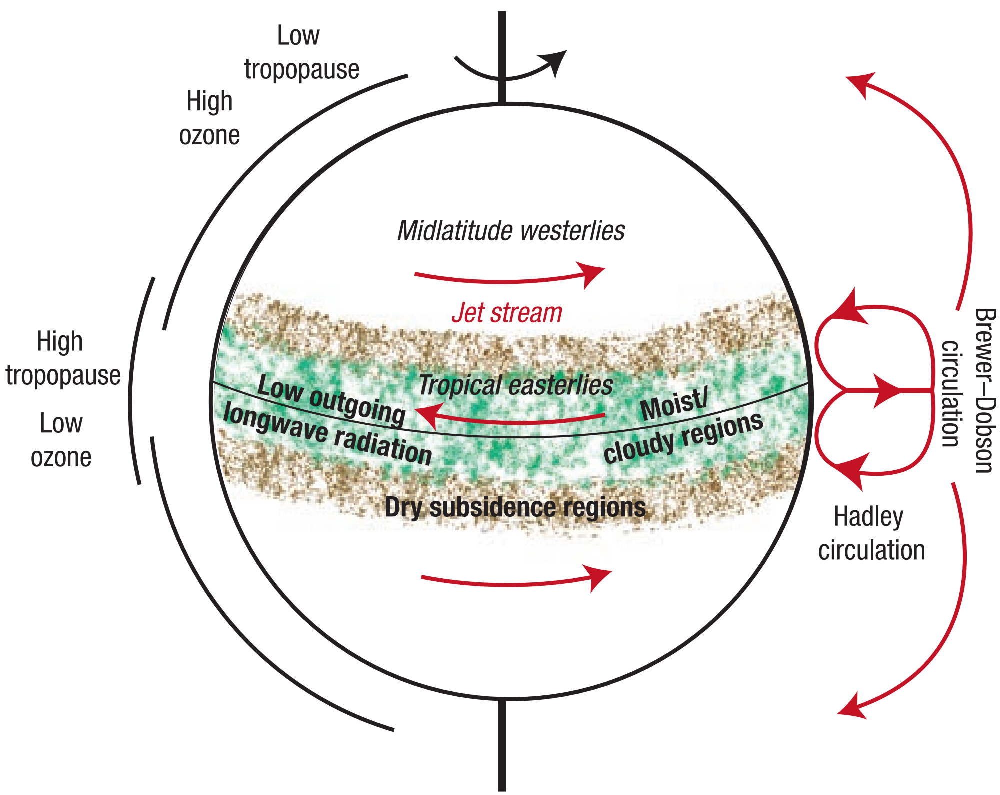
- In AR5



PART III:

An observed/projected variation **of atmospheric circulation** in the global warming

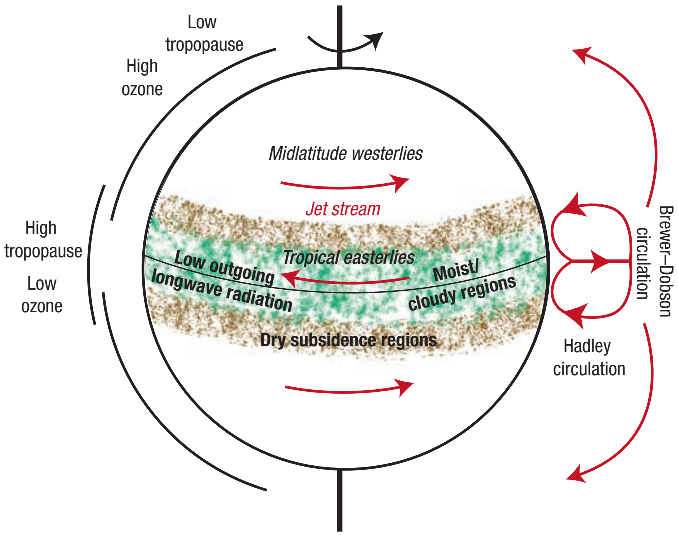
Observed variation of tropical belt/Hadley cell

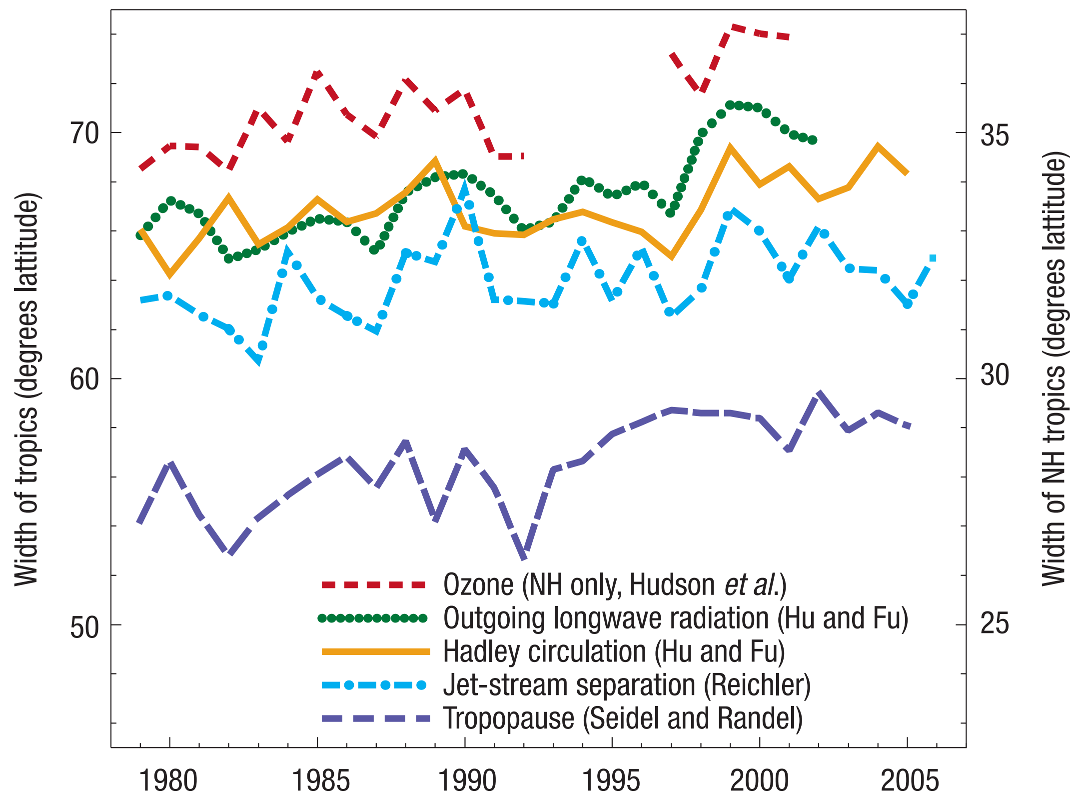


- Identify the boundary of Hadley Cell:
  - Jet stream/subtropical jet
  - Tropopause
  - Zero-latitude of v
  - OLR(outgoing longwave radiation) to find the dry subsidence regions
  - Ozone distribution

Adapted from Seidel et al, 2008

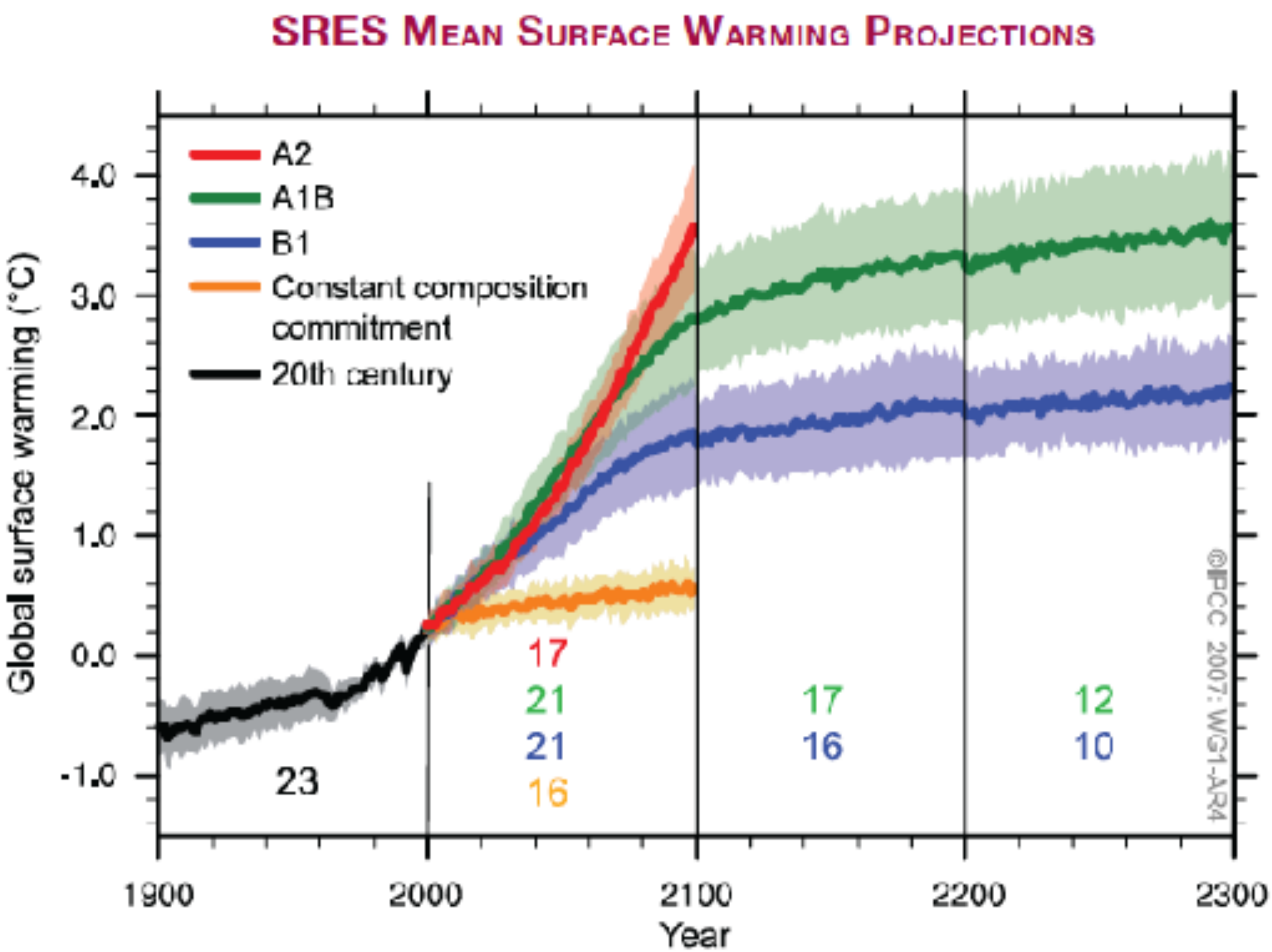
Observed variation of tropical belt/Hadley cell





Adapted from Seidel et al, 2008

AR4 Projected variation of atmospheric circulation



1-globalization

2-regionalization

A-rapid growth

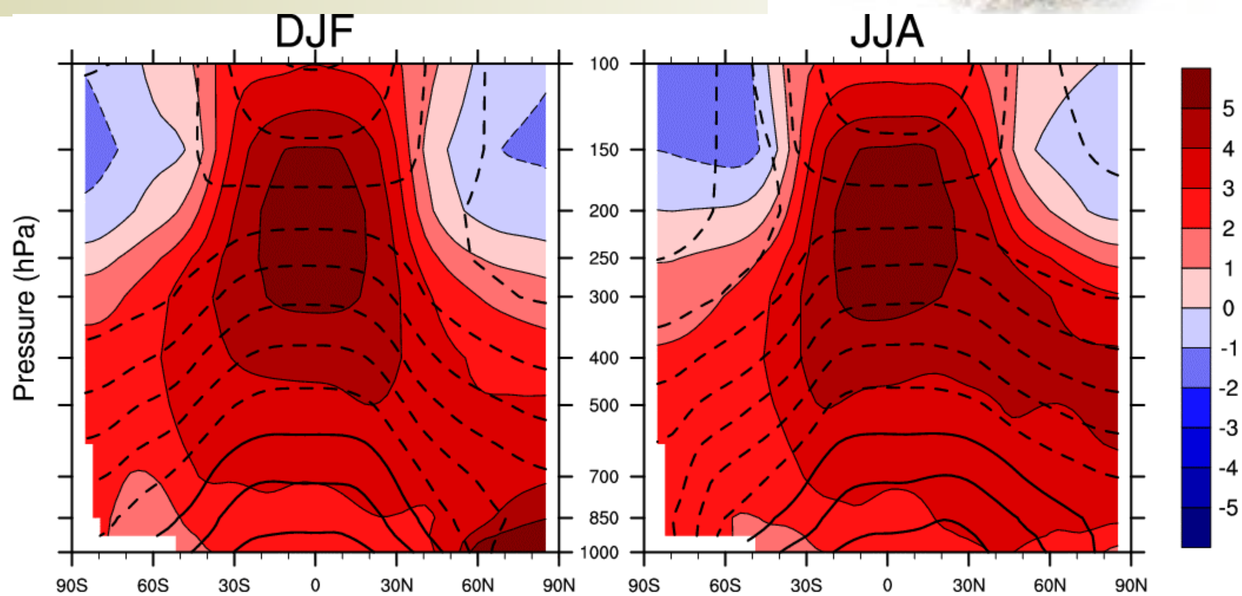
B-sustainability

Projected variation of mid-latitude circulation

- IPCC AR4 model experiments:
  - SRES A1b: 720 ppm CO_2 by 2100
  - 21st Century climate change: Compare years 2081-2100 from SRES A1b with years 1981-2000 from 20th Century Experiment
  - Multi-model ensembles: 15 different coupled GCMs, one member each

Projected variation of mid-latitude circulation

Temperature



Notable features in warming:

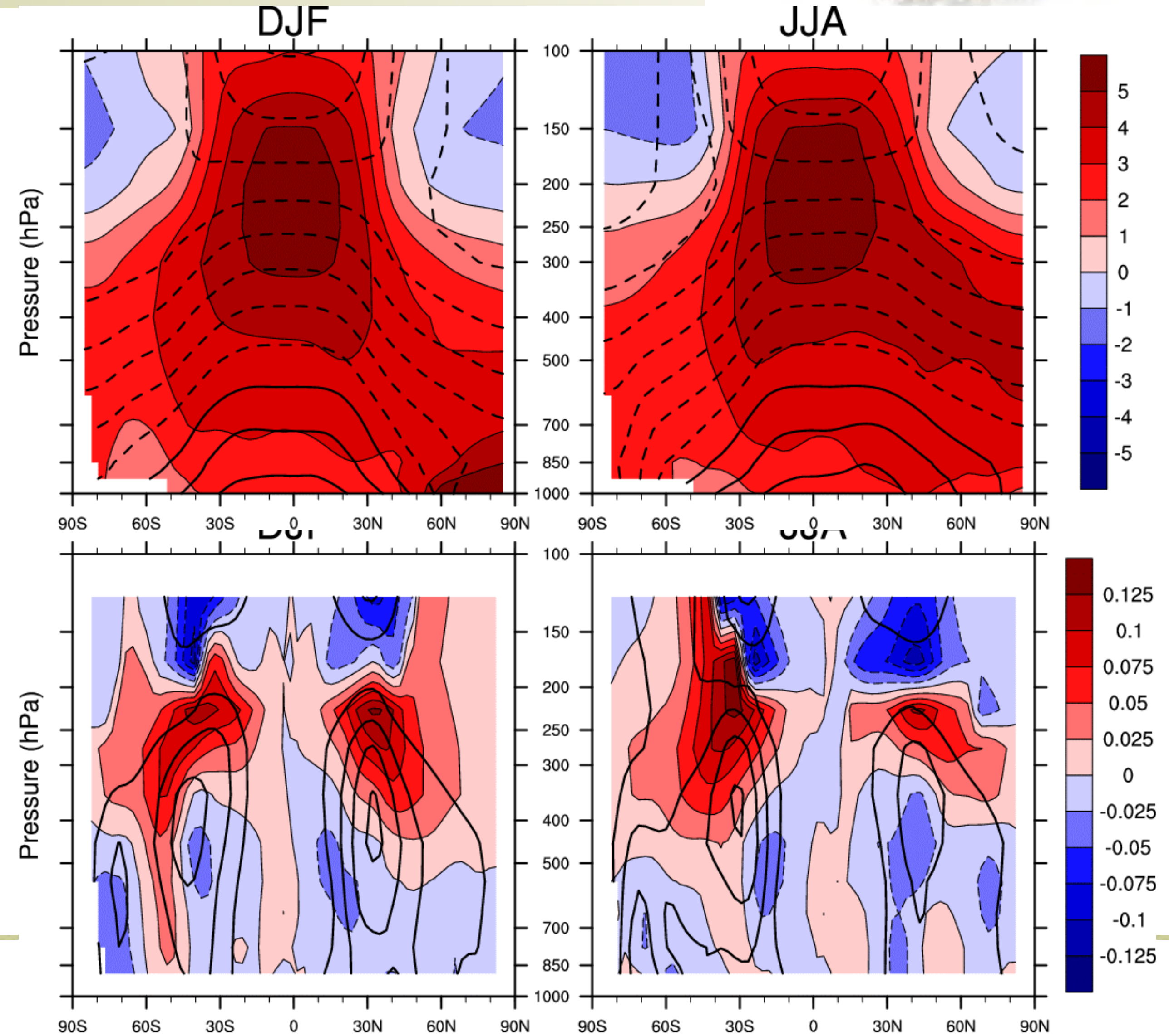
- Maximum in tropical upper troposphere
- Maximum near surface over N. Pole in DJF
- Minimum over Southern Ocean

Adapted from Yin, 2005

Projected variation of mid-latitude circulation

Temperature

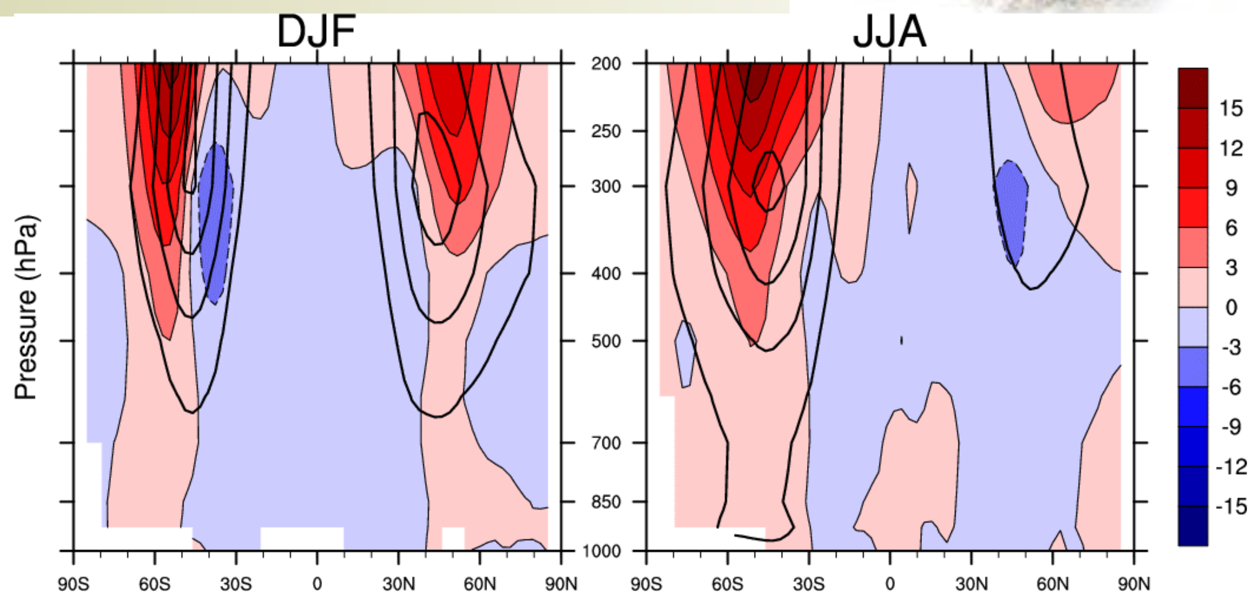
Eady growth rate



Adapted from Yin, 2005

Projected variation of mid-latitude circulation

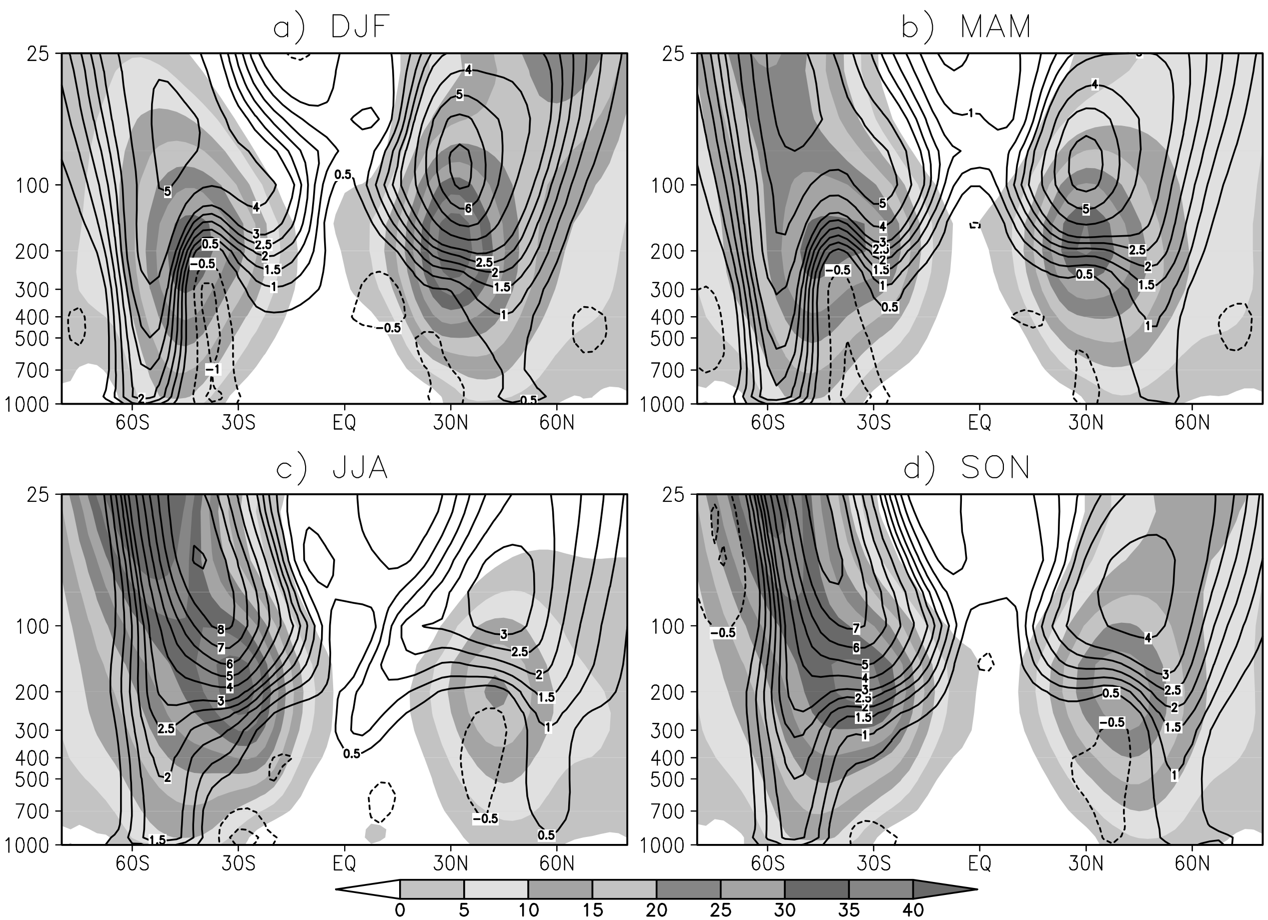
2-8 day
Eddy Kinetic
Energy



- Storm tracks shift poleward and upward
- Storm tracks also tend to strengthen
- Most consistent in seasons with strong storm tracks (SH in DJF, JJA; NH in DJF)

Adapted from Yin, 2005

Projected variation of Jet Stream



Shaded - 20th century climatology

Contours - Variations in 2080-2099 in AR4, A2 scenario

Adapted from Lorenz and DeWeaver, 2007

Observed/projected variation of ENSO variability

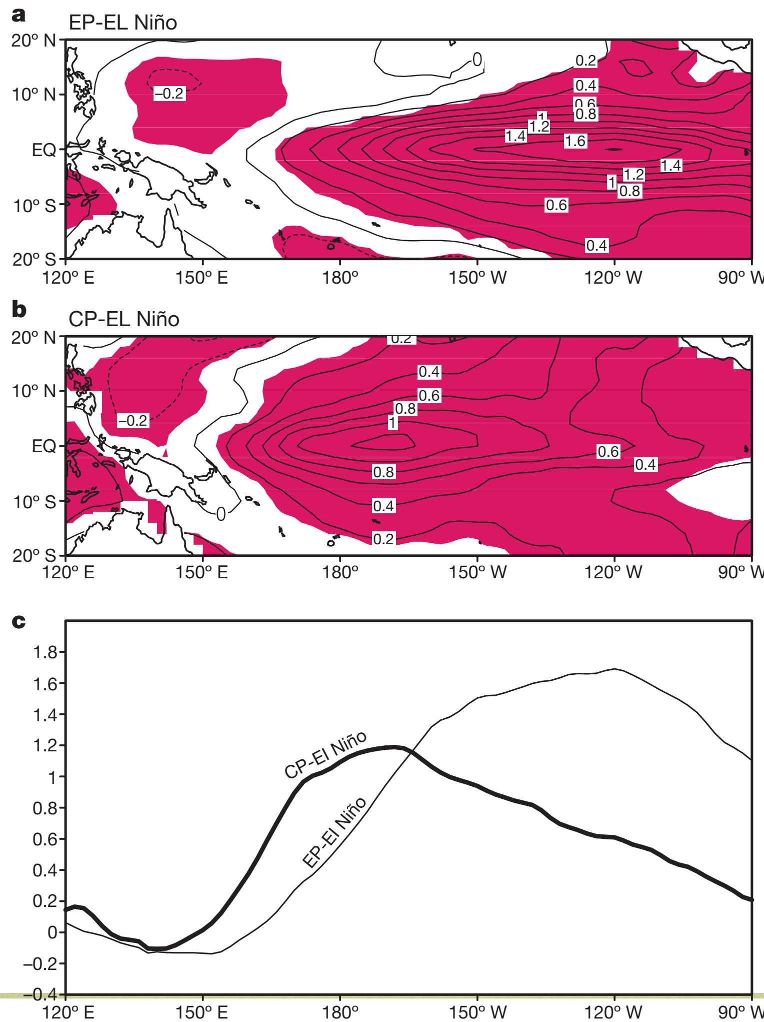
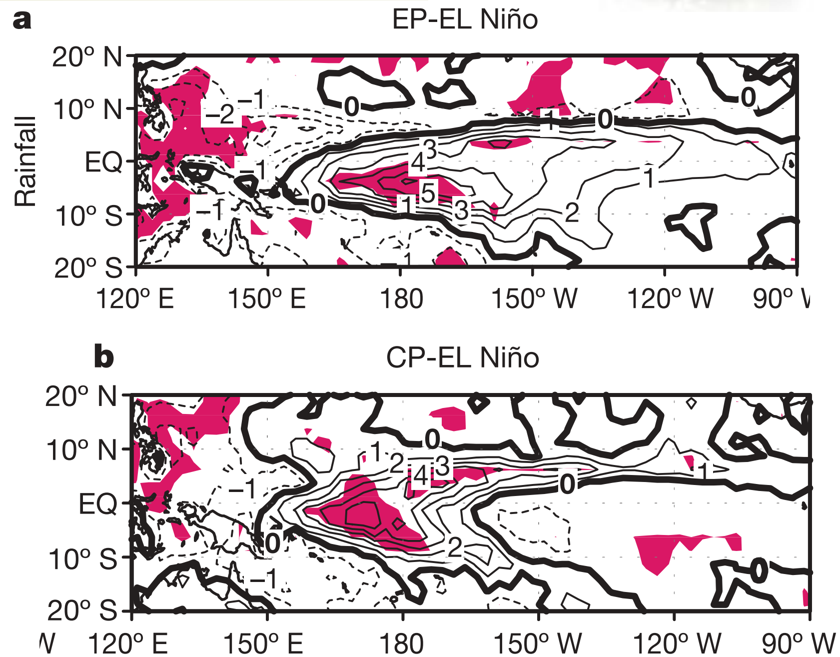
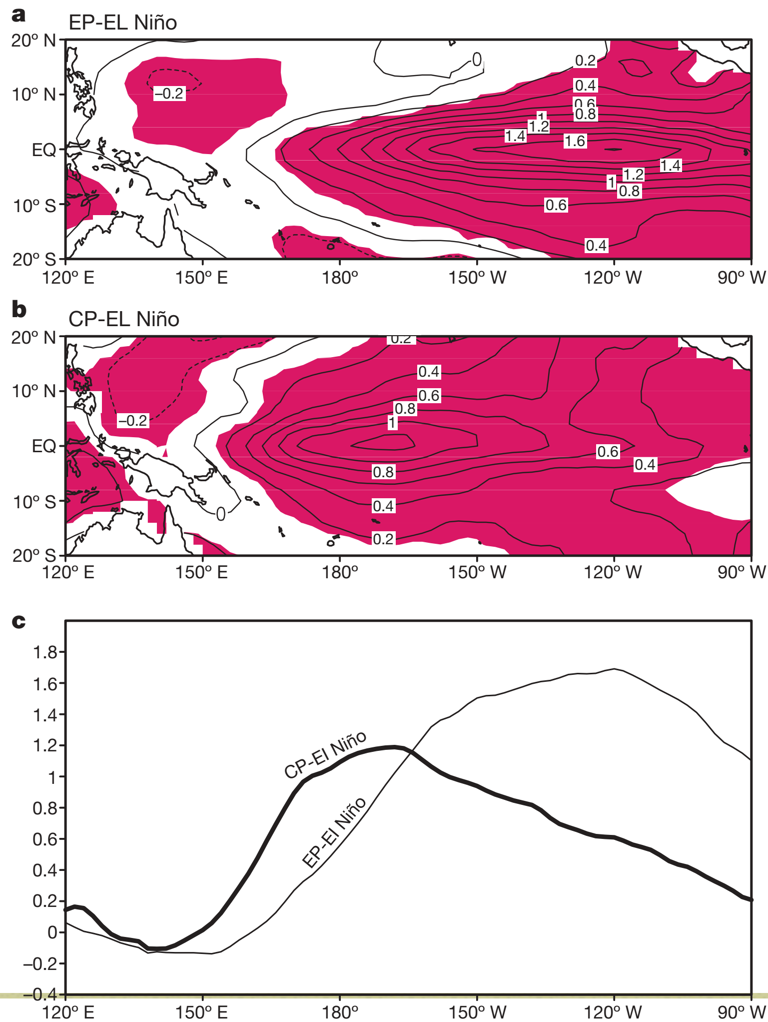


Figure 1 | Deviations of mean SST for the two characteristics of El Niño from the 1854–2006 climatology. **a**, The EP-El Niño; **b**, the CP-El Niño.



Observed/projected variation of ENSO variability



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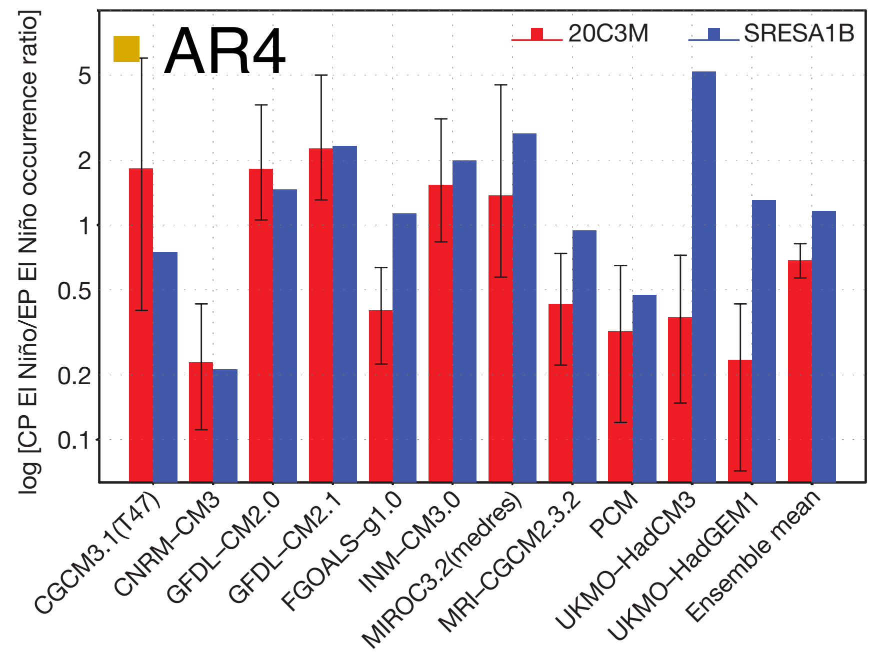
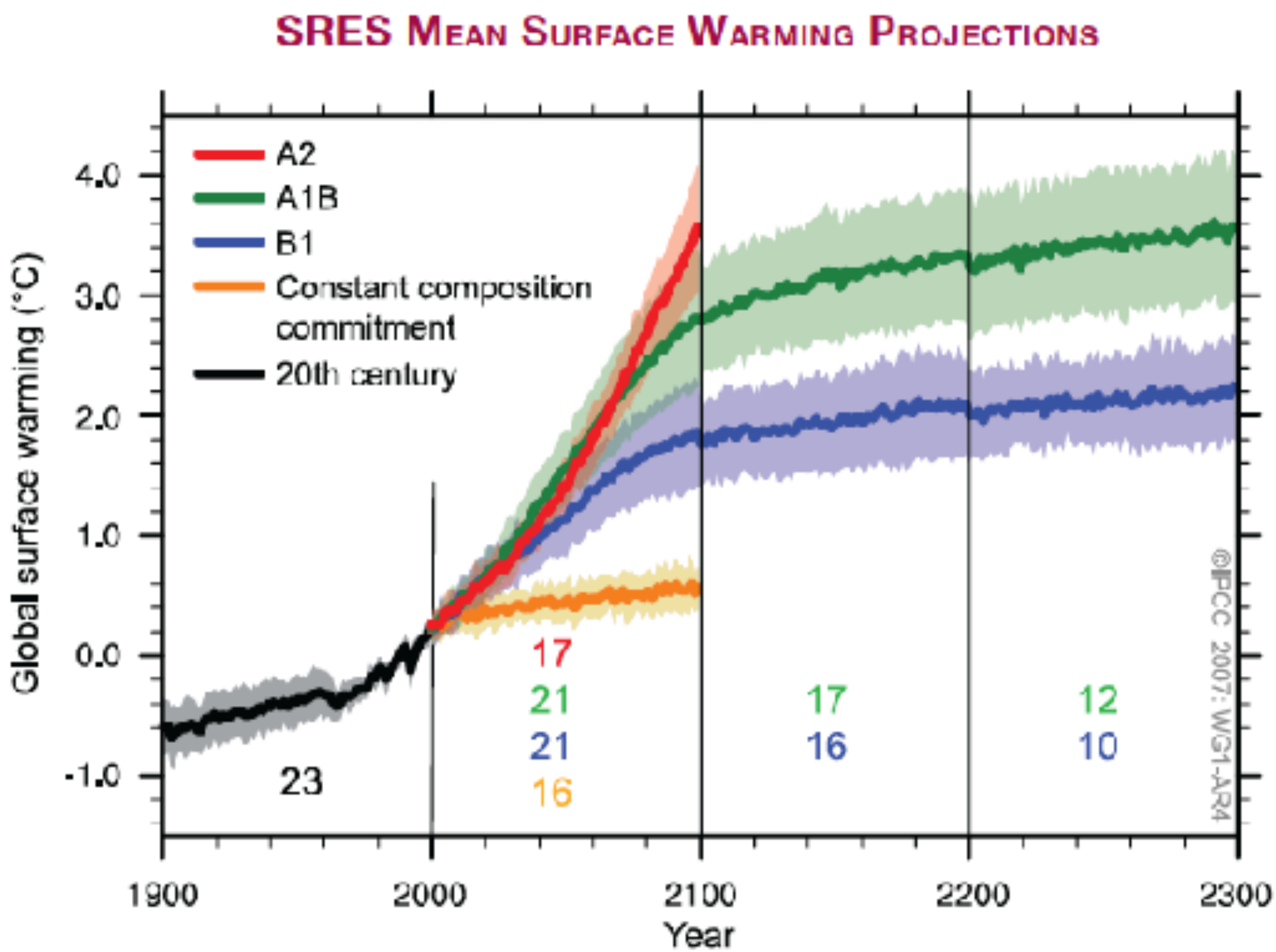


20C3M:
20th Century Climate Coupled Model

AR4 Projected variation of atmospheric circulation



1-globalization

2-regionalization

A-rapid growth

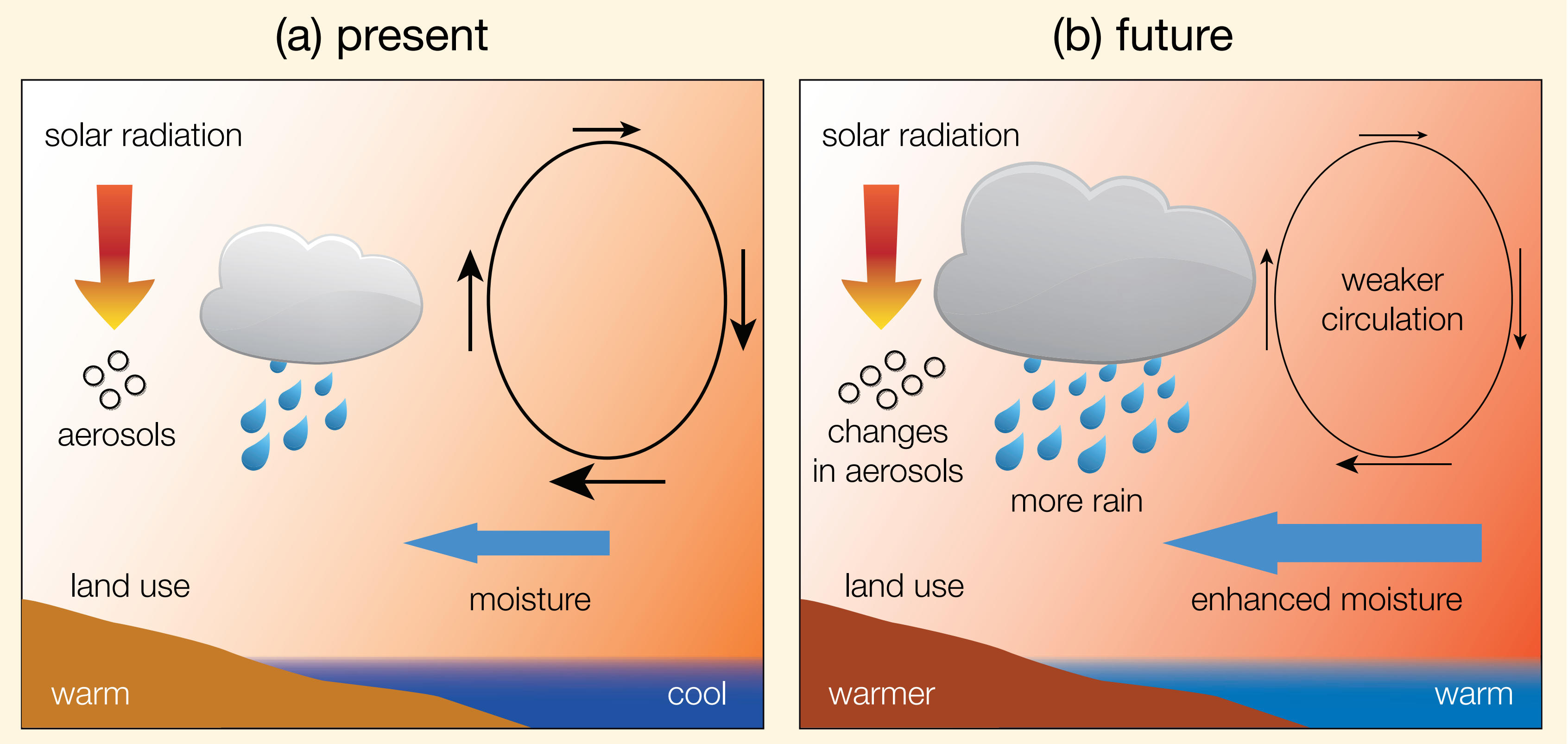
B-sustainability

AR5: Projected variation of atmospheric circulation

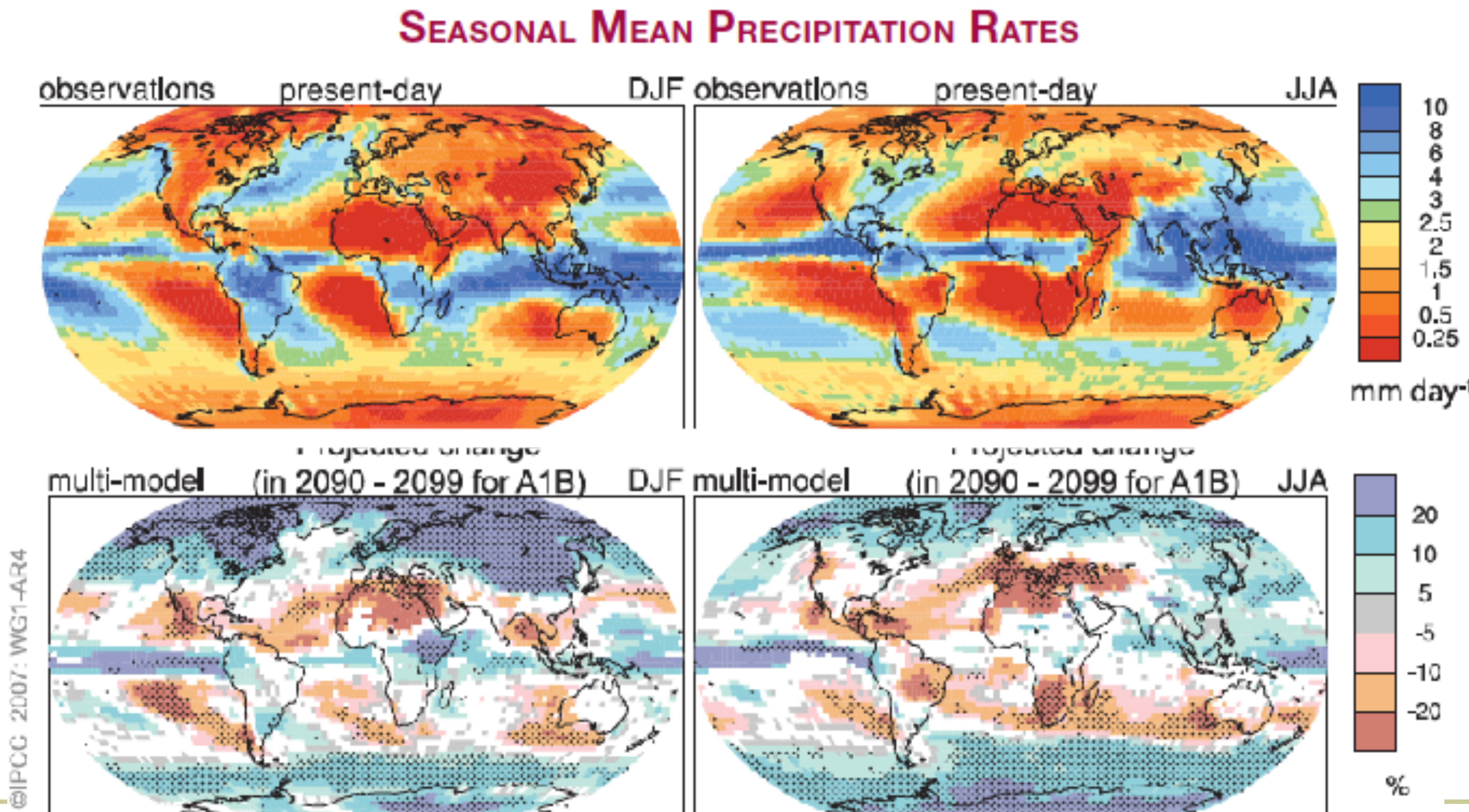
- IPCC5:CMIP5 experiment design: For the Fifth Assessment Report of IPCC, the scientific community has defined a set of four new scenarios, denoted Representative Concentration Pathways (**RCP**)
- They are identified by their approximate total radiative forcing in year 2100 relative to 1750:
  - 2.6 W m^{-2} for RCP2.6, 4.5 W m^{-2} for RCP4.5, 6.0 W m^{-2} for RCP6.0, and 8.5 W m^{-2} for RCP8.5.
  - with prescribed CO_2 concentrations reaching 421 ppm (RCP2.6), 538 ppm (RCP4.5), 670 ppm (RCP6.0), and 936 ppm (RCP 8.5) by the year 2100.
  - Including also the prescribed concentrations of CH_4 and N_2O, the combined CO_2-equivalent concentrations are 475 ppm (RCP2.6), 630 ppm (RCP4.5), 800 ppm (RCP6.0), and 1313 ppm (RCP8.5).

Projected variation of monsoonal circulation

- Monsoonal circulation

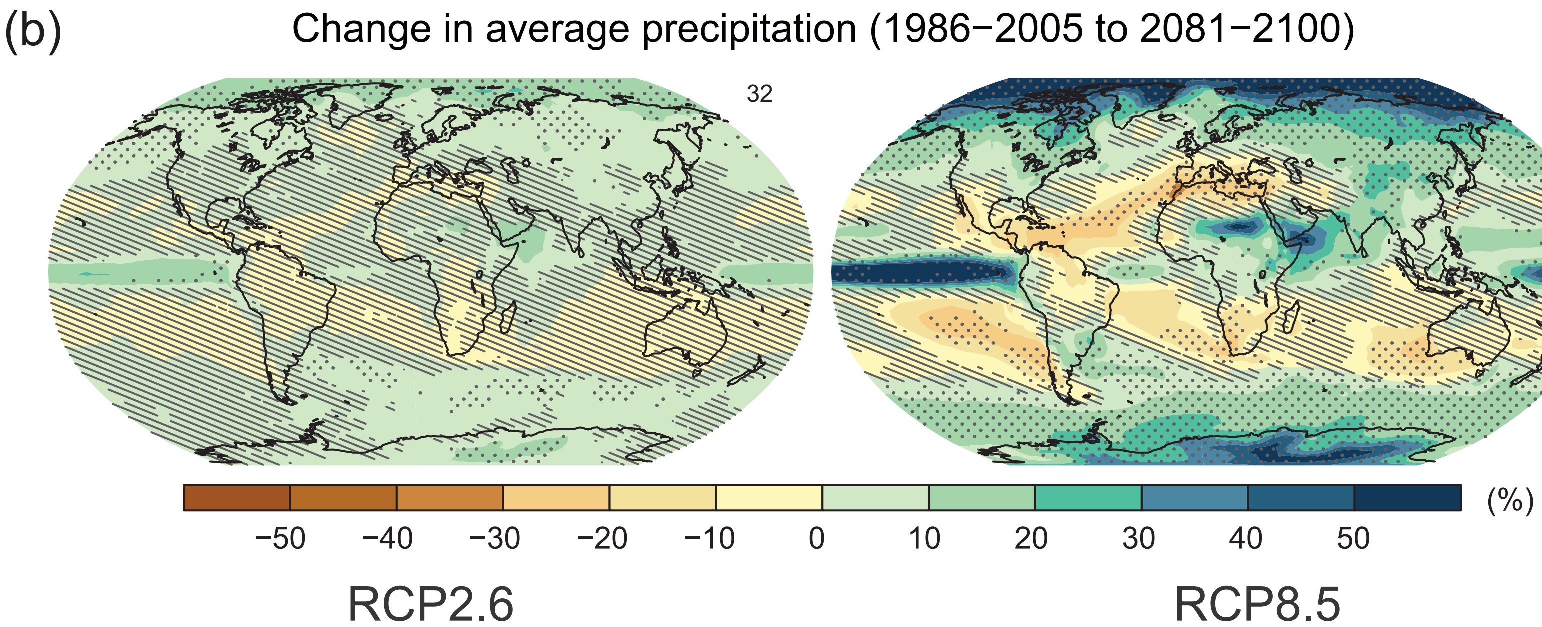


Projected variation of atmospheric circulation



变化的百分比

Projected variation of Precipitation

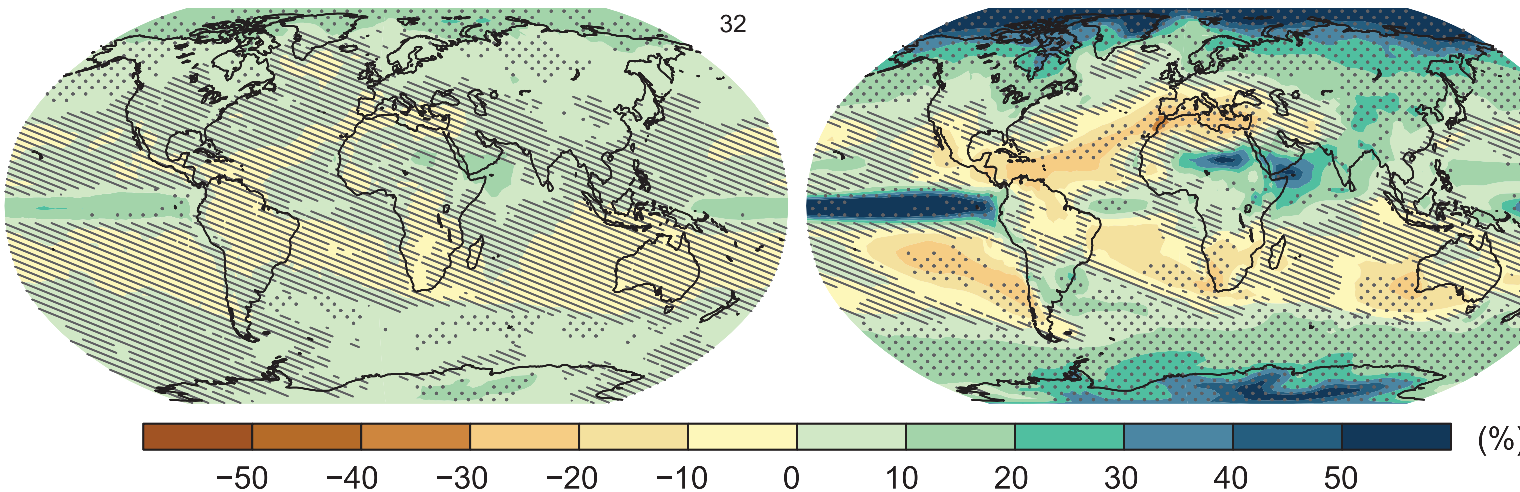


The high latitudes and the equatorial Pacific Ocean are likely to experience an increase in annual mean precipitation by the end of this century under the RCP8.5 scenario.

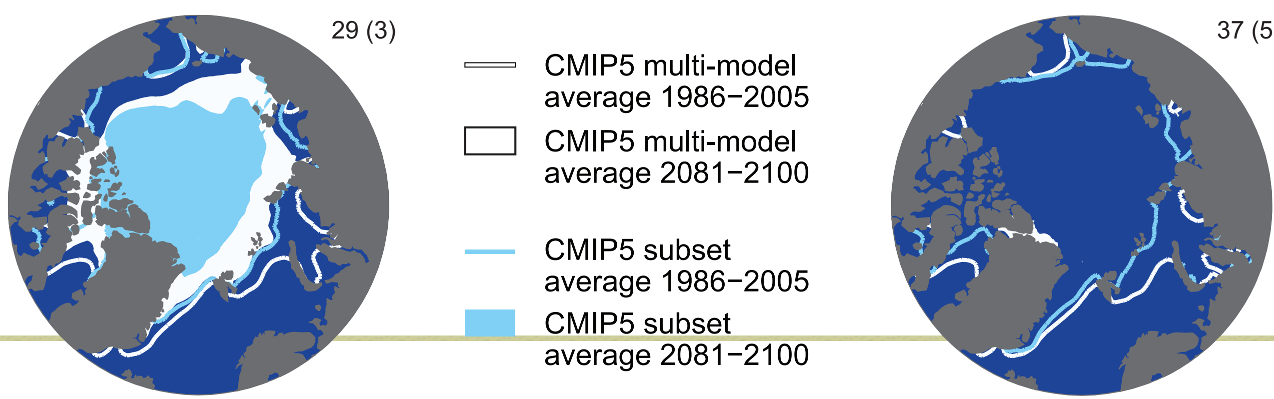
In many mid-latitude and subtropical dry regions, mean precipitation will likely decrease, while in many mid-latitude wet regions, mean precipitation will likely increase by the end of this century under the RCP8.5 scenario.

Observed/Projected variation of atmospheric circulation

(b) Change in average precipitation (1986−2005 to 2081−2100)



(c) Northern Hemisphere September sea ice extent (average 2081−2100)



Observed/projected variation of atmospheric circulation

Summary:

- Variations both observed in the past decades and in the models under the global warming scenario:
    - **Temperature:** warming in the troposphere, cooling in the stratosphere, rise of the tropopause, the resulting variation of the flow baroclinicity.
    - **Tropical belt/Hadley cell:** Hadley cell expansion/widening of tropical belt, poleward shift of jet stream, an increase in tropical precipitation.
    - **Midlatitude:** Poleward migration of storm tracks.
- The model projected:
    - **Precipitation**: an increase in tropical and high-latitude precipitation, decrease in the subtropic.
    - **ENSO**: dominant inter-annual signal with central pacific El Nino seemed appear more frequently.
    - **Monsoon:** enhanced precipitation but weaken circulation.