

# **Radiative forcing and climate feedbacks:**

**News from the 4<sup>th</sup> Assessment Report of the Intergovernmental Panel on Climate Change**

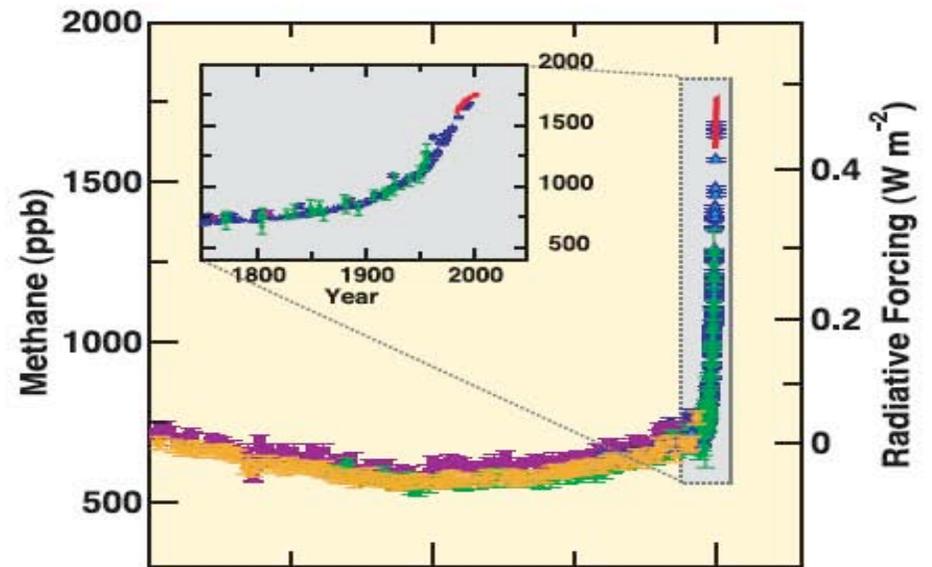
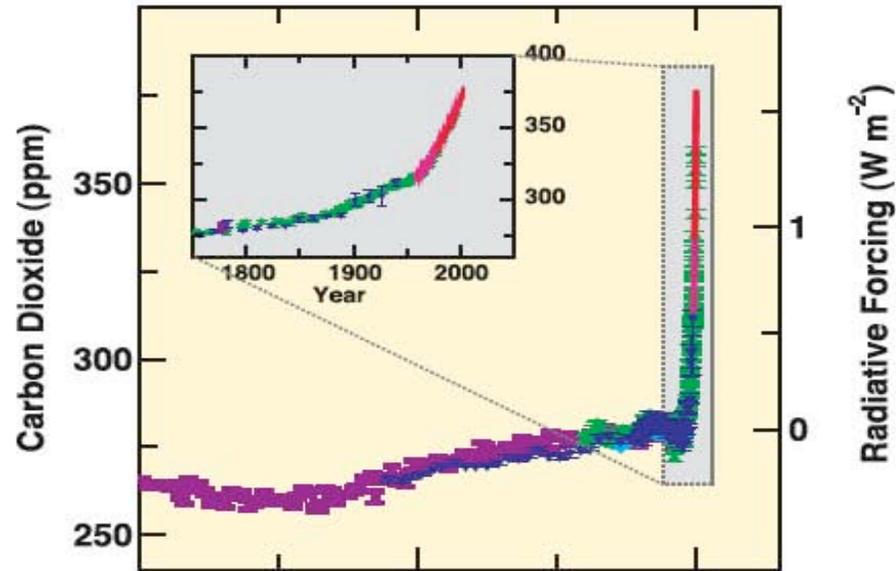
**Ulrike Lohmann**

**ETH Zürich**

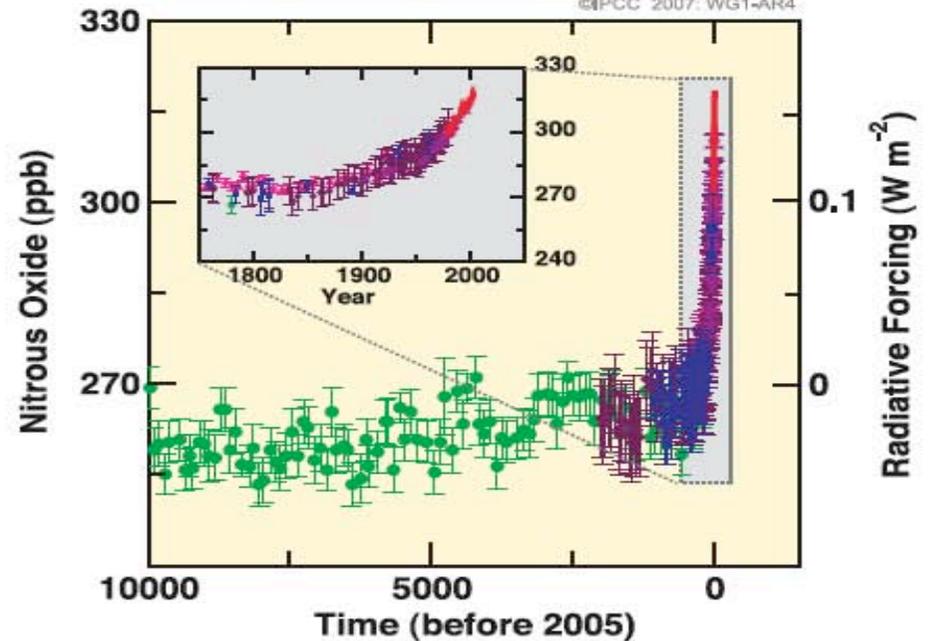
**Institute for Atmospheric and Climate Science**



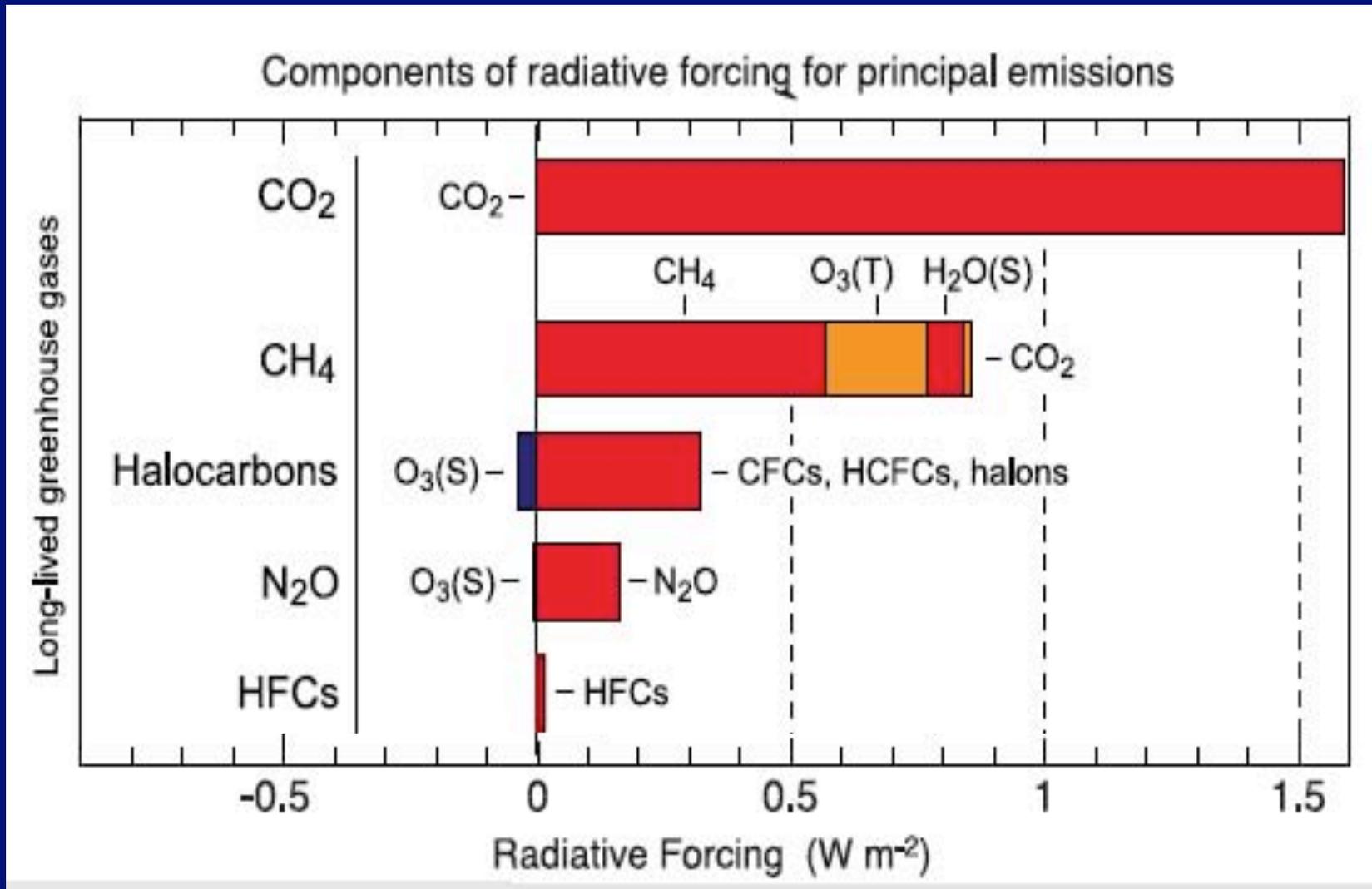
# Drivers of Climate Change (Fig SPM1)



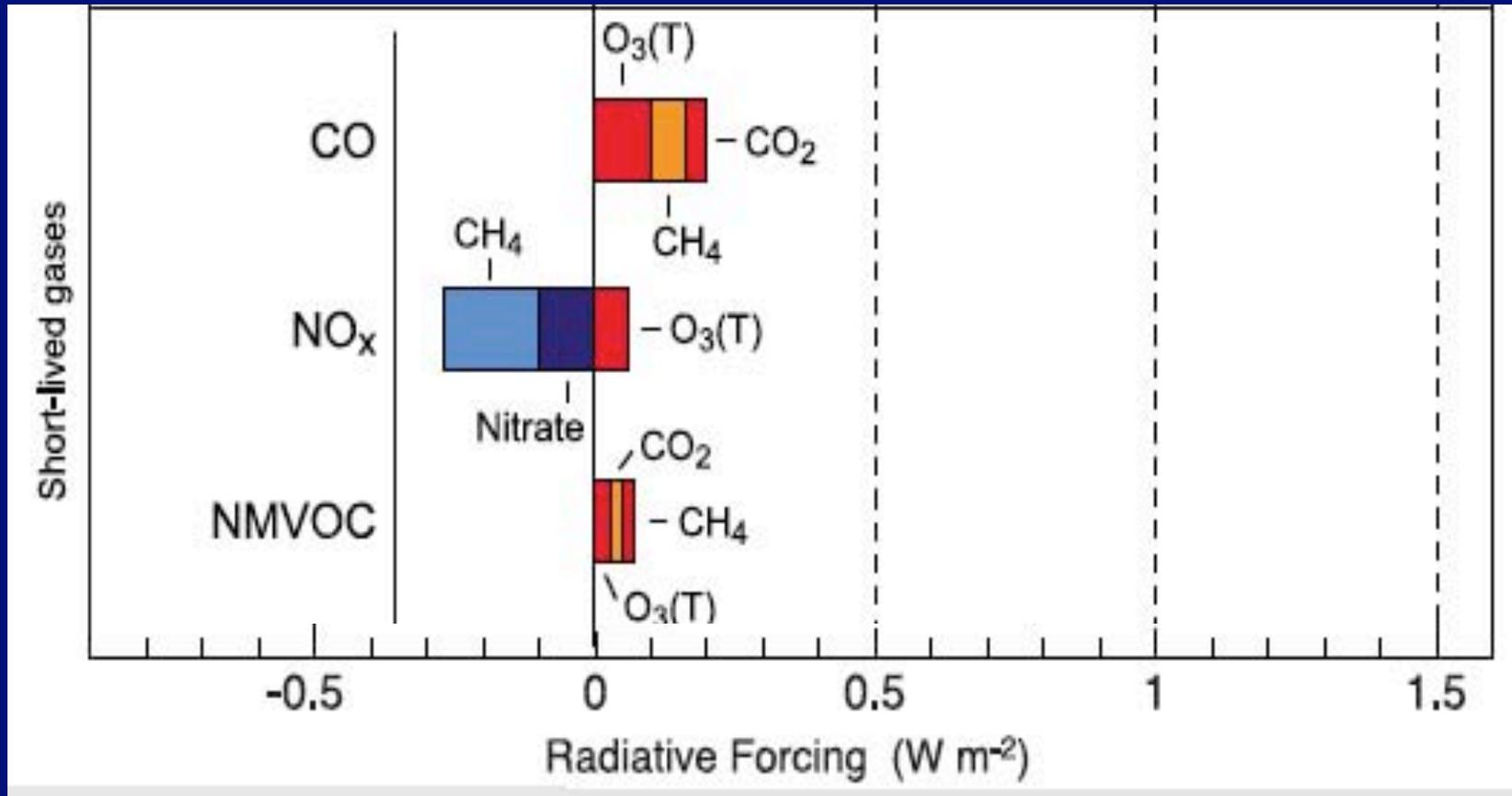
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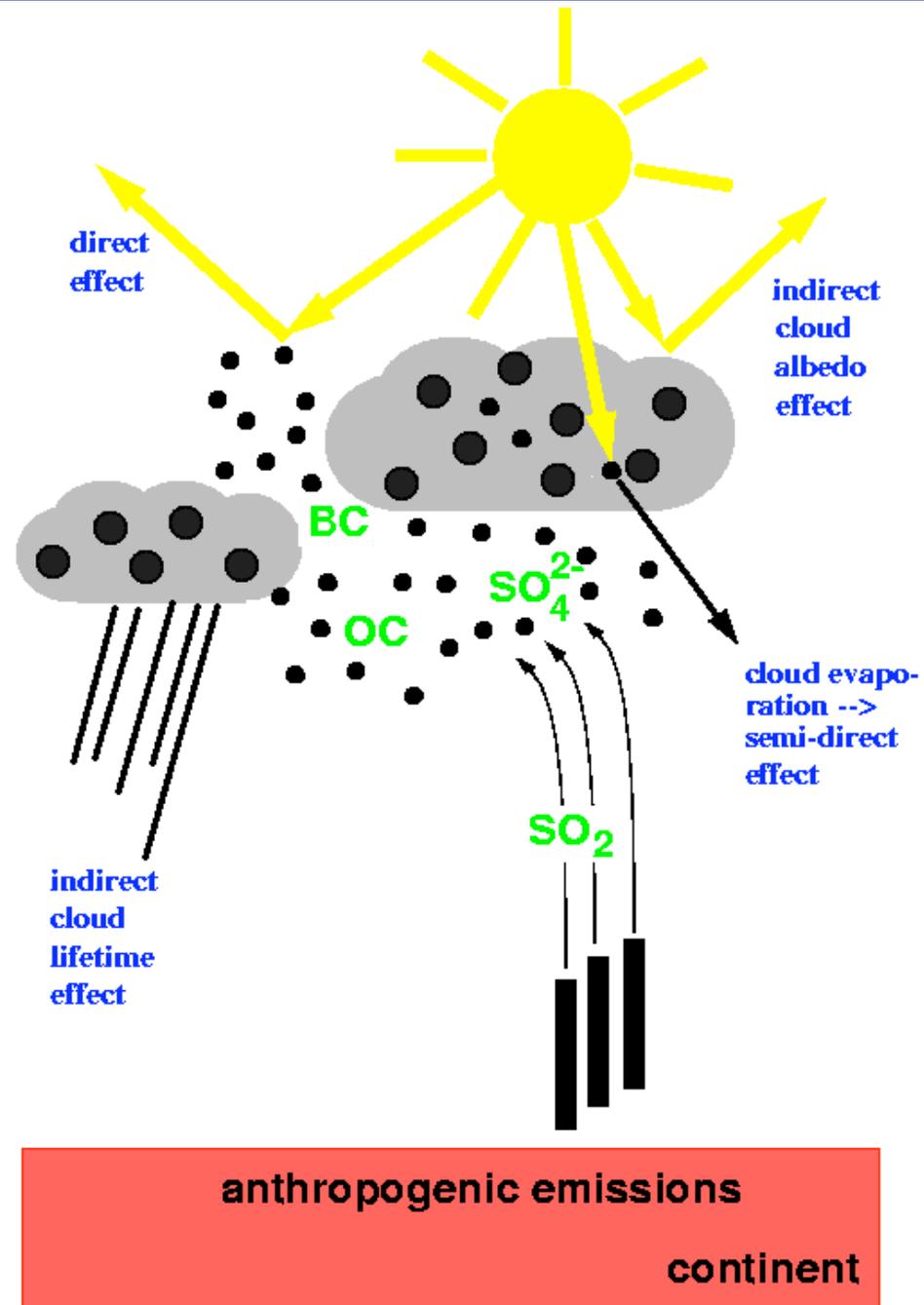
# Forcing due to long-lived greenhouse gases (Fig 2.21)



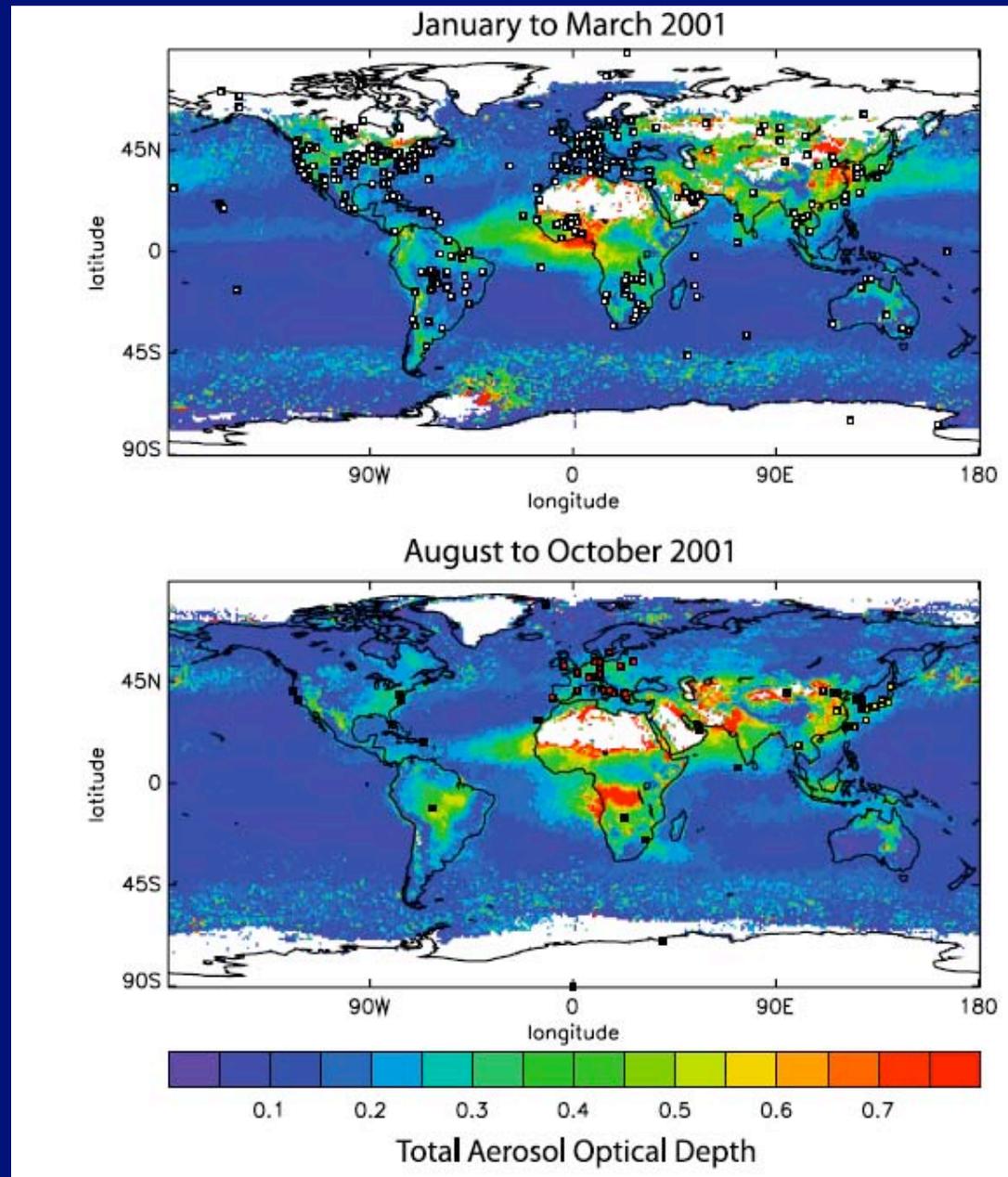
# Forcing due to short-lived gases (Fig 2.21)



# Climate effects of aerosols



# Observed aerosol optical depth (Fig 2.11)



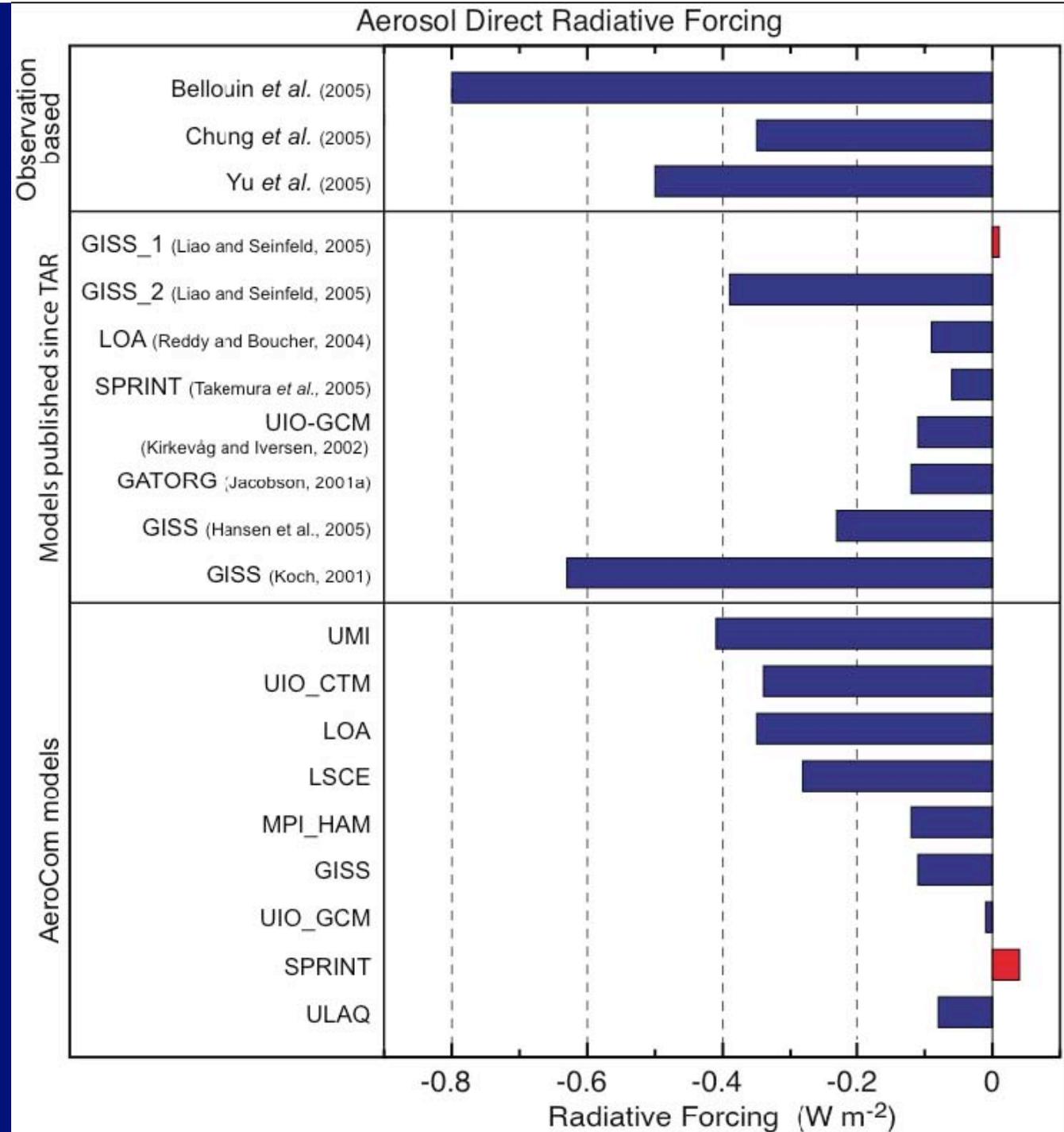
# Direct aerosol forcing (Fig. 2.13):

mean value:

**-0.5 W/m<sup>2</sup>**

range:

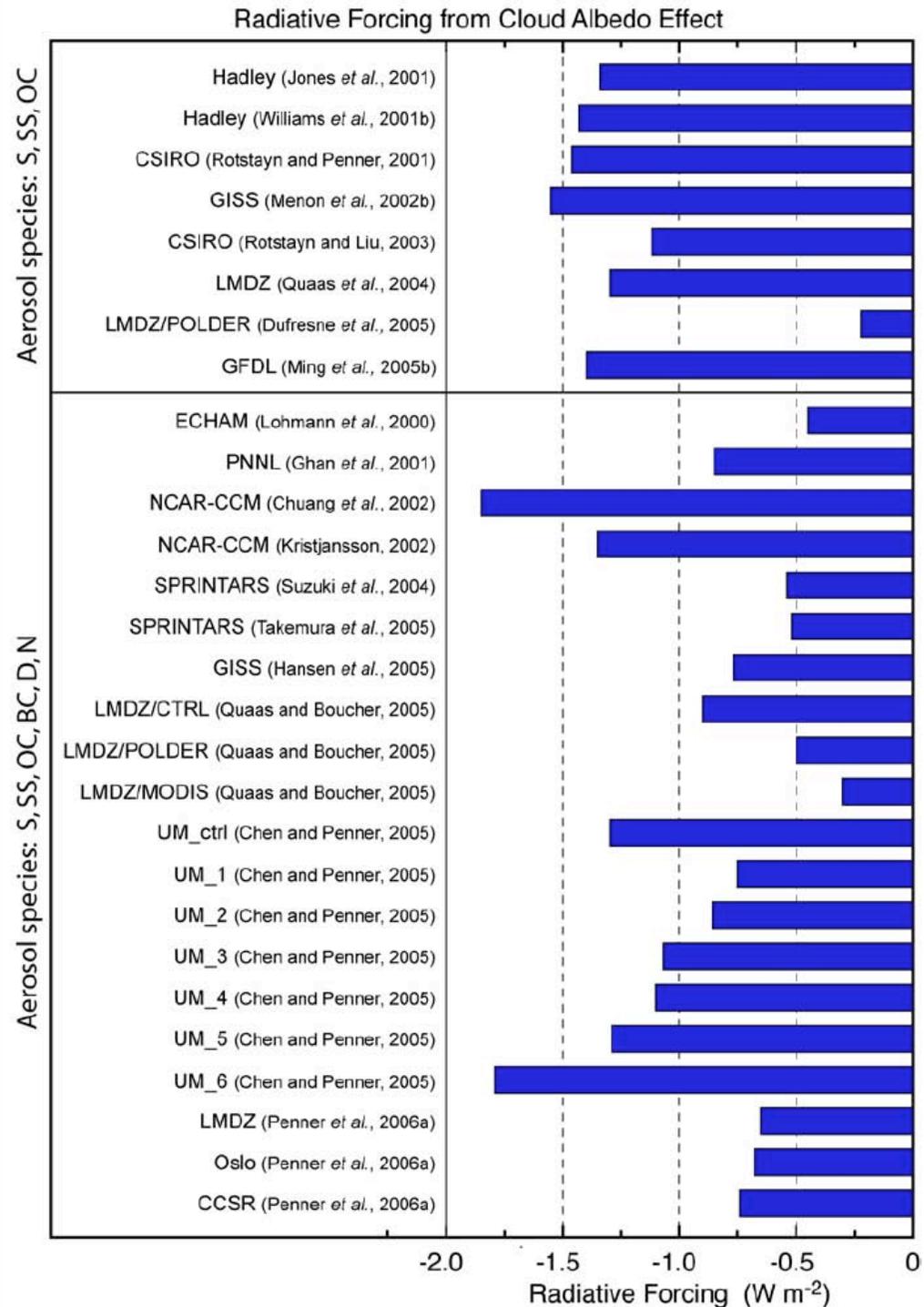
**-0.9 to -0.1 W/m<sup>2</sup>**



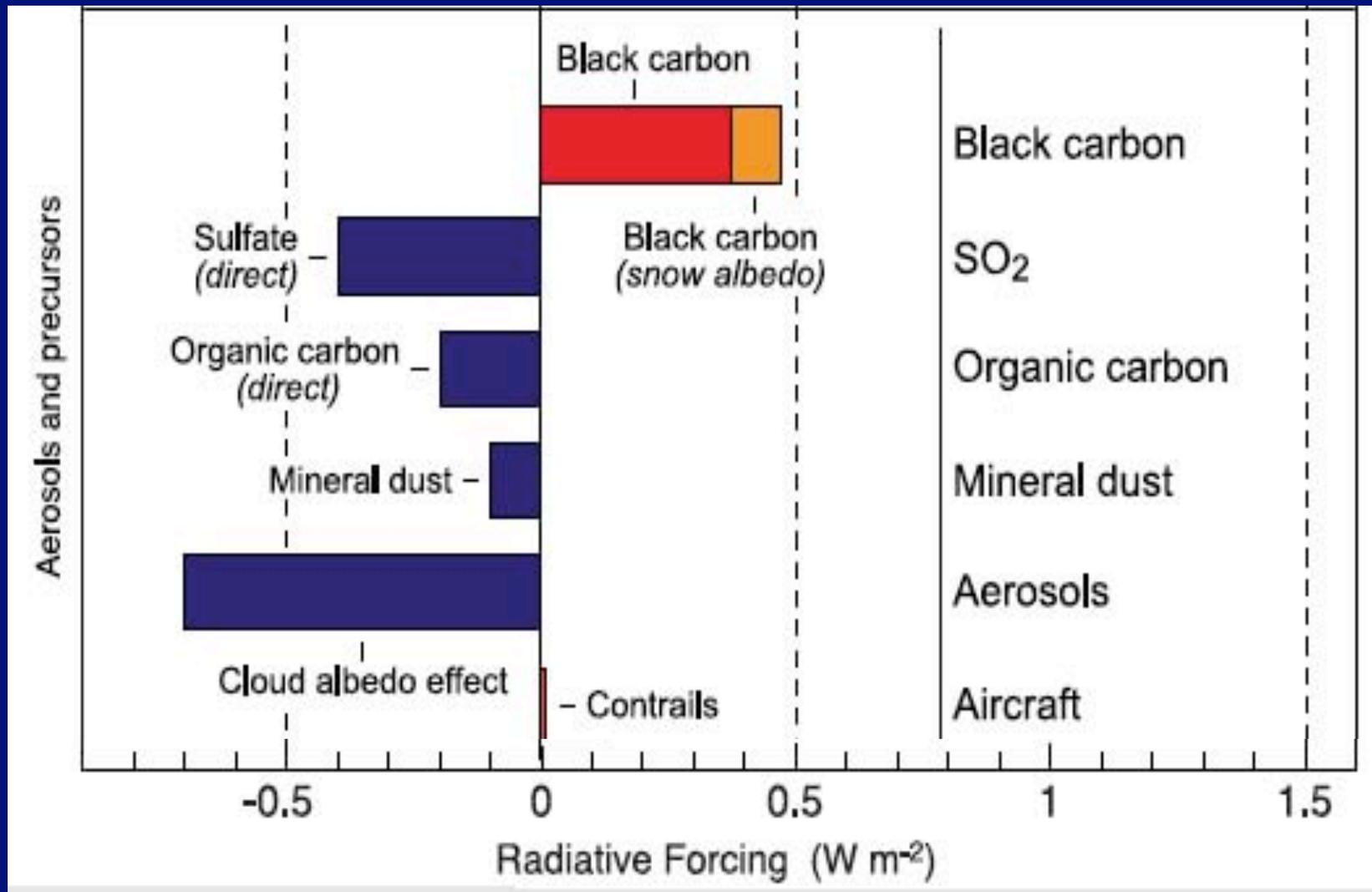
# Indirect cloud albedo effect from different models (Fig 2.14): mean value: $-0.7 \text{ W/m}^2$ range: $-1.8$ to $-0.3 \text{ W/m}^2$

Upper panel: models with sulfate (S), sea salt (SS) and organic carbon (OC),

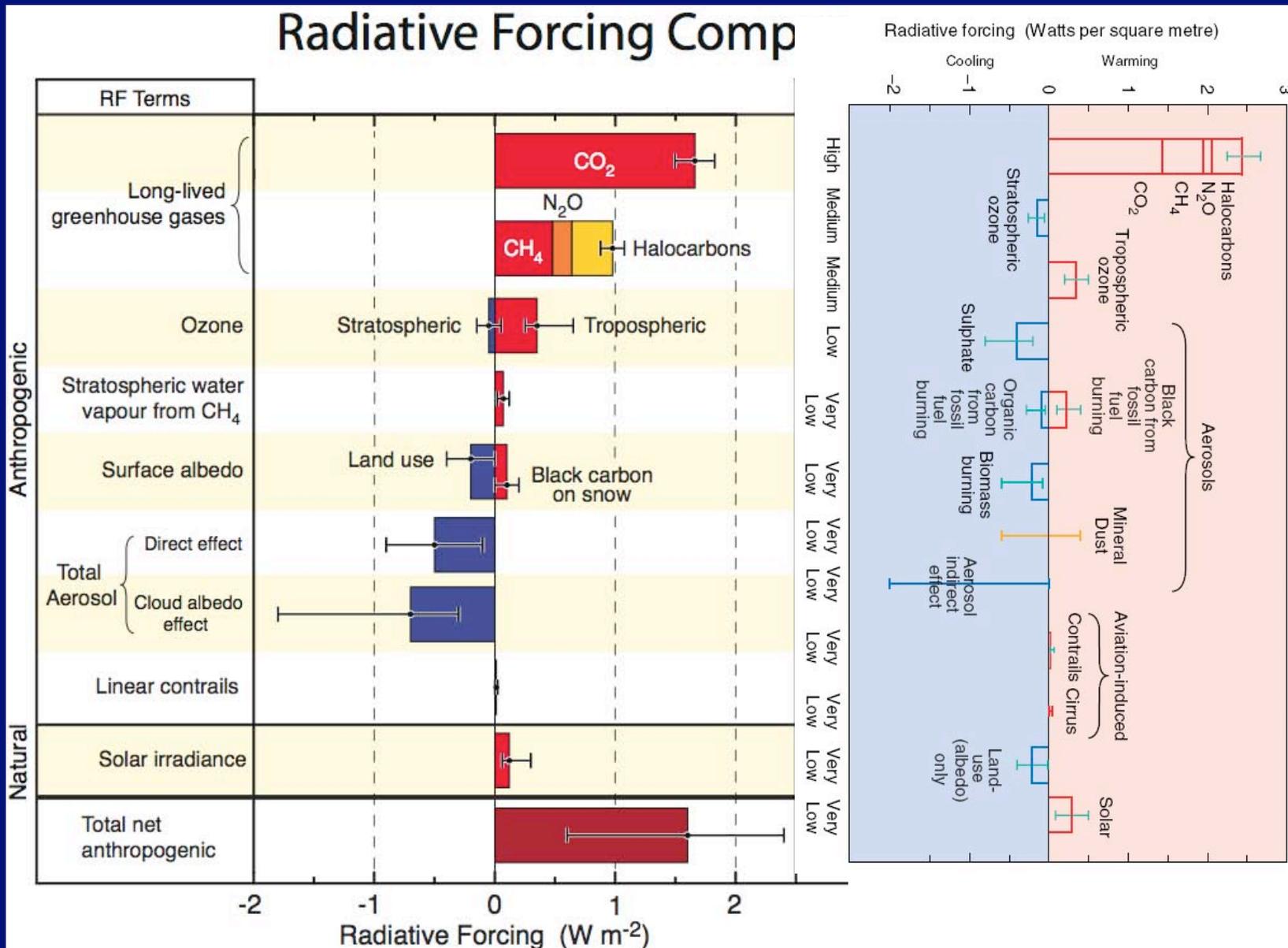
Lower panel: S, SS, OC, black carbon (BC), dust (D) and nitrate (N)



# Forcing due to aerosols and precursors (Fig 2.21)

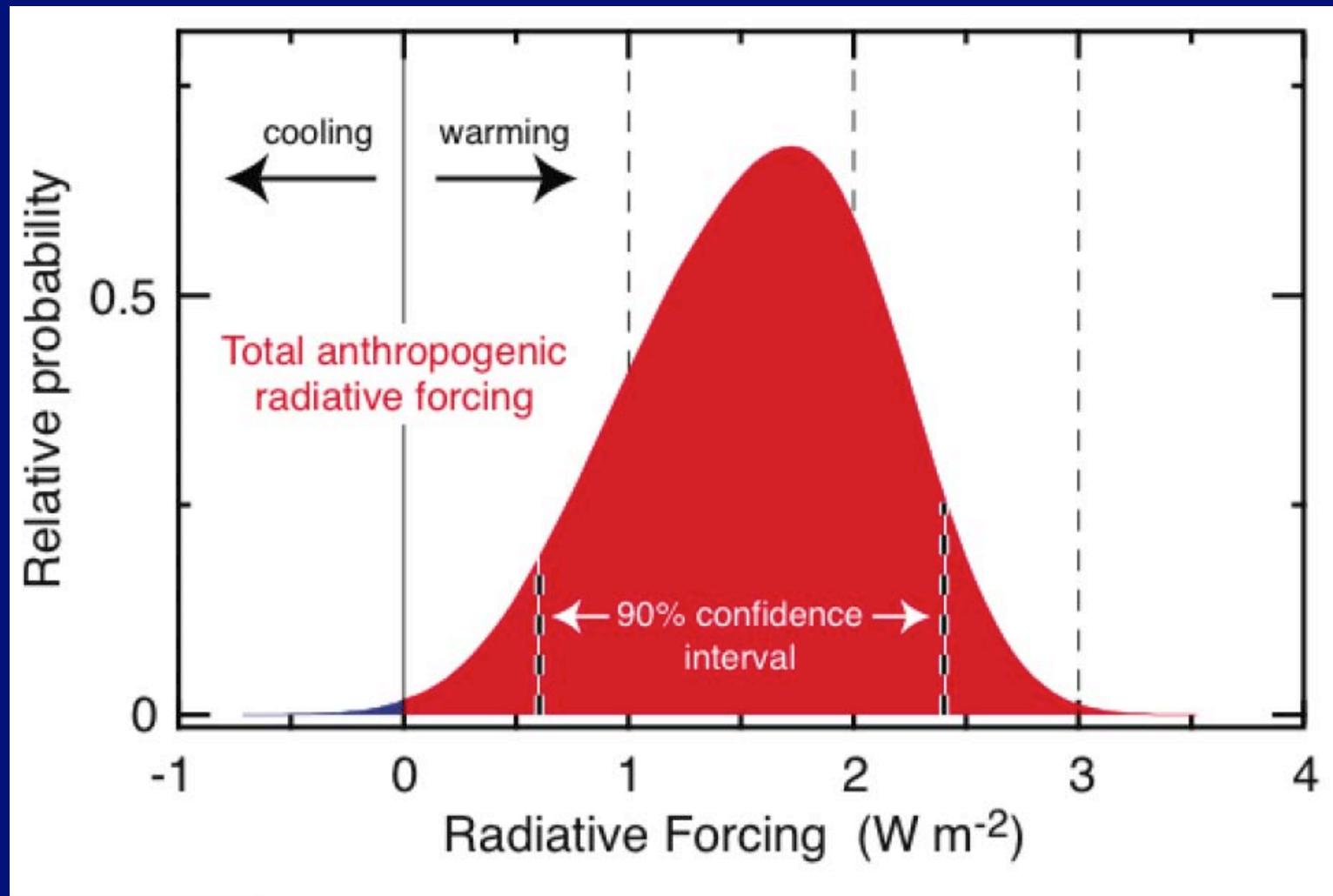


# Radiative forcing: IPCC (2007) vs. IPCC (2001)



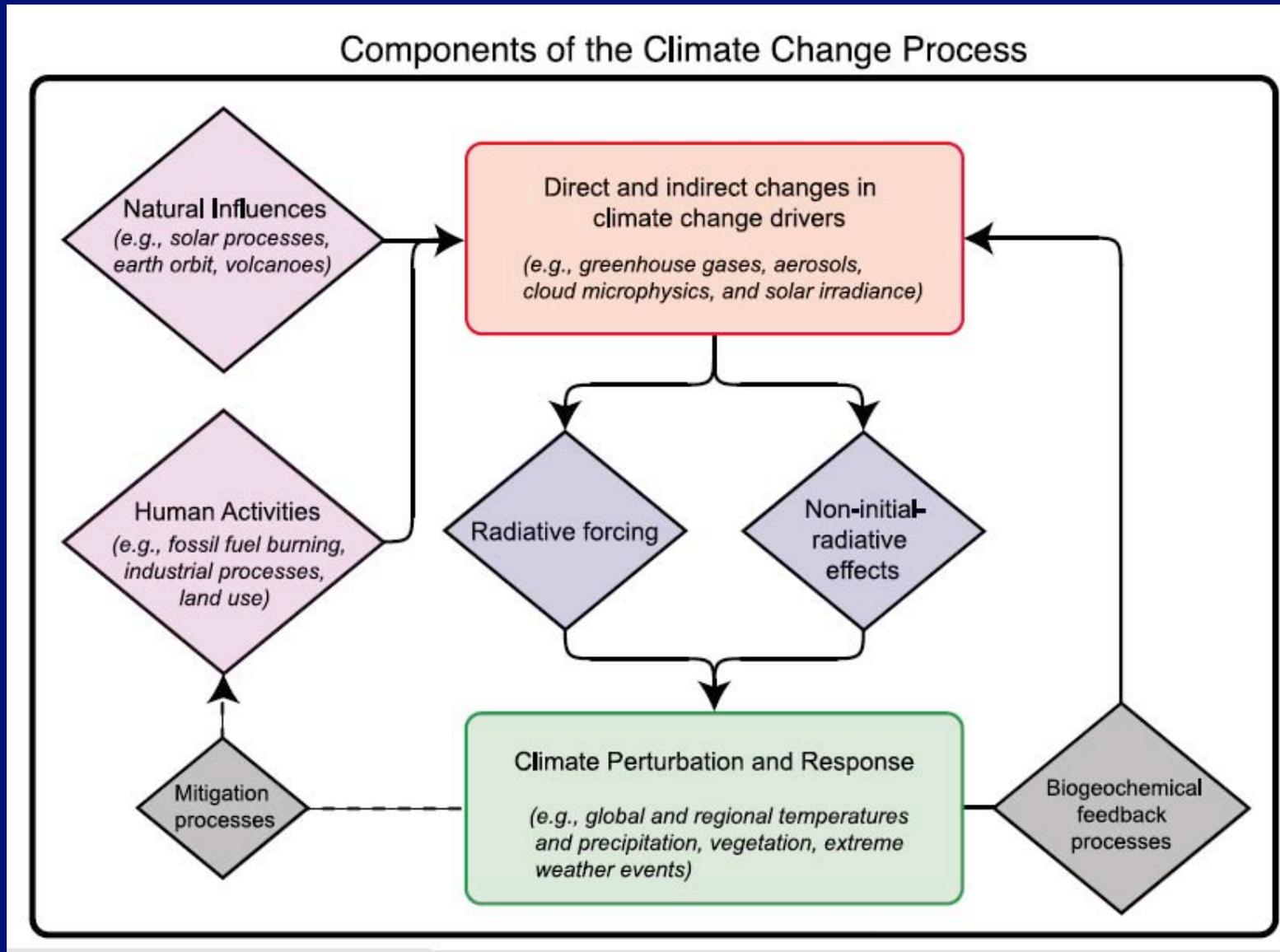
The global mean radiative forcing of the climate system for the year 2000, relative to 1750

## Human & natural drivers of climate change (Fig TS5)

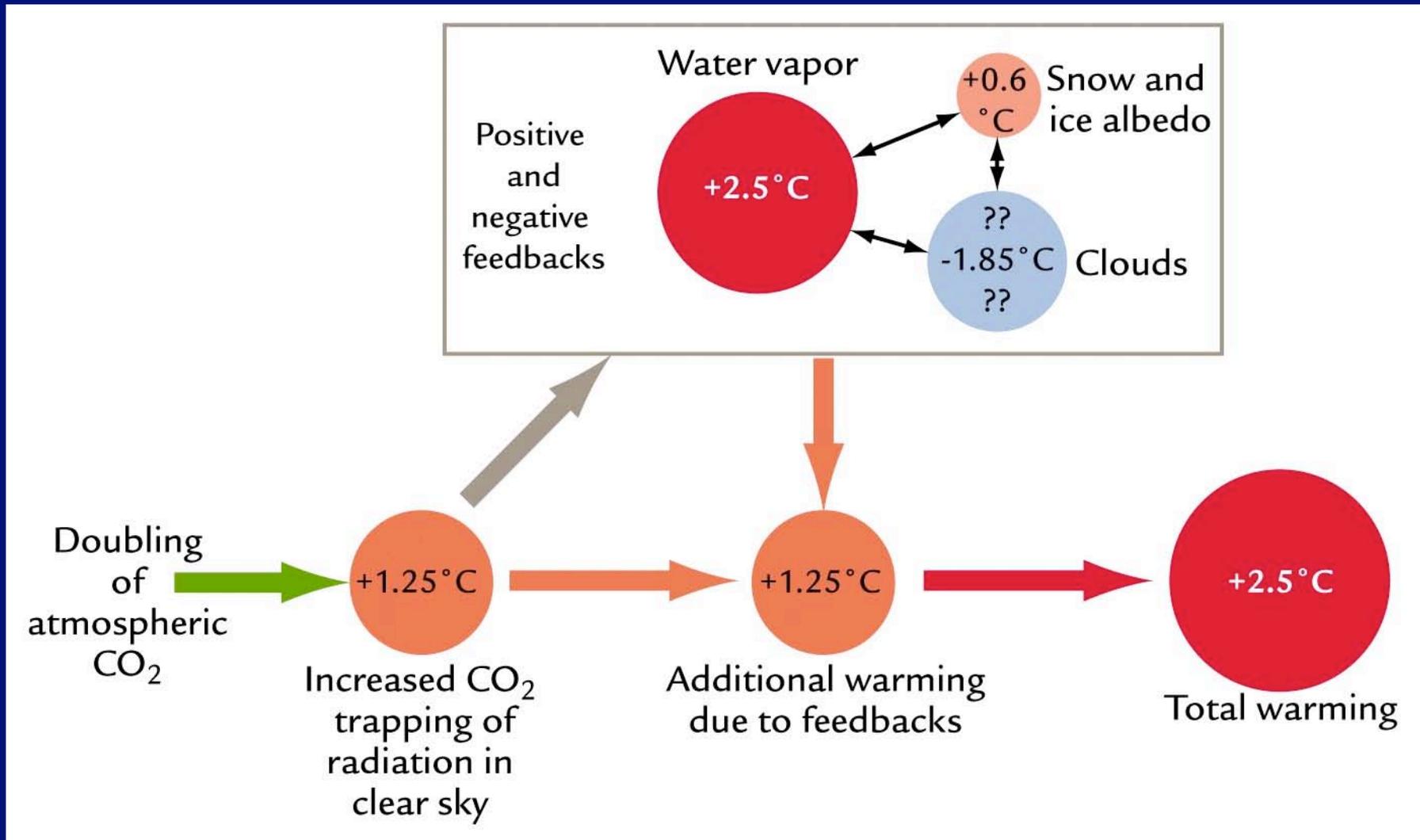


There is *very high confidence* that the globally averaged net effect of human activities since 1750 has been one of warming, with a radiative forcing of +1.6 [+0.6 to +2.4] W m<sup>-2</sup>

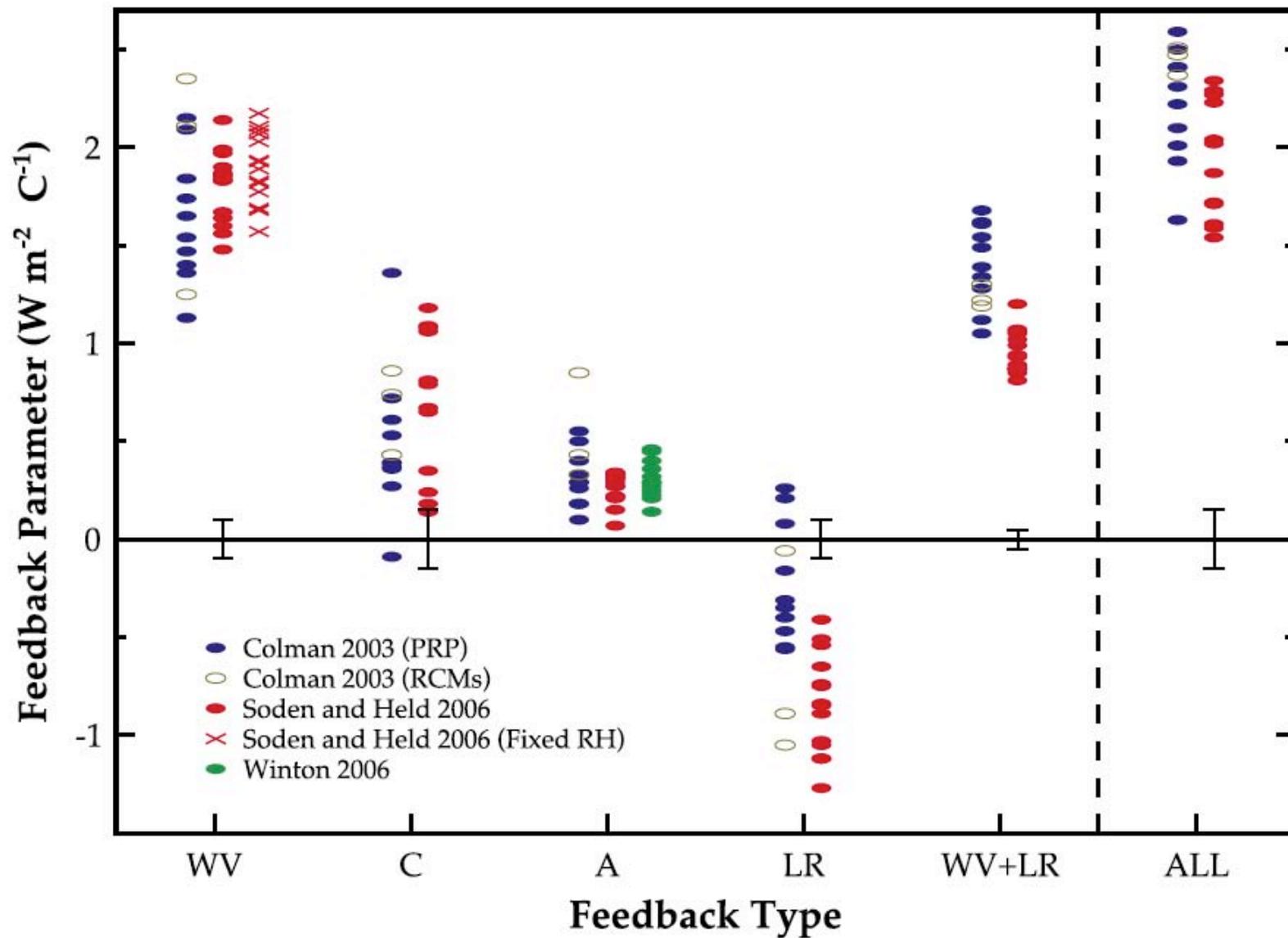
# From forcing to feedback (Fig 2.1)



# Feedbacks for a given forcing (Ruddiman, 2001)



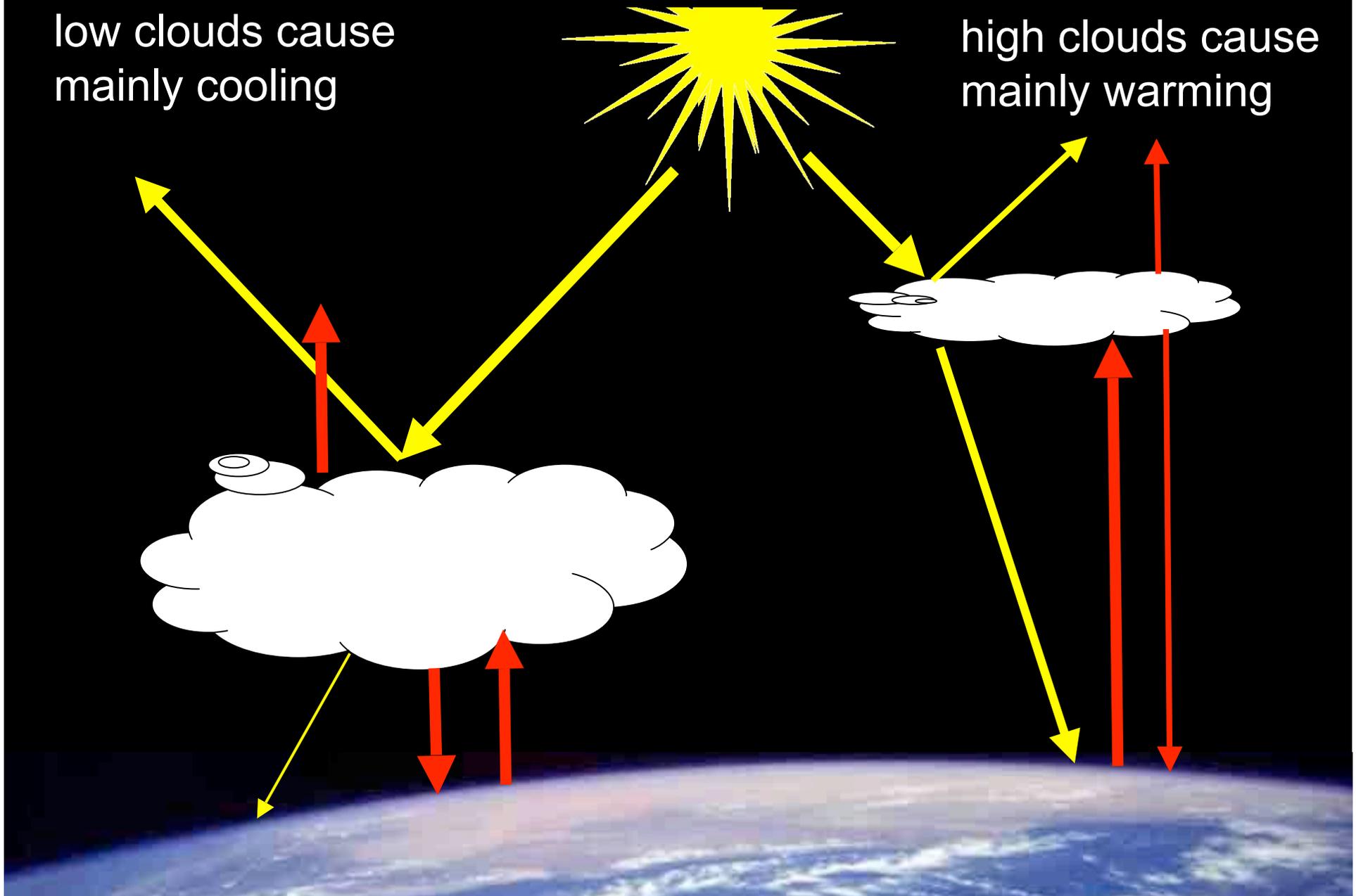
# Physical feedbacks (Fig 8.14)



# Clouds and radiation

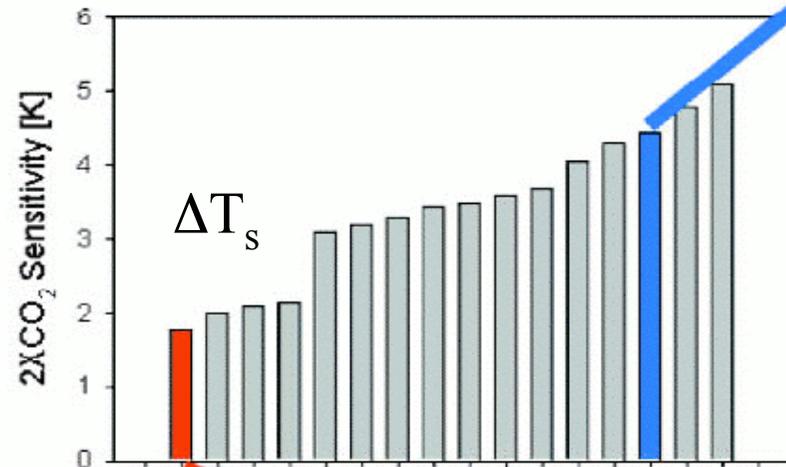
low clouds cause mainly cooling

high clouds cause mainly warming

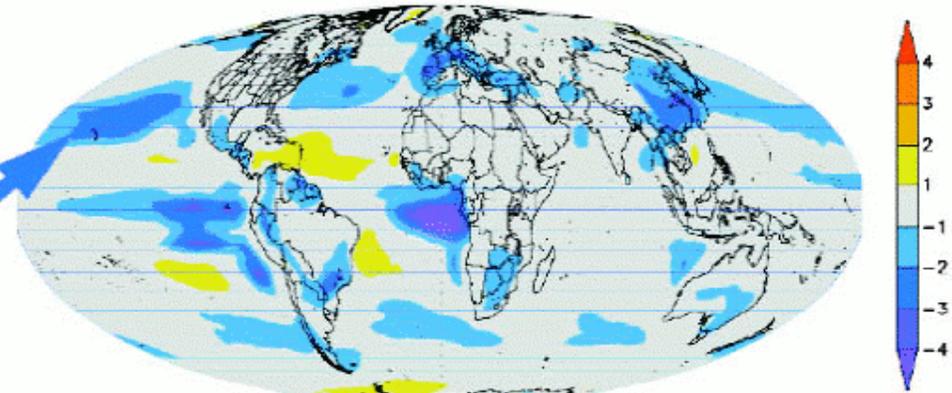


# Cloud feedbacks remain the largest source of uncertainty

Projected global mean surface temperature change

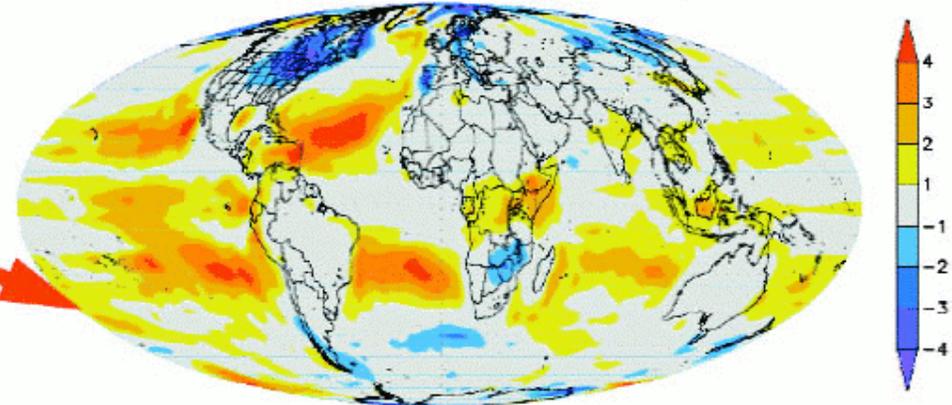


GFDL AM2-ML (2xCO<sub>2</sub> - CTRL)



Change in low cloud amount (%/K)

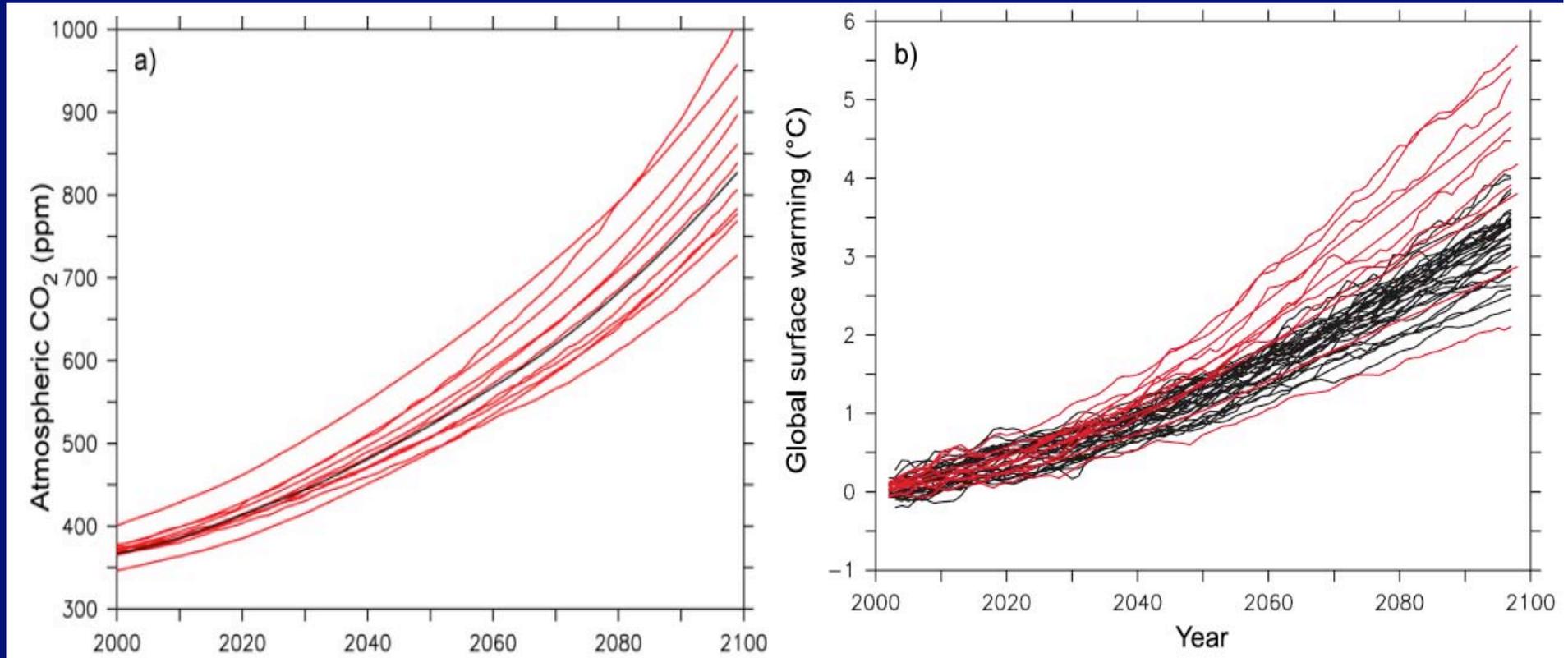
NCAR CAM2 (Year70 @1%CO<sub>2</sub>/yr - CTRL)



Change in low cloud amount (%/K)

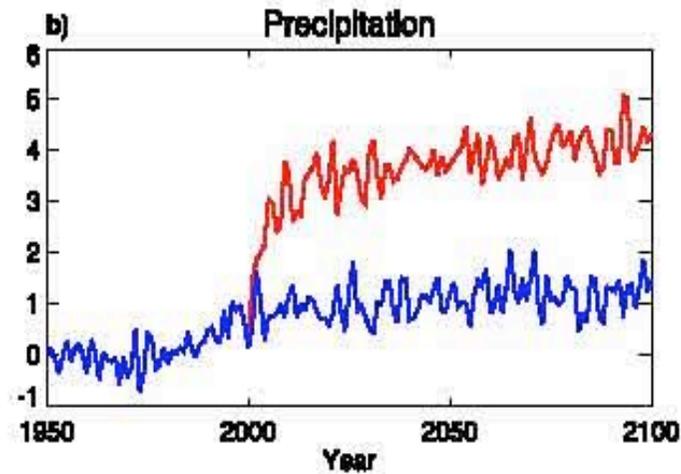
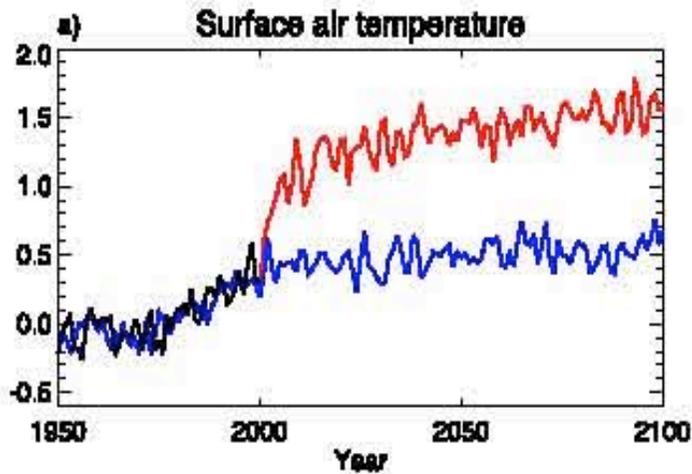
Response of different models to an 1 % yr<sup>-1</sup> increase of CO<sub>2</sub> (Stephens, JC, 2005,)

## Carbon cycle feedback (Fig. 10.20)



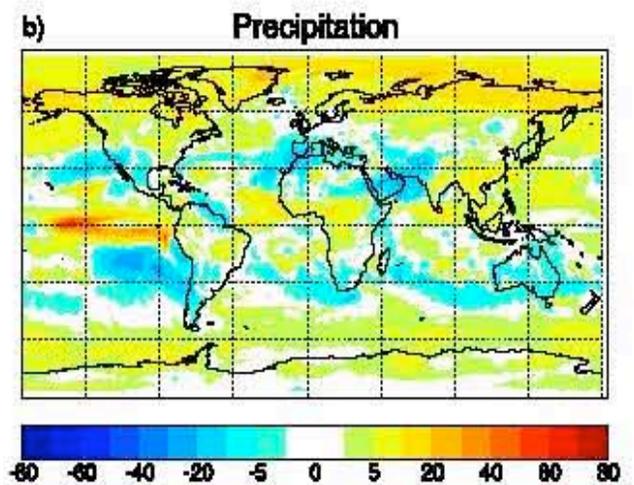
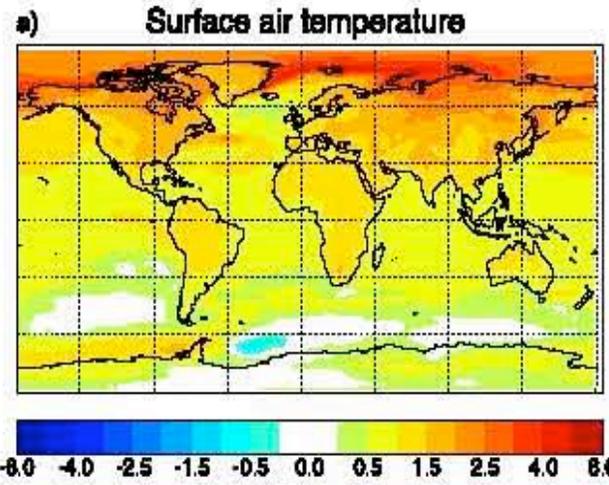
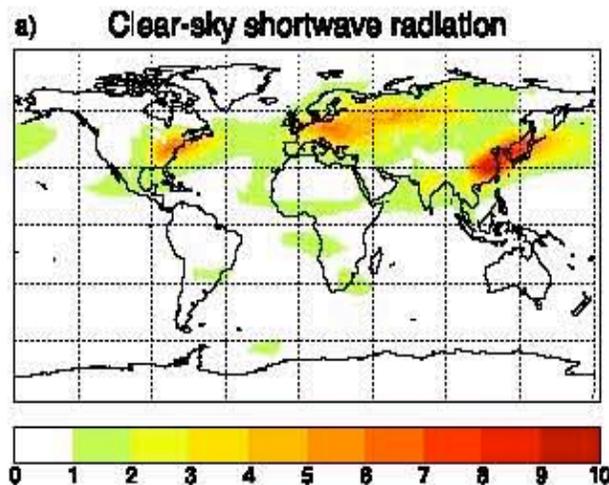
Warming tends to reduce land and ocean uptake of atmospheric CO<sub>2</sub>, increasing the fraction of anthropogenic emissions that remains in the atmosphere (causing a warming of more than 1°C for the A2 scenario).

# Possible effects of a world without aerosols (Fig 7.24)



blue: constant  $\text{CO}_2$  and  $\text{SO}_2$  concentrations

red: only  $\text{CO}_2$  after 2000



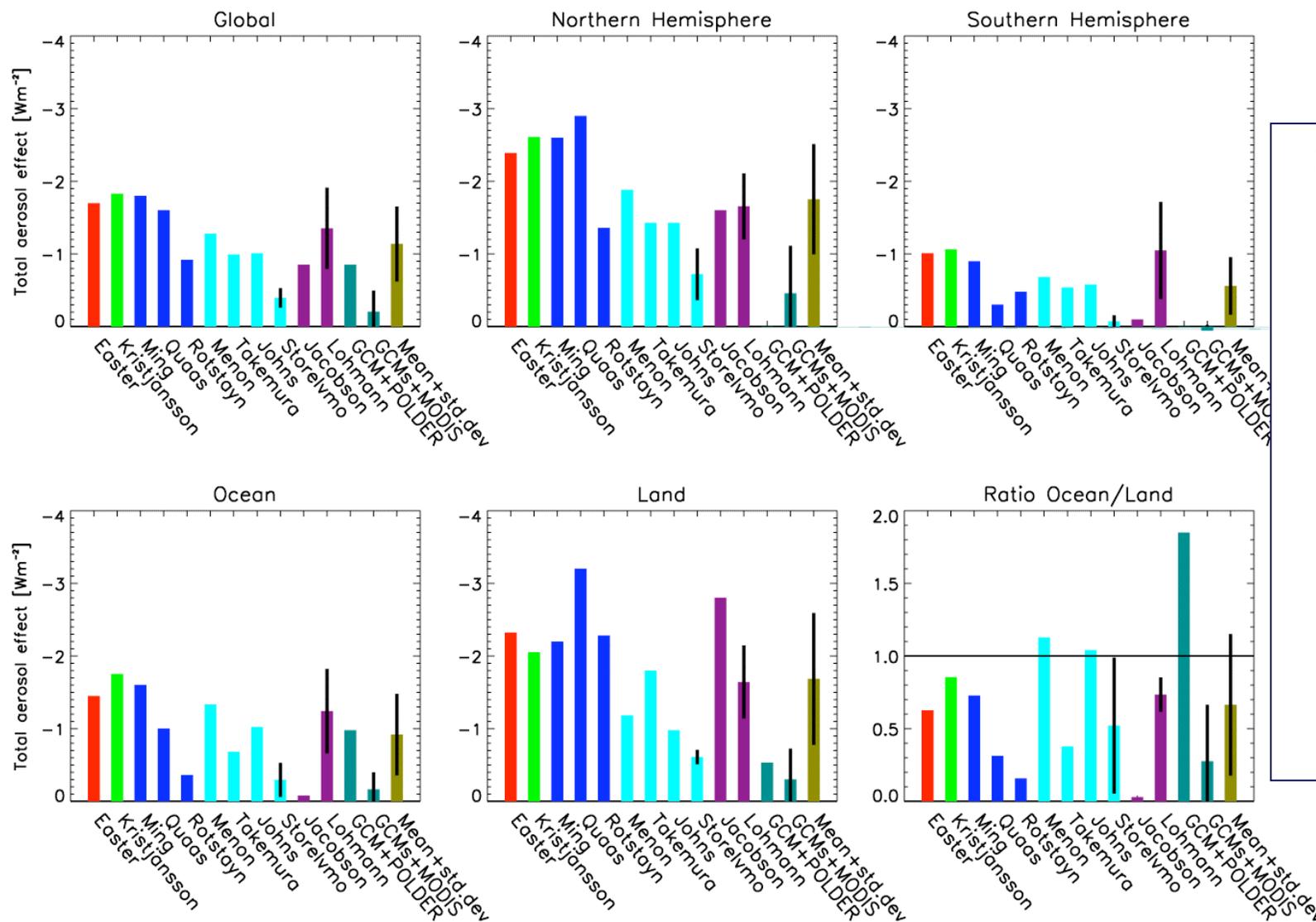
# Summary

- There is very high confidence that the globally averaged net effect of human activities since 1750 has been one of warming, with a radiative forcing of +1.6 [+0.6 to +2.4] W m<sup>-2</sup>
- The combined radiative forcing due to increases in CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O is +2.30 [+2.07 to +2.53] W m<sup>-2</sup>, and its rate of increase during the industrial era is very likely to have been unprecedented in more than 10,000 years
- Anthropogenic aerosols produce a cooling effect, with a total direct radiative forcing of -0.5 [-0.9 to -0.1] W m<sup>-2</sup> and an indirect cloud albedo forcing of -0.7 [-1.8 to -0.3] W m<sup>-2</sup>
- Water vapour changes represent the largest feedback affecting climate sensitivity. Cloud feedbacks remain the largest source of uncertainty.
- Warming tends to reduce land and ocean uptake of atmospheric CO<sub>2</sub>, increasing the fraction of anthropogenic emissions that remains in the atmosphere (causing a warming of more than 1°C for the A2 scenario)

**Thank you very much for your attention!**

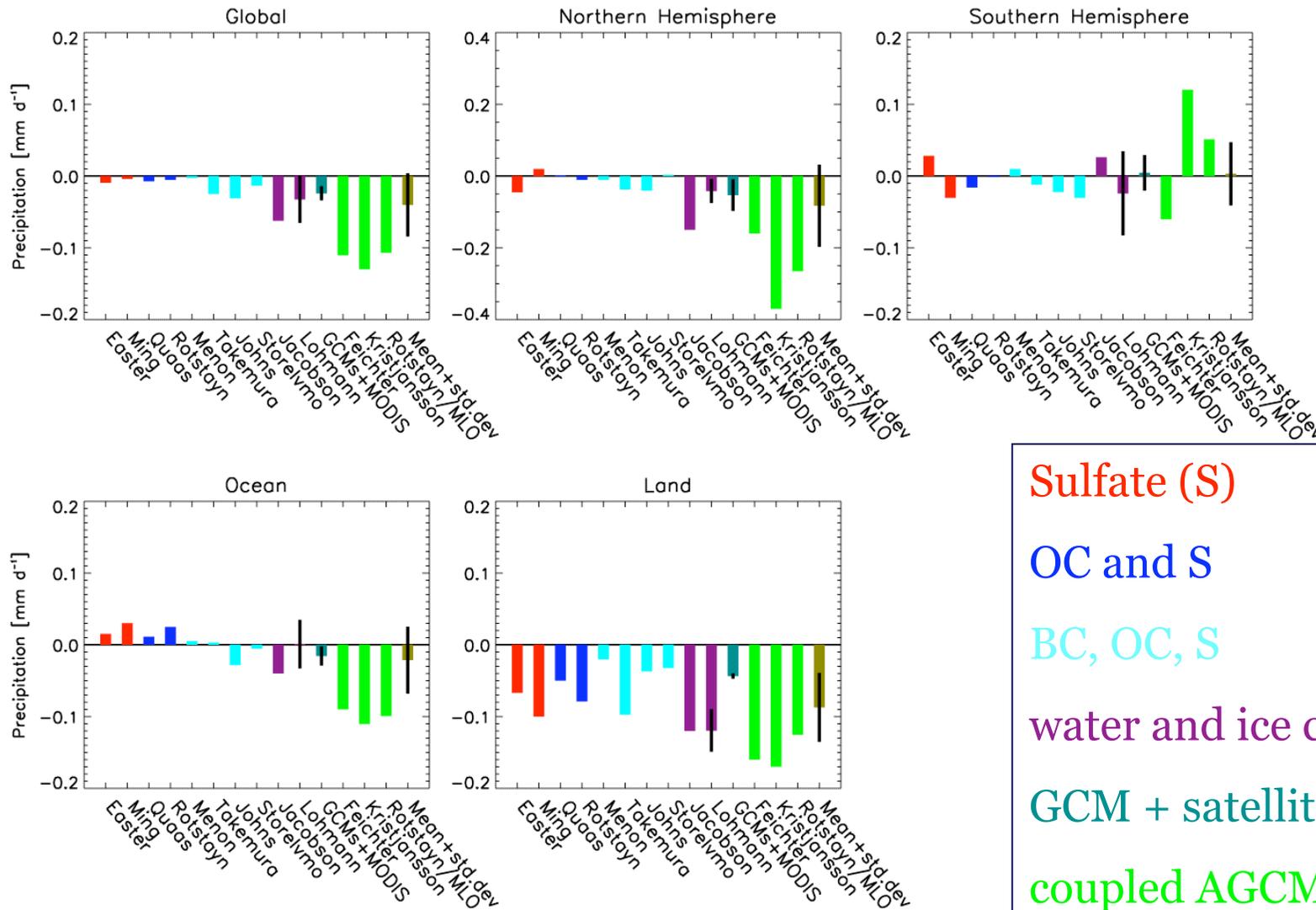


# Total anthropogenic aerosol effect (Figure 7-21)



Sulfate (S)  
 BC and S  
 OC and S  
 BC, OC, S  
 water and ice clouds  
 GCM + satellites  
 Mean

# Impact of anthropogenic aerosols on precipitation (Figure 7-22)



Sulfate (S)

OC and S

BC, OC, S

water and ice clouds

GCM + satellites

coupled AGCM+MLO runs

Mean