



Los acuerdos sobre
cambio climático entre
París y Marrakech:
ratificar e implantar

**La dimensión
ambiental:
las evidencias
físicas en los
informes del IPCC**

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Climate Change 2013: The Physical Science Basis

Working Group I contribution to the IPCC Fifth Assessment Report

El 5º informe del IPCC Cambio climático 2013: los fundamentos científicos

259 autores de 39 países

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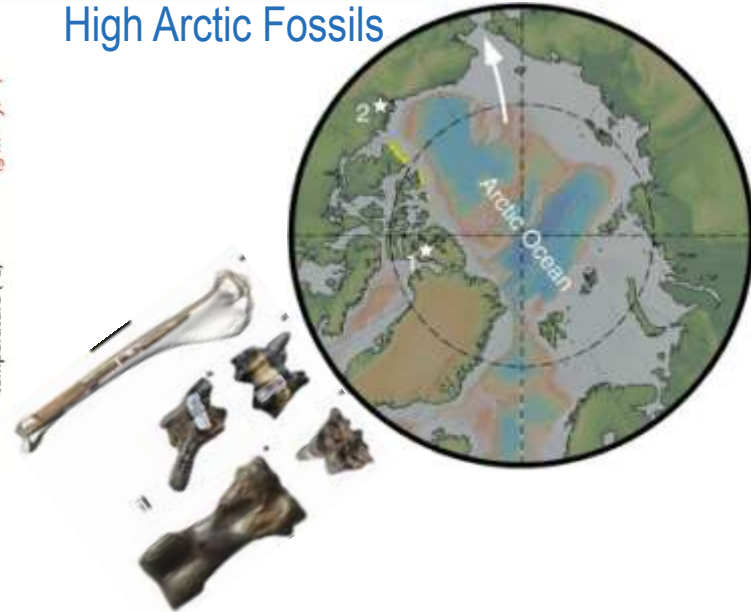
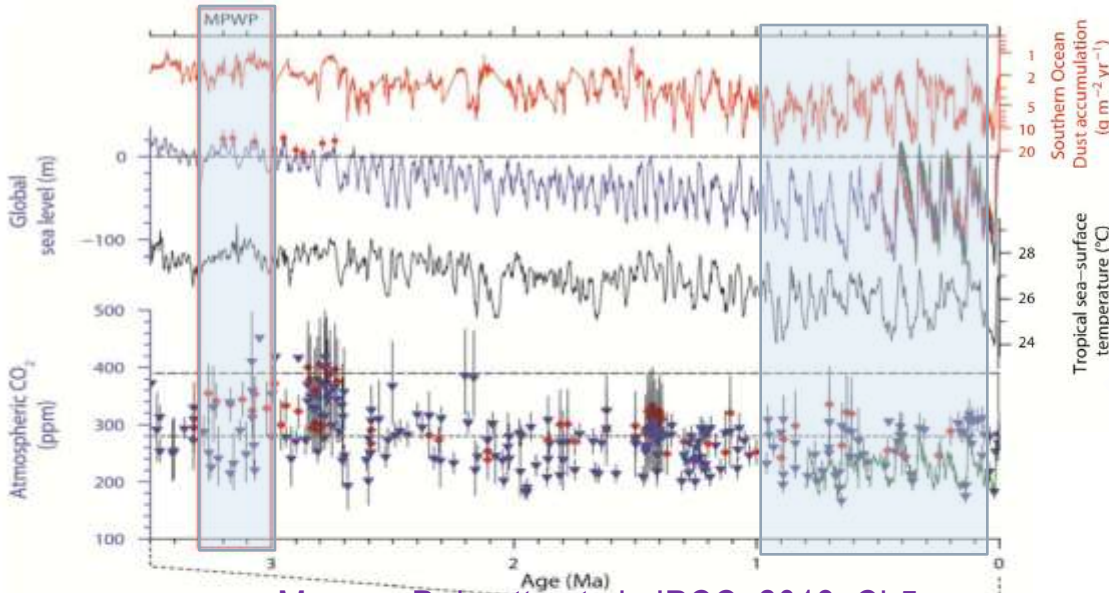
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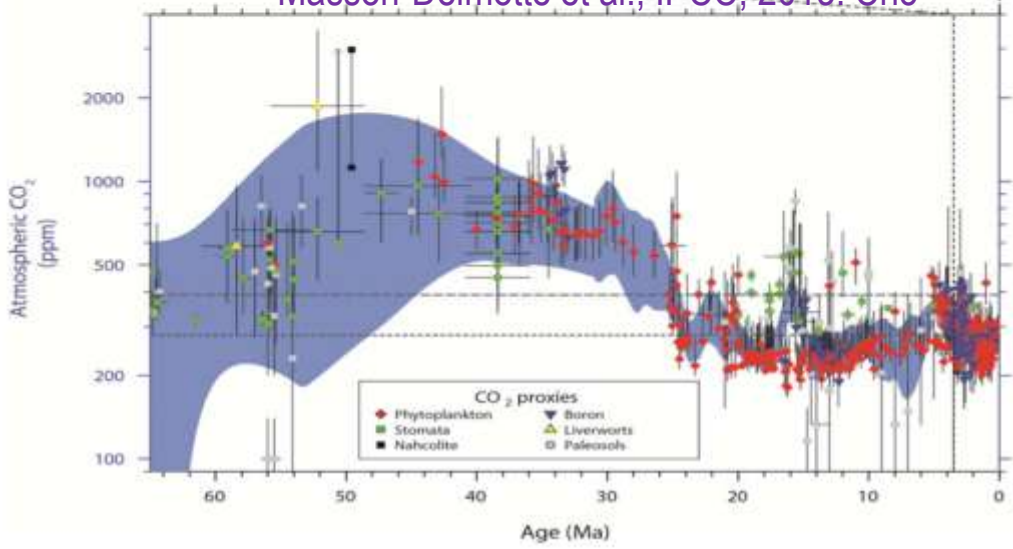


Prelude: Mid-Pliocene Warm Period Maximum (~ 3.6 Ma)

High Arctic Fossils

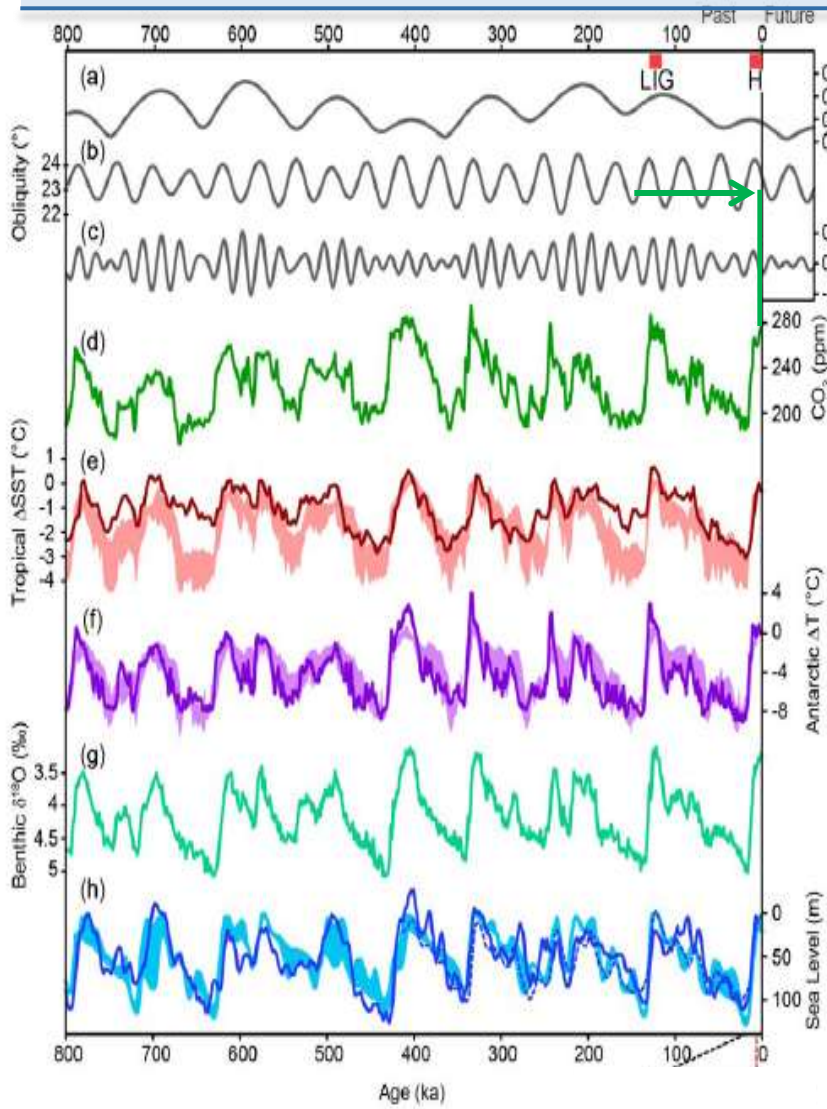


-Masson-Delmotte et al., IPCC, 2013: Ch5-



-Rybczynski et al. Nat. Commun, 4, 1550, 2013-

Prelude: Last Glacial Maximum (~ 20 kya)

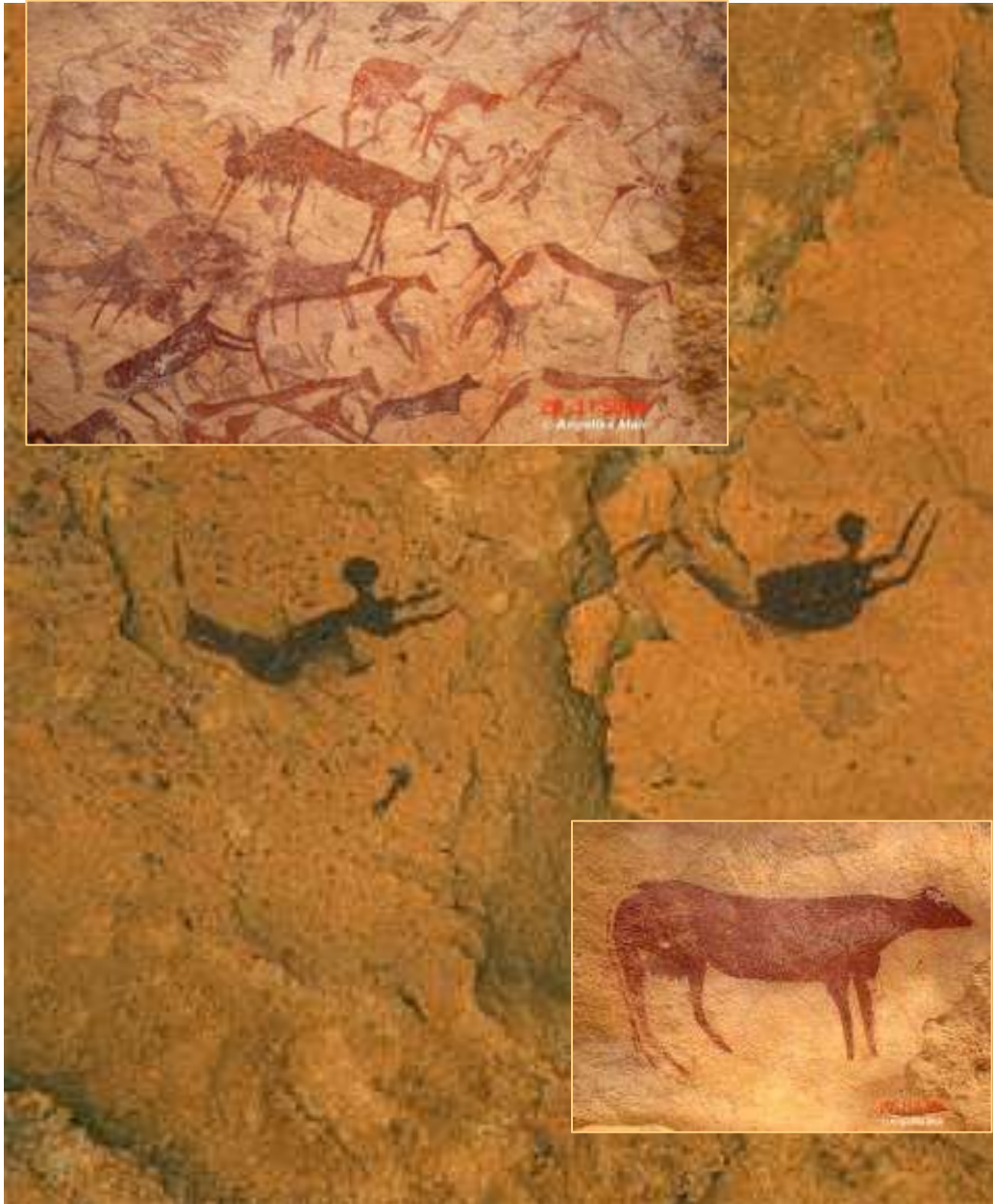


(IPCC 2013, Fig. 5.3)

Cosquer Cave
Calanque de la Triperie Marseille
Dated: 27000 yrs BP
Now :36 m bsl



Prelude: The Holocene (~ 11 kya)



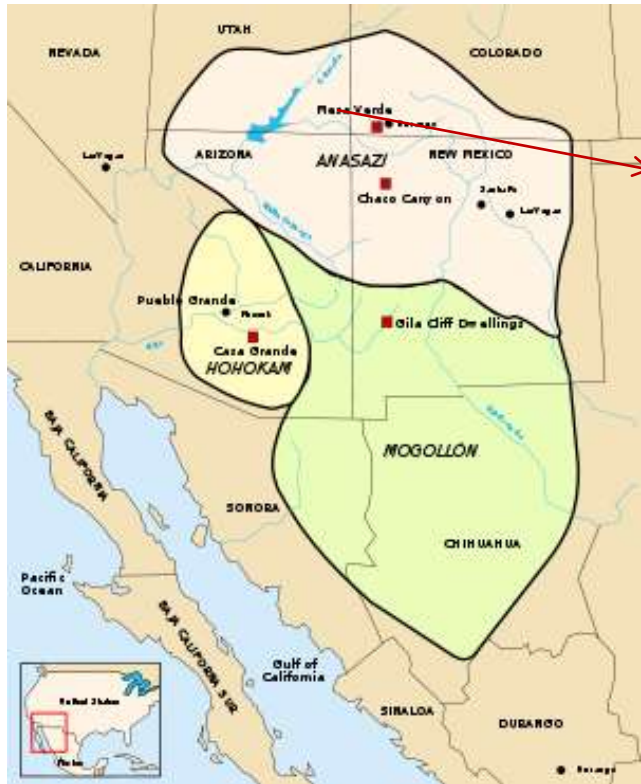
**Gilf Kebir,
La Caverna de los nadadores
1933 L. Almásy.
Sahara Oriental-10⁴ a**



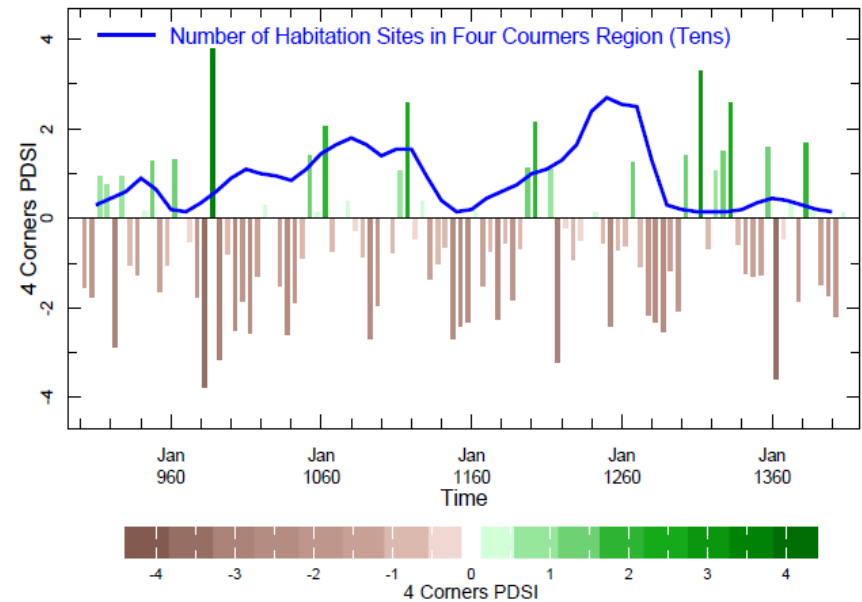
-Claussen et al., Geophys. Res. Lett.
1999-

Prelude: Last Millennium

Four corners

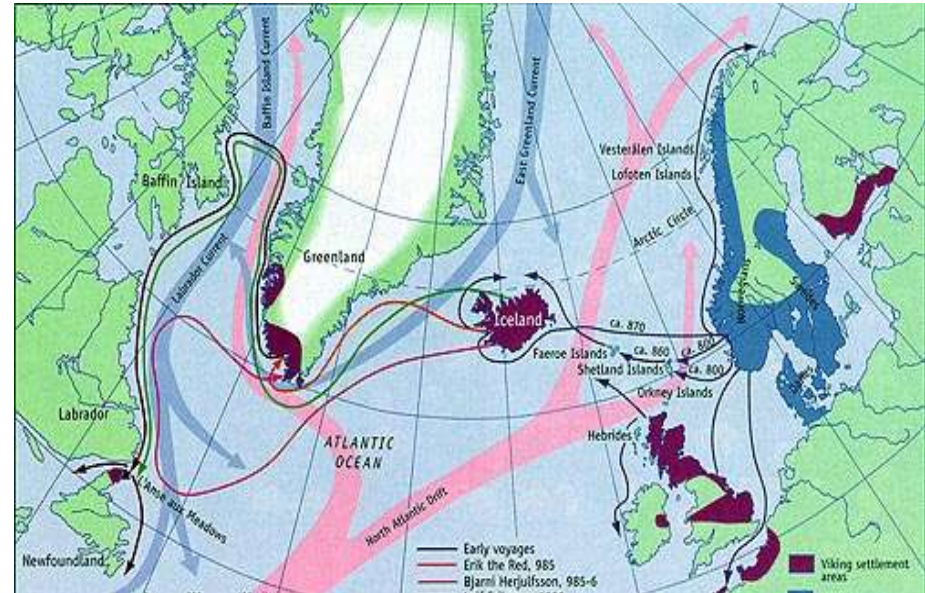


Number of Habitation Sites in Four Corners Region (line) and PDSI (bars)



- Benson et al. *Quat. Sci. Rev.*, 26, 336-350, 2007-
- Herweijer et al., *J. Climate*, 20, 1353-1376, 2007-

Prelude: Last Millennium



Ivar Bardsson (Norwegian priest in Greenland 1341-1364):
"From Snefelsness in Iceland, to Greenland, the shortest way: two days and three nights ... the sea there are reefs called Gunbiernershier. That was the old route, but now the ice is come from the north, so close to the reefs that none can sail by the old route without risking his life."
-Le Roy Ladurie, Doubleday, 1971-

Prelude: Last Millennium

Hendrick Avercamp 1585-1634
Frozen river with skaters ~1620s



Prelude: Radiative balance & Earth's equilibrium temperature



Jean Baptiste Fourier (1827):
Greenhouse effect

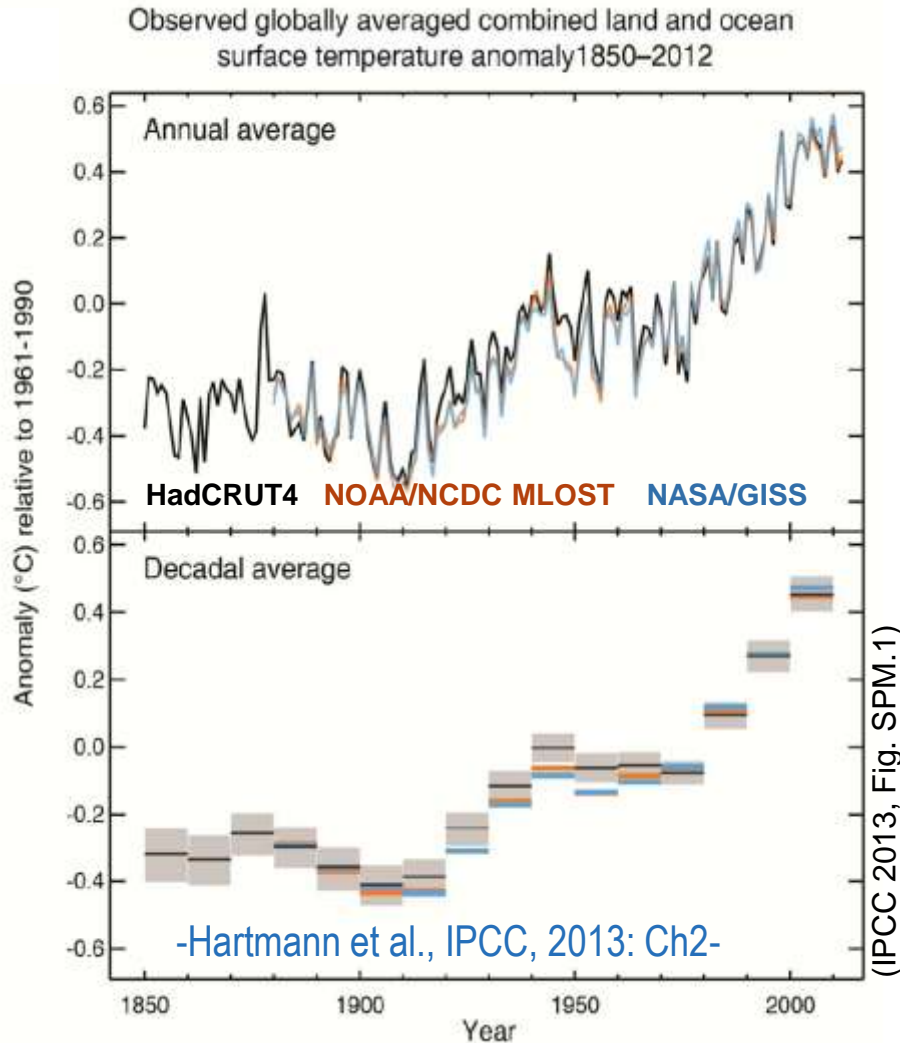


Svante Arrhenius (1896):
Calculates $\Delta T_{\text{global}} (2\times\text{CO}_2) \sim 5\text{-}6 \text{ K}$

-Arrhenius, 1896: *Phil. Mag.*, **41**, 237-276.-

How has the climate system changed ?
Why and what is the influence of human activities climate change?
How is the climate system expected to change in the future?

Observed changes in the climate system: atmosphere



Warming in the climate system is unequivocal
Atmosphere and the ocean have warmed

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

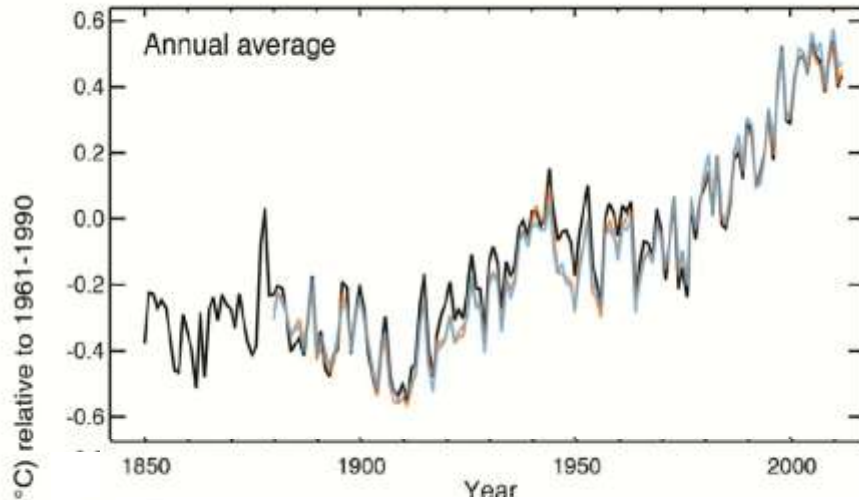
• 1901-2012:
 $\Delta T_{\text{linear}} = 0.89 \text{ }^{\circ}\text{C}$ [0.69-1.08]

• 1951-2012:
 $\Delta T_{\text{linear}} = 0.72 \text{ }^{\circ}\text{C}$ [0.49-0.89]

• Substantial interannual to decadal variability in warming rates

Observed changes in the climate system: atmosphere

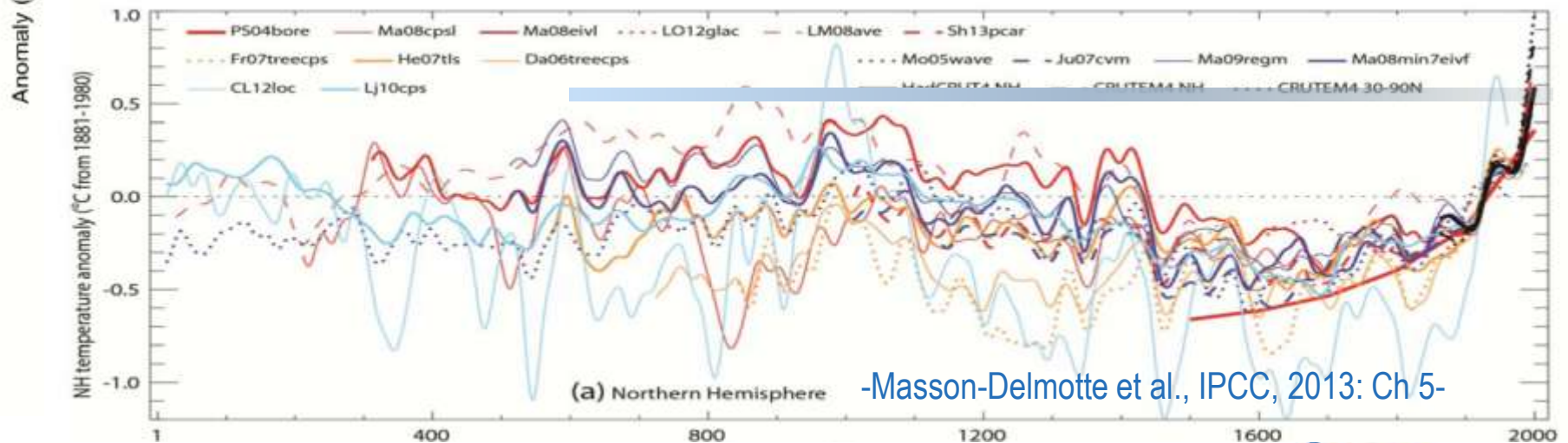
Observed globally averaged combined land and ocean surface temperature anomaly 1850–2012



Warming in the climate system is unequivocal
Atmosphere and the ocean have warmed

1983-2012:

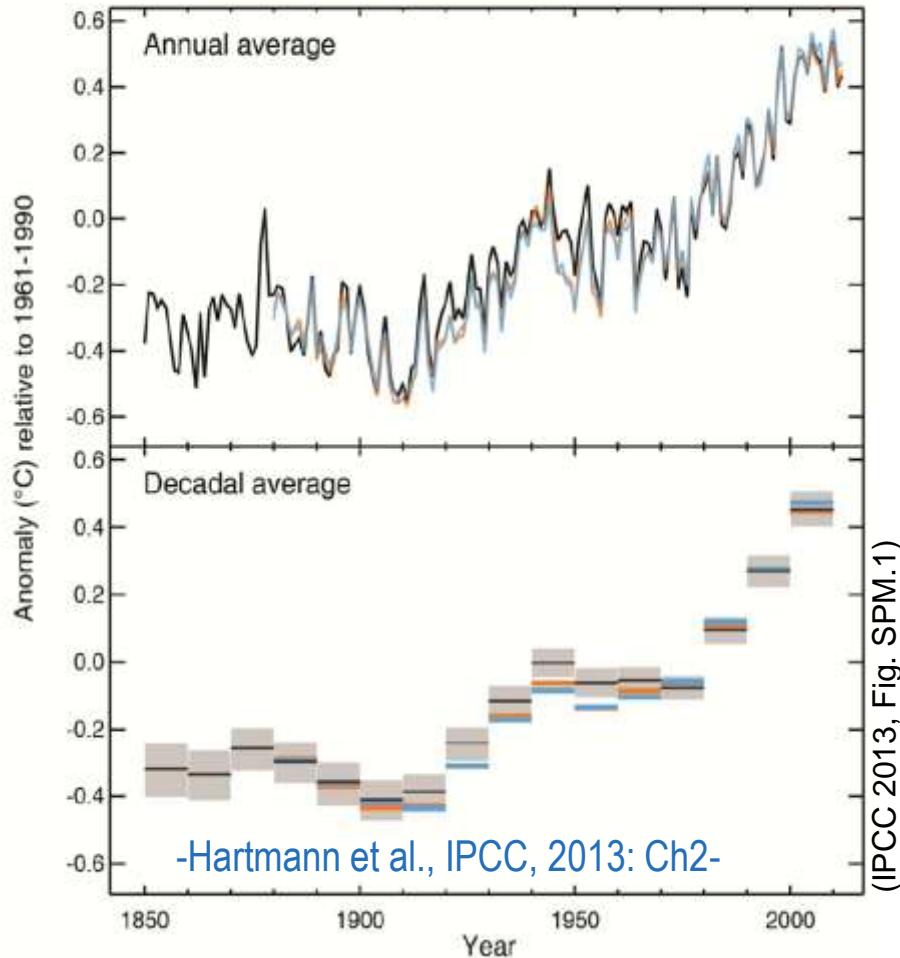
Very likely warmest 30-yr period of the last 800 yrs (high conf.) & likely the warmest of the last 1400 yrs (mid. conf).



-Masson-Delmotte et al., IPCC, 2013: Ch 5-

Observed changes in the climate system: atmosphere

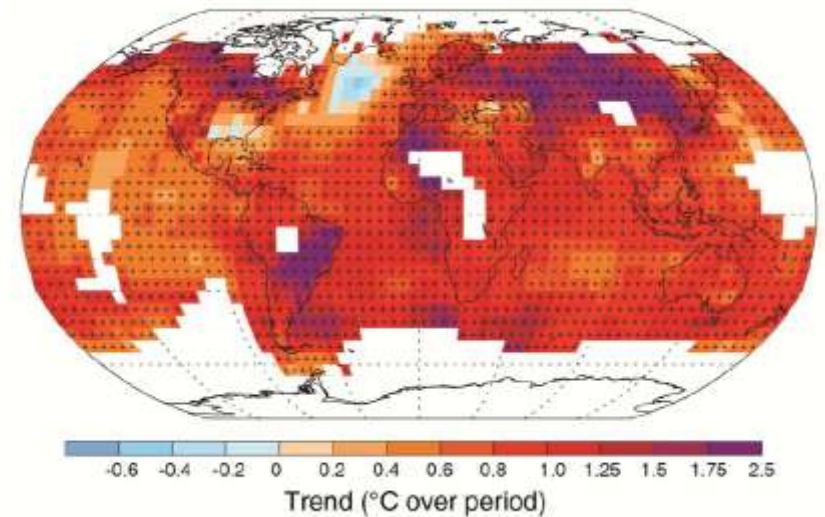
Observed globally averaged combined land and ocean surface temperature anomaly 1850–2012



Warming in the climate system is unequivocal
Atmosphere and the ocean have warmed

- Tmax & Tmin have increased (virtually certain)
- 1901-2012: Almost the entire globe has warmed

Observed change in average surface temperature 1901–2012



Observed changes in the climate system: atmosphere

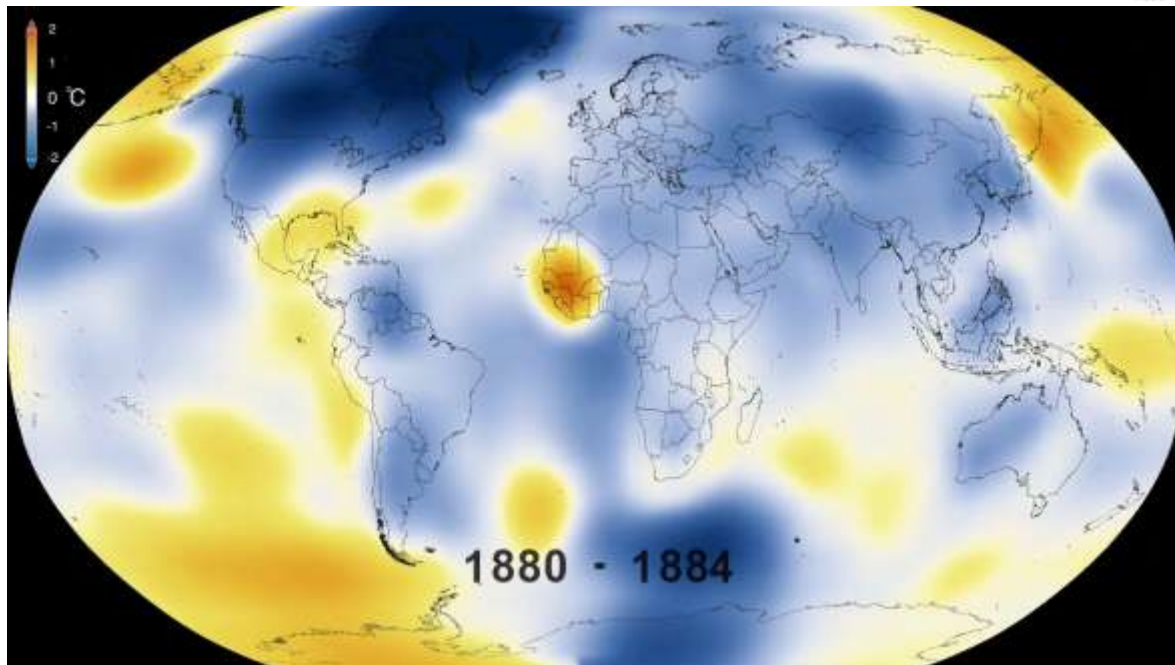
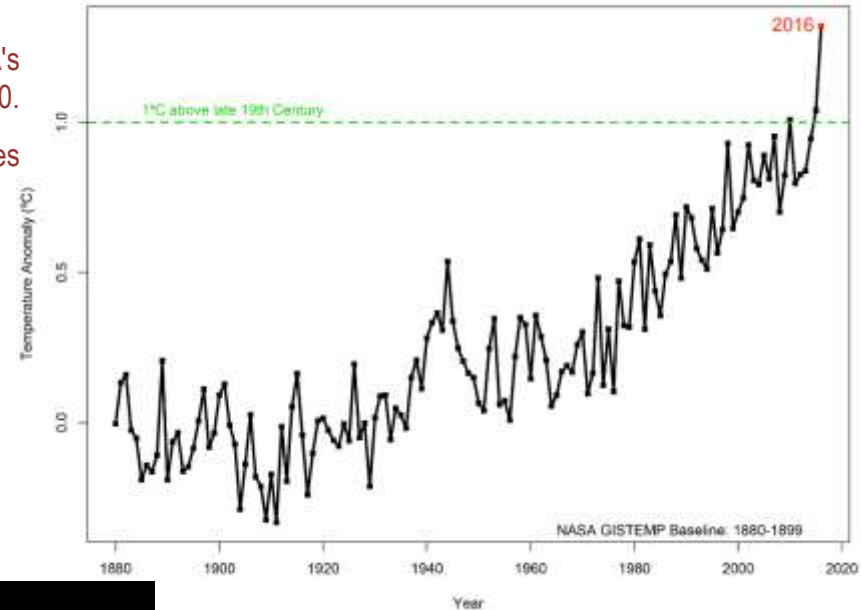
The first six months of 2016 were the warmest six-month period in NASA's modern temperature record, which dates to 1880.

Credits: NASA/Goddard Institute for Space Studies

GISS
GlobalTemperature
1880 to 2015

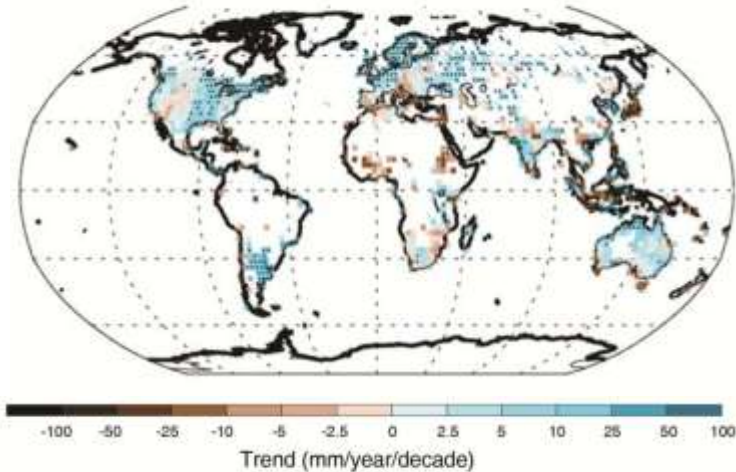
Lori Perkins 20160120

Global Mean Surface Temperature (January-June)

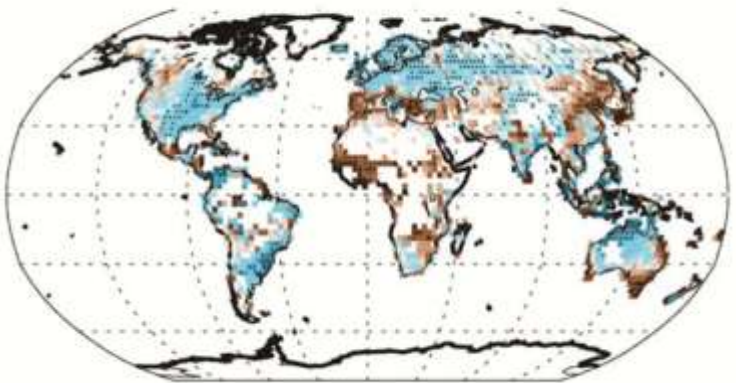


Observed changes in the climate system: atmosphere

Observed change in precipitation over land
1901–2010



1951–2010



-Hartmann et al., IPCC, 2013: Ch2-

Warming in the climate system is unequivocal
Atmosphere and the ocean have warmed

Precipitation has increased since 1901 (med. conf.) and more since 1951 (high conf.) over the mid-latitude land areas of the NH

Circulation features moved poleward since 1970s. Widening of the tropical belt & poleward shift of the storm tracks and jet streams.

Extreme events since 1950:

Very likely increase (decrease) in the number of warm (cold) days and nights.

Likely increase in frequency of heat waves in Europe, Asia and Australia.

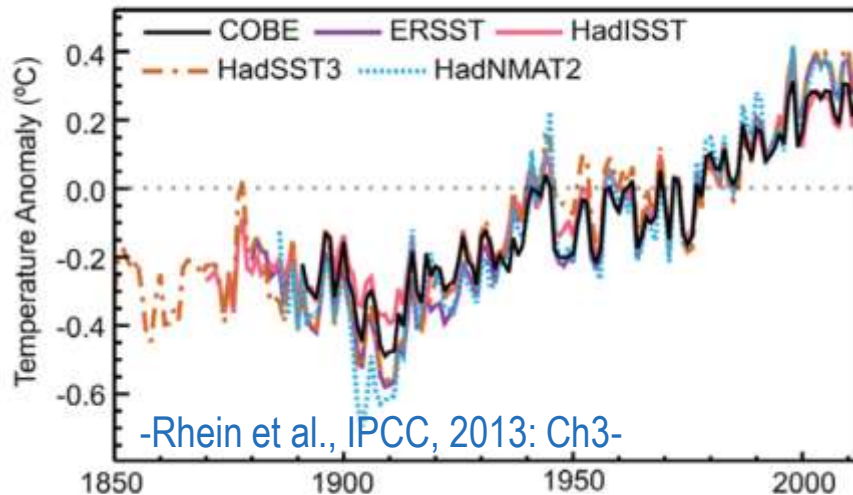
Likely more land regions where number of heavy precipitation events has increased than regions with decrease.

Frequency or intensity of heavy precipitation events has likely increased in N. America and Europe.

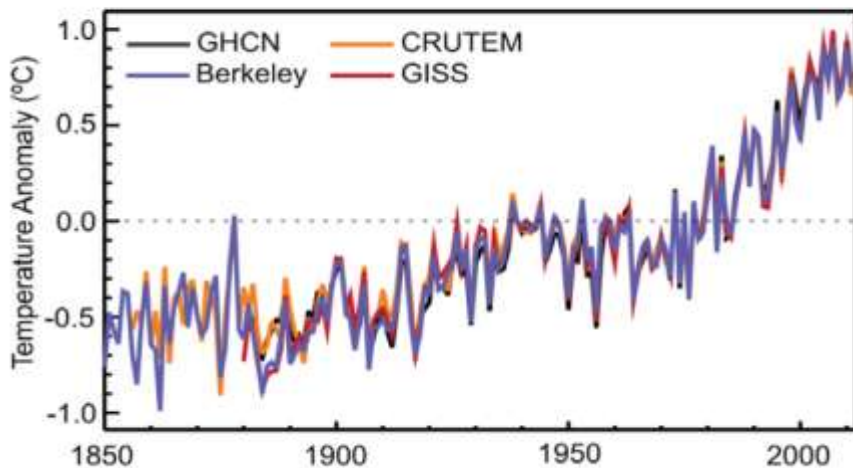
(IPCC 2013, Fig. SPM.2)

Observed changes in the climate system: ocean

Sea Surface Temperature



Land Surface Air Temperature



Warming in the climate system is unequivocal
Atmosphere and the ocean have warmed

Earth has been in radiative imbalance, with more energy from the sun entering than exiting the top of the atmosphere since ~ 1970.

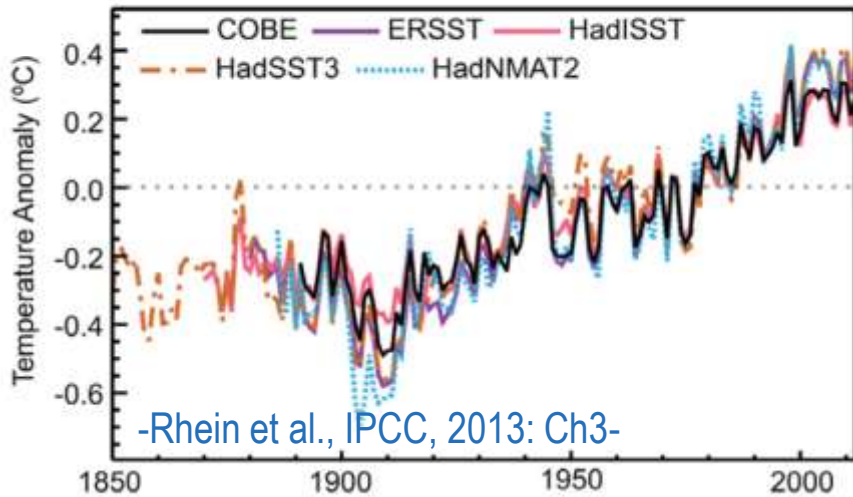
Since AR4 instrumental biases in SSTs reduced;
confidence increased

1971-2010: Ocean warming largest near the surface and upper 75 m with 0.11 [0.09-0.13] °C/decade.

Virtually certain that upper ocean 0-700 m warmed.

Observed changes in the climate system: ocean

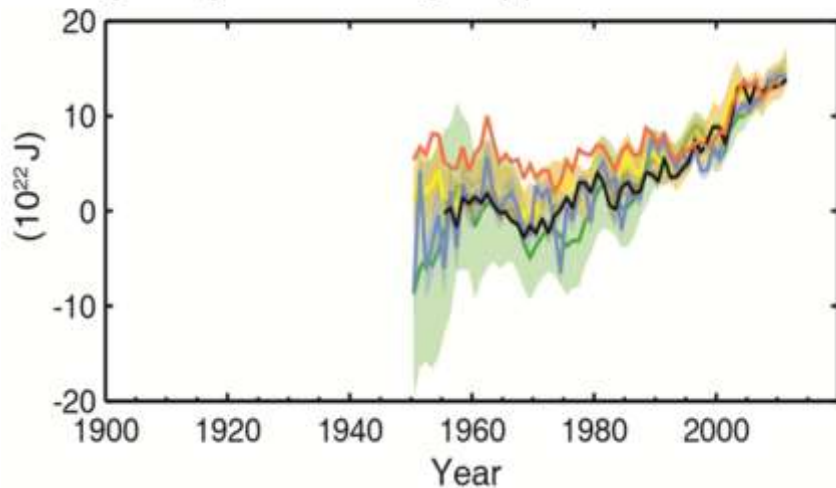
Sea Surface Temperature



Warming in the climate system is unequivocal
Atmosphere and the ocean have warmed
Sea level has risen

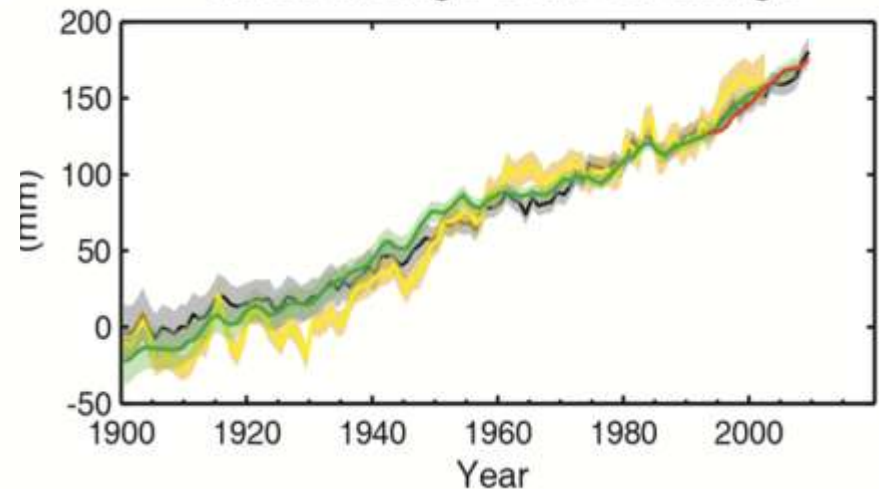
1901-2010: Global mean sea level rose by 0.19 [0.17-0.21] m
Rate of sea level rise larger than mean rate during previous two millennia (high conf.)

Change in global average upper ocean heat content



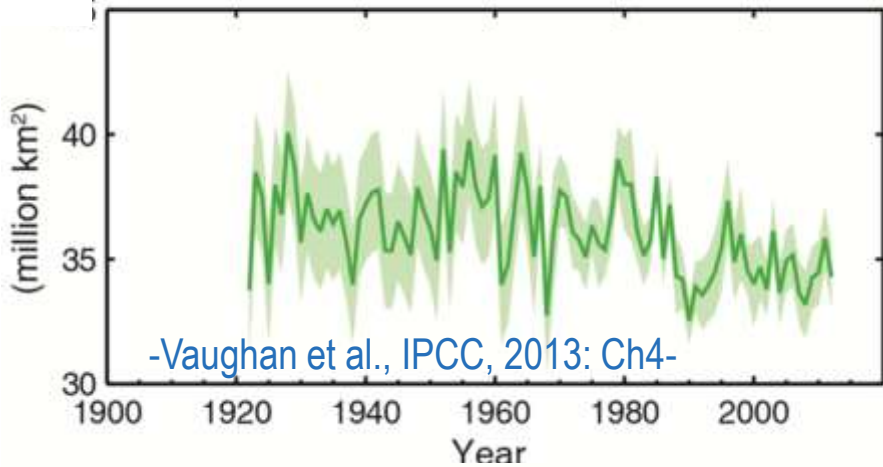
(IPCC 2013, Fig. SPM.3)

Global average sea level change



Observed changes in the climate system: criosphere

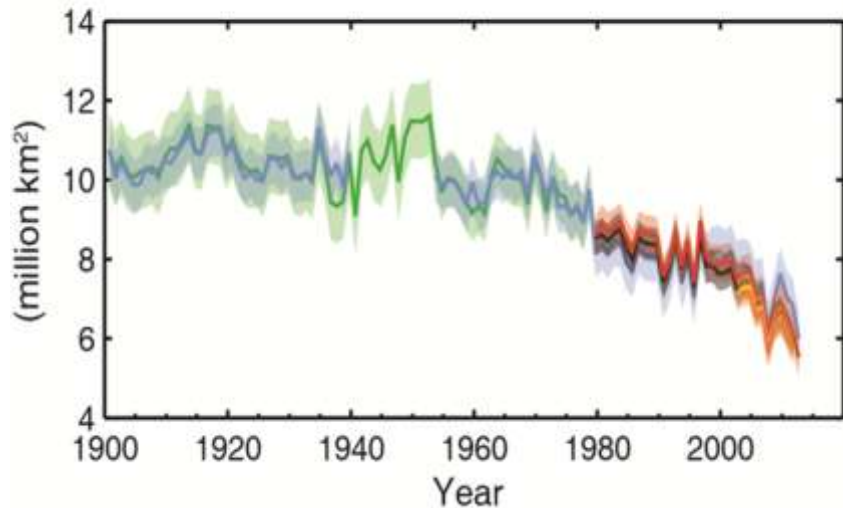
Northern Hemisphere spring snow cover



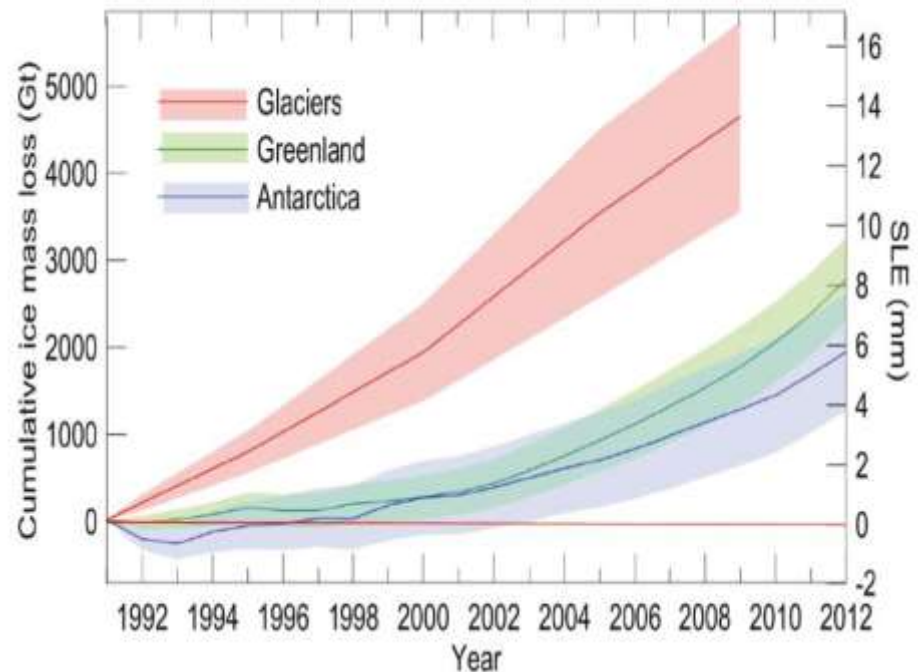
Warming in the climate system is unequivocal
Atmosphere and the ocean have warmed
Sea level has risen
Snow and ice have diminished

1993-2009:
Glaciers have continued to sink
Arctic sea ice & NH spring snow cover decrease

Arctic summer sea ice extent

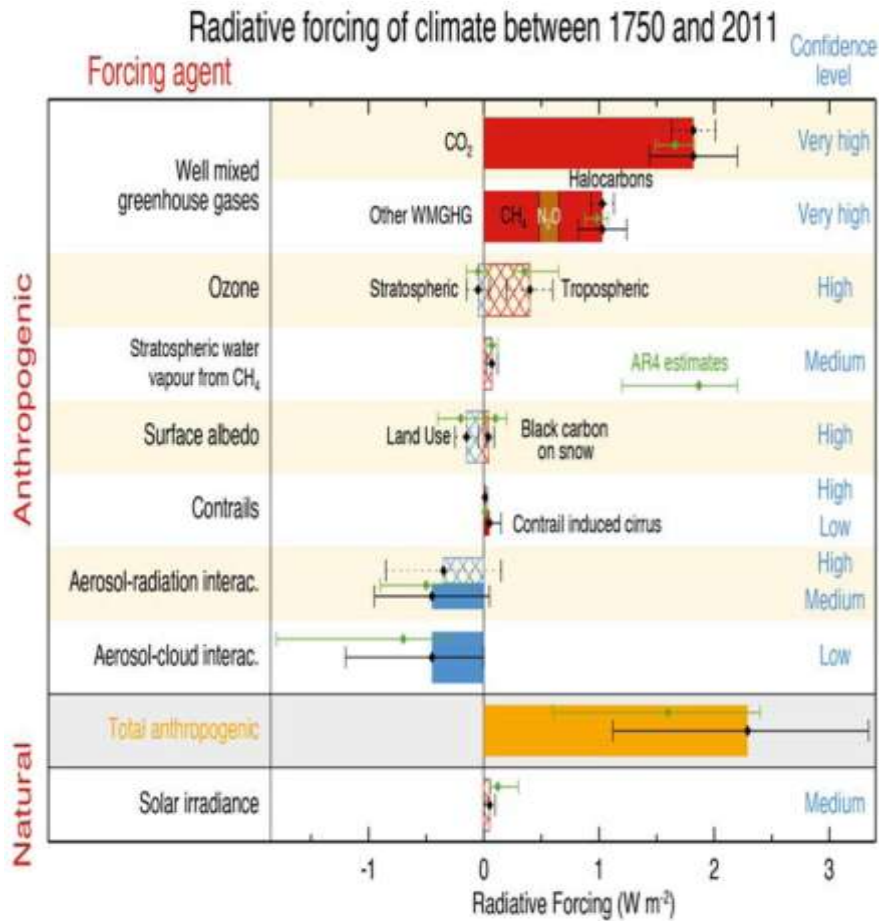


(IPCC 2013, Fig. SPM.3)

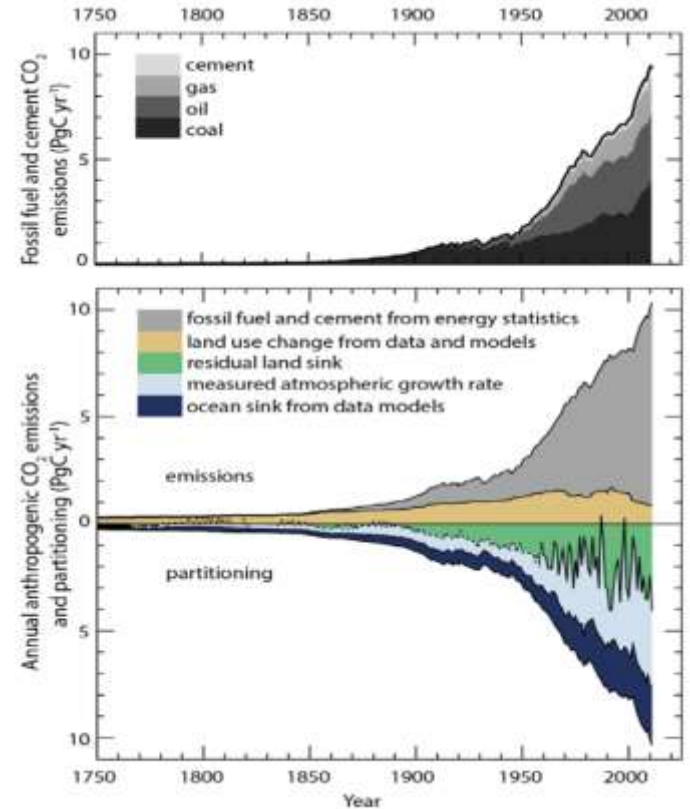


What causes system changes?: drivers of climate change

Total radiative forcing is positive , and has led to an uptake of energy by the climate system
The largest contribution by $\Delta [CO_2]$ since 1750



(IPCC 2013, Fig. TS.6)

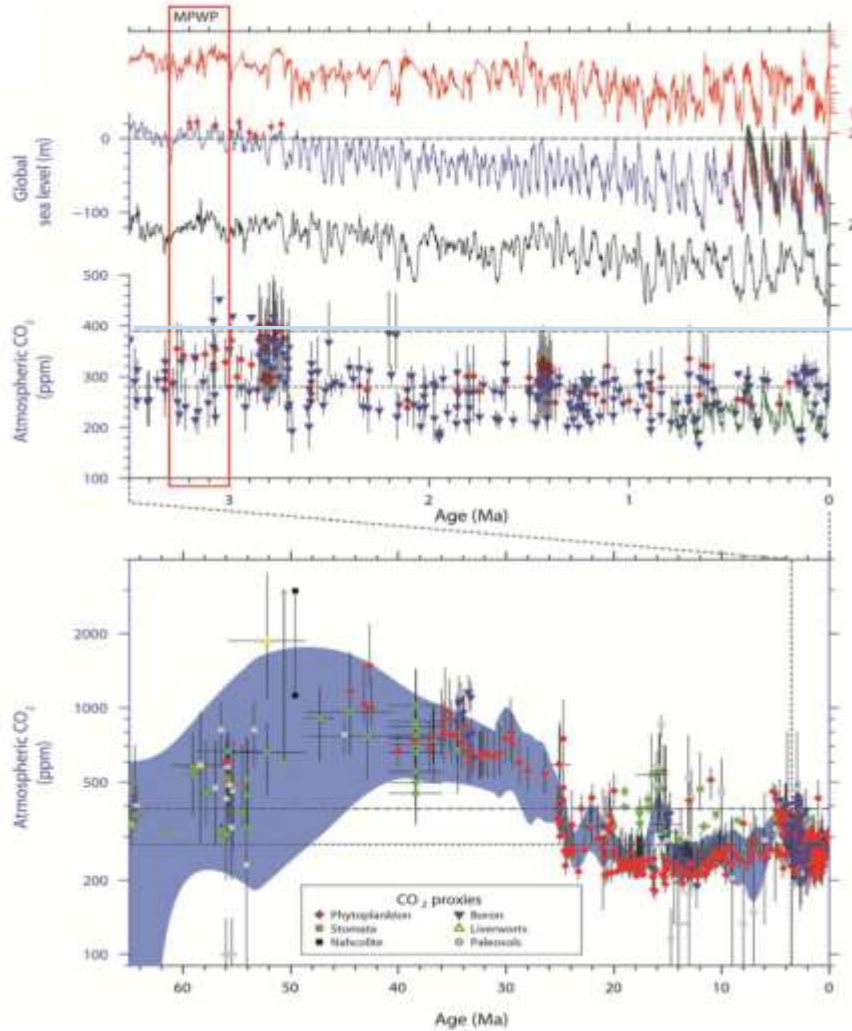


(IPCC 2013, Fig. TS.4)

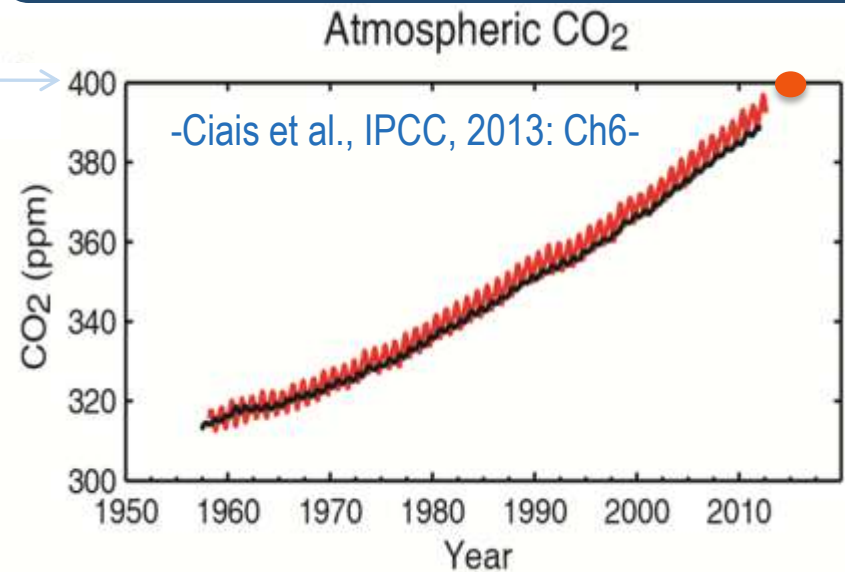
- Boucher et al., IPCC, 2013: Ch7-
- Myhre et al., IPCC, 2013: Ch8-

- Ciais et al., IPCC, 2013: Ch6-

Observed changes in the climate system: carbon cycle



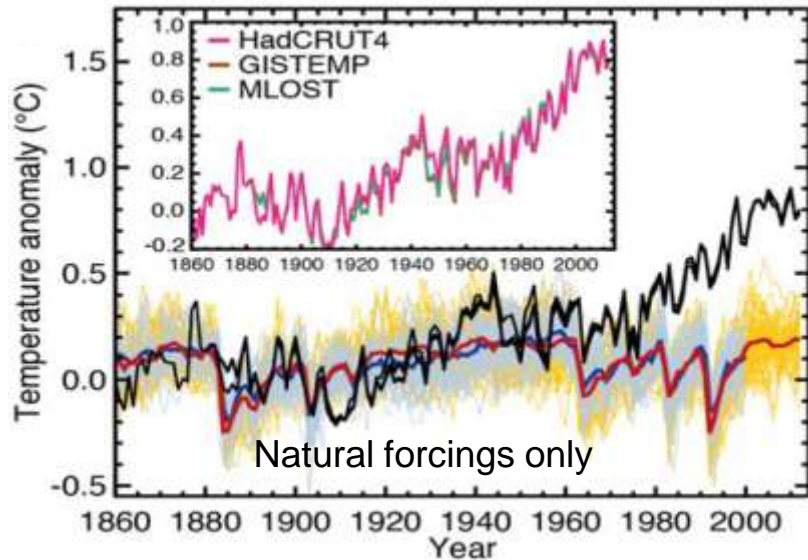
Warming in the climate system is unequivocal
 Atmosphere and the ocean have warmed
 Sea level has risen
 Snow and ice have diminished
 [GHG]s have increased



(IPCC 2013, Fig. SPM.4)

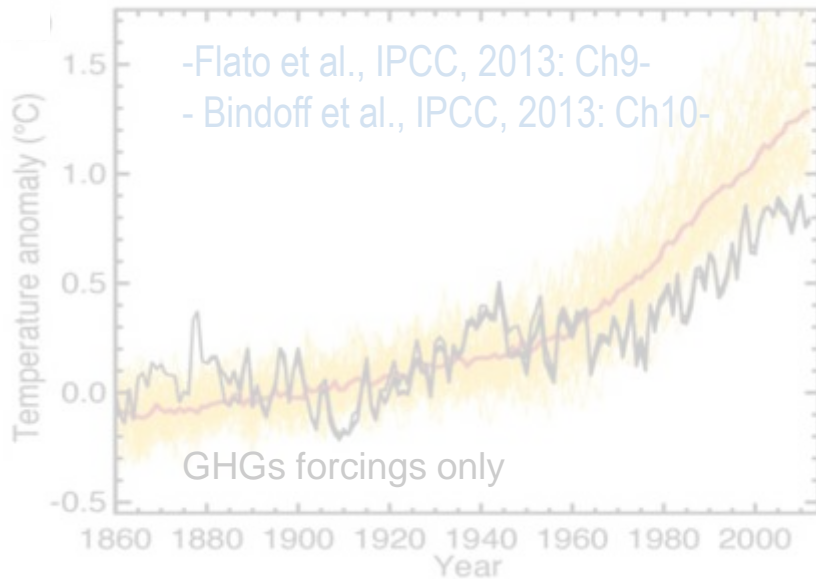
[GHG]s have increased well above levels unpr. in the last 800 kya; mean rates unpr. 22 kya (high. conf.)
 $\Delta[\text{CO}_2] \sim 40\%$ since preindustrial times

What causes system changes?: model evaluation & detection/attribution

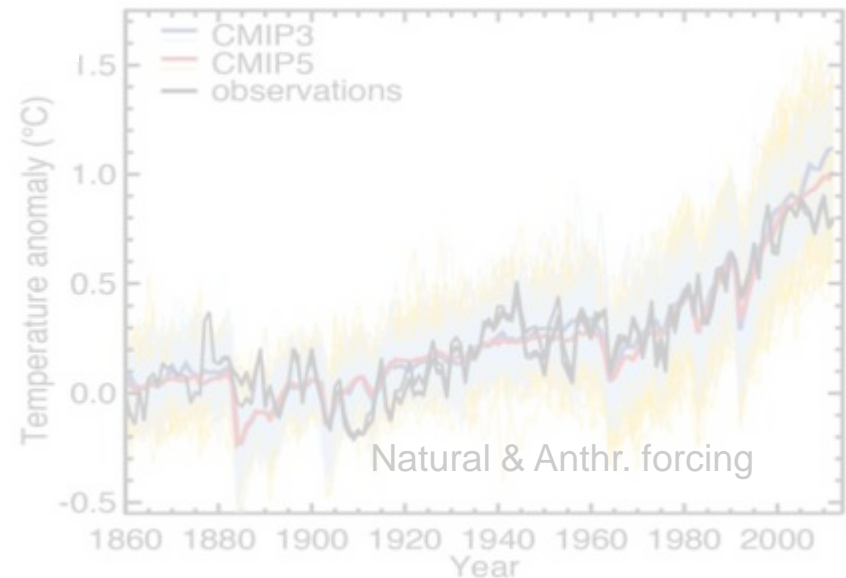


Human influence on the climate system is clear
...from increasing GHGs, radiative forcing,
warming and understanding of changes

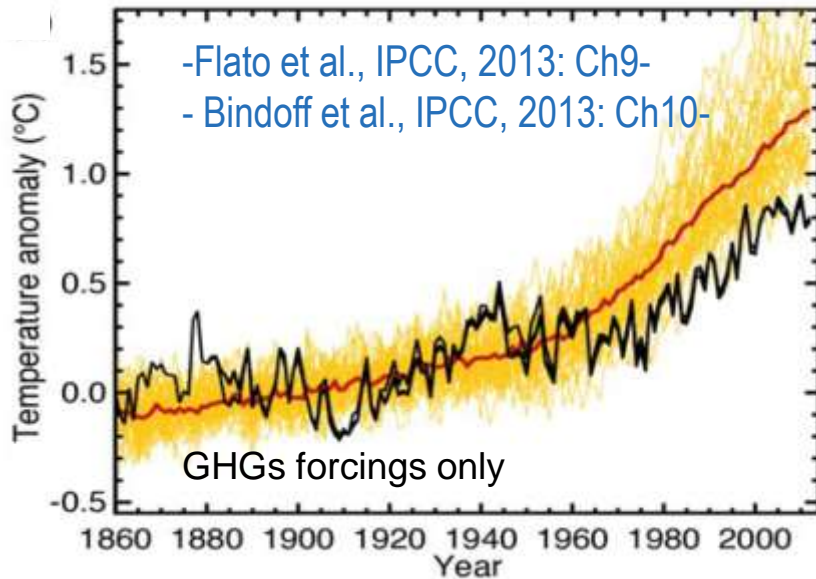
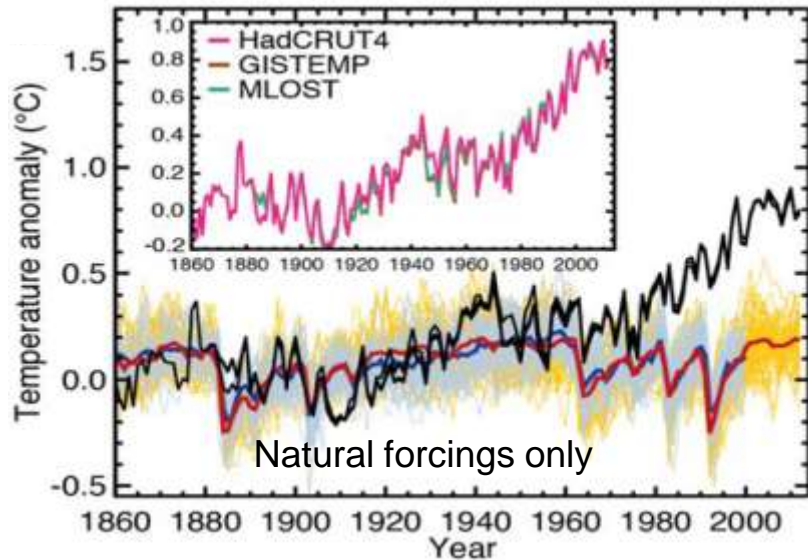
Climate models have improved since AR4
CMIP5 models reproduce observed continental-scale surface T patterns and trends over many decades including the more rapid warming since the mid-20th century and post volcanic cooling (very high conf.)



(IPCC 2013, Fig. TS.9)



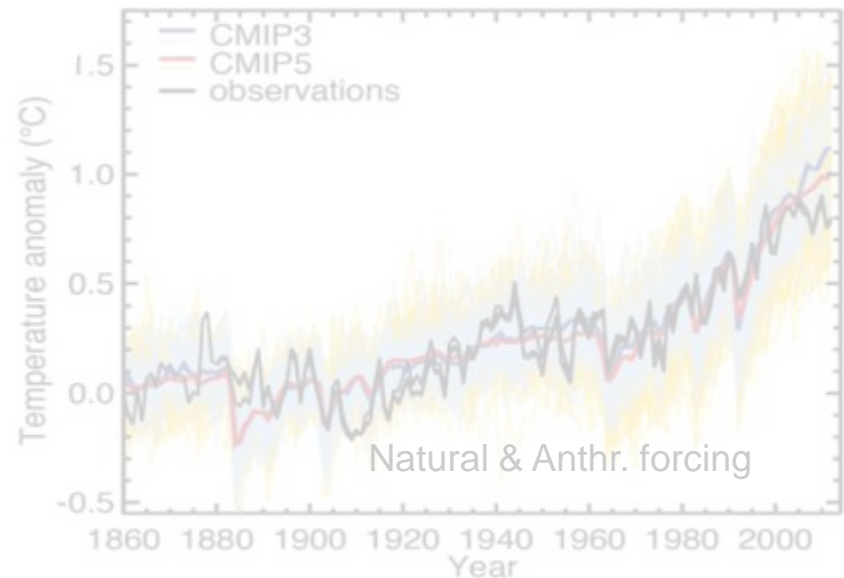
What causes system changes?: model evaluation & detection/attribution



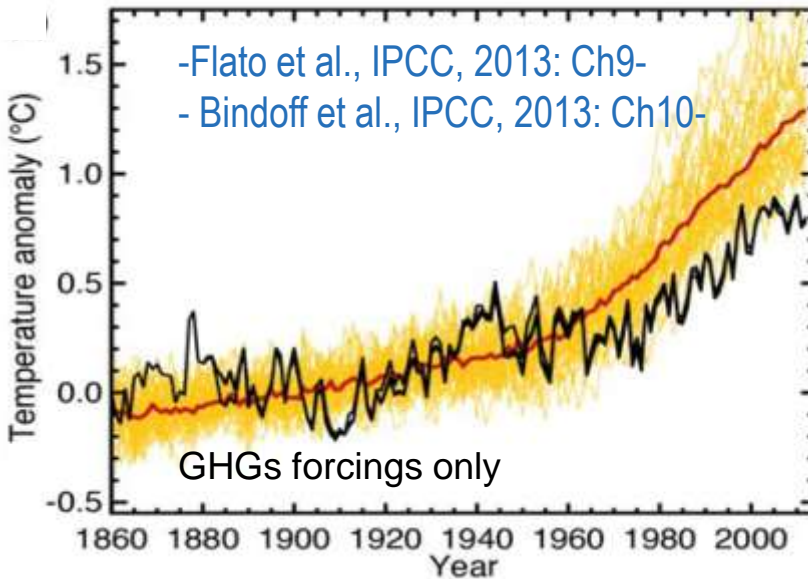
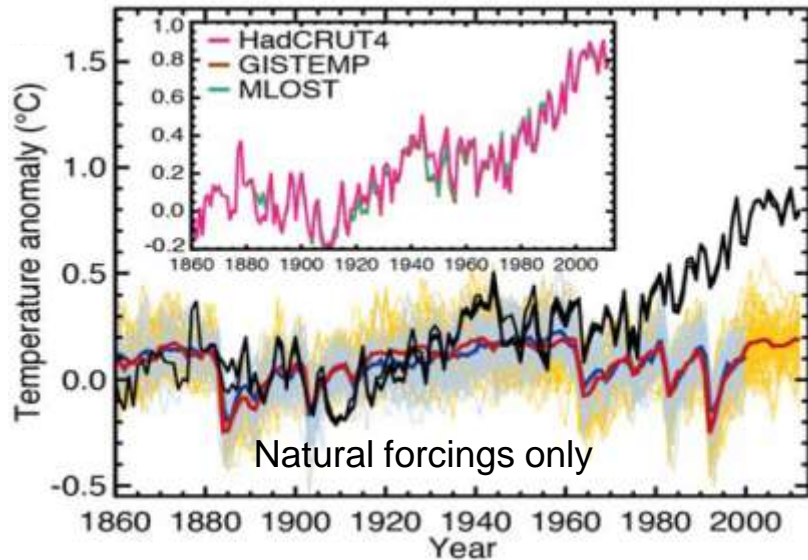
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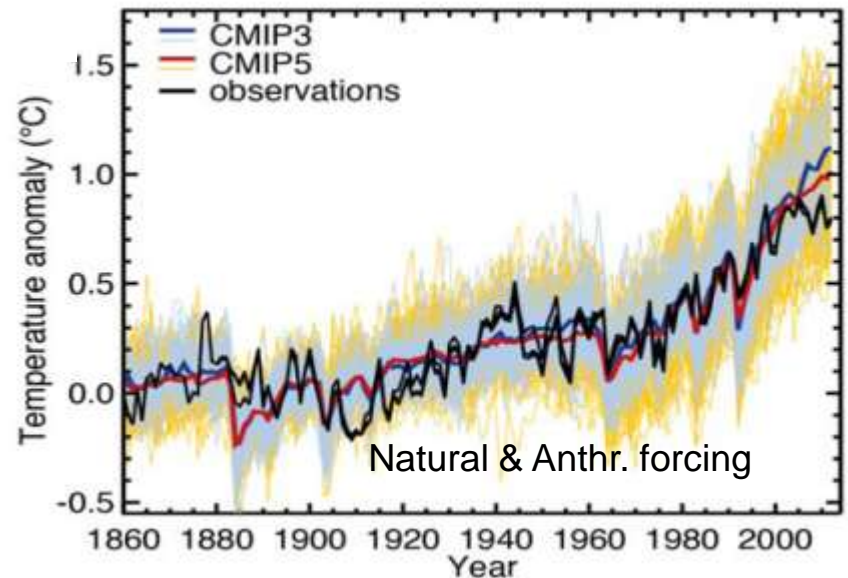
What causes system changes?: model evaluation & detection/attribution



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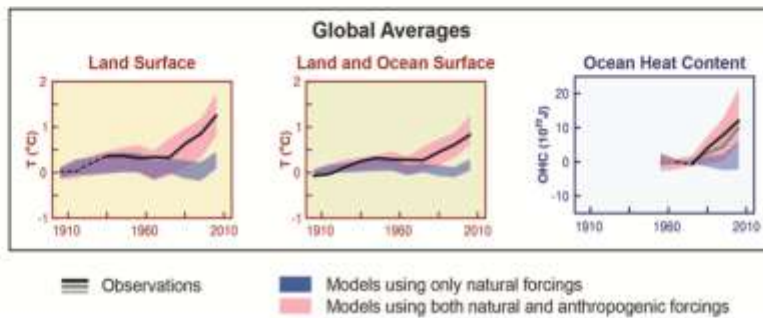
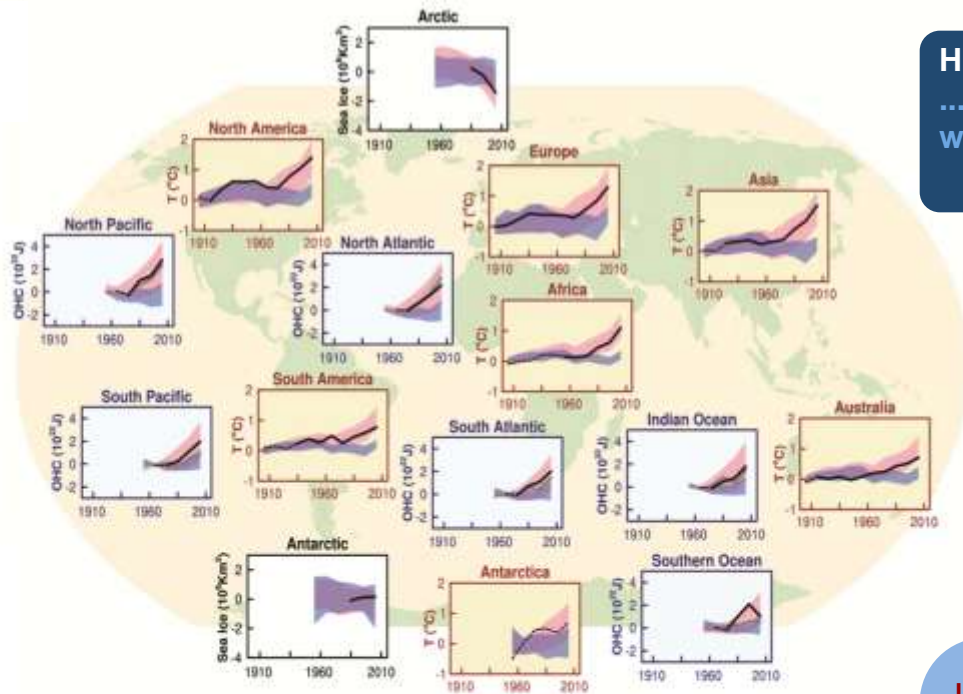


What causes system changes?: model evaluation & detection/attribution

Human influence on the climate system is clear ... from increasing GHGs, radiative forcing, warming and understanding of changes

Stronger evidence allows attribution of changes in several system components to human activities.
Improved understanding of observational uncertainty
Improved understanding of ocean changes.

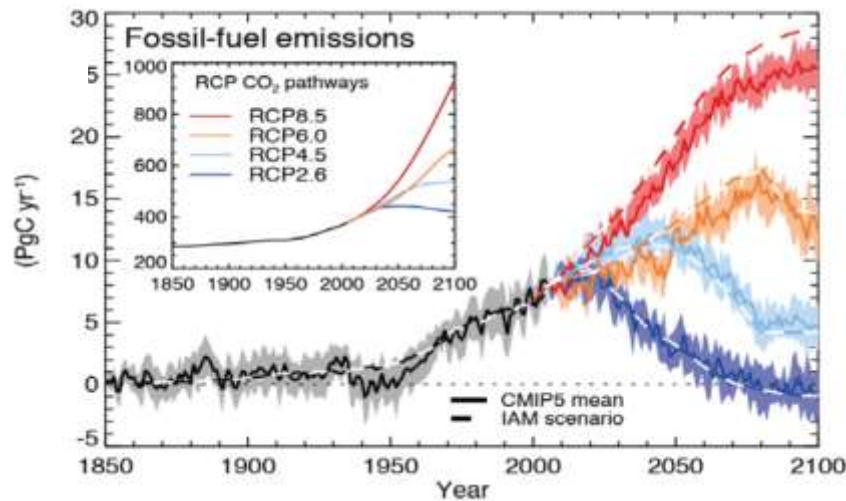
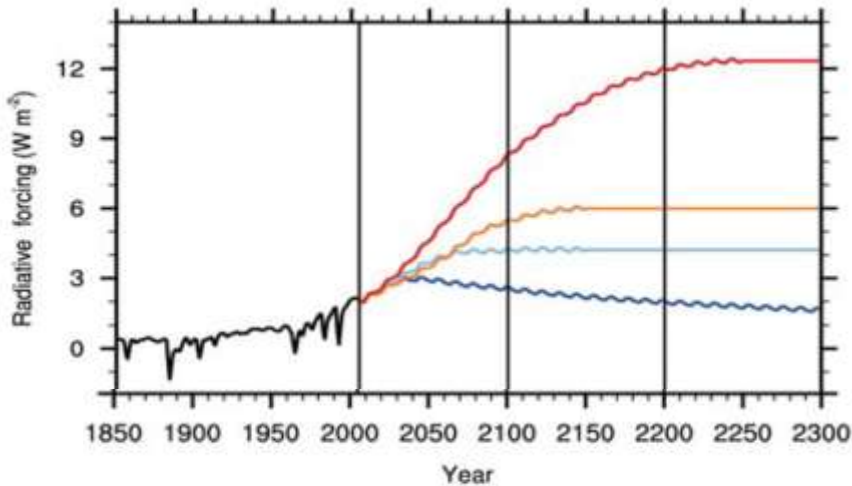
Human influence is detected in nearly all of the major assessed components of the climate system.
Combined evidence increases the overall level of confidence relative to single variable assessments.
It is virtually certain that human influence



(IPCC 2013, Fig. SPM.6)

- Bindoff et al., IPCC, 2013: Ch10-

What are the expected changes for the future?: Representative Concentration Pathways

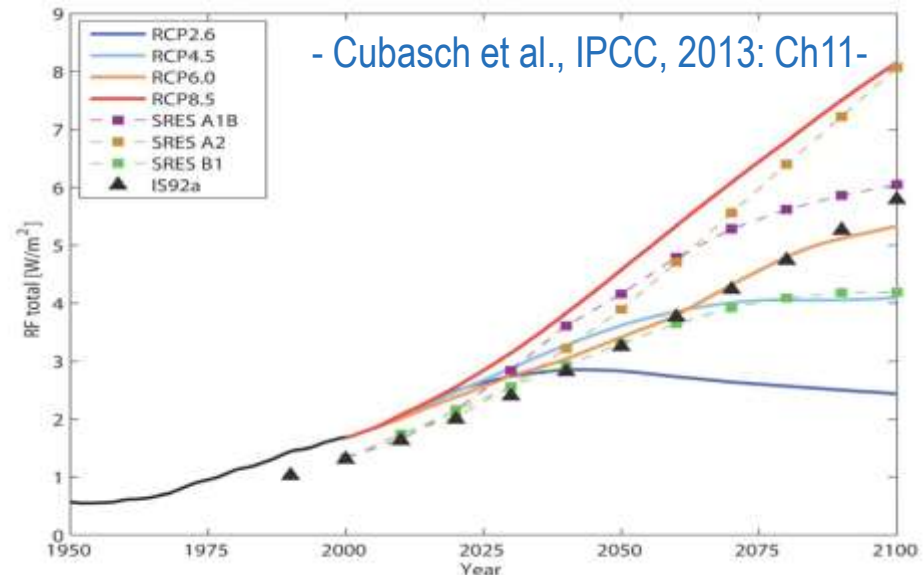


(IPCC 2013, TS, Fig. 15, 19)

-Ciais et al., IPCC, 2013: Ch6-
- Collins et al., IPCC, 2013: Ch12-

RCPs represent a larger set of mitigation scenarios and were selected to have different targets in terms of radiative forcing at 2100: 2.6, 4.5, 6.0, 8.5 Wm^{-2}
... Plausible and illustrative, with no probabilities attached to them

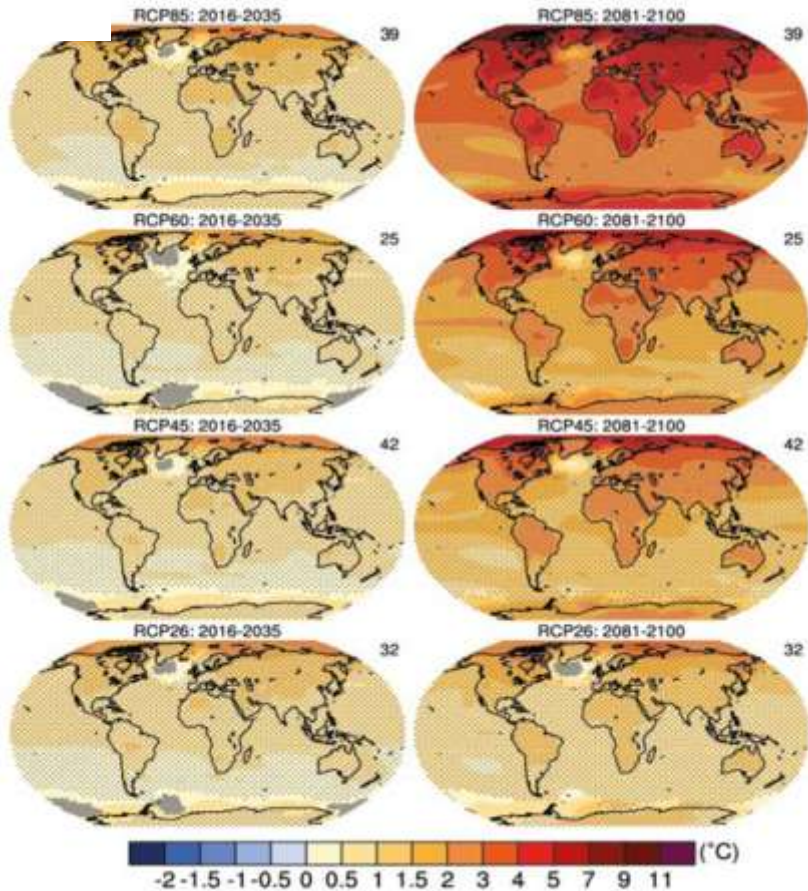
RCPs developed using Integrated assessment Models (IAMs) that typically include economic, demographic, energy and simple climate components. Resulting emission scenarios run in a simple model to produce GHG concentrations to be used in ESM.



- Cubasch et al., IPCC, 2013: Ch11-

What are the expected changes for the future?: Atmospheric temperature projections

Annual mean temperature change

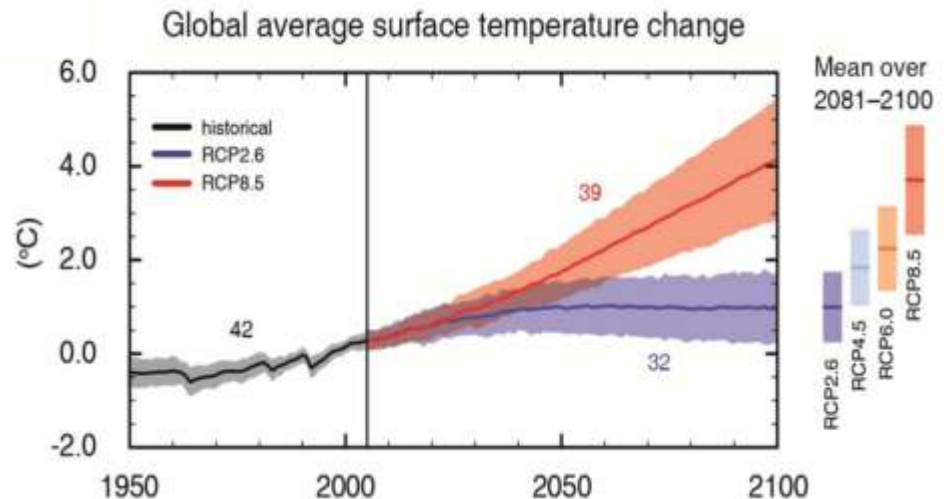


- Collins et al., IPCC, 2013: Ch12-

Continued emissions of GHGs will cause further warming and changes in all components of the climate system.
Limiting climate change will require substantial and sustained reduction of GHGs.

Global surface temperature change for the end of the 21st century is likely to exceed 1.5 °C relative to 1850-1900 for all RCPs
... Likely $\Delta T > 2^\circ\text{C}$ for RCP6.0 and RCP8.5
... More likely than not $\Delta T > 2^\circ\text{C}$ for RCP4.5

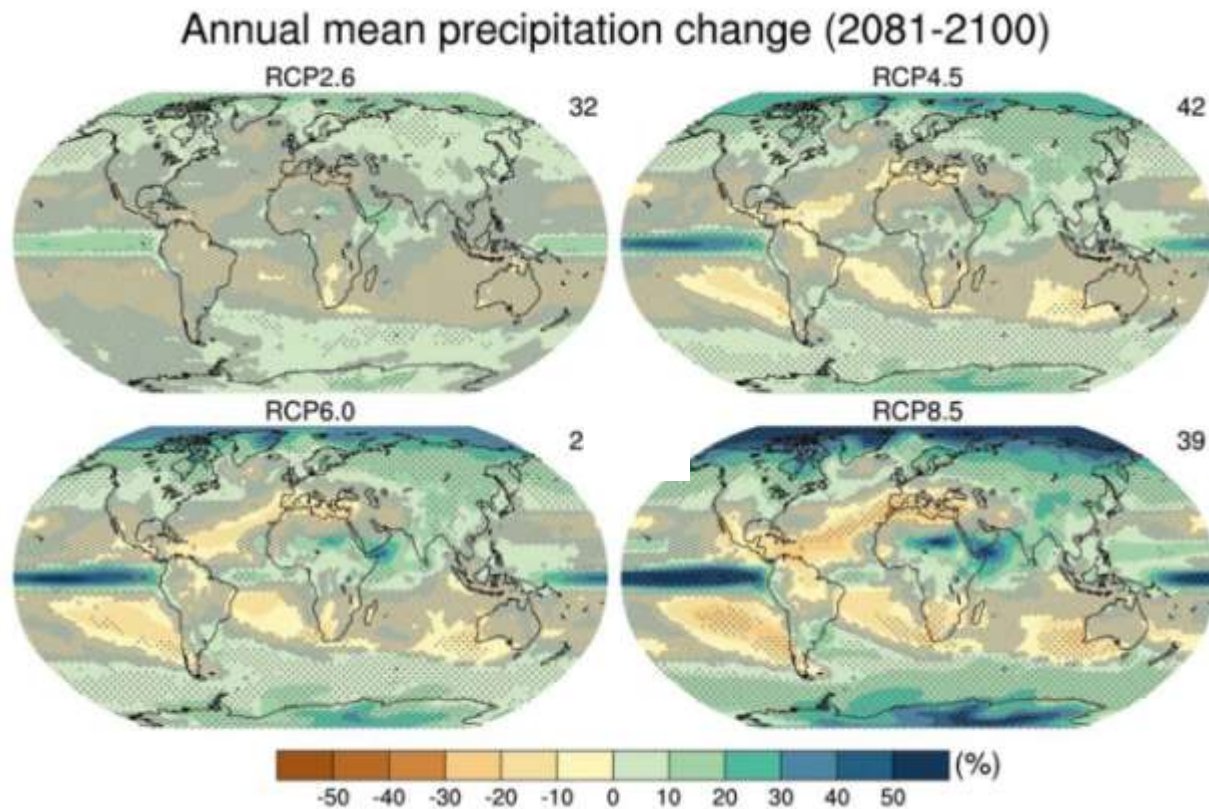
(IPCC 2013, SPM.7 TS.15)



What are the expected changes for the future?: water cycle

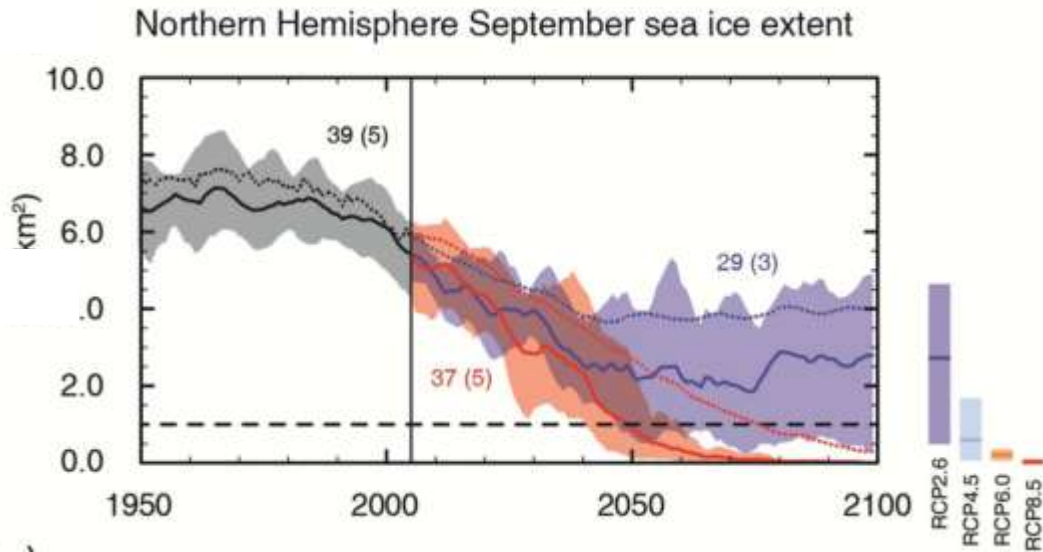
Changes in global water cycle in response to the warming in the 21st century will not be uniform. The contrast in precipitation between wet and dry regions and seasons will increase, although there may be regional exceptions

- Collins et al., IPCC, 2013: Ch12-
- Christensen et al., IPCC, 2013: Ch14-

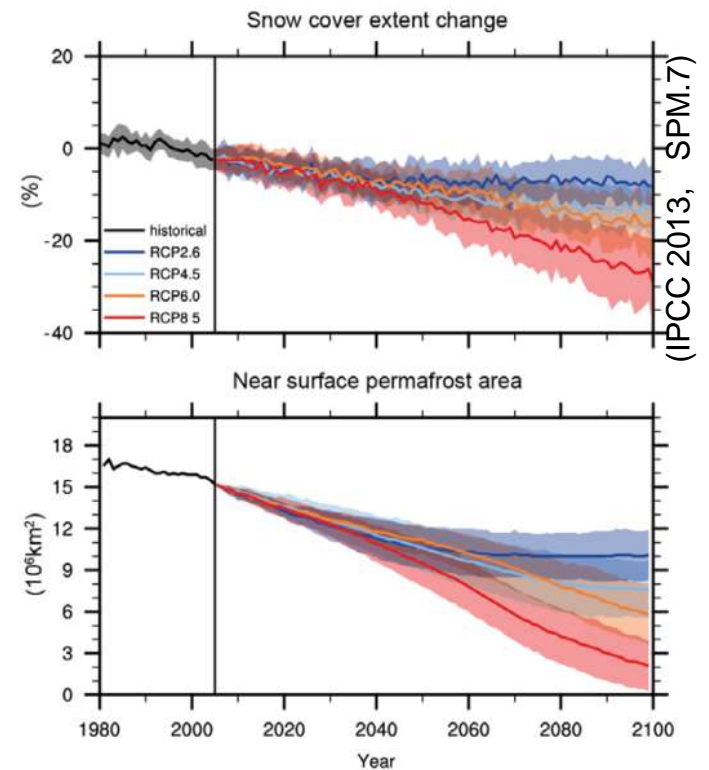


What are the expected changes for the future?: cryosphere

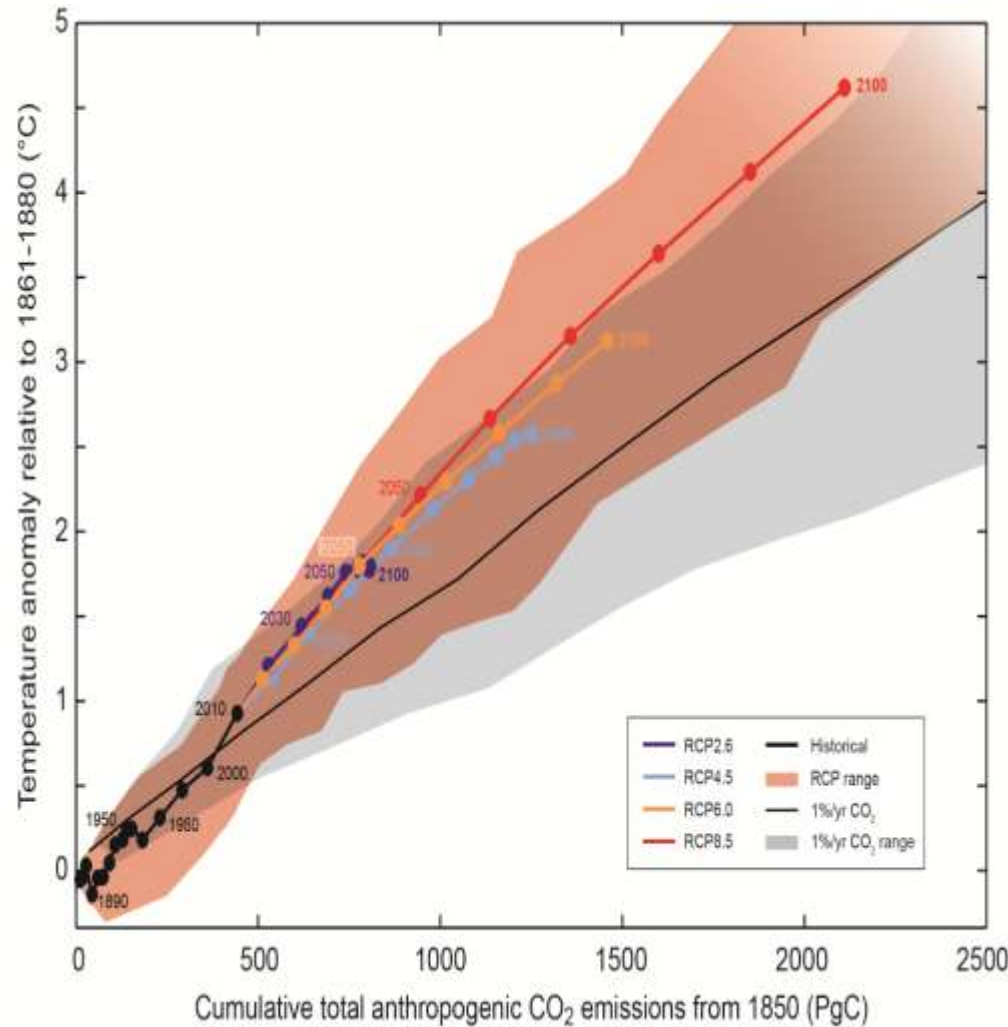
Arctic sea ice cover will very likely continue to shrink and thin
NH spring snow cover will decrease during the 21st century. Global glacier volume will further decrease



- Collins et al., IPCC, 2013: Ch12-



Policy relevant implications: commitment, stabilization & irreversibility



- Collins et al., IPCC, 2013: Ch12-

Cumulative emissions of CO₂ largely determine global mean surface warming by the late 21st century and beyond.

Limiting climate change will require substantial and sustained emission reductions.

This represents a substantial multi century climate change commitment created by past, present and future emissions..

GMST response responds ~ linearly to cumulative total CO₂ emissions. Lower T targets require lower cumulative emissions.

A large fraction of anthropogenic climate change resulting from CO₂ emissions is irreversible on a multi-century to millennial time scale.

Surface temperatures will remain approximately constant at elevated levels for many centuries after a complete cessation of anthropogenic emissions.

(IPCC 2013, SPM.10)