

# Climate Change 2013: The Physical Science Basis

Working Group I contribution to the IPCC Fifth Assessment Report

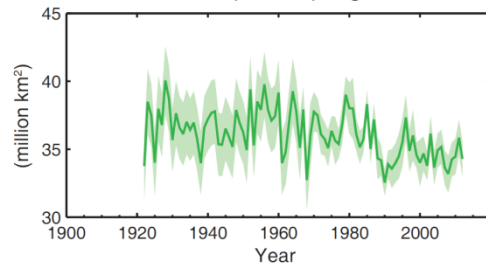
## Observations II: cryosphere and ocean

Monika Rhein

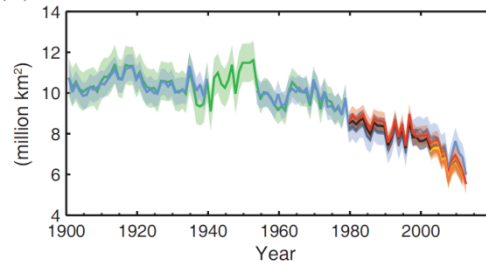
CLA Chapter 3, LA Technical Summary, Summary for Policymakers  
Don Chambers, John Church, Joey Comiso, Richard Feely, Gregory Johnson, Valerie Masson  
– Delmotte, Phil Mote, Steve Rintoul, Chris Sabine, David Vaughan

© Yann Arthus-Bertrand / Altitude

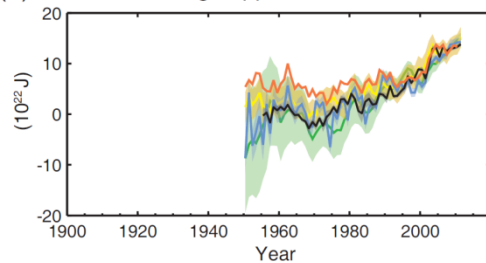
(a) Northern Hemisphere spring snow cover



(b) Arctic summer sea ice extent



(c) Global average upper ocean heat content



(d) Global average sea level

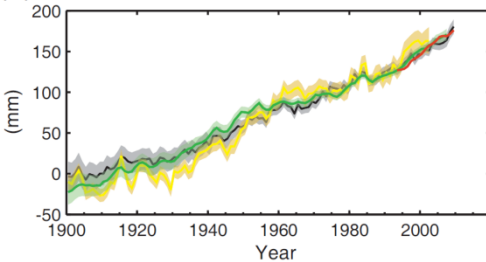
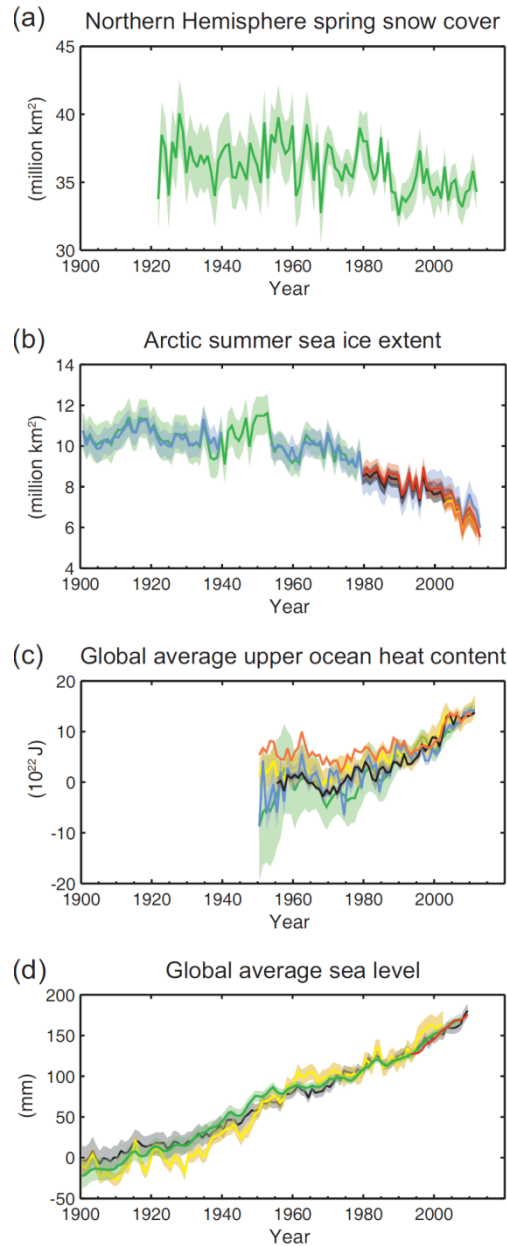


Figure SPM.2

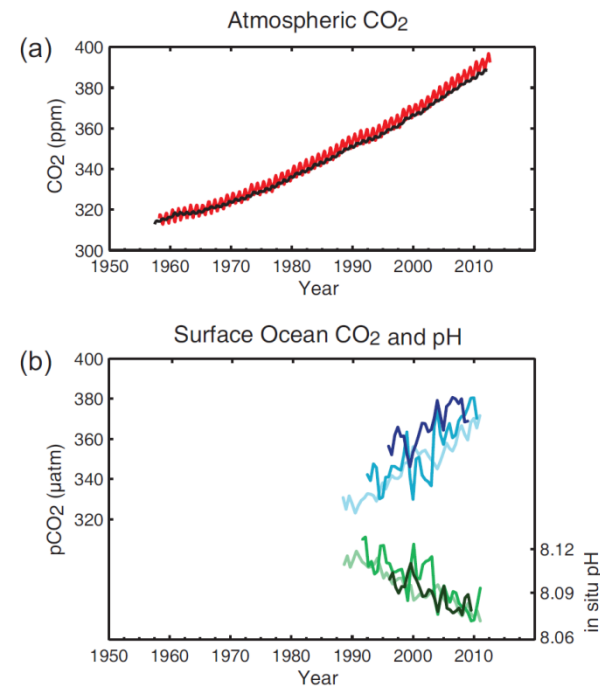
***Observations provide multiple lines of evidence for changes in the ocean and the cryosphere***

***The climate system is out of balance: it is accumulating energy. More than 90% is stored in the ocean.***



**Figure SPM.2**

***The atmospheric CO<sub>2</sub> concentration has increased. The ocean is acidifying.***

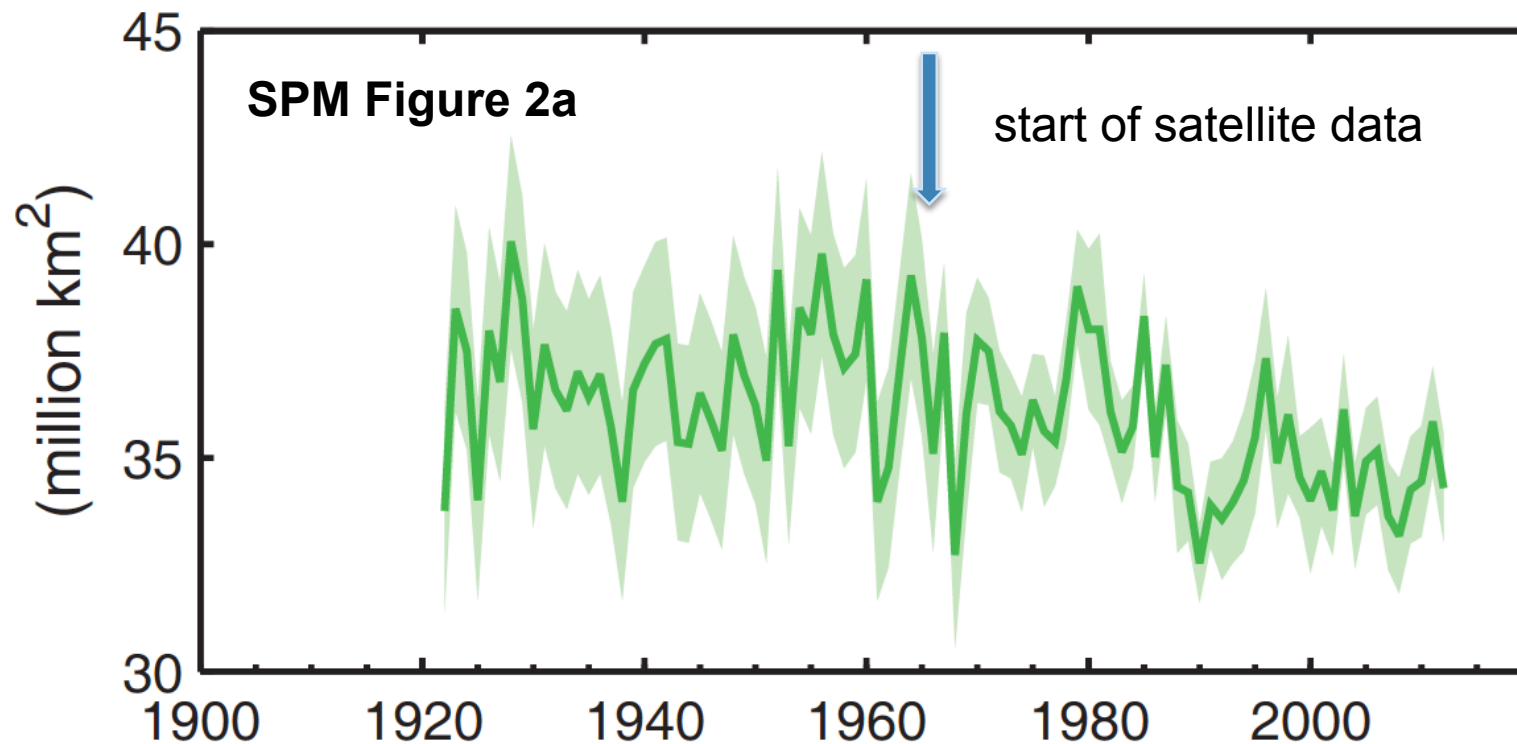


**Figure SPM.3**

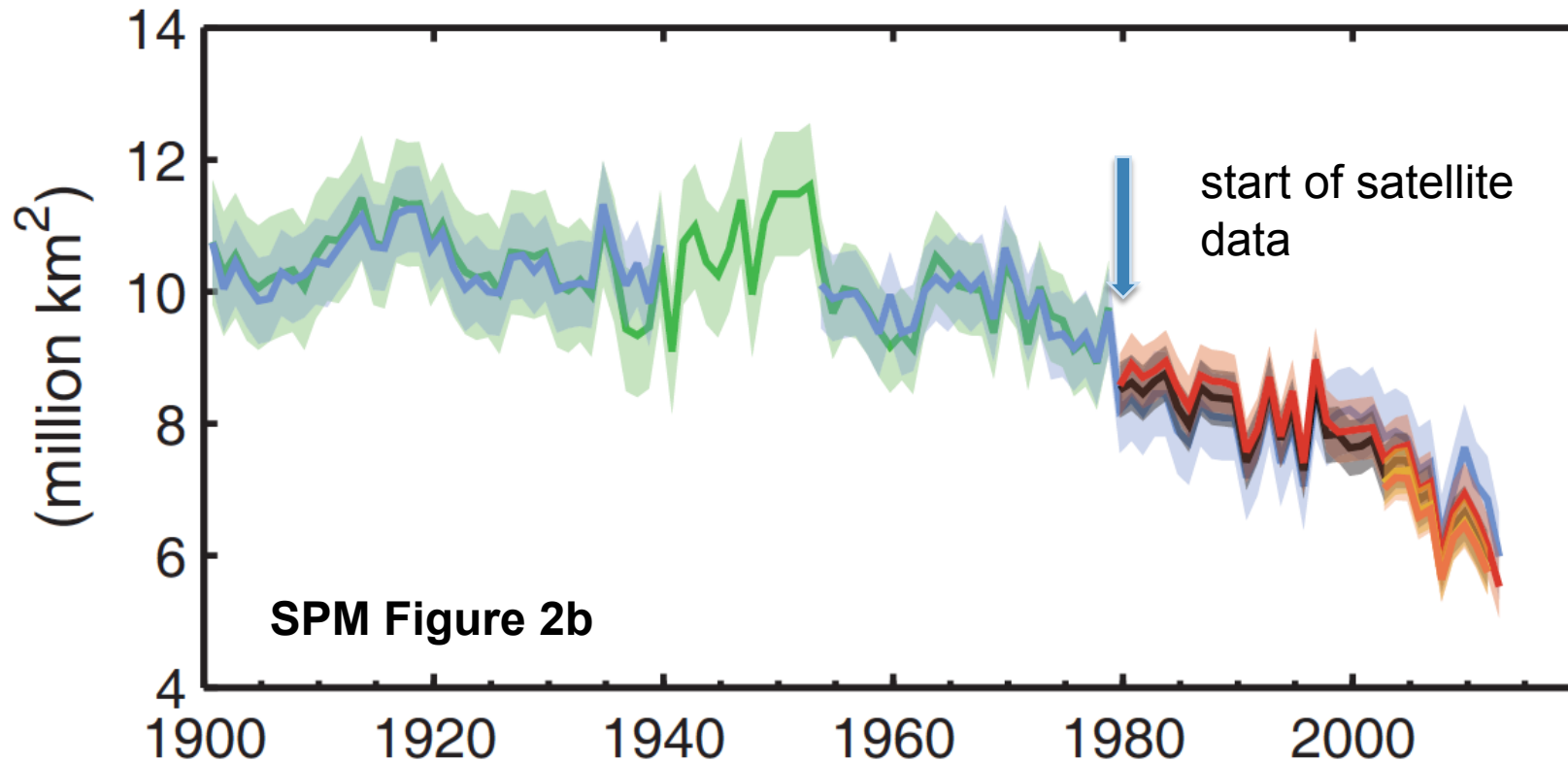
**Very high confidence that Northern Hemispheric snow cover decreased since the mid 20<sup>th</sup> century**

**1.6 [0.8 to 2.4] % per decade 1967-2012 in April / March**

**uncertainty smaller in satellite era**



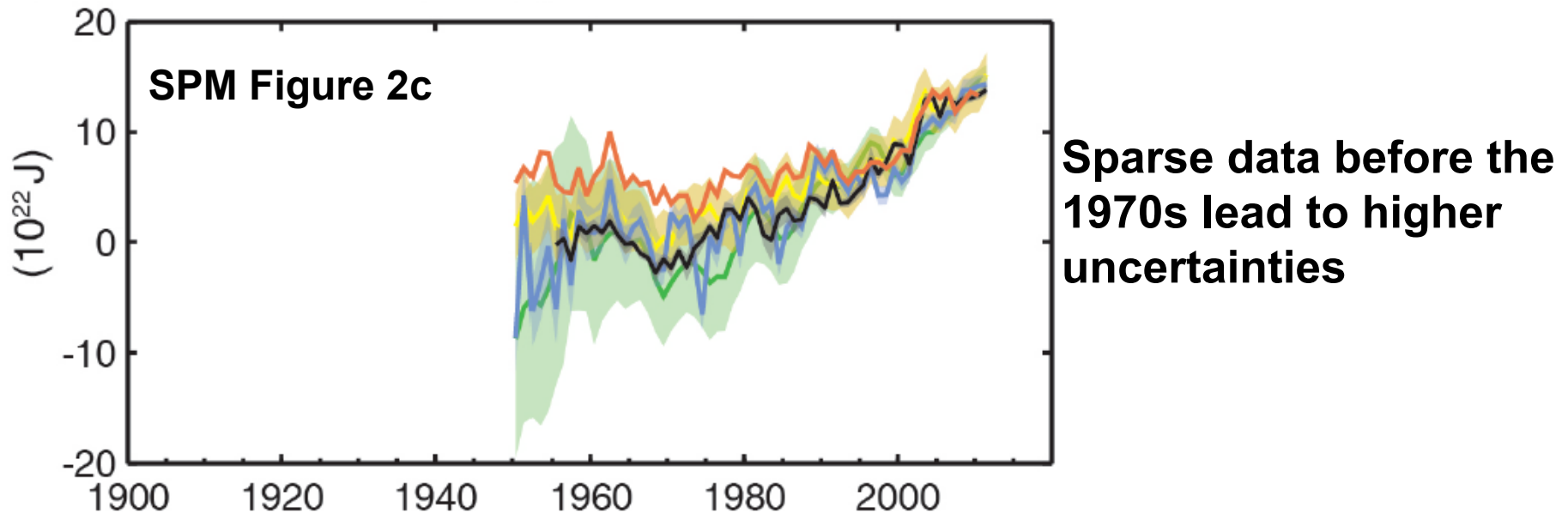
**Annual mean Arctic summer sea ice extent decreased  
*very likely* with a rate of 3.5-4.1% per decade in 1979 – 2012  
decrease was most rapid in summer (*high confidence*)**



**Data normalized to the satellite measured sea ice extent in 1979**

## Upper Ocean Heat Content

It is *virtually* certain that global average upper ocean heat content (0-700m depth) increased. Rate: 17 [15-19]  $10^{22}$  J in 1971 – 2010



Temperature observations made with different instruments drifting profilers (Argo) since the 2000s.

Essentially the same observations are generally used for all five records, but different methods to fill data gaps are applied

## Number of temperature profiles per decade, 0-700m, 1°x1°

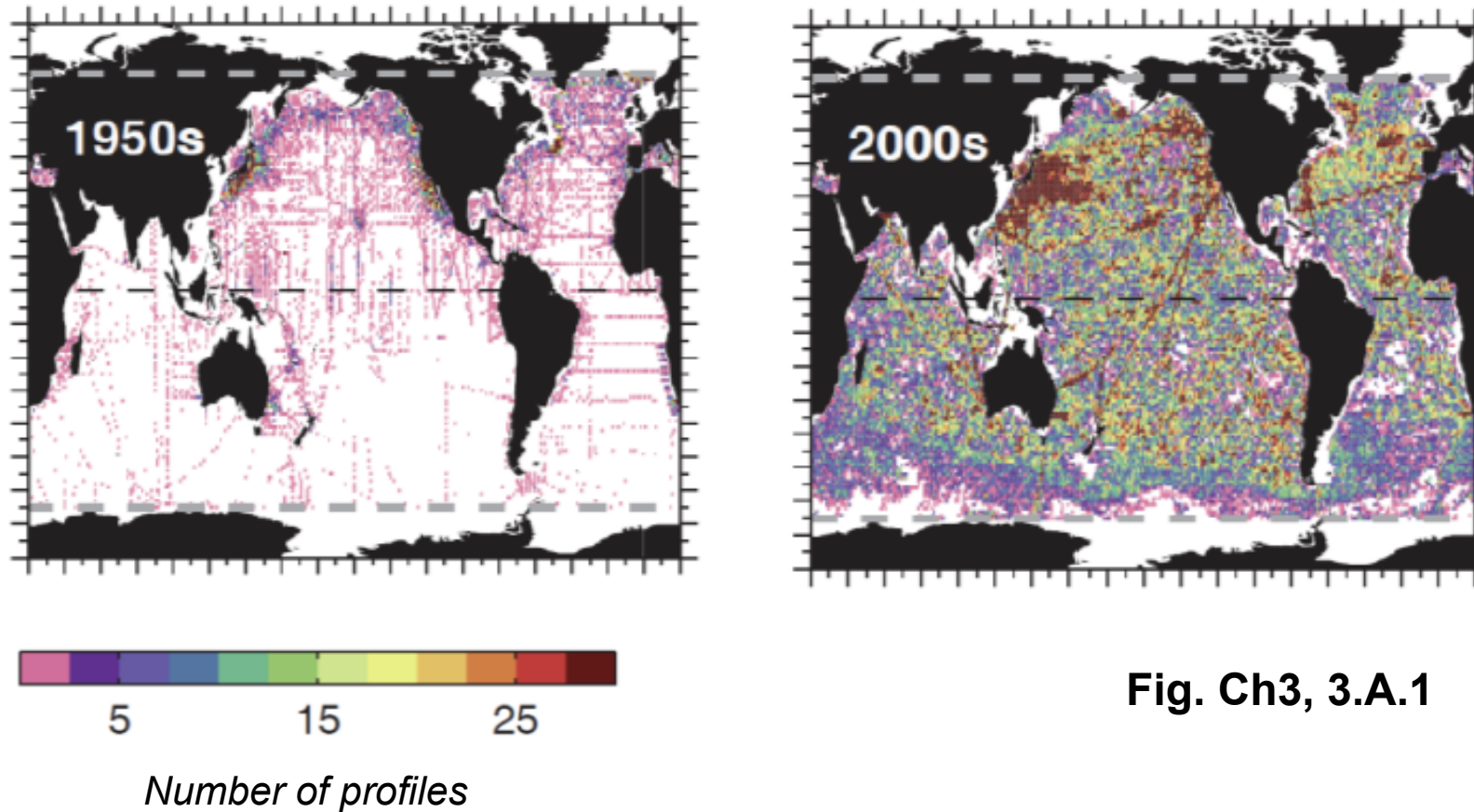
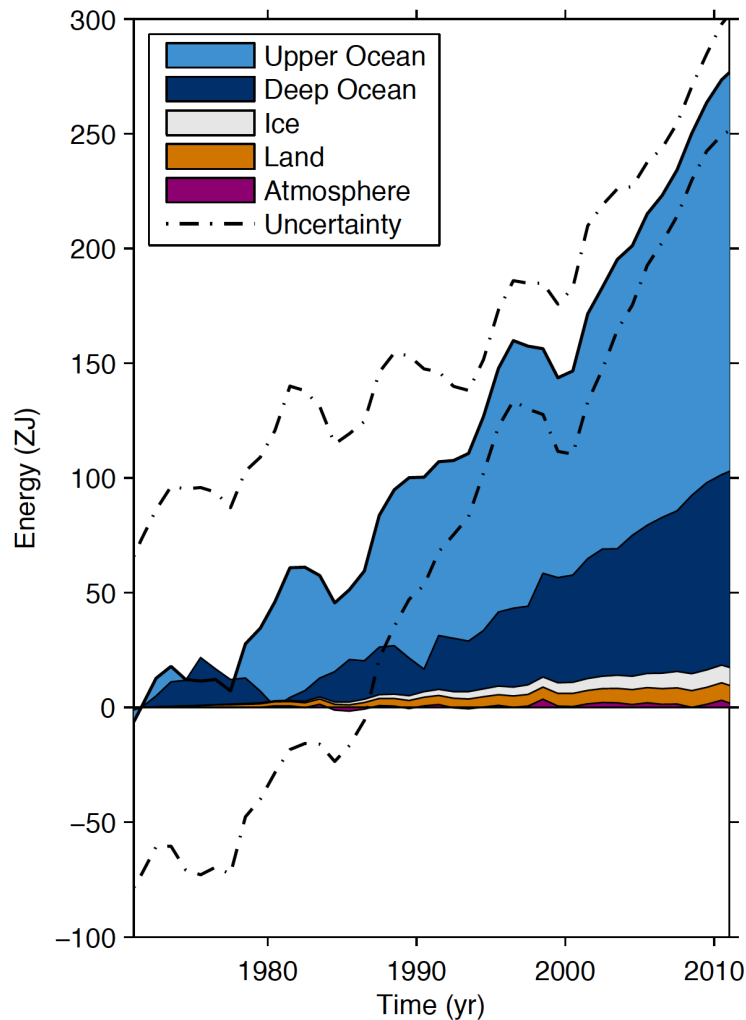


Fig. Ch3, 3.A.1

**Before the 1950s, data too sparse to calculate global mean**

## Change in Global Energy Inventory 1971 - 2010



- ◆ Ocean warming : 93% of the increase in energy in Earth's climate system (*high confidence*)
- ◆ 3% go into warming the land,
- ◆ 1% into warming the atmosphere
- ◆ 3% into melting of ice (glaciers, ice sheets)

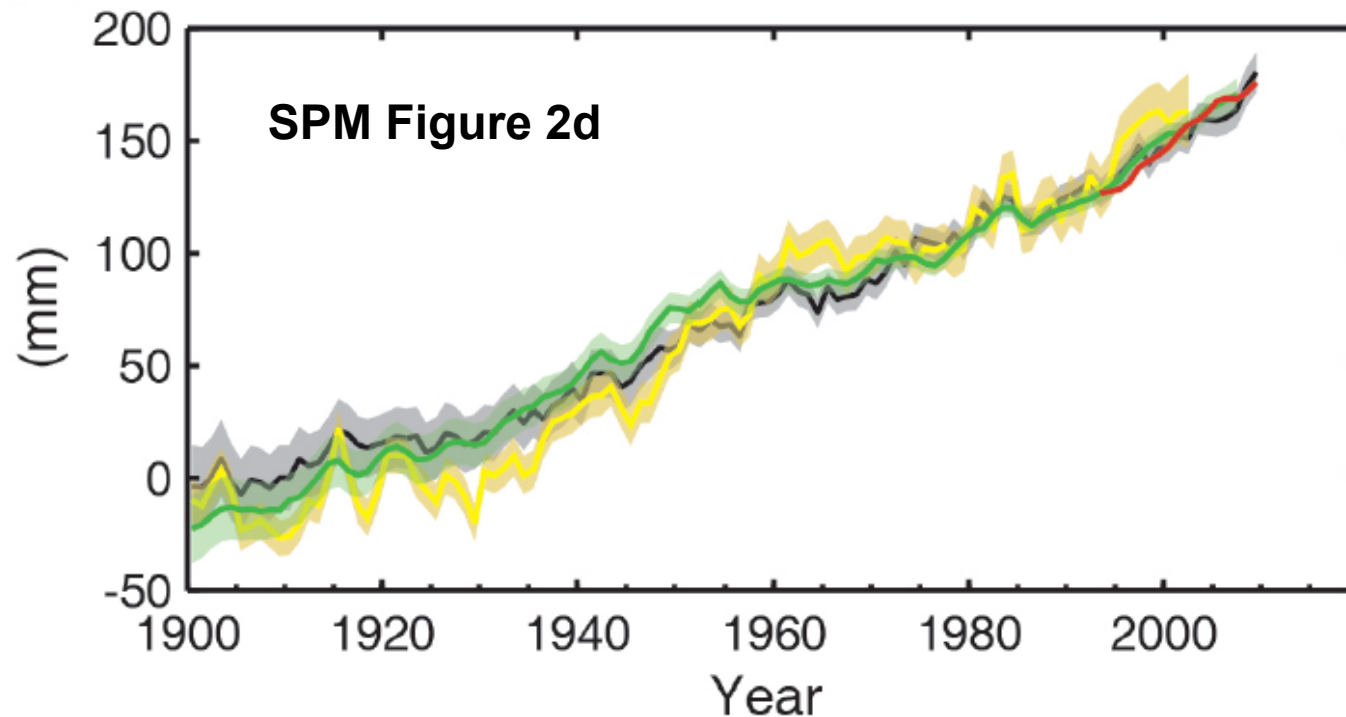
**Box 3.1, Figure 1**



# Global Mean Sea Level

- ◆ Ocean warming leads to thermal expansion of water: sea level rises
- ◆ Additional water is entering the ocean from glaciers and ice sheets, and from changes in land water storage: sea level rises
- ◆ Melting of **sea** ice does not affect sea level

## Global mean sea level has risen by 0.19 m (1901-2010)



**Sea level from different tide gauge reconstructions and since 1992 from satellite altimetry (red)**

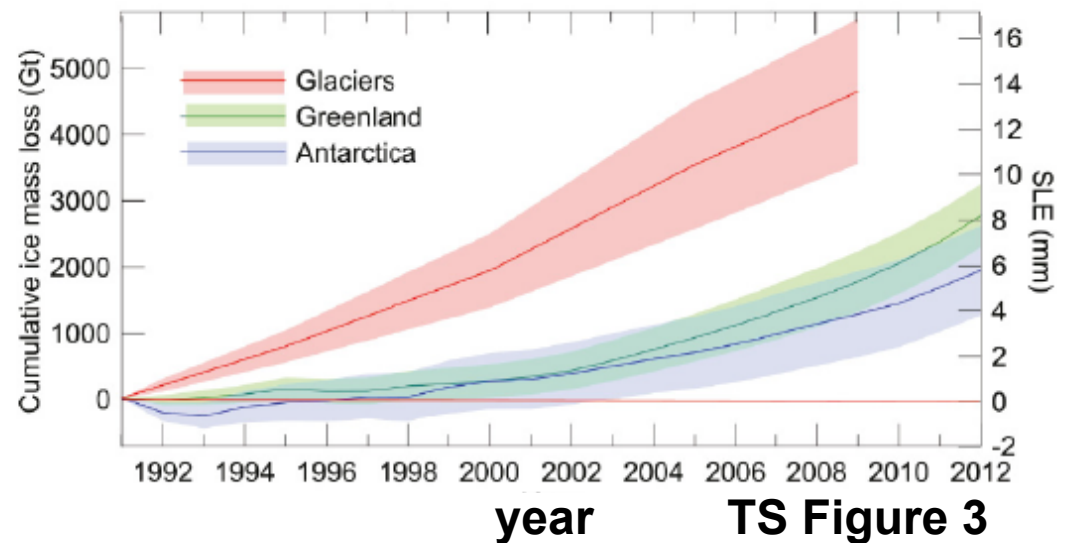
Shaded: uncertainties are one standard error as reported in the publications, smallest for altimeter data

**Mean rates:** 1.7 [1.5 to 1.9] 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 (all *very likely*)

**In well measured time period 1993-2010, global mean sea level is consistent with the sum of observed contributions (*high confidence*)**

### Contribution to sea level rise in 1993-2010

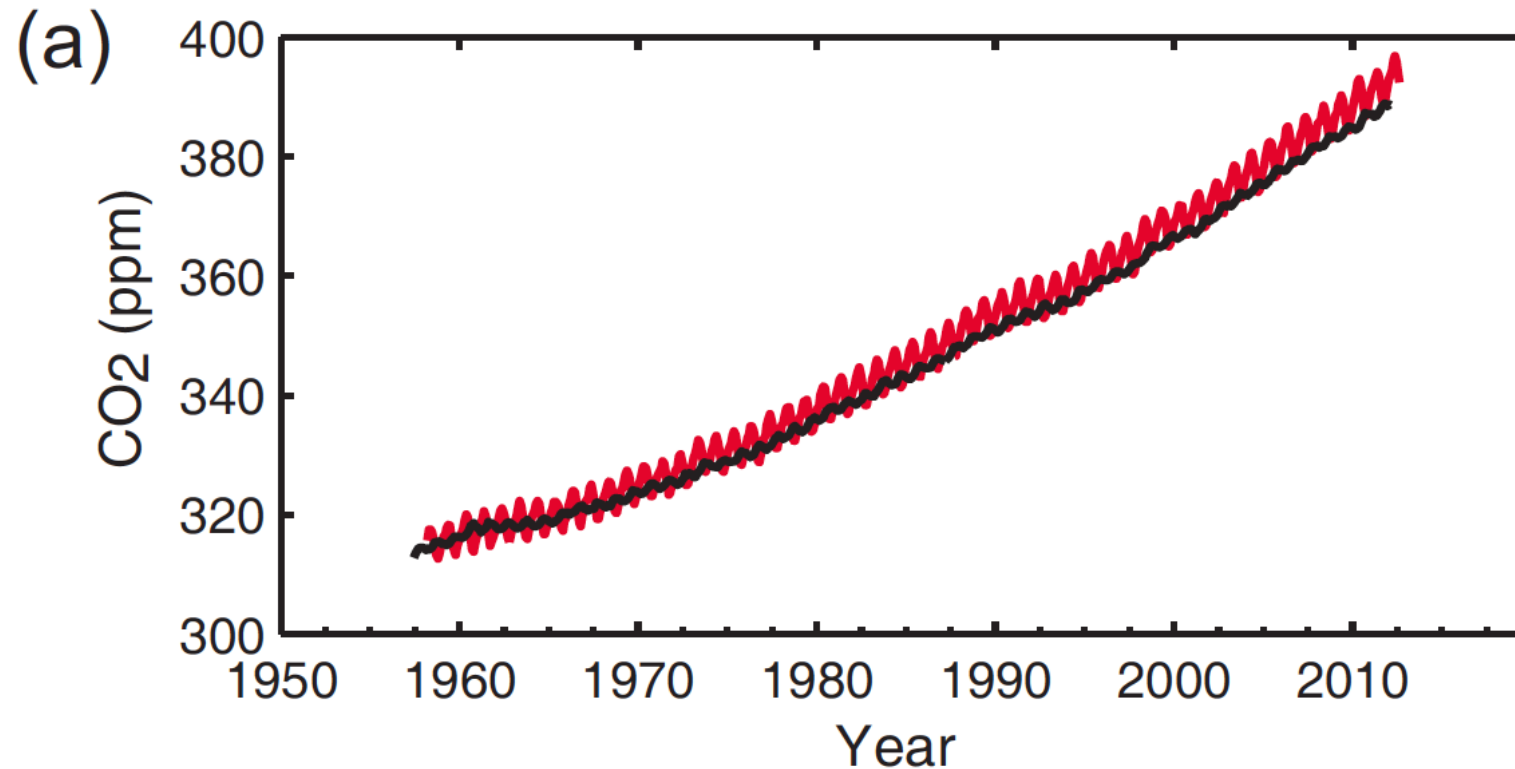
Ocean warming:	38%
Changes in glaciers:	28%
Greenland ice sheet:	10%
Antarctic ice sheet:	10%
Land water storage	14%



# Ocean Acidification

- ◆ Atmospheric CO<sub>2</sub> concentrations today are higher than at least in the last 800 000 years
- ◆ Since 1750, atmospheric concentration increased by 40% by human activities as fossil fuel combustion and land use change
- ◆ From the CO<sub>2</sub> emitted by human activities into the atmosphere, about 30% have been absorbed by the ocean
- ◆ The oceanic uptake of anthropogenic carbon : upper ocean is acidifying

# Monthly mean CO<sub>2</sub> concentrations from Mauna Loa, Hawaii (red) and South Pole (black)

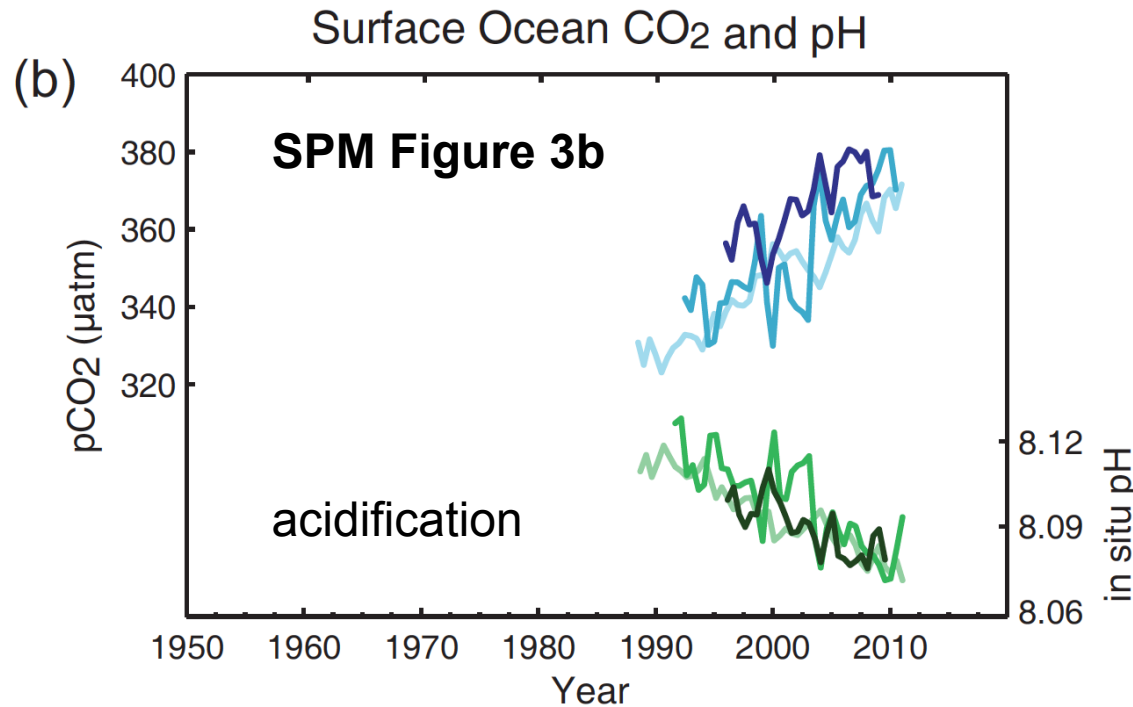


Local measurements, uncertainty small,  
not visible on this plot

## SPM Figure 3a

IPCC AR5 Working Group I  
Climate Change 2013: The Physical Science Basis

The pH of ocean surface water has *very likely* decreased by about 0.1, corresponding to a 26% increase in hydrogen ion concentration



12-months running mean of measurements at fixed locations

Measurement error small against variability, thus not shown

Long time series from ocean stations in Atlantic and Pacific, between 23°N and 32°N.

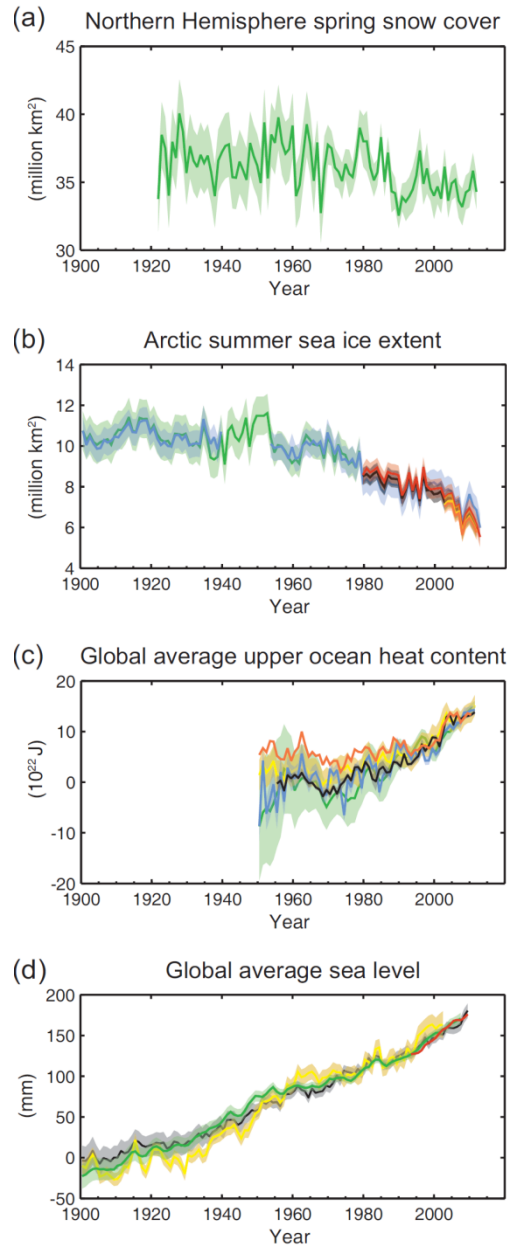


Figure SPM.2

- **Observations provide multiple lines of evidence for changes in the ocean and the cryosphere**
- **The climate system is accumulating energy. More than 90% is stored in the ocean.**
- **The atmospheric CO<sub>2</sub> concentration has increased. The ocean is acidifying.**

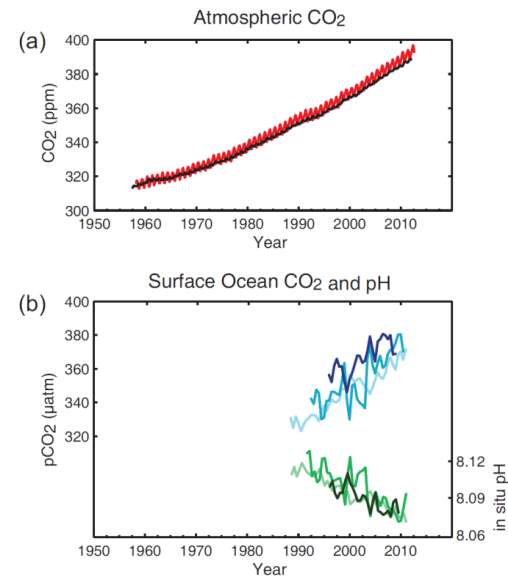


Figure SPM.3

# Climate Change 2013: The Physical Science Basis

Working Group I contribution to the IPCC Fifth Assessment Report

Further Information  
[www.climatechange2013.org](http://www.climatechange2013.org)

© Yann Arthus-Bertrand / Altitude