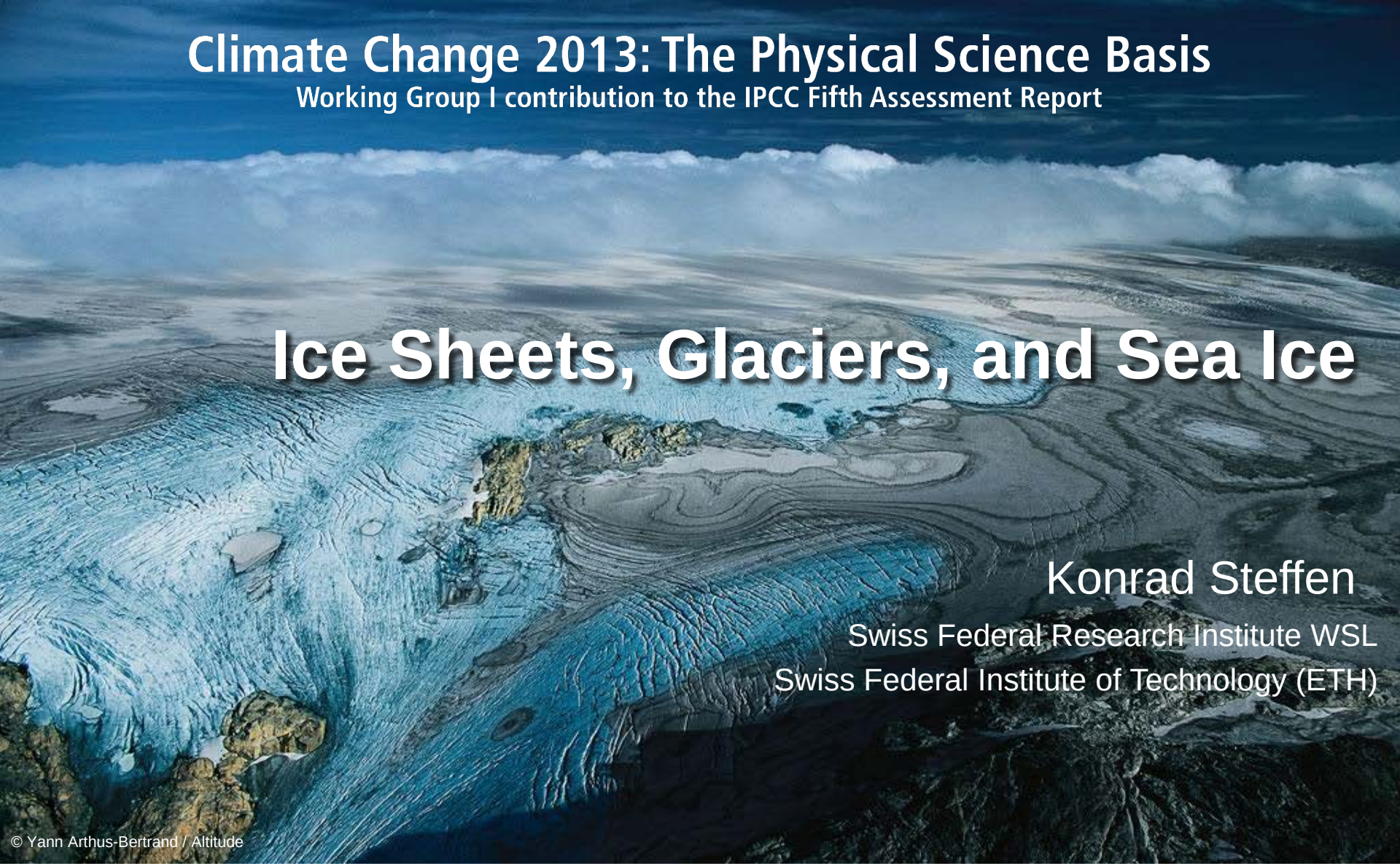
Climate Change 2013: The Physical Science Basis

Working Group I contribution to the IPCC Fifth Assessment Report



Ice Sheets, Glaciers, and Sea Ice

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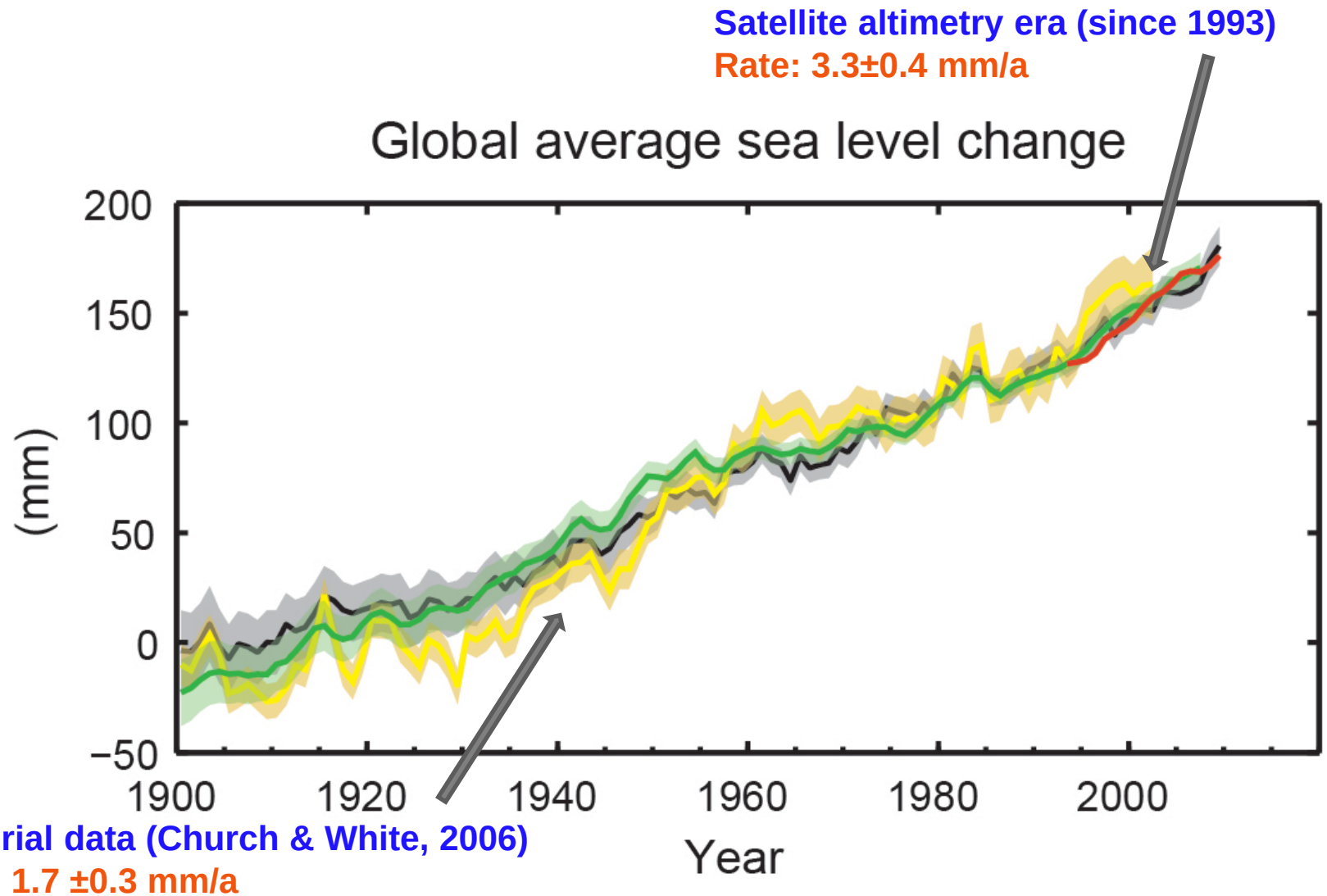
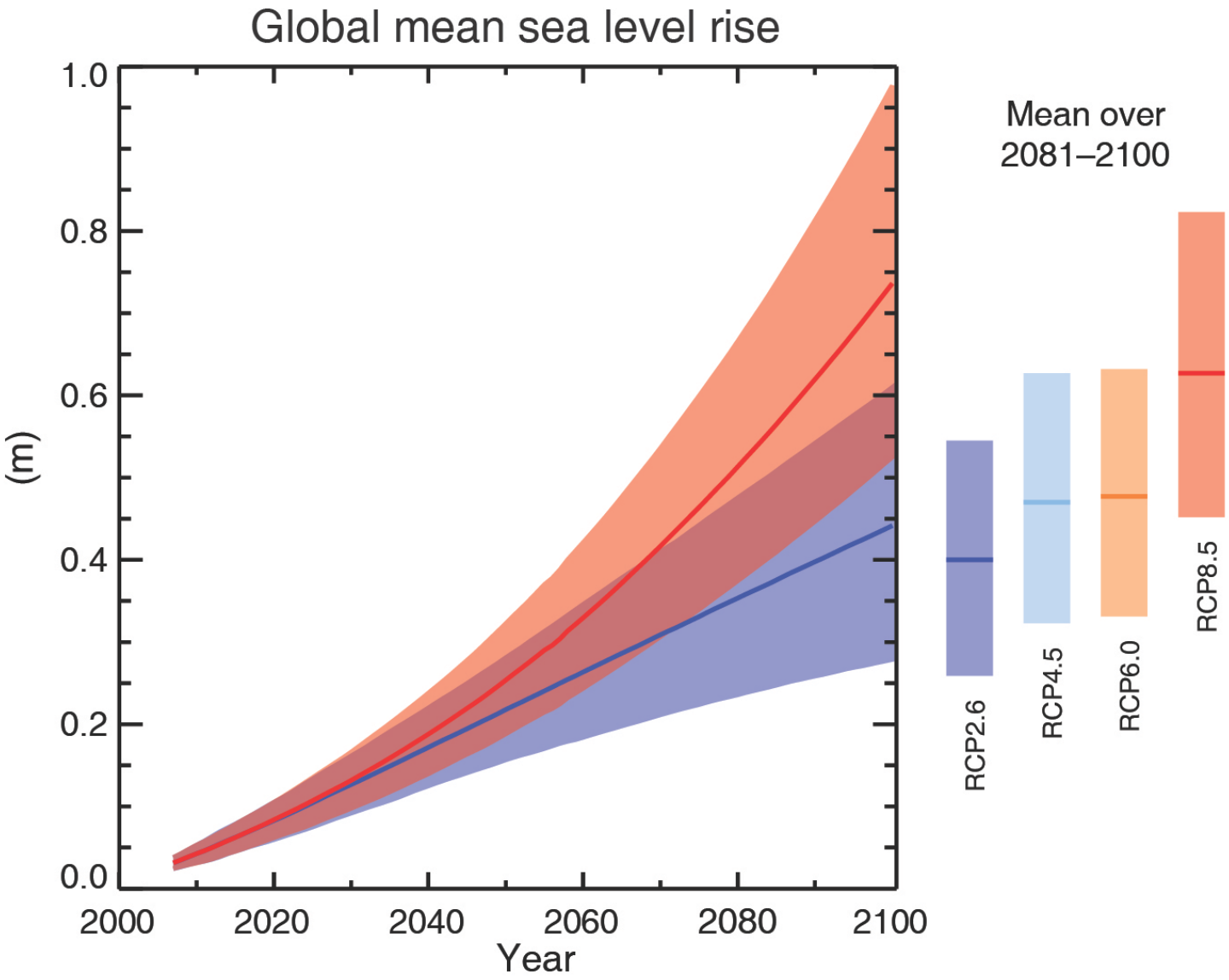
Scope of this Workshop:
Observational and research needs for adaptation to climate variability and change

- **Data availability to inform implementation of adaptation**
  - Very limited for most parts; case studies, remote sensing, modeling for extrapolation
- **Defining core data sets to maintain stewardship in management of resources**
  - Depends of the field of application; examples for sea level uncertainties will be given as examples from the cryosphere
- **Adequacy of networks for detection of climate trends**
  - In general most areas are under-sampled for accurate assessments in polar regions
- **Local capabilities to observe, monitor, rescue, archive, process and sustain climate data and networks**
  - In remote areas such a polar regions the local capabilities are missing; replaced by autonomous monitoring and remote sensing

Global Mean Sea Level since 1900



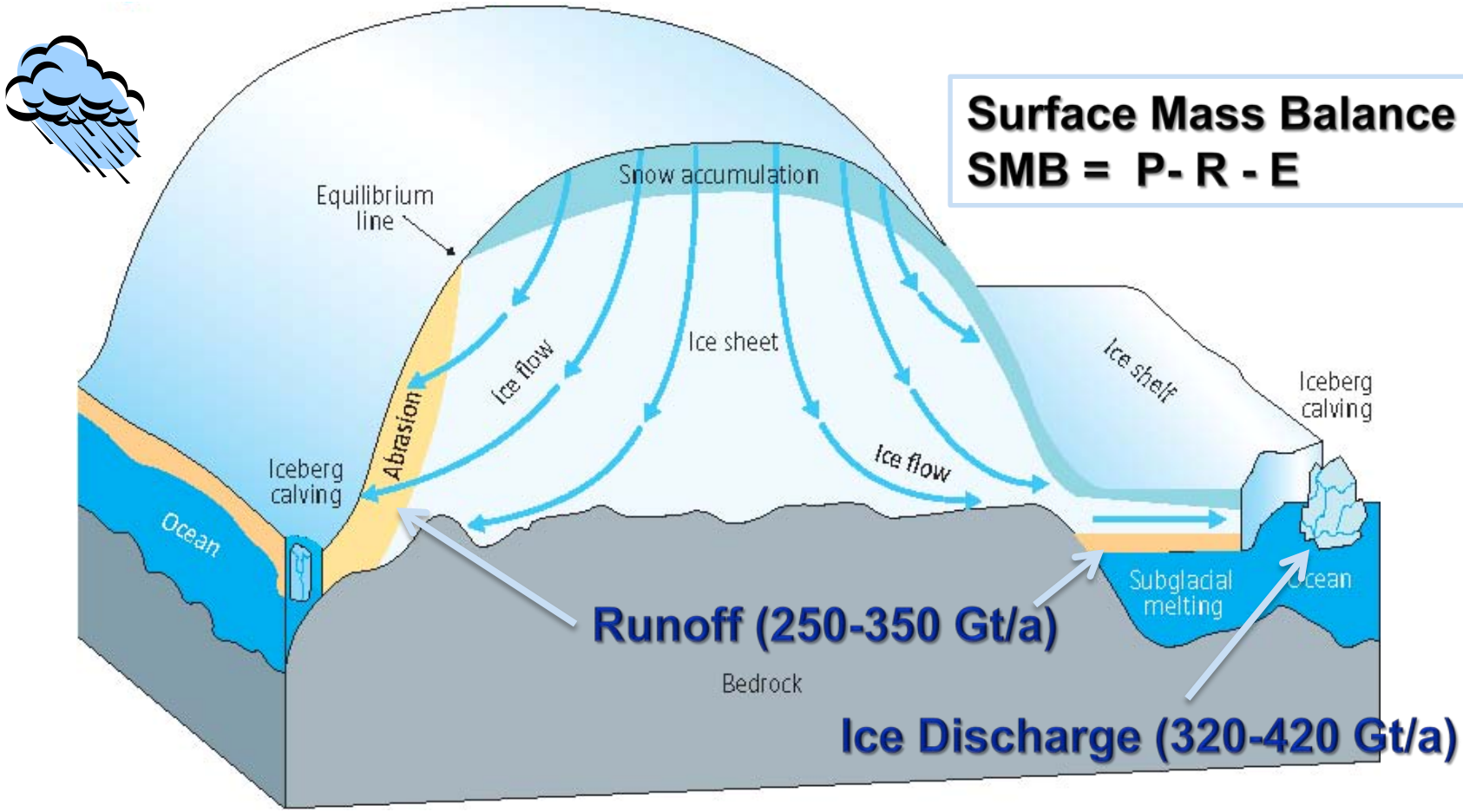
Global Sea Level Rise Scenarios



Greenland Ice Sheet Mass Balance

Precipitation (550-640 Gt/a)

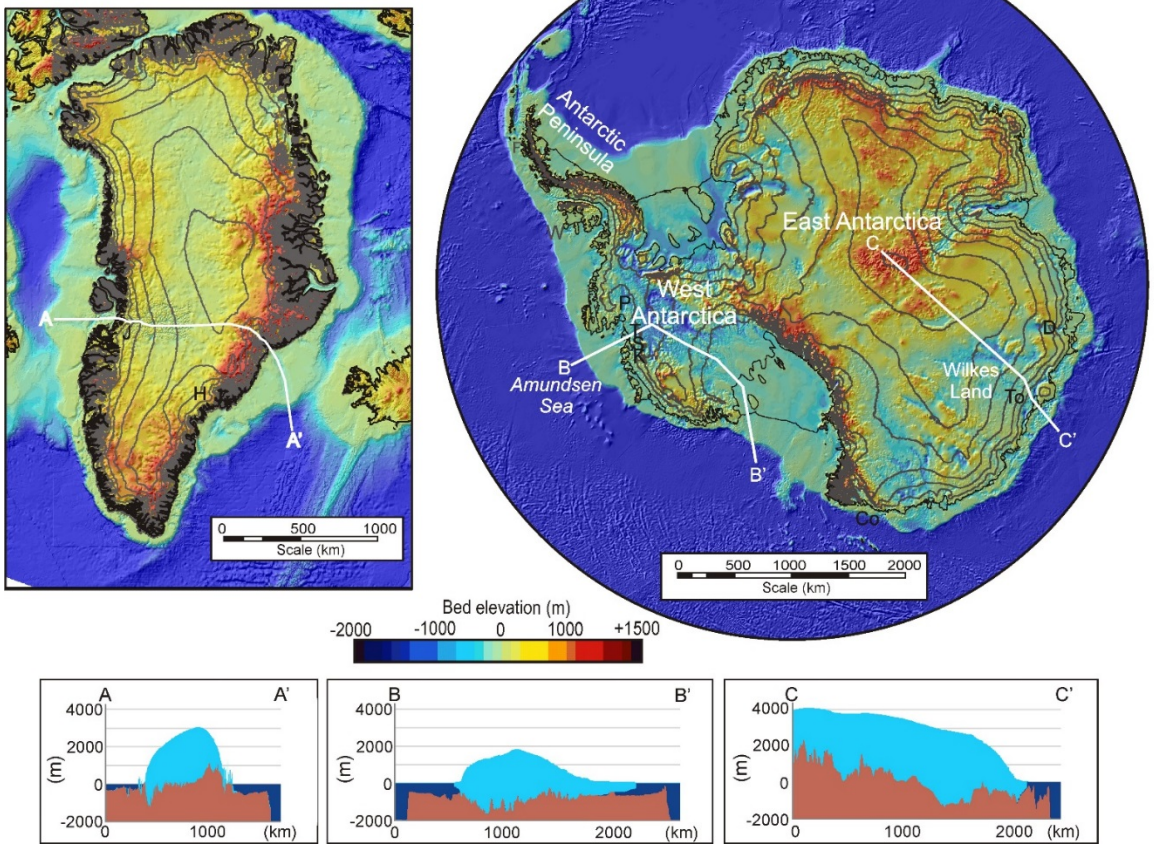
Evaporation (10-45 Gt/a)

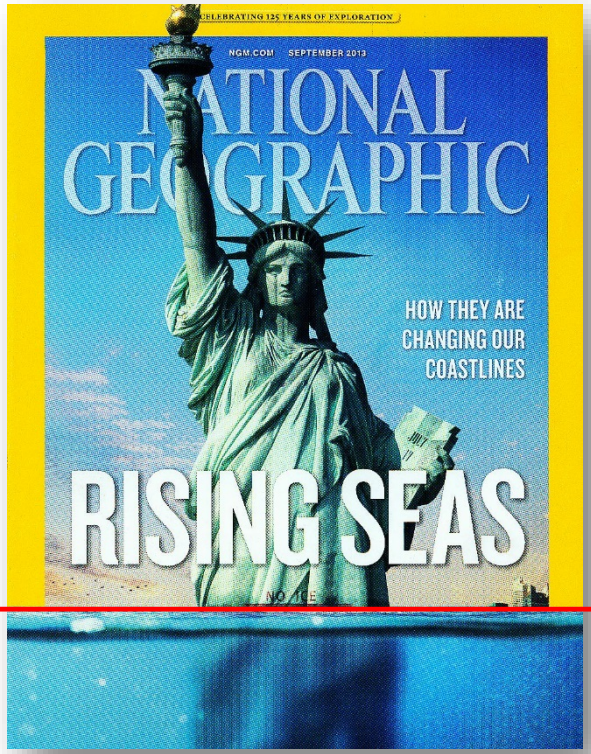


Surface Mass Balance
SMB = P- R - E

Negative Balance (-50 to - 200 Gt/a)

Greenland and Antarctica

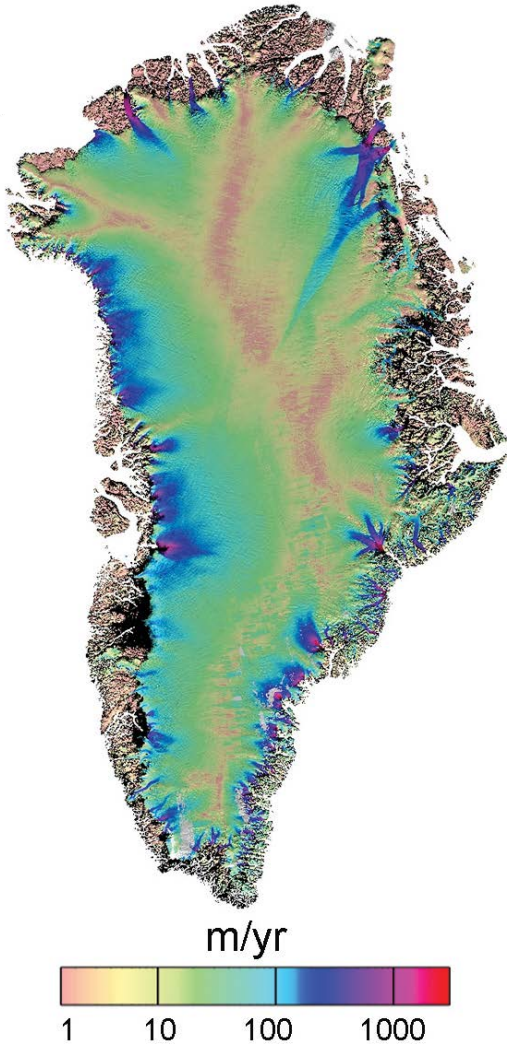




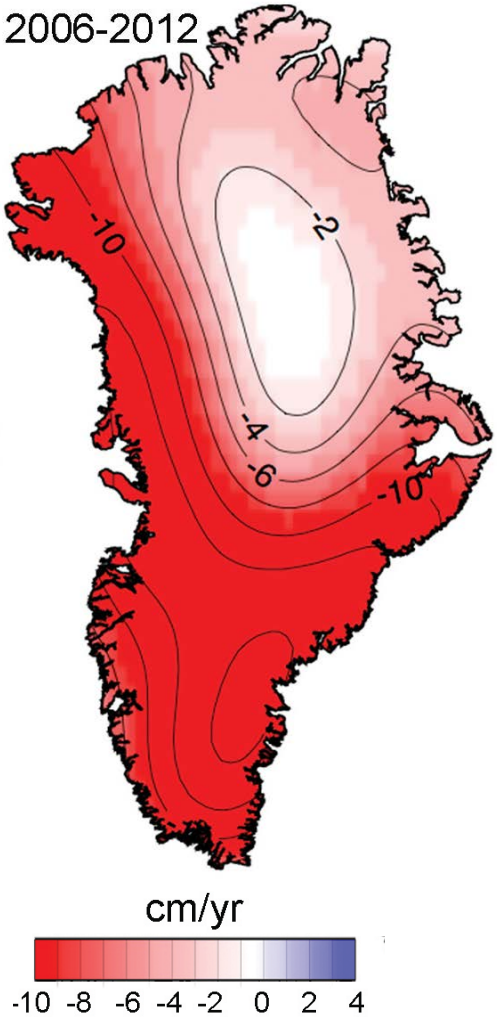
Sea level rise from both ice sheets: 66 m

Greenland Ice Sheet

Ice flow speed



Mass loss



Ice loss 1992-2001:
34±40 Gt yr^{-1}

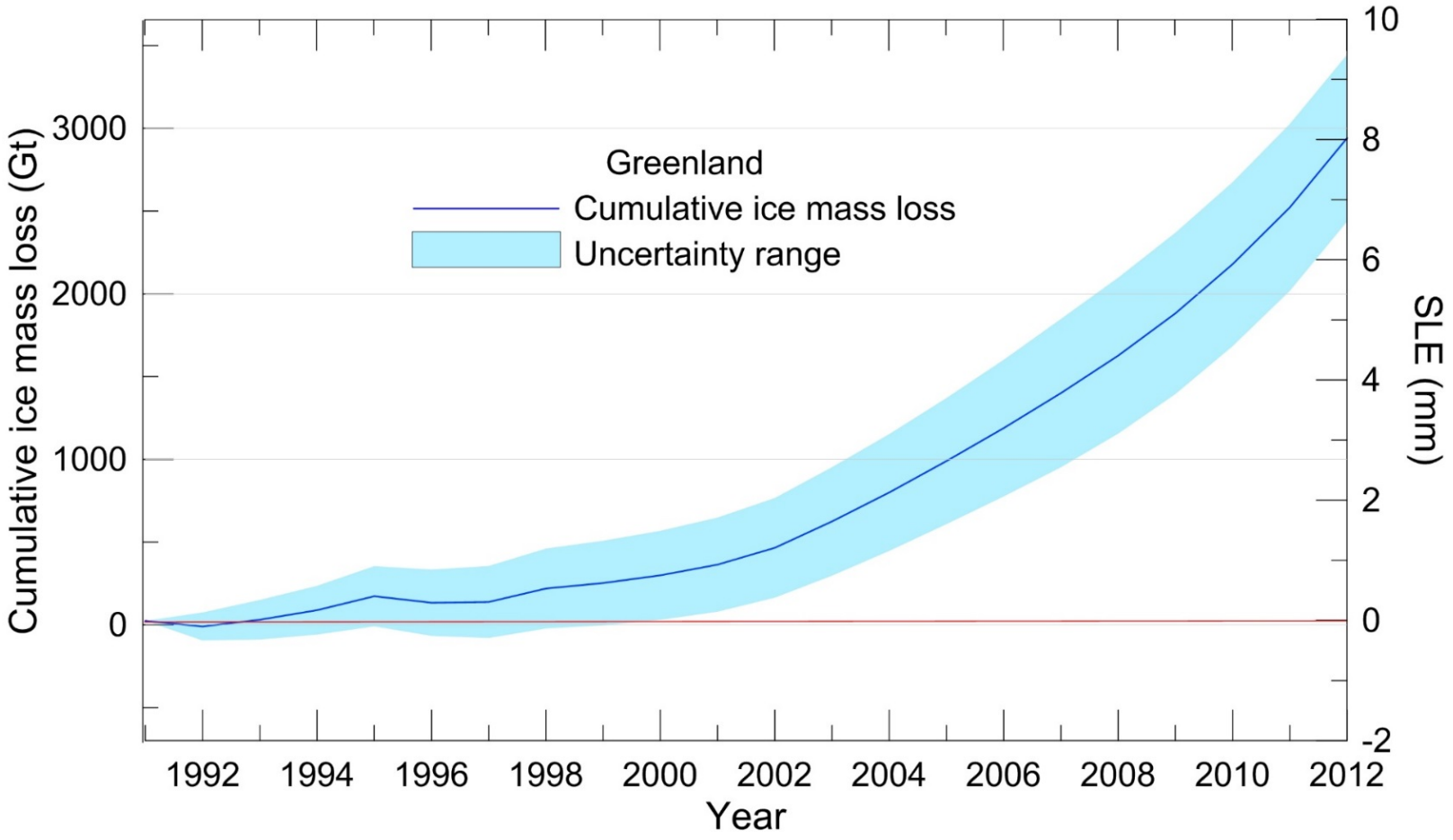
Ice loss 2002-2011:
215±58 Gt yr^{-1}

Melt and ice dynamics make up 50% each for the ice loss

Most outlet glaciers have double their flow speed

Warming of ocean temperature around Greenland played an important role in the ice loss

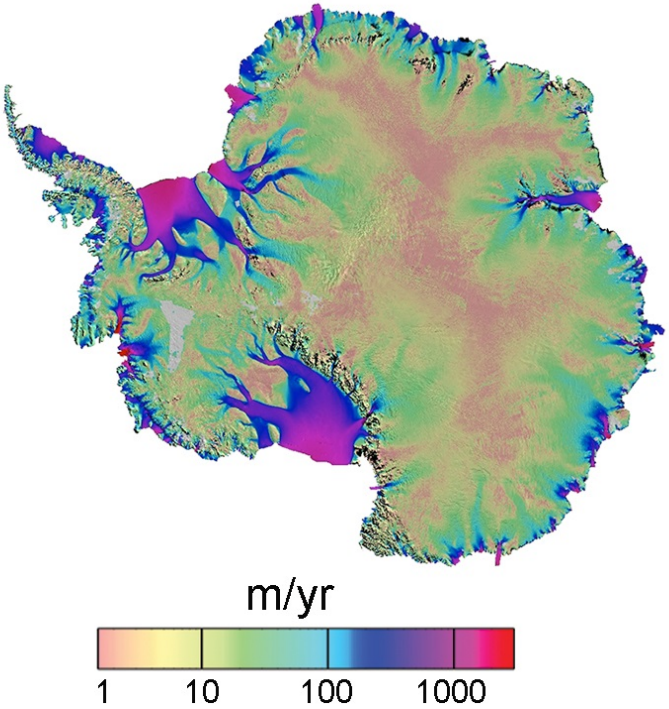
Greenland Ice Sheet Mass Loss



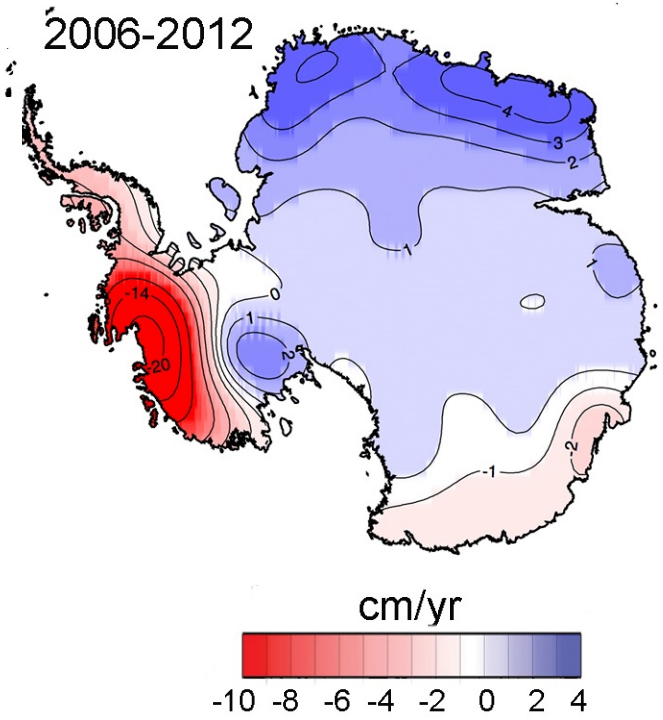
- Mass loss by the Greenland ice sheet increased the global sea level by 8 mm since 1992
- The mass loss accelerated since 2002

Antarctic Ice Sheet

Ice flow speed



Mass loss

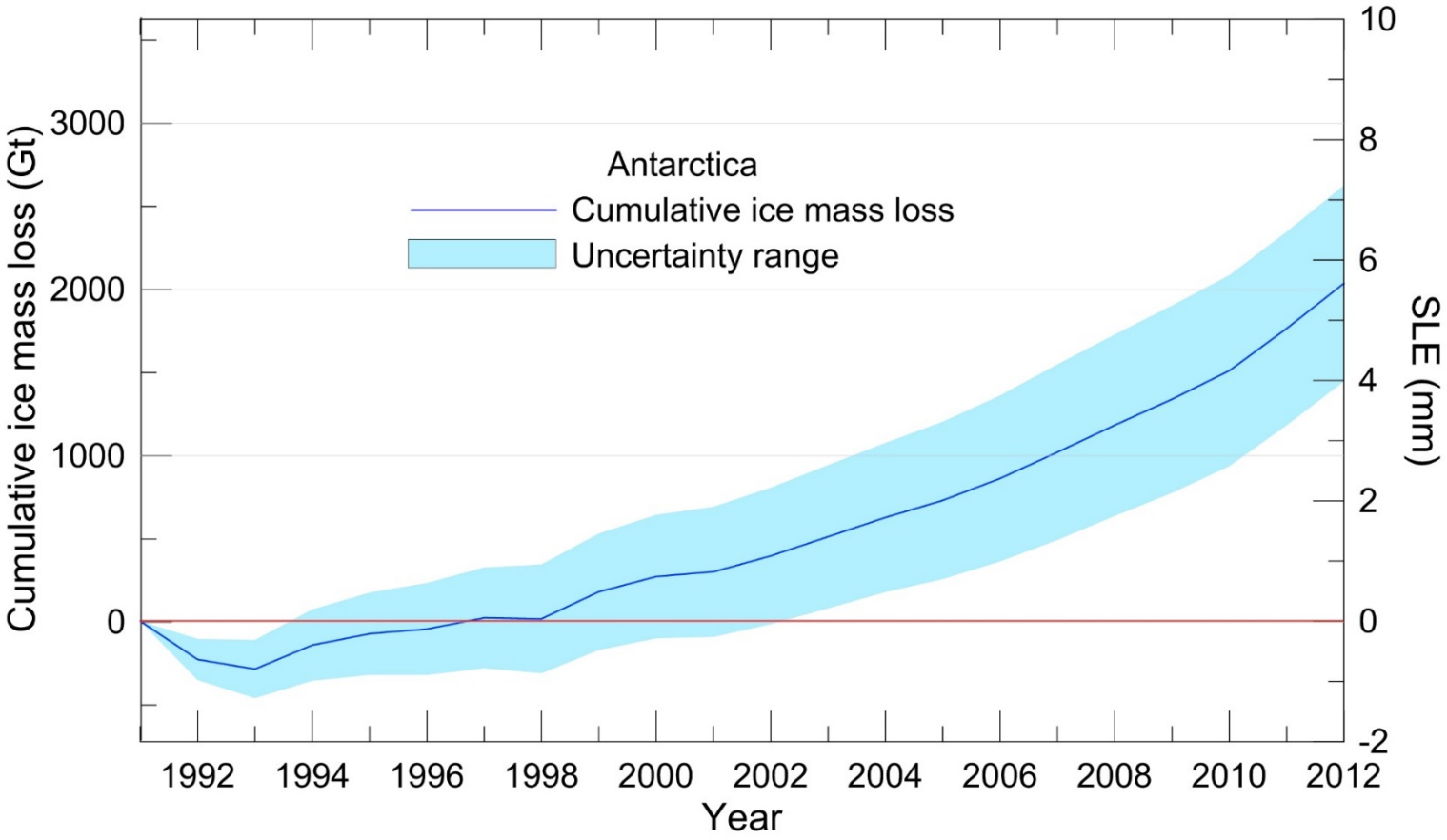


Mass loss 1992-2001: 30±67 Gt yr^{-1}

Mass loss 2002-2011: 147±74 Gt yr^{-1}

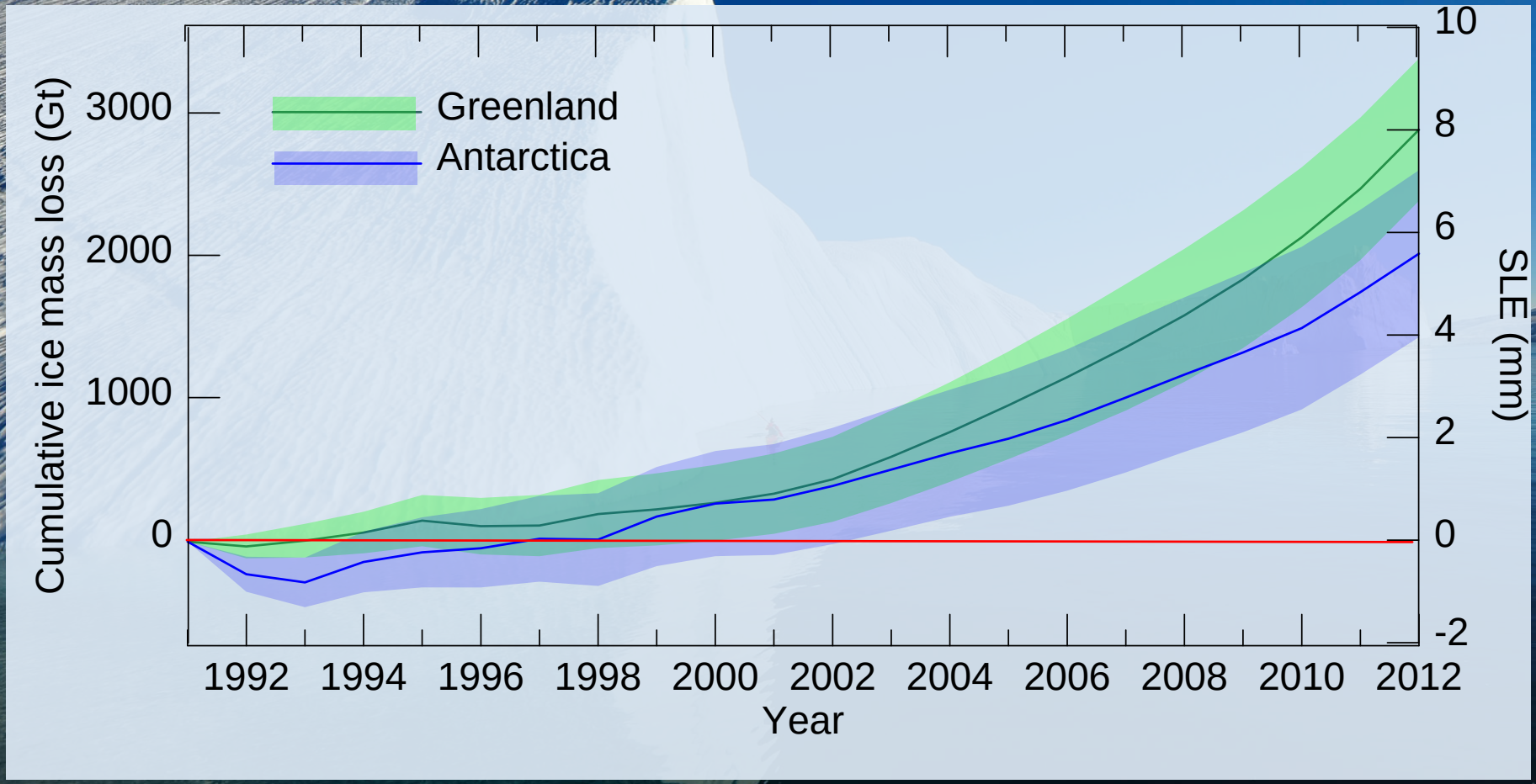
Mass loss in the Antarctic Peninsula and in the Amundsen Sea, West Antarctica

Antarctic Ice Sheet

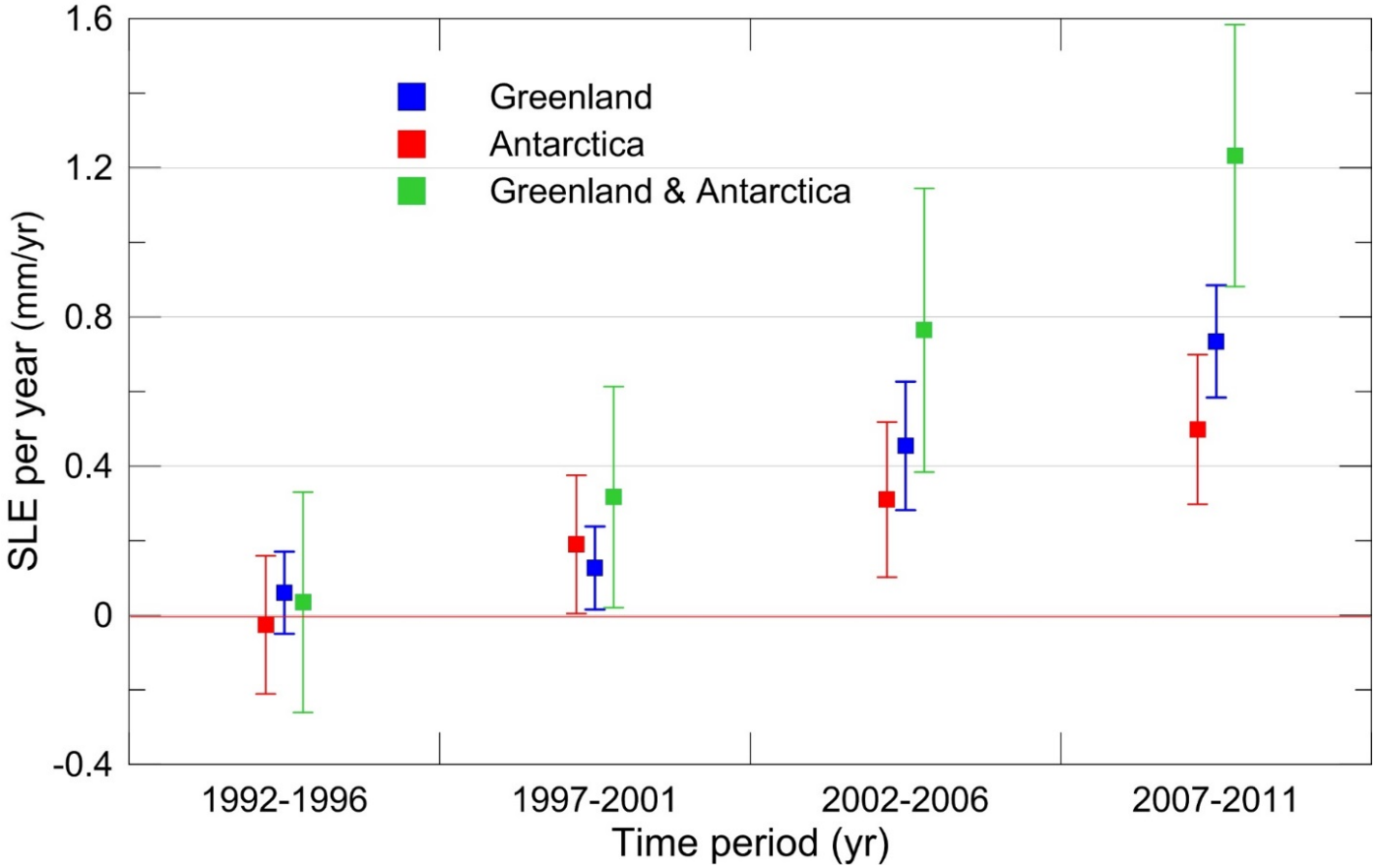


- Ice loss from Antarctica is responsible for 5.5 mm sea level rise since 1992
- Antarctica gained mass in the 90's and show an mass loss (ice loss) since 1998 IPCC, AR5

Mass Loss from Ice Sheets

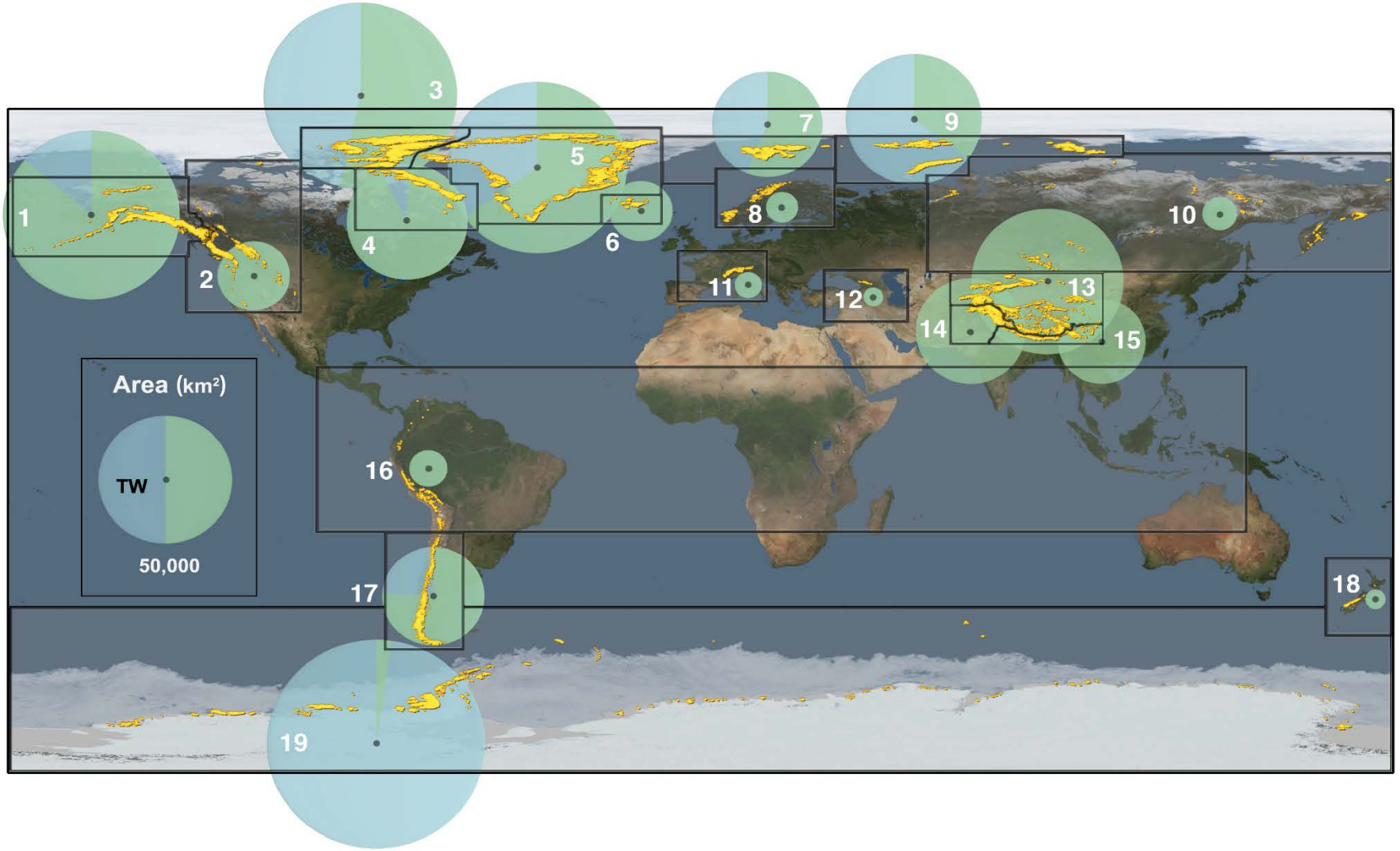


Greenland and Antarctica
5-year mean values



- Greenland and Antarctic ice sheets are responsible for a sea level rise of 1.2 mm/yr during the time period 2007 - 2011

Global Distribution of Glaciers and Ice Caps



Global distribution of glaciers (yellow, area increased for visibility) and area covered (diameter of the circle), sub-divided into the 19 RGI regions (white number). The area percentage covered by tidewater (TW) glaciers in each region is shown in blue. *Data from Arendt et al. (2012) and Gardner et al. (2013).*

Rhone Glacier 2006

Martin Funk, ETH Switzerland

Rhone Glacier 2011

Rhone Glacier 1856

Martin Funk, ETH Switzerland

Rhone Glacier 1962

Martin Funk, ETH Switzerland

Rhone Glacier 2050

Martin Funk, ETH Switzerland

Glacier National Park

Grinnell Glacier from Mt. Gould
1938 - 2006

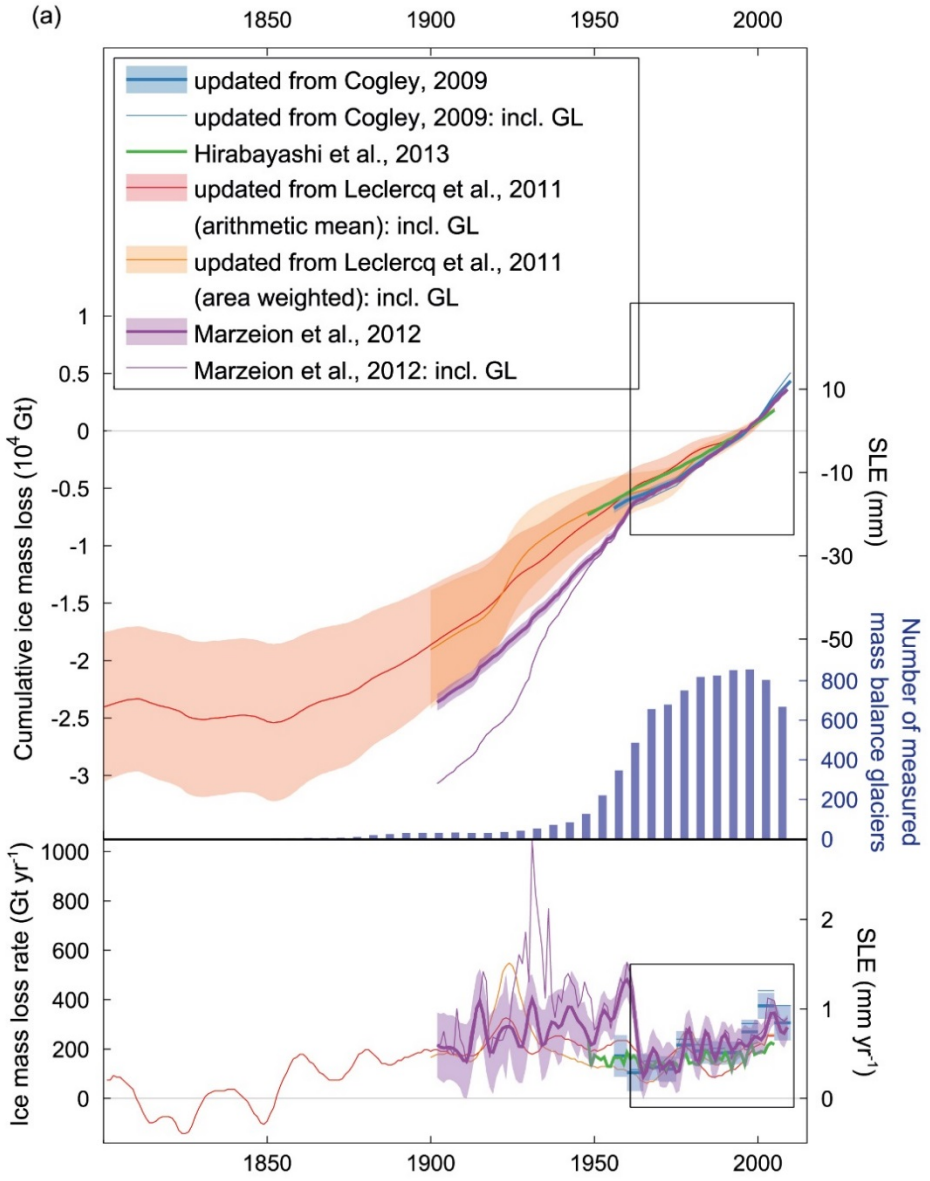
1938
Hileman photo
GNP Archives

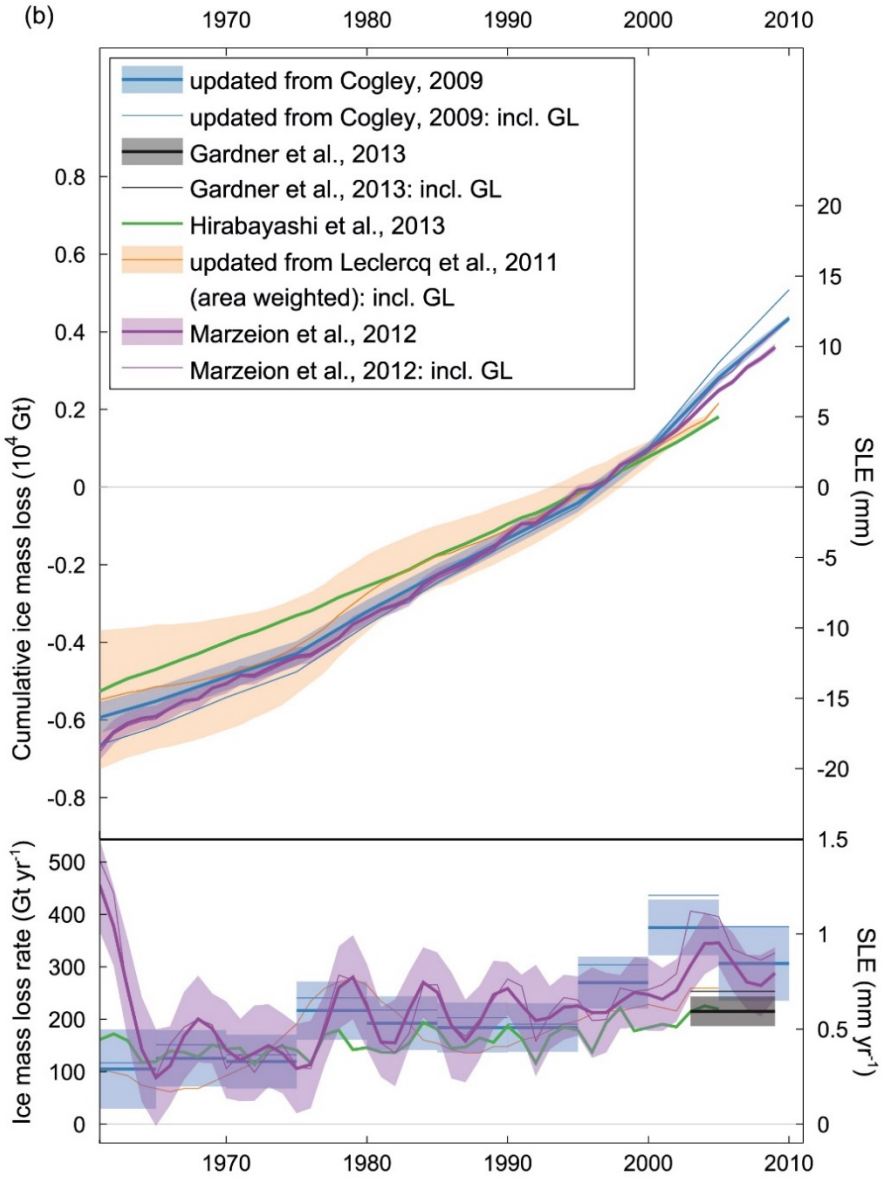
1981
Key photo
USGS

1998
Fagre photo
USGS

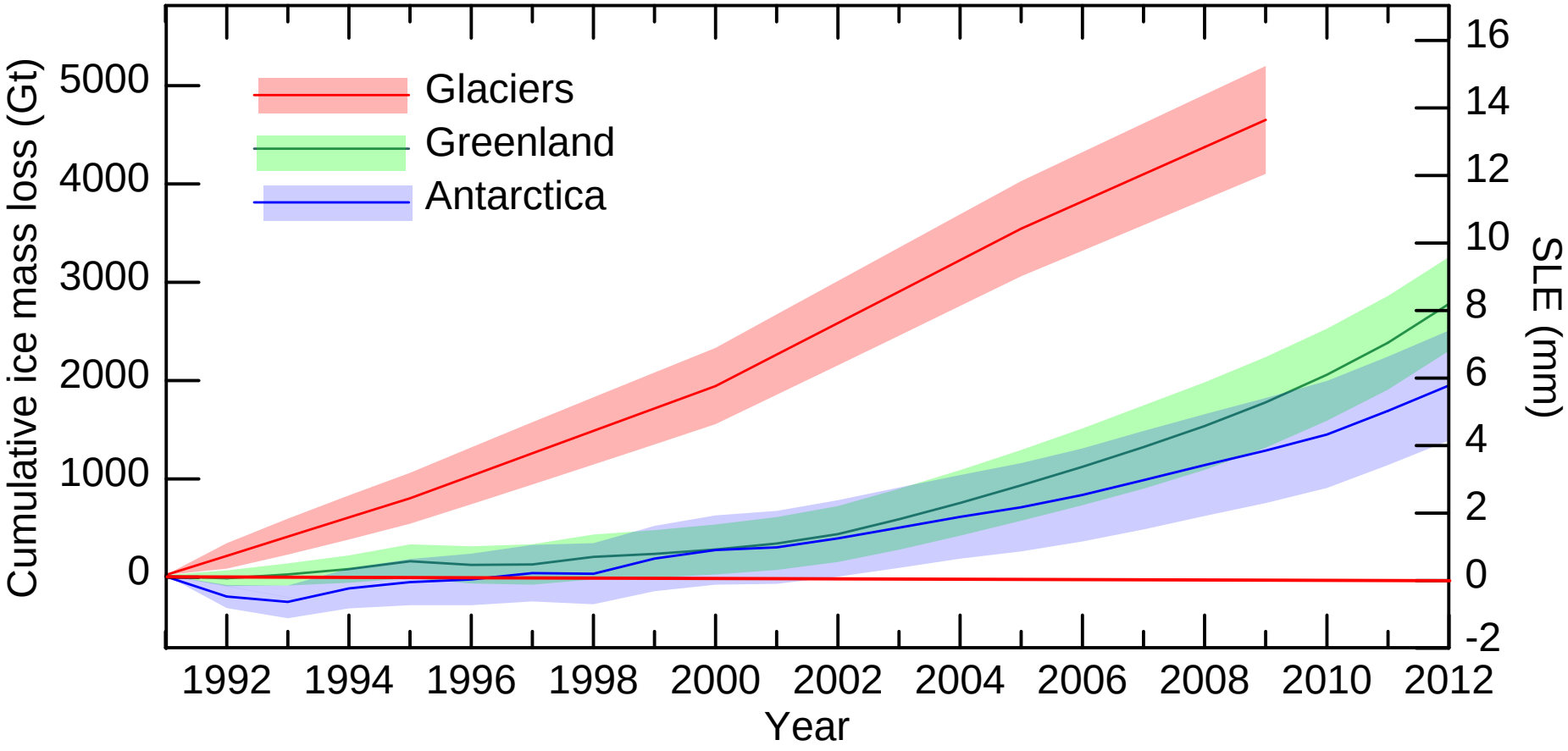
2006
Holzer photo
USGS

Global cumulative (top graphs) and annual (lower graphs) glacier mass change for (a) 1801–2010 and (b) 1961–2010 (IPCC AR5)

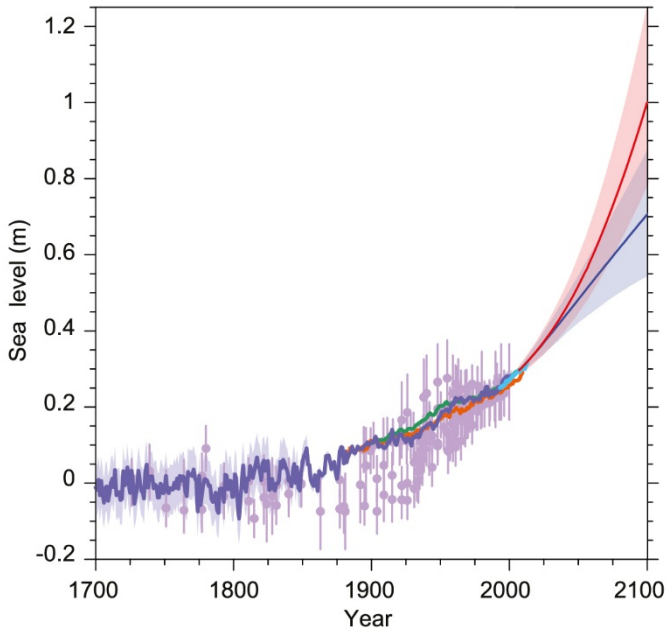




Cryospheric Sea Level Contribution 1992 - 2012

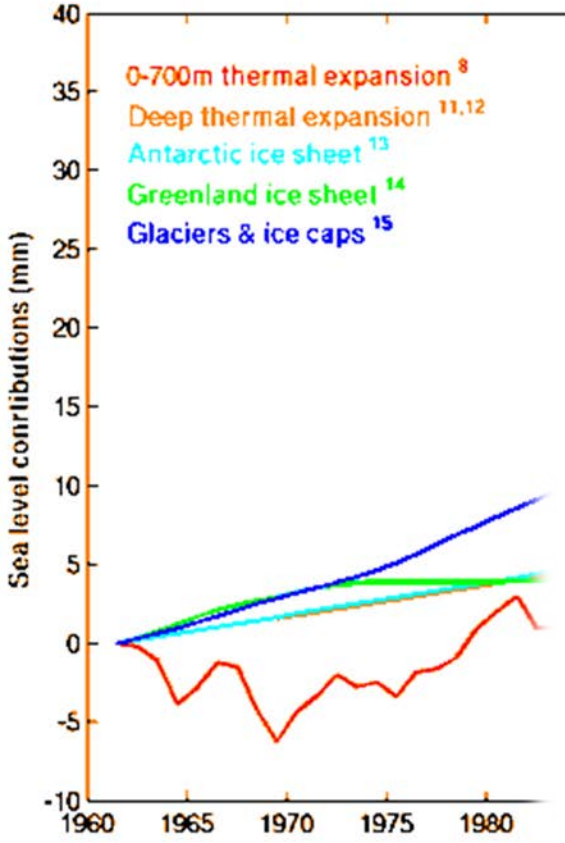


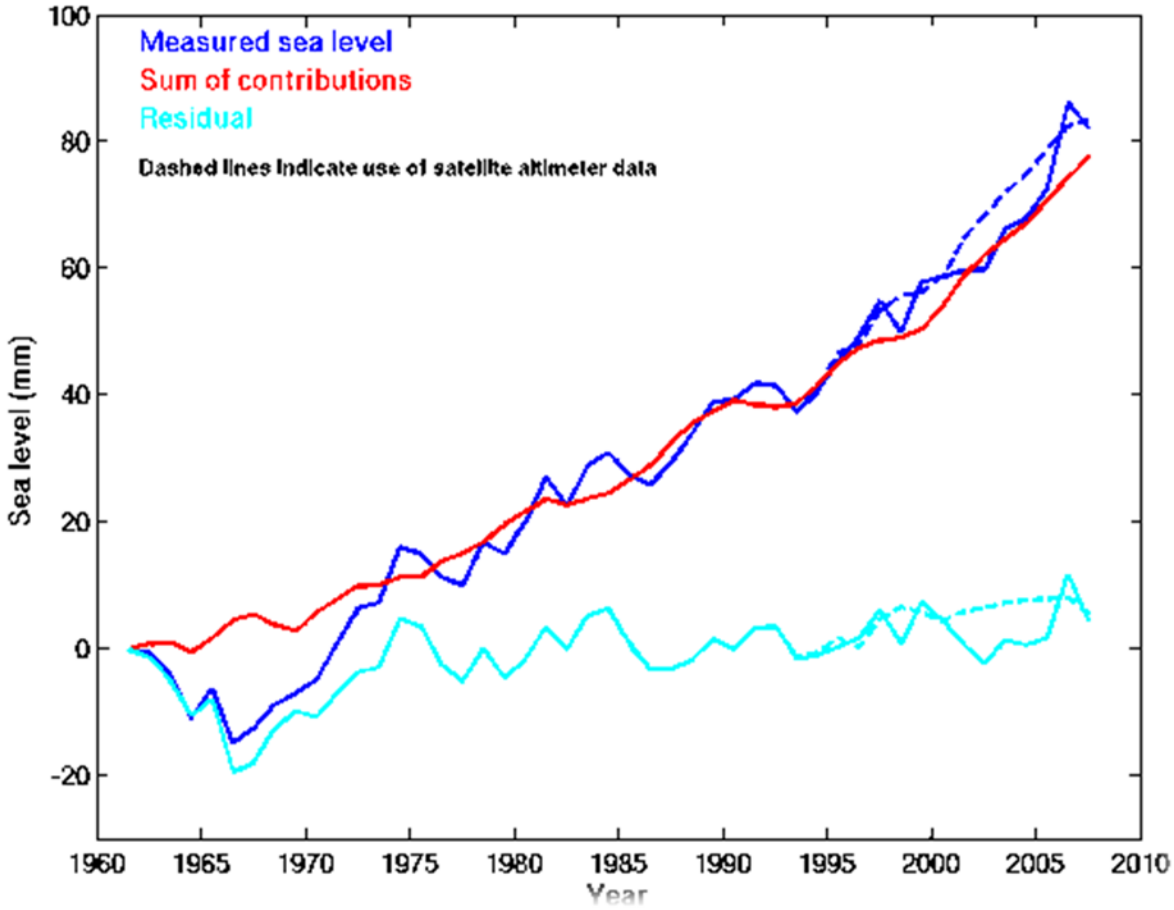
Glacier Number 1, Tien Shan, China



Sea level will increase even if we would stop today all the GHG emissions; the system is not in balance yet with the current warming

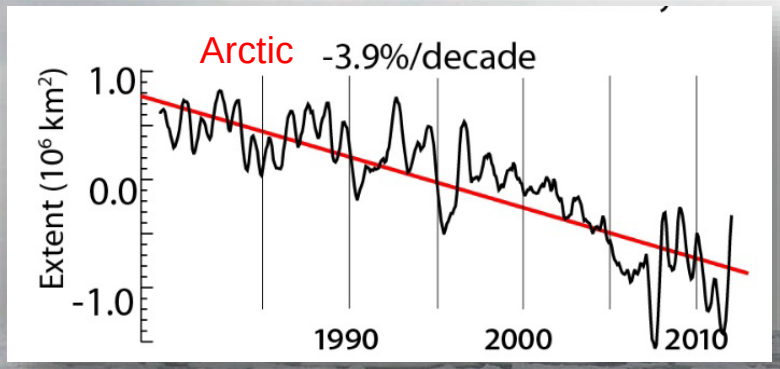
Uncertainties in SLR reduced

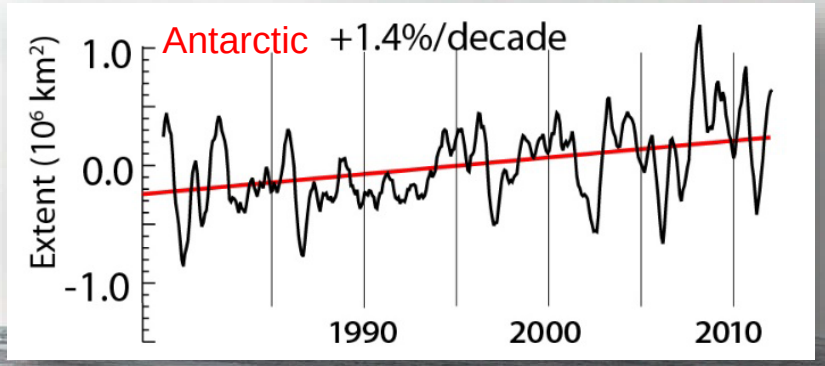




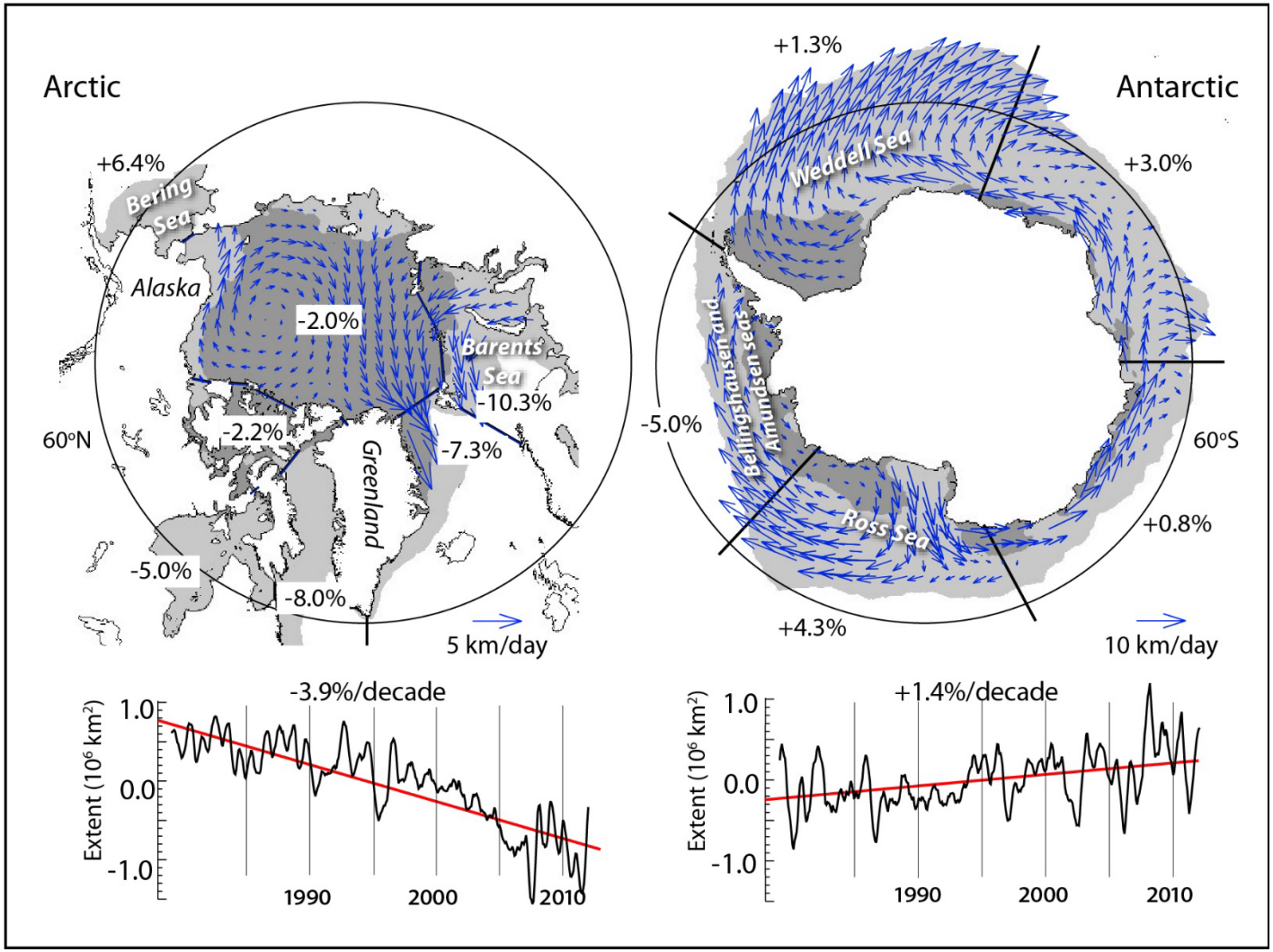
Note: Terrestrial Storage terms
not included.

Sea Ice

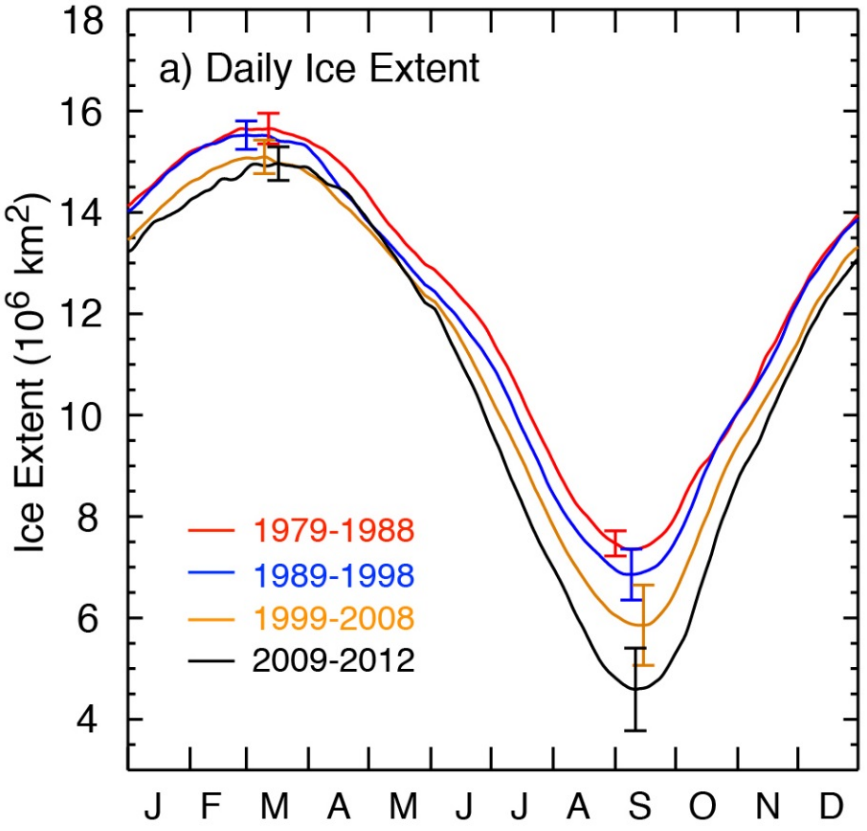

Arctic -3.9%/decade
Extent (10^6 km^2)
1.0
0.0
-1.0
1990
2000
2010


Antarctic +1.4%/decade
Extent (10^6 km^2)
1.0
0.0
-1.0
1990
2000
2010

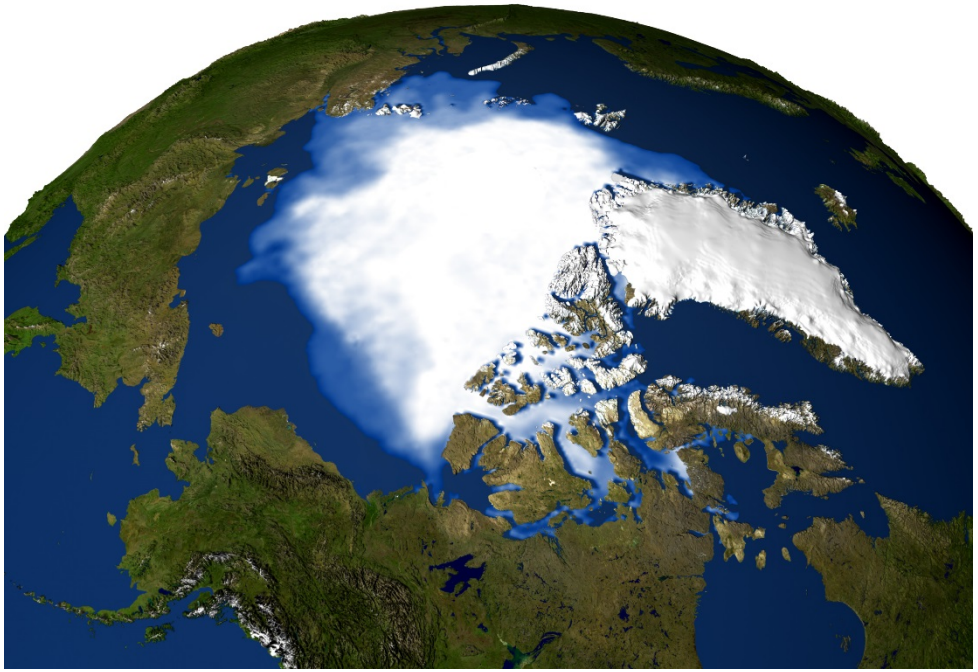
Sea Ice Variability in both Hemispheres



Sea Ice in the northern Hemisphere

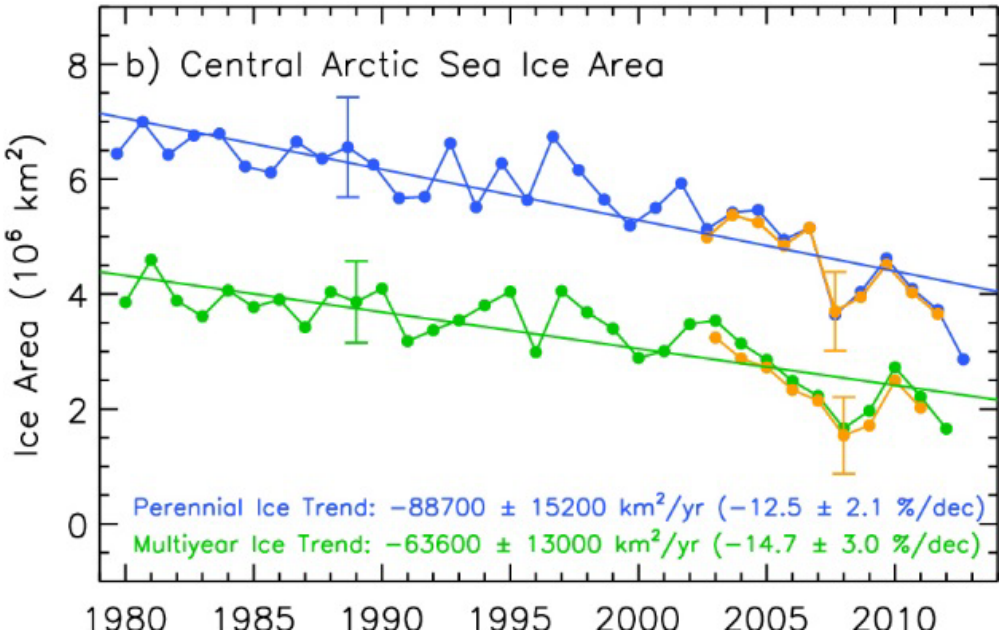


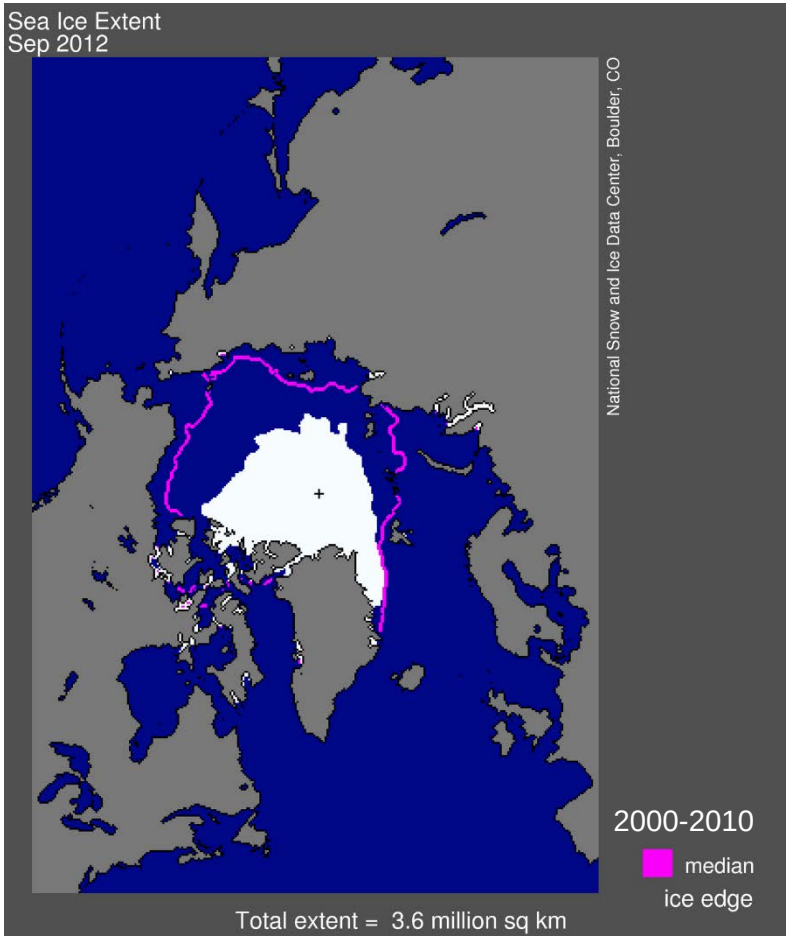
September 2012



- Large ice extent retreat in the summer month
- Sea ice cover has been reduced further in recent years

Sea Ice of the northern Hemisphere





- First-year ice decreased in extend by 13% per decade,
- Multi-year ice decreased by even more – 15% per decade

Summary

Observed changes in the climate system:
The atmosphere and the ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentration of greenhouse gases has increased (IPCC SPM).

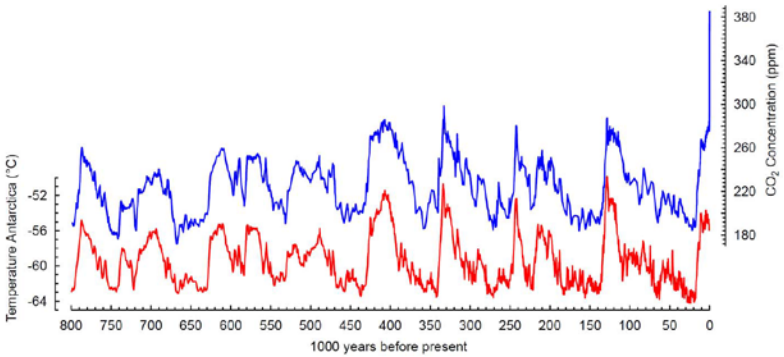
Atmosphere: each of the three decades has been successfully warmer.

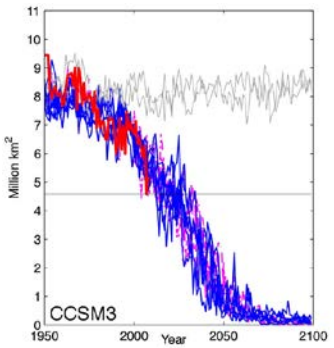
Ocean: Ocean warming dominates the increase in energy stored in the climate system(90%).

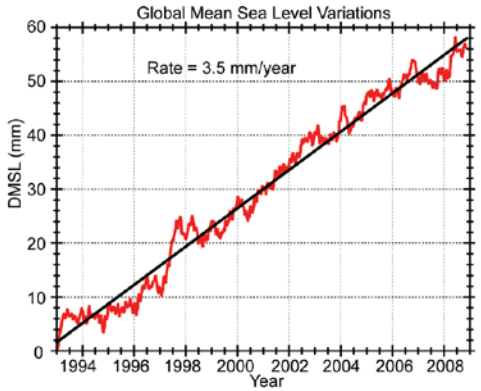
Cryosphere: GIS & Ant have been losing mass, glaciers continue to shrink, and NH sea ice decreases.

Sea Level: SLR has been larger than the previous two millennia.

Carbon and biogeochmical cycle: CO_2, methane, nitrous oxide have increased to levels unprecedented in the last 800,00 years.







Question

Sensitive regions and adaptation:
Where are sensitive regions on Earth where climate change will have an impact first or most significant. Should we implement adaptation in sensitive regions first – or what are the priorities?

Challenge

Regional changes are most important but the least known:
Global sea level rise prediction has little meaning for the Pacific Ocean when the regional footprint is not known or not well understood.