Cryospheric Contributions to Sea-Level Rise and Variability

- Global Sea Level Rise
- Greenland Ice Sheet Mass Balance
- Antarctic Mass Balance

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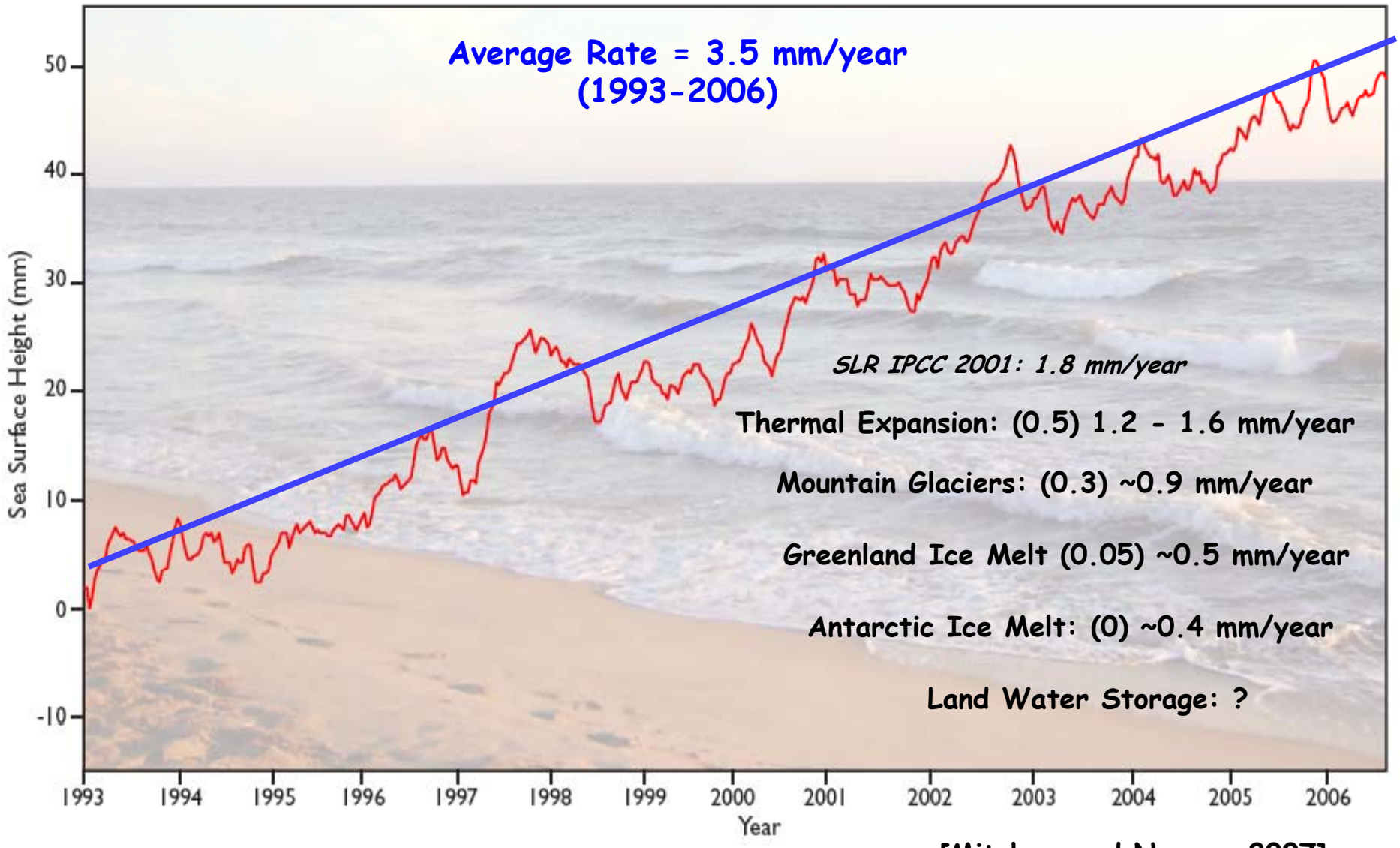
Abrupt Climate Change

A large-scale change in the climate system that takes place over a few decades or less, persists for at least a few decades, and causes substantial disruptions in human and natural systems.

Can a rapid change in glaciers and ice sheets and hence sea level rise cause an abrupt climate change?

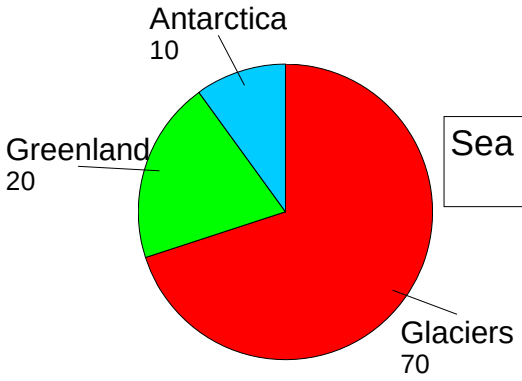
Global Mean Sea Level from Satellite Altimetry



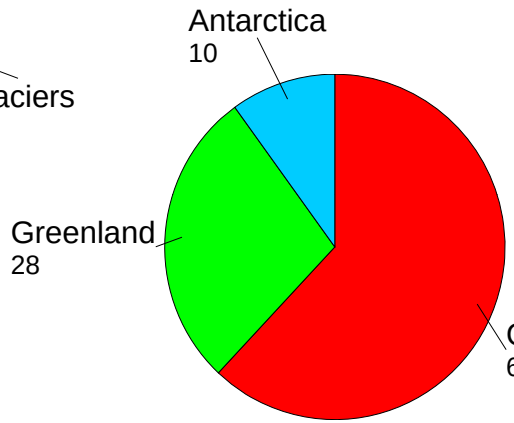
[Mitchum and Nerem, 2007]

Cryospheric SLR

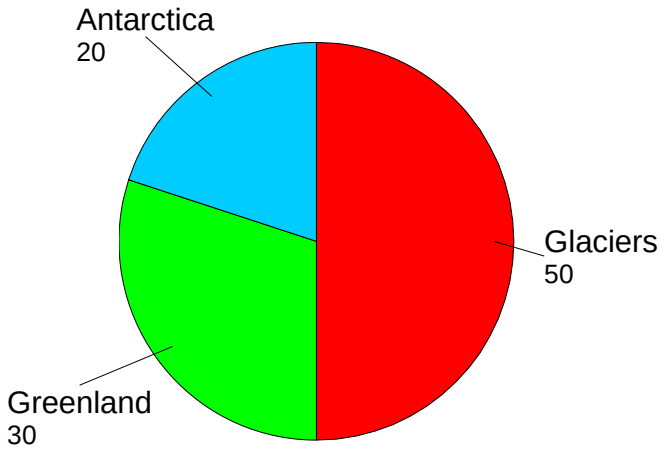
Sea Level Rise (%) [*IPCC*, 2006]]
100% = 1.28 mm a^{-1}



Sea Level Rise (%) [*Meier et al.*, 2007]
100% = 1.8 mm a^{-1}

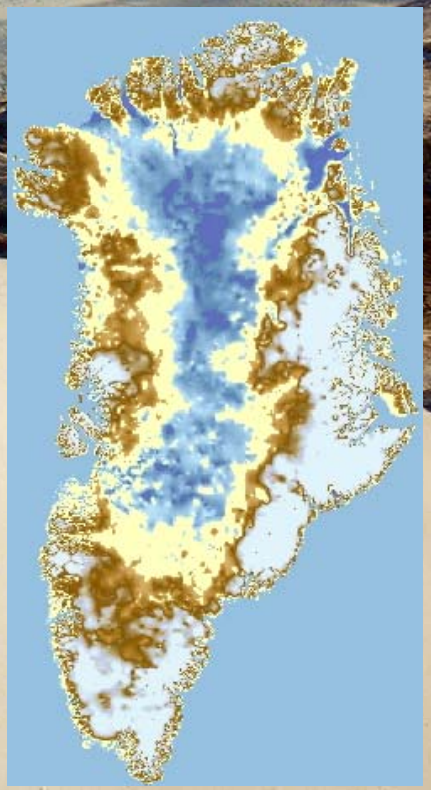


Sea Level Rise (%) [latest GRACE data)]
100% = 2.2 mm a^{-1}



Recent change in the contribution of glaciers and ice sheets (Greenland and Antarctica) to sea level rise.

Greenland Ice Sheet



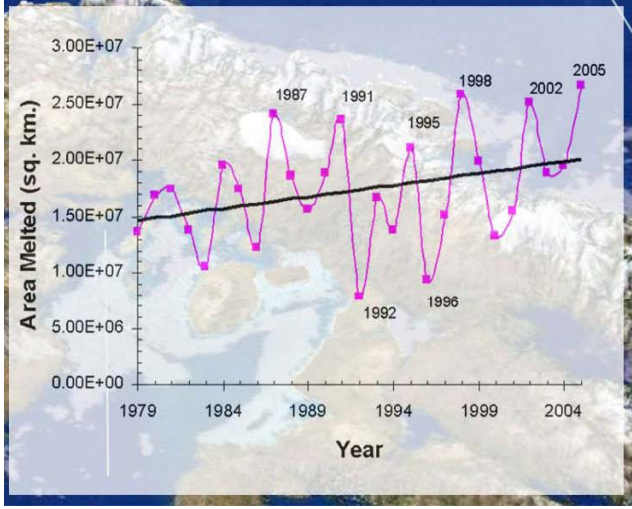
Greenland 2005 Melt Extent

Total Greenland ice sheet melt area increased on average by 20% from 1979 to 2006. On the western part of the ice sheet the melt area increased by 30%

2005 Melt Extent

Mean Melt Extent (1979 - 2005)

The increasing trend in the total area of melting bare ice is unmistakable at 13% per year



Swiss Camp

Aasiaat

Kangerlussuaq

Sisimiut

Nuuk

Paamiut

Qaqortoq

Narsarsuaq

Tasiilaq

Russell Huff and Konrad Steffen, University of Colorado/CIRES

Greenland Ice Mass Loss from GRACE

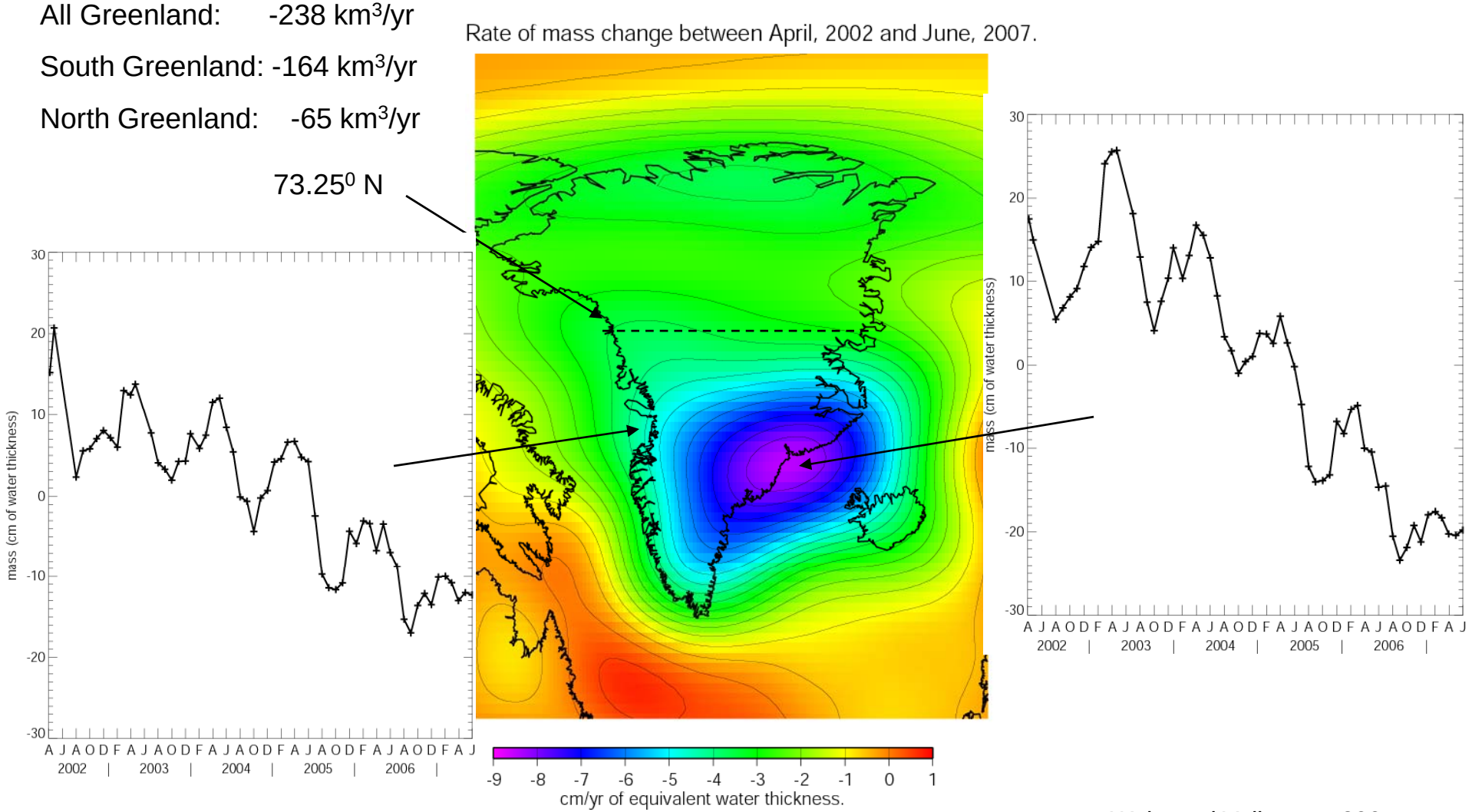
Rate of Ice volume change:

All Greenland: -238 km^3/yr

South Greenland: -164 km^3/yr

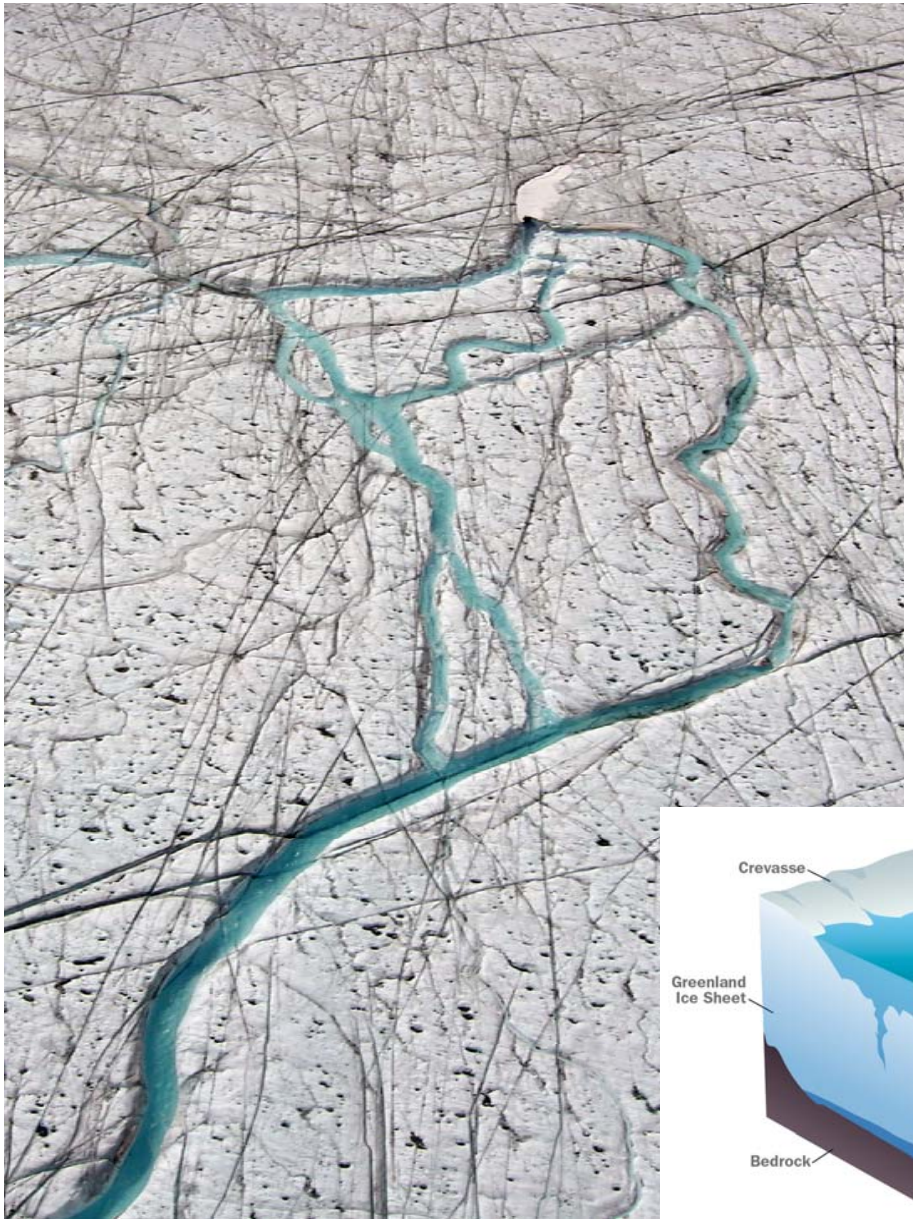
North Greenland: -65 km^3/yr

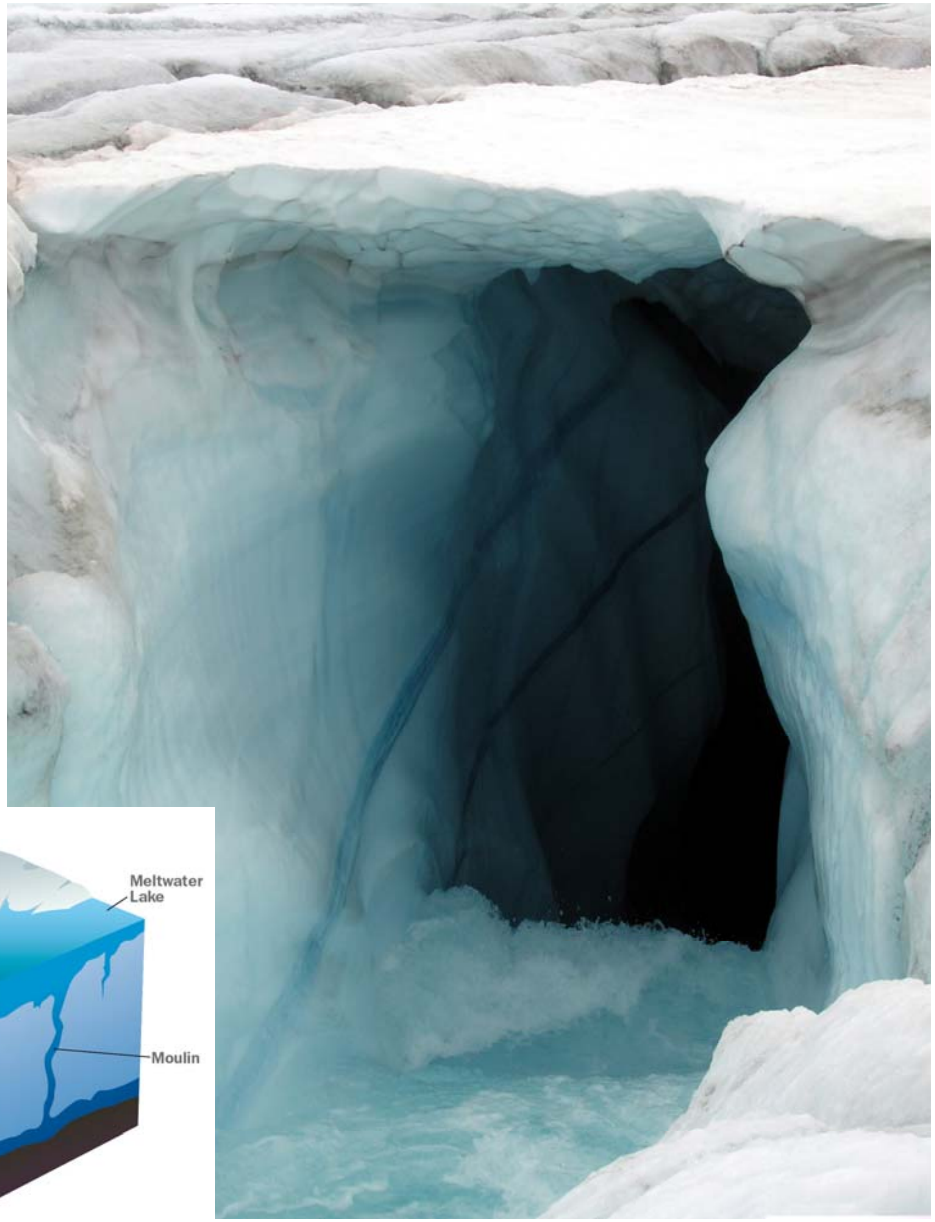
This annual ice loss from Greenland covers the D. C. area with 0.8 miles of water, or the New England States with 4.5 feet of water.



Wahr and Velicogna, 2007

Melt Induced Ice Flow and Moulins





Antarctica

Sea level rise contributions from Antarctica is increasing (~0.4 mm a^{-1})

- Large uncertainty and debate
- Lack of large-scale historic observations

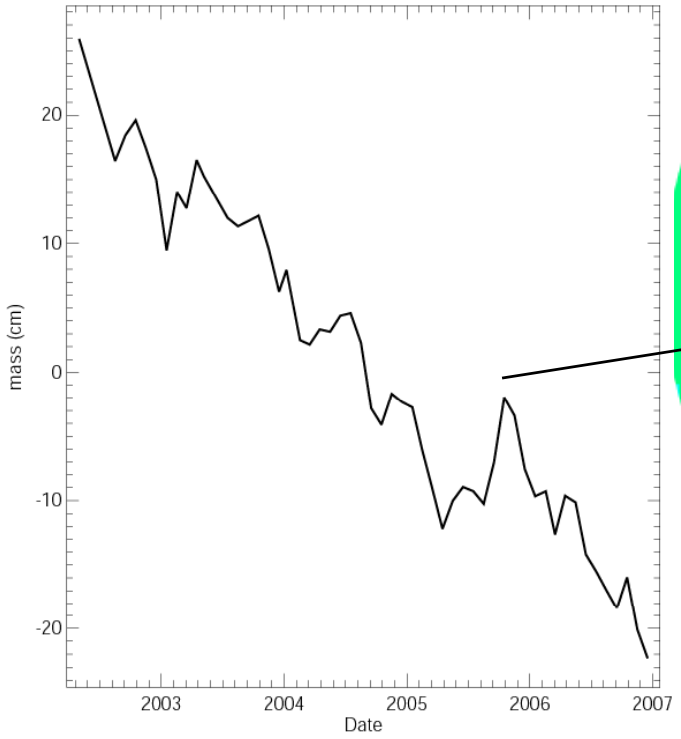
- West Antarctic ice sheet (7 m SLE) grounded below sea level on marine sediment experiencing high geothermal heat flow

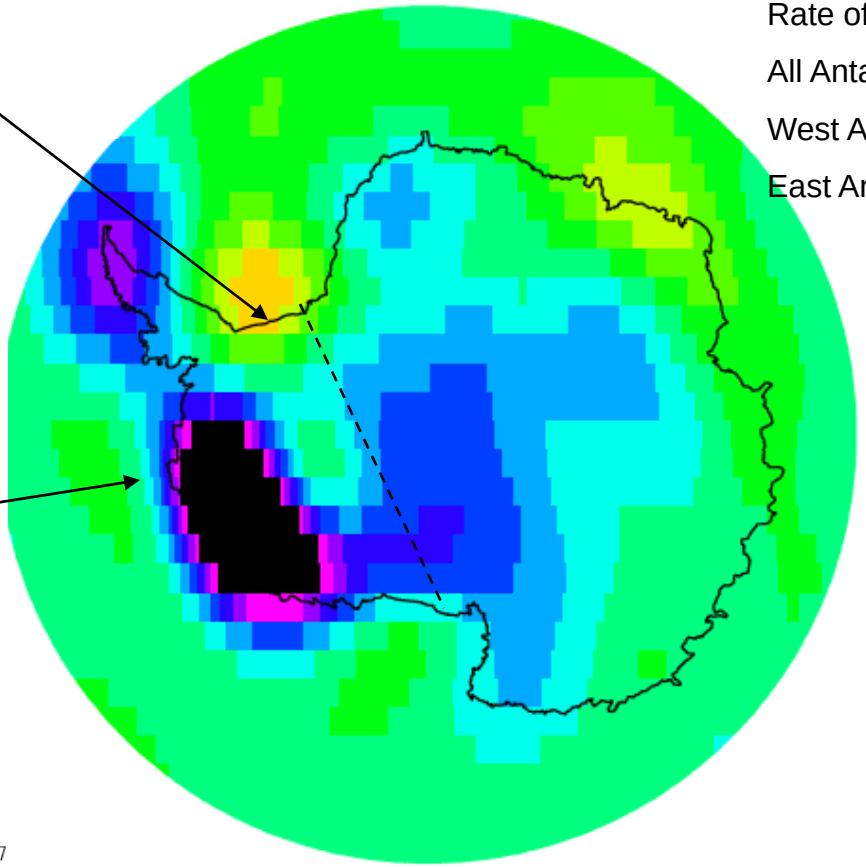
- **Inherently unstable?**

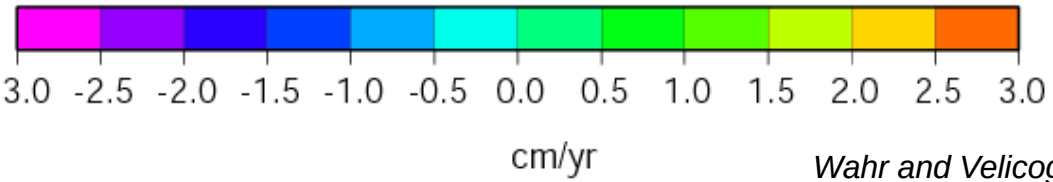
Antarctic Ice Mass Loss from GRACE

East/West dividing line

Rate of mass change between April, 2002 and June, 2007.







Rate of ice volume change:

All Antarctica: -149 km^3/yr

West Antarctica: -115 km^3/yr

East Antarctica: -23 km^3/yr

Wahr and Velicogna, 2007

Facts and Uncertainties

- Glaciers are loosing mass and are the largest cryospheric SLR contributor.
- Rapid changes in marginal regions the Greenland and West Antarctic ice sheets show acceleration and thinning.
- No ice-sheet model is currently capable of capturing the glacier speedups in Antarctica or Greenland that have been observe over the last decade (Ozone hole analogy).
- The potentially sensitive regions for rapid changes in ice volume are the West Antarctic Ice Sheet (7 m SLE), or large glaciers in Greenland.
- Future changes in ocean circulation and ocean temperatures will produce changes in basal melting, but the magnitude of these changes is currently not modeled or predicted.
- The current SLR from glaciers and ice sheets is 2.2 mm/a.
- If the ice loss continues at the current accelerated rate, SLR in 2100 will be >0.5 m and possibly reach 1 m in magnitude or more.