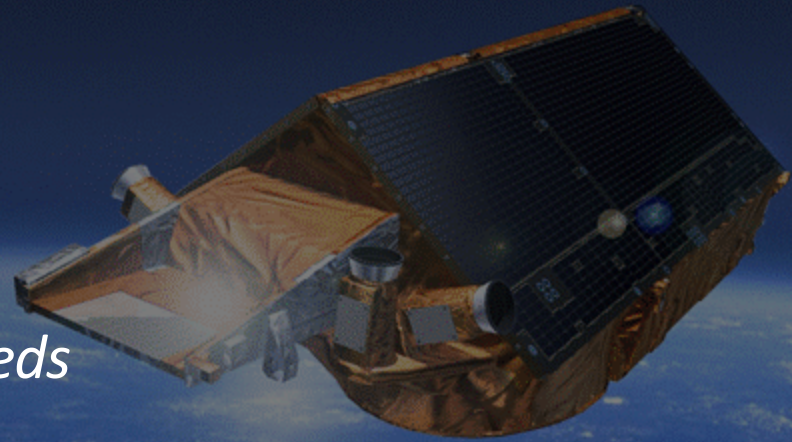


Satellite altimetry = glaciology

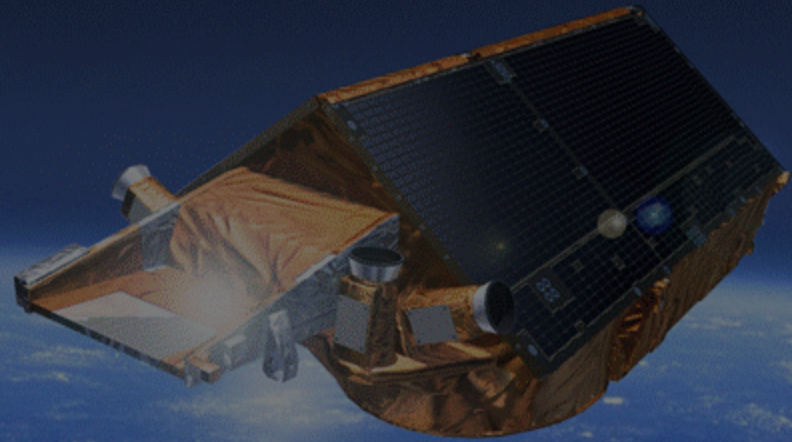
*Andrew Shepherd, Kate Briggs, Lin Gilbert, Anna Hogg,
Hannes Konrad, Malcolm McMillan, Alan Muir, Andy
Ridout, Rachel Tilling*

*Centre for Polar Observation
and Modelling, University of Leeds*

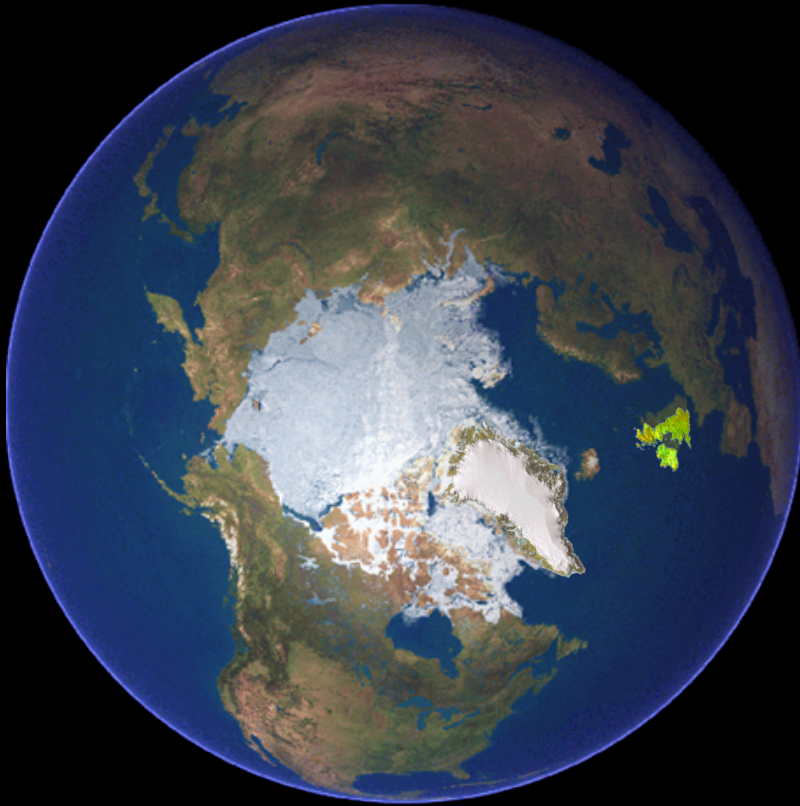


Outline

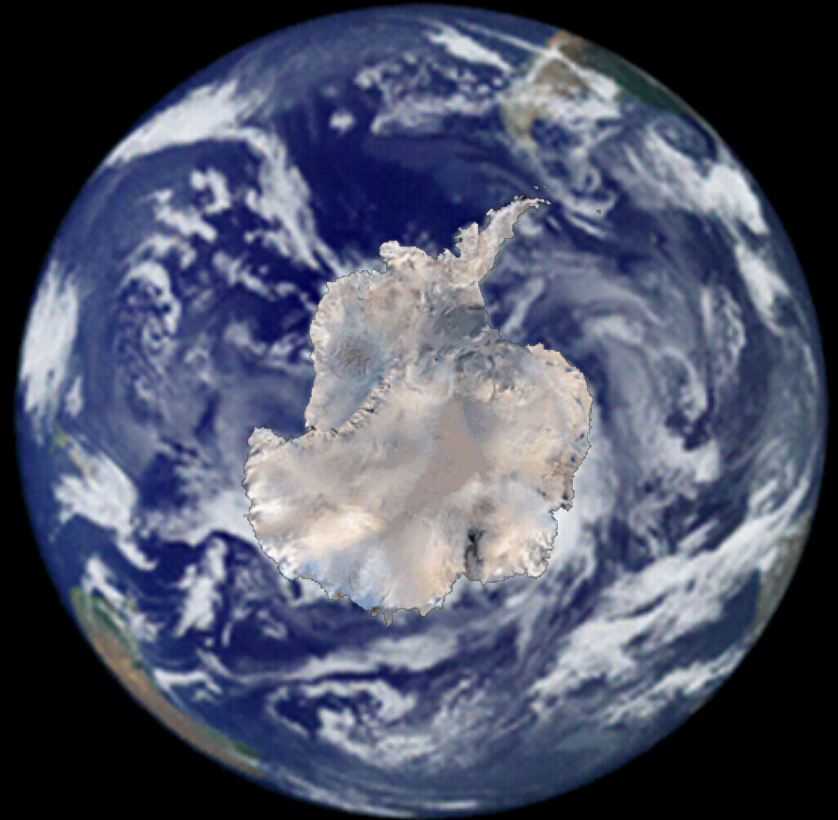
1. Why is ice an important part of Earth's climate?
2. Ice Sheet Altimetry
3. Ice Sheet Mass Balance
4. Sea Ice Altimetry



1. Ice and Climate

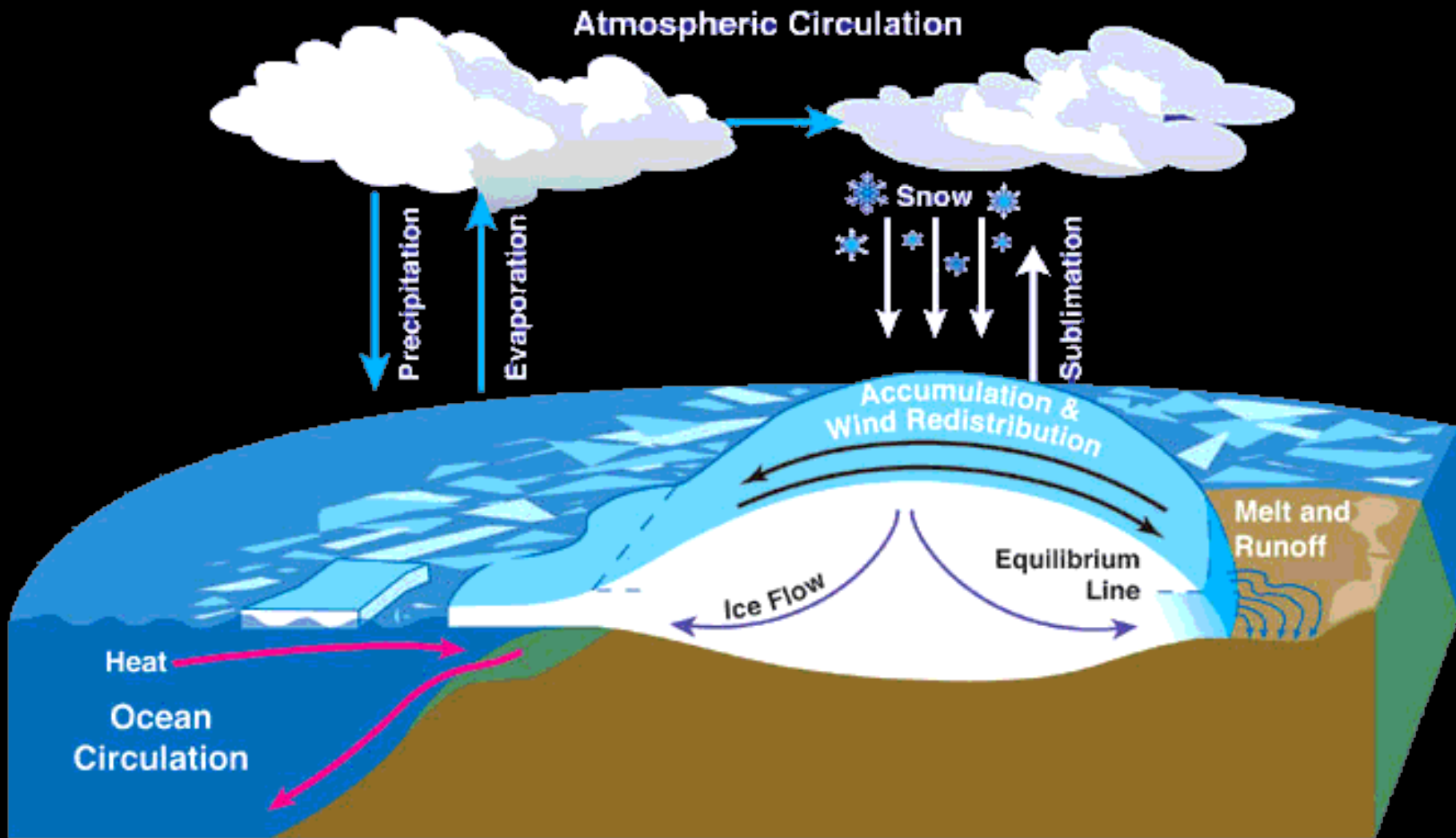


Greenland contains
enough ice to raise
sea levels by 7m



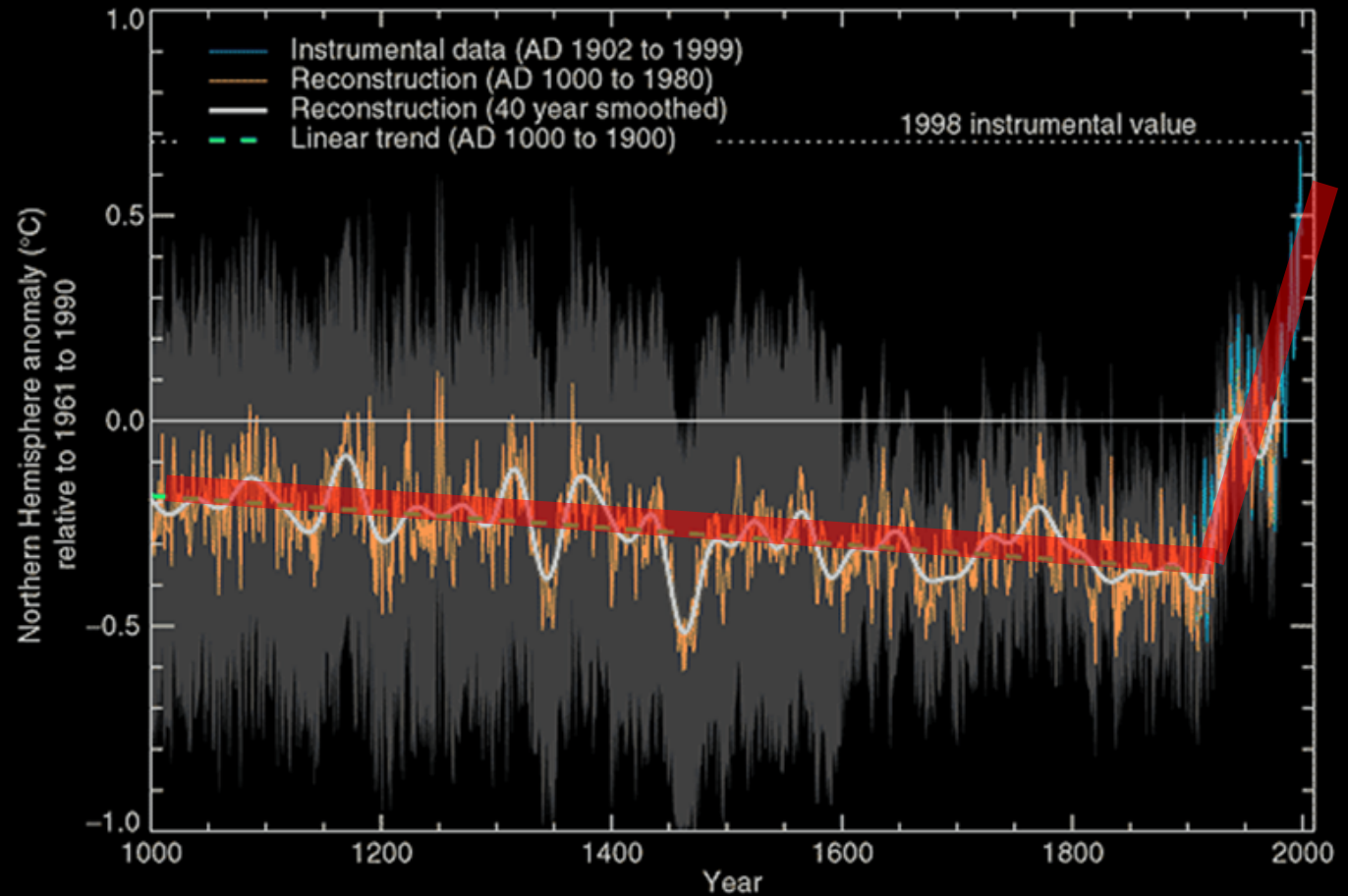
Antarctica contains
enough ice to raise
sea levels by 57m

1. Ice and Climate



1. Ice and Climate

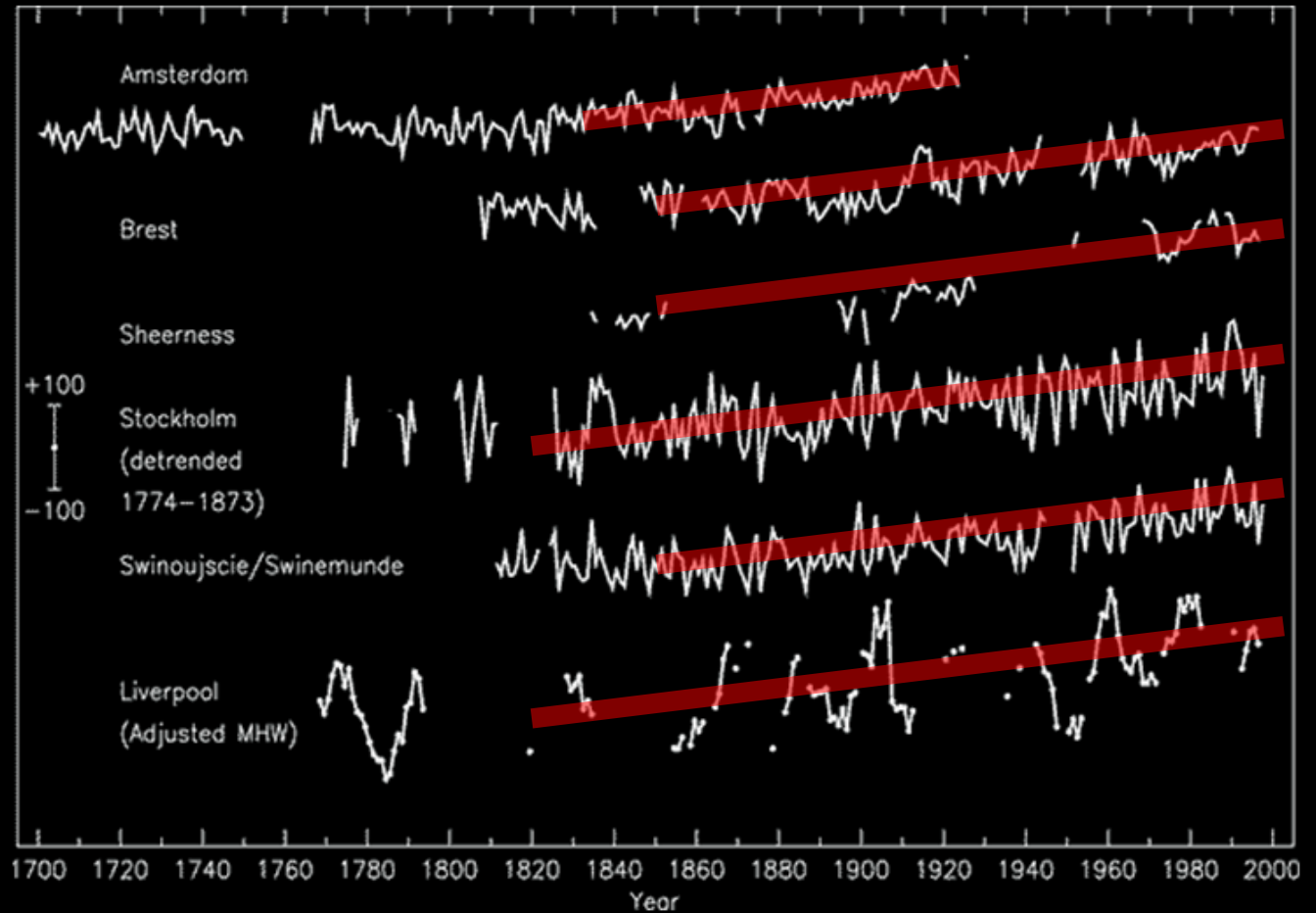
❄ IPCC Assessment reports (1990, 1995, 2001, 2007, 2013)



0.6 °C rise since 1900

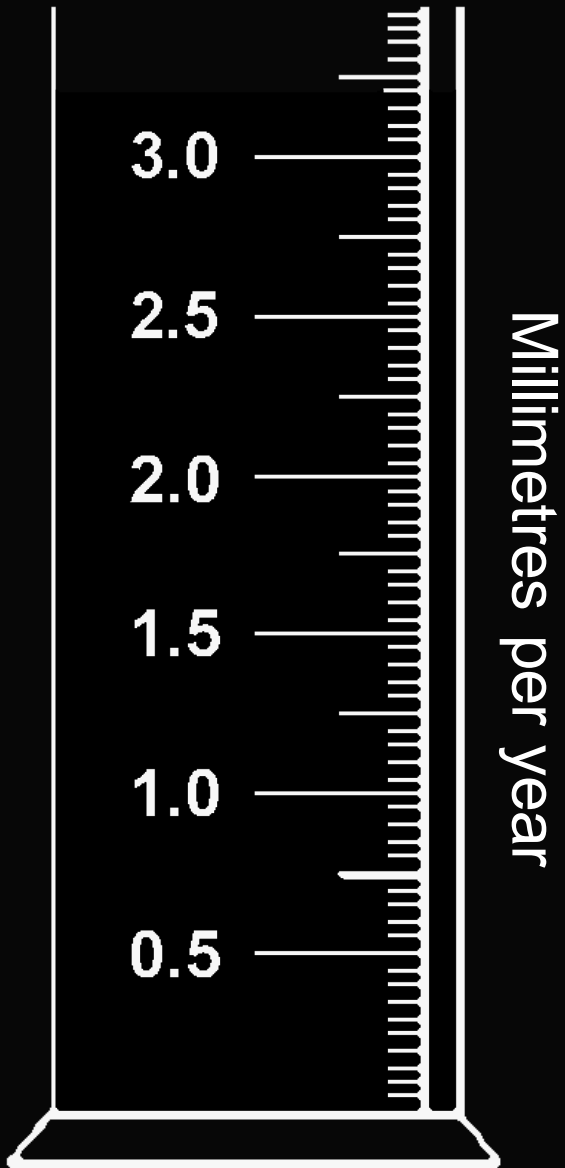
1. Ice and Climate

❄ IPCC Assessment reports (1990, 1995, 2001, 2007, 2013)



15 cm rise since 1900

1. Ice and Climate



- Thermal expansion
- Glaciers & ice caps
- Greenland
- Antarctica

❄️ Slow climate change



Mt Kilimanjaro, 1993

1. Ice and Climate

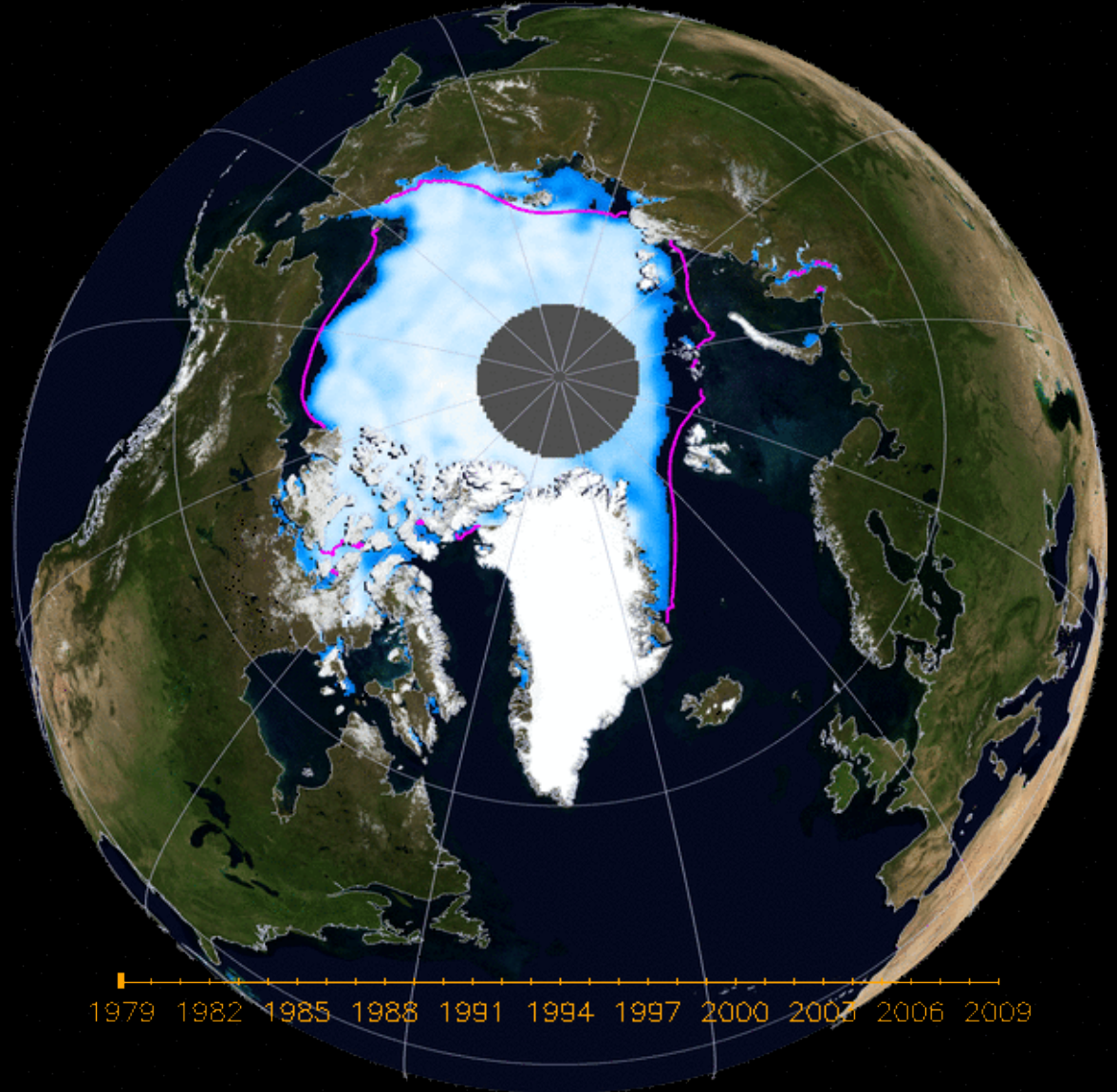
❄️ Slow climate change



Mt Kilimanjaro, 2000

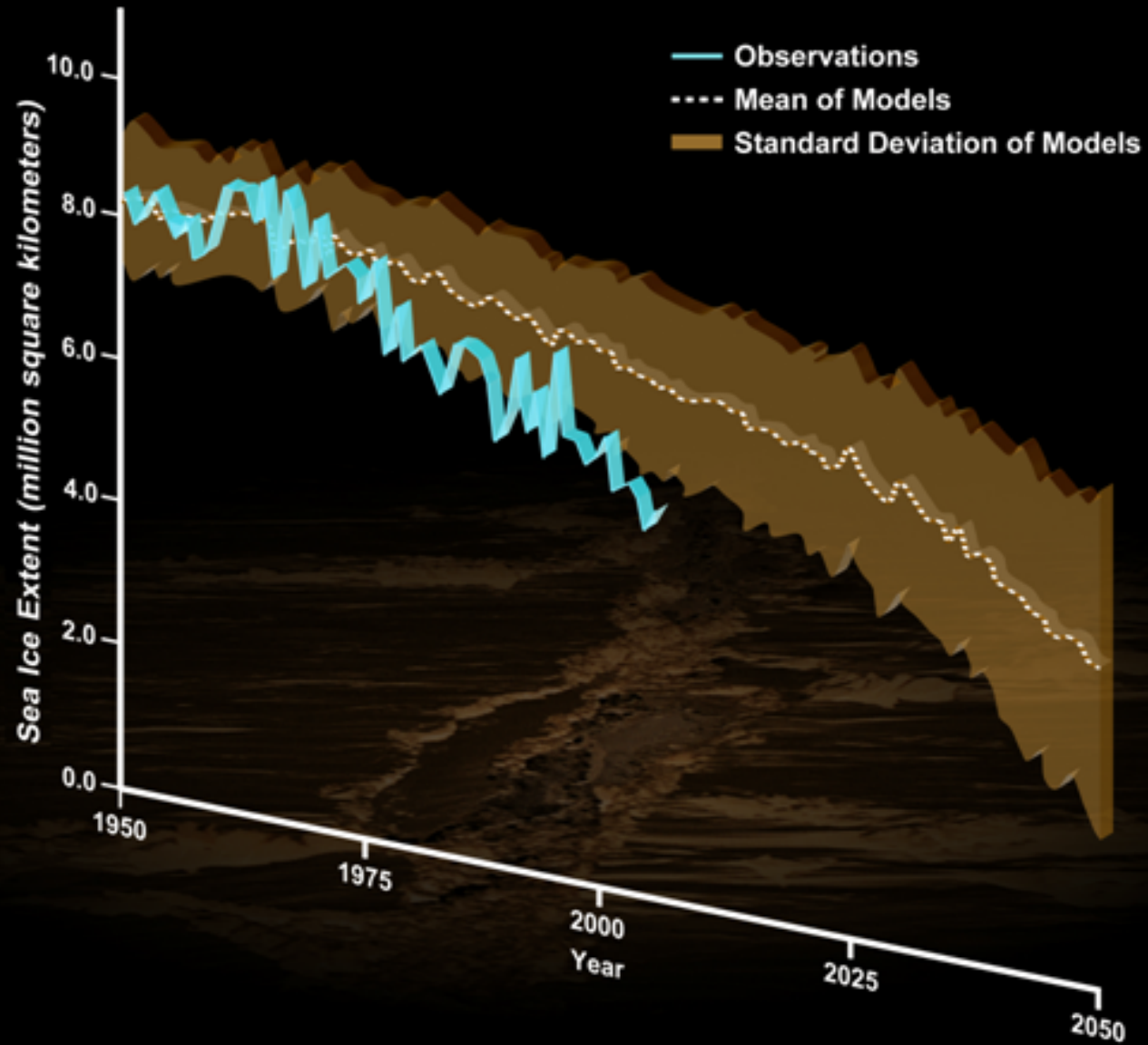
1. Ice and Climate

❄️ Rapid climate change



1. Ice and Climate

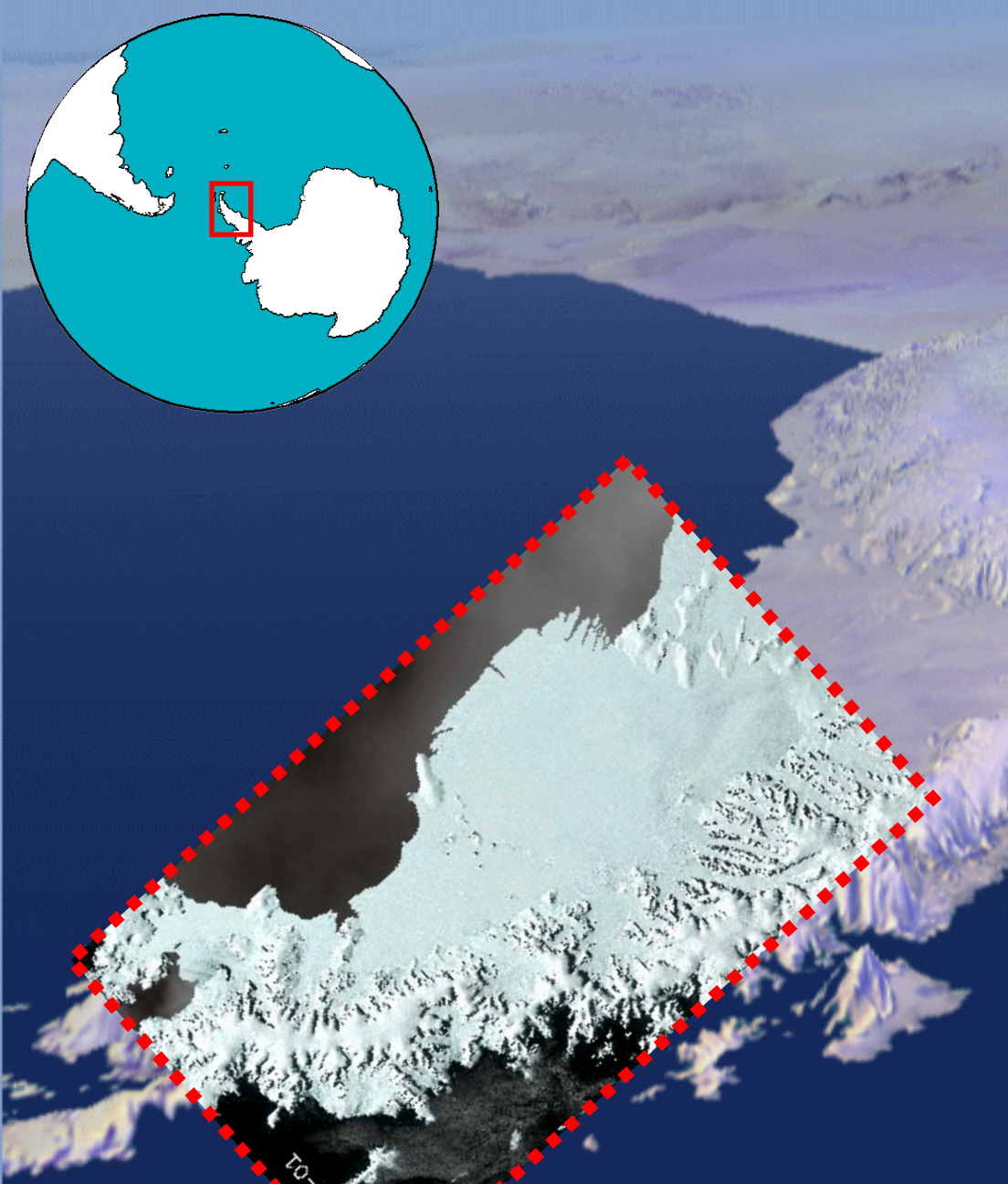
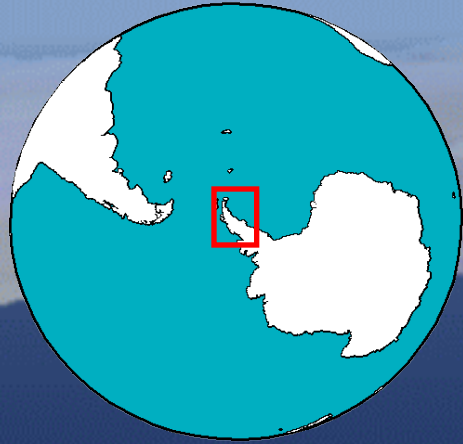
❄️ Rapid climate change



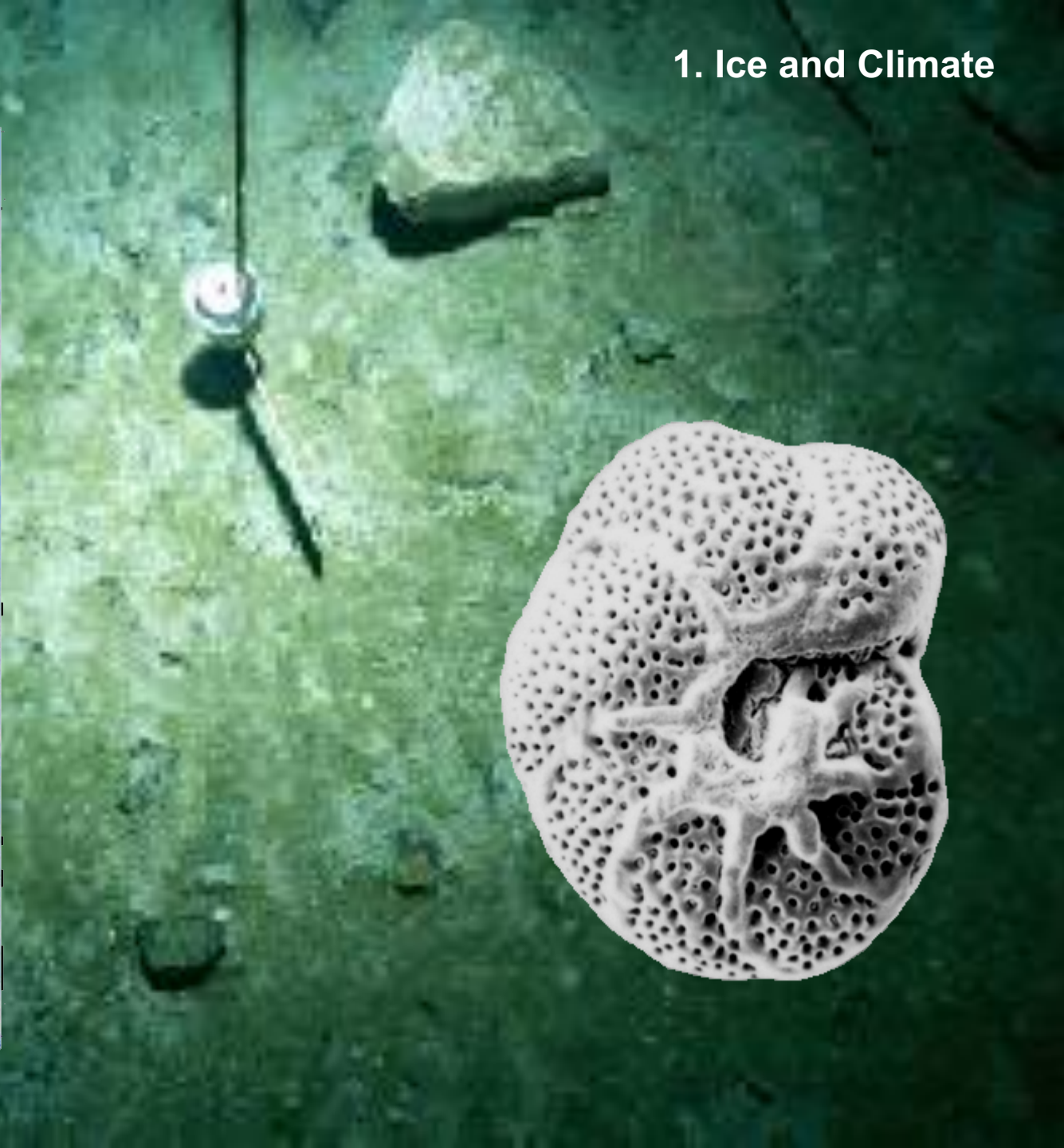
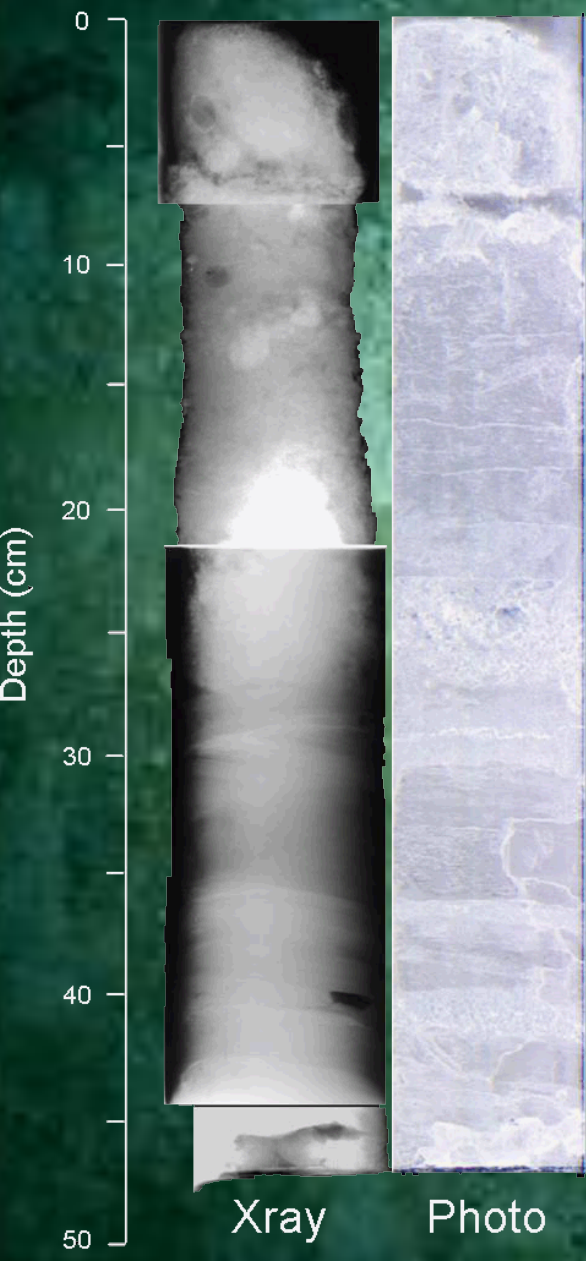
❄️ Abrupt climate change



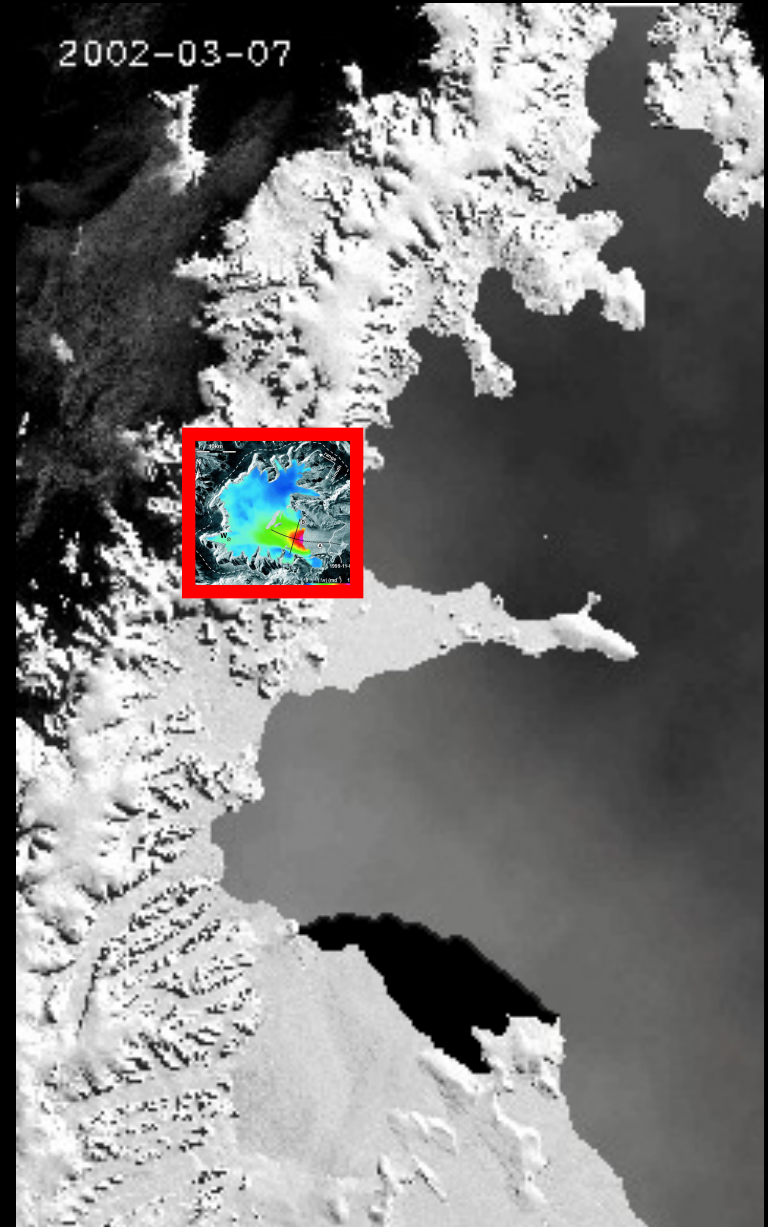
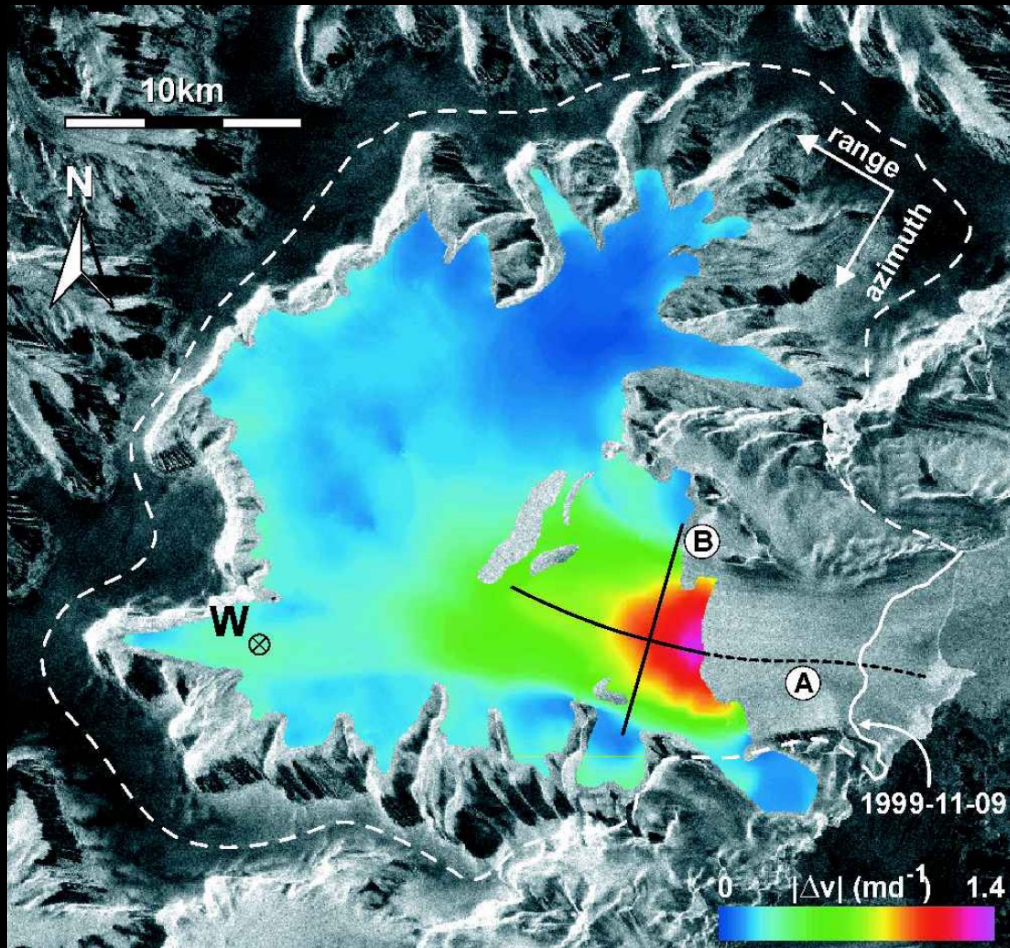
1. Ice and Climate



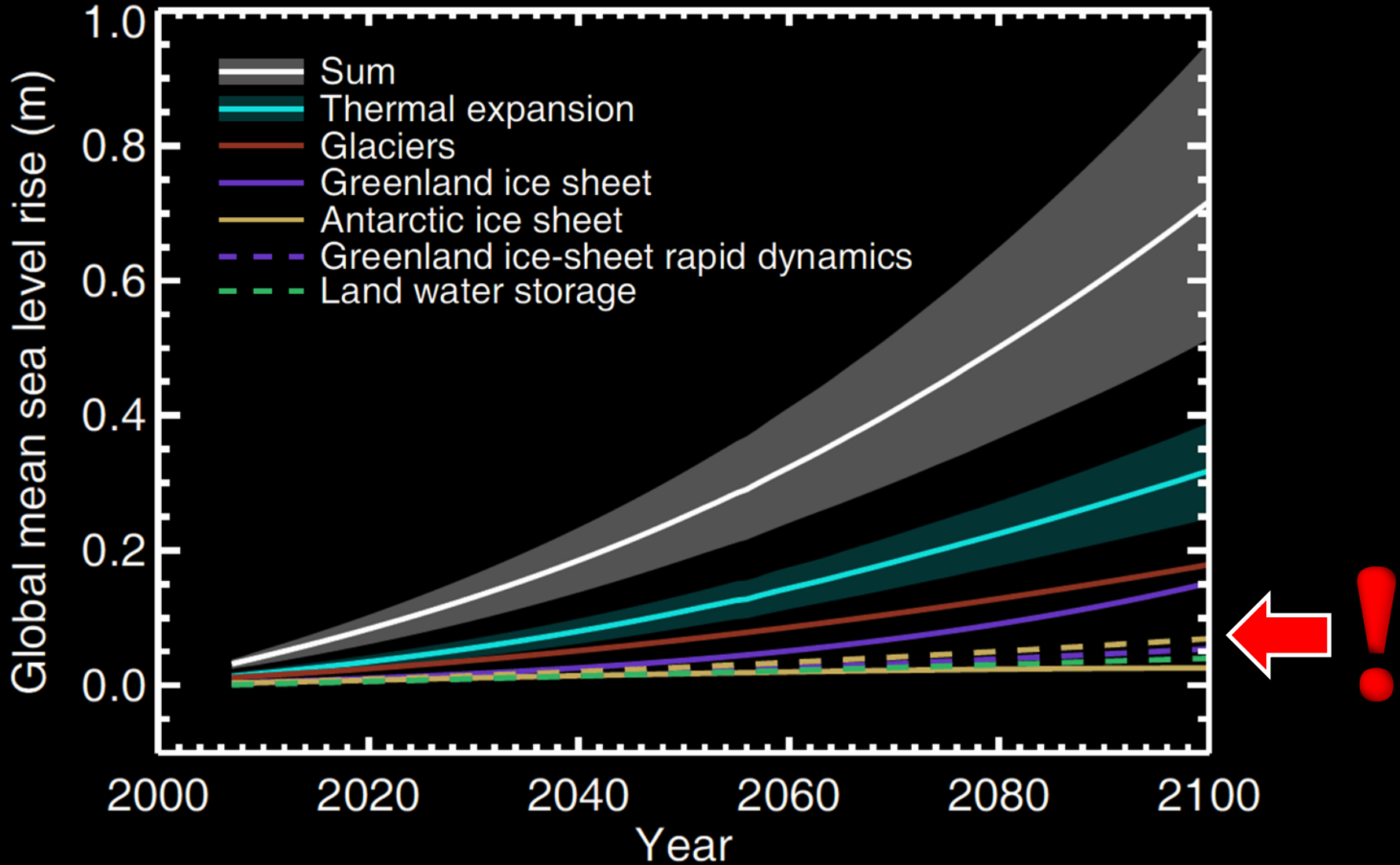
1. Ice and Climate



1. Ice and Climate



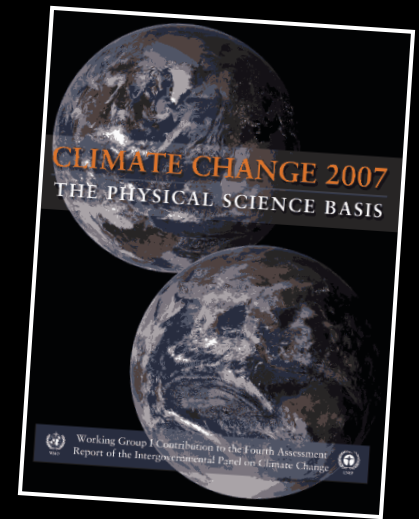
1. Ice and Climate



1. Ice and Climate

AR4 (2007):

“Models used to date do not include the full effects of changes in ice sheet flow, because a basis in published literature is lacking....”



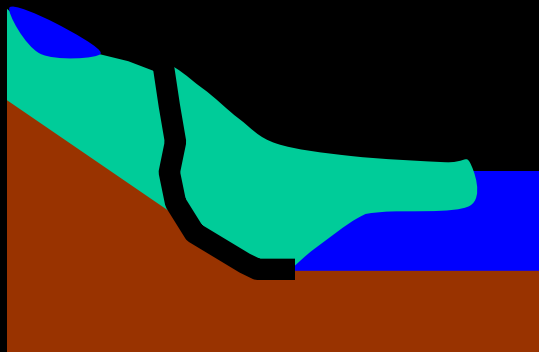
AR5 (2013):

“There has been substantial progress in ice-sheet modelling, particularly for Greenland.”

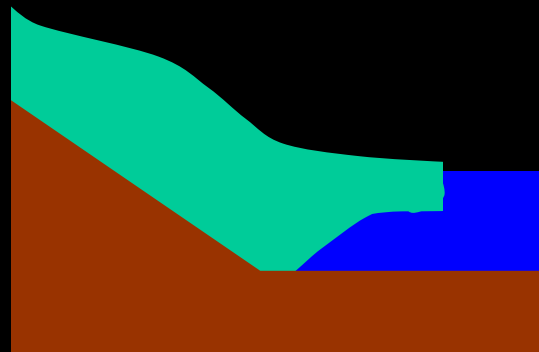
“Significant challenges remain in the process-based projection of the dynamic response of marine terminating glaciers and the Antarctic Ice Sheet.”



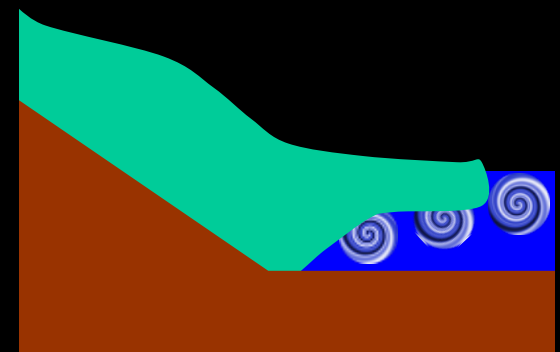
1. Ice and Climate



Lubrication



Calving

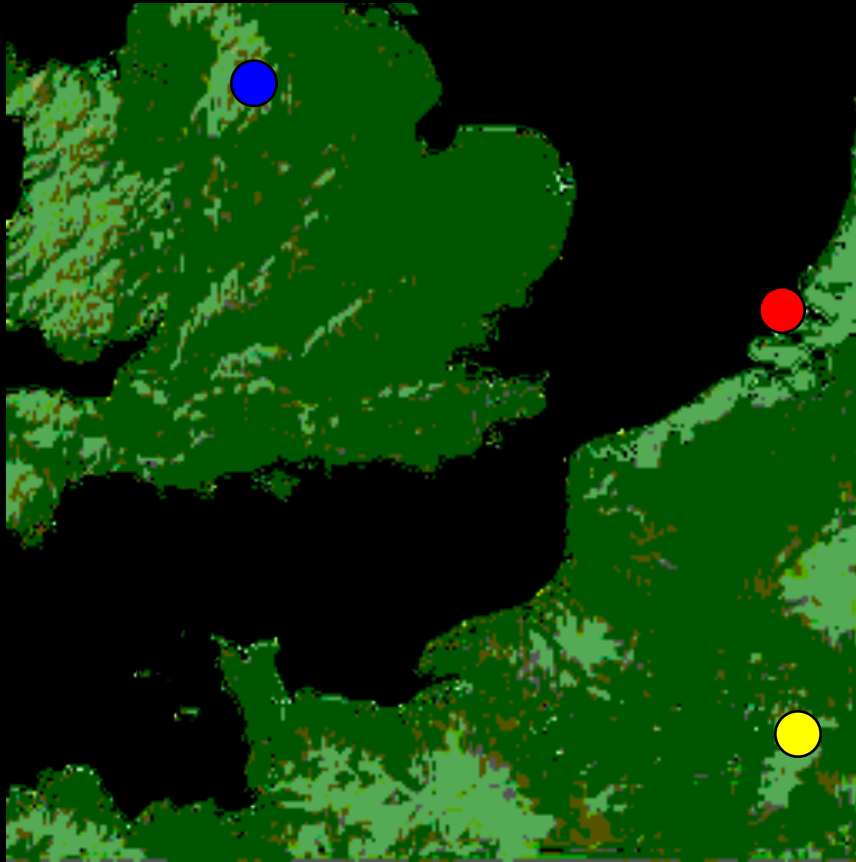


Ocean Melting

1. Ice and Climate



86 m.a.s.l.



50 m.a.s.l.



35 m.a.s.l.



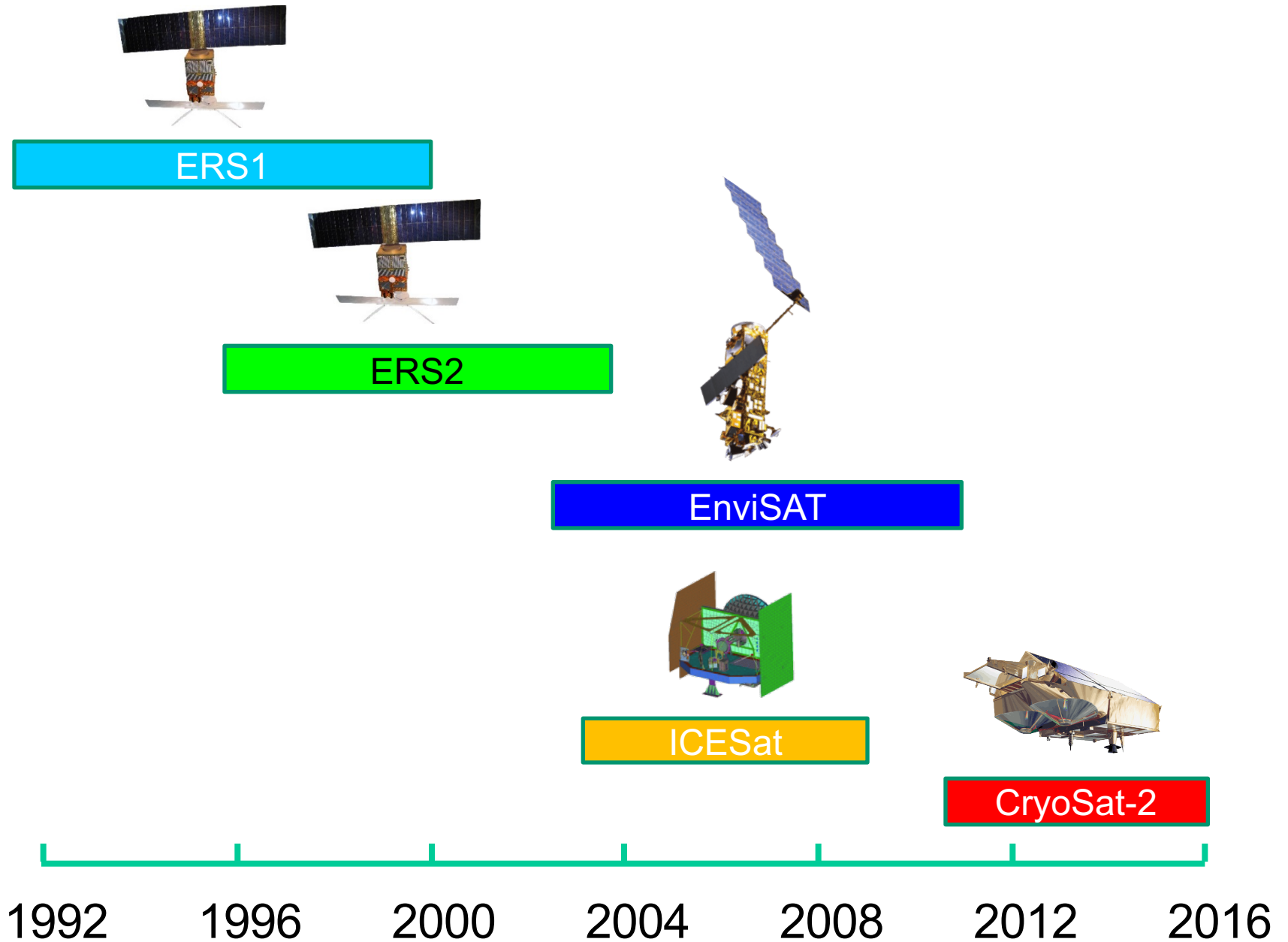
10 m.a.s.l.

Outline

1. Why is ice an important part of Earth's climate?
2. Ice Sheet Altimetry
3. Ice Sheet Mass Balance
4. Sea Ice Altimetry

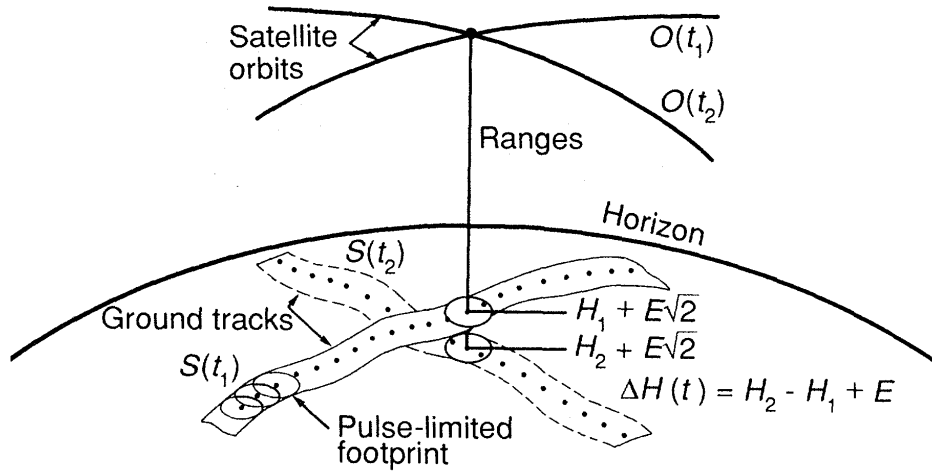


2. Ice Sheet Altimetry

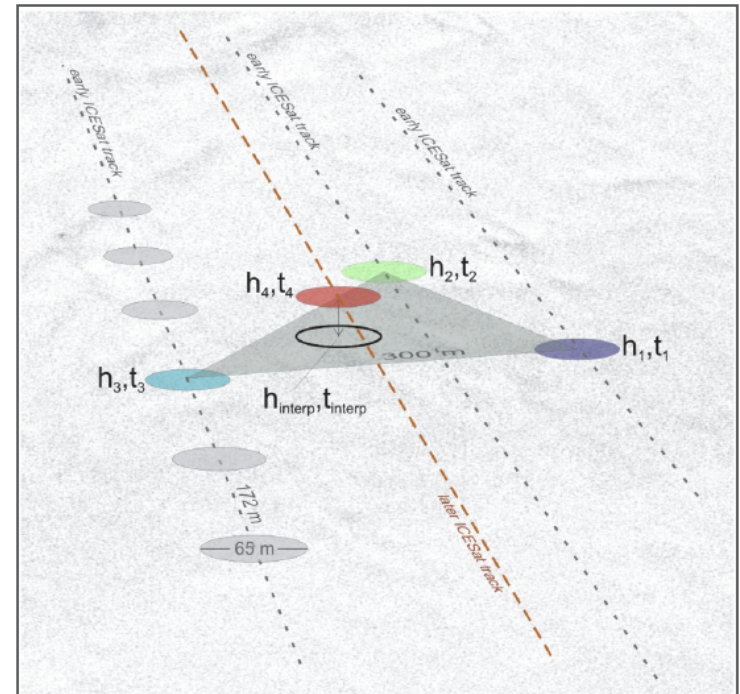


2. Ice Sheet Altimetry

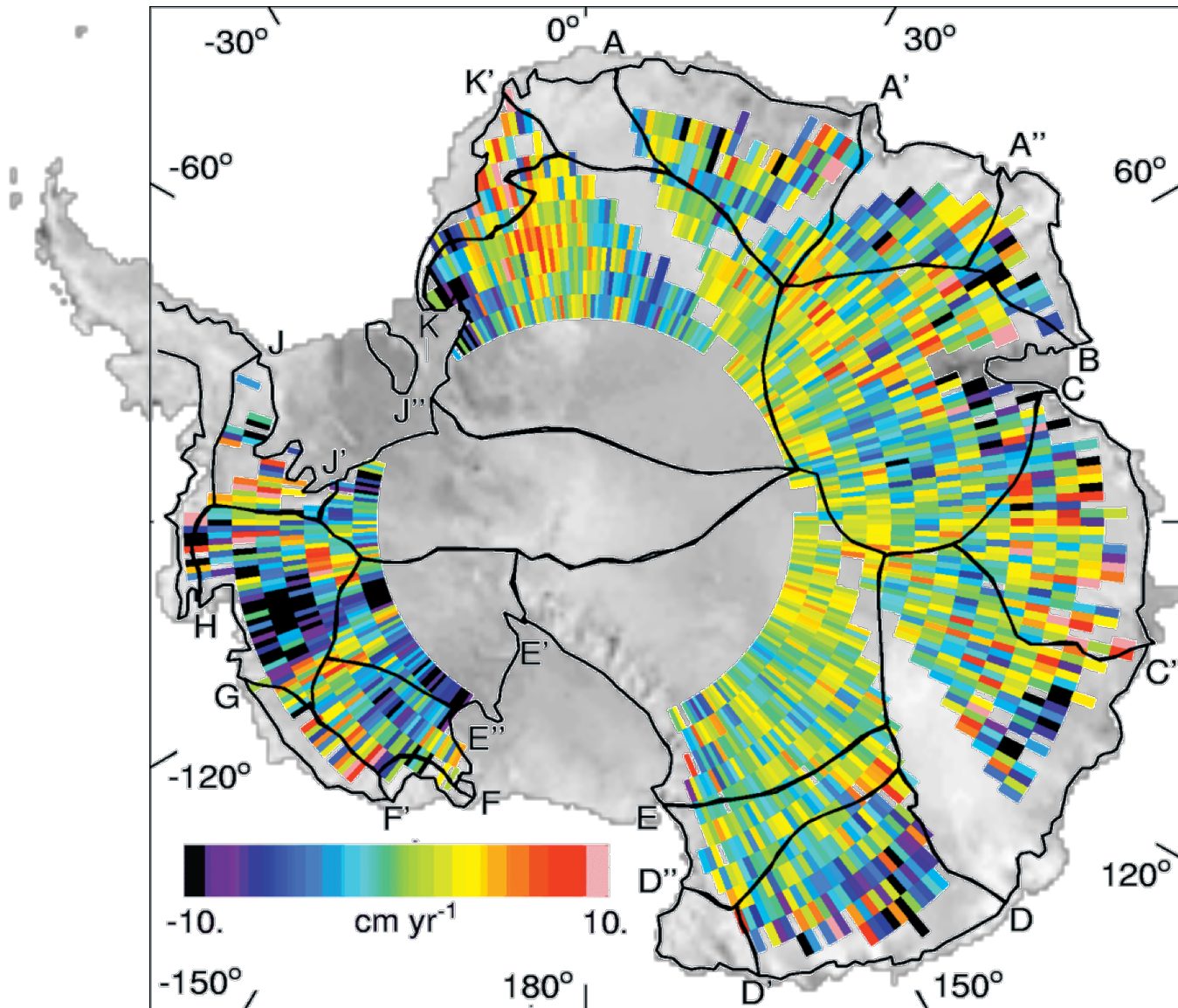
Crossovers



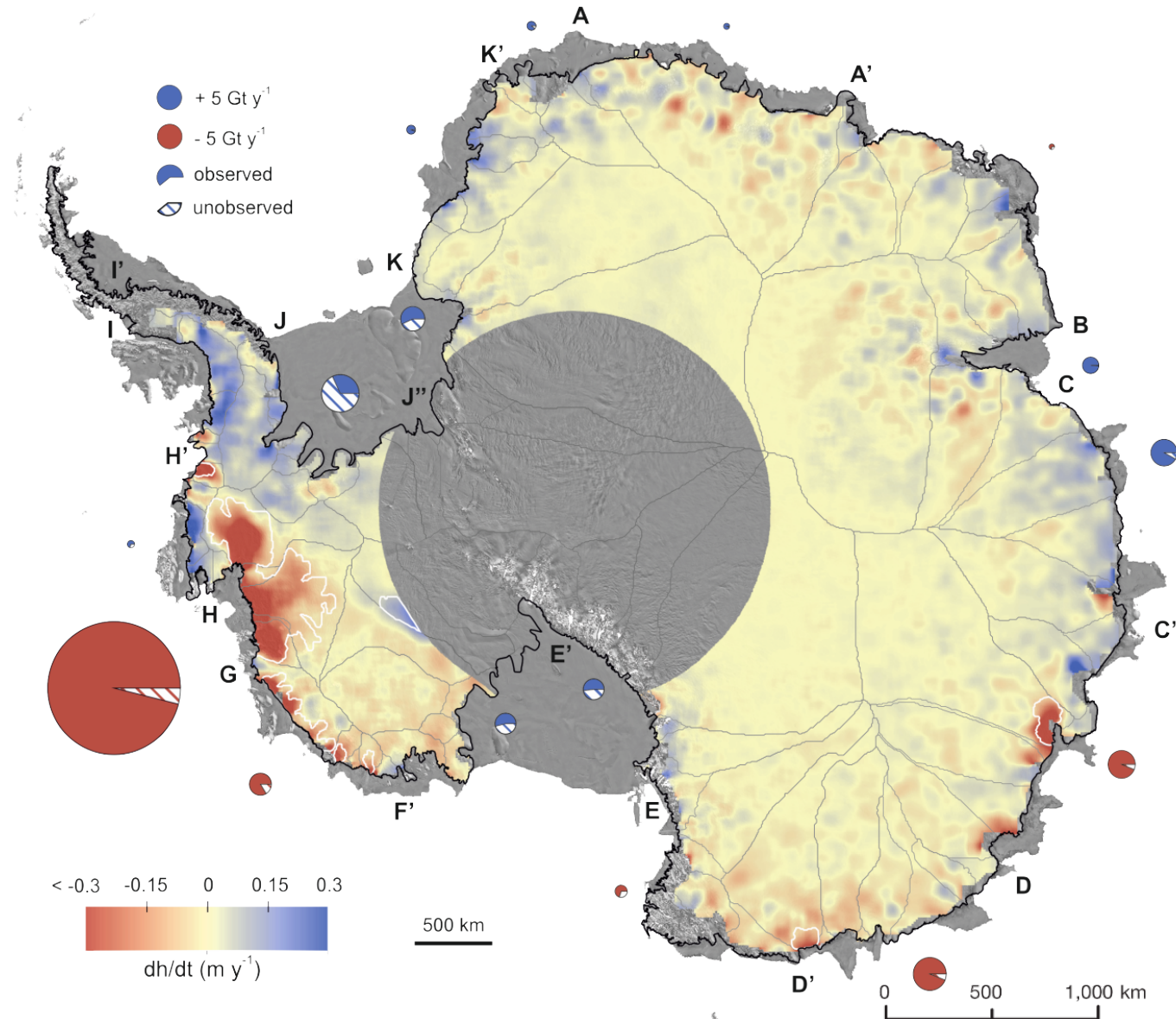
Plane fit



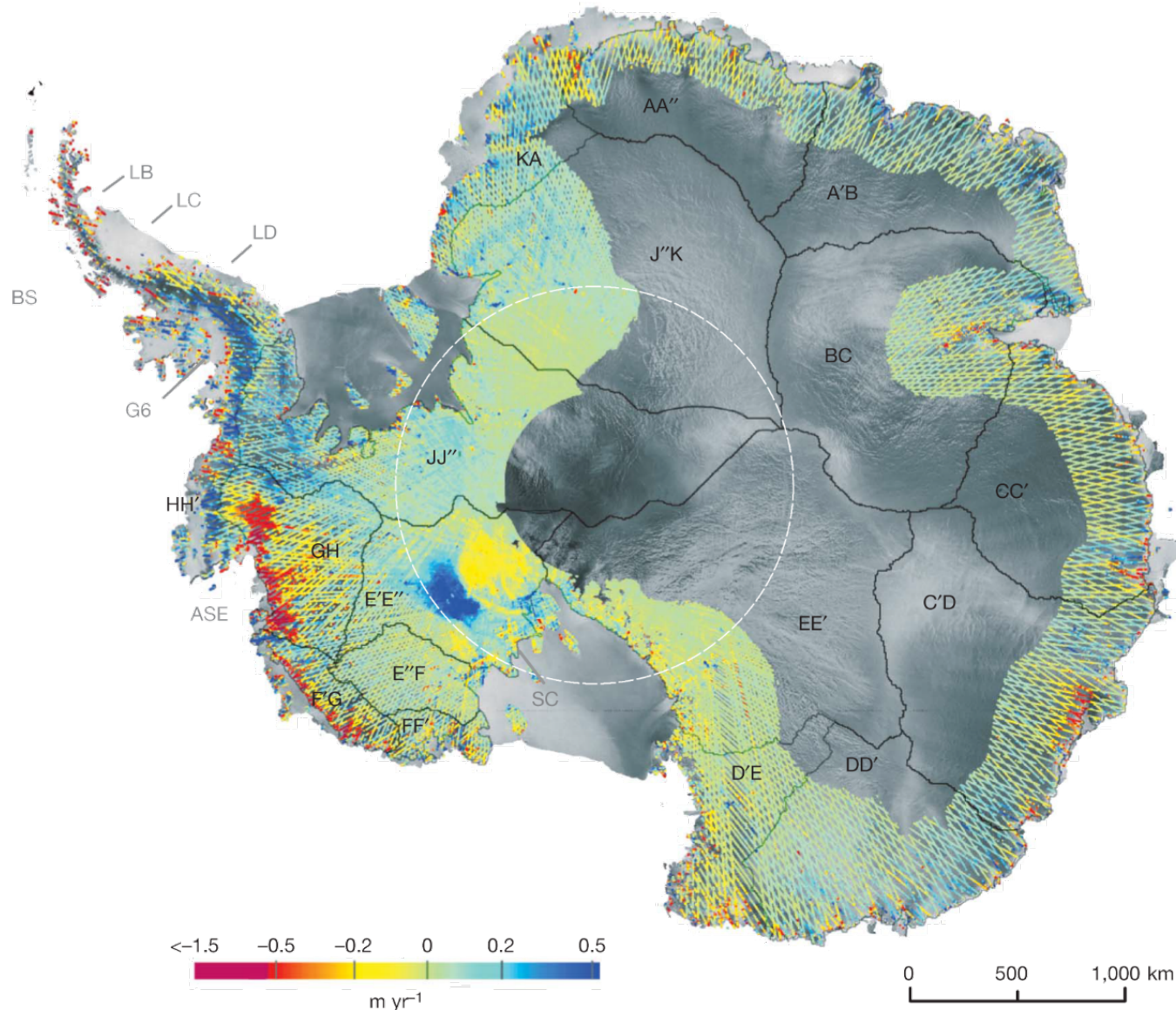
2. Ice Sheet Altimetry



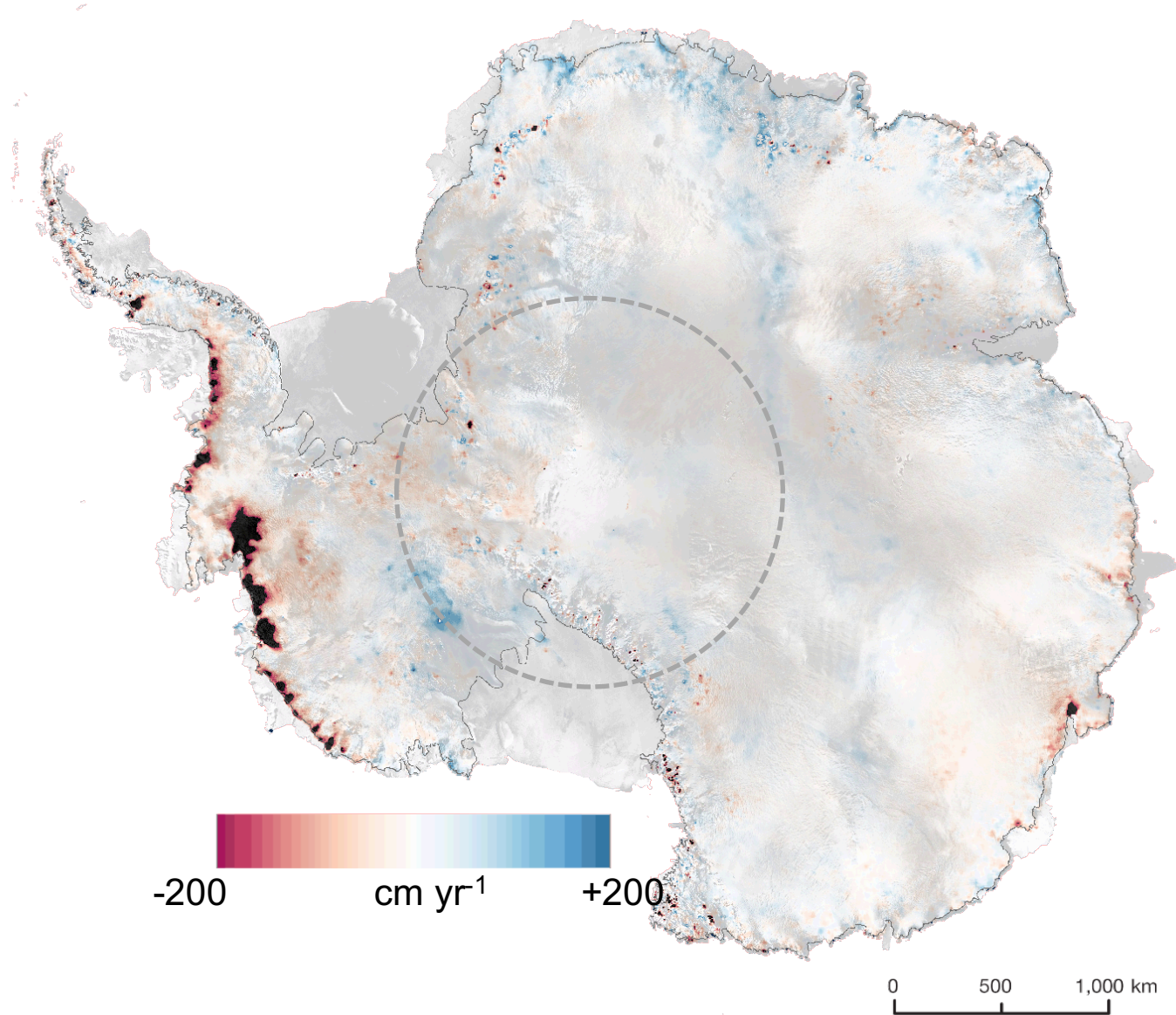
2. Ice Sheet Altimetry



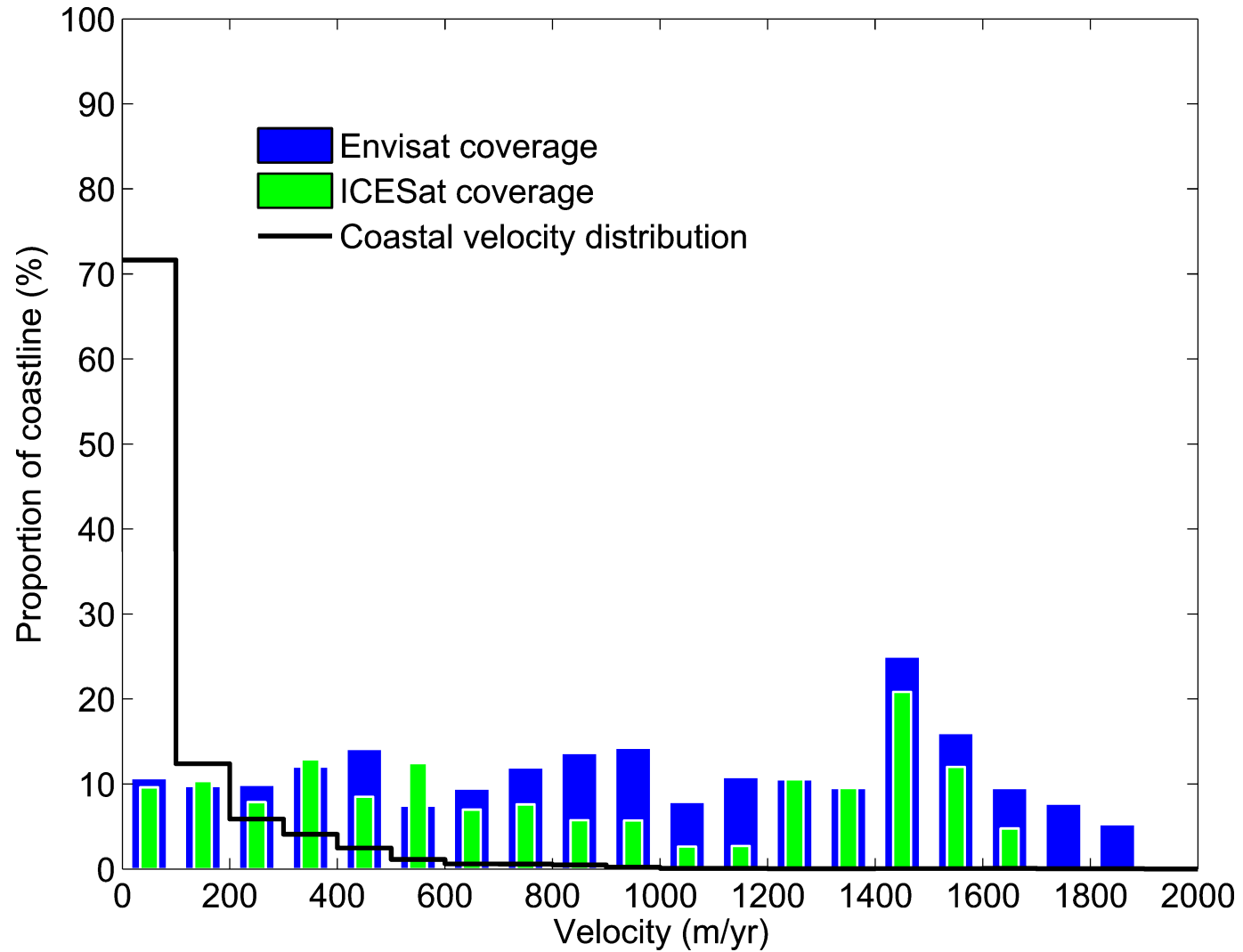
2. Ice Sheet Altimetry



2. Ice Sheet Altimetry

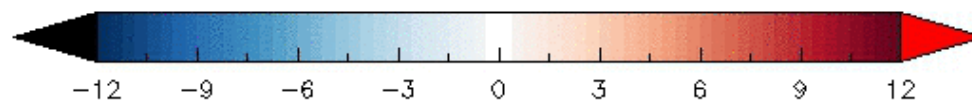
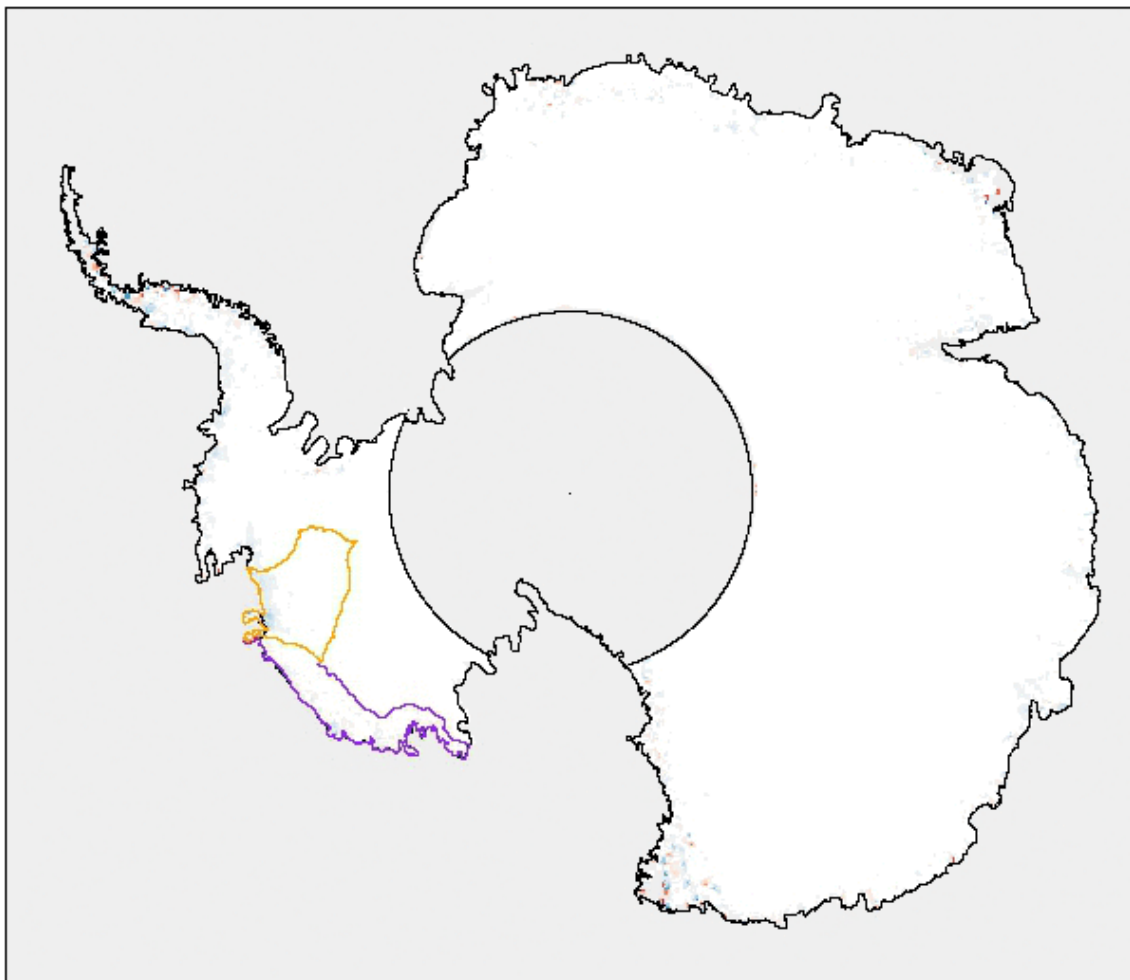


2. Ice Sheet Altimetry



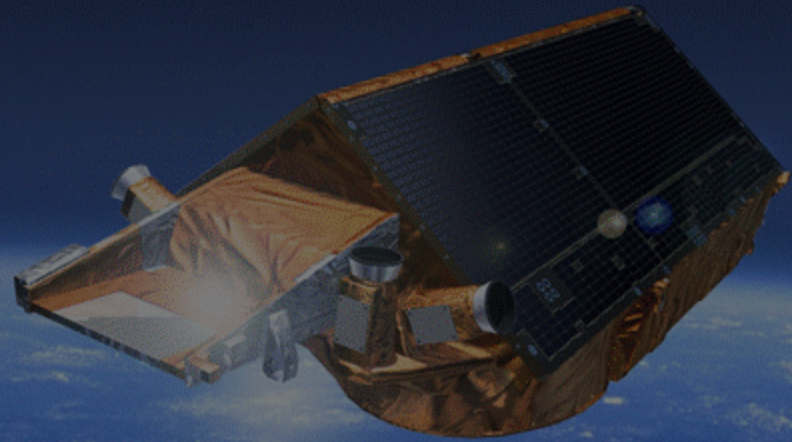
Elevation Change (m) 1992 to 2015

2. Ice Sheet Altimetry



Outline

1. Why is ice an important part of Earth's climate?
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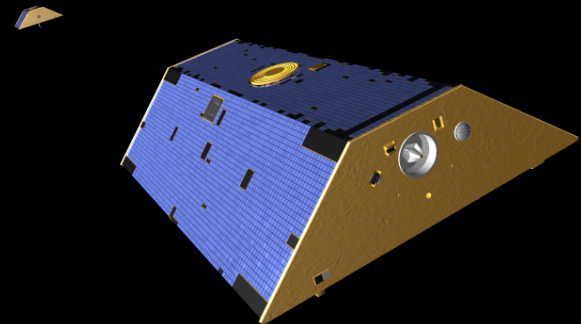
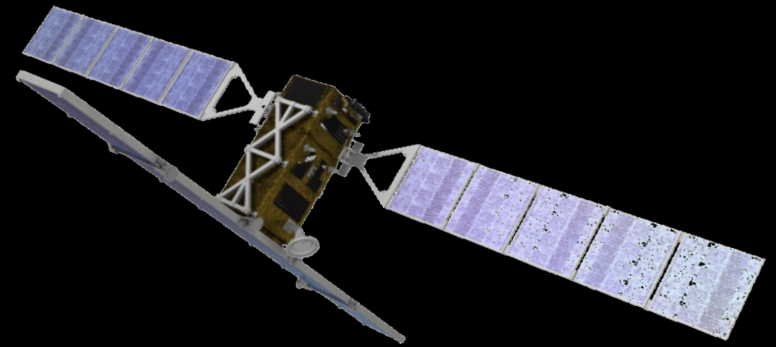


3. Ice Sheet Mass Balance

Altimetry measures changes in ice sheet shape

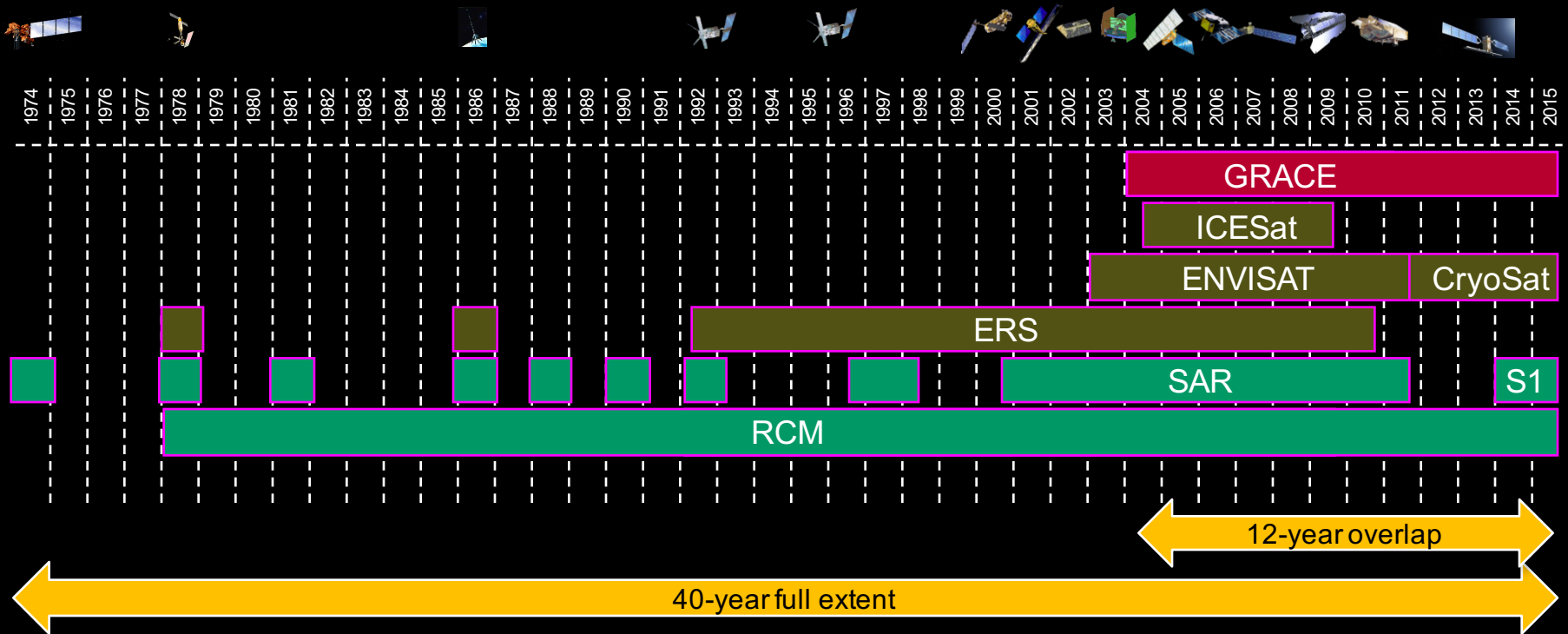
Mass budget differences ice discharge and accumulation

Gravimetry measures changes in ice sheet weight



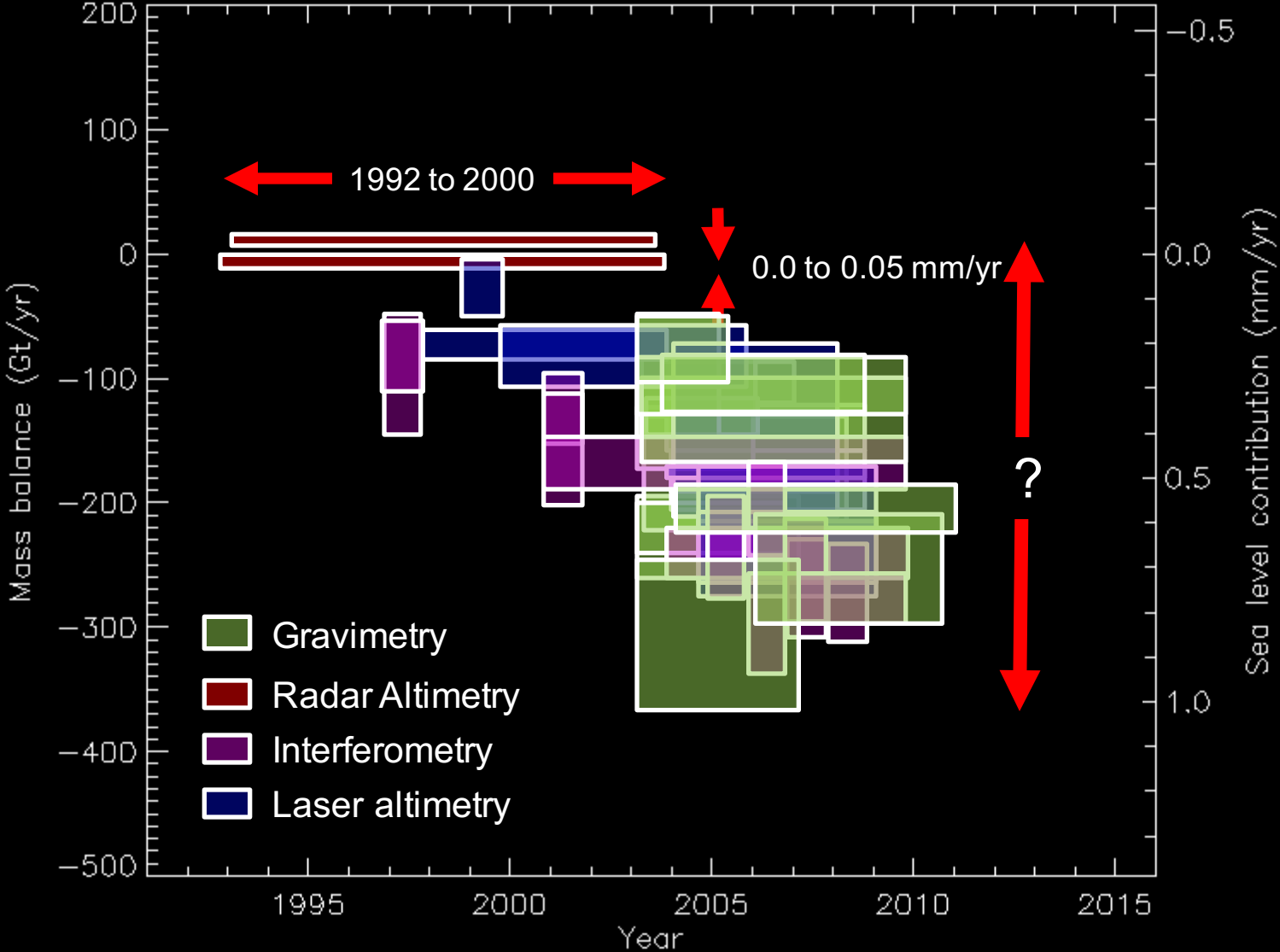
3. Ice Sheet Mass Balance

❄️ 15+ satellite missions, 80+ years of data

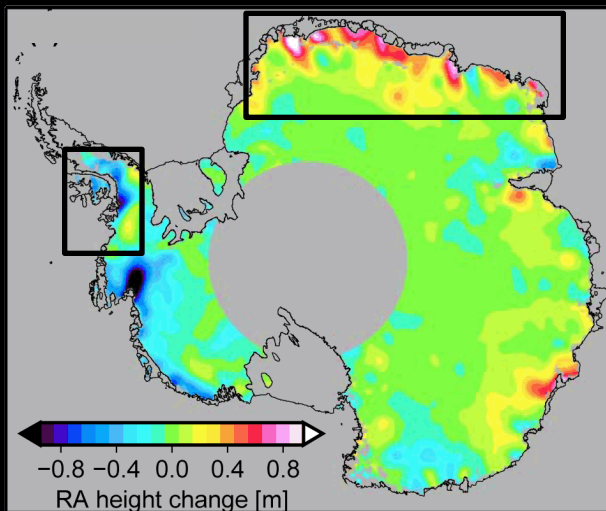


3. Ice Sheet Mass Balance

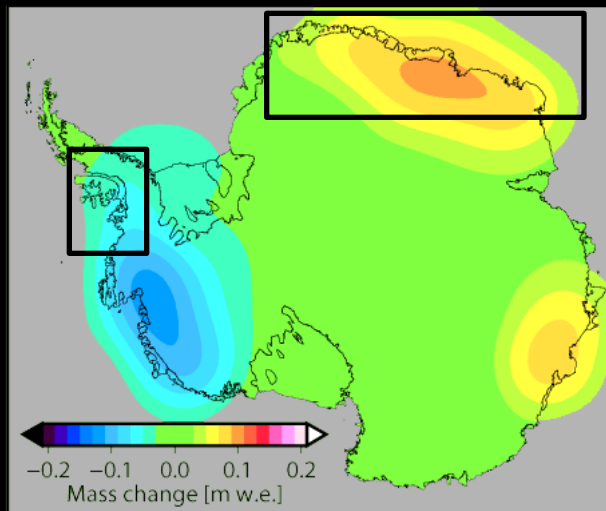
Greenland



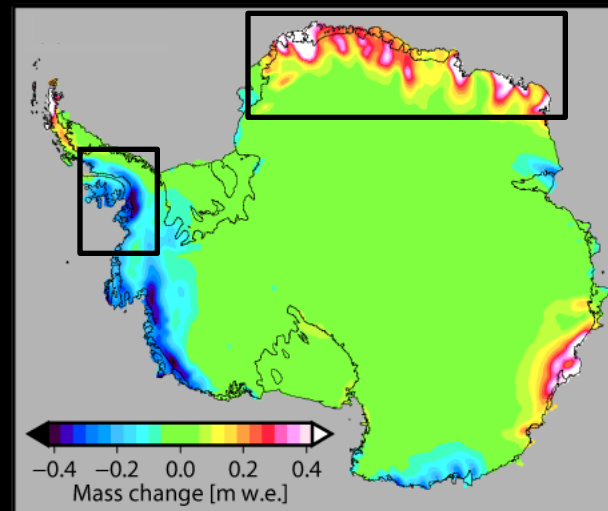
Altimetry



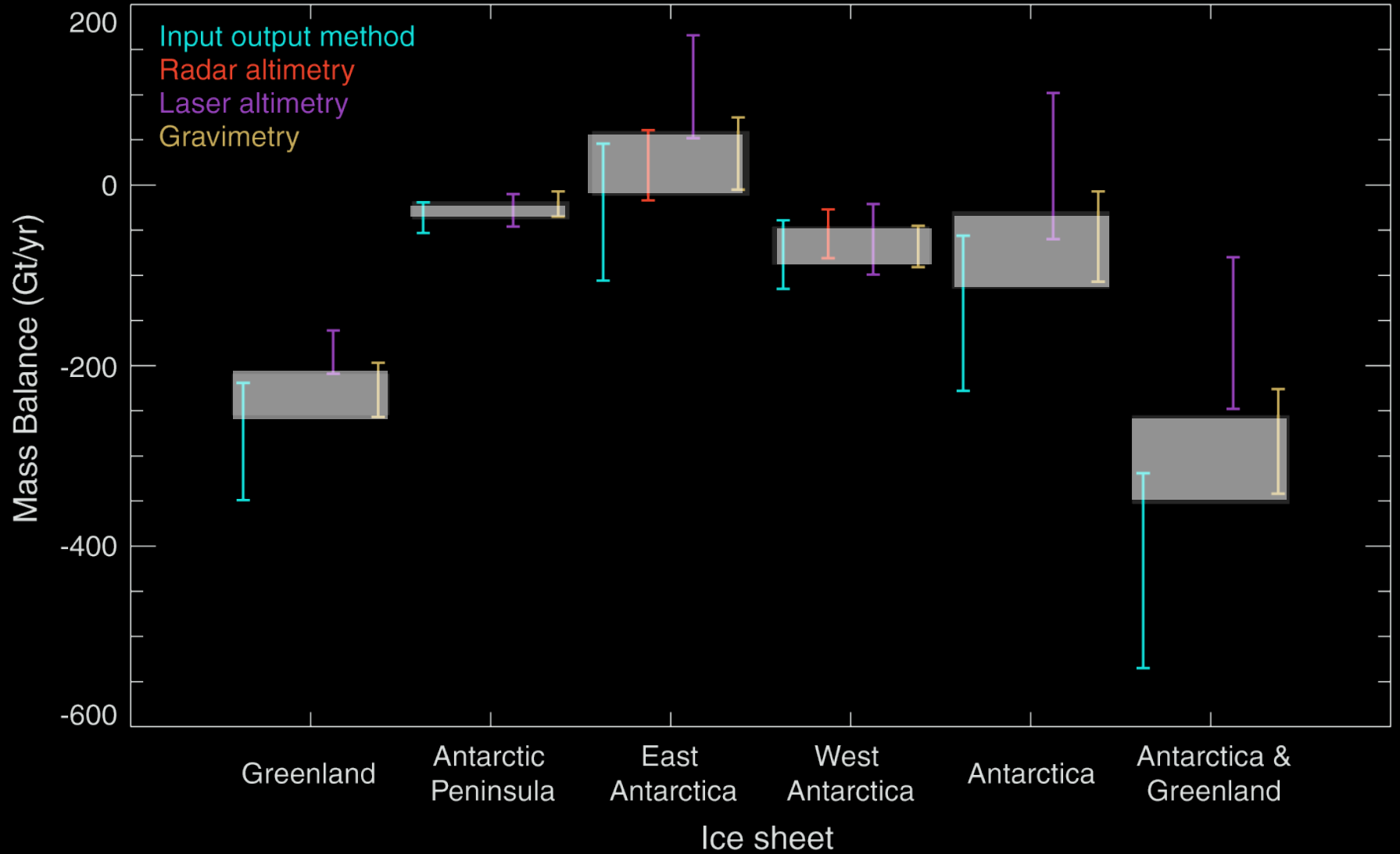
Gravimetry



Surface mass balance

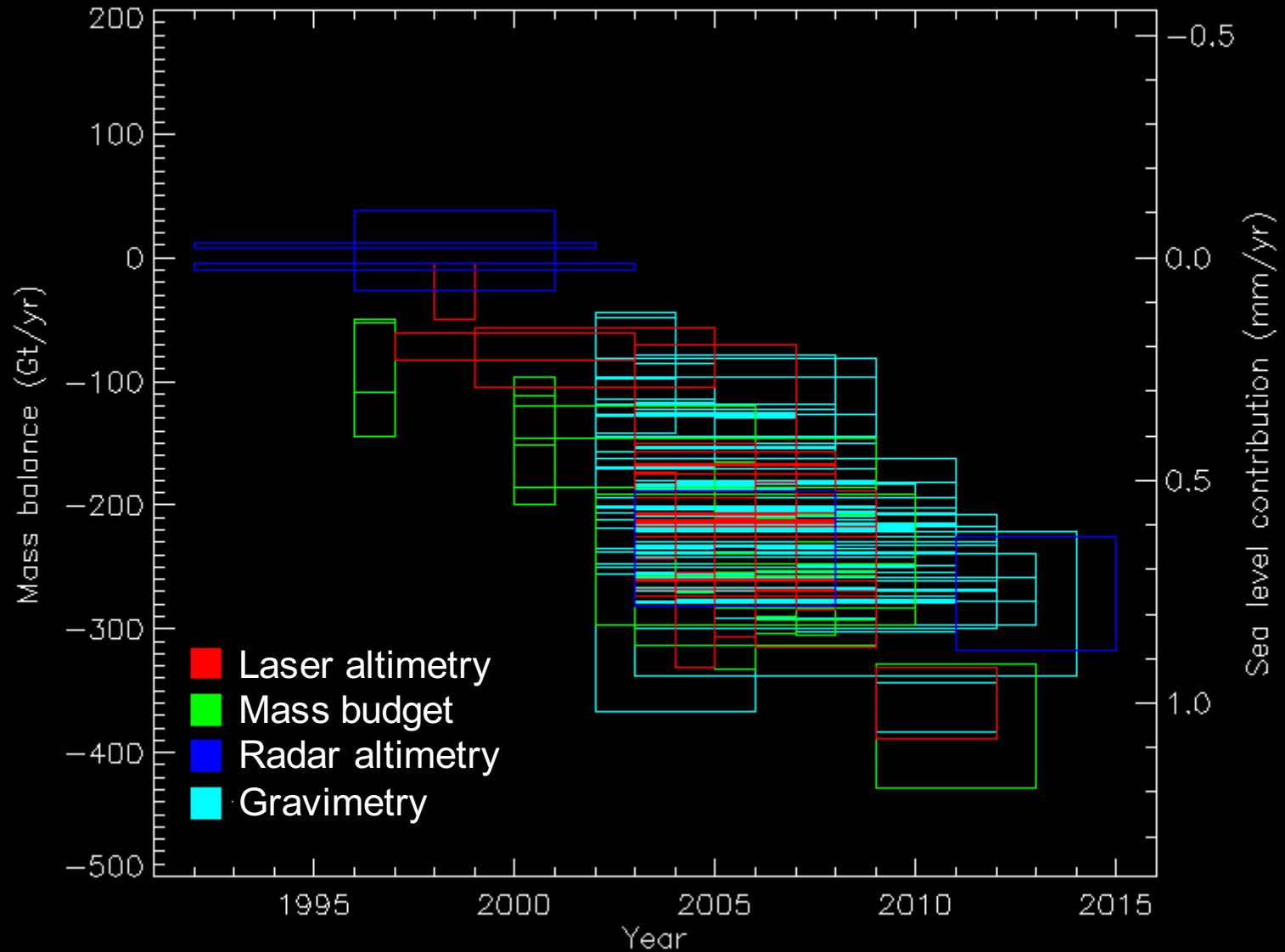


3. Ice Sheet Mass Balance

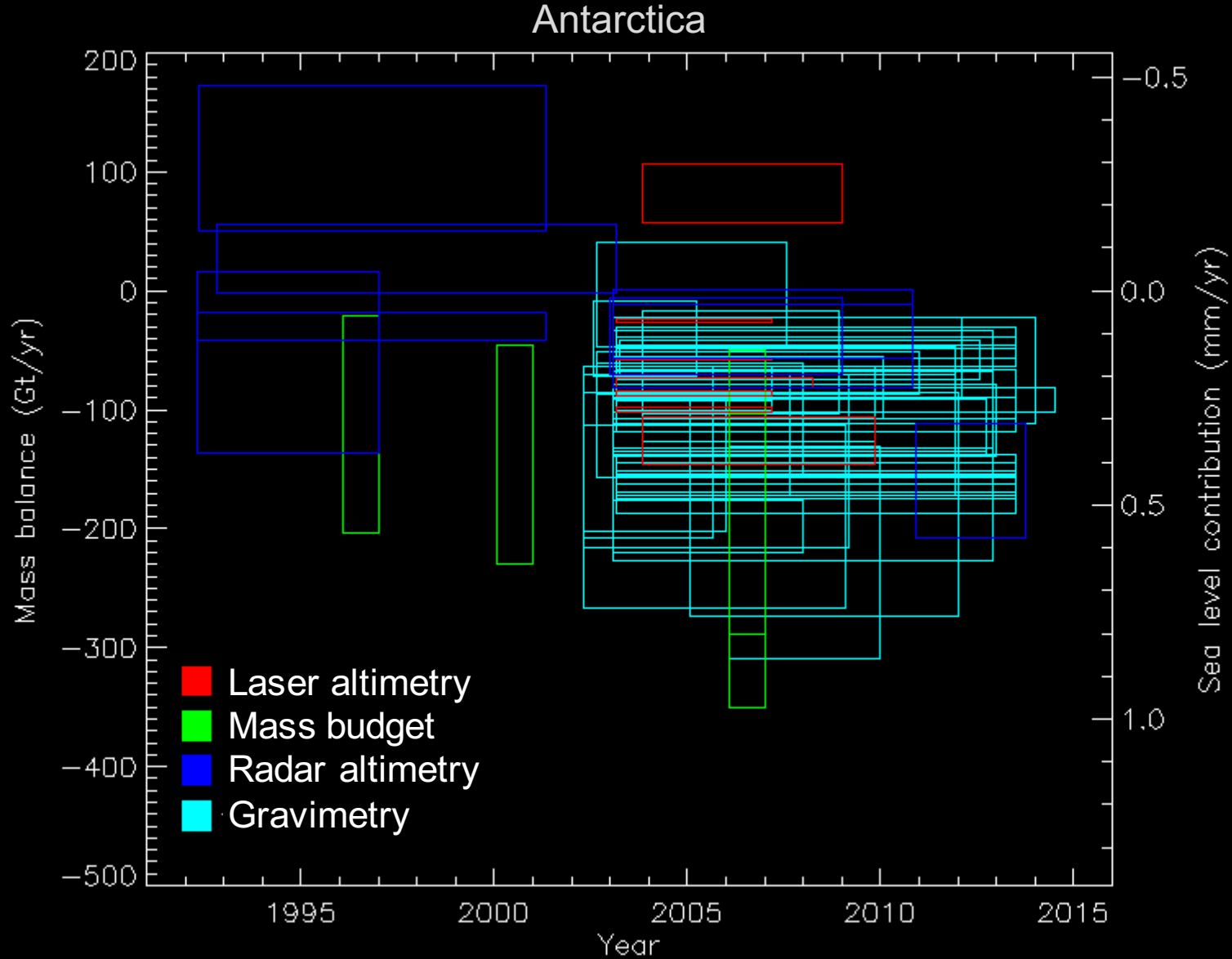


3. Ice Sheet Mass Balance

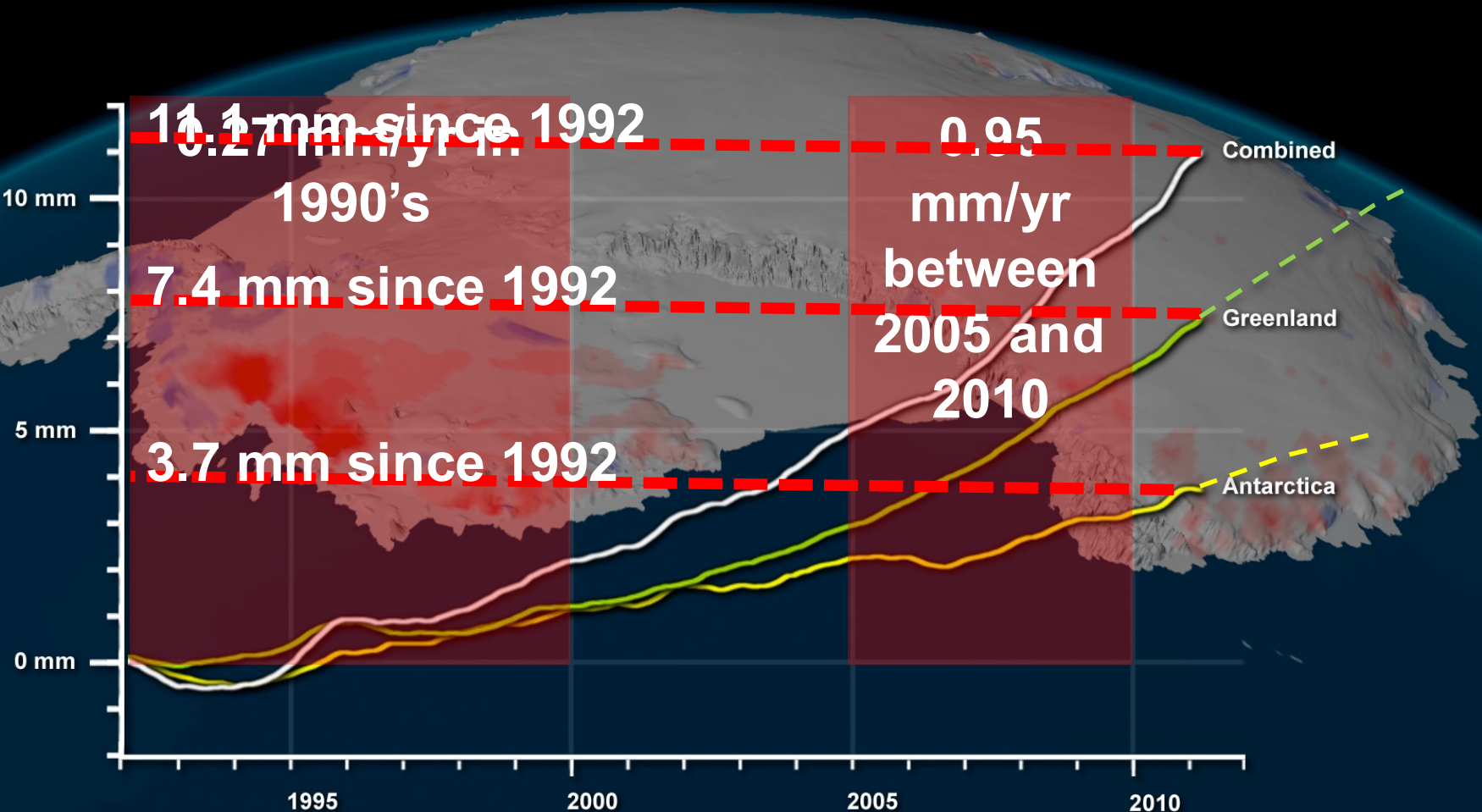
Greenland



3. Ice Sheet Mass Balance

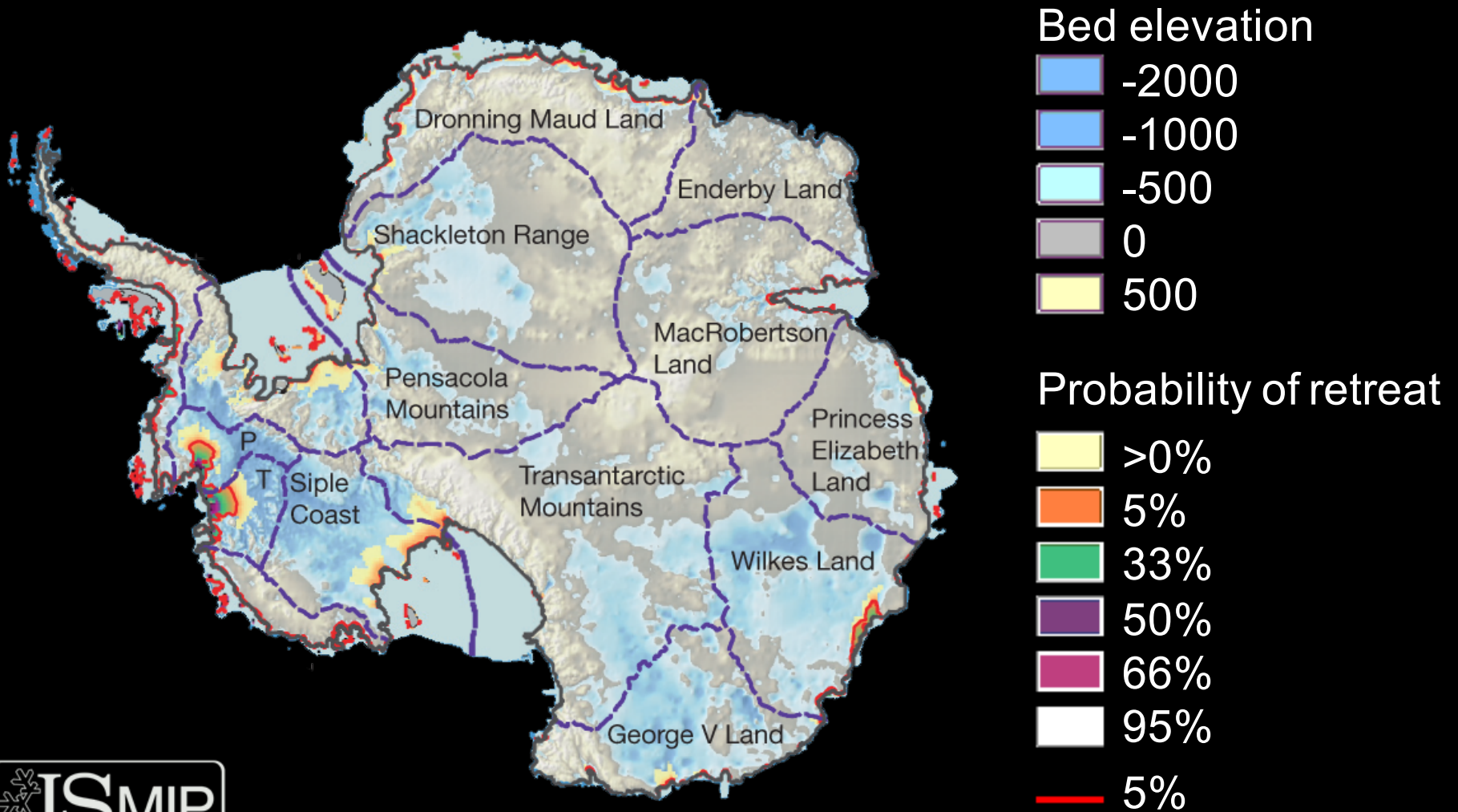


3. Ice Sheet Mass Balance



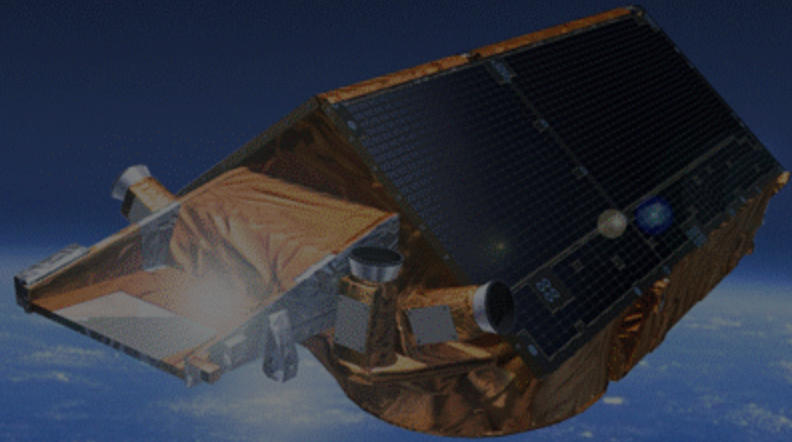
3. Ice Sheet Mass Balance

Simulated Antarctic ice sheet retreat by 2100

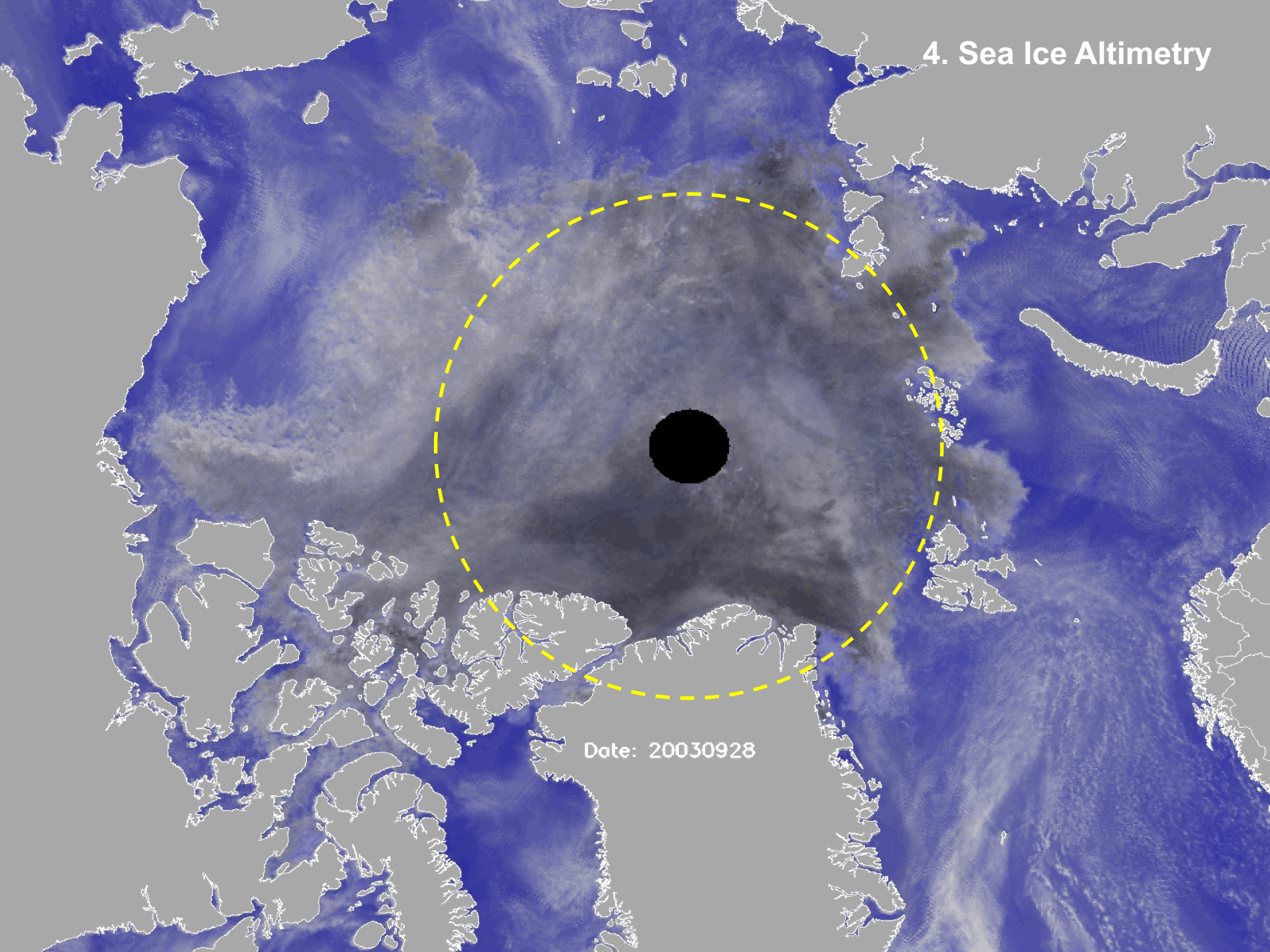


Outline

1. Why is ice an important part of Earth's climate?
2. Ice Sheet Altimetry
3. Ice Sheet Mass Balance
4. Sea Ice Altimetry

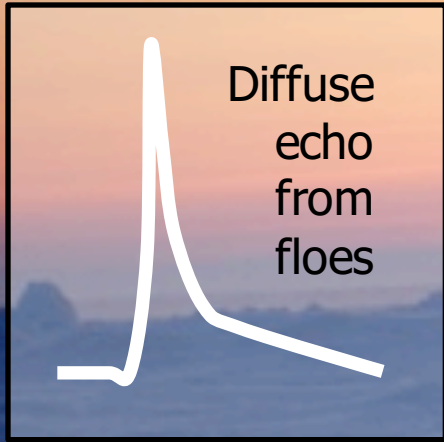


4. Sea Ice Altimetry

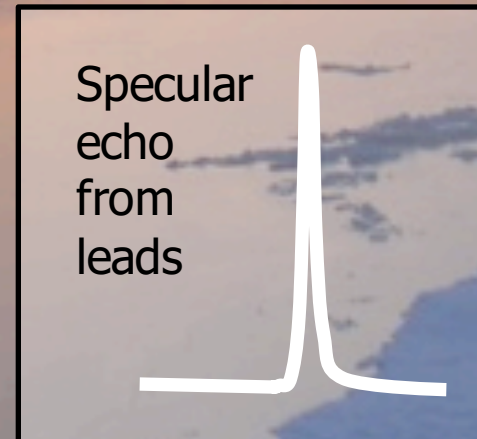


Date: 20030928

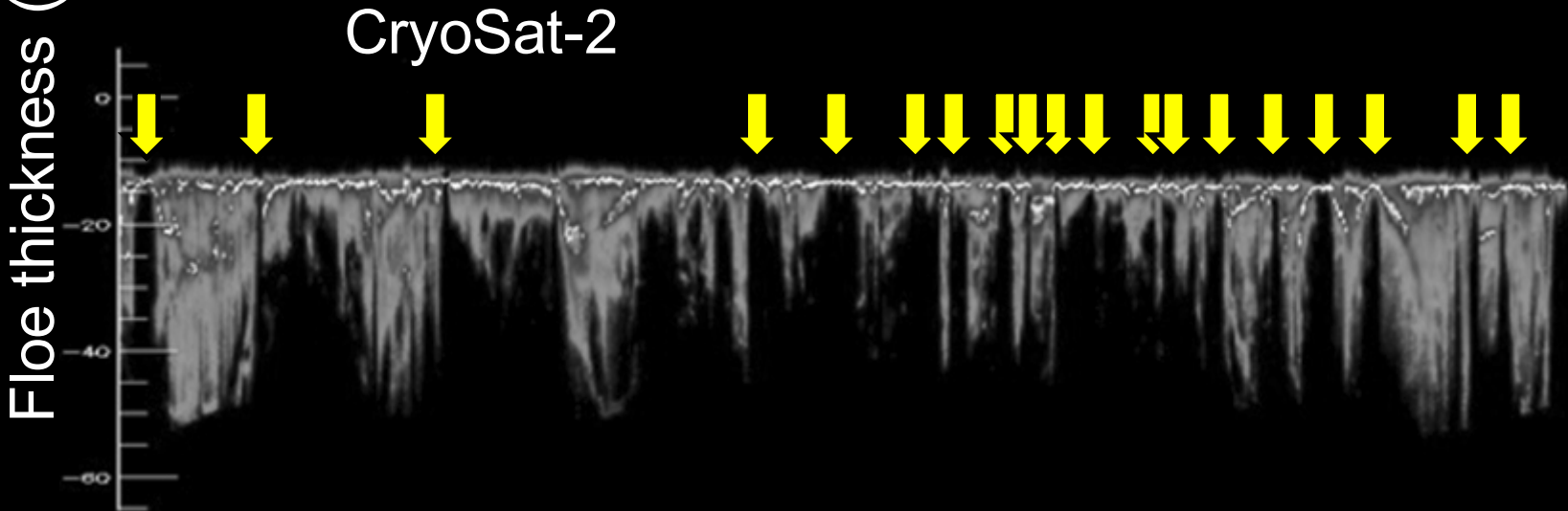
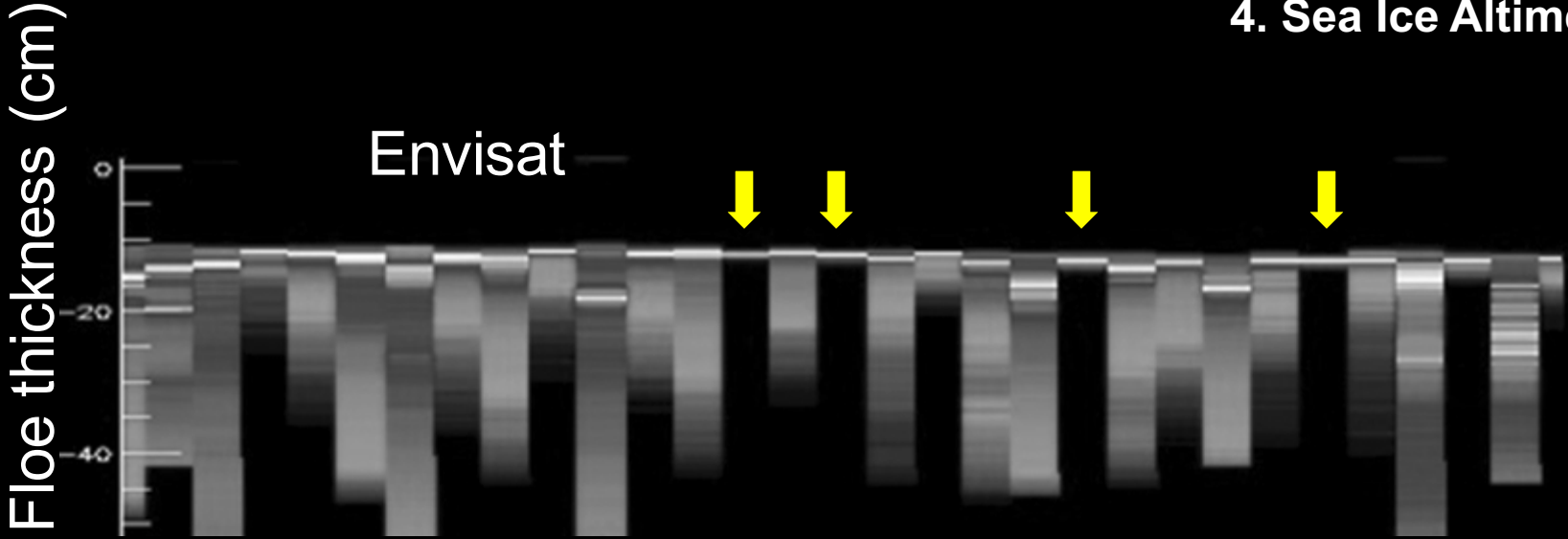
4. Sea Ice Altimetry



} Freeboard

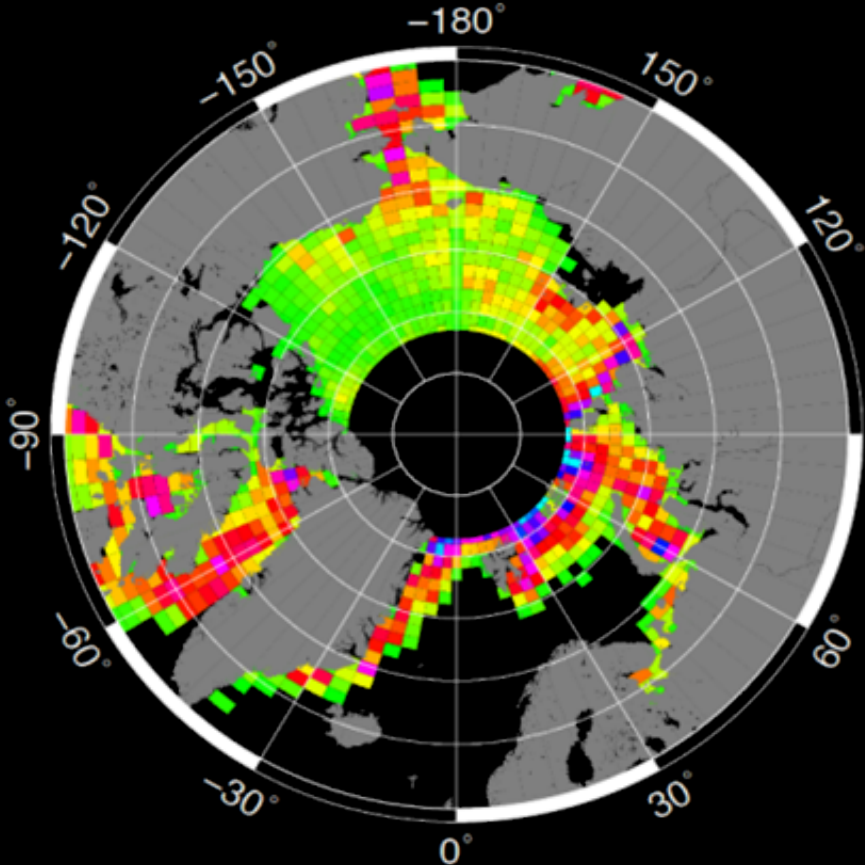


4. Sea Ice Altimetry

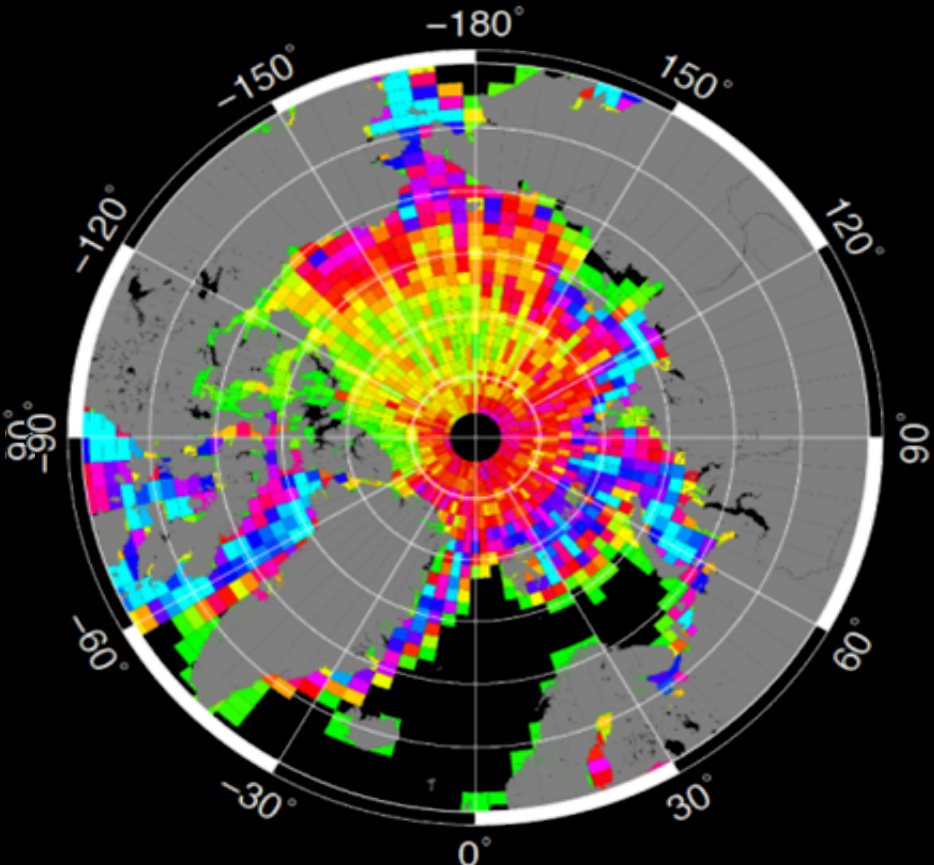


4. Sea Ice Altimetry

Envisat



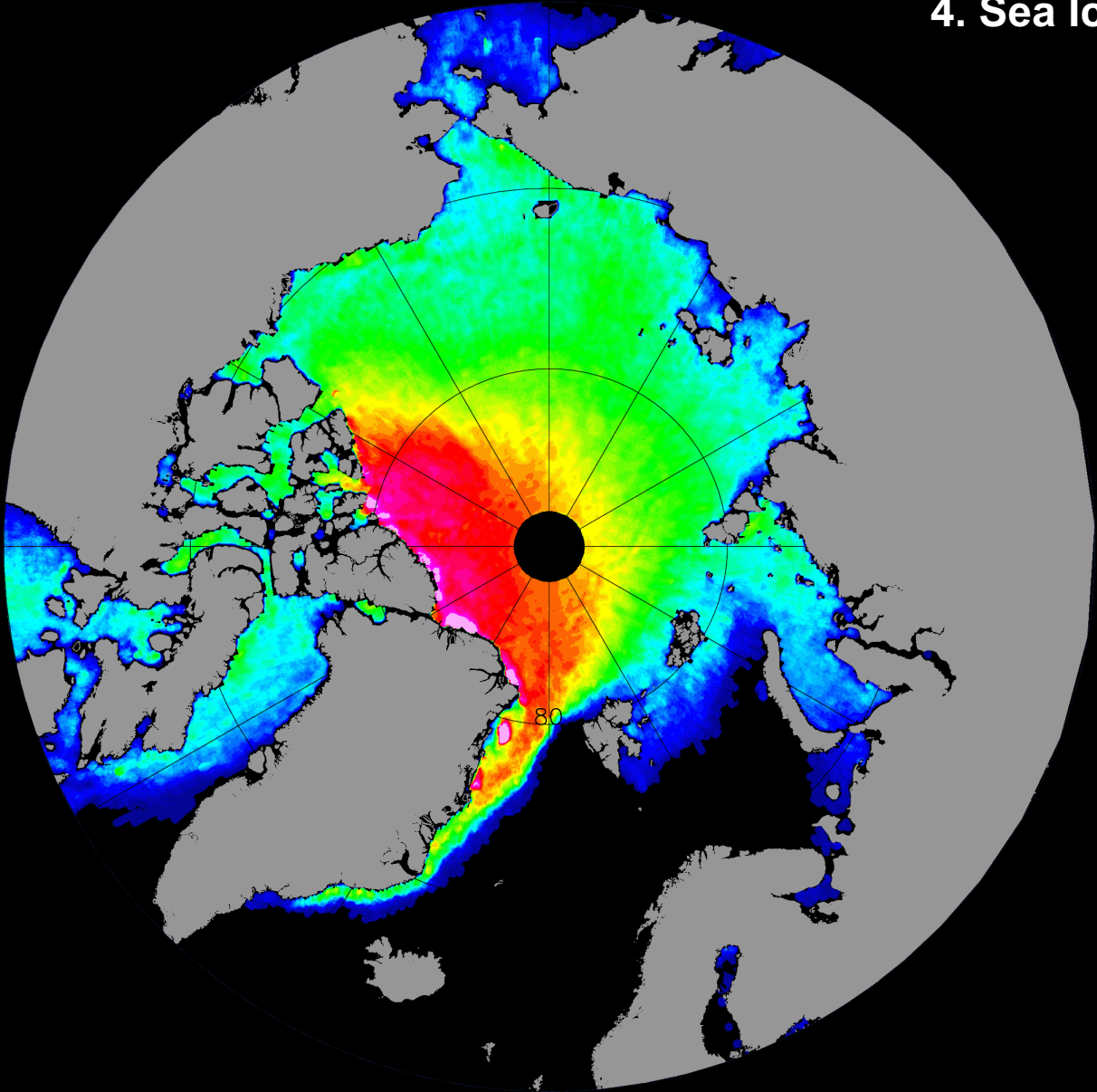
CryoSat



Lead density per 10 km square



4. Sea Ice Altimetry



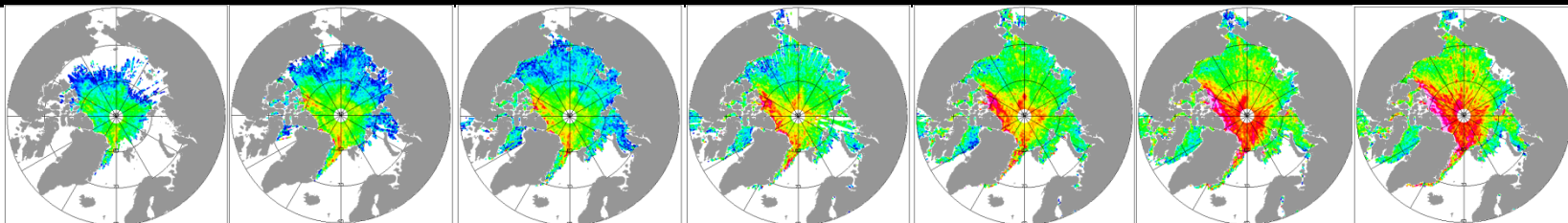
Ice thickness (m)



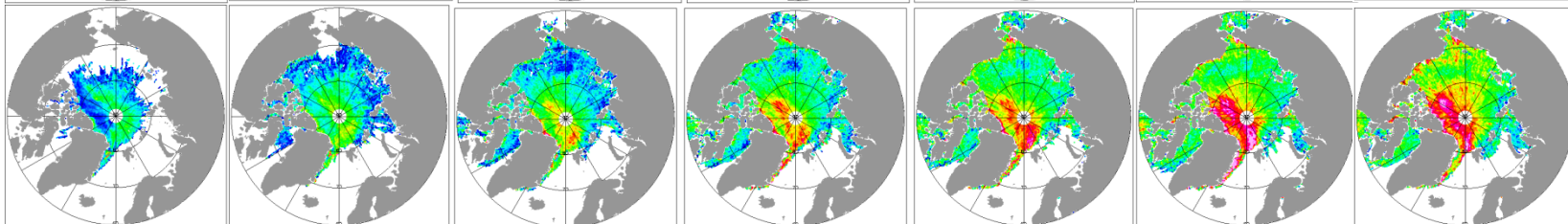
4. Sea Ice Altimetry

Oct Nov Dec Jan Feb Mar Apr

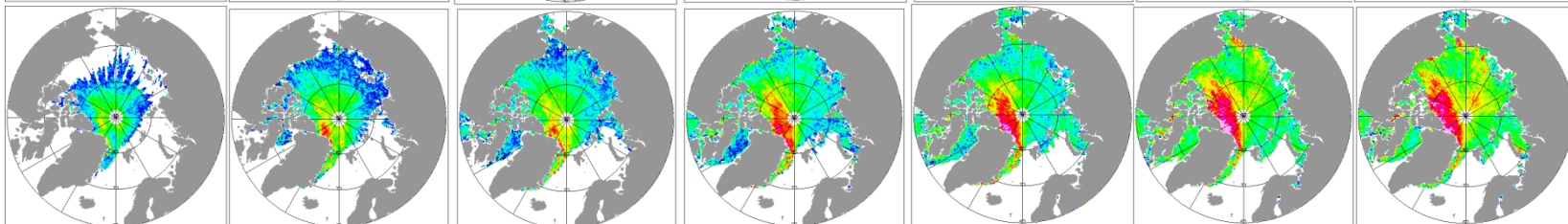
2010/11



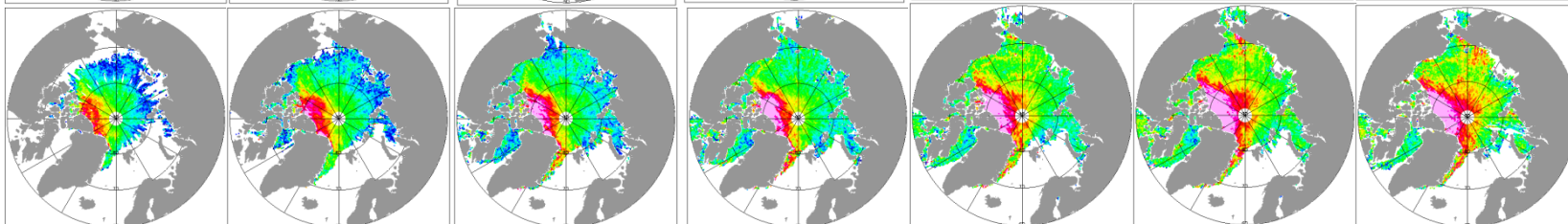
2011/12



2012/13



2013/14



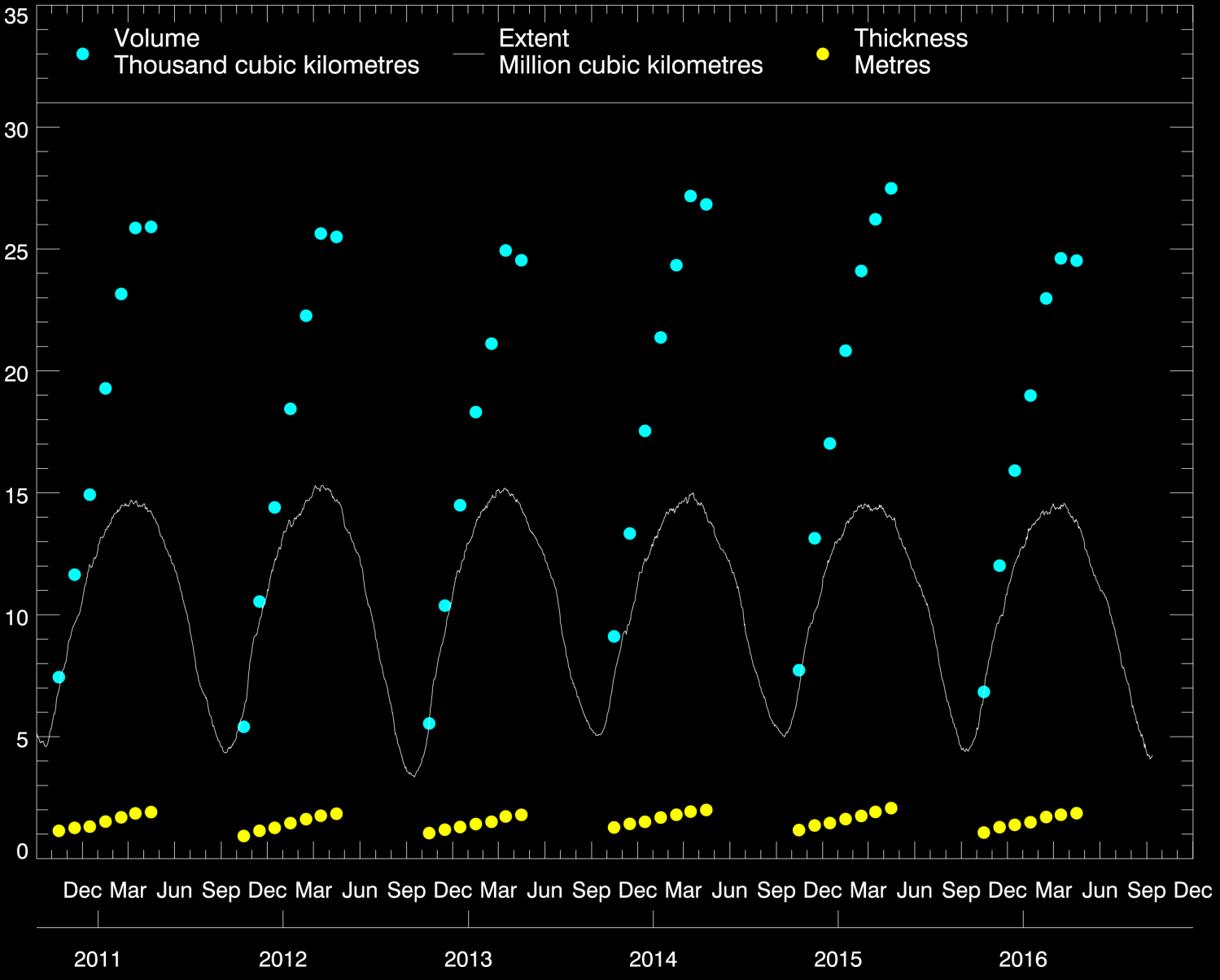
Ice thickness (m)

0

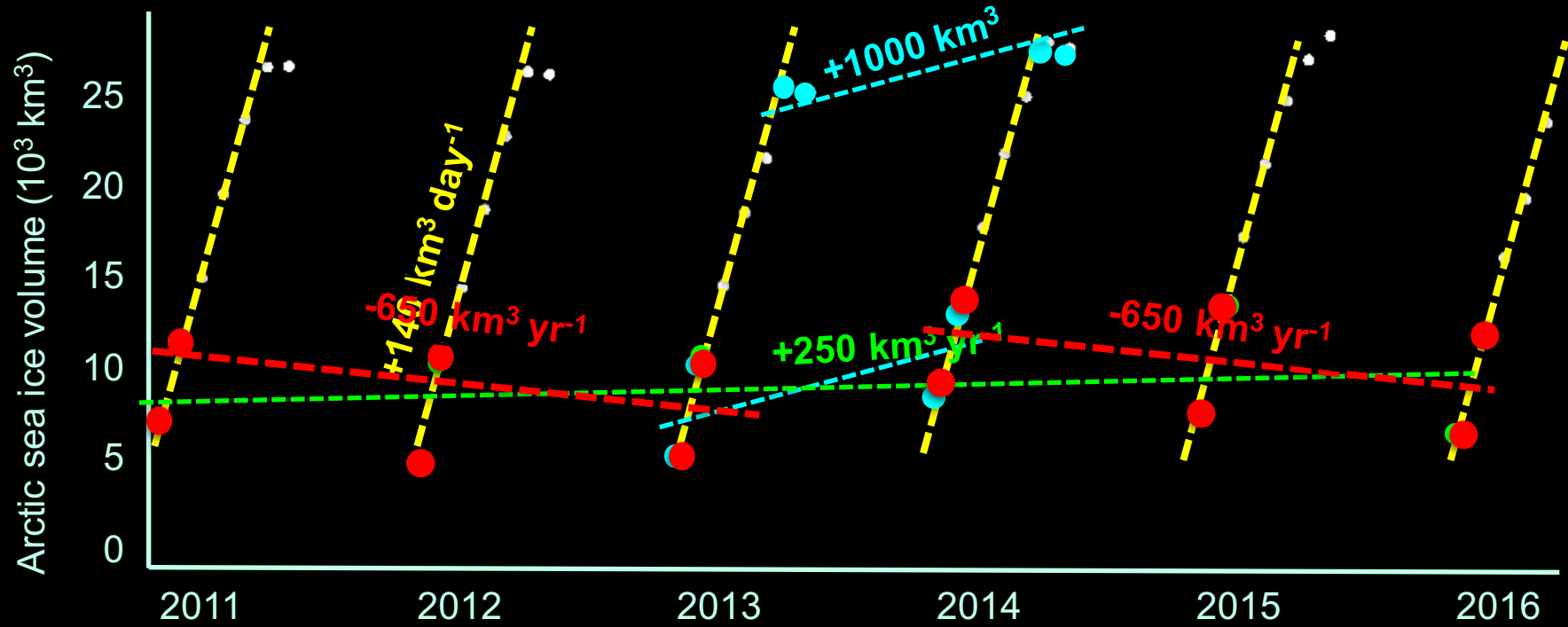


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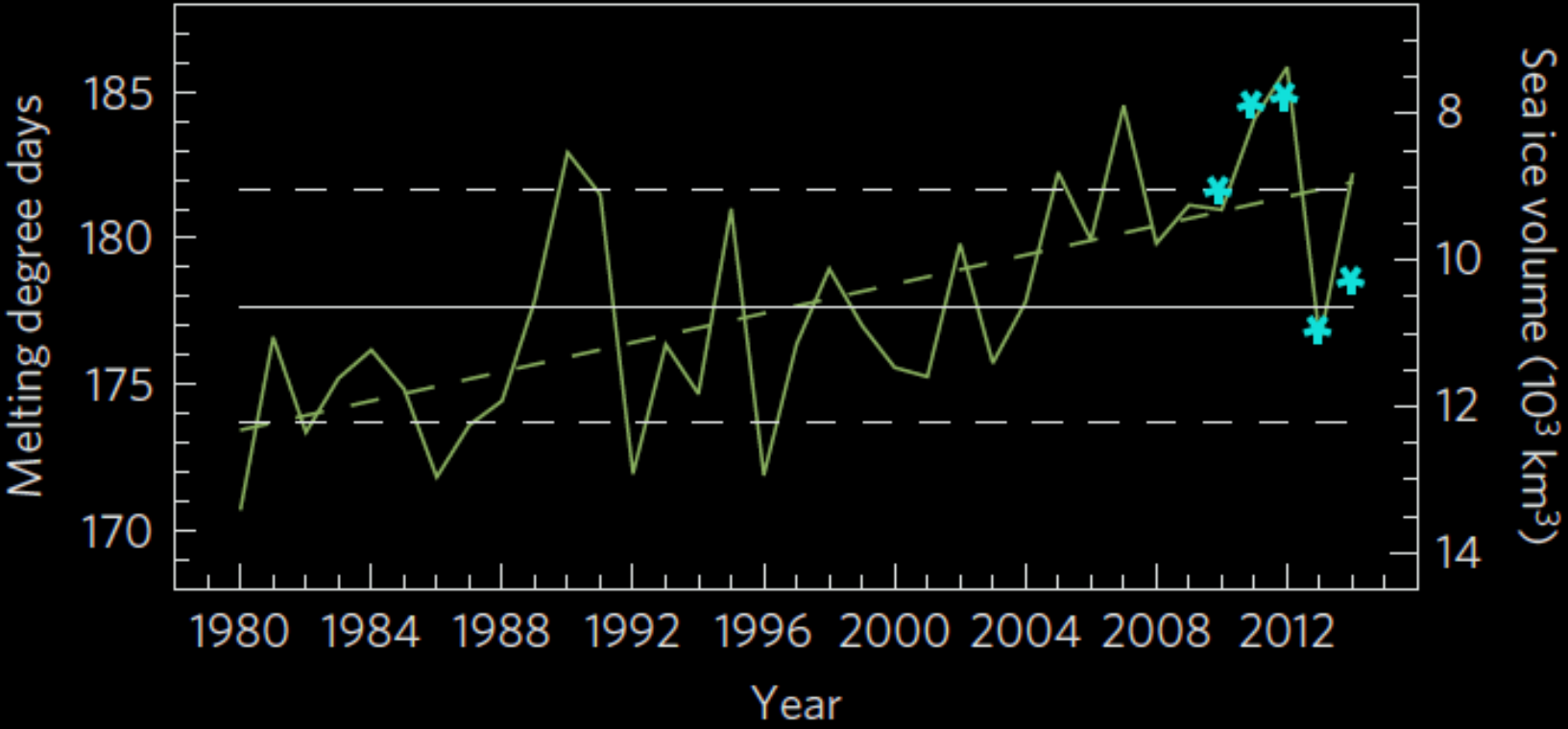
4. Sea Ice Altimetry



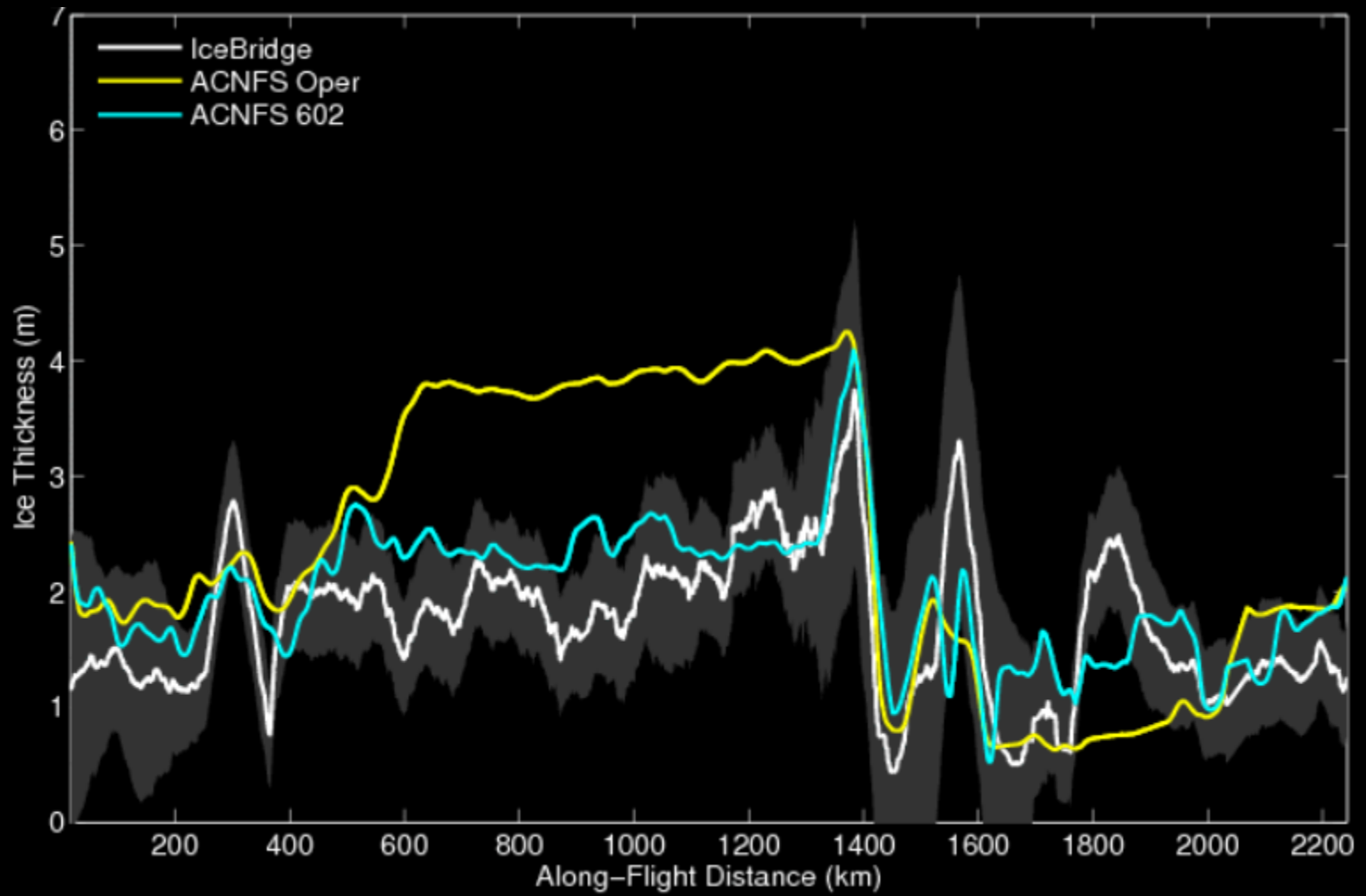
4. Sea Ice Altimetry



4. Sea Ice Altimetry



4. Sea Ice Altimetry



Summary

1. 25+ years of continuous satellite altimetry
2. Powerful EO technique for glaciology
3. Ice dynamical imbalance
4. Ice mass balance
5. Sea ice thickness & volume

