

Improving our understanding of Antarctic sea ice with NASA's Operation IceBridge and the upcoming ICESat-2 mission



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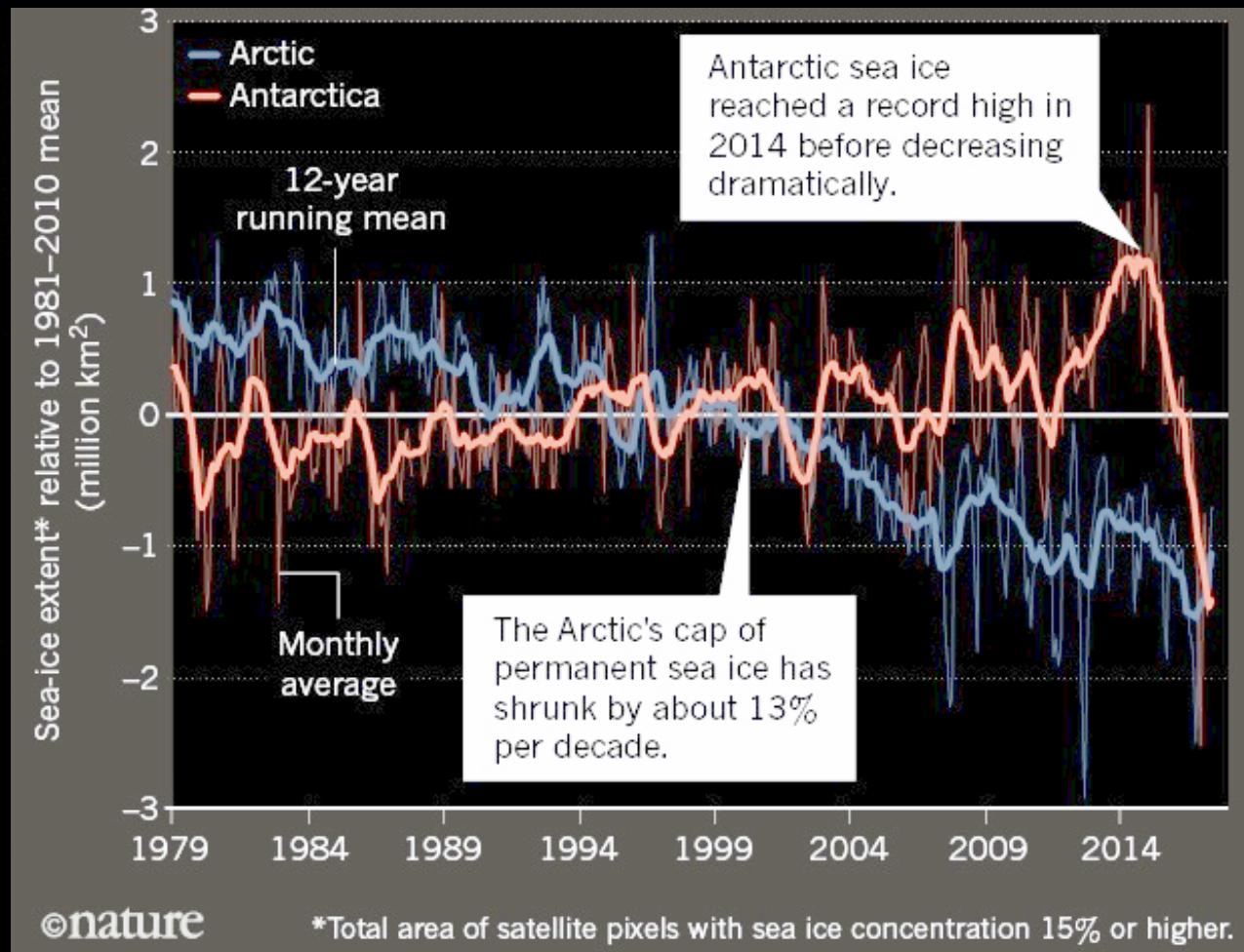


Antarctic sea ice cover



AMSR-2 sea ice concentration on August 28th 2016. Image created by the NASA SVS.

Antarctic sea ice cover



(from 'Solve Antarctica's sea-ice puzzle' by Turner & Comiso, 2017, *Nature*)

Antarctic sea ice cover

- Passive microwave sensors provide a long term record of sea ice cover since the 1970s.
- Captured the small, long-term increase in extent.
- Captured the extreme decline in extent in 2016.

AMSR-2 sea ice concentration on August 28th 2016. Image created by the NASA SVS.

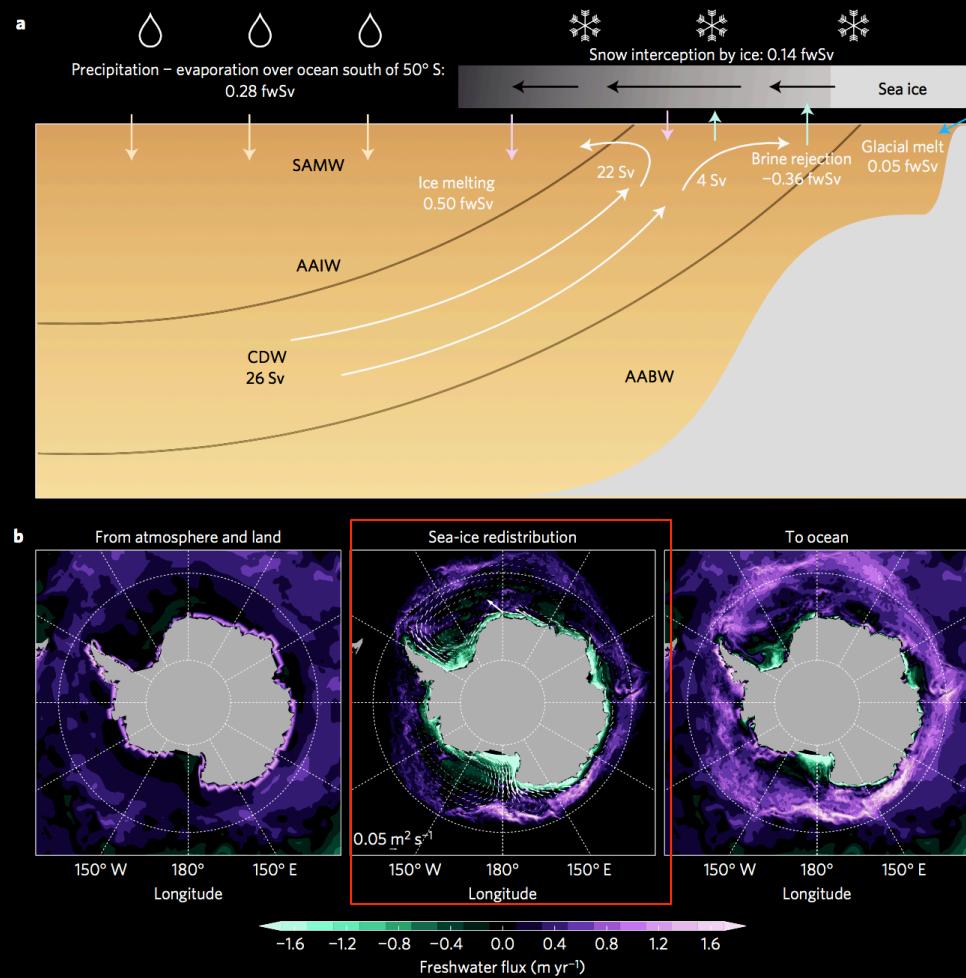
Record low Antarctic sea ice cover



AMSR-2 sea ice concentration: August 2016 to March 2017. Animation by NASA (ft in Nature).

Importance for Southern Ocean circulation

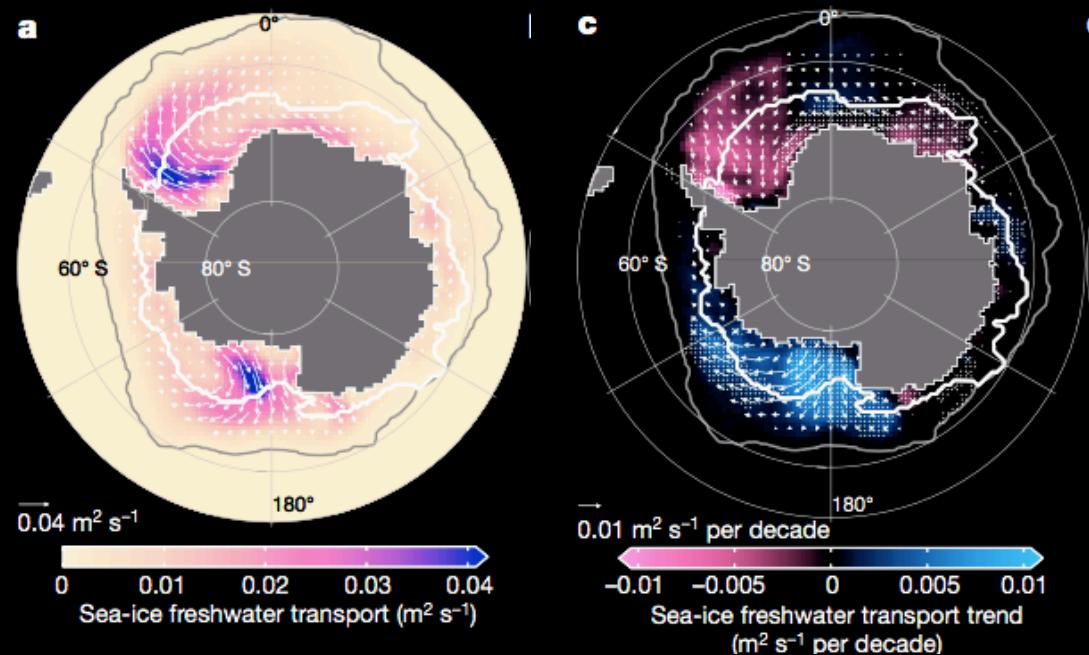
- Ice redistribution transforms the upper branch of the Southern Ocean overturning circulation.



(Abernathay et al., 2016, *Nature Geosciences*)

Importance for Southern Ocean circulation

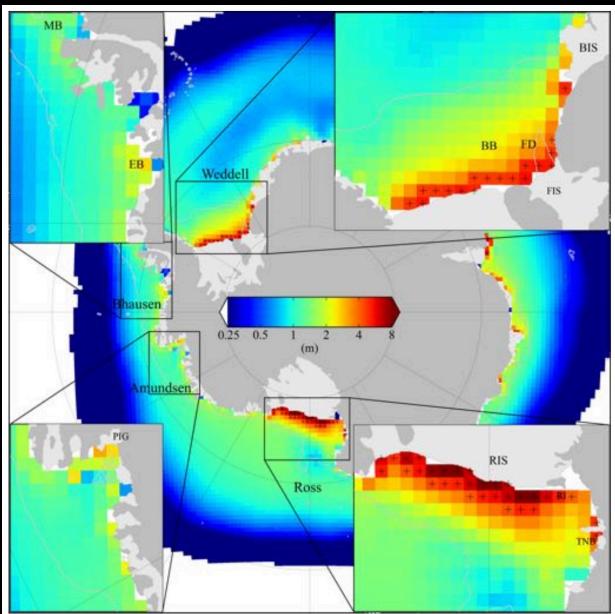
- The northward transport of sea ice is crucial.
- Trends in sea ice transport (positive) imply increasing freshwater export.
- Altered the salinity distribution of the Southern Ocean.



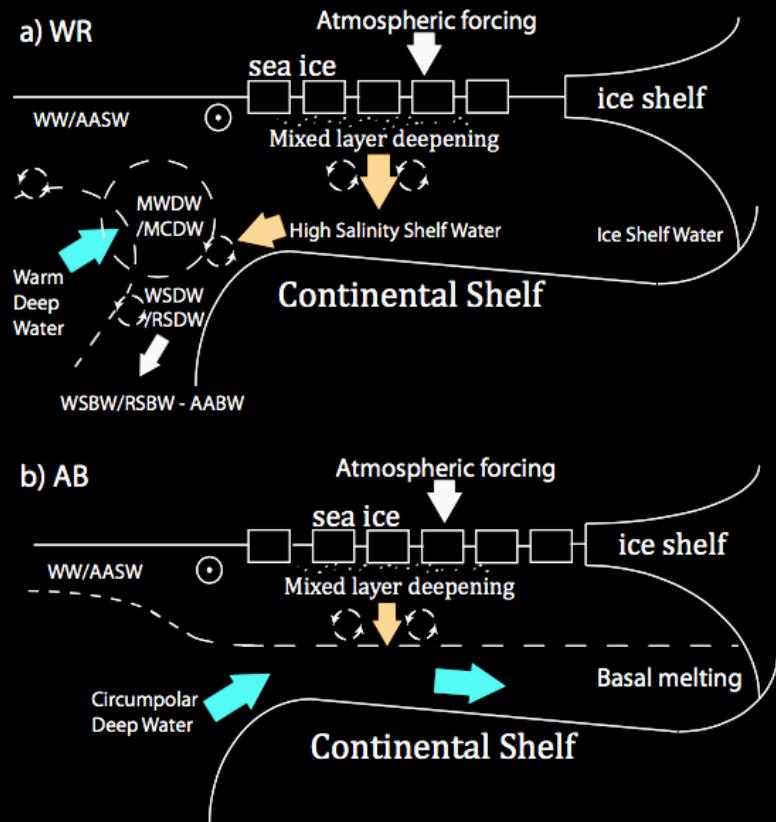
(Haumann et al., 2016, *Nature*)

Importance for shelf water formation

- CICE simulations of sea ice growth.



- Strong regional variability around the coastlines



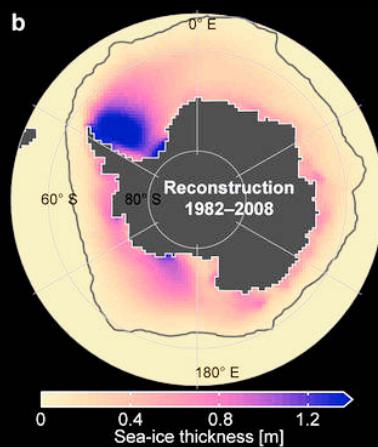
(Petty et al., 2014, *The Cryosphere*)

Importance of sea ice for Southern Ocean

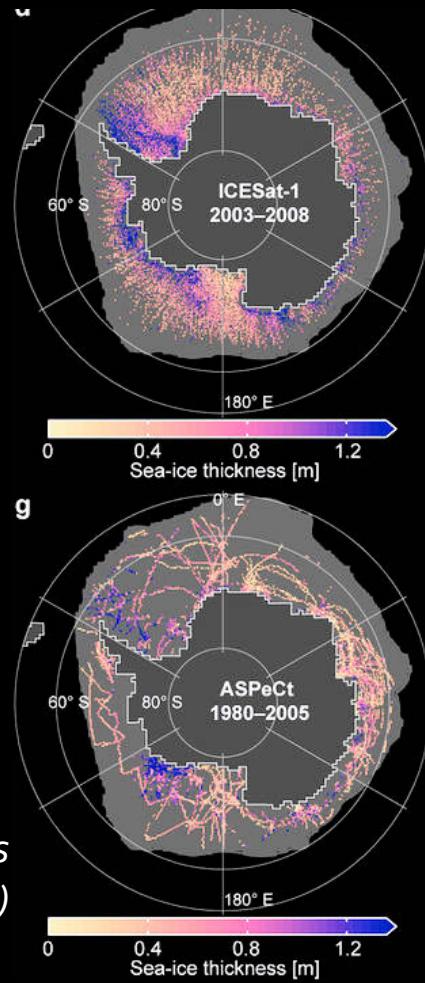
Sea ice thickness/volume and its circulation

Sea ice thickness

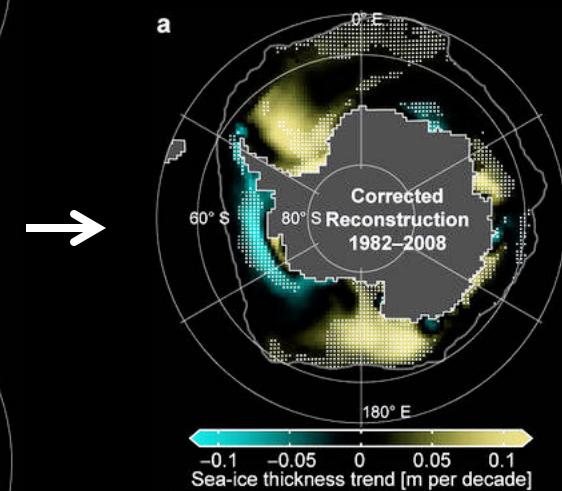
*Ice thickness reconstruction
(Massonnet et al., 2011)*



*ICESat-1 thickness
(Kurtz et al., 2011)*



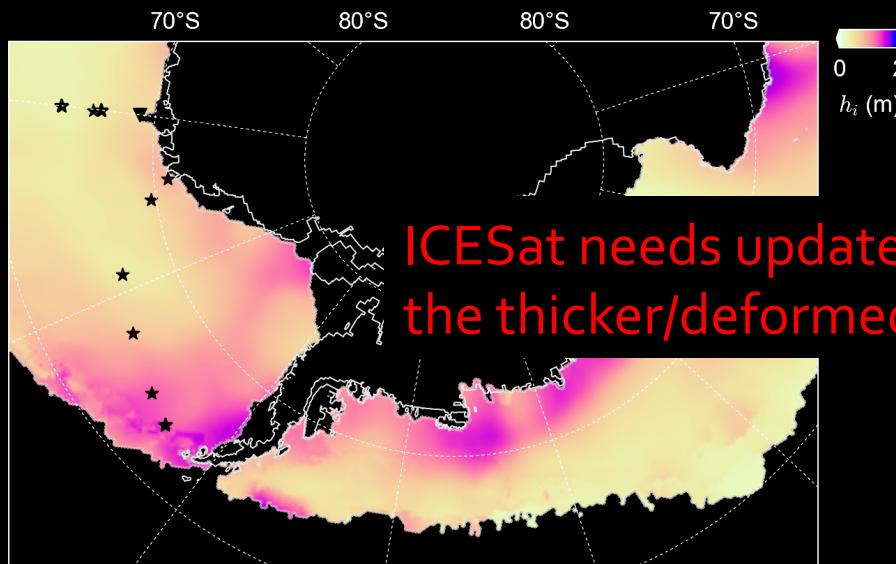
*ASPeCt ship-based obs
(Worby et al., 2008)*



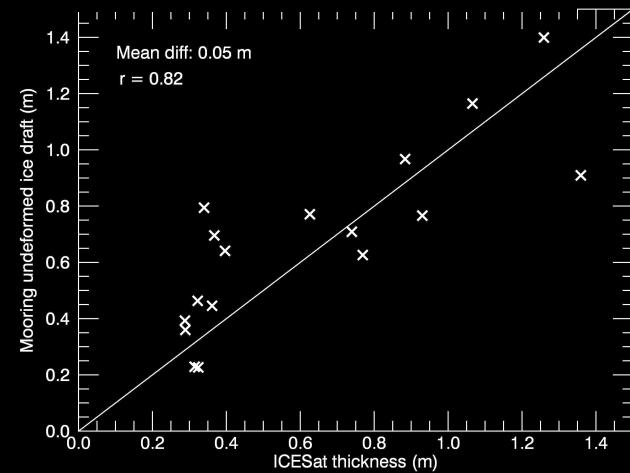
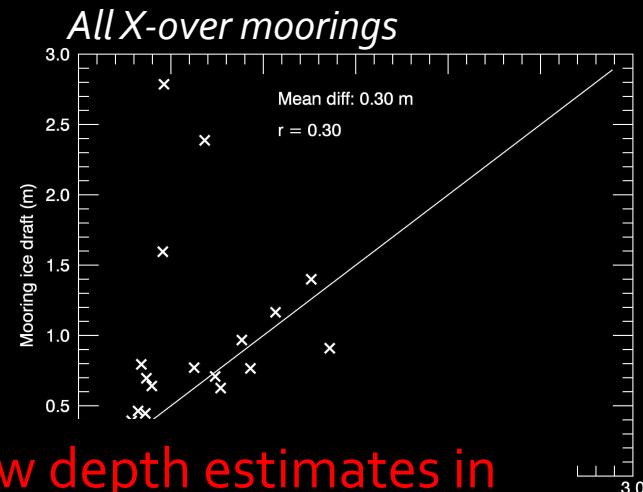
(Haumann et al., 2016, Nature)

Validating ICESat thickness estimates

Single beam profiling laser altimeter with a 70 m footprint at 150 m along-track resolution.

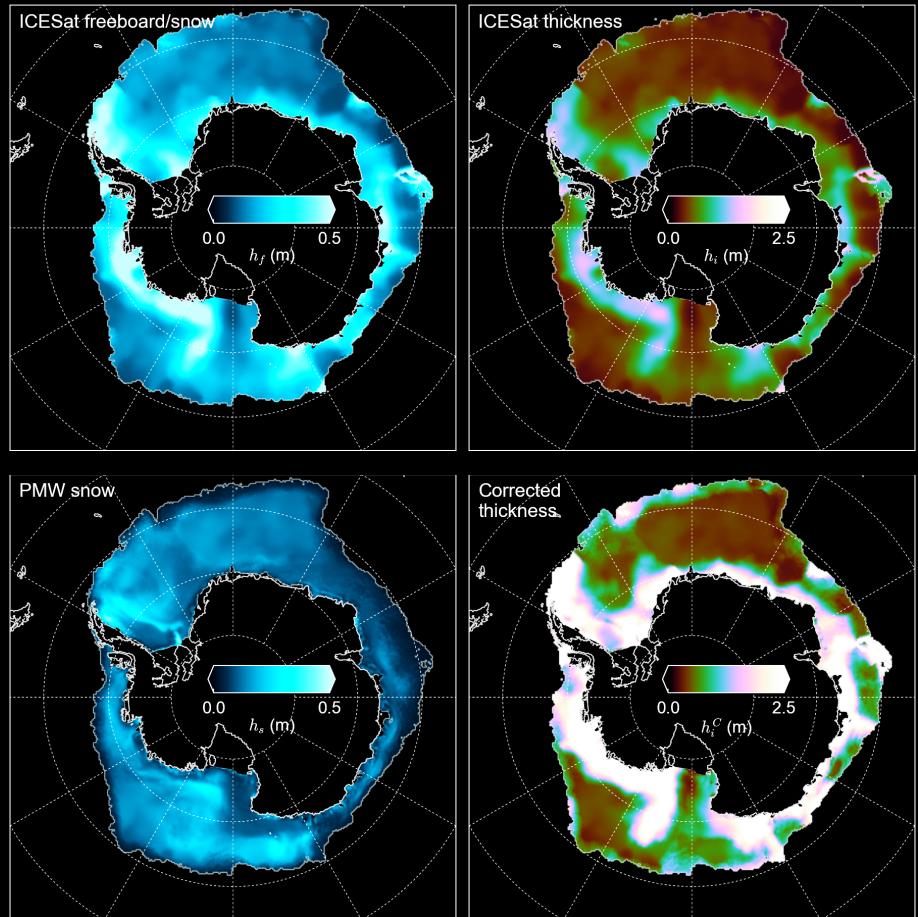
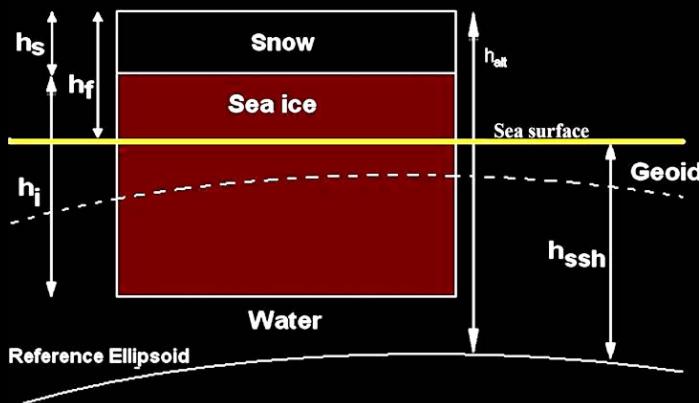


ICESat-1 thickness (October/November, 2003-2008 mean). Black stars indicate the Weddell Sea moorings (various times between 1990 and 2008)



Snow on sea ice

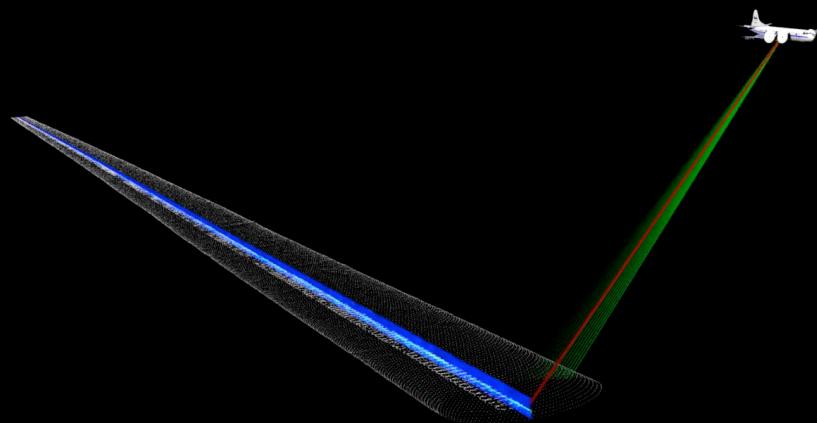
- Current ICESat thickness estimates assume all freeboard is snow.
- Using passive microwave snow estimates generates much higher ice thickness!



ICESat thickness and NASA PMW snow depth (October/November, 2007)

NASA's Operation IceBridge

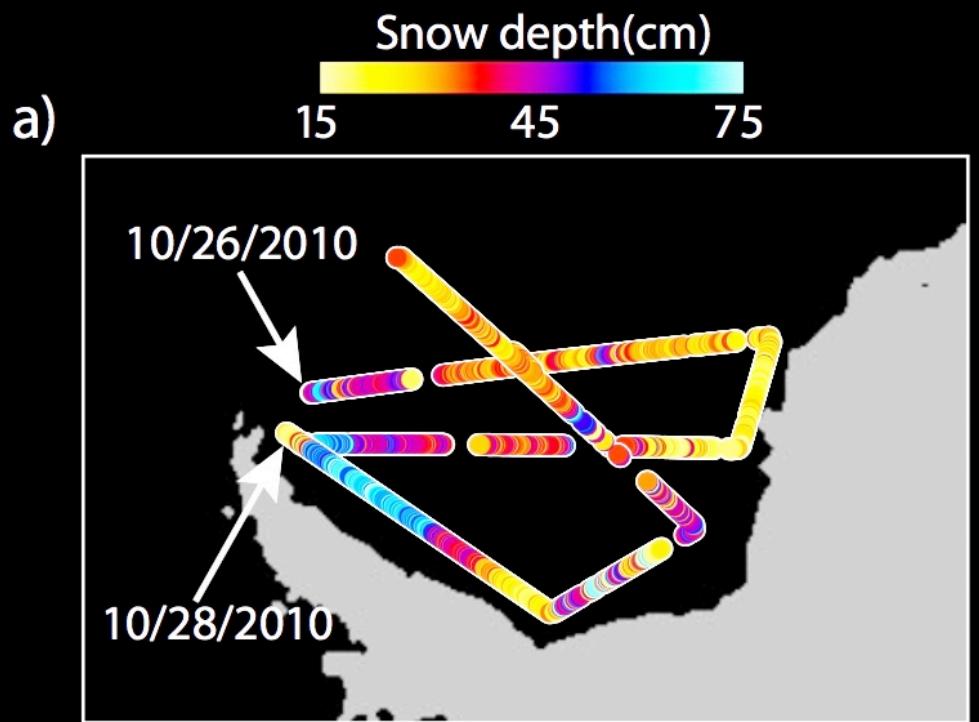
- Suite of sensors to measure both land and sea ice across both poles.
Wide + Narrow ATM Systems + Radar
- Conical scanning laser altimeter (ATM) and snow radar.
- ATM has a 1 m footprint and high vertical accuracy.



NASA's Operation IceBridge

- Suite of sensors to measure both land and sea ice across both poles.
- Conical scanning laser altimeter (ATM) and snow radar.
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Snow depth estimates challenging, but possible!
(e.g. Kwok & Maksym 2014, JGR)

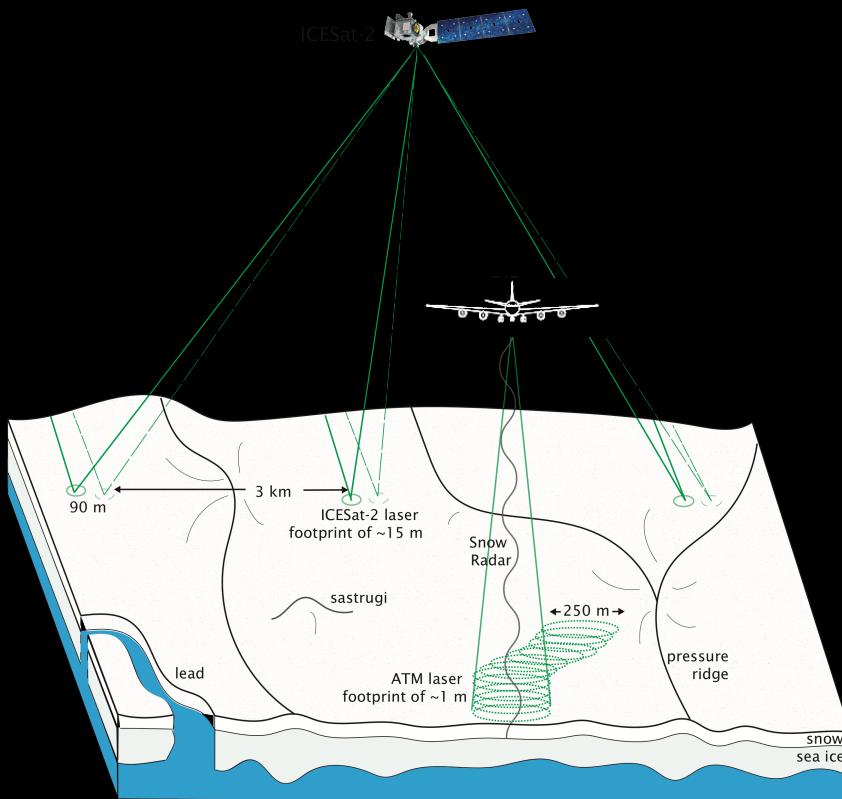


NASA's Operation IceBridge

- Suite of sensors to measure both land and sea ice across both poles.
 - Conical scanning laser altimeter (ATM) and snow radar.
 - ATM has a 1 m footprint and high vertical accuracy.
 - Laser ATM data used to detect surface roughness.
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- Important to understand snow depths (data and accumulation) .
 - Also want to estimate wind drag coefficient, as in the Arctic (*Petty et al., 2017, JGR*).

NASA's ICESat-2 mission

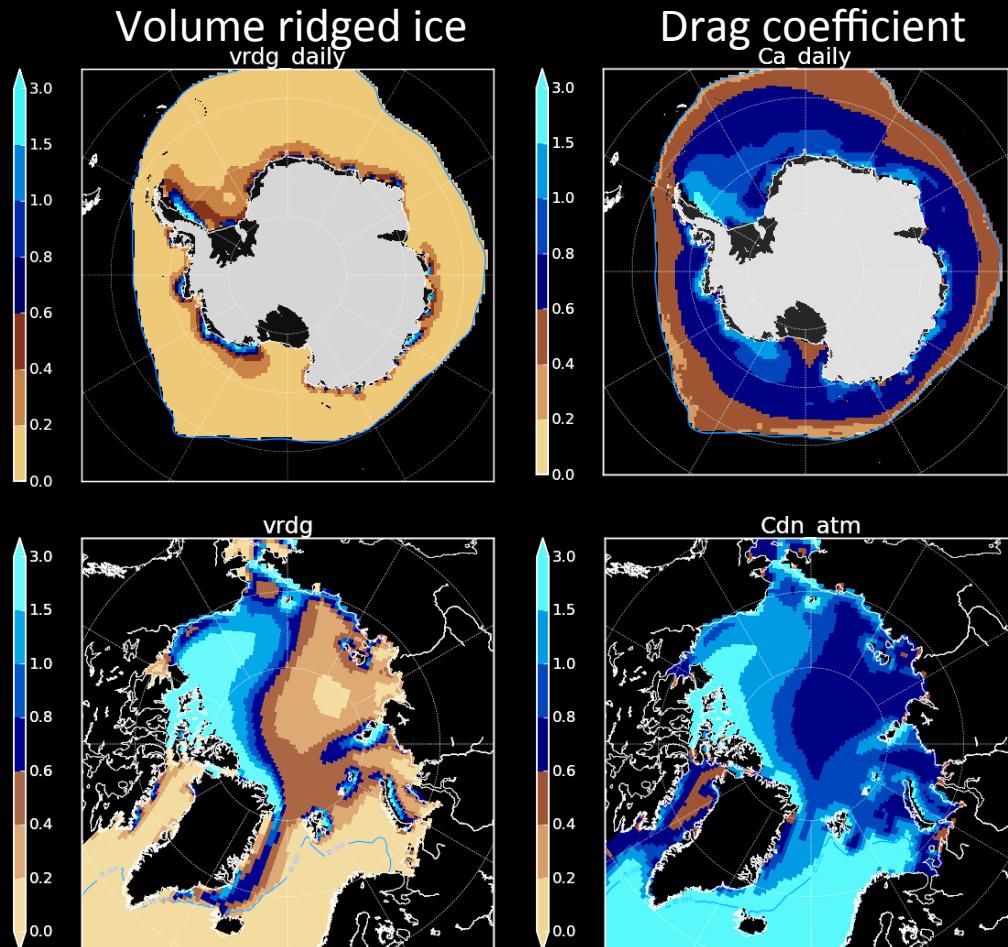
Scheduled for launch in 2018



- Laser altimeter, photon counter.
- Three pairs of beams, footprint of ~15 m.
- Will provide measurements of sea ice freeboard.
- Still need to think about snow depth.
- 70 cm along-track sampling will provide good data for estimating roughness.
- What else can we do?

Sea ice modelling – new physics

- Form drag scheme included in the sea ice model CICE.
- Has a significant impact on Arctic sea ice mass balance.
- Still testing impact on Antarctic simulations.
- Hoping to improve representation of thickness and transport. Need to calibrate with obs.



(Tsamados et al., 2014, JPO, Tsamados et al., in prep)

Summary

- Antarctic sea ice a crucial component of Southern Ocean system.
- Still a lot of unknowns surrounding Antarctic sea ice, especially regarding its thickness distribution.
- Using IceBridge to learn more about the deformed/undeformed ice regimes.
- Looking ahead to the launch of ICESat-2
- Improving physics in sea ice models, which need to be better calibrated/validated with observations.