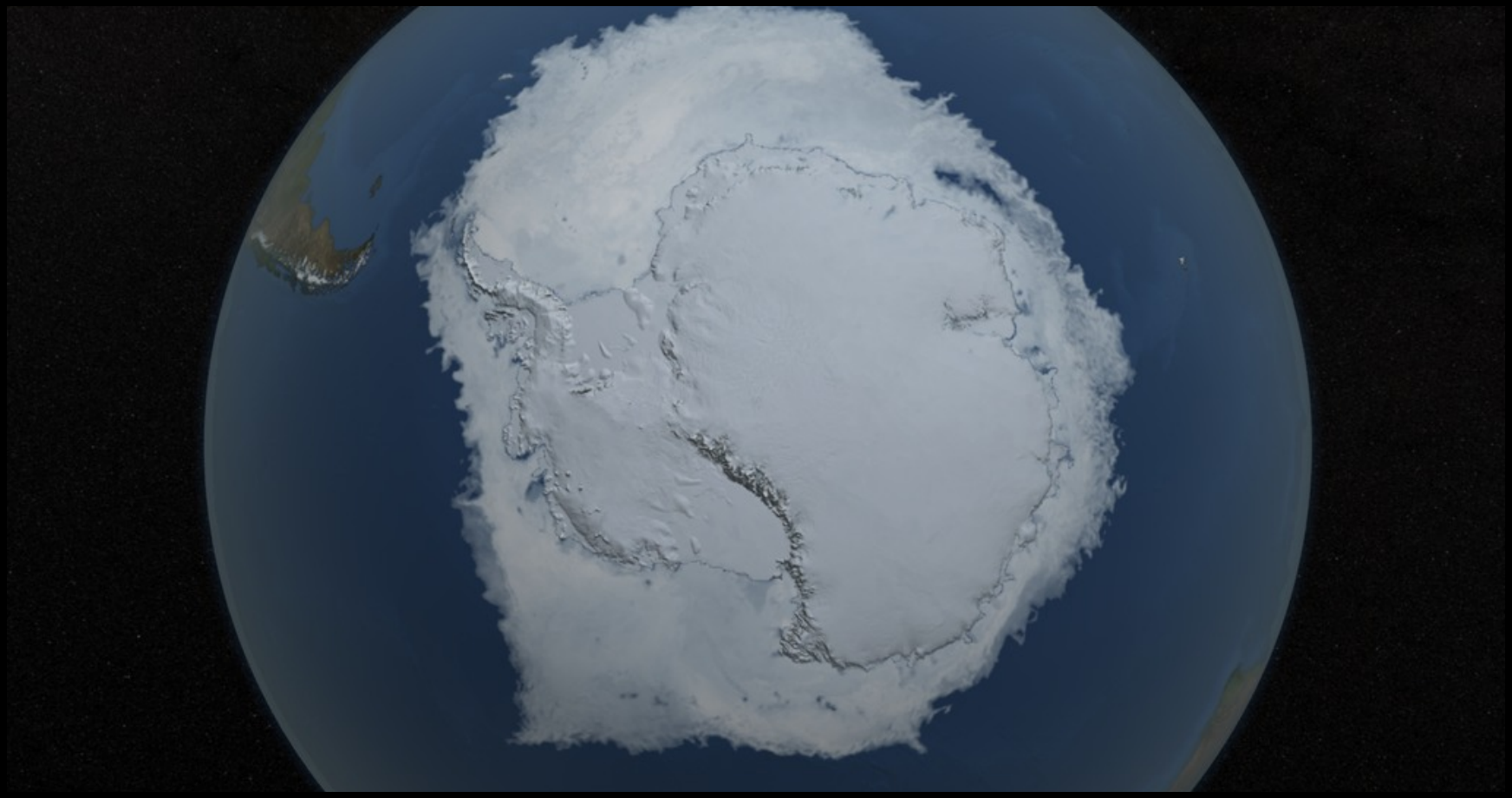
Improving our understanding of Antarctic sea ice with NASA's Operation IceBridge and the upcoming ICESat-2 mission

Alek Petty, Nathan Kurtz, Thorsten Markus, Michel Tsamados

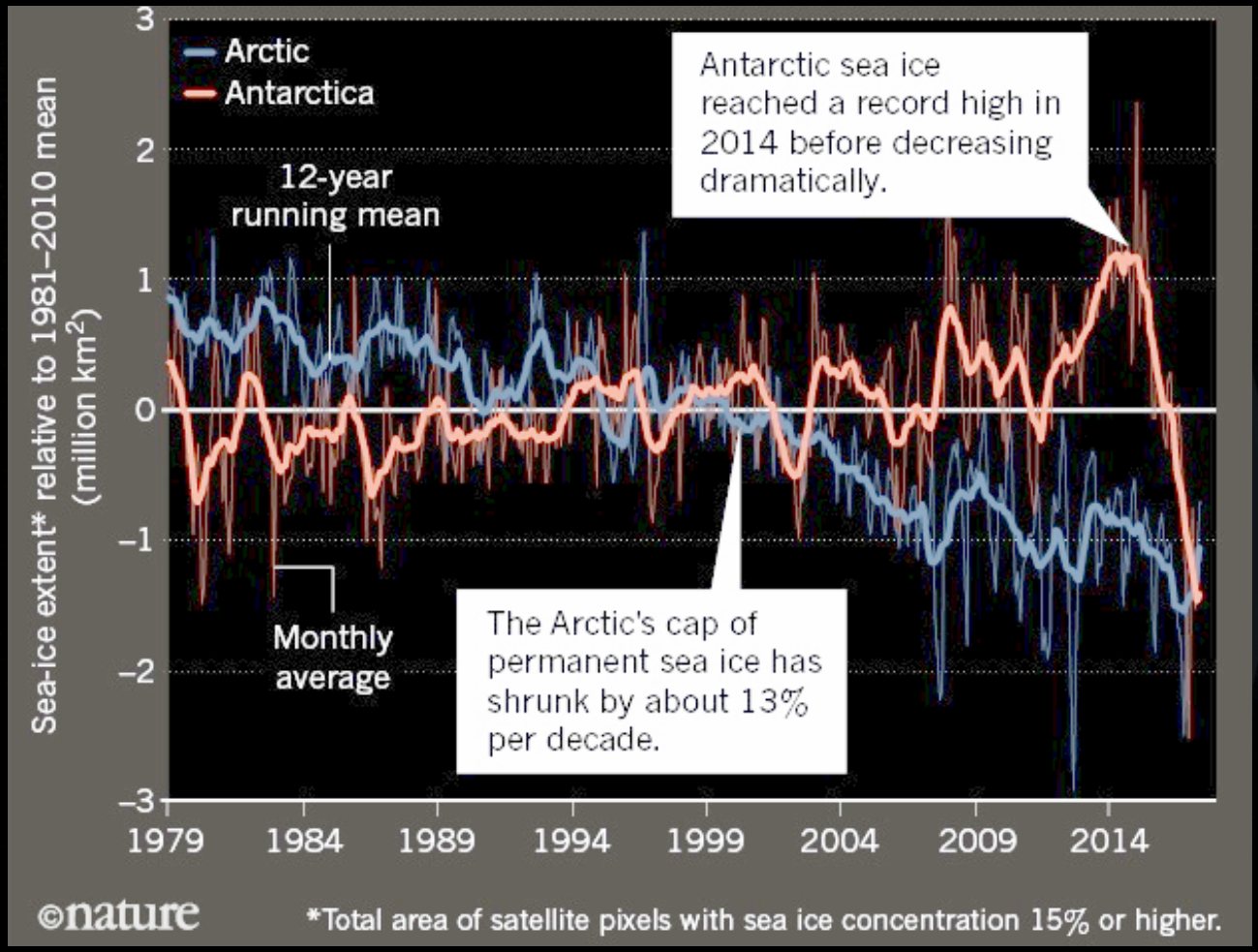
www.alekpetty.com / @alekpetty / alek.a.petty@nasa.gov

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.

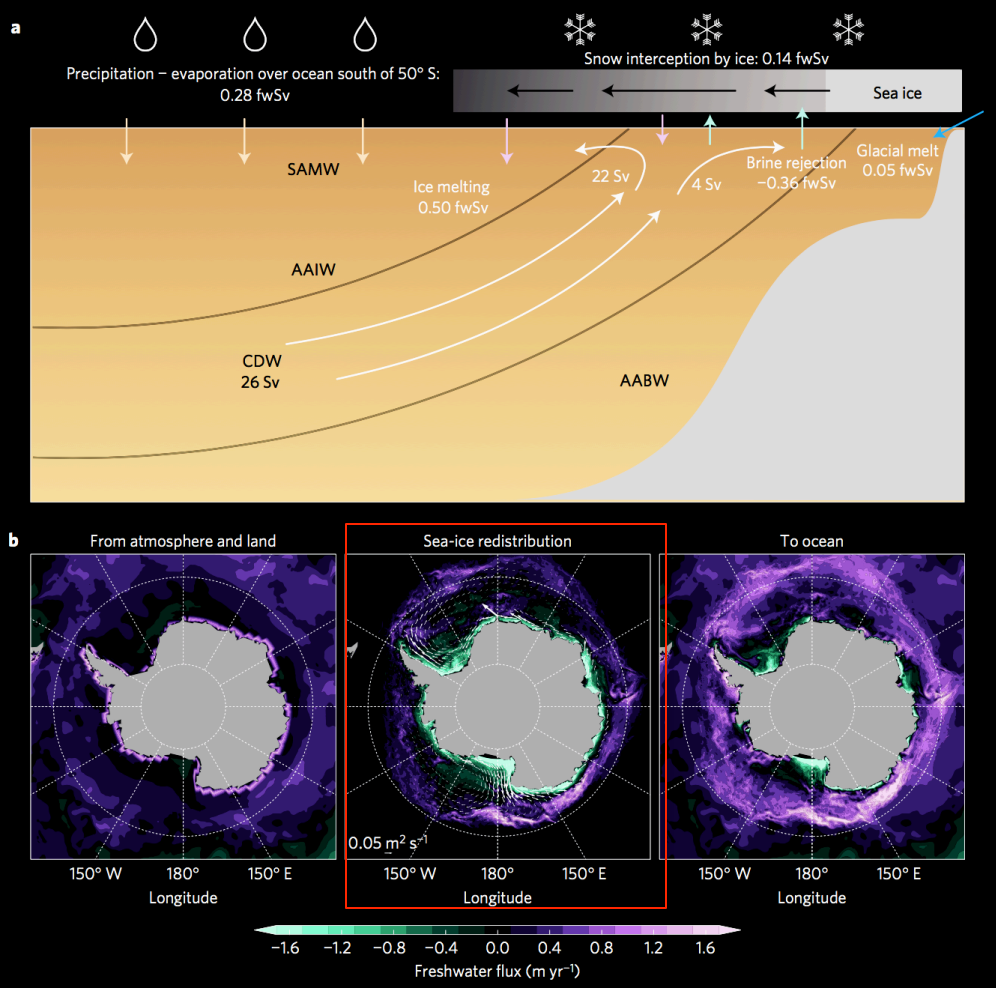
Record low Antarctic sea ice cover

Interesting surprise. But why does Antarctic sea ice matter?

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

Importance for Southern Ocean circulation

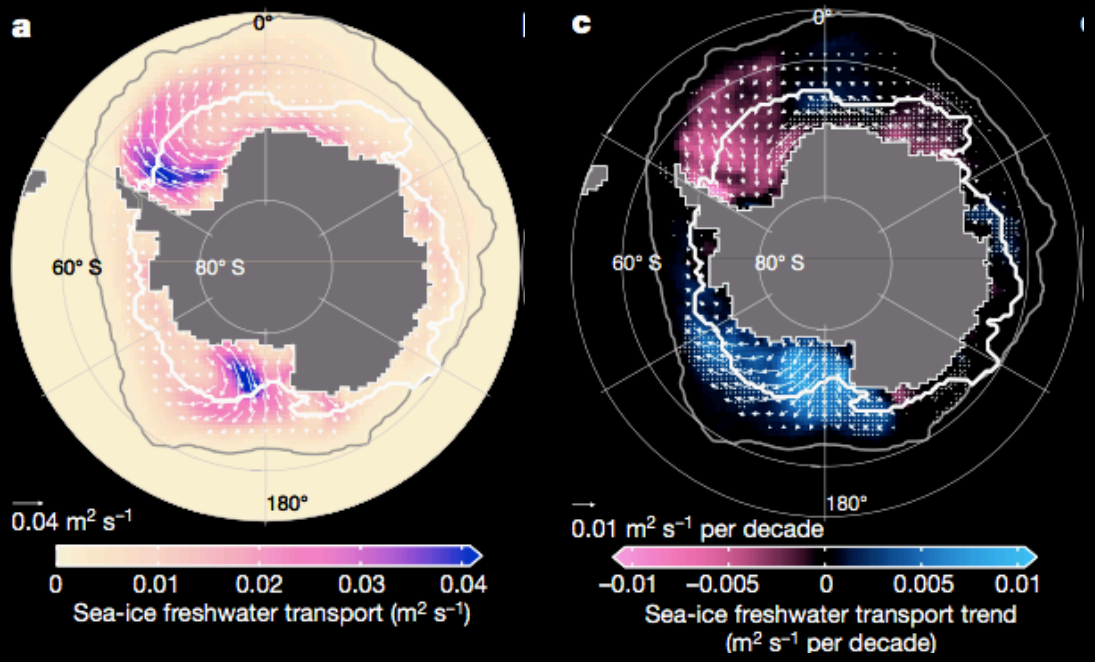
- Ice redistribution transforms the upper branch of the Southern Ocean overturning circulation.



(Abernathey et al., 2016, Nature Geosciences)

Importance for Southern Ocean circulation

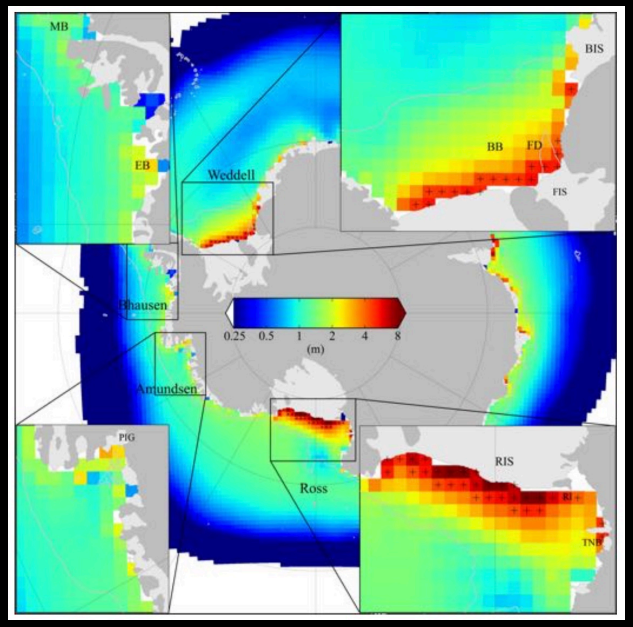
- The northward transport of sea ice is crucial.
- Trends in sea ice transport (positive) imply increasing freshwater export.
- Altered the salinity distribution of the Southern Ocean.



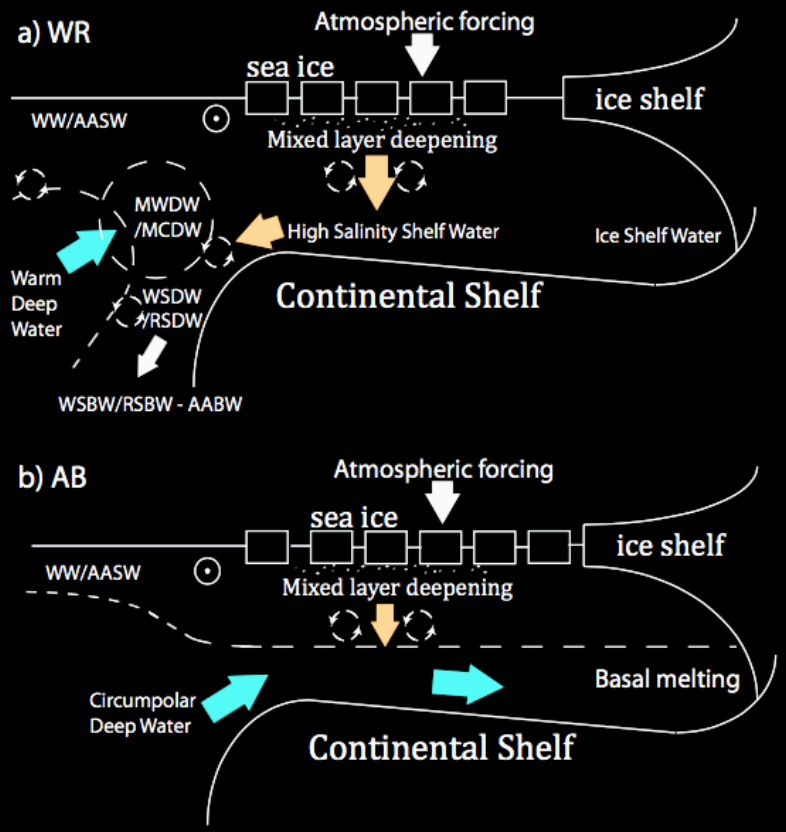
(Haumann et al., 2016, Nature)

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

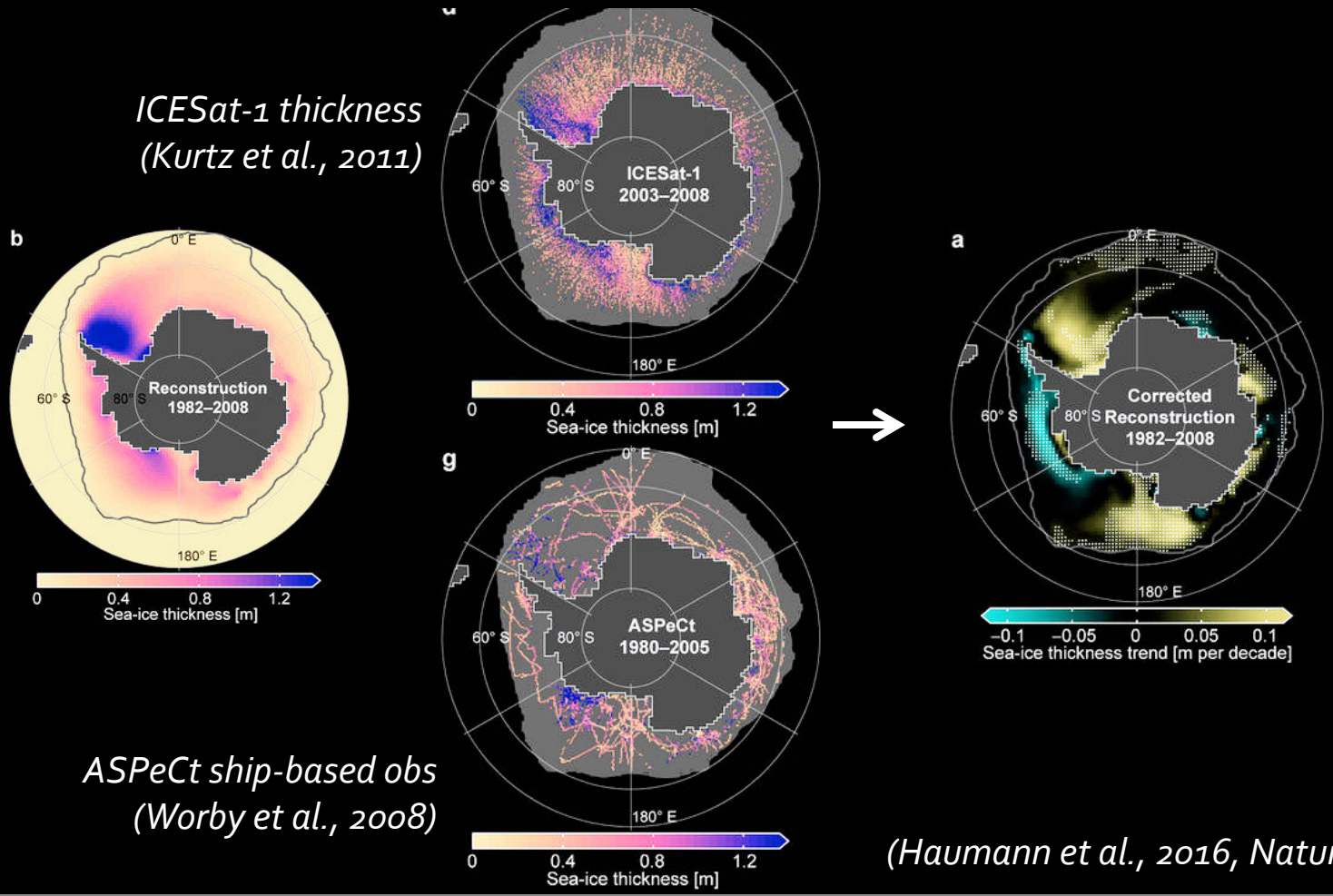
Sea ice thickness/volume and its circulation

Sea ice thickness

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

Ice thickness reconstruction (Massonnet et al., 2011)

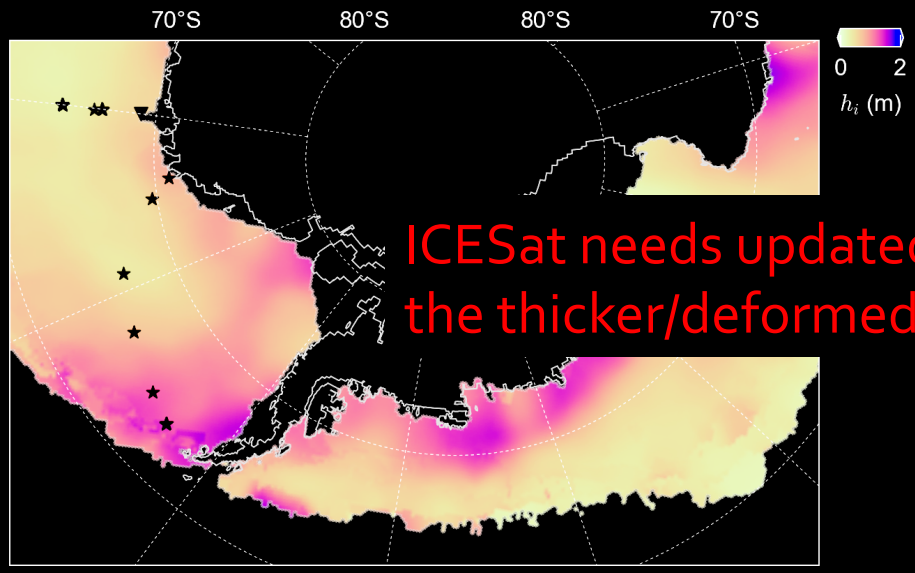
ASPeCt ship-based obs (Worby et al., 2008)



(Haumann et al., 2016, Nature)

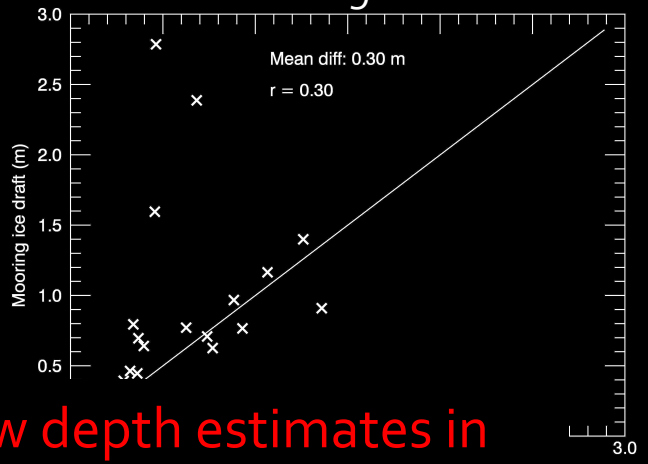
Validating ICESat thickness estimates

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

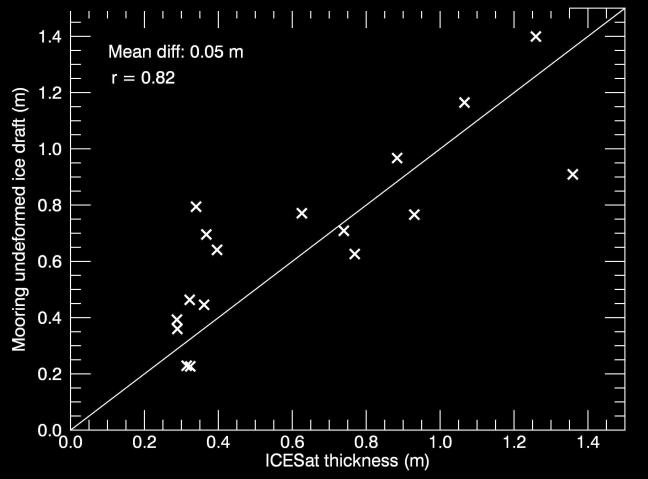


ICESat-1 thickness (October/November, 2003-2008 mean).Black stars indicate the Weddell Sea moorings (various times between 1990 and 2008)

All X-over moorings

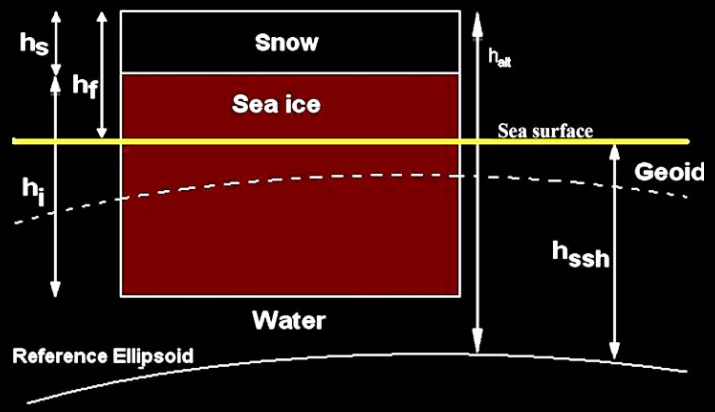


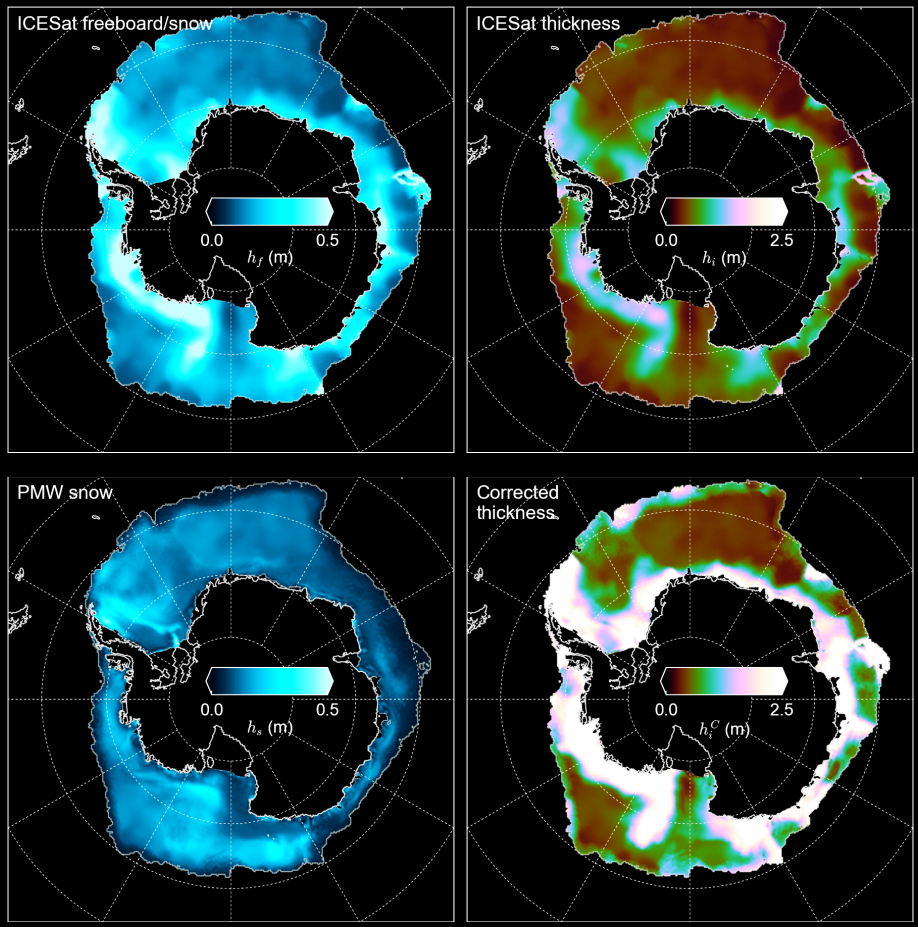
ICESat needs updated snow depth estimates in the thicker/deformed ice?



Snow on sea ice

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

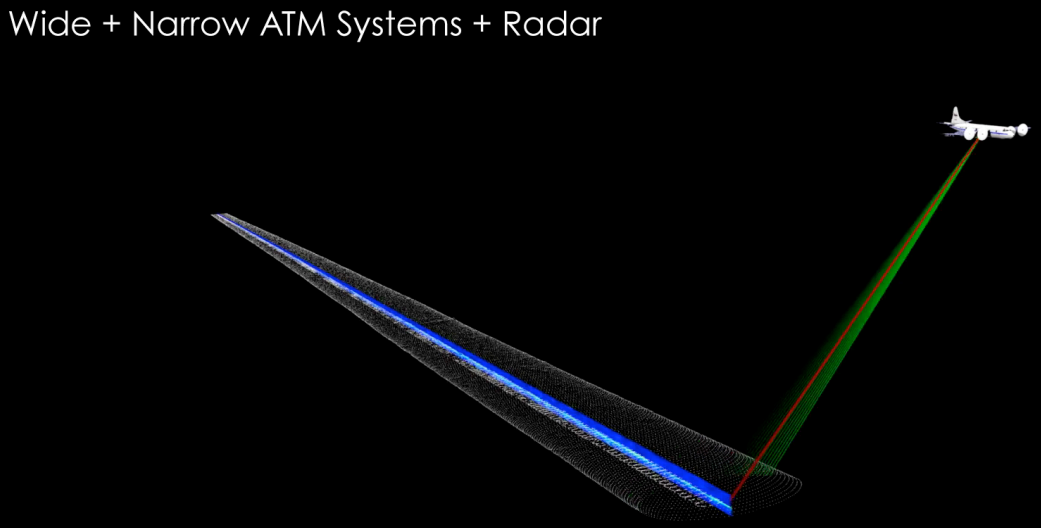




ICESat thickness and NASA PMW snow depth (October/November, 2007)

NASA's Operation IceBridge

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

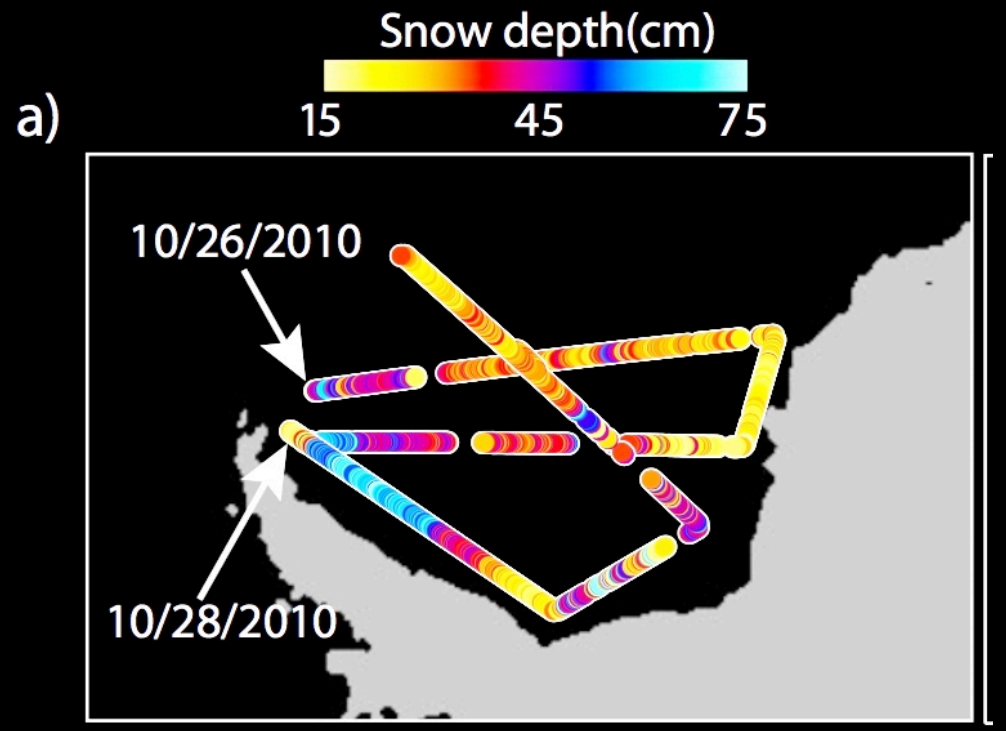


NASA's Operation IceBridge

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

Snow depth estimates challenging, but possible!

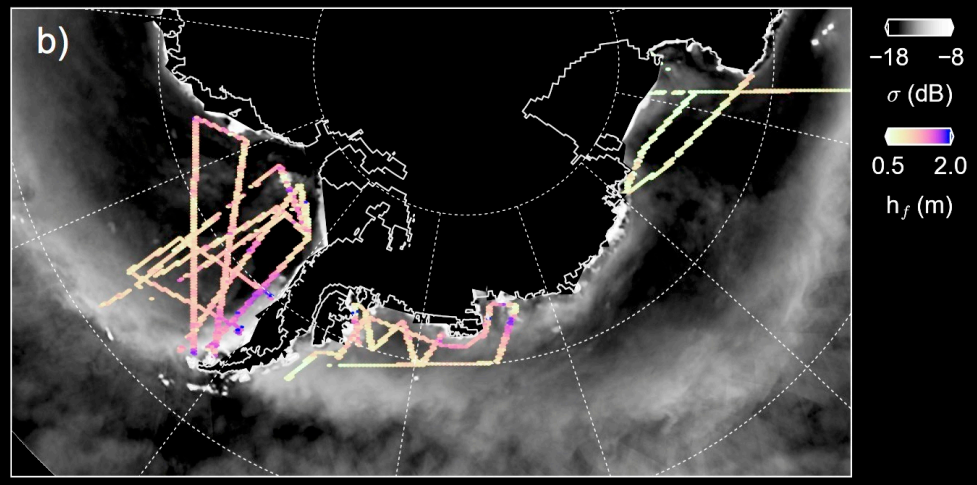
(e.g. Kwok & Maksym 2014, JGR)



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.

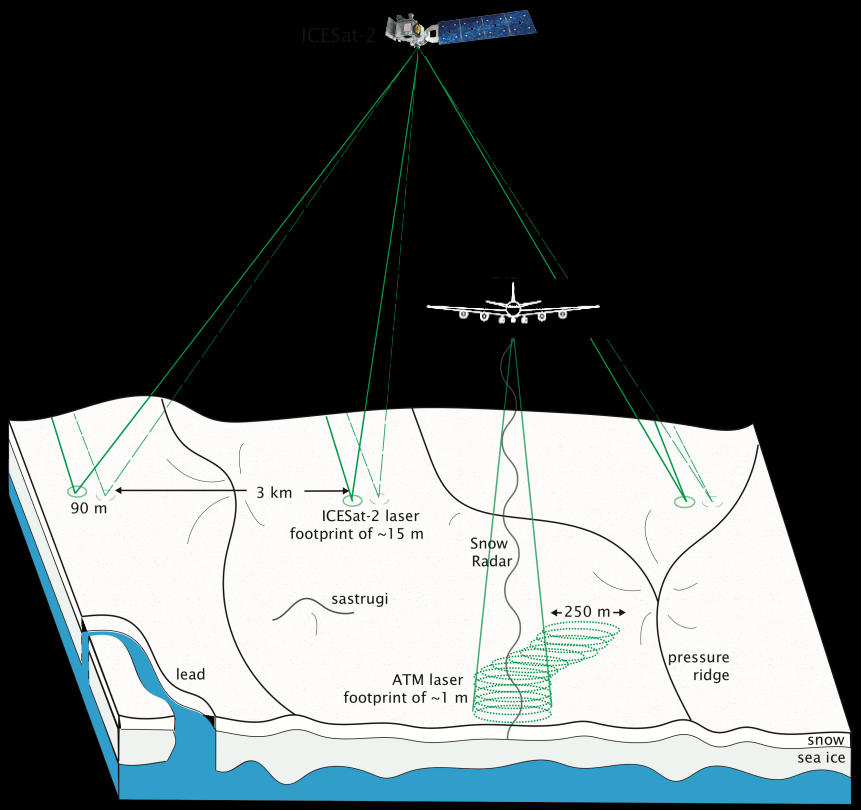
- Laser ATM data used to detect surface roughness.



- 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

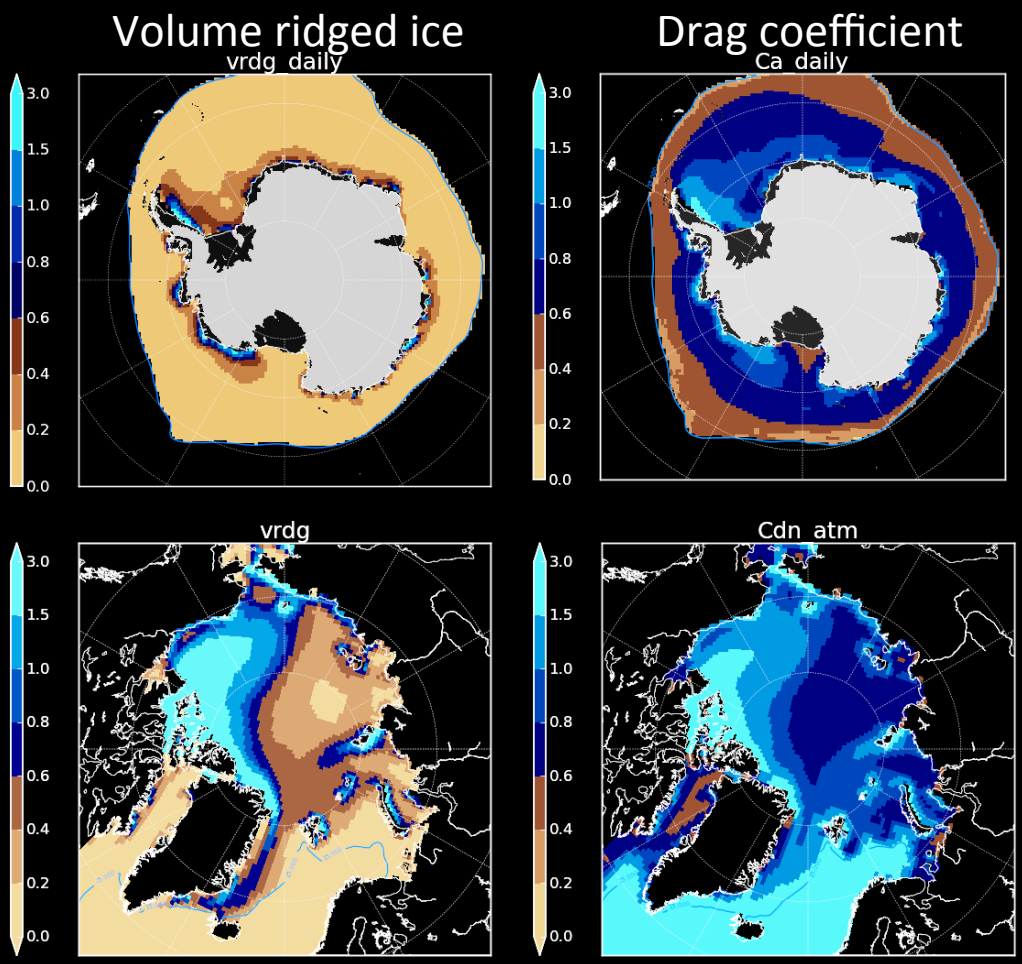
Scheduled for launch in 2018



- 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.