Improving our understanding of polar sea ice with NASA's ICESat, Operation IceBridge, and the upcoming launch of ICESat-2

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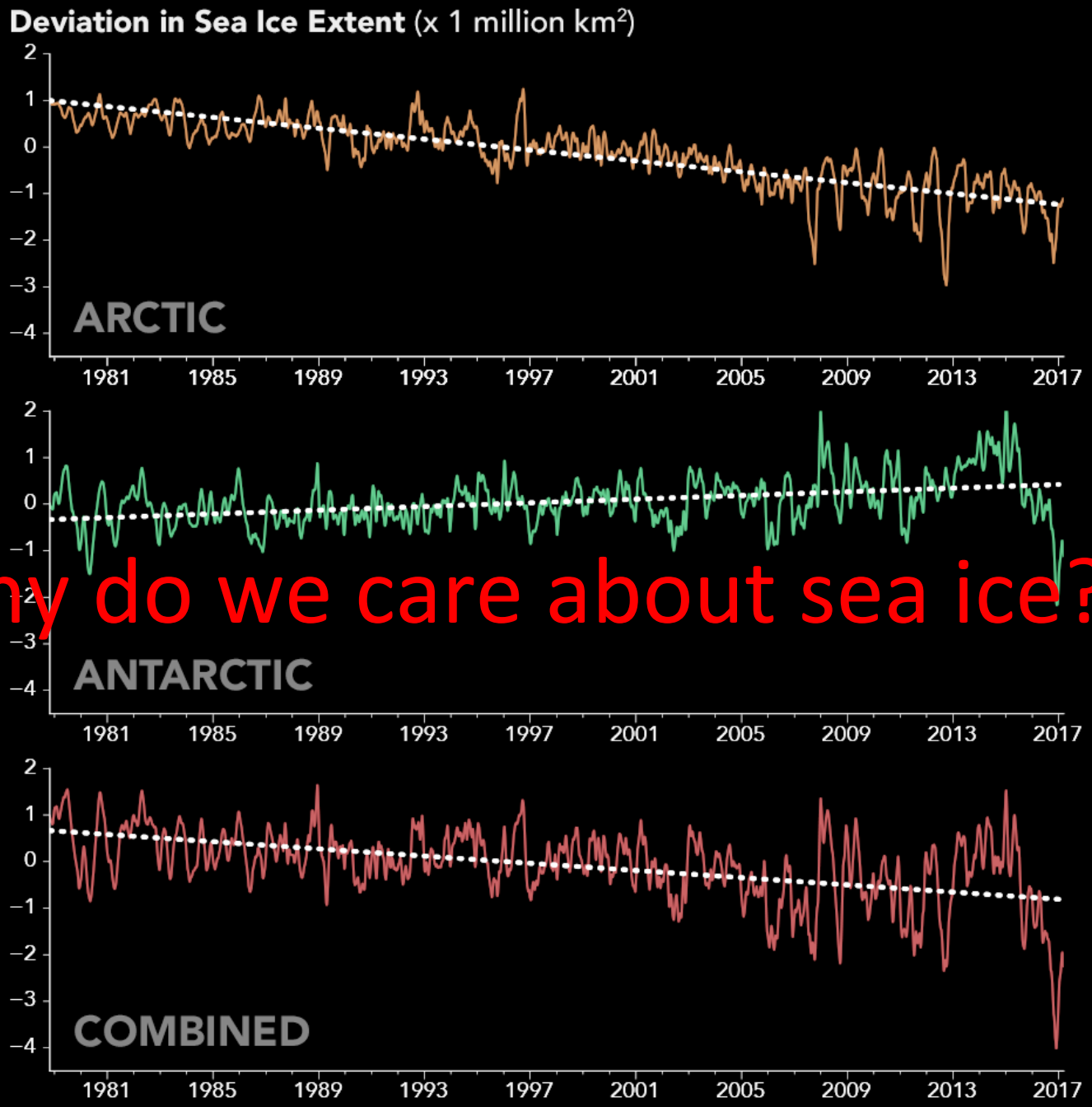


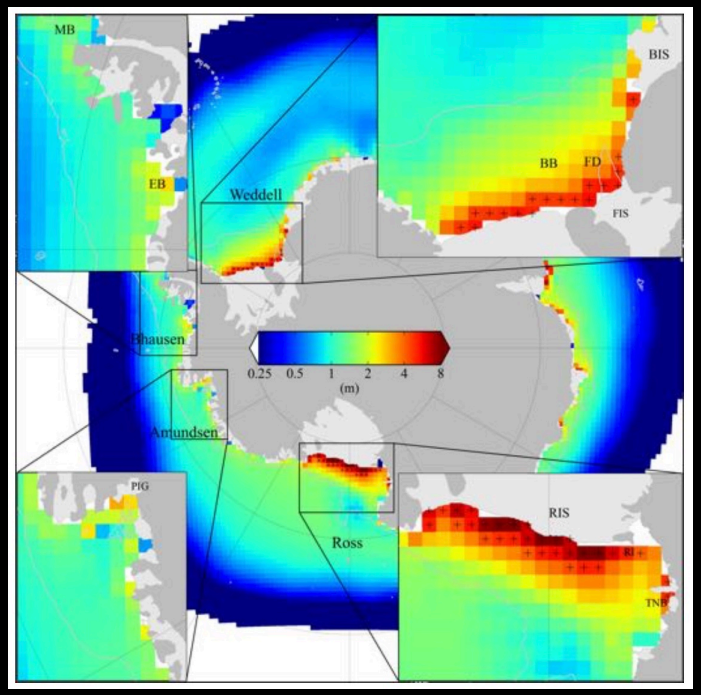
Why do we care about sea ice?

Produced by NASA's SVS

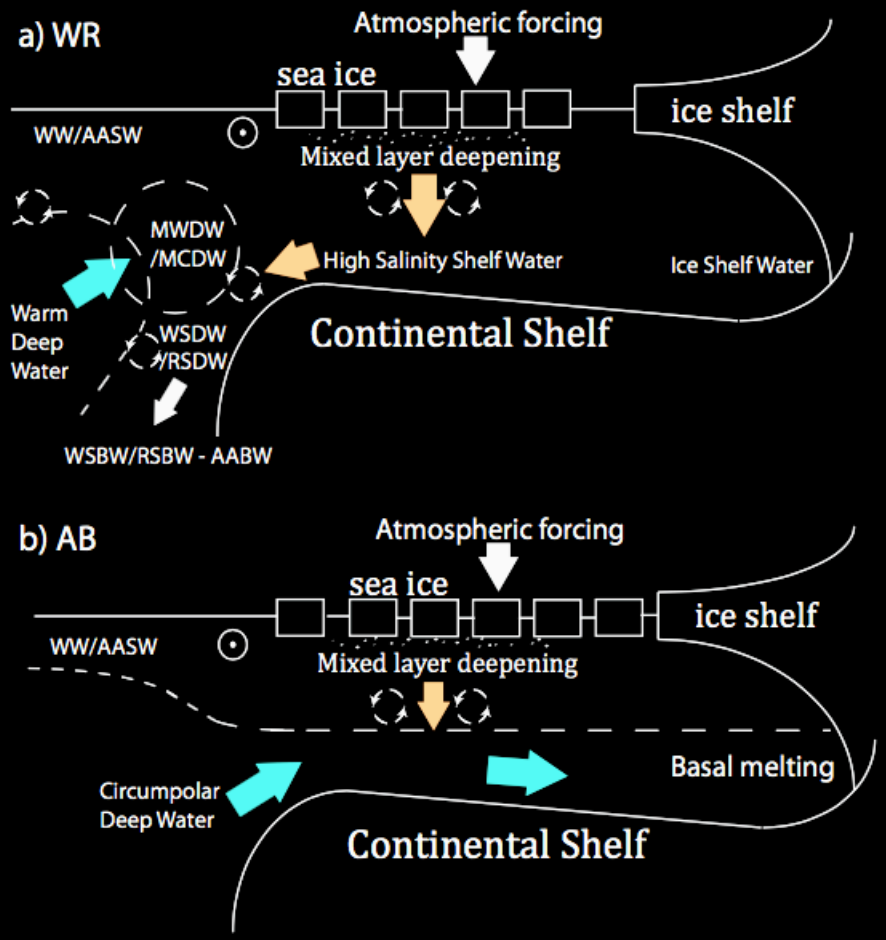
Sea ice and the Southern Ocean

Strong regional variability in:

- atmospheric forcing
- sea ice formation
- shelf water formation



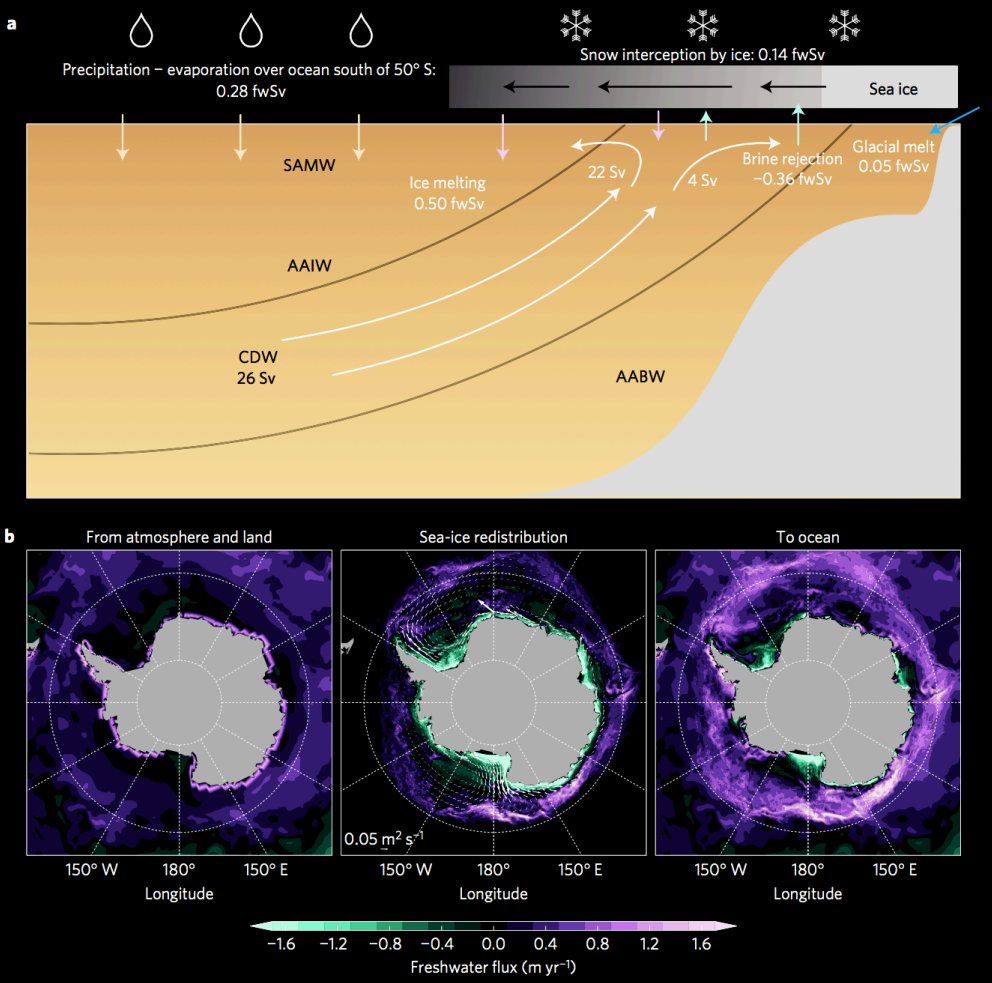
CICE simulations of sea ice growth.



(Petty et al., 2014, The Cryosphere)

Importance for Southern Ocean circulation

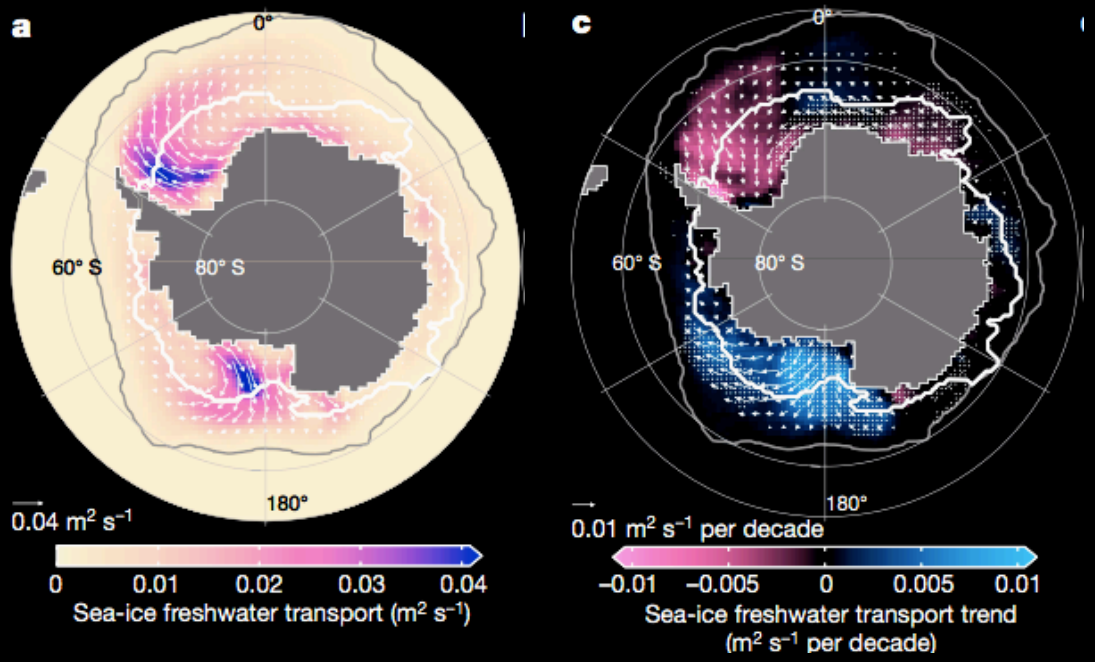
- Ice redistribution transforms the upper branch of the Southern Ocean overturning circulation.



(Abernathey et al., 2016, Nature Geosciences)

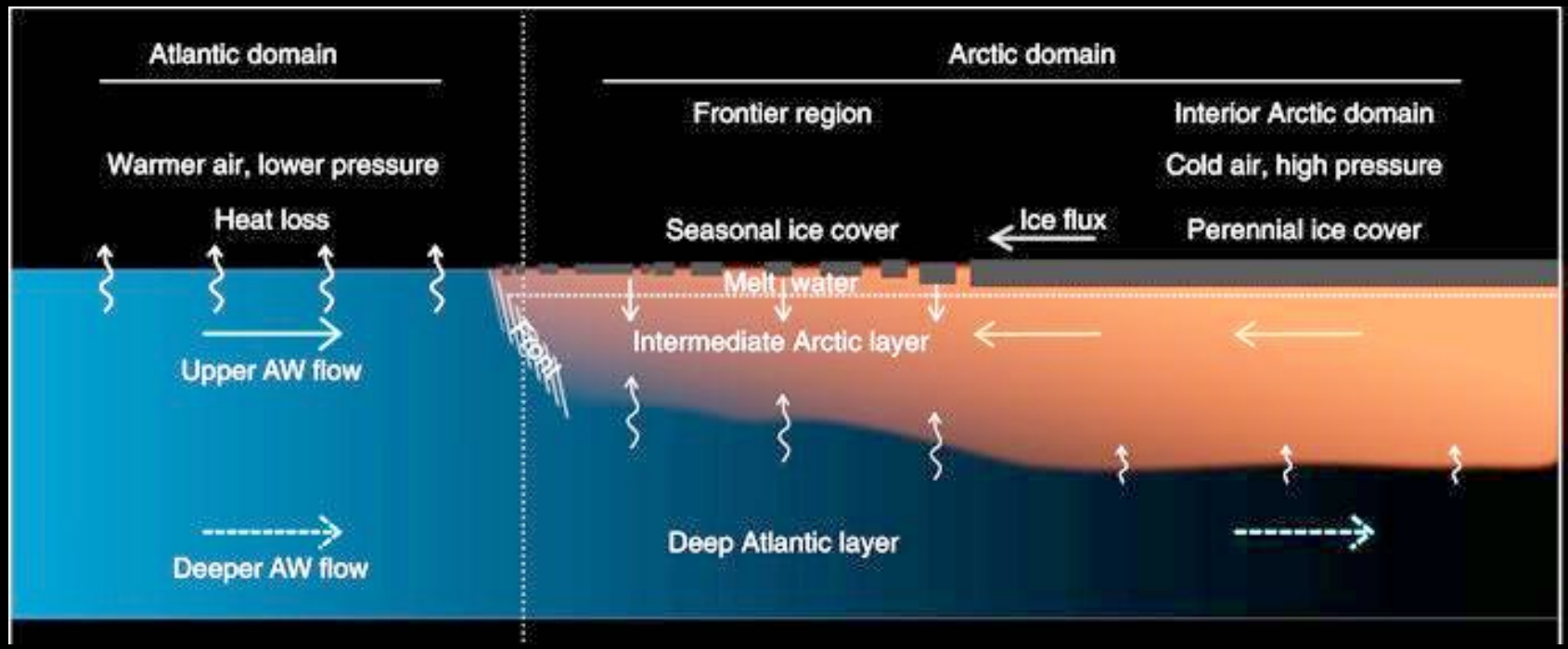
Importance for Southern Ocean properties

- 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)

Atlantification of the Arctic Ocean



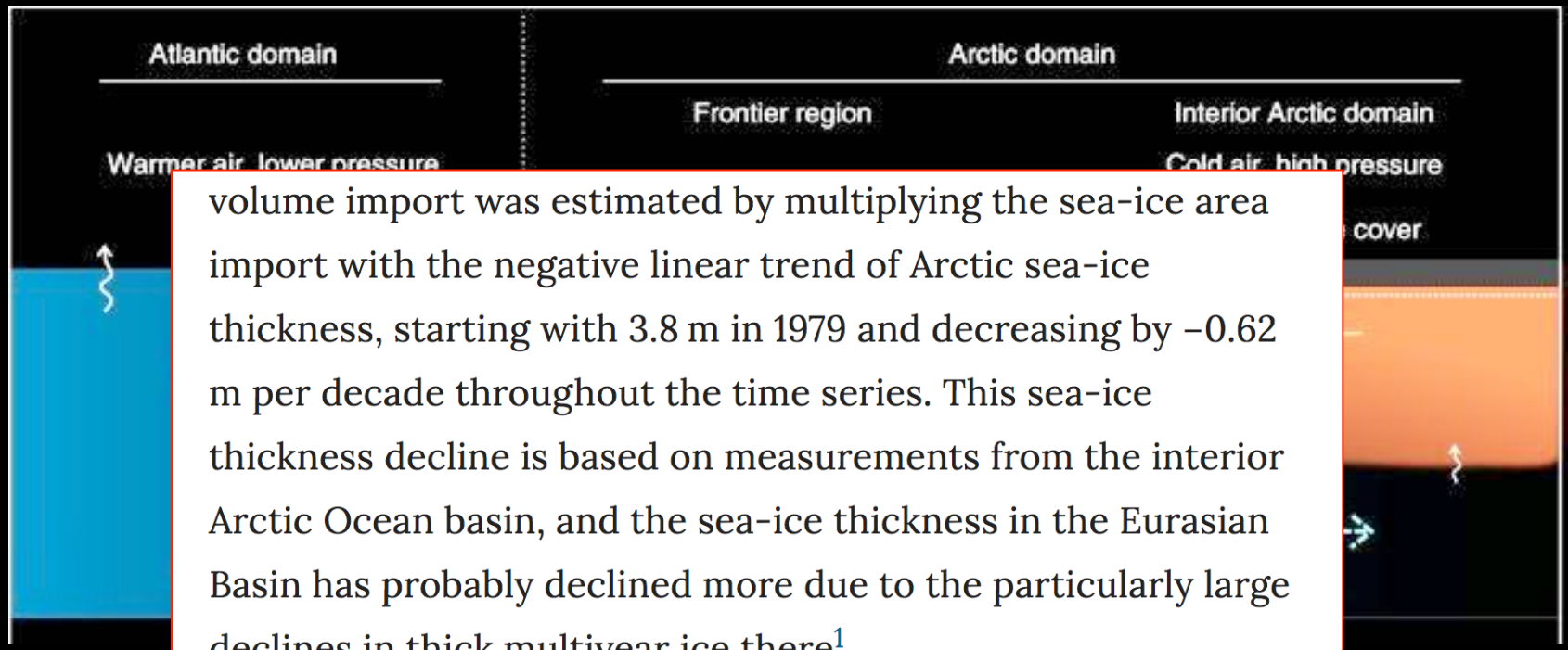
- Reduced import of sea ice volume/freshwater into the Barents Sea from the Arctic interior

(Lind et al., 2018, Nature Climate Change)

Key metric/s:
Sea ice circulation and its thickness/volume

Pretty good Not so good

Atlantification of the Arctic Ocean



volume import was estimated by multiplying the sea-ice area import with the negative linear trend of Arctic sea-ice thickness, starting with 3.8 m in 1979 and decreasing by −0.62 m per decade throughout the time series. This sea-ice thickness decline is based on measurements from the interior Arctic Ocean basin, and the sea-ice thickness in the Eurasian Basin has probably declined more due to the particularly large declines in thick multiyear ice there[1].

- Reduced import of sea ice volume/freshwater into the Barents Sea from the Arctic interior

(Lind et al., 2018, Nature Climate Change)

Importance for Southern Ocean circulation

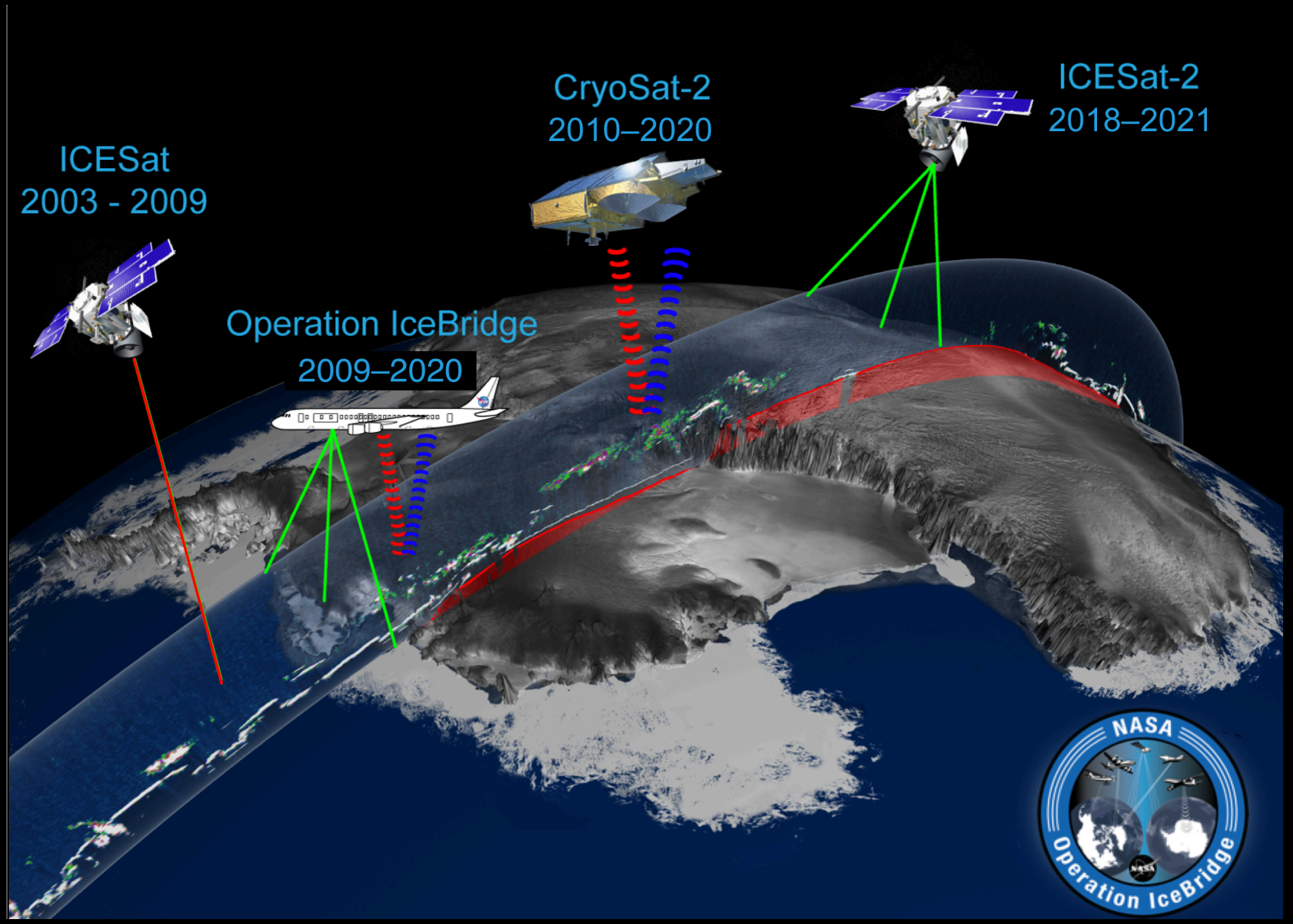
- The northward transport of sea ice is

divergence and local change in sea ice (Methods). The sea-ice concentration is derived from satellite observations[23] (Extended Data Fig. 1) and its thickness from a combination of satellite data[24] and a model-based sea-ice reconstruction that assimilates satellite data[25] (Extended Data Fig. 2). The sea-ice

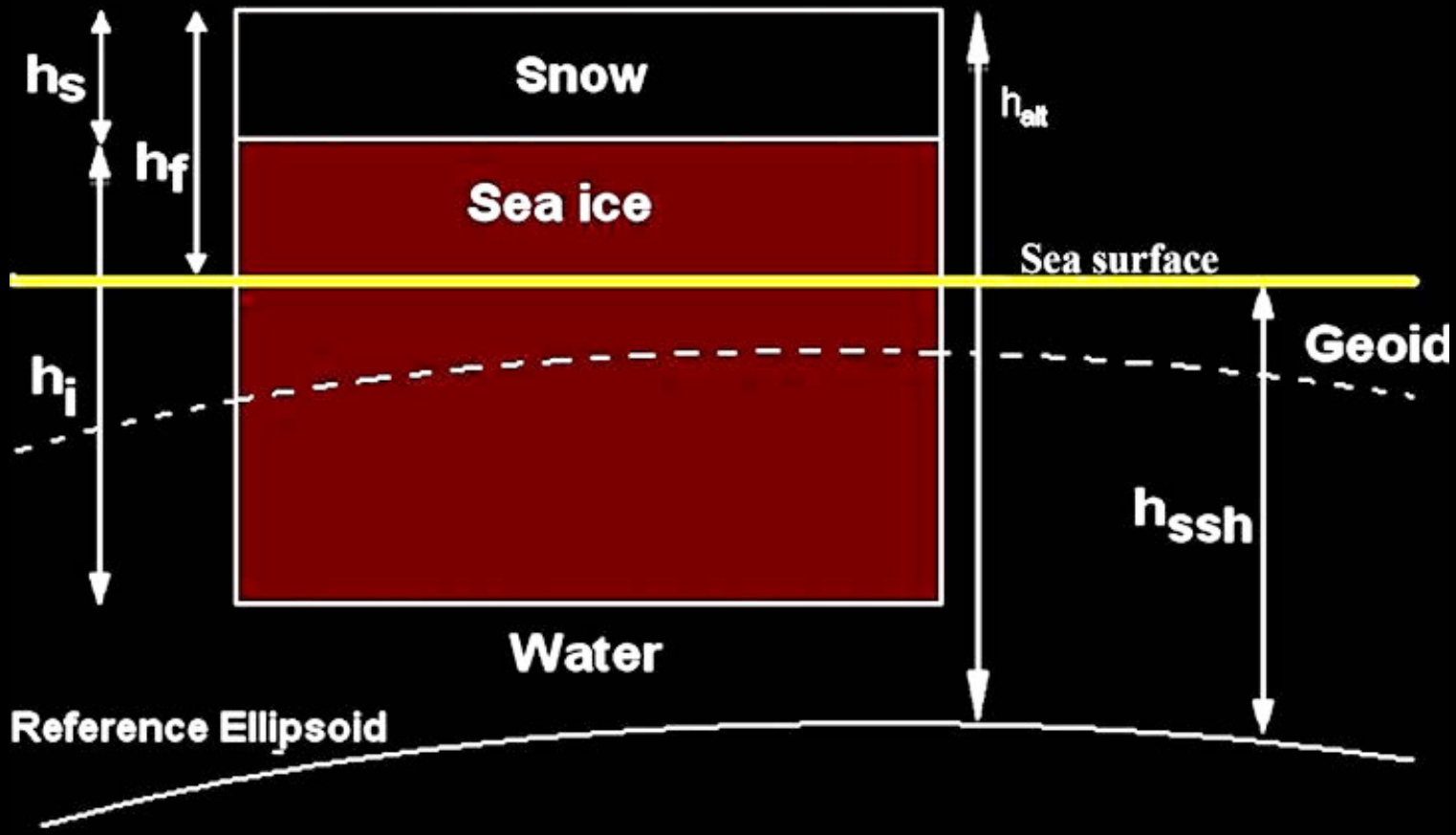
distribution of the Southern Ocean.

(Haumann et al., 2016, Nature)

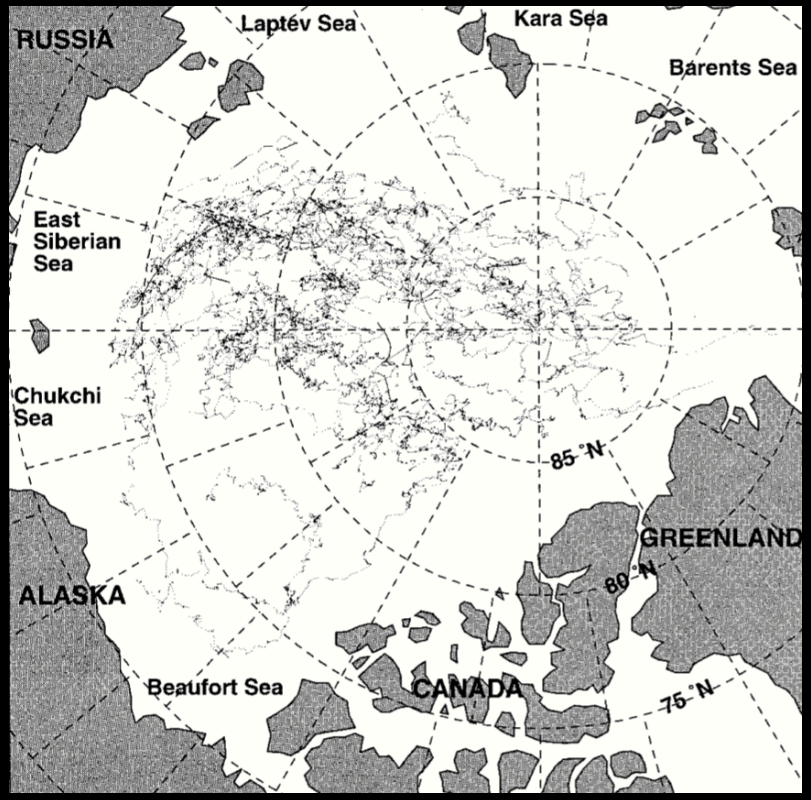
Advent of active remote sea ice sensing



Inferring sea ice thickness remotely

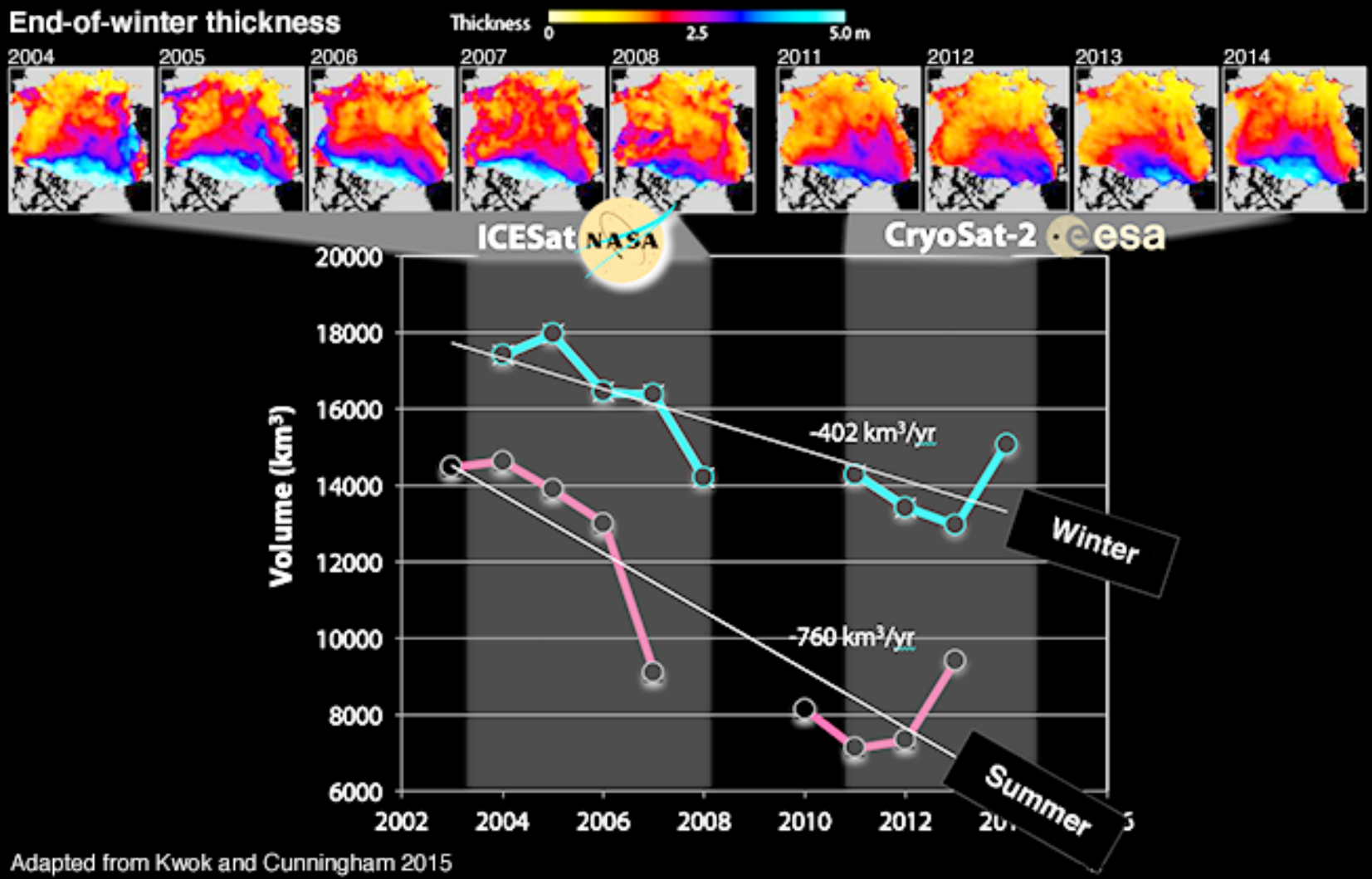


Sea ice community still often using an old snow depth climatology!



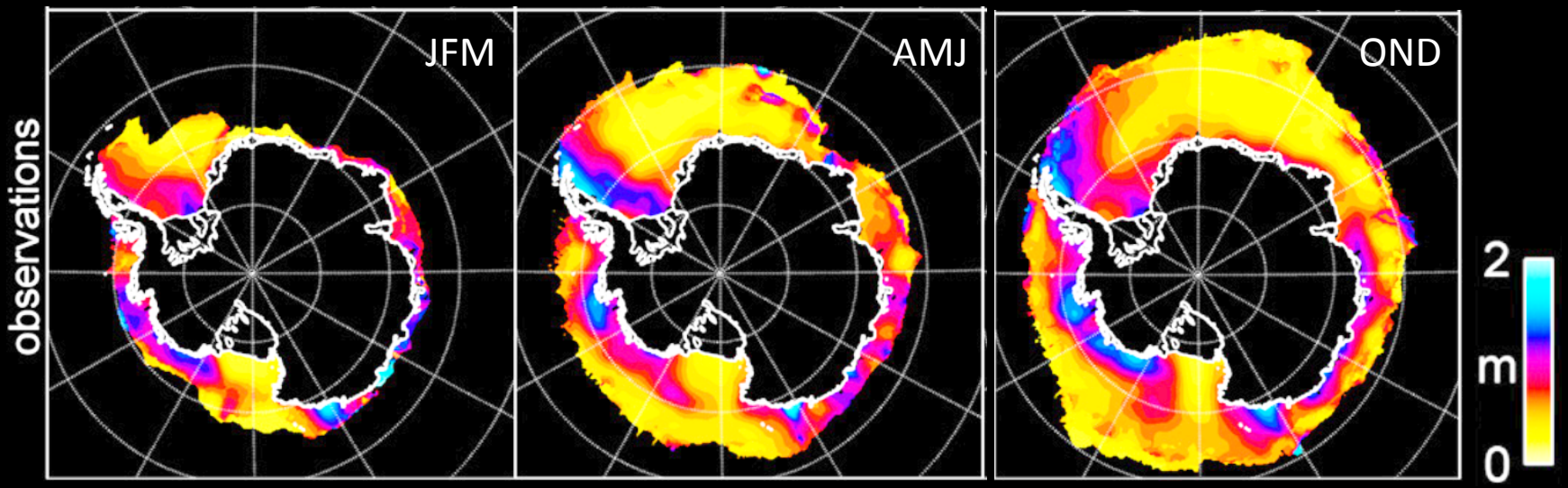
From [Warren et al., 1999]

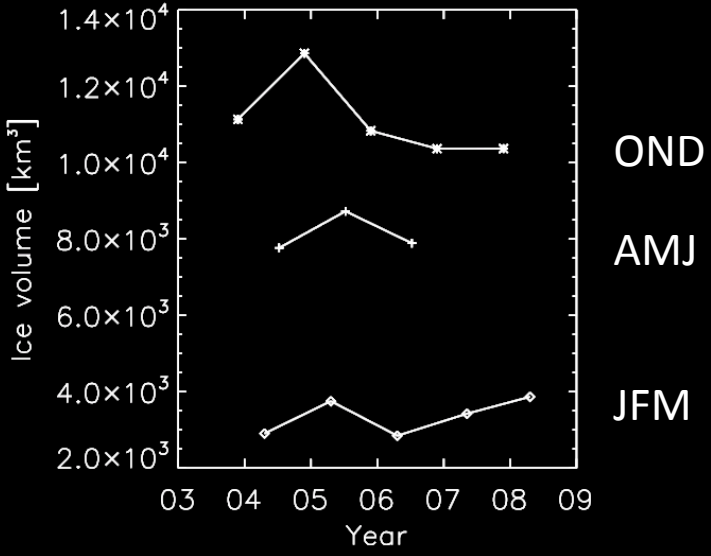
ICESat/CryoSat-2 thickness record based on modified Warren snow depths



Adapted from Kwok and Cunningham 2015

2003-2008 ICESat thickness climatology based on zero-freeboard assumption

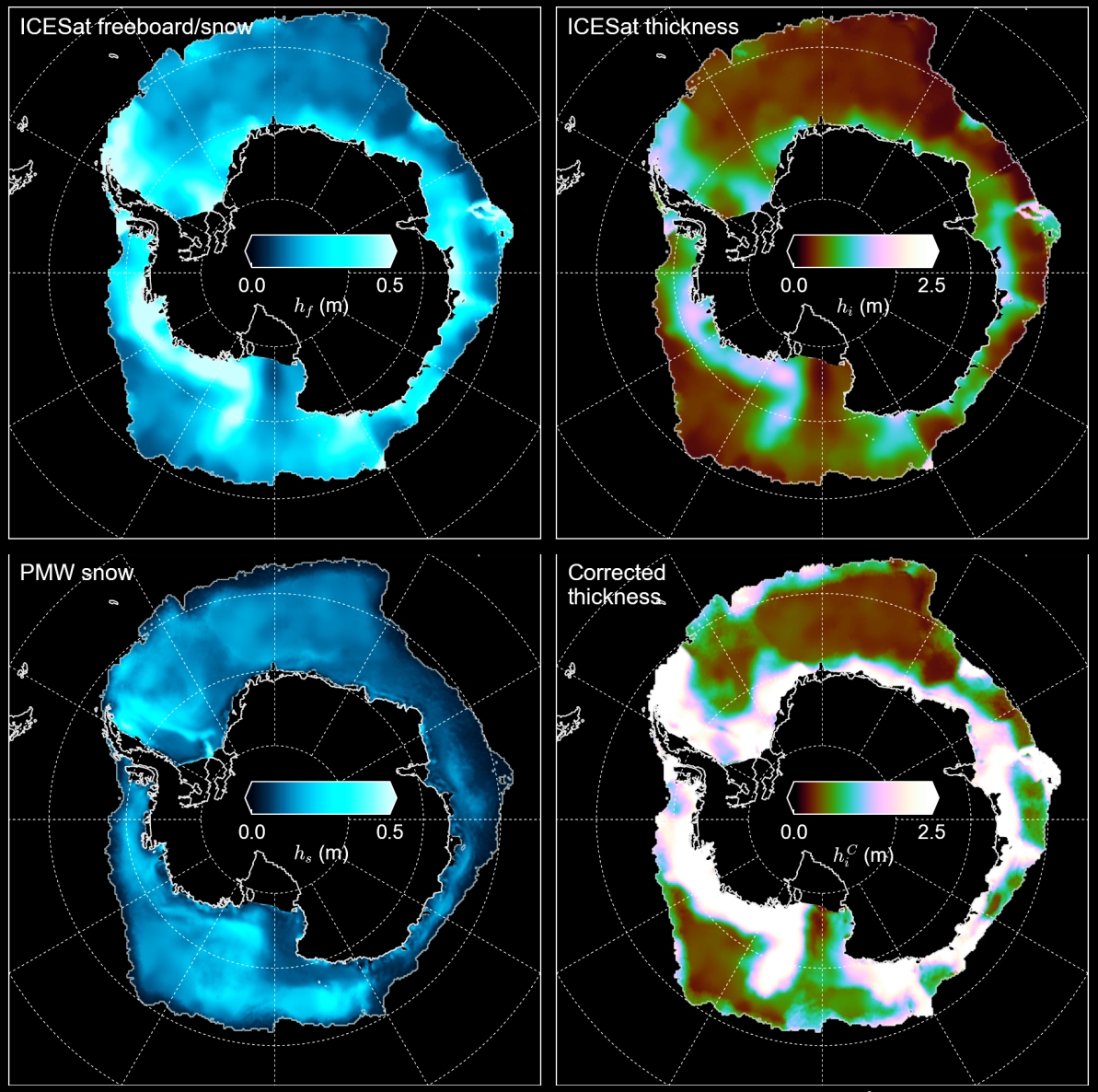




From Kurtz & Markus, (2012)

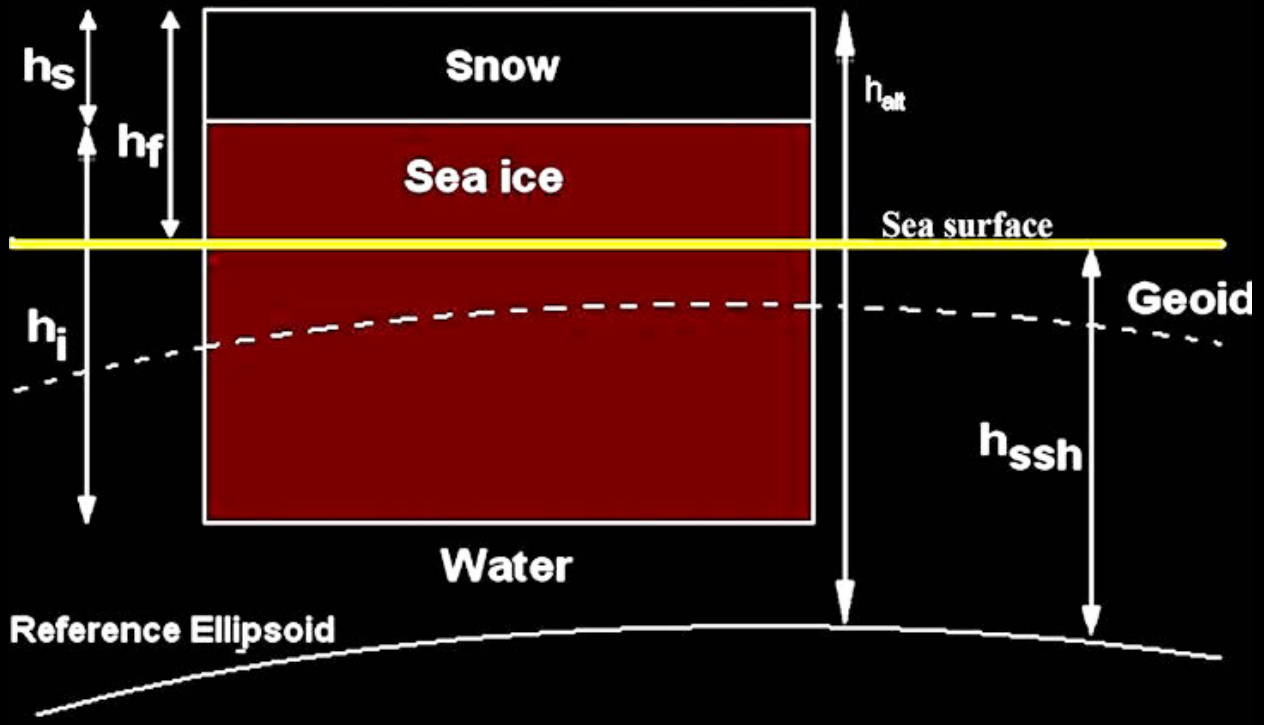
- Current product using zero-freeboard assumption.

- Using PMW snow depths and no zero-freeboard.



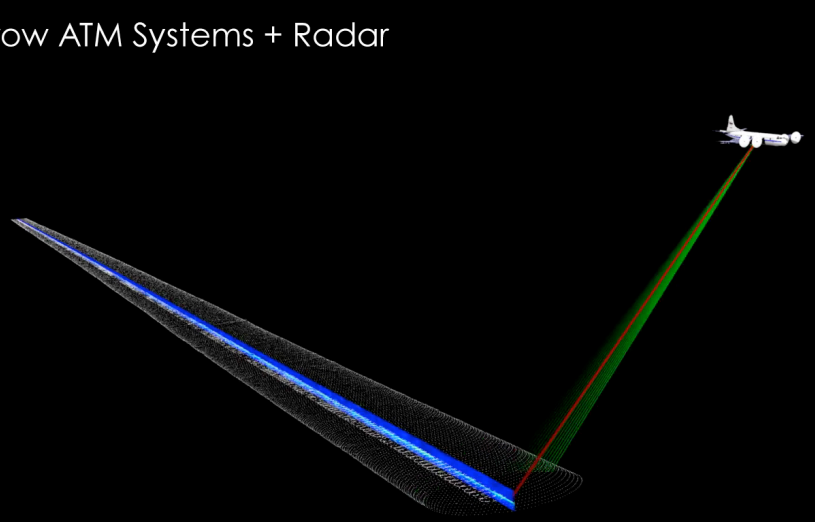
ICESat thickness and NASA PMW snow depth (October/November, 2007)

Need better snow on sea ice estimates!

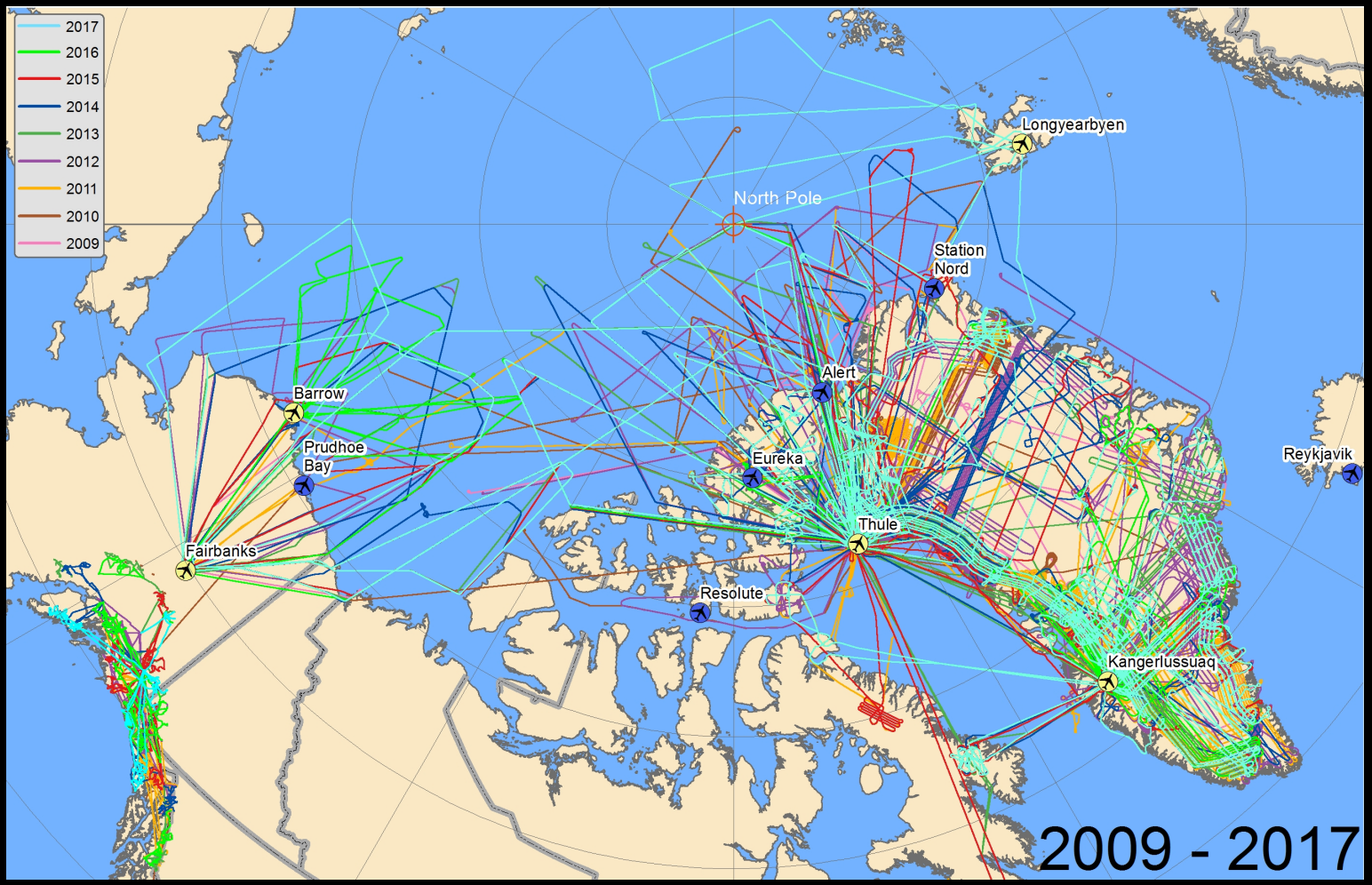


NASA's Operation IceBridge

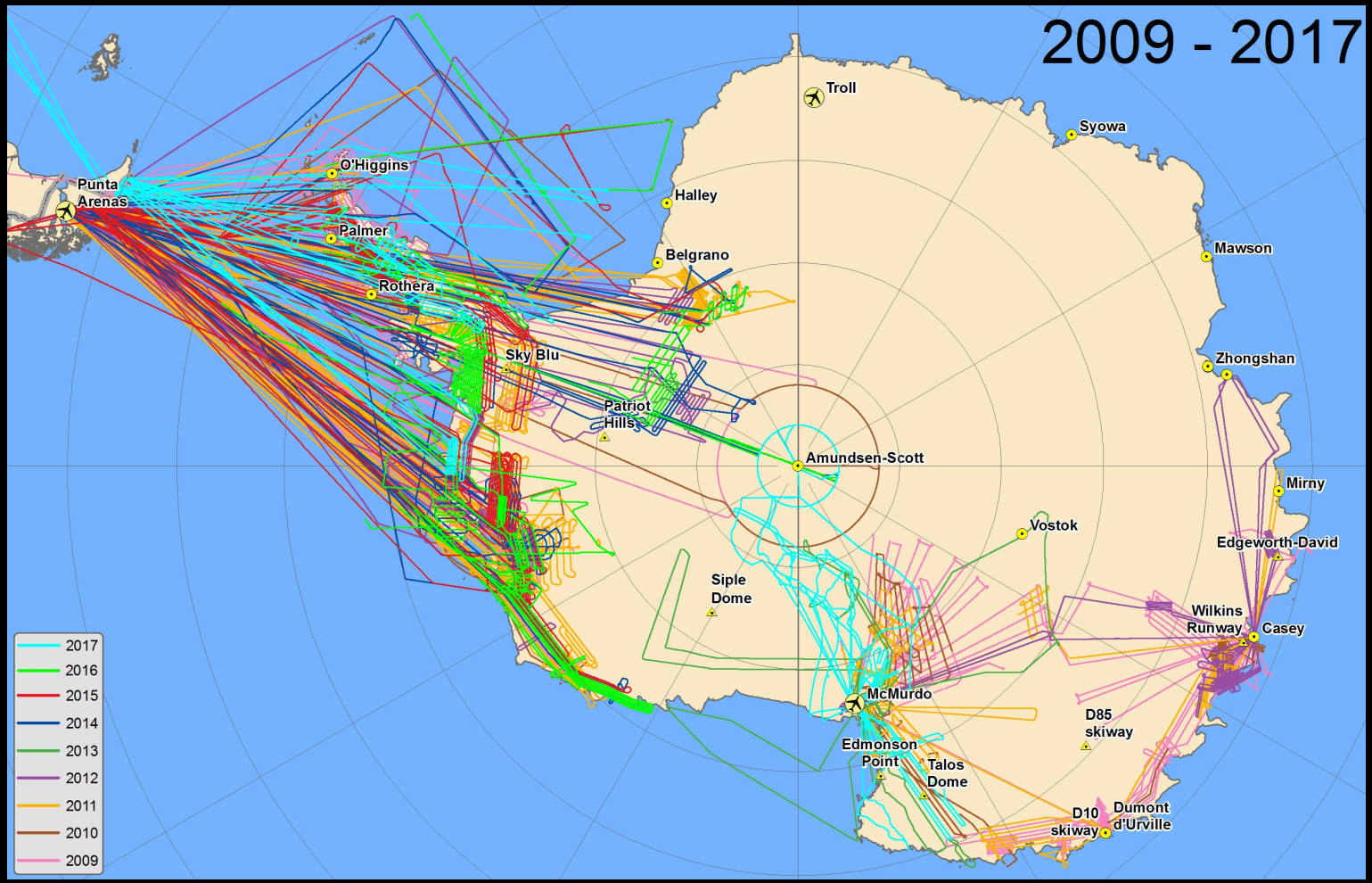
- Suite of sensors to measure both land and sea ice across both poles.
- Conical scanning laser altimeter (ATM) has a 1 m footprint and high vertical accuracy (less than 10 cm).
- Snow radar has a footprint of ~7 m



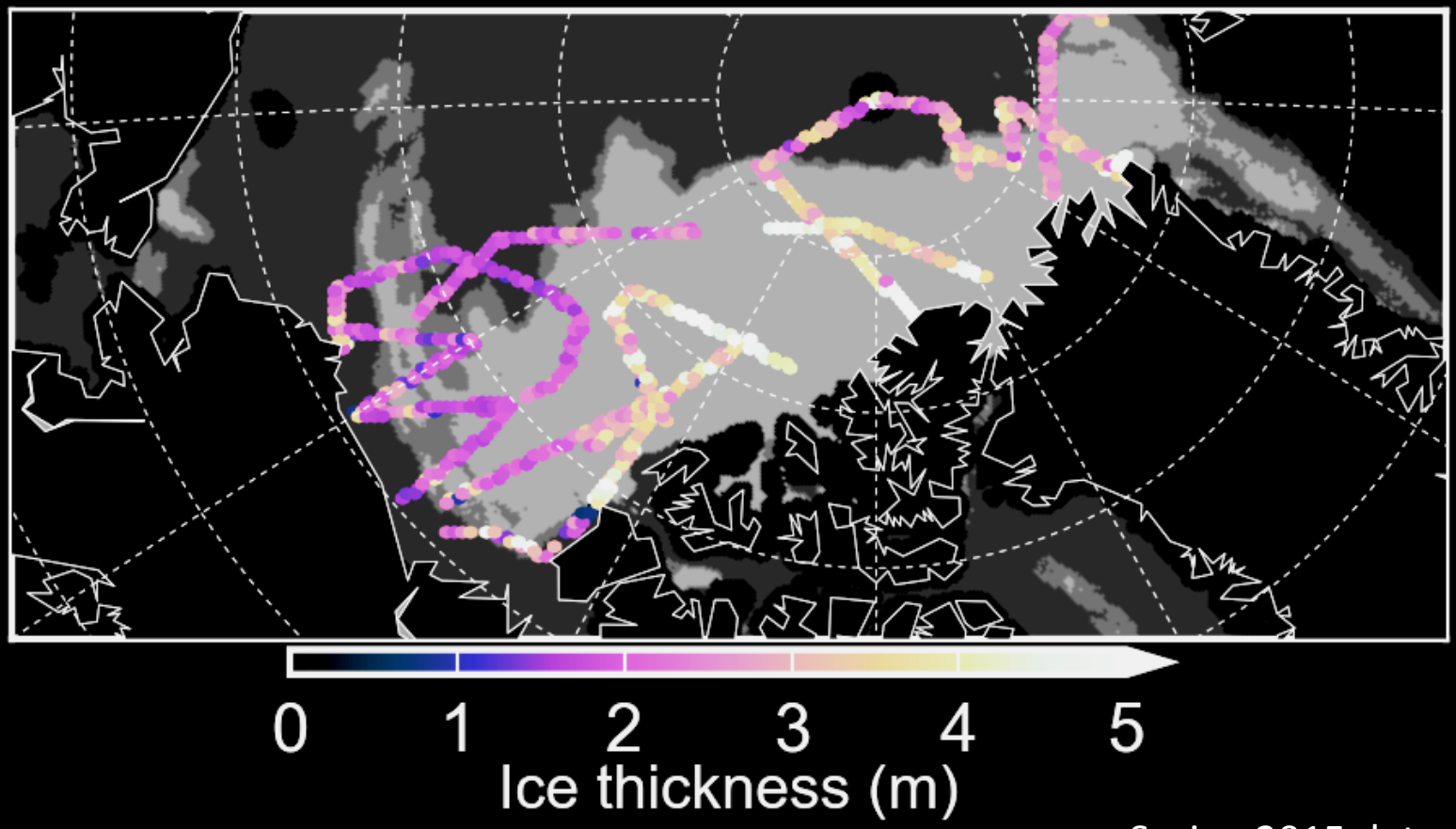
NASA's Operation IceBridge



NASA's Operation IceBridge



Basin-scale sea ice thickness from OIB

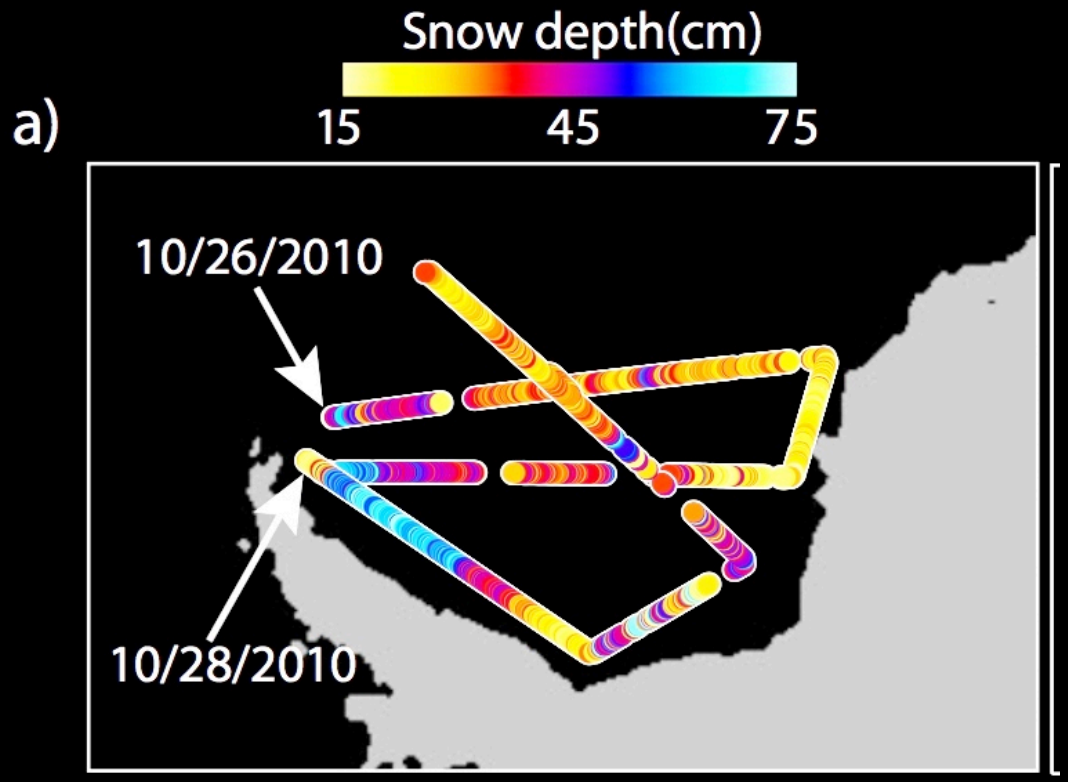


Spring 2015 data

Antarctic OIB data?

Snow depth estimates challenging, but possible!

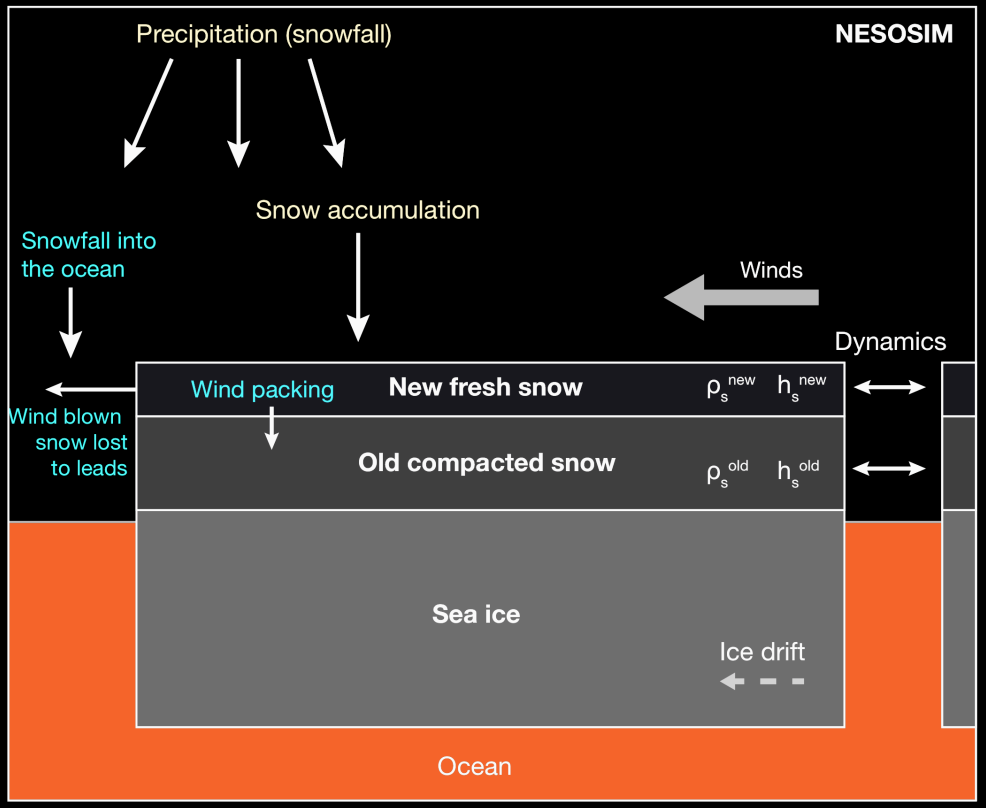
(e.g. Kwok & Maksym 2014, JGR)



Use models to fill in the observational gap

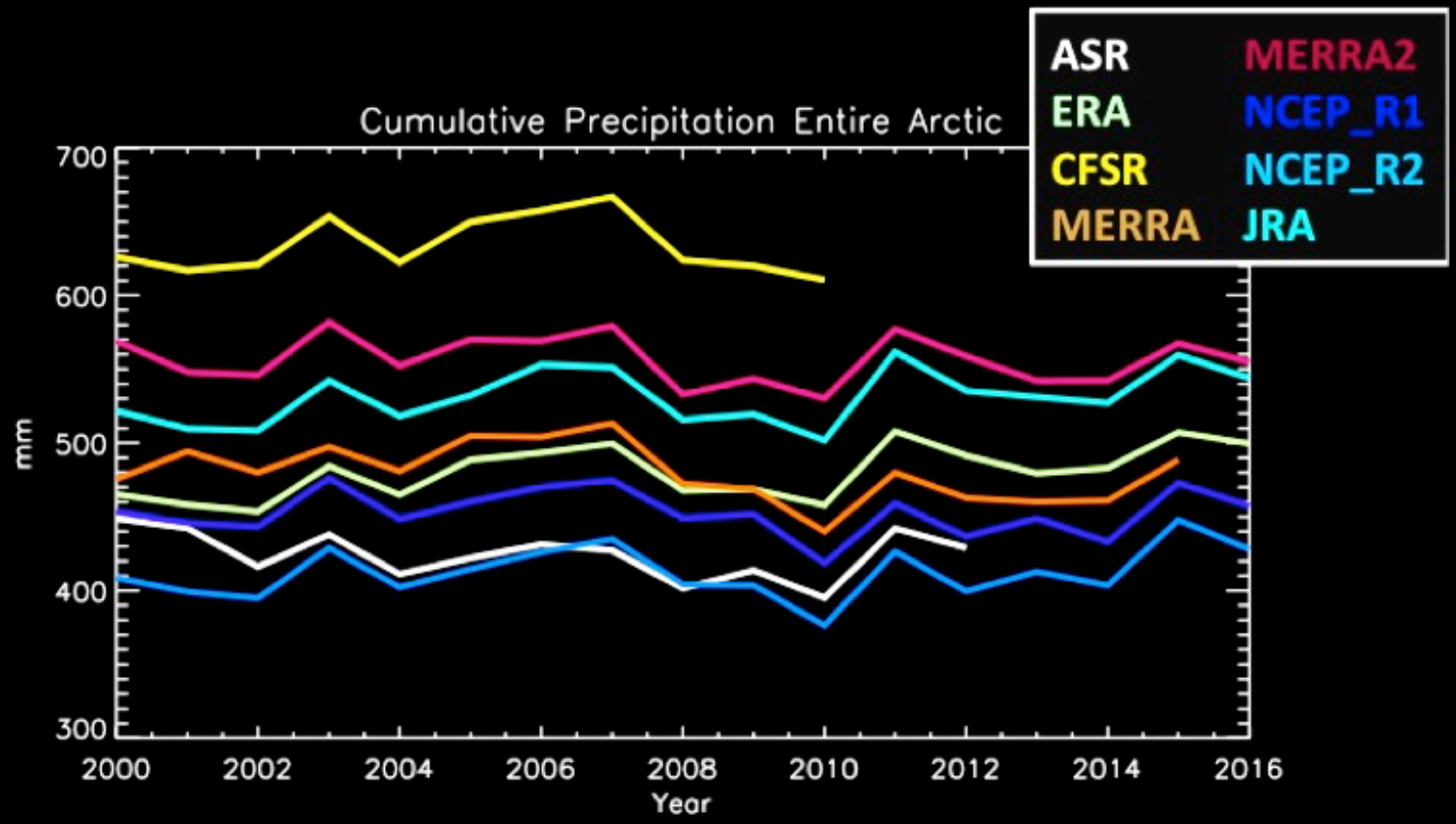
The NASA Eulerian Snow on Sea Ice Model (NESOSIM v1.0)

- Two layer Eulerian model.
- 100 km grid (adaptable).
- Arctic Ocean domain (adaptable).
- Quick to run (~3 minutes for a 30 year run).
- Snowfall/ice conc/ice drift/ winds as forcings.
- Daily (August to May) gridded data output.
- Open source Python code.



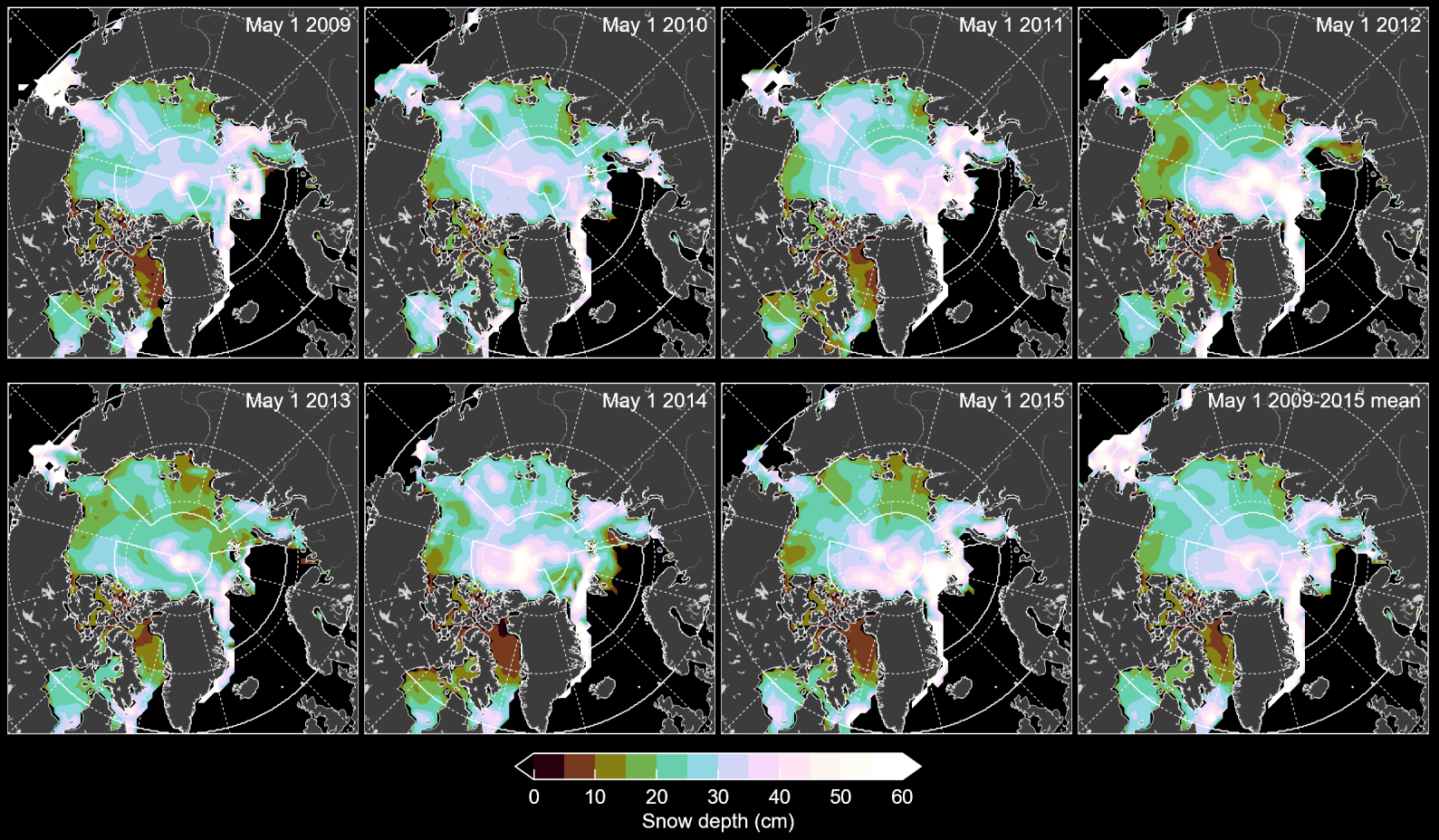
Petty et al., GMD, in review

Annual Arctic precip across 8 reanalyses



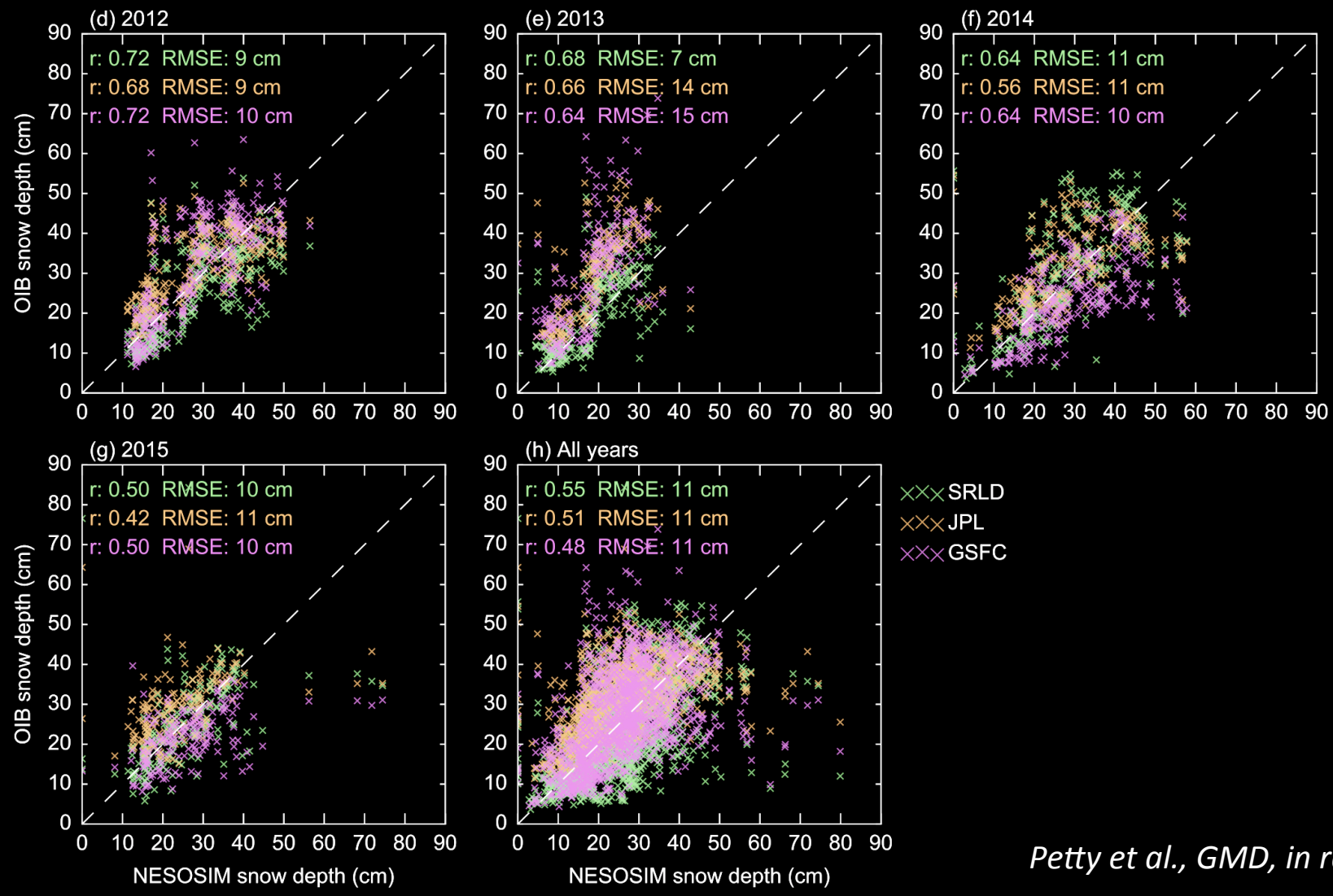
Boisvert et al., 2018 , *in review*

NESOSIM v1.0 spring snow depths



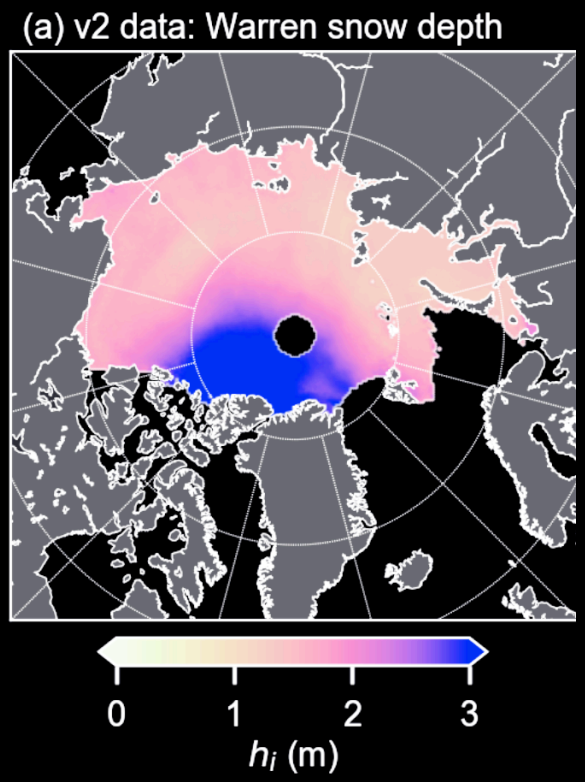
Forced by MEDIAN snowfall, ERA-I winds, Bootstrap SIC, NSIDCv3 ice drift.

Use the Arctic snow depths for model validation



Petty et al., GMD, in review

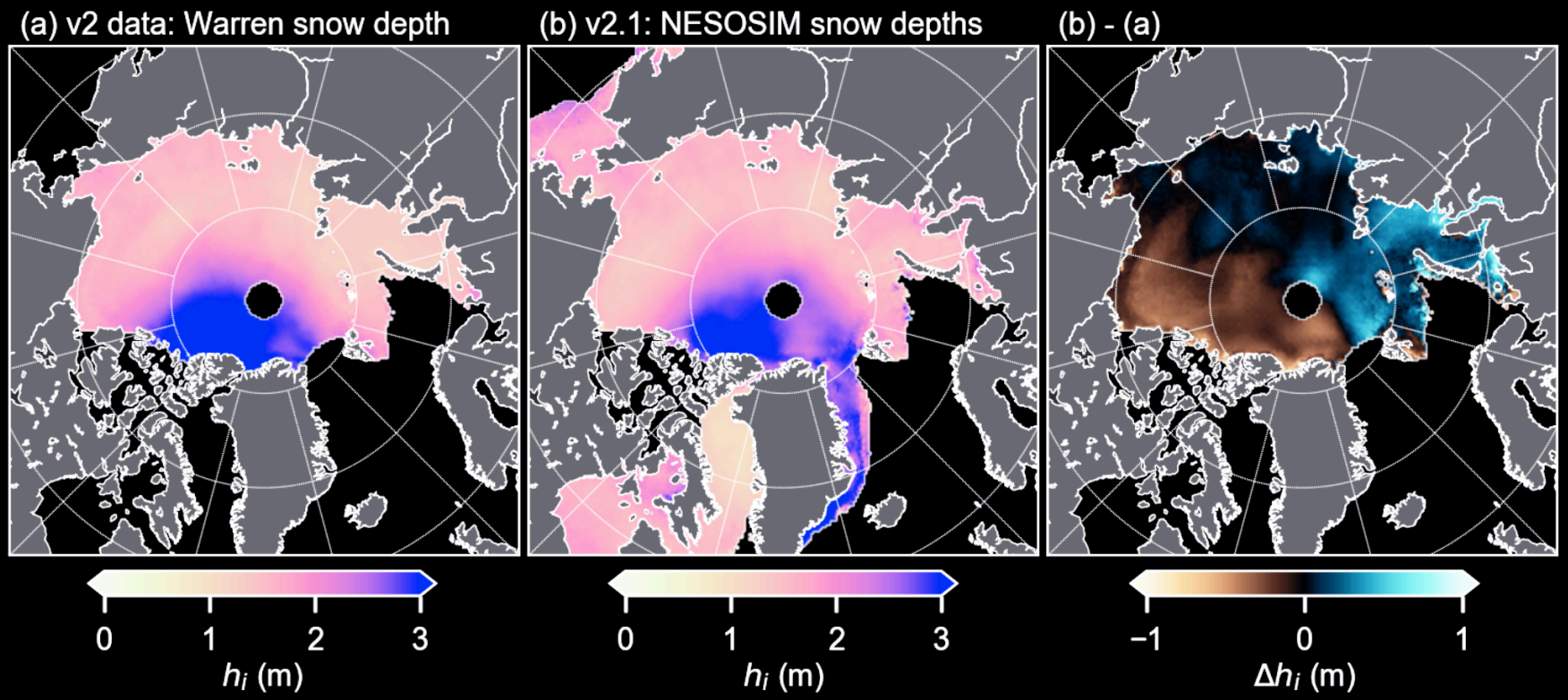
Improving CryoSat-2 thickness estimates



Winter mean (2010-2016)

CryoSat-2 sea ice thickness using Warren snow depth climatology

Improving CryoSat-2 thickness estimates



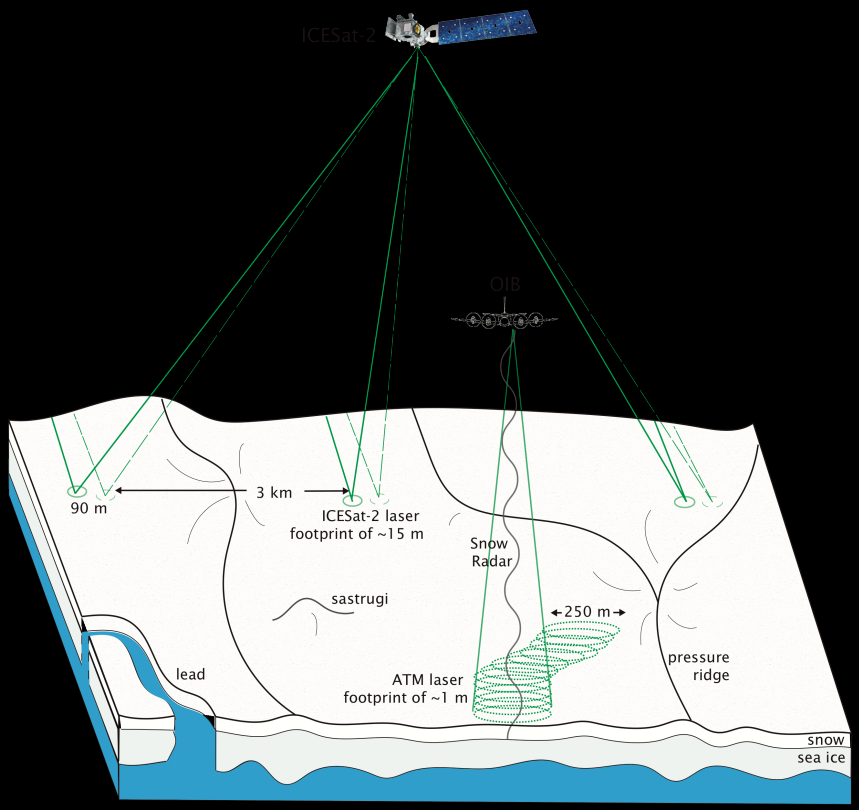
Kurtz et al., in prep

Currently reprocessing the ICESat thickness record…

Watch this space!

Upcoming: NASA's ICESat-2 mission!

Scheduled for launch this September!

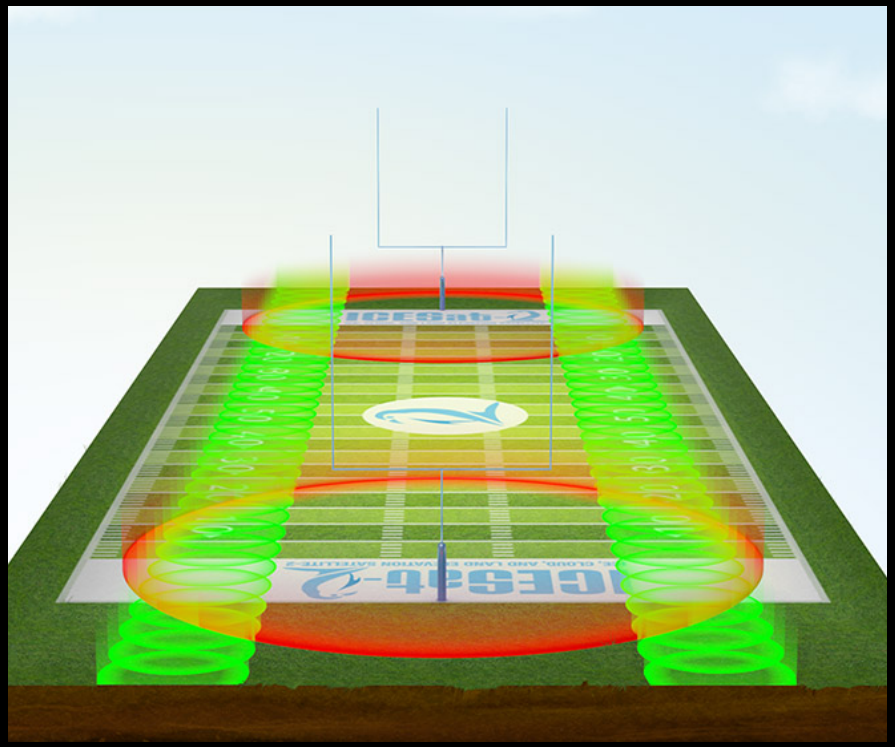


- Laser altimeter, photon counting.
- Three pairs of beams, footprint of ~15 m.


ICESat-2

NASA's ICESat-2 mission

Scheduled for launch this September!



- Laser altimeter, photon counting.
- Three pairs of beams, footprint of ~15 m.
- Official/routine sea ice freeboard product.
- Semi-official sea ice thickness product.
- 70 cm along-track sampling will also provide good data for estimating roughness.
- What else can we do?

Grand vision…

Grand vision…

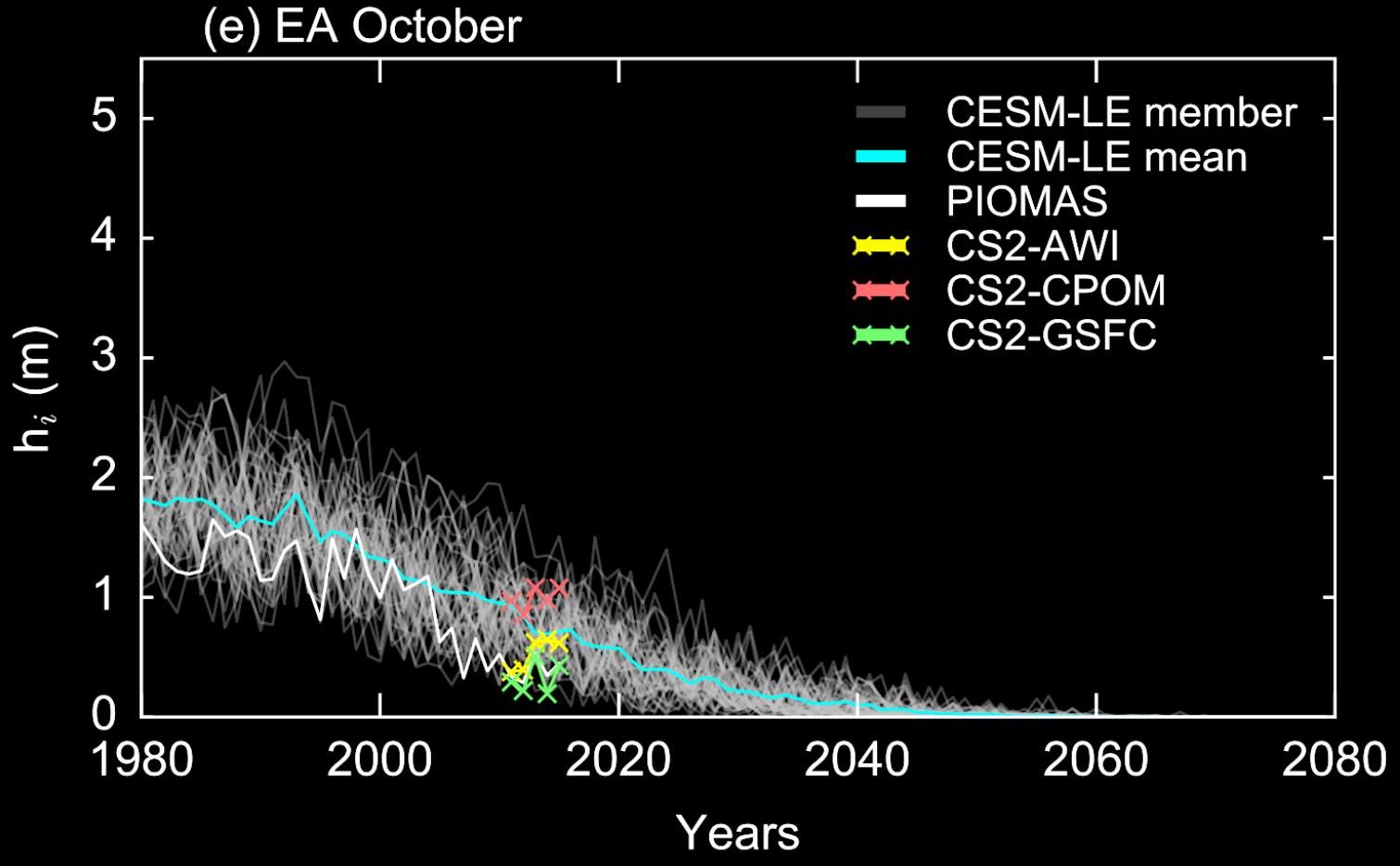
1. Decadal record of polar ice thickness

Grand vision…

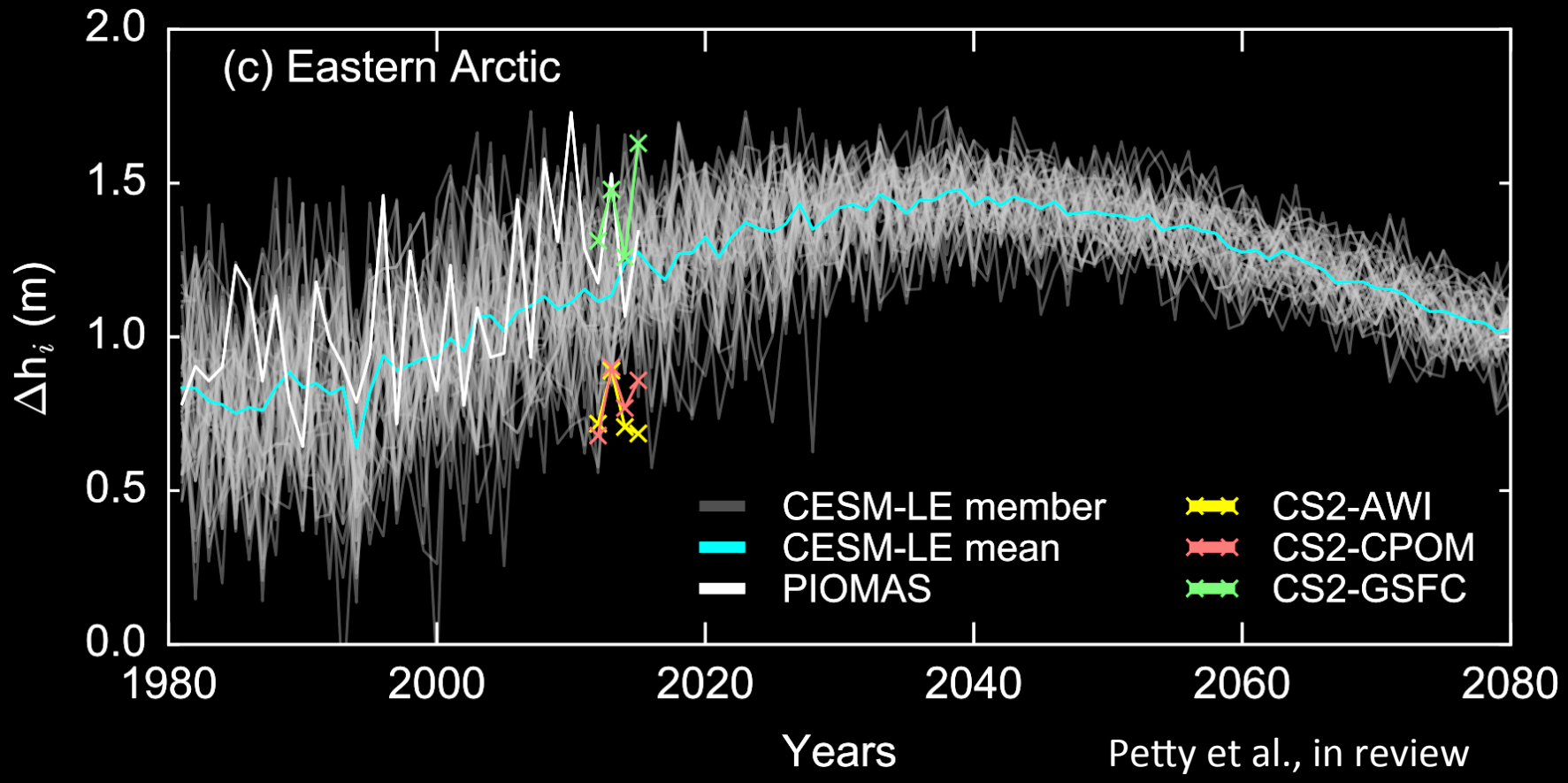
1. Decadal record of polar ice thickness

2. Validate models and provide longer-term understanding.

Use observations and models concurrently

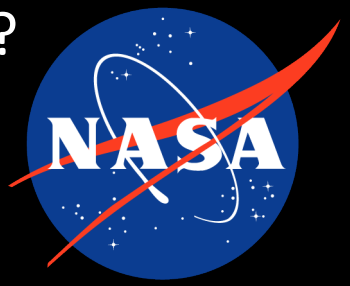


Winter ice growth projected to increase, before decreasing towards the end of the century



Summary

- Sea ice a crucial component of the Arctic and Southern Ocean.
- Still a lot of unknowns surrounding sea ice thickness, especially regarding its thickness distribution.
- Using Operation IceBridge to produce the gold standard of sea ice thickness.
- Improving snow depth estimates.
- Getting ready for the launch of ICESat-2
- Can we use models to provide the long-term context?



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