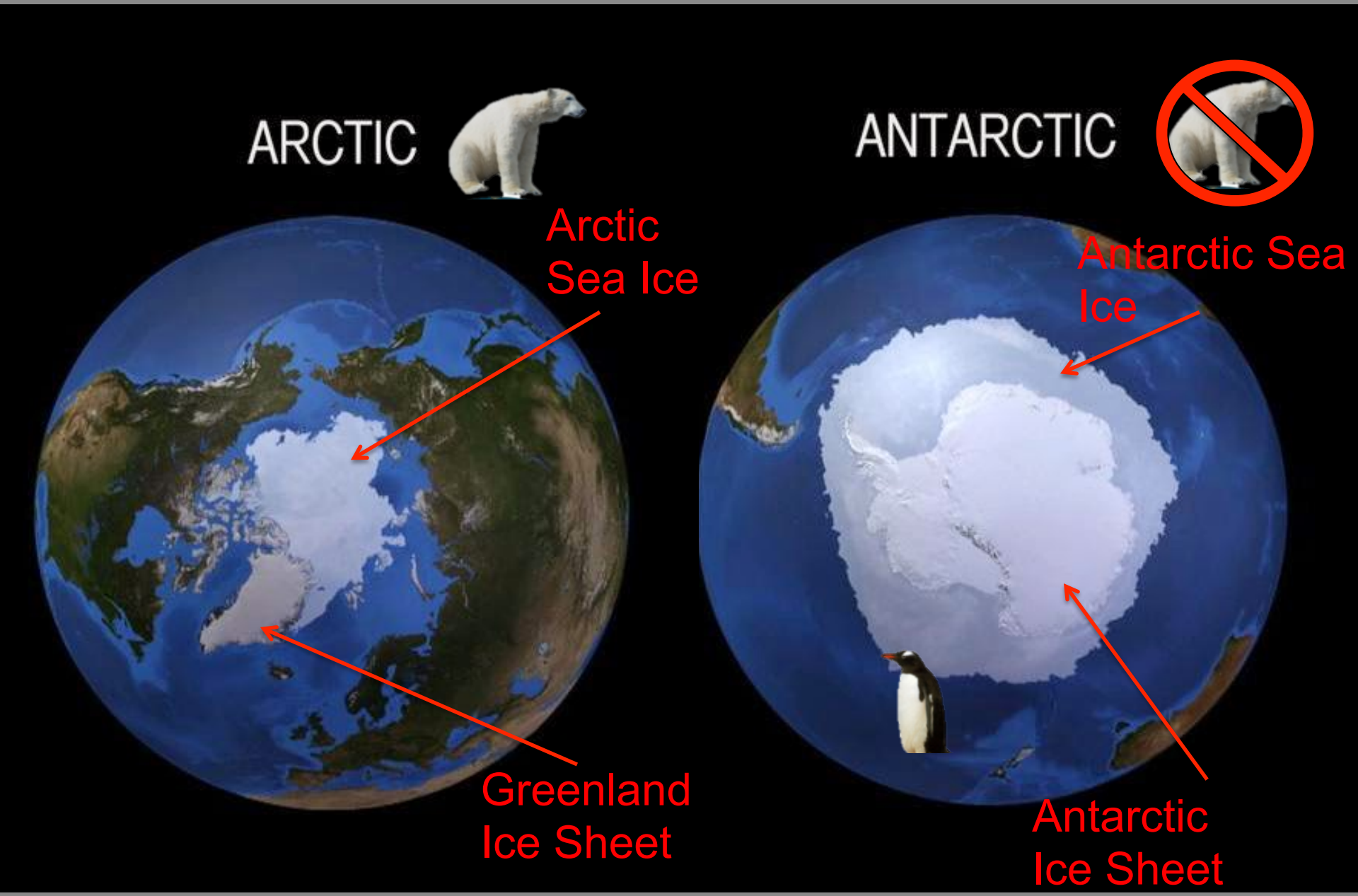
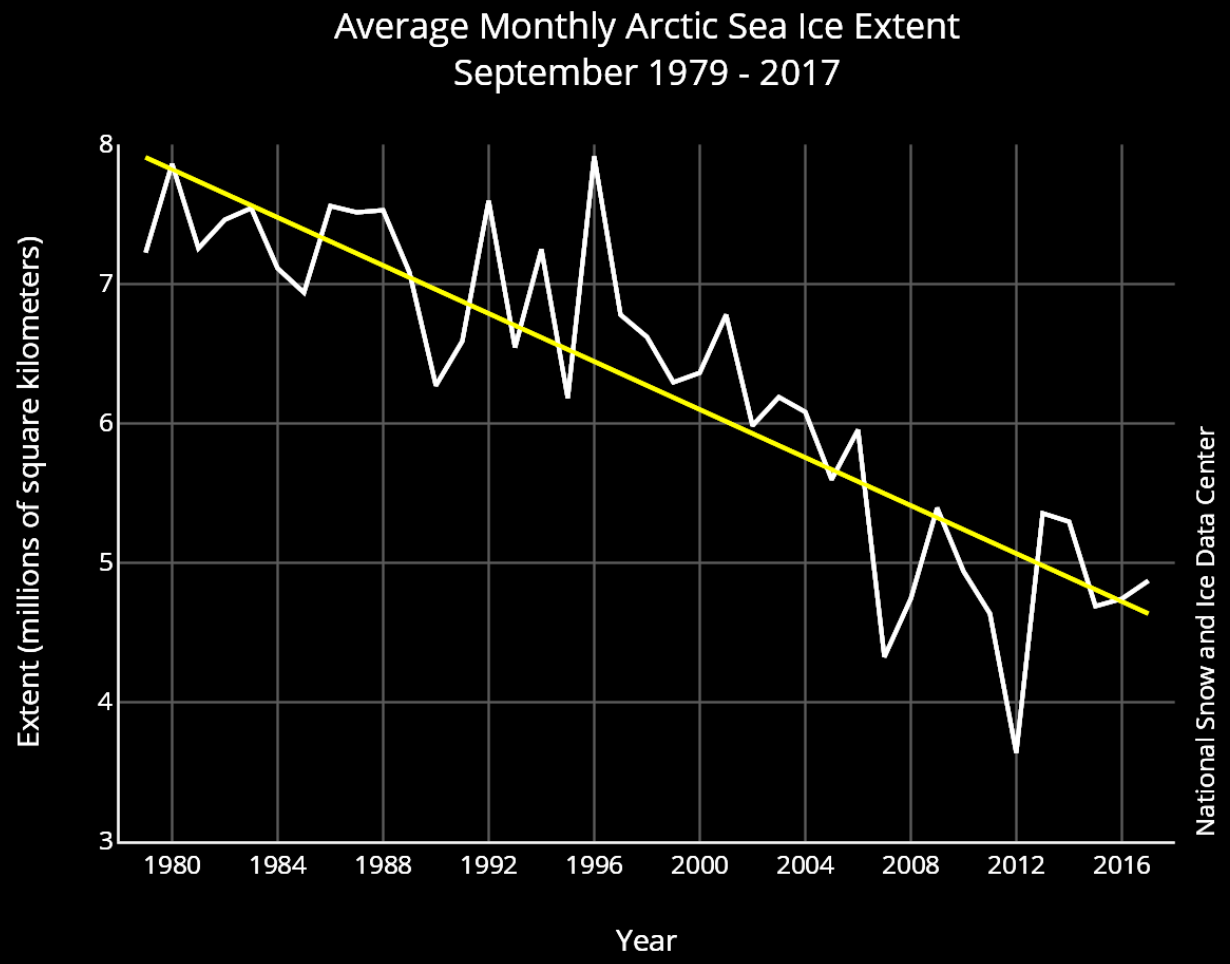
Precipitation, snow accumulation and sea ice thickness over the Arctic Ocean

Alek Petty, *Linette Boisvert, Melinda Webster, Thorsten Markus, Nathan Kurtz, Jeremy Harbeck*

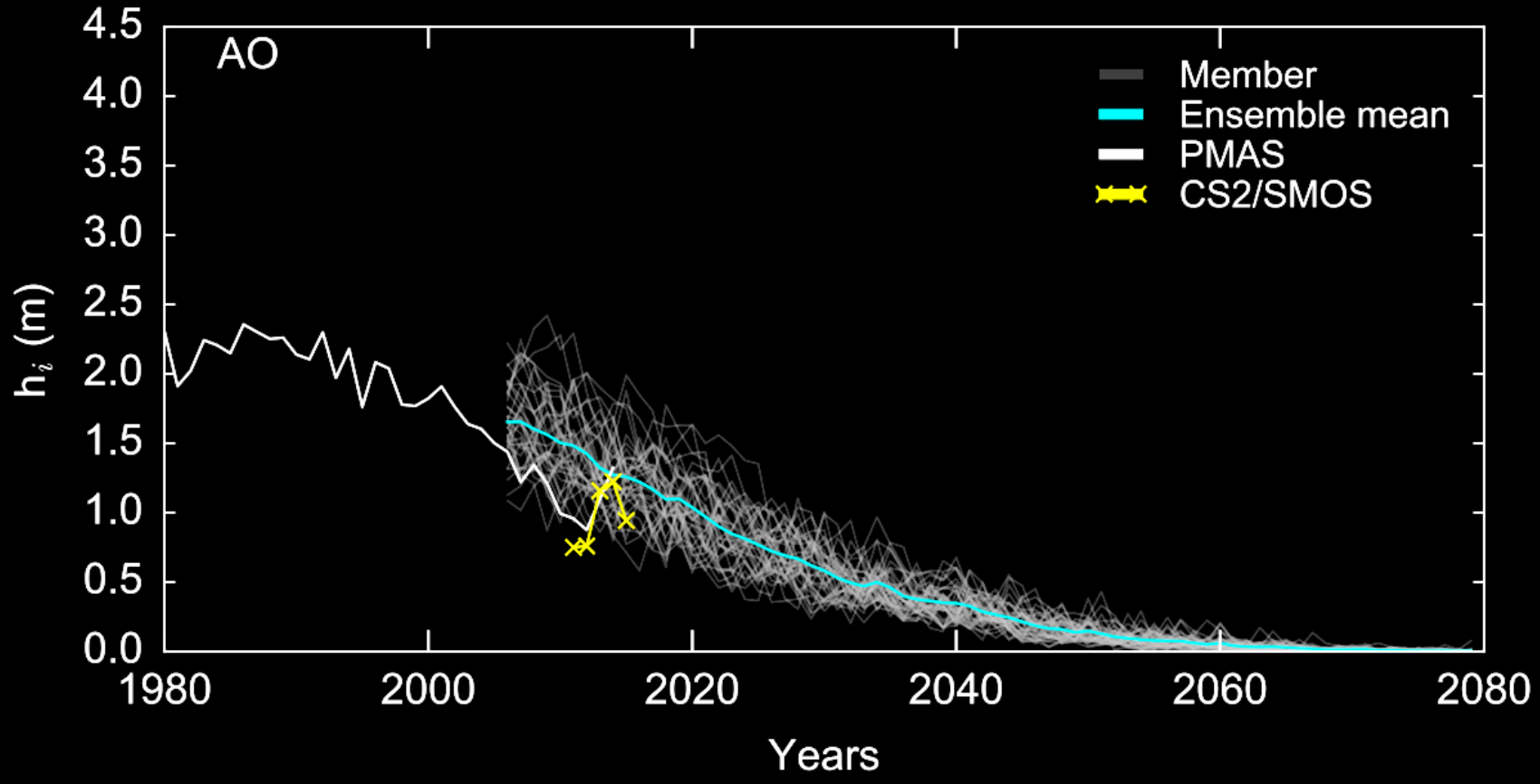
www.alekpetty.com / @alekpetty / alek.a.petty@nasa.gov


ARCTIC
Arctic
Sea Ice
Greenland
Ice Sheet
ANTARCTIC
Antarctic Sea
Ice
Antarctic
Ice Sheet

Arctic sea ice cover in decline



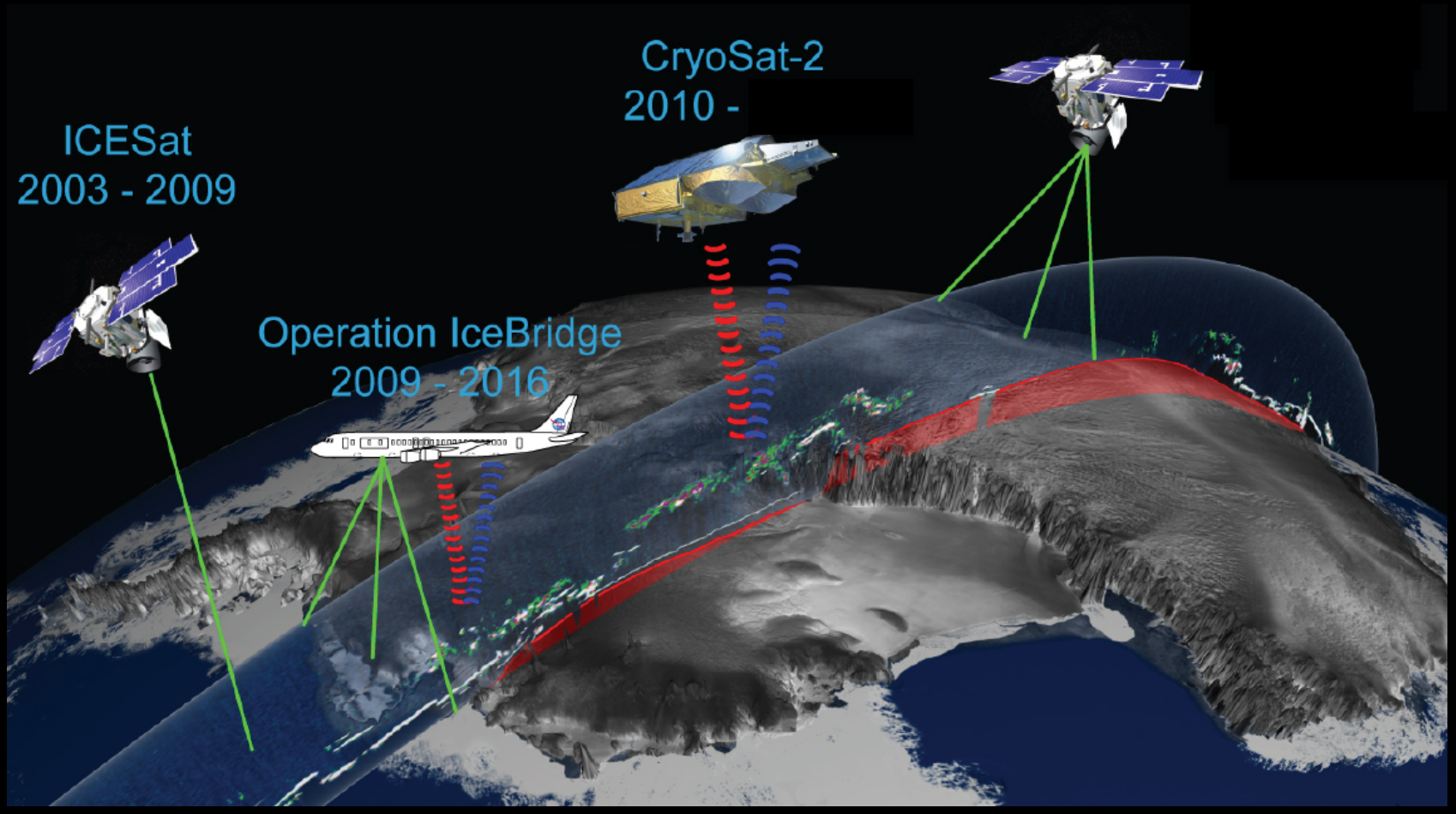
Arctic sea ice thickness in decline



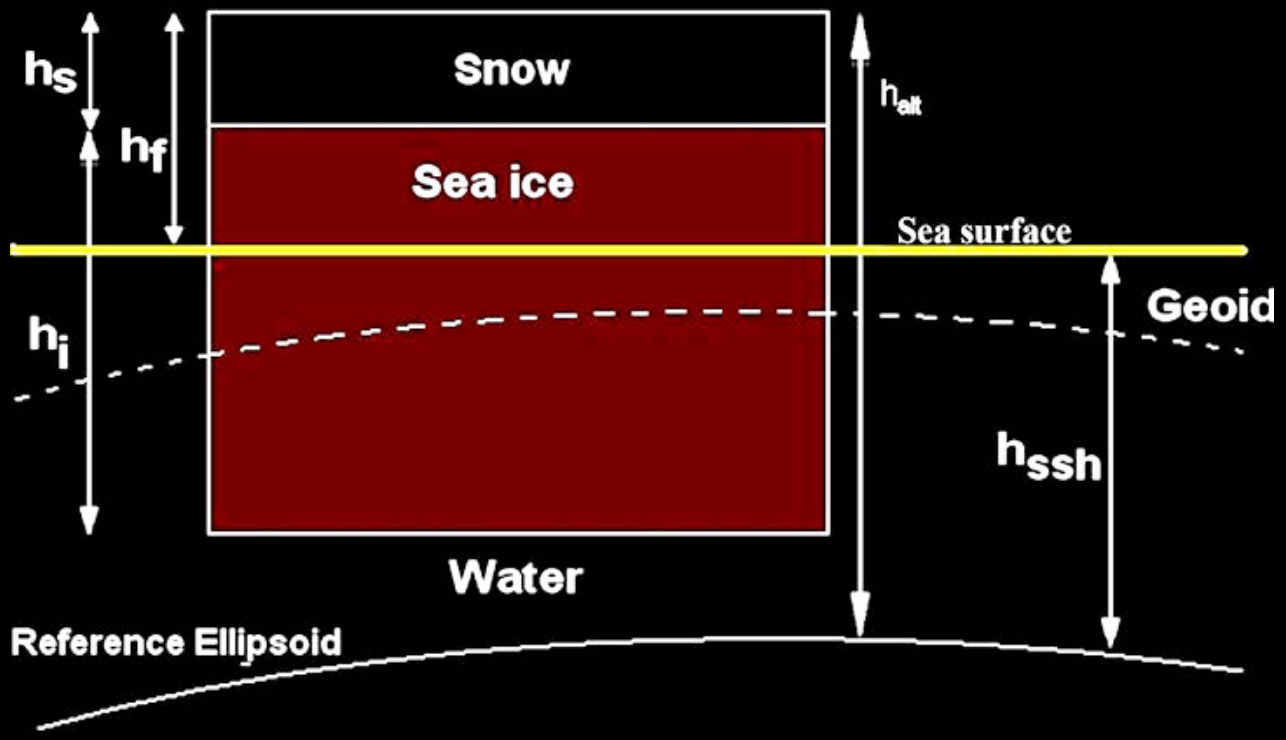
Arctic sea ice thickness in decline

- Changes the momentum transfer through the ice
  - a spin-up of the Arctic Ocean?
- Changes light transmission through the ice
  - phytoplankton blooms/shifting ecosystems?
- Changes the Arctic freshwater budgets
  - sea ice melt becoming significant?

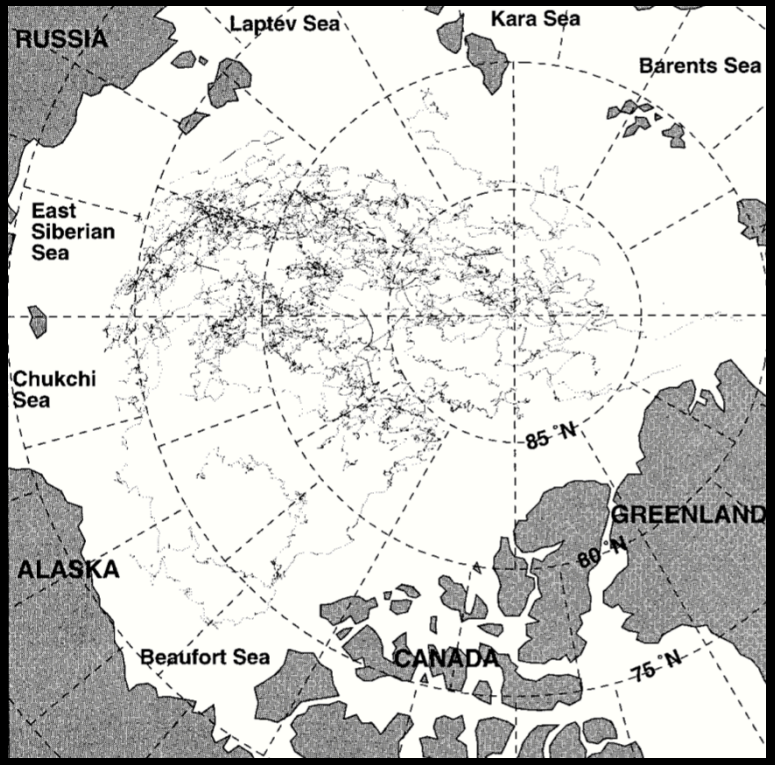
Satellites provide basin-scale measurements of sea ice freeboard



Measuring sea ice thickness from space:



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



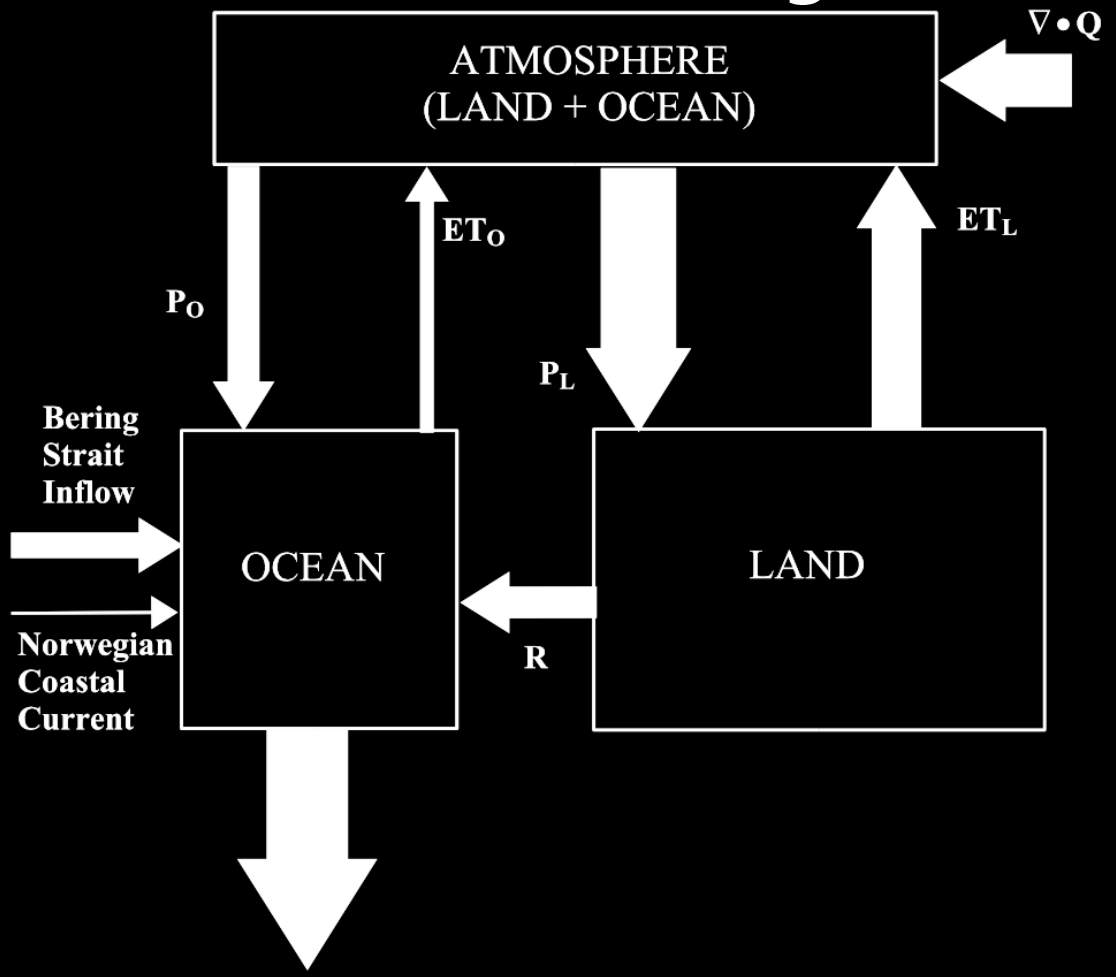
From [Warren et al., 1999]

We need a better snow depth product for sea ice thickness calculations!

We need a better snow depth product for sea ice thickness calculations!

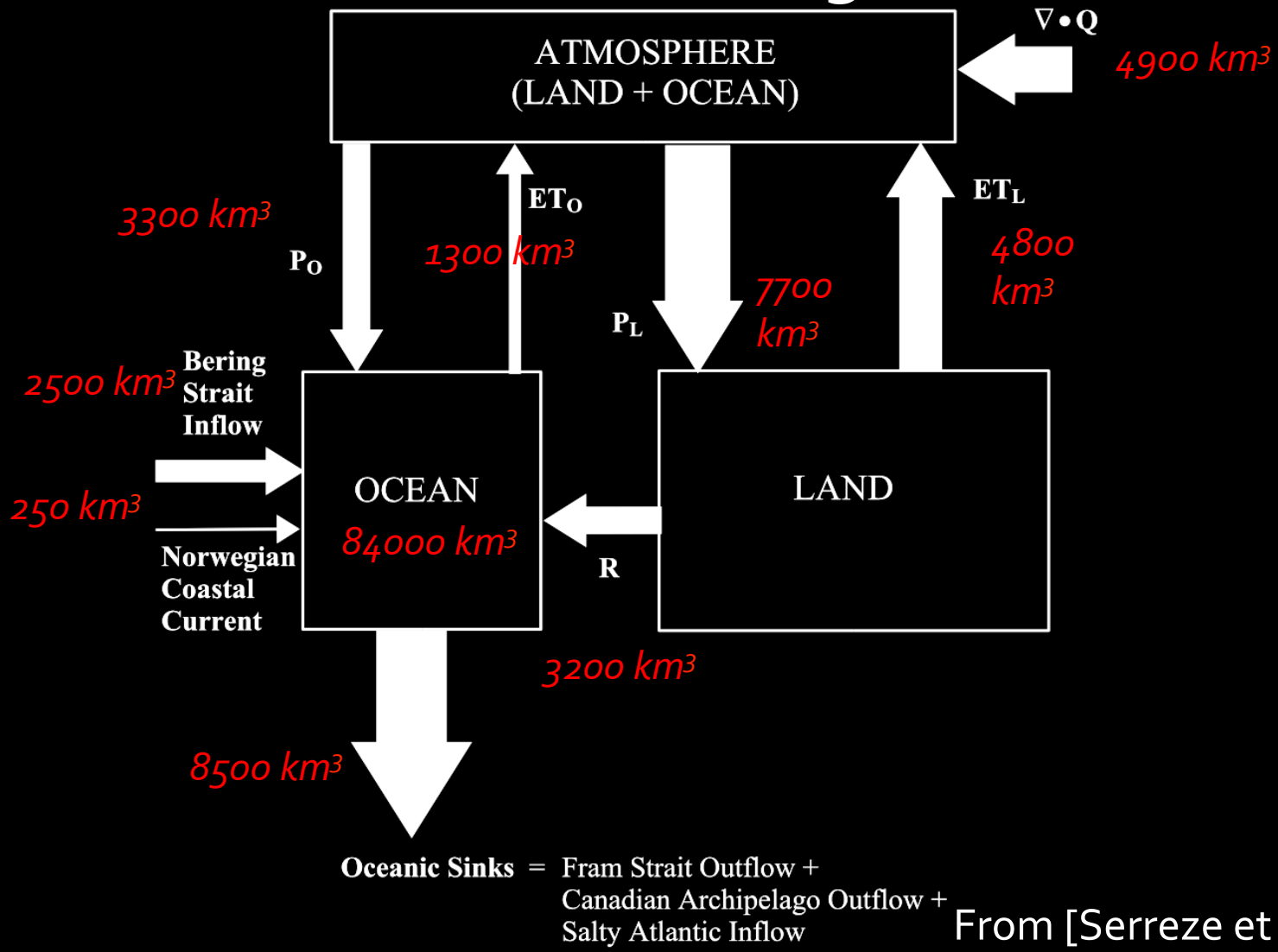
Also need to better understand the Arctic freshwater cycle!

The Arctic freshwater budget



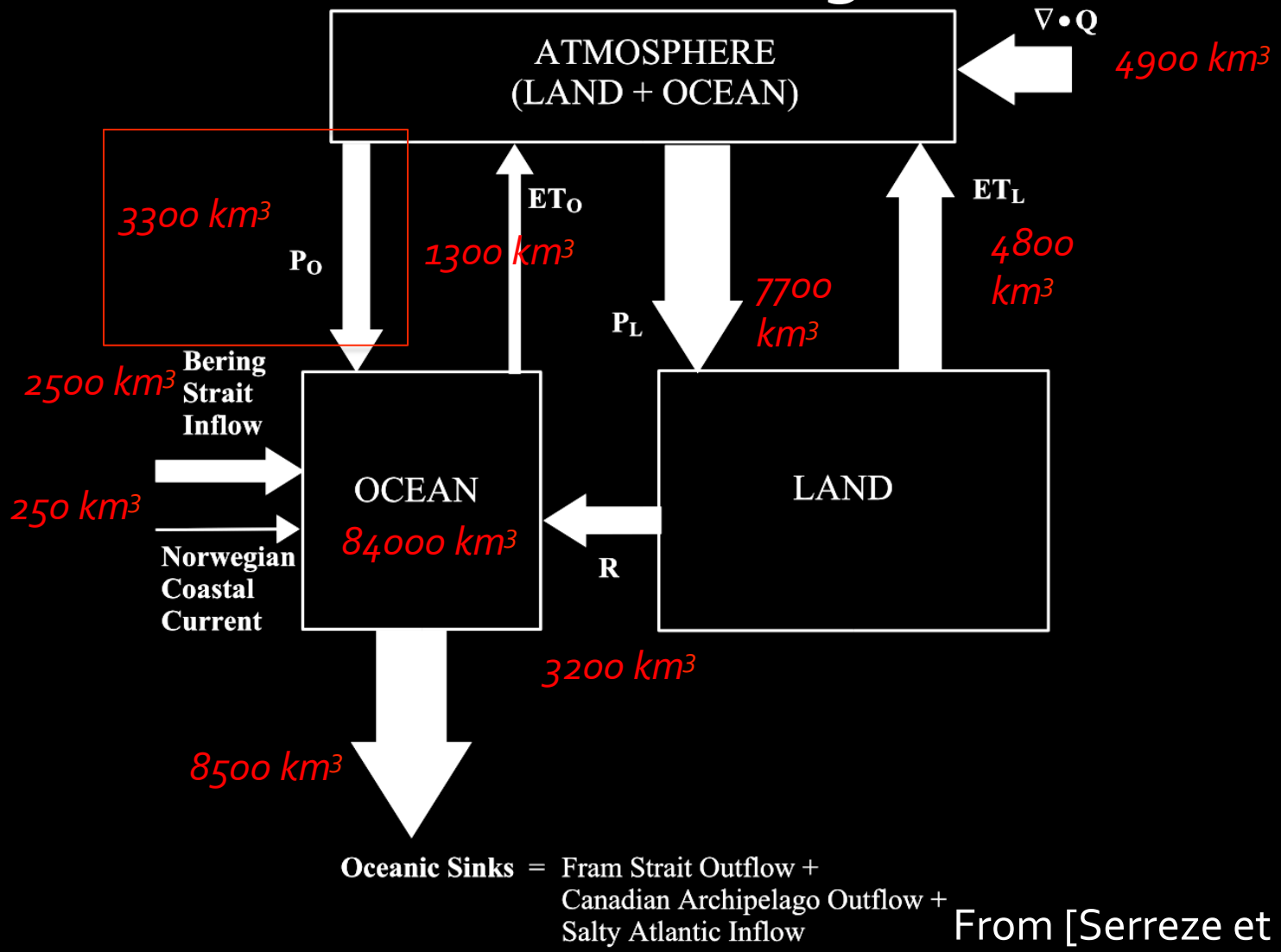
From [Serreze et al., 2006]

The Arctic freshwater budget



From [Serreze et al., 2006]

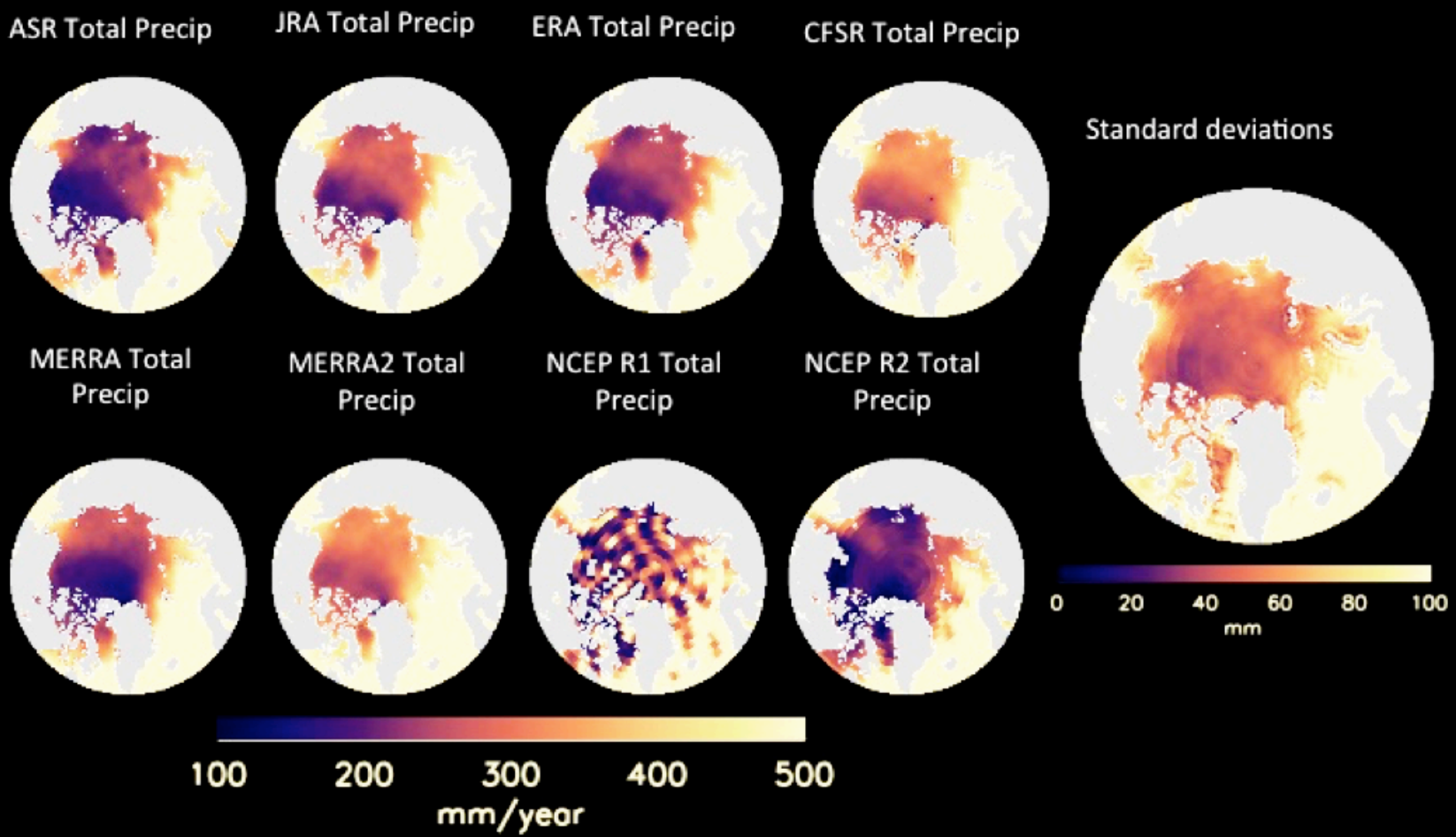
The Arctic freshwater budget



From [Serreze et al., 2006]

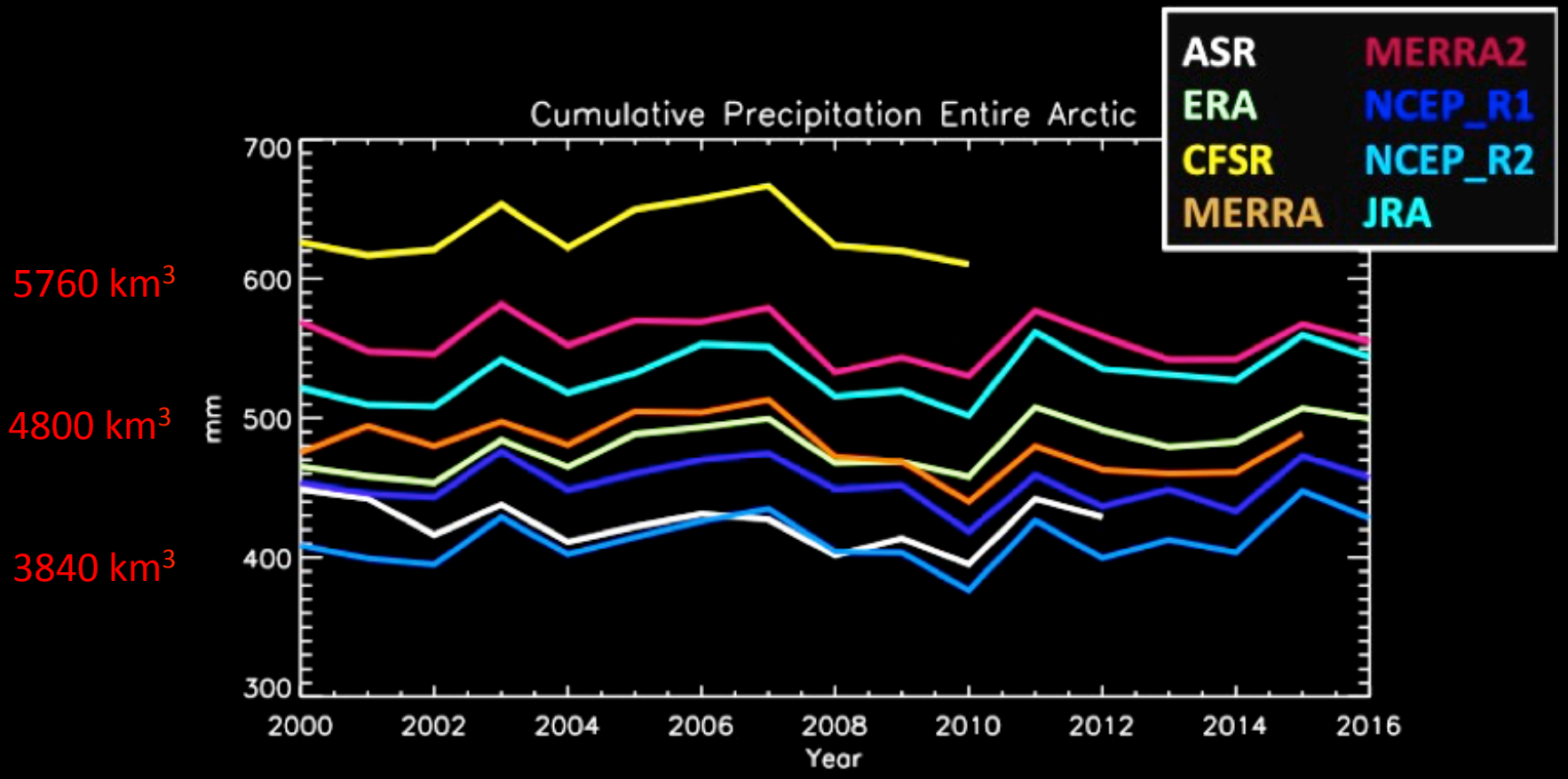
How much precipitation is there over the Arctic Ocean?

Total Arctic precip across 8 reanalyses



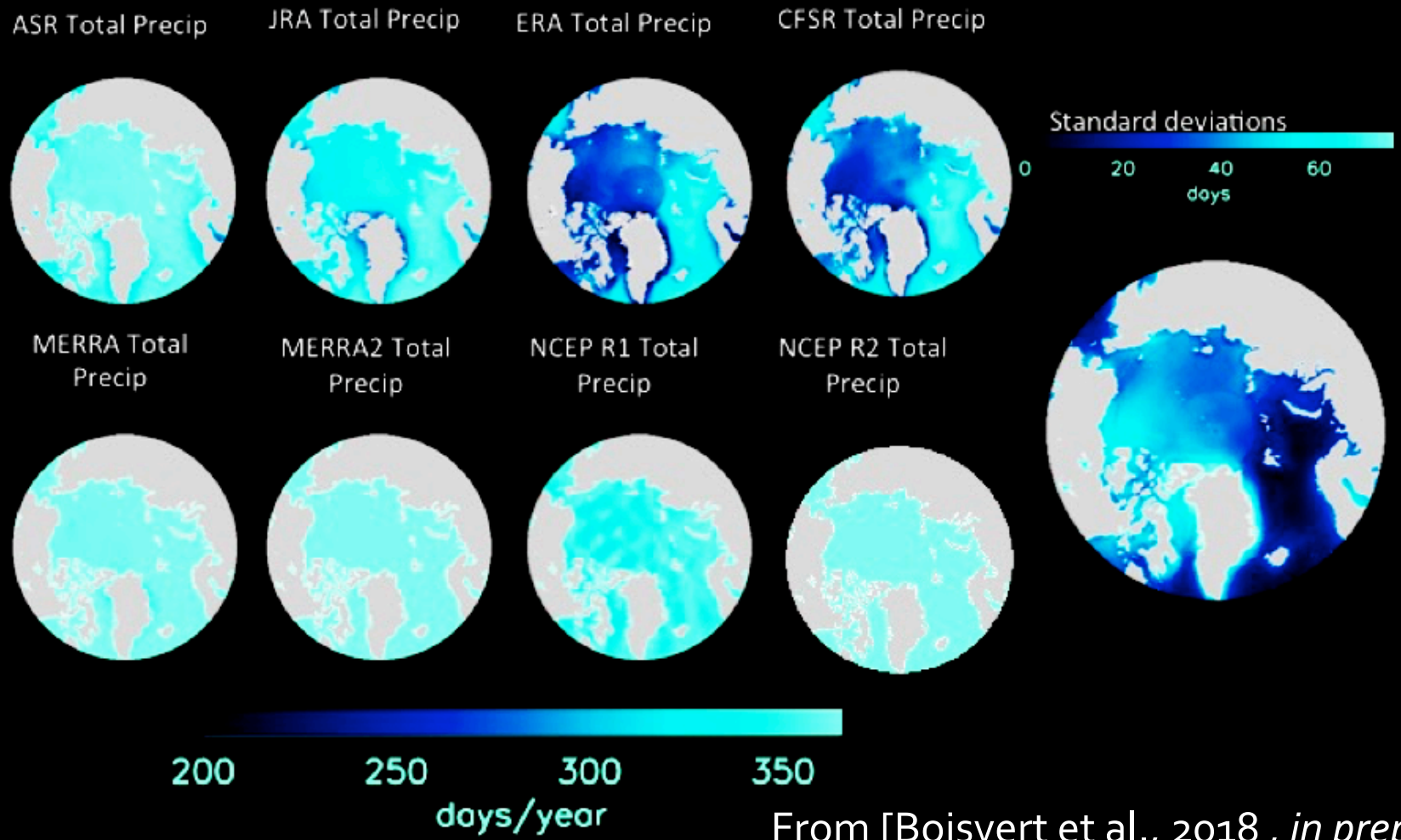
From [Boisvert et al., 2018 , *in prep*]

Annual Arctic precipitation across 8 reanalyses



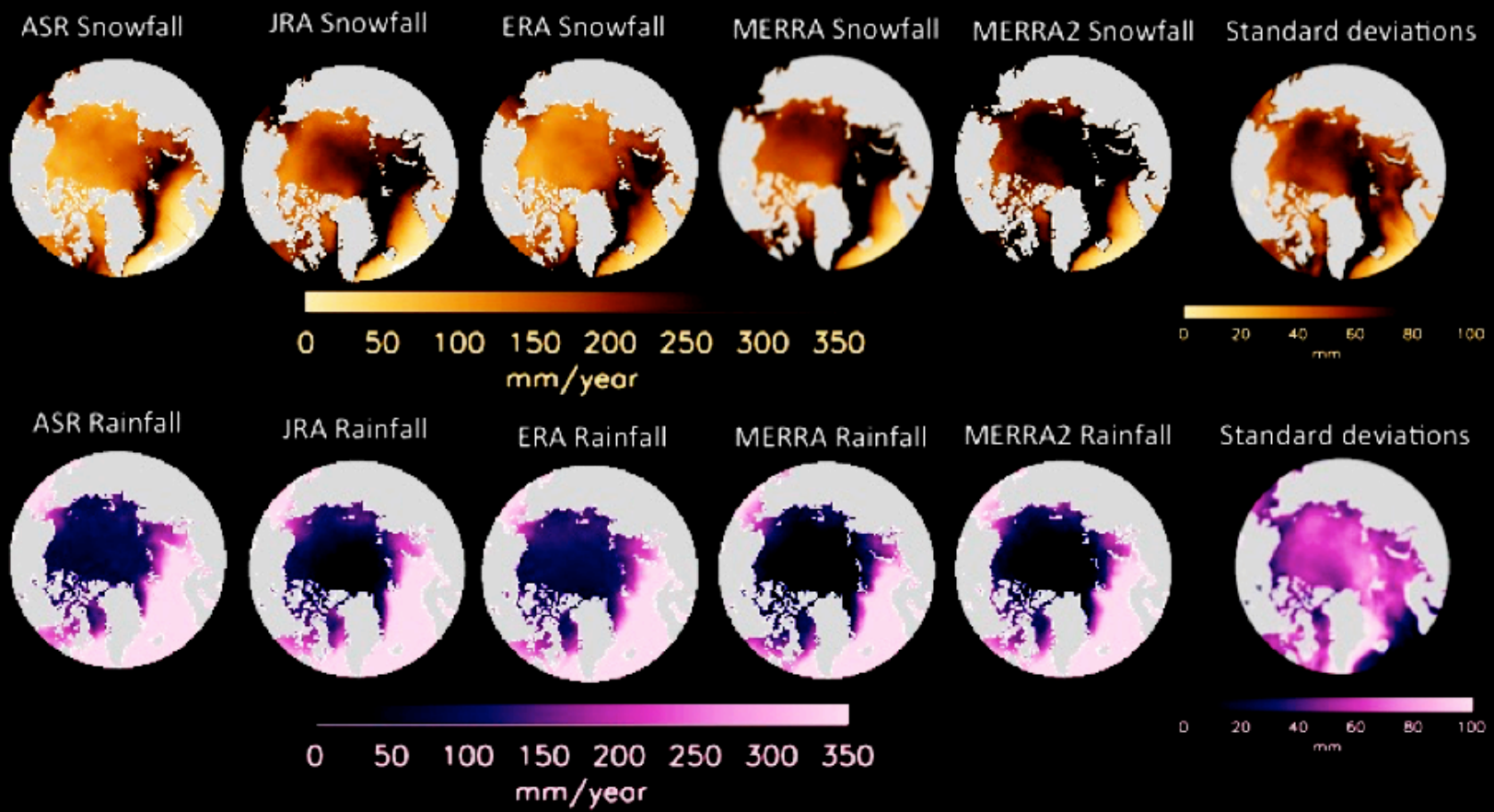
From [Boisvert et al., 2018 , *in prep*]

Days of Arctic precipitation across 8 reanalyses



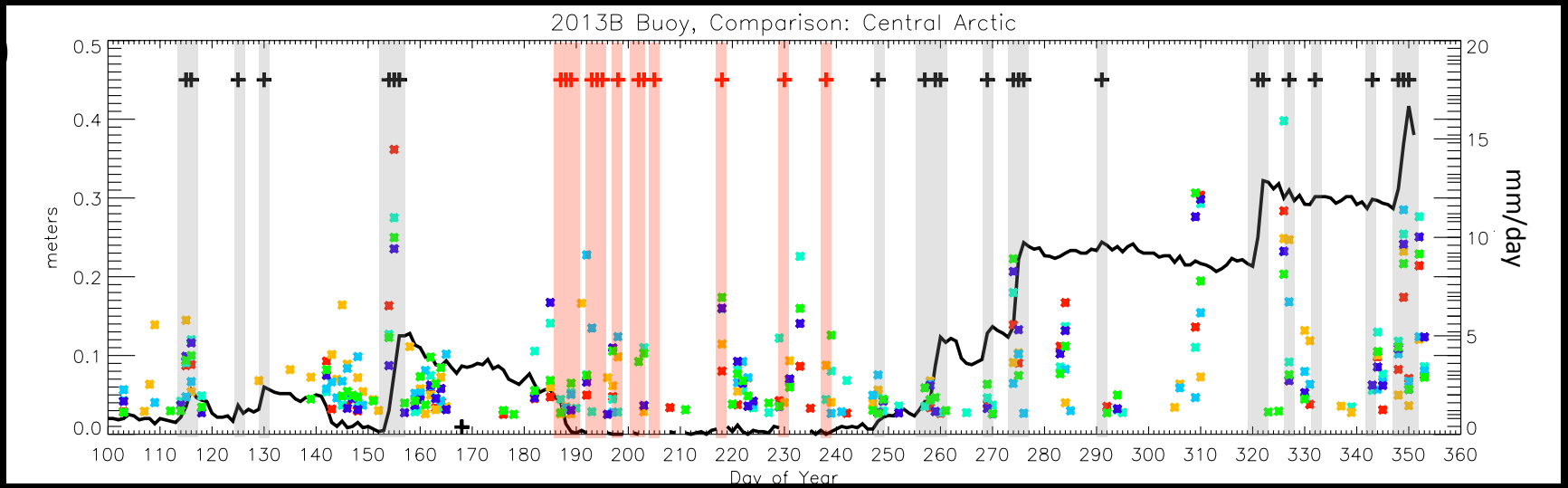
From [Boisvert et al., 2018 , *in prep*]

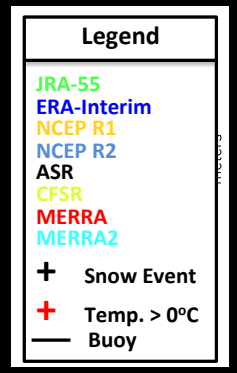
Rain and snowfall in the Arctic



From [Boisvert et al., 2018 , *in prep*]

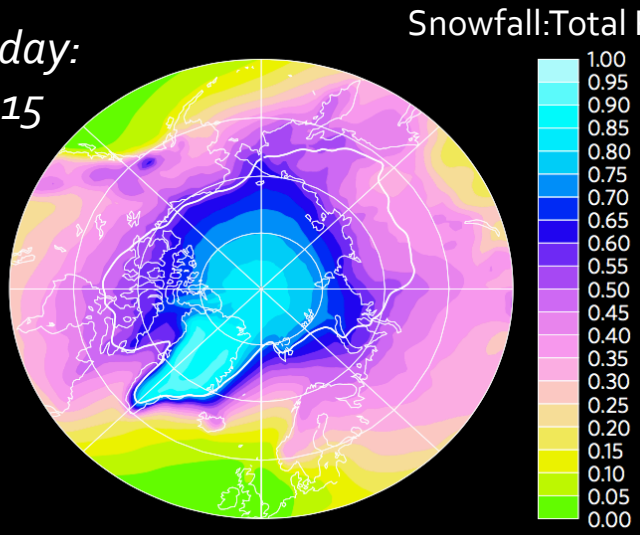
Comparison of precip events with snow buoy data





A future rain dominated Arctic?

Present day: 2006-2015

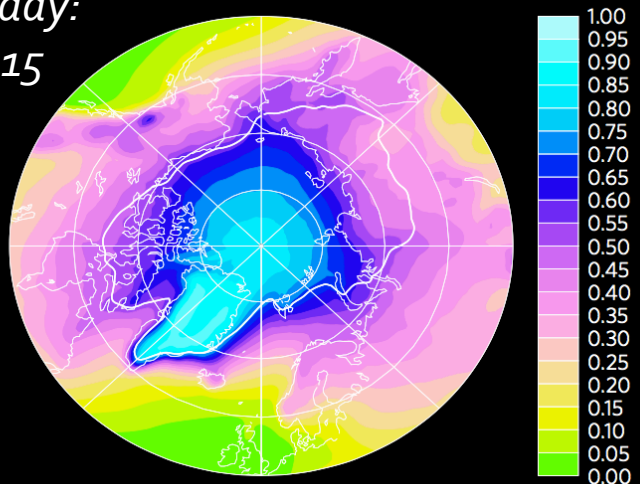


- Fraction of rainfall to total precip from the 37 CMIP5 models.

[Bintanja and Andrey, 2017, Nature Clim Change]

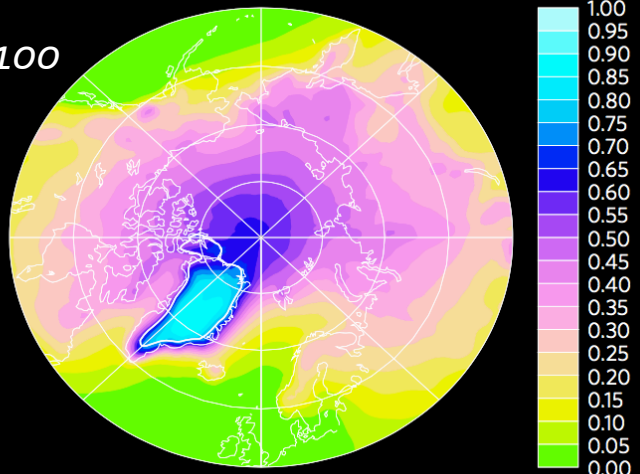
A future rain dominated Arctic?

Present day:
2006-2015



Snowfall:Total Precip

Future:
2091-2100



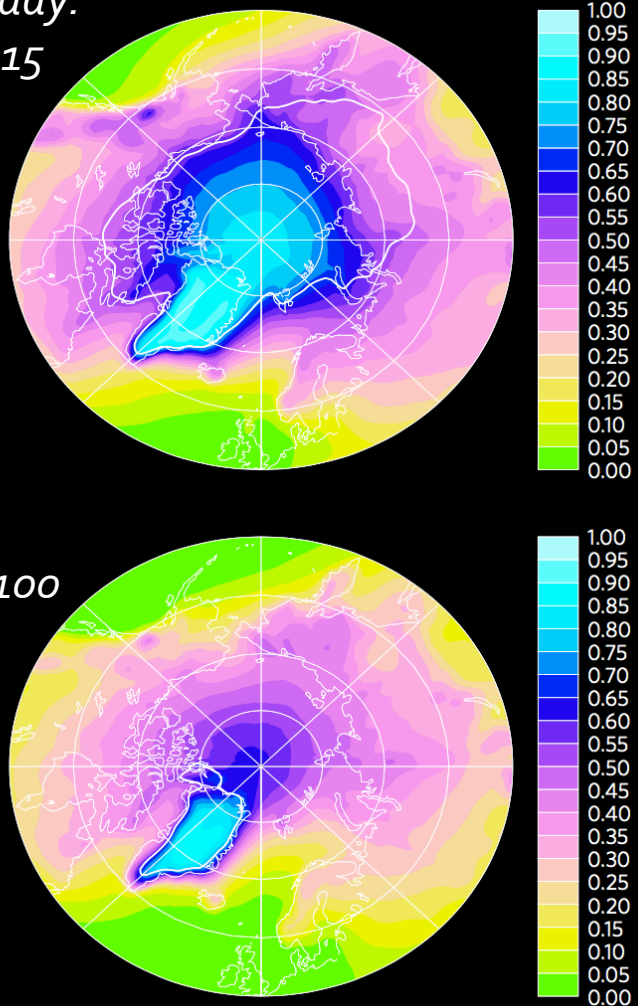
- Fraction of rainfall to total precip from the 37 CMIP5 models.
- Snowfall expected to decrease, rainfall expected to increase.

[Bintanja and Andrey, 2017, Nature Clim Change]

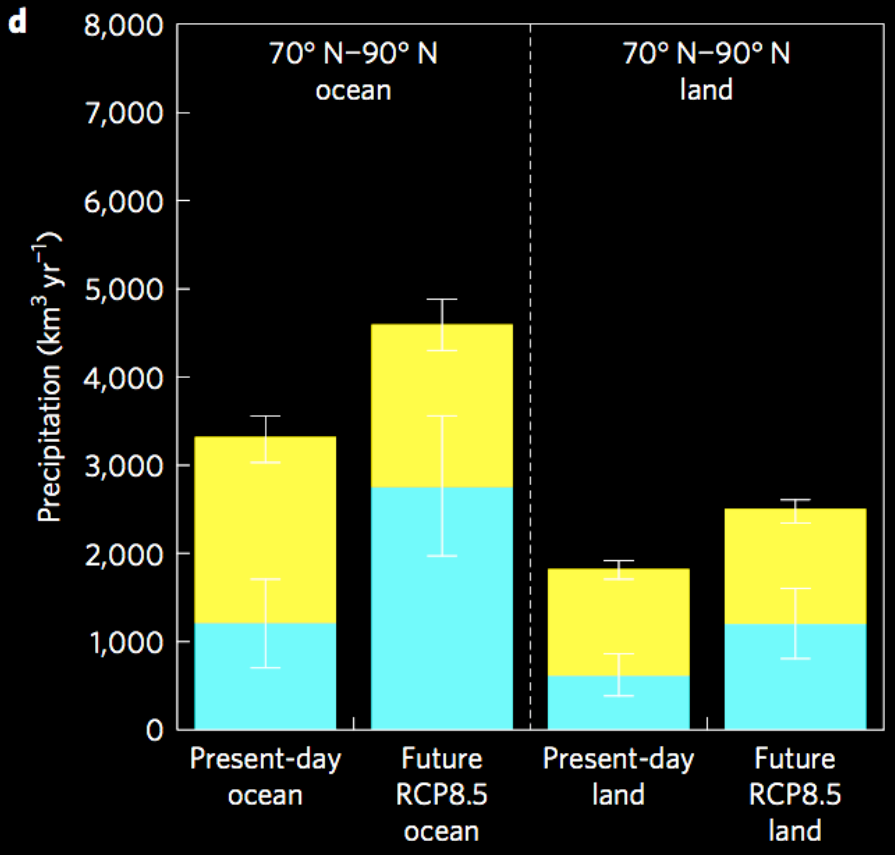
A future rain dominated Arctic?

Present day:
2006-2015

Snowfall:Total Precip



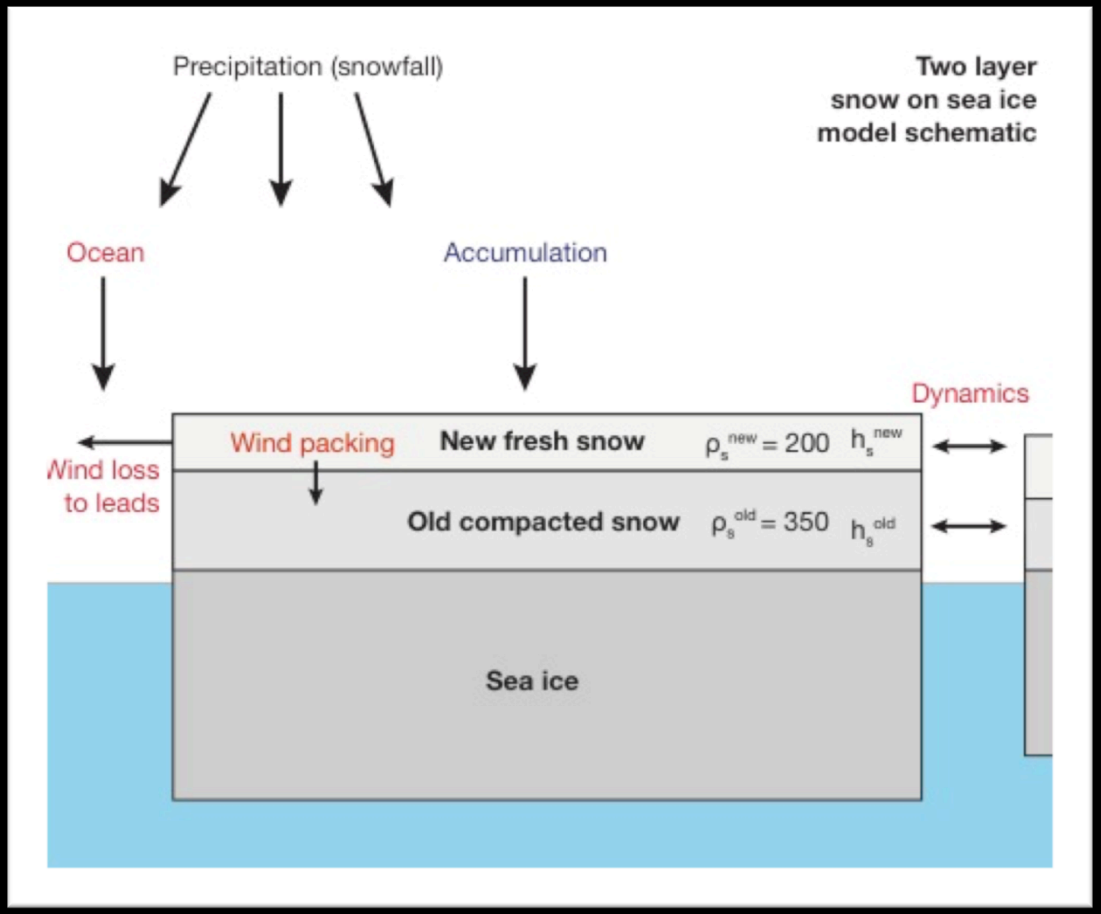
Future:
2091-2100



[Bintanja and Andrey, 2017, Nature Clim Change]

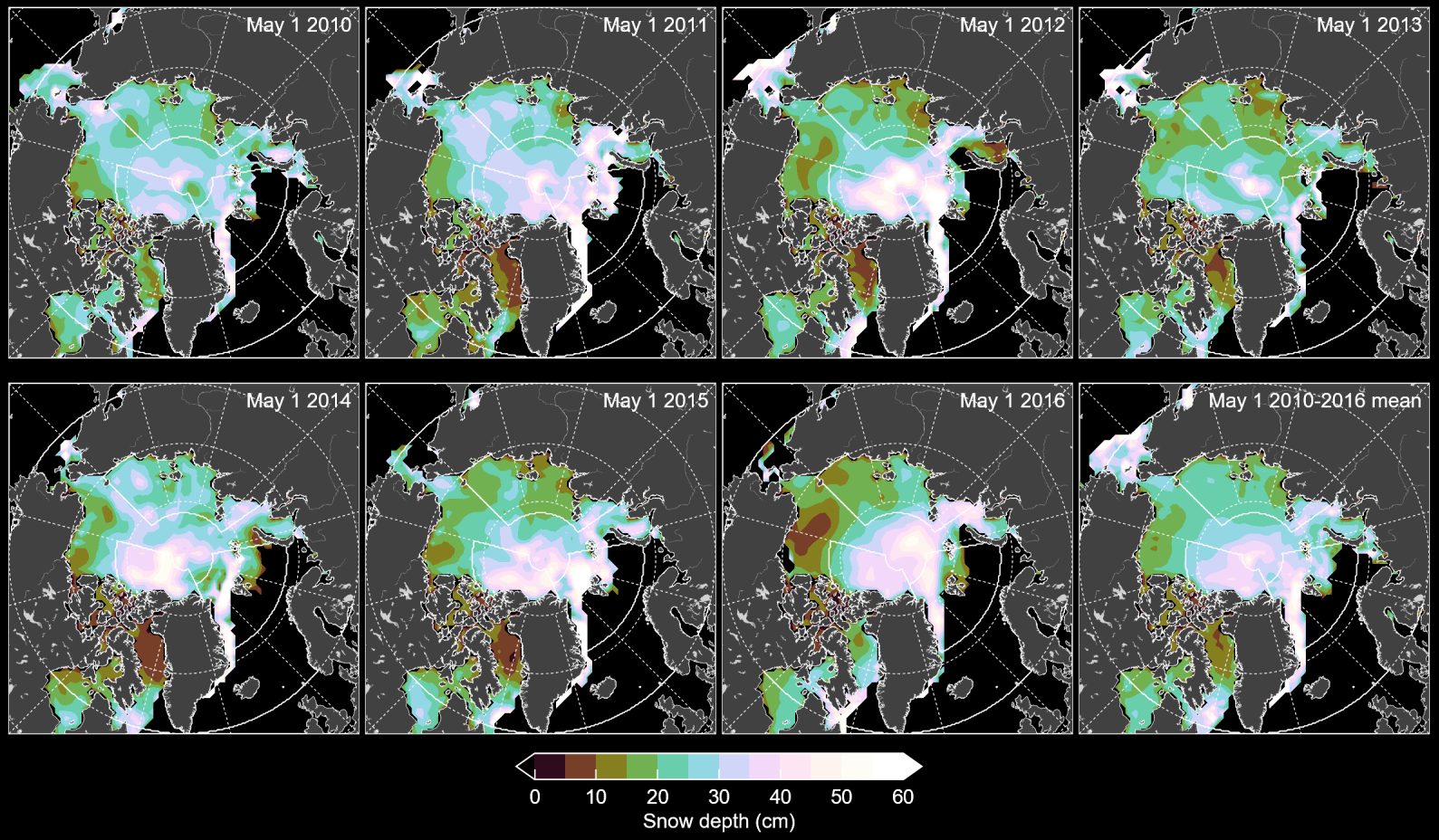
Moving from precip to accumulation and snow depth

The NASA Eulerian Snow on Sea Ice Model (NESOSIM)



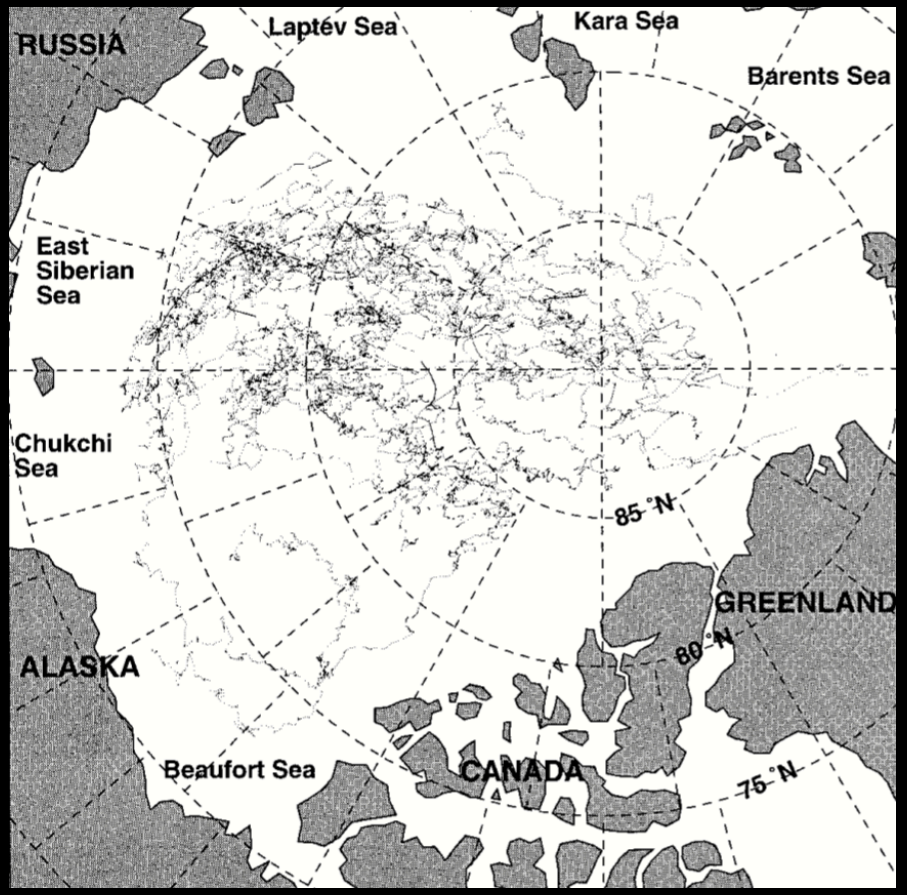
[Petty et al., in prep]

NESOSIM results

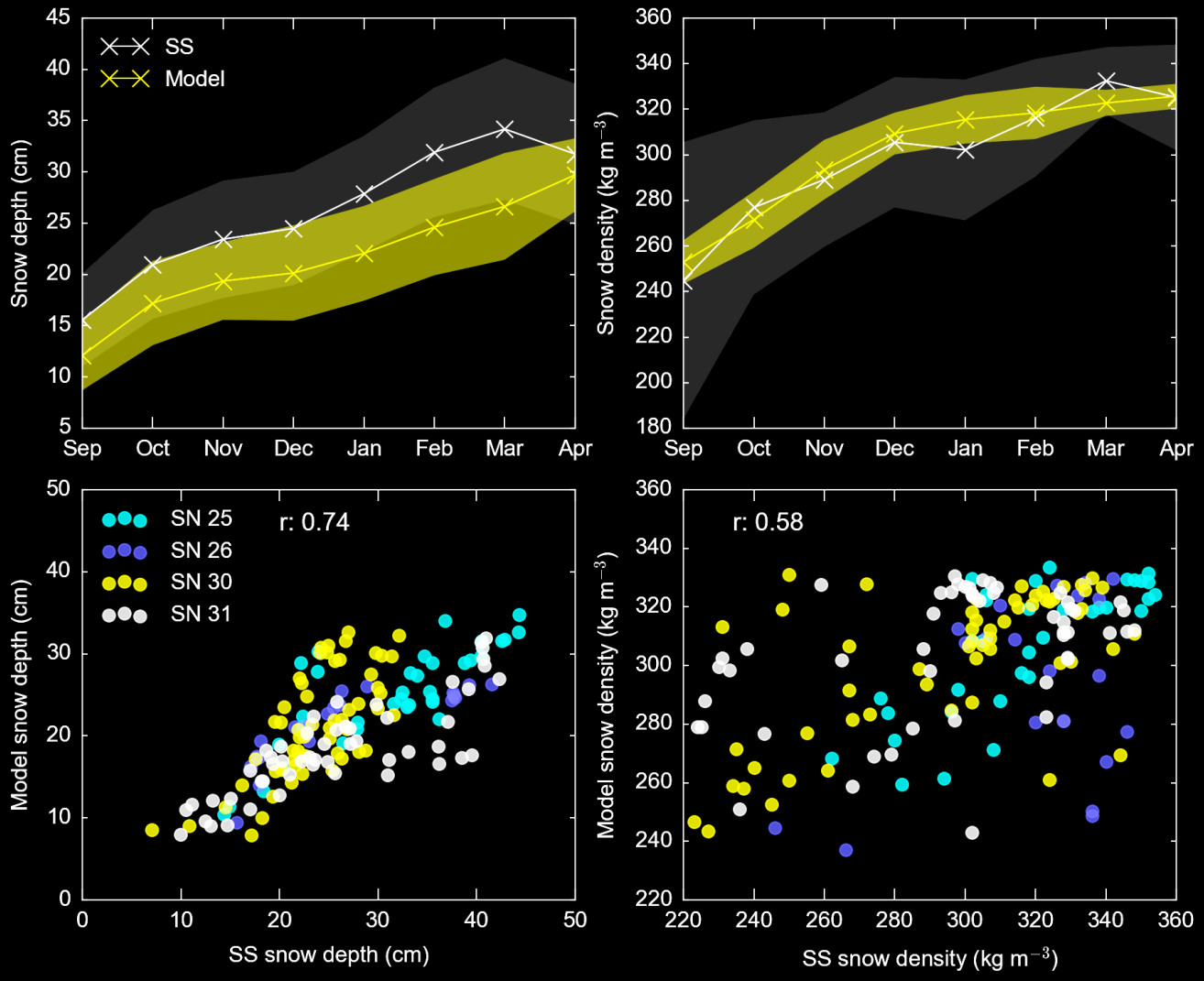


Forced by ERA-Interim snowfall/winds, Bootstrap ice concentration, NSIDC drift.

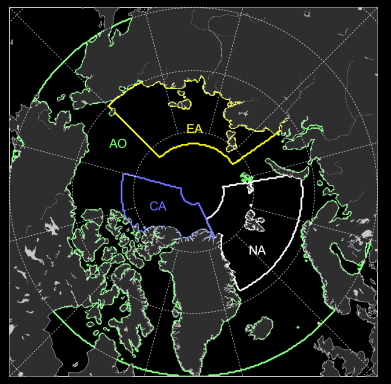
Calibrations with Soviet Station data

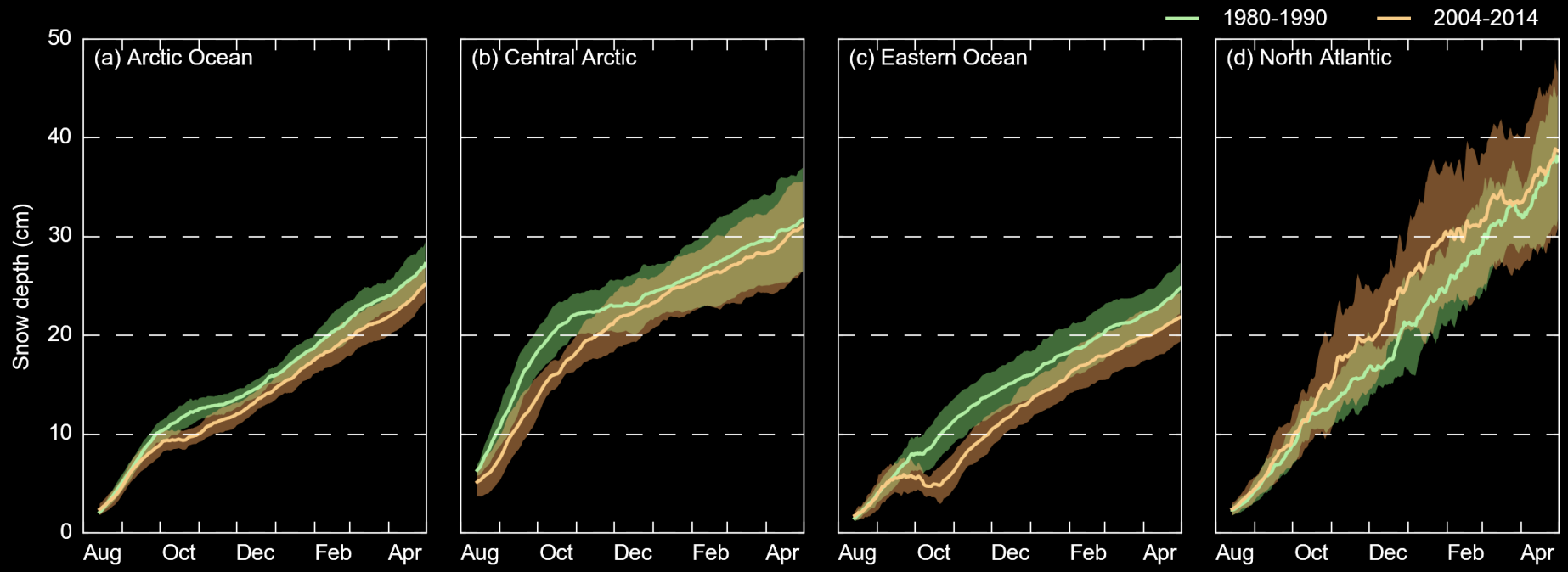


Calibrations with Soviet Station data

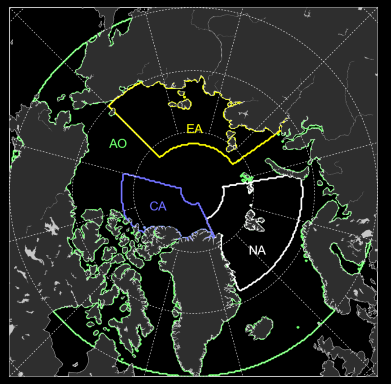


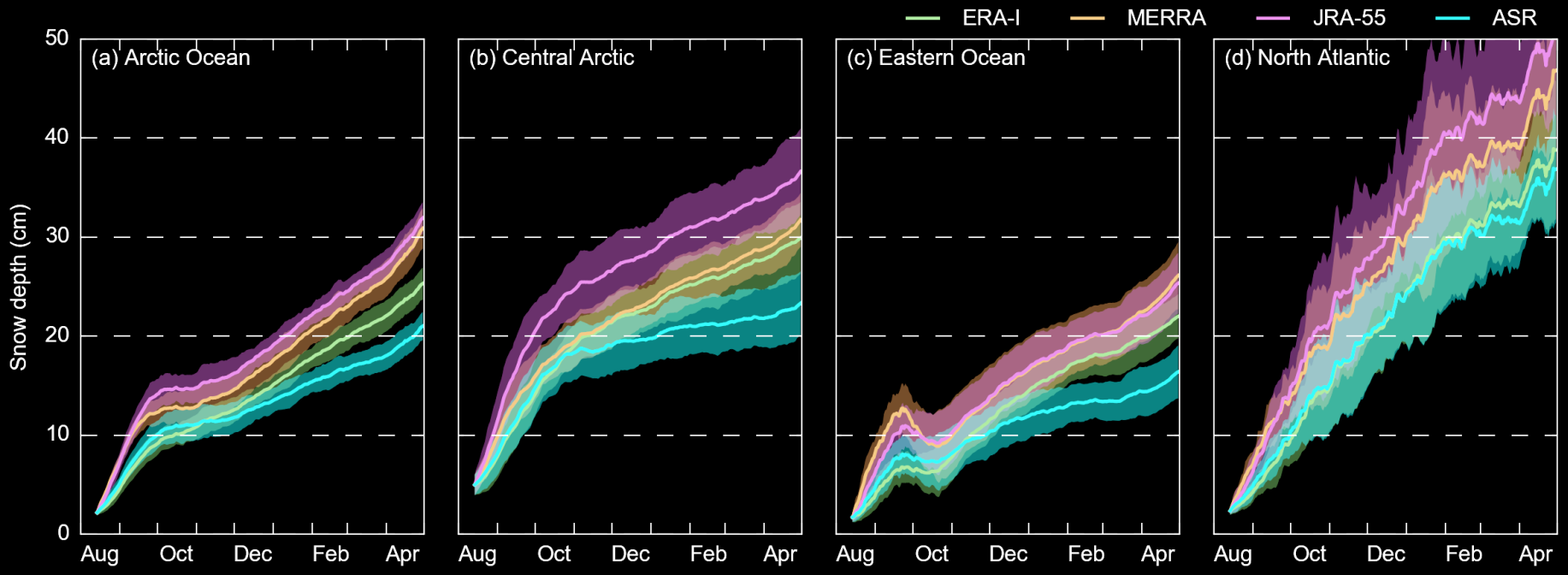
NESOSIM forced by ERA-I



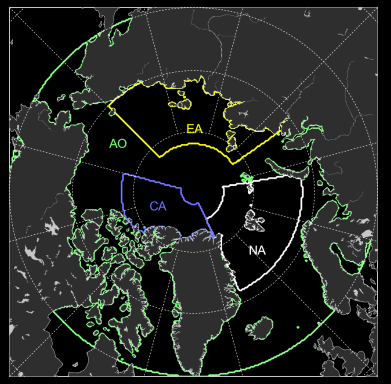


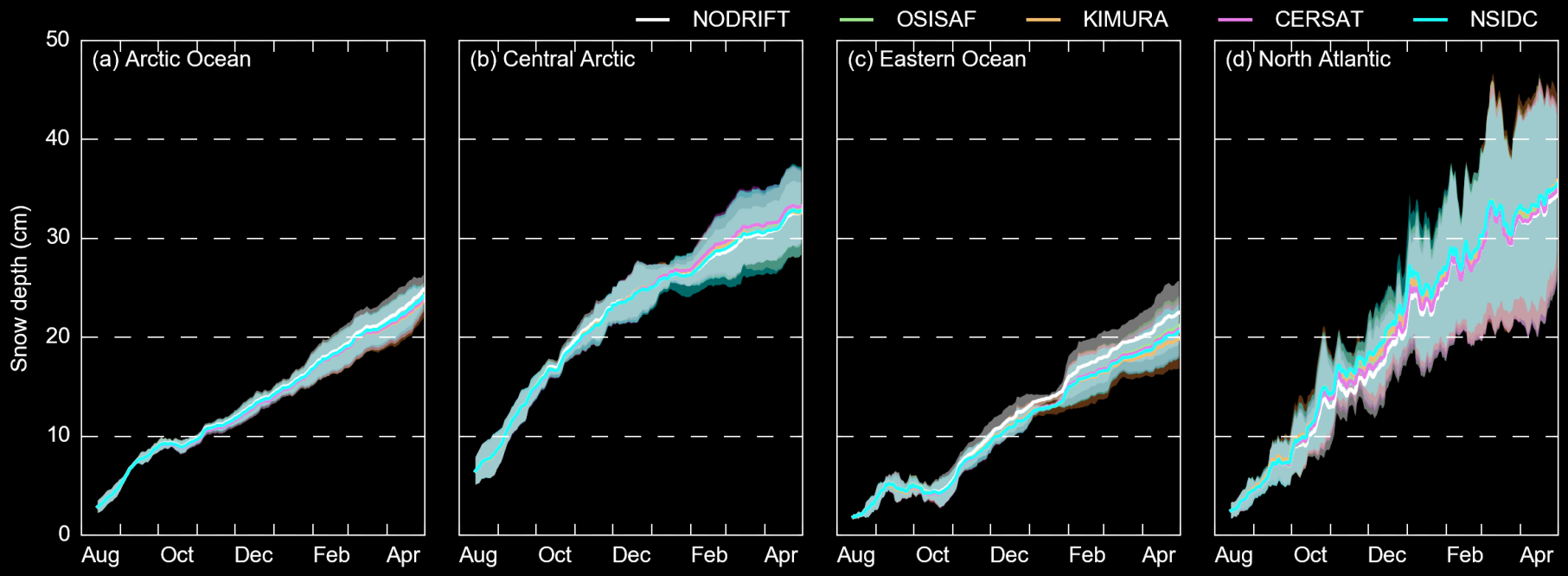
NESOSIM forced by different reanalyses



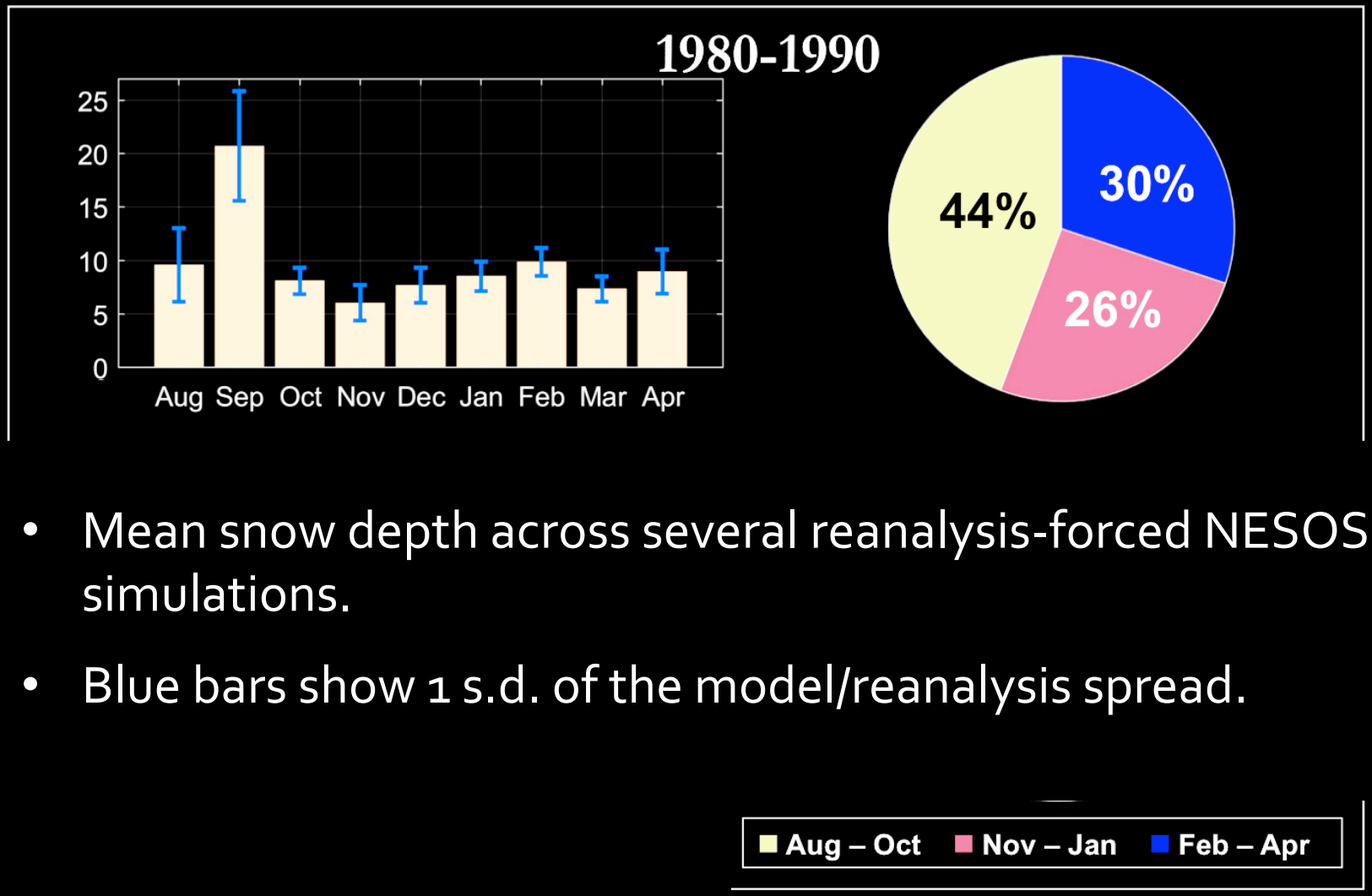


NESOSIM forced by different ice drifts



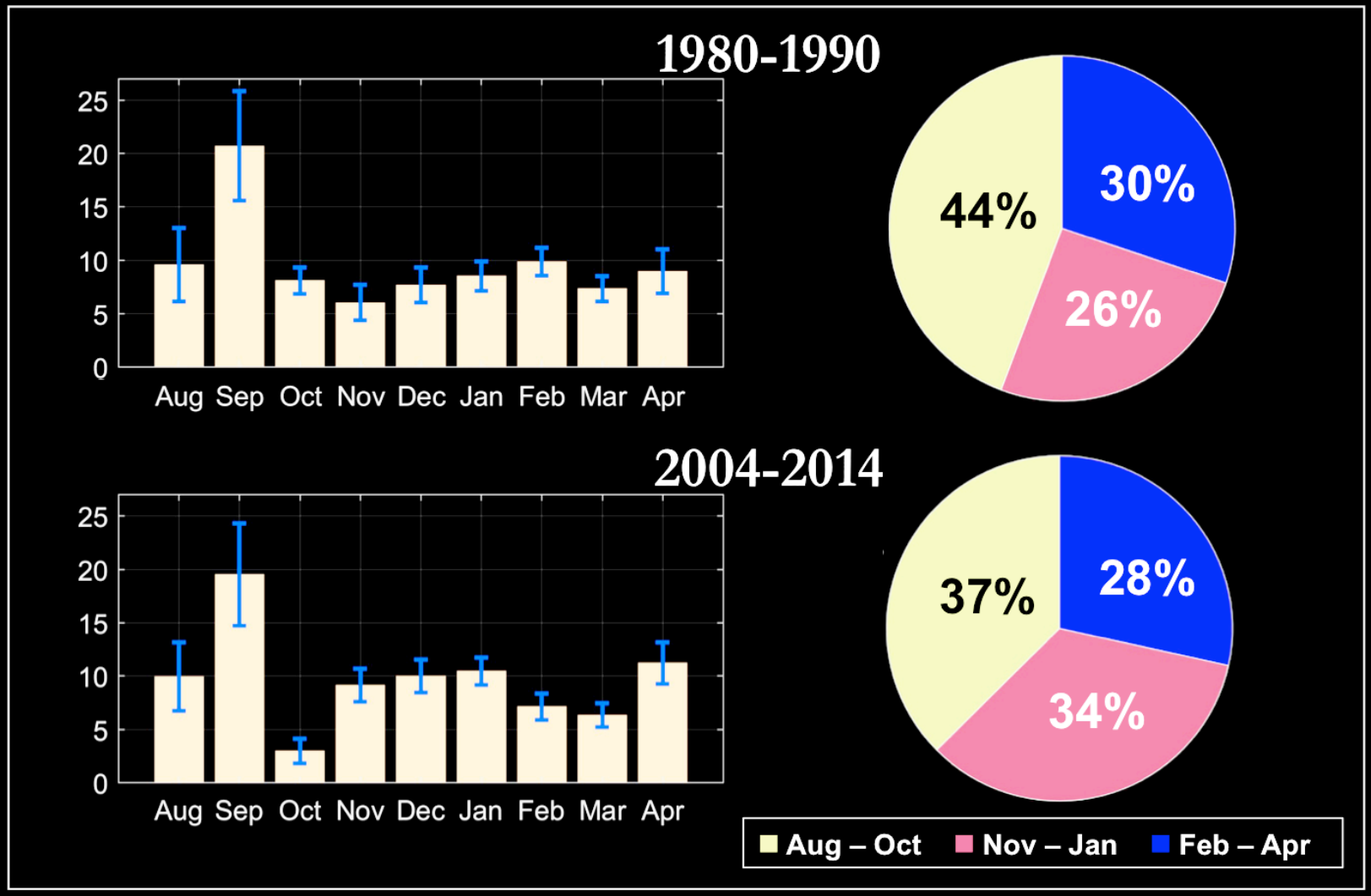


Seasonal snow contributions



- Mean snow depth across several reanalysis-forced NESOSIM simulations.
- Blue bars show 1 s.d. of the model/reanalysis spread.

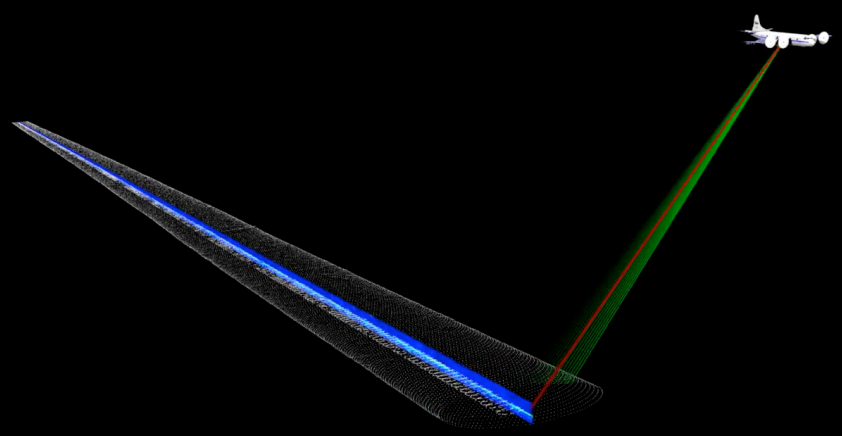
Seasonal snow contributions



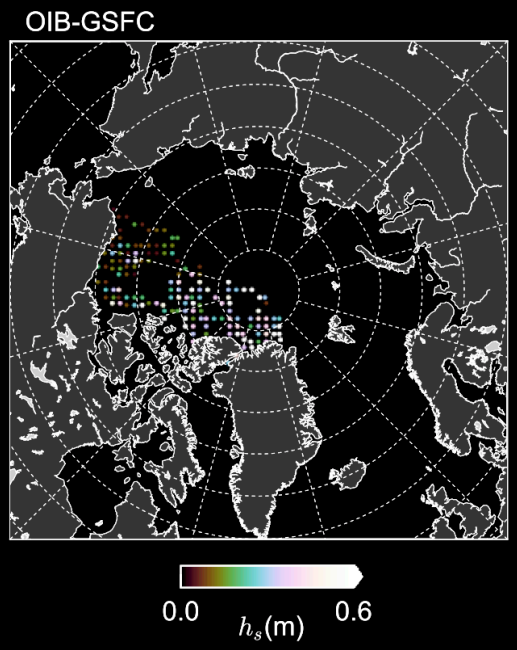
Validate with NASA's Operation IceBridge

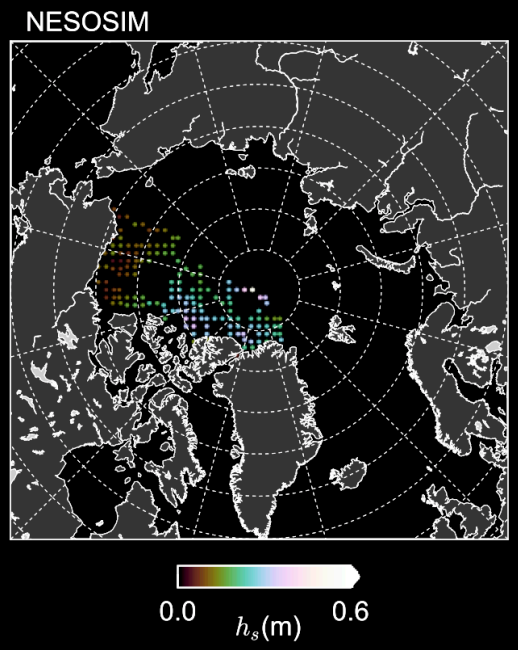
- Suite of sensors to measure both land and sea ice
- Conical scanning laser altimeter (ATM) and snow radar.

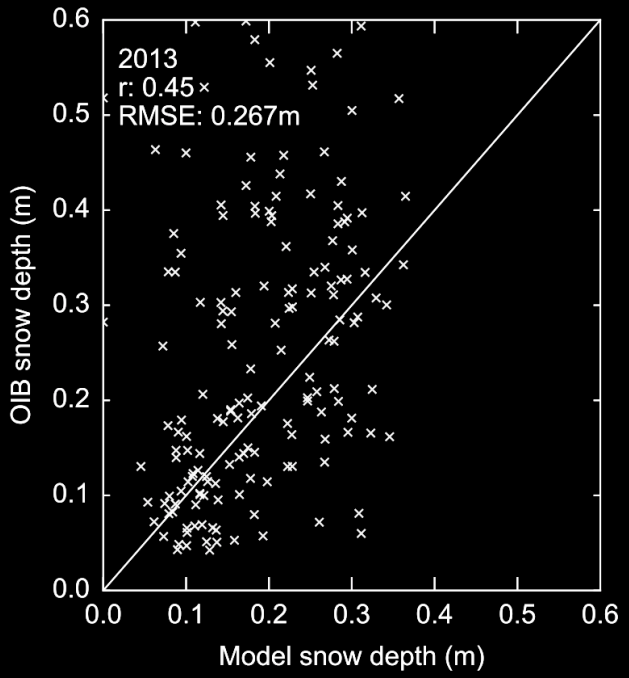
Wide + Narrow ATM Systems + Radar



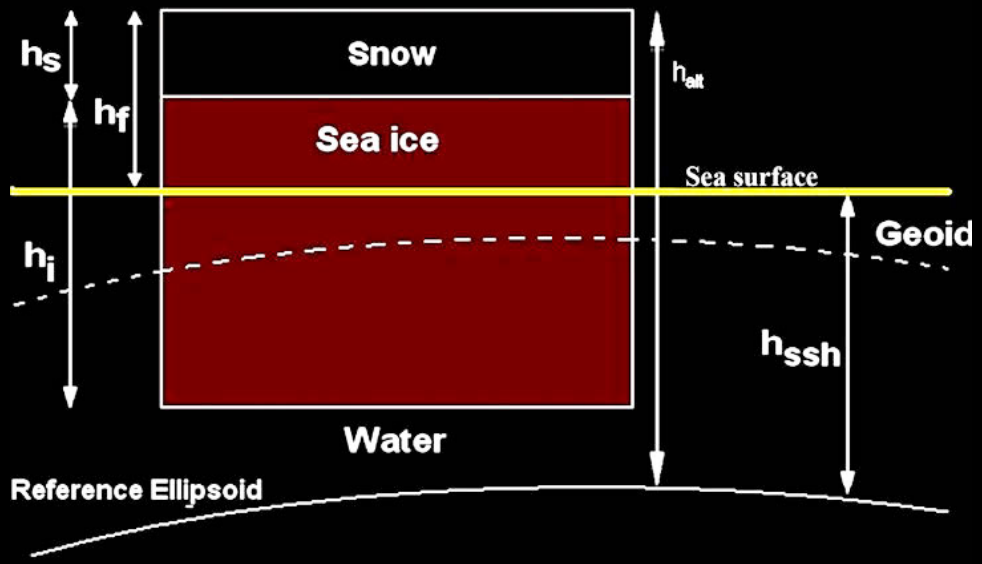
Validate with NASA's Operation IceBridge



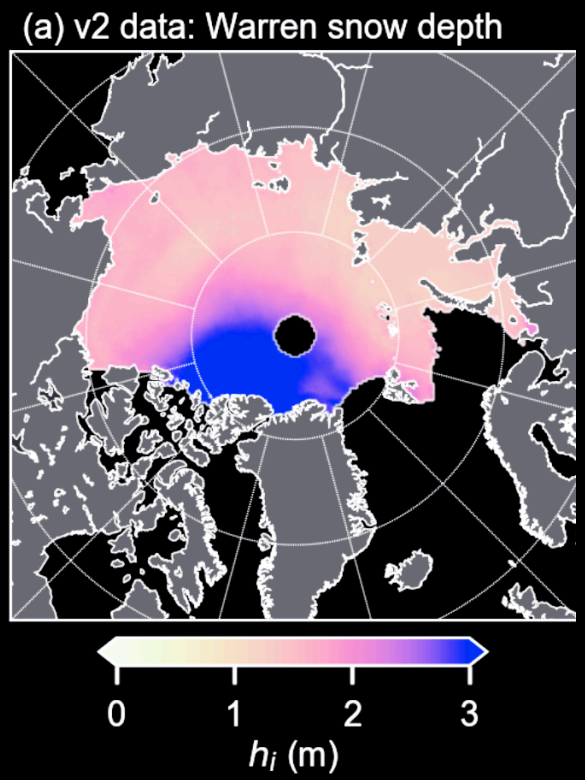




Moving from snow depth to sea ice thickness



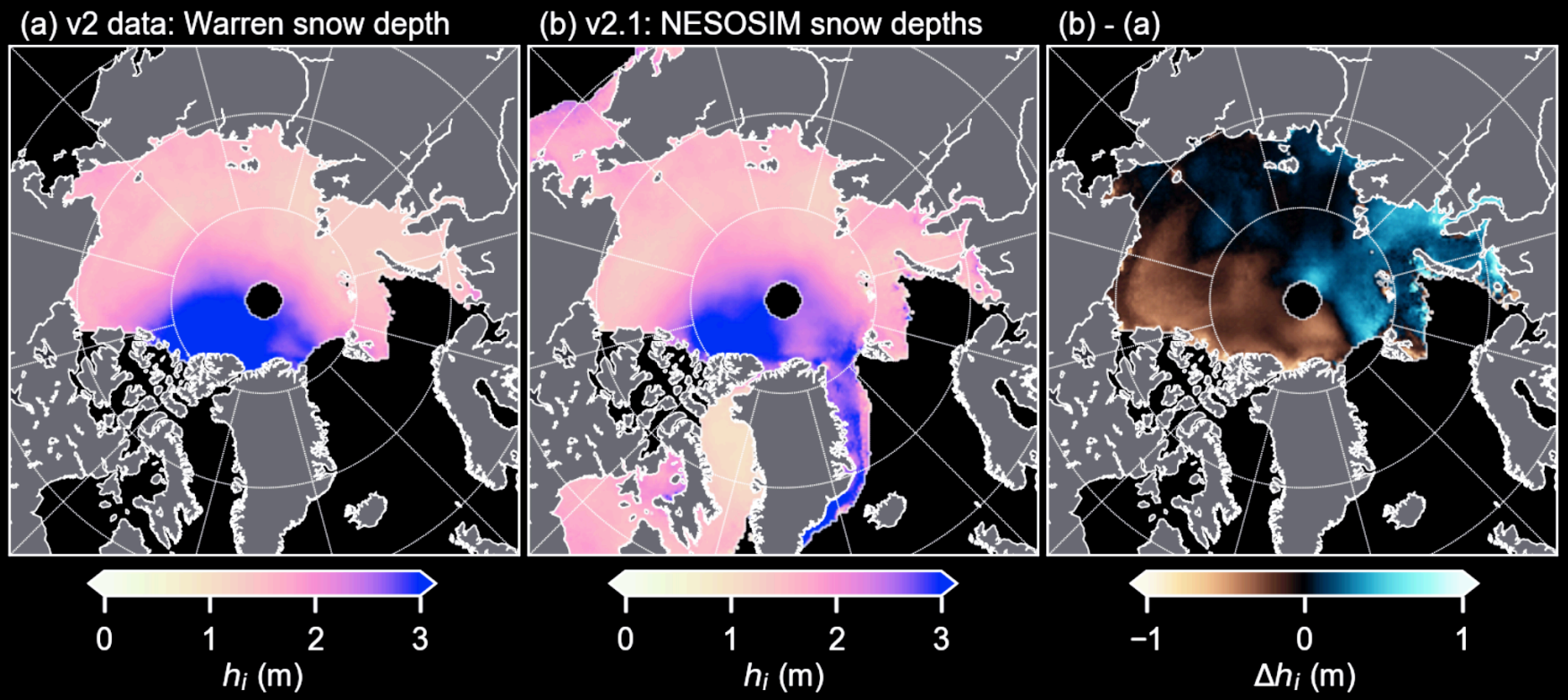
Already improving CryoSat-2 thickness estimates



Winter mean (2010-2016)

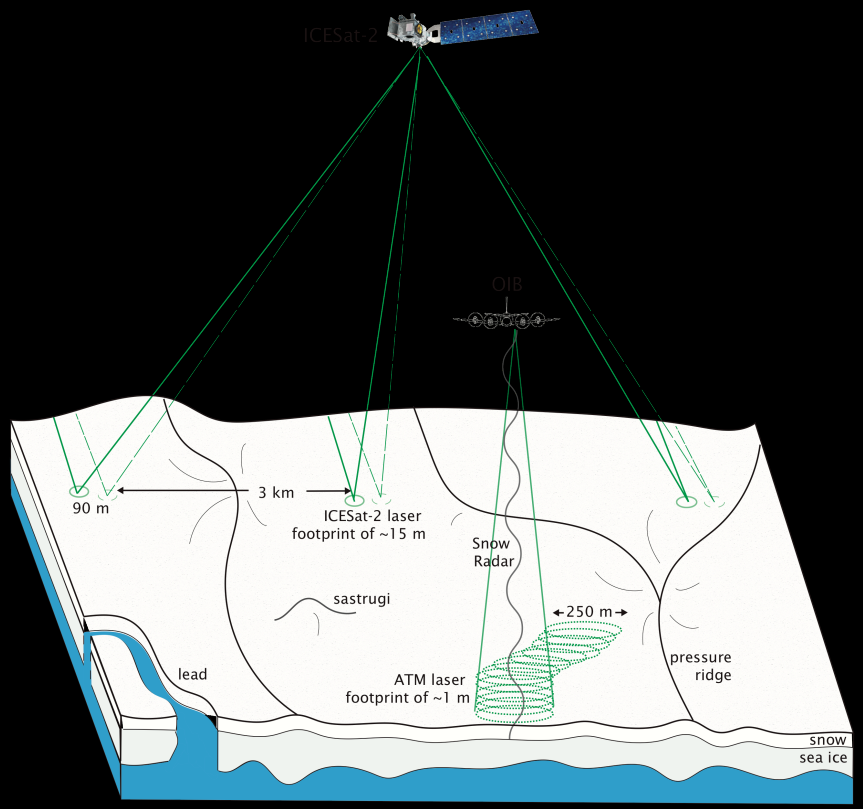
CryoSat-2 sea ice thickness using Warren snow depth climatology

Already improving CryoSat-2 thickness estimates

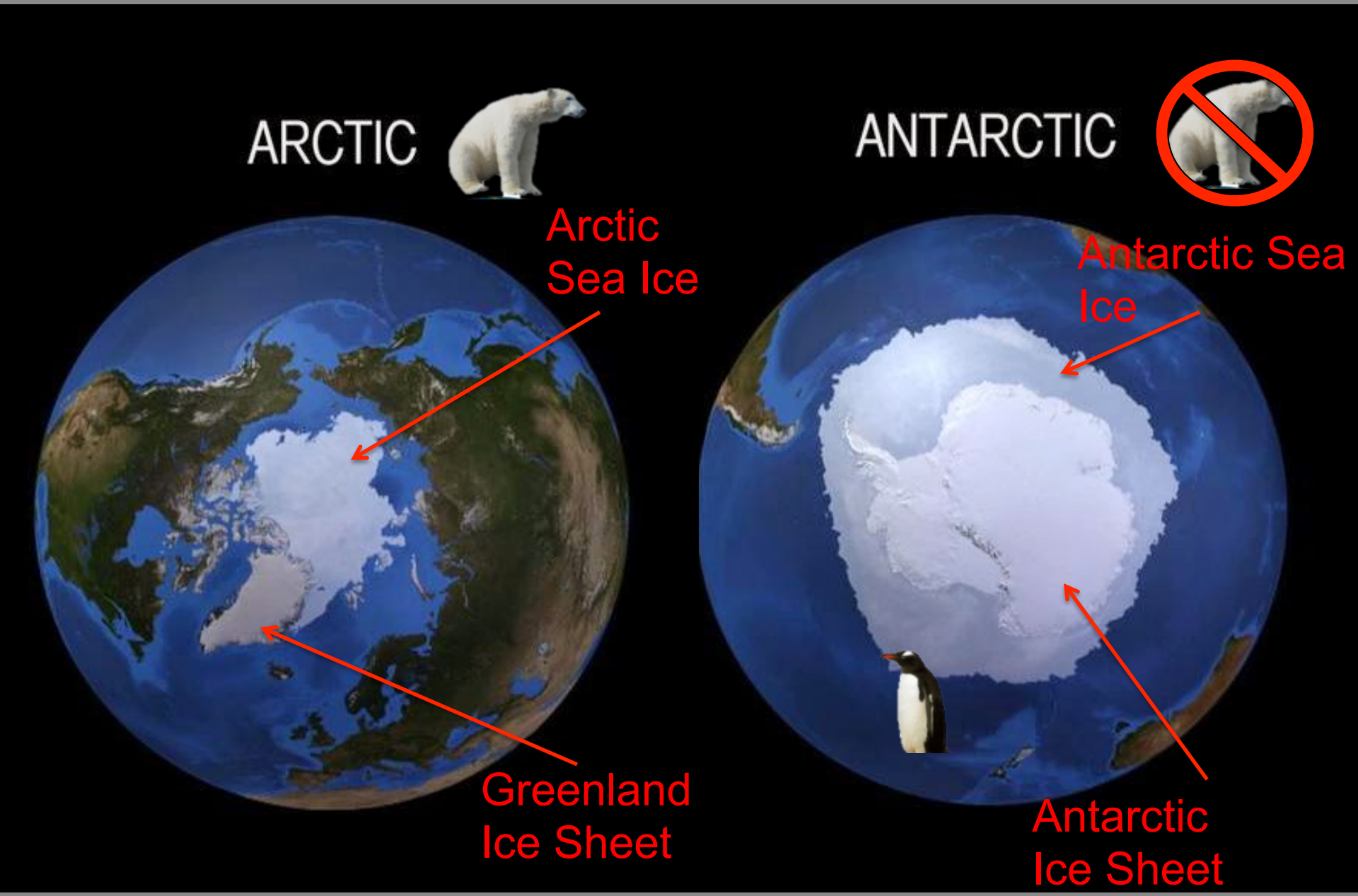


Looking ahead to NASA's ICESat-2 mission

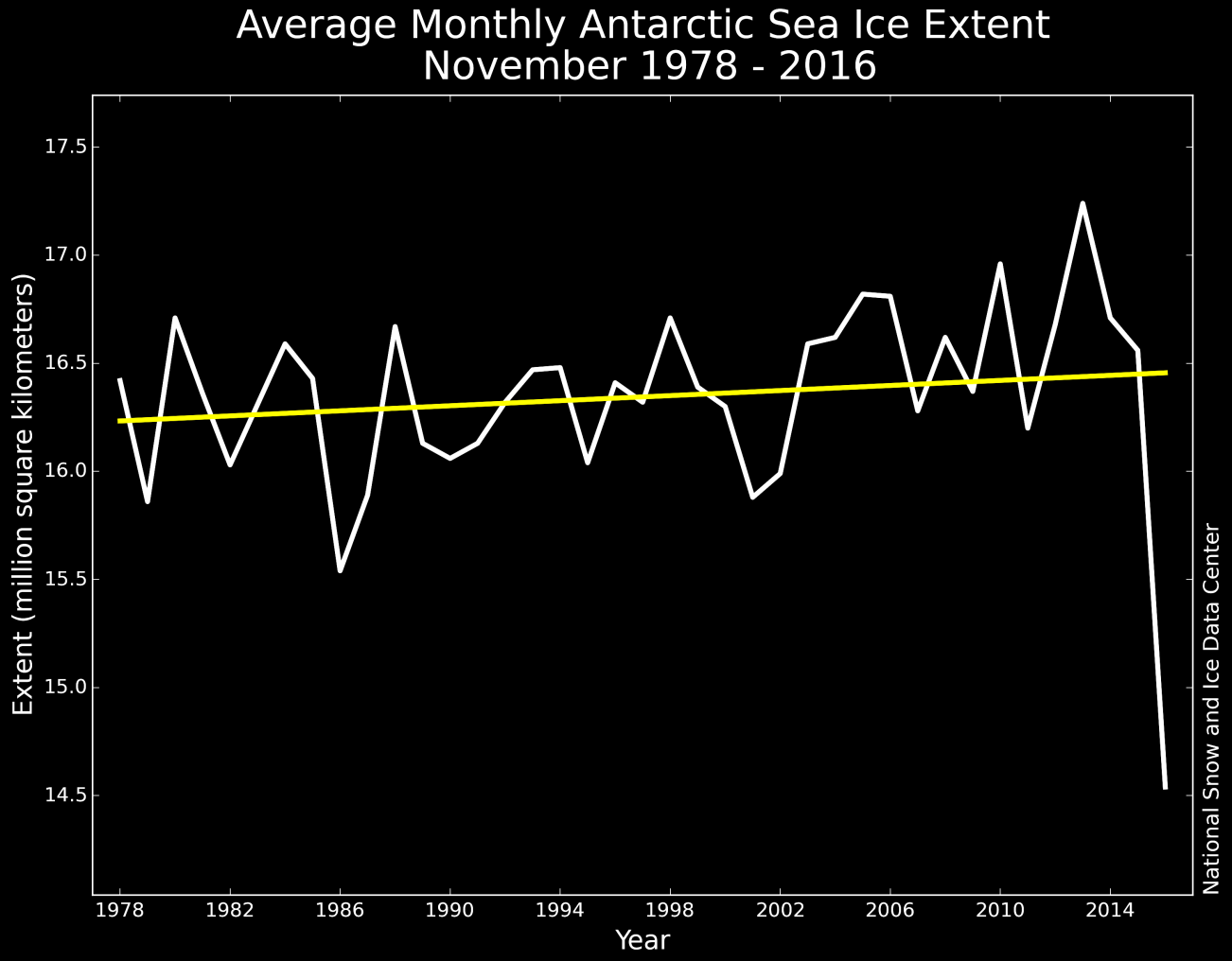
Scheduled for launch later this year!



- 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!


ARCTIC
Arctic
Sea Ice
Greenland
Ice Sheet
ANTARCTIC
Antarctic Sea
Ice
Antarctic
Ice Sheet

Antarctic sea ice in decline?



Antarctic sea ice thickness?

Importance of Antarctic sea ice

- Impacts shelf water formation
  - brine rejection and overturning
- Maybe important for ice shelf melt?
  - Ocean warming, local atmosphere conditions
- Less is known about Antarctic sea ice thickness!

Summary

- Need snow depth/density on sea ice to estimate sea ice thickness.
- Developed a new snow on sea ice model.
- Calibrated against Soviet Station data, captures well the seasonal snow depth/density cycle.
- Reanalysis data needed, but show large differences.

Future work

- Produce updated CryoSat-2/ICESat thickness estimates
- Improve model physics
- Run NESOSIM in the Southern Ocean
- Get ready for ICESat-2