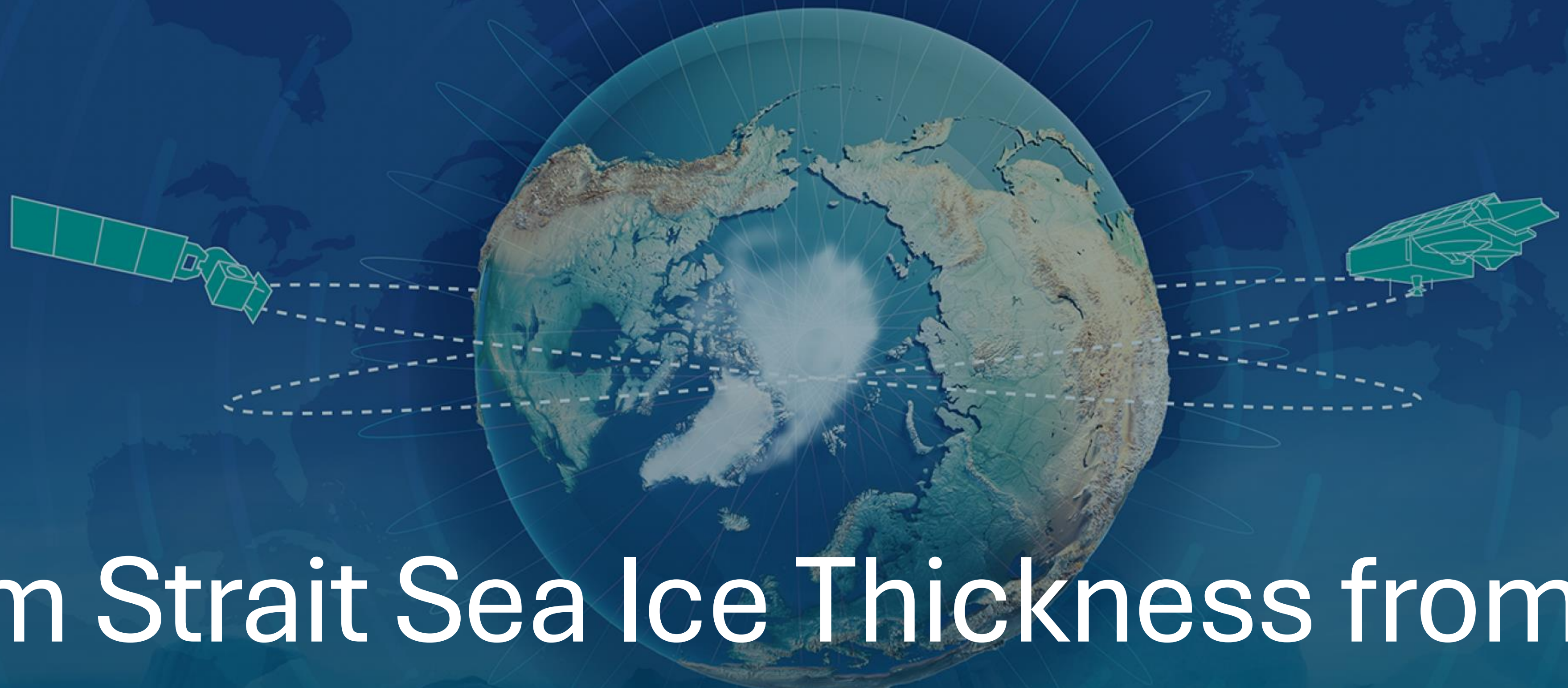


Fram Strait Sea Ice Thickness from ICESat-2 and CryoSat-2 Freeboards

Christopher J. Picard and Waleed Abdalati

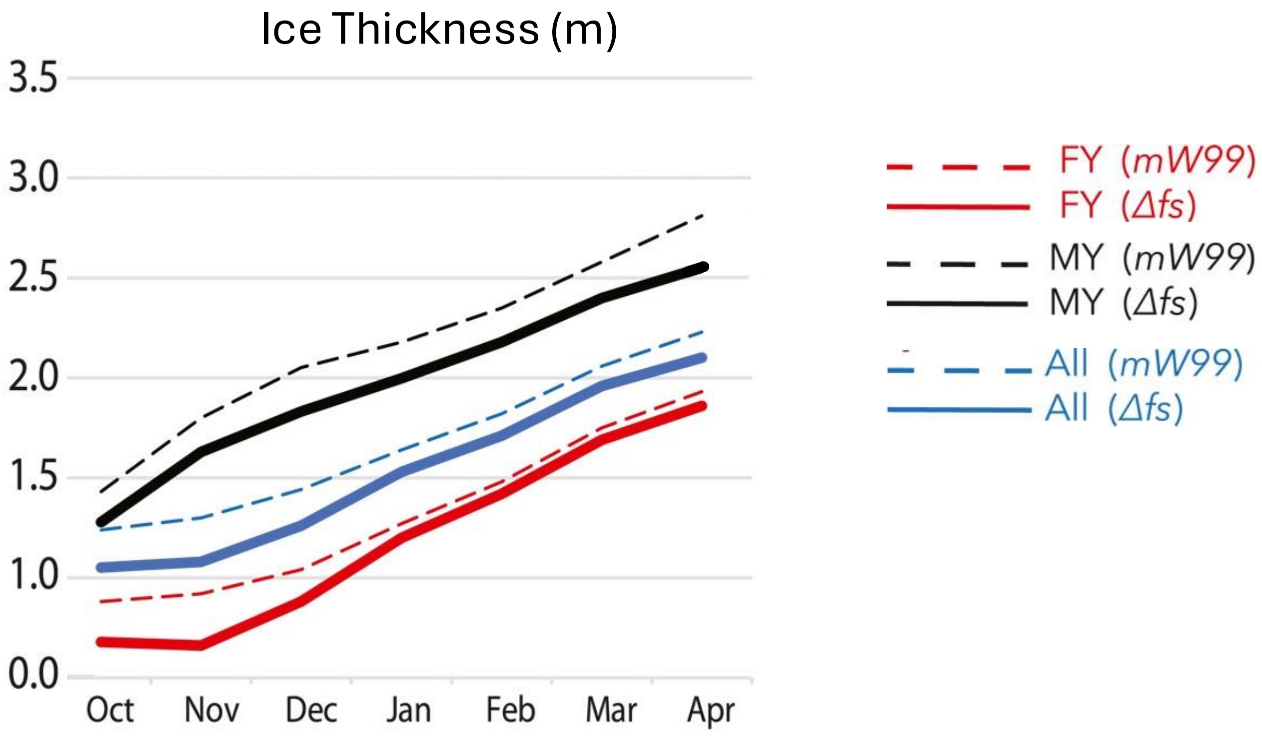
Cooperative Institute for Research in Environmental Science

Department of Geography, University of Colorado Boulder

Sea ice thickness estimates limited by uncertainties in snow depth

Overestimating snow depths can inflate SIT values

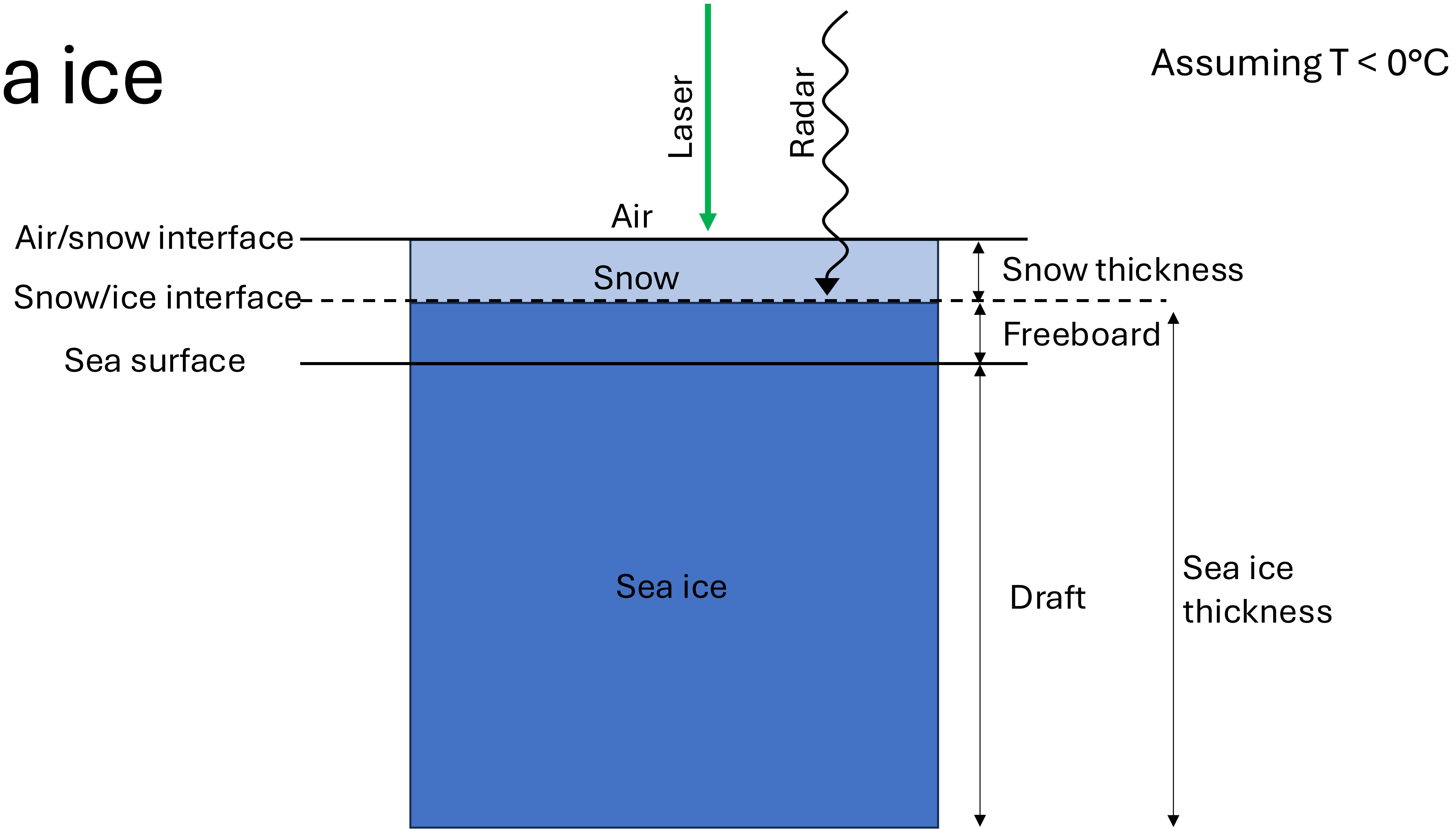
SIT with satellite-derived snow depth (Δf_s) are smaller than with climatological snow depth (mW99)



2020-21

Kacimi and Kwok (2022)

Sea ice


Laser
Radar
Assuming T < 0°C
Air
Air/snow interface
Snow
Snow thickness
Snow/ice interface
Freeboard
Sea surface
Sea ice
Draft
Sea ice thickness

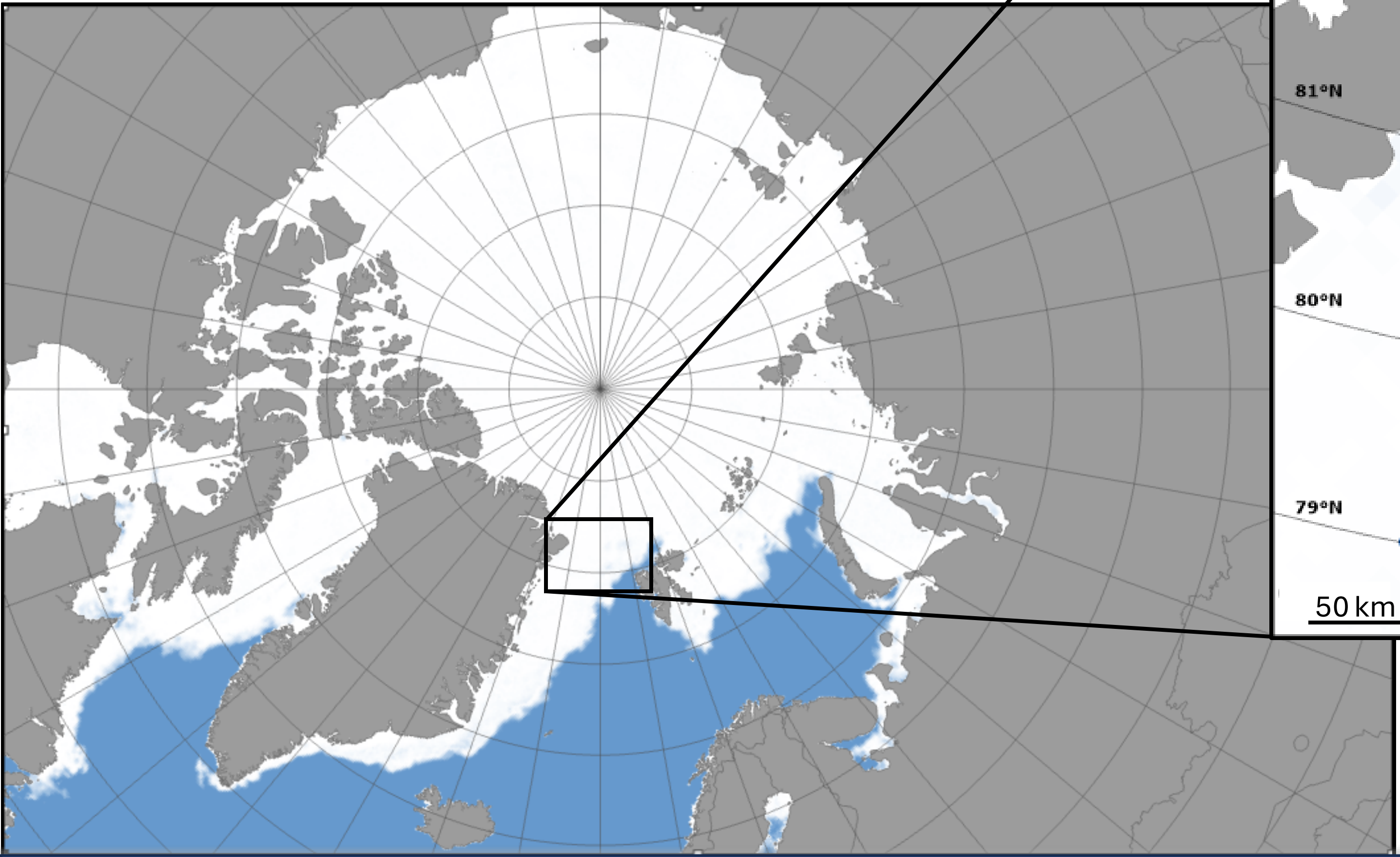
Research Objectives

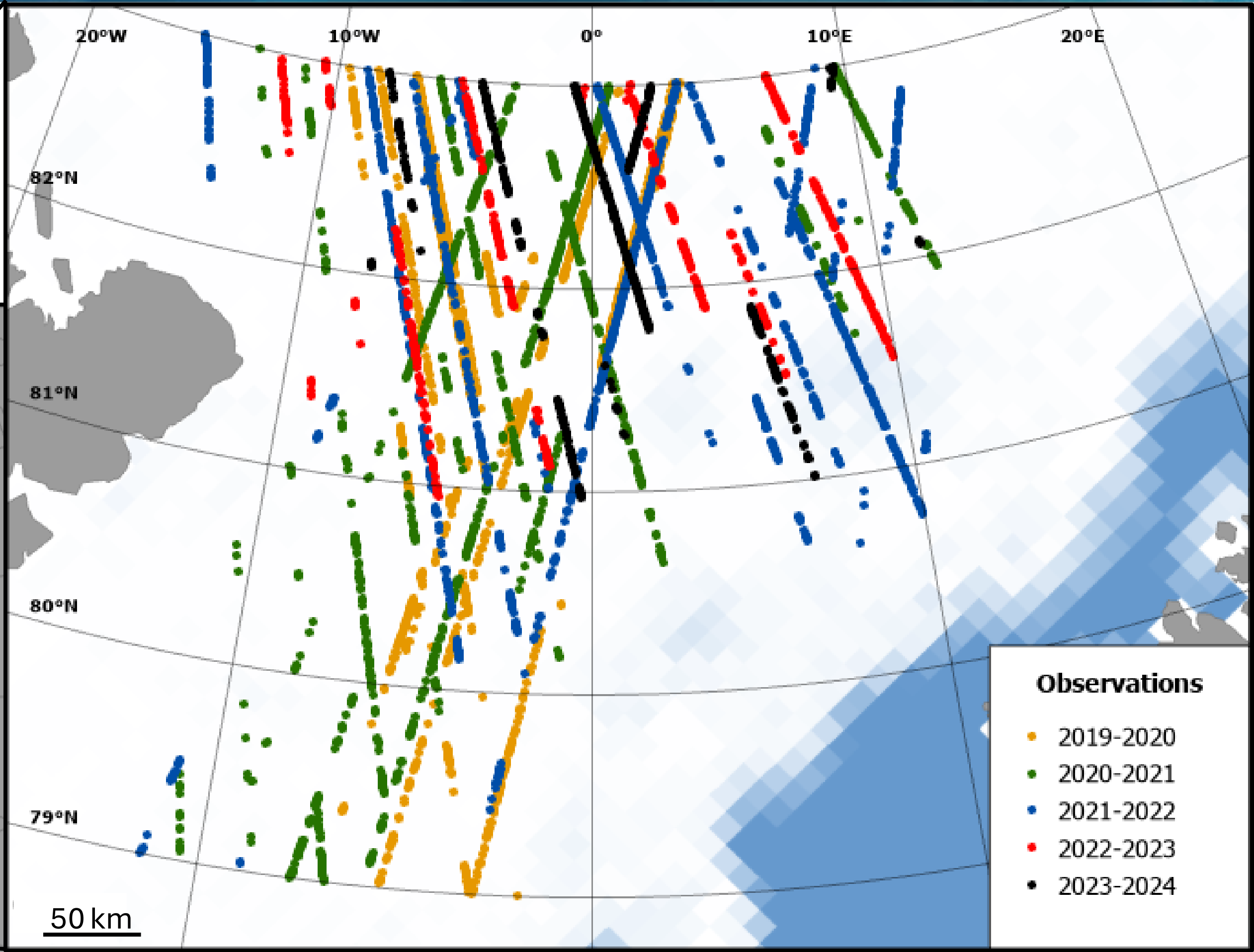
Short term: Constrain wintertime sea ice thickness estimates through the Fram Strait by estimating snow depth from ICESat-2 and CryoSat-2 altimeters.

Long term: Understand the volume of sea ice and freshwater being transported from the Arctic to the Subpolar North Atlantic.

Study domain

Spatial: -17° W to 12° E, 79° N to 83° N
Temporal: October – April, 2019 – 2024





Data

Field	Data	Reference
Lidar freeboards*	ICESat-2 ATL10, V6	Kwok et al. (2023)
Radar freeboards*	CryoSat-2 L2E	European Space Agency
Snow density	MOSAiC Snow Density	Macfarlane et al. (2022)
Sea ice age (FYI vs. MYI)	OSI SAF Sea Ice Type	EUMETSAT; OSI SAF
Monthly NESOSIM snow depth	IS2SITMOGR4; NESOSIM	Petty et al. (2023)
Snow depth	Modified Warren Snow Climatology	Warren et al. (1999)

*Near-coincident IS2/CS2 observations from cs2eo.org

Sea ice thickness derived from laser and radar altimetry

Radar: $$h_i(h_{fi}, h_{fs}) = \left(\frac{\rho_w}{\rho_w - \rho_i}\right) h_{fi} + \left(\frac{\rho_s}{\rho_w - \rho_i}\right) h_{fs}$$

Laser: $$h_i(h_f, h_{fs}) = \left(\frac{\rho_w}{\rho_w - \rho_i}\right) h_f + \left(\frac{\rho_s - \rho_w}{\rho_w - \rho_i}\right) h_{fs}$$

Variables

h_i → sea ice thickness
ρ_w → density of water
ρ_i → density of ice
ρ_s → density of snow

h_{fs} → snow depth
h_f → total freeboard
h_{fi} → ice-only freeboard

Sea ice thickness derived from laser and radar altimetry

Radar: $$h_i(h_{fi}, h_{fs}) = \left(\frac{\rho_w}{\rho_w - \rho_i}\right) \boxed{\boldsymbol{h_{fi}}} + \left(\frac{\rho_s}{\rho_w - \rho_i}\right) h_{fs}$$

Laser: $$h_i(h_f, h_{fs}) = \left(\frac{\rho_w}{\rho_w - \rho_i}\right) \boxed{\boldsymbol{h_f}} + \left(\frac{\rho_s - \boxed{\boldsymbol{\rho_w}}}{\rho_w - \rho_i}\right) h_{fs}$$

Variables

h_i → sea ice thickness
ρ_w → density of water
ρ_i → density of ice
ρ_s → density of snow

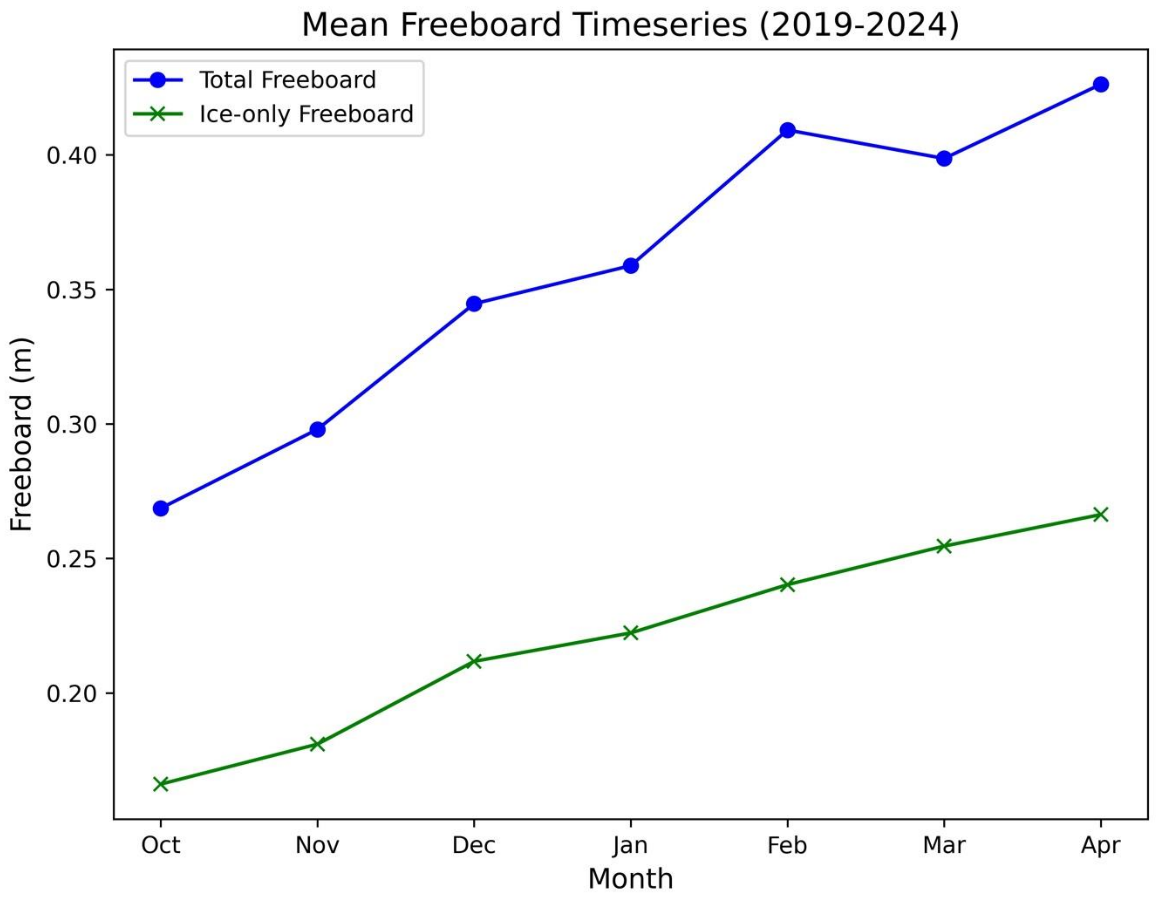
h_{fs} → snow depth
h_f → total freeboard
h_{fi} → ice-only freeboard

Freeboard comparison

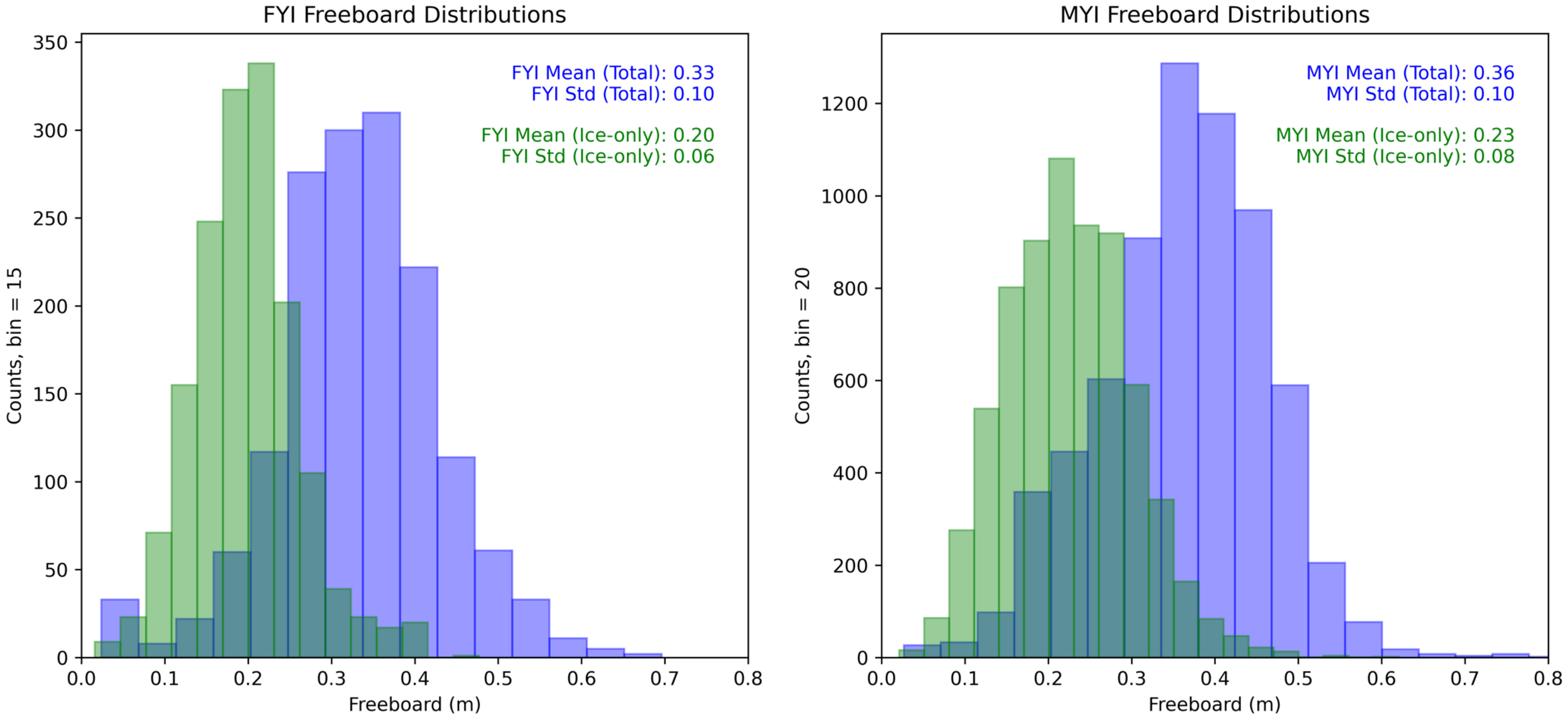
Total freeboard larger than ice-only freeboard

Both show similar seasonal growth

Mean and standard deviation of all observations:
Total freeboard = 0.36m, 0.10m
Ice-only freeboard = 0.22m, 0.07m



Freeboard distribution by ice age



Snow depth: freeboard-derived, climatological, and modeled

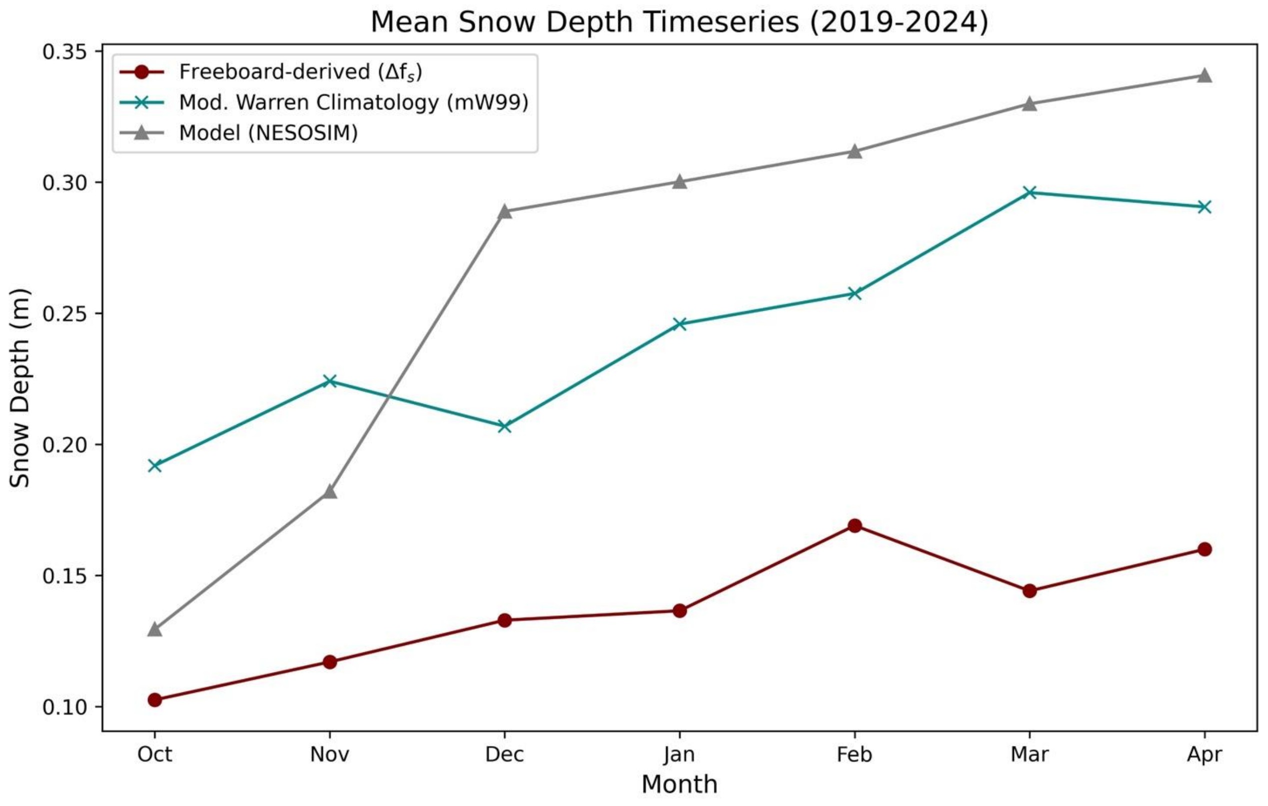
Freeboard-derived snow depths smaller than climatological and modeled snow depths

Mean and standard deviation of all observations:

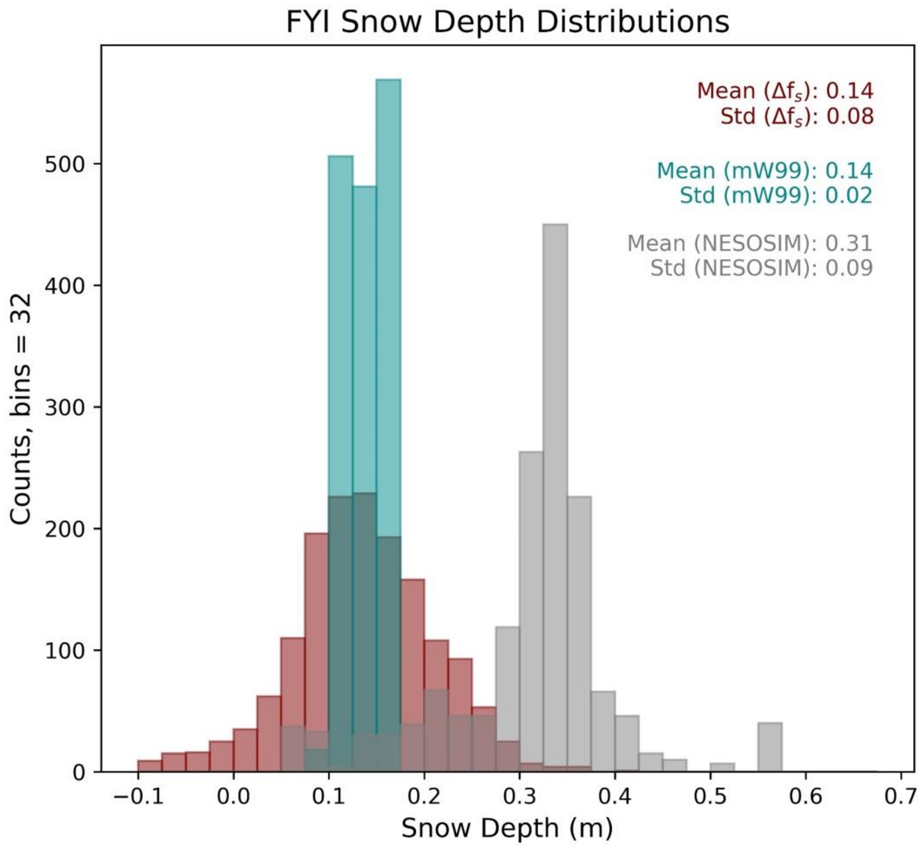
Δf_s = 0.14m, 0.08m

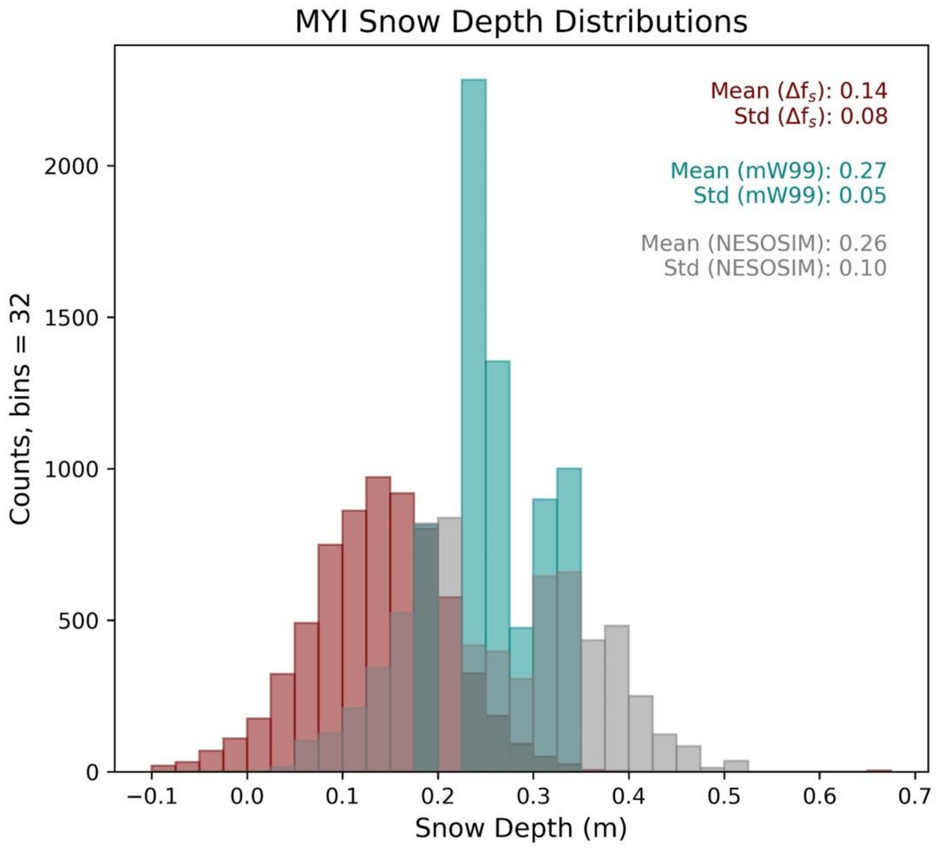
mW99 = 0.25m, 0.06m

NESOSIM = 0.27m, 0.10m



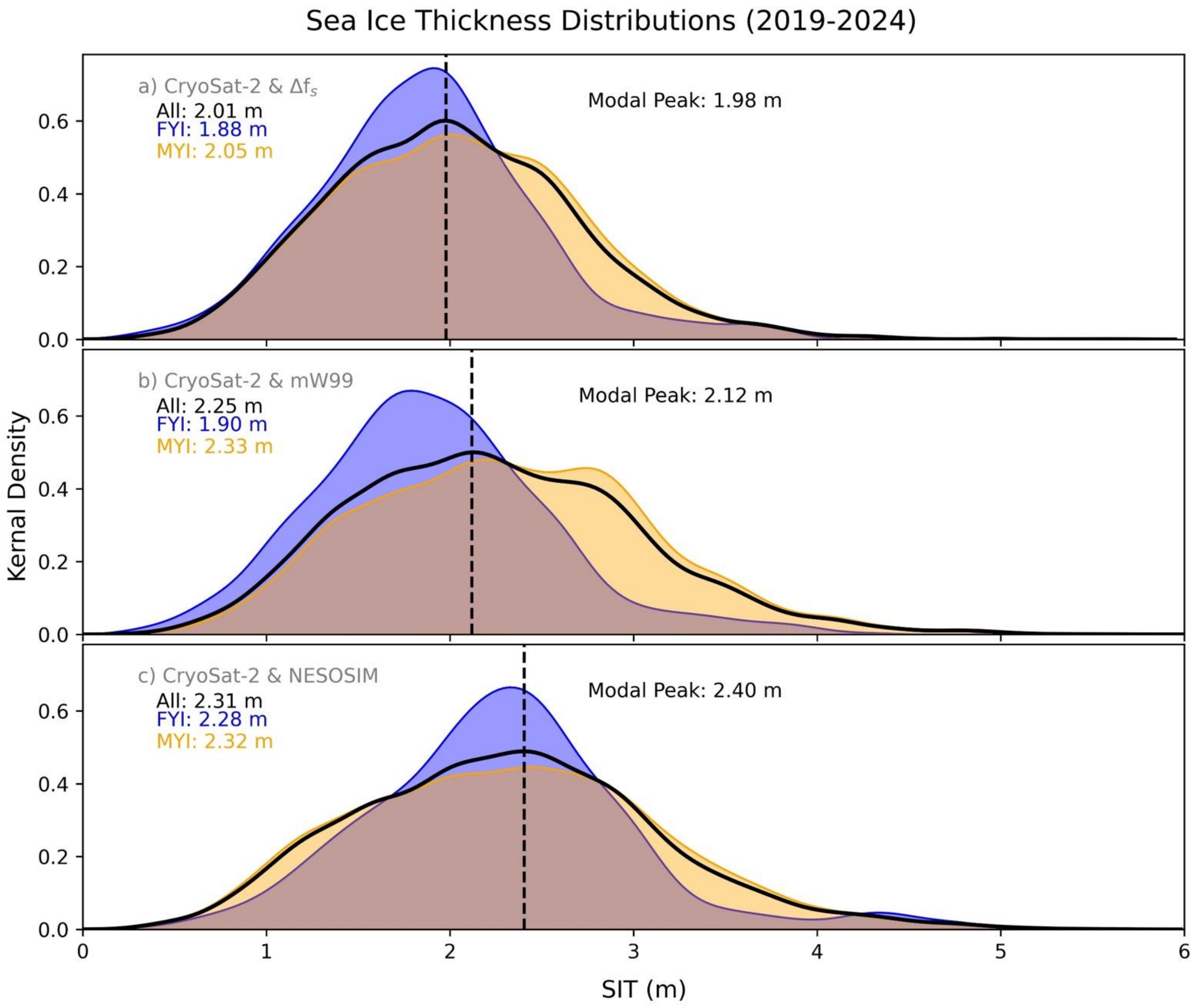
Snow depths by sea ice age



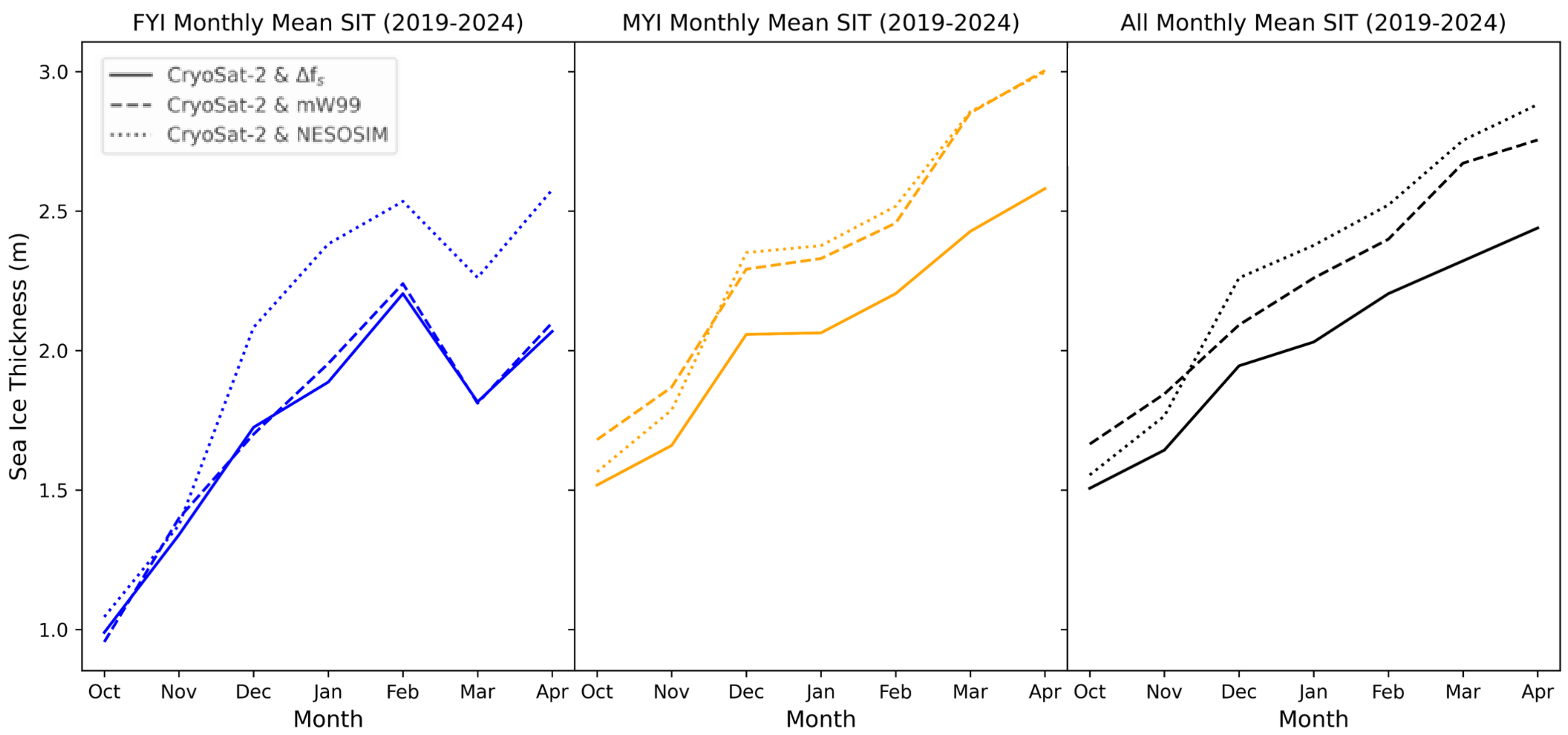


Sea ice thickness comparison

Mean SIT calculated with mW99 and NESOSIM are 7.1% and 21.2% larger, respectively, than SIT calculated with Δf_s



Mean seasonal evolution of SIT



Conclusions and Future Work

- Mean Fram Strait **total freeboard**, **snow depth**, and **SIT** over 2019-2024 are **0.36m**, **0.14m**, and **2.01m**, respectively
- Freeboard-derived snow depths are lower than mW99 and NESOSIM
- The age-thickness relationship observed in the Arctic holds in the Fram Strait
- Future work includes:
  - Comparison with ULS thickness data, once available
  - Examining interannual variability of SIT and its causes
  - Calculating sea ice volume (SIV) flux through the Fram Strait
  - Estimating freshwater transport with SIV estimates