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

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Research Questions

1. Can we accurately constrain sea ice thickness (SIT) using Cryo2Ice within Fram Strait?
2. Which CryoSat-2 (CS2) product, when combined with ICESat-2 (IS2), yields the most accurate SITs?

Fram Strait

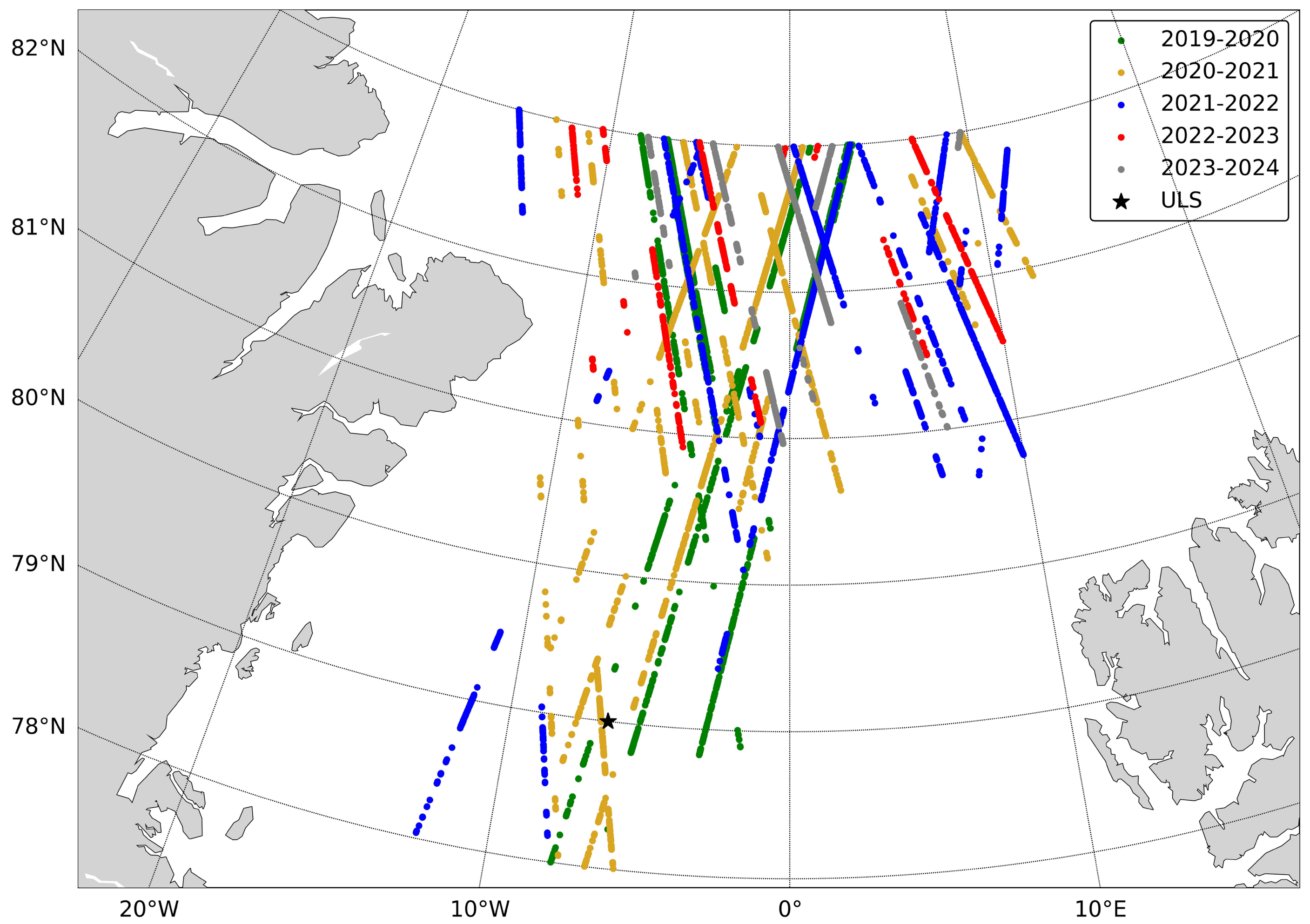


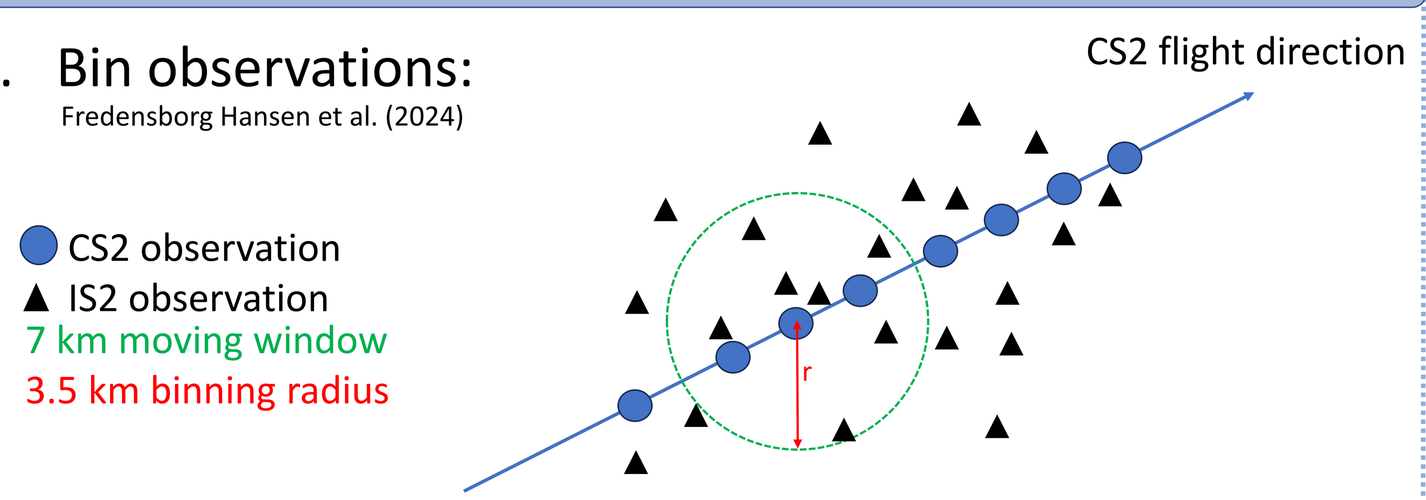
Fig. 1: Cryo2Ice observations within Fram Strait from November to April, 2019-2024. Observations are colored by winter season, and the upward looking sonar (ULS) mooring is shown by the black star.

Data

Product	Parameter	Citation
IS2 ATL10	Lidar freeboard	Kwok et al. (2023)
CS2 ESA-E Level 2	Radar freeboard	ESA (2019)
CS2 AWI Level 2	Radar freeboard	Hendricks et al. (2024)
CS2 LARM Level 2	Radar freeboard	Landy et al. (2019)
Upward-looking sonar	Sea ice thickness	Dmitry Divine, Svetlana Divina
Modified Warren Snow Climatology (mW99)	Snow depth	Warren et al. (1999)
SnowModel-LG (SMLG)	Snow depth	Liston et al. (2020)
NASA Eulerian Snow on Sea Ice Model (NESOSIM)	Snow depth	Petty et al. (2018)
MOSAiC Snow Density	Snow density	Macfarlane et al. (2022)
EUMETSAT OSI SAF Global Sea Ice Type	Sea ice age	EUMETSAT OSI SAF (2021)

Methods

1. Bin observations:
Fredensborg Hansen et al. (2024)



2. Estimate snow depth: $$\Delta fs = \frac{h_f^{IS2} - h_{fi}^{CS2}}{\eta_s}$$

3. Correct for the ice-only freeboard: $$h_{fi} = h_{fi}^{CS2} + \Delta fs\,(\eta_s - 1)$$

4. Estimate SIT: $$SIT = \left(\frac{\rho_w}{\rho_w - \rho_i}\right) h_{fi} + \left(\frac{\rho_s}{\rho_w - \rho_i}\right) \Delta fs$$

Freeboard, Snow Depth, and Sea Ice Thickness

Freeboard

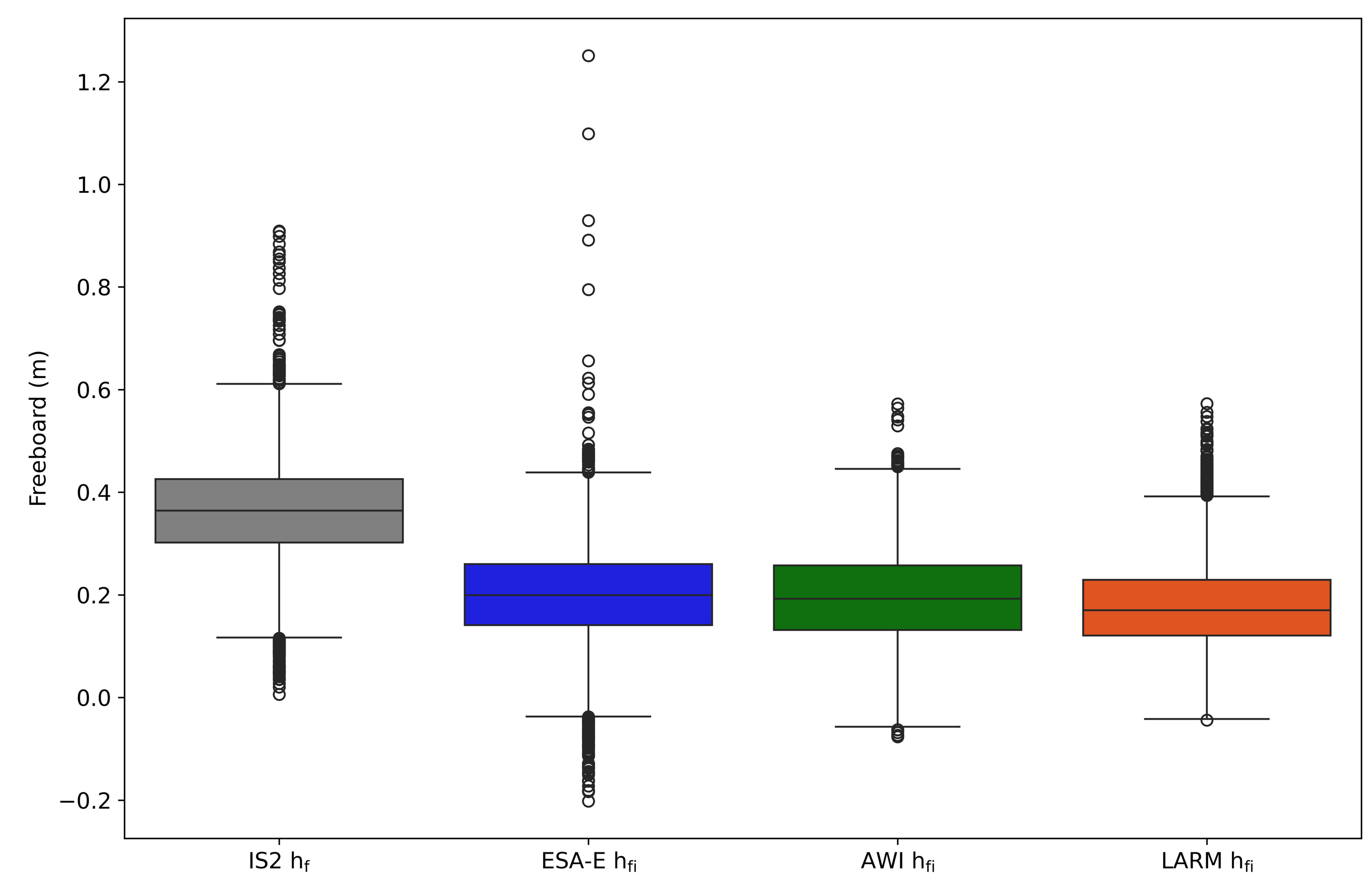


Fig. 2: Boxplots of total freeboard (h_f) for IS2 and the ice-only freeboard (h_{fi}) for the ESA-E, AWI, and LARM products.

Snow Depth

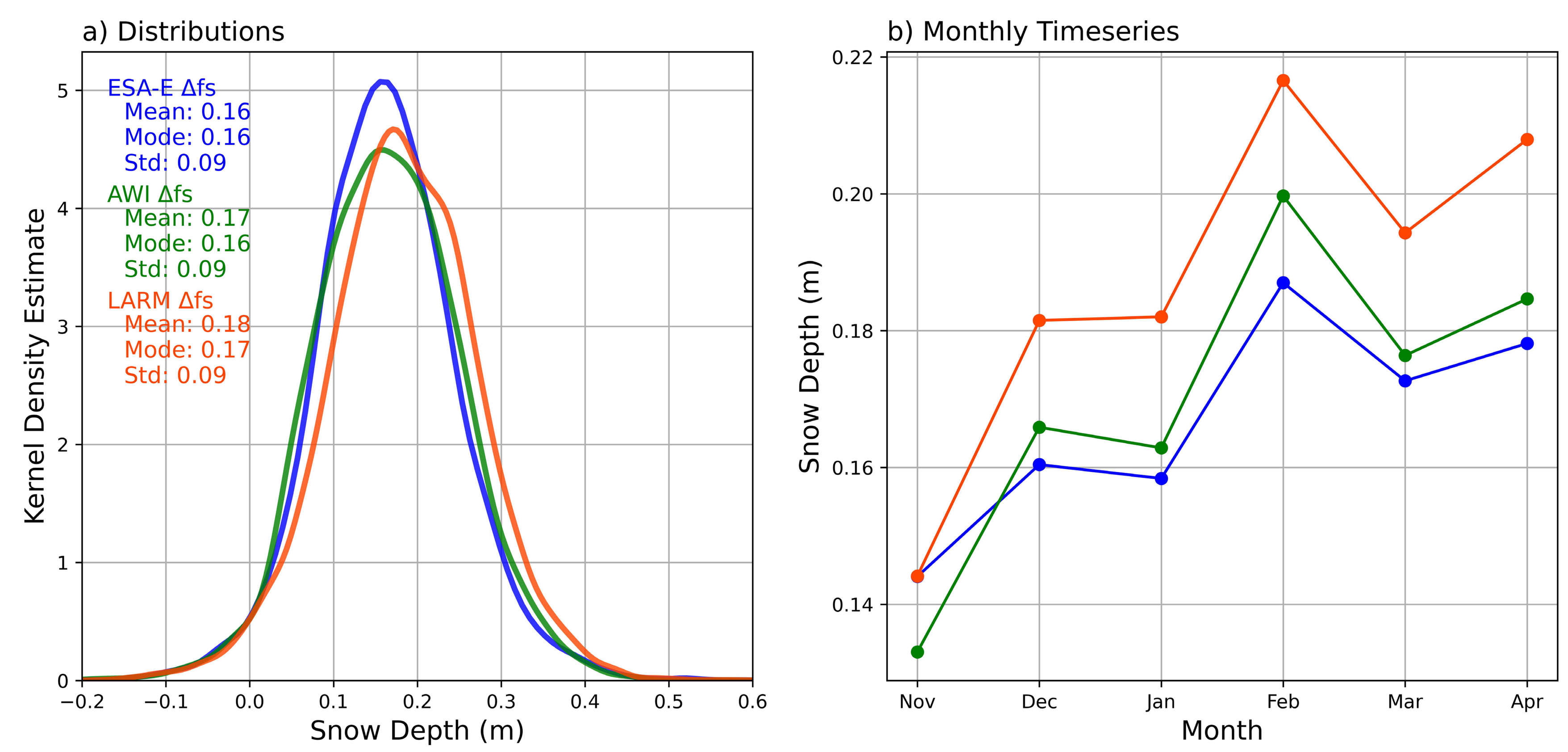


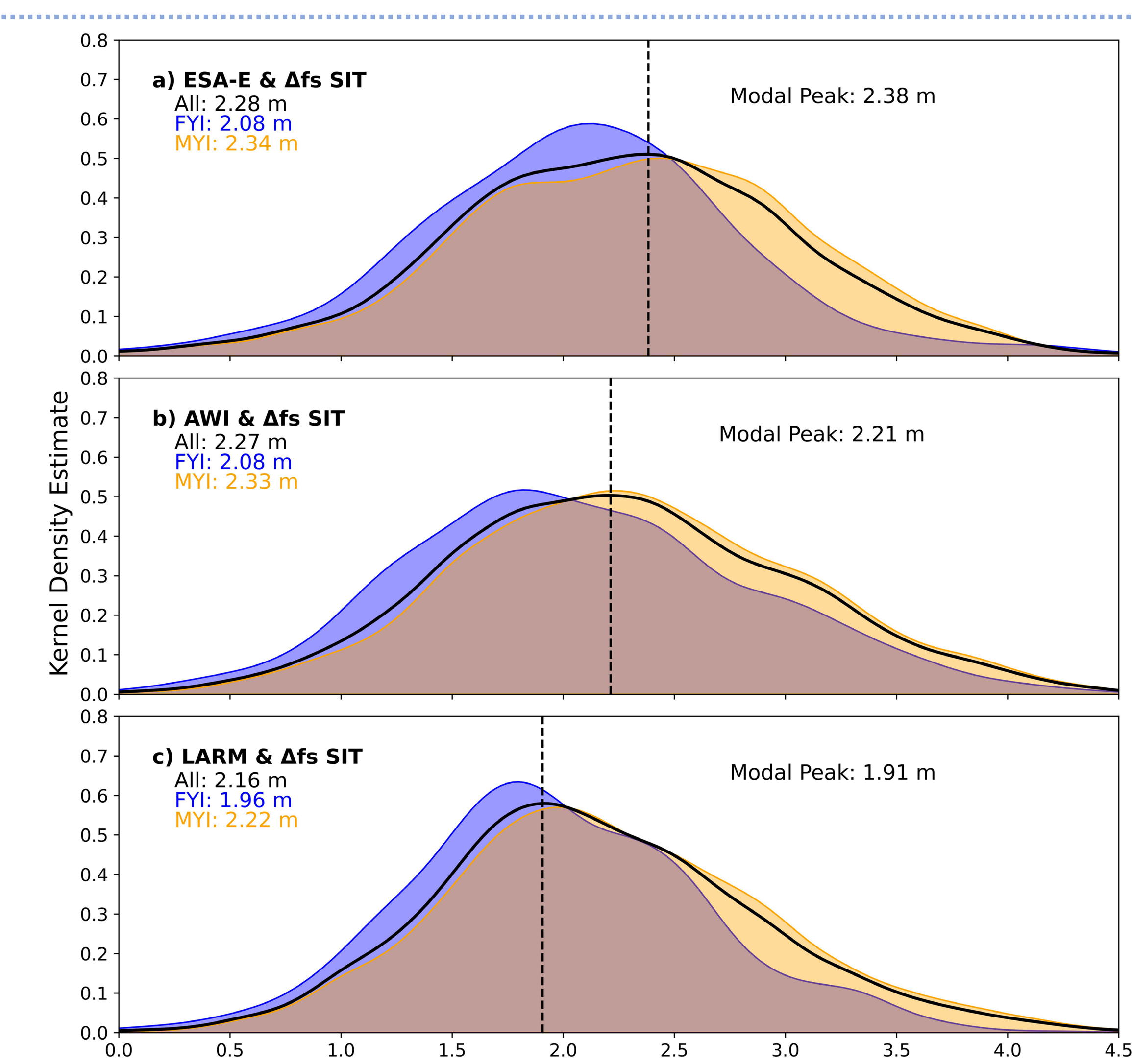
Fig. 3: Plots of (a) kernel density estimates and (b) monthly timeseries of snow depth from November to April for each CS2 product over 2019-2024.

Sea Ice Thickness

Fig. 4: Kernel density estimates (2019-2024) for:
a) ESA-E & Δfs SIT,
b) AWI & Δfs SIT, and
c) LARM & Δfs SIT.

Mean SITs are provided for all ice (black), first-year ice (FYI), and multi-year ice (MYI) in the top left of each panel.

The dashed lines correspond to the modal peaks for all ice.



Key Findings

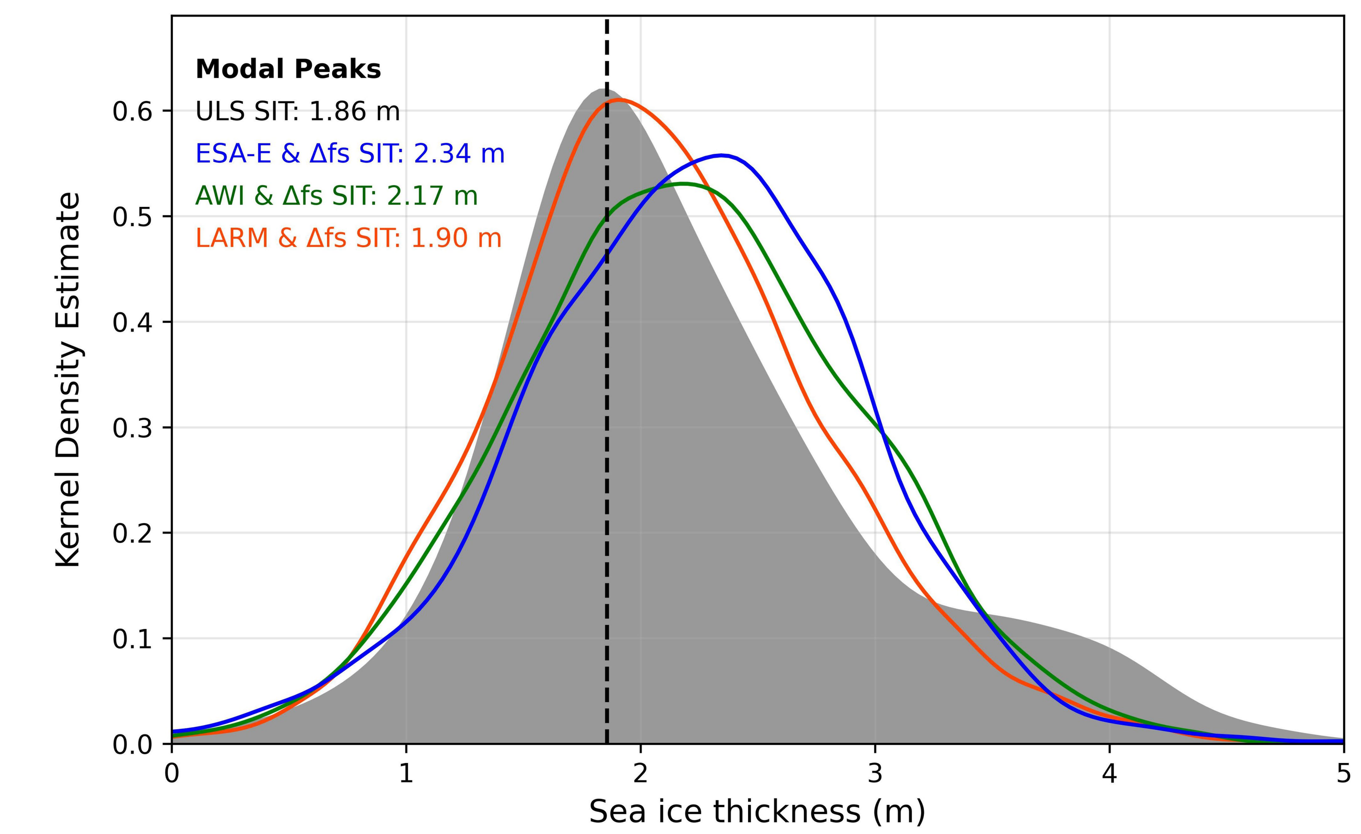


Fig. 5: Kernel density estimates of daily mean SIT for ULS and total Cryo2Ice SIT distributions using ESA-E, AWI, and LARM over 2020-2022. The shaded region is the ULS distribution used for validation, and the dashed line corresponds to its modal peak.

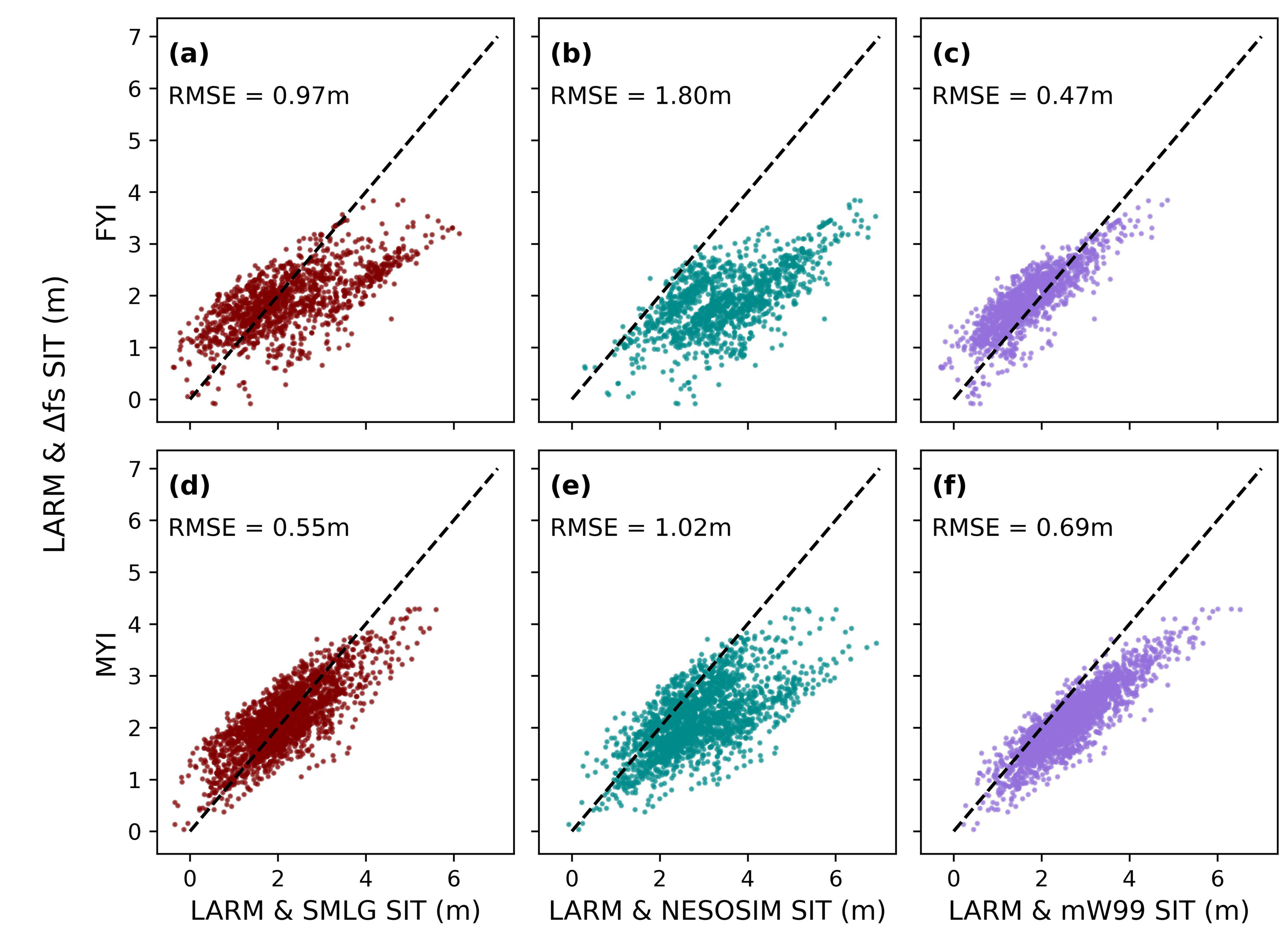


Fig. 6: Scatterplots comparing LARM & Δfs SITs with (a,d) LARM & SMLG SITs, (b,e) LARM & NESOSIM SITs, and (c,f) LARM and mW99 SITs over 2019-2021. The first row of plots (a-c) is for FYI and the second row (d-f) is for MYI. The dashed black lines represent 1:1 slopes.

Takeaways

- The optimal Cryo2Ice combination is IS2 with CS2 LARM
- SIT can be accurately constrained using Cryo2Ice within Fram Strait
    - Cryo2Ice distributions using IS2 and CS2 LARM agree closely with ULS
- Modeled and climatological snow depths lead to SIT overestimates
- ULS provides more continuous sampling than Cryo2Ice and remains the best method for estimating SIT within Fram Strait

References

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