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TAKING THE PULSE OF OUR PLANET FROM SPACE

EUMETSAT ECMWF EUSPA

Arctic summer sea ice thickness observations from CryoSat-2 and their potential for seasonal sea ice forecasting

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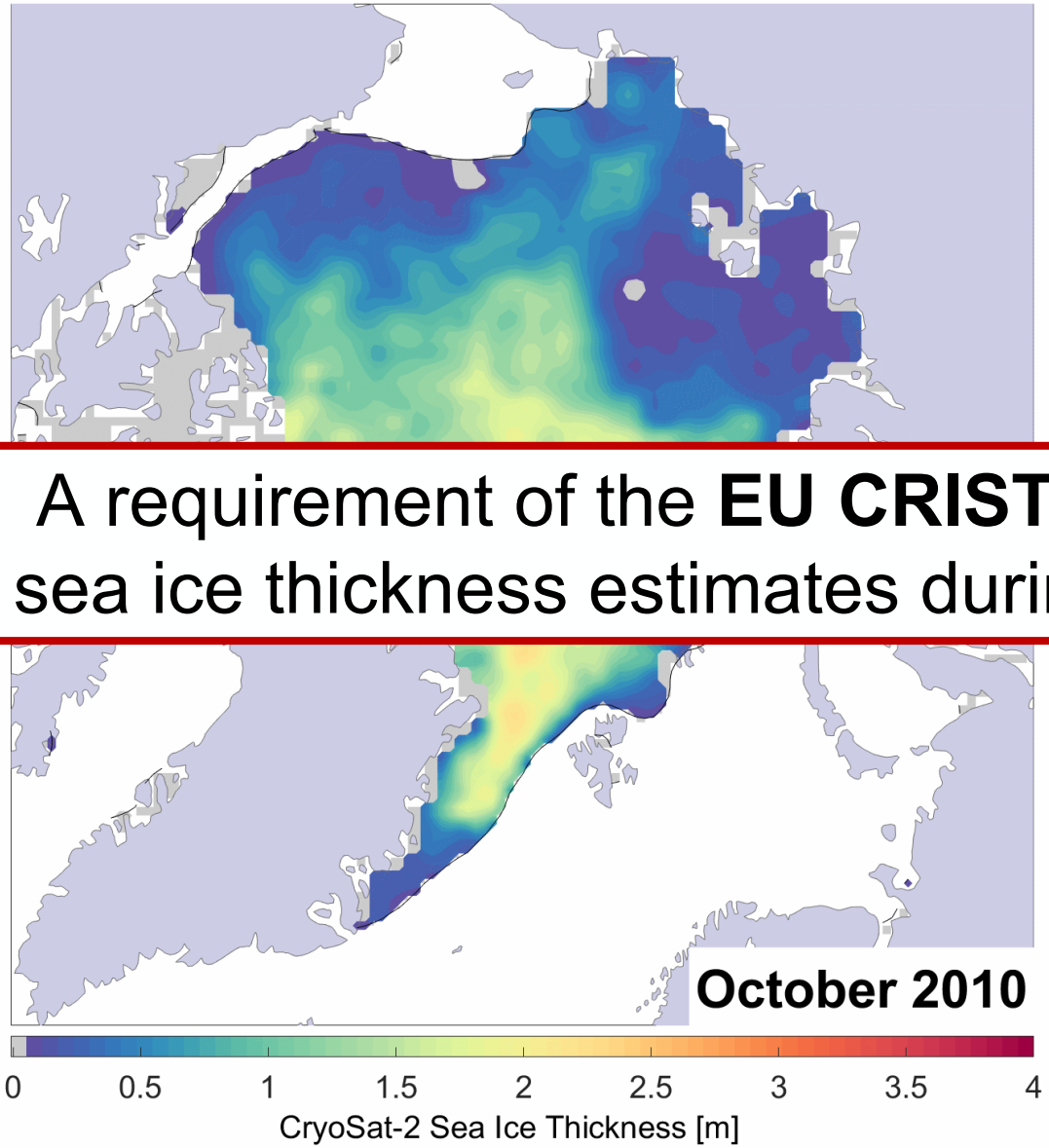
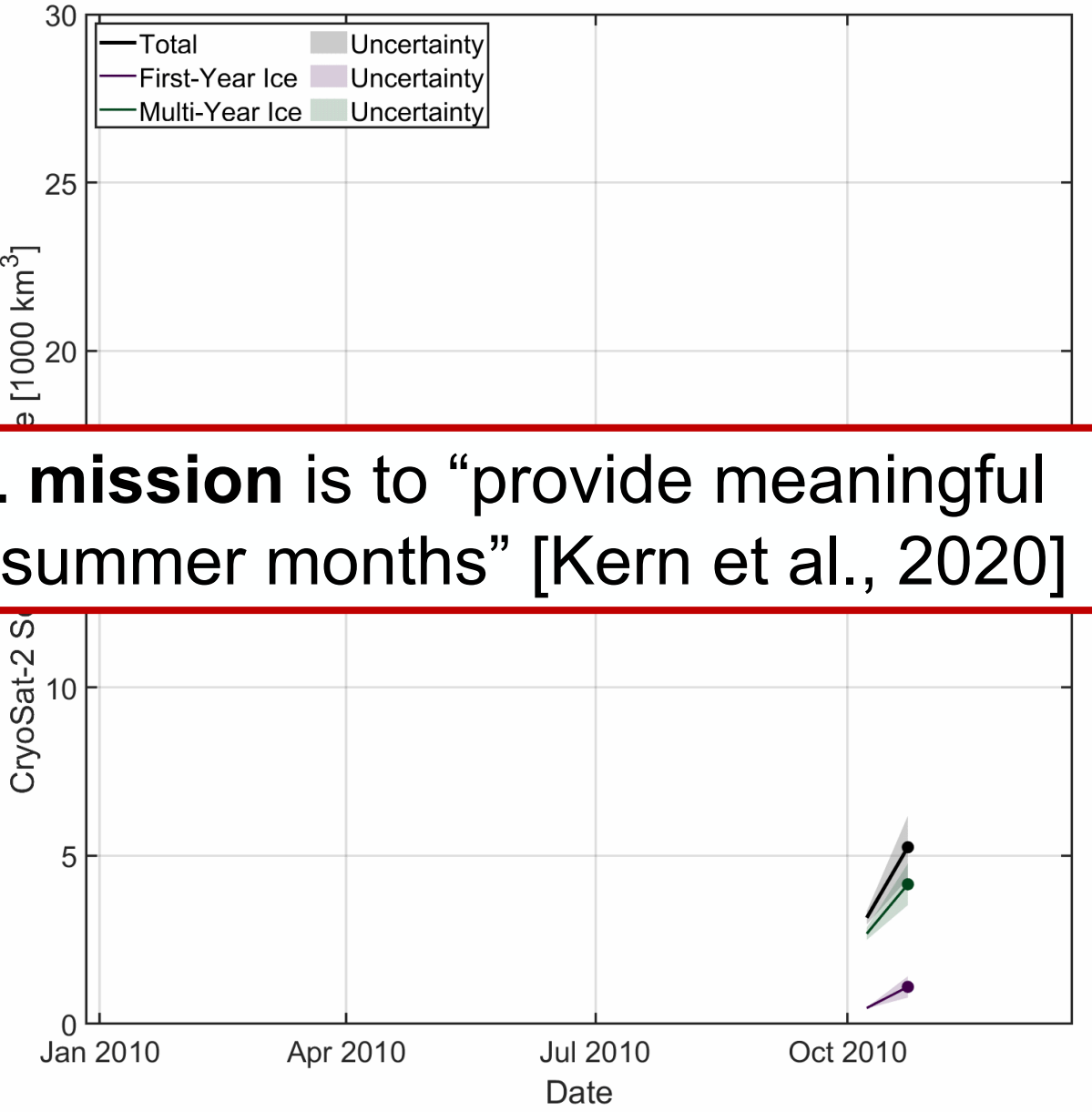
23/05/2022

Arctic-SummIT (Arctic Summer Sea Ice Thickness) 2018-2020

PRE-MELT (Preconditioning the trigger for rapid Arctic ice melt) 2019-2022

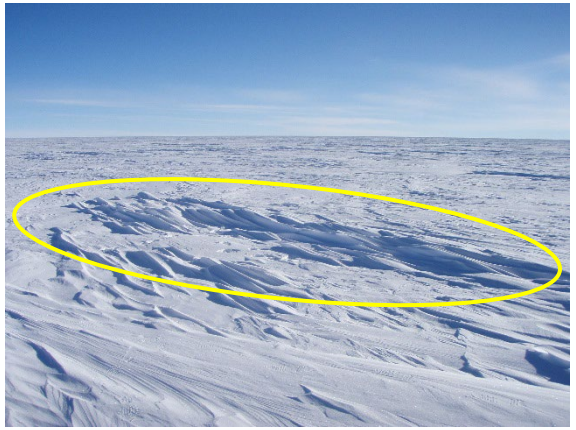
Centre for Integrated Remote Sensing and Forecasting for Arctic Operations 2021-





A requirement of the **EU CRISTAL mission** is to “provide meaningful sea ice thickness estimates during summer months” [Kern et al., 2020]

What happens in summer months...?



sci-news.com

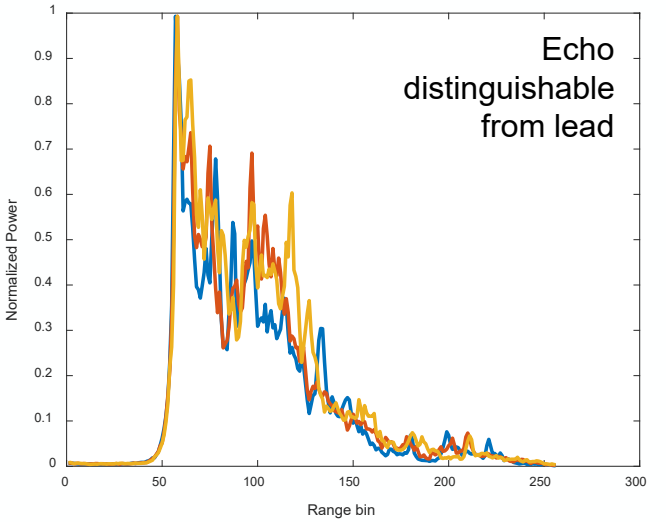
nikkophotography.blogspot.com

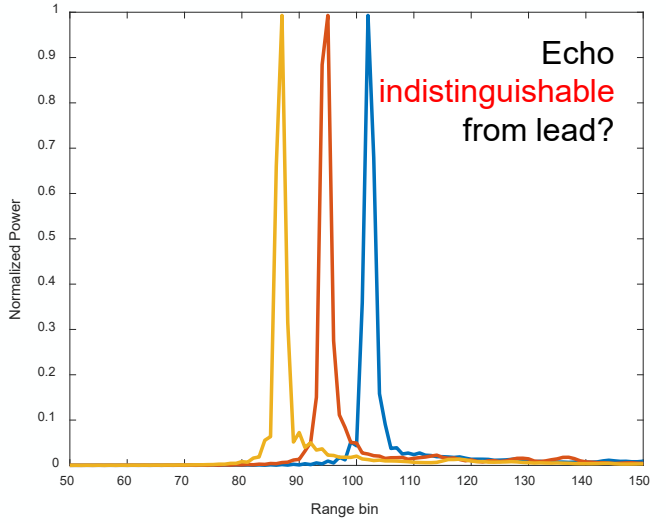
Diffuse Echo

Scattering contributions from across entire Cryosat-2 footprint

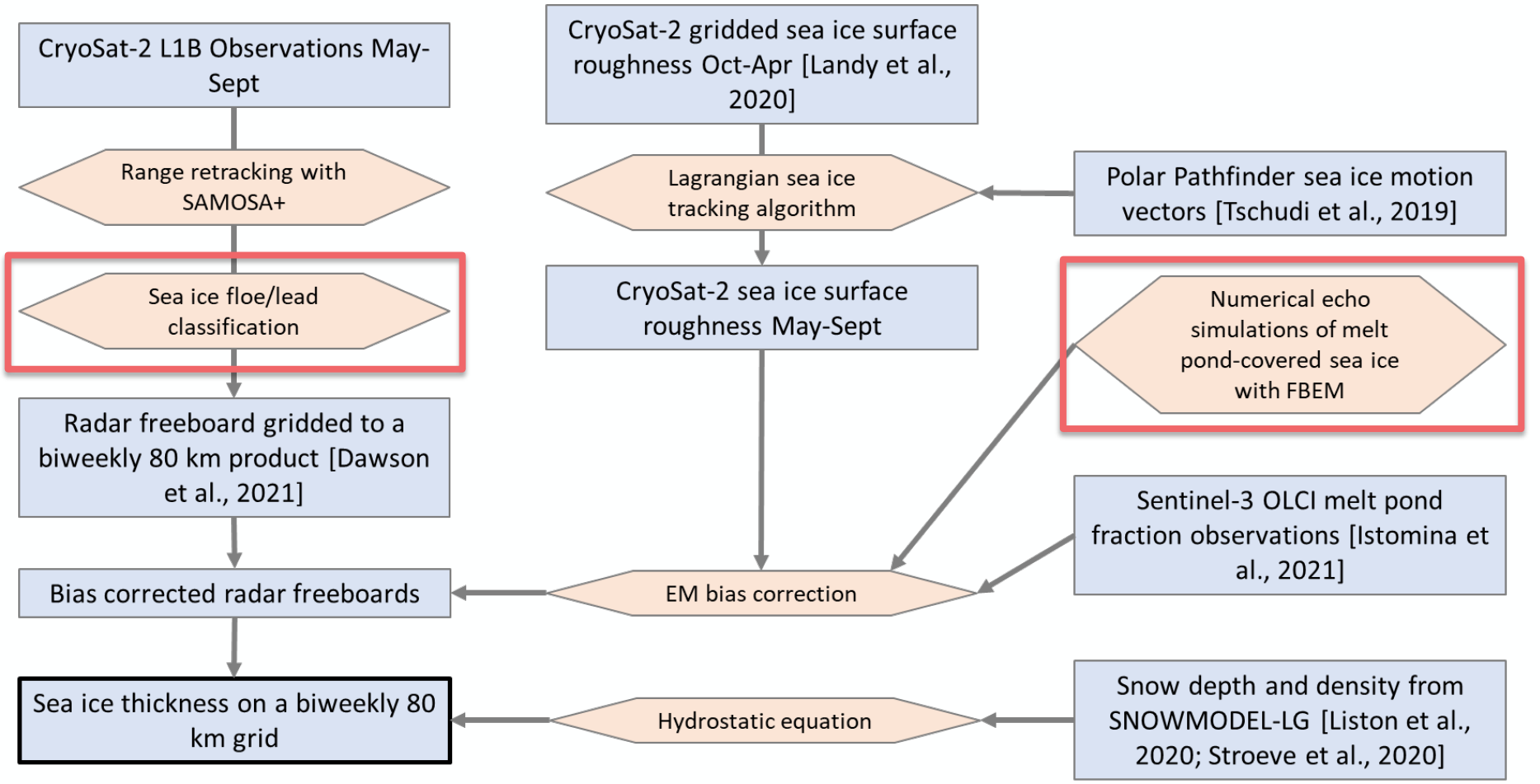
Specular Echo

Coherent reflection from melt pond closest to nadir location



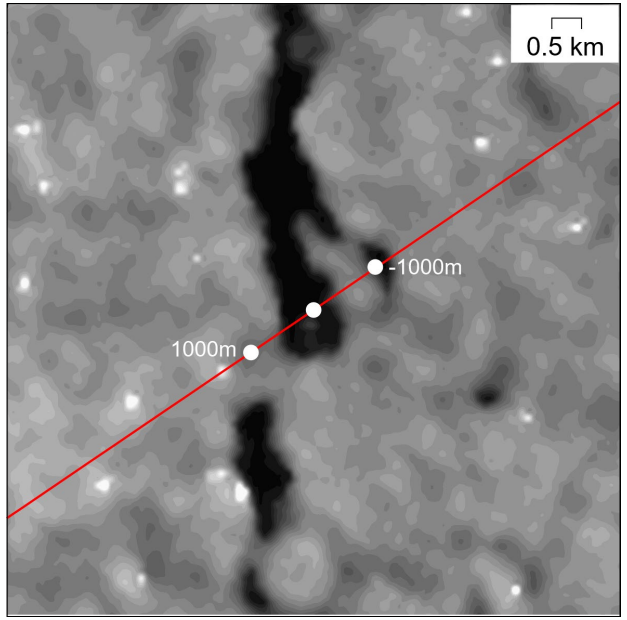


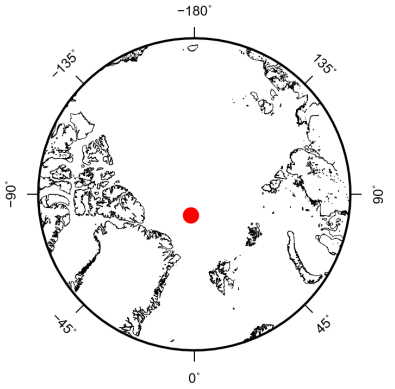
Summer sea ice thickness processing chain

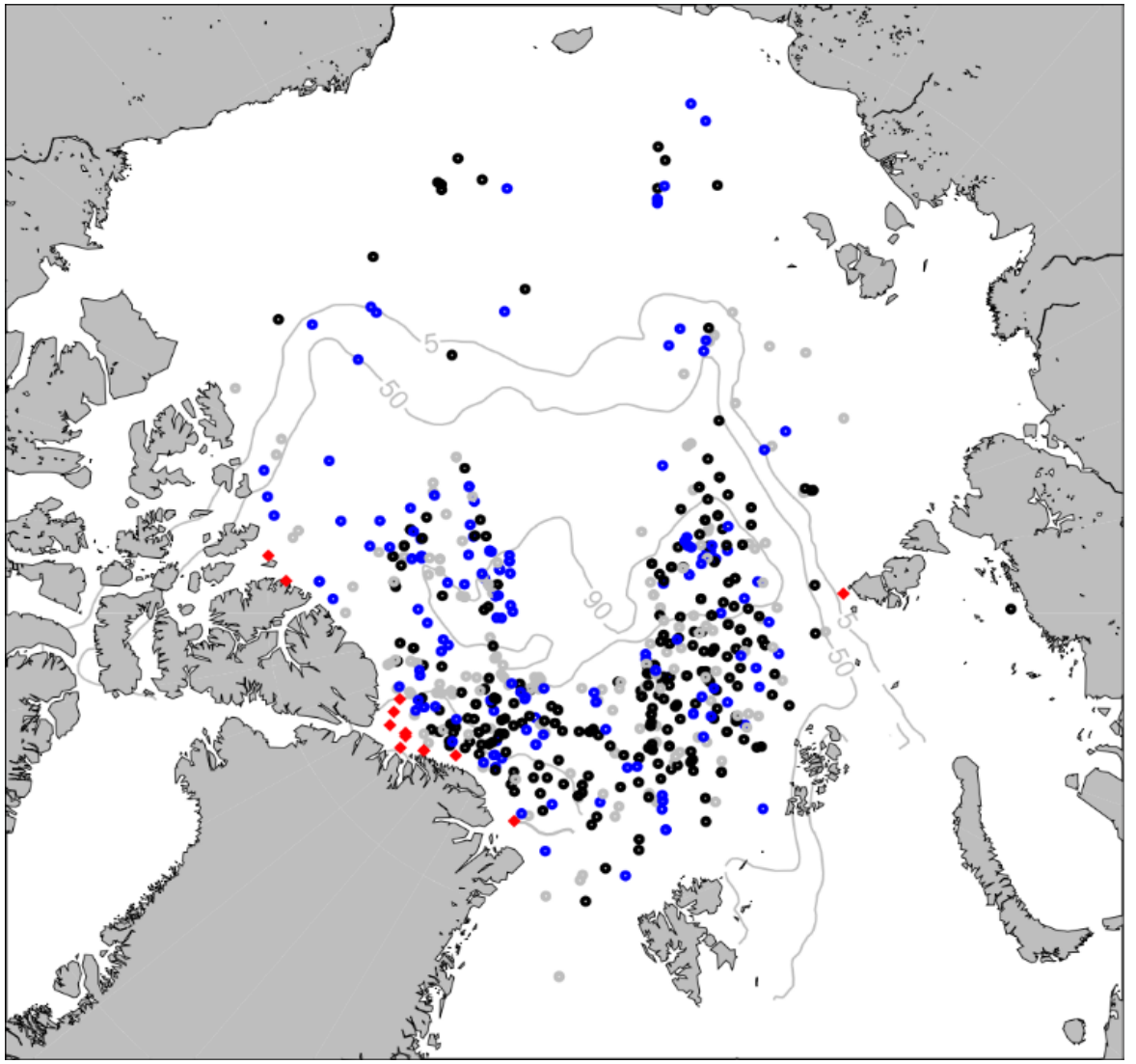


Summer sea ice altimetry: lead detection

Radarsat-2 coincident pass (within 15 min) of CS2



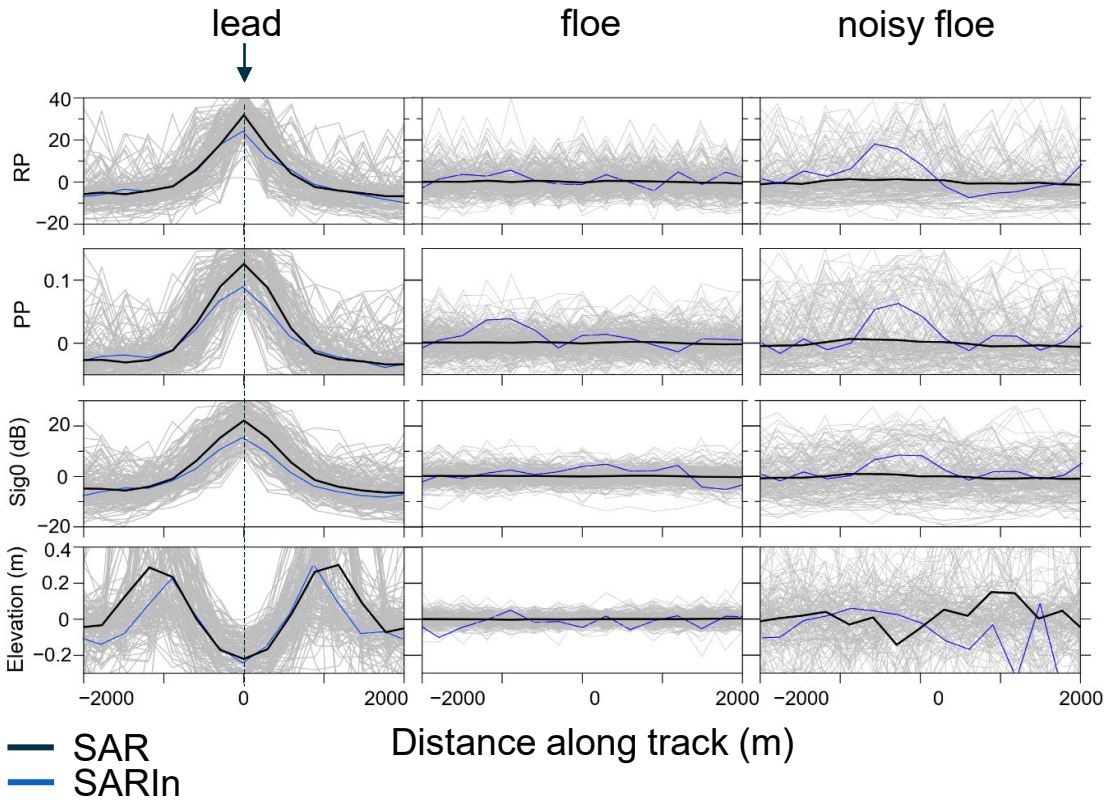




Dawson, G., Landy, J., Tsamados, M., Komarov, A.S., Howell, S., Heorton, H. and Krumpen, T., 2022. A 10-year record of Arctic summer sea ice freeboard from CryoSat-2. Remote Sensing of Environment, 268, p.112744.

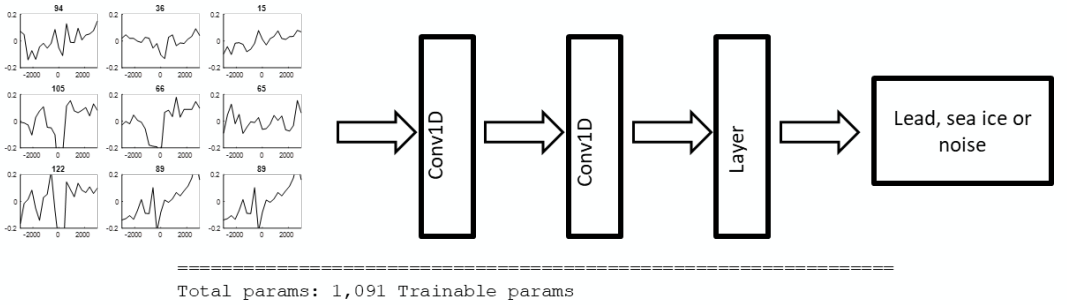
Summer sea ice altimetry: lead detection

Training data verified with coincident optical and SAR images

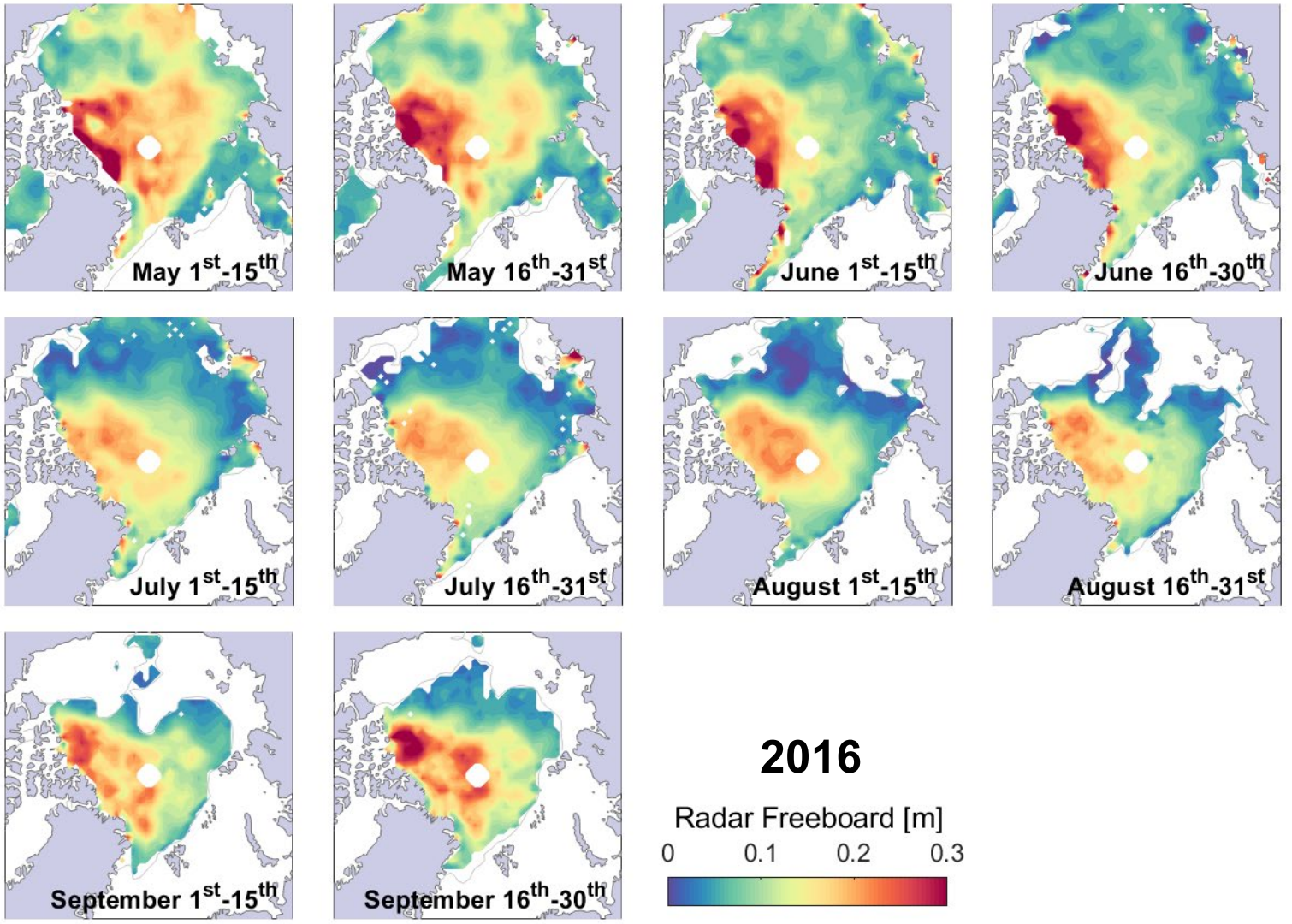


~170 coincident leads & ~400 floes used in the classification

- Tested **Decision tree** and **1D Convolutional neural networks** (CNN) for classification
- The 1D CNN performed better in testing (90% accurate and stable)



Dawson et al, RSE, 2022

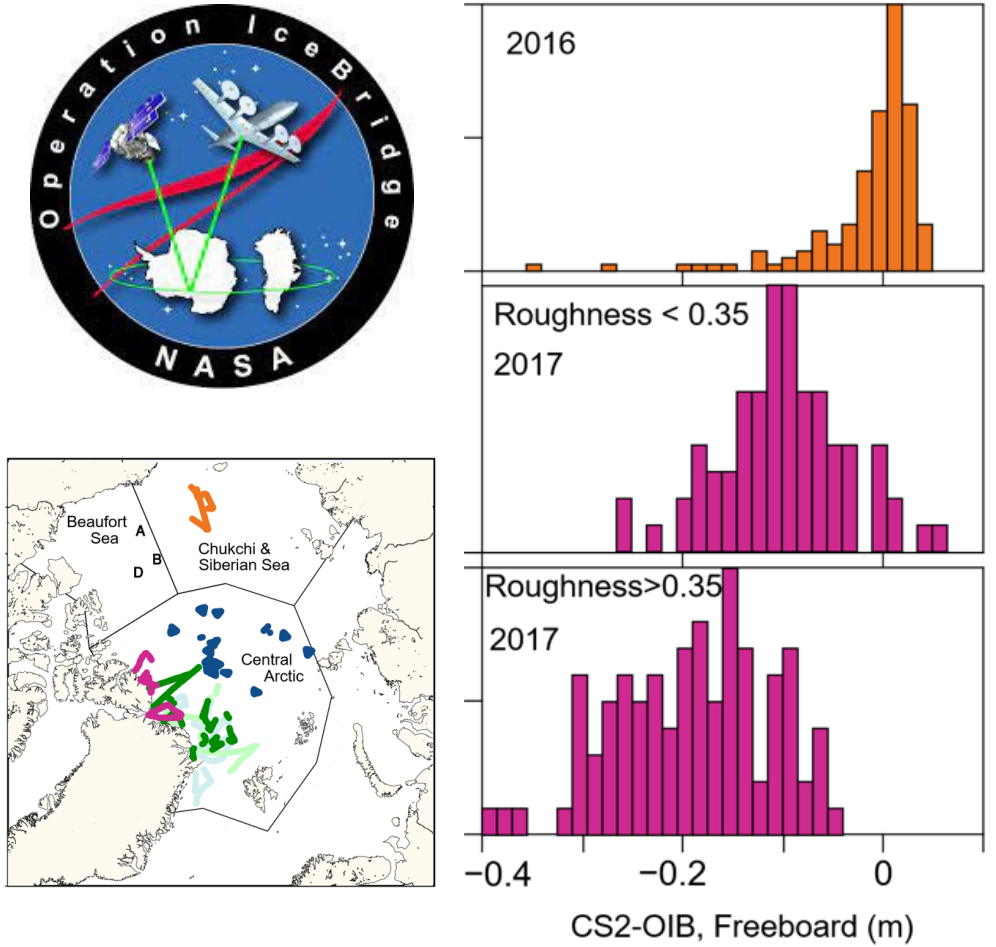


Radar freeboard = difference in elevation between ice floes and leads

Gridded using inverse distance-time weighting

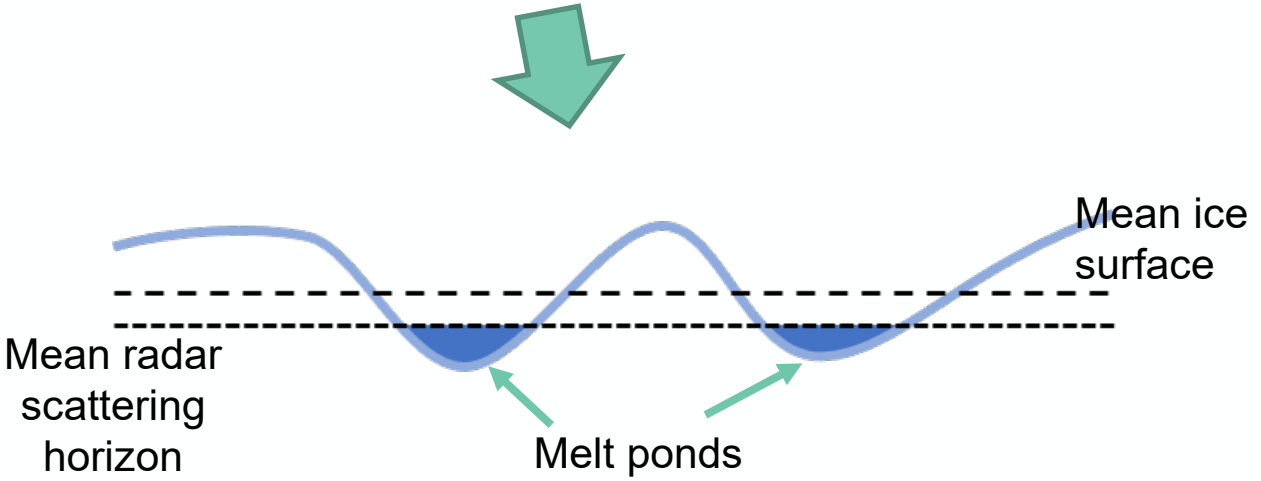
(80 km cell size, 15-day search window)

Summer sea ice altimetry: freeboard bias

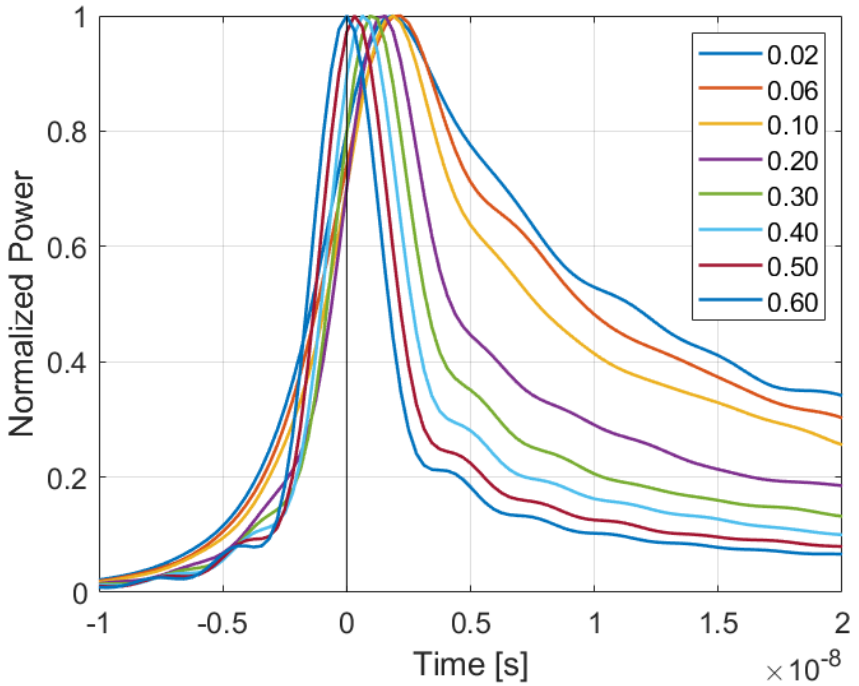


Thickest roughest sea ice freeboard underestimated:

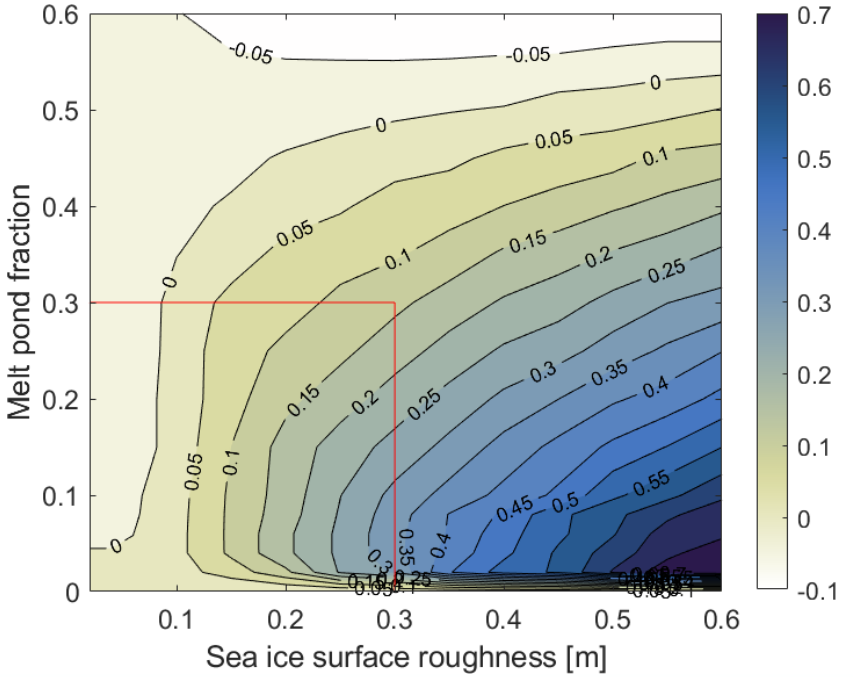
- Errors in the airborne data?
- Bias due to classification?
- EM bias due to melt ponds



Summer sea ice altimetry: freeboard bias correction



SAR altimeter echoes simulations of melt pond covered sea ice (σ = 20 cm) performed with the Facet-Based Echo Model (FBEM) [Landy et al., TGARS, 2019]

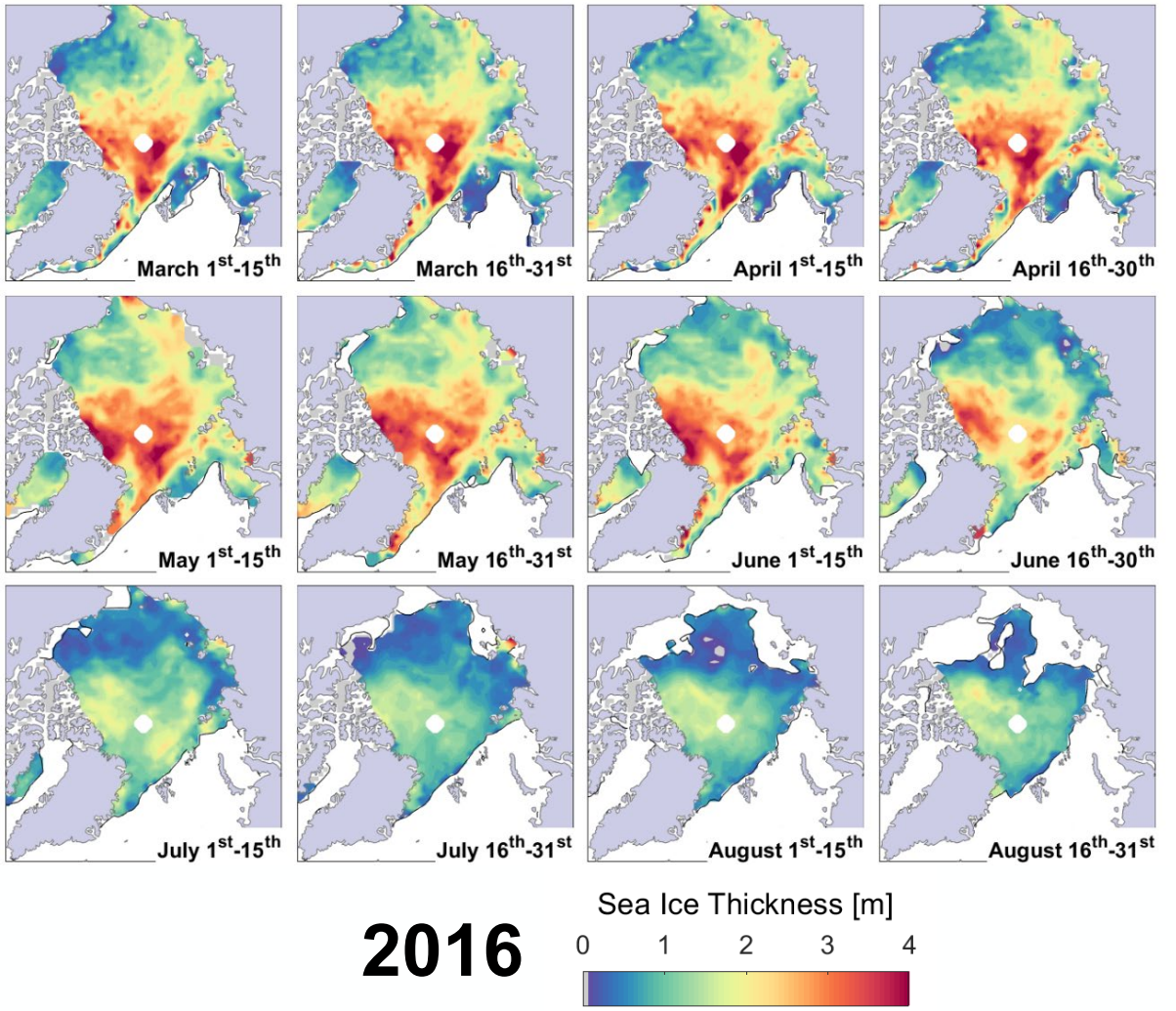


Theoretical bias correction [m] on the radar freeboard due to melt ponds, requiring auxiliary observations of melt pond fraction [Istomina et al., 2021] and sea ice surface roughness [Landy et al., 2020]

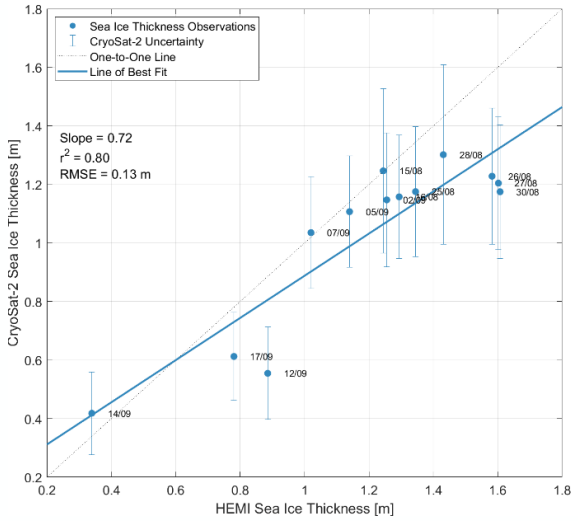
Summer sea ice altimetry: ice thickness calculation

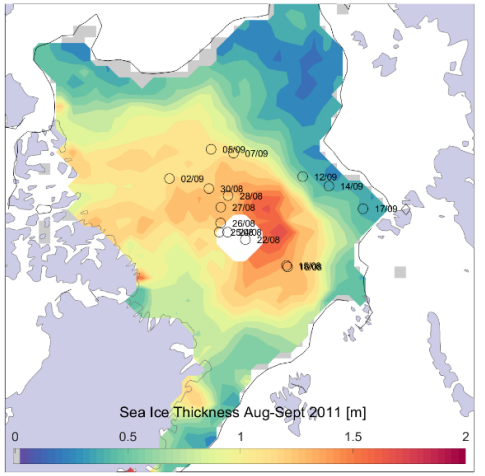
$$h_i = \frac{h_s\rho_w - h_f\rho_w - h_s\rho_s - \delta_p h_s\rho_w}{\rho_i - \rho_w}$$

- Corrected sea ice radar freeboard h_f
- Penetration depth into snow δ_p
- Snow depth h_s and density ρ_s from SnowModel-LG (Liston et al 2020, Stroeve et al 2020)
- Sea ice density ρ_i estimated based on ice type



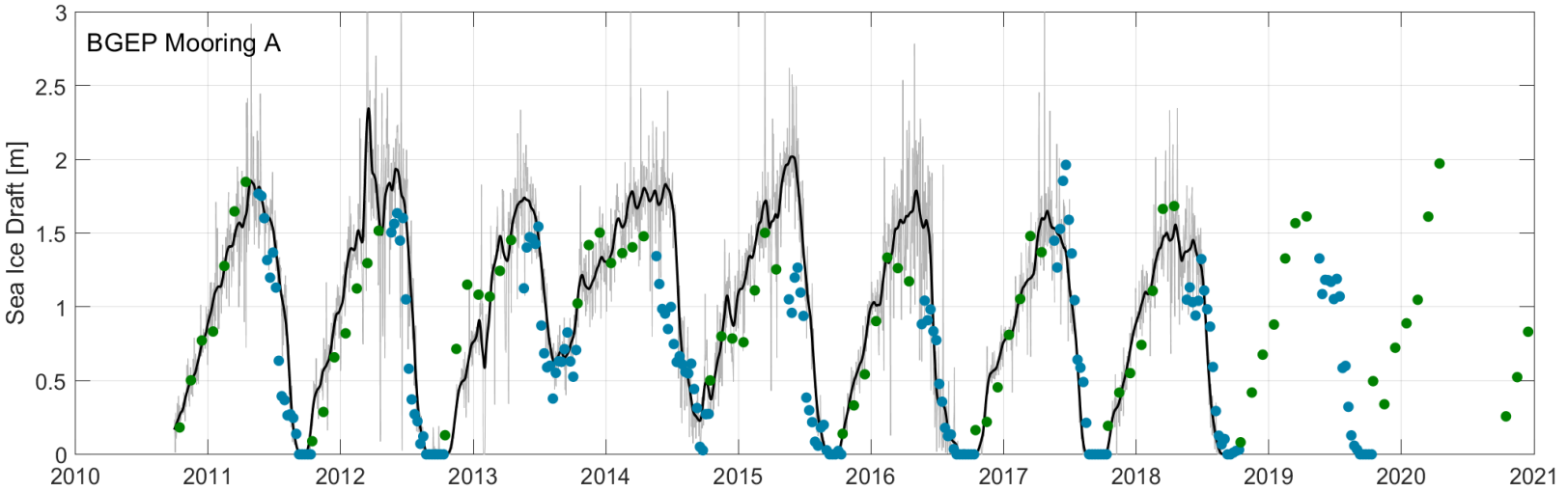
Summer sea ice altimetry: validation

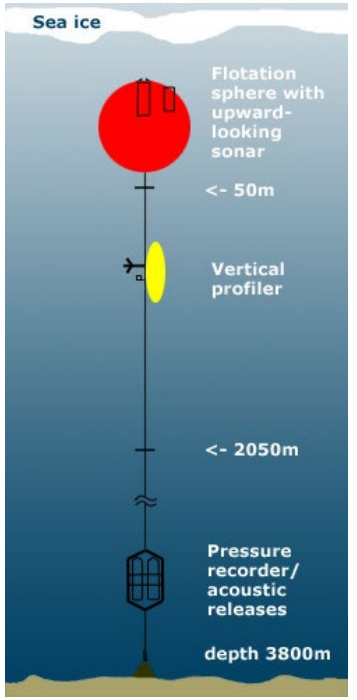


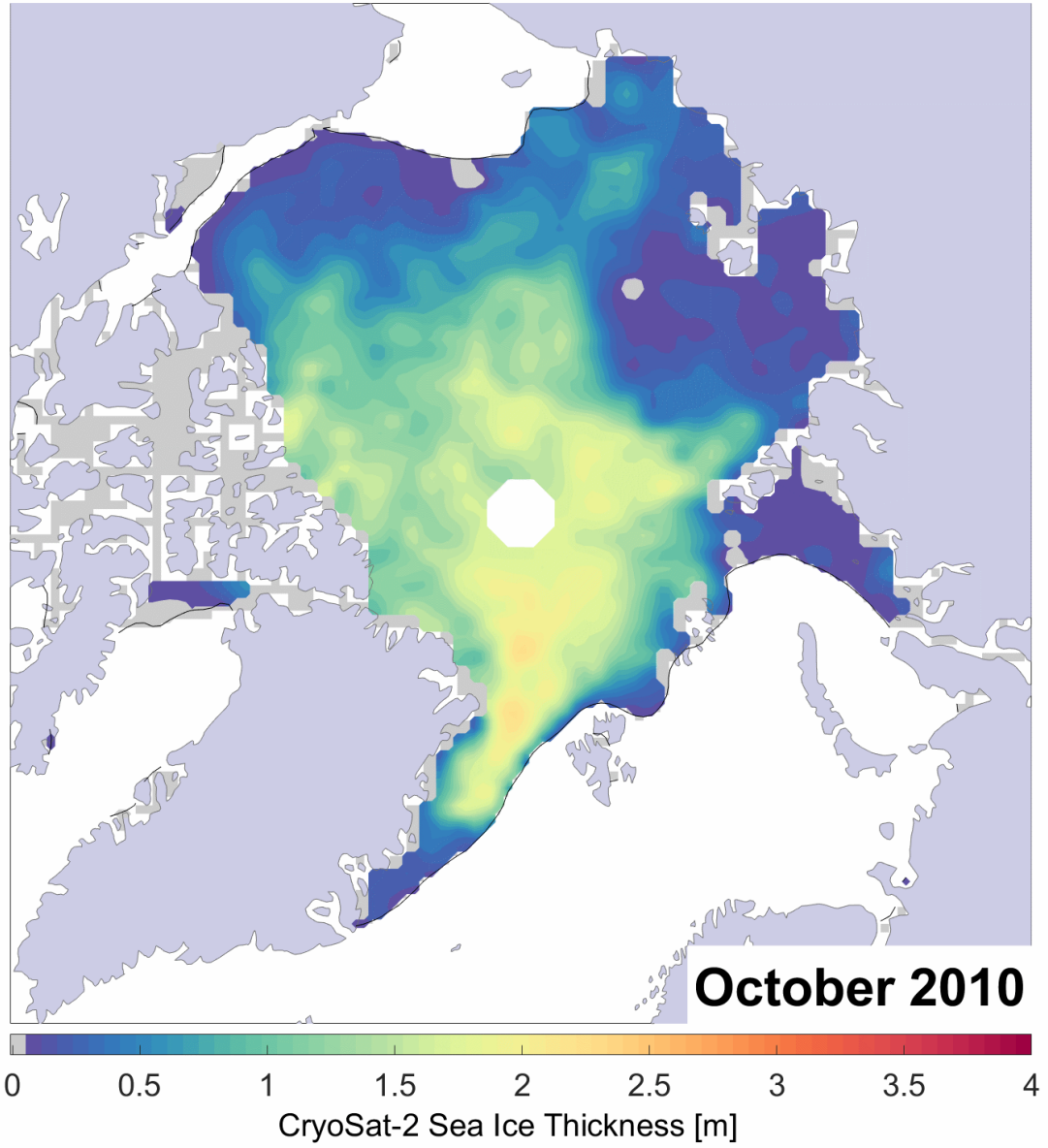


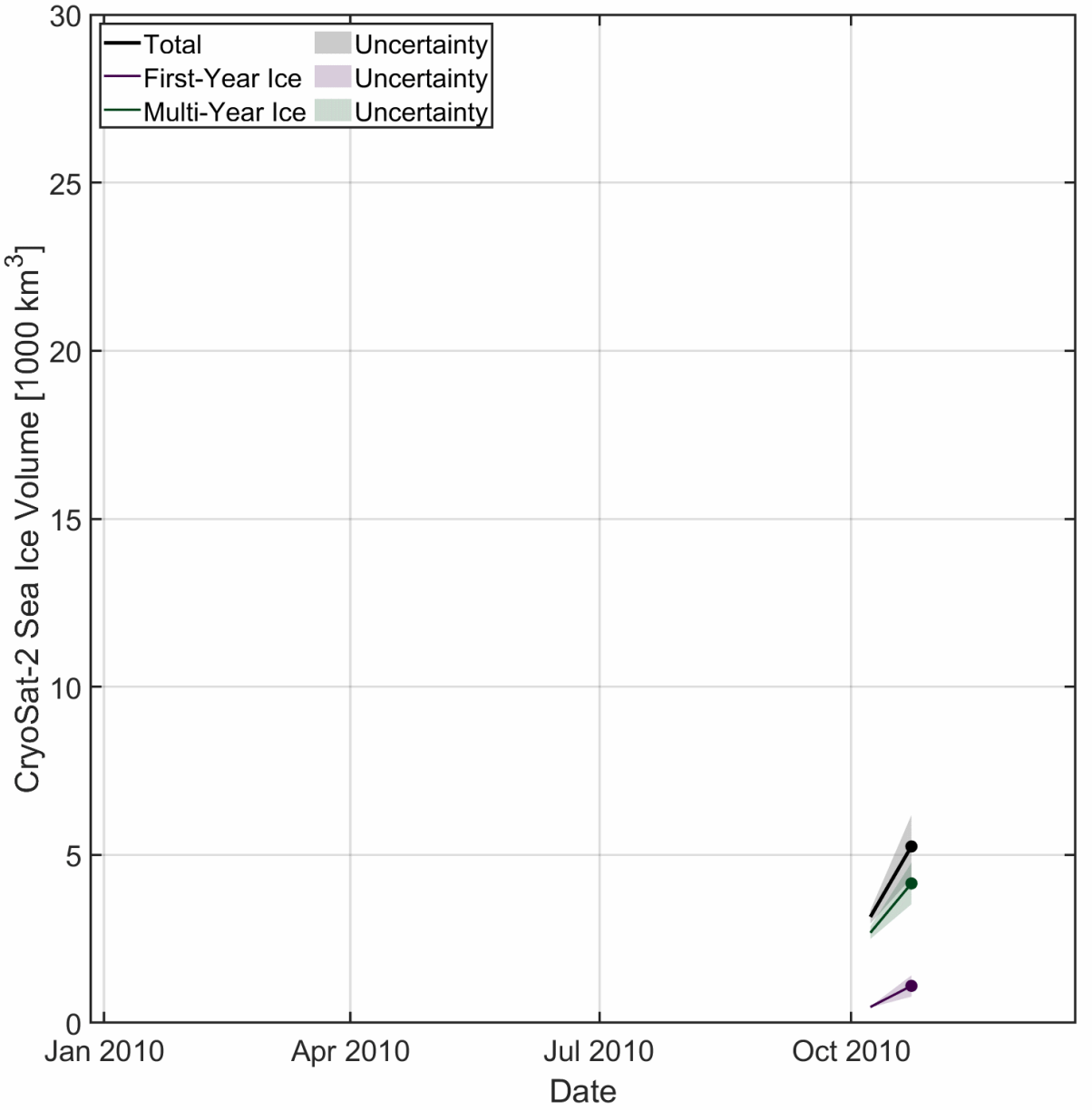
AWI Polarstern
***TransArc* Cruise 2011**

Beaufort Gyre Exploration Program

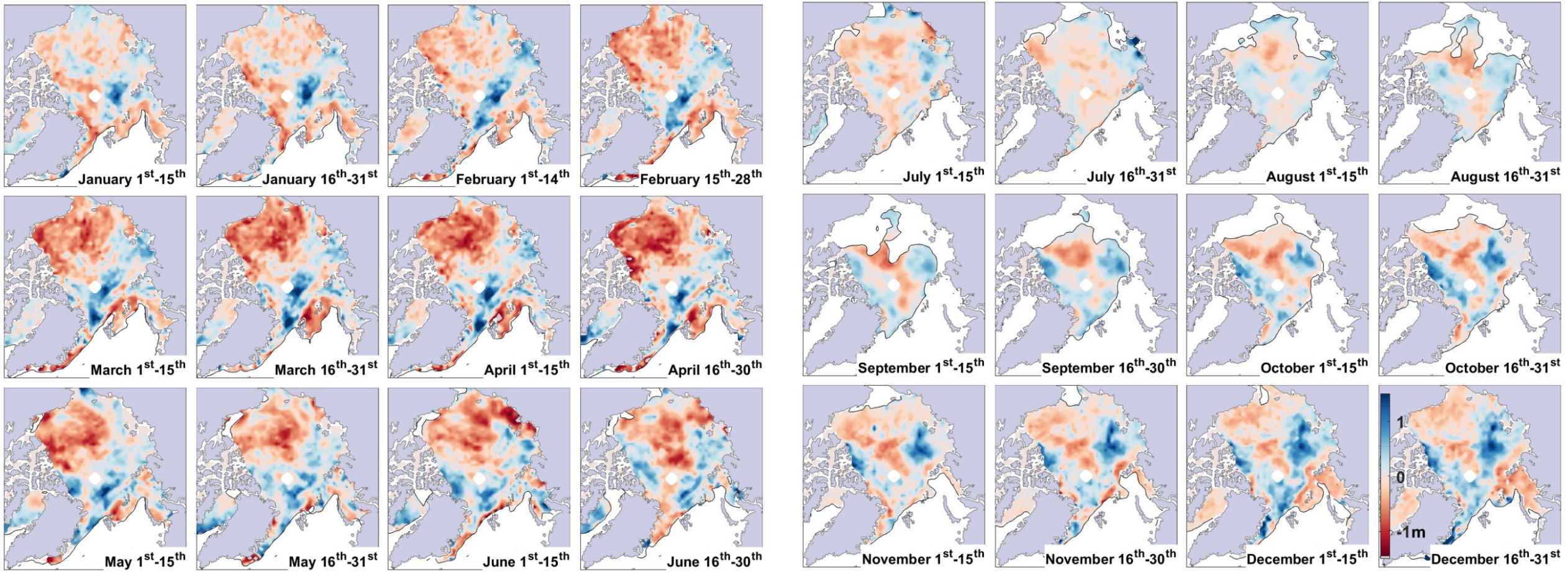





October 2010
0
0.5
1
1.5
2
2.5
3
3.5
4
CryoSat-2 Sea Ice Thickness [m]


Total
Uncertainty
First-Year Ice
Uncertainty
Multi-Year Ice
Uncertainty
CryoSat-2 Sea Ice Volume [1000 km^3]
30
25
20
15
10
5
0
Jan 2010
Apr 2010
Jul 2010
Oct 2010
Date

Sea ice thickness anomaly persistence

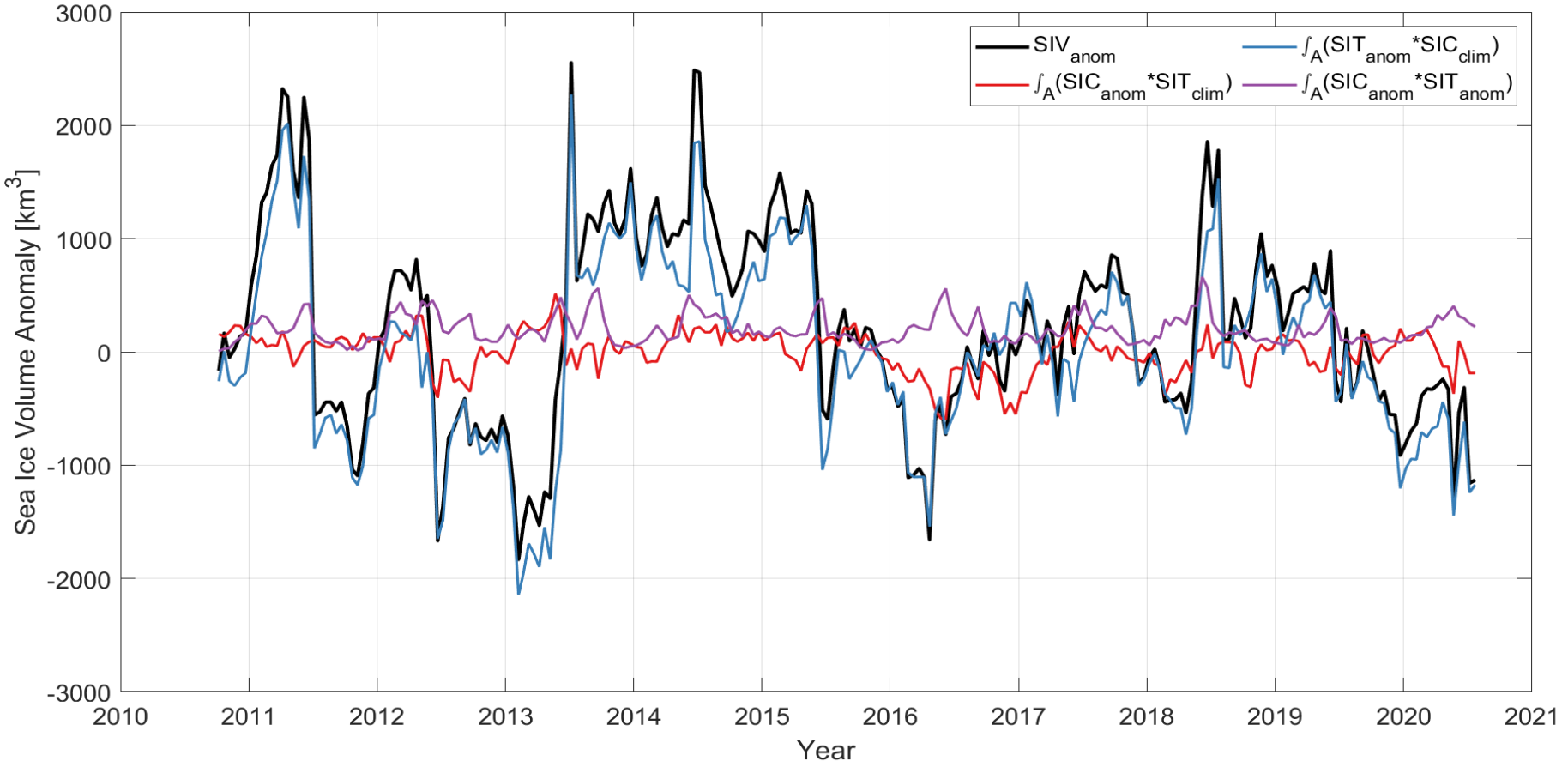


- Western Arctic between Feb-Aug 2016

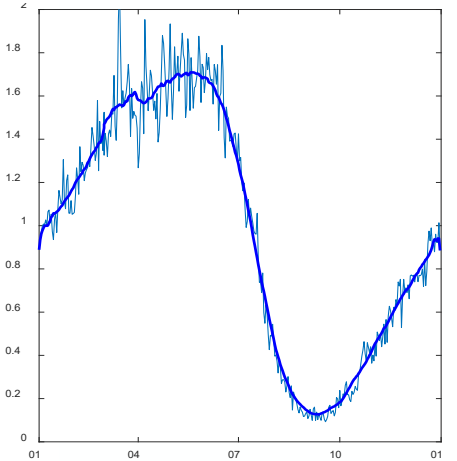
+ in Kara Sea between June-Dec 2016

Where do sea ice volume anomalies come from?

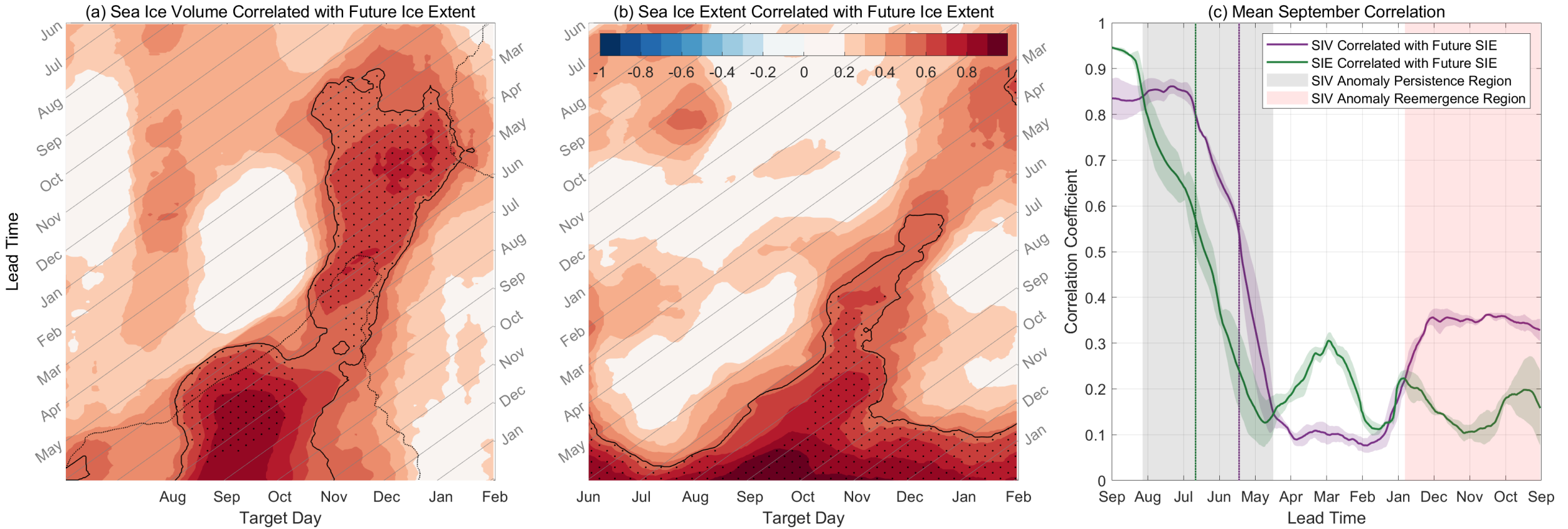
$$SIV' = \int_A \left(SIC'\overline{SIT} + \overline{SIC}SIT' + SIC'SIT' \right) dA$$



Seasonal Cycle Vs Anomalies



Potential for stakeholder-relevant sea ice forecasts



- Using SIV rather than SIE ~doubles the lead time of skilful ice extent forecasts for August and September
- Re-emergence of predictability for Nov-Dec ice extent at 10 month leads, i.e. from preceding Feb-Mar
- Ice thickness anomalies offer substantial skill for predicting future ice extent [e.g. Bushuk et al., 2019]

Summary

- **ESA's CryoSat-2 mission** has monitored Arctic sea ice thickness since 2010, but only in winter months (October-April)
- Conventional processing algorithms fail when **meltwater ponds** form at the sea ice surface in summer
- Supported through the *ArcticSummIT*, *PRE-MELT* and *CIRFA* projects, we have applied **deep learning and numerical radar waveform modelling** to overcome these processing challenges
- Steps towards a goal of the **EU CRISTAL mission** to "provide meaningful sea ice thickness estimates during summer months" [Kern et al., 2020]
- We plan to freely distribute a first **decade-long pan-Arctic sea ice thickness record** without gaps in summer months in the near future
- New opportunities for skilful seasonal (up to 10 months) **summer and autumn sea ice extent forecasts** by assimilating SIT observations into dynamical models