

living planet symposium

BONN
23–27 May
2022

TAKING THE PULSE
OF OUR PLANET FROM SPACE



Arctic Sea Ice Volume and Mass from Data Fusion of CryoSat-2 and SMOS

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[Norwegian Research Centre]
[ESA/ESRIN]

2022/05/26

Sea Ice – Marine Cryosphere

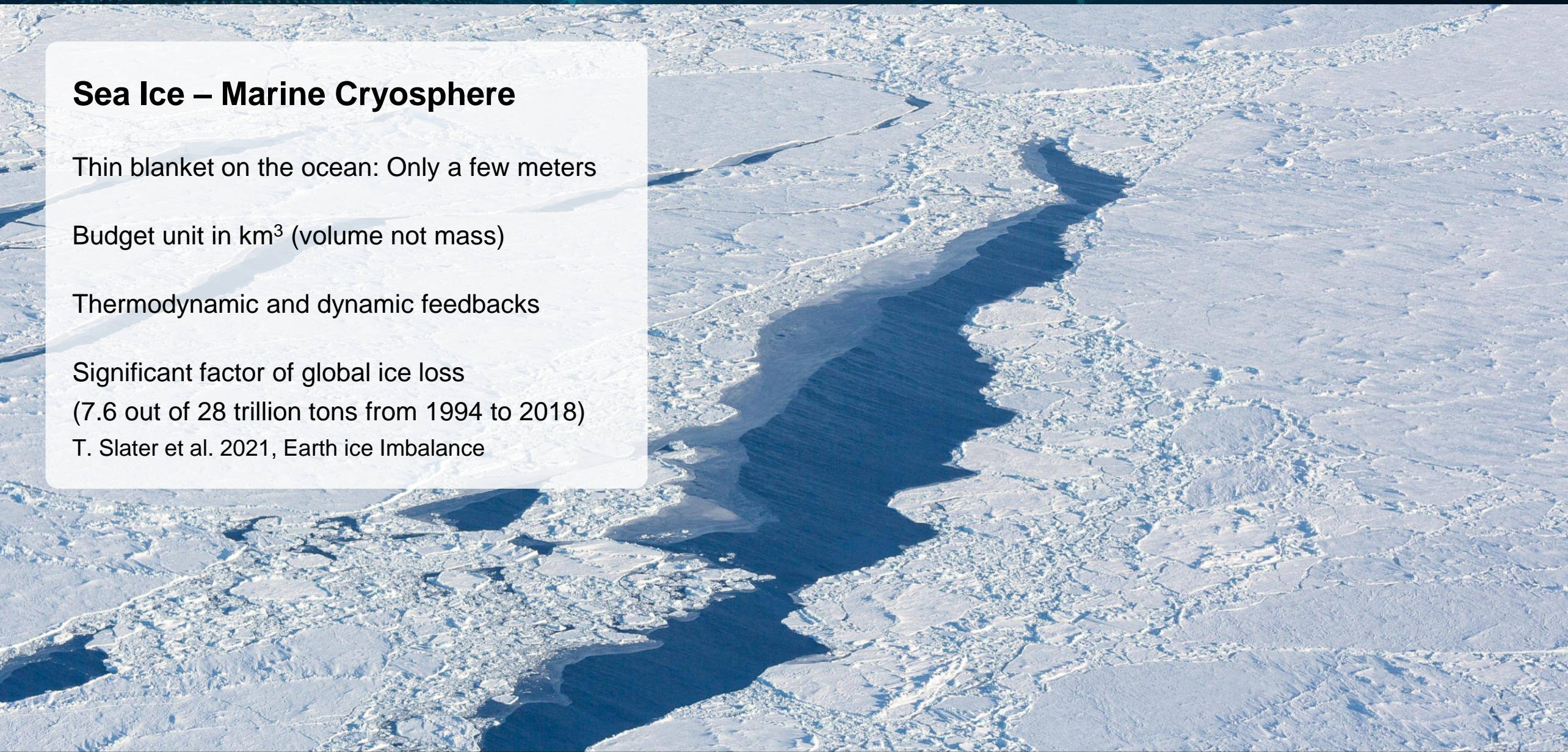
Thin blanket on the ocean: Only a few meters

Budget unit in km^3 (volume not mass)

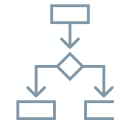
Thermodynamic and dynamic feedbacks

Significant factor of global ice loss
(7.6 out of 28 trillion tons from 1994 to 2018)

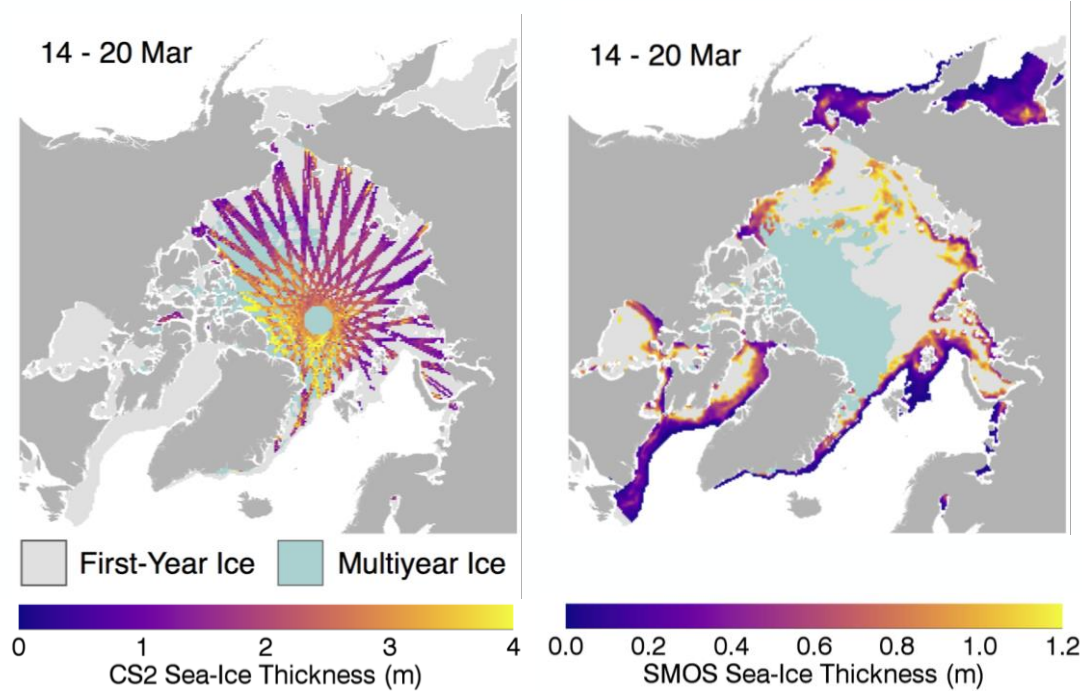
T. Slater et al. 2021, Earth ice Imbalance



CryoSat-2/SMOS (CS2SMOS) Data Fusion



Analysis = Background + Innovation
 Innovation = f(Observations, Weights, Correlation Length Scale)



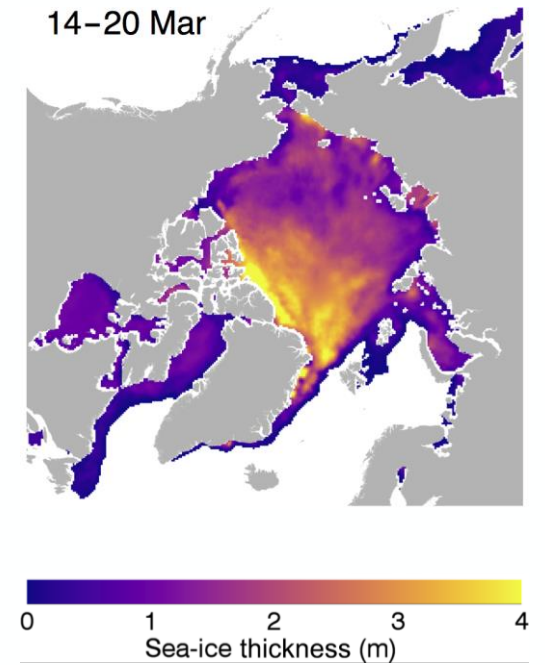
Optimal Interpolation (OI)

OI Parameters

- Observation (CS2 & SMOS)
- Background Field (CS2 & SMOS)
- Correlation Length Scale
- Weight of Observations (Uncertainties)

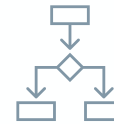
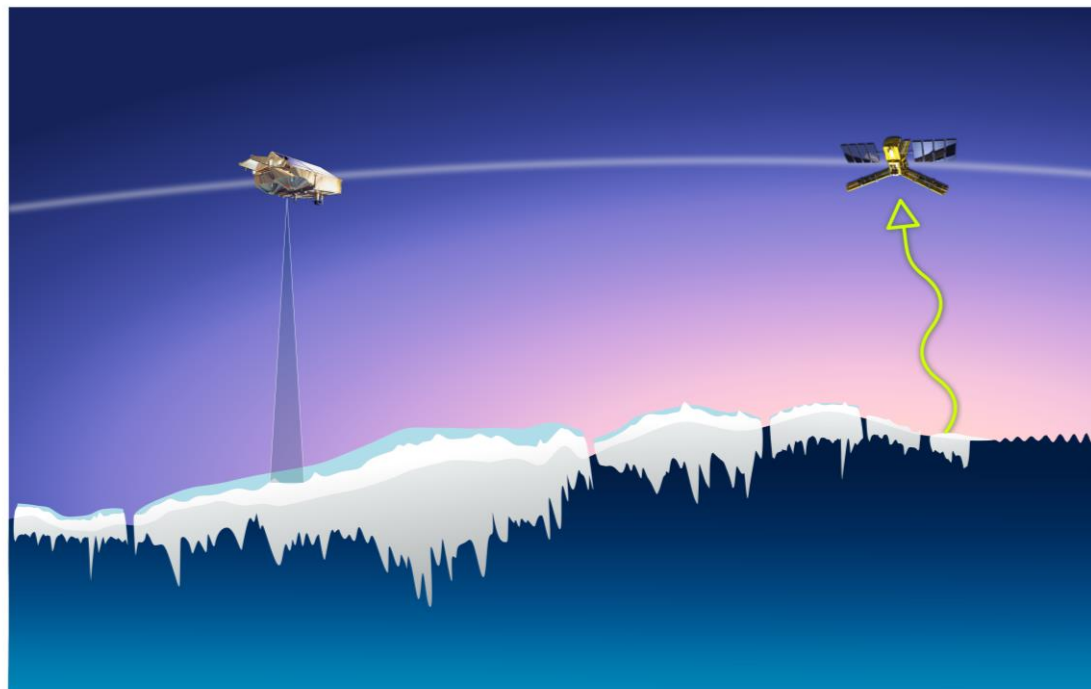
Input

- CryoSat-2 orbit data (I2p)
- SMOS gridded data (I3c)
- Sea Ice Concentration (Mask)
- Sea Ice Type (Filter)



Ricker, R., et al.: A weekly Arctic sea-ice thickness data record from merged CryoSat-2 and SMOS satellite data, The Cryosphere, 2017.

Synergy of CryoSat-2 (thick ice) and SMOS (thin ice)



Analysis = Background + Innovation
 Innovation = $f(\text{Observations, Weights, Correlation Length Scale})$

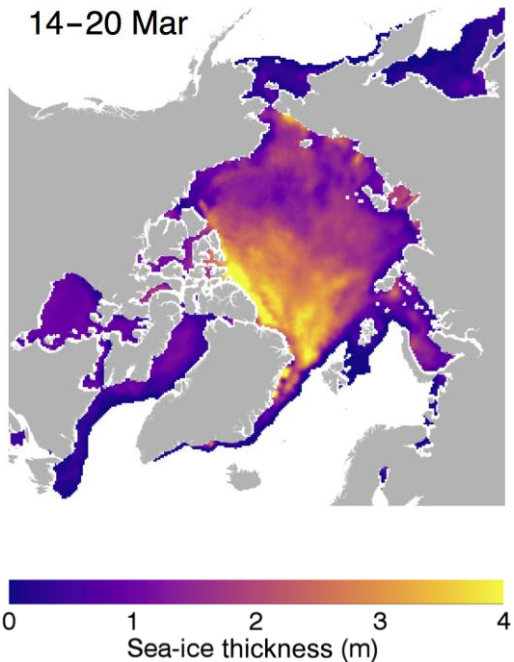
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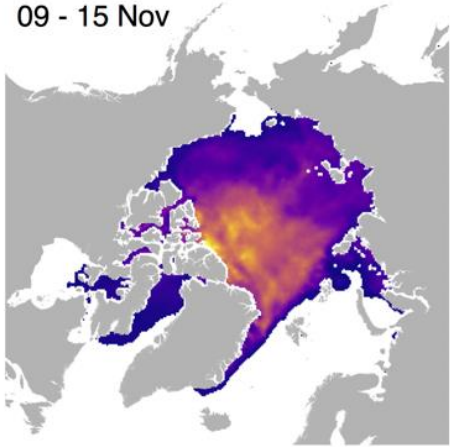
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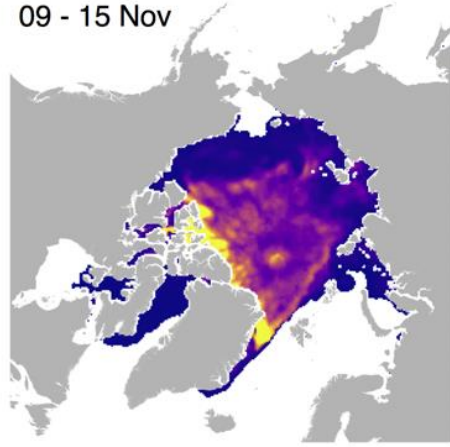


Ricker, R., et al.: A weekly Arctic sea-ice thickness data record from merged CryoSat-2 and SMOS satellite data, The Cryosphere, 2017.

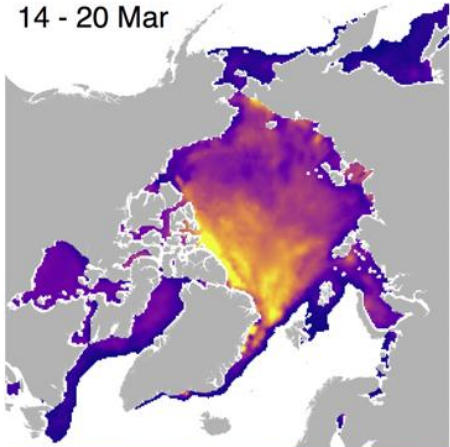
09 - 15 Nov



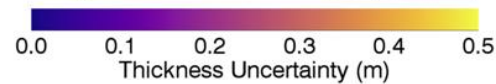
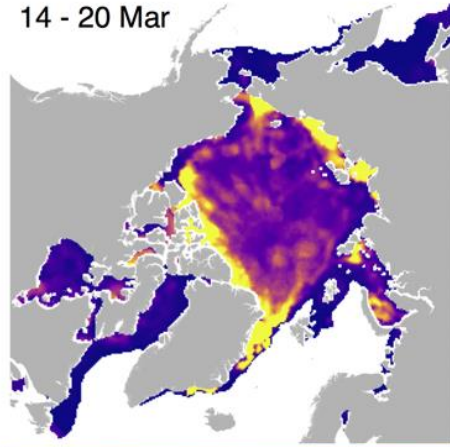
09 - 15 Nov



14 - 20 Mar



14 - 20 Mar



CryoSat-2 & SMOS: 12th winter of operation

Northern hemisphere winter data only (October – April)

SMOS: Oct 15 – April 15

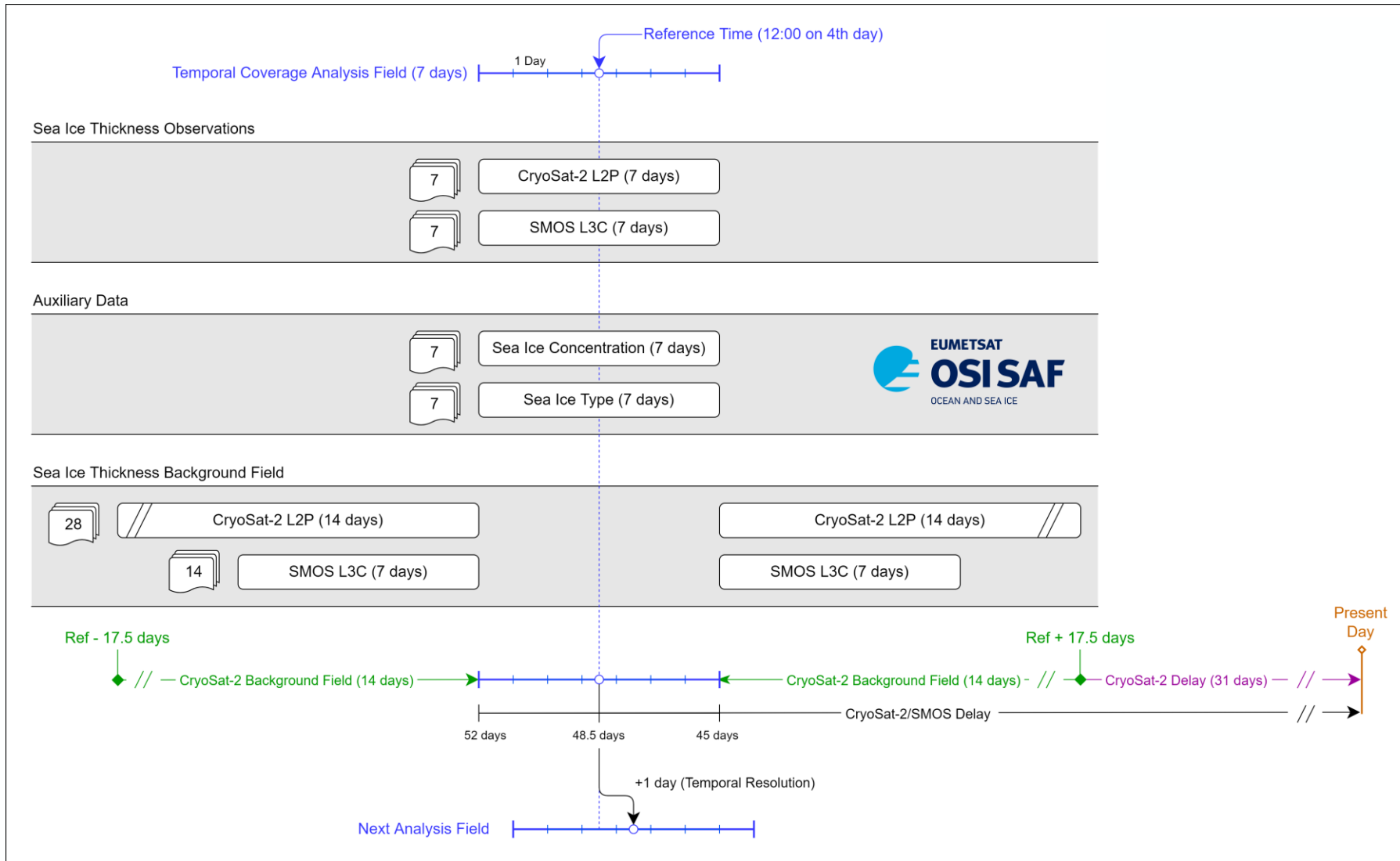
CS2SMOS is generated operationally with annual updates

7 day observation period with 1 day resolution

Spatial resolution: 25 km

2 flavors: reprocessed & near real-time

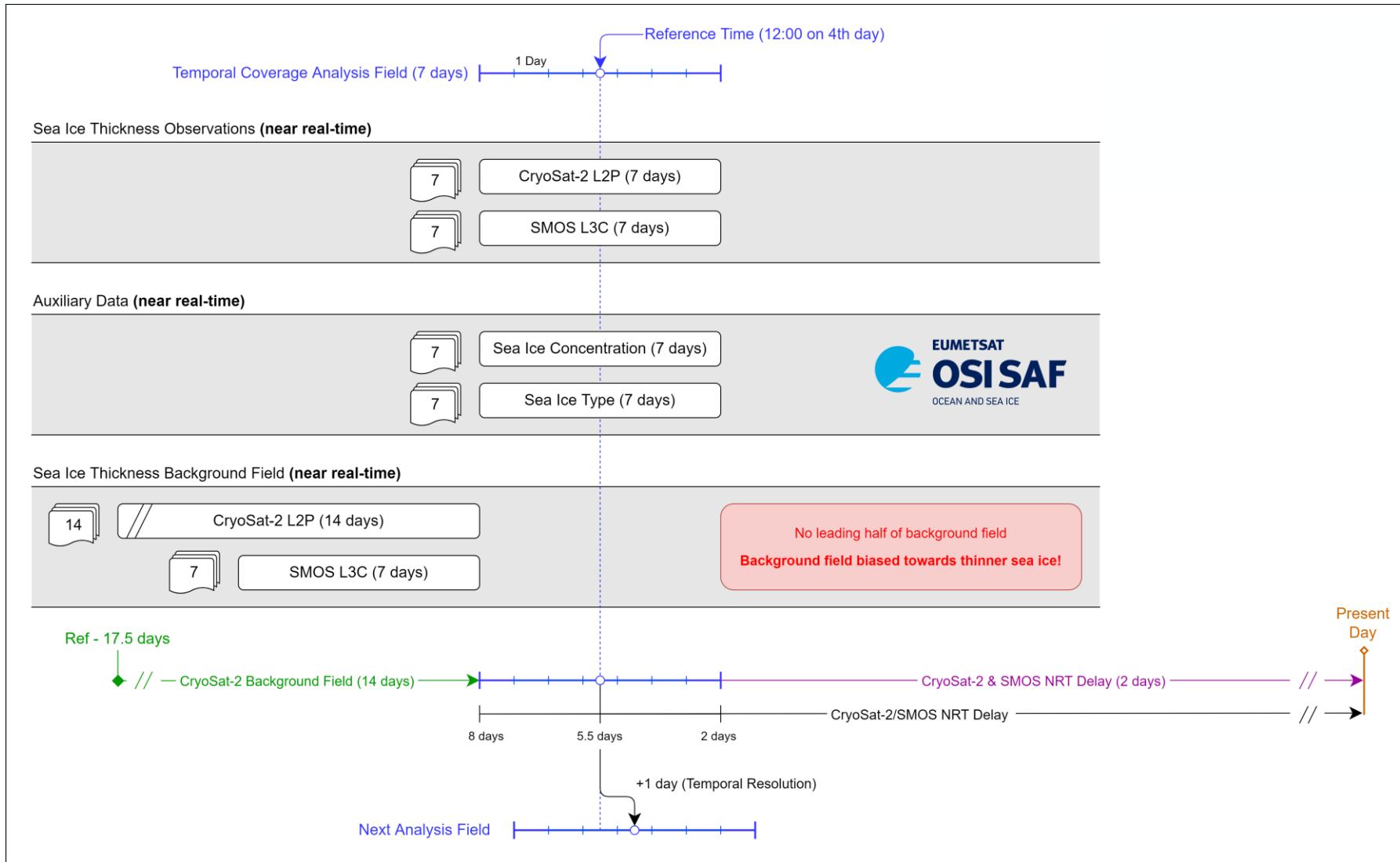
CS2SMOS Properties



CS2SMOS reprocessed

Observation period

Delay 52 – 45 days



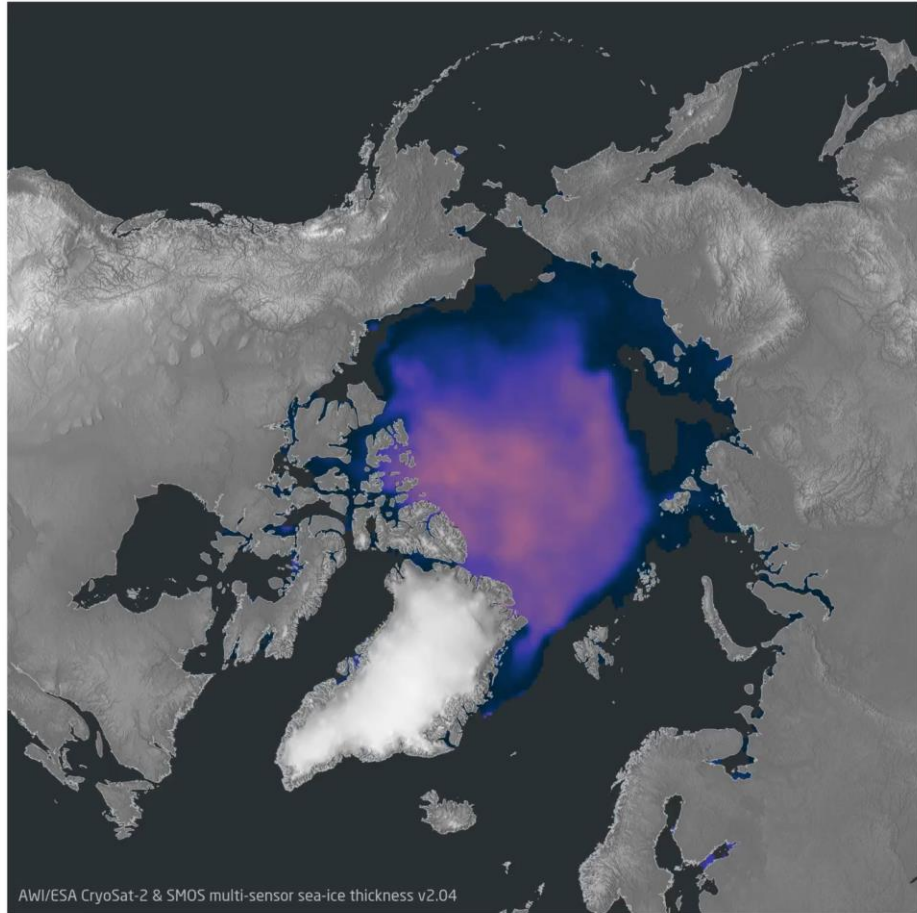
CS2SMOS reprocessed

Observation period

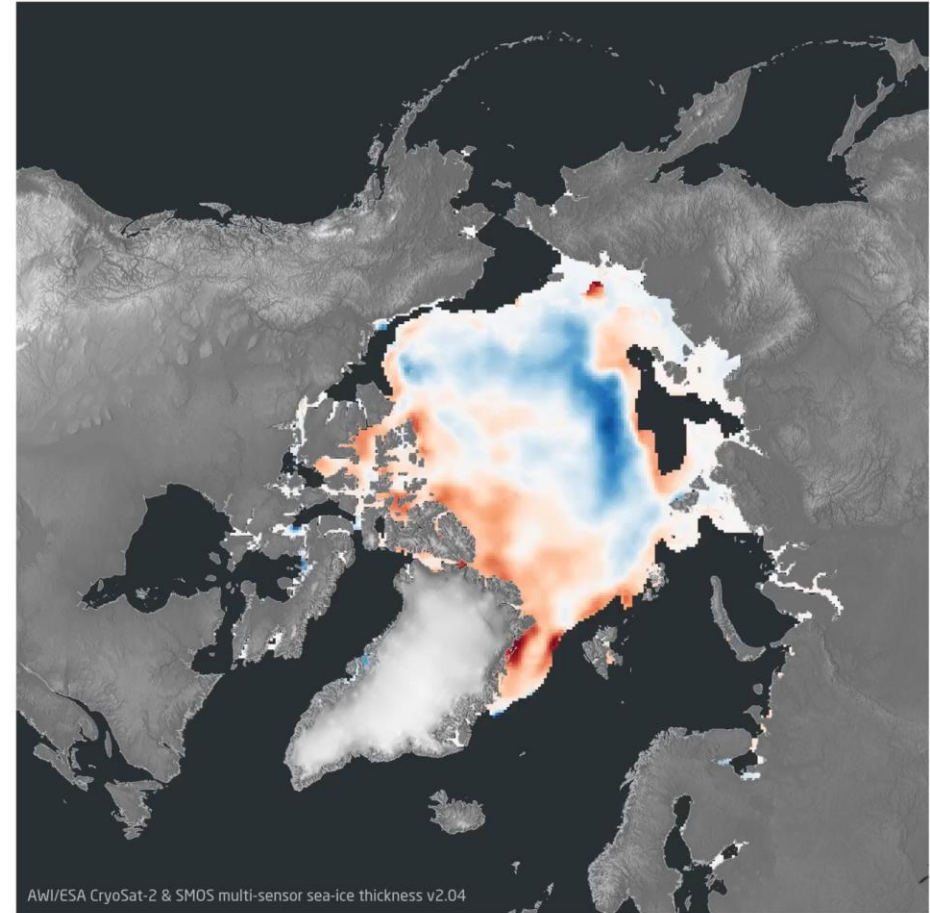
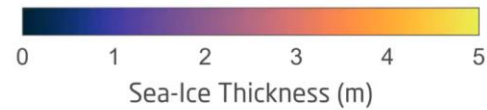
Delay 8 – 2 days

Phasing bias in background field:
CS2SMOS NRT biased low!

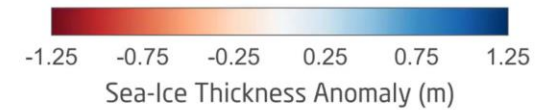
Current Winter Animation



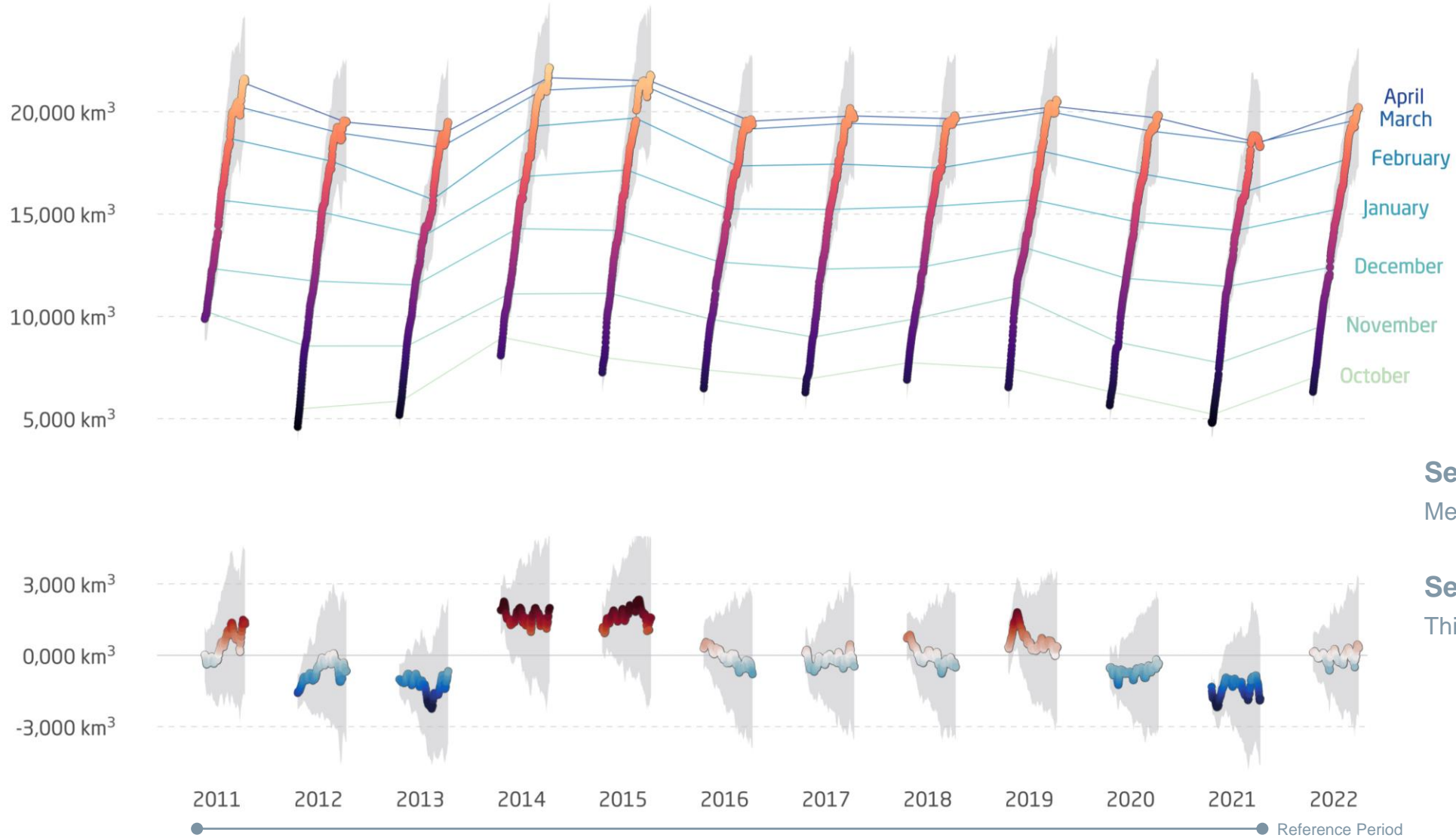
18 October 2021



18 October 2021



Sea Ice Volume Time Series



Sea Ice Thickness

Mean of ice-covered fraction of area

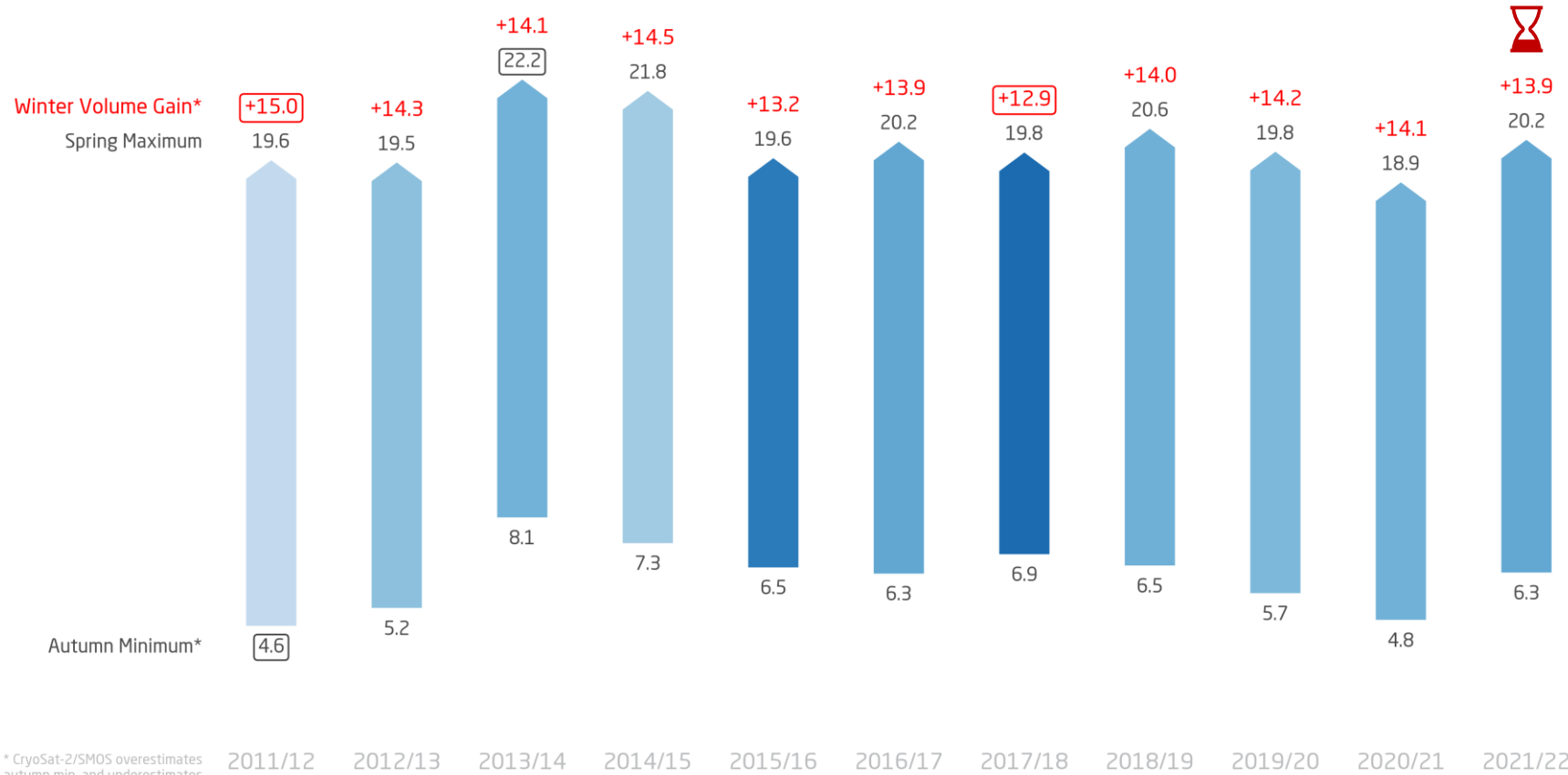
Sea Ice Volume

Thickness \times Concentration \times Area

Sea Ice Volume – Winter Gain Loss

Winter Sea-Ice Volume Gain observed by CryoSat-2/SMOS

Values in 1000 km³

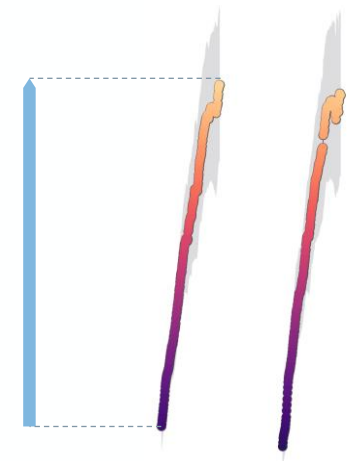


Winter Gain Variability

2100 km³ (12900 km³ – 15000km³)

Caveat:
Full min/max may not be in CS2SMOS winter period

Winter Sea Ice Volume Gain



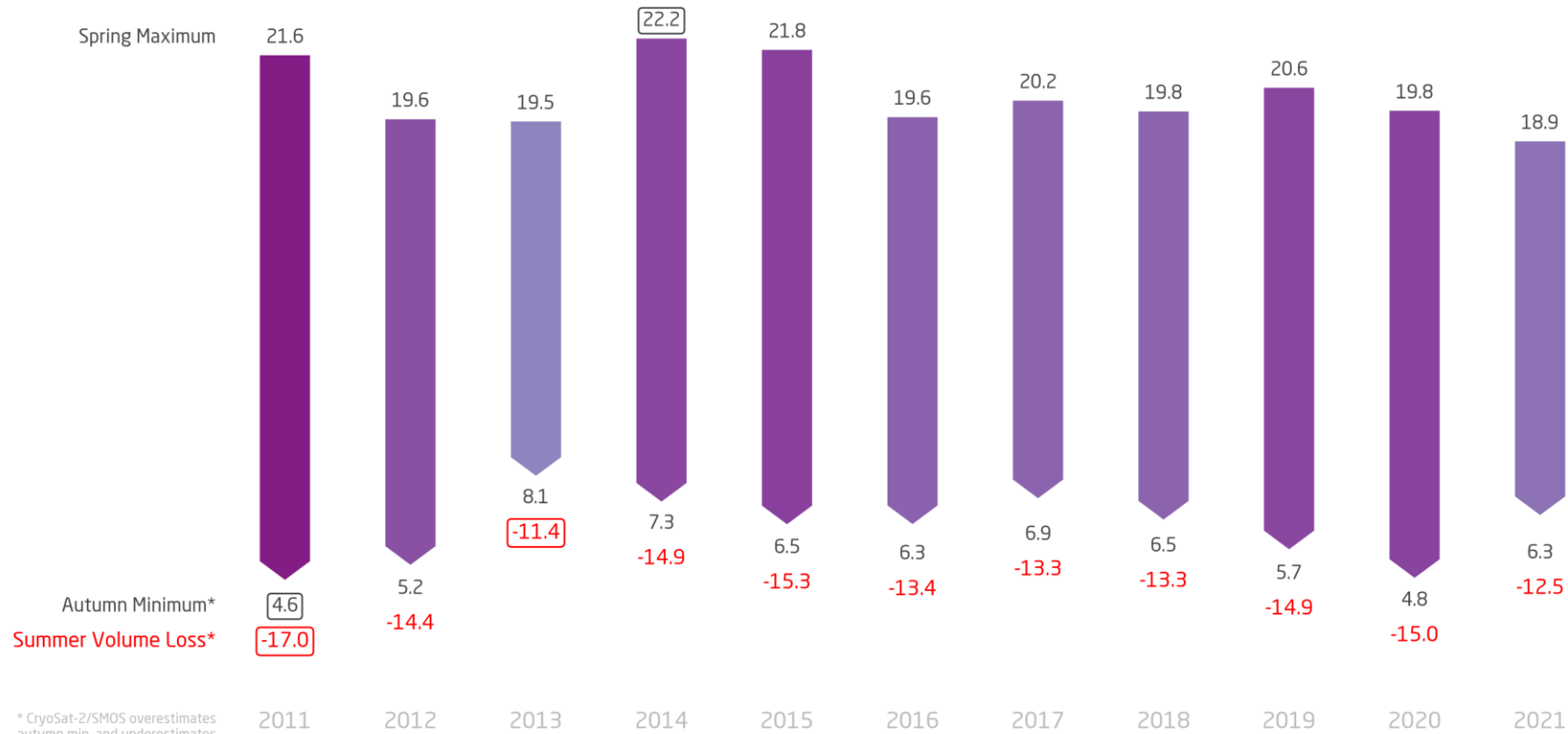
* CryoSat-2/SMOS overestimates autumn min. and underestimates ice loss since data is only available from mid-October on

Dataset: CryoSat-2/SMOS multi-sensor sea-ice thickness and volume (v2.04)

Sea Ice Volume – Winter Gain Loss

Summer Sea-Ice Volume Loss observed by CryoSat-2/SMOS

Values in 1000 km³



* CryoSat-2/SMOS overestimates autumn min. and underestimates ice loss since data is only available from mid-October on

Dataset: CryoSat-2/SMOS multi-sensor sea-ice thickness and volume (v2.04)

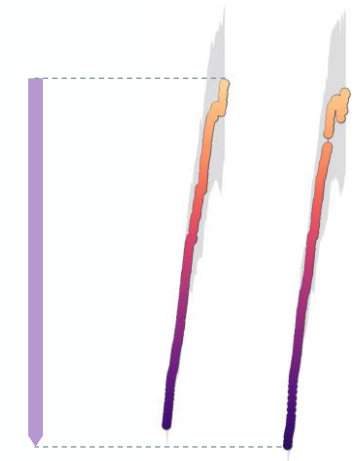
Summer Loss Variability

5600 km³ (-11400 km³ – -17000km³)

Twice as large as winter variability

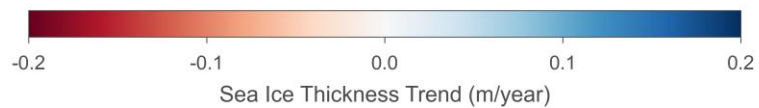
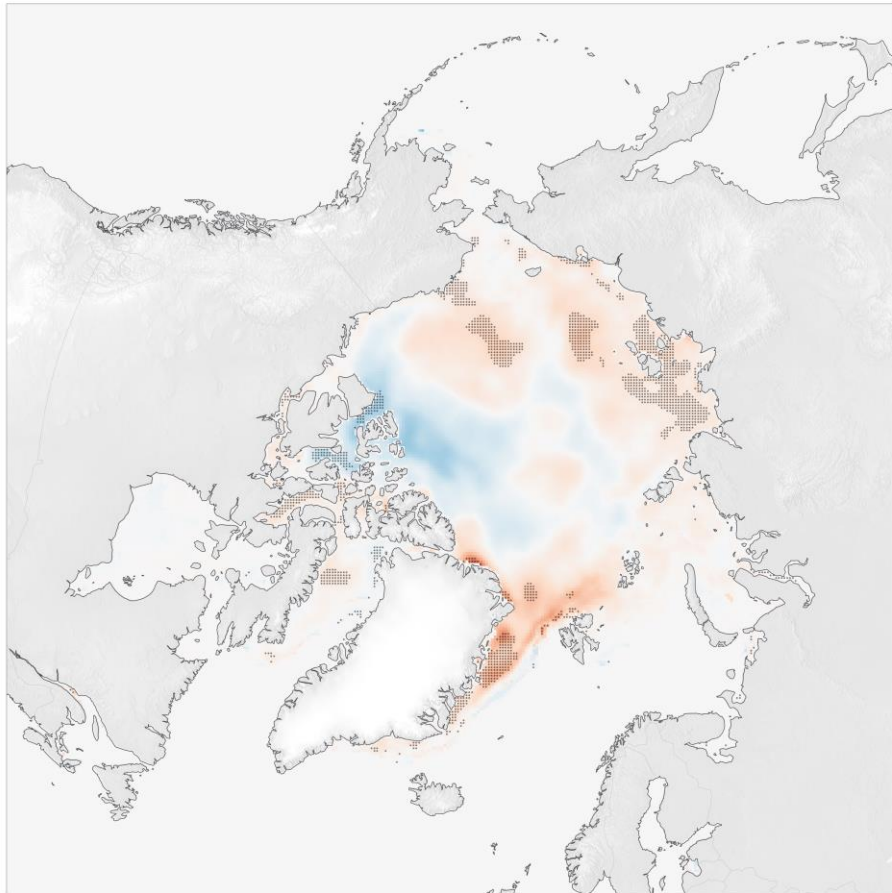
Caveat:
Full min/max may not be in CS2SMOS winter period

Summer Sea Ice Volume Loss

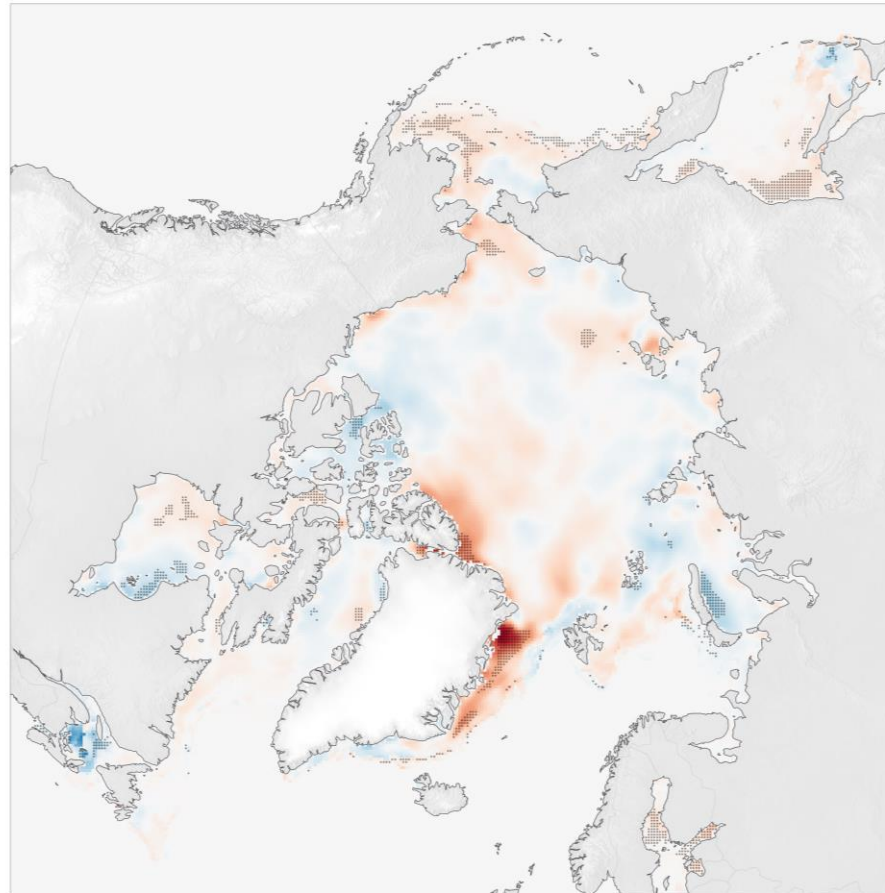


Sea Ice Thickness Trends

November 2010 - 2021



March 2011 - 2022



Few areas with significant trends

even with low probability $p < 0.1$

Observed Trends similar to sea ice concentration trends

Fall and Spring trends differ

Winter dynamics feedbacks?

Continuation & Evolution of CS2SMOS

Evolution of CryoSat-2 & SMOS source data sets

Retracking | dynamic snow load | ...

Sentinel-3A/B to improve spatial & temporal resolution

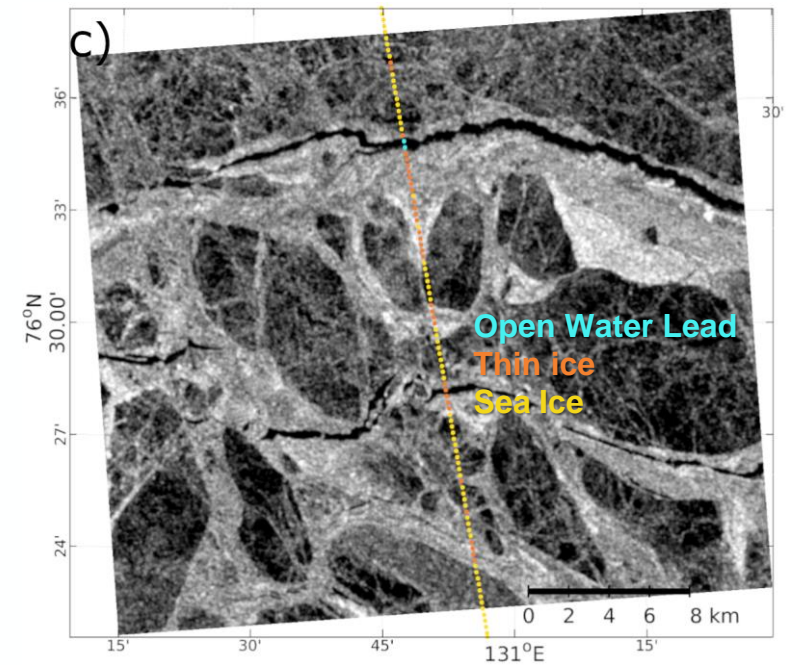
Going to need a new product name (CS2SMOS^{S3} ?)

Extension to southern hemisphere



Monitoring Arctic thin ice: A comparison between Cryosat-2 SAR altimetry data and MODIS thermal-infrared imagery

Felix Müller, A9.06 Sea Ice Remote Sensing



Continuation & Evolution of CS2SMOS

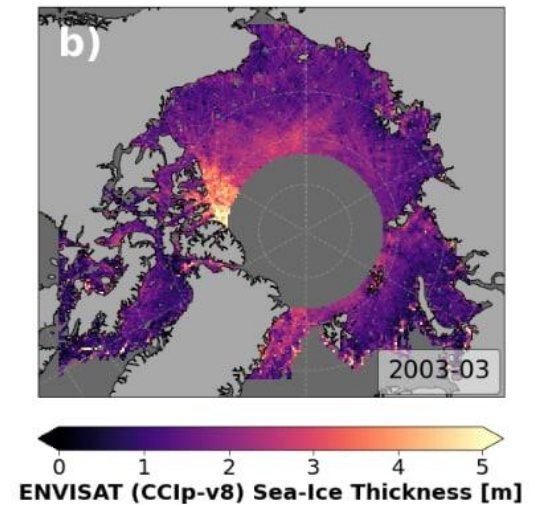
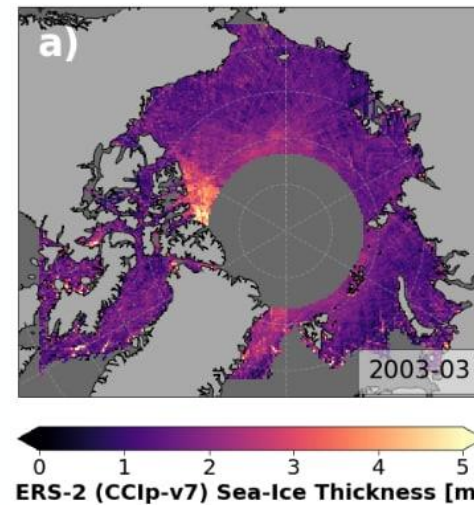
Extension to the past

No SMOS equivalent before 2010

Need to improve thin ice retrieval for radar altimetry

Larger pole hole of Envisat / ERS-1/2

Need for other multi-sensor gap-filling strategies





Documentation & Data Access

<https://spaces.awi.de/display/CS2SMOS>



Long-term Observational Sea Ice Thickness Products from SMOS and CryoSat-2
Xiangshan Tian-Kunze, A9.06 Sea Ice Remote Sensing



SMOS sea ice thickness - a review and way forward
Lars Kaleschke, A9.06.3 Sea Ice Remote Sensing - 3



Co-Authors

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Projects

ESA CryoSat-2/SMOS Processing & Dissemination Service

ESA SMOS Expert Support Laboratories

Copernicus Marine Service

