Beyond L-Band: Wideband (0.4–2 GHz) Radiometry for Observing Surface Salinity in Cold Seawater

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Supported by the ESA CryoRad Earth Explorer 12 Phase 0 Science and Requirements Consolidation Study (SciReC) & CNES R & T ‘Estimation de la salinité dans les eaux froides’

CryoRad mission: science goal

Understanding polar processes in a warming climate from the ice sheet interior to the open ocean

Project status

ESA Earth Explorer 12 mission idea: Phase 0 started in 2024 ;
Continuation to be decided in Summer 2026 (ESA User Consultation meeting)

CryoRad concept

Single satellite; wideband radiometer (0.4-2 GHz); nadir looking; resolution < 50 Km

Project team

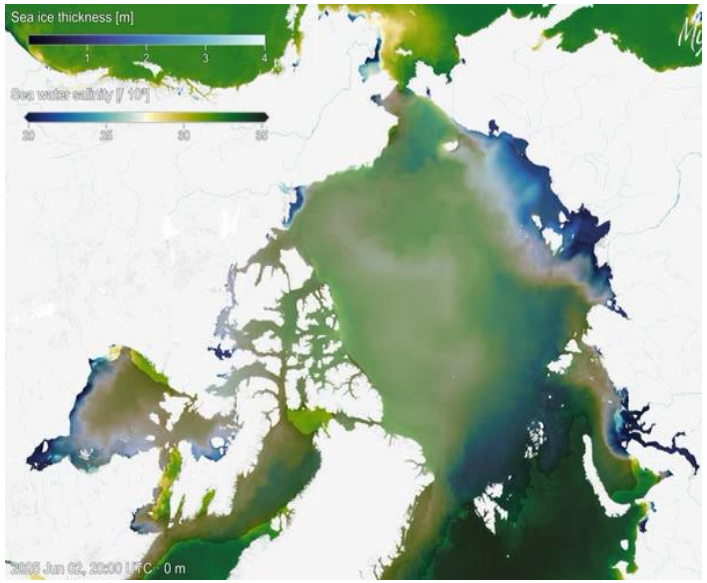
Giovanni Macelloni , Marco Brogioni, Marion Leduc-Leballeur, Ghislain Picard, Jacqueline Boutin, Aurélien Quiquet, Lars Kaleschke, Laurent Bertino, Stef Lhermitte, Anne Munck Solgaard, Kenneth C. Jezek, Anna Kontu, Kimmo Rautiainen, Jean-Luc Vergely, Roger Oliva, Yiwen Zhou, Rasmus Tonboe

CryoRad Primary Mission Objectives:

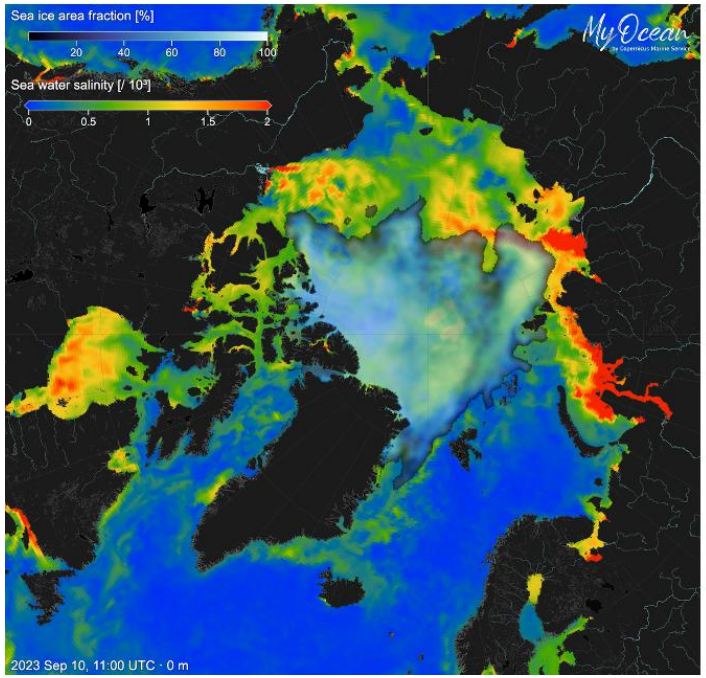
Ice sheet temperature profiles, Sea ice thickness,

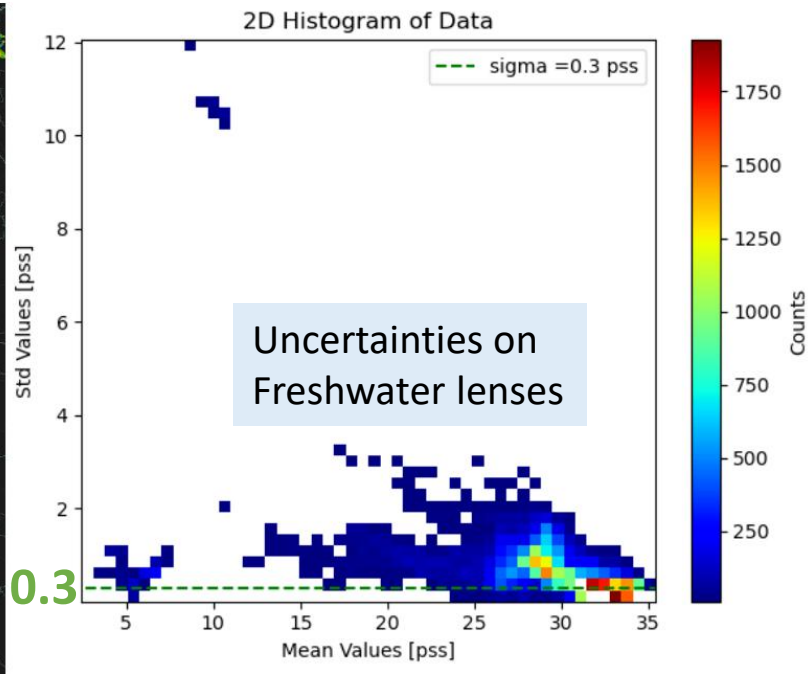
Sea Surface Salinity in cold water

Freshwater lenses
Global NEMO – Summer 2025



Standard Deviation of SSS simulated with various CMEMS reanalysis products





Macelloni et al. 2026, 'Wideband Radiometry From P to S Band for Monitoring Polar Regions', Proceedings of IEEE

Geophysical Research Letters

RESEARCH LETTER
10.1029/2025GL118871

Mackenzie River Freshwater Controls Early Sea Ice Formation in the Eastern Beaufort Sea

M. J. Zahn[1], S. Fournier[1], I. G. Fenty[1], M. Steele[2], M. Wood[3], and P. Gaube[2]

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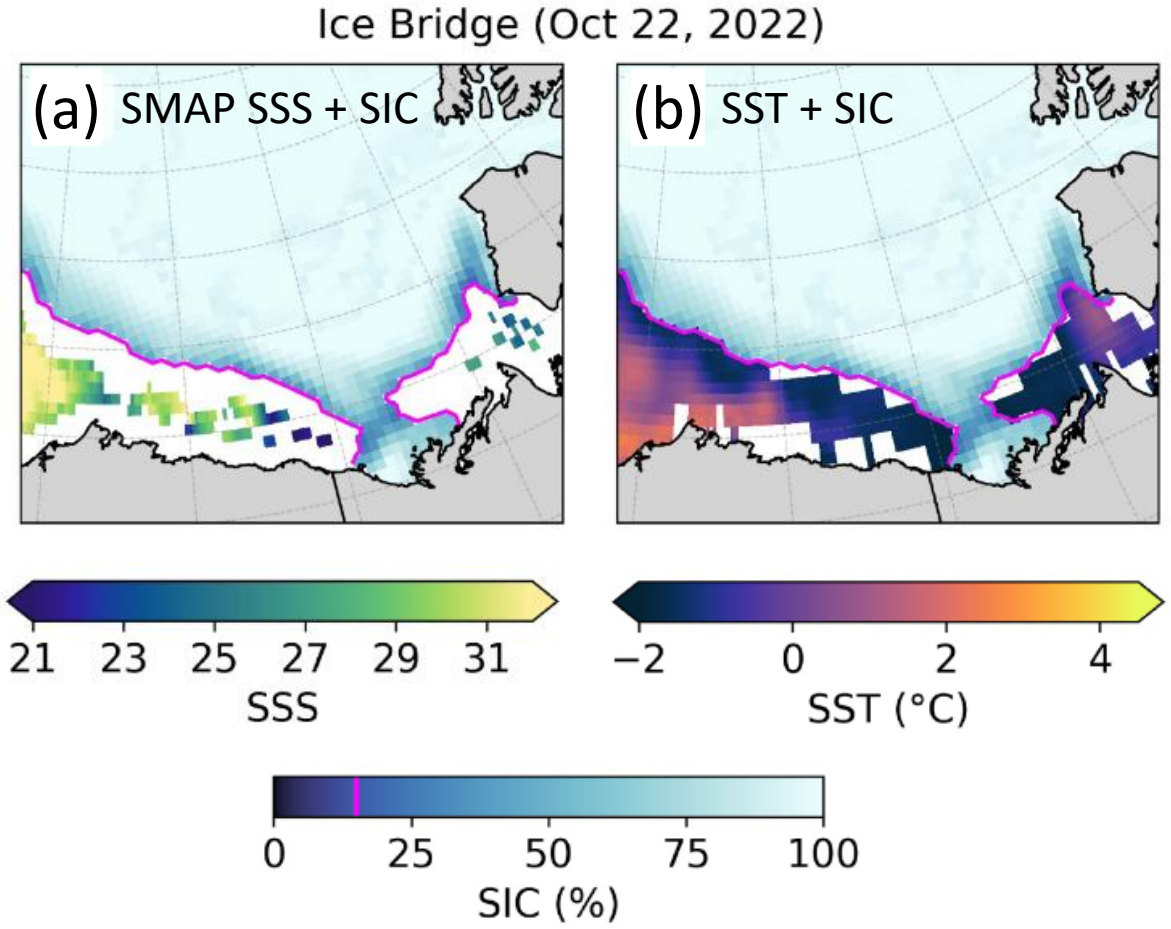
Key Points:

- Sea ice onset occurs earlier in the Mackenzie River plume where freshwater promotes the formation of an ice bridge
- Model simulations reveal that sea ice forms on average 3 weeks earlier in t Mackenzie River freshwater plume than in adjacent, saltier areas
- The Mackenzie River freshwater plume has stronger stratification, shallower mixed layers, and less surface heat than surrounding water



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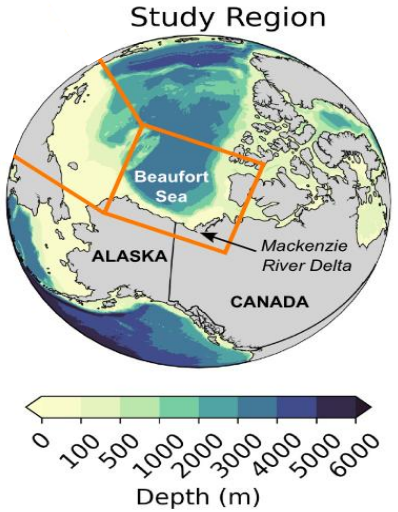
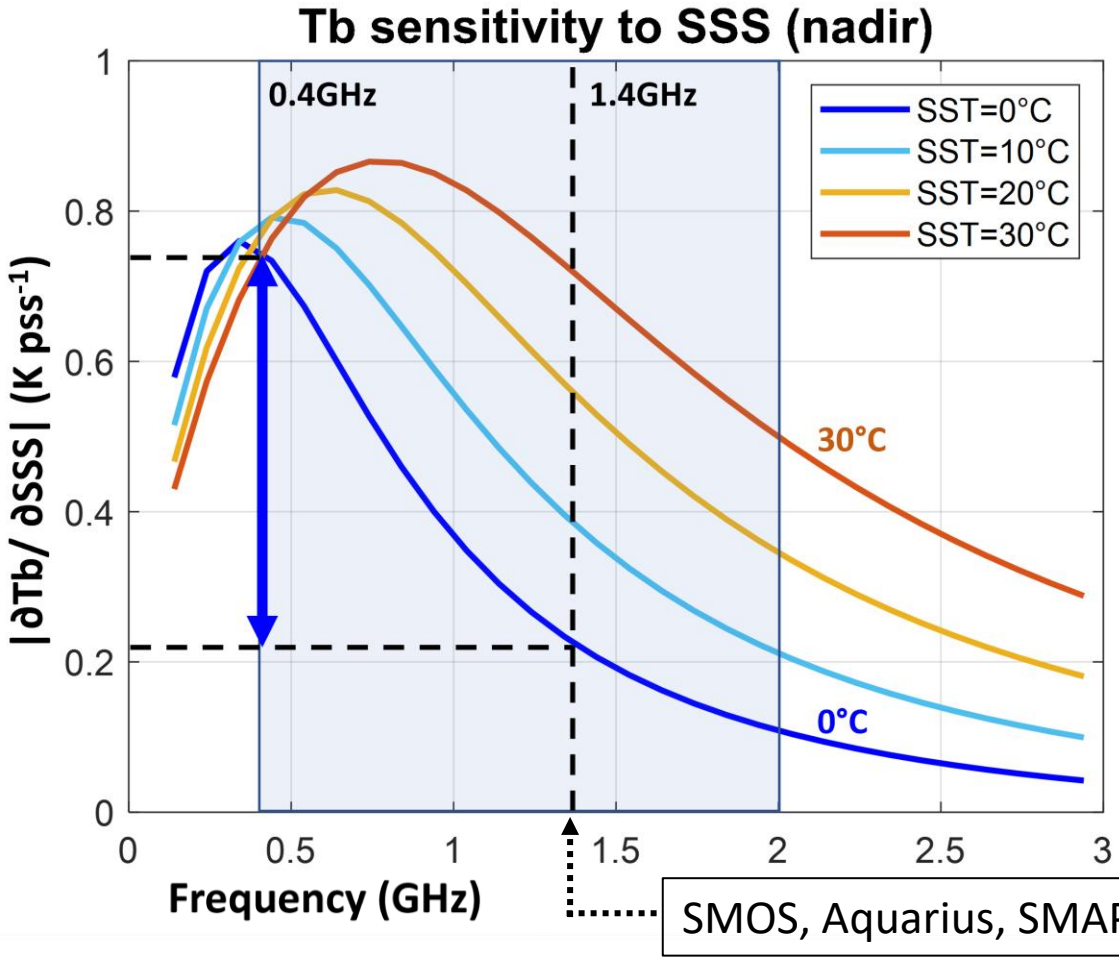


How to measure – the physical basis

- CryoRad: 0.4-2GHz wideband radiometer
- Sensitivity to SSS: ~3 times larger at 0.4GHz than at 1.4GHz in cold sea



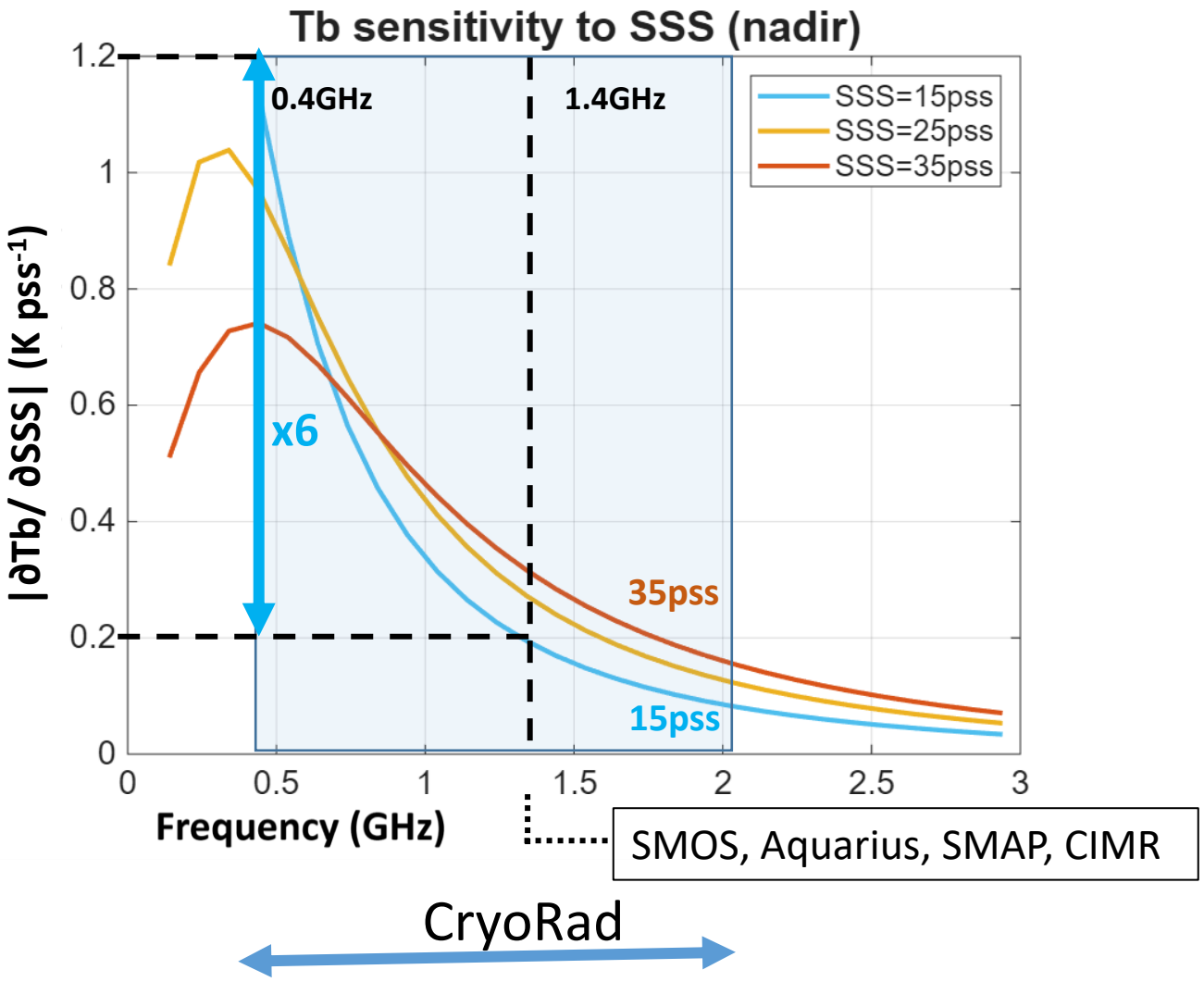
Macelloni et al. 2026, 'Wideband Radiometry From P to S Band for Monitoring Polar Regions', Proceedings of IEEE

How to measure – the physical basis

- CryoRad: 0.4-2GHz wideband radiometer

- Sensitivity to SSS: ~3 times larger at 0.4GHz than at 1.4GHz in cold sea

  ~6 times larger at 0.4GHz than at 1.4GHz in low SSS range



Simulations of SSS uncertainties

- Bayesian approach. Estimate of the maximum of probability. Three parameter retrieval (SSS, SST, WS)
- In CryoRad like simulations, consider the same noise on each 100 MHz band (16 bands)
- Direct models :
  - Dielectric constant compliant with physical constraints and lab. measurements at L- and P-Band (Boutin et al. 2023 ; Levine et al. 2025)
  - PARMIO wind model : 2-scale roughness + foam models (Yin et al. 2016; Dinnat et al. 2023)

Radiometric scenarii & uncertainties

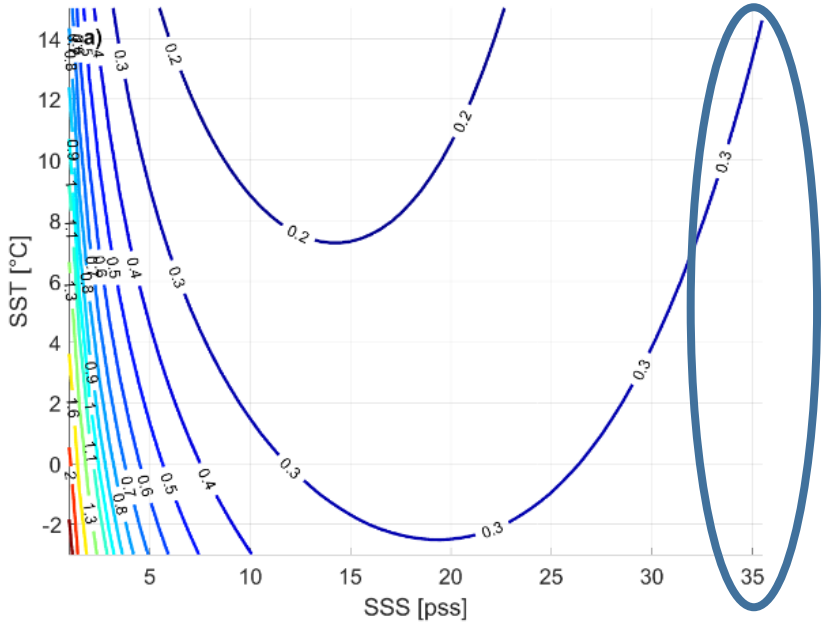
Scenario	Frequencies (GHz)	NeDT†(K)	Tb bias†(K)	σ_{SST} (°C)	σ_{WS} (m.s^{-1})
CryoRad like	**0.4-2 (16 bands)**	0.01-0.5 or **0.35**	**0** or 1	**0.3**	**1**
SMOS like	**1.4 (~200 Multiangular (0-60°) Tb in full polarization)**	**Same as SMOS center dwell line (1.9 K at boresight)**	**0** or 1	**0.3**	**1**

See details in Boutin et al. 2026, submitted to RSE, Accessible on https://doi.org/10.2139/ssrn.6161428

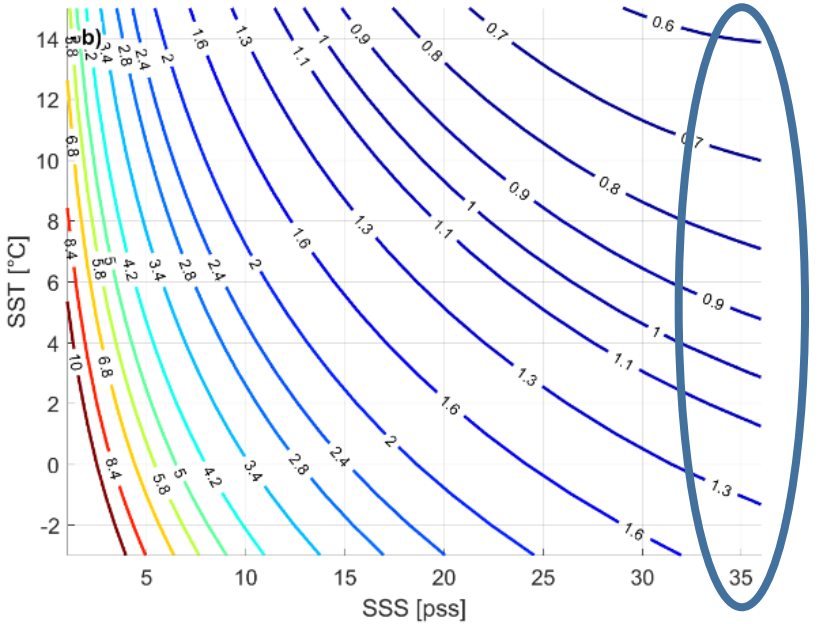
Uncertainties ~0.3pss over 15-35pss SSS range

A decrease by a factor ~ 2-3 in cold salty waters wrt SMOS-like configuration

Wideband (~CryoRad)



SMOS like

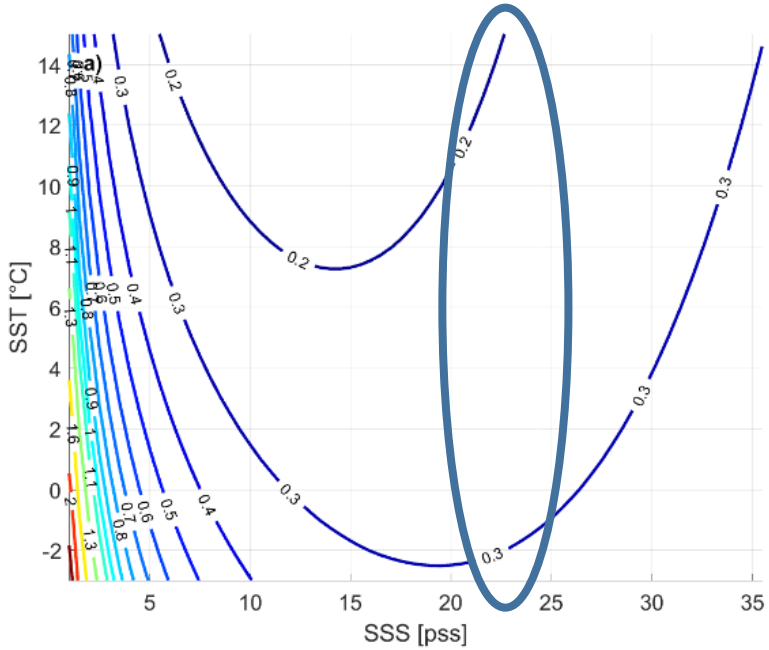


Boutin et al. 2026, submitted to RSE

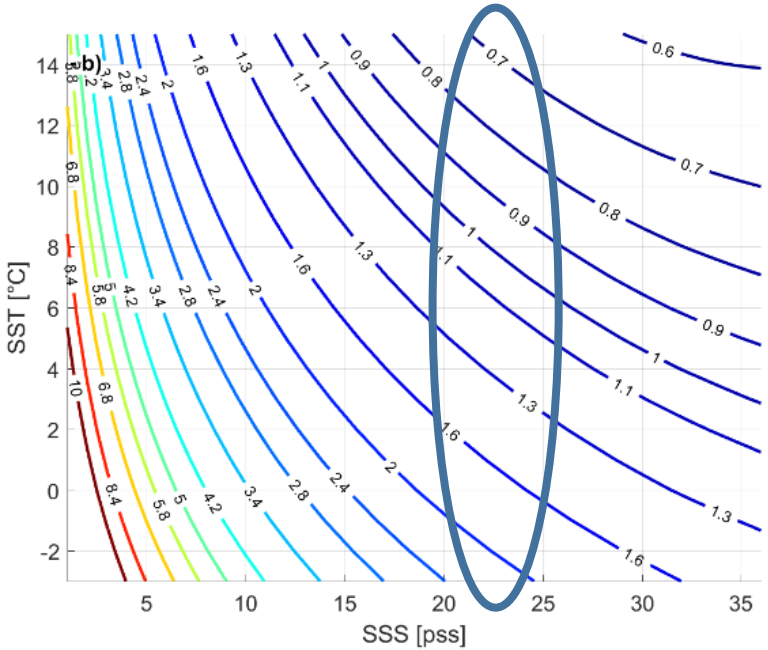
Uncertainties ~0.3pss over 15-35pss SSS range

A decrease by a factor ~ 4-5 in cold and low salinity waters wrt SMOS-like

Wideband (~CryoRad)



SMOS like



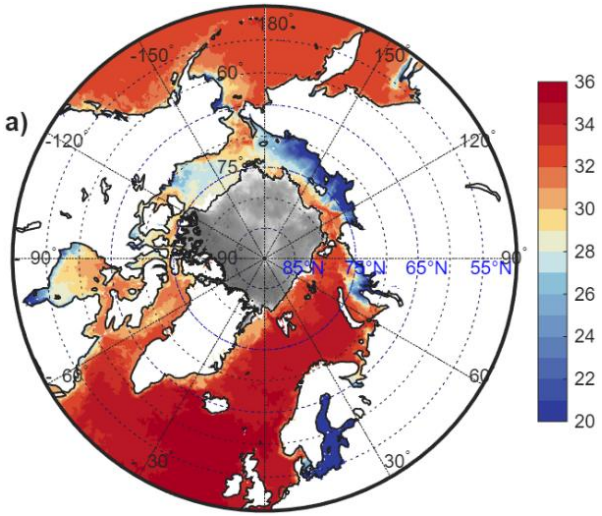
Boutin et al. 2026, submitted to RSE

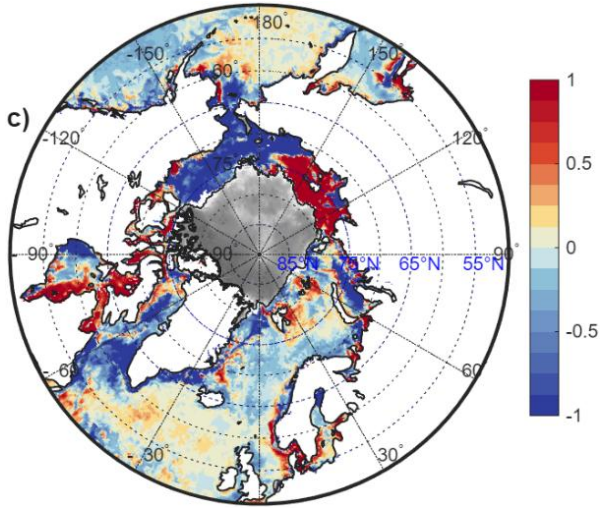
Simulations with realistic scenes

SSS (GLORYS reanalysis)

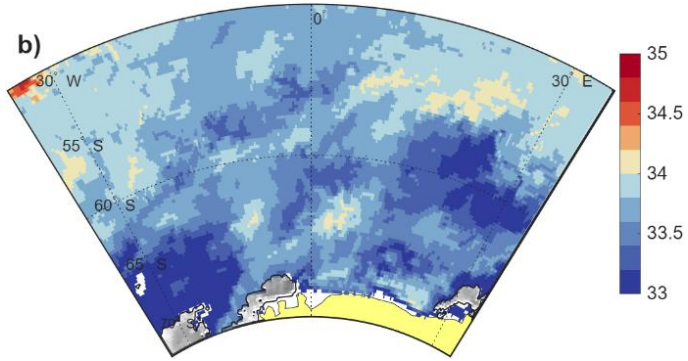
SSS anomalies
(climato 1993-2016)

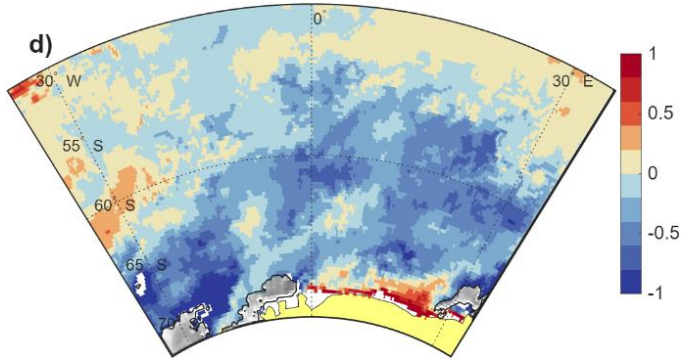
1st September 2024
North Polar





1st January 2022
(Southern Atlantic Ocean)





Boutin et al. 2026, submitted to RSE

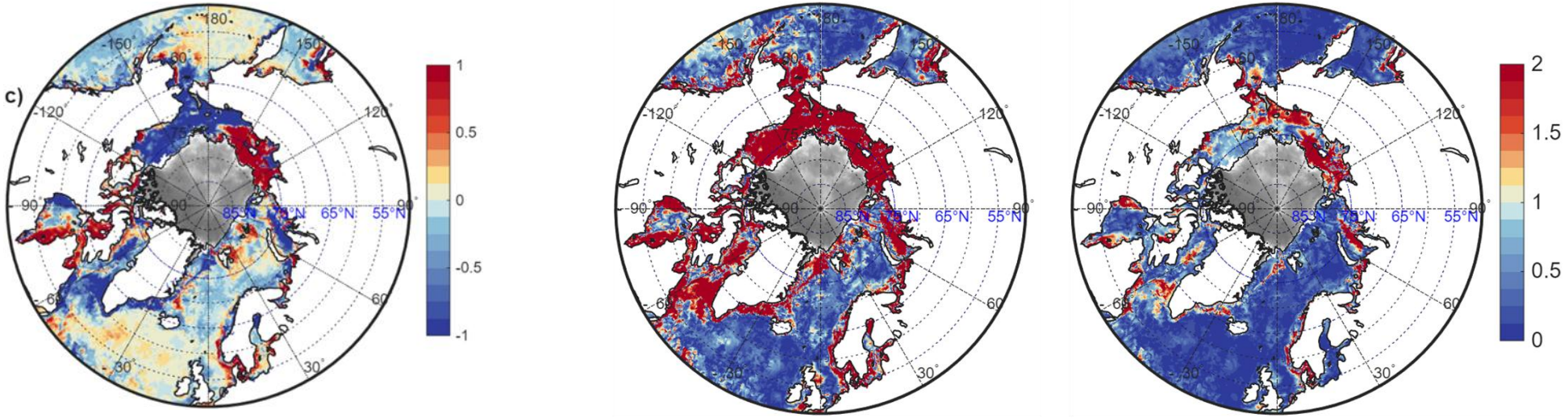
Signal to Noise Ratio = SSS anomaly/SSS uncertainty

SSS anomalies

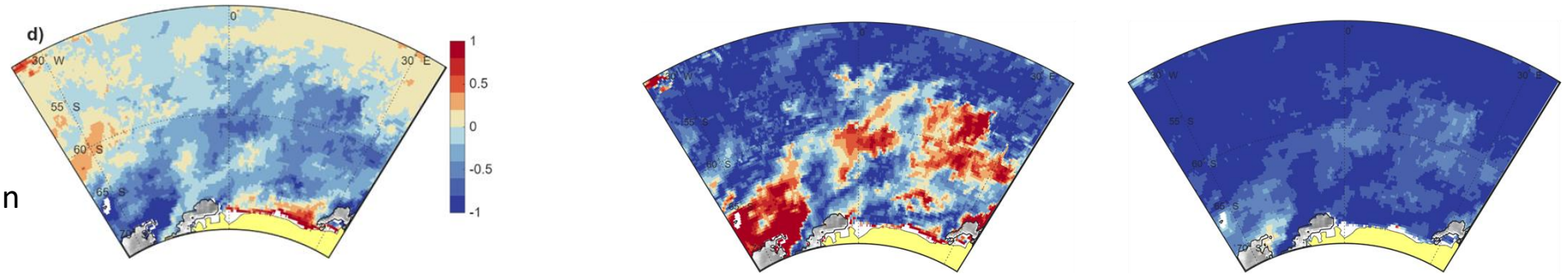
SNR – Wideband

SNR – SMOS-like

1st September 2024
North Polar



1st January 2022
Southern Atlantic Ocean



Boutin et al. 2026, submitted to RSE

Summary and Perspectives

- Advantages of CryoRad concept with respect to current satellite SSS:
  - Increased sensitivity to SSS in cold waters
    - Improved detection of SSS variability
    - Decreased impact of radiometer calibration issues
  - Increased sensitivity to low to moderate SSS (10-25pss)
    - Freshwater lenses

See more in Boutin et al. 2026, submitted to RSE, Accessible on https://doi.org/10.2139/ssrn.6161428

- Definition of mission characteristics and technical solutions under study

ESA EE12 User Consultation Meeting: 7-8th July 2026

https://atpi.eventsair.com/ee12ucm/