Monitoring the Arctic Ocean Freshwater changes from space with SMOS mission

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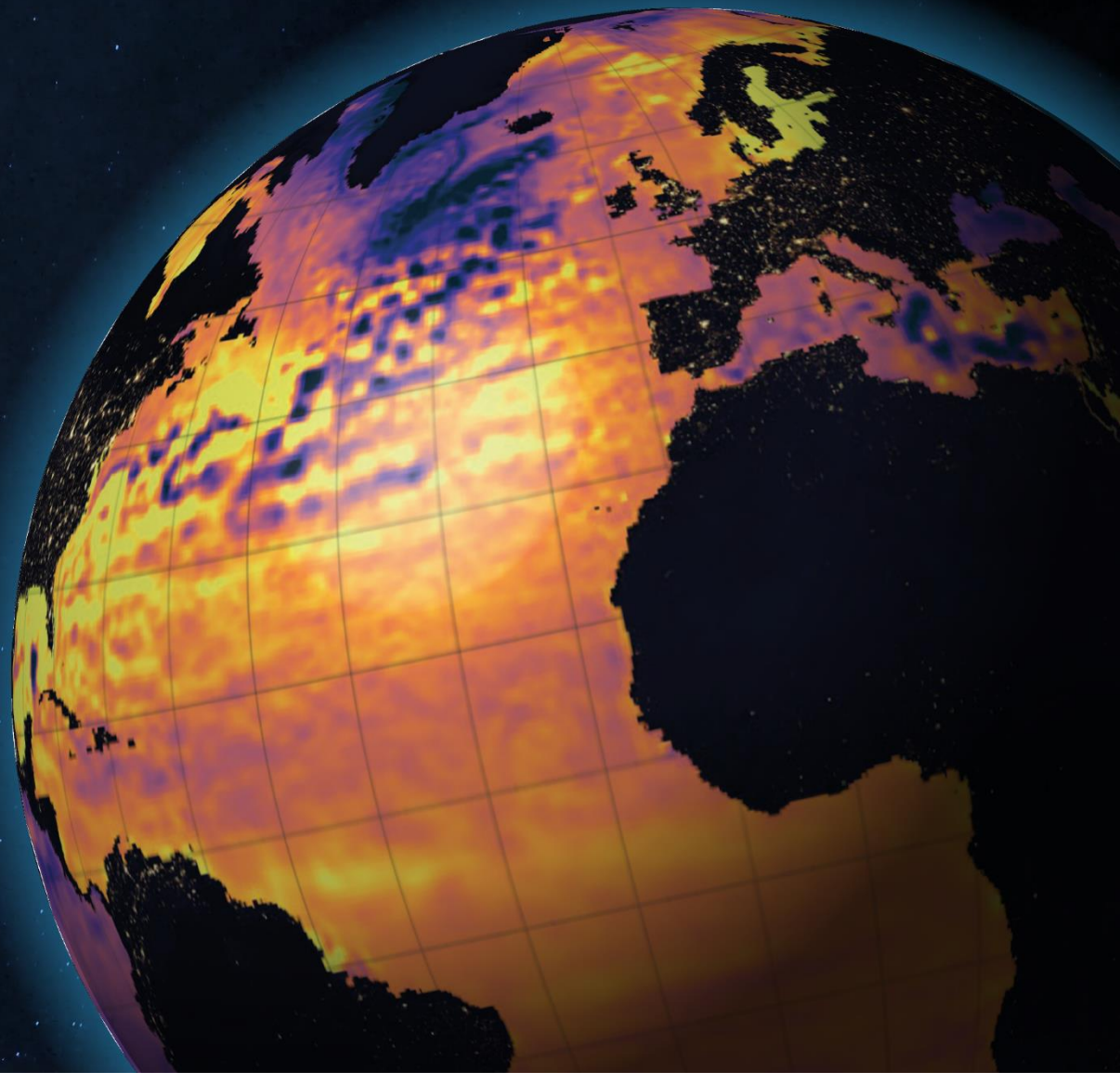

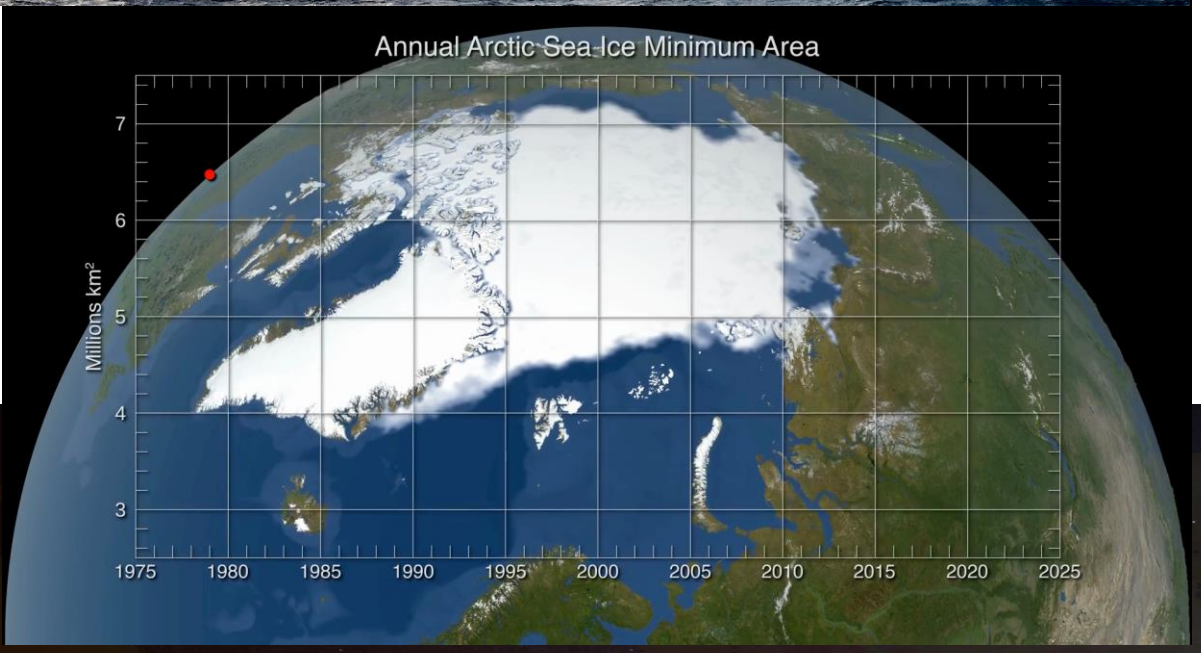

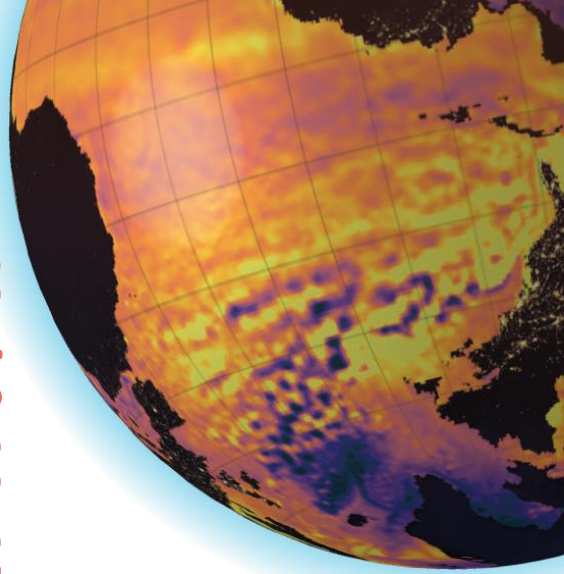

Rapid Arctic warming, causing significant hydrographic changes:

sea ice retreat

freshening

altered ocean currents

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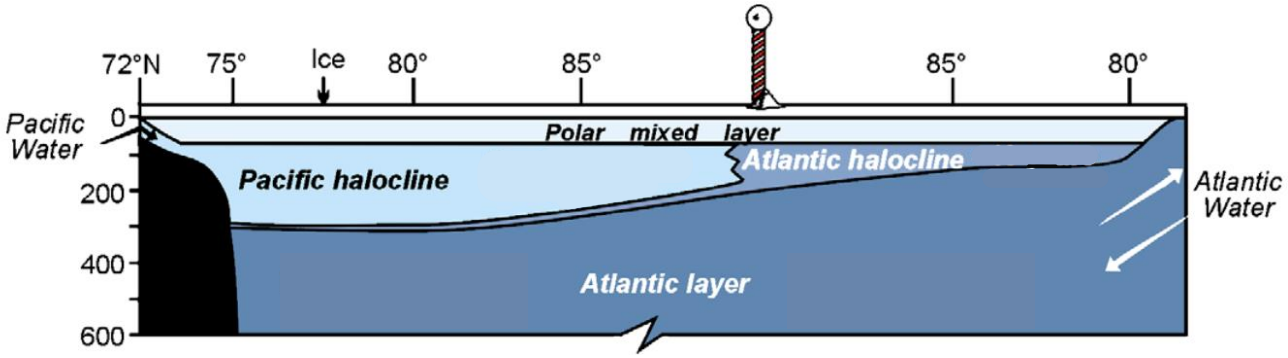
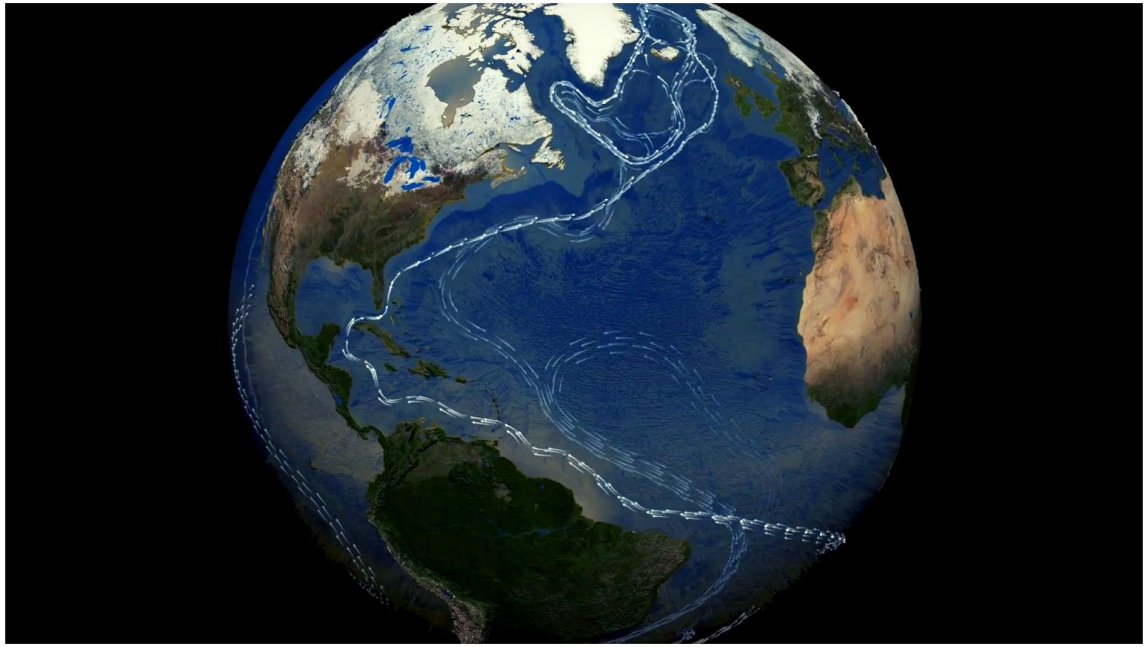
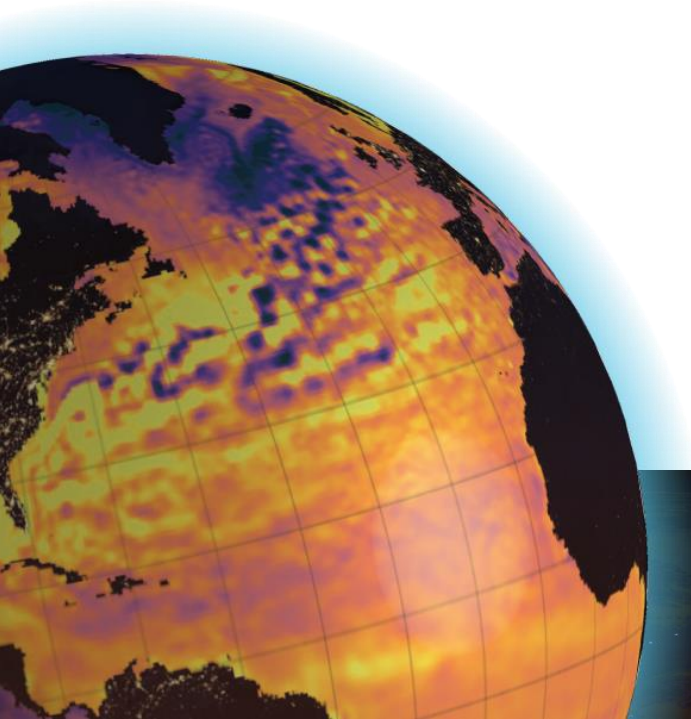
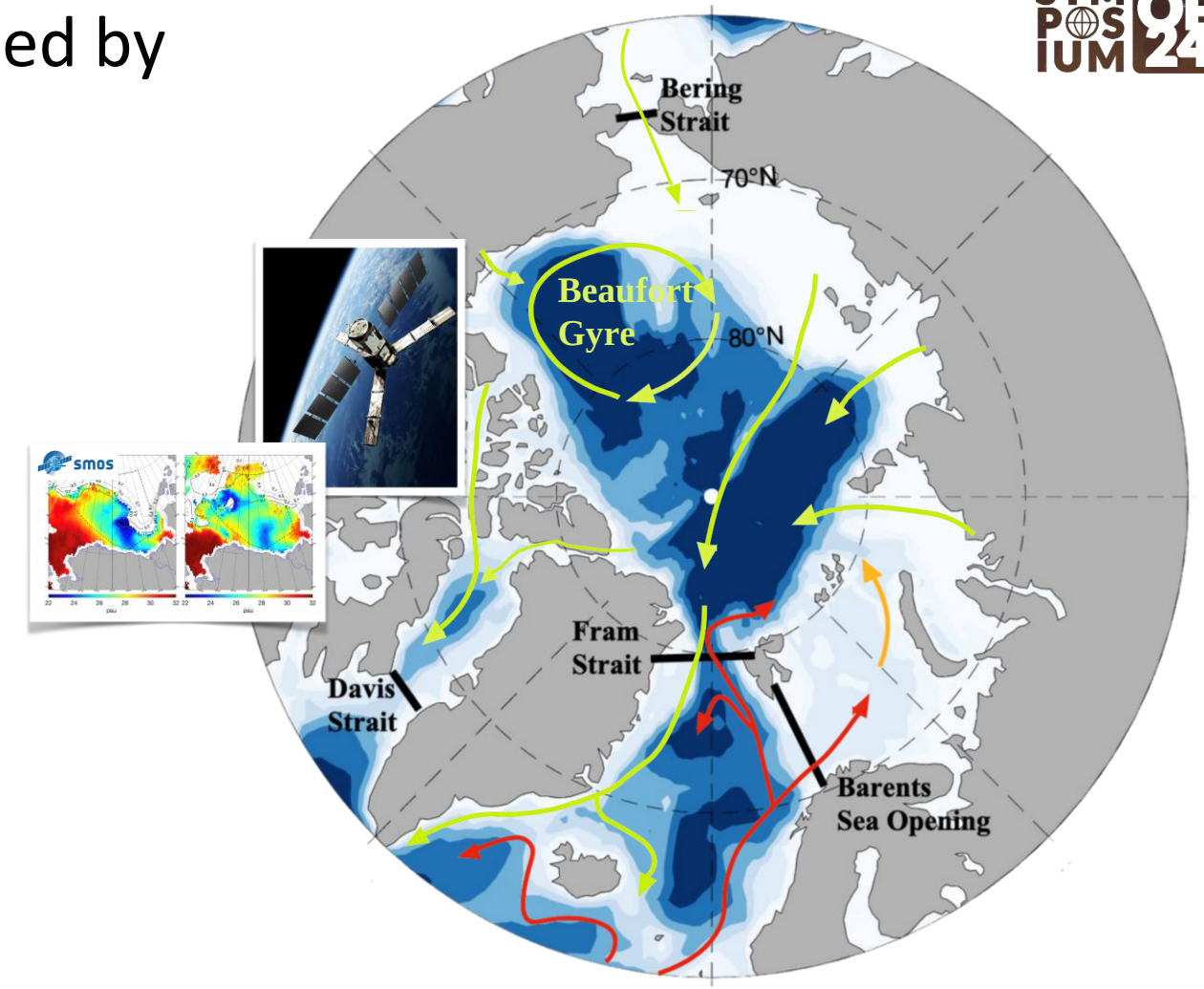


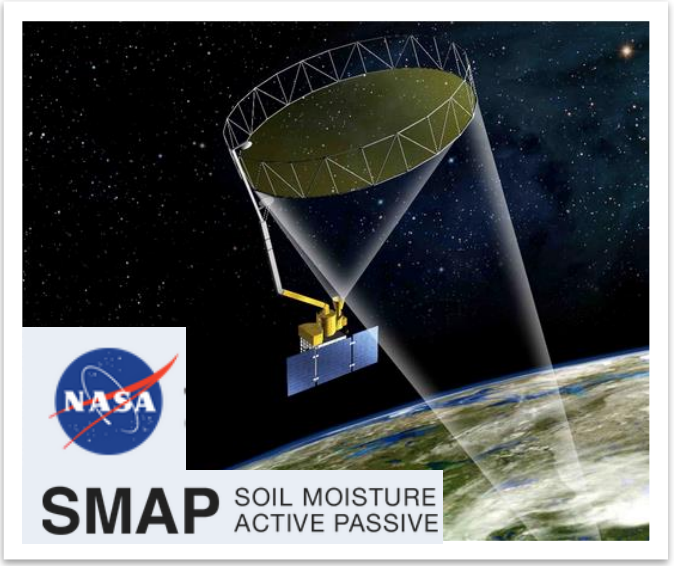


Hydrographic changes in the Arctic intensify water stratification potentially destabilizing Earth's thermohaline circulation, with enormous socio-economic and climate impacts, especially in Europe.

Freshwater understanding is limited by **data scarcity** and **ocean model uncertainties**







2010 — 2015 — 2028

L-band radiometers measure ocean emissivity that depends on water conductivity (SSS)

Salinity is directly related to freshwater

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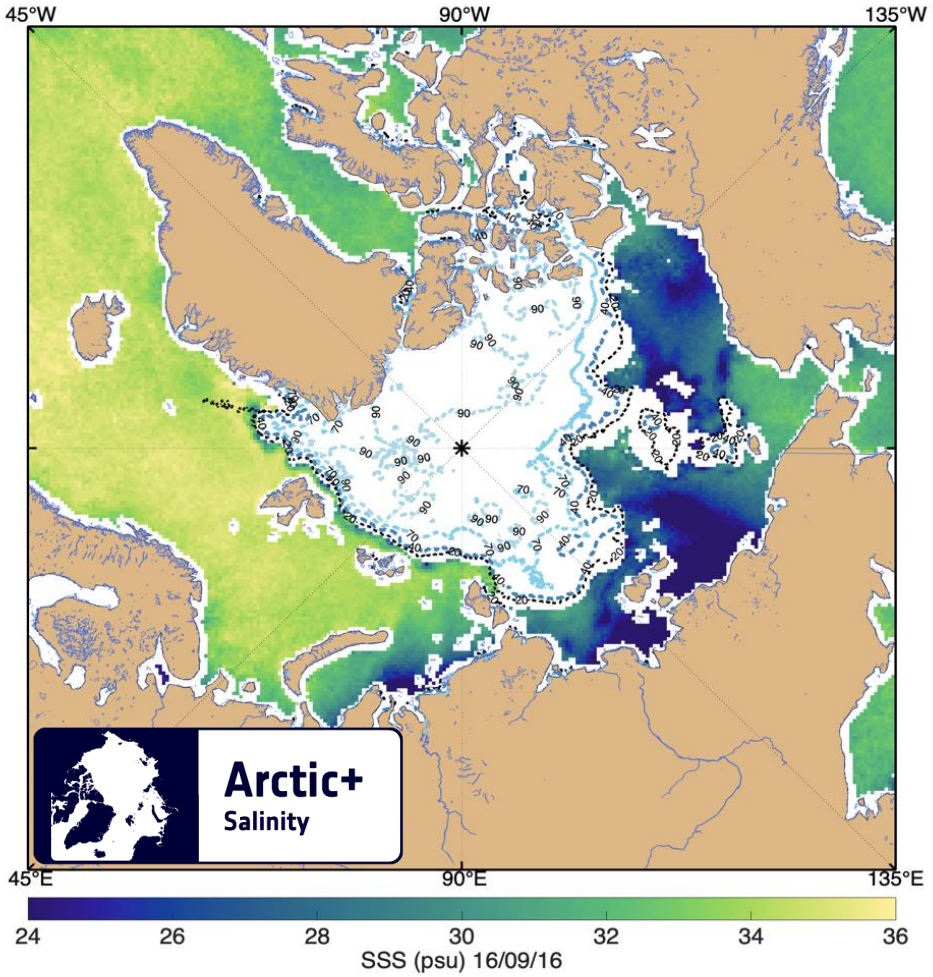
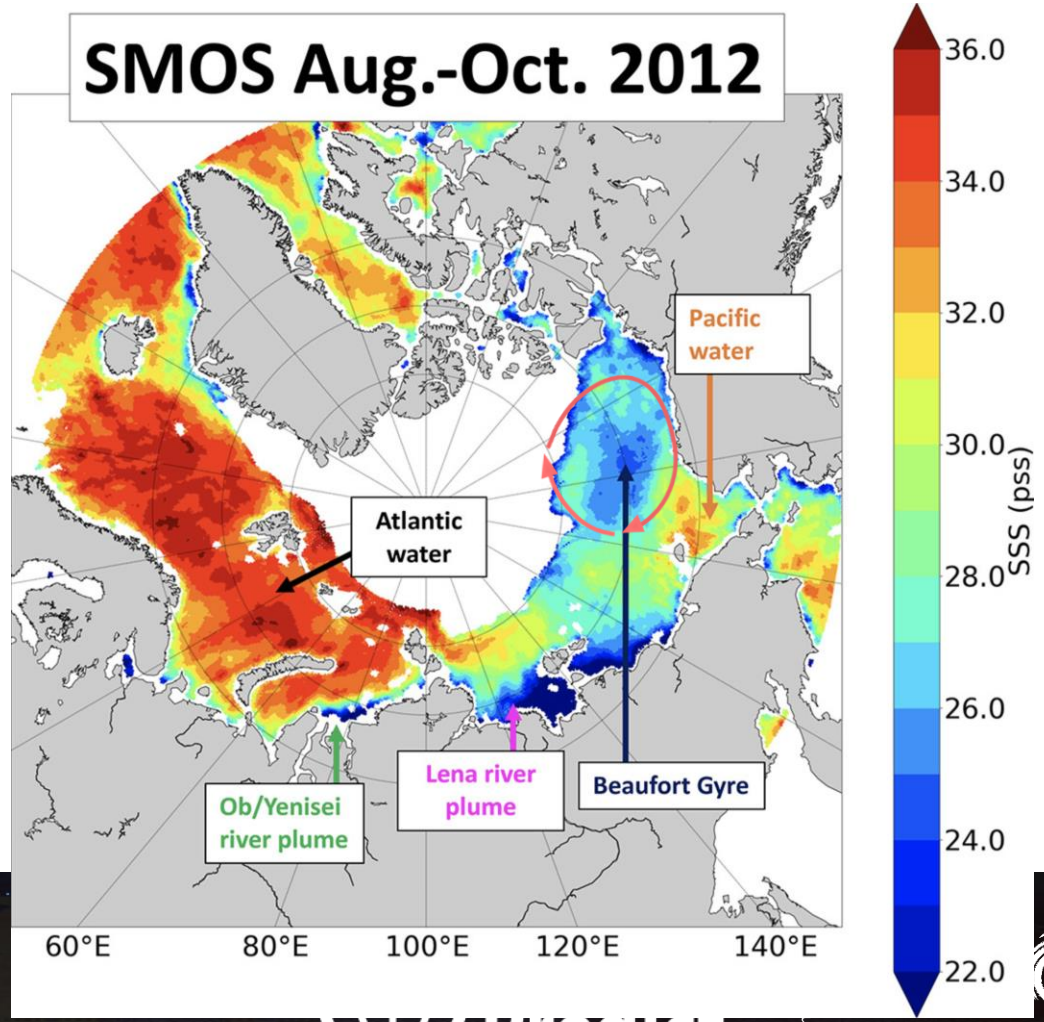
Satellite sea surface salinity products

ESA - ESL BEC (CSIC)
Martinez et al., 2021

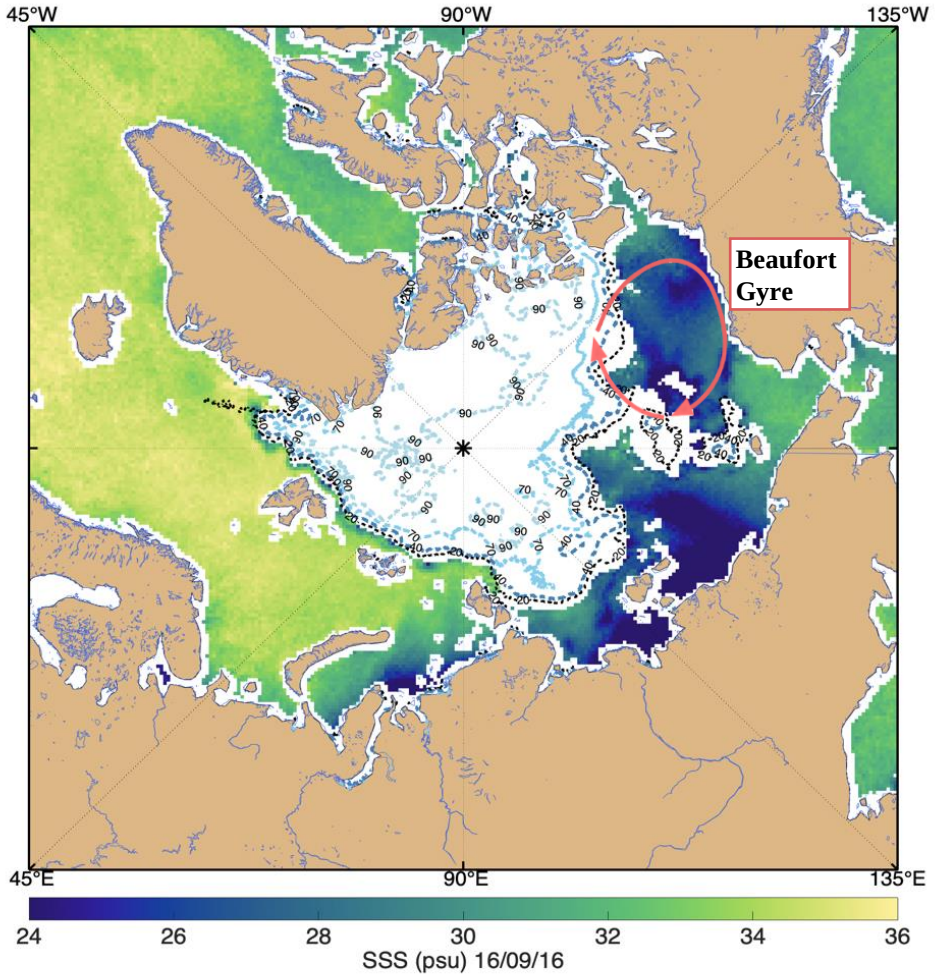


ESA – ESL CATDS (CNES)
Supply et al., 2020



Salinity of the Beaufort Gyre

Surface Salinity
SMOS BEC v3.1

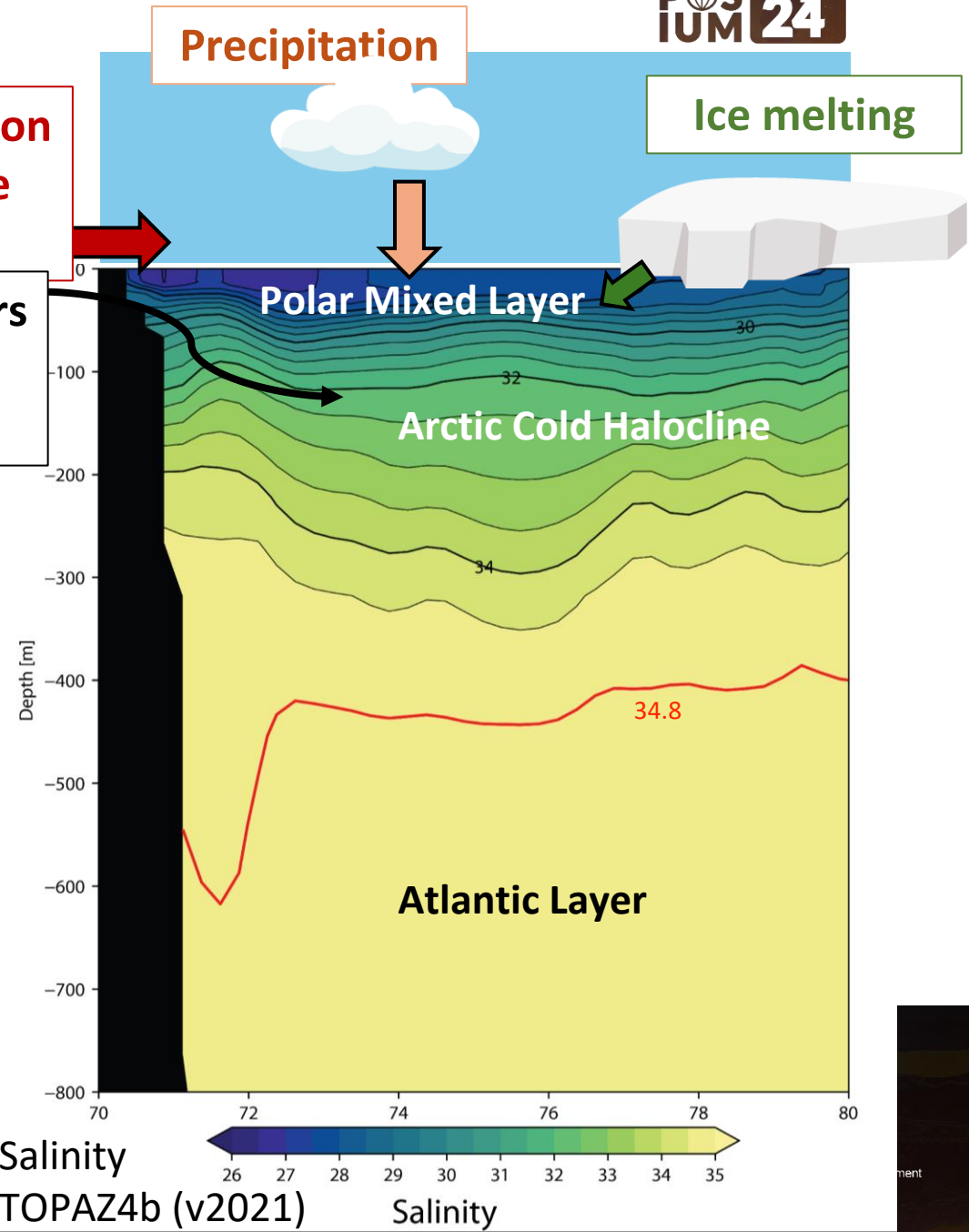


Mackenzie & Yukon rivers discharge

Pacific Waters Inflow

Precipitation

Ice melting



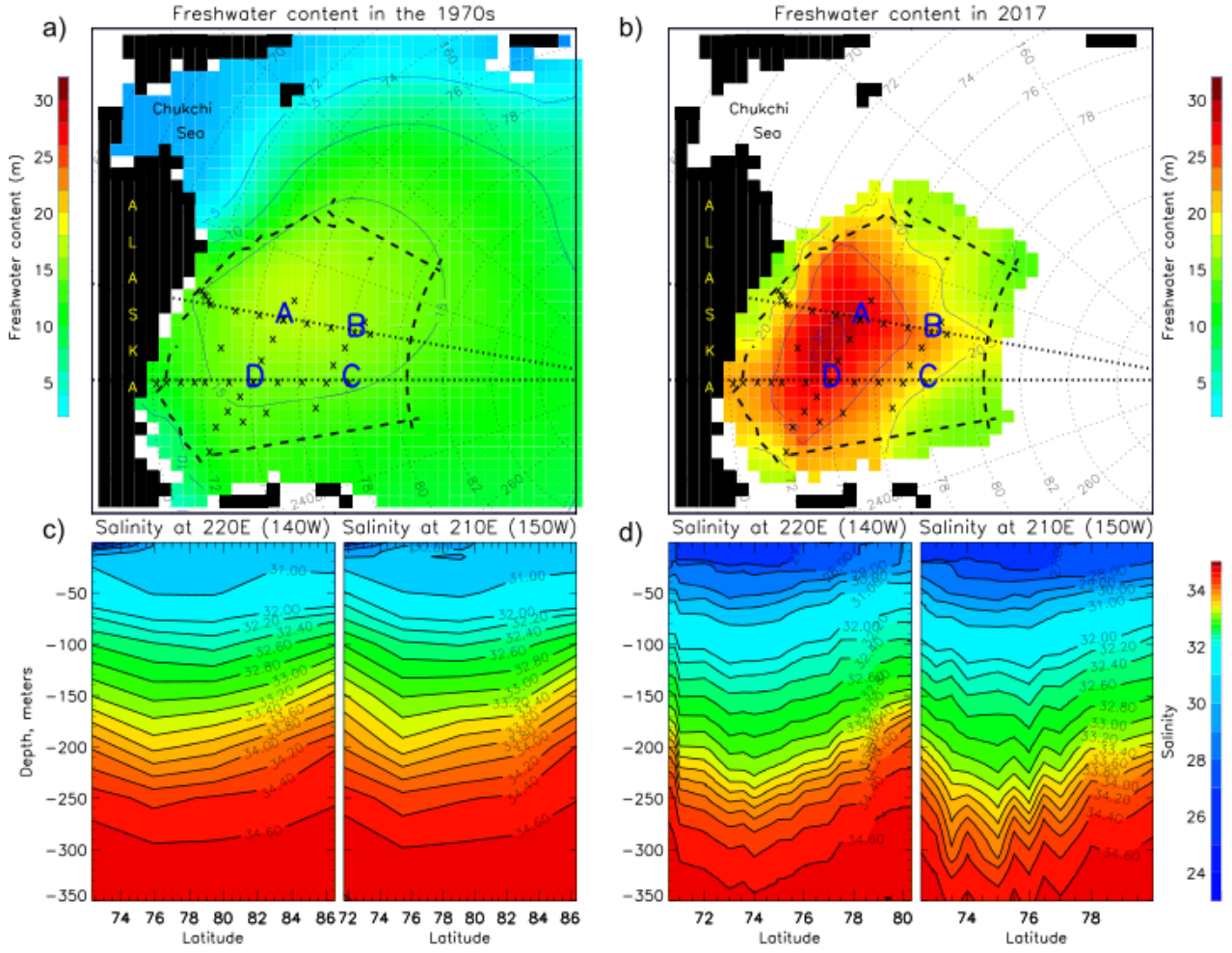
Salinity
TOPAZ4b (v2021)

Freshwater is intimately related with ocean salinity

$$FWC = \int_{Z=0\,\mathrm{m}}^{Z(S_{\mathrm{ref}})} \frac{S_{\mathrm{ref}} - S(z)}{S_{\mathrm{ref}}}\, dz; \qquad S_{\mathrm{ref}} = 34.8\,\mathrm{psu}$$

After the FWC increase observed during 2003-2018; the BG has transitioned to a **quasi-stable state** (*Lin et al. 2023*)

WHOI In-situ hydrographic data



Proshutinsky et al., 2019

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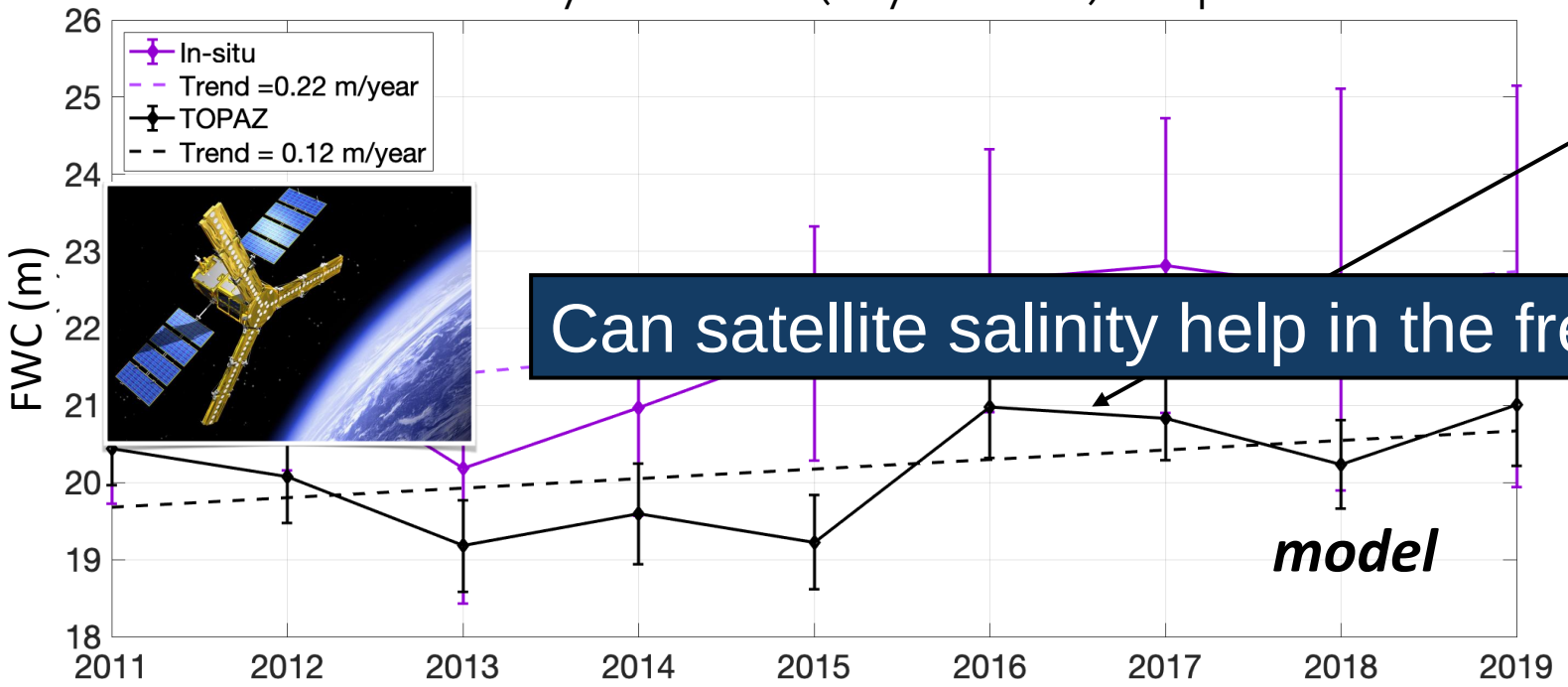
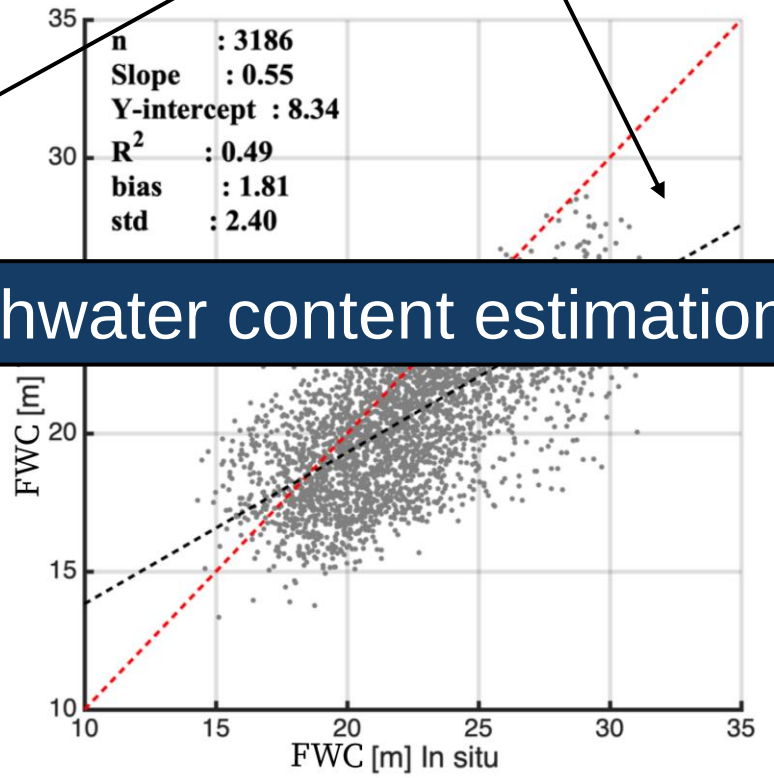
Reanalysis versus In-situ hidrographic data

Model underestimation

Yearly mean FWC (July-October) comparison in the BG



Can satellite salinity help in the freshwater content estimation?

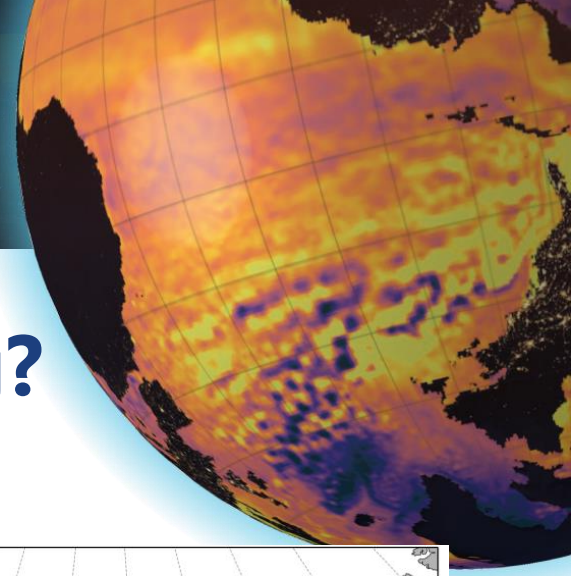


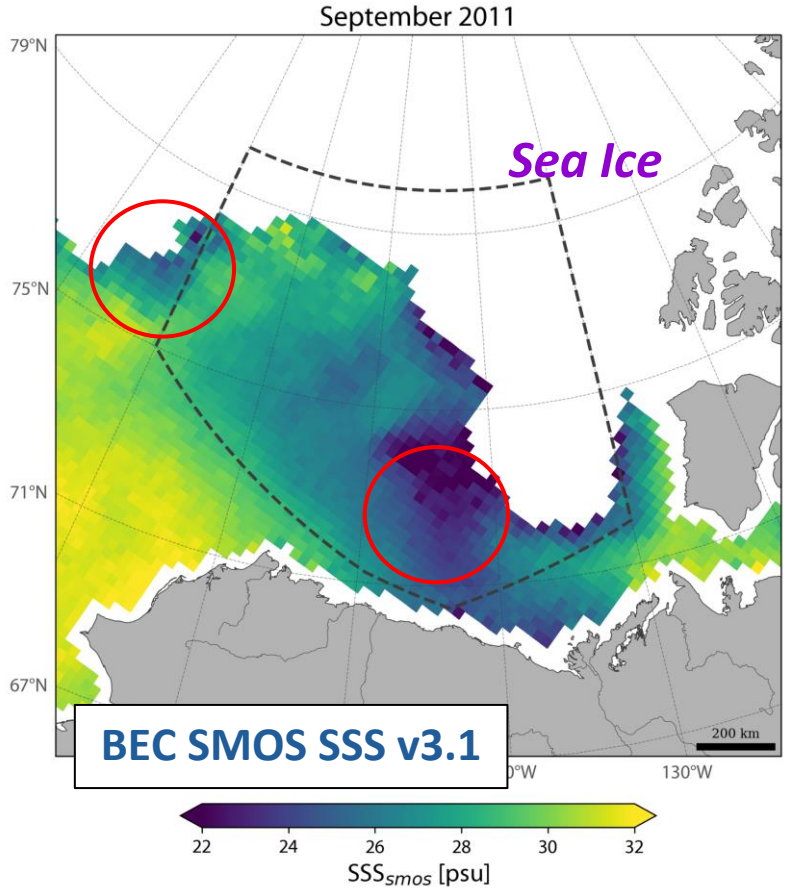
NERSC NANSEN ENVIRONMENTAL AND REMOTE SENSING CENTER

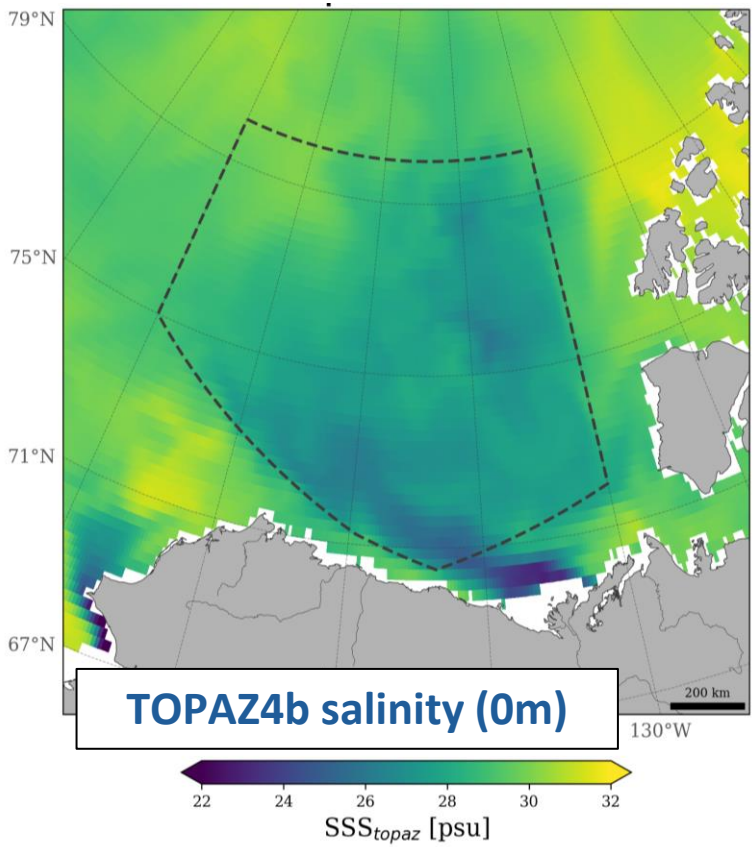
Reanalysis model
TOPAZ4b (v2021)

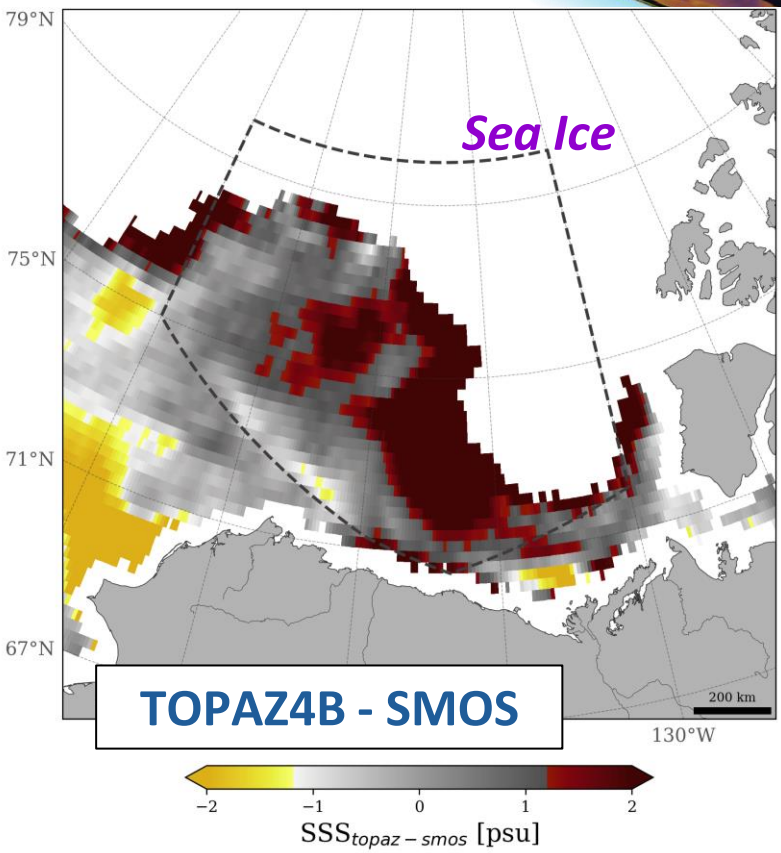
M. Umbert, E. De-Andrés et al. 2024

Underestimation of surface freshening?

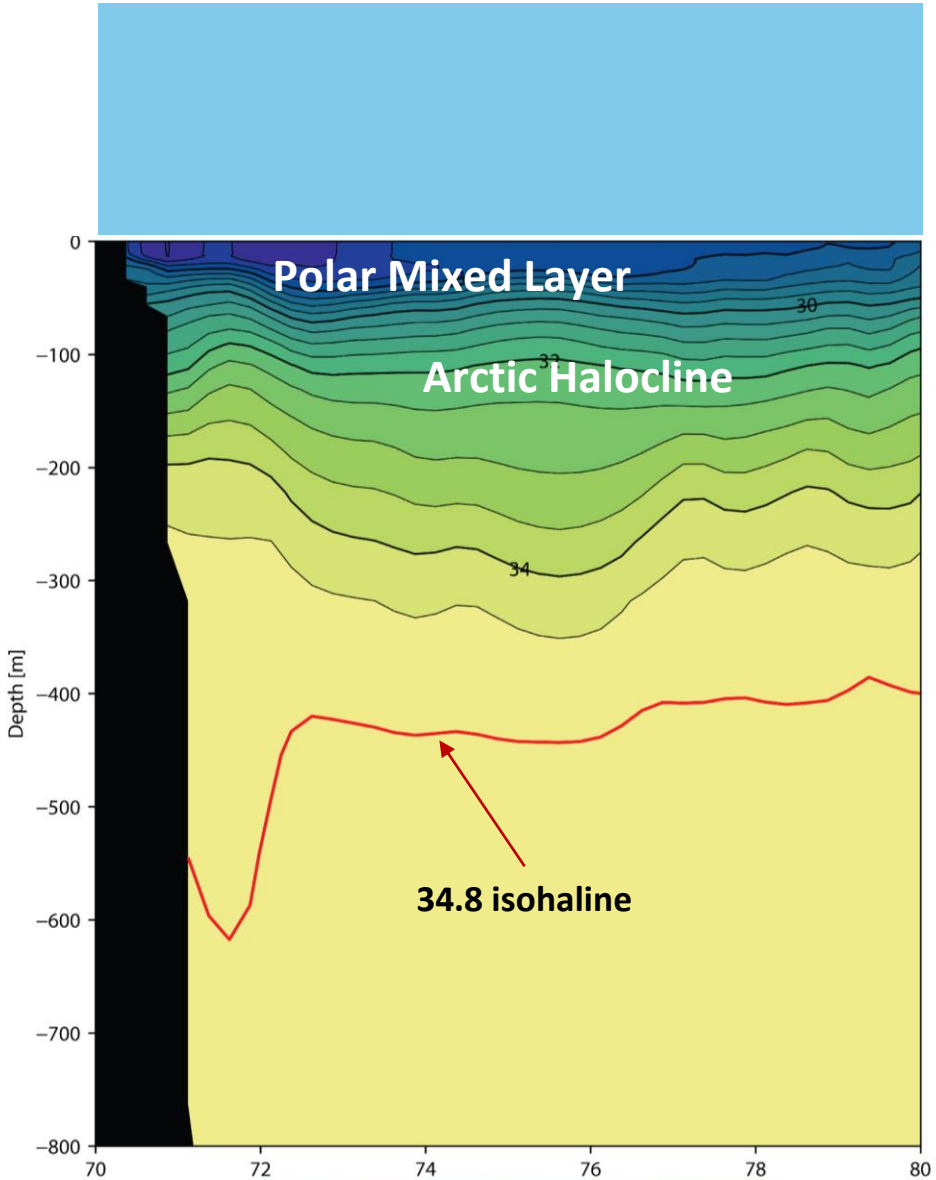


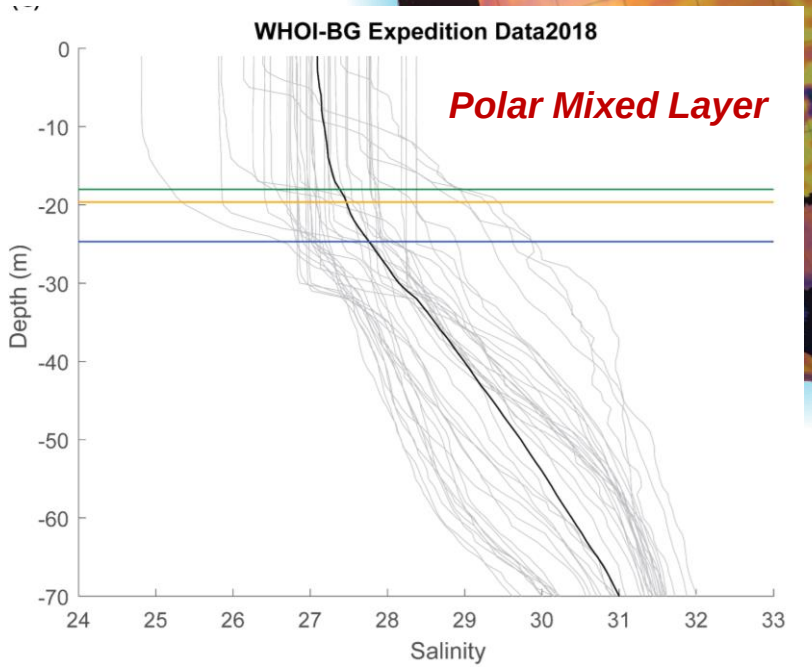


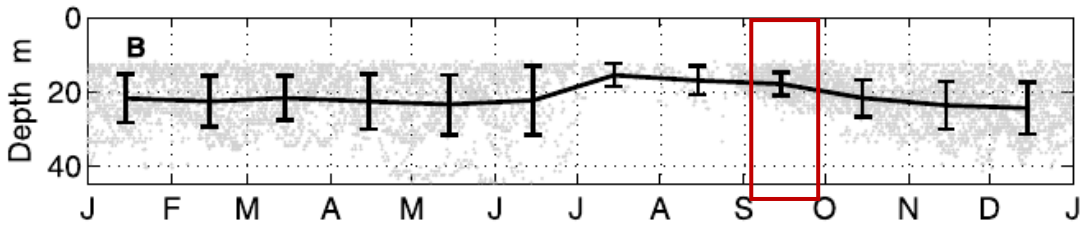




Adding satellite salinity in the Polar Mixed Layer







Toole et al., 2010

TOPAZ4b (v2021)

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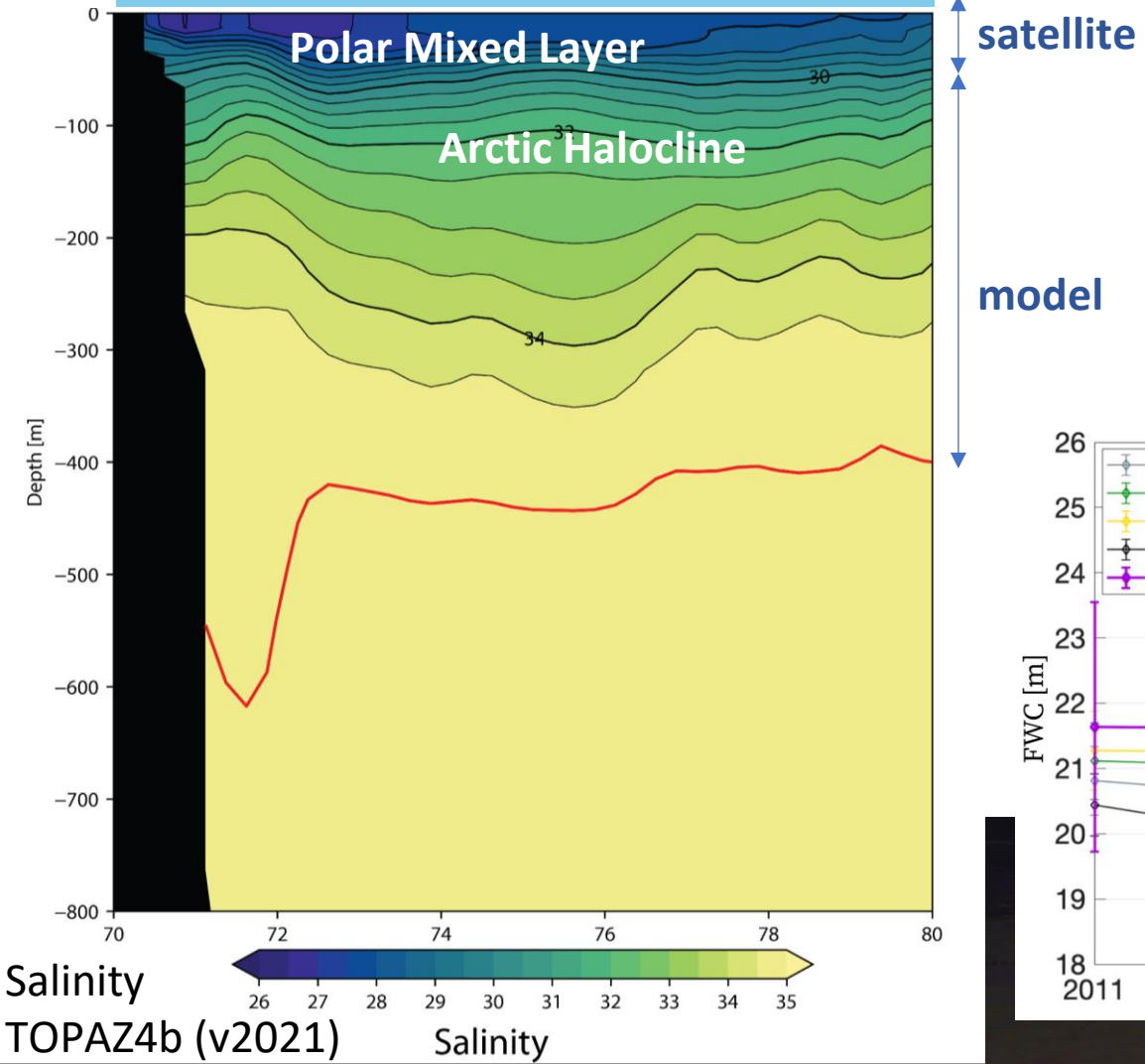
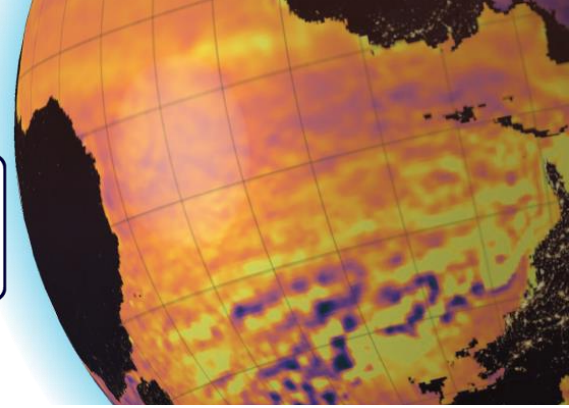
Adding satellite salinity in the Polar Mixed Layer



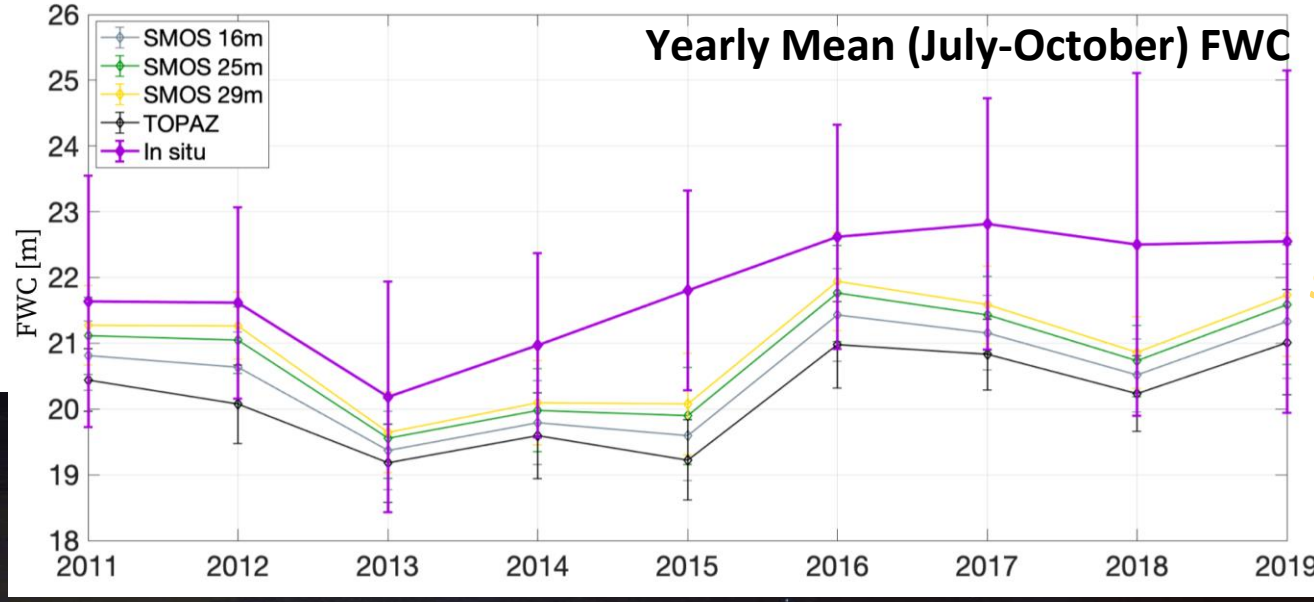
TOPAZ4b (v2021)

Arctic+ Salinity



FWC bias reduction 30-70% when adding satellite salinity

M. Umbert, E. De-Andrés et al. 2024, Ocean Sciences



in-situ

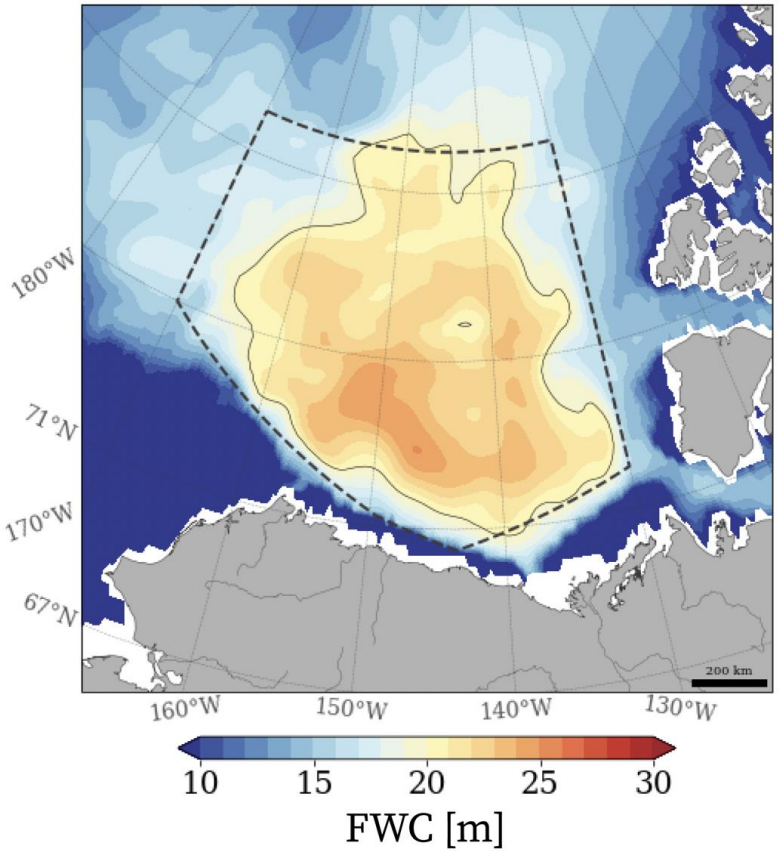
satellite

model

Adding satellite salinity in the Polar Mixed Layer

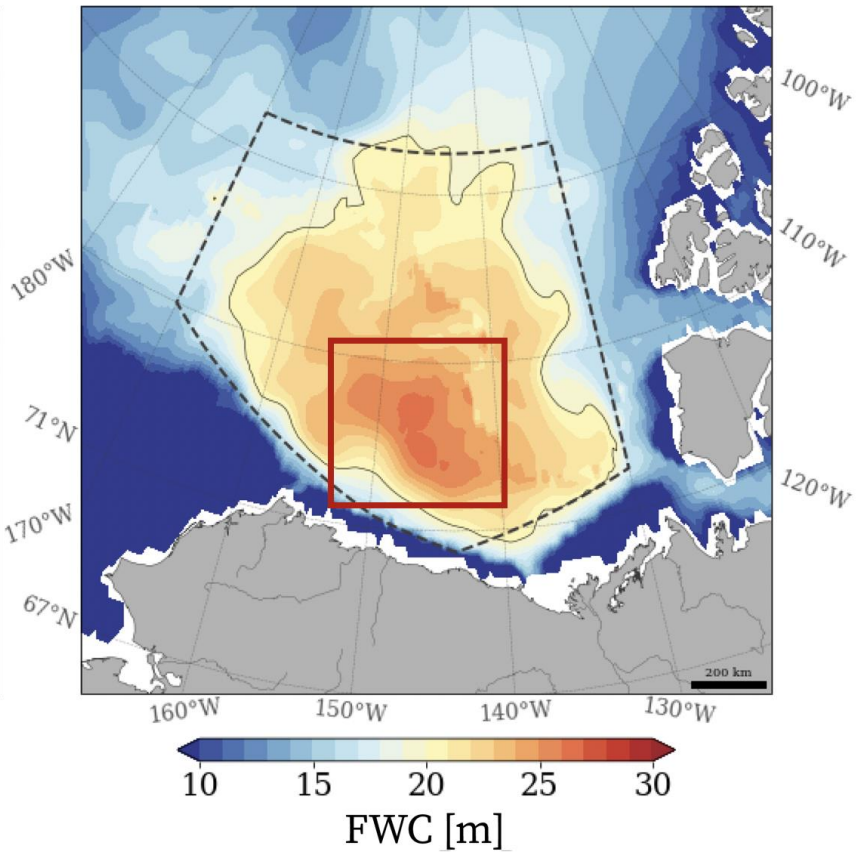
TOPAZ4b

September 2011

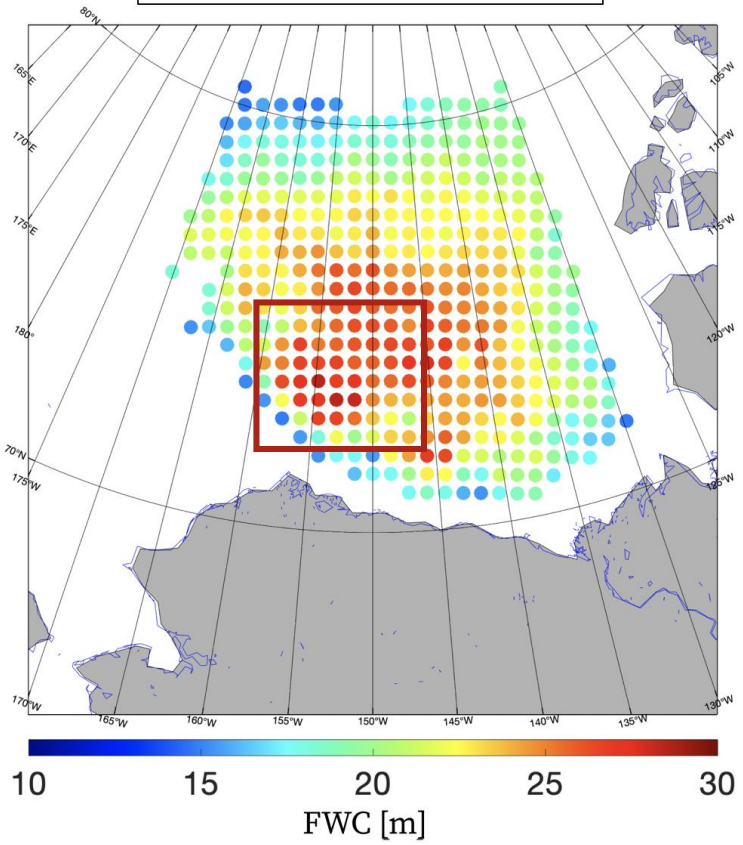


SMOS (25m) + TOPAZ4b

September 2011

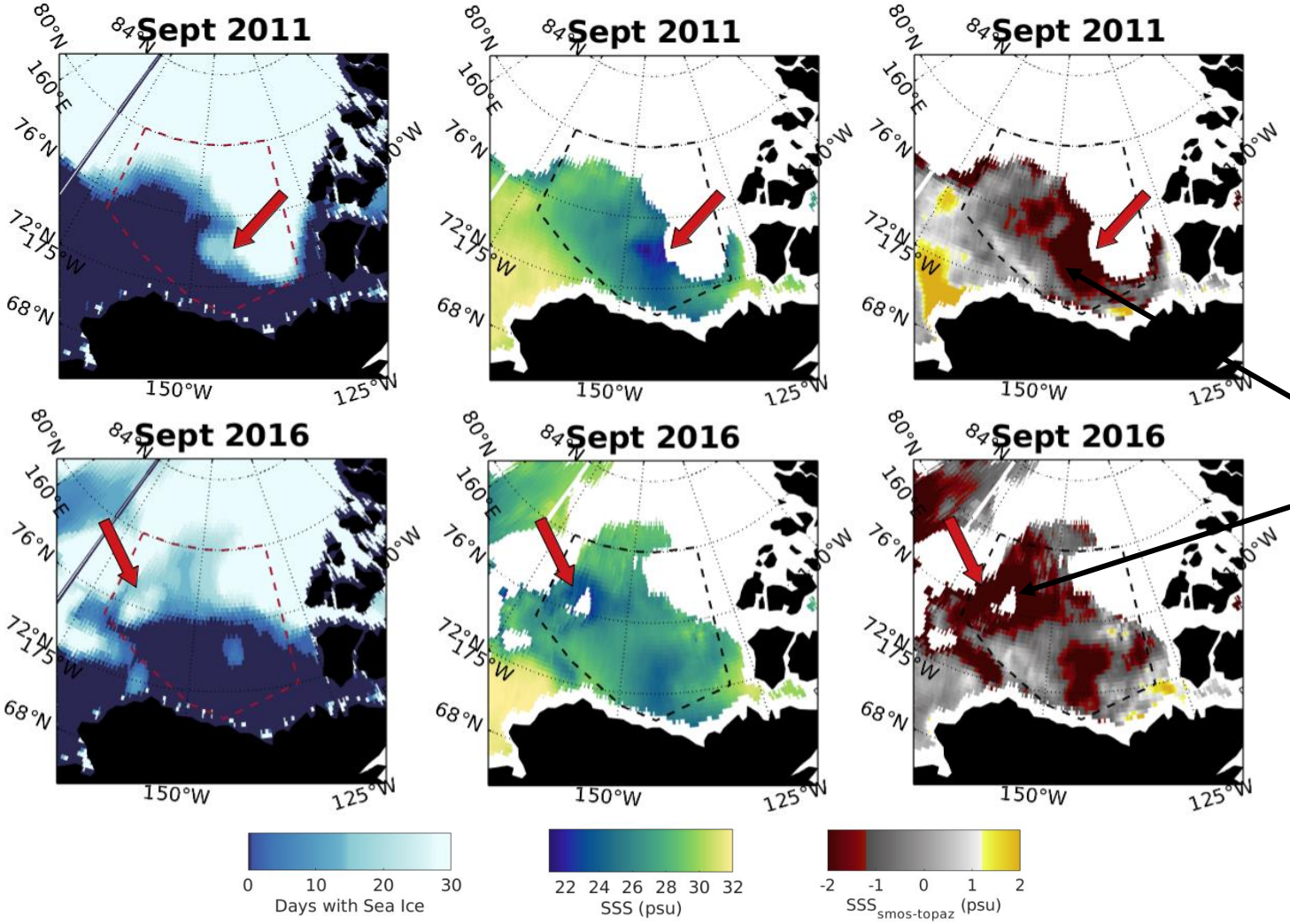


In-situ data



M. Umbert, E. De-Andrés et al. 2024, Ocean Sciences

Melted ice water detected in SMOS salinity



Over the 2011-2019 period, SMOS detects fresh **melting water lenses**.

Off-shore freshening close to ice edges, where sea ice just melted

Near the sea-ice edge (19-25 psu)

E. De-Andrés, M. Umbert et al. 2024 [in revision in JGR Oceans]

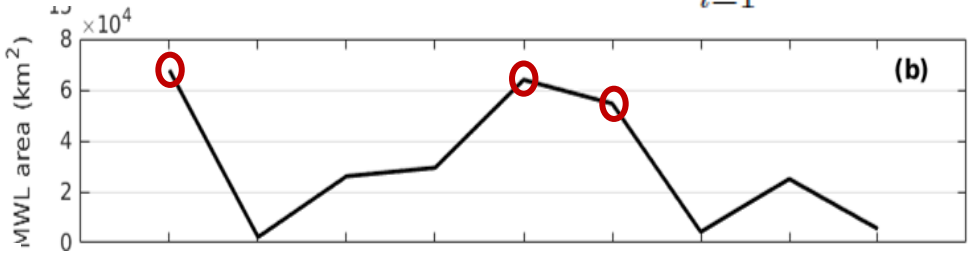
Meltwater lenses detected in SMOS salinity

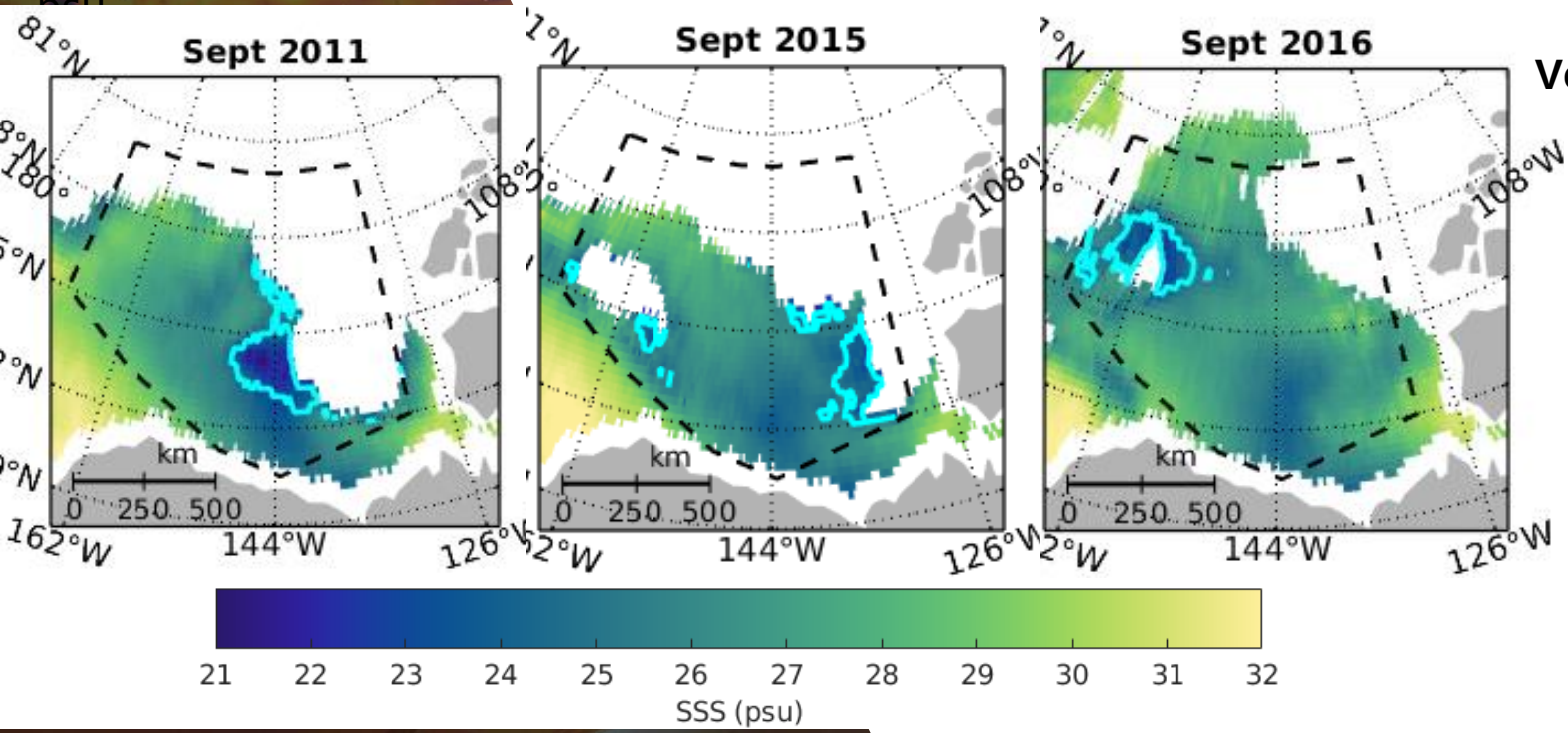
Meltwater lens is defined when a grid cell meet two criteria:

1) The number of days covered by sea ice (OSISAF SIC > 10%) must range between 2 to 29 days.

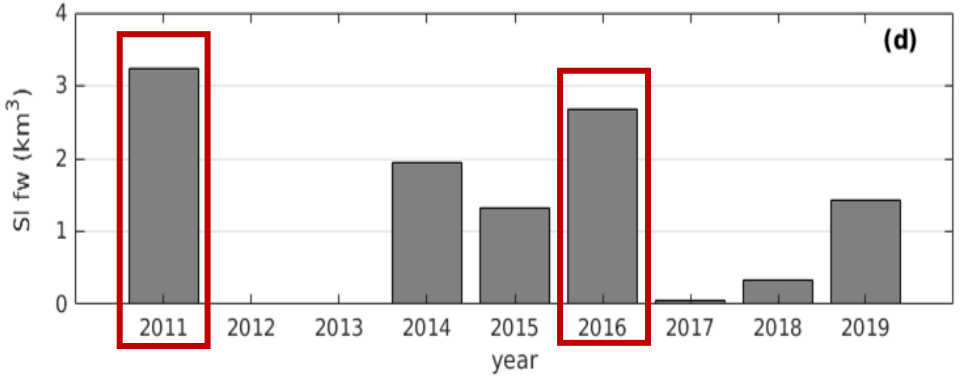
2) Monthly SSS mean values must be less or equal than 25

$$V_{fw} = \sum_{i=1}^{N} \alpha_i a_i h_i \frac{\rho_{ice}}{\rho_{fw}},$$

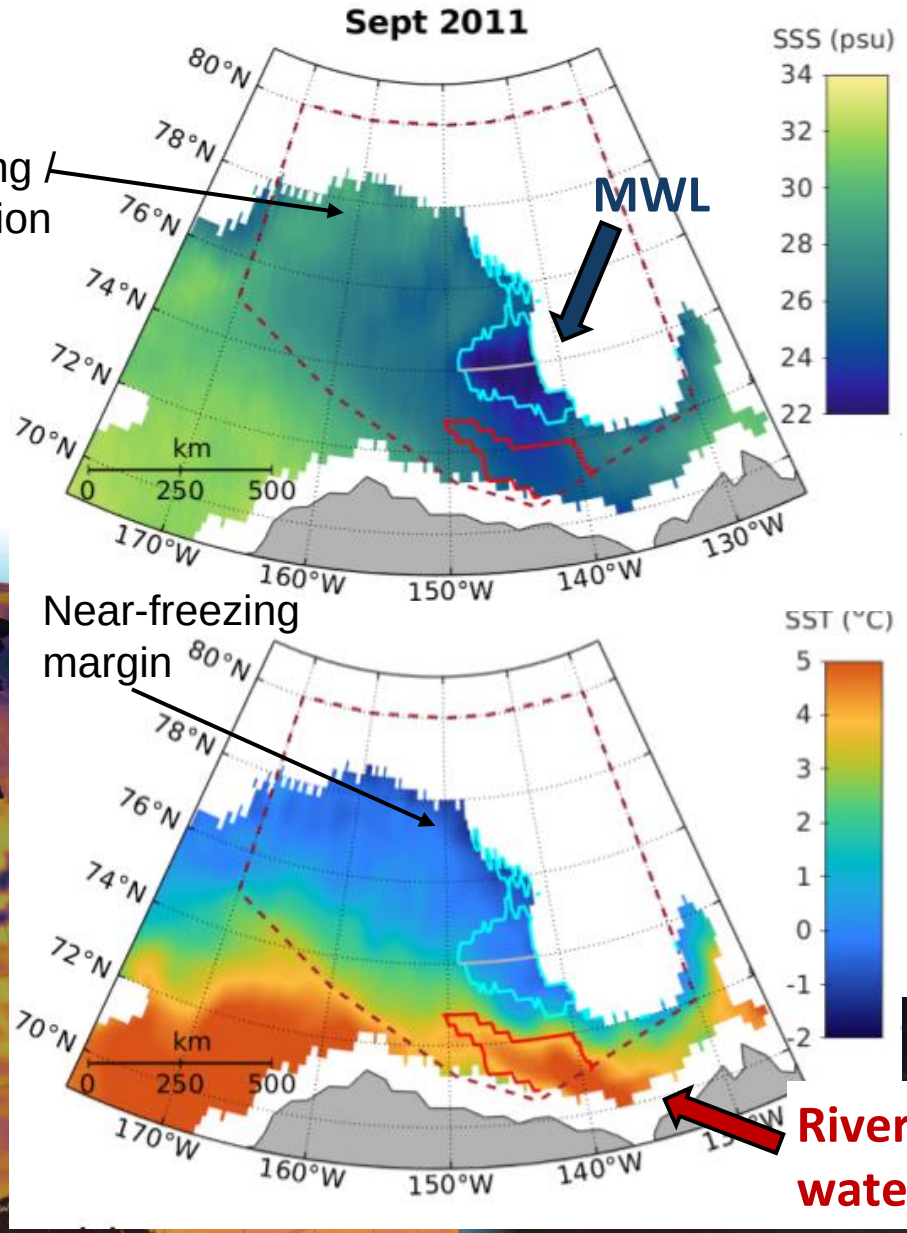




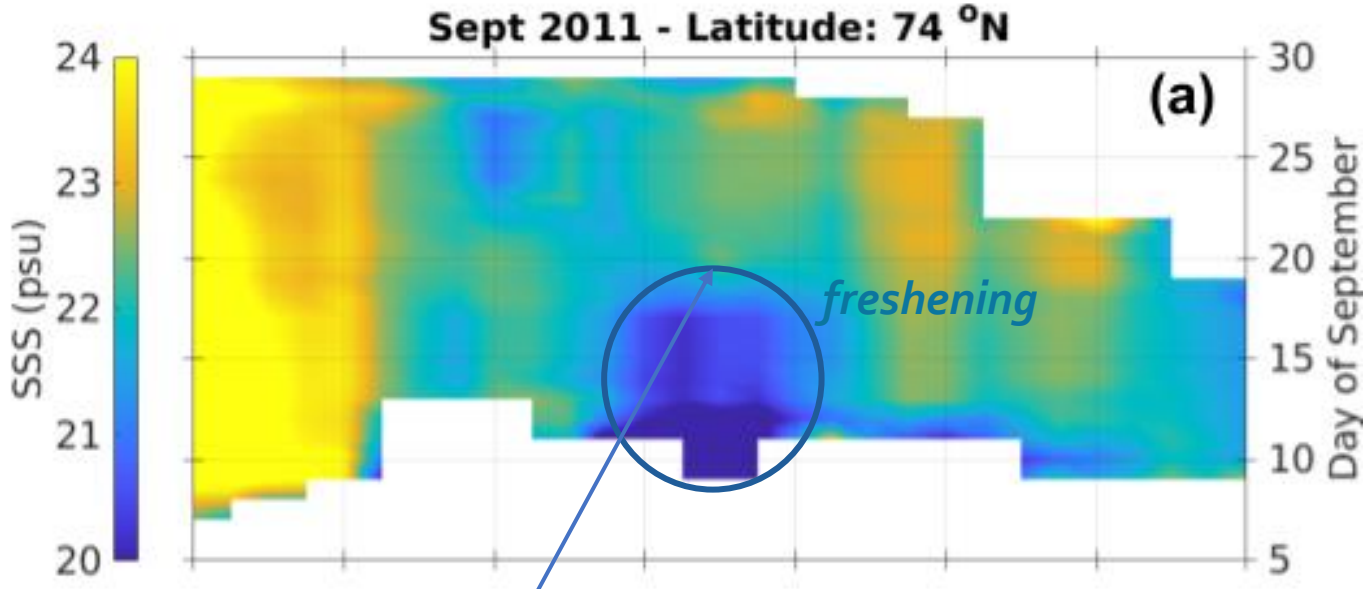
Volume of freshwater released within the MWLs



Melt Water Lens' hydrographic properties



Hovmöller Diagram across latitude transect within the MWL:



Expanse of fresh and low-density water in time (>10 days). Low wind stress contribute to preserve SSS imprint

E. De-Andrés, M. Umbert et al. 2024 [in revision in JGR Oceans]

Key messages

- ✓ **Satellite salinity** combined with model data **improved FWC estimations in the Beaufort Gyre area**
- ✓ Satellite salinity data allows detecting **freshening events induced by sea ice melting**
- ✓ Further **assimilation of satellite salinity data is advised** to improve ice-ocean models
- ✓ Salinity drives the polar ocean dynamics, we need **better integration in ice-ocean models**

European Research Council
Established by the European Commission

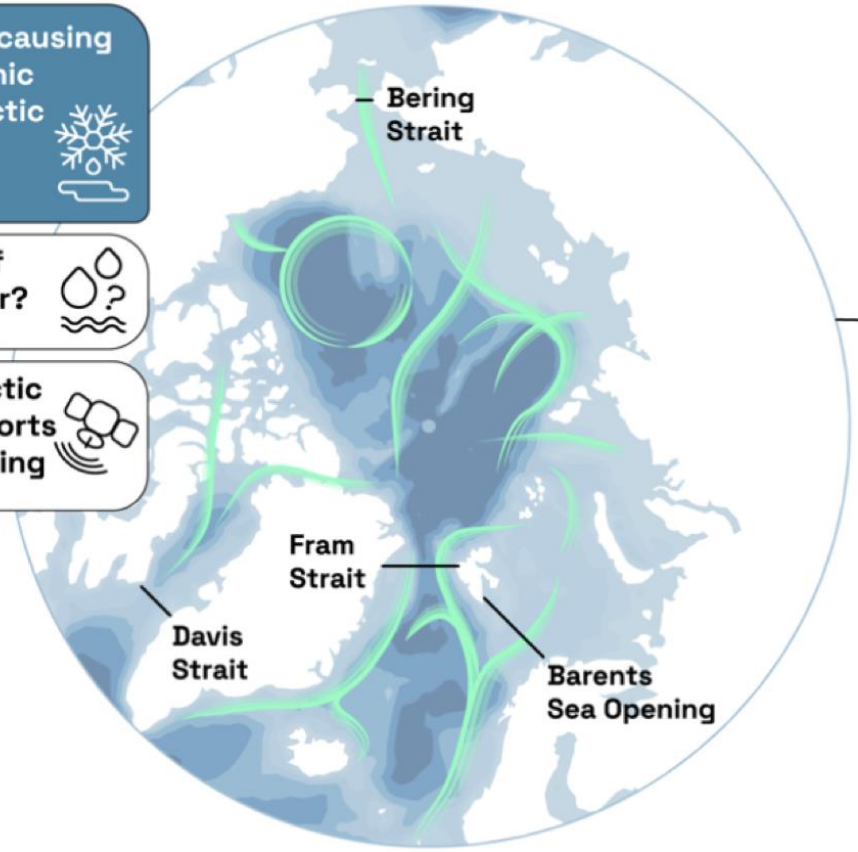
Starting Grant

FRESH-CARE Unraveling FRESHwater and ocean Currents changes in the Arctic using REmote sensing

Global warming is causing severe hydrographic changes in the Arctic Ocean

What is the fate of surging freshwater?

We will unravel Arctic freshwater transports using remote sensing



1. Develop a novel AI methodology to characterize 4D ocean currents
2. Quantify freshwater transports through the main Arctic Ocean gateways
3. Simulate future freshwater scenarios using a coupled ice-ocean model

FRESH-CARE will transform our understanding of Arctic freshwater dynamics by improving resolutions, uncovering drivers and projecting future scenarios

SYMPOSIUM OP'24

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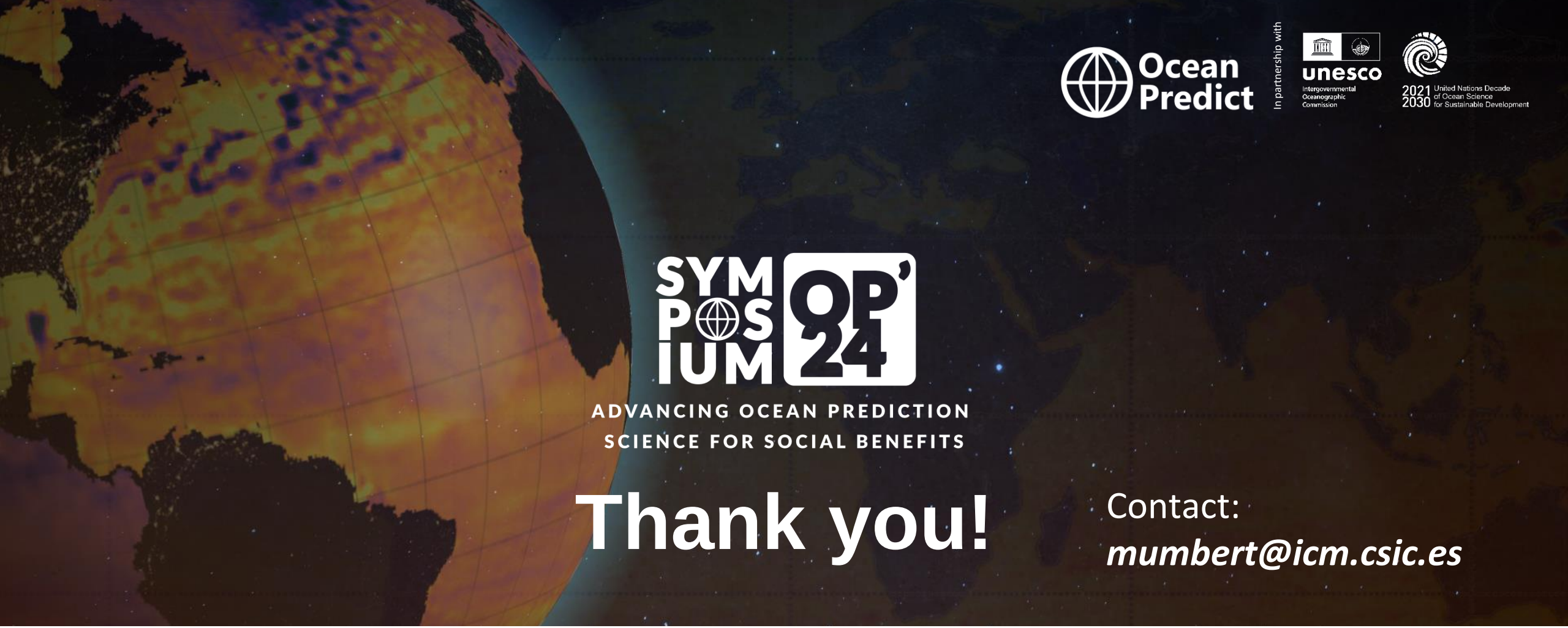

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SYMPOSIUM OP'24

ADVANCING OCEAN PREDICTION
SCIENCE FOR SOCIAL BENEFITS

Thank you!

Contact:
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