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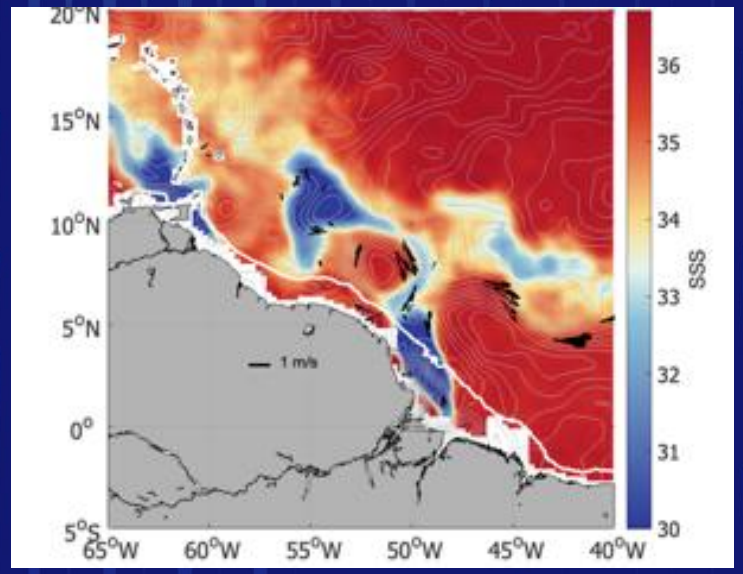
How to monitor the Ocean?



Sea Surface Salinity

Jacqueline Boutin

Laboratoire d'Océanographie et du Climat
Sorbonne Université/CNRS

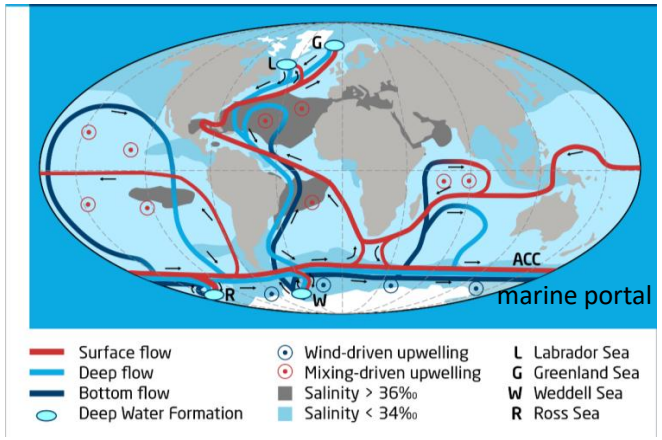
Why monitoring the salinity?

Salinity = amount of salt dissolved in sea water (g/kg)

Sea water density depends on temperature and salinity

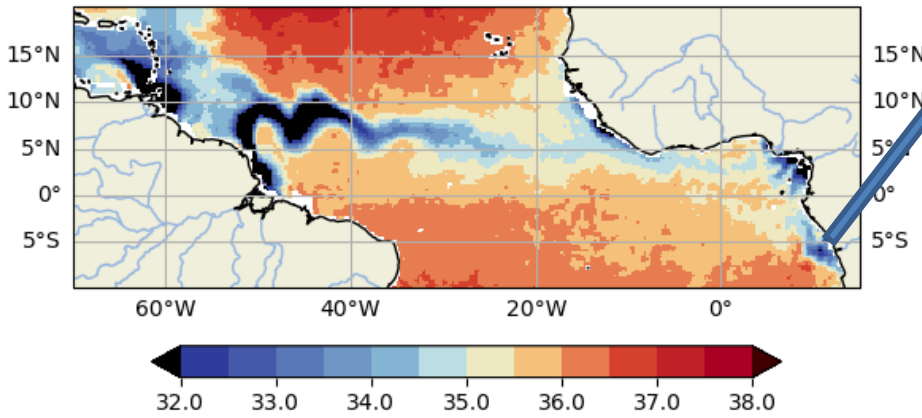
@0°C Δρ (ΔT=1°C) = Δρ (ΔS=0.1g/kg) **@28°C Δρ (ΔT=1°C) = Δρ (ΔS=0.4g/kg)**

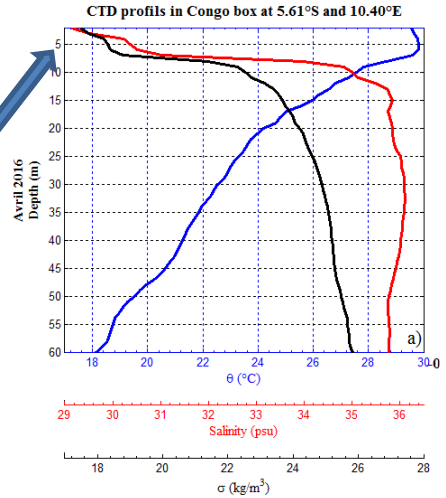
→ thermohaline circulation



→ ocean-atmosphere exchanges

Sea surface salinity - SMOS





Houndegnonto, 2021

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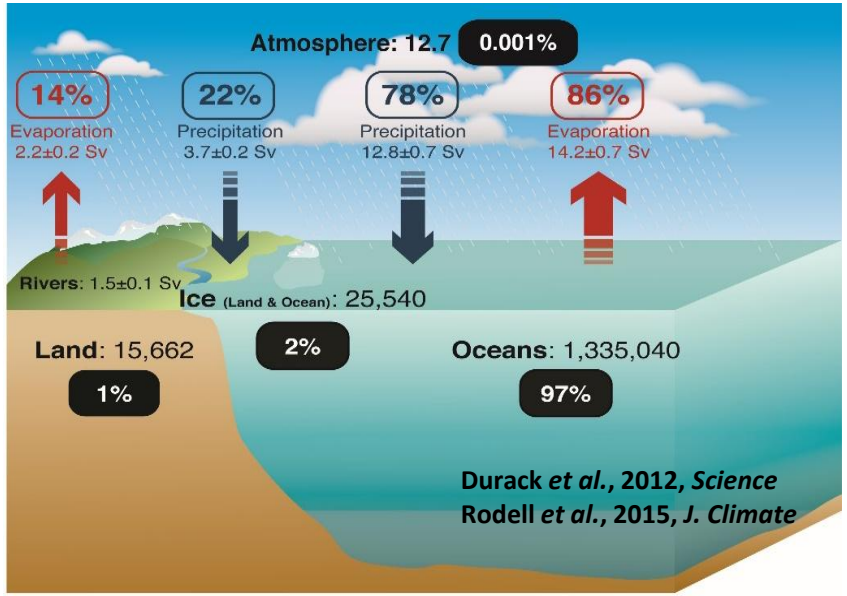
How to monitor the Ocean?

Why monitoring the salinity?

- Ocean is a major component of water cycle: More than ¾ of Evaporation and Precipitation occur over the ocean



Reservoirs represented by solid boxes: 10^3 km^3, fluxes represented by arrows: Sverdrups (10^6 m^3 s^{-1})
Sources: Baumgartner & Reichel, 1975; Schmitt, 1995; Trenberth et al., 2007; Schanze et al., 2010; Steffen et al., 2010; Rodell et al., 2015

- Salinity is a footprint of ocean freshwater exchanges (river run off, precipitation, ice melting)

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How to monitor the Ocean?

Measuring salinity from space?

- **In the microwave domain (1.4GHz, λ=21cm), ocean emissivity depends on the salinity**
- **Weak dependency + long wavelength => very challenging technique**
- **First salinity measurement from space in 2010 (SMOS mission)**

SMOS
Soil Moisture and Ocean Salinity

ESA Earth Explorer (CNES PROTEUS platform)

The first Interferometer for earth observation!

~43km resolution/3 day global coverage

Aquarius
Argentina-USA collaboration (CONAE/NASA)

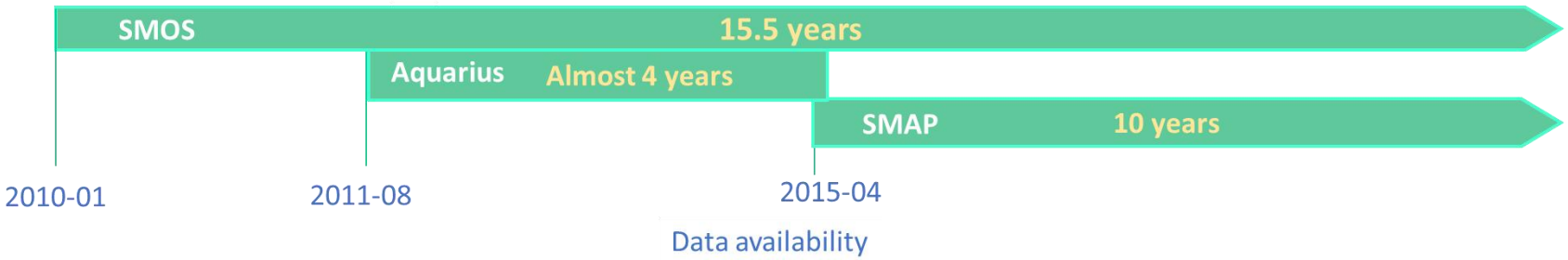
3 radiometers + 1 scatterometer

~150 km resolution/ 7 day global coverage

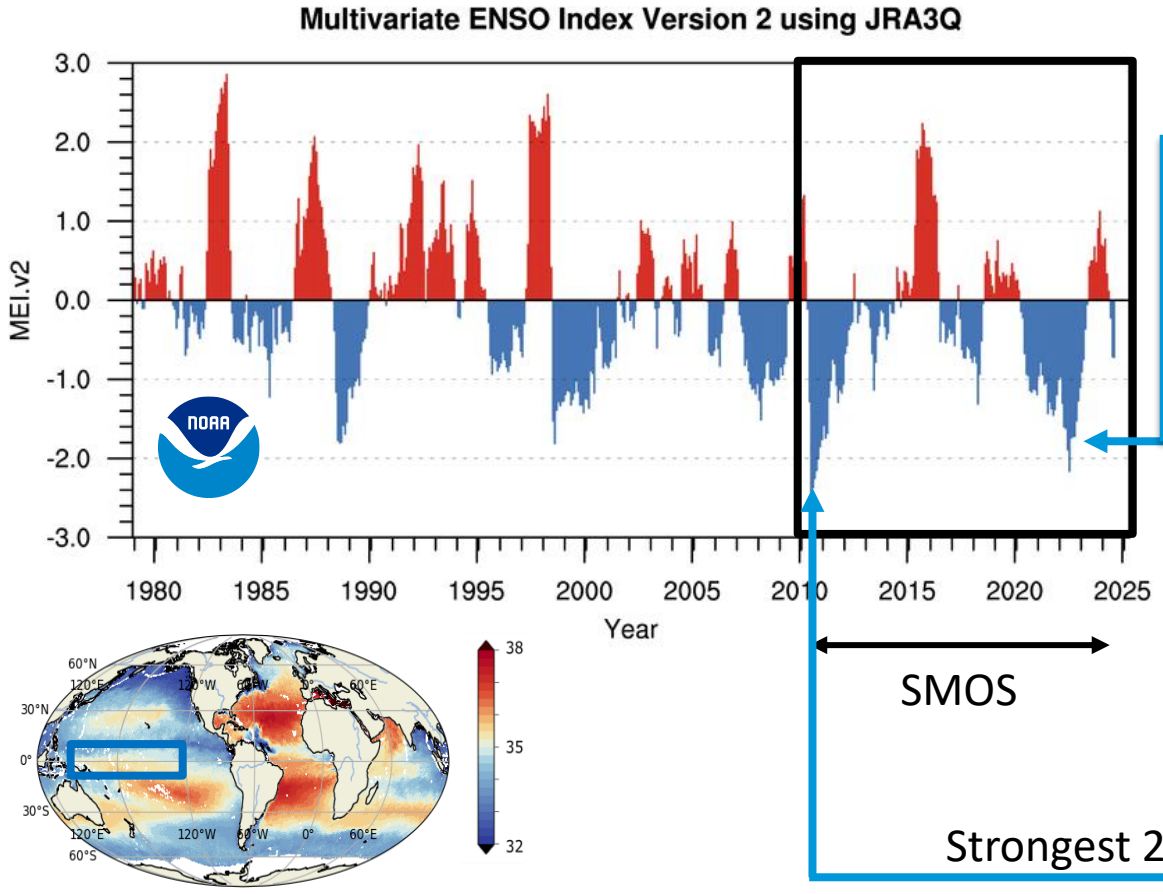
SMAP
Soil Moisture Active Passive (NASA)

Radiometer

~43km resolution / 3 day global coverage



Large scale climate events monitoring: the two strongest & longest La Niña events since 1980



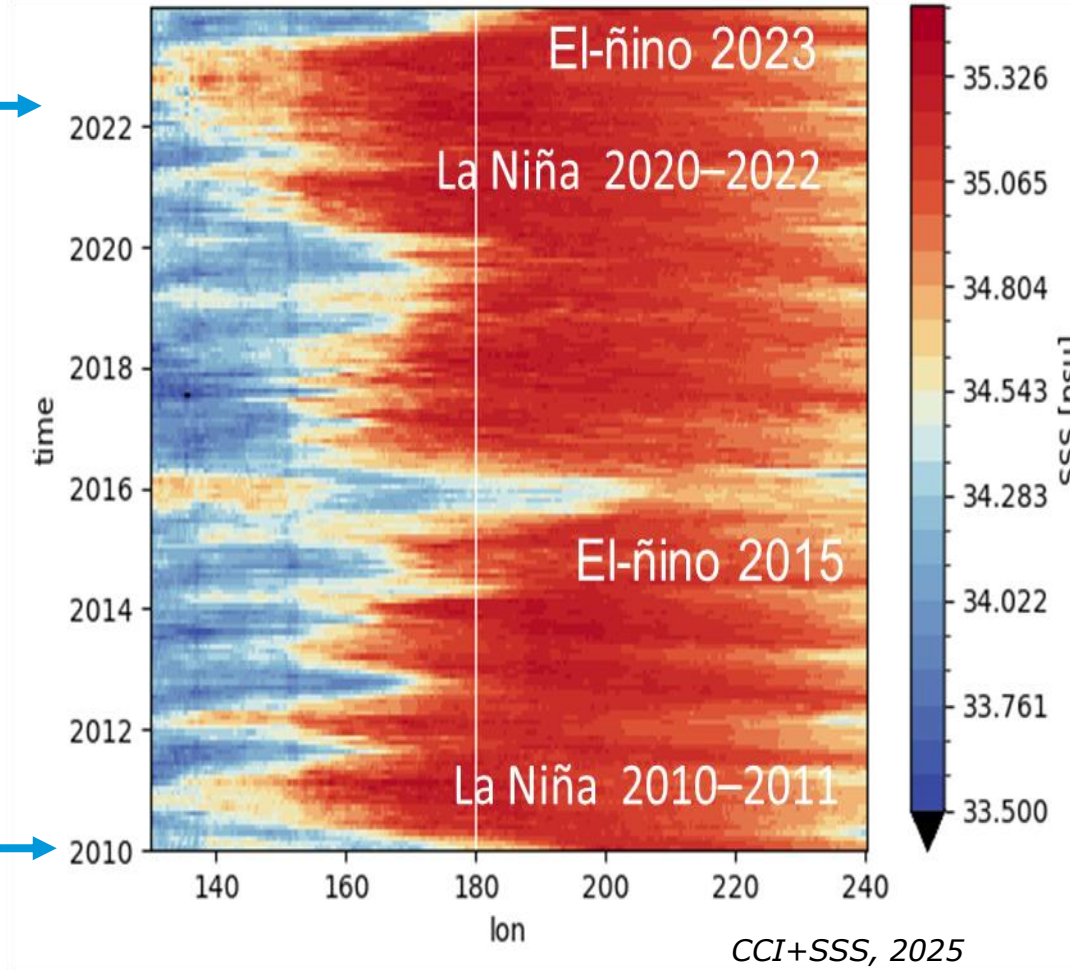
longest

2020-2022

SMOS

Strongest 2010-2011

SSS in the equatorial Pacific Ocean (5N-5S)



CCI+SSS, 2025

Eddies detection

Geophysical Research Letters

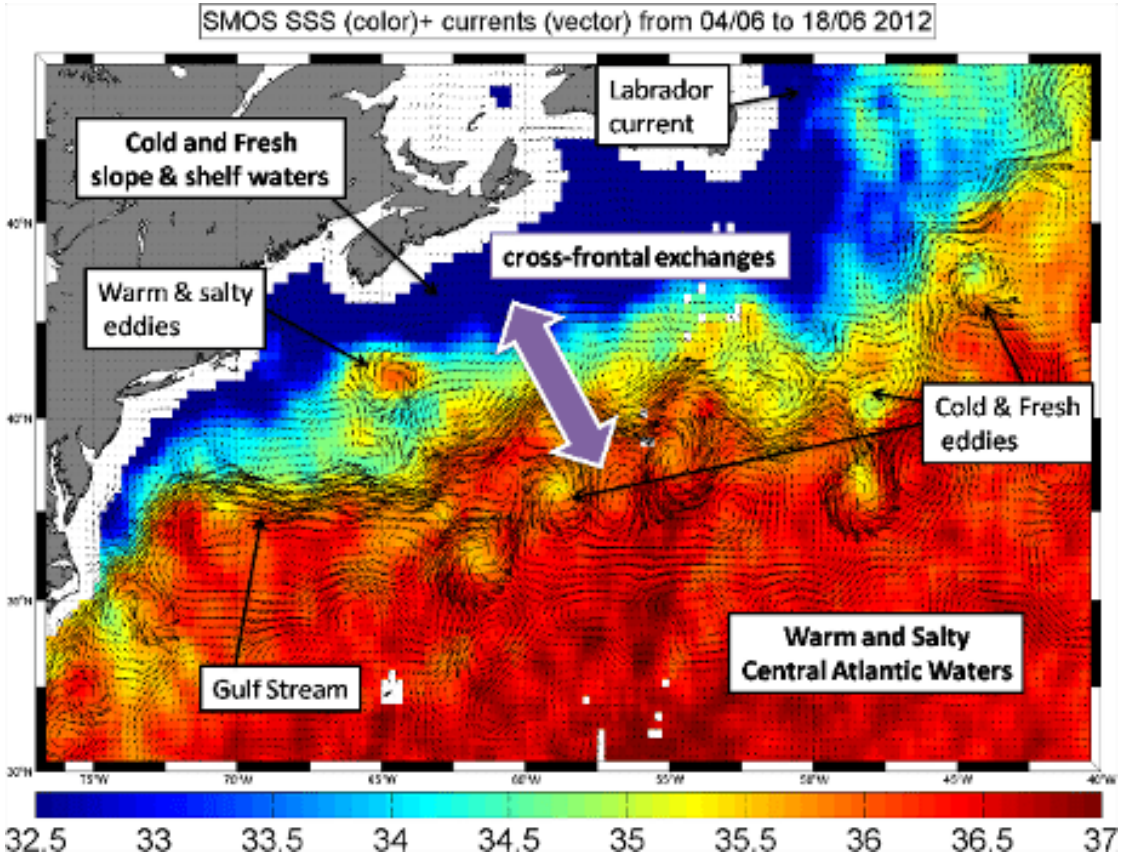
RESEARCH LETTER
10.1002/2014GL059215

Sea surface salinity structure of the meandering Gulf Stream revealed by SMOS sensor

N. Reul[1], B. Chapron[1], T. Lee[2], C. Donlon[3], J. Boutin[4], and G. Alory[5]

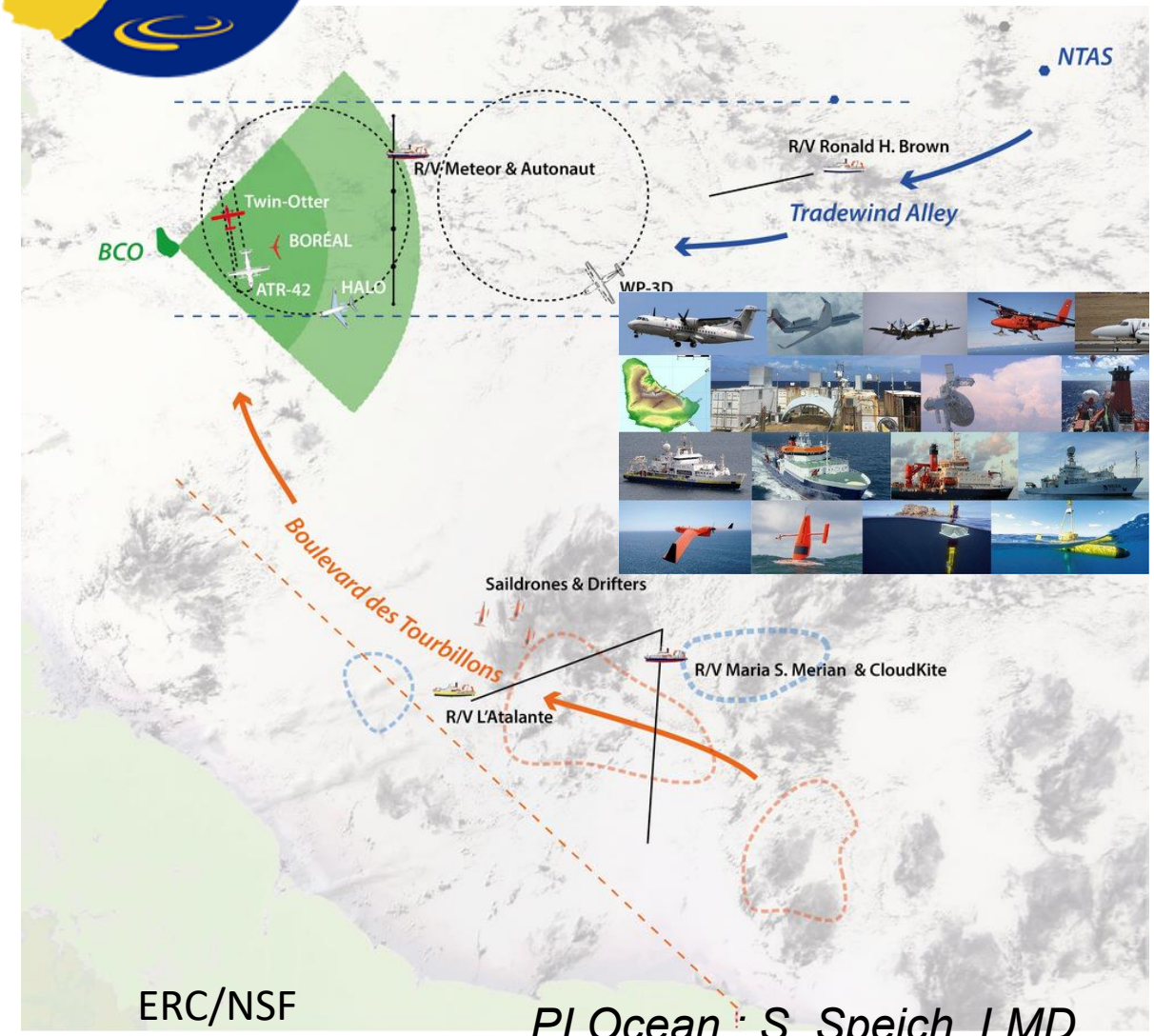
[1]Laboratoire d'Océanographie Spatiale, Institut Français de Recherche et d'Exploitation de la Mer, Plouzane, France, [2]NASA, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA, [3]European Space Agency, ESTEC, Noordwijk, Netherlands, [4]Laboratoire d'Océanographie et du Climat: Expérimentation et Approches Numériques, Paris, France, [5]Université de Toulouse 3, LEGOS, Toulouse, France

Key Points:
- SMOS reveals SSS structure of the Gulf Stream with an unprecedented resolution
- Cold rings are better captured by SSS observations than by SST during summer

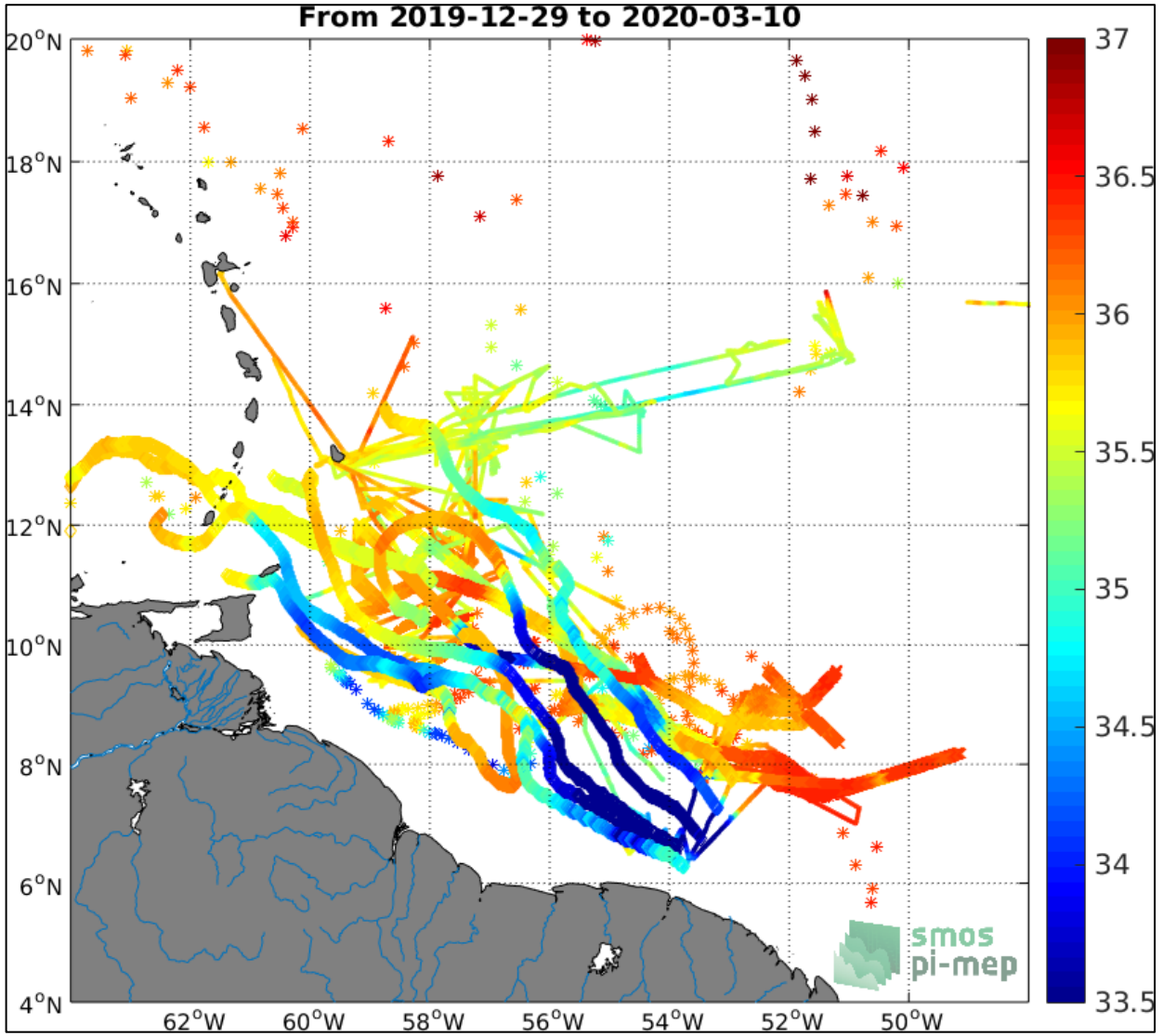


Water mass transport across fronts

The EUREC⁴A field campaign, aims at advancing understanding of the interplay between clouds, convection and circulation and their role in climate change.



ERC/NSF



PI Ocean : S. Speich, LMD

River plume and export with the open ocean

A fresh plume in the northwestern tropical Atlantic during the EUREC4A-OA/ATOMIC program in February 2020

4 Feb

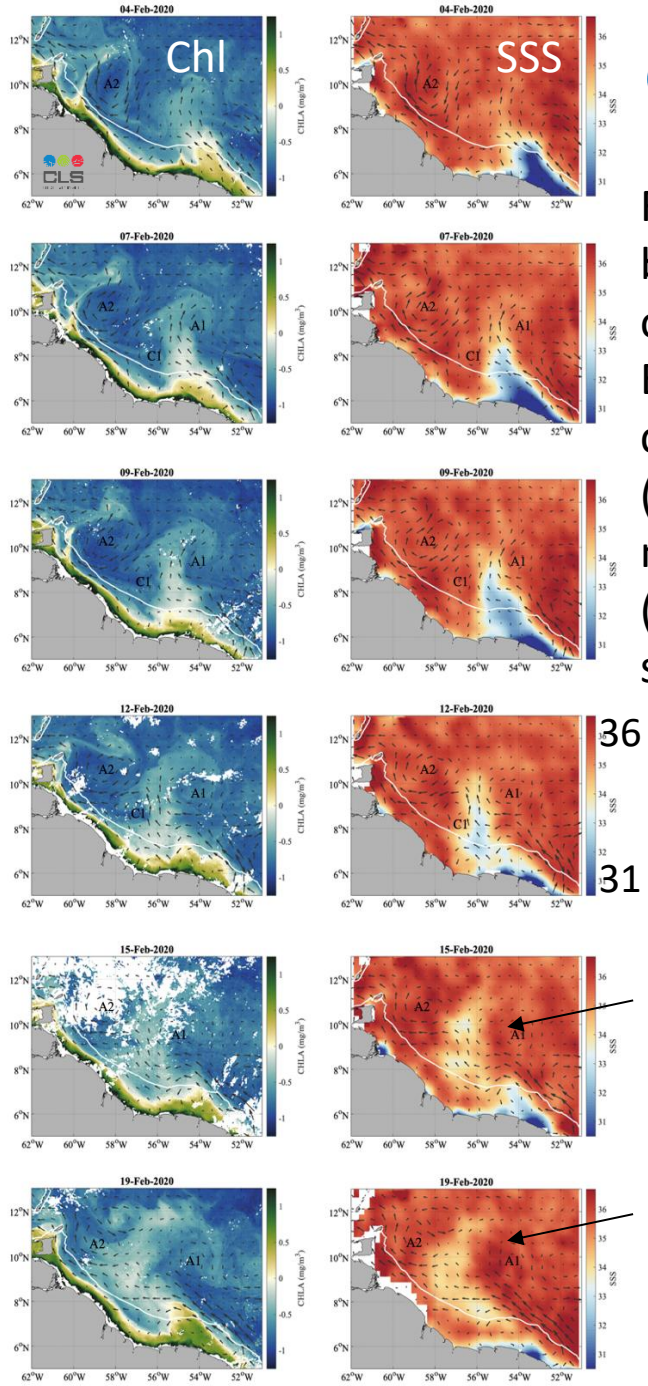
7 Feb

9Feb

12 Feb

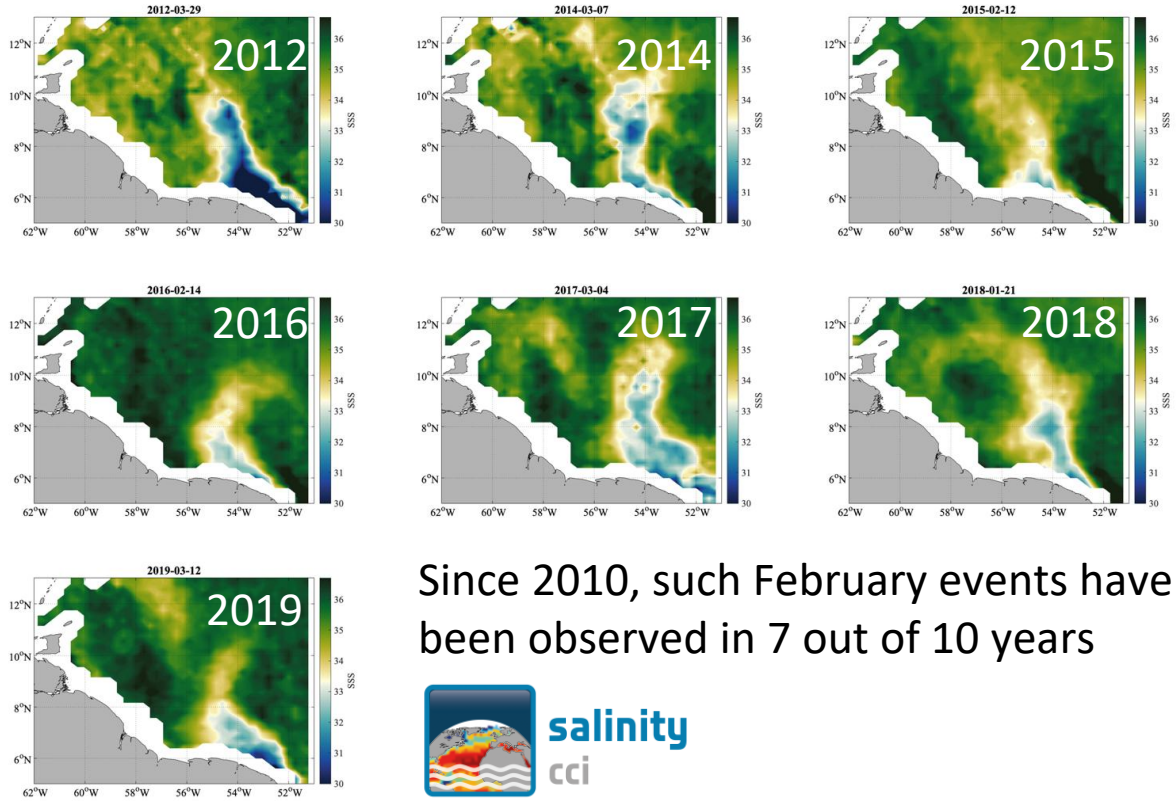
15 Feb

19 Feb



Freshplume detected by satellite observations during Eurec4A 2020 campaign at a period (February) when it is not often observed (=>guidance of the ship)

Export of freshwater (and associated biogeochemical properties, e.g. low pCO_2) towards the open ocean



Since 2010, such February events have been observed in 7 out of 10 years

salinity cci

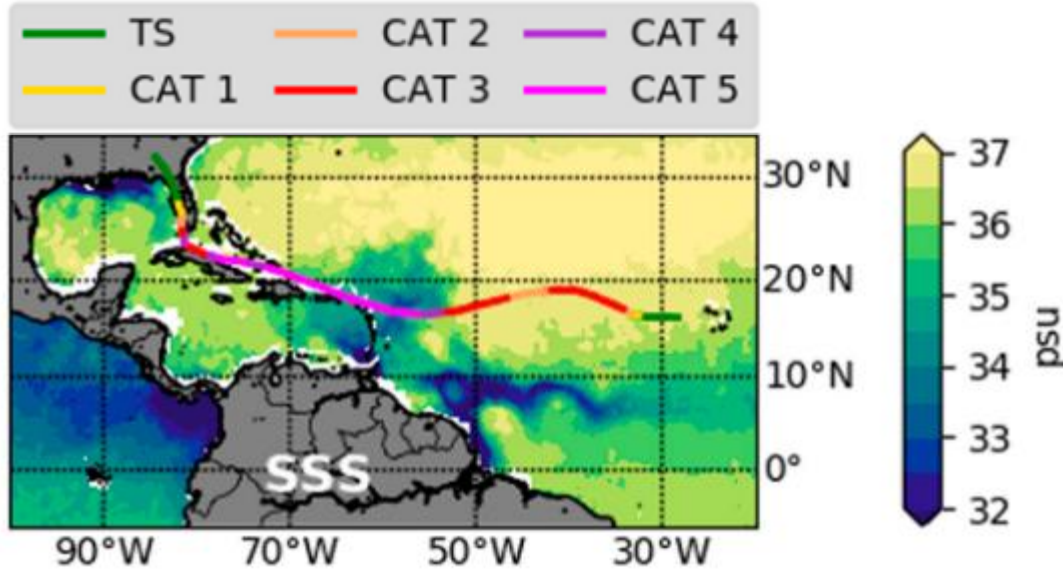
Reverdin et al., JGR-Ocean, 2021

BAMS Article

Pronounced Impact of Salinity on Rapidly Intensifying Tropical Cyclones

Karthik Balaguru, Gregory R. Foltz, L. Ruby Leung, John Kaplan, Wenwei Xu, Nicolas Reul, and Bertrand Chapron

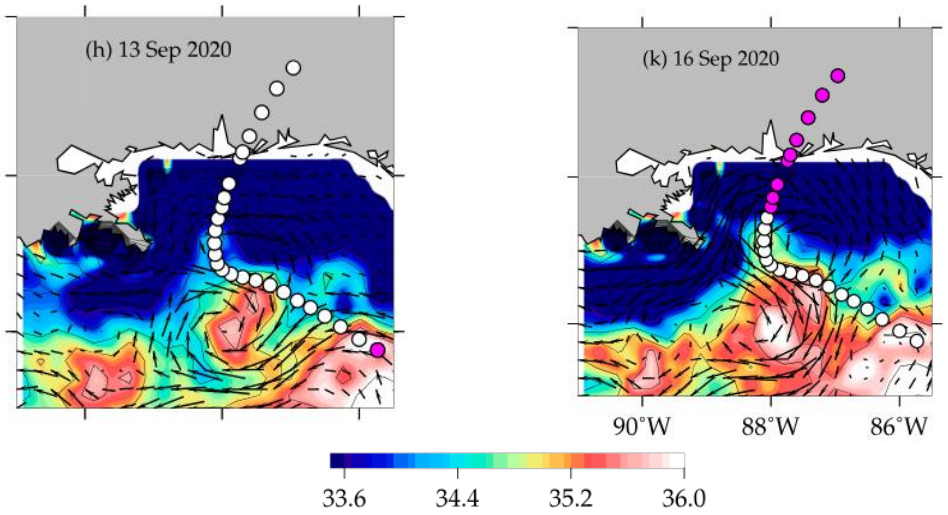
Low sea surface salinity reduces mixing with subsurface cold waters => surface water cooling is reduced=> reinforcement of rapidly intensifying tropical cyclones



AUGUST 2023 WEATHER AND FORECASTING 1391

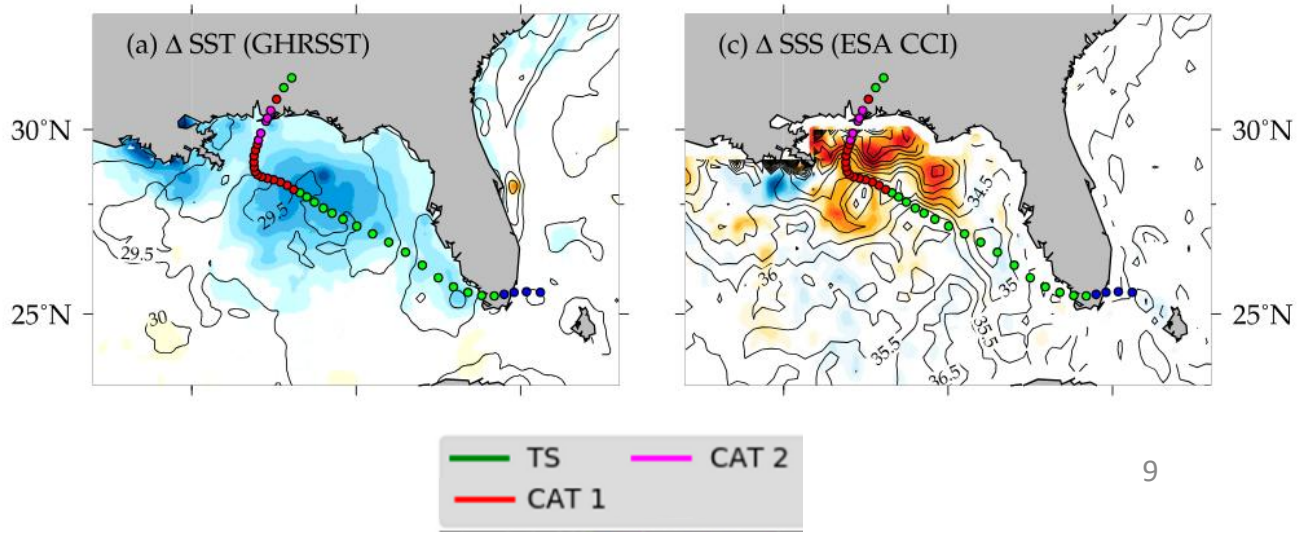
Intensification of Hurricane Sally (2020) over the Mississippi River Plume

EFFY B. JOHN,[a] KARTHIK BALAGURU,[a] L. RUBY LEUNG,[a] GREGORY R. FOLTZ,[b] ROBERT D. HETLAND,[a] AND SAMSON M. HAGOS[a]

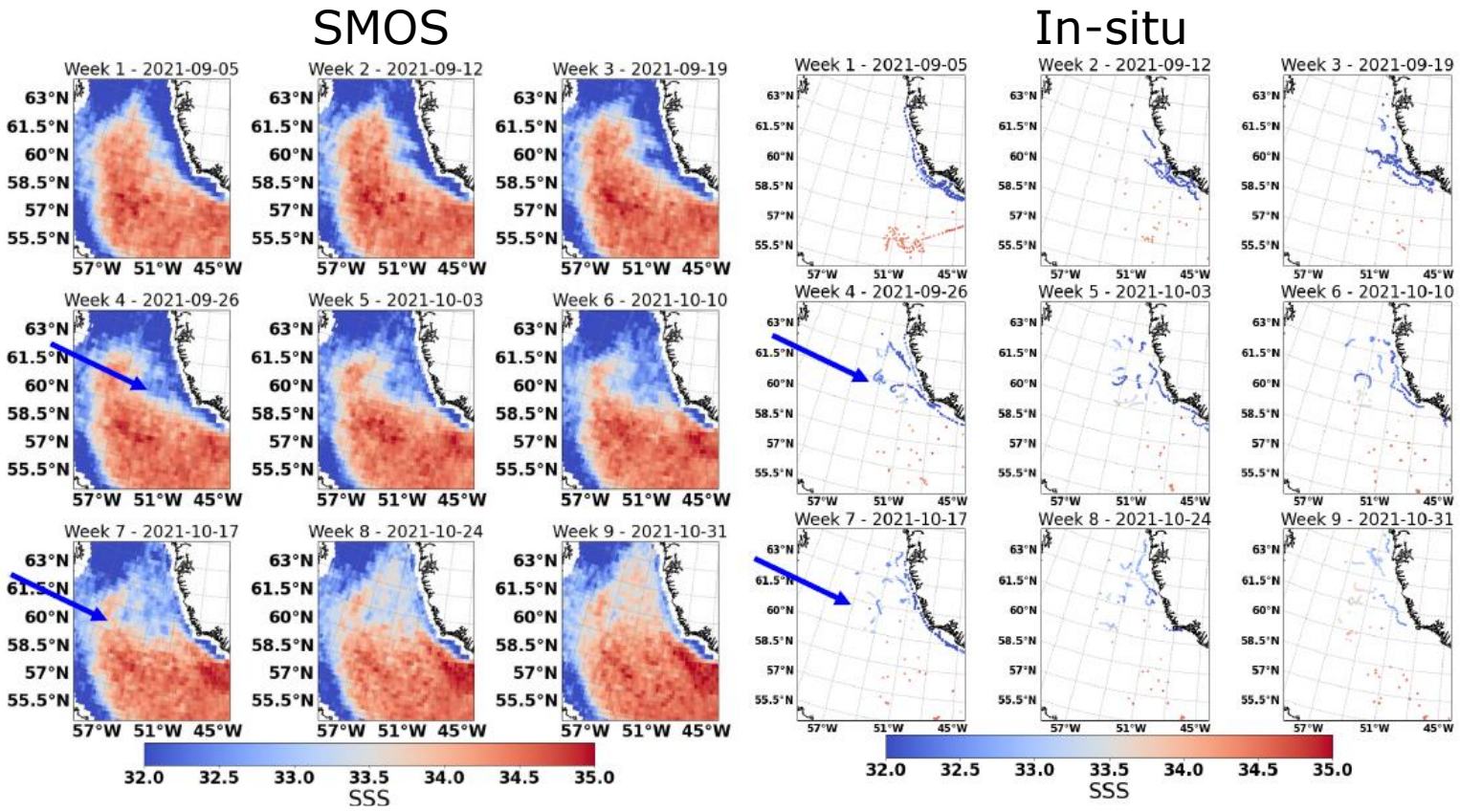


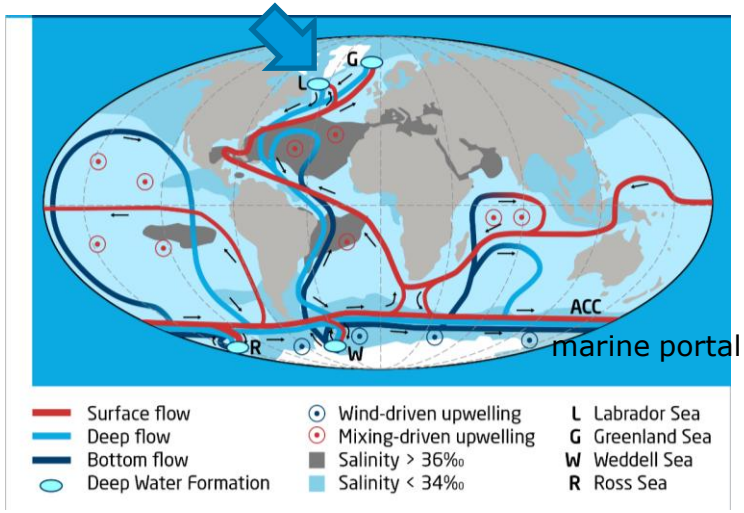
Spatial map of daily CCI v3.21 SSS (psu; filled color) and OSCAR currents (m s^{-1}; vectors)
The TC center location for each day is denoted by magenta circles

SST (°C) and SSS difference between 16 and 12 Sep



Strong salinity anomaly west of Greenland Sept. 2021

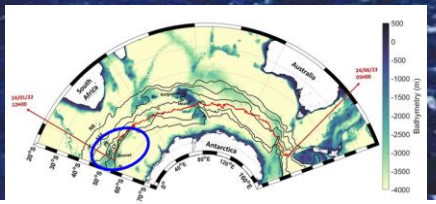


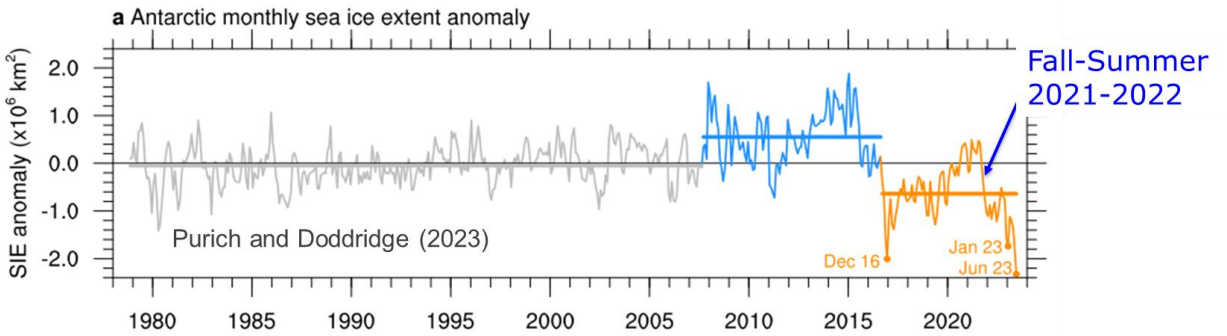


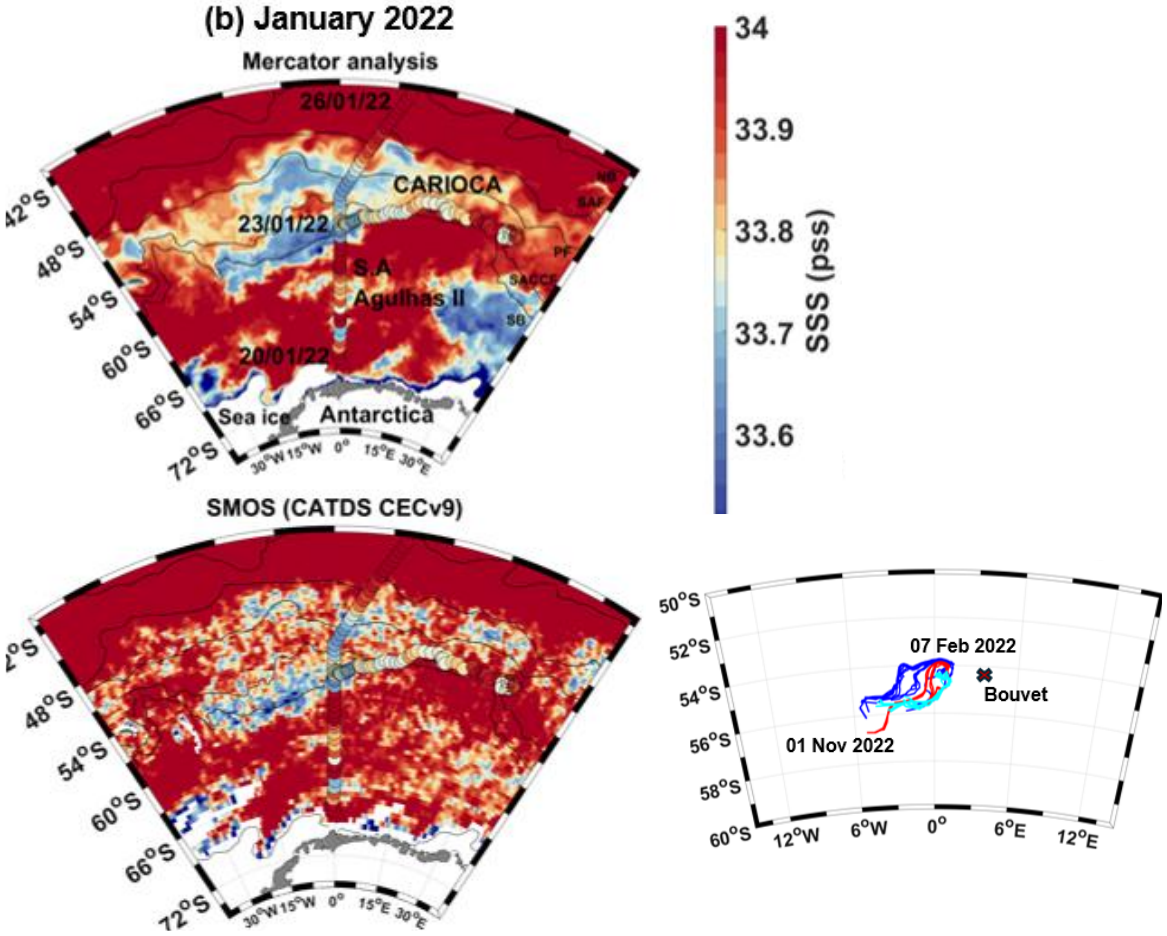
marine portal

Usually, freshwater masses coming from Greenland meltwater and Arctic polar surface water remain on Greenland coastal shelf. A **strong anomalous sea surface salinity event was detected in Fall 2021**. If mixed offshore, these freshwater masses have **the potential to stratify the Labrador sea and inhibit convection**.
(Reverdin et al. 2025, JAOT in rev., Foukal et al. 2025, in prep.)

Southern Ocean is changing







Biogeosciences, 22, 1947–1968, 2025
https://doi.org/10.5194/bg-22-1947-2025

Biogeosciences Open Access EGU

Anomalous summertime CO_2 sink in the subpolar Southern Ocean promoted by early 2021 sea ice retreat

Kirtana Naëck[1], Jacqueline Boutin[1], Sebastiaan Swart[2], Marcel du Plessis[2], Liliane Merlivat[1], Laurence Beaumont[3], Antonio Lourenco[1], Francesco d'Ovidio[1], Louise Rousselet[1], Brian Ward[4], and Jean-Baptiste Sallée[1]

SSS spatial patterns from Mercator analysis and from SMOS both support very low SSS in subpolar region in summer 2022 advected from a region near sea ice
=> More surface stratification

Salinity from space reveals

Large scale variability for more than 15years :

=> Tropical & mid-latitudes (e.g. ENSO, …) : long term, decadal, interannual variability ?

=> need long term time serie

=> Changes at high latitudes: isolated events or long term tendencies ?

=> need long term time serie and reduced uncertainties

Persistence (several week) of fresh cells at the ocean surface (river plumes, ice melt)

=> modify ocean surface stratification

=> modify air-sea interactions (e.g. rapid intensifying cyclones)

=> need higher spatial resolution to observe fresh signatures, especialy near coast and ice

See more on poster # 579

‘SMOS satellite monitors Salinity for more than 15 years’

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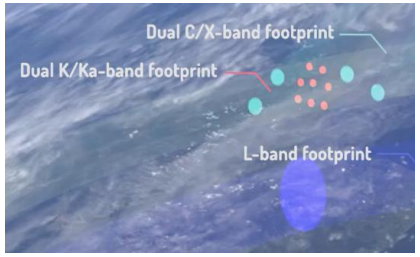
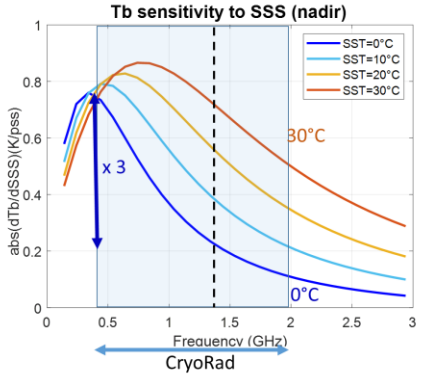
How to monitor the Ocean?

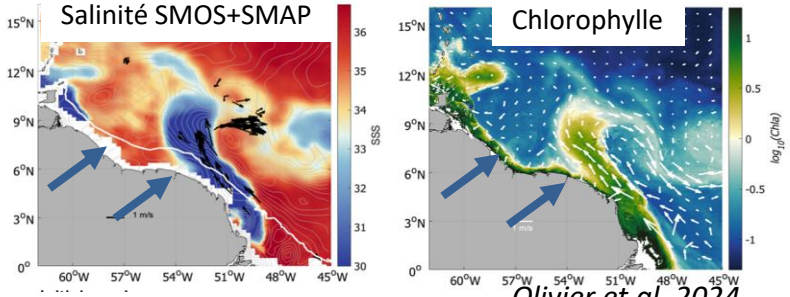
Next: pursue & enhance salinity from space



-Continuity:
Copernicus Imaging Microwave Radiometer
(CIMR, launch >2028)



-Enhance salinity accuracy in polar regions :
CRYORAD ESA Earth Explorer 12 mission idea,
poster # 585



Olivier et al. 2024

-Enhance spatial resolution (10km) and get closer to coast, ice : SMOS-HR / FRESCH mission idea
poster # 579

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Thank you!

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