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Ocean Salinity in Support of Scientific and Environmental Demands

The influence of sea surface salinity information when reconstructing ocean currents. The case of freshwater fluxes in the Arctic Sea

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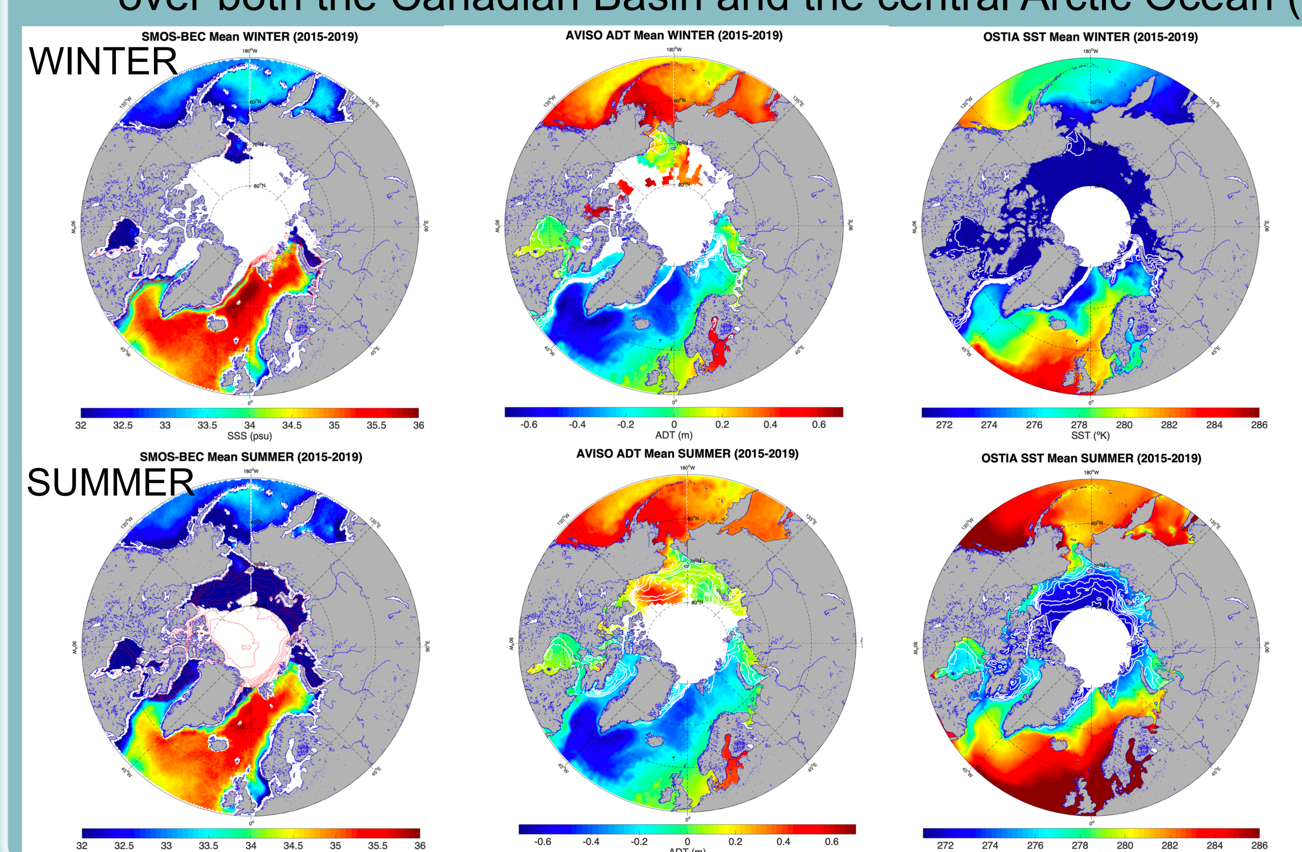
This study focus in the Arctic Ocean, a hotspot of climate change where the precise impact of an increase of the Arctic freshwater runoff on ocean dynamics remains unclear. In the Arctic Ocean, **adding satellite SSS information could potentially provide better estimates of surface currents**, as SSS dominates surface buoyancy in specific regions and seasons and therefore density, as they both are inversely proportional to each other. SMOS SSS maps developed at Barcelona Expert Centre at high latitudes are used to **study the dynamical relation between SST, ADT and SSS**. We analyse the **effective spatial resolution of satellite variables** in order to better understand the dynamical processes that are being described by each one. We also evaluate where and when SSS could have a key role in ocean dynamics and would help provide better estimates of ocean currents. We found that the **satellite SSS information enhance our understanding of the dynamics in the Arctic Ocean**, where fresh water fluxes are of major importance.

1. Arctic Ocean and Freshwater fluxes

- Salinity has a key role in regional dynamics as the **hydrography of the upper Arctic Ocean is changing** (Haine et al. 2015).
- Density stratification has increased in the upper 200m since 1970. Surface ocean warming and addition of freshwater are making the **surface less dense relative to deeper parts of the ocean** and inhibiting mixing between surface and deeper waters (IPCC 2019).
- Increment of global mean annual temperature induce an **increase of freshwater content** over both the Canadian Basin and the central Arctic Ocean (Rabe et al. 2014).



2. Satellite data

The study period ranges between 2015-2019. The following daily data products are used: OSTIA SST 1/20º products, AVISO ADT 1/4º, CCI-ESA Level 4 SSS 1/4º, SMOS-CATDS-LOCEAN v3 SSS 1/4º and SMOS-BEC v3beta Arctic SSS 1/4º products.

Figure 1: *Mean SSS/SST/ADT for winter and summer from 2015-2019. Superimposed mean sea ice cover from TOPAZ4 numerical model.*

3. Greenland Ice Sheet melting and the Nordic Seas

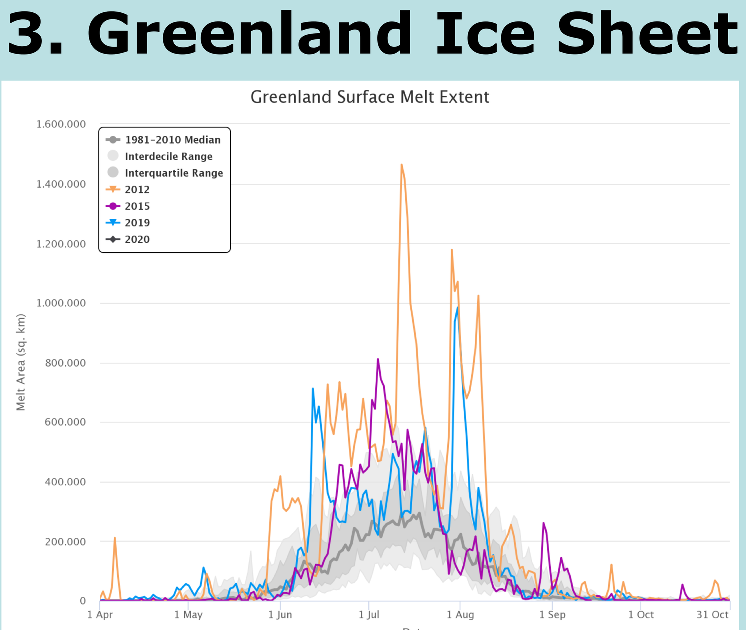


Figure 2: *Mean Greenland Surface Melt Extent from 1981-2010 period in grey, and increased melt extent for years 2012, 2015 and 2019 in orange, purple and blue. Greenland Ice Sheet Today is produced at the National Snow and Ice Data Center with support from NASA.*

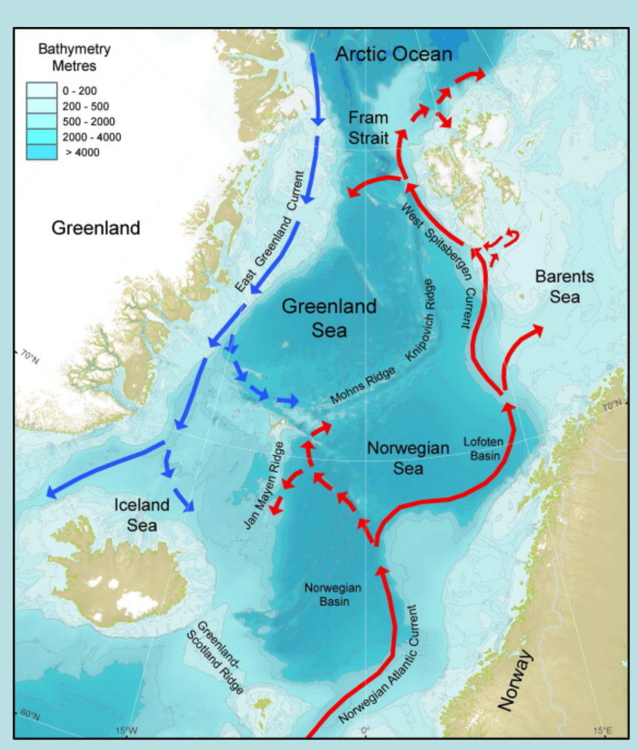


Figure 3: *Upper-ocean hydrography of the Nordic Seas as observed by instrumented seals and Argo floats (Isachsen et al. 2014)*

Greenland Ice Sheet melting has been accelerating and the **increase of freshwater discharge can have consequences for thermohaline circulation** of the sub-Arctic seas. Ramifications of the freshwater flux are increased water column stability and weakening of deep convection in the interior Labrador and Nordic Seas, and sea level rise as the most prominent consequence (Dukhovskoy, et al. 2016).

DYNACLIM PROJECT

OBJECTIVE → DYNACLIM project aims to exploit the available spatiotemporal sampling capacity of **remotely sensed SSS synergistically with SST and ADT** to reconstruct the ocean three-dimensional dynamics (**subsurface velocities and density fields**).

WHERE → The **Arctic Ocean and the Mediterranean Sea**; two regions of relevant importance in order to better understand the consequences of climate change and where enhanced satellite salinity products are recently being produced.

HOW → Study **representativeness of satellite SSS** products as compared to SST/ADT. Combine satellite SSS and SST to **estimate surface density and buoyancy** regional fields. Adapt/Develop **Surface Quasi Geostrophic** approaches (Isern et al. 2008, Wang et al. 2013 and LaCasce et al. 2015) to **reconstruct the 3D dynamics** using satellite data.

Surface Density (SSS & SST)

$$b_s = -\frac{g}{\rho_0}\rho_s = -\frac{g}{\rho_0}(1+\beta S - \alpha T)$$

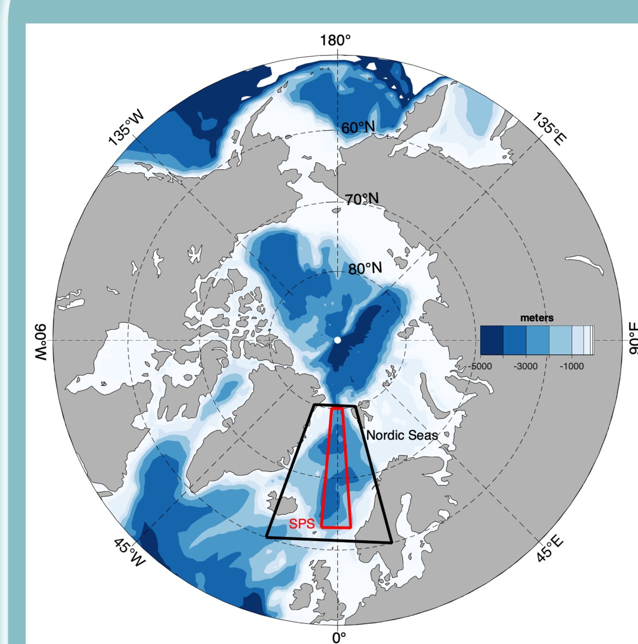
Stratification

$$\hat{\psi}_{surf}(\vec{k},z) = \frac{\hat{b}_s(\vec{k})}{Nk} exp\left(\frac{Nkz}{f_0}\right)$$

Stream function

Validation of reconstructed subsurface velocities and density fields will be done **with operational products, in-situ datasets** and comparison of structure location with Sentinel-3 SST data.

4. Dynamical relation between SSS, SST & ADT



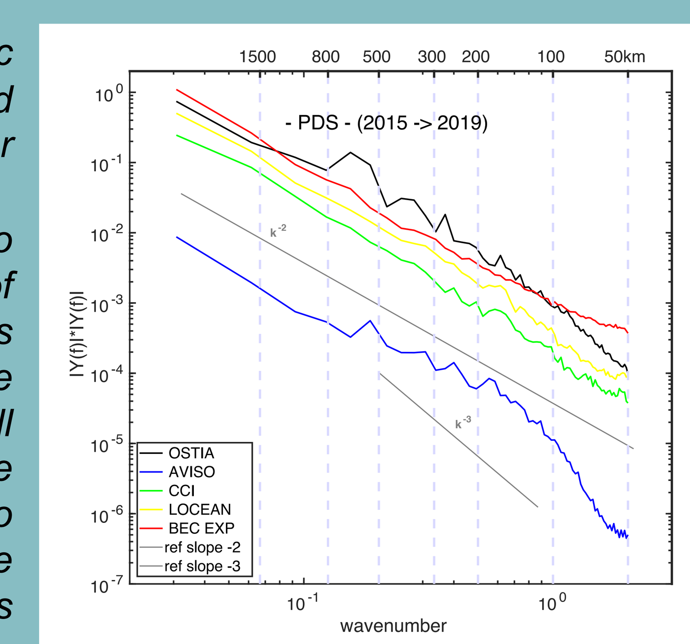


Figure 4 Left: *Arctic bathymetry. Red box area is used to calculate wavenumber power density spectra (PDS)* **Right:** *PDS of SSS compared to SST and ADT. Spectral slopes of -2 and -3 are represented as reference. We observe that the effective spatial resolution of all products is around 100 km. In the Nordic Seas we will be able to study up to mesoscale phenomena (~100-300km) as eddies and fronts.*

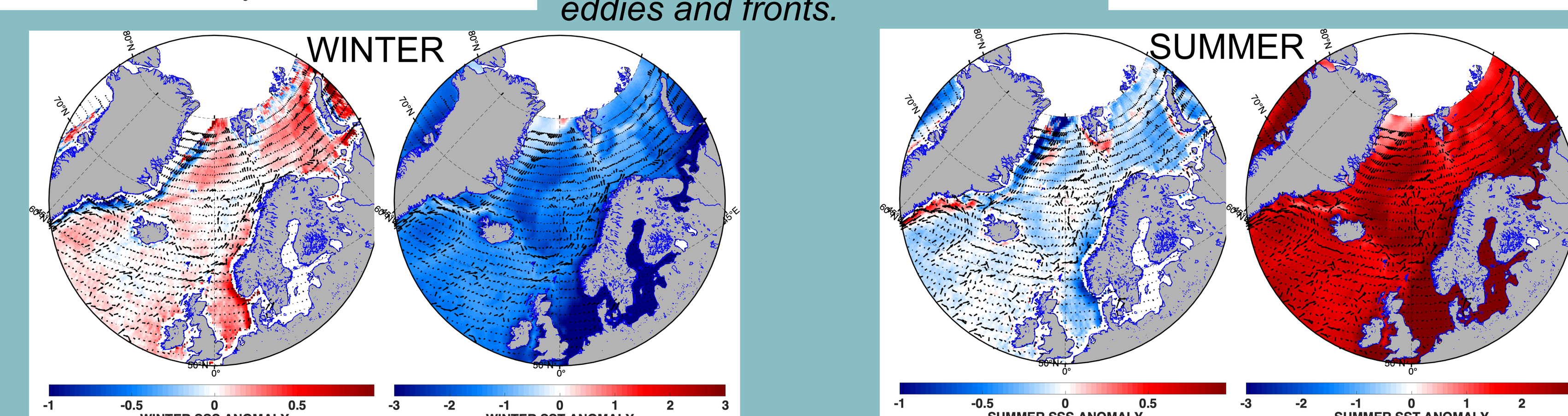


Figure 6: *Seasonal anomalies for WINTER (left) and SUMMER (right) of SSS and SST. Anomalies are computed by subtracting the mean for 2015-2017 to seasonal means. Current vectors from Globcurrent version 3.0 0.25º superimposed.*

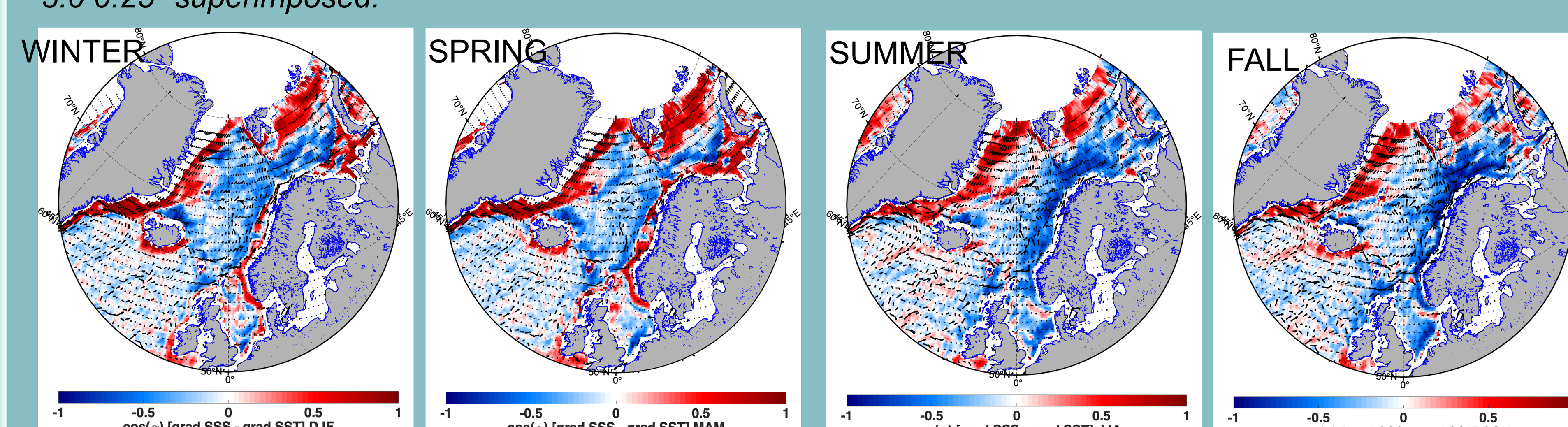


Figure 7: *The alignment between SMOS-BEC SSS and OSTIA SST fronts is analysed computing the angle between their gradients for each daily product, and seasonally averaged for 2015-2017. Current vectors superimposed.*

$$\cos(\gamma) = \frac{\partial_x S \cdot \partial_x T + \partial_y S \cdot \partial_y T}{\sqrt{\partial_x S^2 + \partial_y S^2} \cdot \sqrt{\partial_x T^2 + \partial_y T^2}}$$

In **Greenland continental platform SSS and SST gradients are aligned with same orientation** following east Greenland current during all year. During winter and spring, water is colder and saltier, SSS and SST gradients are aligned with same orientation as they both induce an increase of density. During summer and fall due to warmer weather, melting and freshwater inputs we observe fresher and warmer water that induce a density decrease.

Along **Norway coast**, **we observe SSS and SST aligned with same orientation in winter and spring** as both lower temperature and higher salinity induce an increase in density. However, in **summer and fall, SSS and SST are aligned with opposite orientation** indicating that SSS and SST gradients compensate their effect in water density.

As preliminary results of this study, we found areas and seasons where **currents would benefit from satellite SSS information in order to get the correct amplitude of density gradients** when SSS and SST gradients are aligned with same orientation, and to not **overestimate** density gradients when are aligned with opposite orientation.

Acknowledgements
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MARIE CURIE ACTIONS

SMOS Barcelona Expert Centre

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