3D reconstruction of upper ocean dynamics in the Nordic and Beaufort Seas. Assessment of the Surface Quasi-Geostrophic Approach

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EXCELENCIA SEVERO OCHOA

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Motivation

Polar regions have been changing since the 1990s; Better estimates of 3D ocean circulation are required to improve our understanding of polar dynamics and to better comprehend the impact of the changes caused by climate change. Our objective is to **see if remotely sensed variables may be used to reconstruct 3D** ocean dynamics in Arctic and sub-Arctic Seas.

We have assessed the **capability of Surface Quasi-Geostrophy (eSQG) to reconstruct the three-dimensional (3D) dynamics** in two key areas of the Arctic Ocean: the Nordic and the Beaufort Seas using TOPAZ4 outputs.

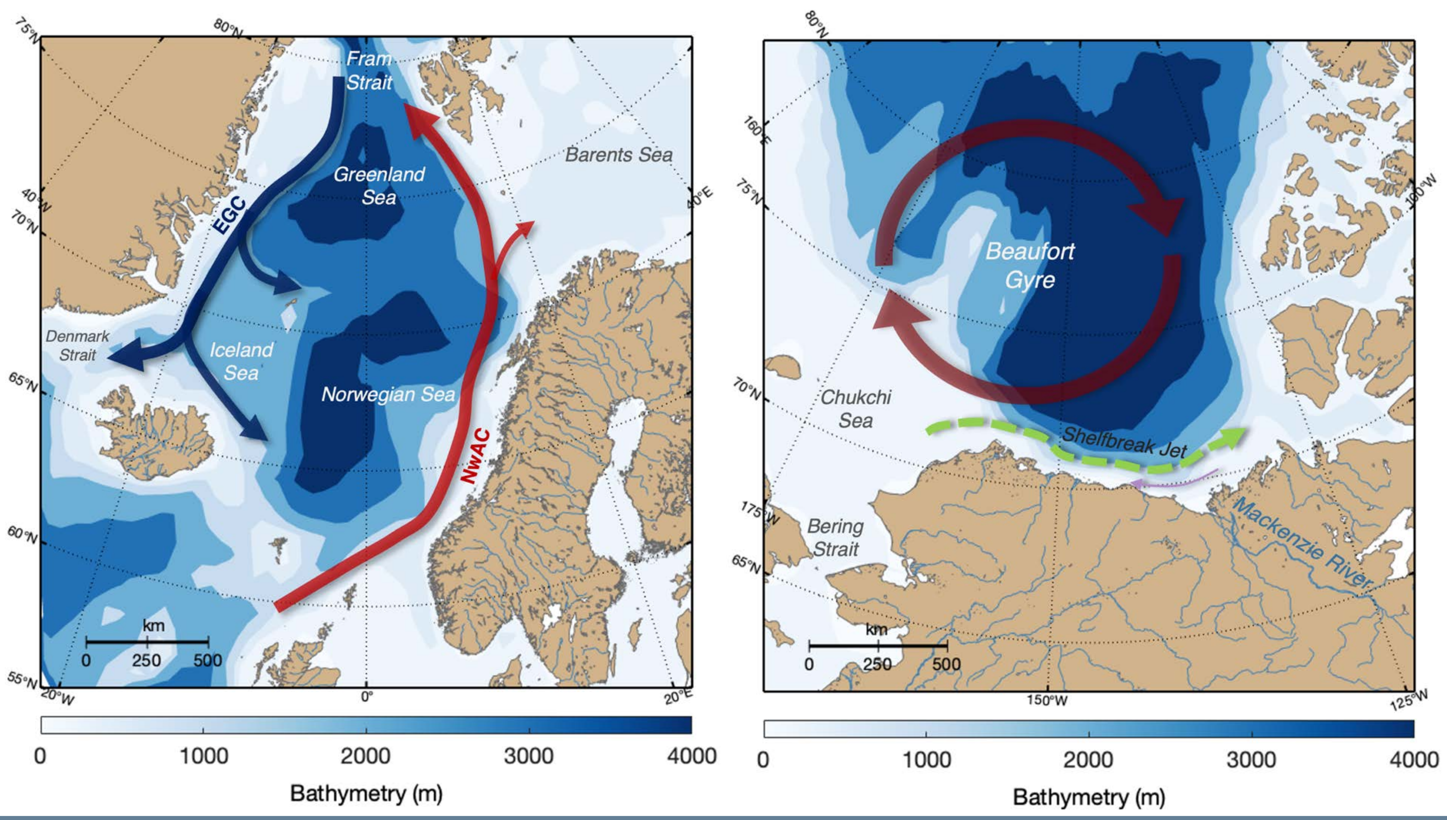


Figure 1: Bathymetry and main upper currents
Left. Nordic Seas: East Greenland Current (EGC); Northwest Atlantic Current (NwAC)
Right. Beaufort Sea: Beaufort Gyre, Beaufort Shelfbreak Jet and shelf current.

Surface Quasi-Geostrophic model

SQG model allows to derive the stream function at each depth from sea surface height (η), from the surface buoyancy (b), or from surface velocities (v) through the effective SQG relations (*Isern et. al, 2008*).

Reconstruction from SSH :

$$\hat{\psi}_\eta(\vec{k},z) = \exp(n_0 k z)\hat{\psi}_s(\vec{k}) \qquad \psi_s(\vec{x}) = \frac{g}{f_0}\eta(\vec{x})$$

(Stream function; SSH)

Reconstruction from SSB:

$$\hat{\psi}_b(\vec{k},z) = \frac{1}{n_0 f_0 k}\exp(n_0 k z)\hat{b}_s(\vec{k}) \qquad b_s(\vec{x}) = -g\frac{\rho'(\vec{x})}{\rho_0}$$

(Surface Density (SSS & SST))

Reconstruction from SSV:

$$\hat{v}_{vel}(\vec{k},z) = \exp(n_0 k z)\hat{v}_s(\vec{k})$$

(Prandtl ratio)

Computation of Prandtl ratio

Summer months exhibit **higher stratification, which is associated to freshwater inflows from ice melting** and warmer temperatures.

Ocean mixing causes lower stratification in the spring and winter months.

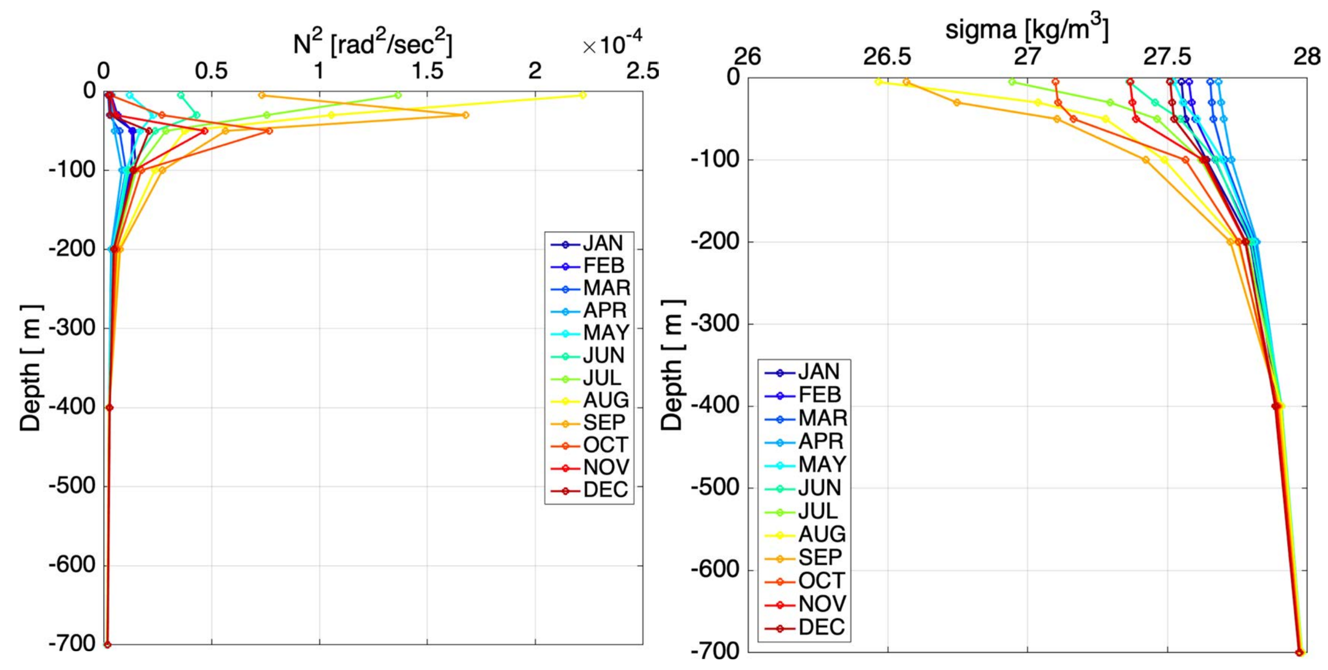
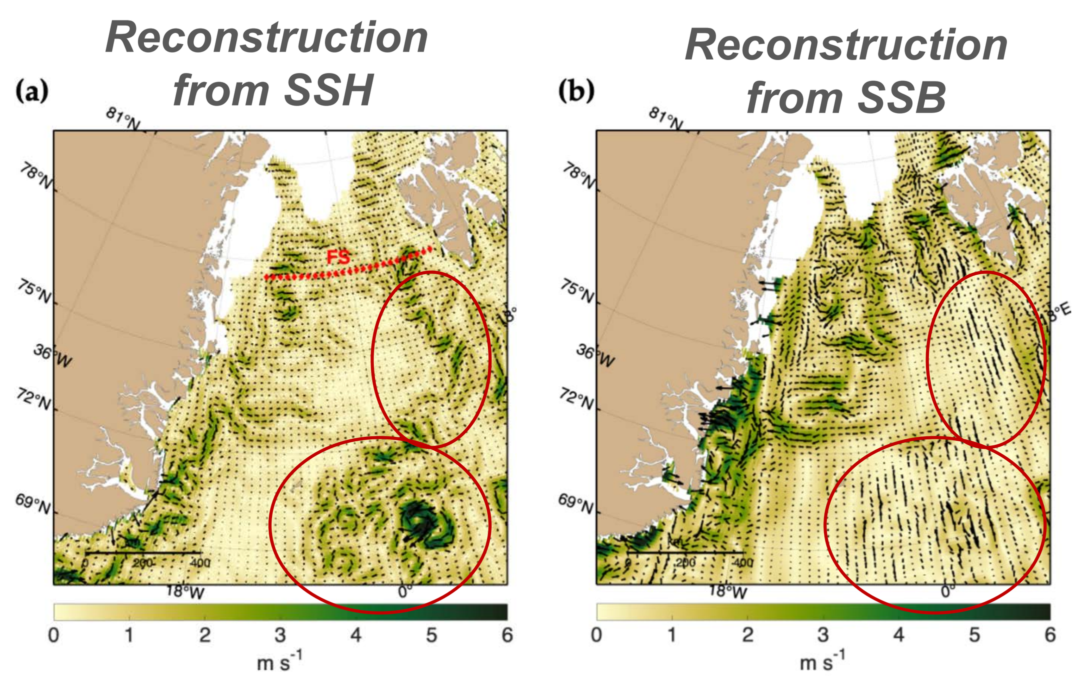


Figure 2: Mean monthly profiles of Brunt Vaisala frequency and density in Nordic Seas

The daily-mean Prandtl ratio (n_0) was calculated by dividing the mean Brunt-Vaisala frequency in the first 100 meters by the mean Coriolis frequency.
The Prandtl ratio is assumed to be constant throughout the water column.

Results

Surface currents in Nordic Seas



SSB is not able to reconstruct key mesoscale surface currents seen in SSH in the Nordic and Beaufort Seas.

Figure 3: Example of surface currents for the 28th August in Nordic Seas. a) reconstruction from SSH, b) reconstruction from SSB

Section along Fram Strait (Latitude = 77.5ºN)

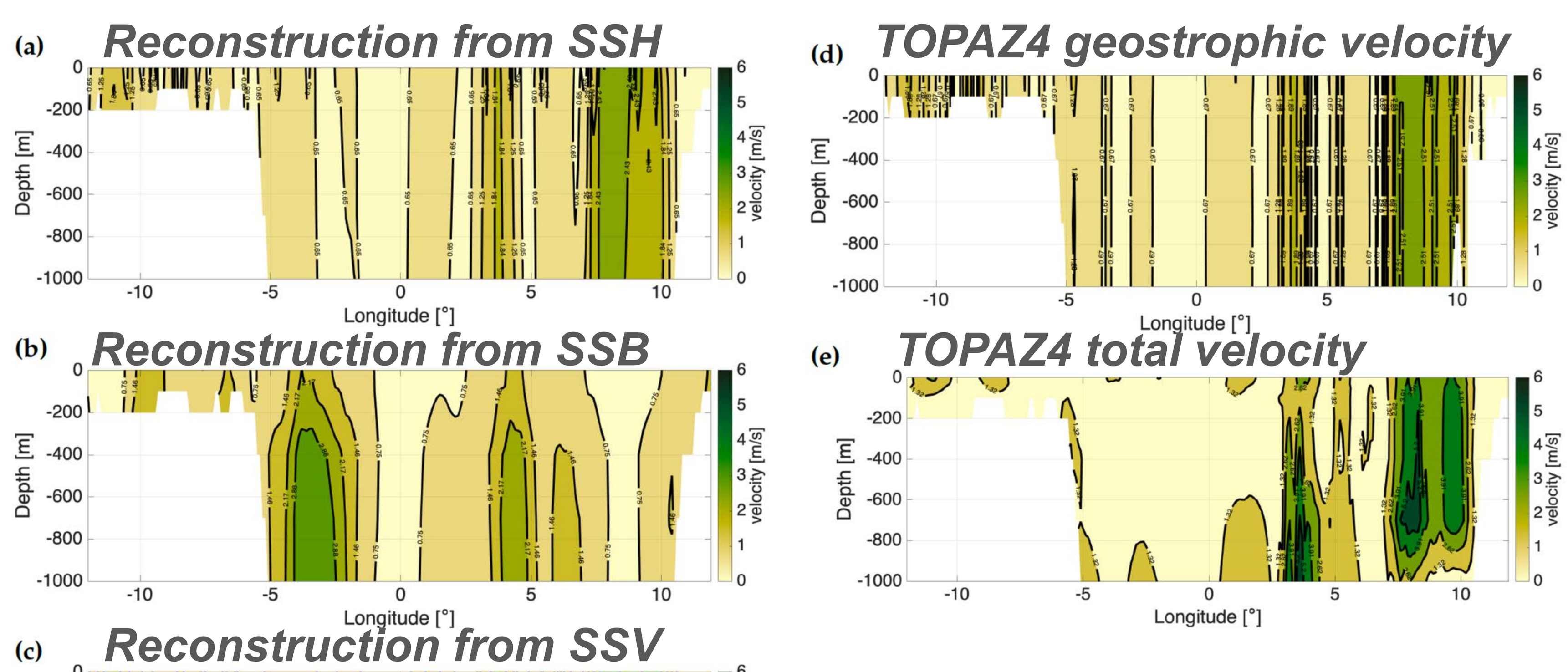


Figure 4: Currents along Fram Strait for the 28th August. a) Reconstruction from SSH, b) reconstruction from SSB, c) reconstruction from SSV, d) TOPAZ4 geostrophic velocity, e) TOPAZ4 total velocity.

Ocean 3D dynamics are reconstructed from surface buoyancy, surface height and surface velocities and compared to model geostrophic current and model total current. **Better results are achieved reconstructing 3D dynamics from SSH and from surface velocities.**

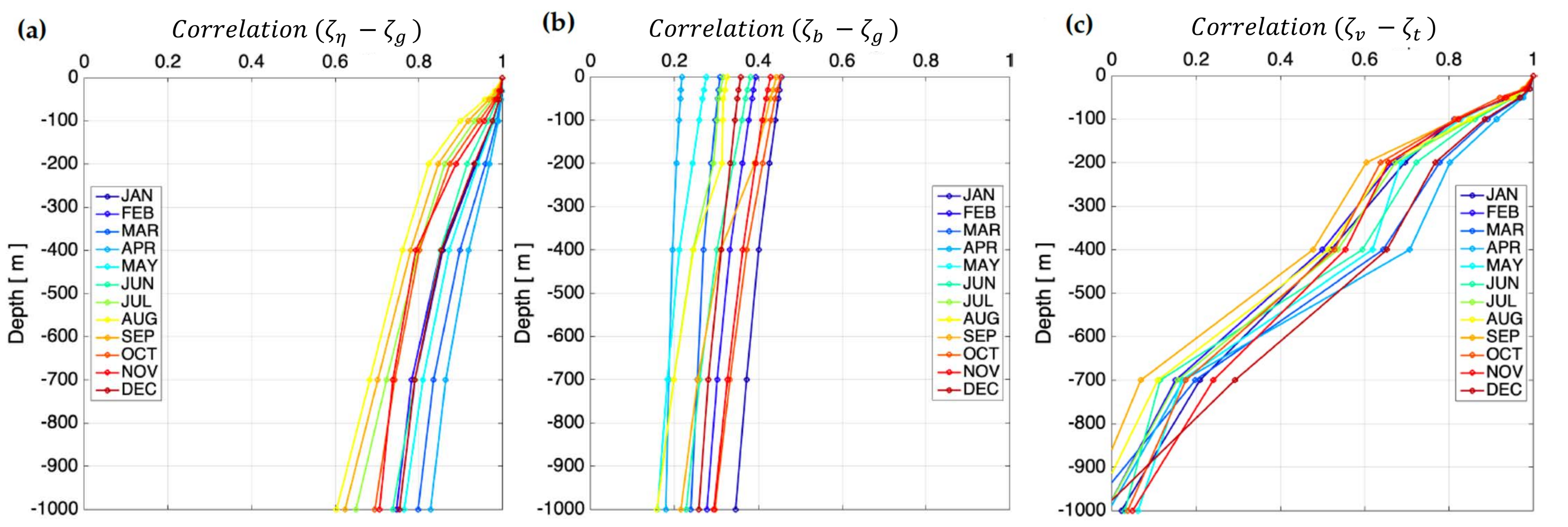


Figure 5: Vorticity correlations. a) Reconstruction from SSH / Model geostrophic velocity , b) reconstruction from SSB / Model geostrophic velocity , c) reconstruction from SSV / Model total velocity.

Vorticity correlations between **reconstruction form SSH** and model geostrophic current, **show good agreement (corr.>0.8) up to 400 meters.** Vorticity correlations between **reconstruction from SSV** and model total currents, **exhibit fairly good agreement (corr.>0.6) up to 200 meters. Reconstructions are better in the winter and spring** in all locations than in the summer and fall, **when the water column is less stratified** and the brunt-Vaisala frequency is fairly constant along the water column.

Summary and conclusions

- **Surface Quasi-Geostrophic (SQG) theory allows 3D dynamics in the Arctic Ocean to be reconstructed using only surface information of SSH or surface velocities, but it does not allow 3D dynamics to be reconstructed using only sea surface buoyancy.**
- **Improved 3D reconstructions are obtained during the winter and spring months when Brunt-Vaisala frequency is the lowest.**
- **The results of the research encourage us to use future remotely sensed SWOT and CRISTAL high-resolution sea surface height (SSH) and Seastar and WaCM direct measurements of ocean surface currents in polar areas to reconstruct 3D dynamics.**

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