Mesoscale dynamics in the Southern Ocean: perspectives for SWOT

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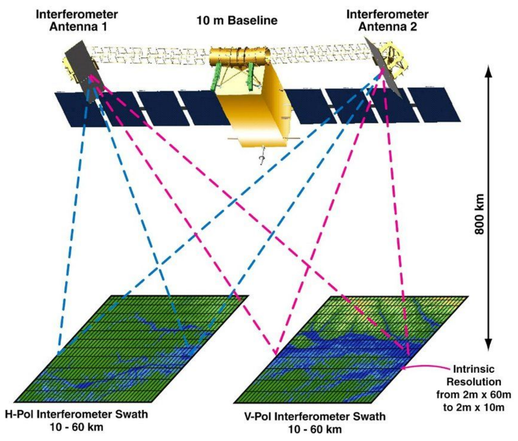
1 - RESEARCH QUESTION AND OBJECTIVES

- **Observability with SWOT**, after processing and reduction of instrumental and geophysical noise
  - ▸ Diagnostic of small scale variability, not possible with conventional altimetry
- Understand if small scale processes (15 to 150 km wavelength) increase or compensate the **mesoscale eddy fluxes** observable nowadays (>150 km) with nadir altimetry



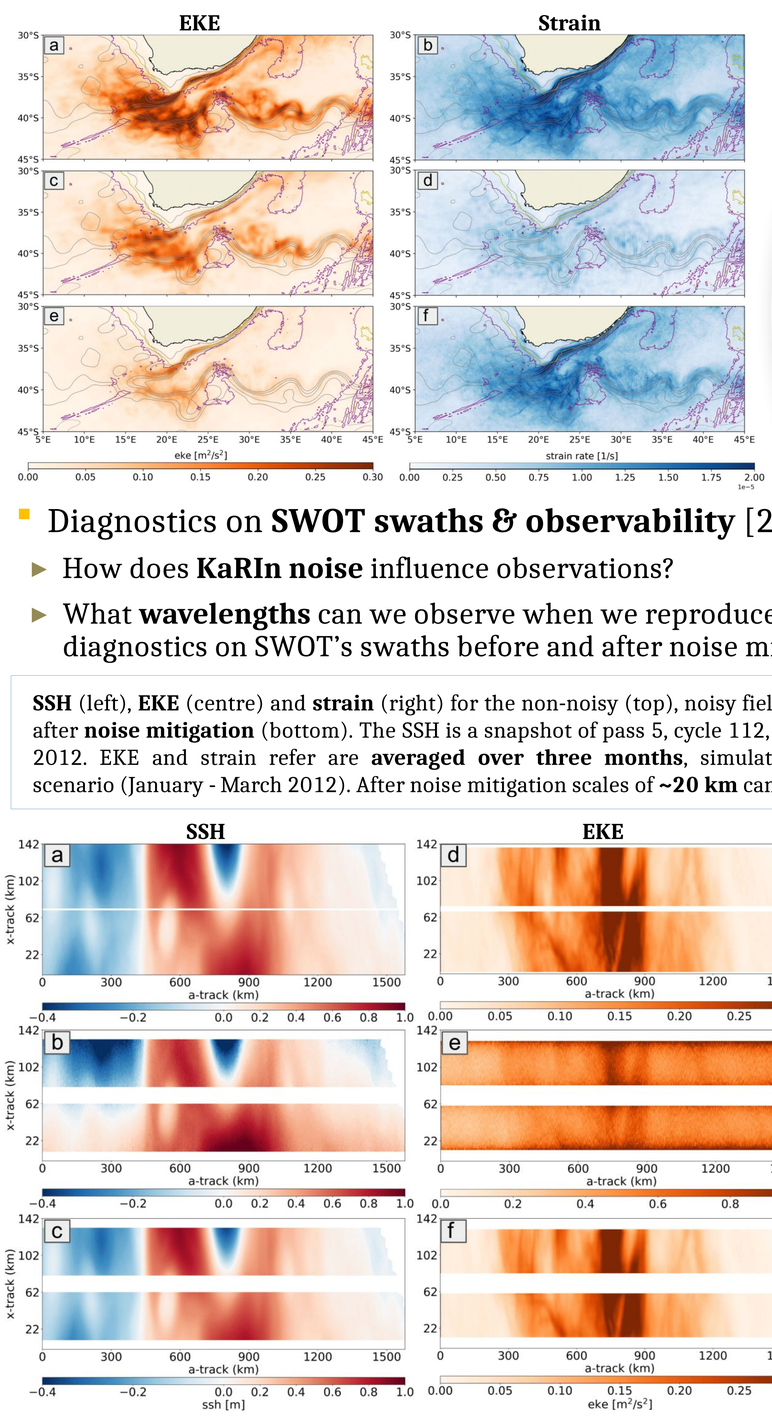
- Reconstruct **vertical velocities** and **vertical and horizontal heat fluxes** on the water column from Sea Surface Height (**SSH**) fields
  - ▸ **COAS coupled ocean-atmosphere model**
  - ▸ SWOT **real fast sampling phase data**

2 – EDDY DIAGNOSTICS

- 2D diagnostics in the **Agulhas region** [1]
  - ▸ What dynamics will **SWOT** be able to observe **compared to traditional altimetry**?

$$EKE = \frac{1}{2}(u'^2 + v'^2) \qquad S_g = \sqrt{\left(\frac{\partial u_g}{\partial x} - \frac{\partial v_g}{\partial y}\right)^2 + \left(\frac{\partial v_g}{\partial x} + \frac{\partial u_g}{\partial y}\right)^2}$$

Average EKE (left) and **strain rate std** (right) for **LLC10** (a, b), **pseudo-DUACS** product (c, d), and the **residuals** small scales (e, f). Small scales add energy on the mean Agulhas Current path, and **most of the strain variability**

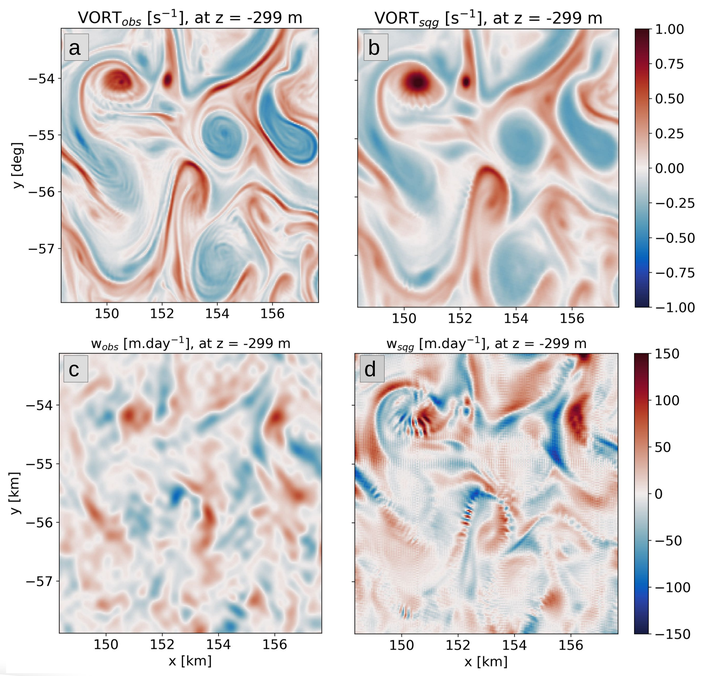


- Diagnostics on **SWOT swaths & observability** [2]
  - ▸ How does **KaRIn noise** influence observations?
  - ▸ What **wavelengths** can we observe when we reproduce diagnostics on SWOT's swaths before and after noise mitigation?

SSH (left), **EKE** (centre) and **strain** (right) for the non-noisy (top), noisy field (centre), and after **noise mitigation** (bottom). The SSH is a snapshot of pass 5, cycle 112, on January 1st 2012. EKE and strain refer are **averaged over three months**, simulating the CalVal scenario (January - March 2012). After noise mitigation scales of **~20 km** can be observed

3 – VERTICAL RECONSTRUCTION

- **Surface Quasi-Geostrophic** (SQG) theory: reconstruct vertical vorticity, velocity (w) and heat fluxes in the ocean interior from SSH [3][4]. Results **below the mixed layer** (ML) in the Southern Oeean south of Tasmania
  - ▸ First on **COAS coupled** ocean-atmosphere model, then on **SWOT real data**
  - ▸ Hypothesis of **uniform potential vorticity** (PV) on the full domain
  - ▸ **Optimized stratification** (N2) in the region and season
  - ▸ COAS w is filtered at 30 km to remove small scale noise



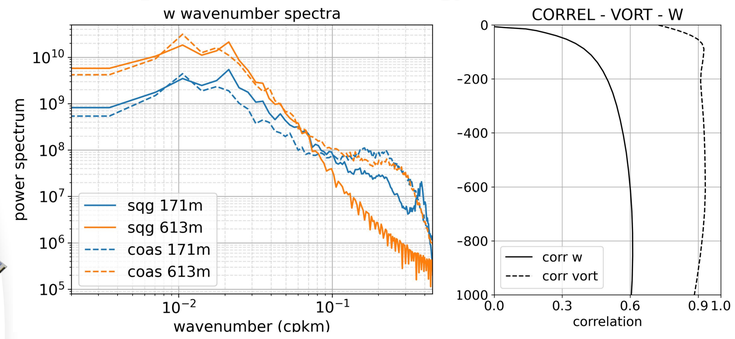
Reults refer to the **Southern Ocean** region south of Tasmania where the SWOT CalVal **ACC-SMST campaign** will take place. We show **daily averaged** variables (normalized vorticity, vertical velocity from SSH) on March 29th 2020. In this season and region the ML has depth of about 100 m.

Top: COAS (a) and SQG reconstructed (b) **normalized vorticity** at 299 m depth.

Bottom: COAS (c) and SQG reconstructed (d) **vertical velocity** at 299 m depth.

SQG is able to reconstruct the vorticity and vertical velocity **mesoscale structures** below the ML with the correct shape and position in space, and correct amplited. **Submesoscale structures** are smoothed with depth (see spectra).

- ▸ Correlation between the modelled and the SQG-reconstructed fileds is **over 0.9** for the vorticity and **over 0.6** for the vertical velocity
- ▸ Spectra of COAS and SQG non-filtered w fields at different depths show **comparable levels of energy down to 30-40 km**



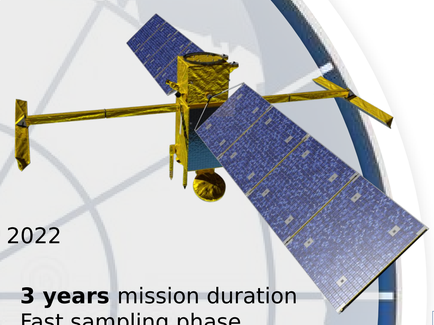
Correlation (a) is consistent below the ML is consistent **up to 1000 m**

The **spectra** (b) at different depths show that SQG is able to reproduce the energy in the **mesoscale down to 30 km**, showing the great potential of the method for SWOT, which will have a similar observability in the Southern Ocean [1][5]

SWOT facts

first **wide-swath 2D altimetry** mission, using **SAR-Interferometry** globally in **Ka-Band**

NASA/CNES mission
https://swot.jpl.nasa.gov/



Launch date
December 16th 2022

Falcon 9 rocket
Vandenberg Air Force Base
California

3 years mission duration
Fast sampling phase
Science phase

10 meters
Antennas separation

120 km
Large swath globally

Primary instrument
KaRIn

High resolution
ocean and hydrology obs

1 or 21 days revisit time
Depending on the mission phase

5 - FUTURE WORK

- Reproduce the SQG w reconstruction over **SWOT swaths** with fast sampling phase 1-day data
- Study the **vertical and horizontal heat fluxes dynamics** in the region and the potential of using SQG to reconstruct them
  - ▸ With **COAS** coupled ocean-atmosphere model
  - ▸ With **SWOT** 1-day real data
- Validate the method with the use of **in-situ data from SURVOSTRAL** 30 years long time-series data and data from **SWOT CalVal** campaign

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REFERENCES

[1] Carli, E., Morrow, R., Vergara, O., Chevrier, R., and Renault, L.: Ocean 2D eddy energy fluxes from small mesoscale processes with SWOT, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2023-1124, 2023
[2] A. Tréboutte, E. Carli, M. Ballarotta, B. Carpentier, Y. Faugère, and G. Dibarboure, "KaRIn Noise Reduction Using a Convolutional Neural Network for the SWOT Ocean Products," Remote Sensing, vol. 15, no. 8, Art. no. 8, Jan. 2023, doi: 10.3390/rs15082183
[3] P. Klein et al., "Diagnosis of vertical velocities in the upper ocean from high resolution sea surface height," Geophysical Research Letters, vol. 36, no. 12, 2009, doi: 10.1029/2009GL038359.
[4] J. Wang, et al., "Reconstructing the Ocean's Interior from Surface Data," Journal of Physical Oceanography, vol. 43, no. 8, pp. 1611–1626, Aug. 2013
[5] J. Wang, L.-L. Fu, H. S. Torres, S. Chen, B. Qiu, and D. Menemenlis, "On the Spatial Scales to be Resolved by the Surface Water and Ocean Topography Ka-Band Radar Interferometer," Journal of Atmospheric and Oceanic Technology, vol. 36, no. 1, pp. 87–99, Jan. 2019, doi: 10.1175/JTECH-D-18-0119.1

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