SWOT in the Tropics (SDT project): High-frequency and small-scale dynamics around New-Caledonia from in situ observations

G. Sérazin, F. Marin, S. Cravatte, L. Gourdeau,
R. Morrow, F. Durand, J.-L. Fuda
LEGOS/IRD, Toulouse, France guillaume.serazin@legos.obs-mip.fr

1) New Caledonia

Mean circulation of the Coral Sea

New Caledonia induces the separation of the southern branch of the South Equatorial Current (SEC) into the North Caledonian Jet (NCJ) and the South Caledonian Jet (SCJ). (*Kessler and Cravatte, 2013*)

Eddy variability was shown to dominate the mean circulation around New Caledonia (*Cravatte et al., 2015*) but this transient circulation is still poorly known.

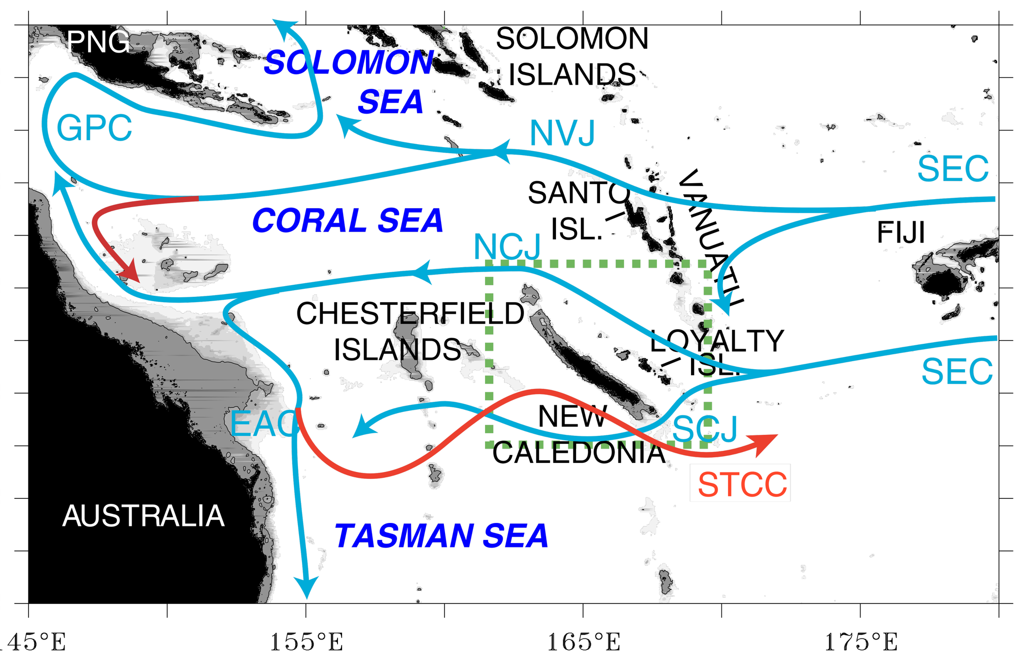

Fig. 1.1: *Sketch of the mean currents of the Coral Sea (Cravatte et al., 2015)*

Current altimetry

What have we learned from current satellite altimetry ?

Eddy Kinetic Energy may be derived from mapped sea surface (AVISO), down to 150-200 km
→ Substantial mesoscale EKE south of New Caledonia

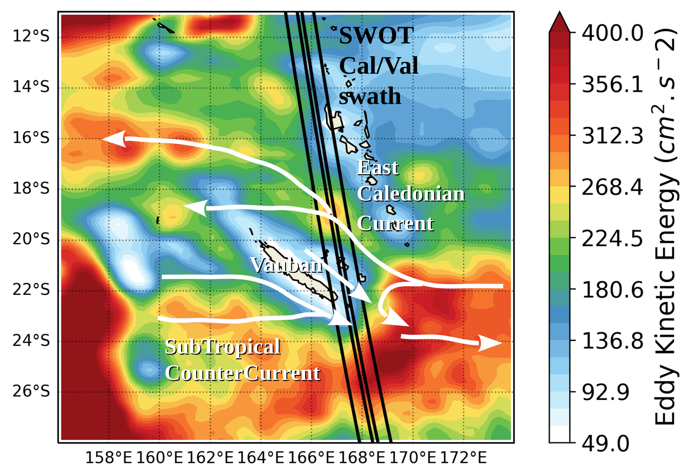

Fig. 1.2: *Eddy Kinetic Energy computed on AVISO for 1992-2017 with mean currents (white)*

Reconstruction of the M2 (coherent) internal wave (*Ray et Zaron, 2016*)
→ M2 IWs are substantial in the South West Pacific, especially North and South of New Caledonia

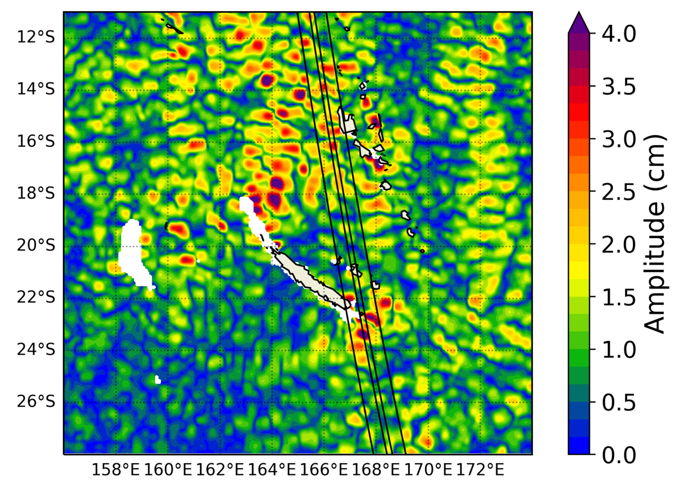

Fig. 1.3: Amplitude of the M2 internal tide on Sea Surface Height (*Ray and Zaron, 2016*)

Future altimetry

What sort of small-scale dynamics are likely to impact on the SWOT signal ?

- Submesoscale features associated with coherent mesoscale structures, frontal structures and mixed layer instabilities
- Internal tides generated by the interaction of the barotropic tides with the steep topography
- Inertial waves generated by strong wind stresses
- Inertia gravity waves related to mesoscale circulation

→ **Need for an understanding of the observed small-scale sea surface height signal and errors from 20-200 km as well as the subsampling errors of scales < 20 km.**

Using the SWOT Cal/Val Swath

The future SWOT satellite will fly next to New Caledonia during the Cal/Val cycle (Fig. 1.2) and will provide an unprecedented opportunity to characterize the small-scale dynamics down to 20 km in this region, with the joint use of in situ observations.

Main motivation of this work:

Characterize high-frequency small-scale dynamics using existing in situ observations in order to prepare a Cal/Val experiment for the SWOT mission

2) Structure functions from ADCP

Method:

Computation of second order structure function D2(r) from observed ADCP longitudinal (//) and transverse (⊥) velocities separated by distance r

$$D2(\boldsymbol{r}) = \left\langle [u(\boldsymbol{x}) - u(\boldsymbol{x}+\boldsymbol{r})]^2 \right\rangle$$

(e.g., *Balwada et al., 2016*)
Hypotheses: homogeneity, stationarity

Argument 1:

Second order structure function D2 is closely related to the classic Kinetic Energy spectrum E and classic power laws (*Lindborg, 2007*):

$$\text{Power law: } E \sim k^{\alpha}, \quad D2 \sim r^{-\alpha-1}$$
$$\text{QG: } E \sim k^{-3}, \quad D2 \sim r^{2}$$
$$\text{SQG: } E \sim k^{-2}, \quad D2 \sim r$$
$$\text{Kolmogorov: } E \sim k^{-5/3}, \quad D2 \sim r^{2/3}$$

Argument 2:

A Helmholtz decomposition is possible if the rotational (ψ) and the divergent (ϕ) are uncorrelated and the flow is isotropic (*Lindborg, 2015*):

$$D2_{\psi}(r) = D2_{\parallel}(r) + \int_0^r \frac{D2_{\parallel}(r') - D2_{\perp}(r')}{r'} dr'$$
$$D2_{\phi}(r) = D2_{\perp}(r) - \int_0^r \frac{D2_{\parallel}(r') - D2_{\perp}(r')}{r'} dr'$$
$$D2 = D2_{\perp} + D2_{\parallel} = D2_{\psi} + D2_{\phi}$$

Results:

- Surface **total D2** (Fig. 2a) scales as a SQG-like regime with a slope close to 1. **Rotational** motions dominate **divergent** motions between 2 and 100 km.
- Interior (500m) **total D2** (Fig. 2b) scales as a Kolmogorov inertial range with a slope close to 2/3. **Rotational** motions dominate for scales > 50 km. At smaller scales, **divergent** and **rotational** motions are equivalent.
- D2 slopes (Fig. 2d) show a transition between a surface regime (~1, < 150 m) and an interior regime (~2/3, > 200 m)

Discussion:

Inertia Gravity Waves are likely to dominate scales < 50 km in the interior and dissipate Kinetic Energy but meso and submesoscale motions may dominate the surface motions. The 2/3 law is consistent with the Garrett and Munk (1972) spectrum, which may suggest that IGWs cascade KE downscale through wave-wave interaction. The source of these IGWs at 500 m depth is unexplored.

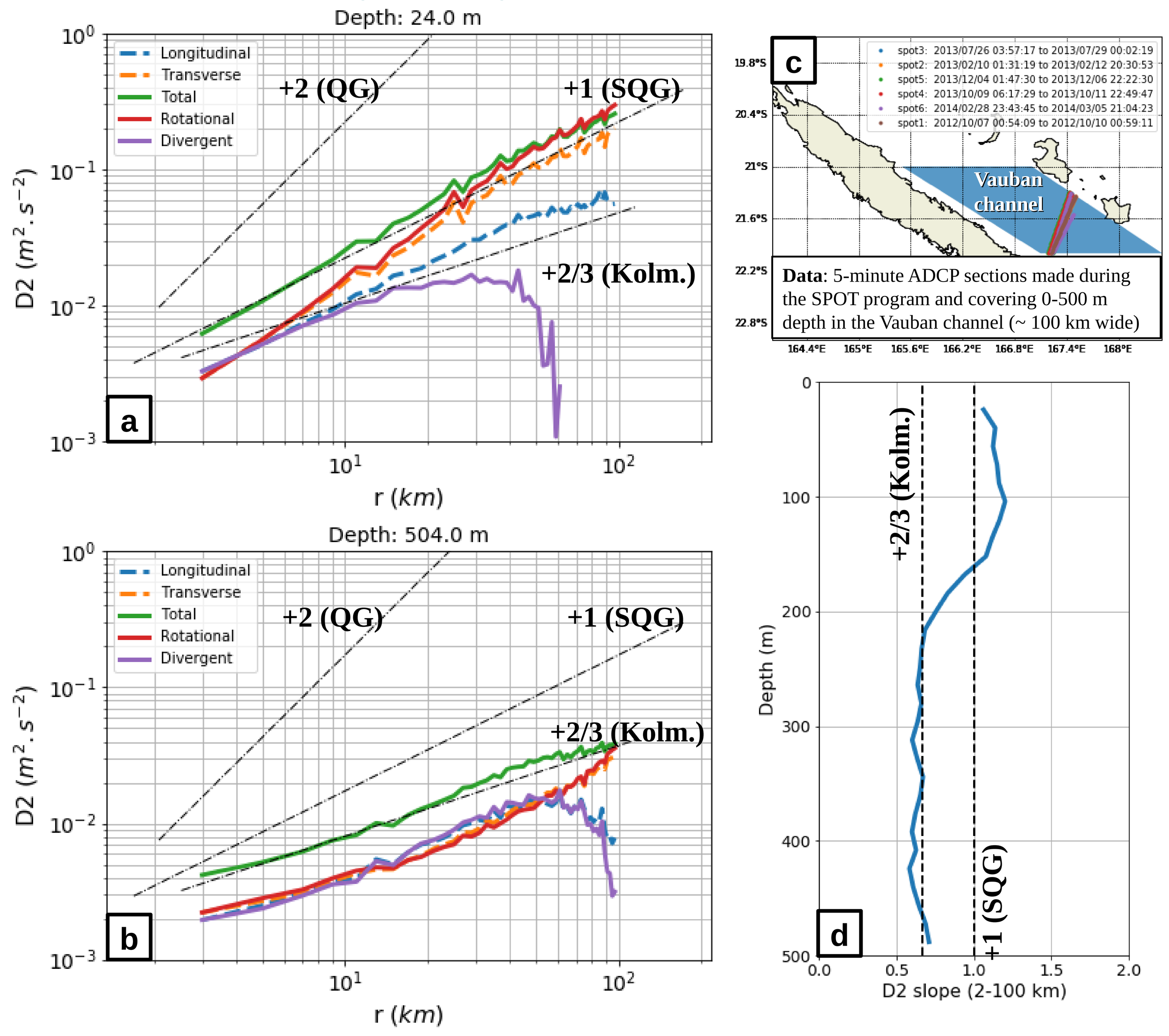

Fig. 2: *Structure functions averaged over six ADCP shiptrack at 24 m (a) and at 504 m (b) with classic turbulence power law (dashed lines). Description of the six shiptrack used for the analysis in the Vauban Channel (c). Structure function slope estimated for each depth level (d).*

3) M2 internal tides estimated with gliders

Method:

Harmonic fitting on M2 period performed on isopycnal displacements estimated over 6-day moving windows

(e.g. *Rainville et al., 2013*)

Data: Two Spray underwater glider sections performed during the AltiGlidex Cal/Val campaign for SARAL/Altika (*Durand et al., 2017*). Only one glider section is shown here for August-November 2013.

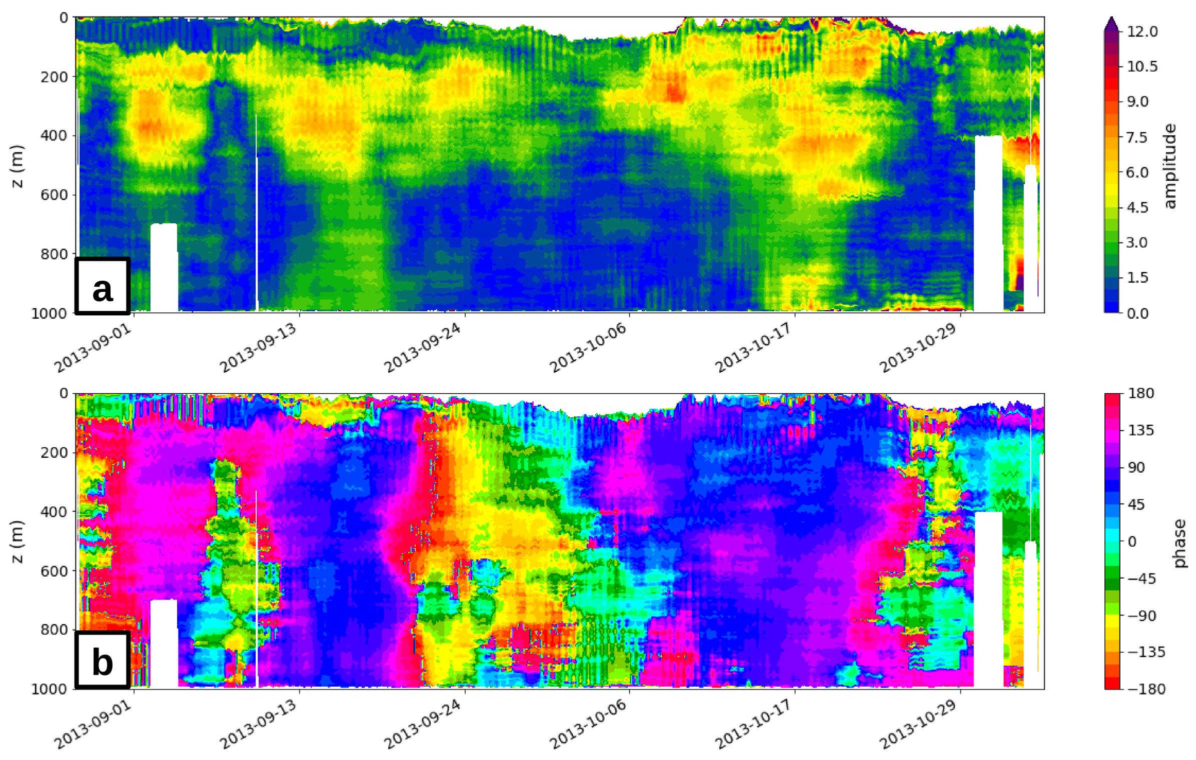

Fig. 3.1: *Amplitude (a) and phase (b) of the isopycnal displacements due to the M2 internal tide, estimated from a glider deployment.*

Results:

- Coherent vertical signal in amplitude and phase is captured with this method. The glider samples well the M2 internal tide.
- Geographic distribution of M2 internal tides estimated from gliders is consistent with altimetry.

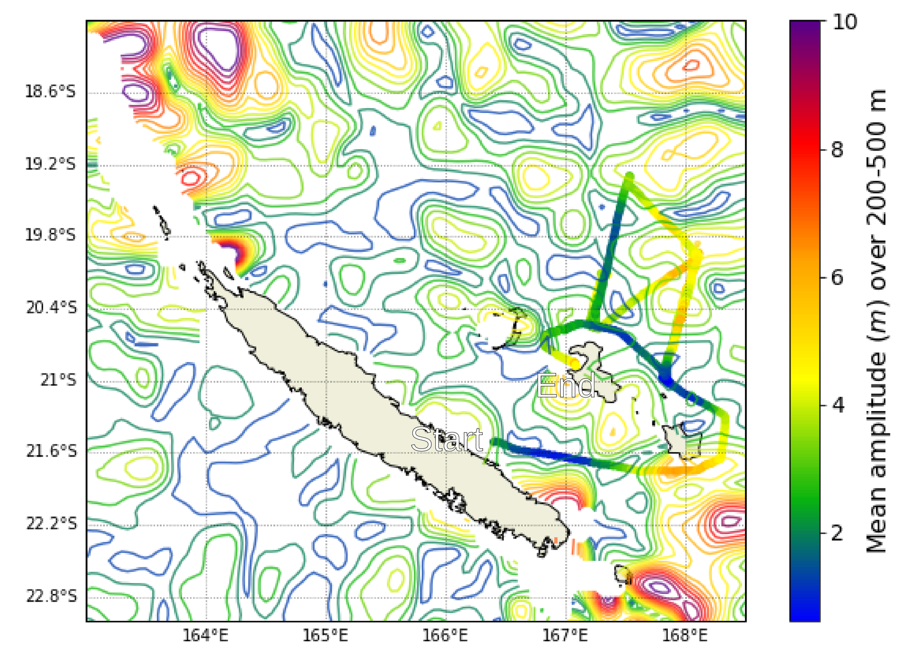

Fig. 3.2: *M2 amplitude of the glider along-track isopycnal displacement (colored scatter), averaged over between 200-500m, compared to mapped M2 amplitude of Sea Surface Height in colored contours (ranging from 0 to 4 cm, similar to Fig, 1,3,, from Ray and Zaron, 2016).*

4) HF vertical velocity

Method:

High-pass filtering of the observed glider vertical velocity (Rudnick et al. 2013)

- Non-linear detrending (LOESS) to remove T > 1.5 h
- Low-pass filtering (T < 130s) for denoising

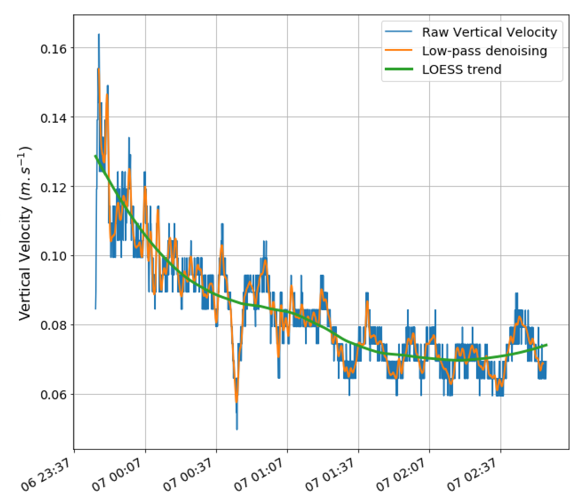

Fig. 4.1: *Glider profile of vertical velocity*

Data:

The two glider sections mentioned in 3).

Results:

In the Vauban channel and in the East Caledonian Current, observed vertical velocities are spatially homogeneous (between 5 and 10 mm/s).

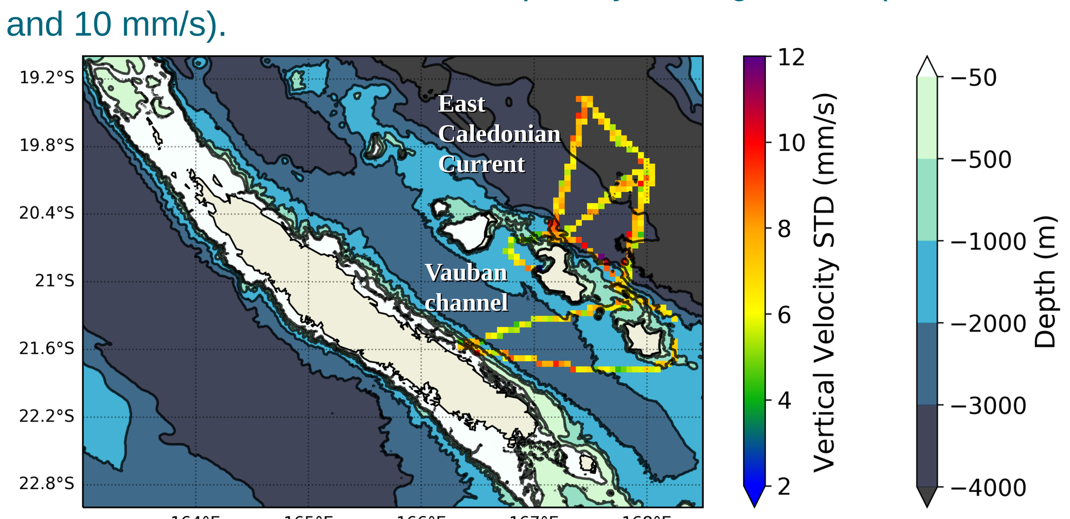

Fig. 4.2: *Standard deviation of HF (130 s < T < 1.5 h) vertical velocity*

5) Keypoints & future work

Keypoints:

- Structure functions are applied on ADCP shiptracks for the first time and give interesting insights to characterize the small-scale distribution of Kinetic Energy.
- In the Vauban channel, we highlight two dynamical regimes between the surface layer, likely SQG dynamics, and the interior, likely internal waves.
- We confirm that gliders are valuable tools to capture the M2 internal wave as well as HF vertical velocities.
- The consistency between altimetry and glider measurements for the M2 internal wave is encouraging for the use of SWOT for describing internal waves.

Future work:

Gliders:

- Perform similar analyses (M2 amplitude/phase and HF vertical velocities on existing glider data north and south of New Caledonia
- Evaluate the contribution of the 1st baroclinic mode and its imprint on sea surface height

ADCP data:

- Extend the structure function analysis to the large ADCP database around the region

Satellite observations: SST to identify submesoscale fronts / Sentinel 3 for along-track spectrum down to 30 km.

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