Characterization of small-scale dynamics around New Caledonia from observational data: S-ADCP, TSG, altimetry, gliders

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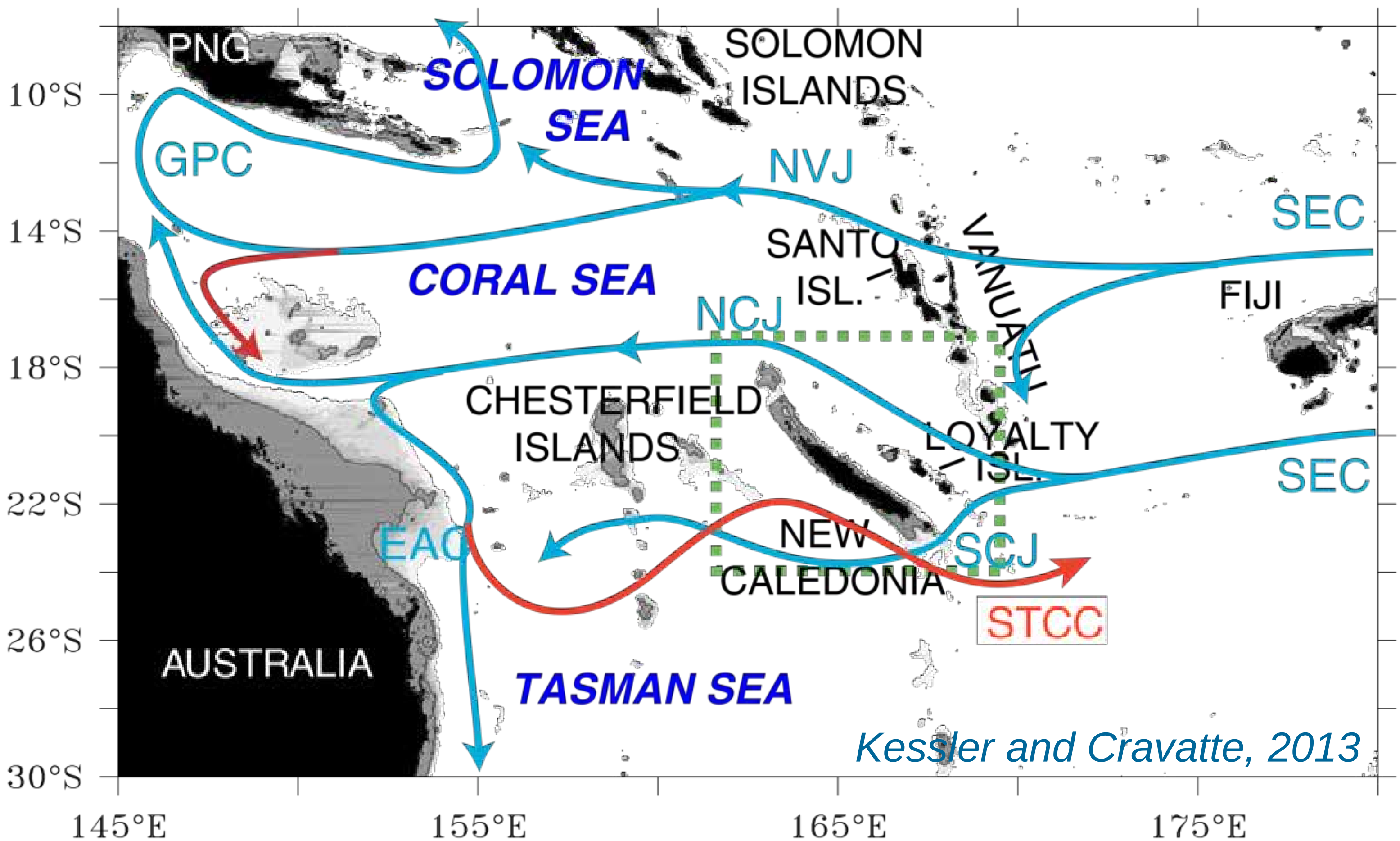
New Caledonia and the Southwest Pacific

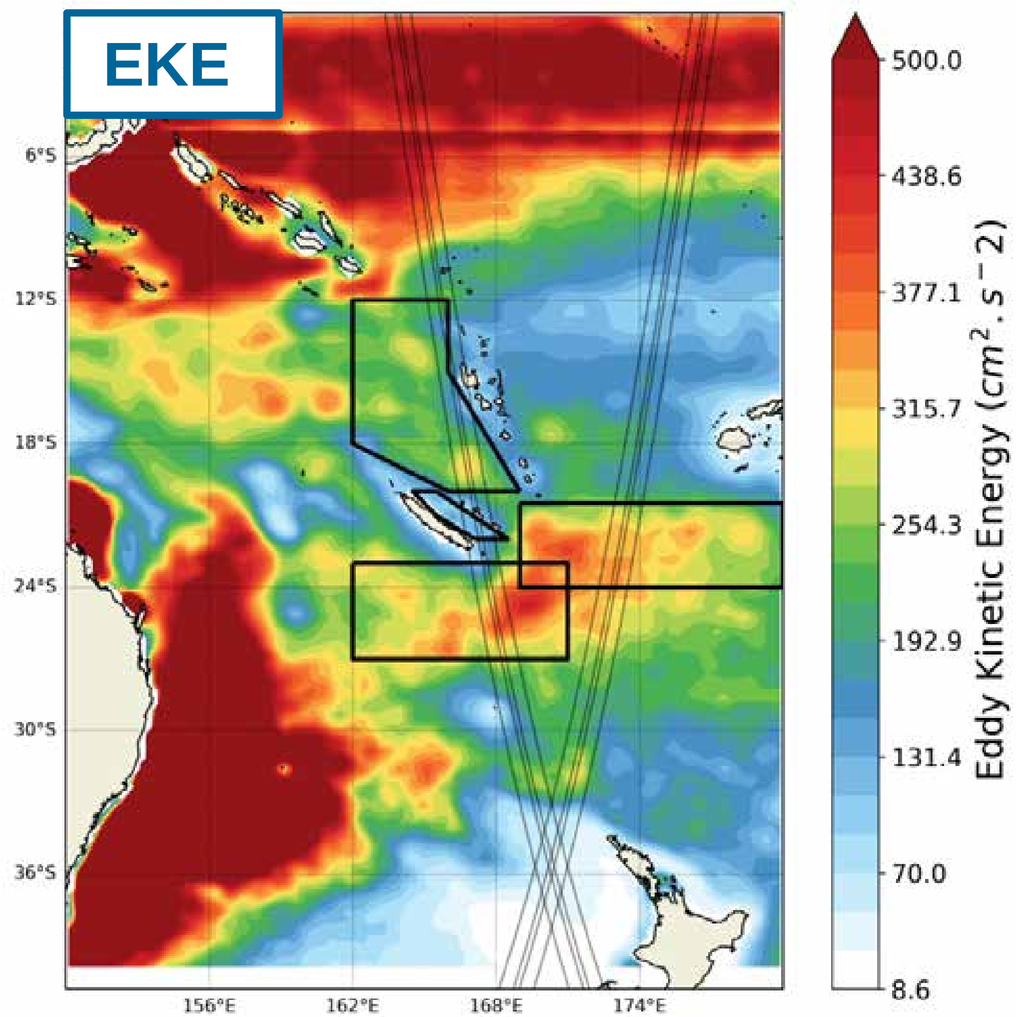


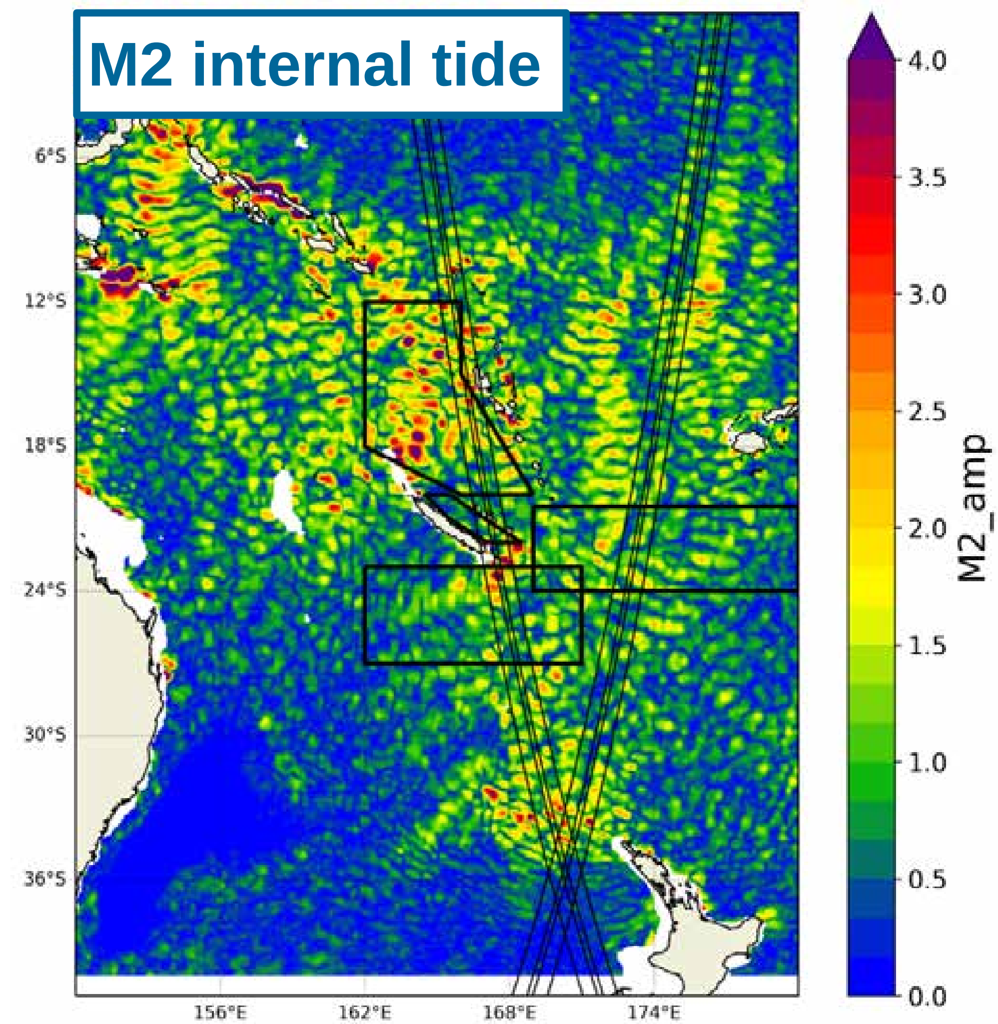
But the transient circulation is also substantial and poorly known

→ Eddy variability dominates the mean circulation around New Caledonia (*Cravatte et al., 2015*)

Mesoscale eddies vs internal waves

What have we learned from current satellite altimetry ?





What small-scale signal will SWOT see in those regions ?

Main goals and contents

Our objectives:

- Achieve a better understanding of small-scale (1-100 km) processes around New Caledonia using in situ and satellite observations
- Assess the capacity of in situ observing systems to measure submesoscale and internal tide features
- Take advantage of this knowledge to design a joint experiment between the SWOT Cal/Val cycle (1-day orbit) and deployed in situ observations

This presentation:

- Velocity structure functions (S-ADCP)
- Surface tracer structure functions (TSGs)
- Along-track sea level spectra (Jason 2 and Sentinel 3)
- Insights from gliders: internal waves and submesoscales

Structure functions applied on shipboard measurements

Lagged difference of a quantity Q (e.g., SST, SSS):

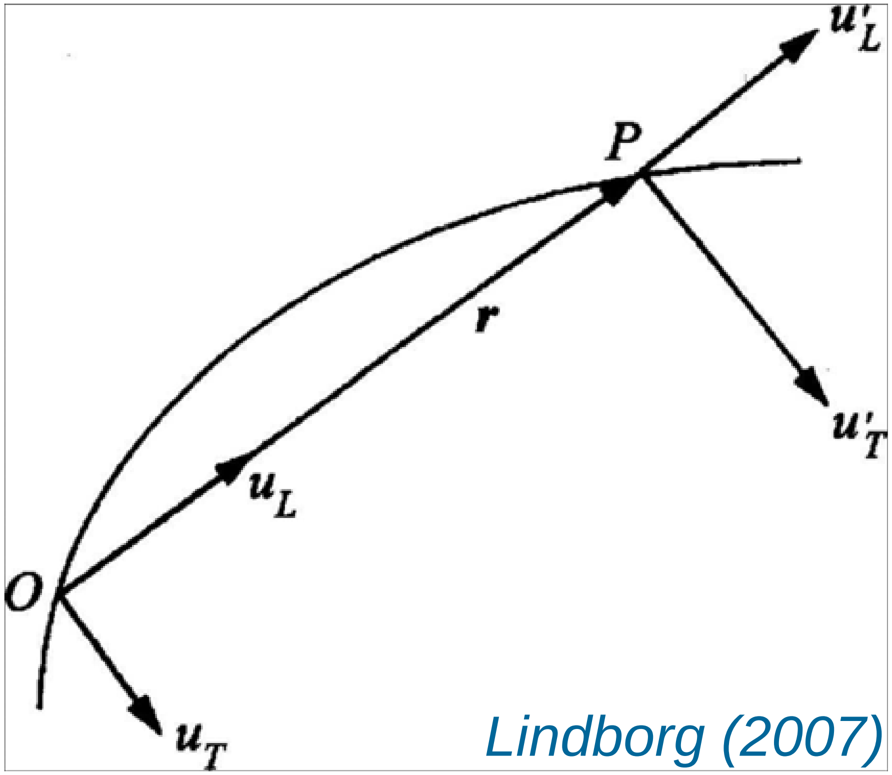
$$\delta Q(\boldsymbol{x}, \boldsymbol{r}) = Q(\boldsymbol{x}+\boldsymbol{r}) - Q(\boldsymbol{x})$$

$$D_{QQ}(\boldsymbol{r}) = \langle \delta Q(\boldsymbol{x}, \boldsymbol{r})^2 \rangle_{\boldsymbol{x}}$$

For horizontal velocity components:

$$D_{\|}(\boldsymbol{r}) = \frac{\langle \| \delta \boldsymbol{U}(\boldsymbol{x}, \boldsymbol{r}) \cdot \boldsymbol{r} \|^2 \rangle_{\boldsymbol{x}}}{\|\boldsymbol{r}\|^2},$$

$$D_{\perp}(\boldsymbol{r}) = \frac{\langle \| \delta \boldsymbol{U}(\boldsymbol{x}, \boldsymbol{r}) \times \boldsymbol{r} \|^2 \rangle_{\boldsymbol{x}}}{\|\boldsymbol{r}\|^2}.$$



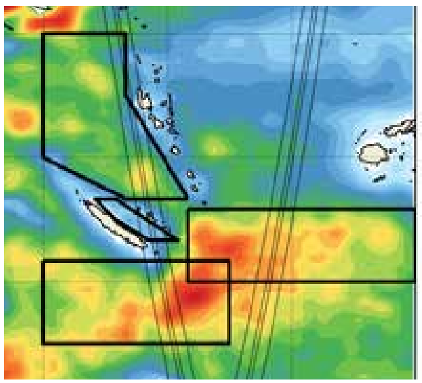
Lindborg (2007)

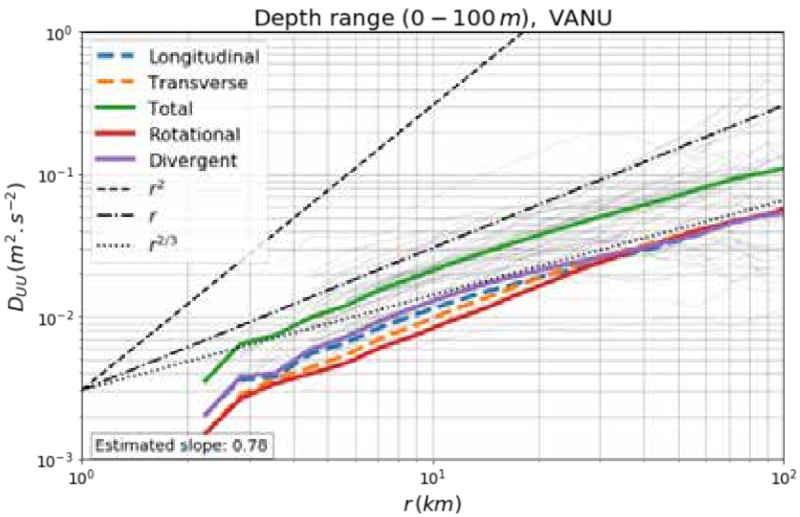
SFs is similar to spectral analysis $r^{\alpha} \leftrightarrow k^{-\alpha-1}$

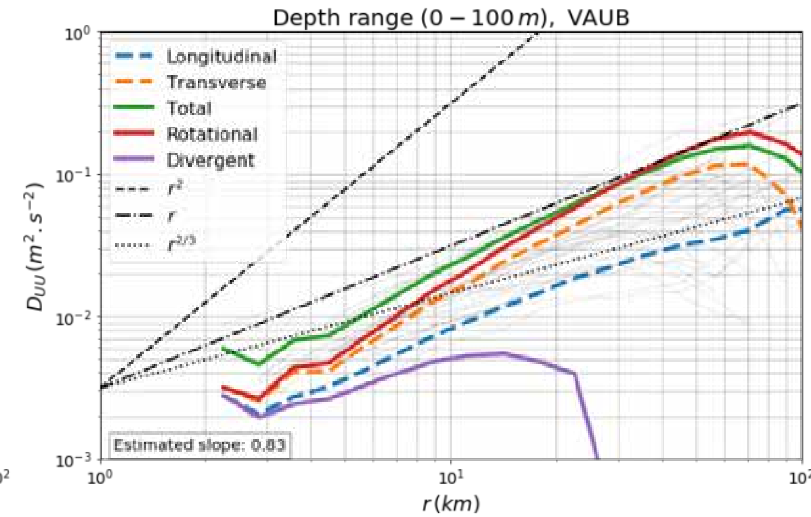
Pro: SFs do not require uniform sampling nor preprocessing

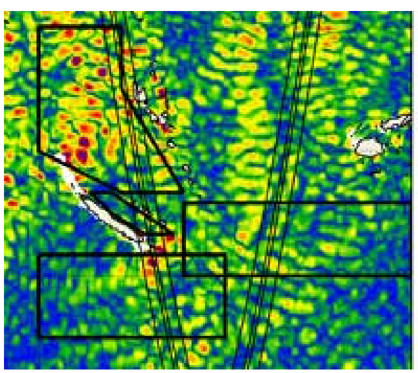
Con: SFs saturate at slopes r^2 (k^{-3}) → Not suited for SSH analysis

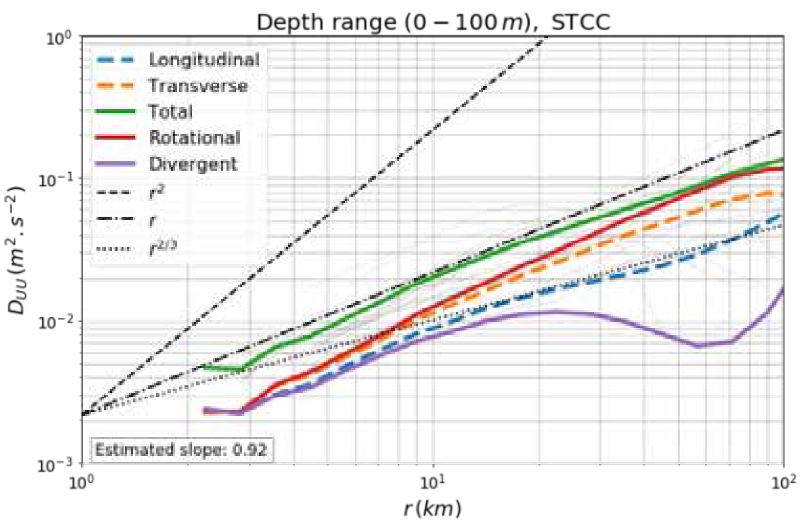
S-ADCP: structure functions & Helmholtz decomposition

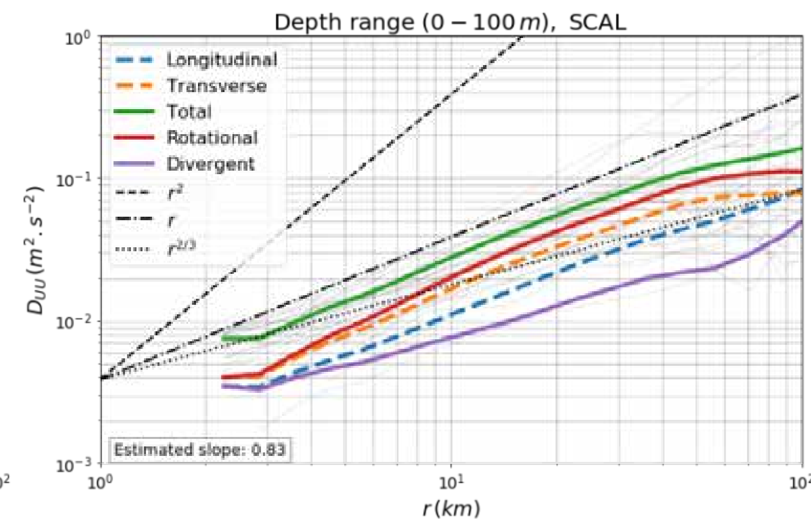






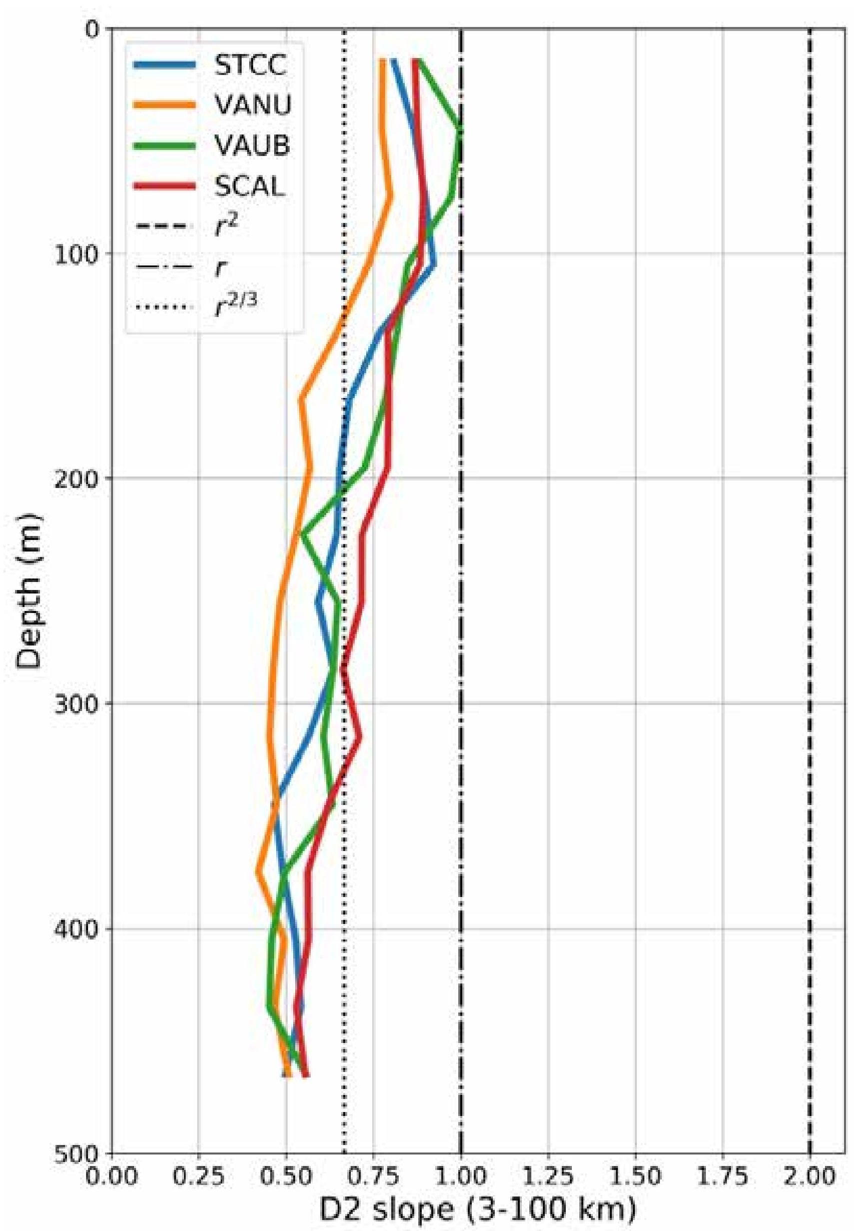






Surface motions are predominantly **rotational** motions in eddy active regions (less steep than 1), expect in VANU where **internal waves** probably dominate

S-ADCP: slopes of structure functions

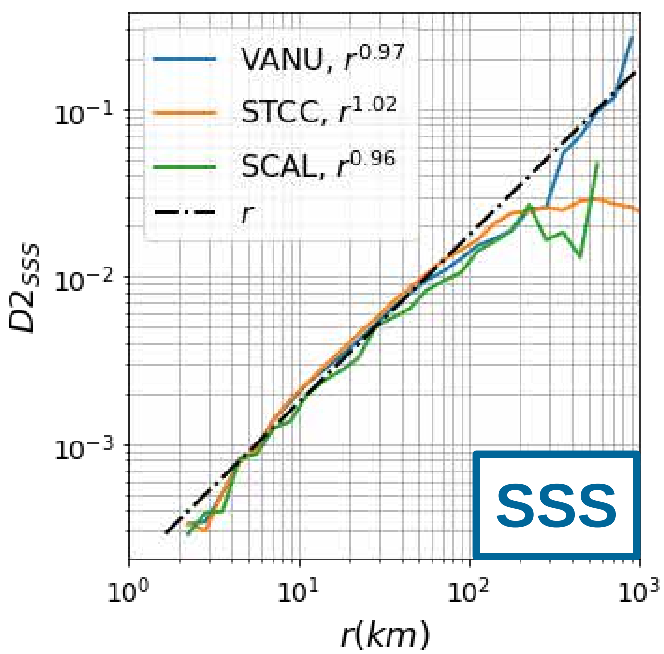


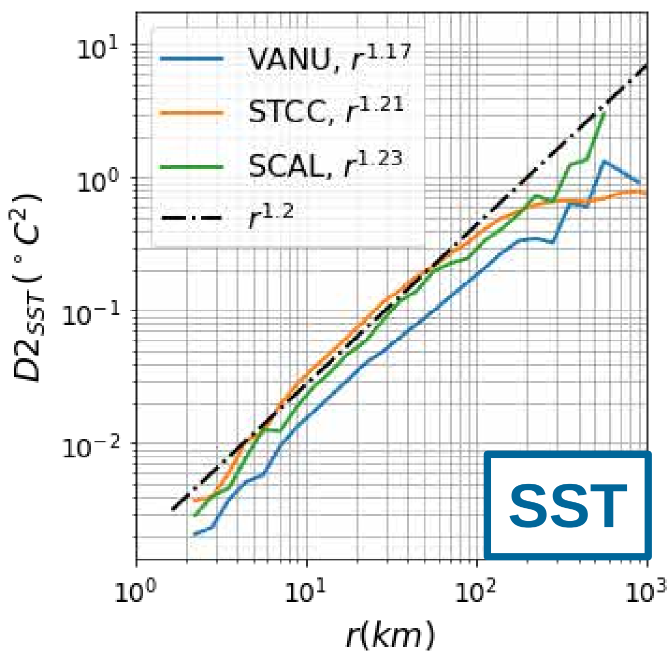
- SF slopes show a clear transition with depth for all regions
- The rotational component tends to weaken with depth (not shown here) → surface intensify regime

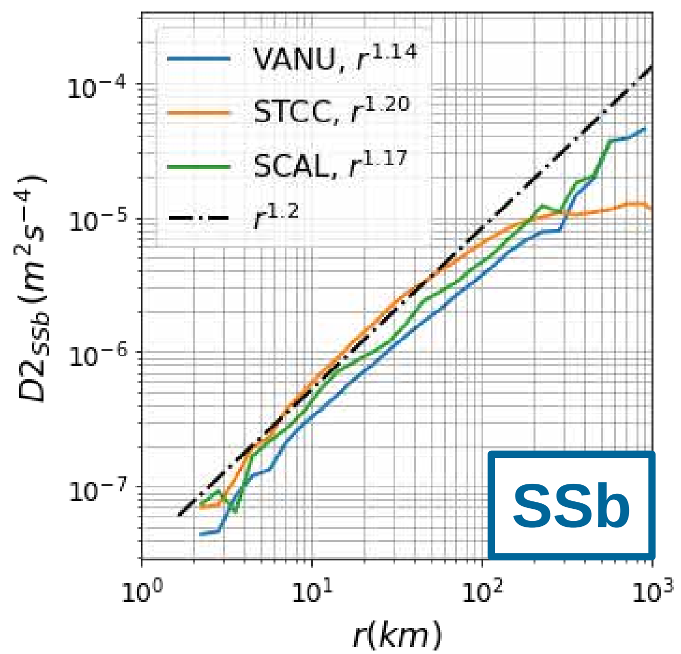
What set this transition?

- No clear link with the thermocline nor the MLD
- Associated with a surface trapped mode?
- Artefact due to ADCP accuracy?

TSGs: SSS, SST & buoyancy structure functions



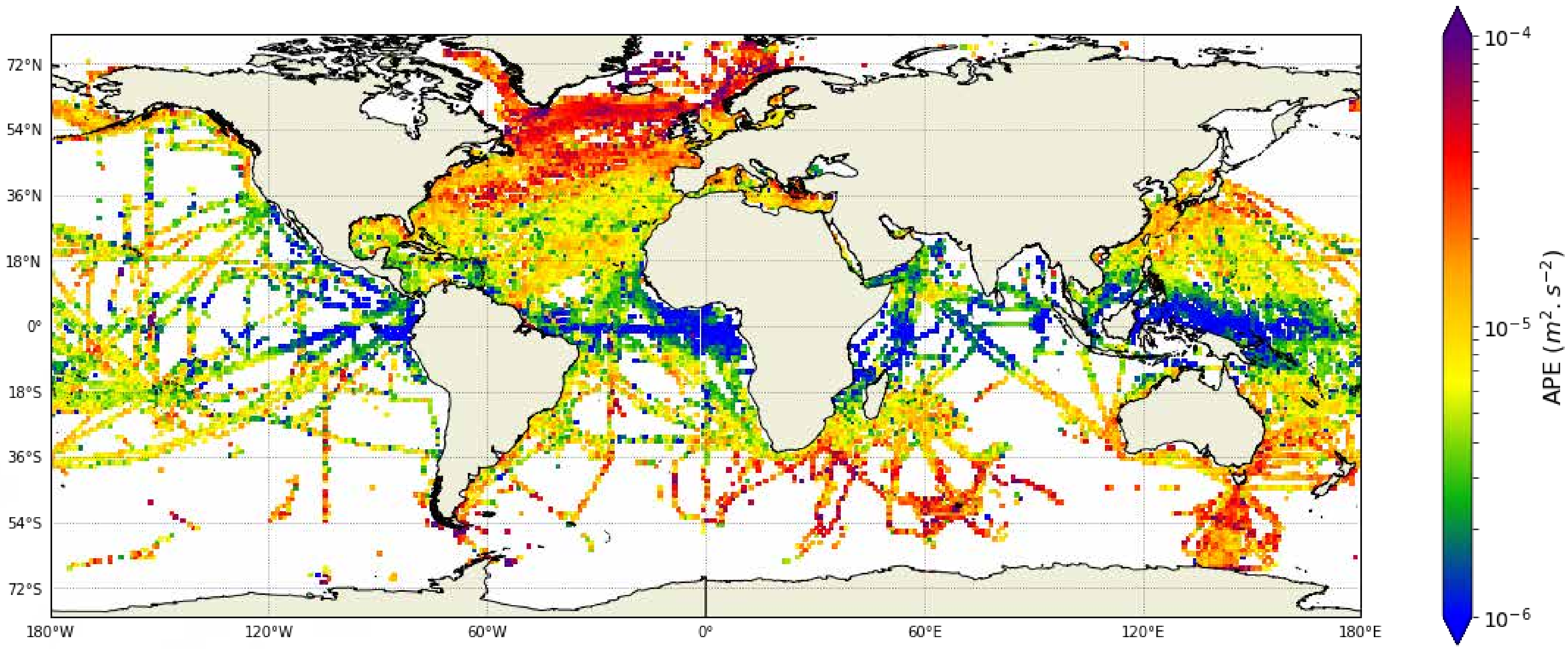




- D2 SSS slope ~ 1 and D2 SST slope ~ 1.2 consistent with frontogenesis predictions for passive tracers
- Weaker SST and buoyancy variance in the Vanuatu region → consistent with weaker rotational motions

TSGs: APE for Mixed Layer Instabilities

$$APE \approx \frac{1}{2} H_b^2 \overline{\|\nabla_h b_{ME}\|},$$



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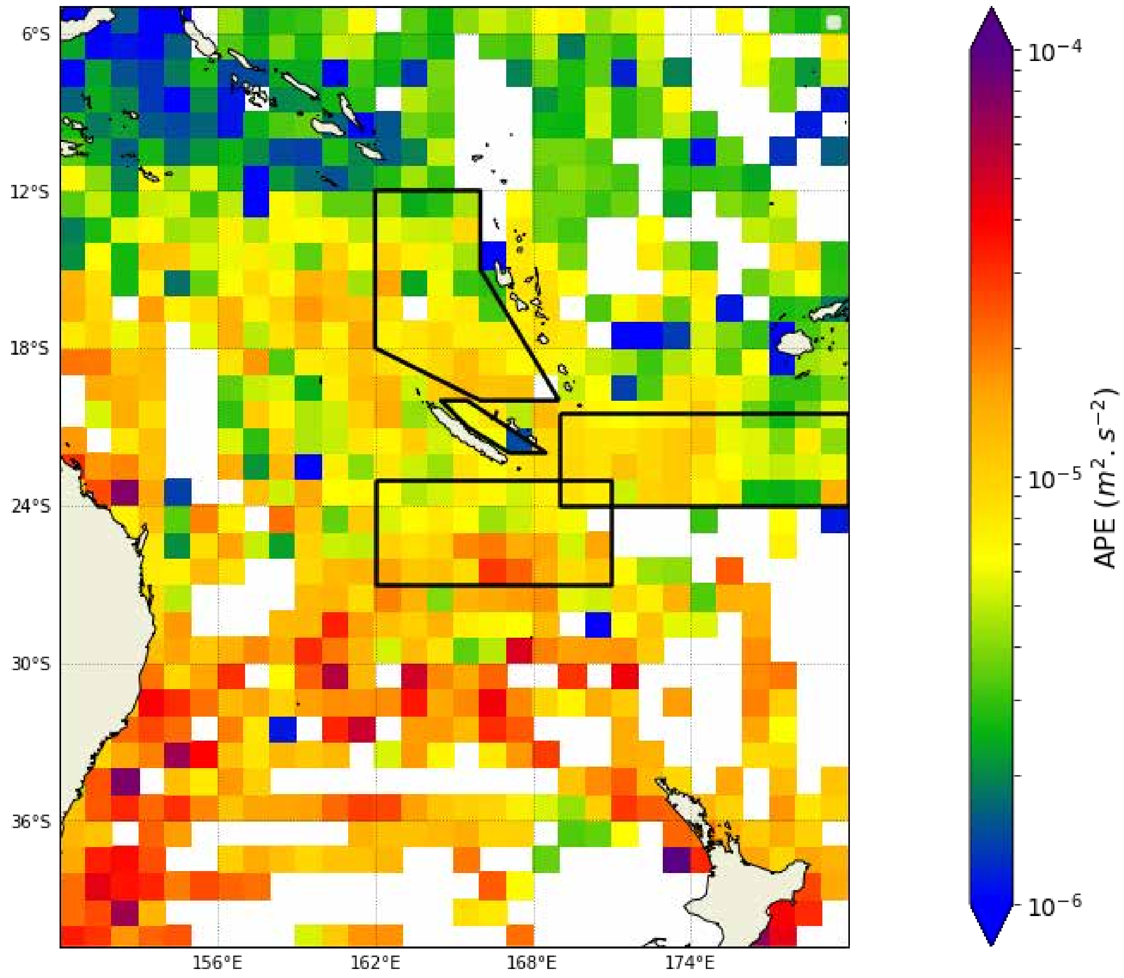
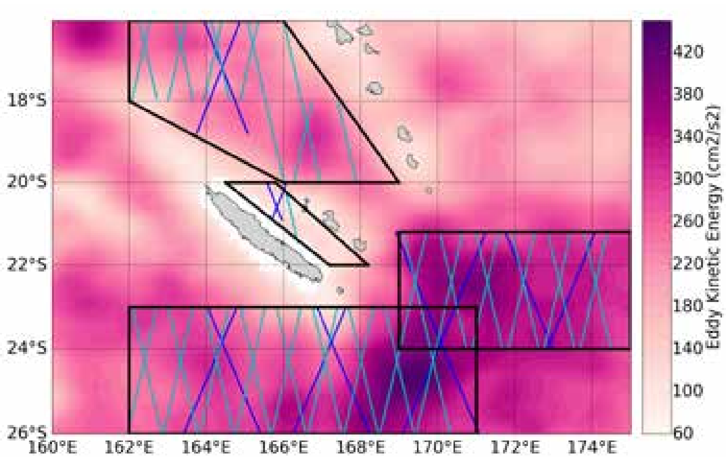
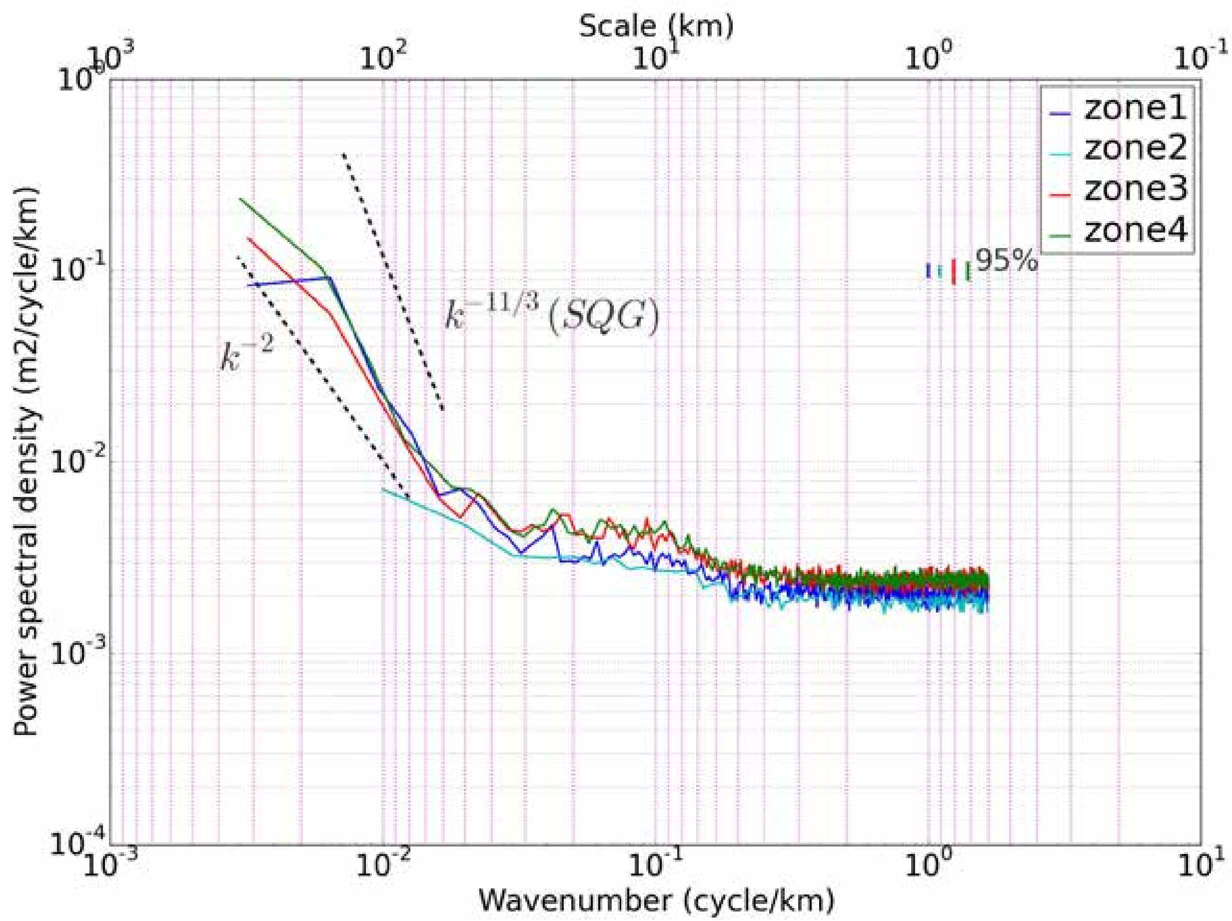


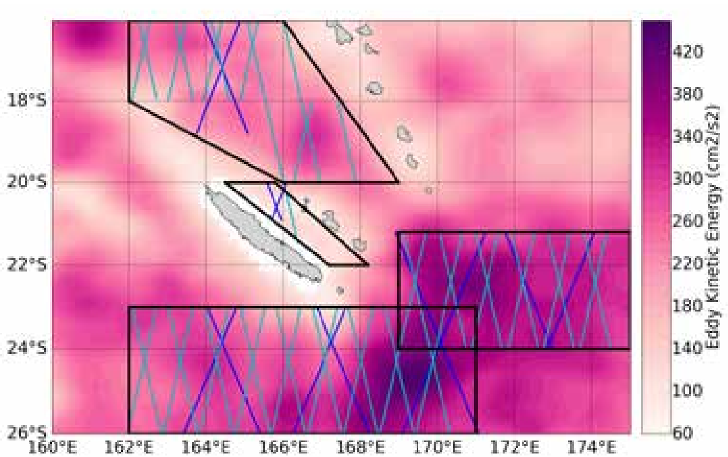
Sea level spectra: Jason 2

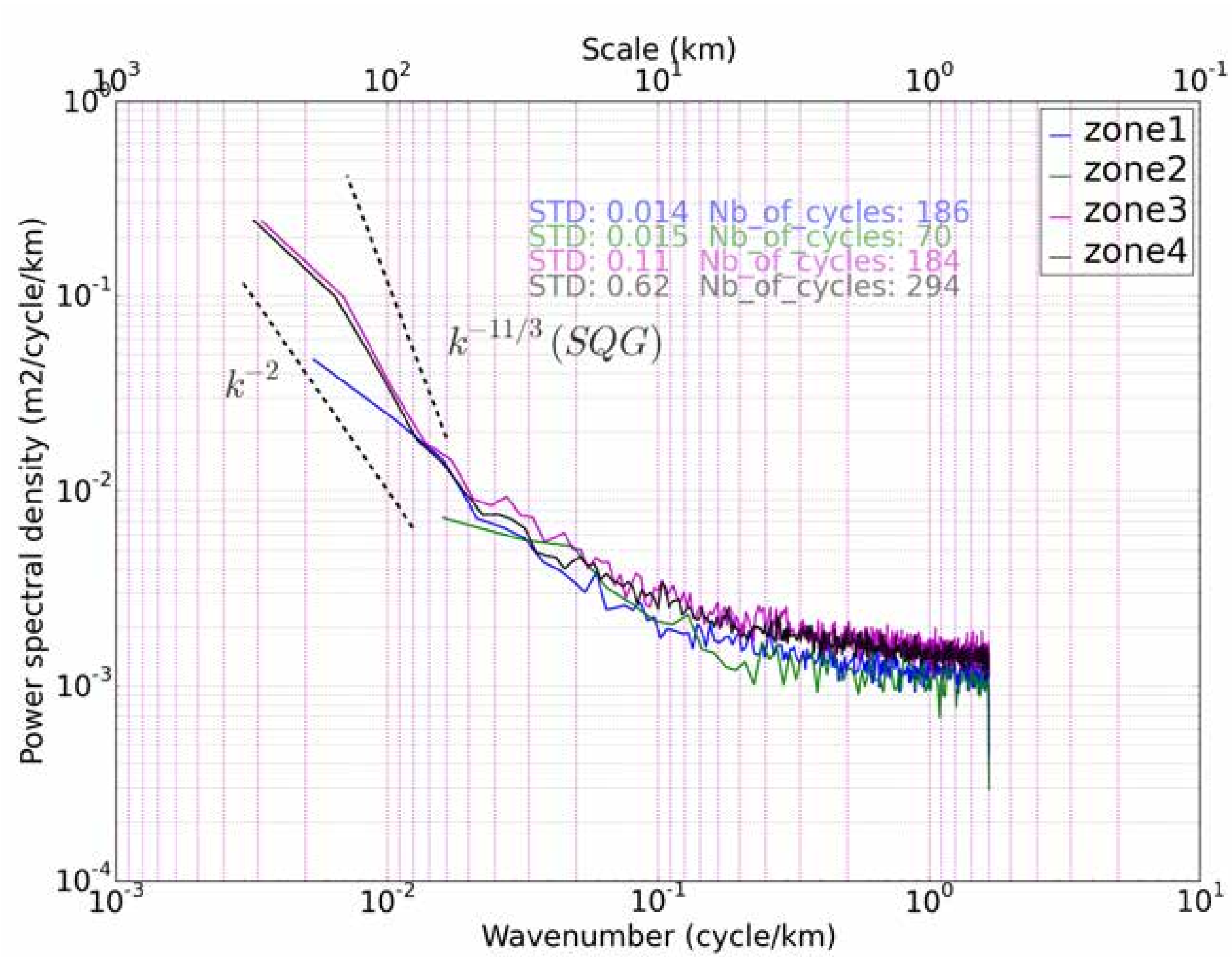




- SSH spectrum slope ~ -2 for scales > 50 km
- Noise level higher for region with high KE

Sea level spectra: Sentinel 3

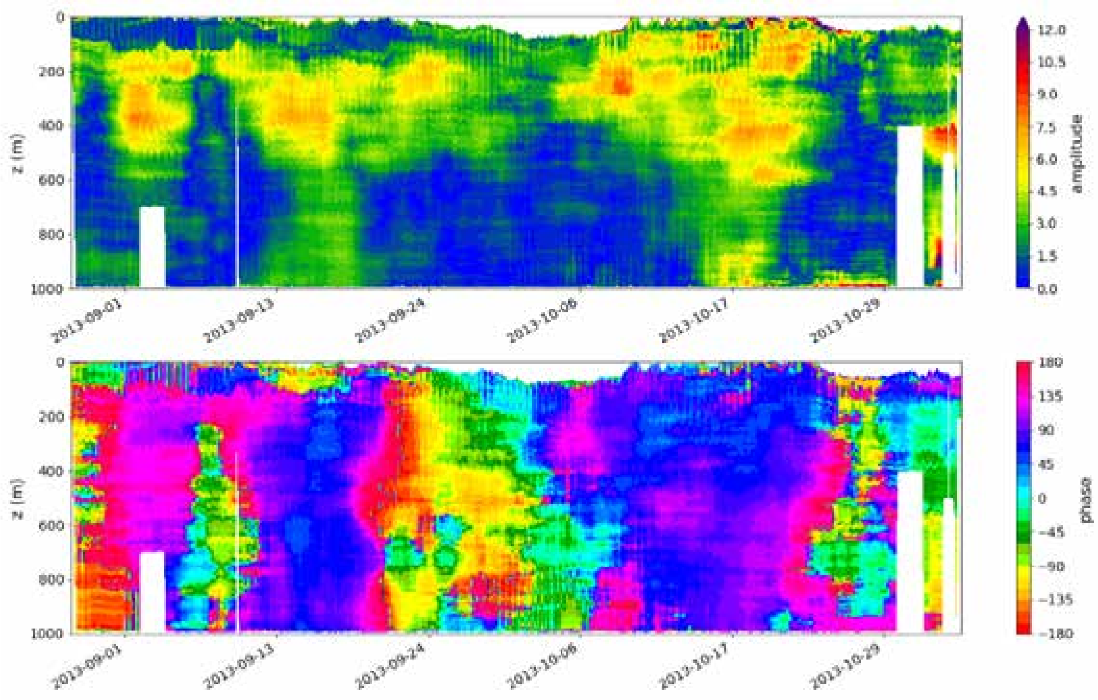


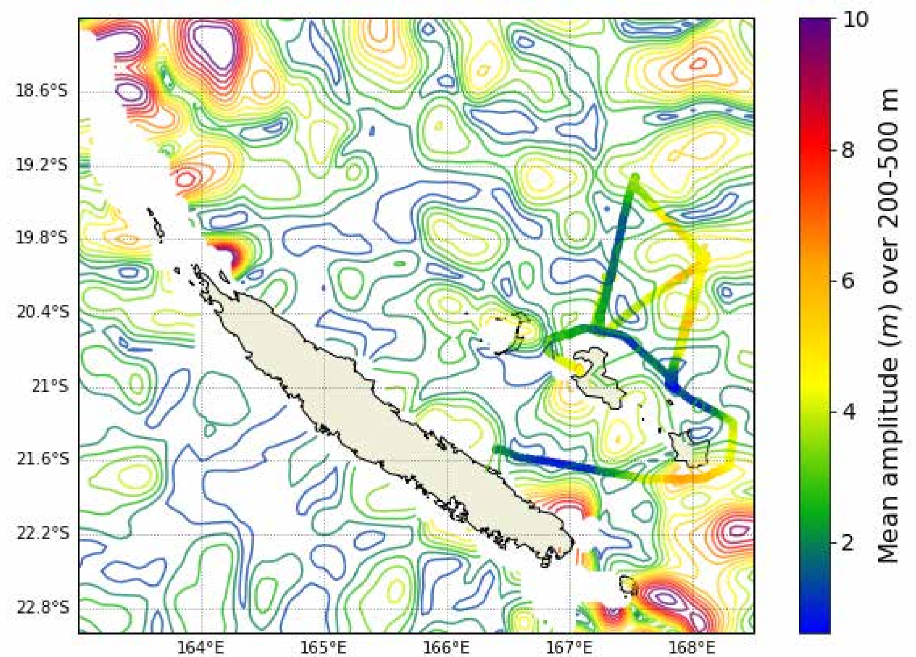


- SSH spectrum slope ~ -2 for scales > 50 km
- Noise level higher for region with high KE (Is it noise ?)

Gliders: M2 coherent internal tide

Harmonic fitting on M2 period performed on isopycnal displacements estimated over 6-day moving windows (e.g. *Rainville et al., 2013*)





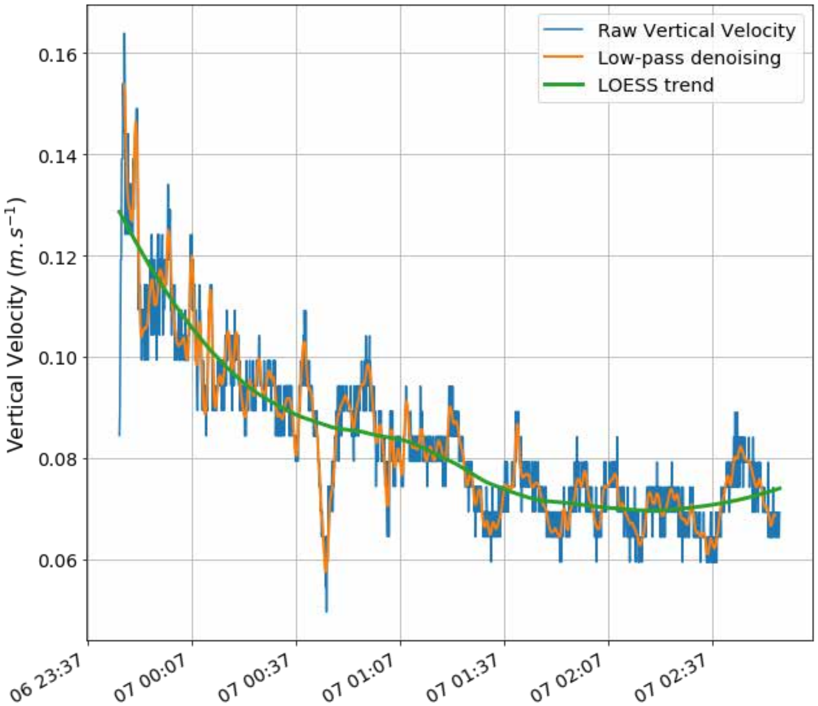
The geographic distribution of M2 internal tide (mean isopycnal displacement over 200-500 m) estimated from gliders is consistent with M2 tide estimated from altimetry *(Ray and Zaron, 2016)*

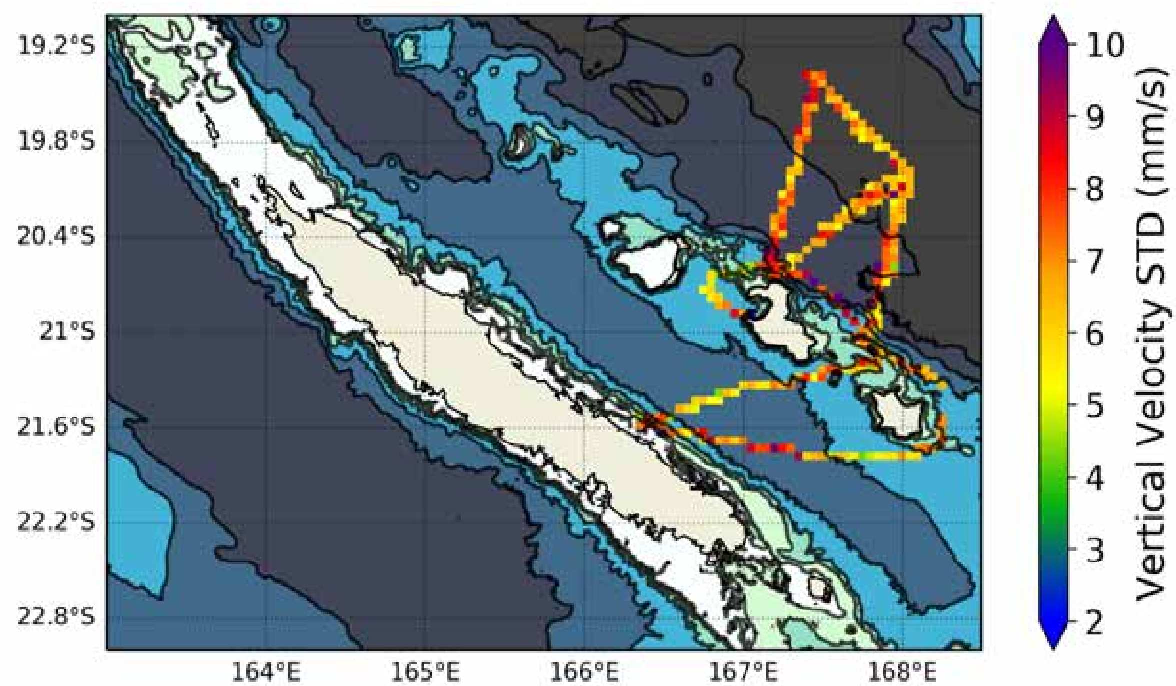
Gliders: supertidal vertical velocities

High-pass filtering of the observed glider vertical velocity

(e.g., Rudnick et al. 2013)

→ Supertidal frequencies between 1.5 h and 2 mins

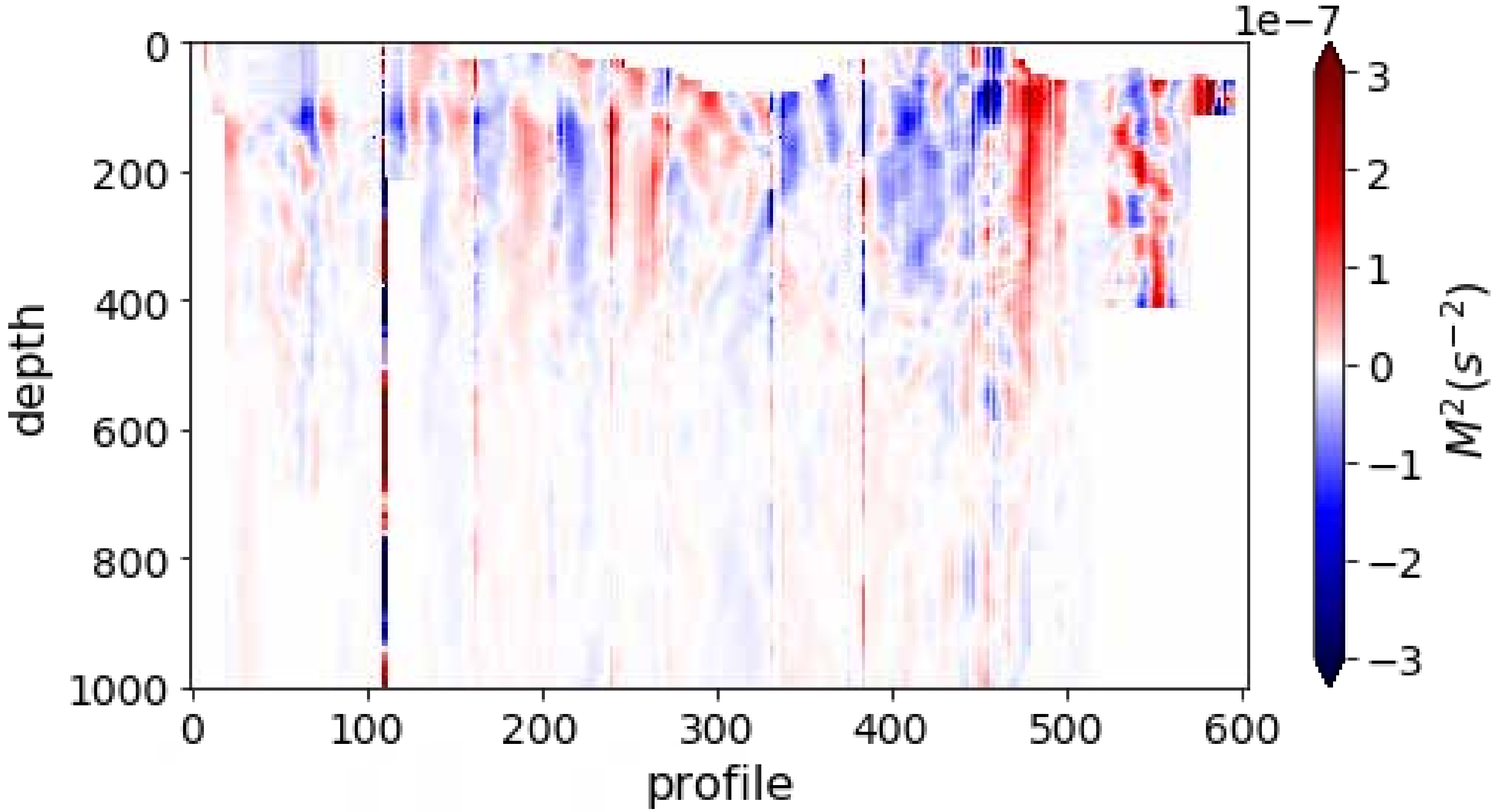




Further work: compare to the variance estimated from the GM spectrum

Gliders: horizontal buoyancy gradients

Low-pass filtering of glider profiles to remove internal tides



Further work: diagnostic of submesoscale instabilities using the balanced Richardson number (e.g., *Thomas et al. 2013, Thompson et al. 2015*)

Summary on observing systems around New Caledonia

- S-ADCP:
  - The surface layer seems dominated by submesoscale activity in regions with substantial EKE (consistent with *Qiu et al. 2016, Qiu et al. 2018*)
  - Surface intensify regime characterized a transition in SF slope.
- TSG:
  - SFs are constitent with surface intensify dynamics (frontogenesis)
  - A way to estimate APE for MLI
- Along-track altimetry:
  - Difficult to get information on scales < 50-40 km but higher noise levels are probably linked to substantial submesoscale activity
- Gliders:
  - Provide useful information on the horizontal and vertical distribution of M2 coherent internal tide
  - Information on part of the supertidal variance
  - Useful tools for studying submesocale and associated instabilties?