ABSTRACT

SWOT will substantially improve our understanding of the fine scales of the ocean circulation. These novel observations will be primarily a leap forward for physical oceanography. At the same time, they will bridge an observational gap on a spatiotemporal domain critical for interdisciplinary problems. Here we aim at identifying some of the new challenges in biogeochemistry and marine ecology that SWOT may contribute to address. In biogeochemistry, a key open question is the effect of filaments on the export of anthropogenic carbon inside the ocean. This question is important for better quantifying the role of the ocean in the climate system and relies on the possibilities of estimating at the ocean upper layer submesoscale vertical velocities, which in turn may be accessible by high resolution measurements of sea surface heights provided by SWOT and re-analysed in theoretical framework like surface quasi-geostrophy. In marine ecology, lot of interest is now concentrated on the connection between submesoscale fronts and patchiness of marine organisms, in particular fish. The possibility of detecting from space ecological hotspots - regions which aggregate biomass, trophic interactions, or biodiversity – would be a major step forward in the design of conservation policies and in the management of marine resources. For both these biogeochemical and ecological applications, we describe here model studies and proposed multiplatform in situ strategies which we are designing in preparation of the SWOT mission, in particular for its fast sampling phase, during which both the spatial and the temporal variability of synoptic maps of sea surface height will be observed for the first time.

Preparing for the next interdisciplinary challenges unlocked by SWOT fine-scale observations

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1. Under which conditions can the ocean vertical dynamics be derived from SWOT sea surface heights?

In order to be used in biophysical applications, sea surface high (SSH) observations have to be translated in higher level products capable of describing horizontal and vertical physical properties of the upper layer that can be compared to biological or biogeochemical observations. In terms of maturity of diagnostics, the situation is quite asymmetric for horizontal and vertical diagnostics, as most of the open challenges are for the vertical. On the horizontal, we are extending nadir algorithms to higher resolution (e.g., for model SSH from the SWOT simulator) and to the computation of maps of diagnostics for the applications, including AirSWOT CalVal operations (see Fig. 1 for an exemple). On the vertical, we are comparing different theoretical frameworks (omega equation, surface quasi-geostrophy,..) in order to check under which conditions and with which precision vertical information can be extracted from the SSH at the scales resolved by SWOT.

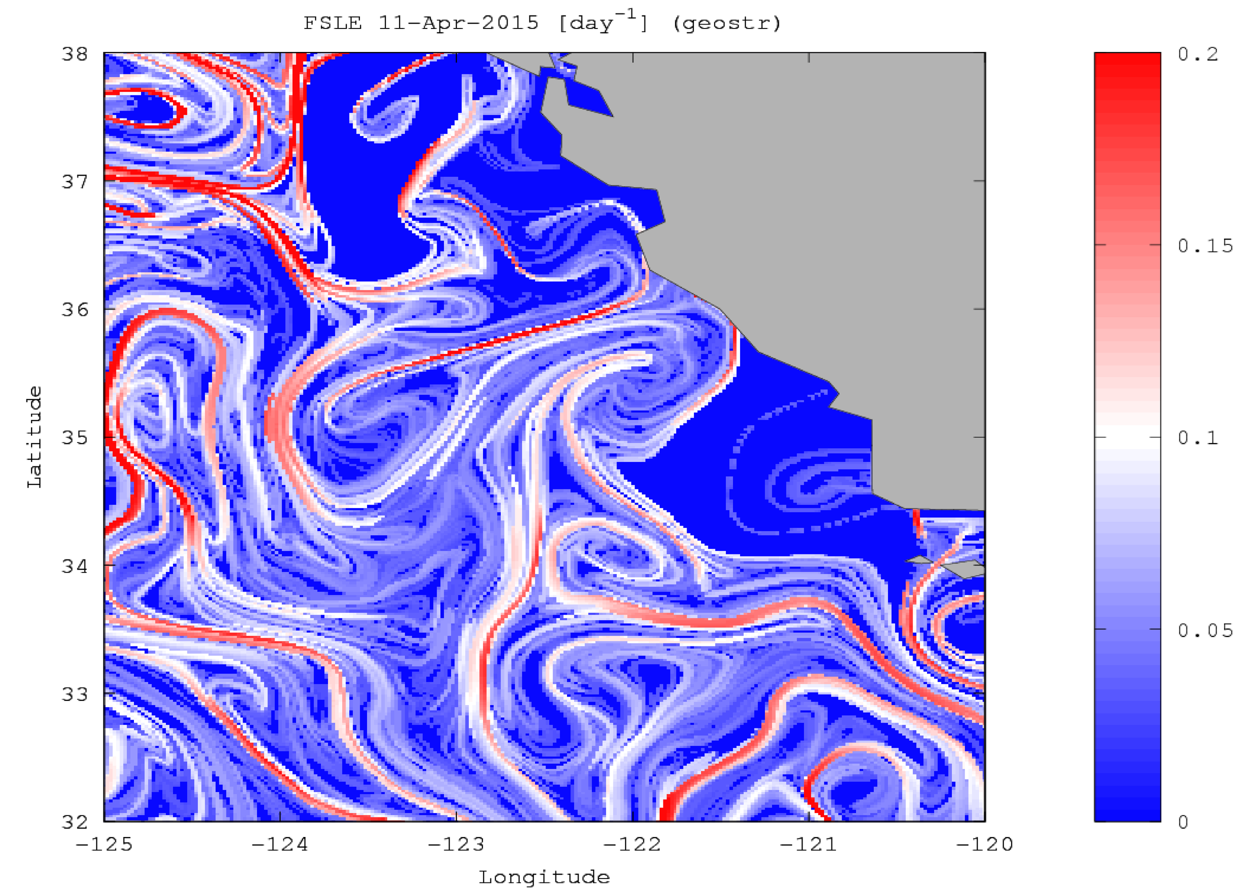


Fig. 1: Exemple of the submesoscale horzontal diagnostics: tra,sport barriers (Lyapunov exponents derived from altimetry) computed for the spring 2015 AirSWOT flight off California coast.

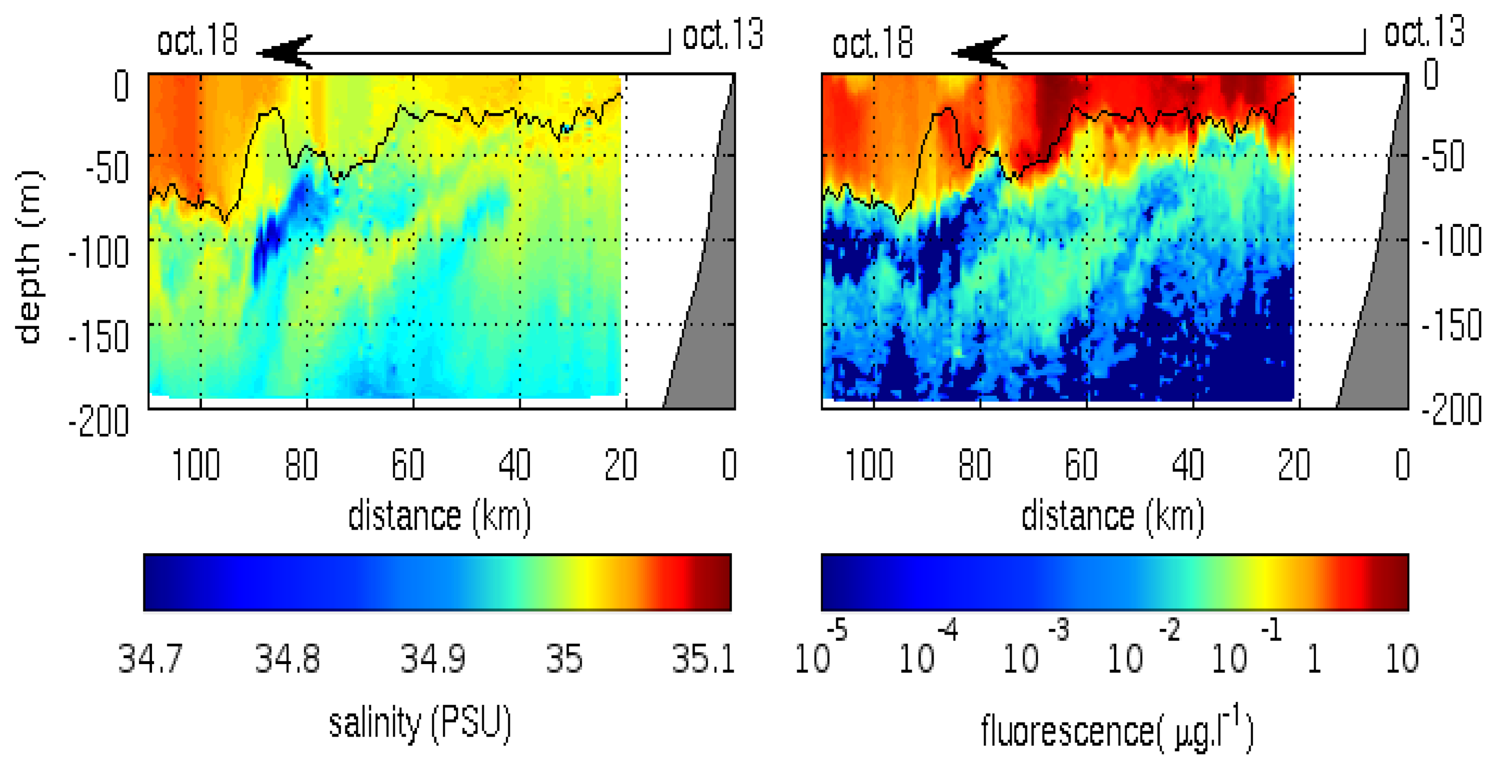
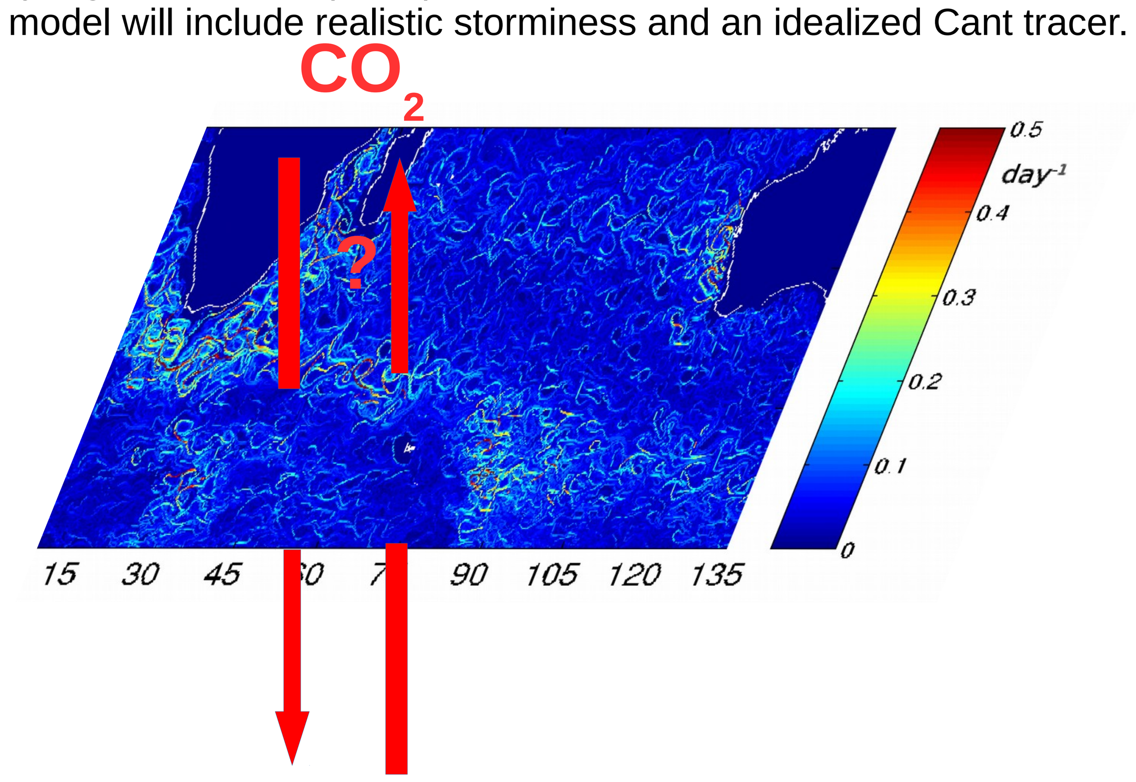


Figure 2: Salinity and fluorescence section offshore of central Peru (14S). Measurements were carried out by a glider between 13 and 18 october 2008. Coastal upwelling brings cold nutrient rich upward near the shore. Part of that cold water is subducted under the influence of mesoscale stirring along upwelling filaments. The manifestation of these subduction events is visible in the form of slanted layers of elevated salinity and fluorescence (tilted upward when approaching the shore). We want to assess how much we will be able to derive from SWOT these vertical fluxes, which are currently not properly quantified and may strongly influence the biogeochemical and biological functioning of the ocean. Image courtesy of A. Pietri.

2. How much anthropogenic carbon is subducted by the submesoscales?

The oceans slow the rate of climate change by absorbing about 30% of anthropogenic carbon dioxide (Cant) emissions annually. The Southern Ocean makes a substantial contribution to this oceanic carbon sink: more than 40% of the anthropogenic carbon dioxide in the ocean has entered south of 40°S. The physical mechanisms responsible for the subduction of anthropogenic carbon dioxide include large-scale Ekman pumping, advection across sloping isopycnals, vertical diffusion at the base of the mixed-layer and subduction by mesoscale and submesoscale processes. Although recent works have estimated the subduction at the larger, the contribution of submesoscale processes is currently missing from our estimates of Cant subduction in both models and data due to lack of resolution. Indeed, the data-based estimate of Cant subduction in Sallée et al (2012) made use of large-scale climatological products, with surface currents derived from an absolute mean dynamic height product which mixes satellite data from the Gravity Recovery and Climate Experiment, altimetry from AVISO and in situ data from Global Drifter Programs (Rio et al, 2005). On the other hand, the latest model estimates of Canth subduction in the Southern Ocean has a resolution of 2° (Bopp et al., in prep). SWOT will provide estimates of horizontal velocities at much higher horizontal resolution. There is also a strong potential to derive vertical velocities at the same resolution. We therefore expect that SWOT data can be used to improve our estimate of Canth subduction. In order to test the potential of this application of SWOT, we are working to a very-high resolution (1/50°) idealized model of the Antarctic Circumpolar Current (ACC). This model will include realistic storminess and an idealized Cant tracer.



3. How does fish distribution respond to the submesoscale variability?

On the continents, the dynamics of the landscape has geological timescales which are decoupled from the ecological processes. In contrast, the oceanic landscape ("seascape") is driven by physical processes with much weaker dissipation mechanisms, so that energy is cascaded down to the ecological timescales more efficiently. The meso- and submeso-scales (1-100 km) in particular are strongly energetic regimes whose temporal scales of days to weeks resonate with key biological processes. At the mesoscale, eddies and fronts strongly constrain marine ecosystems at various levels of the trophic chain, as documented in recent studies. However, the resolution limits of current altimetry has until now hindered the possibility of pushing these analyses towards the finer scales. Nevertheless, the O(10s km) scales resolved by SWOT have a critical importance, because are the ones which can inform policy makers about conservation plans or for managing marine resources like fisheries. In order to prepare for the SWOT data, we are designing adaptive surveys for measuring high resolution phytoplanktonic community structure. Figure 3 presents a first example of the satellite assisted sampling strategy and in situ data analysis which we are developing in order to design nektonic surveys capable to exploit SWOT high resolution.

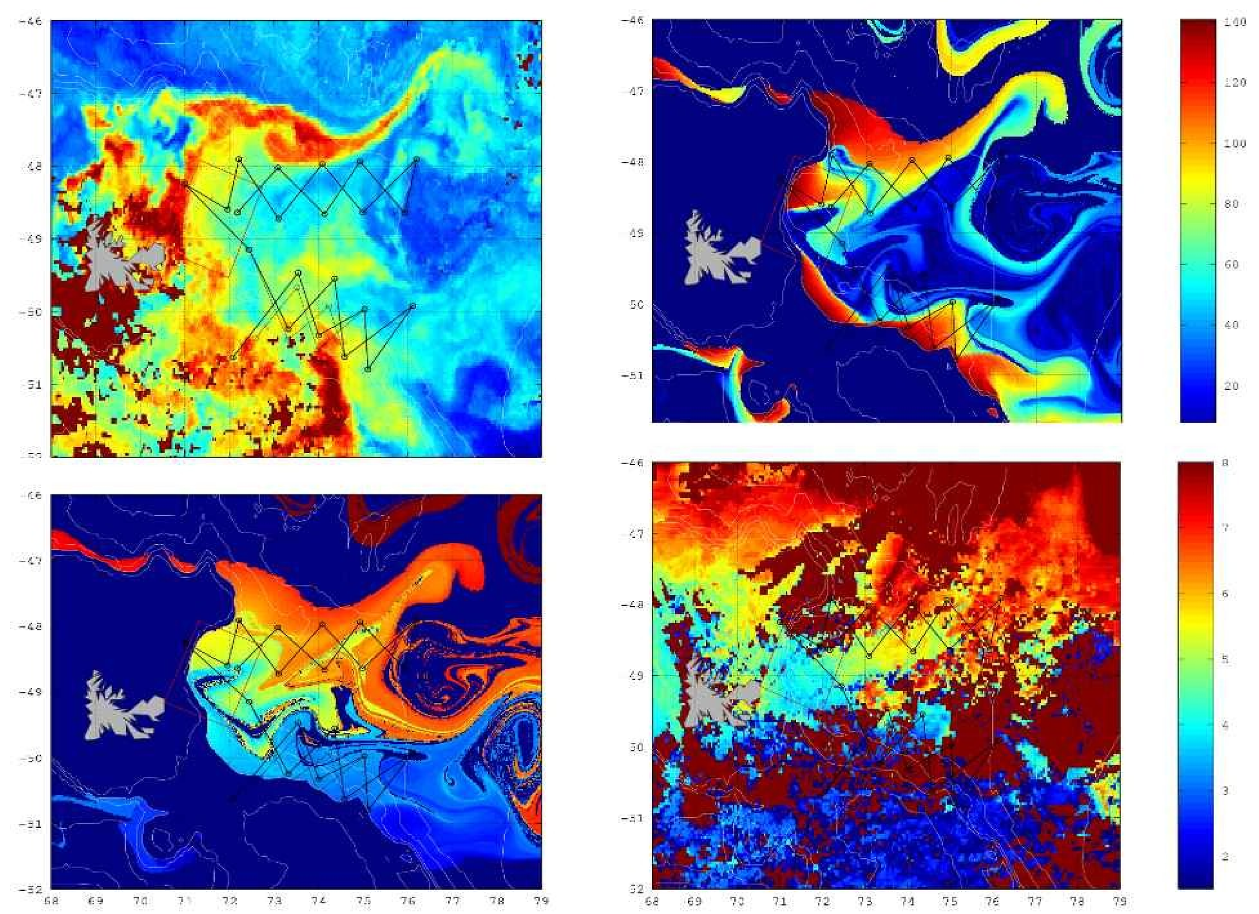


Figure 3: The Mycto-3D-Map cruise (Kerguelen region, January-February 2013) was a fish survey guided by near-real time analysis of altimetry and other satellites data. The black line indicates the trajectory of the ship, adaptively set to cross the stirring patterns reconstructed by Lagrangian diagnostics applied to satellite data. Top left: chlorophyll; top right: time since when Lagrangian particles have left the Kerguelen plateau; bottom left: origin of the Lagrangian trajectories; bottom left: infrared sea surface temperature. See d'Ovidio et al., Biogeo. Disc. 2015