Spectral Energy and Vertical Tracer Fluxes from Surface Currents

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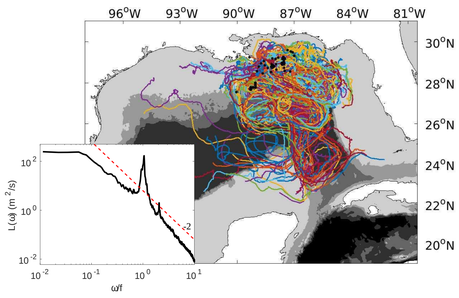
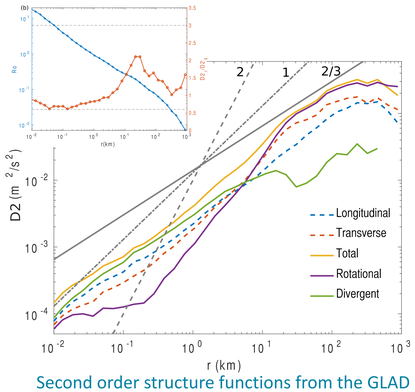
Structure Functions

What can we learn about the turbulence of horizontal surface currents from surface drifters?

a) Multi-scale distribution of energy



Surface drifters from the GLAD Experiment (Poje et al 2014), and the frequency spectrum (inset).



Second order structure functions from the GLAD experiment decomposed into Longitudinal-Transverse and Rotational-Divergent components, and the Rossby number (inset)

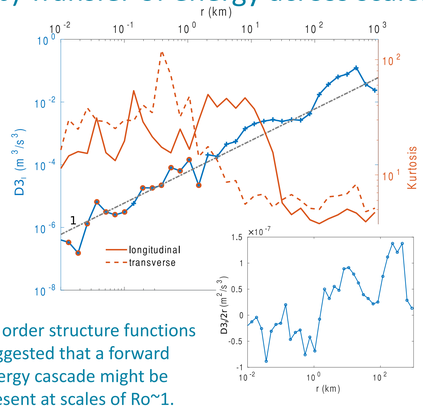
Second order structure functions are a useful metric to use with scattered data, and an integrated estimate of the energy spectrum

$$S2_l = \overline{\delta u_l^2}$$

$$S2(r) = 2\int_0^\infty E(k)(1 - J_0(kr))dk$$

Also, easily amenable to a Helmholtz decomposition.

b) Transfer of energy across scales



3rd order structure functions suggested that a forward energy cascade might be present at scales of Ro~1.

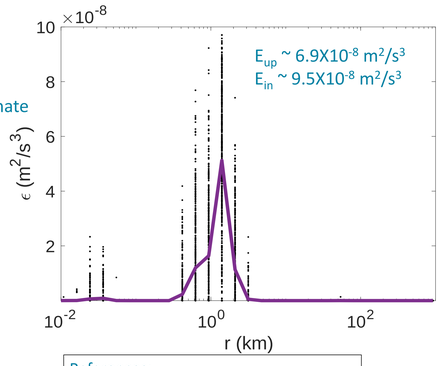
Third order structure functions are related to the dynamics, and allow estimation of the spectral fluxes of energy.

$$S3_l = \overline{\delta u_l(\delta u_l^2 + \delta u_t^2)}$$

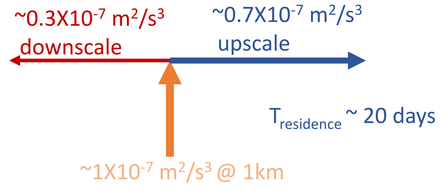
$$S3_l = 2\epsilon r \quad \text{(Lindborg and Cho 2001)}$$

$$S3_l = 2\epsilon_u r - \sum_{j=1}^{N} 4\epsilon_j l_{fj} J_1(r/l_{fj}) \quad \text{(Xie and Buhler 2019)}$$

New method allows to estimate the energy injection rate, and estimate what fraction is fluxed upscale and downscale.



A kinetic energy pathway for surface flows from observations (work in progress):



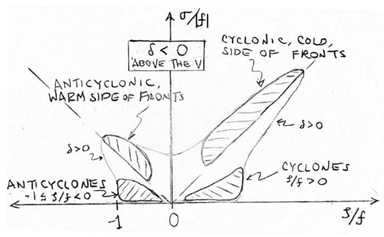
References:
Balwada, LaCasce & Speer, 2016 (GRL)
Xie and Balwada, 2020 (in preparation)

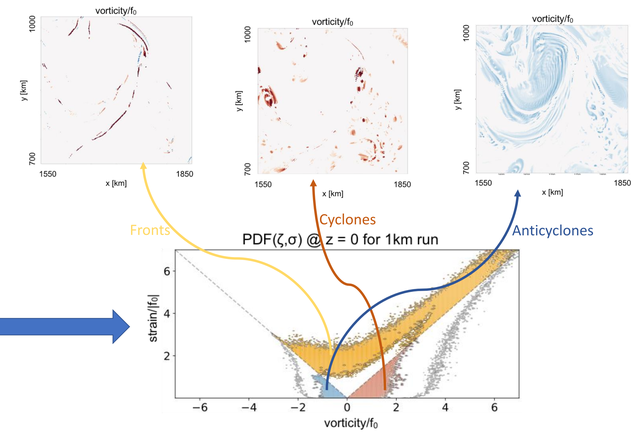
Vertical Fluxes

Where are the tracers transported from the surface ocean to the interior?

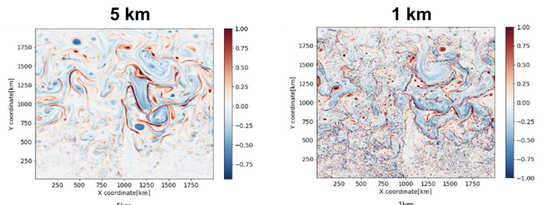
Observational evidence is starting to show that surface fronts are associated with regions of strong vertical velocities (e.g. Omand et al 2015).

- Is this the dominant mechanism for vertical transport? Or just a visual anomaly that humans are biased to detect?

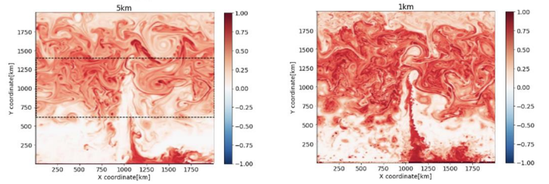




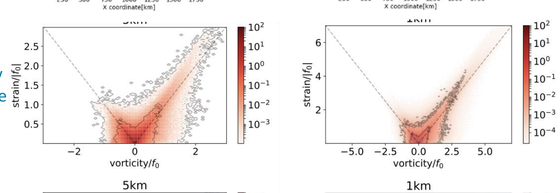
Vorticity @surface



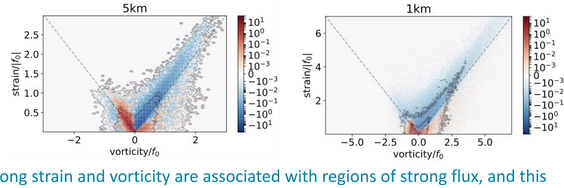
Tracer @100m below the ML after 1 year.



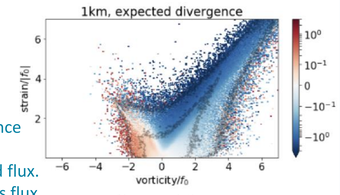
PDF in vorticity strain @surface



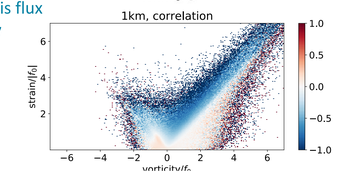
Tracer flux in vorticity strain @surface



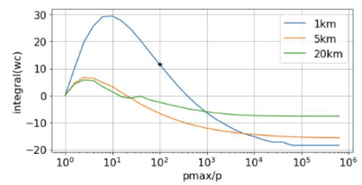
Strong strain and vorticity are associated with regions of strong flux, and this region in the histogram expands at higher resolutions.



Regions of convergence are associated with regions of downward flux. The coherence of this flux increases in strongly convergent regions.



The expanded vorticity strain diagram allows for extra flux in the higher resolution model.



References:
Balwada, Smith & Abernathey, 2018 (GRL)
Xiao, Balwada & Smith 2020 (in preparation)