

Observational characterization of the transition to submesoscale dynamics

Mara Freilich, Luc Lenain, Sarah Gille



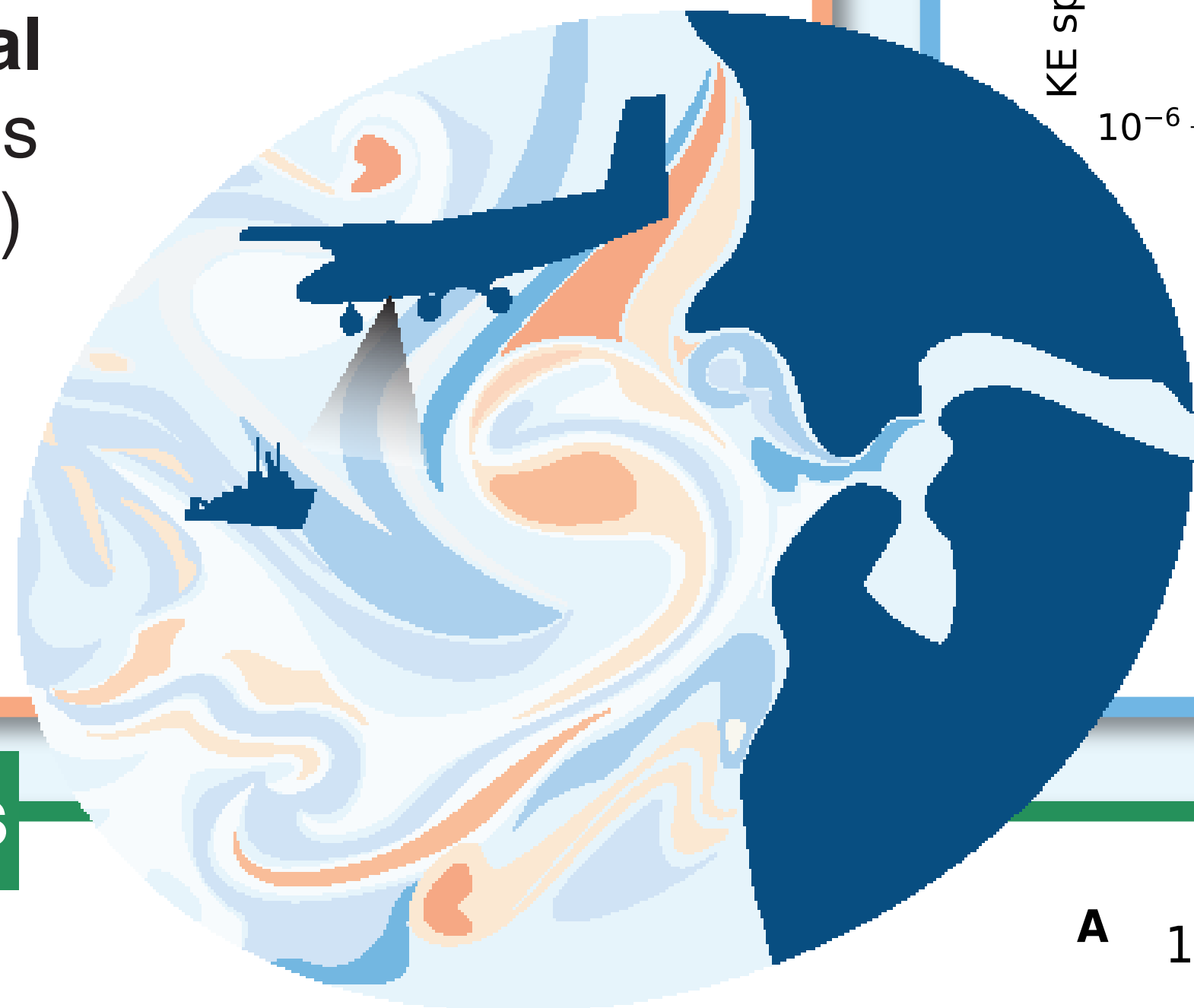
MAF current affiliation Brown University, contact: mara_freilich@brown.edu

UC San Diego

Overview

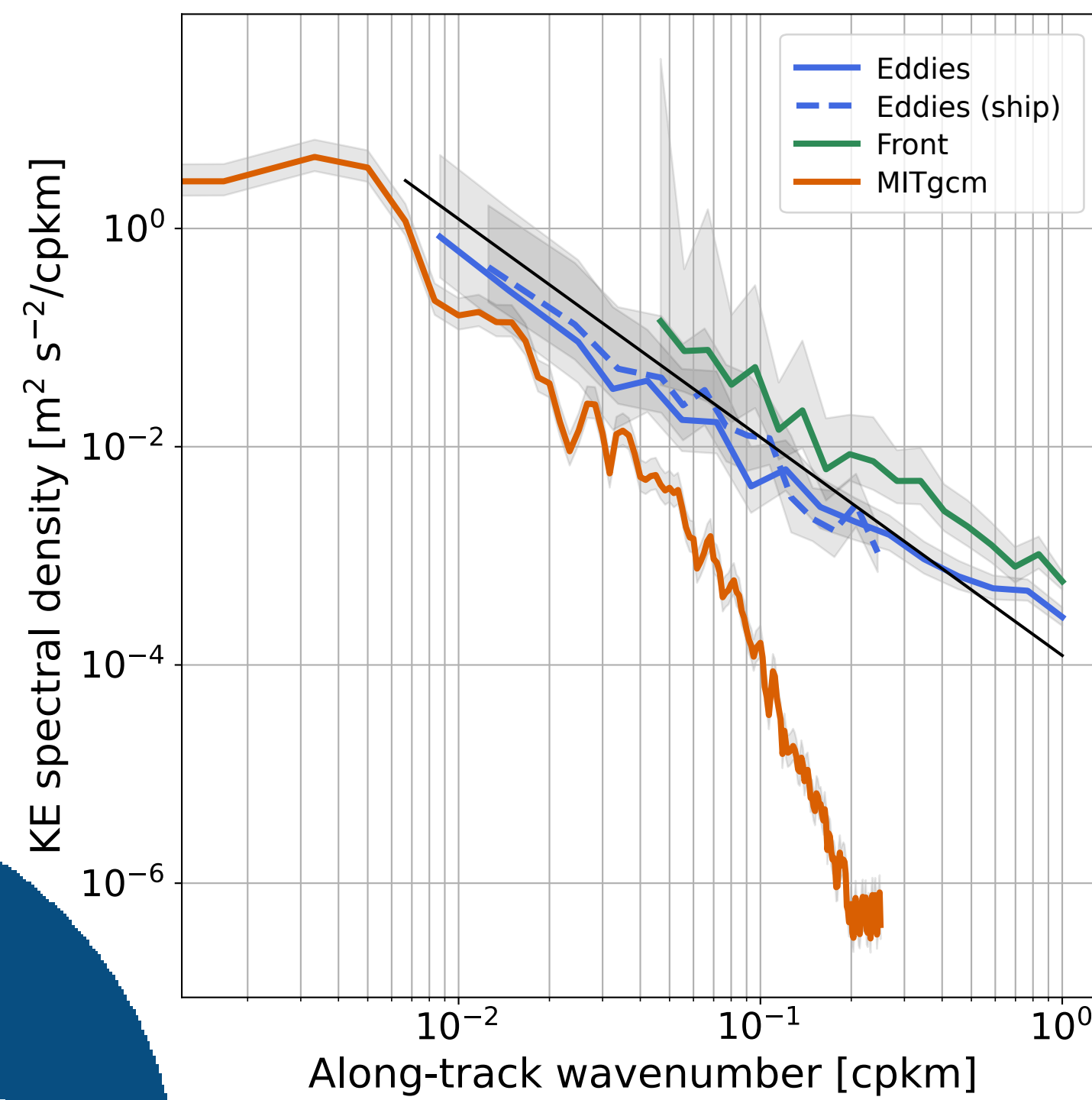
Determining the dynamics that are dominant at the submesoscale has important implications for understanding the vertical structure of ocean flows, vertical transport, air-sea interactions and the spatial distribution of energy dissipation. Quantifying the distribution of kinetic energy at submesoscales and the flux of energy across scales (whether there is an inverse or forward cascade) is essential for understanding and modeling ocean kinetic energy cycles.

We make use of a **sub-orbital remote sensing** (the DoppVis instrument on the SIO-MASS) to observe surface ocean velocity at scales ranging from 100 km to 500 m and ask how dynamics change at submesoscales.

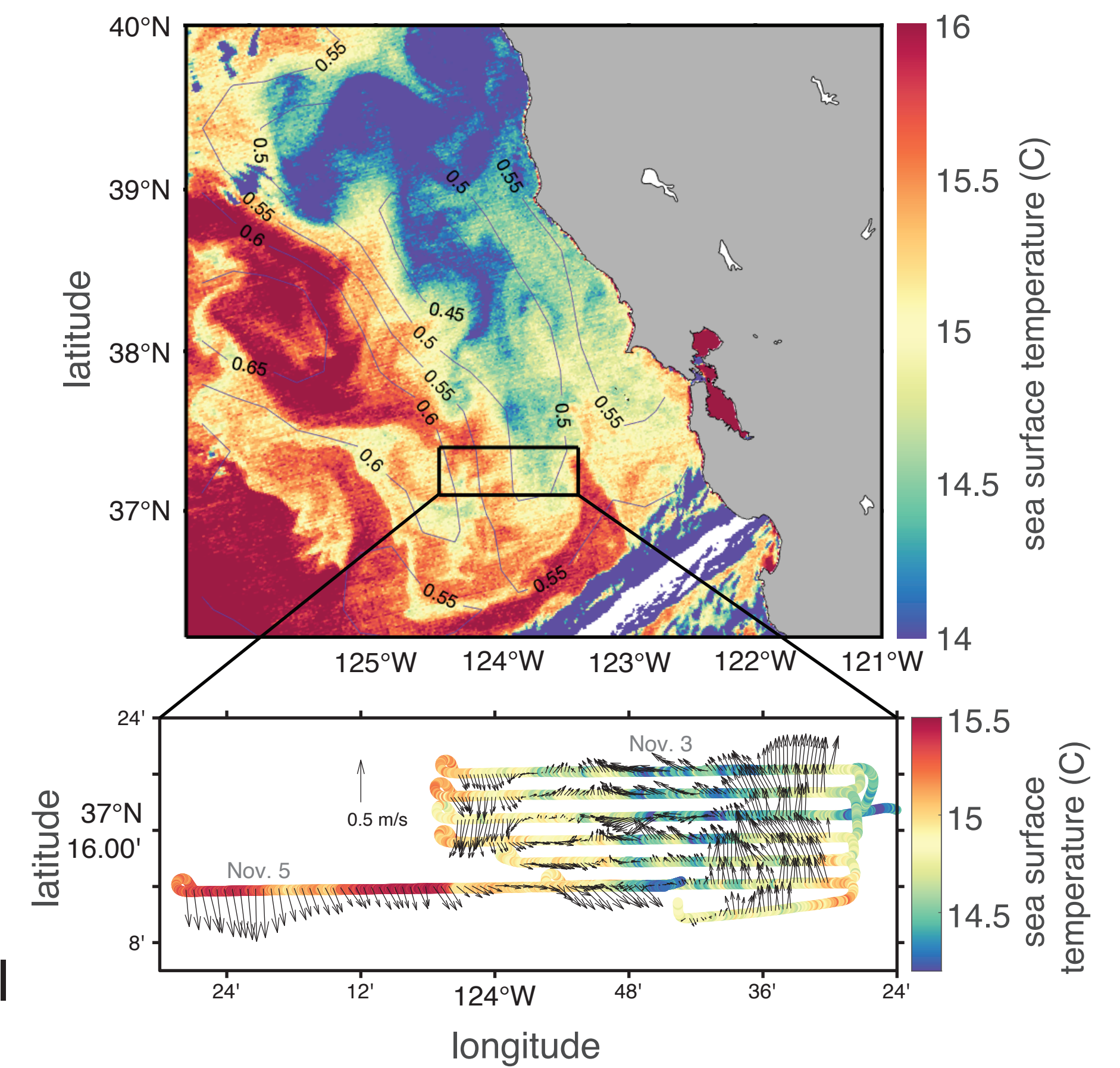


Study sites

Velocity observations from two experiments in the California Current region (an eastern boundary current)



kinetic energy spectrum is continuous to smallest observed scales with a spectral slope of k^{-2} in both regions.



Ageostrophic dynamics

The continuous kinetic energy spectrum belies a transition in the dynamics of the flow field at submesoscales. We quantify the scale where the rotational and divergent components interact using the cross-spectrum between the along track (u) and cross track (v) velocity $\hat{C}^{uv}(k)$ (Bühler et al. 2017).

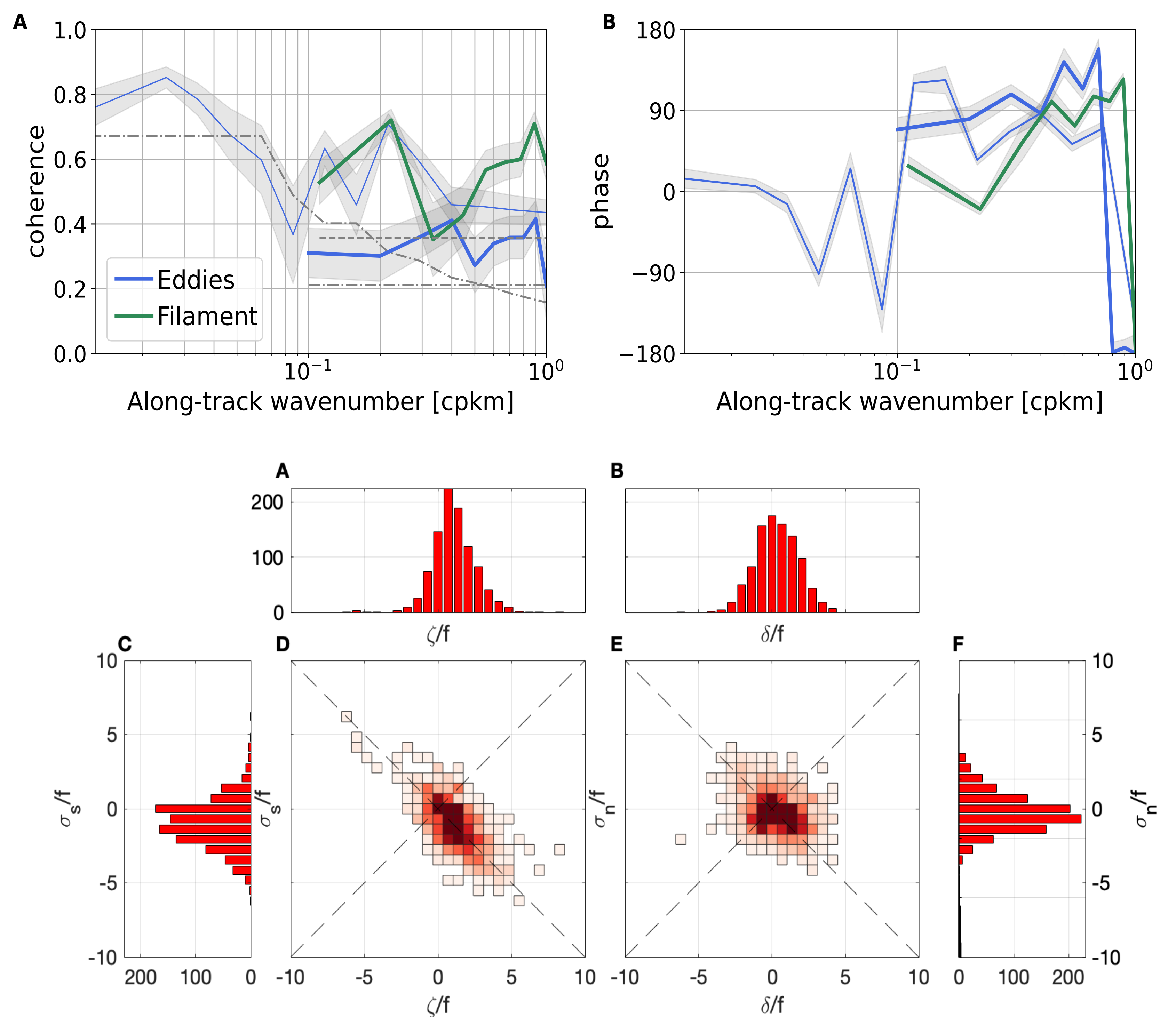
If the streamfunction and potential are uncorrelated then the cross spectrum is real. This is quantified using the phase.

The flow is more anisotropic if the coherence is large.

$$\text{coherence} = \frac{\hat{C}^{uv}(k)}{\hat{C}^u(k)\hat{C}^v(k)}$$

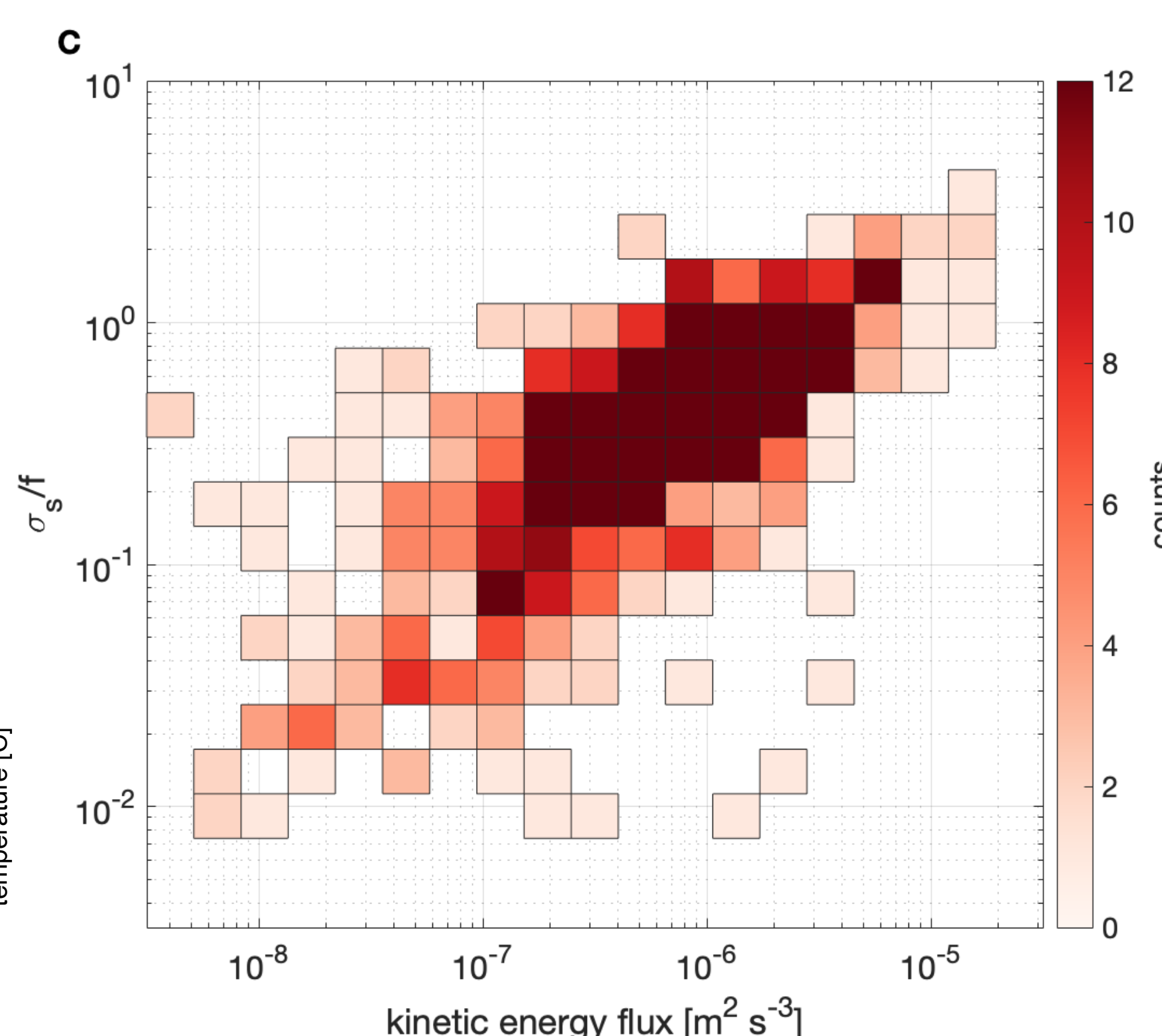
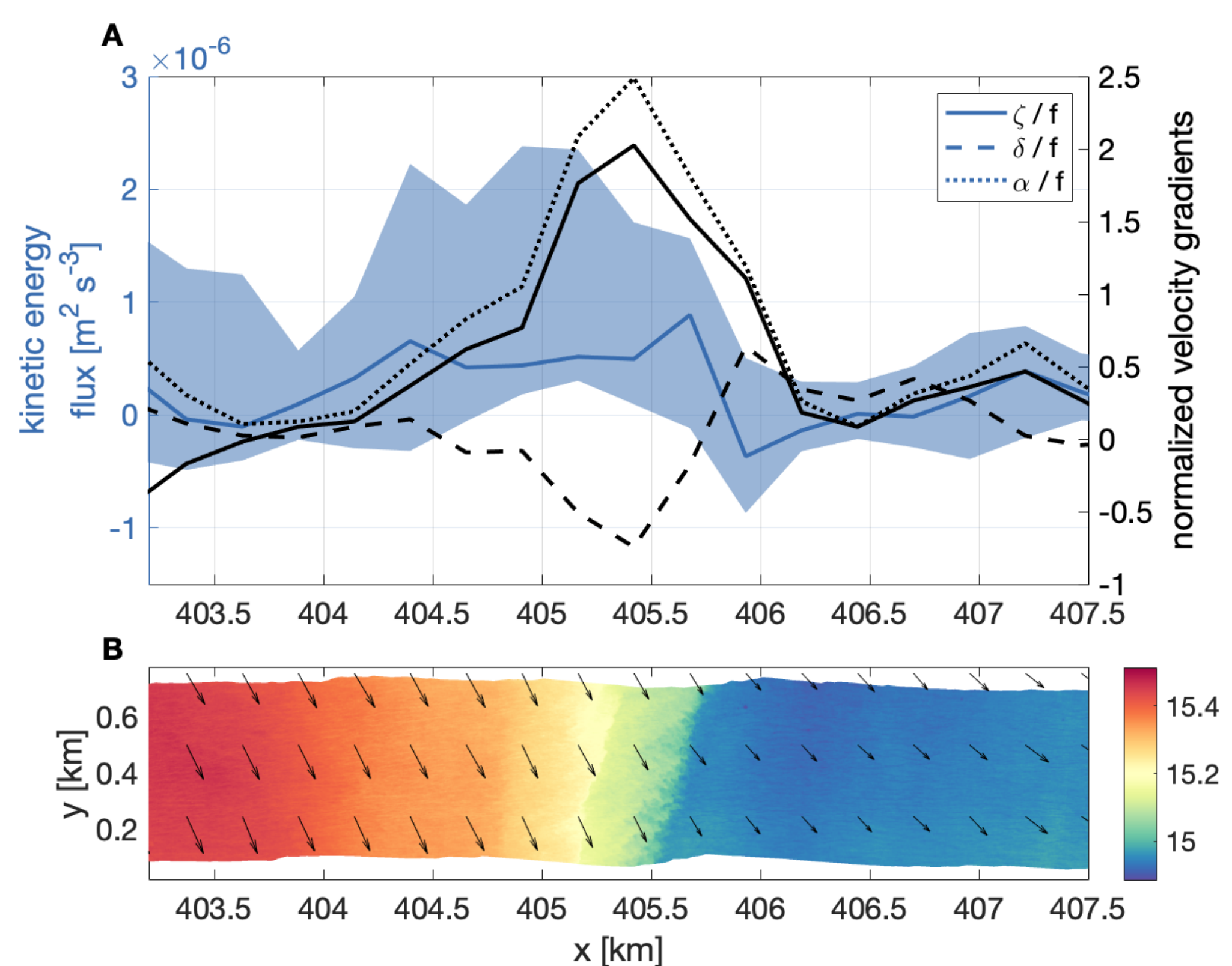
Non-linear interactions become dominant below 10 km in the eddy region and below 4 km in the frontal region. The flow in the frontal region becomes increasingly anisotropic at the same scales while the eddy region does not.

The velocity gradient quantities are skewed, as is expected from submesoscale dynamics. The vorticity and shear strain are correlated.



Energetics of a front

Kinetic energy flux is intermittent and the largest forward cascade of kinetic energy is localized at the front in these observations.



Kinetic energy flux

Using the filtered velocity vector \bar{u}

$$\Pi = -[\tau_{uu}\bar{u}_x + \tau_{vv}\bar{v}_x + \tau_{uv}(\bar{u}_y + \bar{v}_x)]$$

$$\tau_{uv} = \bar{u} \bar{v} - \bar{u}\bar{v}$$

In the frontal region

Kinetic energy flux
 $\sim 5 \times 10^{-7} \text{ m}^2 \text{ s}^{-3}$
 Ekman buoyancy flux
 $\sim -2.5 \times 10^{-7} \text{ m}^2 \text{ s}^{-3}$