Lagrangian predictability in weakly ageostrophic surface ocean turbulence

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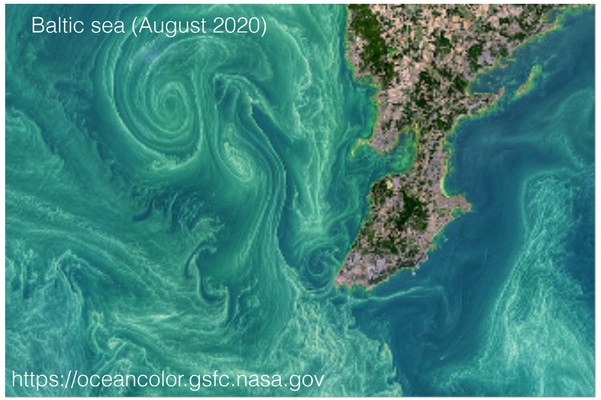
Ocean submesoscales

Horizontal scales $\leq O(10)\,\mathrm{km}$

Rotation: neither dominant nor negligible

Strongly energetic

Difficult to measure from satellites and in oceanographic campaigns



from mesoscales ($\approx 100\,\mathrm{km}$) down to scales of size $\approx 10\,\mathrm{km}$

$\Rightarrow$ 1 order of magnitude improvement

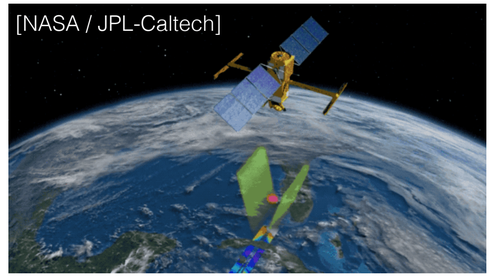
Opportunity to observe energy cascade at finer scales

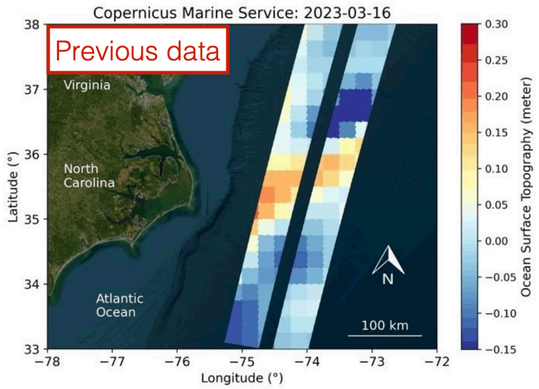
New satellite data

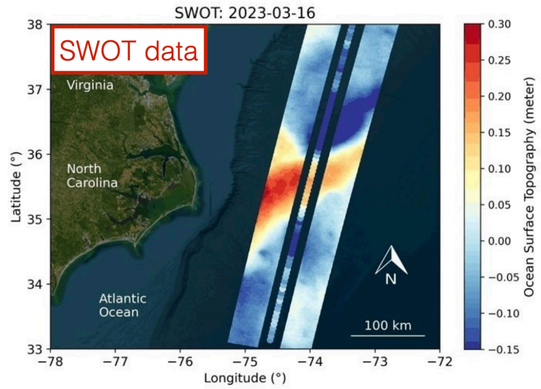
SWOT (NASA/CNES)

launched in December 2022

sea surface height (SSH) at unprecedented spatial resolution







Challenge: surface horizontal flow obtained from SSH via geostrophic balance $\Rightarrow$ impact of unresolved (ageostrophic) processes?

- Implications on and expectations from Lagrangian particle dynamics?

Weakly ageostrophic turbulence (SQG^{+1} model)

Developing PE to next order in Ro:

$\partial_t \theta + \mathbf{u} \cdot \nabla \theta = F + D \qquad \mathbf{u} = \mathbf{u}_g + Ro\, \mathbf{u}_{ag}$ (computed from θ)

Idealized model

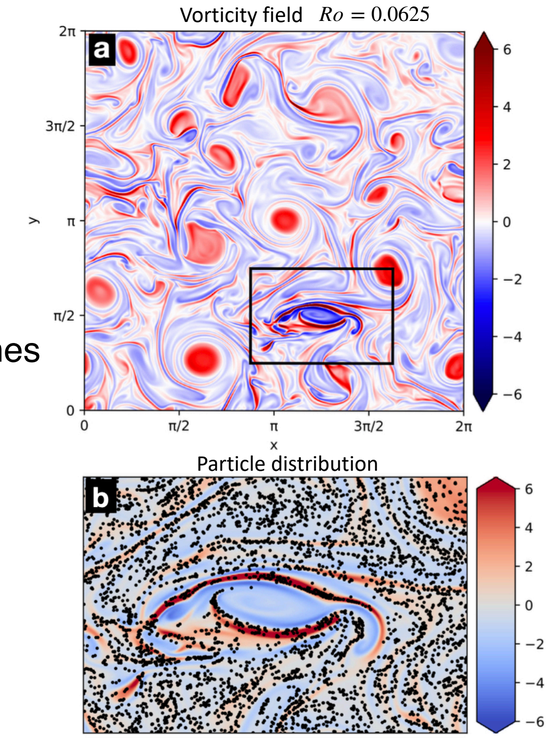
Ageostrophy related to fronts

In agreement with observations:

dominance of cyclones over anticyclones

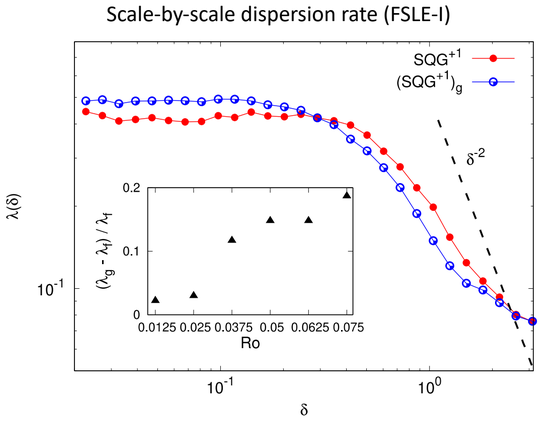
clustering of Lagrangian tracers in cyclonic frontal regions

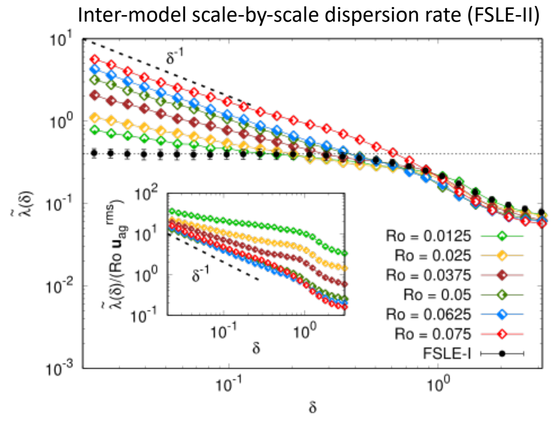
[Maalouly et al., Phys. Fluids (2023)]

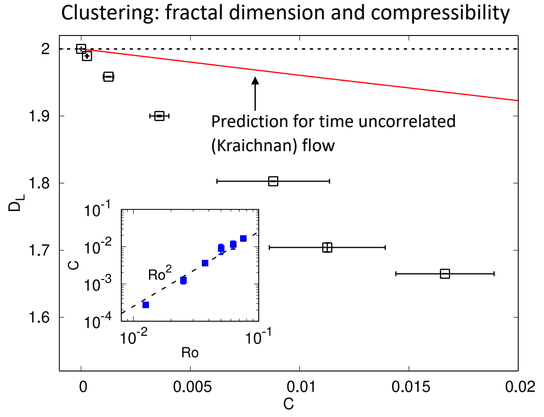


Lagrangian predictability

Advection of tracer particles in the full flow or in the *a posteriori* filtered, geostrophic flow







Weak effect of ageostrophic motions on absolute and relative dispersion

Overestimation of dispersion rate in geostrophic-only flow (FSLE-I)

Ageostrophic flow corrections cause inter-model dispersion on a broad range of scales (FSLE-II)

Important clustering (D_L) is due to the interplay between the weak flow compressibility and persistent structures

Conclusions: the overall effect on Lagrangian dispersion of ageostrophic motions related to fronts should be weak; nevertheless, these results suggest caution in particle advection applications with geostrophically derived flows, as important phenomena (clustering) are missed and trajectories separate, over several scales, from the true ones evolving in the full velocity field

Perspectives: realistic simulations to explore the role of the ocean fast variability, not accounted for by the SQG^{+1} model