

Relative dispersion at the surface of the ocean: role of balanced motions and internal waves

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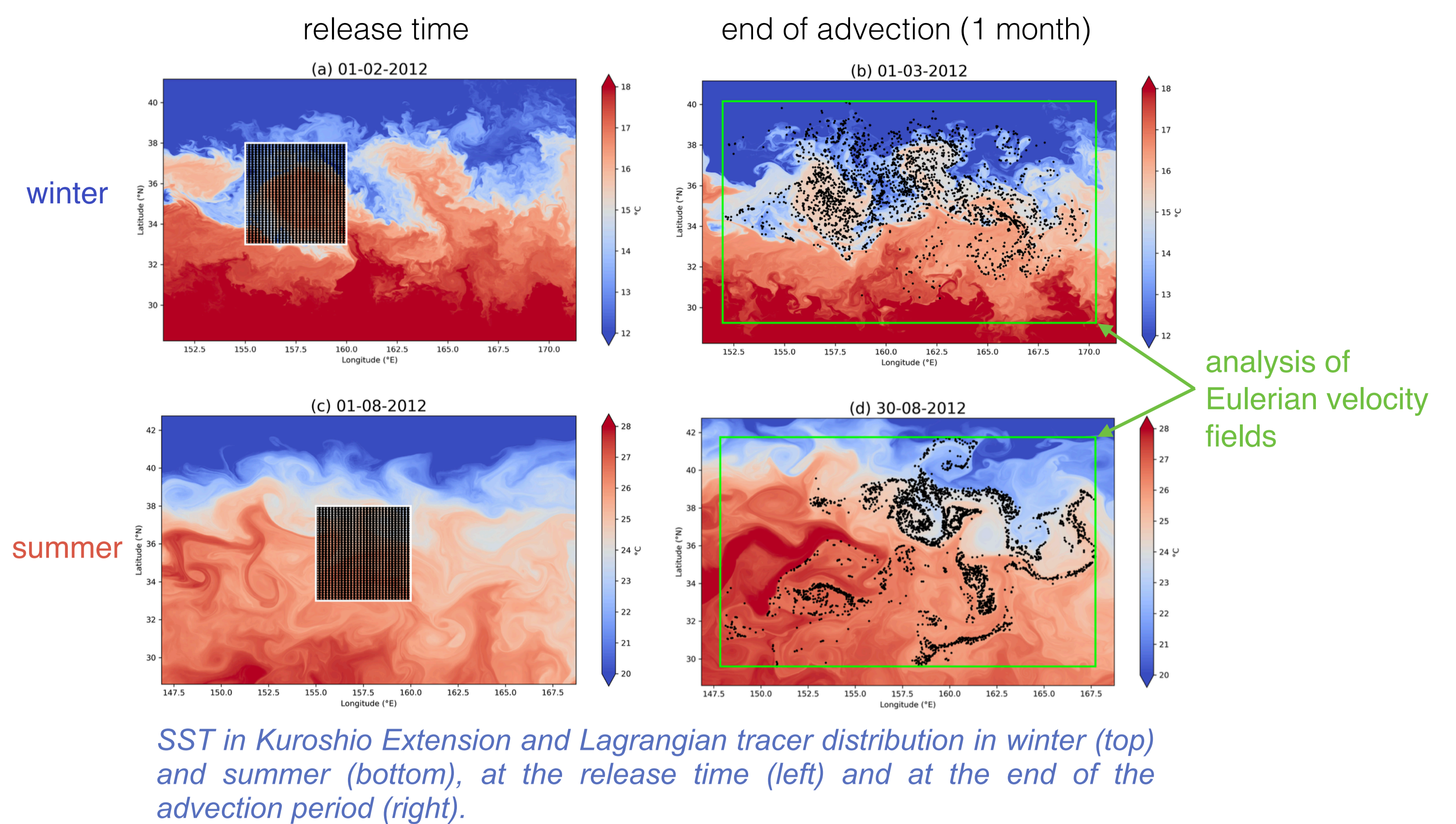
We investigate the properties of relative dispersion of Lagrangian particles in a global-ocean simulation resolving both inertia-gravity waves (IGW) and meso and submesoscale (M/SM) turbulence.

Main question: do dispersion laws depend on the shape of the Eulerian kinetic energy spectrum, as predicted from quasi-geostrophic (QG) turbulence theory?

Relation with SWOT: SWOT SSH will provide a geostrophic kinetic energy spectrum, to be validated e.g. through Lagrangian statistics.

Test case: LLC4320 simulation, advection of Lagrangian tracer particles at the surface.

Focus: Kuroshio Extension (and Gulf Stream) region close to SWOT crossover, for which the relative importance of IGW compared to M/SM vary in summer and winter.



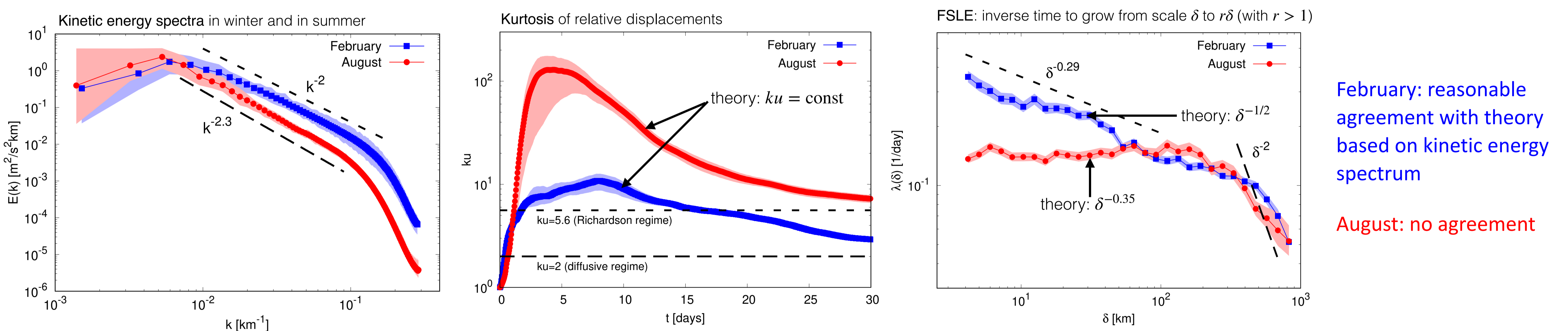
Lagrangian results

We use different Lagrangian indicators of the dispersion process, computed either at fixed time or at fixed length scale: relative dispersion, relative diffusivity, kurtosis of relative displacements, finite-size Lyapunov exponent (FSLE).

Theoretical (QG) predictions [for kurtosis vs time $ku(t)$ and FSLE vs separation $\lambda(\delta)$], assuming a power-law kinetic energy spectrum $E(k) \sim k^{-\beta}$:

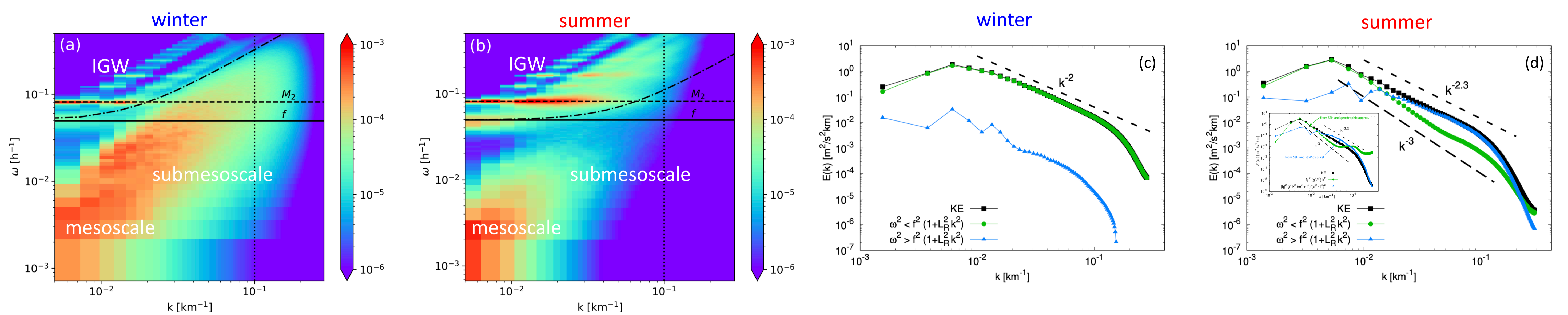
$\beta < 3 \Rightarrow ku = \text{const}$, $\lambda(\delta) \sim \delta^{(\beta-3)/2}$ **local dispersion regime** [note: $\beta = 5/3 \Rightarrow ku = 5.6$, $\lambda(\delta) \sim \delta^{-2/3}$]

$\beta > 3 \Rightarrow ku \sim e^{t/T}$, $\lambda(\delta) = \text{const}$ **nonlocal dispersion regime**



Wavenumber kinetic energy spectrum of the full surface velocity field (left), kurtosis of particle relative displacements (centre), FSLE from particle trajectories (right) in Kuroshio Extension in winter and in summer.

Lagrangian dispersion interpretation based on a slow-fast flow decomposition



Frequency-wavenumber spectra of kinetic energy $E(k, \omega)$ in Kuroshio Extension in February (a) and August (b). The horizontal solid and dashed lines indicate the Coriolis (f) and semidiurnal tidal (M_2) frequencies, respectively, while the dashed-dotted line shows the dispersion-relation curve for the 10th baroclinic mode. The corresponding deformation radii are $L_R = 65$ km (a) and $L_R = 20$ km (b). Decomposition of the kinetic energy wavenumber spectra $E(k)$ for February (c) and August (d). The spectrum of the total kinetic energy (KE) is shown by black square points. The contribution from frequencies such that $\omega^2 < f^2(1 + L_R^2 k^2)$ corresponds to the green dots, while the blue triangles are for frequencies $\omega^2 > f^2(1 + L_R^2 k^2)$. The reference lines k^{-2} in (c), k^{-3} and $k^{-2.3}$ in (d) are also shown for comparison.

To analyze the respective contributions of M/SM motions and IGWs to the Eulerian kinetic energy spectrum, we compute the frequency-wavenumber spectrum of kinetic energy. The distinction between M/SM and IGWs can be made using the dispersion-relation curve of IGWs, $\omega^2 = f^2(L_R^2 k^2 + 1)$. In winter, the energy is mainly concentrated at M/SM; in summer, the energetic content of IGWs increases, while that of submesoscales considerably decreases. **Wavenumber spectra of slow [$\omega^2 < f^2(1 + L_R^2 k^2)$] and fast [$\omega^2 > f^2(1 + L_R^2 k^2)$] motions, computed from $E(k, \omega)$, are compatible with the Lagrangian results (local dispersion in February, nonlocal dispersion in August).**

Conclusions

The summer disagreement is due to IGWs, which contribute to the kinetic energy spectrum at small scales but do not impact the relative dispersion process. Relative dispersion is then essentially controlled by the nearly-balanced (mainly rotational) flow component at larger scales. These results also suggest that SWOT data should allow predicting Lagrangian transport and dispersion properties via the advection of synthetic drifters, as the nearly-balanced flow component computed from SSH seems accurate at large scales.