Objective

- Understand transport mechanisms at the mesoscale by analysing Lagrangian particle statistics of an eddy-permitting model of the North Atlantic with 10 km horizontal resolution.
- Search for a reasonable estimate of spatially varying isopycnal eddy diffusivity.

Lagrangian Method

Diffusivity Tensor

- Uniform release, 120-day pseudo-trajectories in 5.5 years of model velocity
- Efficient sampling:
  - One statistically independent float observed per month per bin: 70 floats in bin
- Horizontal velocity and displacement statistics (v' and r', respectively) yield isopycnal diffusivity tensor \( \kappa_{jk}(x, t) = \langle (v'_i(x, t) v'_k(x, t)) r'_j(x, t) - f(x, b) \rangle \)
  
  \[ \kappa_{jk} \equiv \kappa_{jk}^{sym} + \kappa_{jk}^{asym} \]

- Physical Interpretation of \( \kappa_{jk}^{sym} \): Time derivative of negative displacement covariance tensor, \( \kappa_{jk}^{sym} \approx -2 \partial \bar{r}^2 / \partial t \)

- Principal axis orientation of \( \kappa_{jk}^{sym} \), \( \bar{r}^2 \) is the velocity autocorrelation.

\( \kappa_{jk}^{sym} \) and \( \kappa_{jk}^{asym} \) are orthogonal.

\( \kappa_{jk}^{sym} \): Turbulent diffusivity within a mean isopycnal

Comparison of \( \kappa_{jk}^{sym} \) from Model and Observations

- Estimates of \( \kappa_{jk}^{sym} \) agree in amplitude and pattern, but maximum of North Atlantic Current is shifted southward in the model.

Interpretation of Symmetric Part \( \kappa_{jk}^{sym} \): A Case Study

We look at the timeseries of the minor principal component in a single gridbox.

- Interpretation of \( \lim_{t \to \infty} \kappa_{jk}^{sym} \): Turbulent diffusivity within a mean isopycnal
- Uniform Release: Minor principal component of \( \kappa_{jk}^{sym} \) is insensitive to mean flow shear (Oh et al., 2000)

Future Work

1. Do synthetic drifters follow isopycnals?
2. Under which circumstances is it possible to reach the diffusive limit for \( \kappa_{jk}^{sym} \)?
3. Can we interpret the difference between Eulerian mean flow and Lagrangian mean flow?
4. Interpretation of \( \kappa_{jk}^{asym} \): Is there a way to retrieve phase-averaged displacement statistics from isopycnal floats?
5. Full 3-d diffusivity tensor: are displacements orthogonal to isopycnals relevant?
6. Is the major principal component of \( \kappa_{jk}^{sym} \) relevant to parameterizations of shear dispersion in models that cannot resolve narrow mean-flow shear (e.g. western boundary currents)?

References


Vertical Structure of \( \kappa_{jk}^{sym} \) in the North Atlantic Current

The North Atlantic Current is associated with high eddy kinetic energy and we expect that diffusivity may have a pronounced vertical structure there. The figures indicate that

- \( \max(\kappa_{jk}^{sym}) \) and EKE are both surface intensified and decrease with depth.
- The timelag at which \( \kappa_{jk}^{sym} \) obtains its maximum may be proportional to the average eddy turnarounds time.
- We plot the values of \( \max(\kappa_{jk}^{sym}) \) at a lag of 60 days to demonstrate that our method is not capable of revealing a possible convergence in every gridbox at this lag.

Profiles of the diffusivity tensor’s maximum value are high above the pycnocline and lower at depth. Below the pycnocline, the value is approximately constant and significantly different from zero. Bootstrap error bars suggest that these structures are significant and that the error is proportional to the magnitude of \( \max(\kappa_{jk}^{sym}) \).

Summary: The maximum of the diffusivity tensor’s minor principal component is correlated with EKE, but does not represent an asymptotic value that can be interpreted as a diffusivity.

Estimating horizontal diffusivity in the East Sea (Sea of Japan) and the northwest Pacific from satellite-tracked drifter data

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The Isopycnal Diffusivity Tensor Based on Lagrangian Particle Statistics

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