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Vertical motions of fluid particles near mesoscale ocean eddies and the effect of submesoscales

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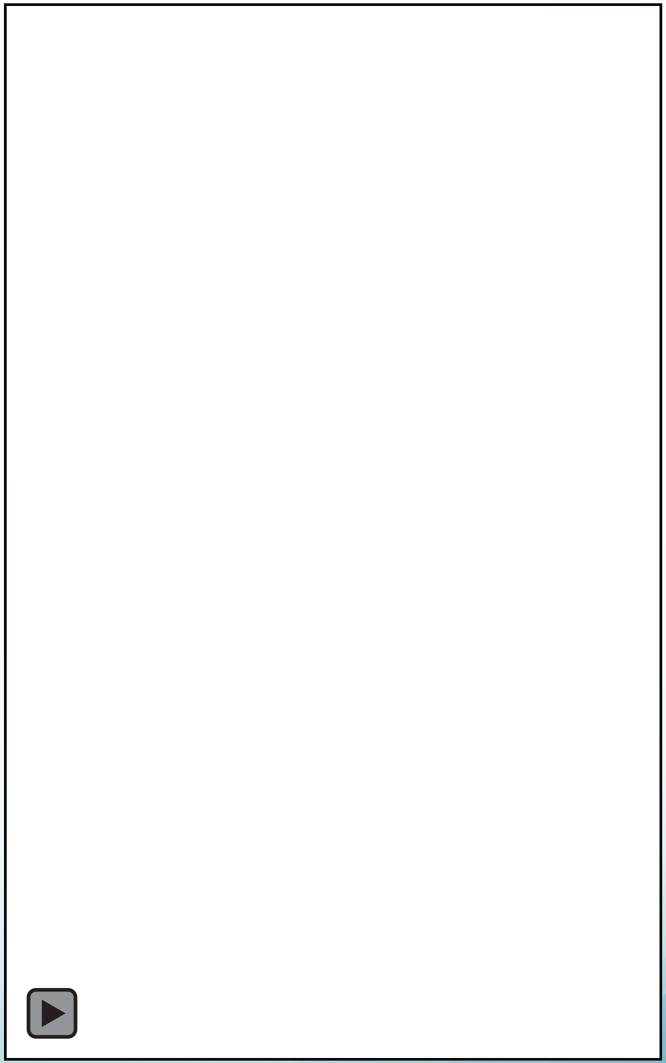
Motivation

- Importance of mesoscale eddies (O(100km)) & in transporting physical, biogeochemical properties in the ocean horizontally & also vertically
- However, the role of submesoscales (O(10km)) in the vertical pumping of these tracers may be as much important as the mesoscale eddies (eg. Klein and Lapeyre (2009))
- Seasonal variation of submesoscale structures due to changes in mixed layer thickness (Mensa et al., 2013) may affect vertical motions in eddy-dominant flow fields



HYCOM 1/48°: Gulf Stream region (Mensa et al., 2013)

Study Objectives

- To investigate the role of submesoscale features on the vertical fluid motions near mesoscale eddies : i.e. combined effect of mesoscale & submesoscales
- For this, we examine vertical dispersions of fluid particles near mesoscale eddies in relation to

1. seasonal variations (summer vs. winter)
2. model grid resolutions (mesoscacle-resolving vs. submesoscale-resolving).

Method

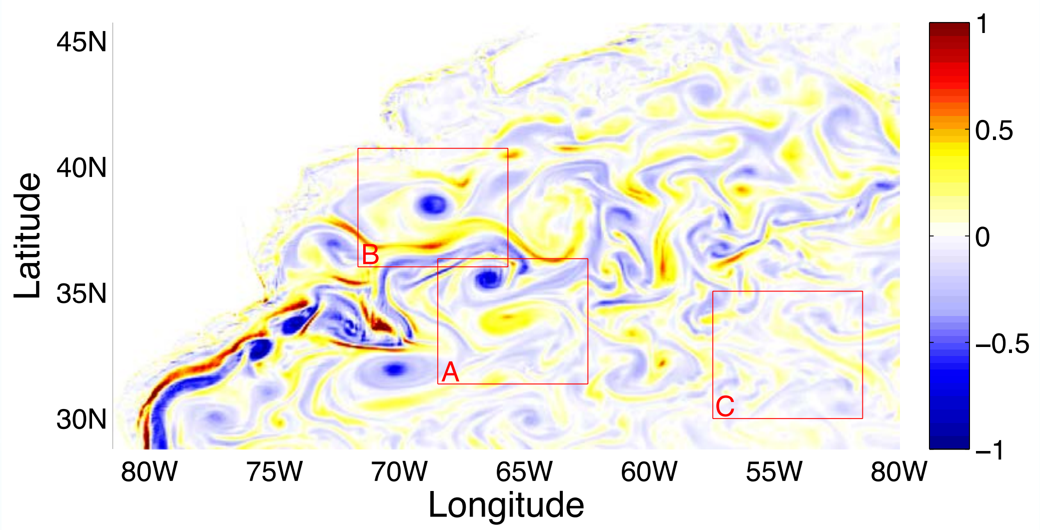
- HYCOM

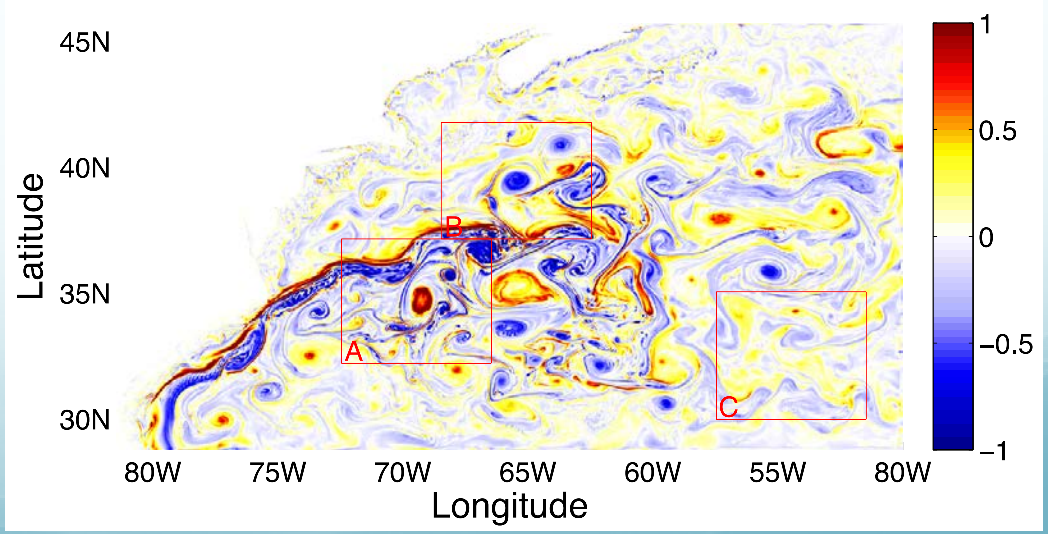
1/12 ° : mesoscale resolving)

Vs.

1/48 ° : submesoscale resolving (partly)

near the gulf stream (50 ~ 80W, 30 ~ 45N).





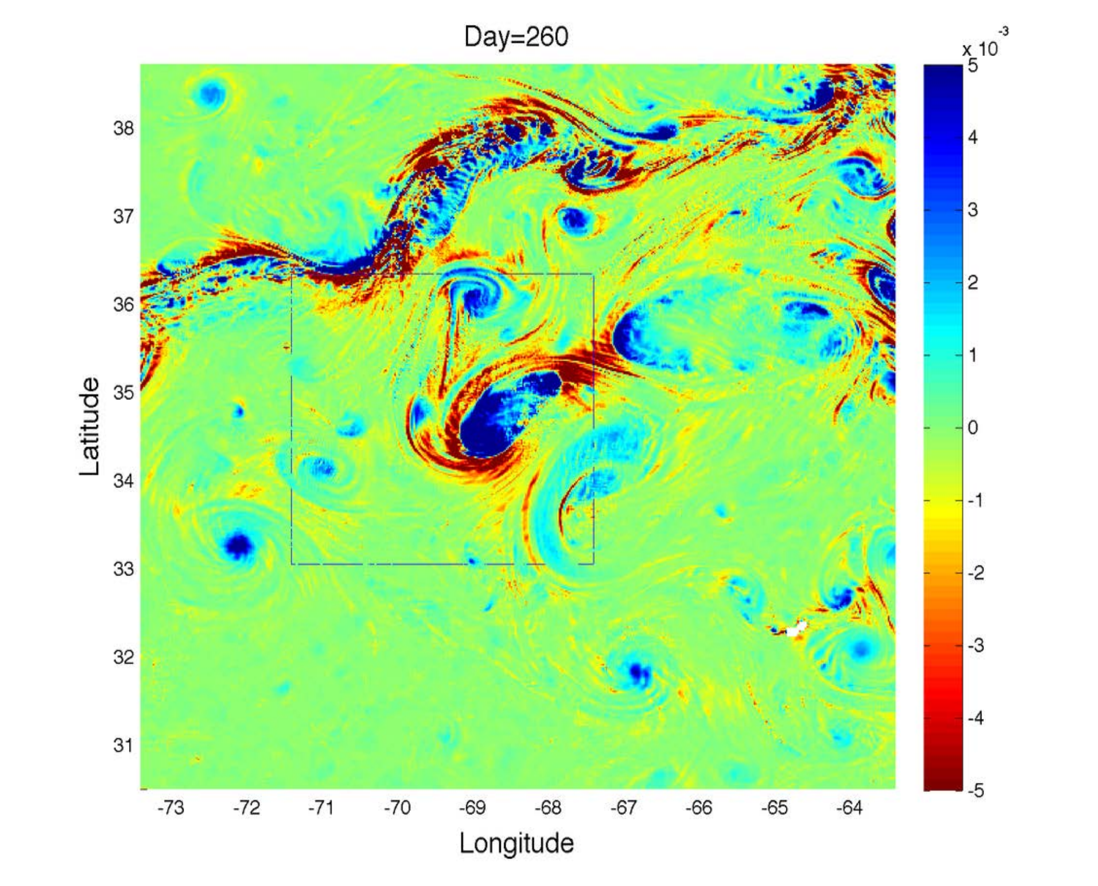
Method

- Eulerian parameter

1. Okubo-Weiss parameter (OW)

$$W = s_n^2 + s_s^2 - \omega^2$$

: separate the vorticity-dominant and strain-dominant regions of an eddy



OW field of a cyclonic mesoscale eddy near the mainstream

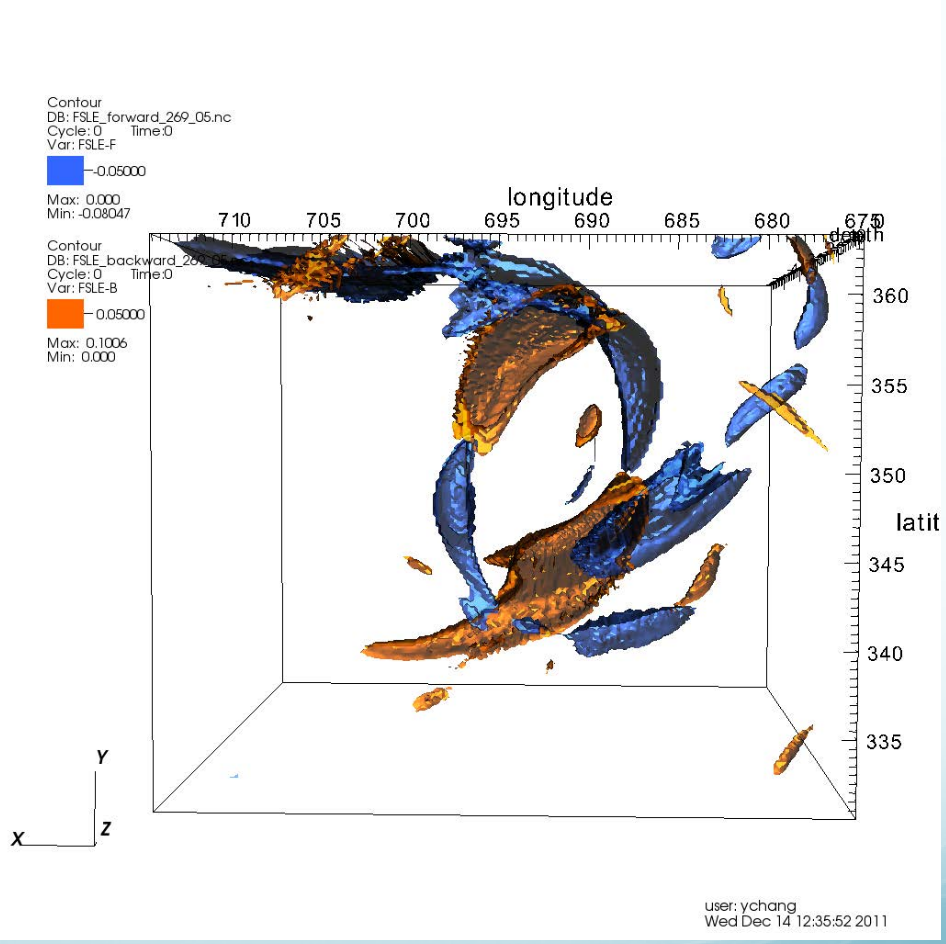
Method

- Lagrangian parameters

1. Finite-size Lyapunov exponents (FSLE)

$$\lambda(\delta) = \log(\alpha) / \tau(\delta)$$

measures time to separate particle pairs from distant δ to αδ



FSLE ridges can be used to identify eddy boundaries

Method

- Lagrangian parameters :

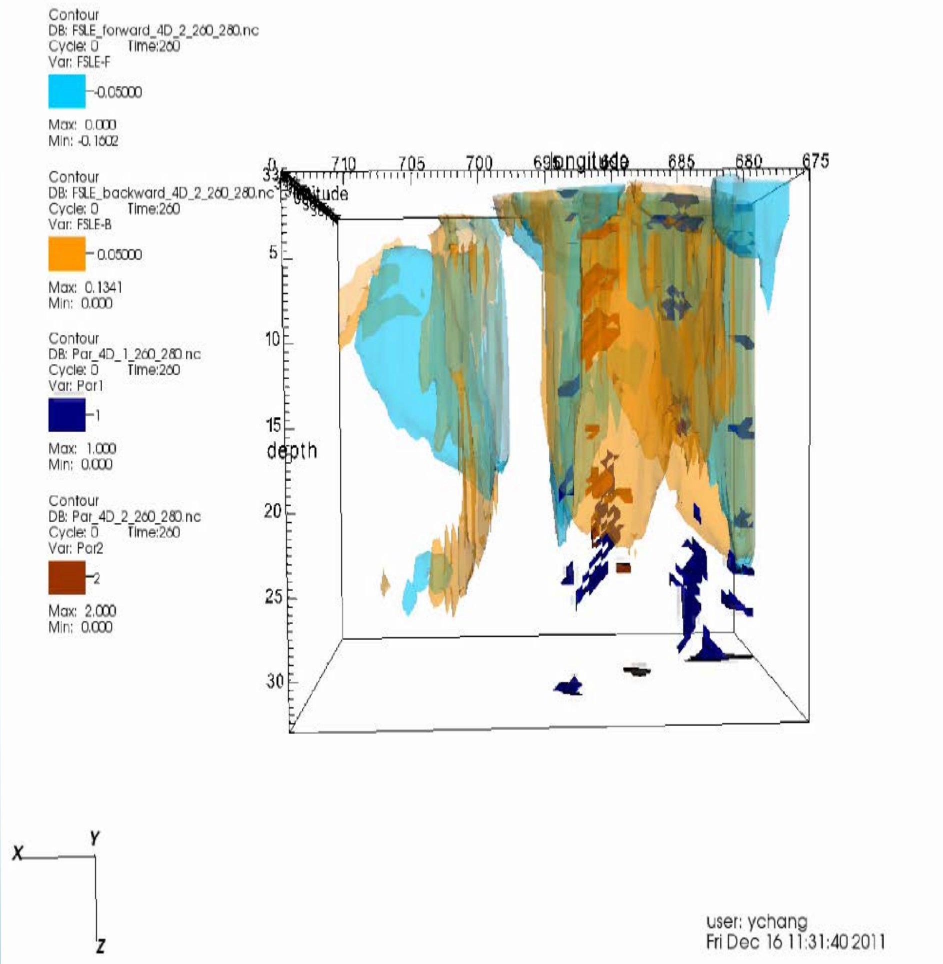
2. vertical particle dispersion (two-particle dispersion)

:

$$D^2(t) = \left\langle \left(r_2(t) - r_1(t) \right)^2 \right\rangle$$

$$Y_z(t, d_0) = \frac{1}{2} \frac{d}{dt} D^2(t, d_0)$$

= rate of vertical dispersion of particles



FSLE (light blue & orange curtains) & particle motions (dark blue & red spots)

Method

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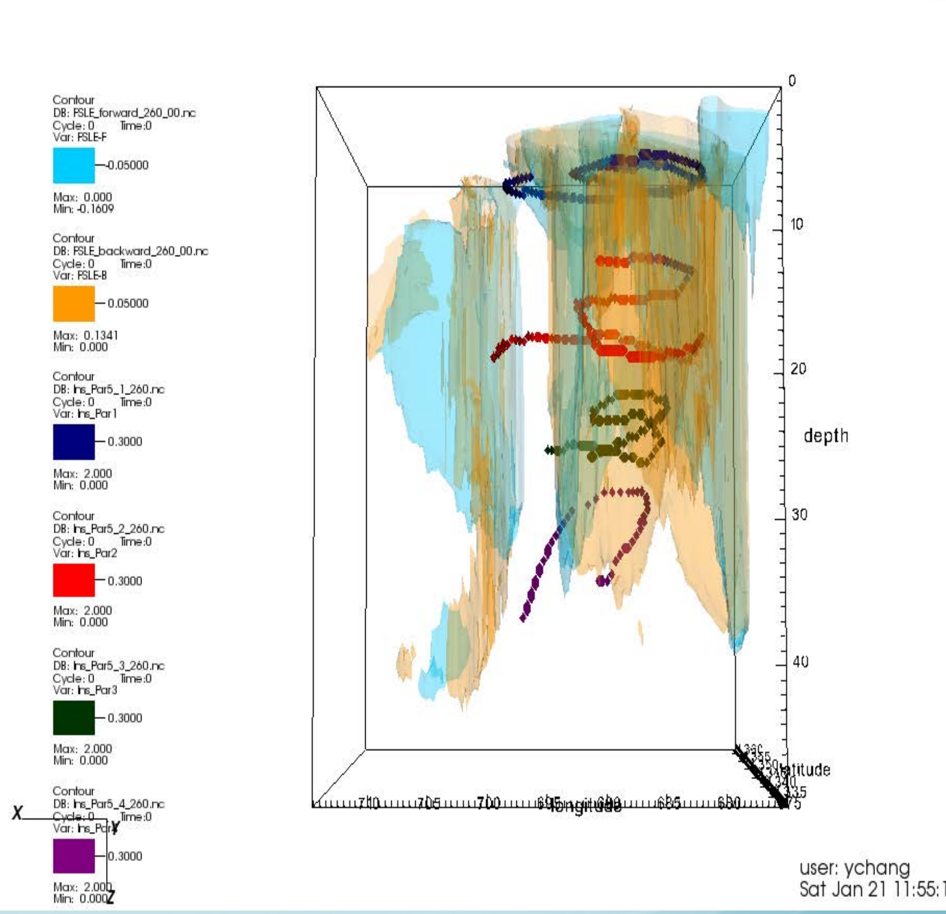
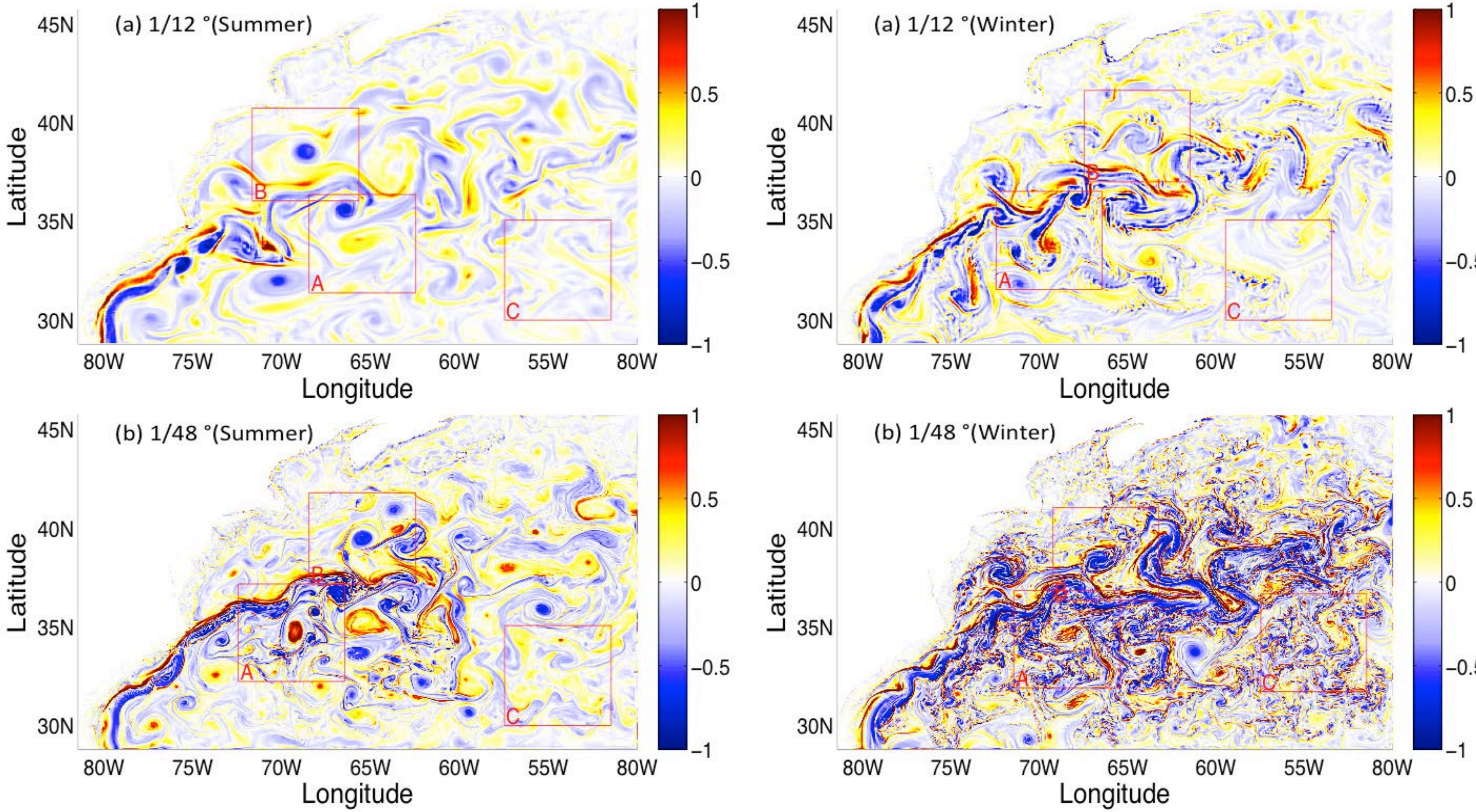


Irregular motions of fluid particles inside the eddy

4 flow fields

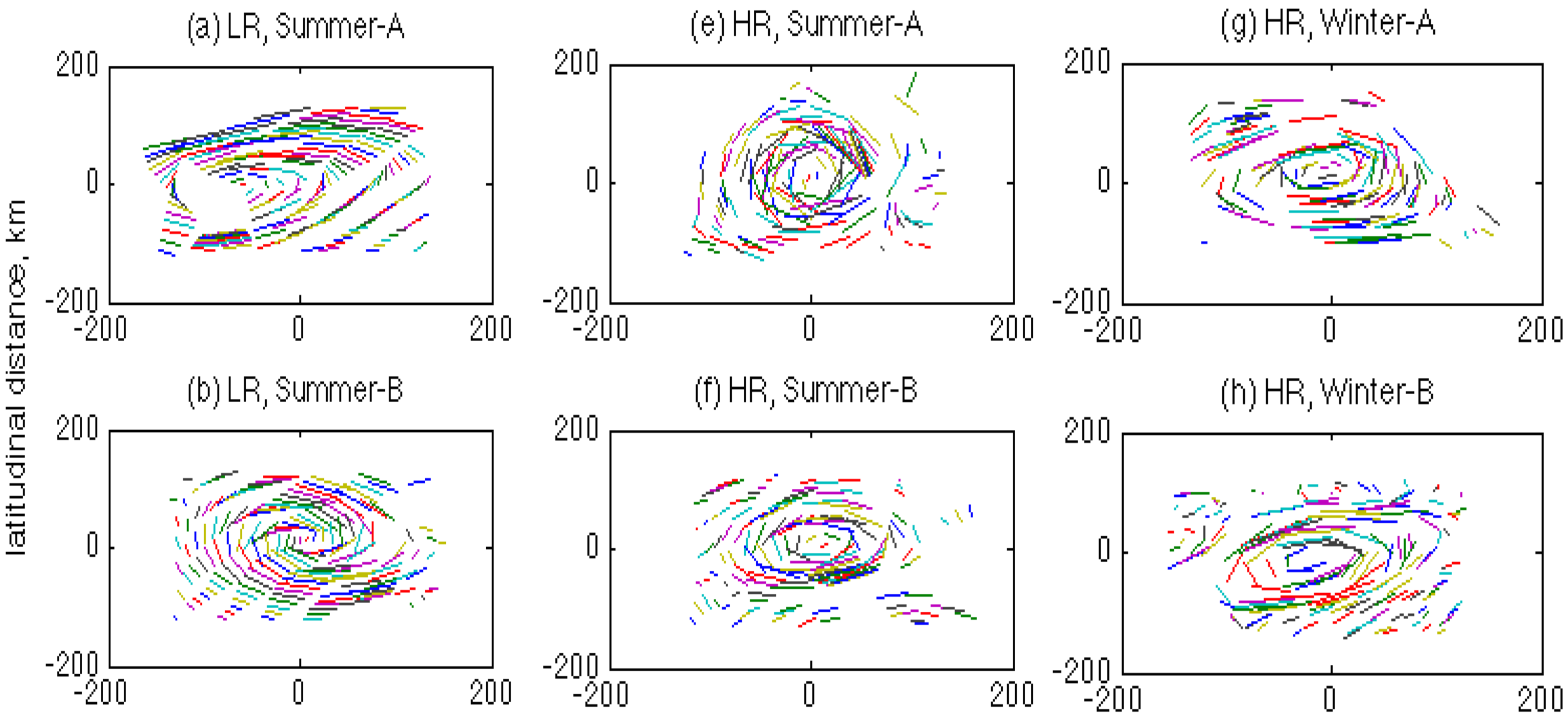
1. Comparisons between summer vs. winter, & High (1/48°) vs. Low(1/12°) resolutions (relative vorticity)

2. Three regions at each case: Two mesoscale rings (cyclonic and anticyclonic), and a region w/o ring from each season.



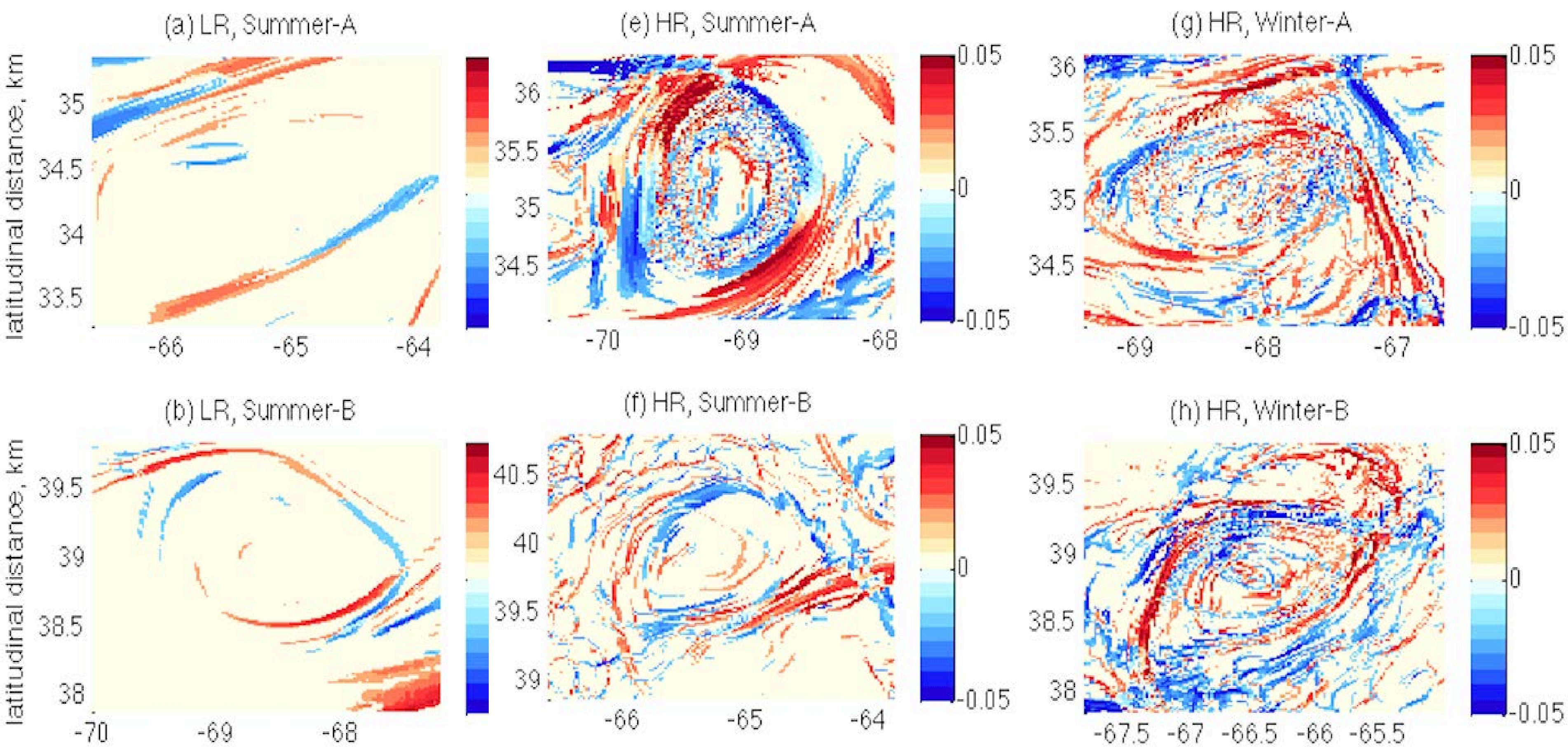
Fluid particle trajectories

Particle motions are more dispersive in high resolutions (HR, finer) than low resolutions (LR, coarser)

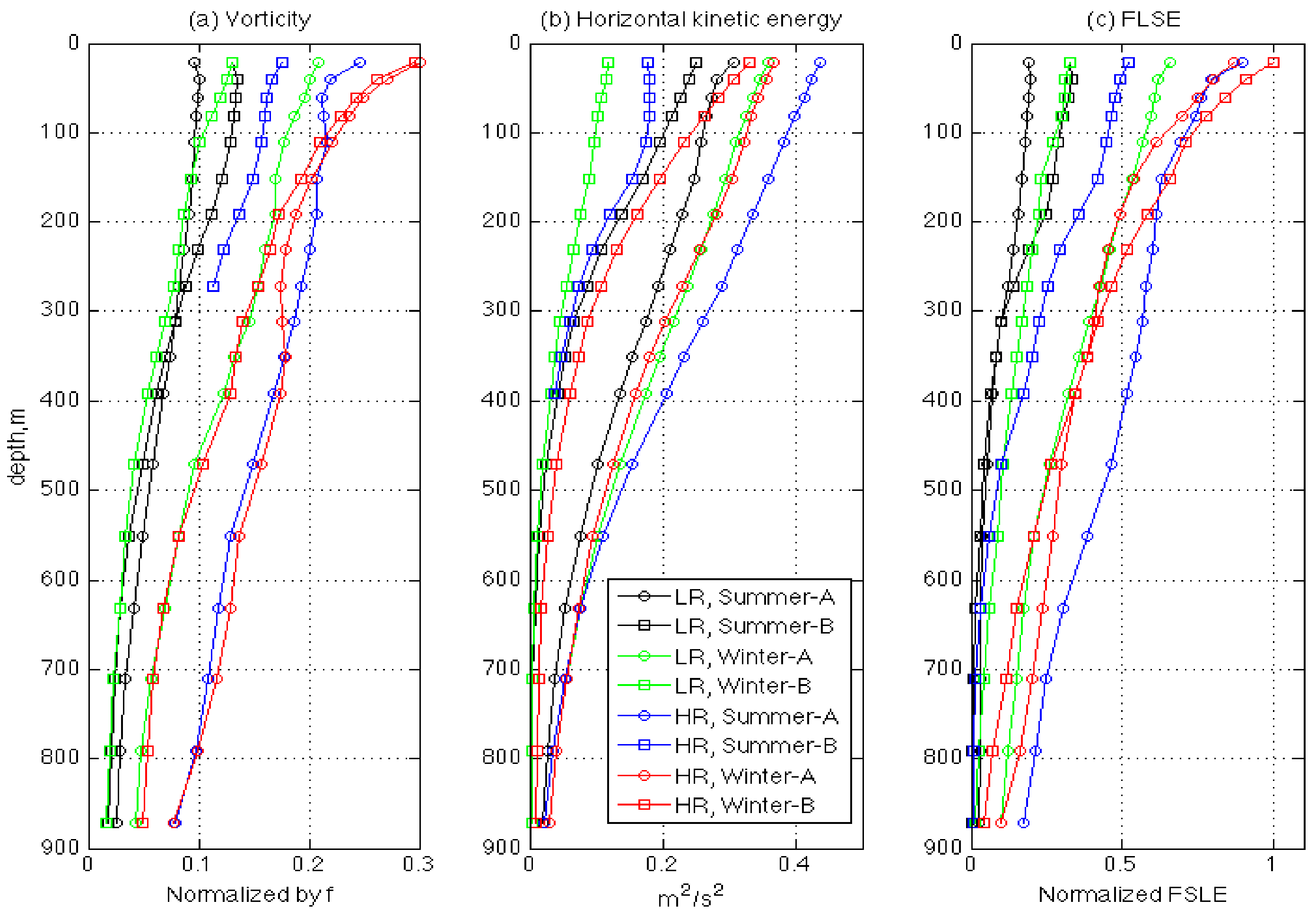


FSLE distribution

Submesoscale features are more dominant in HR (finer) than LR (coarser), and at winter than summer

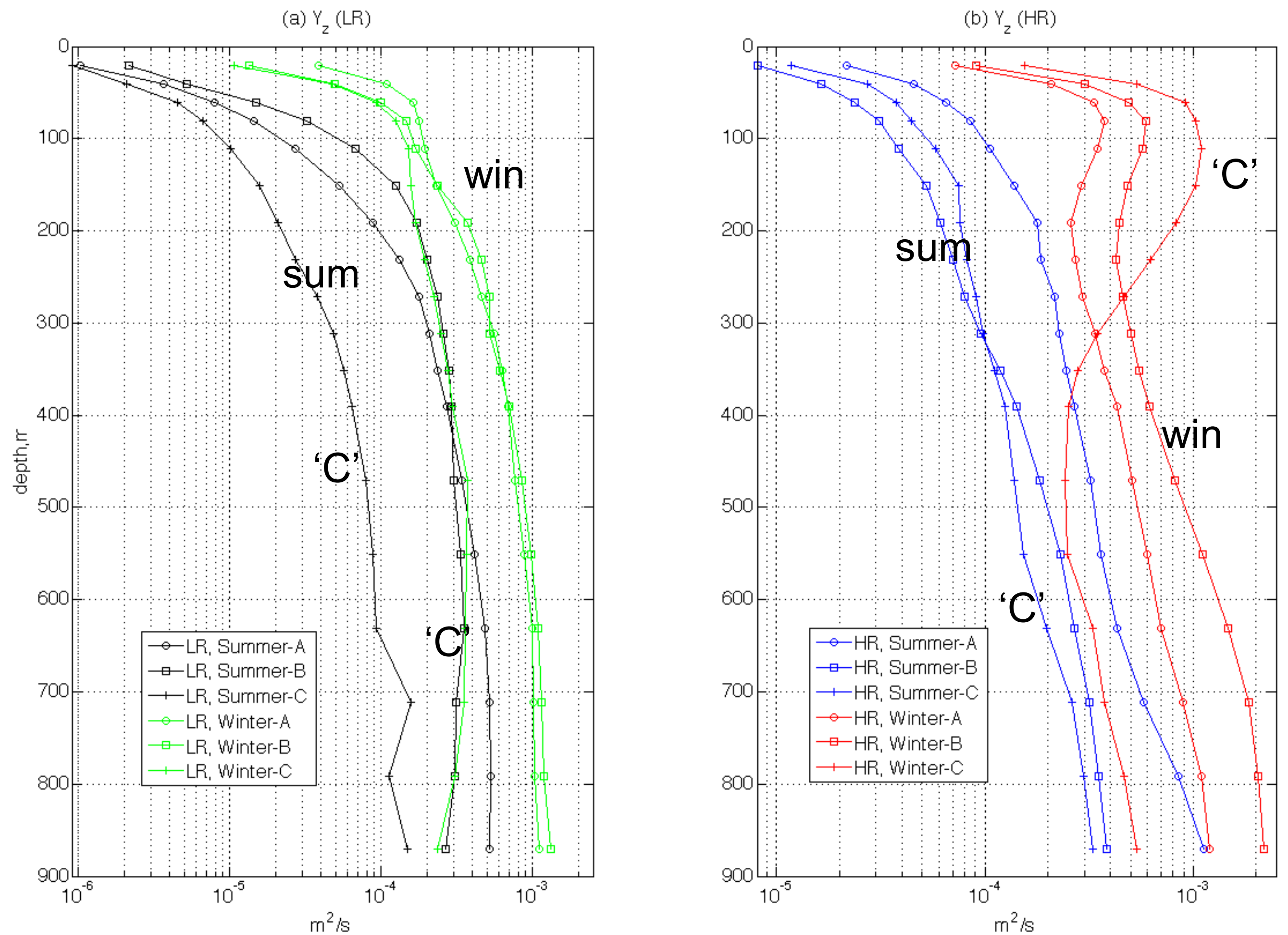


Vertical profiles of vorticity, KE, FSLE magnitudes



No clear differences between the six chosen eddies as their intensities and flow energy are comparable

Relative dispersion coefficients



1) win > sum

2) 'C' : low at deeper ocean

3) Peaks at shallows for winter cases affect on deeper parts

However, clearly different pattern is found between the cases in the vertical dispersion rates.

Conclusion

- Strong stratification at the surface in summer suppresses the vertical mixing of the ring.
- In winter, the vertical momentum transfer is easier between the surface mixed layer and deeper ocean through the rings which may provide the ways of transfer through the density front made by the rings.
- The effect of submesoscales in the mixed layer may reach far below the mixed layer into the deeper part of the oceans, and thus they can affect on the upwelling/downwelling of various properties.