Influence of Mesoscale Eddies on the Deep Ocean Mixing over the East Pacific Rise

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Background and Questions

Mesoscale eddies are ubiquitous in the global ocean. A considerable amount of knowledge about mesoscale eddies has been gained in the past decades, especially since the advent of satellite altimetry. However, the signals of mesoscale eddies in the deep ocean and their influence on the deep-ocean dynamics have not yet been intensively studied. Here we want to address the following questions by combining satellite and deep-ocean measurements:

- Can mesoscale eddies affect the dynamical processes in the deep ocean?
- If so, how do mesoscale eddies influence the various deep-ocean processes?
- What are the implications of deep-reaching impacts of mesoscale eddies for the global climate system?

Deep-Ocean Current Measurements

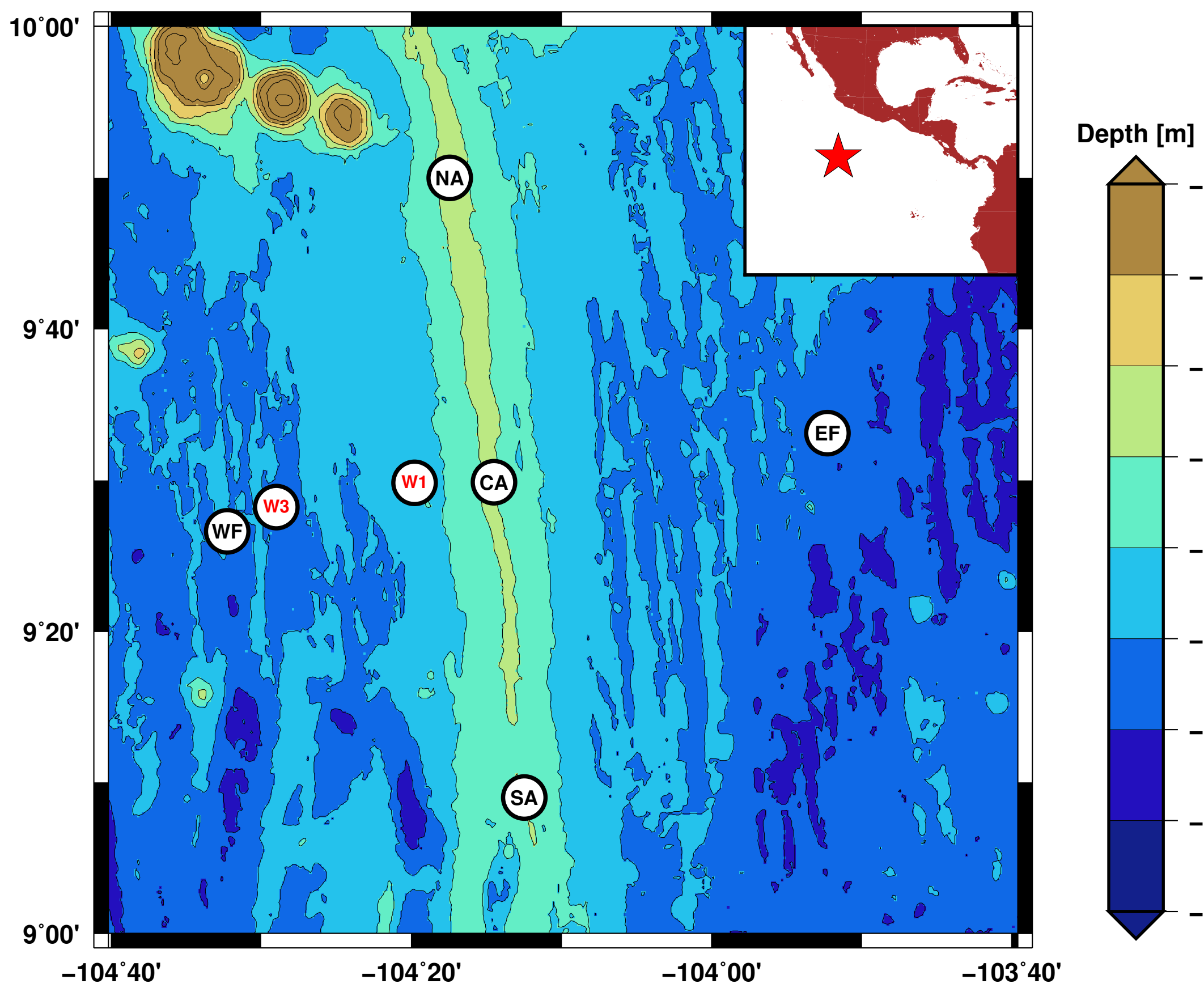

Figure 1: Bathymetry of the East Pacific Rise (EPR) segmenet between 9° and 10°N. Locations of current meter (CM) and McLane Moored Profiler (MMP) moorings are labeled with circles. Names of stations are marked inside the circles (CMs: black; MMPs: red). The red star in the inset shows the location of the study region. From: Liang and Thurnherr (2011).

- During an NSF-funded project LADDER, several moorings were deployed over and near the crest of the EPR in Nov. 2006 and recovered in Nov. 2007.
- On the current-meter moorings, velocities were recorded every 20 minutes.
- McLane Moored Profiler (MMP), deployed on the "W1" and "W3" moorings, recorded temperature, salinity and velocity profiles between 2300 and 2775 m (10 m.a.b.) with a vertical resolution of 2 m, roughly three times per day.
- These deep-ocean measurements can be used to present dynamical processes of various time scales in the deep ocean.

Surface Features of Mesoscale Eddies

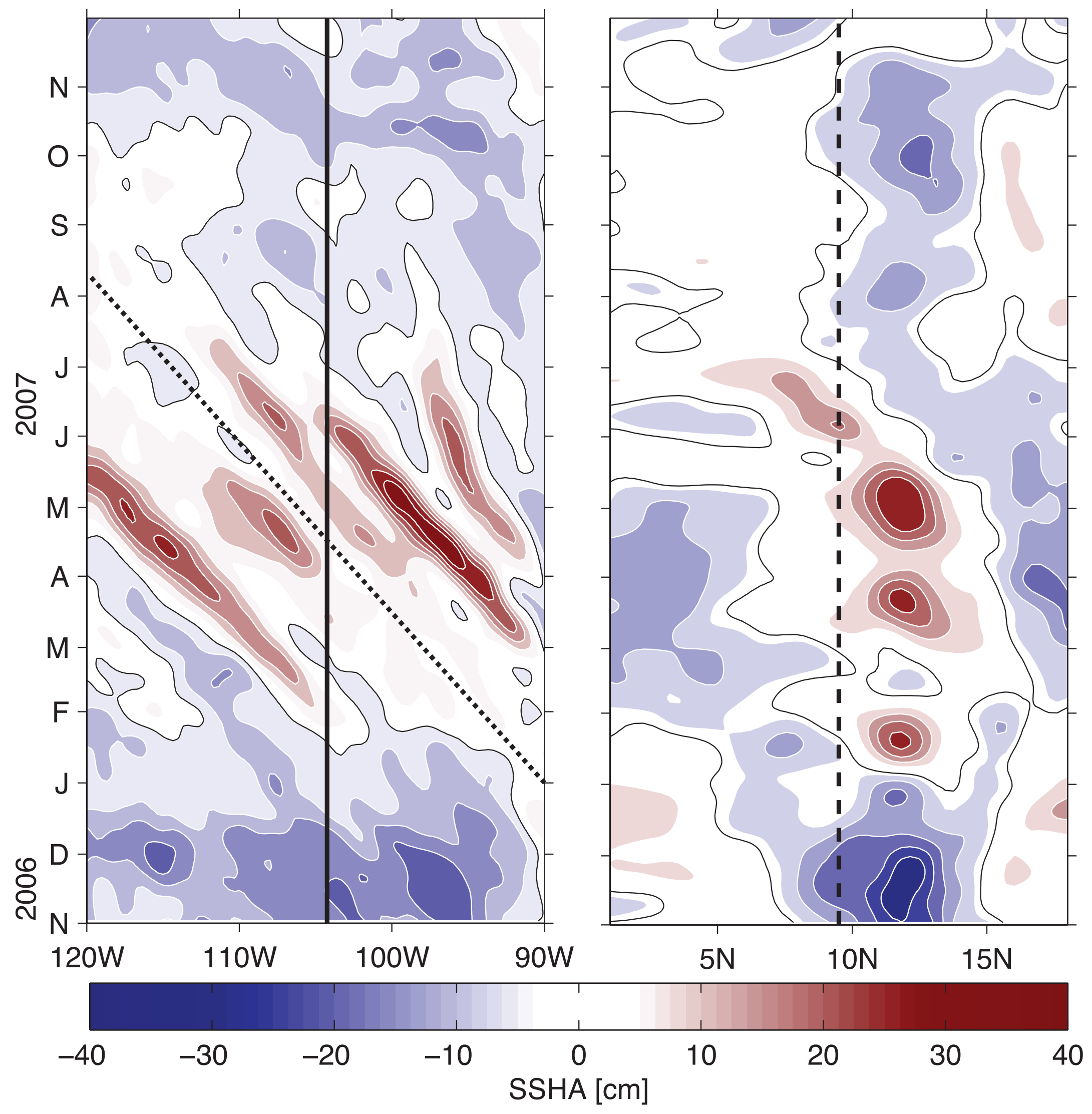

Figure 2: (left) Time-longitude plot of subinertial Sea Surface Height Anomaly (SSHA) at 9.5°N. The solid line shows the longitude of the ridge crest and the doted line indicates a westward propagating speed of 15 cm/s; (right) Time-latitude plot of subinertial SSHA at 104.5°W. The dashed line shows the latitude where the geographic center of the observation is located. From: Liang and Thurnherr (2011).

- SSHA reveal mesoscale eddies passing the observation site during the LADDER period. We can thus examine their potential impacts on the deep-ocean processes.
- Mesoscale eddies passing this region mainly propagated westward, without significant meridional propagation, during the LADDER period.

Deep-Ocean Subinertial Currents

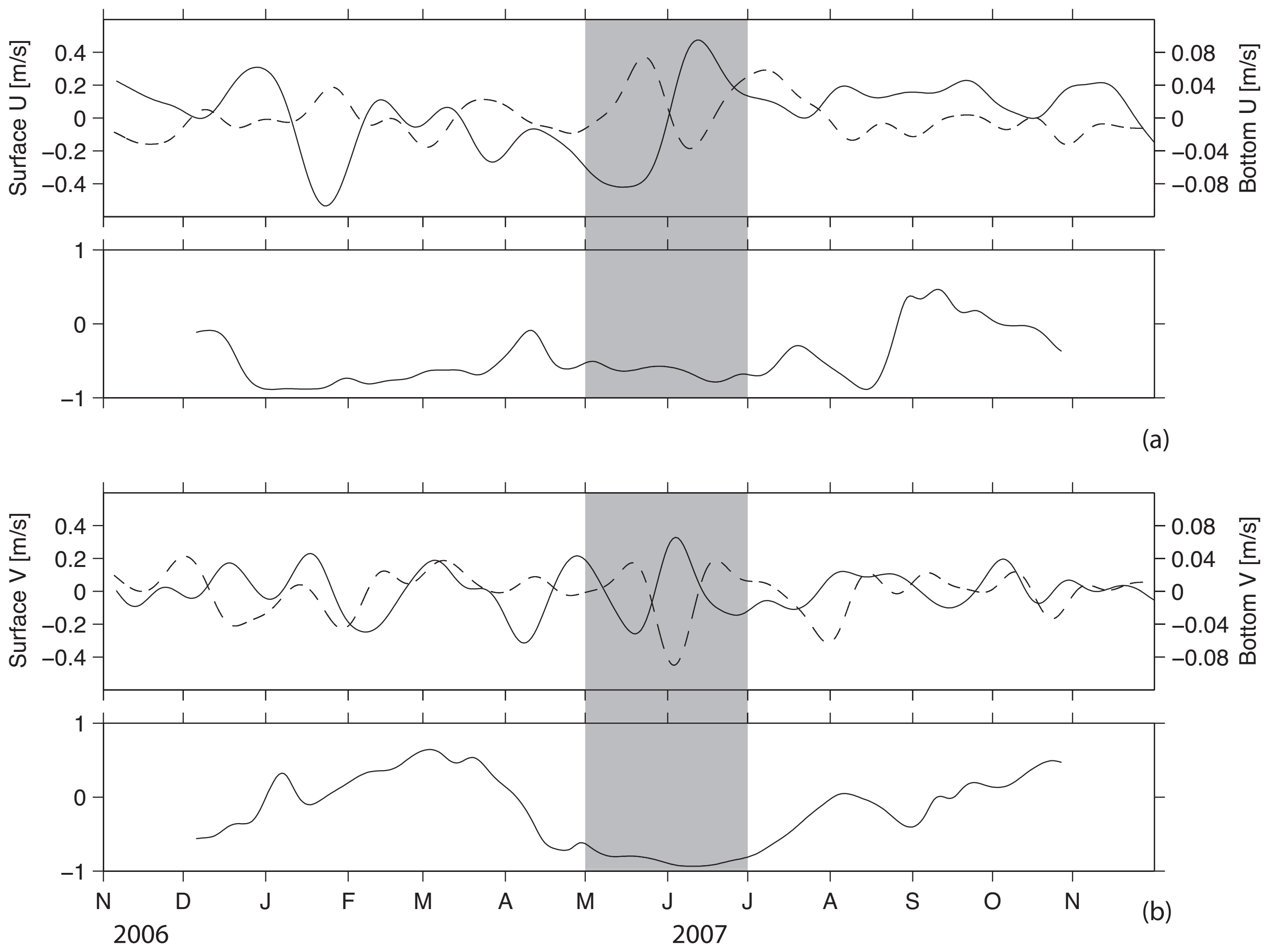

Figure 3: (a) (top) Zonal velocities of geostrophic currents (solid) estimated from the SSHA data near NA and observed deep-ocean currents (dash) at NA; (bottom) their correlation calculated with overlapping two months segments. (b) (top) Meridional velocities of geostrophic currents (solid) and observed deep-ocean currents (dash) at NA are shown; (bottom) their correlation calculated with overlapping two months segments. Shaded regions show the period during which two energetic anticyclonic eddies affected the observation site. The estimated geostrophic currents and the observed deep-ocean currents are plotted with an offset of 8 days. The correlation is also calculated with an offset of 8 days. From: Liang and Thurnherr (2011)

- The comparison of the surface and deep-ocean subinertial currents shows low-frequency variation of the correlations between them, for both the zonal and meridional velocity components.
- Large negative correlations occurred in both zonal and meridional velocities between May and July 2007, when two energetic anticyclonic eddies affected the observation site.
- Note that the deep-ocean current meter record is lagged by 8 days, suggesting a possible vertical tilt.

Deep-Ocean Internal Waves

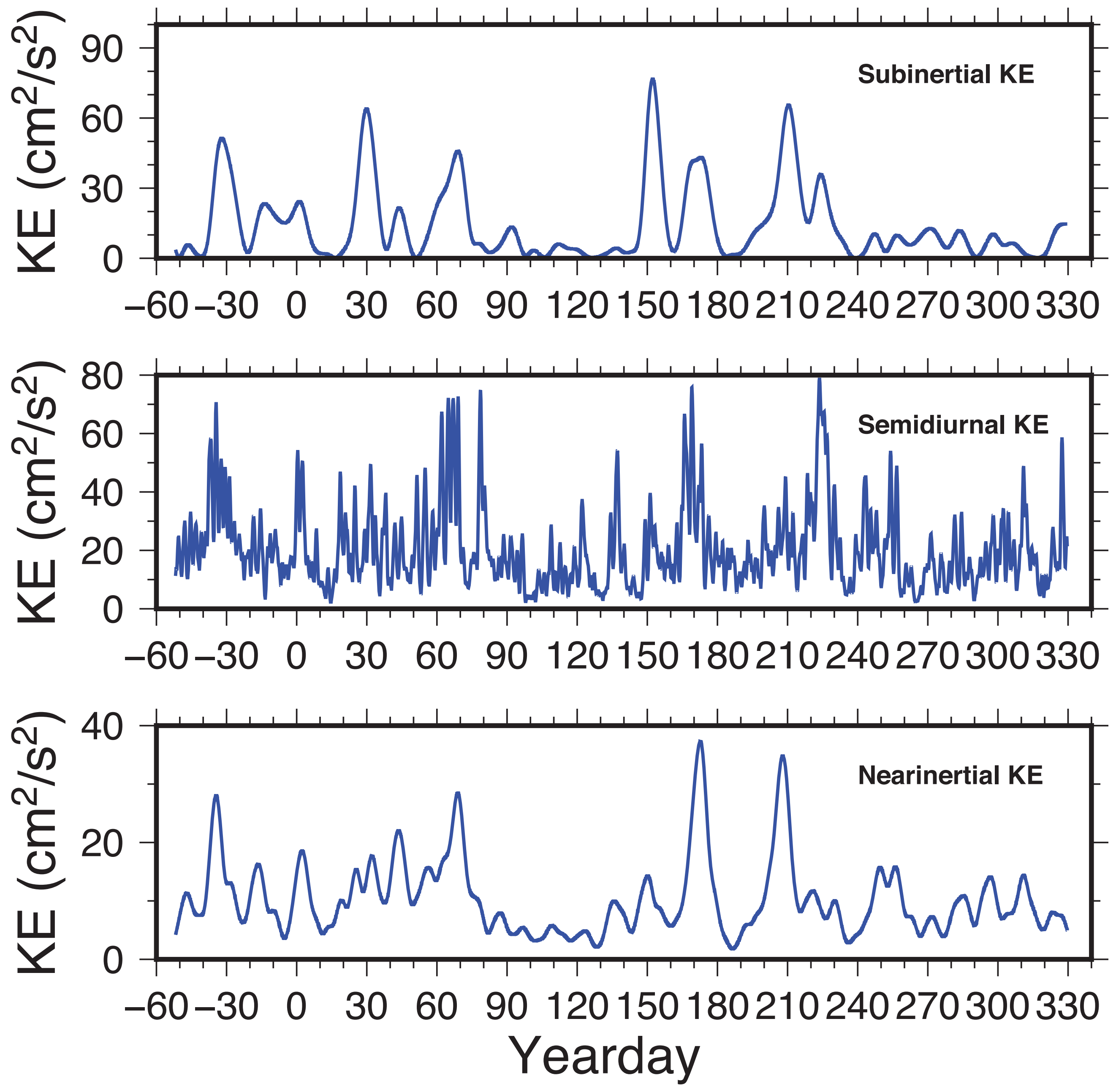

Figure 4: Time series of subinertial KE, semidiurnal KE and near-inertial KE. The results are from current meter at CA. Other moorings over and near the ridge crest show similar results. From: Liang and Thurnherr (2012) and Liang (2014).

- Both the semidiurnal KE and near-inertial KE from moorings over or near the ridge crest show significant subinertial variations.
- The subinertial modulations of semidiurnal and near-inertial KEs are closely related to the deep-ocean subinertial currents, which can be affected by the passing mesoscale eddies.
- However, a more careful examination reveals that the responses of the internal tides and near-inertial oscillations to the deep-ocean subinertial currents are different. See the time period between yeardays 120 and 240. Their different responses to the same subinertial currents suggest that other factors (e.g., topography) also play important roles.

Role of Bathymetry

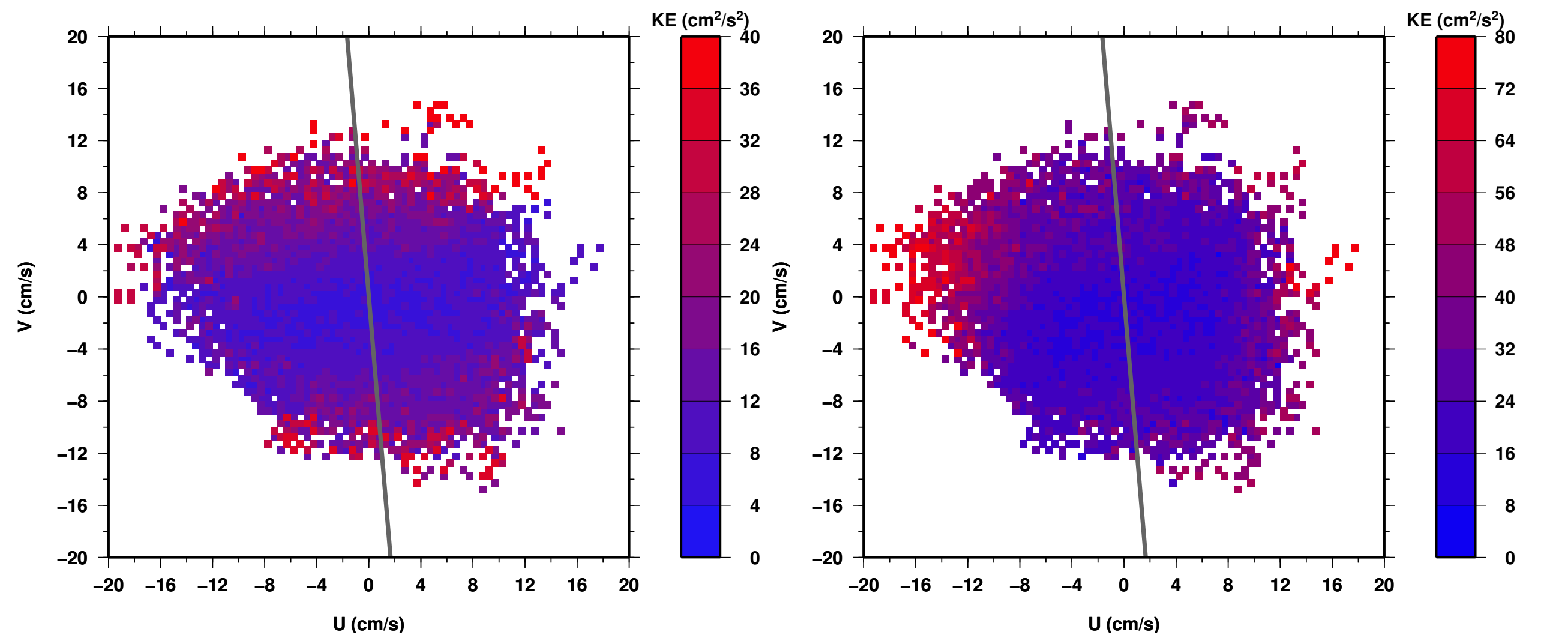

Figure 5: Roles of bathymetry in the response of internal waves to the deep-ocean subinertial currents. (left) Near-inertial KE at CA as a function of velocity. The colored blocks show KE levels gridded into 0.5 × 0.5 cm/s bins. The thick grey line shows the direction of the crest of the EPR in this region. (right) Similar to the left but for the semidiurnal KE. From: Liang and Thurnherr (2012) and Liang (2014).

- In addition to flow speed, the intensity of the near-inertial KE depends on the flow direction relative to the orientation of the EPR crest. In particular, there is a strong correlation between the near-inertial KE and the magnitude of the along-ridge flow. Further examination reveals small topographic features along the ridge crest, favoring the generation of lee waves.
- In contrast to the near-inertial KE, the semidiurnal KE is closely related to the across-ridge flow. This observation is consistent with local generation of internal tides over or near the ridge crest.

Deep-Ocean Mixing

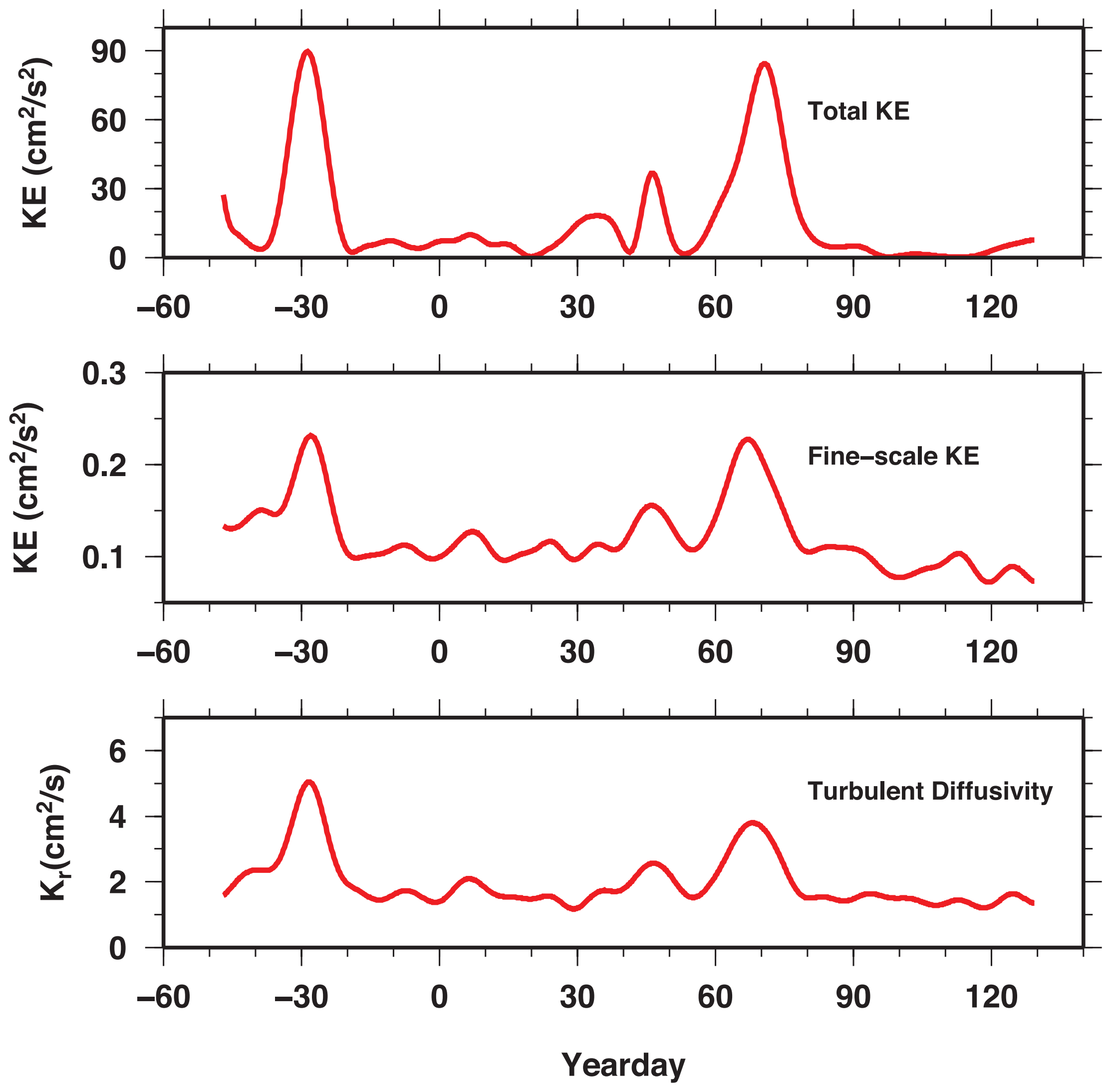

Figure 6: MMP observations from the W1 mooring on the west flank of the EPR. (a) Vertically averaged subinertial KE. (b) Vertically averaged finescale subinertial KE. (c) Vertically averaged turbulent diffusivity from a Richardson-number based parameterization. From: Liang and Thurnherr (2012).

- The finescale KE is much smaller than the subinertial KE but is highly temporally correlated with it, suggesting eddy modulation of finescale processes in this region.
- The parameterized diapycnal diffusivities derived from the Ri time series are highly correlated with the time series of subinertial and finescale KE.
- The correlations between subinertial KE, finescale KE, and inferred diapycnal diffusivity in the W1 record confirm that some of the oceanic turbulence is driven by low-frequency geostrophic motions, some of which are related to mesoscale eddies.

Summary and New Questions

- Mesoscale eddies passing over the East Pacific Rise have clear influence on various deep-ocean dynamical processes, e.g. the subinertial currents, internal waves, and mixing.
- Is this deep-reaching influence of mesoscale eddies universal around the global ocean? What are the roles of other factors (e.g., topography, latitude, etc.)?
- Since mesoscale eddies may vary with the changing climate, is this deep-reaching influence of mesoscale eddies an overlooked way connecting the upper and deep oceans and a neglected important climate feedback mechanism?

Related Publications

- Liang, X., and A. M. Thurnherr, 2011: Subinertial Variability in the Deep Ocean Near the East Pacific Rise Between 9 and 10N. *Geophys. Res. Lett*, 38, doi:10.1029/2011GL046675.
- Liang, X., and A. M. Thurnherr, 2012: Eddy-Modulated Internal Waves and Mixing on a Midocean Ridge. *J. Phys. Oceanogr*, 42, 1242–1248, doi:10.1175/JPO-D-11-0126.1.
- Liang, X., 2014: Semidiurnal tidal currents in the deep ocean near the East Pacific Rise between 9° and 10° N. *J. Geophys. Res*, doi:10.1002/2013jc009522.

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For more information, see marine.usf.edu/liang