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Eddy variability in the Northeast Pacific from a 1/36° regional model

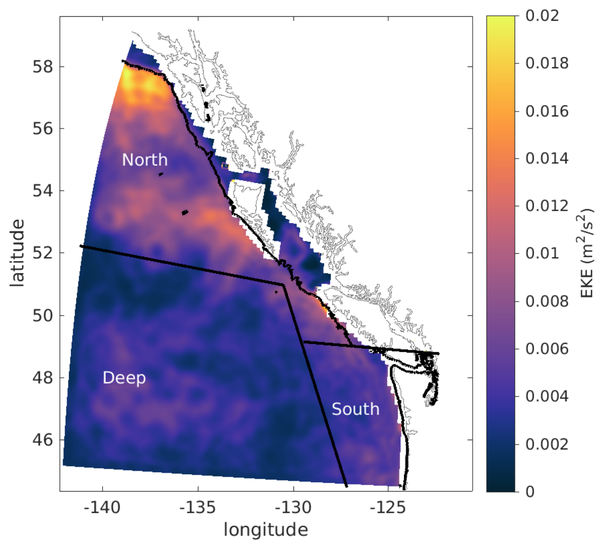
Rachel Horwitz[1] (rachel.horwitz@dfo-mpo.gc.ca), Li Zhai[1], Youyu Lu[1], Xianmin Hu[1], Jean-Phillippe Paquin[2], Angelica Peña[3]
[1]Bedford Institute of Oceanography, DFO Canada, [2]Environment Canada, [3]Institute of Ocean Sciences, DFO Canada

Summary

Mesoscale eddy variability constitutes a significant component of the total kinetic energy of the ocean, and plays significant roles in mixing and transport of heat, salt, and nutrients. In the Northeast Pacific, the spatial variations of eddy energetics are related to their different origins and pathways, as has been shown in previous observational and model studies.

In this study, we analyze the eddy variations from hindcast simulations with high-resolution regional models and demonstrate the **simulated eddy variability is consistent with that derived from satellite altimetry** when horizontal mixing is parameterized correctly.

EKE regional variation

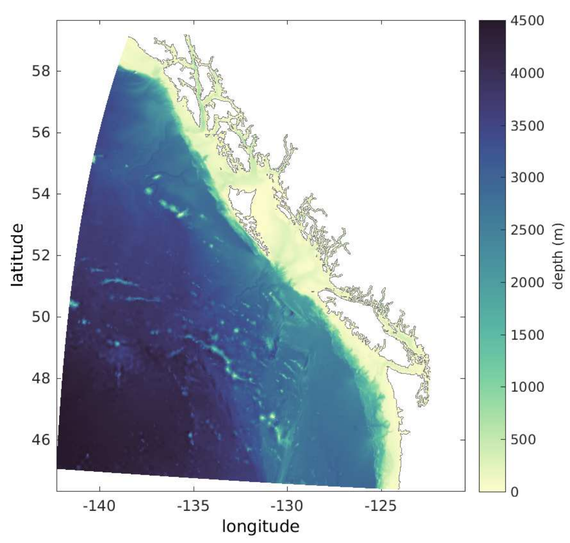


10-year average EKE. Black lines bound three regions of the domain that are used to investigate annual and interannual EKE variation.

- **North:** Haida eddies, Sitka eddies, and other similar eddies are generated by advection of light water off the shelfbreak and then propagate northwestward.
- **South:** The south region contains the Columbia River plume and the mouth of the Strait of Juan de Fuca. Strong horizontal density gradients and a coastal current generate baroclinic instabilities.
- **Deep:** The deep region covers the remainder of the model domain and does not contain eddy generation sites or coastline.

Model

NEP36 is a 1/36° regional model of the Northeast Pacific based on the Nucleus for European Modelling of the Ocean (NEMO) v3.6

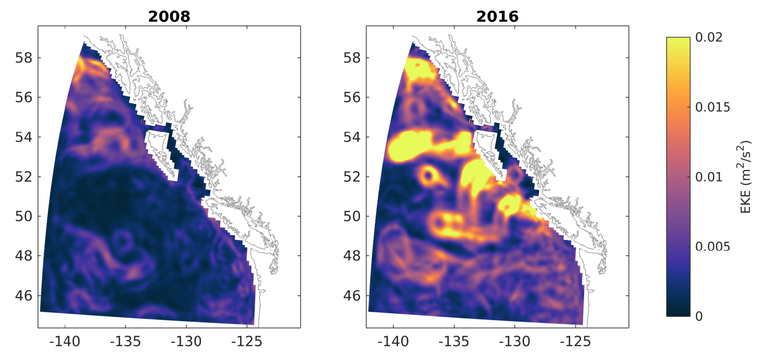


10-year hindcast (2007 to 2017) on 1.7 km grid with 75 vertical z-levels forced by

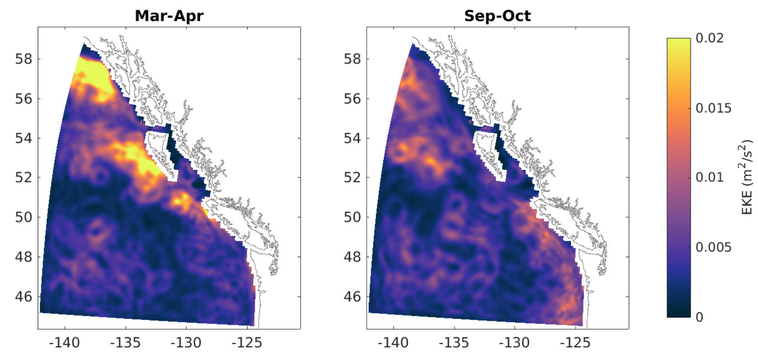
- Hourly surface forcing for wind, air pressure, and heat and fresh water fluxes from CMC GDPS reforecast.
- Daily open boundary conditions for ssh, u, v, T, S from 1/12° PSY4 product (Mercator-Ocean, France)
- 8 tidal constituents at open boundaries from WebTide

Seasonal and interannual variation

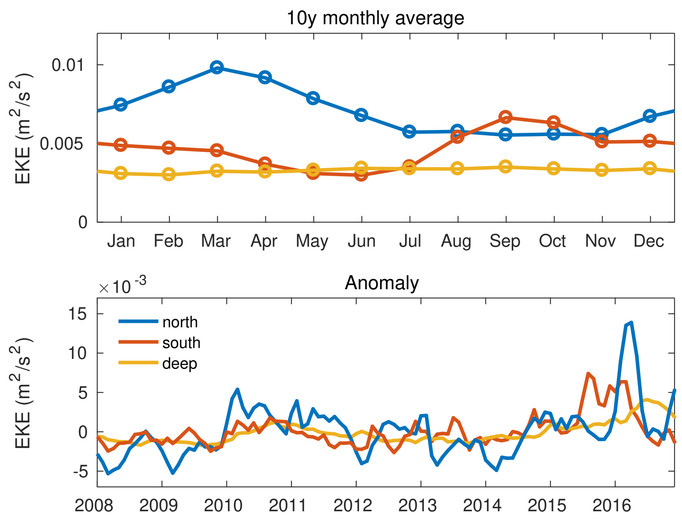
Low and high EKE years
Individual eddy tracks clearly visible in annual average.



High and low EKE seasons
In spring, eddies form as shelf water exits shelfbreak and eddies propagate northwestward. In fall, eddies are generated from instabilities in coastal flow.



Ten year average annual cycle (top) and monthly anomalies (bottom) from north, south, and deep regions



- **North region has peak in spring** as winter downwelling winds relax. High EKE in El Niño years.
- **South region has peak in fall**, when summer upwelling has spread river plumes across the shelf and horizontal density gradients area at a minimum.
- Deep region has small seasonal variation; interannual variation follows PDO index.
- **Anomalies are larger than seasonal cycle** in all regions.

Methods

Circulation associated with mesoscale eddies is primarily geostrophic, so geostrophic currents calculated from sea level anomaly are use to estimate the eddy kinetic energy (EKE).

1. Eddy sea level anomaly, η', estimated by subtracting the 10-year mean and annual & semi-annual harmonic fits from the 5-day averaged time series of dynamic sea surface height. Subtracting harmonics removes seasonal variation in geostrophic currents, but leaves slow moving eddies that vary year-to-year.
2. Model η' averaged over 1/3° to match satellite product resolution. Smoothing reduces peak EKE values, but does not change spatial or temporal patterns.
3. Eddy geostrophic currents:

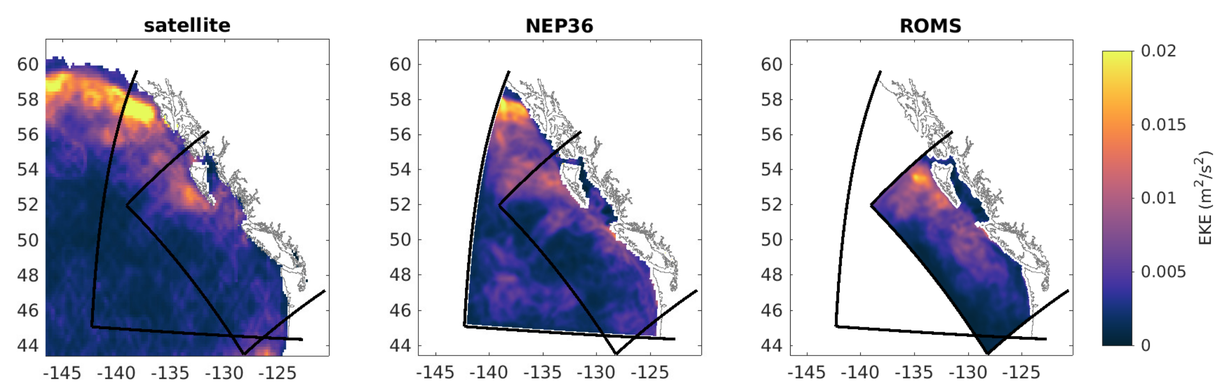
$$u' = -\frac{g}{f}\frac{\partial \eta'}{\partial y} \quad \text{and} \quad v' = \frac{g}{f}\frac{\partial \eta'}{\partial x}$$

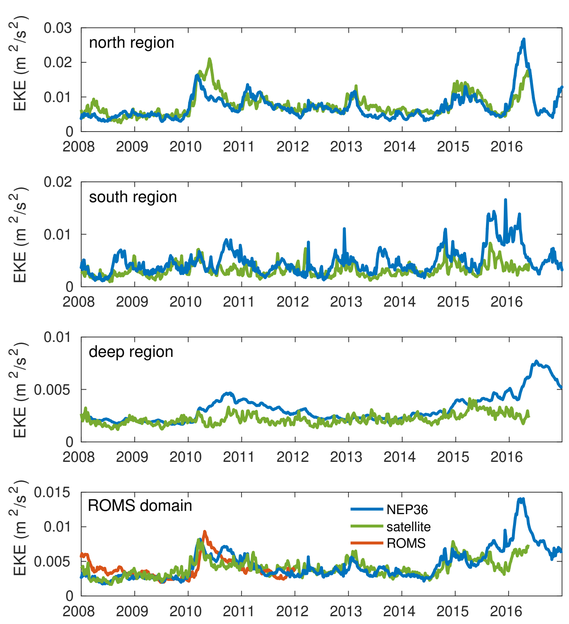
4. EKE from eddy velocities:

$$\text{EKE} = \frac{1}{2}(u'^2 + v'^2)$$

Same steps applied to gridded satellite product, JPL MEaSUREs Gridded Sea Surface Height Anomalies Version 1609.

Comparison to satellite data and a ROMS model





(Above) 5-year average EKE from a satellite product, NEP36, and a ROMS model for ROMS model time range (2008-2012).

(Left) Timeseries of EKE in north, south, and deep regions from NEP36 and satellite product, and ROMS domain area average for all three datasets.

- NEP36 captures observed north region interannual variability well
- In south region, NEP36 has larger seasonal cycle than altimetry product, but satellite may not resolve coastal features well.
- NEP36 eddies propagate westward into deep region more than observed eddies.
- High value of EKE at northern corner of NEP36 domain is accurate, not a boundary artifact.
- Both models reproduce observed 2010 EKE peak.