Cross-shelf exchange by mesoscale eddies in the northeast Pacific Ocean

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Outline of talk:

Sea level viewed from space:
  Eddies along the coast.
  Reference to flat surface.
  True images of sea surface height variability

Chlorophyll and sea level from space:
  Mesoscale eddies along the Pacific Coast
  Lack of eddies off southern Van Is.
  Impact of eddies in northern Gulf of Alaska
  Impact of eddies in Oregon and California
Sea level anomalies

Updated daily by Colorado Center for Astrodynamics Research, U. of Colorado

Plots sea level anomalies relative to a multi-year average sea level in satellite altimetry data, with high-pass temporal filters to remove annual cycle, and spatial filters to remove basin-scale signals.


Fails to represent true sea surface slope due to persistent currents.

TOPEX/Poseidon, Jason-1 and 2, (~10 d)  ERS-1 and 2, Envisat, (35 d)  GFO (17 d)

Image of 30 August 1998
Red = high sea level
Blue = low sea level
Solution:
Find the true sea-surface height relative to the height measured by altimetry.


• Determined average summer and winter baroclinic sea level height based on 100,000 historical temperature and salinity profiles in major archives.

• Fed into a finite element diagnostic model with ~100,000 nodes (tides, friction).

• Forced the model with average summer and winter winds.

• Determined average summer and winter sea level at each node. These sea levels are the absolute heights of sea level above the geoid. Then Interpolated through the year by fitting to a sine wave to produce monthly average (A).

• Computed heights of average monthly sea level measured by altimetry (AVISO data), and adjusted these to match (A).

• Result: Absolute height of sea level relative to a gravitationally flat surface.
Digital files of sea surface heights at 0.25 deg.lat. & long. intervals, provided by AVISO, based on all available altimeters, updated every 3 days, referenced to Foreman et al. surface.
Summer
Sea
Surface
Height
(80-cm drop)

Digital files of sea surface heights at \(\frac{1}{4} \, ^\circ\) lat. & long. intervals, provided by AVISO, based on all available altimeters, updated every 3 days, referenced to Foreman et al. surface.
North Pacific Current
Alaskan Stream
North Pacific Current
Alaska Current
California Current
Note the penetration of high sea level waters toward the Vancouver Island & Washington State coast, and absence of eddies there.
Note the maxima in standard deviation of September sea level heights in these regions.

Similar for other spring and summer months.
Plot ocean chlorophyll onto sea surface height contours.

Chlorophyll composite for June 2006 from SeaWiFS + MODIS, via NASA.

Altimeter data from AVISO for mid-June 2006.
Plot ocean chlorophyll onto sea surface height contours.

Chlorophyll composite for Sept 2006 from SeaWiFS + MODIS.

Altimeter data from AVISO for mid-Sept. 2006.
Plot ocean chlorophyll onto sea surface height contours.

Chlorophyll composite for June 2007 from SeaWiFS + MODIS.

Altimeter data from AVISO for mid-June 2007.
Plot ocean chlorophyll onto sea surface height contours.

Chlorophyll composite for Sept 2007 from SeaWiFS + MODIS.

Altimeter data from AVISO for mid-Sept. 2007.
The image at rights reveals an intense bloom of coccolithophores in June 2006 along the continental shelf break.

Note that few portions of this bloom extend far into deep-sea waters, despite the strong upwelling winds from the northwest.

This bloom defines the most productive waters of the Pacific Coast of USA and Canada.
Large-scale trophic linkage between the annual mean chl-a concentration (NWLR-Off) and the long-term annual yield of resident fish for each of the 11 NPAFC regions from San Diego to the Aleutian Islands.

Solid circles denote upwelling regimes; open circles, downwelling regimes.

Waters in anticyclonic mesoscale eddies will rise as the eddies decay. These waters will also rise to seek waters of the same density as they propagate westward.
WOCE Section P17NE
Musgrave 1993
Colour denotes height.
Numbers denote st’n. #

Left: Nitrate
Right: Sigma-Theta
Nitrate concentration
September 2003

Altimeter + Chlorophyll
(black contours) (Colours)
This image suggests that the northeast limit of HNLC waters is determined by trajectories of large Haida and Sitka Eddies. These eddies are rich in iron and silicate, as well as nitrate.
Dashed lines surround cyclonic eddies with relatively low sea level. These eddies hold denser water (+upwelled nutrients) than in the deep-sea regions into which they are propagating, and water in the eddies will eventually sink.
WOCE Section P17CA
Musgrave 1993
Colour denotes Height. Numbers denote st’n. #
Percent Oxygen saturation on the 26.5 sigma-theta surface.
Conclusions:

- Coastally generated mesoscale eddies impact the productivity of the coastal regions where they form, and the deep-sea regions into which they propagate.

- Anticyclonic eddies propagating into major anticyclonic gyres likely have a greater impact on deep sea life.

- Cyclonic eddies propagating into major anticyclonic gyres likely sequester more carbon.