Global Coastal Upwelling/Downwelling Estimates from SeaWinds

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Objectives:

Develop estimates of coastal upwelling/downwelling globally from satellite scatterometer winds.

Use this global product to describe spatio-temporal variability of upwelling-favorable winds at multiple scales.
Variability in coastal upwelling has important implications for:

- Nutrient supply to large and small marine ecosystems
- Carbon sequestration
- Regional climate
- Cross-shelf transport of biota
- Fate of coastal pollutants
Global maps of daily cross-shelf Ekman transport are computed from the 10-year record of SeaWinds scatterometer observations.

This provides a tool for exploring the spatio-temporal variability of potential upwelling zones over all coastal regions, which is particularly important in regions with sparse in situ observations.
Methodology

- QuikSCAT/SeaWinds (25 km L2B product) swath 10m wind vectors \((u_w, v_w)\) are converted to stresses as

\[
\left(\tau_x, \tau_y\right) = \rho_a \, C_d \, \|u_w\| (u_w, v_w)
\]

\(C_d\) is calculating using the Large and Pond (1982) quadratic formulation.

- \((S_x, S_y)\) are bin-averaged over 50 km overlapping bins (centered every 0.1°) for each day

- Transport in the ocean surface Ekman layer is calculated as:

\[
(S_x, S_y) = \frac{1}{\rho_0 \, f} \left(\tau_y, -\tau_x\right)
\]

The air density \(\rho_a\) and the ocean density \(\rho_0\) are derived from ICOADS monthly climatology data.
Methodology

• The Ekman transport vector is projected onto the (positive offshore) bathymetric gradient.

• Bathymetric gradient computed from the ETOP02 global bathymetry data set for all locations (subsampled to 0.1° resolution) from 15km from the coast out to 70 km or the 200m isobath, whichever is furthest.

• Gradient averaged over 60 km length scales (30 km near the coast).
Very flat regions (bathymetric slope < .001) are masked.
Annual Cycle

Jan-Mar mean offshore Ekman transport ($m^2/s$)

Winter upwelling
Annual Cycle

Mar-May mean offshore Ekman transport (m²/s)
Annual Cycle

Apr-Jun mean offshore Ekman transport (m²/s)
Annual Cycle

Jun-Aug mean offshore Ekman transport ($m^2/s$)

Summer upwelling
Annual Cycle

Sep-Nov mean offshore Ekman transport ($m^2/s$)

Annually persistent easterly trades
Annual Cycle

Nov-Jan mean offshore Ekman transport (m²/s)
Identification of Coastal Zones with Upwelling-Favorable Winds
Austral summer upwelling

Austral winter downwelling
Western Bay of Bengal
Downwelling during
NE Monsoon

Western Bay of Bengal
Upwelling during
SW Monsoon
Summertime upwelling
Under SW Monsoon winds
South Madagascar Upwelling (DiMarco et al., GRL 2000)
Wintertime Sea of Okhotsk Upwelling
Western US coast summer upwelling
Temporal Variability
Interannual Variability: Area of upwelling-favorable winds
Interannual Variability: Area of upwelling-favorable winds

Jun-Aug mean offshore Ekman transport ($m^2/s$)

Arctic: Jul mean upwelling area (percent of total area)
Upwelling Indices

Offshore Ekman transport (m^2/s): 45.0N, 124.9W

7-day average

PFEG Upwelling Index – 7-day average
Conclusions and Next Steps

• Daily estimates of cross-shelf Ekman transport (upwelling/downwelling) have been computed from the ~10-year QuikSCAT/SeaWinds data set

• This product allows inspection of multi-scale spatio-temporal resolution of upwelling/downwelling-favorable winds

• The product has applications to marine ecosystem studies
  • Daily variability
  • Seasonal variability
  • Interannual variability

• Next Steps:
  • A web-based front-end will allow quick generation of map and time series derived products (e.g. upwelling indices).
  • Inclusion of data from multiple sensors
  • Extension to near-real-time