Surface waves as major controls on particulate backscattering distributions in the California Coast

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Summary of Research

Satellite observations of chlorophyll (CHL; proxy for phytoplankton presence / abundance) and optical backscattering coefficients (BBP; proxy for suspended particles) in the California Current System are often described in terms of CHL responses to regional upwelling and BBP responses to episodic inputs from storm runoff. Here I focus on the variability of BBP, and show that surface waves have a larger role in controlling BBP than previously considered. More than 13 years of 2-km resolution SeaWiFS, MODIS and MERIS satellite imagery spectrally-merged with the Garver-Siegel-Maritorena bio-optical model were used to assess the relative importance of various physical forcings in controlling changes in particle load throughout the domain. The space-time distributions of BBP and CHL estimates (Figure 1) were analyzed and compared with several environmental variables. The spatial relationships between CHL and BBP allowed depicting potential controls on BBP variability (Figure 2). Biomass processes likely control BBP in the deeper regions of the Santa Barbara Channel and along the California Current; photoacclimation processes likely control BBP changes in offshore areas; and the very low correlation coefficients between CHL and BBP within a thin band along the coast indicate a strong decoupling between processes controlling BBP and CHL variability. Figure 3 shows how mean BBP values along the coast compare with the temporal variation in discharge and wave heights, indicating that this coastal band is in fact modulated by variations in surface wave heights, which stir the water column and lead to the re-suspension of materials for long periods of time. Together, waves and discharge explain 57% of the variability in BBP over time. However, discharge runoff appears to be important only during the stronger El Niño years of 1997/1998 and 2005. The relationship with waves holds throughout all seasons and often extends offshore until about 100m in depth (Figure 4). The implication of surface waves determining BBP variability beyond the surf zone has large consequences for the life cycle of many marine organisms, as well as for the interpretation of remote sensing signals near the coast.
Figure 1. Mean a) CHL and b) BBP for the 1997-2010 period analyzed here. Mean temporal distributions of CHL and BBP are shown in c) and d). The highest CHL estimates are found in the Santa Barbara Channel, North of Point Conception and along the California Current, as expected from upwelling patterns in the region. A background BBP mimicking CHL distributions is clearly seen in offshore areas, while near the coast the highest values denote the importance of re-suspension, mixing events and advection from riverine plumes. Seasonal patterns are clear for both CHL and BBP, and larger scale trends and multi-year variability are associated with El Niño and PDO extremes.

Figure 2. Correlation coefficients between CHL and BBP for every pixel of the domain, for mean estimates within the 1997-2010 period. Low correlations denote decoupling between processes controlling BBP and variability. High correlations indicate strong coupling, likely related to changes in phytoplankton biomass linked to upwelling-favorable conditions of the domain.
**Figure 3.** a) Mean BBP at a nearshore band along the coast (black) and significant wave height estimates from NDBC buoy 46054 (red); b) Discharge from the Ventura River; c) modeled nearshore BBP using significant wave heights and discharge as inputs in a multiple linear regression model. Alone, waves explain 27% of the variability in BBP. Discharge explains 42%. Together, they explain 57% of the variability. Note that wave heights modulate lower frequency variability of BBP, and are able to explain large increases in BBP during times with negligible discharge (e.g. 2002, 2003, 2007, 2010).

**Figure 4.** Correlation coefficients between significant wave height (from NDBC buoy 46054 in the western Santa Barbara Channel) and optical backscattering coefficients from merged satellite observations. The thin band with elevated correlation coefficients extends to about the 100m isobath, and increases with proximity from shore. Local differences are likely due to the orientation of the coastline with respect to wave propagation and changes in bathymetric slopes.