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Topic: Coastal Environments

Satellite Observations of the Southern California Bight: Circulation, Seeps, and Run-Off

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This study uses ERS-1/2 Synthetic Aperture Radar (SAR) and RADARSAT imagery, complemented by Advanced Very High Resolution Radiometer (AVHRR) and SeaWiFS satellite imagery plus in situ measurements (currents, wind) to describe several features of the Southern California Bight, particularly the Santa Barbara Channel and Santa Monica Bay/Basin regions. This region is a uniquely complex coastal environment affected by wind-driven circulation, offshore islands and coastal promontories, with strong relationship to the offshore California Current. In particular we examine the extensive appearance of small (from 1-50 km in diameter) coastal ocean eddies. Eddies are small (mostly < 20 km diameter), predominantly cyclonic, and possibly seasonal in their distribution. These eddies are smaller in size and are more abundant than previously reported. In addition, we examine the characteristics of natural seeps and rain run-off from the urban Los Angeles Basin. These observations are important in their implications for plankton patchiness, nutrient availability, productivity, larval transport and recruitment, and the impact and dispersal of pollutants.

Satellite Observations of the Southern California Bight: Surface Circulation, Oil Seepage, and Storm Water Runoff

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ABSTRACT: This synergistic, interdisciplinary study uses ERS-1 and ERS-2 Synthetic Aperture Radar (SAR) imagery, complemented by near-coincident satellite (SST: AVHRR; Ocean Color: SeaWiFS) and field (e.g. ship, mooring and drifter) data where available to describe small-scale coastal ocean phenomena in the Southern California Bight (SCB), particularly the Santa Barbara Channel and Santa Monica Bay/Basin regions. Though part of the California Current System, SCB circulation patterns are more complex than elsewhere off the U.S. Pacific coast, due in part to temporally variable winds, eight nearshore islands, coastal promontories, narrow channels, and submarine canyons, basins and ridges. We describe here the extensive appearance of small (from 1-50 km in diameter) coastal ocean eddies in the SCB. Eddies are small (mostly < 20 km diameter), predominantly cyclonic, and possibly seasonal in their distribution. They appear to result from a number of mechanisms, including topographic forcing and current instabilities, and are smaller in size and more abundant than previously reported. They engender significant phytoplankton patchiness in the SCB, and likely have important ramifications for primary productivity, larval transport and recruitment, and the dispersal of pollutants. These pollutants result from both natural and anthropogenic sources. We examine the distribution and persistence of natural hydrocarbon seepage in the Santa Barbara Channel and Santa Monica Bay, likewise the fate of nutrient and pollutant laden storm water runoff from the urban Los Angeles Basin, and subsequent algal bloom events.

INTRODUCTION

- Southern California Bight (SCB) circulation patterns are more complex than elsewhere off the Pacific coast of the United States (Figure 1).
- This complexity is introduced to the large-scale California Current System (CCS) flow regime by temporally variable winds and by eight nearshore islands, coastal promontories, narrow channels, submarine canyons, basins and ridges.
- Previous studies have noted the occurrence of small-scale (< 50 km diameter) eddies, but these remain under-sampled and are generally poorly described.
- These eddies have important ramifications for nutrient flux, plankton patchiness, productivity, larval transport and recruitment, and dispersal of pollutants in the SCB.
- Of related interest, periodic nutrient/pollutant pulses into the SCB are introduced by natural oil seeps and anthropogenic discharge via storm water plumes, and likewise require further characterization.
- Therefore, the goals of this study are to:
  1) describe, qualitatively and quantitatively, the geophysical characteristics of SCB small-scale eddies;
  2) assess their biological impact, particularly their role in fostering phytoplankton patchiness; and,
  3) examine related coastal features of interest, including the temporal and spatial distribution of oil seepage and storm water plumes, and their potential biological effects, e.g. algal blooms.

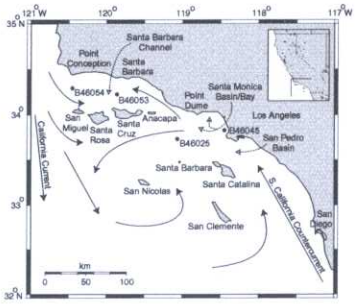

Figure 1. The Southern California Bight (SCB): schematic mean circulation pattern and NDBC buoy locations (B#); after Hickey, B. M., 1992, Prog. Ocean. 30: 37-115.

METHODS

- 134 ERS-1/ERS-2 SAR images of the SCB from 1992-1998 were visually analysed for evidence of small-scale eddies and other coastal features (seepage, plumes, etc.) according to criteria established by SAR feature atlases and published studies.
- Once detected, eddies and other coastal features were measured, mapped, and complemented, where available, by near-coincident satellite (AVHRR) and field (NDBC buoy, Scripps mooring and drifter) data that were used to interpret and/or validate the SAR findings.
- SeaWiFS HRPT data (1997-1999) from the UCSB and MBARI receiving stations were processed and similarly analyzed for evidence of small-scale eddies and other features in the SCB.

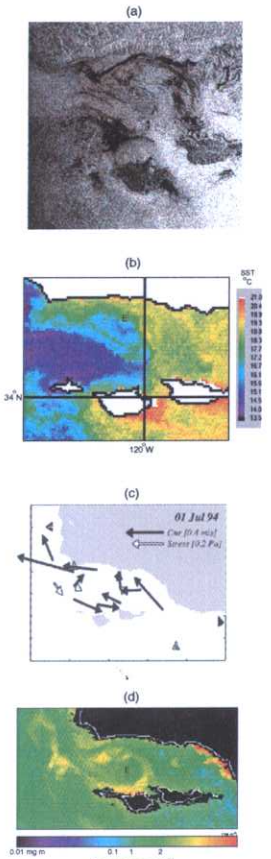

Figure 2. Santa Barbara Channel. (a) ERS-1 SAR, 7/1/94, 'E' denotes ~ 40 km diameter cyclonic eddy; © ESA. (b) Near-coincident (+6 hrs) AVHRR SST image showing above eddy. (c) Daily averaged 5-m currents and wind stress from 7/1/94 indicating cyclonic flow associated with above small-scale eddy; courtesy C. Winant, Scripps. (d) SeaWiFS chlorophyll-a image from 10/26/97 showing this recurring Santa Barbara Channel Eddy.

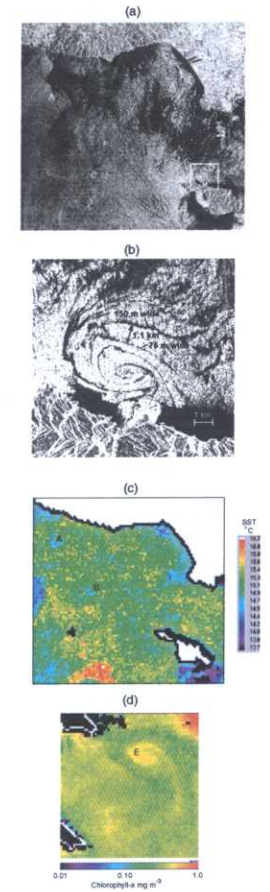

Figure 3. Santa Monica Bay/Basin region. (a) ERS-1 SAR, 12/19/94, letters denote several of the small-scale eddies present; © ESA. (b) Blow-up of eddy 'D' from box in above SAR image. (c) Near-coincident (-15 hrs) AVHRR SST image, note only the largest SAR eddies, e.g. 'A', and 'B', are readily identifiable. (d) SeaWiFS image off SE end of Catalina from 4/9/98, eddy ~12 km in diameter.

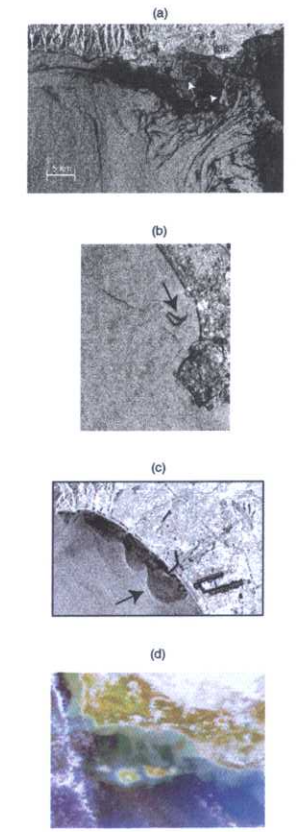

Figure 4. (a) ERS-1 SAR, 11/9/94, showing oil seepage off the Santa Barbara (SB) coast; also note presence of onshore jet seemingly terminating in two small-scale eddies; © ESA. (b) ERS-1SAR, 8/23/95, showing oil seepage off Redondo Beach in Santa Monica Bay, near Buoy 46045 (see Figure 1); © ESA. (c) ERS-1 SAR, 2/14/95, showing large storm water plume in Santa Monica Bay; © ESA. (d) SeaWiFS 'true' color image of Santa Barbara Channel from 2/9/98, browns indicate storm water sediment plumes, greens phytoplankton blooms; image courtesy J. Warrick, UCSB.

RESULTS

- 107 small-scale eddies were detected in the ERS-1/2 SAR images of the SCB (e.g. Figures 2a and 3a); these ranged in size from ~ 1 to 50 km (Figure 5).
- These eddies were predominantly cyclonic (93%), and were more common (~2x) during the fall and winter months than in spring and summer (Figure 5), though this might be an artifact given that stronger winds are characteristic of the latter period.
- The eddies were marginally to moderately persistent (days to weeks), and often recurrent in time and/or space, and they appeared to result from a number of mechanisms, including topographic forcing and current instabilities.
- Phytoplankton patches associated with eddies observed in SCB SeaWiFS images (e.g. Figures 2d and 3d) were ~ 2 to 15 km wide and upwards of 50 km long, and typically characterized by chlorophyll-a concentrations significantly higher than those found in surrounding waters.
- These enhancements generally appeared to result from the lateral entrainment of highly productive offshore and nearshore waters, though other mechanisms are likely important contributors.
- Thermal gradients upwards of 3°C were observed relative to adjacent waters, leading to strong frontal zones within many of these eddies (e.g. Figure 2b).
- Oil seepage was extremely common in the Santa Barbara Channel and to a lesser extent in Santa Monica Bay (Figure 4a-b); large storm water plumes and algal blooms were often observed following periods of heavy rain in the SCB (Figure 4c-d).

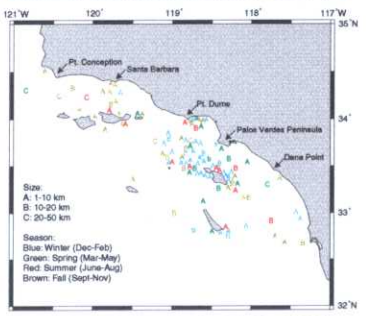

Figure 5. Distribution of small-scale eddies from ERS-1/2 SAR in the Southern California Bight. Upper-case letters indicate cyclonic eddies, lower-case anticyclonic eddies.

CONCLUSIONS

- These eddies are smaller in size and more abundant than previously reported, and they provide further evidence of the complex, near-surface circulation characteristic of the SCB.
- Small-scale coastal eddies appear to play an important role in the formation and maintenance of phytoplankton patchiness in the SCB, and they have important ramifications for higher trophic levels as well (e.g. larval transport and recruitment).
- Oil seepage and storm water plumes appear to be significant pollutant and nutrient contributors to SCB coastal waters, and thus have important biological ramifications (e.g. algal blooms et al.)
- The prevalence and potential impact of these features necessitates high-resolution, coordinated ship-satellite investigations, particularly at eddy convergences. This effort will be enhanced by future availability of hyperspectral ocean color imagery.