Sea Grant California

COASTAL OCEAN RESEARCH

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Ocean Fronts off California: A New Product from GOES Satellite Data

Laurence Breaker
Moss Landing Marine Laboratories

Background

Ocean fronts are narrow areas across which there are large horizontal gradients in water temperature, salinity, density and velocity. Off California, fronts are oceanographically important because they delineate the boundary between different water masses: the relatively warmer water from the California Current and the cooler water associated with upwelling.

Upwelling is the vertical movement of cool, nutrient-rich, deep water to the surface. It is driven by winds and is most intense between March and October. Swimmers and surfers who complain that the ocean is coldest in spring are experiencing first hand the phenomenon of spring upwelling.

In California, upwelling drives the ocean's primary productivity, bringing nutrients to the euphotic zone (the thin layer of the ocean surface in which sunlight is sufficient for photosynthesis). On the East Coast, in contrast, surface waters are replenished with nutrients by organic material in runoff and river flows rather than by upwelling.

Fronts are also convergence zones, congregating nutrients and free-floating organisms that form the base of the food chain. For this reason, fronts are often an important habitat area for many animals in the food chain, including marine mammals, fish and seabirds. Besides attracting animal life, fronts can also separate different fish habitats. Fishers know this, as seen by the fact that albacore tuna fishers usually stay offshore of fronts while salmon fishers—and salmon—stay inshore of them.

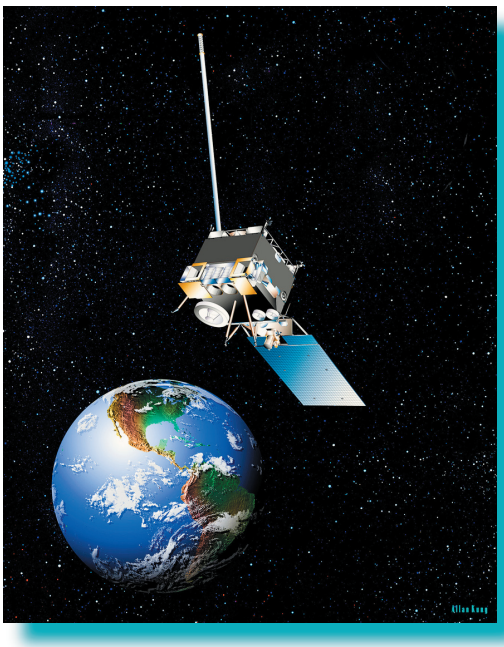
The location of fronts also has implications for California weather. For example, the thick, coastal marine layer that develops in spring and early summer—so-called "May gray" and "June gloom"—is directly related to the presence of cold, upwelled water along the coast. The ocean surface gets warmer farther offshore.

Project

Drs. William Broenkow and Laurence Breaker, both physical oceanographers at Moss Landing Marine Laboratories in Monterey, were funded to develop a method for mapping the location of coastal fronts off California using data collected by the Geostationary Operational Environmental Satellite, GOES-10. A geostationary satellite scans the same area of the globe on a nearly continuous basis. A polar-orbiting satellite, in contrast, orbits around Earth and has at most two chances at viewing an area each day.

In cloudy areas, such as Central California, polar-orbiting satellites obtain relatively few clear glimpses of the ocean surface while geostationary ones have the chance to obtain many. In the case of the GOES-10 satellite, the ocean surface in the Eastern Pacific is scanned 24 times daily by instruments that gather measurements of infrared radiation emitted from the Earth's surface on a 4-kilometer grid. Infrared radiation levels provide an estimate of ocean surface temperature when the ocean is not obscured by cloud cover.

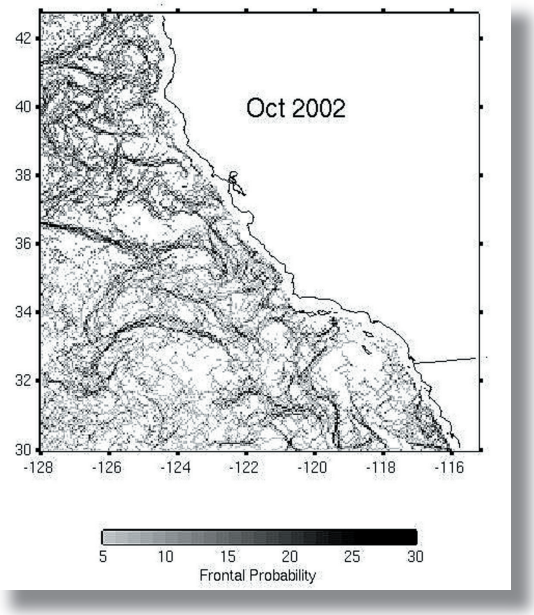
To construct maps of fronts, the core of the project, the scientists converted estimates of ocean temperature into estimates of temperature gradient—the change in ocean temperature over a certain distance.



The first Geostationary Operational Environmental Satellite was developed and launched by NASA. These satellites, now maintained by NOAA, orbit Earth approximately 22,000 miles above the equator at a speed that matches the Earth's rotation, staying above the same location. Equipped with "camera" and sensors, the satellites collect infrared images of the Earth's surface and measurements of temperature and cloud cover at various altitudes. The images are a mainstay of weather forecasting and frequently seen on TV and the Internet. With Sea Grant support, marine scientists are using satellite data to map the location of oceanic fronts off California. Image courtesy of NOAA Satellites and Information Service

The basis of the scientists' work is the assumption that the position of a front is accurately predicted by the strength of the temperature gradient. In particular, they assume that a front is present when the strength of a gradient exceeds a certain threshold. The number of times this threshold is exceeded during a month is then assumed to yield the prob-

ability of encountering a front at that location during that month. Contour maps of these probabilities show the expected locations of fronts off California. To check the validity of the method, the scientists compared their maps to hydrographic data collected off California during CalCOFI cruises. They found generally good agreement between in situ (shipboard) and satellite observations.



The dark areas above show the most likely positions of coastal fronts off California during October 2002. The fronts were mapped using satellite images of infrared radiation from which ocean surface temperature is calculated. Image courtesy Laurence Breaker, Moss Landing Marine Laboratories

Results

Monthly maps of fronts over the last few years show a number of interesting patterns:

- The area of greatest frontal activity occurs in Northern California, where upwelling is generally most intense and occurs in the fall.
- Fronts move farther offshore during the course of the upwelling season. In summer and early fall, the fronts are furthest from the shore. In winter, fronts are very close to shore.
- The locations of fronts appear to be influenced by bathymetric features close to the coast. This observation may make it easier to predict the locations of fronts in some areas.

Applications

Breaker said that knowing the position of fronts has applications for fisheries management. “Fishermen follow fronts because fish follow fronts,” Breaker said. “You’d like to know where fronts are most likely to form. Right now we don’t know that.”

The culmination of this Sea Grant research will be the ability to produce monthly maps that are high quality and easy to read, and to post these maps for public use and downloading on the Internet. At present, it takes some months to process the satellite data and create the maps.

Collaborations

NOAA’s National Environmental Satellite Data and Information Service provides satellite data for the project and in the future may maintain the Web site that the scientists are building to display their maps.

Laurence Breaker, a physical oceanographer at Moss Landing Marine Laboratories. Photo: Christina Johnson, California Sea Grant

The Monterey Bay Aquarium Research Institute provided CalCOFI data.

Publications

Breaker, L.C. 2003. Ocean Fronts off the California Coast: A New Product Based on Imagery from the GOES-10 Geostationary Satellite. *WAVE*: 10 (1): 6–7.

Presentations

Adams, J., and L. Breaker. Sanctuary “Hot Spots:” Satellite Observation of Ocean Fronts and their Composite Histories in and beyond the Monterey Bay National Marine Sanctuary. Monterey Bay National Marine Sanctuary Currents Symposium, 2003.

For more information:

Dr. Laurence Breaker
Moss Landing Marine Laboratories
Tel.: (831) 771-4498
Email: lbreaker@mlml.calstate.edu

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