Multi-frequency and interferometric SAR mapping of wind-driven mesoscale oceanic processes off Northern California and in the lee of the island of Hawaii

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Abstract.

The multi-frequency polarimetric and interferometric Airborne Synthetic Aperture Radar (AirSAR) aboard NASA's DC-8 aircraft was used in summer of 1989 and 1990 to study coastal upwelling and island upwelling mesoscale processes, off California and in the lee of Hawaii.

COASTAL UPWELLING

In summertime, the California Current is characterized by intense jets carrying cold water from nearshore upwelling towards offshore; they appear as cold filaments in satellite infrared images of sea surface temperature. These jets are delimited by sharp thermal and velocity fronts, which are often convergent, and are subject to small scale instabilities.

In previous experiments, clusters of surface drifters were deployed to measure the horizontal velocity gradient across these filaments. In the anticyclonic region, the flow is generally non-divergent with a shear of -0.3 f, but that at the cyclonic front, the flow is discontinuous at the 1 km resolution of the clusters, with a shear larger than 4.5 f, associated with a cross-frontal surface convergence larger than 0.7 f visible as a ~20 m wide accumulation of debris of seaweeds, and sometime variations of surface roughness.

A complete SAR survey of the filament rooted near Point Arena (northern California) was acquired on 8 September 1989, using infrared images from the NOAA satellites to guide the aircraft to features of interest. The radar was illuminating the ocean at three microwave wavelengths: C-band (6 cm, Fig. 1), L-band (24 cm, Fig. 2) and P-band (68 cm, Fig. 3), and was operated in polarimetric mode, including horizontal, vertical and cross-polarization at each wavelength.

At all frequencies, the signatures of the thermal fronts appeared as bright delineations in the radar images, presumably made visible where waves swell were undergoing refraction by the current shear, resulting in increased amplitude. Several dark delineations, often parallel to the front, were also observed, possibly corresponding to internal waves radiating away from the front, made visible by biological films concentrated along convergence zones, thus reducing the amplitude of bragg-scattering waves.

ISLAND UPWELLING

The Hawaiian Islands present obstacles to the northeasterly trade winds, creating calm regions in the lee. Sharp horizontal shear lines usually separate the 10-15 m/s trades from the calm regions. These shear lines extend several island

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radii downwind.

The variations of wind stress along the cyclonic shear line to the northwest of the Island of Hawaii, and the response of the ocean, were studied in August 1990 including along-track interferometry in the L-band. Concurrent data were obtained from ship using a towed undulating CTD, an Acoustic Doppler Current Profiler and satellite-tracked drifting buoys, and from the NCAR Electra meteorological aircraft conducting boundary layer flights. Infrared images from the NOAA satellites, and 10-m resolution sun glint images from the SPOT satellite were also available.

Backscatter intensities in the L- and C- band were strongly modulated by the variations of surface wind stress, and showed that the cyclonic shear line was just a few tens of meters wide, much narrower than the ~2 km height of the planetary boundary layer. There was a strong phase shear between the two along-track L-band images (spaced approximately 50 msec in time), suggesting downwind surface flow in the trade wind regime, and a slight flow towards shore in the calm lee. The correlation image showed high correlation in the lee, and much smaller correlation in the trade wind regime, where white capping was frequent.

Two effects of these variations of wind stress on the upper ocean were observed. One-dimensionally, the mixed-layer depth was modulated by the wind stress: outside the calm region, a deep mixed layer was observed, whereas in the calm region, the mechanical energy provided by the wind was not sufficient to erode the 2-4 m warm buoyant layer resulting from solar heating. Intense diurnal warming was observed at the surface and a thermal front coincided with the shear line observed in the SAR images. Two-dimensionally, the curl of the wind stress along the cyclonic shear line induced upward Ekman pumping, spinning up a cyclonic eddy.

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Fig. 1. C-band image of the upwelling front

Fig. 2. L-band image of the upwelling front

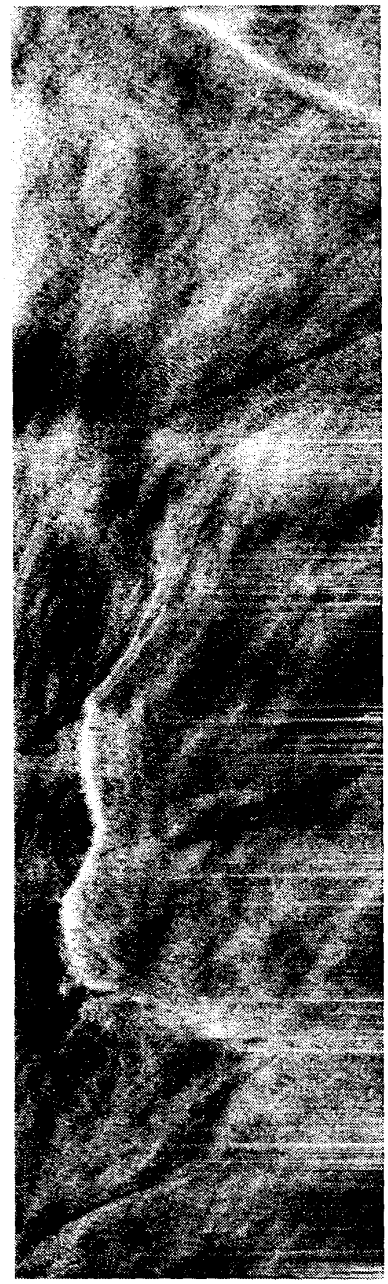

Fig. 3. P-band image of the upwelling front