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# SURFACE CURRENT MEASUREMENTS AT OCEAN FRONTS

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## ABSTRACT

Using a unique slope-following surface current meter , we have obtained measurements of near surface currents during the NORCSEX experiment in March, 1988. These instruments were tethered to subsurface flotation on traditional taut wire moorings at three locations near ocean frontal areas. Several objectives of the experiment included supporting the deeper moored and acoustic doppler measurements with surface information, providing a bottom boundary condition for wind stress analysis, comparison with a CODAR and testing a newly developed ARGOS transmission capability. In this discussion, we provide a general overview of the measurement results.

KEY WORDS: SURFACE CURRENTS, SAR, FRONTS, WIND STRESS, NORCSEX

## 1. INTRODUCTION

The Synthetic Aperture Radar (SAR) has demonstrated a remarkable potential to distinguish surface features associated with ocean fronts. Our fundamental understanding of this complicated process is that features observed in SAR imagery result from wave-current interactions, which block or focus short gravity waves, and from Bragg scattering on the redistributed short wave patterns. This simplistic picture can be complicated by changes in the short gravity wave field related to wind stress changes across a front, a result of differences in boundary layer stability on each side of the thermal gradient associated with some fronts. Further complexities involve the flight direction of the SAR sensor with respect to the surface flow pattern and the bivariate slope distributions of wave facets.

Fundamental to the physics which combines hydrology and wind stress with radar backscatter, and fundamental to our ability to model these processes, is an understanding of the flow patterns at the sea surface where strong wave/current/wind interactions occur. However, because the ocean surface is inherently noisy, it has been extremely difficult to make measurements of the ambient flow associated with open ocean fronts. Although Lagrangian drifters have supplied some information in the past, problems of deployment on scales associated with fronts as well as difficulties in separation of space and time, have clouded interpretation of the results. Acoustic Doppler Current Profilers (ADCP) are obtaining interesting observations of vertical current structure near fronts, but are not reliable in the upper 10 m of the water column due to ambiguous reflections from waves. Standard taut-wire surface moorings have provided useful information, but are difficult to maintain in the strong flows associated with fronts and may not be reliable in anything but very benign conditions.

In order to overcome some of the problems of measuring ambient flow at the sea surface, we have developed a slope-following surface current meter of a unique design which has been tested under various condition over the past several years (Johnson, 1987). During the Norwegian Continental Shelf Experiment (NORCSEX), these Rapid Boundary Current Meters (RBCM) were deployed near ocean fronts. Our objectives were:

* to support deeper current measurements from ADCP and Aanderaa current meters with surface information,
* to provide a bottom boundary condition for wind stress analysis,
* to compare with surface flow measurements from Coastal Ocean Doppler Aperature Radar (CODAR),
* to test a new ARGOS transmission capability.

## 2. RAPID BOUNDARY CURRENT METER

In Fig. 1, the RBCM is shown in its moored configuration. The electronics are contained within a hull which floats at the sea surface and streams with the current. In order to avoid direct wind influence on the instrument, only 2-3 cm are exposed above the surface. Orientation of the hull in the direction of ambient flow is obtained with a gymballed digital compass, and speed of the flow is measured with a near-cosine response propeller (Weller and Davis, 1980) suspended at 50 cm below the surface. An ARGOS PTT and a helical antenna allow data transfer via satellite. The instrument is moored with lightweight polypropelene line and uses small fishing floats at the surface for added bouyancy. The effect is a light, easily deployable, low stress mooring configuration. Microprocessor based electronics allows vector processing and, together with simple design, have significantly reduced the cost of the instrument and simplified maintenance.

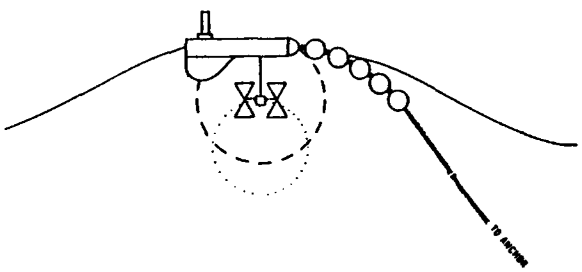

Figure 1: RBCM in its moored configuration.

The design philosophy of the RBCM has centered on a low stress, flexible mooring which permits the hull to follow the surface streamline and the propeller to follow orbital particle motions of gravity waves. In Fig. 1, wave particle orbits are drawn at the surface and at the depth of the sensor. These orbit radii decrease exponentially wit depth. If the propeller followed the particle orbit at its own depth, it would tend to eliminate wave influence and to pick up Stoke's drift (Collar, et al., 1983). Since the propeller is constrained to follow the surface orbit, it is in error by a small amount proportional to the difference in siz of the two orbits. However, it is clear fro this simplified example, that this arrangement is a considerable improvement on a fixed level current meter in the presence of waves, or on a surface following instrument with the sensor at greater depth, or orthogonal sensors spred between two depths. The chosen depth of 50 cm represent a compromise between placing the propeller a near the surface as possible and avoiding hull induced distortion of the flow.

## 3. EXPERIMENT

During March, 1988, RBCM instruments were attached to the main subsurface buoys o taut-wire moorings at three locations (Fig. 2) in the NORCSEX area. Aanderaa current meters were placed at several levels on each subsurface mooring, with the most shallow instruments at 25 m depth. Wavescan buoys, recording wind and wave parameters, were als moored in the vicinity of moorings CM1 and CM2. Figure 2 shows the bathymetry in the experimental area. It should be noted that mooring CMT2 was located at the shelf break in 400 m water depth, and moorings CM1 and CM2 were located along a trough, exceeding 300 m depth, which cut across the shelf and extended behind the Haltenbanken rise.

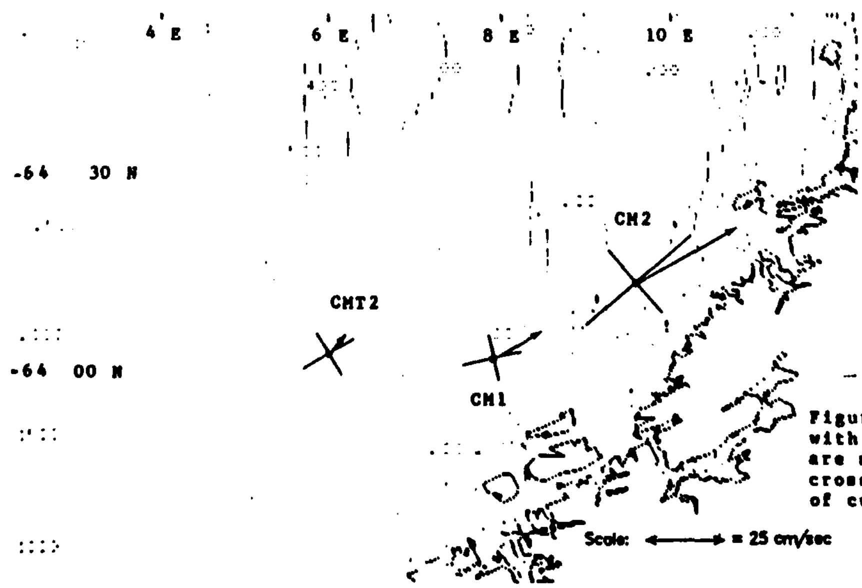


Figure 2: NORCSEX bathymetry with mooring locations. Arrow are mean current vectors; crosses are major and minor ax of current variations.

Figure 4 shows an AVHRR image for 16 March, 1988 covering the experimental area. The image has been composited from two passes, both from NOAA-9 on the 16th. Figure 5 shows an AVHRR image for 25 March, 1988 from a NOAA-10 pass. Comparing the AVHRR images with bathymetry in Fig. 2 (also lightly outlined in Fig 4), it is clear that bathymetry played a major role in the flow regime and the separation of water masses. The Norwegian Atlantic Water, which is the warmest water in the image (darkest color), can be seen following the shelf break adjacent to CMT2. The coolest water (light color) is associated with the Norwegian Coastal Current and is found adjacent to the coastline. One of the most striking features of the two images is the curvature of the thermal boundary (front) from the shelf break, along the trough adjacent to CM1 and CM2, and passing behind Haltenbanken.

Vector summations of 4 hourly averages are shown in fig. 3 for the three moorings. The large gap in mooring CMT2 was caused by entanglement of the propeller. This was noted on the ARGOS transmission and corrected when ship scheduling permitted. Large subtidal variations are seen in all records. The highest surface flow speeds, averaged over a tidal period, occurred at CM2 on 20 March, with an amplitude exceeding 81 cm/s. Aanderaa records at the 25 m depth at this location (courtesy, J.Johanessen) show a speed of 60 cm/s.

Mean velocities at each of the moorings are shown in fig. 2. In addition, major and minor axis of the subtidal flow variations are displayed with the major axis aligned in the direction of dominant variability. The mean flow vectors are all pointed toward northeast, with a near doubling of amplitude at each mooring closer to the coast. Subtidal flow variations at the shelf break are nearly omnidirectional, as seen by the fatter ellipse formed by the principal axis. As the subtidal flow becomes stronger near the coast, it is clear that the ellipses are oriented more nearly with topography.

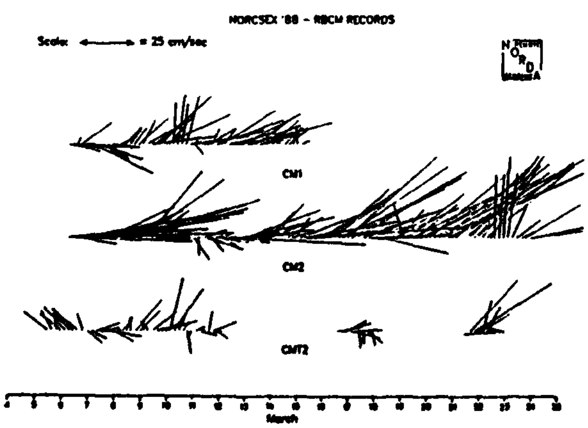


Figure 3: Stick plot of vector surface currents measured during NORCSEX. Locations given in Fig. 2.

## 4. SUMMARY

Three moorings of a unique slope-following surface current meter obtained a total of 36 days of current records during the NORCSEX project of March, 1988. AVHRR imagery showed that the moorings were all placed quite near the thermal boundary between North Atlantic Water and Norwegian Coastal Water. Current speeds at the surface were nearly 30% greater than speeds at the depth of 25 m. Current speeds increased dramatically near the coast and subtidal variations were aligned closely with topography. Near the shelf break, subtidal variations were suprisingly uncoupled from topography.

The easy deployment of the RBCM suggested that we should attempt to "capture" a front by chasing after the aircraft SAR image feature locations. However, deployment of a non-ARGOS transmitting instrument in this mode was unsuccessful as ship scheduling and weather combined to prevent successful retrieval. Future uses of this instrument in frontal locations should probably include more effort in this area.

Finally, the ARGOS transmission capability functioned well and, together with the relatively low instrument cost, opens the possibility of deployment of "expendable" moored current meters in the future.

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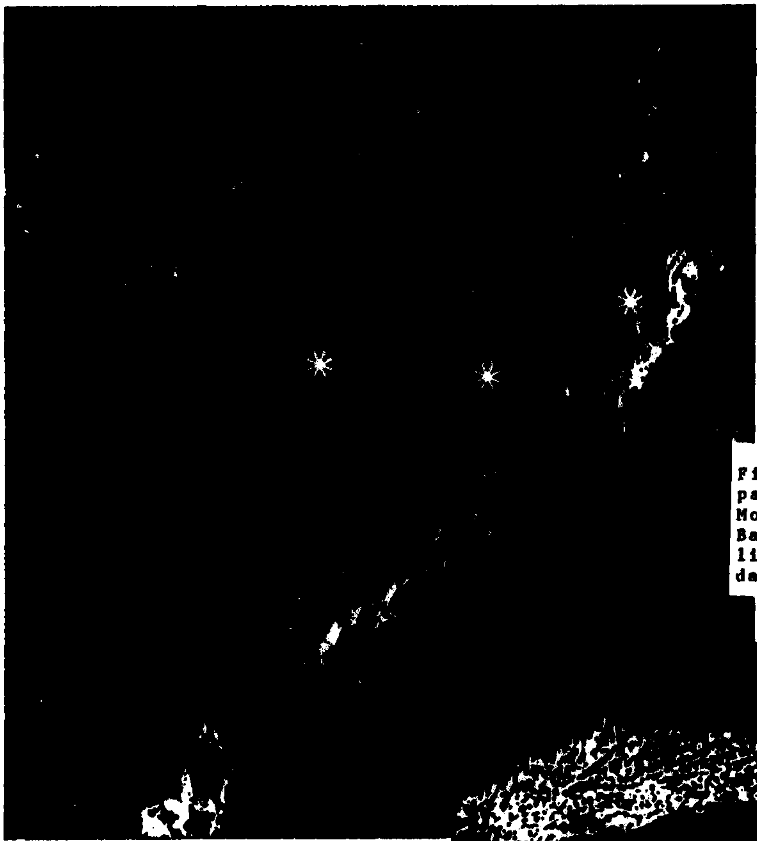

Figure 4: AVHRR composite from two passes on NOAA-9 on 16 March, 1989. Mooring locations given by asterisks. Bathymetry is overlain with dashed lines. Warm water is represented in dark tones; cool water in light.

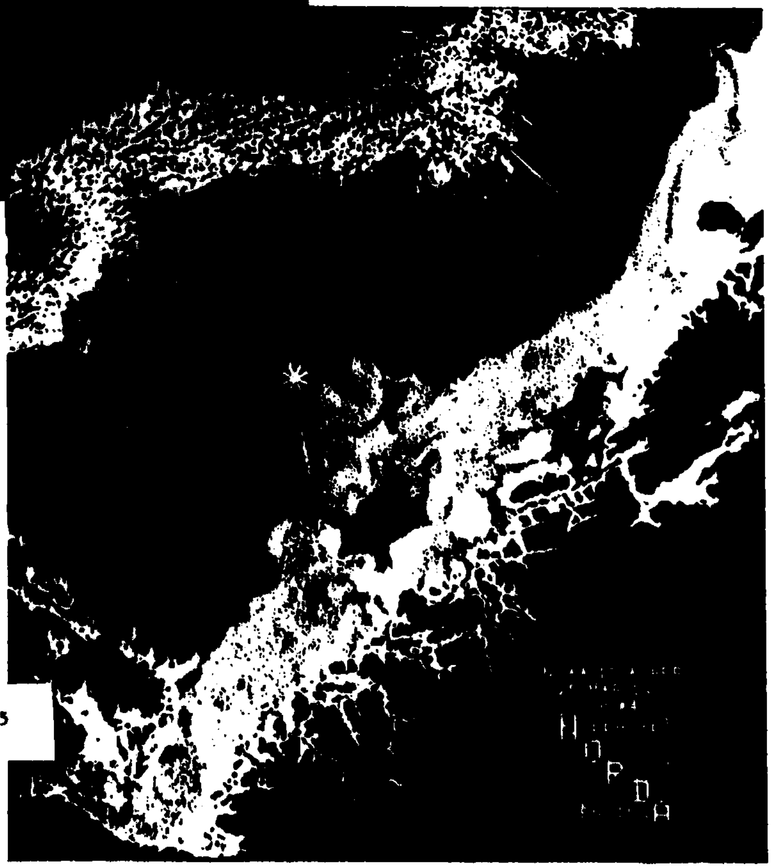

Figure 5: AVHRR from NOAA-10 on 25 March, 1989.