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The Norwegian Continental Shelf Experiment Prelaunch ERS 1 Investigation

JOHNNY A. JOHANNESSEN

Nansen Environmental and Remote Sensing Center, Bergen, Norway

INTRODUCTION

The Norwegian Continental Shelf Experiment (NORCSEX '88), a pre-launch ERS 1 field investigation, was carried out during a 25-day period in March 1988 on the continental shelf off the coast of Norway centered at 64°N with participation from Canada, France, Norway, the United States, and the Federal Republic of Germany. The overall goal was aimed at investigation of the capability of the first European Space Agency (ESA) remote sensing satellite (ERS 1) type active microwave sensors to measure marine variables such as near-surface wind, waves and ocean surface current and their interaction in weather conditions ranging from moderate to extreme. The capability of the ERS-1-type active microwave instruments to sense these variables was investigated by combined use of the Canadian CV-580 C band synthetic aperture radar (SAR), the U.S. Geosat radar altimeter, and a ship-mounted scatterometer. Complementary in situ measurements of characteristic quantities in the lower atmosphere and upper ocean were simultaneously collected from research vessels, moorings, and drifting buoys.

The winter meteorological and oceanographic conditions during the field campaign were characterized by the passage of several storms with gust winds up to 25 m/s accompanied by significant wave height (SWH) of up to 8 m, frequent occurrence of sudden wind shifts of 5–10 m/s with transition zones of less than 1 km, predominantly unstable stratification in the atmospheric boundary layer, and a well-defined oceanic front of 3–4°C between the northward flowing Norwegian Coastal Current and the Norwegian North Atlantic Current.

The primary objectives of NORCSEX '88 include studies of (1) SAR imaging of surface current features, (2) SAR imaging of ocean surface gravity waves, (3) combined airborne SAR and ship-mounted scatterometer measurements of near-surface wind field; (4) radar altimeter measurements of sea surface topography, SWH and wind speed, (5) integrated use of SAR and radar altimeter for SWH measurements, and (6) comparison and validation of numerical ocean circulation model results to remote sensing and in situ observations. An overview of the experiment including preliminary highlights are reported by the *NORCSEX Group* [1989]. This issue includes a collection of six scientific papers presenting specific results from NORCSEX '88. The topics of these papers are listed in Table 1, and the major findings are categorized in the following sections.

OCEAN FRONTS AND RAPID WIND SHIFTS IMAGED BY SAR

A substantial collection of SAR images exist dating back to Seasat in 1978 exhibiting surface expressions from a variety of oceanic phenomena [*Beal et al.*, 1981]. Quantitative understanding of some of the dominating processes that induce the image intensity variations has also recently developed, in particular associated with manifestation of internal waves [*Hughes and Gasparovic*, 1988]. Moreover *Johannessen et al.* [this issue] show that SAR expressions of frontal structures obtained during NORCSEX '88 can be distinguished and classified according to surface shear current and rapid wind shifts. These observations are validated with in situ data documenting that backscatter modulation induced by wave-current interaction is expressed as a narrow, peaklike signature. In contrast, the SAR images manifest the surface roughness change due to rapid wind shifts as a steplike transition from low to high backscatter intensities. The magnitude of the current shear cannot be directly quantified from the peaklike Bragg backscatter intensity variation. This has stimulated further simulation studies (D. R. Lyzenga, Interaction of short surface waves with ocean fronts, submitted to Journal of Geophysical Research, 1990), but further dedicated field campaigns are necessary to accurately quantify the horizontal width as well as strength of the current shear or convergence zones. On the other hand, *Johannessen et al.* [this issue] propose a method to quantify the wind change across the steplike backscatter intensity variation that is promising for example in relation to detection of polar lows.

OCEAN GRAVITY WAVES AND AZIMUTH SMEARING IN SAR SPECTRA

The wave studies during NORCSEX '88 were based on multisided airborne SAR flights, at different altitudes, centered over the four wave directional buoys in order to determine the degradation of the azimuth resolution. It is shown that the along-track resolution loss in SAR images of ocean waves can be modeled as a linear low-pass-filtering process even in the nonlinear region of imaging [*Johnsen et al.*, this issue]. In order to optimize the application of ERS 1 SAR for ocean wave imaging, it is necessary to estimate and correct for this magnitude of smearing. For airborne SAR-derived wave spectra it is also necessary to correct for scanning distortion when swell is present [*Rufenach et al.*, this issue (*a*)]. Furthermore *Rufenach et al.* [this issue (*b*)] developed a model that demonstrates on the basis of observed smearing velocities in the range 0.4–0.7 m/s that azimuth-traveling waves of 130 m or longer will always be detected under light wind conditions (2–6 m/s). In comparison, all azimuth-traveling waves less than about 250 m may be entirely smeared out for strong winds (10 m/s). These limitations of ERS 1 wave imaging capabilities predicted by the model needs validation.

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TABLE 1. Topics of the Six NORCSEX'88 Papers in this Collection

Authors	SAR Imaging of Current	SAR Imaging of Waves	SAR/Scatterometer Imaging of Wind Shifts	Altimeter SWH, Wind, and Current	SAR/Altimeter SWH Comparison	Model and Observation of Current
Johannessen et al.	X		X			
Rufenach et al. (*a*)		X				
Johnsen et al.		X				
Rufenach et al. (*b*)		X				
Mognard et al.			X	X	X	
Haugan et al.	X				X	X

Surface Wind and Waves From Geosat Radar Altimeter and SAR

An important part of the airborne C band SAR campaign was the 400-km underflight along an ascending Geosat pass allowing assessment of the SAR capabilities to quantify wind speed and sea state parameters [*Mognard et al.*, this issue]. During this flight the wind field and sea state conditions were complicated by the presence of an occluded low-pressure system located about 200 km off the coast. SAR-derived wind speed estimates are obtained with the wind model developed by *Attema et al.* [1986]. Minimum SWH and estimates of wavelength and direction obtained with the radar altimeter are compared with the SAR wave spectra. The SAR SWH variations along the track are computed using a wind independent modulation transfer function (MTF). Results of this comparison are discussed in detail by *Mognard et al.* [this issue].

Mesoscale Circulation, Modeled and Observed

Observations of the mean mesoscale sea surface topography variations from the Geosat altimeter, of frontal boundaries and eddies from airborne SAR and NOAA advanced very high resolution radiometer (AVHRR), and of currents and thermohaline structure from moored and drifting buoys and from ship-mounted instruments draw a consistent picture of the mesoscale circulation and variability on the Norwegian continental shelf [*Haugan et al.*, this issue]. They also demonstrate that the general pattern of this variability is reproduced in a simple quasi-geostrophic numerical model. This consistency furthermore allows realistic modeling of wave refraction by mesoscale circulation pattern. The results are compared with SAR-derived wave field in the case when the SAR is not distorted by azimuth smearing.

Conclusion

In summary, the primary results of the NORCSEX '88 campaign described in this collection of papers demonstrate detection capabilities of sea surface phenomena and sea state conditions by ERS 1 C band SAR and radar altimeter. Evidence of SAR imaging limitations under influence of strong surface winds and for near-azimuth-traveling ocean gravity waves are also demonstrated. Techniques to obtain quantitative understanding of the air-ocean interactive processes that determine significant backscatter boundaries in SAR image expressions are proposed, as are methods to quantify the minimum resolvable azimuthal wavelength in SAR image spectra. These results will be validated during a dedicated NORCSEX postlaunch ERS 1 field investigation in November 1991.

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J. A. Johannessen, Nansen Environmental and Remote Sensing Center, Edvard Griegsvei 3a, N-5037 Solheimsvik/Bergen, Norway.

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