The SCAWVEX Project

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Abstract

SCAWVEX is an EU MAST project providing data sets measuring the spatial and temporal variability of ocean waves and currents. Wave measurements obtained during three experiments are discussed in this paper. These include measurements using bottom-mounted pressure sensors, HF and satellite radar and directional wavebuoys. The project has demonstrated the suitability of HF radar for simultaneous wave and current monitoring in coastal waters. The availability of satellite data in coastal waters is limited by the requirements of global coverage. The experiments have revealed interesting insights into wave-current interaction processes.

Introduction

SCAWVEX is the acronym for an EU MAST project called **S**urface **C**urrent **A**nd **W**ave **V**ariability **Ex**periments. The primary objective of SCAWVEX is to provide data sets that measure the spatial and temporal variability of ocean surface waves and currents in coastal seas. Most of the participants in the project came together in the first instance through a common interest in the exploitation of HF radar for surface current and wave measurement. These systems are particularly well suited to monitoring coastal waters due to their spatial and temporal coverage. However, there was a need to validate the HF radar wave measurements. Experiments were designed to achieve this, whilst also simultaneously providing an intercomparison of other modern wave and current instrumentation and an illustration that different measurement systems can

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provide complementarity. Measurements have been made using HF radar, SAR, Altimeter, X-Band radar, S4DW, ADCP as well as more traditional wave and current measuring instruments. At the end of the project the data will be available on CD-roms with documentation describing detailed intercomparisons. The data are already being used in modelling work within the project and it is hoped that they will also be of use to other modellers.

Experiments

The data are from three experiments: Holderness, on the North Sea coast of England, during the winters of 94/5 & 95/6 (Prandle et al, 1996); Maasmond, at the Rhine Outflow in the Netherlands from Feb to Apr 96 (OCN, 1996); Petten, on the North-West coast of the Netherlands, from Oct to Dec 96 (Andorka Gal, 1996). The location of the three sites is shown in figure 1. In all cases a number of different in-situ wave and current measurement systems were deployed. Holderness was anticipated to be dominated by fetch-limited westerly winds and swell from the Northern North Sea. This was the case during the 94/5 winter but the second winter was dominated by easterly winds. The Maasmond experiment was primarily directed at applications in vessel traffic management into Rotterdam Harbour. In this case, the HF radar deployments were optimised for surface current measurements. Some HF radar wave measurements were possible but are not discussed further in this paper. In-situ instrumentation from the Netherlands North Sea network provides some of the sea truth during the experiment. The Petten site was selected because it was already instrumented for a Netherlands coastal protection project and provided a straight coastline with bottom depth varying fairly smoothly away from the coast. All three experiments were scheduled for storm seasons to maximise the chance of obtaining HF and satellite radar data in high sea-states. This situation provides the most difficulty for the HF radar wave extraction algorithms. Altimeter and SAR data are available periodically during all three experiments.

In-situ wave measurements

A number of directional and non-directional wave buoys were deployed during all the experiments. Of particular interest to SCAWVEX as far as in-situ instrumentation is concerned are data from two bottom mounted sensors: a pressure water-level recorder (PWR) and an InterOcean directional wave-current meter (S4DW), deployed at a depth of about 12.5m at Holderness, 18m at Maasmond and 22m at Petten. Strong tidal currents exist in these regions and a correction has to be applied to the S4DW measurements to account for this (Wolf, 1998). The comparisons shows a clear improvement in S4DW wave measurements when the current Doppler (using the S4DW current measurements) is used during the attenuation correction. It has been demonstrated that the S4DW can make good wave measurements at 22m depth when the significant waveheight is greater than 1m.

Figure 1. Map showing the three SCAWVEX experimental sites and the locations of the HF radar systems.

HF RADAR

HF radar has the unique capability to measure directional wave spectra and surface currents over an extensive area and provides, for the first time, a way to study the simultaneous temporal and spatial variability of waves and currents (Paduan & Graber, 1997). Measurements using these systems are therefore central to the objectives of SCAWVEX. The UK OSCR system was used during the Holderness experiment (Wyatt & Ledgard, 1996, Ledgard & Wyatt, 1997).

For the Netherlands experiments, the University of Hamburg have developed the WERA (WEllen RAdar) radar (Gurgel & Antonischki, 1997a). The important differences between this and their CODAR system (Essen et al, 1988, also deployed at Maasmond) are the use of a frequency modulated transmit signal and a linear receive array so that the University of Sheffield wave algorithms could be used. Figure 2 shows a view along the WERA receive antenna array at the Petten site. WERA has been designed to provide a larger working range and more flexible range resolution then the OSCR system. While during these experiments working range was about the same as OSCR (~40km for currents and ~20km for waves), the ability to easily obtain much higher range resolution was demonstrated (Gurgel & Antonischki, 1997b).

Figure 2. View along the Wera receive antenna array at the Petten site.

Wave measurements are made by inverting an integral equation describing the relationship between the backscatter power spectrum and the ocean wave directional spectrum (Wyatt, 1990). The full directional spectrum is measured at frequencies up to about 0.35Hz. In addition the mean direction and directional spreading at about 0.5Hz is determined using a maximum likelihood model-fitting method (Wyatt et al, 1997). The radar measurements are being evaluated by comparing with directional wavebuoy measurements. A maximum likelihood method taking into account the sampling variability of both measurements is being used to determine the bias and variance of the comparisons (Sova, 1995).

WERA wave measurements are available every 20 minutes. Figures 3, 4 and 5 show time series comparisons of: (i) significant waveheight (fig. 3), (ii) mean direction (fig. 4) measured over three frequency bands 0.05-0.15Hz, 0.15-0.25HZ and 0.25-0.4Hz and (iii) shortwave (wind) direction and directional spreading (fig. 5) (both measured in degrees) during the first part of the Petten experiment. In general agreement is good. The differences at the low frequencies are attributable to antenna sidelobe effects (Kingsley et al, 1997) and surface current variability (Ledgard & Wyatt, 1997); those at high frequencies are mainly attributable to inadequacies in the integral equation description of scattering in high sea-states (Wyatt, 1995, 1997). These problems are the subject of research at the University of Sheffield (Traylen & Wyatt, 1997, Vizinho & Wyatt, 1997). Current Doppler has not been accounted for in the wavebuoy shortwave direction measurements and is consequently very noticeable when the waves and currents are roughly aligned.

HF radar wave measurements at Holderness and Petten are also discussed elsewhere in this volume (Wyatt, 1998)

Figure 6 Time series of amplitude (in metres) in three frequency bands, upper: long waves, middle: mid-range waves and lower: short waves.

Figure 7 Time series of direction (degrees) arranged as figure 3.

Figure 8 Time series of shortwave (wind) direction (upper) and spreading (lower)

Satellite Altimetry

The satellite altimeter is a vertically pointing pulsed radar providing remote measurements of significant wave height as deduced from the amount of distortion of the radar pulse returned from the ocean surface. Altimeter data collected during the Maasmond experiment have been obtained from two globally operating satellites: the US/French Topex/Poseidon mission, launched in 1992, and the European Space Agency's ERS-1 mission, launched in 1991.

Altimeter data available from the companies collecting and organising the data are not fully reliable. They need further quality control and also, in general, have to be corrected for systematic biases in order to achieve an error free, unbiased data set. In particular, near-shore measurements are prone to errors as the satellite goes from land to sea. For Topex/Poseidon *Ku*-band significant wave height, SWH_{Ku}, the following correction have been applied (Barstow, 1995):

$$Hm0_{corr} = 1.10 \cdot SWH - 0.165 \qquad (1)$$

The ERS-1 significant wave height, *SWH*, has been calibrated using the recently developed OCEANOR algorithm (Barstow, 1997):

$$Hm0_{corr} = 1.03 \cdot SWH + 0.46, \qquad SWH \leq 2.8m \quad Hm0_{corr} = 1.26 \cdot SWH - 0.19, \qquad SWH \qquad (2)$$

Topex/Poseidon and ERS-1 satellite tracks which passed through the Maasmond area during the experimental period have been identified and data extracted for quality control and calibration. Events with simultaneous (i.e. within one hour) in-situ buoy data available from any stations have been further investigated. Figure 9 shows significant wave heights from two of the events with co-existent measurements from all the buoys. In the leftmost plot the along-track gradient observed from the altimeter is clearly confirmed by the buoy network measurements. Also, the ERS-1 event (on the right) indicates fair agreement between the altimeter data and the *in-situ* measurements.

Maasmond SAR data

27 SAR images received during the period of the Maasmond experiment are being studied for wave and other surface modulation effects. However only on two days are the spectra of these images of sufficient quality to carry out an inversion to get the ocean wave spectrum (Krogstad et al, 1994). Figure 10 shows significant waveheight and mean period determined from the inversions for 17/2/96 combining information from two sequential images. At this time in-situ measurements indicate a significant waveheight of 3.1 - 3.8m (see fig 11 for location of instruments) and a mean period of ~ 6.6s.

Figure 12 Altimeter measurements •, buoys identified below the maps. Left shows Topex-Poseidon data, right ERS-1 data.

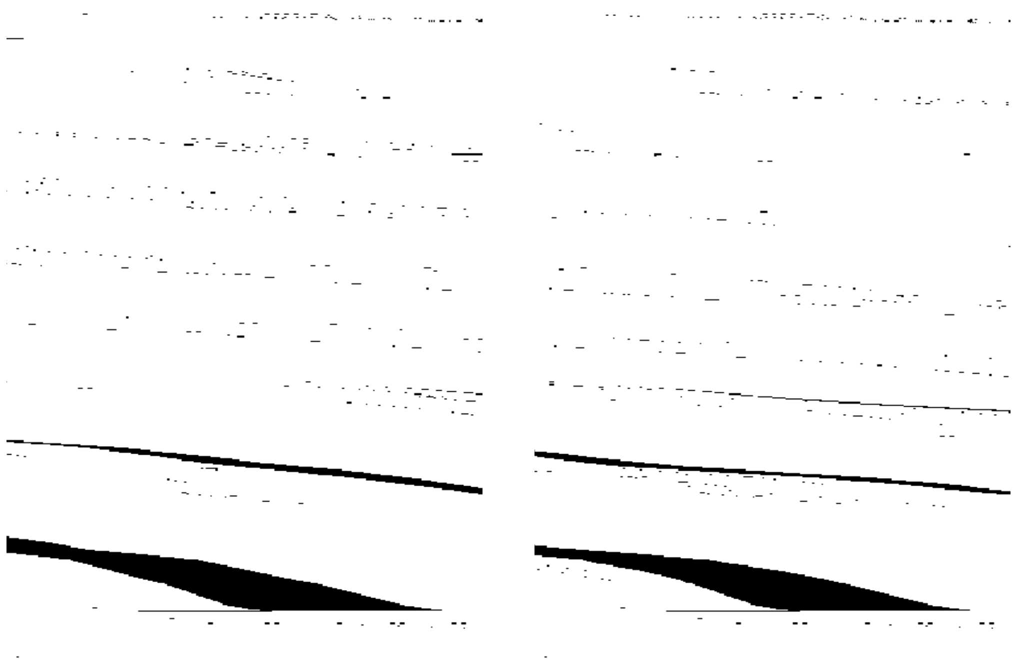

Figure 13 Inverted SAR spectral parameters from 2 images on 17/2/96 at Maasmond (coast - solid region to the bottom right). Significant waveheight is contoured on the left and mean period on the right.

Concluding remarks

This paper has focussed on the experimental part of the SCAWVEX waves work. WERA current measurements are being evaluated at the University of Hamburg. Delft Hydraulics, ARGOSS, the Proudman Oceanographic Laboratory and the University of Sheffield are involved in a range of modelling work linked to the experiments. This includes wave-current interaction and the use of models to improve data retrieval and to determine 3-D currents from surface observations.

The paper has only presented a brief glimpse into the wave data sets collected during SCAWVEX. The wave and current data sets will be available at the end of the project (during 1998) on CD-rom and FTP servers. The measurements show detailed variability on the temporal and spatial scales obtainable with HF radar systems and, on spatial scales, with satellite systems. Such variability clearly shows that point measurements, e.g with wave buoys, are not sufficient for accurate monitoring of coastal regions around the southern North Sea.

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