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THE NOAA OCEAN WAVE MODEL HINDCAST FOR LEWEX

Directional wave spectra from the National Oceanic and Atmospheric Administration (NOAA) model hindcast during the Labrador Sea Extreme Waves Experiment are discussed in detail. The hindcast significant wave heights and spectra are found to be in reasonable agreement with the available estimates from two moored buoys. The NOAA spectra exhibit more energy at high frequencies than other models, possibly because of the lack of a proper dissipation term for whitecapping.

INTRODUCTION

The National Oceanic and Atmospheric Administration (NOAA) global ocean wave model has been operating at the National Meteorological Center since late 1985. It is a second-generation model with the source terms, directional relaxation, and propagation scheme of Cardone's SAIL II model.[1] A swell attenuation term similar to that in the Ocean Data Gathering Project (ODGP) model and the U.S. Navy Global Spectral Ocean Wave Model (GSOWM) was added in September 1988 because the operational forecasts produced by the original model showed that it was retaining an excessive amount of energy in the swell portion of the spectrum.

The NOAA model provides forecasts of the directional wave spectra up to 72 h in the future at 3-h intervals over a 2.5° × 2.5° latitude/longitude grid. Directional spectra are computed in fifteen frequency bands of variable width, with the first band centered at 0.03889 Hz and the last at 0.30833 Hz, and twenty-four directional bands of equal width. Wave growth is limited by the Pierson–Moskowitz (PM) fully developed spectrum corresponding to the input wind speed with Mitsuyasu's directional spreading function.[2]

The operational NOAA model, with the swell attenuation term included and no changes in time step or grid resolution, was used for the Labrador Sea Extreme Waves Experiment (LEWEX) hindcasts. As described by Cardone elsewhere in this volume, LEWEX winds were generated using a subjective blend of all available ship and buoy reports. These winds were provided at 2-h intervals on a 2.5° × 2.5° latitude/longitude grid over the region of interest. Hindcasts were done over this enclosed region with the winds interpolated to the model 3-h time steps.

The NOAA wave model started from a flat sea on 9 March 1987 at 1200 UT. Hindcasts starting 72 h later, from 12 March at 1200 UT, were compared with the available data from a Norwegian Wavescan buoy (see Krogstad, this volume) at the location of HNLMS *Tydeman* (50°N, 45°W), and a Canadian-deployed Wavec buoy (see Keeley, this volume) at the CFAV *Quest* location (50°N, 47.5°W). Each ship was located at a NOAA model grid point.

SIGNIFICANT WAVE HEIGHT

Figures 1 and 2 give the time histories of analyzed wind speed and direction, and hindcast and observed significant wave height H_s at the *Tydeman* and *Quest*, respectively.

In general, the hindcast made at the *Tydeman* agrees better with the Wavescan buoy estimates than the one at the *Quest* agrees with the Wavec buoy. On 15 March, the wind speed at the *Quest* increased from approximately 2 m/s to about 10 m/s and then decreased rapidly, while the wind direction also changed rapidly. The buoy H_s decreased substantially during the second half of 15 March and into 16 March, while the model H_s decreased only during the first half of 15 March and then remained relatively constant. On 16 March, the wind speed at the *Quest* increased from about 4.5 m/s to more than 14 m/s while turning by almost 90°. Although the buoy H_s increased sharply during this time, the model H_s remained almost constant, suggesting a need for improving the directional relaxation mechanism in the model.

During 18 March, the measured wind direction was relatively constant toward the north, while the wind speed decreased. Meanwhile, the buoy H_s decreased more rapidly and to lower values than those of the model, suggesting an insufficient dissipation term in the model.

DIRECTIONAL SPECTRA AT THE *TYDEMAN*

Buoy data were not available at the *Tydeman* until 14 March at 0600 UT. Selected directional spectra from the model and the buoy are shown in Figure 3.

In Figure 3A, the sea toward the north in the model spectrum is still developing, with a peak period of 9.7 s, in fair agreement with the Wavescan buoy (Fig. 3B). The

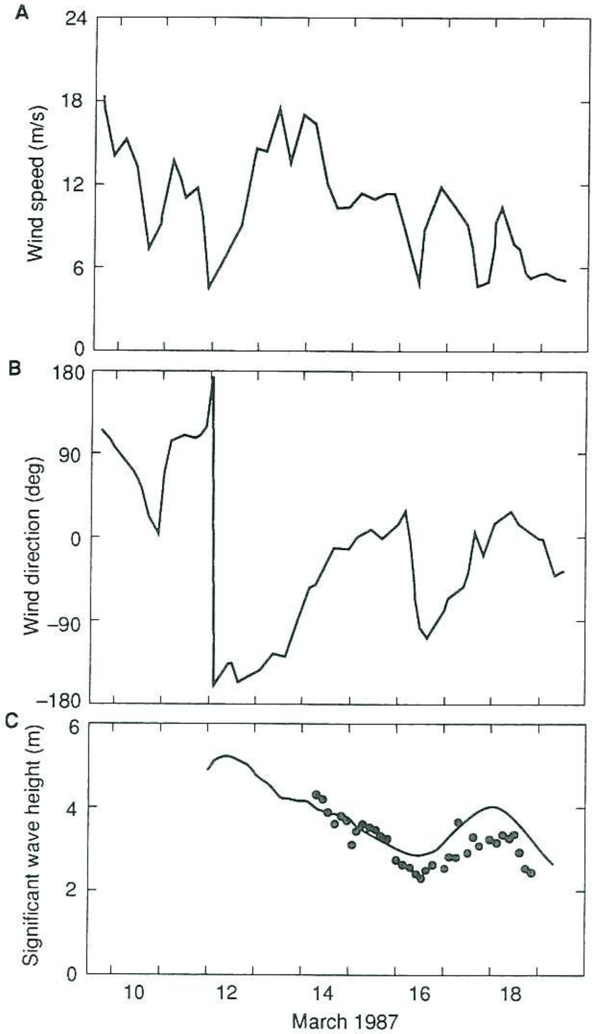

Figure 1. Time histories at the *Tydeman* from 9 March through 19 March. **A.** Wind speed. **B.** Wind direction. **C.** Significant wave height. A and B are LEWEX common winds; C is the NOAA model significant wave height hindcast (solid line) compared to Wavescan buoy measurements (solid dots). Wind directions are positive clockwise from north.

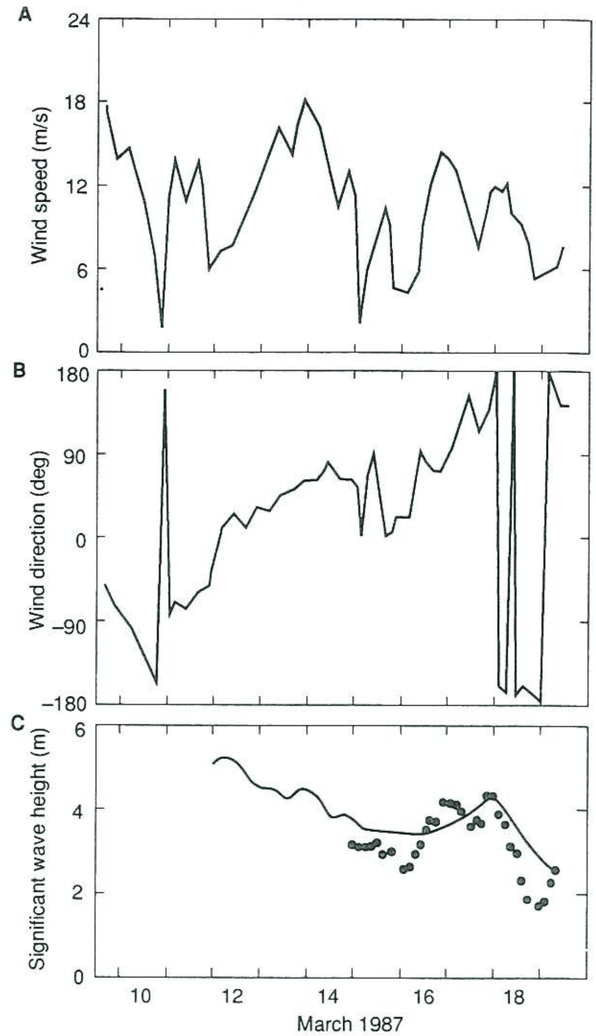

Figure 2. Same as Figure 1, but at the *Quest*. **C.** Solid dots indicate Wavec buoy measurements.

buoy shows an energetic system traveling toward the west-southwest, but this system is absent in the model. In contrast, the model shows a wave system to the south-southeast. This wave system can be traced back to swell from the Labrador Sea and was present in the model spectra since 12 March at 1200 UT.

This south-southeast-traveling swell was generated by strong winds over the Labrador Sea. Although these winds had turned toward the east, a wind toward the south-southeast at the 55°N, 50°W grid point contributed to the swell at the *Tydeman*. The long swell was traveling faster than the wind, with no attenuation in the model until the waves were propagating more than 90° from the local wind direction.

The development of the sea toward the north in the model is consistent with the hindcast winds at the *Tydeman* producing a nearly fully developed PM spectrum. Figures 1A and 1B show that the wind speed at the *Tydeman* during 12 March increased monotonically from less than 6 m/s to less than 14 m/s, with constant direction. On 13 March, the wind speed remained steady at about 15 m/s but began to turn clockwise. The peak period for a fully developed PM spectrum generated by a constant 15-m/s wind is 10.9 s, in fair agreement with the peak period of 9.7 s shown by the model at 0600 UT on 14 March, when the wind speed began to decrease. During 14 March, the local wind continued turning clockwise but decreased in speed to 10.5 m/s at 1200 UT and remained relatively constant through 15 March.

The winds in the Labrador Sea and Davis Strait ceased blowing toward the southeast at 1500 UT on 12 March, decreased, and became intermittent. From 1200 UT, however, weak winds toward the southeast existed in the northern Labrador Sea, and they increased in intensity and extent well into 15 March. On 15 March at 1200 UT, a new Labrador swell arrived at the *Tydeman* with a phase speed of 15.2 m/s, consistent with a travel distance of about 650 km in 24 h. Even 6 h later, however, when this new swell was well established in the model