A MARINE RADAR BASED OCEAN SURFACE FEATURE MONITORING SYSTEM

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1. INTRODUCTION

Today, marine radar-image sequences are used on an operational basis to measure ocean surface wave parameters [1] [2]. In addition, they have shown to be useful in measuring the evolution of individual waves in time and space [3] [4], current and bathymetry fields [5] [6] [7] as well as surface wind fields [8]. The typical marine radar systems used for these applications operate in the X-band at grazing incidence. For this electromagnetic wavelength and incidence angles, microwave backscatter from the ocean surface is primarily caused by small-scale surface roughness (in the range of centimeters). However, at grazing incidence there are several additional important mechanisms leading to the microwave backscatter [9].

2. METHODOLOGY

The normalized radar cross section (NRCS) of the sea surface at grazing incidence is strongly dependent on the local wind speed and wind direction with respect to the antenna viewing direction. However, it is well known that small-scale ocean surface roughness, and subsequently the radar backscatter, is modulated by features such as current shear, bathymetry change, ocean waves, surface winds and internal waves. In this paper we will introduce a methodology that enhances the visibility of ocean surface features in nautical radar-image sequences.

In principal the methodology consist of two steps. In the first step, the decrease in backscatter as a function of range is adjusted by subtracting a ramp, which is the mean radar cross section averaged over all azimuth. For this study, the range-dependent ramp was retrieved from a feature free image in low wind conditions (< 3 m/s). Low wind conditions were selected to retain as much wind speed information as possible in the ramp-adjusted images (higher wind speeds result in larger NRCS). Also, the range-ramp correction removes radar-specific antenna patterns in range, as well as the effect of range spreading loss of the system.

In the second step, the temporal and spatial variability of the radar backscatter due to the modulation of the NRCS by ocean surface waves, as well as speckle (the granular appearance of radar images), is removed. This is achieved by integrating the radar image sequences in time (typically 90 s), which leads to the elimination of signatures with shorter temporal variability such as surface gravity waves, and to a significant reduction of speckle in the images. Only static patterns and slowly propagating signatures remain visible in the resulting radar images. The methodology was incorporated in a system consisting of a nautical radar, a AD-converter and a PC, which enables the real time processing of the radar image sequences and make the resulting surface feature images available in real time.

3. RESULTS

Several weeks of marine radar image sequences have been collected and investigated. Various situations will be presented, showing the observational capabilities of the system in space and time. Fig.1 depicts typical images derived from the original image sequence using the processing chain described above. In the image on the left hand side internal waves are depicted as observed by the radar. The center image shows an internal wave generated by a super tanker in front of Istanbul. In both situations the wind speed was between 7 and 10 m/s and the significant wave height above 1.2 m. On the right hand side wind induced streaks are visible, which can be utilized to estimate the wind direction.

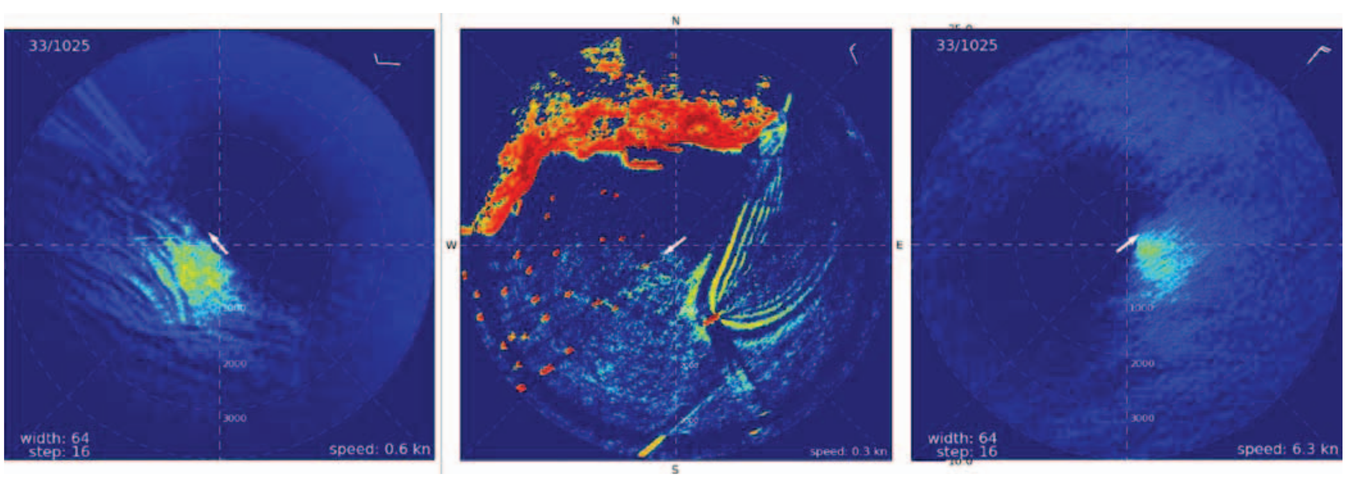

Fig. 1: Individual images derived from original image sequences after processing. The image on the left depicts an internal wave, the center image a ship-generated internal wave and the image on the right wind induced surface streaks.

The processed image sequences showing the internal waves can now be investigated in the temporal and spatial domain, facilitating the retrieval of information such as wavelength, wave propagation direction, phase speed etc. In case of the image sequence depicting the wind streaks, the propagation of the streaks can be investigated in time and space. In addition, wind gusts are visible in the image sequence, which can be studied in time and space to estimate their propagation speed and direction. We will show several other examples and discuss the possibilities of the system, in particular the implications of the real time processing capability.

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