remote sensing

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Editorial

Editorial for Special Issue "Ocean Radar"

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Abstract: This Special Issue hosts papers related to ocean radars including the high-frequency (HF) surface wave and sky wave radars, X-, L-, K-band marine radars, airborne scatterometers, and altimeter. The topics covered by these papers include sea surface wind, wave and current measurements, new methodologies and quality control schemes for improving the estimation results, clutter and interference classification and detection, and optimal design as well as calibration of the sensors for better performance. Although different problems are tackled in each paper, their ultimate purposes are the same, i.e., to improve the capacity and accuracy of these radars in ocean monitoring.

Keywords: ocean radar; HF radar; scatterometer; altimeter; microwave radar; ocean remote sensing

1. Introduction

Oceans cover more than 70% of the surface of the Earth. They play an extremely important role in affecting climate on a global scale, providing survival resources and environments to numerous species, and are the basis of human marine transportation and exploration. Thus, it is a worldwide and continually necessary task to understand and monitor oceans. Radar is one of the most useful tools for obtaining ocean information using the technologies of remote sensing. The most widely accepted ocean sensing radars include but are not limited to the high-frequency (HF) surface wave and sky wave radars, microwave marine radars, and laser radar (LIDAR). These "ocean radars" are able to provide sea surface information such as wind, wave, current, hard target, and bathymetry with different spatial and temporal resolutions. Though many successful applications have been reported for each kind of ocean radar, there are still plenty of questions that deserve to be explored.

The objective of this Special Issue is to provide a forum for ocean radar researchers to present their recent advances in the field. By presenting many important problems as well as corresponding state-of-the-art technologies and methodologies regarding ocean radars, this Special Issue aspires to stimulate further research in this community.

The following Section provides a summary of all the twelve articles published in the current special issue. They are organized thematically, leading with articles on HF radar (6), scatterometry (2), altimetry, L-band, X-band, and K-band radar (1 each).

2. Overview of Contributions

Cosoli and de Vos [1] evaluated the sea surface current estimation results from two typical types of HF surface wave radars: direction-finding SeaSonde and phased-array WERA. Based on 4-month data from Western Australia, both radars are found to be able to provide comparable current fields with high precision. However, both radars are also affected by pointing errors. In addition, the authors investigated the possibility of combining radial current data from these two different radars and obtained surface vector maps with reasonable accuracy. This work confirms the flexibility of constructing a radar networks with different types of HF radars.

In [2], Shen and Gurgel presented a pattern-fitting based method for estimating wind direction from narrow-beam HF radar Doppler spectra and further investigated the factors that affect the measurement accuracy. By employing the data collected by two radars of different frequencies (12 MHz and 27.68 MHz) under varying wind conditions, the authors showed the proposed wind direction algorithm outperformed the least-squares minimum method. They also found that the wind direction estimation accuracy significantly depends on the radar frequency and wind speed. The radar-derived wind direction results agree better with in-situ data with a radar of higher operating frequency and under higher wind speed conditions.

The performance of HF radar in sea state monitoring and target detection is always negatively affected by ionospheric clutter and radio frequency interference (RFI). In order to tackle this problem, Zhang et al. [3] proposed a deep learning based method which involves faster region-based convolutional neural networks (Faster R-CNN) for classifying sea clutter, ionospheric clutter and RFI. By applying the proposed and regular R-CNN methods to the field data collected by a compact HF surface wave radar at the East China Sea, the authors found the proposed method can automatically detect the clutters and RFI with higher efficiency and accuracy than the regular R-CNN.

As we know, the quality of data directly affects the accuracy and reliability of HF radar-derived current, wind, wave and hard target tracking results. In [4], Cosoli et al. present an iterative quality-control procedure that fits a 1-D or 2-D reference signal to the radial signal-to-noise ratio (SNR) map to remove anomalous measurement results. Unlike the QA procedures that use empirical radial velocity and SNR thresholds obtained from quantitative analysis of long-term historical data within the HFR coverage, this scheme updates the thresholds iteratively and it can be employed in real-time and delayed-mode. It provides a widely applicable QA which is not limited to specific radar types or observation area.

In the paper by Ogata et al. [5], a new method that enables real-time tsunami detection using HF radar is presented. Such a method is based on the analysis of the temporal change in the cross-correlation of radial velocities at two different observation points along radar beams. Field HF radar data merged with simulated tsunami velocities caused by the Nankai Trough earthquake were used to validate the new detection technique. Comparison with existing methods shows that the new detection scheme can reduce the underestimation of the tsunami magnitude and provide a 9-minute alarm time with a detection probability of 80% 7 minutes after tsunami occurrence.

The direction of arrival (DOA) estimation is a key measure of HF radar performance. Through both theoretical and experimental analysis, Lai et al. [6] found that the DOA error significantly depends on the ratio of the antenna pattern deviations of two loops for a cross-loop system. Based on this finding, the authors proposed a new method which takes advantage of time-averaged local spatial coverage rate (TLSCR) for mitigating the DOA estimation error. By comparing the ocean current results from using the DOA obtained with the ideal and calibrated patterns, the proposed method is found to be effective in reducing the DOA estimation error and improving the current measurement accuracy.

Nekrasov et al. [7] investigate the accuracy of airborne scatterometric ocean surface wind retrieval for different antenna configurations. Using Monte Carlo simulations with horizontal polarization on transmit and receive and the Ku-band geophysical model, the authors show that the wind direction errors associated with the simplest X-configuration are considerably higher than for all the other configurations. The star geometry antenna configuration, with its increased number of beams and, therefore, better angular resolution, reduces the errors in the wind direction. In contrast, the wind speed accuracy is shown to be largely independent of antenna geometry. These findings could prove useful for sensor development and the enhancement of existing scatterometers.

In reference [8], Rodriguez investigates the optimization of spaceborne Doppler scatterometers for the simultaneous measurement of ocean surface winds and currents. It is shown that, to reduce the radial velocity error, the pulse length should vary with scan angle. The system's performance is also strongly affected by the antenna length, but depends only weakly on transmit power. Furthermore, a high frequency and near-nadir incidence angles are both preferable, however, the latter negatively affects the revisit time. Lastly, it is shown that by varying the PRF the scatterometer's along-track footprint can be increased by up to two orders of magnitude. The results presented in this study are relevant to several proposed space missions with Doppler scatterometers, including the Sea Surface KInematics Multiscale (SKIM) concept, which is currently under evaluation by the European Space Agency.

The validation of significant wave height (H_s) measurements made by the Ku-band altimeter on the HY-2 satellite is the subject of [9] by Chen et al. With NDBC buoy measurements as reference, the root mean square (RMS) error of the HY-2 H_s is 0.33 m, similar to the previously reported Jason-1 and -2 errors. After application of a NDBC buoy based correction formula, which has been obtained through linear regression, the HY-2 H_s accuracy is estimated to be 0.17 ± 0.04 m.

The sea surface backscatter at L-band is studied by Du et al. [10]. The authors modified Apel's omnidirectional ocean wave spectrum to include an improved spreading function, which they built into the existing AIEM model. The thus improved model is shown to successfully simulate the negative upwind-crosswind asymmetry at low wind speeds and the positive upwind-crosswind asymmetry at high wind speeds. Measurements from the Aquarius/SAC-D satellite are shown to be in overall good agreement with the model results.

In reference [11], Kammerer and Hackett investigate the use of proper orthogonal decomposition (POD) to extract ocean surface wave fields from marine X-band radar Doppler velocity measurements. The advantage of POD over the traditional FFT method is that it accounts for non-linear wave characteristics. The surface wave statistics derived from the POD-based Doppler velocity reconstructions agree well with wave measurements from GPS mini buoys. Doppler velocity reconstructions based on the leading 15% of POD modes generally yield the best agreement with the buoy H_s.

Lastly, Cui et al. [12] study the use of a short-range K-band narrow beam continuous wave radar for ocean wave measurements. Numerical simulations and wave tank experiments are conducted to demonstrate the technique's feasibility. The IF power distribution is shown to oscillate in accordance with the numerically simulated and wave tank generated waves. The oscillations are controlled by the dominant wave facet. Wave period and height are derived from the measured Doppler velocity. By changing the orientation of the radar and accounting for the measurement geometry, wave direction can be deduced. This is demonstrated numerically for both a one- and two-wave scenario.

3. Conclusions

Although ocean radar has been an active research topic for a long time, it remains an important but challenging subject and attracts a significant amount of effort and funding. This Special Issue represents a collection of some recent work about several types of ocean radars in the community. It should be noted that a synthetic aperture ocean radar is not included in this issue since such a topic itself involves tremendous research effort worldwide and can be considered for another special issue. This Special Issue provides a timely platform to show the latest progress in the aforementioned ocean radars and stress their significance for ocean applications.

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