

DETERMINISTIC SEA WAVES PREDICTION FROM X-BAND RADAR: NEW ALGORITHM AND SEA TRIAL

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ABSTRACT

Many maritime operations can benefit from short-term deterministic sea wave prediction (DSWP). Conventional X-band radars constitute a convenient cheap source of measurements for DSWP. The radar backscatter measurements suffer from several imperfections such as the effect of larger waves shadowing smaller waves. In order to extract the wave profiles and build a reliable sea prediction model, multiple radar scans must be processed. In this paper, we present a new single-wavenumber least-squares spectral algorithm for wave prediction from radar backscatter. Compared to existing methods, the proposed technique is characterized by its fast output update rate, undemanding computations, numerical stability and its ability to handle the time smearing of the backscatter scans because of the rotating antenna. The proposed technique is evaluated using field data from a dedicated sea trial.

BACKGROUND

DSWP is a new branch of maritime science that aims at providing the sea shape in the vicinity of coastal/offshore structure and floating vessels several tens of seconds ahead. DSWP can identify the occurrence of quiescent waves periods that can be exploited to safely carry out wave limited tasks in sea conditions that based upon sea state statistics alone would be deemed unsafe (Al-Ani et al., 2019a; Al-Ani and Belmont, 2020). X-band radars are the most realistic sensing technology for DSWP. Conventional wave radars return statistical wave data. Some attempts to retrieve the deterministic sea surface elevation from radar scans have been reported, but the quality was shown to be not optimal. Some success has been reported using an algorithm based on the work of Nieto Borge et al. (2004) that employs a 3DFFT. A commercially available wave profiling radar has been built based on this approach. However, the use of classical 3DFFT has certain drawbacks. The natural radar data is helical in space and time because of the rotating antenna. The helical nature of the data would not only introduce error in FFT due to the time smearing effect but it also means that interpolation of each scan into a Cartesian grid is prerequisite. This results into a delay in the output update rate, restricting the benefits of DSWP. Second, radar measurements usually span a large coverage with relatively high resolution, and hence with an FFT a wide spectral sea model with a large number of coefficients is built. However, the wave spectrums are usually limited to a much narrower range of wavenumbers, and hence a considerable part of the FFT calculations can be redundant. Other successful DSWP algorithms overcome these limitations by solving a set of linear equations to obtain the relative spectral coefficients simultaneously, but they suffer from other

problems such as poor-condition number and increased computational cost.

THE PROPOSED ALGORITHM

The algorithm is based on single-point least-squares estimation. It is built on Al-Ani et al. (2019b), where a single radar scan is used and tested on simulated data reporting clear advantages over FFT, which was also tested on single images of wave profiles extracted from radar scans in Al-Ani et al. (2020). The present work extends the algorithm to multiple scans in a sliding window fashion to improve the prediction model accuracy and reduce computational cost, and tests the results on backscatter data from a dedicated sea trial. There are a few key innovative features of the new technique. First, use is made of the standard oceanographic assumption that in the Fourier transform of a particular set of wave profile data, the spectral coefficients are considered to be statistically independent. The second innovative feature is that it can handle the mixed space-time radar data in its natural resolution and it avoids the effects of the poor-condition number behavior associated with the type of matrices involved in DSWP. Third, the algorithm requires no pre-interpolation of the data which means that the radar measurements at each beam can be processed promptly as they are captured by the rotating antenna. Finally, for reasons of computational efficiency, the calculations can be restricted to the relative wavenumbers, and with the use of a sliding window technique redundant calculations can be completely eliminated.

SEA TRIAL RESULTS

Golden Arrow was a sea trial undertaken in the North Atlantic carried out from the vessel Northern River sponsored by the UK Ministry of Defence. The trial was designed to collect real time wave measurements and the corresponding wave driven vessel motion data for the purposes of research into DSWP. Wave data was obtained from X-band radar and from two free-floating heave-pitch-roll buoys deployed in the region probed by the wave radar. Prediction results were evaluated against the vessel movement as well as the two buoys. The correlation coefficient between the predicted and measured wave profiles are as high as 0.9 for prediction horizon of 3 minutes ahead.

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