Ocean Wave Groupiness from ERS-1/2 and ENVISAT Imagettes

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Abstract— **In this study a global data set of reprocessed synthetic aperture radar (SAR) data acquired by the European Remote Sensing satellite ERS-2 is used to study ocean wave grouping using wavelet based methods.**

For more than a decade the ERS-1/2 satellites have continuously recorded SAR images of the ocean surface. Operating in wave mode both instruments have acquired about 1400 imagettes of 10×5 km size (every 200 km along the orbit) each day, which allows to study ocean waves on a global basis.

Only coarsly gridded SAR image spectra are available as official wave mode products from the European Space Agency (ESA). As the full image information is required for the present study about 3 weeks of ERS-2 SAR wave mode raw data were reprocessed to 34000 complex SAR images using the BSAR processor from the German Aerospace Center (DLR). ENVISAT satellite, which was sucessfully launched on February 28, 2002, will provide almost 3000 imagettes a day due to its higher sampling rate (every 100 km).

Applying a wavelet edge detection method on the SAR-amplitude-density image and using a region growing approach for the edgefree areas allows examinations of the wave groupiness on a single image. These examinations include group size and number of large groups. The wavelet coefficient as a measure for edge strength is correlated to both wave height and steepness.

The wavelet method is compared with an alternative approach, which is based on the classical Hilbert-transform technique. For the latter method the actual sea surface elevation field has to be known. Therefore a quasilinear inversion scheme is used which estimates the surface elevation from complex SAR data.

Using this dataset global maps of dangerous areas (high group activity) are provided showing the distribution of the group parameters derived. This can help avoiding ship accidents due to severe weather conditions in dangerous areas. Many of the ships lost in such cases report damage due to a group of several high waves (e.g. three sisters).

Keywords— **Ocean waves, groupiness, SAR, wavelets, edge detection, ENVISAT, Imagettes.**

I. Introduction

BASED on a SAR coastline extraction algorithm [1] a new wave grouping algorithm on SAR imagettes was developed. Its main features are wavelet edge detection, a region growing approach seperating the groups and a selection of large groups. This new algorithm is presented here and compared to results from a (1D→2D) generalized Version of the conventional Hilbert-transform based wavegroup definition. Exemplary maps of group activity are given.

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II. The grouping algorithm

Figure 1 shows an overview of the wave grouping algorithm applied to a ERS-2 SAR imagette from October 7, 1996, 7:31:48 UTC (61°11' S, 22°47' E).

Wavelet edge detection (decomposition & thresholding) as well as Blocktracing are directly taken from the coastline detection algorithm [1]. Wavelet edge detection uses the (2 dimentional) dyadic wavelet transform, which allows a caracterization of the Lipschitz-Regularity of a signal via the decay of the wavelet transform modulus maxima [2].

Grouping now enumerates the disjoint groups and selects those above a certain thrshold (i.e. a group area of at least $8.0 \cdot 10^5\,\mathrm{m}^2 = 10^4$ SLC pixel).

This yields the large groups visible on the SAR imagette. Small areas with strong edges (i.e. from a single high wave) are sorted out.

III. The dataset

The imagette dataset available at DLR consists of some 34000 ERS-2 SAR imagettes from several time periods (August 21–September 8, 1996; October 4–8, 1996; June 1–2, 1997; 25600, 6200, 1600 imagettes resp.). They are distributed all across the planet but mostly within ocean regions.

By the algorithm presented above, maximum (or mean) group size as well as the number of large groups can be studied on each imagette. Looking at the thresholded wavelet-image the edge length and extension can be interpreted as crest or valley length and extension. Finally the maximal coefficients on the wavelet domain are of interest for interpretation purposes (see next section).

These can be added to wave parameters from different algorithms (cf. [3], [4], [5] in this issue) like single or significant waveheight, single wave steepness, highest/deepest elevation from the mean sea level or number of wave crests/valleys.

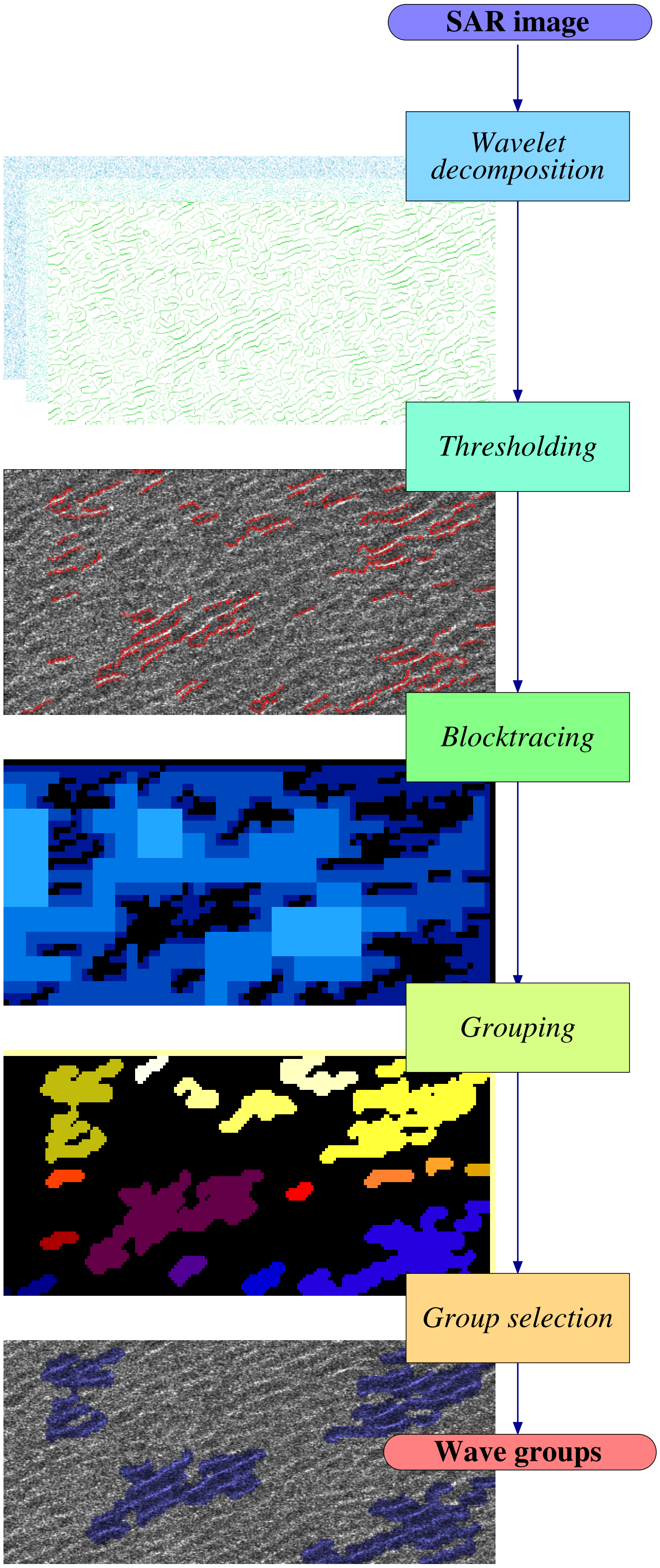

Fig. 1. The grouping algorithm.

TABLE I

Comparing wavelet coefficient to wave height and steepness (Correlation of maximal wavelet coefficient to maximal waveheight/steepness per imagette using all imagettes and correlation of maximal wavelet coefficents per edge to maximal local steepness nearby on single imagette with good correlation).

	all	single
waveheight	0.75	—
steepness	0.63	0.54

IV. Interpretation

Comparing wave steepness and waveheight with the values in the wavelet domain allows an interpretation of the wavelet coefficient in terms of these parameters. Both are well correlated to the wavlet coefficient as table I shows. The wavelet coefficient by this is a measure of both wave height and steepness. As the thresholding is carried out in the wavelet domain using a relative threshold calculated from the mean and standard deviation of the wavelet coefficients, the groups are regions of higher and/or steeper waves in comparison to the rest of the image.

V. Quasilinear inversion

A quasilinear inversion scheme [3] of the SAR imaging mechanism allows the recalculation of the sea surface from the original single look complex SAR image (with best accuracy for range traveling waves). This inversion is basis for most of the ocean wave parameters mentioned in section III. It can also be used as an input for a wave group determination using the historic definition via thresholding the amplitude computed by using the 2D-Hilbert-transform [6]. Generalizing this on a whole imagette also allows a group determination. Figure 2 shows the inverted sea surface and its Hilbert-transform of the SAR image used in Figure 1.

VI. Comparison

Thresholding a smoothed version of the amplitude computed using the Hilbert-transform at mean waveheight level $\overline{H} = \sqrt{2\pi m_0} \approx 0.626 \cdot H_s$ gives the definition of the run groups. For a group definition which is more useful in the 2D case (i.e. the eye catching group like structures on the imagette) a lower thershold value has to be considered ($\approx 0.35 \cdot H_s$ in our case).

Figure 3 shows the groups using a threshold value of 1.2 meters. Again selecting the groups of more then $8.0 \cdot 10^5$ m^2 results in three groups which match in both shape and location to three of the four groups from the wavelet-based algorithm (also Fig. 3, bottom). As the imagette is cut for the FFT in the Hilbert case to a resolution of $2^9 \times 2^8$, the fourth group lying mostly outside this cut-region is not found.

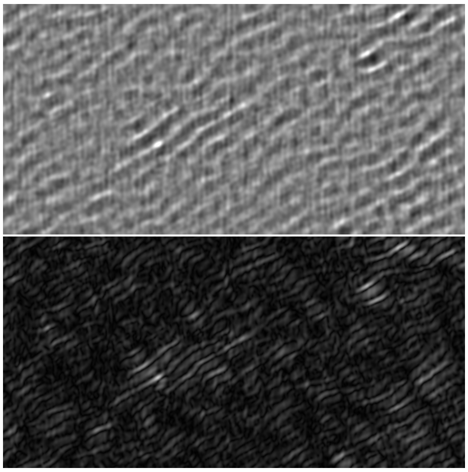

Fig. 2. Sea surface from an imagette and the amplitude from its HILBERT-transform.

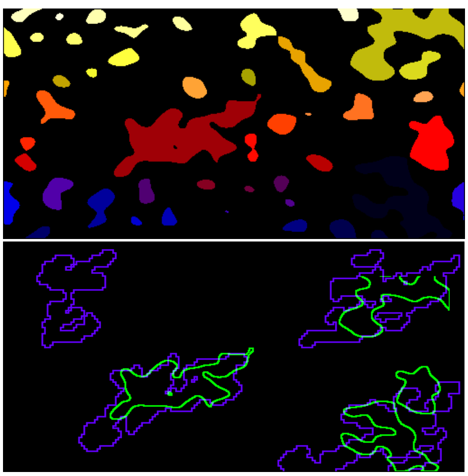

Fig. 3. Groups from thresholding smoothed version of the amplitude from the HILBERT-transform in Fig. 2 and the comparison of the large groups from both algorithms.

VII. Conclusions and Outlook

When applying the algorithm presented here to the whole dataset (34000 imagettes), maps of regions with high group activity (either in means of group size or number of large groups) can be drawn (cf. Fig. 4). These help determination of dangerous regions for shipping, which is of special interest as several ships are lost due to severe sea states every year (due to this reason various examinations are going on [4], [7], also with different sensors [8]).

Processing the whole ERS-1/2 wavemode dataset to imagettes (some 5 million images within 10 years) even better maps schowing seasonal or year by year changes will be possible. This will continue with ENVISAT providing the double ammount of imagettes (about 1 million per year).

Moreover parts of the algorithm can also be used when doing studies on sea ice phenomena [9].

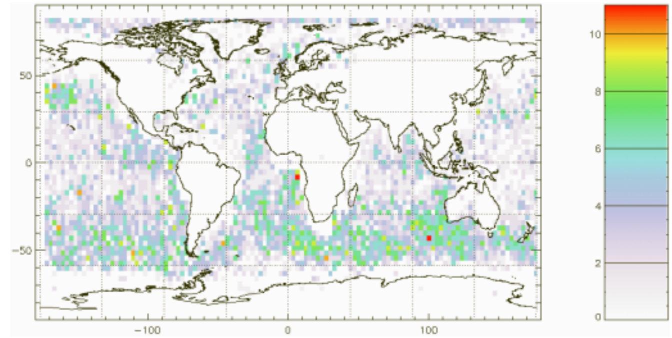

Fig. 4. Map with maximal number of larges groups per imagette. Especially the rough areas in the southern hemisphere and the path of the hurrican 'Fran' in the northern Atlantic are visible.

Acknowledgments

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