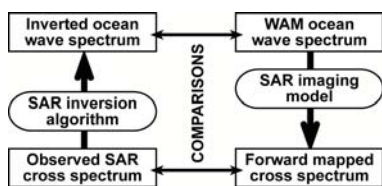


## Introduction

Measurements and studies of ocean dynamics include wind and wave retrieval, meso-scale feature identification, bathymetry, water temperature and ocean productivity. Of main interest here is the sea state represented by a two-dimensional ocean wave spectrum and its measurement. The sea state comprises all ocean surface waves at a certain position and time. Understanding sea state dynamics is important for ship routing, coastal security, forecasting and monitoring storms, as well as for the understanding of the dynamic relationship between ocean and atmosphere for global climate studies.

Many techniques have been devised for measuring waves. Remote sensing offers different methods for acquiring information on the open ocean and coastal regions. The synthetic aperture radar (SAR) is the only instrument capable to provide high-resolution 2D sea surface information (images) on a global and continuous scale. Aim of the present study is the investigation of the performance of the ocean wave model WAM in comparison to marine parameters extracted from complex SAR data as well as the investigation of complex weather situations with SAR imageries and computed spectra.

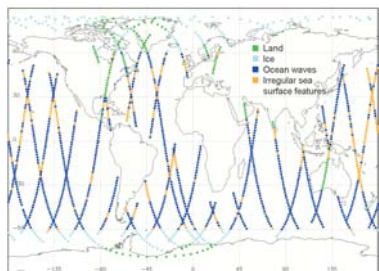
## Scheme of Data Processing and Comparison



## ERS-2 SAR Imageries

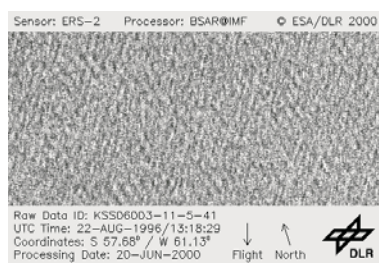
Since the launch of the European Remote Sensing Satellite ERS-1 in 1991, wave mode data have been acquired over the oceans on a continuous basis. Raw data have been processed to complex SAR image data, so-called imageries. They have a size of 5 km x 10 km and are taken every 200 km along the satellite track.

## Global Distribution of ERS-2 SAR Imageries



Global coverage of imageries on August 25, 1996. In total more than 34000 imageries were processed representing 27 days of data in three time intervals (August till October 1996 and June 1997).

## Exemplary Imagerie with Ocean Waves



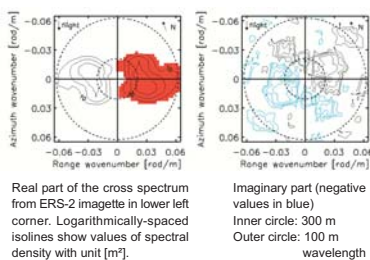
Imagerie acquired in the South Atlantic Ocean showing ocean waves.

SAR imageries show ocean waves as well as irregular sea surface features like rain cells, ships, and oil films.

## Spectra and Parameter Retrieval

Complex SAR cross spectra are estimated from SAR imageries by multi-look processing. Modelled ocean wave spectra are forward mapped into WAM FOMAP cross spectra for the comparison. For a second comparison, SAR cross spectra have been inverted into ocean wave spectra (compare scheme on left side).

## Exemplary SAR Cross Spectrum



Single ocean wave system: 200 m mean wavelength, propagation into eastern direction (dissolving ambiguity with the imaginary part).

All spectra are partitioned into spectral regions associated with local maxima, called component wave systems (CWS). Parameters wavelength, propagation direction as well as variance/significant wave height are extracted from CWS and from the whole spectrum.

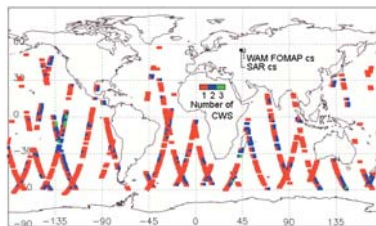
## Comparison of Cross Spectra

Cross spectra partitioning results:

- Same number of component wave systems (CWS) in cross spectra pairs in 71% of analysed cases.
- About 90% of CWS pairs in cross spectra show the same wave situation.

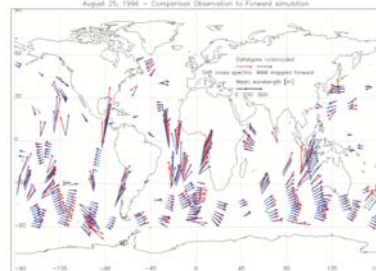
A modification of the forward model is recommended since the contained range-splitting effect is too strong.

## Number of CWS in Cross Spectra (cs)



Map of August 24, 1996, showing the number of component wave systems (CWS) in cross spectra (cs) pairs.

## Mean Cross Spectra Parameters



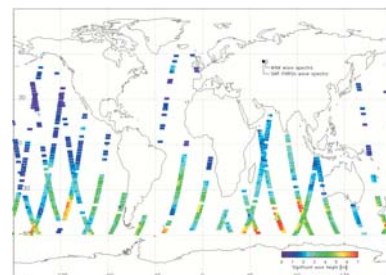
Mean parameters of SAR cross spectra (red) acquired on August 25, 1996, together with collocated WAM cross spectra results (blue).

SAR cross spectra show a slightly longer wavelength (about 15% longer) than WAM forward mapped cross spectra. It has still to be investigated if this is due to an error in the observation, in the forward model, or in the wave model. Wave propagation directions show a high agreement between SAR and WAM.

## Comparison of Ocean Wave Spectra

Cross spectra are inverted by two different algorithms. Best results are retrieved by blending information contained in SAR cross spectra with a priori WAM wave spectra. Results are not independent from WAM ocean wave spectra and the comparison shows very high agreement as expected.

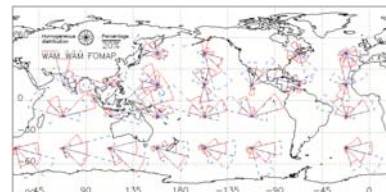
## Significant Wave Height



SAR and collocated WAM ocean wave spectra on August 22, 1996.

Wave heights shows very good agreement in moderate conditions. In storm situations, where strong winds generate high wind seas, SAR wave heights are higher.

## Wave Propagation Direction



WAM FOMAP cross spectra vs. WAM ocean wave spectra. Number per 30° sector in the 45° x 30° grid cells. Clearly visible is the general rotation to range during SAR imaging (also inherent in forward model).

## Summary and Outlook

Results of the ocean wave model WAM were compared to a new ERS-2 SAR wave mode data set of imageries. Different inconsistencies between observation and model were identified and analysed.

The observed SAR and forward mapped WAM cross spectra have a good overall agreement. Besides the presented parameters, there is a reasonable correlation in the spectral energy of cross spectra. Similar high agreement was received in the comparison of inverted SAR ocean wave spectra to WAM model spectra. Again, the wavelengths calculated from SAR wave spectra are slightly longer. Good agreement occurs for wave propagation direction in both cross and ocean wave spectra.

Overall, the investigation showed the high quality of the WAM model as well as of the SAR observation. Now, imageries are available for further investigation as official ESA product for "advanced SAR" (ASAR) wave mode data of the European environmental satellite ENVISAT.

## References

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- Komen, G.J. et al., *Dynamics and Modelling of Ocean Waves*, 554 pp., Cambridge University Press, Cambridge, 1996.
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A CD-ROM containing the complete study with more results and references, as well as access to the whole data set of retrieved parameters together with a small representation program is available from the author: Danielle.Hoja@web.de. Thank you for your interest!