Global Sea State Measurements by ENVISAT ASAR Wave Mode Data

Xiaoming Li, S. Lehner, St. Brusch

German Aerospace Center (DLR), Oberpfaffenhofen
Motivation

Global sea state statistics with SAR wave mode data—Wave Climate

- ERS-2/SAR wave mode data (1995~)
- ENVISAT/ASAR wave mode data (2002~)
- oncoming Sentinel satellite wave mode data

ERS-1/2 UWA spectra

Reprocessed ERS-2/SAR wave mode complex data

Standard ESA ENVISAT product--WVI
Outline

❖ Algorithm development and validation
  ➢ Empirical algorithm (CWave) developed to derive integral ocean wave parameter from ERS without first guess information, (Schulz-Stellenfleth et al)
  ➢ CWAVE_ENV algorithm validation with models and buoy data with two years ASAR global wave mode data, (X.Li et al.)

❖ Global sea state Statistics based on the two months data

❖ Case study
  ➢ Extreme wave height case in NA

❖ Conclusion and outlook
Sea State Parameters – 2D Spectra

- retrieve complete 2d wave spectrum using prior information
  - MPI scheme (power spectra)
  - PARSA scheme (cross spectra)

- retrieve longer waves only using minimum prior information
  - ESA algorithm

Only integral wave parameters, no prior information
- CWAVE model
**CWAVE Algorithm**

**Quadratic Model**

\[ H_s = a_0 + \sum_{i=1}^{N} a_i s_i + \sum_{i=1}^{N} \sum_{j=1}^{N} a_{i,j} s_i s_j \]

The Parameters \( a_0, ..., a_N, a_{1,1}, ..., a_{N,N} \) are fitted using a training data set of ERS-2, ENVISAT wave mode data and colocated ECMWF wave spectra.

\( S_1, ..., S_N \) are N parameters computed from SAR data, e.g., sigma0, spectral parameters.
CWave Algorithm

\[
H_s = a_0 + \sum_{i=1}^{N} a_i s_i + \sum_{i=1}^{N} \sum_{j=1}^{N} a_{i,j} s_i s_j
\]

(\sim 22) \ s_1, \ldots, s_N

The Parameters \(a_0, \ldots, a_N, a_{1,1}, \ldots, a_{N,N}\) are fitted using a training data set of SAR wave mode data and colocated ECMWF wave spectra (\sim 200)
Validation of CWAVE_ENV

- CWAVE_ENV vs. Buoy

Location of Collocated Buoys

Correlation: 0.89
Bias(CWAVE_ENV–BUOY): 0.05m
RMSE: 0.72m
Scatter Index: 0.24
Entries: 1270
Period: 2006/2007 DJFM
vs. ECMWF_WAM -- reanalyzed

- 2D spectra are achieved at 00, 06, 12 and 18 UTC
- spatial resolution 0.5 degree
- 24 direction bins and 30 frequency bins beginning from 0.03452Hz with logarithmic increment of 1.1Hz.
vs. DWD Model-- forecast

- Integral wave parameters given at 00, 06, 12 and 18 UTC
- spatial resolution 0.75 degree

DWD, Th. Bruns
SWH of CWAVE_ENV vs. Second generation wave model in UKMO

Data were provided by Jian-Guo Li from UKMO. UKMO has provided a full year (2006 June~ 2007 May) model results for comparison.
Comparison to RA measurements

Altimeter cross-over measurements of Radar Altimeter
Collocation criteria:
Distance < 100 km
Time < 1 hour

Jan. 01, 2007
Cont. – Comparison to RA measurements

RA: JASON

Correlation: 0.94
Bias(CWAVE_ENV–JASON): -0.13m
RMSE: 0.43m
Scatter Index: 0.13
Entries: 862

RA: GFO

Correlation: 0.93
Bias(CWAVE_ENV–GFO): -0.11m
RMSE: 0.51m
Scatter Index: 0.17
Entries: 1368
Global Maximum Significant Wave Height (CWave 1.0, modified) of Imagettes in 200 km Surrounding

September 1998 - November 2000

From ERS 2
90-Day Zonal Mean Significant Wave Height

Northern Hemisphere

- 90 day global mean
- 45°N - 60°N
- 30°N - 45°N
- 15°N - 30°N
- 0°N - 15°N

Data Source: Remote Sensing Technology Institute
ASAR + RA altimeter – double tracks for storm investigation

Storm on 2007 Feb. 10 at NA
Squares: ASAR    Diamonds: RA-2
Annual (June 2006 ~ May 2007) SWH maps

ASAR wave mode
CWAVE_ENV

Collocated ERA-Interim (reanalysis wave model)
(lon:1.5°, lat:1.5°)

Collocated NOAA Wave model (WW3)
(lon:1.25°, lat:1°)
Seasonal SWH maps (DJF)

ASAR wave mode
CWave_ENV

Collocated ERA-Interim Wave model (WAM)

Collocated NOAA Wave model (WW3)
Cont. – seasonal SWH maps (JJA)

ASAR wave mode
CWave_ENV

Collocated ERA-Interim
Wave model (WAM)

Collocated NOAA
Wave model (WW3)
Conclusion and Outlook

The empirical algorithm CWAVE yields ocean wave measurements with SAR Wave Mode data without first guess information.

CWAVE results have been validated both for ERS and ENVISAT wave mode with scatter index below 24 percent against buoys for significant wave height.

Long time series ERS-2/SAR and ENVISAT/ASAR wave mode data are being processed with the CWAVE algorithm. Wave mode data are available since 19
And thus contribute to global wave climate analyses.

A two year statistical analysis has been performed on ERS data.
Algorithms and Examples published in:

- Li, X.-M.,S. Lehner and Th. Bruns, Ocean Wave Integral Parameter Measurements Using ENVISAT ASAR Wave Mode Data, under submission, 2010