

Global wave model validation using ENVISAT ASAR wave mode data

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Motivation

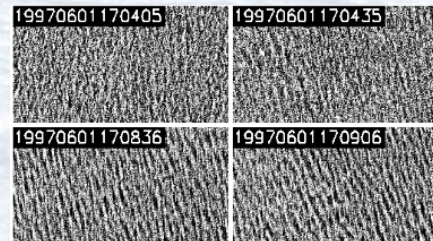
Spaceborne wave observations
used for WAM assimilation and validation

➤ Radar altimeter (RA) products (Topex, Geosat, GFO, Jason, Envisat)

- SWH
- U_{10}

➤ [A]SAR wave mode products (ERS-1, ERS-2, Envisat)

- WVI Imagettes
- WW Ocean wave spectra



➤ New empirical CWAVE_ENV algorithm

- Envisat ASAR-WVI → SWH, T_{m02} , T_{m10}



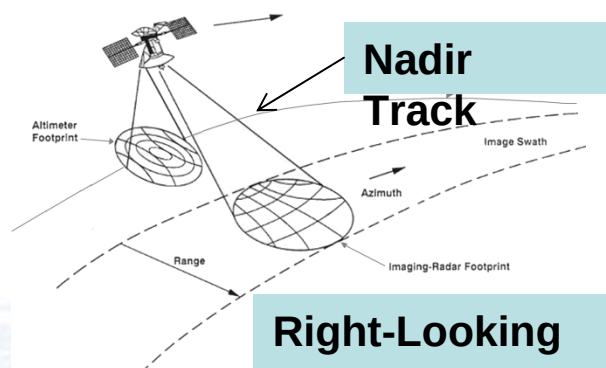
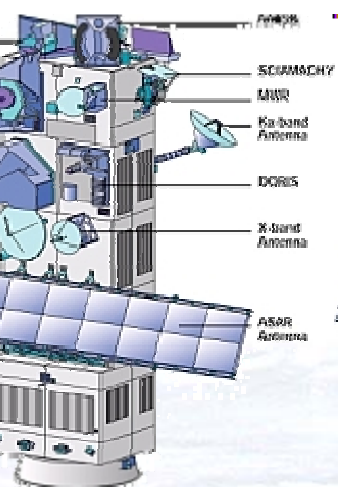
Methodology

- Algorithm development for derivation of integral parameters from ASAR wave mode data.
- Tuning the algorithm using ECMWF re-analyses
- Validation of the empirical model CWAVE_ENV vs. buoy data, altimeter data, wave models
- Validation of DWD wave model under stormy conditions



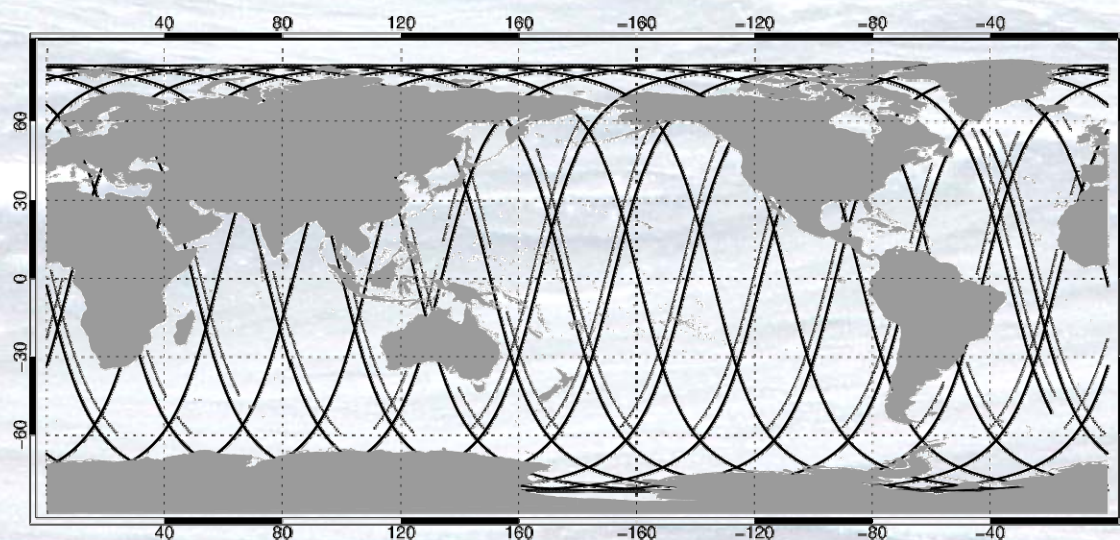
Summary of Conclusions

- CWAVE_ENV provides SWH in high quality
- Accuracy comparable to *in situ* buoy and RA-2 measurements
- For high sea states DWD wave model has large BIAS and RMSE
- Double tracks of ASAR and RA-2 onboard the ENVISAT platform should be used jointly for wave model assimilation and validation

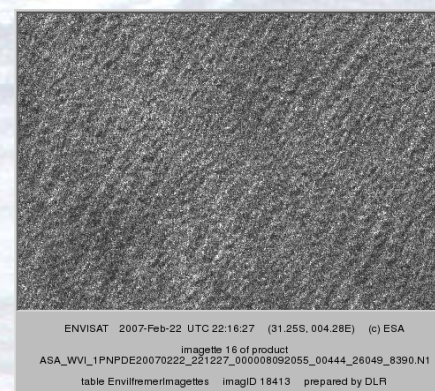


ENVISAT – ASAR + RA-2

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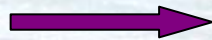
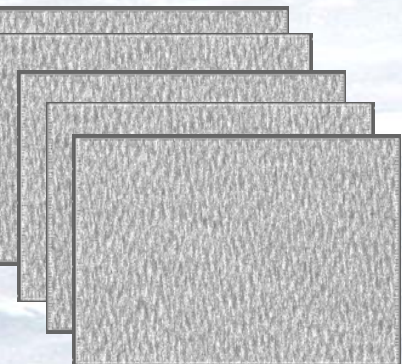
SAR Imagette





Empirical model development (CWAVE_ENV)

- *Multiple Linear Regression*
- *Collocated pairs (Dec 2006) of*
 - ASAR wave mode data
 - ECMWF re-analyses



S_i = ASAR image parameters

W = Integral wave parameters (e.g. SWH, T_{m02})

$$W = a_0 + \sum_{i=1}^{n_s} a_i S_i + \sum_{i=1}^{n_s} \sum_{j=1}^i a_{i,j} S_i S_j$$



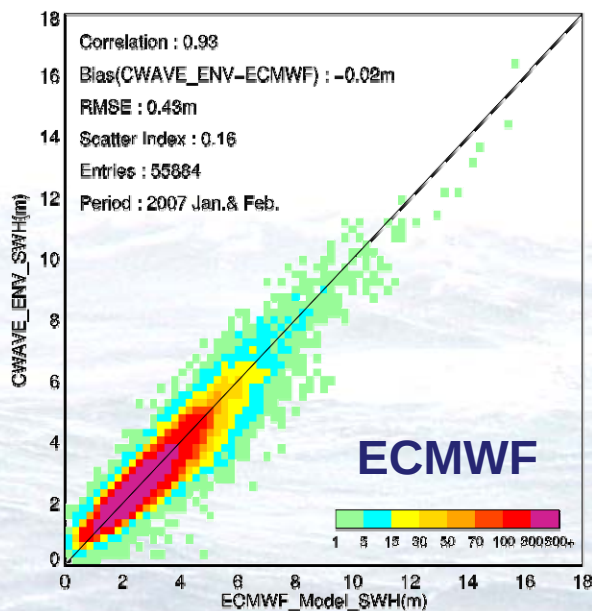
Tuning and Validation of the CWAVE_ENV algorithm

Tuning data		
Model data	Period	Number of collocated data entries
ECMWF re-analyses	2006 Dec	23464

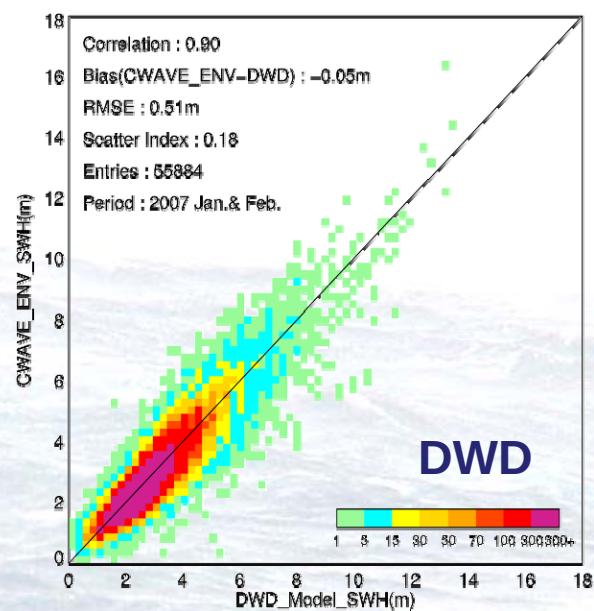
Validation data		
Model data / Measurements	Period	Number of collocated data entries
<i>In situ</i> buoys	2006/2007 DJF+May	1,270
ECMWF re-analyses	2007 Jan&Feb	≈56,000
DWD op. wave model	2007 Jan&Feb	≈56,000
GFO radar altimeter	2007 Jan&Feb	1,368
JASON radar altimeter	2007 Jan&Feb	876



Comparison CWAVE_ENV vs. wave models 2007 Jan&Feb



BIAS -0.02m
RMSE 0.43m



BIAS -0.05m
RMSE 0.51m

ECMWF re-analyses

➤ DWD operational wave model

WAM cycle 4.xx

- WAM cycle 4.yy

1.5° x 1.5°; analyses 00,06,12,18z

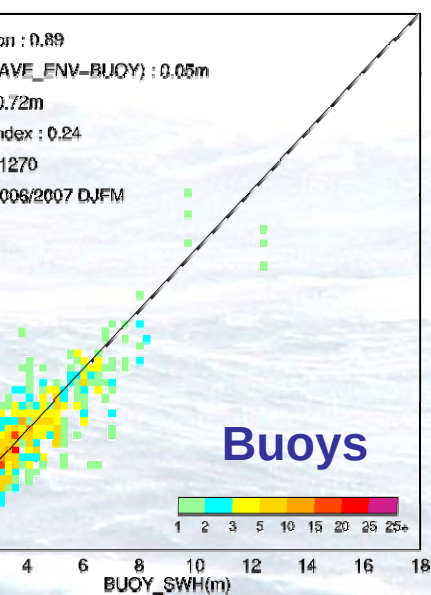
- 0.75° x 0.75°; forecasts T+06,T+12h

assimilation of RA + SAR spectra

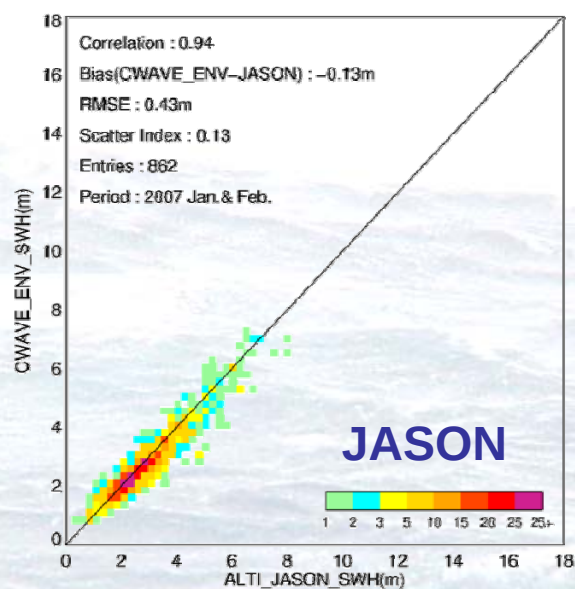
- until 2008 no wave data assimilation



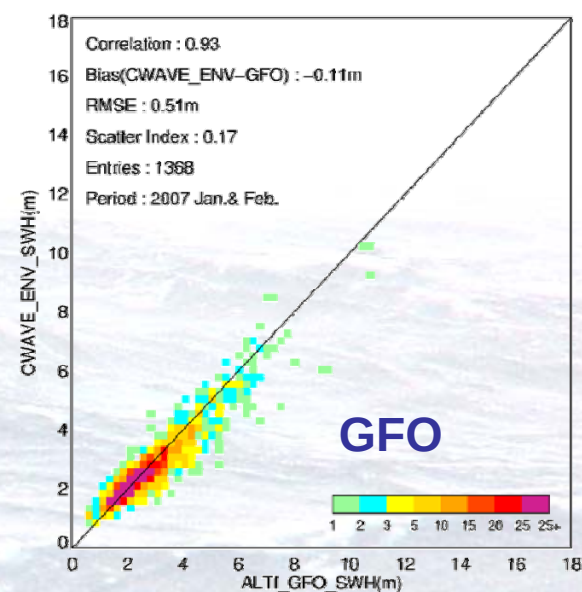
CWAVE_ENV vs. buoys and RA-2



BIAS 0.05m
RMSE 0.72m

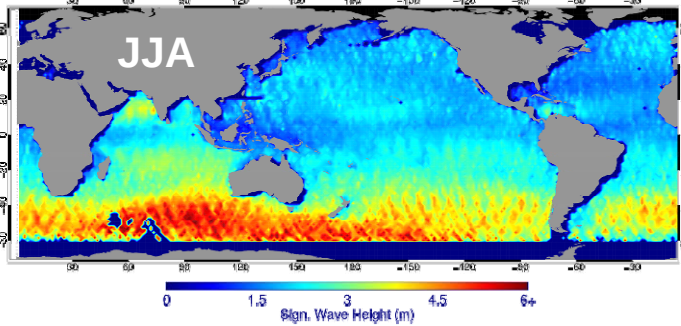


BIAS -0.13m
RMSE 0.43m

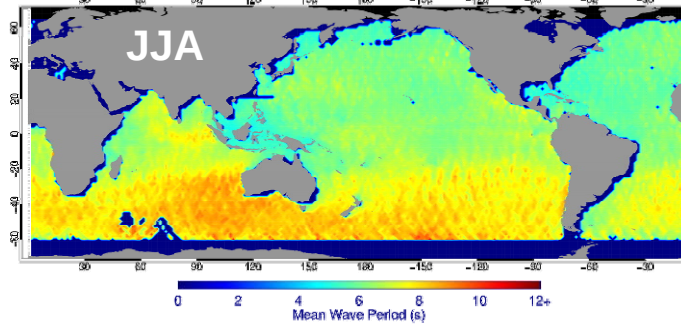


BIAS -0.11m
RMSE 0.51m

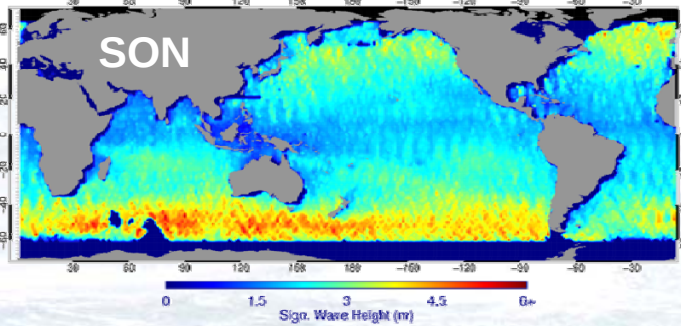
Global Map of Mean SWH derived by CWAVE_ENV from ASAR Wave Mode Data (2006 JJA)



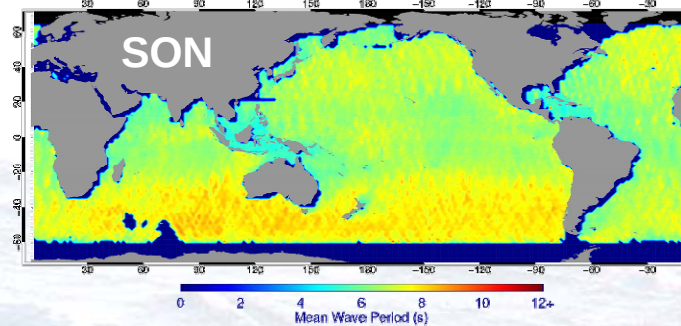
Global Map of Mean T_{m02} derived by CWAVE_ENV from ASAR Wave Mode Data (2006 JJA)



Global Map of Mean SWH derived by CWAVE_ENV from ASAR Wave Mode Data (2006 SON)

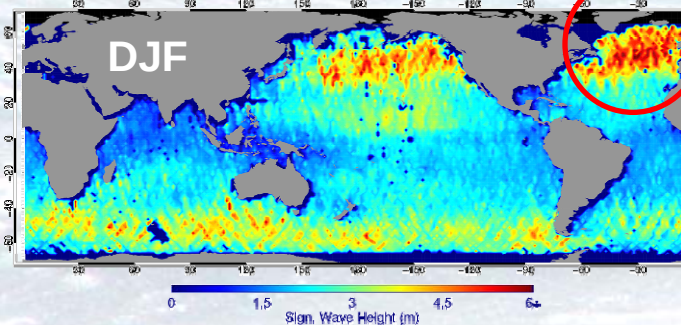


Global Map of Mean T_{m02} derived by CWAVE_ENV from ASAR Wave Mode Data (2006 SON)

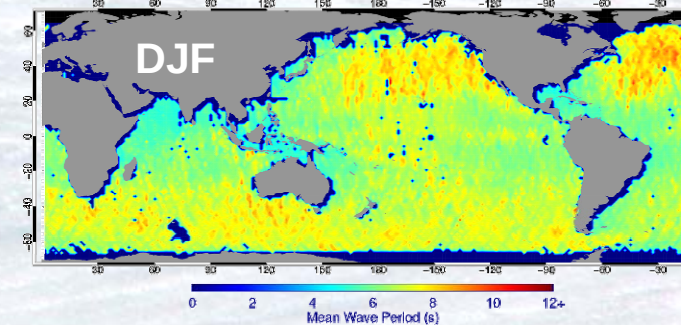


T_{m02}

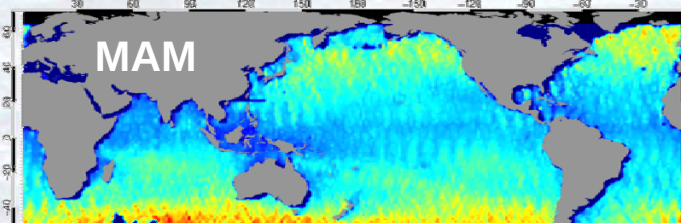
Global Map of Mean SWH derived by CWAVE_ENV from ASAR Wave Mode Data (2006/2007 DJF)



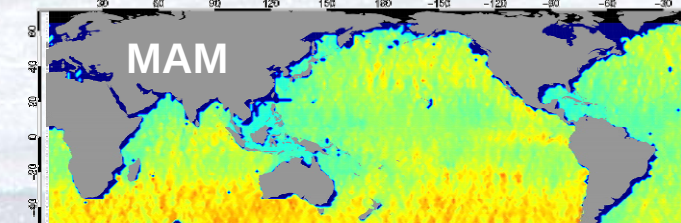
Global Map of Mean T_{m02} derived by CWAVE_ENV from ASAR Wave Mode Data (2006/2007 DJF)



Global Map of Mean SWH derived by CWAVE_ENV from ASAR Wave Mode Data (2006 SON)



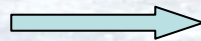
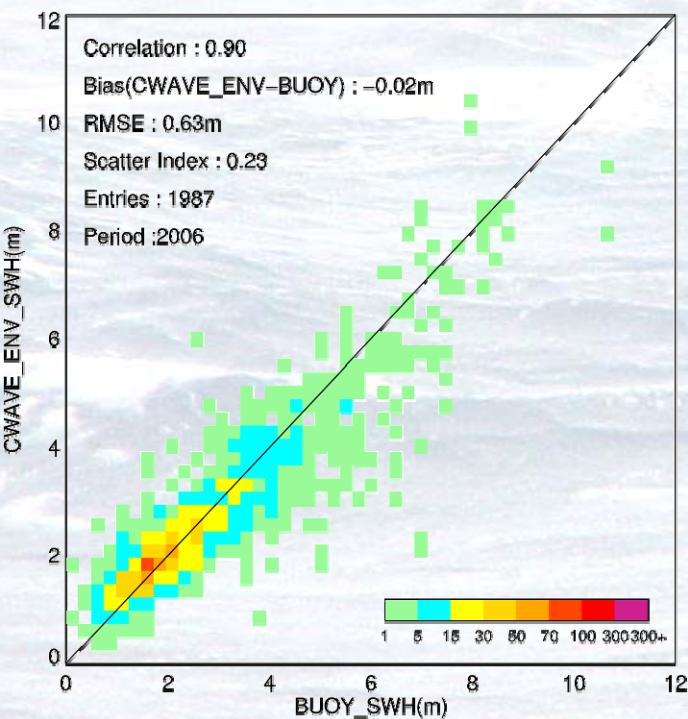
Global Map of Mean T_{m02} derived by CWAVE_ENV from ASAR Wave Mode Data (2007 MAM)





Calibration of CWAVE_ENV using buoy measurements

- One-year collocations (2006 Jan. ~ 2006 Dec.)
- Reducing collocation distance to 100 km, then No. Data pairs is 1987



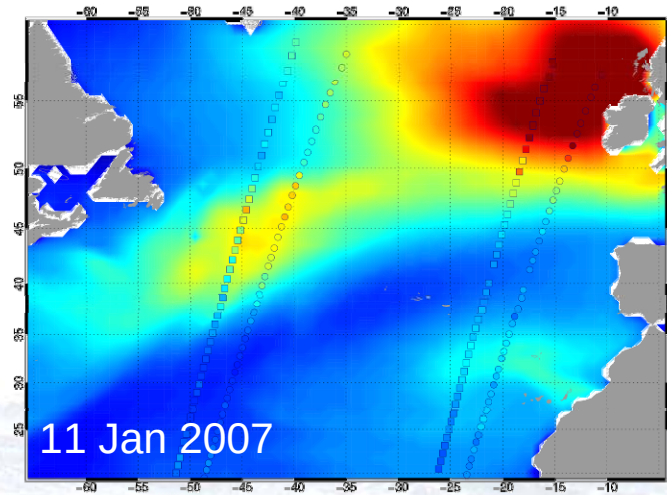
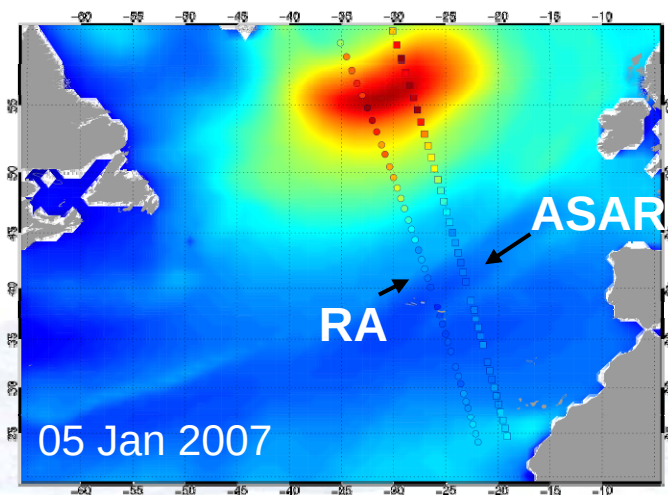
Linear calibration:

$$SWH_{\text{corr}} = a_0 + a_1 * SWH$$

$$a_0 = -0.068 \text{ m}$$

$$a_1 = 1.036$$

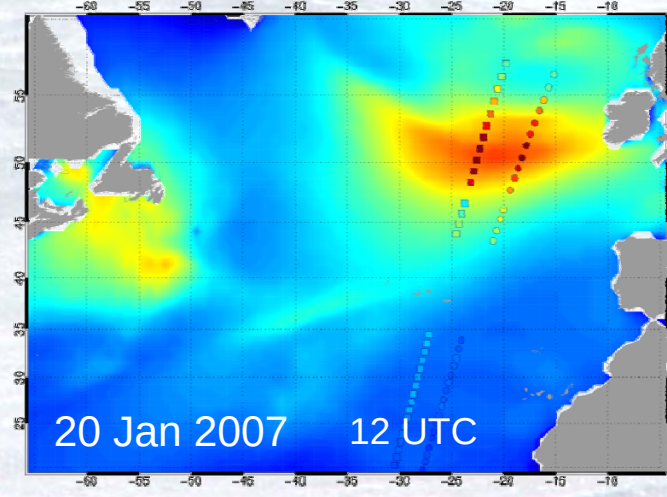
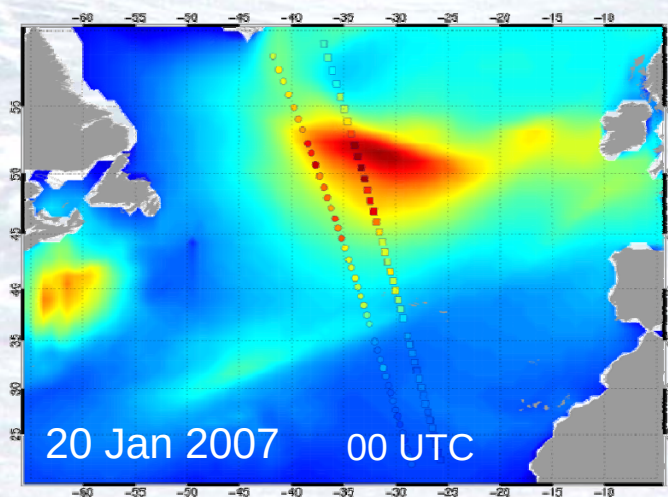
Model validation jointly using ASAR and RA-2 data



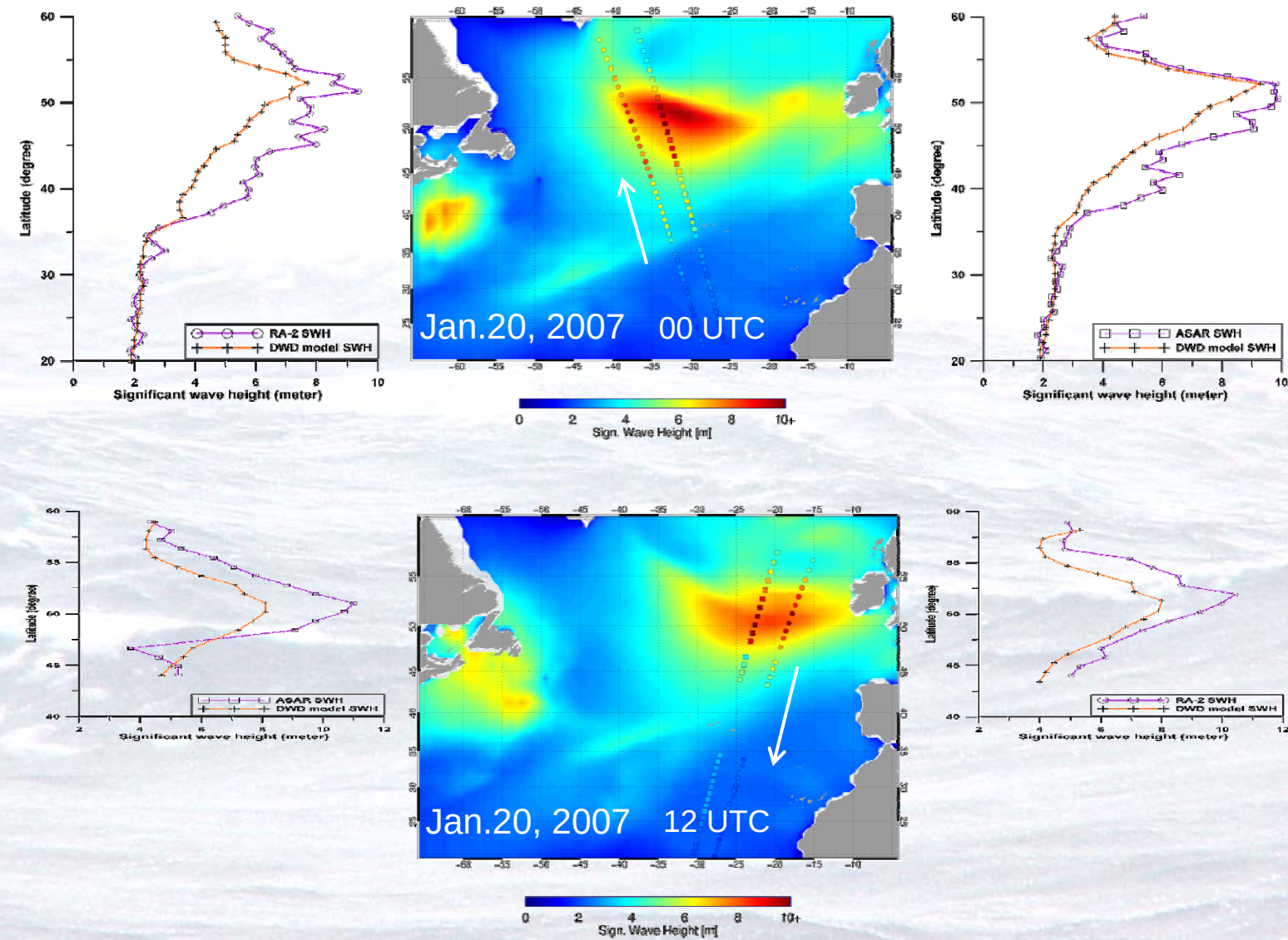
0 2 4 6 8 10+
Sign. Wave Height [m]

DWD model

0 2 4 6 8 10+
Sign. Wave Height [m]



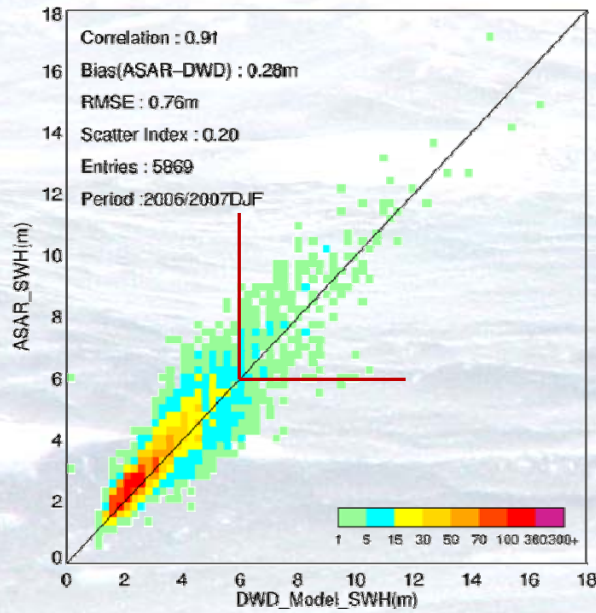
Model validation jointly using ASAR and RA-2 data





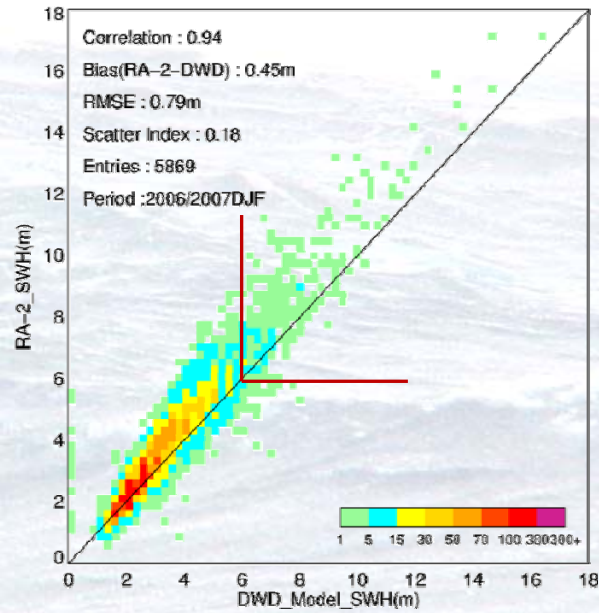
Model validation North Atlantic, DJF 2006/2007 All collocations

DWD vs. ASAR



BIAS 0.28m
RMSE 0.67m

DWD vs. RA-2



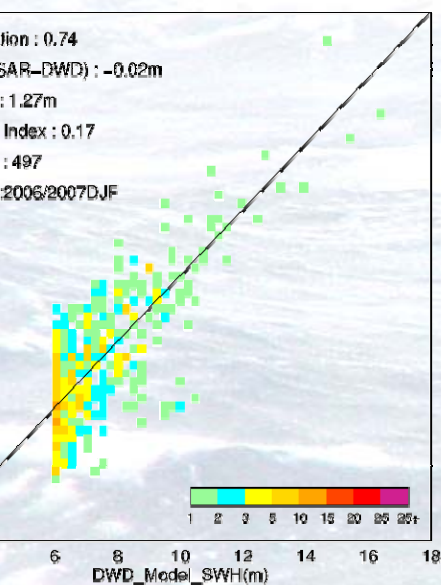
BIAS 0.45m
RMSE 0.79m



Model validation North Atlantic, DJF 2006/2007 Conditional collocations

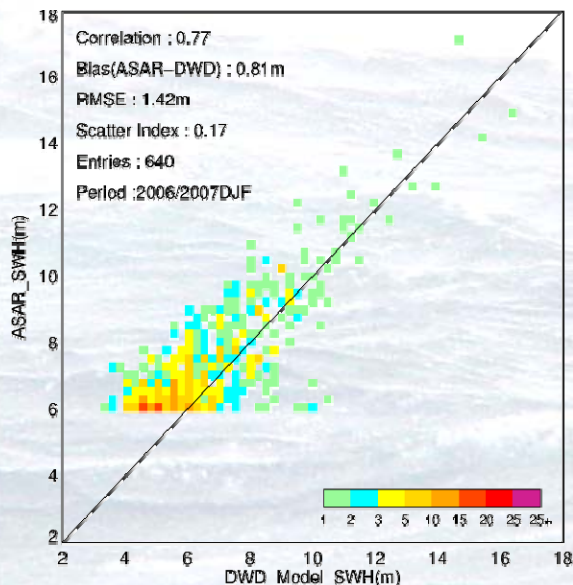
DWD vs. ASAR

DWD SWH > 6m



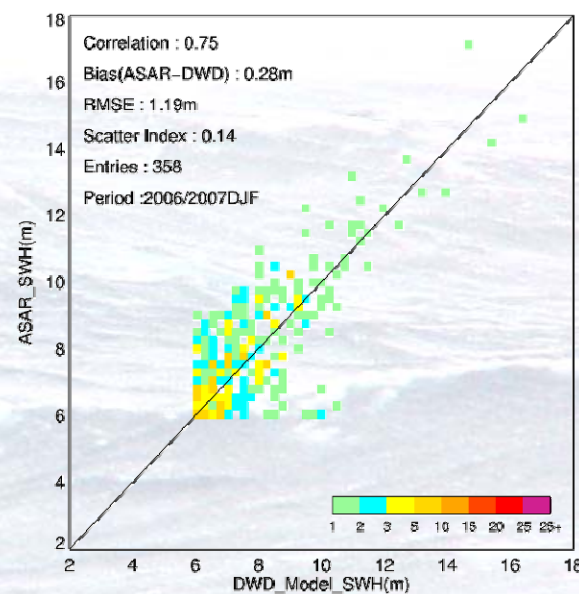
BIAS -0.02m
RMSE 1.27m

ASAR SWH > 6m



BIAS 0.81m
RMSE 1.42m

both SWH > 6m



BIAS 0.28m
RMSE 1.19m

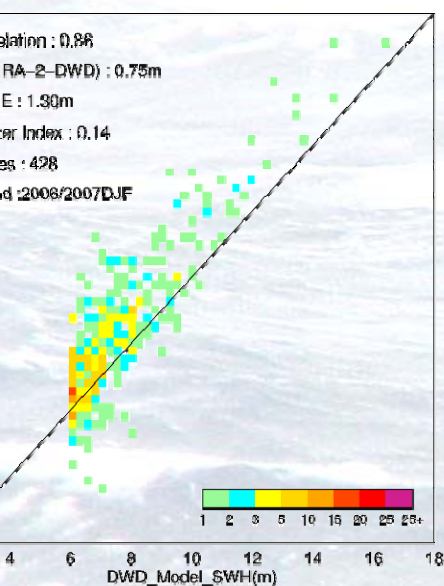


Model validation North Atlantic, DJF 2006/2007

Conditional collocations

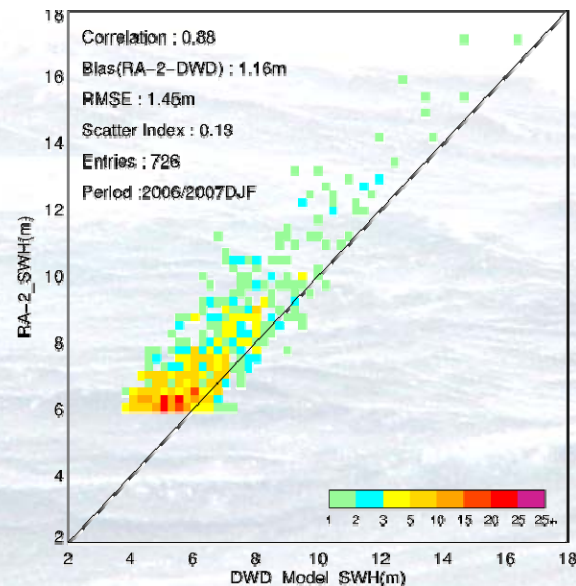
DWD vs. RA-2

DWD SWH > 6m



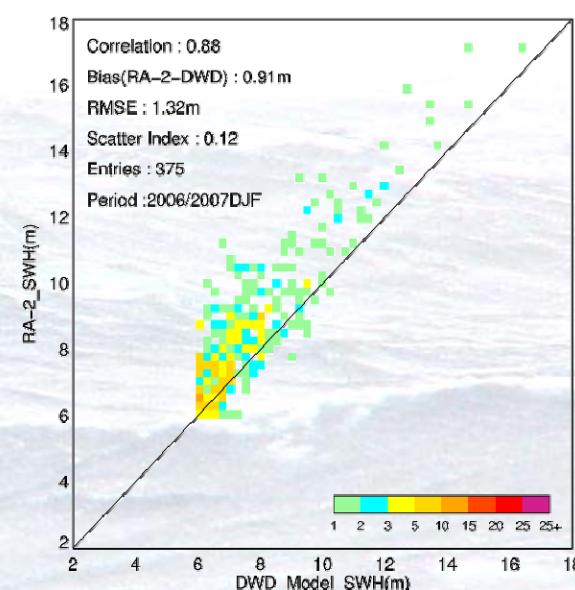
BIAS 0.75m
RMSE 1.30m

RA-2 SWH > 6m



BIAS 1.16m
RMSE 1.45m

both SWH > 6m



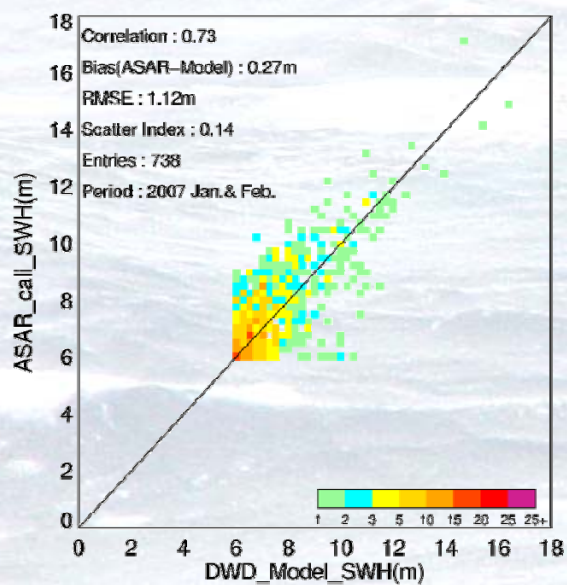
BIAS 0.91m
RMSE 1.32m



Model validation **Global**, Jan&Feb 2007 **Conditional collocations**

DWD vs. ASAR

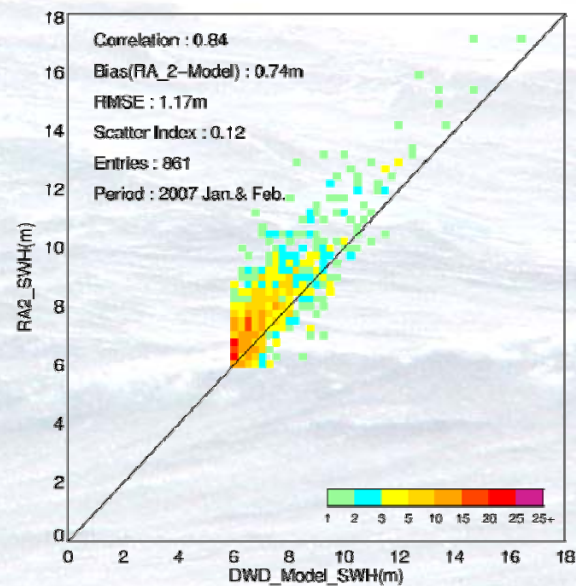
both SWH > 6m



BIAS 0.27m
RMSE 1.12m

DWD vs. RA-2

both SWH > 6m



BIAS 0.74m
RMSE 1.17m



Conclusions and Outlook

- CWAVE_ENV provides SWH in high quality
- Accuracy comparable to *in situ* buoy and RA-2 measurements
- For high sea states DWD wave model has large BIAS and RMSE
- Double tracks of ASAR and RA-2 onboard the ENVISAT platform should be used jointly for wave model assimilation and validation
- Need for an improved assimilation scheme
- ASAR wave mode data since 2003 have to be processed
- Wave model validation to be continued



Thanks for your attention

