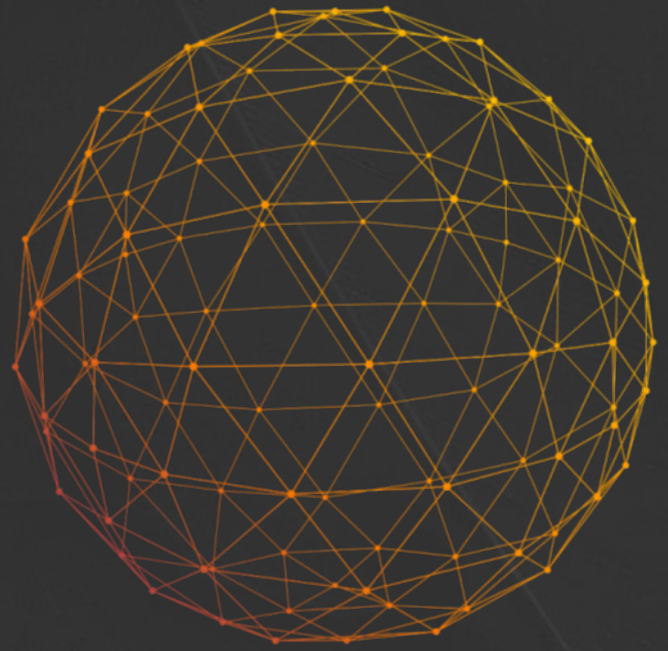


A Global Sea State Dataset by ENIVSAT/ASAR Ten-year Wave Mode Data

Xiao-Ming Li and Bingqing Huang (RADI, CAS)

Alexis Mouche (Ifremer/Cersat)

CONTENTS

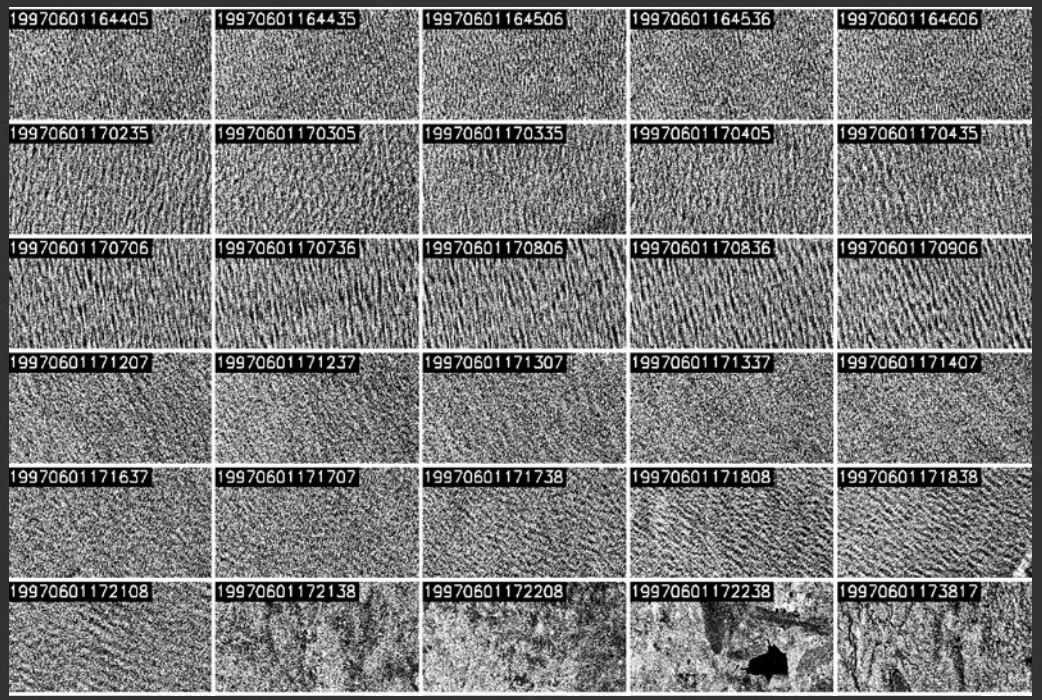
Background

ASAR wave mode dataset, algorithm development

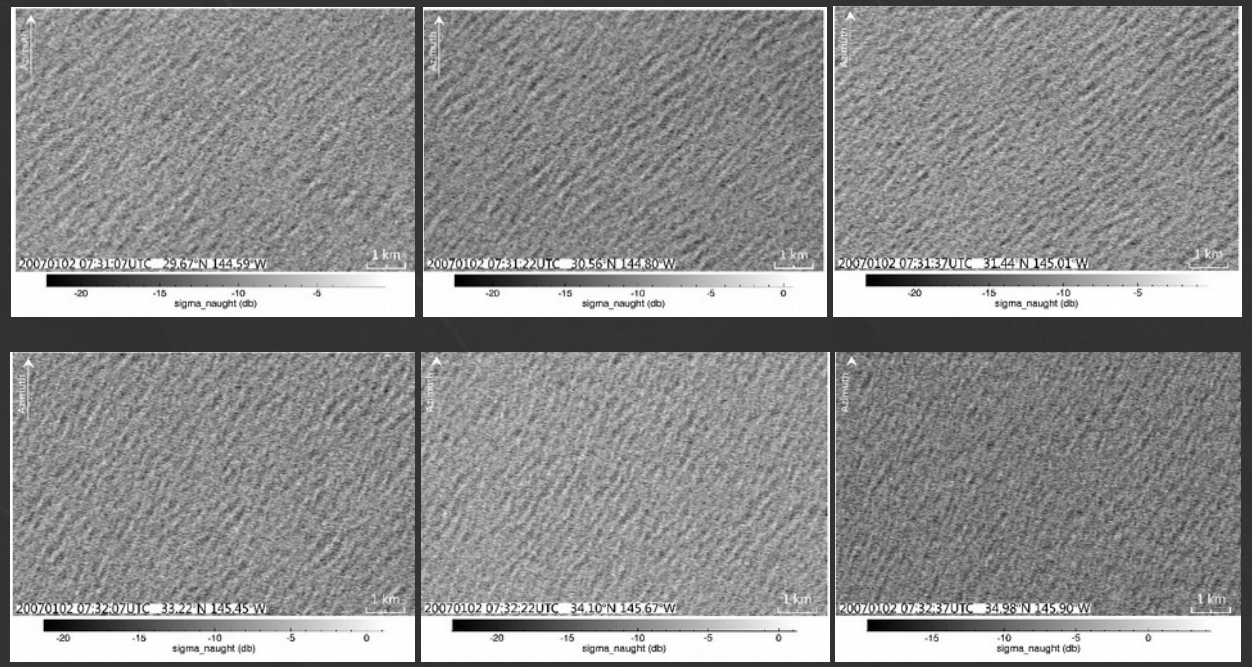
SAR Wave Mode Data

Small SAR images (imagettes) dedicated for global sea state measurement. These imagettes are globally acquired by ESA spaceborne SAR missions since ERS-1(1991), to ERS-2, ENVISAT/ASAR and now Sentinel-1.

ERS-2/SAR WM Imagettes
Not available to users, reprocessed by DLR

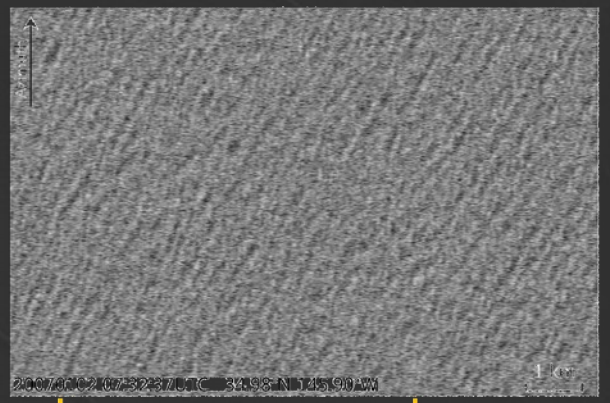


ENVISAT/ASAR WM Imagettes
Available to users, Level b data （ SLC ）



Courtesy by S. Lehner and Th. Koenig

Algorithm development



Inversion

Two-dimensional wave spectrum

Integration

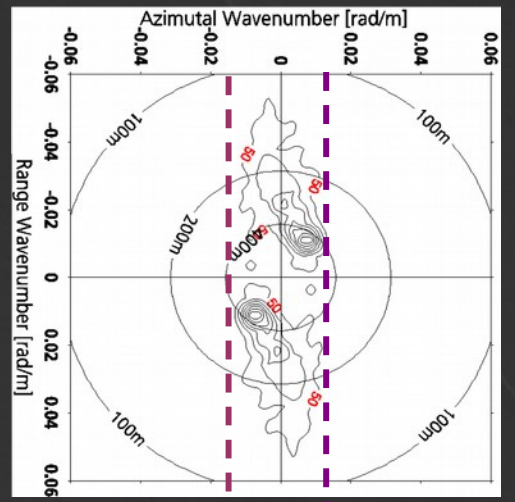
Sea state parameters

Empirical algorithm

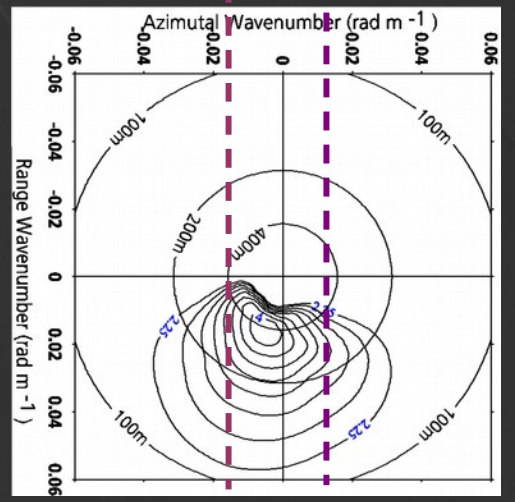
FFT

Non-linear

Quasi-linear



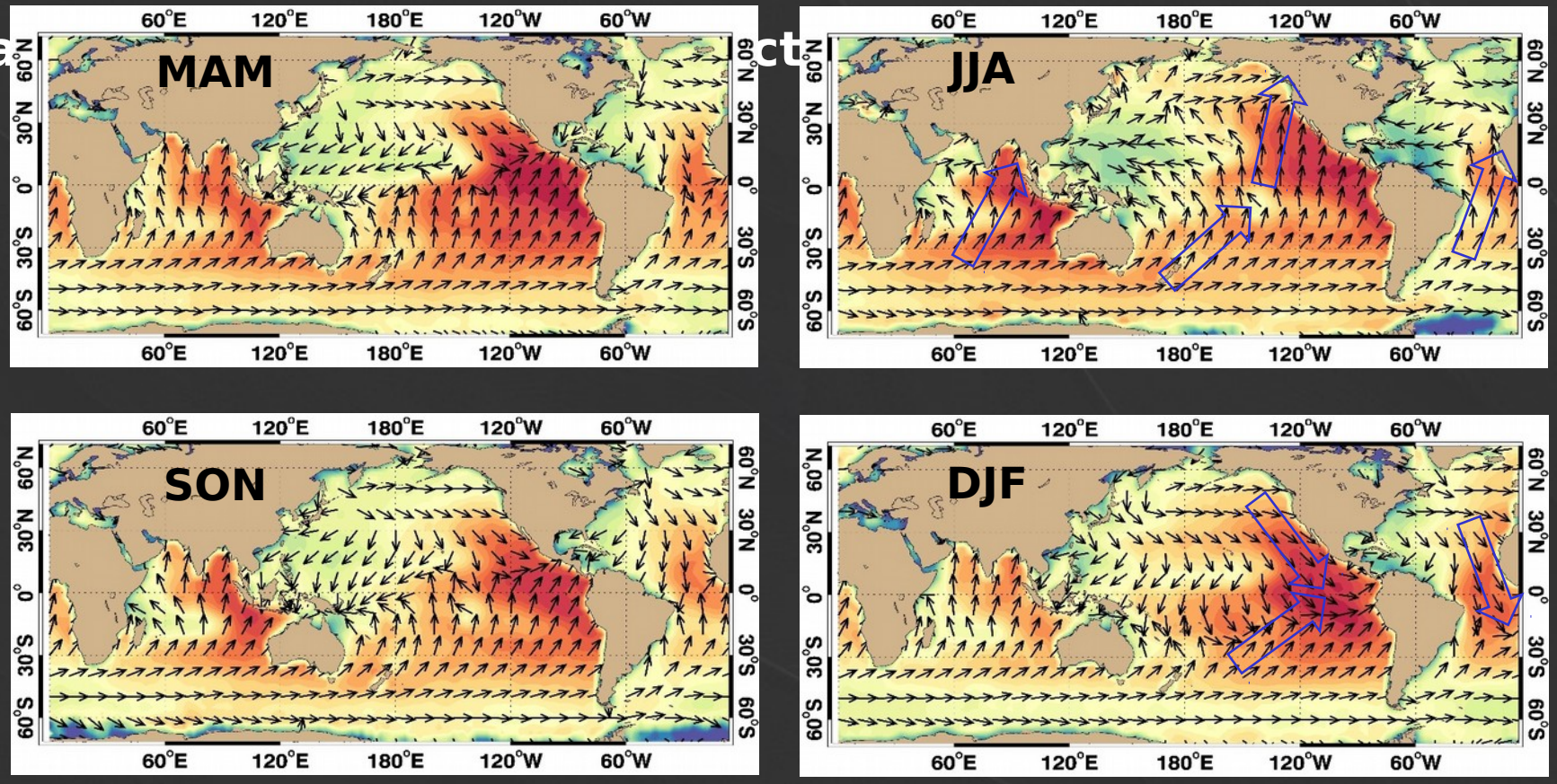
SAR image spectrum



Wave Model Spectrum (First guess)

Algorithm development

Observation of Swell propagation in the global oceans from space based on a ten-year (Oct.2002 – Apr. 2012) ENVISAT/ASAR wave mode data



(Li, 2016, GRL)

Algorithm development - - Empirical algorithm

Tuning data
Wave parameter
W

ASAR
Parameters
S_i

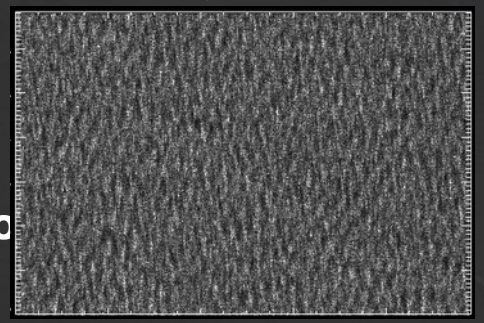
$$J_{cost}(A) = \sum_{j=1}^{N} (W^{(j)} - \sum_{i=1}^{k} A_i S_i^j)^2$$

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

Tuning

Integral Wave Parameters

No prior info
is needed

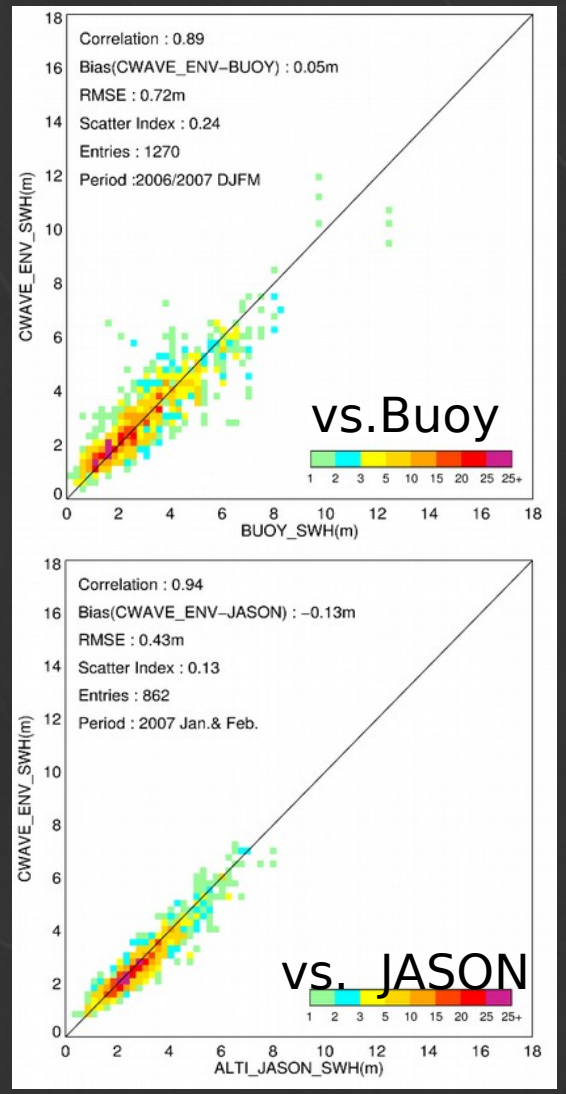


SAR WM data

Implementation

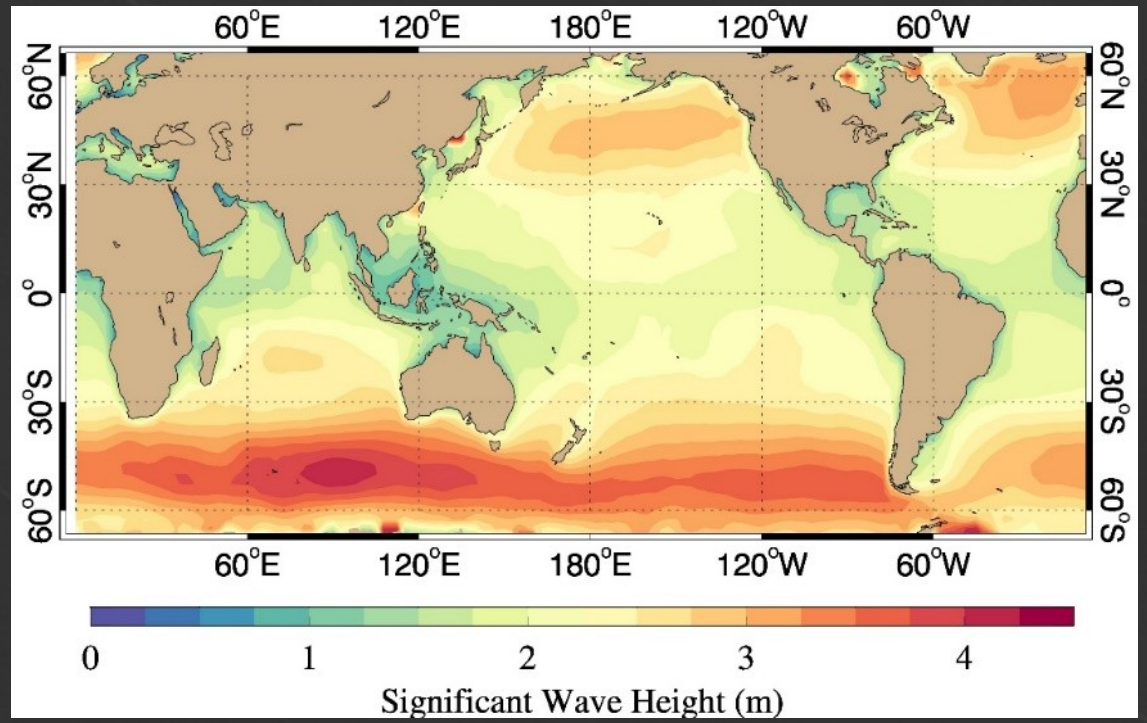
Schulz-Stellenfleth et al., 2007; Li et al., 2011; Stopa and Mouche (2016)

Preliminary validation of CWAVE_ENV

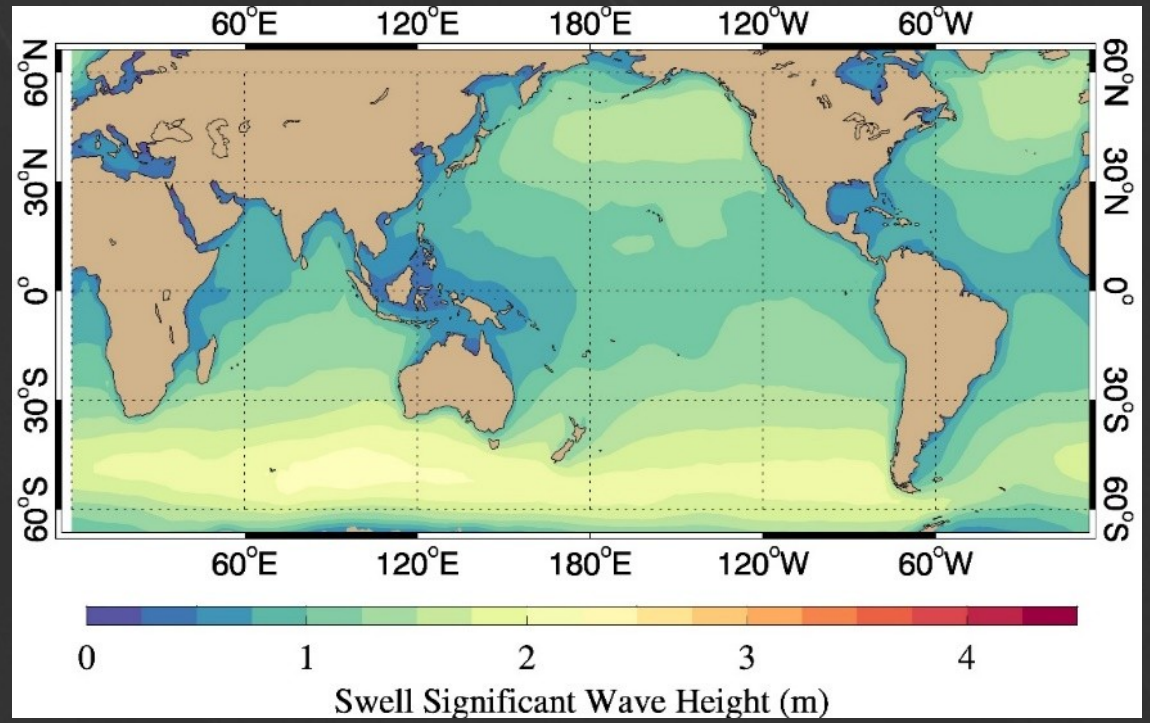


Algorithm development

Mean *sea* and *swell* state based on the ten-year ASAR WM data



Processed by CWAVE_ENV algorithm



Based on ASAR WM level2 product

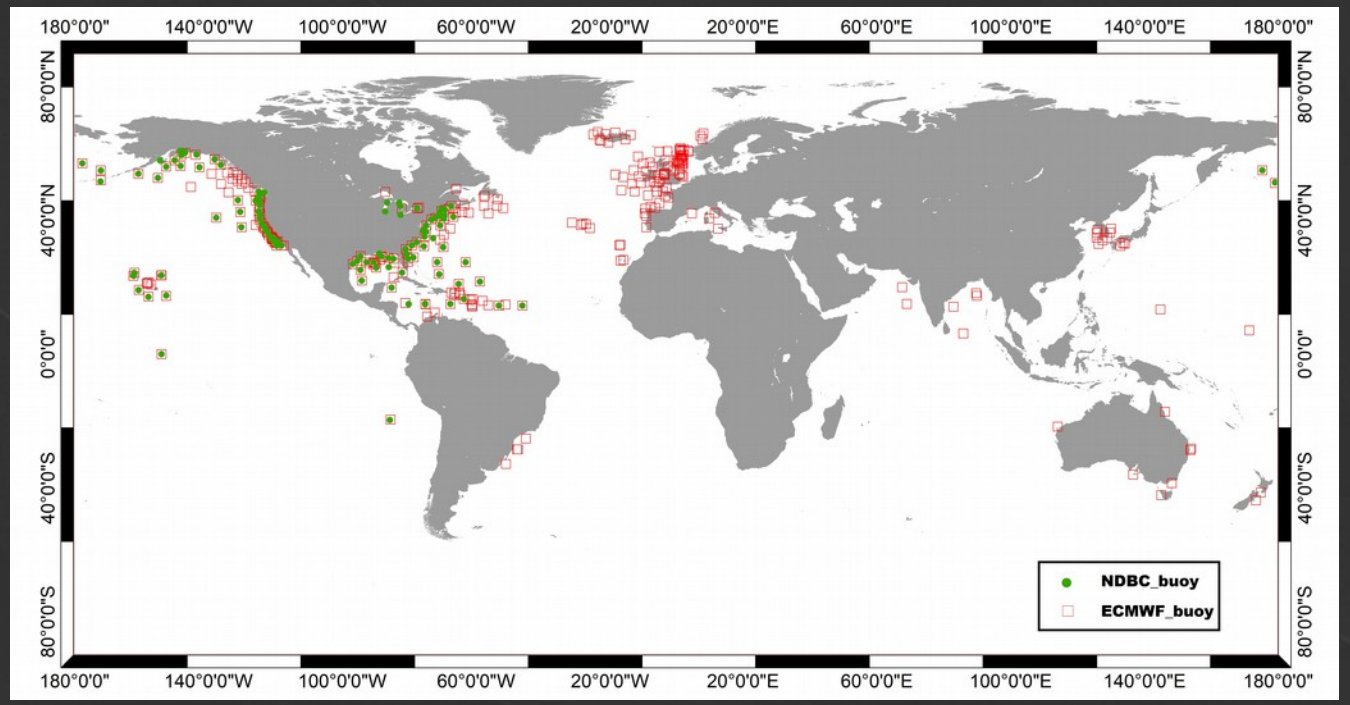
Cal/Val

Processing the ten-year ASAR WM data and their Cal/Val

Vs. Buoy data （Cal.）

Datasets

- CDIP, CETMEF, MEDS, OCEANSITES, NDBC, ECMWF (GlobWave)
- Time Span: Dec. 2002 – Apr. 2012



Collocate criteria

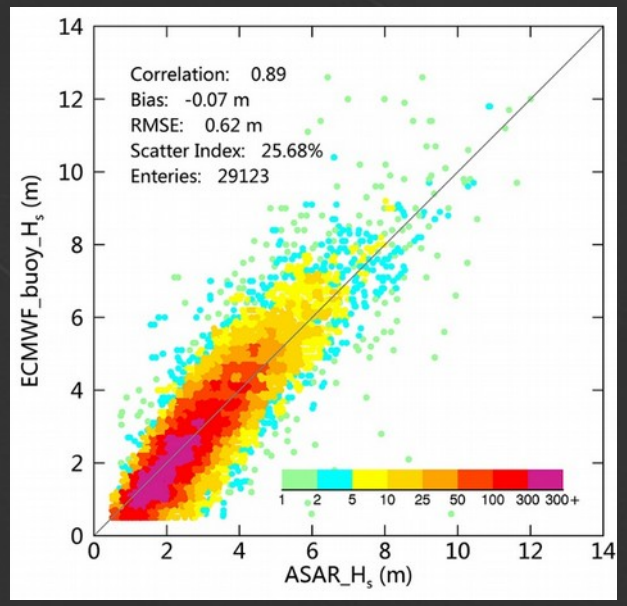
- Space distance: <100 km
- Time difference: <0.5 h
- Range of SWH: [0.5m, 30m]
- Range of MWP: [2s, 20s]
- Homogeneity of image: <1.05

✓✓ **29,123** pairs of SWH collocated with ECMWF buoy data;

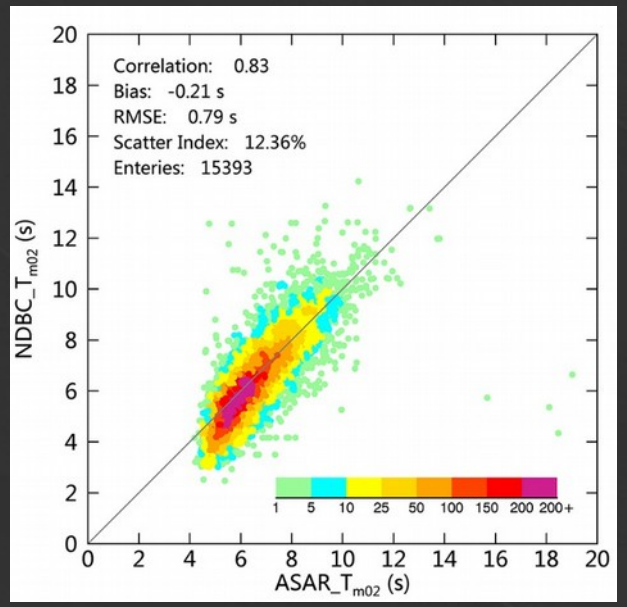
✓✓ **15,393** pairs of MWP (T_{m02}) collocated with NDBC buoy **spectrum** data

Vs. Buoy data

H_s



T_{m02}

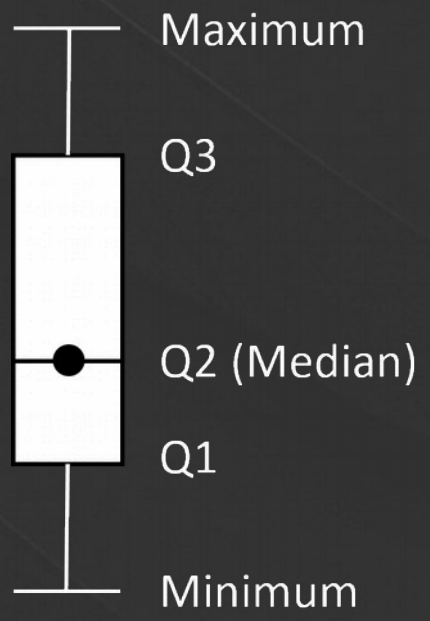


Outliers … …

Vs. Buoy data

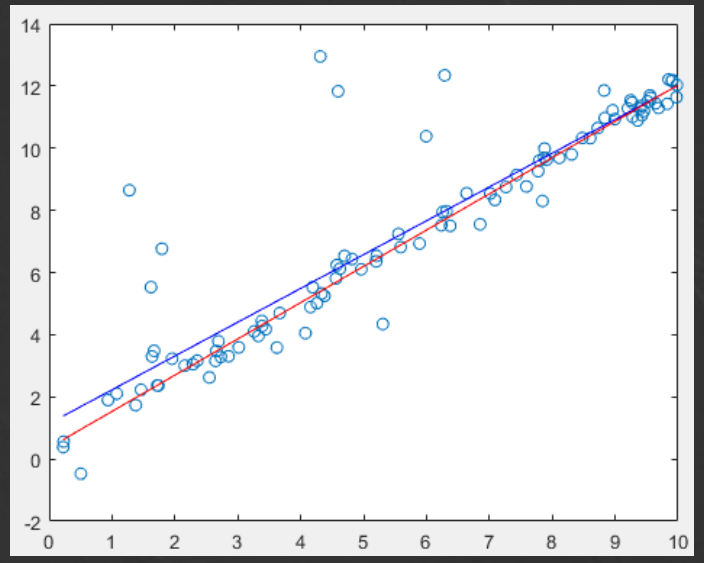
Calibration Method

(1) Quartiles



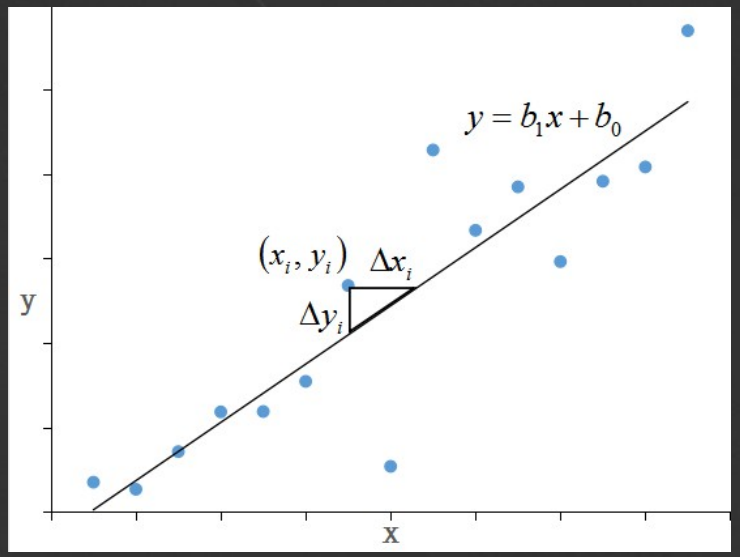
$$\mathrm{IQR} = \mathrm{Q3} - \mathrm{Q1}$$
$$\textbf{lower fence} = \mathrm{Q1} - 1.5\mathrm{IQR}$$
$$\textbf{Upper fence} = \mathrm{Q3} + 1.5\mathrm{IQR}$$

(2) Robust Regression



Robust Regression is not sensitive to outliers, while others (e.g., Ordinary Least Square) are.
Robust regression assigns a weight to each point. The bigger the residual is (outliers), the smaller the weight will be assigned.

(3) RMA calibration



Reduced Major Axis (RMA):

- Errors of variable x and y are both considered
- Minimize the sum of the triangular area $*\Delta x * \Delta y$

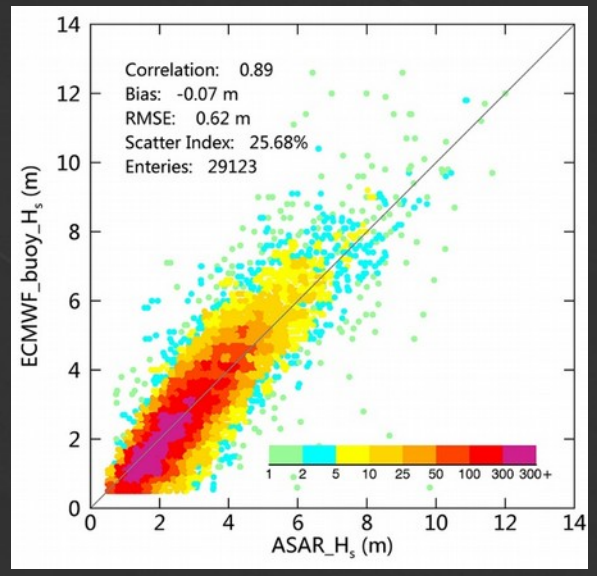
Vs. Buoy data

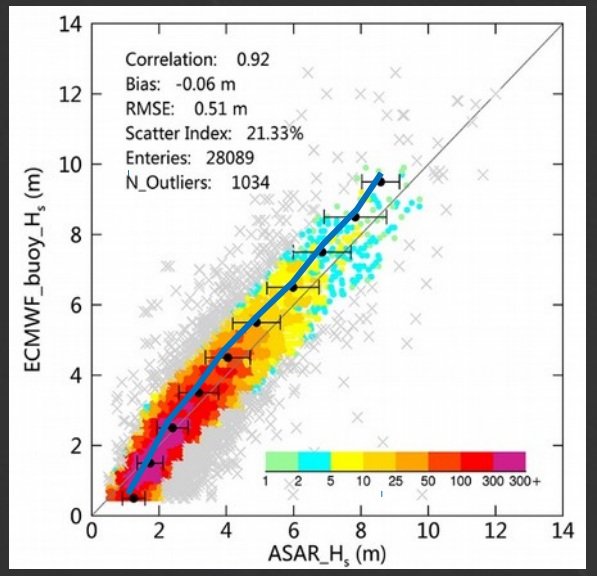
RAW

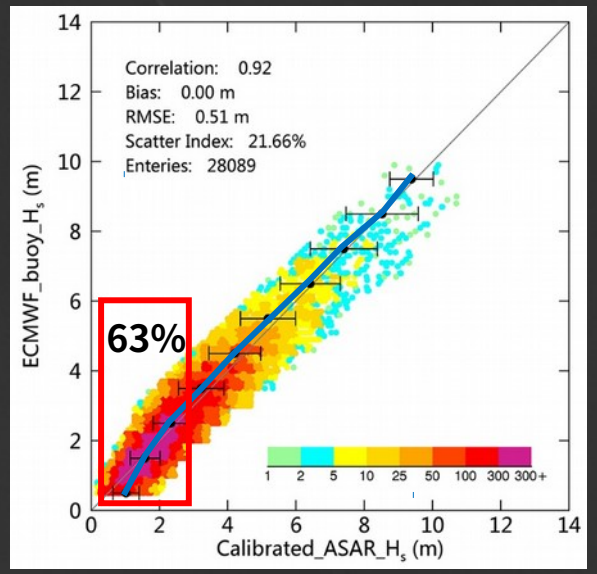
Outliers Detected

Calibrated

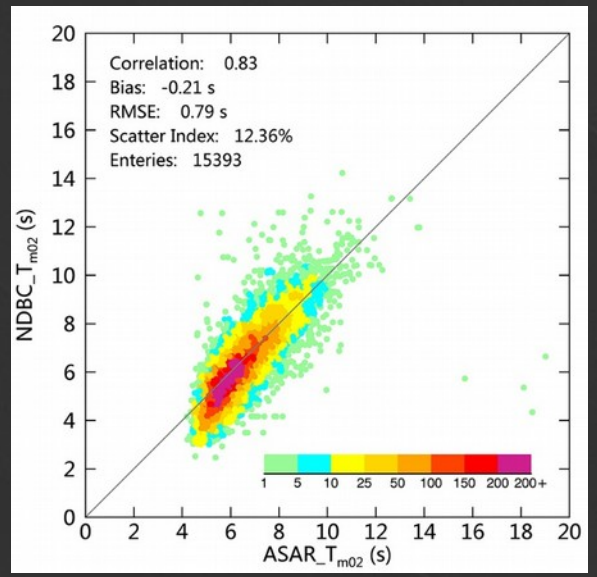
H_s

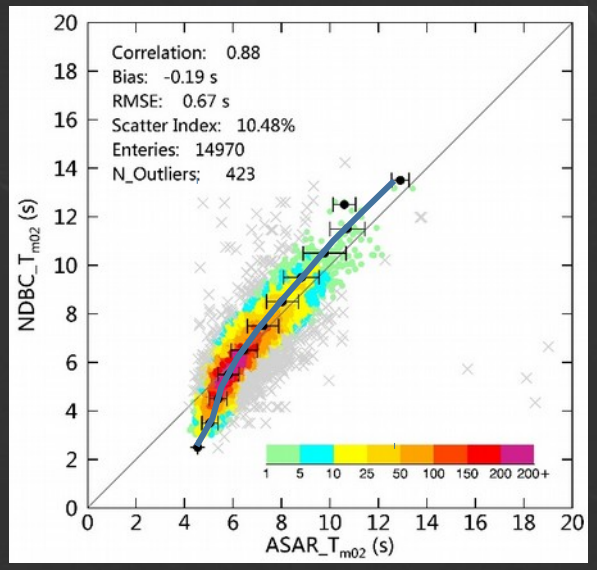


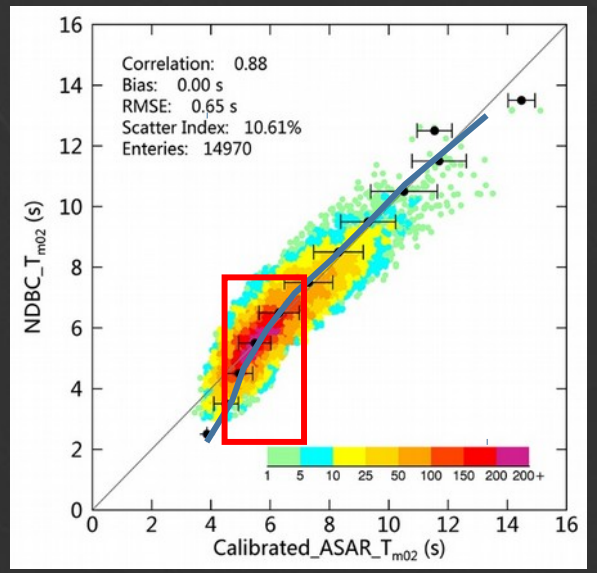




T_{m02}



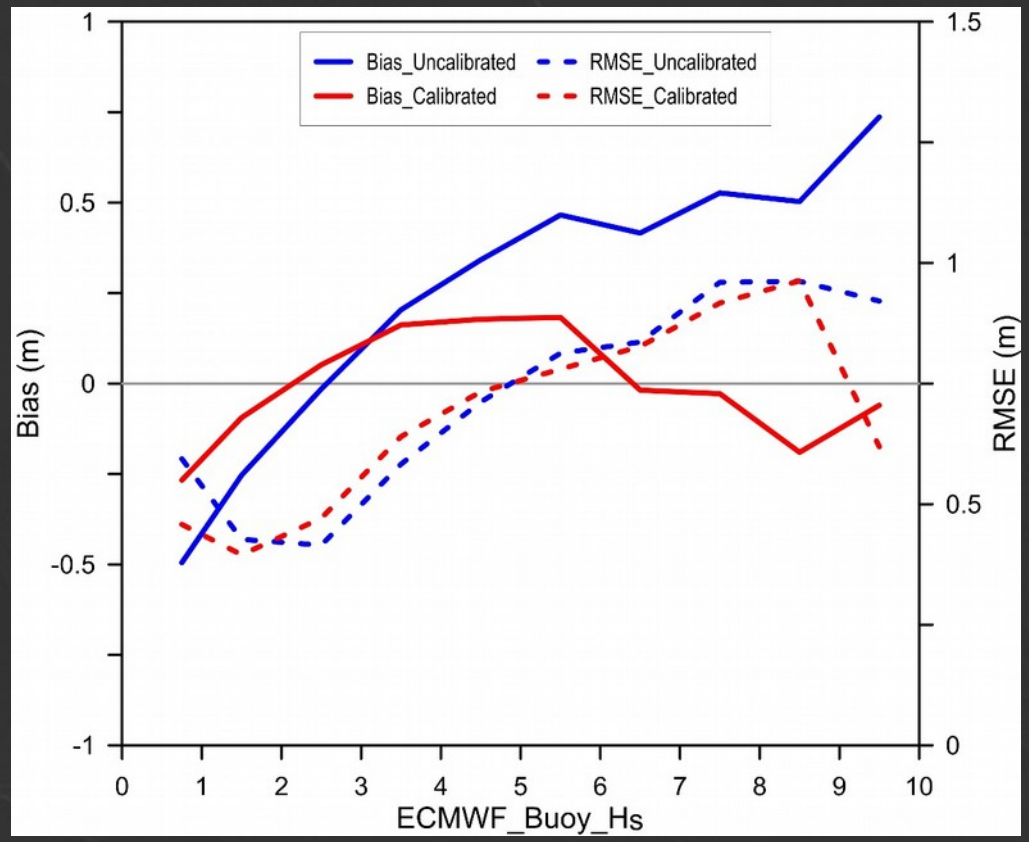




Vs. Buoy data

Comparison along with sea state variations

Range (m)	Bias (m)		RMSE (m)	
	Raw	Calibrated	Raw	Calibrated
0-1	-0.50	-0.27	0.59	0.46
1-2	-0.25	-0.09	0.43	0.39
2-3	-0.02	0.05	0.42	0.47
3-4	0.20	0.16	0.58	0.64
4-5	0.34	0.18	0.71	0.73
5-6	0.47	0.18	0.81	0.78
6-7	0.42	-0.03	0.83	0.83
7-8	0.53	-0.03	0.96	0.92
8-9	0.50	-0.19	0.96	0.96
9-10	0.74	-0.06	0.92	0.62



Vs. RA data (Val.)

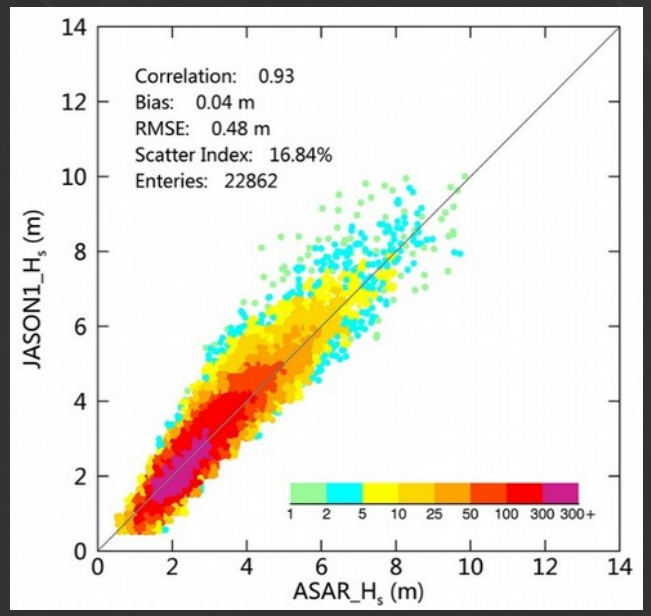
- **Dataset**
  - ✓ Jason-1 Radar Altimeter SWH data (GlobWave)
  - ✓ Time Span: Dec. 2002 – Dec. 2011

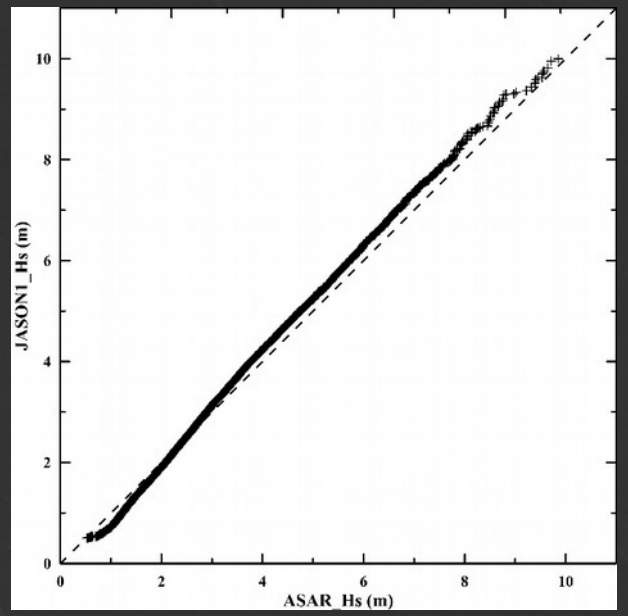
- **Collocate criteria**
  - Space distance: < 100 km
  - Time difference: < 0.5 h
  - Range of SWH: [0.5m, 30m]
  - Homogeneity of image: < 1.05
  - Several RA data may collocated with one SAR data, but only the nearest RA data will be selected;

✓ **22,862** pairs of SWH data were collocated

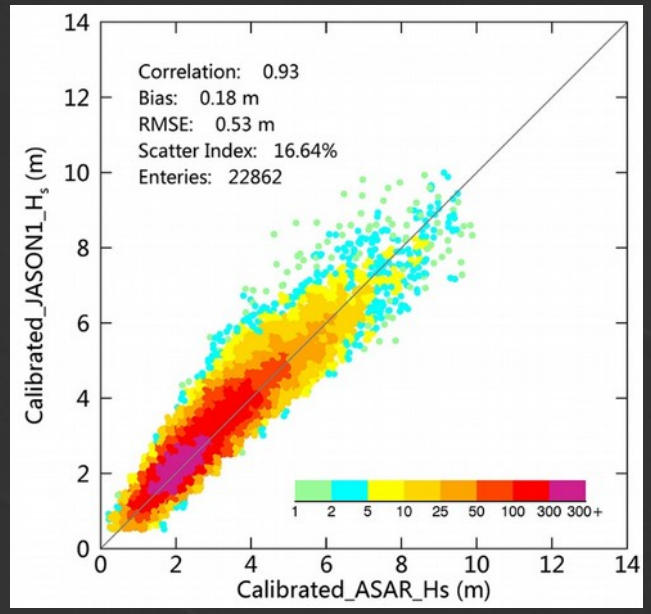
Vs. RA data

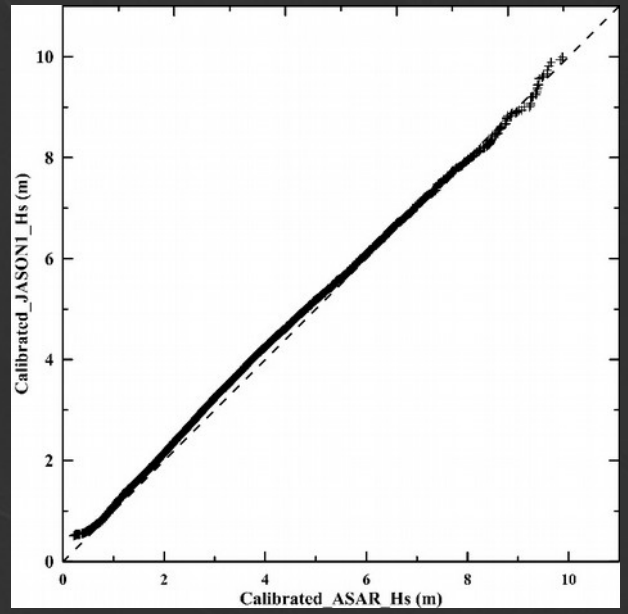
ASAR vs. Jason-1





ASAR_cali vs. Jason-1_cali





Product

Design of the product, format, structure

Product

Product design

- Format: NetCDF-3 format
- Convention: Climate and Forecast Metadata Convention CF-1.7
- Naming:

Satid_Sensor_Type_StartDate_StartTime_EndDate_EndTime_Cycle_Orbit.NC

The naming convention follows the GlobWave Project L2 Product

Product

NC data structure

No.	Variables	Description
1	Time	Seconds since 2000-01-01 00:00:00UTC
2	Latitude	Latitude
3	Longitude	Longitude
4	Heading	Heading of Satellite
5	Inci_angle	Incidence angle in the center of Imagette
6	Homogeneity	Homogeneity parameter of ASAR WVI
7	SWH	Retrieved Significant Wave Height
8	MWP	Retrieved up-crossing zero wave period
9	SWH_Cali	Calibrated significant wave height
10	MWP_Cali	Calibrated Mean Wave Period
11	Rejection_flag	Rejection Flag
12	Land_flag	Land flag (Directly from ASAR WVI Level 1 data)
13	Normalized_variance	Normalized variance of SAR image
14	QC_Flag	Quality Control Flags

Product

Definition of flags

- Rejection_Flag

  0B: accepted
  1B: record on land area
  2B: record on ocean area but homogeneity of image larger than 1.05
  3B: HH polarization (ASAR experimental data)
  4B: incidence angle not equal to 23° (ASAR experimental data with incidence angle of 33°)

- QC_Flag

  Reasonable range of variables (SWH, MWP)
  The normalized image variance ($Normalized\_Variance$)
  The mean sigma naught ($\overline{\sigma_0}$)
  Noise floor (or called Noise Equivalent Sigma Zero, NESZ)

Product

Definition of flags - - QC_Flag

0B (good record)

0 m ≤ SWH ≤ 30m

AND 0 s ≤ MWP ≤ 20 s

AND $Normalized\_Variance$ < 1.6

AND $\overline{\sigma_0}$ - NESZ > 3db

2B (bad record)

SWH < 0 m

OR MWP < 0 s

OR $\overline{\sigma_0}$ - NESZ < 3db

1B (suspect record)

SWH > 30 m or MWP > 20 s

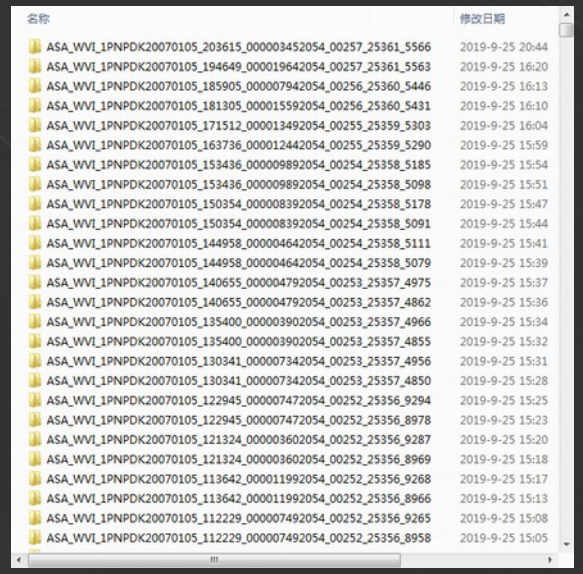
OR $Normalized\_Variance$ > 1.6

$$Normalized\_Variance = \frac{I_{var}\ I_{var}}{I_{mean} * I_{mean} * I_{mean}}$$

3B (unprocessed record)

Rejection_Flag ≠ 0B

Product



WM L1B Product

↓

Read WM L1B data

↓

Radiometric calibration → Imagettes →

↓

CWAVE_ENV retrieval algorithm

↓

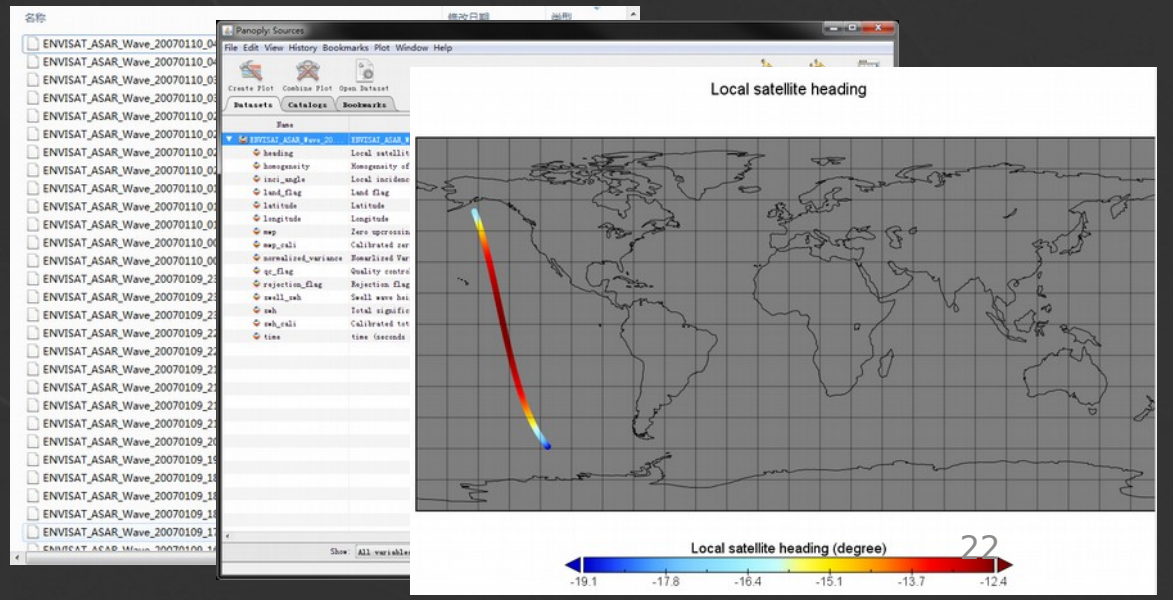
Calibration

↓

Quality control

↓

NC Product →



Summary

Current status, Working plan, acknowledgement

Summary

- ✓ Cal/Val study has been finished. The dataset seems to be in a good quality.
- ✓ We are preparing for producing the whole ASAR WM data to a standard sea state dataset (netcdf format) and the dataset will be published in a publicly accessible repository.
- ✓ The algorithm can be further improved, e.g., machine learning algorithm
- ✓ **Special thanks to**: **Dr. Susanne Lehner** (former DLR employee, retirement), ESA and **Jean-Francois Piolle** (ifremer/Cersat)

MANY THANKS