SARAL/Altika Workshop
New frontiers of altimetry

WIND WAVE STEEPNESS ESTIMATES from SATELLITE ALTIMETRY DATA

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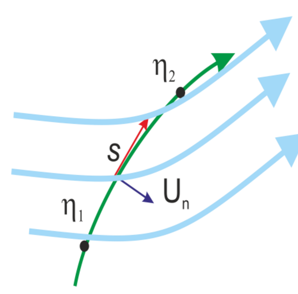
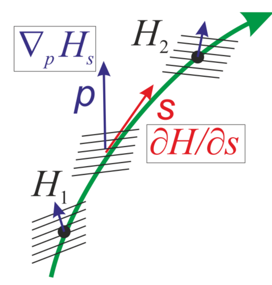
OUTLINES

- **New physical model of sea wave steepness from altimetry data**
- **An approach for the altimeter data processing for retrieving the wave steepness**
- **Modified GlobWave Data Base - options that push the approach ahead**
- **Global Climatology for wave steepness and fluxes as key characteristics of wind-sea coupling**
- **Examples and prospects for the new Ka-band altimeters AltiKa/SARAL data**

The physical models of sea wave steepness and geostrophic currents from altimetry data

Analogies and dissimilarities

Geostrophic currents	*Sea wave steepness from the weak turbulence theory*
Both approaches operate with physical models of natural phenomena, relying upon assumptions and even hypotheses and implying essential limitations to their use *Both models do not rely upon empirical or tuning parameters, i.e. do not require calibration*	
$$fU_n = g\,\partial\eta/\partial s \qquad (2)$$  A velocity component is estimated from the measured component of gradient of SSH	$$\mu = \frac{\alpha_0^{3/5}}{2^{2/5}}\left\|\nabla_p H_s\right\|^{1/5} \approx 0.596\left\|\partial H_s/\partial s\right\|^{1/5} \qquad (1)$$ $\alpha_0 \approx 0.67$ an analogue of the Kolmogorov-Zakharov constant  Wave steepness is underestimated from the measured component of gradient of significant wave height $\partial H_s/\partial s$
The second velocity vector component requires cross-tracking	*Low exponent of the formula (1) reduces the effect of the gradient underestimating dramatically, thus, the cross-tracking is not required*
Linear dependence in (2) makes error analysis to be trivial	*Heavily nonlinear relationship (1) implies dependence of errors on measured magnitudes and options of the sounding (intervals, footprint size etc.)*

How to apply the new method?

From new physical model to new data processing approach

GlobWave altimetry was used as a source. It's well organized data written in NetCDF and one file represents each satellite track. Which is about **10000** files per year for every mission.

```
GW_L2P_ALT_JAS1_GDR_20030101_064924_20030101_074535_036_104.nc
GW_L2P_ALT_JAS1_GDR_20030101_074536_20030101_084146_036_105.nc
GW_L2P_ALT_JAS1_GDR_20030101_084157_20030101_093800_036_106.nc
GW_L2P_ALT_JAS1_GDR_20030101_093801_20030101_103413_036_107.nc
GW_L2P_ALT_JAS1_GDR_20030101_103415_20030101_113027_036_108.nc
GW_L2P_ALT_JAS1_GDR_20030101_113028_20030101_122634_036_109.nc
…
Jason1: 9096 files for 2003
```

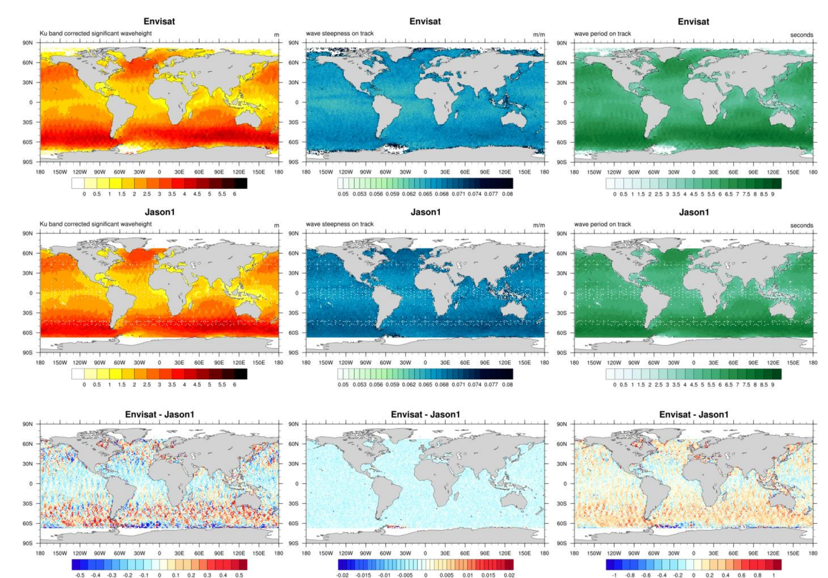
We removed a few variables we don't need, inserted some new parameters (period, steepness, gradient of SWH along the track). And also the tracks were merged yearly.

```
Jason1_2003.nc
Jason1: just 1 file for 2003
```

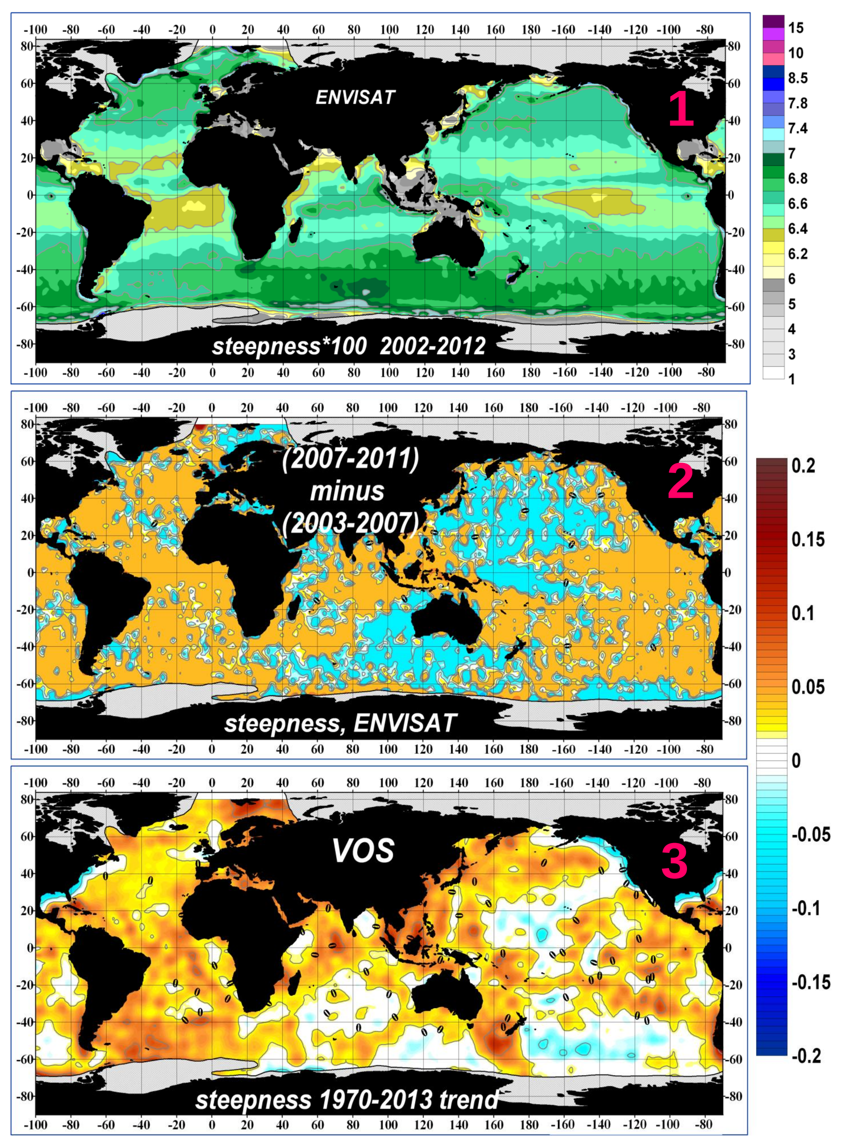
Written in NetCDF. The size of each file is about 1Gb.

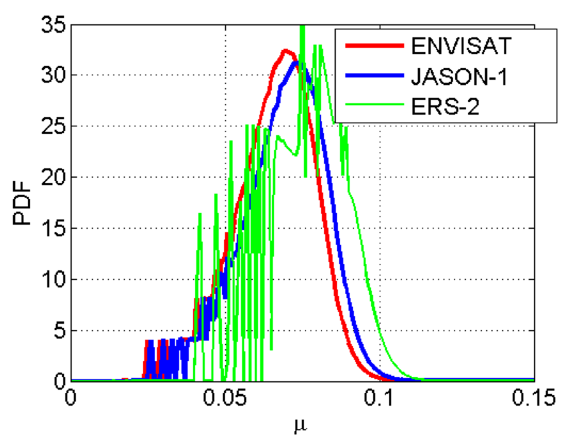
Advantages of the modified GlobWave:

- Processing a large file is much faster than a large number of small files
- There are no more gaps between tracks – since measurements occur continuously, the result of a merger is a continuous vector of variables for the year



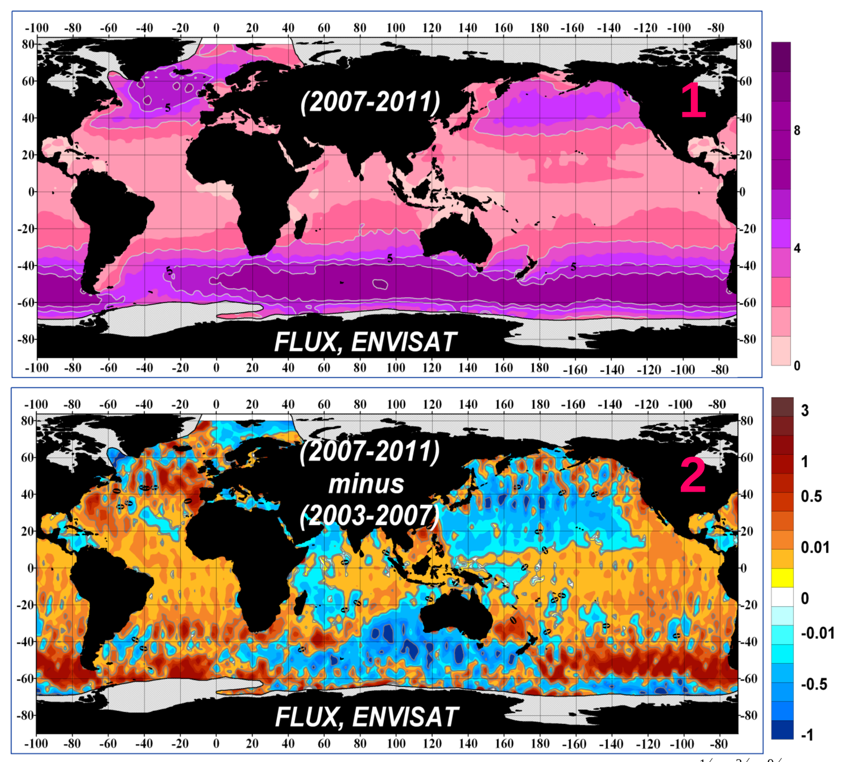
Global Climatology of wave steepness – wind-sea coupling Climatology





Probability Density Functions for the global distribution of wave steepness, satellites are in legend

(1) Steepness distribution for ENVISAT
(2) Changes of the distribution for the periods (2003-2007) - (2007-2011)
(3) long term trends of wave steepness from the Voluntary Observing Ship data

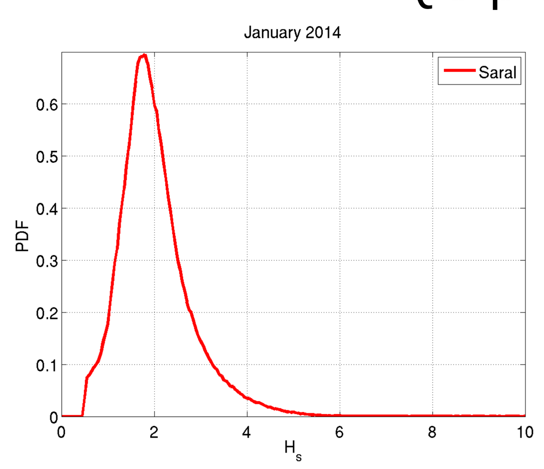


Net wind input to waves $\frac{dE}{dt} = \frac{C_\beta E^4 \omega_p^5}{g^4} = \frac{\pi C_\beta H_s^2 \mu^4}{8T_p} = \frac{C_H g^{1/2} H_s^{1/2} \mu^{9/2}}{\pi}$

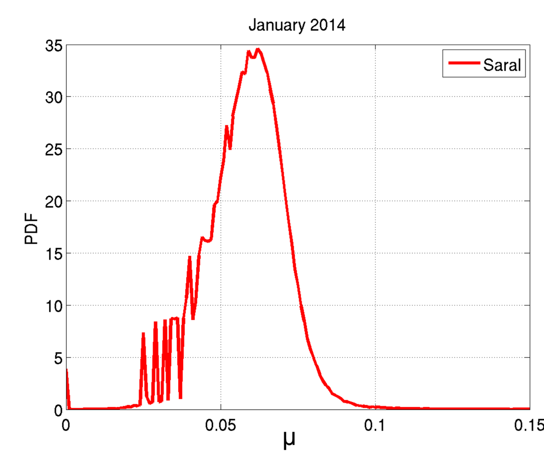
based on physical model of sea wave steepness (1) and its difference (2) between periods (2003-2007) - (2007-2011)

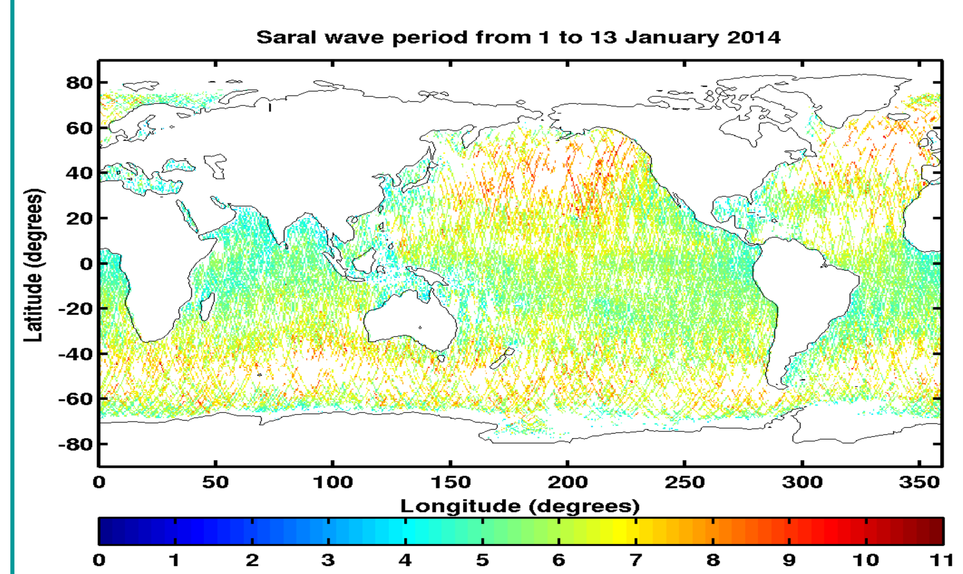
APPLICATION to SARAL/AltiKa DATA

1-month (January 2014) of OGDR SARAL/Altika wave data are used in this study. QC procedures were applied to remove corrupted wave data



Probability Density Functions for the global distributions of significant wave height (left panel) and wave steepness (right panel) from SARAL/AltiKa





An important outcome of the proposed model – the formula for wave period:

$$T_p = 2^{1/5}\pi\alpha_0^{-3/10}\sqrt{H_s/g}\,\left|\nabla_p H_s\right|^{-1/10}$$

Global wave periods derived from SARAL/AltiKa data (1 cycle, 1-13 January 2014)

The preliminary results on steepness and wave periods within the new model for Ku-band altimeters (Envisat, Jason-1,2 etc.) and Ka-band (AltiKa) are quite close quantitatively.

Can we consider the new model as a universal tool?

CONLUSIONS

- A new approach to processing satellite altimeter data is proposed where sea wave steepness is estimated from variations of measured wave height along the satellite track
- Inherent nonlinearity of the model implies both problems (effect of scales and options on errors) and solutions (high immunity to measurement errors)
- New options for optimizing altimetry data processing are proposed
- Sea wave steepness climatology is sketched as one reflecting wind-sea coupling on global scales
- Pilot results for SARAL/AltiKa mission prove the approach validity as a universal tool of sea wave physics from altimetry data

References

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[3] Badulin, S. I., Pushkarev, A. N., Resio, D. & Zakharov, V. E. 2005 Self-similarity of wind-driven seas. *Nonl. Proc. Geophys.* 12, 891–946.
[4] Aouf L., J-M. Lefevre. On the impact of the assimilation of SARAL/Altika wave data on the operational wave model MFWAM. Accepted in *Marine Geodesy Journal.*

Acknowledgments

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