Altika cloud liquid water /rain flag validation

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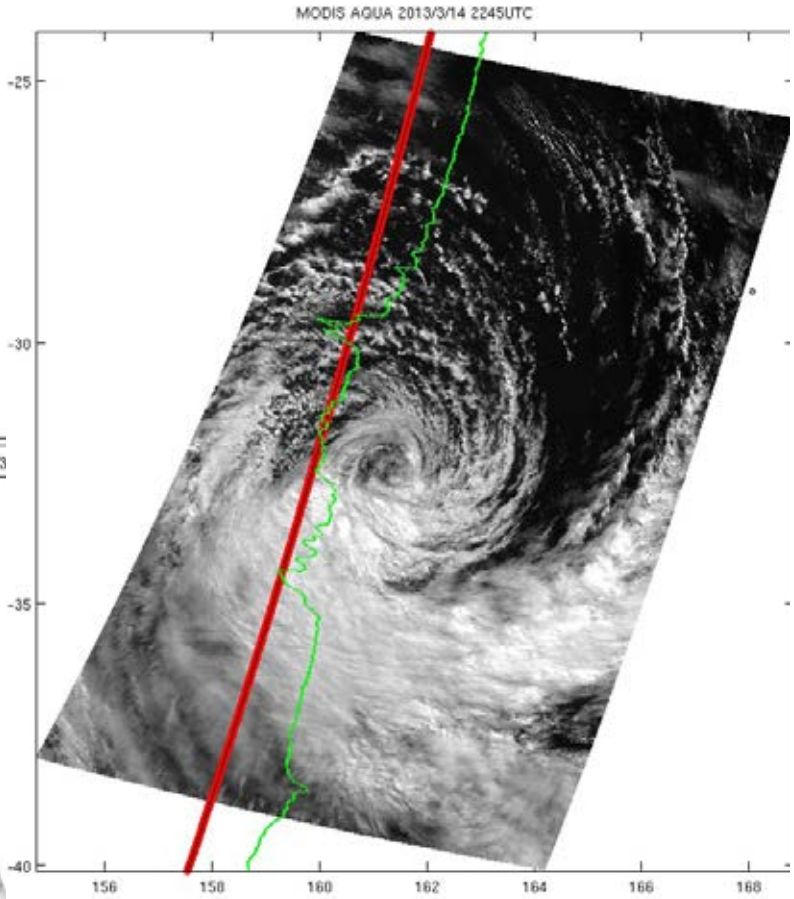
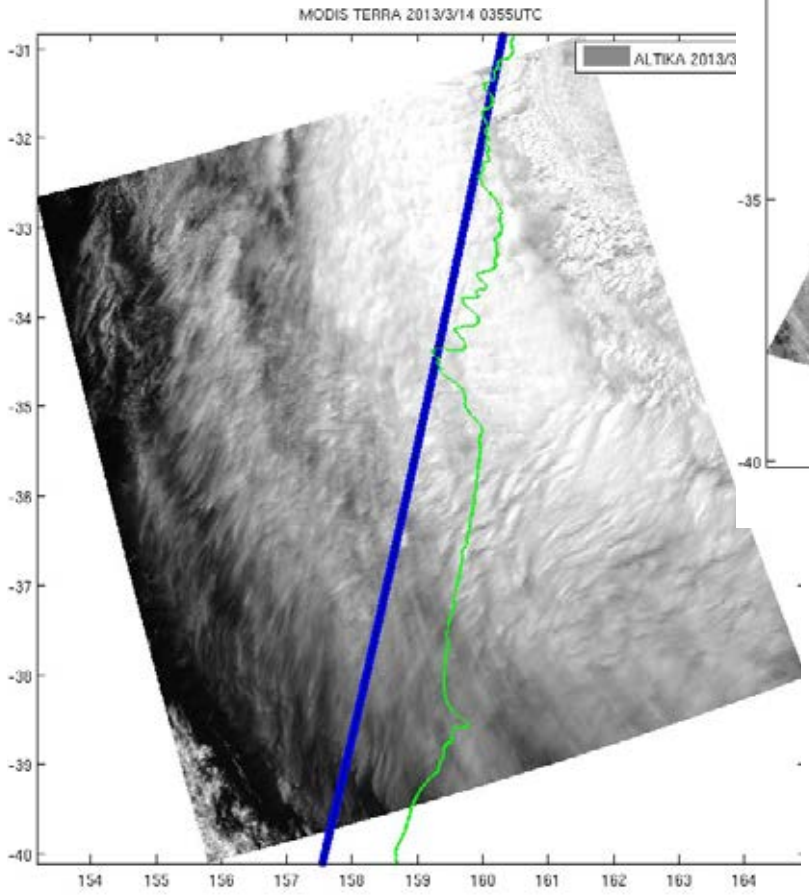
- Altika Altimeter: operates at Ka band 35.75 Ghz : improvments in terms of improvements both in terms of spatial and vertical resolutions.
- This improved accuracy should lead to improved observation of ice, coastal areas, inland waters and wave height.
- ***Major drawback*** of Ka band: high sensitivity to atmospheric liquid water (both rain and clouds), 10x the Ku band one.
- Tournadre et al (2008 a b) shown that even light rain or heavy clouds can strongly attenuate the radar signal, distort the altimeter echo waveform and hamper the retrieval of geophysical;
- **Necessity of an efficient rain/cloud flag**

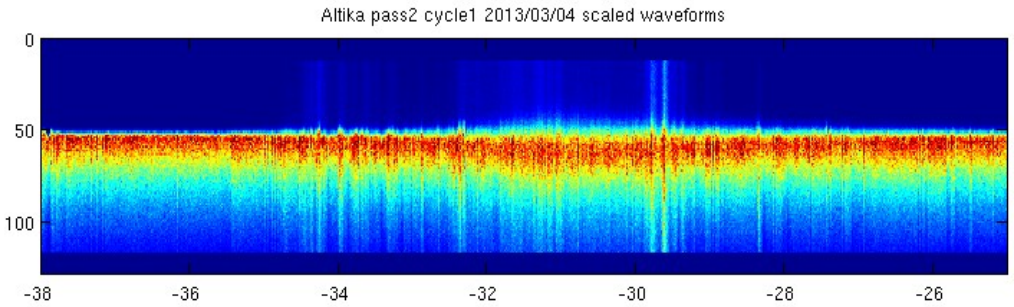
Example of the effect of rain and cloud



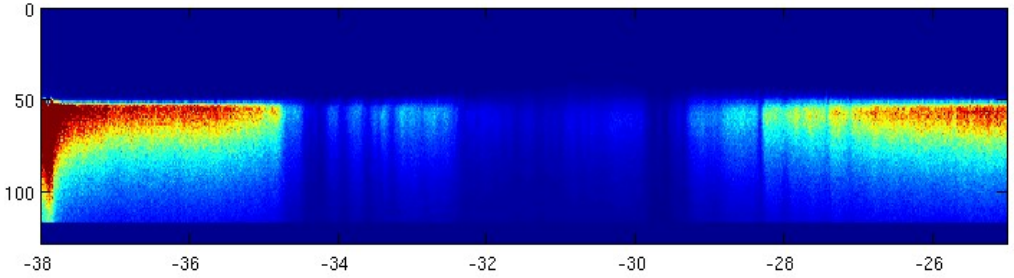


Altika waveforms and sigma0

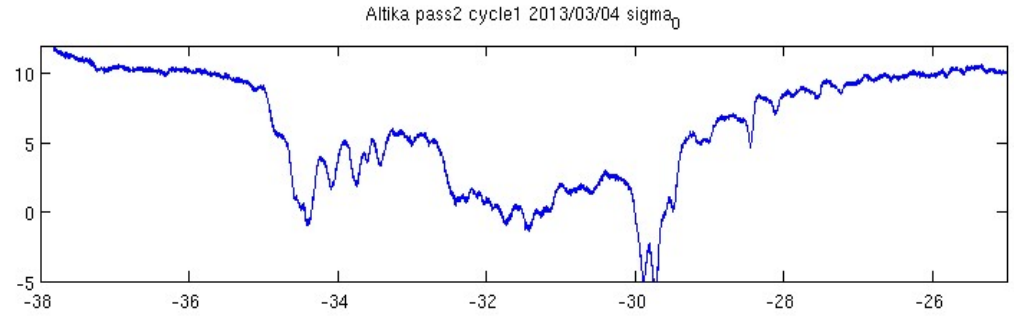
WF



WF
agc scaled



σ0



Strong distortion, and more than 15 dB attenuation and negative sigma0

- Rain was also a problem for dual frequency altimeter : rain flag based on the **differential attenuation** between the 2 freq (Ku/C or Ku/S)

Pre-launch rain/cloud flag

- Altika : single frequency ; New rain flag based on the detection of sharp coherent along-track variations of the slope of the echo waveform plateau (characterized by the off-nadir angle estimate) resulting from the impact of rain/cloud cells [Tournadre et al 2008],
- The flagging algorithm is based on the analysis of the off-nadir angle estimate by a Matching Pursuit (MP) algorithm.
- MP allows the decomposition of a signal into a few salient features or atoms chosen from a dictionary of elementary functions defined by the wavelet decomposition of the signal
- The flag tested pre-launch on simulated Ka-band waveforms and real Jason-1 Ku-band data.
- The tests on Jason-1 data used to define the configuration parameters of the pre-launch MP algorithm: the number of atoms and the mean noise level of the off-nadir angle.
-

Method: Matching Pursuit

Linear decomposition of a signal

g_i chosen from a dictionary of elementary functions **D**

Always possible but computationally impossible; sub-optimal iterative algo. (*Mallat and Chang 1993)*.

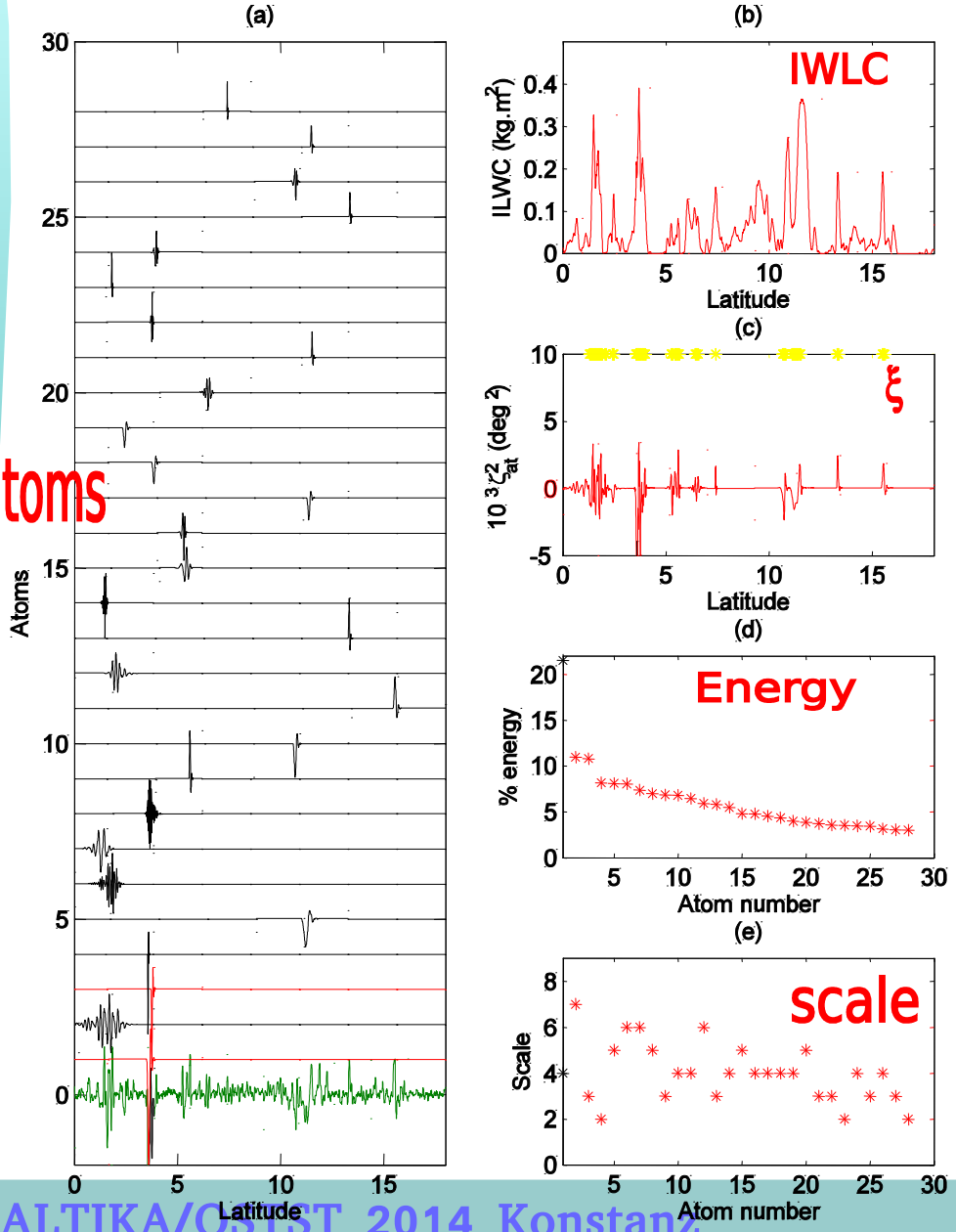
First step : $\mathbf{R_1(t)}$ that gives largest product with *s* , then again on the residue $\mathbf{R_n(t)}$

$$
\begin{aligned}
R_s^0 &= s \\
R_s^n &= < R_s^n, g_{\gamma_n} > + R_s^{n+1} \\
g_{\gamma_n} &= arg\,max_{g_{\gamma_i} \in D}(< R_s^n, g_{\gamma_i} >)
\end{aligned}
$$

For a complete dictionary converges and conserves energy

Dictionary : wavelet decomposition of the signal using Daubechies 8 mother wavelet

Exemple of MP on ξ



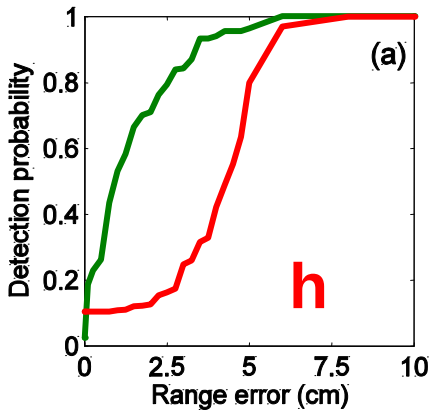
ξ normalized by x noise to avoided false alarm

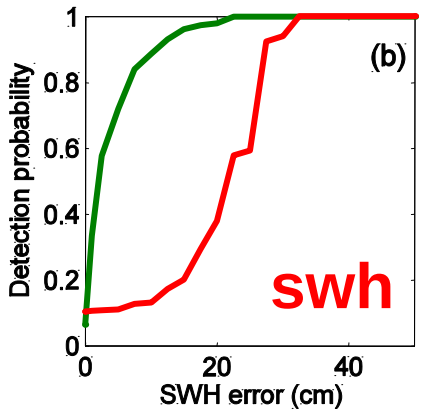
Can be used with series of any length

29 atoms selected

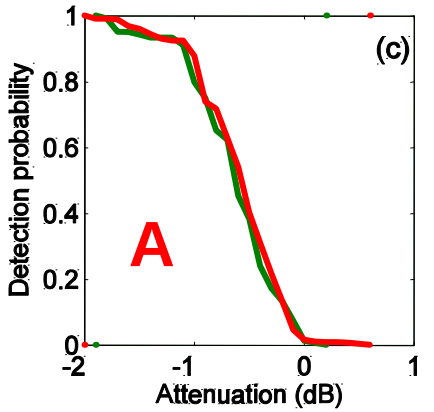
•Sum of atoms= filtered ξ similar to the non-noisy ξ

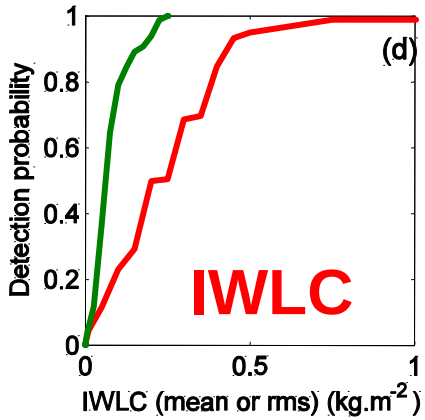
Pre-launch Performances of MP flag on simulated data.





Noisy





Non Noisy

Detect 100% of h errors > 5 cm swh > 25 cm A> 2 dB

False alarm ~0 for IWLC

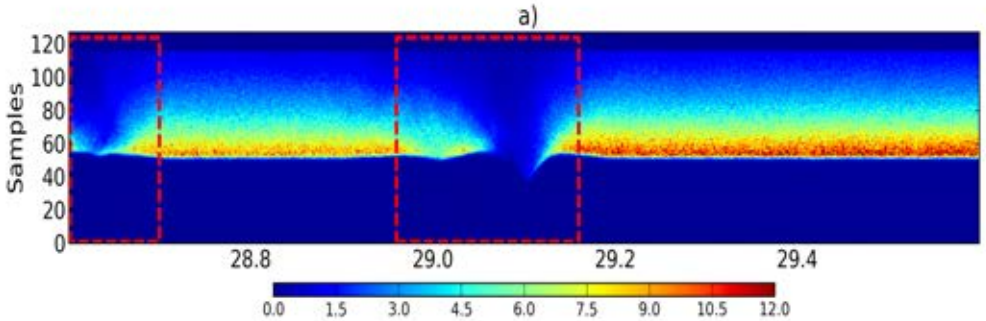
The operational MP flag

- Instrument Signal to Noise Ratio (SNR): main concern pre-launch (pre-flight SNR value =11 dB). **Observed SNR for the first cycles ~20.5 dB**.
- The pre-launch analysis conducted with a maximum of 3 dB attenuation ;
- The global potential loss ~2 % of 40 Hz data and 2.5 % of 1 Hz GDR data.
- **Actual data loss ~0.1%**. rain/cloud flag even more necessary.

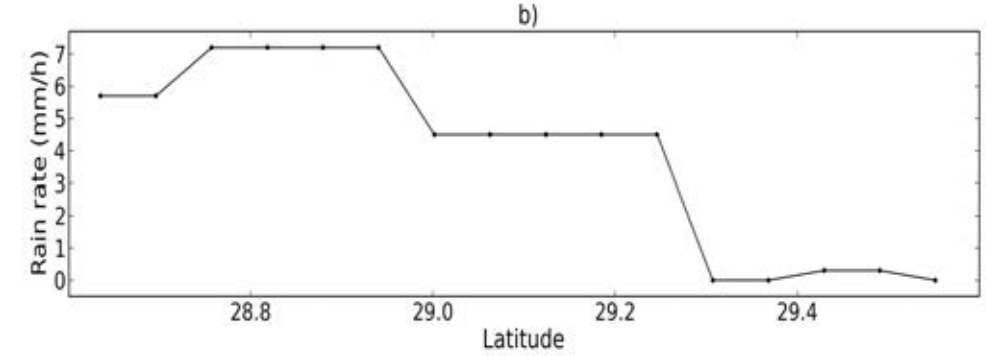
The pre-launch operational MP algorithm did not perform well.

- *Algo designed to process ocean data only. In the ground segment, land editing criterion only, MP disturbed by the presence of sea ice. (saturation of the number of atoms)*
- ***Two modifications**: maximum number of atoms increased (200 to 450) and the square root of the off-nadir angle is considered in order to mitigate the strong variations observed in sea ice data.*
- *Pre-launch settings of noise level (Jason1 data) recomputed from the first 5 cycles : twice smaller than pre-launch value.*
- *Off-nadir angle is recomputed by linear regression of the plateau (81 to 116 bins)*
- *40 Hz data flagged using the MP algorithm, 1 Hz GDR data flagged if 50 % of the 40 Hz data are flagged.*

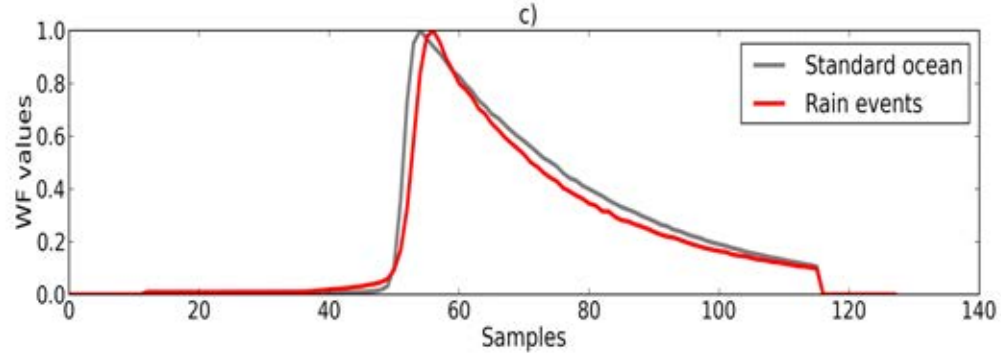
New MP flag



waveforms



Rain rate (collocated)



Distortion of the WF

Geophysical parameters (MLE4)

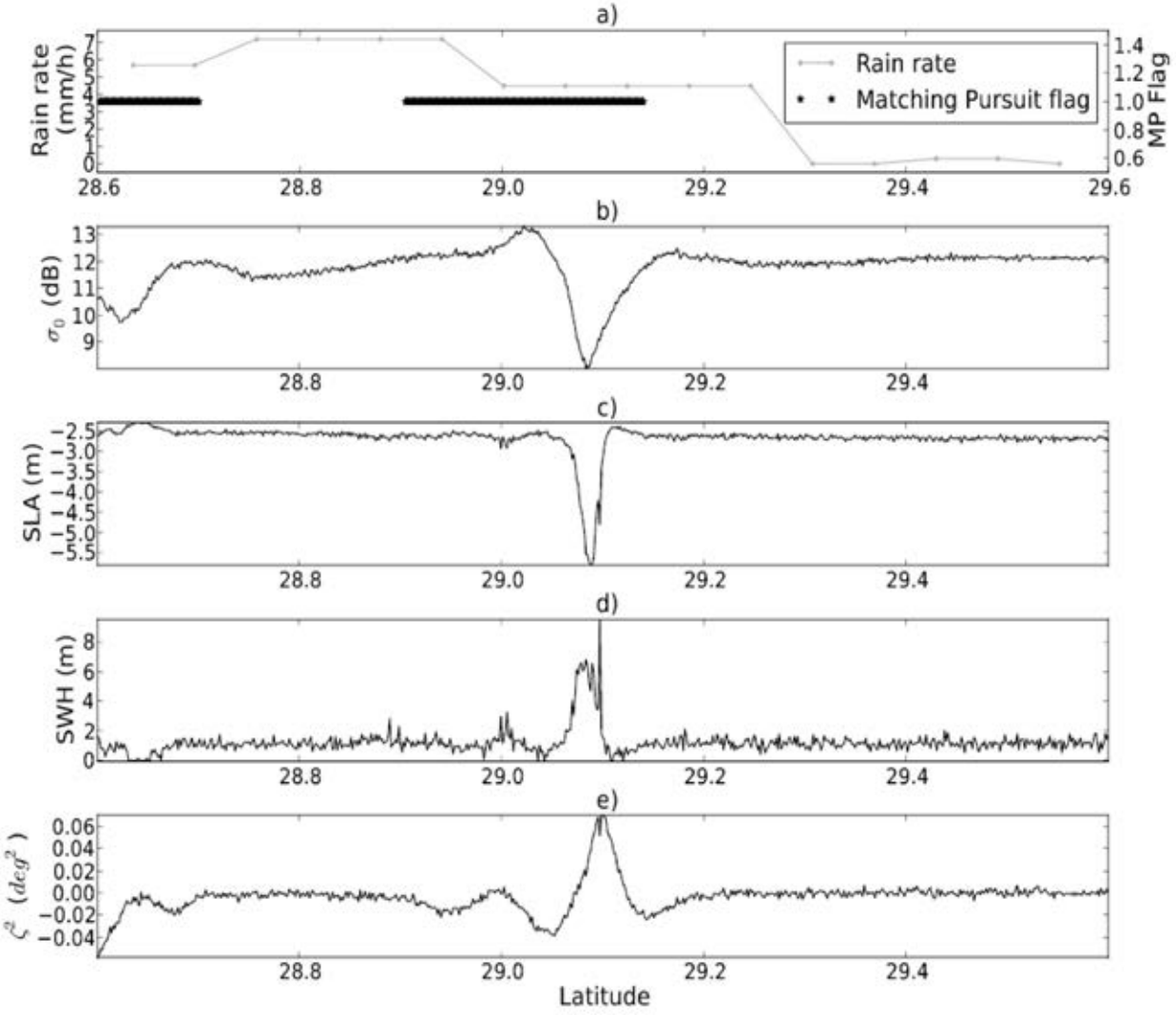
Rain rate and flag

sigma0

Sea level anomaly

SWH

Off-nadir angle



Collocation with SSMI/S Windsat rain rate measurements

- ***Method of validation use of external rain measurement collocated with Altika data and analysis of the geophysical parameters errors;***
- ***Use of Altika microwave radiometer liquid water content (but not fully calibrate)***
- SSMI/S (F16 and F17) and Windsat rain rates products from Remote Sensing System using the Unified Microwave Ocean Retrieval Algorithm (UMORA) [Hilburn et al2008].
- The daily ground track products gridded on 0.25°x0.25° maps.
- Altika data systematically collocated with the rain data from the 3 missions (F16, F17 and Windsat) and the closest observation in time is kept, together with the time lag. 80% of data have a collocated RR and 8% are rainy
- The mean time delay is close to 10 minutes.

Flagged data
New operational flag
Cycles 2 to 9

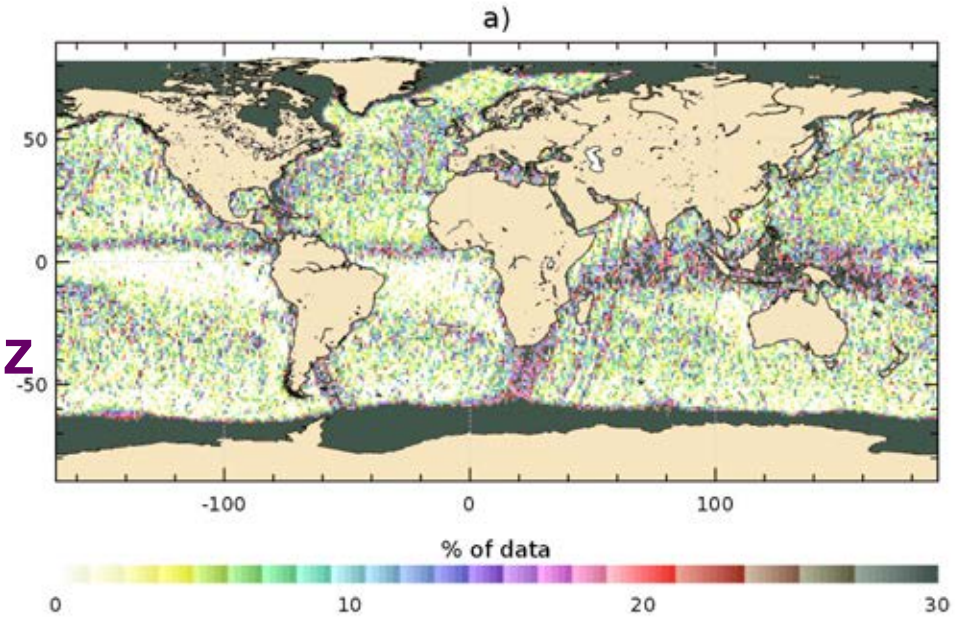
Cycle 1 too many maneuvers:

Mean percentage

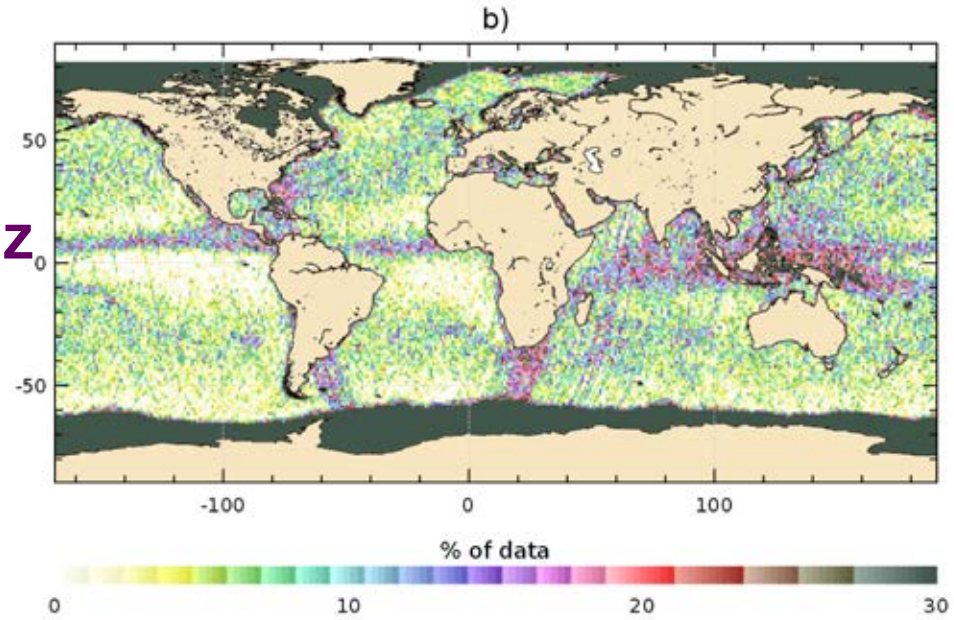
of 40 Hz (top)

and 1 Hz (bottom) flagged samples using the operational MP algorithm

40Hz



1Hz

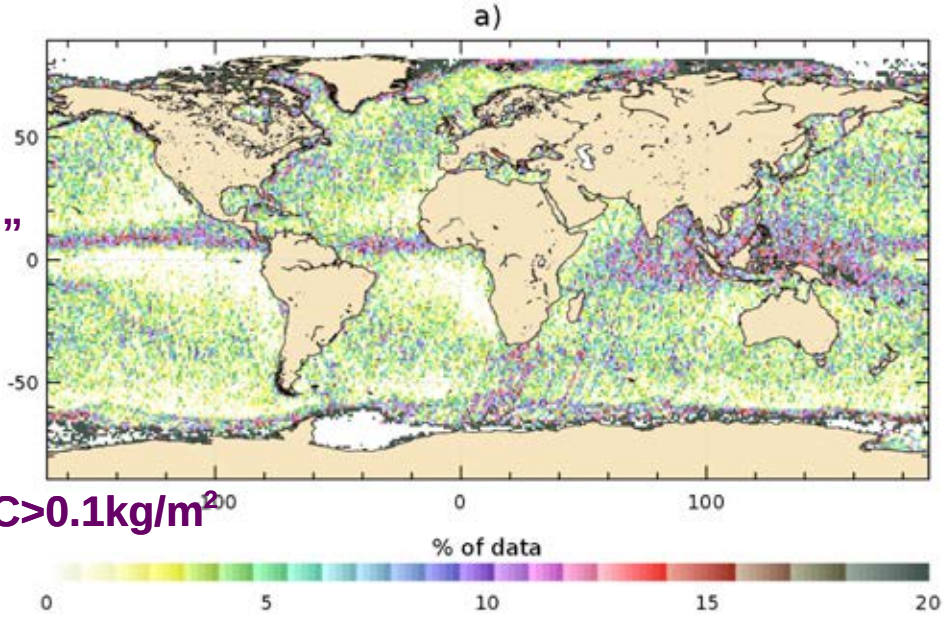


Flagged data
Cycles 2 to 9

Percentage of 1Hz flagged samples using the operational MP algorithm for which the ILWC >0.1 kg/m2 (top)

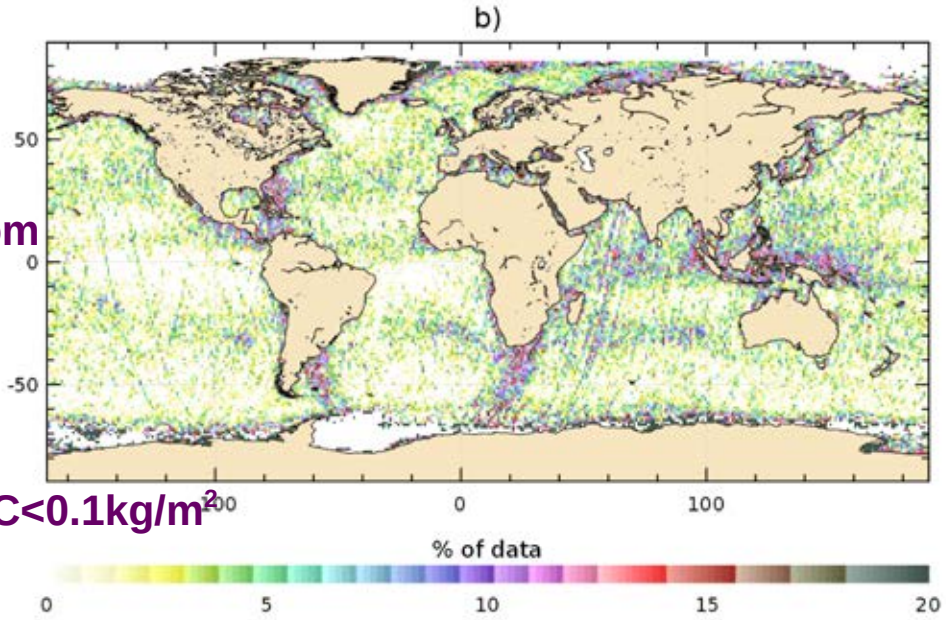
and ILWC<0.1kg/m2 (bottom)

“Rain flag”



1Hz ILWC>0.1kg/m^2

“sigmabloom flag”



1Hz ILWC<0.1kg/m^2

Validation by comparison with SSMI-S Rain rate

Dichotomous discrimination table

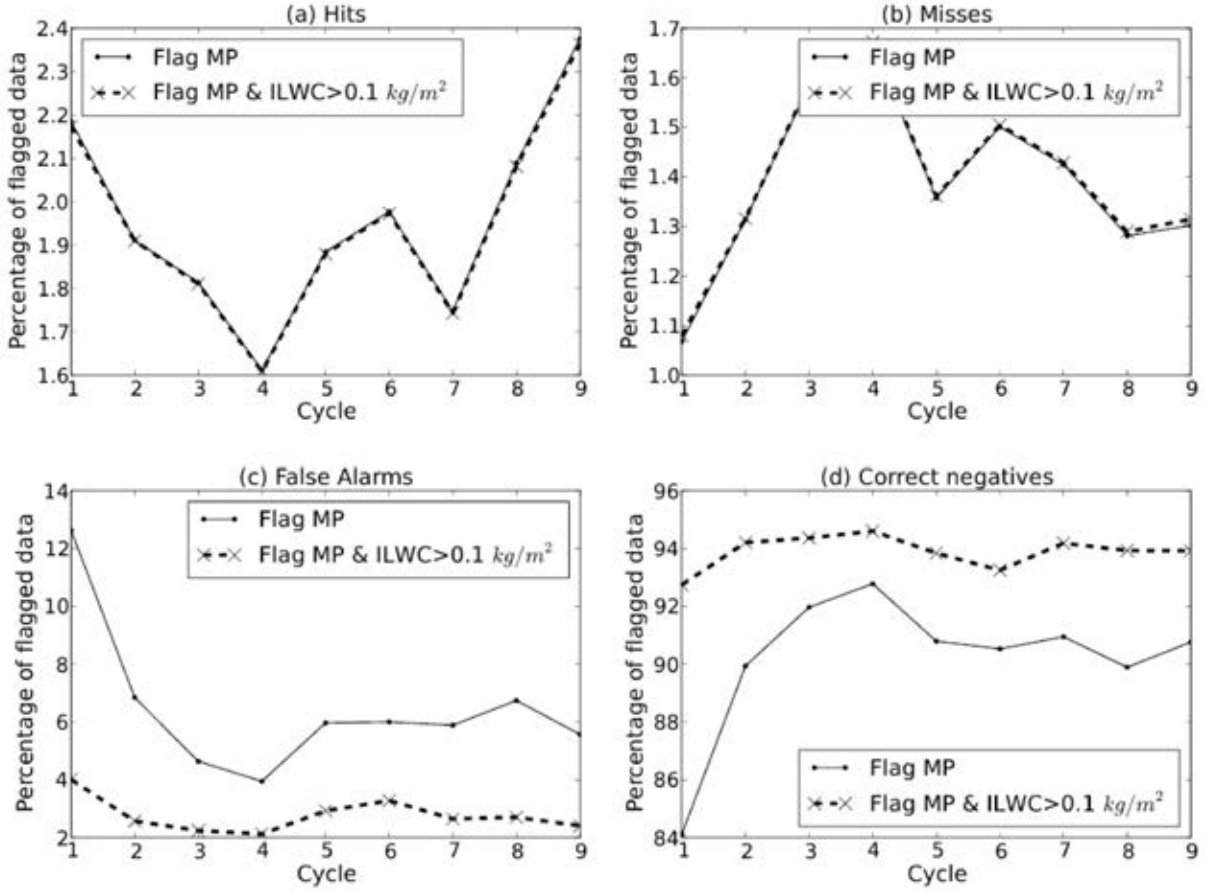
		SSMI/S-Windsat Rain rate > 0.5mm/hr and ILWC> 0.1kg/m^2	
		Yes	No
MP flag	Yes	Hits	False alarms (FA)
	No	Misses	Correct negatives (CN)

Table 3: Percentages of Hits, Misses, FA and CN for cycles 1 to 9 with flag MP and flag MP and ILWC >0.10.1 kg.m^{-2}.

cycle number	1	2	3	4	5	6	7	8	9
MP flag									
Hits	2.19	1.92	1.82	1.62	1.88	1.98	1.75	2.09	2.38
Misses	1.06	1.31	1.58	1.67	1.36	1.50	1.42	1.28	1.30
FA	12.63	6.84	4.64	3.94	5.97	5.99	5.88	6.74	5.56
CN	84.12	89.93	91.96	92.77	90.79	90.53	90.95	89.89	90.76
MP flag and ILWC > 0.1 kg.m^{-2}									
Hits	2.17	1.91	1.81	1.61	1.88	1.97	1.74	2.08	2.36
Misses	1.08	1.32	1.59	1.67	1.36	1.5	1.43	1.29	1.31
FA	4.01	2.57	2.24	2.12	2.92	3.28	2.65	2.70	2.41
CN	92.74	94.2	94.36	94.60	93.84	93.25	94.18	93.93	93.92

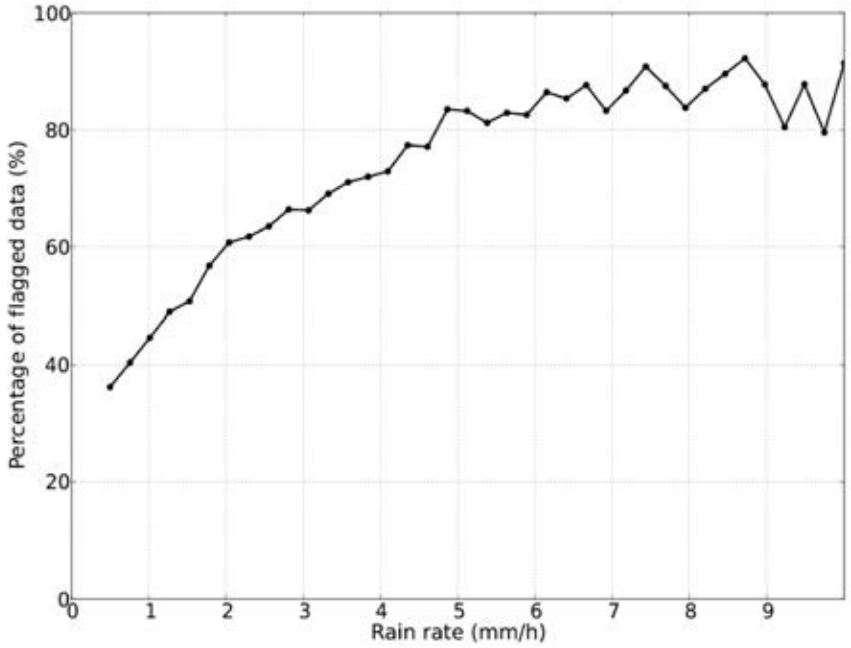
Discrimination results per cycle

The results are similar to the ones found by Tran et al (2006) on Envisat data



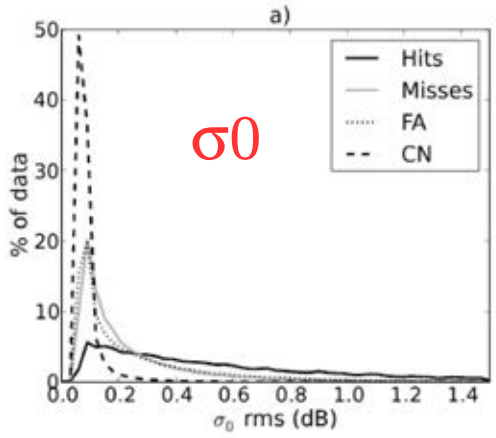
Percentage of flagged samples as a function of rain rate

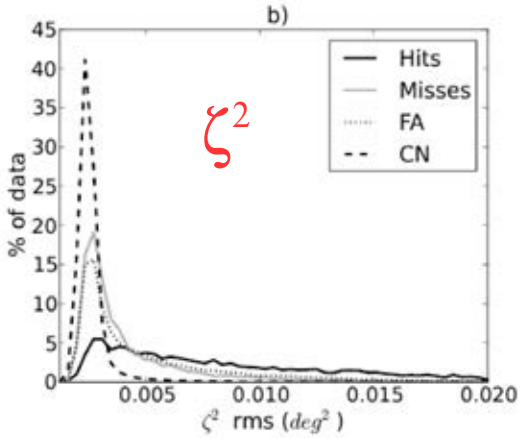
- Dt<5 min (1Hz data)
- ILWC >0.1kg/m² (ensure the presence of at least some atmospheric liquid water near or within the Altika altimeter footprint)
- Number of collocated samples = 1209605 for cyces 2 to 9
- R> 5 mm/hr 80-90% flagged R=0.5 mm/hr 37% flagged

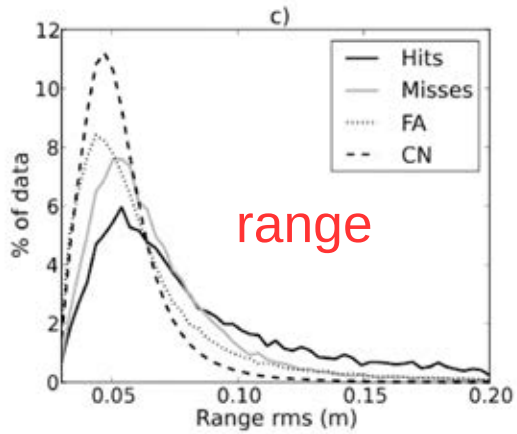


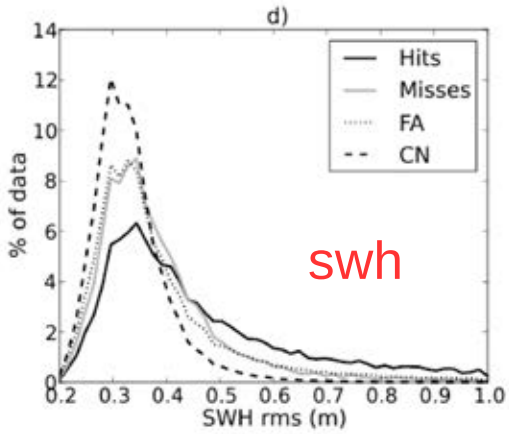
Impact on geophysical parameters estimates

Distribution of the std of each MLE4 parameter estimate (computed from the 40 Hz elementary measurements used to compute a 1 Hz value)









Conclusion

- 1st GDR reprocessing used to upgrade the rain/cloud MP algorithm.
- Globally ~9% of data flagged (maximum between 10 and 25% in the ITCZ, the SPCZ and the mid-latitude storm tracks).
- MP flags not only rain affected data but also distorted waveforms (sigma0 bloom, sea ice).
- ILWC used to discriminate the rain affected samples. The global mean percentage is about 5-6% rainy dataand 3-4% of sigma0 bloom events.
- Validation using collocated rain data from the SSMI/S and Windsat radiometers. The flag detects very well rain rate larger than 2 mm/hr (more 60% detection) and almost all the rain rate larger than 5 mm/hr.
- Dichotomous discrimination(hits, misses, false alarms and correct negative). The correct negative represents 93.5 % of the data, the hits about 2% the false alarms about 3% and the misses about 1.5%.
- std of MLE4 parameters for the four groups shows that MP clearly detects samples with high std for all parameters. The CN group :very narrow distributions with low maximums. The FA and misses groups both contains correct and erroneous data.
- The upgraded MP flag performances are thus very satisfactory and very similar to the ones obtained for dual-frequency rain flag such as the Envisat one.