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CLOUD AND RAIN EFFECT ON ALTIKA/SARAL KA BAND RADAR ALTIMETER: DATA AVAILABILITY AN RAIN/CLOUD FLAG

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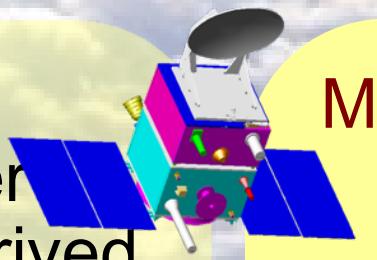
Altika/SARAL : French (CNES)/ Indian (ISRO) mission



Instruments

- Ka-band altimeter (35.575 GHz); derived from the Poseidon altimeter
- Dual frequency microwave radiometer (23.8 & 36.8 GHz) : wet troposphere effects.
- DORIS receiver and a LRA for a precise orbit determination.

Mission characteristics

35-day repeat period sun-synchronous orbit of 800 km altitude and 97 ° inclination

Mission specifications:

- GDR error budget
  - 1.5 cm for the altimeter range noise,
  - 0.5 dB on absolute $\sigma 0$ value,
  - 5% or 25 cm for swh
- Availability > 90%

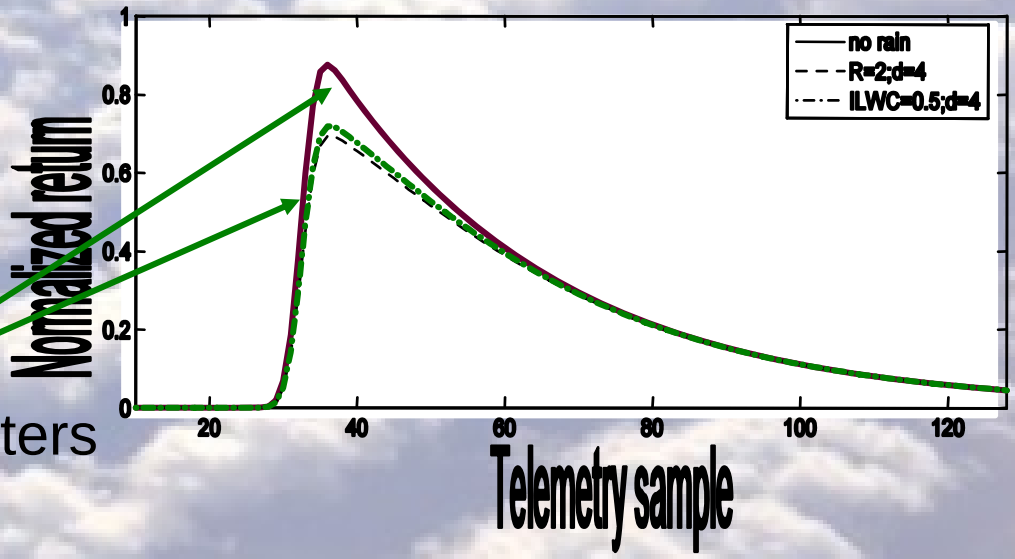
Problem

- Very high sensitivity to atmospheric liquid water
- Instrument link budget limit attenuation ot 3 dB (in worst case)
- Light rain : loss of the signal (2 mm/h x 2km = 3 dB attenuation)
- Cloud liquid water can not be neglected as for Ku-band altimeter

1. **Analysis of the effect of LW on Altika**
2. **Probability of data loss from LW**
3. **Rain/cloud flag**

Method

- Model of WF in presence of LW
- Estimation of WF attenuation and distortion
- Estimation of errors on the geophysical parameters estimates (h, swh, $\sigma 0$)



- Computation of probability of data loss by large attenuation and distortion (outside limit of specifications for geophys. Parameters)

Waveform modeling

- Analytical model of waveform based on Brown model + an attenuation term
- A attenuation field within the altimeter footprint

$$\sigma(\frac{2x}{c}) = \alpha\sigma_0 \int_0^{\infty} e^{-\frac{u}{w_b}} e^{-\frac{(u-a)^2}{2\sigma_p^2}} \left[\frac{1}{2\pi}\int_0^{2\pi} A(u,\theta)d\theta\right] du$$

Cloud IWLC kg.m^2

$$A = 10^{-\frac{1}{5}\kappa IWLC}$$

κ=1.1 dB/(kg.m^2)

Rain rain rate R height

$$A = 10^{-\frac{1}{5}H_c\alpha R^{\beta}}$$

α=0.34 dB/km b=.904

Cloud liquid water

Typical values for different cloud types:

- Stratus: ~0.3 g/m3
- cumulus~0.2 g/m3
- cumulo-nimbus~1-3 g/m3

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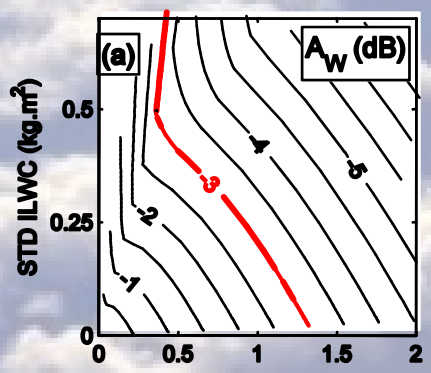
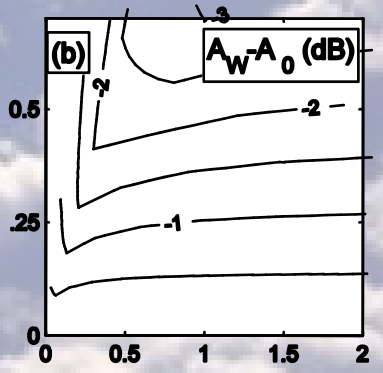
Impact of attenuation cell on 20 Hz Altika data

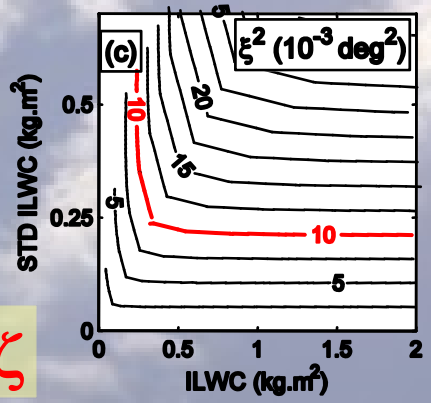
- 3 kind of cells: constantes , gaussian and exponential
- Impact fonction of average value and also variability of attenuation within the altimeter footprint

Attenuation

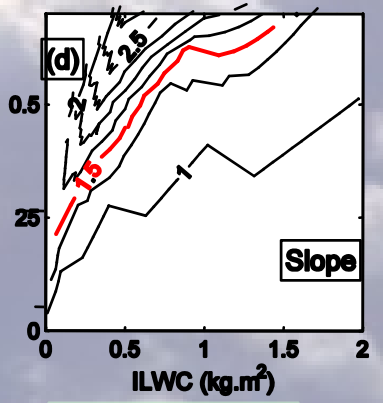


Δ Att





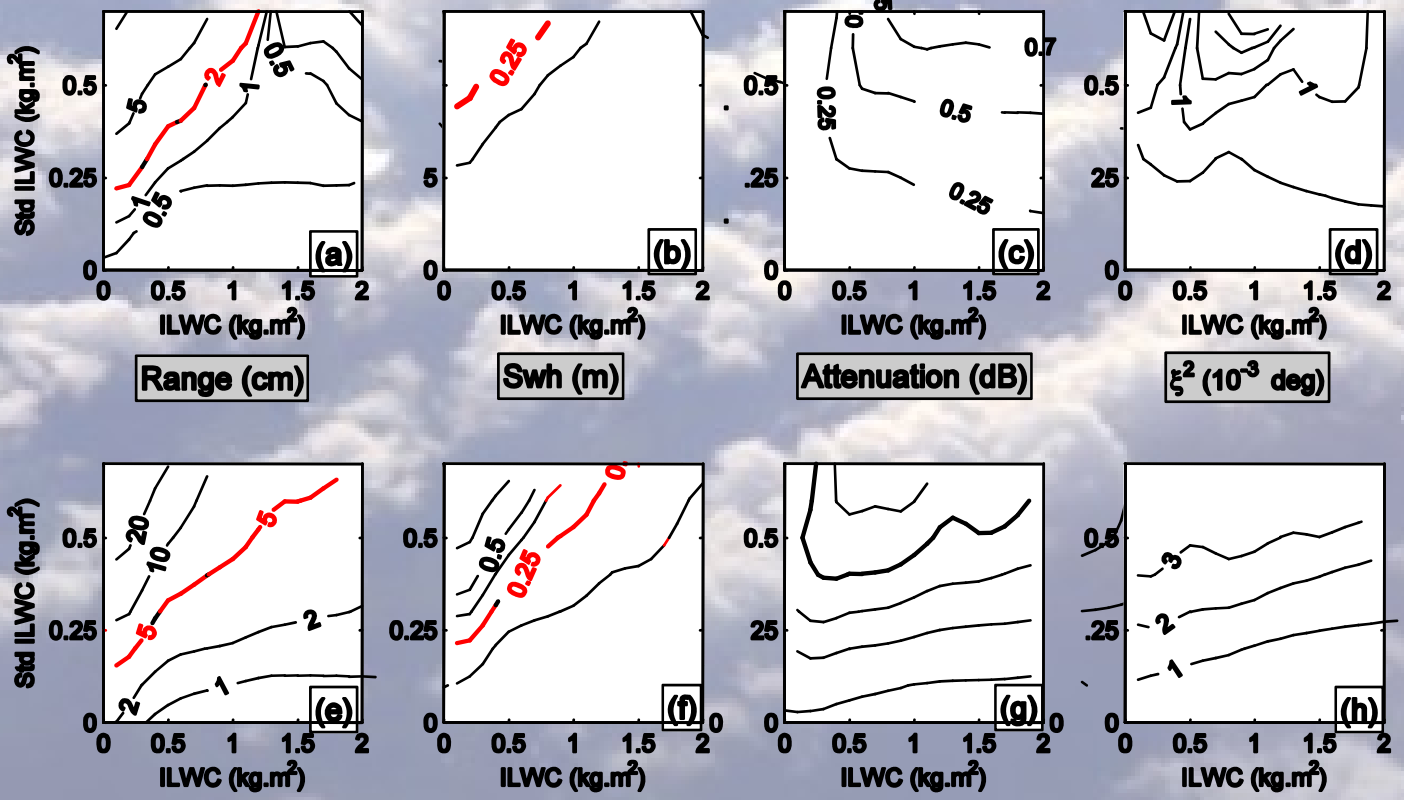
ζ



Slope

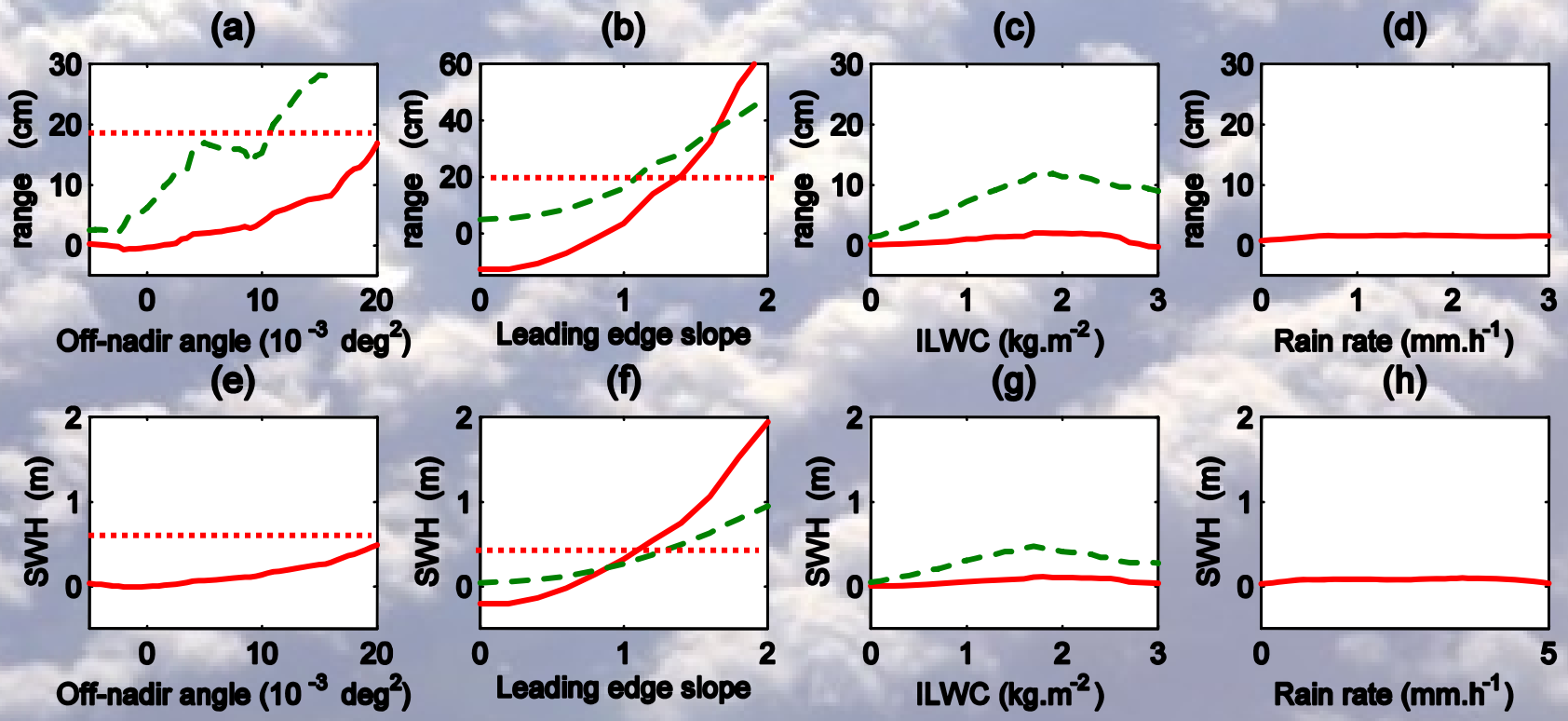
Error on geophysical parameters retrieval

- Use of MLE4 retracking algorithm
- For each modeled WF: computation of range, swh, amplitude (σ0) and off-nadir



Bias and rms on range and swh estimates

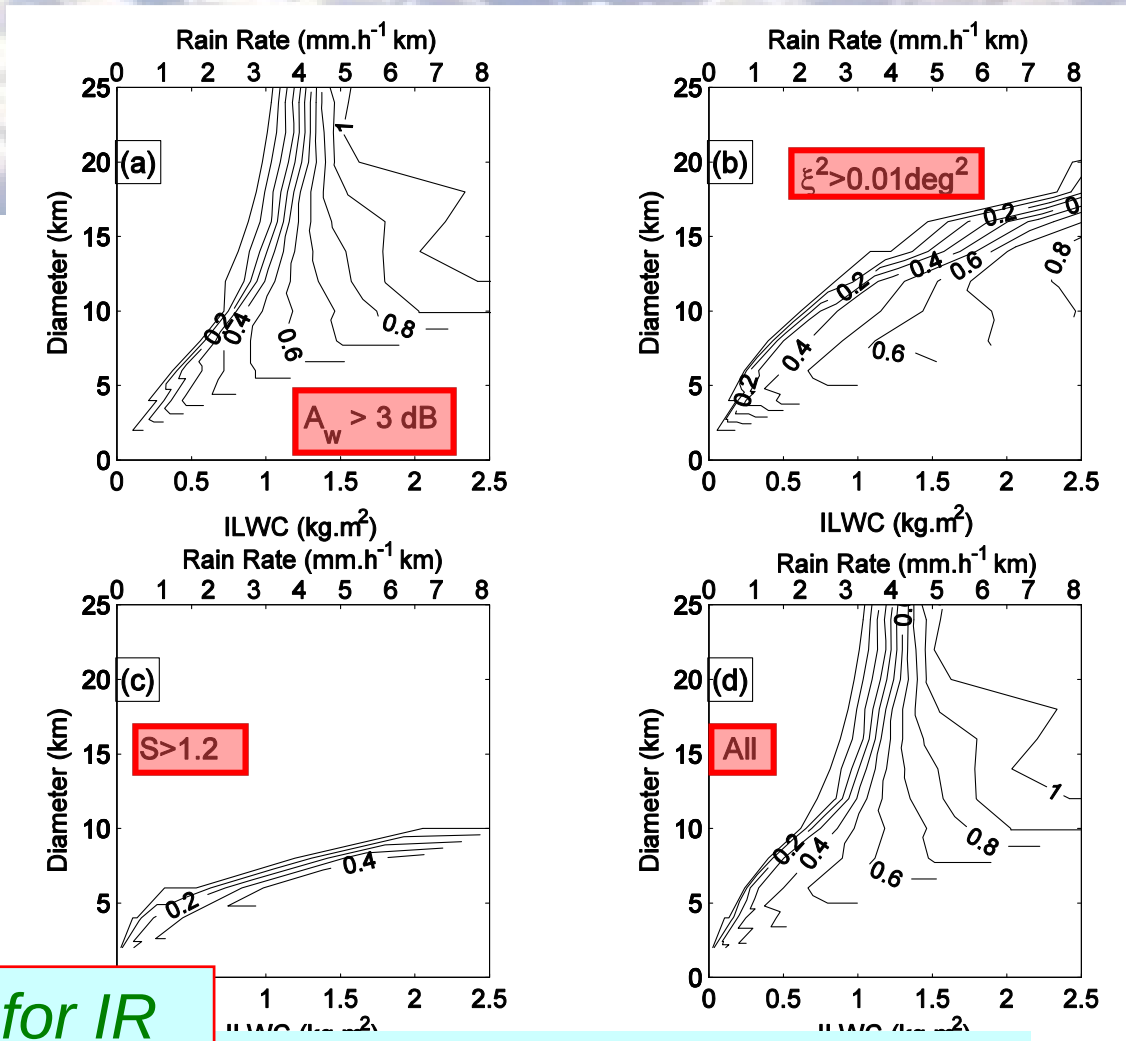
Estimated from the modeled WF for all attenuation cells and MODIS cloud liquid water data



Limits : ξ^2 <.01deg² slope<1.2

Probability of 20Hz data loss

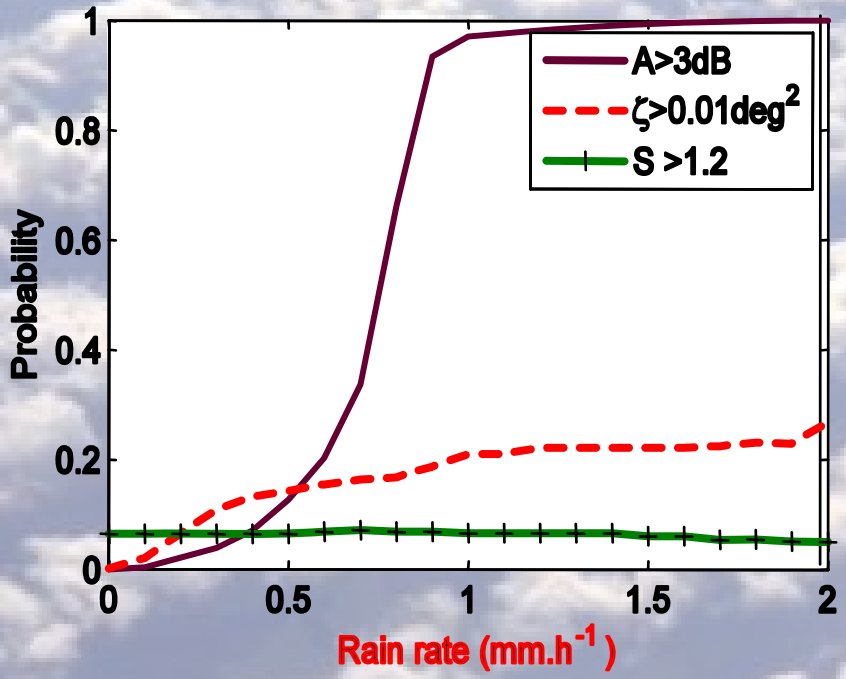
- Probability of A > 3 dB
- ξ^2>0.01deg².
- Slope>1.2
- All 3 conditions
- For Gaussian cells



For rain 100% loss for IR >5km.mm/h

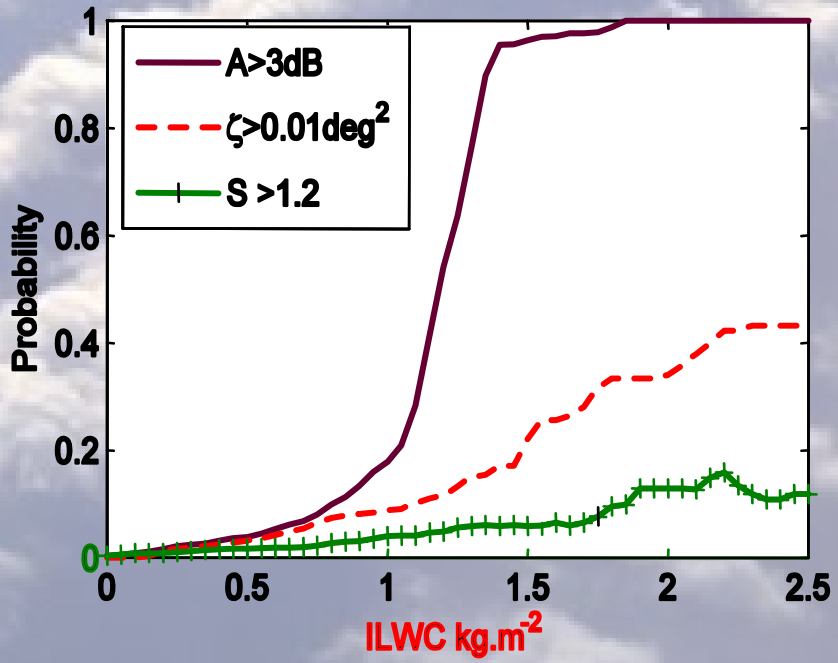
For clouds 100% loss IWLC > 1kg/m²

Synthesis of data loss probability as a function of rain rate and ILWC



Rain : Probability of A>3dB, ξ^2>0.01deg² et slope>1.2

Cloud : Probability of A>3dB, ξ^2>0.01deg² et slope>1.2

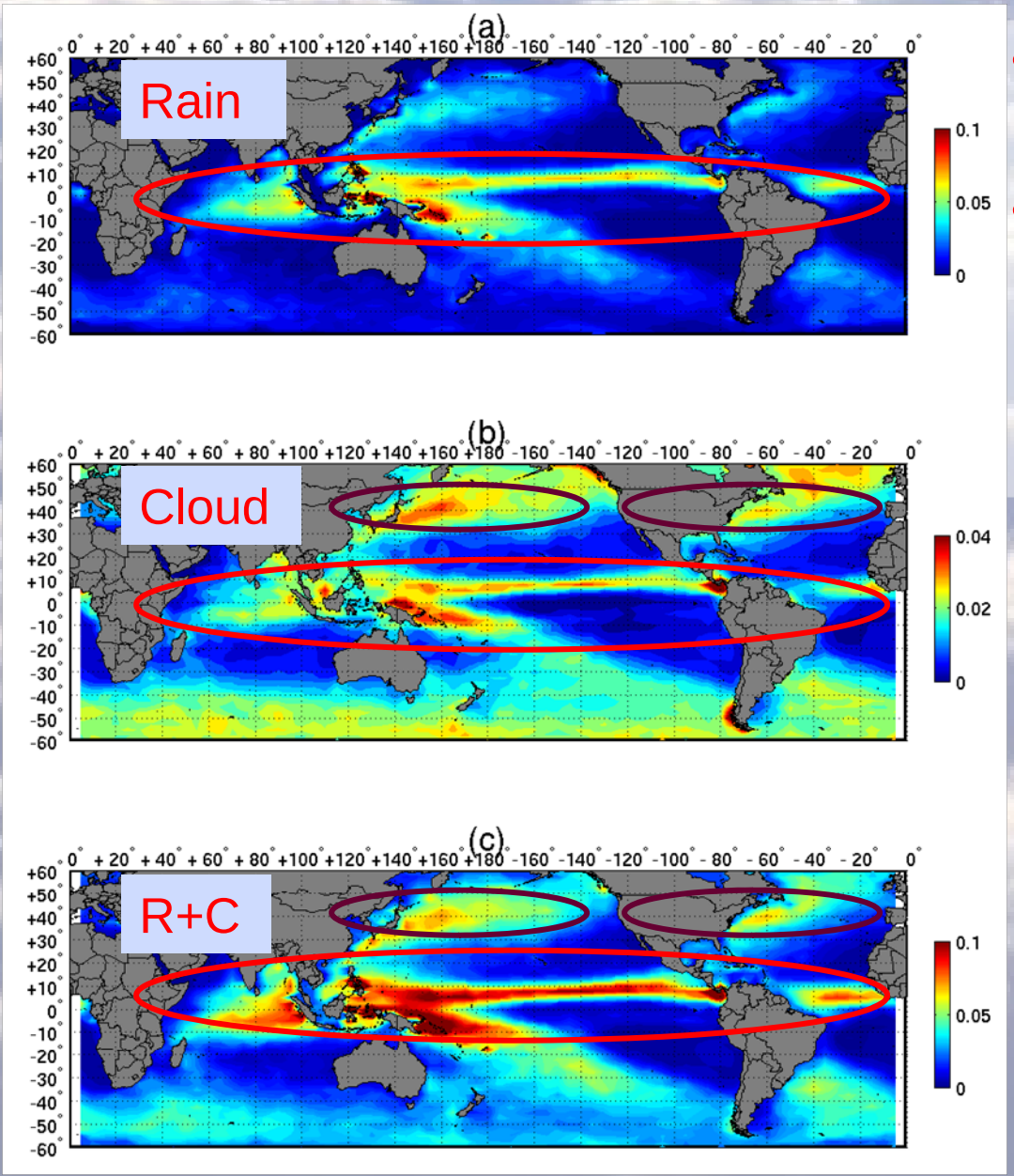


Availability maps

- Data loss probability P_u
- Probability p of *A>3dB* ξ^2*>0.01 deg² or sl>1.2*

$$P_u(x,y)=\int_0^\infty P_R(x,y,R).p(R)dR$$

- $P_R(x,y,R)$: Rain rate (ILWC) probability at location (x,y) (product of rain probability and pdf of rain rate)
- p(R) probability of data loss for tain rate (ILWC) R
- Requires P_R , i.e. pdfs of R and IWLC everywhere
- Use of Topex/Poseidon rain climatology (same sampling, 13 years) and MODIS level 3 Cloud products (2 years)



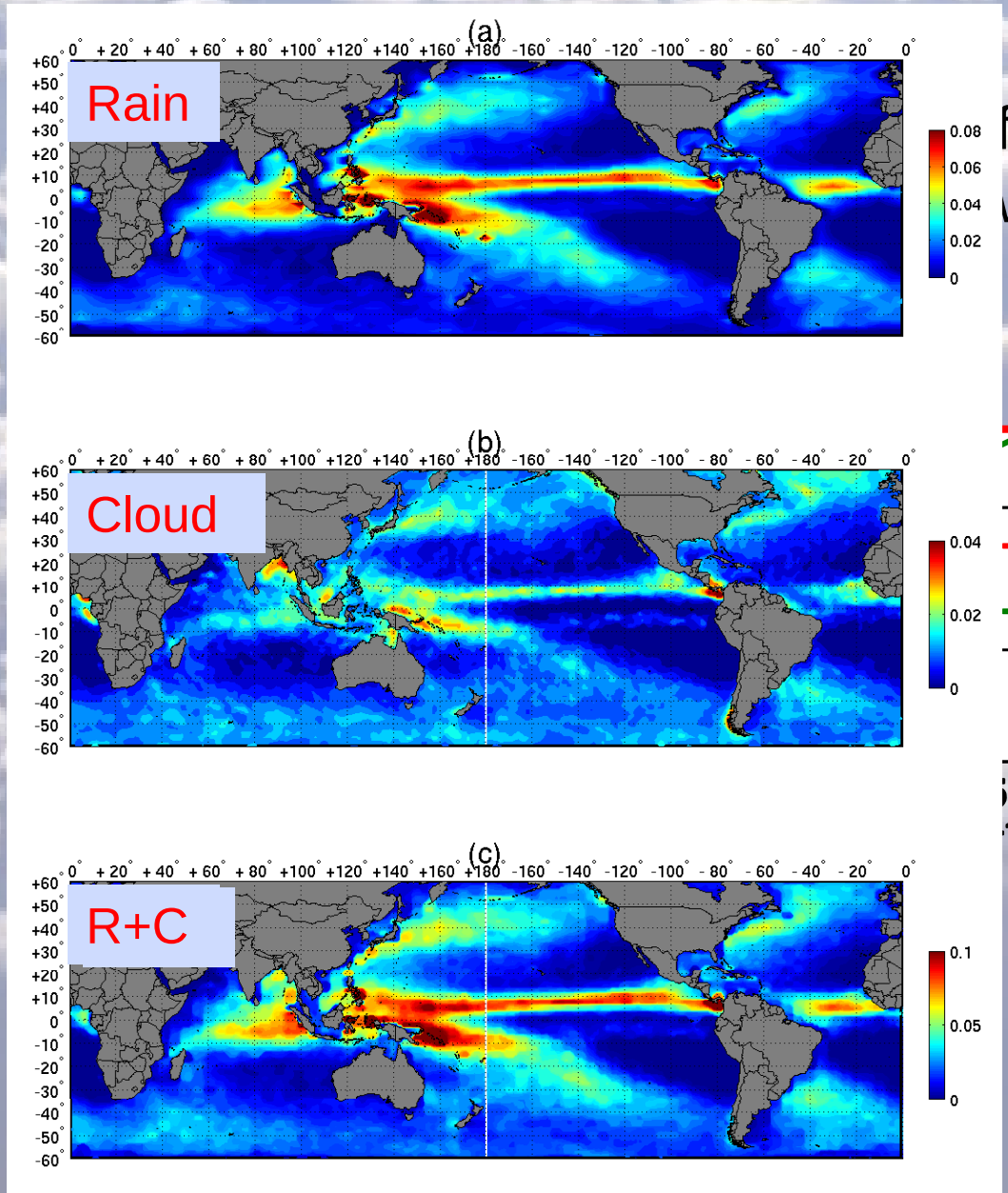
- Rain : Topex (1992-2005)
- Clouds: Level-3 MODIS Atmosphere Monthly Global Products.

Data loss proba.
Maximum in ITCZ

- **R ~8%**
- **Cl ~ 4%**
- **Total~12%**

- Secondary maxima in storm tracks regions
- ~5-6%

1-sec averaged (GDR) Data



- Secondary maxima in storm tracks regions
- Data loss proba. Maximum in ITCZ
  - **R ~6%**
  - **Cl ~ 3%**
  - **Total~10%**
- ~3-4%

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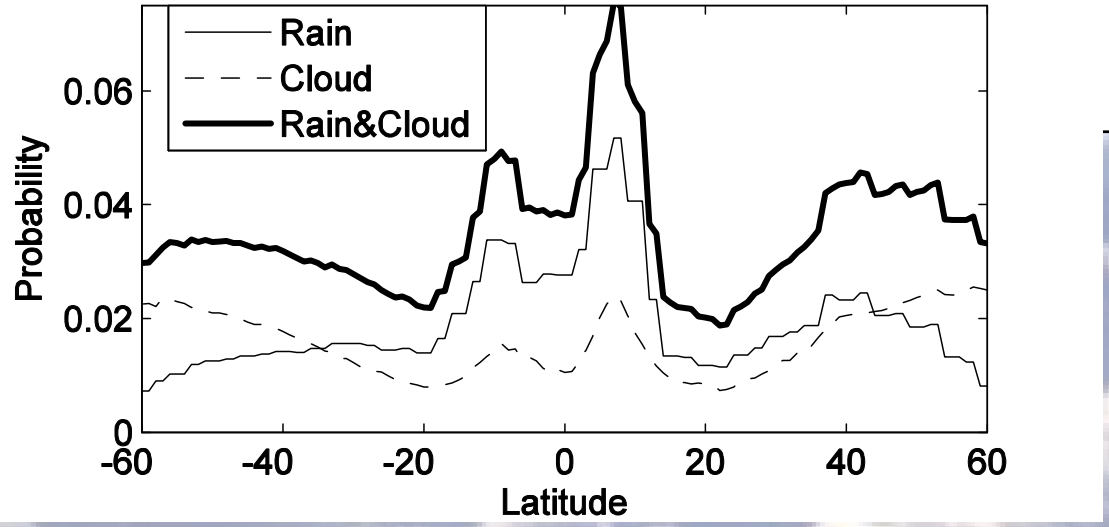

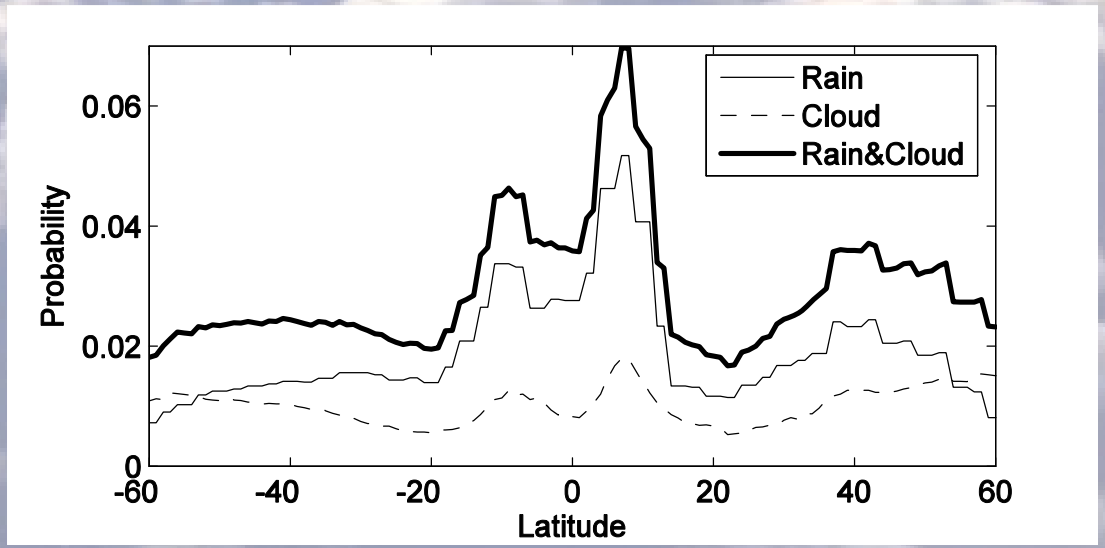

RAIN/CLOUD FLAGGING

- Analysis of modeled WF shows that errors on range and swh can be significant even for low IWLC and Rain rate
- Necessary to define a rain/cloud flag to eliminate data potentially contaminated.
- Problem: single frequency altimeter and radiometer data can not be used
- Definition of a flag based on the signal itself

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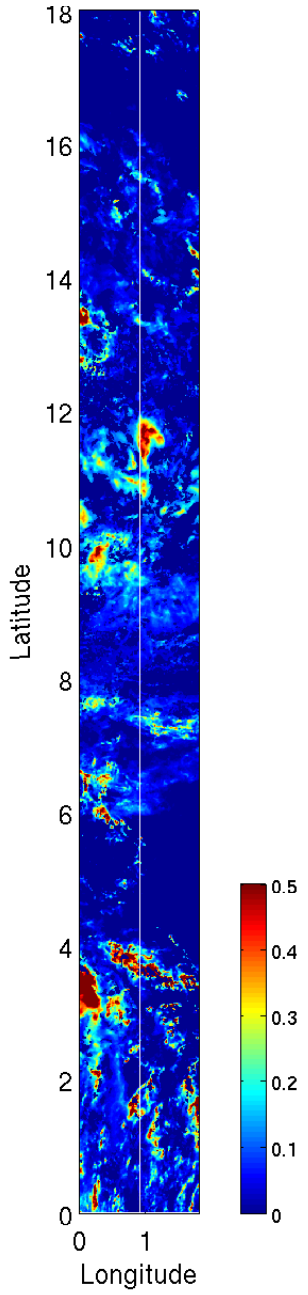
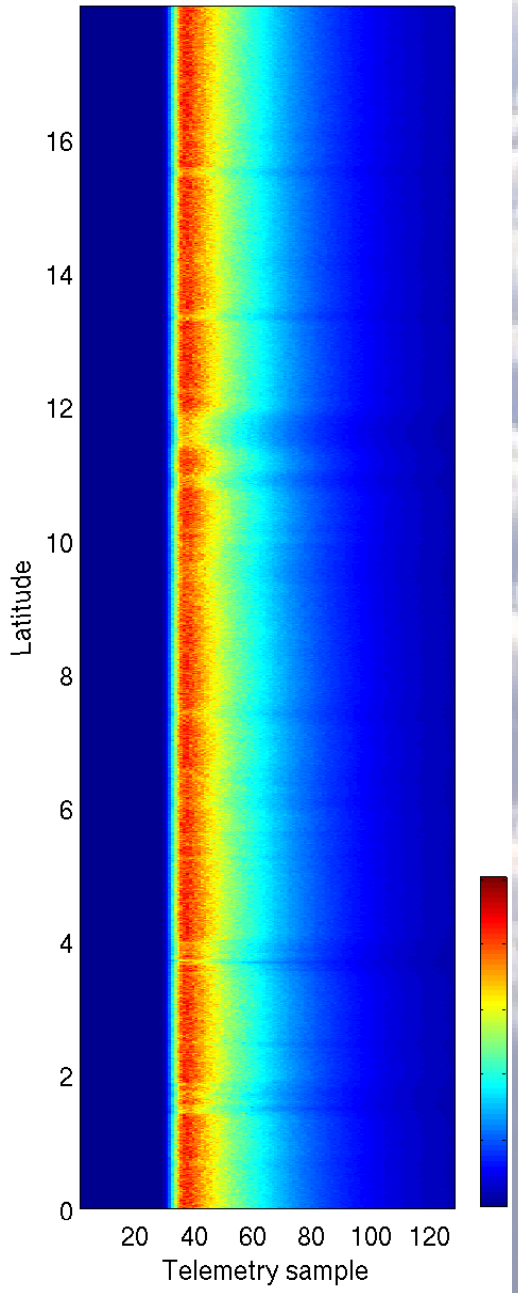
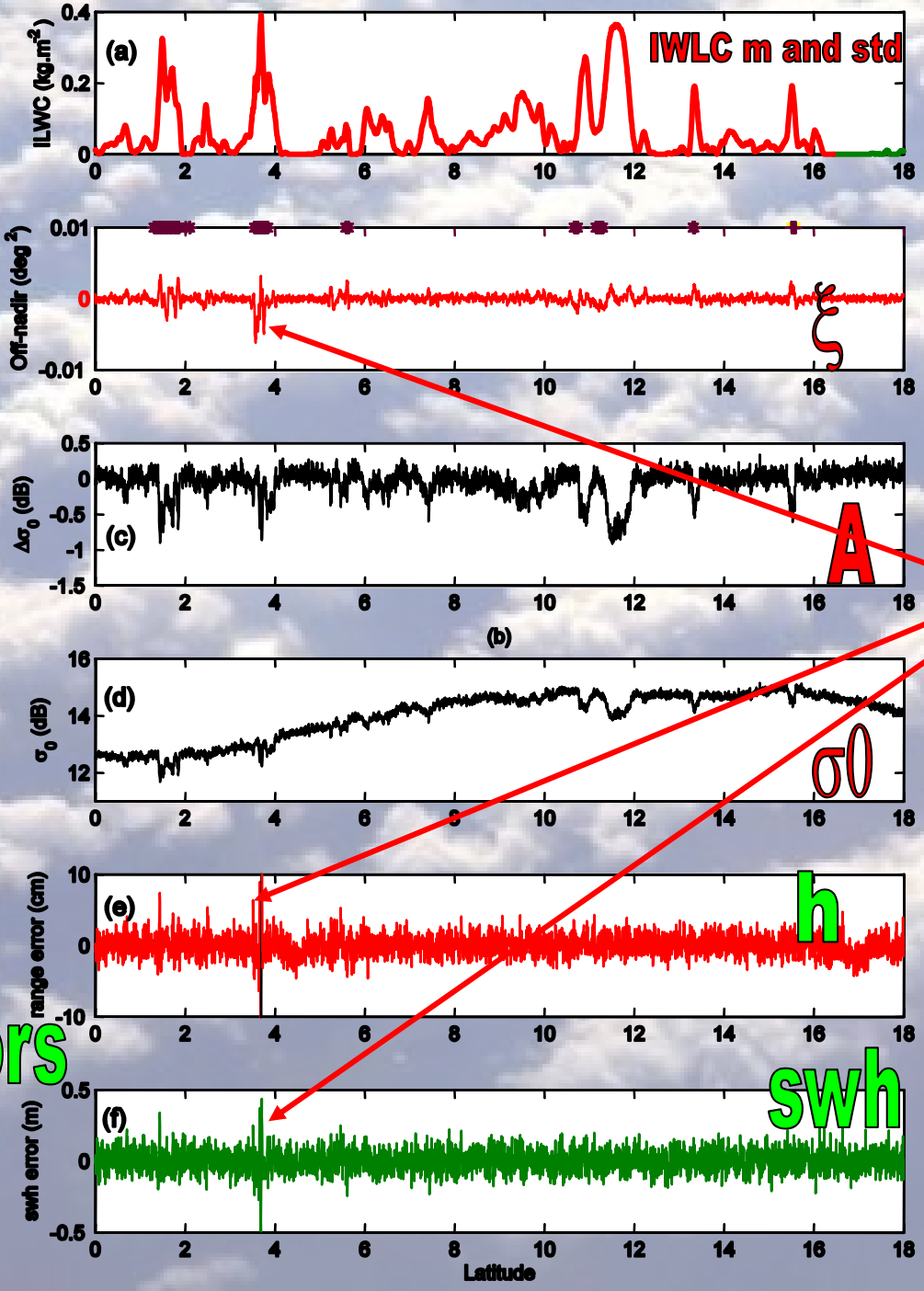
MODIS ILWC



Modeled WF



- Example of Altika WF over a cloud field
- (here MODIS level2 CLW)
- Noise (estimated from Jason data) added to the waveforms



Larges errors on h and swh associated to large ξ^2

Detection of coherent sharp along-track variation of off-nadir angle

Similar to previous results for Topex, Jason

Method: Matching Pursuit

Linear decomposition of a signal

$$s(t) \approx \sum_{i=1}^{M} a_i g_i(t)$$

- 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 $\mathbf{R_n(t)}$

$$R_s^0 = s$$

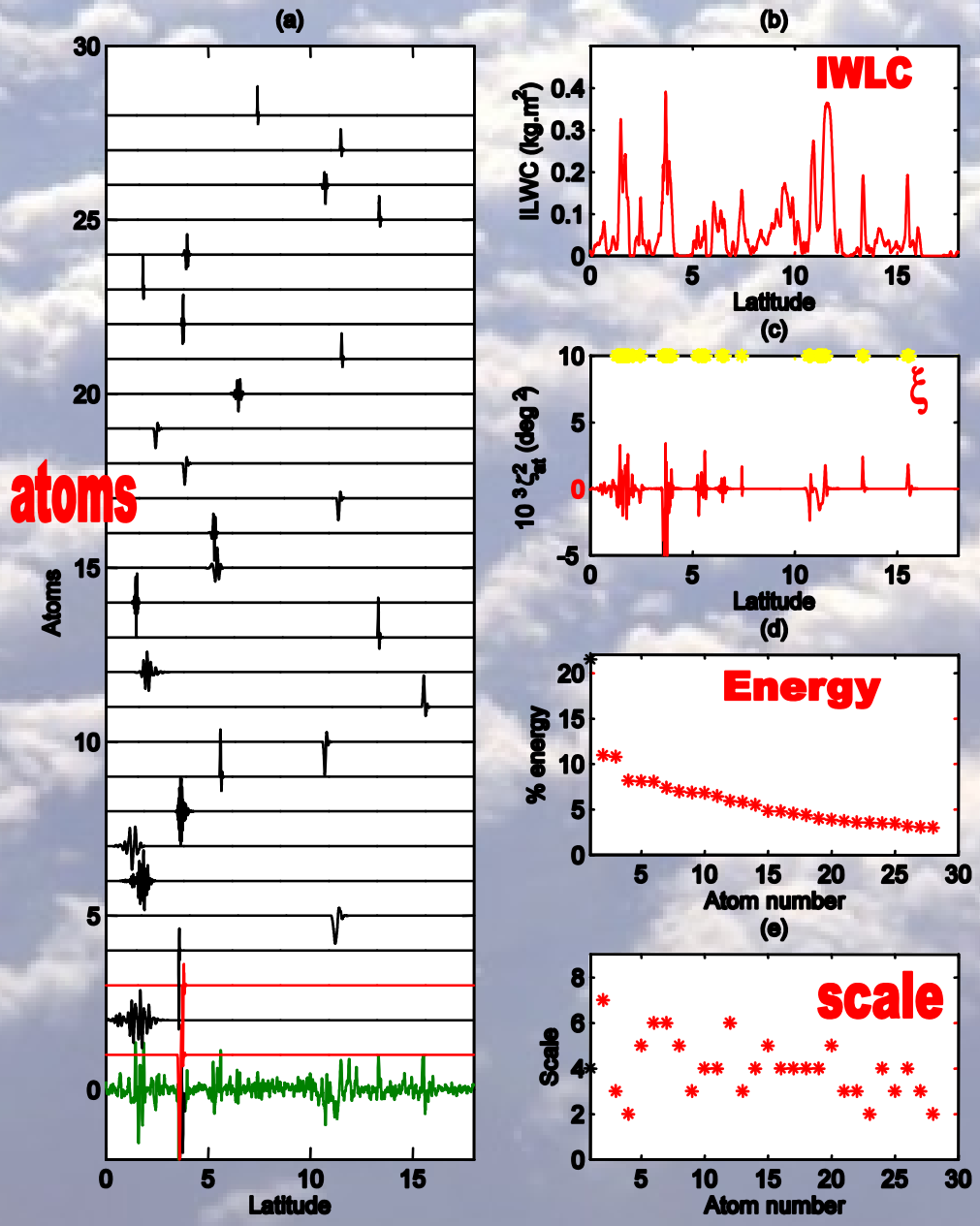
$$R_s^n = < R_s^n, g_{\gamma_n} > + R_s^{n+1}$$

$$\gamma_n = \arg\max_{\gamma} (< R_s^n, g_\gamma >)$$

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

- For a complete dictionary converges and conserrves energy

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

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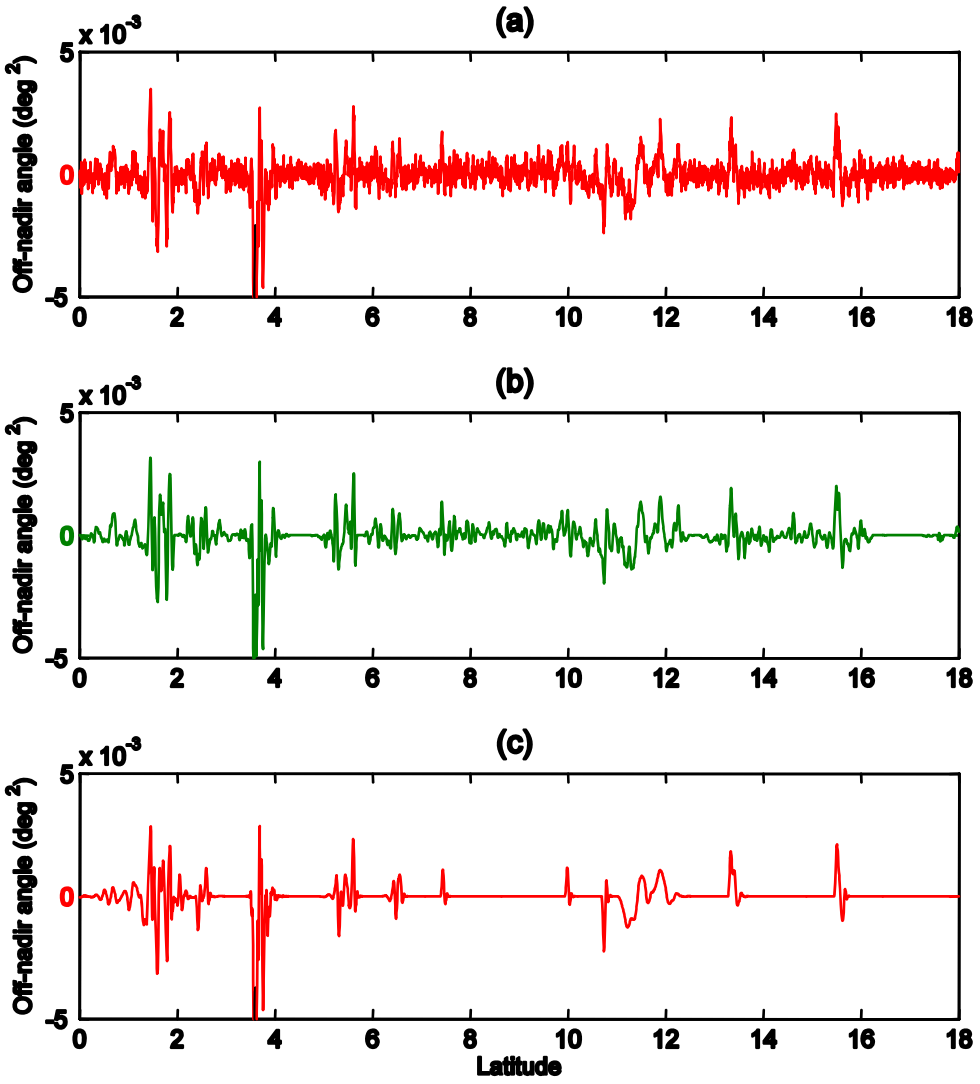
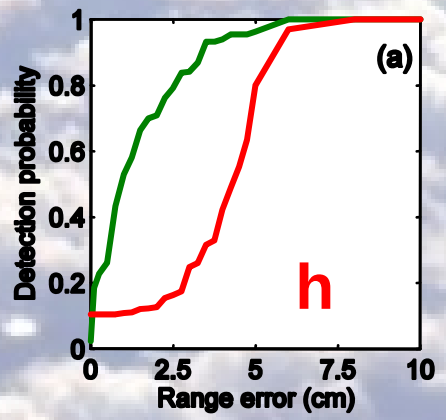
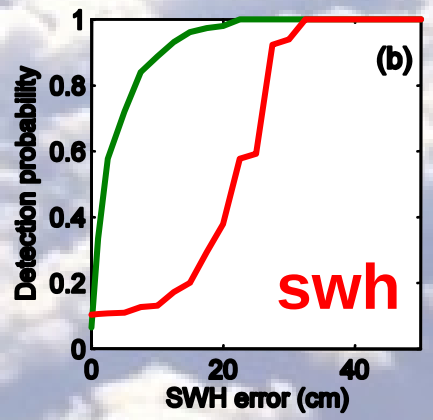
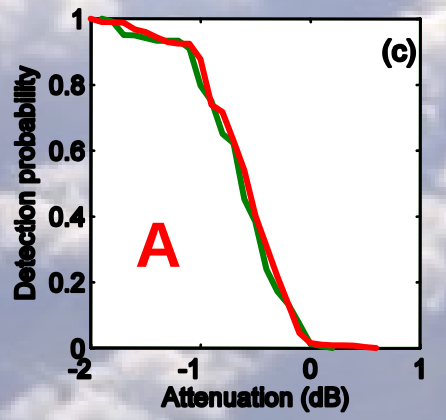


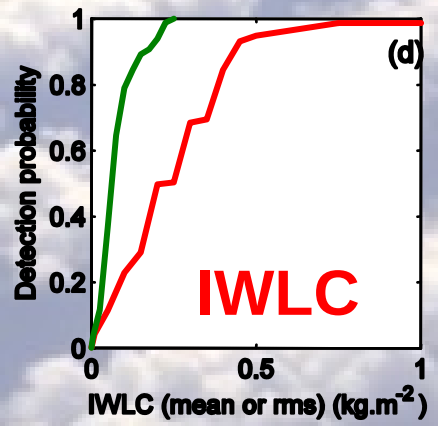
Performances of the MP flag.





Noisy



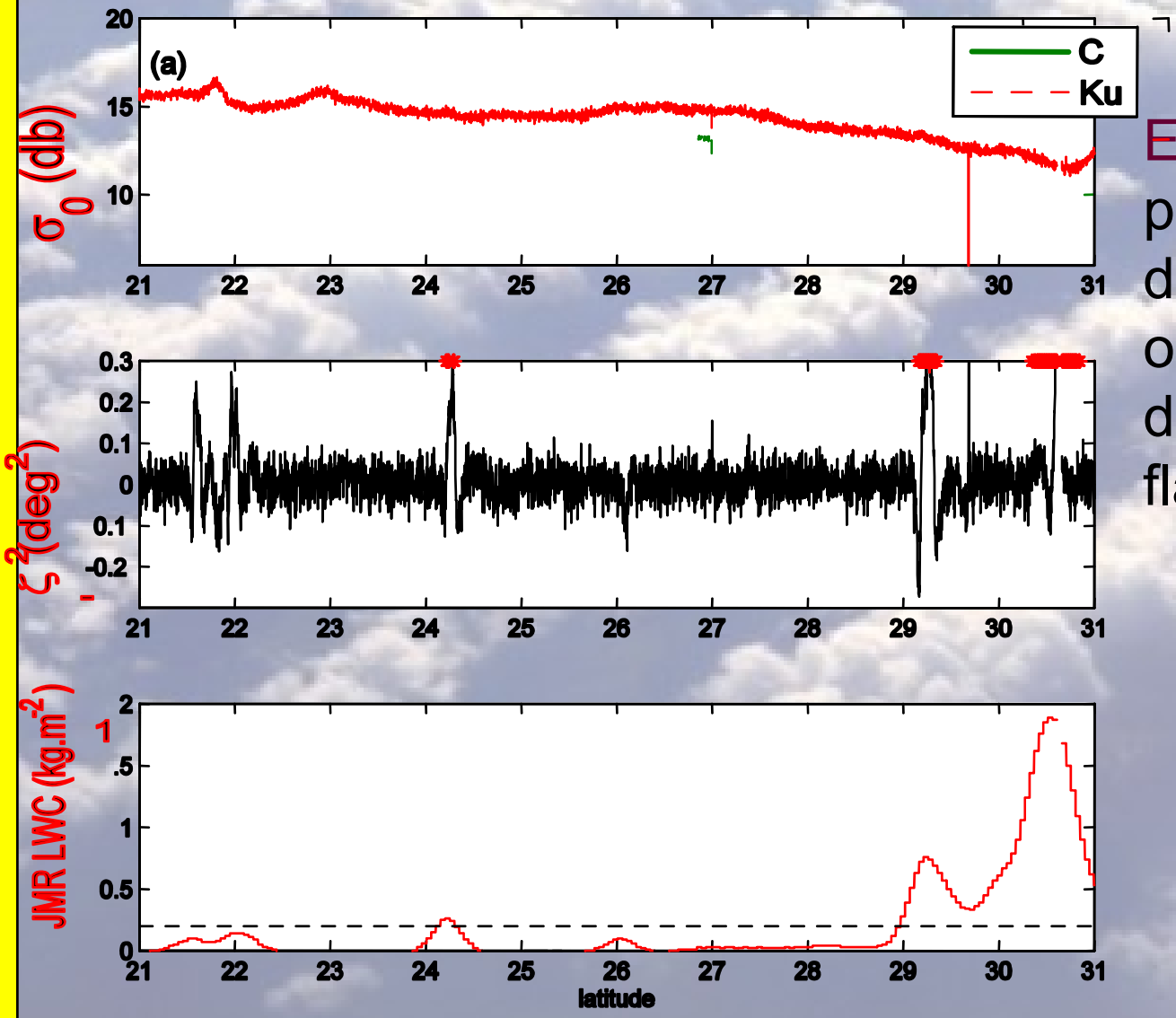


Non Noisy

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

False alarm ~0 for IWLC

Validation with Jason data



Example : Jason pass where rain detected by operational dual-frequency flag

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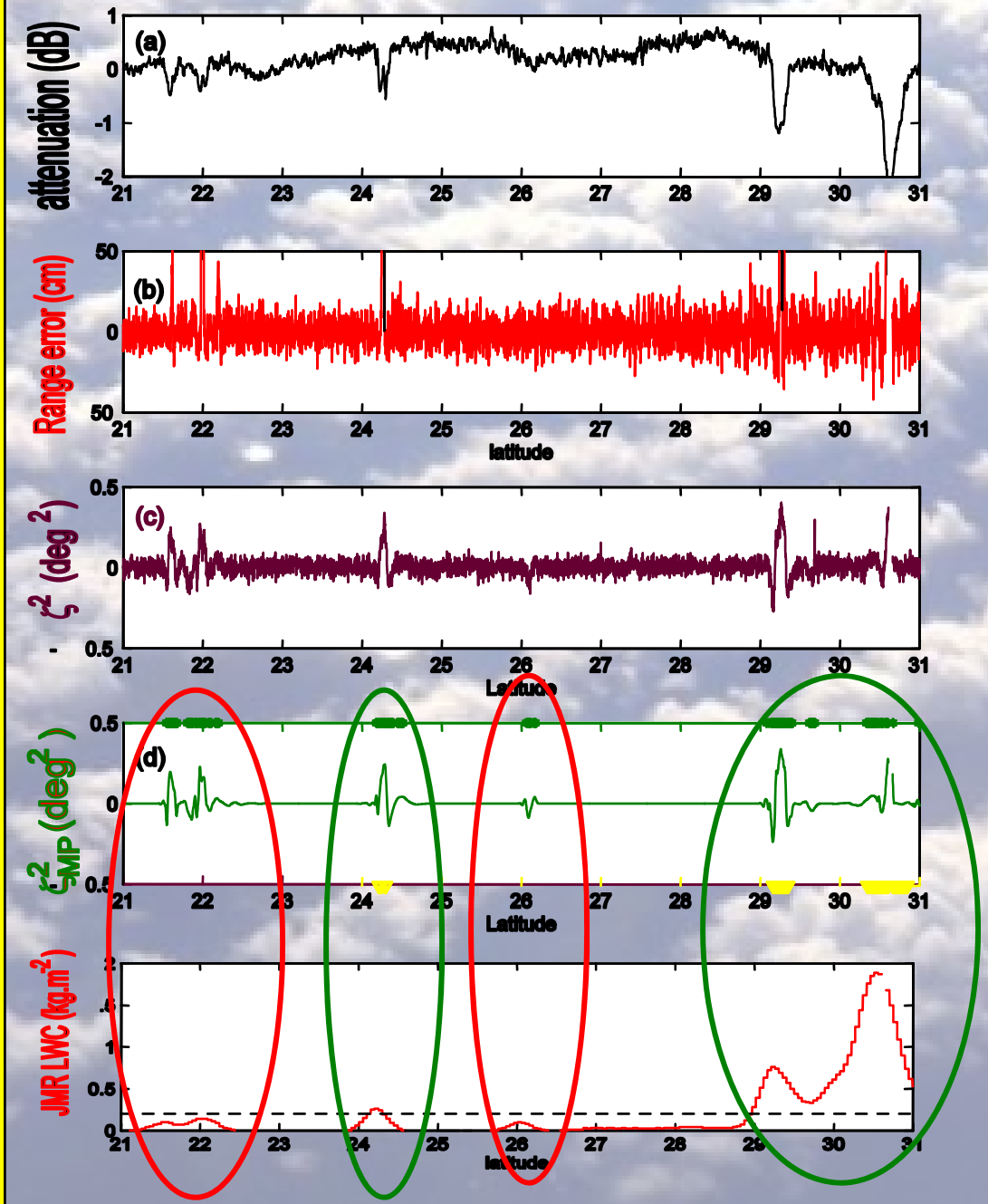
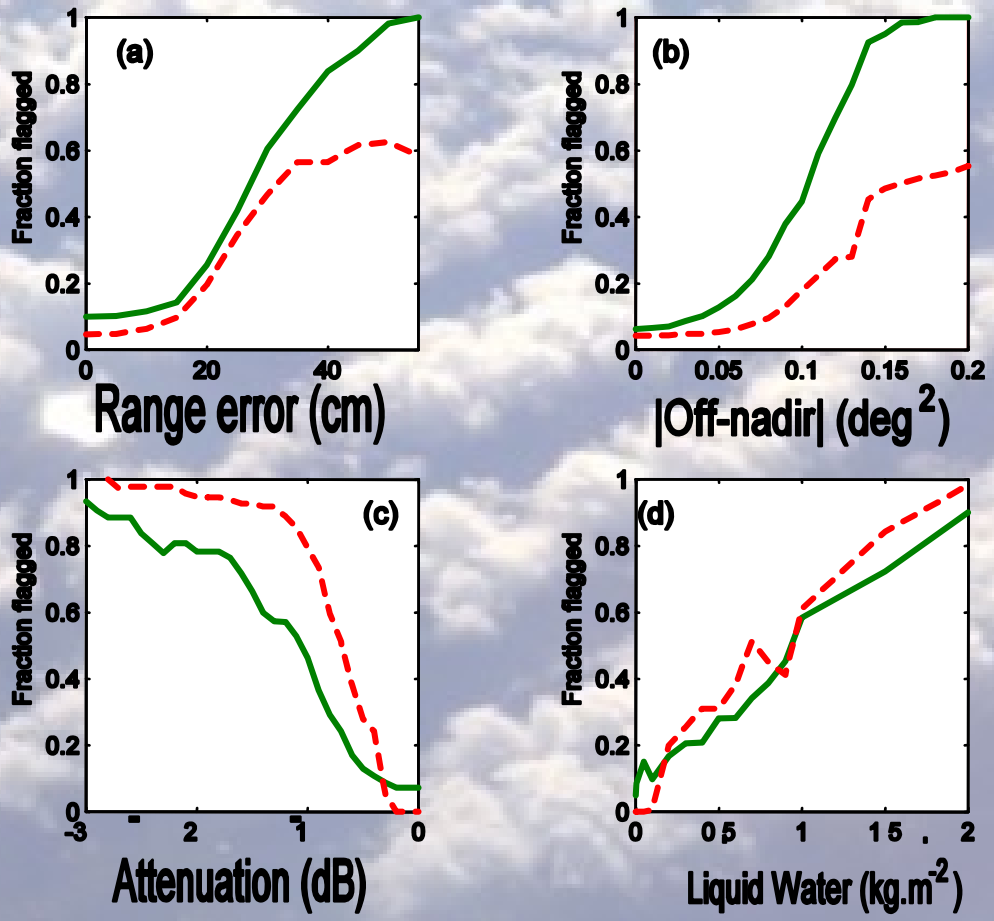


MP flag

MP performs as well as the operational flag

Better for small rain cells with low ILWC

Comparison of MP and Operational Jason flags performances



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Conclusion

- Availability of Altika > 90% (but locally more than 15% data loss : ITCZ)
- Rain/cloud flag based on the analysis of the off-nadir angle variation
- MP flag performs as well as Jason dual frequency rain flag