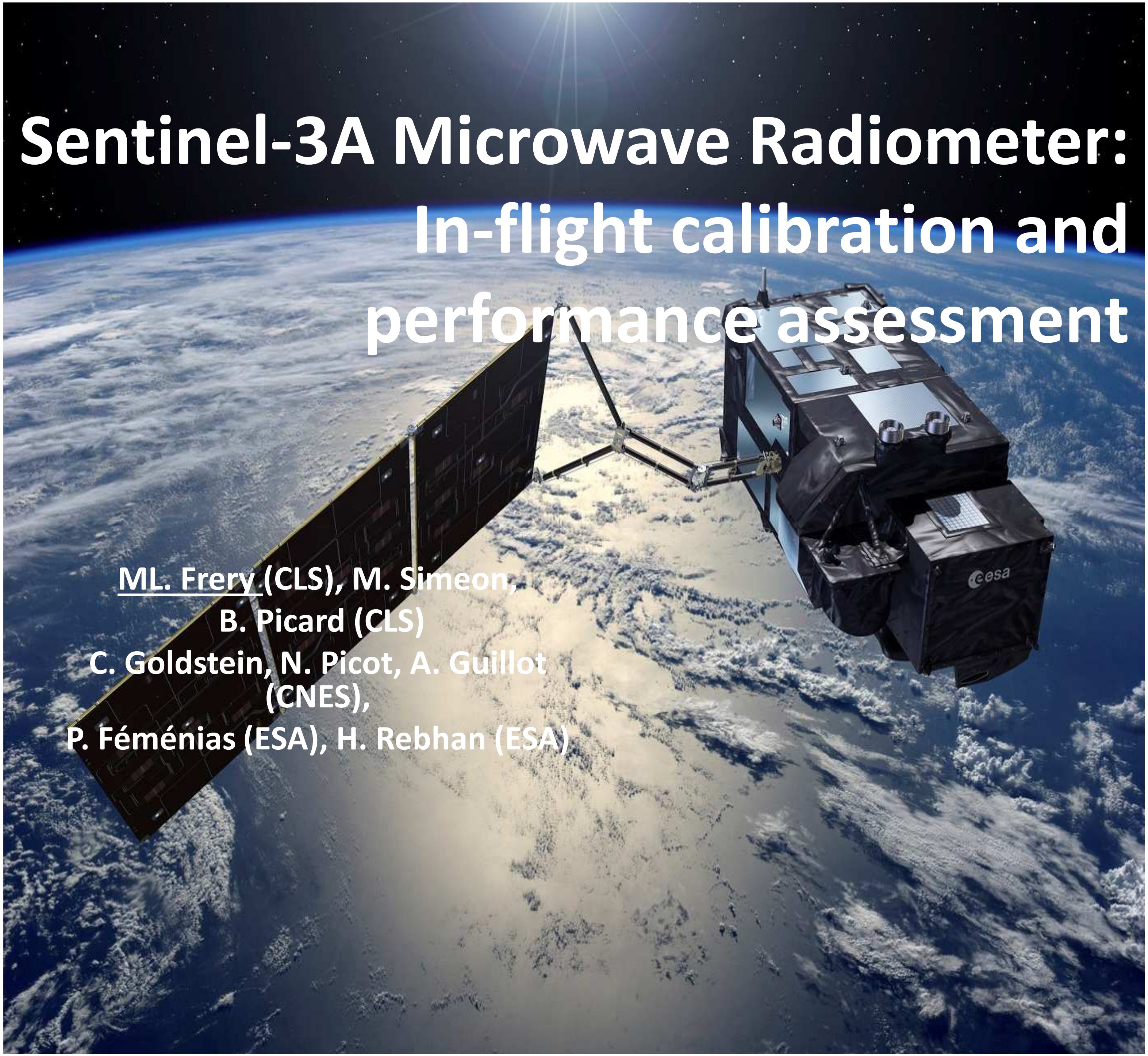


Sentinel-3A Microwave Radiometer: In-flight calibration and performance assessment

ML. Frery (CLS), M. Simeon, B. Picard (CLS)
C. Goldstein, N. Picot, A. Guillot (CNES),
P. Féménias (ESA), H. Rebhan (ESA)

Context

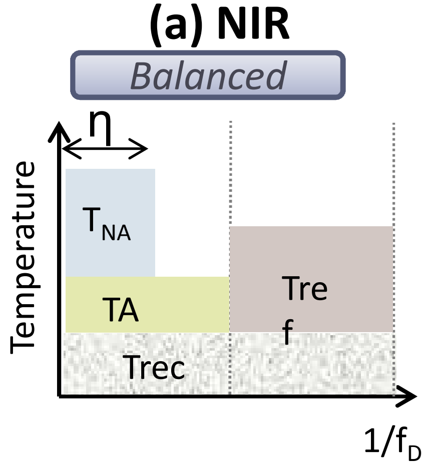
- During PhaseE1,
  - for **CNES** in the context of the cooperation CNES/ESTEC, for Functional verification of MWR , Internal calibration verification, Vicarious calibration, Wet tropospheric correction validation (Assessment of the WTC)
  - **S3/MPC** for Preparation and parametrisation of inversion algorithm for retrieval of geophysical parameters (wet tropospheric correction, atmospheric attenuation,..)
- Phase E2, full hand-over to S3/MPC MWR team for the RampUp and Routine Operational Phases
  - Monitoring of the MWR
  - L1 processor : verification and parametrisation
  - L2 processor : Parametrisation for MWR : inversion algorithms to retrieve the geophysical parameters (wet tropo. Corr., atmospheric attenuation,…)
  - Cal/Val activities

Overview

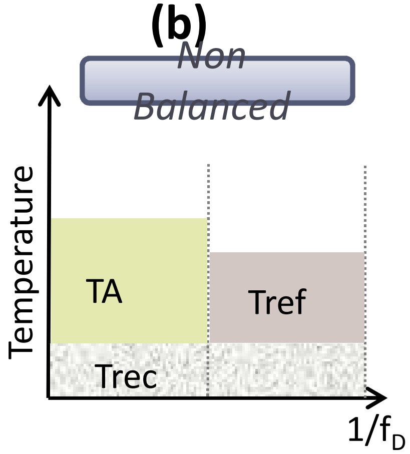
1. S3A/MWR : a noise diode injection radiometer
2. MWR Calibration
3. Wet tropospheric correction
4. Geophysical assessment
5. Conclusion

1. S3/MWR : a noise diode injection radiometer

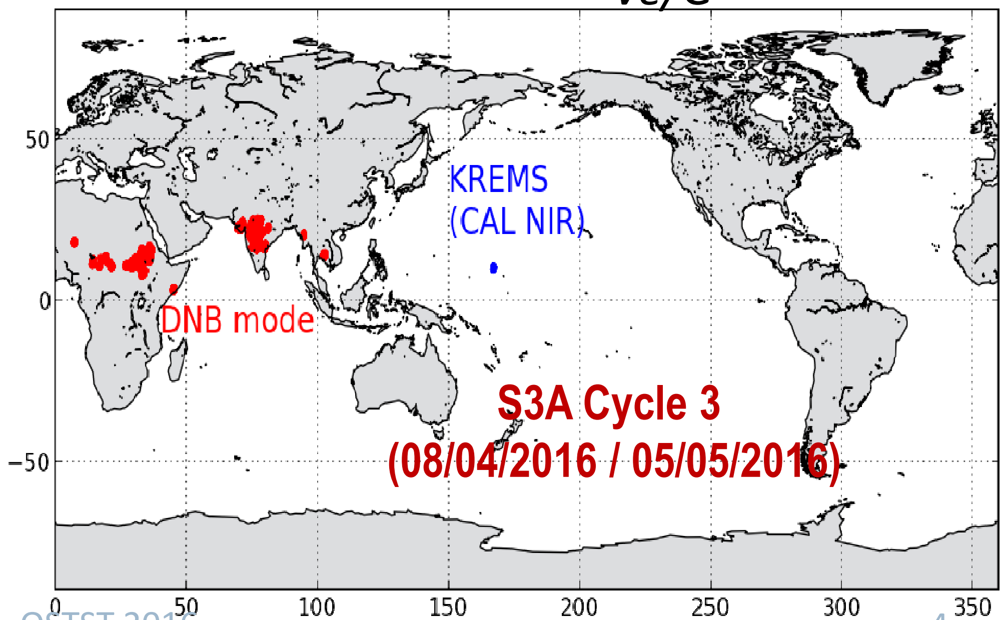
- Two channels radiometer 23.8GHz and 36.5GHz, with the same configuration than Envisat (36.5GHz pointing forward, 23.8GHz pointing backward)
- The MWR operates as a balanced Dicke radiometer for brightness temperatures lower than the reference load (Dicke load temperature).
- The balance is achieved by injection of noise with a noise diode (NIR, **main operation mode**).
- For brightness temperatures higher than the reference, the MWR operates in a conventional Dicke mode (Dicke Non-Balanced , **secondary mode**).
- **Calibration** performed 3 times per orbit (~9s) using dedicated sky horn and hot load
- **Overflight of KREMS radar facility** : switch to calibration mode for protection



$Tref=TA+\eta*T_{NA}$

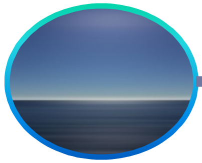


$TA\text{-}Tref = Ve/G$



2. MWR Calibration [1/5]

Lack of **absolute** natural reference target
Comparison to other radiometers (J2, AMSU-A, SARAL)



Coldest ocean points
- Low winds, no clouds, minimal water vapor
- Statistical selection of coldest ocean TB over ocean
- Method developed by Ruf and updated by Eymard to detect and monitor drifts

Simulations (single & double difference)
- Single difference: remove the impact of the instr. conf. & geophysic
- Double difference: assess the calibration difference between two radiometers

Amazon forest
- Naturel target closest to a black body
- Weak dependency with the frequency, polarisation and incidence
- Editing and average of measurements over evergreen forest

2. MWR Calibration [2/5]

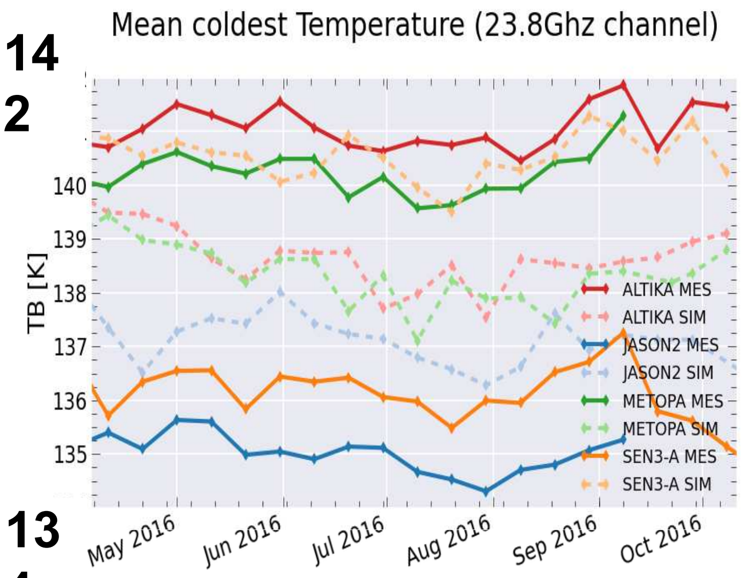
Δ1 =Meas-Sim

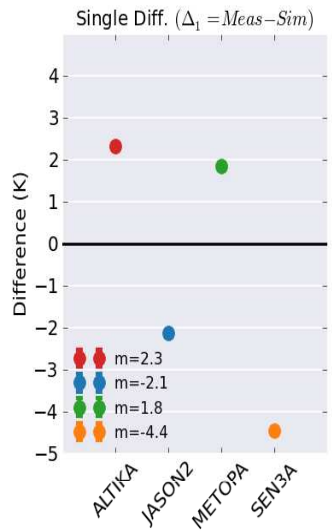
Vicarious calibration: Coldest ocean points

- Coldest ocean selection applied to measurements and colocated simulations (Radiative Transfer Model with ECMWF analysis)
- Consistent results for Sentinel-3A measurements with respect to other radiometers
- Sentinel-3A single difference (Δ1=Meas-Sim) larger than for other radiometers (measurements colder) for both channels

AL:37GHz, J2:34GHz, MetopA: 31.4GHz, S3A: 36.5GHz

14
2





13
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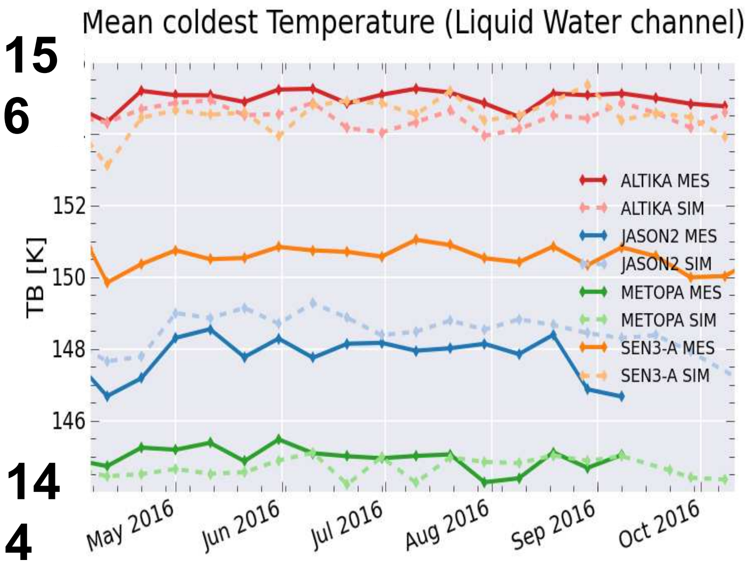
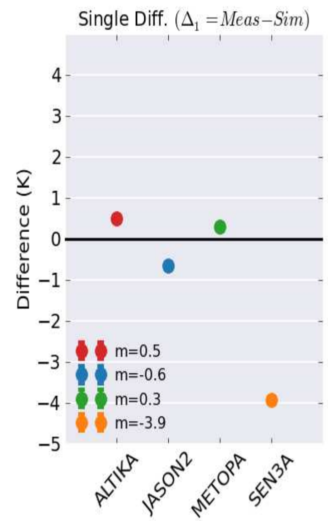
15
6





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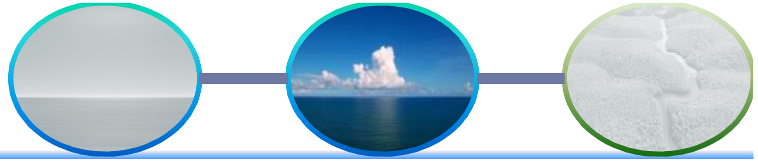
4

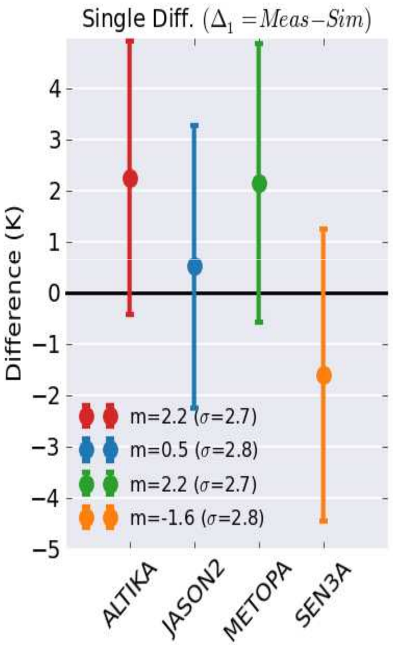
2. MWR Calibration [3/5]



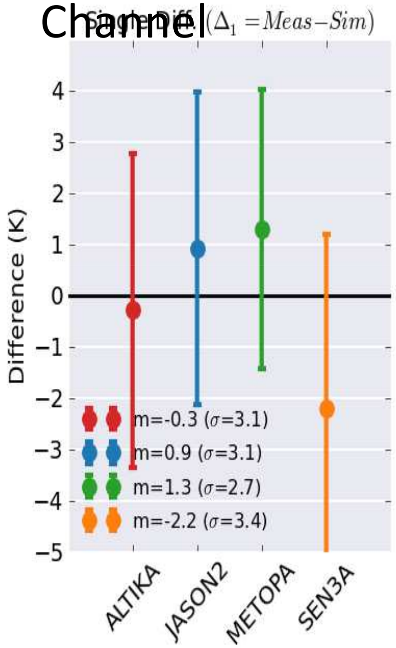
Vicarious calibration: Ocean points

Single Difference (Δ_1=Meas-Sim)

23.8GHz

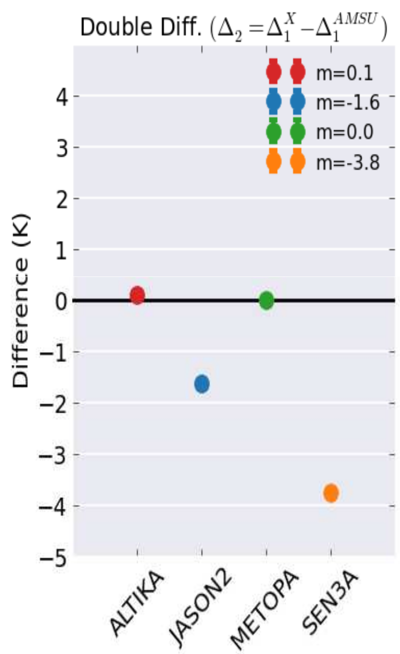


Liquid Water Channel

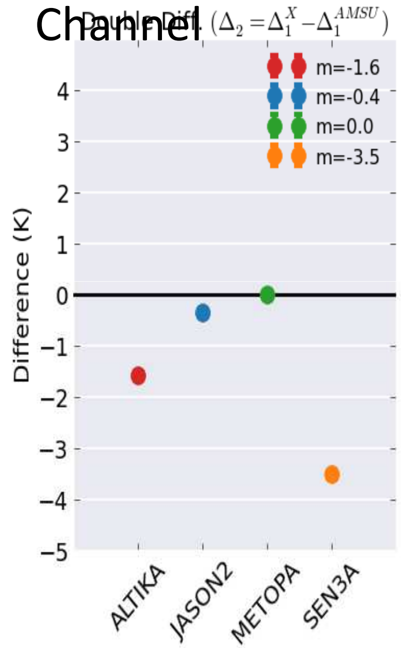


Double difference (Δ_2= Δ_1^X – Δ_1^{METOPA})

23.8GHz



Liquid Water Channel

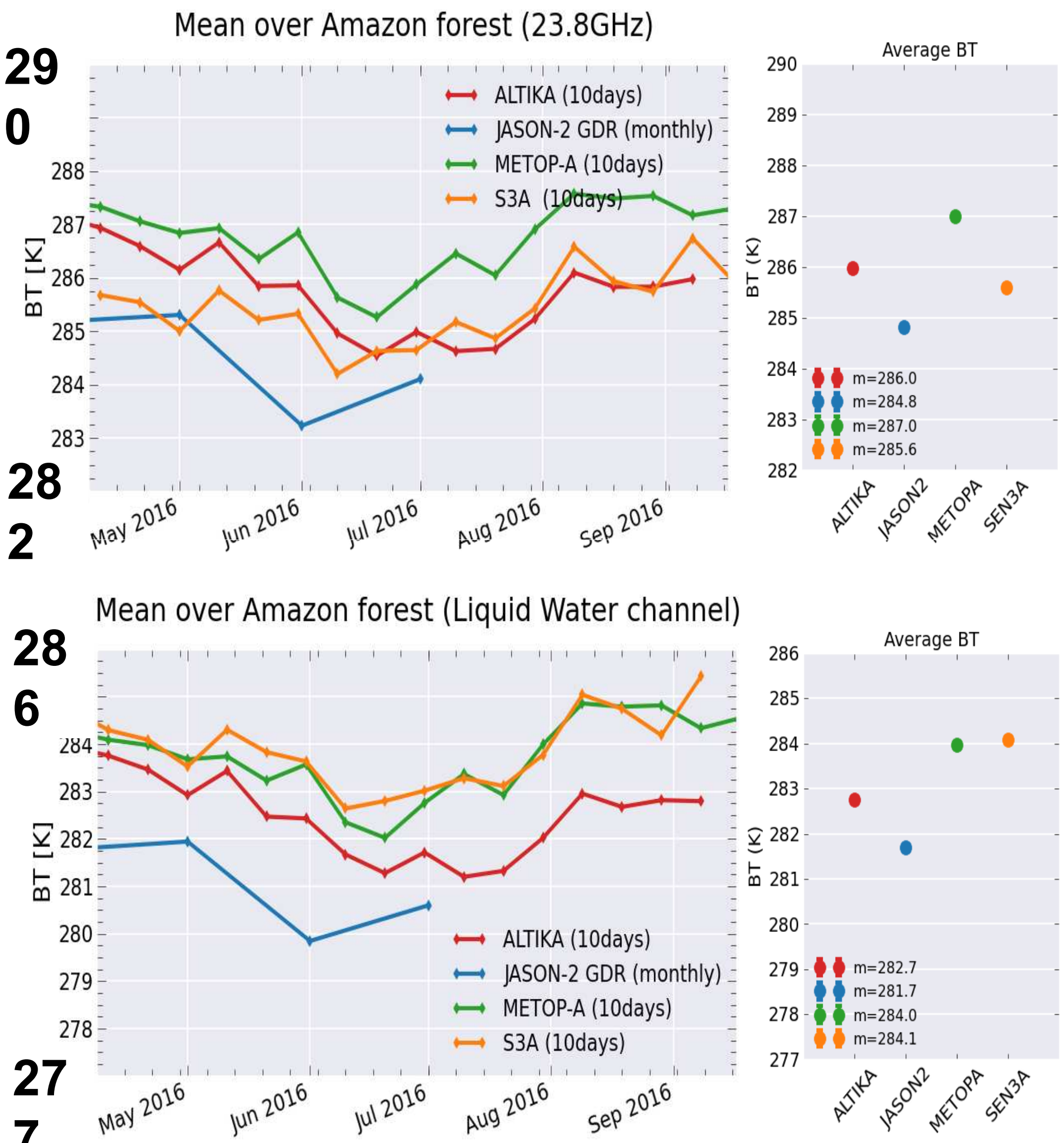


- Global good agreement of Sentinel-3A measurements with other radiometers
- Difference ascending/descending observed on the single difference
- Sentinel-3A colder than other radiometers over ocean : double difference wrt AMSU-A = -3.8 K/-3.5K for 23.8GHz and 36.5GHz respectively

2. MWR Calibration [4/5]

Vicarious calibration : Amazon forest
Selection of night overflight for each mission (different local hour) of evergreen forest
Not enough data to assess drifting but can be used for calibration

Good agreement of Sentinel3A measurements with other radiometers for the hottest temperatures



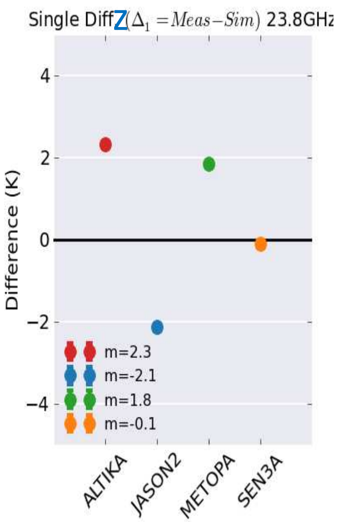
AL:37GHz, J2:34GHz, MetopA: 31.4GHz, S3A: 36.5GHz

2. MWR Calibration[5/5]

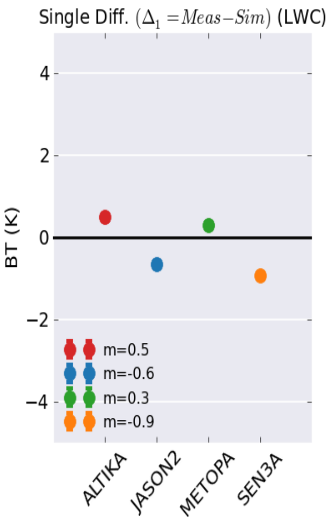
- Coldest temperatures too cold with respect to other radiometers and simulations
- Hottest temperatures very close to other radiometers

➔ Update of characterisation parameters of radiometer model

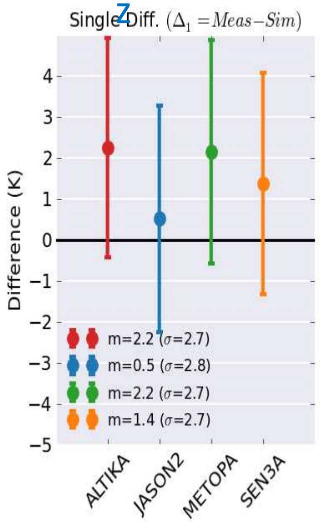
23.8GHZ



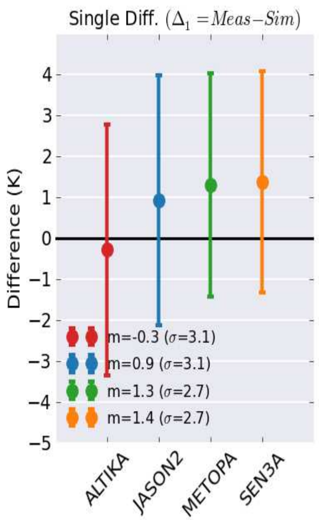
Liq. Water



23.8GHZ

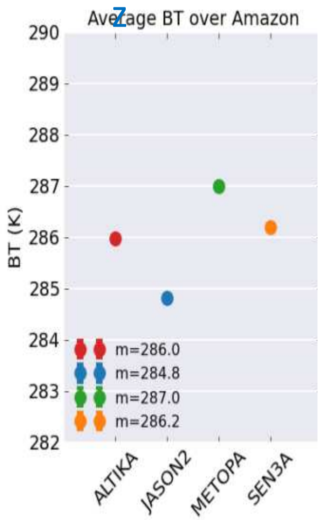


Liq. Water

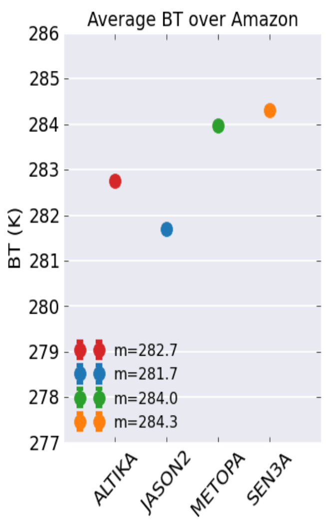


➔ Better agreement over ocean

23.8GHZ



Liq. Water

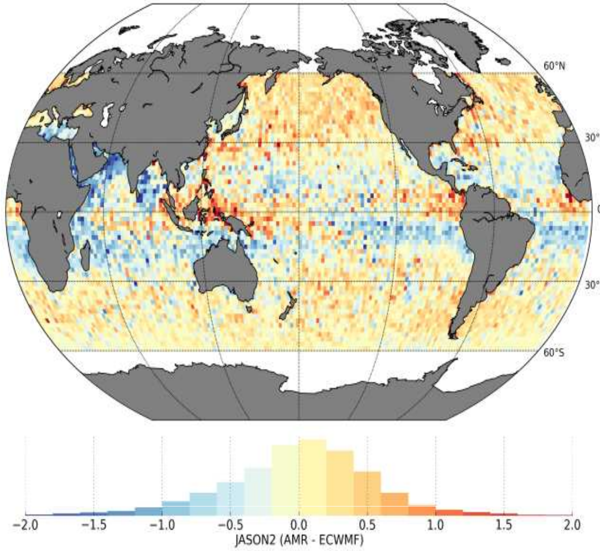


➔ Small impact on hottest temperatures

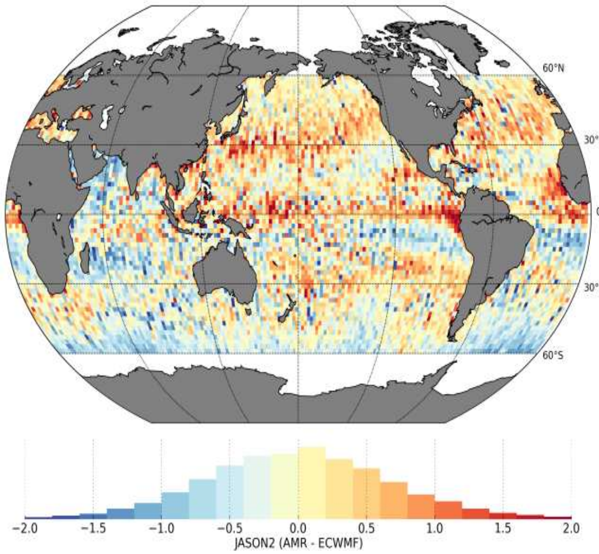
3. Wet tropospheric correction [1/2]

- 2 inversion algorithms based on neural network:
  - 3P : classical algorithm : 2*BTs + sigma0
  - 5P : enhanced algorithm : 2*BTs + sigma0+SST+Gamma
- First adjustment (#1) applied in operational processor
- New adjustment (#2) (for the new calibration) soon in L2 products
- ΔWTC= (WTC_{MWR}-WTC_{ECMWF}) for cycle 4 of Sentinel-3A

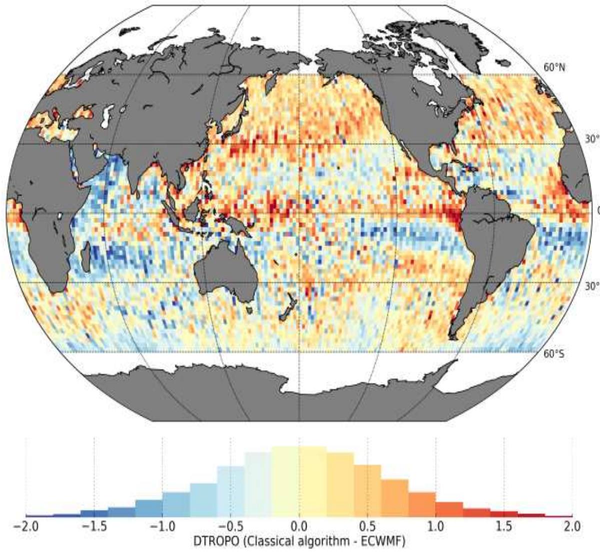
JASON-2 ΔWTC



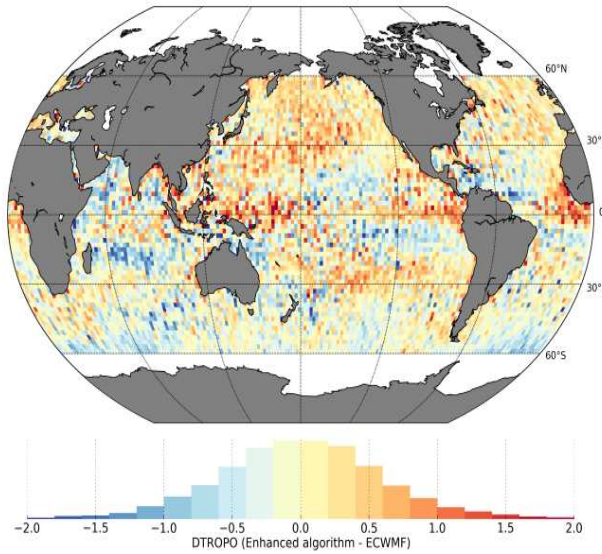
S-3A ΔWTC : 3P(#1)



S-3A ΔWTC : 3P(#2)

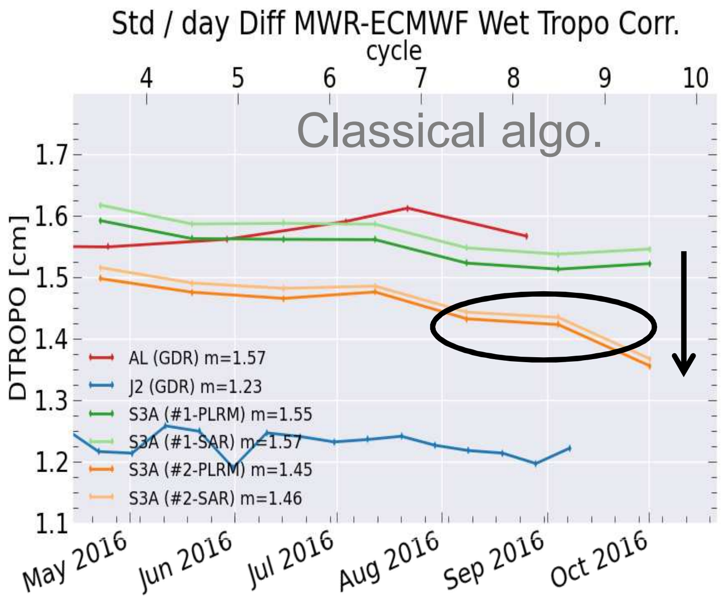


S3-A ΔWTC : 5P(#2)

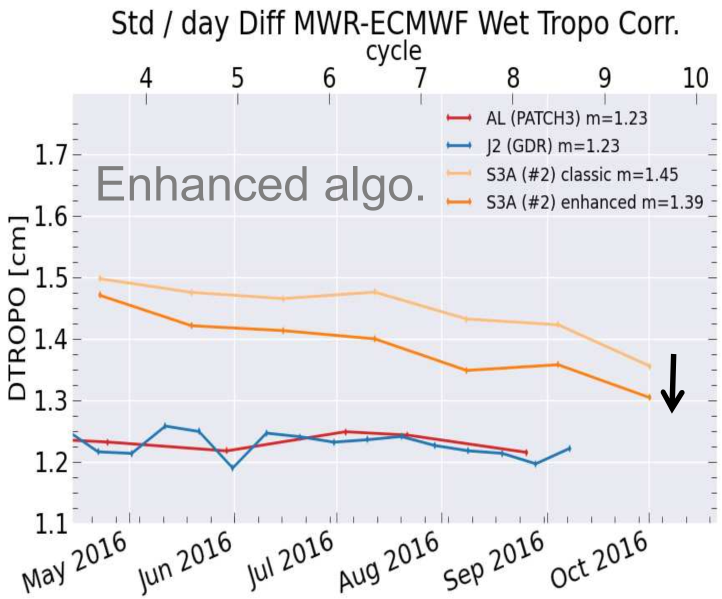


Wet tropospheric correction [2/2]

- 2 inversion algorithms based on neural network:
  - 3P : classical algorithm : 2*BTs + sigma0
  - 5P : enhanced algorithm : 2*BTs + sigma0+SST+Gamma
- First adjustment (#1) applied in operational processor:
- New adjustment (#2) (and the new calibration) soon in L2 products
- $\Delta WTC = (WTC_{MWR} - WTC_{ECMWF})$ with selection shoreline distance > 50km



- Reduction of the standard deviation of ΔWTC with the new adjustment
- **Similar results using PLRM Sigma0 or SAR Sigma0**
- Reduction of the standard deviation with the enhanced algorithm (wrt classical algorithm)
- **Good performances of the wet tropospheric correction according to this metric**



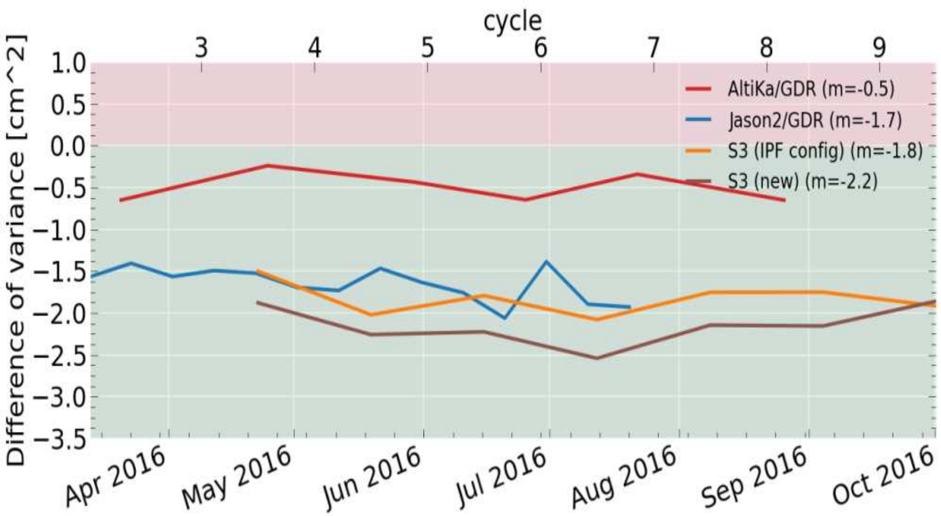
Geophysical assessment of WTC [1/4]

- Geophysical assessment by SSH at crossover points
  - Difference of variance of SSH when using MWR WTC (3P – Sigma0 PLRM) instead of ECMWF correction :

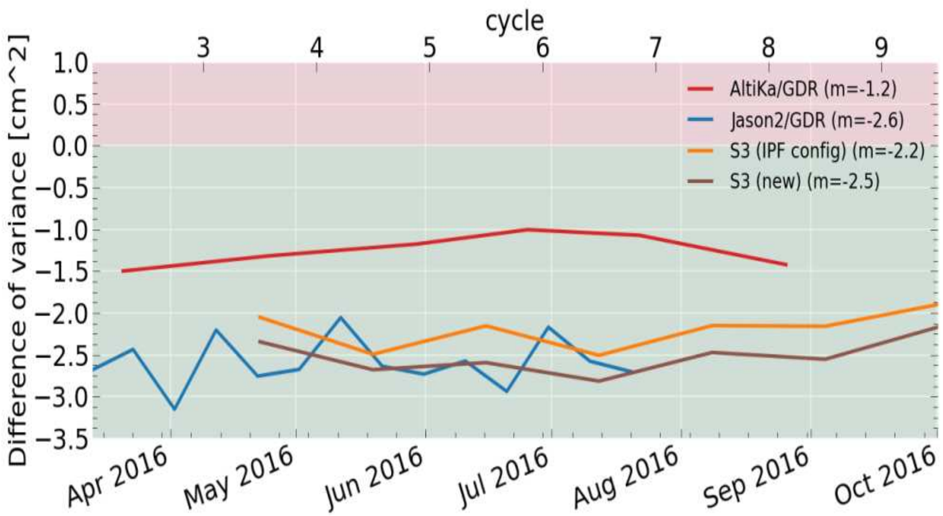
$$\Delta VarSSH = VAR\_SSH\_WTC_{MWR} - VAR\_SSH\_WTC_{ECMWF}$$

- Analysis limited by the number of cycles available
- Surprisingly good results for Sentinel-3A : Mean ΔVarSSH=-2.0cm^2 for S3A (Mean=-1.7cm^2 for J2) whereas S3A is a two-channels radiometer

Sel 1 : |LAT|<60



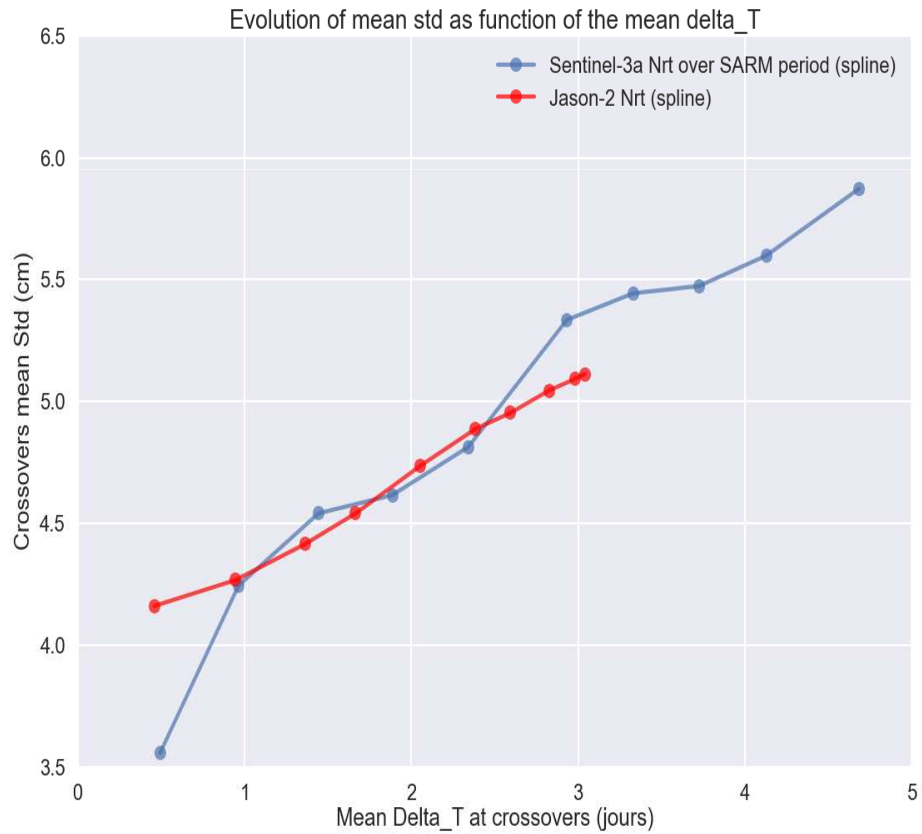
Sel 2 : |LAT|<50, low oceanic variability



Geophysical assessment of WTC [2/4]

- Attention to be paid to the time lag at cross over points:
  - Mean time lag at cross over points (10days window) is varying with the orbit :
    - Jason2 ≈ 3 days
    - AltiKA ≈ 5 days
    - Sentinel-3A ≈ 5 days
  - Std of SSH at cross over points is decreasing with the time lag decrease

See M. Raynal talk during SAR Altimetry workshop: “Sentinel-3a Delay Doppler Processing: Assessment over the Global Ocean”

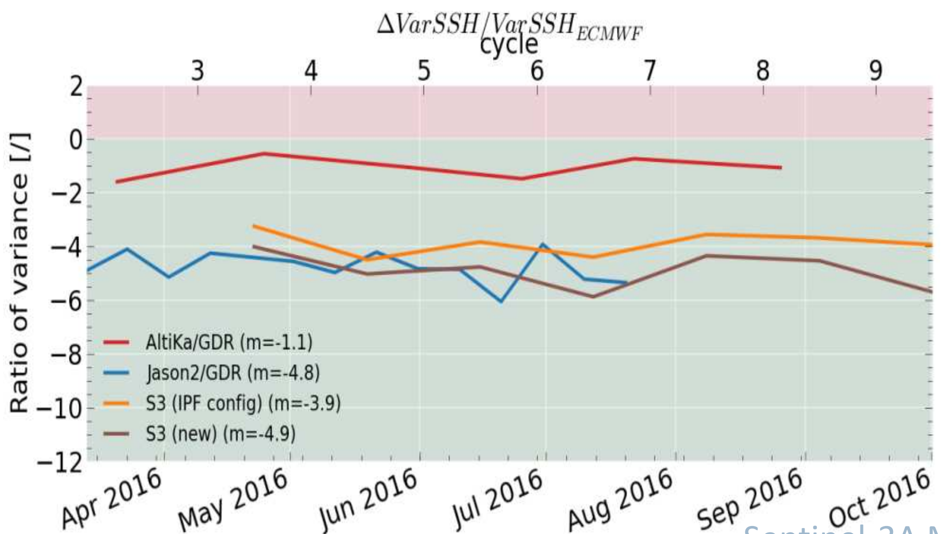


Geophysical assessment of WTC [3/4]

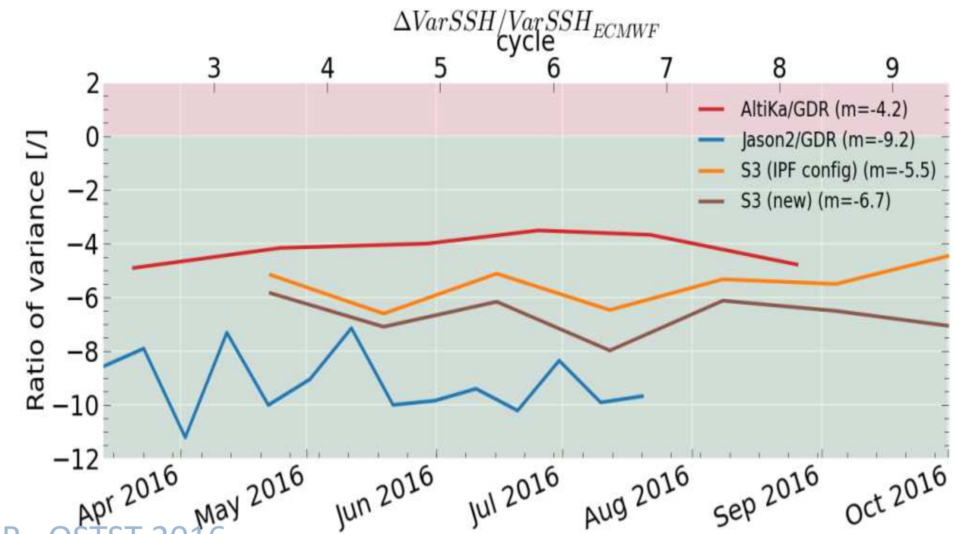
- Attention to be paid to the time lag at cross over points:
  - Mean time lag at cross over points (10days window) is varying with the orbit :
    - Jason2 ≈ 3 days
    - AltiKA ≈ 5 days
    - Sentinel-3A ≈ 5 days
  - Std of SSH at cross over points is decreasing with the time lag decrease
- ➔ Comparison of ΔVarSSH can not be performed directly
- Introduction of ratio to assess the performance of one correction : $R = \frac{\Delta VarSSH}{VarSSH_{ECMWF}}$

Classical algorithm for S3A (Sigma0-PLRM)

Sel 1 : |LAT|<60



Sel 2 : |LAT|<50, low oceanic variability



Geophysical assessment of WTC [3/4]

- Attention to be paid to the time lag at cross over points:
  - Mean time lag at cross over points (10days window) is varying with the orbit :
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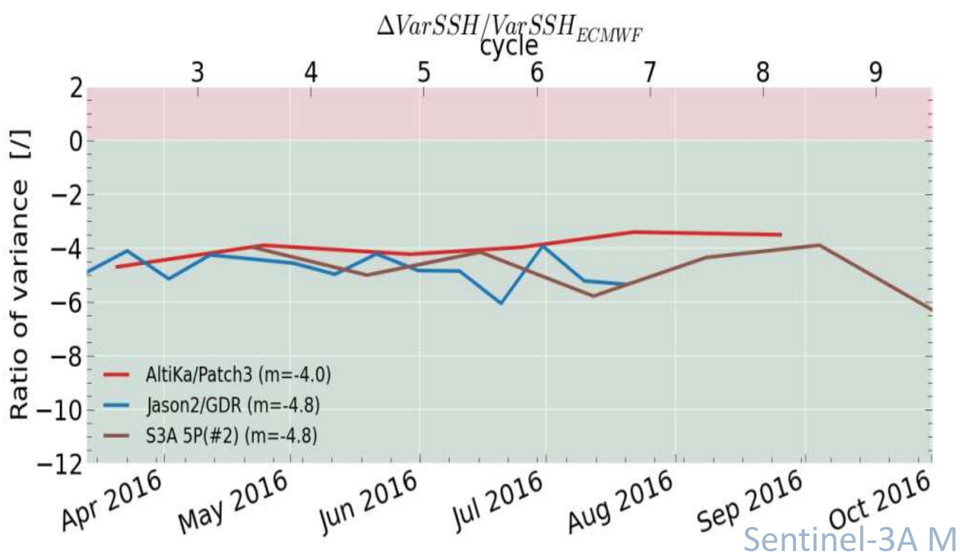
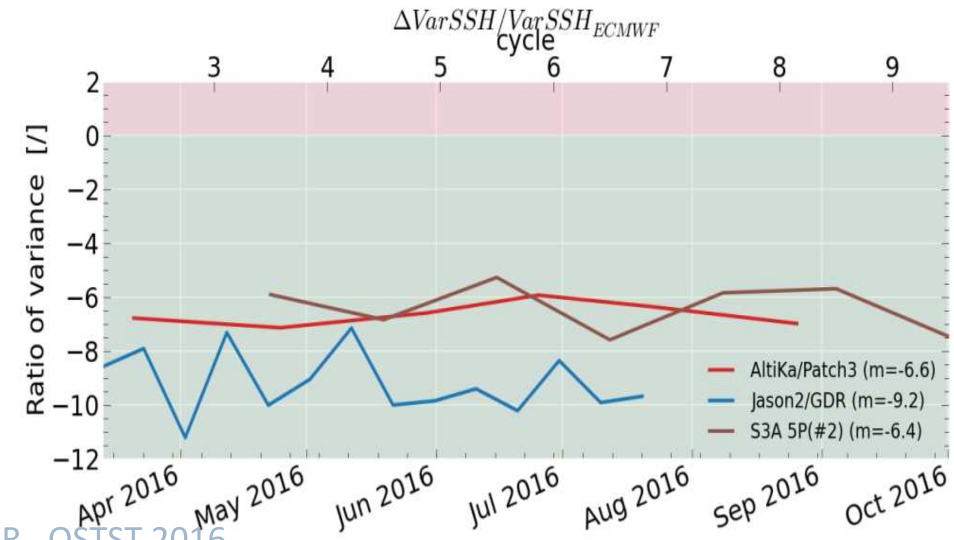
    - Sentinel-3A ≈ 5 days
  - Std of SSH at cross over points is decreasing with the time lag decrease
- ➔ Comparison of ΔVarSSH can not be performed directly
- Introduction of ratio to assess the performance of one correction : $R = \frac{\Delta VarSSH}{VarSSH_{ECMWF}}$

Enhanced algorithm for S3A (Sigma0-PLRM)

Sel 1 : |LAT|<60



Sel 2 : |LAT|<50, low oceanic variability



Conclusion

- Very good performances of S3A/MWR since switch-on: Global good agreement with other radiometers
  - Good performances for hottest BTs
  - Lowest Bts are cooler than other MWR, the new set of calibration parameters address the issue
- Assessment of wet tropospheric correction
  - Good performances on the wet tropospheric correction for both 3P and 5P algorithms
  - Similar performances using PLRM or SAR Sigma0
  - Need for more data to carry on the assessment of the performances : better understanding of the results of ΔVarSSH
- Perspectives
  - New calibration timeline to reduce data gaps in L2 products
  - Ascending/descending analysis

THANKS FOR YOUR ATTENTION

<u>ML. Frery</u>, M. Siméon, B. Picard: Collecte Localisation Satellite, France
C. Goldstein, N.Picot, A. Guillot : Centre National d'Etudes Spatiales, France
H. Rebhan , P. Féménias: European Space Agency