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Independent assessment of Sentinel-3A wet path delay

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Scope and Objective

- Launched on 02 February 2016, Sentinel-3A (S3A) carries a dual channel microwave radiometer (MWR) for the retrieval of the wet tropospheric correction (WTC).
- This study aims at an independent assessment of S3A MWR-based WTC.
- This study is a contribution to the Sentinel-3 Validation Team project VOCALS3 and to project SCOOP.

S3A Data and Methodology

S3A data

- L2 Non Time Critical (NTC) processing Baseline 2.15 available in RADS (rep1) since mid-August 2017
- MWR L1 IPF (MW-1): version 06.04
- Time span: 10 months - from cycle 05 (15 June 2016) to cycle 16 (16 April 2017)
- S3A orbit - 814 km; inclination 98.65°; sun-synchronous; 27-day repeat

Methodology

Assessment of S3A MWR-based WTC data has been performed by means of:

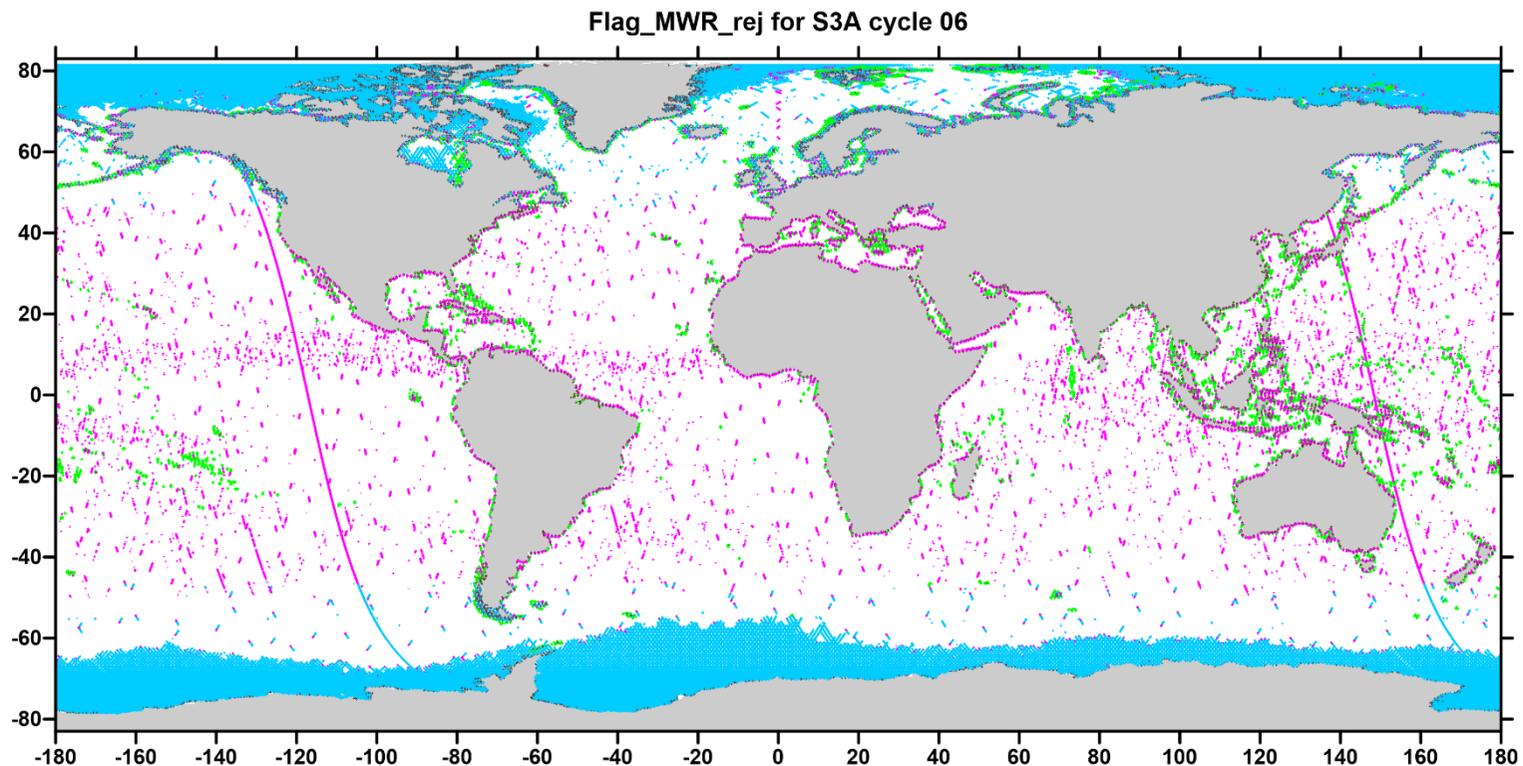
- Comparison with other MWR: GMI, J2, J3, SARAL
- Comparison with a GNSS-derived Path Delay Plus (GPD+) WTC computed only with third party data
- Sea level anomaly (SLA) variance analysis
- Comparison with WTC from GNSS coastal stations

GMI - GPM Microwave Imager

- GMI is a dual-polarization, multi-channel, conical-scanning, passive microwave radiometer on board the Global Precipitation Measurement (GPM) satellite
- Designed with a strict calibration accuracy requirement, enabling the instrument to serve as a microwave radiometric standard
- Launched in February 2014
- Orbit: Altitude - 407 km; inclination 65°; non sun-synchronous
- Orbit plane completes half (180°) a rotation relative to the Sun every 41.1 days
- Yaw maneuvers every 40 days to compensate for the Sun's changing position and prevent the side of the spacecraft facing the Sun from overheating
- Match points with S3A with $\Delta T < 45$ min and $\Delta D < 50$ km were computed
- Only points considered valid by the GPD algorithm are used (contamination by e.g. land, ice and rain are removed)

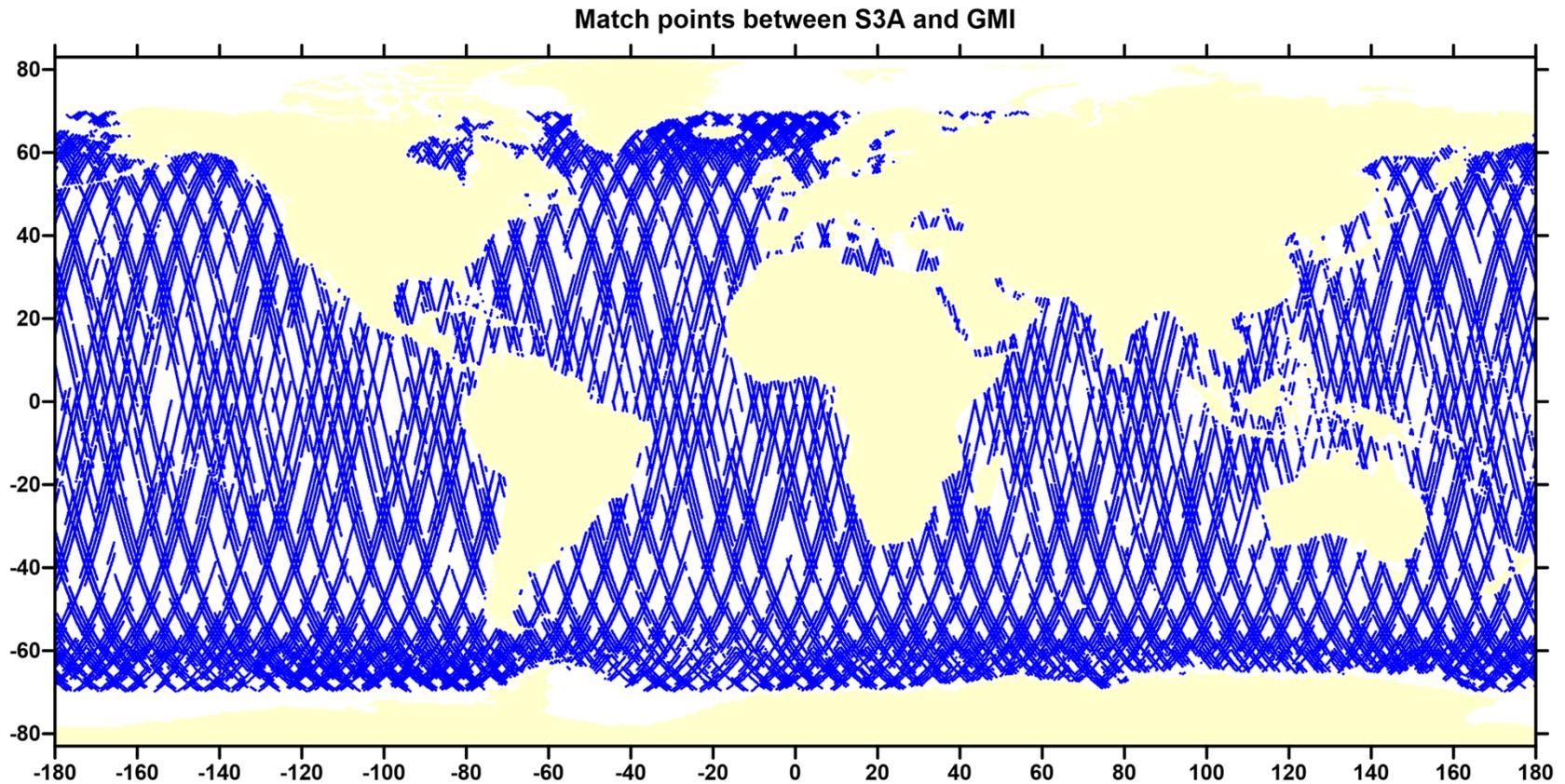
S3A MWR invalid points

The assessment has been performed only for valid MWR points



S3A points for cycle 06 with invalid MWR observations: **green** – land contamination; **blue** – ice contamination; **pink** – rain or outliers; **brown** – land points

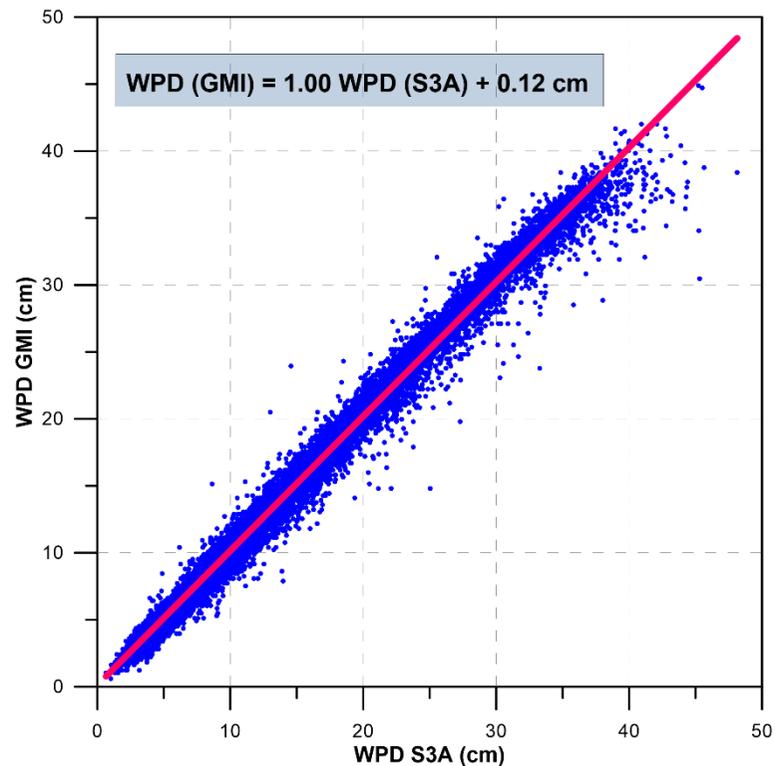
Comparison with GMI



Spatial coverage of match points between S3A and GMI with time difference $\Delta T < 45$ min and distance $\Delta D < 50$ km, for S3A cycles 05-16, used in this study (~219000 points).

Comparison with GMI

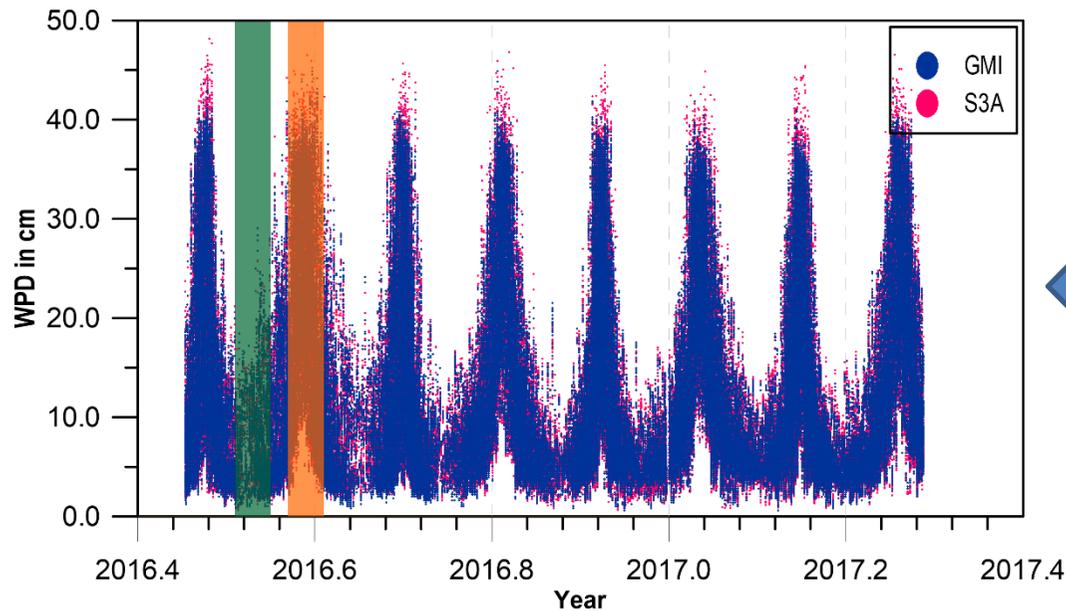
In the comparisons with other sensors, the wet path delay (WPD, symmetric of WTC) has been used. The scale factors, offsets and RMS of differences refer to WPD.



Scale factor: 1.00
Offset: 0.12 cm

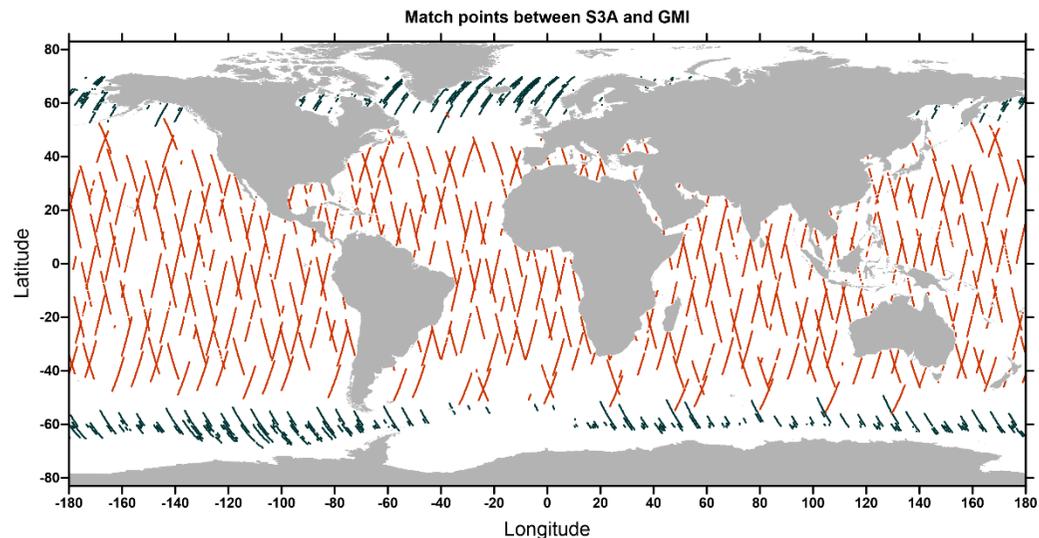
Wet path delay (WPD, symmetric of WTC) from S3A versus WPD from GMI (~219000 points)

Comparison with GMI

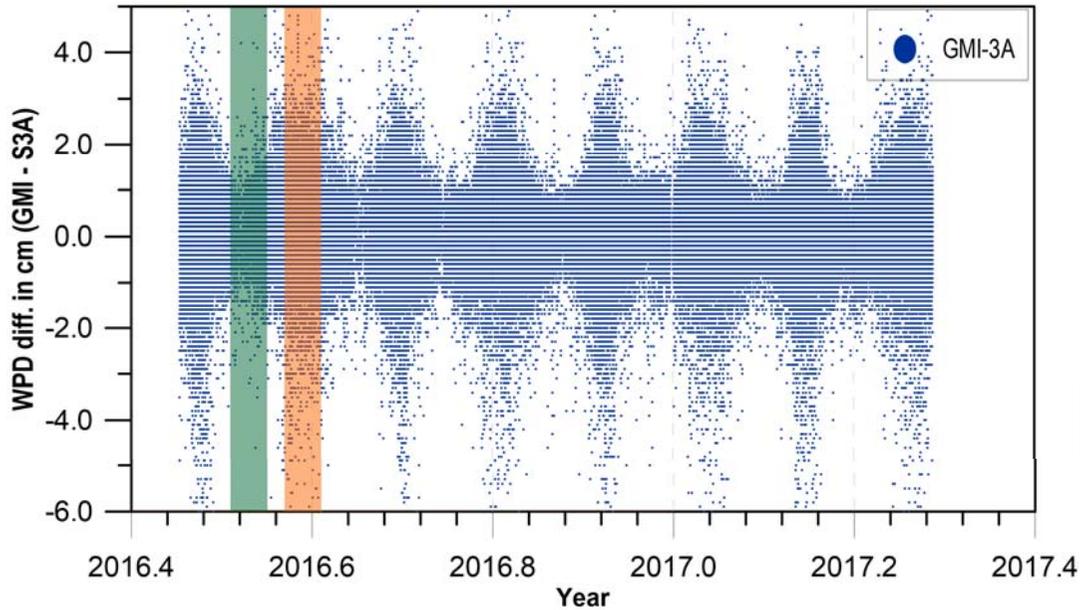


Time evolution of WPD from GMI (blue) and S3A (red).
← Strong periodic (41.1 day) signal due to GPM orbit plane rotation wrt the Sun.

Color bars (top plot) refer to periods when the GMI/S3A match points (right plot) are all located at high latitudes (green) or low latitudes (orange) to which correspond smaller or larger WPD variability.



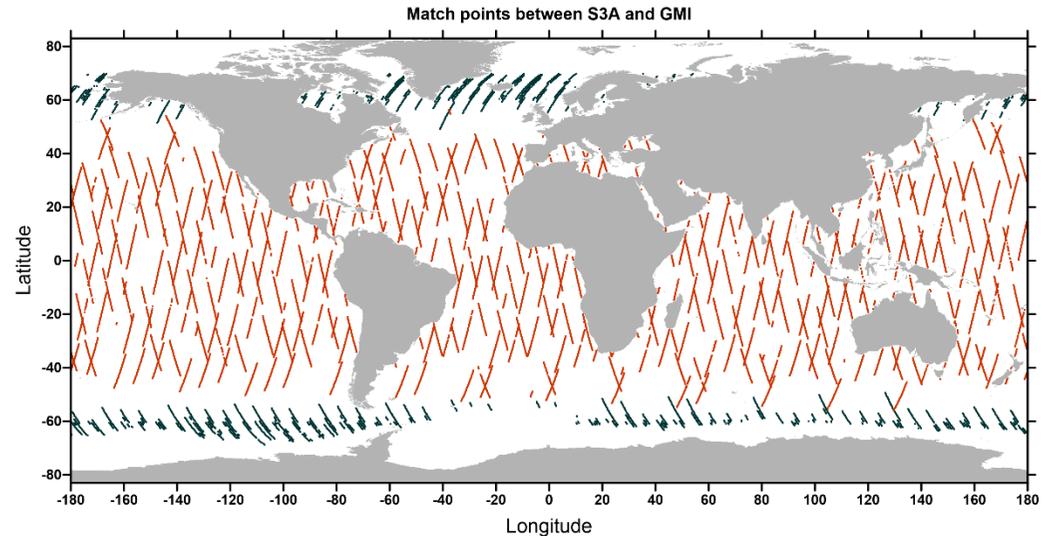
Comparison with GMI



← Time evolution of WPD differences between GMI and S3A.

RMS WPD(GMI)-WPD(S3A)=0.95 cm

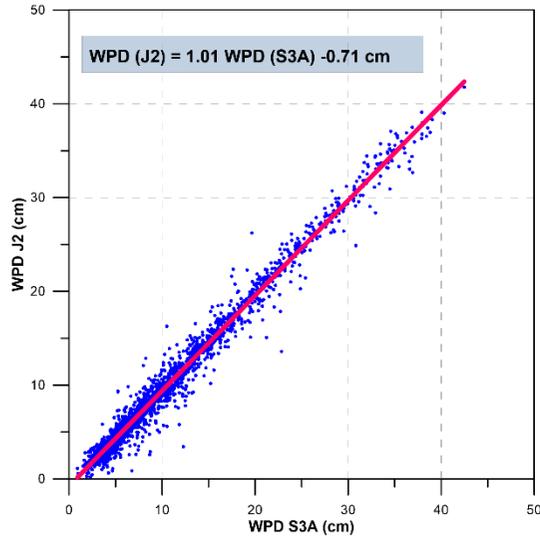
Color bars (top plot) refer to periods when the GMI/3A match points (right plot) are all located at high latitudes (green) or low latitudes (orange) to which correspond smaller or larger WPD differences respectively.



Comparison with J2, J3 and SARAL

- Xovers have been computed between S3A and the MWR on board each of the following missions: J2, J3, SARAL.
- For J2 and J3 xovers with time difference $\Delta T < 180$ min have been considered.
- For SARAL, xovers with time difference $\Delta T < 240$ min have been considered. Due to the fact that S3A and SARAL are both sun-synchronous, with different LTAN, this is the minimum time interval to get Xovers at low latitudes.
 - Sentinel-3: LTAN – 22:00; LTDN - 10:00
 - SARAL: LTAN – 06:00; LTDN - 18:00

Comparison with J2



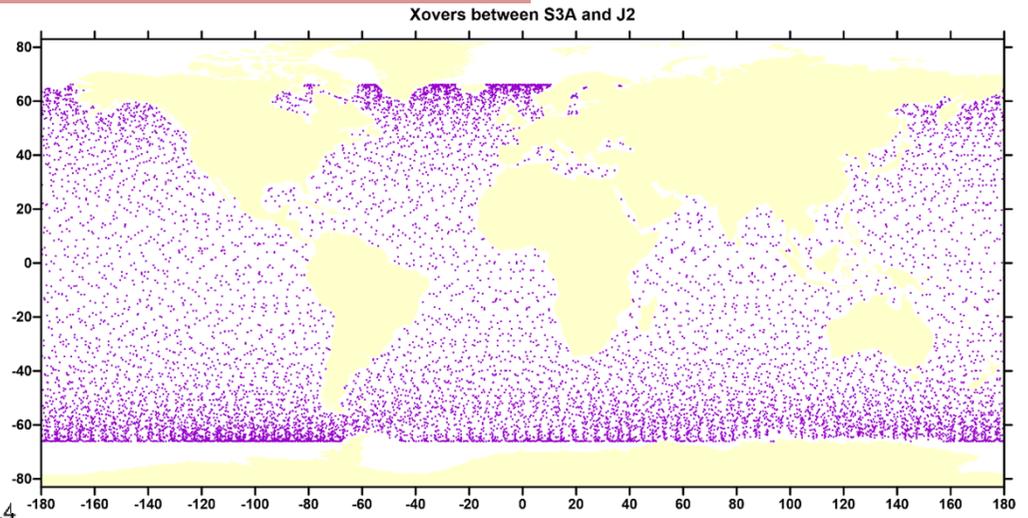
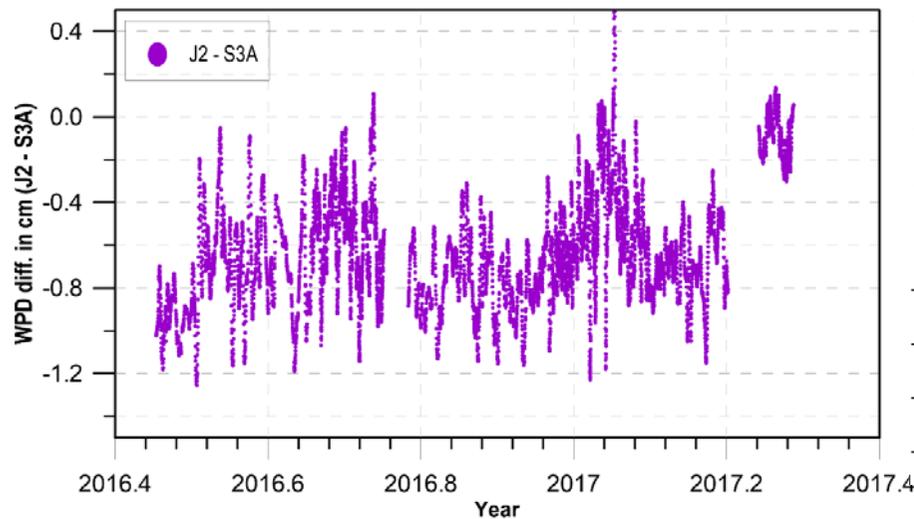
Top left: WPD S3A versus WPD J2, in cm.

Bottom left: Time evolution of WPD differences between J2 and S3A, in cm. Variations within less than 1 day have been removed.

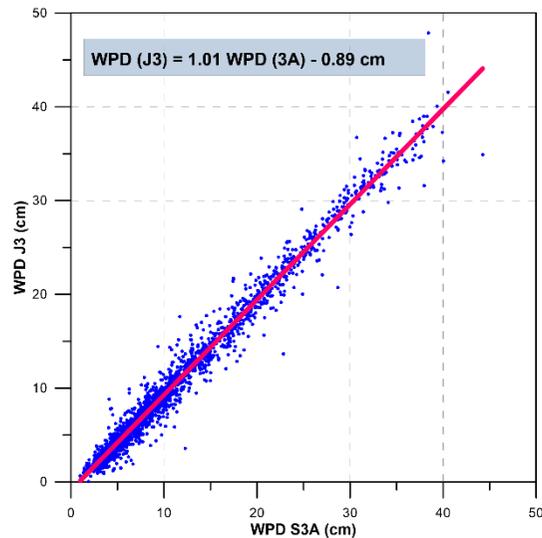
Bottom right: Xovers between S3A and J2 with $\Delta T < 180 \text{ min}$ (~11600 points).

Scale factor: 1.01; Offset: -0.71 cm

RMS $WPD(J2) - WPD(S3A) = 1.3 \text{ cm}$



Comparison with J3



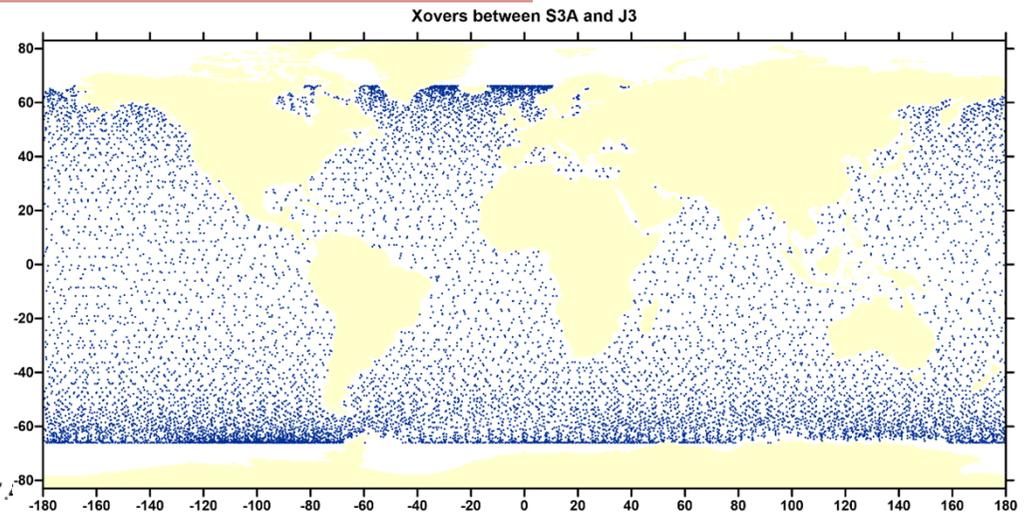
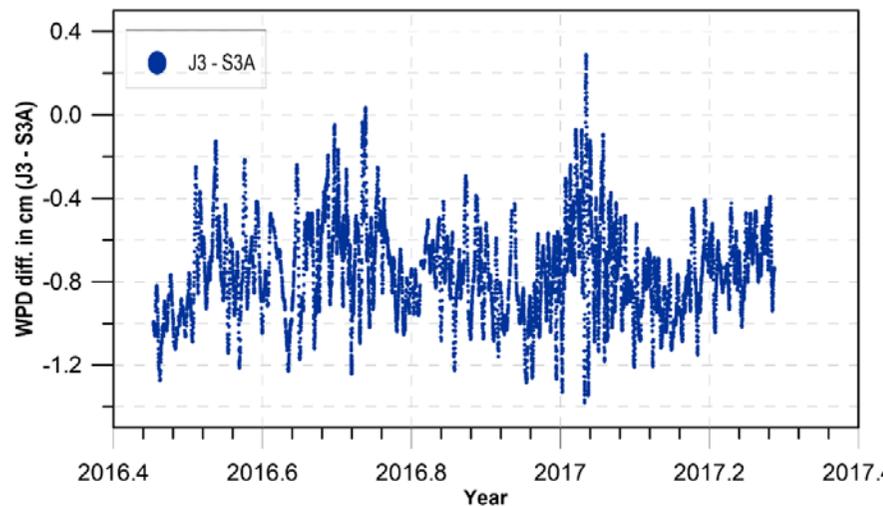
Top left: WPD S3A versus WPD J3, in cm.

Bottom left: Time evolution of WPD differences between J3 and S3A, in cm. Variations within less than 1 day have been removed.

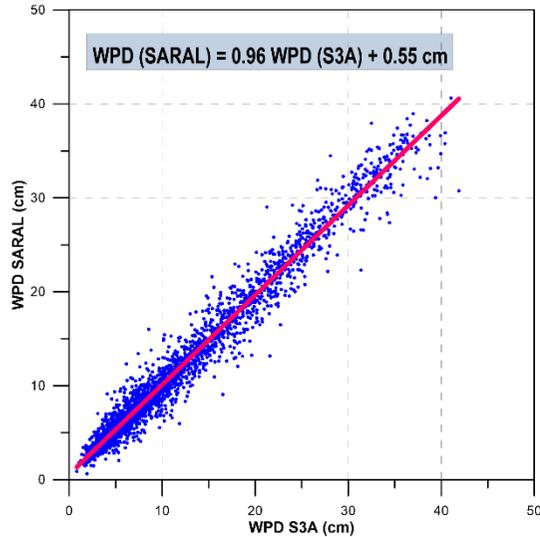
Bottom right: Xovers between S3A and J3 with $\Delta T < 180$ min (~12600 points).

Scale factor: 1.01; Offset: -0.89 cm

RMS $WTC(J3) - WT(S3A) = 1.3 \text{ cm}$



Comparison with SARAL



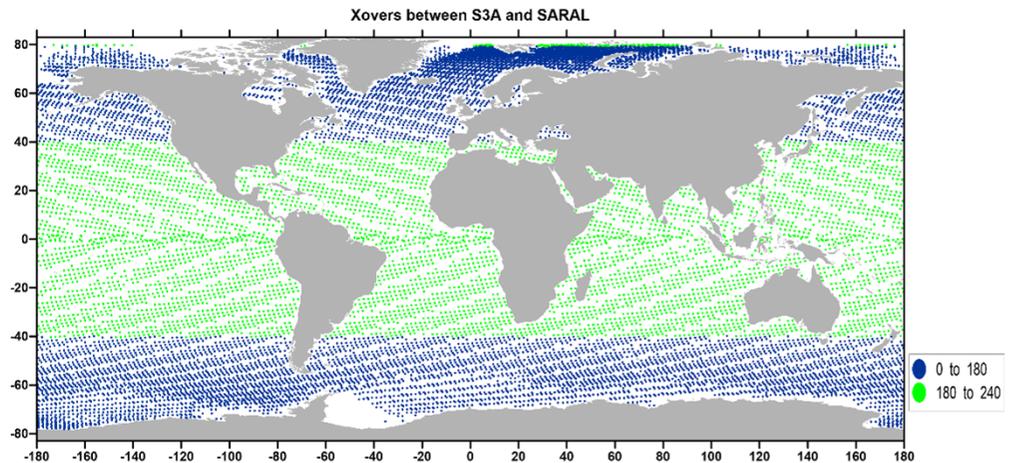
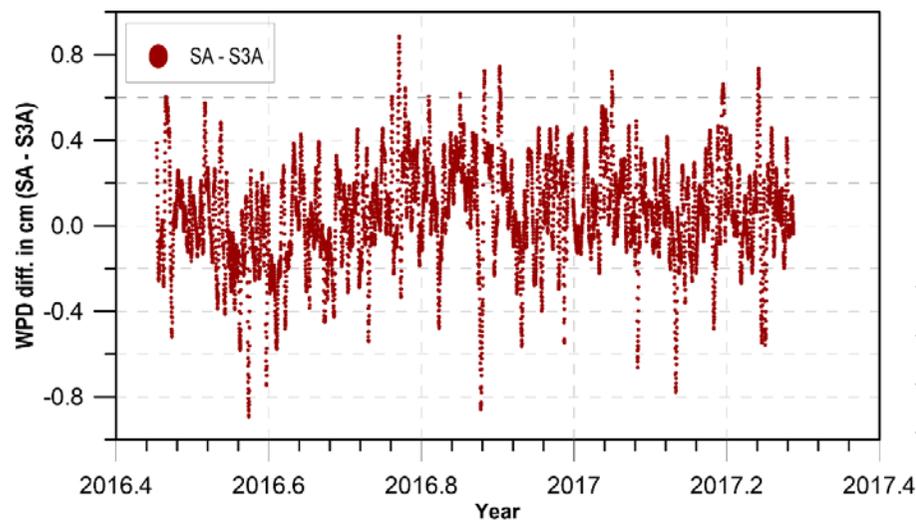
Top left: WPD S3A versus WPD SARAL, in cm.

Bottom left: Time evolution of WPD differences between SARAL and S3A, in cm. Variations within less than 1 day have been removed.

Bottom right: Xovers between S3A and SARAL with $\Delta T < 240$ min (~13700 points).

Scale factor: 0.96; Offset: 0.55 cm

RMS WTC(SARAL)-WTC(S3A)=1.5 cm



GPD+ WTC for S3A

GPD+ algorithm:

- computes an improved WTC for all along-track points with an invalid MWR-derived WTC, using an optimal interpolation of all available observations in the vicinity of the estimation points;
- preserves the MWR-derived WTC, whenever flagged as valid.

GPD+ WTC validated dataset:

- T/P, Jason-1 and Jason-2;
- ERS-1, ERS-2, ENVISAT, SARAL/AltiKa;
- GFO; CryoSat-2.

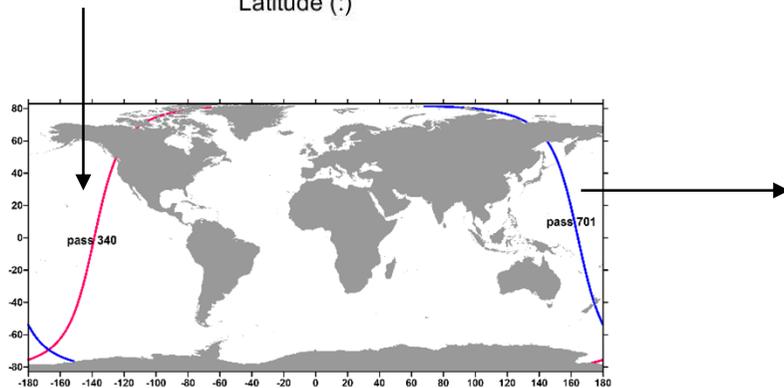
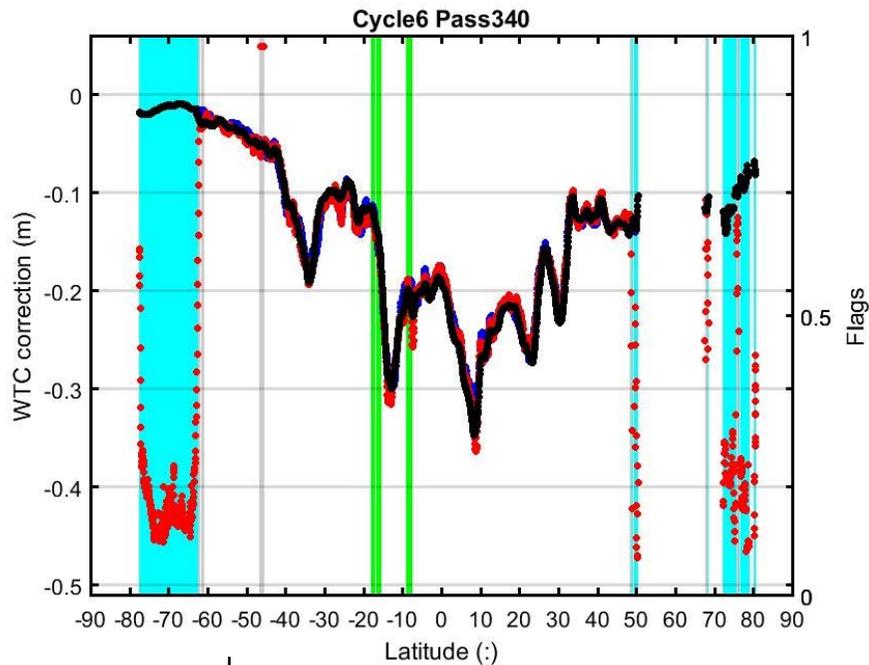
Available data for the S3A mission period:

- valid observations from the S3A on-board MWR
- Scanning imaging MWR (SI-MWR) from 10 different satellites;
- GNSS-derived WTC from more than 500 coastal stations.

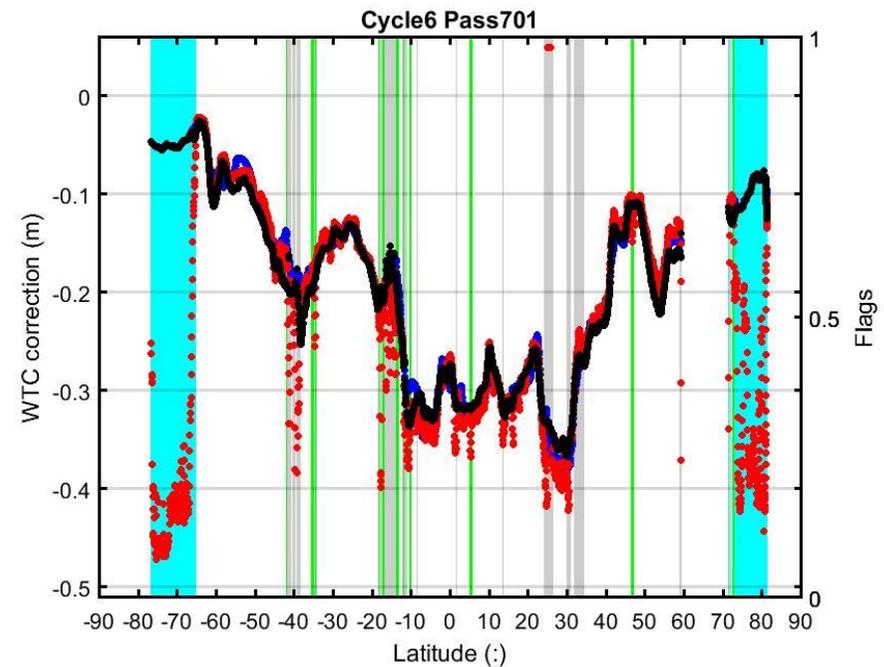
Two types of GPD+ WTC are computed:

- **GPD1** – using only external data sources (SI-MWR and GNSS) – allows independent assessment of the S3A on-board MWR.
- **GPD2** – normal GPD solution, using all data types, including the S3A on-board MWR. Requires tuning of criteria for detecting invalid S3A MWR observations.

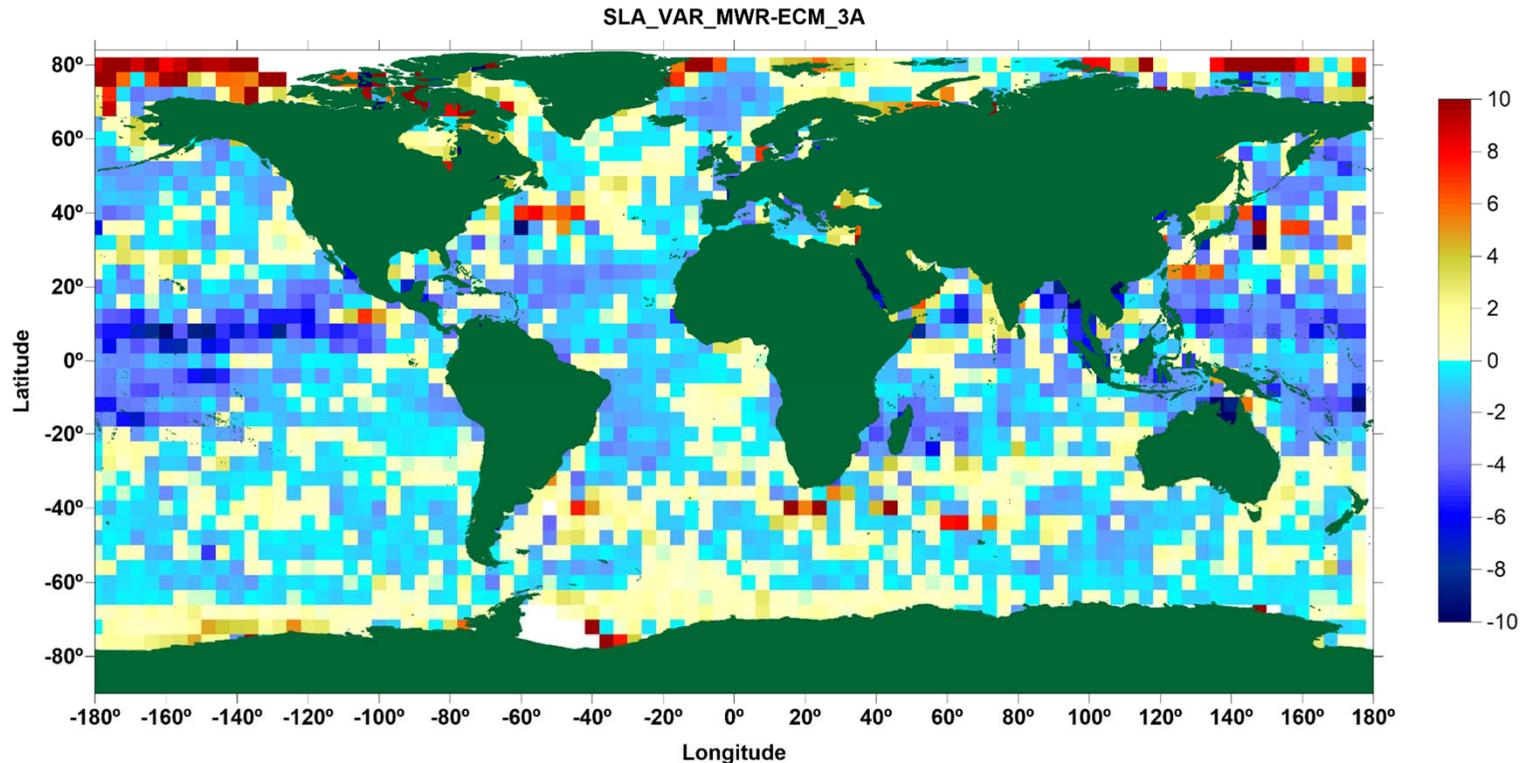
Comparison between MWR, GPD1 and ECMWF Op.



WTC for S3A cycle 06 passes 340 (left) and pass 701 (bottom): ECMWF Op. (blue), MWR (red) and GPD1 (black), solely based on SI-MWR and GNSS. Color bars represent flagged points with invalid MWR due to ice (cyan), land (green) and other criteria (grey).



S3A MWR versus ECMWF Op.

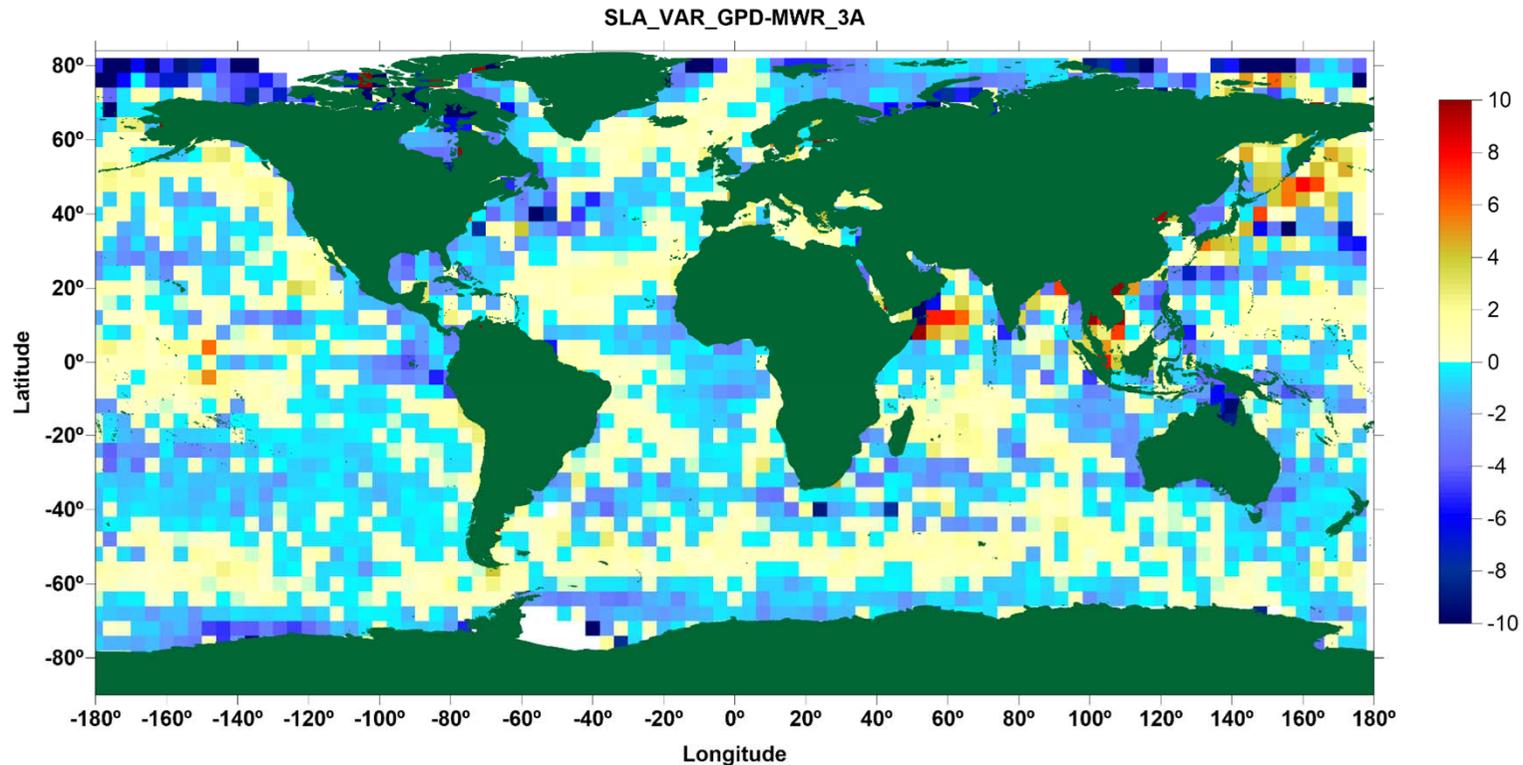


SLA variance difference (SLA_MWR-SLA_ECMWF) in cm^2 , using only points with valid MWR. Ice contamination is still present.

Analyzed points: **85%** of the total points with valid SLA.

Cycle mean SLA variance difference (MWR – ECMWF), for valid MWR points within $|\text{lat}| < 60^\circ = \text{from } -1.6 \text{ to } 0 \text{ cm}^2$

S3A MWR versus GPD1 (solely based on external data)



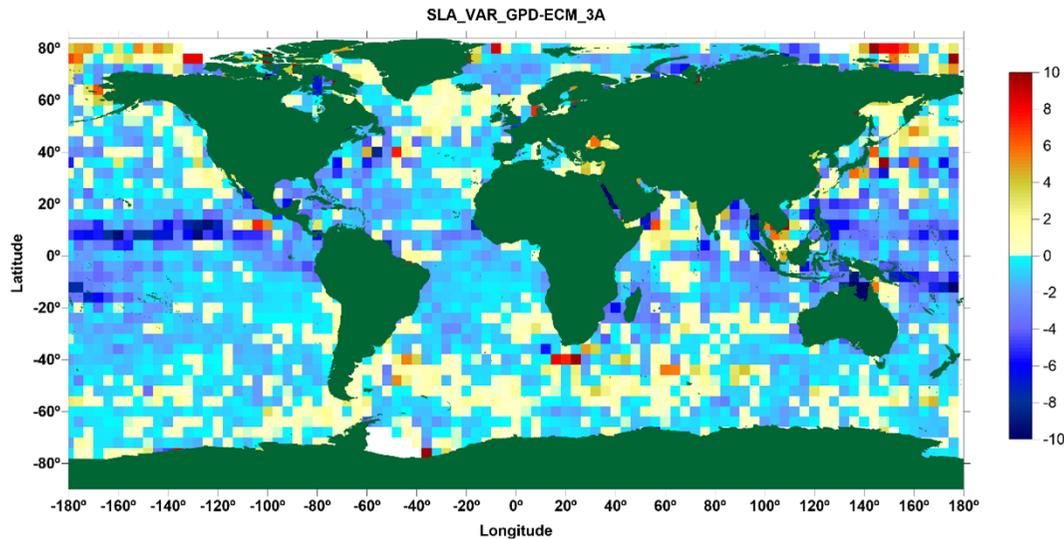
SLA variance difference (SLA_GPD1-SLA_MWR) in cm^2 , using only points with valid MWR.

Analyzed points: **85%** of the total points with valid SLA

Cycle mean SLA variance difference (GPD1-MWR) for valid MWR points within $|\text{lat}| < 60^\circ =$ **from -1-9 to +0.4 cm^2**

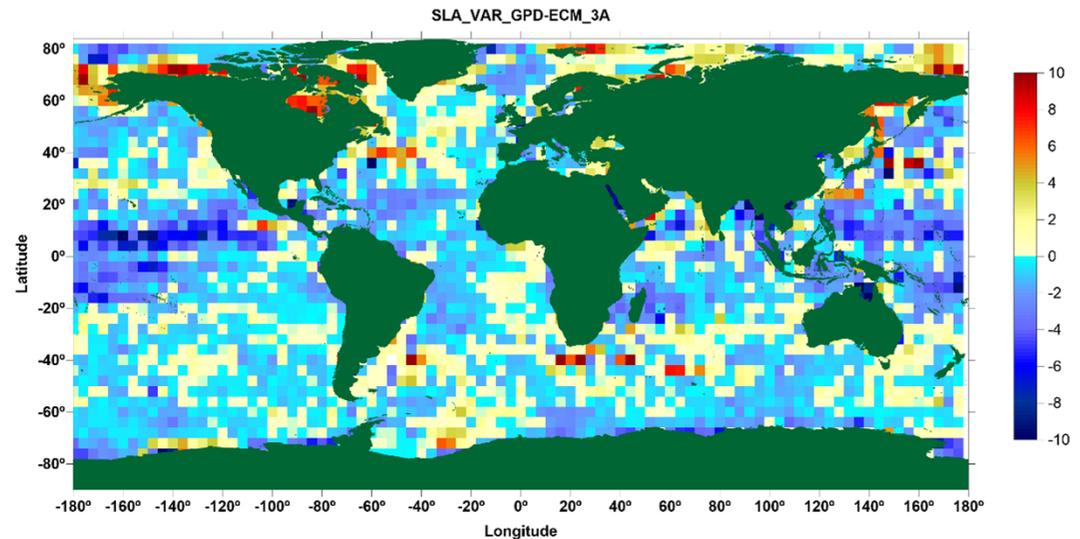
RMS WTC_MWR-WTC_GPD1 = **1.0 cm**

GPD1 and GPD2 for S3A

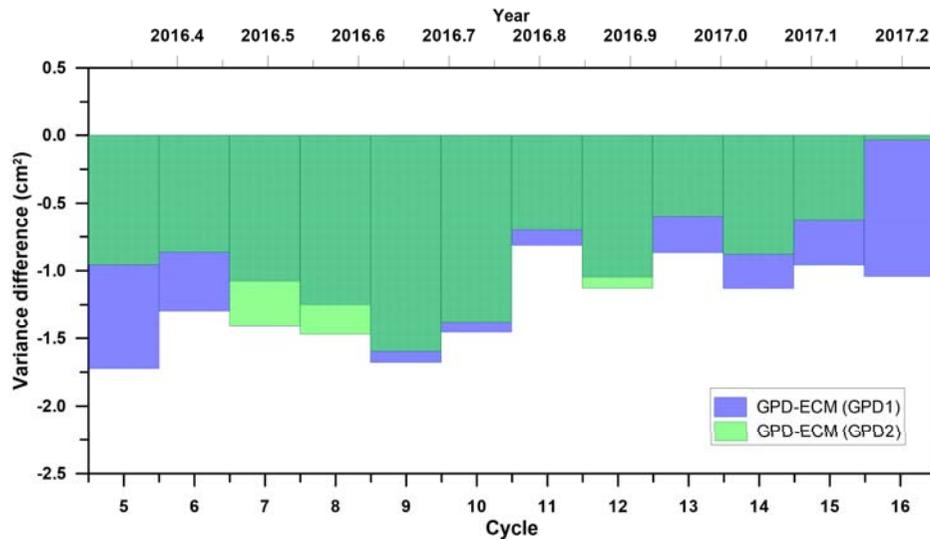


SLA variance difference, in cm², between **GPD1** (solely based on external observations) and ECMWF Op.

SLA variance difference, in cm², between **GPD2** (using all observations, including the S3A MWR) and ECMWF Op.

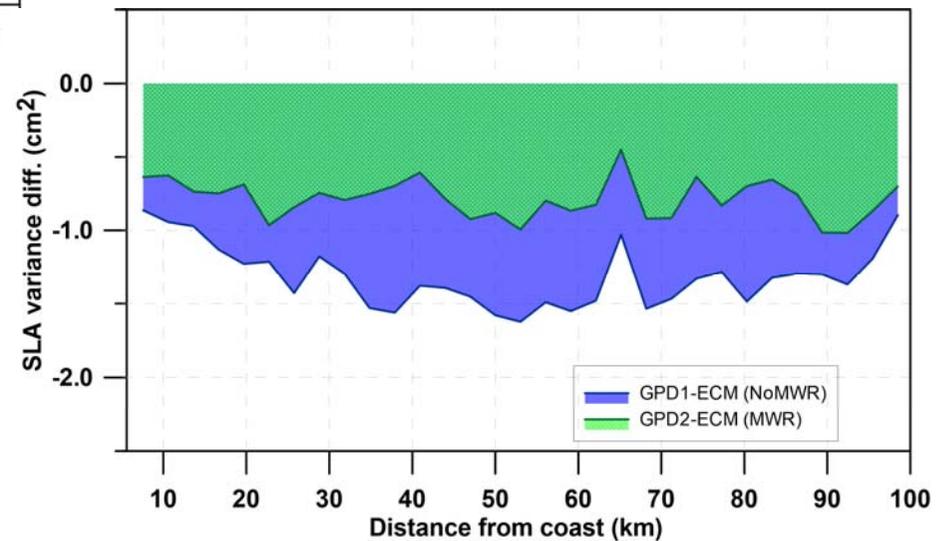


GPD1 and GPD2 for S3A

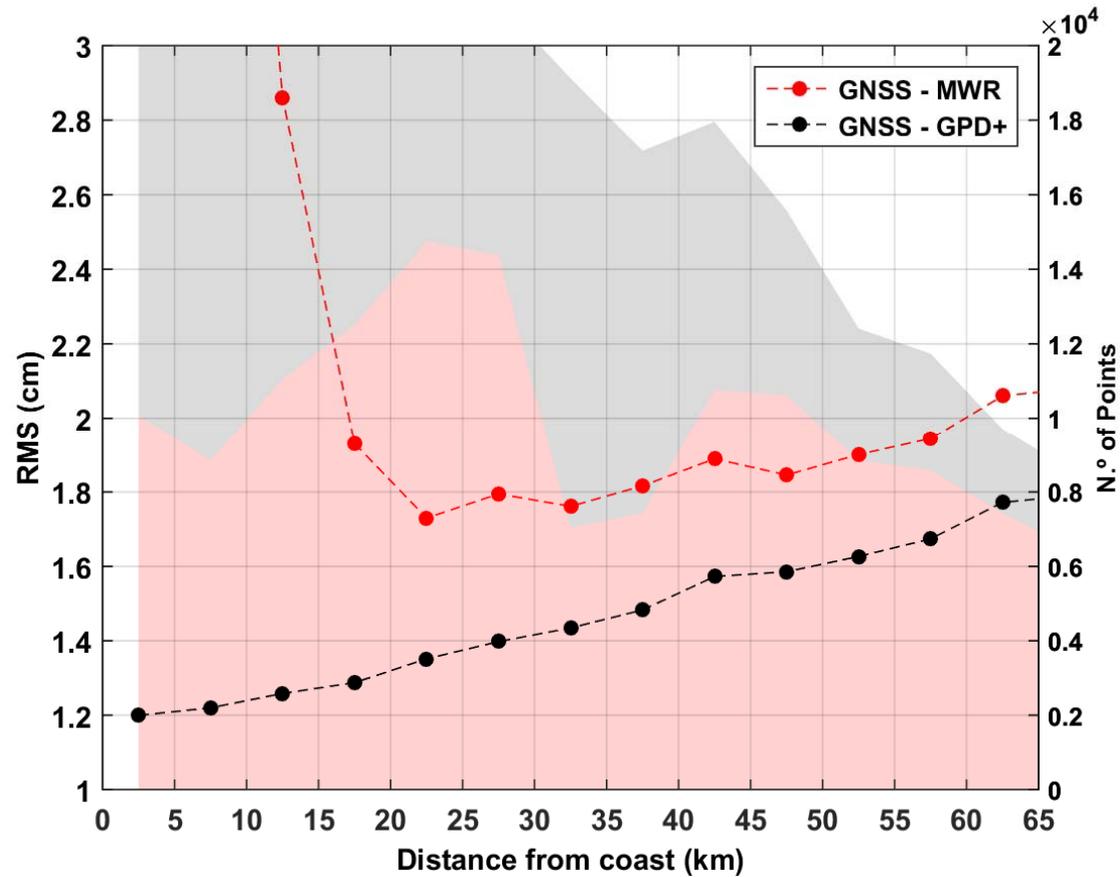


SLA variance differences for each S3A cycle, **between GPD1 (no S3A MWR used) and ECMWF** and **between GPD2 (with S3A MWR) and ECMWF** for points with $|\text{lat}| < 60^\circ$.

SLA variance differences function of distance from coast, **between GPD1 (no S3A MWR used) and ECMWF** and **between GPD2 (with S3A MWR) and ECMWF** for points with $|\text{lat}| < 60^\circ$.



Comparison with GNSS



RMS diff. between WTC from S3A MWR and WTC from GNSS at coastal stations

Conclusions

- Considering the relative short period of the analysis, overall performance of S3A MWR seems good.
- WPD scale factors close to 1 (1.00-1.01) relative to GMI, J2, J3; 0.96 relative to SARAL. Same values for the WTC.
- WPD absolute bias less than 1 cm relative to GMI (0.1), J2 (-0.7), J3 (-0.9) and SARAL (0.6). Corresponding values for WTC are the symmetric of those for WPD.
- RMS differences (cm) of 0.95 (GMI), 1.3 (J2), 1.3 (J3) and 1.5 (SARAL).
- Stable temporal evolution of the WTC. Strong periodic signal wrt GMI due to orbit configurations.
- Strong ice and land contamination. Establishment of validation criteria difficult, particularly at the high latitudes.
- Comparison with GNSS shows land contamination up to 20-25 km.
- Comparison with GPD estimated only with external data shows that, after data editing, contaminated MWR points are still present.

Thank you!

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