GPD WET TROPOSPHERIC CORRECTION FOR ALL ESA AND REFERENCE ALTIMETRIC MISSIONS

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ABSTRACT

In the scope of the ESA Sea Level Climate Change Initiative project, aiming to provide a uniform wet tropospheric correction (WTC) for all altimetric missions, the GNSS-derived path delay (GPD) algorithm for computing the WTC, developed at the University of Porto was, after a "round-robin" selection process, implemented for the main six altimetric missions: TOPEX/Poseidon, Jason-1, Jason-2, ERS-1, ERS-2 and Envisat.

This paper presents an overview of the GPD implementation for these missions.

The GPD products have been validated by comparison with the WTC adopted as the reference correction by the Archiving, Validation, and Interpretation of Satellite Data in Oceanography (AVISO): the so-called composite correction (Comp) for all missions except J2 - for J2 the GDR-D Microwave Radiometer (MWR) WTC is the current AVISO reference. Various sea level anomaly (SLA) statistical analyses have been performed and are summarized in this paper: SLA variance at crossovers; SLA variance difference as function of distance from the coast or function of latitude; difference in regional sea level trends.

1. INTRODUCTION

The aim of the ESA Sea Level Climate Change Initiative (SLCCI) project [1] is to produce and validate the Sea Level Essential Climate Variable (ECV) product. For this purpose, the best algorithms for climate applications are being developed, tested and selected.

As part of this work, aiming to provide a uniform WTC for all missions, the GNSS-derived path delay (GPD) algorithm for computing the wet tropospheric correction (WTC), developed at the University of Porto [2,3] was selected as the best candidate for use in the generation of the final sea level ECV.

This paper presents a summary of the GPD implementation for the six main altimetric missions: the NASA/CNES TOPEX/Poseidon, Jason-1 and Jason-2, and the ESA ERS-1, ERS-2 and Envisat missions.

The basis of the GPD algorithm is the data combination, by objective analysis, of three main wet path delay data types: valid measurements from the microwave radiometer (MWR) on board each altimetric mission, wet path delays derived from Global Navigation Satellite Systems (GNSS) coastal stations, and those derived from a Numerical Weather Model (NWM) such as the European Centre for Medium-range Weather Forecasts (ECMWF) ReAnalysis (ERA) Interim model. According to pre-defined criteria, the algorithm estimates the WTC in all satellite track points for which the MWR WTC has been considered invalid.

For each mission, the correction from the onboard MWR present in the Radar Altimetry Database System (RADS) and associated flags have been used, except for Envisat for which the correction present on the SLCCI database Version 1 was used.

In summary, the following MWR data sets were used:

- ERS-1, ERS-2 – from the REAPER project for the tandem phase and from Geophysical data Records (GDR) modified by R. Scharroo [4] otherwise;
- Envisat – GDR Version 1;
- TOPEX/Poseidon: Topex Microwave Radiometer (TMR) replacement product (http://podaac.jpl.nasa.gov/dataset/TOPEX_L2_OST_TMR_Replacement);
- Jason-1 - Enhanced (improved near the coast) JMR (GDR-C) product [5];
- Jason-2 - Enhanced (improved near the coast) AMR (GDR-D) product [5];

The GNSS data used are zenith total delays available online from a set of the International GNSS Service and from the EUREF Permanent Network.

The algorithm was tuned to each mission to allow a proper detection of the points at which the WTC has to be estimated (either due to, for example, land, ice contamination, or to instrument malfunction).

The GPD products have been validated by comparison with the WTC adopted as the reference correction by AVISO, which is the so-called composite correction

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(Comp) for all missions except J2 and the GDR-D MWR WTC for J2.

The Composite Correction is a conceptually simple method, which consists in replacing the MWR measurements near the coast (<50 km) by ECMWF model values. The ECMWF correction is shifted to the nearest valid radiometer measurement in the transition zone. Interpolation and detrending are also applied in complex cases [6].

Various sea level anomaly (SLA) statistical analyses have been performed. In this paper the most relevant analysis are presented: SLA variance at crossovers; SLA variance difference function of distance from the coast or function of latitude; difference in regional sea level trends.

2. RESULTS

This section presents the most relevant statistical analysis, illustrated by the results obtained for TOPEX/Poseidon (T/P) and Envisat.

2.1 NASA/CNES MISSIONS

Figures 1 to 5 illustrate the results obtained for T/P. It can be observed that the GPD significantly reduces the variance at crossovers (Figs 1 and 2) with respect to the composite correction. This reduction is particularly large in the Indian Ocean and for the last part of the mission, after cycle 370. Figure 2 shows that for most cycles, the GPD reduces the SLA variance at crossovers. A few cycles are shown for which the GPD causes an increase in variance. A closer inspection shown that all these cycles except 371 have problems in the TMR Replacement Product present in RADS and used as the base MWR correction in GPD: 033, 123, 230, 231, 261, 443, 448 and should be corrected or discarded. For cycle 371 it was found that the large differences are due to problems in the implementation of the composite correction.

Figure 3 shows the difference in the mean sea level (MSL) trend computed with GPD and Comp over the period of T/P cycles 001 - 481. Again the GPD has a significant impact in the regional MSL trends, particularly in the Indian Ocean.

Figures 4 and 5 illustrate the differences of SLA variance versus distance from coast between GPD and Comp for T/P phase A and B respectively, revealing that the GPD also decreases the SLA variance near the coast.

The results for Jason-1 show that GPD has no significant impact in the variance at crossovers; however, a small but clear impact can be seen in the coastal regions, both in the regional MSL trends and in the reduction of SLA variance. For Jason-2, the present GPD implementation shows no significant differences with respect to the GDR-D MWR correction. It should be recalled that while the T/P MWR correction present in RADS is a standard product with no coastal improvement, the corresponding MWR corrections for both Jason-1 and Jason-2 are already coastal-improved products [5]. In particular, the GDR-D Advanced Microwave Radiometer (AMR) correction is the result of intensive monitoring and successive calibrations of AMR [6].

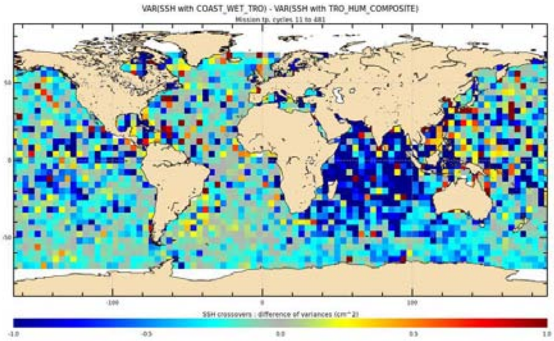

Figure 1 – Map of variance differences of Sea Surface Height (SSH) at crossovers between GPD and Comp over the period of T/P cycles 001 - 481.

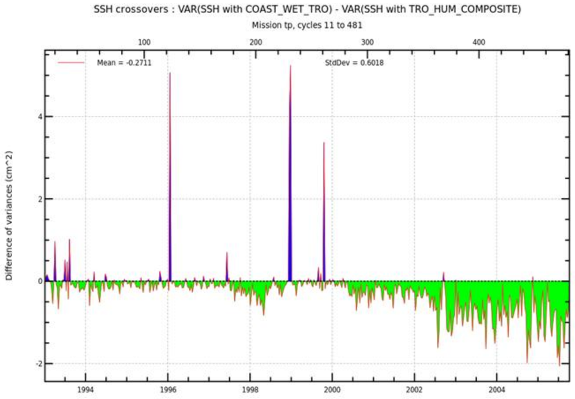

Figure 2 – Temporal evolution of variance differences of SSH at crossovers between GPD and Comp over the period of T/P cycles 001 – 481.

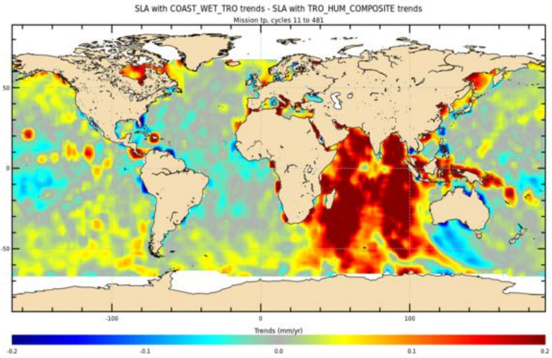

Figure 3 – *Map of MSL trend differences between GPD and Comp (over the period of T/P cycles 001 - 481).*

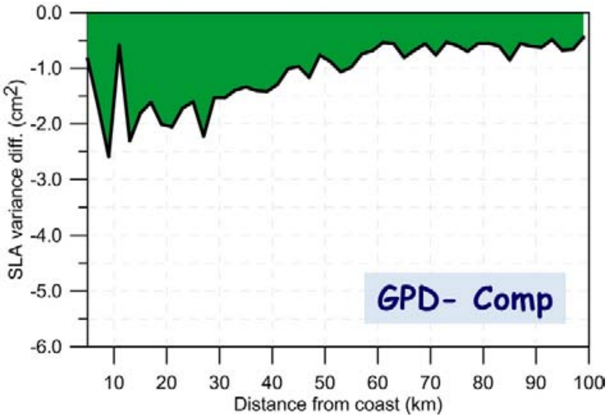

Figure 4 – Variance differences of SLA versus distance from coast between GPD and Comp for T/P phase A (cycles 1-364).

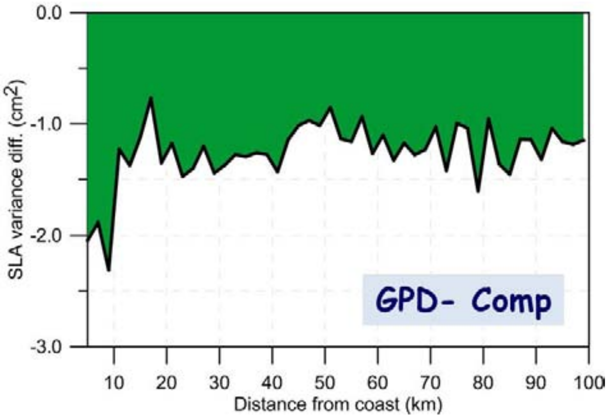

Figure 5 – Variance differences of SLA versus distance from coast between GPD and Comp for T/P phase B (cycles 369-481).

2.2 ESA MISSIONS

Figures 6 to 9 illustrate the results obtained for Envisat. It can be observed that the GPD significantly reduces the variance at crossovers (Figs 6 and 7), particularly in the coastal regions.

Figure 8 shows the mean sea level (MSL) trend differences between GPD and Comp over the period of Envisat cycles 10-93. It shows that the GPD has a significant impact in the regional MSL trends, particularly in the coastal and polar regions.

Figure 9 illustrates the variance differences of SLA versus distance from coast between GPD and Comp for Envisat revealing that the GPD significantly decreases the SLA variance near the coast with respect to the composite correction.

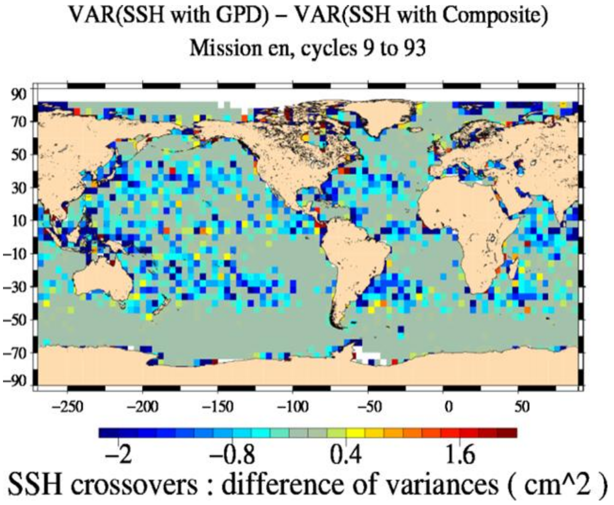

Figure 6 –Map of variance differences of SSH at crossovers between GPD and Comp over the period of Envisat cycles 10-93.

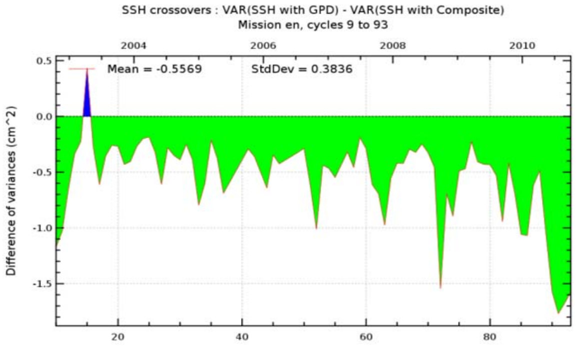

Figure 7 – Temporal evolution of Variance differences of SSH at crossovers between GPD and Comp over the period of Envisat cycles 10-93.

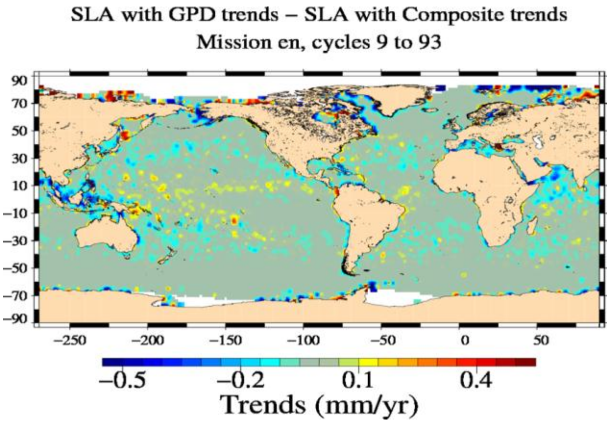

Figure 8 – Map of MSL trend differences between GPD and Comp over the period of Envisat cycles 10-93.

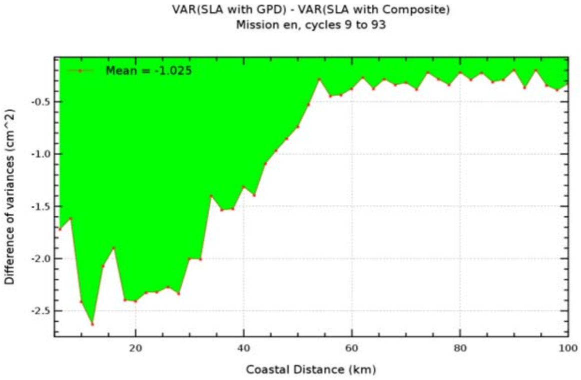

Figure 9 –Variance differences of SLA versus distance from coast between GPD and Comp for Envisat cycles 10-93

For ERS-1 and ERS-2 results are very similar to those obtained for Envisat, with some scale differences in some cases. Overall, for Envisat, ERS-1 and ERS-2, when comparing GPD with the reference (Comp) WTC a significant impact is found on regional MSL trends; for all these missions GPD reduces the SLA variance at crossovers and leads to a significant SLA variance reduction in the coastal and polar regions.

3. Future Work

This work shows that for T/P, Envisat, ERS-1 and ERS-2 the GPD represents a significant improvement over the AVISO reference composite correction (Comp), particularly in the coastal and polar regions. For Jason-1 and Jason-2, for which the MWR correction is already an improved one, the results are different: while for Jason-1 a small improvement is still obtained in the coastal regions, for Jason-2 no significant improvement is found.

Future work shall include the following main issues. For Jason-1 and Jason-2 it shall be checked if a GPD implementation without using NWM data, i.e. using only valid MWR and GNSS data will improve the results for these satellites,
For T/P the problem identified in the Topex Replacement Product shall be addressed.
Further research is needed on the identification of ice contaminated MWR measurements for the ESA missions, for which the 18.7 GHz channel is not present, and on the rain contamination for all missions.
Finally, in the context of the ESA SLCCI project it is very important that the corrections are stable and absent of long term drifts. Therefore the long term stability of the WTC will be a main goal.

4. REFERENCES

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5. ACKNOWLEDGEMENTS

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