Geophysical Research Abstracts
Vol. 19, EGU2017-10437-1, 2017
EGU General Assembly 2017

GNSS-derived Path Delay Plus (GPD+): a methodology for the computation of improved wet tropospheric corrections for coastal altimetry

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Satellite altimetry missions provide the sea surface height above a reference ellipsoid with centimetric accuracy as long as all terms involved in the altimeter measurement system (satellite orbit, altimeter range between the satellite and the sea surface, and instrumental, range and geophysical corrections) are known with the same accuracy. The wet tropospheric correction (WTC), the range correction that accounts for the delay induced by the presence of water vapour and liquid water in the troposphere, has an absolute value less than 50 cm but large space-time variability, being therefore difficult to model.

Despite the progress observed in WTC modelling from numerical weather models (NWM), the accuracy of present NWM-derived WTC is still deficient for most altimetry applications such as e.g. sea level variation. Actually, accurate WTC at time and location of the altimetric measurements can only be achieved through observations of the atmospheric water vapour content, acquired by on-board microwave radiometers (MWR). In open ocean, MWR-derived WTC are centimeter-level accurate; in coastal regions, WTC degrades due to several reasons, among which is the contamination, from the surrounding land surfaces, of the signal measured by the MWR. Also the presence of ice and rain contaminates the MWR observations. Therefore, MWR-derived WTC are generally incorrect or invalid in coastal, rainy and high-latitude regions, and altimeter measurements cannot benefit from MWR corrections.

The GNSS-derived Path Delay (GPD) algorithm was developed by the University of Porto (UPorto) aiming at computing the WTC for coastal regions where MWR observations are invalid, envisaging the recovery of the altimeter data in these regions. The GPD-derived WTC is based on a space-time optimal interpolation that combines path delays measured by MWR and computed at more than 800 coastal/island GNSS stations. Its most recent version, the GPD Plus (GPD+) estimates the WTC globally relying also on path delay observations from 19 scanning imaging MWR on-board various remote sensing missions. After adequate tuning, the GPD+ is applicable to any altimetric mission with or without an on-board MWR, as CryoSat-2 for which only a NWM-derived WTC would be, otherwise, available. To ensure consistency and WTC long term stability, and prior to their use in the GPD+, path delay observations from all radiometers were previously inter-calibrated with respect to the Special Sensor Microwave Imager (SSM/I) and SSMI/I Sounder (SSM/IS).

The GPD+ WTC were computed, in the scope of several ESA-funded projects e.g., Sea Level CCI, CP4O, for 9 altimetry missions and were independently validated through statistical analyses of sea level anomaly variance. Overall, results show that GPD+ recovers a significant number of measurements in the coastal regions, ensuring the continuity and consistency of the correction in the open-ocean/coastal transition zone and also at high latitudes. As a consequence, GPD+ WTC have been chosen as the best available WTC for climate studies and adopted as reference in the Sea Level CCI products; the GPD+ has also been adopted as reference in CrySat-2 Level 2 IOP and GOP products.

The GPD+ algorithm, its implementation, path delay datasets used and sensor calibration are here described.