Independent assessment of Microwave Radiometer measurements in coastal zones using tropospheric delays from GNSS

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1. Introduction and Objectives

- Precise water level estimations require accurate modelling of the **wet tropospheric correction** (WTC), which can be derived from **Microwave Radiometer** (MWR) **measurements**.
- **Independent** monitoring of the MWR measurements is important to ensure an accurate global mean sea level retrieval.
- This study has two main **objectives**:
  - **(i)** to exploit the potential of GNSS data to monitor the stability of MWR measurements of the various altimetric missions in coastal regions;
  - **(ii)** to study the impact of land contamination on the MWR observations of these missions.
- For this purpose, **zenith tropospheric delays** (ZTD) from Global Navigation Satellite Systems (**GNSS**) coastal stations are used to assess the MWR measurements in **coastal zones**, for the following missions:
  - TOPEX/Poseidon (TP), Jason-1 (J1) and Jason-2 (J2);
  - ERS-1 (E1), ERS-2 (E2) and ENVISAT (EN);
  - Geosat Follow-On (GFO) and SARAL/AltiKa (SA).

2. Data and Methodology

- Land contamination does not allow the direct use of the MWR measurements in the coastal regions. Alternative sources of WTC are e.g.: atmospheric models; GNSS at coastal stations; combined values from e.g. GNSS-derived Path Delay Plus (GPD+) algorithm [1], [2].

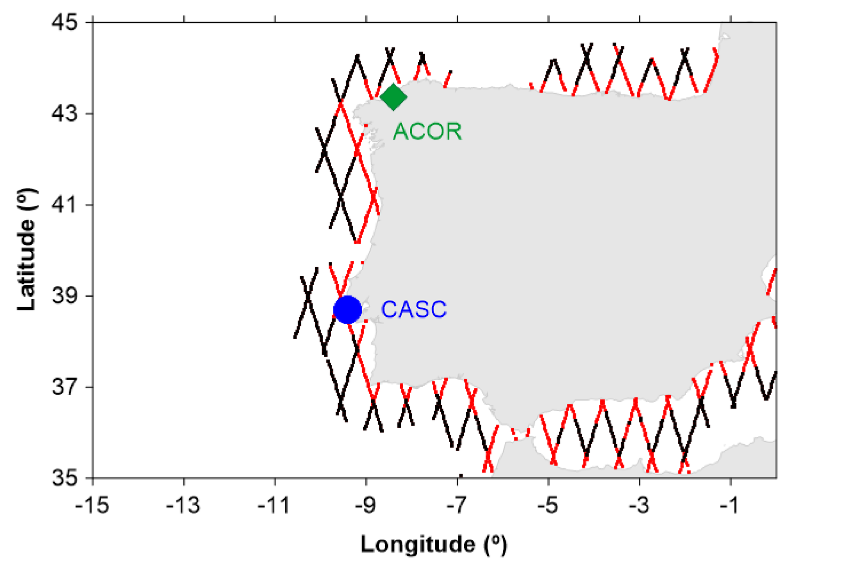


Fig. 2.1 – Altimetry measurements around the Iberian Peninsula for EN cycle 73. Red dots represent those with invalid MWR-derived WTC.

The following datasets have been analysed:

- On-board MWR valid measurements from various altimeter missions, calibrated with respect to SSM/I and SSM/IS [2];
- WTC derived from GNSS (see below);
- WTC from the GPD+ algorithm.

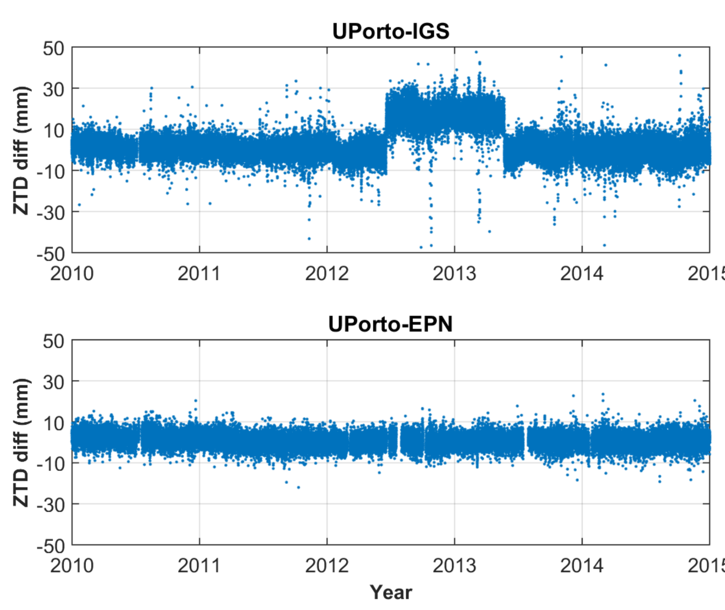
The following methodology was adopted:

- Aiming at having an homogeneous dataset of GNSS-derived WTC, a network of 60 coastal and island GNSS stations (Fig. 3.1) have been chosen for calculating the ZTD (ZTD UPorto) using the GAMIT software [3], for the period 1995 to 2016;
- ZTD UPorto at station height are converted into zenith wet delays (WTC equivalent) at sea level as described in [4];
- Altimetry measurements up to 120 km from each GNSS station are selected (Fig. 2.1);
- For the epoch of each altimetry measurement, a value of WTC UPorto is interpolated from the nearby stations. For the same epoch, two values are available:
  - WTC from MWR observation, at the corresponding point;
  - WTC at sea level from ZTD UPorto, interpolated in time, at the station location;

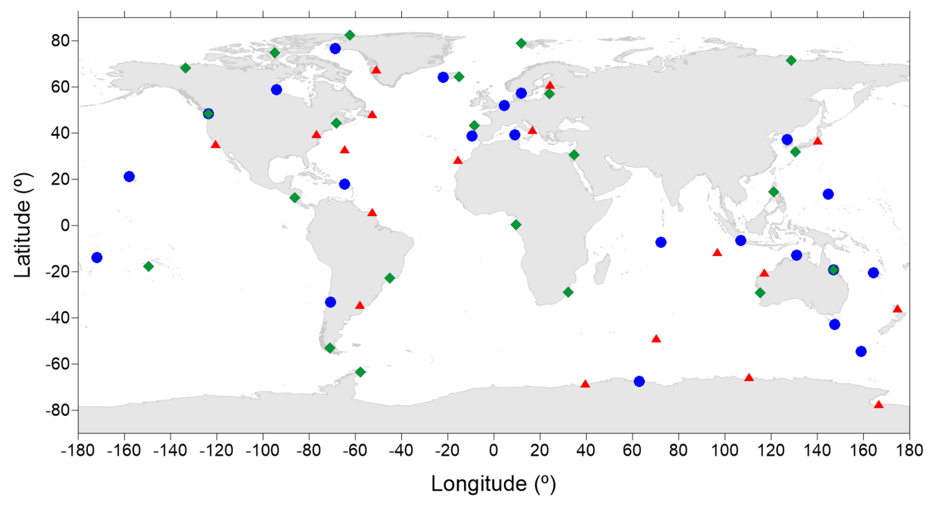
This approach allows the non-collocated comparison between GNSS and MWR data, being this analysis possible only over coastal zones.

3. WTC from GNSS

- ZTD UPorto are computed in three sub-networks, with common stations for validation purposes (Fig. 3.1).
- Inter-comparison of ZTD from different sub-networks demonstrates the influence of network geometry on tropospheric parameters estimation.



←Fig. 3.2 – ZTD differences between UPorto and IGS (top panel) and EPN (bottom panel), in millimetres for station MAS1 [5], [6].

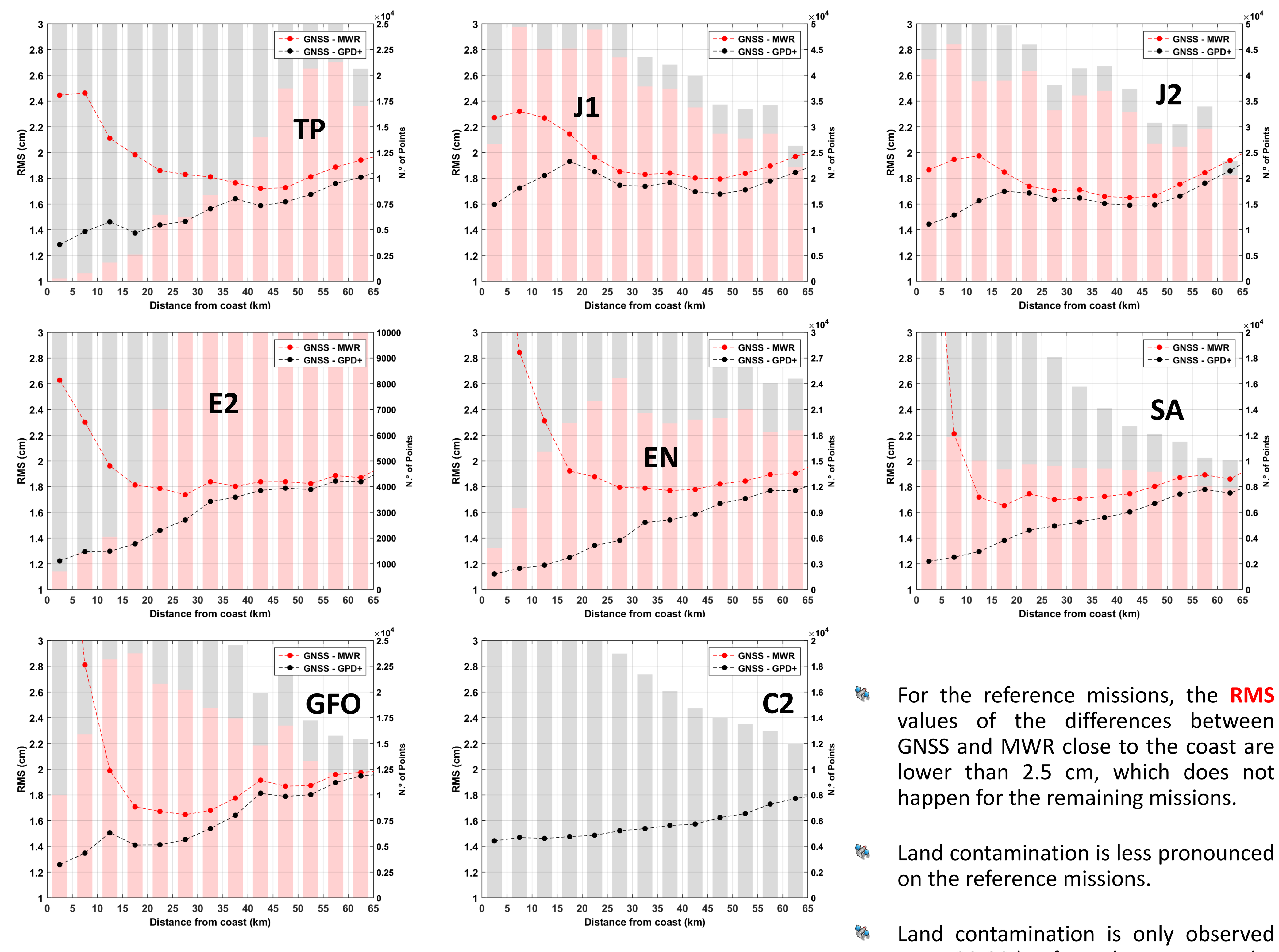


↑Fig. 3.1 – Representation of the 3 sub-networks (UPorto1 – red triangles, UPorto2 – blue points and UPorto3 – green squares).

- ZTD comparisons show that ZTD can be determined with an accuracy of a few millimetres, at the station location. Jumps have been detected in ZTD from a few IGS stations (Fig. 3.2, top panel), highlighting the importance of the computation of the ZTD UPorto using a uniform methodology.

4. Coastal assessment

- Two non-collocated comparisons are performed and analysed function of distance to coast:
  - WTC differences between **UPorto and MWR**;
  - WTC differences between **UPorto and GPD+**.
- Figures below represent the RMS of these differences (left axes) for each class of distance to coast (5 km), for the various missions. Red and grey bars (right axes) represent the number of measurements used to compute these two statistics, respectively.



- For the reference missions, the **RMS** values of the differences between GNSS and MWR close to the coast are lower than 2.5 cm, which does not happen for the remaining missions.
- Land contamination is less pronounced on the reference missions.
- Land contamination is only observed up to 20-30 km from the coast. For the SA mission (smaller footprint) this contamination is observed only up to 15 km.
- **RMS** of the WTC differences between UPorto and GPD+ are also performed for CryoSat-2 (C2) mission. Close to the coast this value is about 1.4 cm.
- For the first missions (e.g. ERS-1) the number of measurements is small, due to a small number of GNSS stations in the UPorto network, which does not allow a significant comparison with altimetry measurements.
- The **RMS values** of the differences between UPorto and GPD+ are always lower than the corresponding **values** of the differences between UPorto and MWR.
- Results show the land contamination on the various **MWR** in the classes close to the coast and the ability of **GPD+ algorithm** to remove this contamination.

5. Long-term variation

- The non-collocated and independent comparison between WTC from UPorto and each MWR, function of time, is shown.

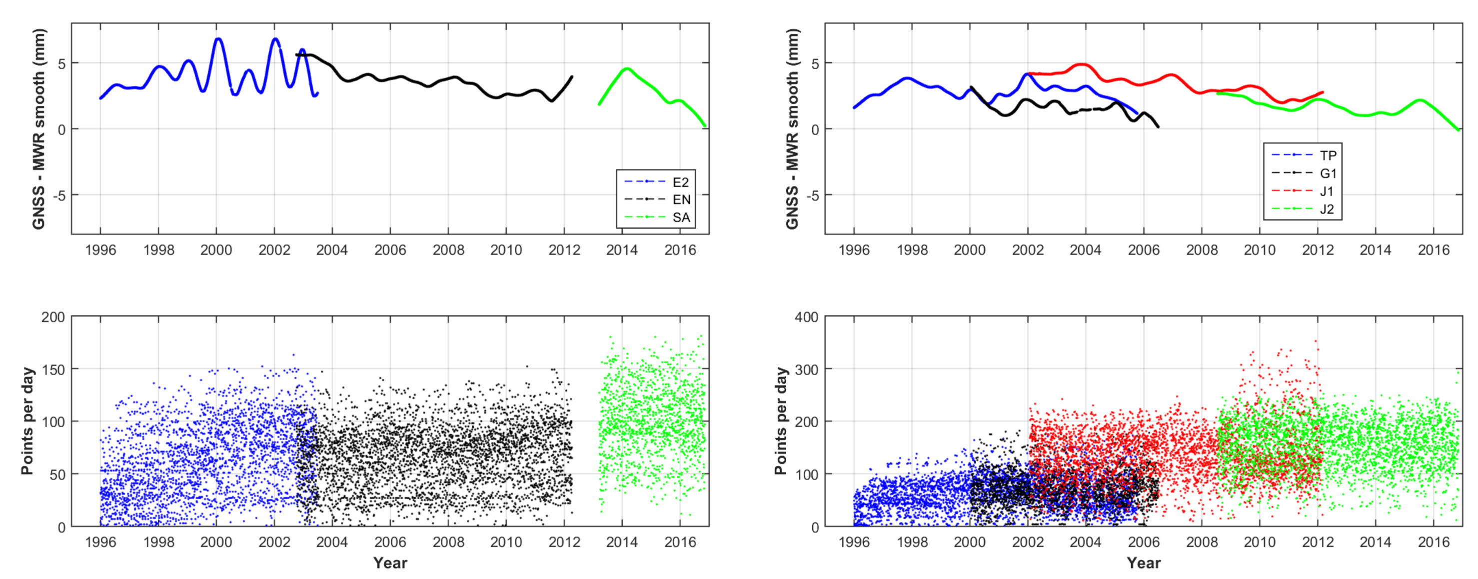


Fig. 5.1 – Time evolution of the smoothed WTC differences between GNSS and MWR (top panels) and number of altimetry points per day (bottom panels).

- Fig. 5.1 represents the time evolution of the smoothed WTC differences for each mission. Only MWR measurements flagged as valid (using the GPD+ derived criteria) have been considered. In the bottom panels the number of measurements per day is represented.
- A linear fit has been applied to these smoothed differences.
- Table 5.1 shows the values of slope and coefficient of determination for each mission.
- Terms as the WTC should be known to better than 0.3 mm/year [7].
- Absolute values of slope are lower than 0.3 mm/year, except for SA, less significant due to its small period.

Table 5.1 – Linear fitting values of the smoothed GNSS-MWR differences for each mission.

Mission	Slope (mm/year)	R^2
TP	-0.06	0.06
J1	-0.24	0.80
J2	-0.15	0.43
GFO	-0.17	0.37
E2	0.14	0.06
EN	-0.27	0.73
SA	-0.82	0.59

6. Summary of results

- ZTD computed at University of Porto using a homogeneous procedure for the whole analysed period are used to assess the performance of MWR over coastal zones.
- ZTD can be determined from GNSS with an accuracy of a few millimetres. However, jumps are detected in ZTD from a few IGS stations. The influence of network geometry on tropospheric parameters estimation is demonstrated.
- The independent comparison between WTC UPorto and MWR-derived shows the effect of land contamination and the distance from coast where this contamination is minimum.
- This distance from coast is different for the several altimetric missions (15 to 30 km), due to their different footprint size and algorithms used to retrieve the WTC from MWR measurements.
- The coastal assessment shows also the ability of the GPD+ algorithm to remove this contamination and to improve the WTC retrieval all over and in particular in the coastal zones.
- The time evolution of the same WTC differences reveals absolute slopes lower than 0.3 mm/year, within the expected error level, showing that the analysed MWR datasets are well calibrated against the SSM/I radiometers.
- In spite of the fact that GNSS-derived and MWR-derived WTC are not collocated measurements, these results show that the former are a useful independent source to inspect the land effects on MWR observations and to monitor the stability of these instruments, thus contributing to the retrieval of precise water surface heights from satellite altimetry.

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