Impact of different NWP-derived mapping functions on VLBI and GNSS analysis

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Introduction

The Vienna Mapping Functions 1 (VMF1) map the atmospheric delay from zenith to the line of sight as an elevation dependent function and are capable of better accounting for real weather phenomena compared to mapping functions (MF) without numerical weather prediction model (NWP) input data. However, the spatial resolution of the NWP itself, directly impacts the ability to model atmospheric conditions effectively. Therefore, we employ the UNB-VMF1 which utilize the high resolution model from the Canadian Meteorological Centre based on the Global Deterministic Prediction System (CMC GDPS). The latter, as a modern operational model, contains the latest application of atmospheric physics and parameterizations, and is relieved from spatially based systematic effects.

Ray-tracing in different NWP models

Employing the independent UNB ray-tracing algorithms (Nievinski, 2009), through the specified NWP model data, we retrieve the hydrostatic and non-hydrostatic delays at a certain elevation angle. We determine the hydrostatic and non-hydrostatic slant factors: realization of the mapping functions. The respective "a" coefficients are estimated by least squares fitting of the continued fraction form (Marini, 1972) normalized to yield unity at zenith (Herring, 1992).

We utilized the Global Deterministic Prediction System provided by the Canadian Meteorological Centre (CMC GDPS), which is employed by the University of New Brunswick's Vienna Mapping Functions Service (UNB-VMF1) to compare against the European Centre for Medium-Range Weather Forecasts (ECMWF) NWP, which is employed by the TU Wien Vienna Mapping Functions (VMF1). The former follows the latter as revised by Boehm et al (2006).

Validation of estimated heights with IGS

Comparing against the IGS weekly solutions we observe that the difference in the height component, rarely exceeds 1cm for both GAPS solutions (1st solution: applying UNB-VMF1 products, 2nd solution: applying VMF1 products). The low standard deviation (0.2mm) of the IGS (http://igs.org/) weekly product can be closely reached also by GAPS after continuous processing the daily observation files. The solutions that utilize the UNB-VMF1 products are consistent with those utilizing the VMF1 products throughout the dataset (hundredths of mm).

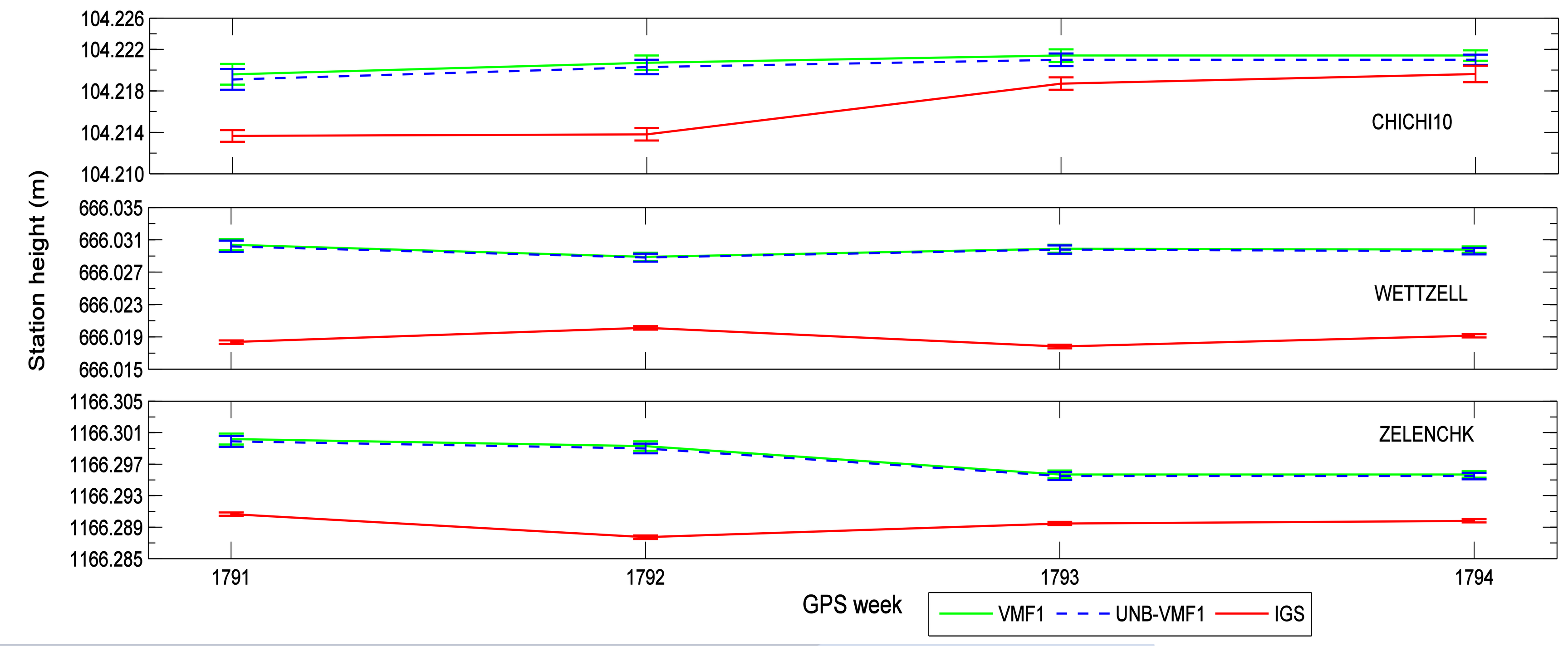


Fig. 5: Station heights as estimated with GAPS for CONT14, applying UNB-VMF1 and VMF1 a-priori delays and slant factors and the respective IGS weekly solution for the stations CCJ2, Ogasawara, Japan, WTZR, Germany and ZECK, Russia. The standard deviations of the values are also noted.

Estimating gradients in VLBI aided by NWP

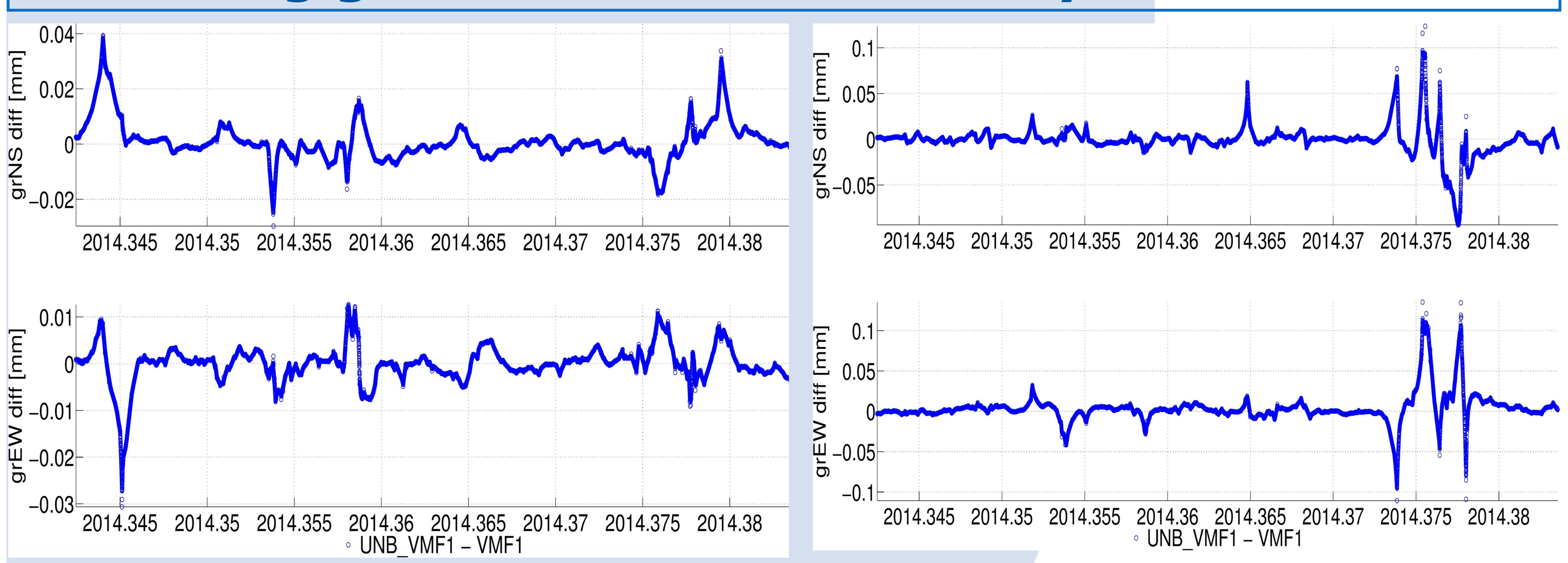


Fig. 4.a &4.b: Differences in North-South (NS) and East-West (EW) gradients as estimated with VieVS@GFZ for CONT14, between UNB-VMF1 and VMF1, for the stations WETTZELL, Germany (left) and TSUKUBA, Japan (right).

Discussion

- Final results between the 2 MF almost identical unless certain conditions apply
- At the observation level, results showed sub-mm level agreement between the 2 products. PPP results are consistent (sub-cm agreement) with the IGS weekly solutions.
- Few cases that the solutions diverged, the difference revealed the sensitivity of the processing software (VieVS@GFZ) to reflect variances in the atmosphere and the response of the 2 mapping functions to that.
- Analysis of longer time series (15 years) recommended. Investigate possible trend in the integrated water vapor. Future work also includes a site specific analysis (coastal areas or at the poles).

Estimating non-hydrostatic delays in GNSS + NWP

Using the ray-traced parameters (a-priori delays, slant factors) into the UNB's GNSS PPP software (GAPS:*http://gaps.gge.unb.ca/*) we estimate the position of the station along other parameters as the zenith non-hydrostatic delay (random walk—5mm/sqrt(h) noise applied).

However, the ray-traced zenith delays and the coefficients, are computed by integrating refractivity profiles, which are calculated as a function of pressure, temperature and specific humidity NWP data. Underlying errors in the NWP will propagate into the height estimation.

Thus we additionally apply the respective VMF1 products to access the NWP's quality.

We employ the Kalman filter module of VieVS@GFZ VLBI software (Nilsson et al., 2015) to analyze interferometric group delay data from the CONT14 campaign, that took place in May of 2014, featuring in total a global 18 station network. We produce 2 solutions alternating only the mapping function employed.

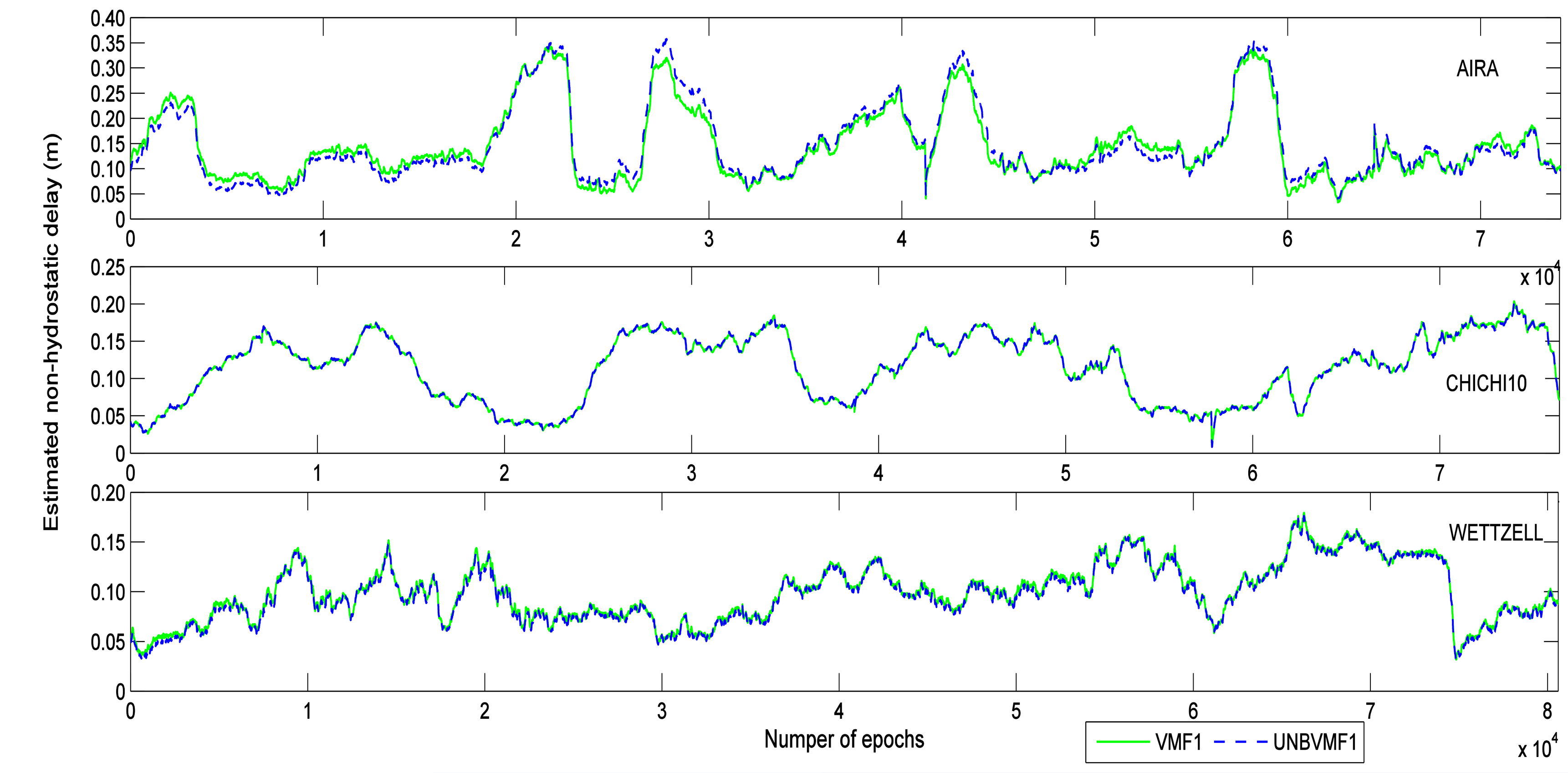


Fig. 2: Non-hydrostatic zenith delays as estimated with GAPS for CONT14, applying UNB-VMF1 and VMF1 a-priori delays and slant factors, for the stations AIRA, Kagoshima, Japan CCJ2, Ogasawara, Japan and WTZR, Germany.

Estimating non-hydrostatic delays in VLBI + NWP

In the presence of severe weather events, the 2 solutions diverge.

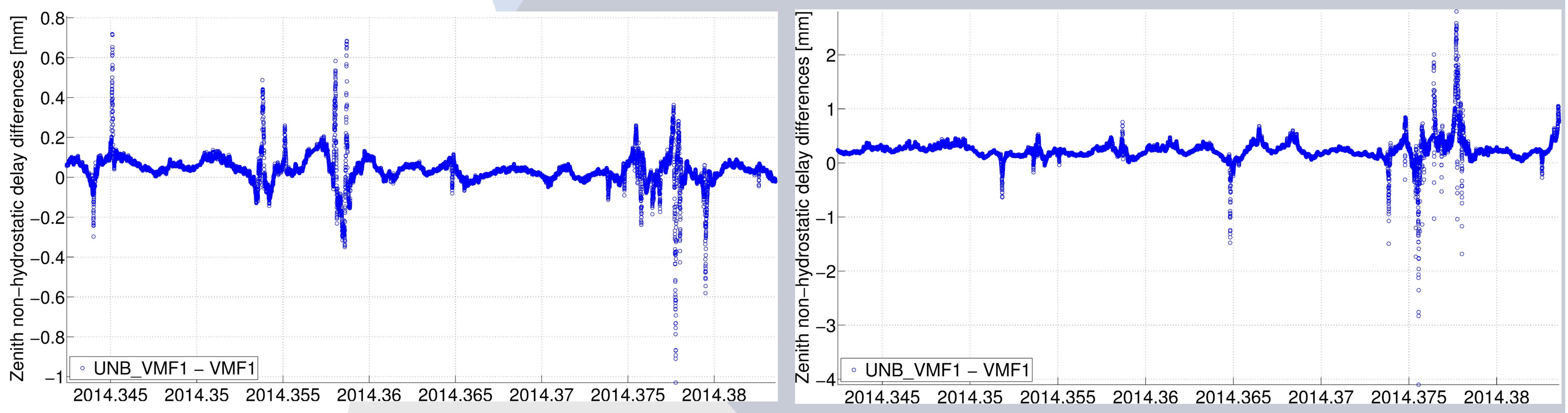
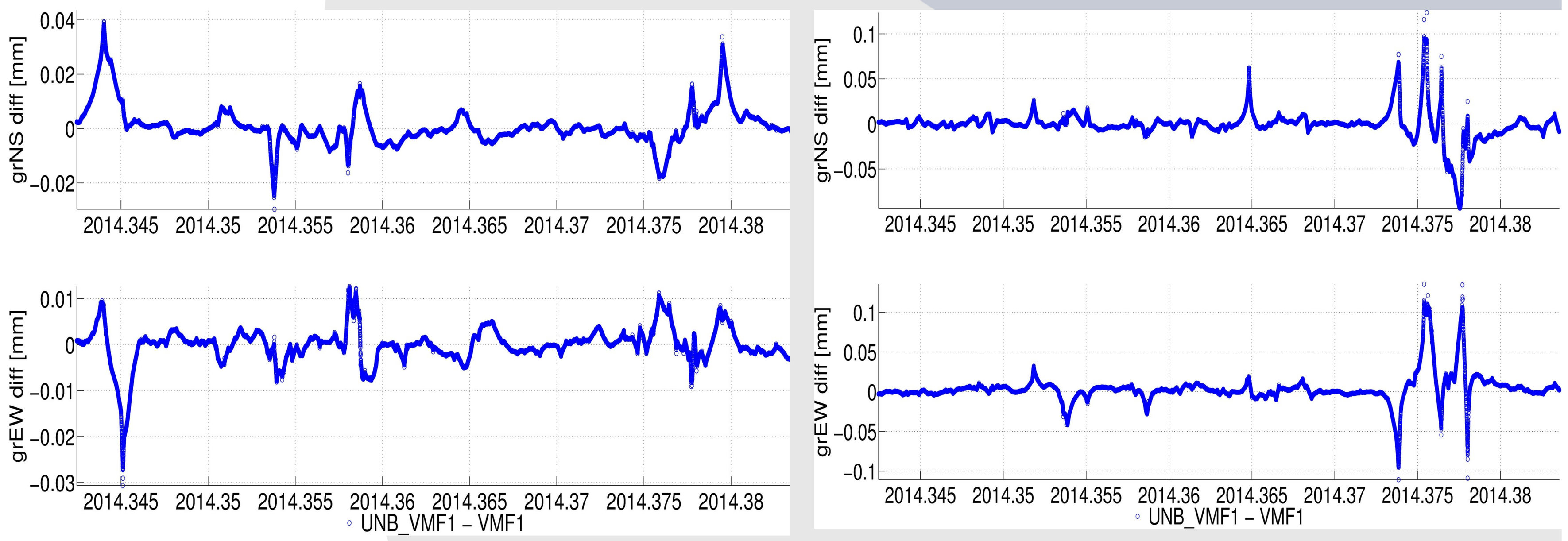


Fig. 3.a & 3.b: Differences in non-hydrostatic zenith delays as estimated with VieVS@GFZ for CONT14, between UNB-VMF1 and VMF1, for the stations WETTZELL, Germany (left) and TSUKUBA, Japan (right).

Estimating heights in VLBI aided by NWP



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UNB Vienna Mapping Function Service

GAPS GPS ANALYSIS AND POSITIONING SOFTWARE