Onsala Space Observatory – IVS Analysis Center

Rüdiger Haas, Hans-Georg Scherneck

Abstract

We briefly summarize the activities of the IVS Analysis Center at the Onsala Space Observatory during 2010 and give examples of results of ongoing work.

1. Introduction

We concentrate on a number of research topics that are relevant for space geodesy and geosciences. These research topics are addressed in connection to data observed with geodetic VLBI and complementing techniques.

2. Calibration of VLBI Atmospheric Delays with External Information

We used the CONT05 campaign to study whether VLBI atmospheric delays can be calibrated using external information. As external information we used atmospheric parameters derived from GPS data analysis and water vapor radiometers (WVR).

All eleven stations that participated in CONT05 are equipped with GPS. The GPS data were analyzed by the precise point positioning (PPP) technique [1] with the Gipsy-Oasis software [2], and zenith wet delays (ZWD) and atmospheric gradients were estimated with five minute temporal resolution. Six of the CONT05 stations also had at least one WVR operating during the campaign. For three of these stations, Kokee, HartRAO and Wettzell, both ZWD and gradients could be derived from the WVR, while for the remaining three stations, Algopark, Onsala and Tsukuba, only ZWD could be derived from the WVR observations. The temporal resolution was 30 minutes.

In a first step, the time series of ZWD and gradients from GPS and WVR were compared to those that result from the analysis of the CONT05 VLBI data. The VLBI results were derived with the Calc/Solve software [3] with a temporal resolution of 1 hour for ZWD and 6 hours for gradients.

As an example, Figure 1 shows the time series of ZWD and gradients for Wettzell and Algopark. Wettzell turns out to be an extreme case in the sense that the east gradient (EGR) bias between VLBI and WVR is as large as 2.5 mm. In general the gradient biases are smaller than 0.3 mm. The gradient RMS is in general on the order of 1–1.5 mm, with the exception of Kokee which is an extreme case with a value of 10 mm for the comparison of VLBI and WVR derived north gradient (NGR). The biases for ZWD are in general on the order of 2–4 mm but can reach in extreme cases up to 20 mm for the comparison of Algopark and Tsukuba VLBI and WVR results. The ZWD RMS are in general on the order of 6–10 mm but can reach in extreme cases up to 20 mm for the comparison of Algopark VLBI and WVR results.

In a second step, slant delays were constructed based on the GPS and WVR results for the atmospheric parameters. The NMF mapping function [4] was used to map the zenith delays into the line of sight of each observation. Also a set of slant delays was generated that was derived from the VLBI results for atmospheric parameters themselves. Then three 'calibration' solutions were produced with Solve—i.e., the three different sets of slant delays were introduced as calibrations. The parameterization was identical to the reference solution—i.e., ZWD and

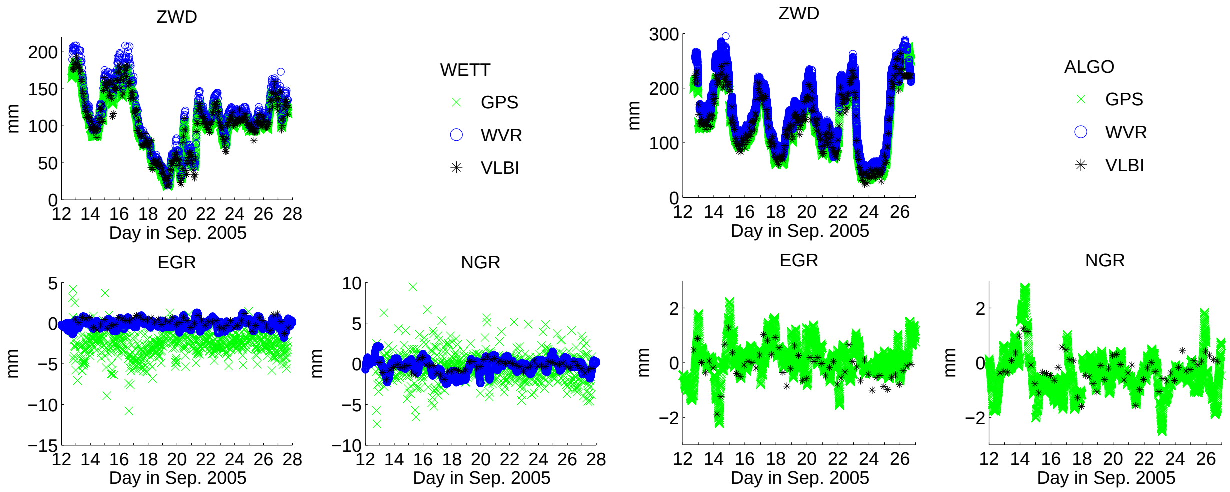

Figure 1. Time series of zenith wet delays (ZWD), east gradients (EGR), and north gradients (NGR) for Wettzell (left) and Algopark (right) during CONT05.

gradients were estimated with 1-hour and 6-hour temporal resolution, respectively. Figure 2 shows the resulting WRMS of the four solutions for all fifteen CONT05 sessions. There is no significant improvement in the WRMS when using GPS- or VLBI-calibration with respect to the uncalibrated reference solution (called NMF-solution in Figure 2). The WRMS fit even deteriorates when the WVR-based slant delays are used as calibration.

Figure 3 presents a comparison of estimated ZWD for Onsala (left), HartRAO (middle), and Tsukuba (right). The ZWD in general reduce to values near zero when slant delays are used as calibration in the analysis. This can be expected if the slant delays were really representing the true atmospheric conditions. However, there are still signatures left in the ZWD time series. At HartRAO there are signatures of up to 20 mm visible when GPS- or WVR-derived slant delays are used as calibration, and at Tsukuba the WVR-calibration even produces a bias of about 40 mm. This indicates strongly that the slant delays used for the calibration are not good enough and for some stations introduce noise and biases.

3. Raytracing through the High Resolution Numerical Weather Model HIRLAM

We used data from the High Resolution Numerical Weather Model HIRLAM to derive slant delays and apply these in the analysis of Europe VLBI data [5]. The slant delays were calculated by 1-dimensional raytracing using the *Davis-Herring-Niell raytracing software* [6]. European VLBI sessions from March 2005 to September 2007 were analyzed and the results from the HIRLAM-calibration were compared to results from a standard analysis. If ZWD are estimated from both approaches, a clear reduction in the estimated ZWD and their variation is visible when using the HIRLAM-calibration. If ZWD are not estimated in the HIRLAM-calibration approach, the baseline repeatabilities improve with respect to a standard solution only if an elevation cutoff angle of 19 degrees or larger is used. Below this value, the standard approach of estimating ZWD still gives superior baseline repeatabilities.

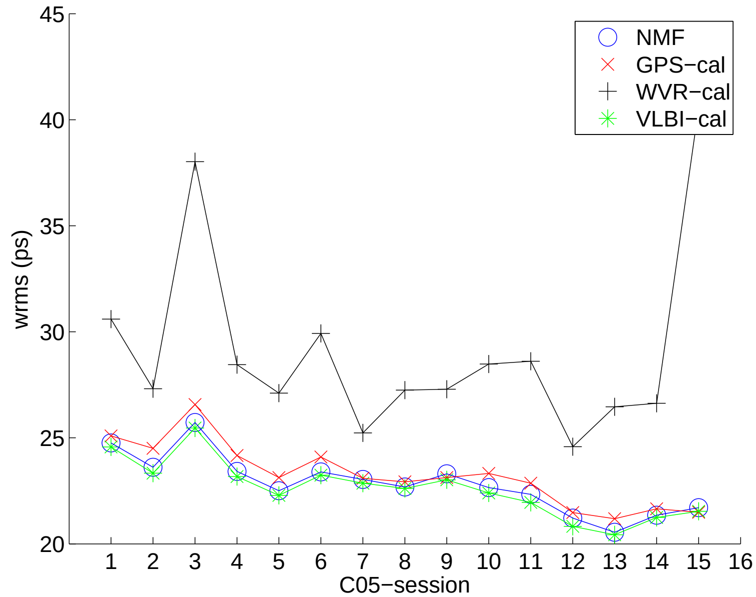

Figure 2. Resulting WRMS for four different analyses: NMF – a standard solution without calibrating atmospheric delays; GPS-cal – a solution using GPS-derived slant delays for the calibration; WVR-cal – a solution using WVR-derived slant delays for the calibration; and VLBI-cal – a solution using VLBI-derived slant delays for the calibration.

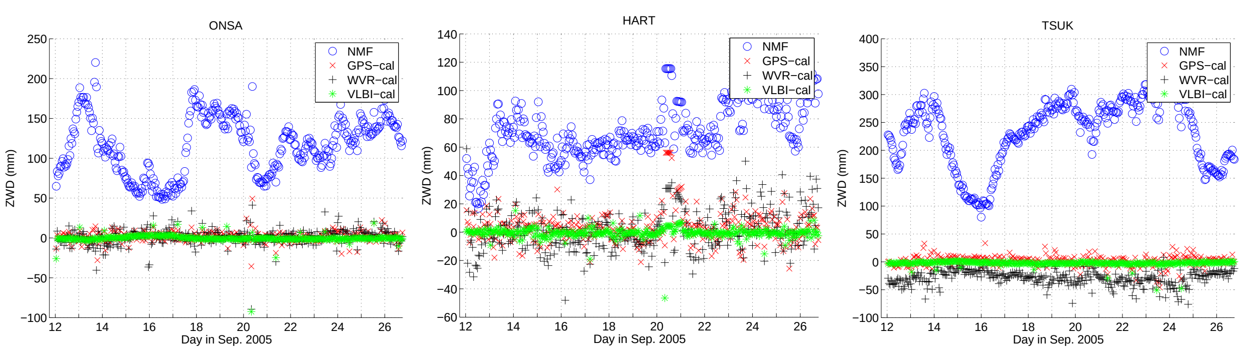

Figure 3. Estimated ZWD for Onsala (left), HartRAO (middle), and Tsukuba (right) when either no calibration is applied (NMF) or a calibration is applied based on GPS results (GPS-cal), WVR results (WVR-cal), or VLBI results (VLBI-cal).

4. Time and Frequency Transfer with VLBI and GPS

We used the CONT08 data to evaluate time and frequency transfer with VLBI and GPS [7]. Those VLBI stations that use the same H-maser for their VLBI and GPS equipment are of major interest. The Onsala-Wettzell baseline shows the best results in CONT08. The VLBI-derived frequency link stability was 1.2E-15 for one day, while the corresponding GPS-derived frequency link stability was between 1.9E-14 and 6.2E-16, depending on which GPS-receiver at Wettzell was included in the analysis. The significant relative frequency offset of about at least 5E-16 can be attributed to either technique, e.g., the absence of integer ambiguity resolution in the GPS-analysis and possible biases introduced by day-boundary problems in the VLBI solutions.

5. Ocean Tide Loading

The automatic ocean tide loading provider [8] was maintained during 2010.

6. Outlook

The IVS Analysis Center at the Onsala Space Observatory will continue its efforts to work on specific topics relevant to space geodesy and geosciences. During 2011 we plan to intensify our activities.

References

[1] Zumberge J.F., Heflin M.B., Jefferson D.C., Watkins M.M., Webb F.H. (1997) Precise point positioning for the efficient and robust analysis of GPS data from large networks. *J. Geophys. Res.*, **102 (B3)**, 5005–5017.

[2] Webb F.H., Zumberge J.F. (1993) An introduction to GIPSY/OASIS-II precision software for the analysis of data from the Global Positioning System. *JPL Publ. No. D-11088*, Jet Propulsion Laboratory, Pasadena, California.

[3] Ma C., Sauber J.M., Bell L.J., Clark T.A., Gordon D., Himwich W.E., Ryan J.W. (1990) Measurement of horizontal motions in alaska using very long baseline interferometry. *Journal of Geophysical Research*, **95(B13)**, 21,991–22,011, `doi:10.1029/JB095iB13p21991`.

[4] Niell A.E. (1996) Global mapping functions for the atmosphere delay at radio wavelengths. *J. Geophys. Res.*, **101, B2**, 3227–3246

[5] Garcia-Espada S. Haas R., Colomer F. (2010) Application of Raytracing through the High Resolution Numerical Weather Model. In:*IVS 2010 General Meeting Proceedings*, D. Behrend and K.D. Baver (eds.), **NASA/CP. 2010 215864**, 232–236, `http://ivscc.gsfc.nasa.gov/publications/gm2010/garcia-espada.pdf`.

[6] Davis J.L, Herring T.A.E., Niell A.E. (1987–1989) The Davis/Herring/Niell Raytrace program.

[7] Carsten R., Haas R., Jaldehag K., Johnasson J. (2010) VLBI and GPS-based Time-transfer Using CONT08 Data, In: *IVS 2010 General Meeting Proceedings*, D. Behrend and K.D. Baver (eds.), **NASA/CP 2010215864**, 365–369, `http://ivscc.gsfc.nasa.gov/publications/gm2010/rieck.pdf`.

[8] Scherneck H.-G., Bos M. (2002) Ocean Tide and Atmospheric Loading. In: *IVS 2002 General Meeting Proceedings*, N.R. Vandenberg and K.D. Baver (eds.), **NASA/CP-2002-210002**, 205–214.