3.6.2.4 Forschungseinrichtung Satellitengeodäsie, Technical University of Munich (FESG)

Introduction

During the year 2005 the major activities of the FESG IERS CRC were concentrating on the following two combination and comparison topics:

1. Long Time Series: Comparison of troposphere parameters from GPS and VLBI
2. CONT02: GPS/VLBI combination studies

Homogeneously reprocessed time series of troposphere parameters for GPS (generated by FESG) and VLBI (generated by DGFI) were generated to detect common signals but also systematic differences between the troposphere results of the two space geodetic techniques. Such comparisons are an important first step before a rigorous combination of the troposphere parameters can take place.

The combination studies using VLBI and GPS normal equations for the time span of the CONT02 campaign started already in 2003 (see previous IERS Annual Reports) and have been continued in 2005, again making use of the good cooperation with the Deutsches Geodätisches Forschungsinstitut (DGFI). The topics of major interest in 2005 were:

- More detailed studies devoted to the combination of troposphere parameters derived from VLBI and GPS,
- Handling of the singularity between a retrograde diurnal term in polar motion and the nutation angles (including offsets and drifts),
- Dependency of the combined UT1–UTC time series on the selected local ties introduced into the combination.

Homogeneous Long Time Series of Troposphere Parameters from GPS and VLBI

Troposphere zenith delays and gradients covering the time period from 1994 to 2005 have been estimated within the reprocessing of a global GPS network, a cooperation of TU Munich and TU Dresden (Steigenberger et al., 2006). The complete and homogeneous reprocessing is essential for the inter-technique comparison with VLBI to avoid inconsistencies due to, e.g., model changes. Comparisons of the zenith total delay (ZTD) at sites with two or more GPS receivers (GPS/GPS co-locations) for our reprocessed GPS solution and for the combined IGS troposphere product revealed the inconsistency of the latter. Fig. 1 shows the ZTD differences for the sites TROM and TRO1 at Tromsø (Norway). The ZTD difference of the IGS series shows a clear annual signal at the beginning whereas the reprocessed solution only shows an increase in the scatter in the summer months.

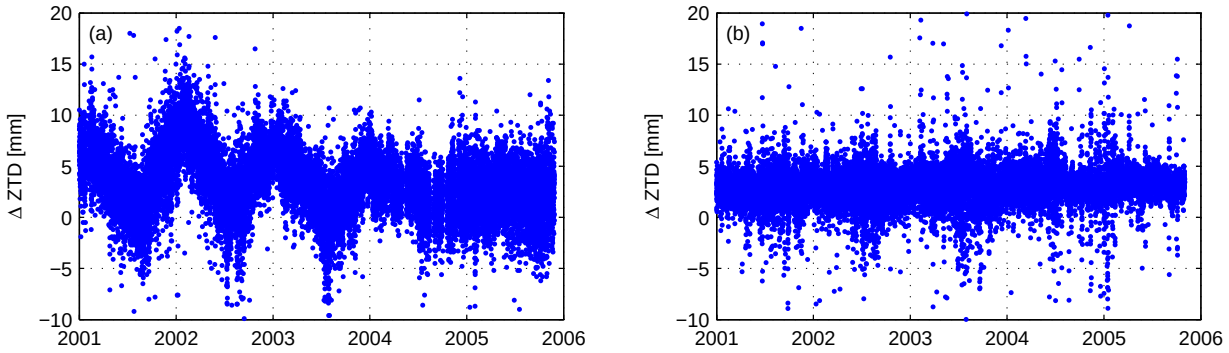

Fig. 1: ZTD differences for the GPS/GPS co-location Tromsø: (a) IGS time series; (b) reprocessed time series. The bias present in both solutions arises from the different antenna heights of TROM and TRO1.

The VLBI solution used for the comparisons was computed by DGFI Munich. The GPS/VLBI difference time series of the estimated zenith wet delay (ZWD) for Wettzell is shown in Fig. 2. The RMS of the difference is only 4.6 mm, the correlation of the GPS and VLBI ZWD time series is 0.994. For other stations, the correlation is in general larger than 0.95 and the RMS varies between 4 and 10 mm. Further details on the comparison of the GPS- and VLBI-derived troposphere zenith delays and gradients are given in Steigenberger et al. (2007). Although the GPS as well as the VLBI series are homogeneously reprocessed, there are still technique-specific systematic errors contained in the results of both techniques that remain the topic of future studies: multipath and receiver antenna phase center variations for GPS; thermal and gravitational deformations of the telescopes for VLBI.

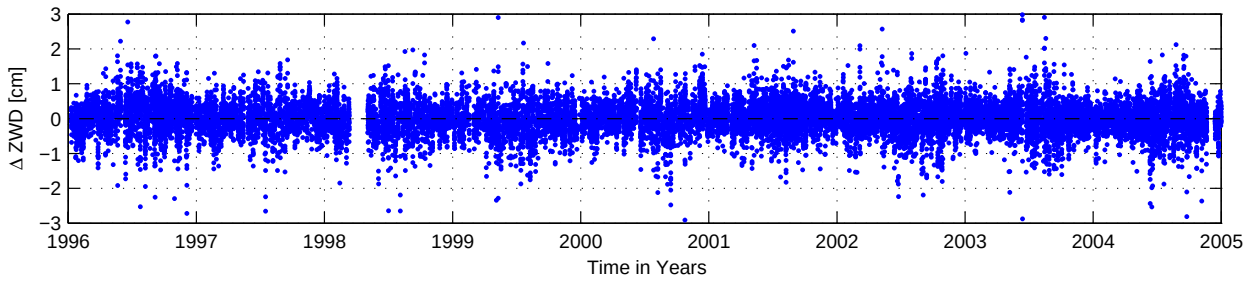

Fig. 2: Time-series of estimated zenith wet delays for Wettzell (Germany): difference between GPS and VLBI.

Inclusion of Troposphere Parameters in the Combination of GPS and VLBI

The parameter space common for the two microwave techniques VLBI and GPS does not comprise solely station coordinates and Earth Orientation Parameters (EOP) but as well the troposphere parameters. This fact has been completely neglected in combination studies up to now. Based on the normal equation systems generated for CONT02 it could be demonstrated that in general a

combination of the troposphere zenith delays derived from GPS and VLBI is possible and stabilizes the combined solution (see Thaller et al., 2006). However, technique-specific specialties like, e.g., radomes on the GPS and/or VLBI antennas or the modelling of the GPS phase centres (relative vs. absolute phase centre calibrations) largely influence the results and could even make them non-interpretable. Consequently, it is indispensable to carefully adapt the a priori troposphere models used for both techniques.

Nutation and Retrograde Diurnal Terms in Polar Motion

The pole coordinates have been estimated with a temporal resolution of one hour. As a consequence of this setup, a singularity between the nutation angles and a retrograde diurnal term in polar motion is present. In order to remedy the singularity a special constraint can be applied in the Bernese GPS Software which prevents retrograde diurnal terms in polar motion by constraining their amplitude to zero. Fig. 3 demonstrates the impact of the singularity on the polar motion estimates (exemplarily for the x-pole): a retrograde diurnal signal with large amplitude is visible which corresponds to an offset in the nutation angles (not shown here). The standard application of the constraint is based on the entire time span of the solution, i.e., 14 days in the case of CONT02. Applying this method, the major part of the singularity is removed (grey line in Fig. 3). However, a retrograde diurnal signal with decreasing and increasing amplitude is still present and corresponds to the linear drift estimated for the two nutation angles. In order to remedy this singularity as well, the third procedure applies the constraint on a daily basis. Fig. 3 shows that this method works well. More details can be found in Thaller et al. (2007).

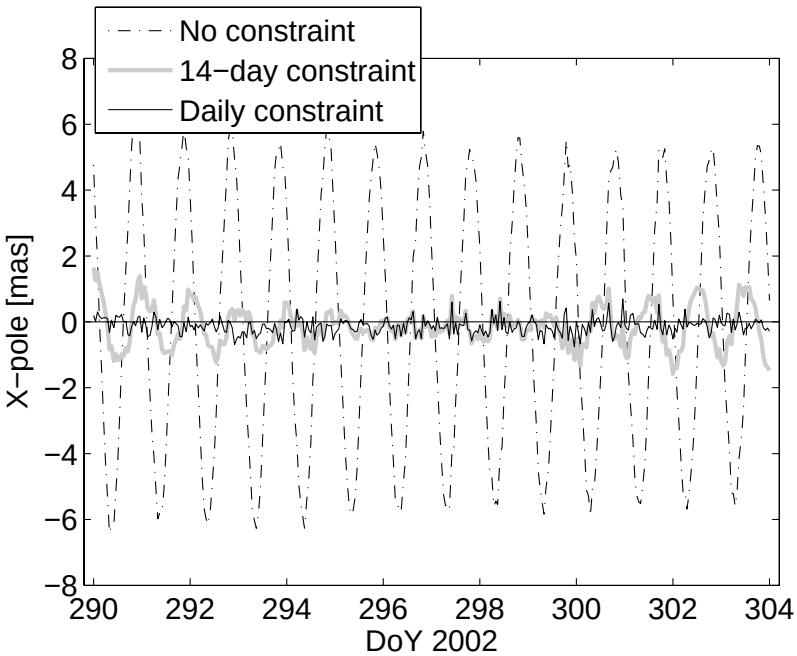

Fig. 3: Hourly polar motion estimate (x-pole component) derived from a VLBI-only solution with different handling of the retrograde diurnal constraint.

Local Ties and the Combination of UT1–UTC

The third topic mentioned at the beginning becomes especially important if the terrestrial reference frame and the EOP are treated together. Using the CONT02 data it could be demonstrated that the introduction of wrong or bad local ties causes a bias in the combined UT1–UTC time series (Thaller et al., 2007): the VLBI-only solution has an offset of only 1 μs compared to C04 whereas the combination, with all eight local ties applied, is shifted by 14 μs compared to C04. As it is well known that the local ties for Fairbanks and Westford do not fit very well to the space techniques they were ignored in another combined solution and, fortunately, the bias of the resulting UT1–UTC time series compared to C04 is reduced to 6 μs. However, the remaining shift of 5 μs w.r.t. the VLBI-only solution cannot be reduced by ignoring additional local ties. But the results clearly demonstrate that the local ties have to be carefully selected in view of a good determination of all parameters involved in the combination.

Acknowledgements

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