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Tropospheric Parameters Estimated by Geodetic VLBI Data IVS

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Abstract

The Institute of Radioastronomy (IRA) joined since the beginning the IVS TROP project providing regular submission of tropospheric parameters (wet and total zenith delays, horizontal gradients) for all IVS-R1 and IVS-R4 sessions since January 1st, 2002. In order to determine reliable time series of tropospheric parameters, we analyzed all the 2000-2003 databases available on the IVS data centers. Some of the tropospheric results are presented here. We have also compared the VLBI tropospheric estimates and the GPS-derived troposphere provided by IGS (International GPS Service), for the co-located sites. Post-processing analysis has been carried out on the time series and trends and seasonal signals are highlighted. Constant biases are found between the zenith delays derived by VLBI and GPS, although the same effects should affect both techniques.

1. Introduction

The Institute of Radioastronomy (IRA) joined the IVS TROP project on Tropospheric Parameters since the beginning, submitting the estimates of tropospheric parameters (wet and total zenith delays, horizontal gradients) for all IVS-R1 and IVS-R4 sessions since January 1st, 2002, on a regular basis. Our institute had a large experience of analyzing VLBI data for studying the effect of the tropospheric delay on the results [1], and participating in the project was a natural broadening of our activity. Our analysis center submits the requested parameters to IVS as a Sinex file. For the VLBI data analysis a 5 degree elevation cut-off angle and Niell mapping functions were used. The solution has been computed into ITRF2000 without fixing the stations coordinates, using a no-net-translation constraint. One total and one wet zenith delay parameter per hour for all the stations involved in the experiment and only one value for both east and north gradient per station per session were computed. The data submitted by the different ACs are combined at the IVS Tropospheric Combination Center at IGG in Vienna in order to obtain IVS combined products, i.e. stable and robust tropospheric parameters with 1 hour resolution and high accuracy [2].

2. VLBI Data Analysis of All 2000-2003 Databases

Space geodesy techniques are proving to be a powerful tool for studying climate change and global warming. An important parameter to monitor is the behavior of the troposphere and VLBI can be very useful, computing long time series of tropospheric parameters. To achieve this goal, we analyzed all the other 2000-2003 databases available on the IVS Data Centers, using a setup identical to the one described above. As a product of this analysis we obtained tropospheric parameters for each station and for every experiment available in our catalogue and the relevant time series. In Figures 1 and 2 the total and wet zenith path delay time series for some of the stations involved into VLBI geodetic experiments are shown. For Wettzell we have quite a continuous time series unlike other stations, such as Medicina or Onsala, where very sparse data are present. It should be noted that all the stations present a strong seasonal signal and a large correlation of this signal between total and wet zenith path delay.

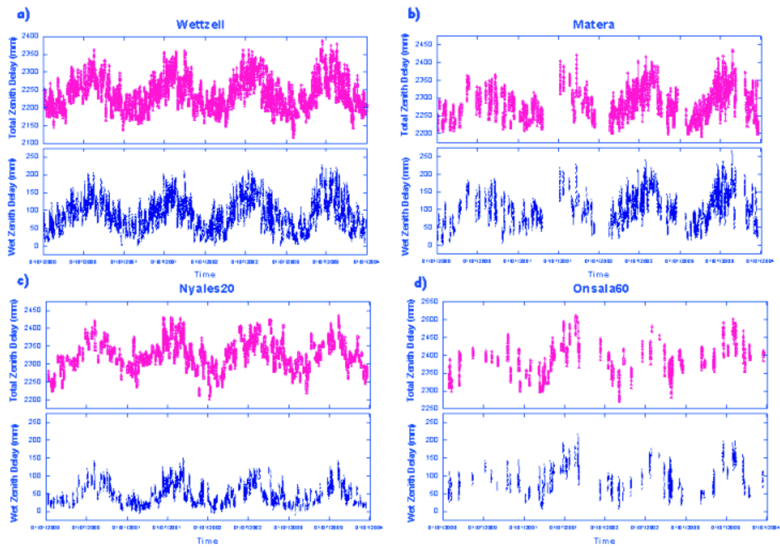

Figure 1. Total (up) and Wet (down) zenith delay time series for: a) Wettzell, b) Matera, c) Nyales20, and d) Onsala60.

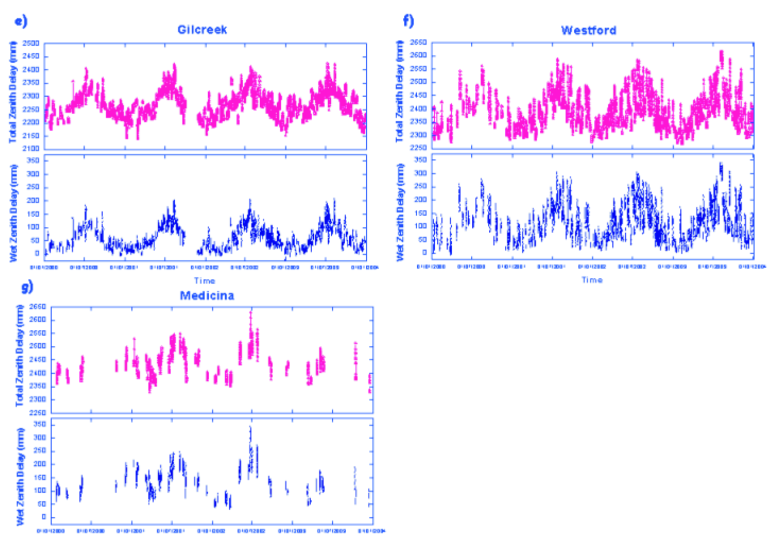

Figure 2. Total (up) and Wet (down) zenith delay time series for: e) Gilcreek, f) Westford and g) Medicina.

3. Post-Processing of the Time Series

The time series of zenith path delay for the stations present in this analysis is an interesting set of data that can be compared with the results coming from independent techniques, like GPS. For that we decided to carry out a comparison between the VLBI tropospheric estimates and the GPS-derived troposphere for co-located sites. We used GPS data available on the web site of the CODE Analysis Center and in particular the COE EUREF daily solutions, where the troposphere parameters have 1-hour resolution and, thus, they are directly comparable with the parameters computed by our VLBI data analysis. For stations not included in EUREF analysis we used the COD solutions, where every 2-hour parameters were estimated. Post-processing analysis have been carried out on both VLBI and GPS time series, spectral analysis was performed. The estimated periods are almost identical for both techniques, differences are at the level of few days.

As an example we plotted in Figure 3 Wettzell time series, both VLBI and GPS, and the seasonal signals highighted by spectral analysis. We were able to compute amplitudes and phases by means of a best-fit wave. VLBI and GPS seasonal signals have quite the same amplitudes and phases. For VLBI we found a period of 365 ± 5 days and for GPS 356 ± 3 days. For the amplitude we found 45.5 ± 0.9 mm for VLBI and 45.5 ± 0.5 mm for GPS.

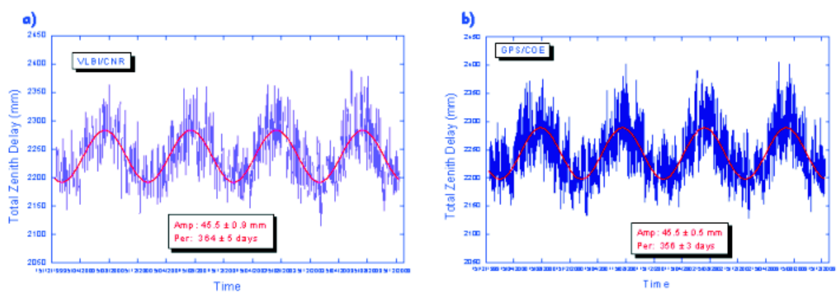

Figure 3. VLBI (a) and GPS (b) time series and best-fit annual waves for Wettzell.

Since signals present in both VLBI and GPS data were comparable, we computed the differences between the two time series and we obtained the relevant residuals. A positive bias is always present and in some cases a positive trend, too, that is to be investigated in order to understand its physical meaning. In fact, both techniques are supposed to be affected by the same effects, so it is not clear what can cause this different behavior found in the residual. One known effect, that has to be taken into account, is the difference in height of the reference points of the different instruments. Thus, for a precise comparison, we have to take into account these differences in height, convert them into differences of tropospheric zenith delay and correct the residuals time series. That is quite easy for the dry component, but not for the wet component. In fact, for the first component we can assume that the delay is a fraction, proportional to the difference in height, of all the dry delay, but that assumption is not true for the wet path delay. Table 1 shows the results for the 7 co-located sites. The first four rows represent the stations for which 1-hour tropospheric parameters from GPS are available, while for the last three we used 2-hour GPS data. After applying the height correction the positive biases are still present. We have to investigate possible causes of remaining bias: different analysis strategies between the two techniques, the different cut-off angles applied that can cause differences when station heights are estimated and, consequently, differences in the signal path through the troposphere. At this step of the work, no conclusion can be drawn.

Table 1. Biases between VLBI and GPS tropospheric zenith delay before and after height corrections

VLBI	GPS	Height diff.(m)	Bias(mm)	Bias(mm) b. corr.	Bias(mm) a. corr.
Wettzell	WTZR	3.1	1.0	4.7 ± 0.1	3.7 ± 0.1
Nyales20	NYA1	3.1	1.1	5.1 ± 0.1	4.0 ± 0.1
Matera	MATE	7.7	2.5	7.8 ± 0.1	5.3 ± 0.1
Onsala	ONSA	13.7	5.1	6.3 ± 0.2	1.2 ± 0.2
Gilcreek	FAIR	13.1	4.4	7.5 ± 0.1	3.1 ± 0.1
Westford	WES2	1.8	0.6	12.3 ± 0.2	11.7 ± 0.2
Medicina	MEDI	17.1	6.3	8.6 ± 0.4	2.3 ± 0.4

4. Long-Term Time Series

Very long-term time series of tropospheric parameters, particularly of wet zenith delay representing the content of water vapor in the atmosphere and one of the greenhouses gases, are useful for meteorological and climatologic studies. Therefore, we decided to analyze all the databases included in our AC catalogue, considering the fact that the time series can go back for about 15 years, including, for the most part, experiments that contain at least three European stations. We re-analyzed all these databases in order to obtain a homogenous set of tropospheric parameters. In Figure 4a there are the results for the wet zenith delay at the station of Wettzell since 1987 till 2003 and the estimated linear trend. We obtained a negative value, -0.5 ± 0.1 mm/yr, but the series is very uneven and with a strong annual signal. We performed a spectral analysis and fitted the wet delay time series with the annual wave and we subtracted the best-fit wave from the data. On the residual series we computed the linear trend and we obtained a slightly positive value, 0.1 ± 0.1 mm/yr, (Figure 4b) different from our previous determination [3]. In any case, the weight of the last dense four years of data certainly influences the determination of the true value. We performed the same analysis also for Medicina. In this case, a positive trend is also present and its original value is 2.7 ± 0.3 mm/yr; it becomes 1.5 ± 0.2 mm/yr for the residual wet component.

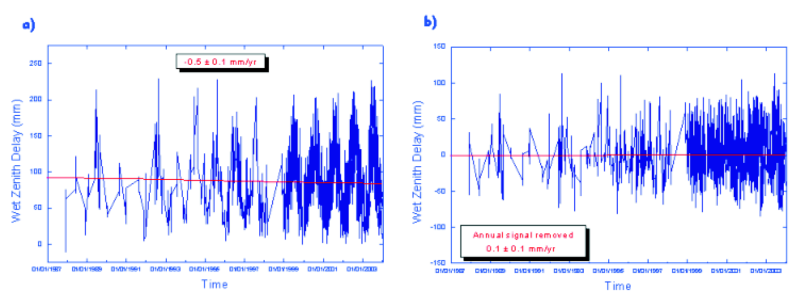

Figure 4. Wet zenith delay time series for Wettzell.

5. Conclusion and Outlook

We analyzed all 2000-2003 databases present in the IVS data centers and, as an output, we obtained time series of tropospheric zenith delays for the stations involved in geodetic VLBI experiments. We performed spectral analysis on these series and we highlighted strong annual signals mainly due to the wet component. We compared VLBI data with GPS-derived tropospheric estimates. We found out common features and differences between the two techniques, even if they are supposed to be affected by the same effects. In particular the biases between the two techniques are confirmed and do not disappear even taking into account the height differences. The long-term time series of tropospheric delays, confirm a positive linear trend, after the subtraction of the seasonal signal, for Wettzell and Medicina. However, it should be pointed out that the period is probably too short to draw a final conclusion on a modification of the trend in global warming. For the future we will continue the participation of our AC in the TROP project, submitting regularly tropospheric parameters for IVS-R1 and IVS-R4 sessions. We also agreed to submit our long-term series of tropospheric parameters. We are working in order to complete our VLBI data catalogue and, at the moment, we are able to provide the project with our available data, only. But very soon we will complete the analysis also for the data bases not present, at the moment, in our catalog. We will continue our test on comparing VLBI and GPS data and we will work on using VLBI wet zenith delay into routinely VLBI data analysis in order to improve the repeatability of station baselines.

References

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[2] Schuh, H., Boehm J., "Status Report of the IVS Pilot Project - Tropospheric Parameters", in *International VLBI Service for Geodesy And Astrometry 2002 Annual Report*, edited by N. R. Vandenberg and K. D. Baver, NASA/TP-2003-211619, 13-21, 2002.

[3] Negusini, M., Tomasi P., "Tropospheric Parameters From Geodetic VLBI Data Analysis", in: *Proceedings of the* 16^{th} *Working Meeting on European VLBI for Geodesy and Astrometry*, 181-194, 2003.