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Ionospheric Parameters Obtained by Different Space Geodetic Techniques during CONT02

Thomas Hobiger, Sonya Todorova, Harald Schuh

Institute of Geodesy and Geophysics, University of Technology, Vienna
Contact author: Thomas Hobiger, e-mail: thobiger@mars.hg.tuwien.ac.at

Abstract

The goal of the CONT02 campaign in October 2002 was the acquisition of the best possible VLBI data to demonstrate the high accuracy of which VLBI is capable. The campaign provides the chance to study the ionosphere continously over a period of more than two weeks by means of VLBI. Vertical total electron content (VTEC) values above the contributing stations were determined. By comparison with results from other techniques, like GPS or satellite altimetry, systematic differences could be detected of which the reasons are still unclear. Anyway, the histograms of the differences show that generally the agreement is very good between the parameters derived by VLBI and the results from other space geodetic techniques. This is also confirmed by Fourier and wavelet analyses which reveal variations with the same periods (diurnal, semi-diurnal and quarter-diurnal) in GPS and VLBI time series.

1. Techniques Used

- VLBI: For the computation of the ionospheric parameters (vertical total electron content - VTEC) the whole 15 days of observations were analyzed. Three continuous days of observations were taken to estimate robust values for the central day. For the first and last day of the data set, i.e. Oct. 16th 2002 and Oct. 30th 2002, two consecutive days were used, only. The vertical total electron content above each station was modeled with a modified piece-wise linear function (PLF) approach [1]. Instead of the classical PLF with constant interval length adaptive interval lengths were chosen. Implementation was done by a reflective Newton method to avoid negative values which are impossible due to the physical nature of wave propagation.
- GPS: Global ionospheric maps provided by the Center for Orbit Determination in Europe (CODE), an analysis center within the International GPS Service (IGS) [2], were used to interpolate VTEC values for the contributing CONT02 stations. The data are given in gridded form and represent the ionosphere as an infinite thin layer at a height of 450 km. As an official IGS ionosphere product is not available for the period covered by CONT02, the CODE solution was chosen, which turned out to be one of the best VTEC estimations within the IGS.
- TOPEX/Poseidon: Data was kindly provided by ADS Central, GeoForschungsZentrum Potsdam (GFZ) [3]. We used only data within ± 5 degrees in latitude and longitude of Kokee Park on Hawaii, which is the only station that is completely surrounded by the sea. The sub-satellite tracks for all observations during CONT02 are plotted in figure 1.

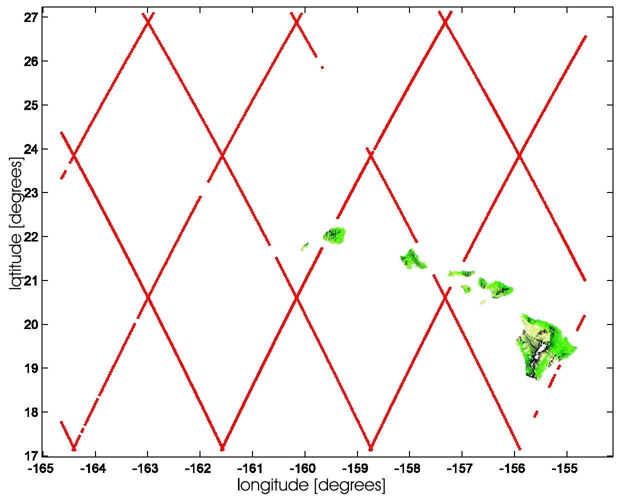


Figure 1. TOPEX/Poseidon footprints during CONT02.

2. Results

In figures 2 and 3 the VLBI solutions (blue-solid line) for station Hartebeesthoek and Westford are plotted together with the corresponding GPS results (red-dashed line).

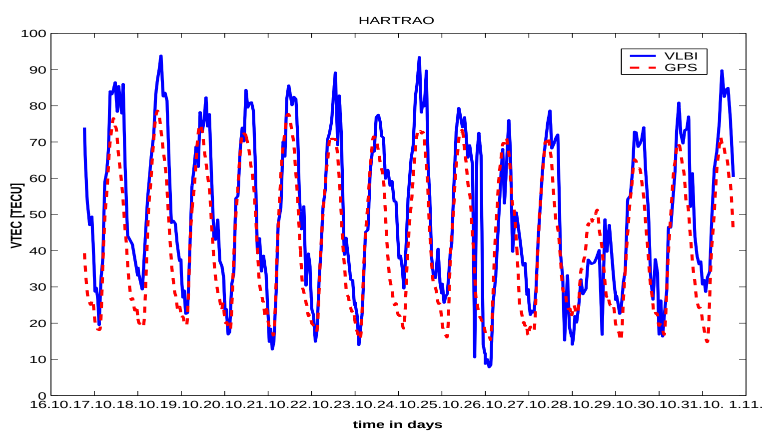


Figure 2. VTEC values for station HARTRAO derived by VLBI (solid line) and GPS (dashed line).

Histograms of the differences for both stations are given in figure 4. The standard deviation between both techniques is about 10 TEC units (TECU), what is quite satisfying. On the other hand, an outlier in the VLBI solution at station Westford at the end of Oct. 25th, 2002 can be detected clearly. Such an effect may be due to the method applied that forces the solution to be strictly positive. The left plot of figure 5 summarizes the results from all eight contributing stations. The values derived by GPS are plotted against the corresponding values from VLBI. The correlation is high ($\sim$ 0.87) and a systematic offset (VLBI minus GPS) of about -3 TECU can be detected. The differences, which are plotted in a histogram (centre, figure 5) are not normally

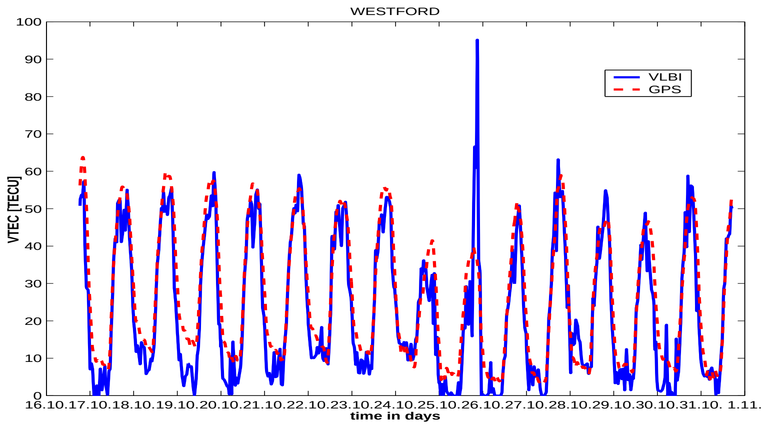
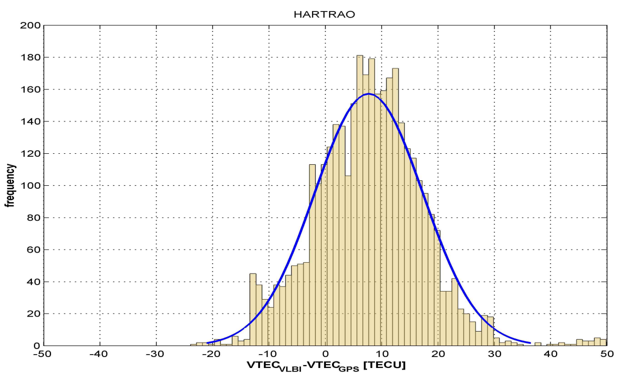
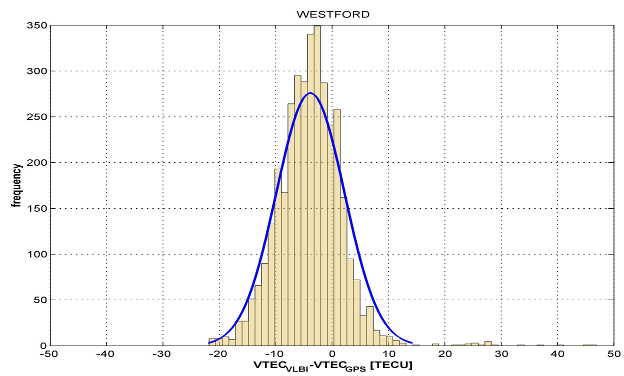


Figure 3. VTEC values for station WESTFORD derived by VLBI (solid line) and GPS (dashed line).

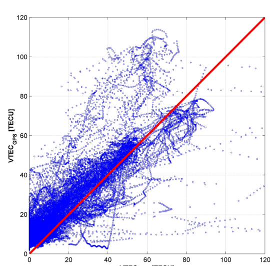


VTEC differences for station HARTRAO

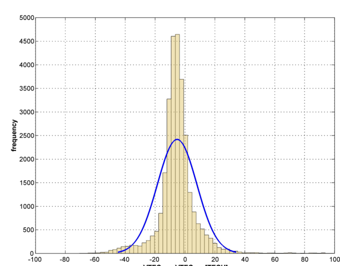


VTEC differences for station WESTFORD

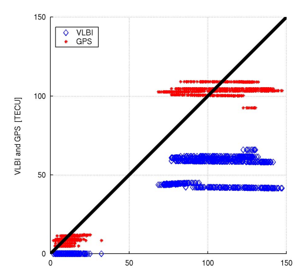
Figure 4. Histograms of the VTEC differences between VLBI and GPS (VLBI-GPS)



VTEC VLBI vs. GPS



VTEC differences between VLBI and GPS, all CONT02 stations (VLBI-GPS)



VTEC T/P vs. VLBI (blue,diamonds) and GPS(red, stars)

Figure 5. Comparison to results from GPS and TOPEX/Poseidon.

distributed and show a positive asymmetry. The standard deviation of the differences is about 11 TECU. Comparisons with the results of TOPEX/Poseidon for station Kokee Park are plotted in the right graph of figure 5. Although the differences between VLBI and TOPEX/Poseidon are bigger than the differences between GPS and TOPEX/Poseidon both results agree within an error range that is due to the assumption that all VTEC values within a range of ± 5 degrees in latitude and longitude can be assigned to station Kokee Park, which is located in a region of high ionospheric activity.

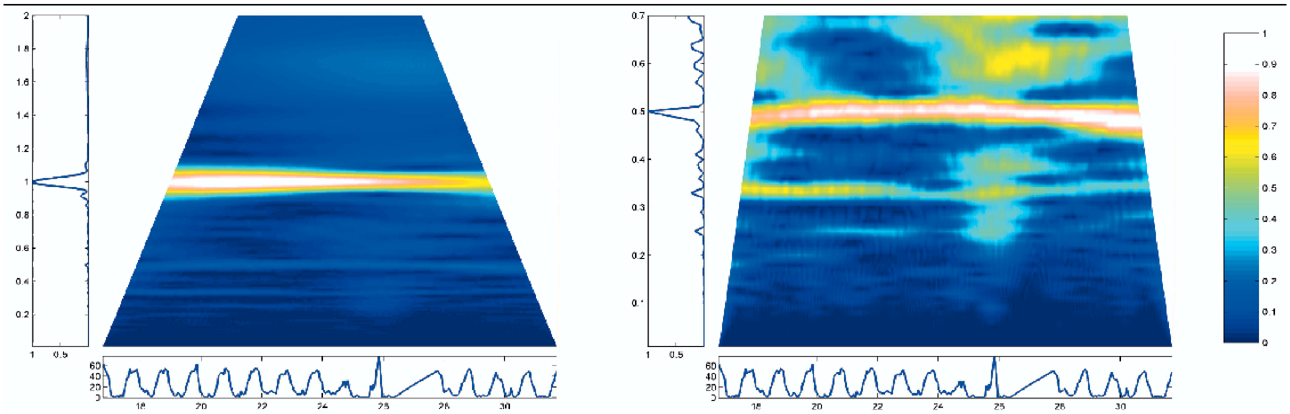


Figure 6. Daily and subdaily periods for station ALGOPARK, VLBI solution, Fourier and wavelet transformation (normalized to maximum amplitude); periods in days.

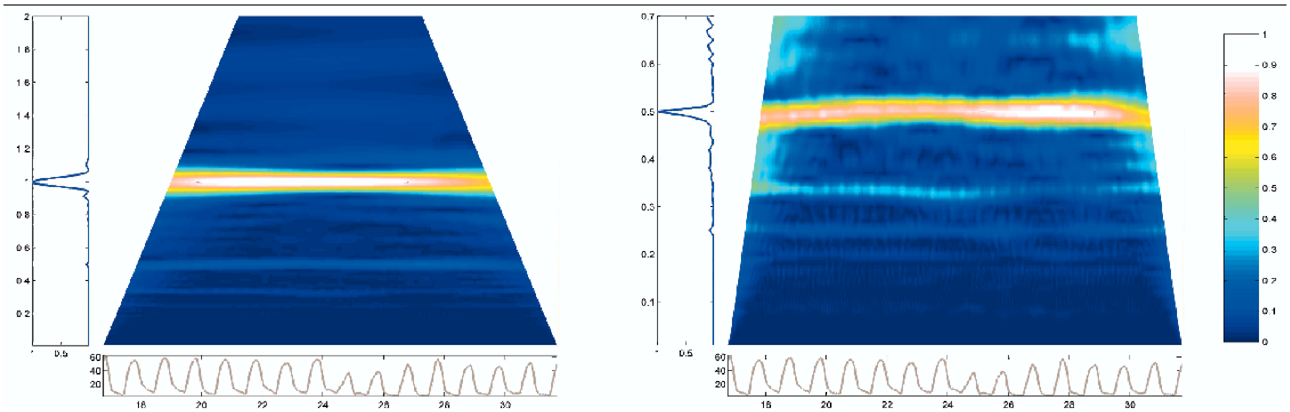


Figure 7. Daily and subdaily periods for station ALGOPARK, GPS solution, Fourier and wavelet transformation (normalized to maximum amplitude); periods in days.

To get an idea about the spectral content of the solutions derived by VLBI and GPS the results for station Algonquin Park were subject to Fourier and wavelet transformations. As on Oct. 27th, 2002 this station did not observe within CONT02 the adaptive PLF approach produces a linear trend for this time span (figure 6, lower graph), which does not influence the results of the frequency analysis because only periods shorter than two days were investigated here. A big diurnal variation can be seen in the Fourier spectrum of the VLBI results (left plot of figure 6), of the GPS data (7), and in the wavelet scalograms (left plots, figures 6 and 7). Both techniques show a decreasing diurnal amplitude during the 15 days covered by CONT02. If we concentrate on the periods shorter than 0.7 days we are able to recover a semi-, ter- and quarter-diurnal signal in the results from both techniques (right plots, figures 6 and 7).

3. Conclusions

CONT02 offers the opportunity to study the ionosphere by means of VLBI during more than two weeks of continuous measurements. Ionospheric parameters derived by VLBI and GPS show similar trends and differ within a few TECU, only. The main periods of the ionosphere (diurnal, semi-, ter- and quarter-diurnal) are found in the Fourier spectrum and the wavelet scalograms of both techniques agree well.

4. Acknowledgements

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