Alternative Products of EPN Analysis at LAC SUT in Bratislava

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Abstract

The EUREF Permanent Network (EPN) Local Analysis Centre at Slovak University of Technology (LAC SUT) in Bratislava is operating since 2002. The analysed subnetwork consists of 34 stations distributed all-over the continent. Routine processing of these stations following the EPN guidelines is resulting to daily and weekly coordinate solutions and hourly troposphere zenith delays. Besides, some alternative products are generated at SUT after completing the standard procedure. On the weekly basis 4-hour separate observing intervals are processed resulting to sub-daily coordinate time series for each analysed station. The routine troposphere zenith delays estimates are alternatively enlarged by local gradient estimates. In parallel the local water vapour content is evaluated. For the continental Europe daily regional ionosphere models are produced. In this paper all the products mentioned and their relevance is discussed.

1. Introduction

LAC SUT is operating since 2002 as 16th official EPN Local Analysis Centre. The original analysed network consisted from 25 stations, the number of stations then progressively increased to 35 stations in May 2004. The network shown in Fig. 1 is focused on stations in Central Europe with addition of some stations in south and north-west Europe. The standard processing follows the guidelines for EPN Analysis Centres. At LAC SUT is used the Bernese GPS software BV42 (Hugentobler et al., 2001) operating in the LINUX environment. Daily networks are referenced to ITRF by strongly constraining the coordinates of ZIMM (until GPS week 1229) and BOR1 (since GPS week 1230).

After the results of standard processing in weekly batches are completed, a set of further processing options is performed. The alternative network solutions are aimed to give more detailed information about the GPS positioning, station behaviour and related atmospheric processes. To enable the study of sub-daily coordinate variations network solution in 4-hour batches is performed. This solution is using ambiguities and troposphere zenith delays estimated in 24-hour sessions and the solved parameters are limited to sub-daily station coordinates only. Study of troposphere variations is supported by additional network solutions with troposphere gradient estimations, where gradients are solved for 24-hour and 6-hour intervals. In addition, troposphere zenith delays are used for definition of maps of precipitable water vapour (PWV) in region of Central Europe. Finally, the whole network is used to form regional ionosphere models for 24-hour time intervals. We will describe all these alternative and additional outputs of regular EPN analysis at SUT Bratislava.
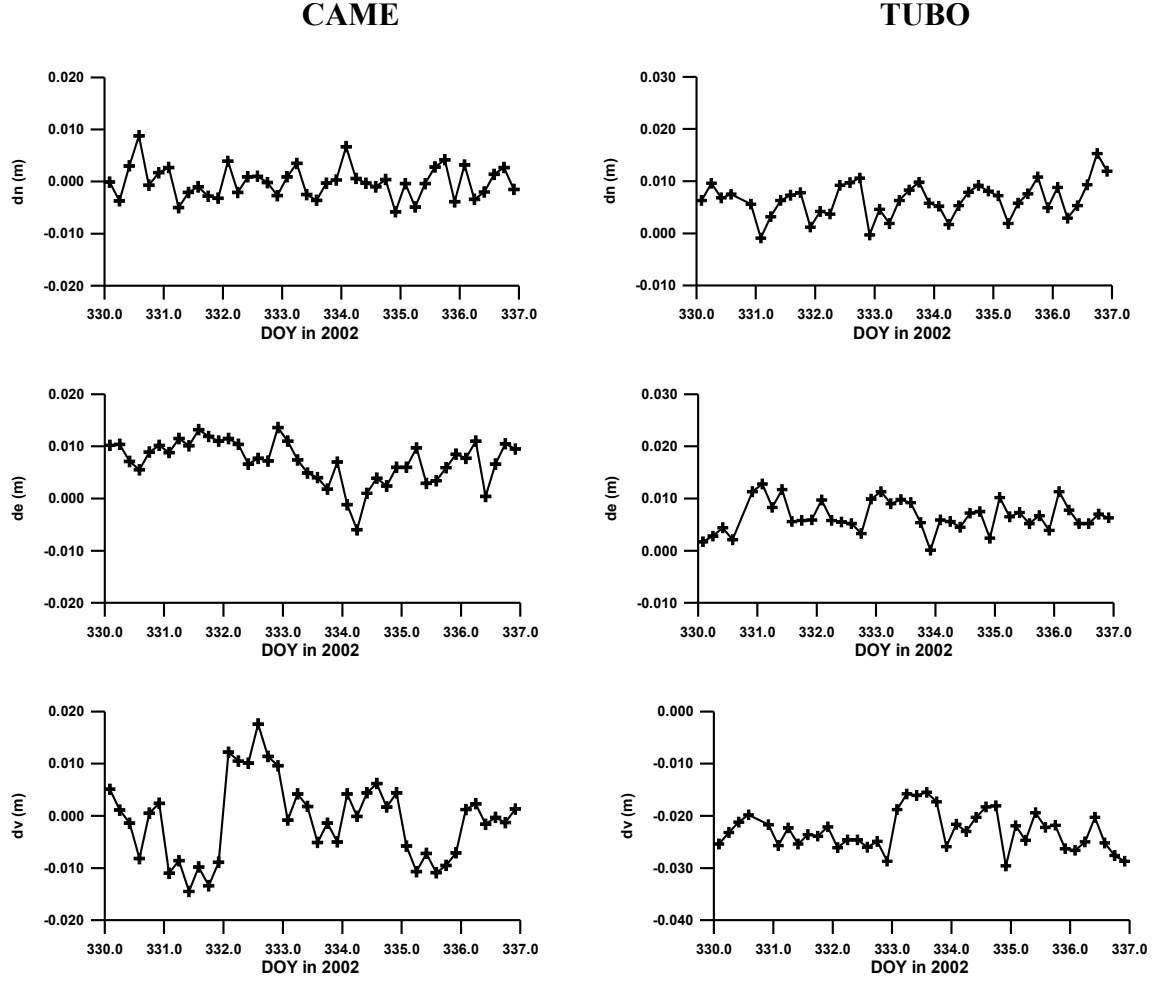
Figure 1. EPN stations analyzed at LAC SUT Bratislava

2. Time series of station coordinates in 4-hour intervals

Main goal of estimation of sub-daily site coordinates is detailed insight into station behaviour during the diurnal cycles. As an example we show in Fig. 2 variations of horizontal coordinates and height during one week for two stations TUBO and CAME. The variations of order of 10-20 mm within the 24-hour intervals are clearly visible. Similar behaviour is observed for all the analysed stations and for any other interval.

After data preprocessing including the jump identification and outlier detection we apply two approaches for analysis of the site coordinate time series with sub-daily resolution. Firstly, spectral analysis is used for general investigation of main constituents in station series. Least-squares approach is then used for amplitude estimates of dominant periodic terms as well as for estimate of amplitudes of sudden jumps due to antenna or receiver replacement, station environment changes, etc. In Fig. 3 we show as an example spectra of short-term coordinate variations of station KOSG. Dominant periods of all series coincide with tidal diurnal periods K_1, S_1 and O_1, and semi-diurnal periods K_2, S_2 and M_2. We stress that the applied processing strategy using the BV42 is including the solid earth tidal modelling and corrections for ocean tidal loading. The observed variations represent relative variations to reference station ZIMM. Figs 4 - 6 show amplitudes of periodic semi-diurnal variations for M_2 and K_2 terms as well as for diurnal S_1 term. The presence of K_2 term is probably consequence of GPS orbits modelling. S_1 wave with exactly 24 h period is associated with complexity of station and environment phenomena having daily variability. Variations with M_2 period are related to unmodelled tidal effects. More details concerning the sub-daily variations can be found in (Hefty et al., 2004).

CAME   **TUBO**

Figure 2. Example of sub-daily variations: coordinates of station CAME and TUBO during one
week (north-south, east-west and up component)

3. Regional daily ionosphere models

The routine processing procedure at LAC SUT is followed by computation of regional
ionosphere model covering the latitude belt from 30 to 73 degrees. Total electron content may be
written as (Hugentobler et al., 2001)

$$E(\beta,v) = \sum_{n=0}^{n_{max}} \sum_{m=0}^{n} \widetilde{P}_{nm}(\sin\beta)(a_{nm}\cos mv + b_{nm}\sin mv) \qquad (1)$$

where n_{max} is maximum degree of spherical harmonic expansion, $\widetilde{P}_{nm}$ are normalized associated
Legendre functions of degree n a and order m of argument $\sin\beta$. The parameters estimated from
GPS observations are the coefficients a_{nm} a b_{nm} included in the ionosphere model (1). The
optimum value for degree suitable for regional ionosphere model computed at LAC SUT was

found as $n_{max} = 5$. In the estimation procedure all coordinate and troposphere parameters are fixed from weekly solution.
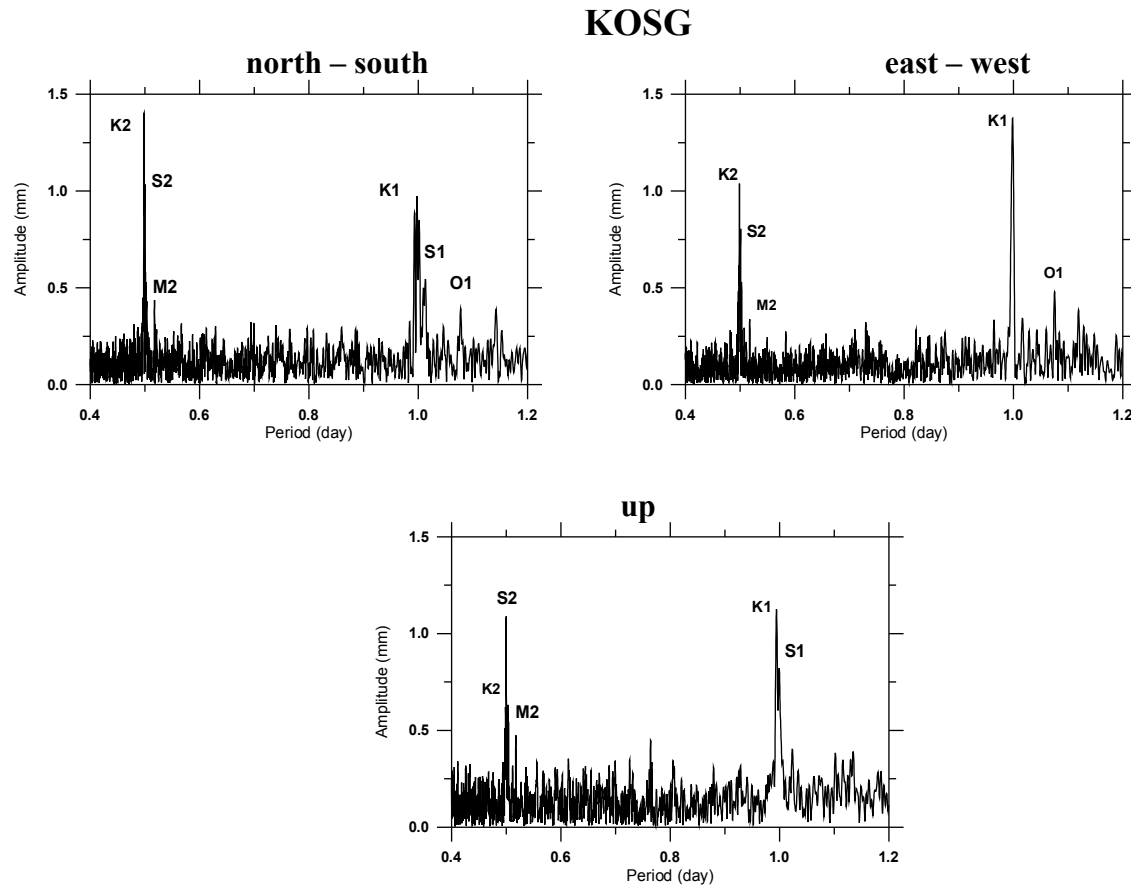
Figure 3. Example of short-term coordinate variations: amplitude spectra for station KOSG
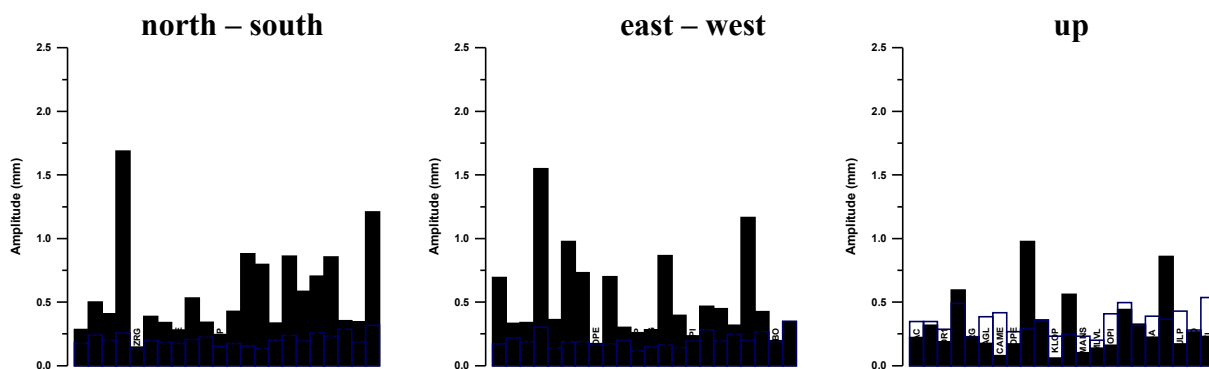
Figure 4. Amplitudes of horizontal and height variations with M_2 period at EPN sites analyzed at LAC SUT. The horizontal lines in bottom part of bars indicate one-sigma level of amplitude estimates.
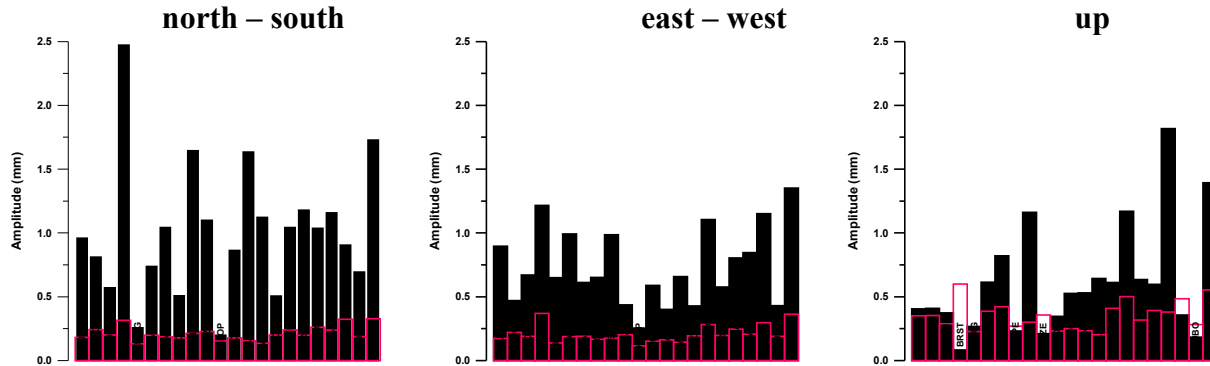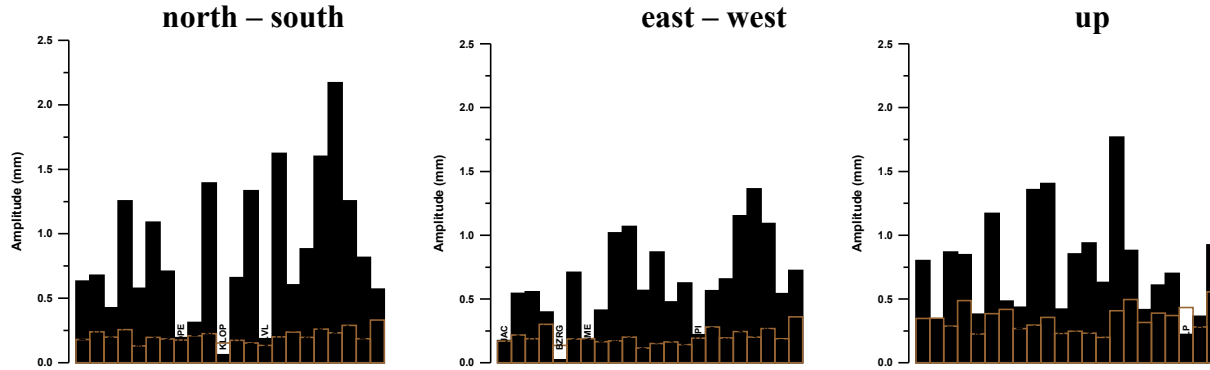
Figure 5 Amplitudes of horizontal and height variations with S_1 period

Figure 6 Amplitudes of horizontal and height variations with K_2 period

In Fig. 7 we show an example of ionosphere evolution inferred from regional ionosphere model during 24 hours evaluated for 4-hour samples. Fig. 8 shows isolines describing the actual state of TEC over Central Europe. Finally, in Fig. 9 the diurnal variations of TEC in two different epochs January 1 - 15, 2003 and August 1 - 15, 2004 are clearly demonstrated.
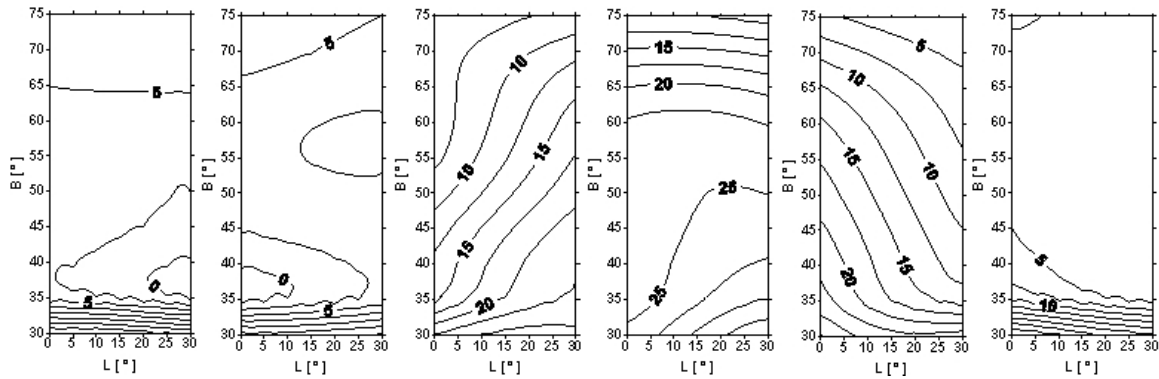
Figure 7 Time evolution of TEC over Europe on Dec. 1, 2003 inferred from regional ionosphere model for 0, 4, 8, 12, 16, and 20 h UT (the values are given in TECU)
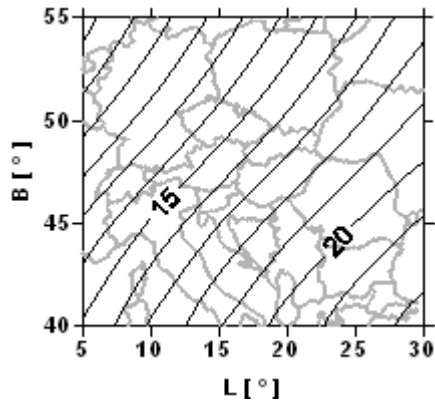
Figure 8. Ionosphere over Central Europe for Dec. 1, 2003 inferred from regional ionosphere model (the values are given in TECU).
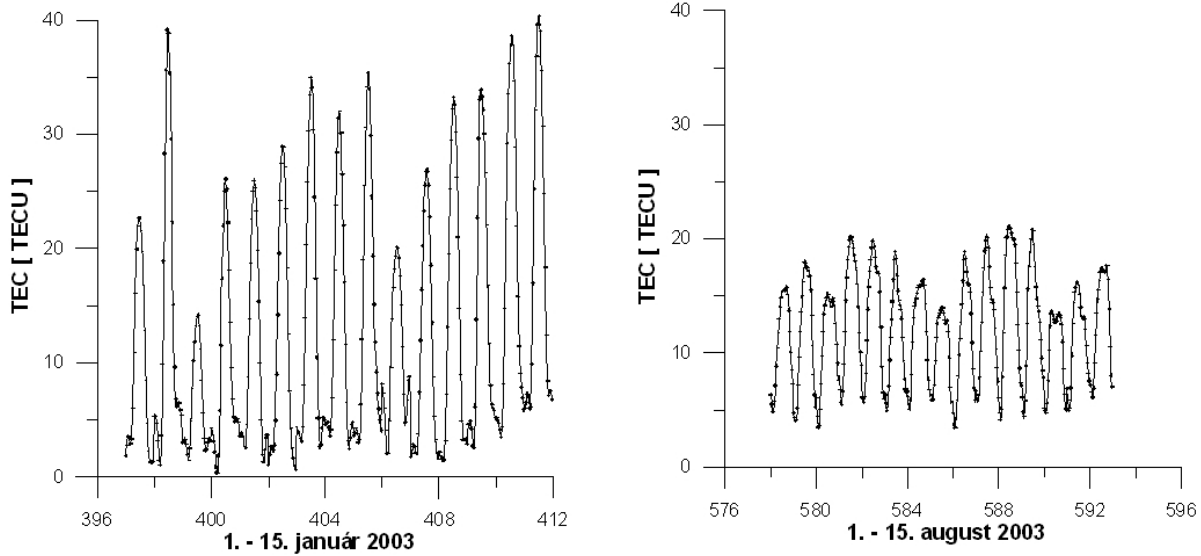
Figure 9. Diurnal variations of TEC in two different epochs: January 1 - 15, 2003 and August 1 - 15, 2003.

4. Troposphere parameters determined at LAC SUT

4.1 Modelling of troposphere water vapour content

Zenith wet delay T_w can be determined from zenith total delay (ZTD) resulting from routine processing at LAC SUT by subtracting the dry zenith delay

$$T_d = \frac{2277 \cdot p}{1 - 0.00266 \cdot \cos(2\varphi) - 0.00028 \cdot H} \qquad (2)$$

where φ is geographic latitude, H [km] is station height and p [hPa] is atmospheric pressure. Instantaneous value of integrated water vapour over the is proportional to T_w

$$IWV = \kappa \cdot T_w \qquad (3)$$

where $\kappa \cdot$ is coefficient defined in (Bevis et al., 1992). The precipitable water vapour is then obtained as

$$PWV = \frac{IWV}{\rho} \qquad (4)$$

with water specific density ρ in the denominator. Fig. 10 shows typical pattern of station *ZTD* and *PWV* with dominating seasonal variation. The general shape of variations determined at TUBO during 1,25 year span is clearly observable also at other GPS stations.

Availability of atmospheric pressure information at individual network stations allows forming map with PWV isolines over the region of Central Europe. Fig. 11 shows regional models in 4-hour steps based on data from seven EPN stations. Comparison of GPS derived PWV and radiosonde values at GANP EPN station is in Fig. 12. The consistency of both values is at very high level with correlation coefficient 0.96. It is worth to mention that GPS station GANP is situated in the same site where the radiosondes are launched.
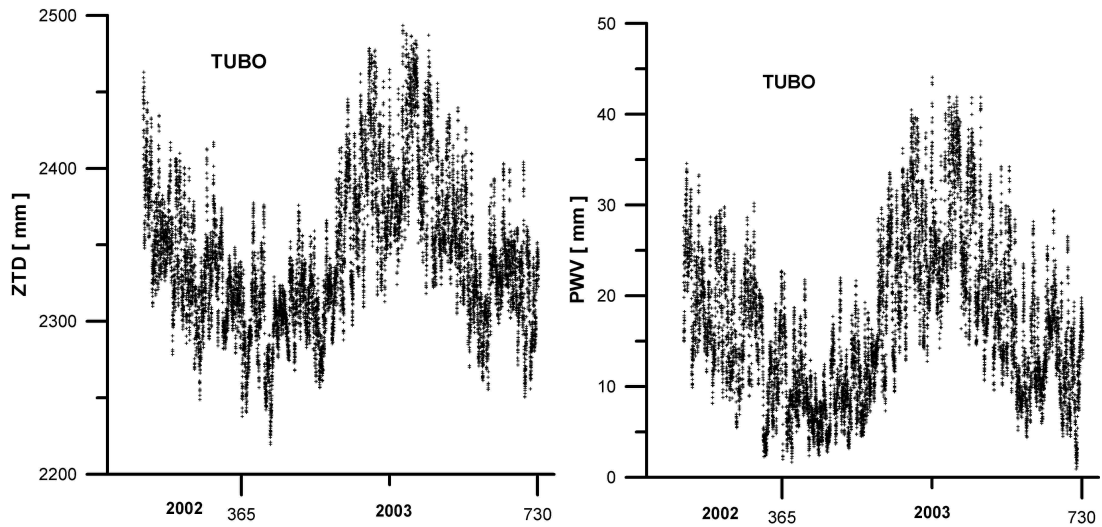

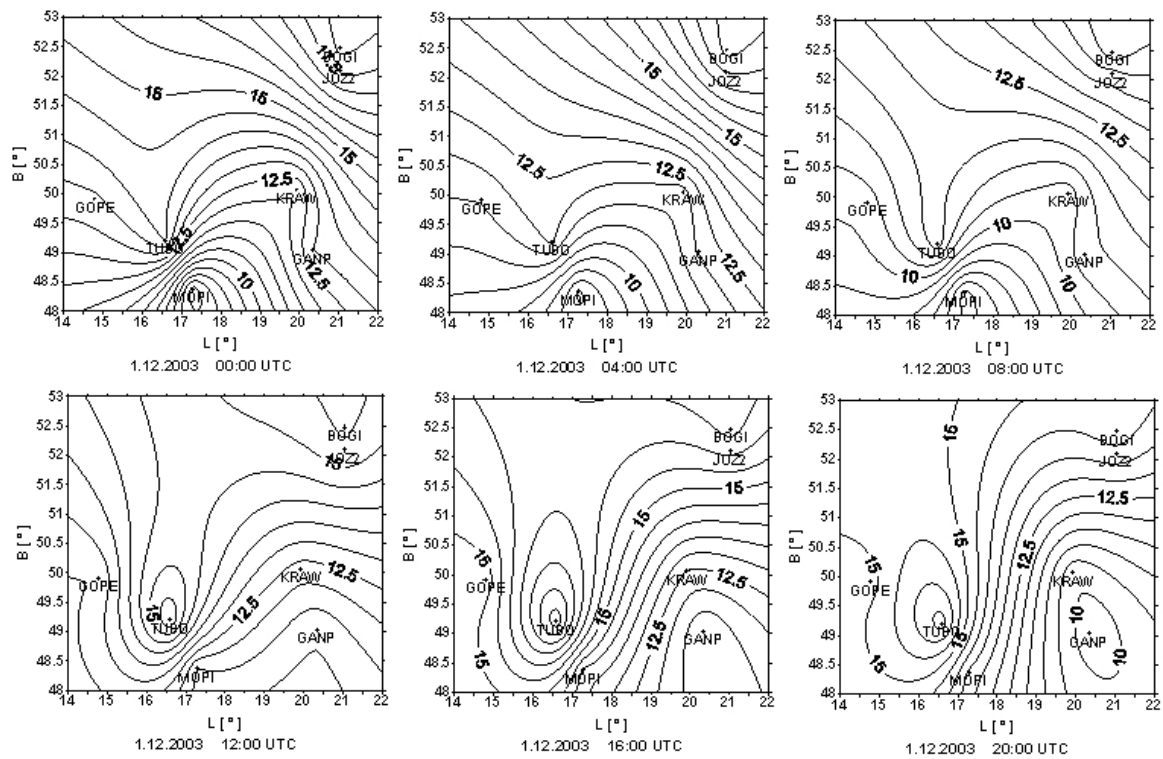Figure 10. ZTD and PWV variations at station TUBO

Figure 11. PWV actual status in Central Europe visualised at 4-hour time step
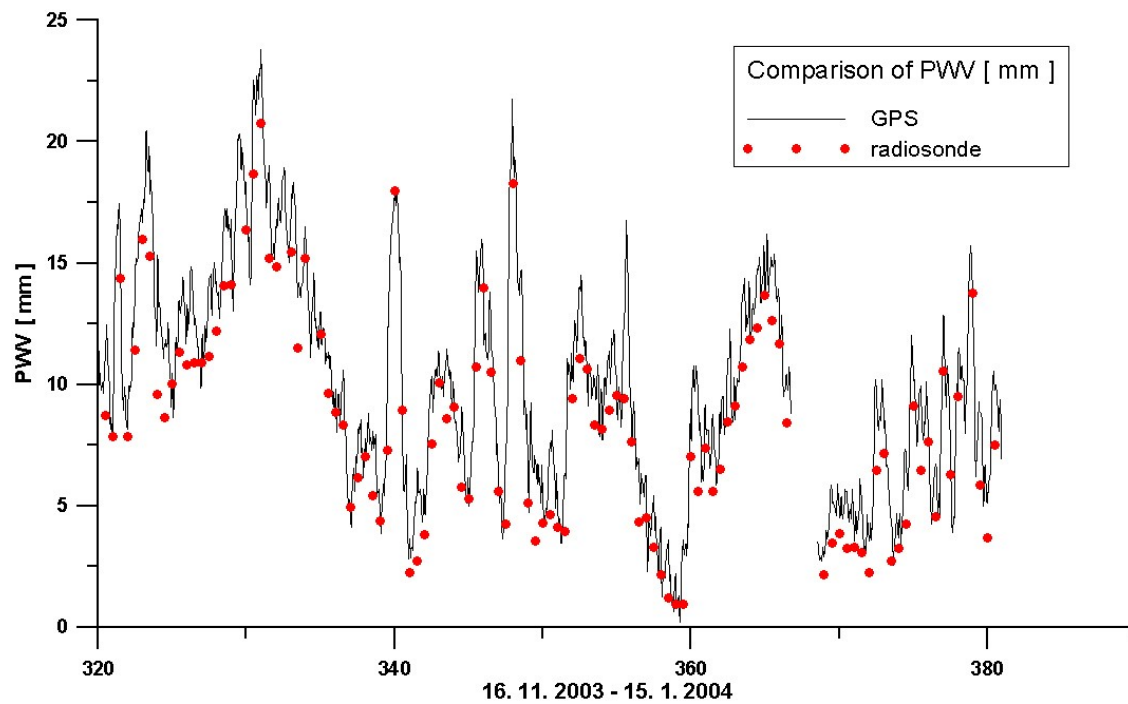
4.2 Modelling of horizontal troposphere gradients

Routine processing of EPN is assuming horizontally isotropic atmosphere. The anisotropy of actual troposphere can be modelled by estimation of troposphere horizontal gradients. Azimuthal asymmetry of tropospheric zenith delay can be evaluated as

$$T_a(z) = f(z) \cdot T(z = 0°) + \delta T_n(t) \cdot \frac{\partial f(z)}{\partial z} \cdot \cos A + \delta T_e(t) \cdot \frac{\partial f(z)}{\partial z} \cdot \sin A \qquad (5)$$

where δT_n and δT_e are horizontal troposphere gradients in north-south and east-west directions, A is azimuth of observed satellite and $f(z)$ is mapping function. Horizontal gradients are estimated at LAC SUT in two modes – for 24-hour observing intervals and with sub-daily resolution for 6-hour intervals. The behavior of daily estimates is shown in Fig. 13 where series of half-year series of δT_n and δT_e at BOR1 station are plotted. Sub-daily variations of both δT_n and δT_e components are clearly visible from 6-hour estimates. We are demonstrating this situation for ZIMM station as an example. For 10 days plotted in Fig. 14 diurnal variability with changing amplitude is clearly visible.
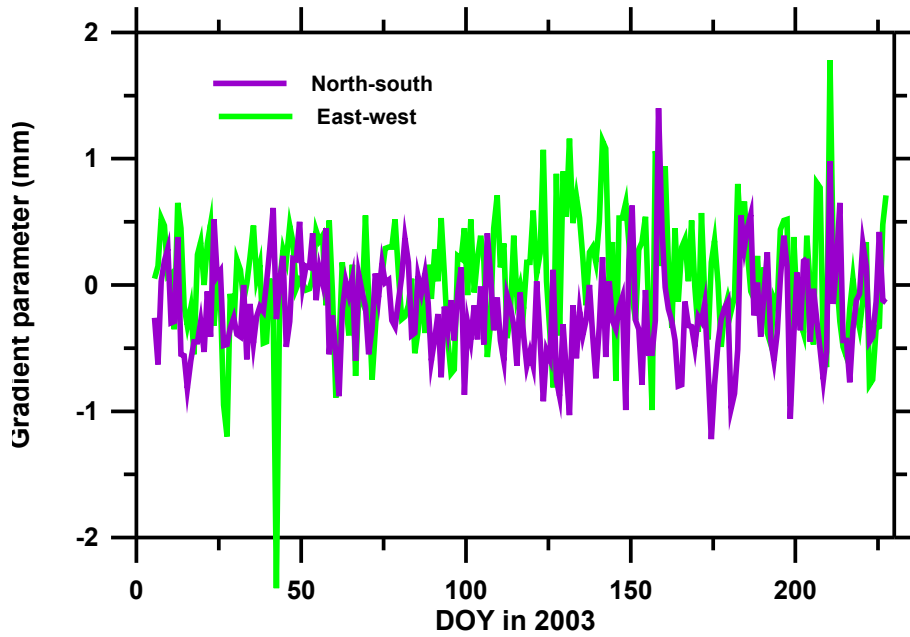

Figure 13. Daily estimates of horizontal troposphere gradients at station BOR1
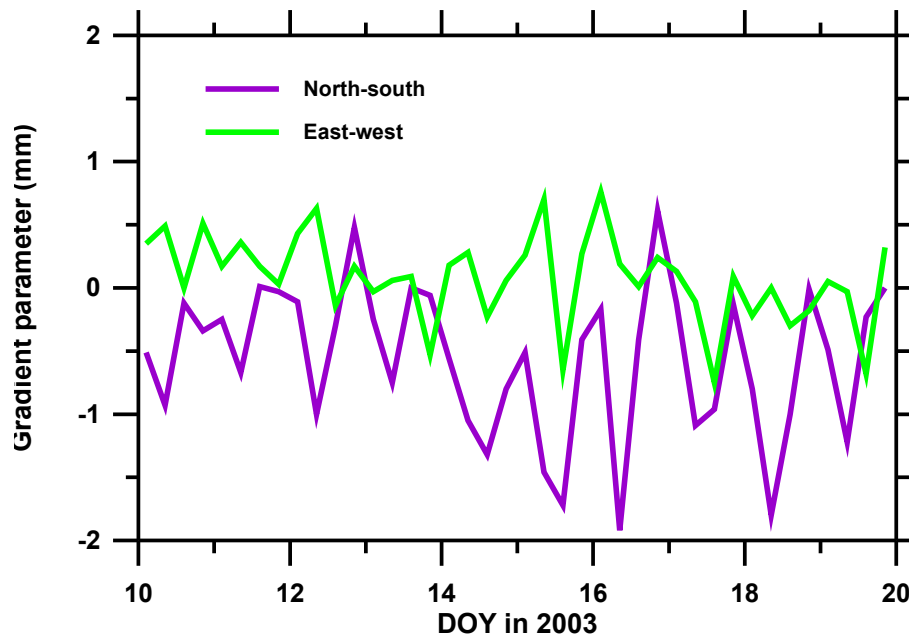
Figure 14. Subdaily 6-hour estimates of horizontal troposphere gradients at station ZIMM

5. Conclusions

Routine processing of subnetwork of EPN analysed at LAC SUT in Bratislava is enlarged by additional analyses resulting to more detailed time resolution and to ionosphere and troposphere regional models. All information obtained enable deeper and more sophisticated insight into station behaviour and to local phenomena influencing the GPS positioning. All the monitored phenomena – coordinate variations, ionosphere variations, troposphere gradients and PWV values exhibit diurnal variations. Further study of mutual relations among the observed phenomena is necessary.

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