ALTERNATIVE PRODUCTS OF EPN ANALYSIS AT LAC SUT IN BRATISLAVA

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Introduction

- LAC SUT: Department of Theoretical Geodesy, Faculty of Civil Engineering, Slovak University of Technology in Bratislava (SUT)
- Main research activities of the department: local and regional geodynamics, geodetic GPS applications, geoid determination, geographical information systems
- Participation of SUT in EPN: Operation of GPS permanent station Modra-Piesok (MOPI) since 1996, EPN LAC from September 2002

LAC SUT : main features

- First weekly solution included into EPN combination: week 1182
- Analysed network in September 2002: 25 stations distributed over the whole European continent, status in June 2004: 34 stations
- Main purpose of the network geometry: focused on Central Europe, regular station distribution all over the continent enabling geokinematic monitoring and geodynamics investigations
- Analysing tools: BERNESE GPS software, version 4.2, Linux operating system, BPE + own scripts
- Standard processing following the guidelines for EPN analysis centres: daily solutions, weekly combination, troposphere zenith delays with weekly coordinates fixed.

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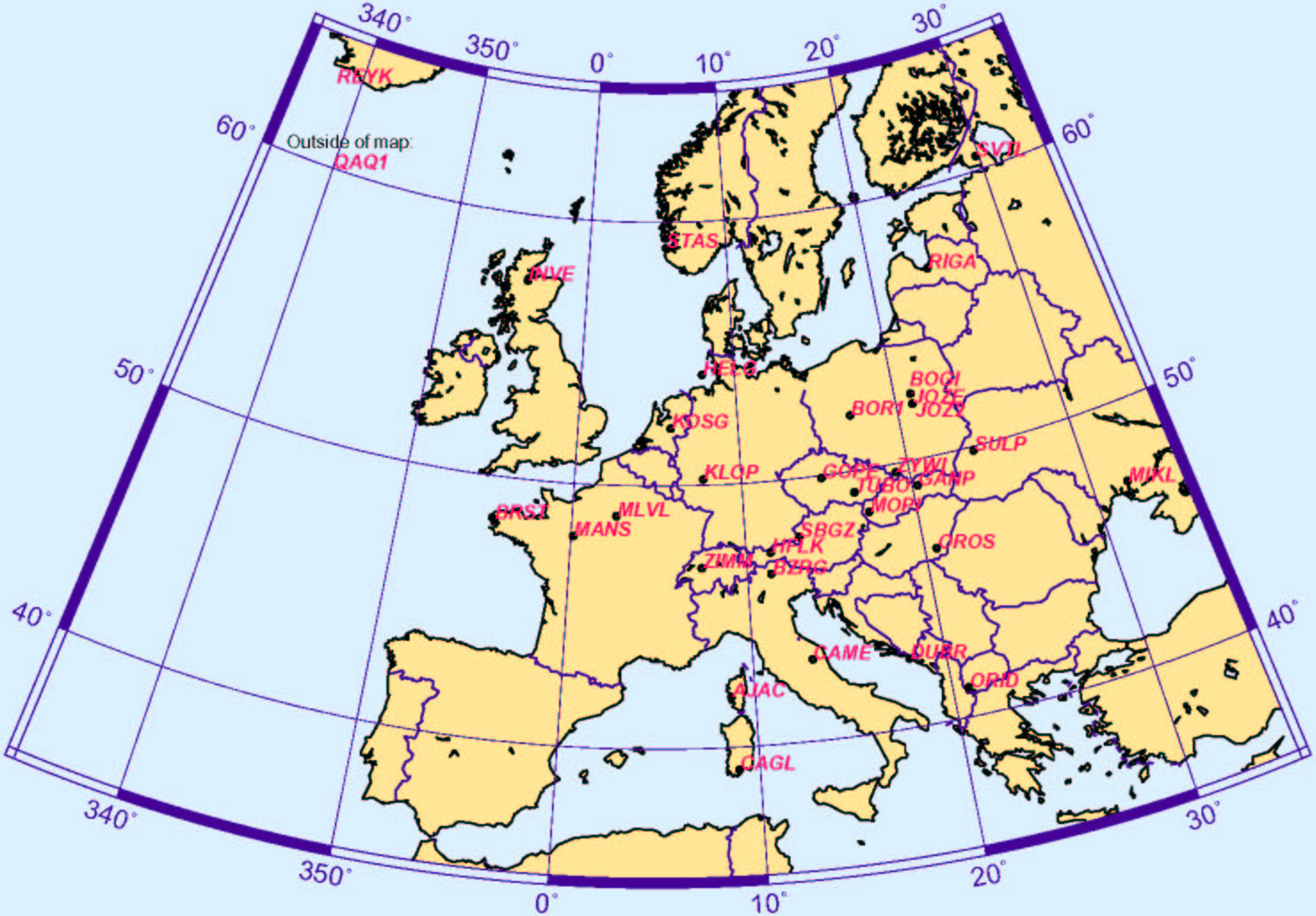
EPN subnetwork processed at SUT Bratislava

(status June 2004)



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Basic information about regular network processing at LAC SUT

- Baselines in range from 40 to 1550 km, average baseline is 500 km. All the baselines are solved without significant problems
- Reference site ZIMM: very stable without any interruptions and without local variations or jumps up to week 1230. Reference site from 1231: BOR1
- Problematic sites with frequent interruptions or breaking of observations: HFLK, SVTL, ORID, DUBR, BRST, REYK, QAQ1
- Sites with larger scatter and specific behaviour: QAQ1, REYK, CAME, DUBR, ORID, MIKL, MOPI

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Additional and alternative solutions at LAC SUT

- Network processing in 4-hour separate intervals - "sub-daily" resolution: only coordinate estimations, ambiguities and troposphere zenith delays taken from 24-hour solutions.
- Regional ionosphere models from 24 h intervals, coordinates and troposphere fixed from weekly and daily solutions.
- Local models of PWV using estimated zenith delays and surface meteo observations.
- Estimation of station troposphere gradients simultaneously with troposphere zenith delays, coordinates are fixed from weekly solutions.

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Time series from sub-daily network solutions in 4-hour observing intervals

- **Main goals: daily coordinate variations, detailed investigation of jumps in the coordinate time series, tidal phenomena in station positions.**
- **Two approaches:**
  - Spectral analysis of individual station series (*n*, *e*, and *up* components), problems with observation gaps and series discontinuities.
  - Least squares estimates of amplitudes and phases of harmonics with known frequencies.
- **Data processing: high-frequency filtration, jumps identification and exclusion, outliers detection, interpolation of sub-daily coordinates, spectral analysis and LS estimates for dominating terms.**

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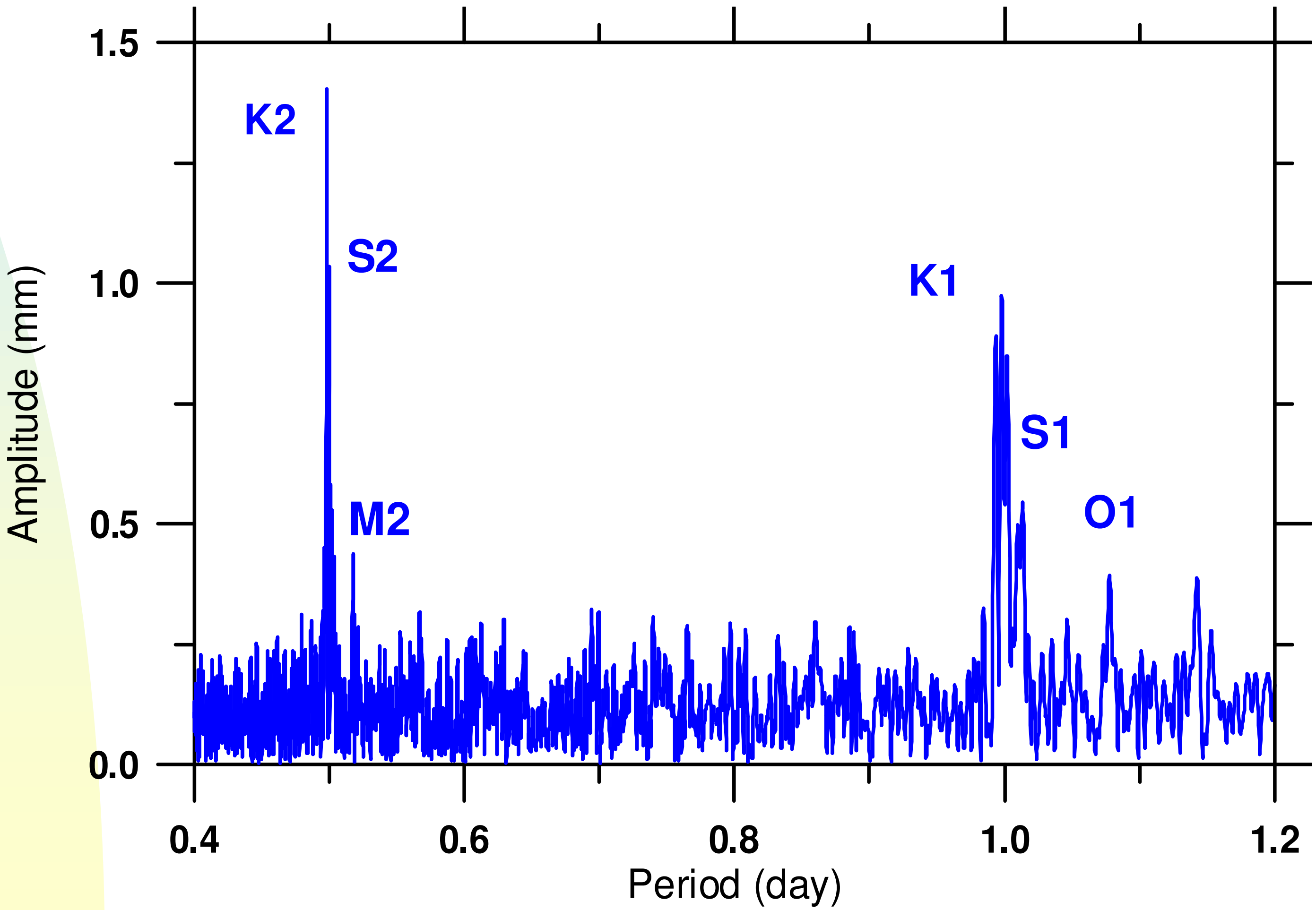
Example of variations in the band 0.4 - 1.2 day
Station KOSG - *n* component

- data from one-year series
- ocean loading effects included in processing
- all the effects are relative to reference site ZIMM



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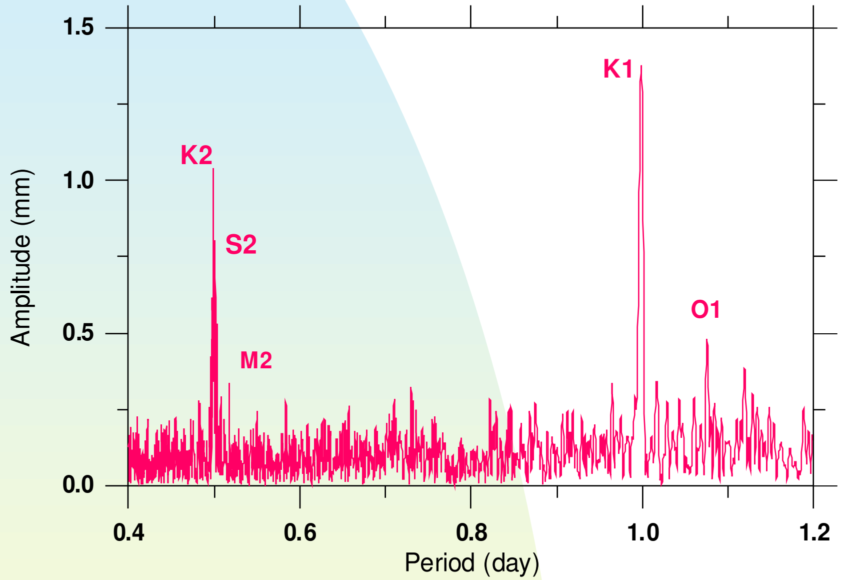
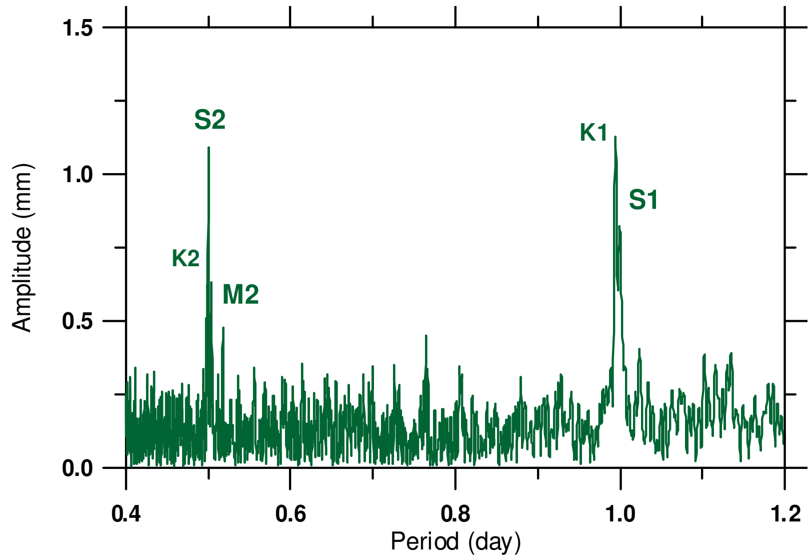
Example of variations in the band 0.4 - 1.2 day
Station KOSG - *e* and *up* components

Direction E-W



Ellipsoidal height



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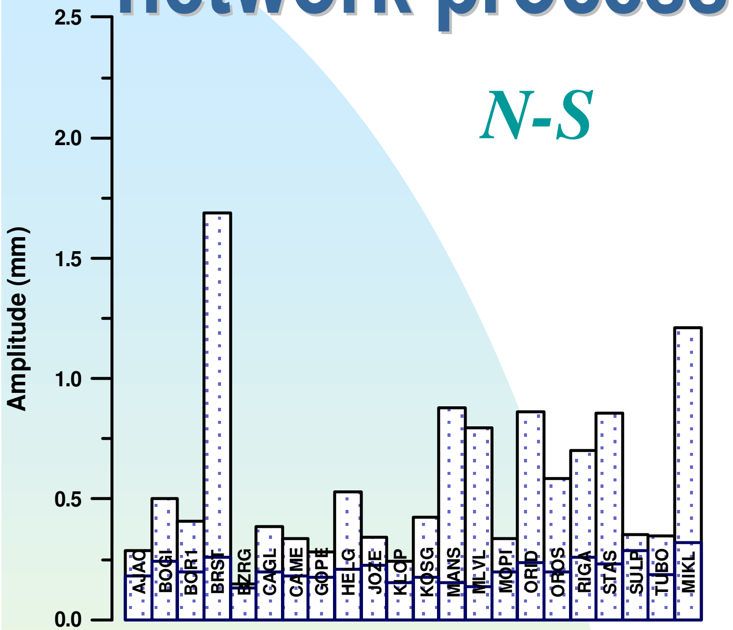
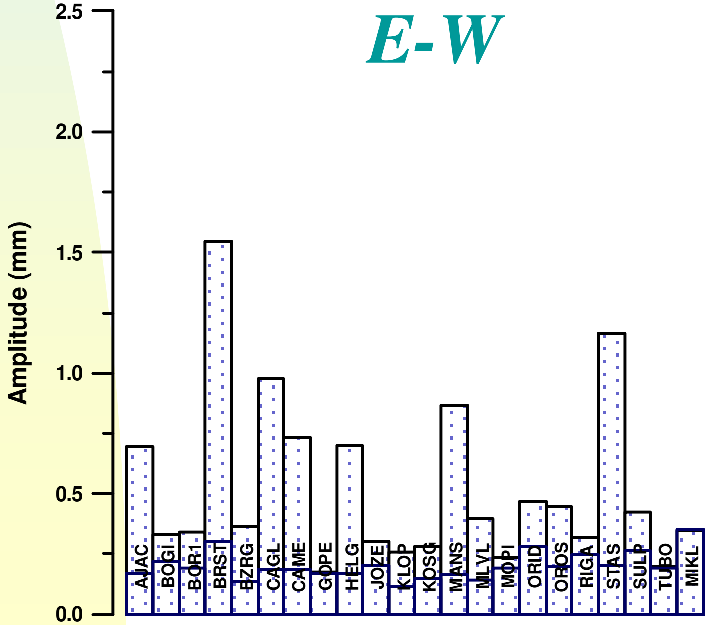
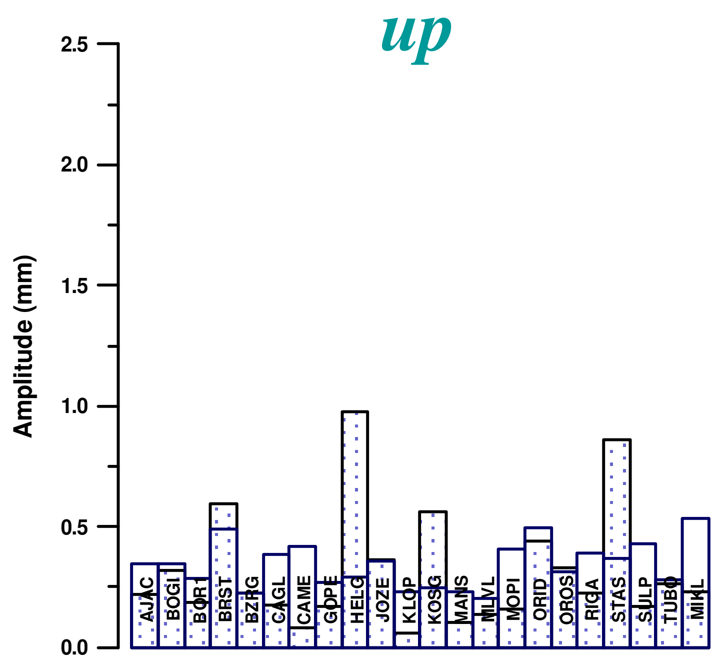
Amplitudes of horizontal and height variations with period M2 (ocean loading effect was included in network processing)







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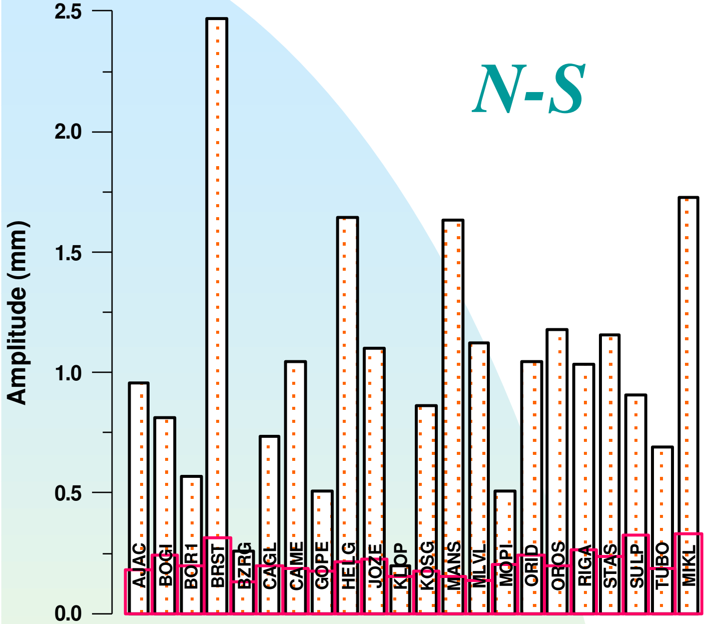
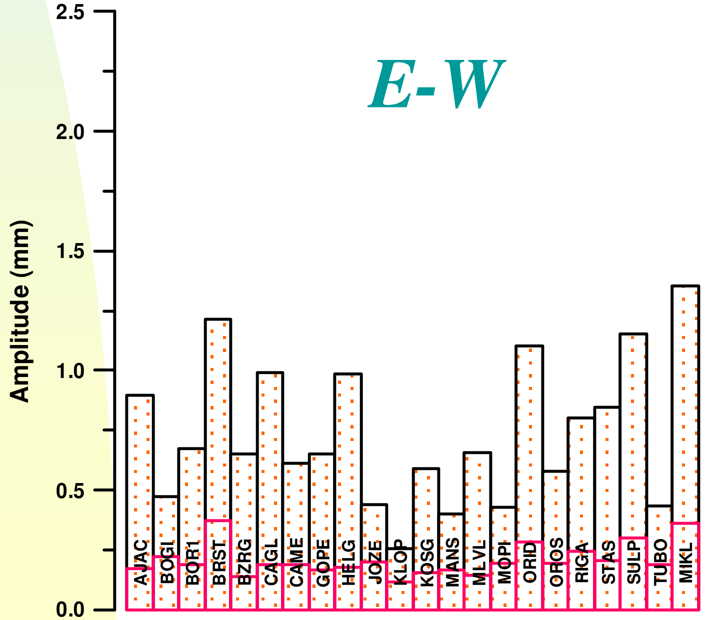
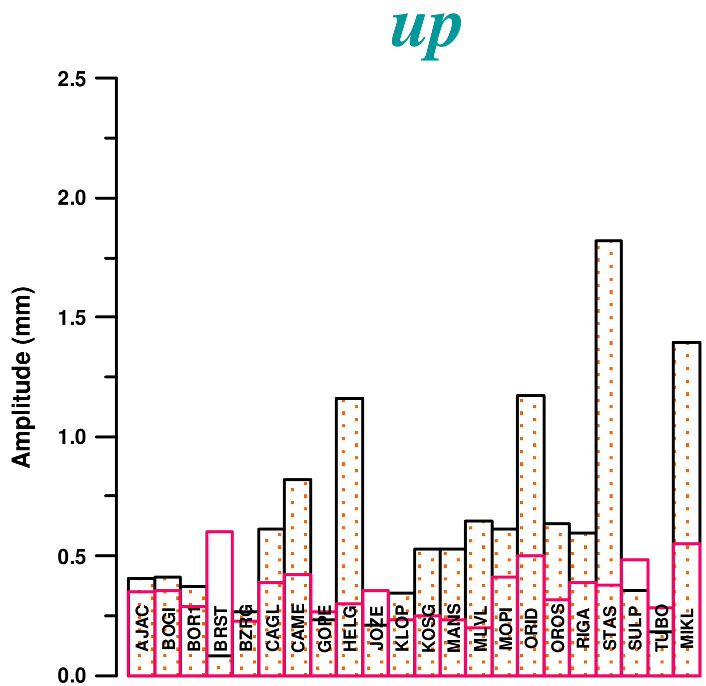
Amplitudes of horizontal and height variations with period S1 (24-hour variation)







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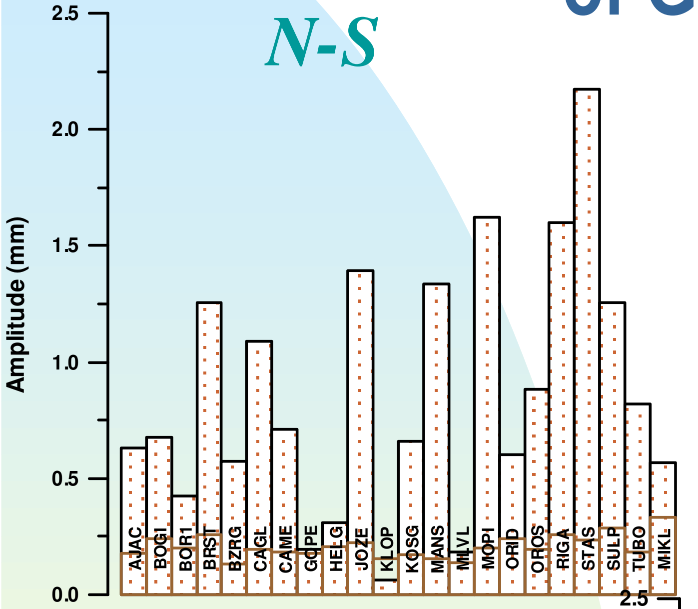
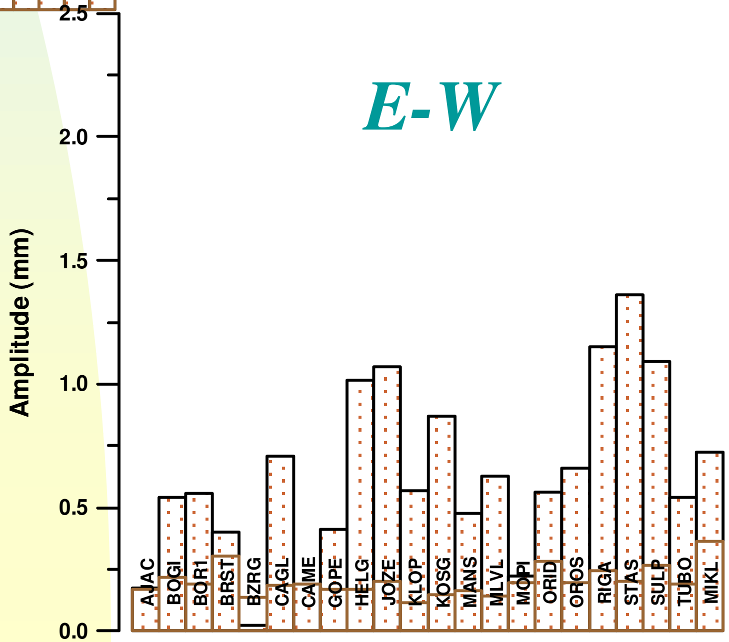
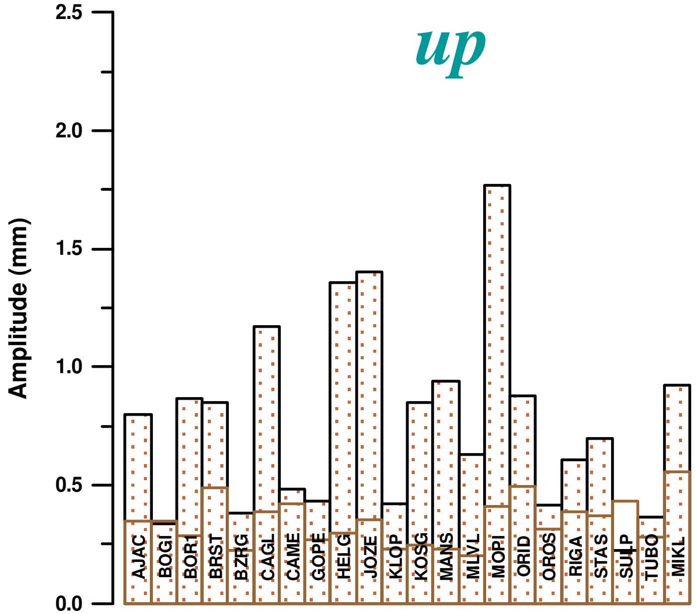
Amplitudes of horizontal and height variations with period K2

(Probably residual effect of GPS orbit modelling. Orbiting period of GPS satellite = period of K2)







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Conclusions related to analysis of sub-daily station coordinate variations

- In all the analysed series dominate in the high frequency spectra the terms with diurnal and semidiurnal frequencies M2, K2, S2, O1, P1, K1, S1
- The observed amplitudes of horizontal *n* and *e* components are in general at the same level (or larger) than of the *up* component
- Observed M2 and O1 waves could be associated with deficiencies in solid Earth, and mainly of ocean loading tidal modelling
- The K2 and K1 residual effects in the series are probably associated with modelling of GPS satellite orbits
- Variations with S2 and S1 frequencies reflect mainly the thermal and atmospheric effects at the observing sites

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Regional daily ionosphere models

- Latitude band covered: from 30 to 75 degrees
- Spherical harmonics representations with degree and order 5 (36 terms).
- One model is produced for 24-hour interval

```
REGIONAL ION. MODEL FOR EUROPE, DAY 213                                  03-SEP-03 15:42
--------------------------------------------------------------------------------
MODEL NUMBER / STATION NAME                               : 2130-00
MODEL TYPE (1=LOCAL,2=GLOBAL,3=STATION)                   :    2
MAXIMUM DEGREE OF SPHERICAL HARMONICS                     :    5
MAXIMUM ORDER                                             :    5
DEVELOPMENT WITH RESPECT TO
  GEOGRAPHICAL (=1) OR GEOMAGNETIC (=2) FRAME             :    1
  MEAN (=1) OR TRUE (=2) POSITION OF THE SUN              :    1
MAPPING FUNCTION (0=NONE,1=1/COS)                         :    1
HEIGHT OF SINGLE LAYER AND ITS RMS ERROR (KM)             :  450.00     0.00
COORDINATES OF EARTH-CENTERED DIPOLE AXIS
  LATITUDE OF NORTH GEOMAGNETIC POLE (DEGREES)            :
  EAST LONGITUDE (DEGREES)                                :
PERIOD OF VALIDITY
  FROM EPOCH / REFERENCE EPOCH (Y,M,D,H,M,S)              : 2003 08 01 00 00 00
  TO EPOCH                                                : 2003 08 01 23 59 59
LATITUDE BAND COVERED
  MINIMUM LATITUDE (DEGREES)                              :   27.64
  MAXIMUM LATITUDE (DEGREES)                              :   76.49
ADDITIONAL INFORMATION
  NUMBER OF CONTRIBUTING STATIONS                         :   27
  NUMBER OF CONTRIBUTING SATELLITES                       :   28
  ELEVATION CUT-OFF ANGLE (DEGREES)                       :   10
  MAXIMUM TEC AND ITS RMS ERROR (TECU)                    :   26.16     0.38
COMMENT / WARNING                                         :
COEFFICIENTS
DEGREE  ORDER    VALUE (TECU)    RMS (TECU)
   0       0    -2224.27609339   438.7100
   1       0     2986.50480350   572.3647
   1       1    -1239.58235990    34.6537
   1      -1     -621.13017670    40.5342
   2       0    -2247.80372712   411.4012
   2       1     1572.30023638    43.4148
   2      -1      798.59563950    50.6915
   2       2     -102.72600247     4.8457
   2      -2      -49.10562126     4.7608
   3       0     1117.25503170   191.3618
   3       1    -1058.14035065    28.8427
   3      -1     -547.92648608    33.5830
   ...
```

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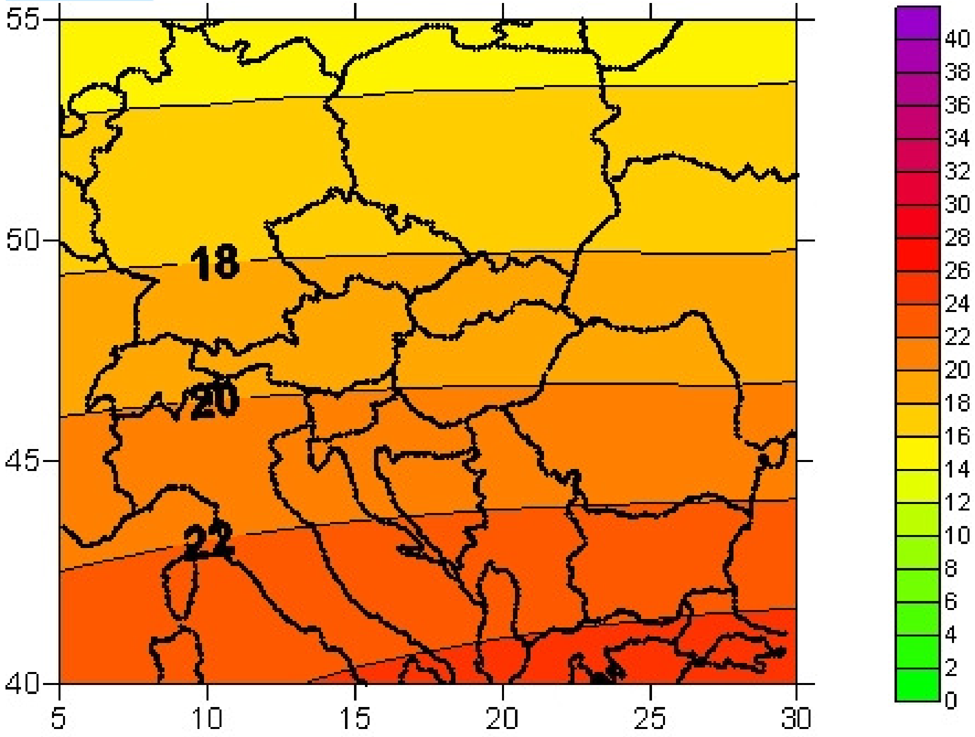
Regional ionosphere model

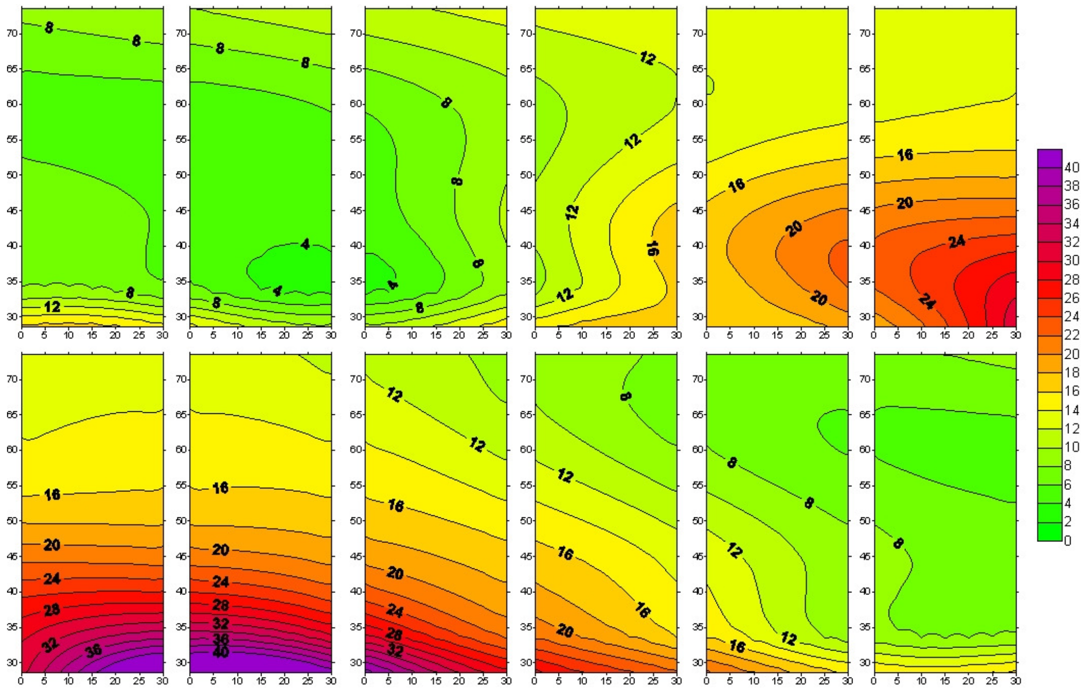


TEC (in TECU) over Central Europe

May 7, 10.00 UT

TEC evolution over Europe during 24 hours

May 7, 2004



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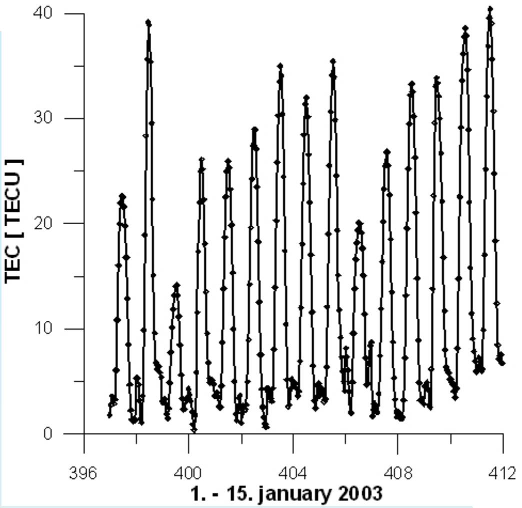
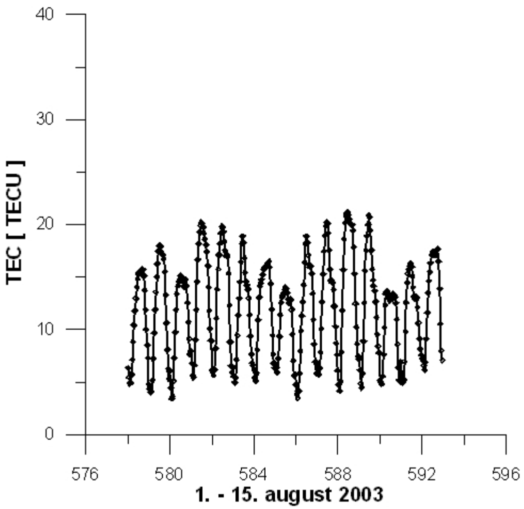
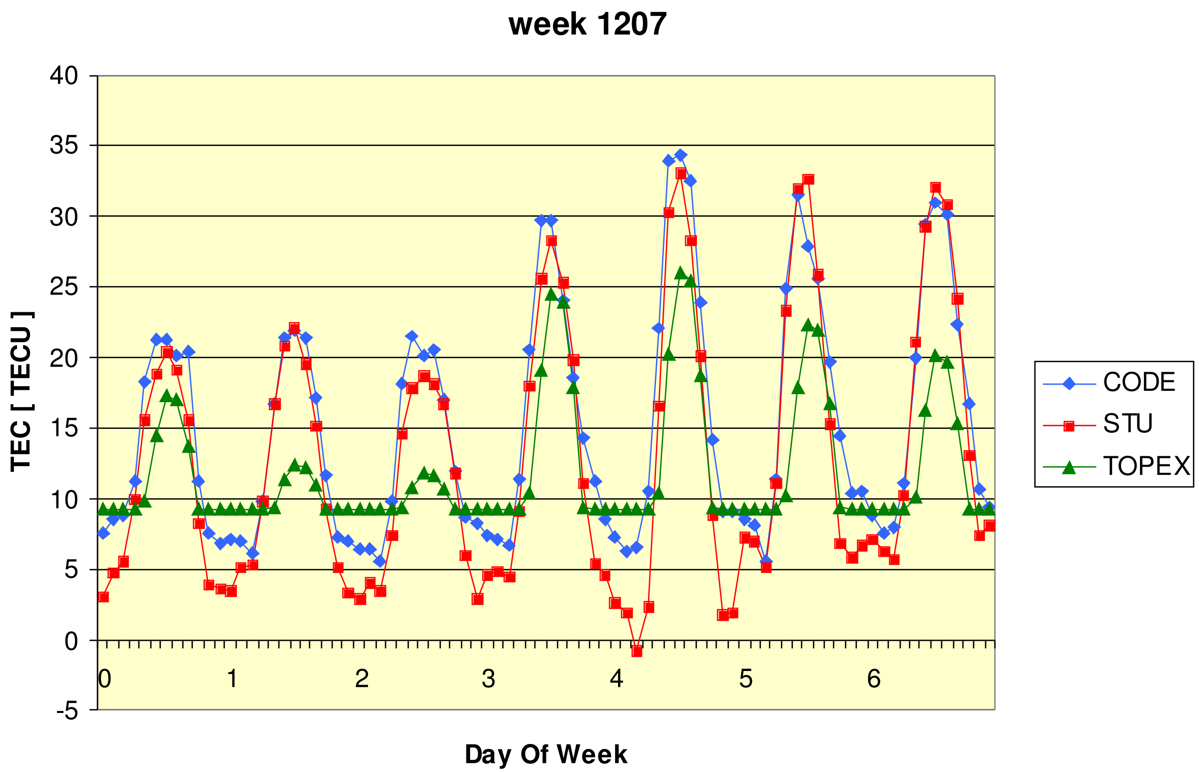
Regional ionosphere model





Comparison of CODE (global), SUT (regional) and TOPEX models

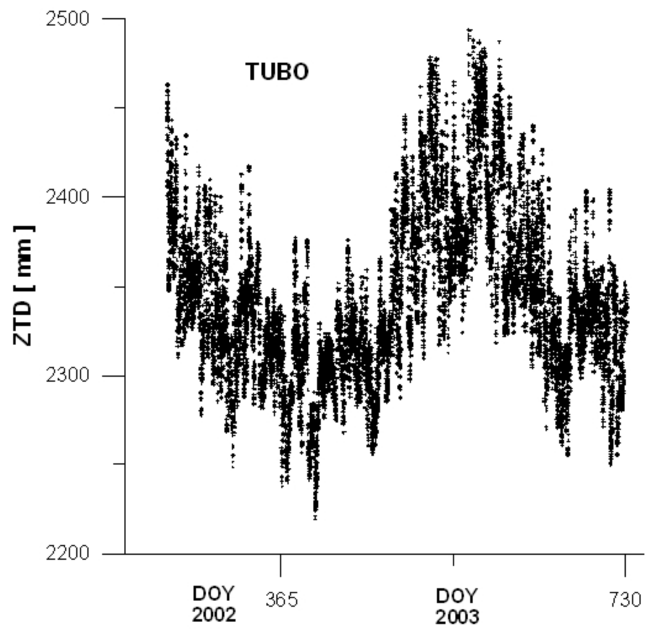
Daily TEC variations over MOPI in January and August 2003

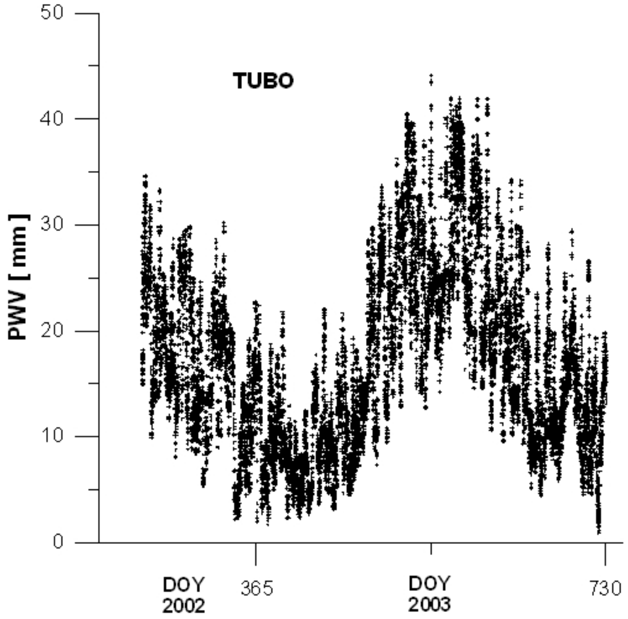


Regional precipitable water vapour models

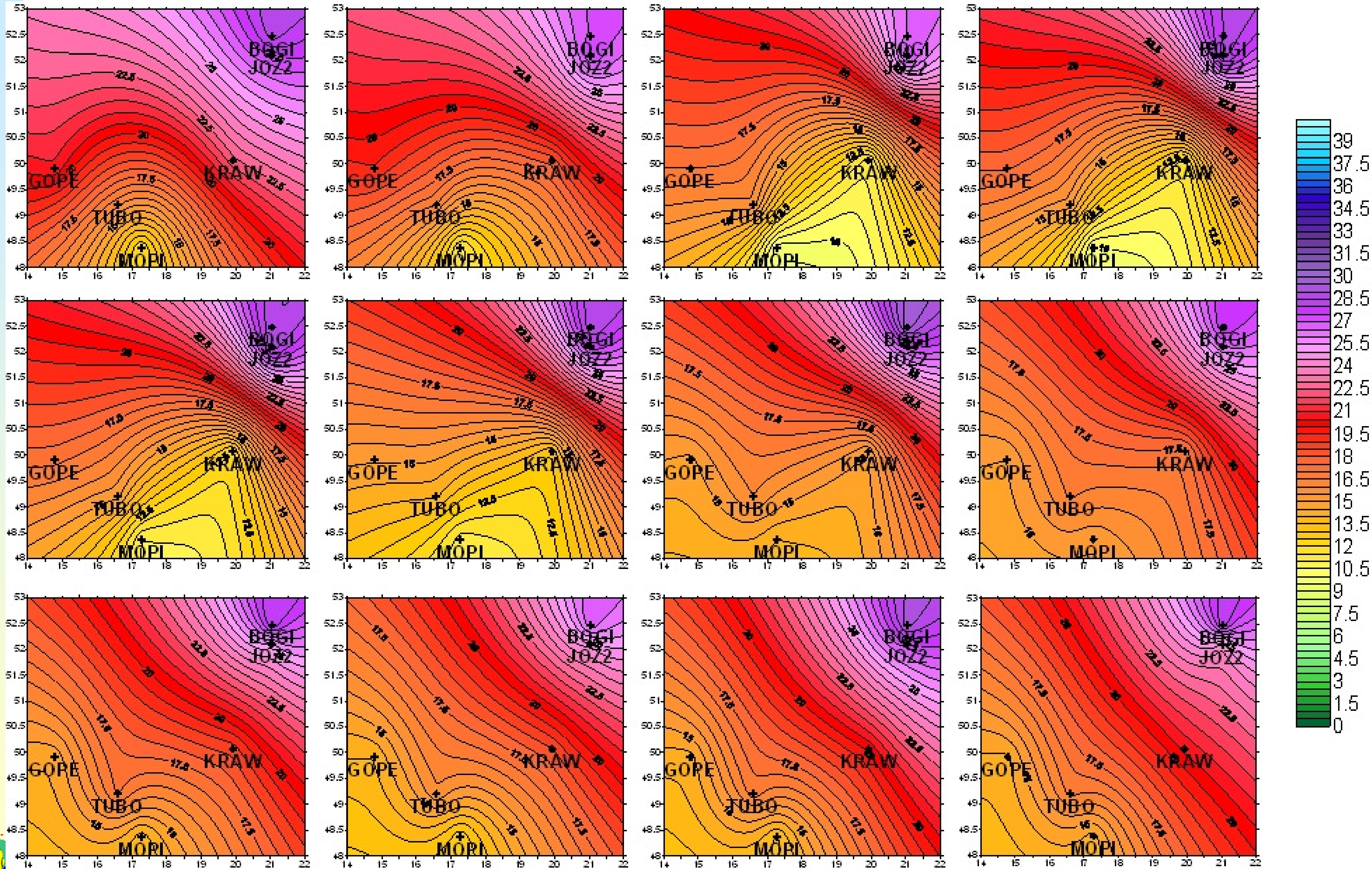
- **Stations in Central Europe equipped with meteo sensors (GOPE, TUBO, MOPI, KRAW, GANP, BOGI, JOZ2) are used to compute precipitable water vapour content (PWV)**
- **Estimated hourly zenith total delays (ZTD) estimated at SUT are reduced for modelled dry troposphere component based on surface atmospheric pressure and temperature**
- **Site values are interpolated to form regional PWV maps**

Annual variation of ZTD and PWV at TUBO station



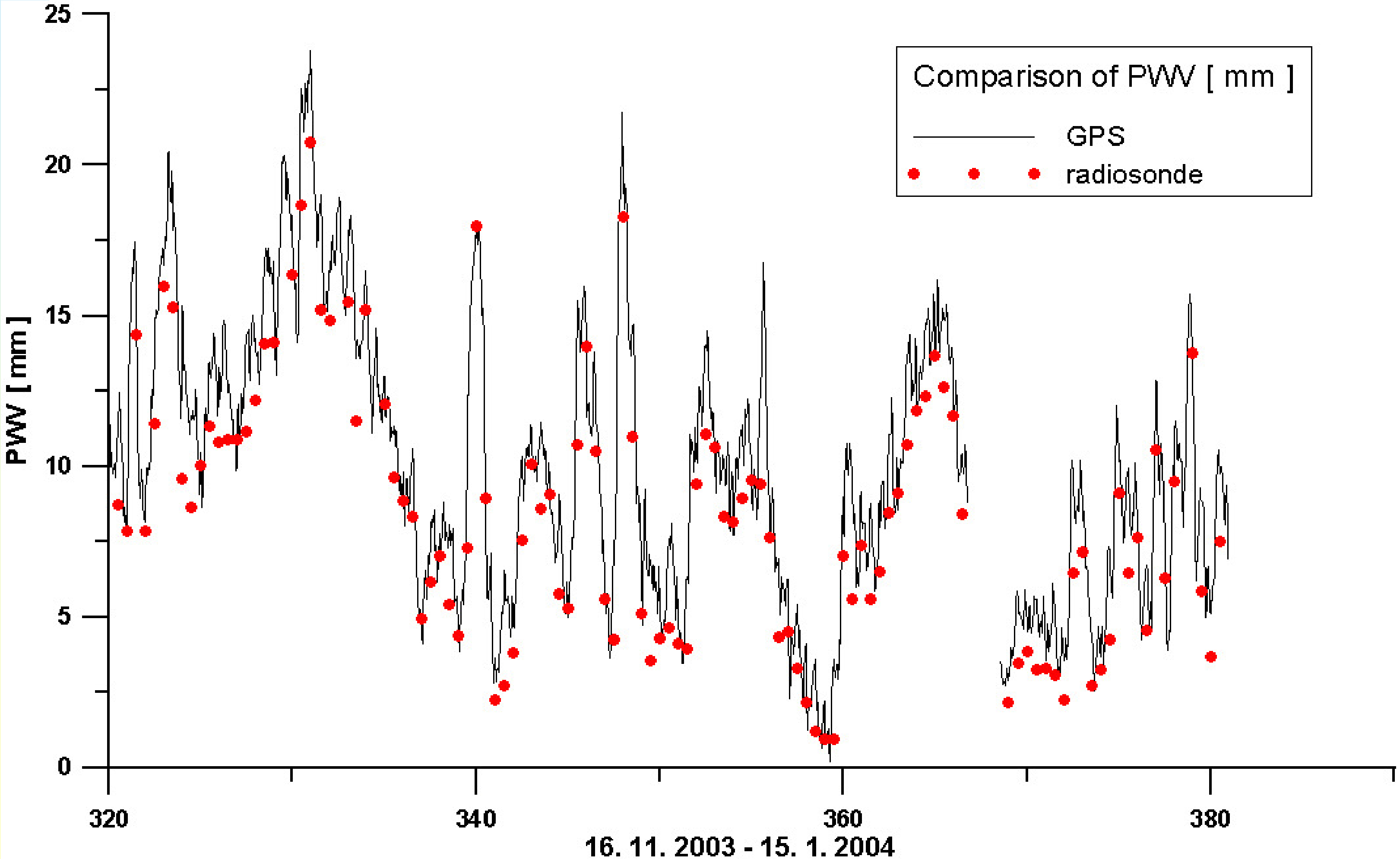


Regional precipitable water vapour models over Central Europe – daily variation



PWV [mm] - 7. 5. 2004 - 0, 2, 4, ... 22 hr UTC

Comparison of GPS derived PWV and radiosonde values at GANP EUREF station



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Estimation of troposphere gradients (azimuthal asymmetry in tropospheric delay)

Tropospheric zenith delay:

$$\Delta\rho(t) = \Delta\rho_{apriori} f(z) + \Delta\rho_h(t) f(z) + \Delta\rho(t)_n \frac{\partial f}{\partial z}\cos(A) + \Delta\rho(t)_e \frac{\partial f}{\partial z}\sin(A)$$

$f(z)$	mapping function
$\Delta\rho_h$	zenith delay parameter
$\Delta\rho_n$	gradient parameter in north-south direction
$\Delta\rho_e$	gradient parameter in east-west direction

- **Troposphere gradients are estimated for 24 and 6 hour intervals**
- **RMS of $\Delta\rho$ estimates are usually less than 0.3 mm**

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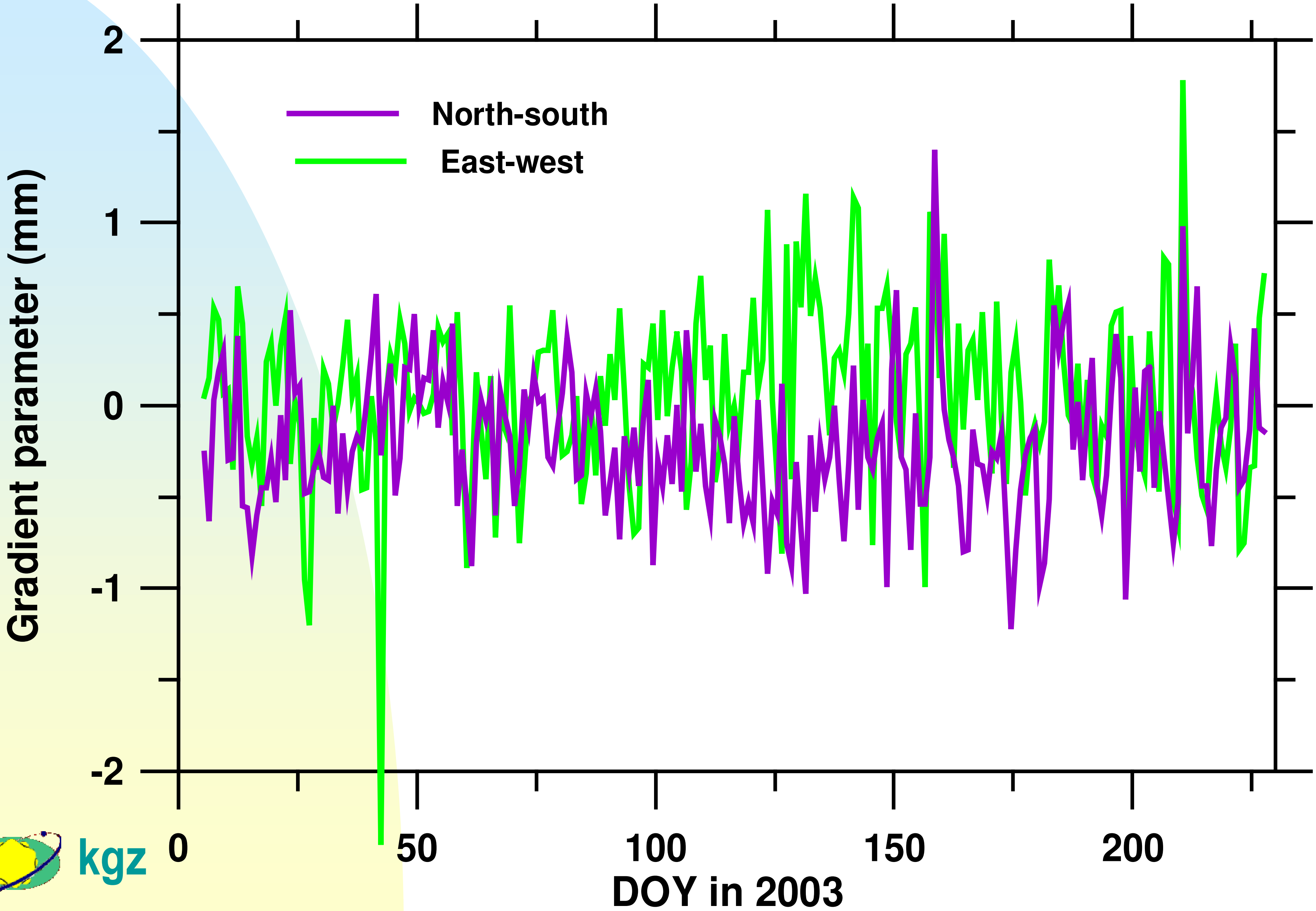
Example of troposphere gradient time series: station BOR1 , 24-hour intervals



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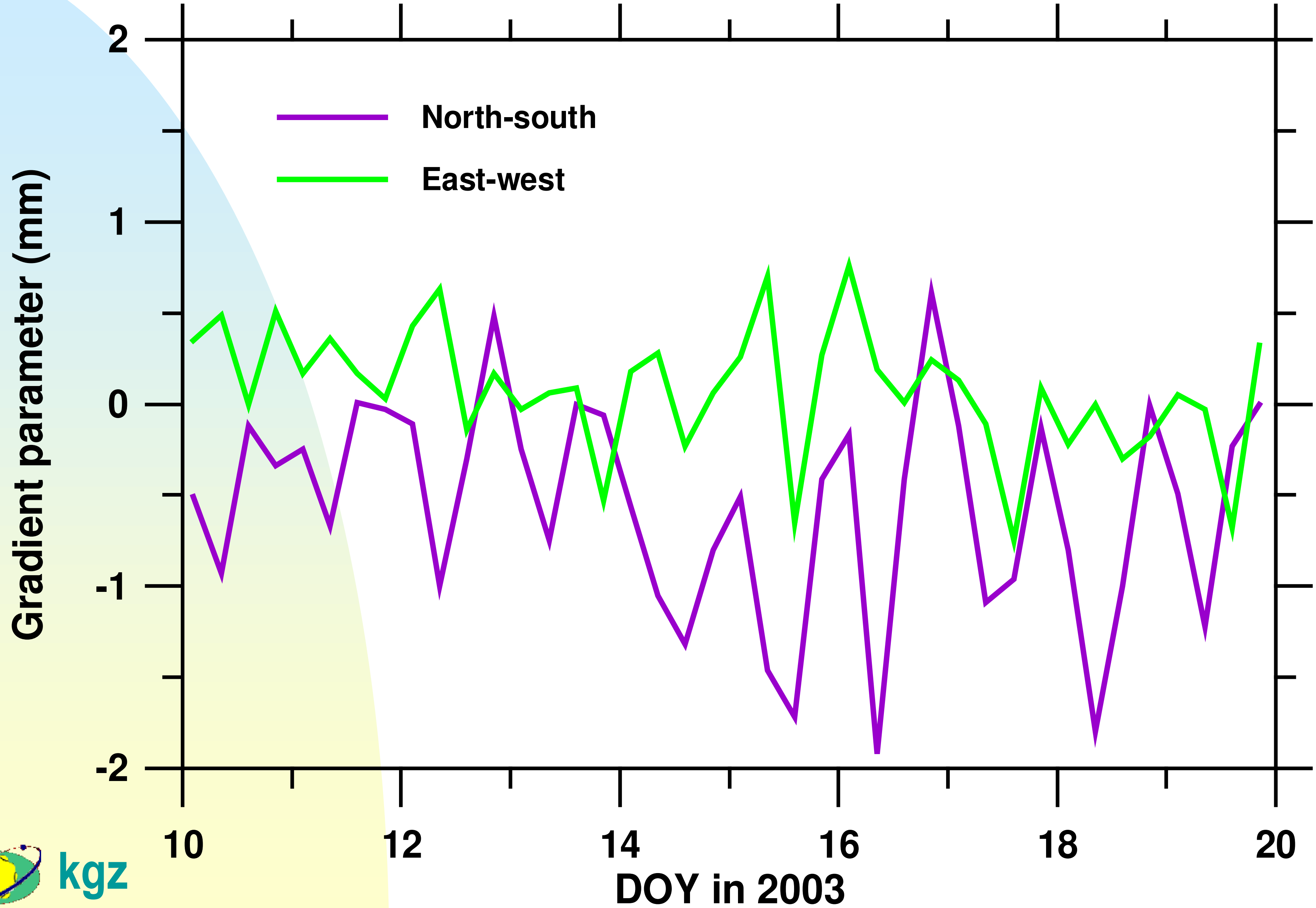
Example of troposphere gradient time series: station ZIMM , 6-hour intervals



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Conclusions related to ionosphere and troposphere issues

- Complex processing of permanent GPS network allows besides the daily and weekly coordinates to estimate set of additional parameters characterizing environment of the region
- For majority of monitored phenomena are characteristic diurnal and seasonal changes
- The separation of individual effects is not trivial and requires further investigations

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