SOME REMARKS ON GPS TROPOSPHERIC DELAY PRODUCTS AND THEIR USEFULNESS

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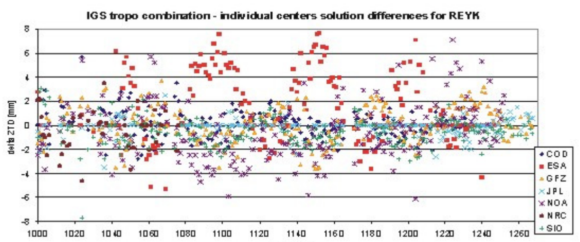
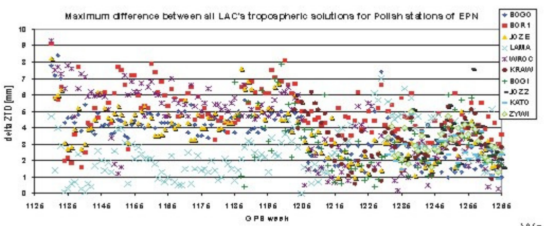
Abstract

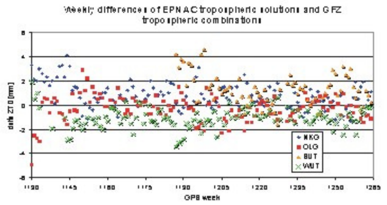
Our paper deals with some areas of our research in GPS meteorology.
We make many statistical quality analysis of the many standard tropospheric solutions and ZTD combined product (EPN and IGS). Factors considered as affecting tropospheric solution quality are network geometry (e.g. range), solution minutes (e.g. software), latitude (climate), height. This work can be useful not only for interested in combined product but also lead to improved processing strategy guidelines.
We report current works and experiences leading to start of NRT tropospheric service in WUT LAC. Finally we present some interesting ideas how to use tropospheric delay in meteorology and climatology (e. g. long IPW series for different climate conditions, IPW distribution maps, TZD in epoch campaigns, correlation of IPW series for different stations and other parameters, comparisons with radiosounding profiles, IPW derivation).

Zenith tropospheric delay from GPS network solution can be separated into hydrostatic part (it is a function of surface pressure) and 'wet' part which can be transformed into IPWV if we can calculate coefficient dependent upon mean temperature in troposphere. We used vertical profiles of temperature and humidity from three radiosounding points in Poland to calculate mean temperature linear regression model and transform different ZTD series to IPW.
Total Zenith Delay above all stations in the network became one of the standard products of IGS
(1998 by GFZ) and EPN (2001 by BKG and GFZ). It is created as a combination of individual AC solutions.
Below you can see for REYK average (weekly) AC solutions IGS combination differences, and next the same quantities for JOZE in EPN solutions.

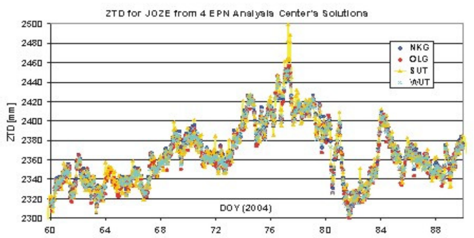


Closer look at some statistical aspects of separate Analysis Centers solutions and combinations for various stations can disclose many interesting regularities.

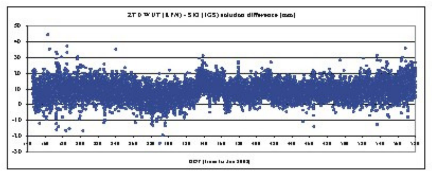


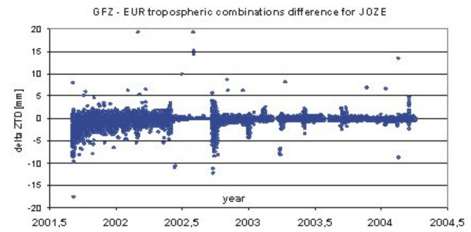


Below you can see ZTD values for JOZE calculated by 4 different stations in the frame of EPN, SUT solutions show some discrepancies.

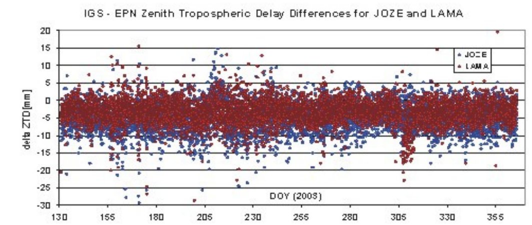


To chose optimal solution of given network (even in case of post processed solutions of EUREF Analysis Centre) still presents some problem. Comparing various solutions we get on the average 1-2 mm IPW differences and about 1 mm difference RMS.

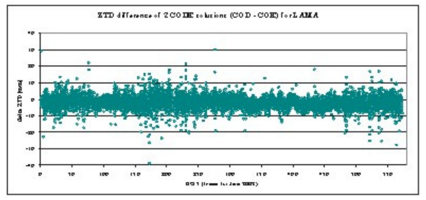




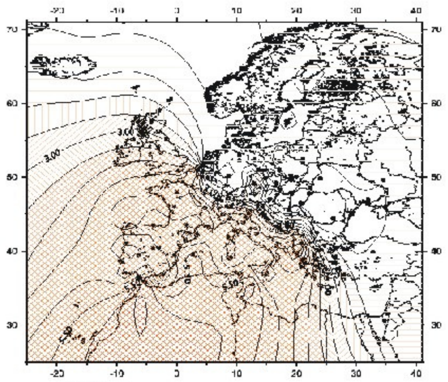
Below difference of global IGS and European combination (ZPD – EUR) for JOZE and LAMA; for both stations we get negative bias of -4 mm and difference RMS of about 3 mm during 2003



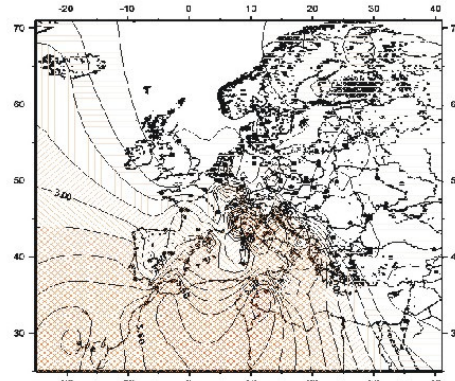
Below difference of 2 CODE solutions (COD – COE) for LAMA
Bias = -2.5 mm, difference STDEV = 3 mm



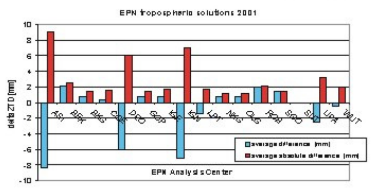
We used differences generated in EPN combination files to calculate averaged differences of ZTD solution for different stations and Analysis Center. We can also assess changes of this discrepancies in time. On the right you can see maps of ZTD differences between EUR combination and all AC's solutions for the whole years 2002 and 2003.
Below you can compare averaged differences and absolute differences for all Analysis Centers in the subsequent four years.

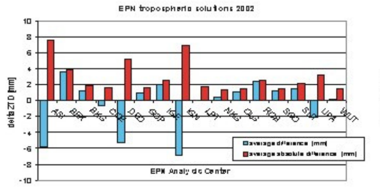


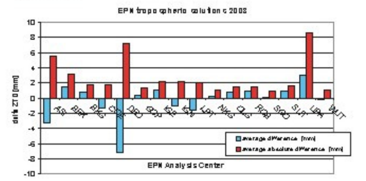
2002

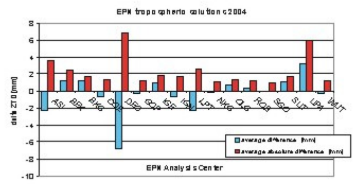


2003

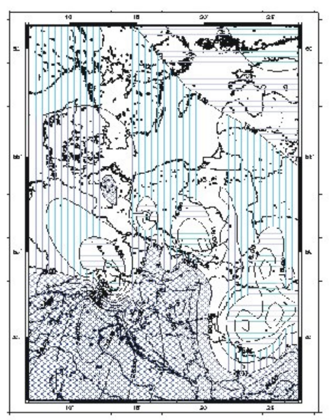


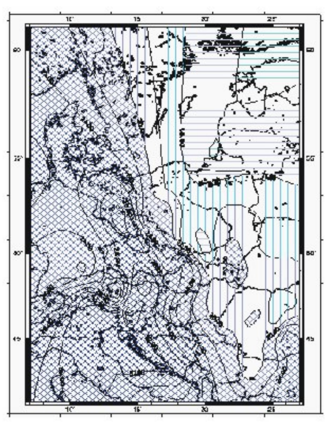


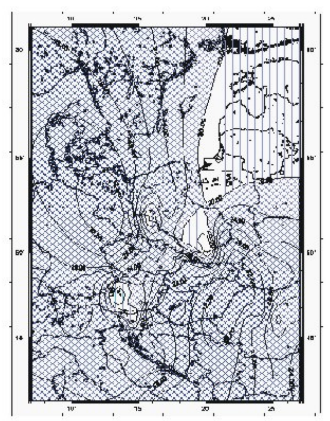


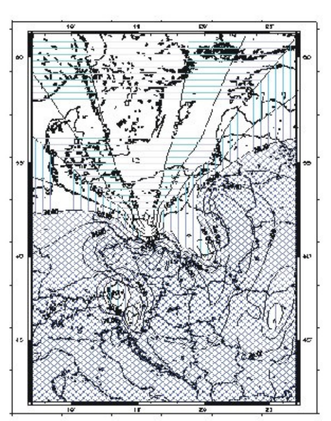


Epoch campaigns are good example of dense network which will be used in synoptic tasks like numerical weather prediction.
On the right you can see maps of IPW distribution over Central Europe during CERGOP-2 2003 campaign.
Each map shows values estimated in WUT solution for the period of 8.00 - 9.00 UT
In subsequent days:
DOY 168, 169, 170, 171



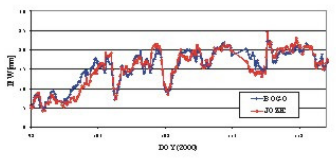


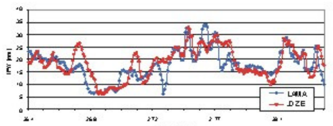




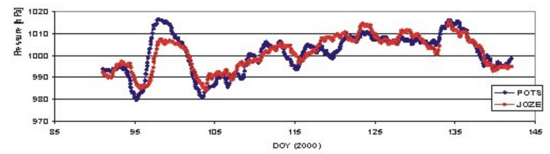
IPW values of two permanent stations show some similarities depending on spatial separation e.g. (see below)

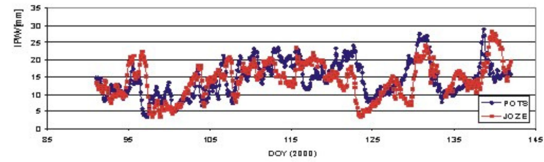
1. BOGO and JOZE – Warsaw vicinity, 42 km distance, 0.96 correlation
2. LAMA and JOZE – about 180 km distance, 0.74 correlation



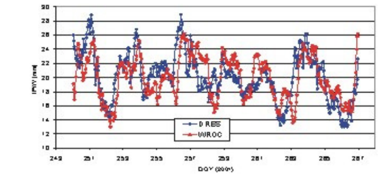


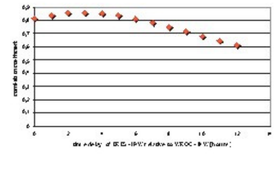
Using IPW derived in the GPS network we can find some interesting meteorological regularities. In Europe atmospheric phenomena migrations are dominated by western circulation.
Setting aside parameters for two stations with the same latitude we can discern time similar IPW changes shifted in time. Also we see strong anticorrelation between IPW and atmospheric pressure on surface.
We illustrate it on the right for POTS – Potsdam, and JOZE – Jozefoslaw near Warsaw.



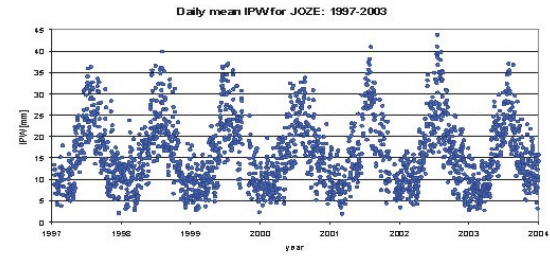


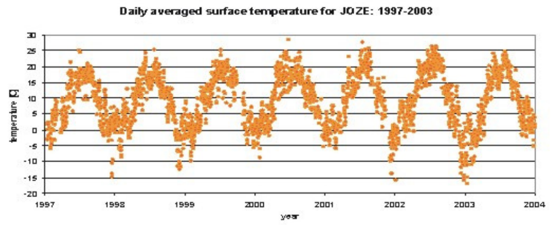
Dresden (DRES) and Wroclaw (WROC) are placed also on the same parallel. We can calculate correlation factor for this two series of hourly spaced IPW (here 1850 points from EPN combination were used). Applying time delay of DRES series with greater steps we see slightly increase of correlation during 4 hours.
See figures below.

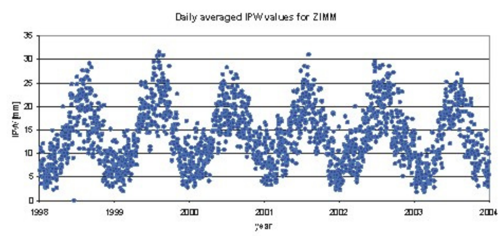


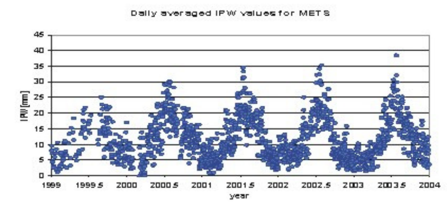


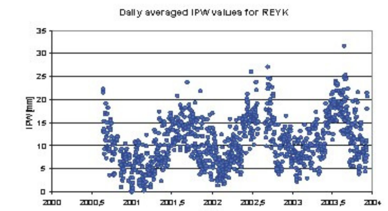
To demonstrate value of IPW as climatological parameter (e. g. global warming indicator) we have calculated daily averaged values of IPWV in the course of 7 years for JOZE, in the course of 6 years for ZIMM, 5 years – HERS and METS and nearly 4 years for MATE and REYK. Average temperature values in JOZE and REYK are also showed on the left. First conclusions: seasonal period with summer IPW maximums dominates all series; ocean climate has smaller seasonal extremes (HERS, REYK, MATE); greater station height implicates lower values; northern stations series can show some linear trend (global warming ?!).

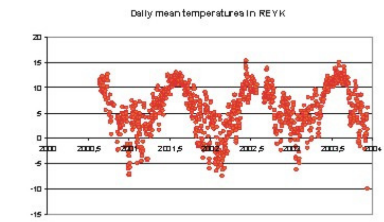


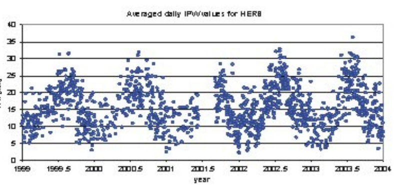


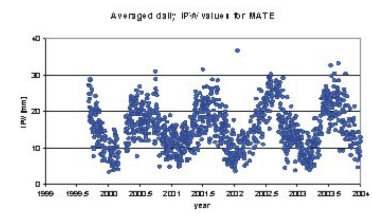












IPW fields derived from GPS network solution can be assimilated to Numerical Weather Prediction models to improve precipitation forecasts.
This will become standard activity of GPS Analysis Centers on national (e.g. NOAA/FSL network in US, German GASP) and international level (TOUGH action, SomiNet).
In our Institute we are working on automatic NRT GPS processing system.
First experiments aiming at establishing all software links and solution minutes are under way.
To show essential difference between different approaches to time basis in the process of ZTD estimation we show below three experiments
1) compare ZTD calculated in 1 Hour and 10 minutes intervals
2) calculate ZTD differences for subsequent hours (some kind of derivative) - such derivatives for classical hourly solution for JOZE (first hour jump) and NRT solution (see it on the right below)
3) Analysing the differences of 30 vs. 10 minutes and 20 vs. 60 minutes solutions (estimation step) we find mean absolute difference (about 3.5 mm) and standard deviation of the difference (4.5 - 5.5 mm) to be much greater than solution error. This means not only independent hourly solution but also shorter estimation steps are needed to derive full GPS IPWV information potential. See below left.