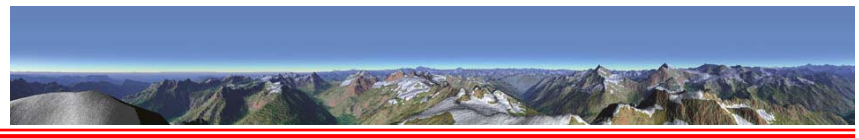
swisstopo

Bundesamt für Landestopographie
Office fédéral de topographie
Ufficio federale di topografia
Uffizi federal da topografia



Activities of swisstopo in GPS meteorology

E. Brockmann[1], D. Ineichen[1], G. Guerova[2], J.-M. Bettems[3], A. Somieski[4], M. Troller[4], M. Becker[5], P. Haefele[5]

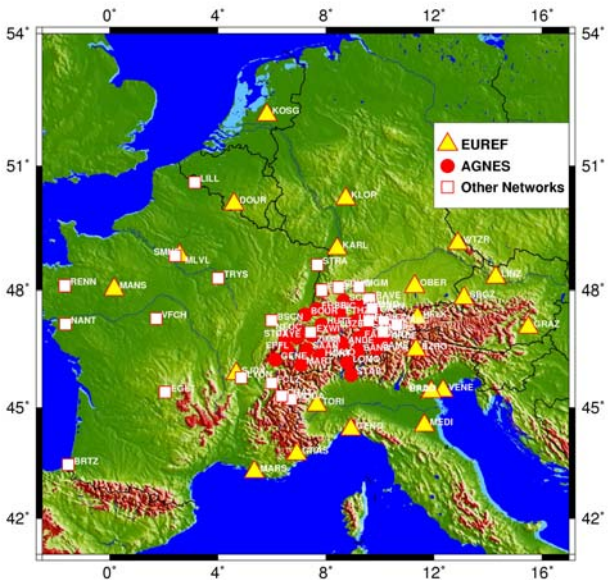
Abstract

Since 1999, the Swiss Federal Office of Topography (swisstopo) actively combines the domains of national surveying using GPS and meteorology.
Swisstopo operates an automated GPS network for Switzerland (AGNES) consisting of 29 sites. AGNES is a multipurpose network serving surveying applications (reference frame maintenance, densification of the reference frame) as well as scientific applications (geodynamics and atmospheric research).
In addition, a positioning service is offered on a commercial basis under the product name swipos-GIS/GEO (Swiss Positioning Service for GIS and Geodetic Applications). The full network together with approximately 30 additional IGS/EUREF sites is analyzed for reference frame purposes with a time delay of about 2 weeks using the final IGS orbits. Hourly tropospheric zenith total delay estimates are a by-product of this processing.
Since the end of 2001, swisstopo contributes hourly zenith path delay estimates with a time delay of 1:15 hours to the European COST-716 project, to the European TOUGH project, and to the Swiss Meteorological Institute (MeteoSwiss) as additional information for numerical weather prediction. Since January 2003, the real-time software, which is used for the positioning service, also delivers zenith total delay estimates. Due to the fact that this software works with 1-second data and a negligible time delay, the troposphere information is already available within time delays of 1 minute (accumulation interval of 10 minutes).
In addition, swisstopo cooperates with different research organizations (ETH Zurich, University of Bern, UniBW Munich) in order to compare the estimated zenith total delay estimates with other measurements, e.g., radiosondes, water vapor radiometers, and a solar spectrometer.

Different ZTD estimation approaches

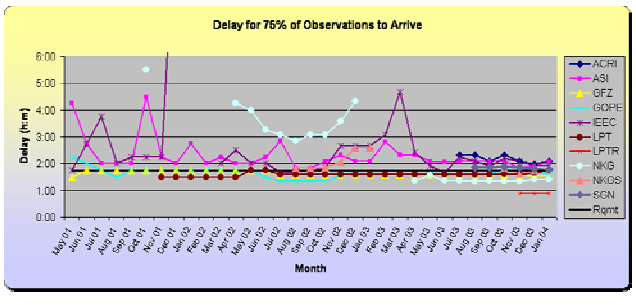
1. Post-processed ZTD's

The complete AGNES network is analyzed together with about 30 European sites for reference frame maintenance using the final IGS orbits with sessions of 24 hours. The time delay of the processing is about 2 weeks. The processing software is the Bernese GPS Software Version 4.2.



2. Near real-time ZTD's

Almost the same network is analyzed in near real-time in collaboration with the European COST-716 project (finished end of 2003) and the European TOUGH Project (2003 – 2006). Since December 2001, hourly results are available with a time delay less than 1 hour 45 minutes using the IGS ultra rapid orbits (solution "LPT", data availability of about 95%).



Two different hourly solution types are generated:

- a solution using only one hour of data
- a loosely constrained solution combining 7 consecutive hours

The second one is officially distributed to COST-716 (label "LPT")

3. Real-time ZTD's

Since the beginning of 2002, the positioning service *swipos*-GIS/GEO enables real-time positioning with an accuracy better than 2 cm horizontally and 4-5 cm vertically. The GPSNet software of Trimble analyzes each second the GPS data of the 29 AGNES sites.
Since January 2003, the new version GPSNet 2.0 also provides ZTD estimates achieved in real-time in intervals of 1 minute. It is obvious that relative constraints are used to stabilize the ZTD estimates in the Kalman filtering.
These solutions are submitted to COST-716 and TOUGH since November 2003 (label "LPTR")

4. ZTD's from numerical weather prediction

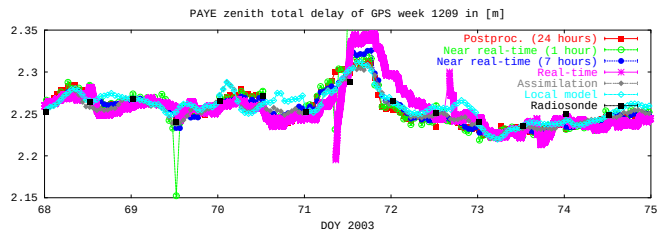
In collaboration with the Institute of Applied Physics (IAP) of the University of Berne and MeteoSwiss, ZTD parameters are determined for every AGNES station from the numerical weather prediction model. ZTD estimates were derived by integration using the following two models:

- "Local Model": Forecast model aLMo (alpine Local Model) used for predicting the next 48 hours. Only the first 3 hours of the day are based on meteo observations. For the comparisons the prediction of the next 12 hours were analyzed. These solutions have been routinely provided since 2002.
- "Assimilation": With a time delay of 2 days, a final assimilation model is available which conists of purely measured meteo data. The data are available since March 6, 2003.

5. Radiosonde observations in Payerne

The GPS station Payern (PAYE) is collocated with the radiosonde observations of MeteoSwiss. Twice a day a radiosonde measures a profile of pressure, temperature and humidity.

ZTD comparisons and validations

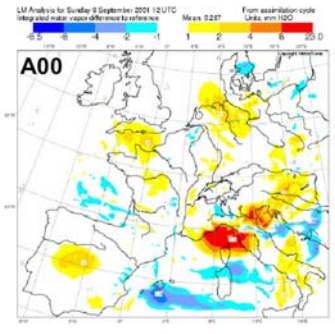


Comparing all the different ztd estimates (3 months validation period February - April 2002) and comparing 2 years of assimilation model values and 3 years of radiosonde-derived ZTD with NRT ZTD estimates we found following conclusions:

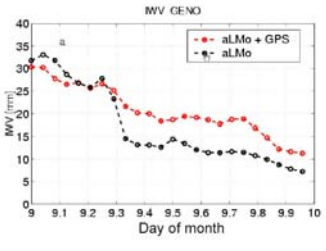
- ☺ All ZTD estimates agree within about 1 cm ZTD.
- ☺ The hourly GPS derived ZTD estimates are almost bias-free compared to the post-processed solution.
- ☹ **GPS slightly overestimates the humidity compared to the assimilation model aLMo in day time.** Expressed in IVW a max. value of this dry bias of 2.8 kg/m^2 was found in 2002.
- ☺ **The real-time results are encouraging, even if the Kalman- filter constraints are presently too tight. Further adjustment is necessary. It might be useful to introduce the forecast information as a priori information in the real-time positioning service swipos GIS/GEO.**

Use of GPS ZTDs for numerical weather prediction

1. Case study: Sept. 9, 2001, Gulf of Genova -> positive impact



"Difference field" of humidity: with GPS ZTD assimilated minus without GPS ZTD



Integrated water vapor (IVW) at the GPS site Genova (GENE)

2. Summary of assimilation experiments

Three different assimilation experiments were performed:

1. 9.-13. Sept. 2001: advective situation, front
2. 10.-14. Jan. 2002: winter high, stratus over CH and D
3. 18.-24. June 2002: summer high, convection, front

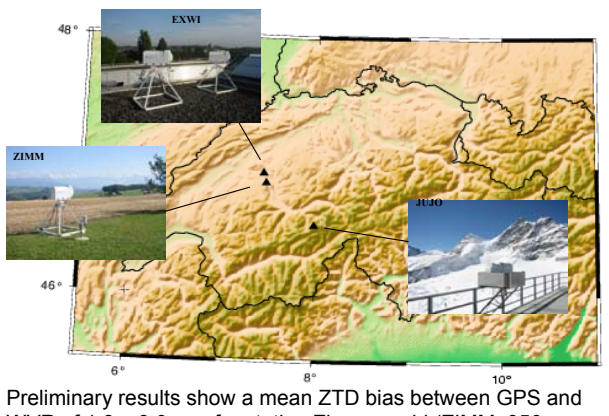
The influence of GPS on the forecast model can be characterized as:

- ☺ Relative strong influence of GPS ZTDs (upto 30% relative change of humidity)
- ☺ Influence mainly for the next 6 hours
- ☺ Tendency to "more precipitation" during day time
- ☺ Slightly positive impact in summer (precipitation score)
- ☺ Slightly negative impact in winter (model improvements necessary)
- ☺ Improvements for special cases visible, but also degradation in special cases possible

MeteoSwiss and swisstopo continue the cooperation. In 2004 additional experiments are performed in order to prepare an operational use of GPS for numerical weather prediction.

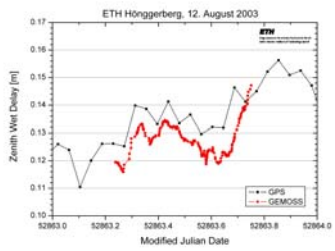
Further validations

1. WVR-Validation Jungfraujoch-Zimmerwald-Bern Sept. 2003 (UniBW Munich)



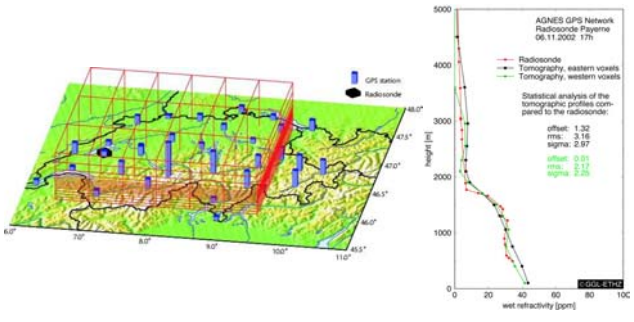
Preliminary results show a mean ZTD bias between GPS and WVR of 1.8 ± 3.0 mm for station Zimmerwald (ZIMM, 950 m altitude) and 16.9 ± 5.8 mm for station Jungfraujoch (JUJO, 3500 m altitude, special antenna with heating!).

2. Sun spectrometer GEMOSS (ETH Zurich)



The sun spectrometer GEMOSS enables (under clear sky conditions) water vapor measurement of high resolution (5 minutes). Example: Roof of the ETH Zurich (Aug. 12, 2003)

3. Tomography approach (ETH Zurich)



For 2 weeks in November 2002 slant delays for all stations of the AGNES network were processed. Using a collocation approach tomographic information was derived with 16 layer model up to a height of 15 km. Each layer contains 6 (long.) x 3 (lat.) voxels.
A comparison of the wet refractivity of the tomography-derived profile with the profile derived from the radiosonde is promising. It can be demonstrated that an accuracy of about 5 ppm in wet refractivity can be expected from GPS tomography.

1 Dr. E. Brockmann, Swiss Federal Office of Topography, Geodetic bases and permanent networks, Seftigenstrasse 264, CH-3084 Wabern, Switzerland, Phone:++41 / 31 / 963 22 56, Fax: ++41 / 31 / 963 24 59, e-mail: elmar.brockmann@swisstopo.ch, Web-Site: http://www.swisstopo.ch
2 Dr. G. Guerova, Inst. Of Applied Physics, Univ. Berne; 3 Dr. J.-M. Bettems, MeteoSwiss 4 A. Somieski, M. Troller, GGL ETHZurich 5 Prof. M. Becker, P. Haefele, UniBW Munich