Name of research institute or organization:

Bundesamt für Landestopografie / Swiss Federal Office of Topography (swisstopo)

Title of project:

Automated GPS Network Switzerland (AGNES)

Project leader and team:

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Project description:

The permanently observing GPS (Global Positioning System) station at Jungfraujoch has been operating since autumn 1998. The station is part of the Automated GPS Network of Switzerland (AGNES) consisting presently of 31 sites. AGNES is a multipurpose network which serves as reference for surveying, real-time positioning (positioning service swipos GIS/GEO) and for scientific applications (geotectonics and meteorology).
Due to the extreme altitude, the station is not optimal for real-time positioning applications. Therefore an additional station was built in Hasliberg (September 2006), which is used for real-time positioning whereas the Jungfraujoch site is used for all scientific applications.
The main important scientific application is GPS-meteorology. From the permanent analysis of the GPS-data zenith total delay estimates (ZTD) can be derived with a time delay of approximately 1:30 hours. These GPS-derived humidity information can be used e.g. for numerical weather prediction. The goal of several European projects, such as COST-716 (ended in 2004), TOUGH (Targeting Optimal Use of GPS Humidity; ended at January 31, 2006) and E-GVAP (EUMETNET GPS Water Vapor Programme; started 2006) is to operationally use these data for numerical weather predictions. Therefore MeteoSwiss and other European meteorological institutes are deeply involved in these activities.

GPS-Meteorology improvements in the year 2006

The big number of model changes in the permanent hourly processing was realized already in the year 2005 when switching also from Bernese Version 4.2 to Version 5.0.
Nevertheless, several processing improvements were realized during the year 2006.
1. Network enlargement: In addition to the network processed so far, seven additional sites (REYK, STJO, PDEL, MAS1, TRAB, ARTU, KIR0) were included in the data analysis (see Fig.2). The main goal was to investigate whether the quality of the estimated ZTD values can be improved by this extended observation network (120º x 45º instead of 30º x 15º). Our conclusion from this test was:
Enlarging the processed network gives results which are closer to CODE's regional solution for Europe (Center for Orbit Determination in Europe located at the Astronomical Institute at the University of Berne). The internal consistency between the near real-time and the post-processed solution does not significantly improve.

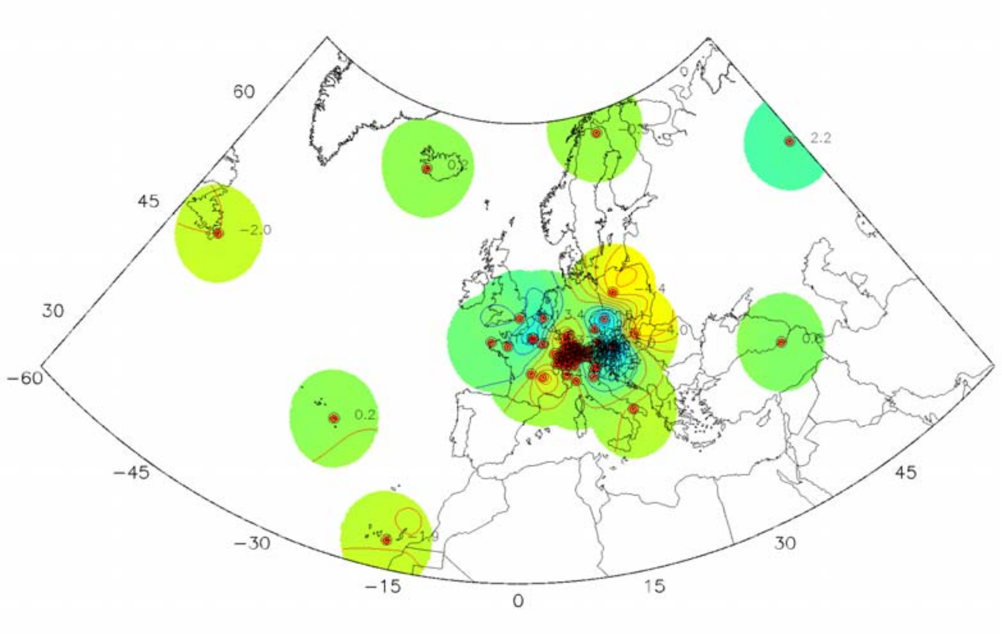

Fig. 2: Enlarged observation network

2. Relative Constraints. Due to the fact that for meteorological applications the estimated formal rms values are not yet used, we tried to investigate to apply constraints on the ZTD-estimates in order to avoid that weak estimates (estimated with a big formal error) are used for numerical weather prediction. Test series of near real-time solutions with different relative constraining of the estimated ZTDs were computed for a time interval of 10 days (DOY 061 – 070, 2006). So far, we used a value of 3 mm for our official solution. The test solutions were computed with relative constraints varying from 30 to 0.3 mm. In addition, these solutions were compared internally with our post-processed solution (LPT PP, no relative constraints) and externally with a near real-time solution computed by GFZ (GFZ NRT) and a post-processed solution of the IGS (IGS PPP). Our conclusion from this test was:
The relative constraining reduces "peaks" in the observed ZTDs at epochs with a weak satellite geometry. For future swisstopo solutions, an optimal relative constraining of 1 mm (for NRT solutions) and 3 mm (for post-processed solutions) was identified.

3. Monitoring of the processing: Similar to the E-GVAP monitor web page (http://egvap.dmi.dk/ where results from more than 500 sites are monitored) a web page was setup at swisstopo showing the status of the processing (see Fig 3.). In addition to the status of the "NRT-Meteo" also information concerning the availability of data ("RINEX-Status") of information concerning the stability of the coordinates ("Coordinate Monitoring") is given.

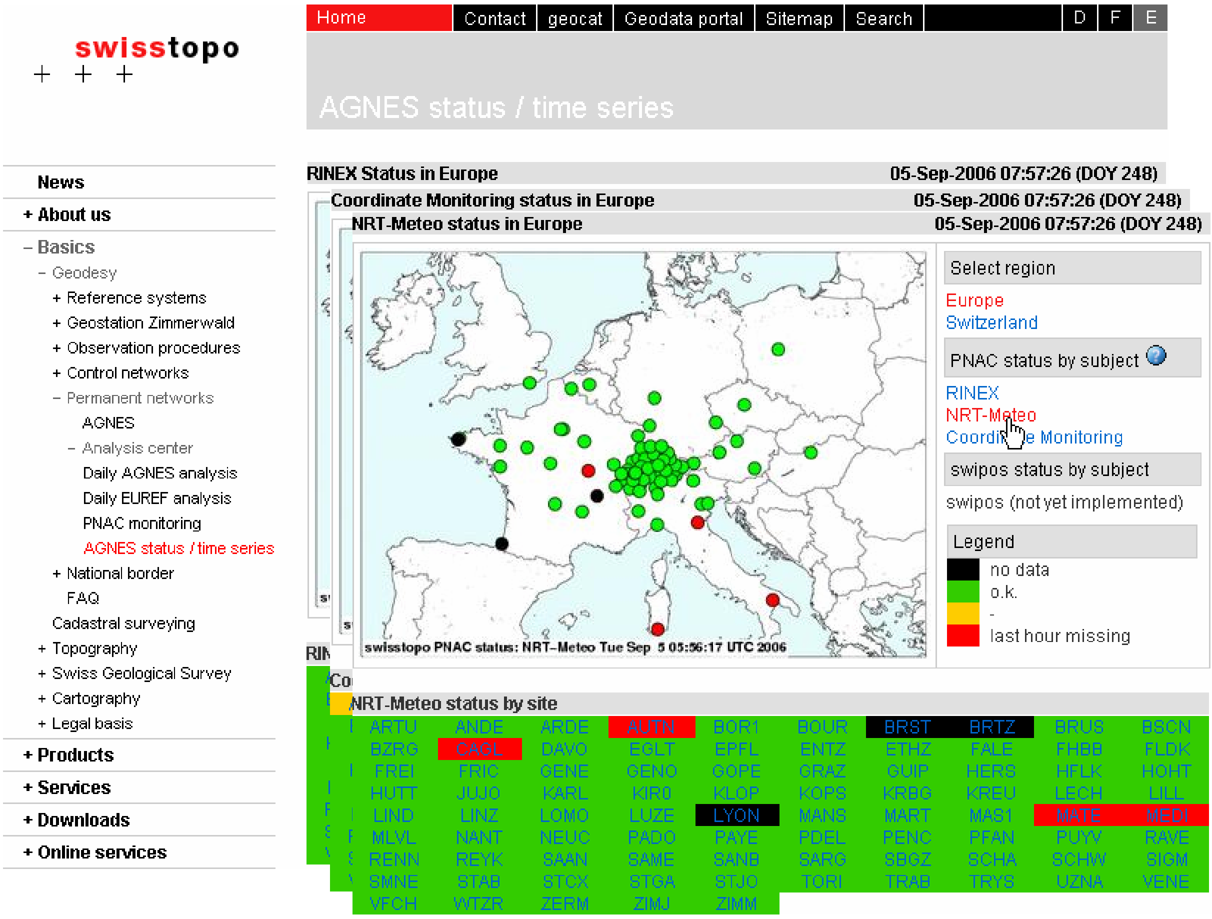

Fig. 3: Monitoring page of swisstopo for the availability of NRT ZTD-estimates. (http://www.swisstopo.ch/en/basics/geo/permnetworks/pnac/timeseries/timeseries_nrtmeteo_europe).

4. Quality check: The ZTD-estimates derived in NRT and RRT are automatically validated by a comparison with the post-processed solutions on a weekly basis. Comparisons are also available on an hourly basis.

5. Antenna phase center model: At GPS-week 1400 (Nov. 5, 2006) the International GNSS Service (IGS) started to distribute the orbits based on an "absolute" antenna phase center model (IGS_05.ATX) instead of a relative antenna model (IGS_01.ATX). swisstopo switched for the NRT processing to this new antenna model in GPS-week 1401 (Nov 14. 2006).
The antenna modeling is of special interest for the Jungfraujoch GPS-antenna, because this antenna type is an individual construction, for which no absolute calibration values exist.

The impact of this processing change is considerable. Due to the fact that the post-processed solution was not switched to that model, we see in average 5-6 mm dryer ZTD-estimates. The influence is station-dependent and varies between 1-2 mm and 8-9 mm ZTD depending on the used antenna type on the station.

Summary and Outlook

In the year 2006 in average 98.78 % of the NRT solutions (maximally 78 processed sites in January 2006 and maximally 91 processed sites at the end of 2006) and 98.45 % of the RRT solutions (maximally 40 processed sites) were delivered to E-GVAP. Outages mainly occurred because of interruptions of the complete communication lines or because of computer shut-downs.

A special acknowledgment is addressed to MeteoSwiss. Without their support swisstopo could not contribute to E-GVAP.

swisstopo plans to equip all AGNES sites with GNSS (Global Navigation Satellite System consisting of the satellite systems GPS, GLONASS and future systems such as Galileo) receivers till end of the year 2007. The new receivers will be able to also collect observations of GLONASS satellites. This might also stimulate the Swiss-internal project GANUWE (project partners ETH Zurich and MeteoSwiss) which has the goal to use GNSS-tomography for numerical weather prediction. The data flow based on post-processed results was already established in 2006.

Key words:

GPS, Meteorology, Positioning, Intergrated Water Vapour, Zenith Path Delay, GPS Tomography

Internet data bases:

http://www.swisstopo.ch; http://egvap.dmi.dk/

Collaborating partners/networks:

Astronomical Institute (AIUB), University of Berne
MeteoSwiss, Zurich and Payern
Institute of Applied Physics (IAP), University of Berne
Institute of Geodesy and Photogrammetry, ETH Zürich
E-GVAP (EUMETNET GPS Water Vapor Programme)

Scientific publications and public outreach 2006:

Refereed journal articles

Somieski A., B. Bürki, A. Geiger, H.-G. Kahle, E. Brockmann, H. Becker-Ross, S. Florek, M. Okruss (2006). Geodetic Mobile Solar Spectrometer (GEMOSS) and Comparison with GPS Estimates of Wet Path Delay, Paper in preparation.

Troller, M, A. Geiger, E. Brockmann, J.-M. Bettems, B. Bürki and H.-G. Kahle (2006): Tomographic determination of the spatial distribution of water vapor using GPS observations. Advances in Space Research, Volume 37, Issue 12 , 2006, Pages 2211-2217, doi:10.1016/j.asr.2005.07.002

Troller M. , A. Geiger, E. Brockmann, H.-G. Kahle (2006). Determination of the spatial and temporal variation of tropospheric water vapour using CGPS networks. Geophys. J. Int., Volume 167, pages 509-520, doi: 10.1111/j.1365-246X.2006.03101.x

Conference papers

Brockmann E., S. Grünig, D. Ineichen, S. Schaer (2006): Monitoring the Automated GPS Network of Switzerland AGNES. In: Torres, J.A. and H. Hornik (Eds): Subcommission for the European Reference Frame (EUREF). Riga, June 15-17, 2006, EUREF Publication in preparation.

Wiget A., E. Brockmann, M. Kistler, U. Marti, A. Schlatter, B. Vogel, U. Wild (2006): Annual Report 2006 of Switzerland. In: Torres, J.A. and H. Hornik (Eds): Subcommission for the European Reference Frame (EUREF). Riga, June 15-17, 2006, EUREF Publication in preparation.

Data books and reports

Vedel H.,(2006): Final TOUGH Report (Targeting Optimal Use of GPS Humidity). EU Project EVG1-CT-2002-00080. EU Publication in preparation.

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