E-GVAP planetary meeting, 2007/06/20, Barcelona

A) E-GVAP Status Report June 2007, from MeteoSwiss

A.1 General information

Pierre Jeannet and Dominique Ruffieux, MeteoSwiss, 18 June, 2007

- Dominique Ruffieux can not attend the meeting. Pierre Jeannet is representing MeteoSwiss.

A.2 Research activities at MeteoSwiss and ETH Zürich

Daniel Leuenberger, MeteoSwiss, and Donat Perler, ETH Zurich, 15.6.2007

In January 2006 ETH has set up a quasi operational production of the 28 tomography humidity profiles over Switzerland in an hourly resolution. Therefore a data set of more than one year is now available for assessing its quality. This is done by a comparison with independent humidity observations from radiosonde and humidity profiles from the Swiss NWP model 12h and 24h forecasts.

A.2.1 MeteoSwiss part of the project

A.2.1.1 Quality assessment of the GPS tomography humidity profiles

The GPS tomography provides wet refractivity defined as

$$N = k_2 \frac{e}{T} + k_3 \frac{e}{T^2}$$

where e is the water vapour pressure, T is temperature and k_2= *64.8 K/hPa*, k_3= *3.776E5 K^2/hPa*. The GPS refractivity is compared with its counterparts calculated from the Payerne radiosonde data and from COSMO NWP model +12h and +24h forecasts and interpolated to the tomography voxel nearest the Payerne radiosonde.

a) Yearly cycle of GPS tomography and Payerne radiosonde data

Figure 1) shows time-height diagrams of wet refractivity from GPS tomography (panel a) and derived from the radiosonde in Payerne (panel b), as well as the bias (panel c) valid from 15.1.2006 – 24.3.2007 at 00UTC.

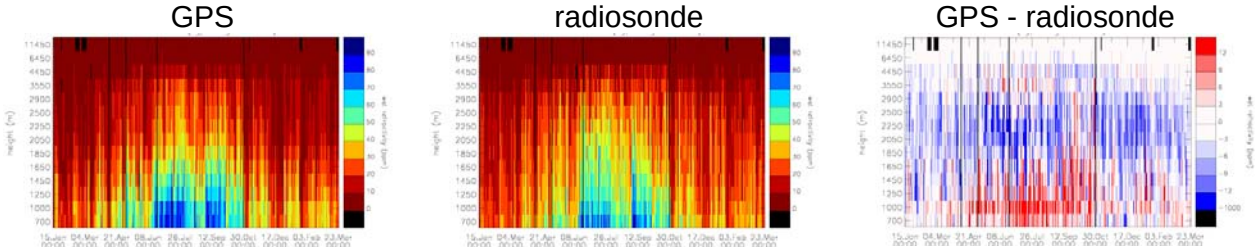


Figure 1. *Time-height diagrams of wet refractivity from GPS tomography (panel a) and radiosonde data (panel b). Panel c shows the bias (GPS – radiosonde).*

b) Comparison of GPS tomography and NWP data with Payerne radiosonde data

Figures 2 shows mean bias and standard deviation with respect to radiosonde data for July/August 2006 and Figure 3 for November/December 2006. Black (red) lines show 00UTC (12UTC) results and solid bold (thin) lines show GPS (NWP forecast) refractivity. Cross (diamond) symbols show +12h (+24h) NWP forecasts.
A large bias in the GPS tomography solution is apparent which depends on height: below (resp. above) 2000m GPS is wetter (resp. drier) than the radiosonde. This bias is larger than that of the NWP forecasts. The standard deviation on the other hand, is comparable with that of the NWP forecasts, which indicates the potential for the assimilation of the GPS tomography wet refractivities.
The reason of the large bias in the GPS data is not clear at the moment and will be subject to further investigation.

July/August 2006

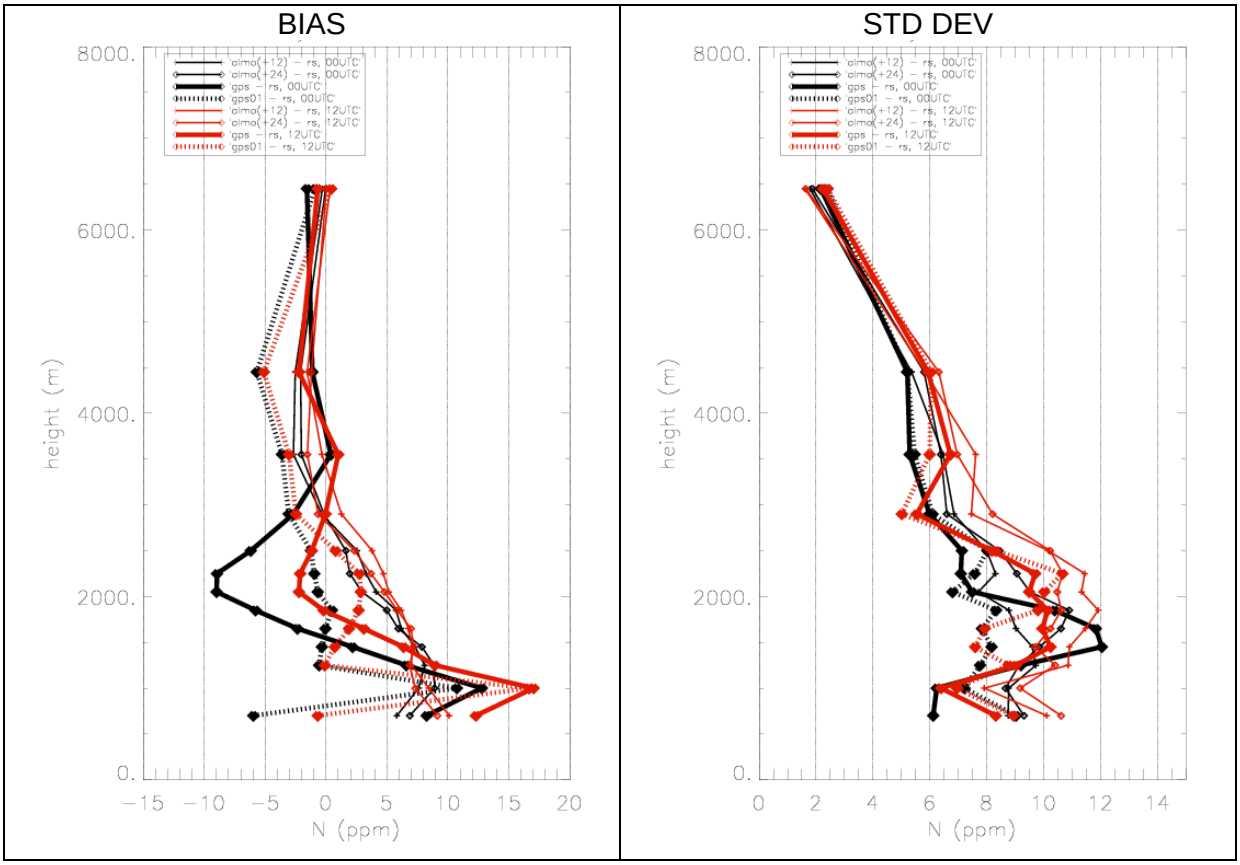


Figure 2. Mean bias and standard deviation of wet refractivity from GPS and NWP forecasts with respect to radiosonde data, valid for July/August 2006. For more explanation see text.

November/December 2006

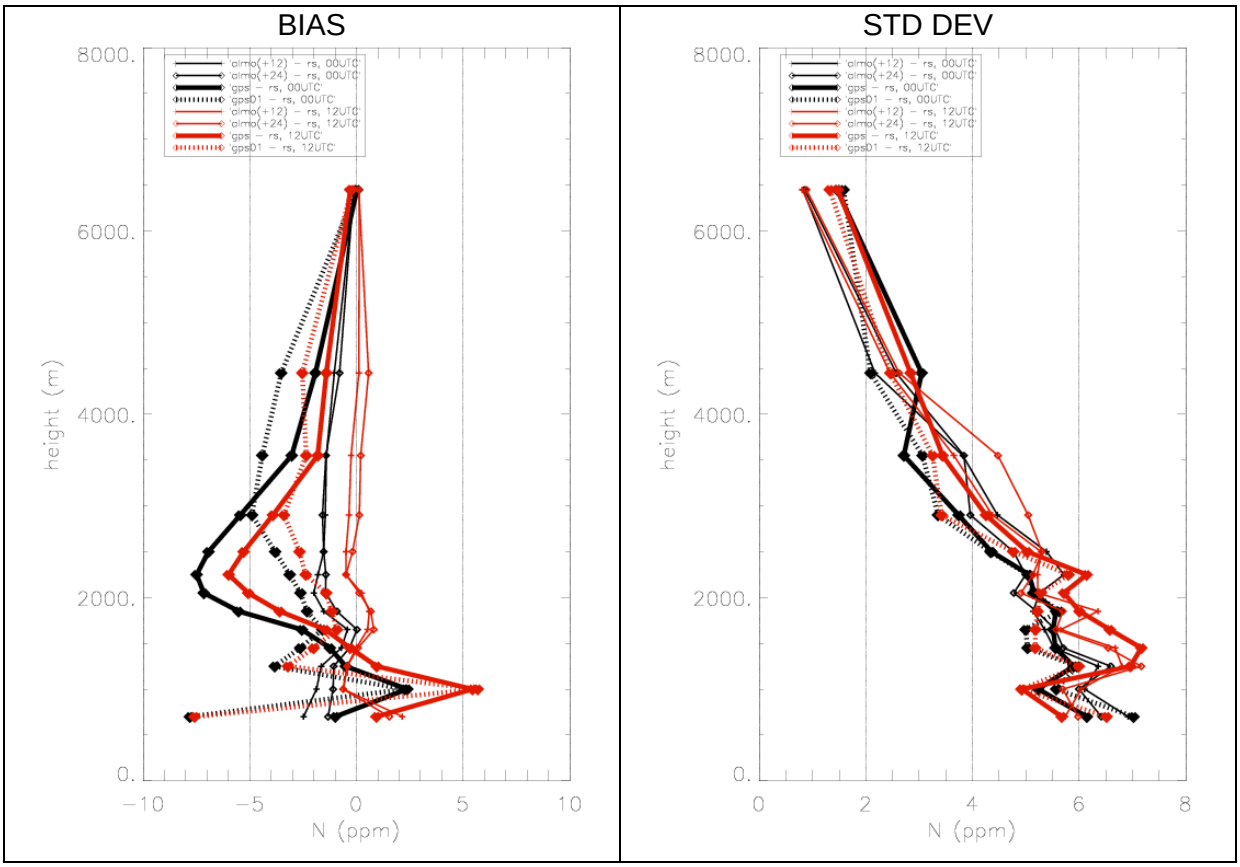


Figure 3. Mean bias and standard deviation of wet refractivity from GPS and NWP forecasts with respect to radiosonde data, valid for November/December 2006. For more explanation see text.

c) Using NWP model forecast data as first guess in the tomography algorithm

Using the NWP +12h forecasts as first guess in the tomography algorithm improves both bias and standard deviation of the GPS refractivity compared to the radiosonde (dashed bold lines in Figures 2 and 3). In this case the GPS standard deviation is almost always smaller than that of the +12h model forecast.

A.2.1.2 Outlook

We aim at the assimilation of the GPS refractivity profiles with a combined 1DVar – Nudging approach. First, temperature and specific humidity profiles will be retrieved with 1DVar and then these profiles will be assimilated into the model using nudging. This allows for a proper separation of the temperature and humidity influence on wet refractivity. Steps to reach that goal include:

- Bias correction of the GPS tomography refractivity profiles
- Development of the forward operator and its tangent linear and adjoint
- Perform assimilation experiments

A.2.2 ETH part of the project

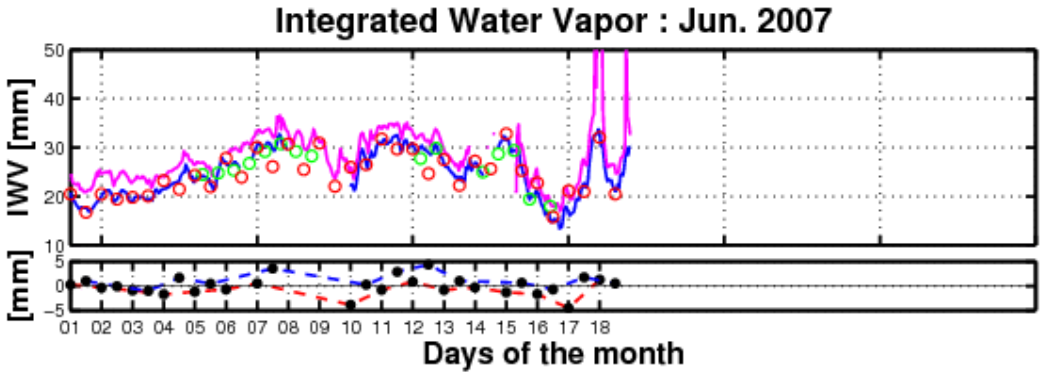
In the beginning of 2007, the tomography software was extended to support new features provided by the GPS-Software (BERNESE 5.0) such as ZTD gradient estimation and additional global navigation satellite systems (GNSS). Moreover, the statistical model of the tomographic processing was improved.

Beside these improvements, simulations of ideal GPS network geometry and different satellite constellations were carried out. They show that a higher accuracy can be expected by increasing the number of receivers.
The height distribution should be considered for the evaluation of possible locations for GNSS receivers. The use of the combination of GPS and Galileo was investigated. Using both systems in the simulation improves the accuracy and leads to a much smaller variation of the quality of the tomographic solution over time.

In the second half of 2007, sensitivity studies are planned. The impact of errors in the input data of the tomography software on the results will be analysed and possible algorithmic improvements will be proposed.

A.3 Operational activities at MeteoSwiss

The operational comparison between GPS and Payerne sounding is going on.



Compare hourly Integrated Water Vapor/IWV measurements by GPS, microwave radiometer and soundings
Upper graph, the blue curve represents the GPS data, magenta curve: Hatpro IWV, the red dots, the values estimated from the sounding at 00 & 12 UTC, the green dots, the values estimated from the other soundings and the cyan dots, the values estimated from the snow white. Lower graph, the difference between sounding and GPS data recorded at 00 UTC (blue line) and 12 UTC (red line).

	00 UTC	12 UTC	00–12 UTC
bias [mm]	–0.99	1.14	0
std [mm]	1.53	1.55	1.86
rms [mm]	1.78	1.88	1.83
corr	0.96	0.96	0.93
mean (sond)	26.55	22.65	24.6
mean (GPS)	25.03	23.35	24.25

Overview of some statistics based on 16 days of Jun. 2007 for the 00 UTC and on 14 days for the 12 UTC.

B) E-GVAP Status Report June 2007, from swisstopo

E. Brockmann, 12.06.2007

Last year swisstopo did quite some tests and improvements, which were put to the 2006 report.
The processing status Mid-2007 is almost the same as last time. News are:
- including of 3 additional permanent sites in the Valais (ETH Project TECVAL),

- generation of a web page showing the status of the toposphere product delivery:

  http://www.swisstopo.ch/de/basics/geo/permnetworks/pnac/timeseries/timeseries_nrtmeteo_europe

  (see Figure 4)

Furthermore, swisstopo (E Brockmann as member of the EUREF Tecnical Working group) supported the finishing of the Memorandum of Understanding between EUREF and EUMETNET. The MoU was signed last week on June 8, 2007 in London during the annnual EUREF symposium. It is worth mentioning that also Switzerland (from the geodesy part) helped to make this MoU possible.

As actual work swisstopo presently start to enhance the GPS network to GPS/GLONASS combined receivers. In PAYE this change was done on 14.06.2007. What also should be mentioned is our contribution to GANUWE. swisstopo delivers the GPS results, ETHZ computes the tomography and the Zurich group of Meteoswiss does the validation (see part A of this report).

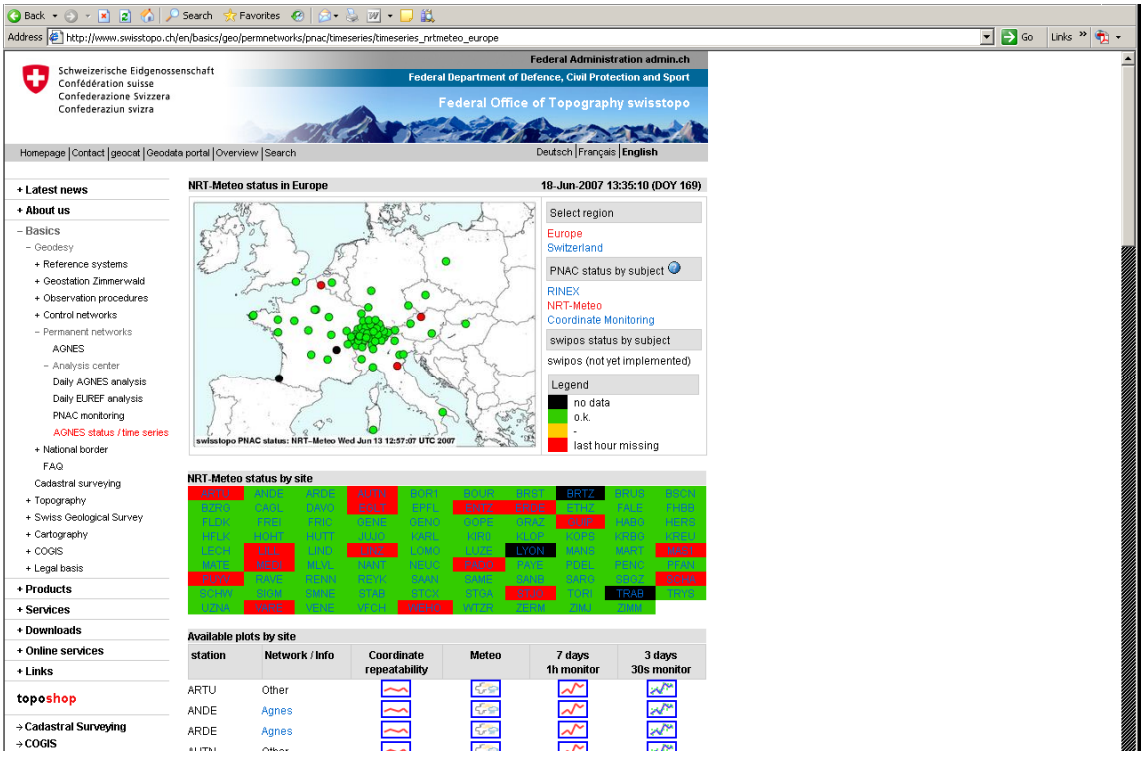


Figure 4. Internet page of swisstopo. More information is provided by clicking on the icons right to the station names.

RINEX data from Payerne

On request of E-GVAP swisstopo sends hourly data of PAYE to the metoffice data server since the 19th of June 2007. swisstopo stays at the moment with the 60 minute interval. We internally have no data flow based on files quicker then 60 minutes. If timeliness is focussed on, we have the real-time, but nothing in between.

C) E-GVAP Status Report June 2007, from IAP-University of Bern

Research activities at the Institute of Applied Physics, University of Bern, J. Morland, 15.06.2007

Summary of a PowerPoint presentation of J. Morland presentation **Water vapour variations in space and time: Observations from the Swiss GPS network and TROWARA microwave radiometer** (without TROWARA results and trend analysis)

- Water vapour measurement with Global Positioning System receivers
  - Water vapour profiles
  - Water vapour maps

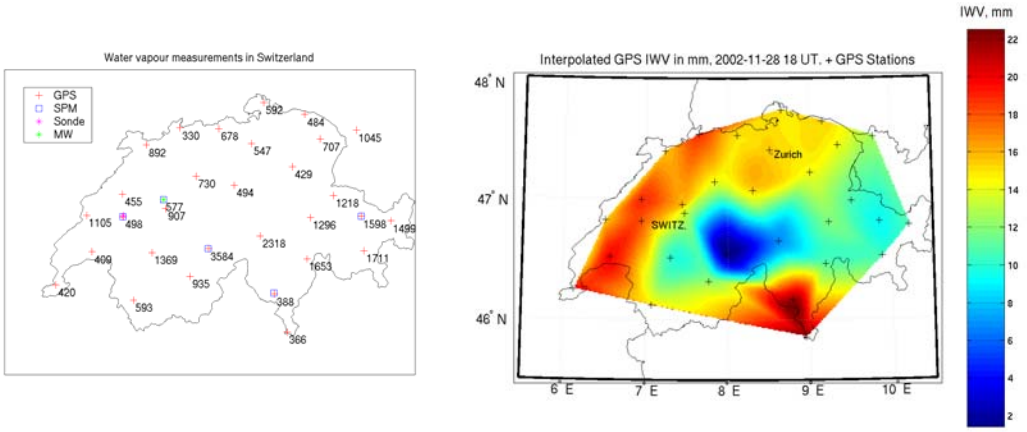


Figure 5: AGNES stations used in the IAP-research: The challenge of water vapour measurements in a mountainous area. Much higher values above sites in the Swiss plains and valleys.

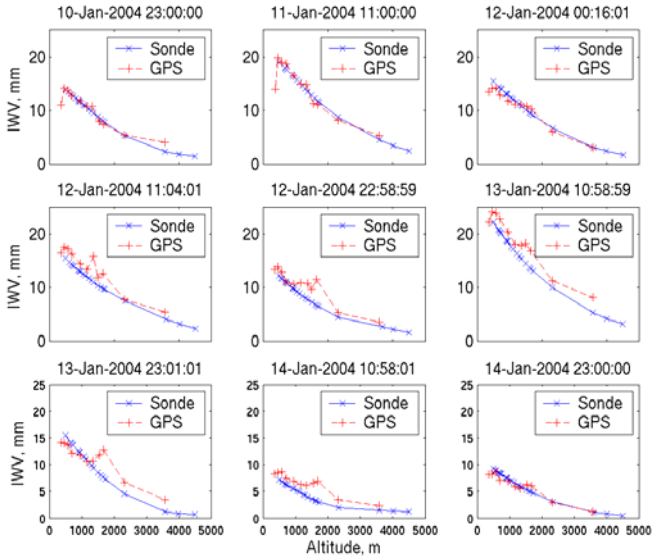


Figure 6: Example of GPS profiles: A series of frontal systems 11-Jan-2004 to 14-Jan-2004. GPS IWV is higher than sonde, particularly between 1000 and 2000 m.

The GPS IWV is higher than the sonde IWV in all seasons. The difference is highest at 1500 m. An altitude correction for the GPS measurements has been developed.

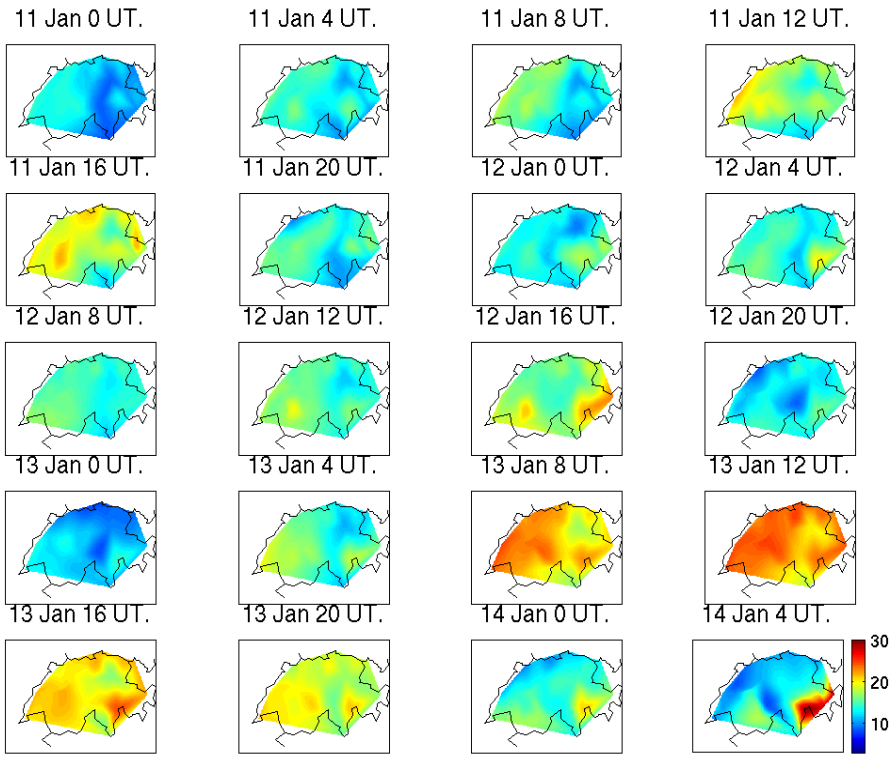


Figure 7: Example of altitude correction: same case study of frontal systems, but IWV has been reduced to 0.5 km altitude using a fitted exponential model.

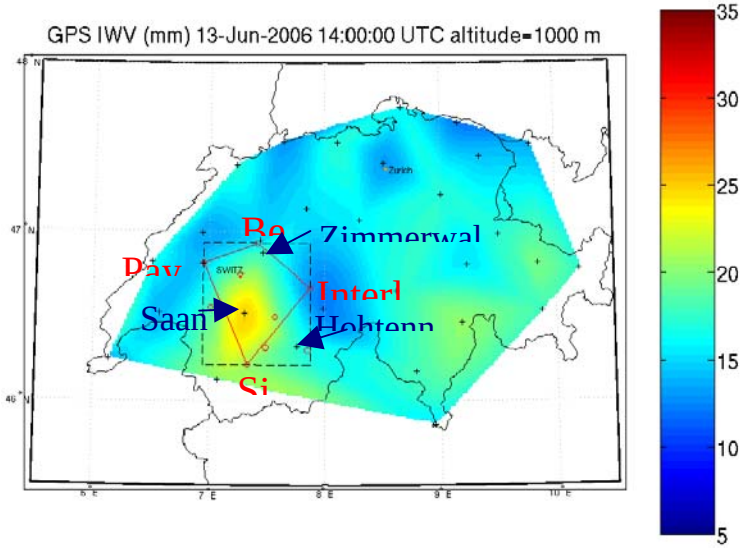


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Figure 8: Research with GPS data: a convection case study. The total IWV contained within the black rectangle is calculated. The total IWV in the area increases sharply from 12 to 15 UT and then decreases slowly. The convergence mirrors the IWV change, it decreases until 15 UT (air is moving into the black rectangle until 15 UTC) and recovers by 18 UT.

Conclusions and outlook of the IAP Research:

- Swiss GPS receivers situated between 330 and 3584 m
  - GPS IWV profile consistently moister than radiosonde profile.
  - Correct GPS IWV measurements to a standard height of 500 m.
  - Alpine region moister than Swiss plains in all seasons except winter
- Outlook
  - Water vapour process studies.
  - IWV from other European GPS stations

Reference

June Morland and Christian Mätzler, 2007, Spatial interpolation of GPS integrated water vapour measurements made in the Swiss Alps, Met. Appl., 14, 15-26.