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Swiss status report
E-GVAP meeting 2011/10/21

- Activities at MeteoSwiss

- PhD thesis of D. Perler at ETH Zürich
  (tomography project)

P. Jeannet, MeteoSwiss, E. Brockmann, swisstopo
and D. Perler, ETHZ

Activities at MeteoSwiss

- Presently no special project is ongoing on GPS IWV at the model group of MeteoSwiss (waiting on a DWD project on the assimilation of wet or slant delays).
- COSMO-2 in operation (COSMO-7 still working).
- The water vapour measurements of the Payerne radiosonde has been improved (new humidity sensor, full digital sonde).
- Measurements of water vapour profiles at Payerne have been extended with a radiometer (RPG Hatpro) and a tropospheric water vapour Raman Lidar.
- Payerne is now a site of the GCOS Global Reference Upper Air Network (GCOS-GRUAN). Good for validation work!

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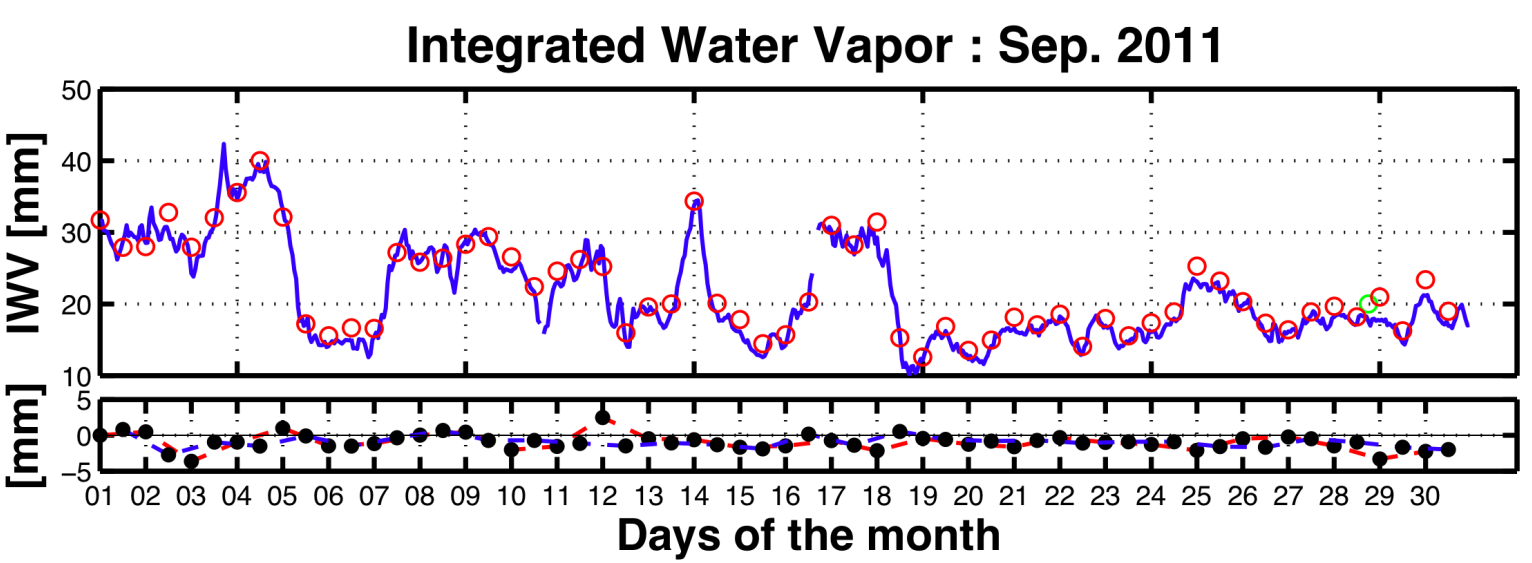
Comparison IWV GPS - Payerne sounding



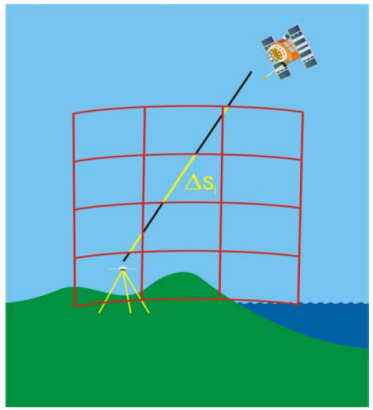
Compare hourly Integrated Water Vapor/IWV measurements by GPS, microwave radiometer and soundings
Upper graph, the blue curve represents the GPS data, magenta curve: Hatpro IWV, the red dots,
the values estimated from the sounding at 00 & 12 UTC, the green dots, the values estimated
from the other soundings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

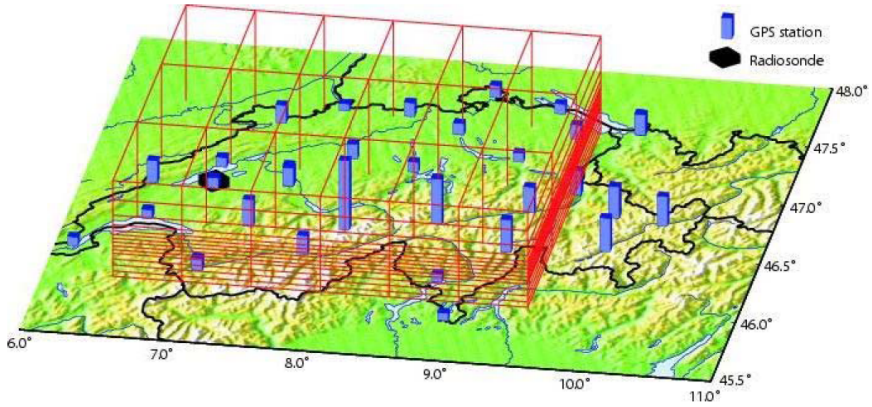
	00 UTC	12 UTC	00–12 UTC
bias [mm]	–0.98	–0.94	–0.96
std [mm]	1.23	0.8	1.03
rms [mm]	1.55	1.22	1.39
corr	0.98	0.99	0.98
mean (sond)	23.06	21.41	22.23
mean (GPS)	22.08	20.48	21.28

Overview of some statistics based on 30 days of Sep. 2011 for the 00 UTC and on 30 days for the 12 UTC.

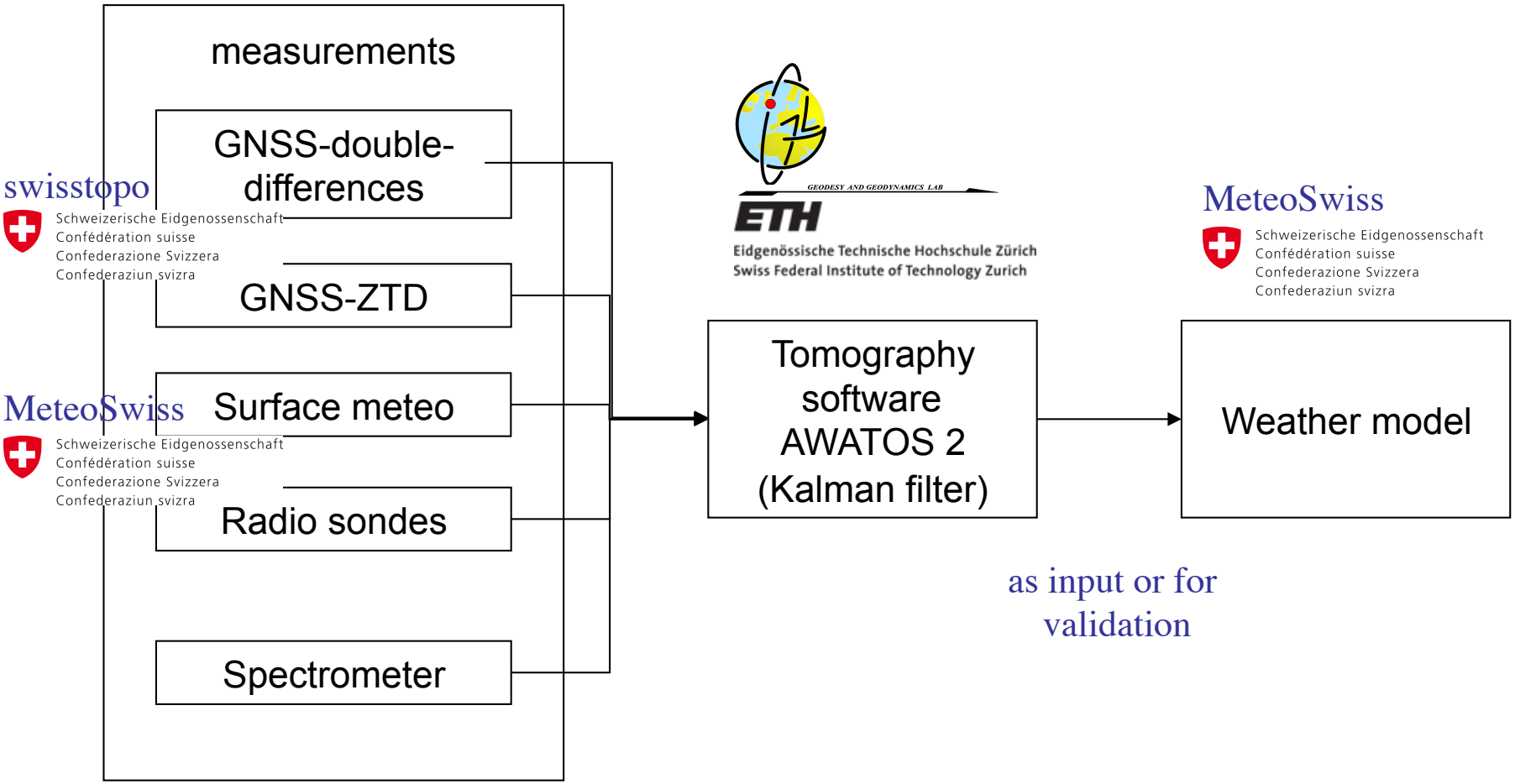
GPS Tomography (ETH Zurich)

- GANUWE Project
  - Swiss project funded by the Swiss Federal Office of the Environment FOEN
  - Partners: ETH Zurich + MeteoSwiss
  - External partner: swisstopo
- Goal: Development of new tomographic algorithms for assimilation in numerical weather models





GPS Tomography: data flow



GPS Tomography: results

- Parts of the results presented in previous annual EGVAP reports
  - Simulations: Improvement due to Galileo and number of stations
  - Comparisons with MeteoSwiss COSMO model

- Phd of D. Perler finished October 2011

  (-> systematic analysis of the data available in 2006)

Water Vapor Tomography using Global Satellite Navigation Systems

Donat Perler, PhD Thesis at ETHZ

Motivation for GNSS tomography

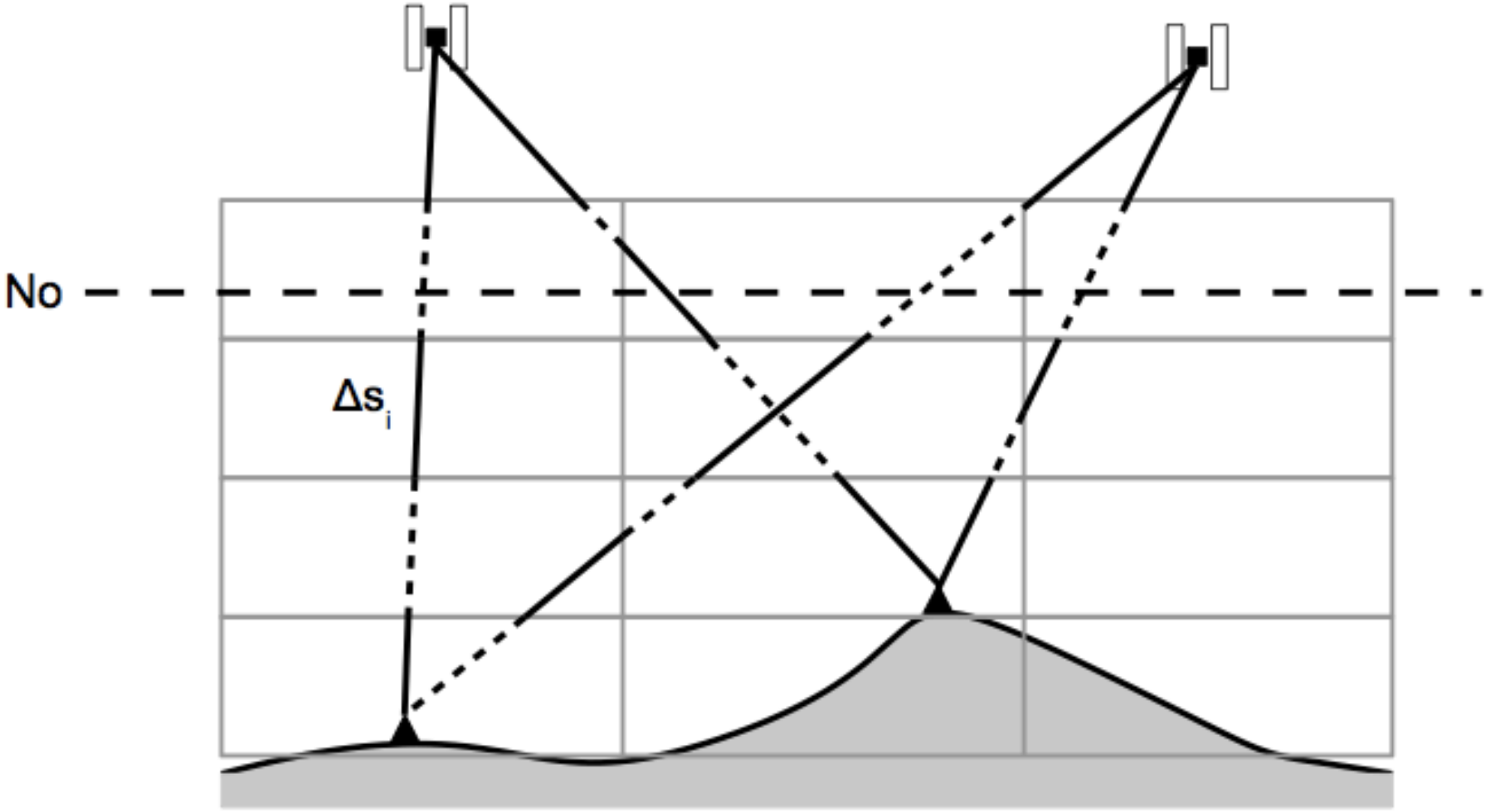
- Improving weather forecasts by assimilating wet refractivity fields into numerical weather prediction models
- Improving GNSS positioning by more accurate tropospheric corrections

Main goals of this work

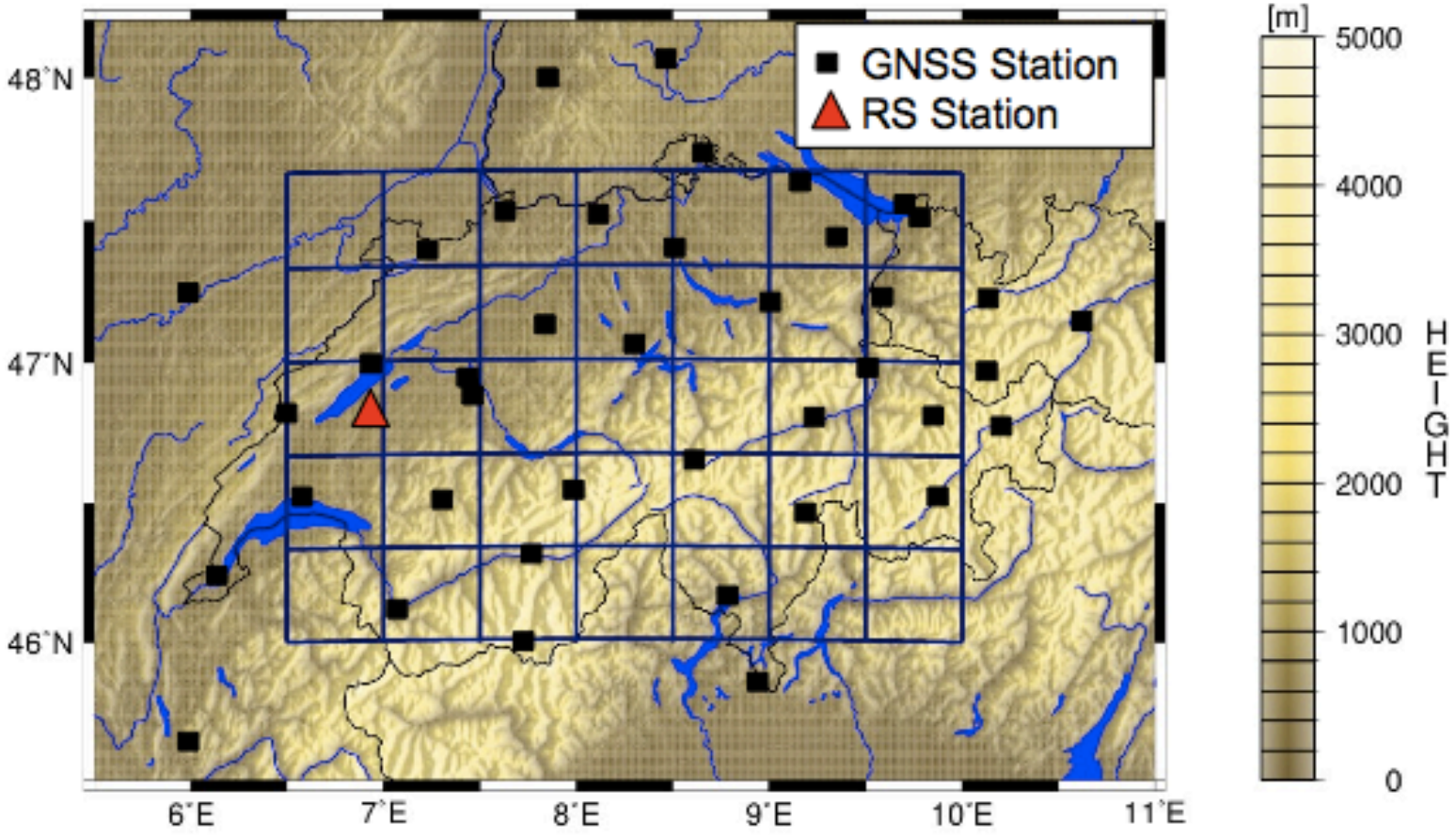
- Accurate estimation of the 4D water vapor distribution from GNSS observations
- A better understanding of GNSS tomography, its potential and limitations
- Provide strategies to overcome the main limitations

Next slides kindly provided by D. Perler

Principle of GNSS tomography



GPS network used in the investigations



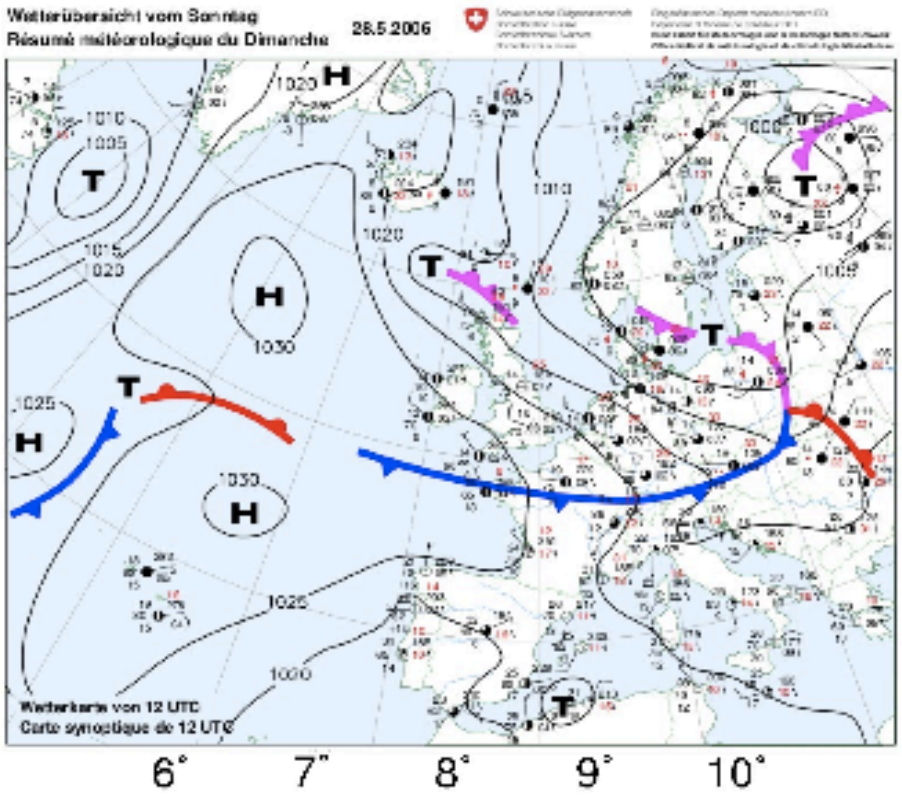
Challenges in ground-based GNSS tomography

- Vertical resolvability due to the measurement setup
- Sparse GNSS network compared to the local variability of the wet refractivity field
- Underdetermination of the tomographic problem (300 observations/epoch vs. 1300 unknowns)

New approach in GNSS tomography

- Simple stochastic prediction model (Kalman filter) to include information from preceding epochs
- New voxel parametrizations for a more accurate representation of the wet refractivity field without increasing the number of unknown parameters
- New intervoxel constraints to stabilize the tomographic solution
- Bias correction model to reduce discretization errors and artifacts related to the NWP model

Results: GNSS tomography with real data



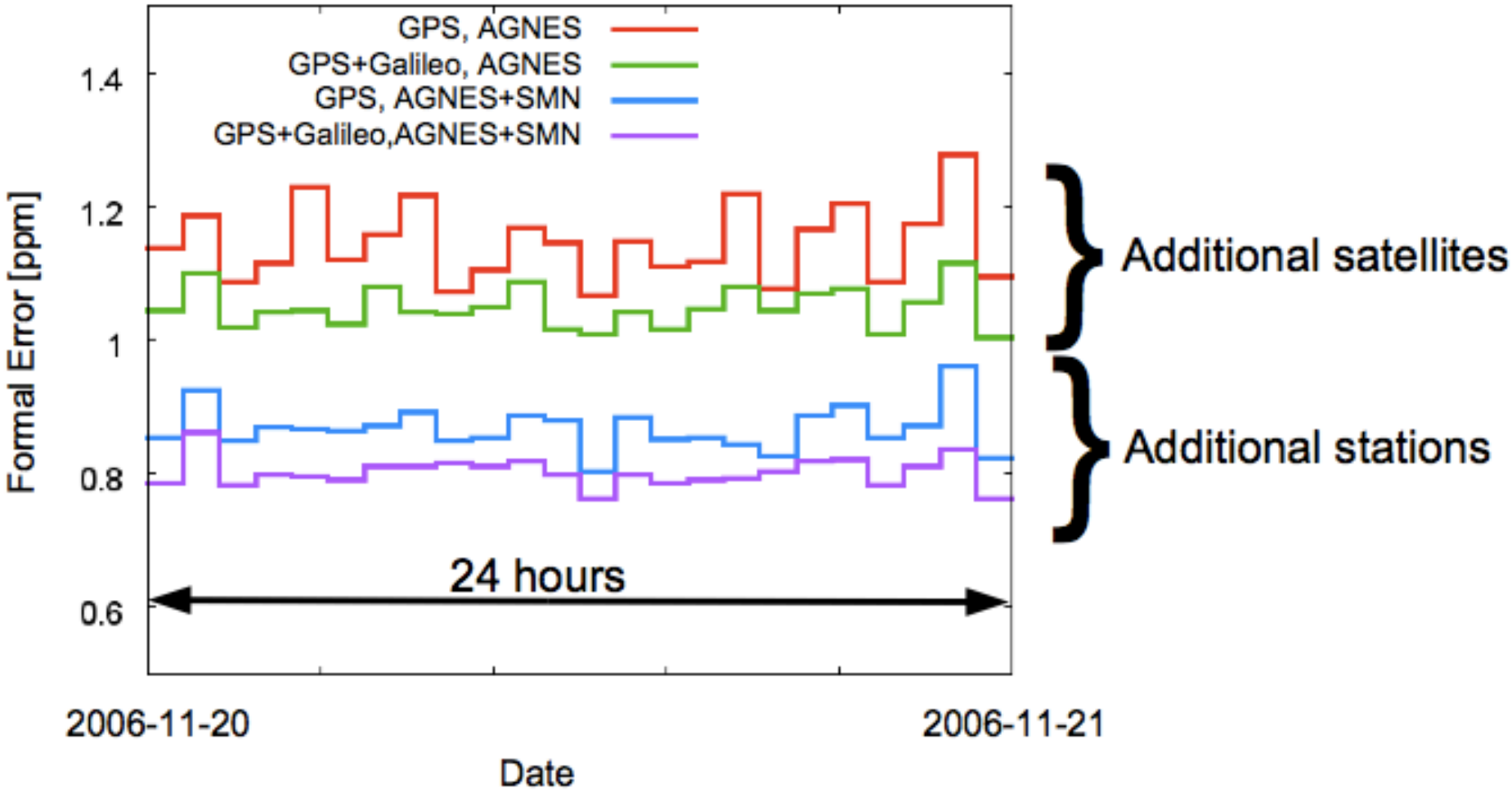
- Cold front passage from 28th/29th May 2006
- Cross section through the wet refractivity field in Switzerland
- Tomographic solution using GPS observations from the AGNES network

Animation allready presented at a previous meeting

RMS of GNSS tomography w.r.t. COSMO-7

Height [m]	Constant [ppm]	Linear [ppm]	Spline [ppm]
1000	11.3	12.0	12.0
2000	9.3	8.9	8.6
3000	8.5	7.4	7.5
4000	7.6	7.3	6.9
5000	4.8	4.1	4.3
0-15000	**3.2**	**3.1**	**3.0**

Error analysis for different improvements in GNSS tomography



Conclusions

- An assimilation system for refractivity observations from GNSS and meteorological sensors successfully implemented
- New parametrizations improve the RMS w.r.t. balloon soundings by about 15%
- Main sources of uncertainty in the validation are
  - The discretization error (std. dev. 1-11 ppm for July 2008 using a horizontal grid spacing of 37 km)
  - Uncertainty in balloon soundings (bias of 3mm ZWD at noon and of 8mm at midnight, std. dev. of 11mm w.r.t. GNSS observations)

Conclusions (cont.)

- Bias correction model improves the RMS of GNSS tomography w.r.t. COSMO-7 up to 35%
- RMS of 3.0 ppm w.r.t. COSMO-7 is achieved with spline parameterization
- Equipping the SwissMetNet with GNSS receivers would improve the formal accuracy about 20%
- Using Galileo in combination with GPS ameliorates the formal error about 10-15%

Outlook

- Improve vertical resolvability
  - Additional complementary observations, such as radio occultations and satellite imagery (IASI, AIRS)
  - Introduce adaptive intervoxel constraints
- Reduce the discretization error
  - Additional observations (IASI, AIRS)
  - Parametrization based on principle EOFs
  - Improve the filter prediction model (e.g. use NWP model)

Main results of the synthetic tests

- Fast convergence rate: GNSS tomography converges to a solution with an inter quartile range smaller than 1 ppm
- Converges to a bias-free solution assuming bias-free GNSS observations
- Good vertical resolvability below the top station of the network
- Limited vertical resolvability above the top station of the network