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# MeteoSwiss Payerne CIMO Testbed
# report on remote sensing activities and interaction with ET-NRST

Terms of Reference for CIMO Testbeds and Lead Centres are available under:
ttp://www.wmo.int/pages/prog/www/IMOP/Testbeds-and-LC.html

| | |
|---|---|
| **Name of Testbed / Lead Centre** | **MeteoSwiss Payerne Testbed** |
| **Location of Testbed / Lead Centre** | **Payerne, Switzerland** |



| Contact Person for the Testbed/Lead Centre | |
|---|---|
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## Report on Activities

# Ground-based remote sensing

## 1. Raman lidar

The Raman lidar deployed at the Payerne site since 2008 is designed to measure humidity, temperature and aerosol profiles for operational meteorology and for long term observations of high quality. A big effort has been made to make the system fully automatic and to achieve a data availability of more than 50% on the basis of several years. This very high availability for a Raman lidar is operationally obtained ever since.

During these last two years, the main activities focused on several topics.

- **Calibration**

In order to improve  calibration of the water vapor measurements a system based on a reference lamp has been installed. Calibration data are acquired once per night and processed automatically.

- **Upgrade of the Raman lidar with a new temperature module (PRR)**

In close collaboration with the EPFL, a new module using fast acquisition was installed on the system. It is now possible to estimate temperature profiles every 30 minutes, weather permitting (Figure 1). This new and essential information is now going through a validation process.

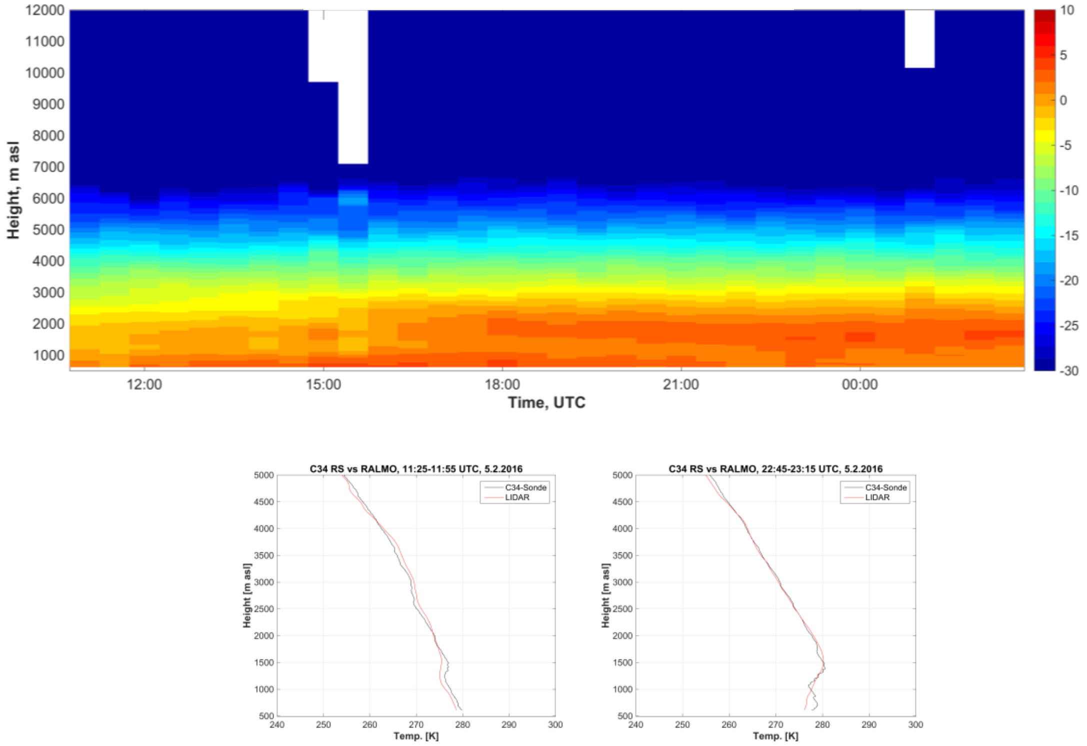


Figure 1 Raman lidar temperature profiles, Payerne, 5 February, 2016. Upper panel: time series (color scale in degrees C); lower panels: single lidar profiles (red) compared to radiosounding temperature profiles (black).

– **Development of a 1D-var retrieval for elastic backscatter and water vapor.**

During the 2014/2015 sabbatical of Prof. Bob Sicca (University of Western Ontario, Canada) at MeteoSwiss Payerne, an Optimal Estimation Method (OEM) was developed for the retrieval of water vapor mixing ratio, aerosol optical depth profile, Ångstrom exponent, lidar constants, detector dead times and measurement backgrounds from multichannel vibrational Raman scatter lidar data. The OEM retrieval provides, in addition to the random uncertainties due to measurement noise, the systematic uncertainties due to the lidar's overlap function and lidar calibration factor, the assumed air density and the Rayleigh-scatter cross sections. The OEM also gives the vertical resolution of the retrieval as a function of height, as well as the height to which the contribution of the a priori is small. The retrieval is demonstrated to give excellent results as compared to the traditional lidar retrieval method as well as with coincident radiosoundings, using measurements in both clear and cloudy conditions, during both the daytime and nighttime.

*Related publications:*

Sica, R.J., and A. Haefele, 2015: Retrieval of Temperature From a Multiple Channel Raman-Scatter Lidar Using an Optimal Estimation Method. Applied Optics, Vol.54, No.8, 1872-1889. http://dx.doi.org/10.1364/AO.54.001872.

Sica, R.J., and A. Haefele, 2016: Retrieval of water vapor mixing ratio from a multiple channel Raman-scatter lidar using an optimal estimation method, Appl. Opt. 55, 763-777.

- **ISSI initiative to harmonize reporting of uncertainties and vertical resolution for temperature and ozone lidars**

The CIMO test bed Payerne participated actively in the ISSI team on “Critical Assessment and Standardized Reporting of Vertical Filtering and Error Propagation in the Data Processing Algorithms of the NDACC Lidars” led by Thierry Leblanc, JPL. Its objective was to review sources of uncertainty in the retrieval of temperature and ozone profiles from lidar backscatter data and the propagation of those uncertainties in the final product. Further, the reporting of vertical resolution has been put on a common basis using two different but equivalent approaches. The full reports are available here: http://www.issibern.ch/teams/ndacc/.

*Publications:*

Leblanc, T., Sica, R. J., van Gijsel, J. A. E., Godin-Beekman, S., Haefele, A., Trickl, T., Payen, G., and Gabarrot, F.: Proposed standardized definitions for vertical resolution and uncertainty in the NDACC lidar ozone and temperature algorithms – Part 1: Vertical resolution, Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2016-119, accepted, 2016.

Leblanc, T., Sica, R., van Gijsel, J. A. E., Godin-Beekmann, S., Haefele, A., Trickl, T., Payen, G., and Liberti, G.: Proposed standardized definitions for vertical resolution and uncertainty in the NDACC lidar ozone and temperature algorithms – Part 2: Ozone DIAL uncertainty budget, Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2016-121, accepted, 2016.

Leblanc, T., Sica, R. J., van Gijsel, J. A. E., Haefele, A., Payen, G., and Liberti, G.: Proposed standardized definitions for vertical resolution and uncertainty in the NDACC lidar ozone and temperature algorithms – Part 3: Temperature uncertainty budget, Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2016-122, accepted, 2016.

- **Generation of O-B statistics using Raman lidar and COSMO humidity profiles.**

Observation minus background (O-B) statistics have been derived for humidity from Raman lidar and COSMO-2 data. The (Figure 9) shows the bias and standard deviation of O-B for different lead times for the 00h UTC run. While the bias stays relatively constant over a 3h forecasting period, the standard deviation increases from 20 to 30% over 3h at 4000 m. This error growth increases with altitude. Note, that at 00h UTC the radiosonde is assimilated into the model, hence the bias and standard deviation of the model analysis is relatively small and comparable to the radiosonde. It could be shown that for the 21h run the bias and standard deviation are significantly bigger and no error growth can be observed, which leads to the conclusion that no update of the humidity field takes in this assimilation cycle. This is due to the lack of continuous humidity observations.

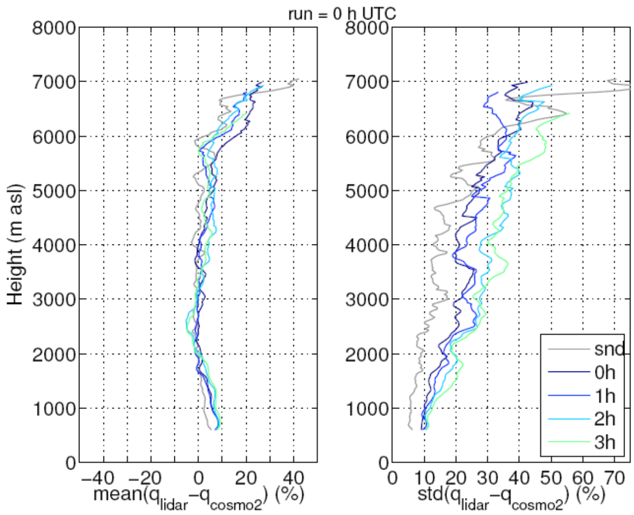


Figure 2 Mean (left panel) and standard deviation (right panel) of the differences between lidar, radiosonde (grey lines), and various lead times of COSMO2 for the 00h UTC run.

– **Contribution to NDACC, GRUAN, NWP**

The data from various systems operated at Payerne and including the Raman lidar are operationally transmitted to NDACC and WMO-GRUAN as well as for NWP models for assimilation (radiosoundings, radar wind profilers) and validation (Raman lidar, microwave radiometer).

## 2. Automatic elastic lidar ceilometer

In the last years it has been realized that the new generation of ceilometers can not only provide cloud base height but also valuable information of the vertical distribution of aerosols. After the eruption of the Eyjafjellajökull volcano in 2010 the ashes have been detected at several sites with advanced ceilometers. Given the relatively low costs and the consequently high density of these instruments, ceilometers have a big potential in the field of aerosol monitoring in the boundary layer and the free troposphere. Calibration of ceilometers is an important step towards data harmonization and quantitative interpretation of the data. In the frame of the EUMETNET program E-PROFILE and the COST action TOPROF calibration procedures are being developed and validated. The Payerne site is taking a leading role in several domains:

- **MeteoSwiss** is actively participating to two important international programmes: the Payerne station has the leadership of the EUMETNET E-Profile Programme as well as the Vice-Chairmanship of the COST Action TOPROF “Towards operational ground based profiling with ceilometers, doppler lidars and microwave radiometers for improving weather forecasts”.
- **An automatic correction of the overlap function of the CHM15K ceilometer** was developed and applied to several ceilometer systems. Imperfections in a lidar's overlap function lead to artefacts in the background, range and overlap corrected lidar signals. These artefacts can erroneously be interpreted as an aerosol gradient or, in extreme cases, as a cloud base leading to false cloud detection. A correct specification of the overlap function is hence crucial to use automatic elastic lidars (ceilometers) for the detection of the planetary boundary layer or low clouds.

*Publication*:

Hervo, M., Poltera, Y., and Haefele, A.: An empirical method to correct for temperature-dependent variations in the overlap function of CHM15k ceilometers, Atmos. Meas. Tech., 9, 2947-2959, doi:10.5194/amt-9-2947-2016, 2016.

- **Operational estimation of the planetary boundary layer**

The planetary boundary layer height (PBL height) is an important parameter for air quality and the dispersion of pollutants in the atmosphere. Four different algorithms have been applied to remotely sense temperature, humidity, wind and aerosol profiles for a continuous monitoring of the boundary layer. The automatic detection of the PBL using ground-based remote sensing systems is still in progress. A publication on retrieval of the PBL using pathfinder methods is in preparation.

## 3. Microwave radiometer profilers

Two microwave radiometers are operationally used in Payerne. The SOMORA ozone profiler is running at 142GHz while the commercially available HATPRO (20-50GHz) provides temperature and water vapor profiles in real-time. Homogenization of the ozone time series (in operation since 2000) is currently under way while. The temperature profiles show still some unexplained biases for which an automatic correction scheme is currently implemented. Finally, HATPRO information is operationally used for the planetary boundary layer detection over Payerne.

*Publicaton:*

Collaud Coen, M., Praz, C., Haefele, A., Ruffieux, D., Kaufmann, P., and Calpini, B.: Determination and climatology of the planetary boundary layer height above the Swiss plateau by in situ and remote sensing measurements as well as by the COSMO-2 model, Atmos. Chem. Phys., 14, 13205-13221, doi:10.5194/acp-14-13205-2014, 2014.
http://www.atmos-chem-phys.net/14/13205/2014/

## 4. Radar wind profilers

The radar wind profiler of Payerne is one segment of the nuclear power plant meteorological surveillance system of Switzerland. Improvement of the system includes some hardware and software upgrades improving the temporal resolution and reducing the external contaminations (i.e. using Gabor algorithm).
The calculation of uncertainties related to radar wind profilers was analyzed by validating profiles from the system at Payerne with 3 years of co-located radiosoundings.

*Publication*:

Haefele A., and D. Ruffieux, 2015: Validation of the 1290 MHz wind profiler at Payerne, Switzerland, using radiosonde GPS wind measurements. *Meteorol. Appl.* (2015), DOI: 10.1002/met.1507.

## 5. Frequency protection

The Payerne test bed is actively engaged on a national and international level to protect frequency bands used by atmospheric remote sensing. This is done in close collaboration with the EUMETFREQ program of EUMETNET and with respective WMO groups. The most urgent issue currently is the protection of the bands used by weather radars around 5 GHz, where RLAN networks cause major interferences.

## 6. Metrology and Meteorology

The Payerne test bed is following closely the preparation of the EMPIR call on environment with the intention to participate in some consortia. Fields of particular interest is are extreme environments (UTLS), traceability of water vapor Raman measurements and Doppler lidar standards.