WMO-CIMO Testbed for In-situ and Remote Sensing Synergistic Profiling (Payerne, Switzerland)

General Site Information

Payerne testbed:
• is the principal atmospheric observing station of Switzerland,
• has operational and research surface and upper air measurement systems as parts of several international long-term monitoring networks and research projects, and
• integrates measurement systems located at higher altitudes on the Alps at some distance from Payerne up to 3500 m asl.

The main objectives are:
• monitoring of a vertical atmospheric column on a long-term basis,
• quality assurance of atmospheric measurement systems, and
• validation of the numerical weather prediction models.

The measurements meet the requirements of several international networks (GSN, GRUAN, GAW, BSRN, NDACC, EMEP). The Payerne observatory is also presently involved in several COST projects and has close collaboration relationships with national and international research groups such as:
• COST Action ES1303 - Towards operational ground based profiling with ceilometers, Doppler lidars and microwave radiometers for improving weather forecasts (TOPROF), and
• EUMETNET – E-PROFILE - Operational use of wind profilers and ceilometers in Europe.

Testbed location:	46.813°N 6.943°E
Climate type:	Dfb (humid continental climate)
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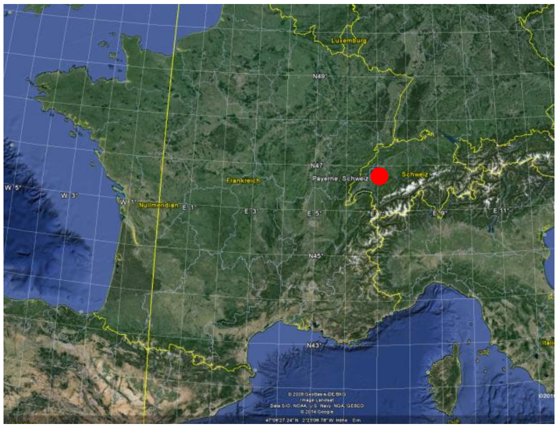
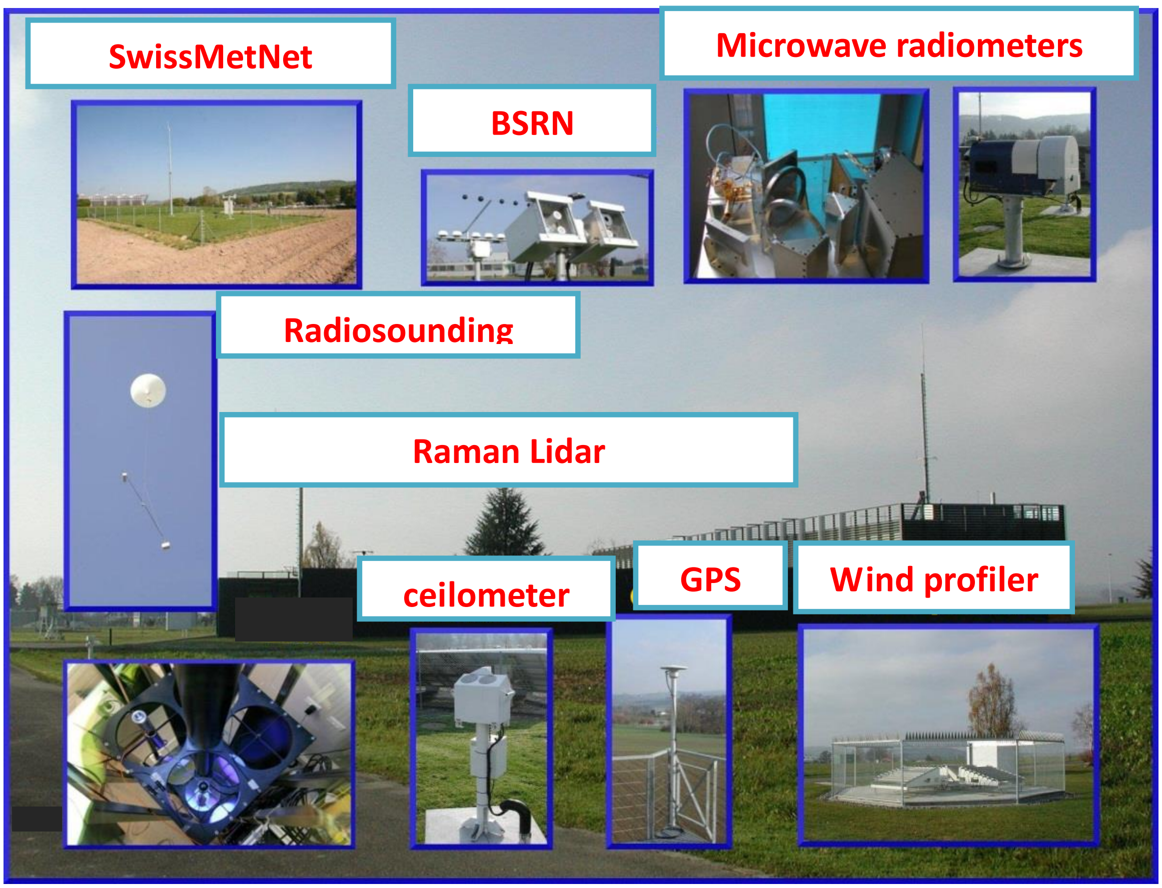


Geographical location of the Payerne station

Wide angle view of the Payerne station.



Measuring systems at the MeteoSwiss Payerne station

Main activities

Areas of special interests and capabilities

In-situ and ground-based remote sensing atmospheric profiling techniques

The main task of the testbed is to test and operate in-situ and remote sensing upper air profiling instruments at the Payerne aerological site. The specific objectives are to:
• compare/assess different in-situ and ground-based remote sensing instruments,
• evaluate and characterize various measurement techniques, and
• determine the measurement uncertainties of each individual instruments.

The final goal will be to establish detailed knowledge on how different upper air parameters (temperature, humidity, cloud cover) can be best measured with lowest uncertainty by integrating different profiling techniques.

The Payerne aerological site is able to:
• provide the core instrumentation at the same location,
• ensure 24-hours 7-day operation of most of the instruments (surface measurements remote sensing, radiation), and
• provide in-situ reference observations using quality operational and scientific radiosondes.

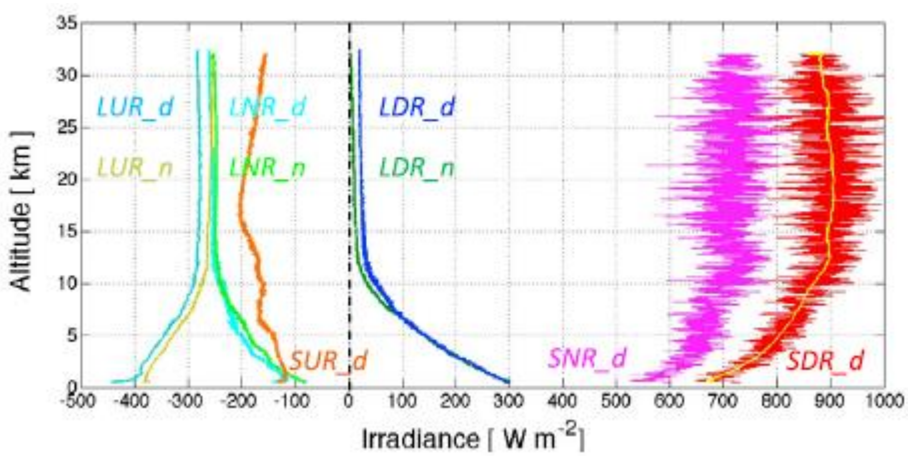
Measurement	Instrument	
Two soundings per day, three ozone soundings per week, one tropospheric *reference* humidity sounding per month	Operational radiosonde station	In-situ
Vertical profile of ozone concentration	Operational ozone microwave radiometer	surface-based remote sensing
Cloud base height and backscatter profiles	Operational ceilometer	
Low-tropospheric wind speed and direction profiles	Operational low level wind profiler (1290MHz)	
Humidity and aerosol profile with high spatial and temporal resolution	Operational water vapour Raman lidar	
Column-integrated water vapour	Operational GPS antenna and microwave radiometer	
Basic meteorological parameters	Operational automatic surface meteorological station	surface condition measurement
Surface radiation measurements	Full Baseline Surface Radiation Network BSRN programme	
	UV components measurement programme	
	surface layer measurements on a 30m mast	
surface air pollution measurement	Operational surface air pollution station	

Selection of projects

Radiosounding of solar and thermal radiation profiles was first made possible at the aerological station of Payerne in September 2011 from the Earth's surface to the stratosphere at 30km above the surface. During the two-hour balloon flights, the solar short-wave and thermal long-wave radiation was measured for both downward and upward directions.

Solar short-wave and thermal long-wave radiation at the Earth's surface and at the top of the atmosphere is commonly measured at surface stations, from aeroplanes and from satellites. However, upper-air observations for climate have recently been given more attention with the initiation of the Global Climate Observing System (GCOS) Reference Upper Air Network (GRUAN) to provide climate-quality measurements of variables in the upper troposphere and lower stratosphere (UTLS). Of greatest importance with regard to climate change are the upward and downward long-wave radiation profiles, which are directly related to the radiative energy flow inside the atmosphere. Measurement of these profiles would contribute to the understanding of radiative forcing and the greenhouse effect.

The radiation profiles could be measured under cloud-free conditions, which constitutes the basis for greenhouse effect studies. Measurement through clouds, aerosols or other atmospheric constituents will allow the investigation of short-wave and long-wave radiative effects of the cloud and its climate forcing at different altitude which is directly related to the greenhouse effect.

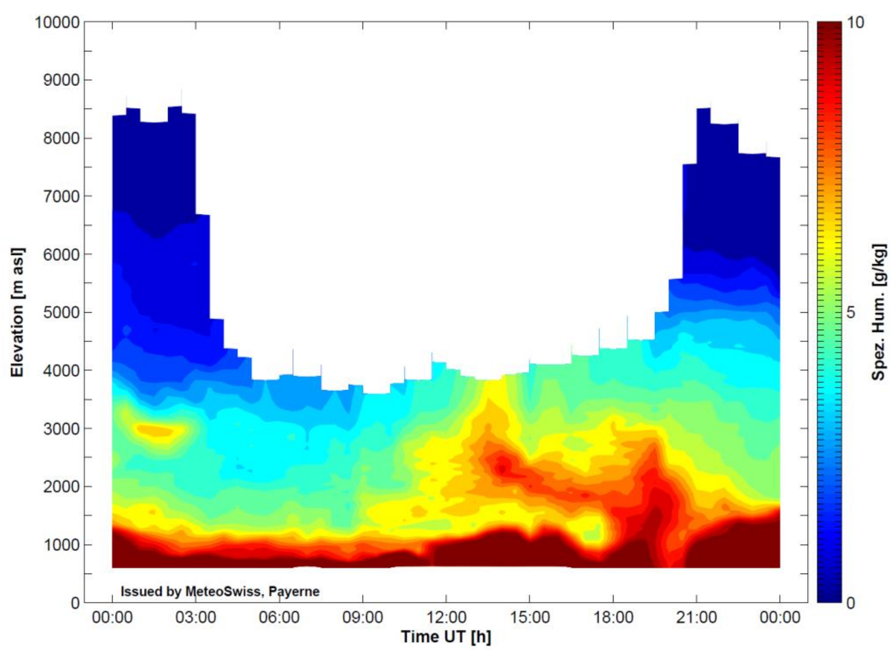


Radiation fluxes profiles measured during daytime (NAME_d) and nighttime (NAME_n) (Philipona et al., 2012).

Raman lidar is one of the few methods that can resolve the very high spatial and temporal variability of water vapor and aerosols in the atmosphere. This technology is hence of greatest interests for meteorology and climatology. The Raman Lidar for Meteorological Observations, RALMO, is a Raman lidar for water vapor profiling. It was built by the Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland, and is operated since 2008 by the Federal Office of Meteorology and Climatology MeteoSwiss, Payerne, Switzerland. RALMO is dedicated to operational meteorology and meets the requirements in terms of data availability (day and night), timeliness and data quality. The lidar is fully automated and eye-safe. Its design guarantees very high system stability and allows water vapor profiling up to 5km during the day and up to 9km at night.

Raman lidar is:
• one of the few methods that can resolve the very high spatial and temporal variability of water vapor and aerosol backscatter profiles in the atmosphere ,
• hence of greatest interests for meteorology and climatology.

The Raman Lidar at Meteorological Observations, RALMO, was built by EPFL, Lausanne, Switzerland, it
• operates since 2008 by the Federal Office of Meteorology and Climatology MeteoSwiss, Payerne, Switzerland,
• is dedicated to operational meteorology and meets the requirements in terms of data availability (day and night), timeliness and data quality. is fully automated and eye-safe,
• features by very high system stability and allows water vapor profiling up to 5km during the day and up to 9km at night, and
• is a demonstrator since Raman water vapor lidars are not yet an established operational observation method.



Specific humidity profile time series measured with the Raman lidar, Payerne, 19 June 2013.

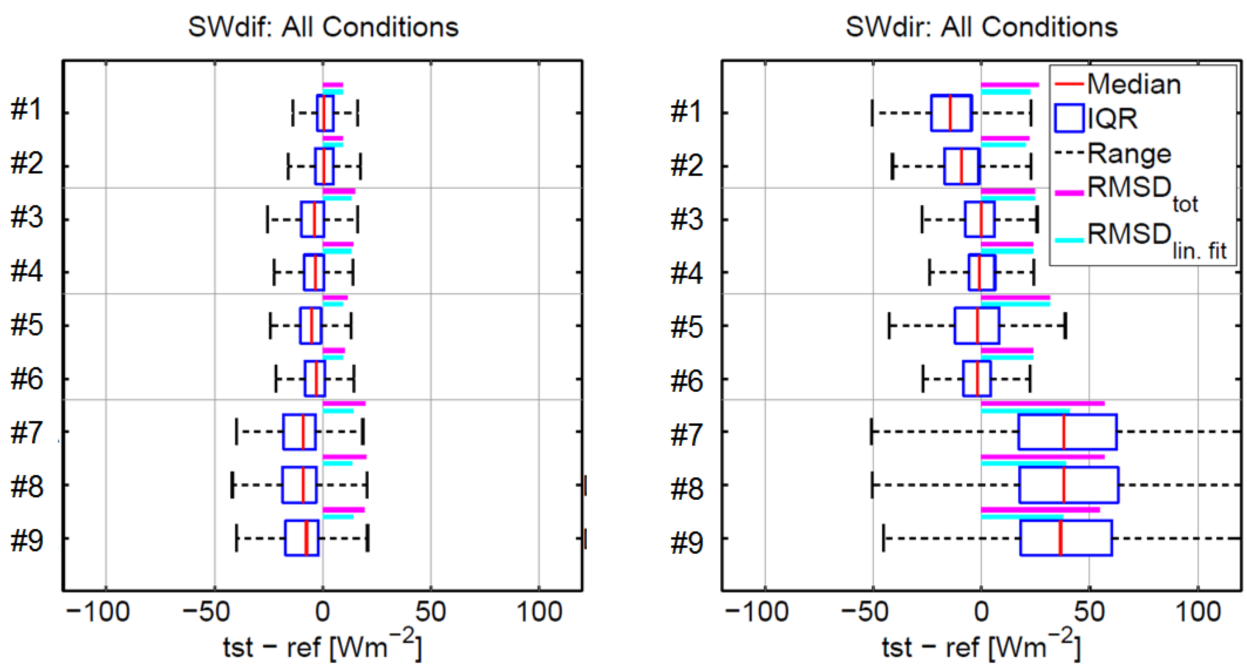
Performance evaluation of radiation sensors for the solar energy sector has got more attention recently. This is because different geometries are used for the solar energy collection devices such as solar concentrators, photovoltaic panels with various orientations or solar thermic panels. Thus, the information about the overall solar energy flux over a horizontal surface is not sufficient for assessing the solar energy input onto the collection devices. Determining angle of the solar direct and diffuse radiation components separately is desired since one can reconstruct the radiance distribution with this information and limited assumptions on the distribution of the diffuse radiance.

COST ES1002 WIRE is a European action aimed at enhancing meteorological forecasting for renewable energy production. Switzerland plays a leading role in COST WIRE, MeteoSwiss being one of the Swiss partners in the collaboration. Within COST WIRE, it was recognized that instruments

- which allow inference of the diffuse and direct component of solar radiation separately, and
- which allow operation in a robust and cost effective way without requiring Sun trackers

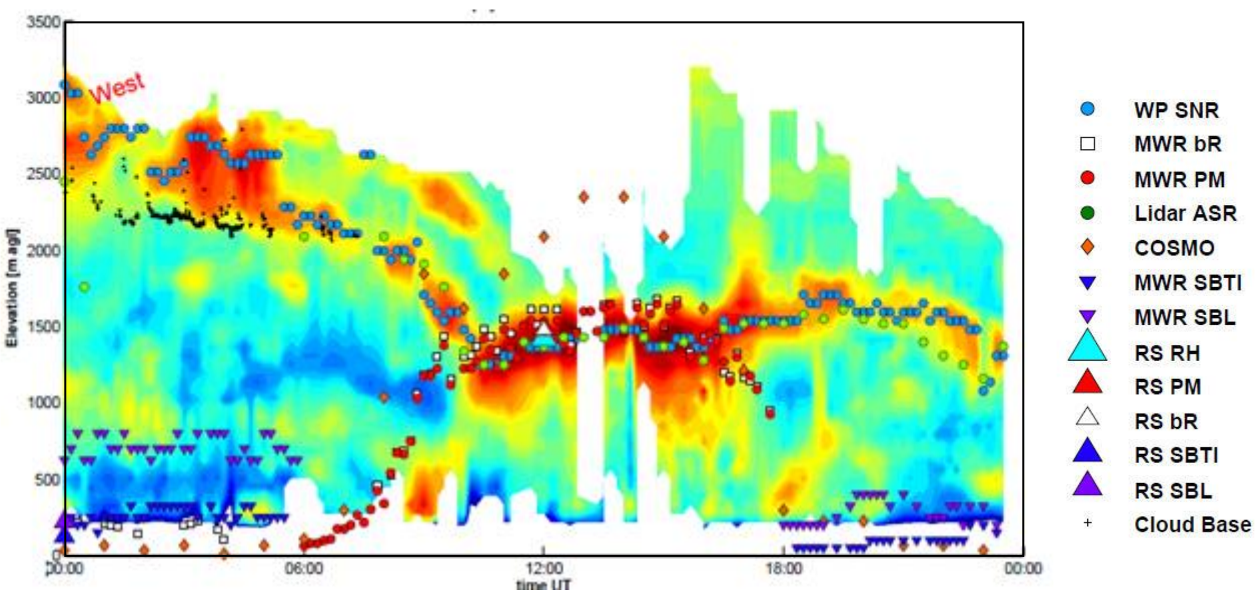
are increasingly used in the solar energy sector.

The necessity of evaluating their performance was emphasized. Following a specific request from COST WIRE, MeteoSwiss took the responsibility of conducting an Inter-comparison of radiometers measuring Direct Normal solar Irradiance (DNI) as contribution to the collaboration. The goal of this on-going project is to compare target instruments to high-accuracy radiation monitoring instruments from the Baseline Surface Radiation Network (BSRN) Payerne site whose reference instruments are directly traceable to the World Radiometric Reference.



Overview of the nine tested instrument performance versus the BSRN reference, for diffuse and direct normal irradiance under all conditions (all solar zenith angles less than 86°).

The planetary boundary layer (PBL) height is a crucial parameter in the dispersion calculation. Therefore the PBL height estimates of the COSMO-2 model have been extensively validated against observations. For comparison PBL height estimates have been derived from measurements from radiosounding, microwave radiometer, windprofiler and Raman lidar using several definitions of the PBL based on atmospheric turbulence and mixing as well as on the thermal structure of the atmosphere. The study revealed that the estimates derived from the observations agree with each other within +/- 100 m on average. Generally good performance of the PBL height estimates from COSMO-2 could be shown but, on average, the PBL height is overestimated by almost 300 m compared to observations. The results have been published in Collaud et al., 2014. Efforts to understand this overestimation and to improve the model estimates are ongoing.



Several automatic detection of PBL height methods from ground-based remote sensing instruments, radiosounding (RS) and COSMO-2 model, Payerne, 31 July, 2012. Background is signal-to-noise ratio profiles from the wind profiler (Collaud Coen et al, 2014).

Selected Publication list

Dinoev, T., V. Simeonov, Y. Arshinov,S. Bobrovnikov, P. Ristori, B. Calpini, M. Parlange, and H. van den Bergh: Raman Lidar for Meteorological Observations, RALMO – Part 1: Instrument description, *Atmos. Meas. Tech.*, 6, 1329-1346, doi:10.5194/amt-6-1329-2013, 2013.

Brocard E, R. Philipona, A. Haefele, G. Romanens, A. Mueller, D. Ruffieux, V. Simeonov, and B. Calpini: Raman Lidar for Meteorological Observations, RALMO – Part 2: Validation of water vapor measurements*, Atmos. Meas. Tech*., 6, 1347–1358, doi:10.5194/amt-6-1347-2013, 2013.

Philipona, R., A. Kräuchi, and E. Brocard, Solar and thermal radiation profiles and radiative forcing measured through the atmosphere, *Geophys. Res. Lett.*, 39, L13806, doi:10.1029/2012GL052087, 2012.

Philipona R., A. Kräuchi, G. Romanens, G. Levrat, P. Ruppert, E. Brocart. P. Jeannet, D. Ruffieux, B. Calpini: Solar and Thermal Radiation Errors on Upper-Air Radiosonde Temperature Measurements, Journal of Atmospheric and oceanic Technology, Vol 30, 2382-2393, DOI: 10.1175/JTECH-D-13-00047.1, 2013.

Milon, A., Bulliard, J.-L., Vuilleumier, L., Danuser, B. and Vernez, D. Estimating the contribution of occupational solar UV exposure to skin cancer, (2014), *British Journal of Dermatology*, **170**, 157–164, doi:10.1111/bjd.12604

Vernez D., A. Milon, L. Vuilleumier, J.-L. Bulliard, A. Koechlin, M. Boniol and J. F. Doré. A general model to predict individual exposure to solar UV by using ambient irradiance data, (2014), *Journal of Exposure Science and Environmental Epidemiology*, **online**, doi:10.1038/jes.2014.6

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