WMO-CIMO Lead Centre on Process-Oriented Observations,
Lindenberg Meteorological Observatory – Richard-Aßmann-Observatory
(Lindenberg, Germany)

General Site Information

For more than 100 years, the Lindenberg Meteorological Observatory (MOL) has been a permanent observing site in a rural landscape with the main focus on vertical profiling of the atmosphere. Today, research activities at MOL are focused on:
• the operational assessment and development of modern ground-based remote sensing techniques,
• the comprehensive quality characterization of radiosonde measurements,
• atmospheric boundary layer and radiation process studies.

Operational measurements carried out in these fields provide comprehensive data sets to characterize the physical state and processes of the atmosphere above Lindenberg, the so-called “Lindenberg Column”.

The observatory
• is a climate reference site of the Deutscher Wetterdienst (DWD)
• operates a 24/7 routine weather station including routine radio soundings every six hours
• hosts the GCOS Reference Upper–Air Network (GRUAN) Lead Centre
• has been approved as a CIMO Tesbed
• contributes to different WMO programs within GCOS and WCRP.

At the Lindenberg Lead Centre on process-oriented observations special activities are carried out that contribute to a detailed and comprehensive measurement-based description and quantitative characterization of atmospheric physical processes, including the quantification of measurement uncertainties. This will be achieved through a synergy between a variety of ground-based remote sensing and in-situ measurement techniques operationally employed at the observatory. The focus is set on aerosol-cloud-radiation as well as on boundary layer and turbulence processes.

Lead Centre location:	52.21°N, 14.12°E
Climate type:	Cfb (maritime temperate, all year wet climate)
Contact person:	Dr. Franz H. Berger – Dr. Frank Beyrich (deputy)
Email:	franz.berger@dwd.de – frank.beyrich@dwd.de
Address:	Deutscher Wetterdienst Meteorologisches Observatorium Lindenberg – Richard-Aßmann-Observatorium Am Observatorium 12 D-15848 Tauche – Lindenberg Germany
Tel:	+49 69 8062 5700

Fax: +49 69 8062 5710

Website: http://www.dwd.de/mol/

Main activities and competences

Radiation processes

For many years now, MOL-RAO has committed itself to be a RA-VI regional radiation center and a Baseline Surface Radiation Network (BSRN) site. To calibrate radiation instruments at the RA-VI radiation centre, three general procedures can be provided:

- Calibration against a secondary standard instrument, which in turn is regularly calibrated versus the World Radiation Centre (WRC) standard,
- Calibration under clear-sky conditions, and
- Calibration under defined standard laboratory conditions – blackbody rooms with / without air conditioning

For more than 75 years, broad-band radiation measurements have been carried out in Potsdam and Lindenberg. For more than 25 years, additional routine spectral and broadband measurements have been carried out at the Lindenberg site, and for aerosol optical thickness also in Zingst (marine site), Hohenpeißenberg (medium altitude mountain site) and Zugpitze (high-level mountain top site). These measurements, in combination with the calibration at the RA-VI center, allow to precisely determine measurement uncertainties and long-term changes in solar and terrestrial radiation. The work at the RA-VI radiation center will soon be accredited according to ISO standardization. As a consequence, guidelines for the measurement principles will be prepared under these regulations. Most recently, activities to measure profiles of radiative fluxes using balloon borne sensors have started.

Vertical profiles

Since the beginning of the implementation of the European Windprofiler Network, previously Eumetnet WinPROF and currently Eumentnet E-PROFILE, MOL-RAO has been deeply involved in the scientific, technical and operational planning and realization of this network and still plays a leading role in the definition of standard operation procedures for radar wind profilers in Europe. Furthermore, MOL-RAO is responsible for the operation of all DWD-482 MHz radar wind profilers. Recently, MOL-RAO started to assess the operational capabilities of state-of-the-art infrared Doppler lidar systems in providing wind profile measurements in the lower troposphere.

In close collaboration with the GUAN and GRUAN network activities, MOL-RAO provides a climate chamber (with variable pressure from 10 to 1000 hPa, variable temperature from 190 to 300K, variable relative humidity from 0 to 100%, and variable wind speed from 0 to 10 m/s) to calibrate routine and research radiosondes. An important task of GRUAN is to determine measurement uncertainty and to document the entire data processing and analysis chain. This information / guidance is provided to all WMO members.
At MOL-RAO, routine radiosondes are launched every six hours, whereas different types of research sondes (see the table above) are launched on a monthly basis. During various experimental campaigns, performed over the past years, a more frequent launch of clusters of routine and research sondes could be realized. For the campaigns, several radiosonde manufactures provided significant contribution, like new or updated research/routine radiosondes. These campaigns/comparison studies led to a close collaboration between

manufacturers and the Lindenberg observatory.

Cloud processes

Based on the continuous operation of a ceilometer, a microwave radiometer profiler, and a cloud radar, MOL-RAO has contributed to the Cloudnet project since 2004. This initiative was started under the EU FP 5 Research Program with the goal to derive cloud microphysical parameters from the synergy of ground based remote sensing data. More recently, emphasis has been put on the additional analysis of Raman lidar measurements, including Raman lidar spectroscopy.

Boundary layer processes

In 1998, MOL-RAO started a comprehensive operational micrometeorological and boundary-layer measurement program. A special facility, the Falkenberg boundary layer field site (in German: Grenzschichtmessfeld <GM> Falkenberg), has been created and equipped for this purpose. The field site consists of a 10m meteorological mast and a 99m tower, both instrumented with standard sensors for detailed profile measurements of wind, temperature and humidity. Radiation fluxes are measured both at 2m height above short grass and on top of the 99m-tower. The measurement program also includes soil temperature and soil moisture profile measurements down to a depth of more than 1 m, near-surface soil heat flux measurements, and turbulence measurements using the eddy-covariance method at several heights. A second permanent measurement site has been set up in 2003 in a pine forest (Forst Kehrigk station) with analog instrumentation at and around a 30m lattice tower.

Special emphasis of the boundary layer measurement program has been put from the beginning on the investigation of land – atmosphere interaction processes over a heterogeneous land surface consisting of patches of forest, farmland, meadows, small lakes and villages. A series of field experiments was performed during the last 20 years within the frame of the LITFASS program (where LITFASS stands for Lindenberg Inhomogeneous Terrain – Fluxes between the Atmosphere and the Surface: a long-term Study) in order to test and to assess different methods to derive area averaged surface fluxes for a patchy heterogeneous land surface. This in particular included the introduction and testing of scintillometry as a remote sensing technique to operationally estimate area-averaged surface fluxes.

Based on the energy flux measurements and related meteorological measurements provided to the Coordinated Energy and water cycle Observations Project (CEOP) of the World Climate Research Program (WCRP), MOL-RAO participated in the definition of standard quality assurance procedures for these fluxes.

Ongoing and planned projects

2014-2016

- Development and testing of algorithms to derive sunshine duration from global radiation measurements and assessment of regionally varying conditions on the results

- Definition of calibration and data processing procedures for optical scintillometers
- Derivation of fog characteristics from ground-based remote sensing (in particular scanning cloud radar)
- Measurement of boundary layer radiative flux profiles by tethered balloon system

2016-2018

- Assessment of the solar radiation influence on pyrgeometer measurements
- Derivation of turbulence parameters / mixing height from IR Doppler lidars
- Automatic detection and quantitative characterization of low-level clouds (derivation of cloud cover and cloud-base height / ceiling) from a combination of ground-based remote sensing instruments Nubiscope + Ceilometer + Doppler-Lidar

Infrastructure description

MOL runs a comprehensive measurement program on an operational basis (24/7), the details are given in the Table below. National and international research groups are welcome to join the scientists and technicians at the observatory for detailed studies on atmospheric processes based on these operational measurements. MOL has available a wide range of logistic capabilities to install and to run additional instrumentation, including

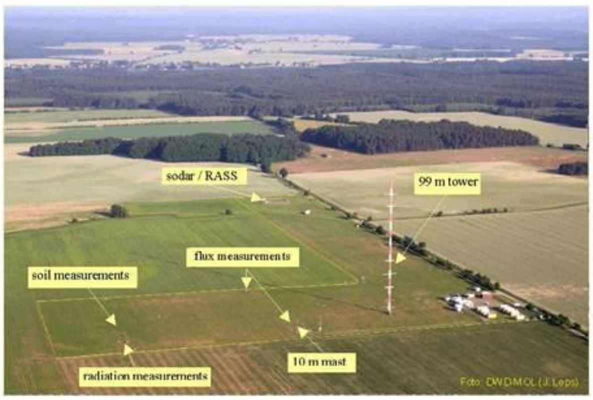
- the remote sensing field site
- a lidar laboratory building with roof platform
- a radiation laboratory building with roof platform
- a large balloon barn
- the boundary-layer grassland field site with its 99m tower

Measurements	Sensors / Systems	Measured / Derived Atmospheric Variables	(Typical) Height Range
in-situ aerological soundings	operational radiosondes (Vaisala RS92, Graw)	horizontal wind vector, temperature, humidity, pressure	0 – 35 km
	research radiosondes (CFH, SnowWhite, Flash)	horizontal wind vector, temperature, humidity, pressure	0 – 35 km
	ozone sonde (ECC)	ozone mixing ratio	0 – 35 km
ground-based remote sensing	482 MHz radar wind profiler / RASS	horizontal wind vector virtual temperature	0.5 – 16 km (0.5 – 3 km)
	Sodar / RASS	horizontal wind vector virtual temperature	0.05 – 0.5 km (0.05 – 0.2 km)
	IR Doppler lidar	horizontal wind vector	0.05 – 2 km
	Raman lidar	water vapour mixing ratio, temperature, aerosol and cloud parameters (e.g., backscatter / extinction coefficients)	0.1 – 16 km

	35.5 GHz cloud radar	reflectivity, Doppler velocity, LDR (CLOUDNET standard products)	0.2 – 15 km
	microwave radiometer profiler	temperature, humidity, liquid water path	0 – 10 km
	laser ceilometer	cloud base height, aerosol layer heights	0.05 – 12 km
	GPS receiver	Column-integrated water vapour content	
micrometeorological and boundary layer measurement techniques and sensors	in-situ sensors on a 10m mast and 99m tower	horizontal wind vector, temperature, humidity	0.5 – 100 m
	sonic + IR gas analyser	turbulence variables (variances, fluxes, …)	2 – 90 m
	soil sensors	soil temperature, soil moisture, soil heat flux	- 0.5 – - 1.0 m
	scintillometers	regional-scale turbulent fluxes	sfc
radiation measurements	broadband radiometers	broadband shortwave / longwave radiative fluxes	sfc
	precision filter radiometers	aerosol optical depth in 8 spectral bands (412 nm – 1024 nm)	sfc
	star photometer	aerosol optical depth in 17 spectral bands (400 nm – 1050 nm)	sfc
	precision spectral radiometer	direct solar irradiance at high resolution (300 nm – 1024 nm)	sfc
	UV spectral radiometers	UV radiation fluxes	sfc
	whole sky imager	macroscopic cloud characteristics	sfc
	broadband radiometers carried by tethered balloon	broadband shortwave / longwave radiative fluxes	sfc – 1.0 km

The remote sensing field with the 482 MHz wind profiler

The lidar laboratory building with the roof platform



The Falkenberg boundary layer field site

The roof platform of the radiation laboratory building

Publications

Braam, M.; A. F. Moene; F. Beyrich, 2014: Variability of the Structure Parameters of Temperature and Humidity Observed in the Atmospheric Surface Layer Under Unstable Conditions. *Boundary-Layer Meteorol.* **150**, 399 – 422, doi: 10.1007/s10546-013-9882-2

Madonna, F., M. Rosoldi, J. Güldner, A. Haefele, R. Kivi, M.P. Caddedu, D. Sisterson, G. Pappalardo, 2014: Quantifying the value of redundant measurements at GCOS Reference Upper-Air Network sites. Atmos. Meas.Tech. 7, 3813-3823, doi: 10.5194/amt-7-3813-2014

Martin, S.; F. Beyrich; J. Bange, 2014: Observing Entrainment Processes Using a Small Unmanned Aerial Vehicle: A Feasibility Study. *Boundary-Layer Meteorol.* **150**, 449 – 467, doi: 10.1007/s10546-013-9880-4

Inai, Y.; F. Hasebe; M. Fujiwara; M. Shiotani; N. Nishi; S.-Y. Ogino; H. Vömel; S. Iwasaki; T. Shibata, 2013: Dehydration in the tropical tropopause. Layer estimated from the water vapour match. *Atmos. Chem. Phys*. 13, 8623-8642, doi: 10.5194/acp-13-8623-2013

Khaykin, S. M.; I. Engel; H. Vömel; I. M. Formanyuk; R. Kivi; L. I. Korshunov; M. Krämer; A.D. Lykov; S. Meier; T. Naebert; M. C. Pitts; M. L. Santee; N. Spelten; F.G. Wienhold; V.A. Yushkov; T. Peter, 2013: Arctic stratospheric dehydration – Part 1: Unprecedented observation of vertical redistribution of water. *Atmos. Chem. Phys*. 13, 11503-11517, doi: 10.5194/acp-13-11503-2013

Köhler, F., U. Görsdorf, 2014: Towards 3D prediction of supercooled liquid water for aircraft icing: Modifications of the microphysics in COSMO-EU. Meteorol. Z., 23,No 3, 253-262, doi: 10.1127/metz/2014/0545

Hünerbein, A., H. Deneke, A. Macke, K. Ebell, U. Görsdorf, 2014: Combining the Perspective of Satellite- and Ground-Based Observations to Analyze Cloud Frontal Systems. J. Appl. Meteorol. 53, 2538-2552, doi: 10.1175/JAMC-D-13-02741.1

Beyrich, F.; J. Bange; O. K. Hartogensis; S. Raasch; M. Braam; D. van Dinther; D. Gräf; B. van Kesteren; A. C. van den Kroonenberg; B. Maronga; S. Martin; A. F. Moene, 2012: Towards a validation of scintillometer measurements: The LITFASS-2009 experiment. *Boundary-Layer Meteorol.* 144, 83-112, doi:10.1007/s10546-012-9715-8

Brabec, M.; F. G. Wienhold; B. P. Luo; H. Vömel; F. Immler; P. Steiner; E. Hausammann; U. Weers; T. Peter, 2012: Particle backscatter and relative humidity measured across cirrus clouds and comparison with microphysical cirrus modelling. *Atmos. Chem. Phys*. 12, 9135-9148, doi:10.5194/acp-12-9135-2012

Junk, J.; U. Feister; A. Helbig; K. Görgen; E. Rozanov; J.W. Krzyscin; L. Hoffmann, 2012: The benefit of modelled ozone data for the reconstruction of a 99-year UV radiation time series. *J. Geophys. Res*. 117, D16102, doi:10.1029/2012JD017659

Van den Kroonenberg, A.C.; S. Martin; F. Beyrich; J. Bange, 2012: Spatially-averaged temperature structure parameter over a heterogeneous surface measured by an unmanned aerial vehicle. *Boundary Layer Meteorol.* 142, 55-77, doi:10.1007/s10546-011-9662-9

Reichardt,J.,U. Wandinger, V. Klein, I. Mattis, B. Hilber, R. Begbie, 2012: RAMSES: German Meteorological Service autonomous Raman lidar for water vapor, temperature, aerosol, and cloud measurements. Appl. Optics, 51, No. 34, 8111-8131

Reichardt, J., 2014: Cloud and Aerosol Spectroscopy with Raman Lidar. J. Atmos. Oceanic Technol. 31, 1946-1963, doi: 10.1175/JTECH-D-13-00188.1

Spänkuch, D.; J. Güldner; H. Steinhagen; M. Bender, 2011: Analysis of a dryline-like feature in northern Germany detected by ground-based microwave profiling. *Meteorol. Z.* 20, 409-421