Deutscher Wetterdienst sites around Germany

Lindenberg Meteorological Observatory – Richard Assmann Observatory
Deutscher Wetterdienst - Weather and climate from a single source

The Deutscher Wetterdienst (DWD) has been the authoritative source of weather and climate information in the Federal Republic of Germany since it was established in 1952. The multitude of services which the DWD provides to all sectors of the economy and society results from its statutory duty to inform and conduct research as laid down in the ‘Law on the Deutscher Wetterdienst’. The DWD is a public institution and, as a federal authority, is directly accountable to the Federal Ministry of Transport and Digital Infrastructure (BMVI).

With around 2,000 weather stations (both automatic and staffed) and measuring sites, the DWD operates one of the densest and most efficient weather and climate observing networks in the world. At present, there are around 2,500 highly qualified people working for the DWD, from weather observers and meteorologists through to IT or administrative specialists.

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Our tasks:

- Weather forecasting and disaster risk reduction
- Safeguarding of aviation and shipping
- Climate and environment consultancy
- Climate monitoring
- International co-operation
- Data acquisition and data management

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The DWD operates two research observatories for the intensive, long-term monitoring of the atmosphere and the improvement of its weather forecasts: the Lindenberg Meteorological Observatory – Richard Assmann Observatory in the federal state of Brandenburg and the Hohenpeissenberg Meteorological Observatory in Upper Bavaria, each of which is responsible for many different scientific tasks. The Lindenberg Meteorological Observatory – Richard Assmann Observatory, mostly abbreviated to MOL-RAO, was initially inaugurated in 1905 as the Royal Prussian Aeronautical Observatory by Richard Assmann, who invented the aspiration psychrometer named after him and, jointly with France’s Teisserenc de Bort, discovered the stratosphere.

The main focus of the work carried out at the observatory for over 100 years has been the vertical profiling of the atmosphere. This was originally done using captive balloons and kites, from the 1930s onwards with radiosondes and, over the last 20 years, increasingly with the help of ground-based remote sensing methods, such as radar and lidar. The world record of 9,750 m for kite ascents was established at the observatory on 1 August 1919, and has not been broken since.

Other current research activities are focused on measuring programmes for the study of solar and terrestrial radiation and interaction processes between the earth’s surface and the atmosphere. The data derived from all the observatory’s measuring programmes are used to produce a reference data set, the ‘Lindenberg Column’, for characterising the vertical structure of the atmosphere from the ground up to the stratosphere.

The observatory is integrated in numerous international and national scientific partnerships. In the context of international programmes, the data obtained in Lindenberg make a significant contribution to the monitoring of the earth’s climate and are used to calibrate satellite sensors and to verify weather prediction and climate models. The observatory’s scientists also test new sensors and observing systems for their potential operational employment in the DWD’s measuring network.
**Aerological ascent and testing site**

Radiosondes on free-flying balloons are still the worldwide standard technique for measuring the vertical profiles of air pressure, temperature, humidity and wind in the troposphere and the lower stratosphere (up to about 35 km in altitude).

Regular daily soundings began at Lindenberg in 1947. At present, four routine soundings are performed every day (at 00, 06, 12 and 18 UTC) and a radiosonde measurement of the ozone profile is carried out once a week. Every month, two research soundings are performed which focus on the exact measurement of the atmosphere’s water vapour content.

The MOL-RAO is also the DWD’s aerological testing site. The activities are aimed at testing and characterising various modern radiosondes and, in particular, at examining the calibration, inertia and radiation sensitivity of the sensors. Special laboratories, experimental systems and a climate chamber are available for this purpose. In addition, special research sondes are used to validate routine radiosonde measurements during simultaneous flights. Procedures for correcting and testing radiosonde sensors are developed and made available internationally in the framework of GRUAN (see page 10). Tests are also performed on, e.g., the balloons and parachutes used for radiosonde ascents and descents.

**Ground-based remote sensing**

Several new and powerful methods to quantitatively characterise the state of the atmosphere have become available over the last three decades. Alongside the satellite-based technologies, a number of ground-based remote sensing techniques have been developed and improved. These include radar systems operating at decimetre and millimetre wavelengths, laser measuring systems (lidar), which function across a spectral range from ultraviolet through to near-infrared, and passive measuring instruments for capturing the atmosphere’s own radiative properties, particularly at centimetre wavelengths.
These complex and powerful remote sensing methods enable the continuous determination of the vertical profiles of thermodynamic parameters, such as wind, temperature and air humidity, at high temporal and vertical resolution. In this way, even small-scale and short-lived structures in the atmosphere can be recorded – which is almost impossible with radiosondes launched every six or twelve hours. It is also possible to obtain indirect information about small liquid and solid particles (clouds, aerosols) which are suspended in the atmosphere. These particles are of considerable relevance to the physics of the atmosphere and thus for the weather and climate (e.g. clouds and precipitation formation, radiation balance). These new measurement methods are being tested and developed further at the MOL-RAO with the aim of using them operationally in the DWD's measuring network or as part of the Lindenberg Column research measurement programme. The most important systems are:

- radar wind profiler (UHF, 62 cm wavelength);
- cloud radar (8.6 mm wavelength);
- infrared Doppler lidar (1.5 µm wavelength);
- Raman lidar (355 nm wavelength);
- microwave radiometer (0.5–1.3 cm wavelength).
Boundary layer measurements

The atmospheric boundary layer is that part of the lower atmosphere which is directly influenced by the earth’s surface. Important processes include radiation, surface friction and the effects of obstacles on the wind as well as the exchange of energy and trace substances between the soil/vegetation system and the air. The atmospheric boundary layer is that part of the atmosphere where humans almost always live and act. This is also where the temporal and spatial variability of temperature, air humidity or wind is most pronounced. Dew, hoar-frost, fog, turbulence and convection are typical boundary layer phenomena.

It is for this reason that understanding boundary layer processes is crucial for a reliable weather forecast and many of the DWD’s advisory services. Therefore, a comprehensive boundary layer measurement programme has been in place at the MOL-RAO since 1998. A special measurement site was set
up for this purpose near the village of Falkenberg, just a few kilometres south of Lindenberg. Another measurement station was established in a pine forest near Kehrigk (approximately ten kilometres to the west of Falkenberg). The profiles of wind, temperature and atmospheric water vapour are measured at both sites on high masts (99 m at Falkenberg and 30 m at Kehrigk). The turbulent fluxes of momentum, energy and water vapour between the ground and the atmosphere are also recorded at high temporal resolution.

Measurements above mast height are carried out using ground-based remote sensing systems, namely Sodar/RASS and lidar. Short and long-wave upward and downward radiation fluxes as well as the temperature and the water content of the soil are also measured. Scintillometry is used between the two locations at Falkenberg and Lindenberg to determine the integral influence of meadows, fields and built-up areas on the transfer of energy. These systems measure fluctuations in the intensity of infrared or microwave radiation along the approximately five kilometre long propagation path.

All the data from the boundary layer measurement programme are primarily used to improve weather forecasting and climate modelling, as well as to describe the conditions for the transport and dispersion of atmospheric pollutants and to characterise the atmospheric conditions for the use of solar and wind power.
Radiation processes - national and regional radiation measurement centre

The short- and long-wave radiation fluxes from the sun, the sky and the earth's surface are the most important factors supporting life on earth and make the biggest contribution to the global energy balance. Temporal and spatial differences in the radiation balance generate the weather and thus have a crucial impact on our climate. As the sun's radiation is altered as it passes through the atmosphere, analysis of its spectral composition, in particular, provides information about atmospheric gases (e.g. ozone, water vapour) or particles (so-called aerosols).

The MOL-RAO's tasks include acquiring and analysing high-time-resolution data of both the direct and diffuse (i.e. scattered by molecules in the atmosphere and/or reflected by the clouds) short-wave solar radiation as well as the global radiation (i.e. the sum of direct and diffuse solar radiation). This is done using pyrheliometers and pyranometers. Pyrgeometers measure the atmospheric thermal radiation which results from the thermal emission by the different constituents of the atmosphere (gases, aerosols and clouds) depending on their temperature. For over 20 years, the resulting data sets have been transmitted to the international data centre at the Alfred Wegener Institute for Polar and Marine Research in Bremerhaven within the framework of the Baseline Surface Radiation Network (BSRN). The BSRN is one component of the WMO's global climate observing activities (see the section on national and international projects and programmes). The data are used in national and international programmes for the purposes of analysis and the monitoring of climate changes as well as for the validation of satellite-based radiation measurements and for the verification of climate models. Data on solar radiation are particularly needed to find suitable sites for photovoltaic energy production, to verify their yield prospects and to optimise and develop further the corresponding technology.

Sun and star photometers can be used during cloudless days and nights to determine the atmosphere's integral aerosol and water vapour content. These are very important variables for climate change studies. Other measurements of spectral radiation provide information about the thickness of the total ozone column and about UV radiation. These data are used to analyse the weathering of paints and varnishes, for example, or to assess the risk of skin cancer. In addition to this, spectral radiation measurements are carried out to obtain information about clouds. Clouds are often highly variable in time and space and have a huge influence on the radiation balance and thus on the climate.

Measuring instruments must be regularly calibrated to international standards to ensure worldwide comparability of the obtained radiation data. All the radiation measuring instruments used in the DWD's network must also be inspected and calibrated. These tasks are undertaken by the MOL-RAO in its function as Germany's national and the WMO's regional (RA VI Europe) radiation measurement centre.

Cleaning of radiation sensor domes

Adjustment of a pyranometer for calibration in the laboratory

✓ Automatic adjustment of the filter radiometer for aerosol optical depth measurements
GRUAN Lead Centre

To date, climate research can make only limited use of the measurement data which the well-developed global radiosounding network collects in the upper troposphere and lower stratosphere. This is primarily due to the wide variety of different radiosonde models in use around the world, as well as to the lack of parallel measurements when changing the type of radiosonde or launch methods and to the insufficient knowledge about errors that could occur in the radiosonde sensors used.

The WMO responded to this deficit by establishing the GCOS Reference Upper-Air Network (GRUAN) as an international observing network of aerological reference stations around ten years ago. GRUAN is designed to meet the specific requirements of climate monitoring and fill an important gap in the current global observing system. GRUAN is envisaged as a global network which will comprise 30 to 40 sites with dedicated equipment to obtain high-quality data from the free atmosphere on a long-term basis. The network currently consists of 22 stations, with Lindenberg taking the role of GRUAN’s Lead Centre and thus being responsible for monitoring and developing the entire network. This includes co-ordinating the network itself as well as organising the co-ordination among the stations, defining, testing and introducing...
quality assurance procedures, training launch staff, archiving and disseminating GRUAN data and reporting to the WMO. Within the GRUAN framework, the results of the MOL-RAO’s work as an aerological testing office and launch station are also made available to a worldwide community. This enables the co-ordinated development of knowledge of radiosonde sensor technology as well as of correction and test procedures.

- Burst of a weather balloon at about 32 km in altitude
Support for numerical weather forecasting

These days, weather forecasts and climate projections are primarily based on model simulations relying on highly complex numerical computer models. Appropriate equations are used to describe the physical and chemical processes which determine the behaviour of the atmosphere and its interaction with the land surface, oceans and ice sheets. The models require data on the current state of the atmosphere for each new simulation. For this purpose, the MOL-RAO transmits the near-ground measurements made in Lindenberg and Falkenberg as well as the data obtained from both radiosonde ascents and radar wind profiler measurements to the DWD headquarters in Offenbach on a regular and real-time basis. From Offenbach, they are subsequently disseminated around the world.

Weather forecast models are unable to explicitly simulate many phenomena and processes, such as the different surface characteristics of lakes, fields, forests and settlements, turbulence in the boundary layer, absorption of light and energy by dust particles or the formation of clouds and raindrops. This requires the integration of simple equations, so-called parameterisations, which are able to describe the effects of small-scale processes (rather than to simulate the processes as such in detail). The extensive data records obtained by the MOL-RAO play an invaluable role in the development and assessment of such parameterisations.

Contributions for the DWD's observing network

Climate reference stations, one of which is in Lindenberg, are one component of the DWD’s dense and powerful measuring network. The climate reference stations must, among other things, ensure that the quality of the DWD’s climatological observation series is guaranteed despite inevitable changes in measurement technology. The introduction of a new type of thermometer, for example, should not lead to a sudden change in the temperature curves just because of the new technology being used. For this reason, the climate reference stations use old and new sensors in parallel for several years in order to determine and, if necessary, correct any deviations. These parallel measurements are made for all important climate variables (temperature, precipitation, air humidity, snow depth, radiation, wind).

The DWD lives up to the claim that it always provides state-of-the-art forecast and advisory services. This involves continuously improving its models,
the use of satellite data and using modern sensors and measurement methods for recording and monitoring the current state of the atmosphere. In recent years, this had led to the complete modernisation of measuring systems such as the weather radars. In many cases, human observations and the manual collection of data have been replaced by automatic sensors.

In connection with the introduction of new measuring instruments, the MOL-RAO regularly takes on tasks relating to market analysis, prototype testing and the operational qualification of procedures and algorithms, particularly in the fields of aerology and radiation measurements. New radiosondes, radiation sensors or ceilometers are always first used in Lindenberg, where their suitability for use in the operational network is tested on a sound scientific basis.

Both the DWD's radiation network (approximately 100 stations) and wind profiler network (four sites) are scientifically supported by the MOL-RAO. The observatory's scientists are also developing methods and algorithms to determine parameters, such as sunshine duration or cloud cover, automatically from a combination of measurements taken by various instruments.

National and international projects

The Lindenberg observatory transfers a large part of its measured data to international data centres. Besides the aforementioned GRUAN and BSRN databases, these also include centres for the collection of aerosol, cloud, ozone, soil moisture and turbulent flux measurements. Some data sets are also provided directly on the Internet for general research purposes. Another important part of the observatory's work is the co-operation with other research institutions in Germany and abroad on projects which, amongst others, are supported by the Federal Ministry of Education and Research (BMBF), the German Research Foundation (DFG) or the European Union. The combination of research and long-term measurements as well as the direct scientific evaluation of measurement data is a unique selling point for the MOL-RAO. With both its observatories, the DWD makes a vital contribution to the monitoring of the atmosphere and the study of the climate.
**Historical milestones**

**April 1905:** Beginning of captive balloon and kite ascents in Lindenberg

**16 October 1905:** Inauguration of the Royal Prussian Aeronautical Observatory in Lindenberg in the presence of Emperor Wilhelm II and Prince Albert of Monaco

**1910:** Warning service for aviation established, with the headquarters in Lindenberg and a measuring network of 15 pilot balloon sounding stations across Germany

**1 August 1919:** Kite world record of 9,750 m with a train of eight Lindenberg kites

**22 May 1930:** First ascent of a radiosonde in Lindenberg (up to 14.5 km)

**15 July 1947:** Beginning of regular aerological radiosonde ascents, which are continued without interruption until today

**1950:** Foundation of the Meteorological Service (MD) of the German Democratic Republic and integration of the Lindenberg Aerological Observatory

**21 October 1964:** Start of the first drifting balloon with a volume of up to 6,400 m³ for wind measurements in the stratosphere

**01 December 1974:** Beginning of routine ozone soundings in Lindenberg

**1975:** First ozone soundings in the Antarctic by scientists from the Lindenberg Observatory

**1983:** Development of a ground-atmosphere spectrometer to determine the spectral aerosol optical depth (from 1986 part of the routine measuring programme)

**21 October 1988:** Launch of the first meteorological rocket at Zingst research station

**1 January 1991:** Integration of the Lindenberg Meteorological Observatory in DWD

**07 October 1993:** Beginning of operation of the first wind profiler radar/RASS at MOL (1,290 MHz)

**1 October 1994:** Beginning of routine measurements at Lindenberg global BSRN station
1998: Beginning of operational measurements at the Falkenberg boundary layer field site

2003: Inauguration of the radiation measurement centre at the observatory

2005: Renaming as Lindenberg Meteorological Observatory - Richard Assmann Observatory on the occasion of the observatory's 100th anniversary

2008: Assignment to MOL-RAO of the function of the Lead Centre for the WMO's Global Reference Upper-Air Network (GRUAN)

<table>
<thead>
<tr>
<th>Weather Records</th>
<th>1907–2014</th>
<th>8.8 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean annual temperature</td>
<td>1907–2014</td>
<td>8.8 °C</td>
</tr>
<tr>
<td>Highest temperature</td>
<td>1906–2014</td>
<td>38.5 °C</td>
</tr>
<tr>
<td>Lowest temperature</td>
<td>1906–2014</td>
<td>-28.0 °C</td>
</tr>
<tr>
<td>Warmest month</td>
<td>1906–2014</td>
<td>24.3 °C July 2006</td>
</tr>
<tr>
<td>Coldest month</td>
<td>1906–2014</td>
<td>-12.1 °C February 1929</td>
</tr>
<tr>
<td>Warmest year</td>
<td>1907–2014</td>
<td>10.9 °C 2014</td>
</tr>
<tr>
<td>Coldest year</td>
<td>1907–2014</td>
<td>6.4 °C 1940</td>
</tr>
<tr>
<td>Mean annual precipitation</td>
<td>1907–2014</td>
<td>557.0 mm</td>
</tr>
<tr>
<td>Highest 24-hour precipitation total</td>
<td>1906–2014</td>
<td>171.7 mm 08.08.1978</td>
</tr>
<tr>
<td>Highest monthly precipitation total</td>
<td>1906–2014</td>
<td>218.4 mm July 1907</td>
</tr>
<tr>
<td>Lowest monthly precipitation total</td>
<td>1906–2014</td>
<td>0.0 mm October 1908</td>
</tr>
<tr>
<td>Highest annual precipitation total</td>
<td>1907–2014</td>
<td>791.8 mm 2010</td>
</tr>
<tr>
<td>Lowest annual precipitation total</td>
<td>1907–2014</td>
<td>344.2 mm 1911</td>
</tr>
<tr>
<td>Longest drought</td>
<td>1907–2014</td>
<td>37 days 28.09.1908–03.11.1908</td>
</tr>
<tr>
<td>Maximum snow depth</td>
<td>1951–2014</td>
<td>45 cm 06.03.1970, 07.03.1970</td>
</tr>
<tr>
<td>Month with the least sunshine</td>
<td>1906–2014</td>
<td>6.6 hrs. December 1913</td>
</tr>
<tr>
<td>Highest air pressure</td>
<td>1906–2014</td>
<td>1041.6 hPa 23.01.1907</td>
</tr>
<tr>
<td>Lowest air pressure</td>
<td>1906–2014</td>
<td>955.8 hPa 26.02.1989</td>
</tr>
</tbody>
</table>