WMO-CIMO Testbed for GAW Observations of Reactive Gases and Aerosols, Hohenpeissenberg Meteorological Observatory (Hohenpeissenberg, Germany)

General Site Information

For more than 230 years the Hohenpeissenberg Meteorological Observatory (MOHp) has been a permanent observing site in a rural landscape with the main focus on meteorological observations and, more recently, on precipitation processes, ozone and atmospheric composition. Mount Hoher Peissenberg is the most noteworthy elevation (989 m a.s.l.) of the Bavarian pre-alpine plateau north of the Alps. It overlooks the surrounding landscapes lying about 350 m below it. Monthly mean temperatures (1961 to 1990) vary between minus 1.6 °C (January) and plus 15 °C (July), while the mean annual precipitation (1961 to 1990) is about 1200 mm. Starting observations in 1781 the observatory holds the longest temperature time series of a mountain station world-wide. Since the late 1960s main research topics are:

- ozone research,
- atmospheric composition (trace species and aerosol measurements), and
- radar meteorology focusing on precipitation processes.

The observatory:
- is a climate reference site of the Deutscher Wetterdienst (DWD),
- operates a 24/7 WMO class I weather station including routine radio soundings and ozone, soundings two times (May to Oct) and three times (Nov to Apr) a week,
- is a Global Station within the Global Atmosphere Watch (GAW) program (since 1994),
- is host of the Dobson Calibration Centre for the RA VI (since 1999),
- is an NDACC (since 1994), NDMC (since 2004) and AERONET station (since 2013), and
- is an EARLINET station since 2015.

Testbed location:	47.801°N 11.011°E
Climate type:	Cfb (maritime temperate, all year wet climate)
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Main activities

Areas of research

The main task of the Hohenpeissenberg Testbed is to test and operate in-situ and remote-sensing instruments (one or multiple instruments using collaboratively) in order to characterize the chemical composition of the atmosphere. These measurements comprise the concentration of key atmospheric species and optical and physicochemical parameters of particles over a heterogeneous landscape including a description of measurement uncertainties. The measurements ideally represent a complete 3D/4D observation of the atmospheric column at the site. Specifically, activities cover:

- Routine and long-term in-situ measurements (since 1994) of reactive atmospheric species (e.g. ozone, nitrogen oxides, carbon monoxide, sulphur dioxide, VOCs, hydroxyl, sulphuric acid) within GAW.

- Routine and long-term in-situ measurements of physical, chemical and optical properties of aerosols, (since 1994) within GAW.

- Regional Dobson Calibration Centre for WMO RA VI.

- Ground-based remote sensing of stratospheric ozone (by LIDAR since 1987).

- Ground-based remote sensing of aerosol parameters (by LIDAR, from 2015 onwards).

- Intercomparison Experiments for NOx and OVOCs in the framework of ACTRIS (www.ACTRIS.net).

- Responsibility for draft preparation of GAW Measurement Guidelines for NOx and VOC (together with EMPA, CH).

Facilities

The core instrumentation will be provided by the observatory and the 24/7 operation of most of the instruments will be ensured. Routine meteorological observations at varying temporal resolution will be available on demand. Note that the available temporal resolution of measurements depends strongly on the measurement method thus ranging from seconds to weeks. MOHp runs a comprehensive measurement program which details are given in the Table below. National and international research groups are welcome to join the scientists and technicians at the observatory for testing and assessment of measurement devices. MOHp offers capabilities to install and to run additional instrumentation for testing and intercomparison, including:

- the GAW roof platform,
- the Dobson Calibration platform,
- the GAW guest scientist laboratory with inlet manifold and air conditioning,
- a second roof platform for radiation measurements,
- a large balloon barn, and
- the grassland field site near the meteorological measurement field.

Measurements	Instrument / Method	Range / type
vertical profiles of temperature, pressure and humidity	radio sondes (Vaisala RS 92)	0 – 30 km
vertical profile of ozone concentration	Brewer Mast ozone sonde, night-time lidar observations (clear-sky conditions), MAX-DOAS	0 – 45 km
Vertical profile of NO2, SO2, HCHO	MAX-DOAS	0 – 5 km
Vertical backscatter profile	Jenoptik CHM15K ceilometer	0 – 15 km
Vertical backscatter coefficient profile	PollyXT multi-wavelength Raman-Lidar (from 2nd half year 2015 onwards, daytime, night-time)	0 – 15 km
Vertical extinction coefficient profile	PollyXT multi-wavelength Raman-Lidar (from 2nd half year 2015 onwards, daytime, night-time)	0 – 15 km
Aerosol type (spherical, non-spherical)	PollyXT multi-wavelength Raman-Lidar (from 2nd half year 2015 onwards, daytime, night-time)	0 – 15 km
PBL height	Jenoptik CHM15K ceilometer	-
Cloud base height	Jenoptik CHM15K ceilometer	-
Total ozone content	2 Dobsons (Nr. 64, 104), Brewer (Nr. 10), 2 Microtops	-
Total sulfur dioxide content	Brewer (occasionally)	-
Ozone	chemiluminescence, UV absorption	surface-based in-situ trace species
Nitrogen oxides (NOx, NOy)	3 Photolysis converters (CLD), CAPS (NO2)	

Carbon monoxide	V-UV resonance fluorimetry, Picarro/cavity Ring down spectroscopy	
Sulfur dioxide	pulsed fluorescence	
PAN	gas chromatography	
Hydroxyl (OH) + sulfuric acid, ROx	CIMS	
Anthropogenic and biogenic volatile organic compounds (VOCs)	gas chromatography, ~120 species	
Methane	Picarro/cavity Ring down spectroscopy	
Carbon dioxide	Picarro/cavity Ring down spectroscopy	
Water vapour	Picarro/cavity Ring down spectroscopy	
Particle number concentration	Grimm, TSI CPCs from 3nm and 10 nm, up to 30 µm	surface-based in-situ aerosols
Particle mass	TEOM (TSP and PM10), SHARP beta-absorption	
Particle size distribution	SMPS 10 -800 nm, GRIMM-OPC 100 nm - 10 µm	
Scattering coefficient	Nephelometer (3 wavelengths)	
Absorption coefficient	7 wavelength Aethalometer AE33	
Soot mass	Carusso-MAAP	
Aerosol Optical Depth	CIMEL (7 wavelengths), PFR/Davos (4 wavelengths)	
pH, conductivity of rainwater	2 electrodes	Chemical compo-sition of rainwater and aerosols
Water-soluble ions in rainwater probes	ion chromatography (DIONEX)	
Aerosol filter measurements of water-soluble ions	4 stages Berner impactor, ion chromatography, up to 2.5 µm particle size	
Aerosol filter measurements of water-soluble ions	PARTISOL filter instrument, ion chromatography, up to 2.5 µm particle size	

Aerosol type and mass concentration	Aerosol chemical speciation monitor (ACSM mass spectrometer), up to 1 µm particle size	
Heavy metals in rain water probes	ICP-MS measurements (retrospectively, analysis only once a year, weekly temporal resolution)	
^{222}Rn	Filter measurements	other
Broadband short-wave and long-wave radiation flux	Broadband short-wave and long-wave radiometers	Surface radiation
UV spectral radiation	Brewer spectrophotometer (290-325 nm)	
Photolysis frequencies of ozone and nitrogen dioxide $J(O^1D)$, J(NO2), actinic flux meas.	Filter radiometer, diode array spectrometer	

Hohenpeissenberg Met. Observatory

GAW roof platform

Meteorological field measurements

Dobson calibration

OVOC intercomparison 2013

NOx intercomparison 2012

Ongoing and planned projects

The main objective is the long-term and process-oriented observation of physicochemical processes at ground but also in the entire atmospheric column, including the estimation of measurement uncertainties. Consequently, MOHp is participating in international research projects supporting this task. MOHp specifically participated in a number of EU projects related to GAW activities and atmospheric composition. Current activities are with the European Research Projects:

- ACTRIS-2 (**A**erosols, **C**louds, and **T**race gases **R**esearch **I**nfra**S**tructure Network, continuing the ACTRIS project 2011-15),
- ICOS (Integrated Carbon Observing Network),
- MACC-III (Monitoring Atmospheric Composition and Climate), starting with GEMS in 2005, and continuing since then through MACC and MACC-II, until end of June 2015, https://www.gmes-atmosphere.eu/, and
- MOSQUITO 2 (Model Output Statistics Qualified by Intercomparison with True Observations, continuing the former MOSQUITO project).

It is anticipated continuing MACC activities from October 2015 onwards under the wings of the Copernicus Atmosphere Monitoring Service (CAMS) of the European Union.

A ceilometer intercomparison campaign is performed at Lindenberg/Germany from June to September 2015 (http://ceilinex2015.de/), which is co-organised by MOHp and DWD's second meteorological Observatory at Lindenberg, and supported by the EUMETNET project E-PROFILE and the COST action TO-PROF (ES 1303).

Finalisation of GAW NMHC (Non-methane hydrocarbons) and NOx (nitrogen oxides NO and NO2) Measurement Guidelines is ongoing. Preliminary draft versions have been prepared in the framework of ACTRIS and are available at http://www.actris.net/language/en-GB/ProjectResults/QualityStandards.aspx.

2016-2018:

- Intercomparison of aerosol parameters originating from ceilometers and lidar; calibration of ceilometers using lidar and sun photometer data and self-calibration methods.
- Enhancement of CIMS system towards routine measurements of the total atmospheric OH-reactivity and ROx.
- Set-up of OVOC routine measurements.
- Perform a NO, NO2, and NOy intercomparison campaign within the framework of ACTRIS but open to other users (scheduled for 2016).
- Perform an OVOC and terpene intercomparison campaign within the framework of ACTRIS but open to other users (scheduled for 2017).

Publication list

More than 120 referred scientific papers related to GAW have been prepared and published since 1995, while another 200 referred papers (since 1967) appeared related to especially ozone research and further complemented by about 35 papers related to radar meteorology and precipitation processes, see:

http://www.dwd.de/EN/research/observing_atmosphere/composition_atmosphere/hohenpeissenberg/cont_nav/publication_node.html.

Two other publications, the GAW newsletter (http://www.dwd.de/DE/forschung/atmosphaerenbeob/zusammensetzung_atmosphaere/hohenpeissenberg/inh_nav/gaw_node.html) and the MOHp ozone bulletin (http://www.dwd.de/ozonbulletin), appear regularly two to four times a year highlighting actual events, scientific findings but also experiences gained with new measurement devices.

Reports/papers from recent comparisons and technical field experiments at the CIMO testbed site Hohenpeissenberg:

C.C. Hoerger et al.: ACTRIS non-methane hydrocarbon intercomparison experiment in Europe to support WMO-GAW and EMEP observation networks, Atmospheric Measurement Techniques Discussion 7, 10423, 2014.

S. Penkett, S. Gilge, C. Plass-Dülmer and I. Galbally (lead authors), and N. Brough, J. Bottenheim, F. Flocke, H. Gerwig, J. Lee, M. Milton, F. Rohrer, T. Ryerson, M. Steinbacher, K. Torseth and R. Wielgosz, K. Suda, H. Akimoto and O. Tarasova (co-authors and contributors), WMO GAW Report 195, A WMO/GAW Expert Workshop on Global Long-term Measurements of Nitrogen Oxides and Recommendations for GAW Nitrogen Oxides Network (Hohenpeissenberg, Germany, 8-9 October 2009) (WMO TD No. 1570) 45 pp. February 2011.

http://www.wmo.int/pages/prog/arep/gaw/documents/Final_GAW_195_TD_No_1570_web.pdf

C. Plass-Dülmer, N. Schmidbauer, J. Slemr, F. Slemr, and H. D'Souza, *European hydrocarbon intercomparison experiment AMOHA part 4: Canister sampling of ambient air*, J. Geophys. Res., 111, D04306, doi:10.1029/2005JD006351, 2006.