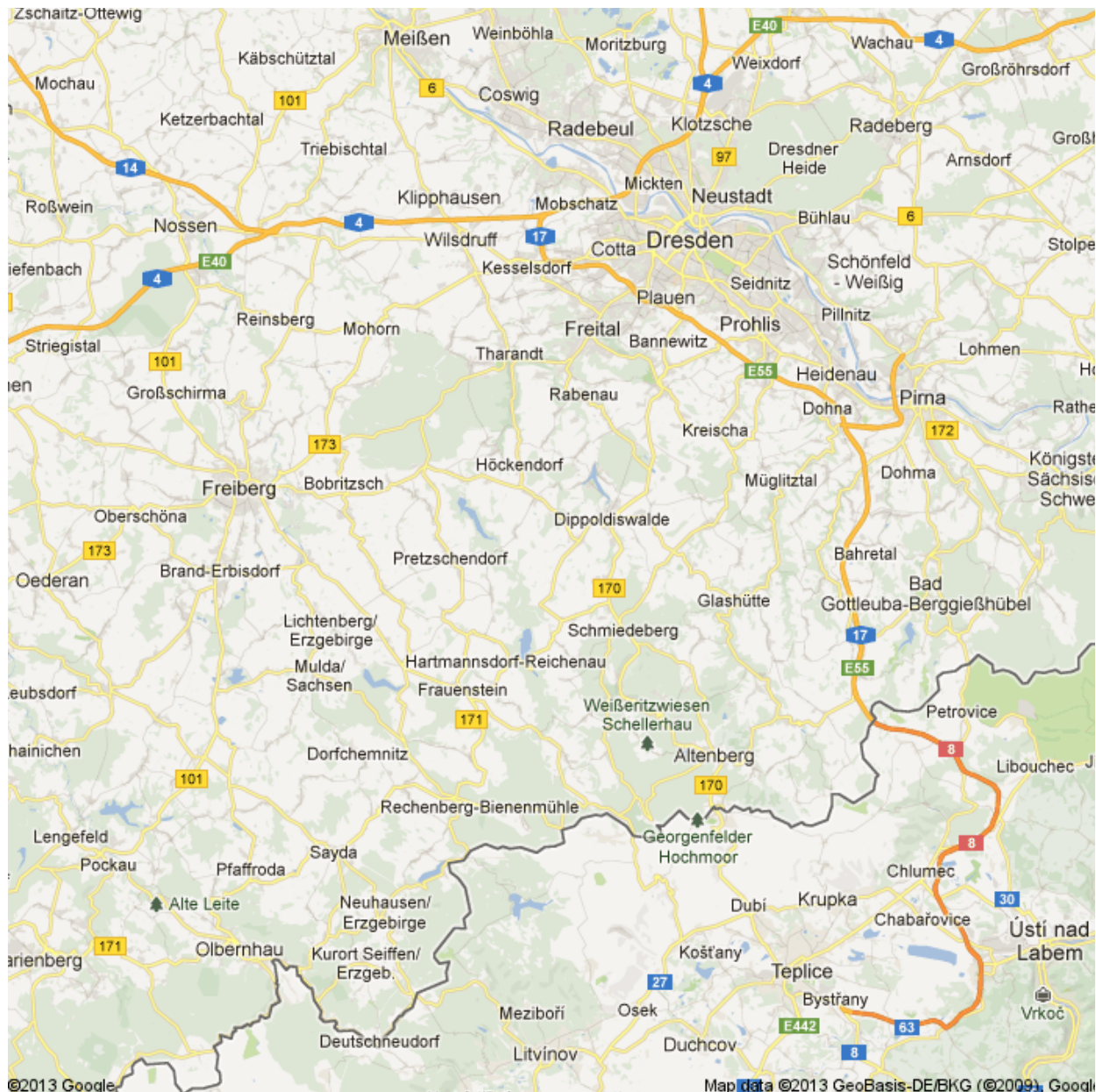


# From Black to Green Triangle

## ERZGEBIRGE – Excursion guide

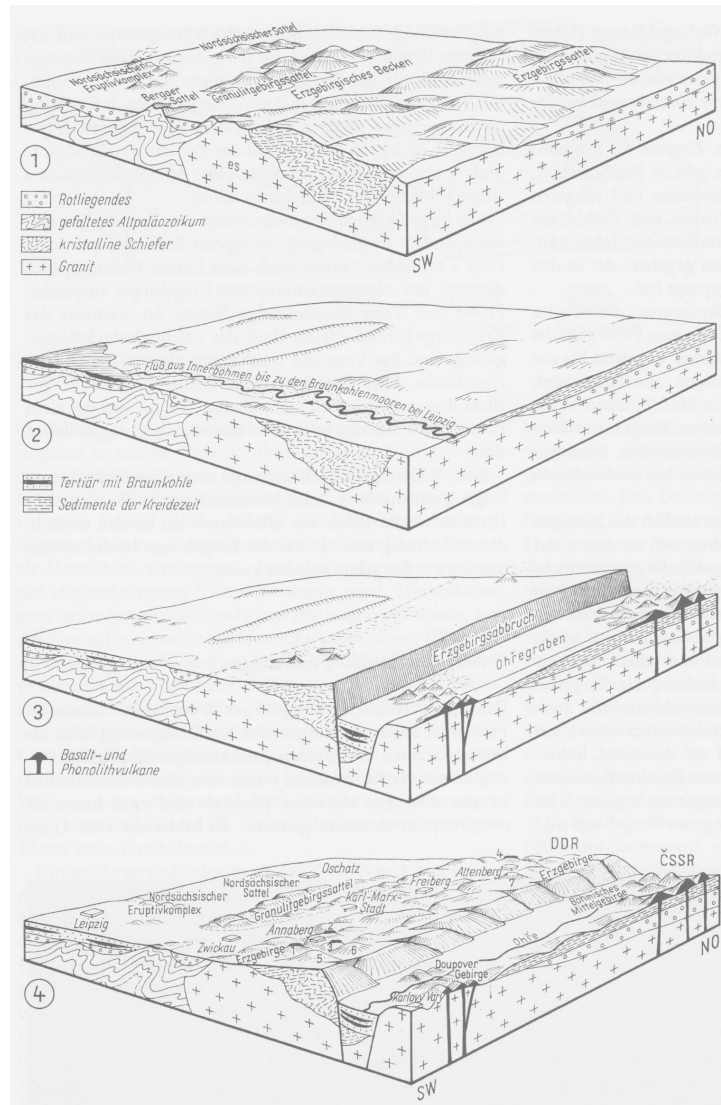
### October 15, 2022; GOAL-2022



**Figure 01.** The map shows Dresden in the North, Freiberg in the centre West and Teplice and Ústí nad Labem in the Southeast. The black line in between represents the Czech-German national boundary. 1 cm equals about 1.7 km (1: 170.000). The map is from Google maps.

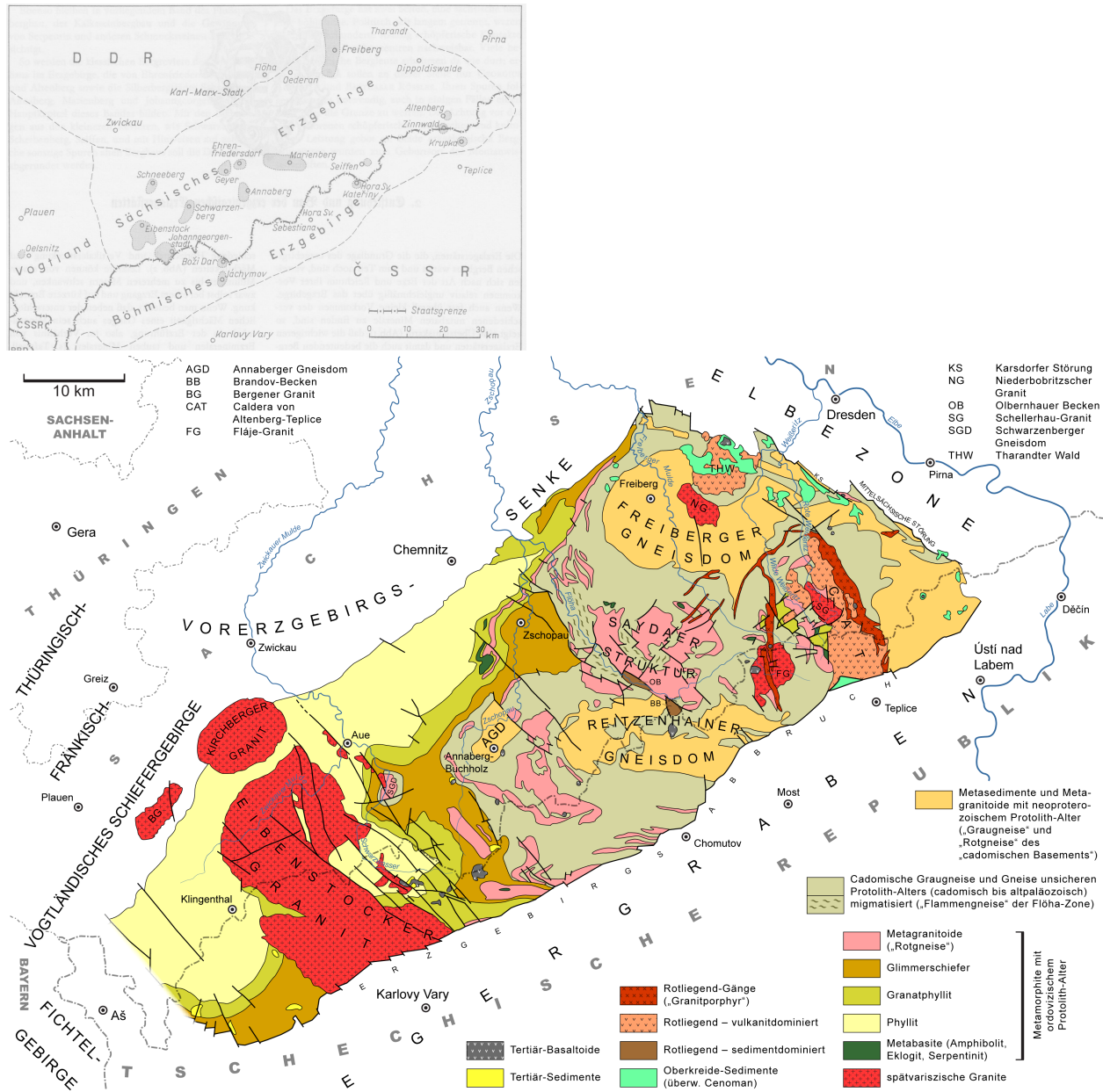
## Geology

The Erzgebirge anticline structure (see figure below) is limited to the East and North by the central Saxon overthrust against the Elbe zone and depression on the Northeast, and against the Nossen-Wilsdruff shales. To the Northwest, the complex is limited by the Riechberg fault zone. In the Southwest, molasse-like sediments of the Erzgebirge foreland depression and the granulite massif border the complex, while in the South to Southeast the Eibenstock granite massif and the Eger rift form the boundary (Pälchen and Walter 2008).



The formation of the Erzgebirge is shown on **Figure 02** on the left (from Wagenbreth and Steiner 1990: p.135):

- (1) Situation of the Variscan mountains in the upper Carboniferous and the lower Permian (Rotliegendes)
- (2) Plain formation during the Cretaceous and Tertiary
- (3) Uplift of the Erzgebirge and collapse of the later Ohre graben structure in the younger Tertiary with basaltic volcanism
- (4) Valley formation in the tilted Erzgebirge slab from the younger Tertiary until today. (ČSSR refers to Czech Republic)



**Figure 03.** a) Key mining districts of the Erzgebirge are shown in the inset above (shaded; Wagenbreth and Wächter 1990: p. 12). b) The geological setting is displayed on the larger map (<https://www.faszination-rohstoffe.de/entstehung-und-vorkommen/sachsen-geologie/sachsens-geologische-bausteine-erzgebirge-und-vogtland>).

The oldest rocks are of Pre-Cambrian age: Gneisses and mica shales of the Central and Eastern Erzgebirge. Carbonates from the lower Cambrium follow. Variscan high intensity magmatism followed and delivered the granites and hydrothermal mineralizations. “Shortly thereafter”, extrusive magmatism around Altenberg (and other places) can be shown in various rhyolites. The entire Mesozoic/Mesolithic era is missing – The Erzgebirge area was being eroded at that time. Minor Tertiary terrestrial sediments (partially subvolcanic) and volcanic material from younger Triassic



age mark the excursion area. During the last glacial maxima, fluvial sediments bear witness of high discharge into the proto Elbe river. Peri-glacial regolith is still visible in places (see Kahleberg). The bog formation is another witness of the peri-glacial conditions that persisted until about 8,000 years ago (Georgenfelder bog).

Material above compiled from Pälchen and Walther (2008)

### Geography and land-use

Elevations on the tilted Erzgebirge platform reach from about 100 m a.s.l. (in Dresden) to almost 900 m a.s.l. (Lugstein near Altenberg). Soils mainly developed in post-glacial times. They vary from nutrient poor (and shallow) podsoles and podsol-cambisols to the dominant gneiss-borne cambisols. While the entire region was densely forested into medieval times, the 16<sup>th</sup> Century saw a vast deforestation already, following centuries of increasing land-use. The wood was needed not only for heating purposes, but for mining. Reforestation started latest in the 18<sup>th</sup> Century. Today, all forests are secondary and tertiary, and cover about 30% of the area. In recent years, major attempts have been undertaken to restructure the forests towards a more sustainable and more resilient form that follows the potentially natural vegetation and includes our knowledge in regional climate change issues. Again today, and already for the last few centuries, agricultural practices (both plant and animal production) occupy a major part of the region and reach up to about 800 m a.s.l.



**Figure 04.** Modern deforestation, here after major recent wind storms (<https://zeitschrift-luxemburg.de/artikel/deutschland-2050/>)



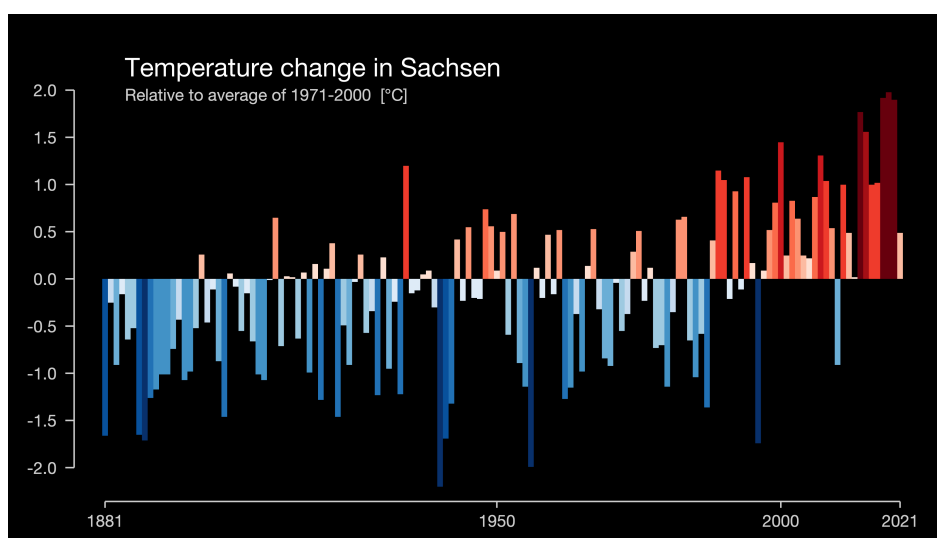
## Climate

From 2008 to 2013, we are part of the large interdisciplinary climate adaptation research project REGKLAM (<http://regklam.de/en/about-regklam>). The REGKLAM model region Dresden that includes the excursion area, lies in respect to its macro climate at the interface of maritime western European and continental eastern European climates. Due to the atmospheric dynamics in this part of the world, frequent changes between more maritime and more continental conditions used to characterise the region, explaining the rich variety of meteorological phenomena; yet, maritime conditions prevail. Compared with regions of similar latitude in North America and Asia, the moderating effect of the Gulf Stream dominates. The average annual temperature in Dresden is about 9°C (delta January to July: 18 K), while in Winnipeg (Manitoba, central Canada) the temperature is 2°C (delta 38 K) and in western Siberia -1°C (with a delta of 40 K). Precipitation averages of the region are around 650 mm per year, while they reach 800 mm for Germany.

On the regional and local level, the influence of the mid-elevation mountains (Erzgebirge) is crucial. While temperatures follow the elevation gradient, precipitation and wind patterns are highly variable, defined by air mass flow directions, convective events. In consequence, foehn-like winds may occur, an above average thunderstorm frequency is typical, and precipitation maxima may easily exceed 1000 mm per year. Local microclimatological conditions may further influence extremes.

As of the 1950's already, regional climate change phenomena emerge. This can be traced back to alterations in large-scale weather patterns (Hoy et al. 2012a-c, 2013) and finds its reflection in extreme behaviour of drought and precipitation (Hänsel et al. 2004, 2005, 2008; Łupikasza et al. 2010). We already see significant shifts in the regional climate with signals that partly exceed the global averages. The most prominent effects so far are increasing droughts during the vegetation periods, while total annual precipitation is still in balance. Towards the end of the Century (2100 AD), we expect more drought and more continental influence.

partly from Bernhofer et al. (2009, 2011)



**Figure 05.** Air temperature changes in Saxony from 1881 to 2021 (<https://showyourstripes.info/c/globe>)

# Anchor station Oberbärenburg (OBB)

**Site history.** The anchor station Oberbärenburg (OBB) near Altenberg (DE) and Zinnwald (Cinovec, CZ) at the German-Czech border, serves the scientific community and stakeholders since 1984. Established to better understand and combat the then pressing issue of acidic precipitation and rapid ecosystem change, OBB experienced significant expansion since 1991 with the establishment of aerosol sampling and analysis, and was further enhanced as of 1999/2000 to incorporate regional climate change issues – and to serve student education.

The station is jointly manned and supported by TU Dresden and TU Bergakademie Freiberg, who join hands to maintain a high level of infrastructure and to jointly engage in ambitious research projects (e.g., VERTIKO in AFO2000 and REGKLAM in KLIMZUG; both BMBF-supported). The partners are open to collaboration projects with others and to support other researchers with an interest in using the available infrastructure.



**Figure 06.** View from the 30 m mast onto the 13 + 7 m tower within the OBB forest stand

**Site characteristics.** The OBB anchor station lies on the higher elevations of the Eastern Erzgebirge, at about 3 km NE from Altenberg city. The station is completely surrounded by managed spruce forests. It lies on the upper slope of a SE-NW-trending ridge (Klinge, 787 m a.s.l.

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to Tellkoppe, 757 m a.s.l.). The immediate surroundings are free from agricultural and industrial activities; the nearest neighbor is the Altenberg bobsleigh track. Thus the station OBB is a recipient of long-distance transport of aerosol, gases and wet deposition from the Bohemian basin, from the industrial centres of Saxony and beyond.

Situated at (N 50° 47' 16", E 13° 43' 22") on 735 m a.s.l., the station offers both an open-field (type forest clearing) and a canopy-covered site (58-year old spruce with up to 20 m crown height). The annual average temperature is 5.5°C; the average annual precipitation sum amounts to 996 mm a<sup>-1</sup>. Table 1 shows the meteorological set-up. The proximity of the bobsleigh track grants access to the reliable high voltage (400 V) net. A tower (13 + 7 m), a 30 m mast in the forest stand and air-conditioned laboratory containers and data assembly huts allow for a broad range of experimental set-ups throughout the year. Meteorological data and gases are permanently collected, while most other parameters are activated in campaigns and during field exercises for the student training.

**Table 1.** Meteorological and atmospheric chemical parameters, installation height and standard registration frequency

Parameter	Installation height	Frequency
3D-wind parameters	30 m	10 min. avg.
Turbulent heat flux	30 m	10 min. avg.
Gas and particle phase chemistry	30 m	campaigns
Total aerosol (PM <sub>10</sub> )	25 m	campaigns
wind speed	20 m; 10 m; 2 m	10 min. avg.
wind direction	20 m	10 min. avg.
vertical wind	20 m	
air temperature	20 m; 10 m; 2 m; -0,10 m	10 min. avg.
soil temperature	- 10 cm	10 min. avg.
relative air humidity	20 m	10 min. avg.
global radiation	20 m	10 min. avg.
leaf humidity	13 m	10 min. avg.
NH <sub>3</sub> (passive sampler)	13 m	campaigns
fog and cloud water	13 m	campaigns
aerosols	13 m	campaigns
3D wind parameters	02 m	10 min. avg.
Turbulent heat flux	02 m	campaigns
Gas and particle phase chemistry	02 m	campaigns
Total aerosol (PM <sub>10</sub> )	02 m	campaigns

In addition, a SODAR (wind profiler) allows for differentiated air mass movement determinations and established our knowledge on boundary layer dynamics above the station. A Visibility sensor constantly registers precipitation type from mist to heavy rains, hail and snow and total visibility range.

The station is equipped with a wide range of tools to sample wet, dry and interception deposition for both qualitative and subsequent quantitative chemical analysis in the laboratories.

## Atmospheric parameters registered

### a) on tower and mast:

- Gaseous N-Species ( $\text{NH}_3$  and  $\text{HNO}_3$ ), nitrate and ammonium particles with filter pack and passive samplers
- Fog and cloud water with 3 passive samplers
- Gaseous and particle-bound nitrogen and sulphur compounds with denuder and filter pack

### b) on the open field site:

- Precipitation amount (Hellmann-rain gauges)
- Precipitation composition (2 wet only samplers)

### c) under canopy (58-year spruce, 2013):

- Precipitation composition of throughfall (2 wet only samplers)
- Litter fall (6 litter samplers)
- Seepage water (Humus layer, 30 cm and 60 cm depth mineral soil layer)

### d) under canopy (108-year spruce, 2013):

- Precipitation composition of throughfall (3 bulk samplers), measurements until 2004

## Sequence and duration of measurements:

- since 1985: Air temperature, relative air humidity, precipitation, soil temperatures
- since 1995: In addition, global radiation, wind direction, wind speed
- 1985–2004: Matter input open space and canopy throughfall
- 1991 to 1996 and as of 2008: Wet deposition open space and canopy throughfall
- 1992–1999 and as of 2007:  $\text{SO}_2$ ,  $\text{O}_3$ ,  $\text{NO}$ ,  $\text{NO}_2$  ambient concentrations
- 1996–2001 (PM 10) and as of 2008 (multi-stage plus PM 10): Aerosols (multielement analysis)
- 2001–2004 (VERTIKO) and as of 2009 (REGKLAM): Reactive nitrogen components ( $\text{HNO}_3$ ,  $\text{NH}_3$ ,  $\text{NO}_3^-$  and  $\text{NH}_4^+$ -particles)
- since 1984: Teaching purposes

## Instrumentation in detail and its purpose at the OBB anchor station

Here, only the more complex installations and infrastructure is mentioned, since most other tools are self-explanatory and standard.

SODAR (SONic Detection And Ranging). This meteorological instrument (AQMR90 by AX-Systems, SE) is also known as wind profiler (Fig. 5). It uses the dispersion of sound waves through atmospheric turbulence to determine three-dimensional air mass movement within the boundary layer. It thus allows measuring wind speeds and directions at various heights above ground (here to about 1000 m) and to study the thermodynamic structure of the lower atmospheric layers.

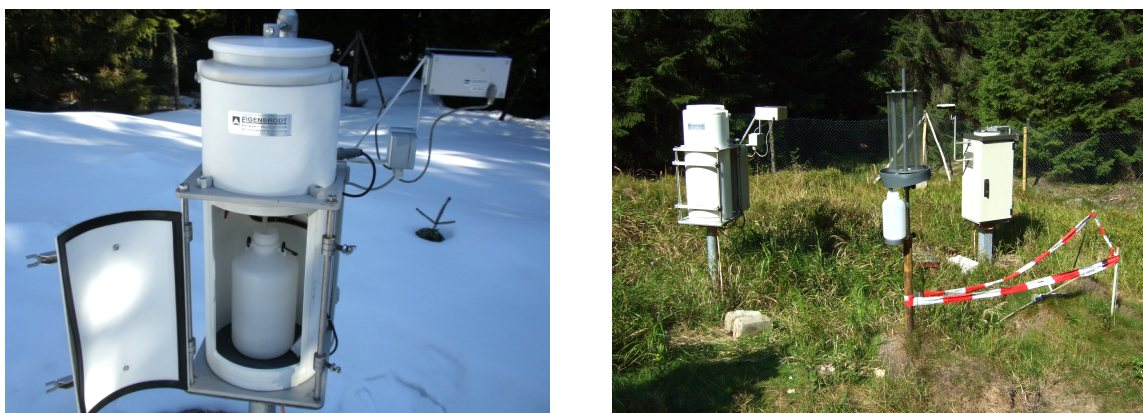


**Figure 07.** A) AQMR90 Doppler-Sodar at OBB. B) Loudspeakers at the back side of the Doppler SODAR (Foltyn 2008)



**Precipitation.** We need both permanent precipitation registration (Hellmann, Vaisala Visibility sensor) and contamination-free precipitation sampling for the analysis of major, minor and trace components (bulk samplers, wet-only samplers, fog and cloud water samplers). Related quality-controlled data are available (and largely published) since 1985.

Wet-only sampler: Since the precipitation amount, as measured by wet-only samplers, tend to deliver a negative bias (lower values as compared to true precipitation), the amounts are additionally registered with a heated Hellmann gauge (Thies Clima). Reasons for the systematic bias are wetting and evaporation errors, related to the sorption characteristics of funnel and recipient materials and the total amount of precipitation and its duration (sampler reaction). Further mistakes relate to wind around the sampler that influences air mass movement for being a significant hindrance (EMEP 2002; LAWA 1998; Sevruk 1989). While wetting and evaporation errors prevail in the summer half year, the wind errors dominate in the winter half-year, particularly under snowfall conditions. The selection of wind-protected sites may alleviate such problems to some extent. Last but not least, the sensitivity of the opto-electronic sensor defines the trueness of the sampled precipitation amount (EMEP 2002; Sevruk 1989).



**Figure 08.** Left: Wet-only-sampler (UNS 130/E by Eigenbrodt). The upper parts are the Teflon reception funnel, covered under no-precipitation conditions by a Teflon lid. The electro-optical precipitation sensor is visible to its right. The lower part shows behind the open door, the 5 L collection bottle. Right: With the same Eigenbrodt sampler on the left, the Freiberg workshop built wet-only sampler is visible on the right, and a simple fog sampler (“fog harp”) with collection bottle stands in between in the foreground.

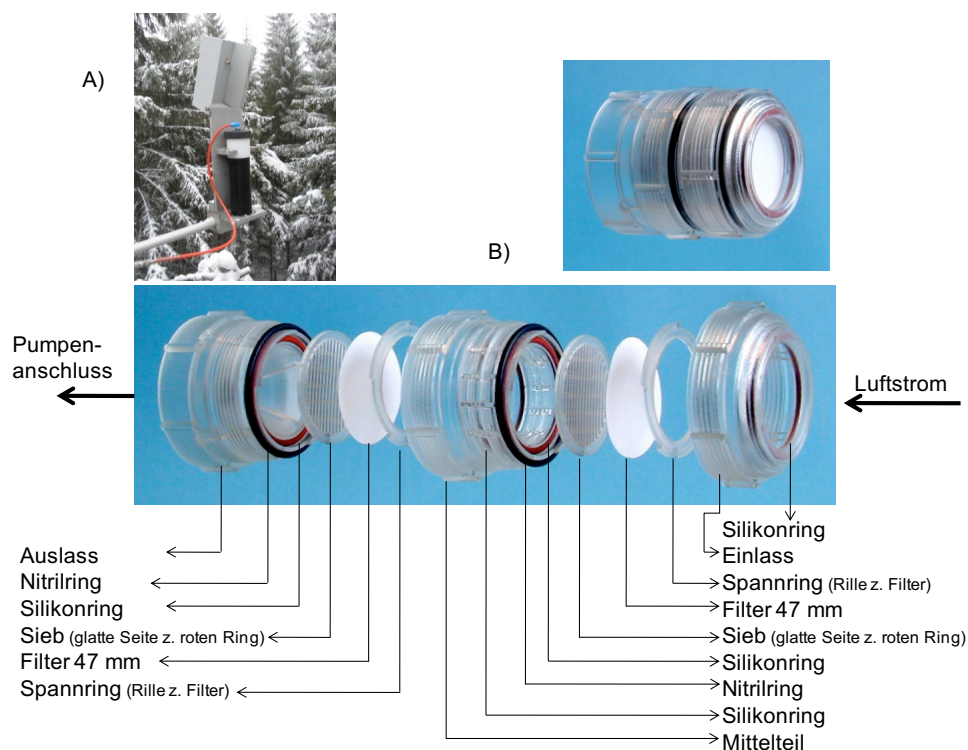
The samplers sit at about 1.7 m above ground (at top) – Fig. 08. Both models open and close triggered by opto-electronic precipitation sensors. At locations such as OBB, machines and materials must be very robust to reliable function across the wide range of partly extreme conditions.

**Aerosols (dry deposition).** The first regional dry deposition measurements were undertaken at OBB as of 1991 with low volume samplers (LVS:  $PM_{10}$ ), demonstrating the rather radical decline of air pollutants in the 1990's, following the fall of the Iron Curtain and the re-organization (and modernization) of Central Eastern European industries. Following the LVS, two Gent samplers were additionally set-up to capture both  $PM_{10}$  and  $PM_{2.5}$ , followed by a Partisol sampler and more recently (as of 2009) a multistage impactor Berner sampler.

Gent sampler. This device is another “Low-Volume” sampler to collect both  $PM_{10}$  and  $PM_{2.5}$ . Construction and design were described by Maenhaut et al. (1994) and Hopke et al. (1997). The Gent

samplers of our group used at OBB (and other sites) were built in the workshop of the IÖZ of TU Bergakademie Freiberg (Fig. 07).

Ambient air is pumped with a flow rate of ca.  $15 \text{ L min}^{-1}$  via one impactor stage onto a stacked filter unit (SFU). This unit consists of a filter holder with two sequentially arranged filters, developed by the Norwegian Institute for Air Research (NILU). The flow rate results in a sampling efficiency of 50% with particle sizes of 2.2 to  $2.5 \mu\text{m}$  equivalent aerodynamic diameter (Hopke et al. 1997). Particle sizes between 10 and ca.  $2.2 \mu\text{m}$  are captured on the initial polycarbonate filter (Nuclepore® filter by Whatman, 47 mm diameter with a pore opening of  $8 \mu\text{m}$ ). The smaller particles ( $< 2.2 \mu\text{m}$ ) are sampled onto the second filter with a pore opening of  $0.4 \mu\text{m}$  (Cahill et al. 1979; Hopke et al. 1997).



**Figure 09.** A) Gent sampler location at OBB. The grey PVC hood (weather protection) is closed during sampling. B) Design of the NILU filter holder system (closed on top right) and in its individual components (bottom)

**Partisol-Sammler.** To simultaneously determine reactive gases ( $\text{NH}_3$ ,  $\text{HNO}_2$ ,  $\text{HNO}_3$ ,  $\text{SO}_2$ ) and volatile aerosols (measured ions:  $\text{NH}_4^+$ ,  $\text{NO}_3^-$ ,  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Mg}^{2+}$ ,  $\text{Ca}^{2+}$ ,  $\text{Cl}^-$ ), we use the Partisol Speciation Sampler 2300/Chemcomb 3500; UMEG 2002 (Rupprecht & Patashnick, USA, today Thermo). It combines the standard aerosol sampler Partisol 2300 with one to eight sampling cartridges with a combined denuder/filter pack system (Figs. 08A, B).

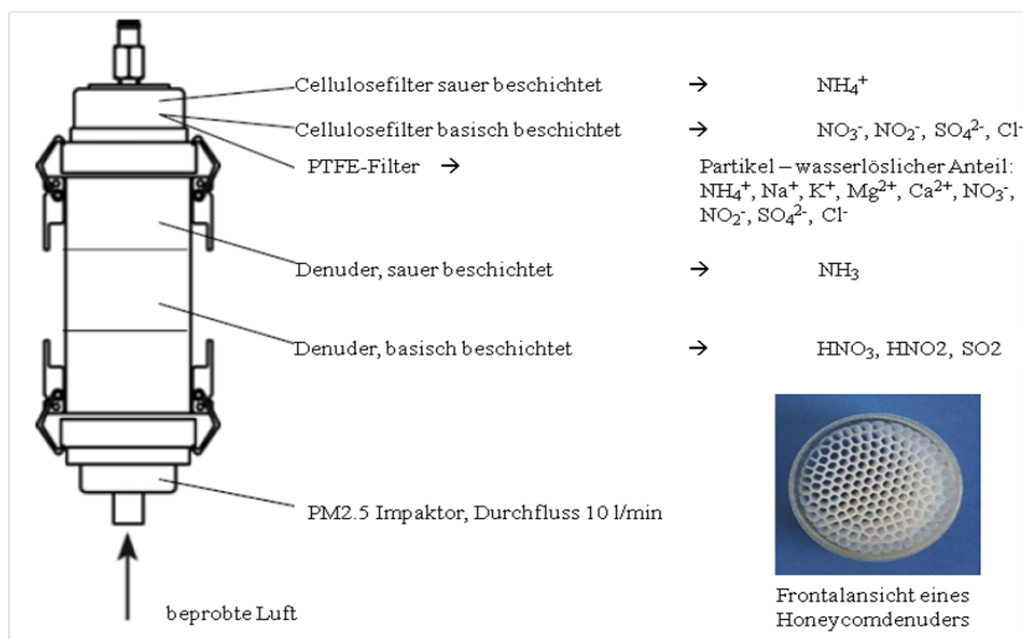
The denuder/filter-system consists of a  $\text{PM}_{2.5}$ -inlet system, two sequential Honeycomb denuders to separate gases and a filter pack system to sample aerosols. Figure 09 shows the general design and set-up of the cartridges with filters and denuders. With their very large surface area, honeycomb denuders have a high sampling efficiency (Koutrakis et al. 1993; Sioutas et al. 1996).



Ambient air is being pumped at a constant flow rate of  $10 \text{ L min}^{-1}$ . Only particles with  $d(p) < 2,5 \mu\text{m}$  pass the impactor plate at the inlet. Then acidic gases ( $\text{HNO}_2$ ,  $\text{HNO}_3$ ,  $\text{SO}_2$ ) are captured onto a basic-plated denuder ( $\text{Na}_2\text{CO}_3$ /glycerine/water/ethanol), while the basic gas  $\text{NH}_3$  is captured onto an acid-plated denuder (phosphoric acid/water/ethanol); see Figure 09. Behind the denuders, a filter pack system follows. A PTFE-filter collects the particle phase, and two likewise basic and acid-coated cellulose filters serve as back-up filters to collect volatile acidic or basic gases and aerosols that may have been liberated via desorption or sublimation from the PTFE-filter (Koutrakis et al. 1993).



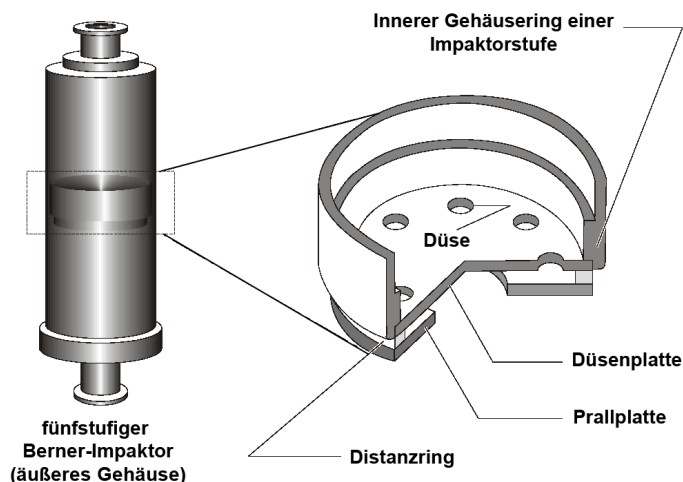
**Figure 10.** (Left) A) Sampling unit with pump and digital control for up to eight channels. B) Cartridge ready for sampling at the 30 m mast on the forest site OBB



**Figure 11.** Schematic design of the denuder and filter pack system ChemComb sampling cartridge (left) and overview of sampled species (modified after Plessow and Zimmermann 2004). The lower right picture shows the honeycomb structure of a glass denuder in frontal view

The capturing capacities of the honeycomb denuders for  $\text{NH}_3$  and  $\text{HNO}_3$  are 1.2 mg and 10 mg, respectively (Koutrakis et al. 1993). We analyzed the denuder sampling efficiency during the VERTIKO project at TU Bergakademie Freiberg (Plessow et al. 2005). Two cartridges were actively sampling in parallel at OBB, one with two  $\text{H}_3\text{PO}_4$ -coated denuders, the other one with two  $\text{Na}_2\text{CO}_3$ -coated denuders. The gases  $\text{NH}_3$  and  $\text{HNO}_2$  were captured to 100%;  $\text{HNO}_3$  and  $\text{SO}_2$  to 94% and 98%, respectively, on the first denuder already. Only  $\text{HCl}$  yielded a limited efficiency of 77% on the first denuder. We thus did not further evaluate the  $\text{Cl}^-$  results. Based on these rather fine sampling efficiencies, we currently (REGKLAM-project) use the cartridges with two differently coated denuders as described above.

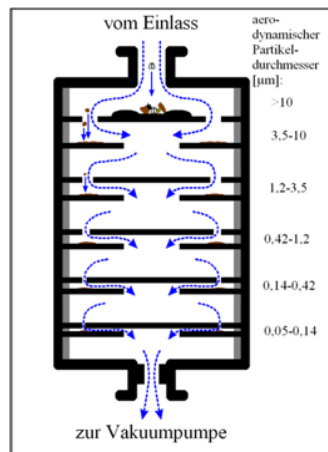
**Berner Impactor.** To sample a size-resolved profile of atmospheric particles in their possible dependency on wind directions and large-scale weather patterns, we use a 5-stage Berner-Impactor (Typ LPI 80/0,05; Hauke, Austria). This is a low-pressure cascade impactor, consisting of a series of nozzle and baffle plates (Figure 12). The nozzle diameter decreases from stage to stage, increasing the airflow. The baffle plates between the nozzle plates host filter discs. The aerosol-laden airstream hits a filter and will be diverted. While small particles can follow the subsequently faster airflow, larger ones will impact the baffle plate and filter, based on their mass. The increasing speed from cascade to cascade thus separates the individual grain sizes (Baron and Willeke 2001; Lodge and Chan 1986).



**Figure 12.** Impactor stage design in a five-stage Berner-Impactor (from Maga 2008; modified after Ernst 2003 and Berner and Lürzer 1980)

A vacuum pump sucks ambient sample air steadily from the outside of the lab container via an anisokinetic inlet and through a connecting tube to the Berner-Impactor. A critical nozzle at the inlet of the Berner impactor guarantees a constant airstream of  $82.7 \text{ L min}^{-1}$  (at  $20^\circ\text{C}$ ). Within the impactor, the outside air first passes an impactor plate (Fig. 14). Its greased surface collects all particles with diameters  $> 10 \mu\text{m}$ , to guarantee that all subsequent stages will collect particles below  $\text{PM}_{10}$ . With our model (identical to the one used by the Leibniz-Institute for Tropospheric Research, a project partner in Leipzig), the cut-offs lie at  $3.5 \mu\text{m}$  (stage 5; 15 nozzles),  $1.2 \mu\text{m}$  (stage 4; 40 nozzles),  $0.42 \mu\text{m}$  (or  $0.39 \mu\text{m}$  respectively at OBB; stage 3; 81 nozzles),  $0.14 \mu\text{m}$  (stage 2; 133 nozzles) and  $0.050 \mu\text{m}$  (or  $0.049 \mu\text{m}$  respectively at OBB; stage 1; 244 nozzles); Figure 14.





**Figure 13.** Impactor casing in the lab container. **Figure 14:** Aerosol size separation principle in a multi-stage impactor



**Figure 15.** Impactor details when dismantled (left); impactor press to remove the shell (centre); vacuum pump (right)

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**Figure 16.** Left: the laboratory containers (right) and guest containers (left). Centre: the 30 m mast. Right: Canopy throughfall samplers; all at OBB

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