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Abstract title: The use of a wind profiler for meteorological studies of transboundary transport of particulate matter on the example of the Upper Oder Valley (PL-CZ border)
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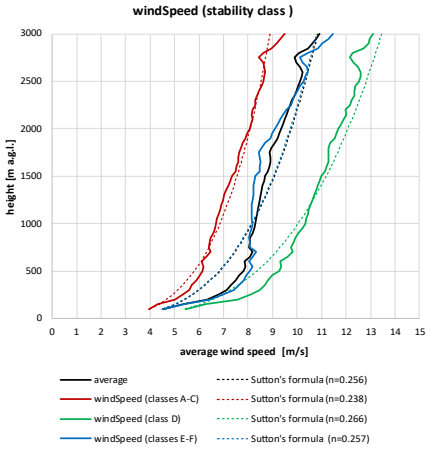
Admission

The Polish-Czech border in the Upper Oder Valley constitutes a critical air mass transport corridor in the Central European meridian system. This flow is also accompanied by long-distance transport of atmospheric aerosols (volcanic and desert ash, as well as anthropogenic pollutants). Let's add that the transport channel's axis is located in one of the largest industrial and urban center in Central Europe (Ostarva-Karviná Oblast and Upper Silesian Industrial Region), with significant emissions of various dust fractions. In this case, the structure of atmospheric aerosols is very complex and strongly influences environmental conditions. Furthermore, given significant climatic changes and, consequently, changes in meteorological conditions, the balance of these pollutants' flows is highly variable and has not been thoroughly studied.

To address these issues, leveraging the capabilities of the ACTRIS (Aerosol, Clouds, and Trace Gases Research Infrastructure) project (https://actris.eu) of which IMWM-NRI is one of the Polish co-executive partners (along with the Institute of Geophysics of the Polish Academy of Sciences in Warsaw (IG PAS), the University of Warsaw, the University of Wrocław in Wrocław, the University of Silesia in Katowice, the Institute of Fundamentals of Environmental Engineering of the Polish Academy of Sciences in Zabrze (IFEE PAS), the Poznań University of Life Sciences, and the Warsaw University of Technology in Warsaw), the ACTRIS-ERIC w framework ACTRIS-PL measurement platform was located in Racibórz on the Polish-Czech border. It is part of a network of eight such platforms in Poland. The main objective of the project is to adapt both the measurement methods and the method of presenting the results to the implementation of the new Directive (EU) 2024/2881 of the European Parliament and of the Council of 23 October 2024 on ambient air quality and cleaner air for Europe (The Ambient Air Quality Directive AAQD), which tightens the permissible levels of substances in the air and also changes the provisions on the measurement and assessment of air quality, the use of mathematical modelling methods in the transport and transformation of substances in the air and informing the public about high concentrations of air pollutants.

The observation platform of the Institute of Meteorology and Water Management – National Research Institute (IMWM-NRI) is located at Broniewskiego 2 Str. in Racibórz located in the area National Weather Station (NWS). It is part of the Institute of

Environmental Engineering Fundamentals of the Polish Academy of Sciences (IEEF PAS) in Zabrze and the Institute of Geophysics of the Polish Academy of Sciences in Warsaw (IG PAS), which is situated in the Silesian Geophysical Observatory at Chłopska 1 Str. also in Racibórz. The IMWM-NRI platform in Racibórz features a meteorological measurement (among other devices) base that provides comprehensive support for aerosol testing in the region. This includes ceilometer Cl51 (Vaisala) and Cl61 (currently being purchased), an automatic meteorological station, the MPT-5 microwave radiometer (ATTEX), and the LAP®3000 wind profiler (Scientec). Since January 2023, these devices have been operating continuously, offering both current and historical data on the physical conditions of the lower atmosphere in the Lower Oder Valley of the Racibórz region.



Averaged vertical wind speed profile in Racibórz obtained from the WP LAP®3000 for various atmospheric stability classes based on Pasquill's formula from August 2023 to July 2024.

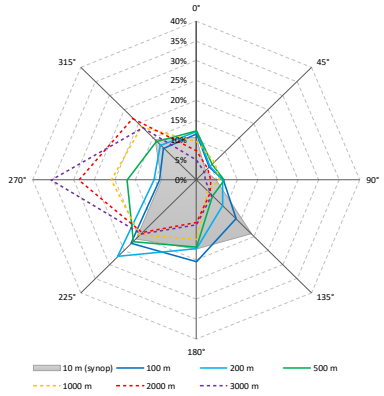
Selected results of WP LAP®3000 measurements

Current analyses

Notably, the perfect convergence of the averaged vertical wind profile measurements obtained from WP LAP®3000 with the profile obtained from the empirical Hellman-Sutton formula:

$$u = u_1 \cdot \left(\frac{z}{z_1}\right)^n$$

where: u - wind speed at level z, u_1 - wind speed at level z_1, n - coefficient depending on the atmospheric equilibrium state and the roughness characteristics of the active surface ($0< n<1$).

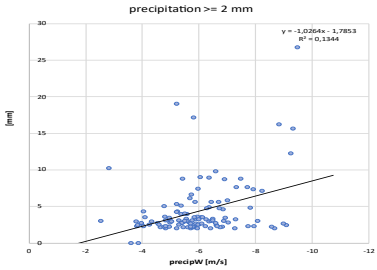


Wind direction rose near Racibórz – data from WP LAP®3000 from August 2023 to July 2024.

The variability of the wind profile depends on the atmosphere's stability, presented here as the atmospheric stability class, Pasquill's formula, where A - C are unstable classes, D is the neutral class, and E - F are stable classes. This means that for average values, using the Hellmann-Sutton formula to determine the vertical wind profile is correct when using exponents determined from comparing the measured profiles and those obtained from the formula.

For precipitation of ≥2 mm over a half-hour period, the relationship between precipitation totals and air particle settling velocity was examined. It was found that as

the air particle settling velocity increases, the half-hourly precipitation total increases. However, this relationship is not apparent and requires further research.



Half-hourly total precipitation ≥ 2 mm and the average velocity of vertical air particle movements in the layer from 0 to 3000 m a.g.l., obtained from WP LAP®3000 from August 2023 to July 2024.

Episodes of high concentrations of dust in the atmosphere

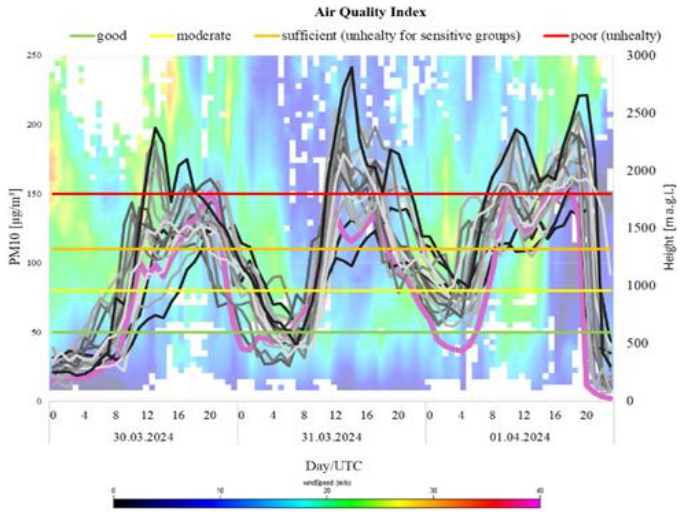
Between March 30 and April 1, 2024, elevated PM10 concentrations were recorded at Chief Inspectorate for Environmental Protection/State Environmental Monitoring (GIOŚ/PMŚ) stations in the Silesian Voivodeship, exceeding the information level for human health protection, which in Poland is 100 µg/m^3 for daily concentrations. However, the alarm level of 150 µg/m^3 for daily concentrations was not exceeded.

The situation was caused by a specific air circulation pattern that brought in a hot air mass from North Africa and an influx of Saharan dust particles. While this type of occurrence is relatively common in this region of Europe, the scale and duration of this particular phenomenon were remarkable. Noteworthy is the unusual daily course of pollutant concentrations during low emission conditions, with peaks occurring around noon and significant atmospheric activity.

At all stations of the Silesian Voivodeship selected in the study, the concentration of PM10 from 10 UTC on 31 March increased sharply to values exceeding the aforementioned information level (>100 µg/m^3). This situation lasted until midnight on April 1. The highest maximum value occurred on 31 March and reached 242 µg/m^3 at the Złoty Potok station at 15 UTC. Values exceeding 200 µg/m^3 were also recorded on that day in Zawiercie (236 µg/m^3) at 15 UTC, in Cieszyn (211 µg/m^3) at 13 UTC and in Ustroń (206 µg/m^3) at 14 UTC, and the next maximum occurred on 1.04. o 20 UTC in Gliwice (204 µg/m^3). At the remaining stations, on 31 March in the early afternoon and on 1 April in the late evening, the maximum hourly concentration of PM10 ranged from 154 µg/m^3 in Racibórz to 193 µg/m^3 in Katowice. Because of the size of African dust particles, the increases in concentration were not as pronounced for the smaller PM fractions, specifically PM2.5. As a result, no significant changes in values were observed for this parameter, unlike the more noticeable jumps recorded for PM10. The upper winds predominantly came from the west-southwest (WSW) during the event's peak. This indicates that the general atmospheric circulation was aligned with the direction of pollution transport from the Sahara. Additionally, there was a low wind speed in the vertical column of the atmosphere at the height of the episode.

Cloud cover at the IMWM-NRI station in Racibórz was caused by the inflow of aerosols from the Sahara on April 1, 2024 (author B. Kwaśnica, IMWM-NRI)

The influx of Saharan sand led to a decrease in both horizontal and vertical visibility. The photograph below shows how direct solar radiation was reduced during this event.



PM10 concentrations 1h were measured at selected stations of the Chief Inspectorate of Environmental Protection/State Environmental Monitoring in the Silesian Voivodeship from March 30 to April 1, 2024. These measurements were analysed in conjunction with the vertical profile of the horizontal component of wind speed in Racibórz (purple line) obtained from WP LAP®3000.

Summary

The primary objective of operating the IMWM-NRI ACTRIS observation platform at the Polish National Weather Service (NWS) in Racibórz is to integrate it into the ACTRIS framework. This involves obtaining all necessary labelling documents and transmitting measurement data to the ACTRIS structure. By doing so, we aim to enable the free exchange of information and data on an equal partnership basis, allowing for the full utilisation of ACTRIS instrumentation resources. The deadline for achieving this readiness is December 31, 2025. Another way to fully utilise the ACTRIS equipment (along with the associated infrastructure) is the IMWM-NRI accession to the e-PROFILE program implemented within EUMENET. Data exchange of meteorological measurement results (WP, MTP-5, CL51, and, in the future CL61) will enable research on the structure of the atmospheric boundary layer at specific points and spatially. This information will enrich the knowledge base acquired about the planetary atmospheric boundary layer through other remote sensing methods and expand the research offerings in this area. Finally, in light of the preliminary announcements of the Chief Inspectorate of Environmental Protection, it is possible to include the ACTRIS platform located at the IMWM-NRI station in Racibórz in the supersites system.

This concept involves establishing multiple stations in Poland equipped with a comprehensive array of air quality measurement tools, particularly aerosols. The observation platform in Racibórz meets these criteria effectively.

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This concept involves establishing multiple stations in Poland equipped with a comprehensive array of air quality measurement tools, particularly aerosols. The observation platform in Racibórz meets these criteria effectively. The piece was developed as part of various projects.

The fully developed research profile of the aerosol testing platform at the IMWM-NRI station in Racibórz will be able to serve as a research base for the implementation of strictly scientific projects, both in the field of basic research: National Science Center Poland (NCN) or National Centre for Research and Development (NCBR) grants e.g. research on the impact of aerosols (radiative forcing) on climate change, as well as implementation projects: INTERREG, HORYZONT, COST, EC etc., assimilation of measurement data in the atmospheric boundary layer for modeling atmospheric processes, including the pollutant immission field, and ending with the sale of know-how to strictly commercial customers (management of the process of construction and operation of renewable energy facilities such as wind and photovoltaic power plants).

The work was created as part of the projects:
ACTRIS-ERIC – Aerosol, Clouds and Trace Gases Research Infrastructure, Program: „Supporting the participation of Polish scientific teams in international research infrastructure projects", Financing institution: Ministry of Science (period of realisation 1.01.2024 – 31.12.2028) and ACTRIS-PL 2 (RI ACTRIS-PL) – Aerosol, Cloud and Trace Gas Research Infrastructure, Project No: FENG.02.04-IP.04-0008/24-00, Program: 2 Programme Priority EU Funds for Modern Economy, 2027 (FENG), realisation from 2024 to 2027.