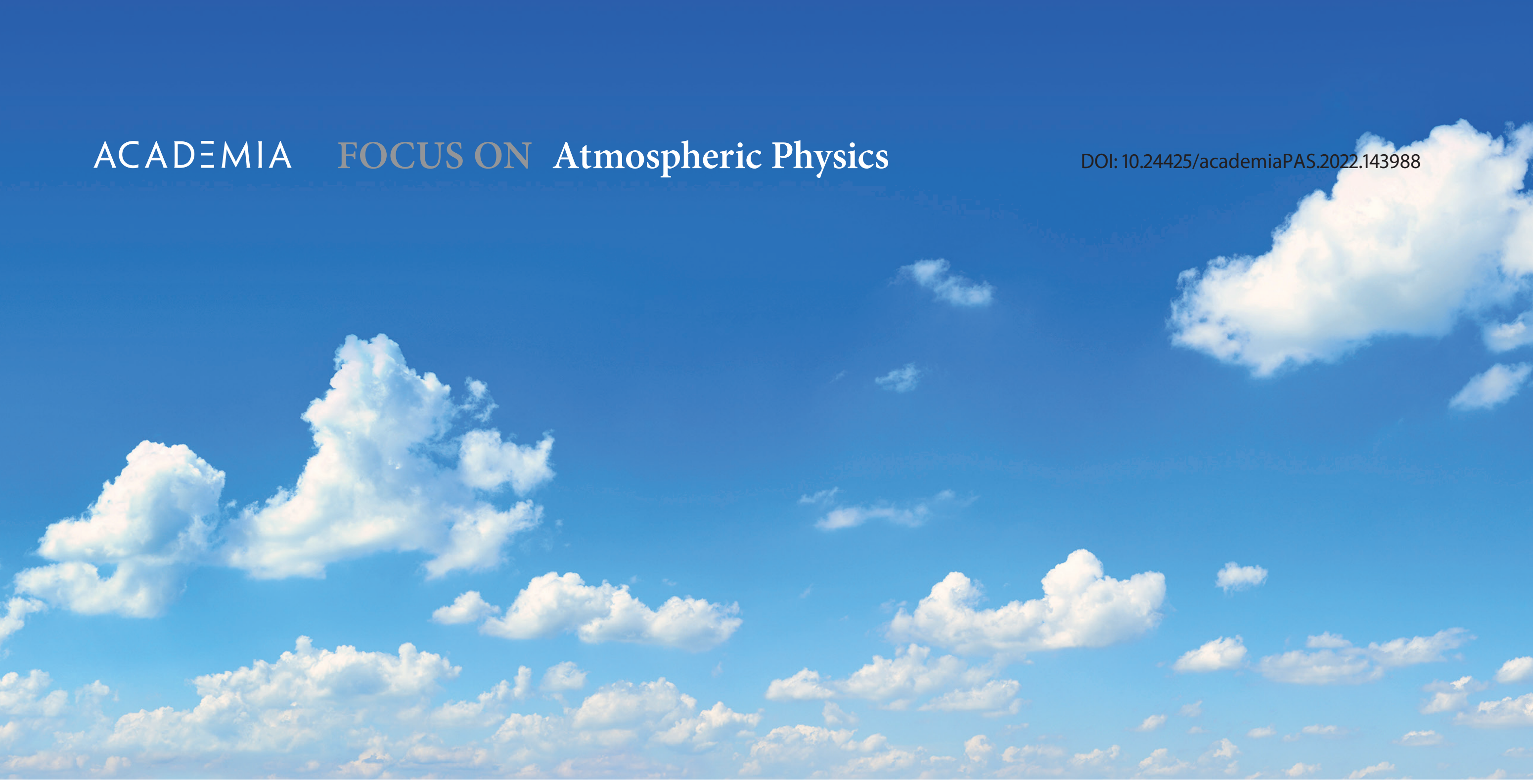

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What's Suspended in the Atmosphere

The Earth's atmosphere contains various dust particles that scatter and absorb solar radiation. Their amount and type affect the temperature on Earth – but how do we know what's up there?

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The Earth's atmosphere consists predominantly of gases, but also contains suspended liquid or solid particles called "atmospheric aerosol," which plays an extremely important role in the Earth's radiation balance. Such particles range in size from several nanometers (in the case of those freshly formed from gaseous precursors) to even 1 mm (in the case of large desert dust particles), and they exist in the atmosphere as physical masses of mixtures of particles with various sizes and physicochemical properties. One peculiar property involves the ability to scatter and absorb the Sun radiation that reaches the Earth's surface. An aerosol may be "anthropogenic," the result of human activity (such as traffic pollution, biomass combustion, and soot), or "geogenic," the result of natural processes (such as desert sand dust, plant pollen, volcanic ash, and sea salt particles).

A research network

The study of atmospheric aerosol is important in view of its impact on local and regional climate and air quality. As our knowledge about aerosol becomes more complete, we can better predict its movements, concentrations, and effects on weather and air quality conditions. Therefore, atmospheric aerosol must be measured adequately, both in the planetary boundary layer – the layer of the atmosphere closest to the Earth's surface, which undergoes considerable daily

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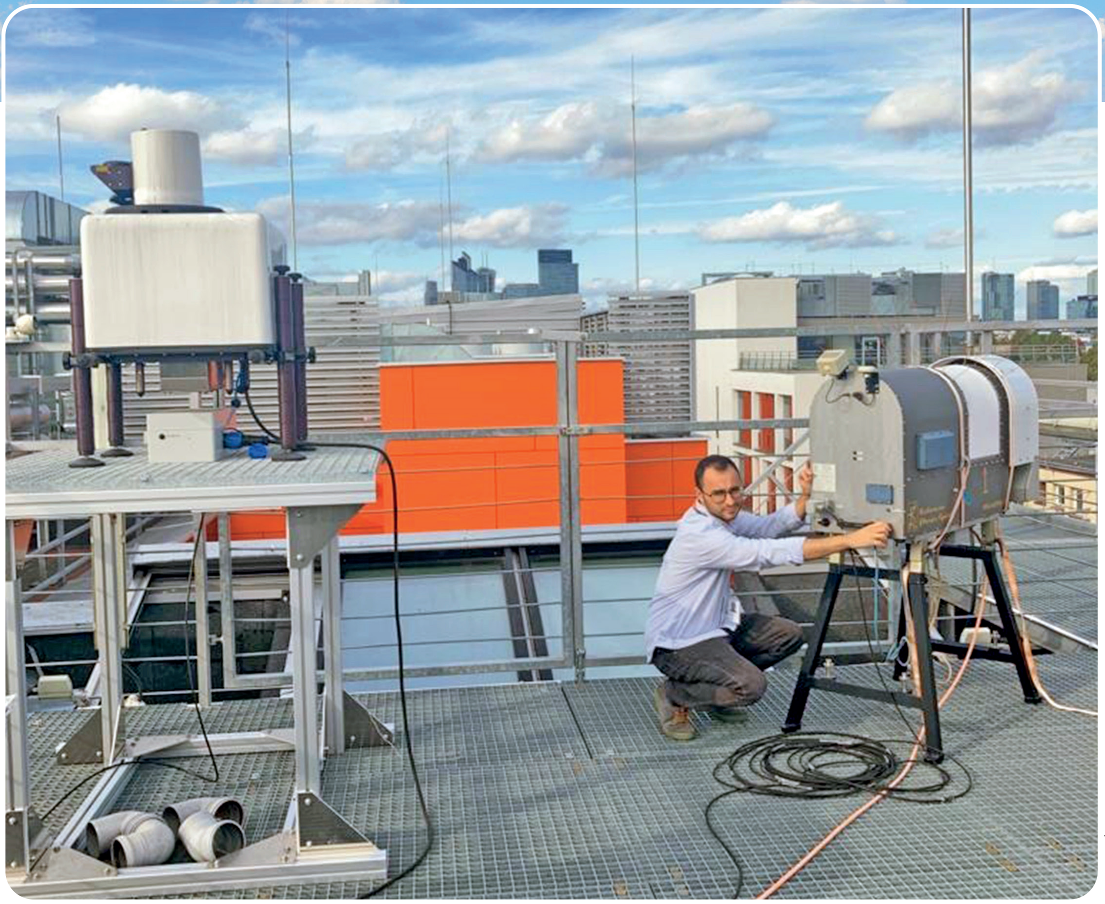
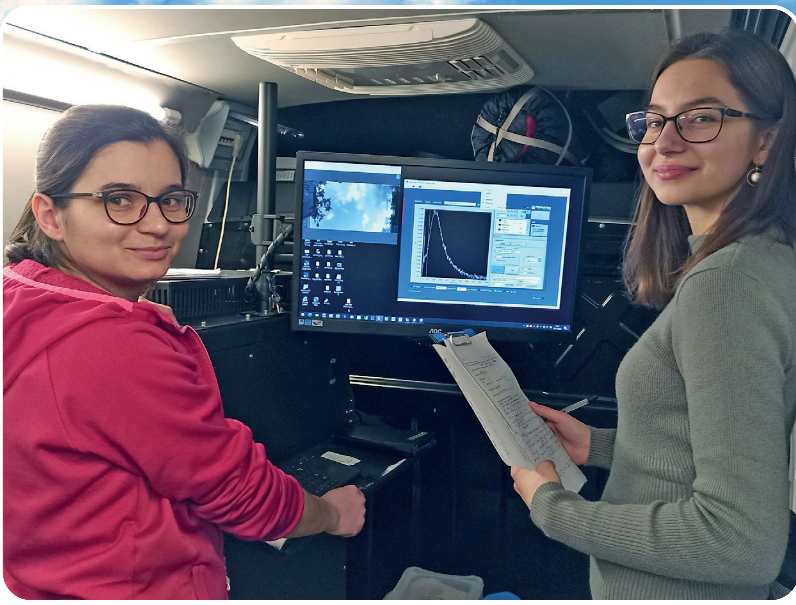


DĄBRÓWKA STĘPNIEWSKA, UNIVERSITY OF WARSAW

RS-Lab team member Pablo Ortiz-Amezcua with equipment for remote meteorological measurements (microwave radiometer and Doppler lidar)

and seasonal variations – as well as higher up, in the free troposphere and the low stratosphere. Atmospheric aerosol can be studied using various methods and techniques. The most obvious of these are *in situ* measurements, taken from specific samples of atmospheric air collected at a given location (for example, near the ground surface, from an airplane, or a drone). Another, less obvious method called remote sensing (RS) involves optical examination of radiation. Both techniques complement each other, but remote sensing offers a lot more information. For example, it can tell us how the various properties of aerosol – such as particle size, shape, hygroscopic properties, ability to scatter or absorb radiation – change over time and with altitude. This involves using specially developed algorithms, including those detecting the altitude of the boundary layer top.

The creation of the Remote Sensing Lab (RS-Lab) at the University of Warsaw, fitted with modern, high-tech equipment (instruments for both remote and *in situ* measurements), has opened up the way to study what in atmospheric science are considered hot topics – which include, for instance, the detection of biogenic aerosol using fluorescence lidar. The RS-Lab was established to take regular measurements of atmospheric aerosol and clouds using various comple-



MACIEJ KARASEWICZ, UNIVERSITY OF WARSAW

RS-Lab team members Łucja Janicka and Zuzanna Rykowska conduct measurements using the EMORAL mobile lidar in Kraków, January 2022

mentary remote sensing techniques, as a part of the broader Aerosol Cloud and Trace-gases Research Infrastructure (ACTRIS).

Setting up the RS-Lab in Warsaw involved a long and difficult process. In 2012, in collaboration with researchers from the Leibniz Institute for Tropospheric Research (TROPOS), we built the first RS-Lab remote sensing instrument – a next-generation lidar system. This instrument has been in continuous operation for many years, providing high-quality data (containing many variables) to the European Aerosol Research Lidar Network (EARLINET). In the following years, the RS-Lab infrastructure was further expanded to include more lidar systems, photometers, radiometers etc., but that first lidar remained the most important research instrument for us. Raising funds for investments in research infrastructure and creating the RS-Lab research team was an arduous task, but in the end these initiatives culminated in the successful integration of the RS-Lab into the ACTRIS infrastructure.

People – a crucial resource

The RS-Lab owes its success to the devoted people who comprise its staff. In creating the RS-Lab team, we have mainly made use of soft funds and various forms of employment, ranging from volunteer work (with full appreciation of the commitment of the volunteers), through part-time work (allowing a better balance between professional development and family life or the pursuit of passions outside science), to full-time non-research positions: technical or administrative, depending on the needs of specific projects and activities. We also work with people with disabilities.

Teamwork is valued very highly at the RS-Lab, and our overarching goal is to find the best way to harness the potential of group members for the benefit of the whole team. Everyone has opportunities for personal development, both in Poland and abroad. Teamwork is further facilitated by the complementary roles and skills of individual team members, the minimization of redundancy in the competencies of the people in the group, as well as care to ensure the proper communication and cooperation. We recognize the importance of jointly and critically discussing the results of the research and evaluating the quality of the work performed, assigning tasks to individual team members based on their competencies and capabilities, and quite simply always trying to offer one another a helping hand. Equally important aspects include fostering the development of individuals by adjusting career paths to their personal-life situations and scientific potential, and promoting an attitude of self-appreciation, recognizing not only one's own strengths and weaknesses but also how they dovetail with those of

RAFAŁ FORTUNA, UNIVERSITY OF WARSAW

RS-Lab team member Patryk Poczta checks the quality of the laser beam in the EMORAL lidar

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The RS-Lab Team:
Iwona Stachlewska (**Leader**)
Doctors: Wojciech Kumala, Dongxiang Wang, Dominika Szczepanik, Pablo Ortiz-Amezcua, Christiana Olusegun
PhD students: Artur Tomczak, Emeka Ugboma, Maciej Karasewicz, Afwan Hafiz, Patryk Poczta, Fatima Mirza-Montoro
Technicians: Łucja Janicka, Rafał Fortuna.
Former members: Stefanie Horatiu, Olga Zawadzka-Mańko, Alex Louridas, Artur Szkop, Eleni Tetoni, Karolina Borek, Konstantina Nakoudi, Michał Pądłowski, Paulina Sokół, Anna Górska, Szymon Migacz, Paweł Swaczyna, Anna Zielińska-Szkop, Montserrat Costa-Surós, Katarzyna Misiura, Aleksandra Lewczuk

the other members of the group. Staff turnover rates are high: some individuals achieve their goals and stay on, whereas others opt to leave after a certain time, which is seen as a normal process. If involvement in the work of the RS-Lab marks a turning point for individuals, as it has in several cases, this means that the most important goal has been achieved.

Global cooperation

The RS-Lab carries out various studies in the field of atmospheric physics. An important aspect of the RS-Lab's activity consists of projects that involve developing instruments and software that support them, as well as algorithms for synergistic data analysis and visualization. We conducted Poland's first comprehensive study of various types of atmospheric aerosol, using a combination of state-of-the-art remote sensing equipment over Warsaw. Collaboration between a carefully selected team and experts from Poland and abroad led to a spectacular research success, and the findings contributed to several doctoral dissertations. We are engaged in pursuing numerous research projects on anthropogenic and geogenic aerosols. One of them, involving a unique study of the optical properties of aerosols in the boundary layer, demonstrated and evaluated how strongly these properties depend on various conditions: the time of the day, relative humidity, and the aerosol concentration. We showed that the burning of biomass (from forest fires and grass-burning), even in very remote regions of the world, can significantly affect the state of the troposphere over Poland. At the same time, we identified distinctive paths of such inflows, including those from North America and Eastern Europe, and differences in their characteristics. Moreover, we developed a calendar of the increasingly frequent inflows of desert sand dust over Warsaw. Recently, we created a novel methodology for using lidar measurements to study plant pollen in the boundary layer. Our own research would not have been possible without the support obtained through the participation of RS-Lab in measurement networks within the pan-European ACTRIS infrastructure.

We are guided by a consistent vision of development, facilitated by the simultaneous use of specific types of equipment and measurements (remote, *in situ*) and types and locations of measurement platforms (ground-based, single-point, mobile, satellite). This approach provides an excellent source of information that can be used in developing models, among other things. In pursuing this approach, the RS-Lab participates in research projects in which it plays leading and key roles. In collaboration with ESA, since 2017 we have been the leader of international activity within the Polish Radar and Lidar Mobile Observation System (POLIMOS) – support for lidar and radar measurements in Poland. In the European Commission's Horizon 2020 program, in the pilot project Sustainable Access to Atmospheric Research Facilities (ATMO-ACCESS), we are in charge of tasks that optimize access to distributed atmospheric research infrastructures that bring together several institutions from the whole of Europe. Playing such roles is not so much about prestige, but more about taking shared responsibility for the state of science in Poland and Europe.

Conducting remote sensing studies of atmospheric aerosol requires a specific infrastructure – top-notch research equipment consisting of instruments selected to work efficiently within scientific research networks (lidar networks such as EARLINET and PollyNET, photometric networks such as AERONET, spectrometry networks such as PGN, and radar networks such as CLOUDNET). Together, they belong to and form a larger research infrastructure. In the case of the RS-Lab, this means the team's active participation in the pan-European ACTRIS research infrastructure. Becoming part of such an infrastructure requires adequate measurement equipment and human resources.

The RS-Lab has become an important facility in the international arena. We collaborate with NASA, ESA, and ECMWF-CAMS. We provide services of physical and remote access to our research infrastructure (used by 19 scholars from Poland and 9 from abroad) and virtual access to measurement data (about 4,000 data downloads from our research station through the ACTRIS Data Center). We also perform specific research on request, including science for the private sector. ■

Further reading:

The ACTRIS network: actris.net.

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