Romanian atmospheric 3D research observatory

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Combining lidar observations with in situ measurements and models aids monitoring of different atmospheric parameters over various space-time scales.

Understanding the causes, potential range, timing, and future impact of changes in climate and air quality is essential to the continued health of economies and societies. The Romanian Atmospheric research 3D Observatory (RADO) is an ambitious facility that aims to improve modeling of physical, chemical, and biological processes, to assess the effects of climate change, and to quantify and reduce uncertainties in evaluating the hydrological cycle and its influence on natural resources.

Over the last five years, environmental research at our institute has focused increasingly on remote sensing of the atmosphere. Starting with a simple aerosol backscatter lidar (light detection and ranging) system in 2005 and a sun photometer in 2006, we have continued to improve the infrastructure. Both a multi-wavelength Raman lidar and an ozone lidar are now operating at the Magurele supersite, which is part of RADO. The station is able to monitor a number of atmospheric parameters, including trace gases and aerosols, as well as meteorological ones. Microwave spectroscopy and mass spectrometry are the latest techniques to be implemented at this site. To help promote remote-sensing approaches in environmental applications, our team has been involved in developing four new lidar stations in Romania in the framework of the national research project Romanian LIdar NETwork.

The main function of the observatory is to carry out experimental and theoretical research in assessing atmospheric composition and air quality, including effects on climate and climate variability. Observational data (e.g., air chemistry, layering, and meteorology) are collected at four urban sites—Baneasa (north Bucharest), Iasi, Timisoara, and Cluj-Napoca—and one supersite: Magurele (south Bucharest). In addition to operational monitoring activities, advanced data processing, analysis, and correlations are conducted to study the planetary boundary layer, the climatology of aerosols and their impact on cloud formation, the influence of various pollutants, and seasonal and regional factors.

One of our main research issues at RADO concerns the direct and indirect effects of aerosols on the radiative budget (i.e., gains and losses in energy). Each day, lidar systems measure vertically resolved profiles of the optical properties of aerosols and ozone. These studies have made it possible to quickly extract data on the vertical structure of the atmosphere. Aerosols measured using lidar serve as valuable tracers of air motion in the planetary boundary layer.¹ The height of layers in the lower troposphere is calculated using the so-called gradient method—the minima of the first derivative—of the range-corrected lidar signal (see Figure 1). Many scientists are still skeptical about the accuracy of the layer altitude retrieved from lidar data. For this reason, at the observatory we also use the Richardson number method to estimate the height of the planetary boundary layer height from radio soundings and to check whether it is consistent with the lidar data (see Figure 2).

Figure 1. Data analysis: layer heights from lidar data. UT: Universal Time.

Figure 2. Richardson number method.
We use multi-wavelength Raman lidar to observe significant variations in the characteristics of aerosols that are dependent on their internal particles. We derive first-level (backscatter and extinction coefficients) and second-level (lidar ratio, Ångstrom exponents, and color ratios) optical properties of aerosols in order to assess the aerosol class, which we then confirm by airmass backward-trajectory analysis. (Numerous prior experimental studies\(^2\) have found that backscatter- and extinction-related Ångstrom exponents and color ratios have specific values for various aerosol categories. This enables lidar scientists to reliably assess the aerosol type—fresh or small aerosol, smoke or sea salt—based on the multi-wavelength instrument measurements.) We use the HYSPLIT 4.6 (Hybrid Single-Particle Lagrangian Integrated Trajectory Model, Version 4.6) back-trajectory model to estimate the origin of aerosols in conjunction with associated meteograms (see Figure 3).

Quantifying the impact of aerosols on climate and analyzing, in turn, the feedback of climate change on aerosols require a thorough understanding of physicochemical processes at the microscale as well as the evolution of aerosols in the context of regional and global circulation. This understanding can only be obtained by combining all available information using state-of-the-art experimental techniques and modeling tools, which is the job of our team at RADO. The next step in developing the existing observational setup is to create an early-warning network for greenhouse gases and other atmospheric phenomena that have an impact on human life, and to build an operational decision-making tool.

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References