Appl. Phys. B 57, 1–2 (1993)

Applied Physics B Photophysics and Laser Chemistry

Editorial

SODAR Monitoring of the Atmosphere - Recent Developments

The knowledge of both vertical wind profiles and turbulence structure is of outstanding importance for the study of the dispersion processes of air pollution and for monitoring local meteorological conditions with regards to airport safety. Complete information on the three-dimensional wind pattern and knowledge of the turbulence structure is needed to predict, e.g., the migration of accidentally released toxic air pollutants, the advection of urban smog plumes or shear flows in the proximity of runways. Beside these applications, the knowledge of wind and turbulence is also of major importance for scientific approaches to meteorological processes driving the dispersion of air pollutants.

Wind sensors mounted on towers, radio sonds, tethered balloons or instrumented aircrafts are traditional ways to acquire information on parameters appropriate to describe the relevant processes. Their disadvantages are the poor spatial representativity or poor temporal resolution and high costs. Therefore, the need for stand-alone remote-sensing techniques is crucial.

For many years the application of acoustic sounding systems, in particular **SODAR** (**SO**und **D**etection **A**nd **R**anging), meets this requirement. It is the aim of the present feature issue to review the field of SODAR applications and its further development. Since SODAR can be regarded as a complementary instrument to the LIDAR for the lower part of the troposphere, this issue follows a special issue of **Applied Physics B** published in 1992.

According to the historical steps of the development of the SODAR and following the review of Singal in this issue, the practical capability of this instrument can be devided into two groups:

- With a single-beam vertical SODAR, the time needed for a narrow acoustic burst reflected by inhomogeneities within the planetary boundary layer (PBL) is measured and displayed in form of an *echogram* or facsimile record.
- If the SODAR backscattering signal is analyzed by means of its Doppler frequency shift, a three-dimensional vertical wind profile can be obtained by using three single SODAR beams at different angles. This can also be achieved by phased array antennas. The availability of Doppler-SODAR instruments allows the determination of the PBL layer structure and wind profiles with high resolution both in time and space.

The definition of characteristic heights specifying the thermal structure and their evaluation directly from SODAR data or by means of boundary layer parameter models is discussed by Beyrich. In particular the evolution of the stable boundary layer and the currently not yet well understood phenomenon of the accompanying low-level jet gives an example for a process-oriented study with SODAR. The exploration of gravity waves, as one application of SODAR instruments in studies of local processes given by Bull and Neisser, is also of special interest in regions with Alpine foehn phenomena flowing above cold air lakes.

A wide and important range of applications of SODAR deals with the characterization of turbulence by means of diffusion and PBL parameters, as e.g. the temperature structure coefficient, the coefficient for Gaussian plume dispersion or the friction velocity, but also sensible heat flux, as shown in detail by Melas.

The development of the technical realizations of SODAR points towards the application of phased-array antenna systems and to the use of multi-frequency bursts. The trend towards smaller instruments, as documented by the high-frequency Mini-SODAR from Mursch and Wolfe in combination with effective and low cost display techniques, as demonstrated by Papageorgas et al., makes possible to build up future SODAR networks as an effective tool for monitoring the dynamical aspect of pollution dispersion.

Summerizing the advantages of SODAR, the most outstanding feature is the permanent monitoring of height profiles with high temporal resolution. This feature is common to all remote-sensing techniques and fills the gap of knowledge in the vertical direction. A special advantage of SODAR is also its volume-averaging ability, which leads to large volumes of representativity for the measurements, compared to traditional in situ techniques.

On the other hand, the application of SODAR is limited by its reachable height of several hundred meters, which is often much lower than, e.g. the convective boundary-layer height during daytime, where the relevant processes of air pollution take place. Futhermore, pollution dispersion is controlled by velocity fluctuations, whereas SODAR is sensitive to temperature fluctuations, thus resulting in an underestimation of the stable nocturnal boundary layer. A simple limitation in practical applications, mainly in areas with a high population density as given right in the case of interesting pollution situations, is the fact, that SODAR is noisy and its functionality is disturbed by ambient noise. Also, for practical applications one has to be aware of the fact that the sound backscatter is sensitive to the inclination of the SODAR beam, as deduced by Kallistratova and Petenko. Due to high inhomogeneities and backscatter anisotropy, the error with a three-horn SODAR for the evaluation of the wind velocity in 3 dimensions is high.

Large uncertainties arise in specifying turbulent parameters from SODAR data, e.g. the temperature structure coefficient is overestimated under stable conditions by a factor of two. In general, all parameters derived from the PBL-model approaches contain the uncertainties of the models in addition to the uncertainties given by the SODAR measurement itself, as demonstrated by Melas. Although the determination of certain turbulence parameters with the help of established theories is encouraging, the recommendation to use SODAR in an operational way for these parameters is premature. Further improvement in the application of suitable models and serious comparisons with other measurement techniques, as is done for the wind variances by Thomas and Vogt, is needed.

Overall, the SODAR can be judged to be a useful tool for remote monitoring wind, pronounced thermal stratification and certain turbulence parameter profiles up to several hundred meters. In networks and in combination with other techniques, the high temporal and vertical resolution of SODAR leads to a fairly complete documentation of local to mesoscale phenomena in the research of short-range diffusion.

The interpretation of the echograms needs a great amount of new experience for qualitatively judging a meteorological situation, as shown by Pekour and Kallistratova. This experience has to be categorized in a classification scheme and compared to a classification of weather types. Among the traditional parameters such as pressure, temperature and humidity, SODAR is a new "eye" looking from a different point of view into the atmosphere, but with the appropriate experience, it is a better-suited instrument for specifying local phenomena relevant for pollution dispersion than the general weather-type classification.

Villigen, May 1993 W.K. Graber