Appendix VIII - Backscatter Sonde Instruments

The development and systematic use of the backscatter sonde began about 1990 with a self-contained, two wavelength instrument weighing approximately 6 kg. (Rosen and Kjome, 1991). In general, the backscatter sonde produces a data product very similar to that of a lidar and the data analyses of the two systems incorporate related features. The essential measurement is a wavelength dependent aerosol and molecular backscatter, which, when coupled with a calculated molecular backscatter from the concurrent temperature and pressure (using standard, integrated radiosonde sensors), produces a scattering ratio. The multiple wavelength measurements provide a rough indication of particle size. Other features include depolarization measurements (providing shape information), and cloud vertical structure (for dense and thin layers) as well as inter-cloud structure. Its relatively small cost and portability make it available for a wide range of investigators. It has been used to study volcanic aerosol (e.g. Rosen, J, and N. Kjome, 1994), biomass burning (e.g. Rosen, J, et. al., 2000), and polar stratospheric clouds (e.g. Suortti, T, et al. 2001). Additional references are given in the backscatter sonde metadata file.

There are some special attributes of the backscatter sonde that, when employed, allow it to be especially well suited for long term monitoring. One such feature is its ability to be absolutely calibrated in terms of molecular scattering before it is sent into the field. The instrument in this form was flown through 2010.

Although no significant changes were made in the Wyoming backscatter sonde design that would impact the associated archived data, advances in technology have led to a smaller, lighter weight (0.58 Kg) instrument that can easily be integrated with other sensors and commercial radiosonde telemetry for a total payload weight of less than 2 Kg. A manuscript providing the complete instrument details is still in its draft stages (F.G. Wienhold, et. al.). However, its use in various studies has been extensively documented (A. Cirisan et al, 2014; I. Engel et al., 2014; Q. He et al., 2017; S. Khaykin et al., 2013; S. Khaykin et al., 2016; J.-P. Vernier et al., 2015; J.-P. Vernier et al., 2016). While there is a noticeable loss in effective sensitivity associated with this instrument, but that may be overcome with advancing technology and development.

Quality criteria for the evaluation of new instruments and instrument teams
The backscatter sonde type instrument is potentially capable of providing valuable aerosol and cloud profiles relevant to the NDACC database. However, individual instruments must still meet the NDACC definition of validation for formal acceptance.

In general, the validation procedure includes a complete description of the instrument (preferably appearing in an easily accessible refereed journal), a description of the data analysis (consistent with NDACC Data Protocol) in sufficient detail that an independent investigator could develop an equivalent algorithm, uncertainty and error analyses (consistent with NDACC Theory and Analysis Protocol), and participation in a continuing inter-comparisons with identical and/or similar instruments (following the NDACC Instrument Inter-comparison Protocol).

Specifically, the following is a guide for the initial and continuing validation of backscatter sondes. It is expected that much if not all of these points would be covered in refereed journals and also in the corresponding metadata file.

1. Complete optical description including drawings and the quantitative range of angles employed.
2. Wavelength distribution description of light sources and sensors.
3. Theoretical response of the instrument to various relevant aerosol size distributions.
4. Description of electronics employed for data collection and processing.
5. Description of analysis, errors, noise, statistical fluctuations and background corrections.
6. Sensitivity to ambient environmental conditions such as pressure and temperature.
7. Sensitivity to particles emanating from the balloon or other on-board instruments.
8. Assessment of inflight calibration/sensitivity drifts using, for example, ascent/descent comparisons.
9. Calibration procedure and shipping effects on calibration stability.
10. Discussion of measurement reproducibility using techniques such as two closely spaced soundings during stable conditions, two identical instruments on the same sounding, a series of several soundings during relatively stable conditions.

An initial Metadata file for a new instrument/team should be prepared and submitted for examination by members of the Sonde Instrument Working Group (IWG). This file should be up-dated regularly and include the following:

1. A running history of changes in design and data processing
2. Reports/references of validation exercises
3. History of inter-comparisons with other instruments
4. Table of stations, number of soundings with the backscatter sonde at the station, and date range

When possible, it would be highly useful to include supporting data such as ozone and humidity/frost point in the same file as the aerosol data. Such additional information has often proven indispensable to the interpretation of aerosols and atmospheric processes. However, if included, a specific statement in the file should qualify the data as being of validated quality or presented for supporting information only.

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