Appendix III - Lidar Instruments

Lidar spectroscopy is an analytical technique with a long history in environmental science and chemistry. This method has been used widely in atmospheric studies and has a heritage in ground-based as well as space-based instruments. Thus, lidars are well justified as NDACC primary measurement techniques for determining the atmospheric vertical profiles of ozone, temperature, aerosols, and water vapor. Nevertheless, each individual instrument must still be validated. This appendix is intended to help guide the validation process.

Quality Criteria for the Evaluation of New Instruments and Instrument Teams

Independent Evaluation of the Instrument Design and Data Analysis

The NDACC has accepted lidar measurement techniques as valid methods for measuring and monitoring stratospheric temperature, aerosols, and ozone, wind, tropospheric ozone, and tropospheric and lower stratospheric water vapor. Additional lidar techniques can also be considered, e.g. tropospheric temperature by rotational Raman lidar or stratospheric winds by Doppler lidar. Prior to a formal intercomparison of the new instrument(s), the Investigator should supply the NDACC Lidar Working Group (LWG) with a detailed technical description of the instrument and its general operating parameters. In the case of water vapor measurement, and other techniques that require external calibration, such as rotational Raman lidar or certain Doppler lidars, the Investigator should supply the NDACC LWG with a detailed description of the calibration procedure, with special emphasis on its accuracy and long-term stability.

Instrument and Data Analysis Intercomparison

There are several ways recommended for the validation of NDACC lidar instruments:

1. A formal and impartial (semi-blind) intercomparison of lidar systems located at the same site for a given period of time may be conducted. Such validations can be conducted either through a validation exercise using an NDACC mobile lidar system, or by comparing a new instrument with an already established lidar system operating at the same NDACC site. The NDACC Instrument Intercomparisons Protocol details the recommended procedures to be followed for such intercomparisons.
2. Intercomparisons on a statistical basis with a satellite-borne instrument measuring the same quantity as the lidar can also be performed (for example, solar occultation instruments for ozone and/or aerosols measurements). Such intercomparisons have to be made over the long term to remove as much natural variability as possible. In this respect, the satellite instrument is essentially used as a traveling standard between the various lidar stations.
3. Intercomparisons on a statistical long-term basis may also be made with other lidar instruments located at neighboring NDACC sites. However,

such intercomparisons must take into account any atmospheric variability associated with the site locations.

4. Side-by-side intercomparisons with other instruments measuring the same atmospheric species or parameter at the same NDACC site are also recommended. Such intercomparisons must take any differences in viewing geometry into account.
5. For the measurement of water vapor and other techniques that require external calibration (e.g. rotational Raman lidar, incoherent Doppler lidar), calibration methods should be optimized, validated and compared with the primary purpose of maintaining the best possible accuracy and long-term stability. For each instrument, the use of multiple and/or time-overlapping calibration procedures is recommended.
6. As stated in the Instrument Intercomparisons Protocol, formal instrument intercomparison could be preceded by, accompanied by, or followed by formal or informal data analysis intercomparisons, since full certification involves the intercomparison of the instruments and their associated analysis procedures. Such algorithm intercomparisons should use a common database established by the NDACC Lidar Instrument Working Group (IWG), which includes synthetic data derived from atmospheric and instrument models, raw data provided by validated lidar systems within the NDACC, and the ancillary data required for data inversion.

The minimum validation requirements for an NDACC lidar system are given in items 2 – 6 above. In so far as resources, staffing, and logistics permit, a plan should also be established for a formal intercomparison as described in item 1 within the first three years of operation.

Quality Criteria for the Evaluation of Continuing Instruments and Instrument Teams

The Lidar IWG will evaluate the validation record of a given instrument on a two-year basis. To facilitate this, NDACC Lidar Investigators should provide the following information to the IWG.

- A document describing the instrument and data acquisition procedures.
- A document describing the algorithm used, including the forward and retrieval models, the method of uncertainty analysis, and the ancillary data (spectroscopic data, atmospheric parameters, etc.) used for the inversion.
- The validation record of the instrument.
- For water vapor and other techniques that require external calibration (e.g. rotational Raman lidar), a document describing the calibration history of the instrument.

In addition, NDACC lidar Instrument Investigators are required to participate in any ongoing exercises conducted by the Lidar IWG that support continued NDACC certification, such as new algorithm intercomparisons and the long-term analysis of satellite data.

Changes in Instruments and Data Analysis

Since one of the major goals of the NDACC is the detection of long-term trends, care should be used with any modifications of the instrument or data analysis that may affect the results. Once the regular operation of an instrument has begun, such changes should not be undertaken lightly and consultation with the Lidar IWG is recommended. The primary data (raw signals) should be retained by the Investigator indefinitely (although not deposited in the NDACC archive), so that any improved data-retrieval processes can be applied retrospectively to the earlier data. In such cases, the entire dataset should be reprocessed and archived, along with (at least) reference to earlier versions. For the measurement of water vapor, instrumental changes should be immediately preceded by and followed by intensive calibration evaluation campaigns. The change in the calibration parameter(s) resulting from instrumental changes should be clearly reported and documented when archiving the data.

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