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Study and mitigation of calibration error sources in a water vapour Raman lidar

Leslie David (1), Olivier Bock (1), Pierre Bosser (1,2), Christian Thom (3), and Jacques Pelon (4)
(1) IGN LAREG, Univ Paris Diderot, Sorbonne Paris Cite, Paris, France (leslie.david@ign.fr), (2) IGN ENSG, Champs-sur-Marne, France, (3) IGN LOEMI, Saint-Mandé, France, (4) CNRS IPSL LATMOS, Paris, France

The monitoring of water vapour throughout the atmosphere is important for many scientific applications (weather forecasting, climate research, calibration of GNSS altimetry measurements). Measuring water vapour remains a technical challenge because of its high variability in space and time. The major issues are achieving long-term stability (e.g., for climate trends monitoring) and high accuracy (e.g. for calibration/validation applications). LAREG and LOEMI at Institut National de l'Information Géographique et Forestière (IGN) have developed a mobile scanning water vapour Raman lidar in collaboration with LATMOS at CNRS. This system aims at providing high accuracy water vapour measurements throughout the troposphere for calibrating GNSS wet delay signals and thus improving vertical positioning. Current developments aim at improving the calibration method and long term stability of the system to allow the Raman lidar to be used as a reference instrument.
The IGN-LATMOS lidar was deployed in the DEMEVAP (Development of Methodologies for Water Vapour Measurement) campaign that took place in 2011 at the Observatoire de Haute Provence. The goals of DEMEVAP were to inter-compare different water vapour sounding techniques (lidars, operational and research radiosondes, GPS,. . .) and to study various calibration methods for the Raman lidar. A significant decrease of the signals and of the calibration constants of the IGN-LATMOS Raman lidar has been noticed all along the campaign. This led us to study the likely sources of uncertainty and drifts in each part of the instrument: emission, reception and detection. We inventoried several error sources as well as instability sources. The impact of the temperature dependence of the Raman lines on the filter transmission or the fluorescence in the fibre, are examples of the error sources. We investigated each error source and each instability source (uncontrolled laser beam jitter, temporal fluctuations of the photomultiplier gain and spatial inhomogeneity in the sensitivity of the photomultiplier photocathode,. . .) separately using theoretical analysis, numerical and optical simulations, and laboratory experiments. The instability induced by the use of an optics fibre for coupling the signal collected by the telescope to the detectors is especially investigated. We quantified the impact of all these error sources on the water vapour and nitrogen Raman channels measurements and on the change in the differential calibration constant and we tried to implement an experimental solution to minimize the variations.