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End-to-end Simulator of a space-borne Raman Lidar for the thermodynamic profiling of the atmosphere

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An end-to-end model has been developed in order to simulate the expected performance of a space-borne Raman Lidar, with a specific focus on the Atmospheric Thermodynamics LidAr in Space – ATLAS proposed as a "mission concept" to the ESA in the frame of the "Earth Explorer-11 Mission Ideas" Call. The numerical model includes a forward module, which simulates the lidar signals with their statistical uncertainty, and a retrieval module able to provide vertical profiles of atmospheric water vapour mixing ratio and temperature based on the analyses of the simulated signals. Specifically, the forward module simulates the interaction mechanisms of laser radiation with the atmospheric constituents and the behavior of all the devices present in the experimental system(telescope, optical reflecting and transmitting components, avalanche photodiodes, ACCDs). An analytical expression of the lidar equation for the water vapour and molecular nitrogen roto-vibrational Raman signals and the pure rotational Raman signals from molecular oxygen and nitrogen is used. The analytically computed signals are perturbed by simulating their shot-noise through Poisson statistics. Perturbed signals thus take into account the fluctuations in the number of photons reaching the detector over a certain time interval. The simulator also provides an estimation of the background due to the solar contribution. Daylight background includes three distinct terms: a cloud-free atmospheric contribution, a surface contribution and a cloud contribution[1]. Background is calculated as a function of the solar zenith angle. In order to better estimatethe background contribution, an integration on slant path is performed instead of a classical parallel-planes approximation. The proposed numerical model allows to better simulate solar background for high solar zenith angles, even higher than 90 degrees. Signals simulated through the forward model are then fed into the retrieval module. A background subtraction scheme is used to remove the solar contribution and a vertical averaging is performed to smooth the signals. Based on the application of the roto-vibrational Raman lidar technique, the vertical profile of atmospheric water vapour mixing ratio is obtained from the power ratio of the water vapour to a reference signal, such as molecular nitrogen roto-vibrational Raman signal or an alternative temperature-independent reference signal. A vertical profile of temperature is then obtained through the ratio of high-to-low quantum number rotational Raman signals by the application of the pure rotational Raman lidar technique. Both atmospheric water vapour mixing

ratio and temperature measurements require the determination of calibration constants, which can be obtained from the comparison with simultaneous and co-located measurements from a different sensor [2]. The simulator finally provides statistical (RMS) and systematic (bias) uncertainties. Estimates are provided in terms of percentage and absolute (g/kg) uncertainty for water vapour mixing ratio measurements and in terms of absolute uncertainty (K) for temperature measurements.

References

1 - P.Di Girolamo et al., "Spaceborne profiling of atmospheric temperature and particle extinction with pure rotational Raman lidar and of relative humidity in combination with differential absorption lidar: performance simulations"Appl.Opt. 45, 2474-2494(2006)

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