Identification of fog Particle Size Distributions by inverting the radiative transfer equation

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Degraded meteorological conditions, including fog, limit the performance of optical sensors used in various fields of application (avionics, intelligent road vehicles, etc.). Cerema, the French research and expertise center under the supervision of the Ecological Transition Ministry, conducts evaluations of these sensors under artificial and controlled fog conditions in the dedicated PAVIN Fog&Rain platform. In order to perform a digital twin of the platform, it is necessary to develop robust modeling of the propagation of electromagnetic waves in fog. Propagation is governed by the phenomena of scattering and absorption of photons in contact with fog droplets. The fog Droplet Size Distribution (DSD) is a key parameter of the propagation models.

In the present work, we investigate the DSD identification from spectral radiation measurements by inverting the stationary radiative transfer equation (RTE). This distribution together with Lorenz-Mie scattering theory allow to compute the optical properties (scattering coefficient, absorption coefficient, and phase function). First, we prove the well-posedness of the underlying inverse problem, then we perform some numerical experiments using synthetic data. The numerical results suggest that the method allows to identify the DSD.

We present some numerical results obtained by using various models describing the particle size distribution (e.g. Shettle and Fenn models) and some experimental distribution measured in the Cerema platform. Afterwards, the identification of the DSDs is carried out using the radiative transfer equation with the collision term (multiple scattering) and by performing direct scattering and backscattering measurements. The robustness of the reconstruction was studied numerically by introducing several noise levels to the measurements.