Stochastic polarized scattering tomography for the retrieval of scatterers in the atmosphere

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Optical tomography estimates a digital volumetric model of an object. A source illuminates the object, through which the radiation propagates. The object is imaged from multiple viewpoints. Each image measures the optical field at this viewpoint. Tomographic recovery is based on fitting an image formation model (i.e. forward model) to these measurements. We believe that tomography has the potential to be used for retrieval of aerosols and cloud droplets in 3D. This is opposed to legacy approaches, which assume a plane parallel structure of the medium and 1-D radiative transfer (RT). Several studies have shown, however, that the plane-parallel assumption can lead to errors in retrieved cloud parameters.

In the atmosphere, the dominant light source is the sun. As solar radiation travels through the atmosphere, the radiation is affected by scattering and absorption due to molecules, aerosols, and hydrometeors. Even though solar radiation entering the atmosphere is unpolarized, scattering leads to partial polarization. We believe that modeling these interactions comprehensively should assist in the recovery process. Hence, we seek a retrieval process, which relies on a polarized RT model, accounting for scatterer variation in the 3D domain.

We present initial results in a 2D domain, using simulated data. The results do not rely on a plane-parallel assumption. The forward model is a 2D polarized RT, expressed by a statistical Monte Carlo (MC) model. MC is scalable, parallelizable, and hence the solution can be potentially fast. As for the recovery process, instead of fitting a scalar radiance field, we fit three components of the Stokes vector, which represent the radiance and the state of polarization. Consequently, we define a cost function for fitting the image formation model to the vectorial measurements. The optimization is done using gradient descent, where the gradient is estimated stochastically by the MC process. We work to expand this method to a 3D domain, using 3D polarized RT. In addition to simulated tests, we plan recovery using real measured data. These results may improve capabilities of the CloudCT mission (funded by ERC), as well as other planned atmospheric sensing projects.

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