# Large Eddy Simulation and 3D Radiative Transfer Modeling in Support of Multi-Angle Remote Sensing of Clouds and Aerosols, With or Without Imaging

*Anthony B Davis[1], Georgios Matheou[1], Feng Xu[1], Claudia Emde[2], Zheng Qu, Aviad Levis[3], Yoav Y Schechner[3]

1. Jet Propulsion Laboratory / California Institute of Technology, 2. Meteorologisches Institut, Ludwig Maximilians-Universität, 3. Department of Electrical Engineering, Technion - Israel Institute of Technology

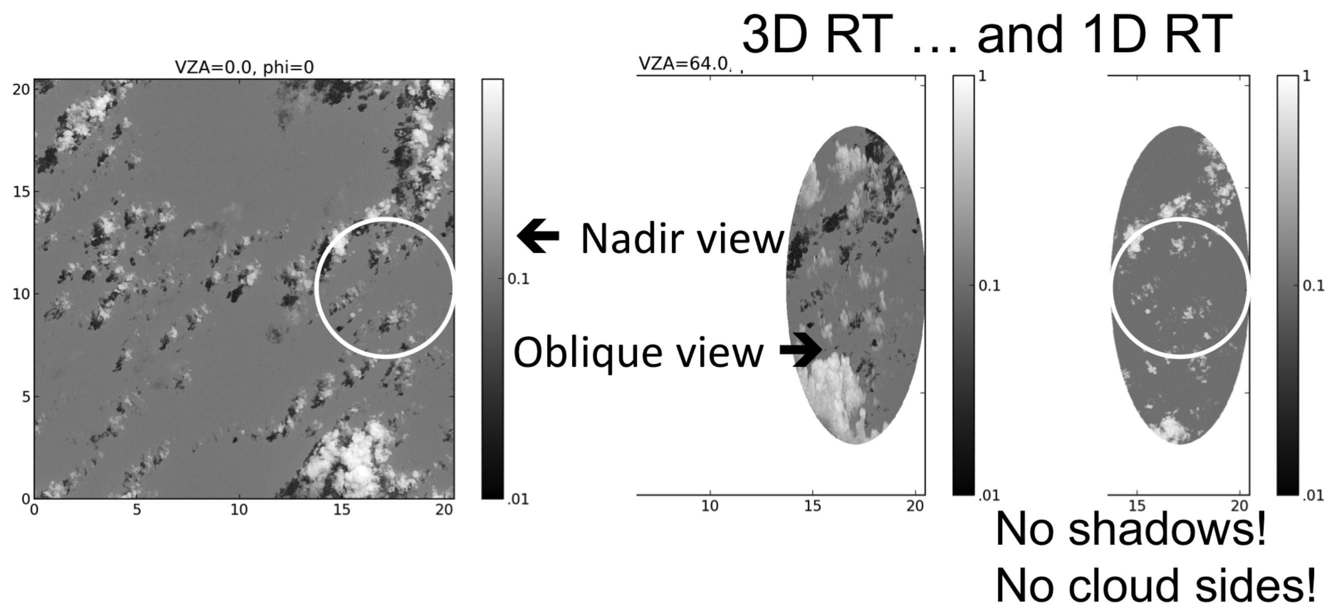
Although real clouds and aerosols vary in all three spatial dimensions, operational remote sensing of their inherent physical properties is invariably predicated on one-dimensional (1D) radiative transfer (RT) theory. We therefore always need to worry about the resulting forward signal model error. It needs to be quantified and, if possible, mitigated. Computational 3D RT has been brought to bear on this issue for decades, with 3D cloud models that have evolved from simple shapes such as cuboids and spheroids to deterministic fractal geometries on to stochastic multifractal distributions of scattering particle density that realistically mimic turbulent flows. More recently, computational fluid dynamics have been applied to cloud-scale process modeling with spectacular success, especially using Large-Eddy Simulation (LES) techniques. It was just a matter of time before this LES-based cloud modeling would be combined with 3D RT, on the one hand, to assess the visual verisimilitude of the synthetic clouds and, on the other hand, to apply the whole high-fidelity simulation framework to challenging problems in remote sensing.

We will report on three projects that use the "LES + 3D RT" toolbox at JPL. They cover the two broad categories of 3D RT issues: sub-pixel variability and cross-pixel radiative exchanges. Non-imaging (single-pixel) instruments, such as the Aerosol Polarimetric Sensor (APS) on the (doomed) Glory mission, only has the former problem. Airborne imagers, such as the Multi-angle Spectro-Polarimetric Imager (MSPI) with very high spatial resolution are affected by the later.

We used LES clouds and a proprietary Monte Carlo 3D RT model to explore the non-linear mixing of aerosol and broken cumulus cloud signals in the APS footprint (~10 km) over a wide range of viewing angles. We used the same LES clouds and an open-source deterministic 3D RT model to demonstrate 3D cloud reconstruction using a new kind of tomography, and then applied it to clouds captured with AirMSPI multi-angle/multi-pixel data. Finally, we retrieve from AirMSPI images of marine stratocumulus the radiative smoothing scale (where pixel cross-talk becomes less significant), and describe a path toward a robust retrieval of optical and geometrical thicknesses.

Keywords: Clouds, Aerosols, Large eddy simulation, Three-dimensional radiative transfer, Inverse problems, Remote sensing


3D RT … and 1D RT
VZA=0.0, phi=0
VZA=64.0
Nadir view
Oblique view
No shadows!
No cloud sides!