Forward Modeling and Retrieval OSSEs for the Tomorrow.io Radar Constellation

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Tomorrow.io is planning to launch a constellation of Ka-band precipitation radars, beginning with a non-scanning Pathfinder design in late 2022 followed by swath-capable instruments in 2023. In order to optimize the design of the radar and the constellation, the impact of each design choice (e.g., antenna size) must be evaluated with respect to its impact on the quality of the real-time global precipitation product. In order to accomplish this, a series of end-to-end retrieval Observing System Simulation Experiments (rOSSEs) were conducted. These rOSSEs required the following three components: 1) three-dimensional, high resolution atmospheric data fields; 2) a forward model capable of simulating realistic radar measurements for a given set of system parameters; and 2) retrieval algorithms that are flexible with respect to these parameters.

For the first step, Tomorrow.io's Comprehensive Bespoke Atmospheric Model (CBAM) was run at 1 km resolution for several selected cases representing a wide variety of precipitation regimes. Each of these cases was selected for having a representative NASA/JAXA GPM core observatory overpass. In order to constrain the CBAM microphysics and scattering assumptions used for the radar forward model, the measured DPR reflectivity profiles were used to simulate microwave brightness temperatures from different ice aggregate particle shapes and orientations. These simulations were compared to observed brightness temperatures from GMI to provide a spatially varying distribution of likely microphysical habits present in each case. A time-dependent two-stream radiative transfer model (RTM) was then used to simulate the Ka-band reflectivity profiles, and output was compared to GPM DPR observations statistically via CFAD diagrams, which showed good structural agreement for the optimized microphysics options. A final post-processing step was then applied which mimics the process by which a radar samples the RTM-generated profiles, injecting realistic noise and a sensitivity floor that depends on the radar system parameters. A suite of retrieval methods ranging from iterative attenuation correction to inversion of the RTM and ML-augmented Bayesian methods were applied to the simulated profiles, each having a performance advantage in different rain intensity regimes, in order to evaluate the radar design parameters with respect to precipitation detection and quantification metrics.