Forward Modeling and Data Assimilation Research Utilizing GPM Observations

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Research Goals:

(1) Provide a physical basis for 1-D variational retrievals using radar observations
(2) Simulate active sensor platforms within CRTM/ARTS
(3) Enhance all-sky data assimilation capabilities by providing increased access to active sensor dataset
(4) Development of database of realistically shaped hydrometeors and associated scattering and extinction properties

Status and Scope:

(1) Presently covers satellite-based radar simulations with path-integrated attenuation
(2) Working on complete integration into CRTM
(3) New scattering database interface layer under development for CRTM, also to be implemented in ARTS for MIIST
(4) Updated single particle melting model (SPMM) to provide more realistic melting-layer simulations

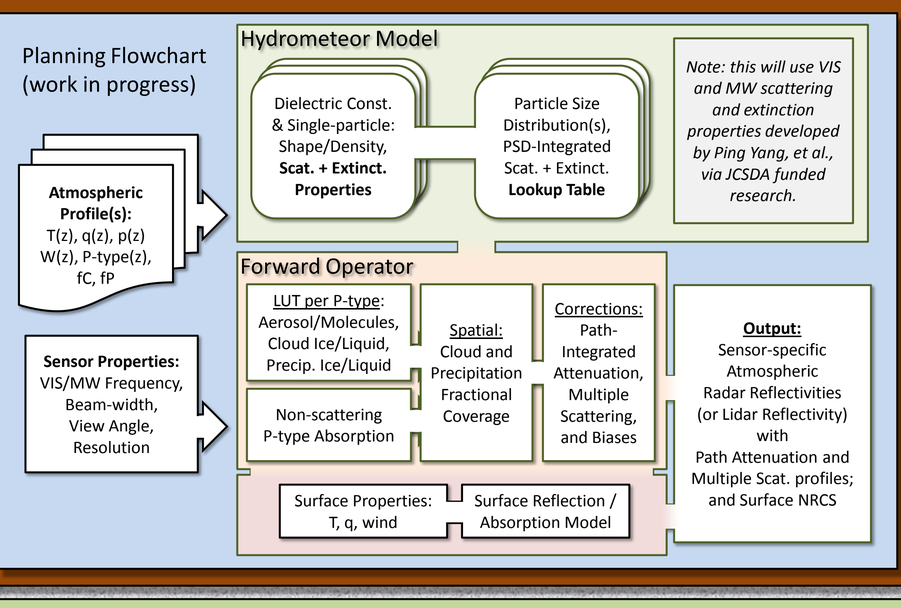
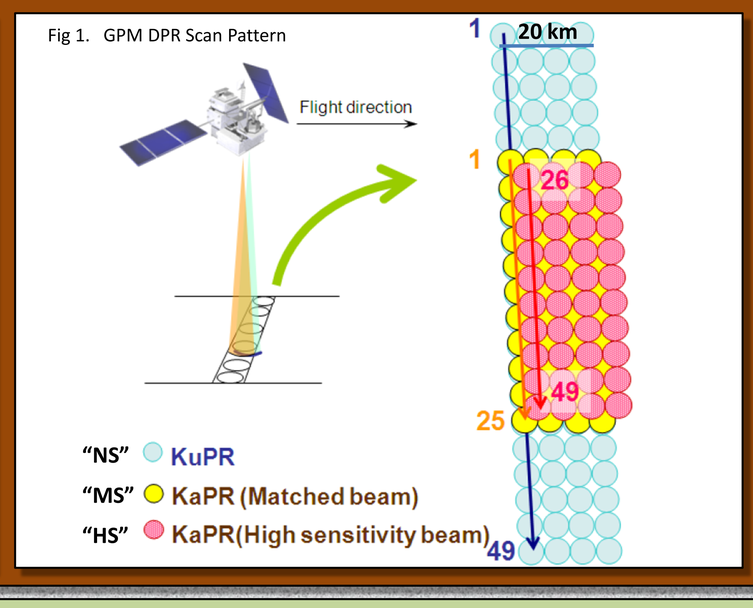
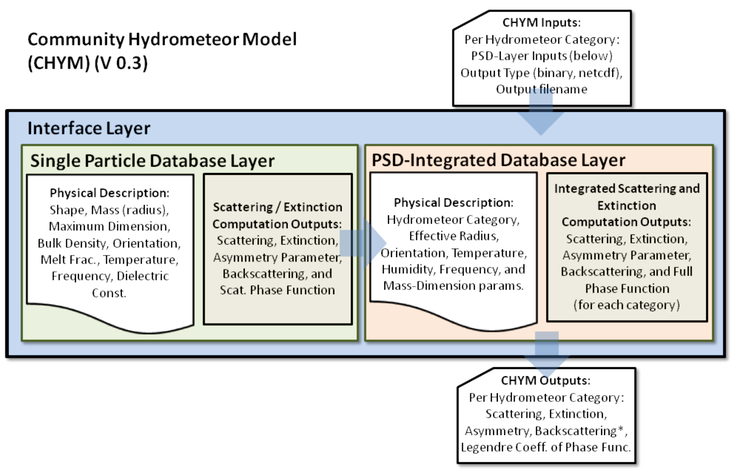
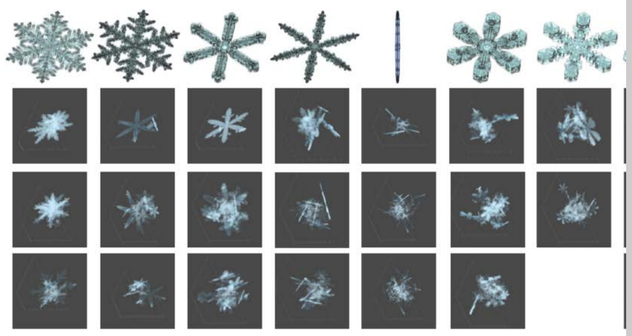


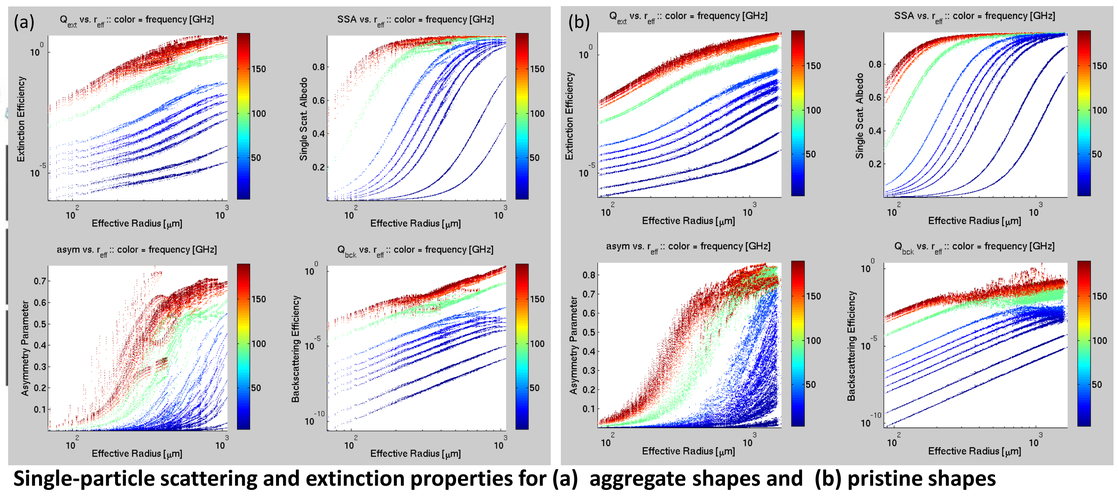
Fig 1. GPM DPR Scan Pattern







Simulated aggregates with their constituent base shapes (top row) [Image courtesy of K.-S. Kuo]



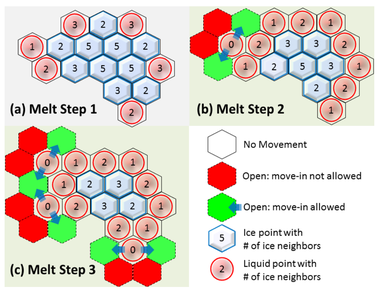
Single-particle scattering and extinction properties for (a) aggregate shapes and (b) pristine shapes

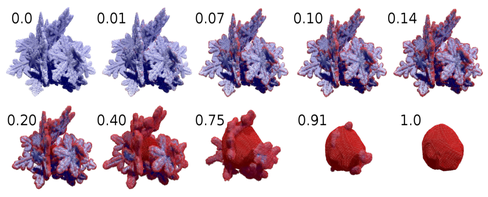
Single Particle Melting Model (SPMM):

Heuristic melting algorithm: 2 iterative operations: melt mode and movement mode. Can be easily run on any desktop computer, requiring at most a few hours to simulate the entire melting process.

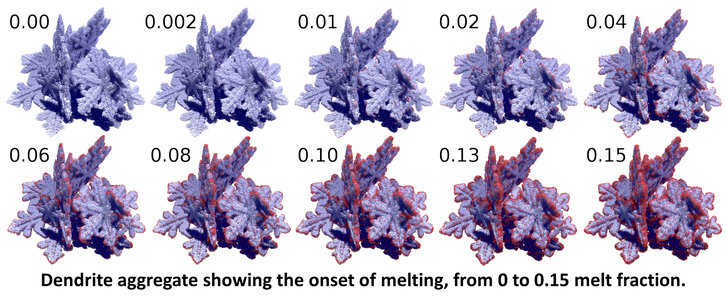
Melt Mode: Nearest neighbor approach, similar to cellular automata; fixed ice points having the fewest ice neighbors melt first -- iterate.

Movement: Liquid points having only liquid neighbors are free to move, subject to the following constraints: (i) Can only move to locations having other water neighbors, (ii) movement must always be toward the center of mass (parallel movements allowed).

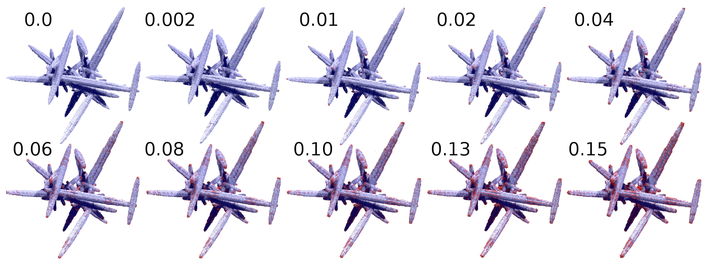




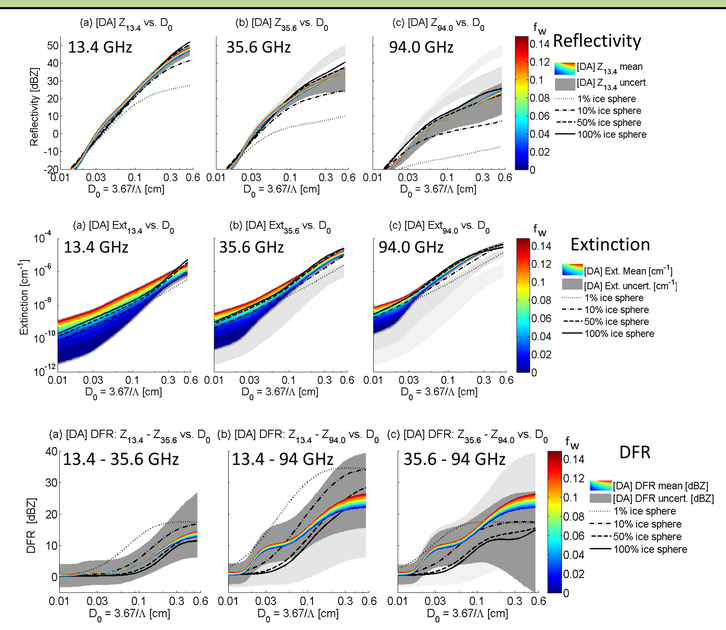
Dendrite aggregate showing the full range of melting, from 0 to 1.0 melt fraction.



Dendrite aggregate showing the onset of melting, from 0 to 0.15 melt fraction.



Needle aggregate showing the onset of melting, from 0 to 0.15 melt fraction.



Community Active Sensor Module (CASM)

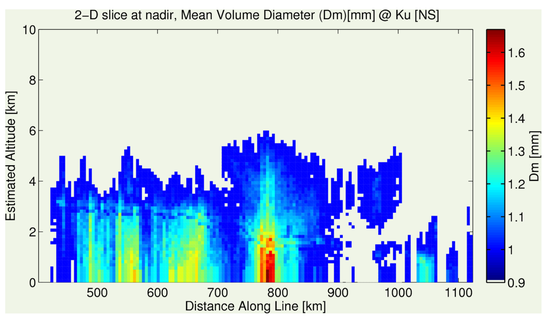
CASM Capabilities:

(1) Simulation of multi-frequency radar reflectivities and path-integrated attenuation
(2) Simulation of coincident passive microwave TBs
(3) FOV + antenna pattern matching possible (not tested yet)
(4) Swappable single-particle scattering tables*

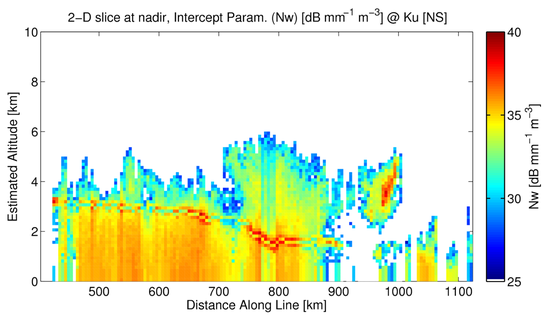
CASM Goals:

(1) Forward-model various active sensor platforms (currently sat. radar), extending to scatterometer, altimeters, and lidar
(2) Provide a physical basis for 1-D variational retrievals (e.g., MIIDAPS) of active observations;
(3) Enhance data assimilation capabilities by providing increased access to active sensor datasets
(4) Provide an independent forward model for radar to compare with ARTS approach for MIIST
(5) For use as a testbed for physics testing in combined radar/radiometer algorithms

(a) DPR SRT-Derived D_m [mm]

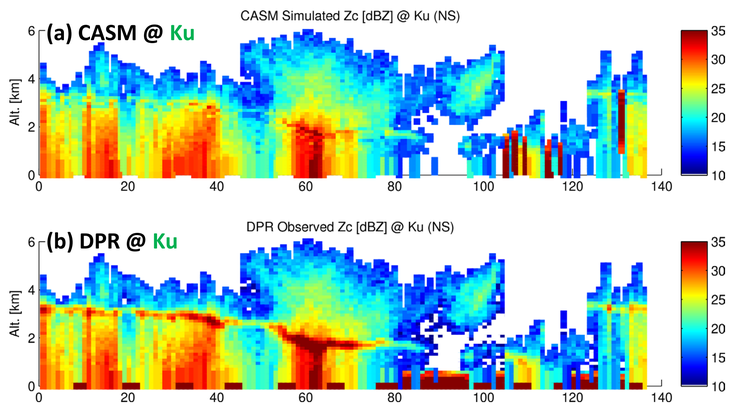


(b) DPR SRT-Derived N_w [db mm^{-1} m^{-3}]

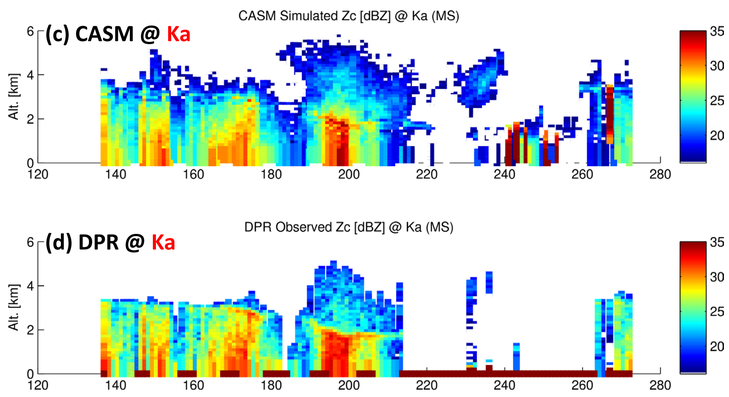


A 2-D vertical slice of SRT-derived DSD parameters. Panel (a) shows the median volume diameter (Dm), and (b) shows the normalized intercept parameter (Nw). Both quantities are derived from the Ku-band observations, after correcting for path-integrated attenuation, and removal of surface clutter.

2D Vertical Slice Zc (Corrected Z) at Ku band.



2D Vertical Slice Zc (Corrected Z) at Ka band.

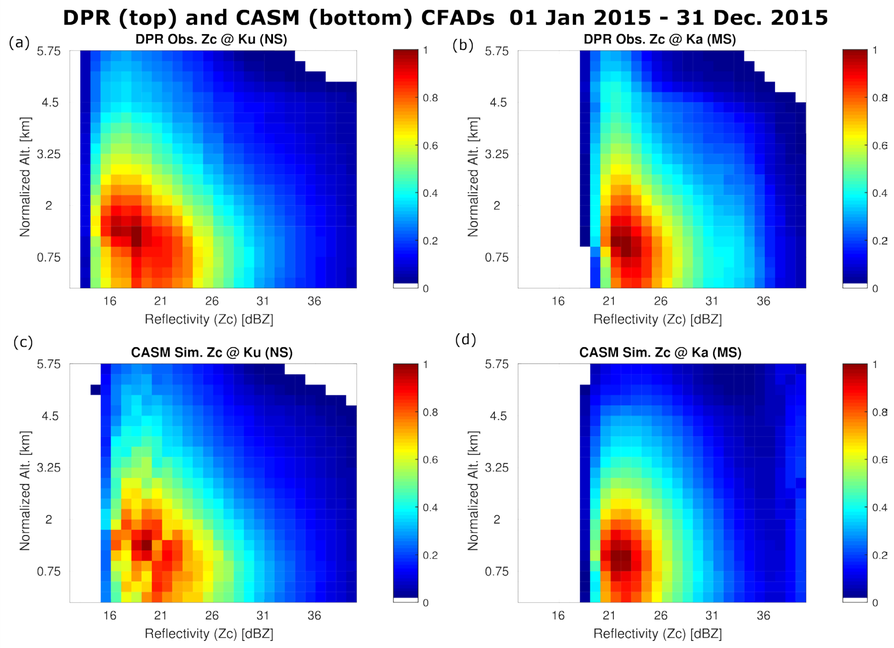


Attenuation-corrected radar reflectivities at Ku band: (a) is the CASM simulation at Ku-band, (b) is DPR corrected reflectivities at Ku-band. (c) and (d) are the same as (a) and (b), except at Ka-band. Note the significant attenuation corrections at Ka-band, compared with Fig. 7c. and 7d.

One year of GPM DPR level 2A (V6) data was downloaded and processed. Following the previous approach, the N_w, D_m, temperature, and reflectivity information was obtained from each DPR file -- only the nadir beam was selected. Processing these variables using CASM, the figure below shows CFADs of attenuation-corrected reflectivity (Zc) for GPM DPR observed Ku- and Ka-band reflectivities in panels (a) and (b), respectively; and for the CASM simulations at Ku- and Ka-band in panels (c) and (d), respectively.

Altitudes were normalized to be height above the land surface. Range bin height was estimated using the number of range gates in the Ku-band (NS) products and the Ka-band (MS) products. Radar echoes are over-sampled at twice the rate of the corresponding resolution, i.e.,125 m for the matched beams. CASM simulated reflectivities were computed at the same range gates as the DPR observations, so there's a one-to-one correspondence between observation and simulation on a profile-by profile basis. The CFAD vertical bin resolution was set to 250 meters to provide smoother sampling. The horizontal bins are set to 1 dBZ width.

DPR (top) and CASM (bottom) CFADs 01 Jan 2015 - 31 Dec. 2015



CFADs of GPM DPR observations (top row) and CASM simulations (bottom row) for Ku band and Ka band (beam matched). One year of data was used for the analysis, nadir beam only, from 01 January 2015 to 31 December 2015.

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