GPM Observed Mesoscale Convective Systems (MCSs) over the Great Plains: Characteristics and Applications in Model Improvement

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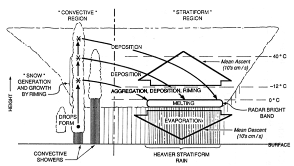
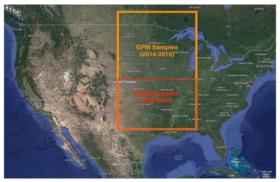
Motivation

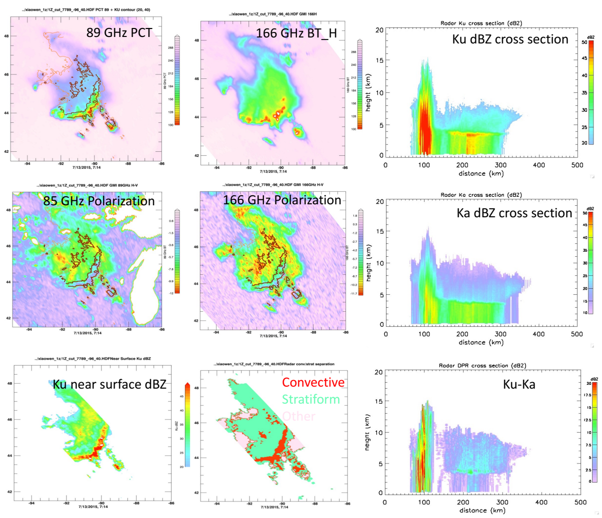


Schematic MCS cross section with a trailing stratiform region, copied from Houze (1989, QJRMS).



Mesoscale Convective Systems (MCSs) over the Great Plains occur in the highest frequency over the spring and summer time, often organize into squall lines with a leading convective line and an expansive trailing stratiform region. These MCSs have long lifespans, with quasi-steady mature stages that last from several hours to more than ten hours. The extensive, homogeneous stratiform region in MCSs show consistent characteristics which can be reliably observed by satellites. Here we study some of these characteristics in order to help validating and improving model microphysics.

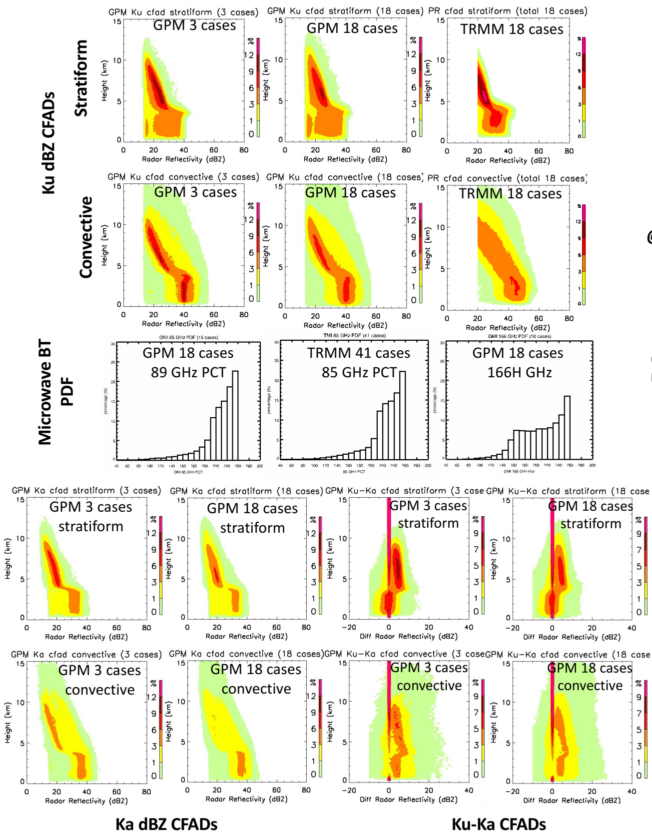
A Case Study (7/13/2015)



GPM observation of a textbook MCS with optimal radar coverage on July 13, 2015.

MCS Statistics by GPM and TRMM

MCS cases at their mature stages with widespread trailing stratiform region are identified using 3-year's GPM data (2014~2016) and 9-year's TRMM data (1998~2007), during the months between May and August, at the North America Great Plains as shown to the left. The satellite observations show remarkably consistent statistics among different cases, and between the two satellites. This indicates that comparisons between single case model simulations and long-term satellite observations are feasible. The results can be used to validate and improve cloud-resolving model simulations, especially processes associated with microphysics.

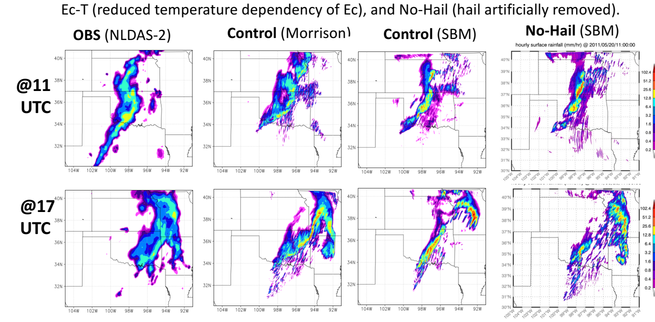


WRF Model Simulations

Model Description: We used WRF model Version 3.6.1 with a single domain, 2km horizontal resolution and 44 vertical levels to simulate the MC3E May 20 case. Simulations were initialized with NCEP FNL Operational Global Analysis starting at 00 UTC, May 20, 2011 and updated every 6 hours for a total simulation time of 24 hours.

Microphysical Schemes: The Hebrew University Spectral Bin Microphysical (SBM) scheme and Morrison two-moment scheme are used. The SBM scheme uses 43 mass size-doubling bins to explicitly simulate aerosol and all hydrometeor particle size distributions, including ice crystals (columns, plates and dendrites), snow aggregates, graupel, hail and cloud/rain. Morrison scheme assumes inverse exponential size distributions for ice, snow, graupel and rain, and Gamma distribution for cloud droplets.

Microphysics Sensitivity Tests: SBM is a good tool for understanding sensitivities of simulated MCS to microphysical processes because of its more detailed approaches. Several tests have been carried out with the general goal of increasing stratiform coverage and/or reducing ice-phase particle mean sizes, especially with the high-density graupel and hail. These include Control (original runs), Alt-Ec (reduced ice particle collection efficiency Ec), Aero-Control (Control run with varying aerosols concentrations) Ec-T (reduced temperature dependency of Ec), and No-Hail (hail artificially removed).



Conclusions and Ongoing Work

- GPM and TRMM observations of summertime US continental MCSs show consistent statistics such as radar CFADs and brightness temperature distributions, especially for the widespread stratiform region. This indicates that comparisons between MCS case simulations (with multiple time frames) and long-term TRMM/GPM observations (with single time frames for different cases) are meaningful. They can be used to understand the MCS dynamics and microphysics, their interactions, and to validate and improve model microphysics. Ongoing work includes using GPM satellite simulator(s) to calculate satellite observables and comparing them with TRMM/GPM observations.
- New variables observed by GPM, e.g., the differential reflectivity, 166 GHz brightness temperature and polarization, offer additional constraints and possibly new insights for model microphysics. They also require improved satellite simulators to take full advantages of both satellite data and the sophisticated SBM scheme simulations.
- WRF simulations of the May 20 MC3E case reproduced surface rainfall patterns and their evolutions reasonably well. However, the MCS structures show sensitivities with different microphysical schemes, as well as when tuning various SBM parameters. Future work will include comparing these sensitivity tests with GMP observations and identify best configurations.