Moving From Establishing Model Deep Convective Biases Toward Constraining Their Causes

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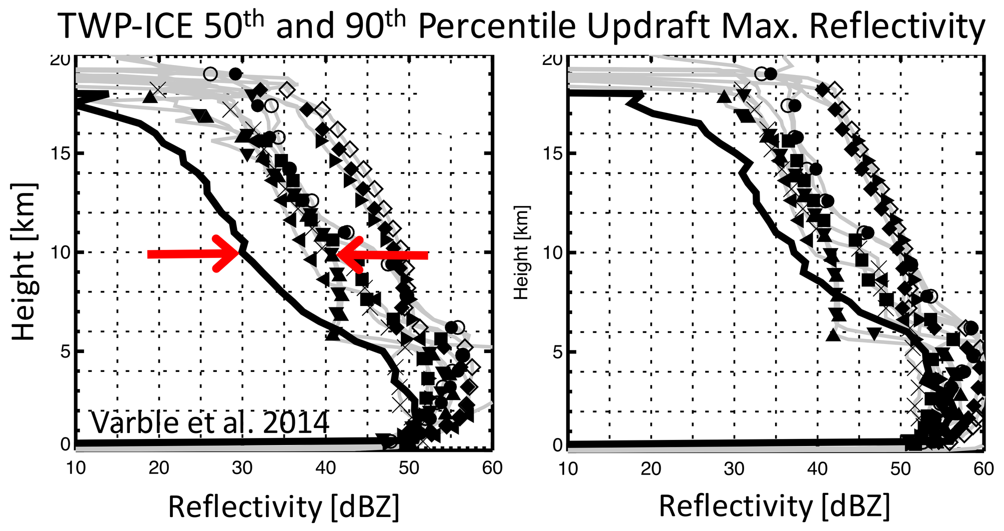
MODEL DEEP CONVECTIVE BIASES

High-resolution simulations of deep convective systems are used for improving cumulus parameterizations or replacing them in coarser grid models, but exhibit a high bias in convective reflectivity across a range of CRM, LAM, and LES models, microphysics schemes, and case studies around the world.

These same high-resolution simulations often exhibit larger than observed regions of high reflectivities and rain rates with a low bias in stratiform precipitation.

There are several causes of deep convective precipitation biases that interact in complex ways and are unconstrained by observations.

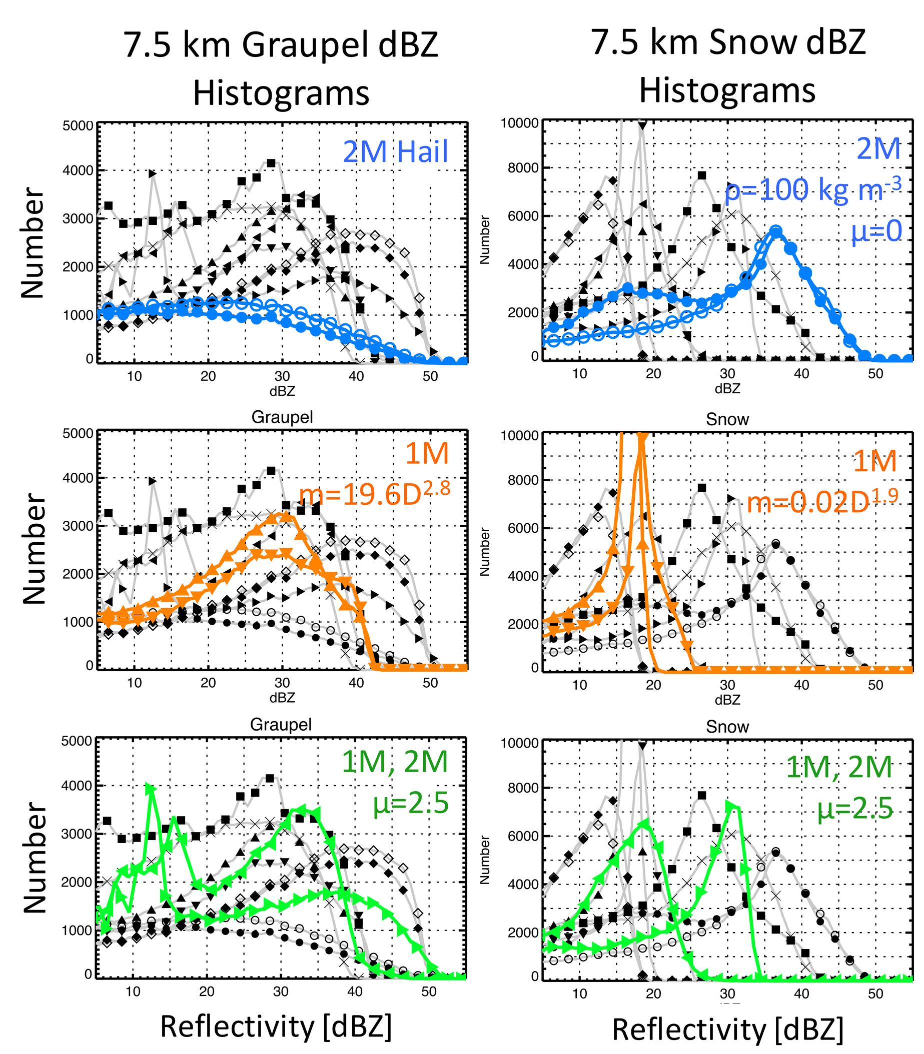
TWP-ICE 50th and 90th Percentile Updraft Max. Reflectivity



CAUSES OF DEEP CONVECTIVE PRECIPITATION BIASES

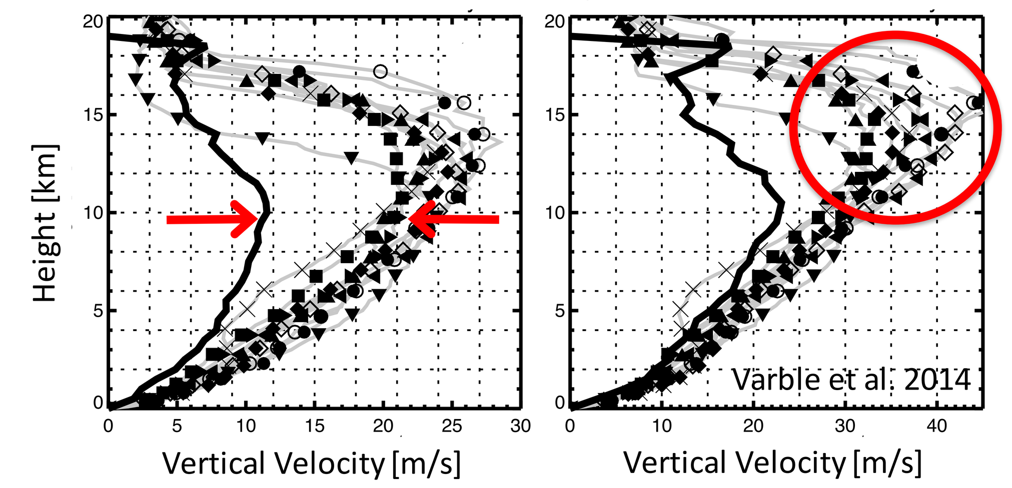
HYDROMETEOR PROPERTIES

Number of predicted PSD moments, assumed PSD shape, and assumed mass-size relationships strongly impact reflectivity values.



VERTICAL VELOCITY

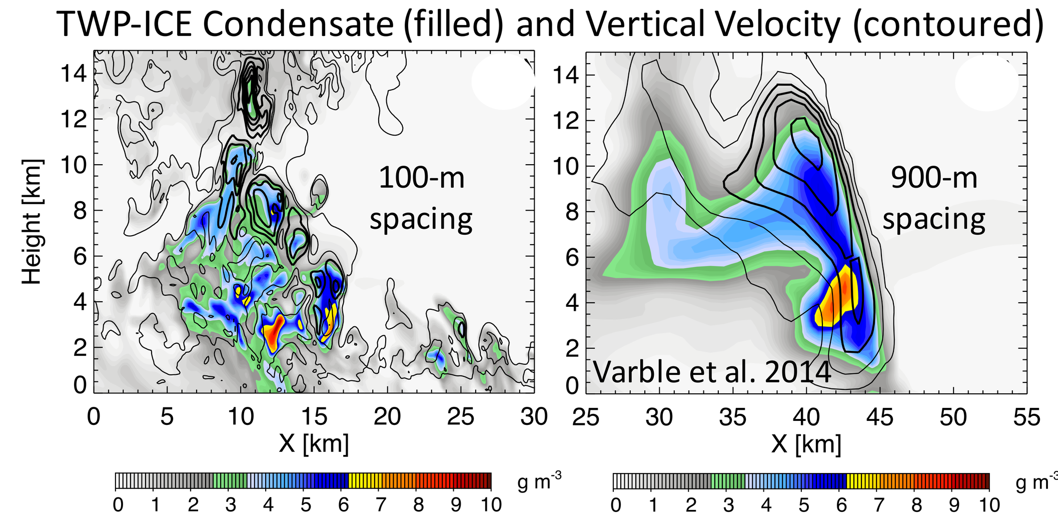
TWP-ICE 50th and 90th Percentile Updraft Max. Vertical Velocity



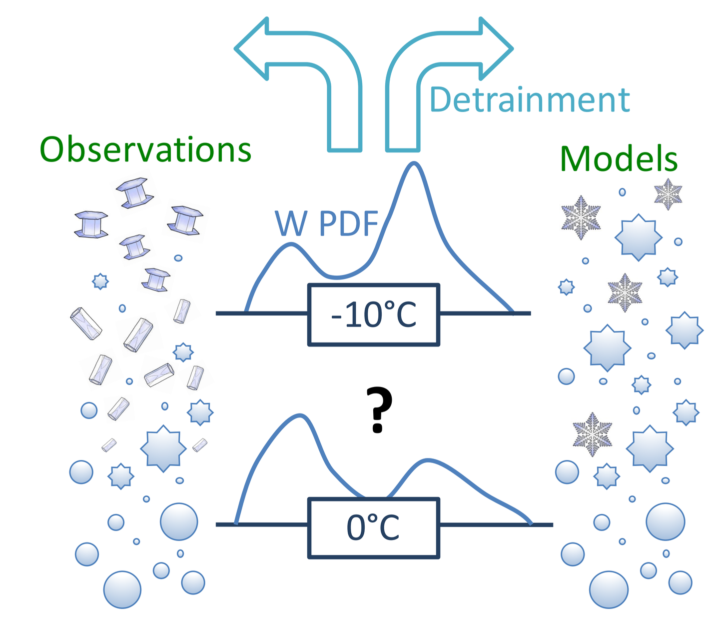
Simulations significantly overestimate peak updraft core vertical velocities and peak at higher altitudes.

Decreasing grid spacing slightly improves results, but convergence to observations appears unlikely.

TWP-ICE Condensate (filled) and Vertical Velocity (contoured)



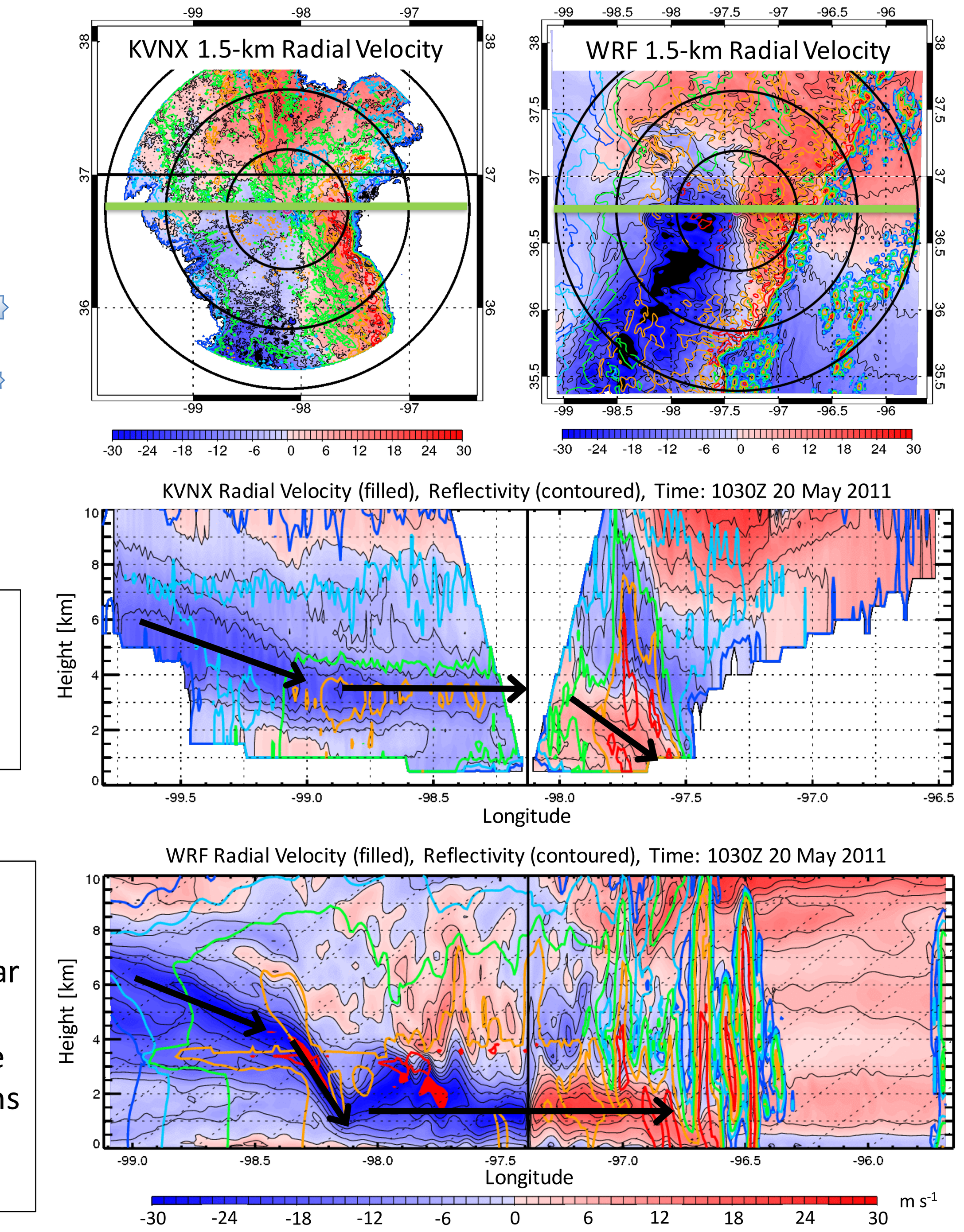
MICROPHYSICAL PROCESSES



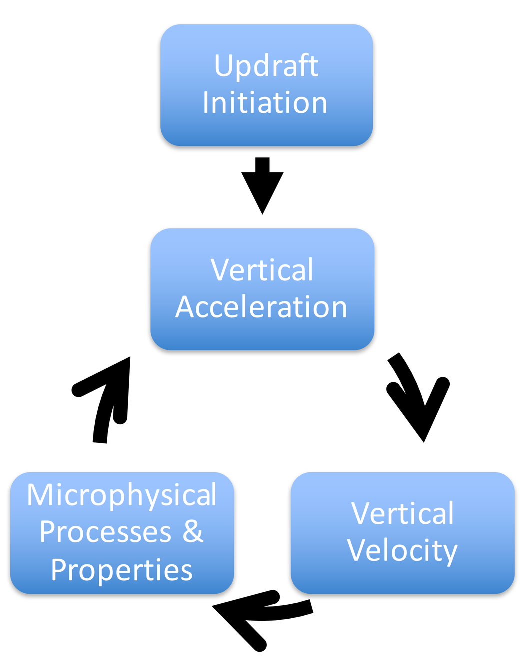
Microphysics schemes fail to reproduce large ice concentrations in mixed phase regions of updraft cores observed in recent tropical field campaigns.

Simulated rear inflow for WRF simulations of the 20 May 2011 MC3E event appears amplified relative to radar observations. In general, squall and supercell modes seem to appear more frequently in cloud-resolving simulations than observations. Are mesoscale circulations biased too strong?

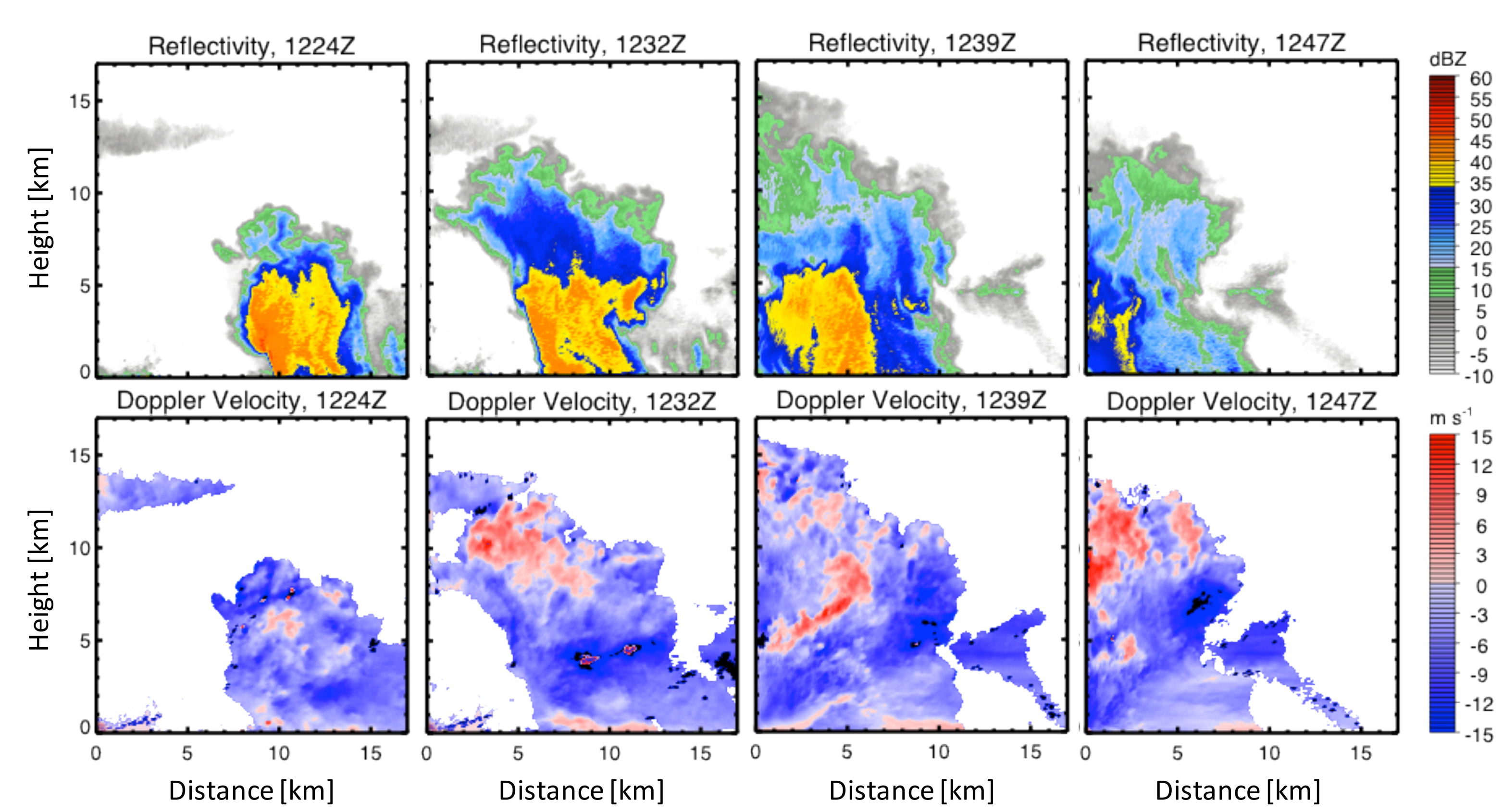
MESOSCALE CIRCULATIONS



CONSTRAINING BIAS CAUSES WITH STRATEGIC OBSERVATIONS OF PROCESSES



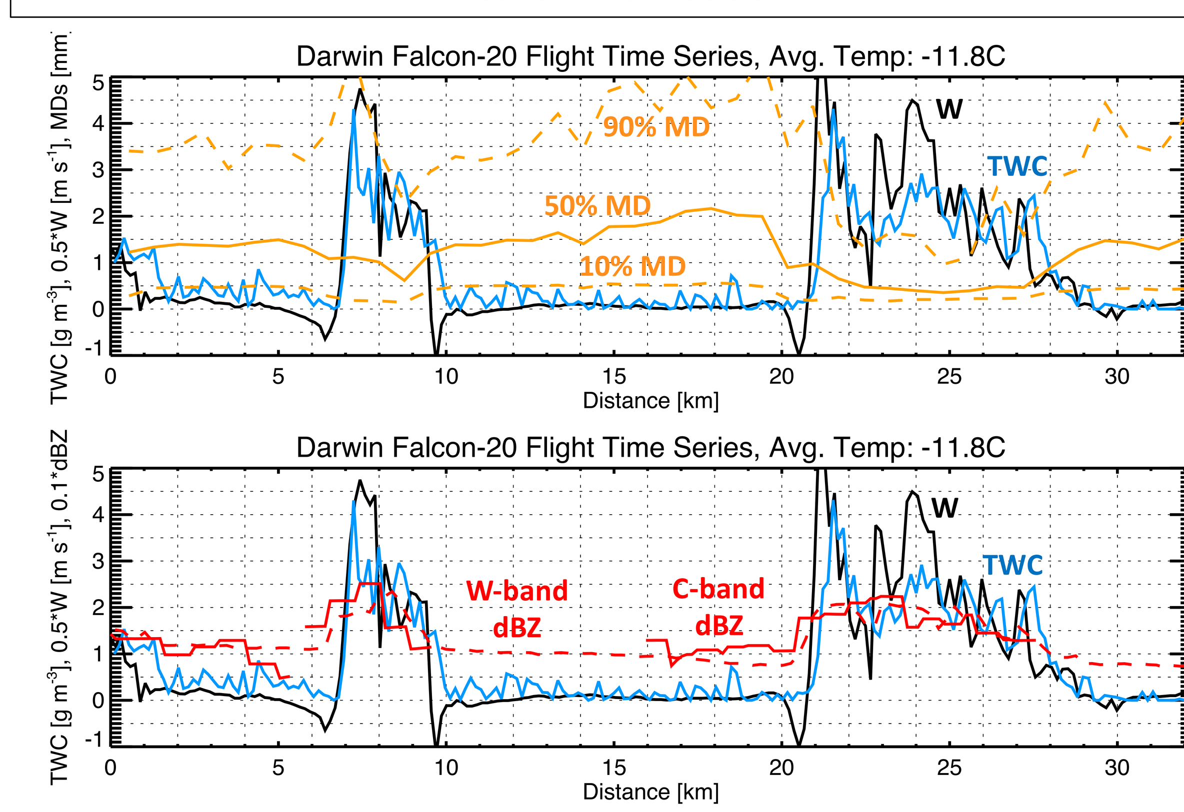
Observing impacts of vertical velocity on microphysics and vice versa requires frequent sampling of the same cell so that interactive processes can be inferred. This is the strategy for the CACTI field campaign.



Manus C-SAPR RHIs show detailed dynamical and precipitation structure, but also show large changes over 7.5 minutes that make it impossible to quantify dynamics-microphysics interactions. Coordinated radar observations more frequently sampling the convection have a chance of detecting interactions between dynamics and microphysics at different stages of the convective life cycle.

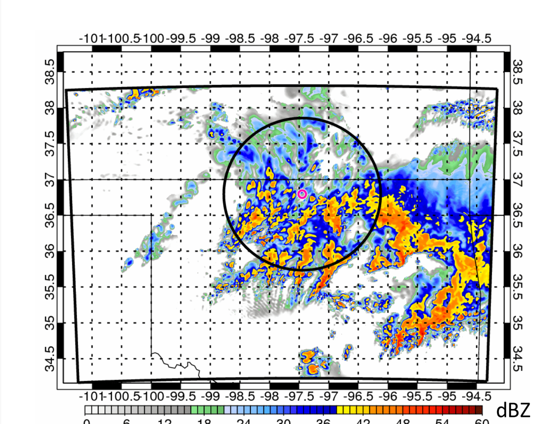
AIRCRAFT OBSERVATIONS ARE CRITICAL

Only aircraft in situ observations can quantitatively determine hydrometeor shape, phase, PSD, and bulk mass in a manner that constrains models.

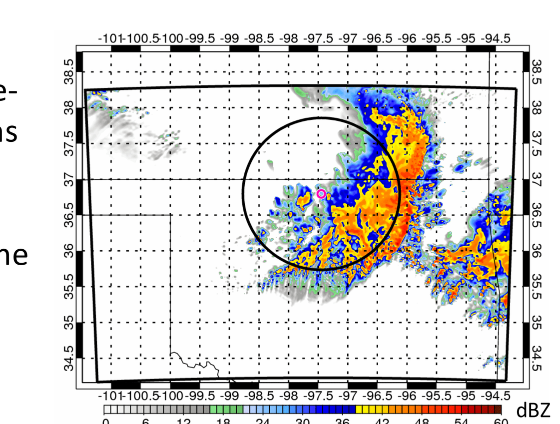


Radar measurements can be trained to extend these in situ measurements, and therefore, in situ measurements increase the value of radar measurements.

REPRESENTATIVE COMPARISONS ARE CRITICAL

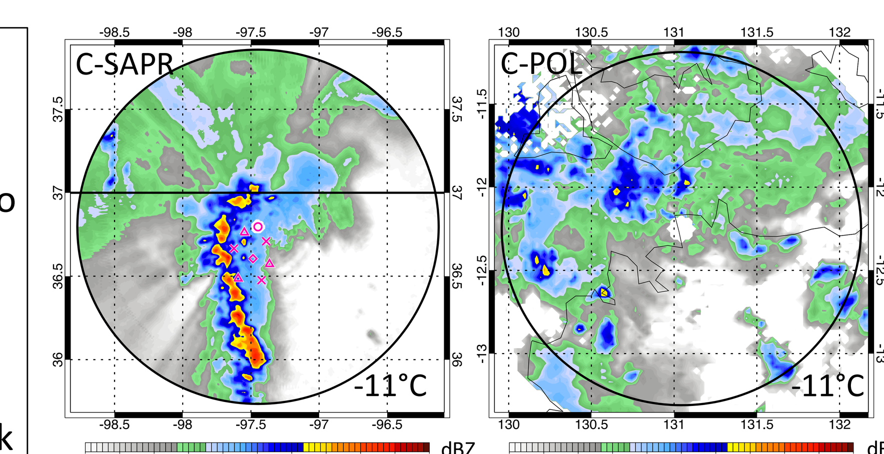


Perturbed large-scale conditions creates very different simulations of the 25 April 2011 MC3E case



Convection is non-deterministic. To ensure robust conclusions, ensembles and stochasticity should be used more, and limited measurements relative to model output need to be put into context.

Convection exhibits a wide variety of properties around the world with sensitivity to many environmental variables. Many regimes need to be observed so that parameterizations work everywhere.



Typical continental system   Typical tropical coastal system

CONCLUSIONS

Convective precipitation biases consistent across a range of models and microphysics schemes have several complexly interacting causes including hydrometeor properties, vertical velocity, microphysical processes, and mesoscale circulations. To eliminate these biases requires constraining all of these causes, which can only be done by strategically observing deep convective processes with radars, gathering in situ measurements from aircraft, and performing representative comparisons between model output and observations that take into account the non-determinism of deep convection and its wide variety of properties around the world.

FUTURE WORK

The role of amplified mesoscale circulations in producing model precipitation biases and the causes of amplification will be further explored. Measurement strategies targeting convective processes will be further developed and potentially tested ahead of the 2018-19 CACTI field campaign in Argentina.

REFERENCES: Varble, A., and coauthors (2014), Evaluation of cloud-resolving and limited area model intercomparison simulations using TWP-ICE observations: 1. Deep convective updraft properties. *J. Geophys. Res.*, 119, 13,891-13,918.

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