MC^{3}E: Real Time Forecast and Post Mission Simulations

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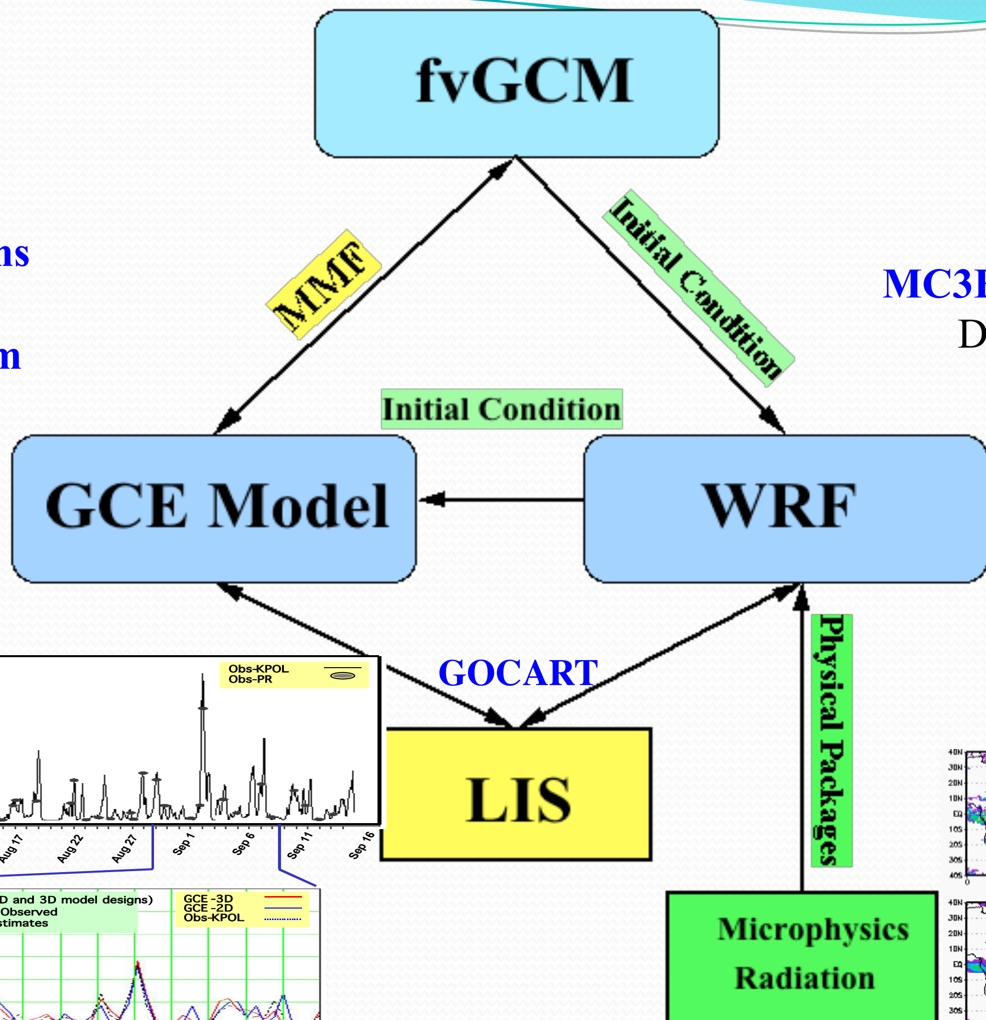
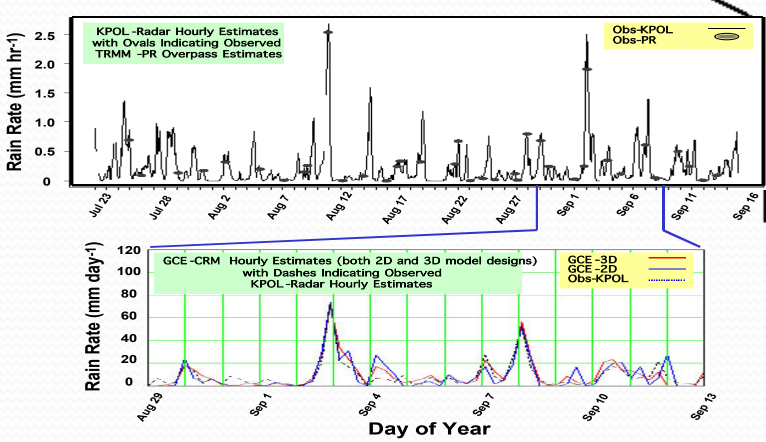
Goddard Multi-scale Modeling System with Unified Physics

GCE Model
~10 field campaigns
TRMM LH and
Rainfall Algorithm
S. Lang, X. Li

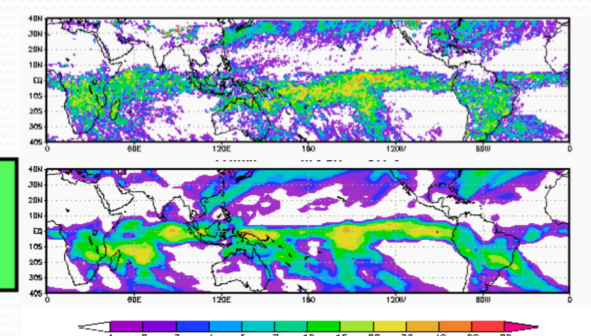


NASA Unified WRF
MC3E, C3VP, NAMMA, LPVex
D. Wu, R. Shie, T. Iguchi

MMF-LIS (2006)
GPM Rainfall
Mohr, Matsui, Chern



GCE long-term simulated rainfall and observed for KWAJEX

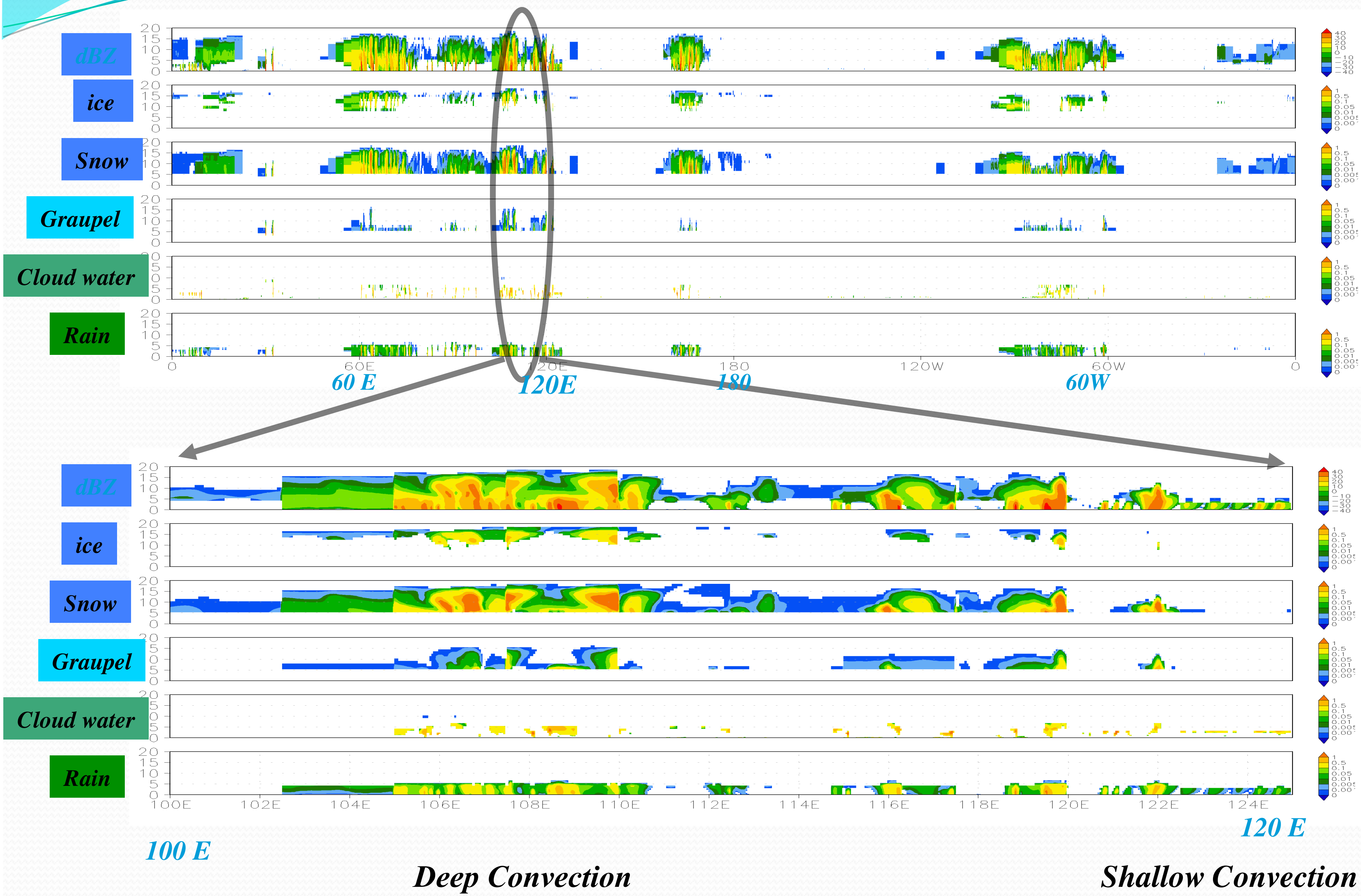


MMF simulated and TRMM observed rainfall.

MMF: Multi-Scale Modeling Framework
LIS: Land Information System
GCE: Goddard Cumulus Ensemble Model
WRF: Weather Research Forecast

Tao, W.-K., D. Anderson, J. Chern, J. Estin, A. Hou, P. Houser, R. Kakar, S. Lang, W. Lau, C. Peters-Lidard, X. Li, T. Matsui, M. Rienecker, M. R. Schoeberl B.-W. Shen, J.-J. Shi, and X. Zeng, 2009: Goddard Multi-Scale Modeling Systems with Unified Physics, *Annales Geophysics*, **27**, 3055-3064.

Goddard MMF Simulated Cloud Species (at Equator, 0000UTC December 2004)

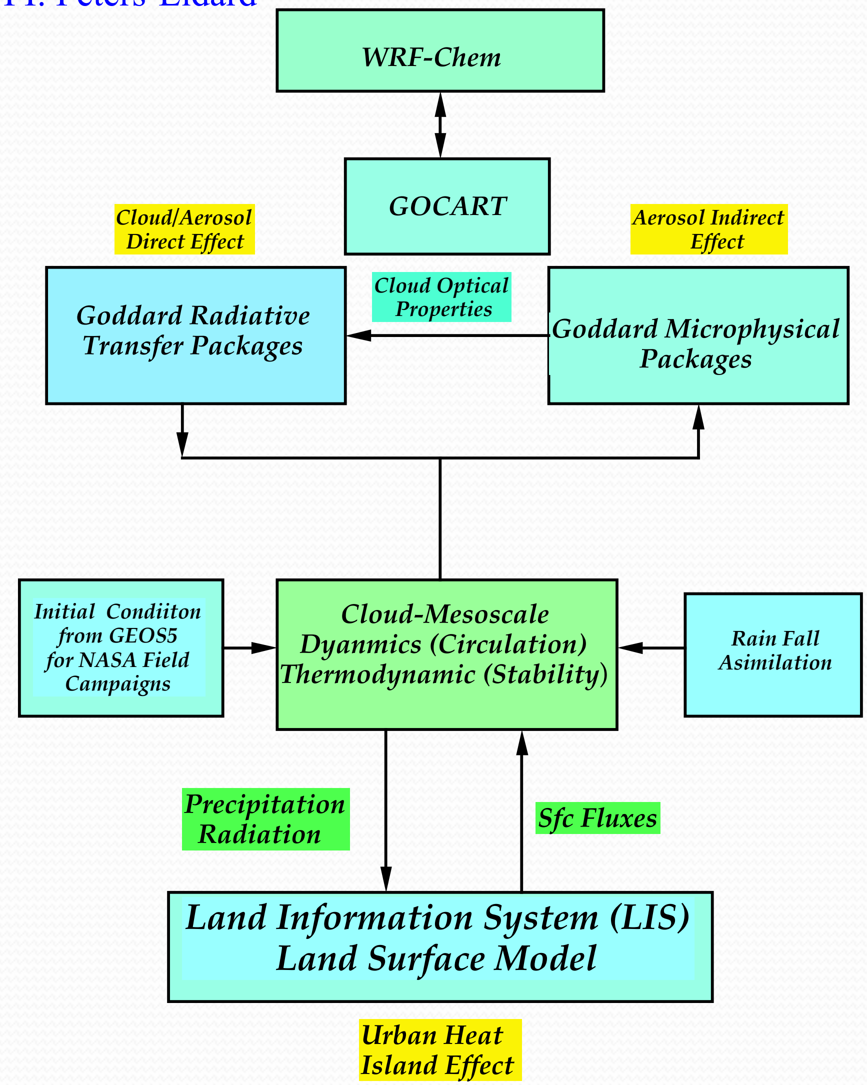


Objectives (nu-WRF - Real Time Forecast)

- During Field campaign:
  - Provide model forecast twice a day before morning briefing and afternoon updates.
    - High temporal and spatial resolution.
  - Maintain ftp update: ftp://meso-a.gsfc.nasa.gov/mc3e/img/
  - Evaluate model performance and identify cases for post mission simulations.
- After field campaign:
  - Conduct high resolution model (WRF and GCE) simulations – microphysics and land surface model, and utilize satellite simulator to compare model results with observation
- Data for model validation (physical validation)
  - DSDs at various layers (gamma or exponential distributions for cloud water, rain, cloud ice, snow, and graupel), 3D liquid and ice water contents and median diameters, mixed phase information, particle number concentrations for cloud ice, snow, graupel and hail, aerial ratios (ice habits), and the liquid water fraction of melting snow, graupel and hail, over the life cycle of clouds and cloud systems.

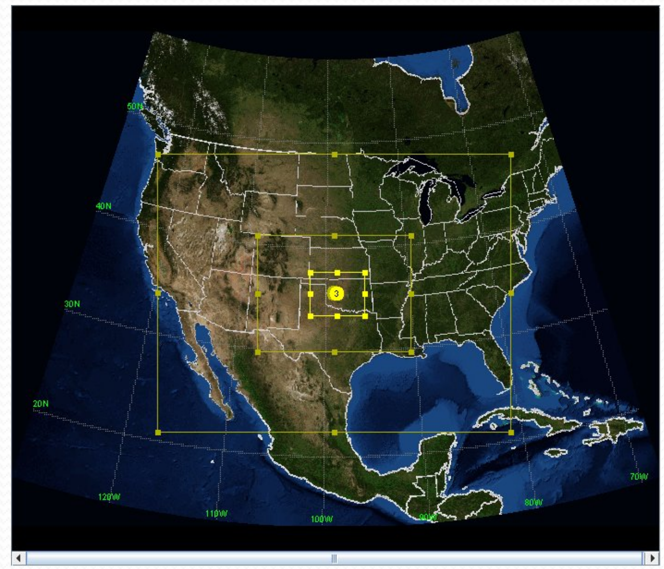
NASA Unified WRF (nu-WRF)

PI: Peters-Lidard



Blue Boxes:
NASA Physical Packages

MC3E Model Configuration

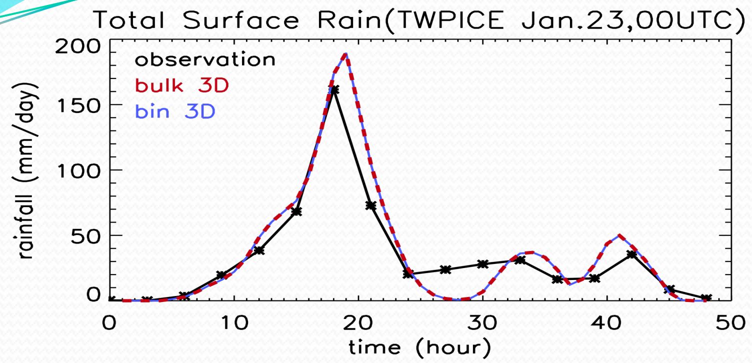


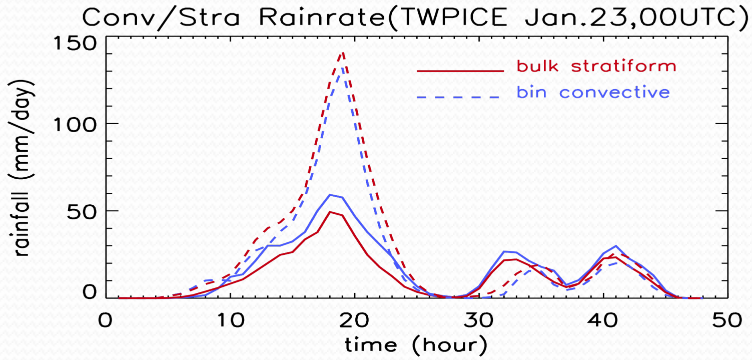
Three nested domain (18km, 6km, 2km) with 40 vertical layers.

Physics:

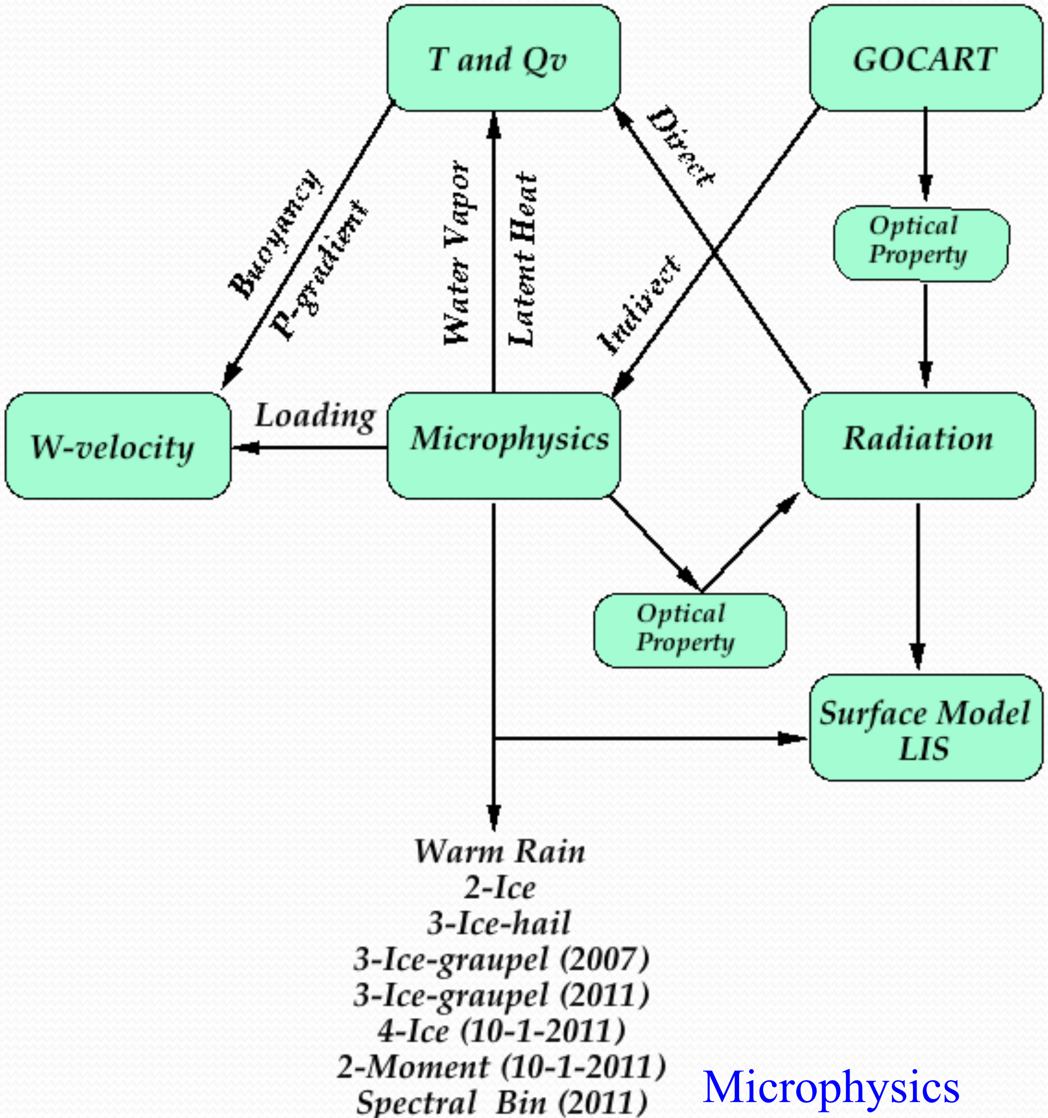
- Goddard Microphysics scheme
- Grell-Devenyi ensemble cumulus scheme
- Goddard Radiation schemes,
- MYJ planetary boundary layer scheme,
- Noah surface scheme,
- Eta surface layer scheme.

Goddard Microphysics and its interactions with other components in GCE, WRF





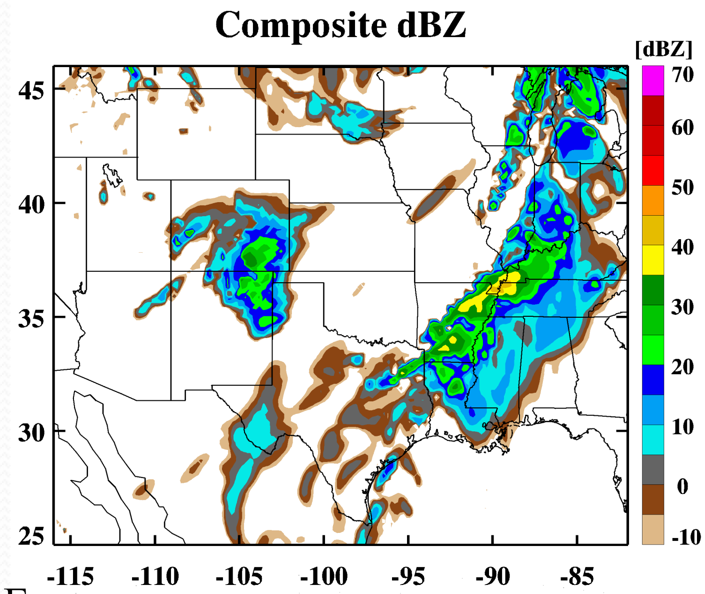
3D GCE with Spectral Bin Microphysics
TWP-ICE (***MC3E***) Simulation

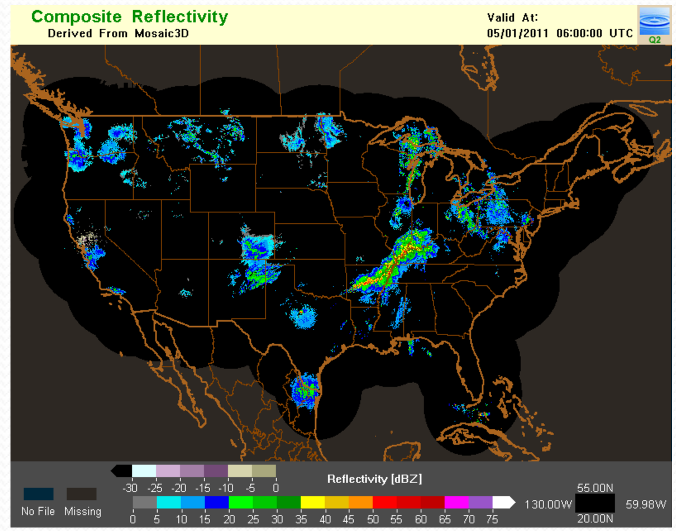


4-options in NCAR WRF (V2, V3)
5-options in nu-WRF
2 additional options by January 2012:
Spectral bin microphysics and two-Moment

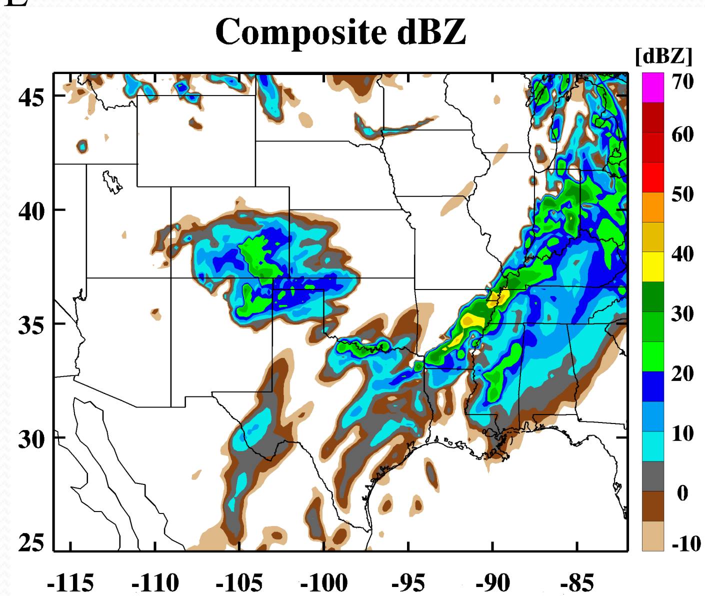
Microphysics
Surface Rainfall
(intensity) -> LIS

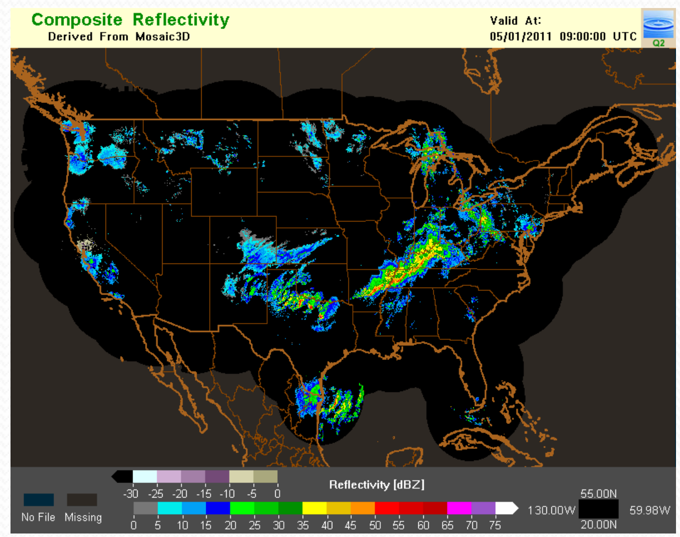
Example of Real Time Forecast (May 1 2011)



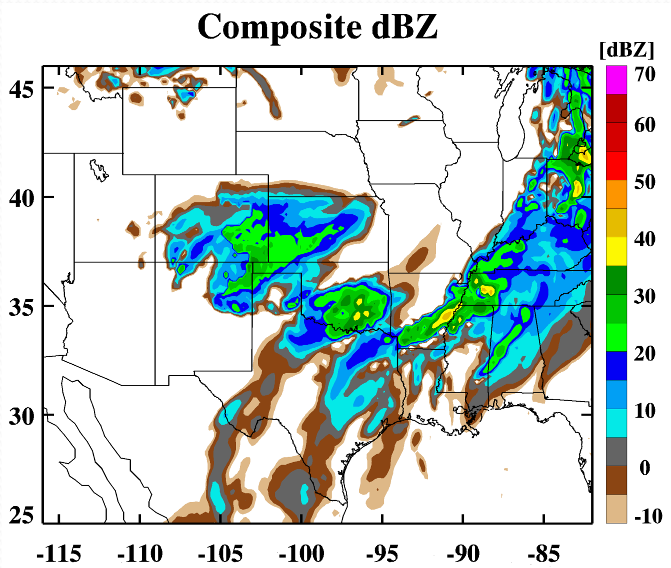


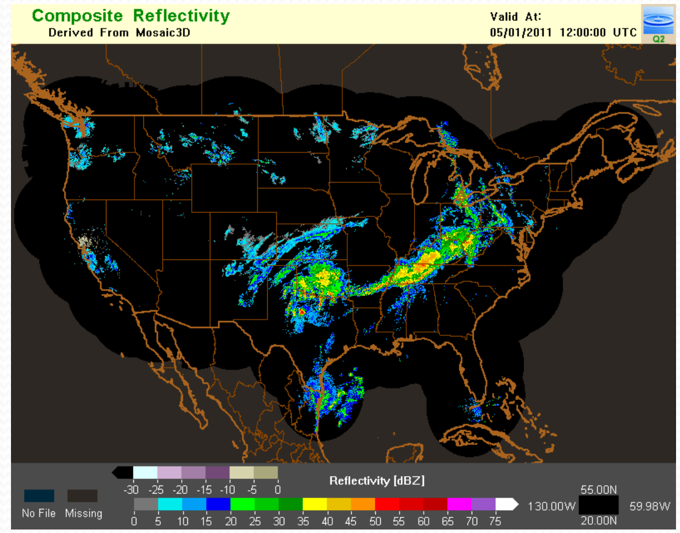
Modeled storm captures overall structure, but it is outside of MC3E domain

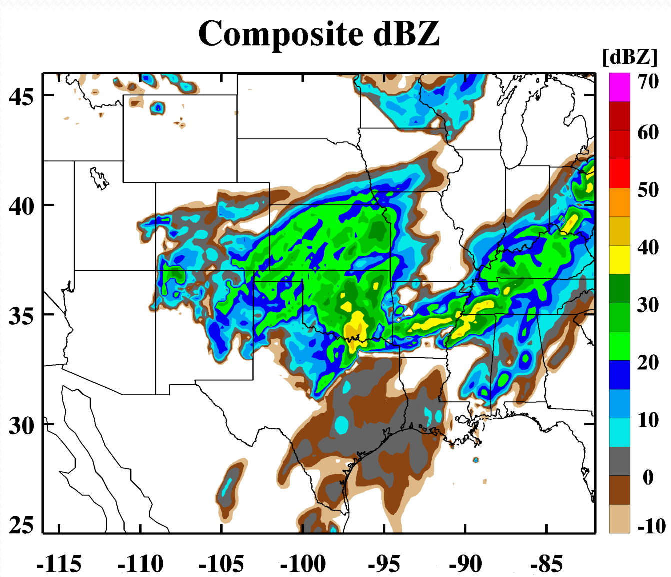


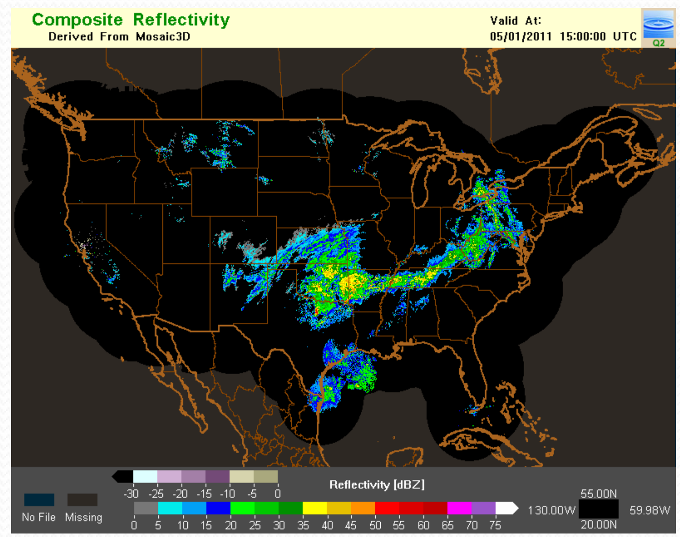


Modeled storm is weaker than observed at MC3E site

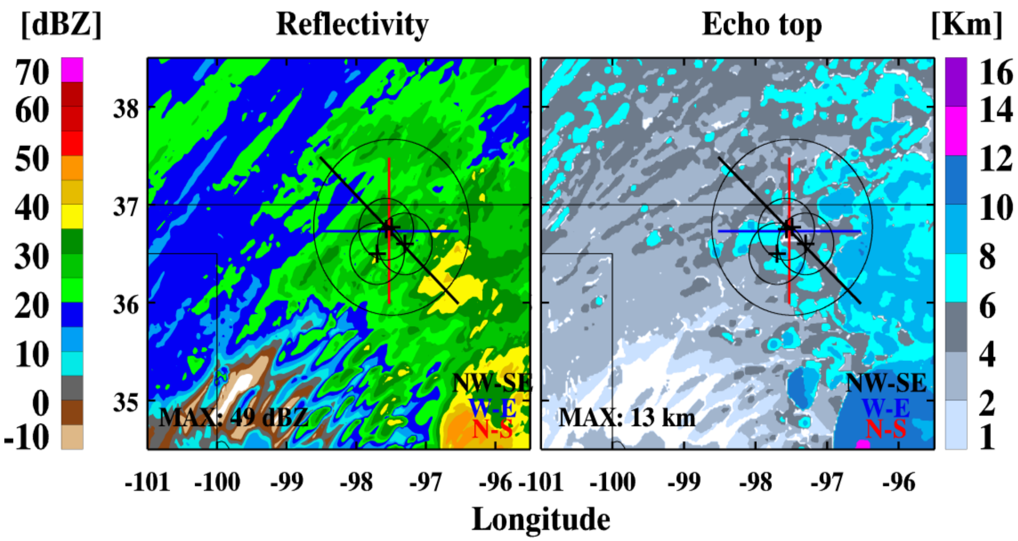


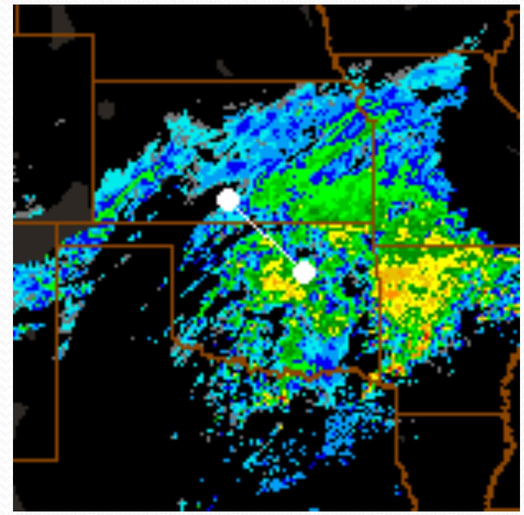


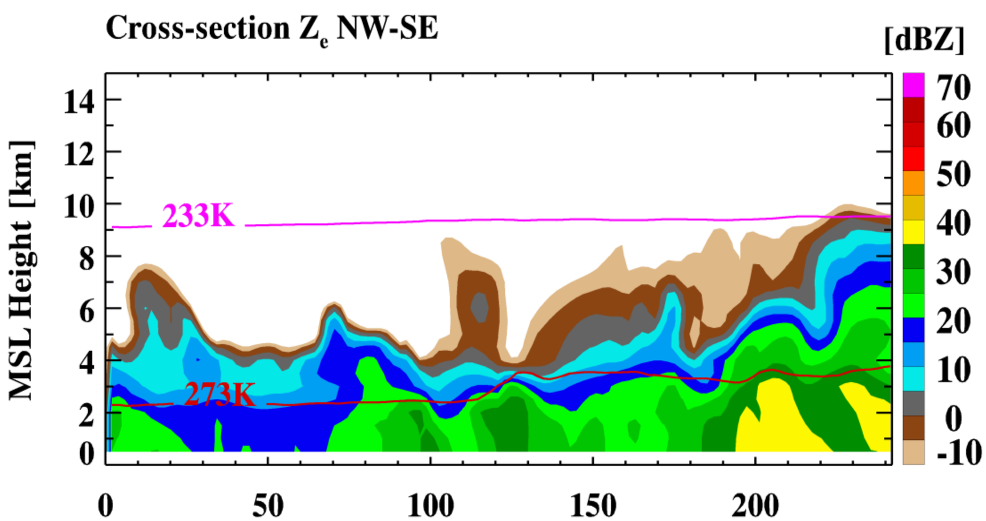


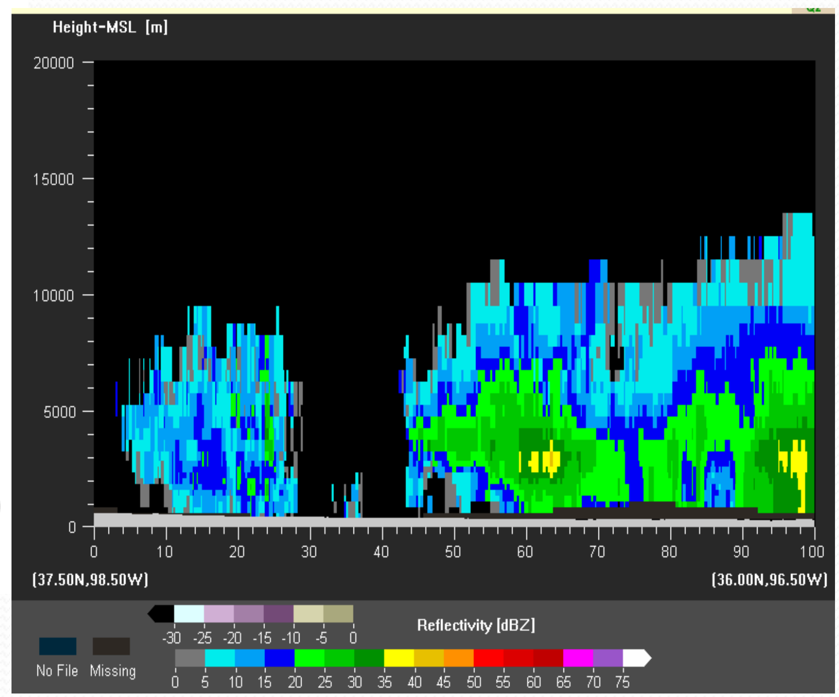


2011.05.01 16:00 UTC

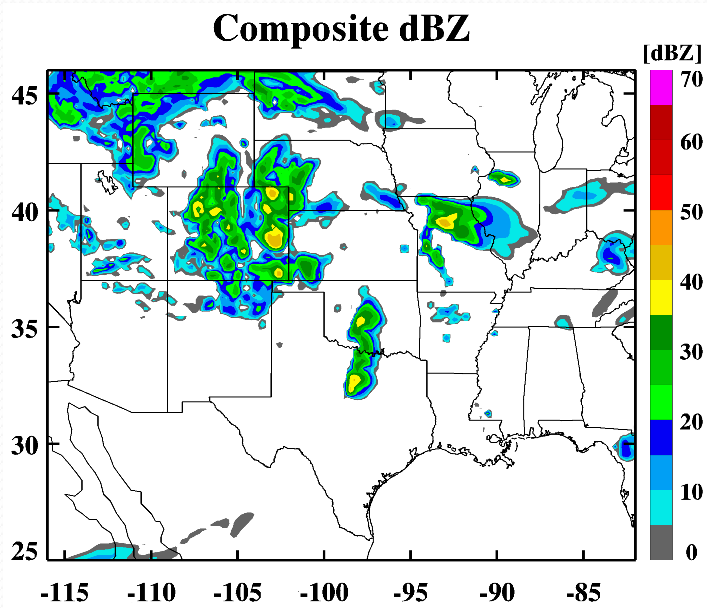


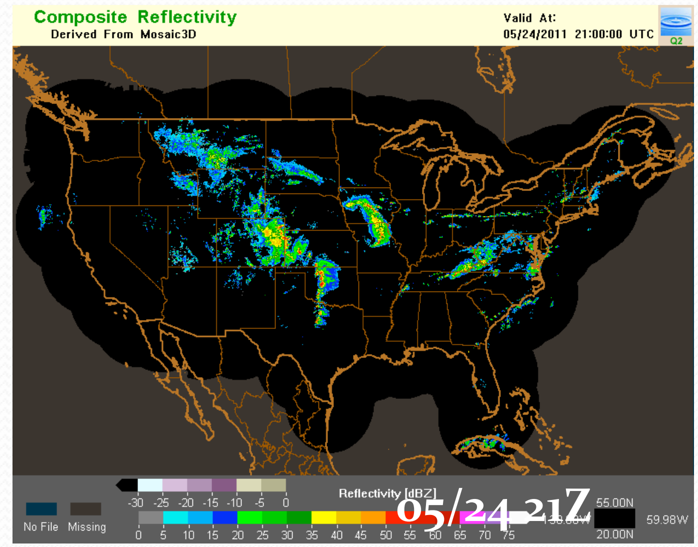


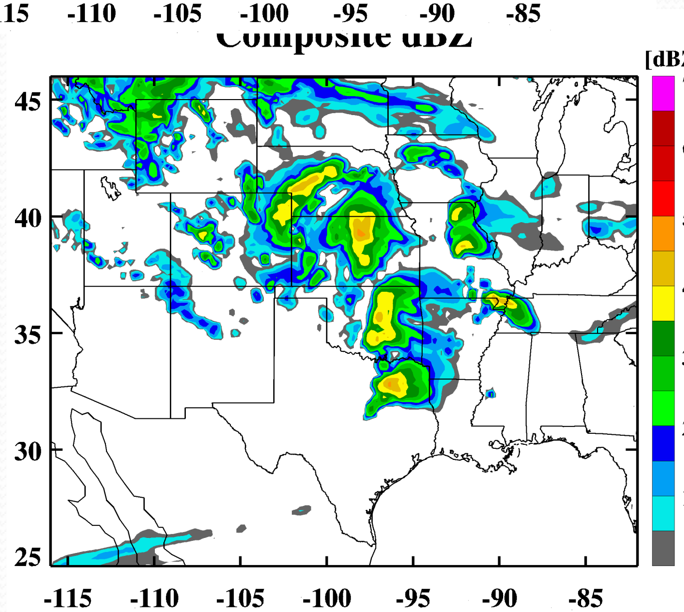


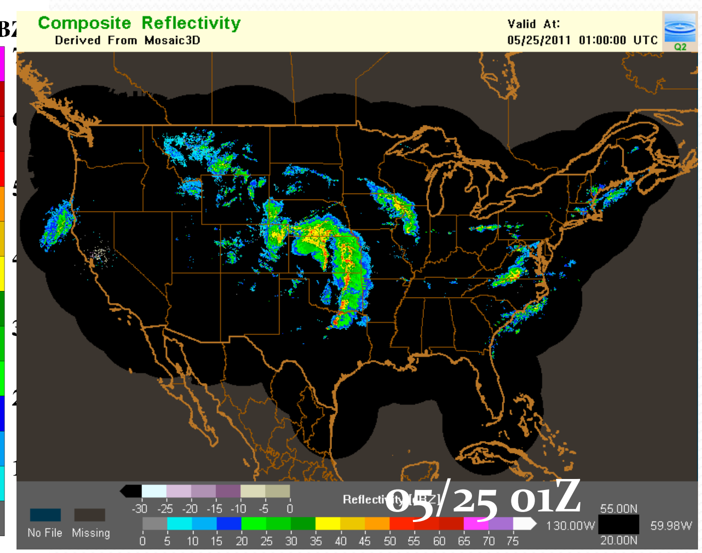


Example of Real Time Forecast (May 24-25, 2011)



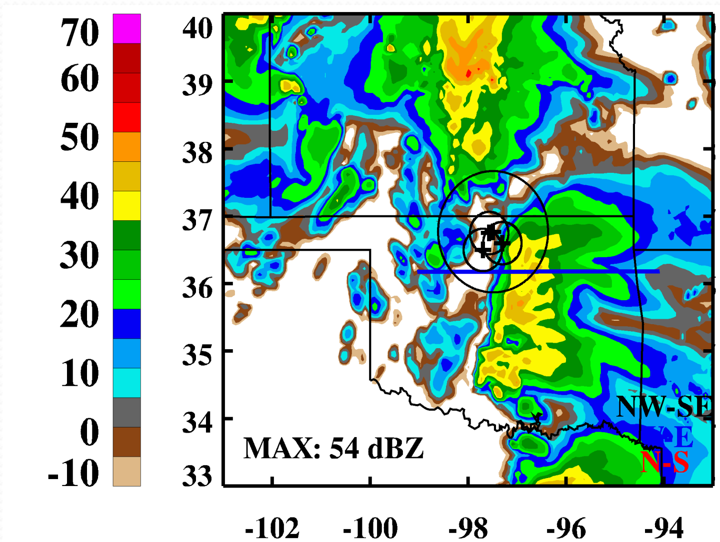


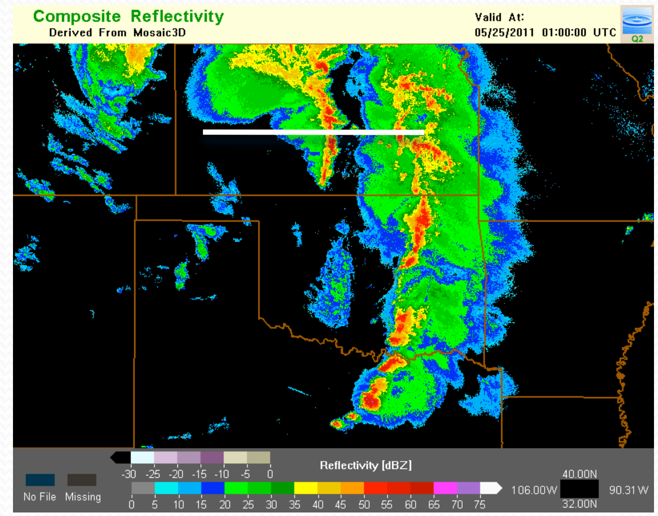


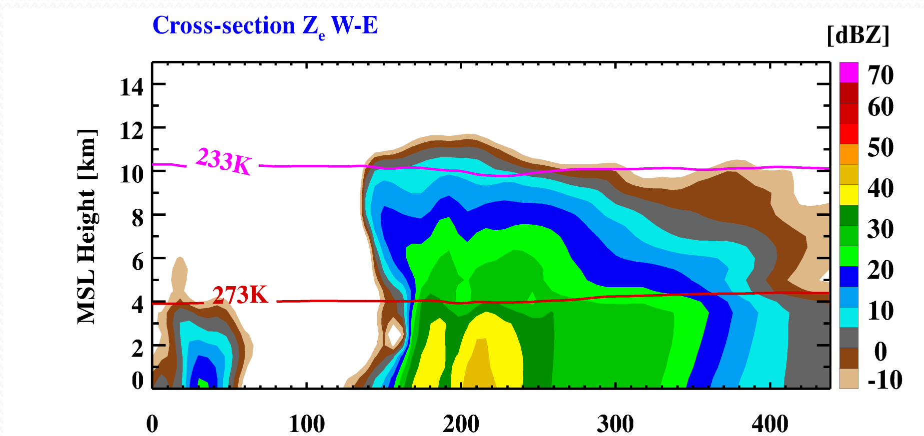


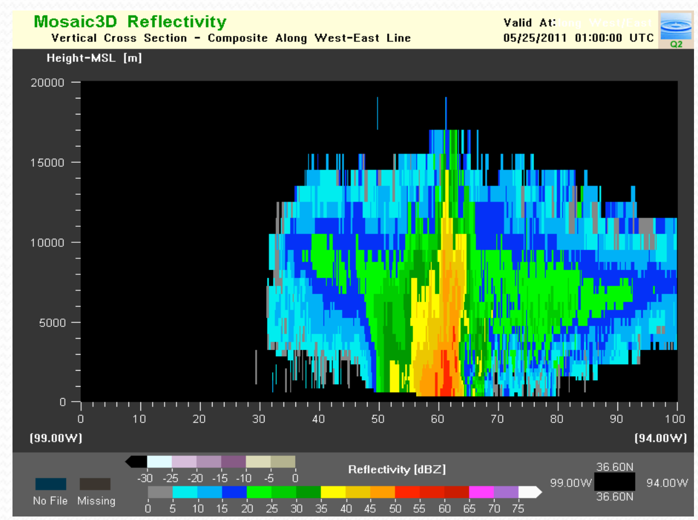
Modeled storm captures observed arc-shape structure

Modeled storm is less organized as observed at MC3E site.
It is also weaker than observed. However, its associated stratiform is at at leading edge of system as observed.

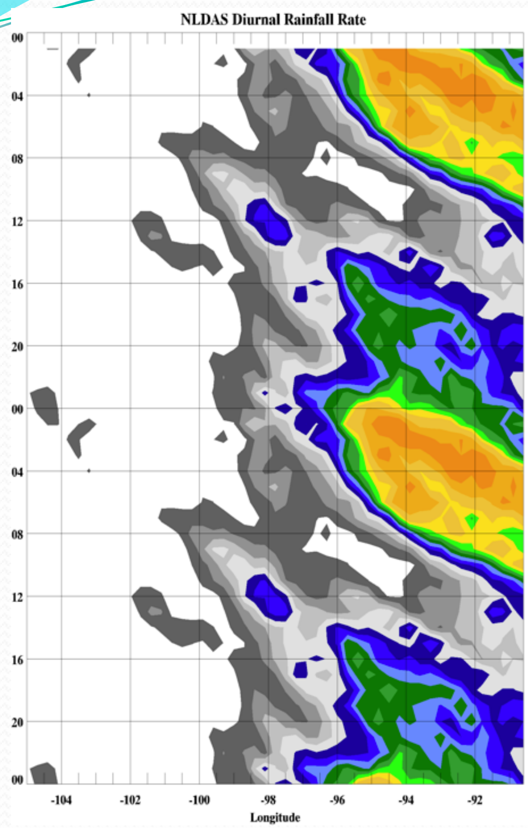


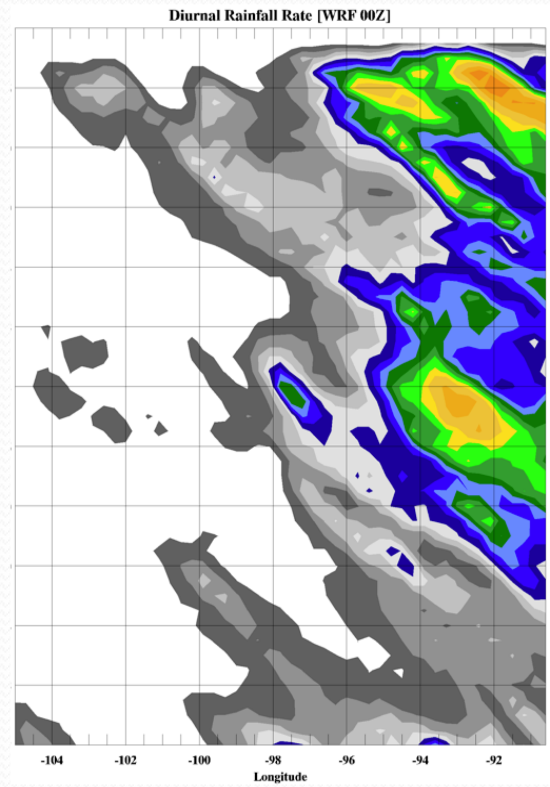






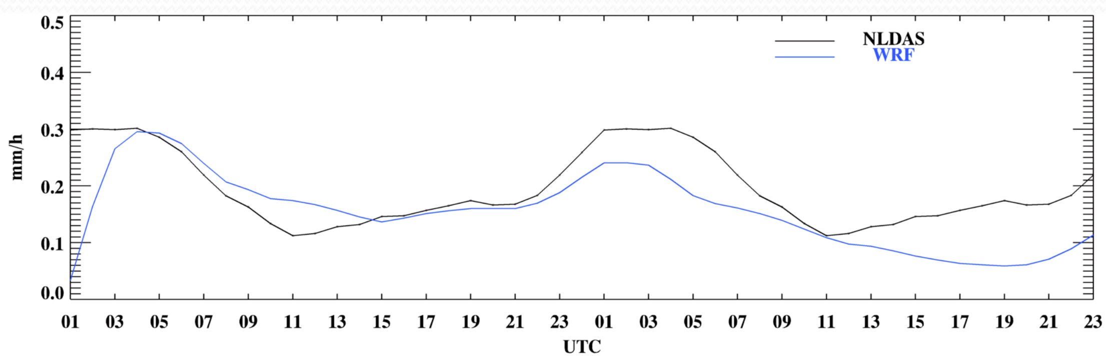
Diurnal Variation (composite all real time cases)





Hovemollar diagram
Lat: 37°N ~ 40°N

Afternoon onset (4pm LST) of moist convection that agrees with NLDAS and nu-WRF



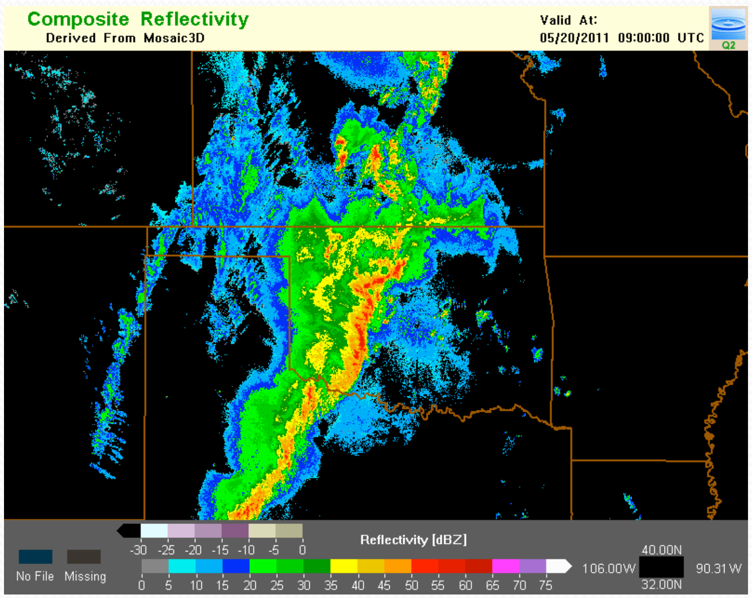
Time series of WRF model-estimated domain mean surface rainfall rate (mm h^{-1}).

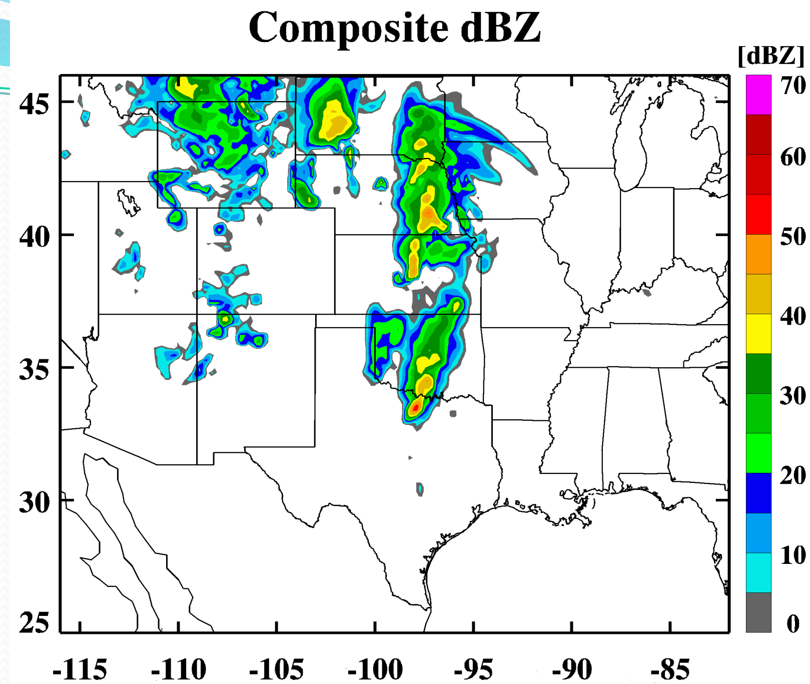
The model simulated diurnal variation of rainfall captures observed well.

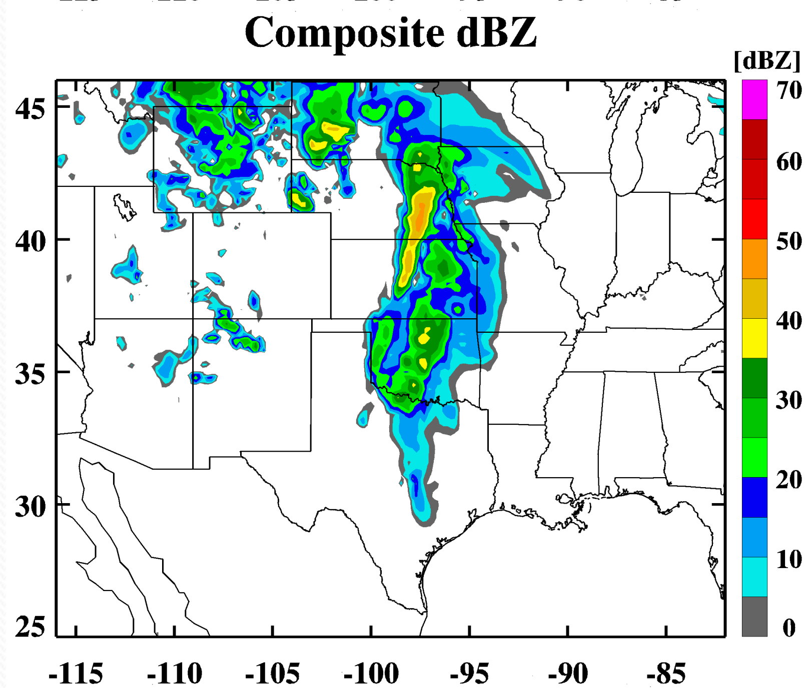
Microphysics (Case 1)

3ICE-Hail →

Observation



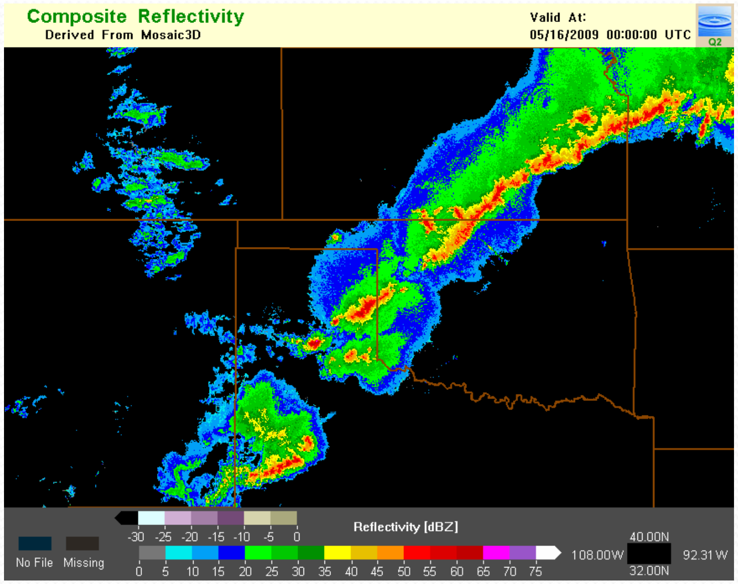




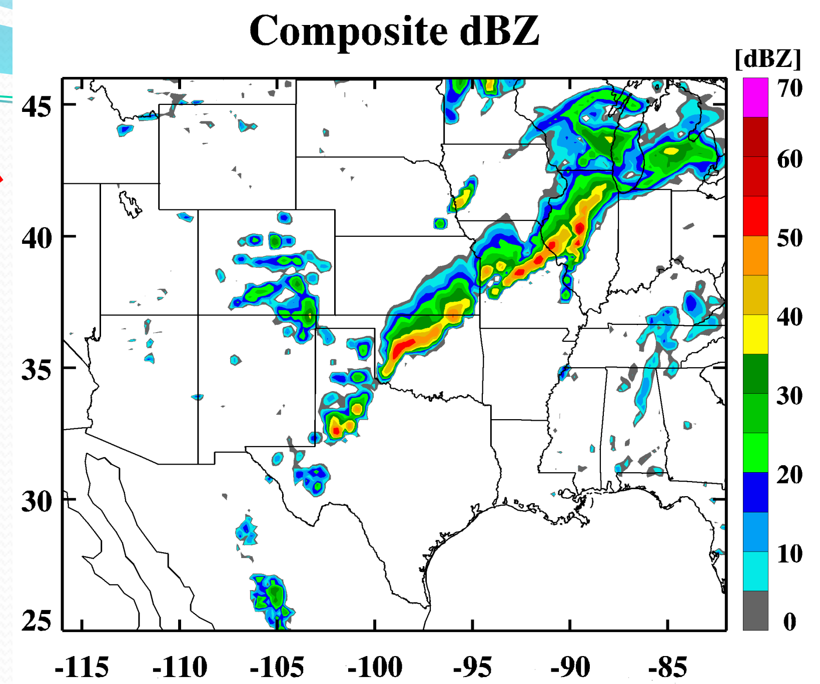
3ICE-Graupel →

Microphysics (Case 2)

Observation



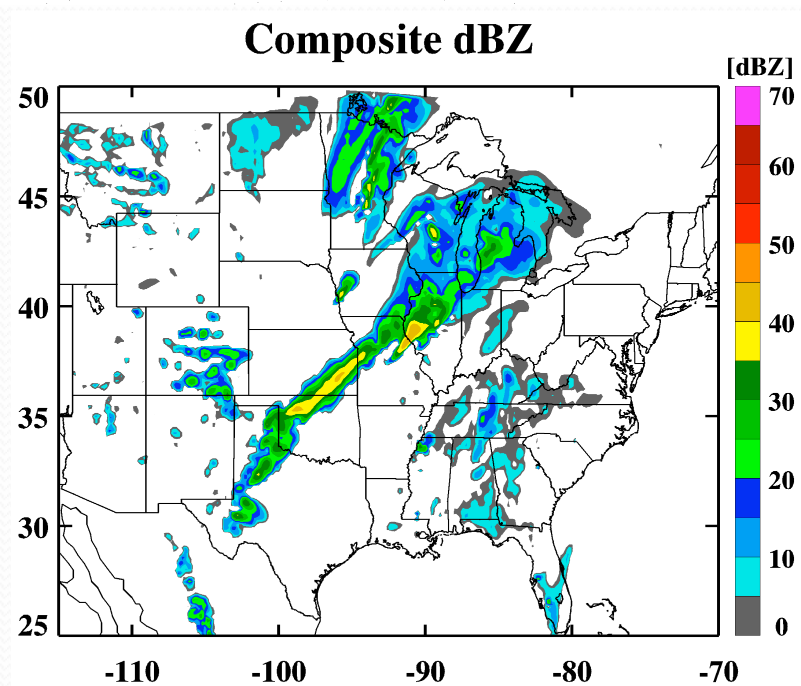
3ICE-Hail →



3ICE-Hail scheme is better for simulating vigorous storms (w >20 m/s), tornado and local thunderstorm

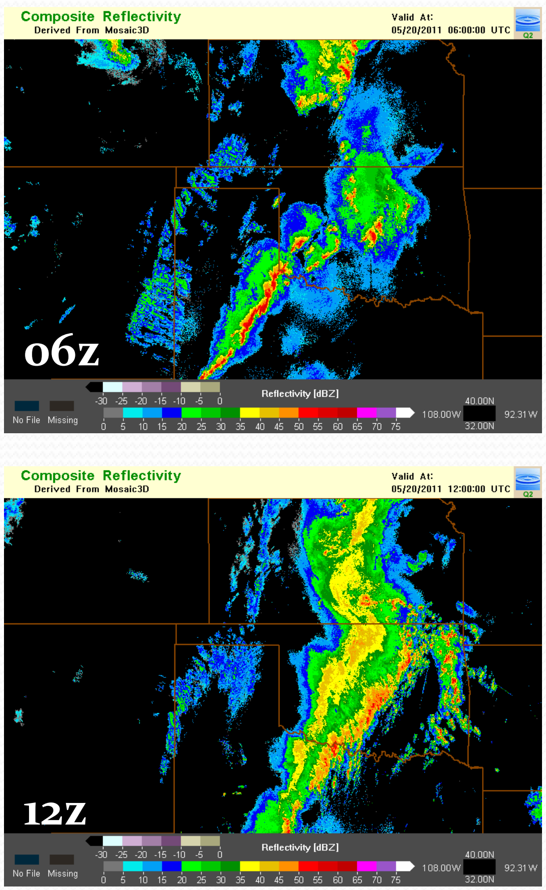
3ICE-graupel scheme is better for simulating tropical storms (hurricane) and winter fronts

3ICE-Graupel →



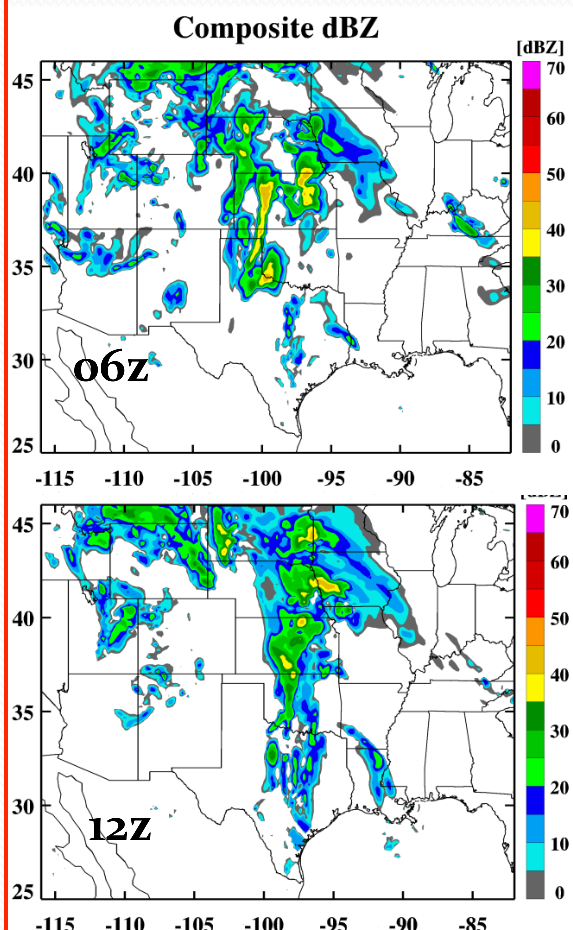
Initial Conditions (Large scale forecast vs analysis)

Radar



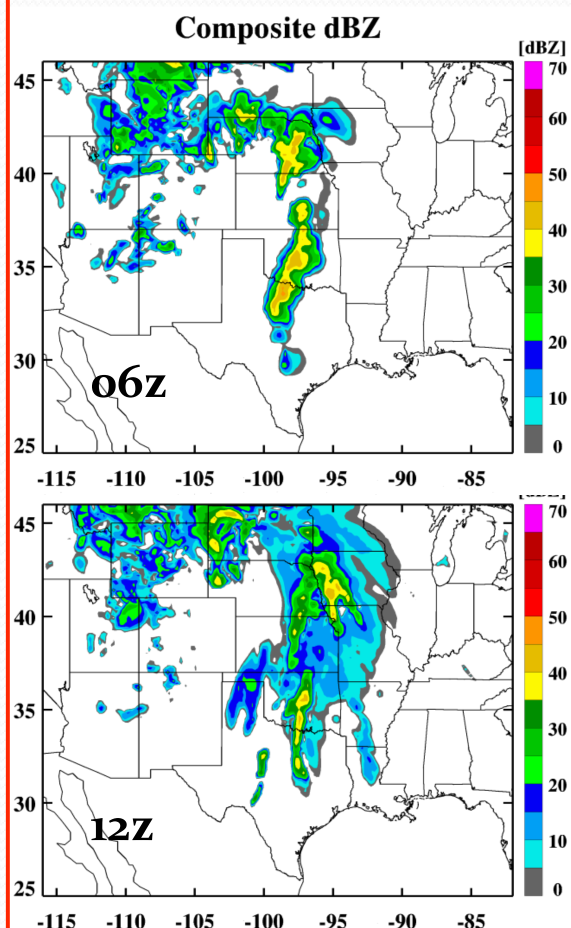
WRF

Init. with NAM



WRF

Init. with NARR



Priority Cases

IOP #	Date	System	Forecast	Flight duration
1	21Z April 22 to 08Z April 23	Squall line with leading stratiform	Accurate	ER2: 1919Z on 22^{nd} to 0113Z on 23^{rd} Citation: 2234Z on 22^{nd} to 0057Z on 23^{rd}
2	07Z April 25 to 12Z April 25	Scattered storms	12Z previous day location is off	ER2: 0712Z to 1246Z on 25^{th} Citation: 0921Z to 1222Z on 25^{th}
3	23Z April 26 to 15Z April 27	Scattered storms with stratiform	Location is a bit off, too much cloud	ER2: 0500Z to 1123Z on 27^{th} Citation: 0802Z to 1123Z on 27^{th}
4	09Z May 01 to 21Z May 01	Scattered storms with widely covered stratiform	Accurate	Citation: 1629Z-1842Z on 01^{st}
5	19Z May 10 to 03Z May 11	Scattered storms with Stratiform and mixed type of precipitation	Location is a bit off, too much cloud	Citation: 2151Z on 10^{th} to 0011Z on 11^{th}
6	12Z May 11 to 00Z May 12	Squall line with trailing stratiform	00Z missed the event	ER2: 1505Z to 1923Z on 11^{th} Citation: 1602Z to 1927Z on 11^{th}
7	07Z May 18 to 15Z May 18	Squall line with leading stratiform	Accurate	ER2: 0512Z to 0955Z on 18^{th} Citation: 0720Z to 0922Z on 18^{th}
8	05Z May 20 to 06Z May 21	Squall line with extended trailing stratiform	19 12Z missed the event, 00Z doing ok	ER2: 1315Z to 1855Z on 20^{th} Citation: 1306Z to 1702Z on 20^{th}
9	20Z May 23 to 07Z May 24	Organized quasi-linear storms	Accurate	ER2: 2055Z on 23^{rd} to 0235Z on 24^{th} Citation: 2130Z on 23^{rd} to 0041Z on 24^{th}
10	19Z May 24 to 05Z May 25	Squall line	00Z missed the event, 12Z is good	Citation: 2018Z to 2228Z on 24^{th}

Post Mission Simulations

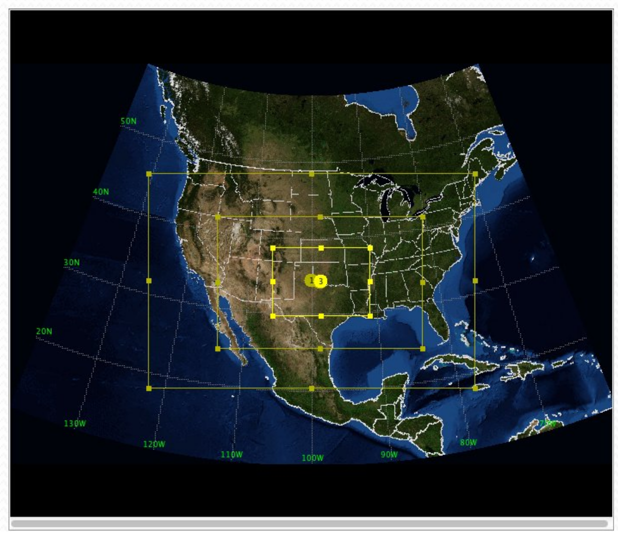
Three nested domain: 18, 6, and 2 (**1 or finer**) km, and 61 vertical layers. Larger inner domain

Physics:

- Goddard Microphysics scheme **(Spectral bin, 2-moment)**
- Grell-Devenyi cumulus scheme
- Goddard Radiation schemes
- MYJ planetary boundary layer scheme
- **Land Information System (LIS)**
- Eta surface layer scheme

Initial condition (NFS)

- **MERRA, GEOS5, ECMWF**



Summary (Real-Time Forecast)

Goddard WRF model did a good job in the May 1st and May 24th-25th case.

Goddard 3-ice microphysics scheme with hail option is well-suited for strong convective storm simulations.

Simulations are quite sensitive to initial and boundary conditions.

Post-Mission (Physical Validation)

Conduct high resolution CRM (GCE and WRF) simulations

Compare the model-simulated cloud microphysical properties (DSDs at various layers, 3D liquid and ice water contents and median diameters, mixed phase information, and the liquid water fraction of melting snow, graupel and hail, over the life cycle of cloud systems)

Use satellite simulators and CRM results to provide to GPM rainfall algorithm developers

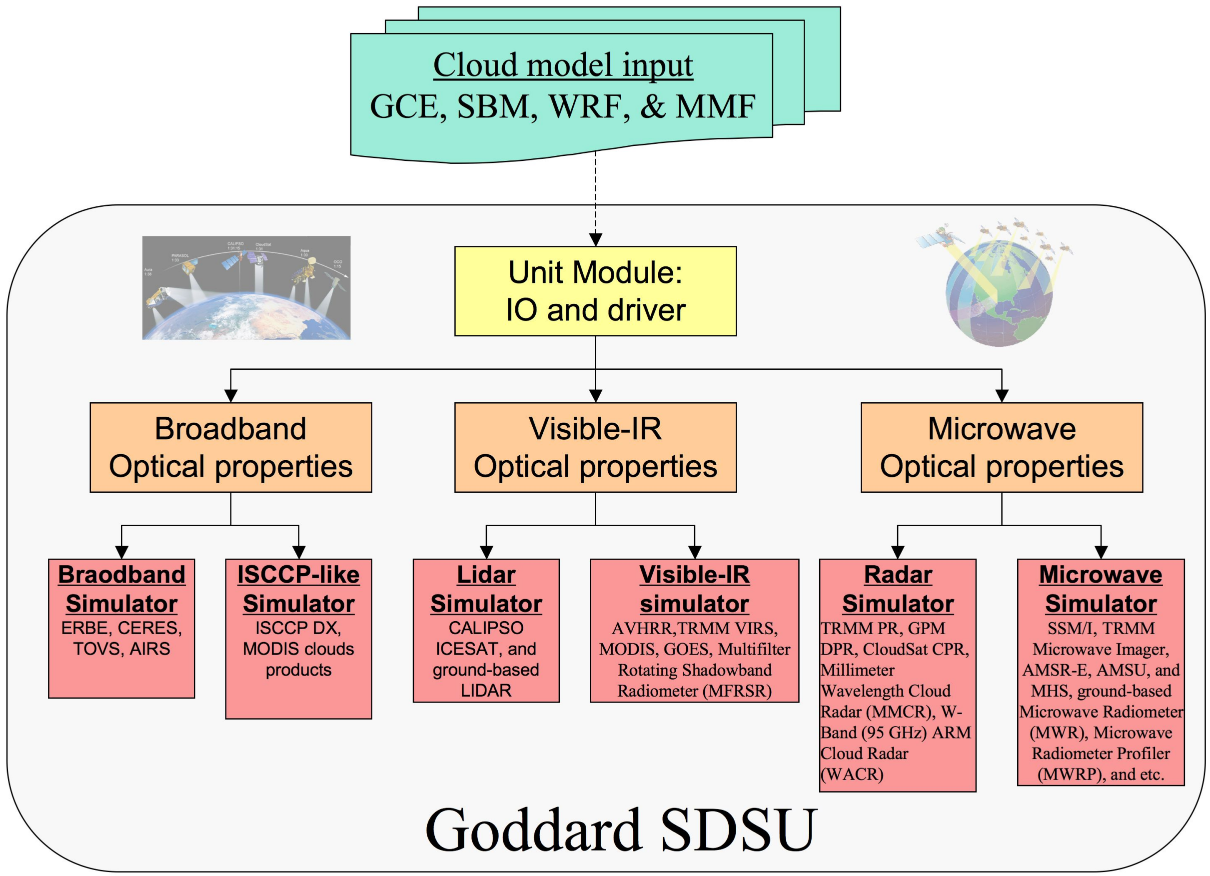
Provide better CRM-simulated data to GPM LH algorithm developers

Physical Validation

S. Rutledge, R. Johnson, W. Petersen, A. & G. Heymsfield, C. Williams, and many others (DOE/ASR Team)

Goddard Satellite Data Simulation Unit (SDSU) for evaluating models' performance and supporting NASA's satellite missions

T. Matsui



Examine an evaluation method for Goddard multi-scale modeling system by using direct measurements from space-born, airborne, and ground-based remote sensing.

Support the NASA's satellite mission (e.g., A-Train, GPM and ACE) through providing the virtual satellite measurements as well as simulated geophysical parameters to satellite algorithm developers.

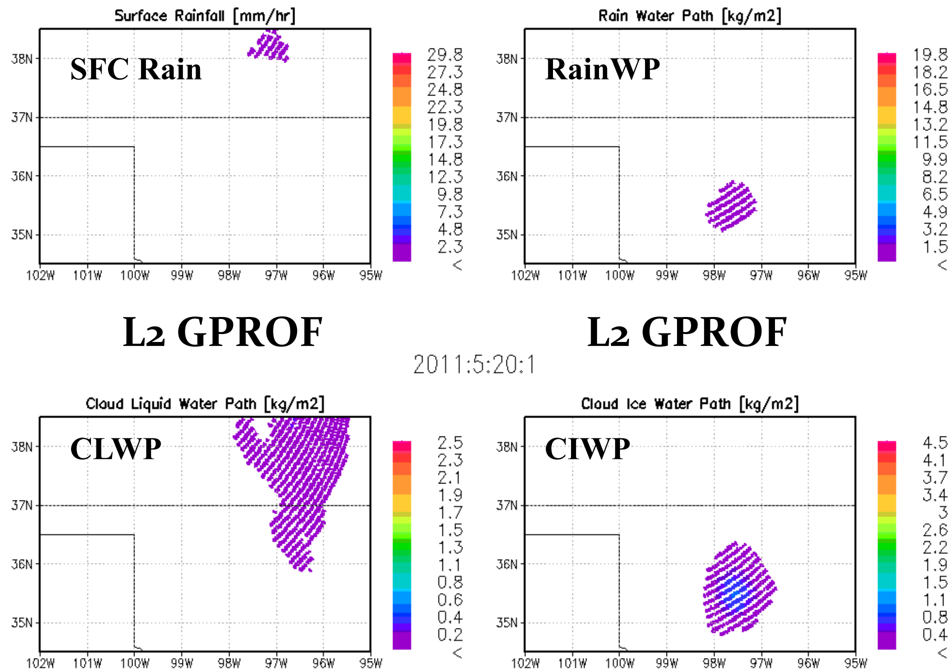
Masunaga, H., Matsui, T., W.-K. Tao, A. Y. Hou, C. Kummerow, T. Nakajima, P. Bauer, W. Olson, M. Sekiguchi, and T. Y. Nakajima, 2011: Satellite Data Simulation Unit: Multi-Sensor and Multi–Frequency Satellite Simulator package, *Bulletin of American Meteorological Society*.

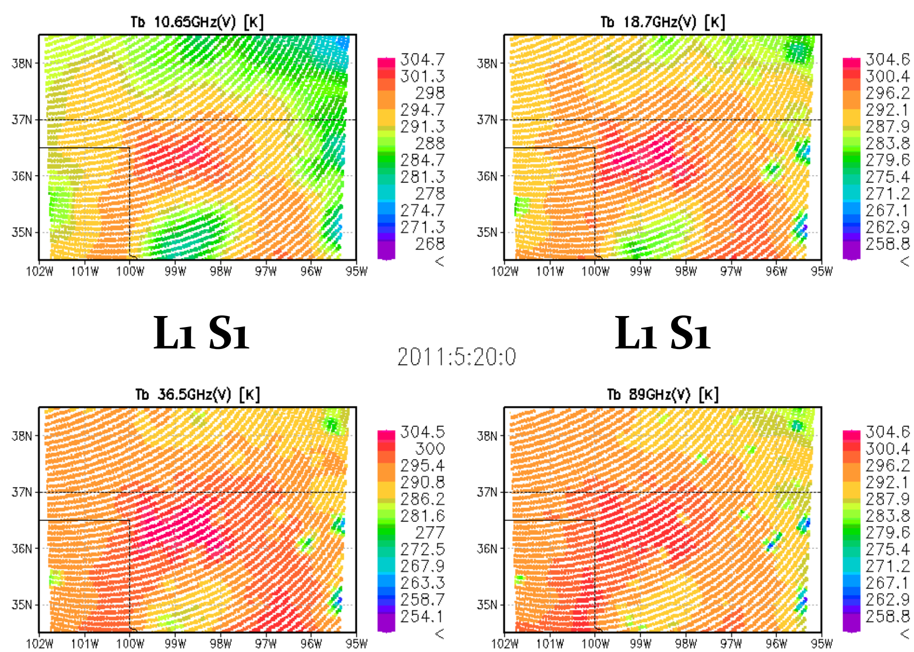
Simulated GMI L1B/L2 signals

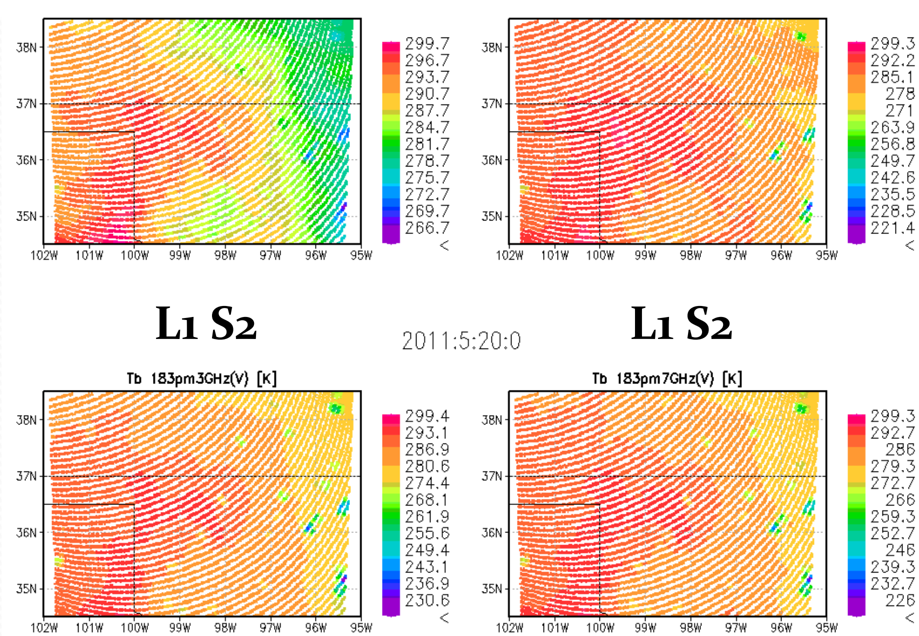
• GMI signals are computed from the WRF simulation through detailed GPM orbit and GMI scan modules.

• GMI L1 signals are computed through delta-Eddington 2-stream radiative transfer in slant-path option. Background surface emissivity is derived from NESDIS emissivity model V1.

• GMI L2 GPROF is rainfall parameters re-sampled through GMI 37GHz antenna-gain pattern.

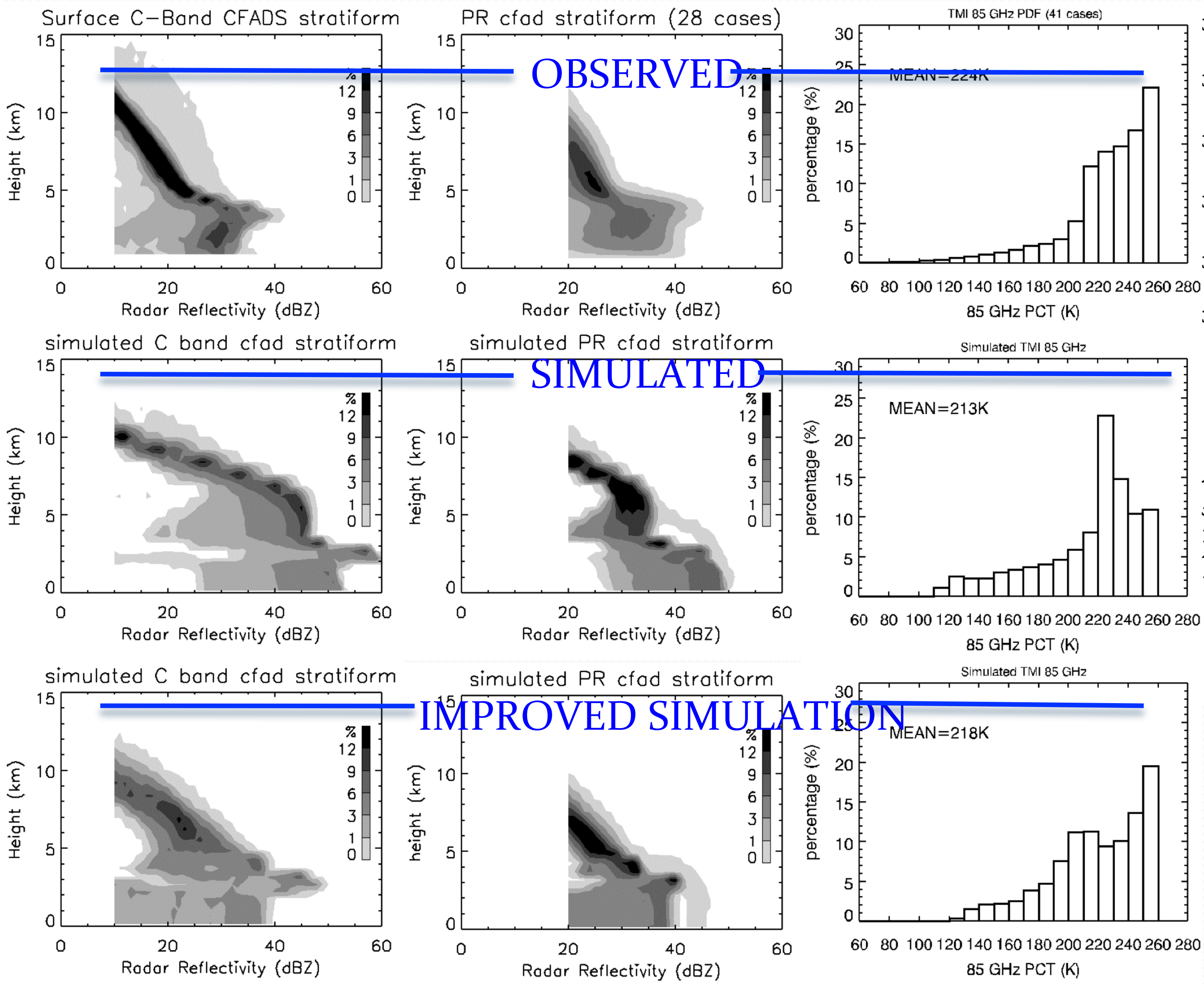


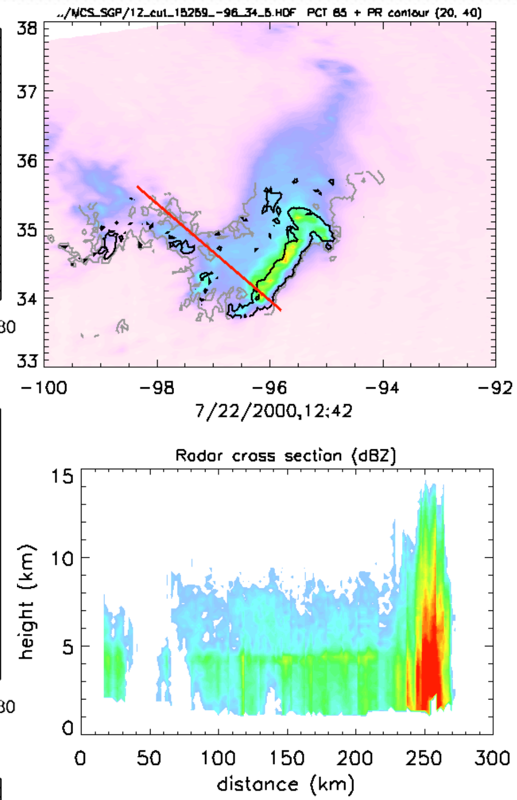




Improve Bin (***Bulk***) Microphysics Scheme Using TRMM (***MC3E***) Data

C-band surface radar | TRMM PR | TMI 85GHz





Squall lines in central US

Li, Tao et al., 2010: Improving a spectral bin microphysical scheme using TRMM satellite observations. *Quart. J of Royal Meteo. Soc.*

- Tao, W.-K., J.-P. Chen, Z.-Q. Li, C. Wang and C.-D. Zhang, 2011: The Impact of Aerosol on convective cloud and precipitation. Rev. Geophys., (accepted – revised and submitted).
- Tao, W.-K., and M. Moncrieff, 2011: Cloud Modeling, 2nd Edition, Encyclopedia of Atmospheric Sciences, Edited by G. North, F. Zhang and J. Pyle, (accepted).
- Tao, W.-K., and Toshi Matsui, 2011: Cloud System Modeling and Aerosol, 2nd Edition, Encyclopedia of Atmospheric Sciences, Edited by G. North, F. Zhang and J. Pyle, (accepted).
- Iguchi, T., T. Nakajima, A. P. Khain, K. Saito, T. Takemura, H. Okamoto, T. Nishizawa, and W.-K. Tao, 2011: Evaluation of cloud microphysics simulated using a meso-scale model coupled with a spectral bin microphysical scheme through comparison with observation data by ship-borne Doppler and space-borne W-band radars, J. Atmos. Sci., (accepted).
- Jiang, X., D. E. Waliser, W. S. Olson, W.-K. Tao, T. S. L'Ecuyer, S. Shige, K.-F. Li, Y. L. Yung, and S. Lang, 2010: Vertical diabatic heating structure of the MJO: Inter-comparison between recent reanalyses and TRMM estimates, Mon. Wea. Rev., (in press).
- Lang, S., W.-K. Tao and X. Zeng, 2011: Reducing the biases in simulated radar reflectivities from a bulk microphysics scheme: Tropical convective systems, J. Atmos. Sci., (in press).
- Tao, W.-K., J. J. Shi, P.-L. Lin, M.-Y. Chang, M.-J. Yang, C. Peter-Liddard, C.-H. Sui, 2011: High Resolution Numerical Simulation of Typhoon Morakot: Part I: Impact of Microphysics and PBL. Special Issue on Typhoon Morakot, Terrestrial, Atmospheric and Oceanic Sciences (in press).
- Masunaga, H., Matsui, T., W.-K. Tao, A. Y. Hou, C. Kummerow, T. Nakajima, P. Bauer, W. Olson, M. Sekiguchi, and T. Y. Nakajima, 2010: Satellite Data Simulation Unit: Multi-Sensor and Multi–Frequency Satellite Simulator package, Bulletin of American Meteorological Society, 91, 1625-1632.
- Shi, J. J., W.-K. Tao, T. Matsui, A. Hou, S. Lang, C. Peters-Lidard, G. Jackson, R. Cifelli, S. Rutledge, and W. Petersen, 2010: Microphysical Properties of the January 20-22 2007 Snow Events over Canada: Comparison with in-situ and Satellite Observations. J. Applied Meteor. Climatol. 49, 2246-2266.
- Li, X., W.-K. Tao, T. Matsui, C. Liu and H. Masunaga, 2010: Improving spectral bin microphysical scheme using TRMM satellite observations. Quart. J. Roy. Meteor. Soc. 136, 382–399.
- Zhang, C., S. Hagos, W.-K. Tao, S. Lang, Y. N. Takayabu, S. Shige, M. Katsumata, W. S. Olson, and T. L'Ecuyer, 2010:MJO signals in latent heating: TRMM observations. J. Atmos. Sci., (in press).
- Chen, W.-T., C. P. Woods, J.-L. F. Li, D. E. Waliser, J.-D. Chern, W.-K. Tao, J. H. Jiang, and A. M. Tompkins, 2011:Partitioning CloudSat ice water content for comparison with upper tropospheric ice in global atmospheric models, J.Geophys. Res., 116, D19206, doi:10.1029/2010JD015179.