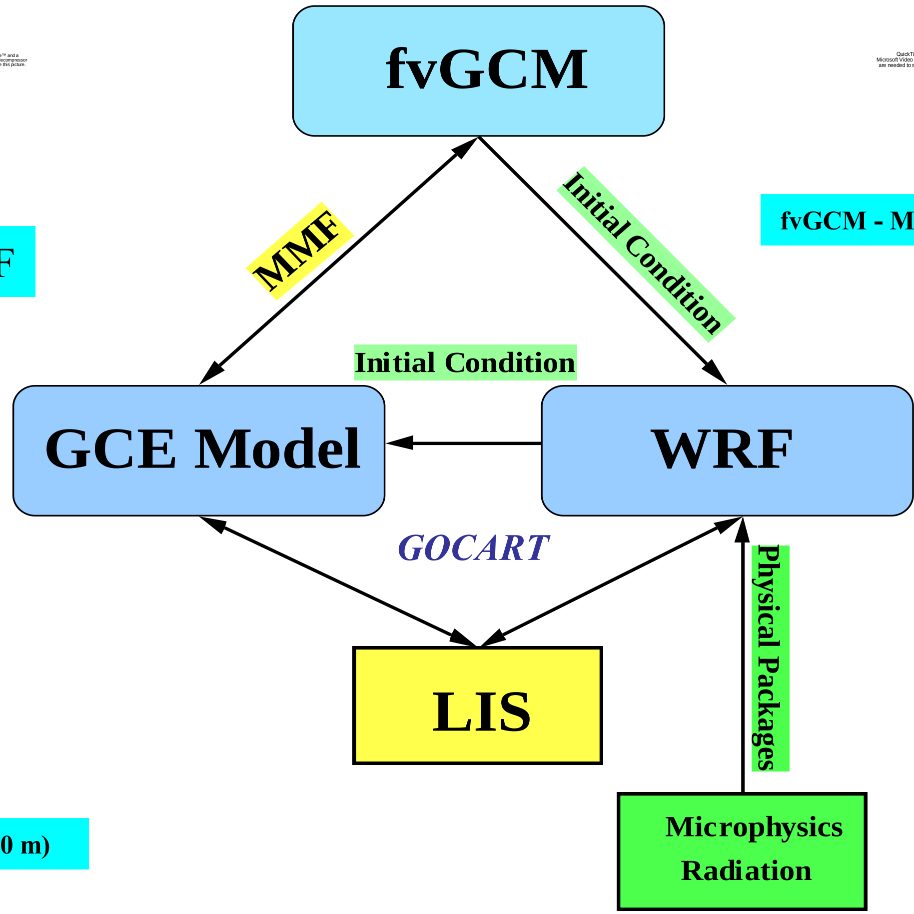
# Multi-Scale Modeling Systems with Unified Physics

QuickTime™ and a YUV420 codec decompressor are needed to see this picture.

MMF

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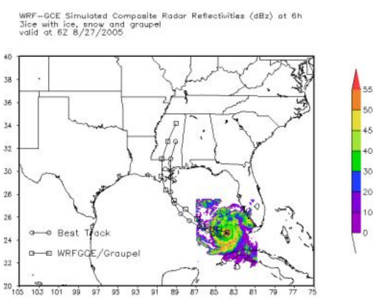
fvGCM - MJO (0.25° x 0.25°)

QuickTime™ and a YUV420 codec decompressor are needed to see this picture.

GCE - LBA (250 m)

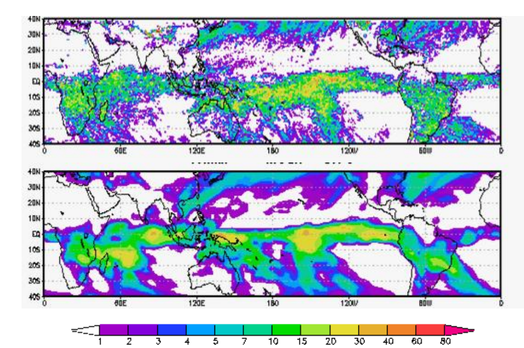
**Observation**

Satellite Data
Field Campaigns
Re-analyses




WRF- *Hurricane Katrina* (1.67 km)

**TRMM**



*MMF*

**MMF: Multi-Scale Modeling Framework**
**LIS: Land Information System**
**GCE: Goddard Cumulus Ensemble Model**

**WRF: Weather Research Forecast**

**Microphysical Package (5 options)**
**& Long/Shortwave Radiative Transfer**
**(including cloud-radiation interaction)**

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*, (**accepted**).

# *Improving the Simulation of Convective Cloud Systems: higher resolution and improved ice physics*

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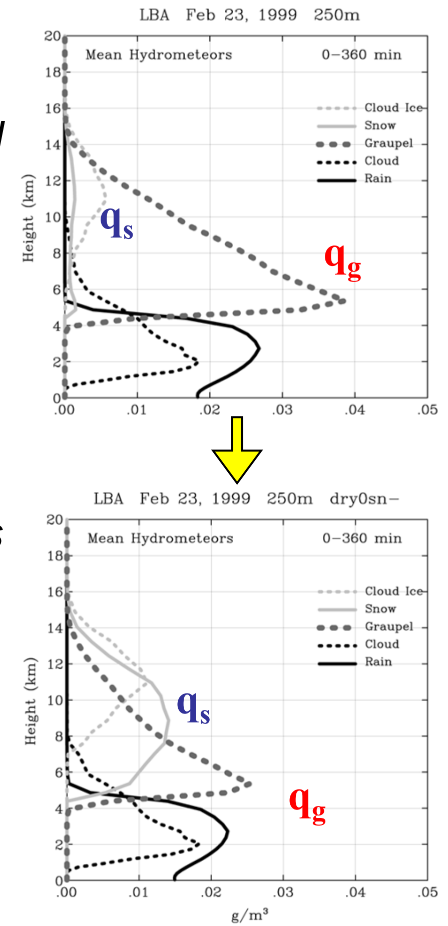
YUV420 codec decompressor
are needed to see this picture.

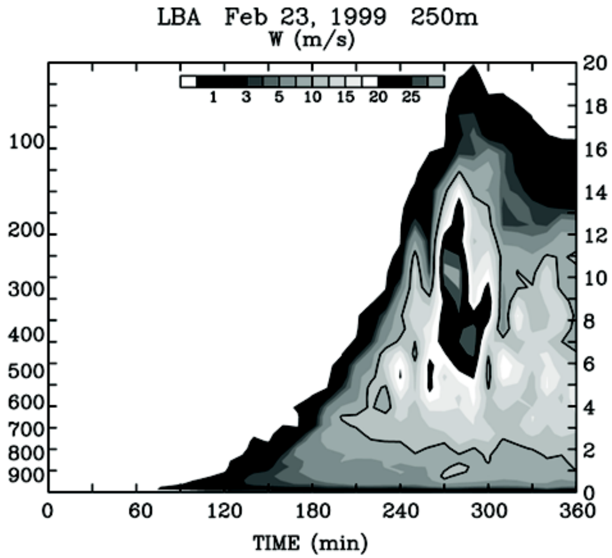
*The Goddard Cumulus Ensemble (GCE) model is a cloud-resolving model developed at NASA Goddard by the Mesoscale and Dynamics Group to simulate convective cloud systems.*




*Improvements to the cloud microphysics results in less high-density ice and more realistic hydrometeor profiles for use in satellite retrievals*

*High resolution simulation of 23 Feb 1999 TRMM LBA case*

*Image by J. Williams (Scientific Visualization Studio)*

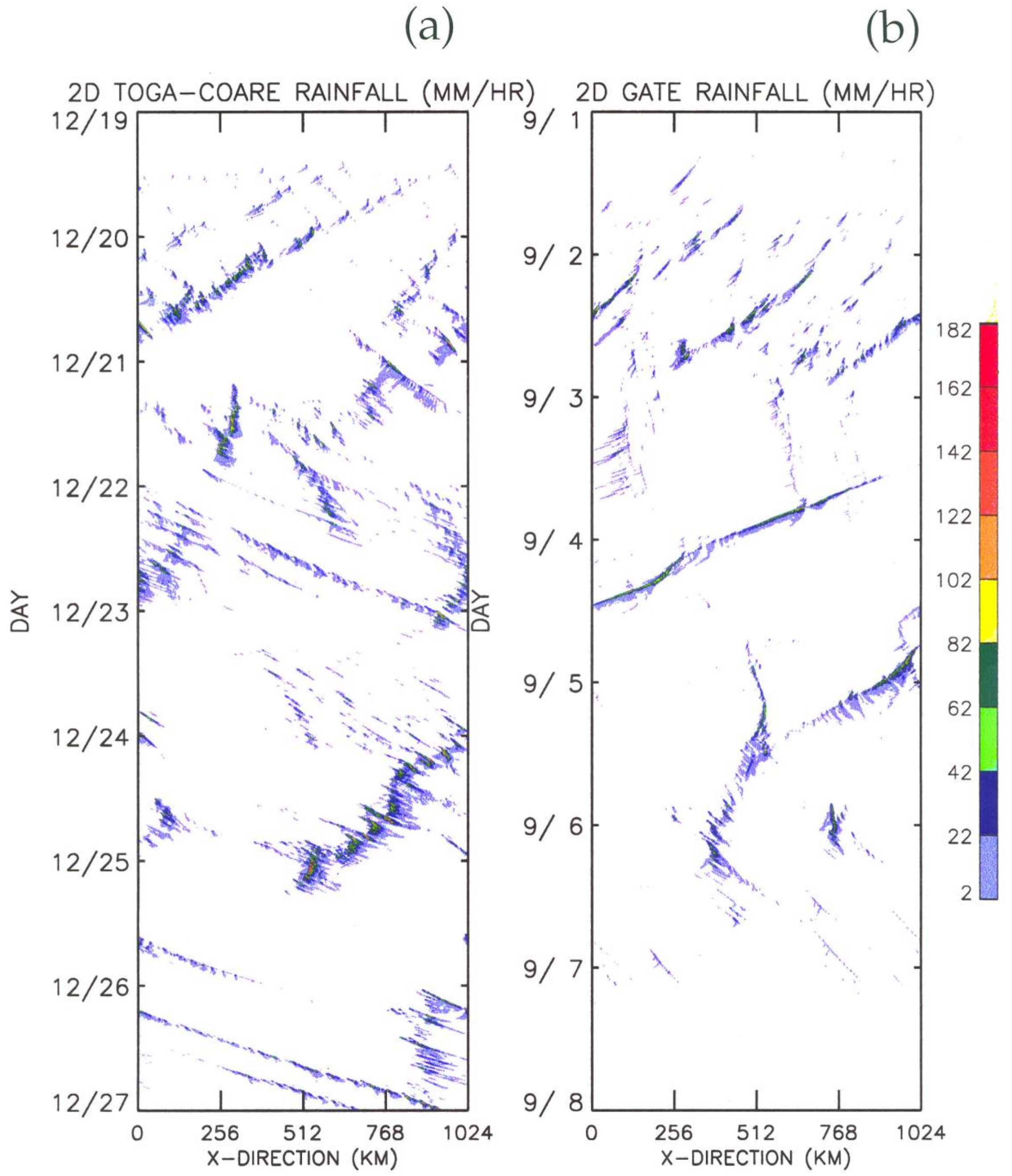



*Higher horizontal model resolution leads to a more realistic, gradual transition from shallow to deep convection*

Need to continue improve the microphysics

Lang, S., W.-K. Tao, R. Cifelli, W. Olson, J. Halverson, S. Rutledge, and J. Simpson, 2007: Improving simulations of convective systems from TRMM LBA: Easterly and westerly regimes. *J. Atmos. Sci.*, **64**, 1141-1164.

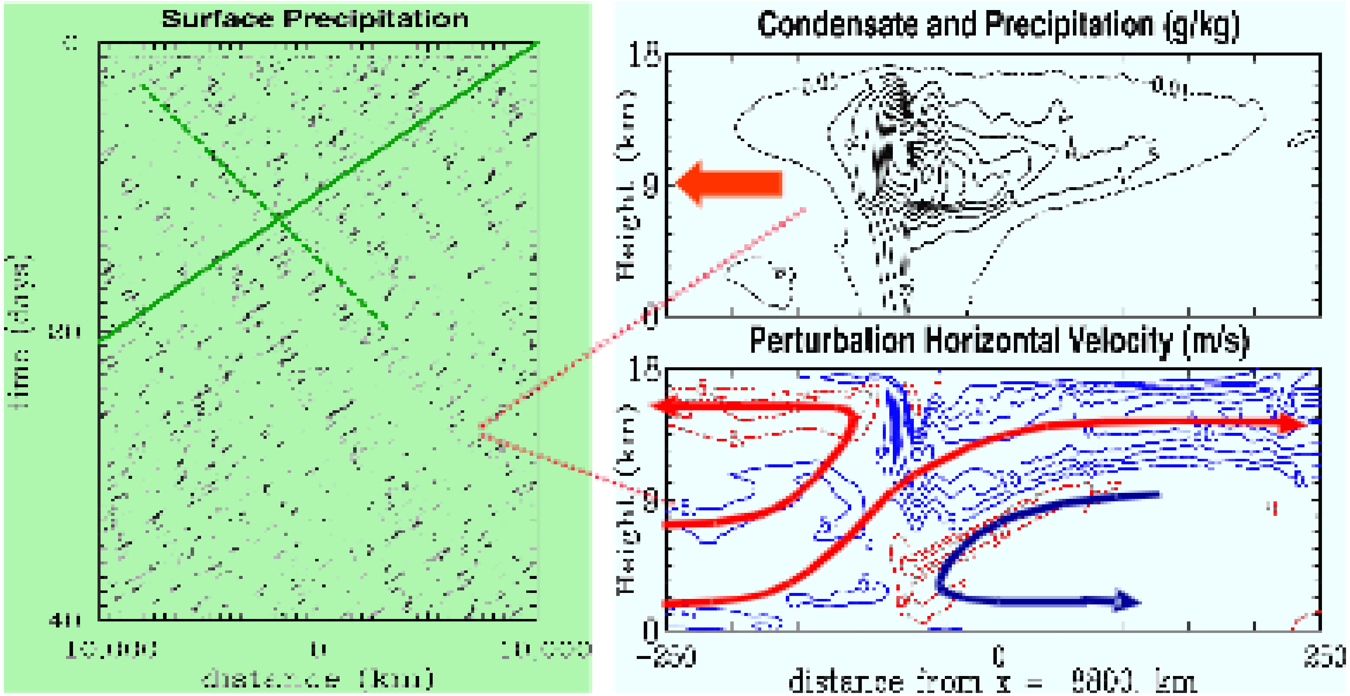
TOGA
COARE




GATE

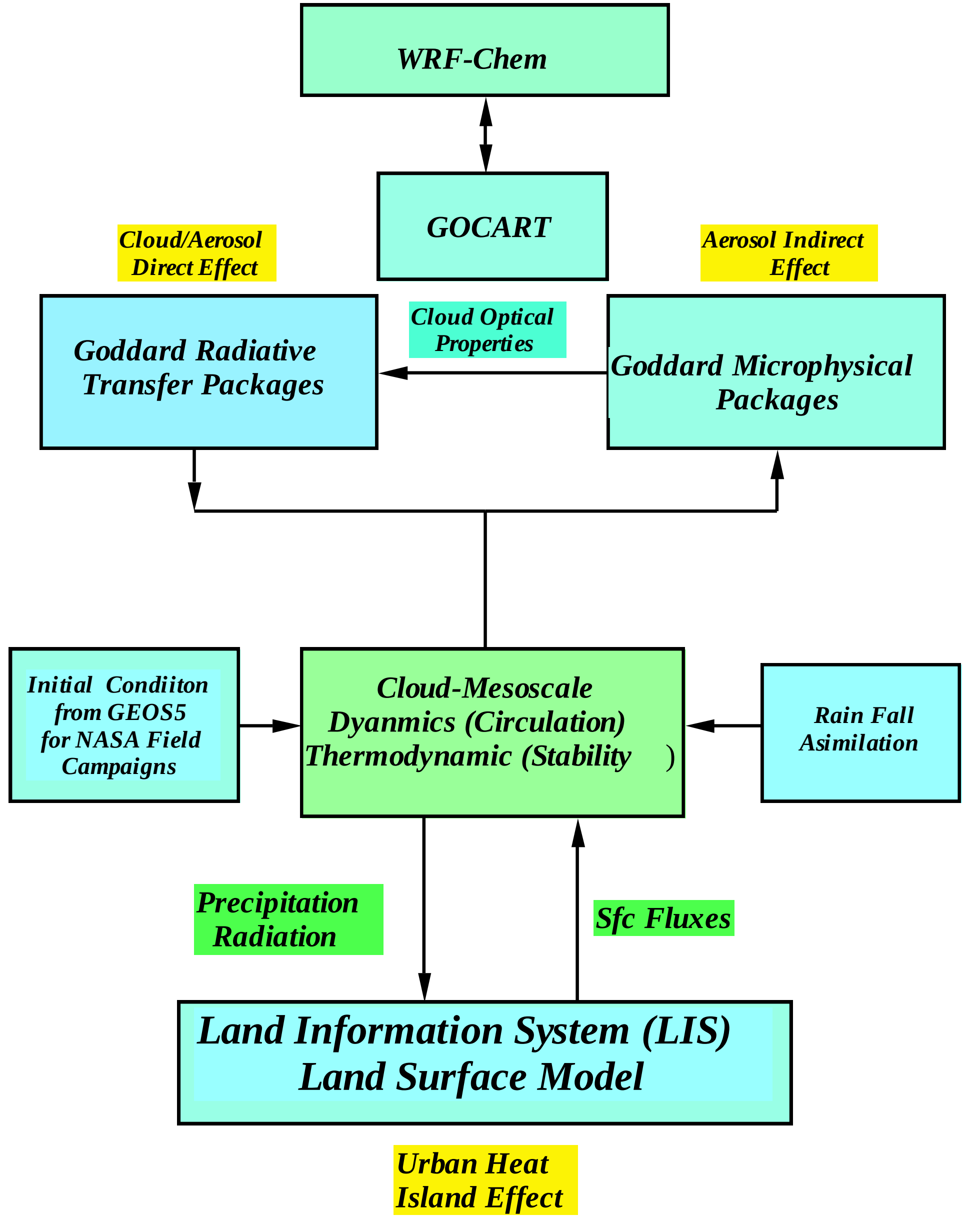
MJO Like

Tao (2003)




Multiscale convective organization in a two-dimensional CRM with a 20,000 km domain: westward-propagating precipitating systems embedded in a eastward-propagating cloud-cluster envelopes. The vertical section shows the three -branch MCS-type airflow organization of the westward-moving systems. The multiscale organization developed from a randomly perturbed horizontally homogenous motionless state. Adapted from *Grabowski and Moncrieff* [2001].

# NASA Unified WRF

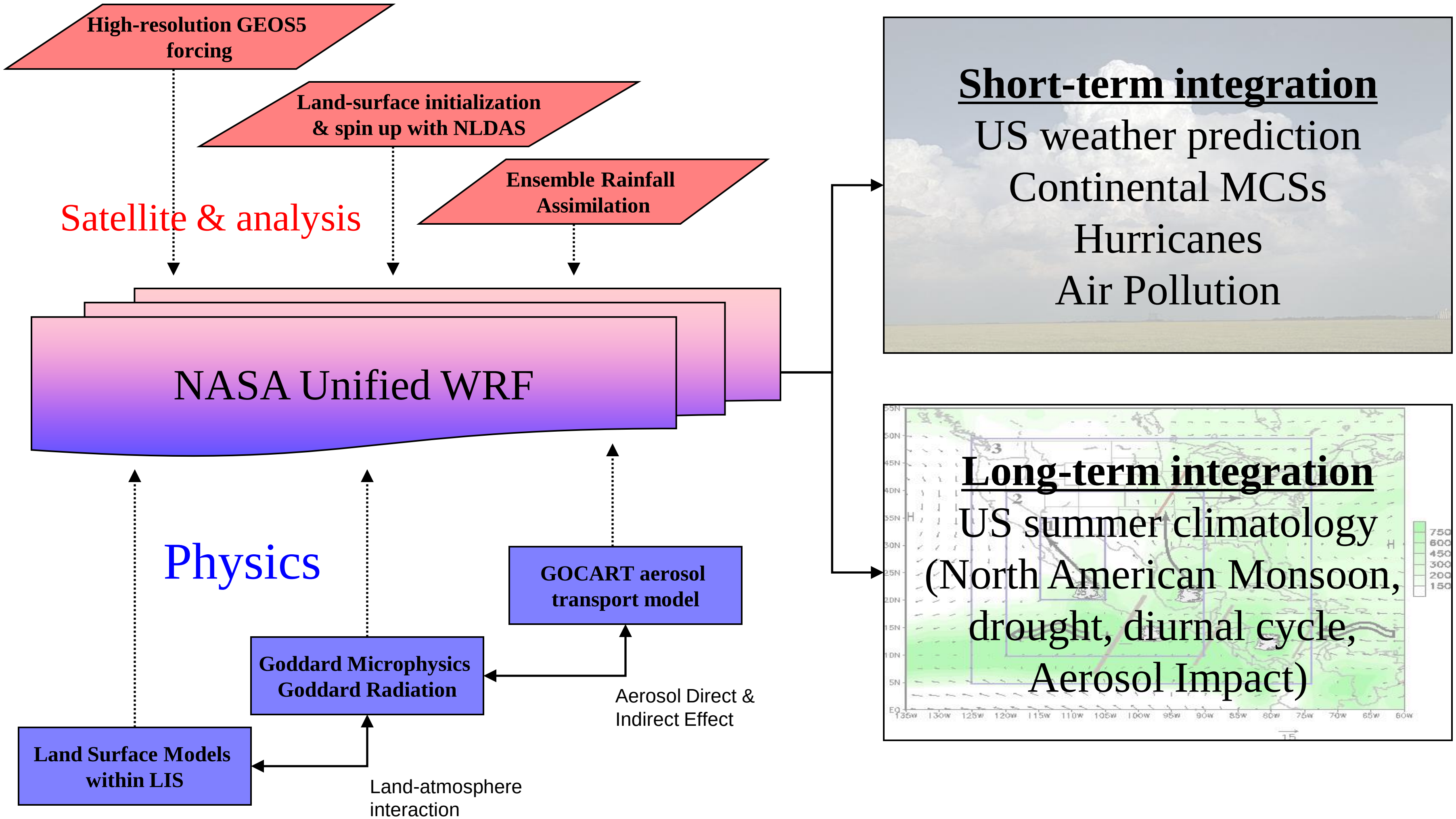



*Blue Boxes: NASA Physical Packages*

# Integrated Modeling of Aerosol, Cloud, Precipitation and Land Processes at Satellite-Resolved Scales

Co-PIs: Christa Peters-Lidard, Wei-Kuo Tao, and Mian Chin

Co-Is: Scott Braun, Jonathan Case, Arthur Hou, Sujay Kumar, William Lau, Toshihisa Matsui, Tim Miller, Joseph Santanello, Jr., Jainn Shi, David Starr, Qian Tan, Benjamin Zaitchik, Jing Zeng, Sara Zhang



Shape/size of the eye

*WRF simulated snow - 1 min*

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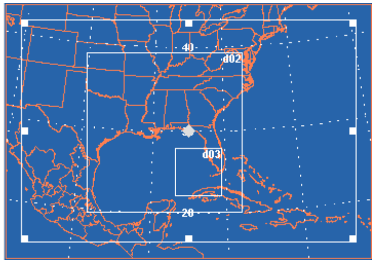
YUV420 codec decompressor
are needed to see this picture.

***NASA Ames Visualization Group***

## Katrina 2005

**Resolutions: 15, 5 and *1.667 km*    Grid size: 300x200, , 418x427, *373x382***
**Dt = 60, 20, 6.67 seconds Starting time: 00Z 8/27/2005**

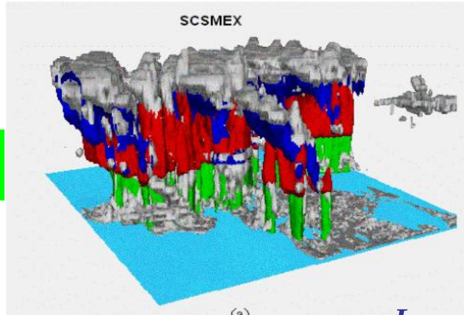
**Initial and Boundary Conditions: NCEP/GFS, with bogus but no data assimilation**

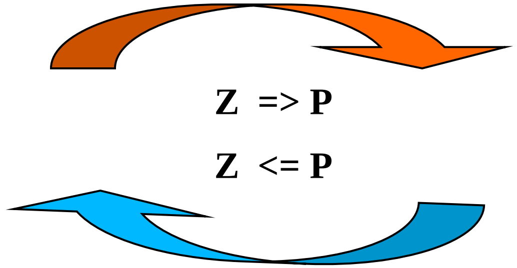


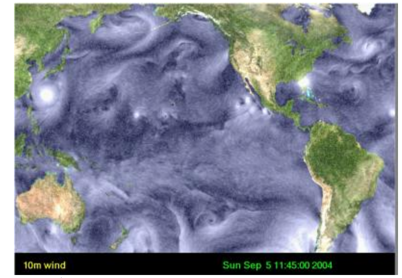
# *NASA Goddard MMF*

*Moist physics tendencies (T and q) Cloud and precipitation*

**GCE**




***fvGCM***

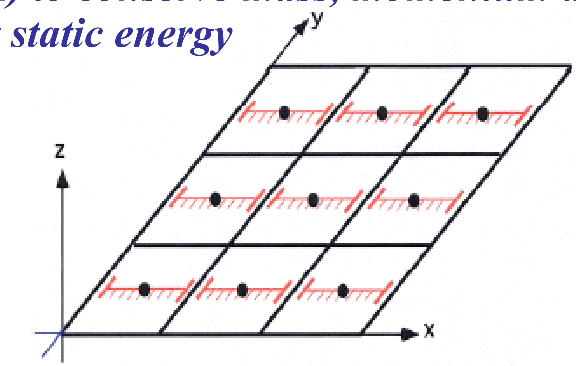
*Large-scale forcing, Background profiles (T, q, u, v, w)*

| NASA MMF |
|---|
| Goddard fvGCM – GCE Model |
| 2 x 2.5 degree (*13,104 CRMs*) |
| Microphysics (>40 processes) |
| Positive definite advection scheme |
| 1.5 order TKE |
| Radiation (every 3 min) |
| Time step (10 s) |
| 28 vertical layers (32 in fvGCM) |
| V Š Component (no PGF) |
| Online cloud statistics (every 2 min) |
| 278 hours/per simulated year on a 512 CPU computer |

**2D GCE has 64 x 28 (x-z) grid points with 4 km horizontal resolution**

**fvGCM and GCE coupling time is one hour**

***Interpolation between hybrid P (fvGCM) and Z (GCE) coordinate: using finite-volume Piecewise Parabolic Mapping (PPM) to conserve mass, momentum and moist static energy***





**Tao, W.-K**., J. Chern, R. Atlas, D. Randall, X. Lin, M. Khairoutdinov, J._L. Li, D. E. Waliser, A. Hou, C. Peters-Lidard, W. Lau,J. Jiang and J. Simpson, 2009: Multi-scale modeling system: Development, applications and critical issues, *Bull. Amer. Meteor. Soc*. **90**, 515-534.

# Goddard Multiscale Modeling Framework (MMF)

QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

**1) Tropical waves move off the coast of Africa and propagate westward. [ It is known that tropical cyclogenesis can be initialized (or triggered) by these tropical waves. Therefore, accurate simulations of their interactions with small-scale convection are important for improving the simulations of TC genesis. ]**
**2) The eastward-traveling system in the southern hemisphere (SH) are the so-called the polar vortex, which is most powerful in the hemisphere's winter (JJAS, in the SH).**
**3) The equatorial Amazon has abundant rain between November and May. During the Brazilian spring season (October/November/December), most of the countries get wetter, except for the Brazilian northeast.**
**4) In comparison, during this period (winter in the northern hemisphere), mid-latitude periodic frontal systems move eastward across the USA.**
**5) Near the end of simulations, heavy precipitations appear near the ITCZ**

# NASA Goddard Multiscale Modeling System simulated MJO

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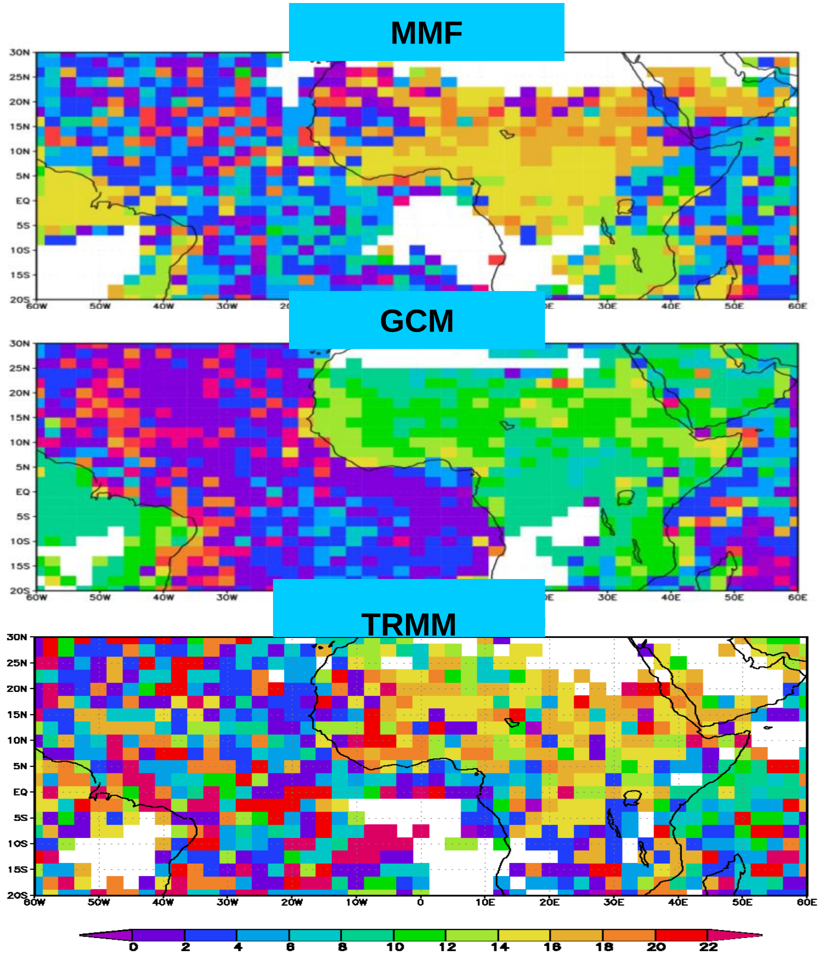
are needed to see this picture.

**In a 30-day simulation of the MJO in late 2006 and early 2007, it is found that the location and propagation speed of the MJO are simulated reasonably well, including the formation of large-scale convective system in the Indian Ocean and its eastward propagation.**

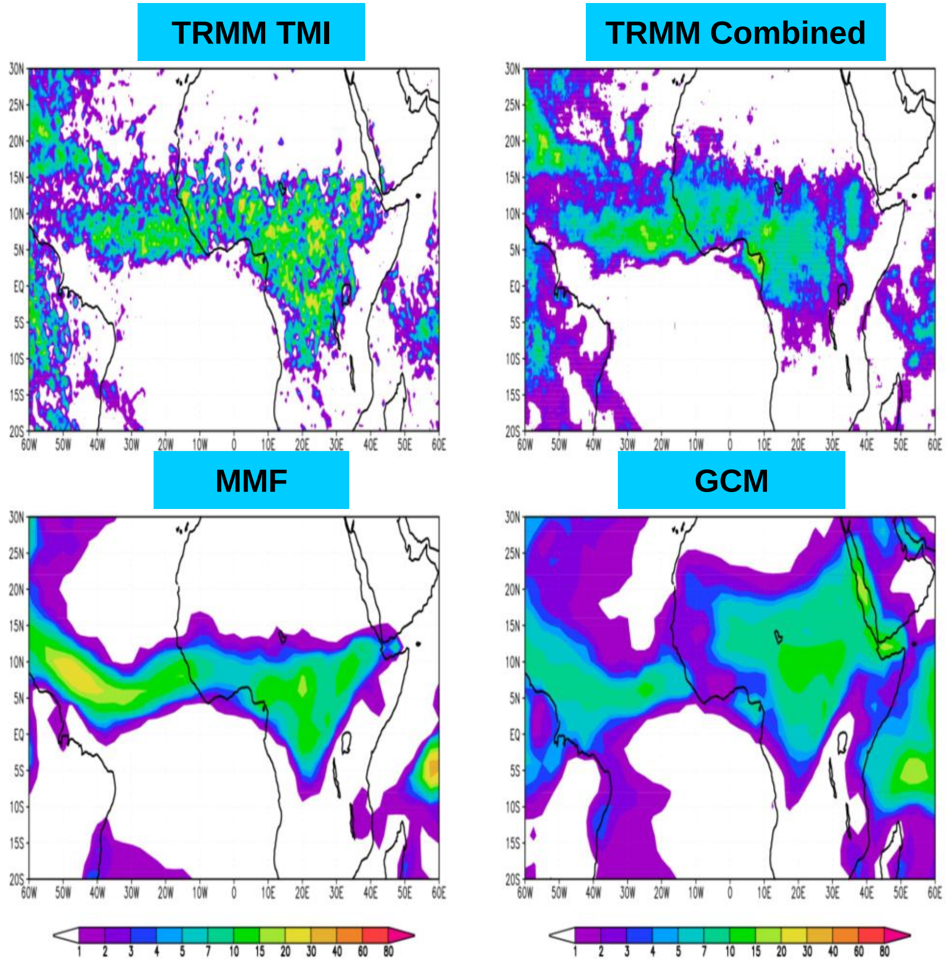
# Monthly precipitation and local time of precipitation frequency maximum over West Africa

***MMF captured satellite observed surface precipitation and its diurnal variation.***

***The results imply that the MMF could be used to study local and regional surface water/energy cycle***



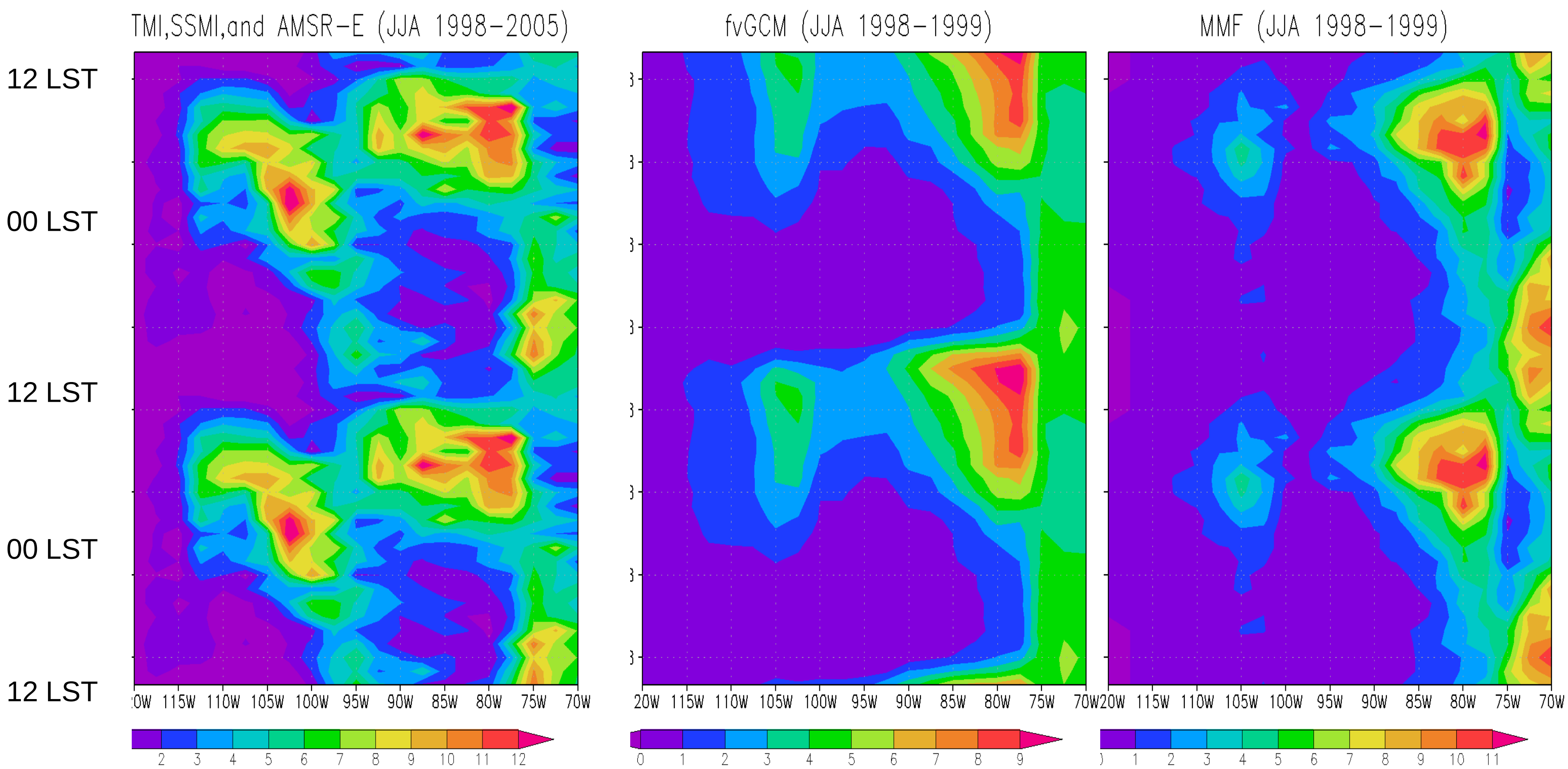

Geographical distribution of the local solar time (LST) of non-drizzle precipitation frequency maximum over West Africa in summer 1999 as simulated with the Goddard MMF (upper panel) and the GCM (middle panel) and as observed by the TRMM TMI (bottom panel). Blank regions indicate no precipitation.




Monthly precipitation rates (mm/day) over West Africa for September 1999 from TRMM observations (TMI, top-left, and Combined, top-right) and simulations from the Goddard MMF (lower-left panel) and the GCM (lower-right panel).

# Diurnal Cycle of Summer Precipitation over USA along 35N

Merge MV (1998-2005) | GCM (1998-1999) | MMF (1998-1999)



# YOTC

- **MMF: 1997 - present / MJO simulation (Oct 08 - June 09)**
- **WRF: Target Integration**
- **CRM: Driven by MERRA (Forcing/Tendency)**

**WRF Simulated Snow**
**6.67 s, 1.67 km resolution**

QuickTime™ and a
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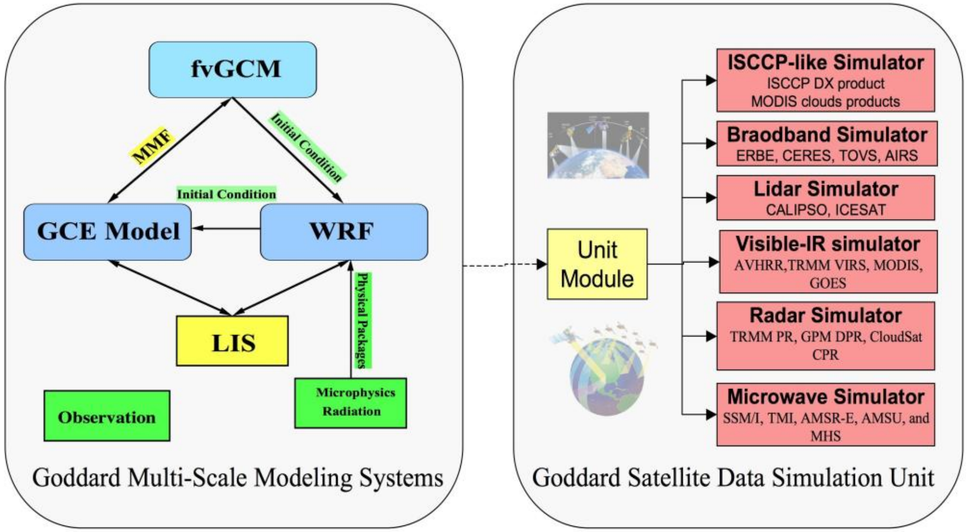
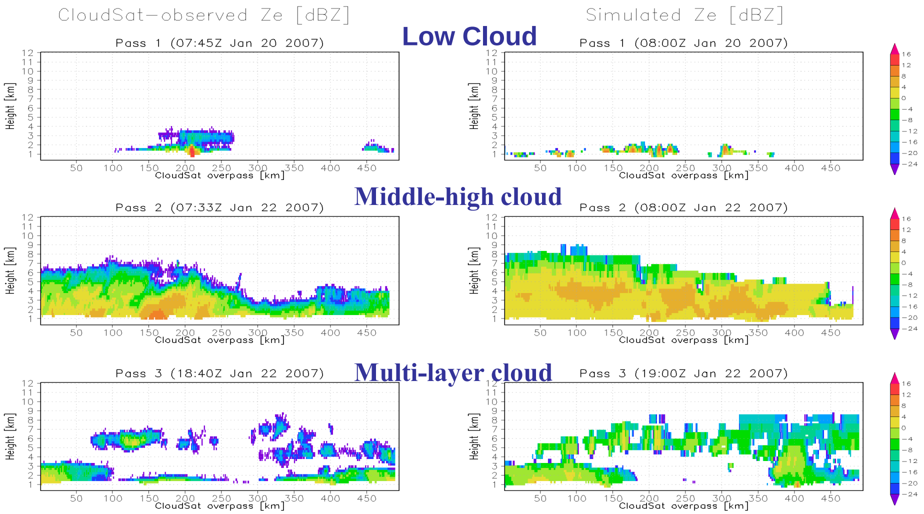



CloudSat-observed and WRF-simulated *Ze*




***Trajectory/Inert tracer***

Website for mesoscale modeling group and cloud library

http://portal.nccs.nasa.gov/cloudlibrary/index2.html

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