
**MC3E Rainfall – Composited (72 h)**

**Three Model Deficiencies**

Rainfall amount, Stratiform rainfall area, Rain intensity

1/16 +1
High resolution model simulations for MC3E
Comparison with observation
Sensitivity of Microphysics schemes

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(¹NASA GSFC, ²SSAI)

Issues Related to Microphysics Schemes (2)

NASA Multi-Scale Modeling Systems with
Unified Physics (1)

Goddard 4ICE Microphysics (3, GCE results)

WRF Results
Issues of Microphysics Schemes in Numerical Cloud Models

What are the main characteristics and differences / similarities of these microphysics schemes?
   One-moment, two-moment, three-moment, spectral bin microphysics
   Assumed or pre-determined parameters and transfer processes between cloud species

What is the sensitivity of model resolution on the performance of the microphysics schemes?
   (1, 2, 3.5, or 7 km)

What are the main methods to evaluate the performance of these microphysics schemes?
   Ground, Aircraft and Satellite observation

What are the main issues for inter-comparison study of different microphysics schemes?
Modified two transfer processes related to snow

Increase the snow intercept

An old version of WSM6

(a)

Modified two transfer processes related to snow

Increase the snow intercept (0.03 – 0.16)

Purdue-Lin

(b)

(c)

Tao et al. (2008)
Goddard Multi-scale Modeling System with Unified Physics

fvGCM

GCE Model

WRF

MMF

Initial Condition

GCE ~10 field campaigns
(MC3E, DYNAMO, TWP-ICE, SCSMEX)
TRMM LH and Rainfall Algorithm
S. Lang, X. Li

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

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

MMF-LIS (Yr 2006)
MMF (1998-2012)
GPM, TRMM
Mohr, Matsui, Chern

Microphysics
Radiation

LIS

GOCART

GCE simulated rainfall MC3E - 22 days

MMF simulated and TRMM observed rainfall
Latent Heating Profiles aloft are quite different between these two schemes.

**3ICE Scheme**: Need to pre-determine whether a 3ICE-graupel or a 3ICE-hail

Weather Forecast/MMF/Climate Model

Lang et al. (2014, JAS – 4ICE scheme) + reduction of rain evaporation (derived from spectral bin microphysics)

Two Moments 4-ICE (2014-2015) - Collaboration (Grad. Student)
Key features of the Goddard 4-ICE scheme


Added a **snow density mapping** (smaller=higher density, Heymsfield et al. 2004)

**Modified the** Lang et. al. 2011 **graupel/snow size mapping** (reduced sizes in tail)

**Modified the saturation adjustment:**
cloud ice can persist in sub-saturated air down to RHI=90%
allows for a 5% background super-saturation w.r.t. ice
cloud evaporation only when $W < -0.1$ m/s (limit spurious evaporation, Reisner)

Added a **correction to water diffusivity** (constant in original Rutledge and Hobbs scheme)

**Added “physical” rain evaporation correction** based on bin (Li et al. 2010) but with limits

**Added two-tier graupel density scheme** (0.3 < 2.0 g/m$^3$ > 0.5) including fall speeds

**Fixed artifacts in accretion terms** (minimum slope parameters = accretion w.o. collectors)

**Shortened time-scale for snow auto-conversion** (1000 s to 300 s)

**Added threshold to snow from ice term** (Psfi, because of time scale approach, always active)
Observed and GCE Modeled CFADs
May 20 MC3E (top 3 panels) and Feb 23 LBA (bottom 3 panels) cases
NASA Unified (NU) WRF

Blue Boxes: NASA Physical Packages

Short-term integration
US weather prediction
Continental MCSs
Hurricanes
Air Pollution

Long-term integration
US summer climatology
(North American Monsoon, drought, diurnal cycle, Aerosol Impact)

C. Peters-Lidard
Three domains (9km, 3km, 1km) with 60 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

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<td>As Tao et al. (2013) except for 1 km</td>
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<td>1 km with 3ICE - hail option</td>
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Morrison, WSM6

**ARW WRF:** Tao et al. (2003, 3ICE-hail) and Lang et al. (2007, 3ICE-Graupel)
**NU-WRF:** Tao et al. (2003), Lang et al. (2007, 2011, 2014)

Both 3-Ice scheme (hail option) and 4-Ice scheme have improved the (heavy) rain intensity. 4-Ice scheme has also improved the coherence of leading edge of heavy intensity.
Maximum Reflectivity

4ICE simulated Max dBZ agrees very well with observation

3ICE-Hail simulated Max dBZ has better agreement with observation than those of 3ICE-Graupl schemes (Goddard, Morrison,, WSM6)
Counter Frequency Altitude Diagrams (CFADs)

4ICE simulated CFADs agrees very well with observation

Morrison 3ICE-Hail simulated CFADs has better agreement with observation than those 3ICE-Graupel schemes (Goddard, Morrison,, WSM6)
What is the precipitation properties that cause high (> 45 dBZ) and low dBZ (RED) aloft?

- Snow
- Graupel
- Hail
- Rain
4ICE scheme only slightly simulated more stratiform area (2.7%)

Both 4ICE and 3ICE-Hail simulated more heavy rainfall than 3ICE-Graupel
Models could provide the following simulated cloud/precipitation properties

Precipitation efficiency
4D distribution of cloud and hydrometeor, liquid/ice particles
Vertical velocity
Cloud/precipitation properties: convective, stratiform. anvil-cirrus, shallow cloud
Cool Pool strength
Mixed phase processes
Multi-layer clouds processes/properties
Radiation/latent heating profiles & impact

What are the uncertainty of cloud / microphysical processes in high-resolution CRMs?

The vertical profiles of the cloud/precipitation properties in convective and stratiform regions, mixed phase (melting, riming), life cycle

**SBM:** Cloud droplet spectrum, cloud particles, dew point temperature, droplet condensation/size, liquid water and ice water content, melting,

**Bulk scheme:** Inverse exponential slope, intercept and bulk density (for frozen and liquid particles), particle type (i.e., frozen drops, rimed or dendrites, etc.), gamma distribution parameters, temp and relative humidity, radar reflectivity and aircraft position relative to radar image of the storm

GCE, NU-WRF and CSU RAMS
Goddard
3ICE - Graupel

20110520 10:00 UTC

Cross-section Z, NW-SE

20110520 10:00 UTC

Cross-section Z, NW-SE

Goddard
4ICE Scheme

20110520 10:00 UTC

Cross-section Z, NW-SE

20110520 10:00 UTC

Cross-section Z, NW-SE
Bin model improvements:

1. Reduce temperature dependent ice particles collection efficiencies;

2. Adjust graupel production terms when snow aggregates or ice crystals collect cloud droplets.