nu-WRF model simulations and real time forecasts for MC³E

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Prior to Field Campaign
• Conduct real time forecast (dry run) using NASA Unified WRF (nuWRF) at Goddard.
• Develop visualizations software (i.e., tracer transport) for real time forecast system

During Field campaign:
• Conduct real time forecast for aircraft missions and ground based observation

After field campaign:
• Prepare documentation for the real-time forecast (i.e., identify cases for post mission simulations, describe the model performance)

Data for model validation (GPM rainfall/snowfall/LH retrieval)
• 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 (nu) WRF

WRF-Chem

GOCART

Cloud Optical Properties

Goddard Radiative Transfer Packages

Cloud Aerosol Direct Effect

Goddard Microphysical Packages

Aerosol Indirect Effect

Cloud-Mesoscale Dynamics (Circulation)

Thermodynamic (Stability)

Initial Conditions from GEOS5 for NASA Field Campaigns

Precipitation Radiation

Sfc Fluxes

Land Information System (LIS)

Land Surface Model

Urban Heat Island Effect

Rain Fall Asimilation

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)

PIs: C. Peters-Lidard, M. Chin, Tao

Blue Boxes:
NASA Physical Packages
Microphysics in GCE, nu-WRF, MMF and Stretched Global CRM

One-Moment (Warm Rain only, 2ICE, 3ICE-graupel, 3ICE-hail) (Tao and Simpson 1993, Tao et al. 2003, Lang et al. 2007)

One-moment 3ICE-graupel but improved - reducing 40 dBz aloft (Lang et al. 2011 – in press)

One-moment 3ICE-graupel - Temperature Dependent Drop Size Distribution (TDDD) (Matsui et al. 2009; Zeng et al. 2010)

One-moment - 4ICE (cloud ice, snow, graupel and hail)

Two-moment - 2-liquid, 3ICE-graupel (based on spectral bin microphysics – could add more moments for chemistry, testing now) 30% more expensive than one-moment bulk scheme

Spectral bin microphysics (Tao et al. 2007; Li et al., 2009; Iguchi et al. 2011) 16 times or 1600% more expensive; 256 CPUs
Reduce the graupel, but increase both cloud ice and snow

Lang et al. (2011)
Model Setup for MC$^3$E

- Three nested domain
  18km (212,167), 6km (276,210), 2km (294,234) grid spacing
  61 vertical layers
- Physics:
  Goddard Microphysics scheme
  Grell-Devenyi cumulus scheme
  Goddard Radiation schemes
  MYJ PBL
  Noah surface scheme
  Eta surface layer scheme
- Initial Condition
  Forcing data (NAM 218)
- Computational Cost: 320 CPUs, 1 and half hours wall clock time produces 24 hours forecast.

Post MC$^3$E: conduct higher horizontal resolution, and test microphysics schemes and land surface models
Nu-WRF test cases for MC³E

Case I: May 15-16, 2009
Case II: April 29-30, 2009
Case III: 01-02 Jan. 2011 Snow Storm

Other cases
East Coast Snow Storm (December 26-28, 2010), Typhoon Morakot (2009), AMMA (2006, 2008), Monsoon (aerosol, 2008), C3VP (2007) and many others
Case I: May 15-16, 2009

- Initialized at 00Z on May 15th
Rain water

Snow

Cloud water

Cloud ice

Graupel
Case II: April 29-30, 2009

- Initialized at 12Z on April 28th

WRF

06Z, April 29

12Z, April 29

Radar
## Time Line for Real Time

<table>
<thead>
<tr>
<th>UTC</th>
<th>CDT</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>02 Z</td>
<td>9 PM</td>
<td>Start download the NCEP data (need a few minutes)</td>
</tr>
<tr>
<td>03 Z</td>
<td>10 PM</td>
<td>Start NU-WRF 24-h forecast</td>
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<td></td>
<td></td>
<td>Requires 4 hour using 240 CPUs</td>
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<tr>
<td>07 Z</td>
<td>02 AM</td>
<td>Finish forecast and Start post processing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Requires up 2 hour</td>
</tr>
<tr>
<td>09 Z</td>
<td>04 AM</td>
<td>Examine the results and archive the data</td>
</tr>
<tr>
<td>10 Z</td>
<td>05 AM</td>
<td>Modeled forecast data will be available to Team</td>
</tr>
</tbody>
</table>

## Forecasted Fields (visualization and regular plots)

<table>
<thead>
<tr>
<th>Radar Reflectivity (vertical cross section)</th>
</tr>
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<tbody>
<tr>
<td>Cloud fields (i.e., large precipitating ice) (vertical cross section)</td>
</tr>
<tr>
<td>Wind (vertical cross section)</td>
</tr>
<tr>
<td>Inert Tracer (vertical cross section + wind)</td>
</tr>
<tr>
<td>Echo top and CAPE (horizontal)</td>
</tr>
<tr>
<td>Surface rainfall, RH, temperature, wind</td>
</tr>
<tr>
<td>850 hPa (RH, temperature, wind)</td>
</tr>
<tr>
<td>700 hPa (RH, temperature, wind)</td>
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<tr>
<td>500 hPa (RH, temperature, wind)</td>
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<tr>
<td>300 hPa (RH, temperature, wind)</td>
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Early onset (11am LST) of moist convection probably due to closure in RAS.

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

WRF overestimated rainfall near Rocky Mts. MERRA does better job.

Hovemoller diagram
Lat: 37°N ~ 40°N
Period: 05/15/09 ~ 05/16/09.
Climatologically, 40-dBZ penetrations above 10 km are rare even over land (Zipser et al. 2006; Liu et al. 2008)

Reduce 40dBZ at high altitude

Long-term (multi-weeks) model simulations

TRMM

Zeng et al. 2010

High resolution simulation of 23 Feb 1999 TRMM LBA MCS case

Improve riming, contact nucleation, immersion freezing and others (Lang et al. 2011)