NGGPS Physics Team Plan and Progress

James Doyle (NRL)
Bill Kuo (NCAR)
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NGGPS Physics Team Short Term Priorities

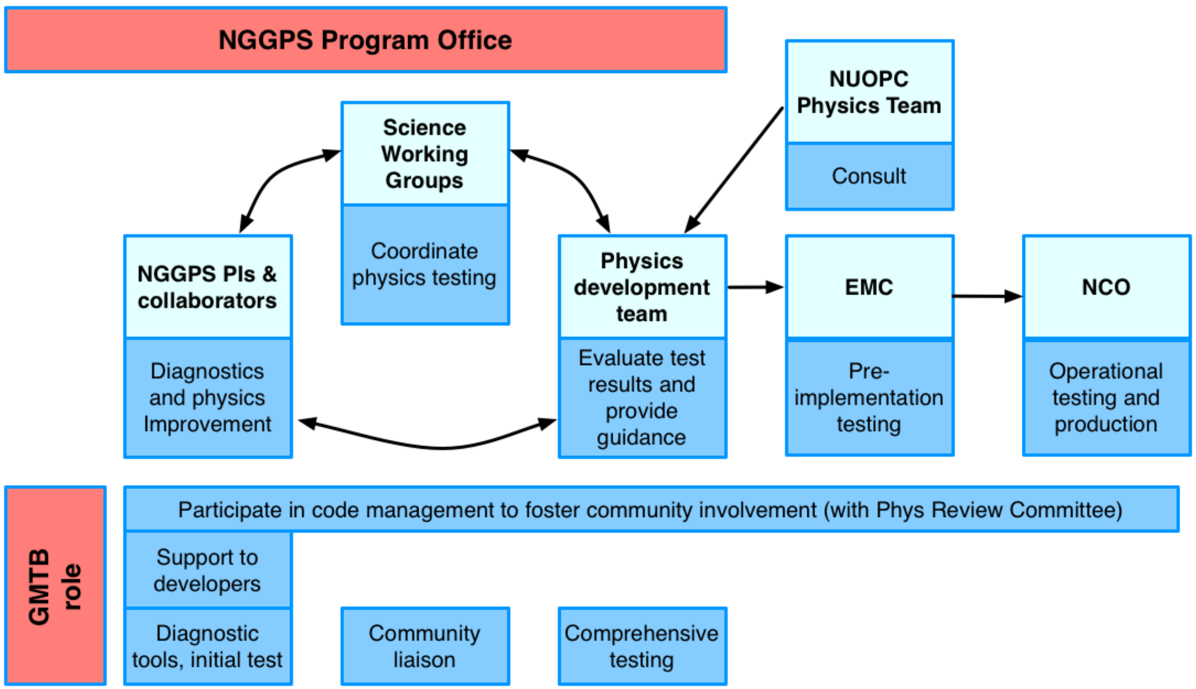
1. New unified convection parameterization that provides a scale-aware capability.
2. Advance the microphysics parameterization, which should include a double moment capability for some species and an option for coupling with aerosols.
3. Improved boundary layer parameterization coupled with turbulence, clouds, shallow convection, and radiation. Approaches include the Simplified Higher-Order Closure (SHOC) and moist version of the Eddy Diffusivity-Mass Flux (EDMF) approach.
4. Advance the parameterization of the land surface to address systematic biases and errors and to improve the representation of the diurnal cycle.
5. Improved parameterizations to represent stationary and non-stationary orographic and non-orographic gravity wave drag to improve model representation of momentum fluxes, momentum budget and phenomena such as the QBO.
6. Advance the radiation parameterization and in particularly the interaction with clouds and microphysics.

NGGPS Physics Team
Short Term Organizational Goals

- Host physical parameterization workshop (Done)
- Assess current state-of-the-science with regard to physical parameterizations (Done)
- Establish working groups, biweekly telecons (Done)
- Leverage the collaborative development with NUOPC/National ESPC for the physical parameterization driver interface with 1-D physics capability (Prototype delivered)
- Establish Test and Evaluation Group (TEG) (Ongoing).

GMTB's Role in Physics Development

GMTB will provide **codes, protocols, and a testbed** to support transition of development of physical parameterizations to operations



GMTB is leading the development of a <u>Common Community Physics Package (CCPP)</u>, a library of physics for use with any dycore that connects with the NUOPC Interoperable Driver

Also see Bernardet's presentation, including Physics PI Workshop (tentative 09/2016)

NGGPS Physics Team Plan Long Term Priorities

1. Convection and Boundary Layer

Unified approach to deep convection and Planetary Boundary Layer (PBL) convection that is scale aware.

2. Cloud Microphysics

Improve definition of cloud microphysical content, including cloud properties and precipitation type. Scale and aerosol aware cloud microphysics.

3. Radiation

Improve accuracy of radiative processes leading to improved weather and climate forecasts

4. Gravity Waves and Large-scale Orographic (and non-Orographic) Drag

Improve representation of gravity wave drag and orographic drag

5. Earth System Surface Fluxes and State

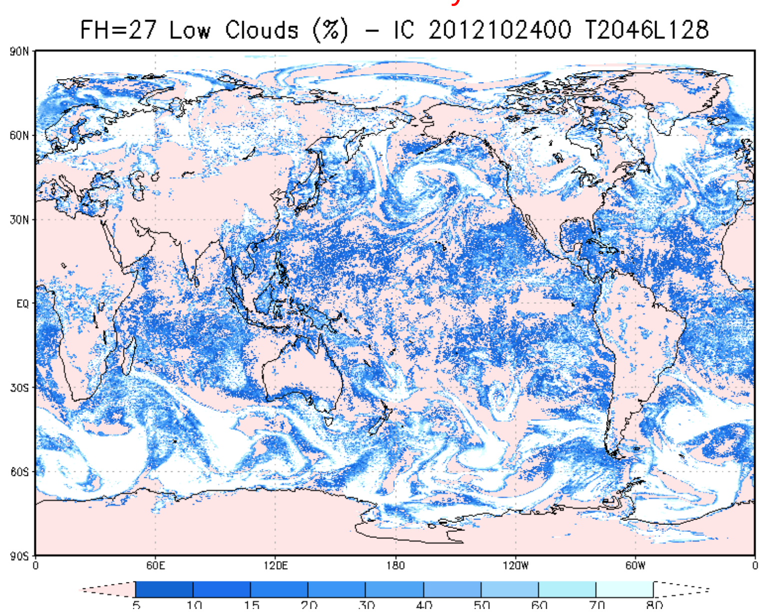
Improve representation of surface fluxes from all earth domains (land, ocean, sea ice) and the near-surface state of each domain

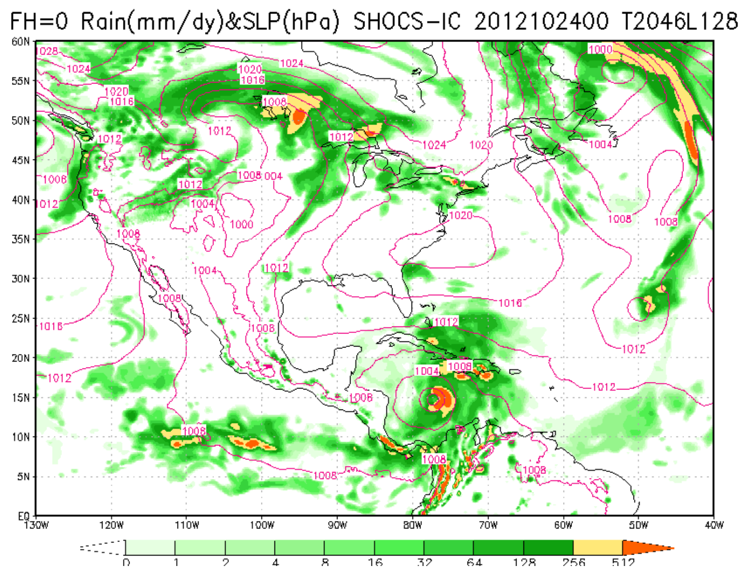
NGGPS Physics Project Updates

Accelerated Implementation of Scale-aware Physics into NEMS

- **Name and Organization:** **Shrinivas Moorthi, Yu-Tai Hou, Anning Cheng - EMC/NCEP**
  Steven Krueger - U. Utah, Donifan Barahona – NASA/GMAO
- **A collaborative project with EMC, GSFC, U. Utah, CSU, ESRL, SUNYA**
- **Objective(s):** **To accelerate the implementation of scale aware physics in Krueger CPT and Lu CPT funded by NOAA/CPO via NCEP/CTB**
- **Deliverable(s):** **Implement Morrison double moment microphysics (from GMAO's GEOS model); Chikra-Sugiyama (CS) convection with Arakawa-Wu (AW) extension into NEMS**
- **Current Status :** **Morrison microphysics installed in NEMS and tested at T62.**
  CS installed in NEMS, tested at resolutions from T62 to T2046 (w/o AW)

10 day NEMS run at T2046 L128 with CS scheme and SHOC



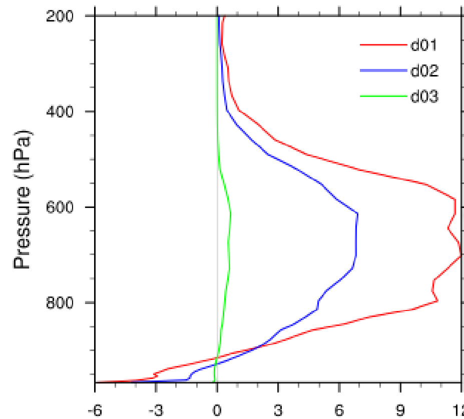


Scale-aware Stochastic Convection

- **Name and Organization:** **Georg A. Grell (NOAA/ESRL/GSD)**
  Jian-Wen Bao (NOAA/ESRL/PSD)
- **Project Title:** **Further Testing and Evaluation of a Scale-Aware Stochastic Convection Parameterization in NOAA's Next Generation Global Prediction System**
- **Objective(s):** **Implement scale-aware GF convective parameterization into HWRF and later into NGGPS**
- **Deliverable(s):** **Evaluated working version of GF in HWRF and publication describing implementation and evaluation**
- **Collaborators:** **Vijay Tallapragada (NOAA/EMC)**

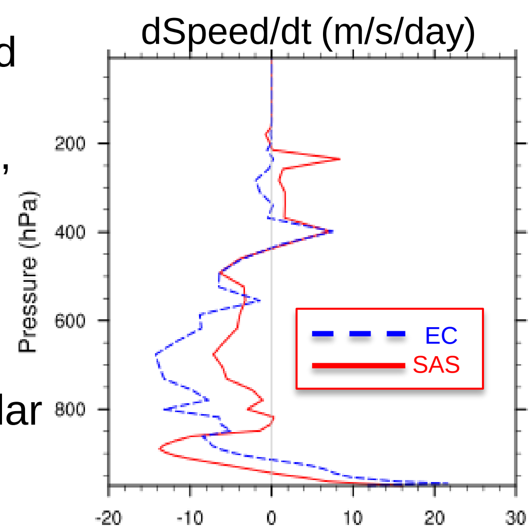
Further Testing and Evaluation of a Scale-Aware Stochastic Convection Parameterization in NOAA's Next Generation Global Prediction System

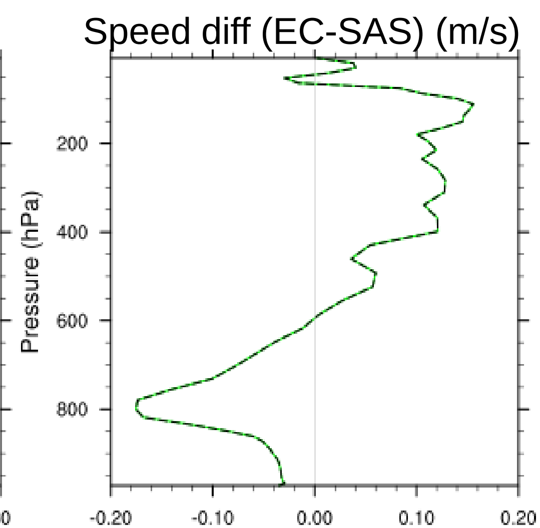
- Grell-Freitas (GF) has been implemented into HWRF, scale awareness works well
- 27/9/3km resolution experiments (d01,d02,d03) with Sandy and Daniel



Heating (deg/day) from GF on different resolutions, **averaged using 3 degree radius**, centered on Sandy

- Momentum transport (ECMWF type and SAS type) evaluation
- Wind speed tendency from GF scheme, **averaged over 3 degree radius** centered on Hurricane Sandy
- Significant impact when changing momentum transport constants, even though momentum tendencies are similar
- Not much impact on track forecasts





Next Steps:

- **Evaluate impact of vertical mass flux PDF's**
- **Seasonal evaluation**

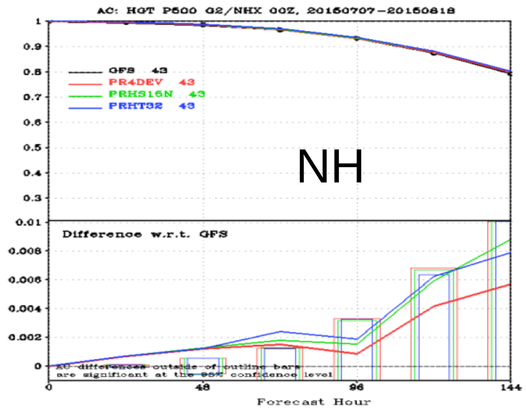
Update in GFS Cumulus Convection Scheme with Scale- and Aerosol-aware Capability

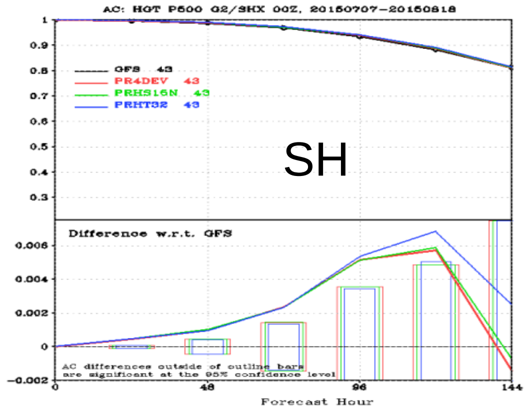
- **Name and Organization:** **Jongil Han (NCEP/EMC)**
- **Project Title:** **Update in GFS Deep and Shallow Cumulus Convection Schemes with Scale- and Aerosol-aware Capability**
- **Objective(s):** **Implement scale- and aerosol-aware GFS deep and shallow cumulus convection schemes into GFS, HWRF, and later into NGGPS**
- **Deliverable(s):** **Evaluation of Scale- and aerosol-aware GFS deep and shallow cumulus convection schemes**
- **Collaborators:** **Weiguo Wang, Vijay Tallapragada (NOAA/EMC); Young C. Kwon, Song-You Hong (KIAPS)**

Update in GFS Cumulus Convection Scheme with Scale- and Aerosol-aware Capability

Accomplishment Title: Tests of Updated GFS Deep and Shallow Cumulus Convection Schemes with Scale- and Aerosol-aware Capability in GFS

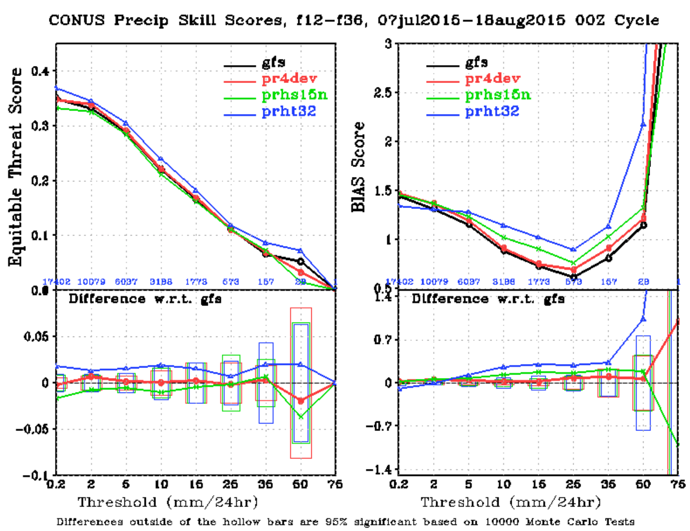
Anomaly Corr.



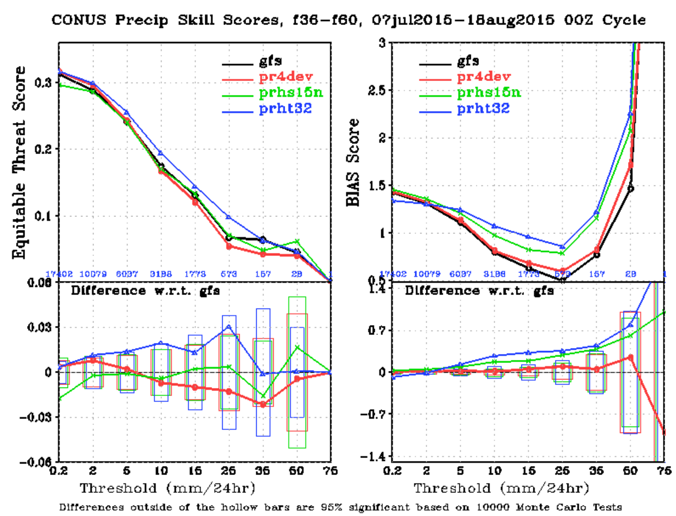


PRHS15N: Control
PRHT32: Updated

CONUS Precip



FH 12-36



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Update in GFS Cumulus Convection Scheme with Scale- and Aerosol-aware Capability

Key Take Away Message

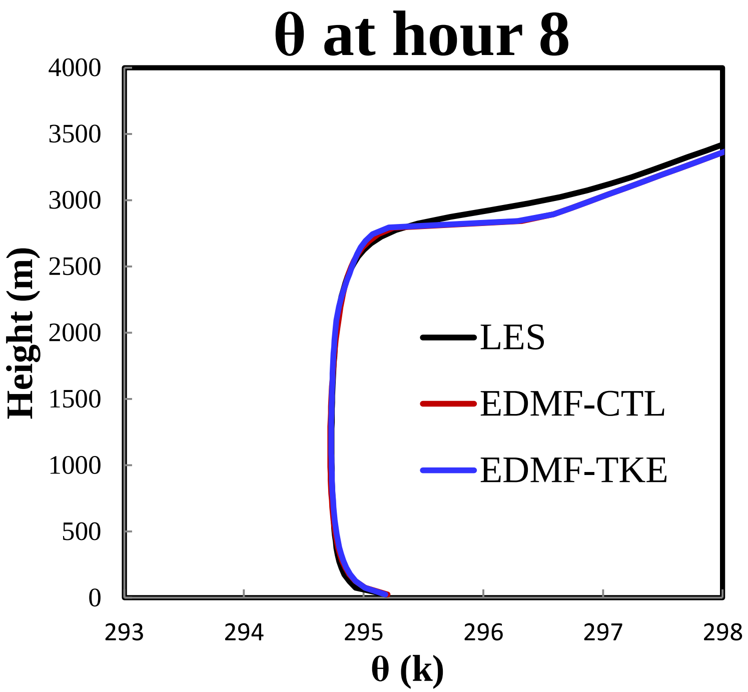
- The current operational **GFS deep** and **shallow cumulus convection** schemes has been **updated** with **scale-aware parameterization** based on Arakawa & Wu (2013) and Grell & Freitas (2014).
- A **aerosol-aware parameterization** based on Lim & Hong's (2012) study where rain conversion and cloud condensate detrainment in the convective updraft are given by a function of CCN number concentration is also included in the update.
- The **cloud base mass-flux computation** in the **deep convection** scheme has been **modified** to use convective turn-over time as cumulus time scale.
- **Rain conversion rate is modified** to decrease with decreasing air temperature above the freezing level.
- **Convective inhibition (CIN)** in the sub-cloud layer is also used for **trigger** condition.
- **Convective cloudiness is enhanced** by considering suspended cloud condensate in the updraft.
- **Auto conversion rate** from ice to snow in cloud microphysics scheme is **enhanced** to reduce too much detrainment of cloud condensate in the upper updraft layers.
- Xu-Randall's (1996) **cloud fraction** scheme is **modified** to **increase cloudiness**.
- **The GFS cumulus convection schemes with all the updates above shows significant improvement especially in the CONUS precipitation forecasts.**

Cloud and Boundary Layer CPT

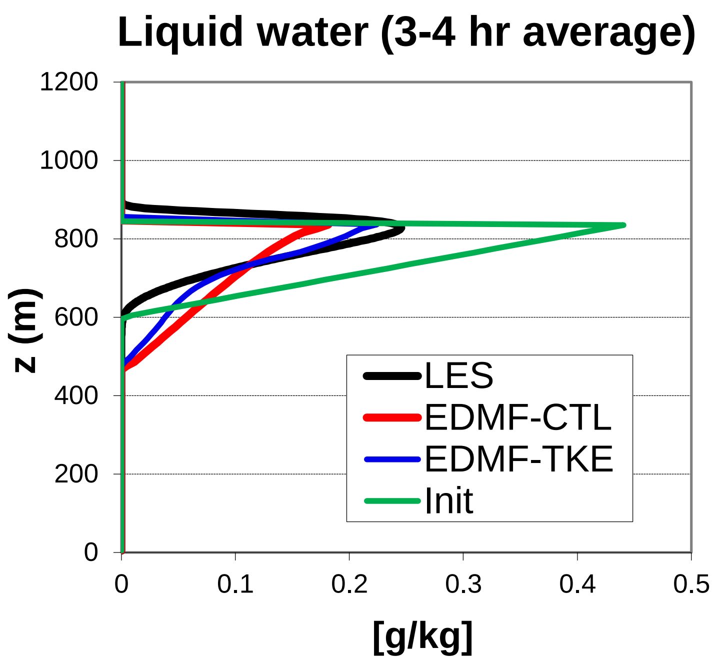
- **Name and Organization:** Jongil Han and Ruiyu Sun (NCEP/EMC)
  Ming Zhao and Chris Golaz (GFDL)
  Chris Bretherton (U. Washington)
  J. Teixeira (NASA/JPL)
- **Project Title:** CPT to Improve Cloud and Boundary Layer Processes in GFS/CFS
- **Objective(s):** Improve fidelity of cloud and boundary-layer processes in GFS/CFS and reduce cloud-related radiative flux biases
- **Deliverable(s):** TKE-based Eddy-Diffusion Mass-Flux (EDMF) Parameterization of Moist Boundary Layer Turbulence and Tests of Advanced Microphysics Schemes in GFS
- **Collaborators:** Marcin Witek (JPL), Chris Jones and Peter Blossey (UW), Krueger and Lu CPTs.

Accomplishment Title: **A TKE-based Eddy-Diffusivity Mass-Flux (EDMF) Parameterization for Convective Boundary Layer (CBL) and Stratocumulus-top-driven Turbulence Mixing**

Single Column Model Test Results



CBL



Stratocumulus-topped Boundary Layer

TKE-based EDMF Parameterization of Moist Boundary Layer Turbulence

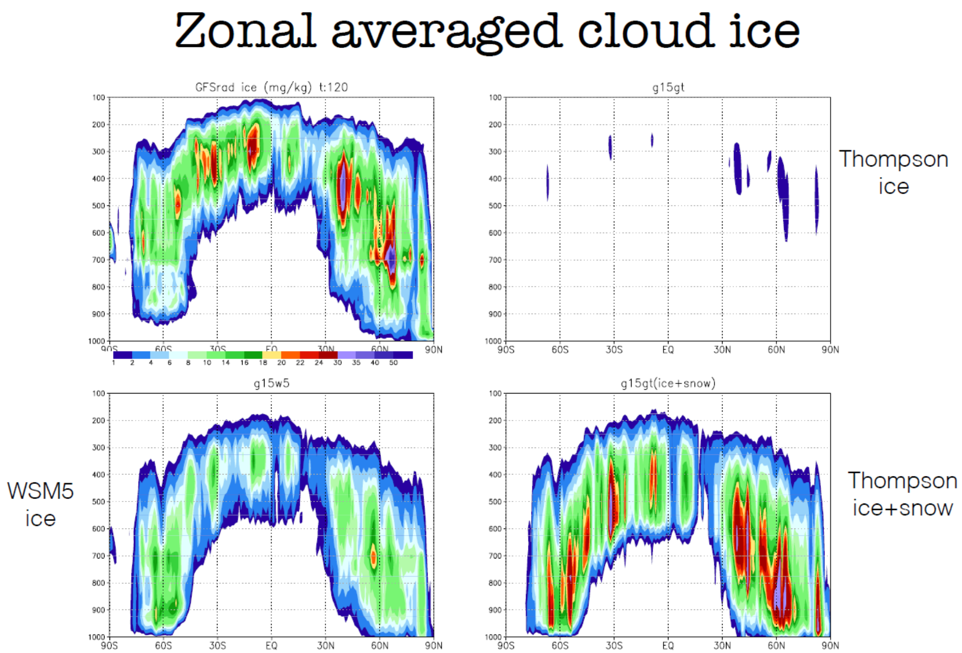
Key Take Away Message

- A **TKE-based EDMF planetary boundary layer** (PBL) scheme has been **developed** and **successfully simulates daytime well-mixed CBL** with a good agreement with the LES result.
- For the **CBL**, the new TKE-based EDMF PBL scheme is **similar** to that from the current **operational GFS** hybrid EDMF PBL scheme (which is based on first-order K-profile method).
- Compared to the LES result, the **new scheme also well simulates the marine stratocumulus-topped boundary layer**, showing somewhat **better** prediction than the operational one.

Implementation of Advanced Microphysics Schemes (MPs) in GFS

Accomplishment Title: Tests of WSM5/6 and Thompson MPs in GFS

GFS parallel 5-day fcst test



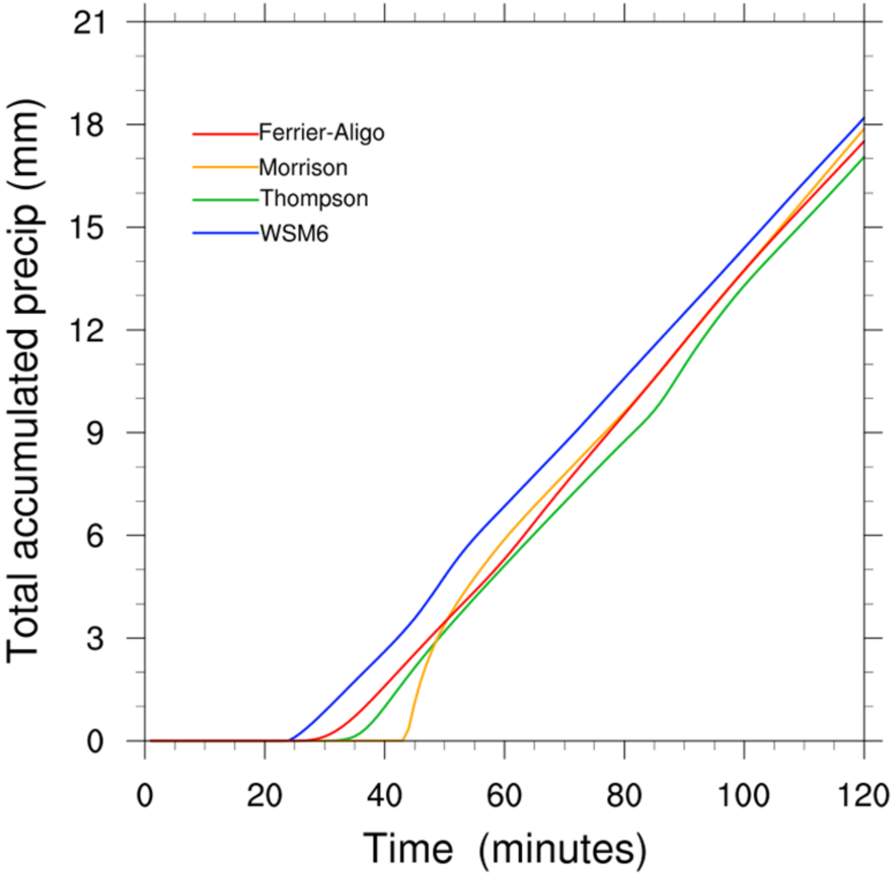
- WSM5/6 and Thompson MPs in original form **generate less ice** in the GFS when compared with the GFS with **default** MP.
- **LW radiative forcing** is significantly **less**
- LW radiative forcing can be improved when **snow** is counted as condensation.
- Using **particle sizes** in **radiation** consistent with MPs helps to **improve** the radiative forcing.
- **Partial cloudiness** may help to **improve** the ice generation and LW radiative forcing.

Evaluation of Advanced Microphysics Schemes

- **Name and Organization:** Jian-Wen Bao and Robert Cifelli
  NOAA/ESRL/PSD
- **Project Title:** Evaluation and Adaptation of Advanced Microphysics Schemes in NOAA's Next Generation Global Prediction System Using NOAA-HMT Observations
- **Objective(s):** Advanced bulk microphysics schemes are compared with each other and observations to facilitate the selection of a computationally efficient and physically sufficient scheme for the NGGPS
- **Deliverable(s):** Analysis of microphysics budgetary evaluation and results of comparing model simulations of selected NOAA-HMT cases with observations
- **Collaborators:** Brad Ferrier and Eric Aligo (NOAA/NCEP/EMC)
  Sara Michelson and Evelyn Grell (NOAA/ESRL/PSD)

Evaluation of Advanced Microphysics Schemes

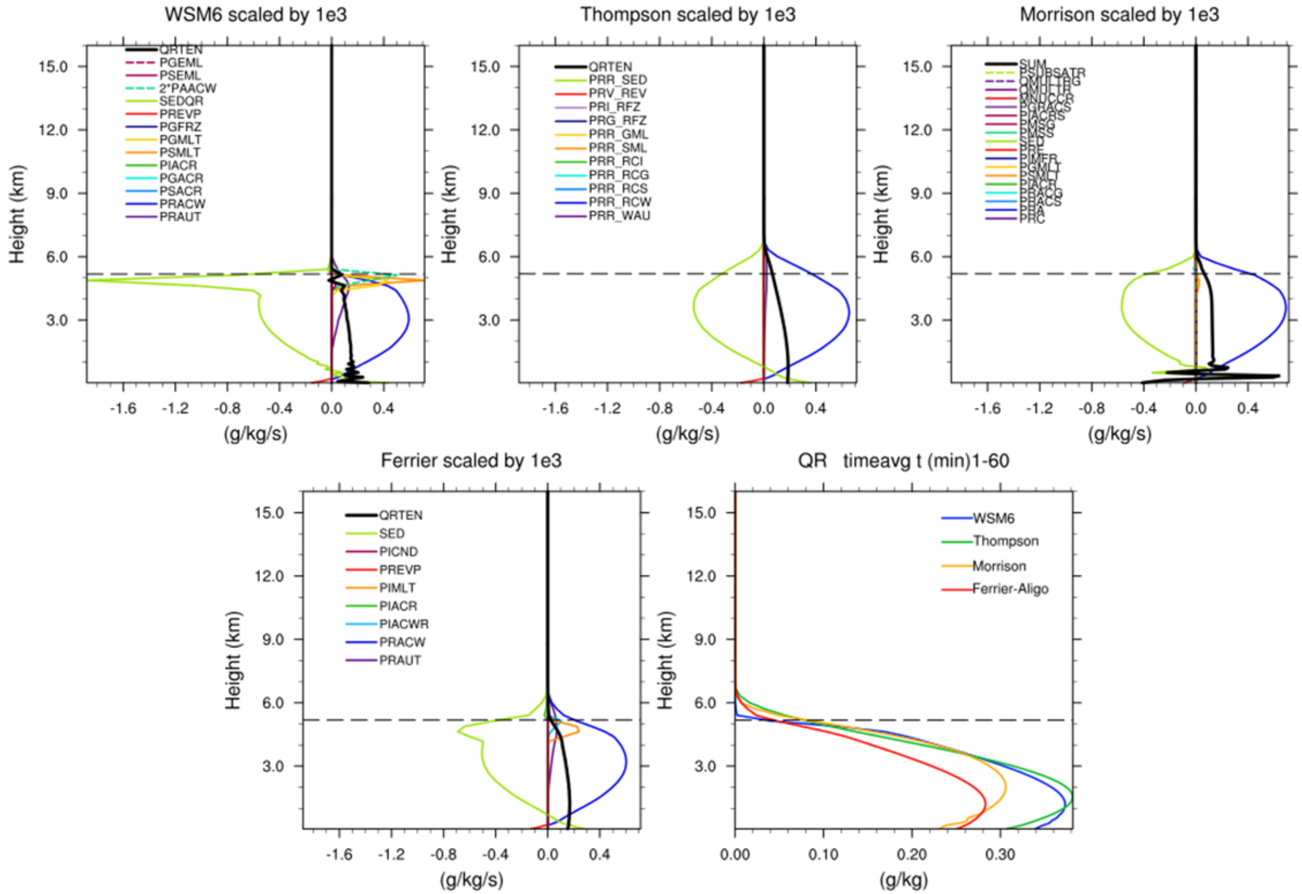
Evaluation in the Tropics Using the WRF Single Column Model (SCM)



Total Accumulated Precipitation:
Initiation time of surface precipitation varies with different schemes, with the WSM6 scheme starting the earliest and the Morrison scheme the latest. The precipitation rates from all the schemes are about the same after 80 min. Overall, the Thompson scheme produces the least amount surface precipitation and the WSM6 scheme produces the most, while the F-A and Morrison schemes produce similar amounts of surface precipitation.

Evaluation of Advanced Microphysics Schemes

Evaluation in the Tropics Using the WRF Single Column Model (SCM)



Rain water budget terms: All panels are averaged over minutes 1-60 of the simulations and the tendency terms are scaled by 10^3. The bottom right panel is the rain water mixing ratios from the 4 schemes. The largest differences in the rain water tendency budgets are the autoconversion term, the rain water/cloud water collecting term and the melting term for precipitating frozen hydrometeors, indicating different droplet size distributions assumed in these terms.

Improving Land Model in NCEP CFS

- **Name and Organization:** Fei Chen – NCAR/RAL
- **Project Title**: Improving the NCEP Climate Forecast System (CFS) through Enhancing the Representation of Soil-Hydrology-Vegetation Interactions
- **Objective(s):** Incorporate Noah/MP into CFSv2 to enhance the representation of the soil –hydrology-vegetation interactions
- **Deliverable(s):** The latest version of the community Noah-MP land-model has been implemented into the experimental version of CFSv2
- **Collaborators:** Co-I: Michael Barlage (NCAR); Co-PI: Zong-Liang Yang (UT-Austin) Co-PI: Michael Ek, Co-I: Rongqian Yang and Jesse Meng (NCEP)

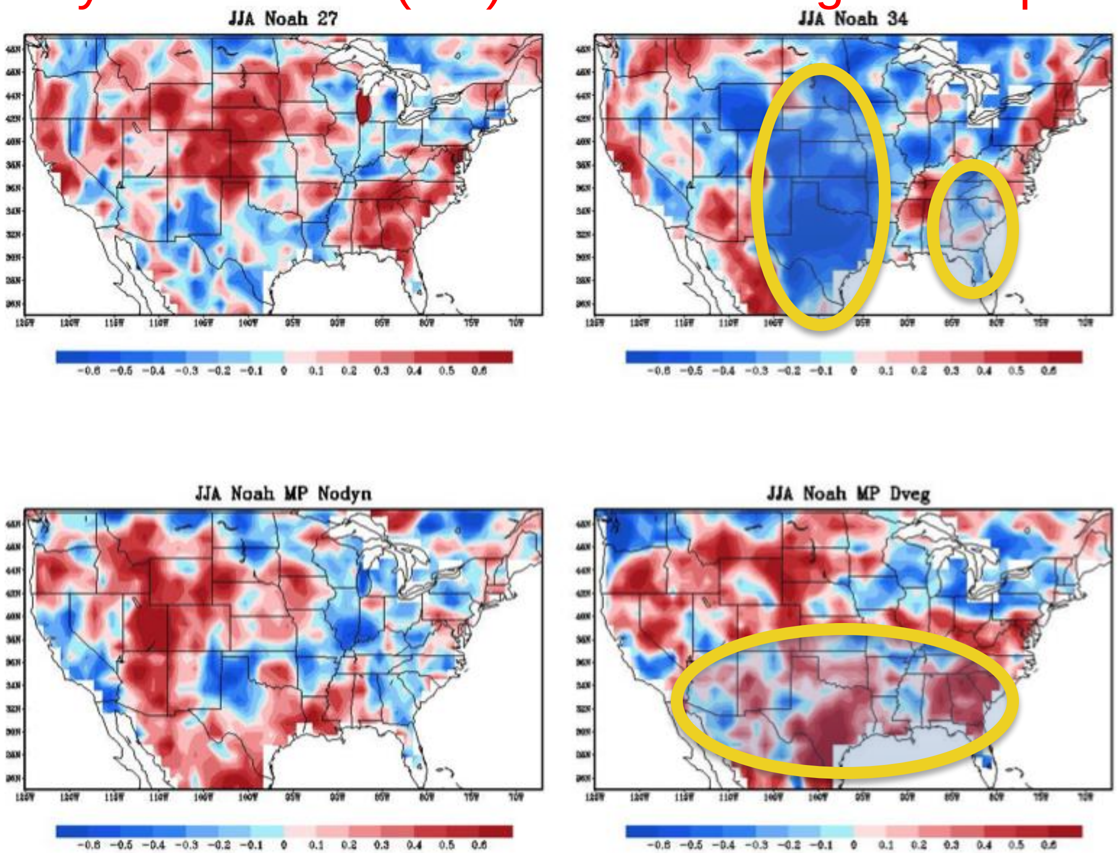
Improving Land Model in NCEP CFS

T126 CFS reforecasts using different land models: eleven years (1982, 1987, 1996, 1988, 2000, 2007, 1986, 1991,1999, 2011, 2012)

Anomaly Correlation (AC) skill of averaged JJA precipitation

Noah V 2.7

Noah V 3.4



Noah-MP

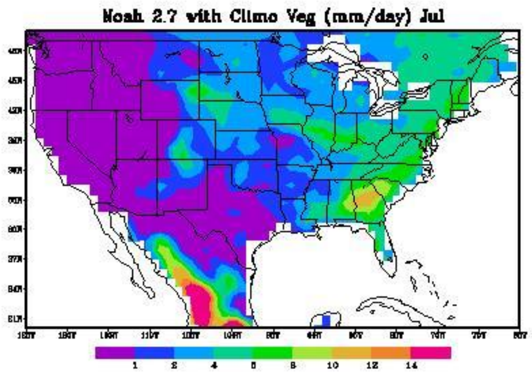
Noah-MP with dynamic vegetation model

Hydrology- vegetation interactions are critical to forecasting summer precipitation. More realistic representation of such interactions leads to improved seasonal forecast skills.

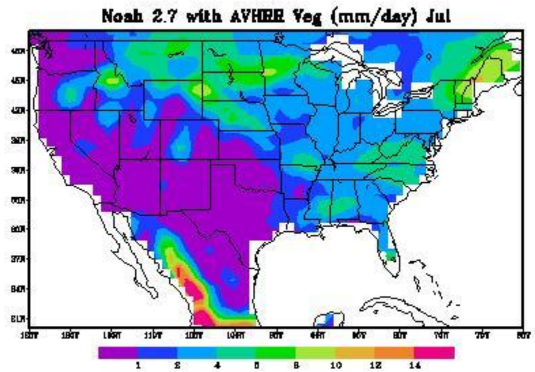
Improving Land Model in NCEP CFS

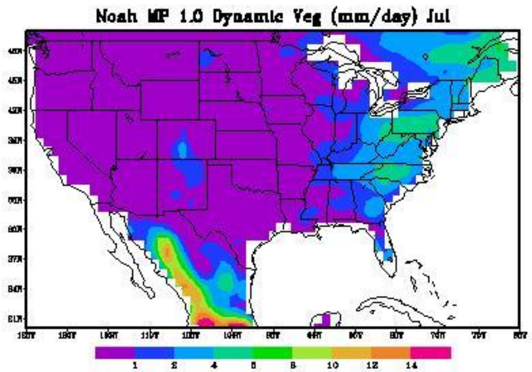
July daily averaged precipitation for the 2011 Texas Drought reforecast

Noah 2.7 Climo GVF

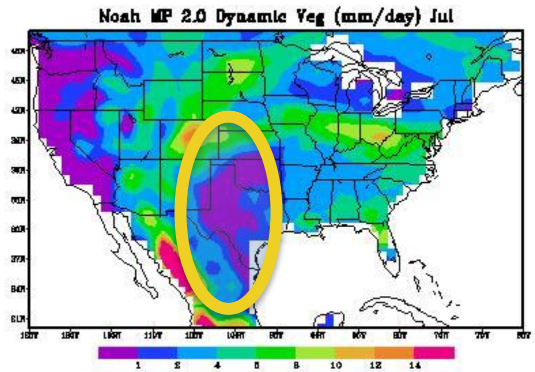


Noah 2.7 AVHRR GVF

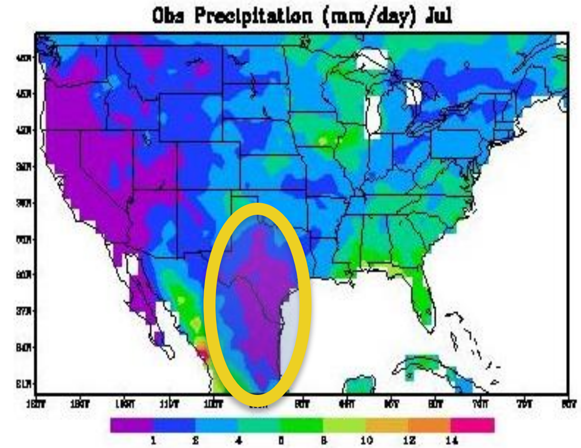




Noah-MP V1



Noah-MP V2



Observation

Using realtime AVHRR vegetation in the default Noah LSM slightly improves CFS Texas drought prediction. However, employing the dynamic vegetation model in the latest version of Noah-MP correctly captures the spatial extent of severity of Texas drought..

Unified Gravity Wave Physics

- **Name and Organization:**

  Tim Fuller-Rowell and Valery Yudin (University of Colorado, CIRES)

  Collaborators: J. Alpert (NCEP/EMC) and R. Akmaev (NWS/SWPC)

- **Project Title:** **Integrating Unified Gravity Wave Physics into the Next Generation Global Prediction System**

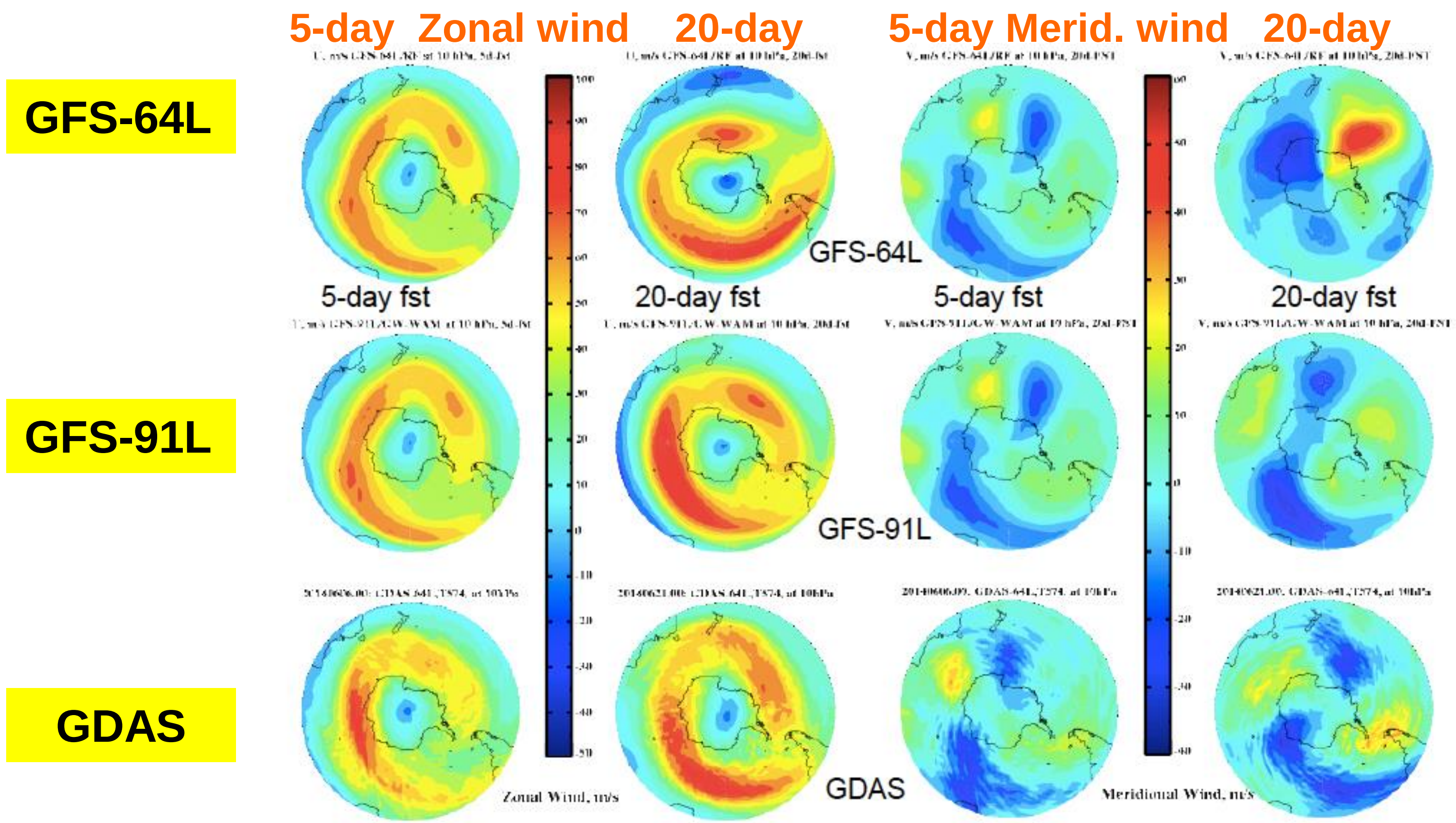
- **Objectives:** **Development of the vertically extended configurations of NOAA atmosphere models across the stratopause *with realistic representations of sub-grid scale eddies by unified Gravity Waves (GW) schemes that improve the troposphere-stratosphere coupling, predictors of AO and NAO and propagation of atmospheric tides and planetary waves.***

- **Deliverable(s):** **A unified GW schemes in the vertically extended GFS and future NGGPS global atmosphere model configurations.**

- **Deliverables of 2015:** **The GFS-91L with GW physics were delivered to EMC GW group (J. C. Alpert); NEMS/WAM-150L simulations with GWs were used and evaluated by SWPC-WAM researchers (R. Akmaev and T.-W. Fang)**

Extended GFS-91L: Unified GW Physics

Horizontal winds of GFS-64L (~55 km lid, T574), GFS-91L (~80 km lid and GW-physics, T574) at 10 hPa after 5- and 20-day forecasts, since 01-06-2014.



Improving the 20-day wintertime stratospheric polar wind forecasts from 01-06-2014 by GFS-91L, as verified by GDAS (bottom, 20-01-2014).

NGGPS Physics Summary

- **Major Accomplishment to Date:**
  - Development, evaluation, testing of next generation parameterizations:
    - scale- and aerosol-aware physics, including cumulus param. promising
    - cloud and boundary layer processes are promising (EDMF, SHOC)
    - microphysics (multiple schemes tested)
    - land surface processes (improved seasonal forecasts)
    - gravity wave drag (improved 20 days forecasts)
  - Establishment of GMTB; facilitate physics driver applications
- **Priority Focus for FY16**
  - Advance the development, evaluation, testing of a next generation physics suite suitable for NGGPS priorities (e.g., initially medium range NWP).
- **Key Issue**
  - Close coordination between NGGPS PIs, GMTB, EMC, CPTs in order to jointly develop and test new physics suite for the NGGPS.
  - Systematic testing of the most mature and promising schemes.

Appendix: Long Term Goals

NGGPS Physics Team Plan
Long Term Goals

1. Convection and Boundary Layer

A. Purpose

Improve the overall conceptual approach to deep convection and Planetary Boundary Layer (PBL) convection by

- Considering PBL convection and turbulence together
- Introducing scale-awareness in horizontal dimension for deep convection and vertical dimension for PBL (stratiform and shallow convection)

B. Development Activities

a. Deep Convection

b. Vertically unresolved shallow, PBL-originated convection

c. Simplified higher order closure approach for turbulence parameterization, stratiform clouds and shallow convection

d. Scale-awareness in both deep and PBL convection

e. Coordinate with Aerosol SWG for cloud-aerosol interactions

f. Coordinate with Cloud Microphysics SWG on cloud properties and precipitation type

g. Improved prediction of 2m T, q and 10 m winds, gustiness, PBL depth

h. Physically-based framework for stochastics

i. Optimize computational efficiency

NGGPS Physics Team Plan
Long Term Goals

2. Cloud Microphysics

A. Purpose

Improve definition of cloud microphysical content, including cloud properties and precipitation type

B. Development Activities

a. Evaluate impact of Single Moment and Double Moment schemes
b. Add aerosol-aware microphysical processes
c. Diagnostic algorithm for precipitation type at surface
d. Coordinate w/ Aerosol SWG on defining cloud-aerosol interactions
e. Coordinate with Radiation SWG on input to radiation param.
f. Optimize computational efficiency

NGGPS Physics Team Plan
Long Term Goals

3. Radiation

A. Purpose

Improve accuracy of radiative processes leading to improved weather and climate forecasts

B. Development Activities

a. Improved cloud macrophysical and microphysical formulations
b. Aerosol interactions
c. Surface radiation balance
c. Improved diagnostics for long-wave and short-wave radiation balance
e. Improved spectroscopy as basis for radiation band modeling
f. Optimize computational efficiency

NGGPS Physics Team Plan
Long Term Goals

4. Gravity Waves and Large-scale Orographic (and non-Orographic) Drag

A. Purpose

Improve representation of gravity wave drag and orographic drag

B. Development Activities

a. Improve model performance in upper stratosphere and mesosphere (will also improve data assimilation in entire vertical column)
b. Develop non-orographic and non-stationary gravity wave drag
c. Scale-aware orographic drag formulation
d. Gravity wave physics that is adaptable to variable horizontal and vertical resolutions

NGGPS Physics Team Plan
Long Term Goals

5. Earth System Surface Fluxes and State

A. Purpose

Improve representation of surface fluxes from all earth domains (land, ocean, sea ice) and the near-surface state of each domain

B. Development Activities

a. Improved parameterized of surface fluxes to and from atmosphere over all domains, including dependencies on wind speed, fetch, vegetation and surface roughness, terrestrial as well as marine (e.g. the effect of ocean waves)
b. Improved skin temperature for all domains (via interaction with the land-surface, and with the upper ocean, ocean mixed layer and below).
c. More complete inventory of surface data from sites over all global domains
d. Maintain SLS compatibility with evolving atmospheric Single-Column Model
e. Improved SST analysis and forecast
f. Coupled hydrological processes such as river flow, ground water, irrigation etc.
g. Improve sea ice physics representation, including radiative, heat, melt-water fluxes

NGGPS Physics Team Plan Long Term Goals

Development Infrastructure Functions and Resources

Basic development functions for all projects include:

- Executing jobs, including scripting development, disk management, job coordination, monitoring and prioritization;
- Code management and coordination between all projects;
- Diagnostics development and code maintenance, including EMC standard codes and newly developed codes;
- Development and maintenance of component simulators such as a SCM and SLS; and
- Verification, including development and integration of new metrics

Appendix: Working Groups

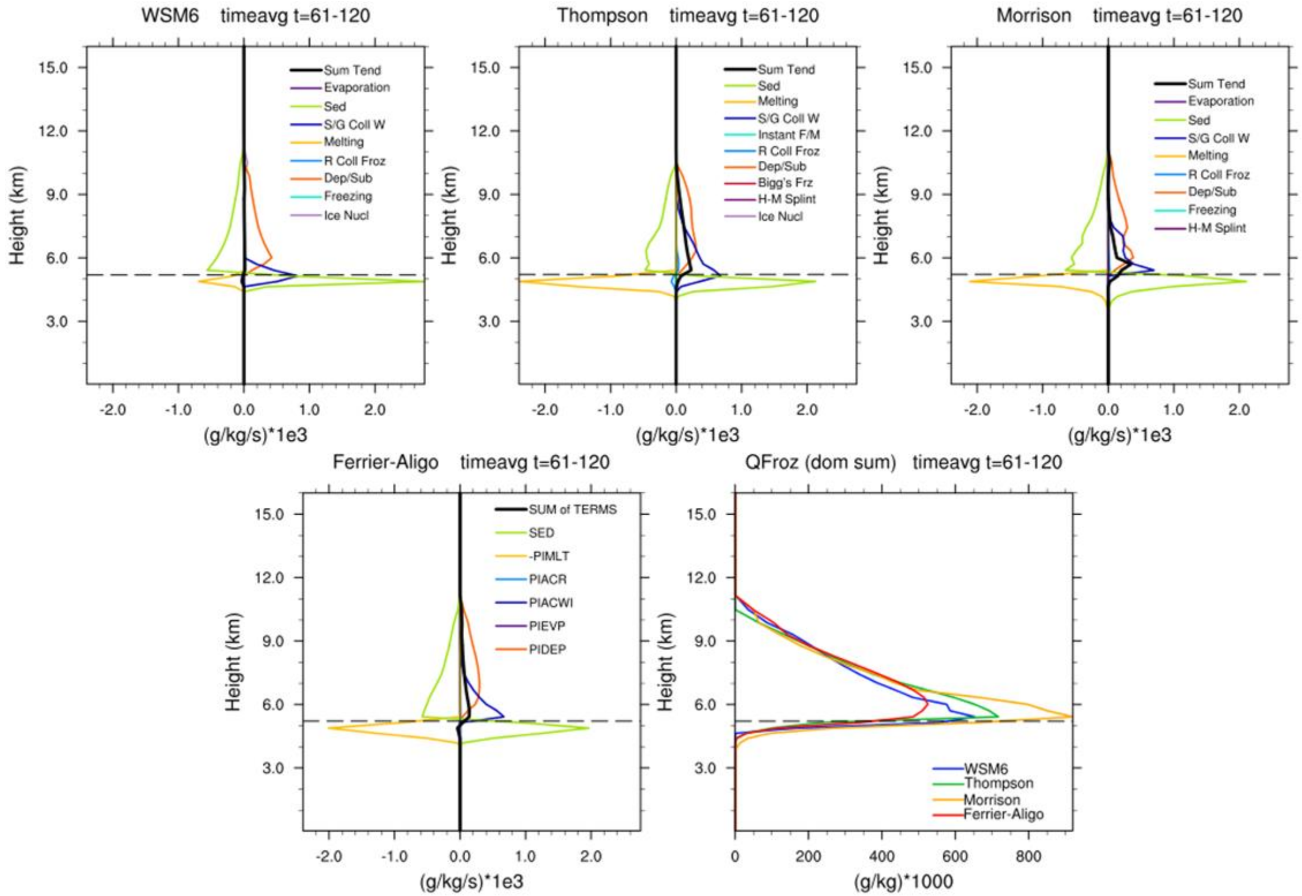
NGGPS Physics Team Working Groups

1. Convection and Boundary Layer
2. Cloud Microphysics
3. Radiation
4. Gravity Wave and Large-scale Orographic (and non-Orographic) Drag
5. Earth System Surface Fluxes and State

Appendix: Additional Results

Evaluation of Advanced Microphysics Schemes

Evaluation in the Tropics Using the WRF Single Column Model (SCM)



Frozen hydrometeor budget terms: All panels are averaged over minutes 61-120 of the simulations and the tendency terms are scaled by 10^3. The tendency budgets indicate differences in the pathways to frozen hydrometeor production. Major differences are in the rain collection, deposition and melting terms.

Evaluation of Advanced Microphysics Schemes

Evaluation in the Tropics Using the WRF Single Column Model (SCM)

Experiment Name	Microphysics Scheme	Predicted Mixing Ratios	Predicted Number Concentrations
Ferrier-Aligo	Ferrier-Aligo	Qc, Qr, Qf	None
WSM6	WSM6	Qc, Qr ,Qs, Qi, Qg	None
Thompson	Thompson	Qc, Qr, Qs, Qi, Qg	Ni, Nr
Morrison	Morrison	Qc, Qr, Qs, Qi, Qg	Ni, Nr, Ns, Ng

Microphysics Schemes Evaluated