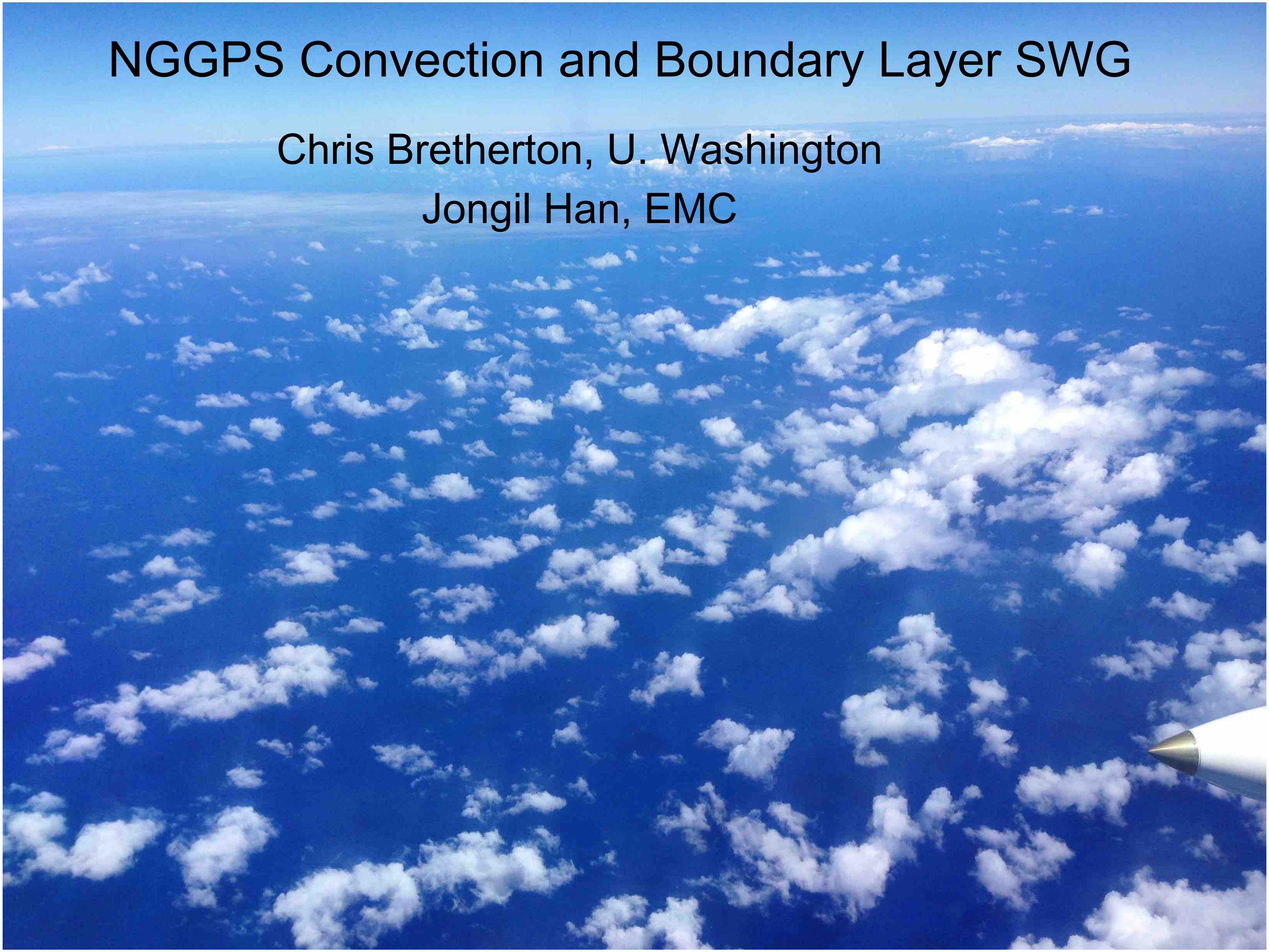
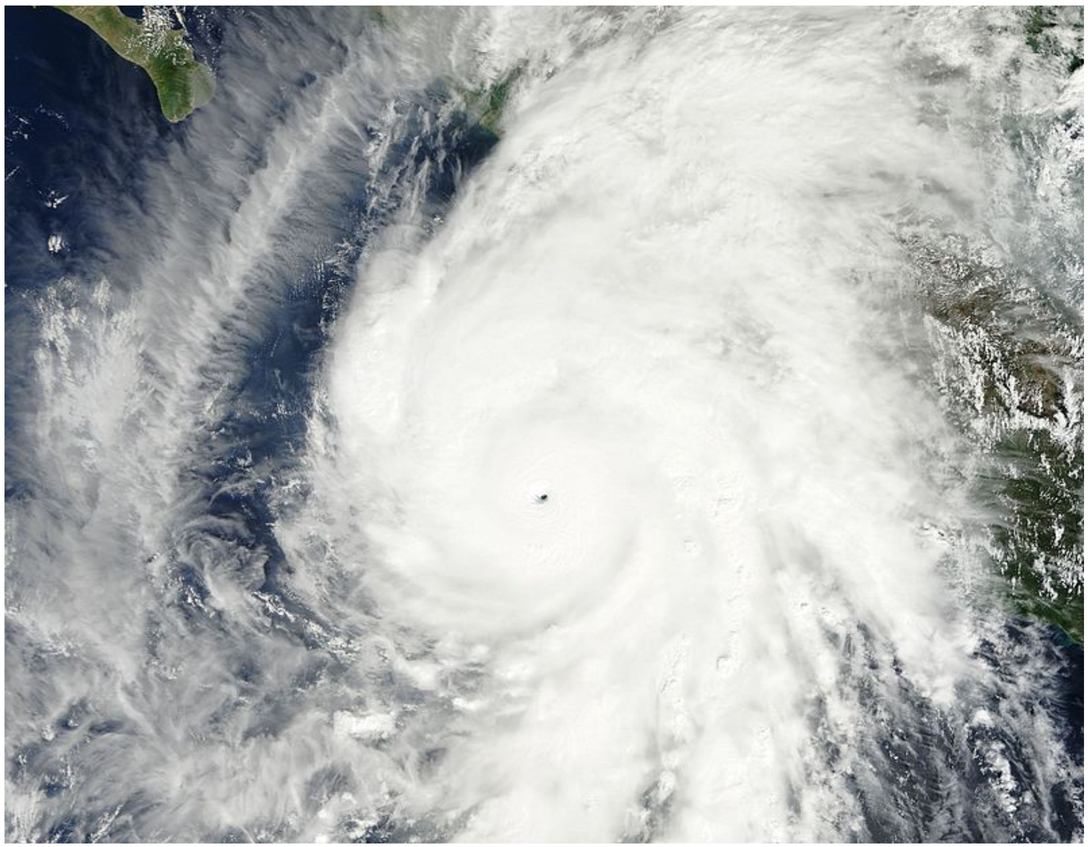
NGGPS Convection and Boundary Layer SWG

Chris Bretherton, U. Washington
Jongil Han, EMC



Roadmap

- Current NGGPS and MAPP-funded model development
- Mapping onto current EMC-identified GFS problems
- Systemic challenges for NCEP model improvement



NGGPS priorities for this SWG

NGGPS Physics Overview

- Objective
  - *Systematically* develop a next generation physics suite for NGGPS for weather to climate for deterministic, ensemble, and coupled applications
  - Physics suite should be scale and aerosol aware, and contain options for varying degrees of sophistication and physical realism
  - Emphasis on the interactions between components within the suite

NGGPS Physics Team Plan Broad Focus Areas

- Scale aware convective and boundary layer formulations.
  - Address grey zone issues with convection and boundary layer clouds and shallow convection

Priorities

- Unified convection parameterization that provides a scale-aware capability.
- Boundary layer parameterization improvements that are coupled with turbulence, clouds, shallow convection, and radiation.

NGGPS and MAPP-funded Cu/PBL model development

Physics: Two-Stream Strategy

Physical Process	Operational Physics (Evolved)	Advanced Physics
Penetrative convection and Shallow convection	SAS RAS	Scale-aware Chikira-Sugiyama & Arakawa-Wu Grell-Freitas (GF)
Turbulent transport (PBL)	Hybrid EDMF	CS+SHOC (unified convection & turbulence)

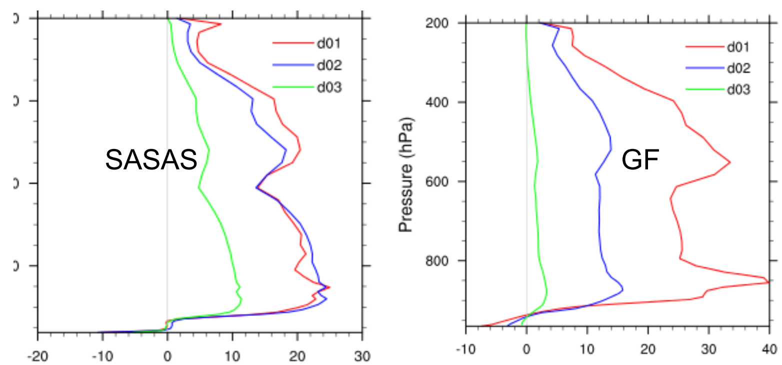
NGGPS Physics Development in Progress

- *Further Testing and Evaluation of a Scale-Aware Stochastic Convection Parameterization in NOAA's Next Generation Global Prediction System*
  - Georg Grell, (2015 AO) (in HWRF)
- *Accelerated Implementation of Scale-aware Physics into NEMS*
  - Shrinivas Moorthi, EMC (2015 AO) Chikira Cu + Morrison uphys
- *Moist EDMF for shallow PBL convection*
  - Chris Bretherton, Univ. of Washington (CPO) Moist EDMF + Thompson uphys
- *SHOC for PBL turbulence and shallow convection*
  - Steve Krueger (CPO)

Further Testing and Evaluation of a Scale-Aware Stochastic Convection Parameterization in NOAA's NGGPS

Georg A. Grell (ESRL/GSD), Jian-Wen Bao (ESRL/PSD) and Evelyn Grell (CIRES/ESRL)

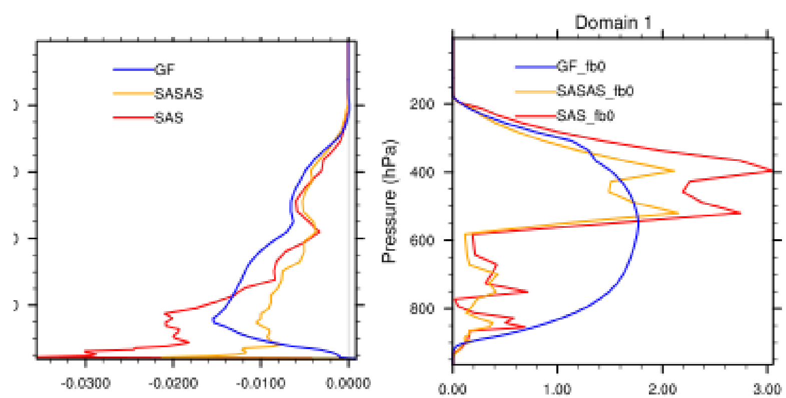
- The Grell-Freitas (GF) parameterization has been implemented into the latest HWRF version
- HWRF simulations are being evaluated in comparison with scale-aware SAS (SASAS) scheme
- 18/6/2km resolution experiments (d01,d02,d03)



Heating tendencies (deg/day) for HWRF runs (comparing scale aware SAS and GF) averaged with a 1 deg radius around the storm center

New improvements (also lead to improvements for global modeling)

- ECMWF momentum transport
- Diurnal cycle effect closure (also from ECMWF)
- Rain evaporation term (as is used in SAS)
- Probability Density Functions (PDFs) are used for normalized mass flux profiles – smooth profiles!
- Updated GF scheme also implemented into GFS

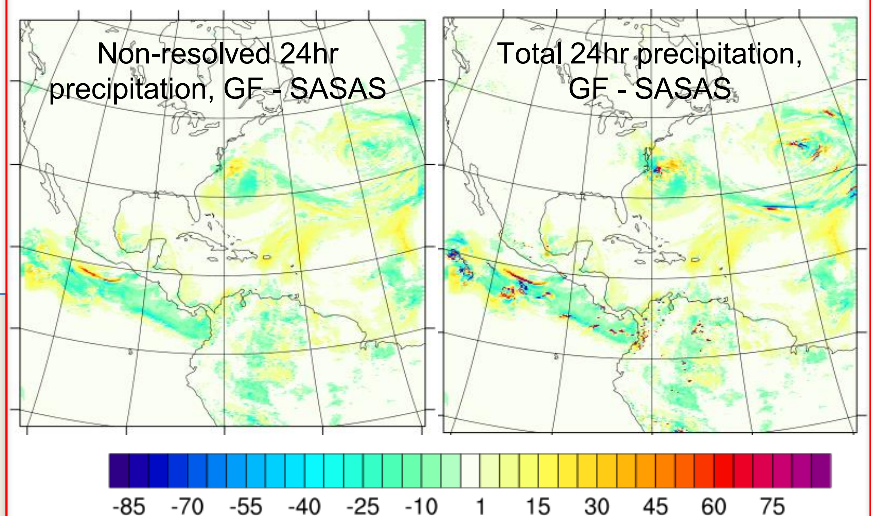


Drying and clw/ice tendencies (g/kg/day) for runs with GF, SAS, and SASAS schemes, averaged with a 1 degree radius around the storm center

Further Testing and Evaluation of a Scale-Aware Stochastic Convection Parameterization in NOAA's NGGPS

Georg A. Grell (ESRL/GSD), Jian-Wen Bao (ESRL/PSD) and Evelyn Grell (CIRES/ESRL)

- Large drying rates in lowest levels from SAS and SASAS schemes
- GF has much smoother cloud water/ice tendencies
- In general scale-awareness appears to work well. Non-resolved tendencies may still be somewhat large for HWRF with SASAS on 6km and 2km horizontal resolution
- Microphysics tendencies are very sensitive to convective tendencies for cloud water



Precipitation differences (mm) from HWRF runs with GF and SASAS, for precipitation from convective parameterization (non-resolved) and explicit microphysics. Precip appears a little lighter in ITCZ when using GF.

Transition to operations is optional, depending on seasonal evaluation of track and intensity forecasts

Further improvements may be possible if:

- GF is ideally suited to couple with stochastic approach
- For global modeling the implementation of memory and organization (how long was non-resolved convection active) may be promising – could also be used for HWRF
- NGGPS (global modeling) will offer more options for evaluation

Accelerated Implementation of Scale-aware Physics into NEMS

PI :Shrinivas Moorthi, GCWMB/EMC/NCEP
CO-I Steven Krueger, University of Utah
CO-I Yu-Tai Hou, GCWMB/EMC/NCEP
Collaborator – Donifan Barahona, NASA/GSFC

- **Employee supported by this project – Anning Cheng**

- **Objective(s): To accelerate the implementation of scale aware physics in S. Krueger CPT and S. Lu CPT funded by NOAA/CPO via NCEP/CTB**

- **Deliverable(s): Implement Morrison double moment microphysics (from GMAO's GEOS model) and Chikra-Sugiyama (CS) convection with Arakawa-Wu (AW) extension into NEMS**

Connection to NGGPS :

- **Advanced scale-aware atmospheric physics that are applicable for both high resolution weather and low resolution climate models.**

- **They are being implemented in NEMS, thus readily available to NGGPS.**

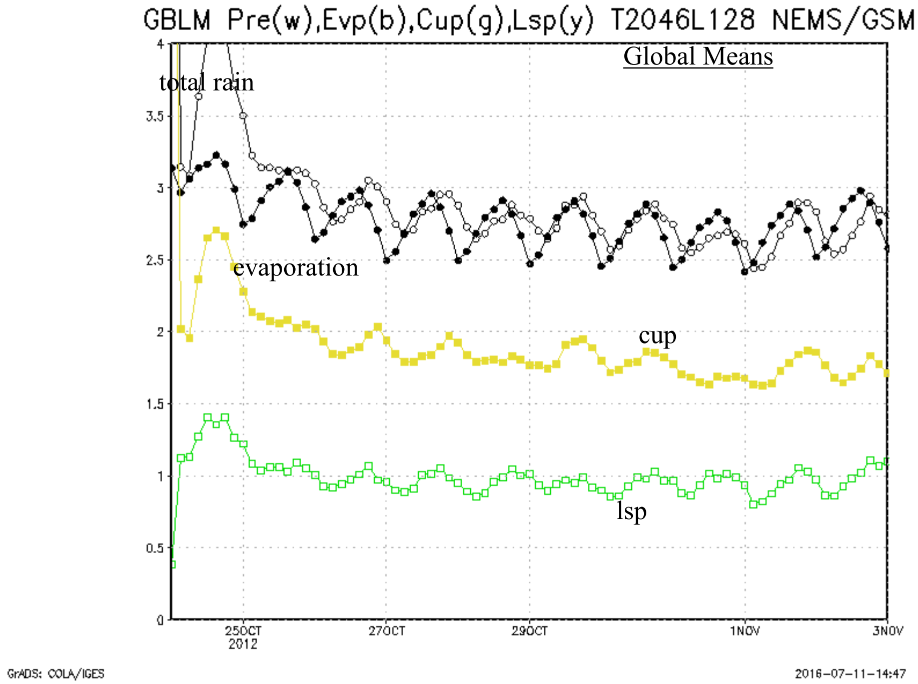
Accelerated Implementation of Scale-aware Physics into NEMS

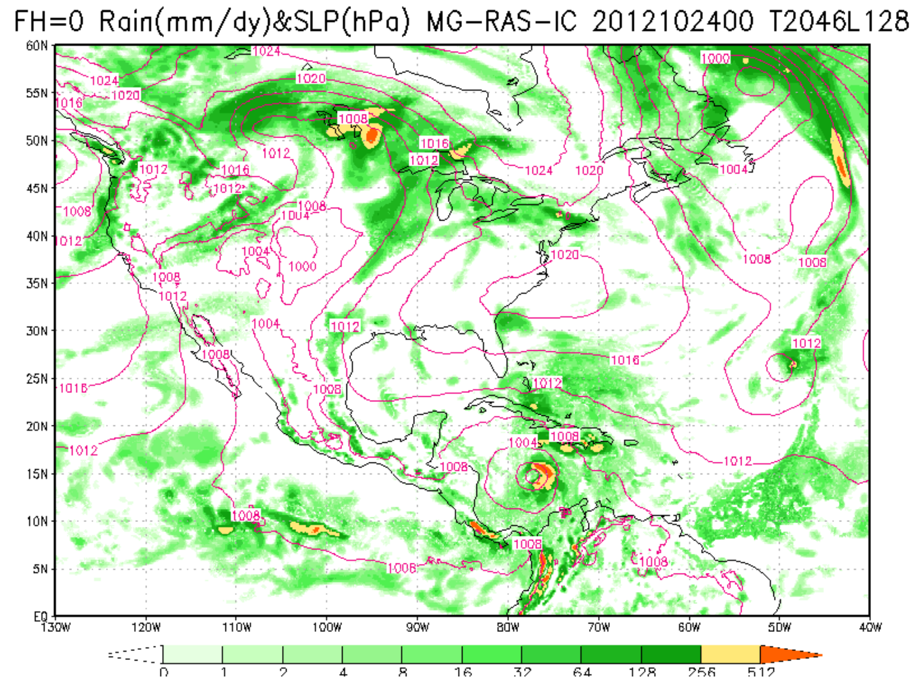
Current Status :

- The Chikira-Sugiyama convection parameterization with prognostic closure is implemented in NEMS and tested with GSM from resolutions of T62 to T2046 and L64/128 (the Arakawa-Wu scale-aware extension is still pending)
- Morrison double moment microphysics from GSFC has been installed in NEMS and tested at T62, T574 and T2046 at both L64 and L128 (still needs tuning/optimization)
- Current installation is coupled to the RAS convection parameterization and GMAO Macrophysics and optionally includes GMAO Aerosol Activation package
- Additional work needed to couple to Chikira-Sugiyama convection and SHOC (Krueger CPT) and to unify cloudiness and it's interaction with radiation and McICA
- Current implementation has cloud water/ice and their number concentrations as prognostic variables
- Need to extend the scheme to optionally include snow/rain as prognostic variables – needed for high resolution weather – not so important for low resolution climate

Accelerated Implementation of Scale-aware Physics into NEMS

Preliminary Results : Results from a ten day forecast from Oct 24, 2012 – T2046 L128 with 2m MG and RAS





Path toward transition to operations:

Need to : optimize and tune the package
couple with other physics packages
perform cycled experiments with data assimilation and show forecast improvements for both weather and climate

CPT to Improve Cloud and Boundary Layer Processes in GFS/CFS

Lead PI: Chris Bretherton (U. Washington); Institutional Pis: Jongil Han (EMC), Ming Zhao (GFDL), J. Teixeira (JPL)

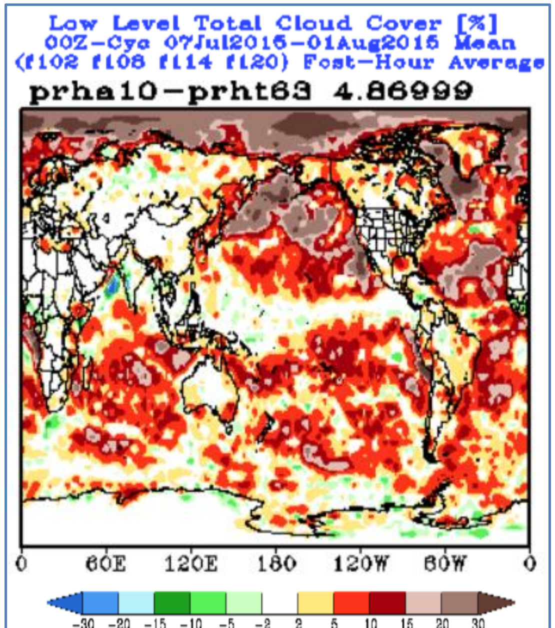
Goals: Improve fidelity of cloud and boundary-layer processes in GFS/CFS and reduce cloud-related radiative flux biases

GFS/CFS Deliverables: Eddy-Diffusion Mass-Flux (EDMF) parameterization of moist boundary layer turbulence and shallow cumulus (right).

Modified Thompson cloud microphysics scheme

Modernized daily cloud diagnostics

NGGPS connection: This CPT aims to modernize GFS physical parameterizations to reduce substantial underprediction of cloud and its radiative effects that are particularly important for seasonal forecast applications, while not degrading weather forecast skill.



New EDMF scheme desirably increases GFS marine low cloud cover

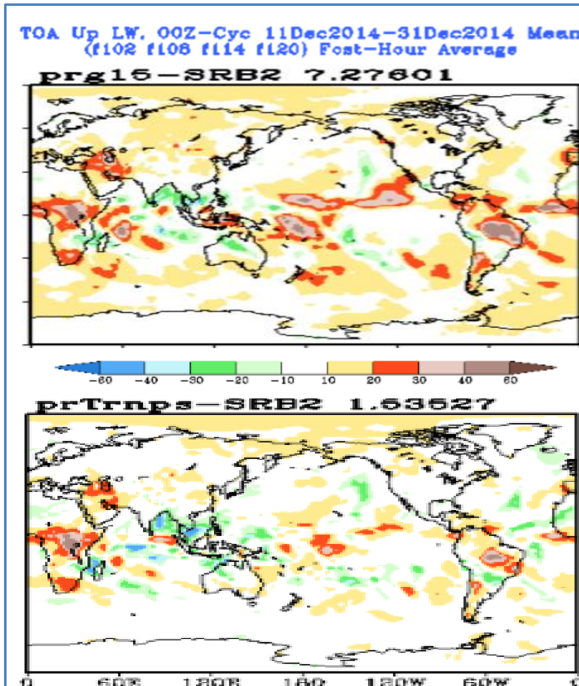
CPT to Improve Cloud and Boundary Layer Processes in GFS/CFS

Lead PI: Chris Bretherton (U. Washington); Institutional Pis: Jongil Han (EMC), Ming Zhao (GFDL), J. Teixeira (JPL)

Progress so far:

Han (EMC), advised by the CPT, implemented a new TKE-based moist EDMF scheme in GFS that increases cloud cover and maintains mid-latitude and CONUS forecast skill but slightly degrades tropical winds.

Sun (EMC), advised by the CPT, developed a modified Thompson GSM6 microphysics scheme in GFS that increases cloud and removes most global TOA radiation biases



Modified Thompson microphysics (bottom) reduce operational GFS OLR biases (top); also true for shortwave.

Potential transition to operations:

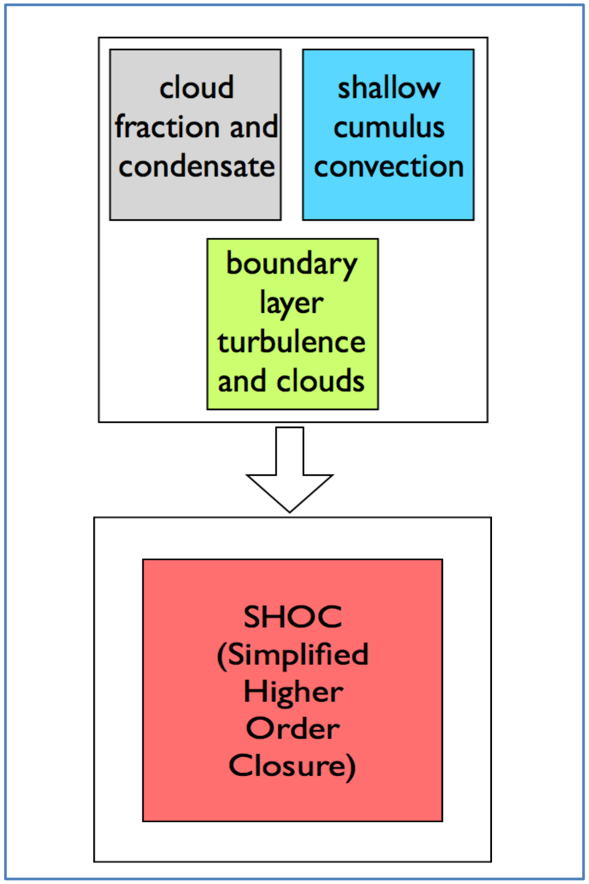
Both of the above schemes are being further tuned and developed for possible implementation in a 2018 release of GFS and will be tested in seasonal forecast mode for possible implementation in CFSv3.

A CPT for Improving Turbulence and Cloud Processes in the NCEP Global Models

Steven Krueger - U. Utah, Shrinivas Moorthi - EMC/NCEP, Robert Pincus – U. Colorado, David Randall – CSU, Peter Bogenschutz - NCAR

- Objective(s): Install an integrated, self-consistent description of turbulence, clouds, deep convection, and the interactions between clouds and radiative and microphysical processes.
- Deliverable(s): Implement a PDF-based SGS turbulence and cloudiness scheme, a "Unified" cumulus parameterization that scales continuously between simulating individual clouds and conventional parameterization of deep convection, and an improved representation of the interactions between clouds, radiation, and microphysics.

- The connection to NGGPS is obvious.

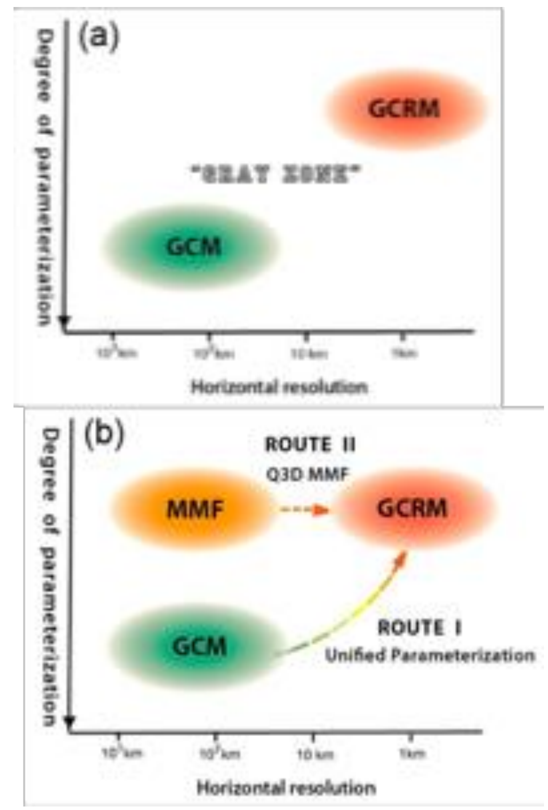


A CPT for Improving Turbulence and Cloud Processes in the NCEP Global Models

Steven Krueger - U. Utah, Shrinivas Moorthi - EMC/NCEP, Robert Pincus – U. Colorado, David Randall – CSU, Peter Bogenschutz - NCAR

- We have installed and tested our PDF-based SGS turbulence and clouds scheme called SHOC (Simplified Higher-Order Closure) into the NEMS as well as the operational versions of the GFS, and are improving SHOC's coupling to parameterized deep convection.
- The (conventional) Chikira-Sugiyama (CS) cumulus parameterization has been installed into the GFS in flux divergence source/sink form and tested.
- A closure for updraft fraction of multiple cloud types has been developed and tested diagnostically.

- All three aspects of our project have the potential for transition to operations/future implementation.



NGGPS Physics Team Plan

Convection and Boundary Layer SWG

GFS Upgrade Timeline — GFS V15 — New Dycore Operational — GFS V16 — GFS V17

Two-Stream Strategy

Operational Physics (Evolved)

Advanced Physics

(Candidates incl: Scale-Aware Chikira-Sugiyama and Arakawa-Wu , CS +SHOC (unified convection and turbulence), Grell-Freitas)

Convection and Boundary Layer SWG

Current capability (SAS, RAS, Hybrid EDMF)

Choice of advanced scale-aware and aerosol aware convection scheme: Advanced Turbulence and Shallow/Deep Convection (Primary Thrust)

Accelerate Implementation of Scale-Aware Physics into NEMS (Moorthi)

(Chikira-Sugiyama (CS) Convection has been implemented in NEMS/GSM; Morrison double moment (DM) microphysics installed in NEMS; Current install coupled to RAS and convec and GMAO microphysics)

- Arakawa-Wu scale-aware extension pending (EMC?/date?)
- Couple install to CS convec and SHOC (EMC?)
- Tune Morrison DM (EMC?)
- Couple w/ other (which?) physics packages (EMC?)
- Perform cycled DA experiments/show forecast improvement (EMC?)

Dependencies for achieving? Subtask chart could include task leads, testing responsibilities, dates, decision points

Test/Evaluation of Scale-Aware Stochastic Convection Parameterization (Grell, Bao)

(GF implemented in HWRF)

- HWRF simulations being evaluated in comparison w/ SAS (SASAS) scheme (date?)

Next step(s)? Testing thru EMC/TEG or GMTB? Implementation in GFS (timing)?

CPT to Improve Cloud and Boundary Layer Processes in GFS/CFS (Bretherton)

(Implemented TKE-based moist EDMF scheme in GFS; Developed a modified Thompson GSM6 microphysics scheme in GFS)

- Tune and develop above schemes for possible implementation in 2018 GFS implementation
- Test above schemes in seasonal forecast mode for possible implementation in CFSV3 (timing?)

Need to adjust/add timelines/ responsibilities (use color bar) where applicable

SHOC for PBL Turbulence/Shallow Convection (Krueger)

(Installed/tested PDF-based SHOC into NEMS/operational GFS)

- Improving SHOC's coupling to parameterized deep convection
- CS parameterization (flux divergence source/sink form) installed/tested in GFS
- Closure for updraft fraction of multiple cloud types developed/tested diagnostically

- Other convec/BL activities needed to address high priority gaps? What are primary candidate schemes and where do they fit in the evaluation/testing timeline?

- Development, testing, transition addressed for each SWG?

- Path(s)/timeline(s) for above to transition to ops?

1 Jan 2017 | 1 Jul 2017 | 1 Jan 2018 | 1 Jul 2018 | 1 Jan 2019 | 1 Jul 2019 | 1 Jan 2020 | 1 Jul 2020 | 1 Jan 2021

Legend: Red text = unfunded; (add colors to indicate funding source?)

Red = Phys Dev; Blue = DTC; Green = EMC

Distilled from Glenn White's EMC ppt: 'Top GFS problems'

- Suppressed W Pac warm pool convection (smeared into adjacent regions) and sporadic failure to maintain MJO after a few days into forecast.
- Bogus tropical cyclone development in the western Caribbean (CAPE closure?).
- Atlantic hurricane track errors larger than ECMWF.
- Inferior equitable threat precipitation scores to other models and popcorn-pattern convective precipitation over hilly terrain (improved by Jongil's new Cu param mods).
- Low-level inversions are too weak and diffuse
- Boundary-layer dry bias vs. sondes
- Nocturnal cold biases due to decoupling of surface from the stable boundary layer

GFS problems vs. Cu/PBL development effort

- More model development effort needed on stable and land boundary layers (connected to land surface)?
- TCs are well known to be sensitive to ocean coupling… shouldn't we be worrying about this?
- A neglected grey area: how sensitive to grid resolution are convection and PBL over complex terrain?
- How to better interface Cu/PBL parameterization development and tuning with DA?
- A new Cu parameterization is a huge challenge to successfully operationalize, and may take extensive retuning of other model components to achieve its potential. Who decides to take this plunge, and based on what metrics?

Systemic challenges for NCEP model improvement

- Strategic planning and management to best allocate/ coordinate resources to improve overall model skill
- Human capacity at EMC for integrating and operationalizing new physics approaches
- An easy to use GFS/CFS testbed for external users
- Appropriate standardized evaluation metrics suitable for unified weather and (sub)seasonal climate modeling.
- Clear planning for a changing NCEP model landscape
- User-friendly community-accessible model documentation

Some suggested discussion topics

- Are current NGGPS convection/PBL model development priorities right?
- Are we paying enough attention to improving GFS PBL simulation over land?
- If we compare GFS with HRRR, are systematic benefits of 3 km convection-resolving resolution apparent?
- Should we be using combined weather/seasonal forecast performance metrics (with more focus on skill at longer leads) as a basis for evaluating GFS/CFS improvements?
- Should NGGPS try to sponsor a GFS cumulus parameterization 'bakeoff'?
- Are there enough skilled scientists within EMC to integrate/maintain/evaluate promising new developments? If not, how can NGGPS help?
- Should DA play stronger role in convection/PBL development?