Advancements in Physics Parameterizations for Global Earth System Modeling: GFSv17/GEFSv13/SFSv1 Physics under the Unified Forecast System (UFS).

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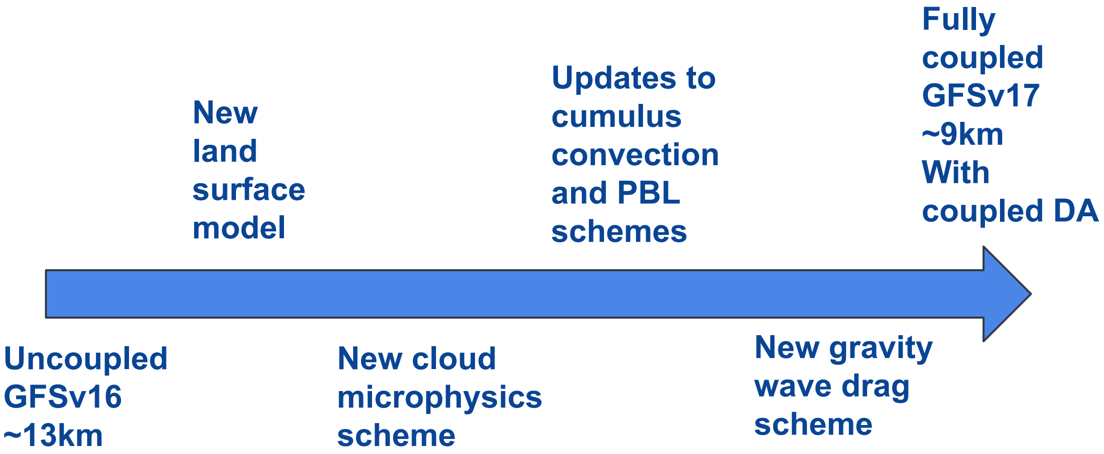
GFSv17/GEFSv13/SFSv1 prototype development

- The GFSv17/GEFSv13 and SFSv1 includes innovations which have been included in so-called “coupled prototypes” coordinated between NOAA and the community under the UFSR2O project in a *stepwise* manner.
- The GFS will thus go from a atmosphere only global NWP model at 13 km, to a fully coupled earth system model at 9km, with many updates to model physics.



P6 — P7 — P8 — HR1 — HR2 — HR3

P6

Land: **Noah**
PBL: **TKE-EDMF**
Microphysics: **GFDL MP**
Deep convection: **saSAS**
Shallow convection: **saMF**
Radiation:**RRTMG**
Gravity wave drag: **uGWDv0**

P7

Land: **Noah-MP +**
Compositing surface layer variables, albedo/emissivity
PBL: **TKE-EDMF**
Reduced background diffusivity, limit PBL updraft overshoot.
Microphysics: **GFDL MP**
Deep convection: **saSAS**
Stricter trigger criteria, reduced entr. rate, reduced rain evap. rate
Shallow convection**: saMF**
Radiation:**RRTMG**
MERRA2 aerosols
Gravity wave drag: **uGWDv0**

P8

Land: **Noah-MP**
Tuning, use CICE albedo in atm, new ice climatology, VIIRS based land/lake mask, spun up land IC's.
PBL: **TKE-EDMF**
Positivie definite massflux scheme, reduced entrainment rate
Microphysics: **Thompson MP +**
Semi-Lagrangian Sedimentation + refined ice microphysics
Deep convection: **saSAS**
Cellular automata convective org scheme.
Positivie definite massflux scheme
Shallow convection: **saMF**
Positivie definite massflux scheme
Radiation:**RRTMG**
Gravity wave drag: **uGWDv0**

HR1

Land: **Noah-MP**
Bug-fixes
PBL: **TKE-EDMF**
Microphysics: **Thompson MP**
Improve radiative fluxes and cloud cover
Deep convection: **saSAS**
Prognostic closure
Shallow convection: **saMF**
Prognostic closure
Radiation:**RRTMG**
Couple convective cloud to radiation
Gravity wave drag: **uGWDv0**

HR2

Land: **Noah-MP**
Bug-fixes
PBL: **TKE-EDMF**
wind shear effect and TKE dependent entrainment.
CONUS CAPE enhancement
Microphysics: **Thompson MP**
Reduce stratus and downwelling rad. fluxes
Deep convection: **saSAS**
wind shear effect and TKE dependent entrainment
Shallow convection: **saMF**
Radiation:**RRTMG**
Gravity wave drag: **uGWDv0**

HR3

Land: **Noah-MP**
PBL: **TKE-EDMF**
Microphysics: **Thompson MP**
Deep convection: **saSAS**
Shallow convection: **saMF**
Radiation:**RRTMG**
Address excessive large net SW net to ocean at low sun angles
Gravity wave drag: **uGWDv1**

UFSR2O physics/dynamics development coordination
Fanglin Yang, Lisa Bengtsson

Acknowledgement to ALL UFS coupled/infrastructure/physics/dynamics/DA developers, application/project leads , and evaluators!

Physics suites are shared among many UFS applications

- GFSv17 - 9km medium range
- GEFSv13 - 25km sub-seasonal range
- SFSv1 - 50km seasonal range
- HAFSv1 - 6 km / 2 km hurricane forecasts
- AQMv7 - 12 km Air quality forecasts for North America

- Poses challenges for scale-adptivness in applications with different dx and dt, as well as challenges for different target lead-times (e.g Hurricane application vs Seasonal prediction)

- Poses challenges for coupled vs un-coupled applications due to complex interaction between clouds and mixing with ocean/ice/waves/aerosols.

Example of scale dependent challenges seen in SFS

L. Bengtsson (PSL), S. Sun (GSL), W. Li (DTC), F. Yang, J. Han, R. Sun (EMC), X-W Quan (PSL)

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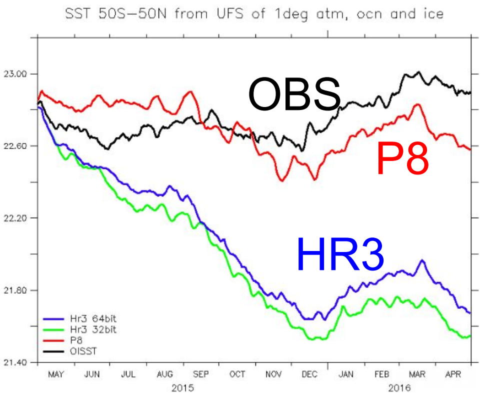
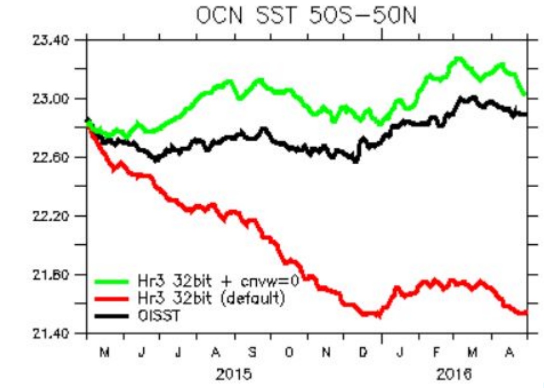




Examination by Shan Sun, GSL

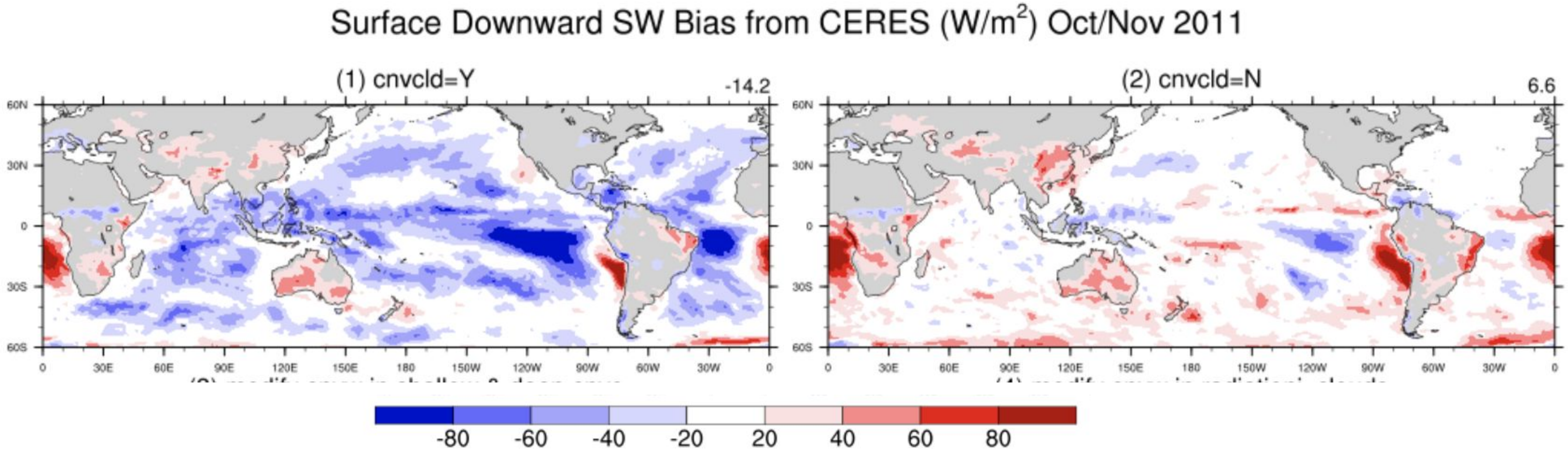
This drift is only seen at 100 km res simulations

Remove conv. cloud from radiation-cloud intreaction

Include conv. cloud from radiation-cloud intreaction

Removing convective clouds from cloud radiation interaction at C96 (100km resolution)

L. Bengtsson (PSL), S. Sun (GSL), W. Li (DTC), F. Yang, J. Han, R. Sun (EMC), X-W Quan (PSL)



Removing suspended convective cloud liquid improves the negative bias in Downward SW. But in regions of the world dominated by sub-grid clouds a positive bias strengthens.

Examination by Shan Sun, GSL

A scale-adaptive solution

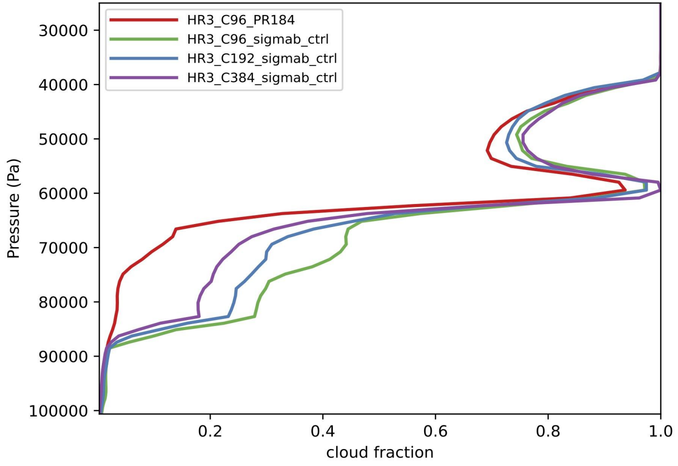
L. Bengtsson (PSL), S. Sun (GSL), W. Li (DTC), F. Yang, J. Han, R. Sun (EMC), X-W Quan (PSL)

Proposal to use **convective updraft area fraction** used in convective scheme (Bengtsson et al. 2023) to provide **in-cloud** suspended convective cloud passed into the Xu-Randall cloud fraction computation, and optical depth caluculation to provide in-cloud cumulus condensates to the cloud-radiation interaction.

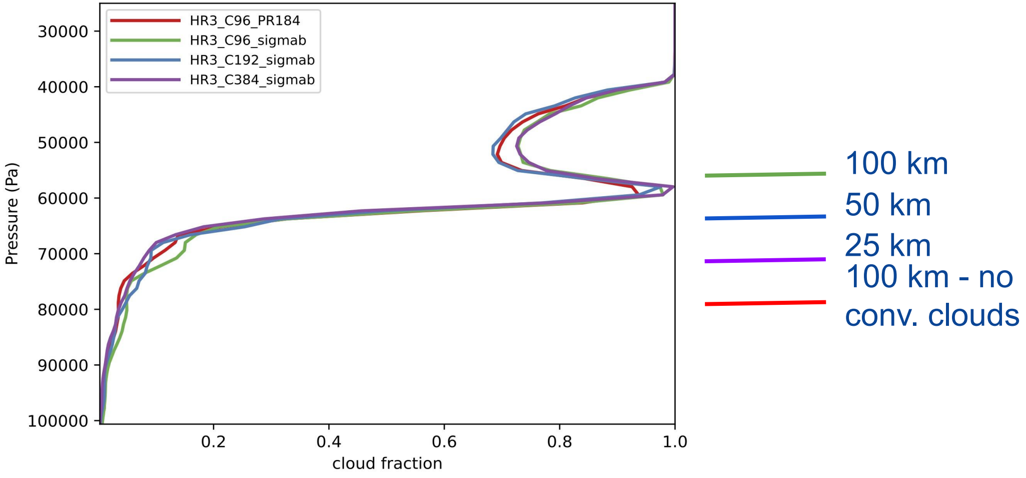
Cloud fraction - DYNAMO SCM

SCM analysis by Weiwei Li, DTC

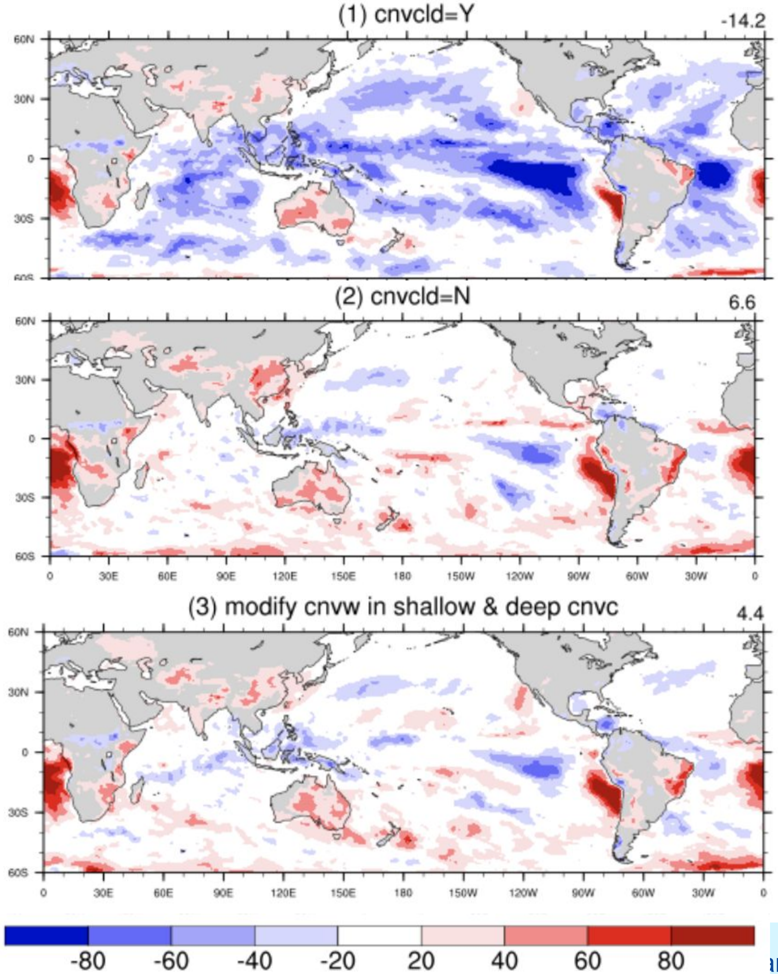
control



Scale adaptive conv.



Impact on short wave down, bias from CERES (W/m2)



All conv. cloud added

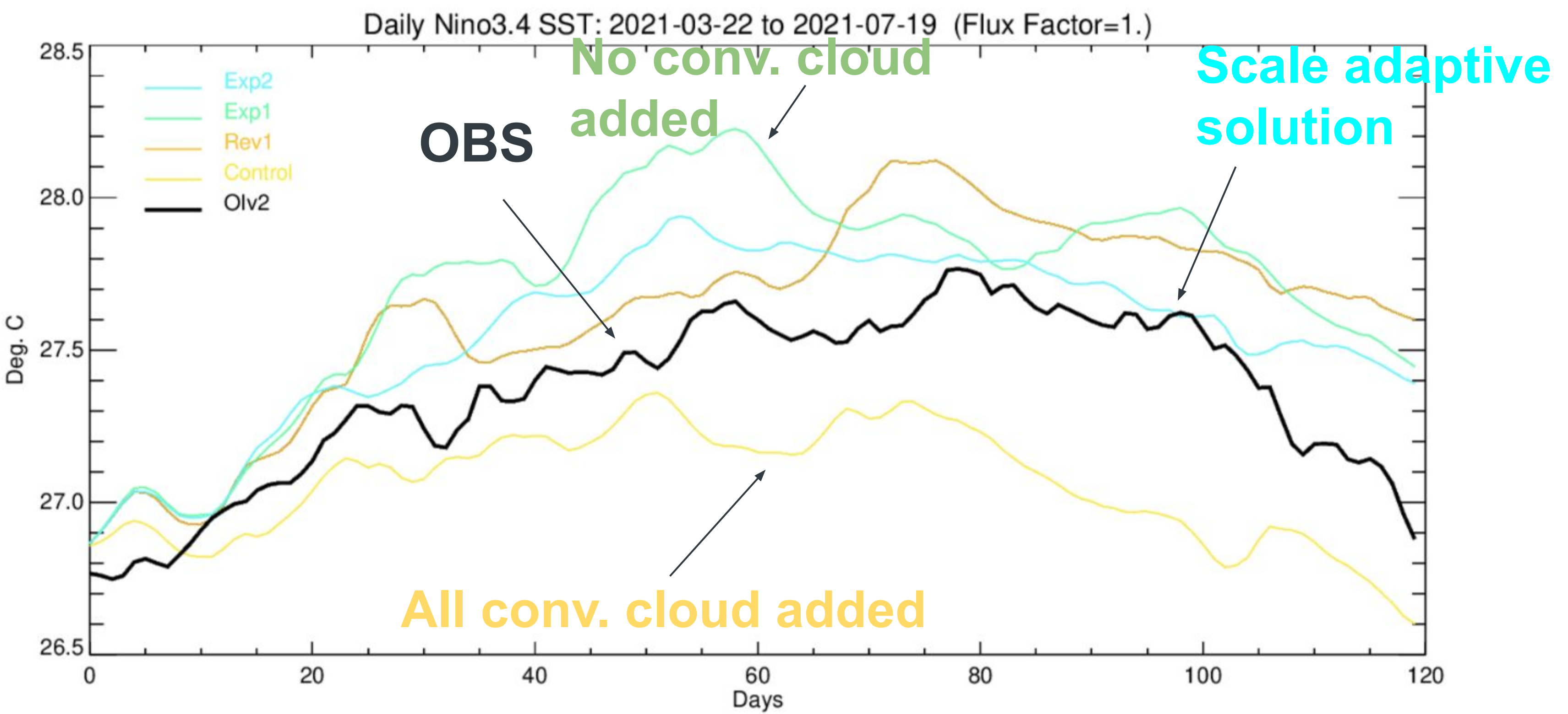
No conv. cloud added

Scale adaptive solution

Analysis by Shan Sun, GSL

Impact on Nino3.4 SST

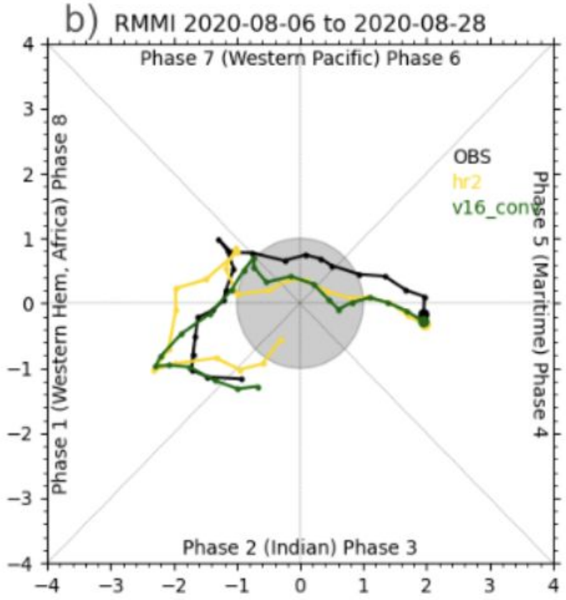
Analysis by Xiao-Wei Quan, PSL



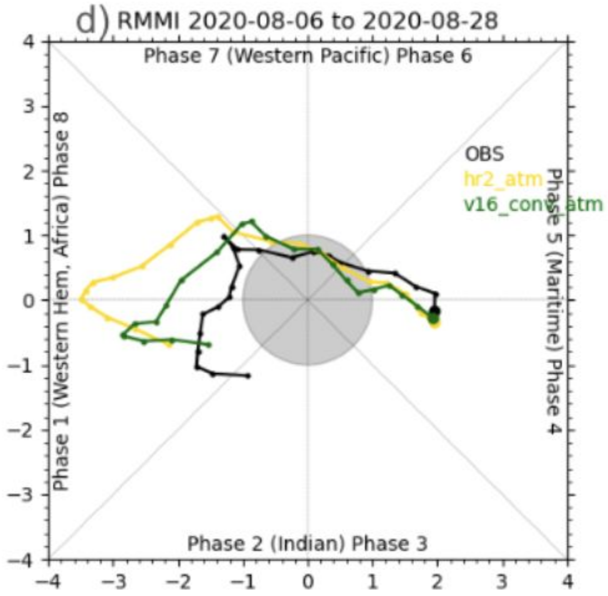
Example impact of coupled vs uncoupled simulations of the MJO

Another challenge we face is the response of atmospheric physics to the choice of coupling

Coupled



Uncoupled



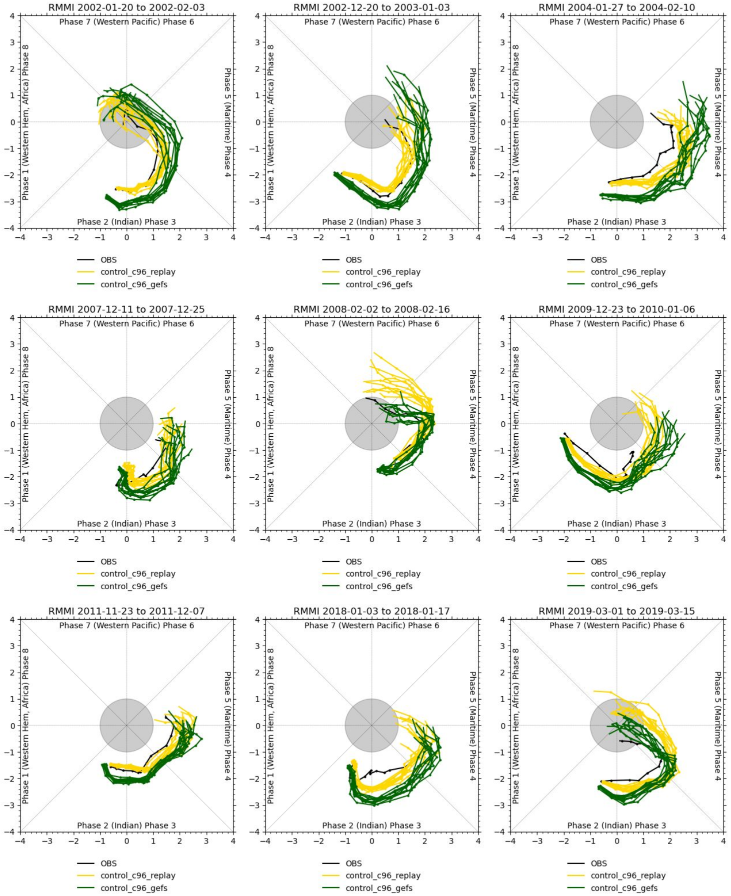
HR2 physics

HR2 physics with GFSv16 convection

Bengtsson and Han 2024

The Crucial Role of Initial Moisture in Predicting the MJO Advancement Across the Maritime Continent

L. Bengtsson, S. Tulich, J. Dias, K. Hall, M. Gehne, G. Kiladis, J. Whitaker and P. Pegion, (PSL)



HR3 at 100km res. Initialized with UFS replay reanalysis

HR3 at 100km res. Initialized with GEFSv12 reanalysis

- The MJO when initialized in an active phase, propagates well across the Maritime Continent.
- A statistically significant difference in amplitude (and sometimes propagation) is seen depending on the initial condition used

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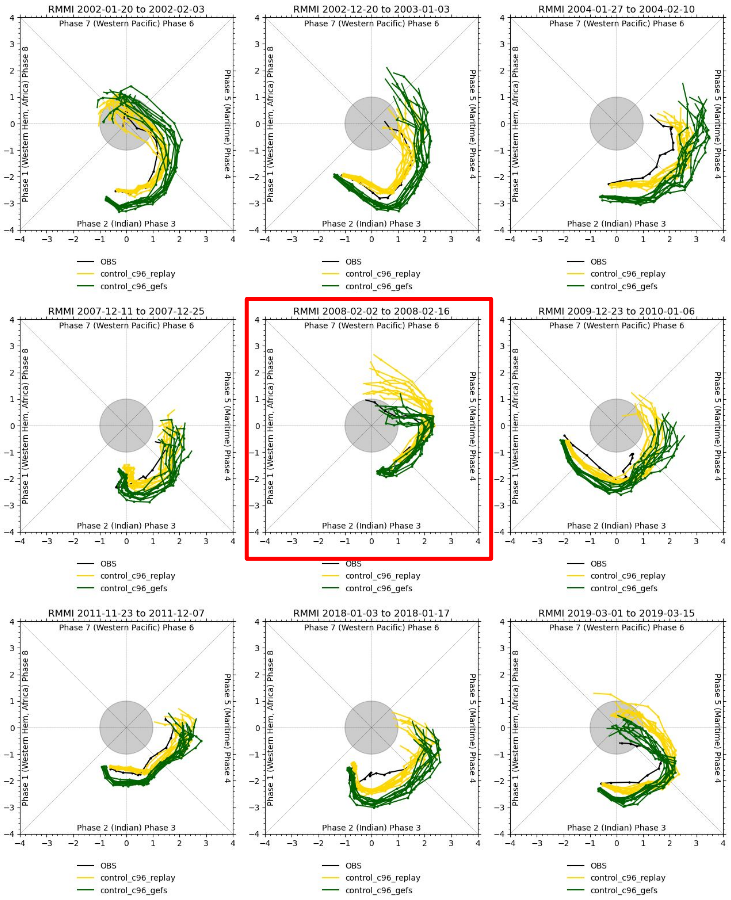

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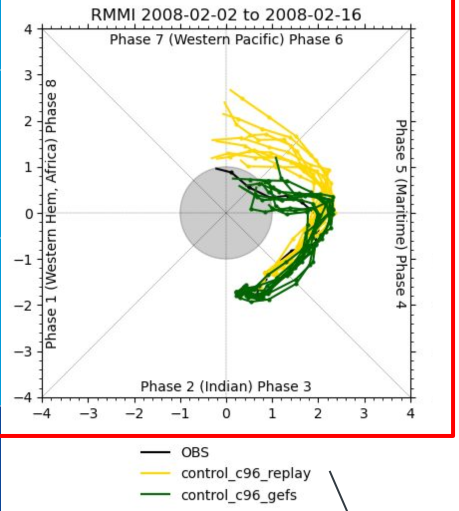

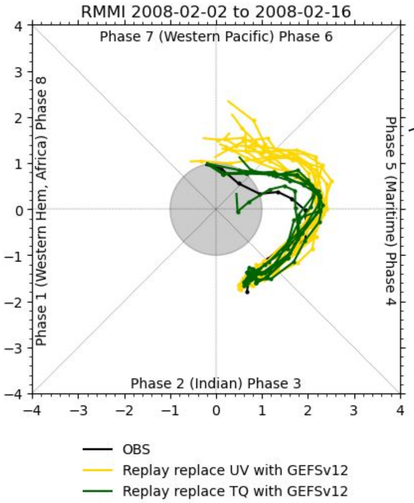

Initialize from UFS replay, but replace U,V with GEFSv12 fields

Initialize from UFS replay, but replace T,Q with GEFSv12 fields

- When we replace the thermodynamic fields in the UFS replay initialized runs IC, with those from GEFSv12, the MJO propagation and amplitude imprvoves throughout the forecast lead time, suggesting initial moisture plays a crucial role for the evolution of the MJO

HR3 at 100km res. Initialized with UFS replay reanalysis

HR3 at 100km res. Initialized with GEFSv12 reanalysis

Summary and future plans

- The UFS infrastructure has opened up incredible opportunities for collaboration on model development between NOAA and the community.
- Thanks to DTC's Common Community Physics Package we can easily use the same physics across scales and applications in the UFS.
- Since physics development spans many UFS applications, there's an increasing need for scale-adaptive development, and a need to avoid application specific tuning, but coupled/uncoupled configurations poses new challenges.
- For many applications, physics is very important to get at systematic biases, but let's not forget the crucial role of the initial state in predicting phenomena even on S2S time-scales.