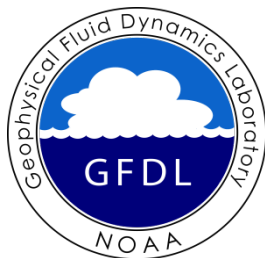


The GFDL FV3 Dynamical Core Configuration and Applications

Jan-Huey Chen, Linjiong Zhou, Lucas Harris, and Xi Chen
for the GFDL FV3 Team



UFS MRW Application Training

5 November 2020

Outline:

- Who is using FV3?
 - The global FV3 community
- FV3 at GFDL
 - History of climate modeling
 - The unified modeling suite
- Modern NWP
 - Seamless weather-climate prediction/projection
- Special focuses:
 - Hurricanes, severe weather, MJO, diurnal cycle...
- Global cloud-resolving modeling

Who is using FV3?

– The Global FV3 Community



GEOS, DAS, MERRA(2)
Ames Mars GCM



GEOS Chem
GEOS-Chem High-Performance



CAM-FV
CAM-FV3

NCAR



Taiwan Central Weather Bureau

CWBGFS



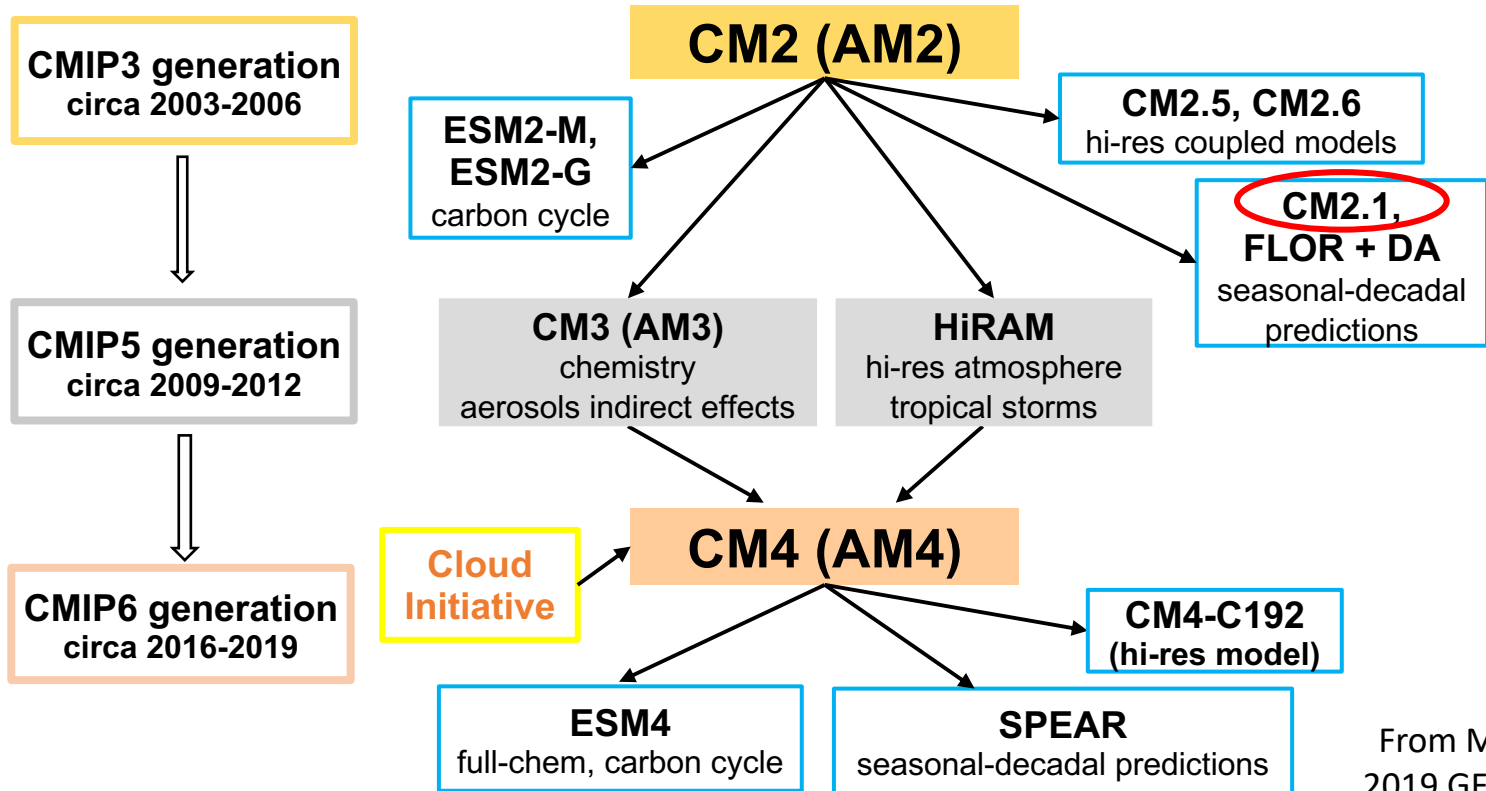
LASG FAMIL

Chinese Academy of Sciences

Fork FV3 on GitHub
github.com/NOAA-GFDL/GFDL_atmos_cubed_sphere

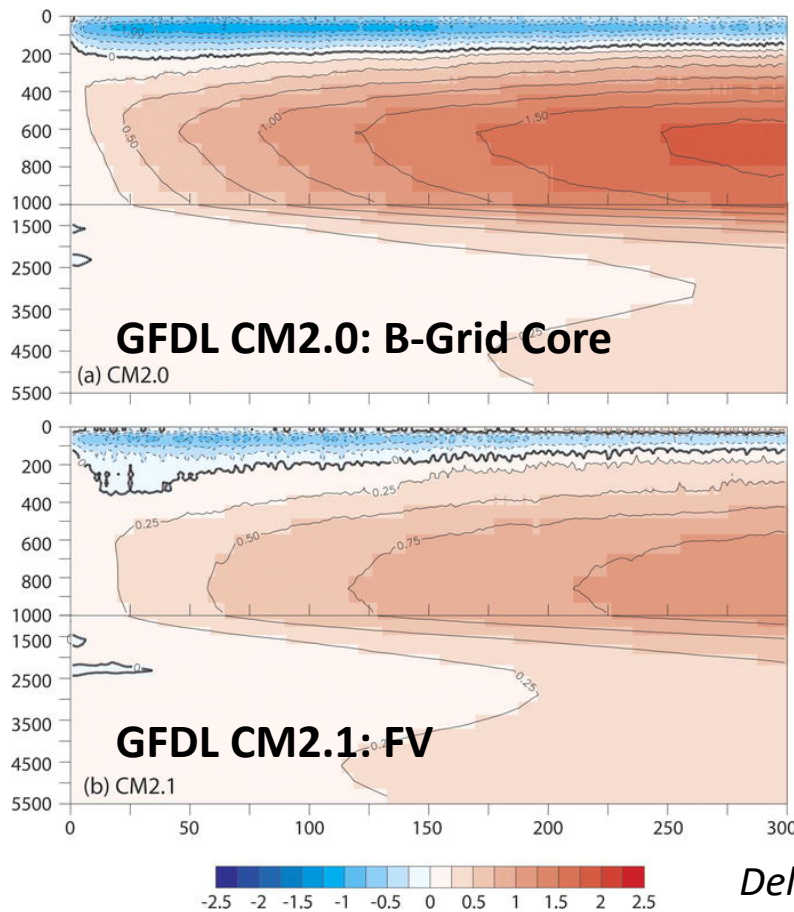
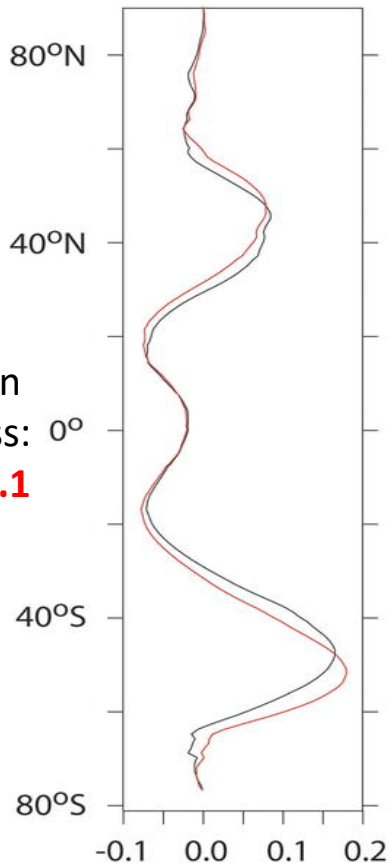
FV3 at GFDL

Recent history of GFDL Global Climate Models



From CM2.0 to CM2.1 -- The importance of vorticity

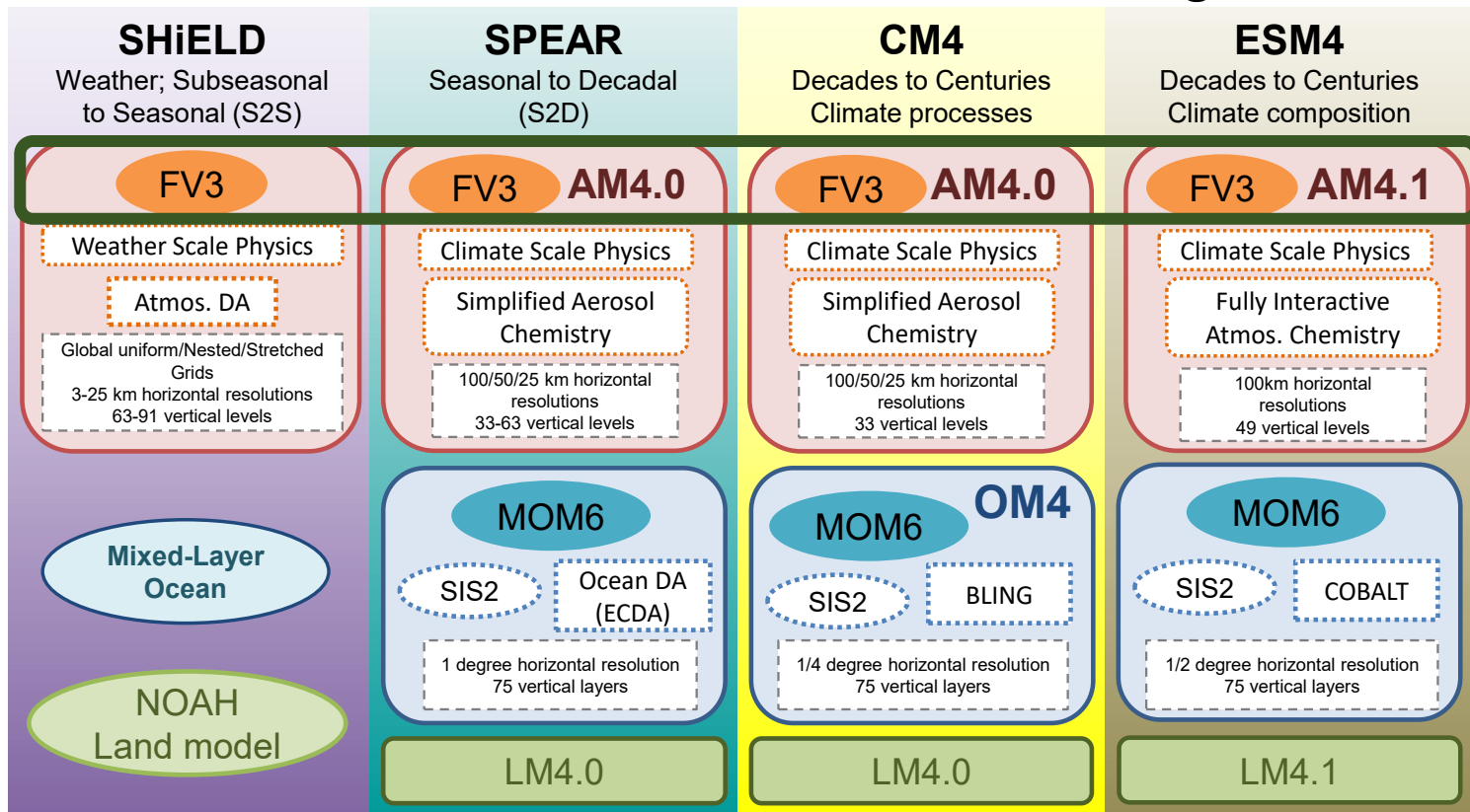
Zonal-mean
wind stress: 0°
CM2.0 vs. CM2.1



Global-mean Ocean
Temp diff. (K) in
control-climate
integrations

FV3 at GFDL

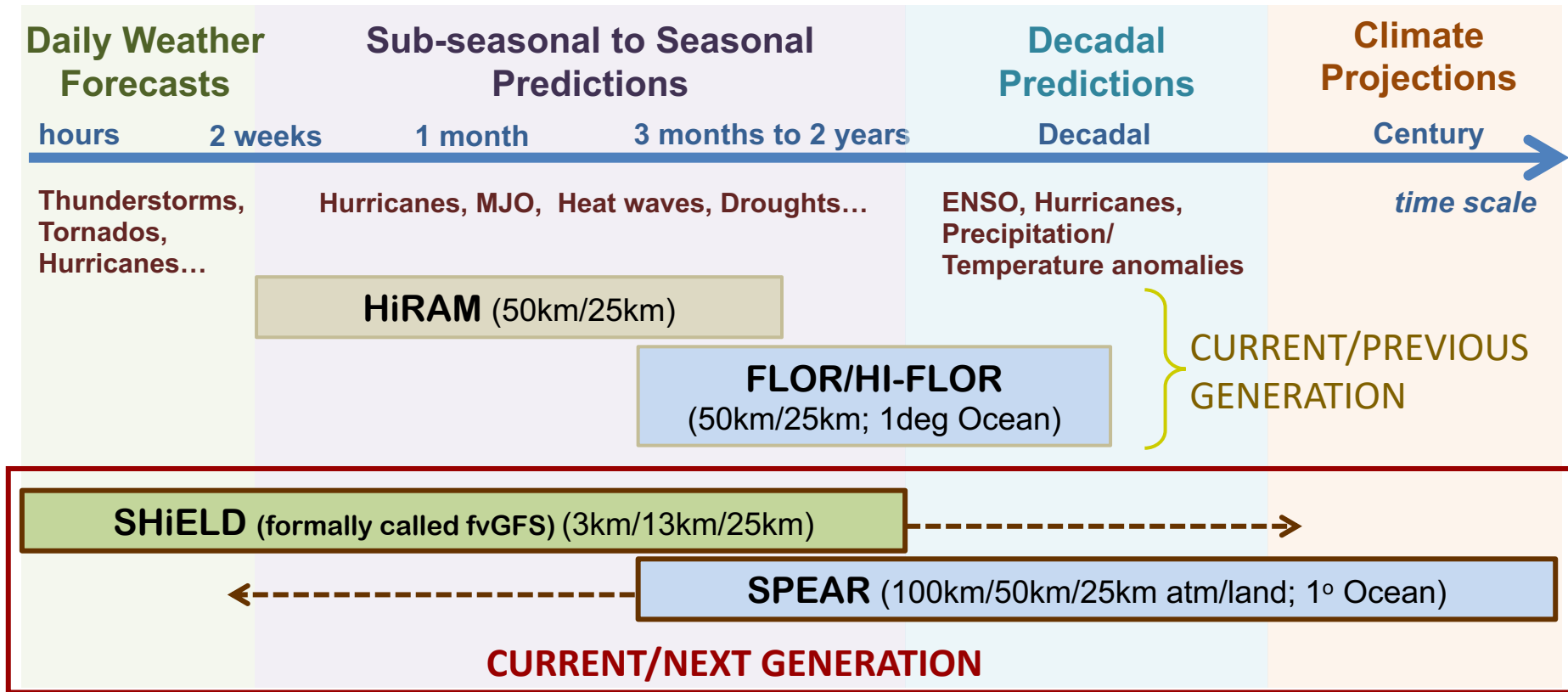
The GFDL Fourth-Generation Unified Modeling Suite



All models use the Flexible Modeling System (FMS) framework and are part of the Unified Forecast System

Modern NWP

GFDL seamless prediction/projection modeling system



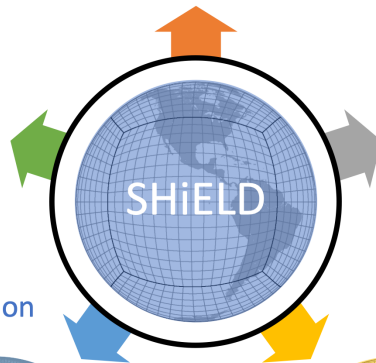
SHiELD system for High-Resolution Prediction on Earth-to-Local Domains

Weather- to-Seasonal Application

3km
Regional Storm Prediction
Idealized Test



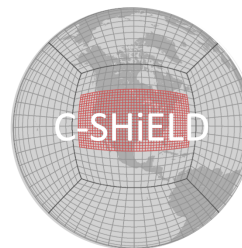
C768: 13km
Global Weather Prediction



C3072: 3km
Global Cloud-resolving Simulation



C384: 25km
Subseasonal-to-seasonal Prediction



C768r15n3: 20-3km
Severe Weather Prediction



C768n4: 13-3km
Tropical Cyclone/MJO Prediction

GLOBAL:

- ✓ SHIELD – current real-time
- SHIELD – 2019-2020 real-time

CONTINENTAL:

C-SHIELD – current real-time

HURRICANE:

- T-SHIELD – current real-time
- T-SHIELD – 2020 real-time (07/20-09/04)
- hfvGFS – 2018 real-time

- Atlantic
- Central Pacific
- Continental US
- Eastern Pacific
- ✓ Global
- New Jersey
- North America
- Western Pacific
- stormscale_AL93
- stormscale_EP19
- stormscale_WP16
- stormscale_WP94

Model Selection

Changing an option below will update the subsequent options automatically

Model

SHIELD – current real-time

Model run

Current UTC: 18:03

2020-10-15 (06Z)

< Previous > Next >> Latest

Region

Global

Global Products

6-hr Rain/Mix/Snow, MSLP, anc

Load and Animate

Currently Viewing: SHIELD – current real-time

Initialization time: 2020-10-15 (06Z)

Region: Global

Product: 6-hr Rain/Mix/Snow, MSLP, and 10 m Wind

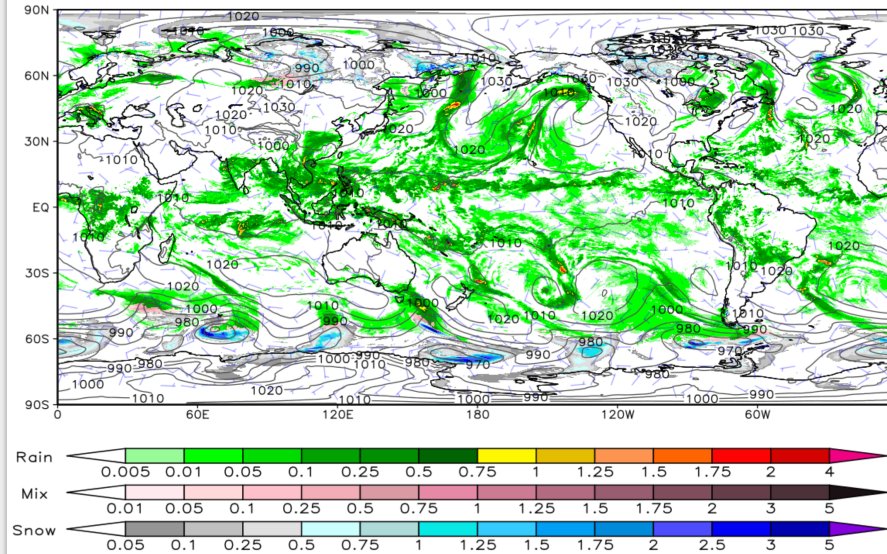
Note: snowfall=(snow+ice)*9+graupe1*2

Zoom in 200% Loop speed

Loop Rock None

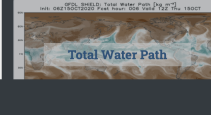
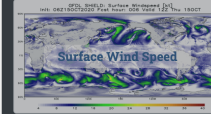
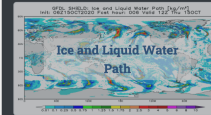
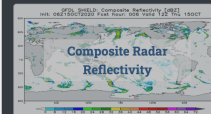
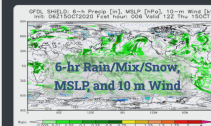
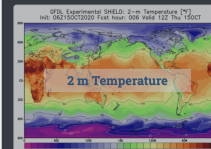
<< First Previous Play Next >> Last

GFDL SHIELD: 6-h Precip [in], MSLP [hPa], 10-m Wind [kt]
Init: 06Z15OCT2020 Fcst hour: 006 Valid 12Z Thu 15OCT



Products

Global plots



The GFDL SHIELD Real-Time Model Website

<https://shield.gfdl.noaa.gov/new>

Operator: Matt Morin

GFDL
Princeton University Forrestal Campus
201 Forrestal Road
Princeton, NJ 08540-6649

Phone: (609) 452-6500
Fax: (609) 987-5063

About Privacy Policy Help

Questions or comments: SHIELD support
Website issues: Webmaster
Security issues: Security officers

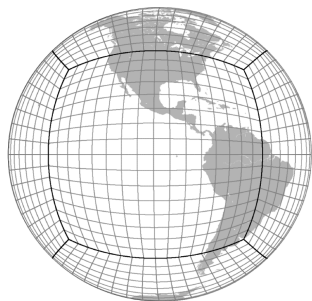
Disclaimer: These are experimental research products and are not intended to replace any official forecasts.



U.S. Department of Commerce
National Oceanic & Atmospheric Administration
Office of Oceanic & Atmospheric Research

13-km SHiELD Evolution

Courtesy Linjiong Zhou
Harris et al, 2020, JAMES



Incremental improvements in FV3 and Physics

● 2016

Tuned NGGPS
GFS Physics

● 2017

GFDL Microphysics
EMC SA-SAS

● 2018

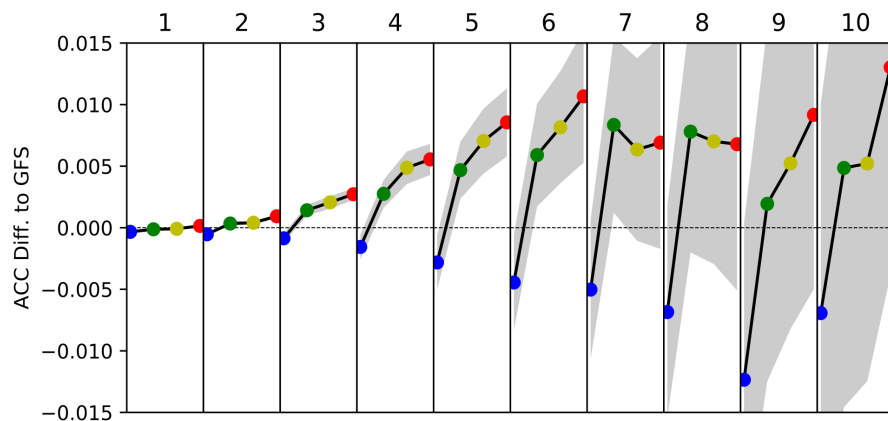
Inline GFDL MP
Pos-Def Advection
YSU Turbulence
Mixed-layer Ocean

● 2019

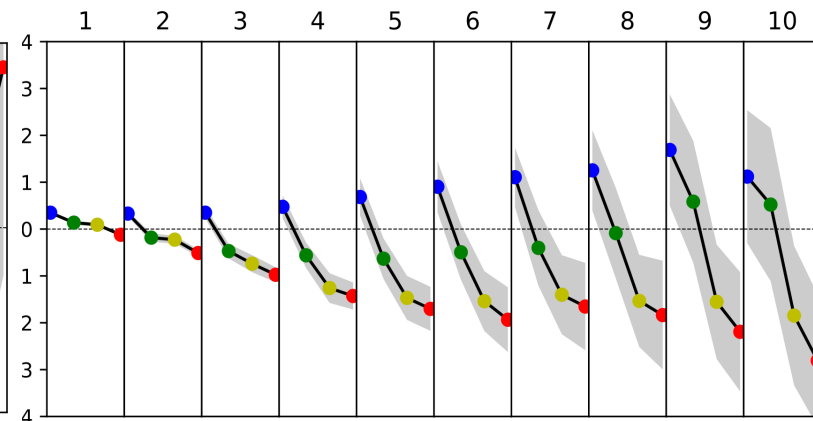
Updated FV3
Revised GFDL MP
URI-GFDL Sea State

2020

Overhauled GFDL MP
New cloud-radiation
UW/EMC TKE-EDMF



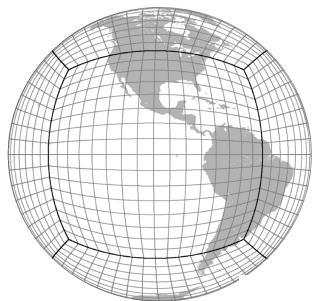
Global H500 ACC Diff. to GFS



Global H500 RMSE Diff. to GFS

13-km SHiELD Evolution

Courtesy Linjiong Zhou
Harris et al, 2020, JAMES



Tropical
Precipitation
vs. TRMM
25-km data

CONUS
Precipitation
vs. StageIV

Incremental improvements in FV3 and Physics

● 2016

Tuned NGGPS
GFS Physics

● 2017

GFDL Microphysics
EMC SA-SAS

● 2018

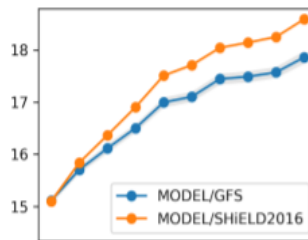
Inline GFDL MP
Pos-Def Advection
YSU Turbulence
Mixed-layer Ocean

● 2019

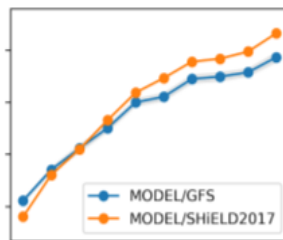
Updated FV3
Revised GFDL MP
URI-GFDL Sea State

2020

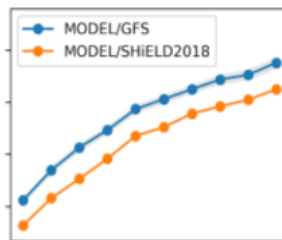
Overhauled GFDL MP
New cloud-radiation
UW/EMC TKE-EDMF



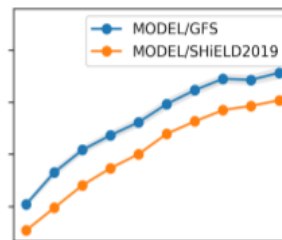
RMSE: CONUS, 13km



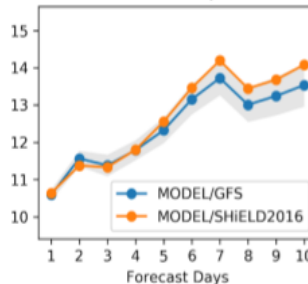
RMSE: CONUS, 13km



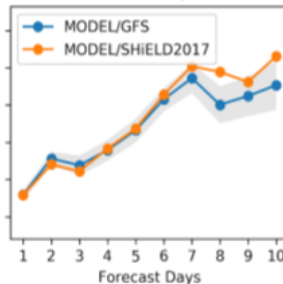
RMSE: CONUS, 13km



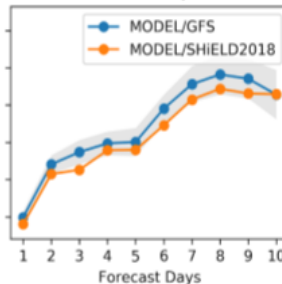
RMSE: CONUS, 13km



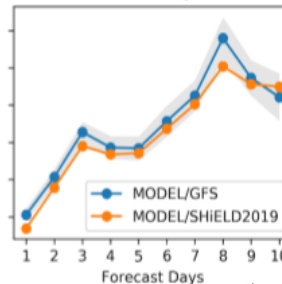
Forecast Days



Forecast Days



Forecast Days



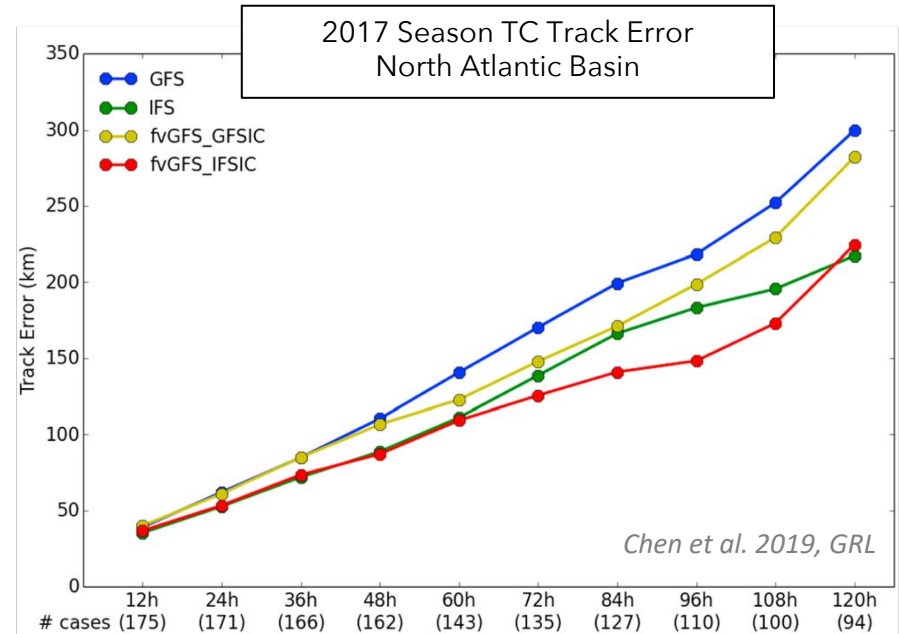
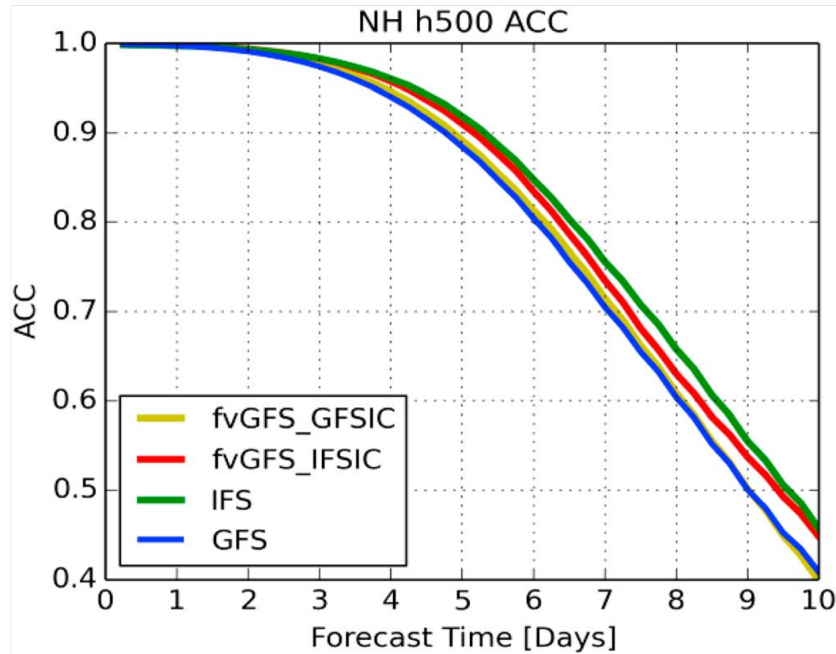
Forecast Days

RMSE
Lower is Better

Year-over-year reduction in precipitation forecast error

The importance of initial conditions

SHIELD C768 (13km)



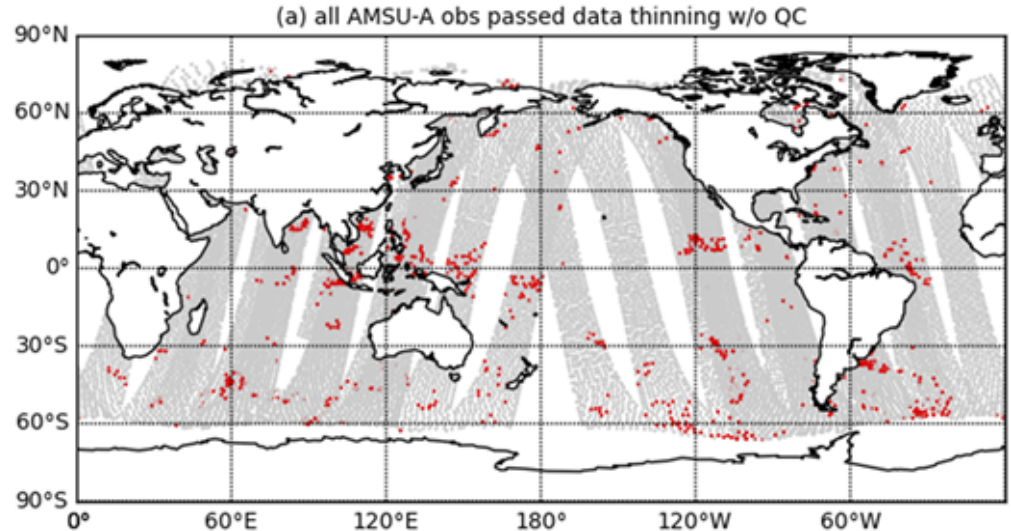
Ongoing Collaborations with ECMWF: **DIMOSIC** Project (**D**ifferent **MO**delS - **S**ame **I**nitial **C**onditions) based on

- Chen et al. 2019, GRL
- Magnusson et al. 2019, QJ

Data Assimilation in SHiELD

DA in FV3-based GFSv15 prototype

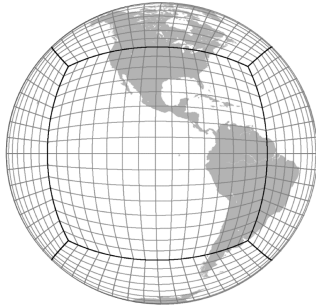
Benefited from the use of the GFDL microphysics scheme, the all-sky radiance assimilation framework was expanded to include **precipitating hydrometeors**.



Locations of AMSU-A **observations that meet the precipitation screening criterion in deep-convection (high-impact) areas** are rejected in the original all sky framework but are kept in the new all-sky framework

SHiELD v2020

Push our flagship to **8.5 km** resolution
(C1152)

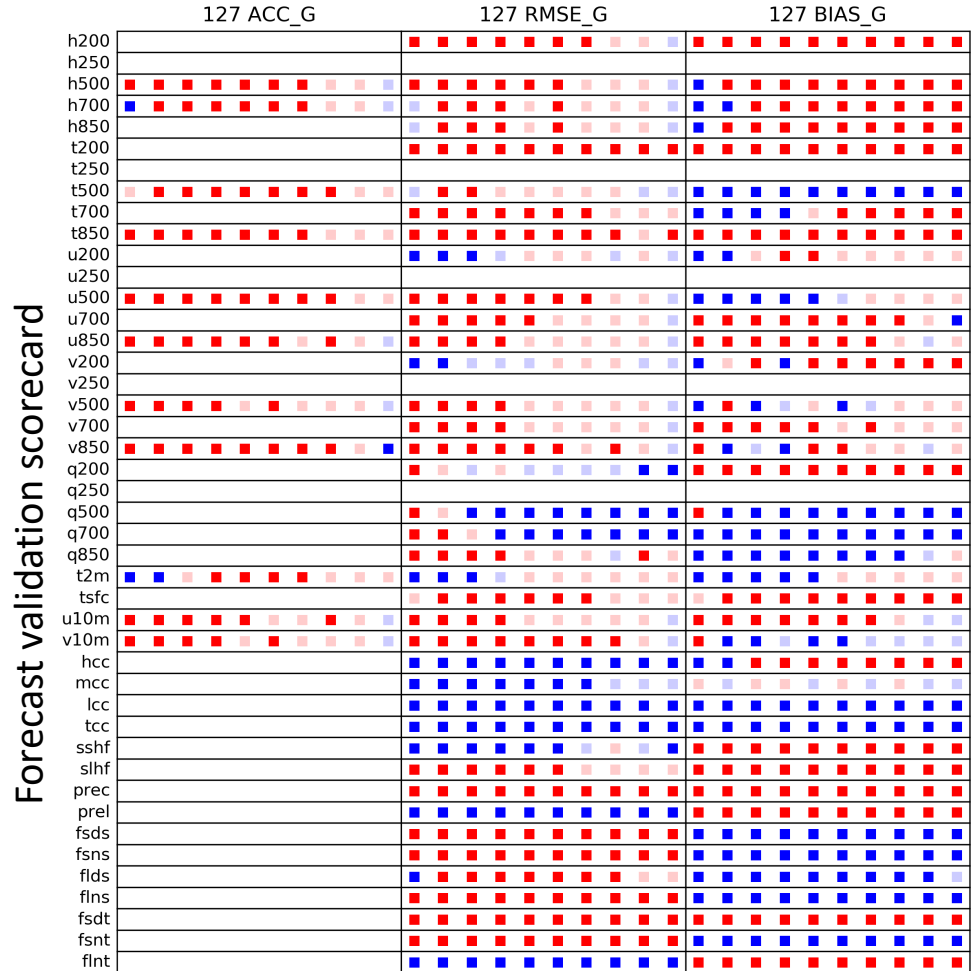


Major changes:

- 2020 version of FV3
- 2020 version of GFDL MP
- YSU PBL -> TKE-EDMF PBL
- GFSv14 ICs -> GFSv15 ICs

Other changes:

- Horizontal resolution: 13km -> 8.5km
- Latest version of fix_am
- Mountain block intensity
- 2020 version of FMS

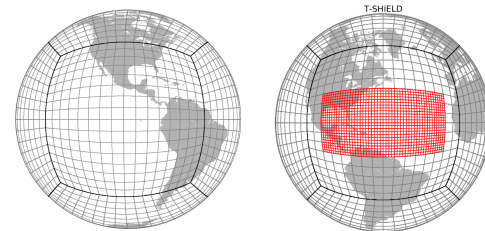


Reference: SHiELD 2019
Case: SHiELD 2020

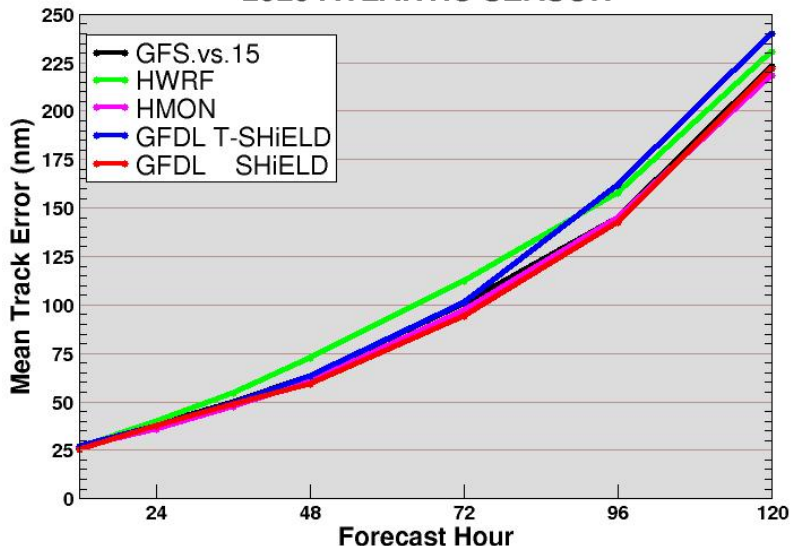
█ better (95%)
█ worse (95%)

Hurricane forecasts

SHiELD C768 (13km) and T-SHiELD (3-km two-way nest)

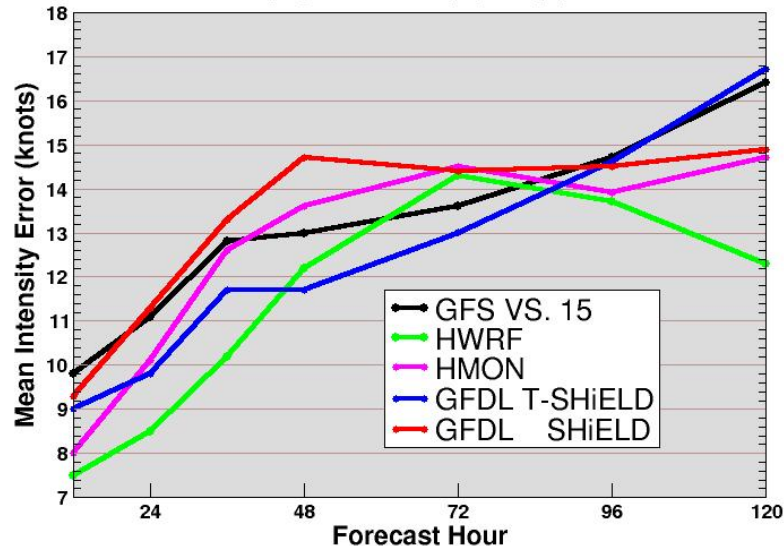


**COMPARISON of GFDL MODELS vs. GFS
2020 ATLANTIC SEASON**



NUM. OF CASES 341 267 201 149 102
 % IMP. SHLD/GFS 2% 6% 7% 2% 1%

**COMPARISON of HAFS MODELS vs. OPERATIONAL MODELS
2020 ATLANTIC SEASON**



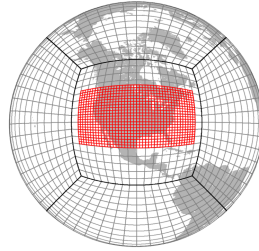
NUM. OF CASES 341 267 201 149 102

Results as of 26 October 2020.

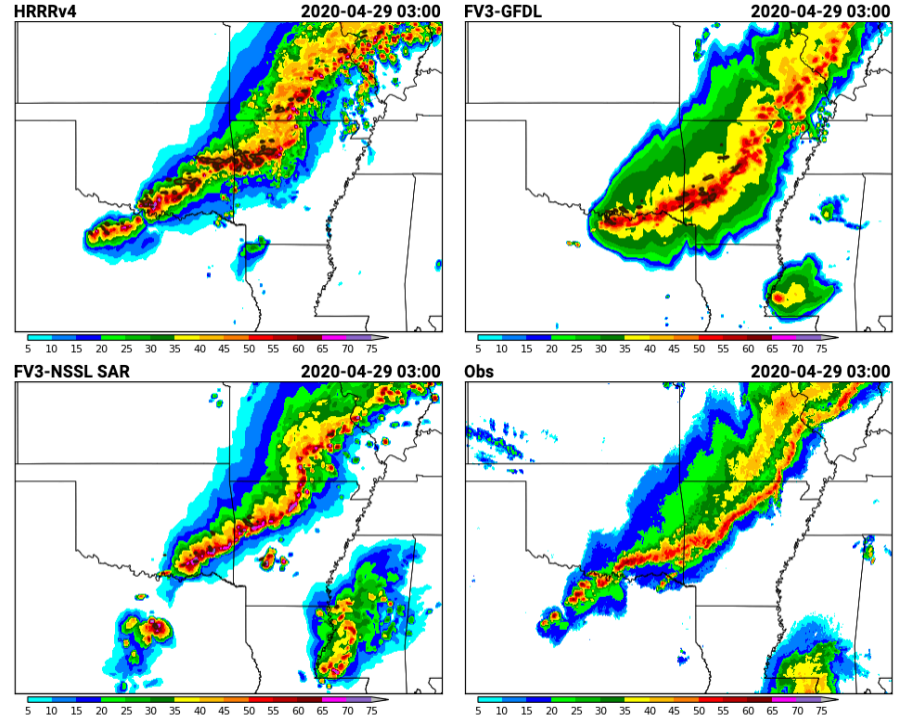
Courtesy Kun Gao & Morris Bender

Severe Storm Forecasts

C-SHiELD (3 km)



- 3-km CONUS nest for severe weather prediction out to 5 days
- Leverages advances from other SHiELD configurations
 - Revised diffusion and shallow convection, updated GFDL microphysics and PBL
- Submitted to 2020 Spring Forecasting Experiment at the NOAA Hazardous Weather Testbed in Norman, OK
 - Received high marks for pre-storm environment and cold pools
 - FV3-NSSL (diff. MP, PBL, LSM) does very well with storm structure every year



From NOAA Hazardous weather testbed:
<https://hwt.nssl.noaa.gov/>

Madden-Julian Oscillation

Seamlessness in the GFDL Modeling Suite

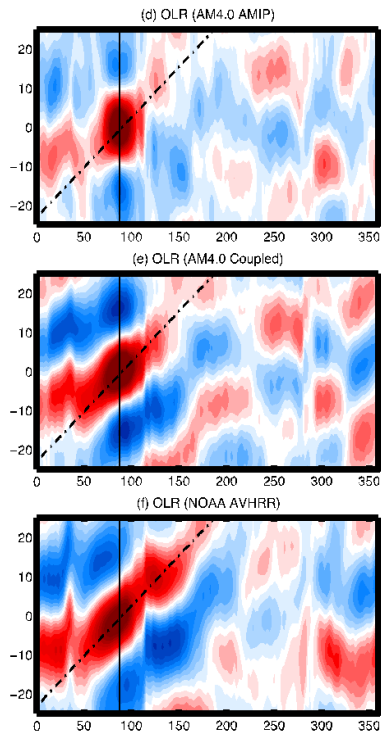
CMIP Earth-System Models

100-km AM4 Atmosphere
(C96 FV3 + GFDL Climate Physics)
+ 25-km MOM6 + LM4

CM4 Coupled Climate
Model

Even at 100-km good MJO
propagation is found...if
coupled to an ocean

Zhao et al. 2018a,b

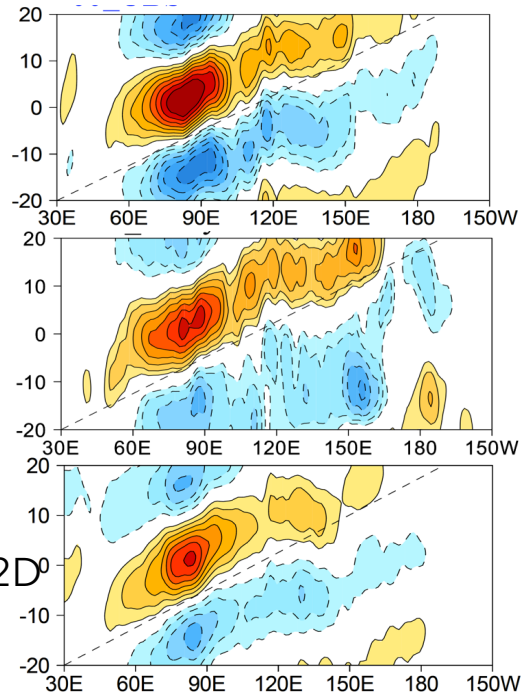


S2S & S2D Prediction Models

Observations

25-km S-SHiELD
Atmos. w/ MLO

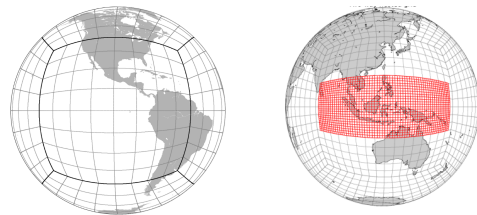
50-km SPEAR
MOM6-Coupled S2D⁰



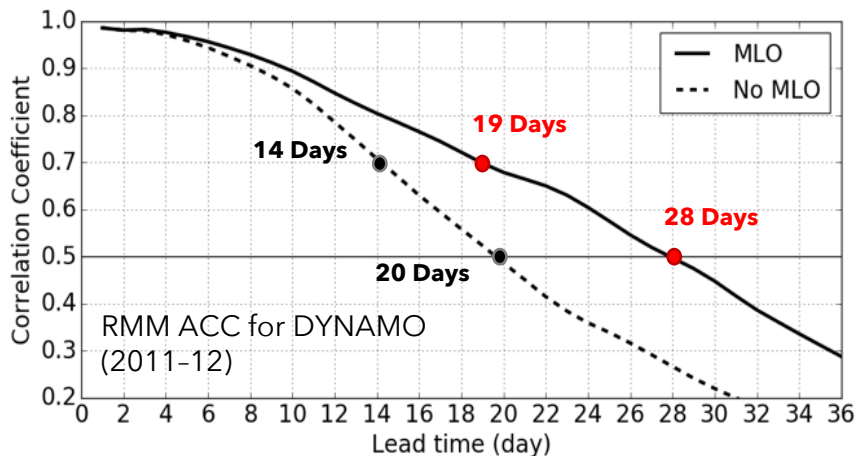
Courtesy Baoqiang Xiang and Yongqiang Sun

Madden-Julian Oscillation

S-SHiELD (25km) and T-SHiELD (4-km two-way nest)

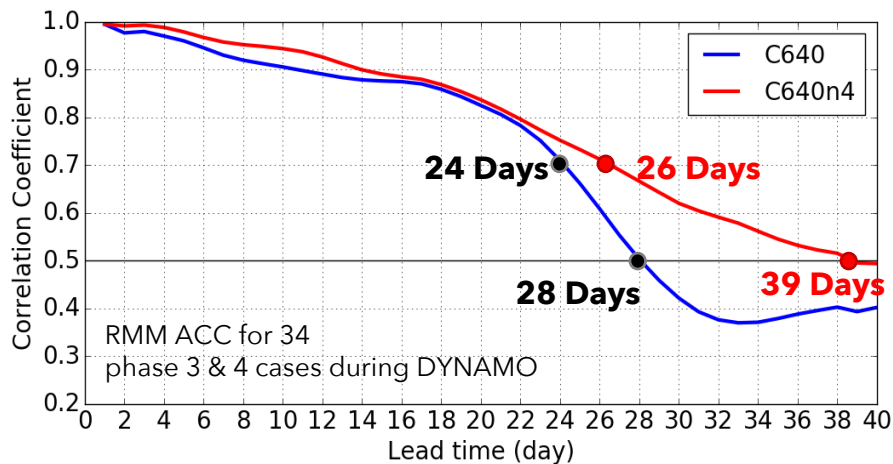


25-km S-SHiELD



Harris et al. 2020, JAMES

4-km nested T-SHiELD



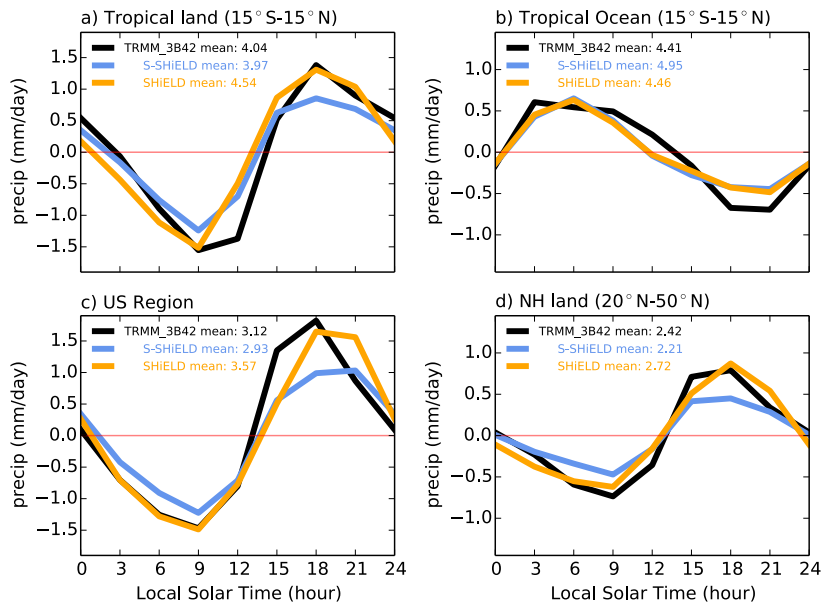
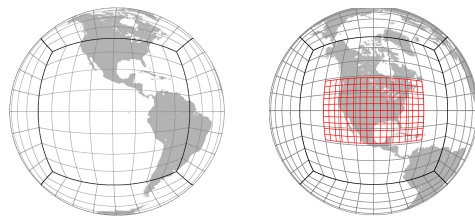
Courtesy Kun Gao

Mixed-layer ocean adds 8 days of useful skill

4-km Maritime Continent Two-Way Nest *efficiently* improves predictability and propagation of MJO compared to **16-km uniform parent**

Diurnal Cycle

S-SHiELD (25km) and T-SHiELD (5-km two-way nest)

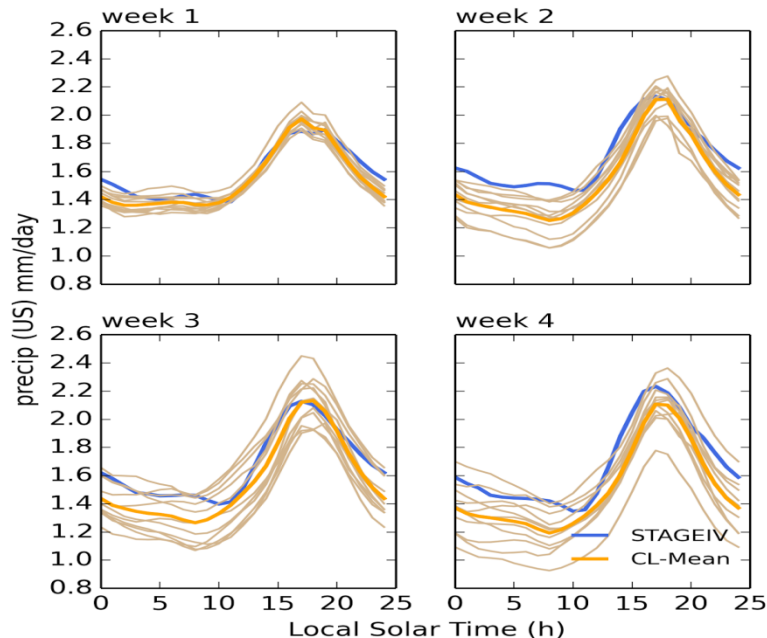


JJA Diurnal Cycle for 25-km S-SHiELD climate sim and 13-km SHiELD forecasts vs. TRMM

► Superior to all CMIP5 Models

Harris et al. 2020, JAMES

Diurnal Cycle (US)



US MAMJ Diurnal Cycle for 5-km C-SHiELD S2S forecasts vs. StageIV

Courtesy Kai-Yuan Cheng

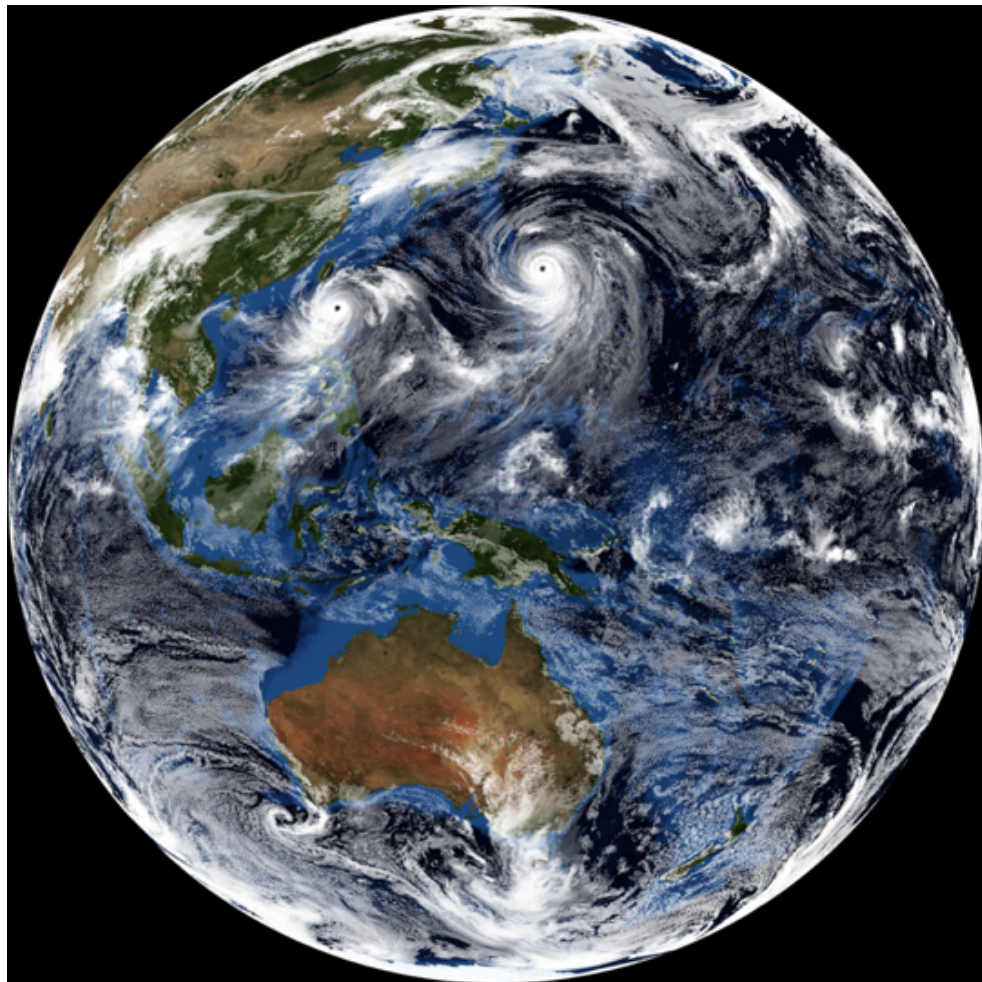
Global cloud-resolving modeling

X-SHiELD
C3072 (3.25km)

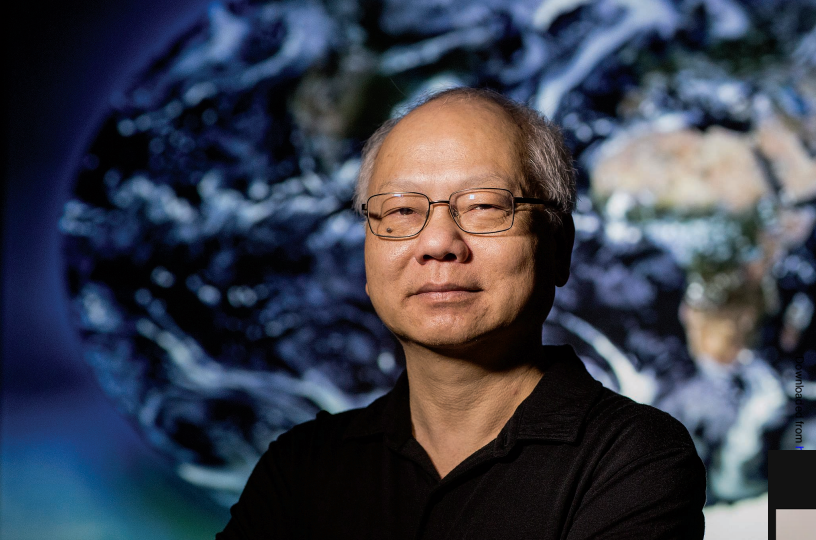


3.25-km GCRM seamlessly integrated with other GFDL models

Partnering with Vulcan, Inc and the University of Washington to build a hybrid ML model to emulate X-SHiELD in a cheap low-resolution model



Courtesy S-J Lin, Xi Chen, and Linjiong Zhou



www.gfdl.noaa.gov/fv3

shield.gfdl.noaa.gov

github.com/NOAA-GFDL/GFDL_atmos_cubed_sphere

THE WEATHER MASTER

How Shian-Jiann Lin's atmospheric grids could unify weather forecasts and climate models

By Paul Voosen

