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

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

UFS
UNIFIED FORECAST SYSTEM

GFDL
AM4 CM4 ESM4
SHiELD SPEAR

GFSv15 v16 GEFSv12
MRW SRW HAFS …

NOAA RESEARCH
NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION

GFDL FV3

NASA
GEOS, DAS, MERRA(2)
Ames Mars GCM

HARVARD
GEOS Chem
GEOS-Chem High-Performance

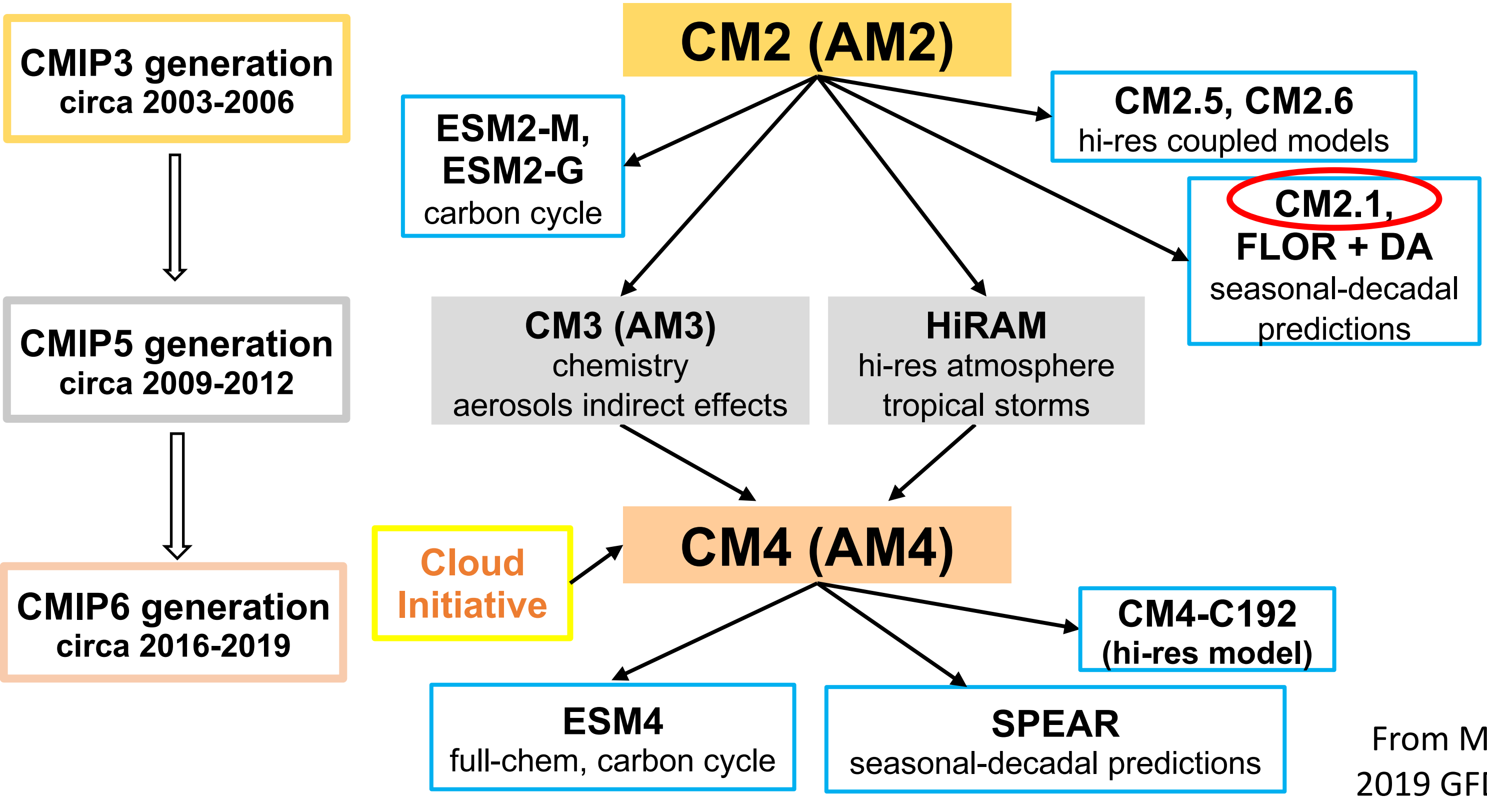
NCAR
CAM-FV
CAM-FV3

IAP
Chinese Academy of Sciences
LASG FAMIL

Taiwan Central Weather Bureau
CWBGFS

FV3 at GFDL

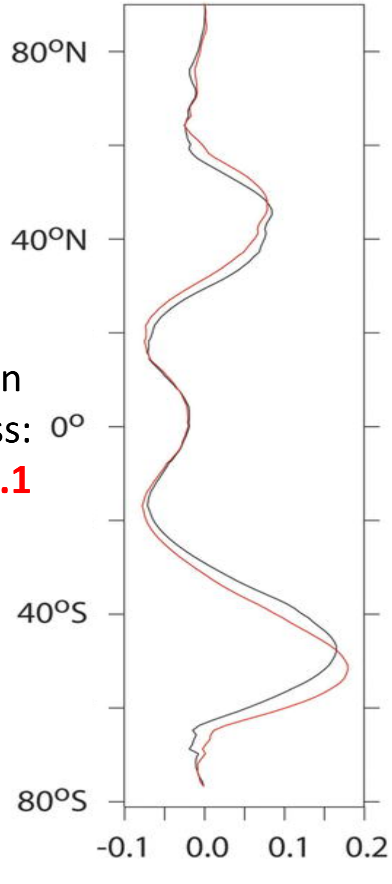
Recent history of GFDL Global Climate Models

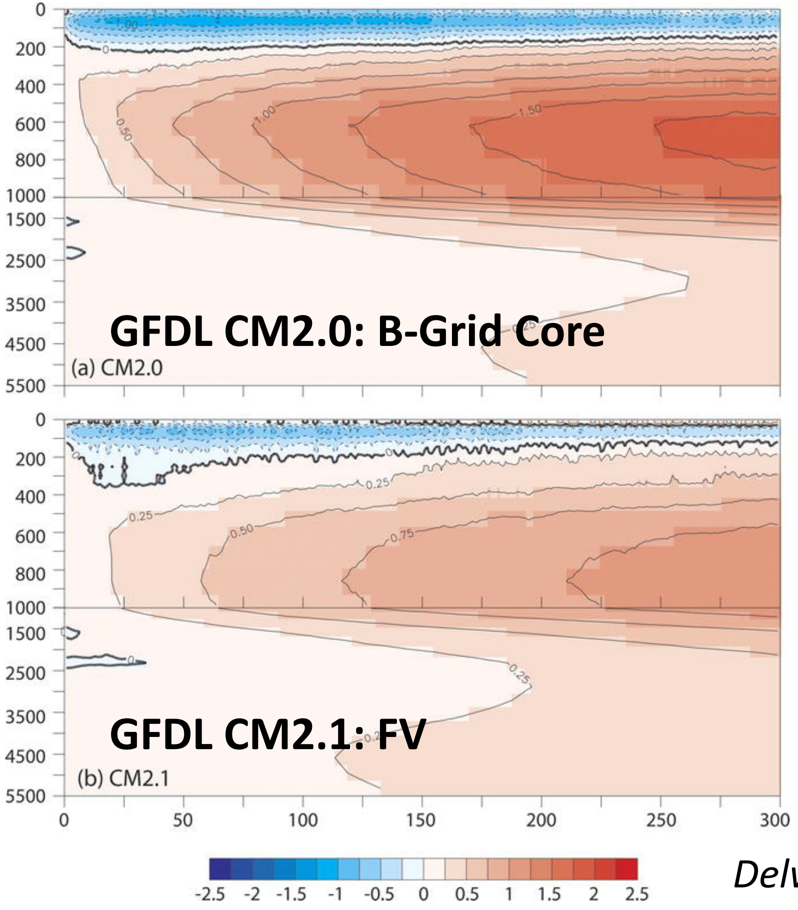


From Ming Zhou
2019 GFDL Review

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

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

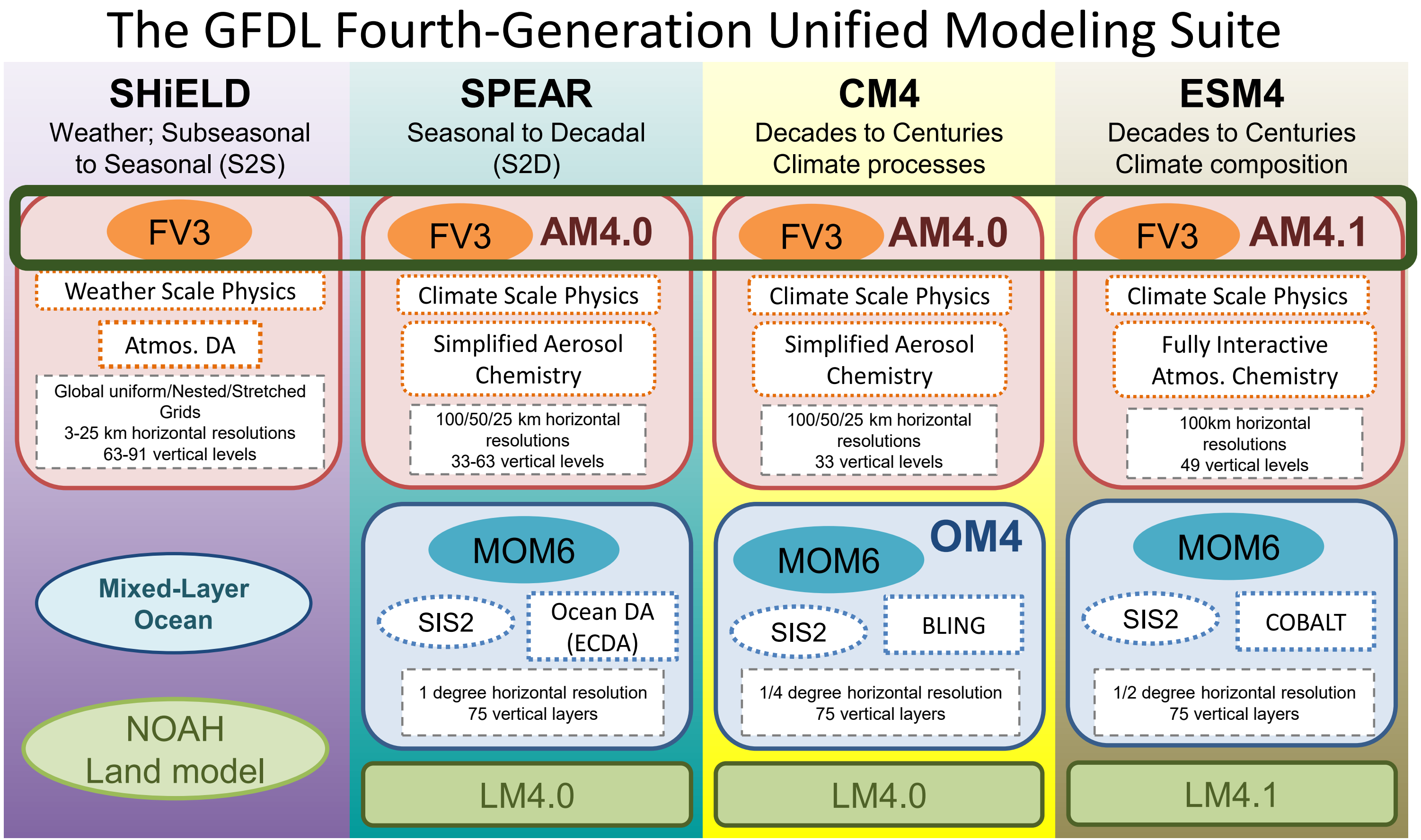




Global-mean Ocean Temp diff. (K) in control-climate integrations

Delworth et al. 2006 JClim

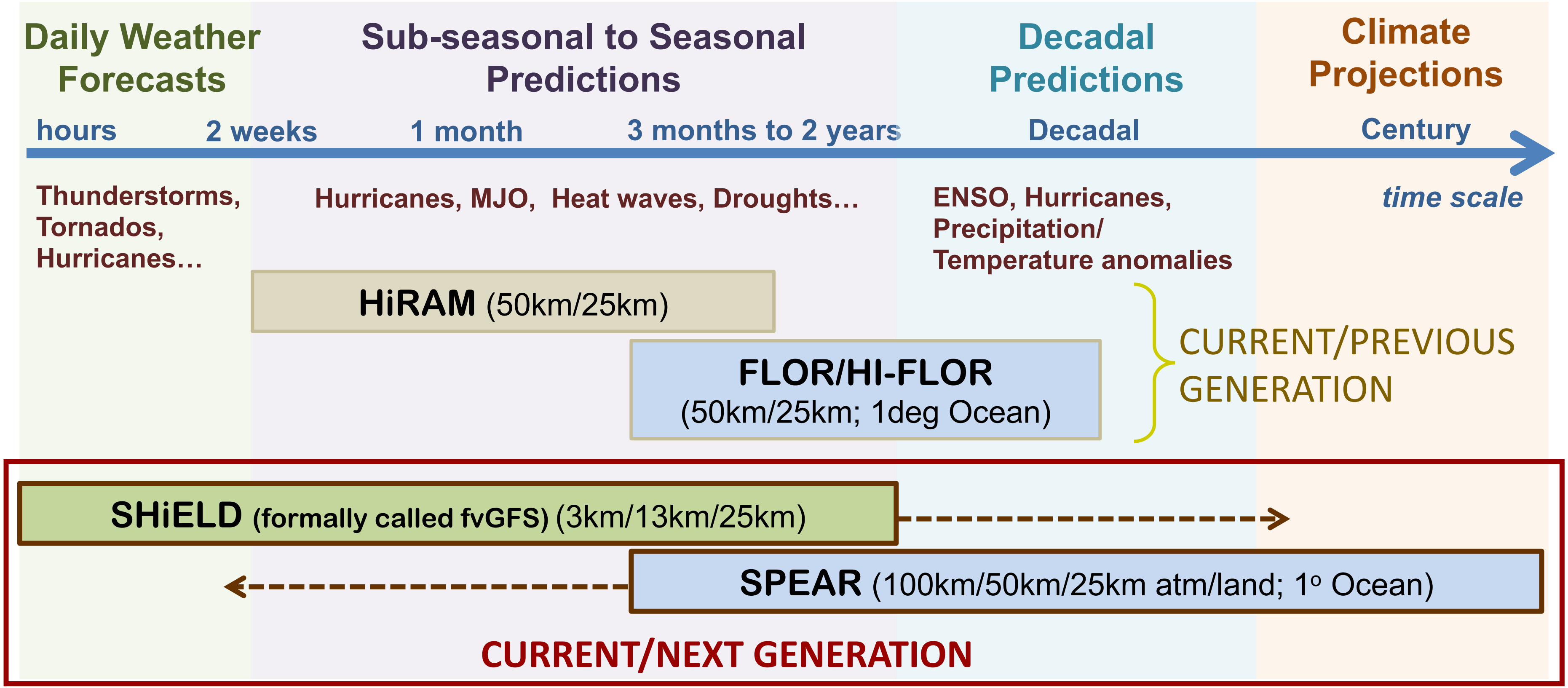
FV3 at GFDL



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

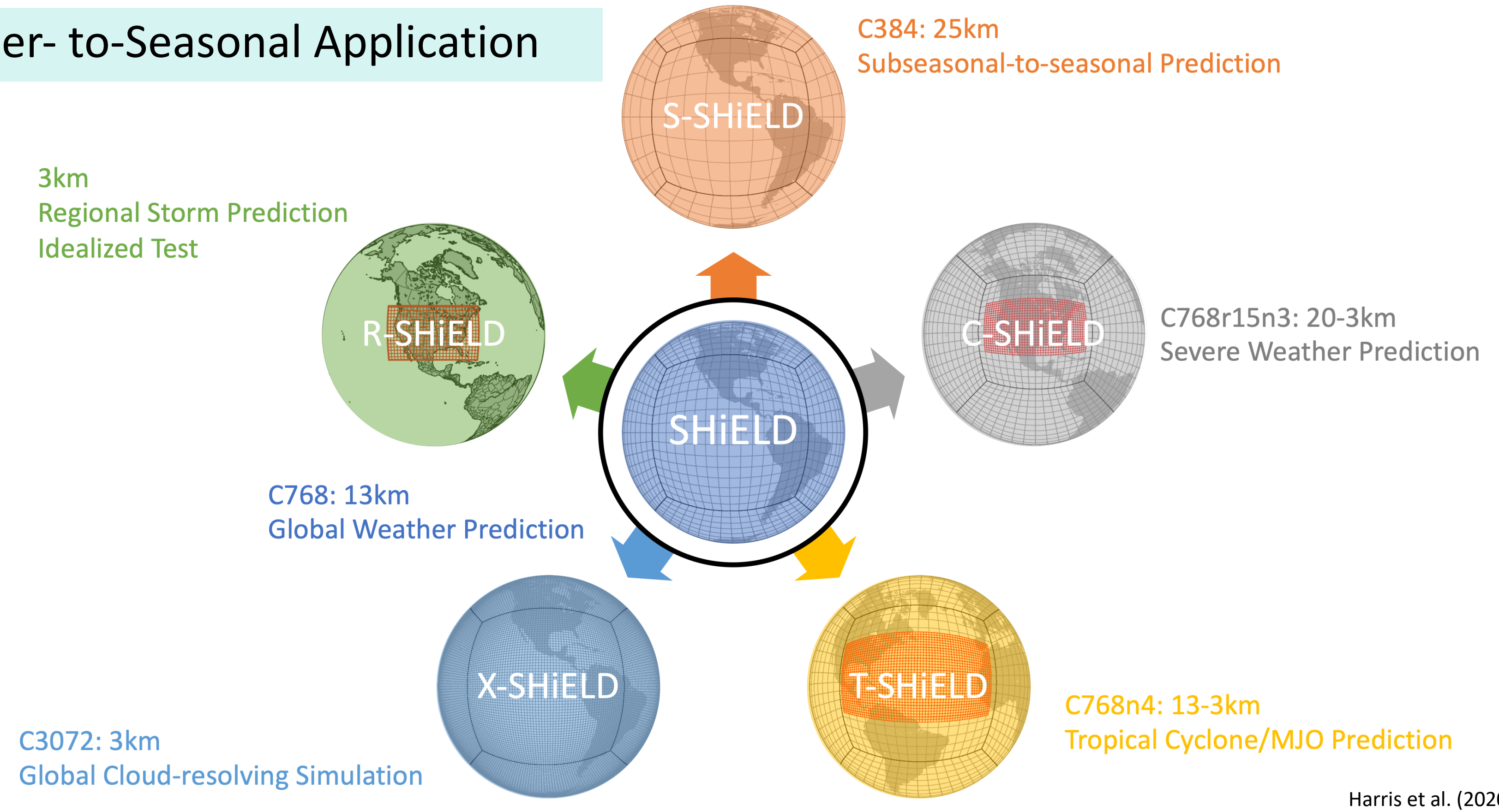
Modern NWP

GFDL seamless prediction/projection modeling system

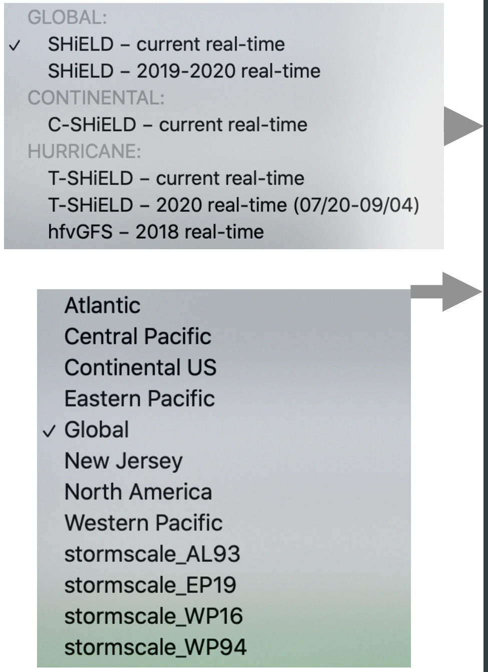


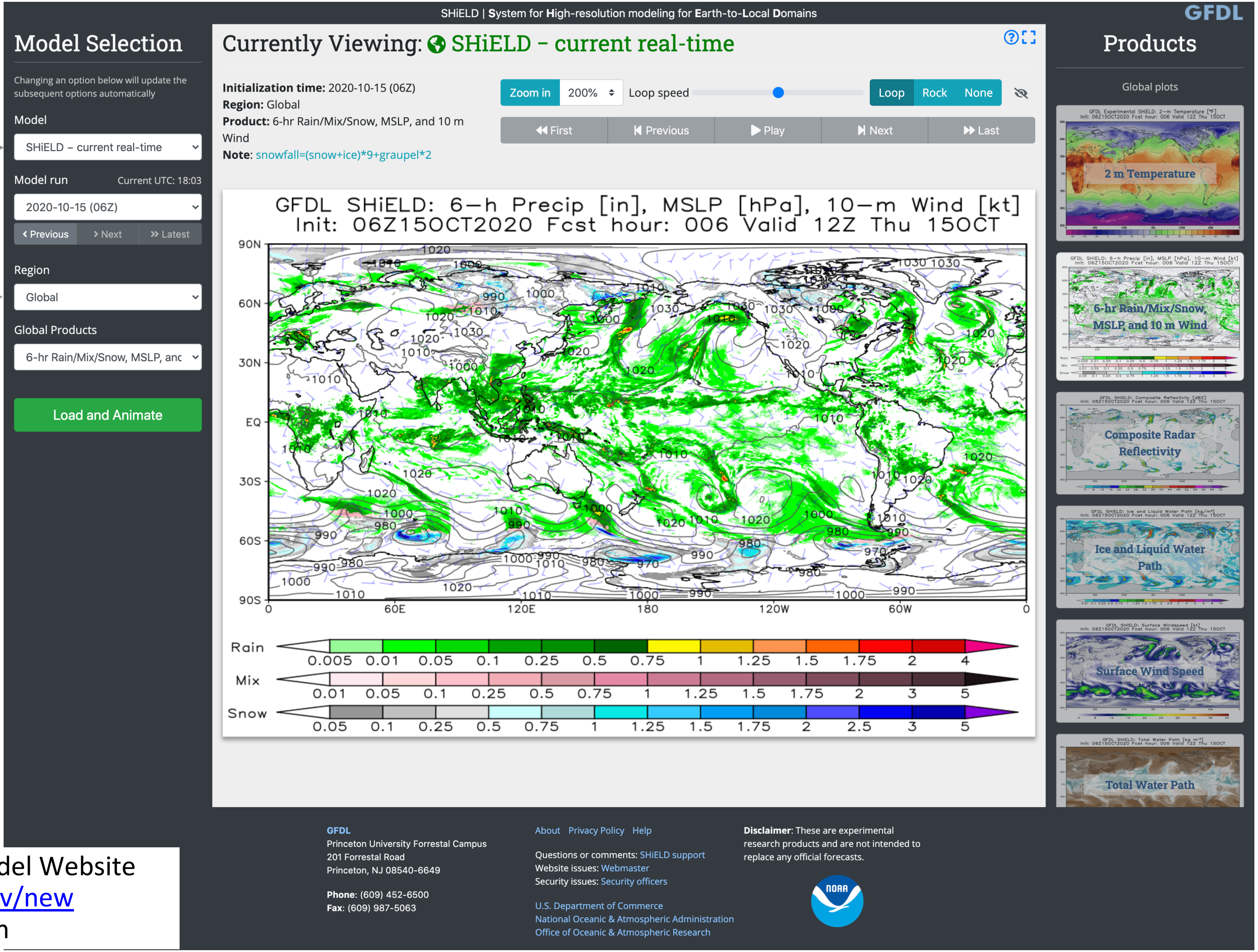
SHiELD **S**ystem for **Hi**gh-Resolution Prediction on **E**arth-to-**L**ocal **D**omains

Weather- to-Seasonal Application



Harris et al. (2020)
Courtesy of Linjiong Zhou, Kun Gao, Kai-Yuan Cheng





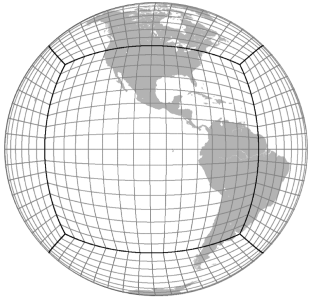
The GFDL SHiELD Real-Time Model Website

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

Operator: Matt Morin

13-km SHiELD Evolution

Courtesy Linjiong Zhou
Harris et al, 2020, JAMES



Incremental improvements in FV3 and Physics

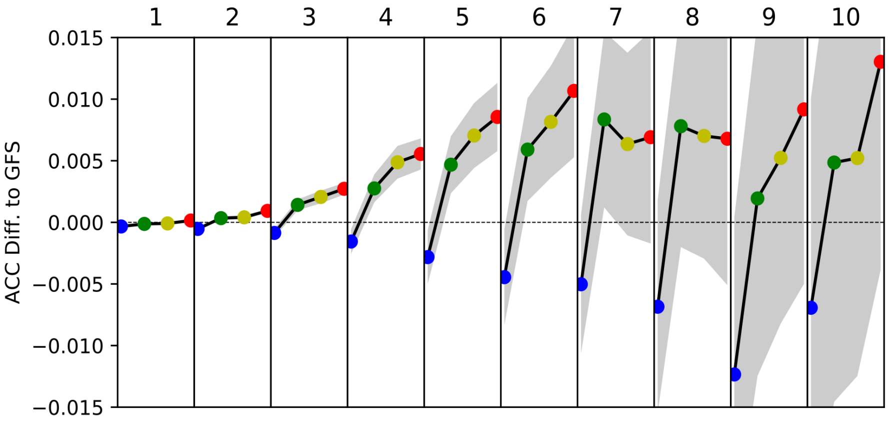
2016
Tuned NGGPS
GFS Physics

2017
GFDL Microphysics
EMC SA-SAS

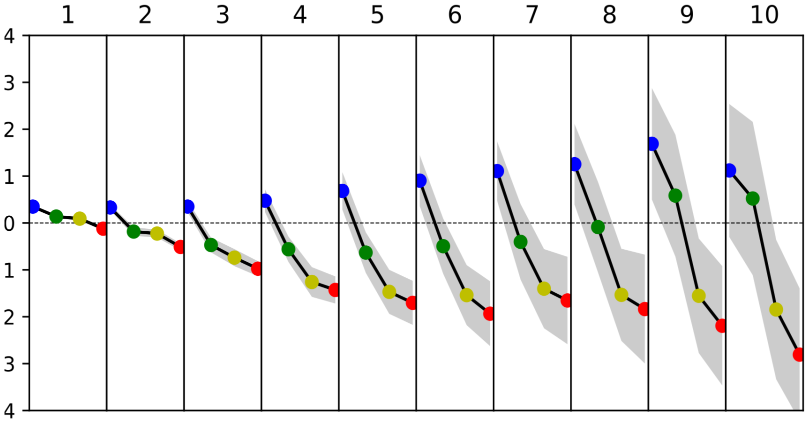
2018
Inline GFDL MP
Pos-Def Advection
YSU Turbulence
Mixed-layer Ocean

2019
Updated FV3
Revised GFDL MP
URI-GFDL Sea State

2020
Overhauled GFDL MP
New cloud-radiation
UW/EMC TKE-EDMF



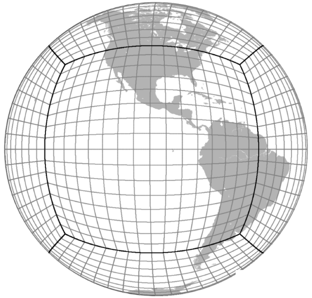
Global **H500 ACC** Diff. to GFS



Global **H500 RMSE** Diff. to GFS

13-km SHiELD Evolution

Courtesy Linjiong Zhou
Harris et al, 2020, JAMES



Incremental improvements in FV3 and Physics

2016
Tuned NGGPS
GFS Physics

2017
GFDL Microphysics
EMC SA-SAS

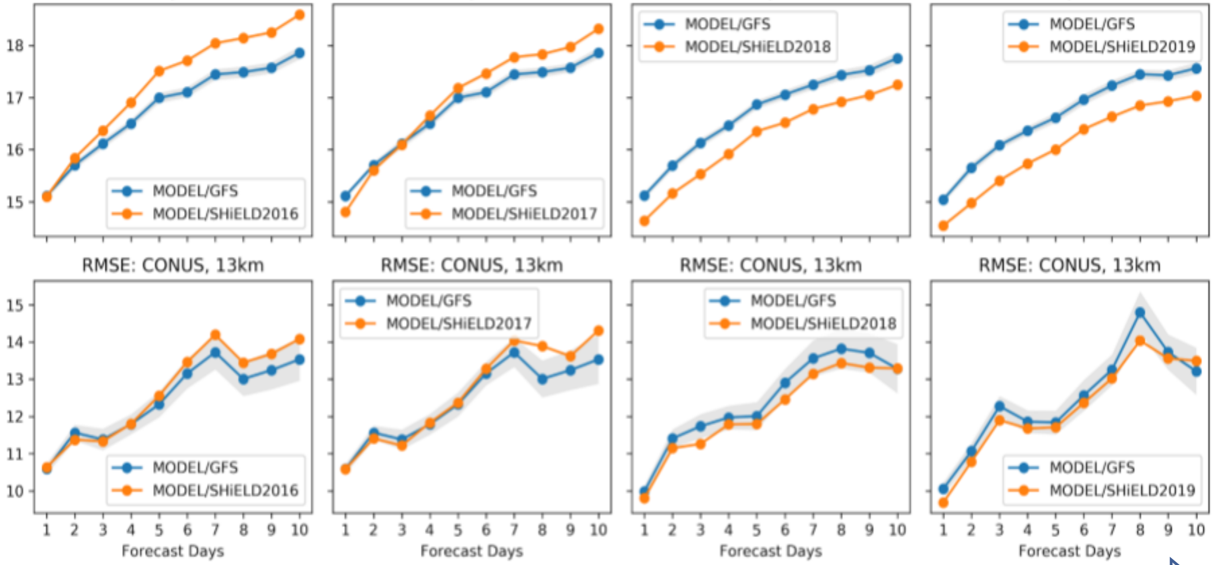
2018
Inline GFDL MP
Pos-Def Advection
YSU Turbulence
Mixed-layer Ocean

2019
Updated FV3
Revised GFDL MP
URI-GFDL Sea State

2020
Overhauled GFDL MP
New cloud-radiation
UW/EMC TKE-EDMF

Tropical Precipitation vs. TRMM
25-km data

CONUS Precipitation vs. StageIV

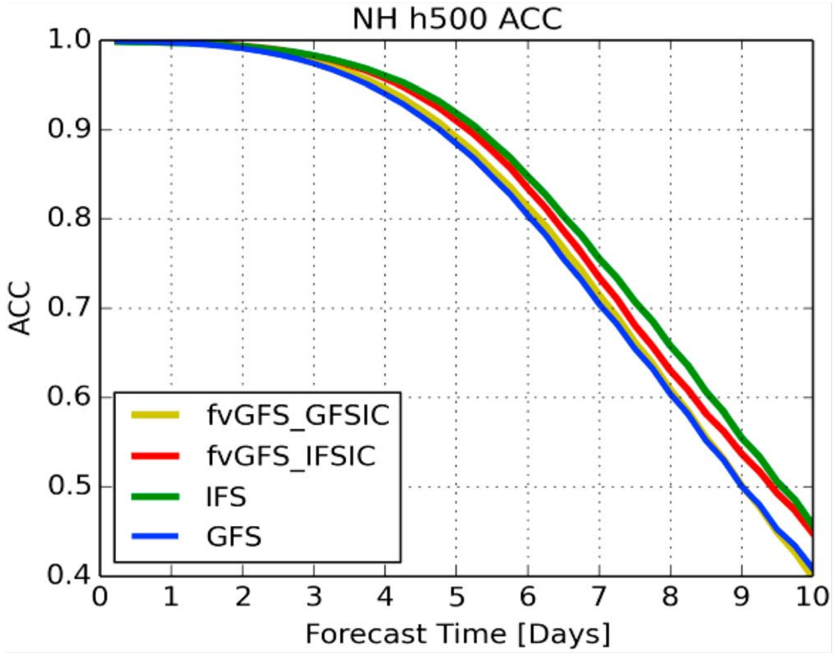


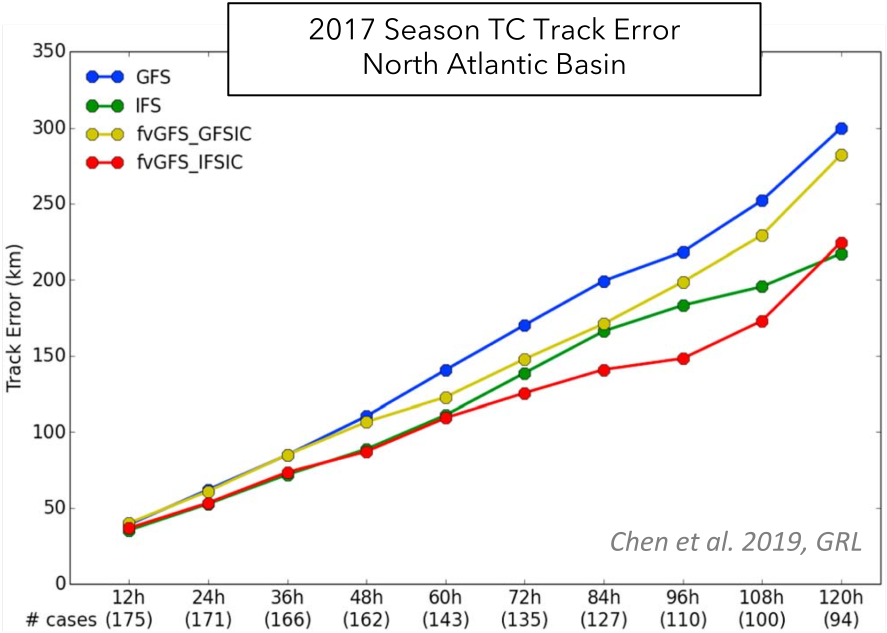
RMSE
Lower is Better

Year-over-year reduction in precipitation forecast error

The importance of initial conditions

SHiELD C768 (13km)





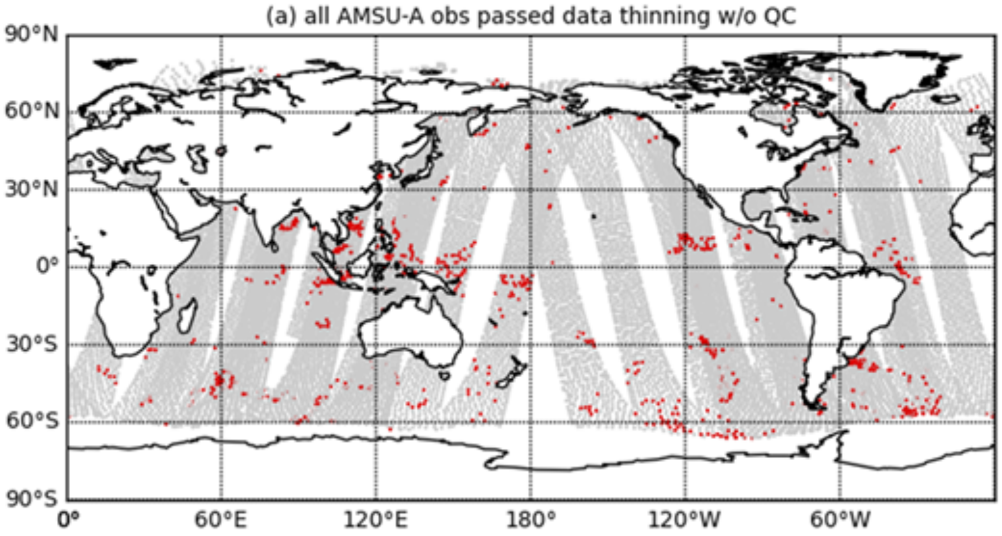
Ongoing Collaborations with ECMWF: **DIMOSIC** Project (**DI**fferent **MO**dels - **S**ame **I**nitial **C**onditions) based on

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

Data Assimilation in SHiELD

DA in FV3-based GFSv15 prototype

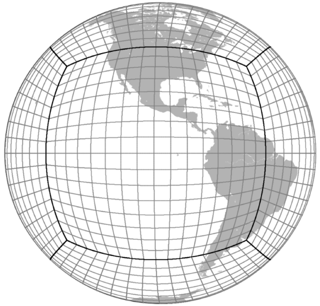
Benefited form the use of the GFDL microphysics scheme, the all-sky radiance assimilation framework was expanded to include **precipitating hydrometeors**.

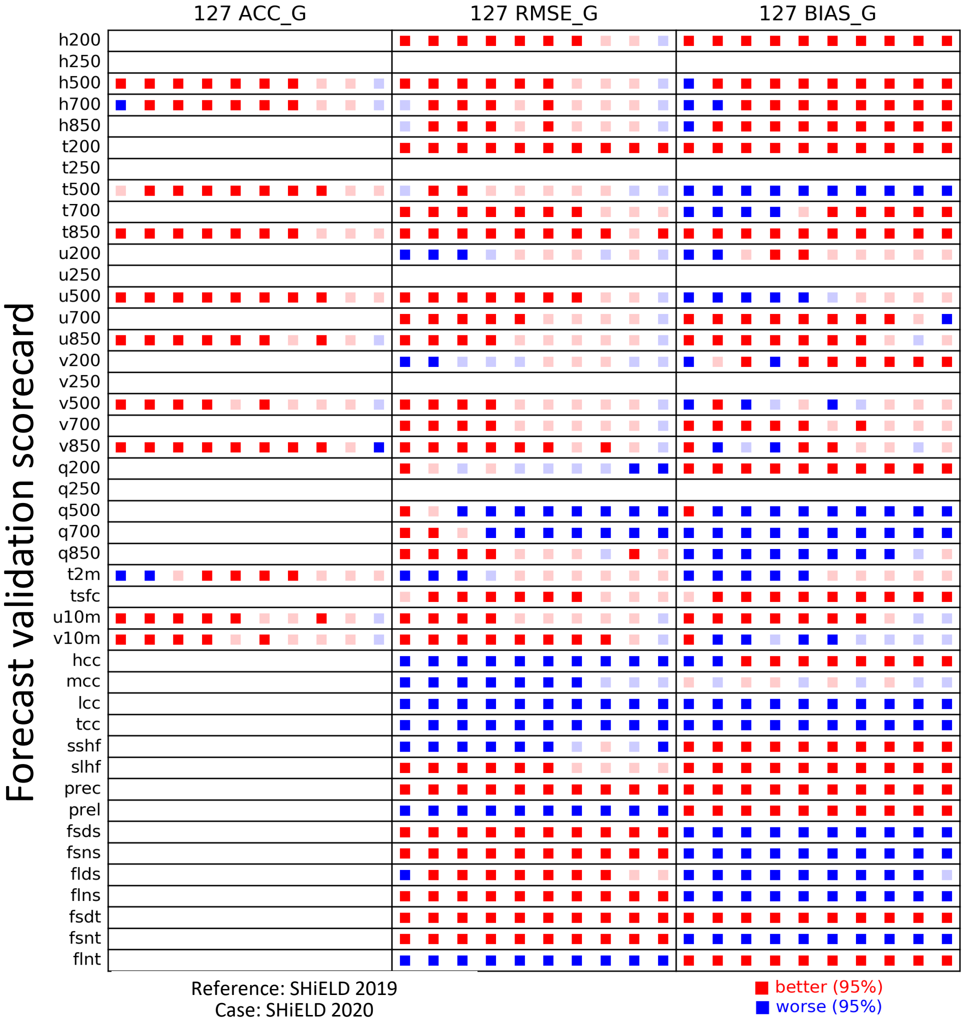


Locations of AMSU-A **observations that meet the precipitation screening criterion in deep-convection (high-impact) areas** are rejected in the original all sky framework but are kept in the new all-sky framework

M Tong et al. 2020, MWR

SHiELD v2020
Push our flagship to **8.5 km** resolution (C1152)



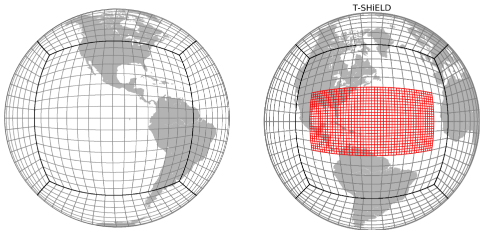


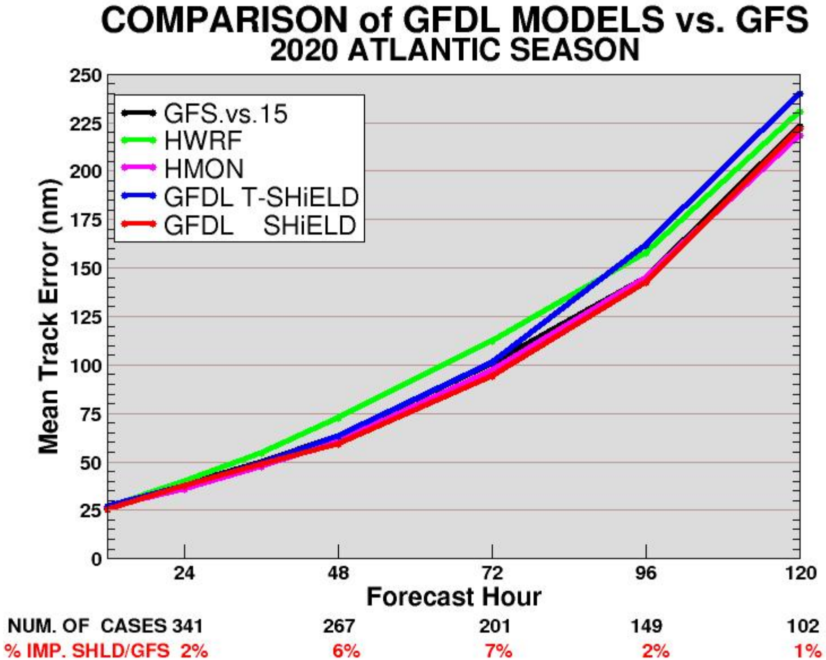
Major changes:
- 2020 version of FV3
- 2020 version of GFDL MP
- YSU PBL -> TKE-EDMF PBL
- GFSv14 ICs -> GFSv15 ICs

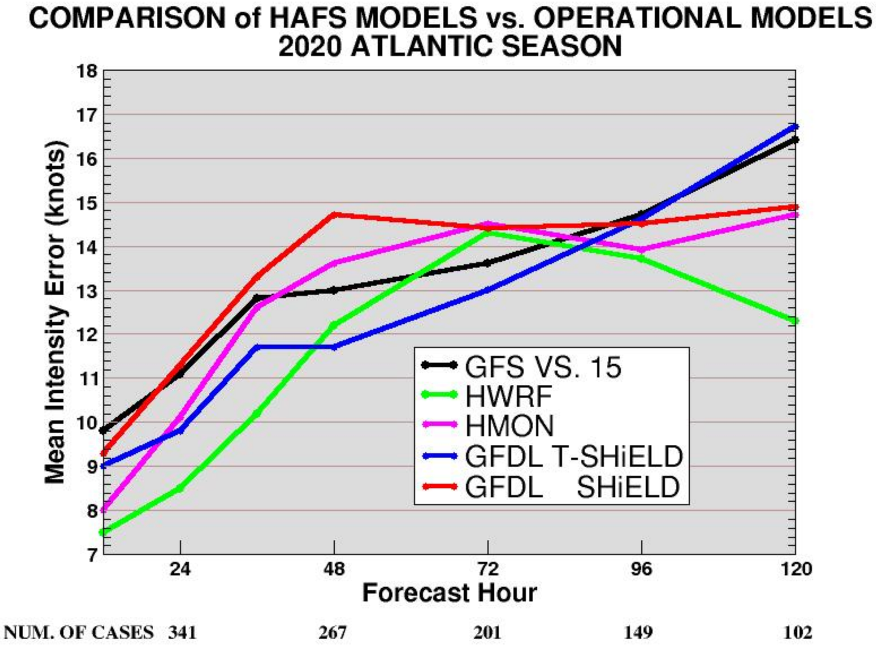
Other changes:
- Horizontal resolution: 13km -> 8.5km
- Latest version of fix_am
- Mountain block intensity
- 2020 version of FMS

Hurricane forecasts

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





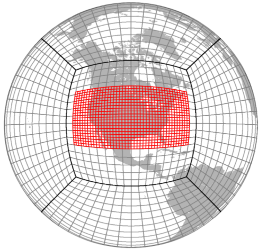


Results as of 26 October 2020.

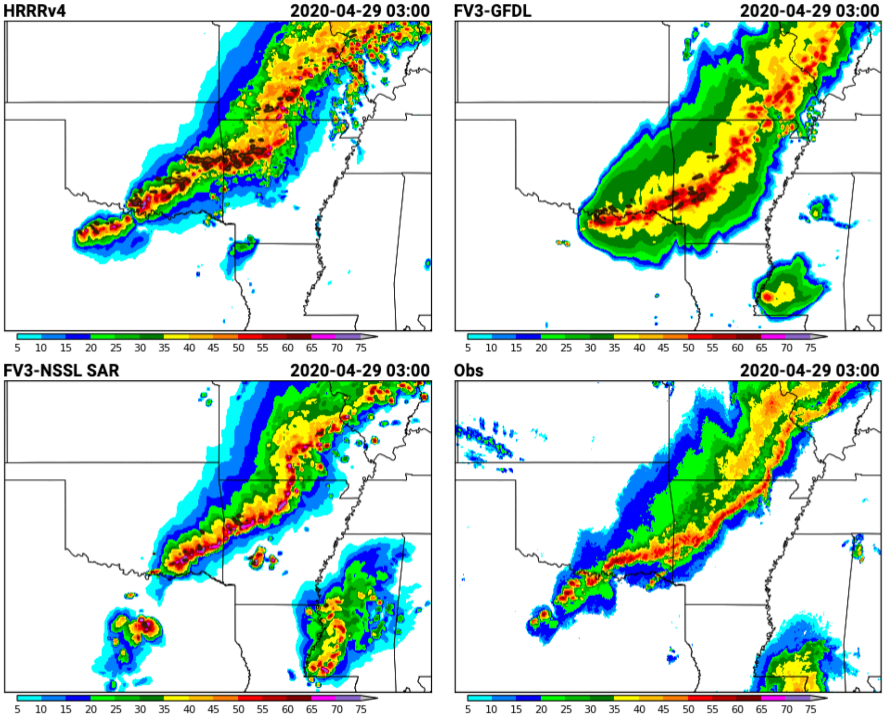
Courtesy Kun Gao & Morris Bender

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

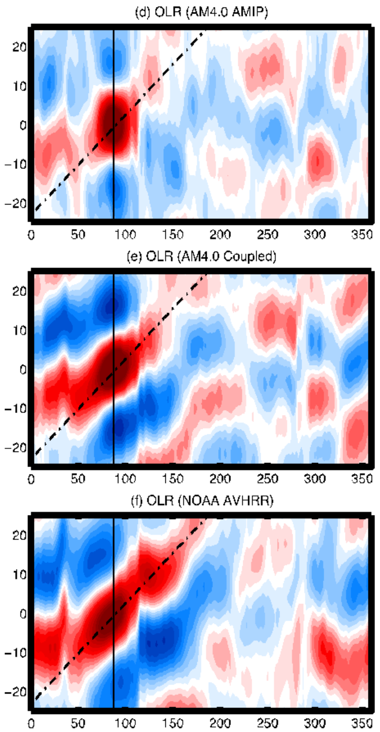
CMIP Earth-System Models

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

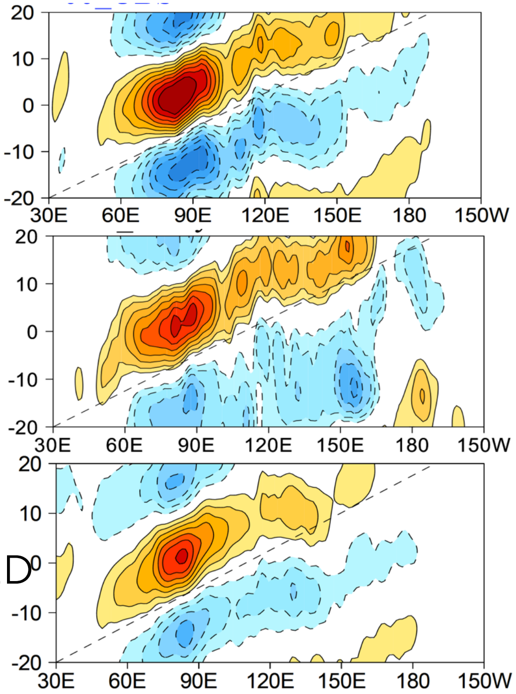


S2S & S2D Prediction Models

Observations

25-km S-SHiELD Atmos. w/ MLO

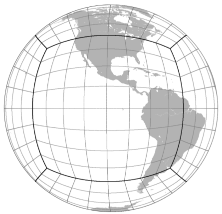
50-km SPEAR MOM6-Coupled S2D

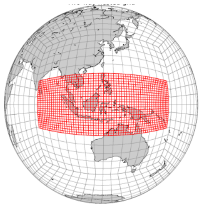


Courtesy Baoqiang Xiang and Yongqiang Sun

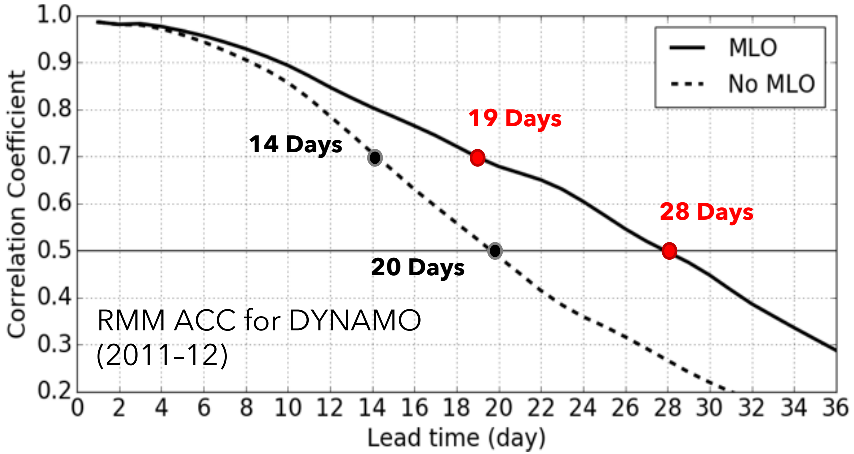
Madden-Julian Oscillation

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





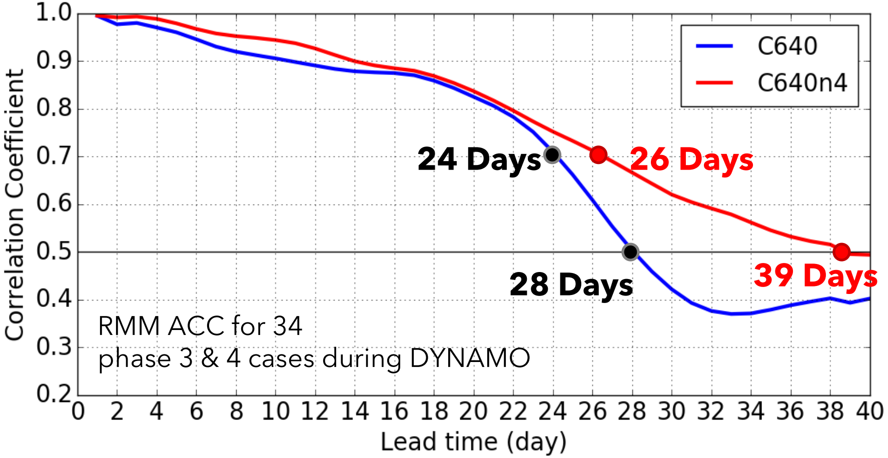
25-km S-SHiELD



Harris et al. 2020, JAMES

Mixed-layer ocean adds 8 days of useful skill

4-km nested T-SHiELD

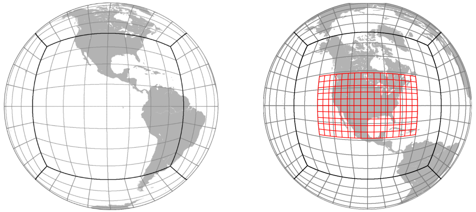


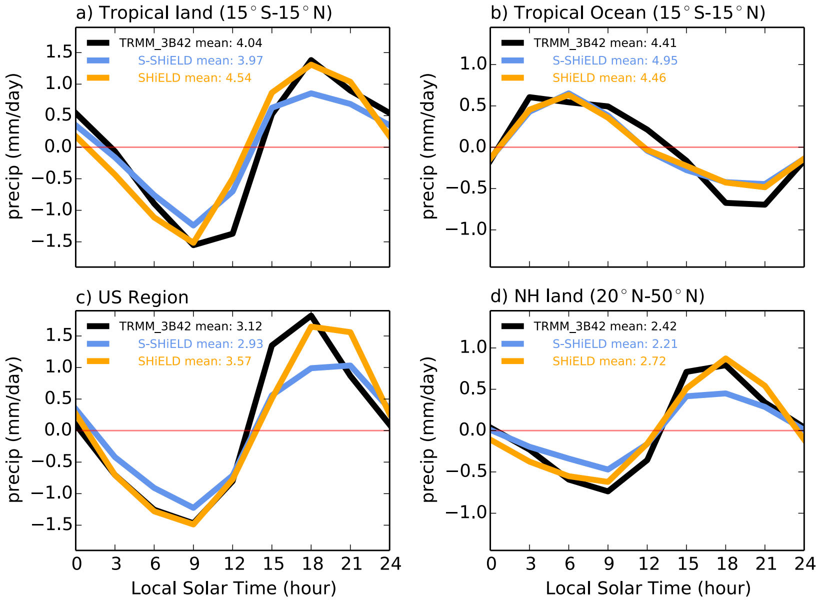
Courtesy Kun Gao

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)

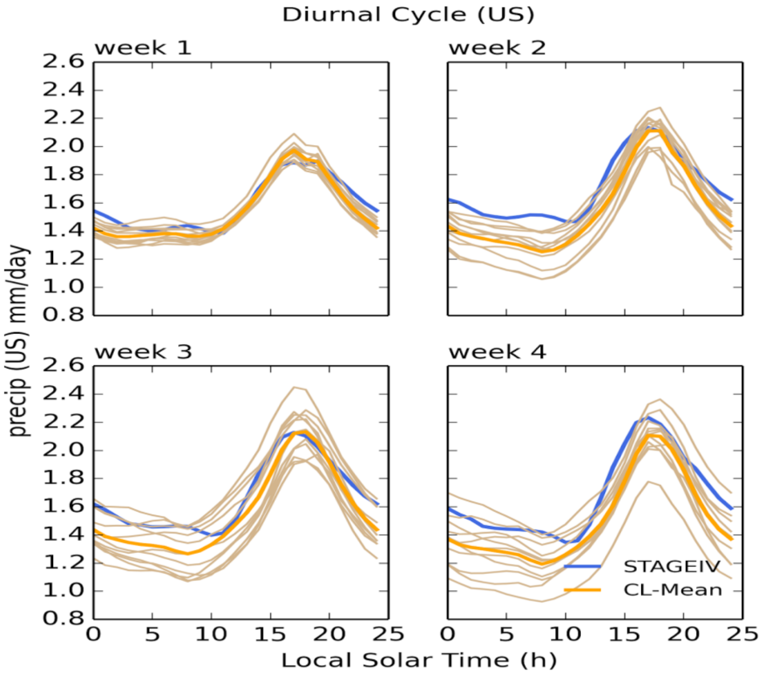




JJA Diurnal Cycle for 25-km S-SHiELD climate sim and 13-km SHiELD forecasts vs. TRMM

➤ Superior to all CMIP5 Models

Harris et al. 2020, JAMES



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

Courtesy Kai-Yuan Cheng

Global cloud-resolving modeling

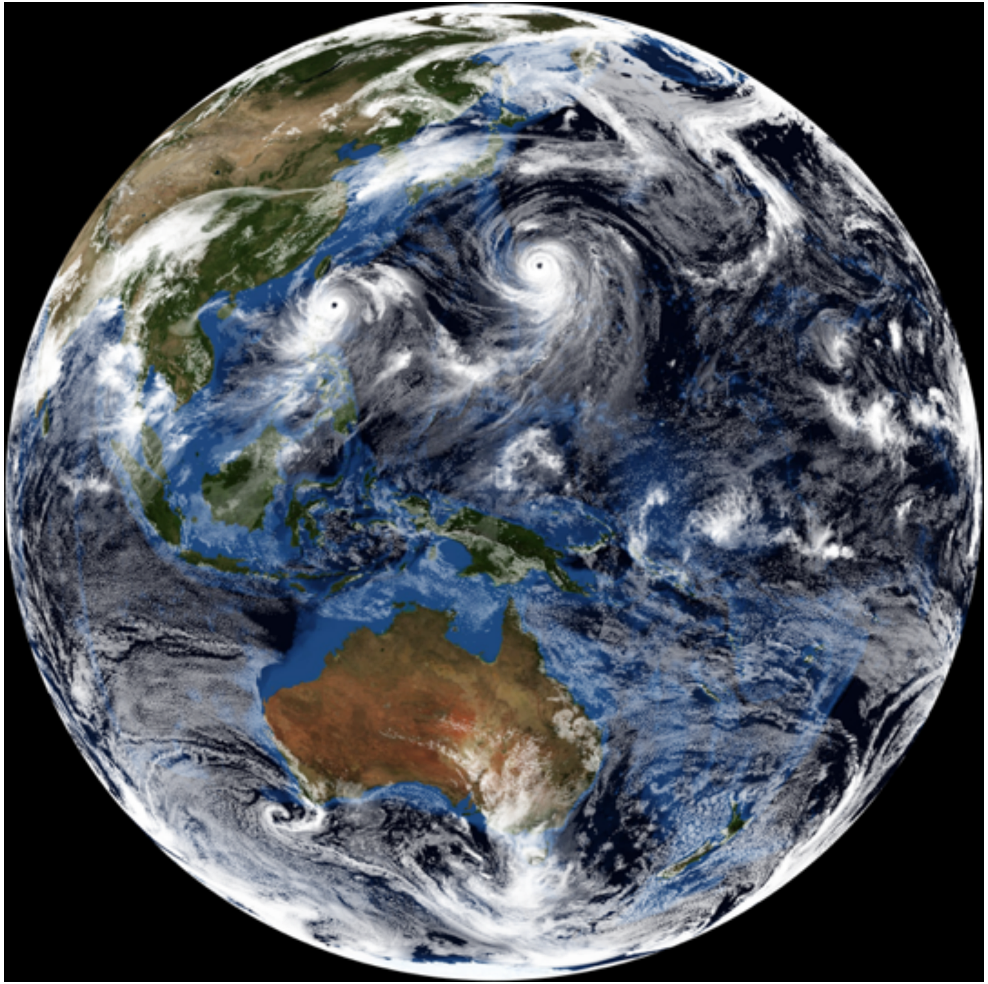
X-SHiELD
C3072 (3.25km)

3.25-km GCRM seamlessly integrated with other GFDL models

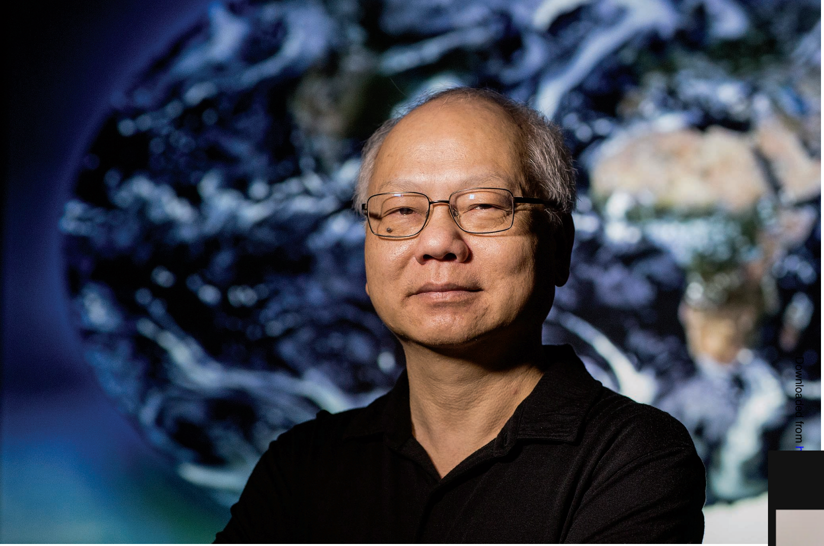
Partnering with Vulcan, Inc and the University of Washington to build a hybrid ML model to emulate X-SHiELD in a cheap low-resolution model

VULCAN

GFDL



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



THE WEATHER MASTER

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

By **Paul Voosen**

www.gfdl.noaa.gov/fv3

shield.gfdl.noaa.gov

github.com/NOAA-GFDL/GFDL_atmos_cubed_sphere