Next Generation Global Prediction System:
FV3 Dynamic Core Powered Unified Model Development for NCEP Operations

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Outline

FV3 Dynamic Core: Central component for NOAA's Next Gen. Prediction Systems

Progress on FV3GFS and FV3GDAS Developments

Plans for Assimilation of JPSS Data

Results from Real-Time Experiments

FV3 Dynamic Core for Regional Convective Allowing Modeling Applications and moving nests for hurricanes

FV3GFS Implementation Plan

FV3GFS	FY17				FY18				FY19				FY20			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Evaluate and Document FV3	Evaluate, prepare and document FV3 dycore for GFS															
FV3 Dycore in NEMS		Implement FV3 dycore in NEMS@														
FV3 Dycore with GFS Physics			Couple FV3 to GFS physics (NUOPC physics driver) perform forecast-only experiments, tuning and													
Preliminary GSI/EnKF DA for			Develop DA techniques % (native grid vs physics grid; New data)													
Cycled FV3GFS* experiments (real-time parallels)				Cycled experiments, benchmarking, efficiency and optimization												
							Real-time parallel FV3GFS forecasts to the field									
Develop end-to-end FV3GFS					Pre- and post-processing, verification & downstream											
Pre-implementation T&E for FV3GFS@&%								3-year retrospective + real-time parallels, EMC and Community Evaluation								
Transition to operations							Experimental (beta) implementation of FV3GFS*			NCO Parallel	NEMS/FV3GFS in operations					
Advancement of FV3GFS											Further advancements of FV3GFS with inputs from NGGPS and community contributions & Global-Meso unification (Unified					

* Q3FY18 FV3GFS will be very similar to operational GFS being implemented in May 2017

'@ Q3FY19 FV3GFS target resolution is ~10km grid with 127 layers, extends up to 80 km.

'& Advanced physics: Scale-aware convection, SHOC PBL, Double-moment microphysics, Unified convective and orographic gravity wave drag etc

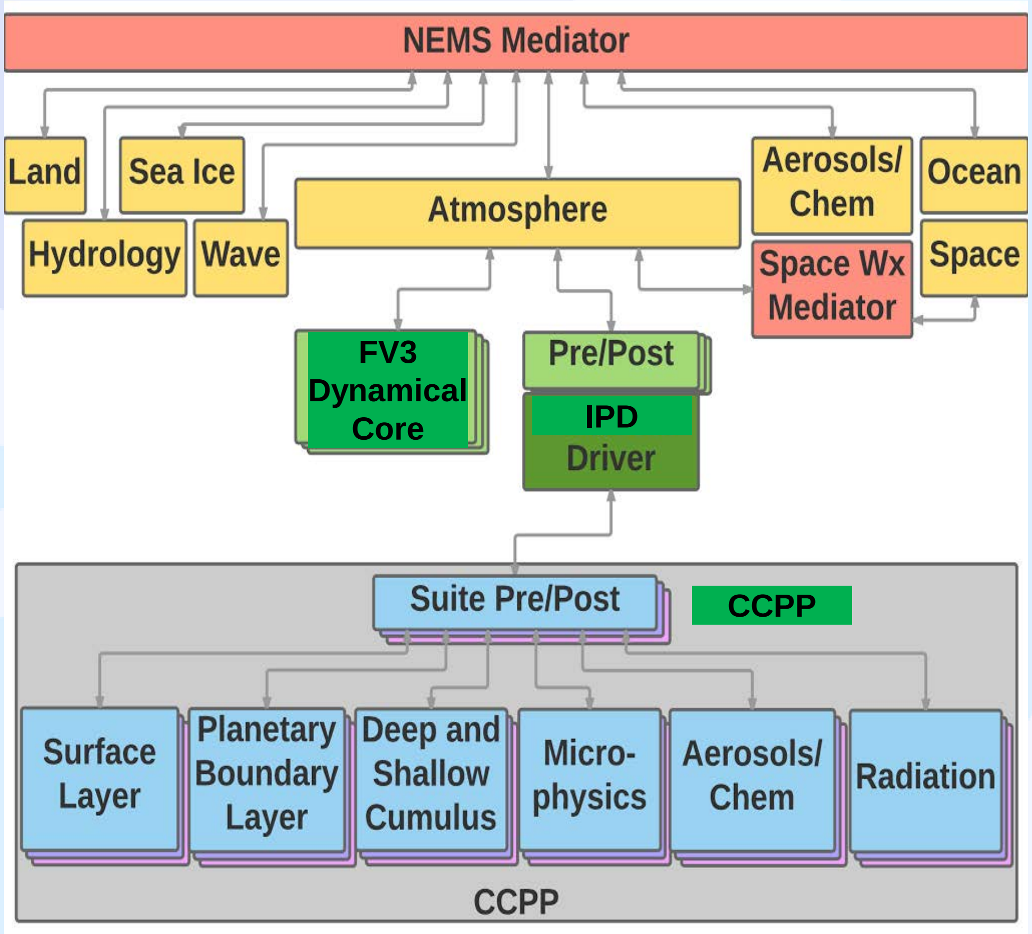
'% DA system will be @35 km 127 levels using 4d-Hybrid EnVAR

FV3GFS CAP and Write Component
ESMF Based NEMS FV3GFS - Object Oriented Design

NEMS is based on ESMF and follows NUOPC convention

A numerical model in NEMS is represented by software and implemented as an ESMF grid component.

Each ESMF grid component has its own internal state with internal methods



Physics: Two-Stream Strategy

NUOPC Physics Driver in NEMS using Community Common Physics Package (EMC, GFDL, ESRL, GMTB)

Physical Processes	Operational Physics (Evolved)	Advanced Physics* (CCPP)
Radiation	RRTMG	RRTMG (scale and aerosol aware, w/sub-grid scale clouds)
Penetrative convection and Shallow convection	SAS RAS	Scale-aware Chikira-Sugiyama & Arakawa-Wu; Grell-Freitas
Turbulent transport (PBL)	Hybrid EDMF	CS+SHOC (unified convection & turbulence)
Cloud microphysics	Zhao-Carr WSM-6	Double Moment scheme (Morrison, Thompson Barahona)
Gravity wave drag	Orographic GWD Stationary convective GWD	Unified representation of GWD
Ozone physics	NRL simplified scheme	Modified NRL scheme
Land surface model (LSM)	Noah	Noah and LIS
SST	Reynolds/RTG SST	NSST

Includes aerosol chemistry (NGAC) module

Progress on FV3GFS Development

- **FV3GFS Superstructure is created on EMC subversion to manage the code and workflow repositories**
  - *ESRL, GFDL and EMC are currently primary developers*
- **FV3GFS Forecast only experiments run in real-time four times a day**
  - *Uses operational GFS IC and GFS Physics, results available online*
  - ***http://www.emc.ncep.noaa.gov/gmb/wx24fy/NGGPS/fv3gfsb/***
- **FV3GFS is now in NEMS**
  - *NEMS CAP is available for FV3GFS*
  - *Real-time experiments switched to NEMS/FV3GFS by April 1, 2017*
  - *Interoperable Physics Driver (IPD V4.0) is delivered by GFDL*
  - *FV3GFS is coupled to CCPP style GFS Physics using IPD V4*
- **Data Assimilation for FV3 is progressing well**
  - *Stochastic Physics is implemented into FV3GFS*
  - *ESMF Regridding Tools are available in NEMS/FV3GFS*
  - *Cycled DA system in experimental mode by May 2017*

Resolution, Physics Grid, and Run-time on Cray
10-d forecast, 6-hourly output, 3.75-minute time step
C768, 13km, 3,538,944 points

Hydro/ non-hydro	precision	threads	nodes	CPU (min/10day)
Non-hydro	32-bit	2	64	89
Non-hydro	64-bit	2	64	137
Non-hydro	64-bit	2	144	69
hydro	64-bit	2	64	95
hydro	64-bit	2	144	51

Current Default Setting for Benchmark Test

Production requirement

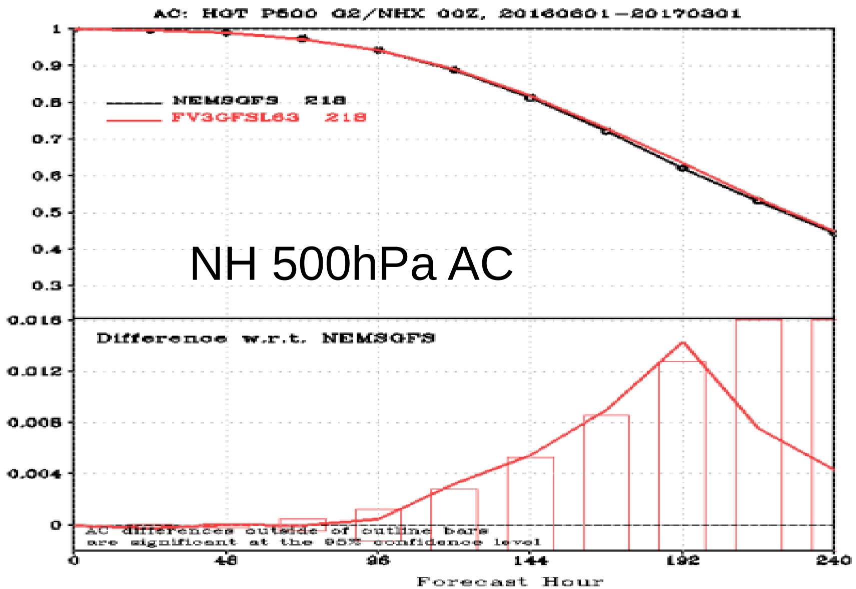
T1534 NEMS GFS (~13 km, 3072x1536), 61 nodes, 73 minutes

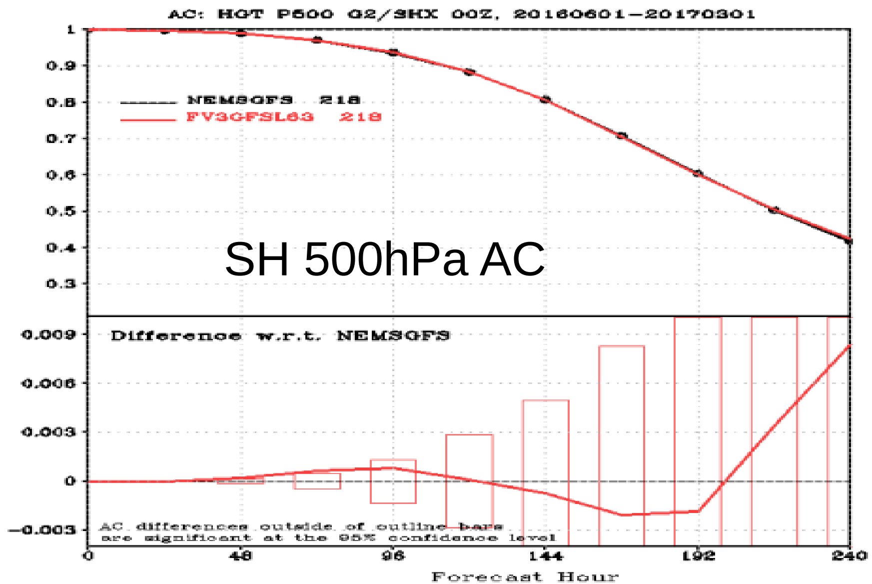
Benchmark Test of NEMS FV3GFS w/IPDv4 & NSST

- **Model:** NEMS FV3GFS + CAP + IPDv3 +NSST, non-hydrostatic, non-mono, 32-bit
- **Physics**:   Q3FY17 NEMS GSM physics, including NSST model, updated convection, new high-resolution MODIS land datasets and a few other minor updates.
- **Initial Conditions:** NEMS GSM (global spectral model) ICs, converted to FV3 grid using CHGRES
- **Forecast Length**: 240 hours, 3-hourly output
- **Control**: NEMS GSM parallels

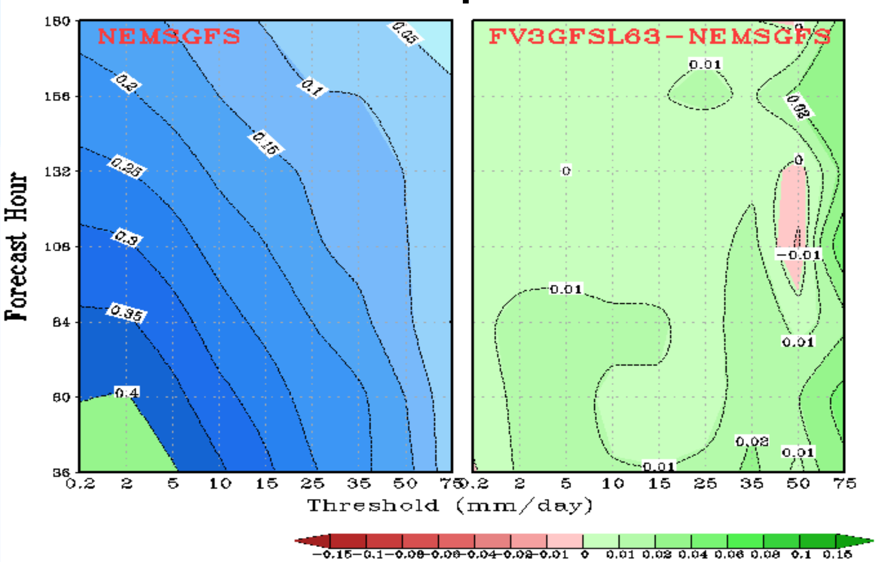
- **Benchmark Test 1**: L63 (top at ~1.0 hPa), C768 (~13km), Jun2016-Mar2017
  - http://www.emc.ncep.noaa.gov/gmb/wx24fy/NGGPS/fv3ipd4/
- **Benchmark Test 2**: L64 (top at ~0.4 hPa), C768 (~13km), Jun2016-Jul2017
  - http://www.emc.ncep.noaa.gov/gmb/wx24fy/NGGPS/fv3gfs_L65/

Test1: C768L63, Jun2016-Mar2017

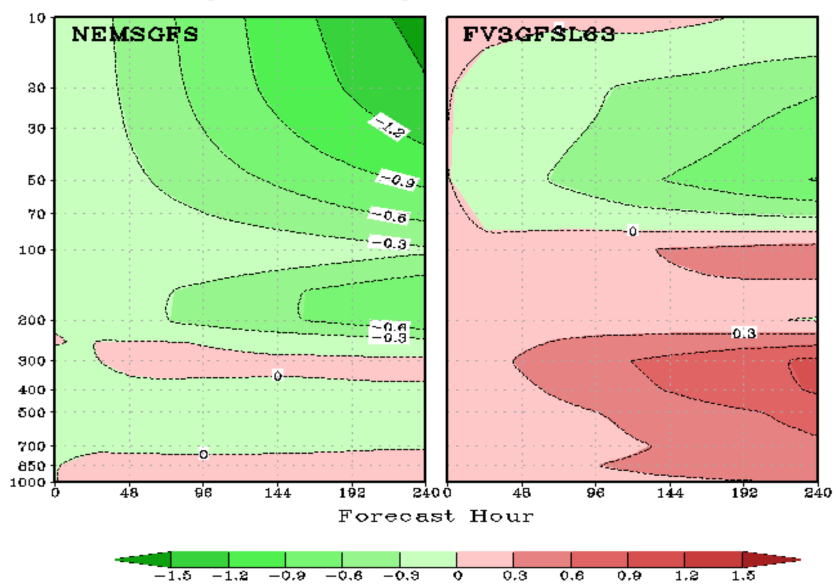




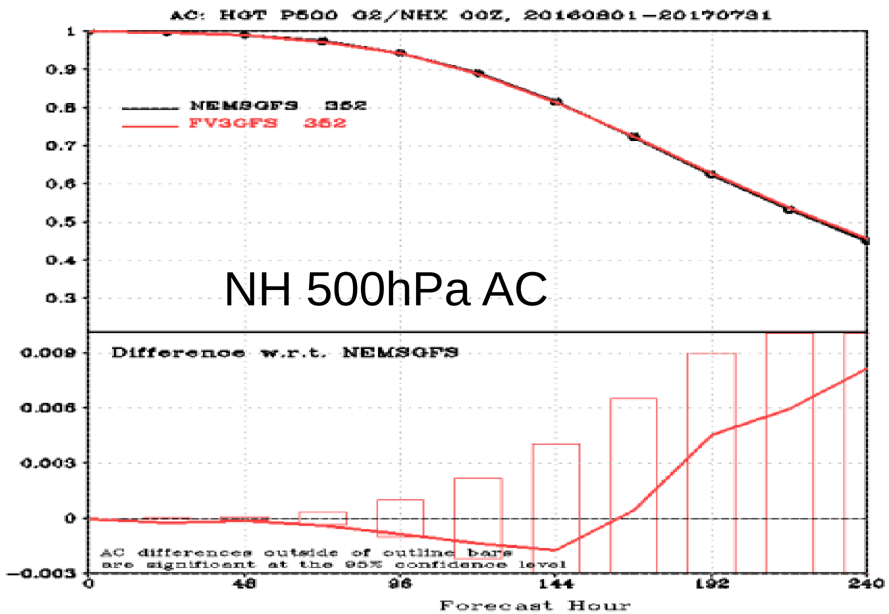
CONUS Precipitation ETS

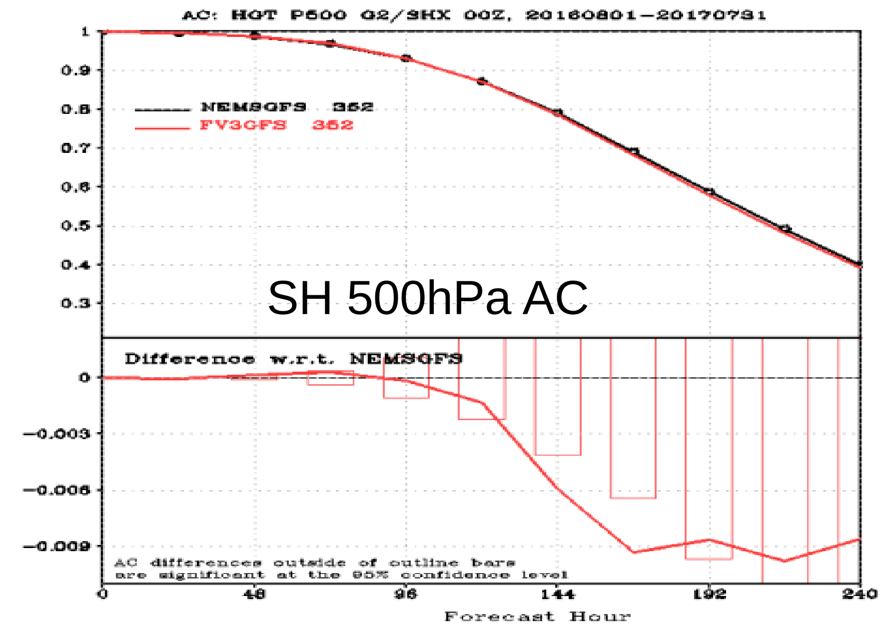


Tropical Temperature Bias



Test2: C768L64, Aug2016 – Jul2017





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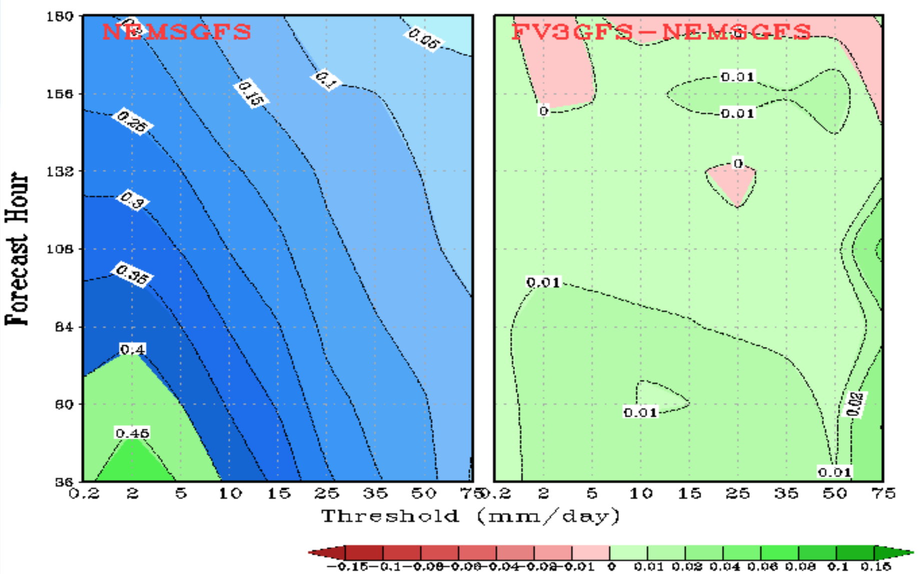
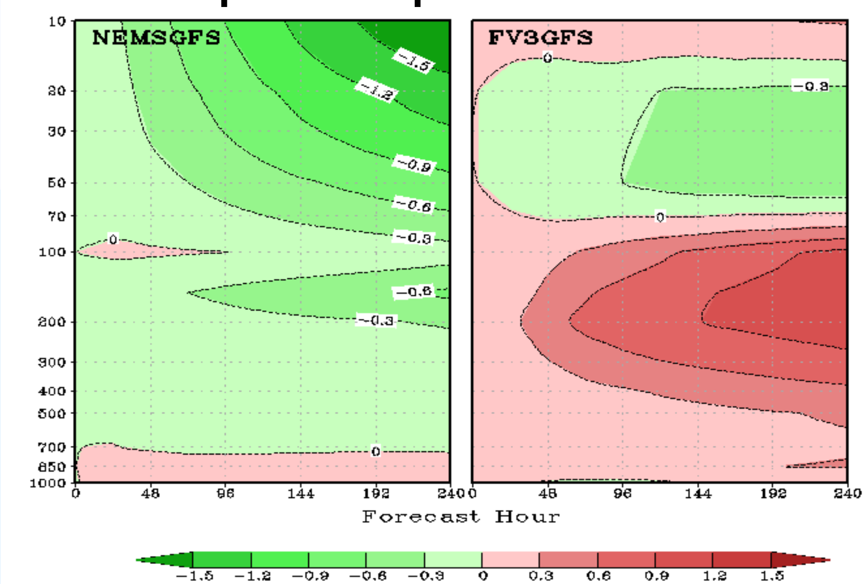
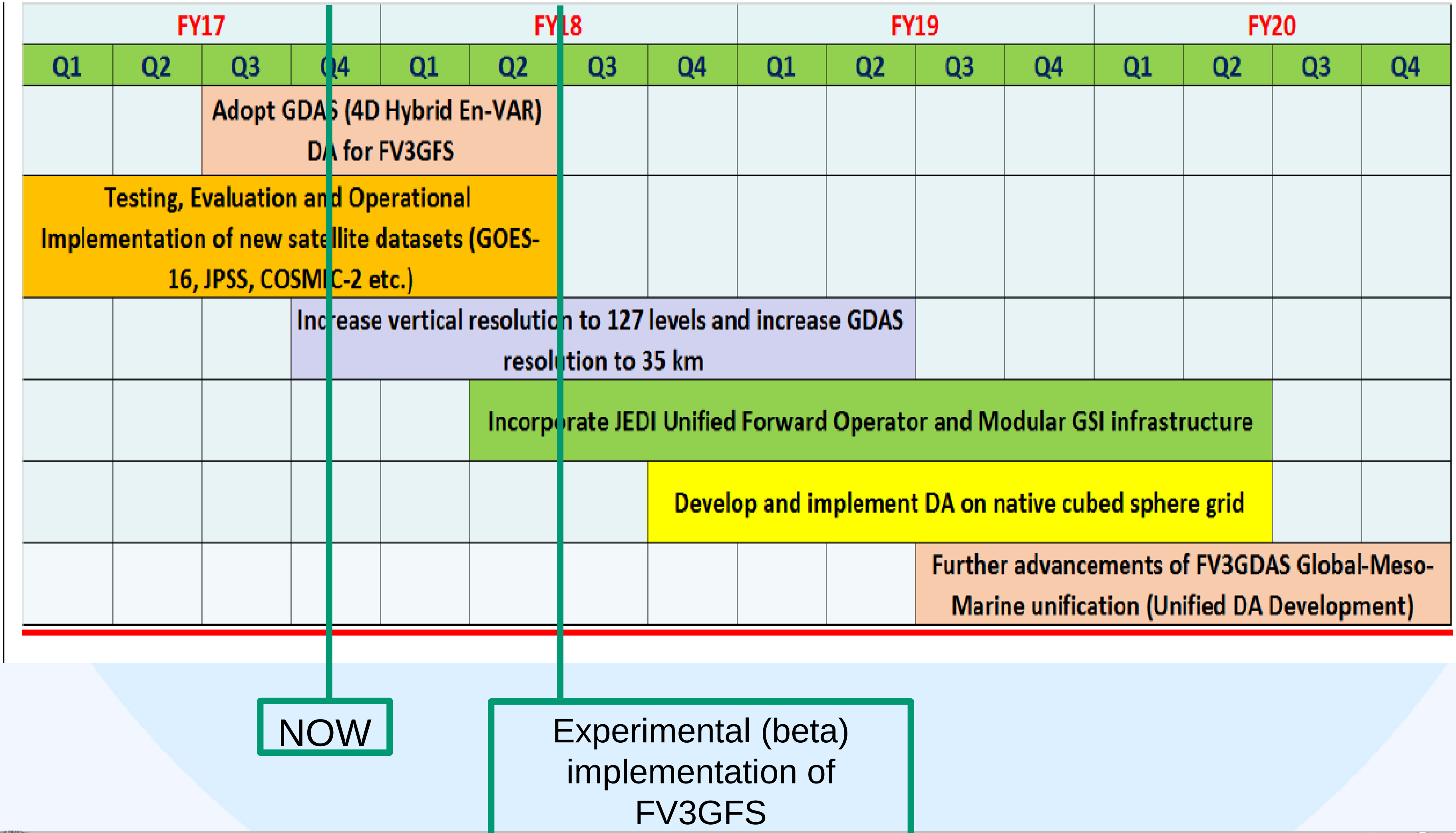


Tropical Temperature Bias



FV3 GFS DA Timeline

FV3-GFS Data Assimilation (DA) Plan (FY2017-2020)



Status of FV3GFS DA at EMC

Rocoto-based workflow 90% done. We can now fully cycle NEMS-FV3 similar to NEMS-GSM

- GSI requires rectilinear grid (Gaussian or regular lat-lon). Utilizing intermediate NEMSIO-Gaussian grid files for DA. No substantive changes to GSI.
- FV3 receives Gaussian grid ***increments*** and interpolates to native grid.

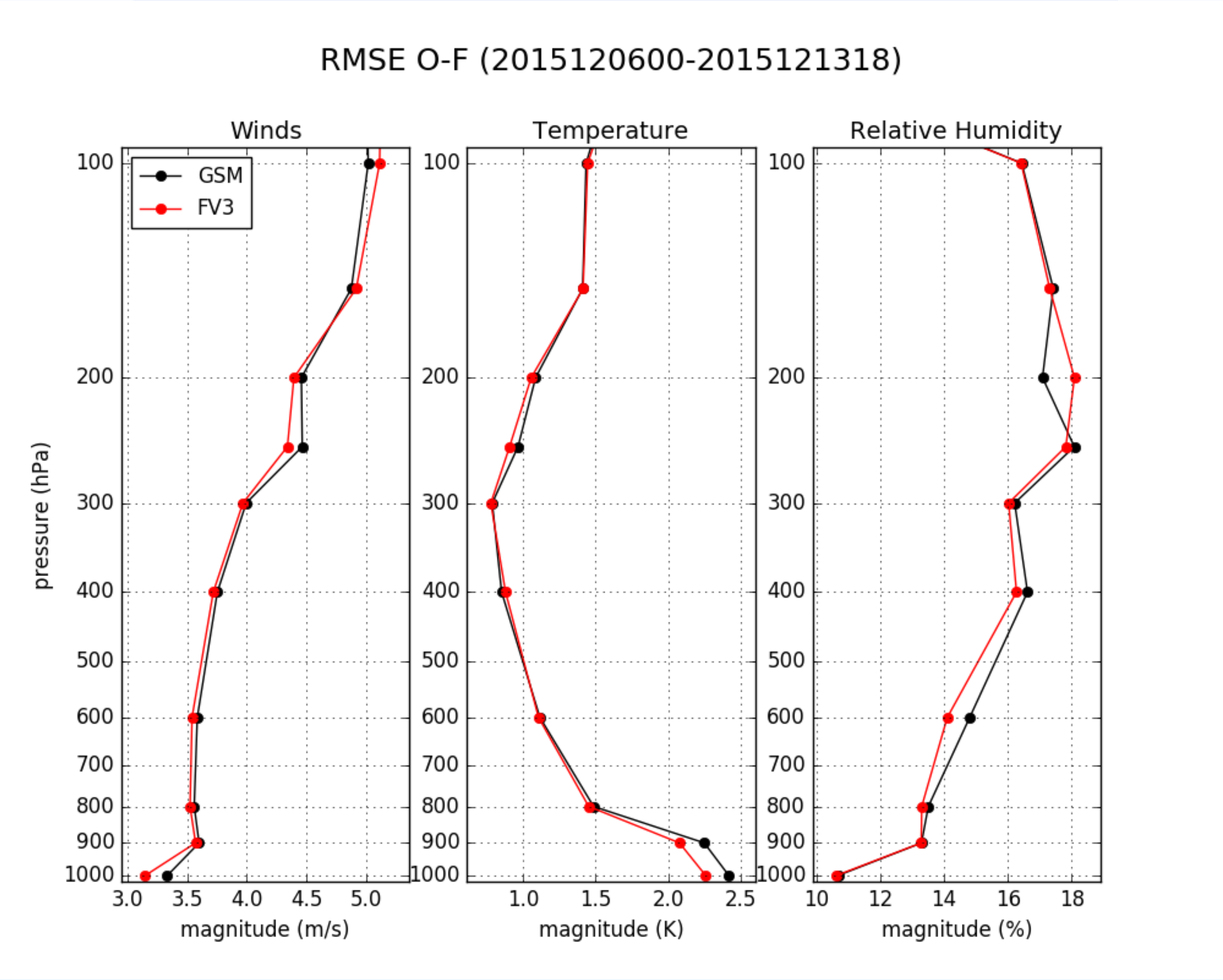
Using GSM-based climatological background error, analysis is effectively hydrostatic

No fully functioning stochastic physics or initialization

- Collaborating with NOAA/ESRL on SPPT, SHUM, SKEBS (nearly ready) and IAU (shortly thereafter)
- TLNMC still applied within assimilation itself

Cycling of surface fields slightly different for now (no global_cycle)

Model Equivalents (06hr FGAT)
Our first result at EMC*



Next Steps

- Start testing of stochastic physics
- Integration and testing of IAU
- 4DEnVar benchmark testing including real-time at full resolution
- Work toward higher vertical resolution, advanced physics configuration

- In Parallel
  - NGGPS-era offers both a challenge and an opportunity for broader coordination and significant generalization
  - A new effort in the US on coordinated data assimilation development is gaining traction: JEDI
  - All slides and discussion that follow are courtesy of Tom Auligne (JCSDA Director) and Yannick Tremolet (JEDI Master)

Plans for the assimilation of JPSS-1 Data: ATMS

JPSS-1 will launch in Fall 2017.

At NCEP we have plans to assimilate CrIS, ATMS and OMPS-N data. These instruments are currently flying on S-NPP and we currently assimilate both CrIS and ATMS

- ATMS
  - We currently assimilate all S-NPP ATMS channels except for Ch 15 which affected by the model top.
  - The assimilation configuration closely follows the clear sky configuration used for AMSU-A and MHS, but AMSU-A like channels need are remapped to improve the noise characteristics.
  - The impact of ATMS on the forecast skill is close to neutral
  - Assimilation of ATMS on JPSS-1 will closely follow the configuration of S-NPP.
  - Be more aggressive with observation errors as the striping effect noted on the S-NPP version should not be seen on JPSS-1.
  - Upgrade the ATMS to all-sky assimilation as part of this upgrade or in the near future.

Plans for the assimilation of JPSS-1 Data: CrIS

For JPSS-1 we plan to receive the full FSR spectrum at NCEP – allowing us to be more flexible in our channel selection.

- We aim to use more of the 15µm CO_2 band channels than is possible with the current selection.
- We will also make use of channels from the water vapor band.

A channel selection for NWP has also been produced with Antonia Gambacorta of NOAA-NESDIS

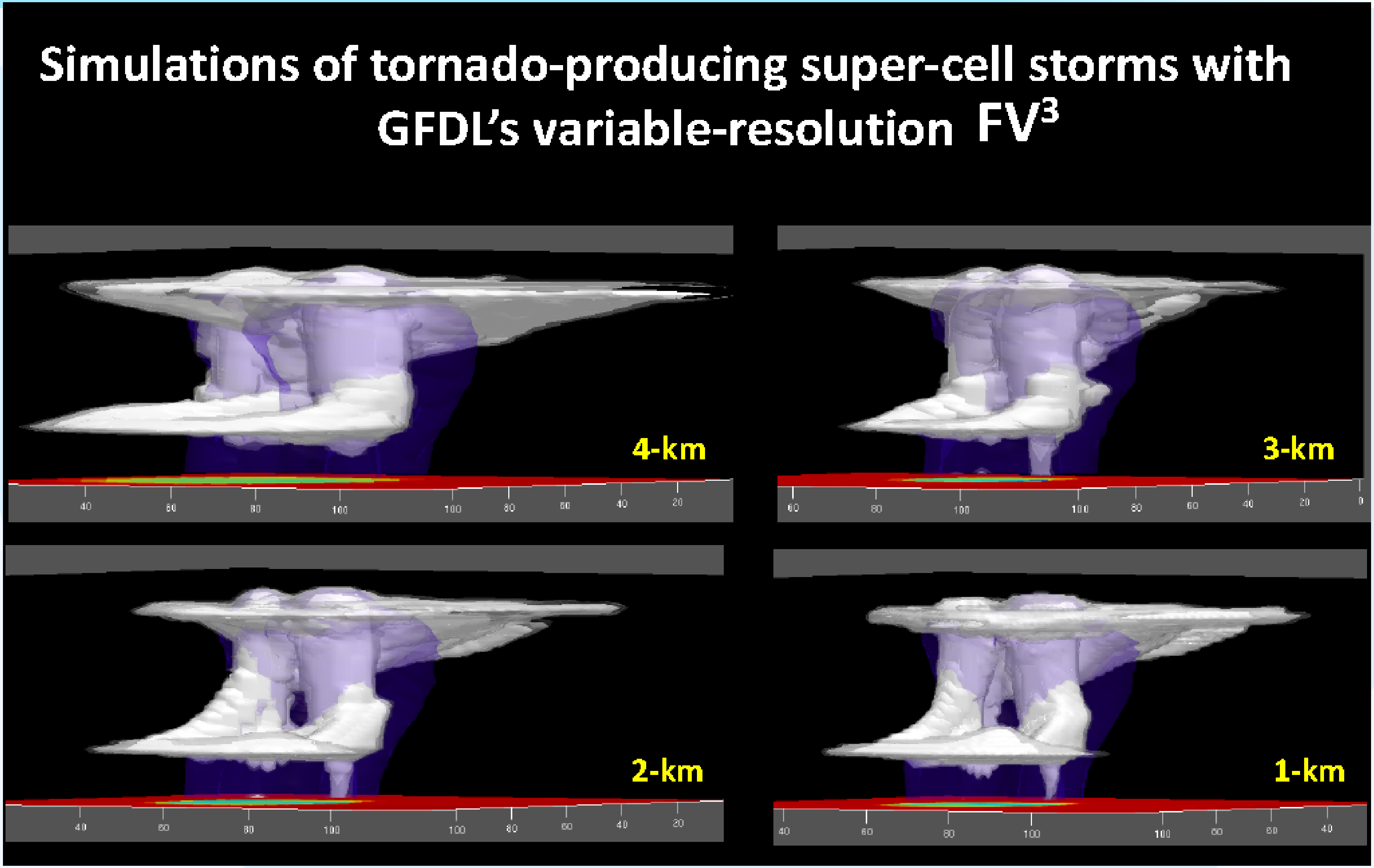
- We consulted widely in the NWP community on this channel selection (mostly through the ITSC NWP Working Group)
- This channel selection is suggested for direct broadcast and GTS distribution as well as being the default subset being distributed by NESDIS (the full spectrum is also being distributed).

Plans for the assimilation of JPSS-1 Data: OMPS-N

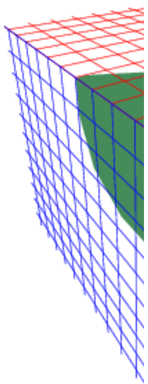
- Assimilation of data from the OMPS Nadir sounder from S-NPP will be tested once Version 8 retrieval products are delivered via the PDA.
- It is likely that both S-NPP and JPSS-1 OMPS data will be switched on in the JPSS implementation.

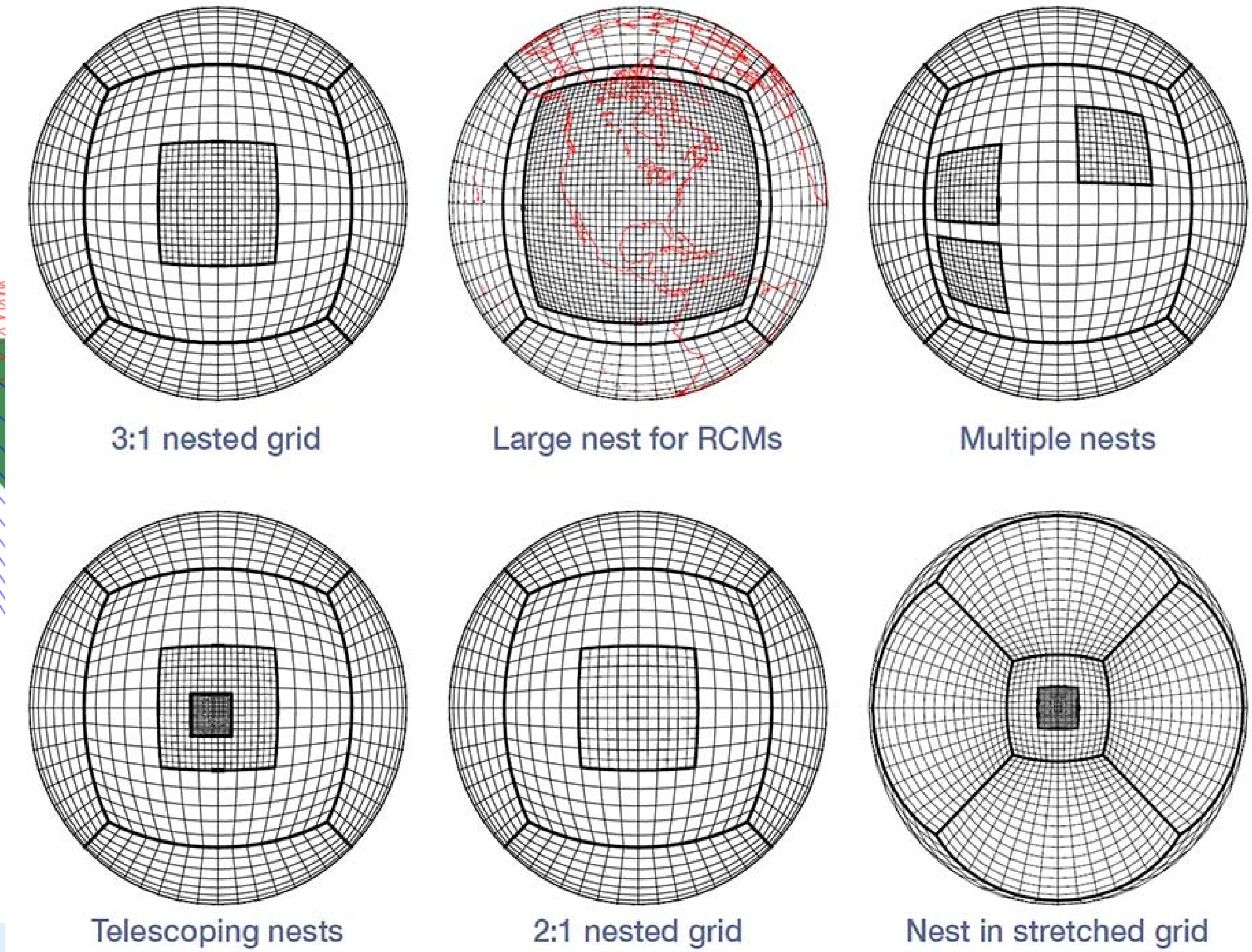
FV3 for convective allowing model and predictions

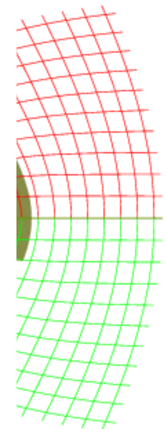
FV3 Grid refinement for higher-resolution convection allowing model forecasts



Tropical Cyclone Forecasts in FV3







Development of next generation nesting techniques to address the tropical cyclone forecast problem within the global model

fvGFS Design and setup for HWT

fvGFS = FV^3 + GFS Physics + NOAH land model

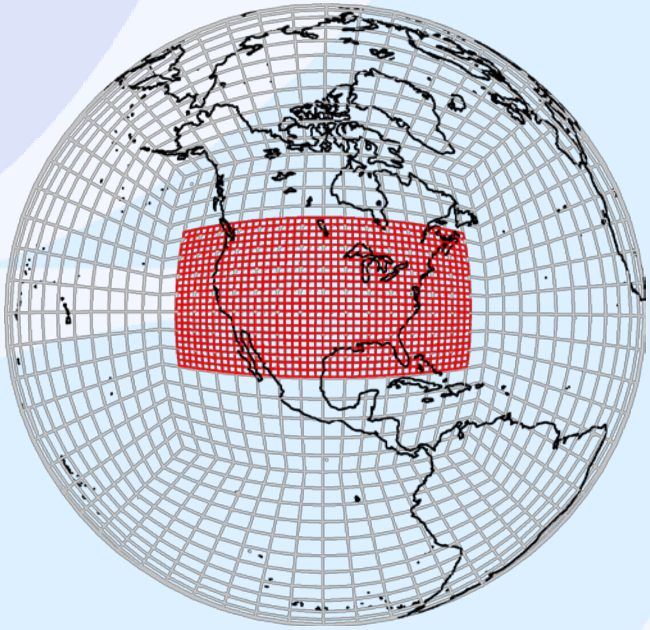
13-km global and 13 & 3-km CONUS nest

Replaces GFS Zhao-Carr with six-category GFDL microphysics

Uses IPDv4 designed at GFDL: Prepared for future physics upgrades!

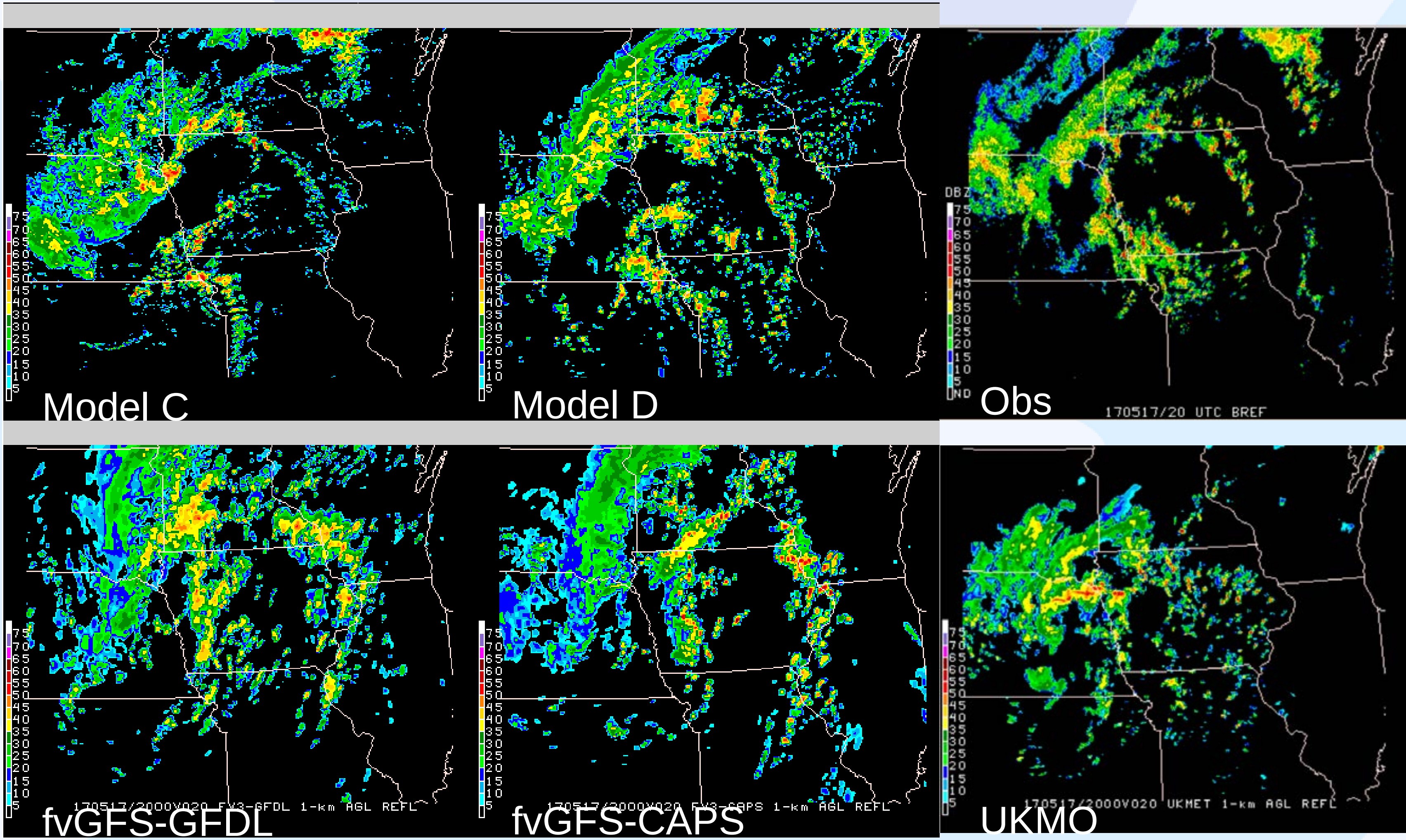
Model cold-started from GFS analyses.

No regional initialization yet.



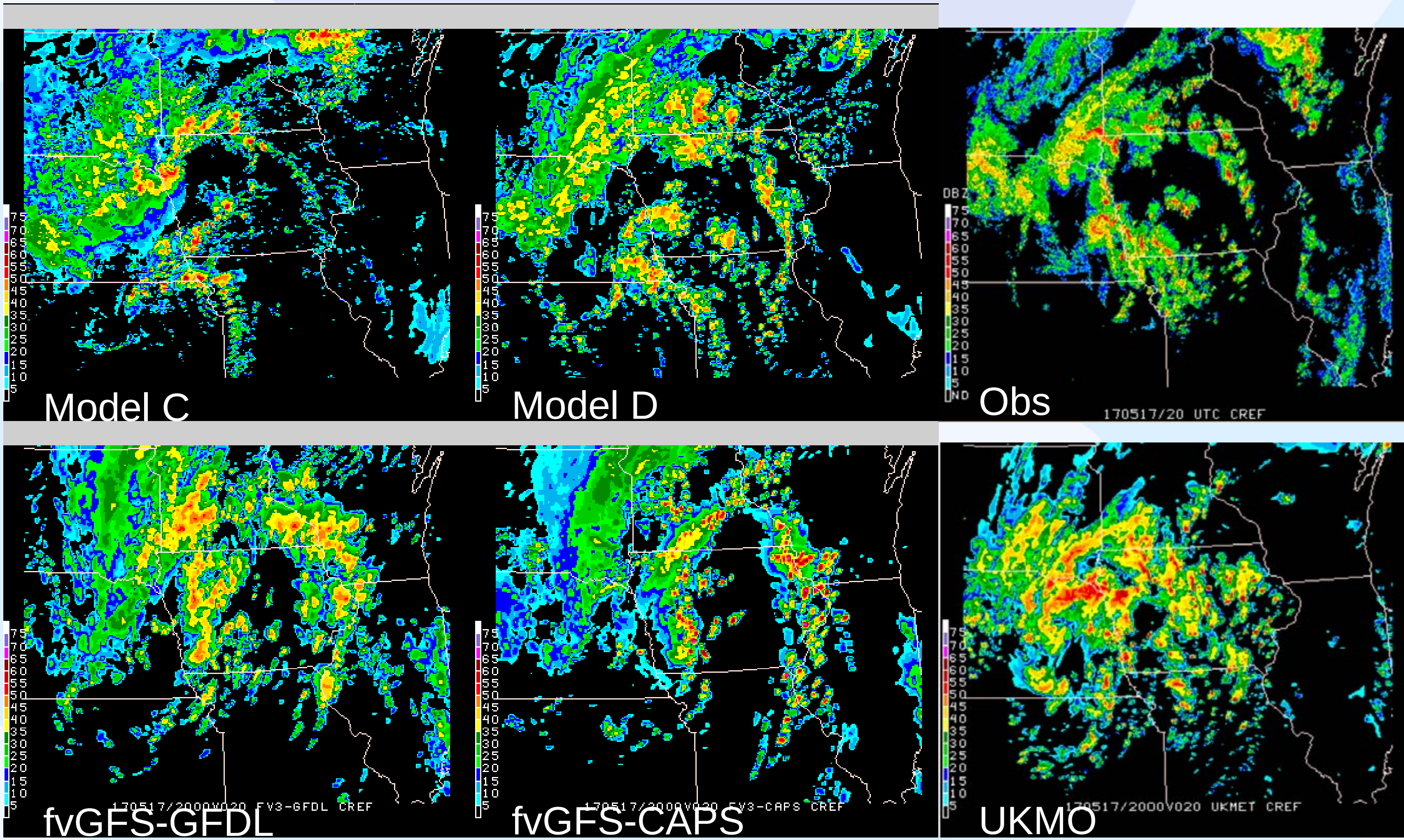
Courtesy: Lucas Harris, GFDL

Base Refl. +20 hr init 00z 0517



Courtesy: Lucas Harris, GFDL

Composite Refl. +20 hr init 00z 0517



Courtesy: Lucas Harris, GFDL

FV3GFS As a Community Model: Version 0 Code Release 05/15/17

- **Configuration**: **NEMS + FV3_CAP + FV3_Dycore + IPDv4 + GFS_Physics**

  Same model used for Phase-2 dycore comparison with upgrade of physics to Q3FY17 GFS configuration.

- **Resolution**:   C96 (~100km), C384 (25km), C768 (~13km)
- **Build the model:** On WCOSS, THEIA and Jet, with pre-installed libraries and utilities.
- **Data**: Initial conditions for selected cases, and fixed fields
- **Release Date: May 15, 2017**
- **Method of Release: VLab GIT;** EMC Subversion
- **Running the model**: simple shell script and configuration files
- **Post Processing**:   **Fregrid** and **Remap** tools to convert 6-tile model output to global lat-lon grid with user defined resolution

NOAA Virtual Lab (VLab) to host FV3GFS Code Release

- ➢Access FV3GFS Project on VLab

https://vlab.ncep.noaa.gov/web/fv3gfs

- ➢Code repositories set up on

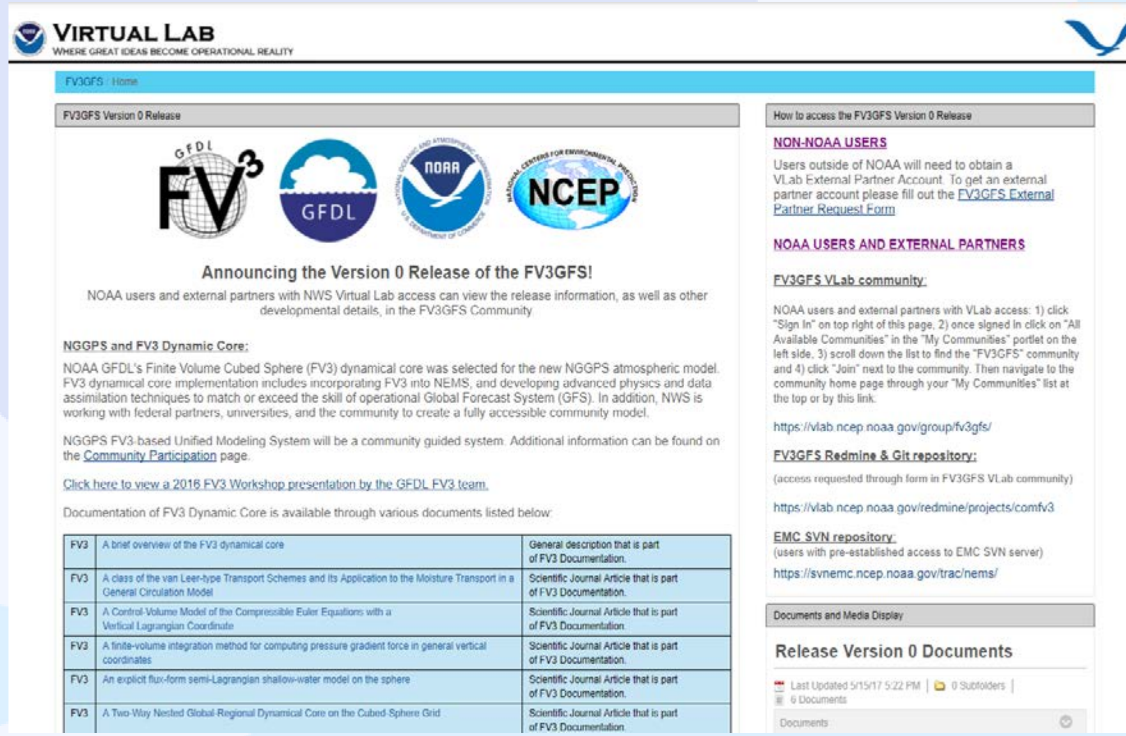
VLab GIT & EMC Subversion

- ➢Community Wiki page, Forums and Developers Pages on VLab
- ➢Case Studies:

Sept. 29, 2016 **Hurricane Matthew**
Jan. 18, 2016 **East Coast Blizzard**
Aug. 12, 2016 **Louisiana Flooding**

- ➢Model Resolutions:

C96 **(~100km**), C382 **(~25km**) or C768 **(~13km**)



- Limited support from EMC to run FV3GFS forecast only experiments on WCOSS, Theia and Jet
- Unified Community Research and Operations Workflow (CROW) under development

Strategic Implementation Plan for Unified Modeling

Strategic Vision for Evolution of NGGPS to a National Unified Modeling System

- Unified Modeling based on FV3 – Short term implementation plans through FY20
- Evidence based decision making process
- Community engagement from the beginning
- Working groups met at NCWCP during April 17-19, and August 1-4 2017 to draft SIP Draft V1, first draft developed
- Leading to more detailed Strategic Plan and Road Map being developed by NWS STI in collaboration with partners & community

Governance	**Data assimilation**
System architecture	**Ensembles**
Infrastructure	**Post Processing**
Dynamics and Nesting (including hurricanes)	**Verification & Validation**
Model physics	**Convective allowing models**

NGGPS Goals and Objectives[1]

Next Generation Global Prediction System (NGGPS)

Design/Develop/Implement the Next Generation Global Atmospheric Prediction Model

- Non-hydrostatic Scalable Dynamics
- Accelerated Physics Improvement Profile

Improve Data Assimilation

Position NWS for Next Generation High Performance Computing (HPC)

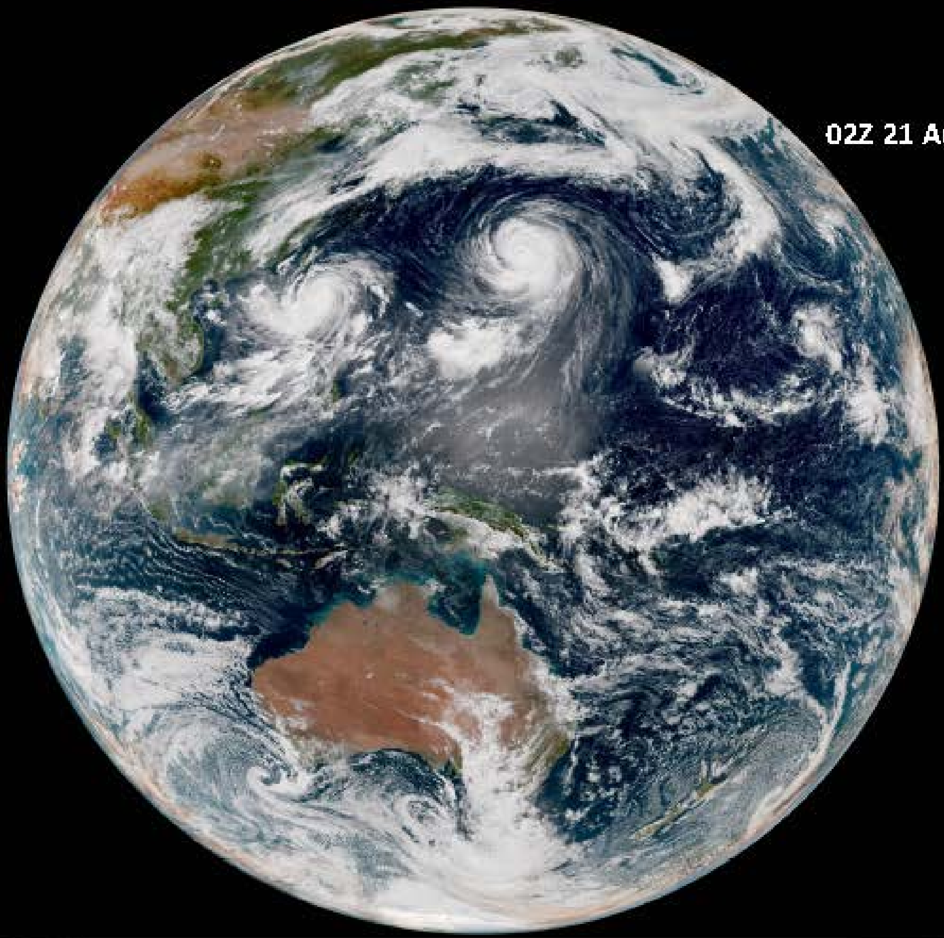
Ultimate Goal: World's Best Global Forecast Guidance!

1 – From NWS Budget Initiative proposal to OMB

A glimpse into the future of NWP

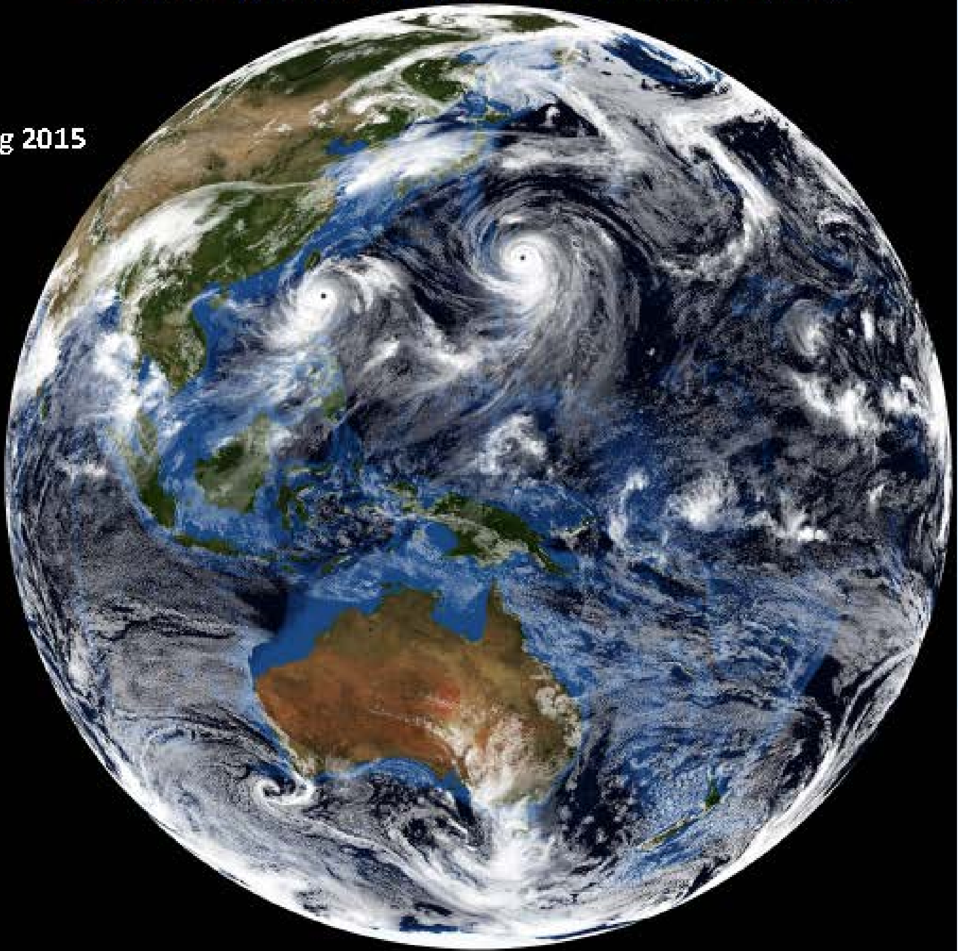
Global cloud-resolving prediction with FV3-powered NGGPS

Himawari Satellite



02Z 21 Aug 2015

50-hour prediction (INIT: 00Z 19AUG 2015)



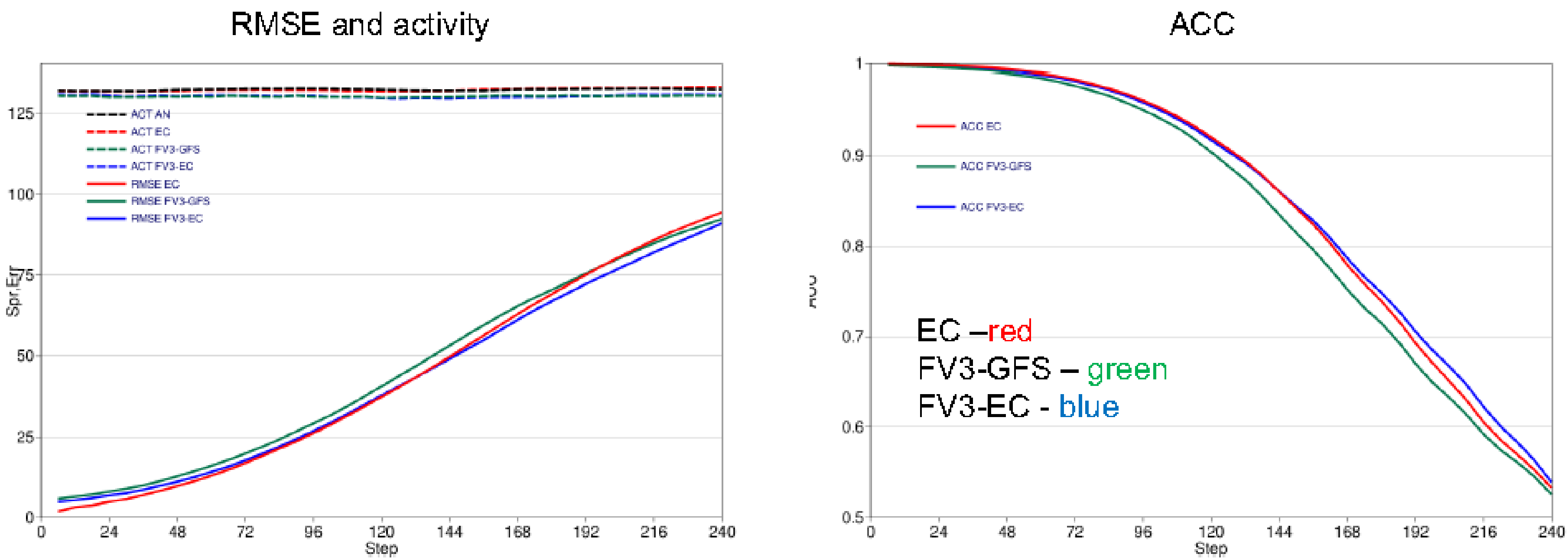
Courtesy: SJ Lin, GFDL

FV3 initialized with IFS IC (courtesy of Linus Magnusson, ECMWF)

Forecast skill of the 13-km FV3-GFS forecasts vs. operational ECMWF-IFS (9-km)

- ❖ August 2015 to August 2016, every 5th day = 73 cases

Scores for z500 N.Hem for all cases



(Courtesy of Linus Magnusson, ECMWF)

ECMWF EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS

Courtesy: SJ Lin, GFDL

x Questions?