Next Generation TC modelling System
-- Towards Unified Forecast System (UFS)

Presented by

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Based on work done by EMC MDA, VPPP, and EIB branches, GFDL and PSD collaborators, and various GFS downstream code managers and external collaborators

Outlines

- **Introduction and Evaluation of FV3GFS (GDAS/GFS V15.0)**
- **Downstream Impact of FV3GFS on HWRF track/Intensity Forecasts**
- **Development of Hurricane Analysis and Forecast System (HAFS)**

Change History of GFS Configurations

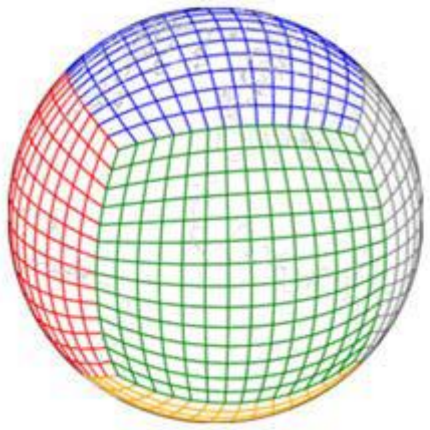
Mon/Year	Lev	Truncations	Z-cor/dyncore	Major components upgrade
Aug 1980	12	R30 (375km)	Sigma Eulerian	first global spectral model, rhomboidal
Oct 1983	12	R40 (300km)	Sigma Eulerian	
Apr 1985	18	R40 (300km)	Sigma Eulerian	GFDL Physics
Aug 1987	18	T80 (150km)	Sigma Eulerian	First triangular truncation; diurnal cycle
Mar 1991	18	T126 (105km)	Sigma Eulerian	
Aug 1993	28	T126 (105km)	Sigma Eulerian	Arakawa-Schubert convection
Jun 1998	42	T170 (80km)	Sigma Eulerian	Prognostic ozone; SW from GFDL to NASA
Oct 1998	28	T170 (80km)	Sigma Eulerian	the restoration
Jan 2000	42	T170 (80km)	Sigma Eulerian	first on IBM
Oct 2002	64	T254 (55km)	Sigma Eulerian	RRTM LW;
May 2005	64	T382 (35km)	Sigma Eulerian	2L OSU to 4L NOAH LSM; high-res to 180hr
May 2007	64	T382 (35km)	Hybrid Eulerian	SSI to GSI
Jul 2010	64	T574 (23km)	Hybrid Eulerian	RRTM SW; New shallow cnvtion; TVD tracer
Jan 2015	64	T1534 (13km)	Hybrid Semi-Lag	SLG; Hybrid EDMF; McICA etc
May2016	64	T1534 (13km)	Hybrid Semi-Lag	4-D Hybrid En-Var DA
Jun2017	64	T1534 (13km)	Hybrid Semi-Lag	NEMS GSM, advanced physics
Jun 2019	64	FV3 (13km)	Finite-Volume	NGGPS FV3 dycore, GFDL MP

GSM has been in service for NWS operation for 38 years !

NGGPS FV3GFS-v1 Transition to Operations

Configuration of GDAS/GFS V15.0.0:

- **FV3GFS C768 (~13km deterministic)**
- **GFS Physics + GFDL Microphysics**
- **FV3GDAS C384 (~25km, 80 member ensemble)**
- **64 layer, top at 0.2 hPa**
- **Uniform resolution for all 16 days of forecast**



Evaluation Strategy:

- **Retrospective experiments from May 2015 – May 2018**
- **Real-time parallel experiments from May 2018 – implementation date**
- **Independent EMC MEG Evaluation and Stakeholder Evaluation**

FV3GFS was implemented in operation on June 12, 2019 12Z

Model: Infrastructure, DA, Physics

Forecast Model Changes:

- FV3 dynamic core into NEMS
- Interoperable Physics Driver (IPD)
- Write grid component to produce output in native cubed sphere and Gaussian grids
- GFDL microphysics
- Upgrade Ozone photochemistry; New middle atmospheric water vapor photochemistry
- revised bare soil evaporation scheme
- reduce excessive cloud top cooling in the convection scheme
- Updated Stochastic physics (SKEB, SHUM and SPPT)
- GMTED2010 terrain to replace TOPO30 terrain

Data Assimilation Changes:

- DA increments on Gaussian grid interpolated to the cube-sphere grid
- Analysis and EnKF components are at ~ 26 km (C384) instead of 35km
- Tropical cyclone relocation and digital filter removed
- Five separate hydrometeors in GDAS
- All-sky assimilation of ATMS
- CrIS on Suomi-NPP to use full spectral resolution
- Add 10 water vapor channels for IASI
- Turn on Megha-Tropiques Saphir (humidity)

Post Processing Upgrade and Changes

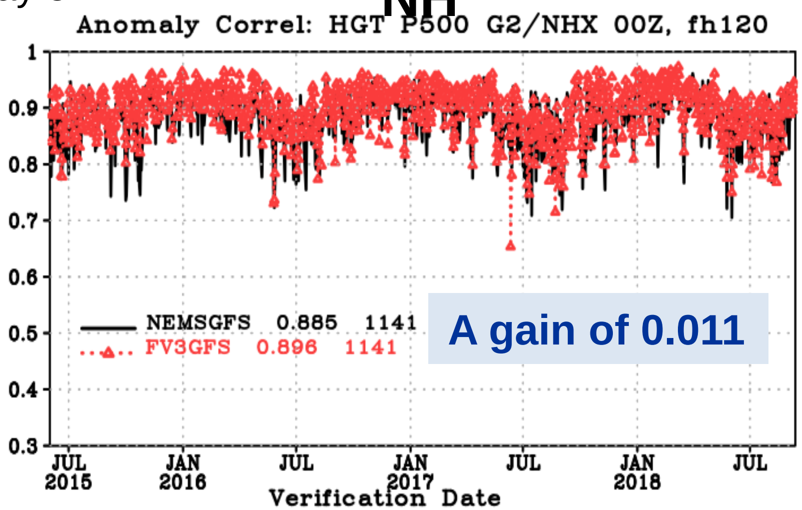
➢ **Changes in products:**

- **Vertical velocity from FV3GFS is dz/dt in m/s but omega will be derived in UPP using hydrostatic equation and still be provided to users**
- **More cloud hydrometeers predicted by the advanced microphysics scheme**
- **Global composite radar reflectivity derived using these new cloud hydrometeers**
- **Isobaric (3D) cloud fractions**
- **Continuous accumulated precipitation bucket**

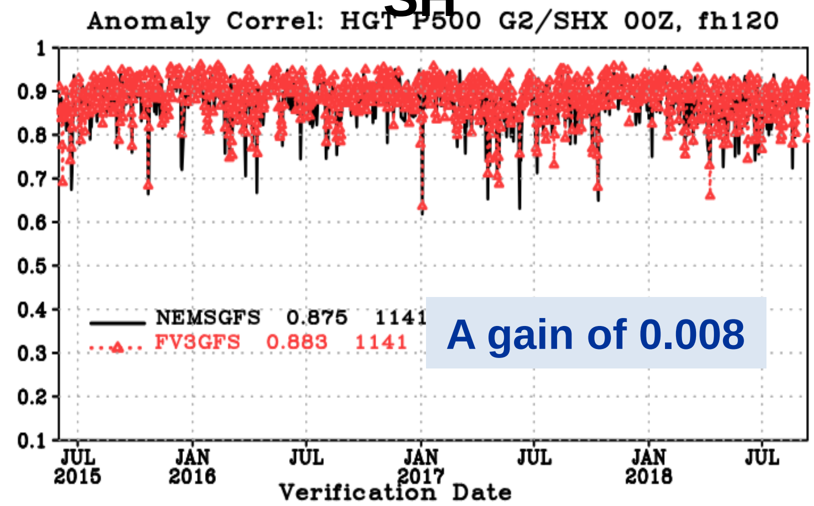
500-hPa HGT Anomaly Correlation
(20150601 ~ 20180912)

Day-5

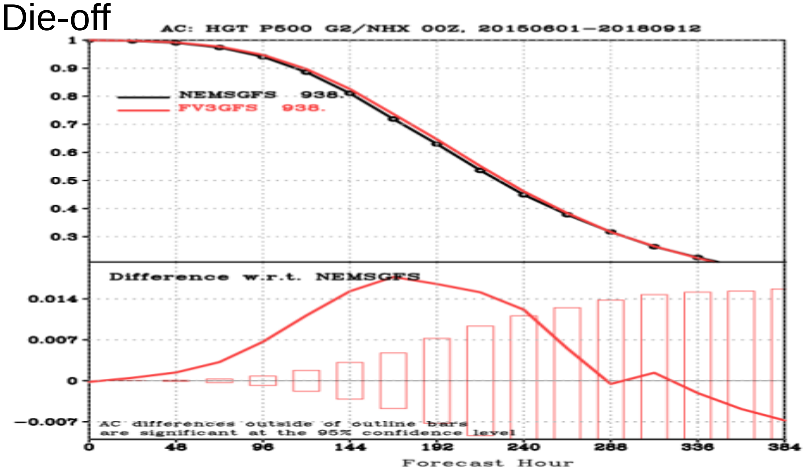
NH



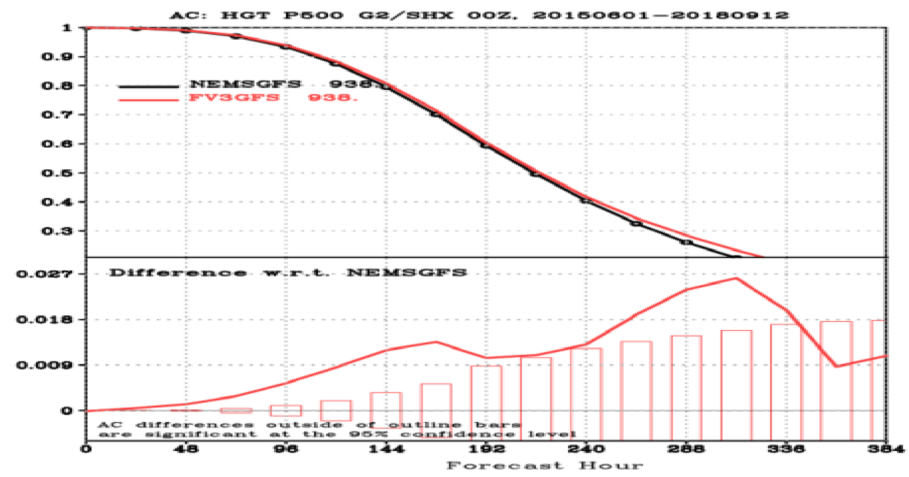
SH



Die-off



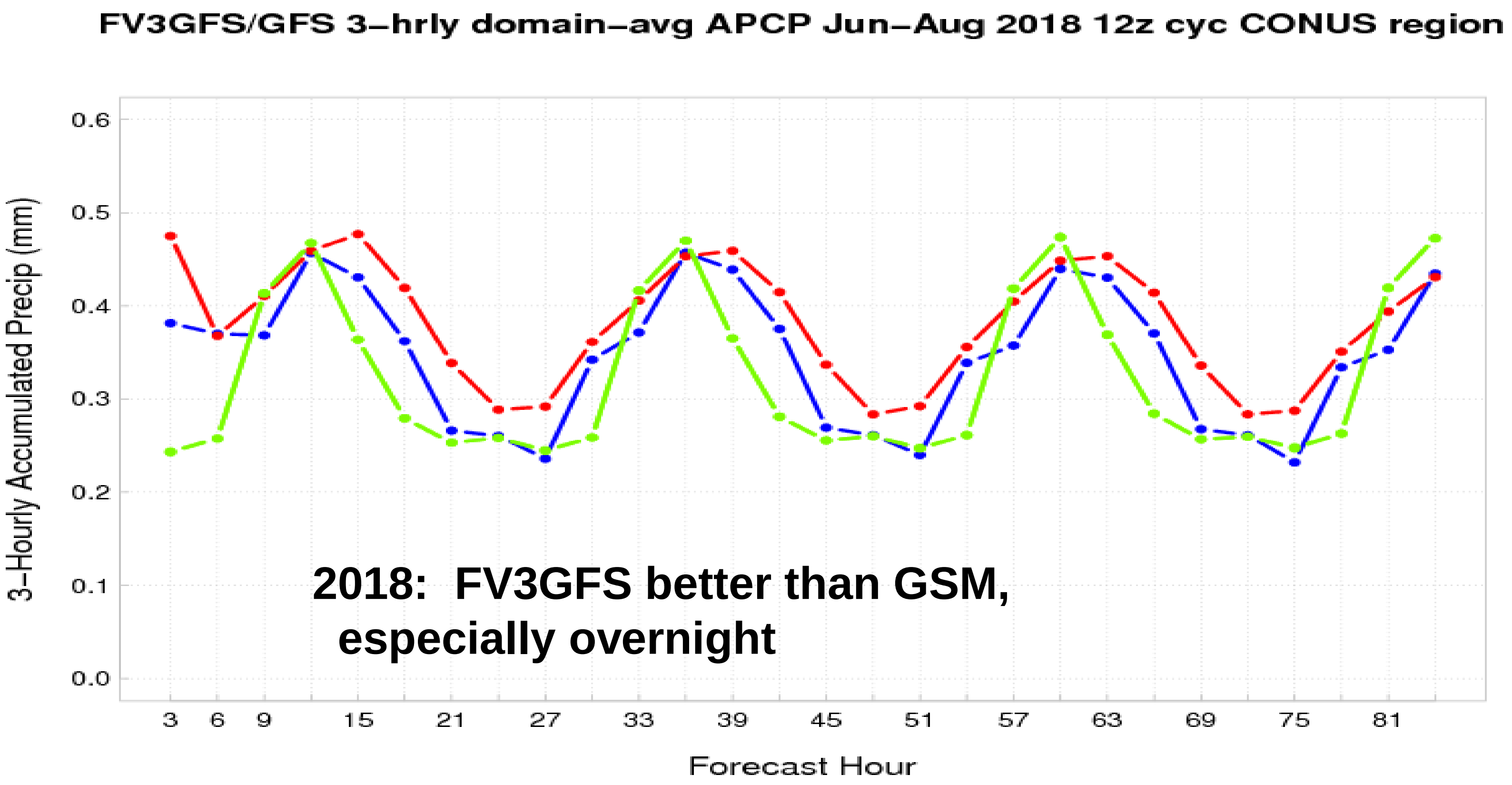
Increase is significant up to day 10



Increase is significant up to day 14

Improved Precipitation Diurnal Cycle

SUMMER 2018 CONUS DOMAIN-AVG PCP



FV3GFS **ops GFS** **OBS**

From: Ying Lin

Choice of Horizontal Advection Scheme

Comparing FV3GFS with current operational GFS:

- Large-scale verification stats are improved, including ACC and precip ETS scores
- Hurricane tracks are improved over Atlantic and Eastern Pacific basins.
- Hurricane intensity is too weak
- Upper air RMSE/Bias scores are worse than operational GFS

Actions Taken:

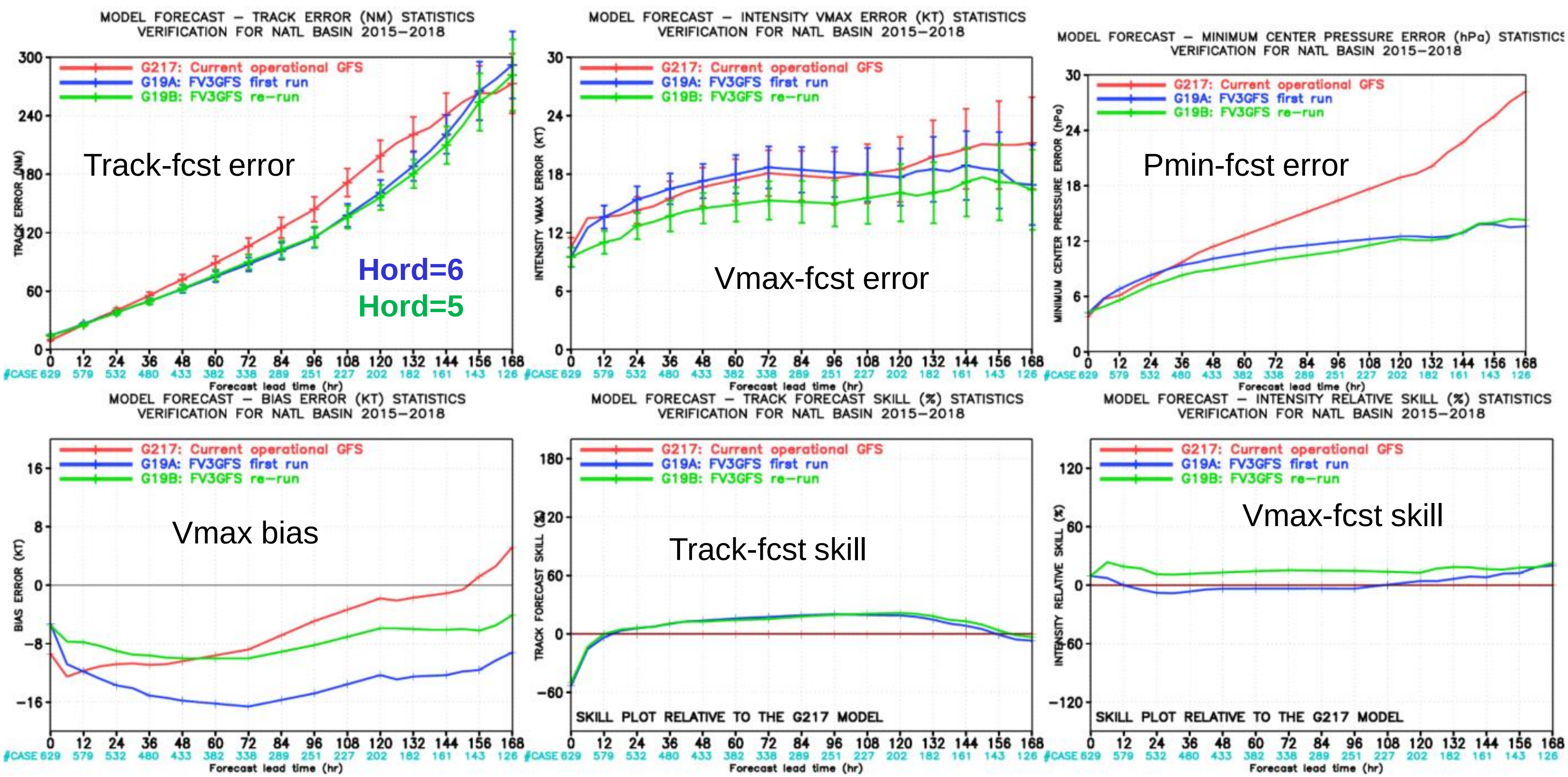
•Consulted with GFDL. SJ-Lin stated that using the advection scheme hord=6 gives better ACC scores but weaker storms, while using hord=5 gives better storm intensity but lower ACC.

•Diffusivity: ord2 < ord5 < ord3 < ord4 < ord6 < ord7
•Hord=5: Unlimited Colella and Woodward (1984) Piecewise-parabolic method, using Hunyh's second constraint to enforce monotonicity
•Hord=6: unlimited "fifth-order" PPM. This option may be useful for 4D-DA.

•SJ Lin recommended to run GDAS cycle with hord=6, and GFS forecast with hord=5

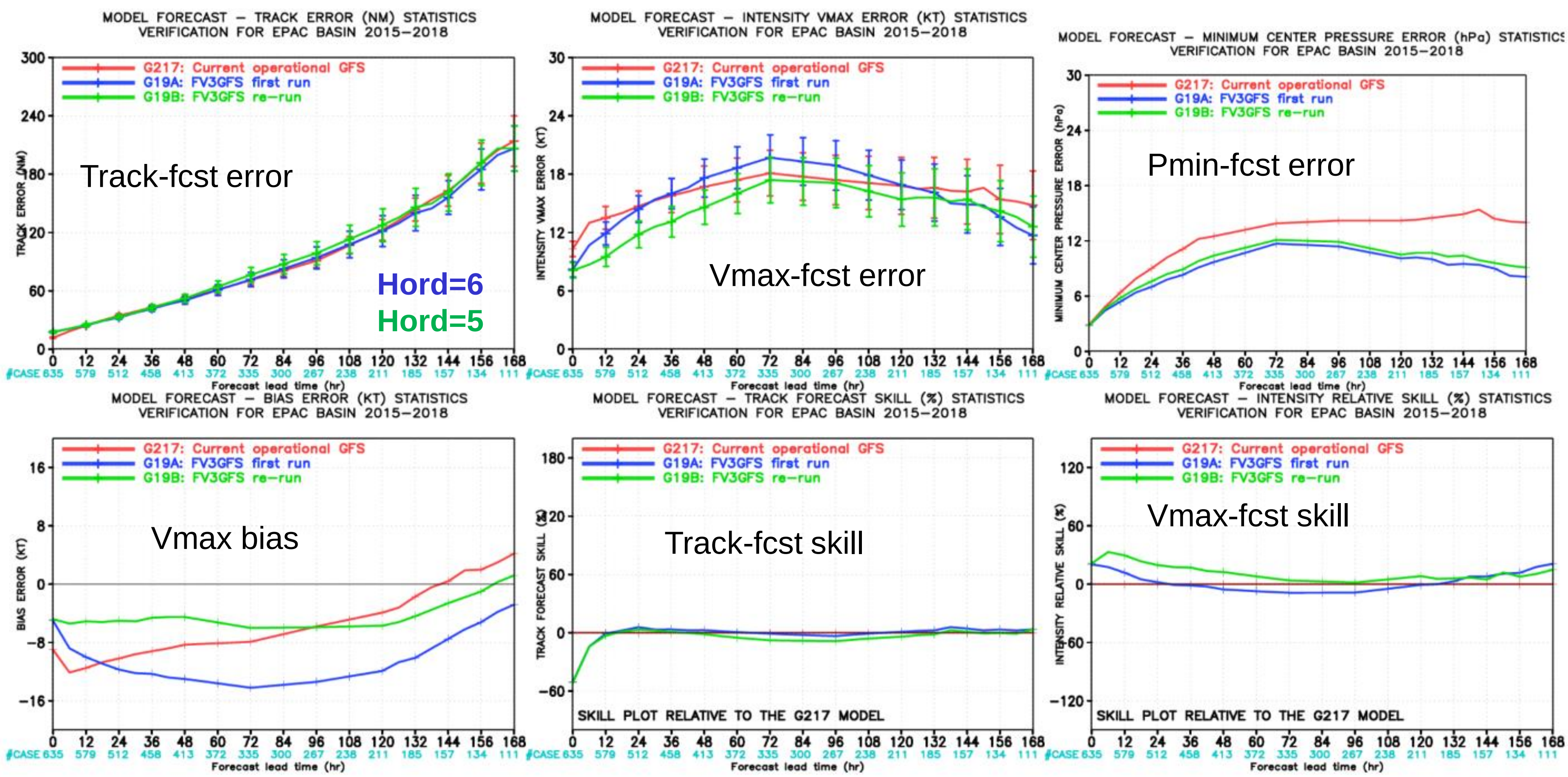
•Compare FV3GFS upper air scores with ECMWF scores; Verified against rawinsondes

Hurricane Track/Intensity Verification at NATL Basin
Hord=6 vs. Hord=5

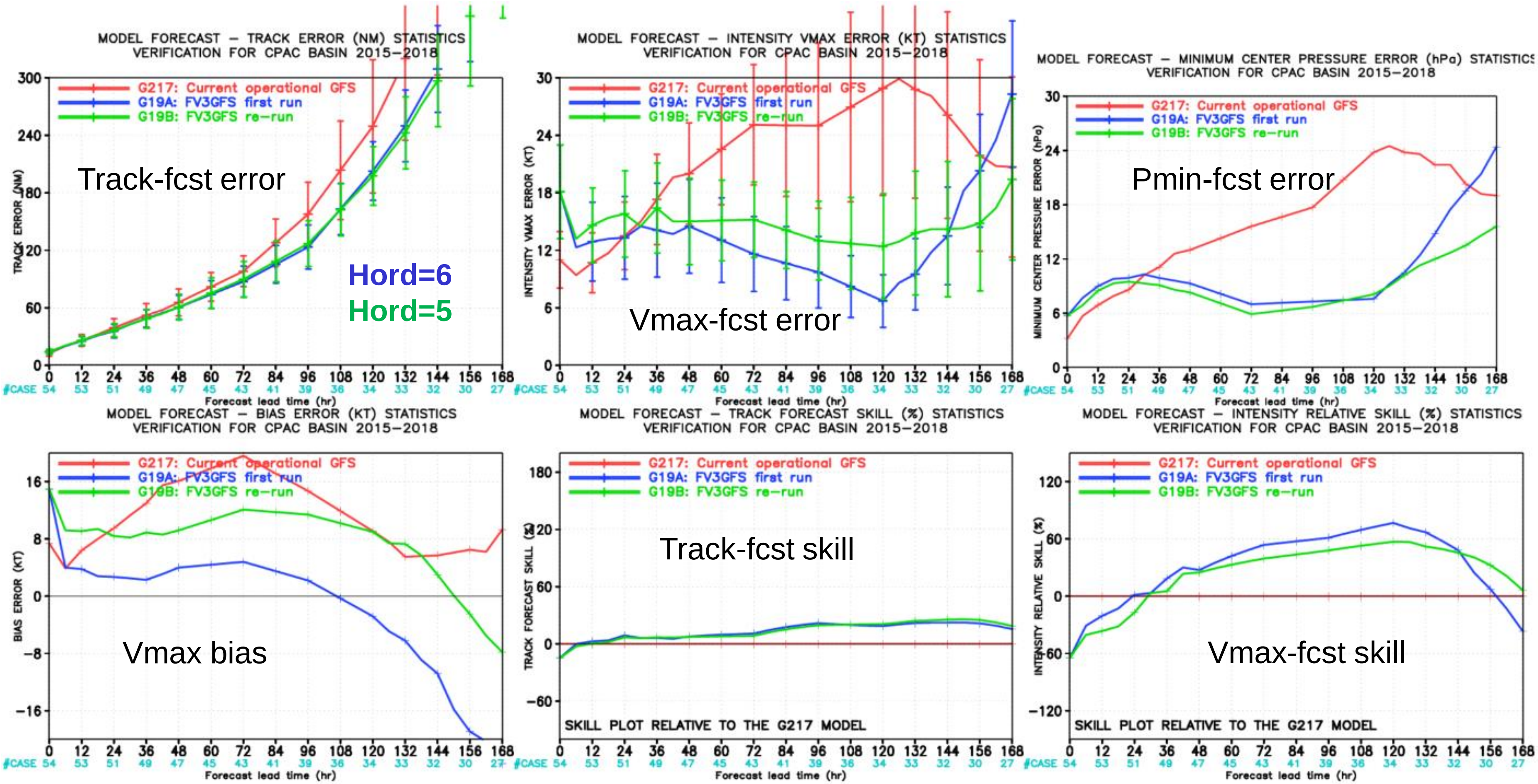


Both intensity rms error and bias are improved by using Hord=5 option

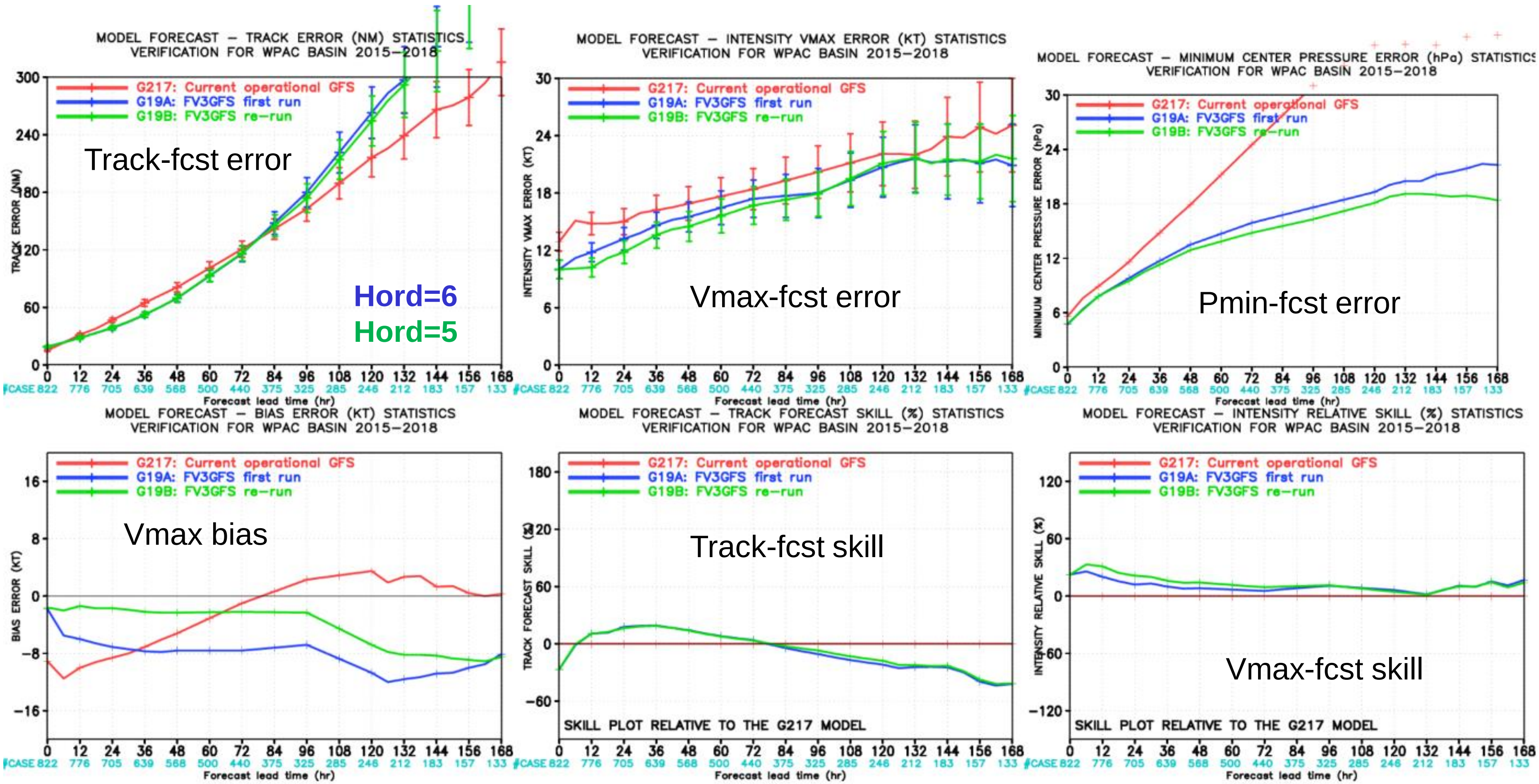
Hurricane Track/Intensity Verification at EPAC Basin
Hord=6 vs. Hord=5



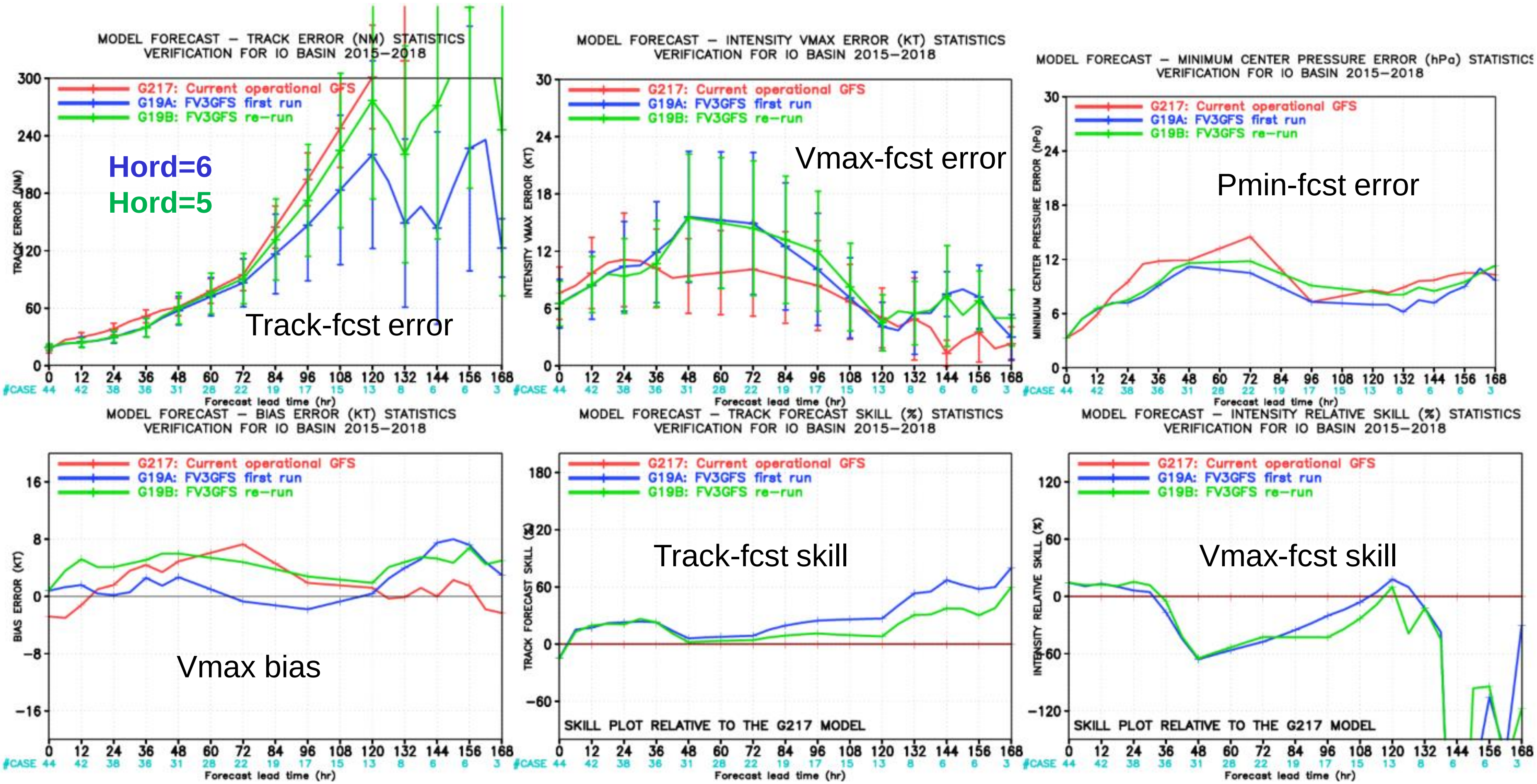
Hurricane Track/Intensity Verification at CPAC Basin
Hord=6 vs. Hord=5



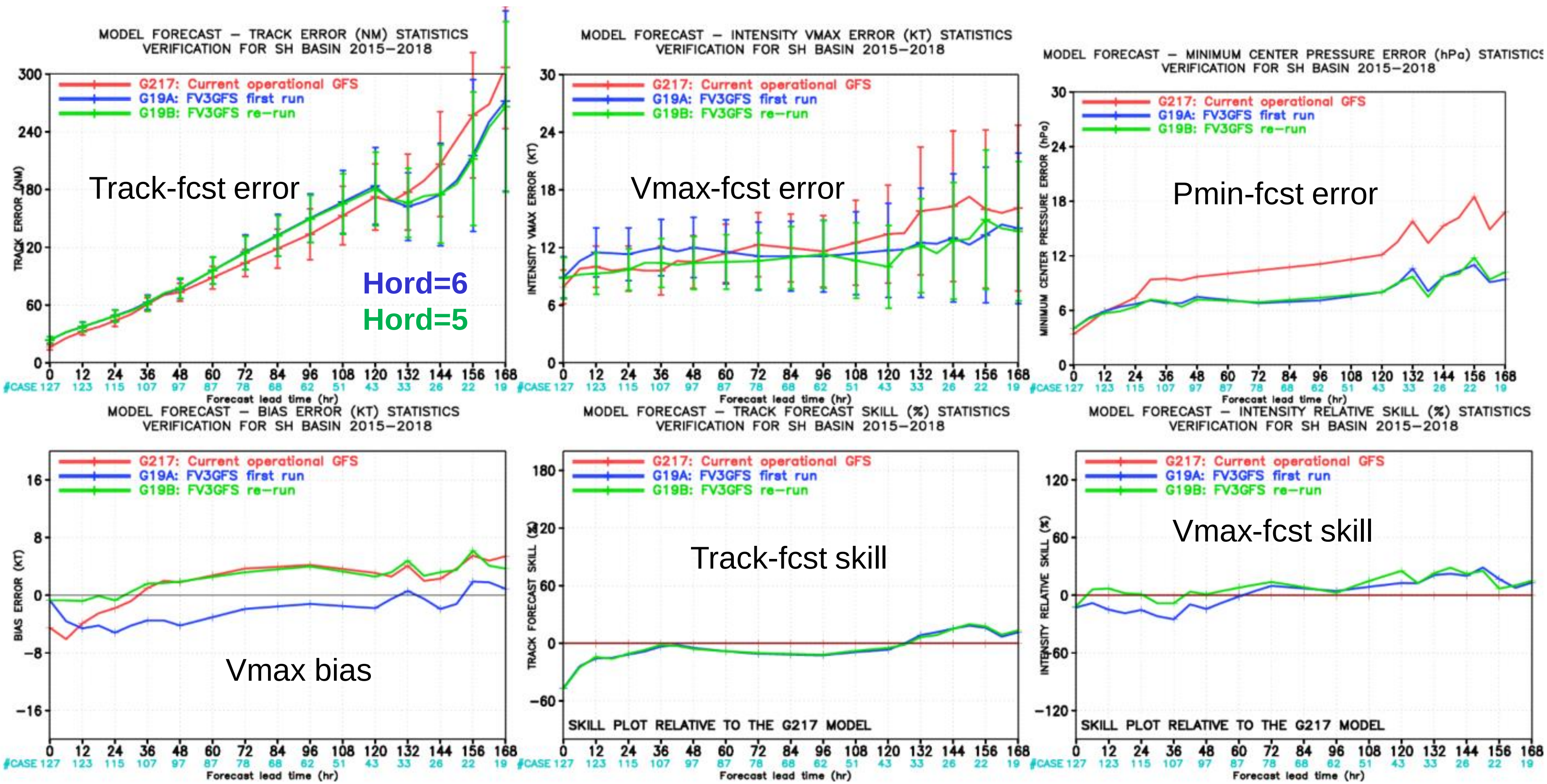
Hurricane Track/Intensity Verification at WPAC Basin
Hord=6 vs. Hord=5



Hurricane Track/Intensity Verification at NIO Basin
Hord=6 vs. Hord=5



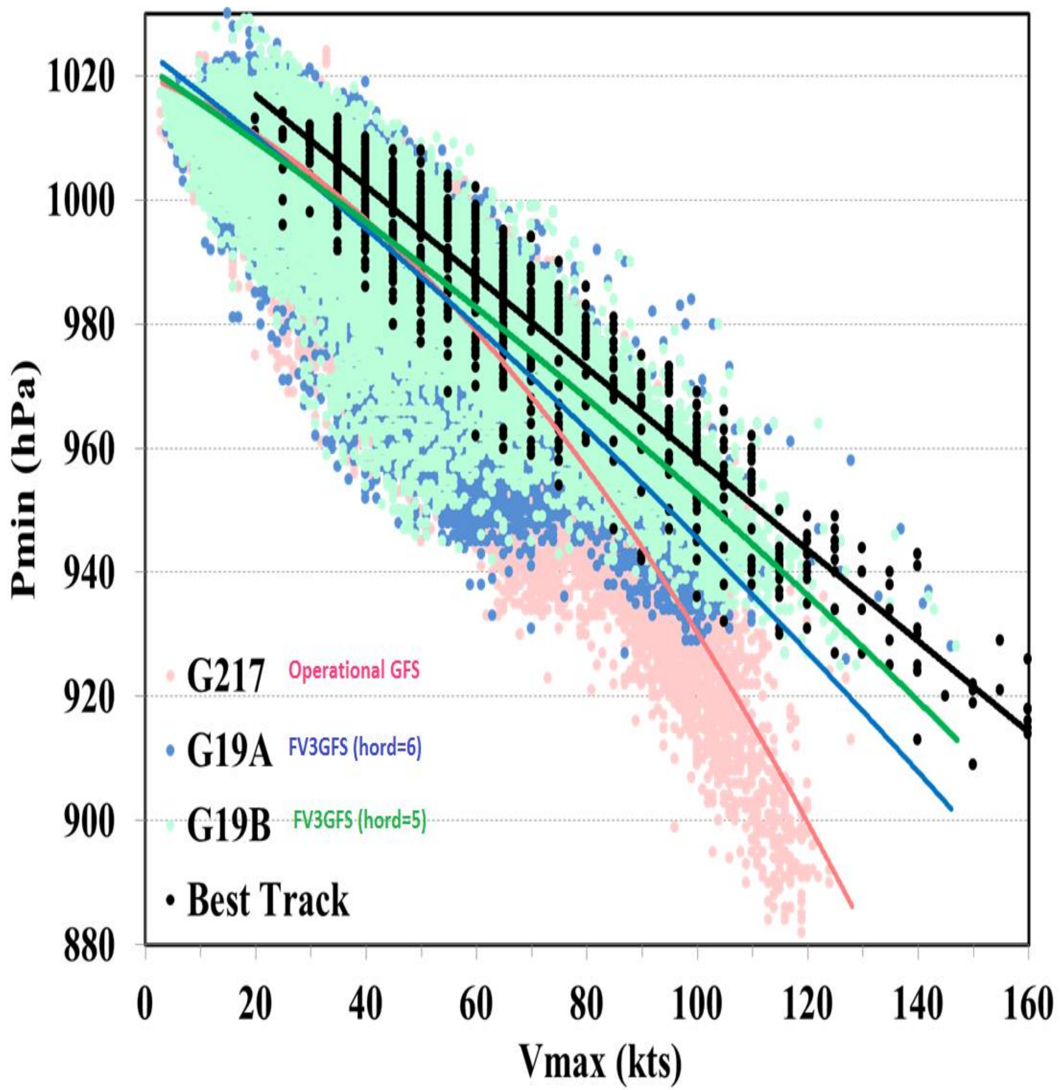
Hurricane Track/Intensity Verification at SH Basin
Hord=6 vs. Hord=5



Improved Wind-Pressure Relationship

FV3GFS shows a much better W-P relation than ops GFS for strong storms

For FV3GFS, W-P relation with hord=5 is better than hord=6



Graph made by HWRF group

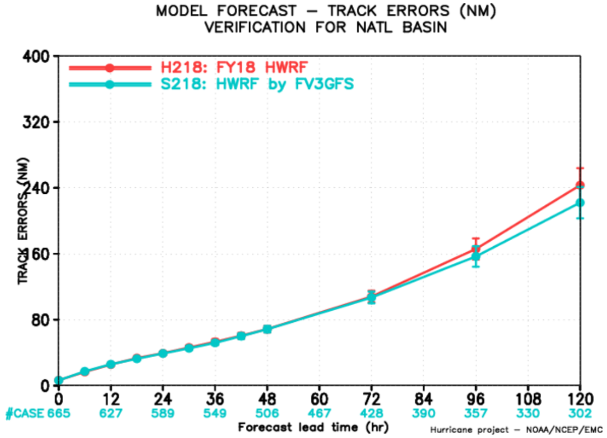
Comparison of POD and FAR between GSM and FV3GFS

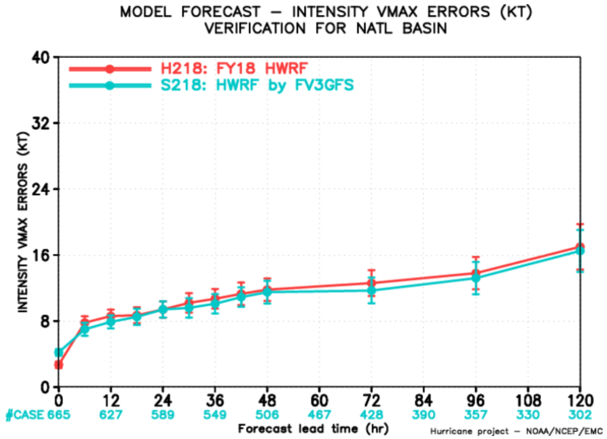
		AL2016	AL2017	EP2016	EP2017
# Cases	Ops GFS	145	119	234	100
	FV3GFS	161	172	227	116
Hit (POD)	Ops GFS	60%	92%	65%	63%
	FV3GFS	63%	73%	77%	70%
Miss	Ops GFS	40%	8%	35%	37%
	FV3GFS	37%	27%	23%	30%
False Alarm	Ops GFS	49%	64%	28%	57%
	FV3GFS	52%	56%	56%	67%

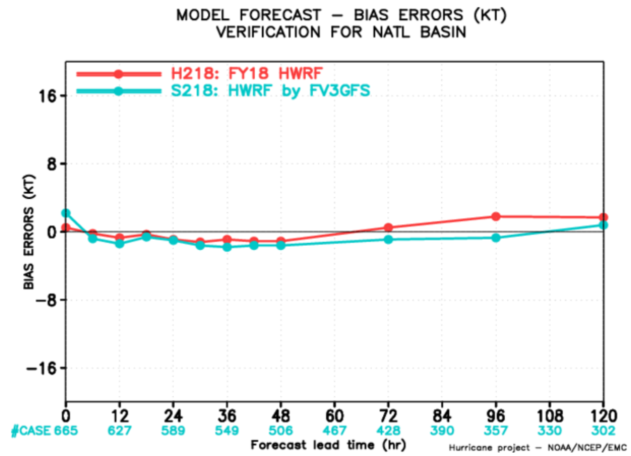
FV3GFS has overall higher POD, but also higher false alarm rate.

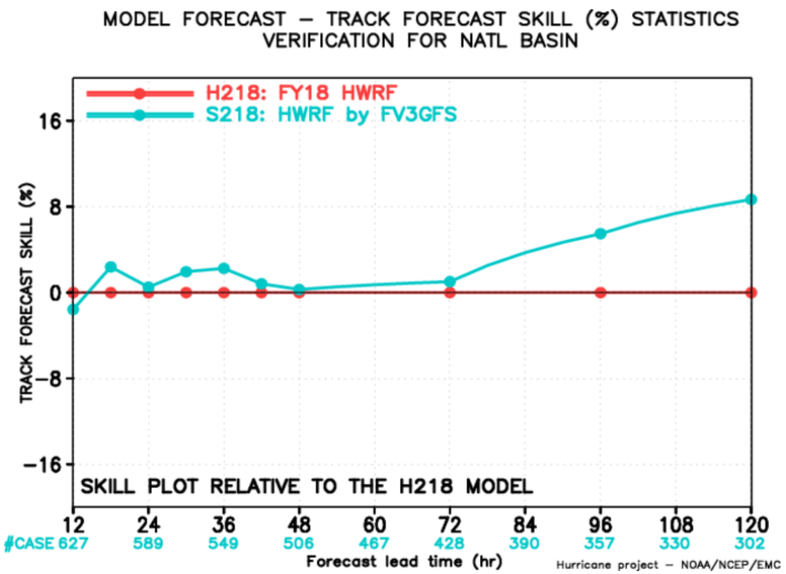
Downstream Model Impacts HWRF/HMON

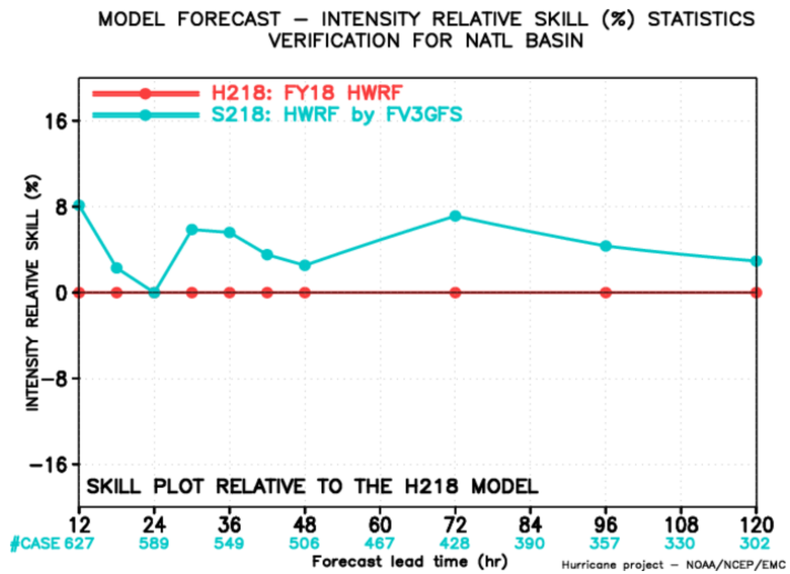
Track/Intensity Verification comparison between HWRF Driven by GSMGFS and FV3GFS (Atlantic Basin)



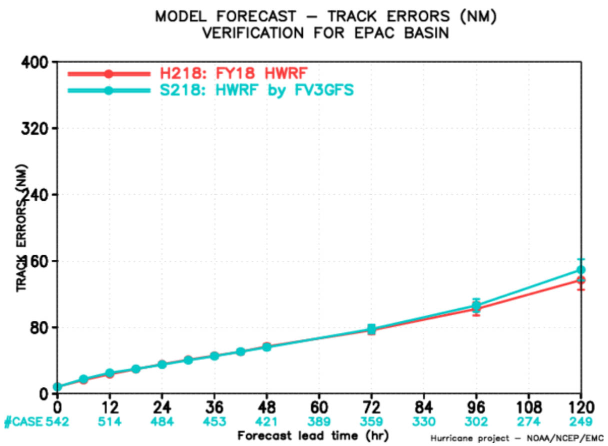


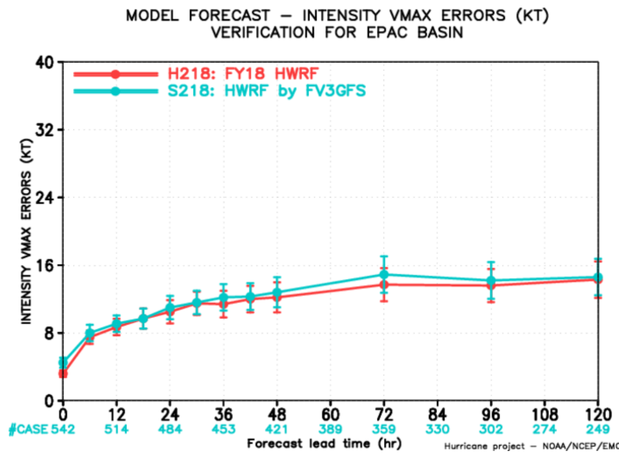


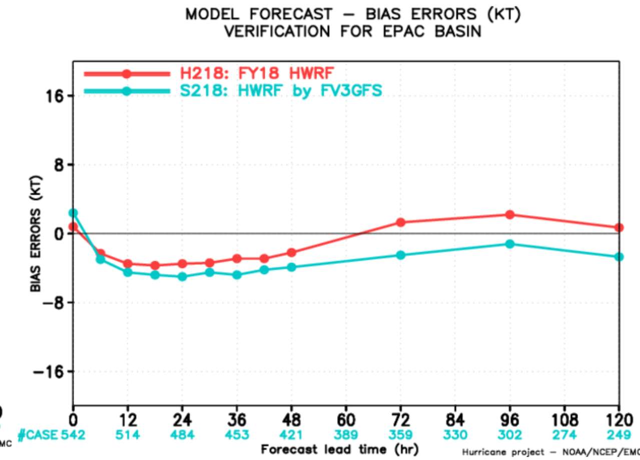


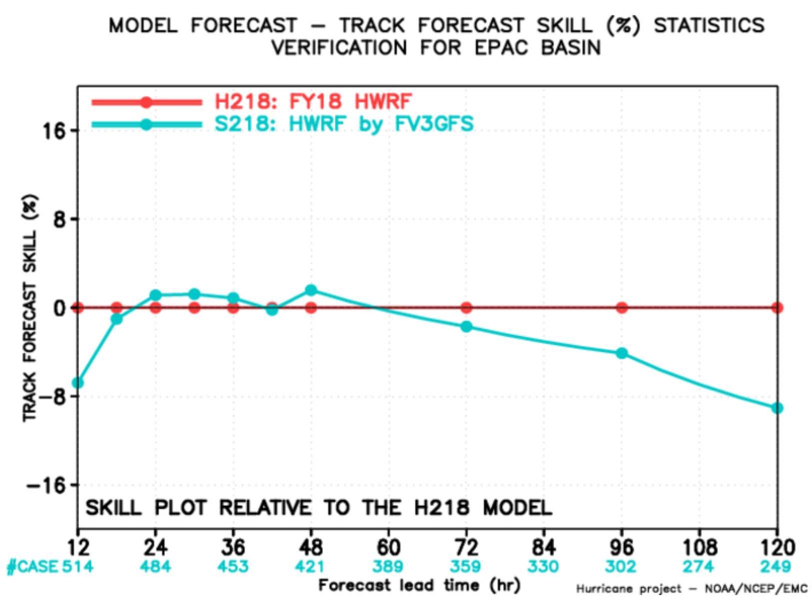


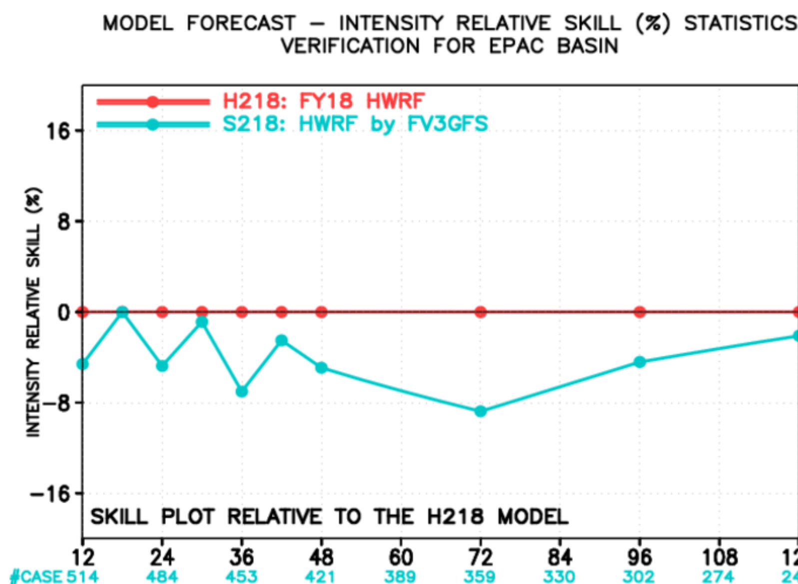
Track/Intensity Verification comparison between HWRF Driven by GSMGFS and FV3GFS (East Pacific Basin)



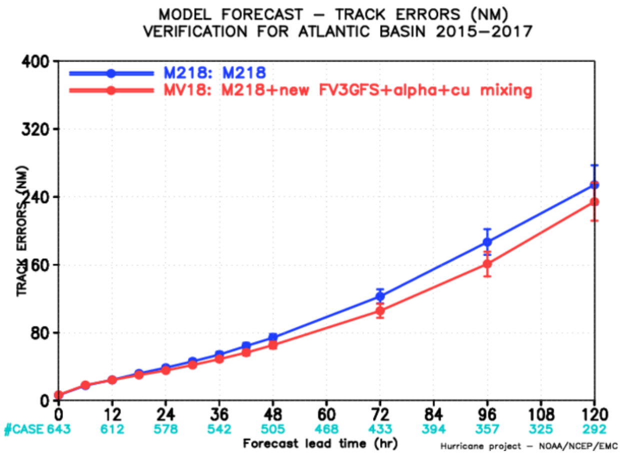


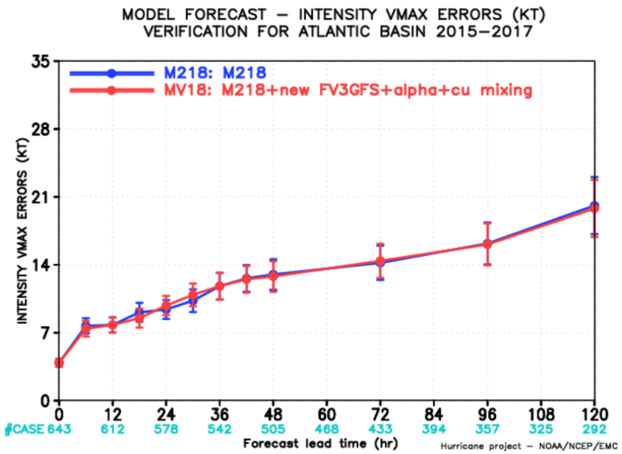


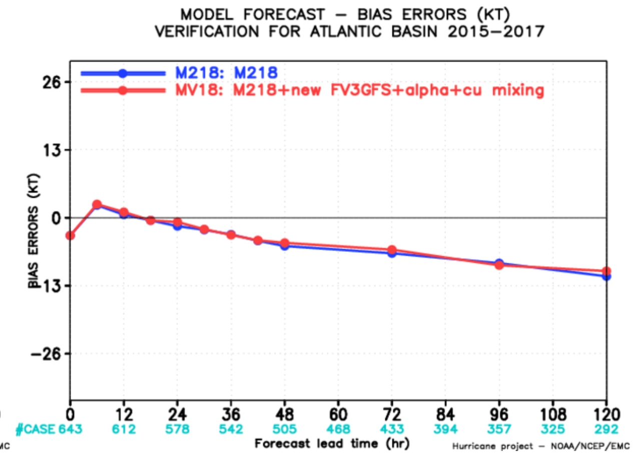


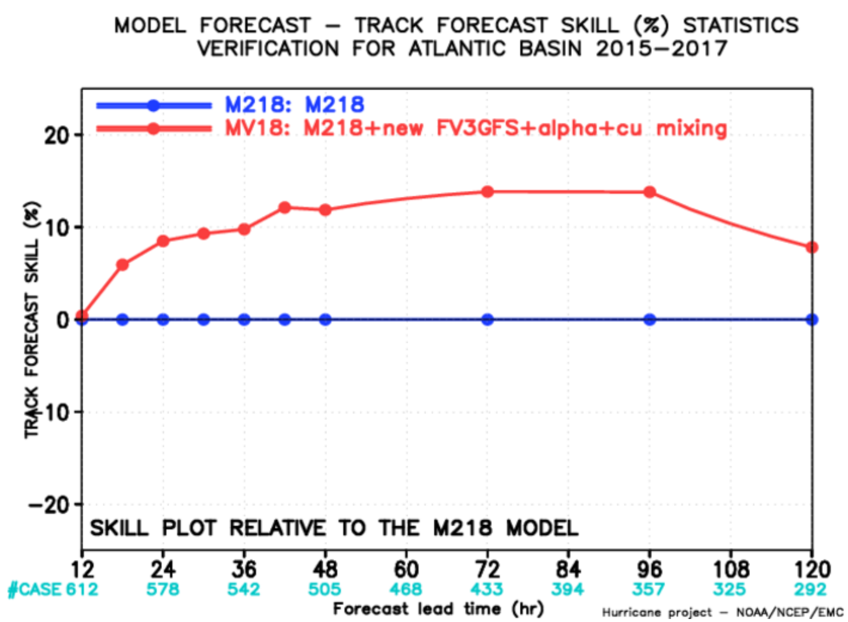


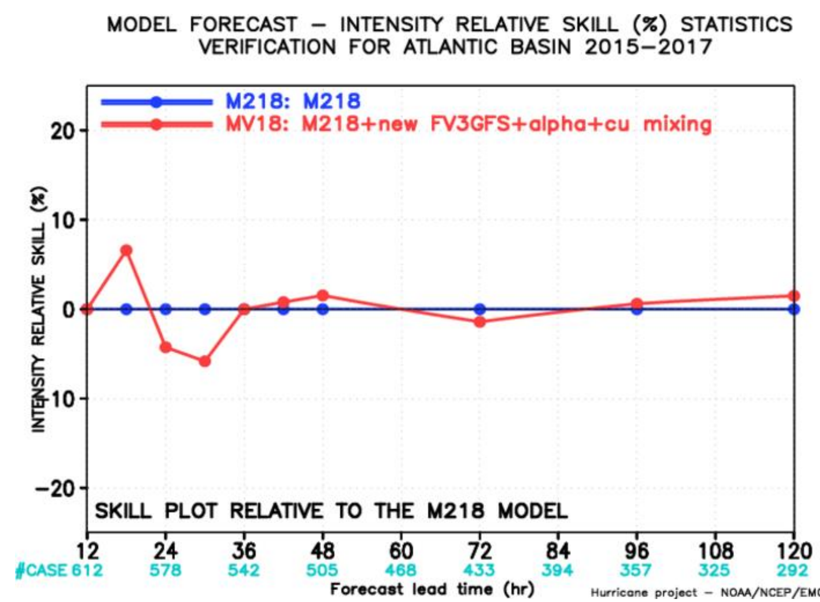
Track/Intensity Verification comparison between HMON Driven by GSMGFS and FV3GFS (Atlantic Basin)



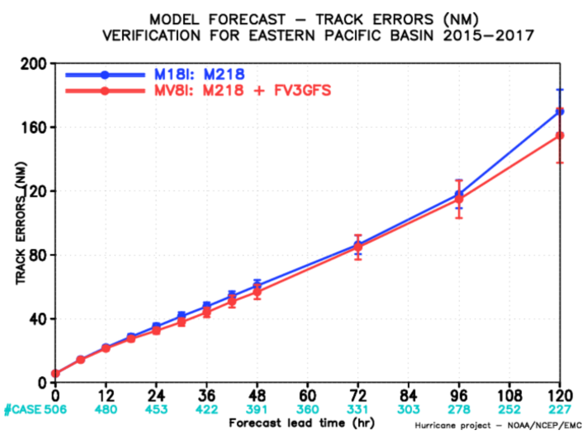


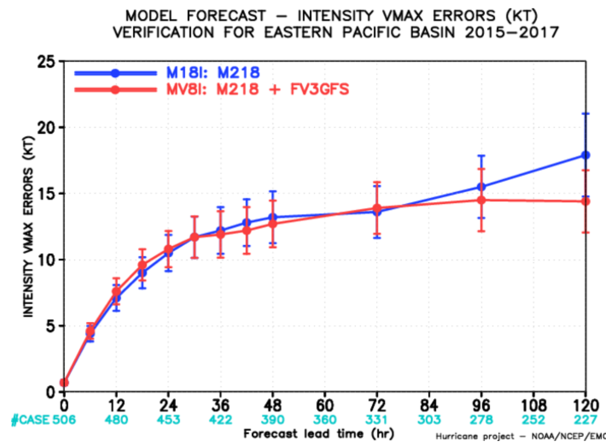


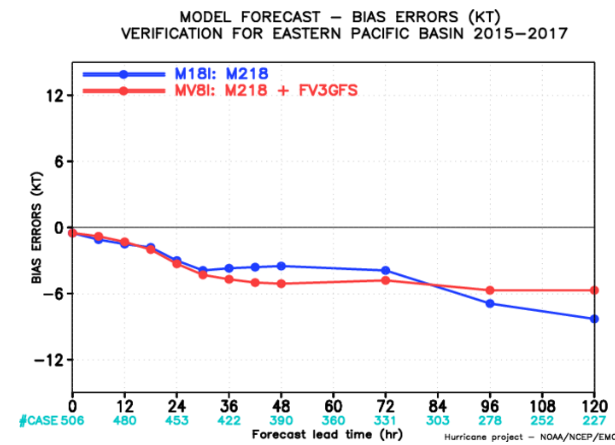


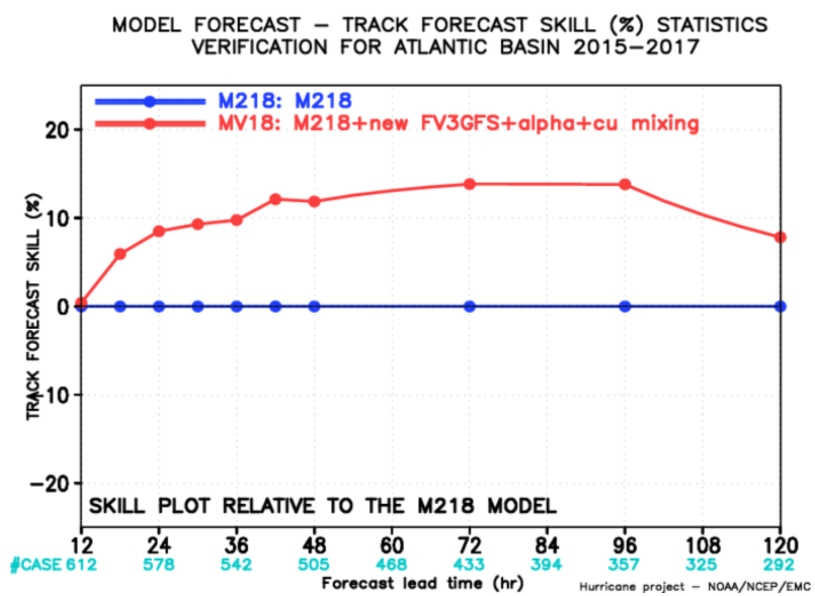


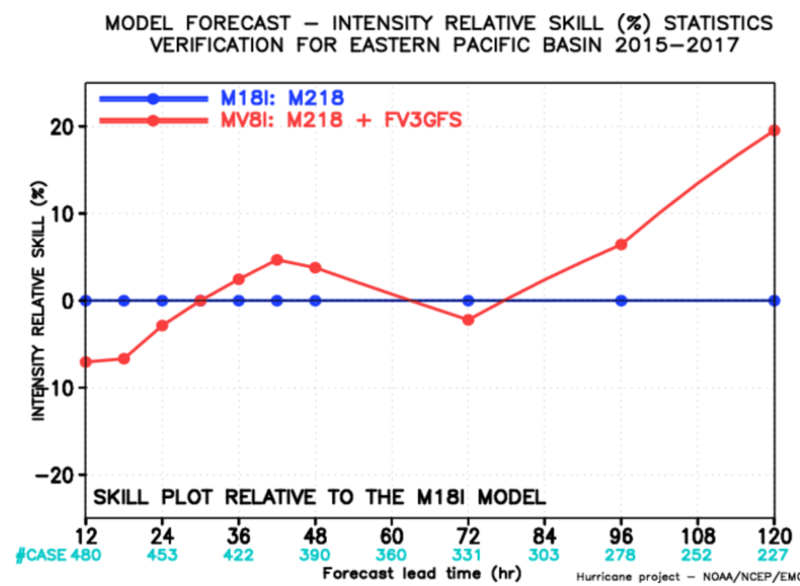
Track/Intensity Verification comparison between HMON Driven by GSMGFS and FV3GFS (East Pacific Basin)











Hurricane Analysis and Forecast System (HAFS): A collaborative Project in UFS Framework

HAFS Overview and Objectives

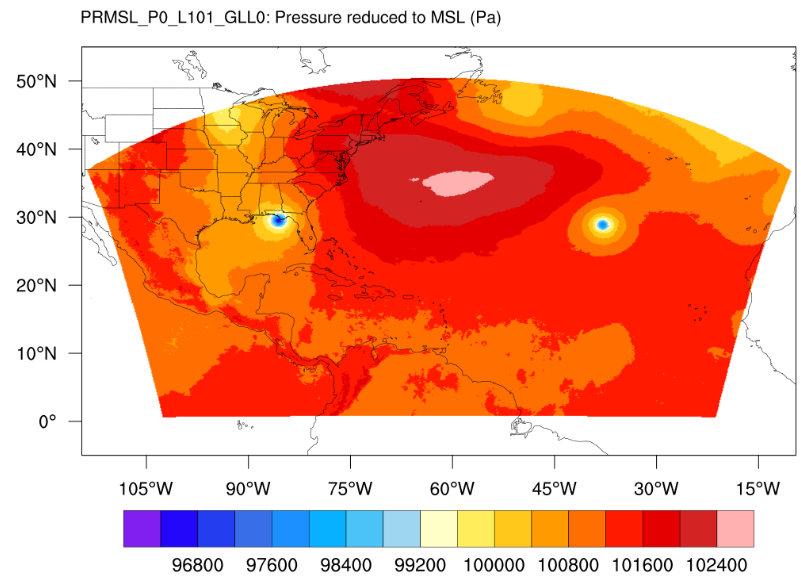
- Goal of the next generation of HFIP will build upon the original goals of the project through the following specific goals and metrics:
    1. Reduce forecast guidance errors, including during RI, by 50% from 2017.
    2. Produce 7-day forecast guidance as good as the 2017 5-day forecast guidance;
    3. Improve guidance on pre-formation disturbances, including genesis timing, and track and intensity forecasts, by 20% from 2017;
    4. Improve hazard guidance and risk communication, based on social and behavioral science, to modernize the TC product suite (products, information, and services) for actionable lead-times for storm surge and all other threats.
- Developing and advancing the Hurricane Analysis and Forecast System is one of the key strategies to address the next generation HFIP's science and R2O challenges.

HAFS Overview and Objectives

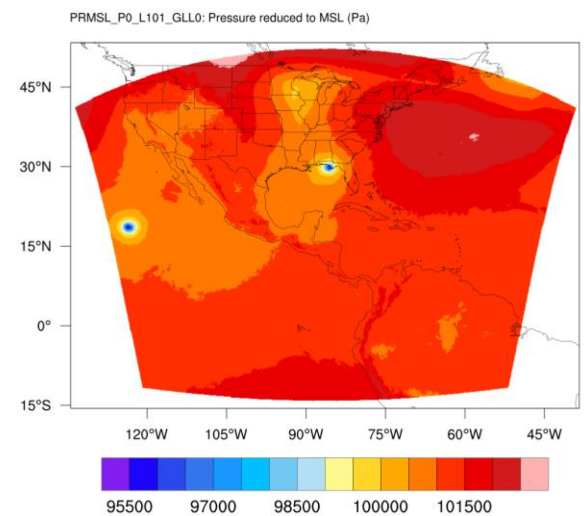
- As a Unified Forecast System (UFS) application, HAFS is an FV3 (Finite Volume Cubed-Sphere Dynamical Core) based multi-scale model and data assimilation system capable of providing tropical cyclone (TC, including hurricane and typhoon) analyses and forecasts of the inner core structure and the large-scale environment.
- The HAFS development targets an operational analysis and forecast system for TC forecasters with reliable, robust and skillful guidance on TC track and intensity (including rapid intensification), storm size, genesis, storm surge, rainfall and tornadoes associated with TCs.
- HAFS will provide an advanced analysis and forecast system for cutting-edge research on modeling, physics, data assimilation, and coupling to earth system components for high-resolution TC predictions within the outlined Next Generation Global Prediction System (NGGPS)/Strategic Implementation Plan (SIP) objectives of the Unified Forecast System (UFS).

HAFS Development

1. Current HWRF will be used to as a benchmark
2. Specialized for TC applications:
   - Storm-triggered or continuously cycled systems;
   - TC specific physics and products
3. Current applications
   - ➢ HAFS V0.A ---- Stand Alone Regional (SAR)
   - ➢ HAFS V0.B ---- Global-nest



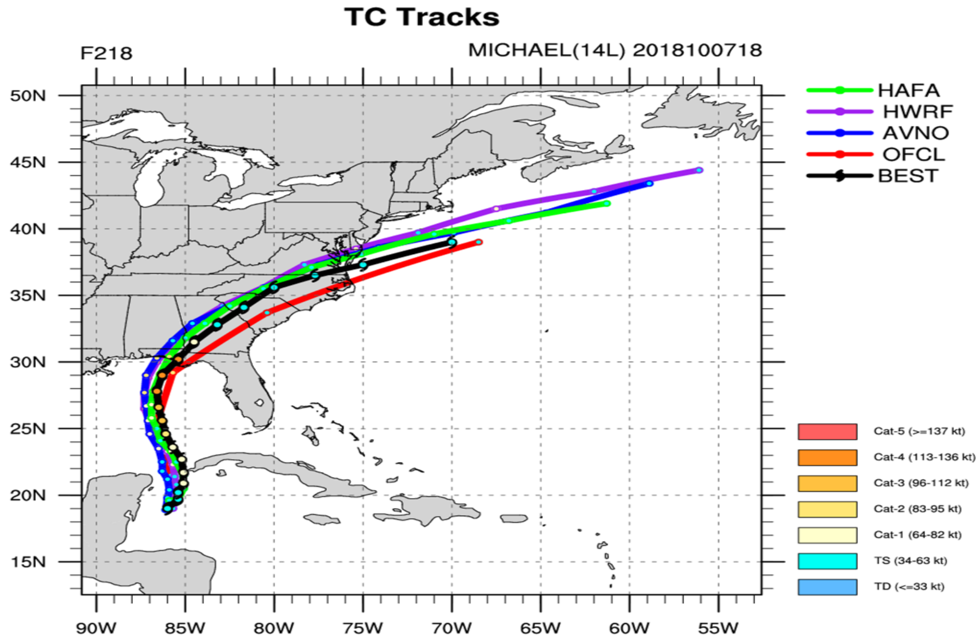
basin-focused

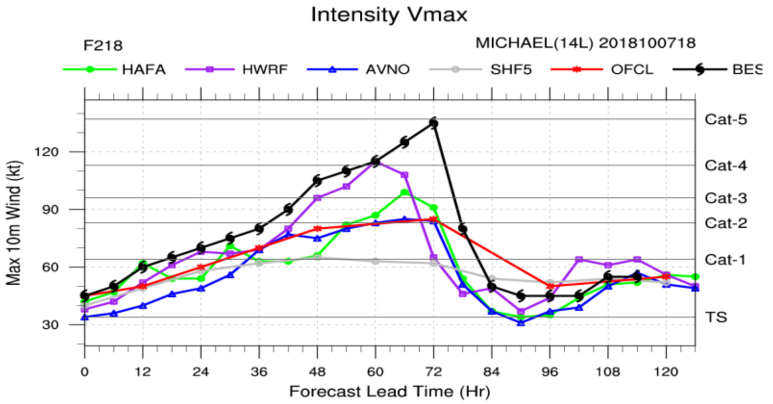


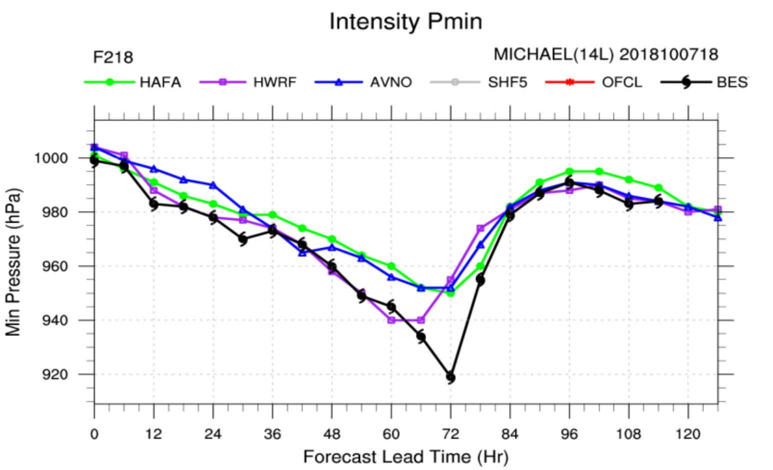
storm-focused

HAFS V0.A example

retrospective run for Michael (2018)



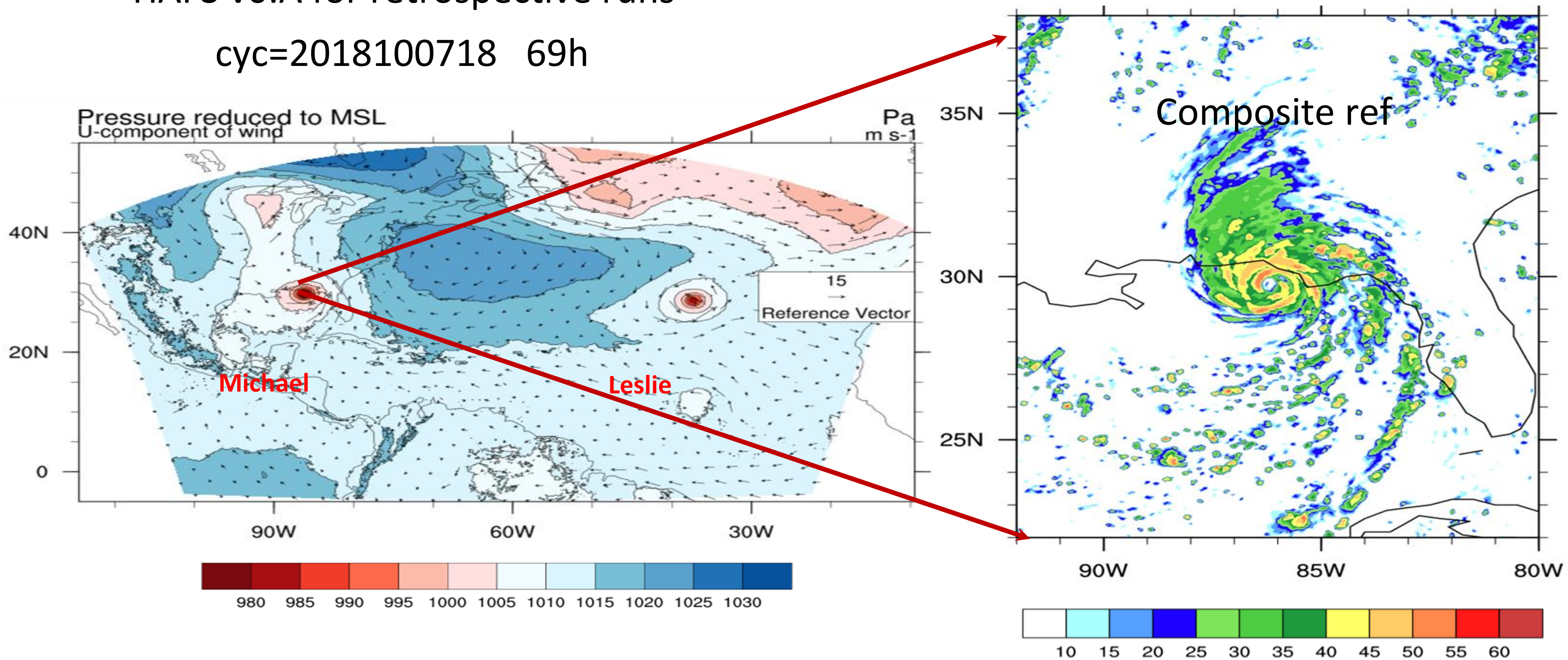




HAFS v0.A examples

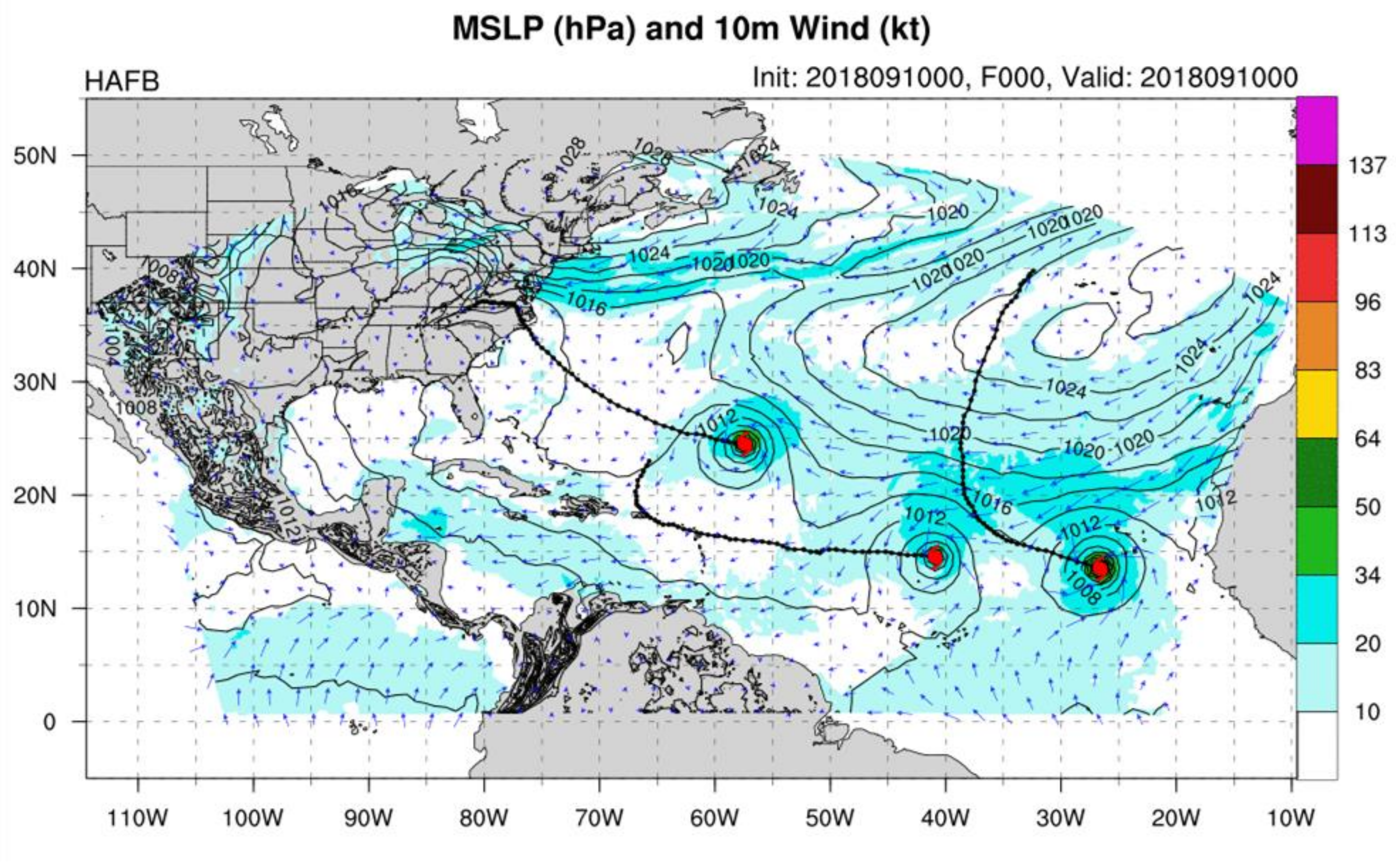
HAFS v0.A for retrospective runs

cyc=2018100718   69h



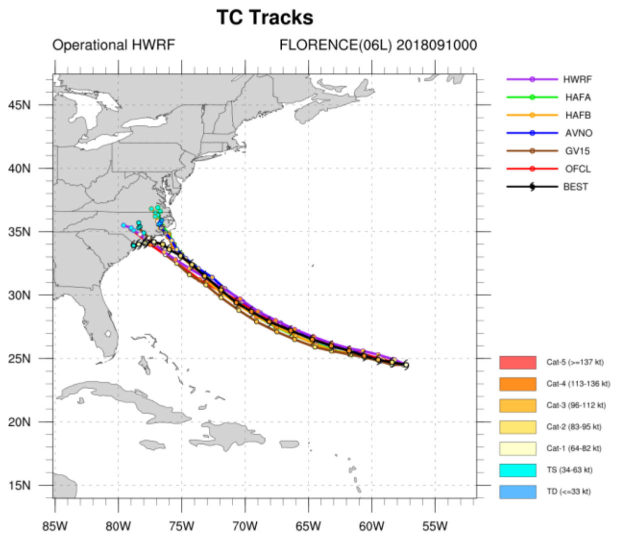
Plots from grib2 product

HAFS V0.B 7-day Forecasts
20180910 00Z

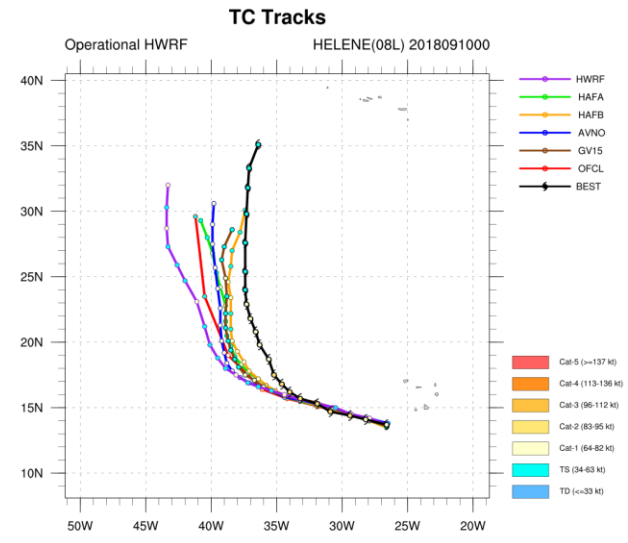


Comparison of Track Forecasts between HAFS V0.A and V0.B

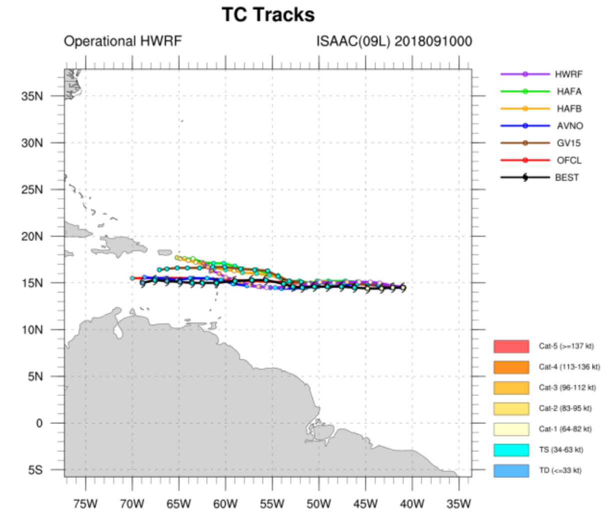
20180910 00Z



Florence, 06L



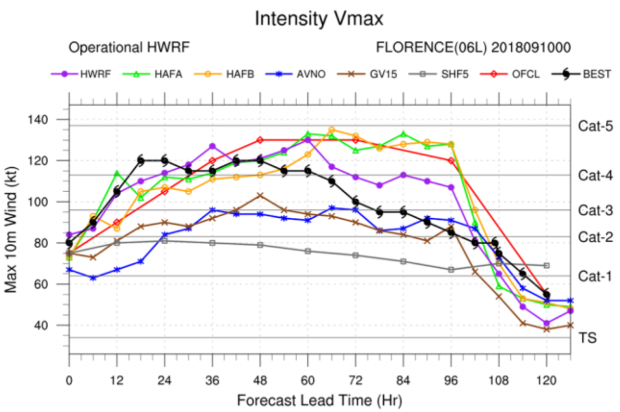
Helene, 08L

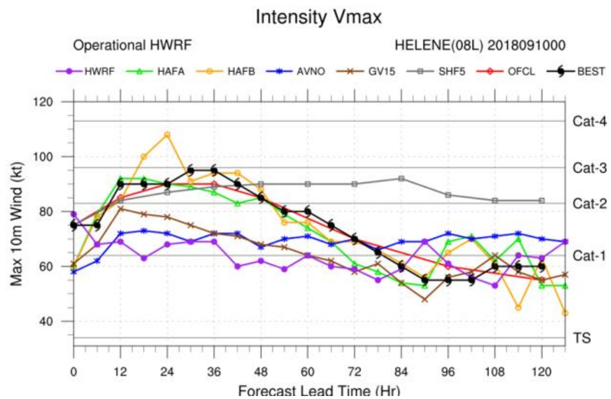


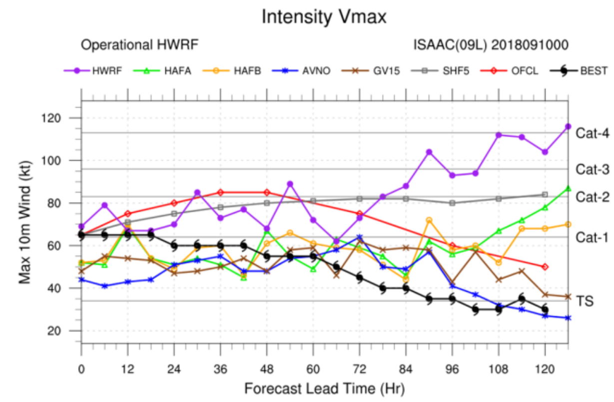
Isaac, 09L

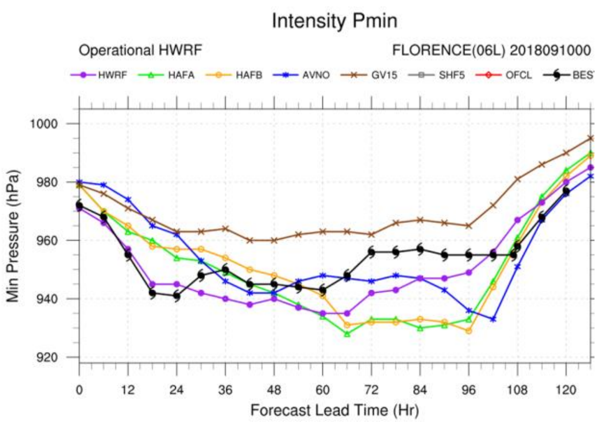
Comparison of Vmax/Pmin Forecasts between HAFS V0.A and V0.B

20180910 00Z

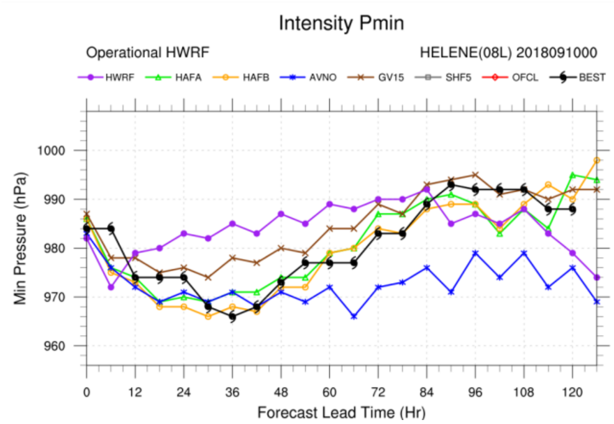




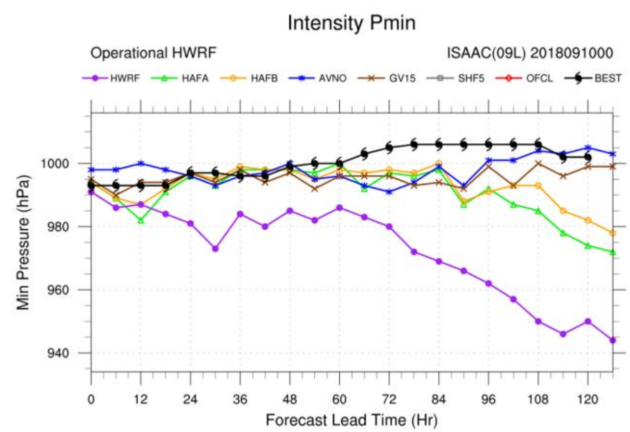




Florence, 06L



Helene, 08L



Isaac, 09L

HAFS Ongoing Tasks

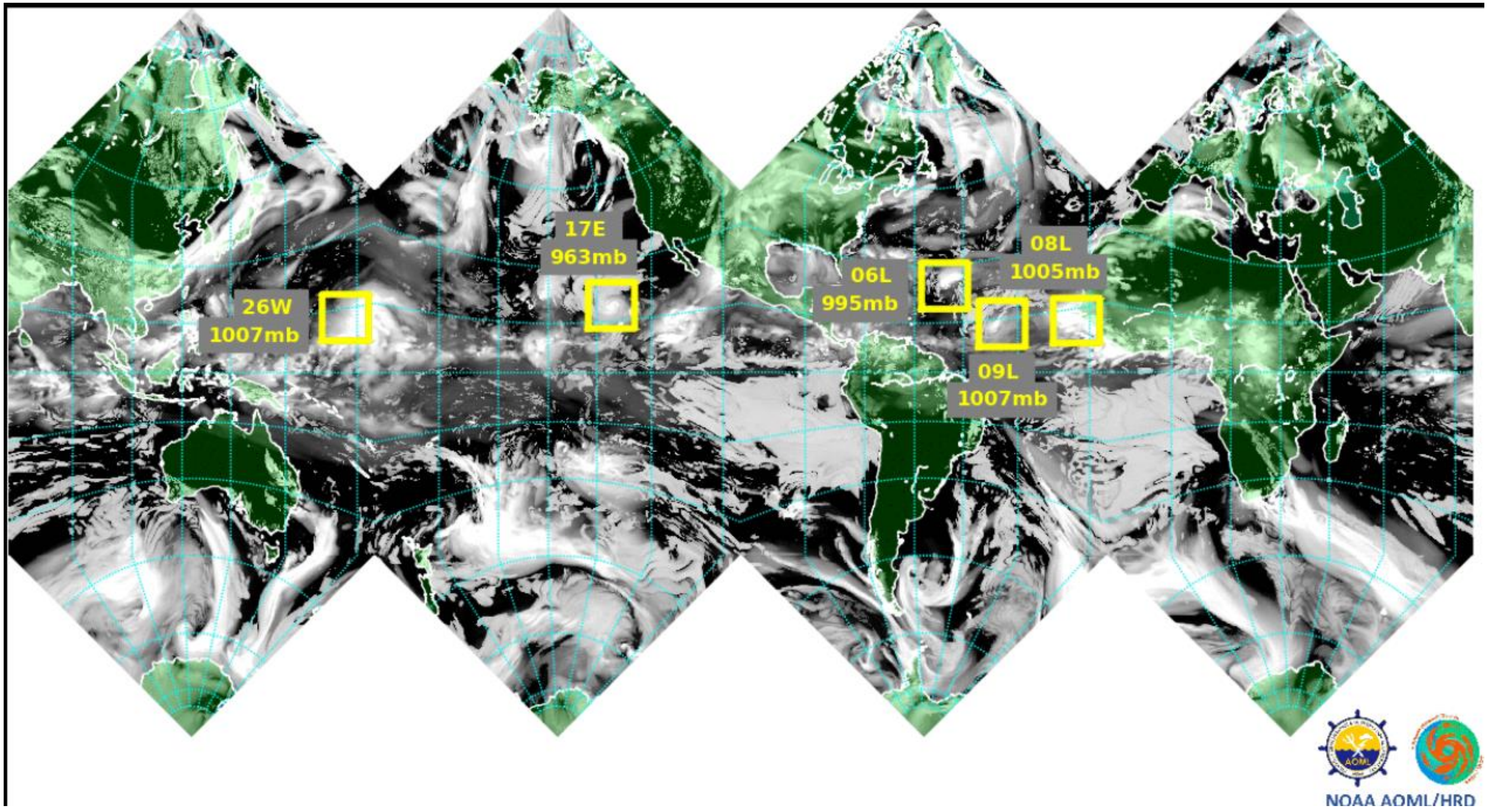
- Finalizing configurations for HAFS v0.A and v0.B real-time experiments (EMC and HRD)
  - Creating a branch in HAFS repository for the code freeze and support for HAFS V0.A and V0.B experiments
  - Turning on and testing the real-time data transfer for HAFS/HWRF/HMON needed input files to Jet
    - Data transfer for HAFS input files is already being tested
- Planning and conducting HAFS-related physics scheme tests
- Establishing Vortex Initialization capability for HAFS
- Developing HAFS DA capabilities
- Developing Ocean and Wave coupling, HYCOM/MOM6 and WW3
- Generating HAFS graphics and setup websites for display

HAFS Future Developments

- Accelerate multiple, moving nest implementations in FV3 (HRD, GFDL)
- FV3 nests coupling to ocean and waves using NEMS/CMEPS (NESII, EMC)
- Implement HWRF Physics in FV3 using CCPP (GMTB, EMC)
- Implement inner-core Hybrid En-VAR DA (EMC, HRD)
- Advanced TC-specific products
- Coupling advanced LSM, hydrology, inundation and surge models (future)

What do multiple moving nests look like in global model?

06L: Florence; 08L: Helene; 09L: Isaac;
17E: Olivia; 26W: Mangkhut



Thanks!