Operational Hurricane Modeling Plans at NCEP

- ***FV3GFS Development and Implementation in 2018***
- ***HWRF/HMON Upgrades for 2018***

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NOAA/NWS/NCEP/EMC

72nd IHC and TCORF, FIU, Miami, FL, March 13-15, 2018.

With inputs from SJ Lin & GFDL fvGFS Team

FV3 dycore and global models: GFS

Completed

- Q3FY17: Implement FV3 into NEMS
- Q4FY17: Couple FV3 to GFS Physics+ GFDL Microphysics & complete forecast only experiment for benchmark evaluation
- Q4FY17: Adapt existing DA techniques for FV3.
- Q1FY18: Update DA to ingest and properly process additional cloud hydrometers and non-hydrostatic pressure and height fields.
- Q1FY18: Complete Pre/Post processing, verification, and downstream product generation
- Q2FY18: Code freeze of FV3GFS-beta, run real-time parallel

Near-term Milestones

- Q2FY18: FV3GFS-beta V1 public release
- Q2&Q3FY18: 3-year retrospectives and case studies, real-time EMC parallel for 2018 hurricane season, downstream products generation, testing downstream NPS models, science evaluation, NCEP Center engagement
- Q4FY18: final field evaluation, OD Brief, code handoff and public release of operational code, 30-day IT testing.
- 12/1/18: FV3GFS V15 operational implementation (replace GSM with FV3GFS)
- Q4FY18: Advanced physics; increased resolution and enhanced DA
- Q2FY19: Finalize FY19 FV3GFS implementation configuration
- Q3FY19: Conduct real-time EMC parallel for 2019 hurricane season and 3-year retrospective experiments
- Q4FY19: Complete 3 year retro & real time parallel and Evaluation
- Q1FY20: Advanced FV3GFS V16 operational implementation

FV3GFS-Beta: Infrastructure and Physics Upgrades

- Integrated FV3 into NEMS
- Added IPD in NEMSfv3gfs
- Newly developed write grid component -- write out model history in native cubed sphere grid and Gaussian grid
- Replaced Zhao-Carr microphysics with the more advanced GFDL microphysics
- Updated parameterization of ozone photochemistry with additional production and loss terms
- New parameterization of middle atmospheric water vapor photochemistry
- a revised bare soil evaporation scheme.
- Stochastic physics and IAU
- Enable NSST in FV3

other minor changes:

- correction bugs related to the convective cloud water
- radiation bug fix
- slight modification in scale-aware mass-flux deep or shallow convection schemes

Data Assimilation – GSI and New Observations

- GSI bug-fixes and efficiency changes
- Update of the GSI IO in producing analysis file to structurally resemble the model generated forecast nemsio file.
- Update of the GSI IO to read in combined surface and NSST file from the model.
- Inclusion of GFDL microphysics.
- Compute delp and delz increment hydrostatically from surface pressure and temperature increments.
- Improved ensemble IO speeds are obtained in GSI by reading the 4D ensemble in parallel.
- Increase in ensemble resolution from roughly 39km to 25km.
- Adaptation of stochastic physics parameterizations from the spectral model eexcept SKEB.

- IASI moisture channels
- ATMS all-sky radiances
- A fix for an issue with the Near Sea Surface Temperature (NSST) in the Florida Strait
- An upgrade to the use of CrIS radiances: Addition of NOAA-20 CrIS and ATMS data (will not be used until available on NESDIS operational server - expected in April 2018)
- Addition of Megha-Tropiques Saphir data
- Addition of ASCAT data from MetOp-B
- And several additional minor changes

Real-time and Retrospective Experiments

C768 (~13km deterministic), C384 (~25km, ensemble)
64 layer, top at 0.2 hPa

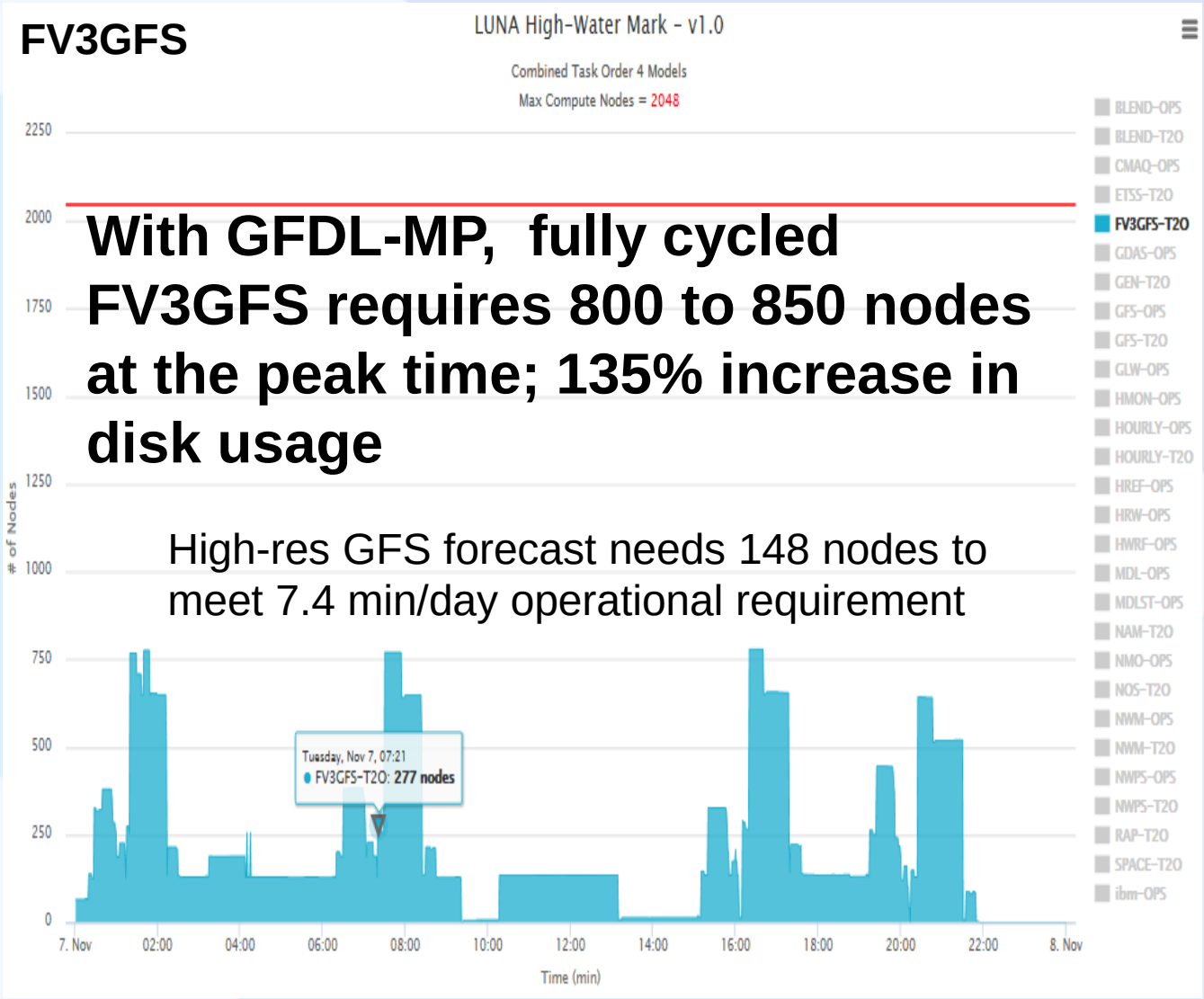
Real-time Runs: April 2018 – November 2018
Retrospective Experiments: December 2015 – March 2018

- **4 times daily**
- **Hourly output up to 120 hours, then three-hourly output up to 384 hours**

0.25-deg pgb files and certain other products from the real-time parallel will be uploaded to paranomads, NHC subset for genesis verification

Computation Resource Requirement -- HWM Test

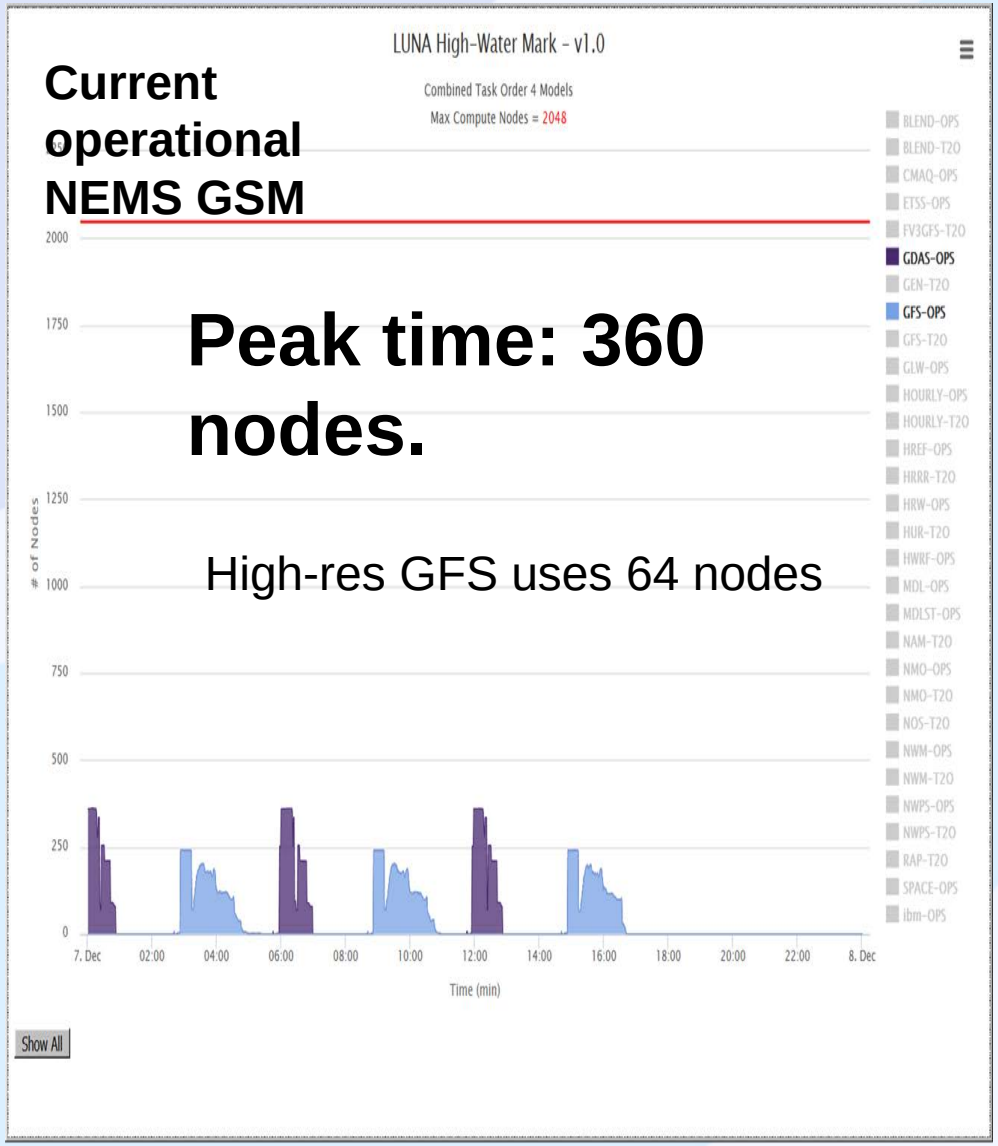
FV3GFS



With GFDL-MP, fully cycled FV3GFS requires 800 to 850 nodes at the peak time; 135% increase in disk usage

High-res GFS forecast needs 148 nodes to meet 7.4 min/day operational requirement

Current operational NEMS GSM



Peak time: 360 nodes.

High-res GFS uses 64 nodes

Benchmark Test -- FV3GFS with GFDL MP (Forecast Only)

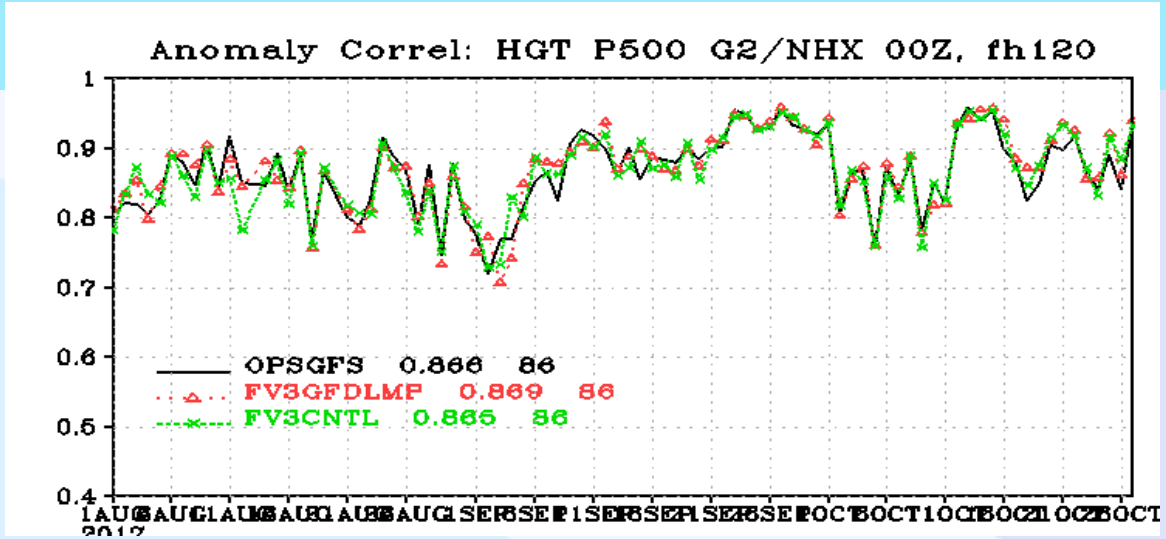
http://www.emc.ncep.noaa.gov/gmb/wx24fy/NGGPS/fv3gfdlmp/

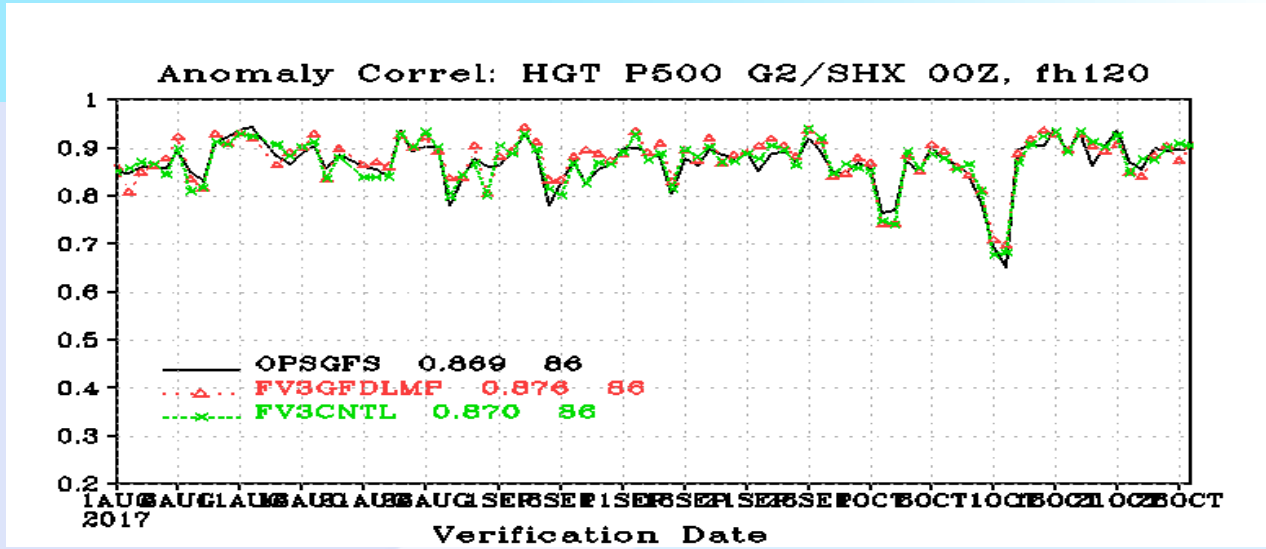
- C768L64 FV3GFS forecast-only experiment
- Initialized with operational NEMS GSM initial conditions
- Covers the period from 20170721 through 20171027, 00Z cycle every day, 10-day forecast
- All runs used the same operational NEMS GSM physics except for microphysics scheme

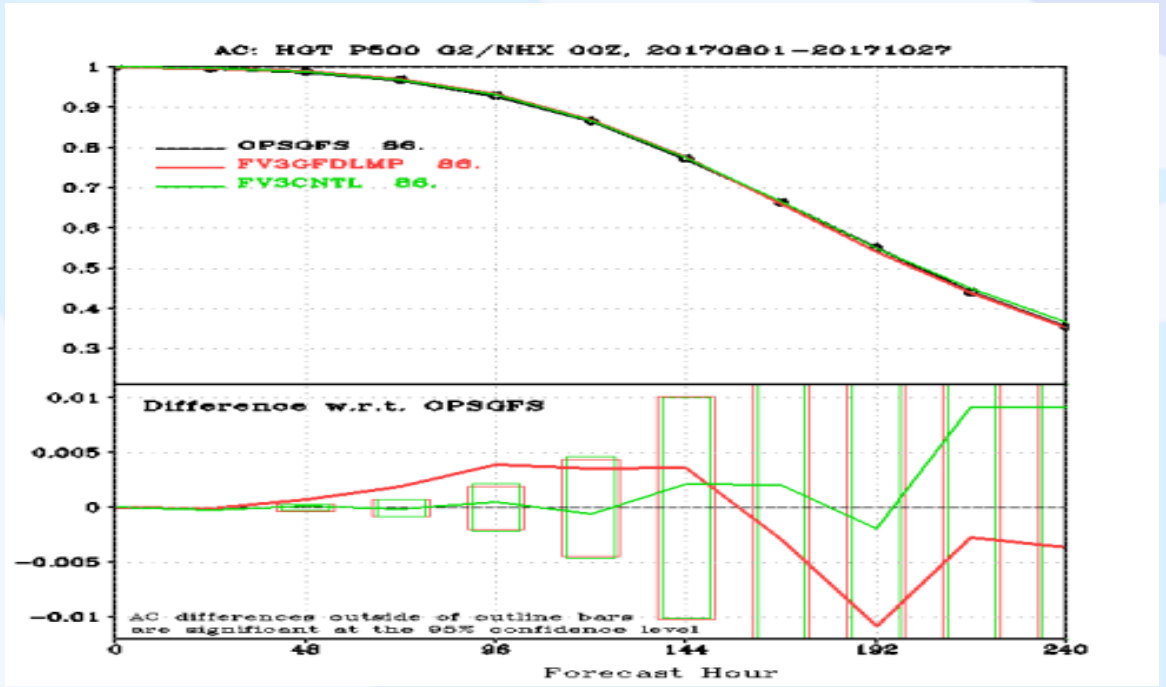
Opsgfs – NEMS GSM
fv3gfdlmp – GFDL Microphysics
fv3cntl -- Zhao-Carr Microphysics

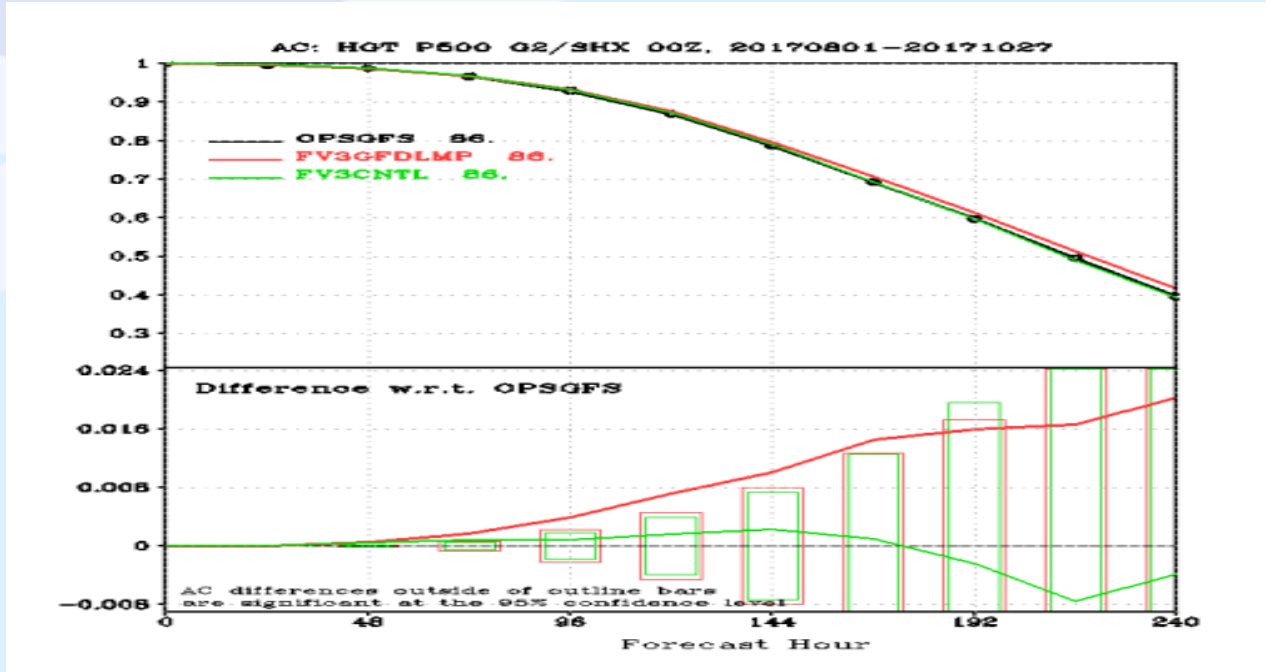
500-hPa HGT AC

http://www.emc.ncep.noaa.gov/gmb/wx24fy/NGGPS/fv3gfdlmp/

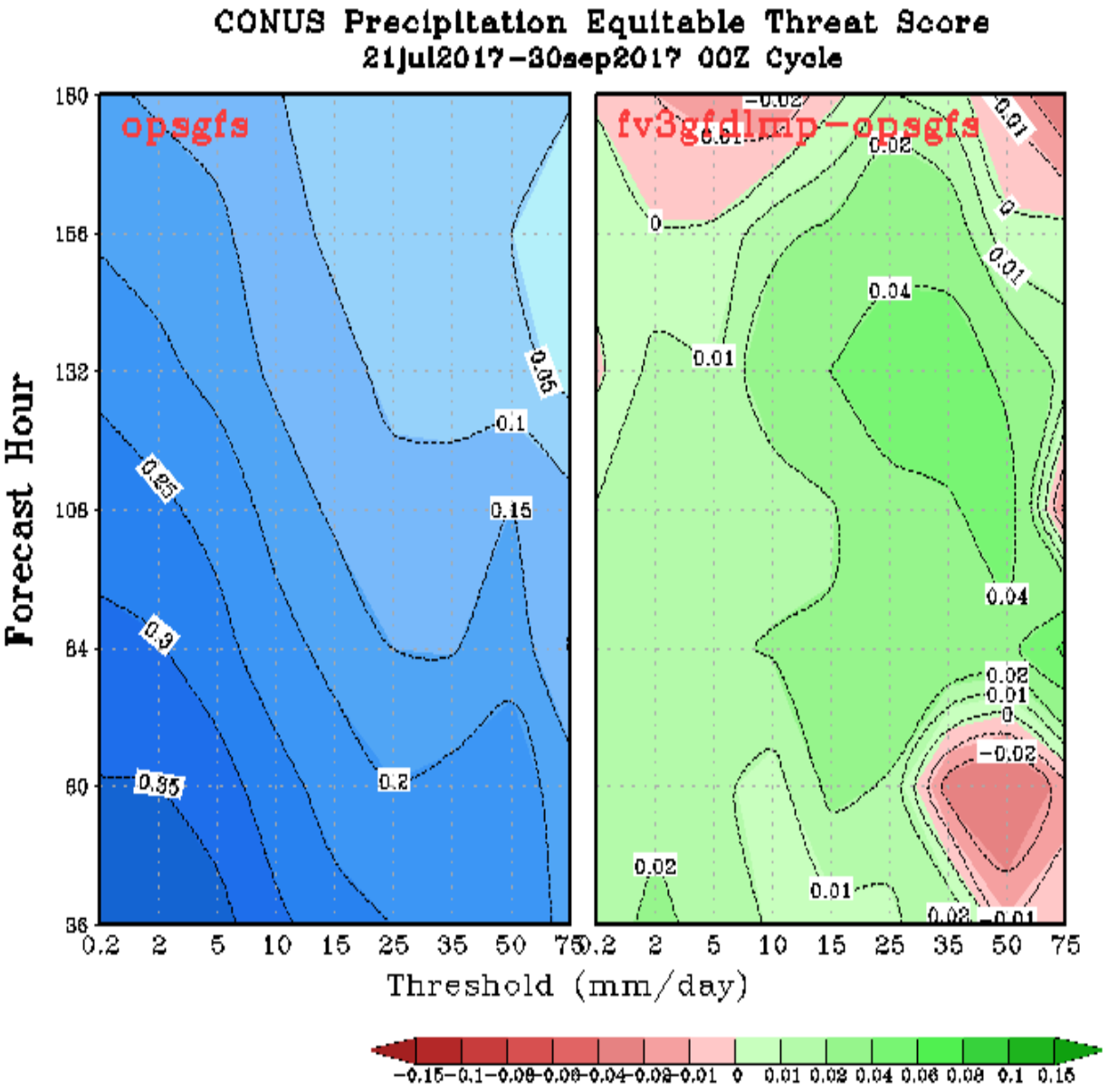


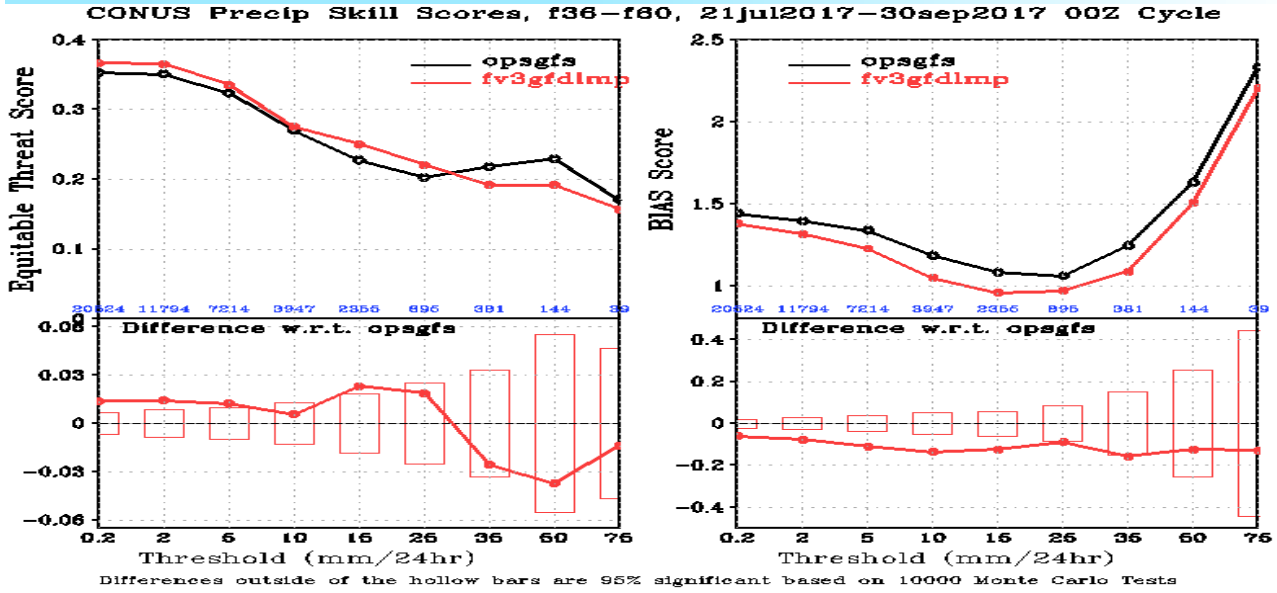


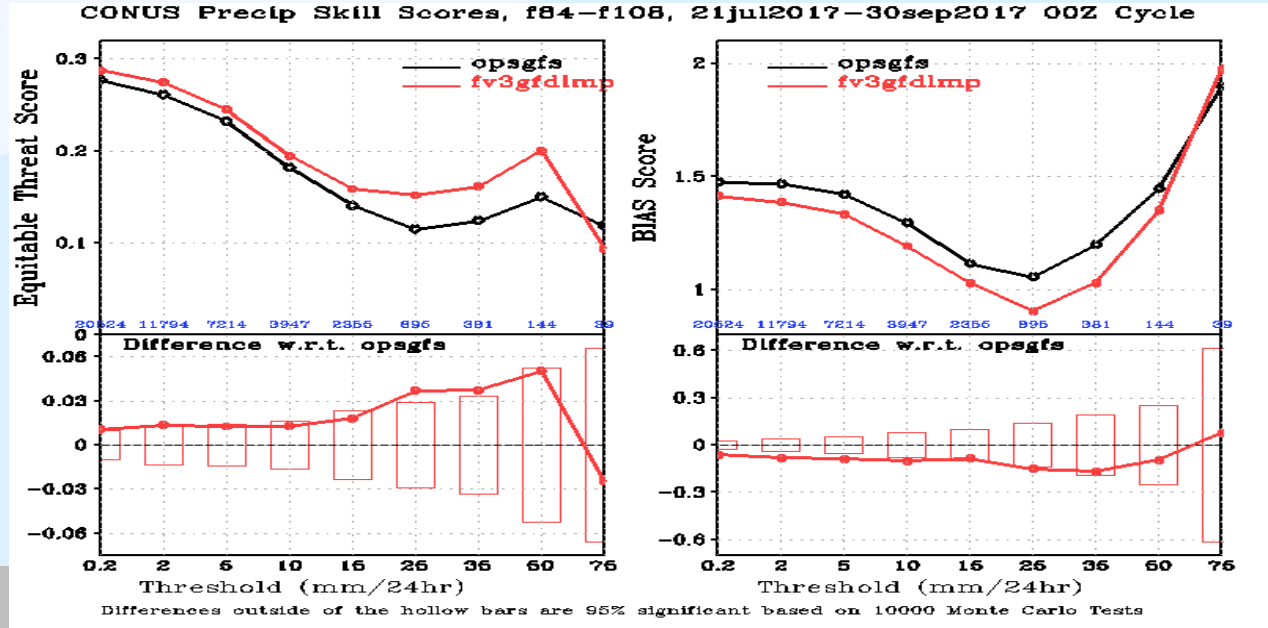




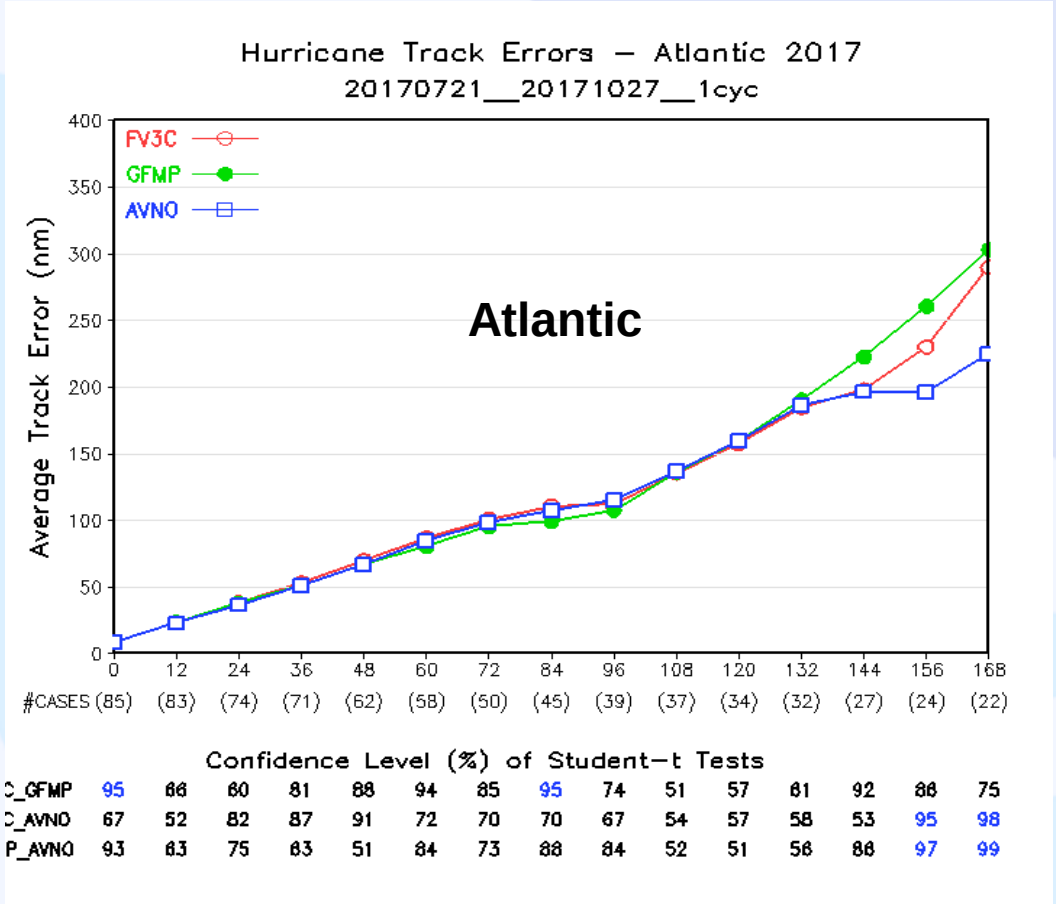
CONUS Precip

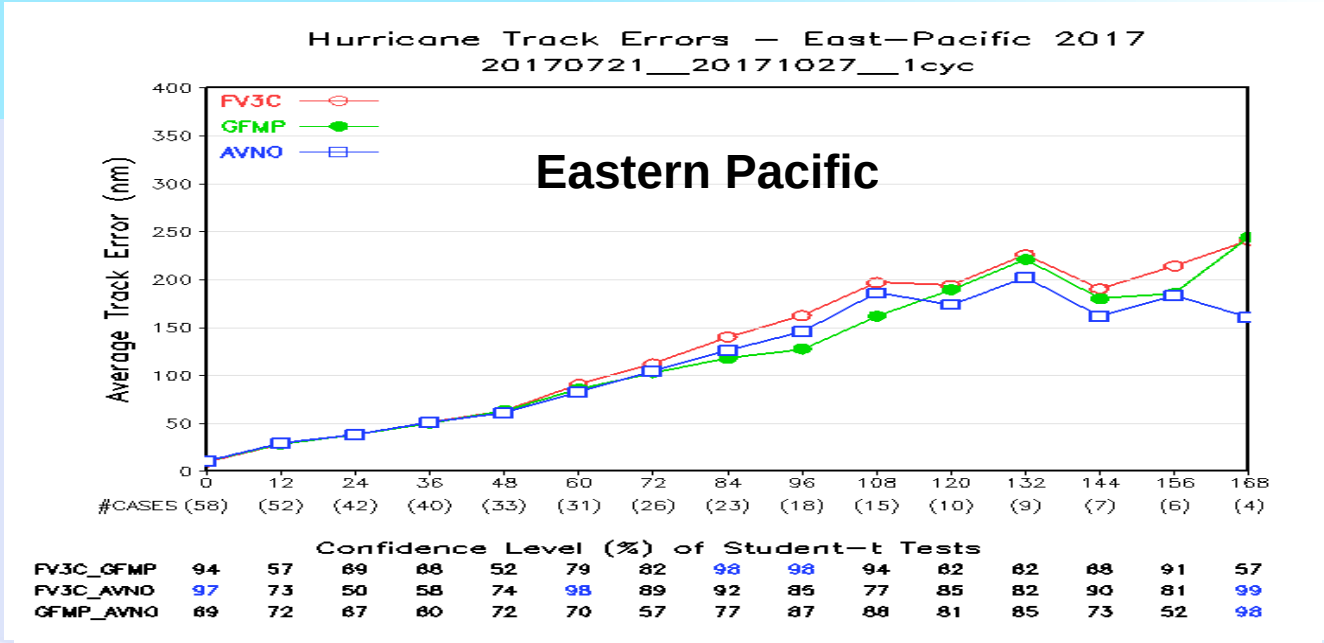


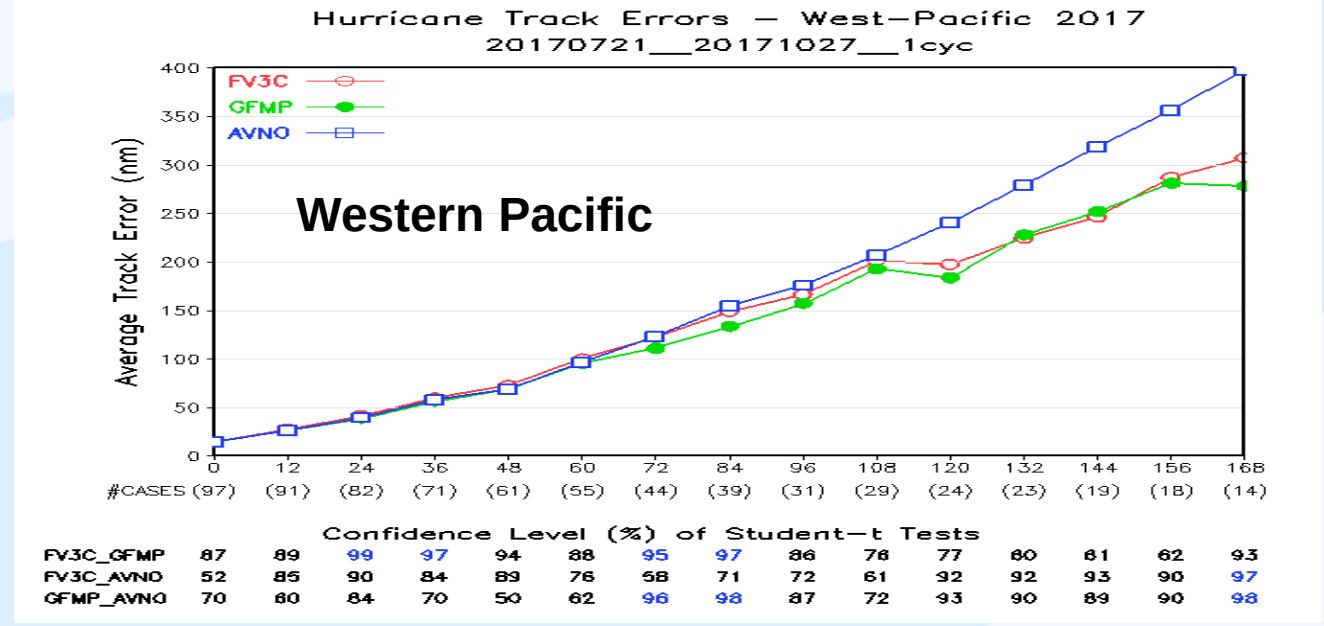




2017 Hurricane Track Errors
20170721-20170930





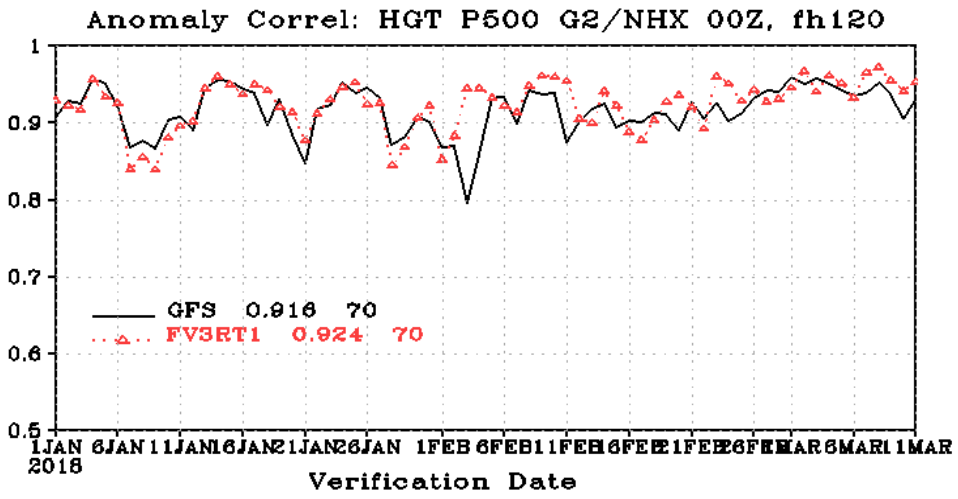


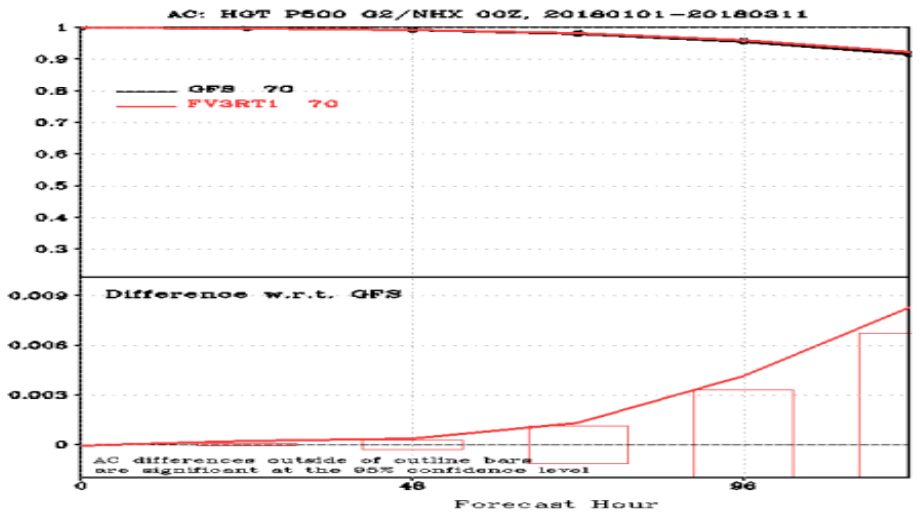
FV3C – FV3GFS with Zhao-Carr MP
GFMP – FV3GFS with GFDL MP
AVNO – operational NEMS GSM

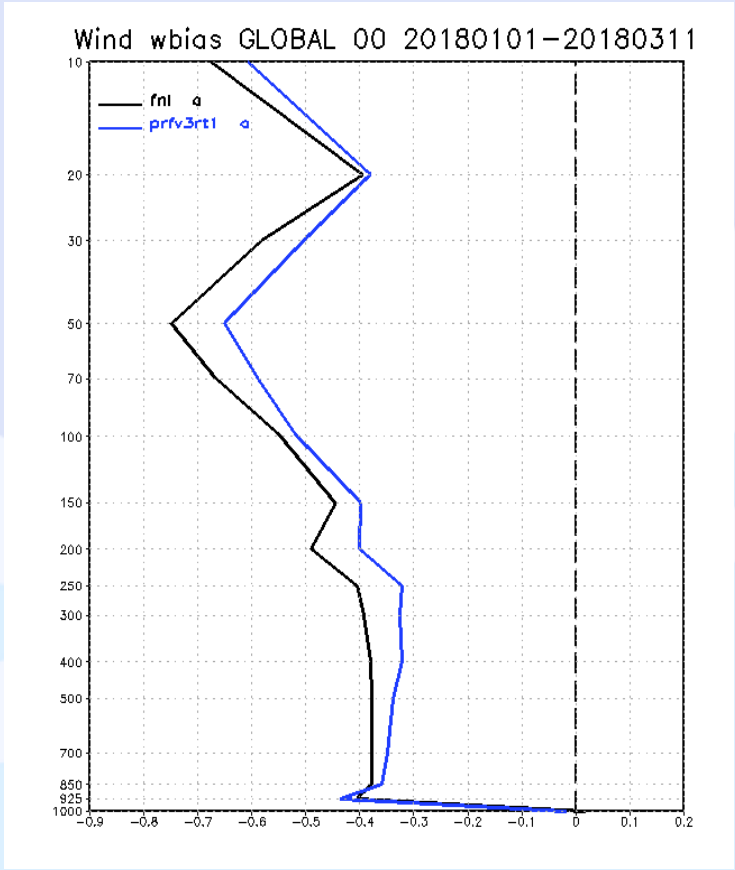
FV3 Evaluation Web Pages

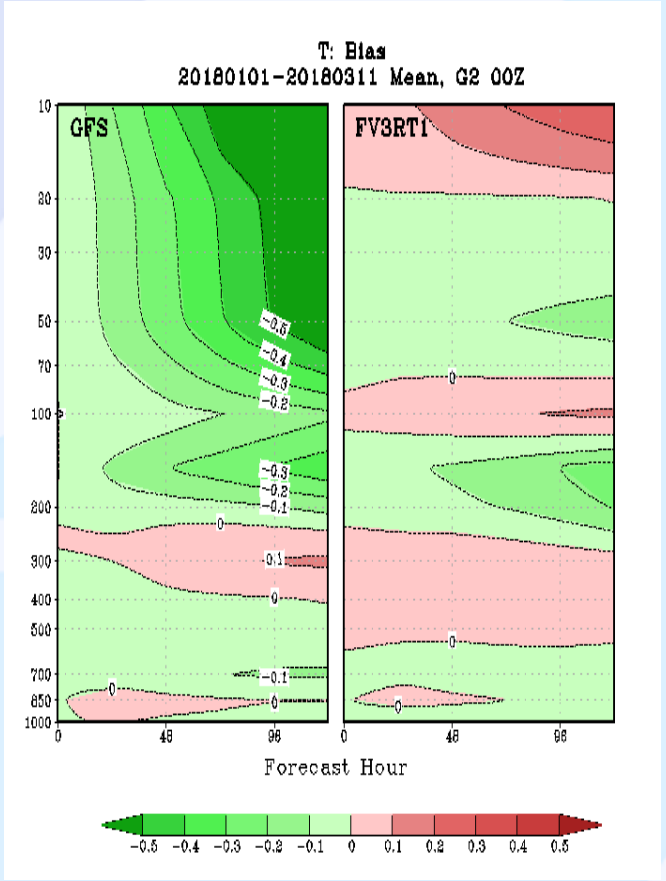
Real-Time Experiment (C768/C384 L64, full cycled)

http://www.emc.ncep.noaa.gov/gmb/emc.glopara/vsdb/prfv3rt1/

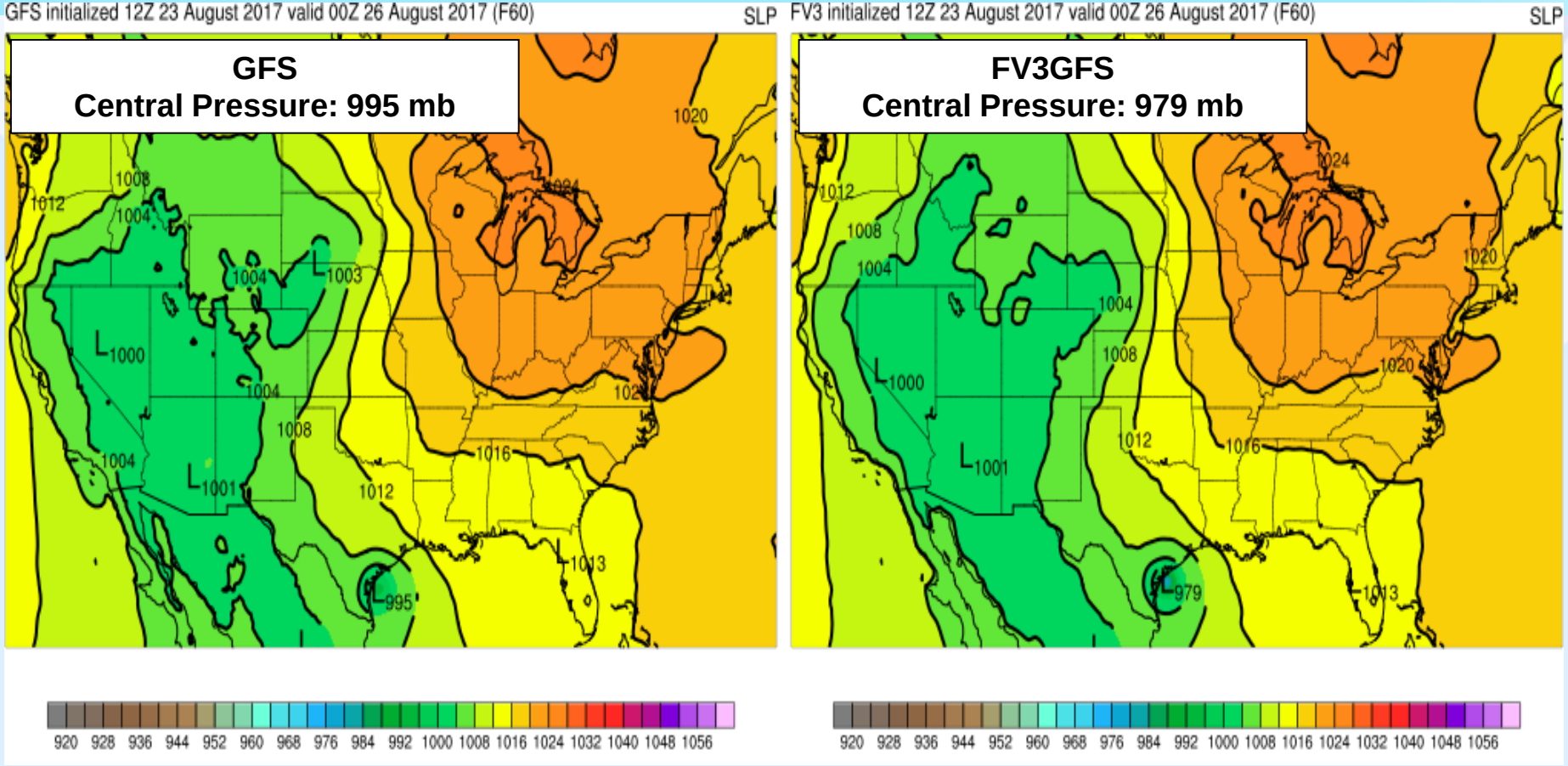








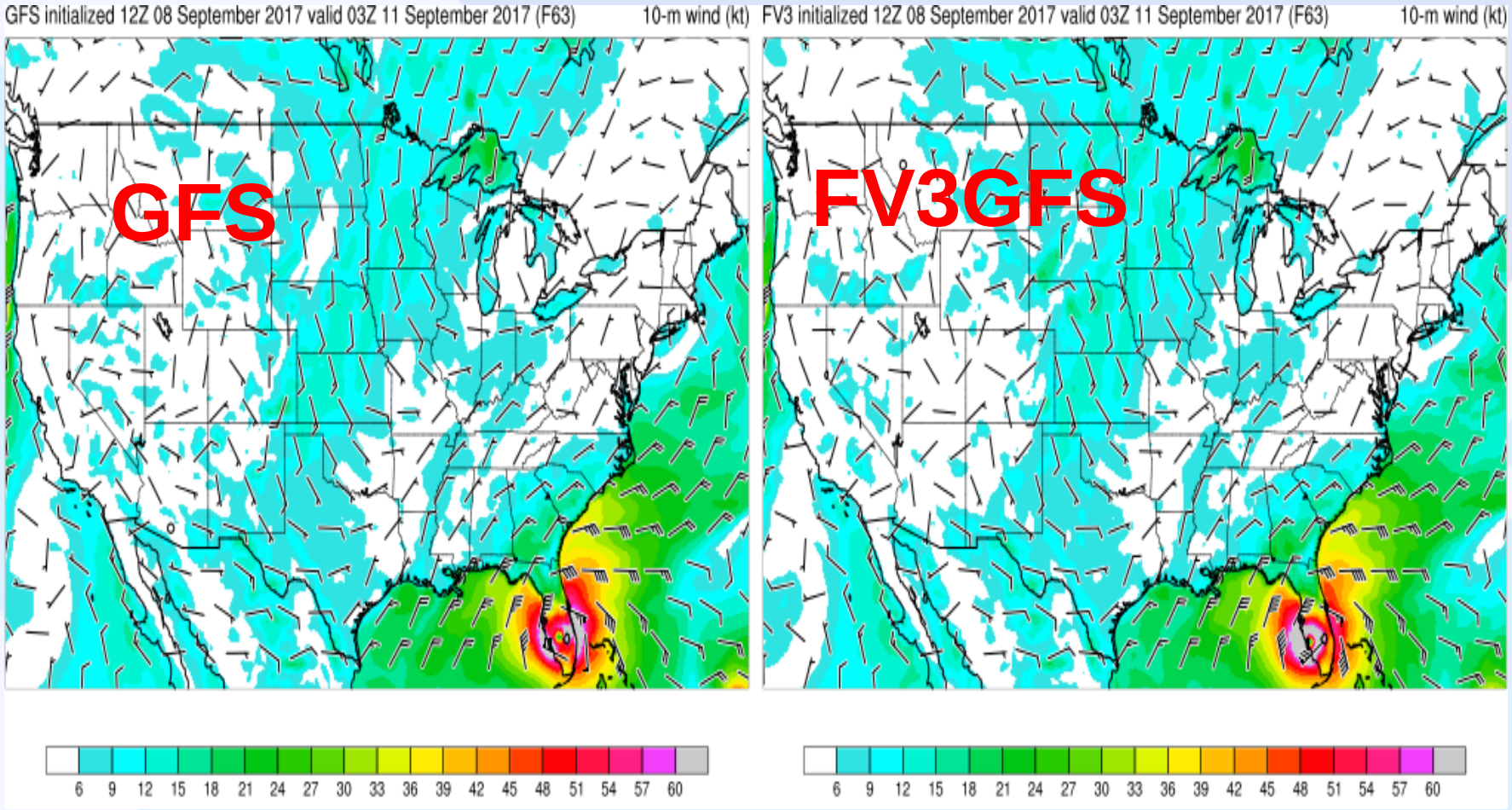
Hurricane Harvey, IC2017082312, FH60



MSLP forecasts valid at 00Z Saturday, 8/26 (F060)

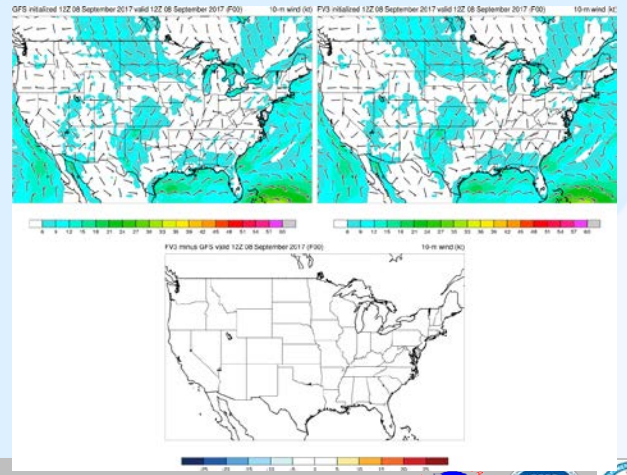
- During the first five days of each cycle, GFS and FV3 generally provided similar guidance with some subtle differences
- Example above shows **FV3 suggested rapid intensification and a deeper storm at landfall** before the GFS (which caught on in later cycles)

Hurricane Irma, IC 12Z08Sep2017

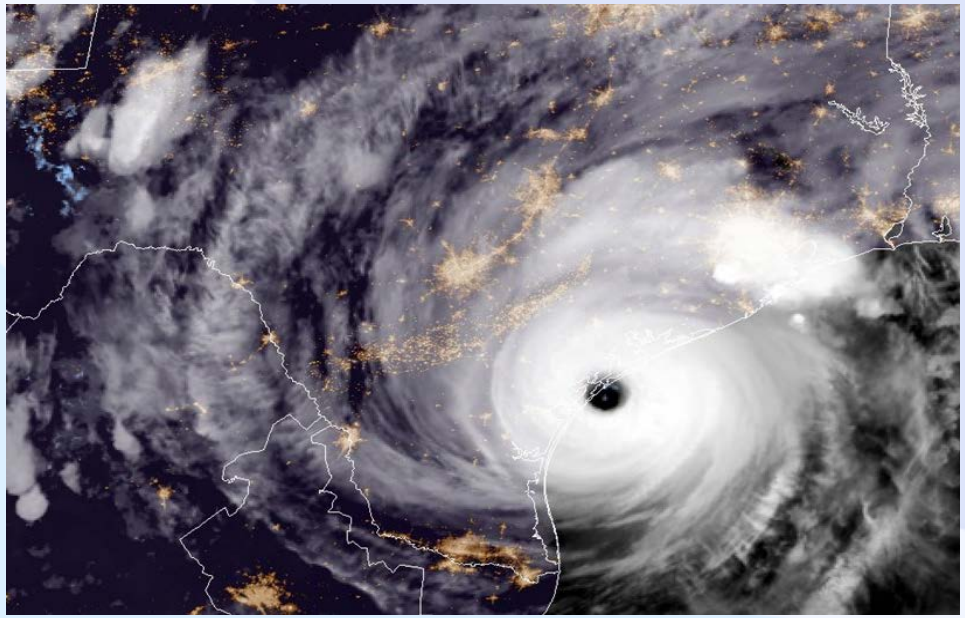


63-hr Forecast Valid at 03Z 11 Sept 2017

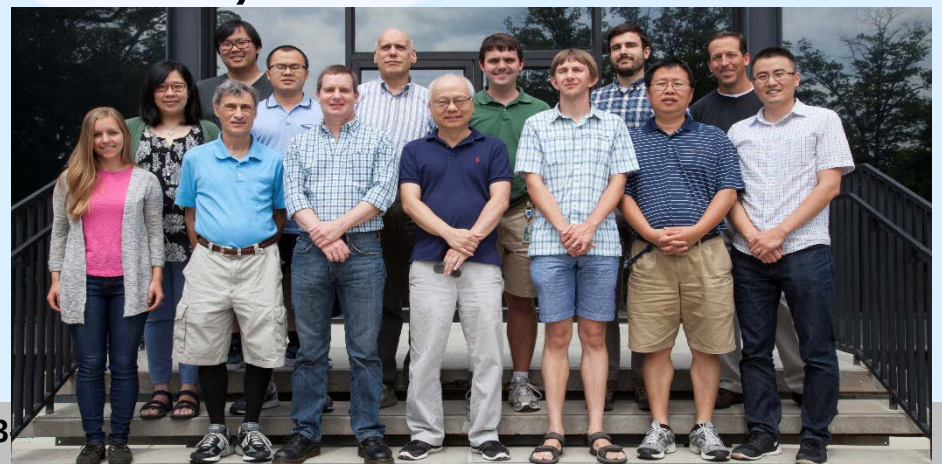
The center of Irma forecasted by FV3GFS was shifted towards west of GFS center, verified better against observations.



Evaluation of 13km Global fvGFS on Hurricane Prediction

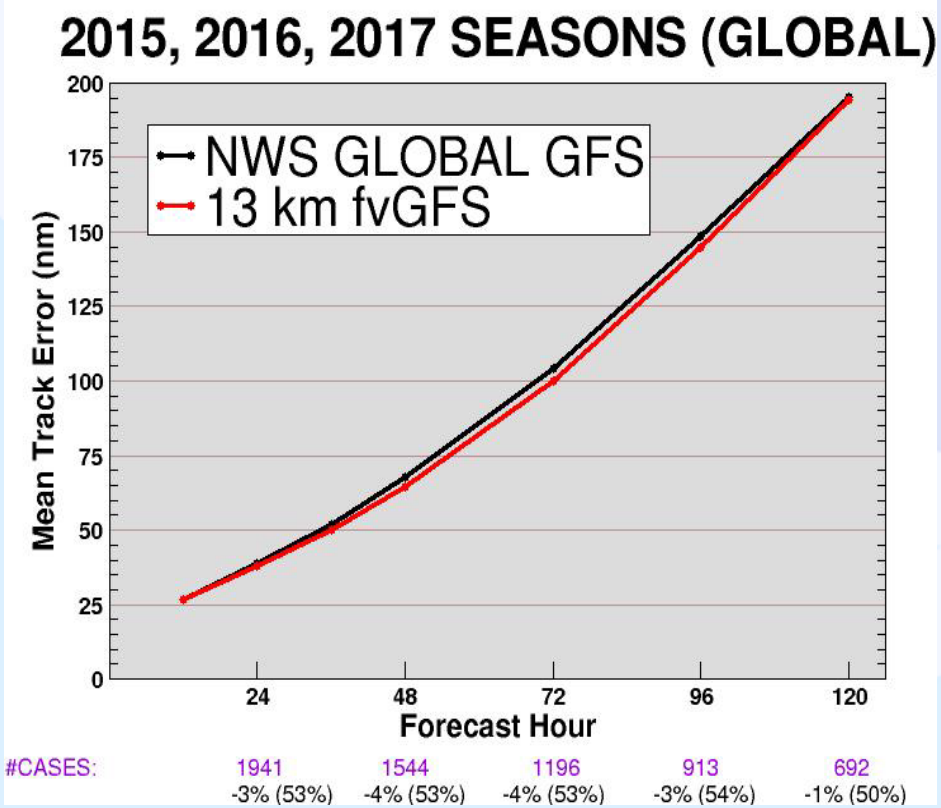


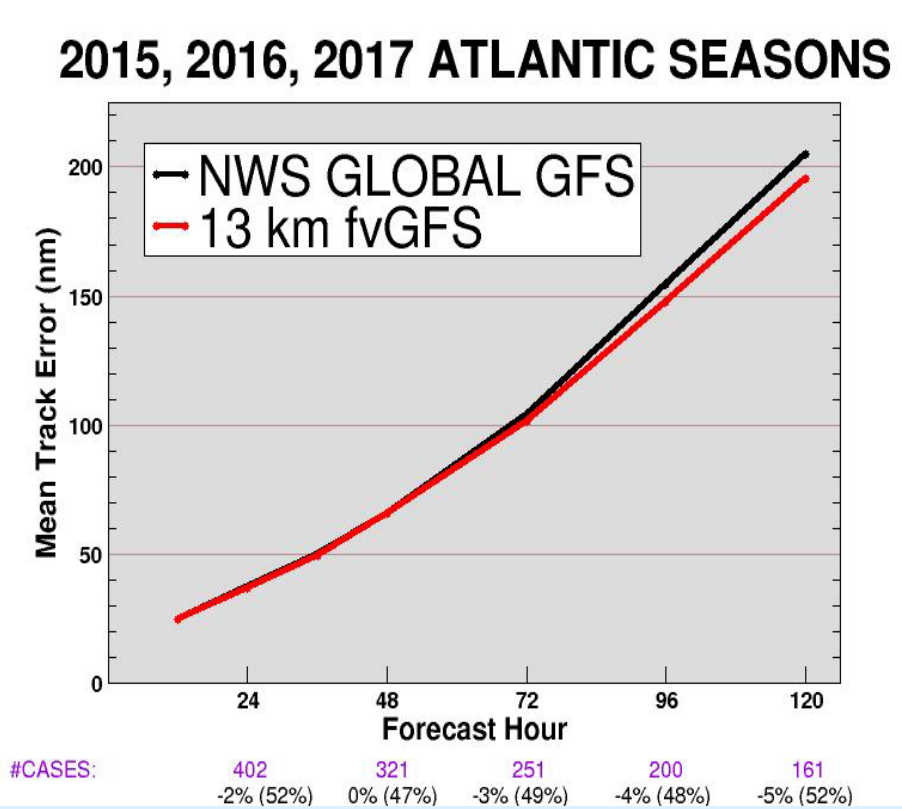
Morris Bender, Matthew Morin, Andrew Hazelton, Shian-Jiann Lin, and the GFDL FV³ Team



Average Track Errors (nm)

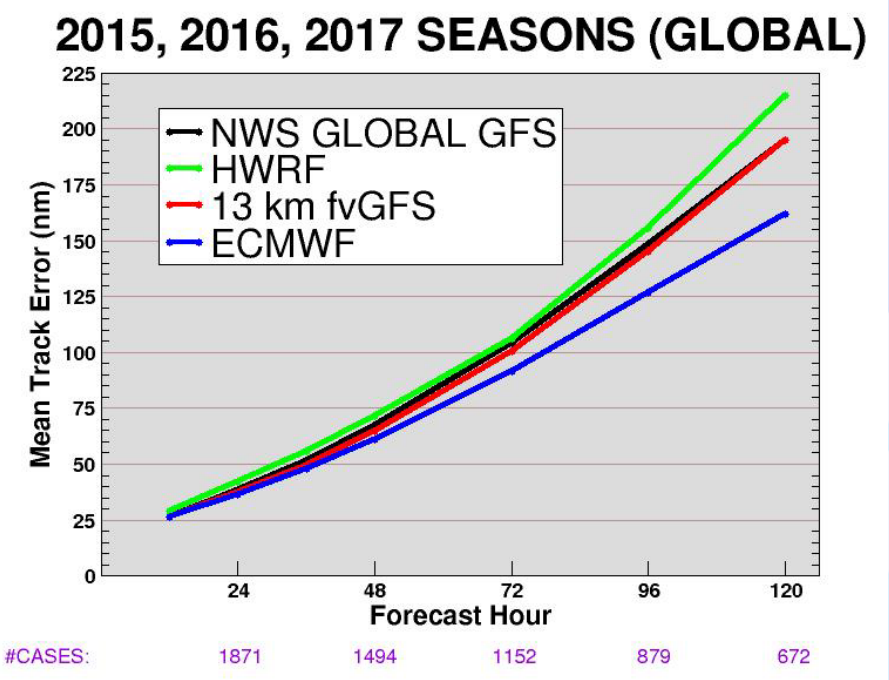
GFS vs. fvGFS



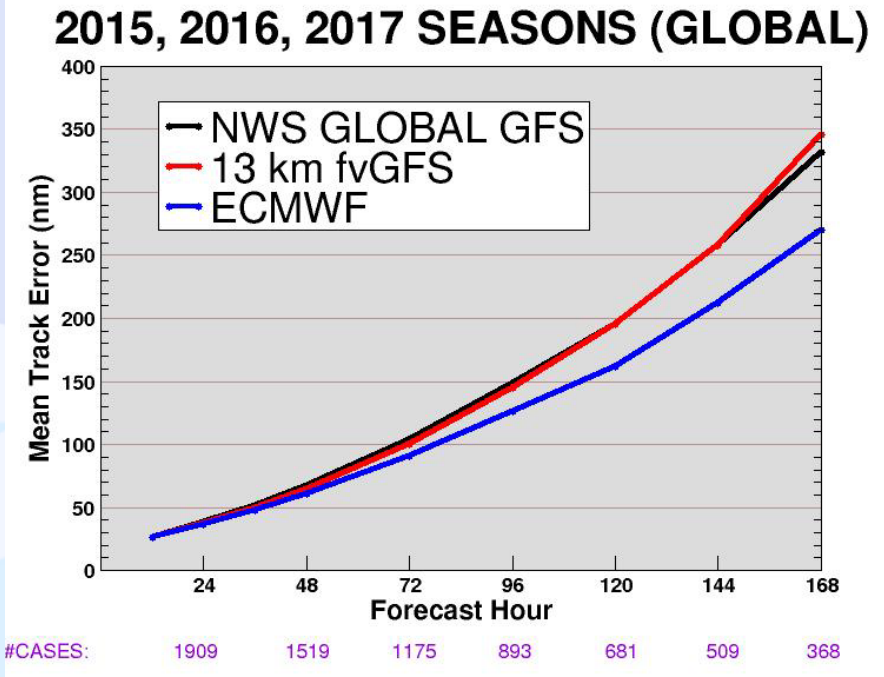


Comparable track errors between fsGFS and the GFS.
3-4% reduced track errors 1-4 days

Average Track Errors (nm)
fvGFS vs. Other Guidance



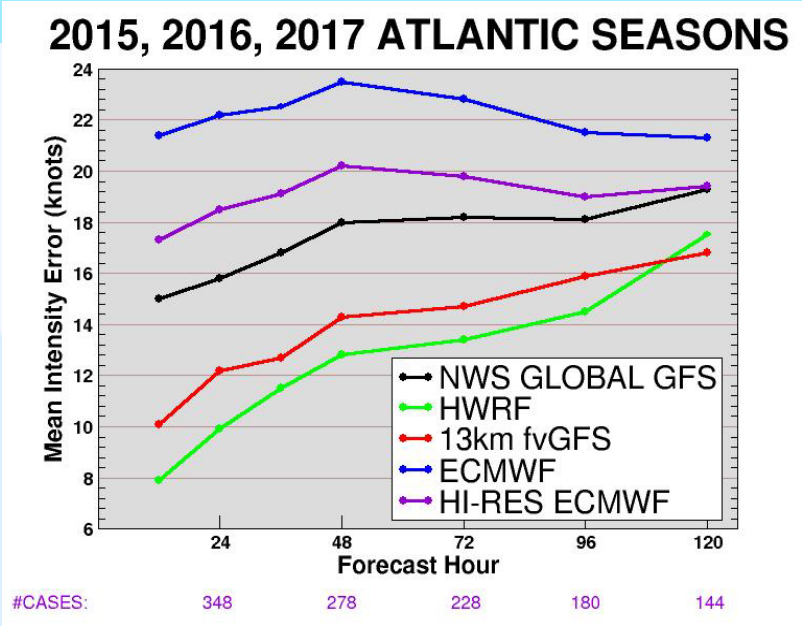
7 Day Track Errors (nm)



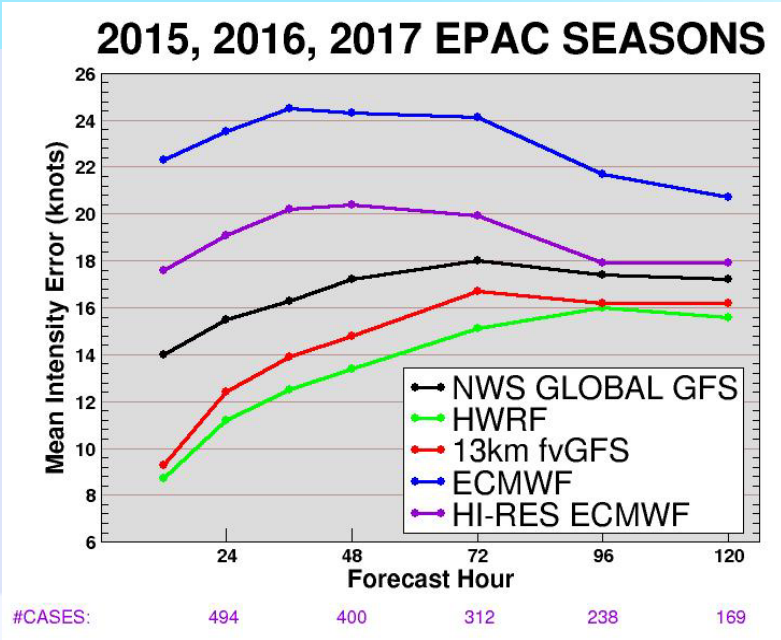
ECMWF track errors significantly lower then GFS based guidance

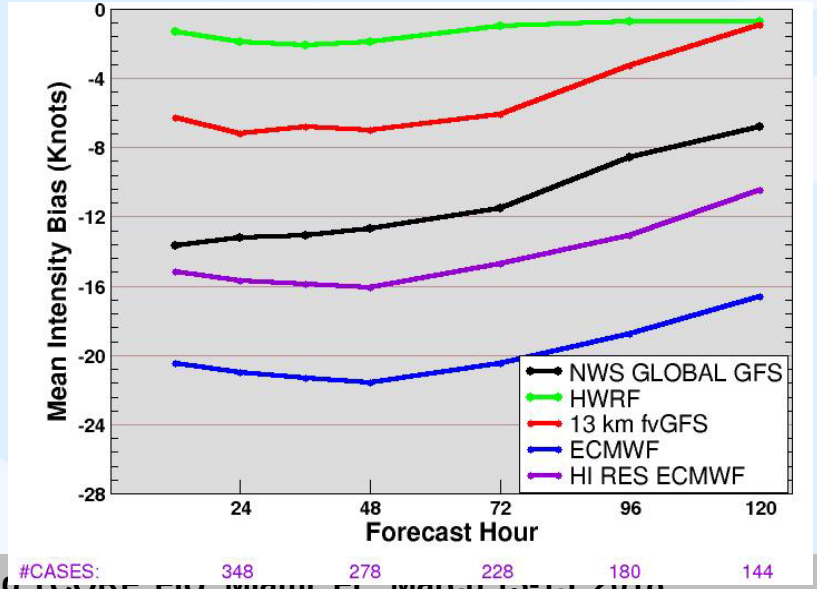
Days 6-7 ECMWF track errors 18-20% lower then GFS or fvGFS

Average Intensity Errors (knots)

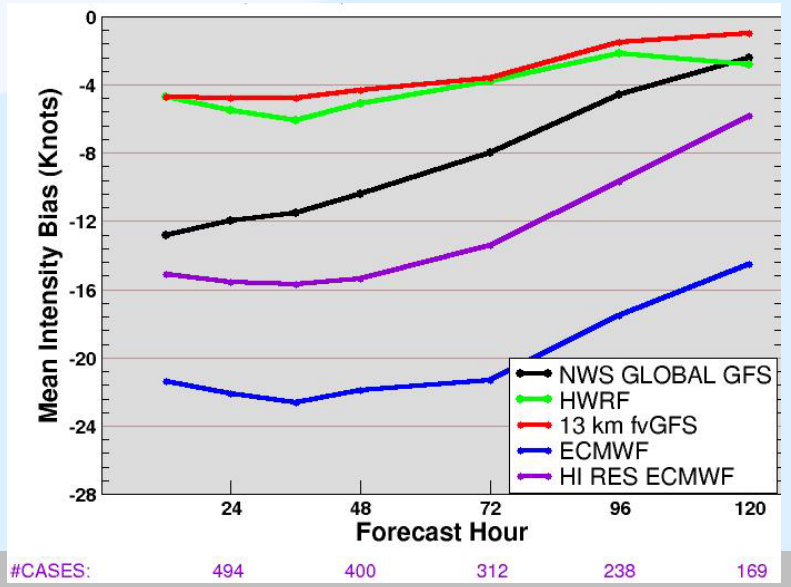


INTENSITY ERROR



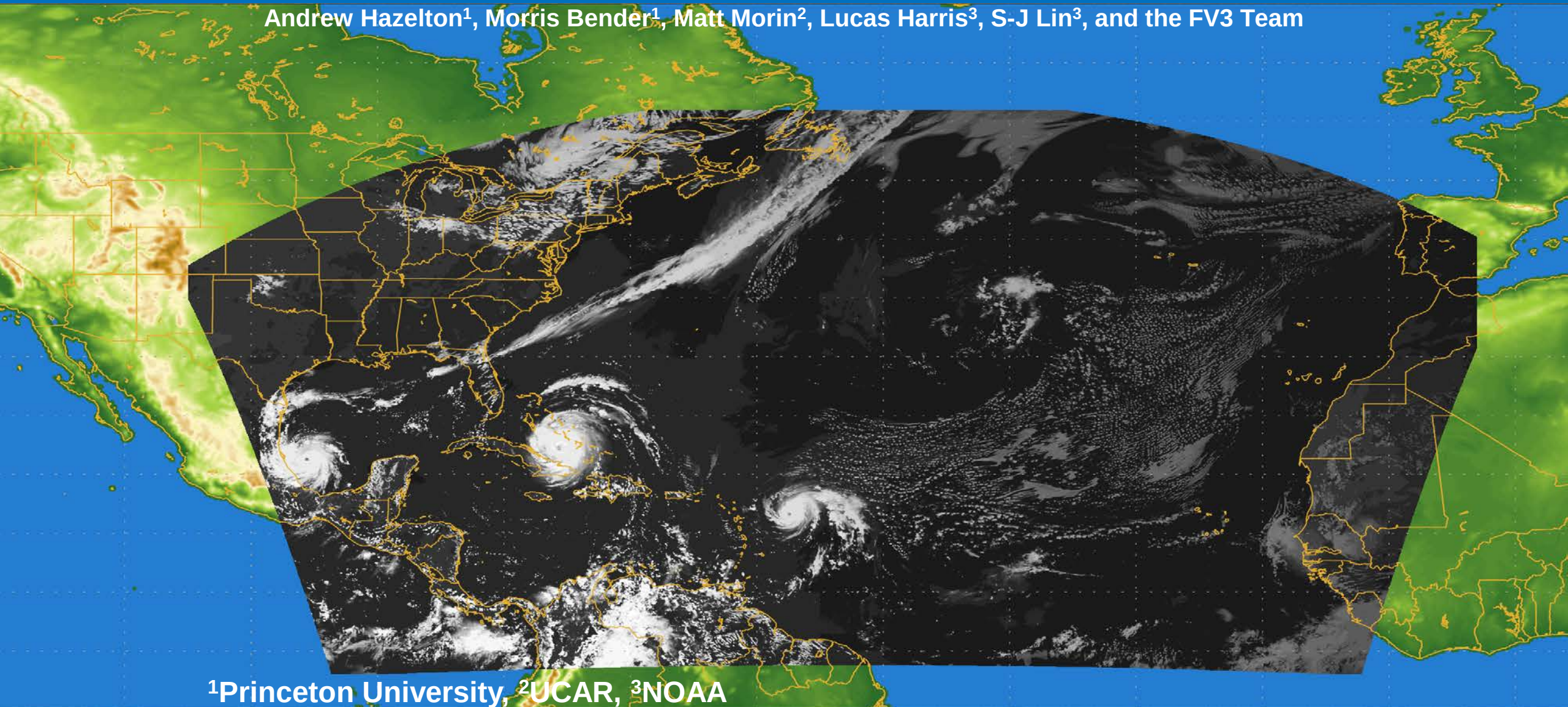


INTENSITY BIAS



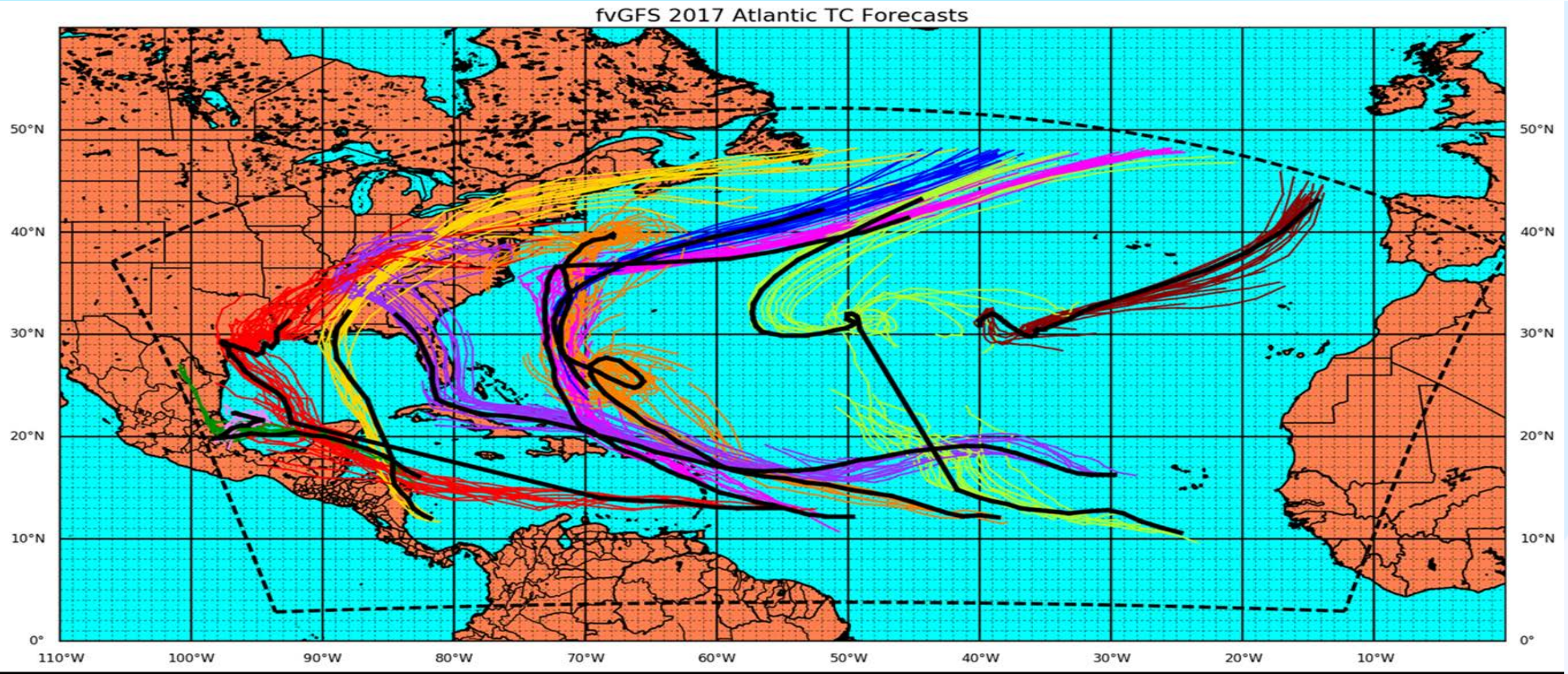
Nested fvGFS Forecasts of the 2017 Atlantic Hurricane Season

Andrew Hazelton[1], Morris Bender[1], Matt Morin[2], Lucas Harris[3], S-J Lin[3], and the FV3 Team

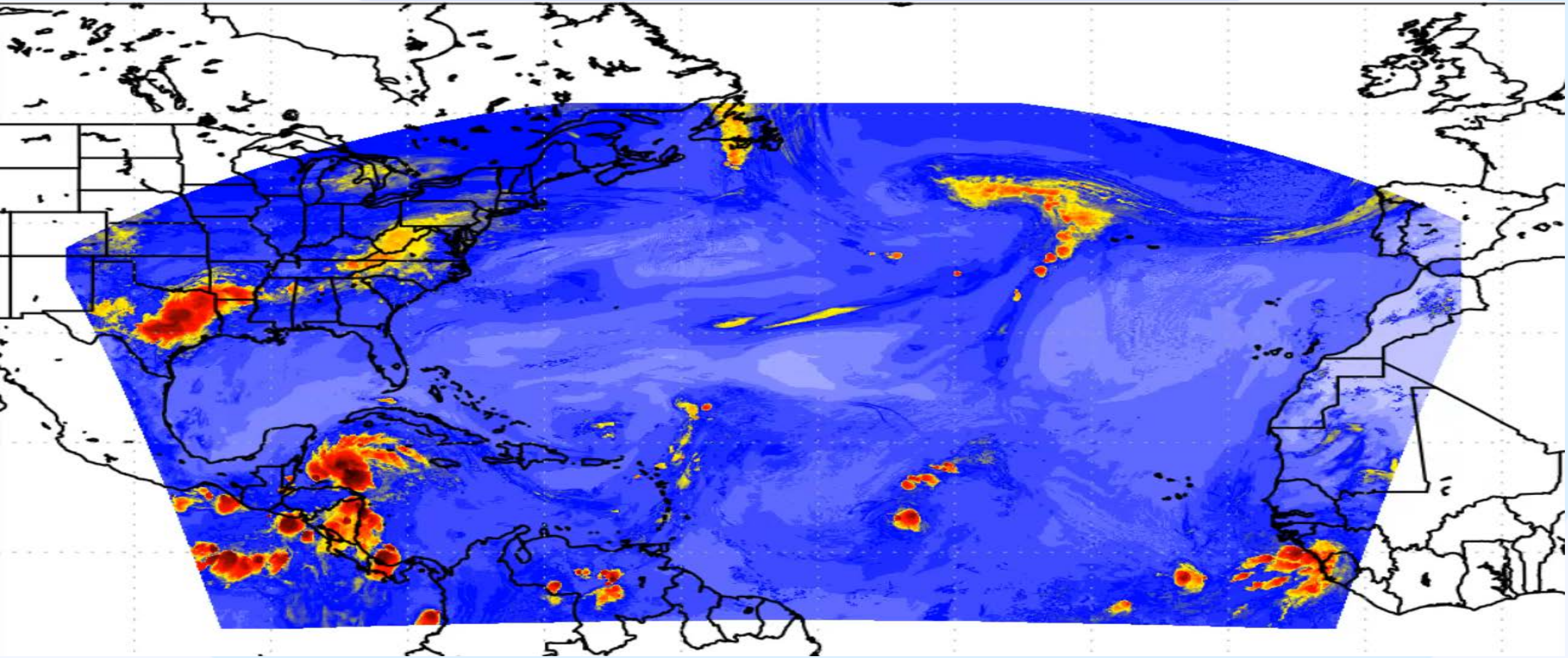


[1]Princeton University, [2]UCAR, [3]NOAA

Cases Used

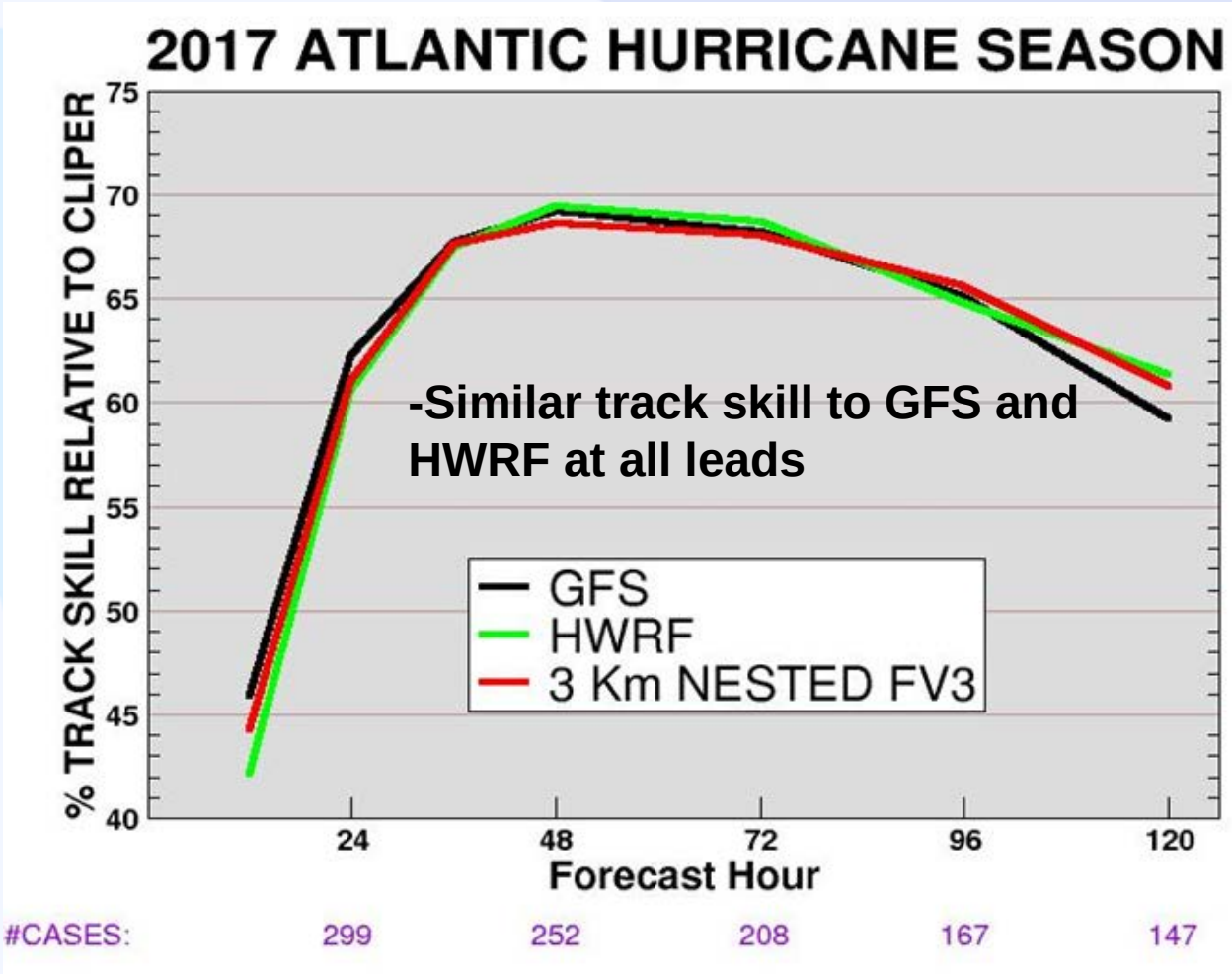

fvGFS 2017 Atlantic TC Forecasts
50°N
40°N
30°N
20°N
10°N
0°
110°W
100°W
90°W
80°W
70°W
60°W
50°W
40°W
30°W
20°W
10°W
Franklin Gert Harvey Irma Jose Katia Lee Maria Nate Ophelia

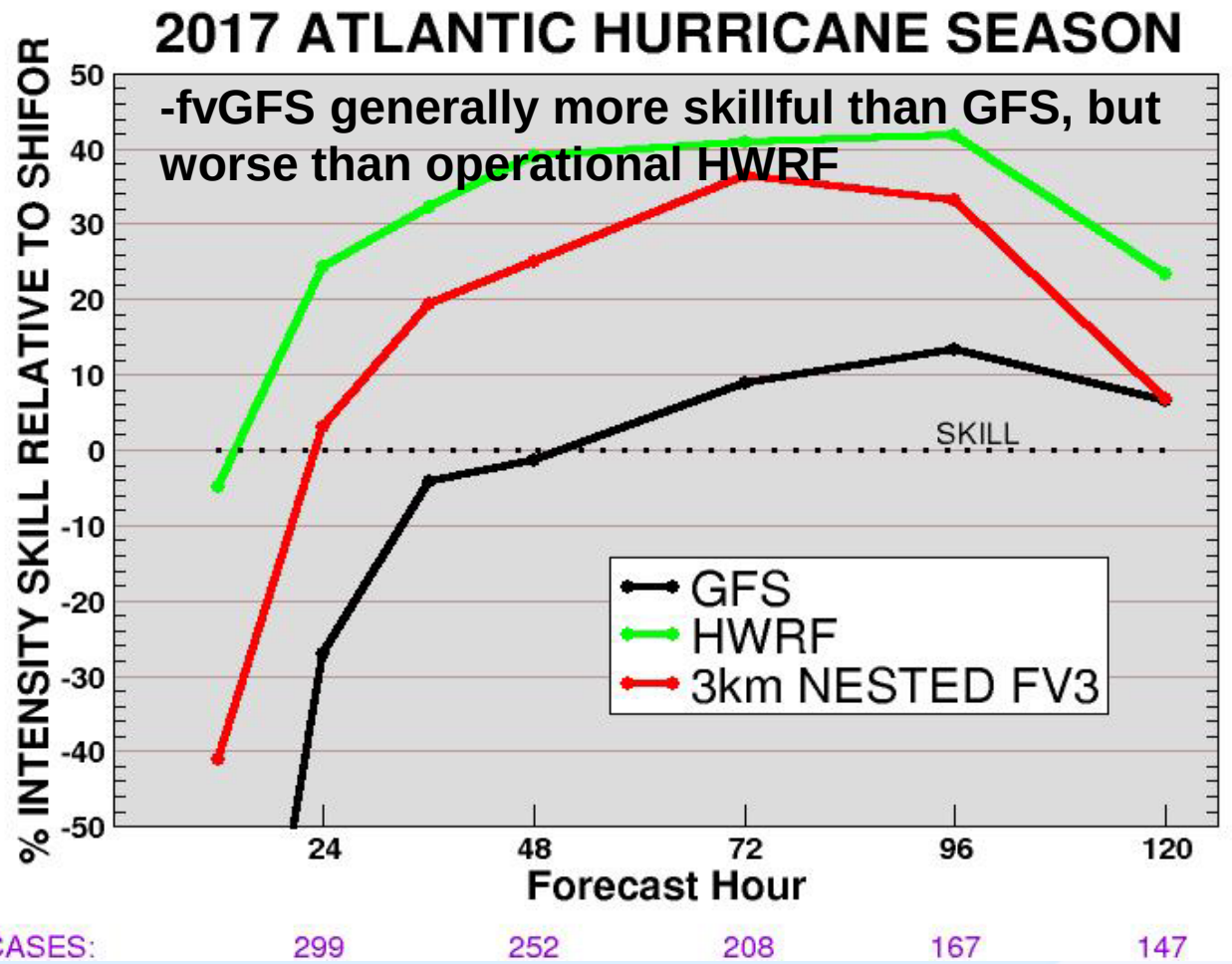
Animation of August-October 2017



All 12-hour fvGFS forecasts (simulated IR imagery)

Track & Intensity Forecast Skill





2018 Hurricane Model Upgrades (HWRF & HMON)

The EMC Hurricane Team

(with ongoing collaborations from AOML, DTC, NHC, GFDL, ESRL, CCU, OU and others)

[1]***Environmental Modeling Center***
NOAA / NWS / NCEP

IHC/TCORF Meeting, March, 2018

Potential FY18 HWRF Upgrades

System & Resolution Enhancements

- Increase domain size (do1, do2, do3) with 18/6/2 km configuration (see next slide)

or

- Increase horizontal resolution to 1.5/4.5/13.5 km, with adjusted domain sizes for do1, do2 and do3
- Increase vertical resolution for non-NHC basins to 75 levels

Physics Advancements

- Improve radiation, surface exchange coefficients
- ~~Improve EDMF PBL, test YSU PBL~~

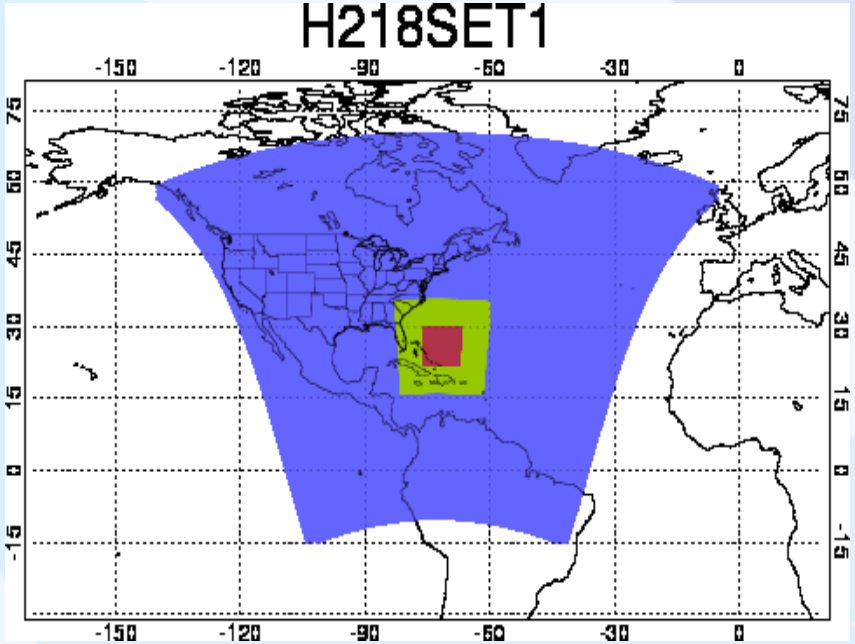
Data Assimilation & Initialization Improvements

- Stochastic physics for DA ensembles
- GSI code upgrades; add new data sets (GOES-16 AMV's, SFMR, Dropsonde drifts, TDR from G-IV)
- Extend DA to Western Pacific Basin
- ~~Use full ensemble covariances~~

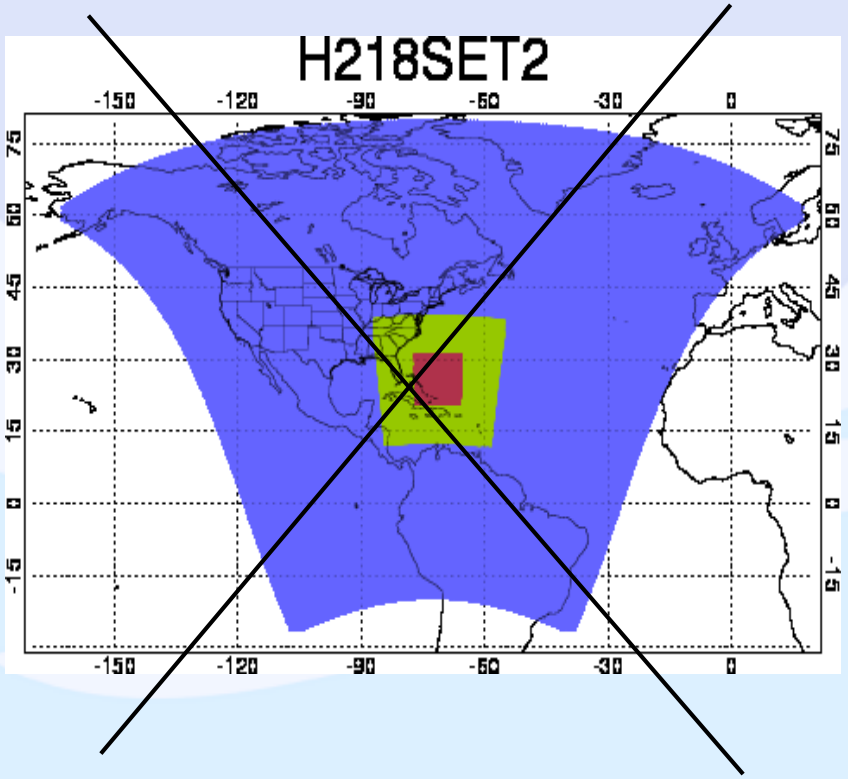
Coupling and other upgrades

- Unified HMON/HWRF coupler
- Use RTOFS SST's for NATL basin
- Add ocean coupling (HYCOM) for Southern Hemisphere basins

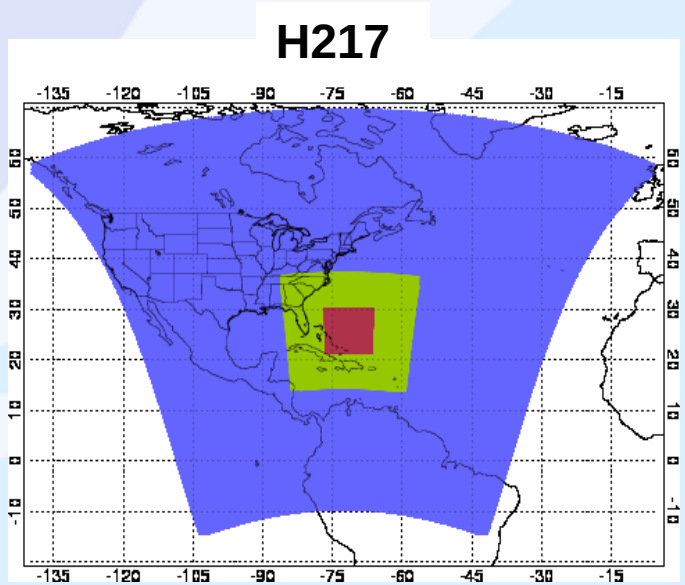
Adjusted Domain Sizes for 2018 HWRF (some examples)



Res: 1.5/4.5/13.5 km
d01: 393 x 786
d02: 256 x 508
d03: 256 x 508

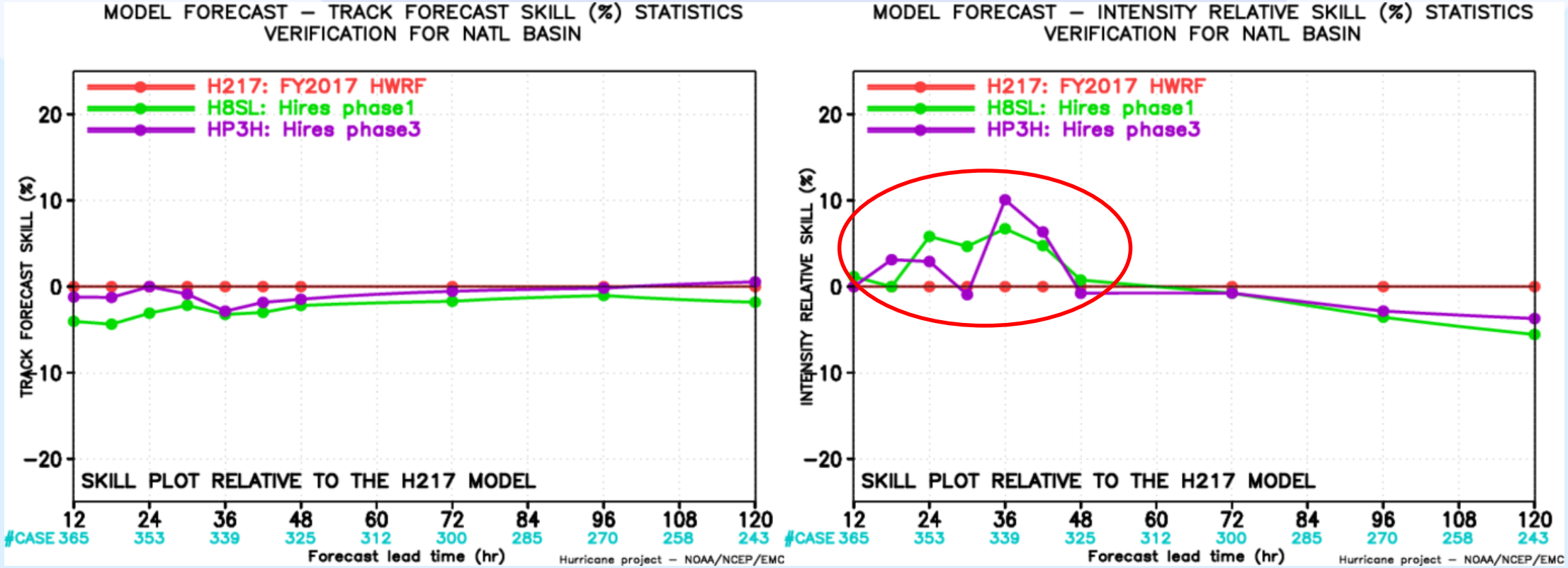


Res: 2/6/18 km
d01: 360 x 720
d02: 256 x 508
d03: 235 x 472



Res: 2/6/18 km
d01: 288 x 576
d02: 265 x 532
d03: 235 x 472

HP3H vs H8SL (Late Model)



HP3H has better track skill than H8SL at all lead times but is neutral with respect to H217. For intensity, both HP3H and H8SL show increased skill (>10% for HP3H at 36 hr) compared to H217 for the early lead times till Day 2. There is some degradation for Days 4 and 5 with HP3H ahead of H8SL.

Scope of FY18 HMON Upgrades

➢System & Resolution Enhancements

- Upgrade to the latest NMMB dynamic core with bug fixes
- Add Vertical level from 42 to 51
- NMMB Dycore optimization (IBM analyst)
- Change diffusion parameterization

➢Initialization/Data Assimilation Improvements

- Updated composite vortex
- Change co-ordinates for VI

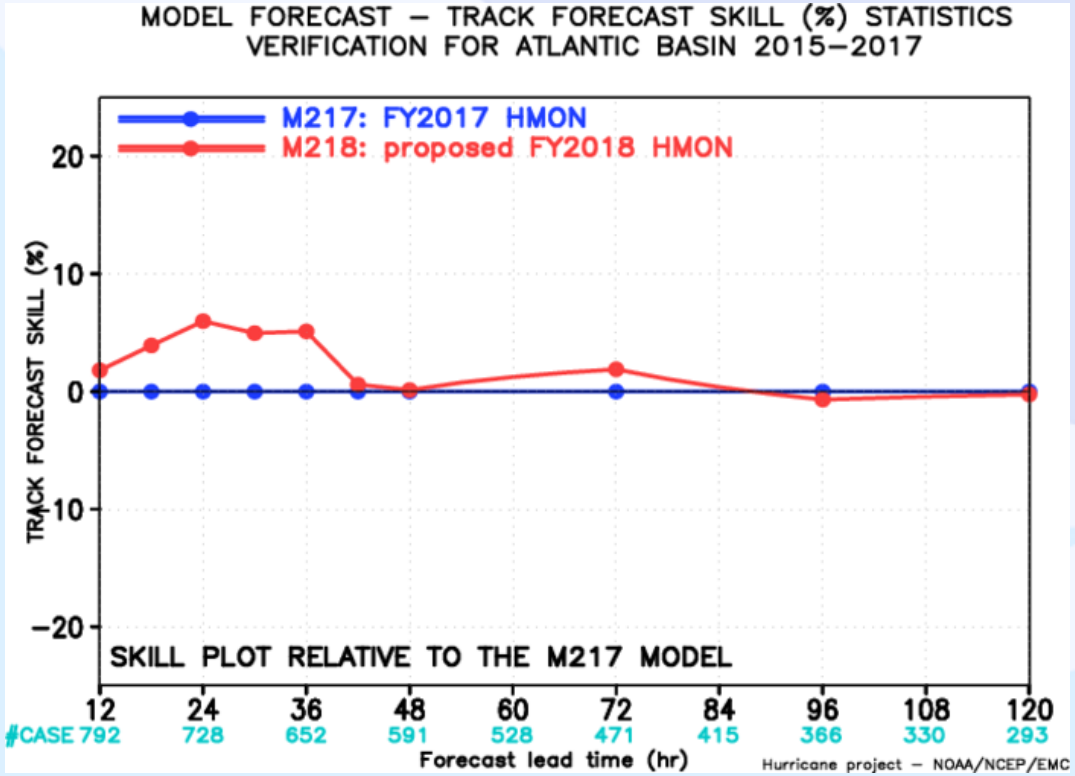
➢Physics Advancements

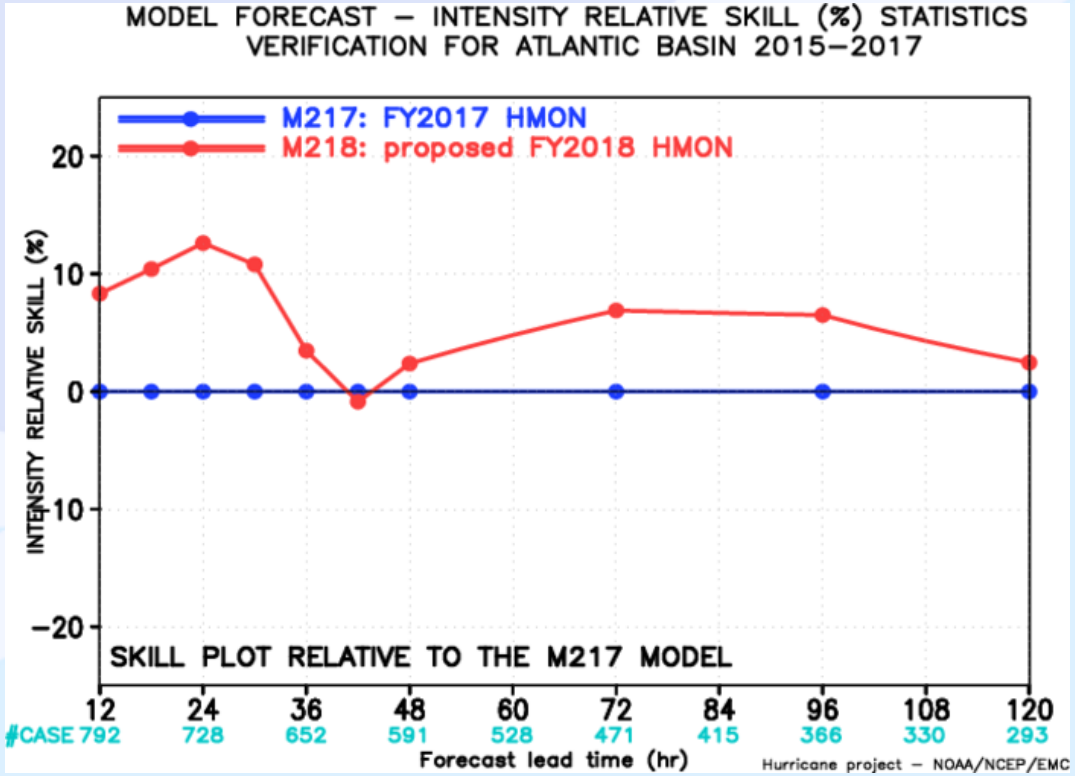
- Use scale-aware SAS scheme
- Update momentum and enthalpy exchange coefficients(Cd/Ch)
- Use GFS-EDMF PBL scheme
- ~~Explore use of MYJ surface layer + MYJ PBL~~

➢ Coupling Upgrades

- Add HYCOM coupling in NATL basin
- Use unified HWRF/HMON coupler

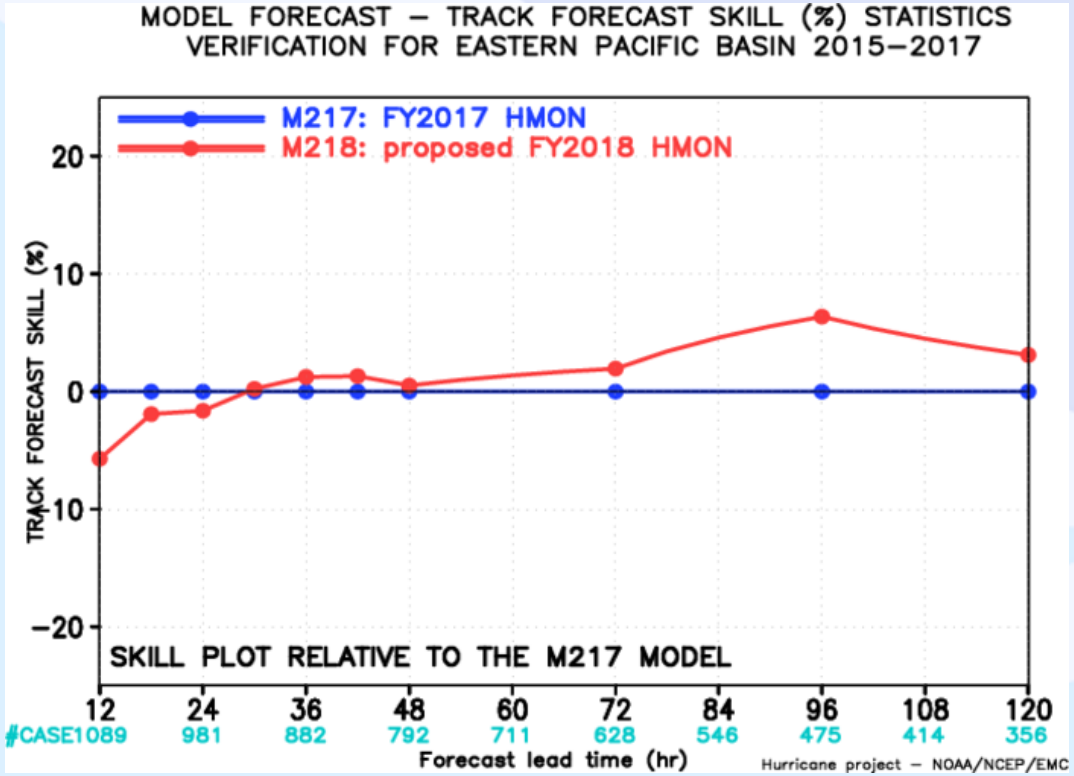
Track and Intensity skill for NATL basin (2015-2017): (Early Model)

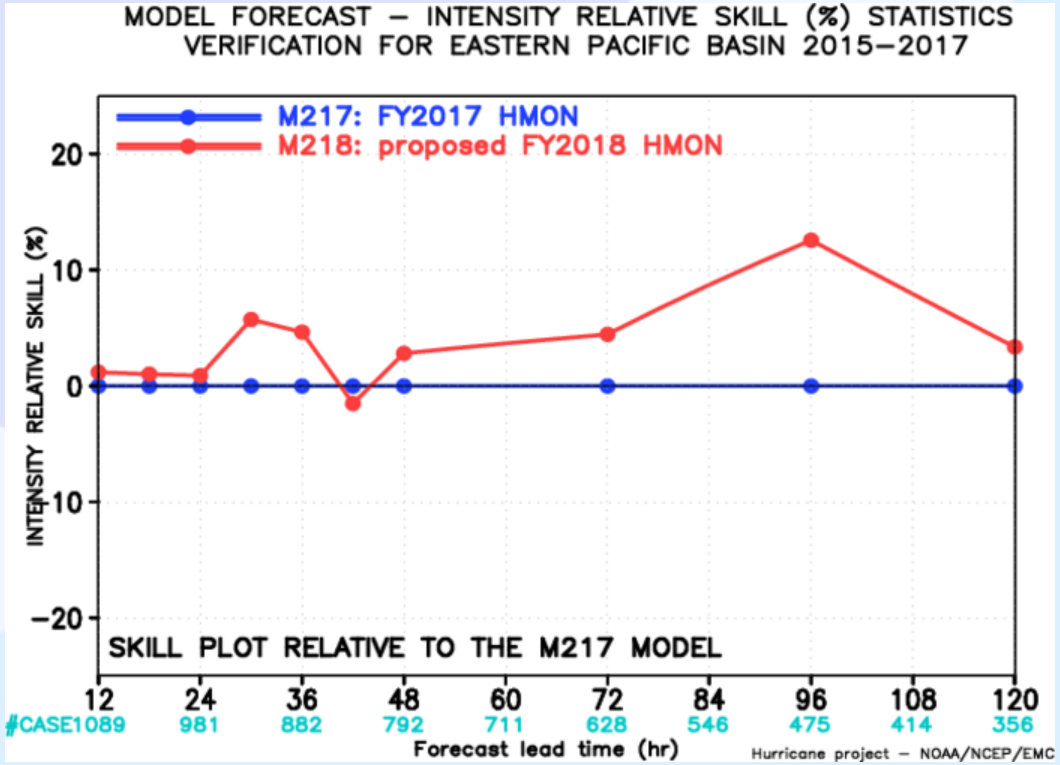




There is improvement in track skill for the early lead times of around 6% (at hr 24) while it is mostly neutral beyond day 4. Intensity skill improvements are significant at early lead times (> 10%) and then again for late lead times of about 7-8%.

Track and Intensity skill for EPAC basin (2015-2017): (Early Model)





Other than for the first 24 hrs, there is improvement in track skill for all lead times which reaches around 7% at Day 4. We also find significant intensity skill improvements at day 4 (> 10%) and intensity skill is positive at all lead times.

FY2018 HWRF/HMON Configurations maintain diversity

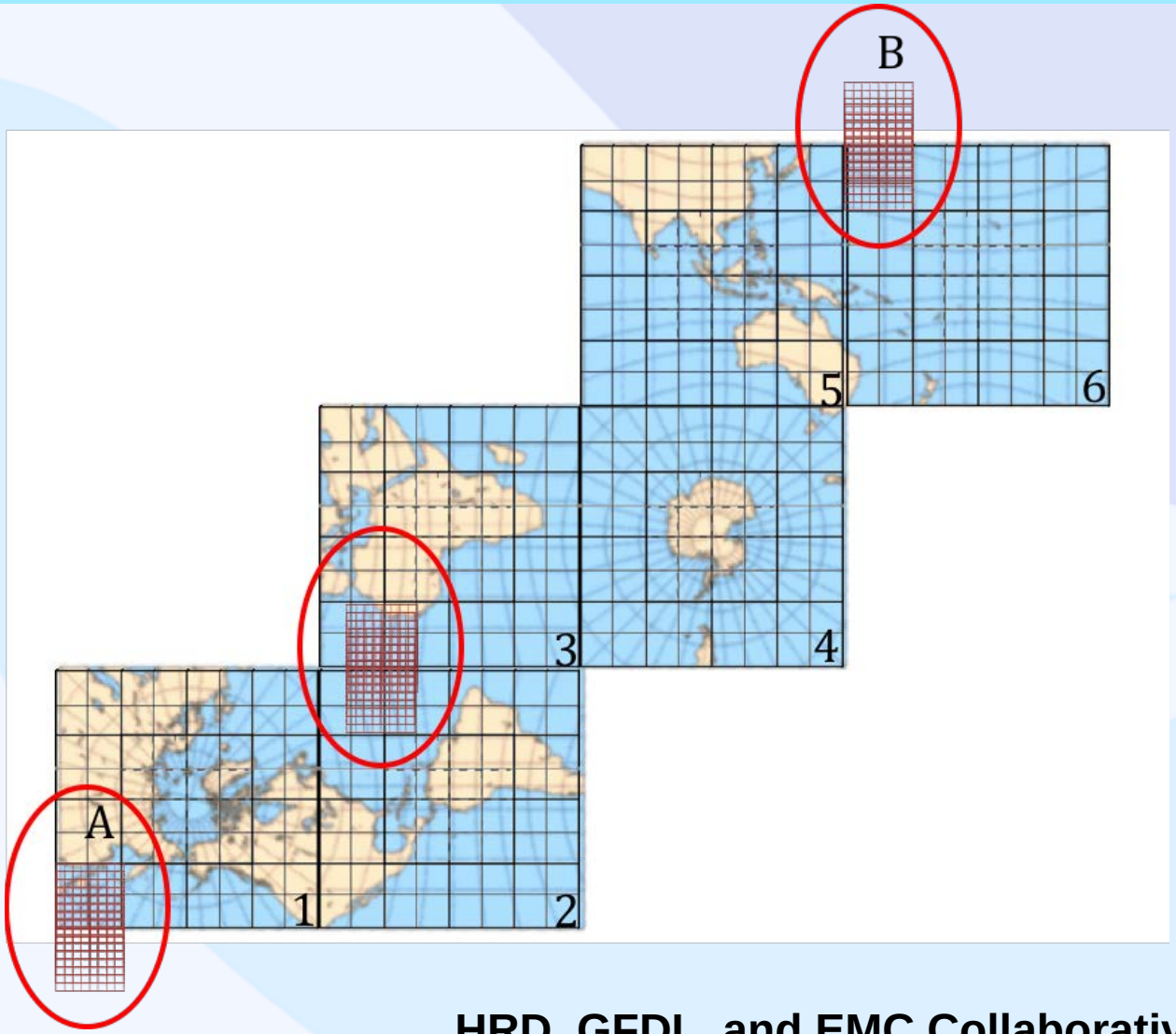
	HWRF	HMON
Dynamic core	Non-hydrostatic, NMM-E	Non-hydrostatic, NMM-B
Nesting	13.5/4.5/1.5 km; 75°/25°/8.3°; 75 vertical levels Full two-way moving	18/6/2 km; 75°/12°/8°; 51 vertical levels Full two-way moving
Data Assimilation and Initialization	Vortex relocation & adjustment Self-cycled hybrid EnKF-GSI with inner core DA (TDR)	Modified vortex relocation & adjustment
Physics	Updated surface (GFDL), GFS-EDMF PBL, Updated Scale-aware SAS, NOAH LSM, Modified RRTM, Ferrier	Surface (GFDL), GFS-EDMF PBL, Scale-aware SAS, NOAH LSM, RRTM, Ferrier
Coupling	MPIPOM/HYCOM, RTOFS/GDEM, WaveWatch-III	HYCOM, RTOFS/NCODA, No waves
Post-processing	NHC interpolation method, Updated GFDL tracker	NHC interpolation method, GFDL tracker
NEMS/NUOPC	No	Yes with moving nests
Computation cost	86 nodes in 95 mins	26 nodes in 95 mins

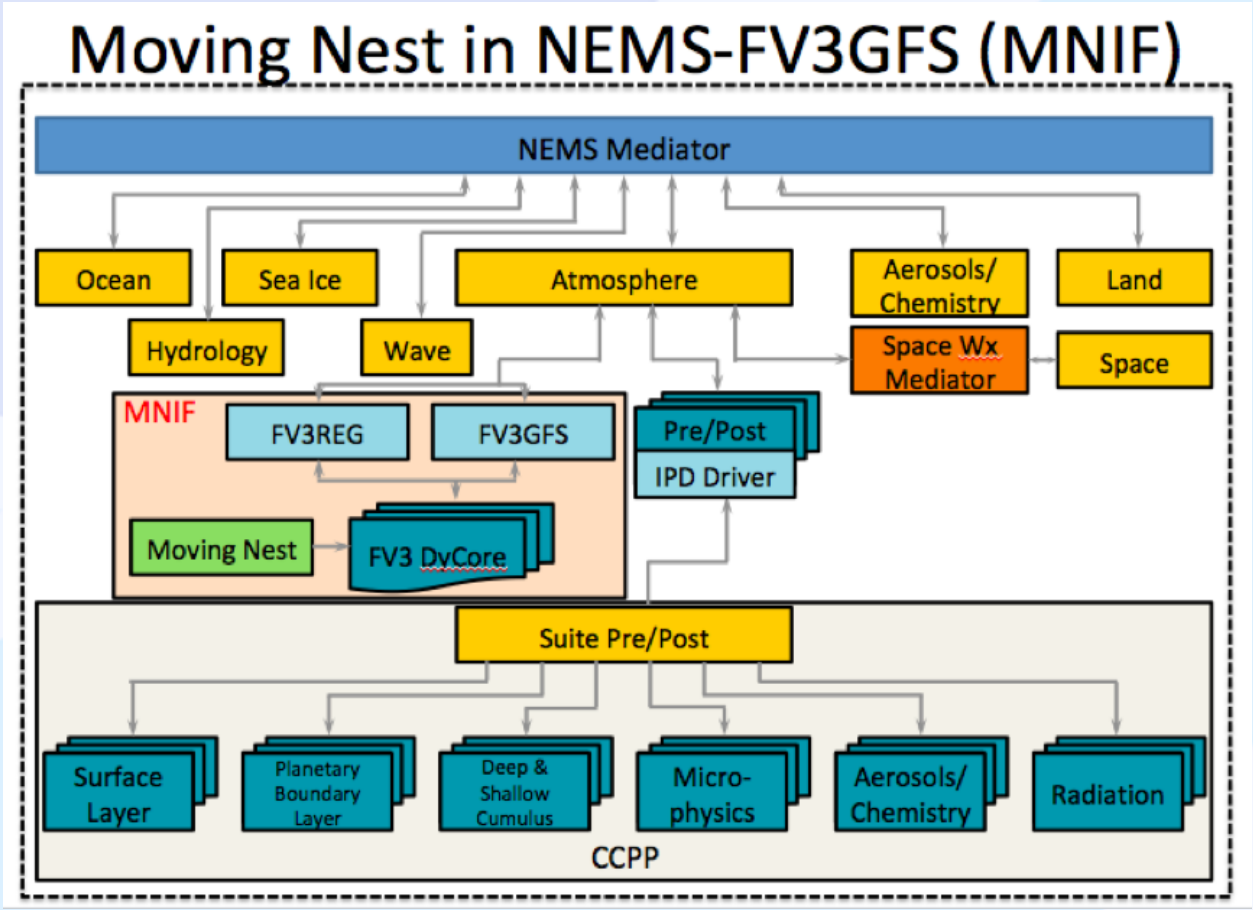
Operational Resources for Hurricane Modeling (maximum per storm forecast)

Operational System	2017 (nodes)	2018 (nodes)	Max Storms	Comments
HWRF	63	86	7	Max # of storms decreased by 1
HMON	26	26	5	Uses much less resources than HWRF
TOTAL	**89**	**112**	**--**	20% resource increase*

*The larger node requirement for 2018 HWRF with one less storm slot (only in some circumstances) keeps us within the allocated 20% increase.

Next Generation Hurricane Nests in FV3GFS





HRD, GFDL and EMC Collaborative Effort: Target 2021 Implementation

Thanks for your attention

Questions?

Backup Slides

Model Infrastructure, I/O, etc

1. Integrate fv3 into NEMS
2. Add IPD in NEMS fv3
3. Write grid component, write out model history in native cubed sphere grid and Gaussian grid
4. Stochastic physics and IAU
5. Enable NSST in FV3

other minor changes:

1. correction of a bug related to the convective cloud water
2. radiation bug fix
3. slight modification in scale-aware mass-flux deep or shallow convection schemes

Utilities

New nc2nemsio and regrid-nemsio for converting 6-tile netcdf files to global lat-lon grid

"global_cycle": Updated to run on the cubed-sphere grid. Added MPI to process multiple tiles simultaneously. Added update of NST fields using Gaussian increments from GSI.

"global_chgres": Incorporated GFDL logic required for fv3 core. Ensure consistency between the NST TREF field and SST at isolated lakes.

New utility "gaussian_sfcanl" - creates a gaussian surface analysis file from the tiled analysis files produced by global_cycle.

New program "enkf_chgres_recenter" - Interpolates atmospheric fields from one Gaussian grid to a lower-res Gaussian grid. Required by ENKF recentering step.

Add option to use GMTED2010 terrain data to create orography.

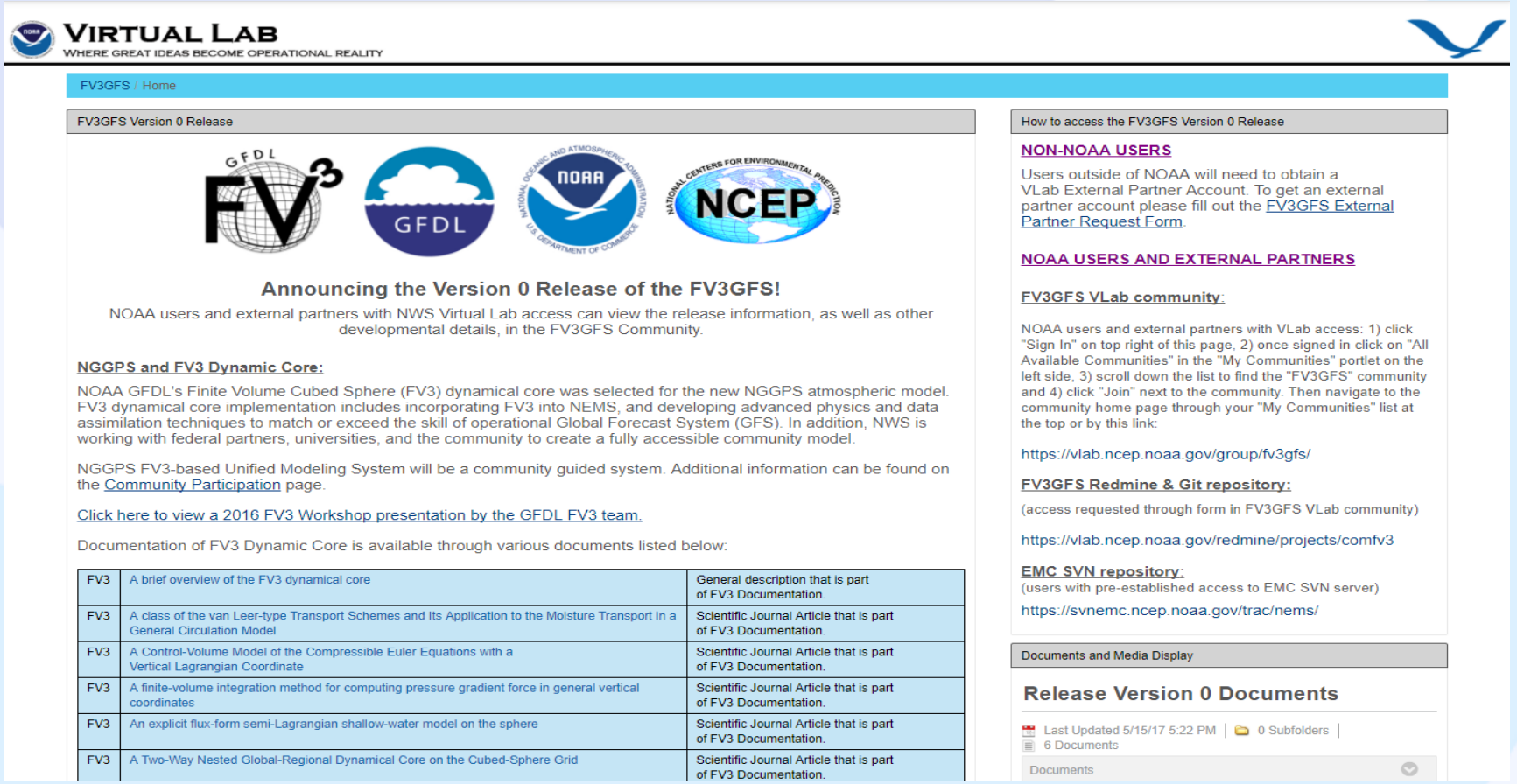
NOAA Virtual Lab (VLab) to host FV3GFS Code Release & Git to host the repositories

- Access FV3GFS Project on VLab

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

- Code repositories set up on VLab GIT
- Community Wiki page, Forums and Developers Pages on VLab

Next Release of FV3GFS (including DA and post-processing) planned for March 2018 through github.com



VIRTUAL LAB
WHERE GREAT IDEAS BECOME OPERATIONAL REALITY

FV3GFS / Home

FV3GFS Version 0 Release

Announcing the Version 0 Release of the FV3GFS!

NOAA users and external partners with NWS Virtual Lab access can view the release information, as well as other developmental details, in the FV3GFS Community.

NGGPS and FV3 Dynamic Core:

NOAA GFDL's Finite Volume Cubed Sphere (FV3) dynamical core was selected for the new NGGPS atmospheric model. FV3 dynamical core implementation includes incorporating FV3 into NEMS, and developing advanced physics and data assimilation techniques to match or exceed the skill of operational Global Forecast System (GFS). In addition, NWS is working with federal partners, universities, and the community to create a fully accessible community model.

NGGPS FV3-based Unified Modeling System will be a community guided system. Additional information can be found on the Community Participation page.

Click here to view a 2016 FV3 Workshop presentation by the GFDL FV3 team.

Documentation of FV3 Dynamic Core is available through various documents listed below:

FV3	A brief overview of the FV3 dynamical core	General description that is part of FV3 Documentation.
FV3	A class of the van Leer-type Transport Schemes and Its Application to the Moisture Transport in a General Circulation Model	Scientific Journal Article that is part of FV3 Documentation.
FV3	A Control-Volume Model of the Compressible Euler Equations with a Vertical Lagrangian Coordinate	Scientific Journal Article that is part of FV3 Documentation.
FV3	A finite-volume integration method for computing pressure gradient force in general vertical coordinates	Scientific Journal Article that is part of FV3 Documentation.
FV3	An explicit flux-form semi-Lagrangian shallow-water model on the sphere	Scientific Journal Article that is part of FV3 Documentation.
FV3	A Two-Way Nested Global-Regional Dynamical Core on the Cubed-Sphere Grid	Scientific Journal Article that is part of FV3 Documentation.

How to access the FV3GFS Version 0 Release

NON-NOAA USERS

Users outside of NOAA will need to obtain a VLab External Partner Account. To get an external partner account please fill out the FV3GFS External Partner Request Form.

NOAA USERS AND EXTERNAL PARTNERS

FV3GFS VLab community:

NOAA users and external partners with VLab access: 1) click "Sign In" on top right of this page, 2) once signed in click on "All Available Communities" in the "My Communities" portlet on the left side, 3) scroll down the list to find the "FV3GFS" community and 4) click "Join" next to the community. Then navigate to the community home page through your "My Communities" list at the top or by this link:

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

FV3GFS Redmine & Git repository:

(access requested through form in FV3GFS VLab community)

https://vlab.ncep.noaa.gov/redmine/projects/comfv3

EMC SVN repository:
(users with pre-established access to EMC SVN server)
https://svnemc.ncep.noaa.gov/trac/nems/

Documents and Media Display

Release Version 0 Documents

Last Updated 5/15/17 5:22 PM | 0 Subfolders | 6 Documents

Documents

- Limited support from EMC to run FV3GFS forecast only experiments on WCOSS, Theia and Jet

Workflow

- Almost all scripts adopted from the NEMS GFS were rewritten for the FV3GFS
- The old psub/pend job submission system is replaced by Rocoto drivers
- The 4-package superstructure workflow was merged into one package with a flat structure
- All JJOBS were rewritten. Both EMC parallels and NCO operation will call the same JJOBS
- EMC parallels and NCO operation follow the same file name convention and directory structure

An important achievement to simplify and unify the GFS systems between NCO and EMC

Changes in Disk Usage --- GFS single forecast hour

(~13km)	ops GFS (GB)	FV3GFS (GB)
gfs.t00z.atmf$fhr.nemsio	7.361	15.779
gfs.t00z.sfcf$fhr.nemsio	0.868	2.756
gfs.t00z.flxf$fhr.nemsio	2.189	N/A
gfs.t00z.nstf$fhr.nemsio	0.396	N/A
total	10.814	18.535 (71.4% more)

Changes in Disk Usage -- one cycle

~130% increase

	anl+forecast	products & misc	total
ops gfs	1.70 TB	0.30 TB	2.0 TB
ops GDAS	0.157 TB	0.029 TB	0.186 TB
ops ENKF	1.831 TB	0.043 TB	1.874 TB
ops total			4.06 TB
FV3 GFS	2.91	0.30	3.21
FV3 GDAS	0.471	0.029	0.50
FV3 ENKF	5.493	0.043	5.536
FV3 total			9.246 TB

Ops GDAS and ENKF are run at T574 (1152x576), while FV3GFS is run at C384, e.g. T766 (1532x768). This is equivalent to a 77.7% increase in forecast file size. Factoring in the increase of output variables, **ENKF and GDAS file size will increase by 200%.**

POST and Downstream Processing

Precipitation bucket is changed from 6 hours to continuous

Velocity from FV3GFS is dz/dt in m/s instead of omega in pa/s

More cloud hydrometers predicted by the advanced microphysics scheme will be included in the products.

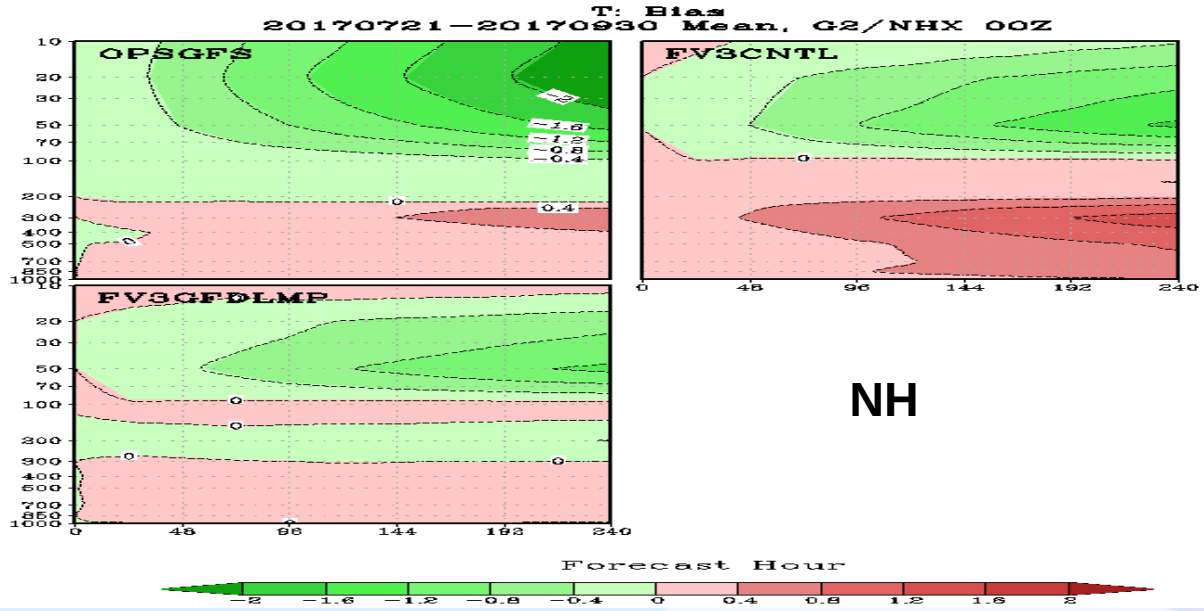
Radar reflectivity derived using these new cloud hydrometers will also be added to GFS products.

Height, pressure, and vertical velocity will be non-hydrostatic computed in model instead of being derived hydrostatically in Unified Post Processor.

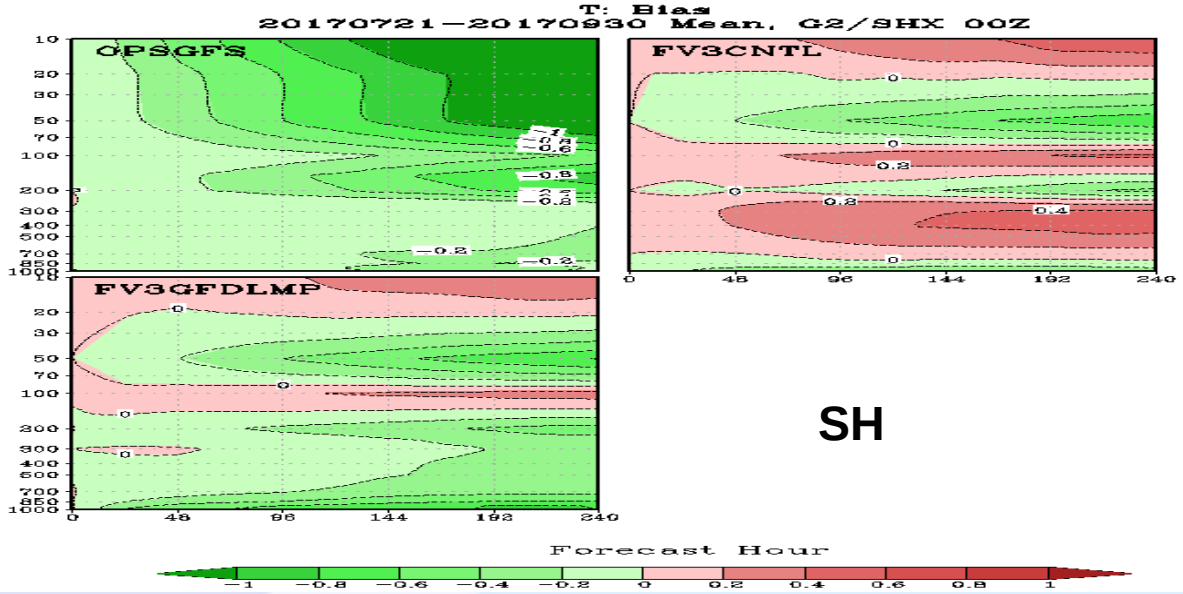
The Guam RTMA product will switch to use HIRESW Guam as its initial guess in its Q1FY19 upgrade.

This Google Sheet contains a complete list of product changes.

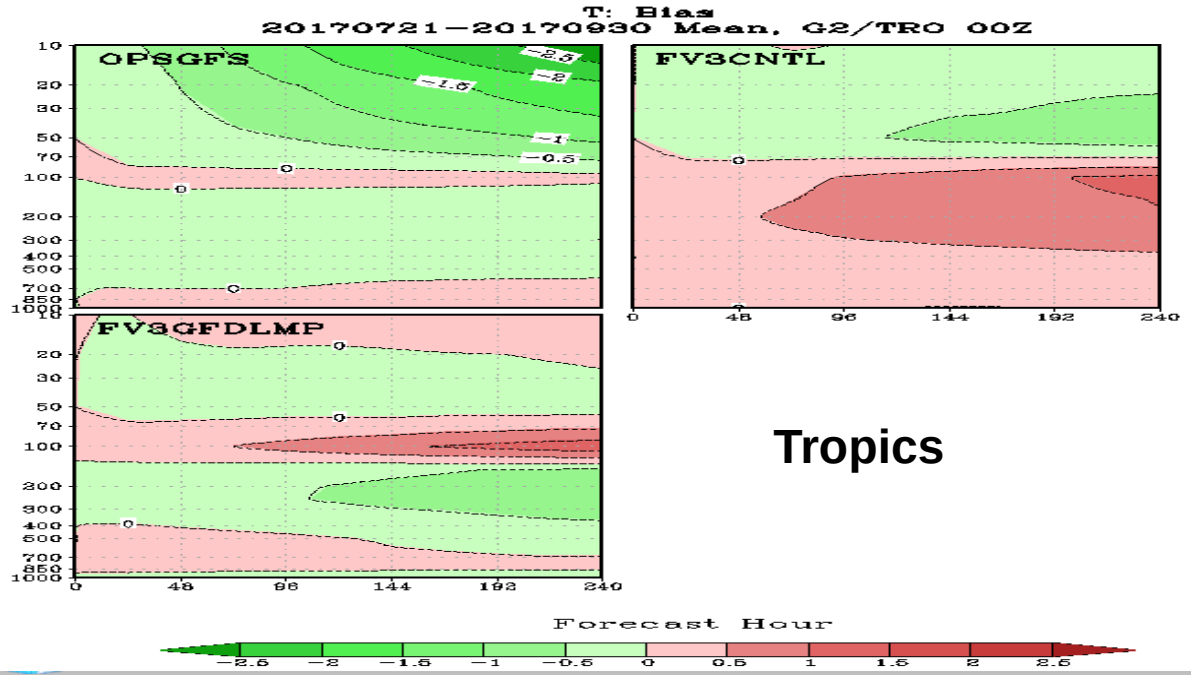
Temperature Bias



NH



SH



Tropics

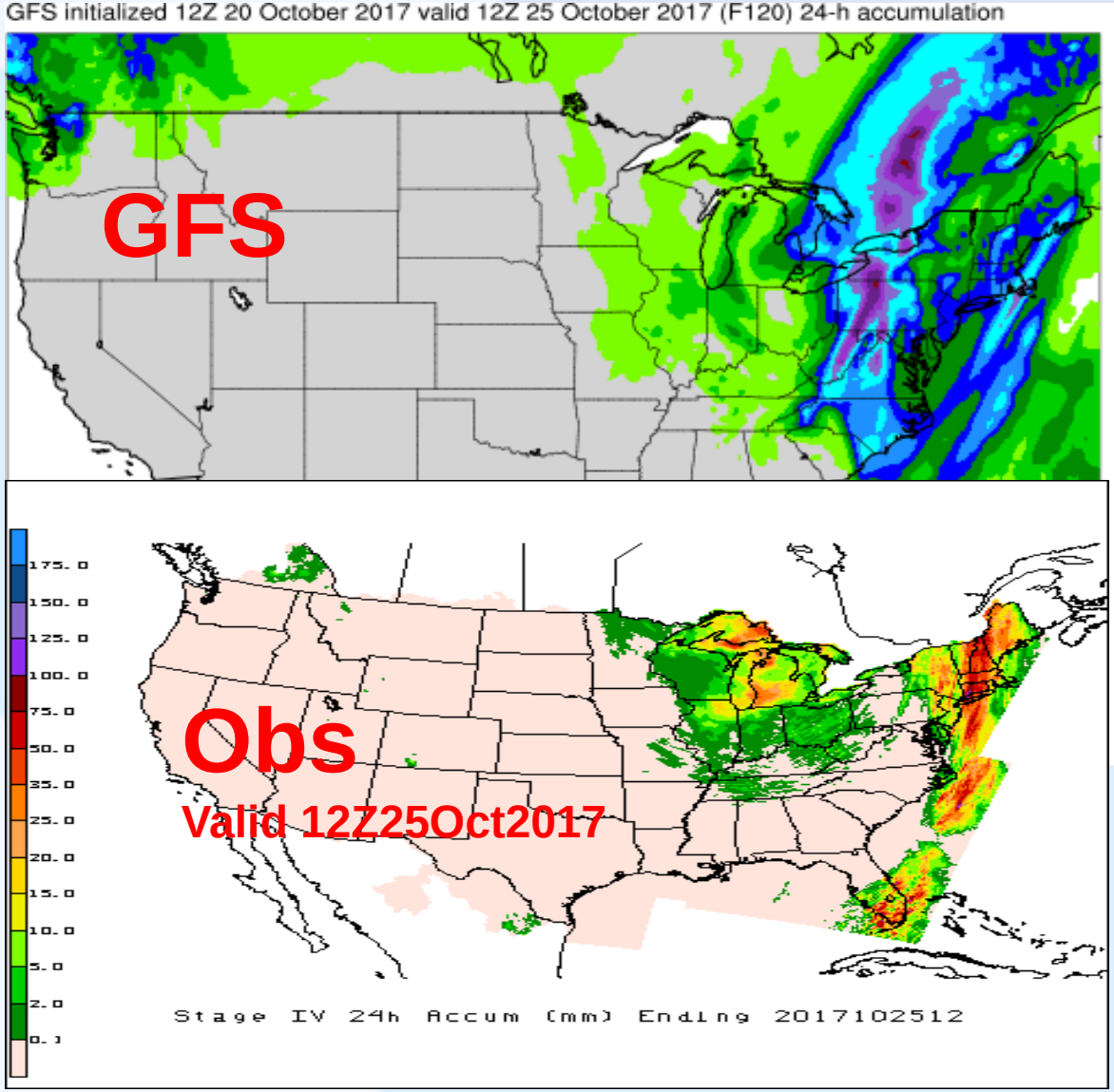
- Compared to opsgfs, fv3gfdlmp and fv3cntl both reduced the cold biases in the stratosphere
- Fv3cntl is too warm in the troposphere. Fv3gfdlmp does not have this warm bias.

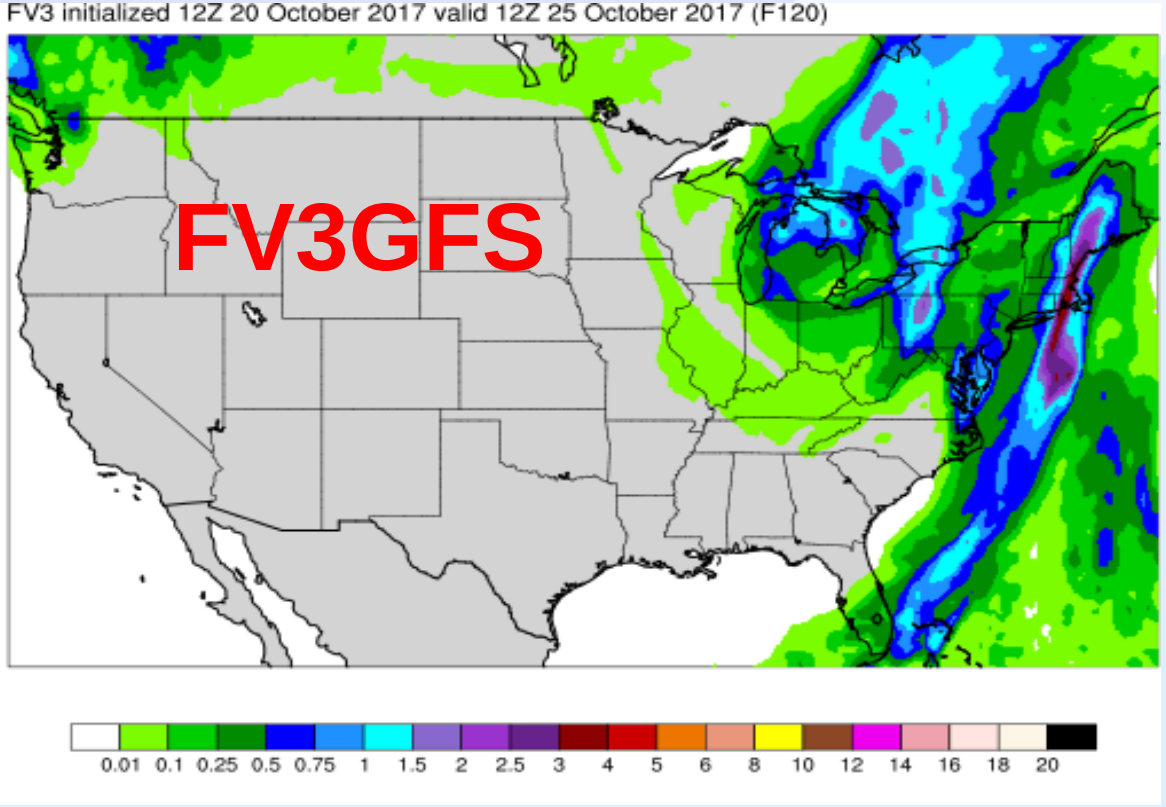
MEG Evaluation of FV3GFS in Collaboration with the Field

MEG has initiated the “FV3 Evaluation and Dissemination group”

- Members include representatives from various centers and regions including OCONUS and Alaska region
- Identified fields and metrics important for evaluation
- Established FV3/GFS comparison site
- Established VLab Forum for active discussion
- NCO was represented on the group (both Becky Cosgrove and Carissa Klemmer)
- NCO expressed a willingness to place the data on Para NOMADS even before they run FV3 parallel themselves (Thanks Becky)
- Having the data on paranomads would make the data available for ingestion into the WAVE viewer, a resource that would aid the field in evaluation
- Plan to conduct one full year of retrospectives for the beta version of FV3GFS
- Will seek feedback from “regular” evaluators before starting the official parallels in May/June 2018

Northeast Heavy Precipitation, IC12Z20Oct2017





FV3GFS correctly places the heavy rainfall band off the coast instead of inland, better matches the observed rainfall pattern.

fvGFS Model Setup

Evaluation of Global 13km fvGFS run on the Jet Computer facility by GFDL group

63 Vertical Levels

GFDL 6-class Micro-Physics replaced GFS Zhao-Carr Micro-Physics

All forecasts started from GFS initial fields *(cold start)*

Evaluated performance for Atlantic, East Pacific, West Pacific, Indian Ocean and Southern Hemisphere Basins and compared with operational guidance *(i.e., GFS, HWRF, ECMWF).*

0 and 12z Synoptic times from April 1st – December 31st, 2015, 2016, and 2017 Seasons.

fvGFS intensity guidance diagnosed with ~ 1/8 degree grid. Operational GFS still uses coarse ¼ degree grid to diagnose intensity ! ECMWF intensity errors and bias significantly improved using high resolution output grid.

Average Track Errors *(NHC Basins)*