Unified Forecast System: Advancing NCEP Operational Global Modeling Systems for 2021 and Beyond

NATIONAL WEATHER SERVICE

Tropical Cyclone Operations and Research Forum, March 4, 2021

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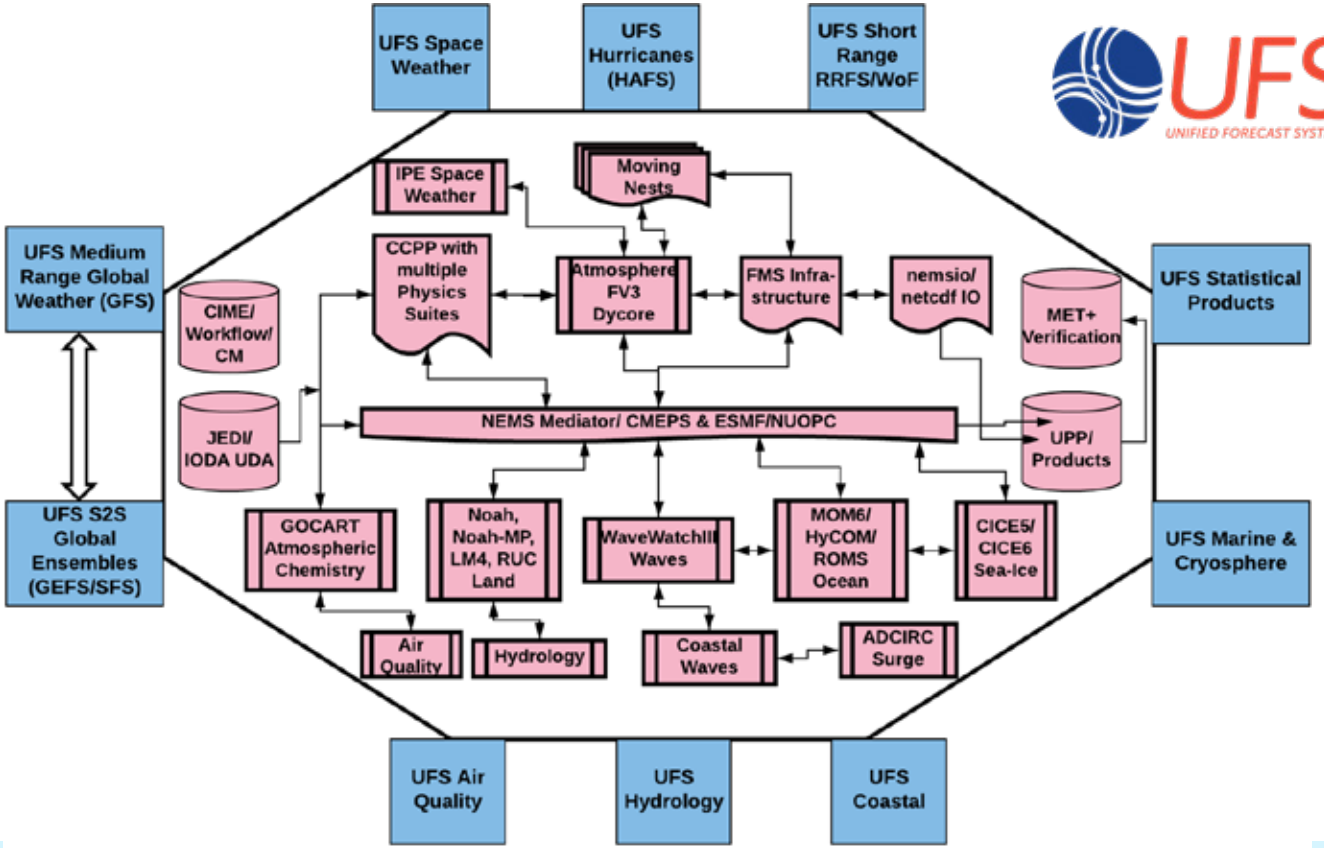
Outline

- Implementation of UFS Sub-Seasonal Application (GEFSv12, September 23, 2020)
- Upgrades to UFS Medium-Range Weather Application (GFSv16, March 17, 2021)
    - *Assimilation of HDOBS and improved use of dropsonde data in GFSv16*
- Addition of Commercial RO Data in GFSv16.1 (May 2021)
- UFS-R2O Project
- Fully coupled UFS MRW/S2S Forecast System for FY24 (GFSv17/GEFSv13)

NPS Transitioning to UFS Applications

Conceptual UFS applications in production covering all NPS applications.

Components of UFS are configured to develop distinct applications while maintaining the dependencies between the applications and products



GFS.v15.2 Transitioned to Operations on November 6, 2019

New Observations:

- Assimilate GOES-17 AMVs
- Assimilate Metop-C AMSU and MHS
- Assimilate KOMPSAT-5 (GPS-RO)
- Assimilate buoyb sst data
- Ingest VIIRS AMV data using new format

GFSv15.3 Transitioned to Operations on May 26 ,2020

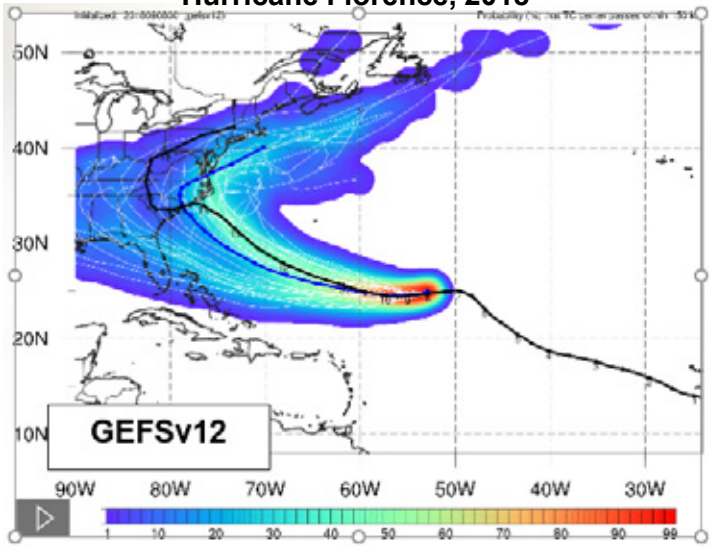
New Observations:

- Assimilate GNSS-RO COSMIC-2
- Assimilate METOP-C GRAS and IASI

GEFS.v12: First FV3 based UFS Sub-Seasonal Global Ensemble Forecast Application (Implemented on Sept. 23, 2020)

Global Ensemble Forecast System GEFS v12

Hurricane Florence, 2018



Significant improvement in ensemble spread

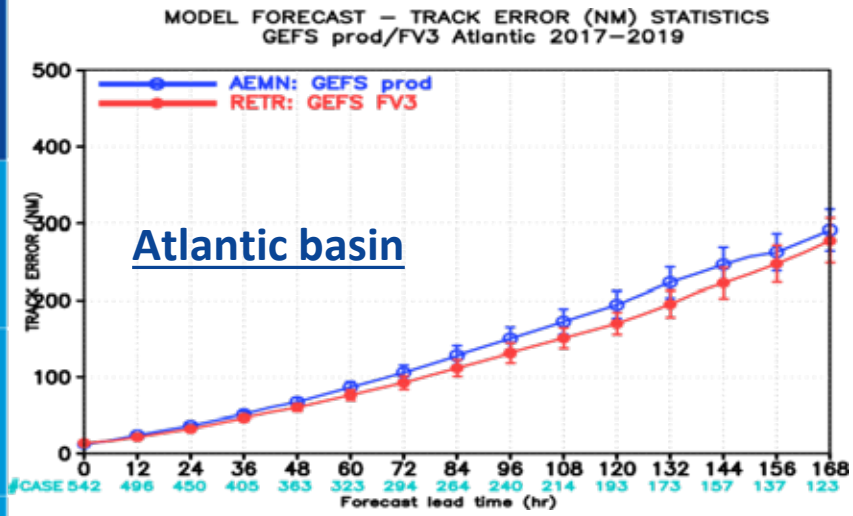
- Configuration
  - C384L64 (~25km); L64; GFSv15 physics
  - 31 members, 4 cycles/day, 35 days forecasts at 00Z and 16-day at 06/12/18Z
  - Uniform resolution throughout the forecast period
  - No TC relocation
  - One-Way coupling to waves (Global Wave Ensemble System) and chemistry (NEMS GFS Aerosol Component)
  - Physics perturbations using SPPT, SKEB; and GDAS 6-hr EnKF for IC perturbations, 2-tiered SSTs driven by CFSv2 forecasted SSTs
- 20 years (1999-2018) reanalysis; 30 years (1989-2018) reforecast; Retrospective runs (3.5 years)

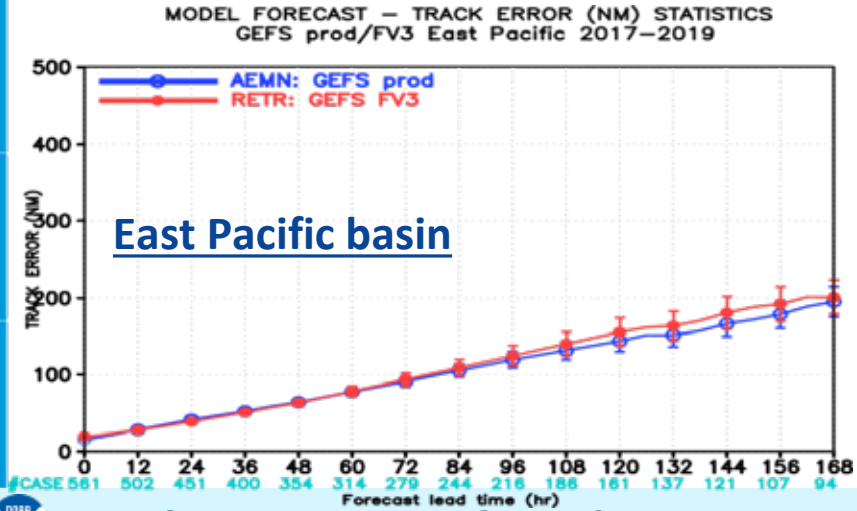
GEFSv12 TC track verification

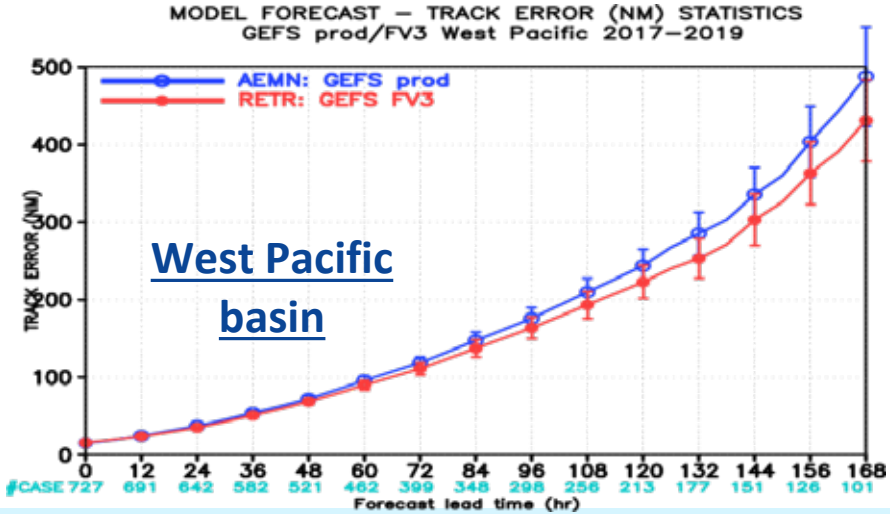
2017: 00Z 06/01----11/30 ; 12Z 07/01----10/31

2018: 00Z 05/01----11/30; 12Z 07/01----10/31

2019: 00Z 05/01----11/30; 12Z 07/01----10/31







GEFSv12 TC intensity verification

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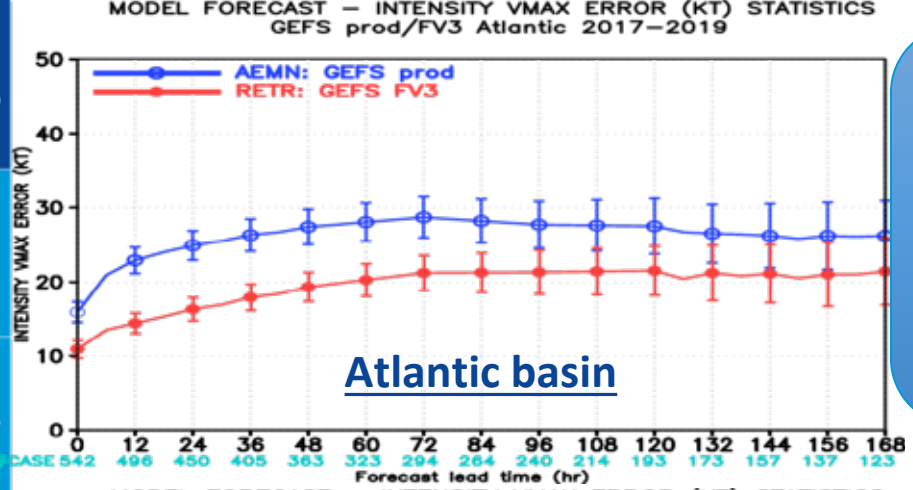
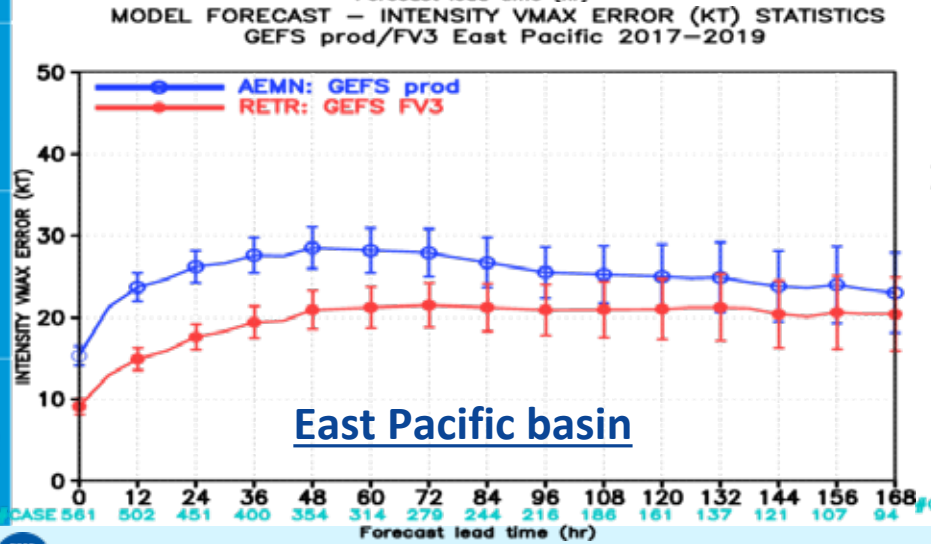
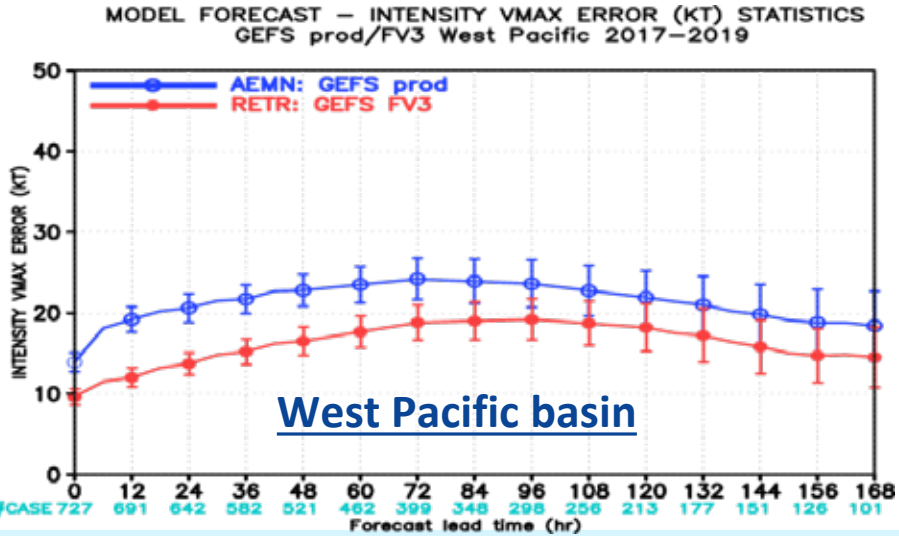
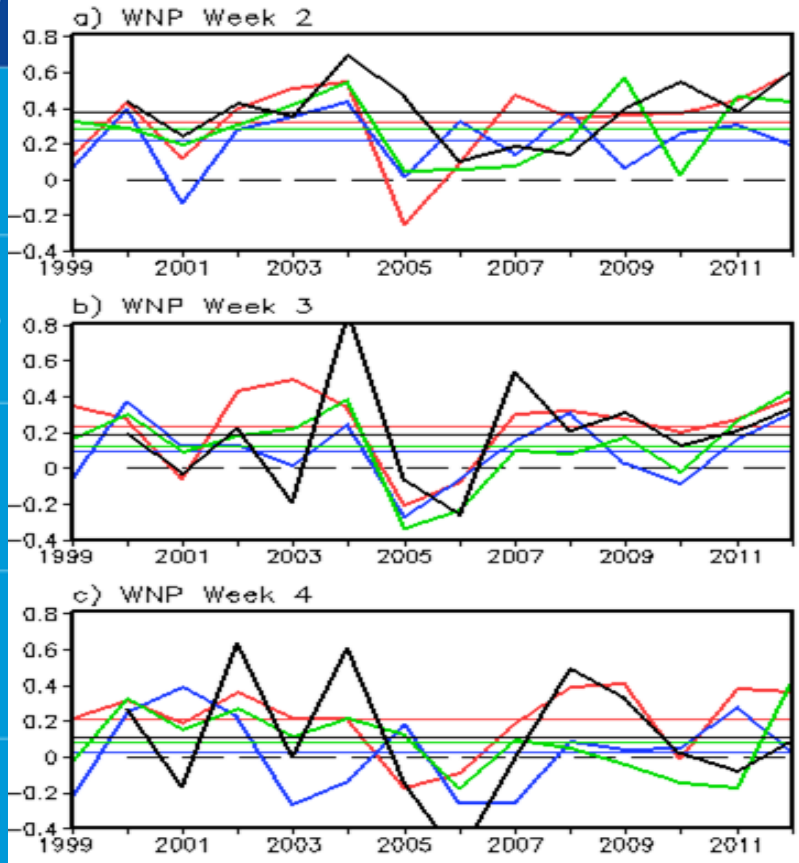


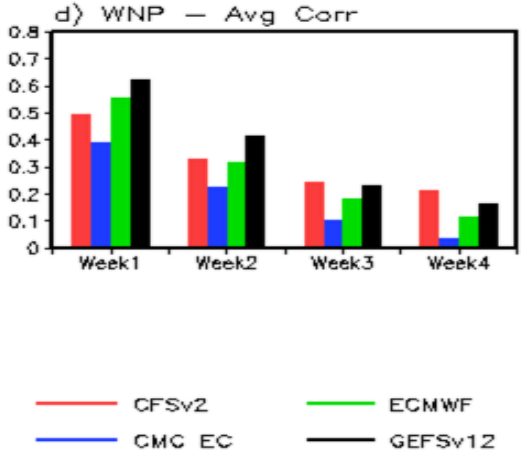




TC Count and Tracks: Anomaly Correlations - WNP

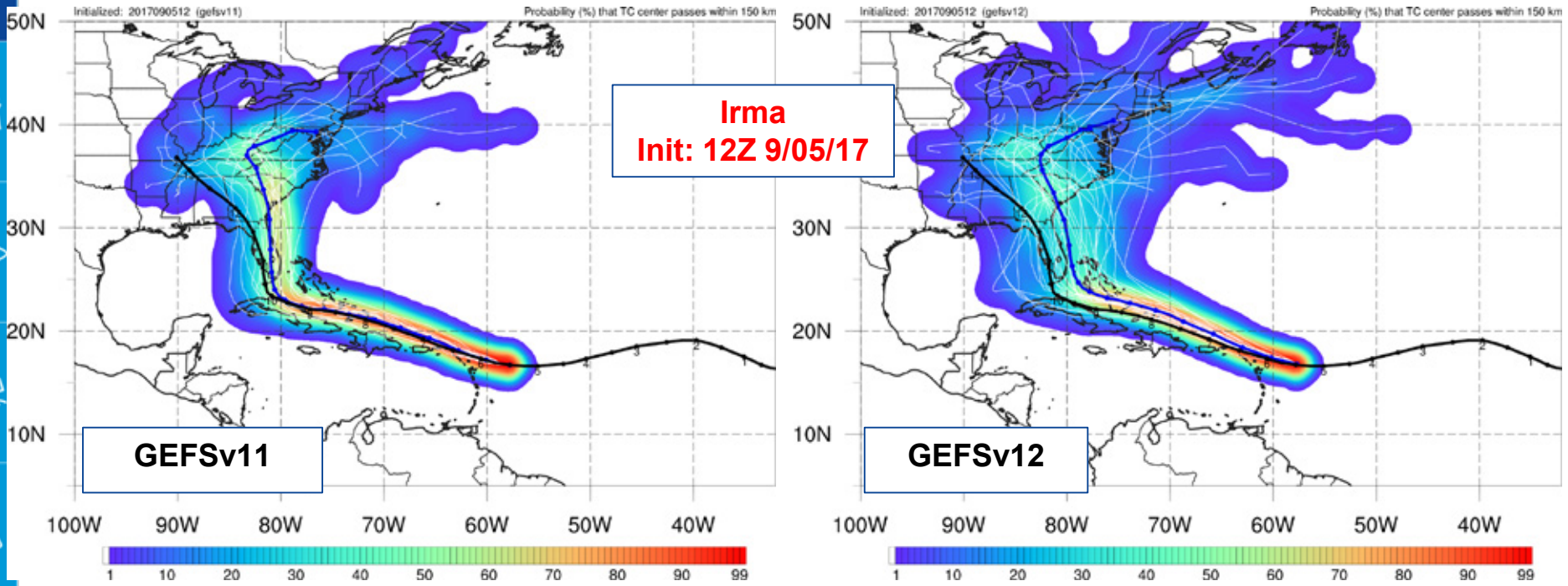


- GEFS outperforms the other models in Weeks 1-2 and is on par with CFS in weeks 3-4.



- Years of Note
- Good: 2004, 2005?
- Bad: 2006

Concerns: TC Right-of-Track Bias



GEFSv11 is in good agreement with Best Track at shorter lead times, but becomes right of Best Track at longer lead times. GEFSv12 is further right than GEFSv11 at all lead times.

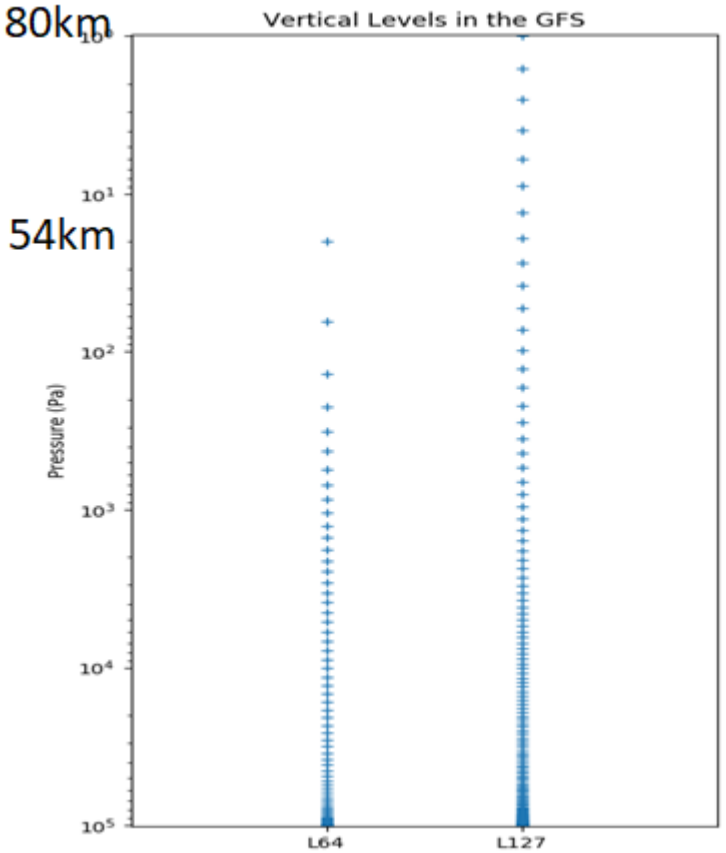
GDAS/GFSv16.0 to be implemented on March 17, 2021

- Increase the vertical resolution (long awaited) and advanced physics to enhance the model representation of the atmosphere, improve the DA algorithms, and include more observations (satellite and in-situ) for better initial conditions
- Couple the deterministic global wave model with the atmospheric model using the UFS coupling framework (simplification of production suite)
- Scientific priorities: Improve the forecast skill while addressing known issues from GFSv15 evaluation
  - Excessive cold bias in the winter season
  - Progressive bias for synoptic scale systems
  - Less skillful TC track forecasts, especially for stronger storms
  - Low bias for stratospheric temperature forecasts
  - Precipitation dry bias for moderate rainfall
  - Poor representation of boundary layer inversions
- Improve products and add new variables requested by the users
- Conduct comprehensive testing and evaluation including downstream models to demonstrate the benefits of this upgrade

Change History of GFS Configurations

Mon/Year	Lev	
Aug 1980	12	rhomboidal
Oct 1983	12	
Apr 1985	18	
Aug 1987	18	diurnal cycle
Mar 1991	18	
Aug 1993	28	ion
Jun 1998	42	GFDL to NASA
Oct 1998	28	
Jan 2000	42	
Oct 2002	64	
May 2005	64	; high-res to 180hr
May 2007	64	
Jul 2010	64	ıvtion; TVD tracer
Jan 2015	64	CA etc
May2016	64	
Jun2017	64	sics
Jun 2019	64	, MP
Feb 2021	127	, uGWD

18 years !



GFSv16: Major Changes to the Forecast Model

Model resolution:

Increased vertical layers from 64 to 127 & raised model top from 54 km to 80 km

Physics updates:

PBL/turbulence:	Replaced K-EDMF with sa-TKE-EDMF (Revised background diffusivity as a stability dependent function)
GWD:	Added a parameterization for subgrid scale nonstationary gravity-wave drag
Radiation:	Updated calculation of solar radiation absorption by water clouds; Updated cloud overlap assumptions.
Microphysics:	Updated GFDL microphysics scheme for computing ice cloud effective radius
Noah LSM:	Revised ground heat flux calculation over snow covered surface; Introduced vegetation impact on surface energy budget over urban area

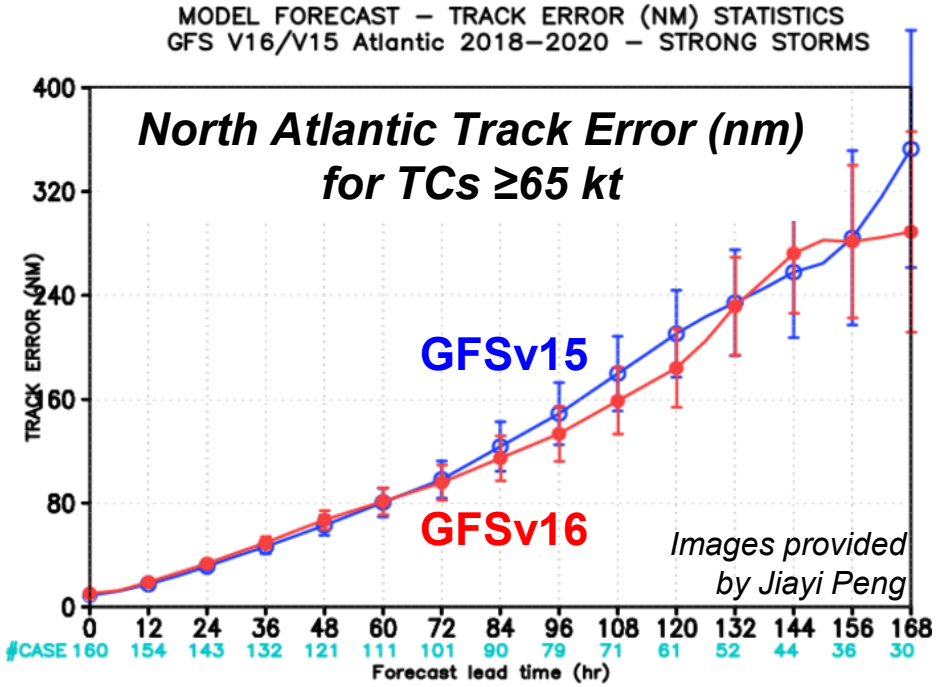
Coupling to Wave Model:

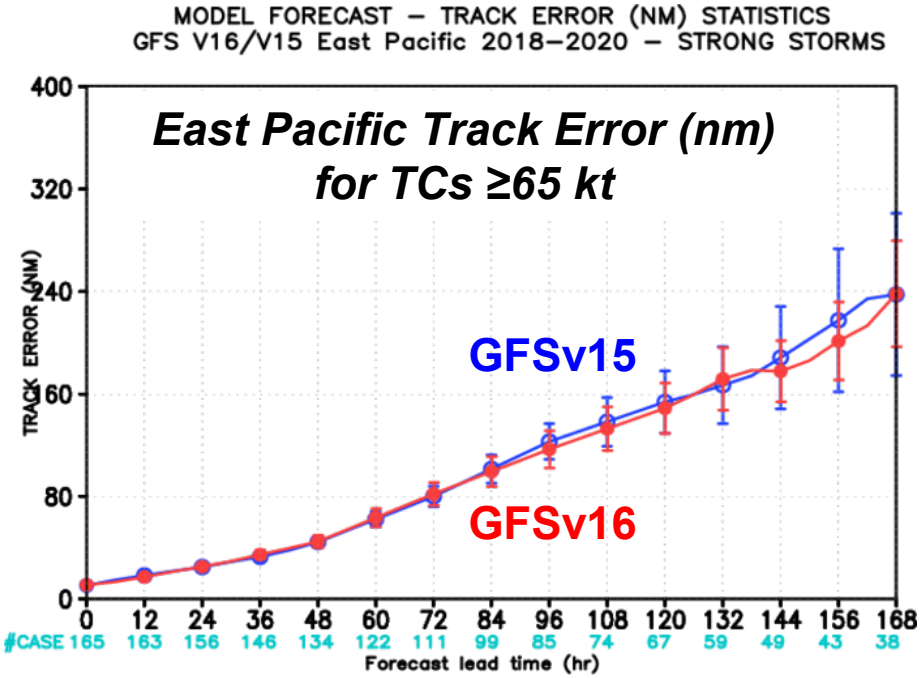
One-way coupling of atmospheric model with Global Wave Model (WaveWatch III, Multi_1)

Major Upgrades to GDAS

- **Local Ensemble Kalman Filter (LETKF)** with model space localization and linearized observation operator
  to replace the Ensemble Square Root Filter (EnSRF)
- **4-Dimensional Incremental Analysis Update (4D-IAU)**
- T**urn on SKEB** in EnKF forecasts
- **New variational QC**
- Apply Hilbert curve to aircraft data
- **Correlated observation error** for CrIS over sea surfaces and IASI over sea and land
- Update temperature aircraft bias correction with safeguard
- Assimilate AMSU-A channel 14 and ATMS channel 15 w/o bias correction
- **Assimilate CSR data from ABI_G16, AHI_Himawari8, and SEVIRI_M08; AVHRR** from NOAA-19 and Metop-B for NSST
- **Assimilate additional GPSRO** (add Metop-C GRAS, More Cosmic-2)
- **Assimilate** high-density flight-level wind, temperature, and moisture observations **(HDOBS) in tropical storm environment (first time in operations for GFS)**
- Reduce the distance threshold for inner core dropsonde data to 55km (from 111km or 3*RMW) and add a wind threshold of 32 m/s to **allow more dropsonde data being assimilated**
- **Use CRTM v2.3.0**

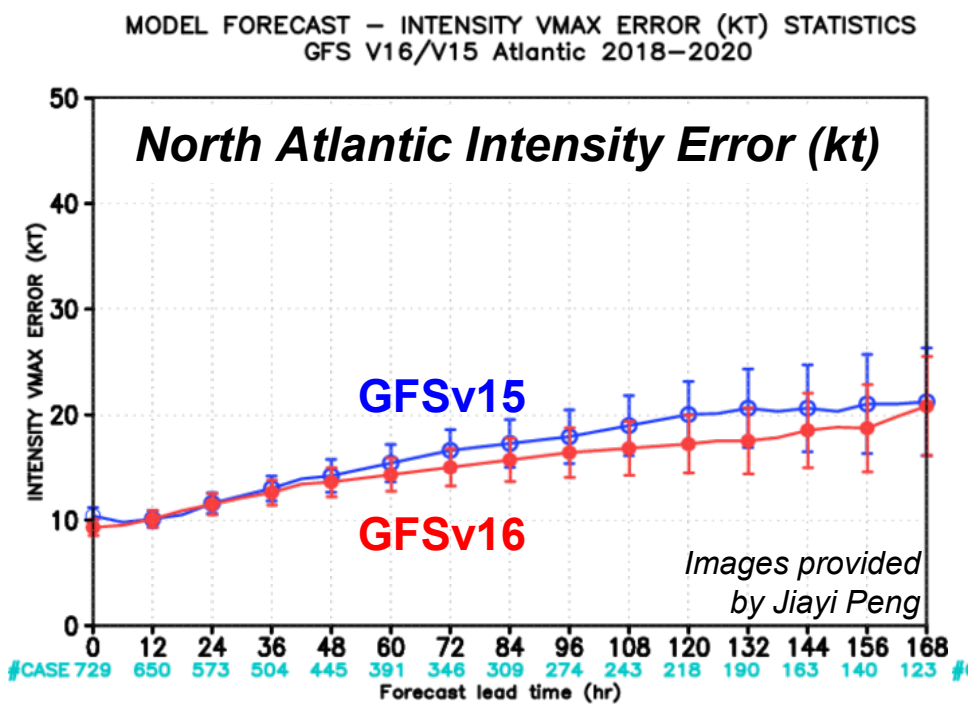
Strengths: Improved Medium-Range Track Error

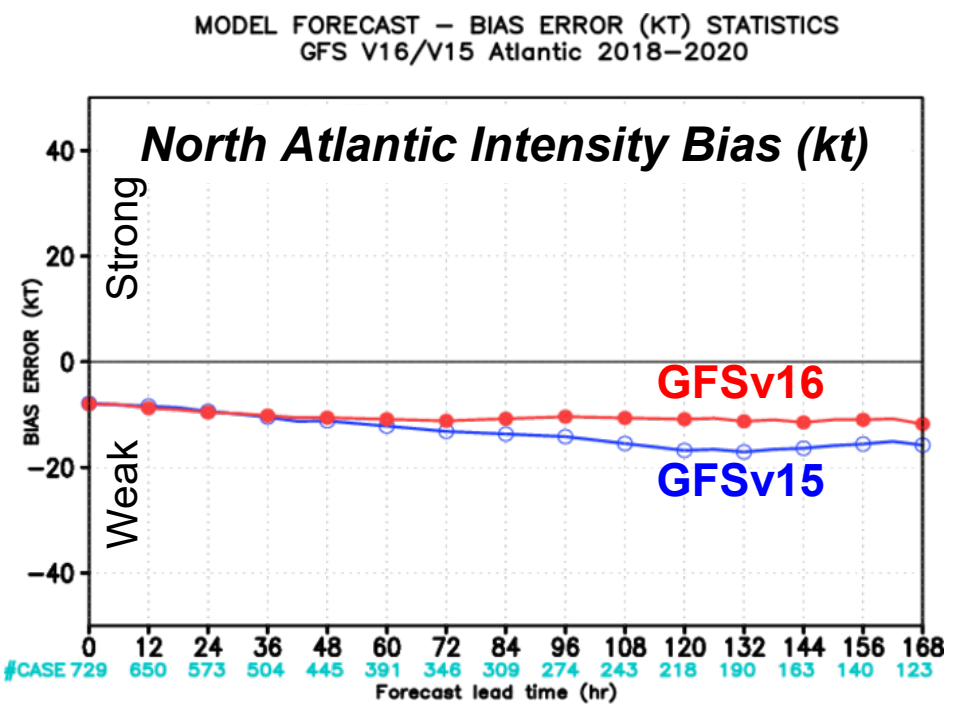




GFSv16 has lower track error than **GFSv15** for strong TCs (≥65 kt) during most of the medium range in both the North Atlantic and East Pacific

Strengths: Improved TC Intensity in N Atlantic

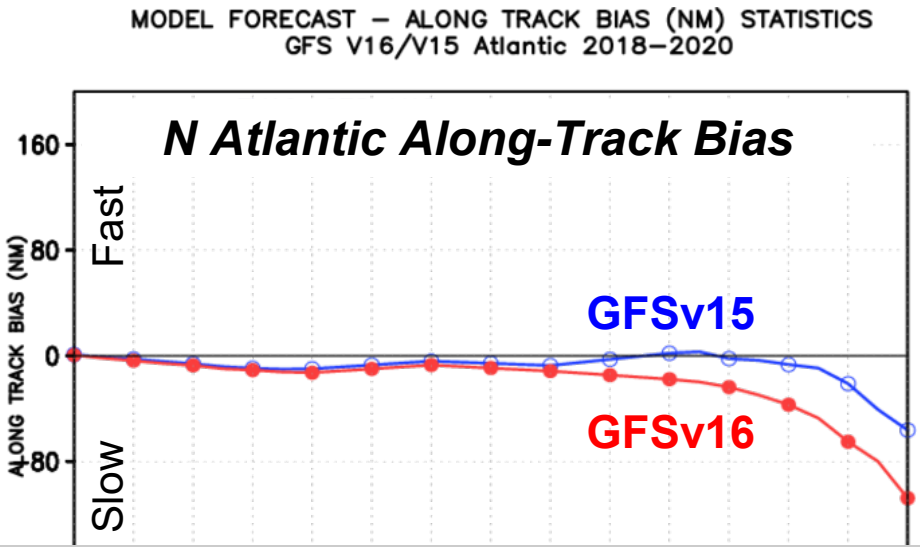


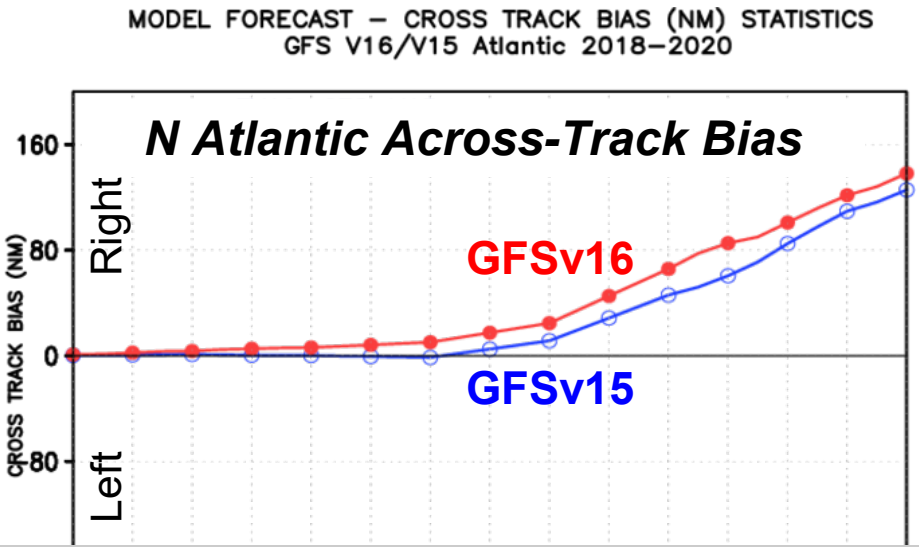


GFSv16 has lower intensity error than **GFSv15** at almost all lead times in the N Atlantic

GFSv16 has less of a weak bias than **GFSv15** at longer lead times

Concerns: Increased Right-of-Track Bias





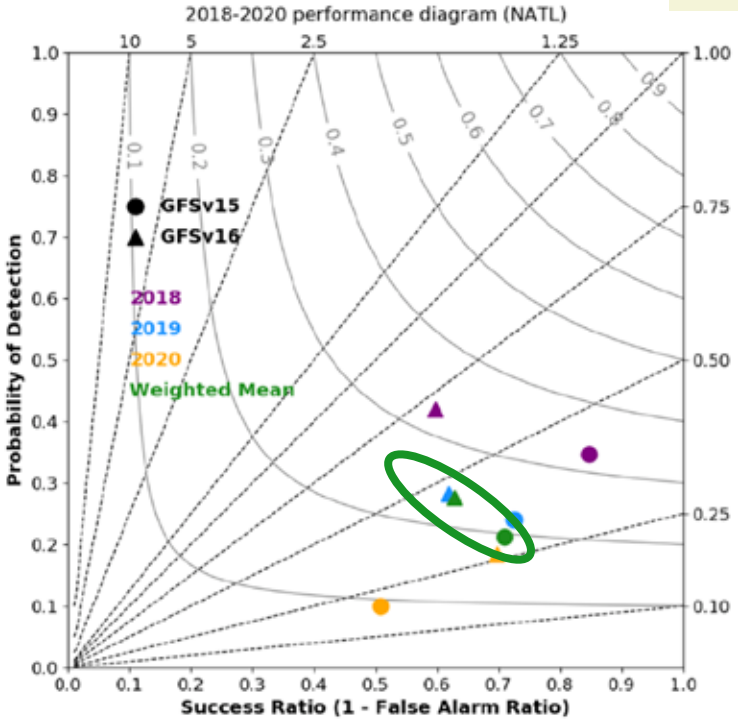
A slower and right-of-track bias at longer lead times suggests that GFSv16 may be recurving TCs earlier than GFSv15

GFSv16 has a larger slow bias than **GFSv15** that grows with forecast length in the N Atlantic

GFSv16 has a larger right-of-track bias than **GFSv15** that is largest at longer lead times

Larger TC False Alarm Rate

From Dan Halperin, ERAU



- Forecast verification by year for each model configuration.
  - x-axis: success ratio
  - y-axis: probability of detection
  - Dashed lines: frequency bias
  - Curved lines: critical success index
- All values would equal 1 for a perfect performing model.
- Compared to GFSv15, GFSv16 exhibits on average:
  - Larger probability of detection
  - Smaller success ratio
  - Larger critical success index
- Overall, GFSv16 is more cyclogenetic than GFSv15.

A ▲ further left than the ● of the same color indicates that v16 has a higher false alarm rate for that season

While preliminary 2020 numbers look good for v16, the weighted mean for the three TC seasons shows that v16 has a larger FAR

Larger TC False Alarm Rate

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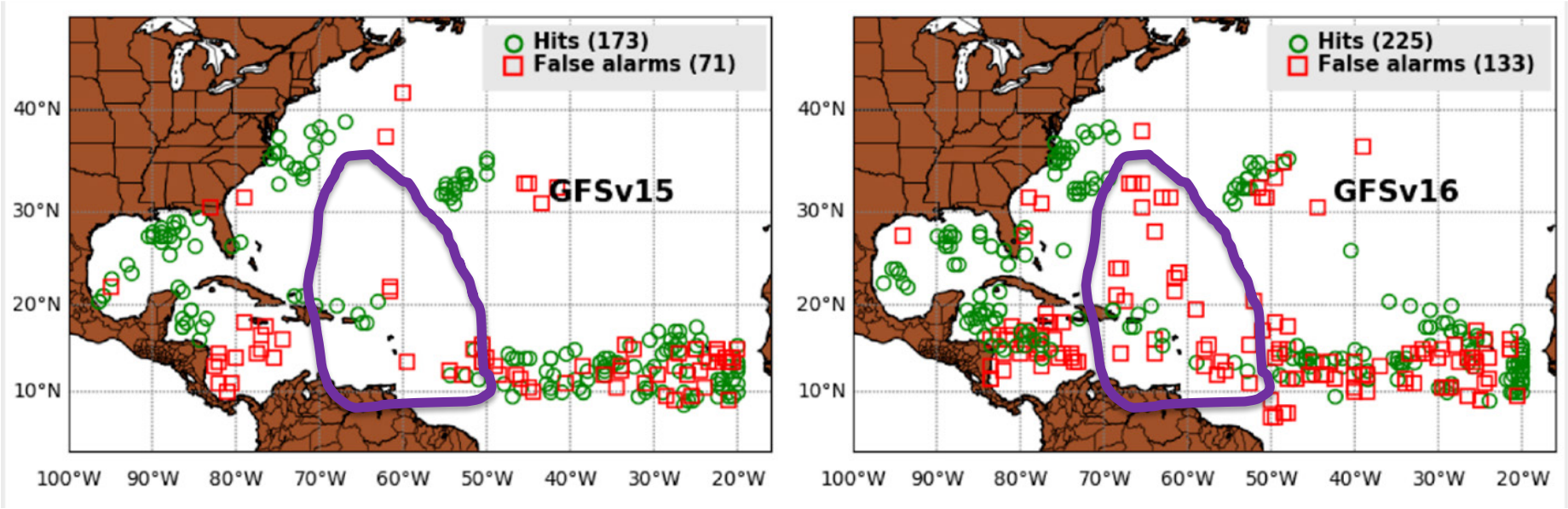
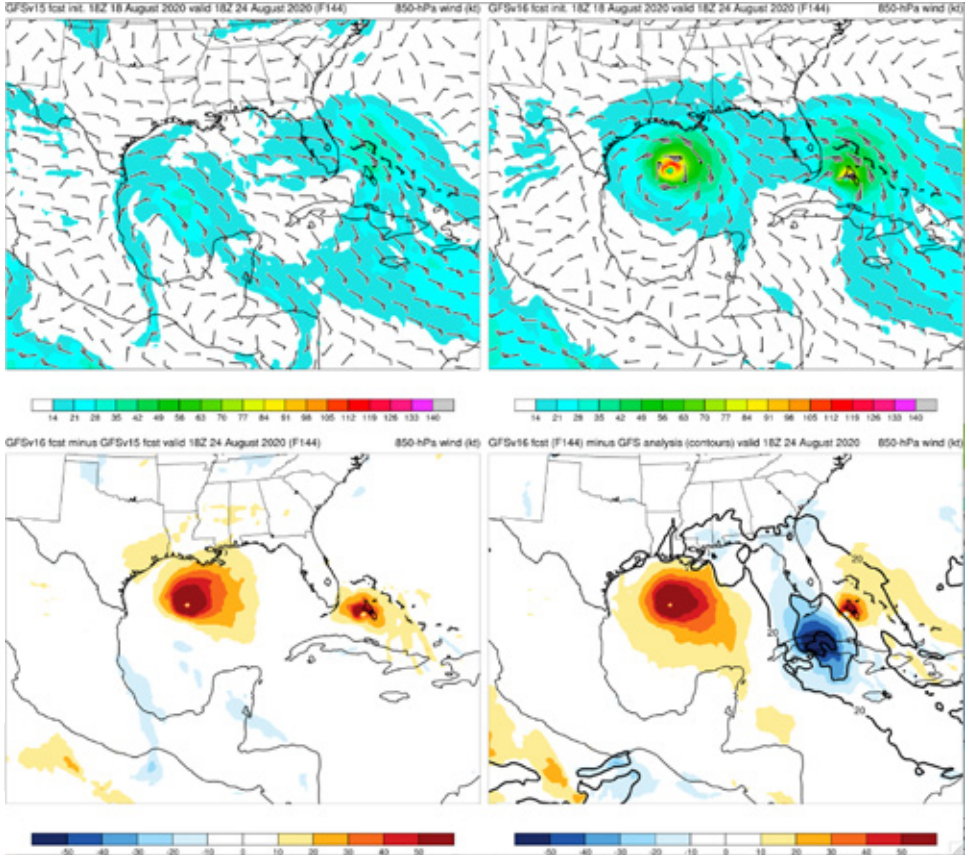


Large number of false alarms in GFSv16, relative to v15, between 50º and 70º W

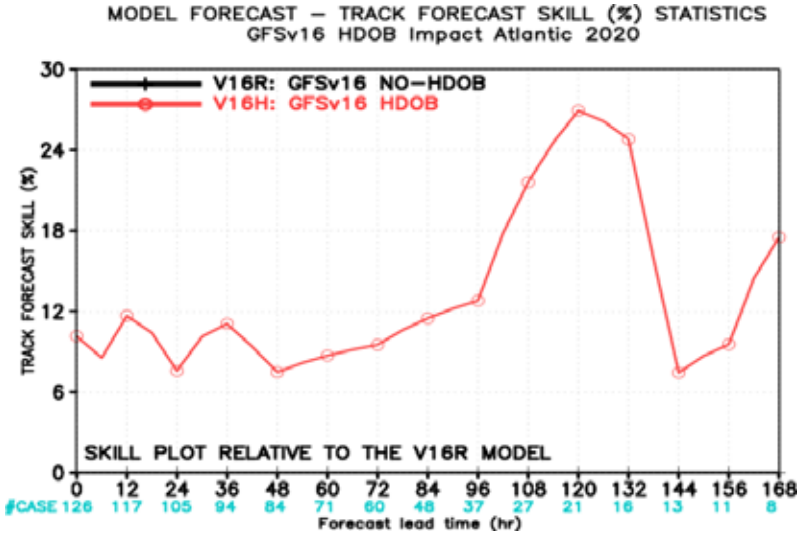
Concerns: Strengthens Too Many TCs

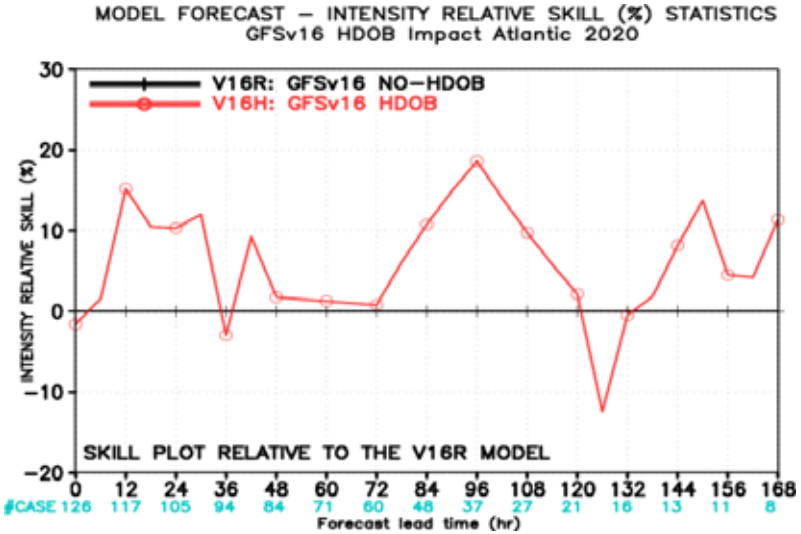


TCs Laura/Marco
Fcst: 18z 08/18/20(F144)
Valid: 18Z 08/24/20

- **Marco**: GFSv16 had better track forecasts, but 15 consecutive v16 cycles had Marco as a sub 982 low (with many in the 950s and 960s); no GFSv15 cycle was that intense
- **Laura**: GFSv16 did well with many aspects of the intensity forecast, but this example shows a major threat to south FL that did not materialize

Impact of Assimilation of HDOBS & improved use of dropsondes





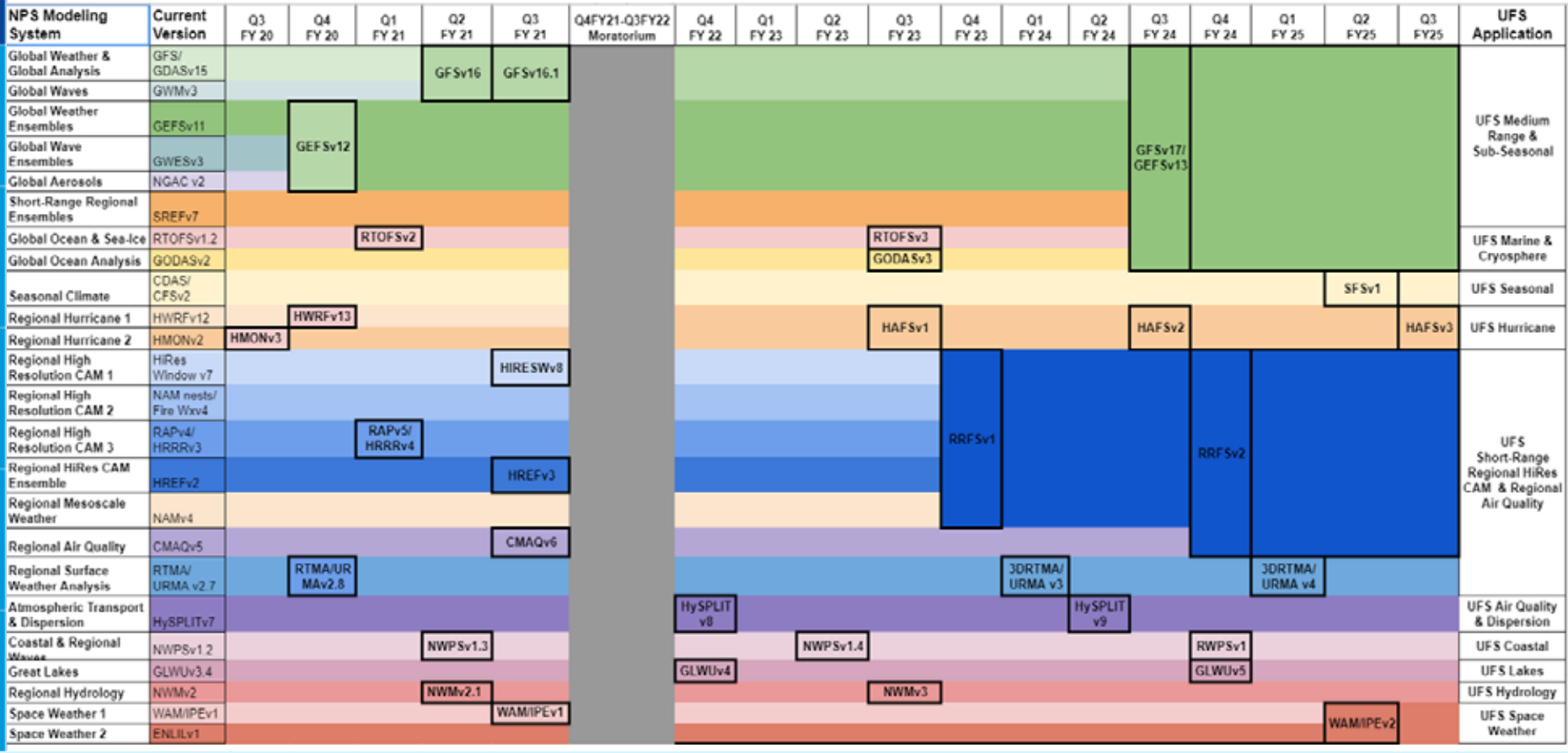
Significant improvements in track and intensity forecasts, especially for strong storms (About 20% more dropsonde data, and about 800 more HDOBS data (u,v,t,q) per cycle)

GFS.v16.1 Planned for implementation in May 2021

New Observations:

- Assimilation of commercial RO data which will become available by March 2021
- Addition of Metop-C IASI data that will start flowing into operations and possibly become the primary/operational satellite from EUMETSAT (replacing the aging metop-a)
- GOES AMV quality marks will need to be updated in response to the heat-pipe cooling issues to take better advantage of AMVs during problematic periods

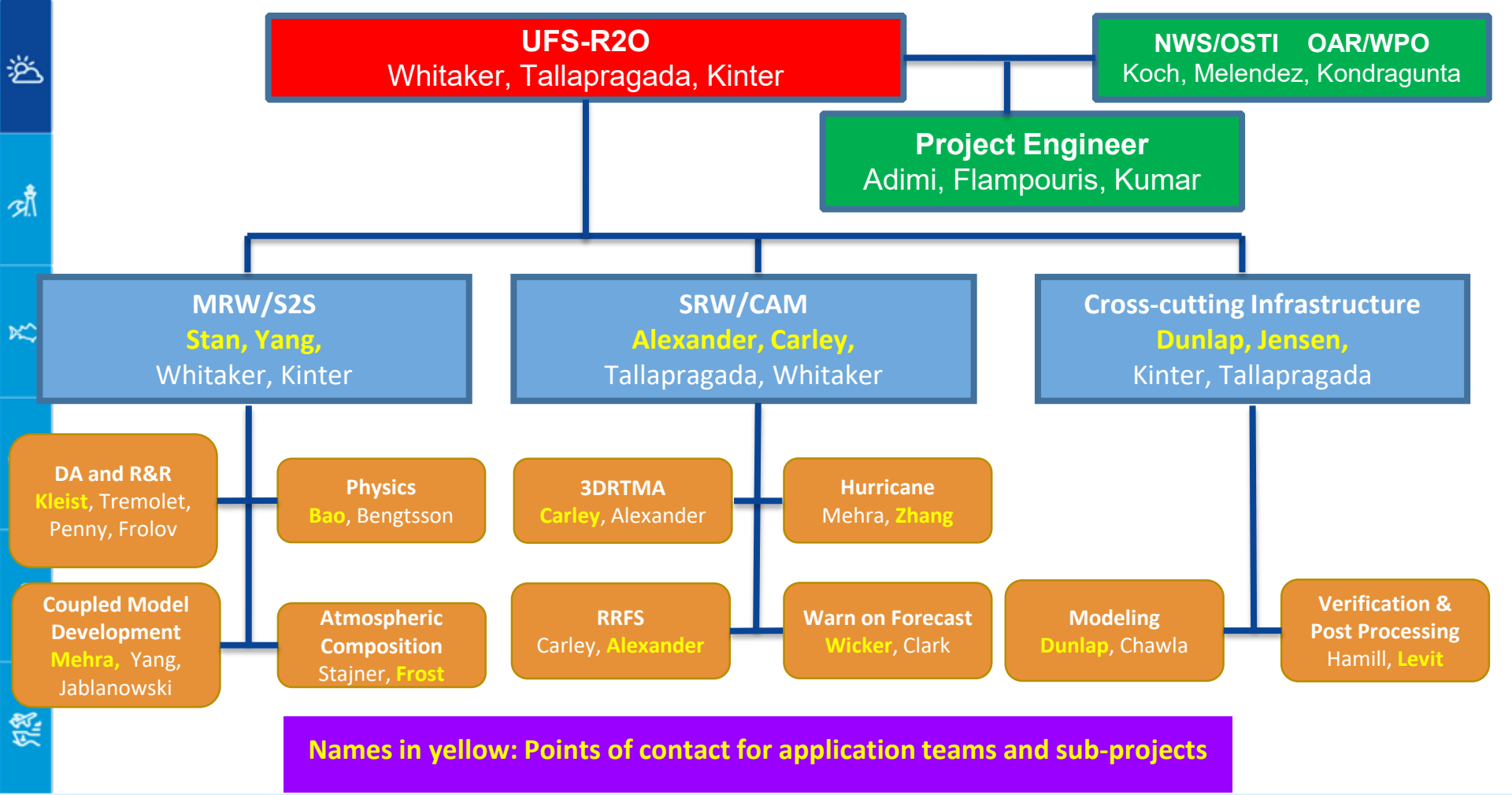
Notional Post-WCOSS Moratorium Implementations



UFS R2O Project

https://ufscommunity.org/ufsr2oproject/

Vijay Tallapragada, Jeff Whitaker, Jim Kinter


UFS-R2O
Whitaker, Tallapragada, Kinter
NWS/OSTI OAR/WPO
Koch, Melendez, Kondragunta
Project Engineer
Adimi, Flampouris, Kumar
MRW/S2S
Stan, Yang,
Whitaker, Kinter
SRW/CAM
Alexander, Carley,
Tallapragada, Whitaker
Cross-cutting Infrastructure
Dunlap, Jensen,
Kinter, Tallapragada
DA and R&R
Kleist, Tremolet, Penny, Frolov
Physics
Bao, Bengtsson
3DRTMA
Carley, Alexander
Hurricane
Mehra, Zhang
Coupled Model Development
Mehra, Yang, Jablanowski
Atmospheric Composition
Stajner, Frost
RRFS
Carley, Alexander
Warn on Forecast
Wicker, Clark
Modeling
Dunlap, Chawla
Verification & Post Processing
Hamill, Levit
Names in yellow: Points of contact for application teams and sub-projects

UFS-R2O Project Outcomes – Years 1-2

- First 2 major operational systems, global and regional, to be developed jointly between NOAA and the community!
  - Initially targeting GFSv17/GEFSv13/HREFv3/RRFSv1/HAFSv1
- Fully coupled (L-O-SI-A-Ae) global ensemble prediction system, including coupled DA, ready for pre-operational testing and suitable for community research use
  - Addressing science priorities and leading to operational forecast improvements in priority areas
  - Reanalysis/reforecast capability for calibration/bias correction (production in years 3-4)
  - Public releases of coupled Medium-Range weather/S2S application
  - Public releases of JEDI data assimilation framework
- Regional rapid refresh (1-hour cadence) ensemble forecast system for convection-allowing scales ready for pre-operational testing
  - Public release of Short-Range weather application
- Start to sunset existing global and mesoscale prediction systems in collaboration with academic and forecast communities
  - Forecast system unification – simplification of operational product suite

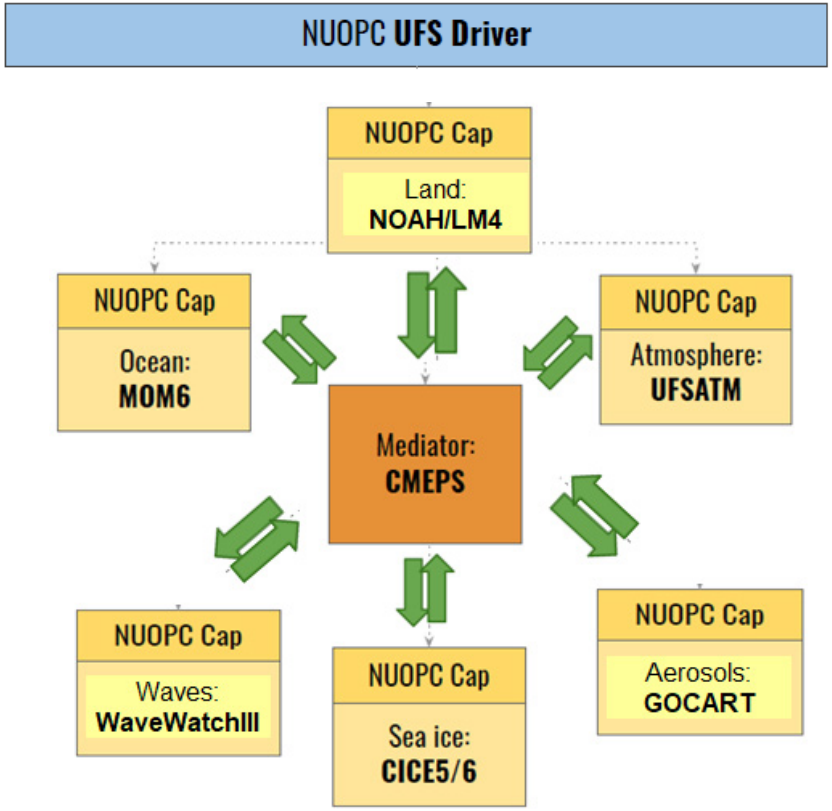
Future: Coupled UFS Applications for global medium range, sub-seasonal and seasonal predictions

GEFS v13: Fully coupled system for sub-seasonal predictions

- FV3+MOM6+CICE6+WW3+GOCART Coupled Model
- Advanced Physics, Weakly Coupled DA
- FY24: Implement GEFS v13.0
- Combine with GFSv17

Seasonal Forecast System (SFS v1.0/CFS v3)

- Fully coupled Unified Forecast System
- Seasonal ensemble forecasts with reanalysis and reforecasts
- Advanced coupled DA
- FY25: Implement SFS v1.0



Thanks for your attention

Questions?