Operational Implementation of NOAA's new Generation Hurricane Prediction System: Hurricane Analysis and Forecast System (HAFSv1)

Zhan Zhang[1], Xuejin Zhang[2], Bin Liu[3], Avichal Mehra[1],Vijay Tallparagada[1], S. Gopalakrishnan[2], Frank D. Marks, Jr[2]

[1]NOAA/NWS/NCEP/EMC, College Park, MD
[2]NOAA/AOML/Hurricane Research Division, Miami, Florida
[3]Lynker at NOAA/NWS/EMC, College Park, MD

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Acknowledgement of ALL Active HAFS Developers

Atmospheric model dynamics/configurations/workflow **NCEP/EMC** Avichal Mehra, Zhan Zhang, Bin Liu, Dusan Jovic, JungHoon Shin,Vijay Tallapragada, Biju Thomas, Jun Wang **AOML/HRD** Xuejin Zhang, Ghassan Alaka, S. Gopalakrishnan, William Ramstrom **DTC** Kathryn Newman, Mrinal Kanti Biswas, Linlin Pan **GFDL** Rusty Benson, Lucas Harris, Joseph Mouallem	**Ocean/Wave coupling through CMEPS** **NCEP/EMC** Maria Aristizabal, Matthew Masarik, Jessica Meixner, John Steffen **AOML/HRD** Lew Gramer **AMOL/PhOD** Hyun-Sook Kim **ESMF** Rocky Dunlap, Dan Rosen, Gerhard Theurich, Ufuk Turuncoglu,	**Data Assimilation** **NCEP/EMC** Li Bi, Yonghui Weng, Ting Lei, Shun Liu, Daryl Kleist **AOML/HRD** Jason Sippel, Sarah D. Ditchek **OU** Xu Lu, Xuguang Wang **UM/CIMAS** Altug Aksoy, Dan Wu **UMD** Joseph Alan Knisely, Kenta Kurosawa, Jonathan Poterjoy **SUNY/U at Albany** Ryan Torn, Eun-Gyeong Yang
Model Pre- and Post-processes **NCEP/EMC** George Gayno, Hui-Ya Chuang, Bantwale Enyew, Qingfu Liu, Chuan-Kai Wang, Wen Meng, Lin Zhu, Rahul Mahajan **GFDL** Timothy Marchok	**Atmospheric Physics** **NCEP/EMC** Jongil Han, Ruiyu Sun, Xu Li, Chunxi Zhang, Weiguo Wang, Fanglin Yang **AOML/HRD** Andrew Hazelton, Xuejin Zhang **UAH** Xiaomin Chen	**Verification/Evaluation** **NCEP/EMC** Olivia Ostwald, Jiayi Peng, Hui Ya Chuang **NHC** Michael Brennan, Jon Martinez, Ben Trabing, David Zelinsky, Wallace Hogsett **JTWC** Brian Strahl, Levi Cowan

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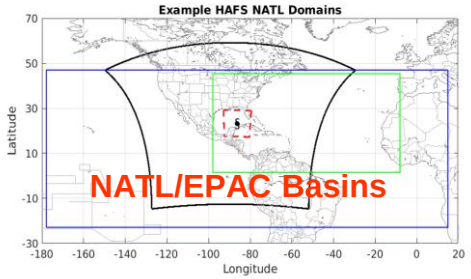
BLUF & Key Points

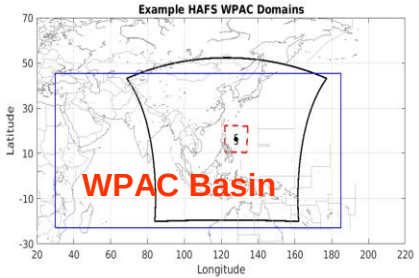
- **Two configurations (HFSA and HFSB) of HAFSv1 became operational on June 27 2023, running along with HWRF and HMON**
  - HFSA: max 7 storms for all global basins, No DA for JTWC storms
  - HFSB: max 5 storms for NHC/CPHC basins only.
  - HWRF/HMON will continue running operationally in reduced capacity (max 3 storms) and ~30 min delayed in products delivery

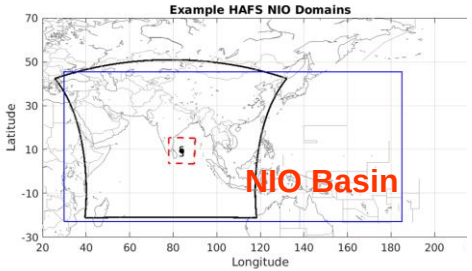
- **Salient features of HAFS**
  - FV3 based dyn-core
  - CEMPS based ocean/wave coupling.
  - Improved Vortex initialization
  - 4DEnVar inner-core data assimilation
  - CCPP based TC-specific physics
  - Updated workflow
- Overall, evaluation metrics in skill space for HAFS v1 confirm positive improvements over operational HWRF and HMON.

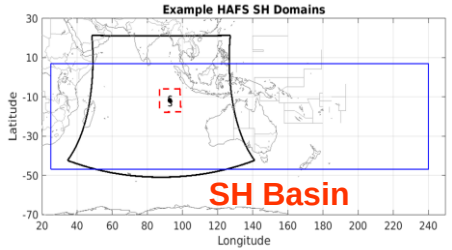
HAFSv1 Operational Configurations

HAFSv1.0	Domain	Resolution	DA/VI	Ocean/Wave Coupling	Physics	Basins
HFSA	Storm-centric with one moving nest, parent: ~78x75 deg, nest: ~12x12 deg	Regional (ESG), ~6/2 km, ~L81, ~2 hPa model top	Vmax > 50 kt warm-cycled VI and 4DEnVar DA	Two-way HYCOM, one-way WW3 coupling for NHC/CPHC basins	Physics suite-1	All global Basins NHC/CPHC/JTWC Max 7 Storms similar to HWRF
HFSB	Storm-centric with one moving nest, parent: ~75x75 deg, nest: ~12x12 deg	Regional (ESG), ~6/2 km, ~L81, ~2 hPa model top	Vmax > 40 kt warm-cycled VI and 4DEnVar DA	Two-way HYCOM No Waves	Physics suite-2	NHC/CPHC Max 5 Storms similar to HMON









atmospheric domain, ocean domain, wave domain

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HAFSv1 Physics Schemes

	Suite 1	Suite 2	References
Land/ocean Surface	NOAH LSM VIIRS veg type, HYCOM	NOAH LSM VIIRS veg type HYCOM	Ek et al. (2003) …
Surface Layer	GFS, HWRF TC-specific sea surface roughnesses	GFS, HWRF TC-specific sea surface roughnesses	Miyakoda and Sirutis (1986); Long (1984, 1986)
Boundary Layer	Sa-TKE-EDMF, TC-related calibration, **mixing length adjustments**	Sa-TKE-EDMF, TC-related calibration, **tc_pbl=1, mixing length adjustments**	Han et al. (2019) Wang et al. (2022) Chen et al. (2022)
Microphysics	**GFDL single-moment**	**Thompson double-moment**	Lin et al. (1983) Chen and Lin (2013) Thompson et al (2008) Thompson and Eidhammer(2014)
Radiation	RRTMG Calling frequency **720 s**	RRTMG Calling frequency **1800 s**	Iacono et al. (2008)
Cumulus convection (deep & shallow)	Scale-aware-SAS, **calibrated deep convection entrainment**	Scale-aware-SAS	Han et al. (2017)
Gravity wave drag	uGWPv1	uGWPv1	Alpert et al. (1988)

Upstream Data Inputs and Flowchart

TCVital
Used for TC location/relocation

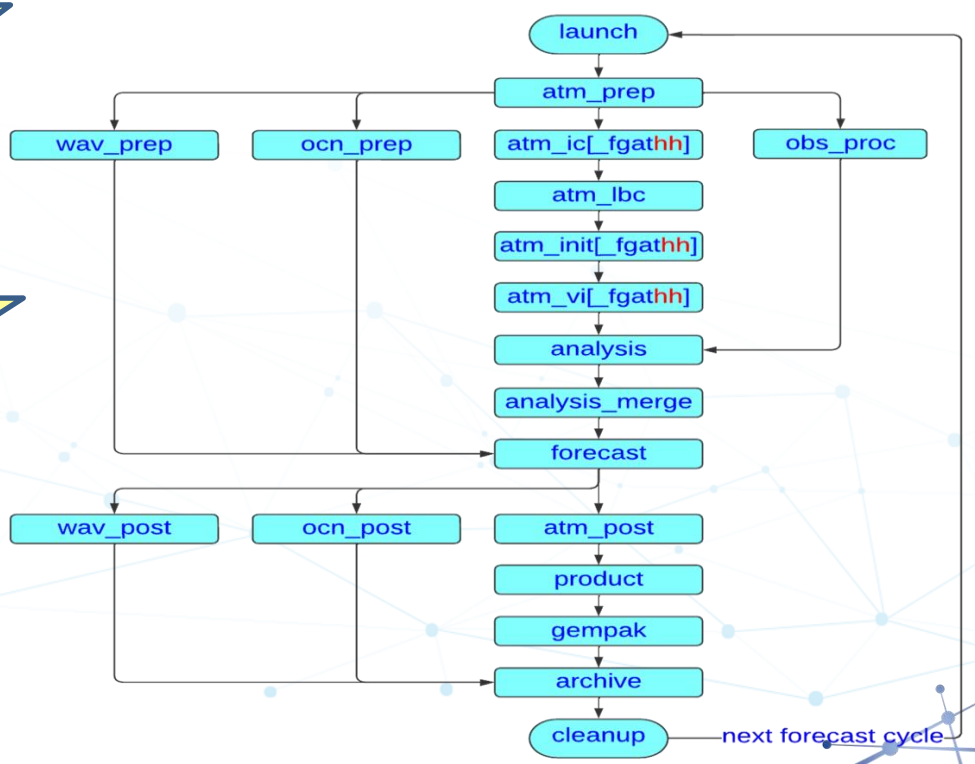
GFS Analysis & 0-129hr fcst
Used to generate atm/ocean/wave IC/BC

RTOFS
Used to generate ocean IC

Prior GDAS forecasts at 03,06,09 h
Used to FGAT files

80 GDAS member Ens. forecasts at 03,06,09 h
Used for 4DEnVAR DA

Observation files in obsproc and DCOM



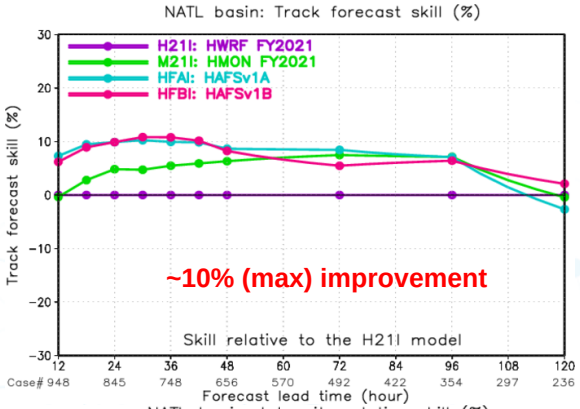
HAFSv1 Operational Flowchart

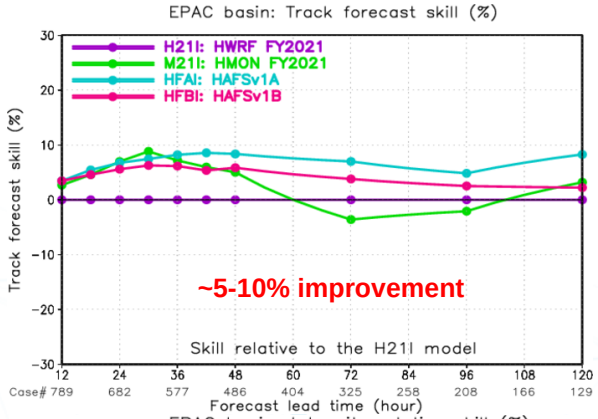
Track and Intensity Skill: NHC Basins (2020-2022) (Early Model)

NATL

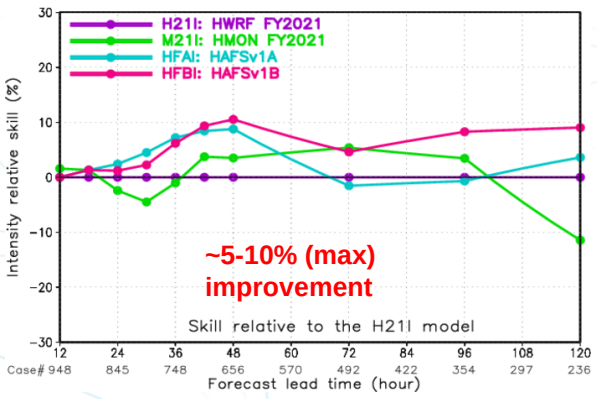
EPAC

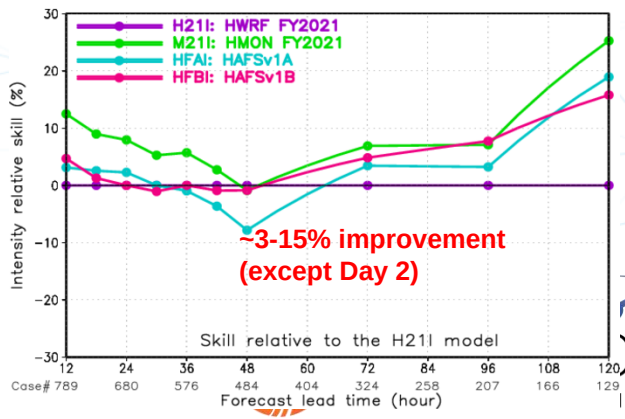
Track





Intensity



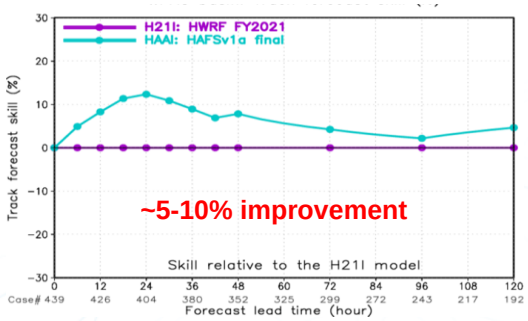


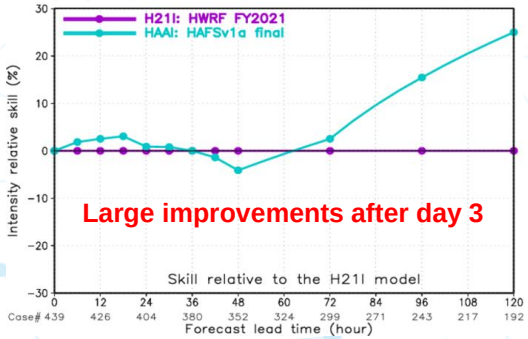
Track/Intensity Forecast Skill: WPAC/NIO/SH Basins (2021-2022)
Early Model Verification

Track

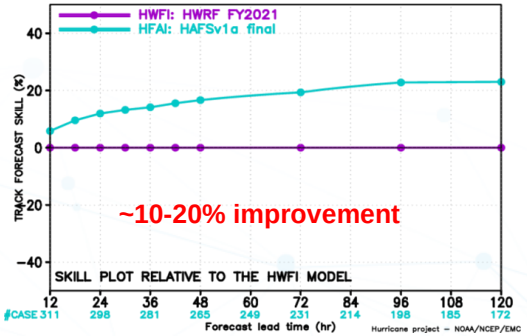
Intensity

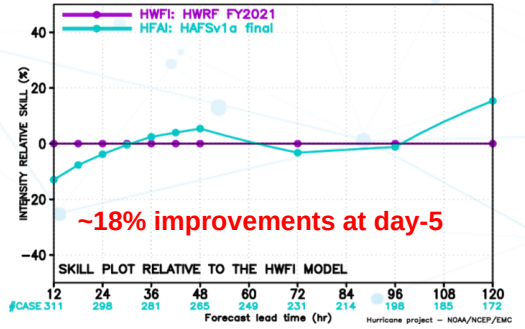
WPAC



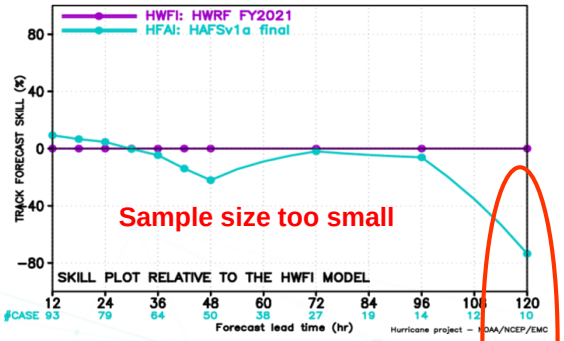


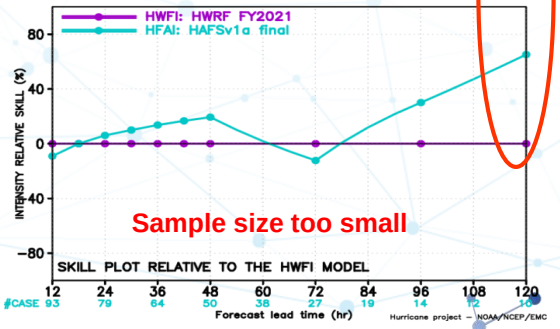
SH





NIO





Data Assimilation is turned off for JTWC basins. For WPAC/SH storms, HFSA has improved track skill over HWRF for all lead times. Intensity forecasts are also largely improved especially after Day 3. NIO sample size is small.

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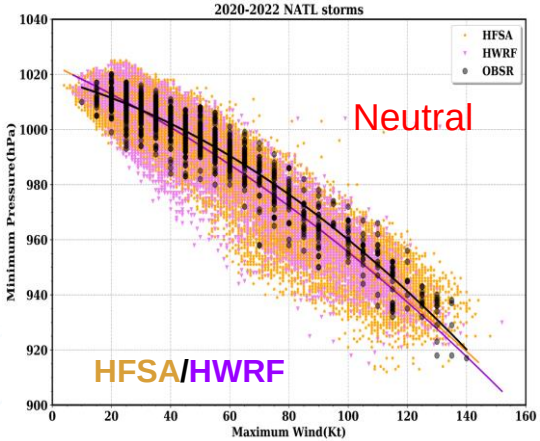
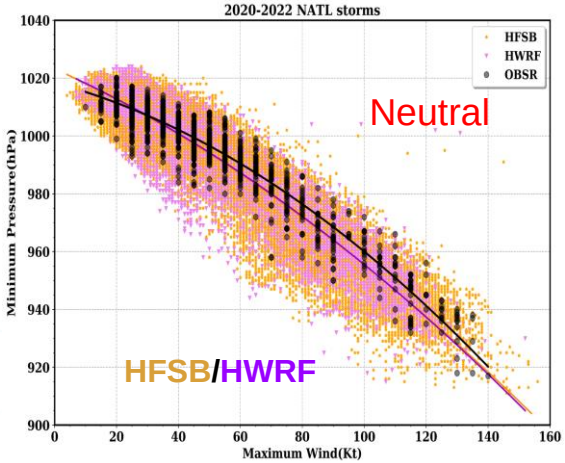
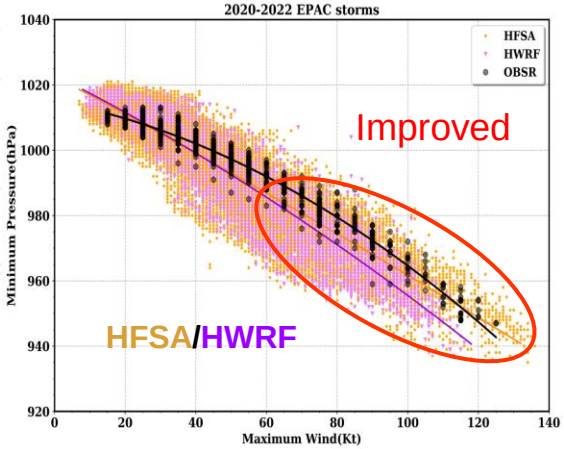
Pressure/Wind relationship (2020-2022)

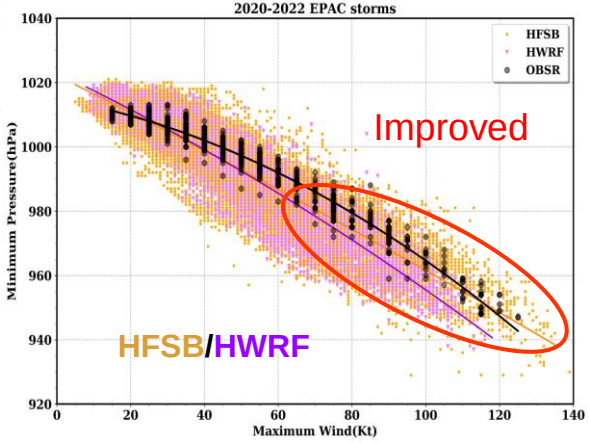
NATL





EPAC





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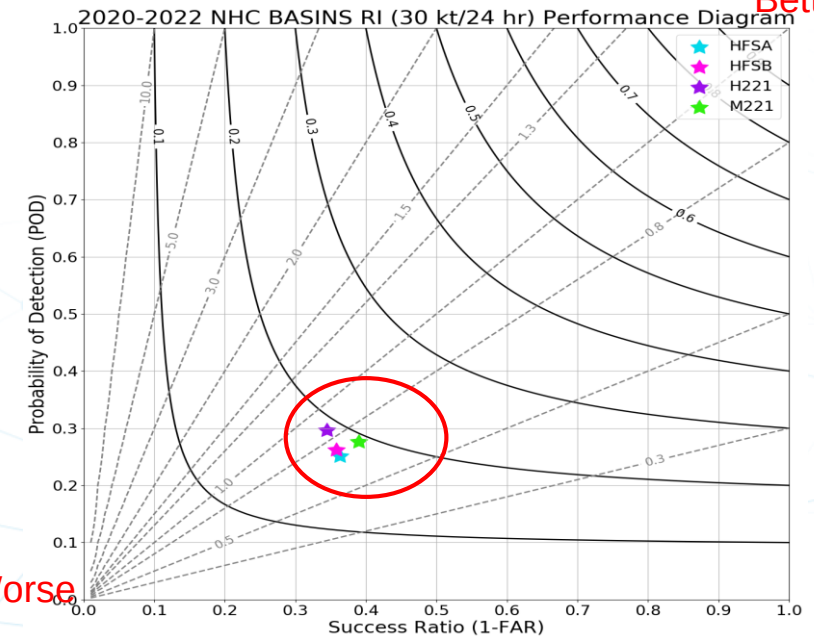
Rapid Intensification Verification

Combined NHC (NATL+EPAC) and JTWC (WPAC+SH+NIO) basins

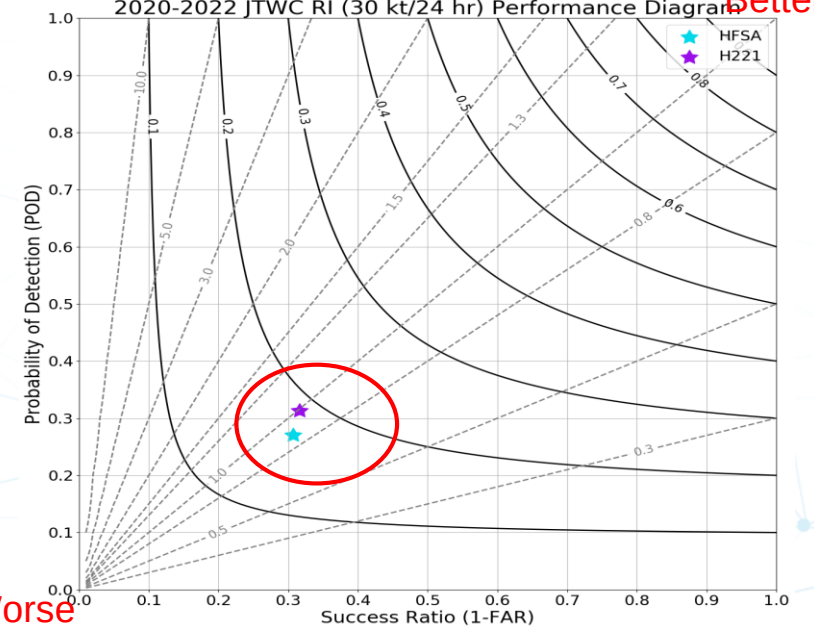
NHC



Better

Worse

JTWC



Better

Worse

In general, HAFS RI prediction performance is similar to HWRF/HMON in both NHC and JTWC basins

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Summary: Improvements for HAFS in Skill Space vs HWRF

Metric	NATL		EPAC	
	HAFS-A	HAFS-B	HAFS-A	HAFS-B
Track Skill	***Mostly improved***	***Improved***	***Improved***	***Improved***
Intensity Skill	Neutral to ***improved***	***Improved***	Neutral to ***improved***	***Mostly improved***
Storm Size Bias	RMW neutral, mixed for 34 kt, ***reduced*** for 50 kt and 64 kt radii	RMW neutral, increased for 34 kt, ***reduced*** for 50 kt and 64 kt radii	***Reduced*** for RMW, 34 kt, 50 kt and 64 kt radii	***Reduced*** for RMW, 34 kt, 50 kt and 64 kt radii
RI Cases	Track errors are ***reduced,*** intensity slightly behind	Track errors are ***reduced***, intensity slightly behind	Track errors are ***reduced***, neutral for intensity	Track errors are ***reduced***, intensity slightly behind
RI Metrics	Slightly behind HWRF	Slightly behind HWRF	***Improved***	***Improved***
P-W relationship	Neutral	Neutral	***Improved***	***Improved***
Waves	Neutral to ***Improved***	N/A	***Improved***	N/A

Negative **Mixed/Neutral** **Positive**

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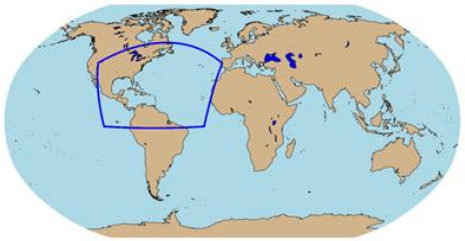
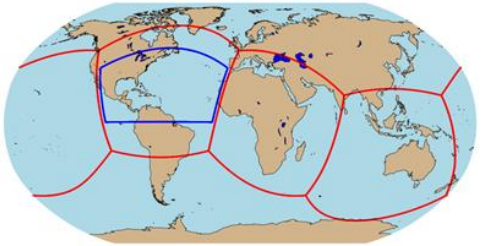
Available Configuration Options for Research

- **Domain Options**
  - Global-nest
  - Regional: Storm-Centric, Basin-Centric
  - Horizontal & vertical resolutions
- **VI and DA options**
  - Warm-start threshold
  - Nest vs parent domain DA
  - 3DEnVar, 4DEnVar, GDAS and/or HAFS ensembles
- **Model Physics Options**
  - Various model physics suites
- **Coupling Option**
  - Ocean coupling: HYCOM, MOM6
  - Wave coupling: One-way, two-way coupling

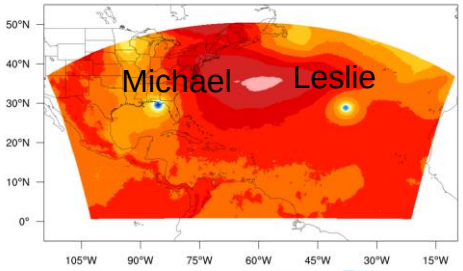
regional



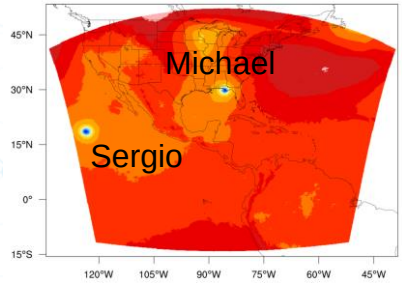
global-nesting



basin-focused



storm-focused



Basin-centric domain can be run with zero-storm and multiple storms. The domain center is relocatable

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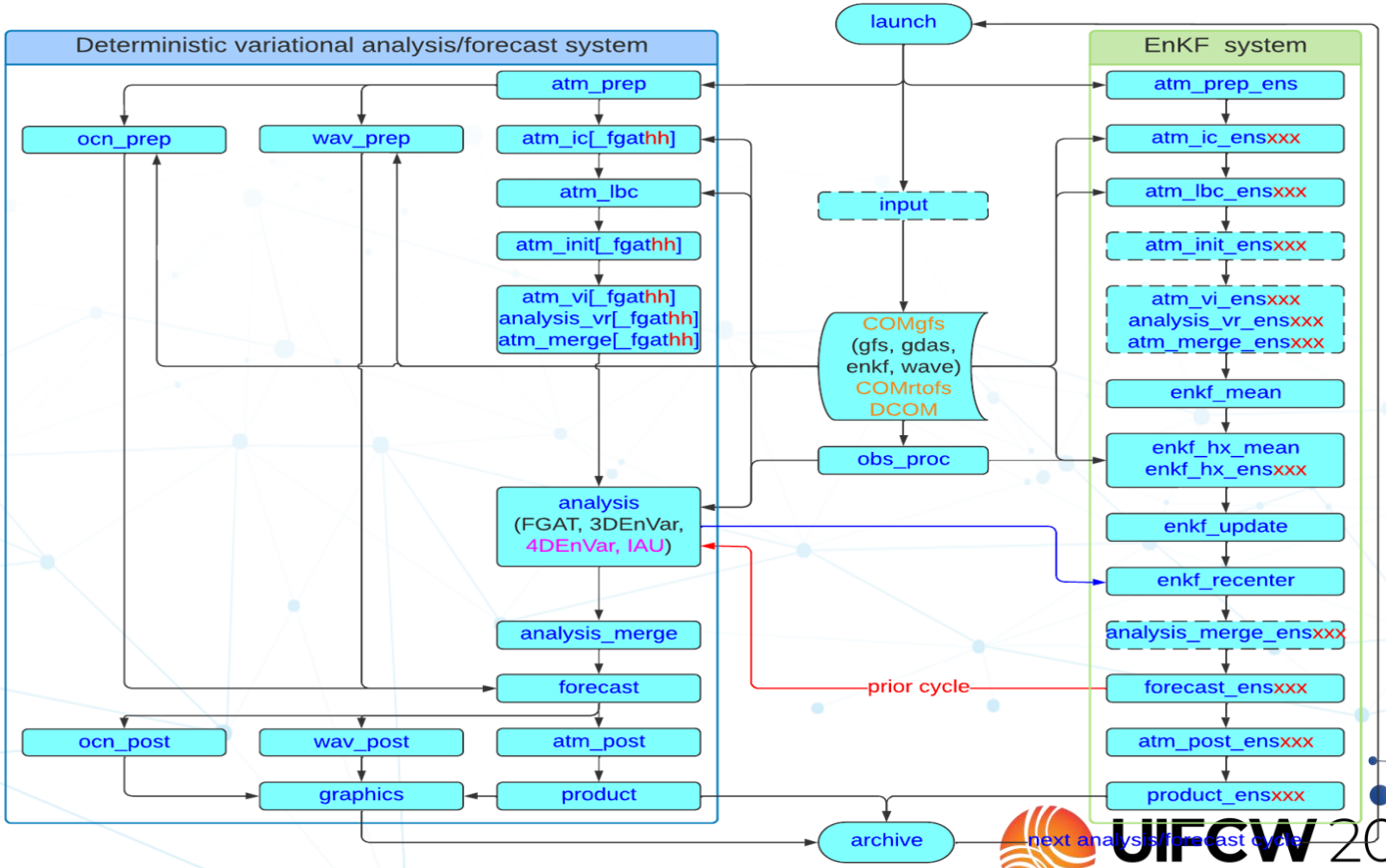
HAFS Application Flowchart



Summary

- Evaluation metrics in skill space for both operational configurations of HAFSv1 indicate positive improvements over operational HWRF and HMON
- Various options available for research to further development and improvement
- HAFSv1, as a UFS-based hurricane application, lays down a foundation for making further enhancements, for both research and operations with community involvement, and serves as an **exemplar** for the broader UFS-R2O project
- Seek more direct engagement of forecasters and the wider UFS community in active participation for model enhancements and future R2O
- **Full credit to the entire EMC Hurricane team, NHC team, HRD team, DTC team and all our research and operational collaborators for successful execution of pre-implementation T&E for NOAA's next generation of Hurricane modeling systems proposed for operations**