Hurricane Analysis and Forecast System (HAFS) based Ensemble Prediction System: Real time Experiments and Future Plan

[1]Zhan Zhang, [2]Bin Liu, [3]Weiguo Wang, [3]Yonghui Weng, [4]Jiayi Peng
[1]Avichal Mehra, [1]Vijay Tallapragada

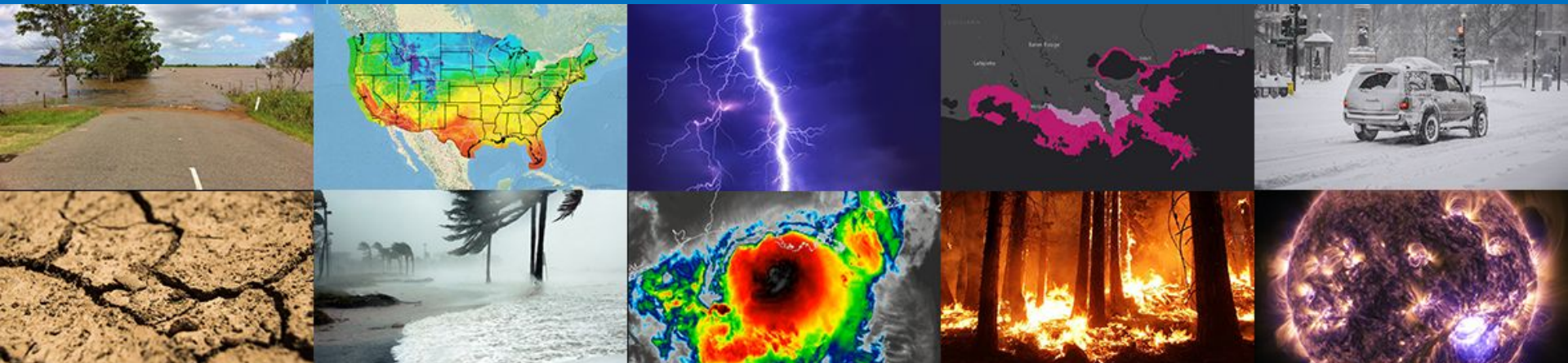[1]NOAA/NWS/NCEP/Environmental Modeling Center
[2]Lynker at NOAA/NWS/NCEP/EMC
[3]SAIC at NOAA/NWS/NCEP/EMC
[4]Axiom at NOAA/NWS/NCEP/EMC

NATIONAL
WEATHER
SERVICE

9th NOAA Ensemble Users Workshop. August 22 to 24, 2023, College Park, Maryland
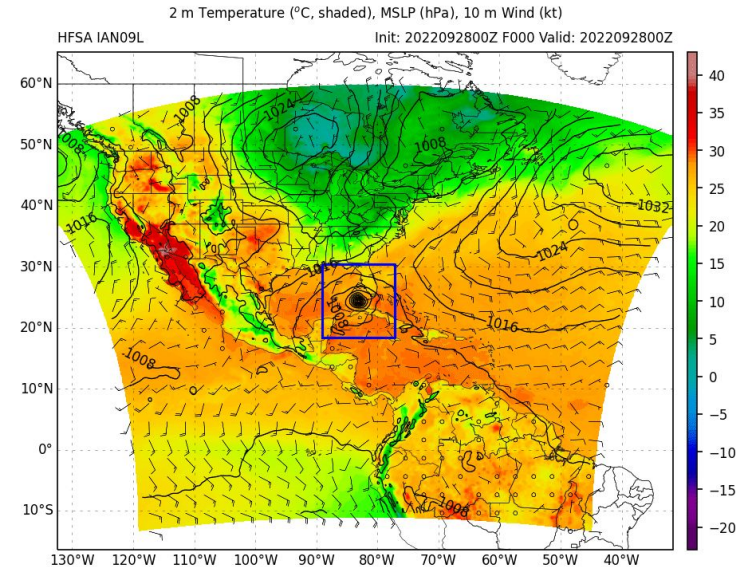
Operational HAFSv1

- **Two configurations of Hurricane Analysis and Forecast System (HAFS) v1 became operational on June 27, 2023**
- **Overall, evaluation metrics in skill space for HAFS v1 confirm positive improvements over operational HWRF and HMON.**

Salient features of HAFS

- FV3 based dyn-core
- Cloud-allowing, high resolution moving nest
- CEMPS based ocean/wave coupling.
- Improved Vortex initialization
- 4DEnVar inner-core data assimilation
- CCPP based TC-specific physics
- Updated workflow

HAFS parent domain with a moving nest

2 m Temperature (°C, shaded), MSLP (hPa), 10 m Wind (kt)
HFSA IAN09L   Init: 2022092800Z F000 Valid: 2022092800Z

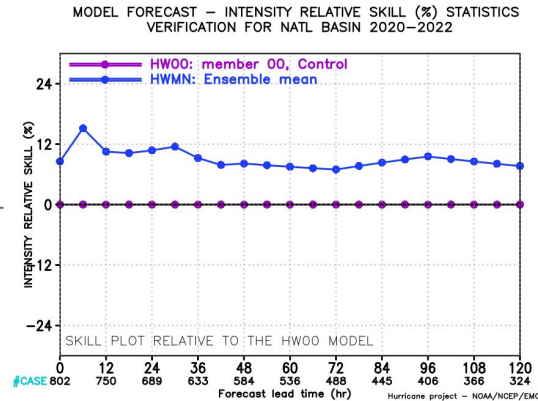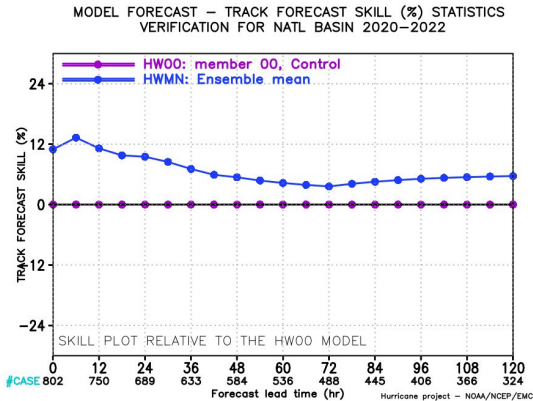# Real-time Hurricane Ensemble Experiments

- 2014-2019: HWRF-based, 2020-2022: HAFS-based
- Project goals:
  - Improved ensemble mean track/intensity forecast, compared to the deterministic model
  - Uncertainties and probabilistic forecasts
  - Uncertainty-based analyses for adaptive recon. flight mission track design
  - Input for downstream probabilistic forecast models

Department of Commerce // National Oceanic and Atmospheric Administration // National Weather Service   Environmental Modeling Center Review   **3**

3

Hurricane Ensemble Track/Intensity Forecast Skills

Track | Intensity

HWRF-EPS
2014-2019

HAFS-EPS
2020-2022
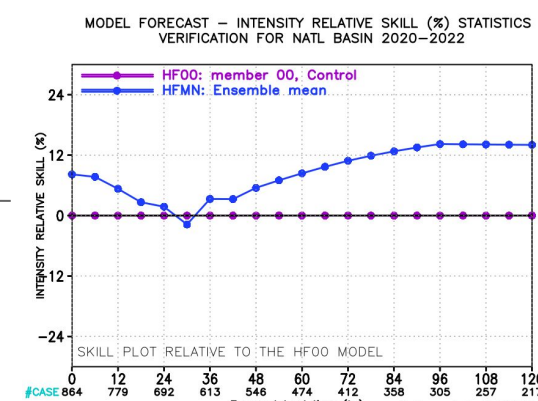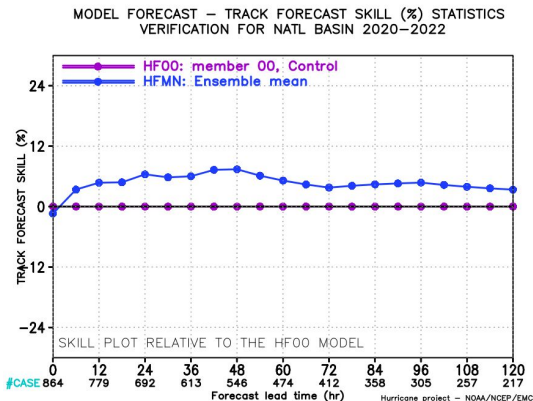
Hurricane Track and Intensity Ensemble Mean
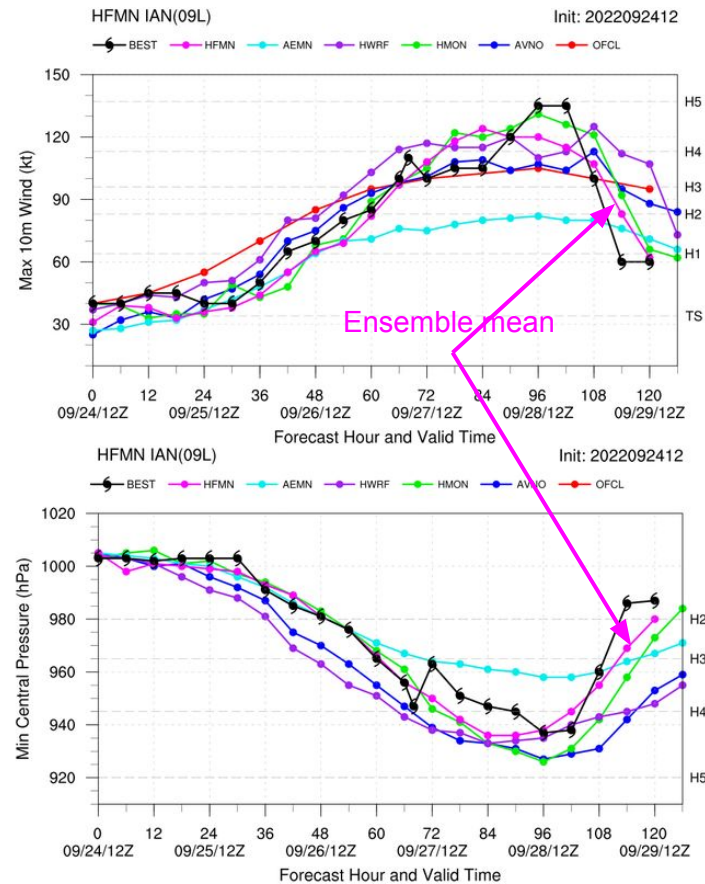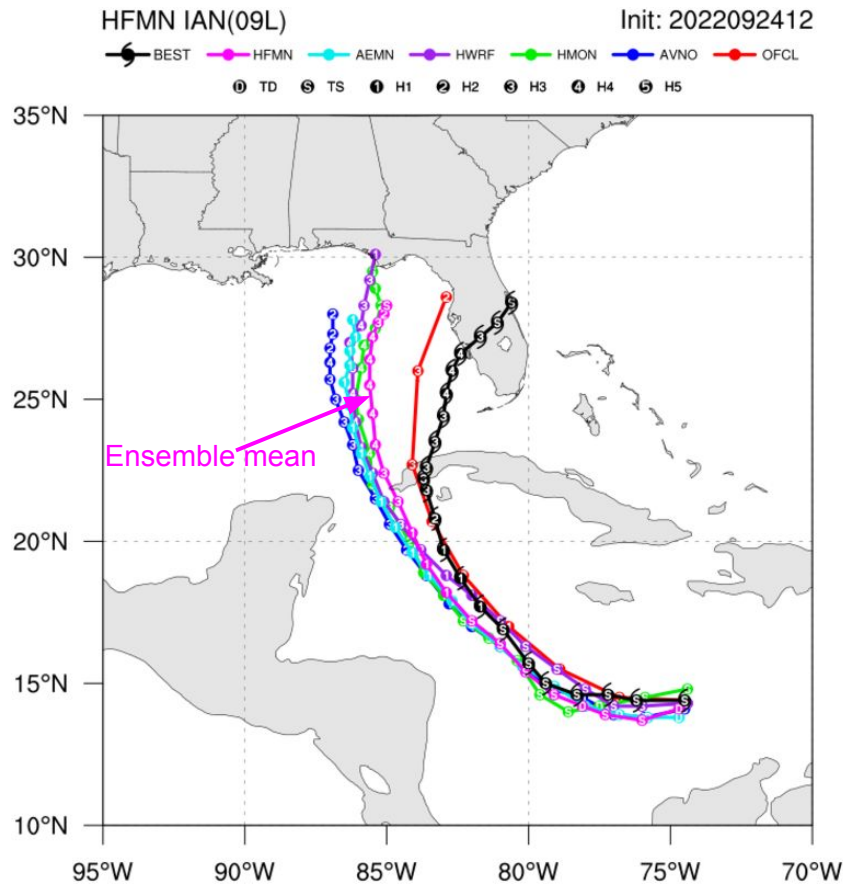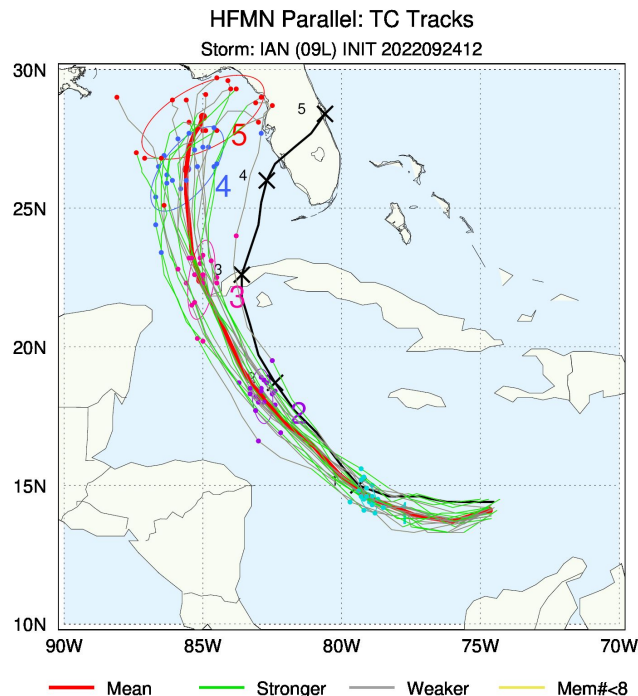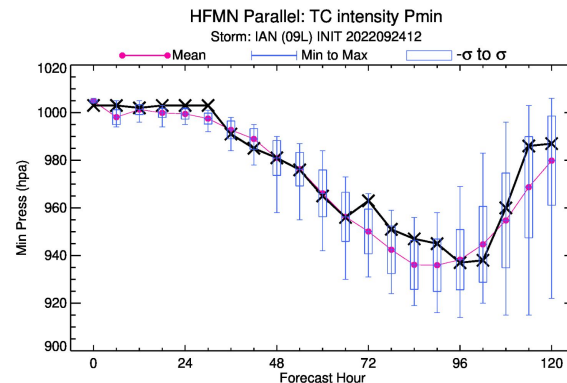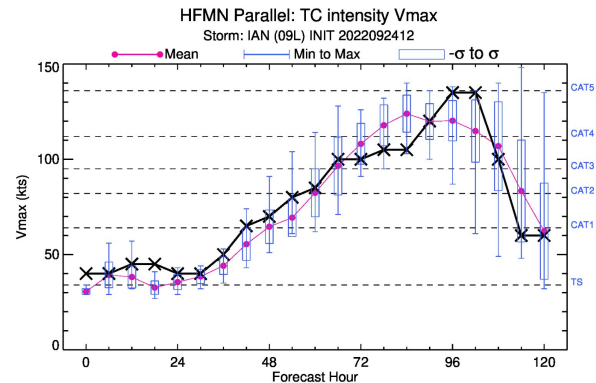
Track/Intensity Ensemble Mean Forecast Products
With uncertainties

HFMN Parallel: TC Tracks
Storm: IAN (09L) INIT 2022092412

Mean   Stronger   Weaker   Mem#<8

Ellipses indicate 90% confidence interval

HFMN Parallel: TC intensity Vmax
Storm: IAN (09L) INIT 2022092412

HFMN Parallel: TC intensity Pmin
Storm: IAN (09L) INIT 2022092412

Vertical bars indicate Vmax/Pmin spread

Wind Speed Probability (> 34 kt in 24 h period)
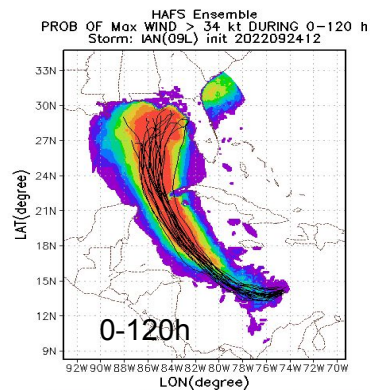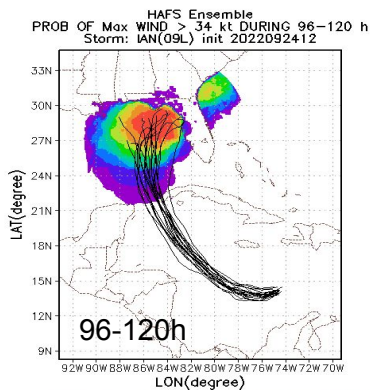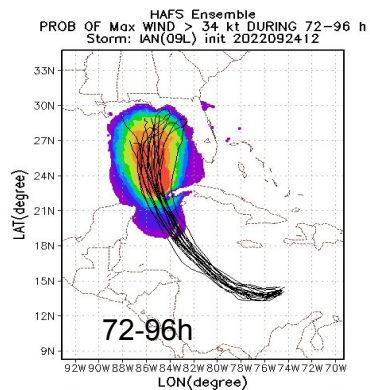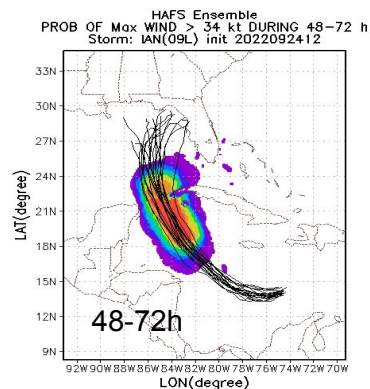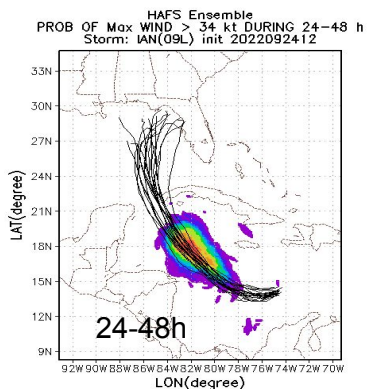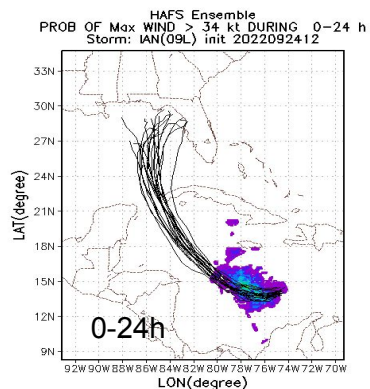
Rapid Intensification Probability
New Product in 2023
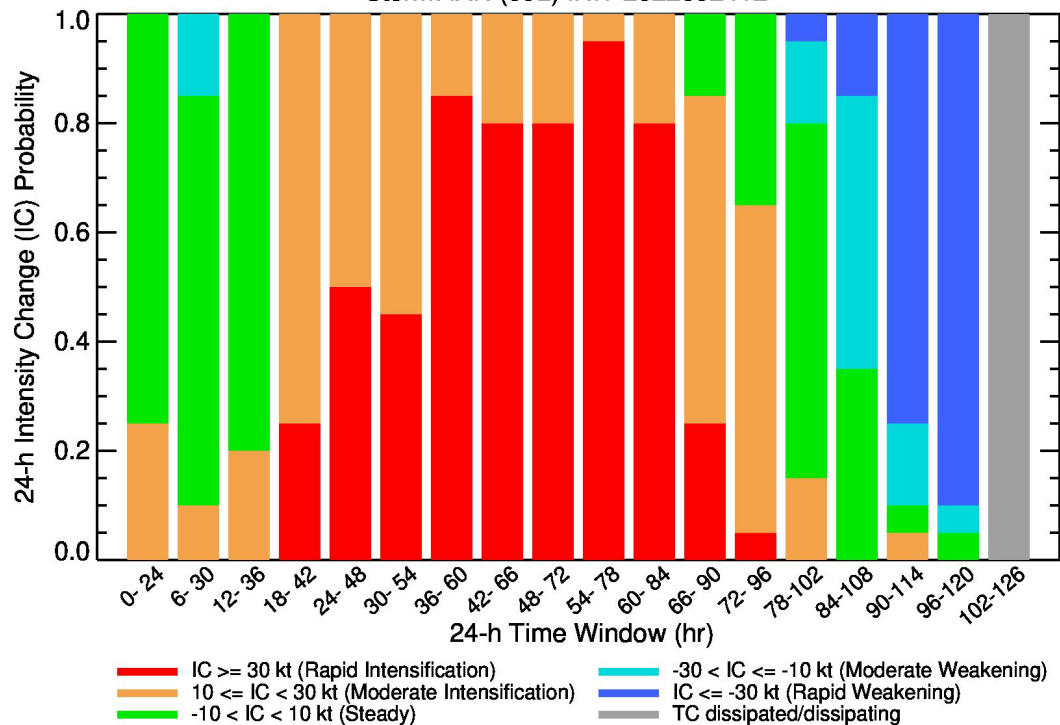
RI: Intensity increases 30 kt in 24 h period

Forecast Error vs Ensemble Spread

HWRF-E Track Forecast Error and Ensemble Spread Relationship
2019 Atlantic Basin

Track

HWRF-E Vmax Forecast Error and Ensemble Spread Relationship
2019 Atlantic Basin

Vmax
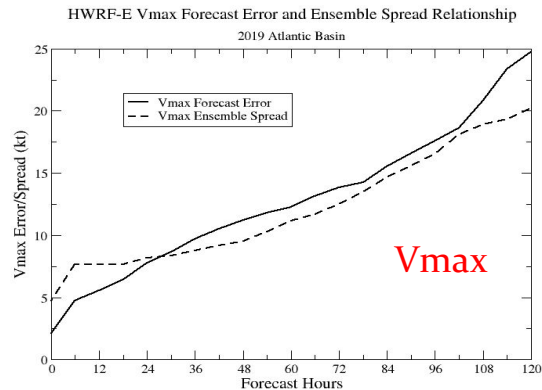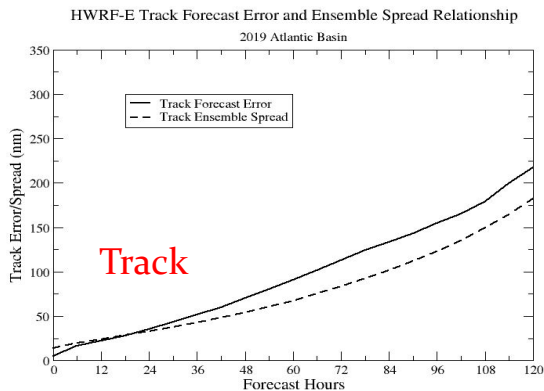
HWRF based ensemble, 2019

HAFS-E Track Forecast Error and Ensemble Spread Relationship
2020 Atlantic Basin

Track

HAFS-E Vmax Forecast Error and Ensemble Spread Relationship
2020 Atlantic Basin

Vmax
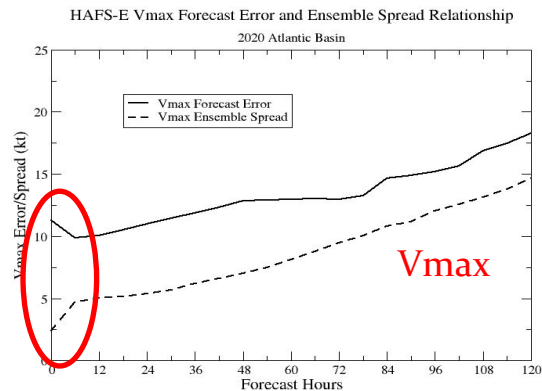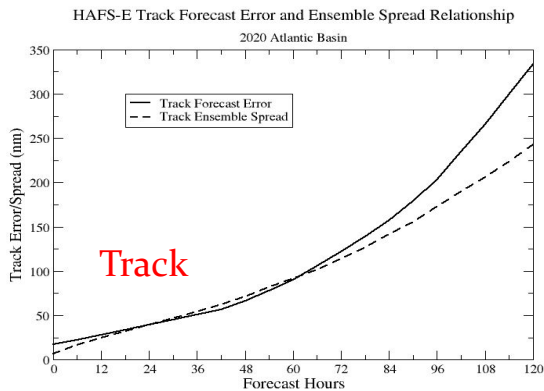
HAFS based ensemble, 2020

Challenges

- Computer resources
- Interpreting ensemble results/designing probabilistic products
- Improving on underdispersed ensemble spread

Hurricane Ensembles in Realtime on the Cloud (HERC)

Porting HAFS related codes, scripts, workflow leverages past and future UFS-based applications on AWS. This will also enhance avenues of collaboration and community contributions to future versions of HAFS.

Can we conduct HAFS ensembles in *real-time on AWS/cloud*?

Need to experiment with Hurricane ensembles to optimize strategy -- explore R&D issues related to domain configurations, moving nests, physics options, stochastic physics, size and cadence of running ensembles.

Probabilistic numerical guidance is an outlined goal for HFIP. Explore uncertainty products. There are possibilities of multi-model operational ensembles in the future.

Activity will leverage existing Disaster Supplemental projects for use of dynamic inputs via Hurricane ensembles for storm surge and flooding downstream applications within NHC and NOS.

HERC Configuration
2023 HFIP Real-time Demo

- **Basic configuration, based on HAFSv1.1A**
  - Lower horizontal resolution: refine ratio=2, ~6 km vs. 3 km, Lower vertical resolution: L66 vs. L81, with smaller domain
  - Coupled with HYCOM
  - One control member plus 20 perturbed ensemble members
  - Runs 4 cycles a day (00Z, 06 Z, 12Z, 18Z), Atlantic basin only
  - Computer resources: On AWS cloud 6 nodes or 576 cores per fcst jobs.

- **IC/BC Perturbation:**
  - IC/BC: GEFS grib2 (0.5x0.5)

- **Model Physics:**
  - Stochastically perturbed physics tendencies (SPPT)
    - Represents uncertainties in physical parameterizations
    - Multiplicative noise modifies total parameterized tendency
  - Stochastic kinetic energy backscatter (SKEB)
    - Counteract excessive energy dissipation from numerical diffusion and interpolation, mountain and gravity wave drag, and deep convection
    - Stream function is randomly perturbed to represent upscale kinetic energy transfer
  - Stochastically perturbed PBL humidity (SHUM)
    - Represents variability in the sub-grid humidity field
    - Similar to SPPT, but directly modifies low-level humidity field instead of tendency

Grid(ESG)::6-km_HAFS_Ensemble::C1541::Cell Size

Max=6.53, Min=6.45, Avg=6.49
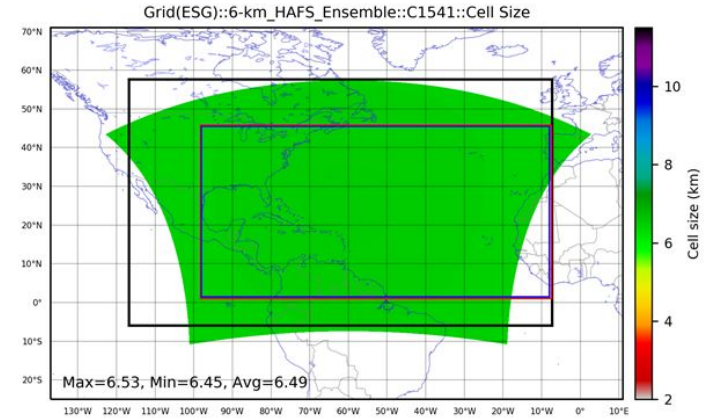
Questions?

Email to: zhan.zhang@noaa.gov

HAFS ensemble real time website:
https://www.emc.ncep.noaa.gov/HAFS/HAFSEPS/tcall.php

NATIONAL WEATHER SERVICE