DATA ASSIMILATION UPGRADES FOR THE OPERATIONAL HWRF AND HAFS SYSTEMS: H219 AND BEYOND

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Outline:

1. Motivation

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2. Data-Assimilation Infrastructure Upgrades

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4. Conclusions

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- Modernizing the HWRF-based HAFS data-assimilation system:
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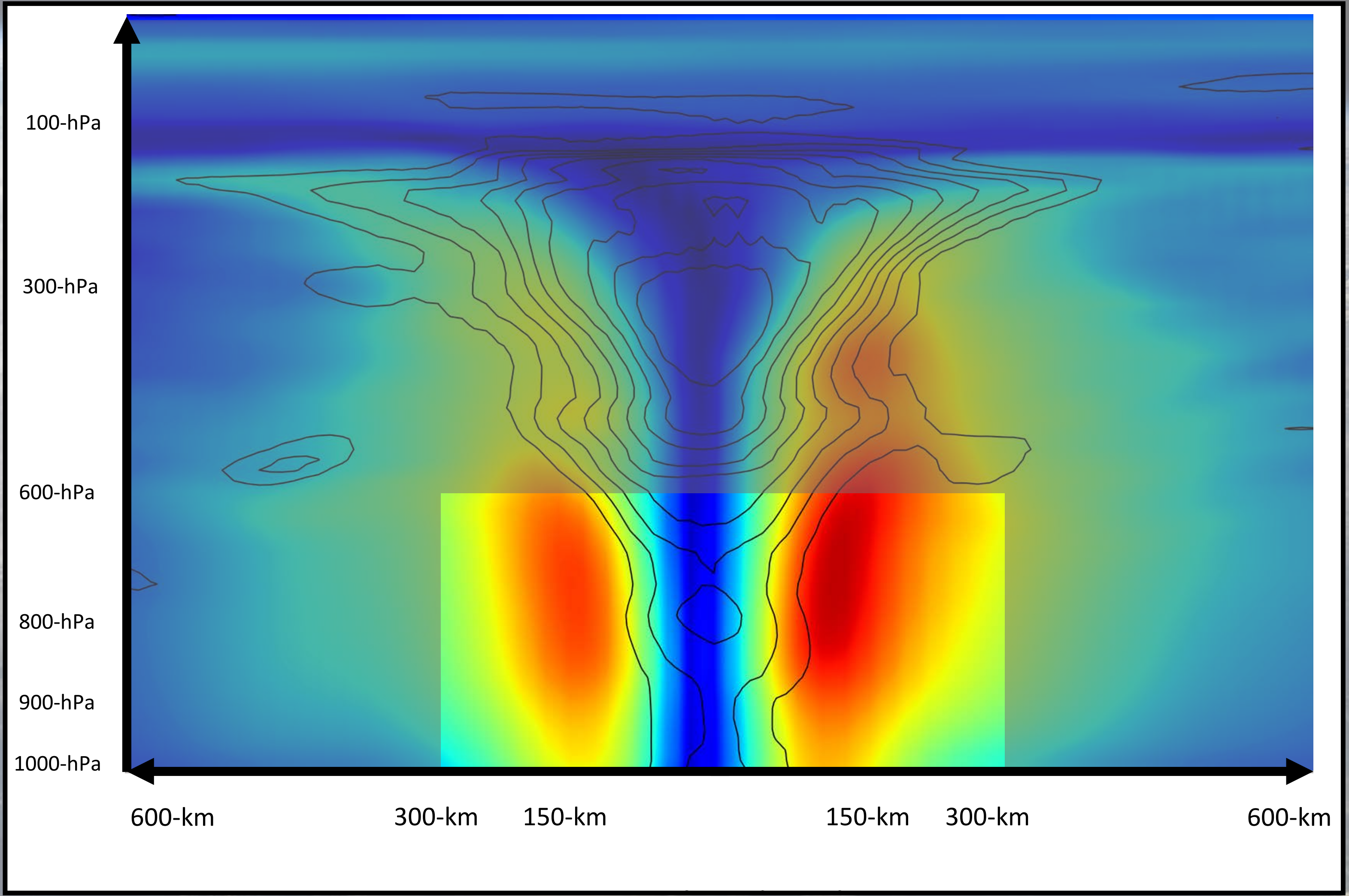
  - Streamline and modernize the coding base
  - Increase both the portability and flexibility (e.g., for FV3-based HAFS)
  - Develop software that addresses multiple problems
  - Make R2O, especially with respect to data-assimilation, easier!

Data-Assimilation Infrastructure Upgrades:

H218 data assimilation approach:

- To suppress spin-down, HWRF DA increments are zeroed out below 600-hPa and within 150-km of the TC position
- Beyond 300 km of the TC position and above 600 hPa, the full increments are used
- Although spin-down is reduced, it comes at a cost of rejecting real data



HWRF Latitudinal Cross-section For TC Lane (2018; 14E) Valid 0600 UTC 22 August

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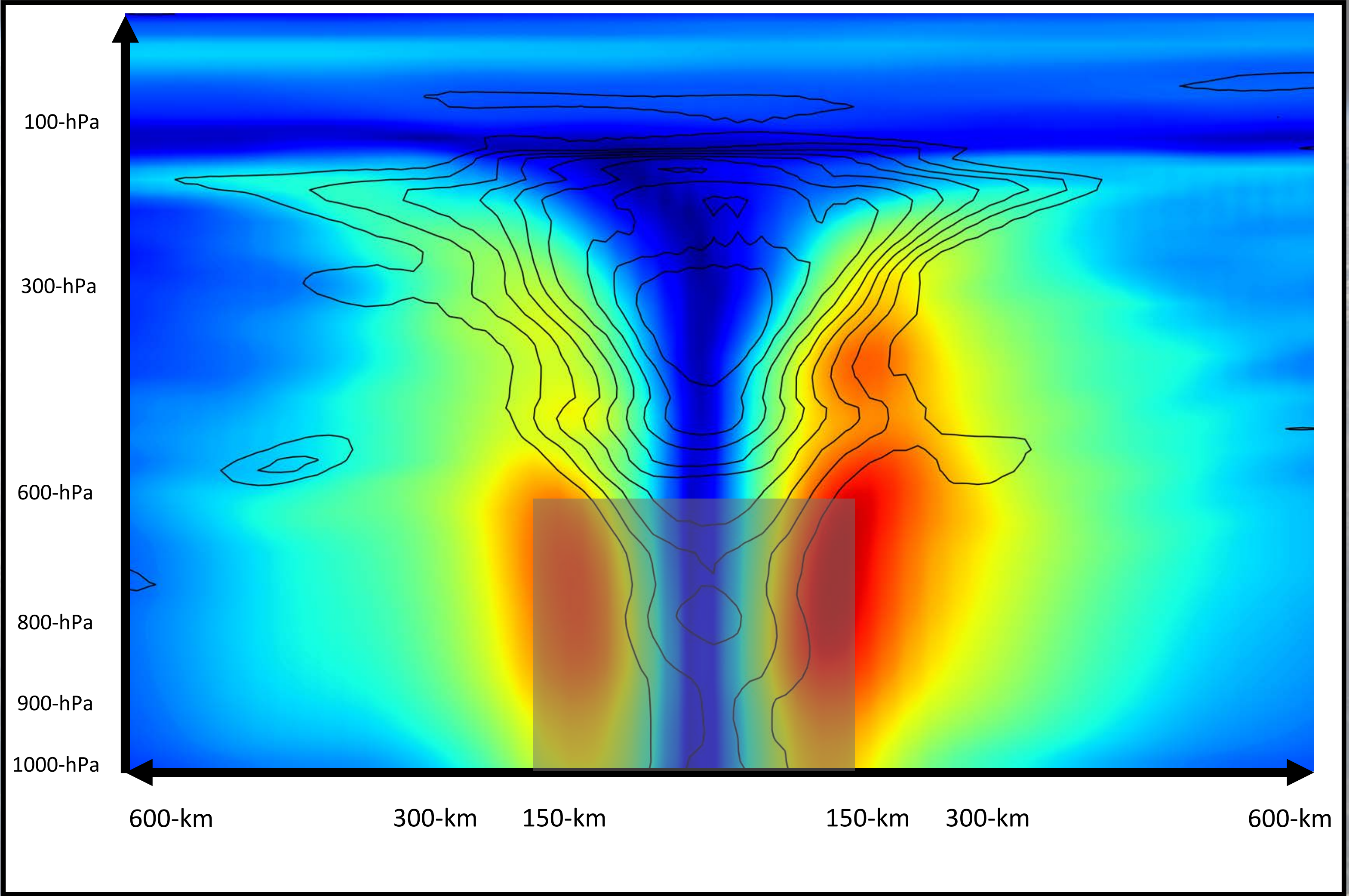

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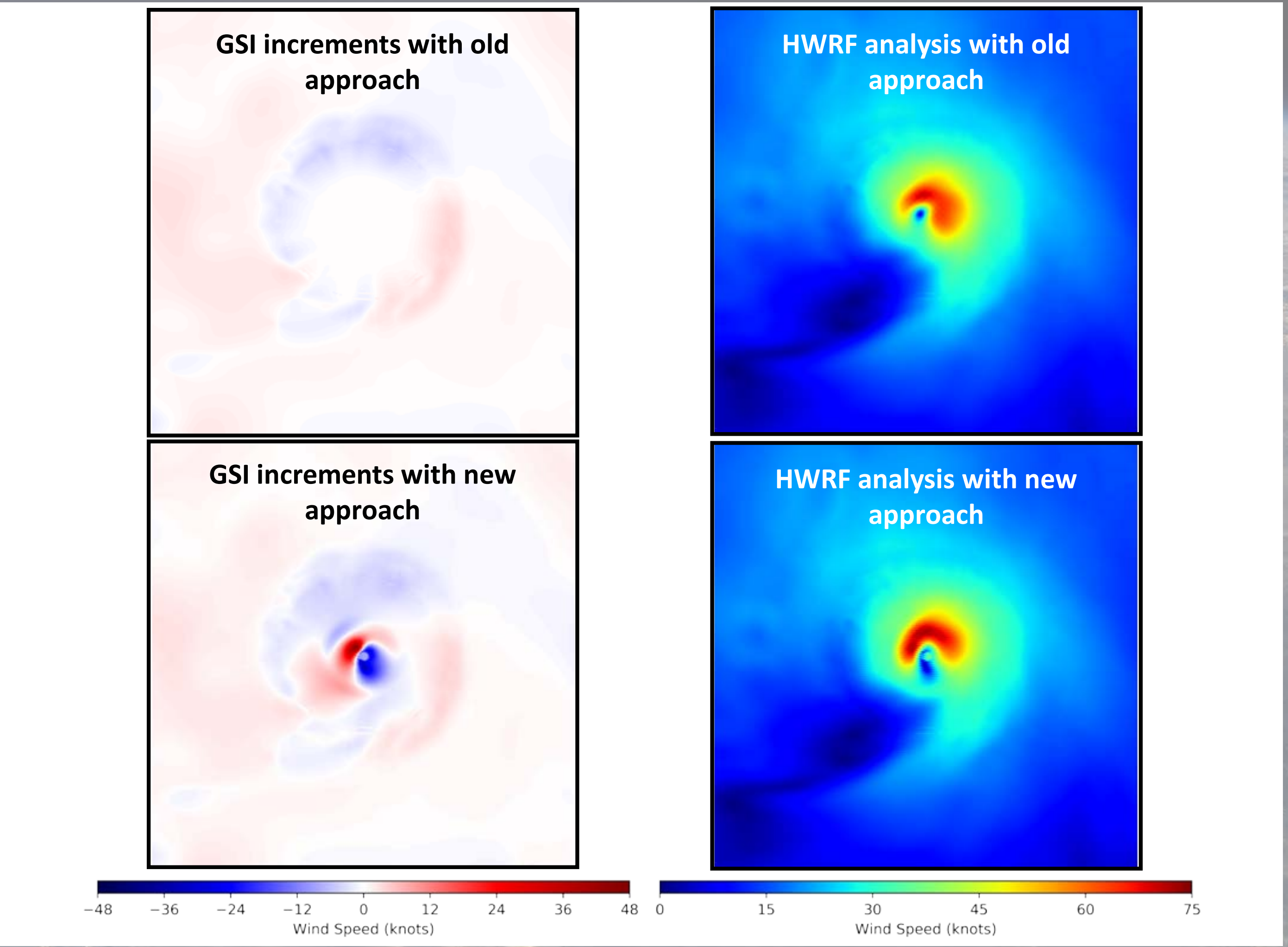
Data-Assimilation Infrastructure Upgrades:

New data assimilation approach:

- For *hurricane-strength* events, we retain only the wavenumber 0 and 1 increments within 150-km of the TC position and relax to the full GSI increment at a distance of 250-km
- Inner-core observations (e.g., dropsondes, SFMR, TDR, etc.,) are now more impactful on the TC initial structure and subsequent forecasts
- Both the maximum wind-speed MAE and bias are improved



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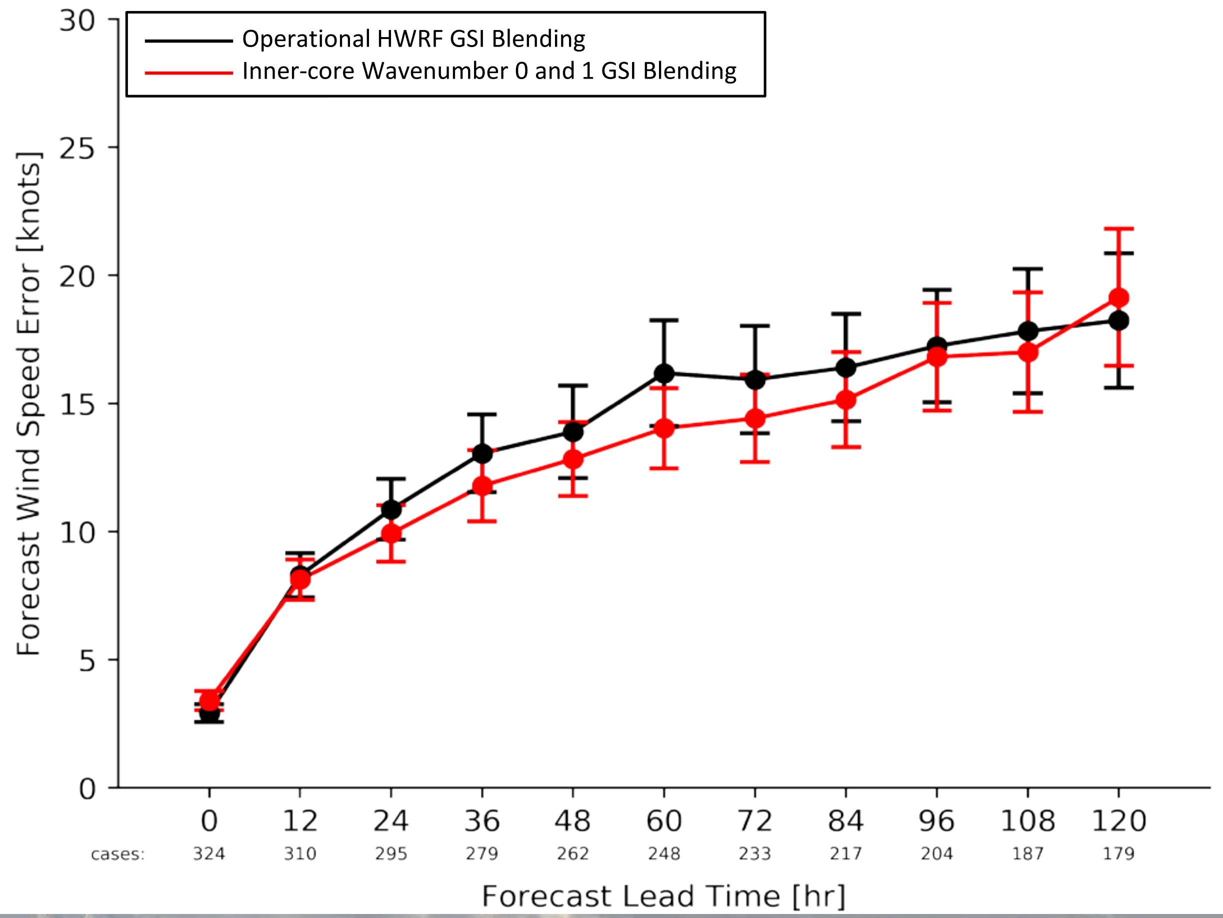
TC Forecasted Maximum Wind Speed Error Relative to Observations



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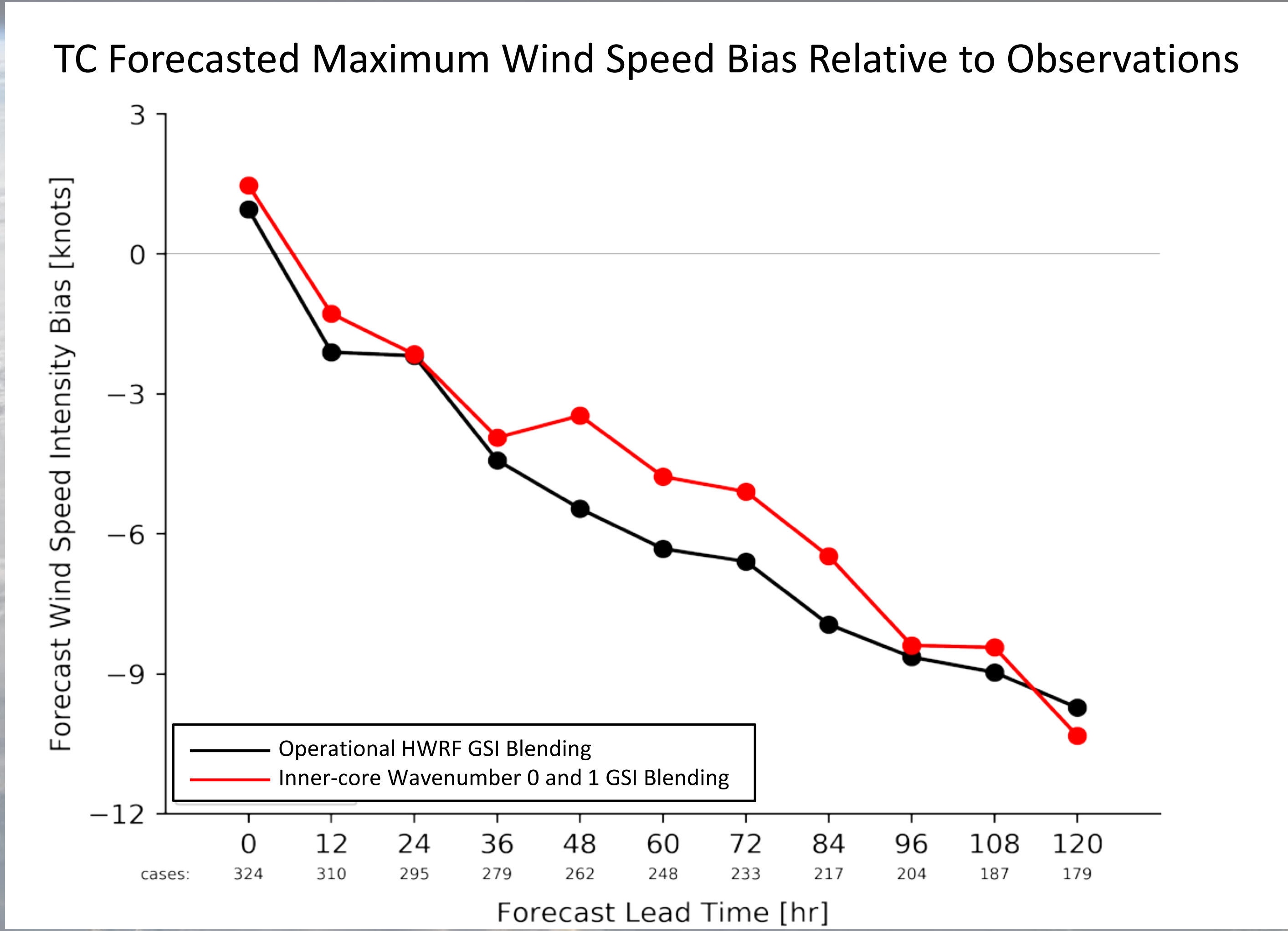
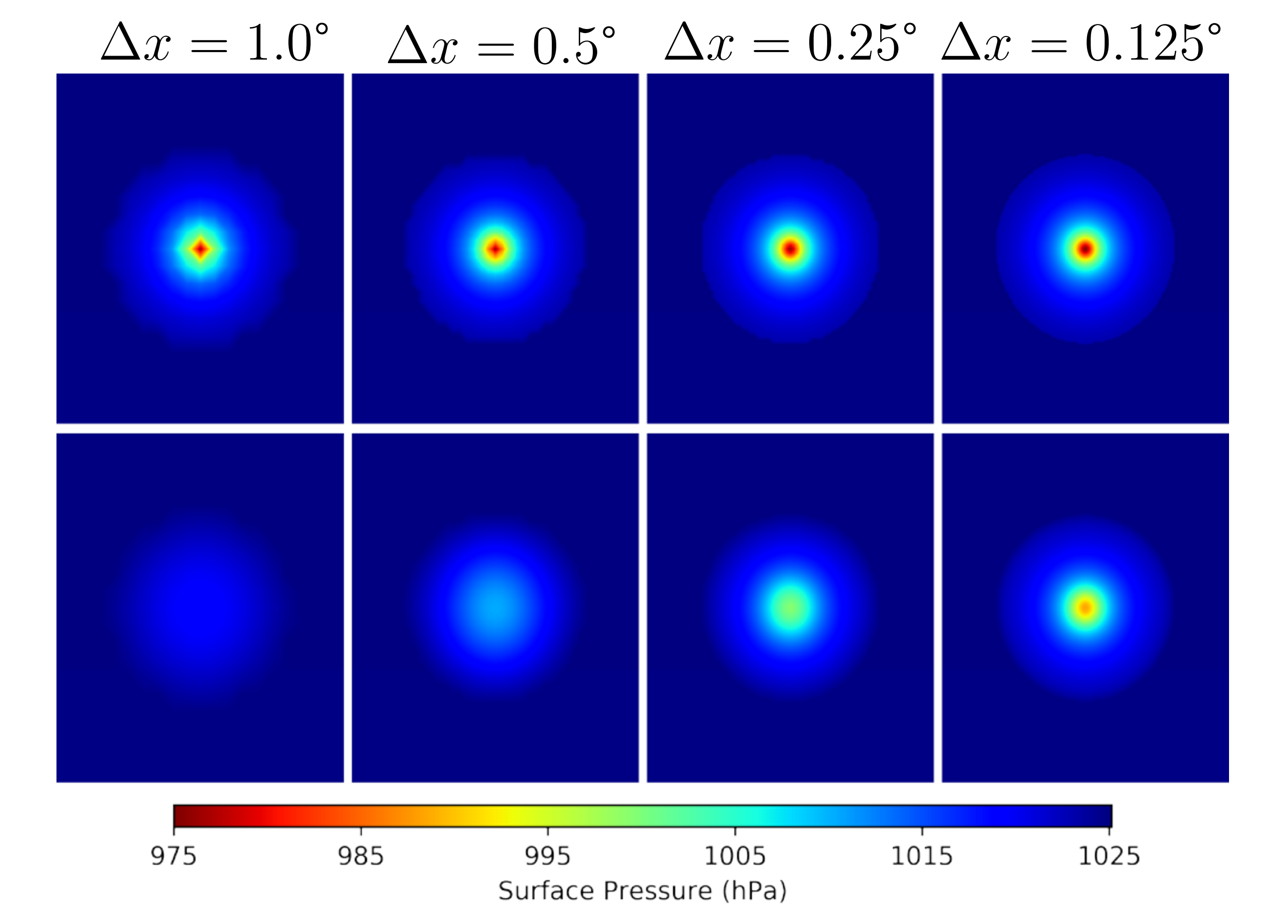


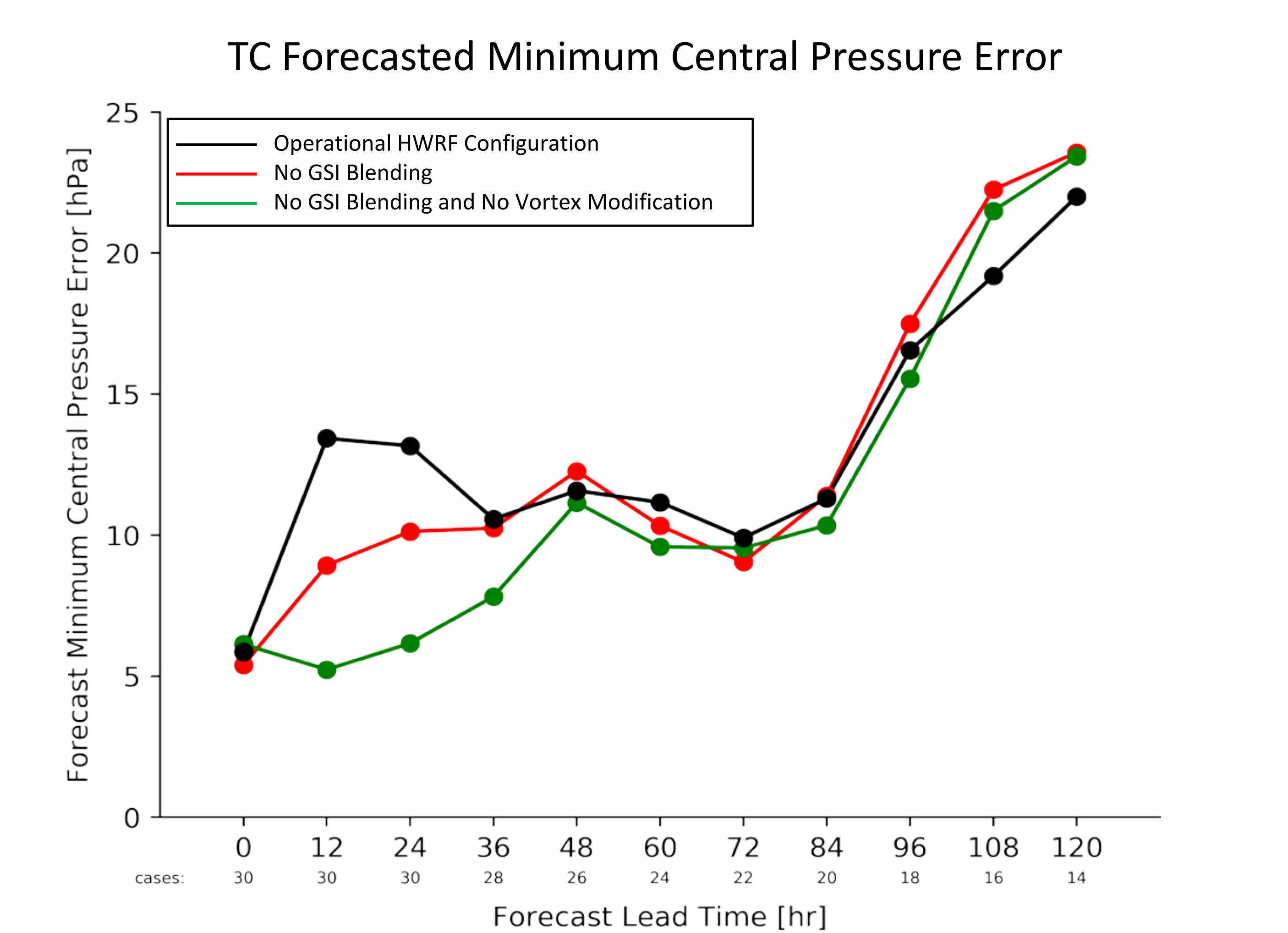
Data-Assimilation Infrastructure Upgrades:

- Investigating methodologies for HWRF/HAFS TC relocation that do not require analysis resolution degradation
  - HWRF makes use of the filtering methodologies within *Kurihara et al.*, [1993] and *Kurihara et al.*, [1995] to relocate the TC vortex
  - These methods perform best for TC prognostic variables on coarse (e.g., 1-degree or more) analysis grids
  - The effectiveness of the filtering is reduced as the spatial-resolution increases
  - Successive interpolation methods during the HWRF TC relocation step will ultimately impact the assimilation of inner-core observations



Data-Assimilation Infrastructure Upgrades:

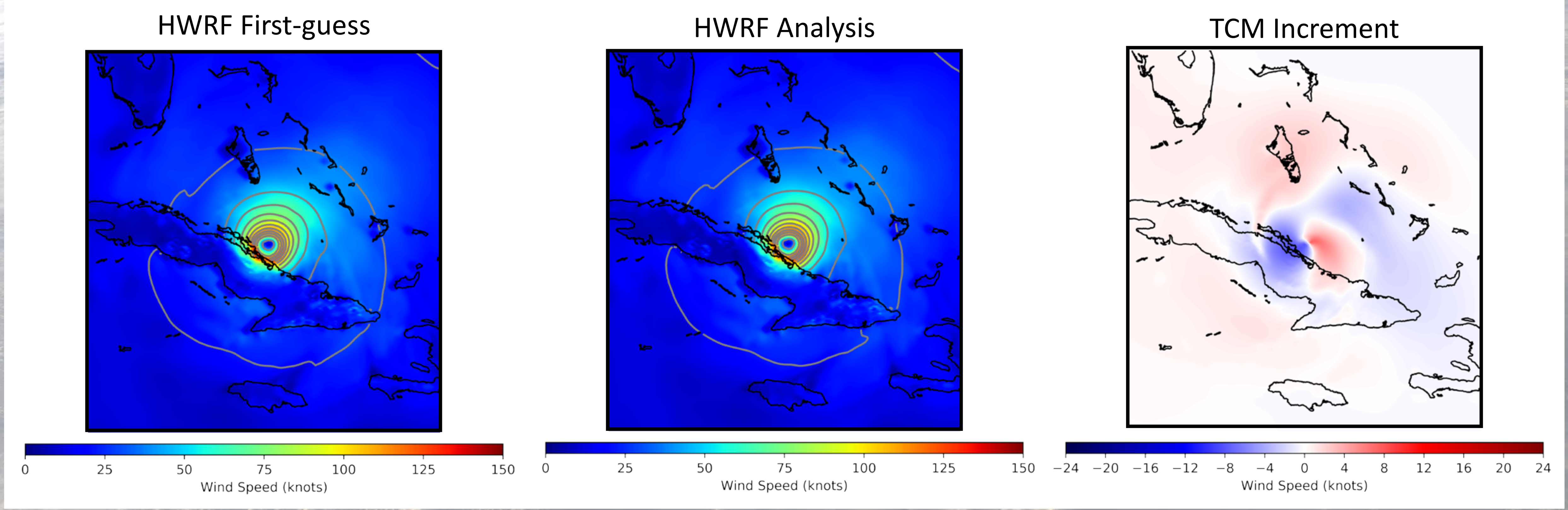
- Forecasts initialized using TC vortex modification (e.g., TC vortex adjustment) can have large adjustments at short lead-times
- The adjustment is a result of imbalances inherent in bogus-vortex methodologies
- This problem is evident in SLP error evolution in TC Irma (2018; right) with the H218 configuration (old DA approach)
- Adding analysis increments reduces but does not eliminate the adjustment



TC Irma (2017; 11L) :: 0600 UTC 30 August – 0000 UTC 12 September

Data-Assimilation Infrastructure Upgrades:

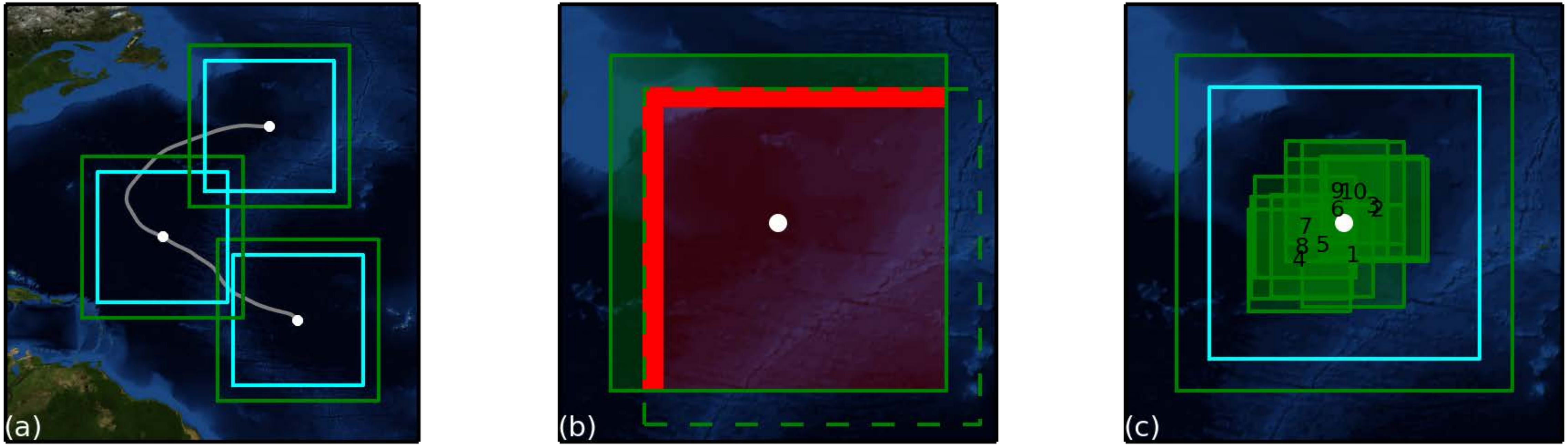
- Exploring the assimilation of TC wind-profile parameterizations (e.g., NHC gTCM) to reduce and/or remove the HWRF dependencies upon TC vortex initialization



HWRF Lowest-model Level For TC Irma (2017; 11L) Valid 0000 UTC 09 September

Data-Assimilation Infrastructure Upgrades:

- Cycling a greater portion of HWRF inner- (e.g., moving) nests



Moving nest positions

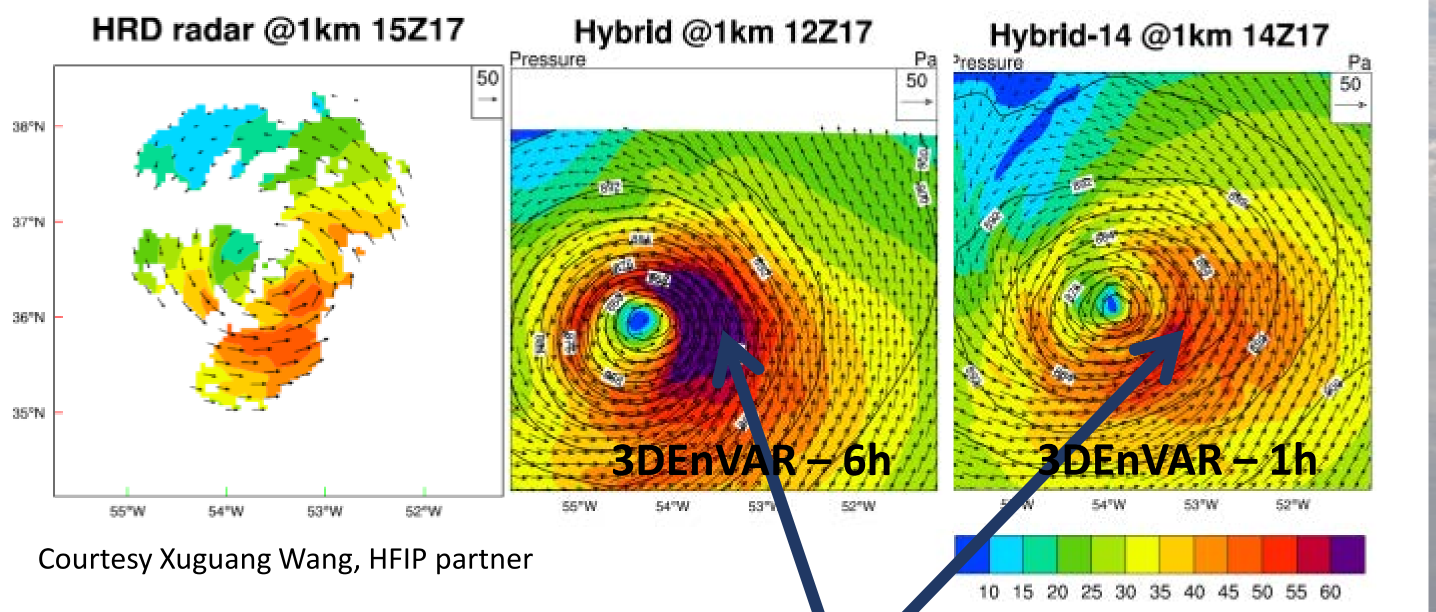
Blending of inner-nest with parent domain

Ensemble cycling example

Data-Assimilation Infrastructure Upgrades:

High(er) Frequency Cycling

- HWRF, similar to the global model, uses a 6-hour data-assimilation cycle
- DTC is working to enable more flexible HWRF cycling intervals
- Experiments suggest that this option will improve forecasts
- HAFS **must have** this capability



Courtesy Xuguang Wang, HFIP partner

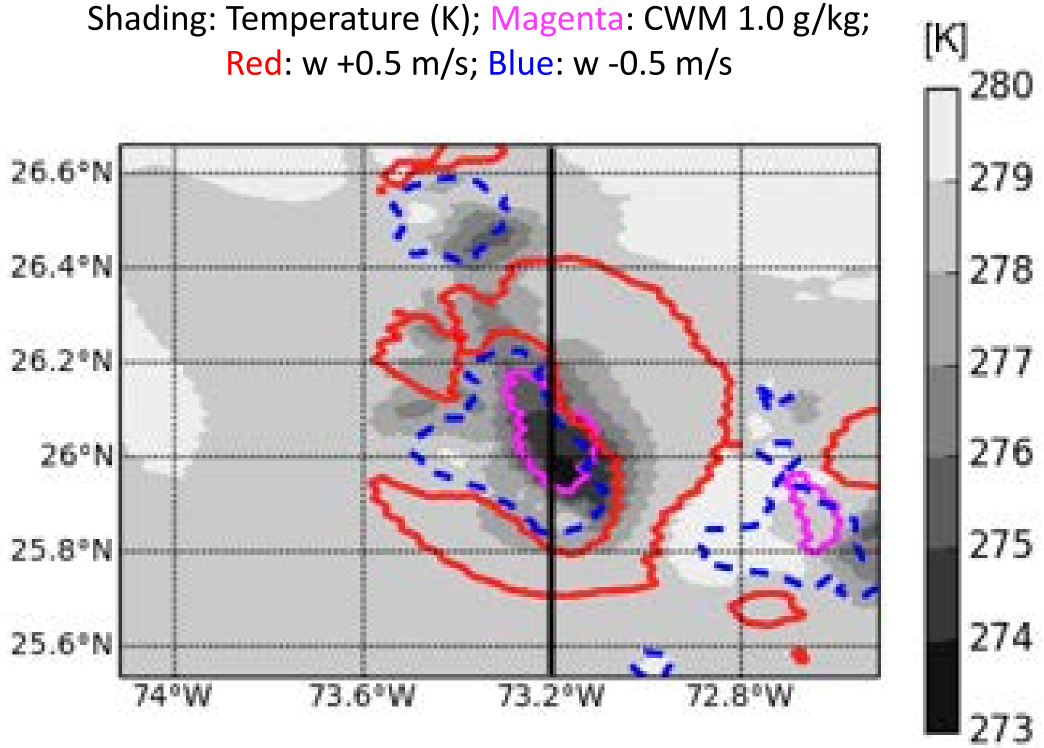
High-frequency full cycling alleviates imbalance.

Data-Assimilation Infrastructure Upgrades:

Condensate and Vertical Motion

- The operational HWRF does not cycle condensate or vertical motion
- Studies have demonstrated an unphysical evolution of the TC if these are mishandled
- This also allows more effective satellite and radar data assimilation
- HFIP-funded partners are working on this
- HAFS would benefit from flexibility in specifying which state variables are cycled

Shading: Temperature (K); Magenta: CWM 1.0 g/kg; Red: w +0.5 m/s; Blue: w -0.5 m/s

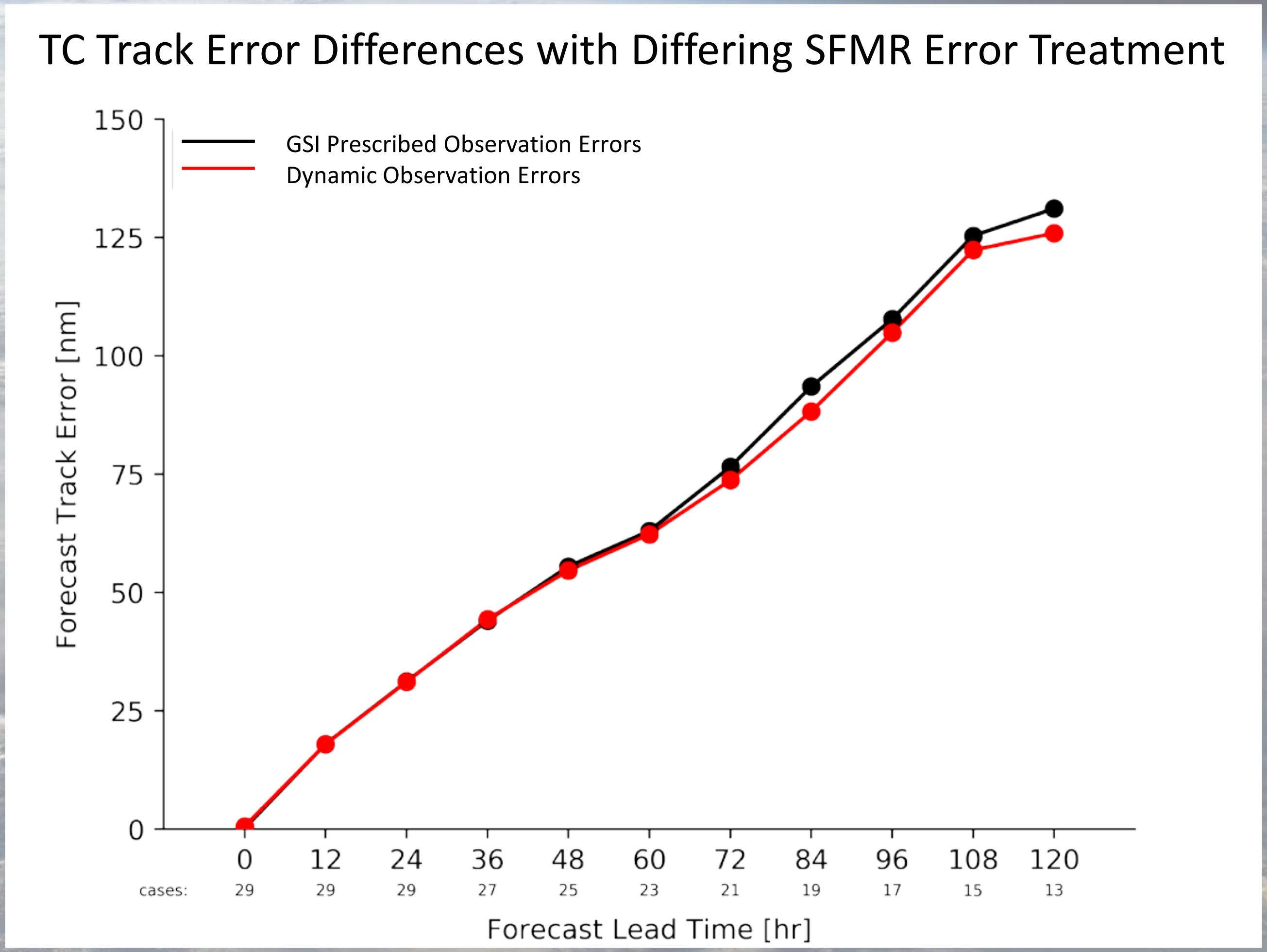


Wu et al., [2017]: When condensate is initialized without vertical motion, evaporation cooling and precipitation settling cause unphysical adjustments.

Data-Assimilation Data Upgrades:

Dynamic Observation Errors

- GSI does not support and adequate range of specified observation errors
- Ongoing work at HRD is developing this for airborne datasets
- Results show benefits for both track and intensity
- HAFS/JEDI would benefit from flexibility in assigning observation errors



* Valid for SFMR observations only.

Data-Assimilation Data Upgrades:

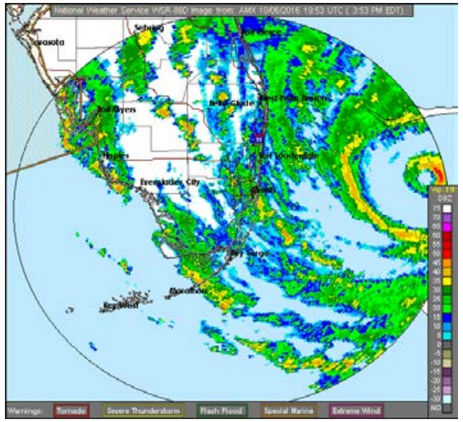
WSR-88D Radar Reflectivity and Radial Velocity

- The operational HWRF does not assimilate radar reflectivity or radial velocity from the WSR-88D network

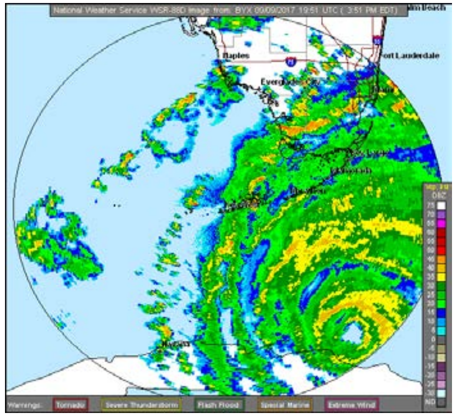
- Several recent land-falling events (right) may have benefitted from this data

- The impacts from WSR-88D observations will be tested during FY19-FY20

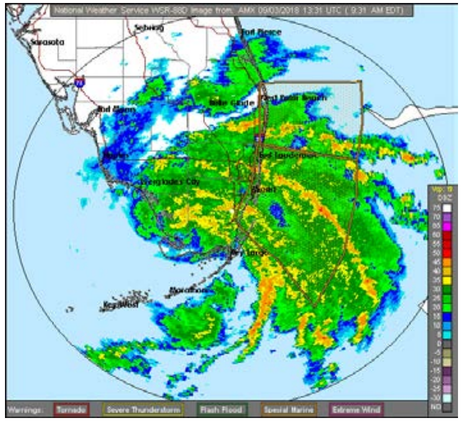
- HAFS must be able to assimilate these observation types



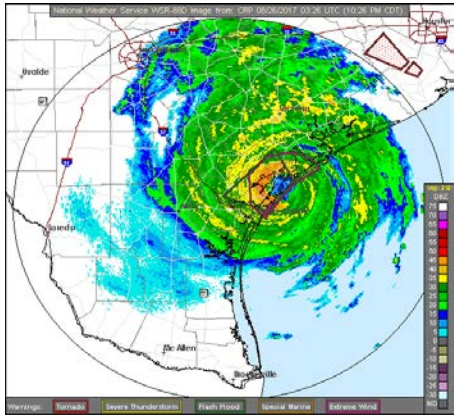
Matthew - 2016



Irma - 2017



Gordon - 2018

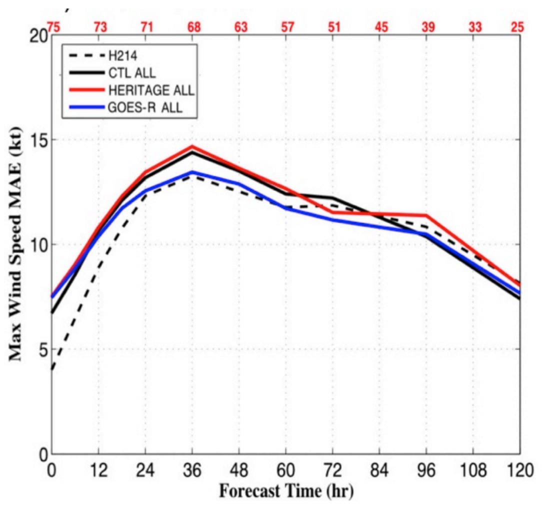


Harvey - 2017

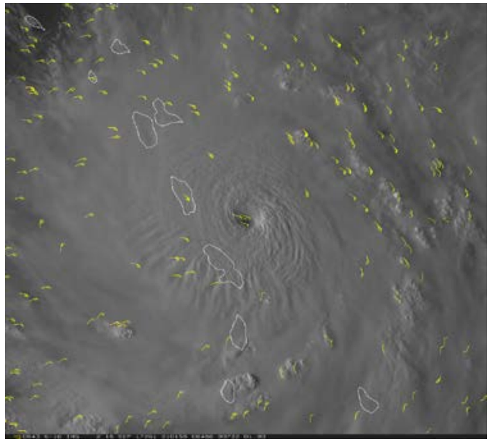
Data-Assimilation Data Upgrades:

Satellite Atmospheric Motion Vectors (AMVs)

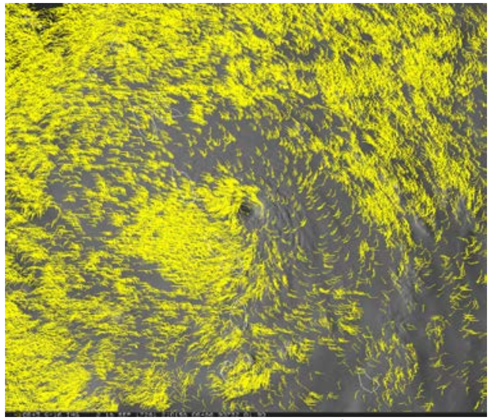
- NESDIS AMV processing is currently geared toward the global model
- Recent studies have shown that mesoscale AMV assimilation improves HWRF forecasts
- Chris Velden working with NESDIS for operational mesoscale-AMV processing
- Other HFIP-funded research ongoing to assimilate GOES-R SWIR, CAWV, and VIS AMV observations



Maximum wind-speed forecast errors when assimilating mesoscale (blue) and currently processed (red) AMVs processing for TCs Gonzalo, Edouard, and Sandy [*Velden et al.*, 2017].



Maria – Operational AMVs

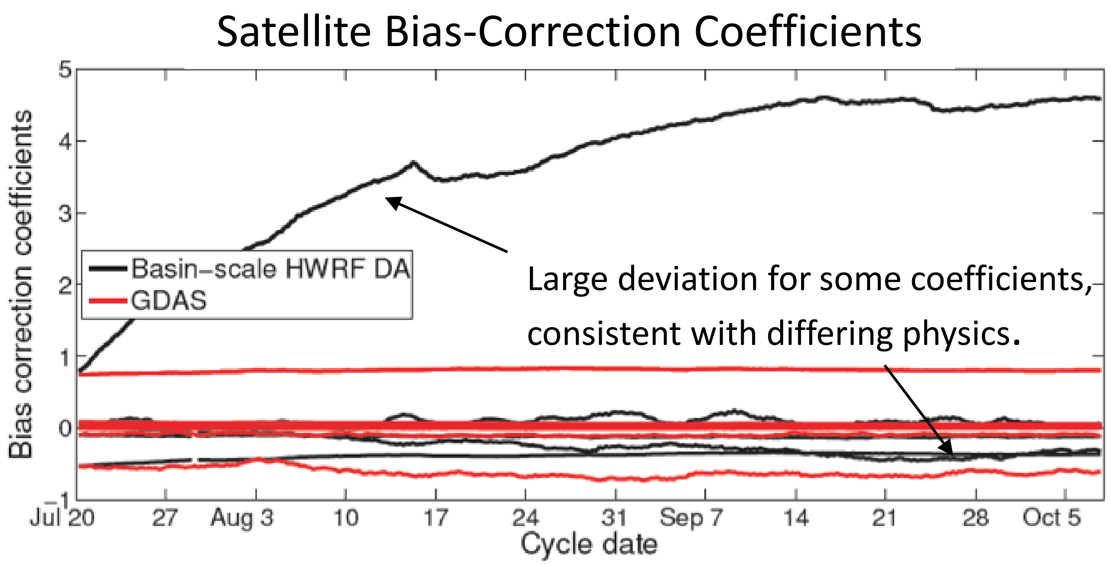


Maria – Enhanced AMVs

Data-Assimilation Data Upgrades:

Satellite Radiance Bias Correction

- HWRF makes deficient use of clear-sky satellite radiances
- GDAS bias-correction coefficients are used due to current HWRF configuration
- Upcoming testing within the operational system will explore the use of HWRF-generated BC coefficients
- If HAFS and FV3-GFS implement differing physics schemes, suboptimal assimilation of satellite radiances may persist

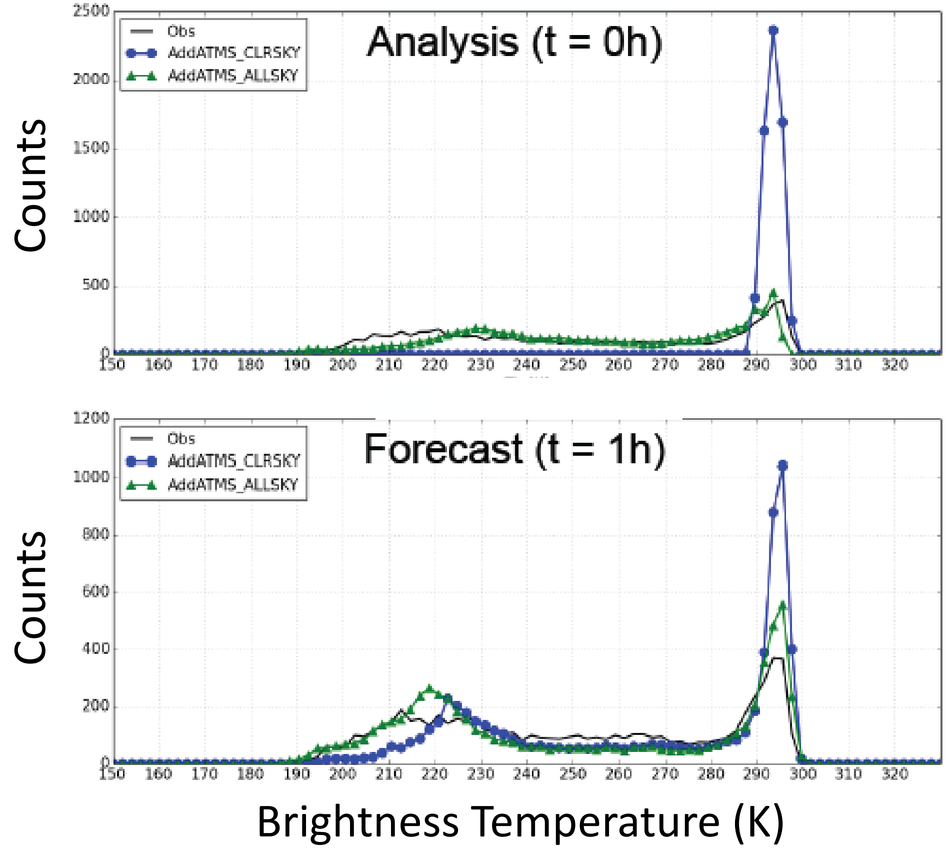


Satellite bias correction coefficients computed using a cycled large, static domain in HWRF vs. GDAS bias correction coefficients during the 2017 NATL and EPAC hurricane seasons.

Data-Assimilation Data Upgrades:

Cloud-affected Satellite Radiances

- HWRF does not assimilate cloudy radiances
- Recent HFIP-funded research has tested cloudy radiance assimilation within HWRF
- Ongoing HFIP effort to transition cloudy radiance assimilation research to operations (R2O)
- FV3-HAFS should inherit this from the FV3 data-assimilation system



Histograms of observed and simulated ATMS brightness temperatures from research HWRF system (Wu et al. 2017)

Conclusions:

- The HWRF/HAFS data assimilation system is rapidly advancing and contributing to lower forecast errors
- Potentially major changes in the near future as we add new observation types and improve upon existing methods
- HFIP is improving and expediting research to operations
- Some advances (HWRF satellite bias-correction, frequent cycling, etc.) will require significant computational resources
- Ongoing development is mindful of HAFS and methodologies will be transferred to FV3-based HAFS as needed