



FV3 Model and Ensemble-based Data Assimilation for Convection-permitting Hurricane Analysis and Prediction

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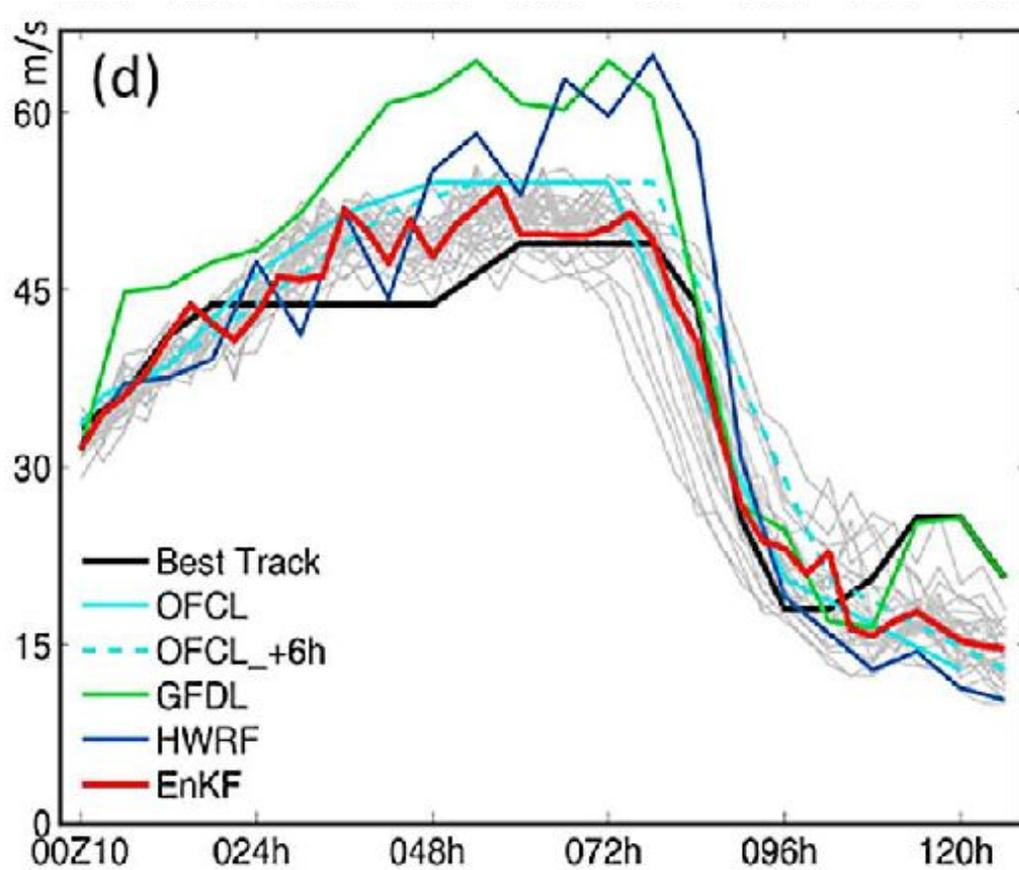
HFIP Annual Meeting
15-18 November 2021

Purpose & Objectives

1. Evaluate the performance of a regional-global nested FV3 system at convection-permitting resolutions (~3 km) for TC analysis and prediction. Examine the sensitivity of FV3 TC forecasts to different physics configurations (**completed**).
2. Develop and conduct experimental hurricane forecasts with the FV3 model initialized with analyses produced by the PSU-EnKF system which assimilated satellite all-sky infrared radiances from GOES-16 (**completed**).
3. Develop a FV3-based EnKF system for convection-permitting hurricane analysis and prediction (**completed**).
4. Explore the potentials of satellite all-sky radiances data assimilation and atmosphere-ocean strongly coupled data assimilation for convection-permitting hurricane analysis and prediction (**ongoing**).

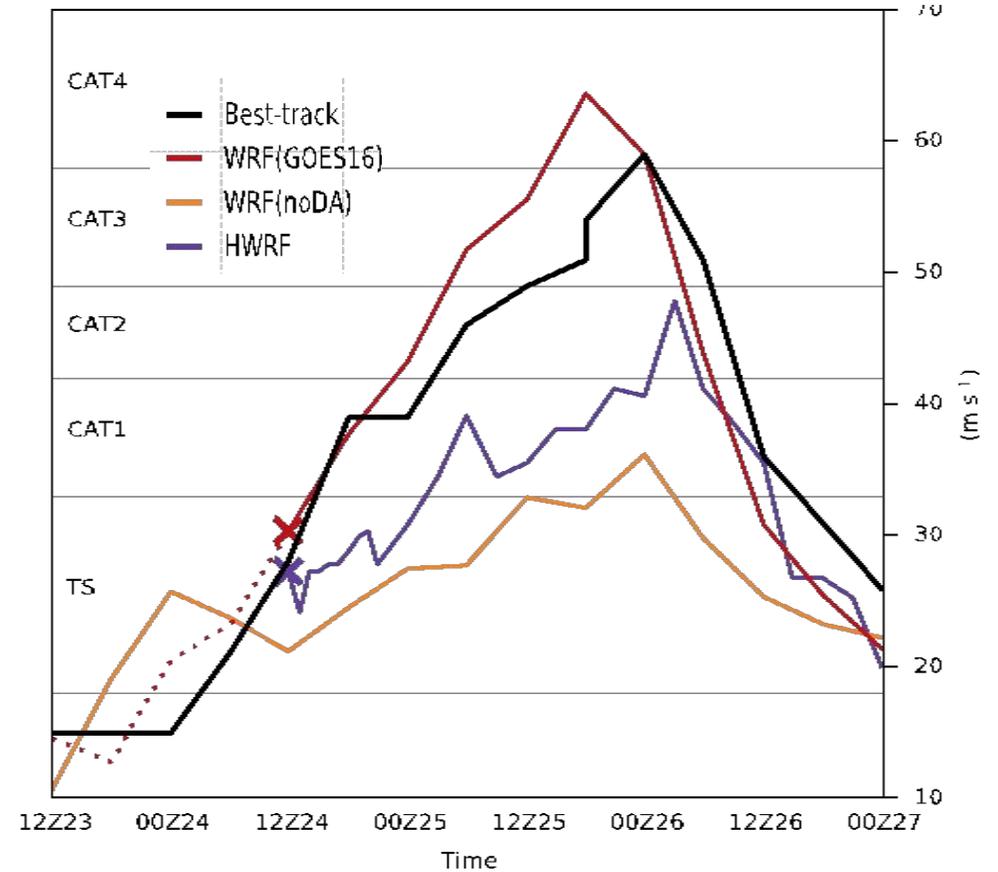
Data assimilation improves convection-permitting hurricane intensity forecast

TDR DA



Operational and experimental intensity forecasts of Hurricane Ike (2008), The EnKF forecast assimilated TDR velocity data (Zhang et al., 2011)

All-sky infrared radiances DA



Operational and experimental intensity forecasts of Hurricane Harvey (2017), The EnKF forecast assimilated all-sky IR from GOES-16 (Zhang et al., 2019)

TDR data began being assimilated in HWRF in 2013

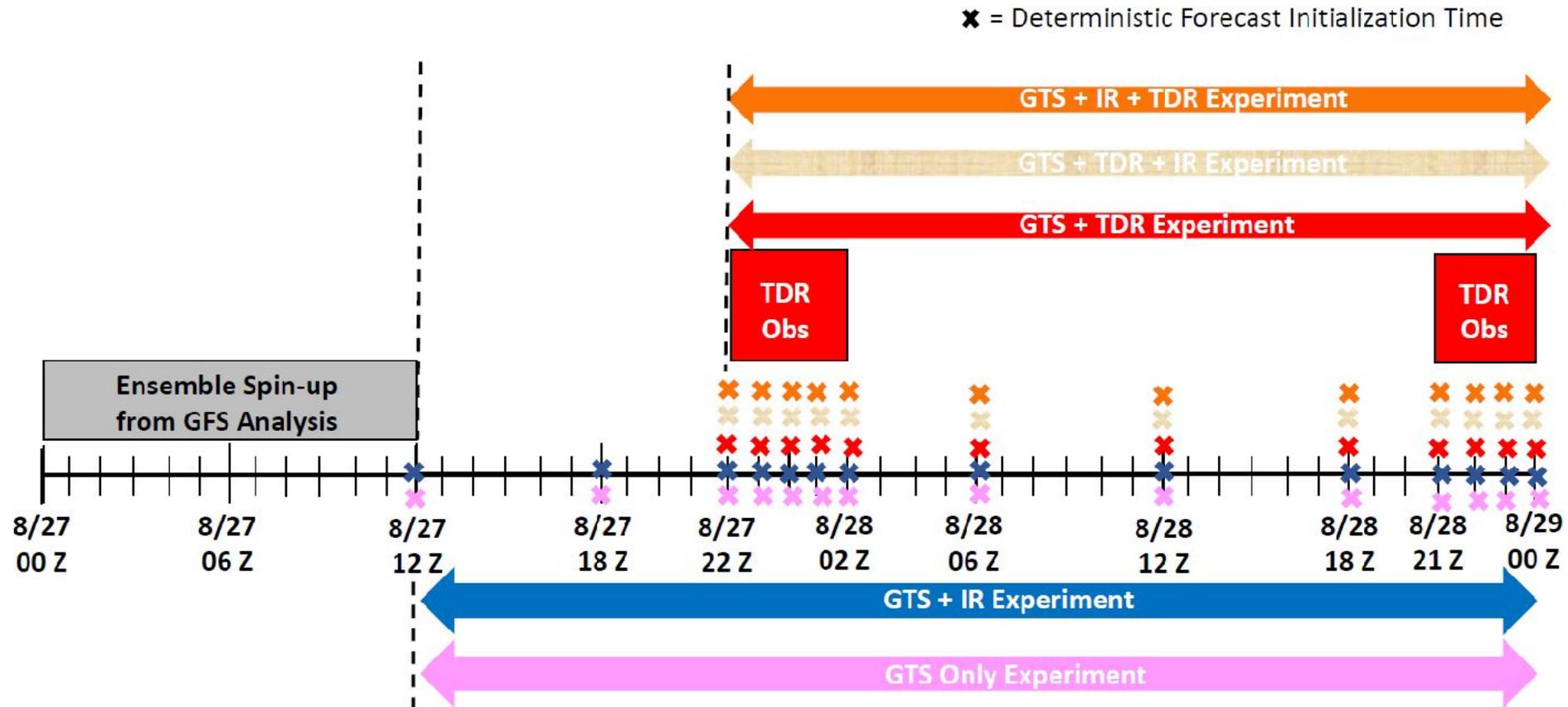
Simultaneous assimilation of GOES-16 all-sky infrared radiances and Tail Doppler Radar radial velocities

Case: Hurricane Dorian (2019)

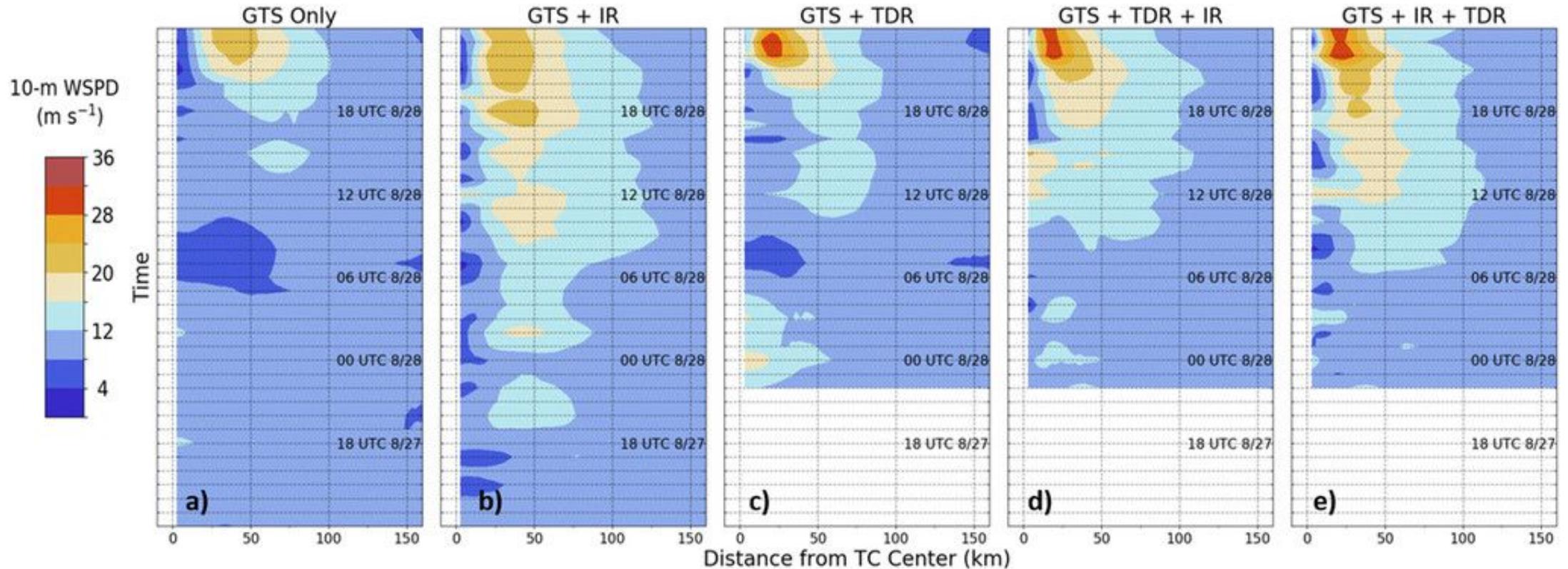
Model: WRF model

Model domains: Three two-way nested domains (27, 9, and 3 km)

Data assimilation frequency: hourly EnKF



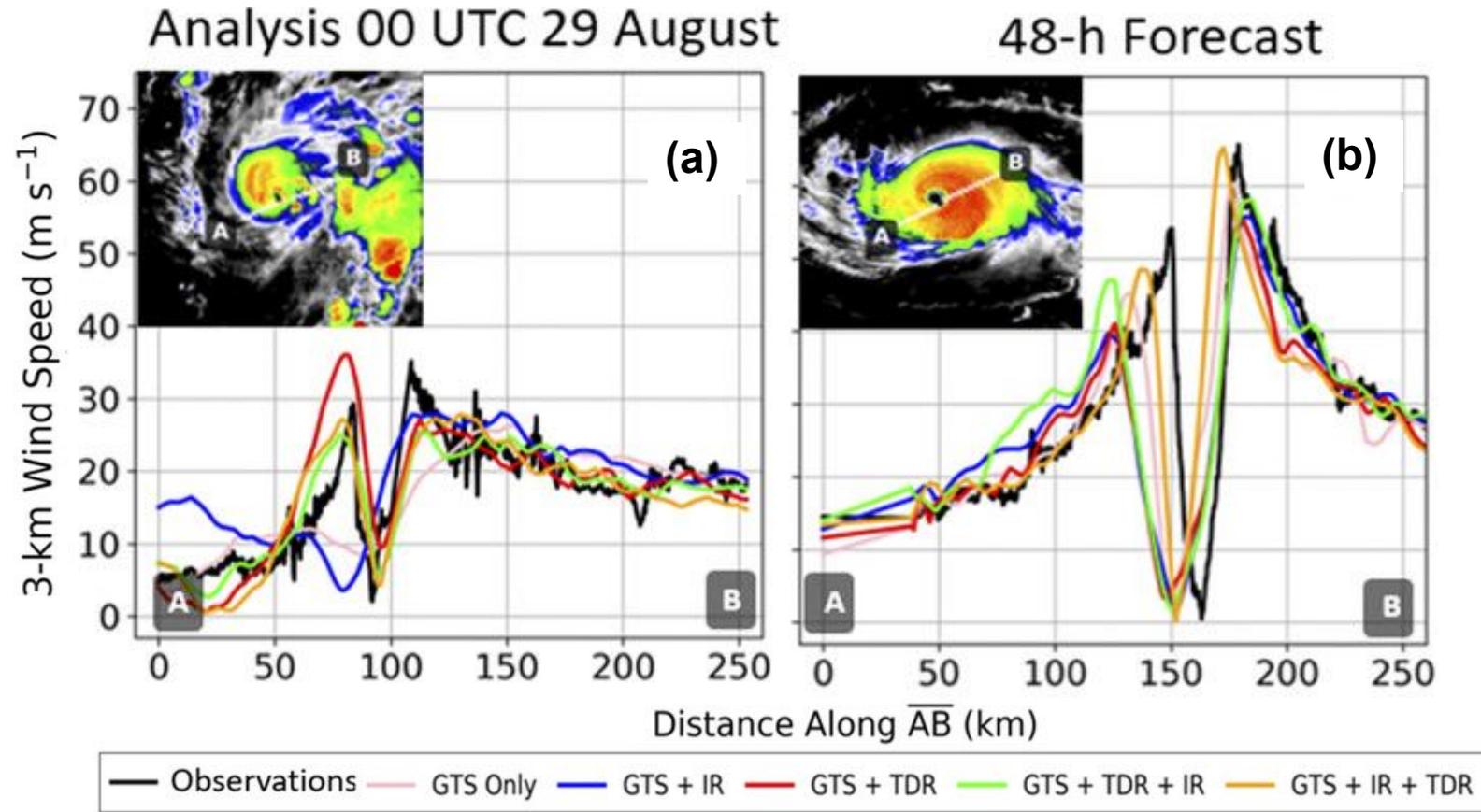
Simultaneous assimilation of GOES-16 all-sky infrared radiances and Tail Doppler Radar radial velocities



Temporal evolution of 10-m wind speeds of Hurricane Dorian (2019) in the EnKF analysis mean for the (a) GTS Only, (b) GTS+IR, (c) GTS+TDR, (d) GTS+TDR+IR, and (e) GTS+IR+TDR experiments.

1. The experiments assimilating IR observations produced high (e.g., 16 m s^{-1}) azimuthally averaged 10-m wind speeds sooner than experiments that did not.
2. Simultaneously assimilating TDR and IR observations tightened the low-level vortex relative to the GTS+IR experiment.

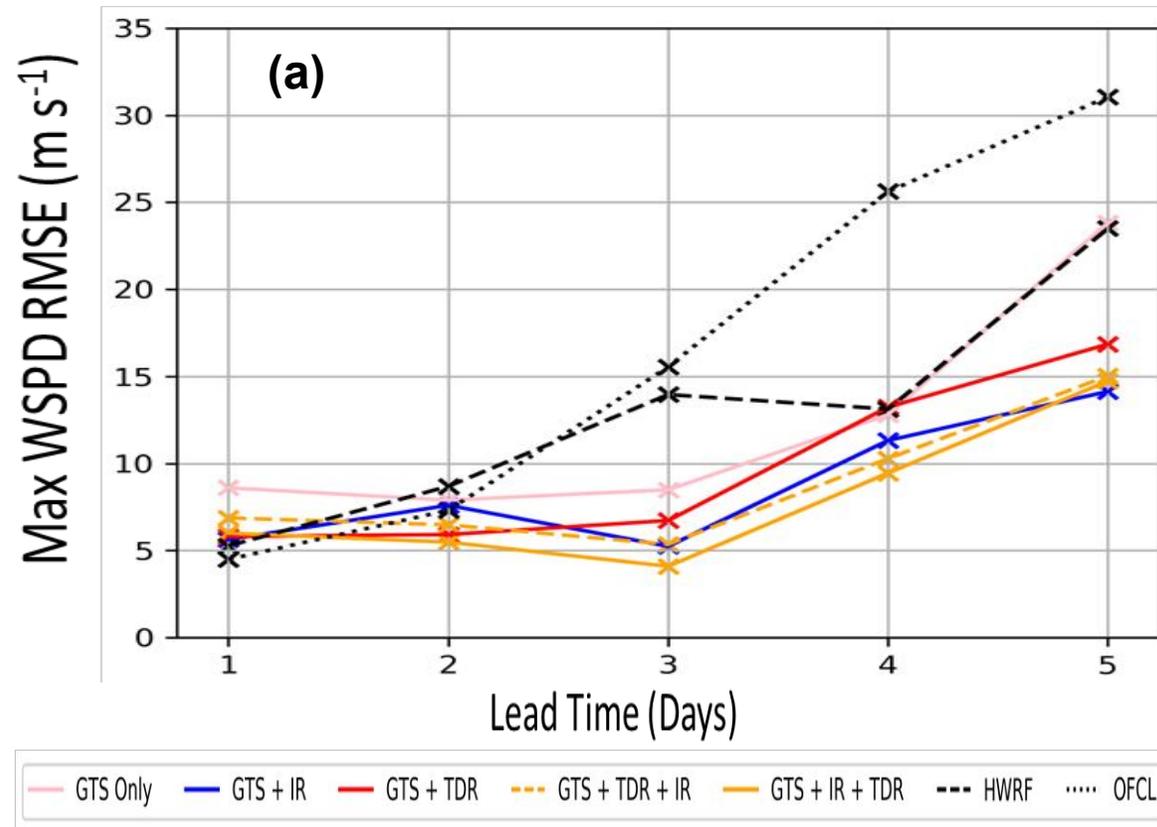
Simultaneous assimilation of GOES-16 all-sky infrared radiances and Tail Doppler Radar radial velocities



Comparisons with observed 3-km wind speeds measured by flight-level probes aboard NOAA aircraft.

Simultaneously assimilating both IR and TDR observations better capture the intensity and location of the eyewall wind maxima.

Simultaneous assimilation of GOES-16 all-sky infrared radiances and Tail Doppler Radar radial velocities



Mean absolute errors relative to the HURDAT2 best track values of maximum surface wind speed from 12 deterministic forecasts as a function of lead time

Simultaneously assimilating both IR and TDR observations improves the intensity forecast of Hurricane Dorian (2019)

Simultaneous assimilation of GOES-16 all-sky infrared radiances and GPM all-sky microwave radiances

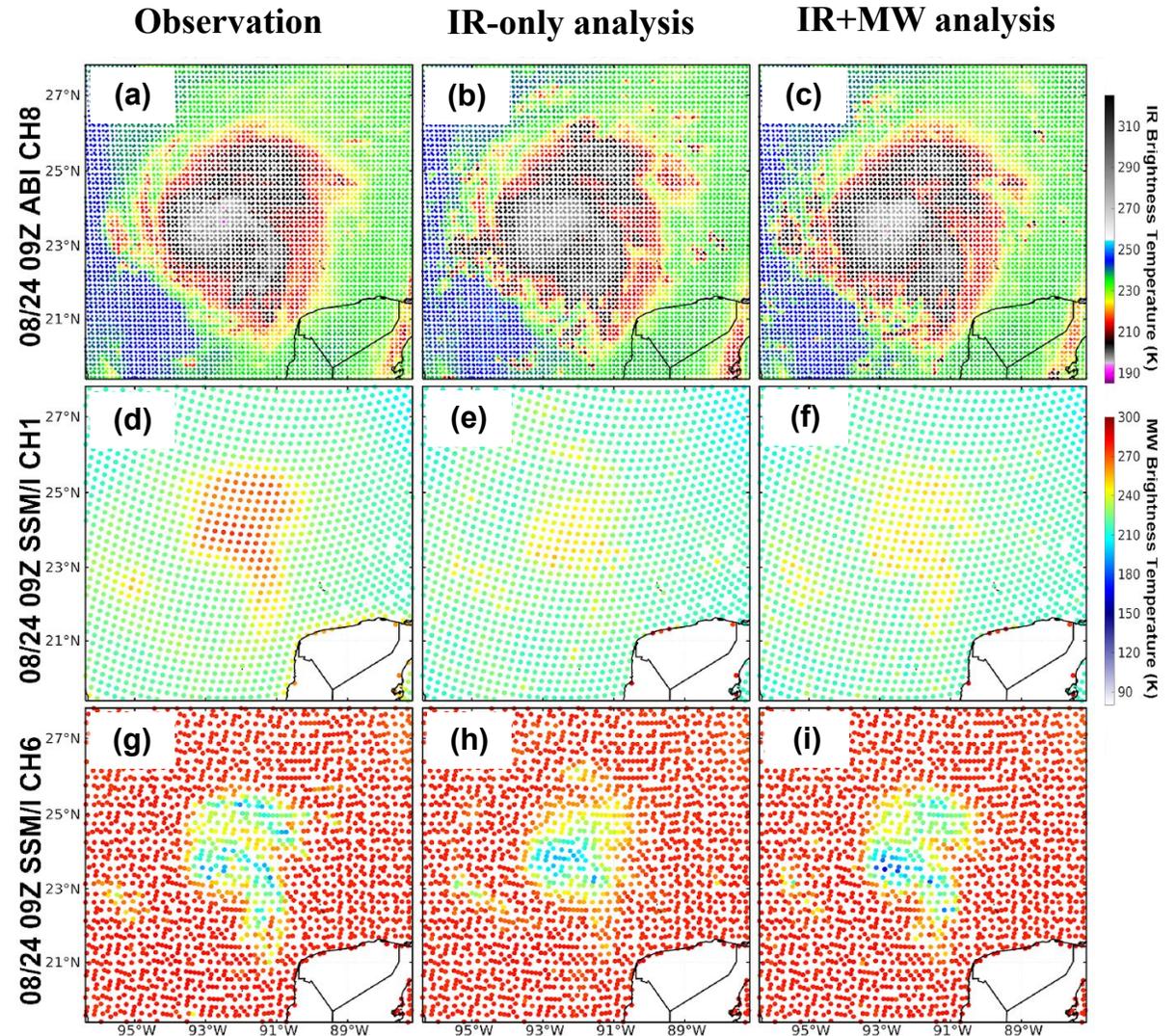
Case: Hurricane Harvey (2017)

Model: WRF model

Model domains: Three two-way nested domains (27, 9, and 3 km)

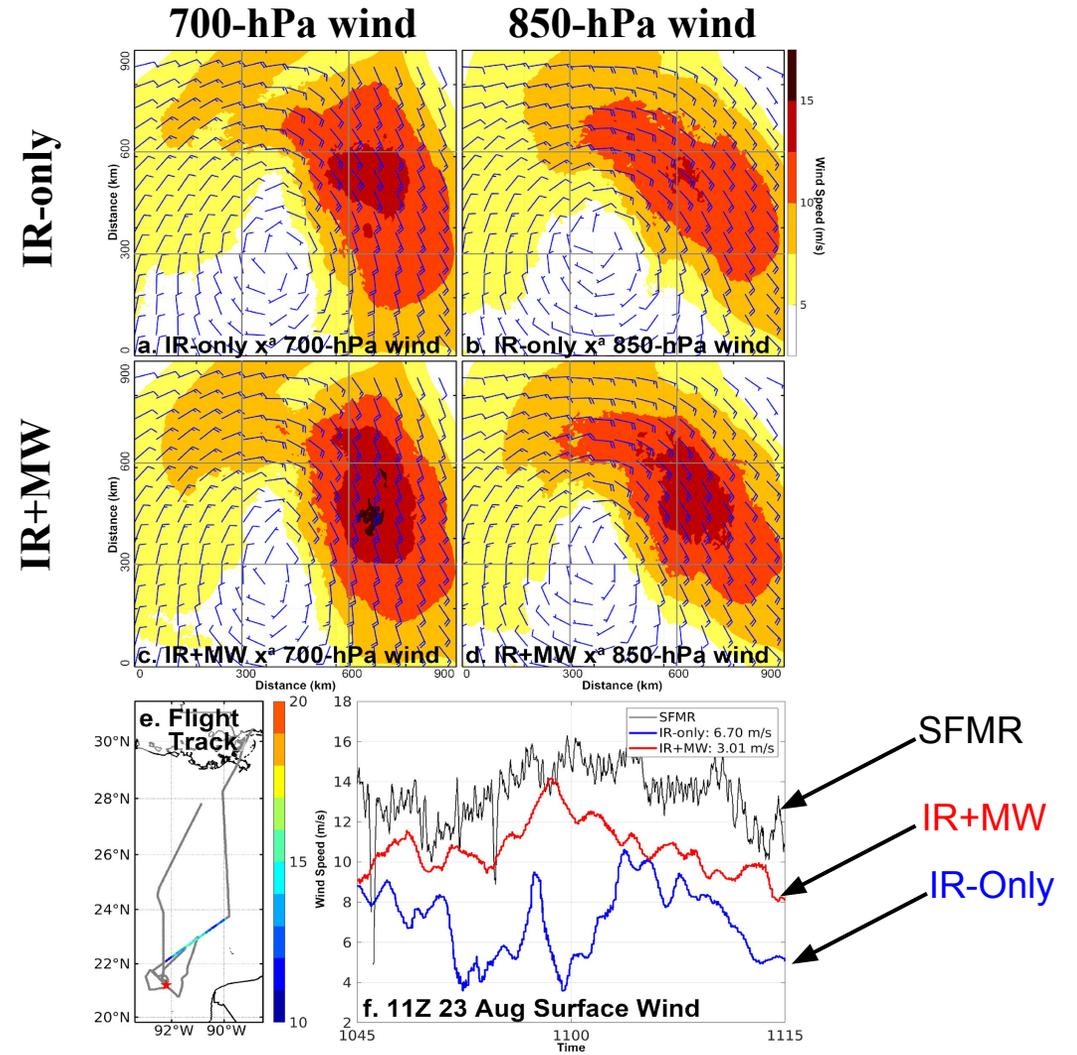
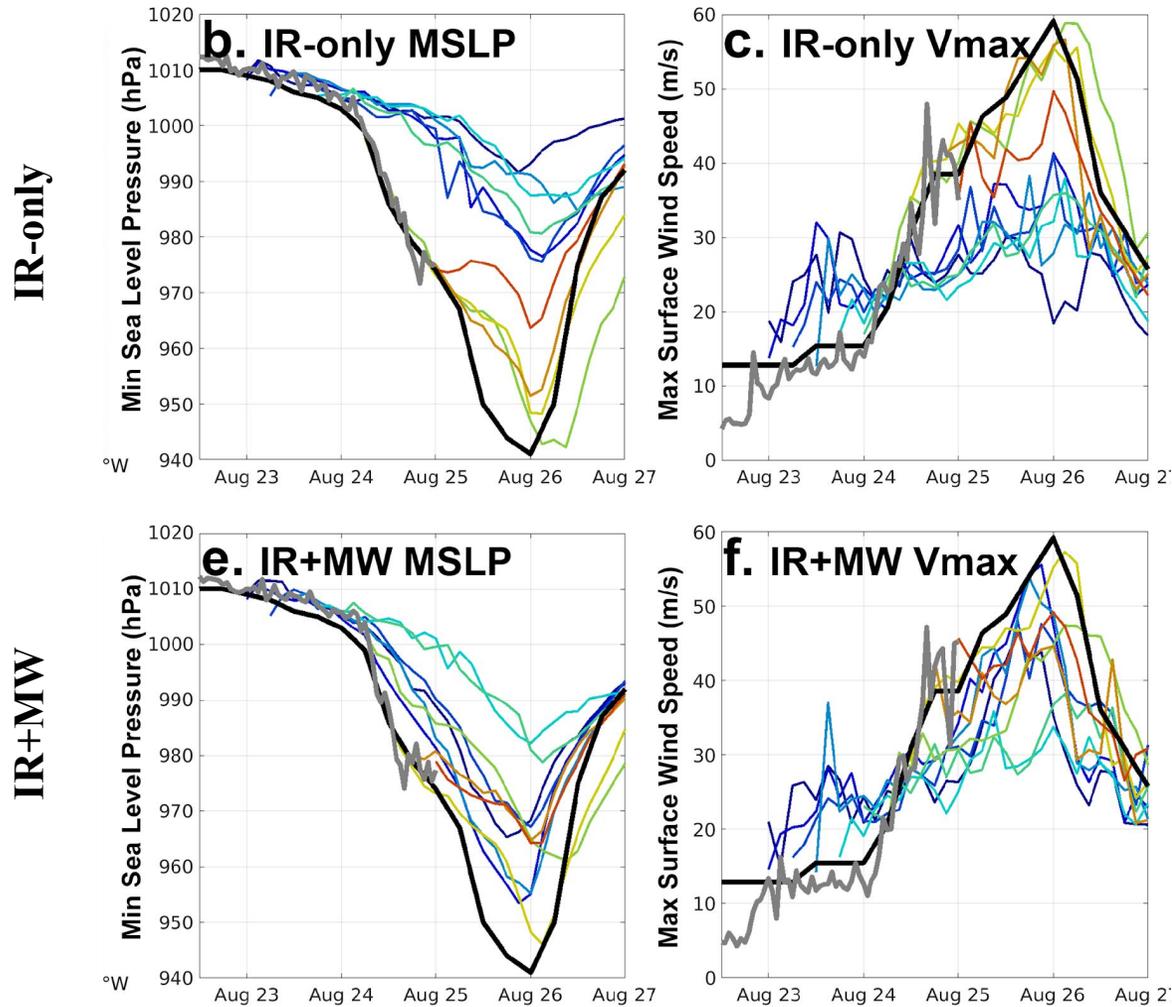
Data assimilation frequency: hourly EnKF

Experiment	Data assimilation
IR-only	(1) Conventional observations from GTS (2) IR BTs from GOES-16 ABI's channel 8
IR+MW	(1) Conventional observations from GTS (2) IR BTs from GOES-16 ABI's channel 8 (3) MW BTs from GPM (~19 GHz low frequency channel and 183.31 ±6.6 GHz high frequency channel)



(First column) Observed and (second and third columns) simulated BTs at 0900 UTC 24 August for Hurricane Harvey (2017)

Simultaneous assimilation of GOES-16 all-sky infrared radiances and GPM all-sky microwave radiances

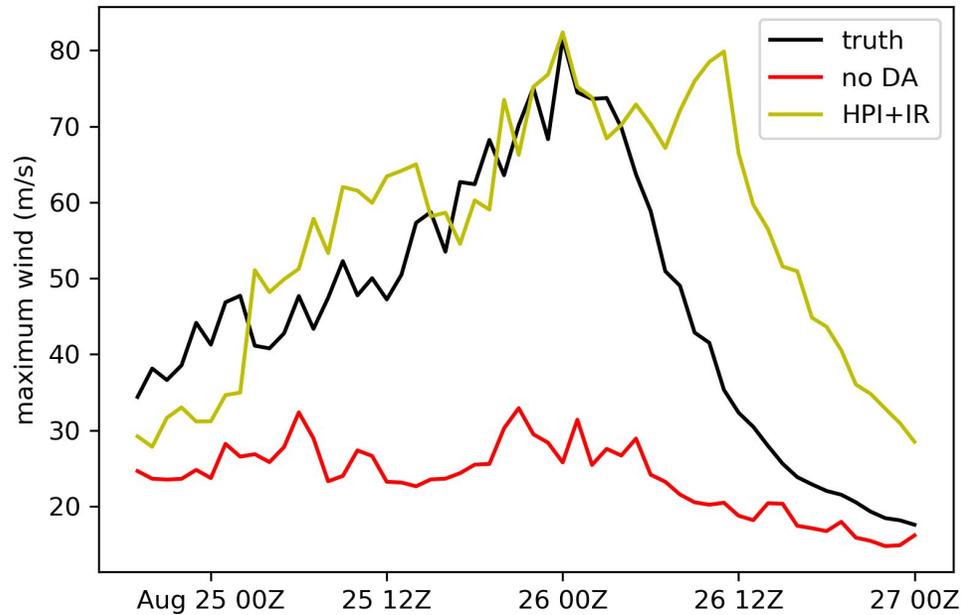


Analyses and forecasts of (first column) minimum sea-level pressure, and (second column) maximum surface wind speed for the (first row) IR-only and (second row) IR+MW experiments.

(a, c) 700-hPa and (b, d) 850-hPa horizontal winds (barbs) and wind speeds (shading) averaged every 6 hours from 1800 UTC 22 August through 1200 UTC 23 August

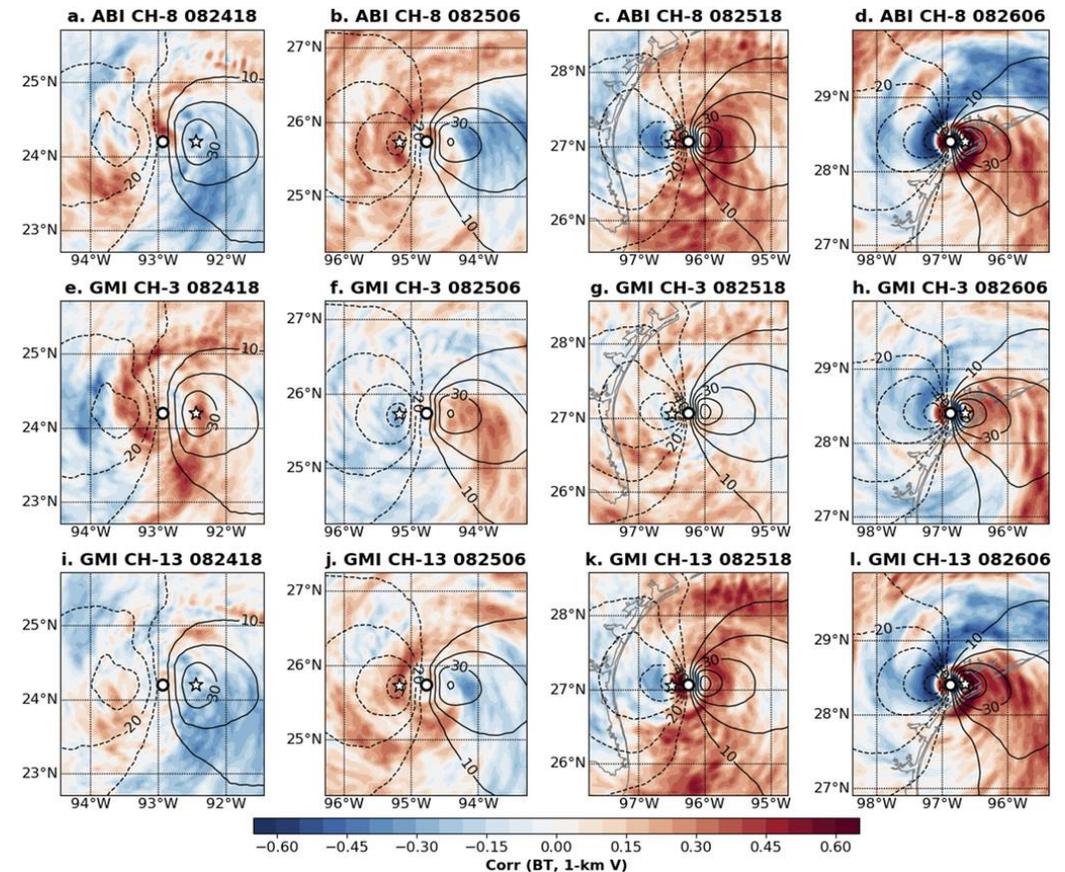
Exploring all-sky radiances data assimilation in the FV3 model

Track and intensity forecasts of Harvey (OSSE)



Intensity forecasts of Hurricane Harvey (2017) from a OSSE, The HPI+IR forecast used assimilation of IR BT data

Correlations between IR and MW BTs and FV3 model states



Horizontal cross sections at 1 km above mean sea level of correlations between IR/MW BTs and V-wind (shading) and ensemble-mean V-wind (contours; every 10 m s⁻¹ with solid lines representing positive values and dashed lines representing negative values).



NWS/OSTI 2018 FFO PI Presentation

Project title

Project Status as of November, 2021



Project Information and Highlights

Leads: Xingchao Chen (Penn State University)

Scope:

1. Evaluate convection-permitting hurricane analysis and prediction in the FV3 model
2. Explore ensemble-based data assimilation in the FV3 model using OSSEs

Expected Benefits:

- The evaluations of the sensitivity of hurricane forecasts to physics configurations and initial conditions in the FV3 model can benefit the development of operational models
- Explored the ensemble-based satellite all-sky infrared radiances data assimilation for hurricane analysis and prediction in the FV3 model
- All-sky microwave radiances DA and atmosphere-ocean strongly coupled DA would open up the possibility for further improving TC forecasts
- Publications: Four papers have been published in 2021.

Implementation Date:

- All-sky microwave radiances DA could be useful for the future HAFS development.

Challenges/Problems:



Deliverables

Milestones	Completion Quarter	Status
Evaluate the performance of a regional-global nested FV3 system at convection-permitting resolutions (~3 km) for TC analysis and prediction.	2019Q1	Completed
Examine the sensitivity and uncertainty of FV3 forecasts to different physics configurations, in particular with regard to the PBL and surface flux parameterization schemes.	2019Q4	Completed
Develop and conduct experimental hurricane forecasts with the FV3 model initialized with analyses produced by the GFS and the PSU-EnKF system	2020Q2	Completed
Explore the use of a FV3-native cubed-sphere-based EnKF in convection-permitting hurricane forecast using simulated observations (OSSEs).	2021Q2	Completed
Explore satellite all-sky microwave radiance data assimilation and atmosphere-ocean strongly coupled data assimilation	The milestone was not included in our original proposal	On track



Program Attention Required



Potential Program Attention Needed



On Target