Combined Hyper-spectral Sounder and Advanced Baseline Imager Temperature and Watervapor Retrieval's(PHSnABI) Impact on Numerical Weather Prediction

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Research Founded by:

Outline:

- I Brief Introduction to PHSnABI Data and its impact in Numerical Weather Prediction System
- II How to optimize PHSnABI retrieval's performance in NWP system
- III Results from Operational Implication of PHSnABI
- IV Next Stage Plans of Cooprating with City of Hampton

Part I

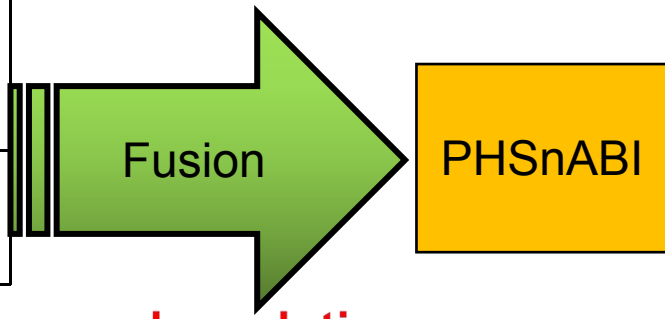
Brief Introduction to PHSnABI Data and Retrieval Assimilation

What is PHSnABI and What is its Advantage

PHSnABI = Combined Polar Hyperspectral Sounding and Advanced Baseline Imager Temperature and Water Vapor Retrieval

The word "Polar" Can be deleted, because we have FY-4A

	Advantage	Disadvantage
ABI retrieval	**High Horizontal and temporal Resolution**	**Low Vertical Resolution**
PHS retrieval	**High Vertical Resolution**	**Low Horizontal and temporal Resolution**



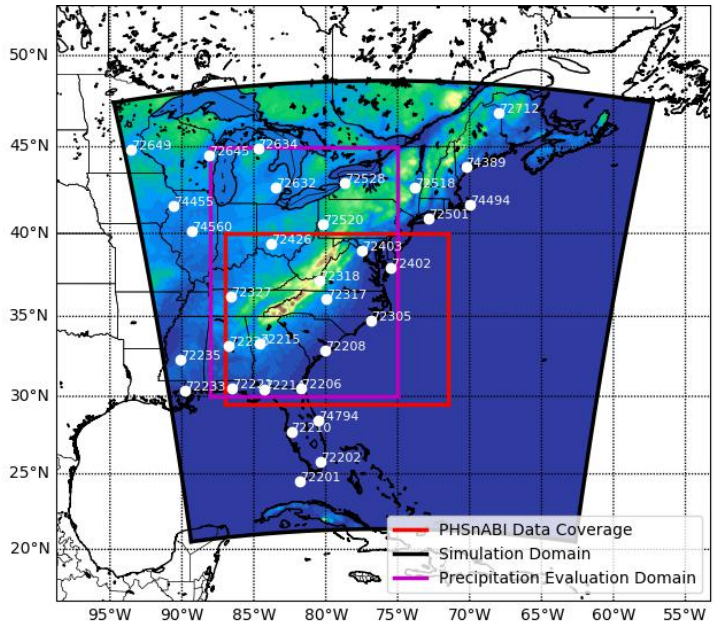
PHSnABI acquires very hight spatial and temporal resolution

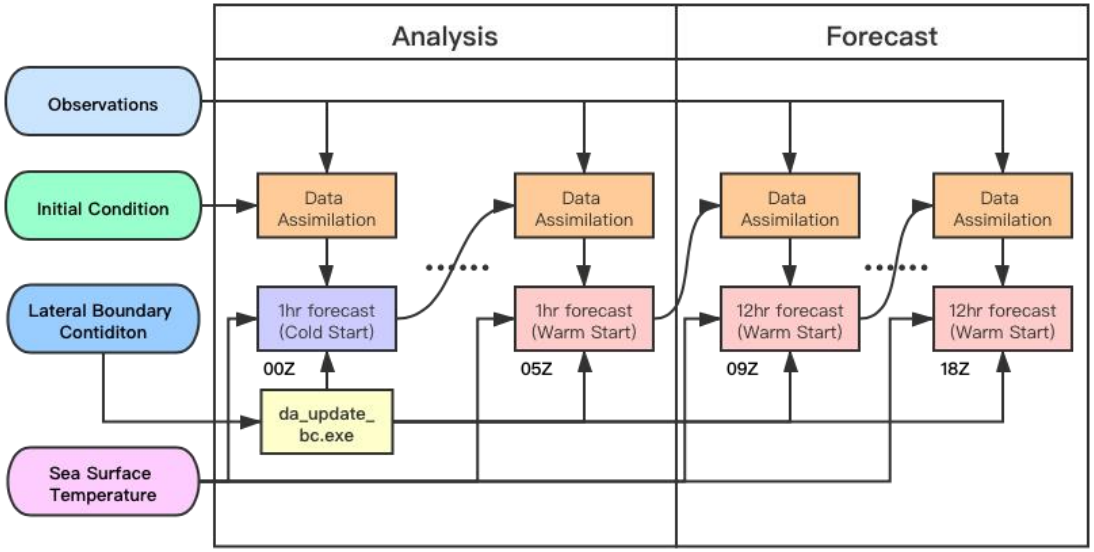
Instrument	IASI	CrIS	GIIRS	ABI/AHI
Satellite	Metop-A, Metop-B	Suomi-NPP, JPSS-1	FY-4A	GOES-16,17 Himawari
Instrument Type	Michelson Interferometer	Michelson Interferometer	Michelson Interferometer	Multi-spectral Radiometer
Spectral Resolution	0.25 cm^{-1}	0.625 cm^{-1}	0.625 cm^{-1}	34 – 2456 cm^{-1}
Spectral Range	645 - 2760 cm^{-1} 15.5 – 3.62 μ m	650 – 2550 cm^{-1} 15.4 – 3.9 μ m	700 – 1130cm^{-1} 8.8 – 14.3 μ m 1650 – 2250 cm^{-1} 4.4 – 6.1 μ m	751– 21277 cm^{-1} 13.3– 0.47 μ m
Number of Channels	8462	2211	1650	16
Spatial Resolution	12 km	14 km	16 km	2 km
Launch Year	2006, 2012	2011, 2017	2016	2016/2014

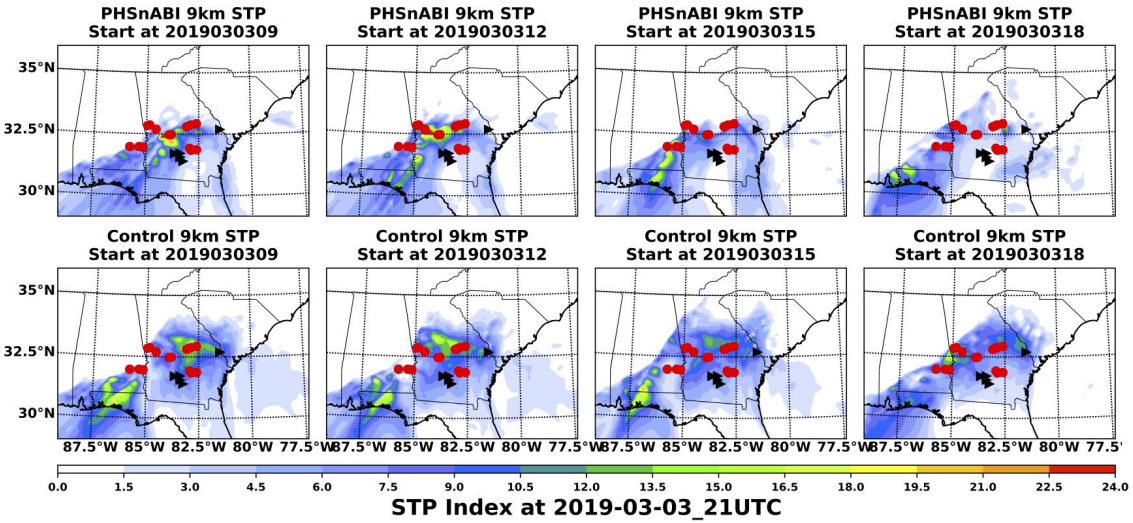
With so many instruments flying in space, data coverage for PHSnABI over the globe is very promising!

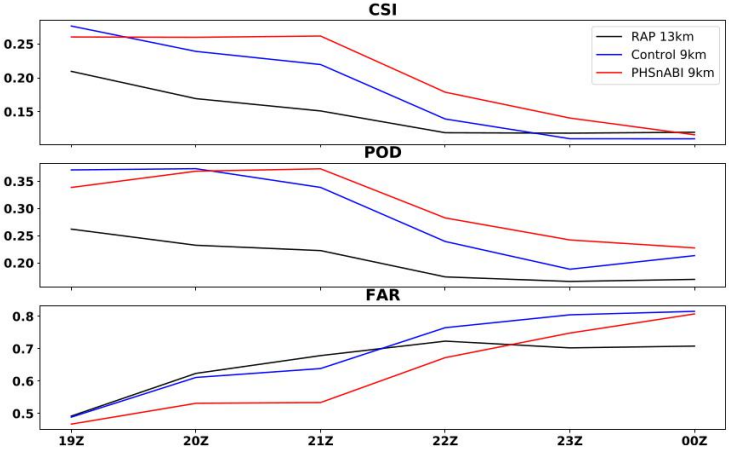
Can this data improve the accuracy of Numerical Weather Prediction, especially severe weather storms?

Case1, Tornado Outbreak on 3rd Mar. 2019



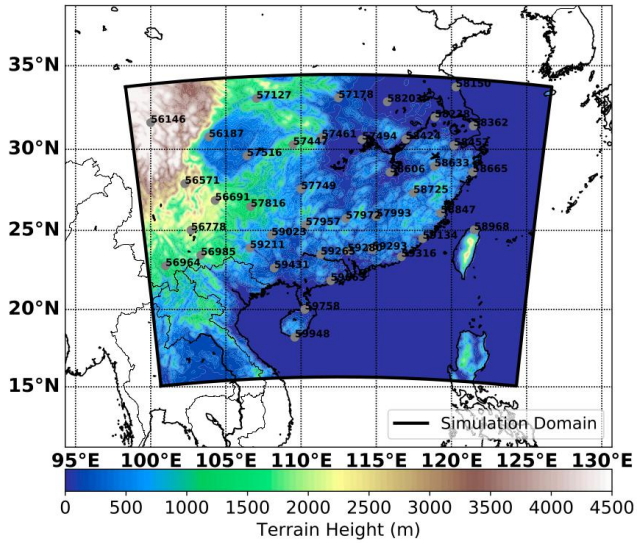


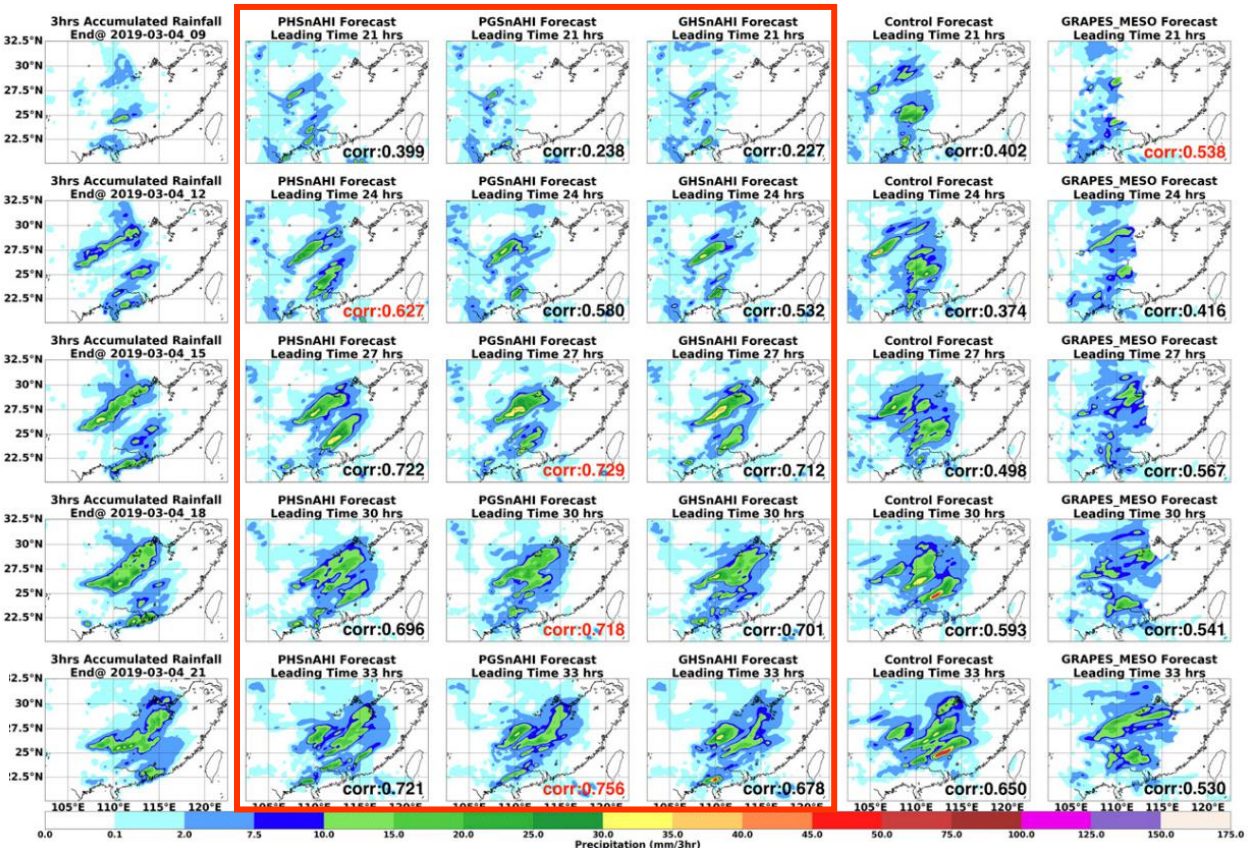


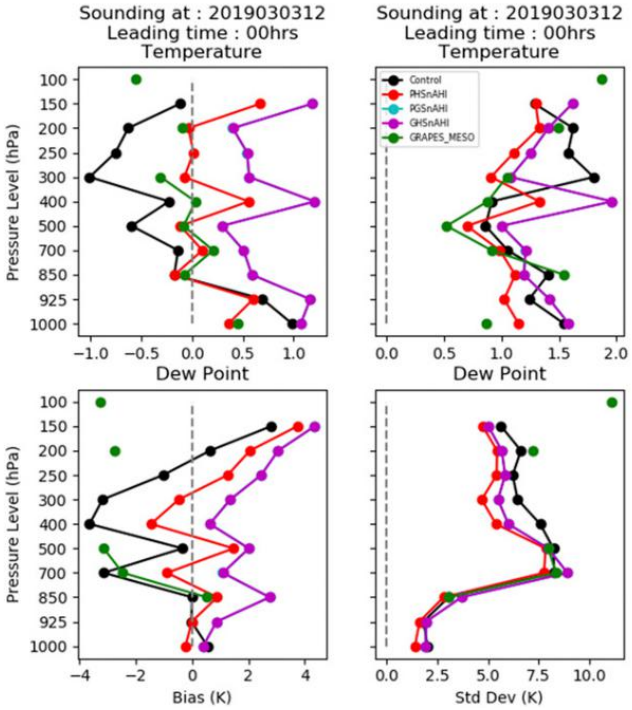


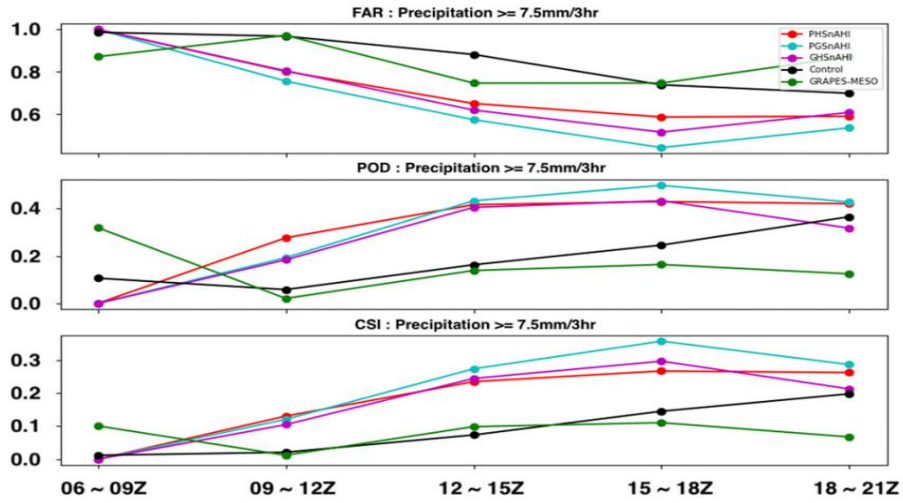
Positive Impact on Tornado and Precipitation Forecast can be dectected after assimilating PHSnABI retrievals

Case2, Heavy Precipitation on 4th Mar. 2019

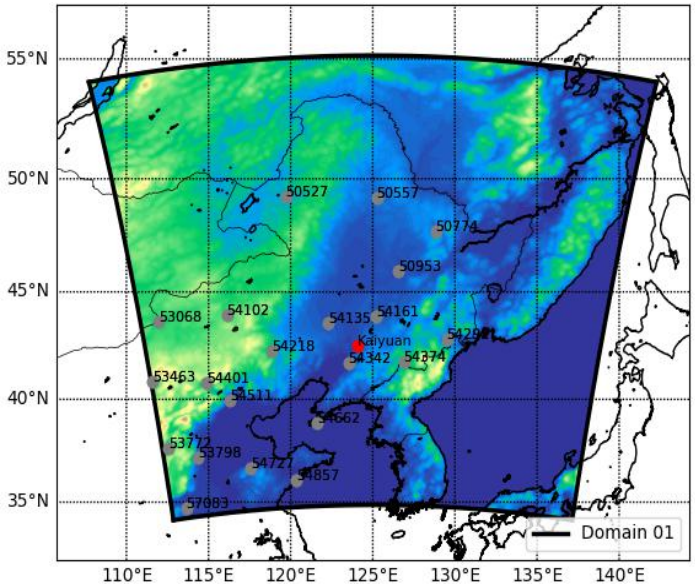


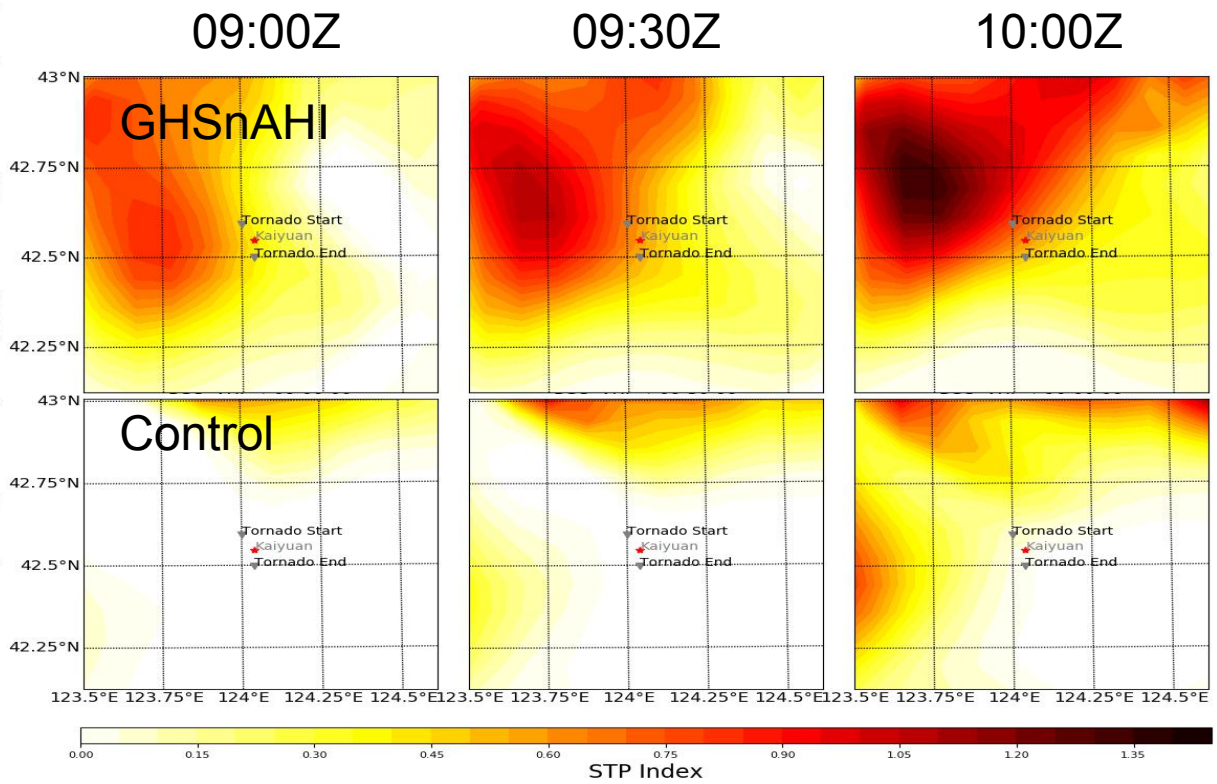






Case3, Tornado Outbreak on 3rd Jul. 2019





Conclusions:

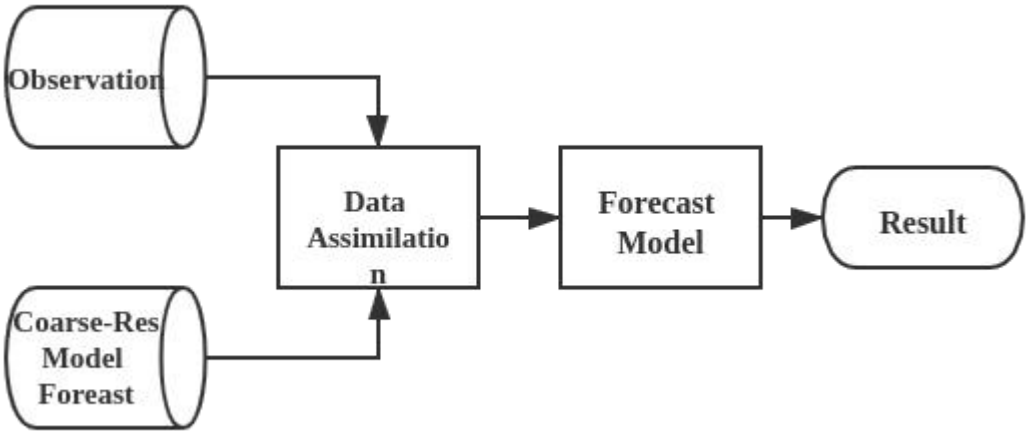
- **PHSnABI temperature and water vapor retrievals do have positive impact on improving tornado outbreak and severe precipitation prediction**
- **The Performance of GEO-hyperspectral combined PHSnABI and LEO-hyperspectral combined PHSnABI are identical**
- **GEO-hyperspectral combined PHSnABI's impact on NWP is more significant than LEO-hyperspectral combined PHSnABI**

Part II

How to optimize PHSnABI retrieval's performance in NWP system

How do observations impact NWP results

Breif workflow of Regional NWP System



Penalty Function (Cost Function) used in PHSnABI Retrieval Assimilation

$$J_{(x)} = (x - x_b)B^{-1}(x - x_b)^T + (H_{(y)} - x)R^{-1}(H_{(y)} - x)^T$$

Calculated based on Model Forecast and Operational Analysis
CAN BE TUNED

x: Best Estimation Field
X_b: Background Field from Operational Forecast
y: Observed Hyper-spectral Radiance
B: Background Error Covariance Matrix
$H_{()}$: PHSnABI Retrieval Algrothim
R: Observational Error Covariance Matrix
$J_{()}$: Penalty Function

Calculated based on Radiosnode and Reanalysis Dataset
FIXED

Ought to Be a State-of-art Retrieval and Fusion Algrothim

How Background Error Covariance works in Data Assimilation

How Many Components are there in Background Error Matrix

Ideally, B Matrix is Calclulated Like this:

$$B = Forecast - Truth$$

Data Volume should be larger than 1 month!

But, The size of B Matrix is too big to use and it also contains noize. So, we need to simplify it to 5 parts:

$$B = F_{(B_{balance}, B_{unbalance}, B_{vertical}, B_{zonal}, B_{meridinal})}$$

Here, balance stands for geostrophic equilibrium

p.s., in an Operational Application, $B_{vertical}$, B_{zonal}, $B_{meridinal}$ are smpilified to a Gaussian Distribution Function: The nearer an observation is to model grid point, the more significantly it's going to influence the Data Assimiliation result.

$B_{unbalance}$ Plays a more important part in Convective-scale system prediction

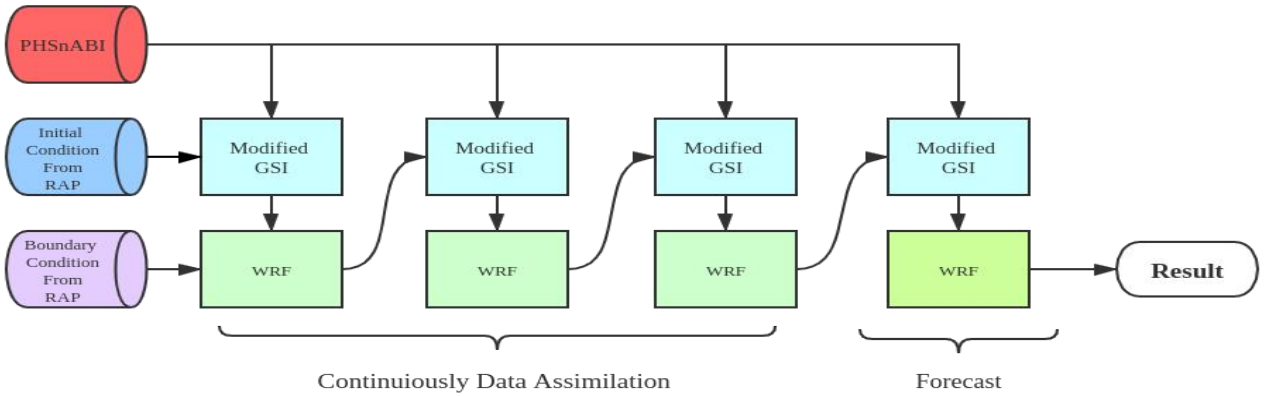
In GSI's default settings, unbalanced temperature and unbalanced water vapor part in B are given the same weighting of 0.75.

This will be the parameter which we can play with!

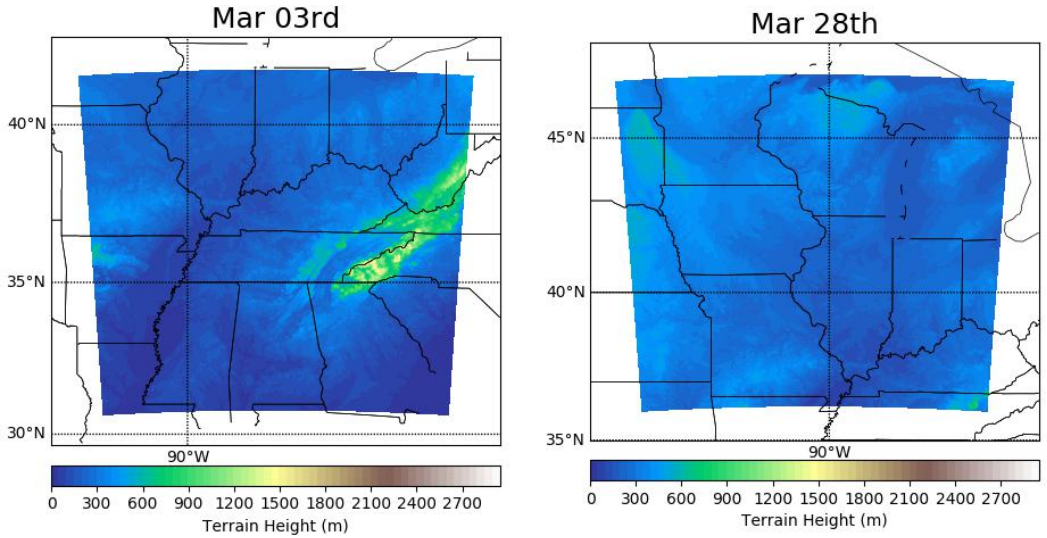
Case Selection

Name	Nashvelle	Wisconsin
Date	2020-03-03	2020-03-28

Workflow Design



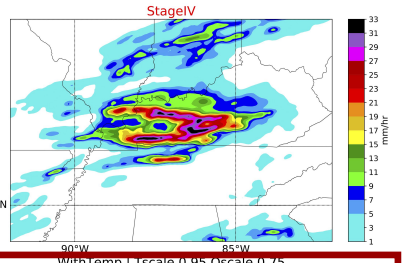
Domain Settings

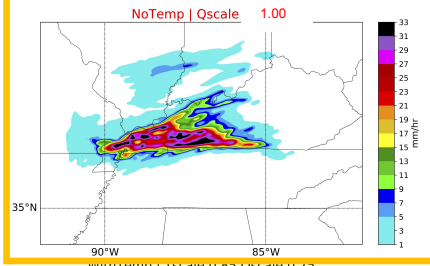


Experiments

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Tscale	Nan	0.05	0.05	0.05	0.15	0.25	0.35	0.45	0.55	0.55	0.55	0.65	0.75	0.85	0.95
Qscale	1.0	0.75	0.85	0.95	0.75	0.75	0.75	0.75	0.75	0.85	0.95	0.75	0.75	0.75	0.75

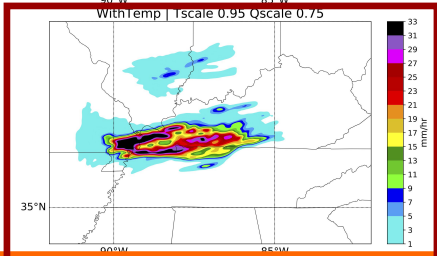
Accumulated Precipitation from Mar 3rd 0400UTC to Mar 3rd 0800UTC

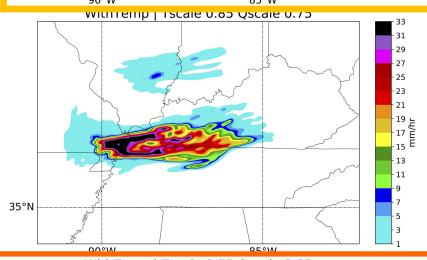


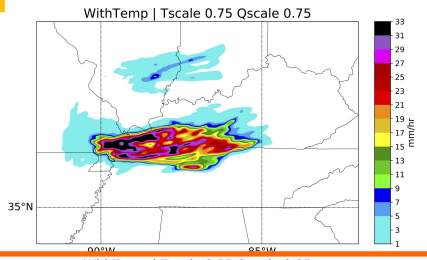


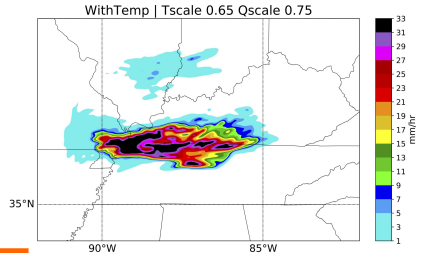
Temperature Do Have Positive Impact to Precipitation Forecast

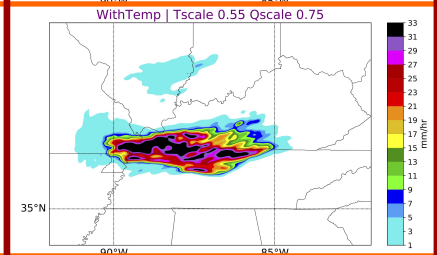
But No Temperature is still the Best

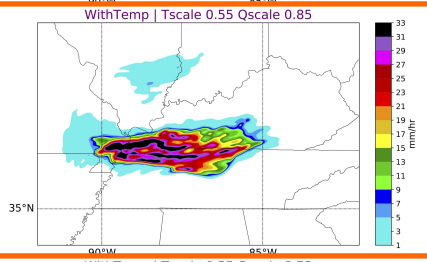


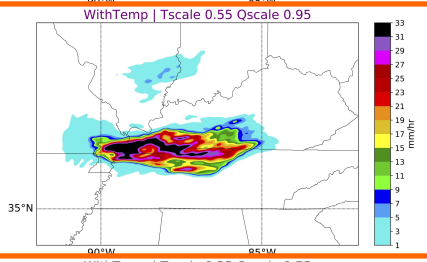




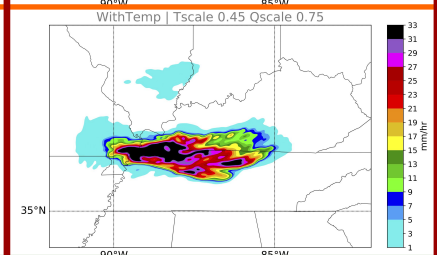


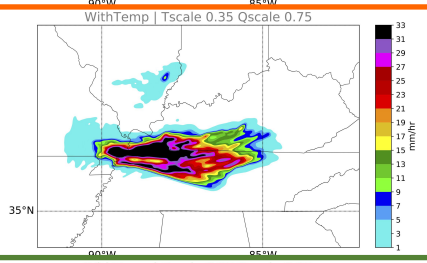


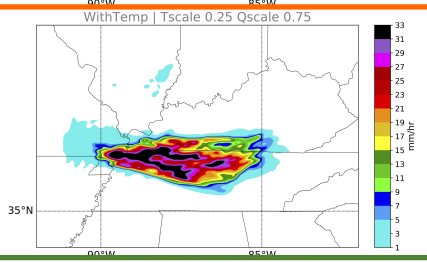


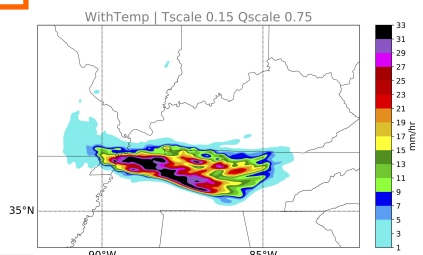


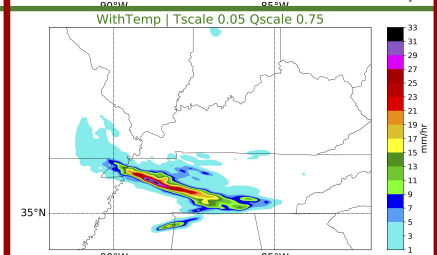
When Tscale is LARGE, it hinders Water Vapor's impact in NWP system

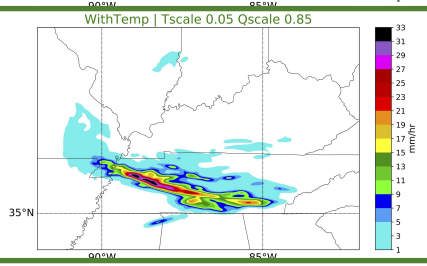


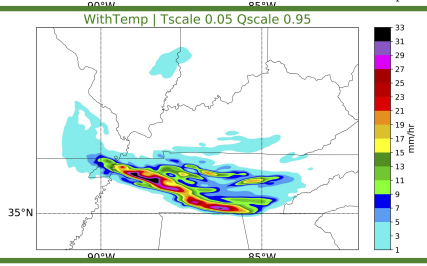






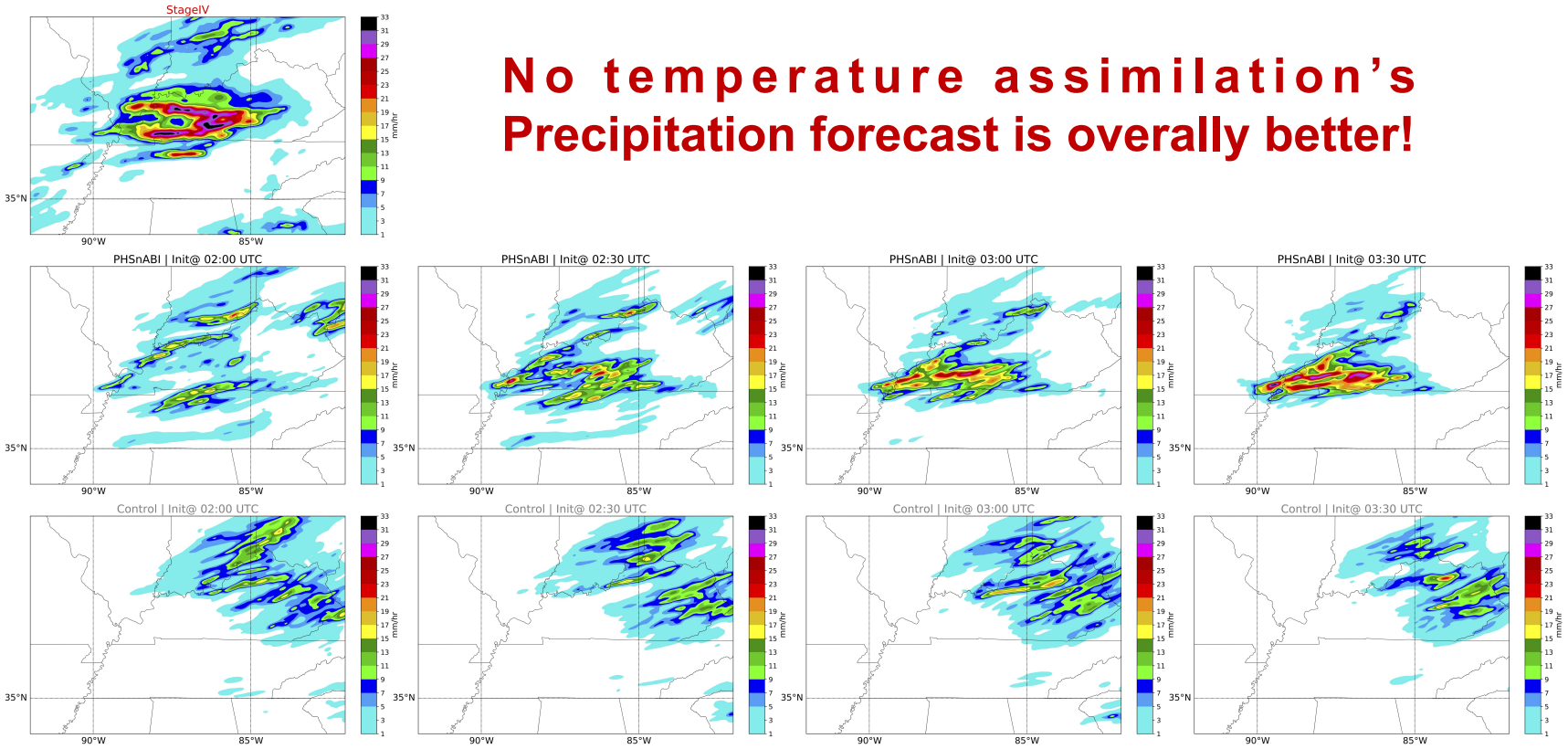






When Tscale is SMALL, it optimizes Water Vapor's impact in NWP system

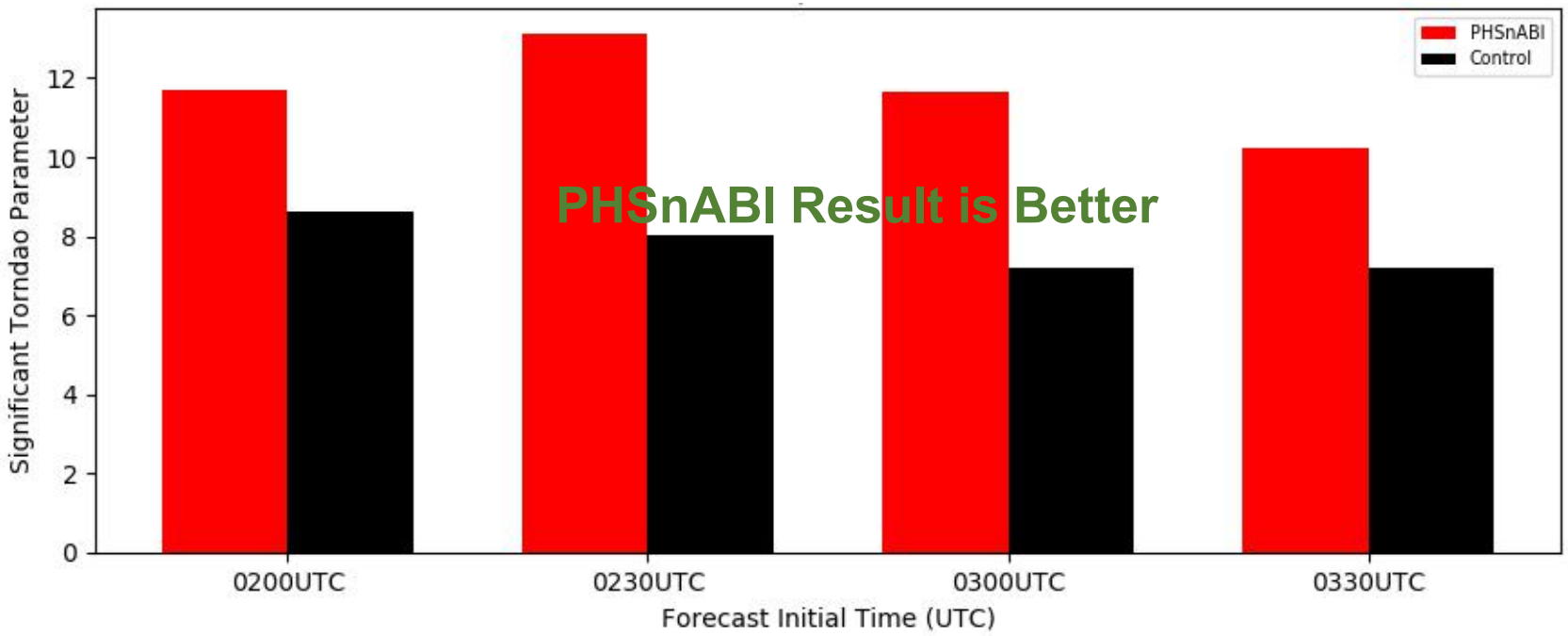
Does PHSnABI make anything better compared to Control Run?



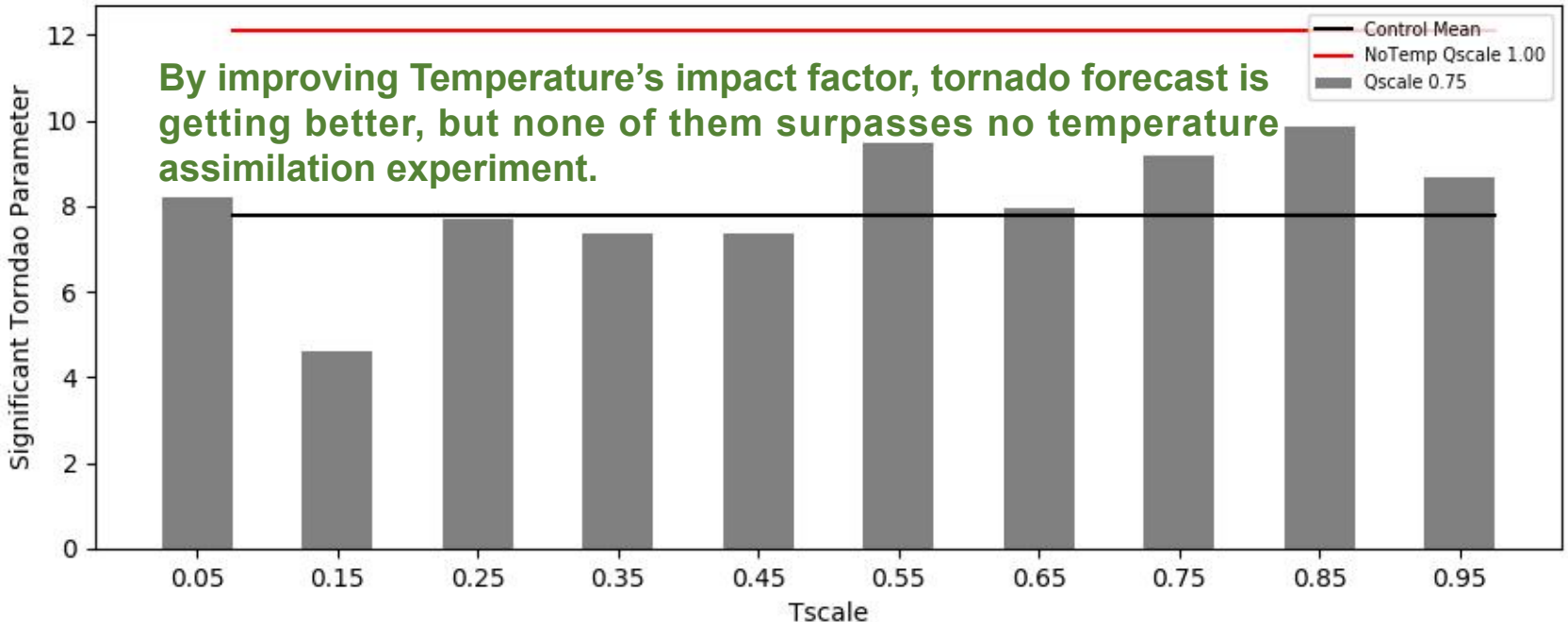
No temperature assimilation's Precipitation forecast is overally better!

- **PHSnABI temperature retrieval has positive impact to precipitation forecast in NWP system, but the impact can be neglected as the difference is too small compared to No temperature assimilation**
- **In GSI, temperature's impact to initial condition is over-estimated and it hinders water vapor observational information getting into the initial condition.**

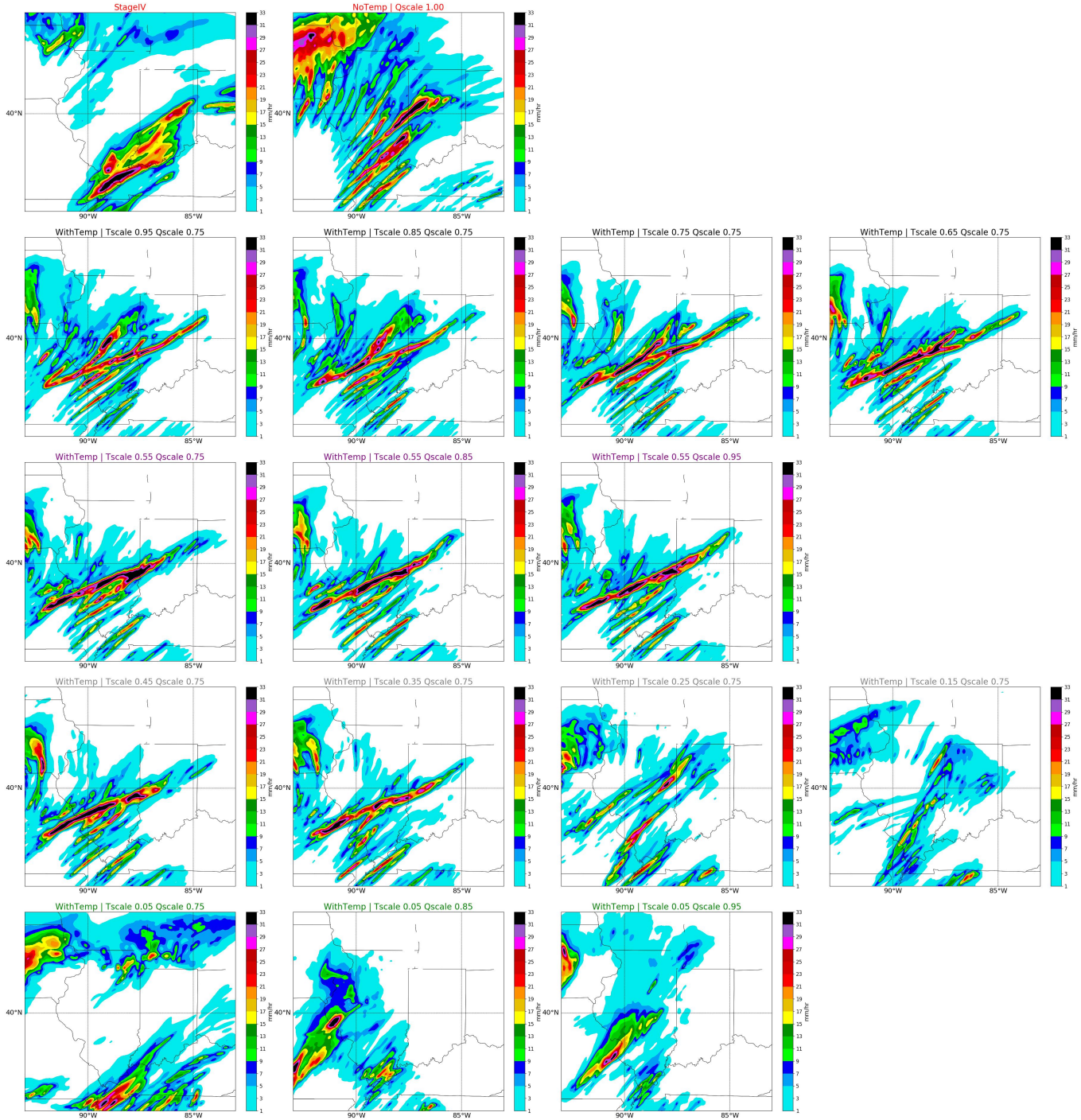
How about the Tornado Prediction Skill?



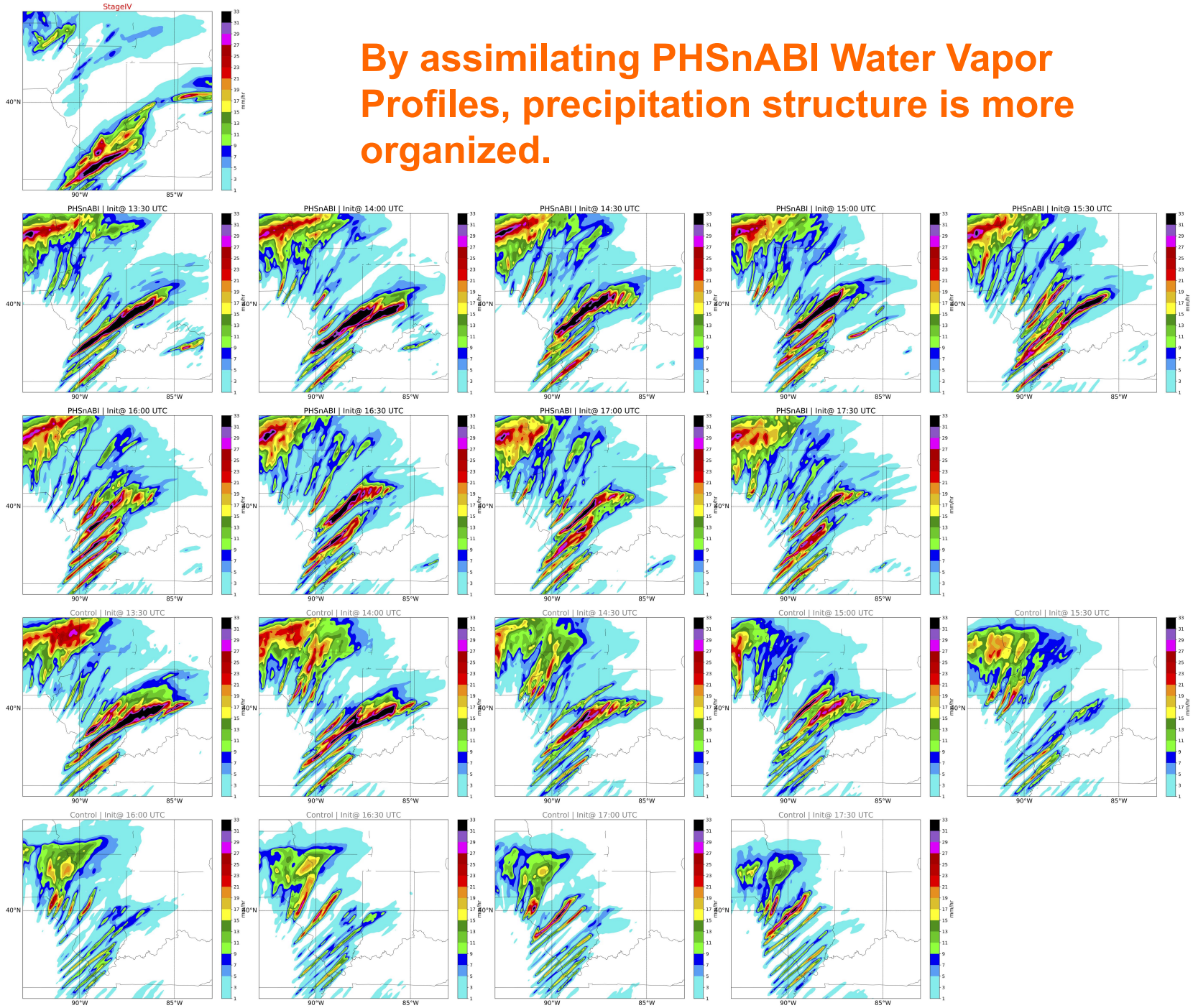
PHSnABI Result is Better

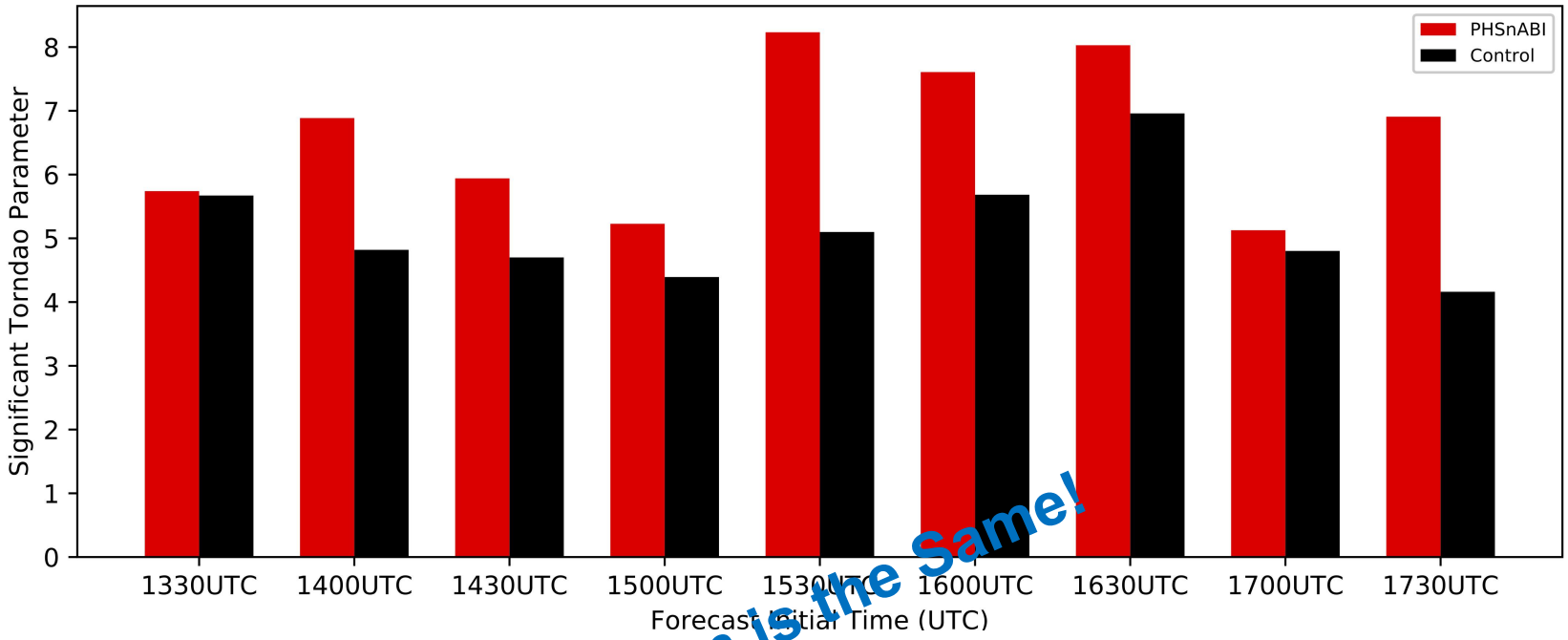


By improving Temperature's impact factor, tornado forecast is getting better, but none of them surpasses no temperature assimilation experiment.

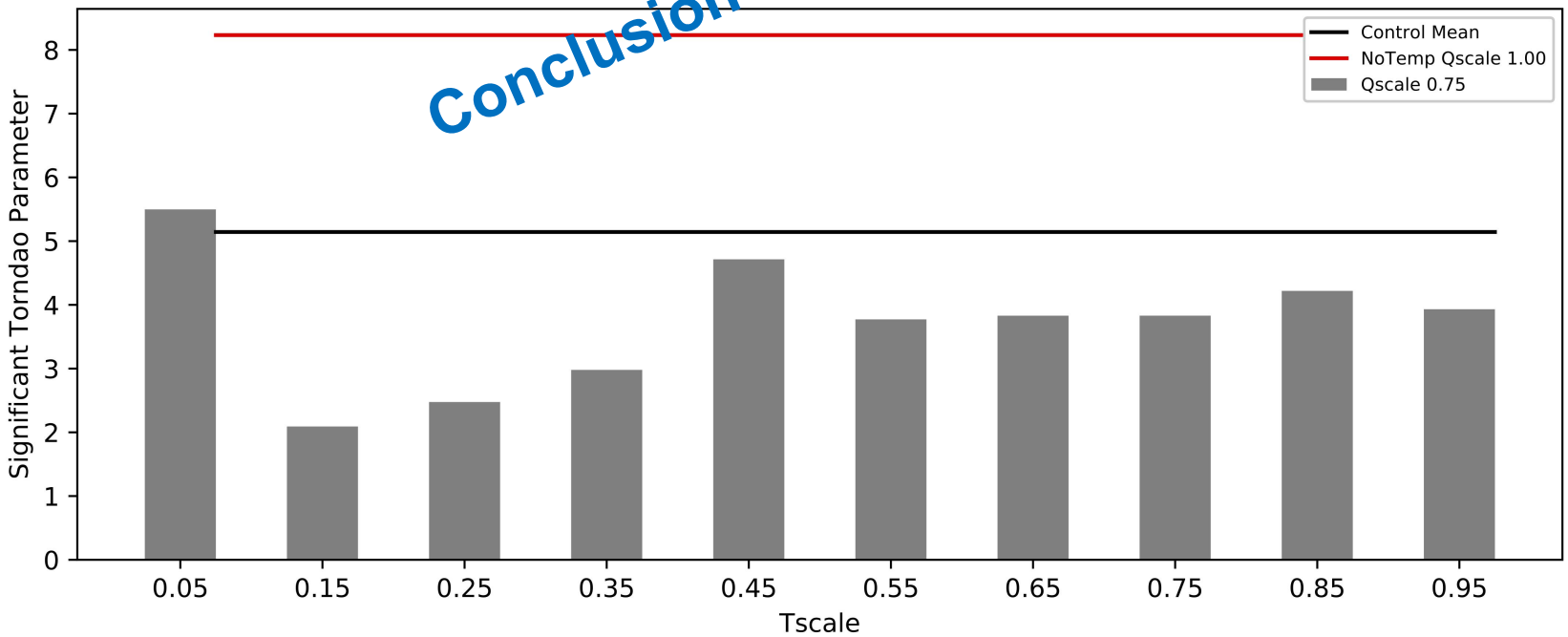

StageIV
NoTemp | Qscale 1.00
WithTemp | Tscale 0.95 Qscale 0.75
WithTemp | Tscale 0.85 Qscale 0.75
WithTemp | Tscale 0.75 Qscale 0.75
WithTemp | Tscale 0.65 Qscale 0.75
WithTemp | Tscale 0.55 Qscale 0.75
WithTemp | Tscale 0.55 Qscale 0.85
WithTemp | Tscale 0.55 Qscale 0.95
WithTemp | Tscale 0.45 Qscale 0.75
WithTemp | Tscale 0.35 Qscale 0.75
WithTemp | Tscale 0.25 Qscale 0.75
WithTemp | Tscale 0.15 Qscale 0.75
WithTemp | Tscale 0.05 Qscale 0.75
WithTemp | Tscale 0.05 Qscale 0.85
WithTemp | Tscale 0.05 Qscale 0.95
40°N
90°W
85°W
mm/hr

By assimilating PHSnABI Water Vapor Profiles, precipitation structure is more organized.





Conclusion is the Same!



Part III

Results from Operational Implication of PHSnABI

Operational NWP Systems running at CAS/SWRC

8km with 12hrs-leadtime focusing on Central and Eastern US

http://cas.hamptonu.edu/~qi.zhang/Hurricane_8km

8km with 72hrs-leadtime focusing on Eastern Coast Hurricane Landfall

http://cas.hamptonu.edu/~qi.zhang/home/mainpage.html

3km with 12hrs-leadtime focusing on the State of Virginia

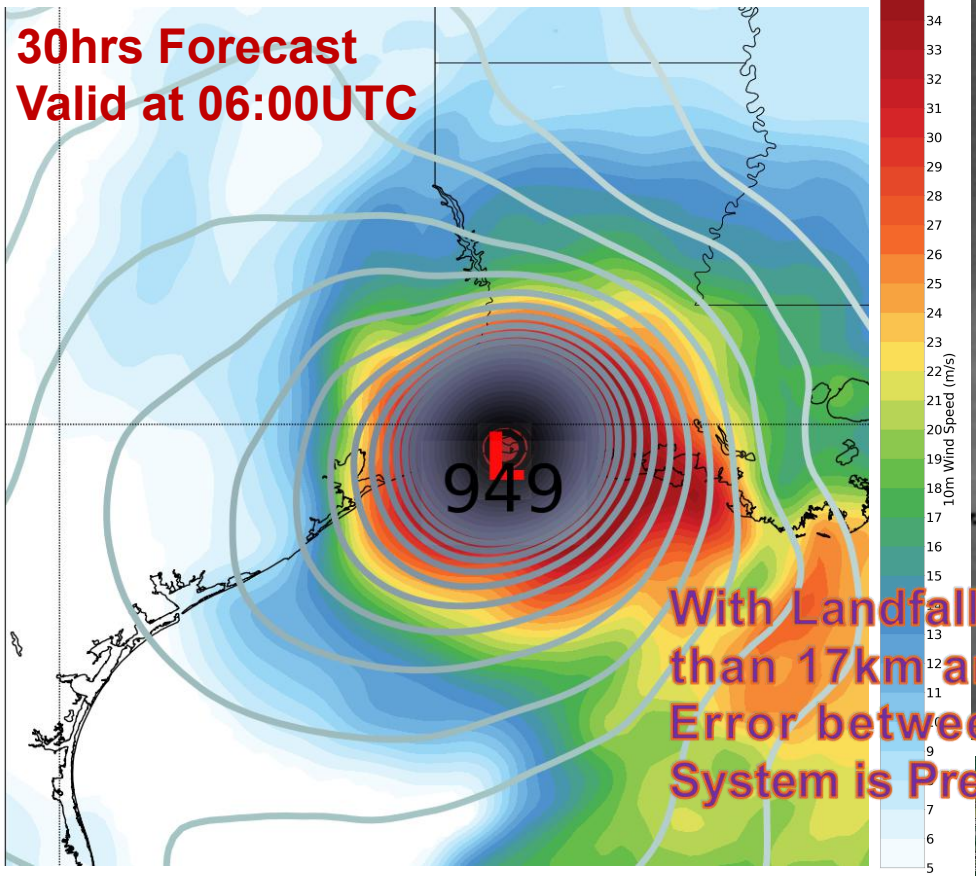
http://cas.hamptonu.edu/~qi.zhang/HWT3km/Mainpage.html

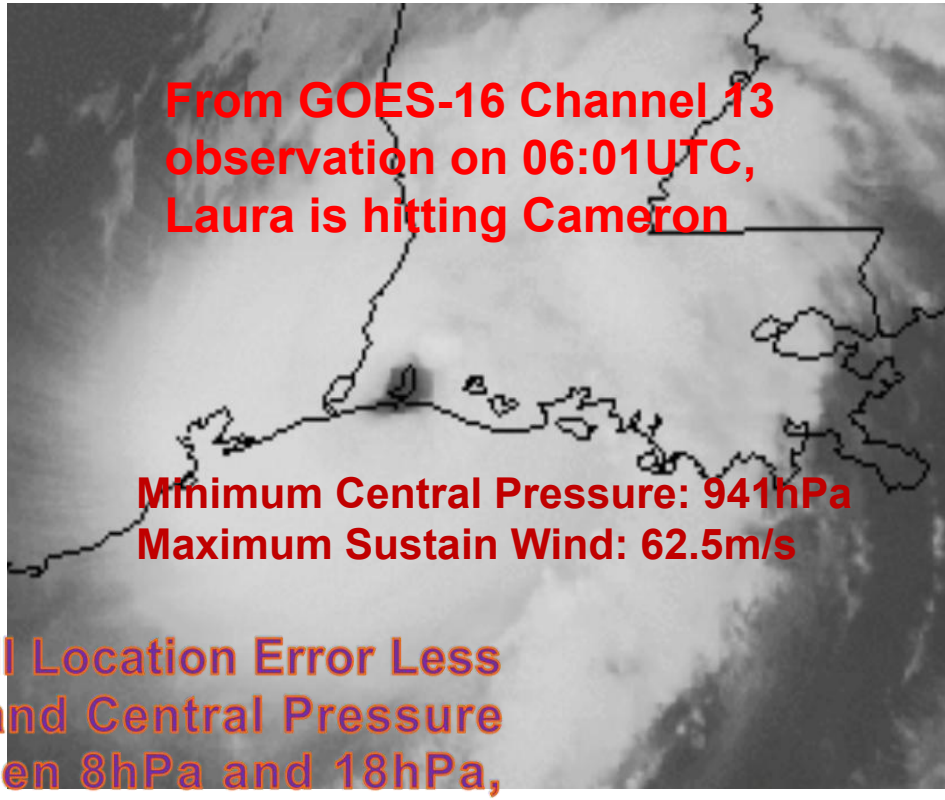
Here’re some Cases

Hurricane Laura’s Landfall

Squall line on Aug. 28th

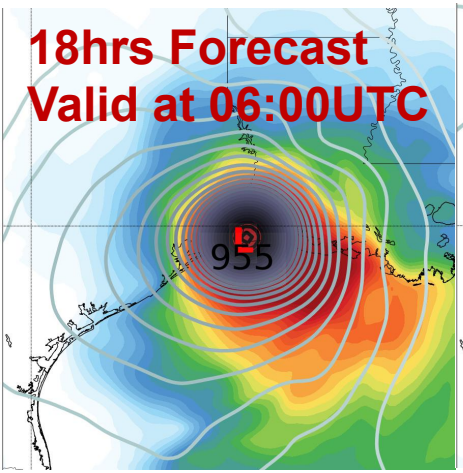
Hurricane Laura's Landfall

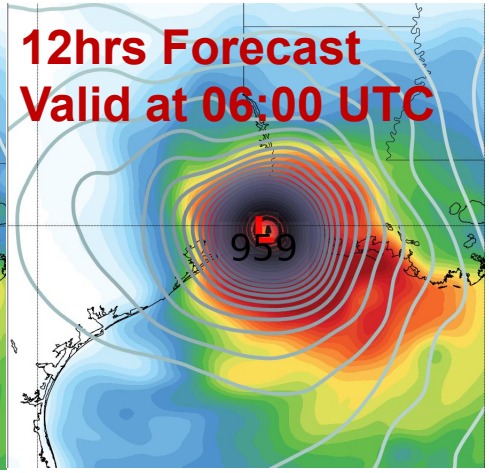


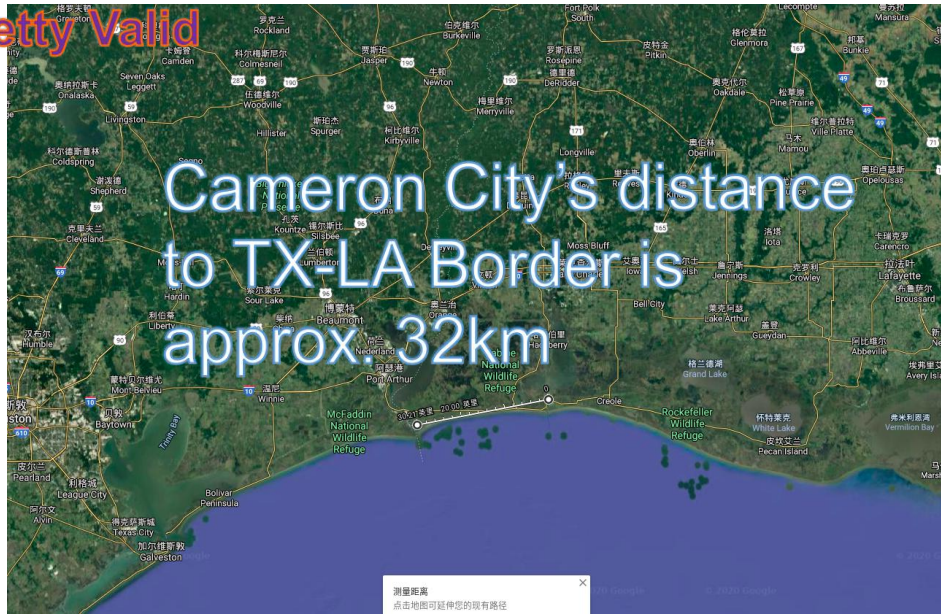


Minimum Central Pressure: 941hPa
Maximum Sustain Wind: 62.5m/s

With Landfall Location Error Less than 17km and Central Pressure Error between 8hPa and 18hPa, System is Pretty Valid

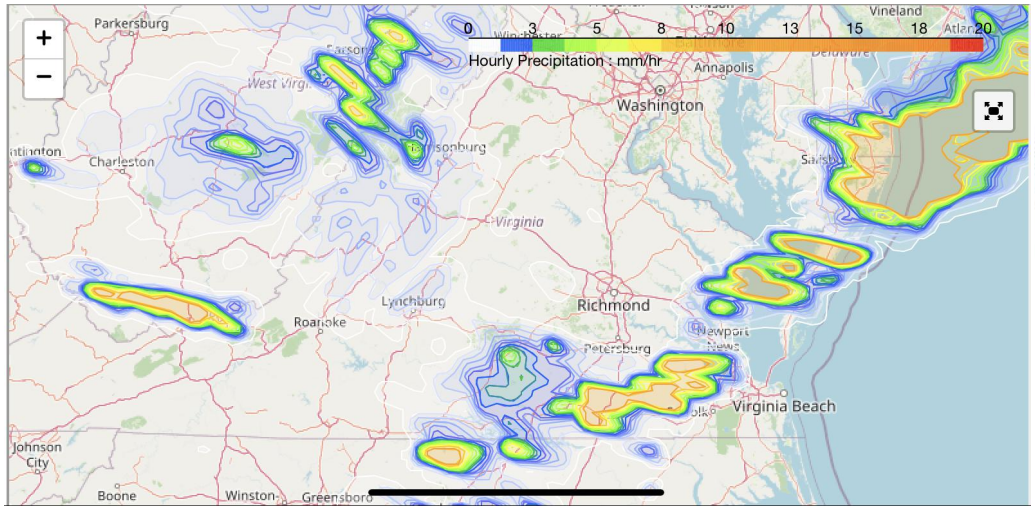




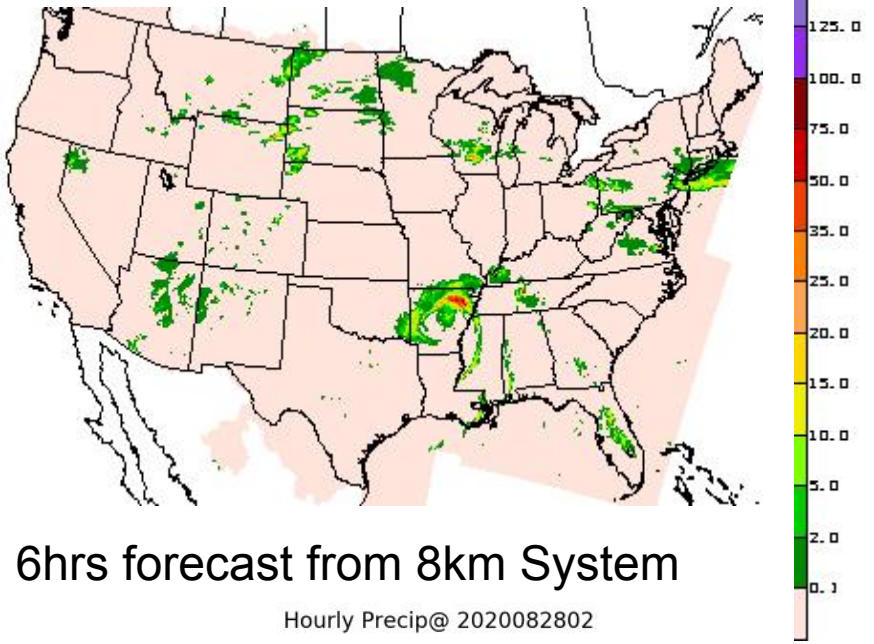


Squall line at 0200UTC Aug. 28th

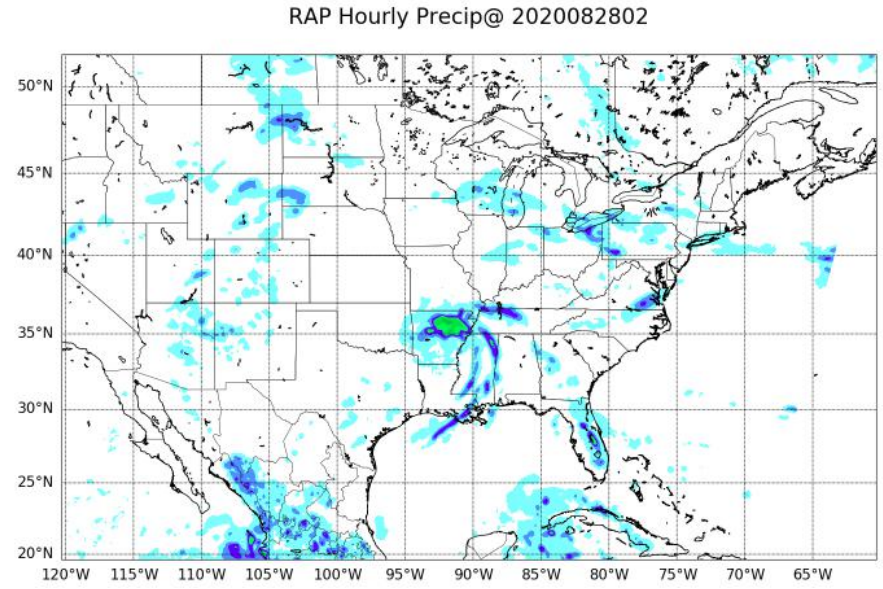
6hrs forecast from 3km System



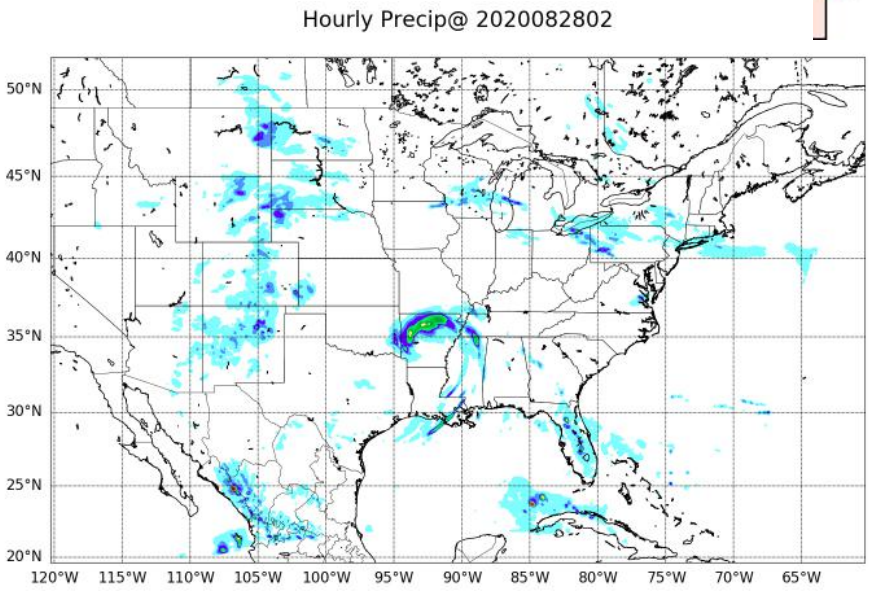
StageIV QPE



6hrs forecast from RAP



6hrs forecast from 8km System



Part IV

Next Stage Plans of Cooperating with the City of Hampton

Devasitating Weather-related Disasters Since 1950

Thunderstorm	Hail	Flooding	Winter Storm	Strong Wind	Heavy Snow	Tropical Cyclone	Ice Strom	Dense Fog	Wildfire
2064	896	335	126	124	48	31	21	2	2

Forecast Products	Parameters Needed	Status				Comments
		Finished	Easy	Moderate	Hard	
Tropical Cyclone	Mean Sea level Pressure 10m AGL Wind Speed Precipitation	√				
Winter Strom and Heavy Snow	Low Level Air Temperature Low Level WInd Speed Precipitation	√				Add some Plots
Flooding	Terrain Precipitation 10m AGL Wind				√	River Model and Ocean Wave Model Needed
Thunderstrom and Hail	Cloud Microphysics		√			Lightening Index Needed
Ice Storm	Precipitation Surface SKin Temperature Road Type			√		Quantify Highway Interchange

Resource is Not Enough and Not Capable to do this


Thanks for listening!
Any Questions?