# Leveraging Ensemble Prediction Developments in HAFS to Evaluate Tropical Cyclone Hazards

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University of Maryland, College Park, MD

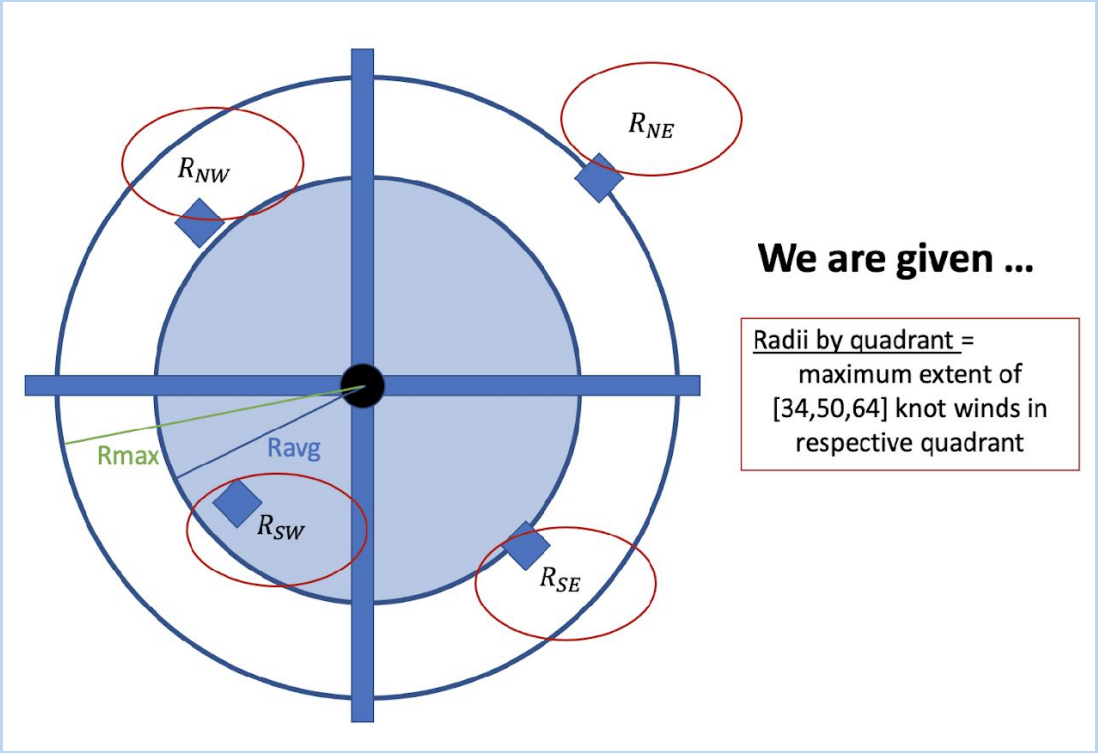
- Evaluate impact of data assimilation strategy on tropical cyclone prediction

How does relaxing Gaussian error assumptions impact the prediction of tropical cyclones?

- Evaluate impact of data assimilation strategy on tropical cyclone prediction

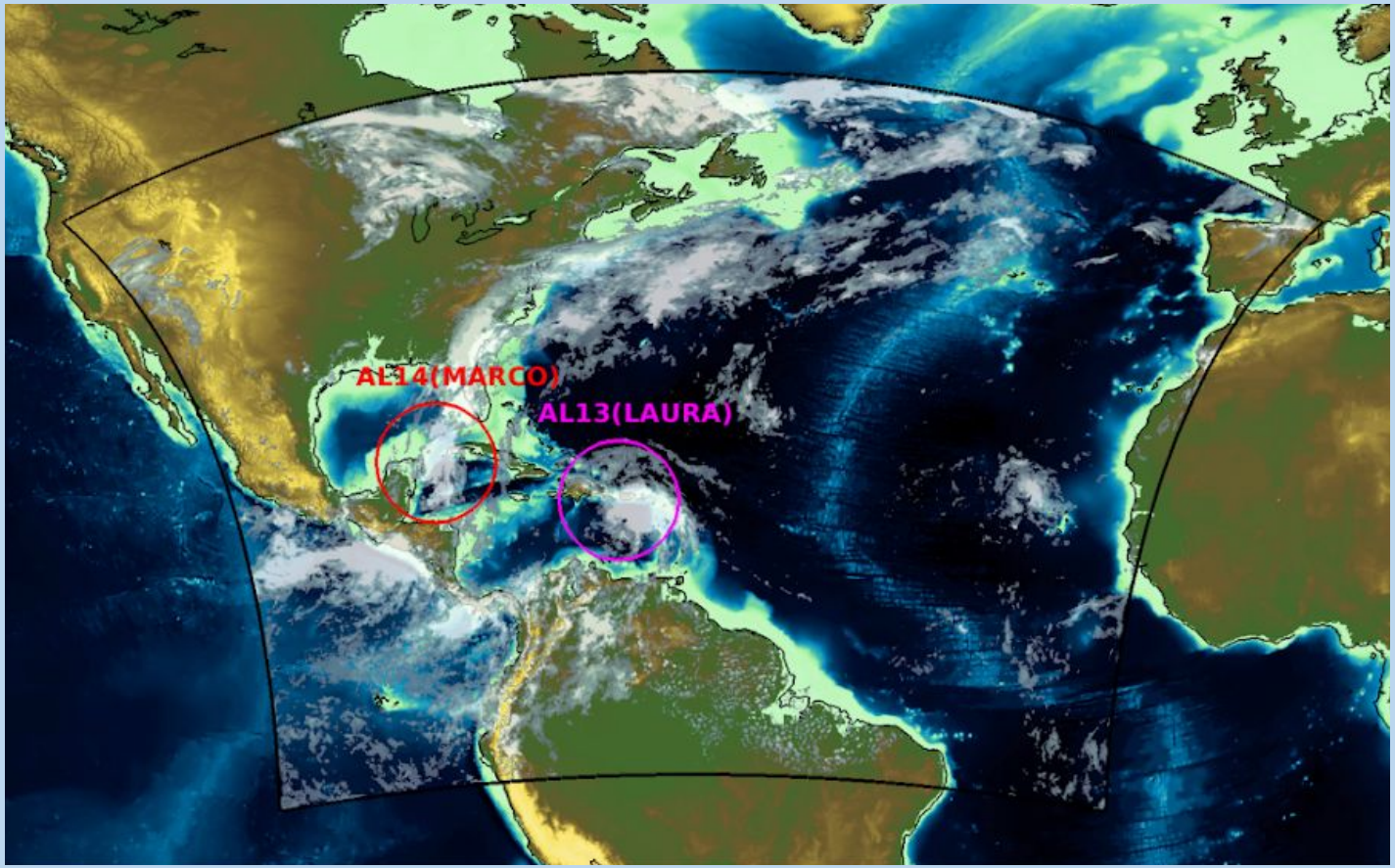
- Extend impact assessment to hazard-driven metrics

Track
Intensity
**Wind distribution (size, asymmetry)**
**Storm Surge** (wind distribution)
**Rainfall** (wind distribution)
**Severe** (wind distribution)




Symmetric TC "size" (defined by radius of 34-knot winds) correlates with associated surge/rainfall

# Regional configuration of HAFS




## Model

- FV3 using physics from 2021 real-time implementation
- 6 km grid
- 81 vertical levels up to 2 hPa

## 19-days of fully cycling DA

- 5 day spin up
- 6-hourly cycling (40 members)
- Forecasts out to 4 days for deterministic solutions and 10 individual members

**Two Atlantic tropical cyclone cases**

# Data assimilation comparison

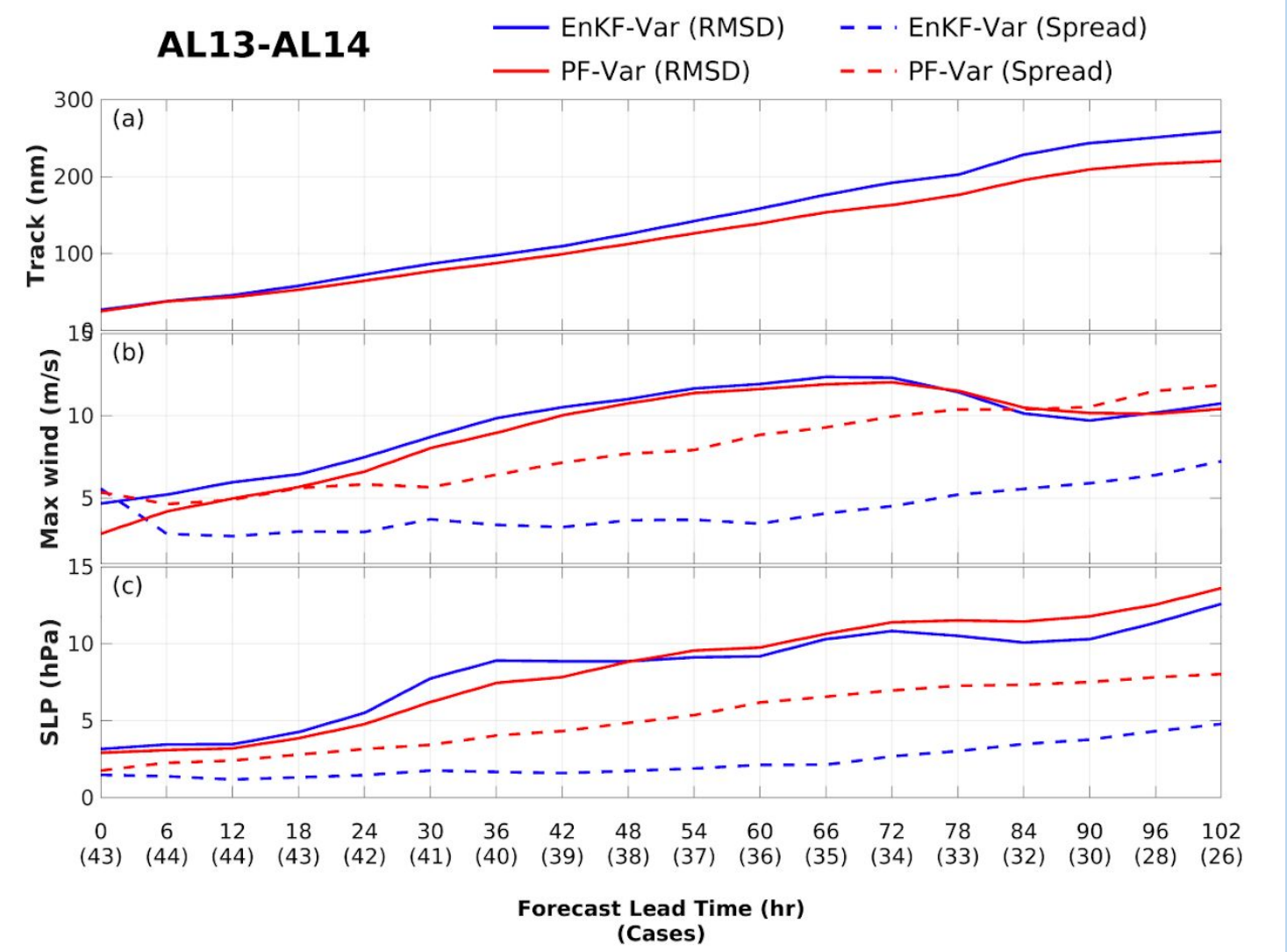
- Updates 40 HAFS ensemble members about variational analysis using:

**EnKF-Var** ← Assumes gaussian error characteristics

**LPF-Var** ← Not constrained by gaussian assumptions

Poterjoy, J. 2022a: Implications of multivariate non-Gaussian data assimilation for multi-scale weather prediction. Mon. Wea. Rev.,
Poterjoy, J., 2022b: Regularization and tempering for a moment-matching localized particle filter. Q. J. Roy. Meteor. Soc.

Comparable mean errors



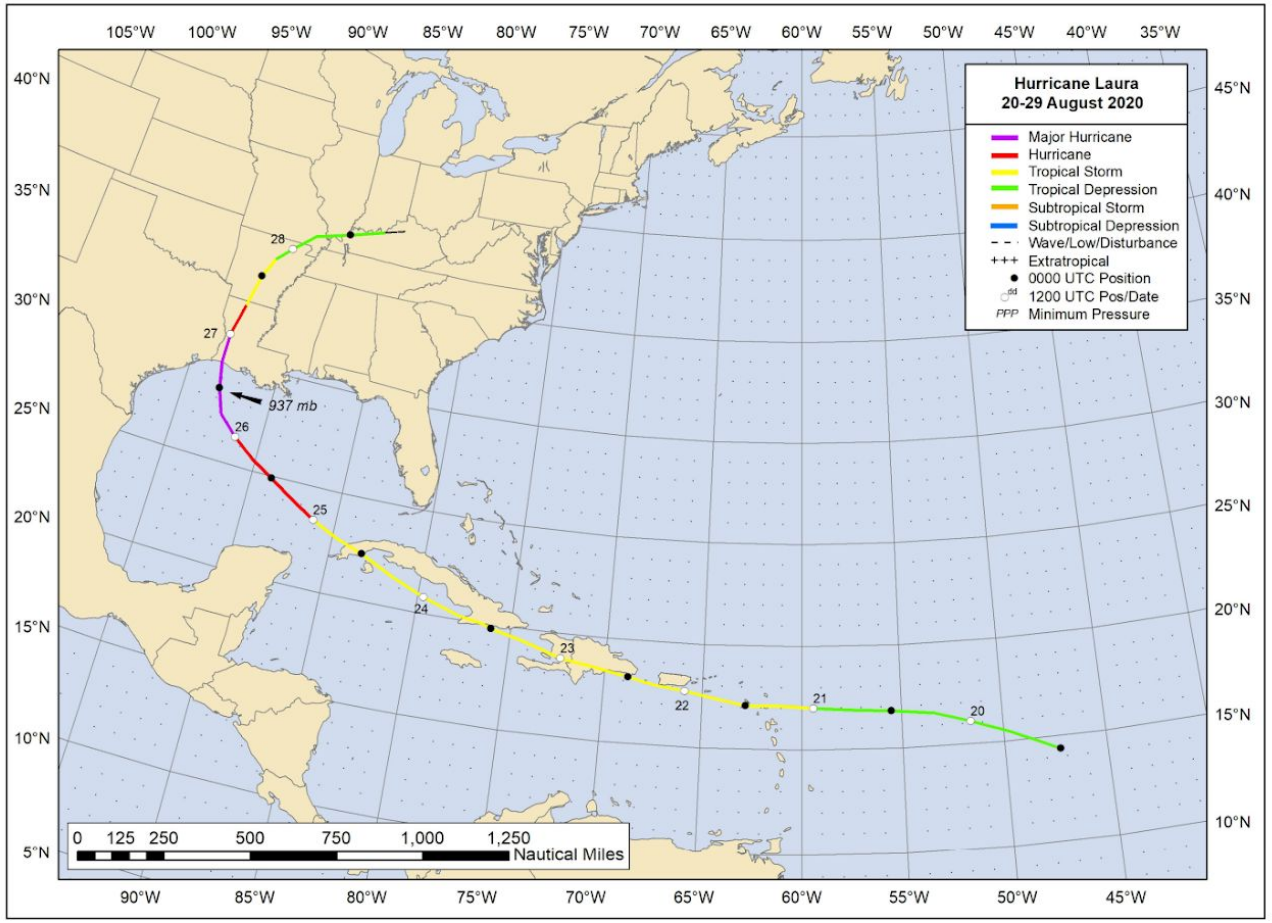

Substantial differences in ensemble spread

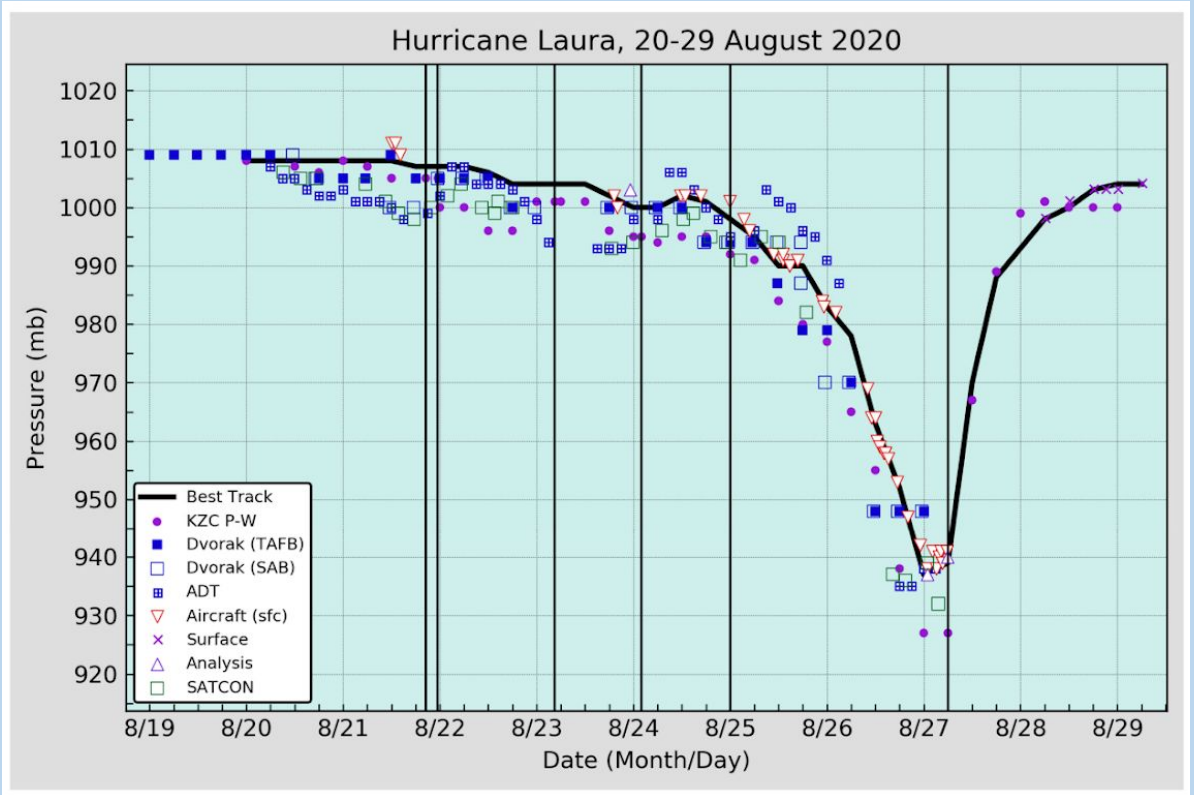
Motivation | Experiments | **Results** | Conclusions

# Tropical Cyclone Case: Laura 2020

Multiple island landfalls

RI in Gulf of Mexico



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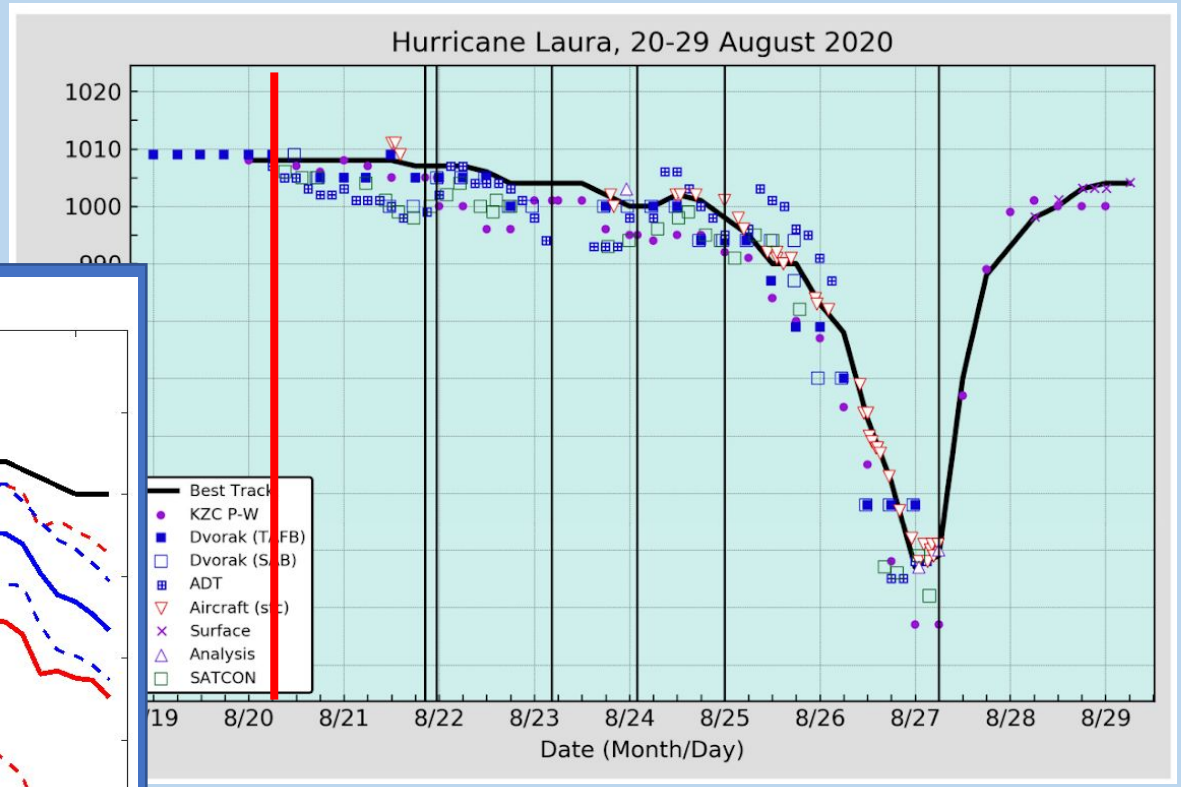
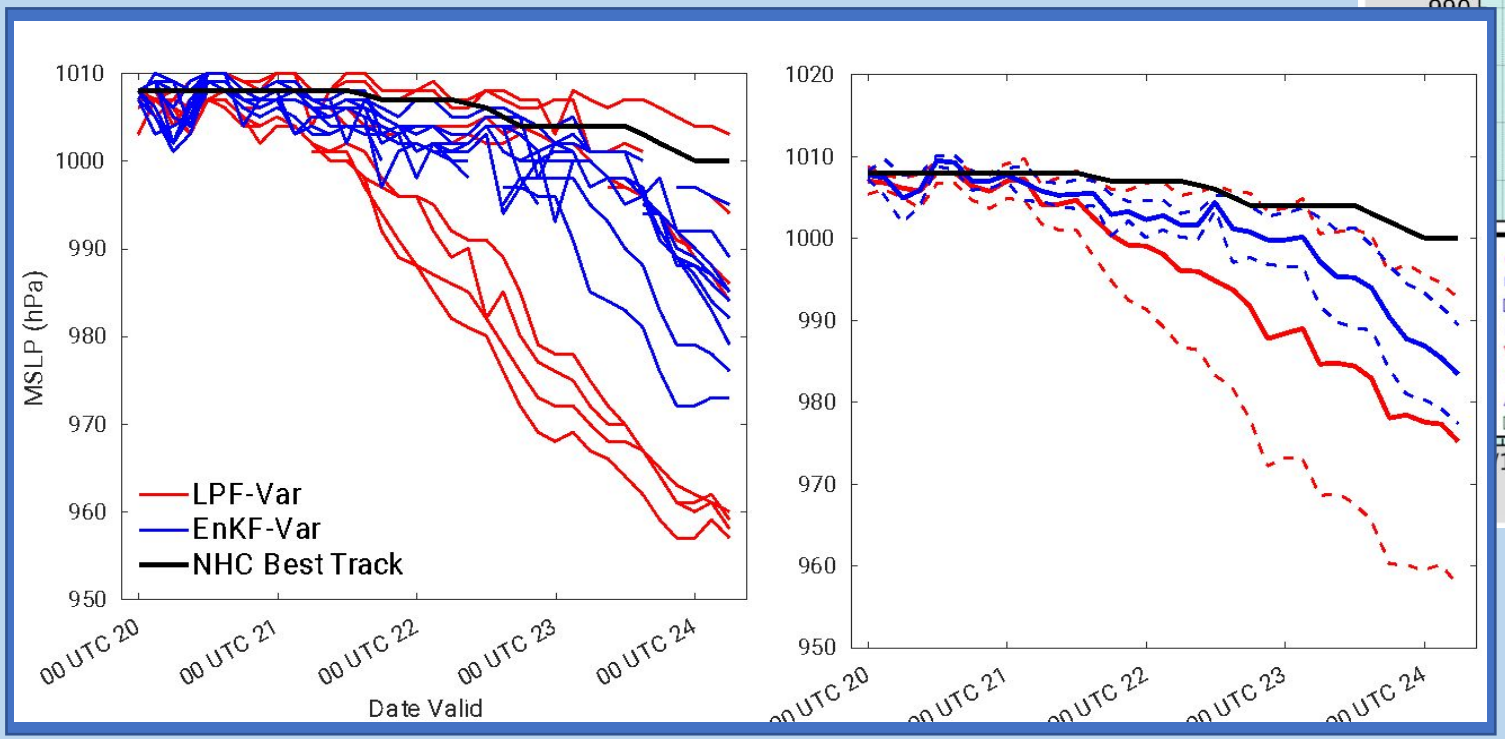
Intensity influenced by island topography



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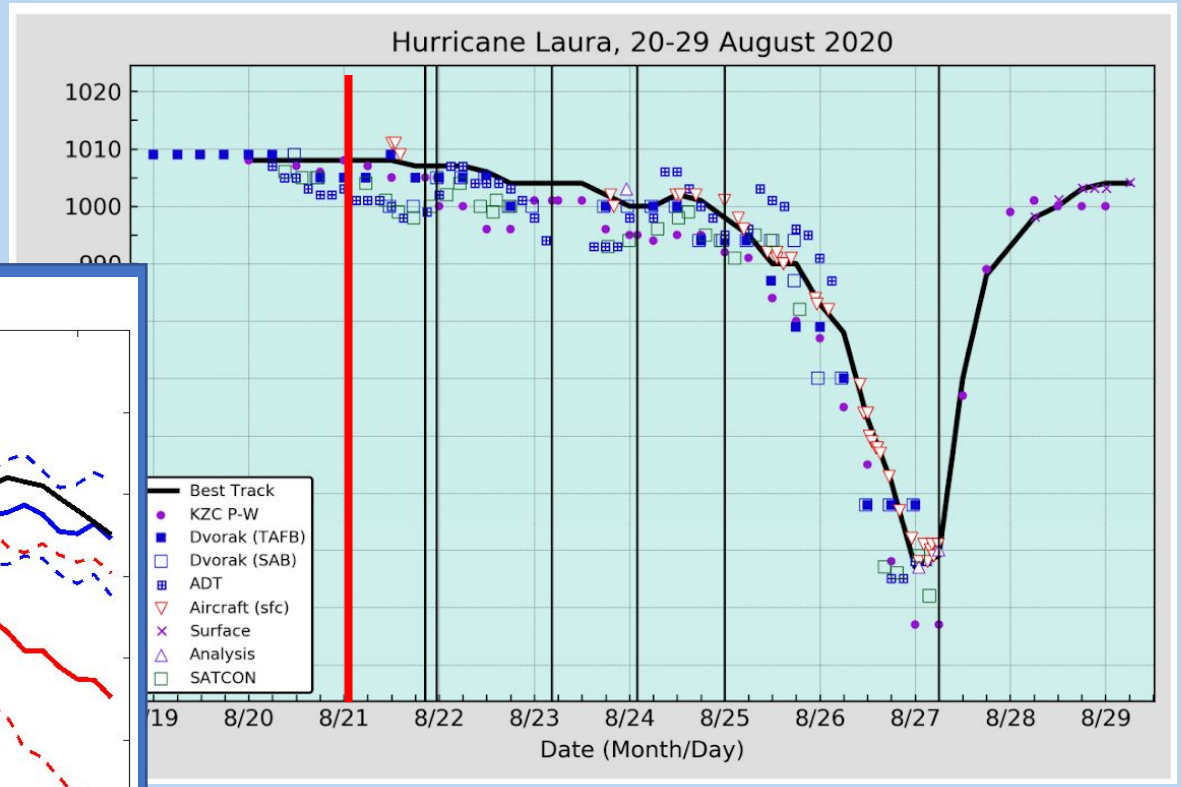


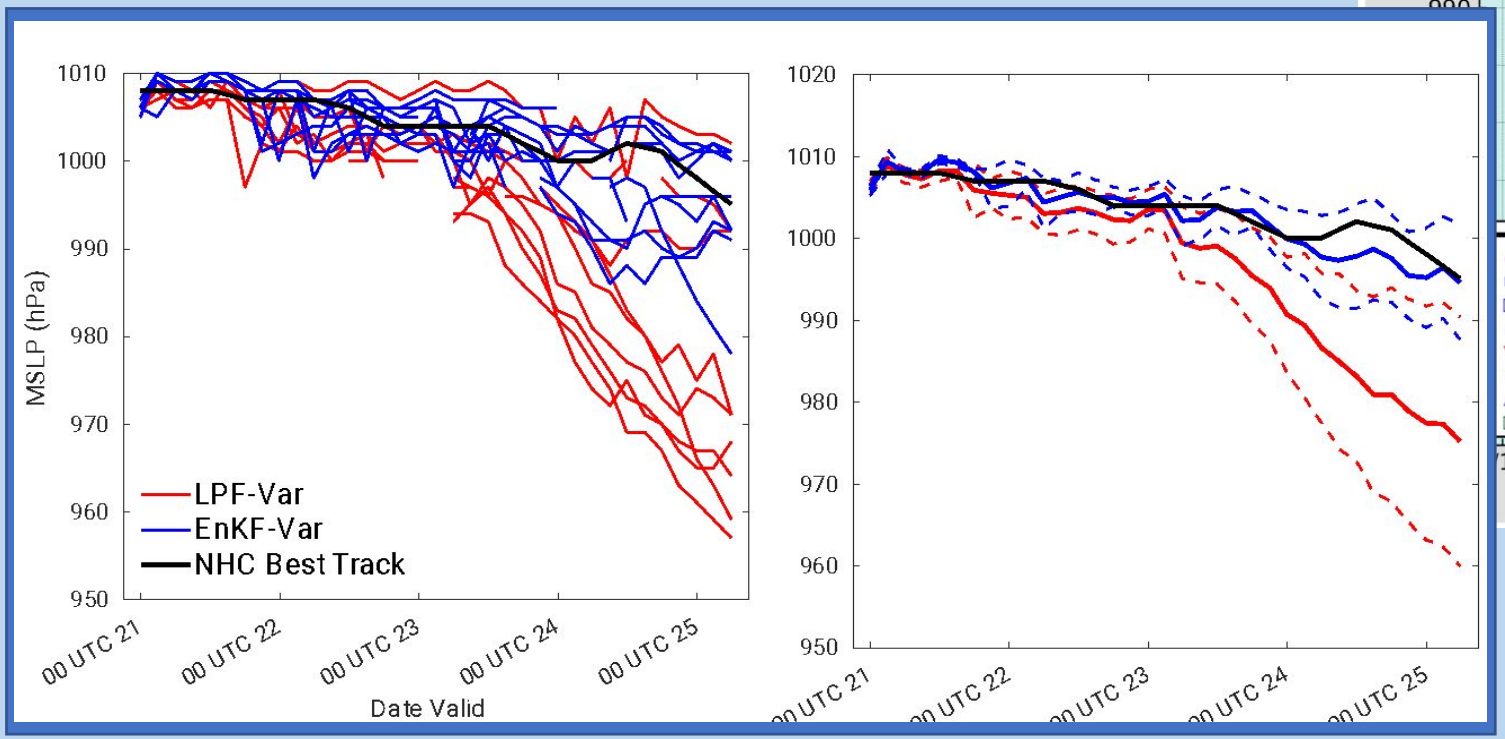

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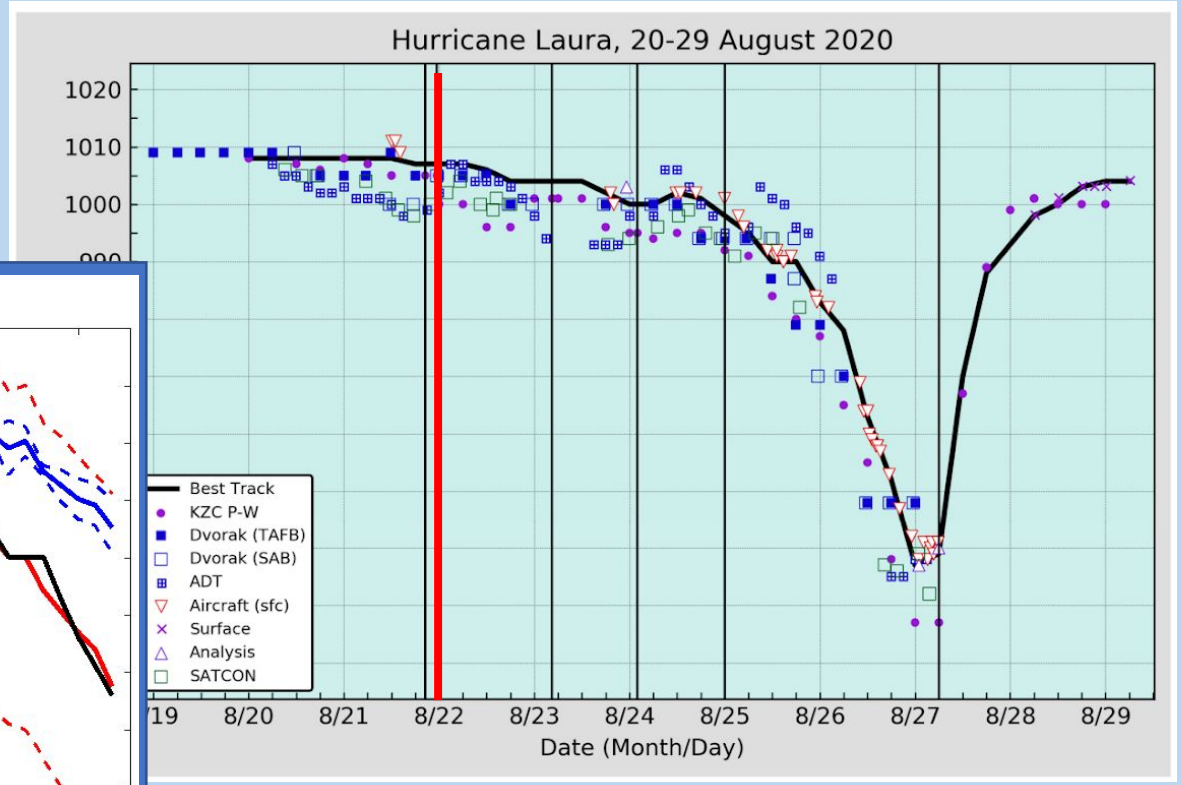


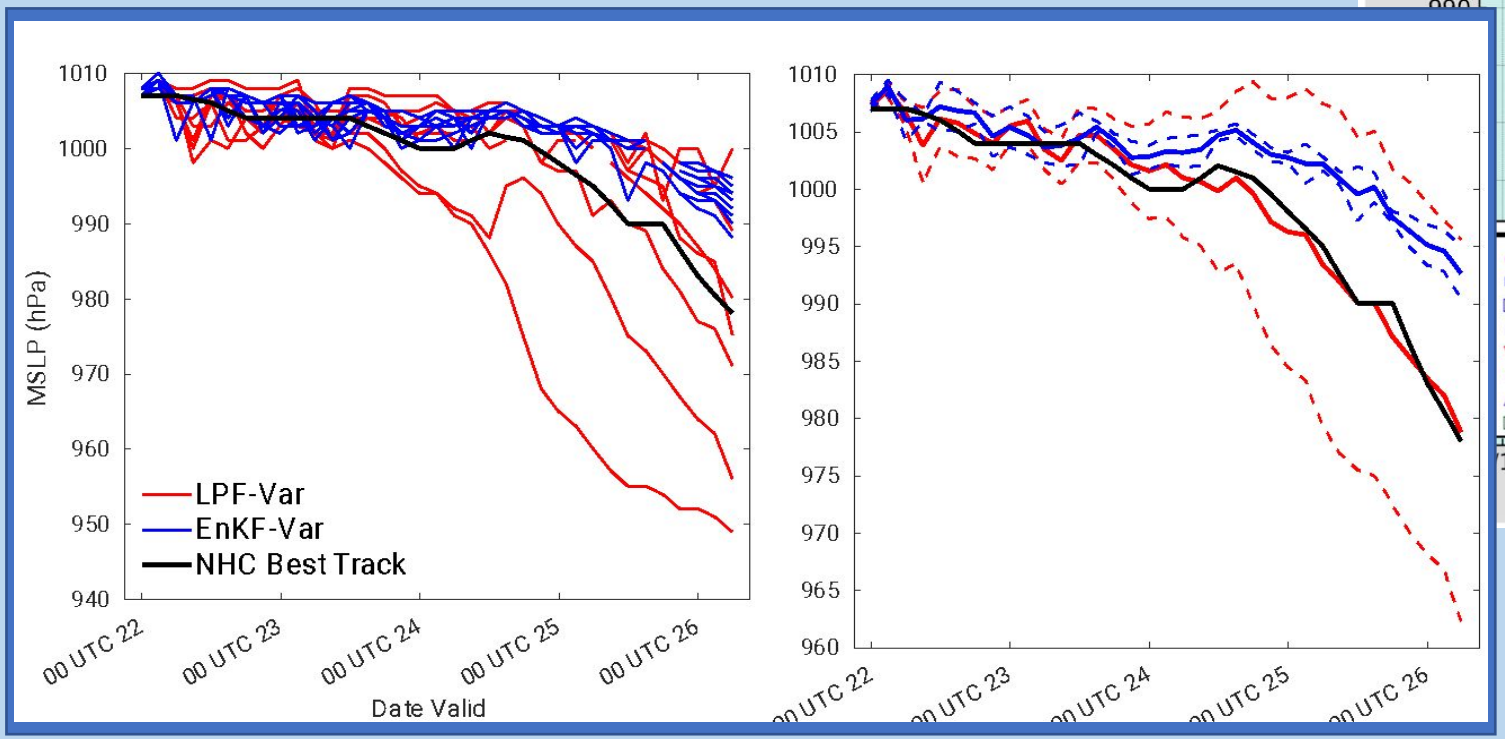

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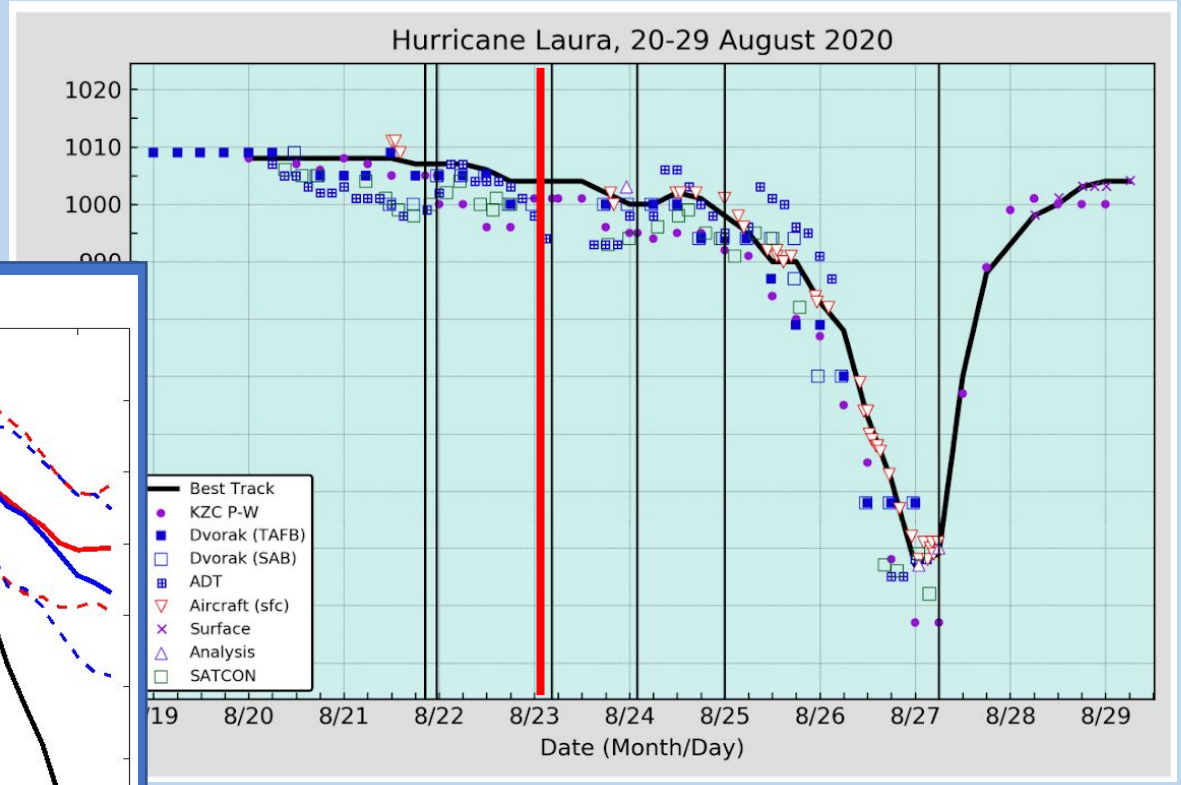


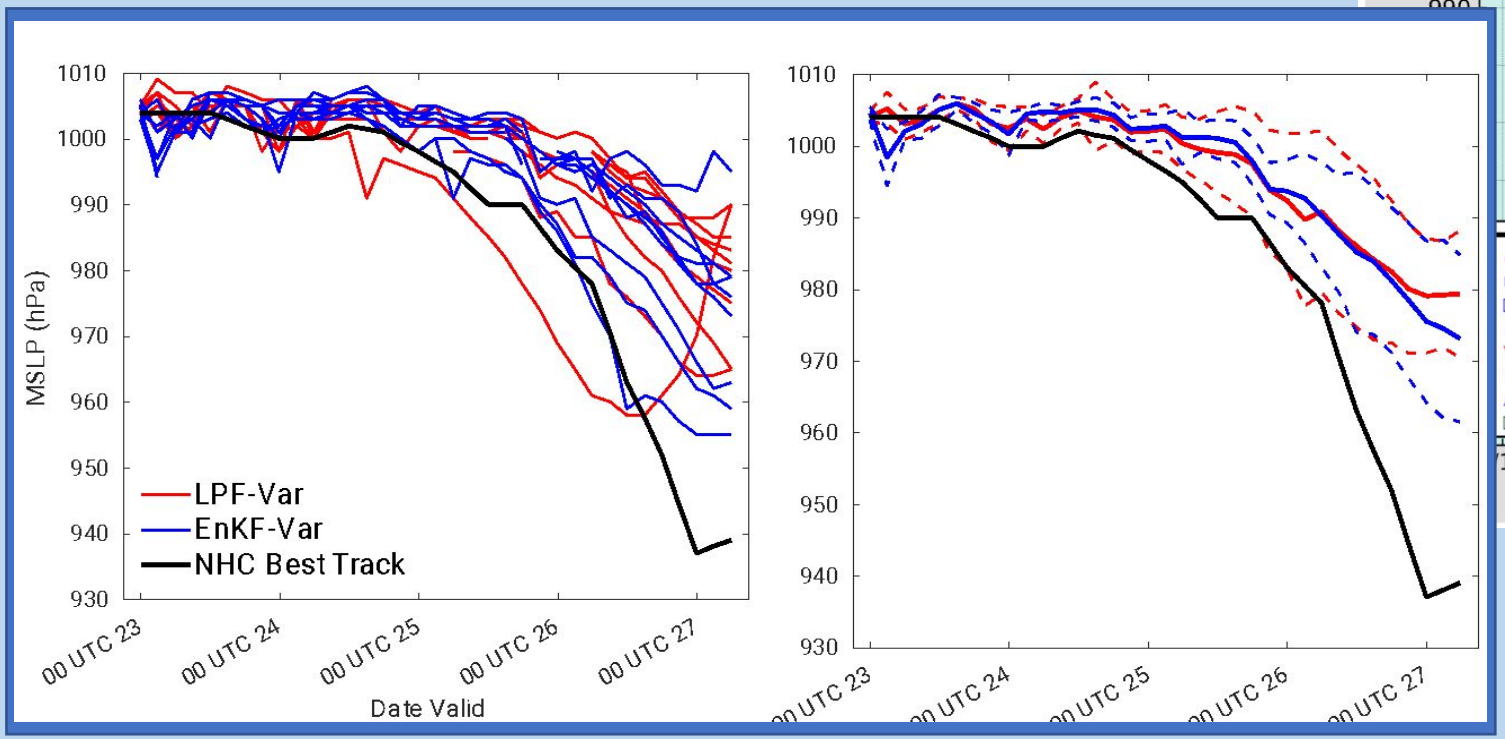

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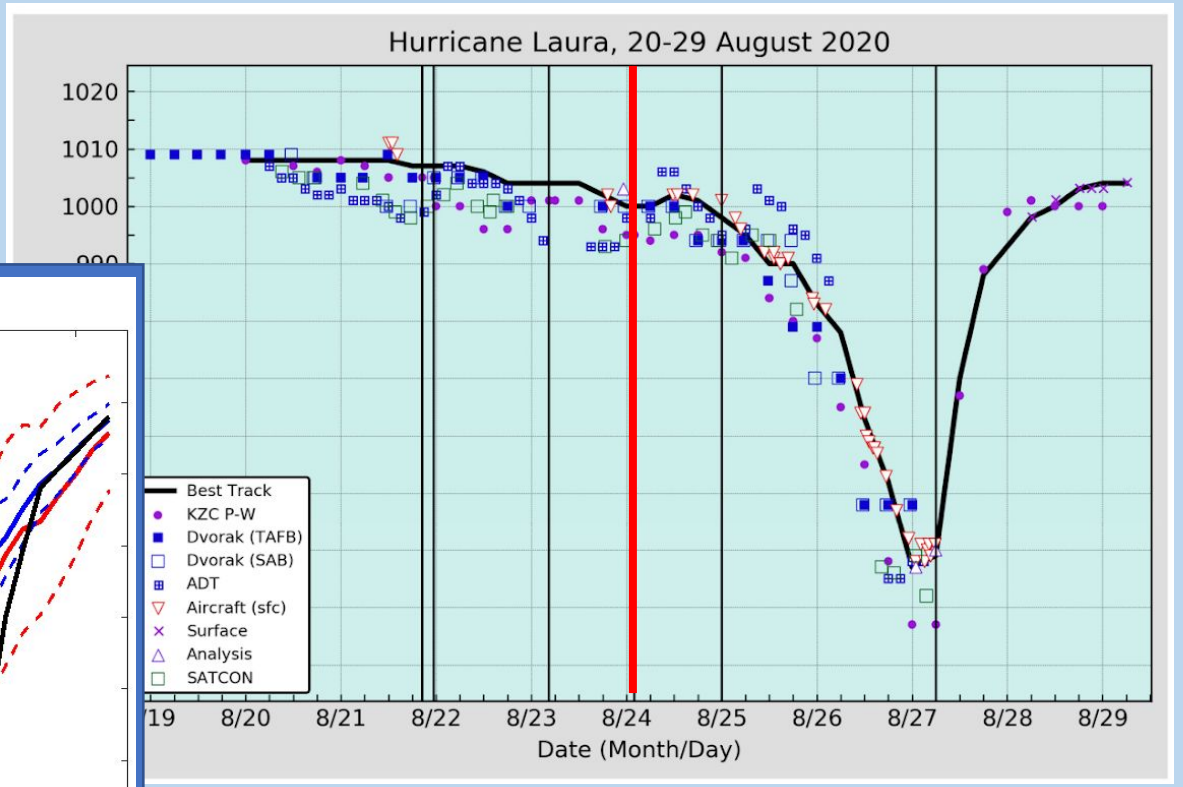
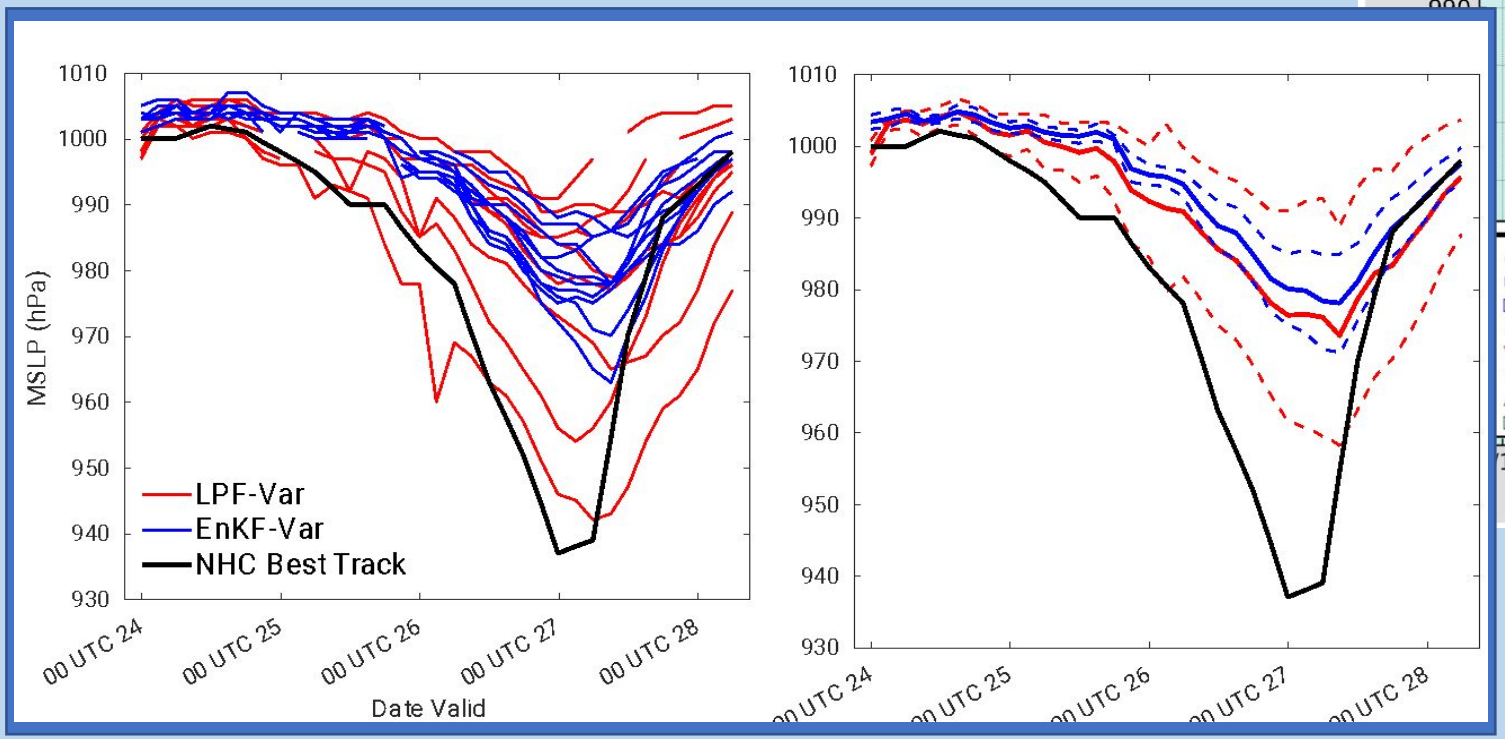


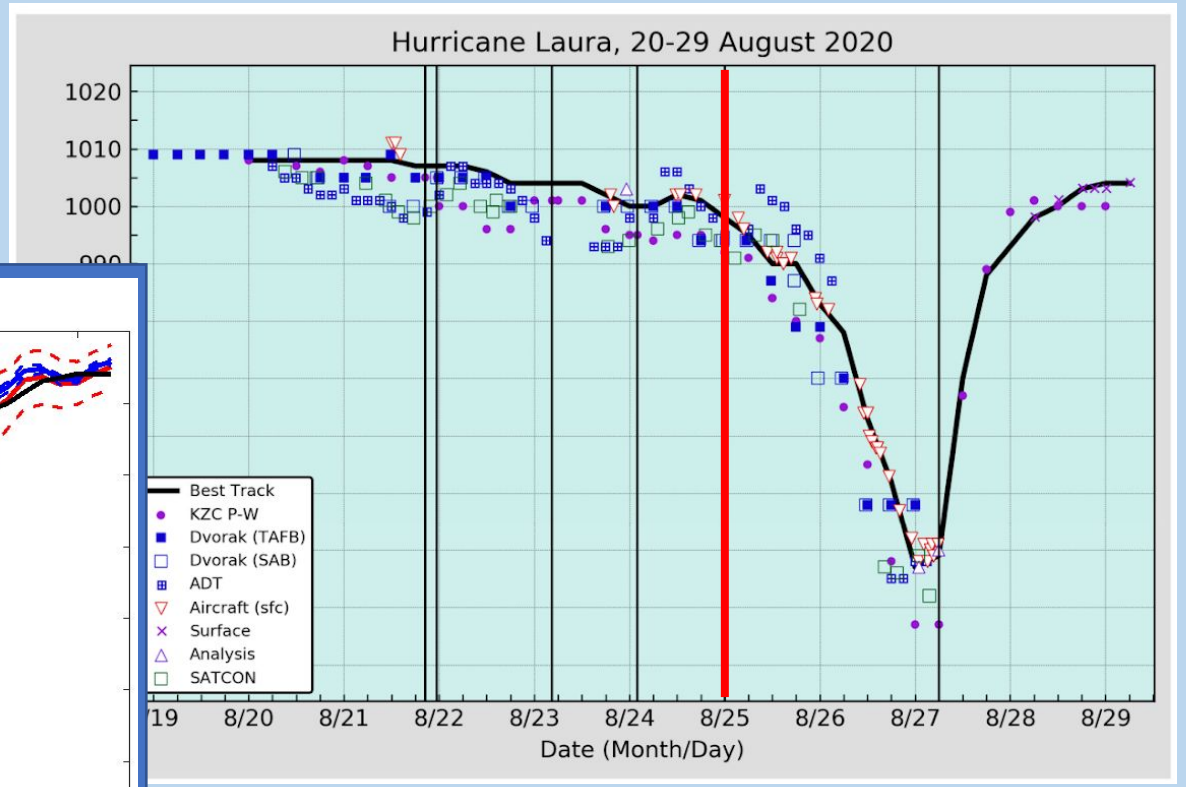



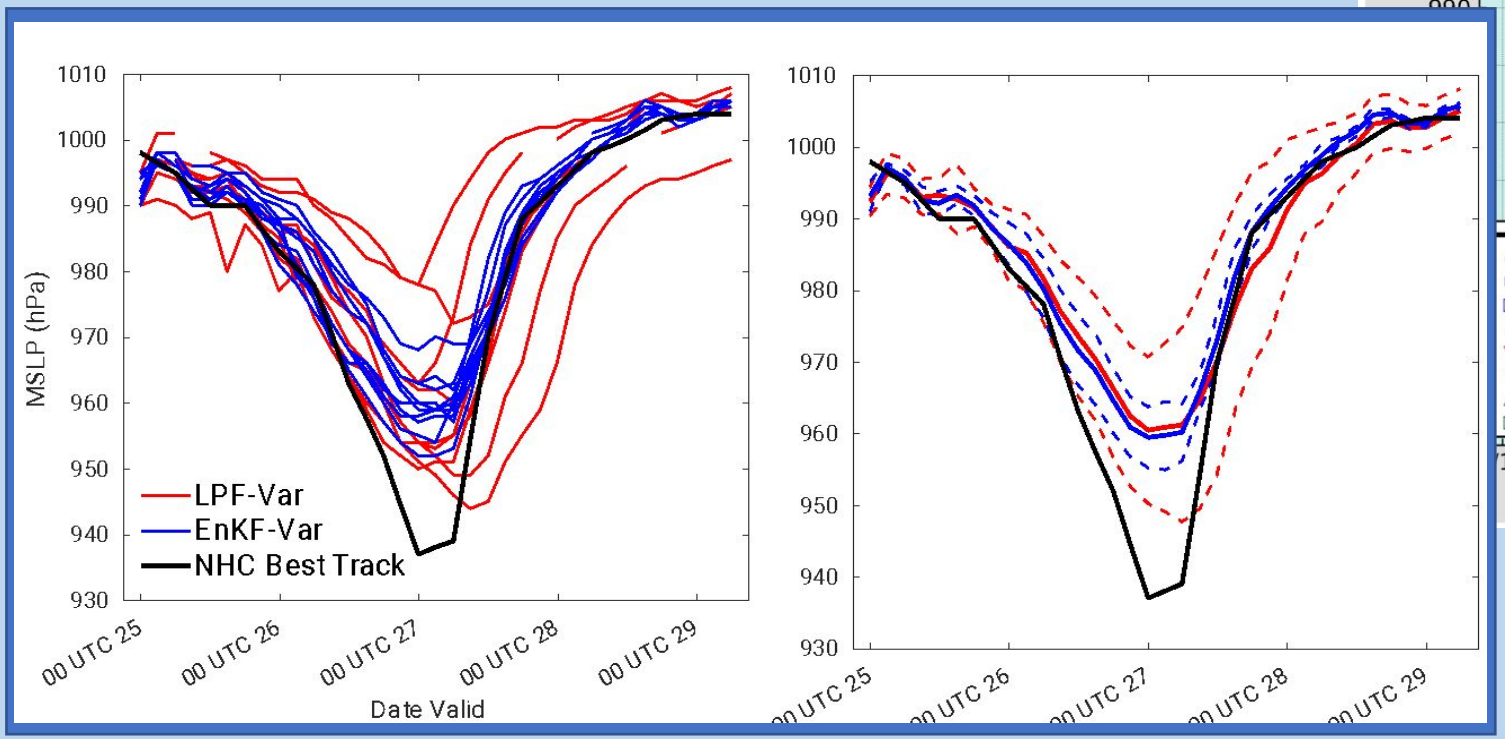
# Tropical Cyclone Case: Laura 2020

Multiple island landfalls

RI in Gulf of Mexico

Rapid intensification has begun



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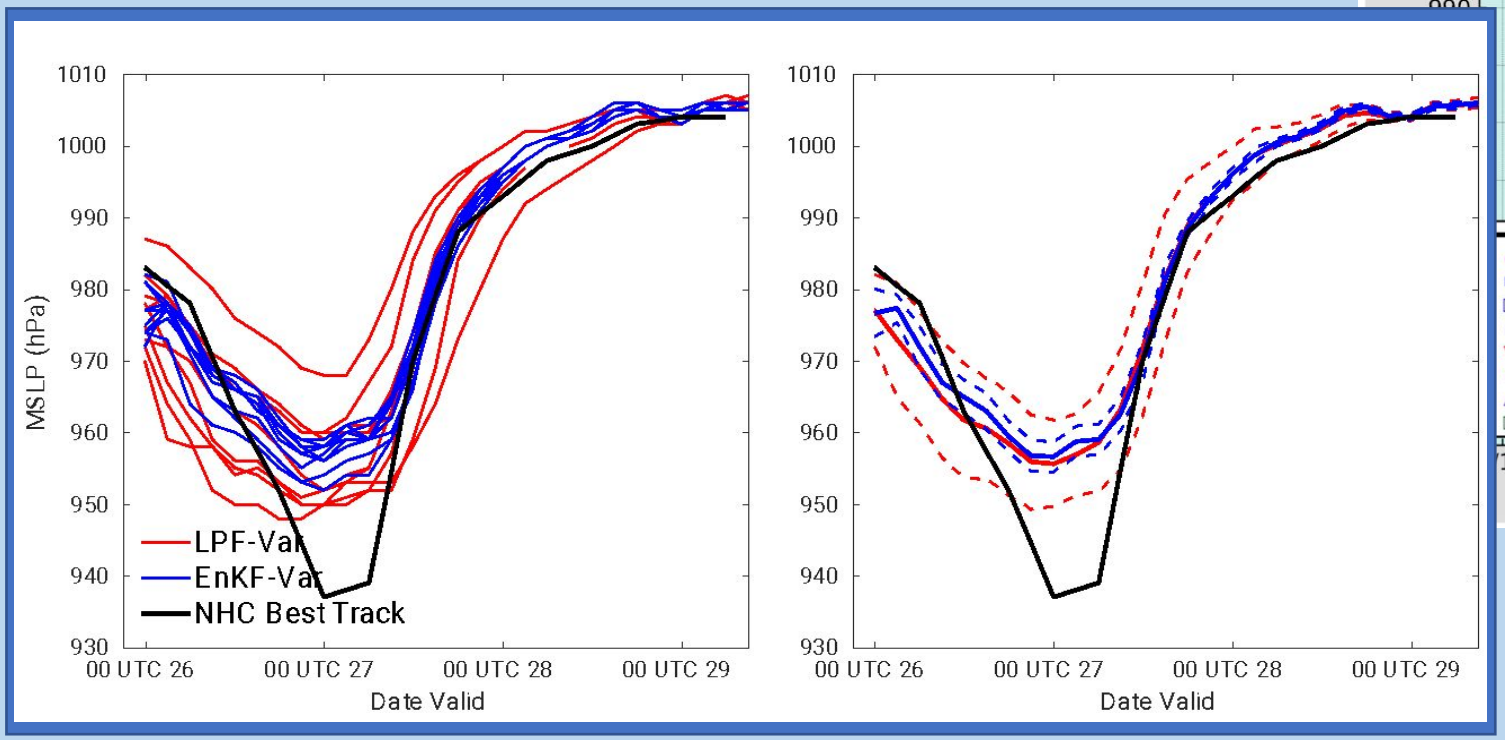


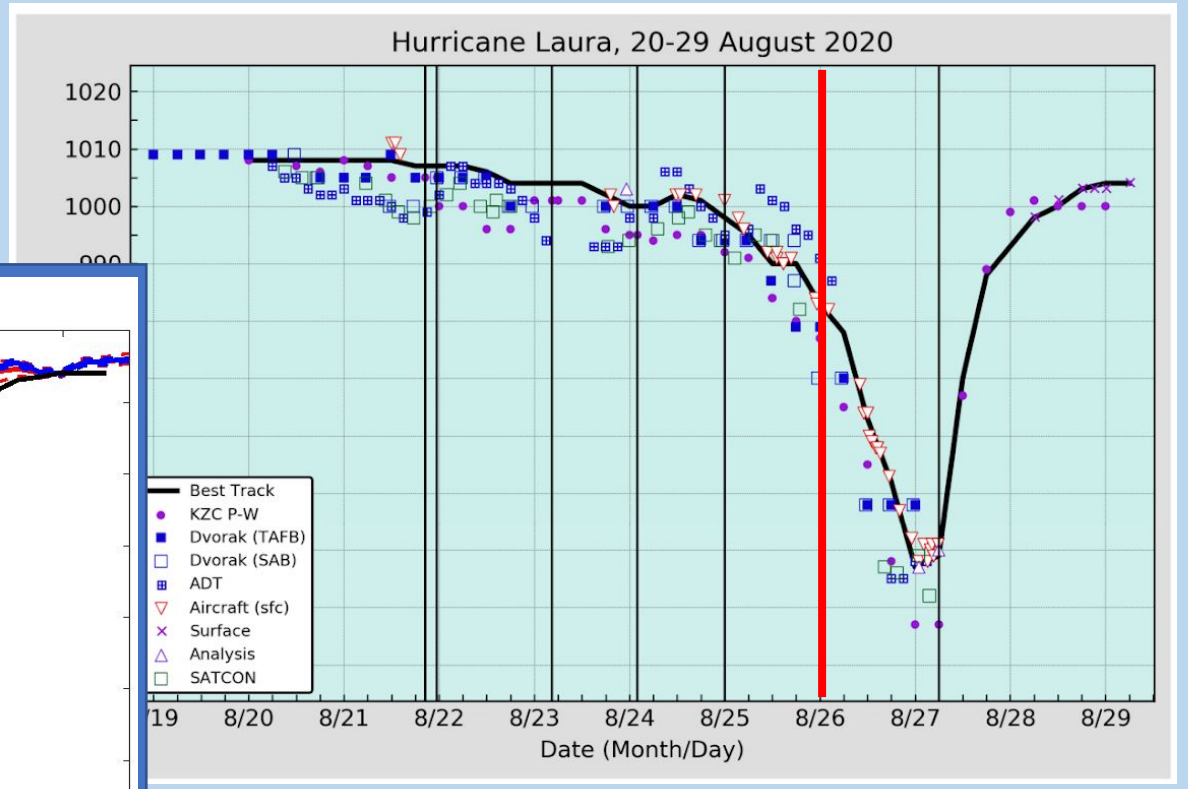

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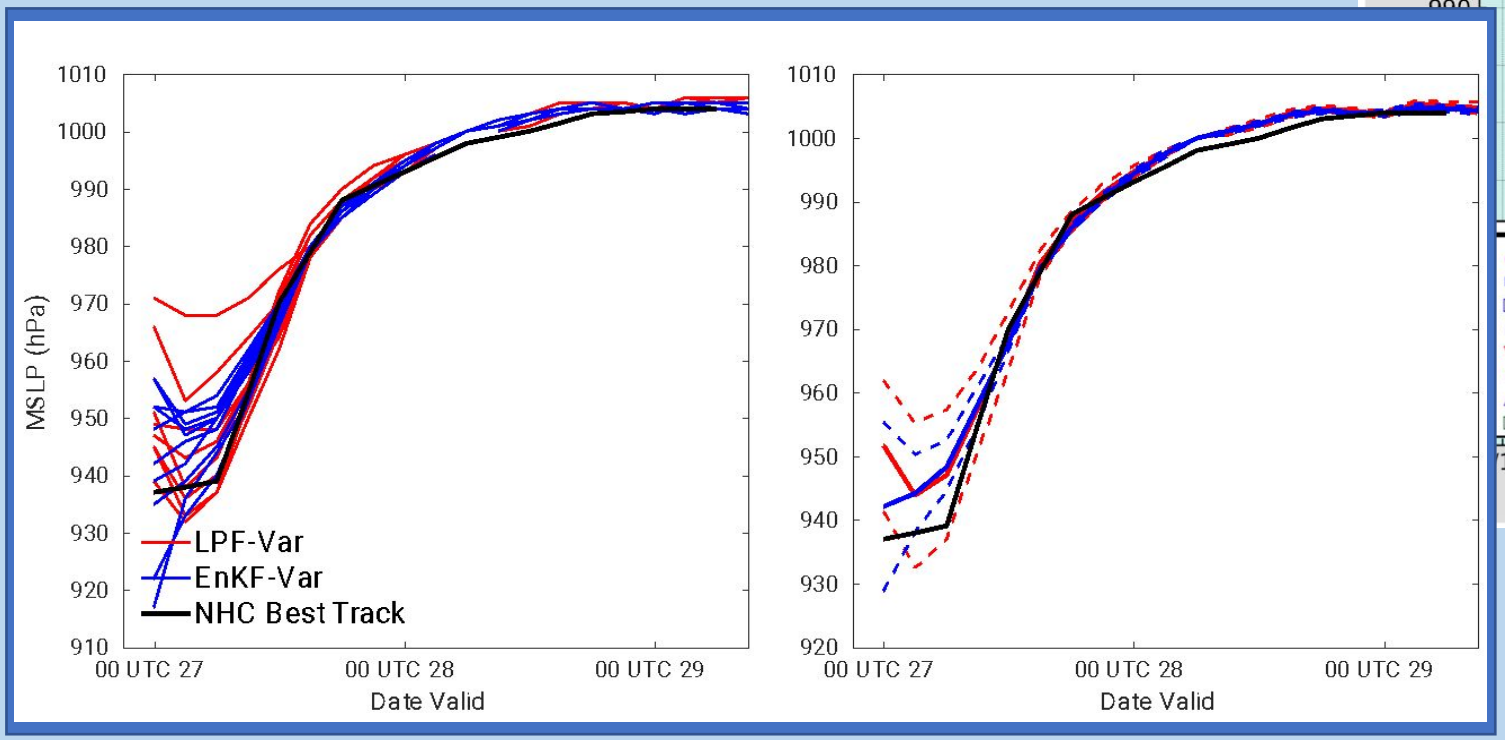
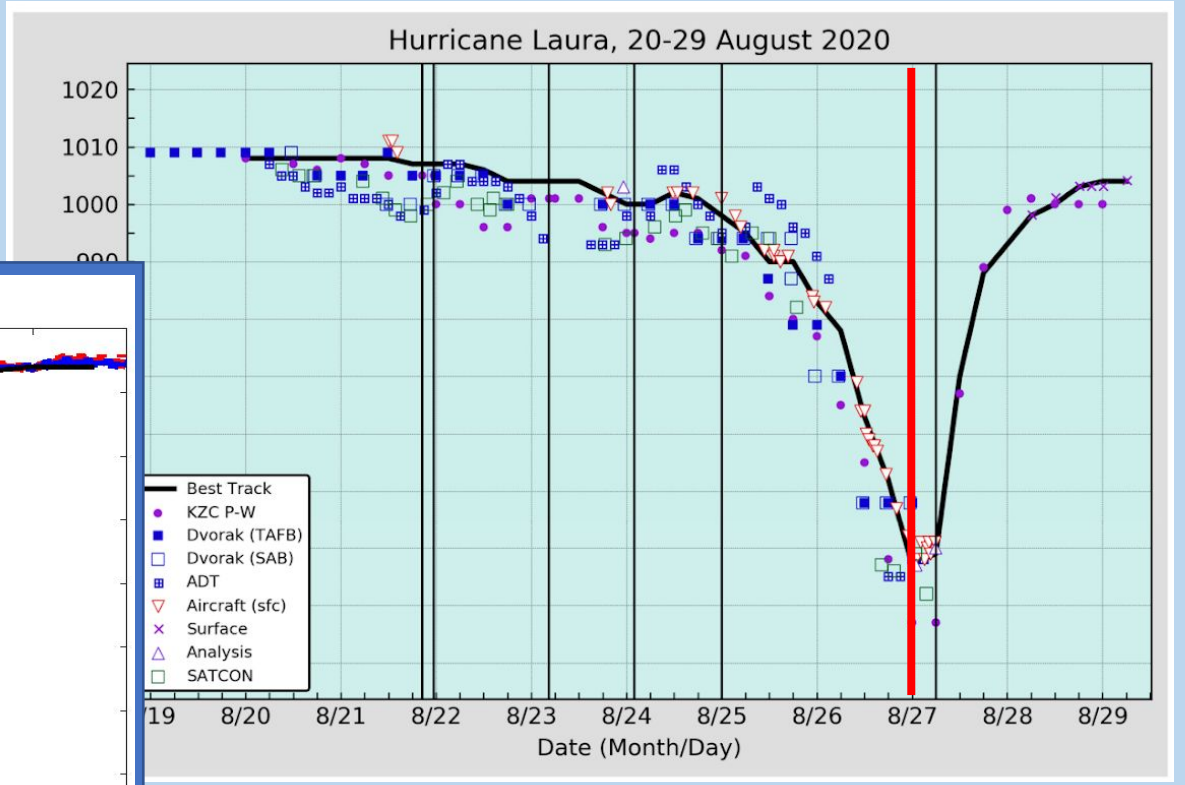
Landfall



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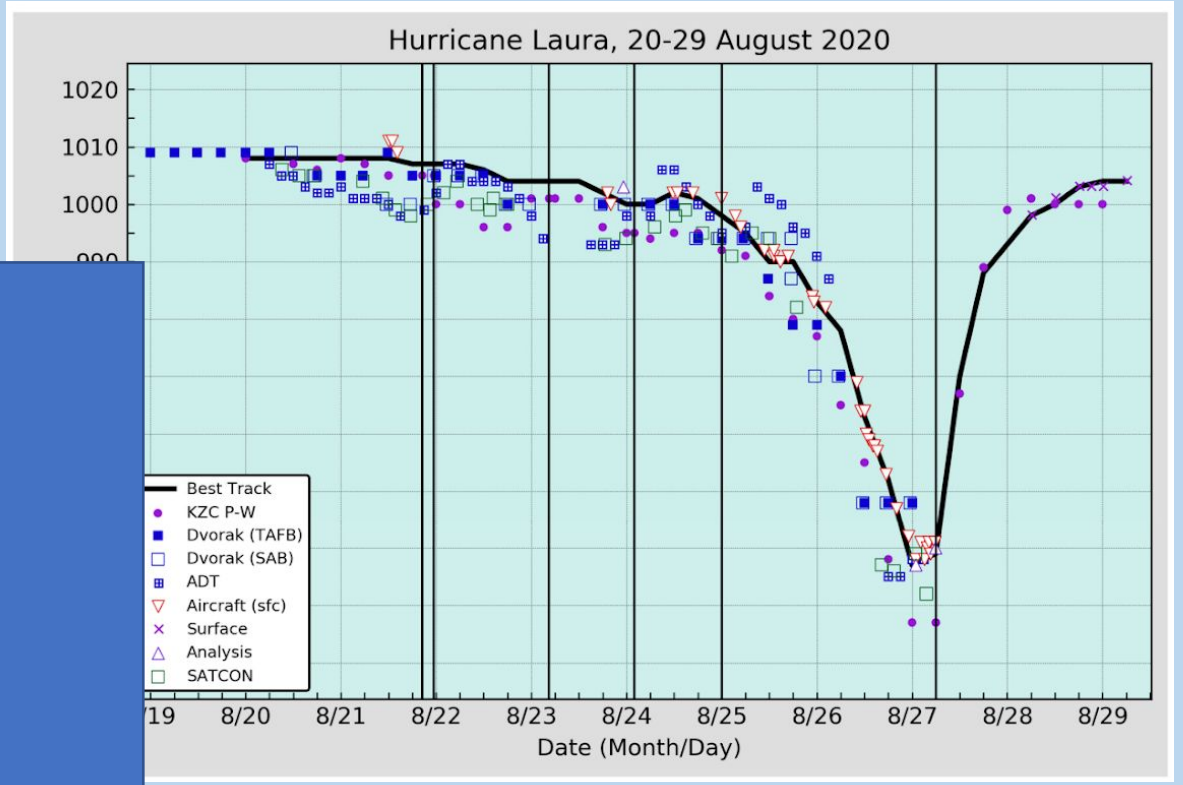

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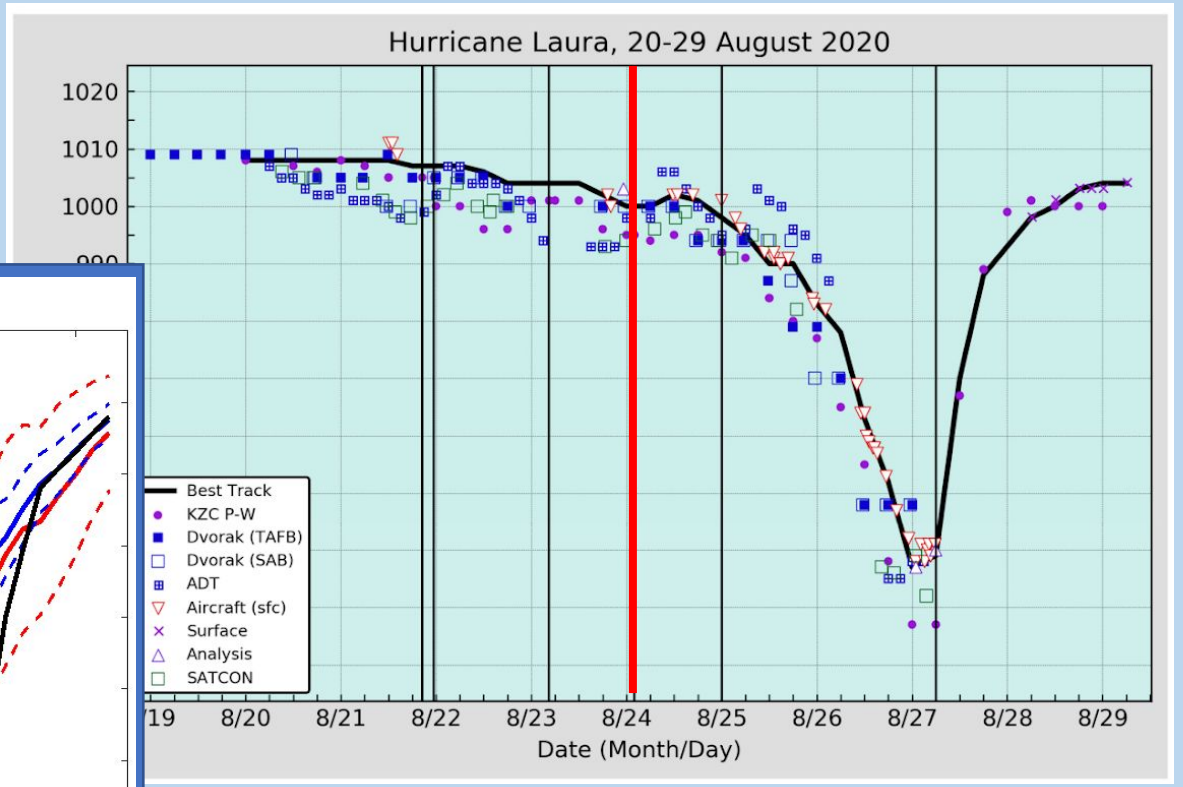


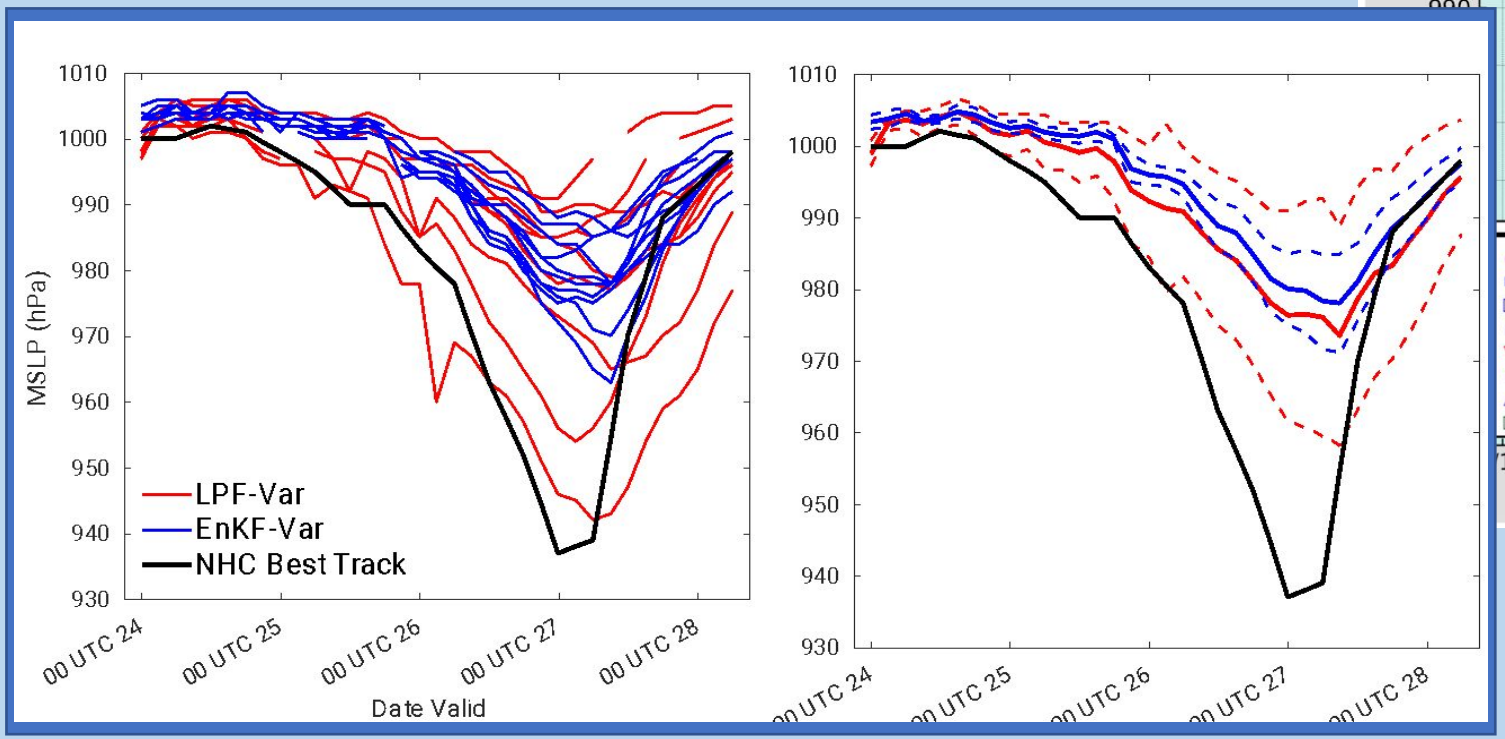

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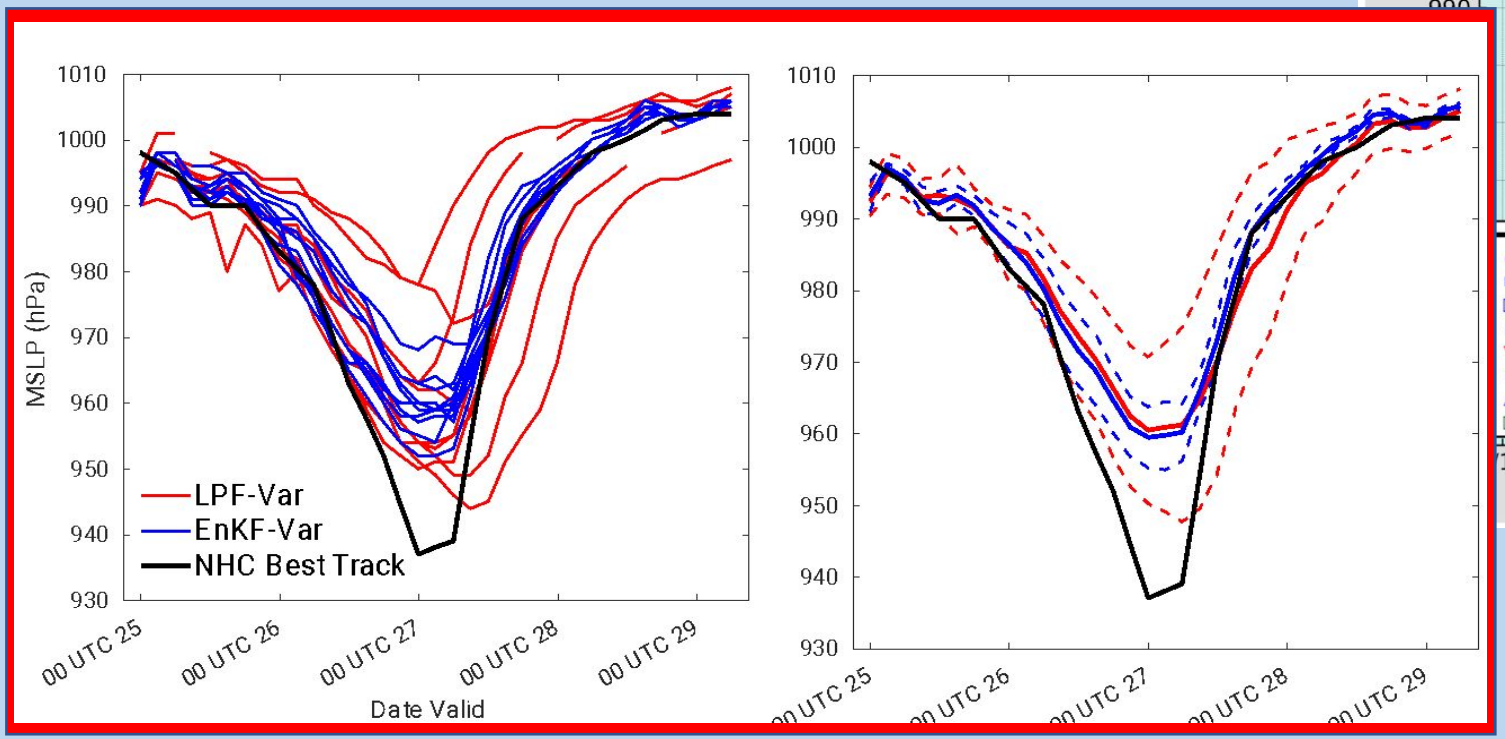
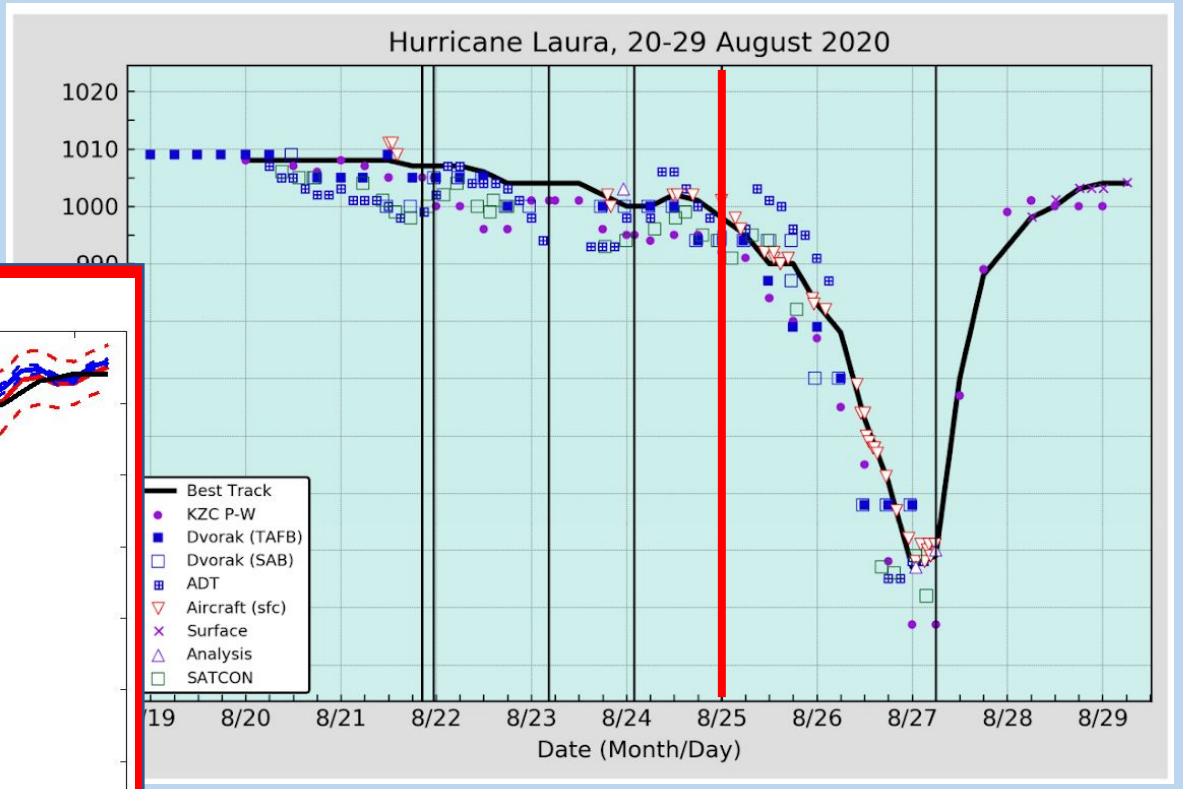
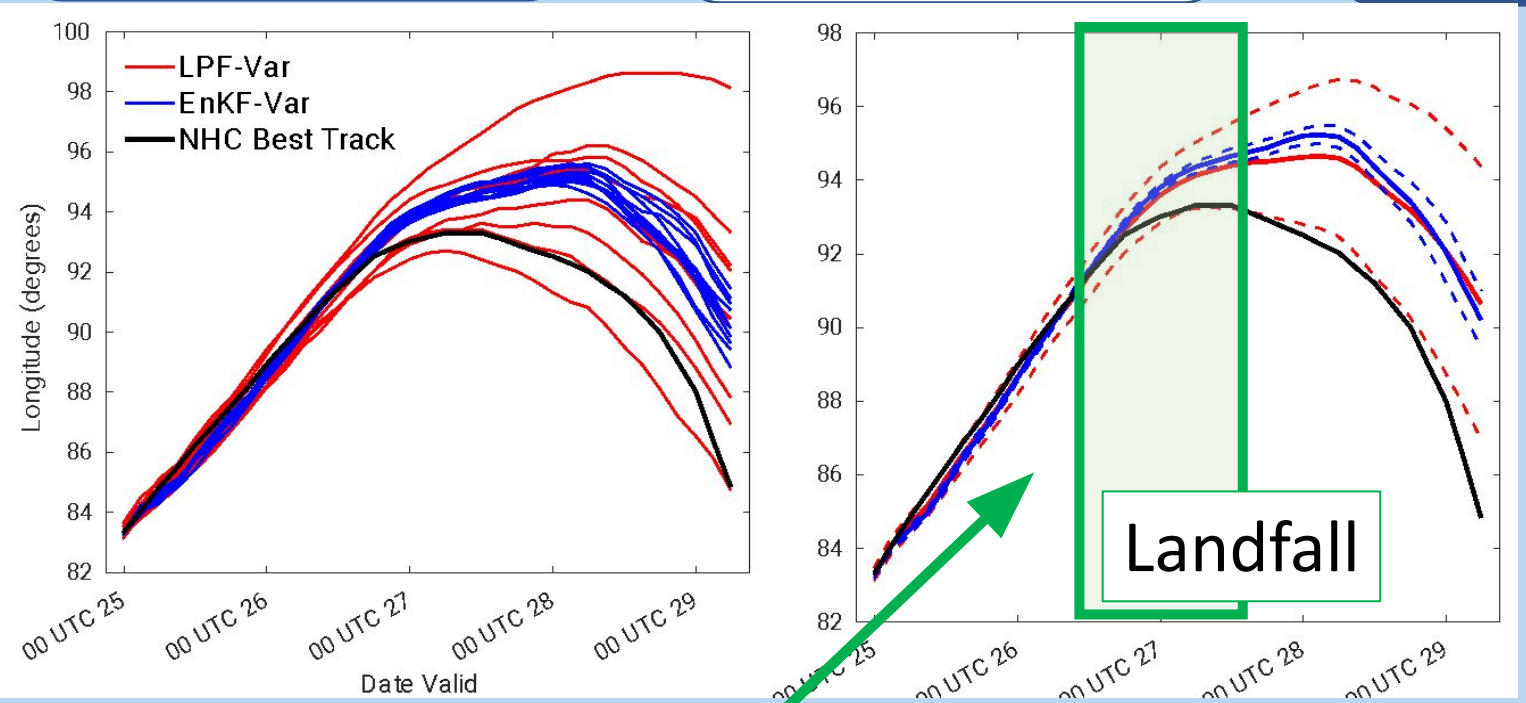
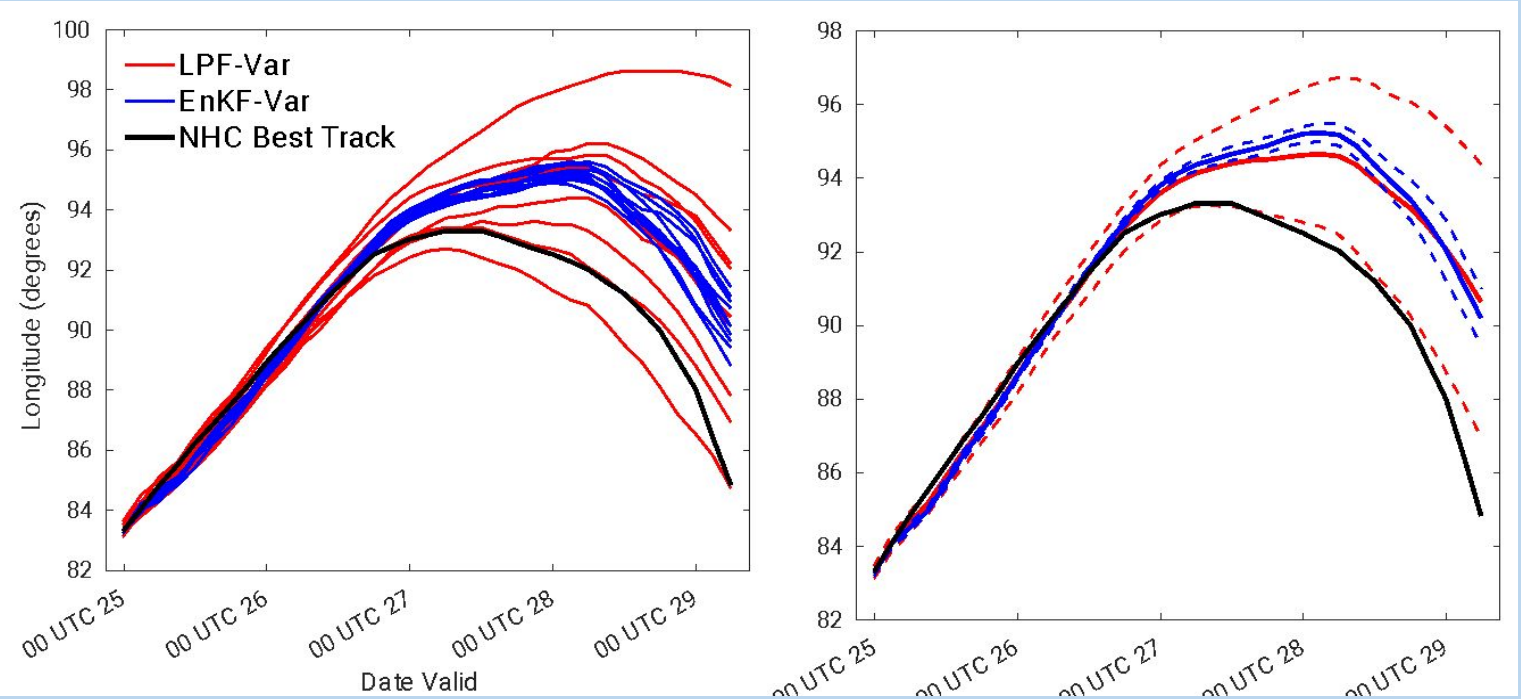





## Location

**VarPF** Mean ~ **VarEnKF** Mean
**VarPF** Spread > **VarEnKF** Spread

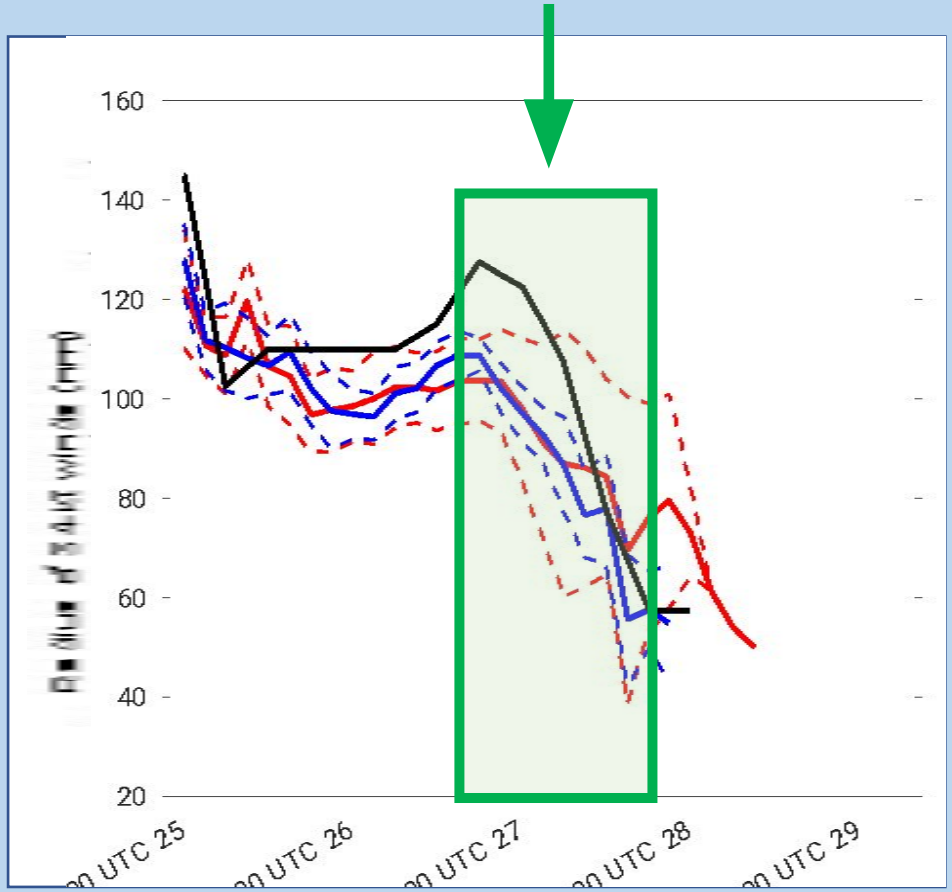



## Location

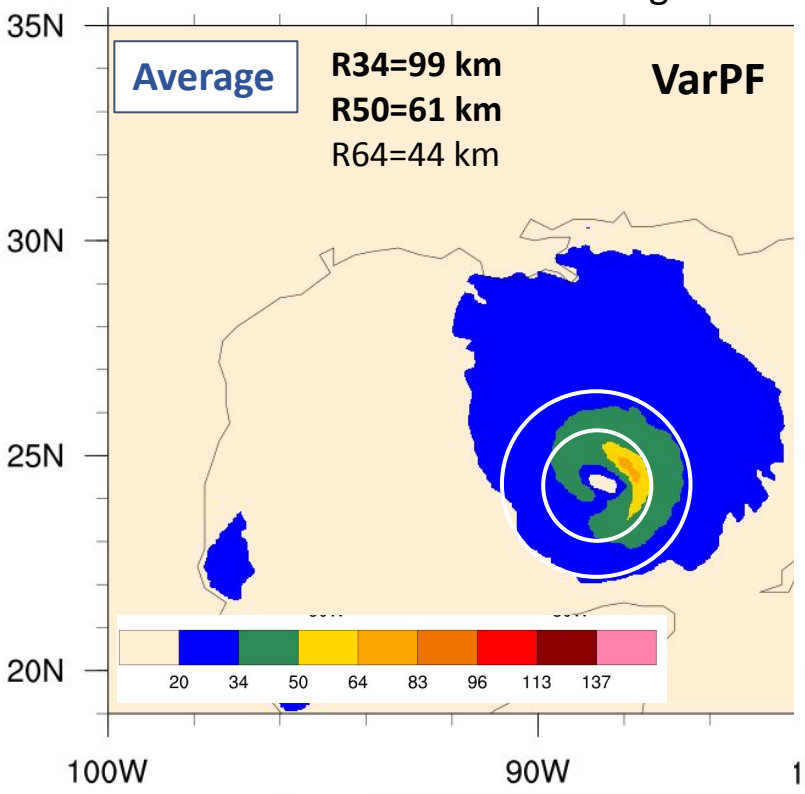
**VarPF** Mean ~ **VarEnKF** Mean
**VarPF** Spread > **VarEnKF** Spread

## Distribution at landfall:

**VarPF** Spread ~ **2x** **VarEnKF** Spread



24-hr Forecast valid 00 UTC Aug 26

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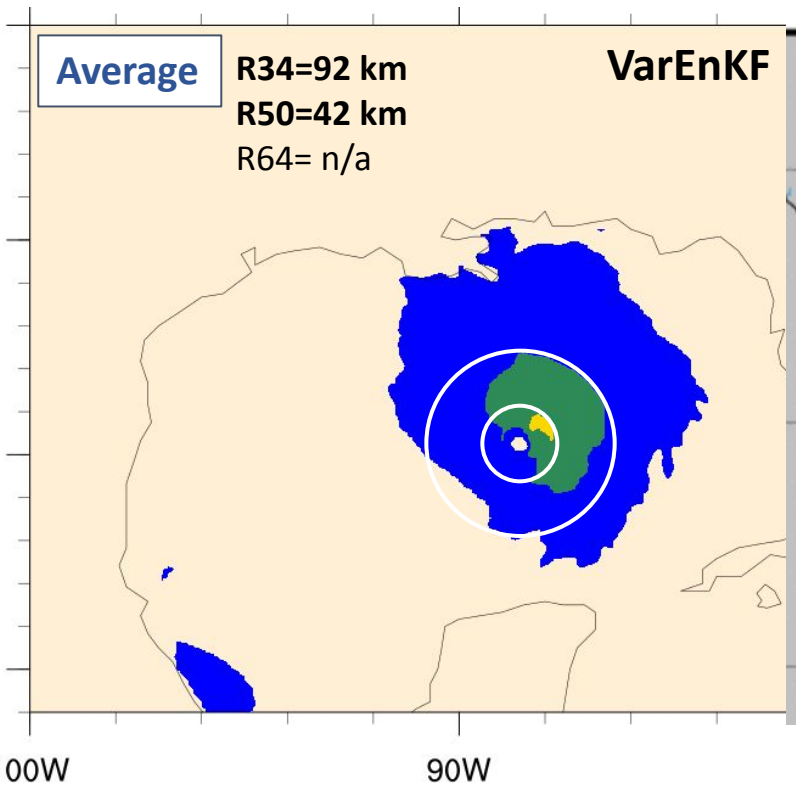


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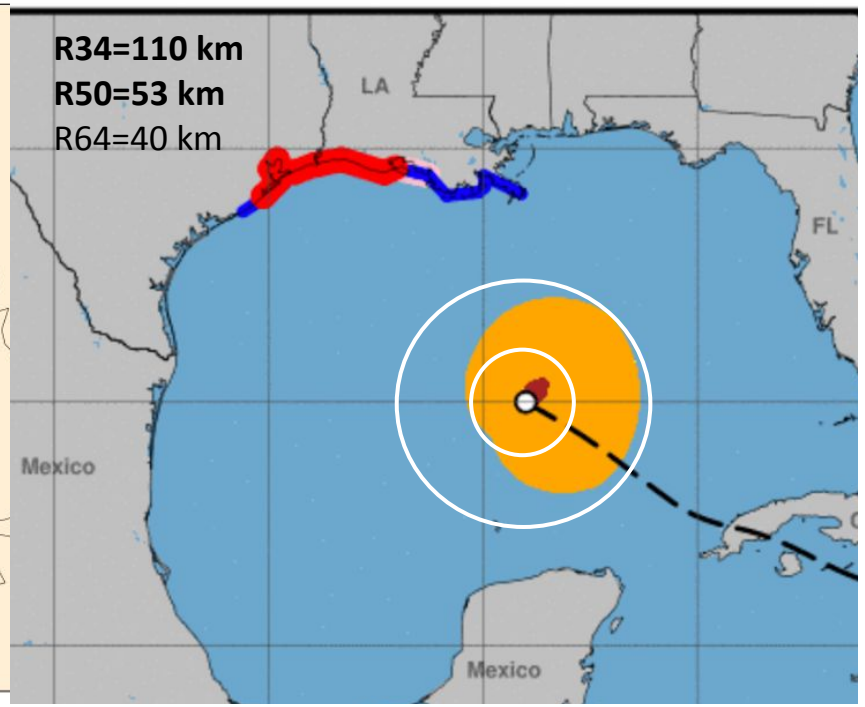
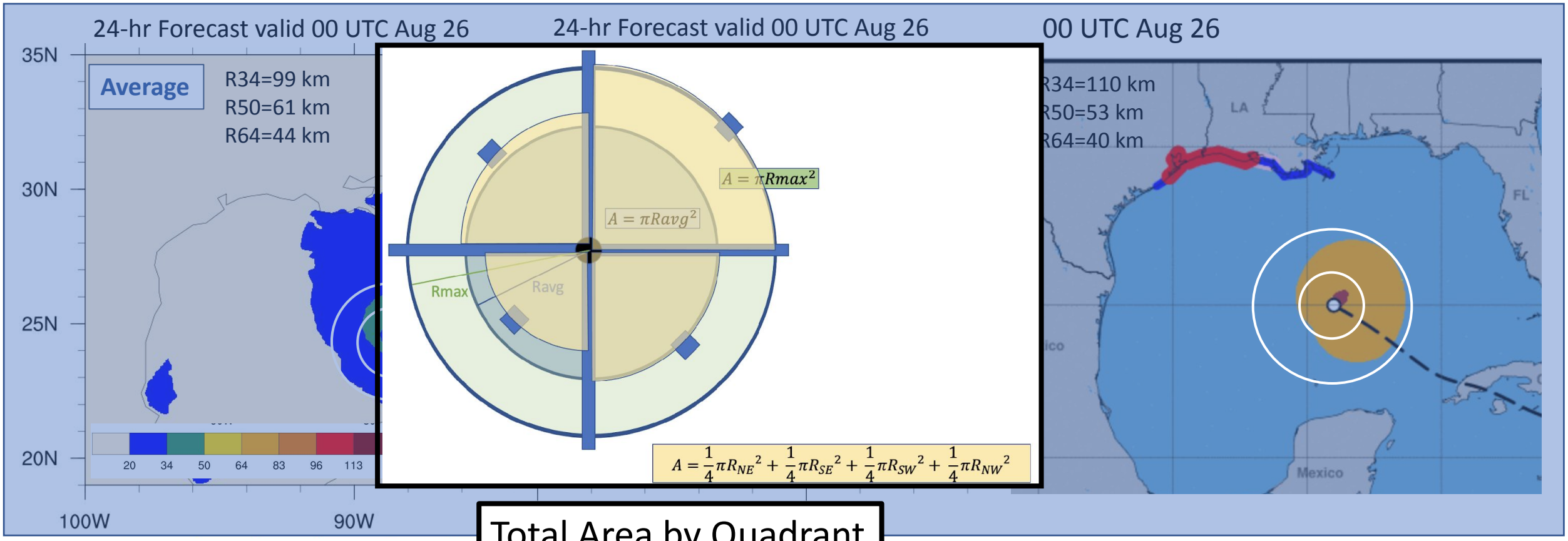



| | | |
|---|---|---|
| Area of Hurricane-force winds: | | |
| 2973 nmi$^2$ | 0 nmi$^2$ | 3770 nmi$^2$ |
| Area of TS-force winds: | | |
| 33254 nmi$^2$ | 33533 nmi$^2$ | 50736 nmi$^2$ |




## Total Area by Quadrant

| | | | |
|---|---|---|---|
| Area of Hurricane-force winds: | | | |
| 2973 nmi$^2$ | 0 nmi$^2$ | 3770 nmi$^2$ | |
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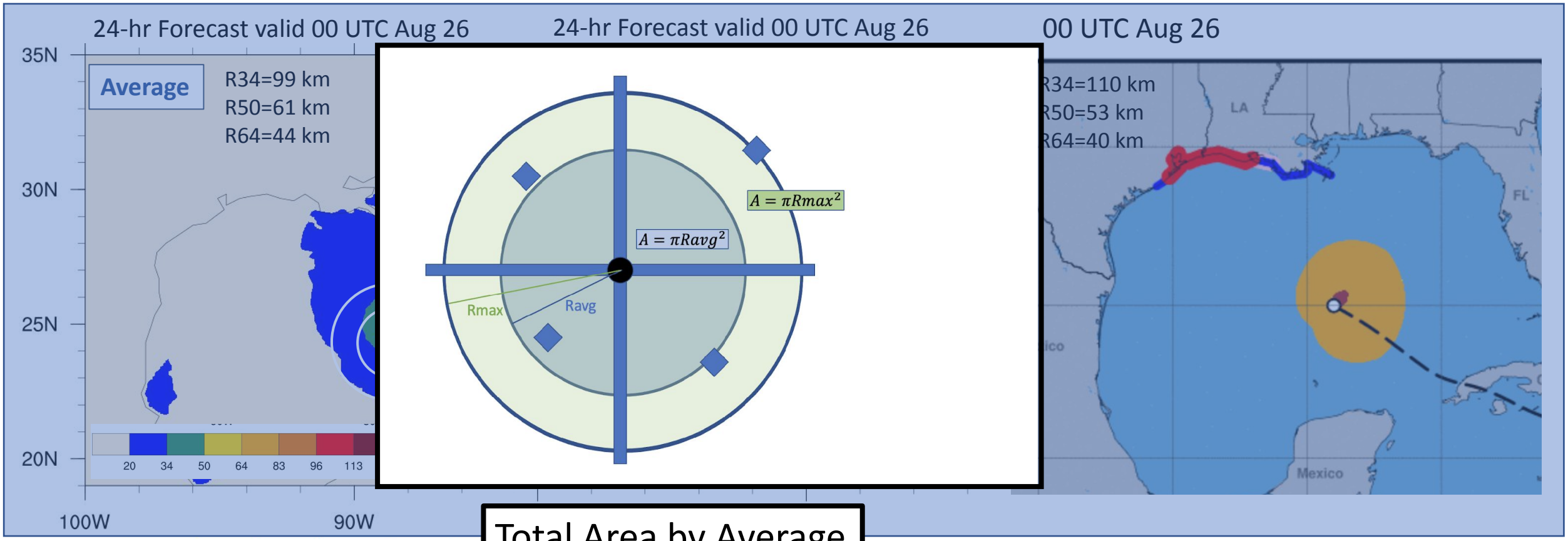



## Total Area by Average

Area of Hurricane-force winds:
2973 nmi$^2$

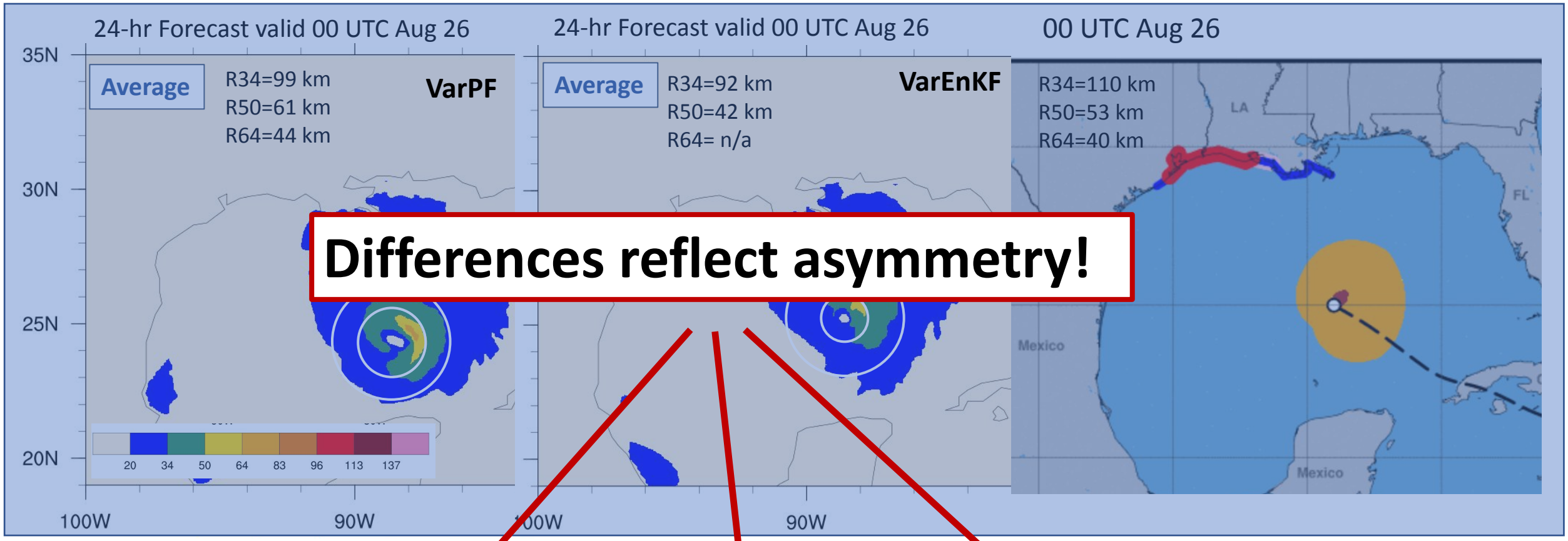
Area of TS-force winds:
33254 nmi$^2$

6082 nmi$^2$
30790 nmi$^2$
nmi$^2$

3770 nmi$^2$
50736 nmi$^2$

0 nmi$^2$
26597 nmi$^2$

5026 nmi$^2$
38013 nmi$^2$

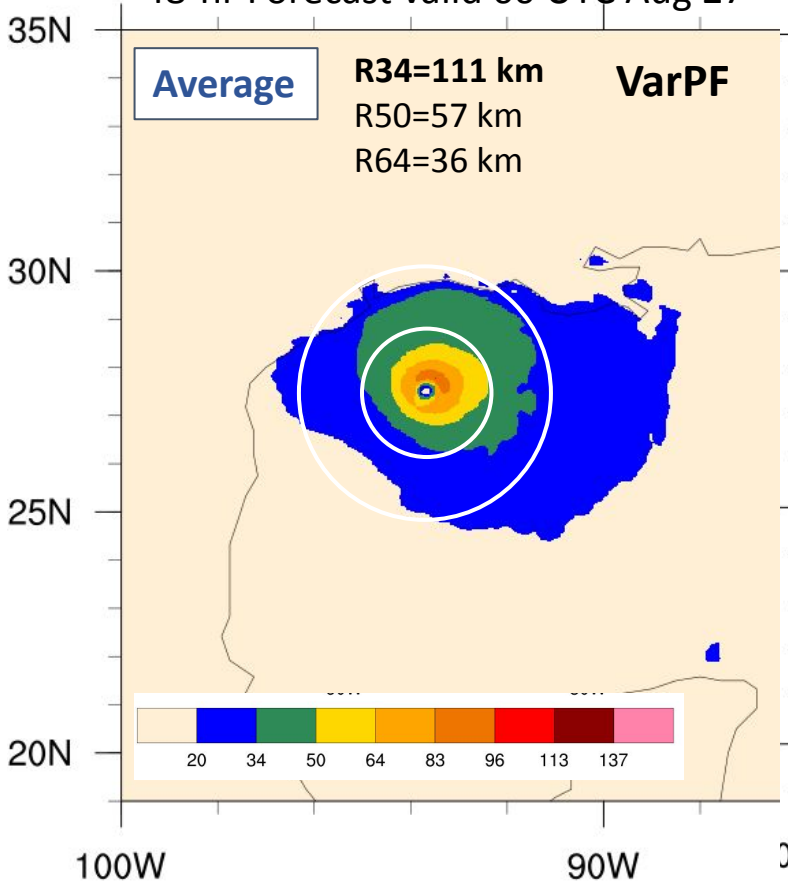



**Differences reflect asymmetry!**

Area of Hurricane-force winds:

| | | |
|---|---|---|
| 2973 nmi$^2$ | 6082 nmi$^2$ | 3770 nmi$^2$ | 0 nmi$^2$ | 5026 nmi$^2$ |
| Area of TS-force winds: | | | | |
| **33254 nmi$^2$** | **30790 nmi$^2$** | **50736 nmi$^2$** | **26597 nmi$^2$** | **38013 nmi$^2$** |

48-hr Forecast valid 00 UTC Aug 27

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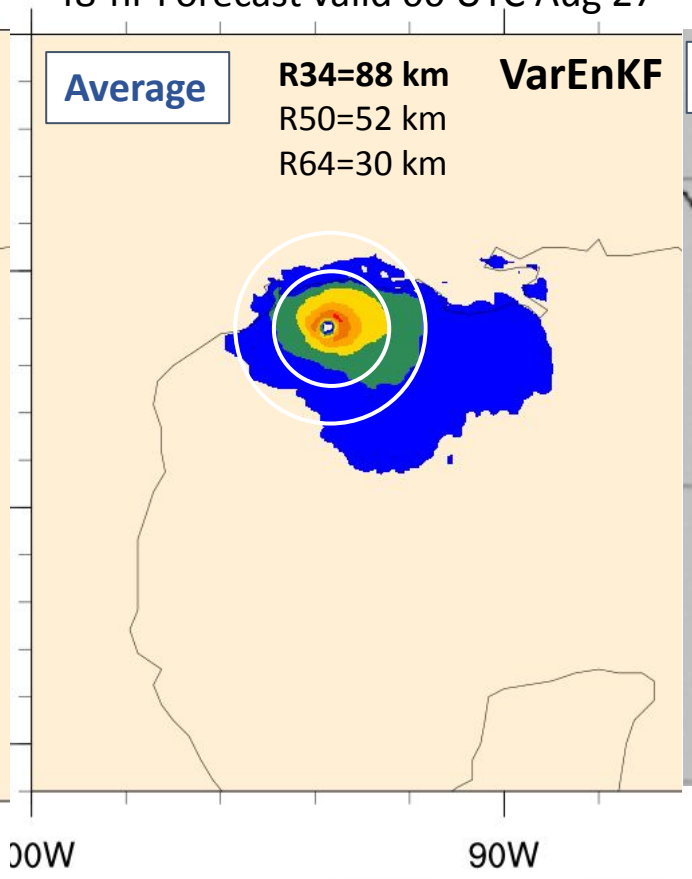
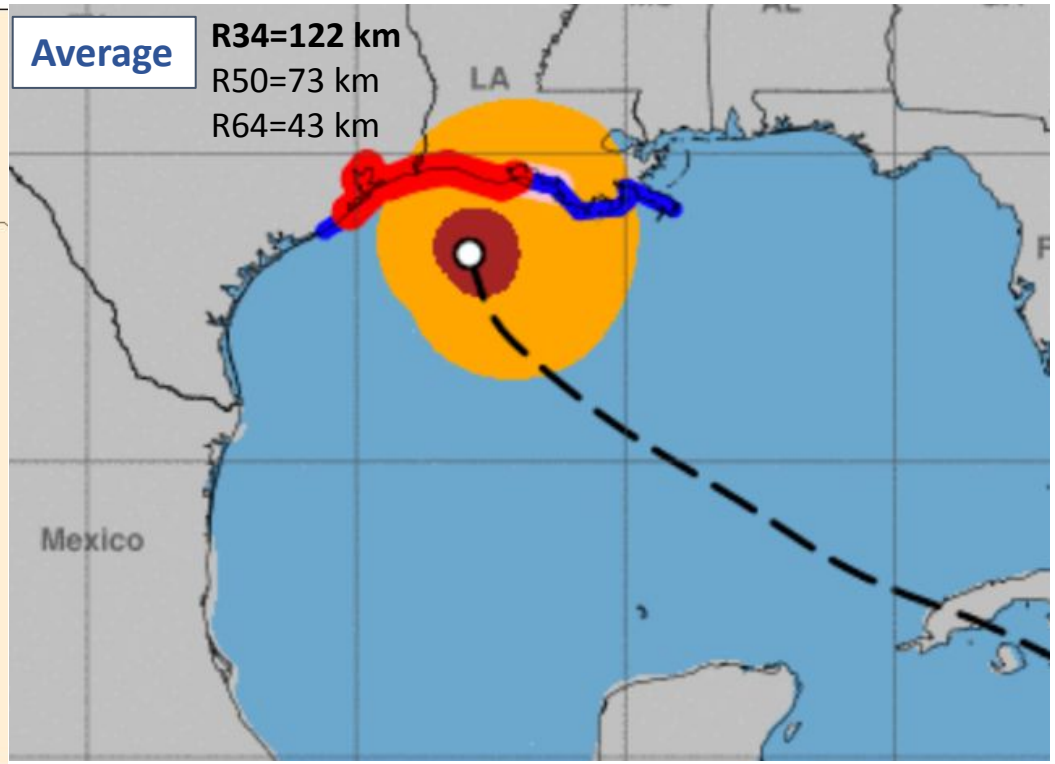



00 UTC Aug 27



48-hr Forecast valid 00 UTC Aug 27

**Average** R34=111 km R50=57 km R64=36 km **VarPF**

**Maximum** R34=135 km R50=69 km R64=43 km

48-hr Forecast valid 00 UTC Aug 27

**Average** R34=88 km R50=52 km R64=30 km **VarEnKF**

**Maximum** R34=109 km R50=66 km R64=35 km

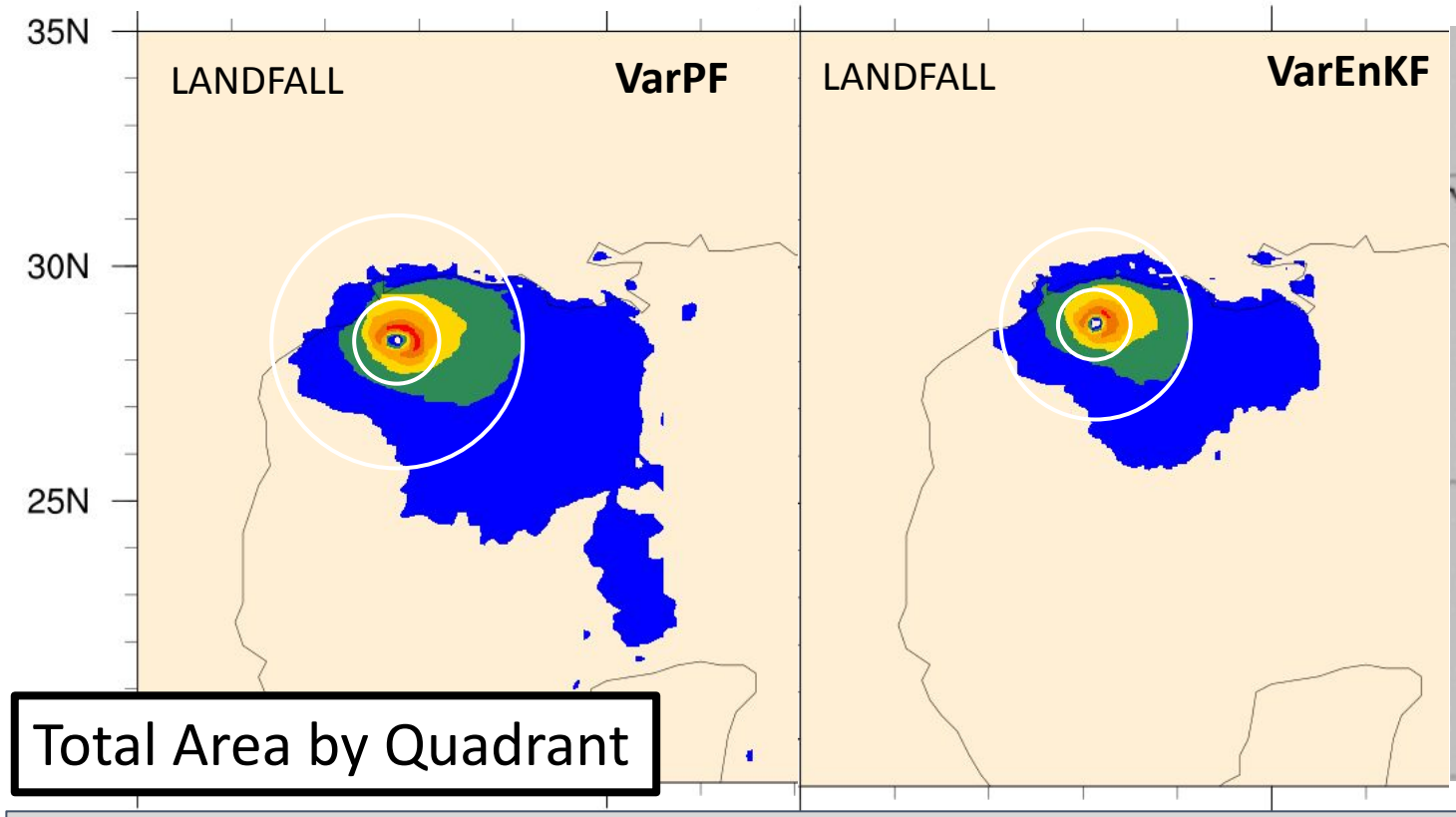
00 UTC Aug 27

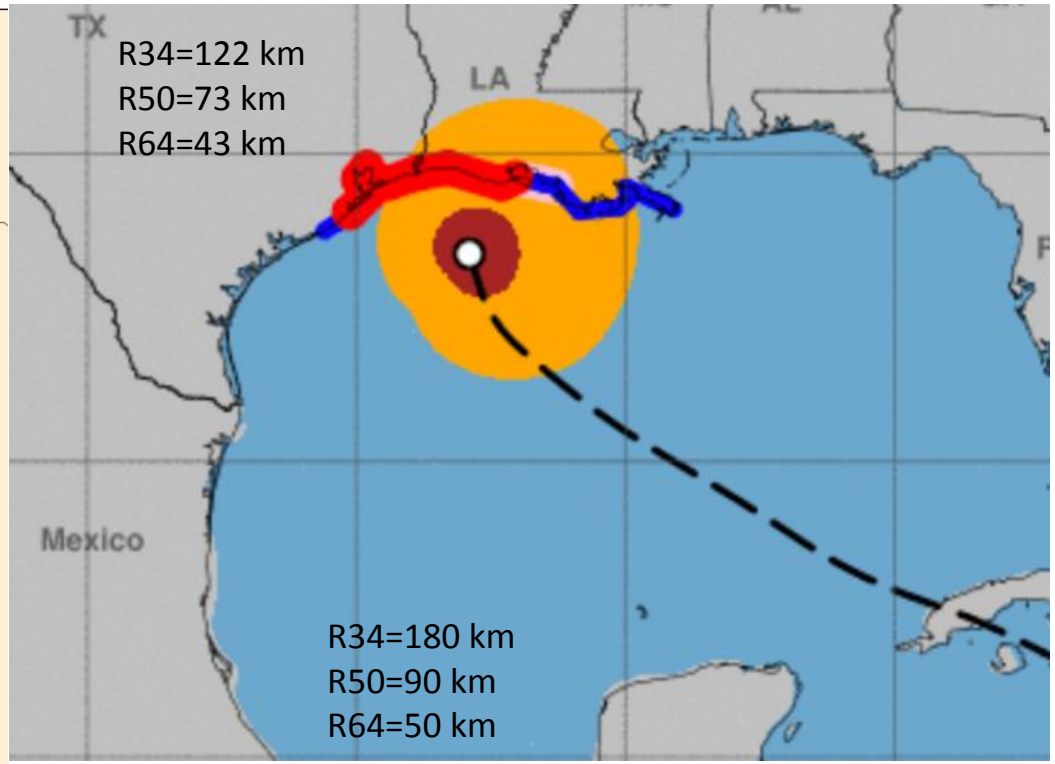
**Average** R34=122 km R50=73 km R64=43 km

**Maximum** R34=180 km R50=90 km R64=50 km

35N 30N 25N 20N 100W 90W 90W

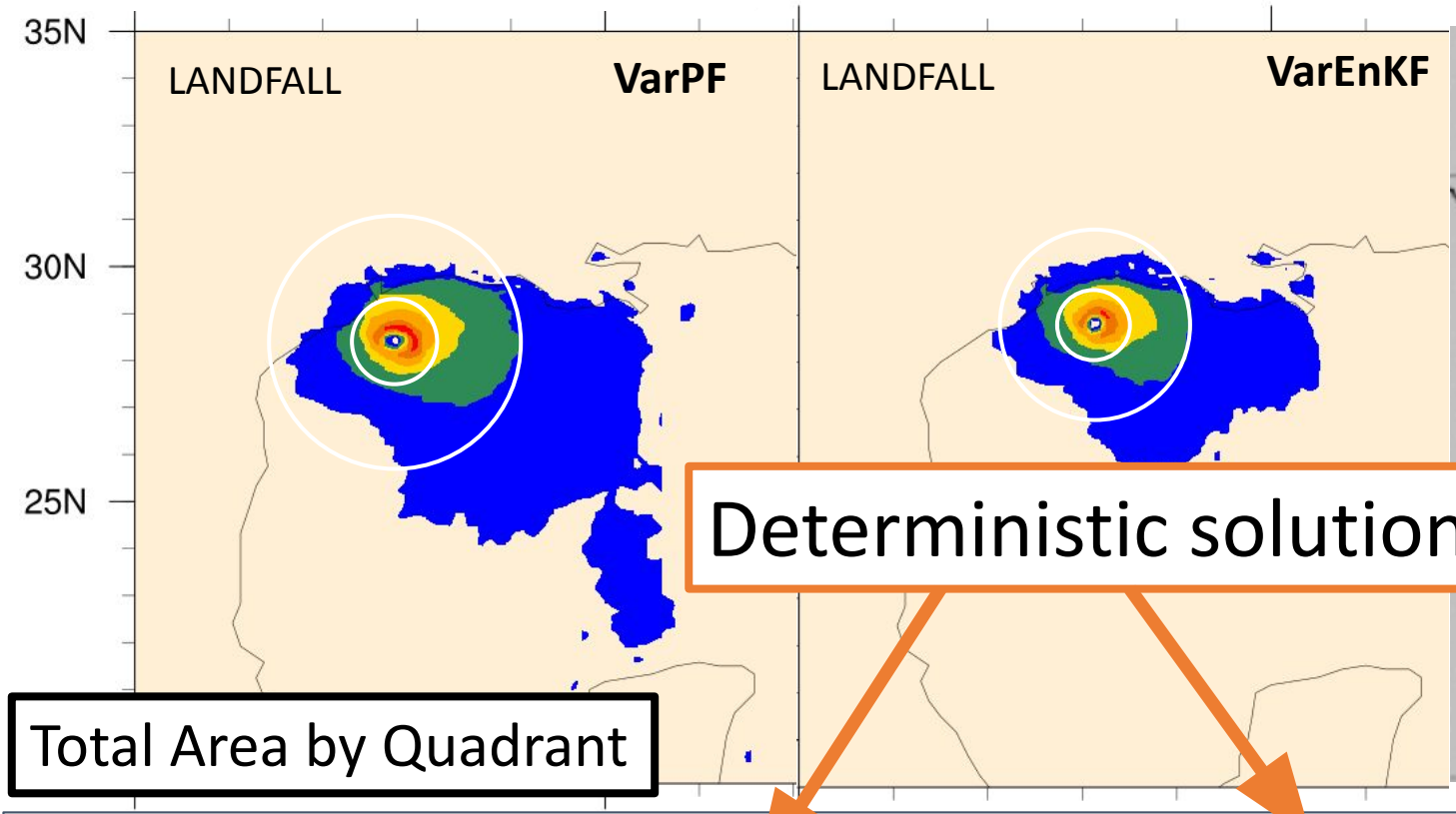
**Area by averaged radii does not adequately reflect wind distribution!!**

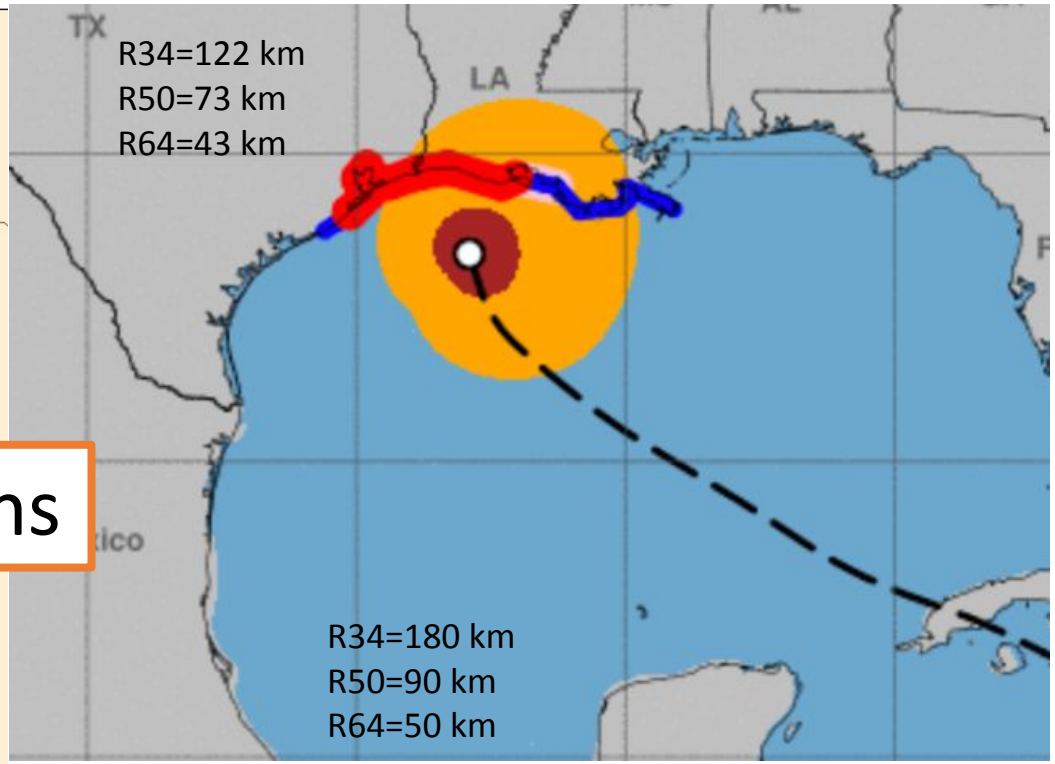



## Total Area by Quadrant

| | | |
|---|---|---|
| Area of Hurricane-force winds at landfall: | | |
| 5134 nmi$^2$ | 3274 nmi$^2$ | 5105 nmi$^2$ |
| Area of TS-force winds at landfall: | | |
| 44976 nmi$^2$ | 29966 nmi$^2$ | 44060 nmi$^2$ |




Deterministic solutions

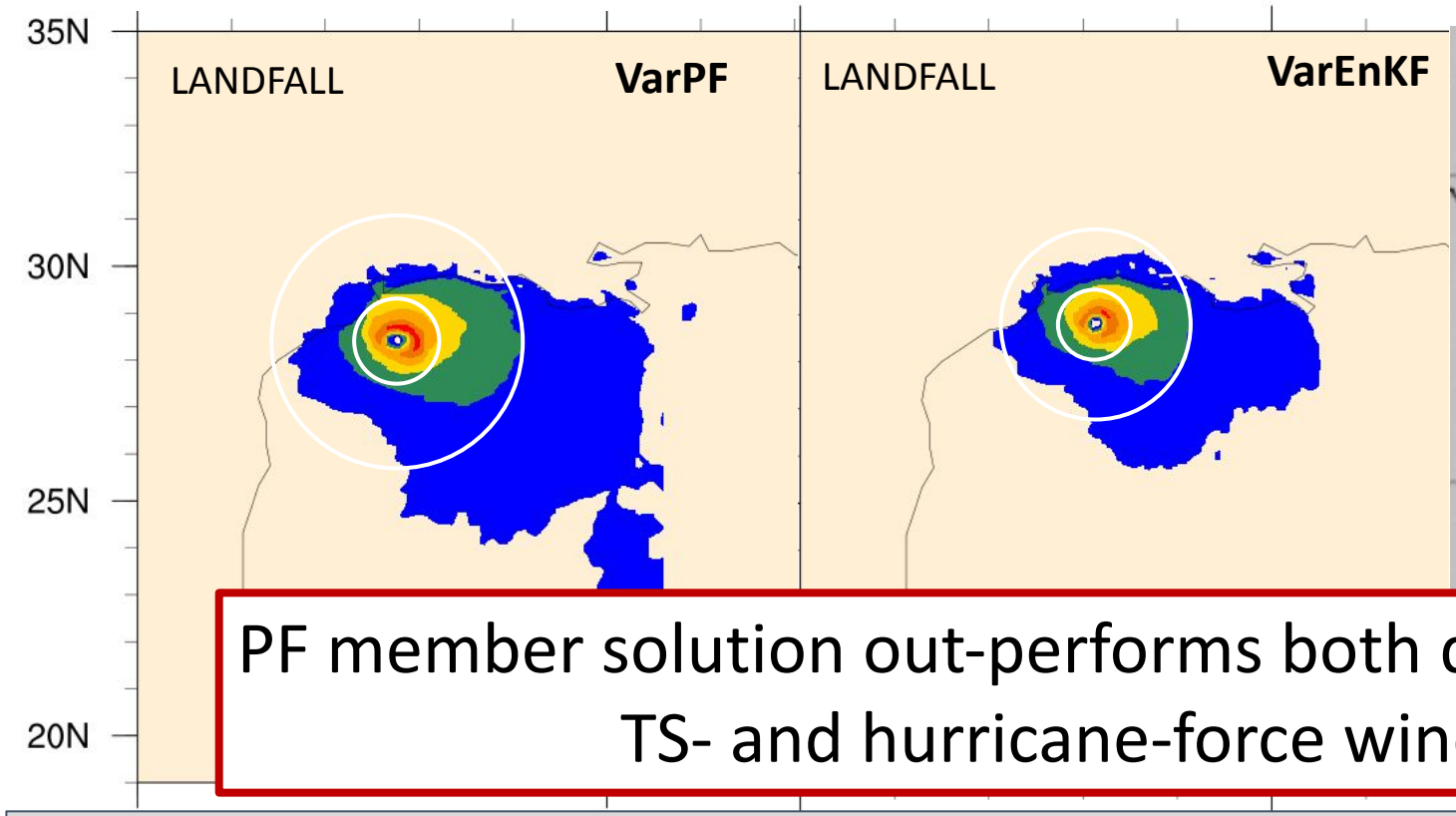
Total Area by Quadrant

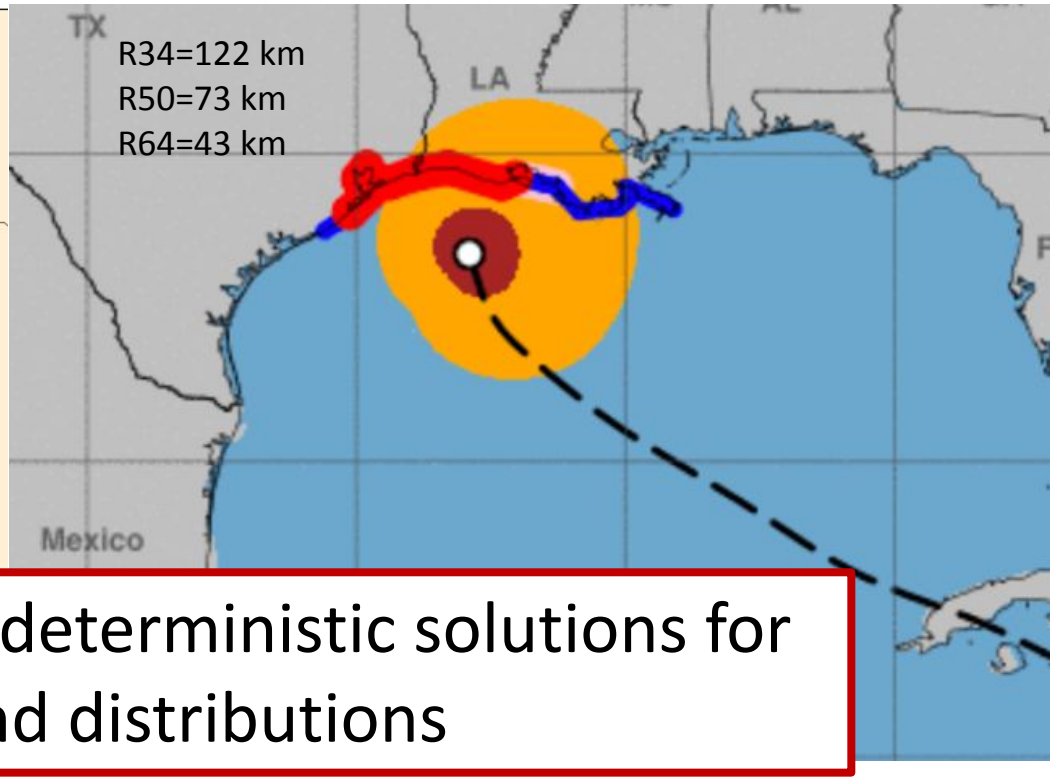
Area of Hurricane-force winds at landfall:

| | | | |
|---|---|---|---|
| 5134 nmi$^2$ | 3591 nmi$^2$ | 3274 nmi$^2$ | 5105 nmi$^2$ | 3424 nmi$^2$ |

Area of TS-force winds at landfall:

| | | | |
|---|---|---|---|
| 44976 nmi$^2$ | 37648 nmi$^2$ | 29967 nmi$^2$ | 44060 nmi$^2$ | 39921 nmi$^2$ |




PF member solution out-performs both deterministic solutions for TS- and hurricane-force wind distributions

Area of Hurricane-force winds at landfall:

**5134 nmi²** | 3591 nmi² | 3274 nmi² | **5105 nmi²** | 3424 nmi²

Area of TS-force winds at landfall:

**44976 nmi²** | 37648 nmi² | 29967 nmi² | **44060 nmi²** | 30921 nmi²

## Relaxing Gaussian assumptions:

- Increases ensemble spread despite similarities in deterministic solutions or ensemble means

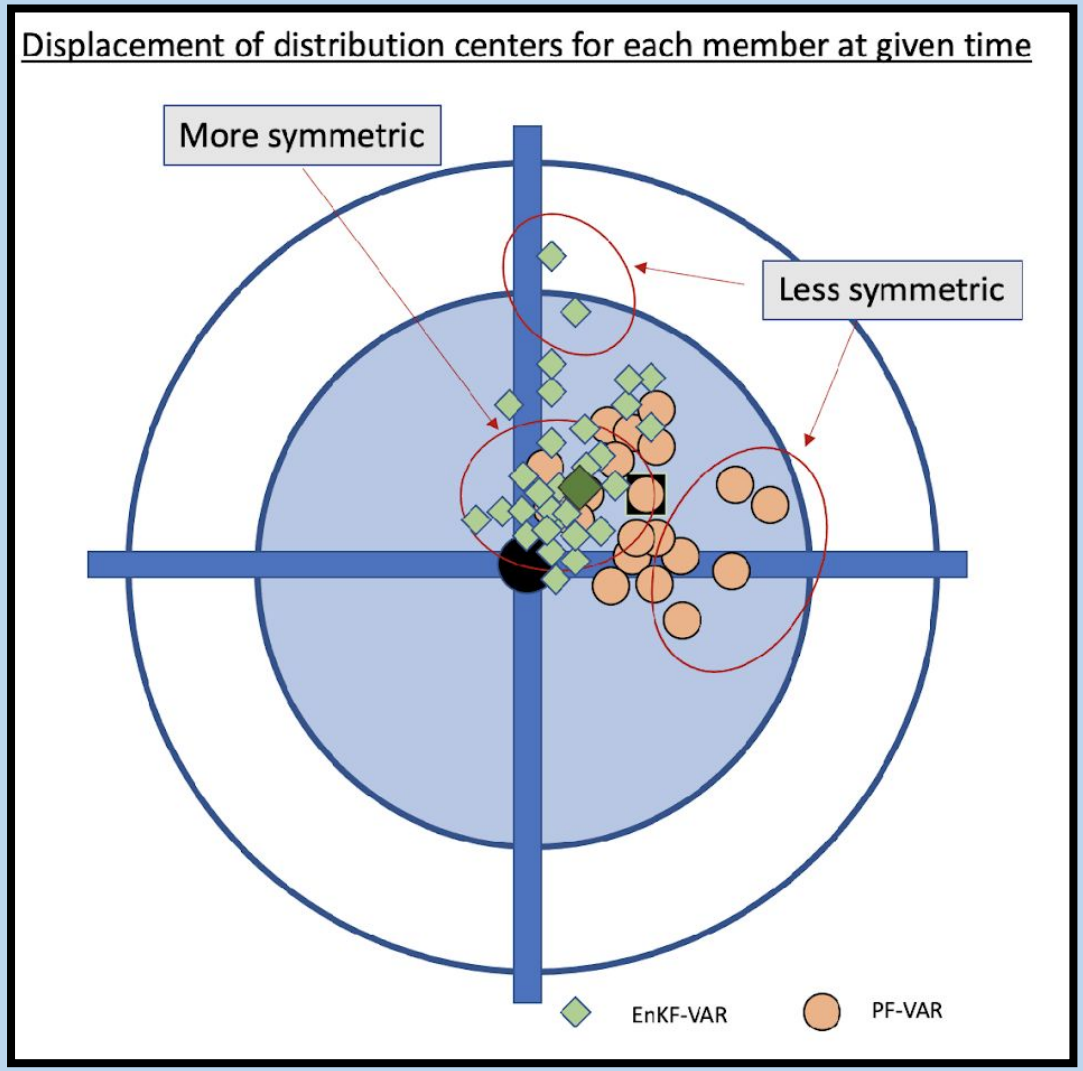
  True for all verifying metrics (location, intensity, size, wind distribution)

- Allows ensemble members to reflect variety of possible wind distributions
  - better reflect associated hazard potential

## Future/continuing assessment

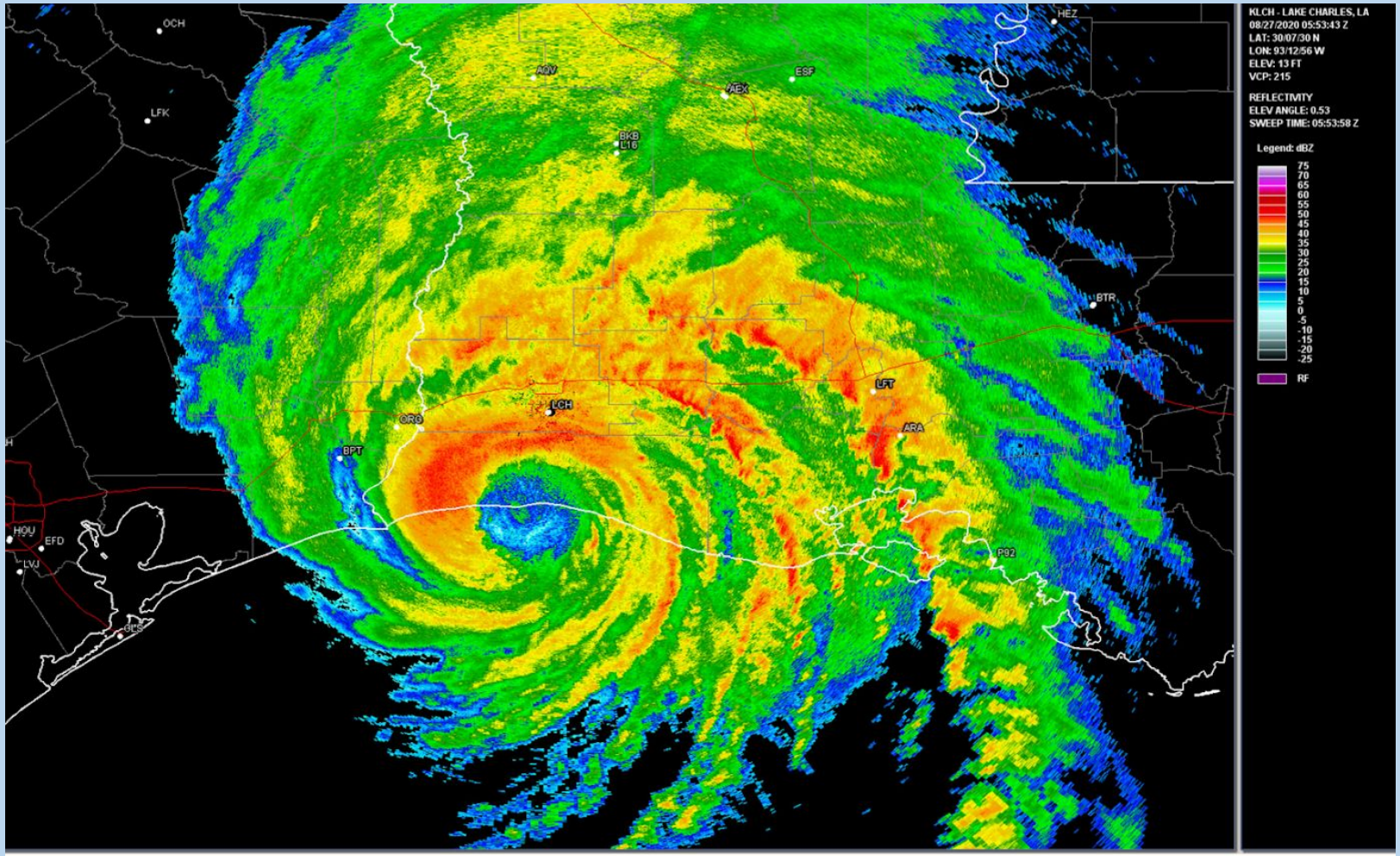
Wind distribution asymmetries

(degree of asymmetry, direction of asymmetry)

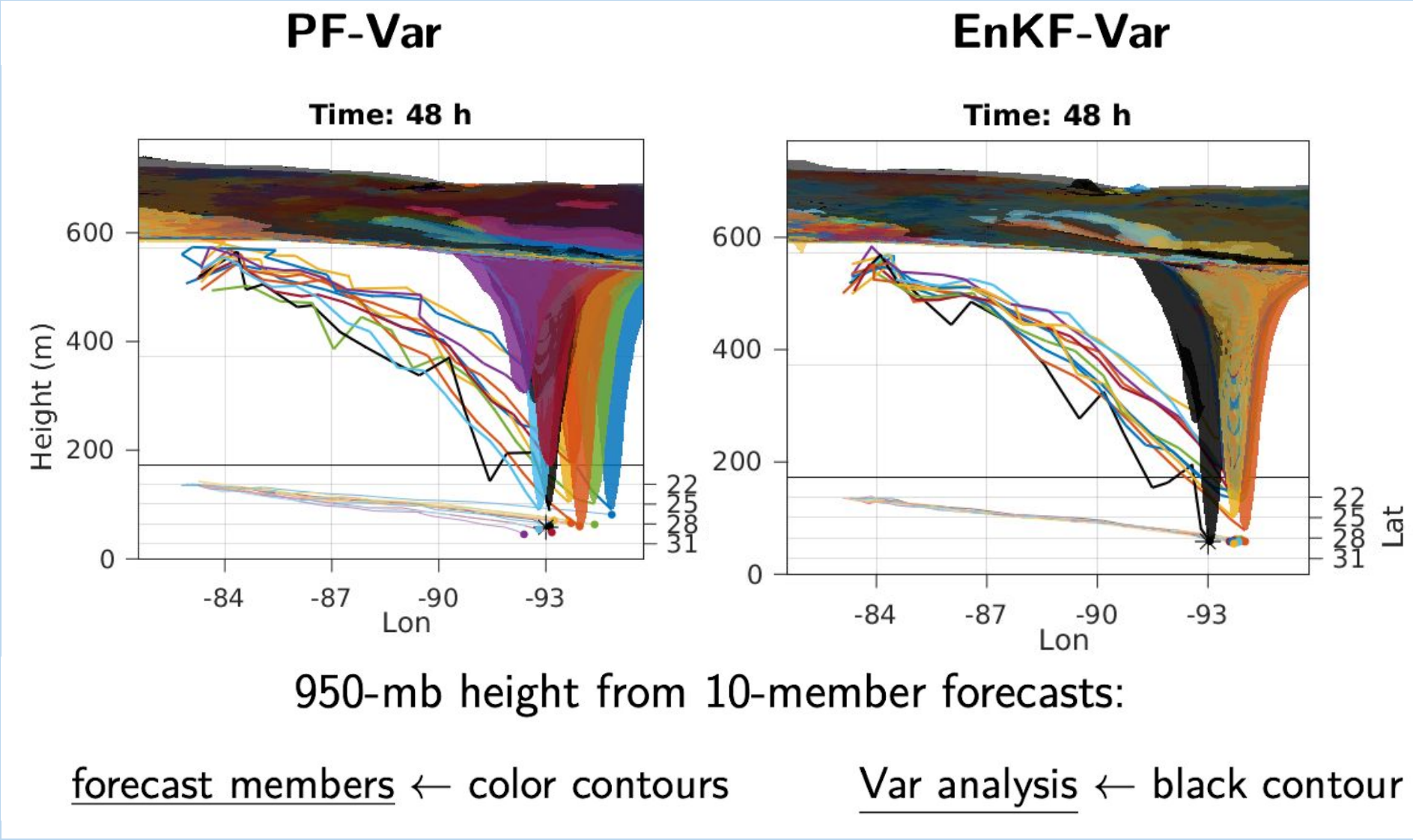



Contact: Kelly.Ryan@noaa.gov

# Supplementary




Last KLCH WSR-88D radar reflectivity image of Hurricane Laura at 0554 UTC 27 August 2020 before the radar was destroyed
Image courtesy of NWS Lake Charles WFO.




950-mb height from 10-member forecasts:

forecast members ← color contours

Var analysis ← black contour