# Simultaneous Multiscale Data Assimilation with scale dependent localization (SDL) for HAFS 4DEnVar


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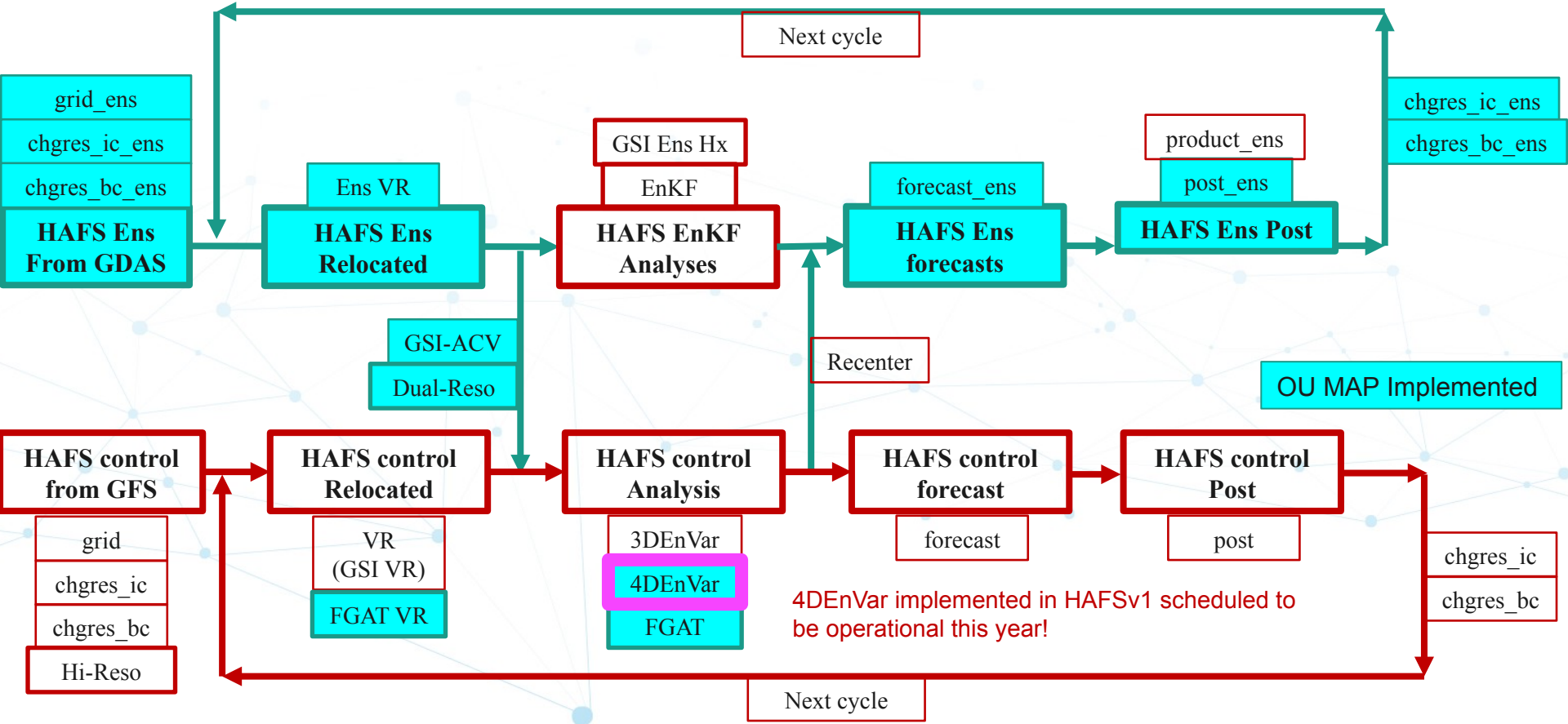
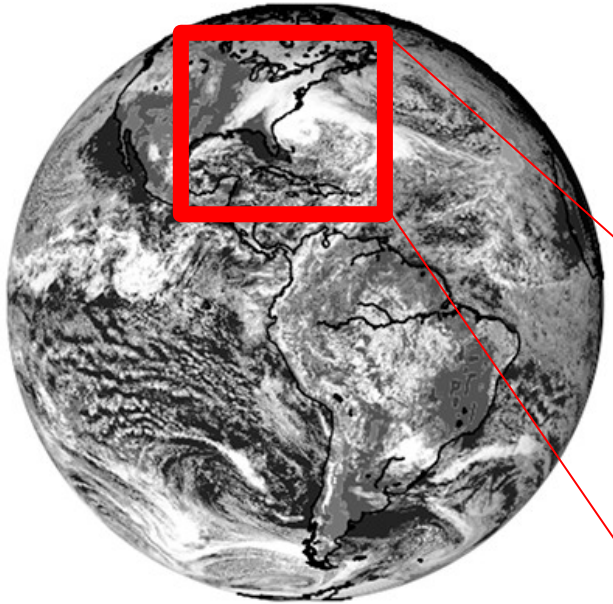
A UFS Collaboration Powered by EPIC

# Cycled, self consistent EnVar DA for HAFS

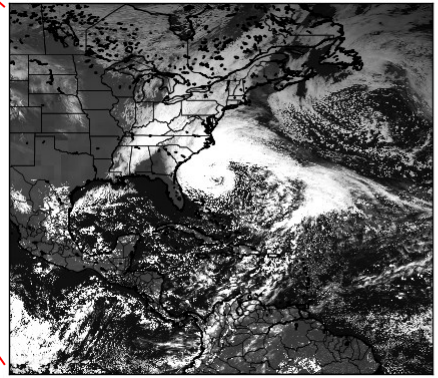


# Why Multiscale DA?

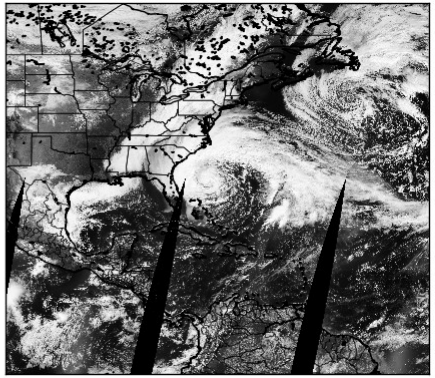


FV3 convection permitting forecast of GOES visible imagery during Hurricane Sandy 2012

- New computing resources and technologies allow
  - Next generation NWP models to resolve a wide range of scales for individual earth system component
  - Coupled earth system modeling
  - ingesting a myriad of existing and new observations that sample a variety of scales to the NWP models
- The next generation data assimilation system is required to **effectively analyze the state and quantify its uncertainty across multiple scales**, termed as “multiscale data assimilation (MDA)” (Wang et al. 2021).



FV3 model



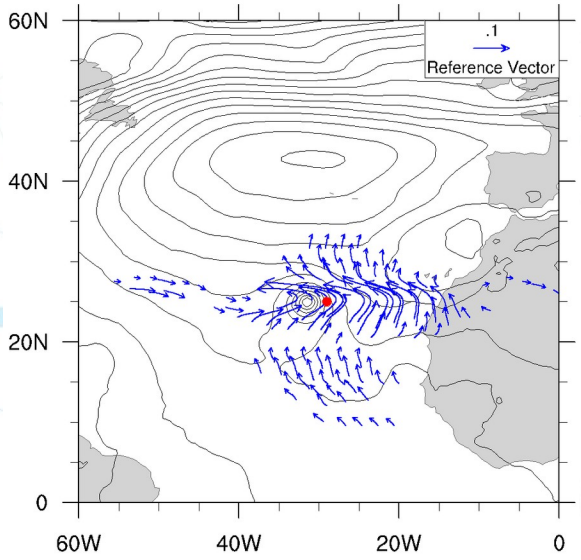
MODIS visible imagery

Source: https://www.gfdl.noaa.gov/fv3/fv3-applications/fv3-full-physics-cloud-permitting-simulation/

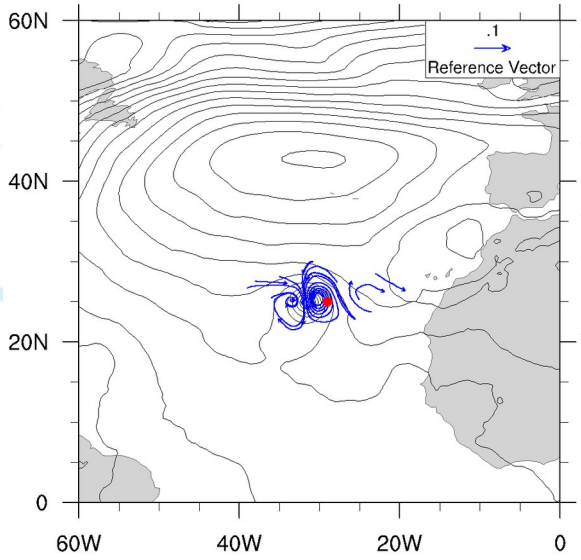
# *Simultaneous* Multiscale DA in 4DEnVar

- A simultaneous multiscale DA approach, as opposed to a sequential approach, allows all observations to correct all resolved scales at once (e.g. Wang et al. 2021).

Increment for scales >4000km




Increment for scales < 4000km

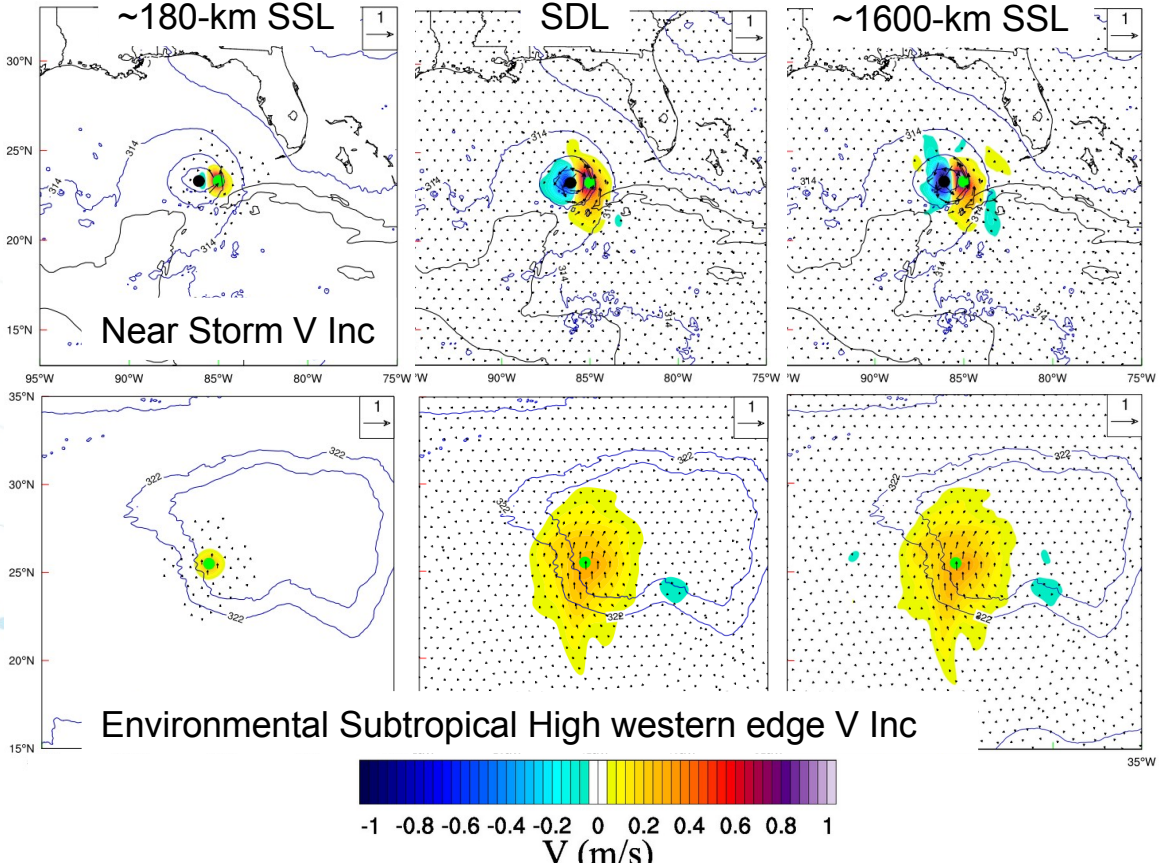



- A single obs. can correct multiple scales in simultaneous MDA
- Simultaneous multiscale DA also defines cross scale band error correlation
- Scale dependent localization (SDL) is implemented in EnVar to realize simultaneous MDA
- SDL has been implemented and tested for FV3GFS 4DEnVar and show improvement on global and hurricane forecasts (Huang* et al. 2021)

Huang*, Wang et al. 2021

* Denote OU MAP student/early career scientist

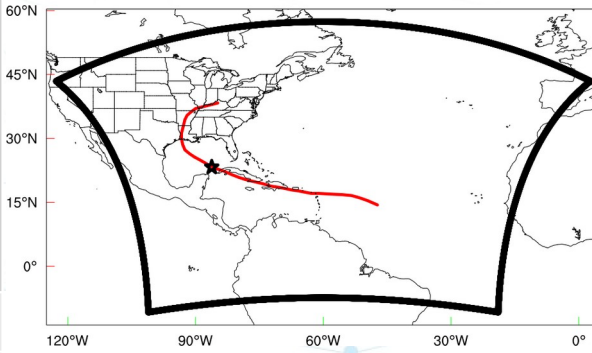
# Development of Simultaneous MDA in HAFS 4DEnVar




- The simultaneous MDA with SDL is recently further extended and implemented for HAFS EnVar
- Two-observation experiments show MDA with SDL can simultaneously properly correct both the TC and its large-scale steering environment (subtropical high)

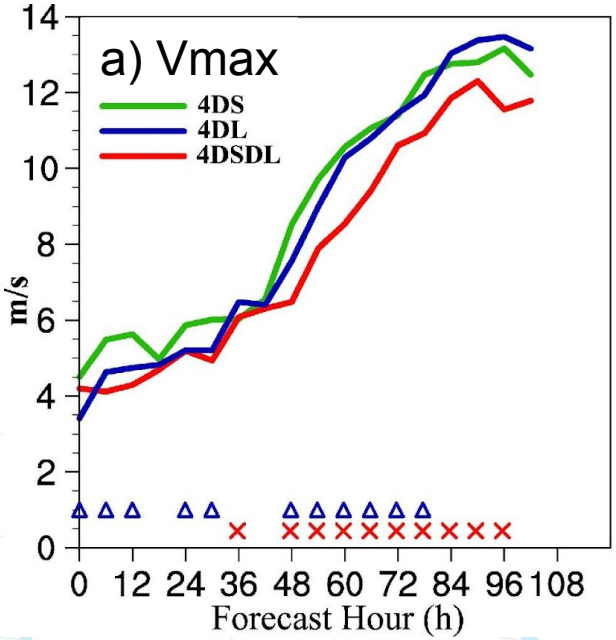
# Experiment Design

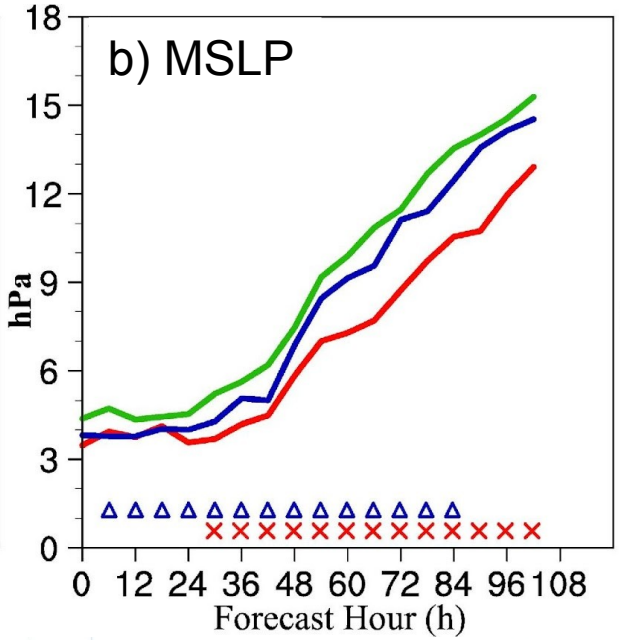
| Exp Names | 4DS | 4DL | 4DSDL |
|---|---|---|---|
| Localization Scale (e-folding scale) | SSL (~180 Km) | SSL (~1600 Km) | SDL (~180, 1600 Km) |
| Domain Size | 2160 X 2880 horizontal grid points (~65 X 85°) | | |
| Assimilated observations | conventional observations (contained in prepbufr file) with some satellite AMVs; NOAA P3 aircraft Tail Doppler Radar; satellite radiance observations; HS3 Global Hawk dropsonde and TCVital mean sea-level pressure (MSLP) data; High-resolution flight-level data; Hourly shortwave, clear air-water vapor, and visible Atmospheric Motion Vectors (AMVs) from GOES | | |
| Ocean Coupling | HYCOM | | |
| Ensemble | 80-member GFS ensemble | | |
| Physics Schemes | GFDL microphysics; RRTMG radiation; Scale-aware SAS convection; Noah LSM; GFS surface layer with HWRF exchange coefficients; Modified GFSv16 scale-aware TKE-EDMF PBL scheme; orographic GWD | | |

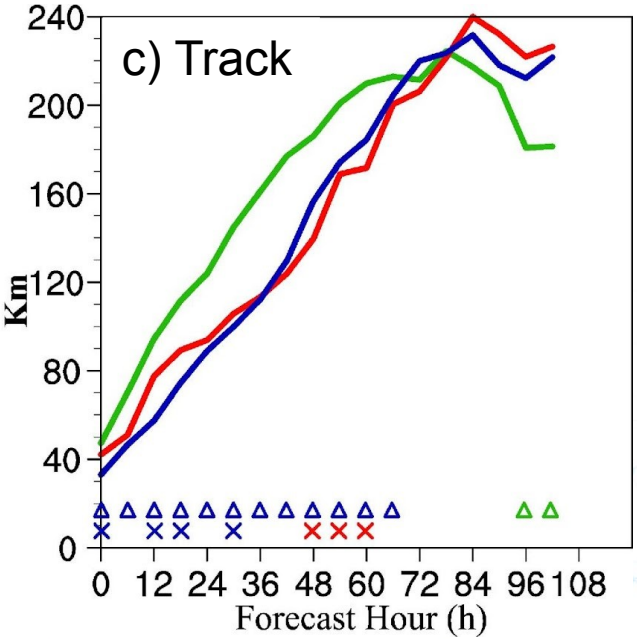


# Impact of simultaneous MDA

## Mean Absolute Forecast Errors during Hurricane Laura (2020)



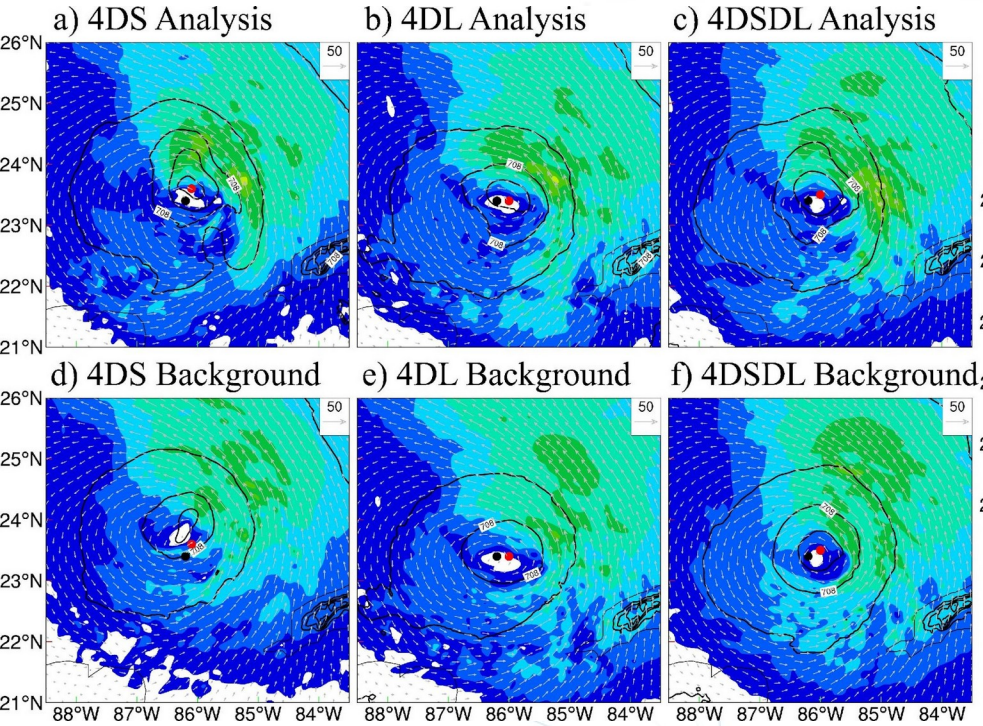



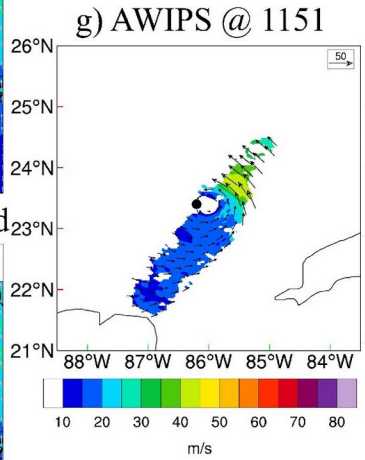




- ***Localization Impacts on Forecasts***
  - 4DL outperforms 4DS for almost all aspects
  - 4DSDL outperforms 4DL and 4DS in intensity predictions
  - 4DSDL outperforms 4DS in track prediction and has mixed results compared to 4DL

# Impact of localization MDA

## Single small scale localization issue

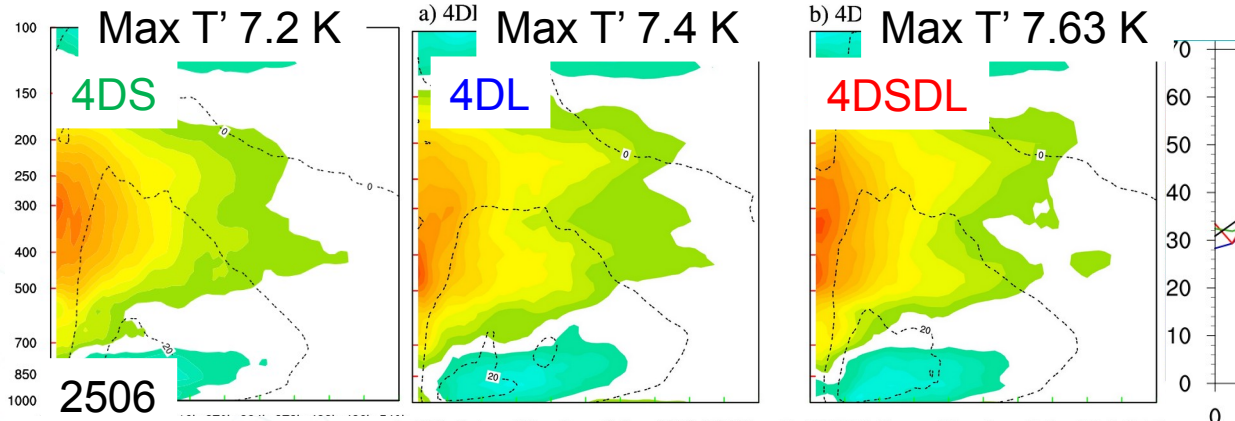


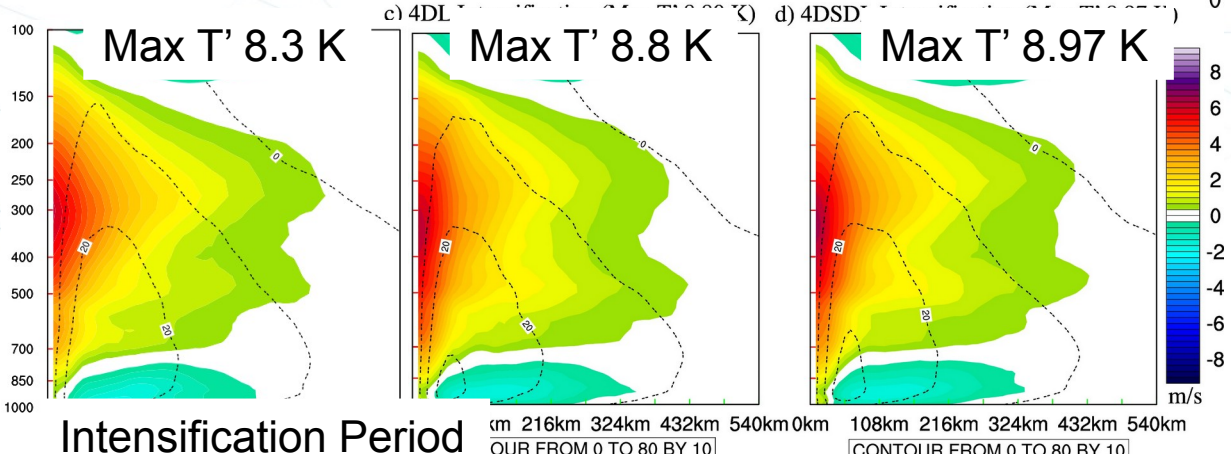



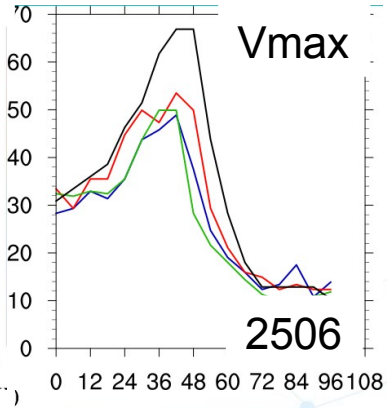

- When inner-core observations are unavailable during the early cycles, small localization in 4DS are unable to leverage nearby observations for correction. The accumulated background has larger location error and therefore leads to worse analysis.
- Such issue is alleviated by 4DL & 4DSDL, which result in better analyses and forecasts during the cycling.

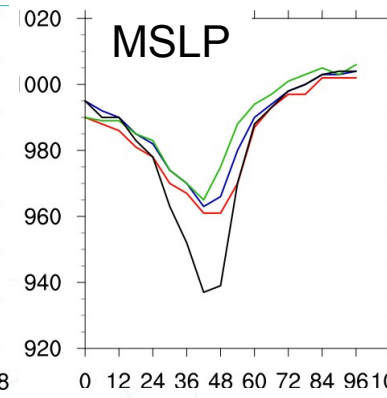
# Why MDA improves intensity predictions?

## Azimuthal mean temperature anomaly comparison at 2020082506 UTC



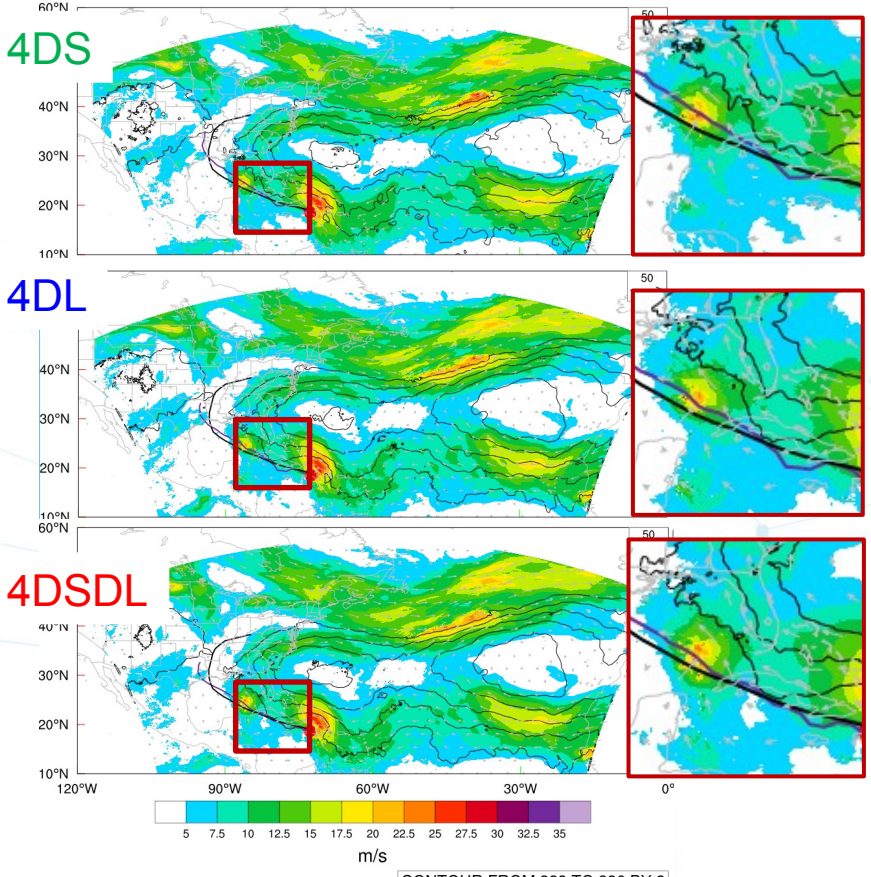



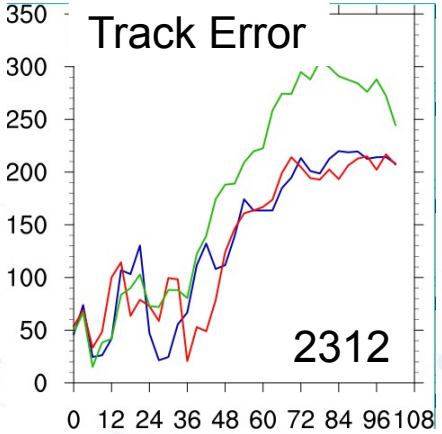

— 4DS
— 4DL
— 4DSDL

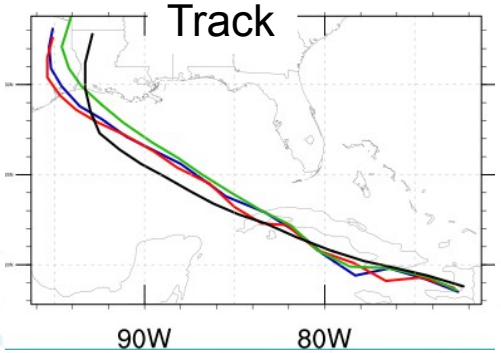
- MDA improves the intensification predication due to a stronger warm-core analysis.

# Why MDA improves track predictions?

## Steering flow analysis comparison at 2020082100 UTC



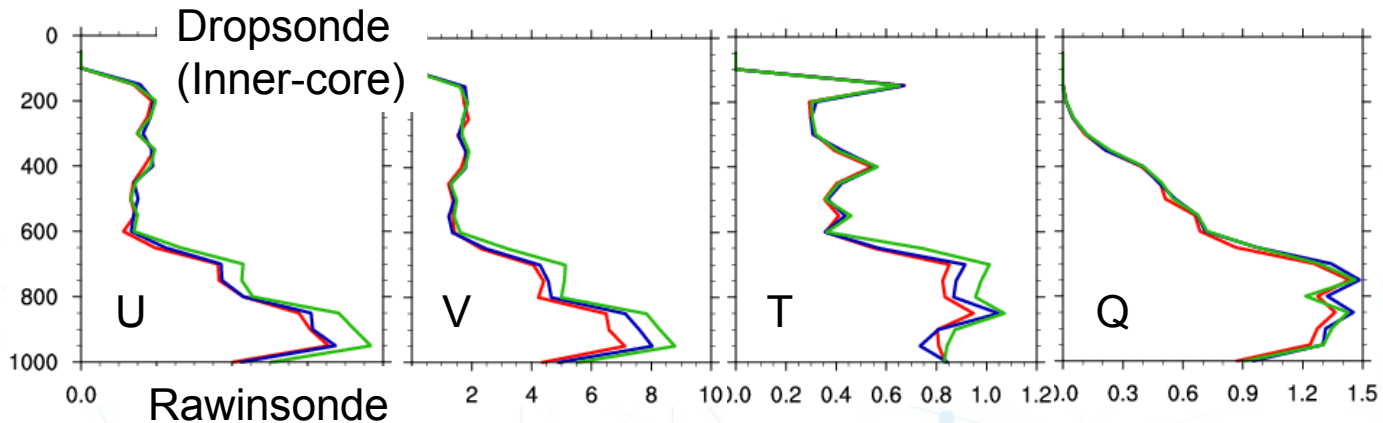



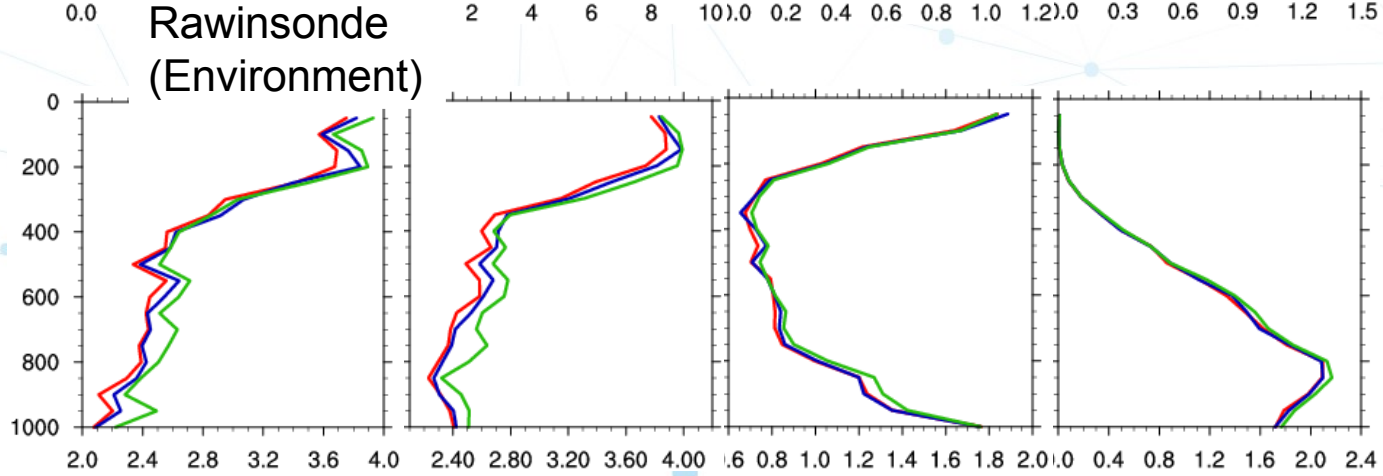

— 4DS
— 4DL
— 4DSDL
— Best

- MDA improves track predications due to better environmental analysis (e.g. the extent of the southwest edge of the Atlantic Subtropical High)

# Impact of Simultaneous Multiscale DA

## Background Verification against Dropsonde & Rawinsonde




— 4DS
— 4DL
— 4DSDL

- MDA produces better background than SSL in both vortex scale and TC environment.

# Summary

- ✔ SSL using large localization outperforms SSL using small localization in almost all aspects;
- ✔ MDA using SDL outperforms SSL using small localization for both intensity and track forecasts and outperforms SSL using large localization for intensity prediction;
- ✔ Diagnostics suggest
  - MDA using SDL produces better inner-core warm-core analyses that improves the intensity predictions during the intensification period than both SSL
  - MDA using SDL produces better synoptic scale analyses that improves the track predictions during the early period than small-scale SSL
  - MDA using SDL produces both better forecast structures when compared to observations at almost all levels as compared both SSL

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