

Impact of Assimilating Atmospheric Boundary Layer Observations on the Rapid Intensification of Hurricane Idalia (2023) in Self-cycled HAFS-JEDI System

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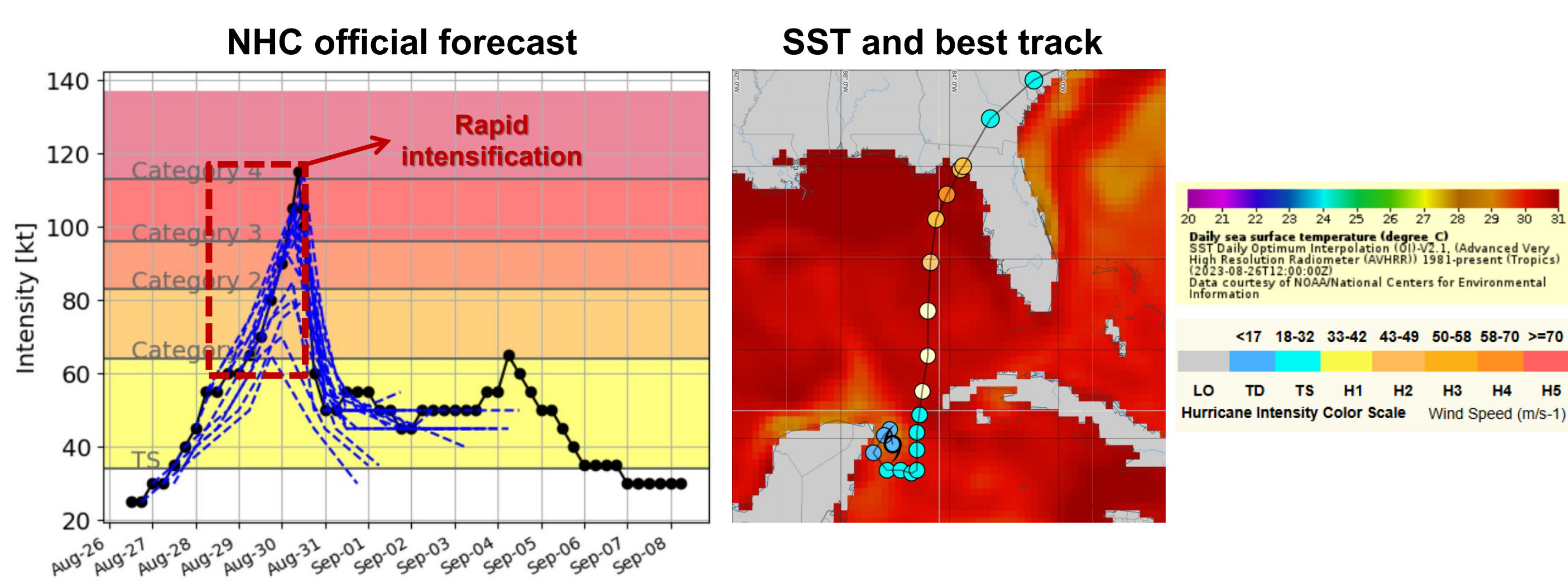
Introduction

- The **rapid intensification (RI)** of tropical cyclones is strongly influenced by *air-sea interactions*, particularly the exchange of heat and moisture across the interface. (e.g., Lin et al. 2005, 2008; Lee and Chen 2014; Halliwell et al. 2015; Hlywiak and Nolan 2019).
- The **atmospheric boundary layer (ABL)**, representing the atmospheric component of this interface, plays a critical role by modulating the inflow of warm, moist air from the ocean surface—the primary energy source for tropical cyclone development. (Wadler et al. 2020; Chen et al. 2021).
- During Hurricane Idalia (2023), a targeted field campaign collected **unique ABL observations** using *dropsondes and a Saildrone*.

This study investigates the impact of assimilating ABL observations on the simulation of the RI of Hurricane Idalia (2023), using the self-cycled Hurricane Analysis and Forecast System (HAFS) – Joint Effort for Data assimilation Integration (JEDI) framework, developed by CADRE.

Case overview

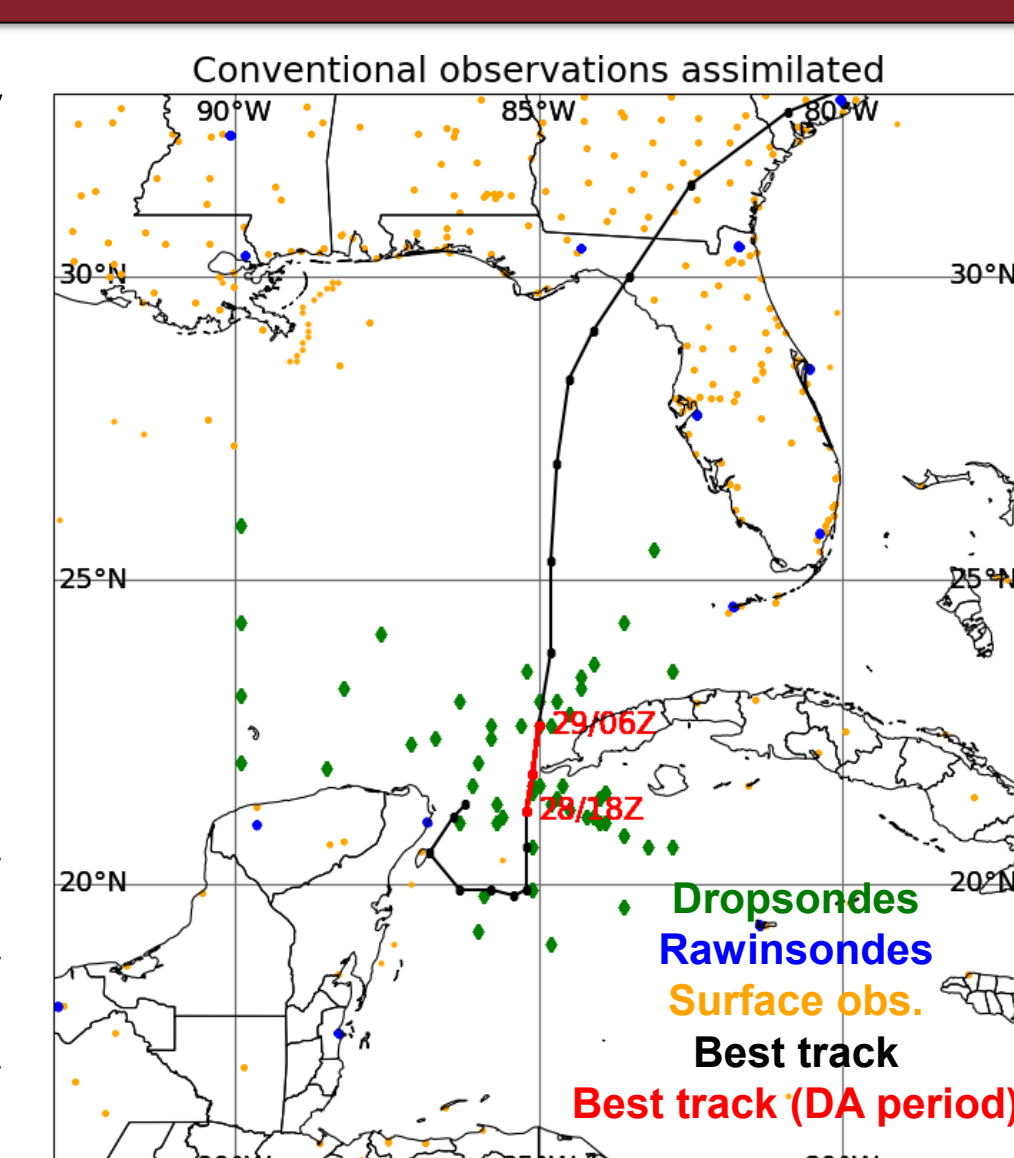
- Hurricane Idalia (2023) underwent rapid intensification over the warm ocean surface of the Gulf of America and Caribbean Sea, with wind speeds increasing from 60 kt (tropical storm) to 115 kt (Category 4 hurricane) within 33 hours.
- However, this rapid intensification was underpredicted in early forecasts issued by the National Hurricane Center (NHC) (NHC Tropical Cyclone Report).



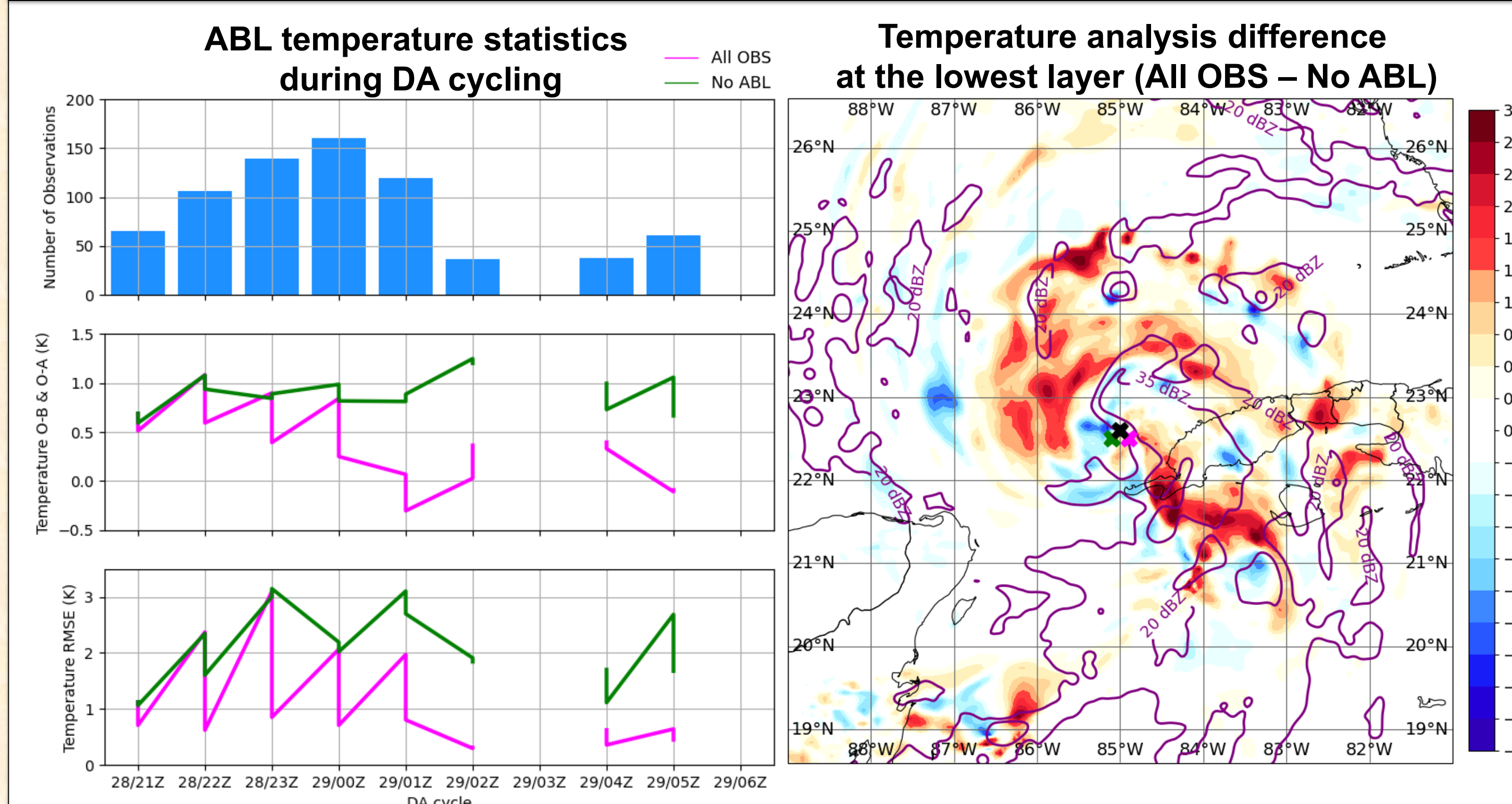
Experiment design

- Using the self-cycled HAFS-JEDI system developed by CADRE, observations are assimilated hourly during the RI period (21 UTC 28 Aug – 06 UTC 29 Aug) via 3DnVar and GETKF (similar to Li et al., 2024; Lu and Wang, 2024, 2025).
- Two DA cycling experiments are conducted: one including and one excluding ABL dropsonde observations.

Experiment	Assimilated observations
No ABL	Conventional & satellite obs. + dropsonde above ABL
All OBS	Conventional & satellite obs. + dropsonde at all layer

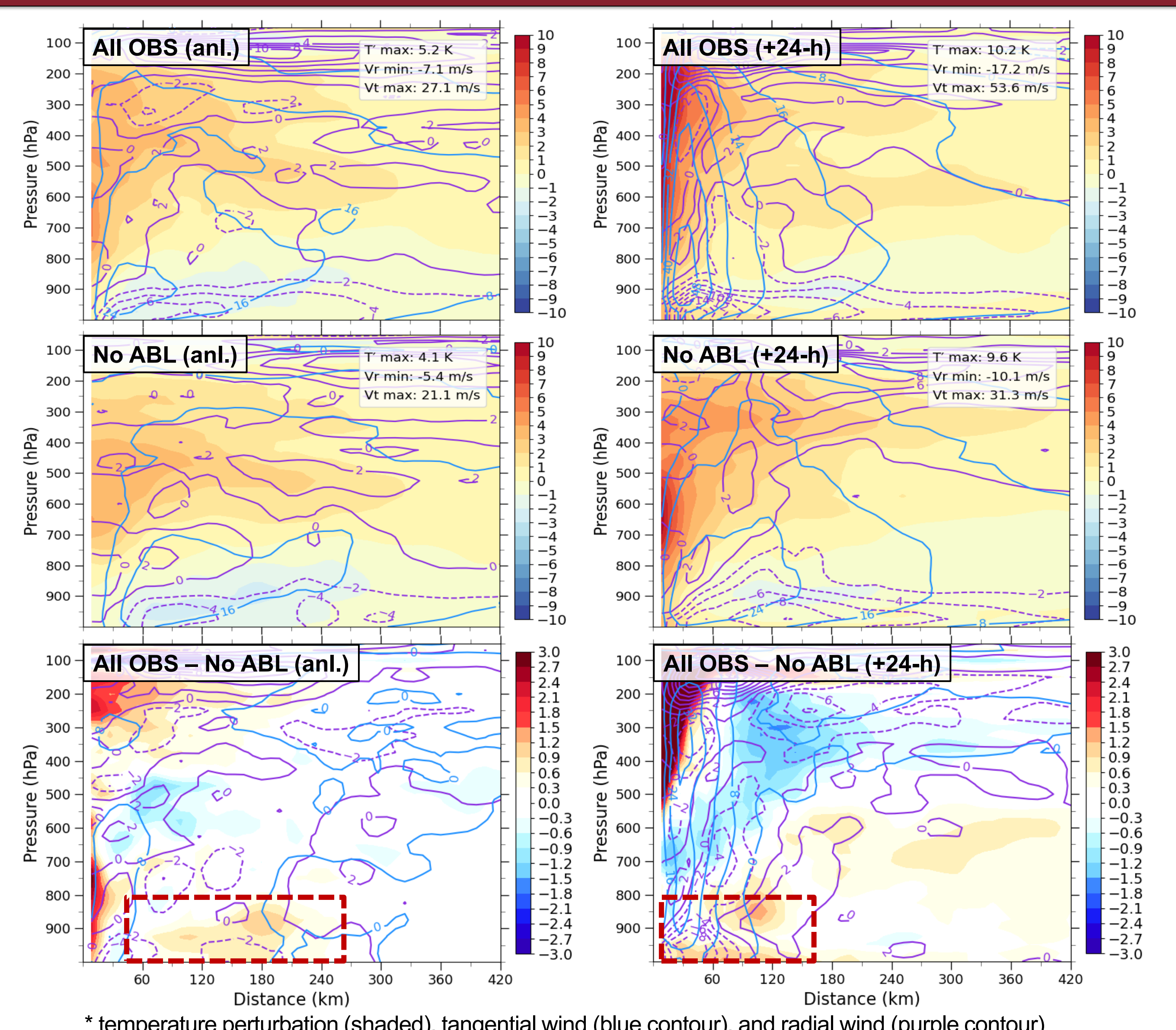


DA cycling and analysis difference within ABL



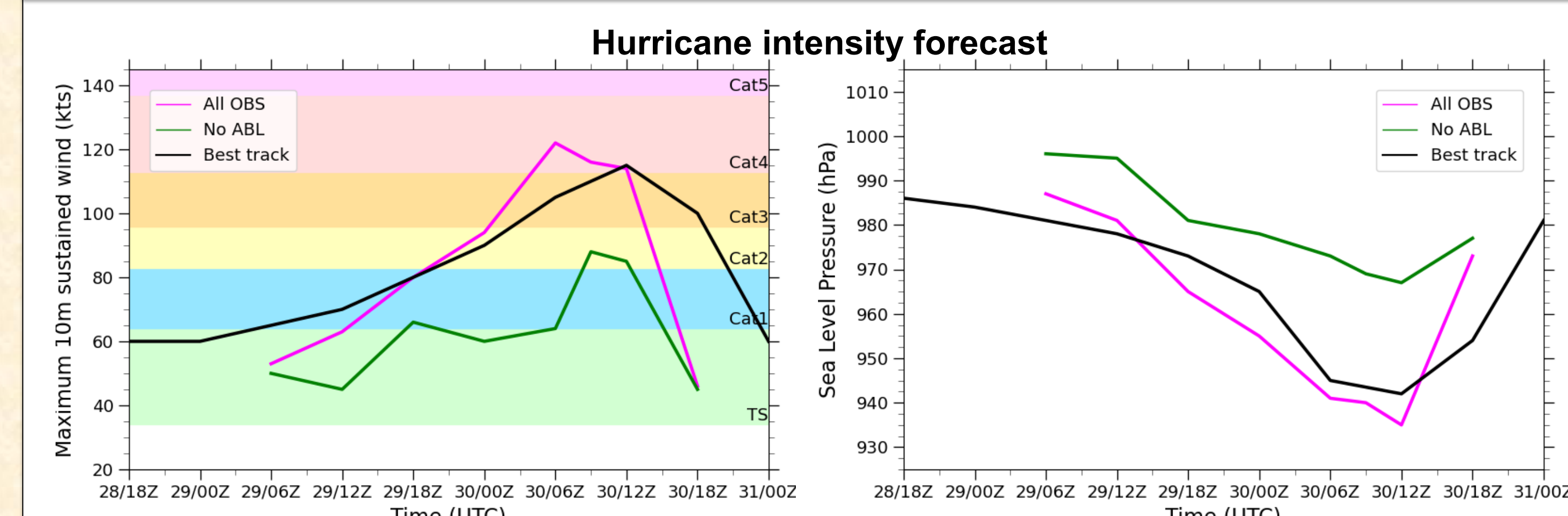
- During the DA cycling period, the ABL temperature is generally underestimated relative to the assimilated dropsonde observations.
- Assimilating ABL observations reduces the positive O-B error throughout the cycling.
- By the final DA cycle (29/06Z), the *All OBS* experiment analyzes a noticeably warmer ABL near the hurricane core compared to the *No ABL* experiment.

Radial mean structure analysis and forecast

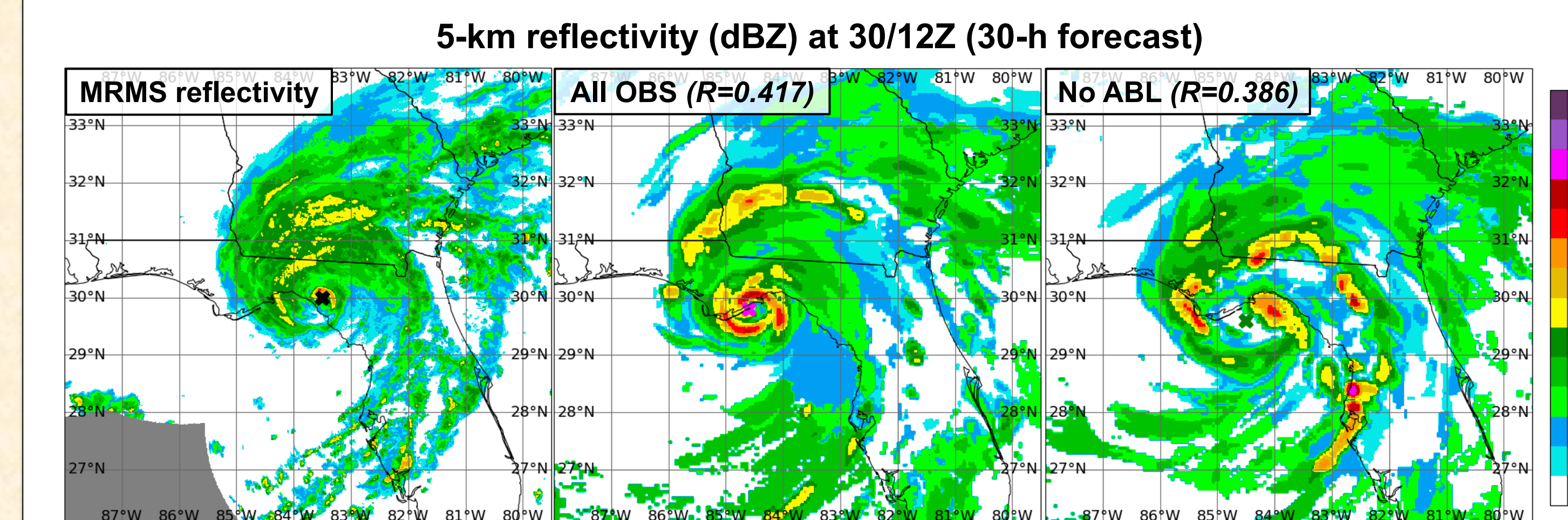
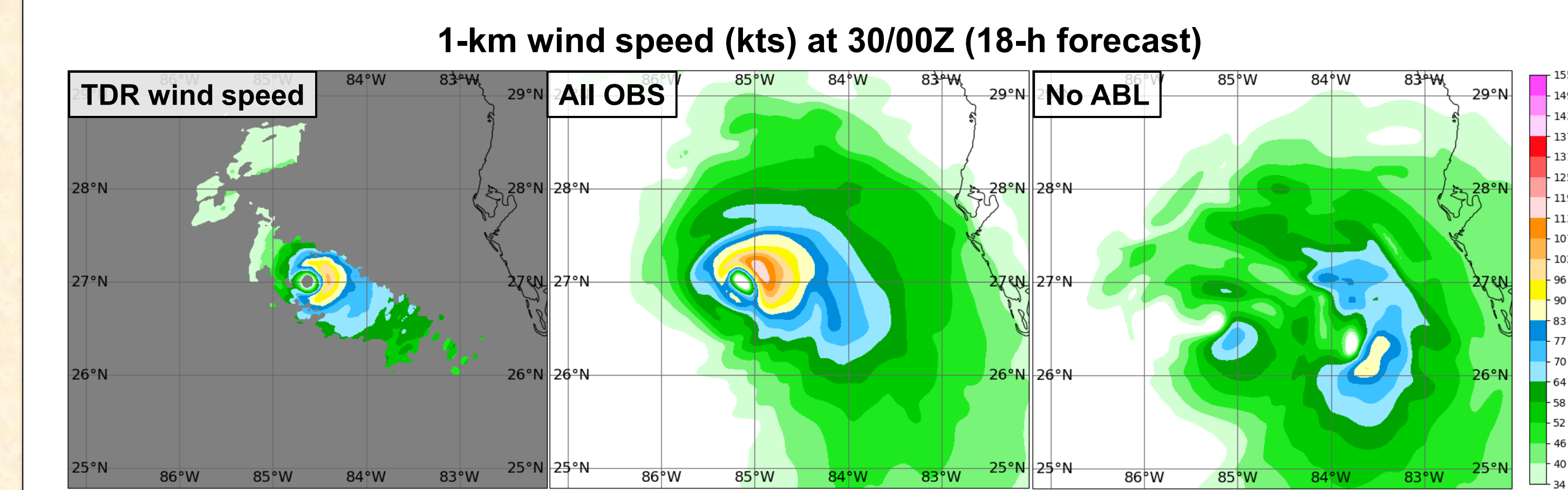


- All OBS* analyzes higher ABL temperatures than *No ABL*, leading to a stronger warm core at mid-levels and enhanced low-level radial inflow toward the hurricane's center.
- In the 24-hour forecast, *All OBS* simulates stronger tangential and radial winds along the hurricane's core, maintaining higher ABL temperatures through air-sea interaction.

Hurricane forecast verification



- The *All OBS* experiment more accurately reproduces the observed peak intensity of Hurricane Idalia as a Category 4 tropical cyclone compared to the *No ABL* experiment.



- The improved hurricane intensity forecasts in the *All OBS* experiment correspond to a more organized and compact core structure—both in wind and hydrometeor fields.

Conclusions

- This study underscores the value of assimilating atmospheric boundary layer observations in improving forecasts of tropical cyclone rapid intensification within coupled prediction systems.
- To explicitly account for air-sea interactions, CADRE will further develop and evaluate **strongly and weakly coupled DA systems** within the **self-cycled HAFS-JEDI framework**.

Acknowledgment and selected references

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Lu, X., and X. Wang, 2025: GOES-16 ABI All-Sky Brightness Temperature Into the HAFS Dual-Resolution Self-Consistent EnVar DA System: Methods for Observation Error Estimation and Impact on Hurricane Laura (2020). *Earth and space sciences*, 12, e2024EA004058, <https://doi.org/10.1029/2024EA004058>.