Advancing Data Assimilation Techniques

And How We Navigate the Complete Research Cycle of Data Assimilation in an Operational Environment

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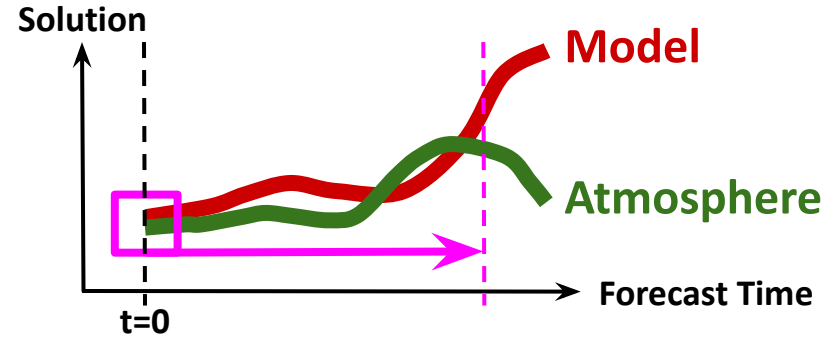U.S. Department of Commerce

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What Is Data Assimilation (DA)?

Problem **Atmosphere Is A Chaotic System:**

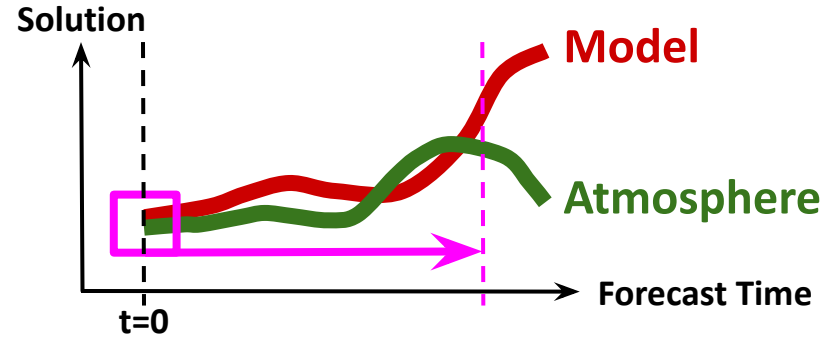→ Slightly different conditions will evolve very differently

What Is Data Assimilation (DA)?

Problem

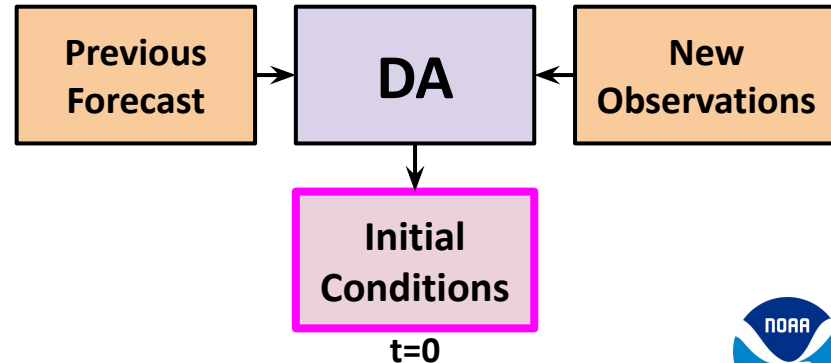**Atmosphere Is A Chaotic System:**

➔ Slightly different conditions will evolve very differently
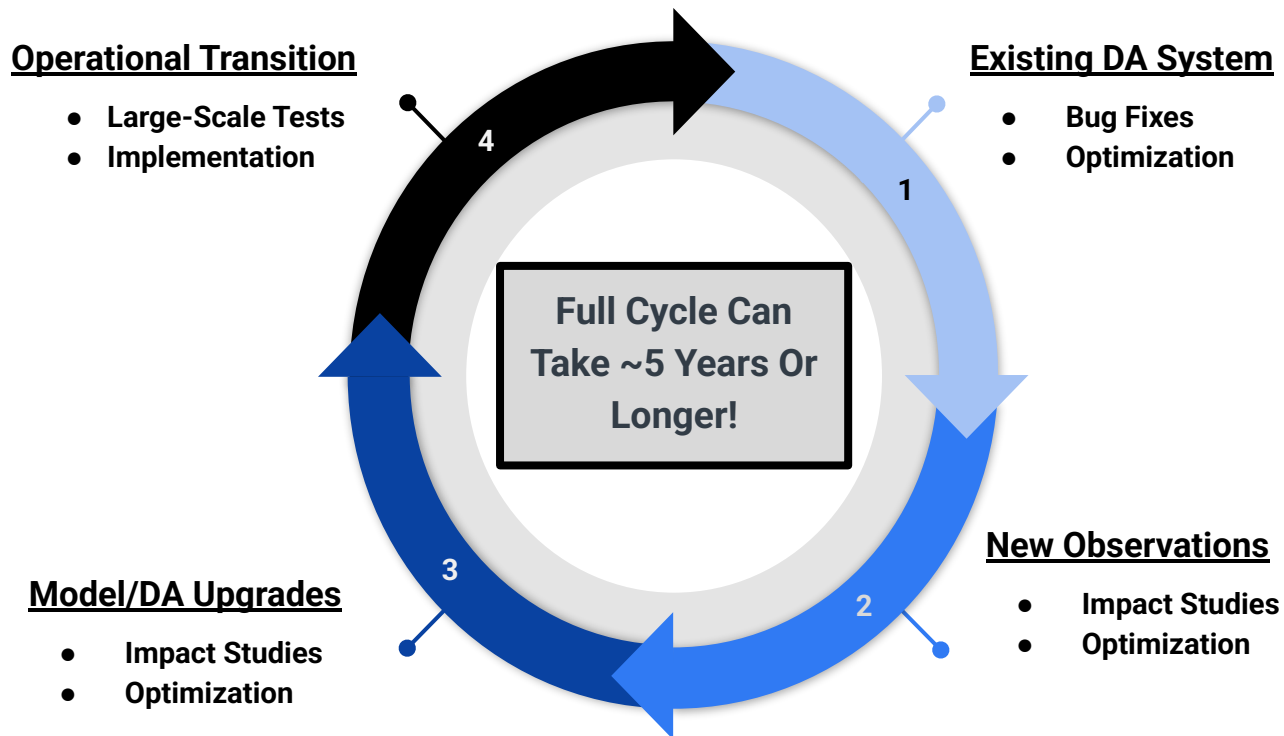
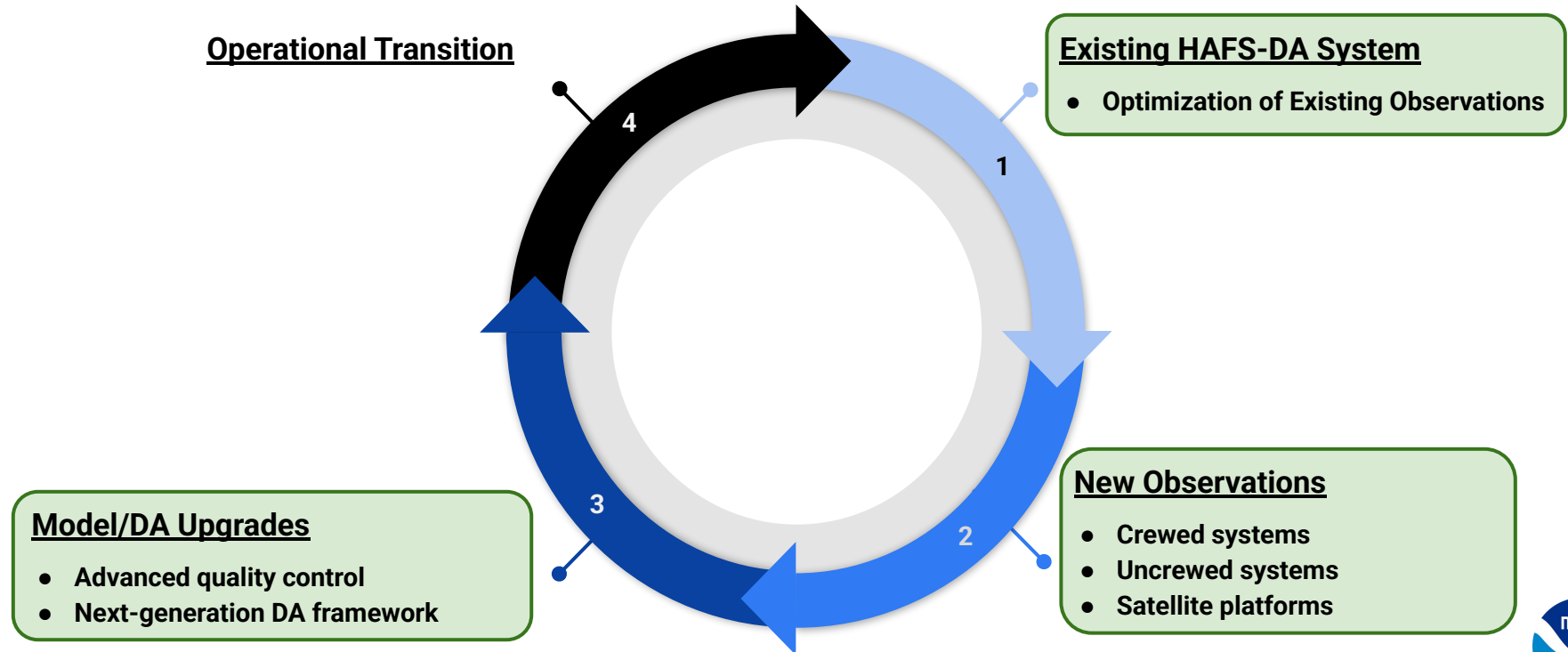**Solution**

Data Assimilation (DA):

➔ Combine previous forecast with new observations: minimize difference between model and atmosphere at initial time

The DA Research and Transition Cycle

Operational Transition
- **Large-Scale Tests**
- **Implementation**

Existing DA System
- **Bug Fixes**
- **Optimization**

Model/DA Upgrades
- **Impact Studies**
- **Optimization**

New Observations
- **Impact Studies**
- **Optimization**

Full Cycle Can Take ~5 Years Or Longer!

AOML/UM's DA Research on The HAFS-DA System

Operational Transition

Existing HAFS-DA System
- **Optimization of Existing Observations**

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New Observations
- **Crewed systems**
- **Uncrewed systems**
- **Satellite platforms**

Model/DA Upgrades
- **Advanced quality control**
- **Next-generation DA framework**

Optimization of Existing Observations

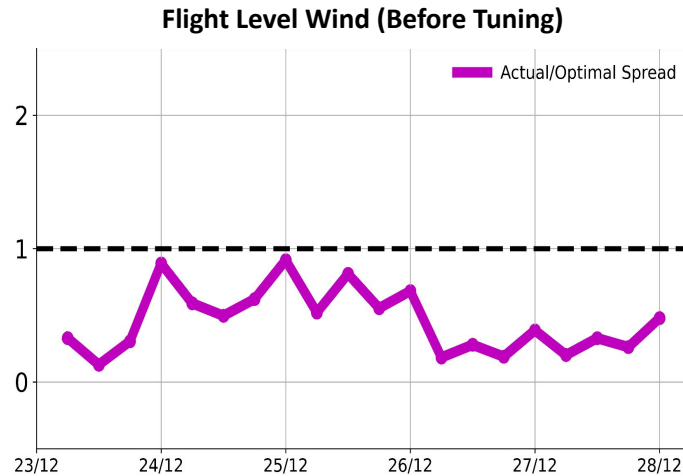**Diagnosing DA Performance in Observation Space Is Critical:**

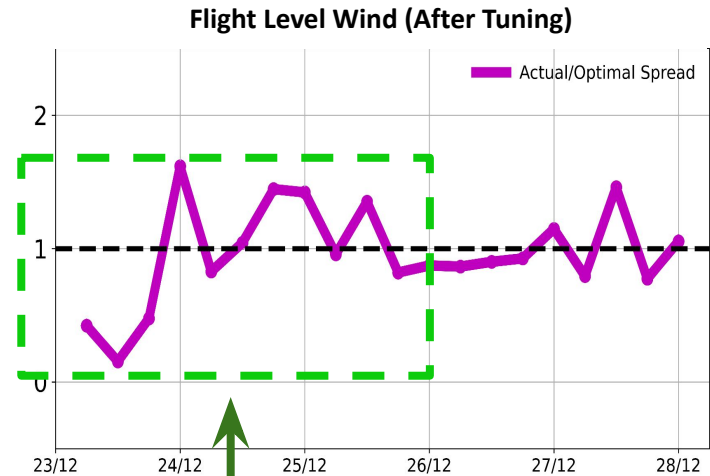➔ Tuning observation errors in the HAFS-DA system

Optimization of Existing Observations

Diagnosing DA Performance in Observation Space Is Critical:

➔ Tuning observation errors in the HAFS-DA system

Flight Level Wind (Before Tuning)

Original

Flight Level Wind (After Tuning)

Tuned

Led to **20% Position Error** and **30% Central Pressure Error Improvement**

Assimilation of Dropsonde Superobs

Dropsondes measure the structure of the TC inner core:

➔ Operational HAFS: assimilates low-resolution data

➔ Goal: assimilate newer high-resolution data

**Critical data
below aircraft**

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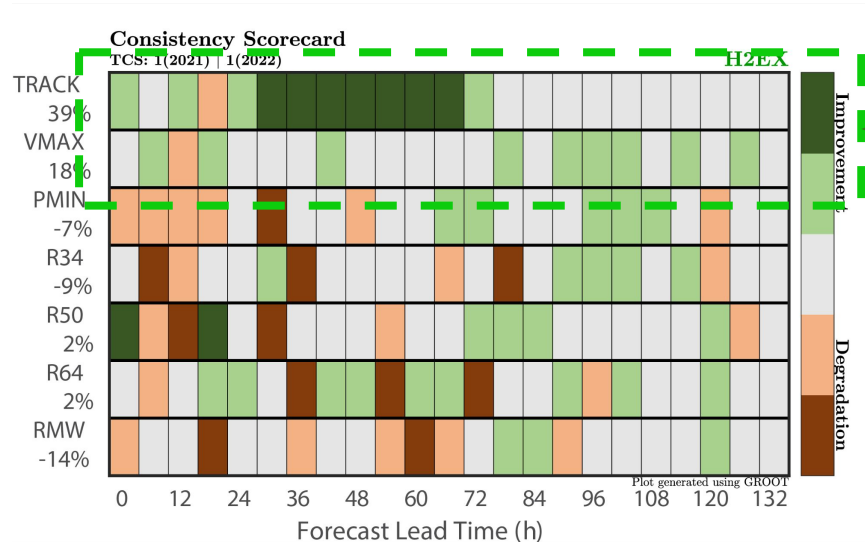➜ Goal: assimilate newer high-resolution data

Critical data below aircraft

Consistency Scorecard
TCS: 1(2021) | 1(2022)   H2EX

| | TRACK 39% | VMAX 18% | PMIN -7% | R34 -9% | R50 2% | R64 2% | RMW -14% |

Forecast Lead Time (h): 0 12 24 36 48 60 72 84 96 108 120 132

Plot generated using GROOT

Improvement / Degradation

Improved track and intensity forecasts!

Assimilation of Altius sUAS Observations

Small Uncrewed Aircraft Systems (sUAS) are an exciting new observing capability:

➔ Operational HAFS: doesn't assimilate sUAS observations
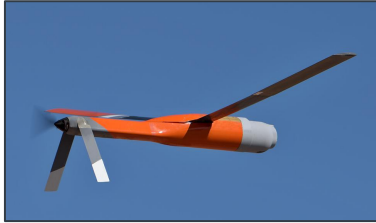
➔ Goal: investigate sUAS impact on HAFS
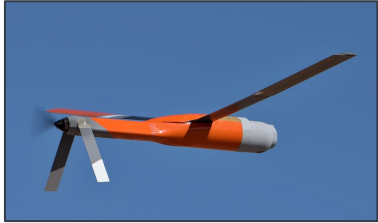
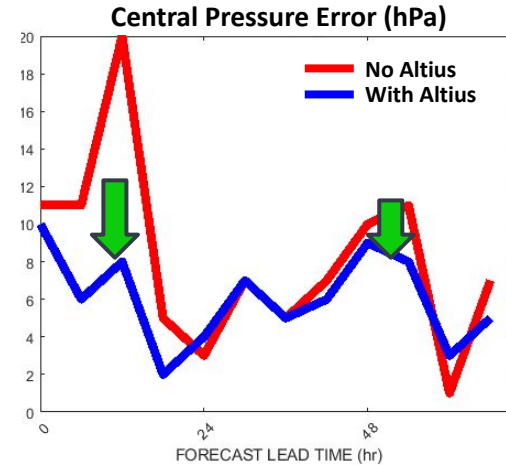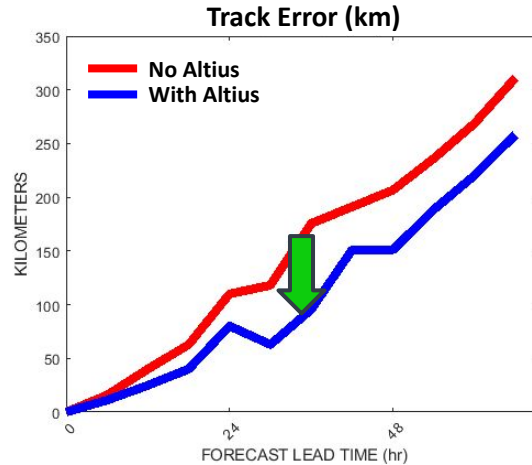**Critical data at very low altitudes**

Assimilation of Altius sUAS Observations

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Critical data at very low altitudes

Track Error (km)
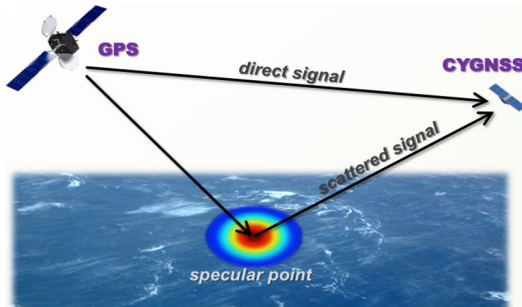
Central Pressure Error (hPa)

Improved track and central pressure forecasts!

Assimilation of CyGNSS Satellite Observations

CyGNSS is a new space-based platform that expands our TC observing capabilities:

➔ Operational HAFS: doesn't assimilate CyGNSS observations

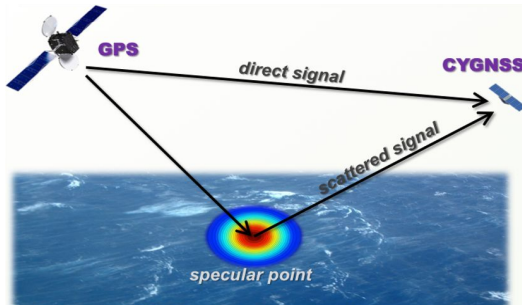➔ Goal: investigate CyGNSS impact on HAFS

Retrieves wind data utilizing signals from existing GPS signals

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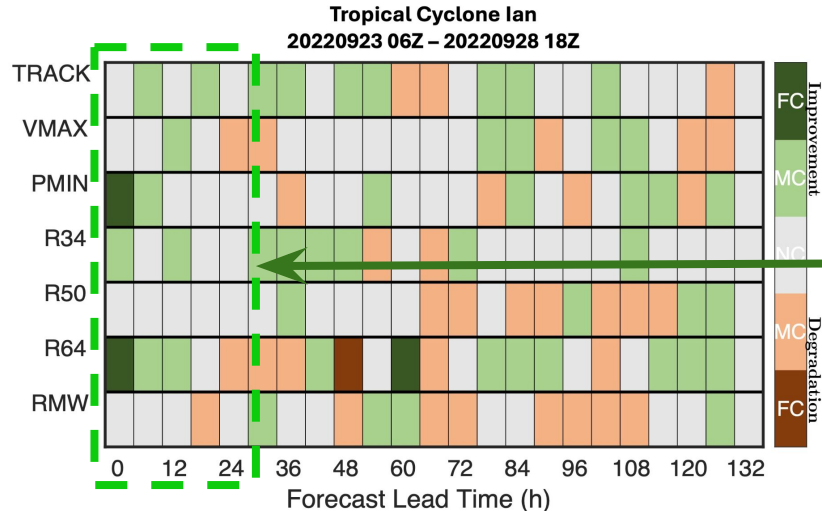Retrieves wind data utilizing signals from existing GPS signals

Tropical Cyclone Ian
20220923 06Z – 20220928 18Z

Improved the first 24-hour forecasts!

Assimilation of TROPICS Satellite Observations

TROPICS is a cubesat constellation that adds to our TC observing capabilities:

➔ Operational HAFS: doesn't assimilate TROPICS observations

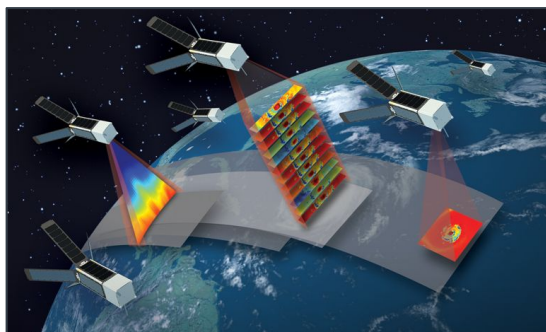➔ Goal: investigate TROPICS impact on HAFS
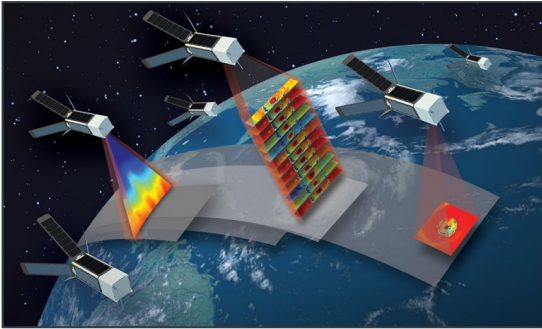
Constellation of satellites with 12 microwave channels targeting precipitation, temperature, humidity, and cloud ice

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NO TROPICS **WITH TROPICS**

Constellation of satellites with 12 microwave channels targeting precipitation, temperature, humidity, and cloud ice
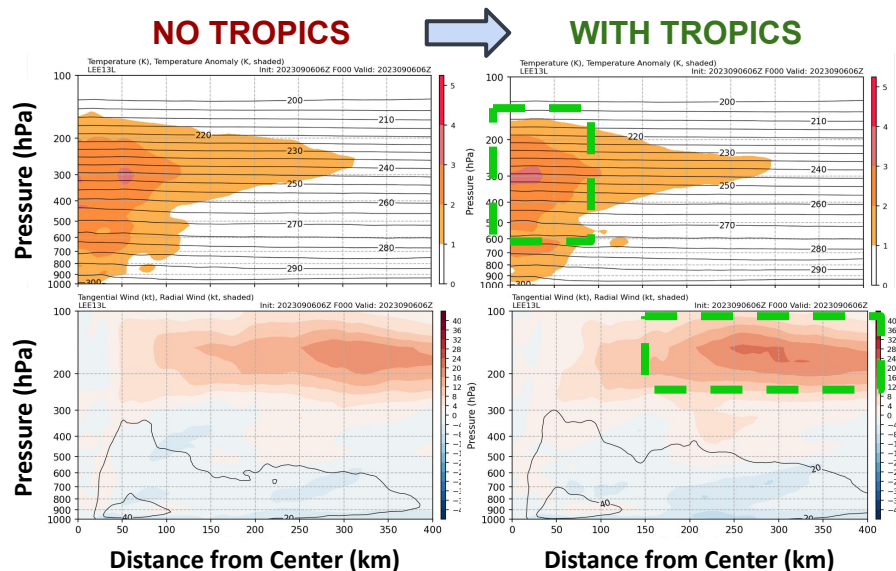
Improved the modeled TC structure!

HAFS Model and DA System Upgrades

Advanced Quality Control

A new experimental technique that carries out quality control online during DA is being **transitioned** to the HAFS-DA system for future operational implementation.

Next-Generation DA (JEDI*)

We are a part of the NOAA/EMC HAFS-JEDI **transition** team and working on TC inner-core DA capabilities in JEDI for future operational implementation.

> ***JEDI: The Joint Effort for Data assimilation Integration**
> <u>All NOAA models</u> are being integrated under this new DA platform (developed by the Joint Center for Satellite Data Assimilation, JCSDA)
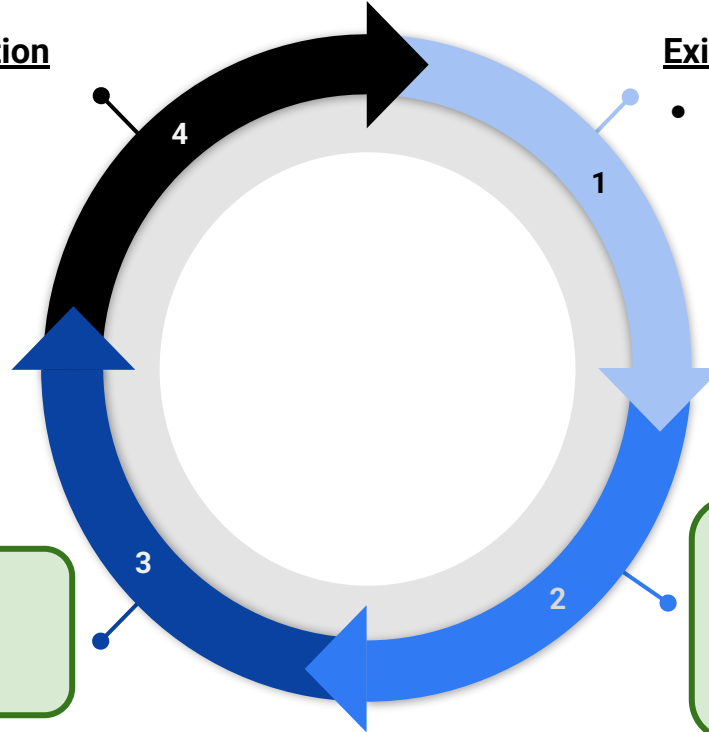
Future Goals and Projects for HAFS-DA

Operational Transition

Existing HAFS-DA System

- **Optimization of Existing Observations**

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1

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New Observations

- **Uncrewed systems with private industry collaboration**
- **New instruments on crewed aircraft**

Model/DA Upgrades

- **New Quality Control Techniques**
- **Machine-learning-based DA**

New proposals to NOAA and NASA

Summary

01 AOML and University of Miami are engaged in a number of projects to advance NOAA's HAFS-DA system

02 **Present:** improving assimilation of existing TC inner-core observations

03 **Future:** advance HAFS-DA capabilities:
- ✓ Expand sUAS observing/DA technologies
- ✓ Improve assimilation of existing aircraft platforms
- ✓ Invest in new DA technologies such as machine learning
- ✓ Expand partnerships with private industry and other agencies