NOAA's Atlantic Oceanographic and Meteorological Laboratory
U.S. Department of Commerce

Regional ocean modeling in support of hurricane forecast improvements

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CIMAS

UNIVERSITY OF MIAMI
ROSENSTIEL SCHOOL of MARINE & ATMOSPHERIC SCIENCE

UNITED STATES NAVY

IOOS Integrated Ocean Observing System

CARICOOS

SECOORA Southeast Coastal Ocean Observing Regional Association

MARACOOS Ocean Information for a Changing World
Mid-Atlantic Regional Association Coastal Ocean Observing System

Motivation

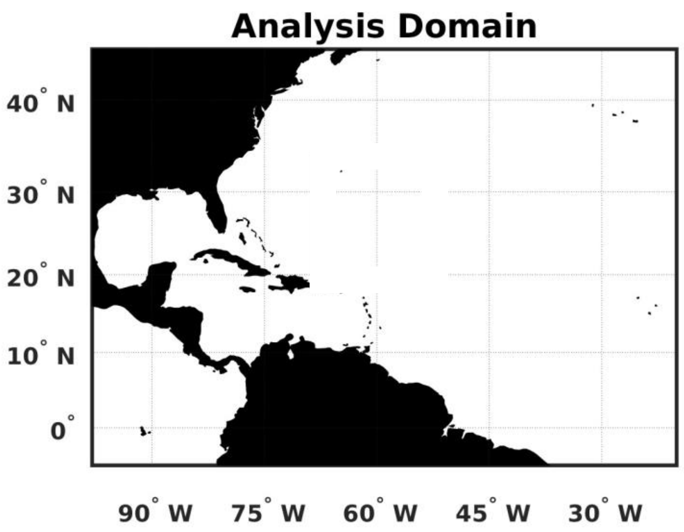
- **Improve hurricane forecast** by:
    1. Deploying **dedicated ocean observation** platforms
    2. Assessing the **impacts of ocean observations** on **hurricane forecasts**

- The first component is based on the **deployment of ocean gliders**, which observe the **vertical structure** of the ocean (temperature and salinity) at high frequency

- The second component requires the use of a **coupled ocean-hurricane model**, in which the ocean initial conditions integrate the impacts of ocean observations via **ocean Observing System Experiments**

Impacts of ocean observations on hurricane forecasts: approach

- **Coupled HYCOM-HWRF** model adapted from **operational NOAA EMC** HWRF-HYCOM
- **HWRF H218** version (**3 domains** of increasing resolution)
- **HYCOM** ocean component of the coupled model:
  - **North Atlantic domain** (includes the Caribbean Sea and the Gulf of Mexico)
  - 1/12^{o} horizontal resolution
  - **Assimilates ocean observations** prior to coupling with HWRF
  - Used to examine **various initial ocean conditions** for the coupled experiments, depending on the **ocean observations assimilated** in the ocean model, while keeping the **same atmospheric component**



Impacts of ocean observations on hurricane forecasts: ocean representation during Hurricane Michael (2018)

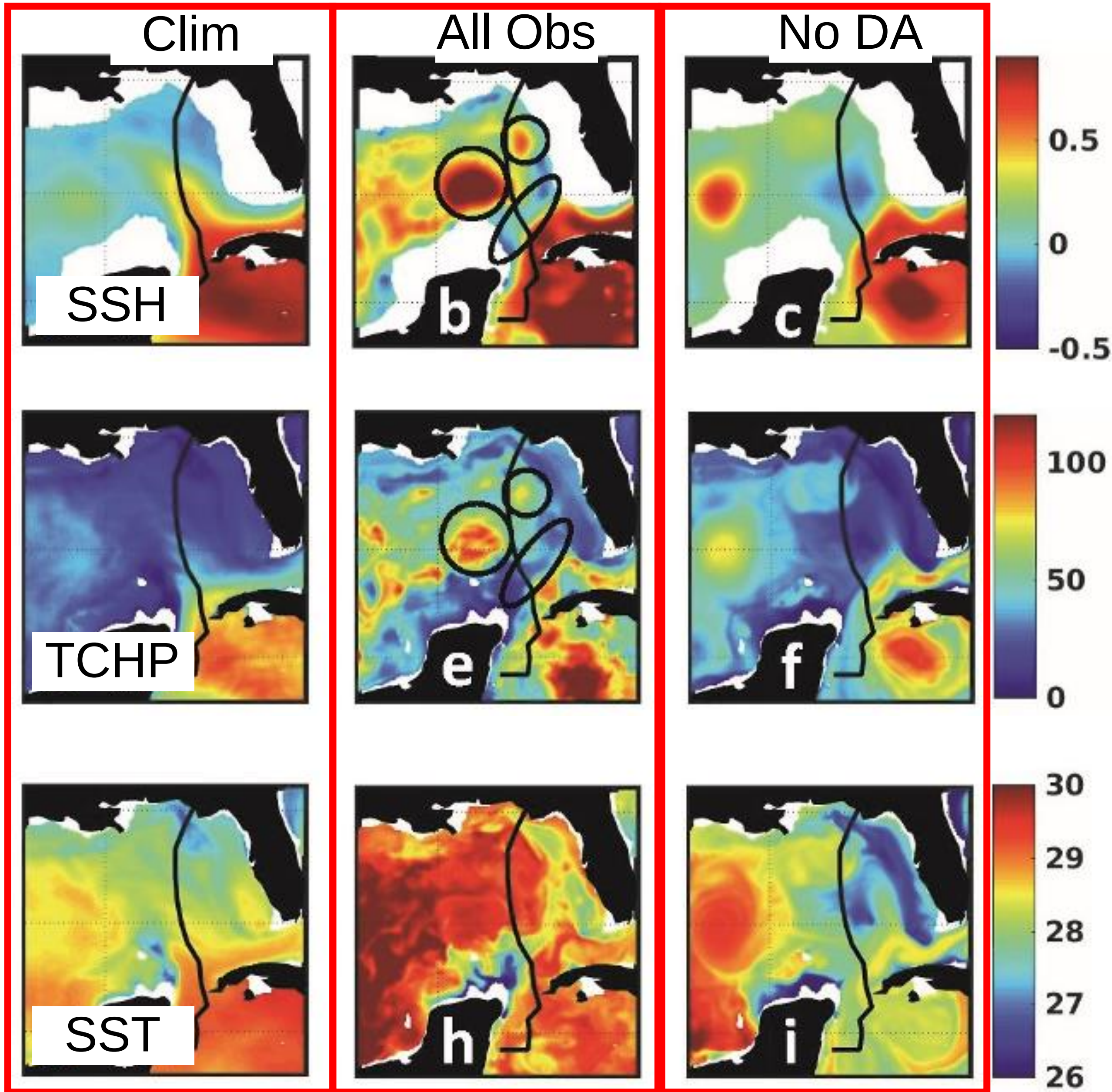
- We performed **various ocean simulations** with the HYCOM model:
  - A simulation forced to represent **climatological ocean conditions** (“Clim”)
  - A simulation in which **all available ocean observations** (altimetry, SST, in situ float data) are **assimilated** to make the simulation as close to reality as possible (“All Obs”)
  - A **free-running simulation**, without constrain from data assimilation of observations (“No DA”)
- The simulations started on January 1st, 2018 (i.e., before hurricane season)

Impacts of ocean observations on hurricane forecasts: ocean representation during Michael

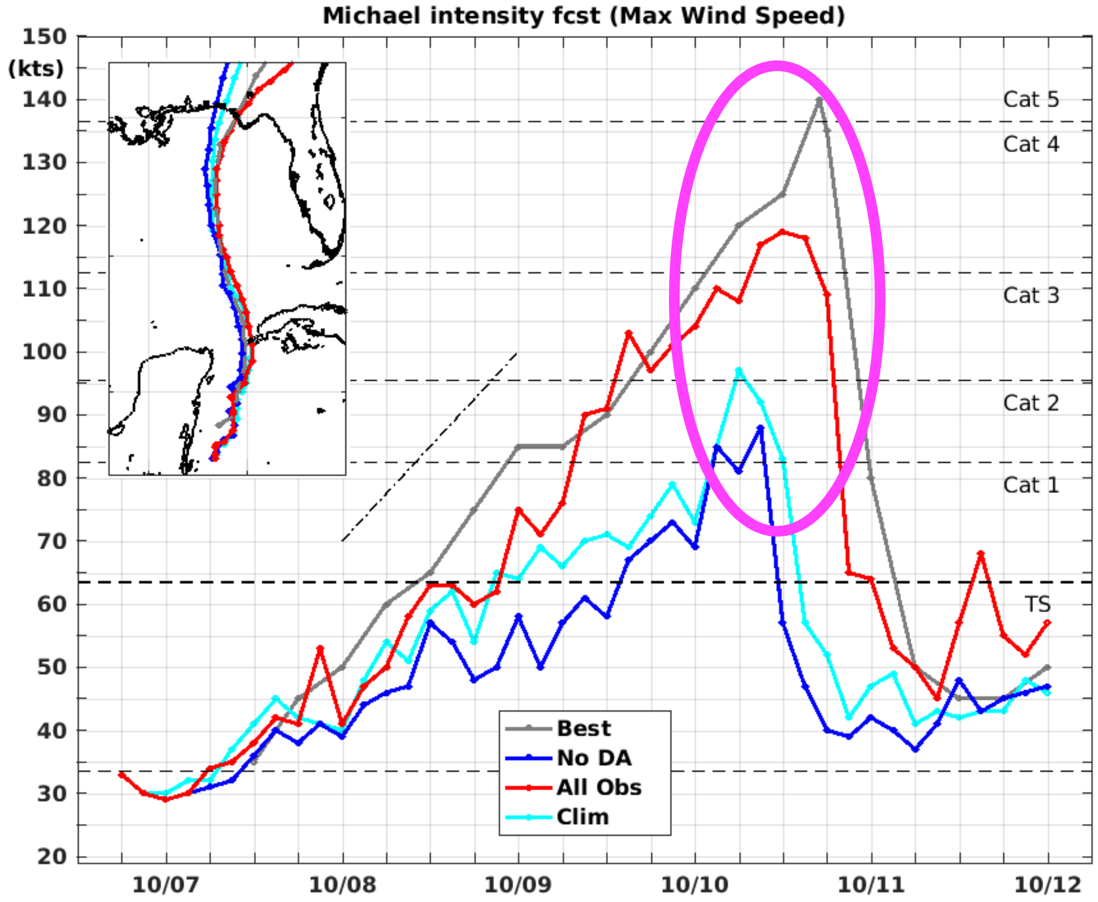
• The data assimilative ***All Obs*** simulation represents the **ocean features of interest**: anticyclonic eddies with high Tropical Cyclone Heat Potential (TCHP), warm surface waters

• The climatological simulation ***Clim*** has **diffuse Loop Current** without eddies, and very low TCHP inside the Gulf

• The free running ***No DA*** simulation has a retracted Loop Current but **no warm-core eddies**, and overall lower TCHP and SST than observed



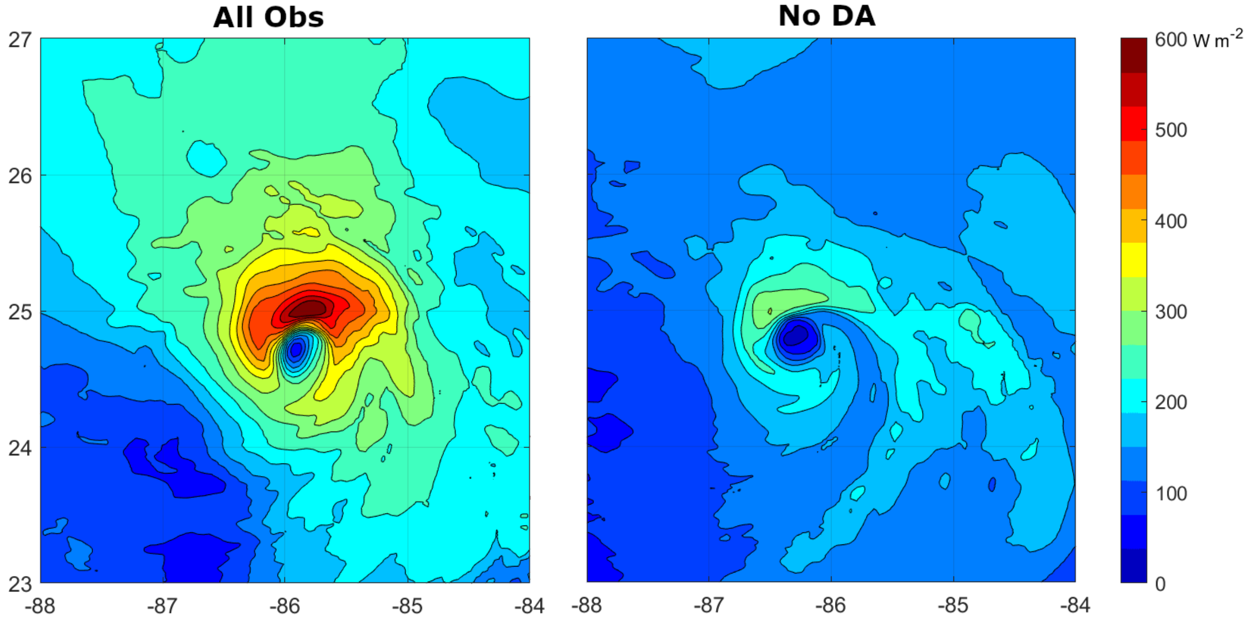
Example of a 5-day coupled simulation of Hurricane Michael (2018)



Observed wind intensities (Best, grey), with simulated ones for the All Obs (red), No DA (blue), Climatology (cyan) cases starting on 6 Oct., 18Z.

- Hurricane **tracks close to observed** track
- "***All Obs***": **rapid intensification** to **Cat. 4**
- Unconstrained ("***No DA***") case and climatological ocean ("***Clim***") case **do not intensify as much** (Cat. 1-2)

- **Ocean DA** leads to **higher enthalpy fluxes** from the ocean to the atmosphere



Surface enthalpy flux averaged over the 60-66 hour period (left: All Obs, right: No DA)

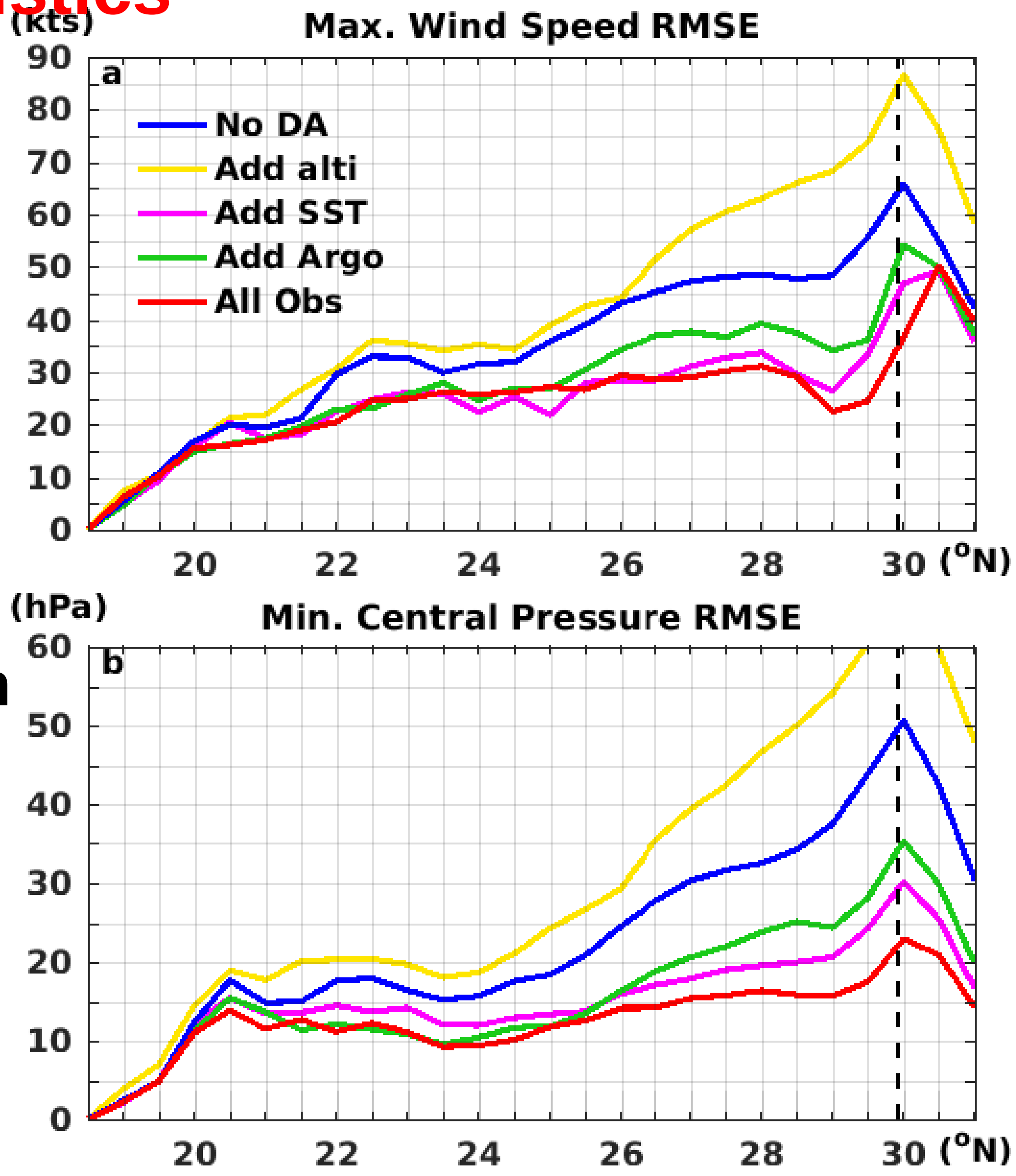
Hurricane Michael (2018): ensemble statistics

- Wind intensity and central pressure **RMSE** over **4 forecast cycles** (every 6 hrs on 6 Oct. 2018, early stage of the storm):

- "***No DA***": **large error** (33.6 kts on average, 55.7 kts at landfall)

- "***All Obs.***": **lowest error** (22.8 kts on average, 24.5 kts at landfall): **assimilating ocean observations** leads to an error reduction of **32% on average, 56% at landfall**

- "***Add SST***" (magenta, 23.9 kts on average) and "***Add Argo***" (green, 26.6 kts on average) show **significant contributions** of the respective platforms to error reduction (first Argo, then SST)



(a) Wind and (b) Pressure (hPa) RMSE as a function of latitude following the hurricane

Conclusions

- The **coupled model HWRF-HYCOM** is able to **reproduce** the **rapid intensification** of Hurricane Michael (2018)

- **Assimilating ocean observations** leads to **large error reduction** in wind intensity forecast of Hurr. Michael: **strong impacts of the ocean** on the storm

- Other hurricanes investigated: Hurricane Gonzalo (2014), Hurricane Maria (2017)

- The **correct representation** of the **ocean** leads to **reduced error** in **hurricane intensity** forecasts, which is best achieved by **assimilating** a **combination of observations** (altimetry: mesoscale features, profilers: vertical structure, SST: mixed layer temperature and heat)