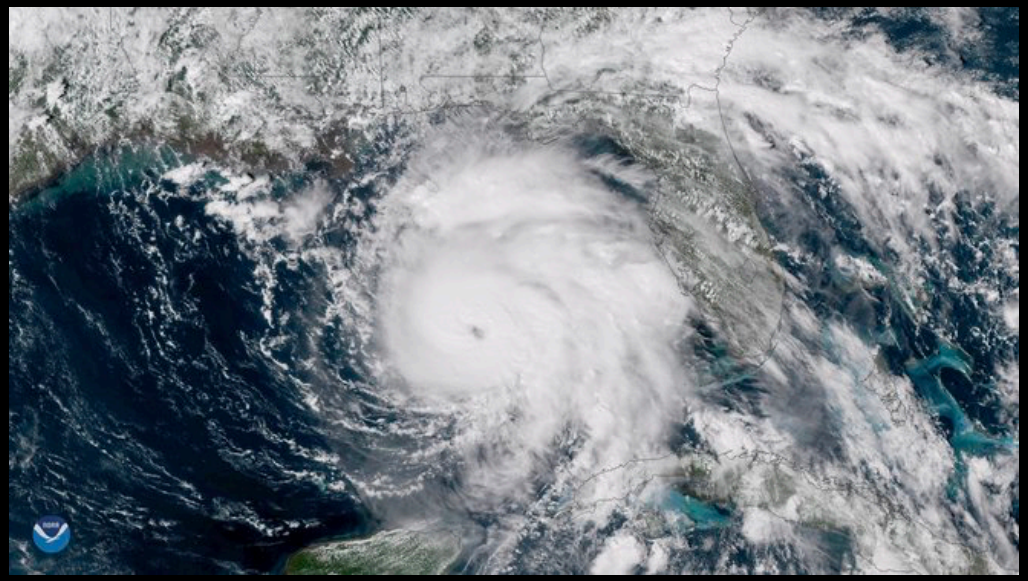
Impact of Glider Data Assimilation on Operational Ocean Models During the 2018 Hurricane Season



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Scott Glen
Travis Miles

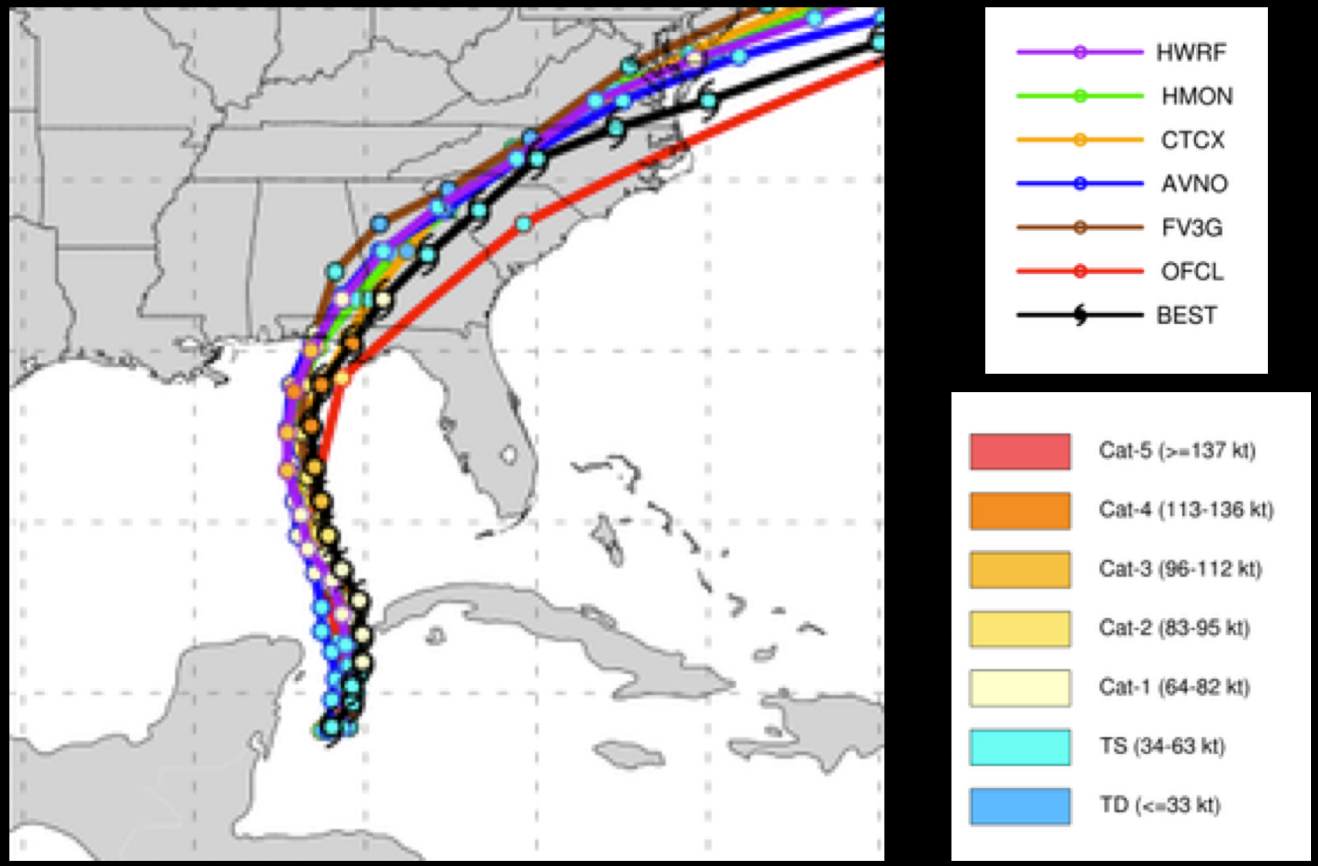
Avichal Mehra
Hyun-Sook Kim

Pat Hogan
Gregg Jacobs
Sue Chen

Motivation

Assess the impact of glider data assimilation on the operational hurricane models

Hurricane Michael Forecast

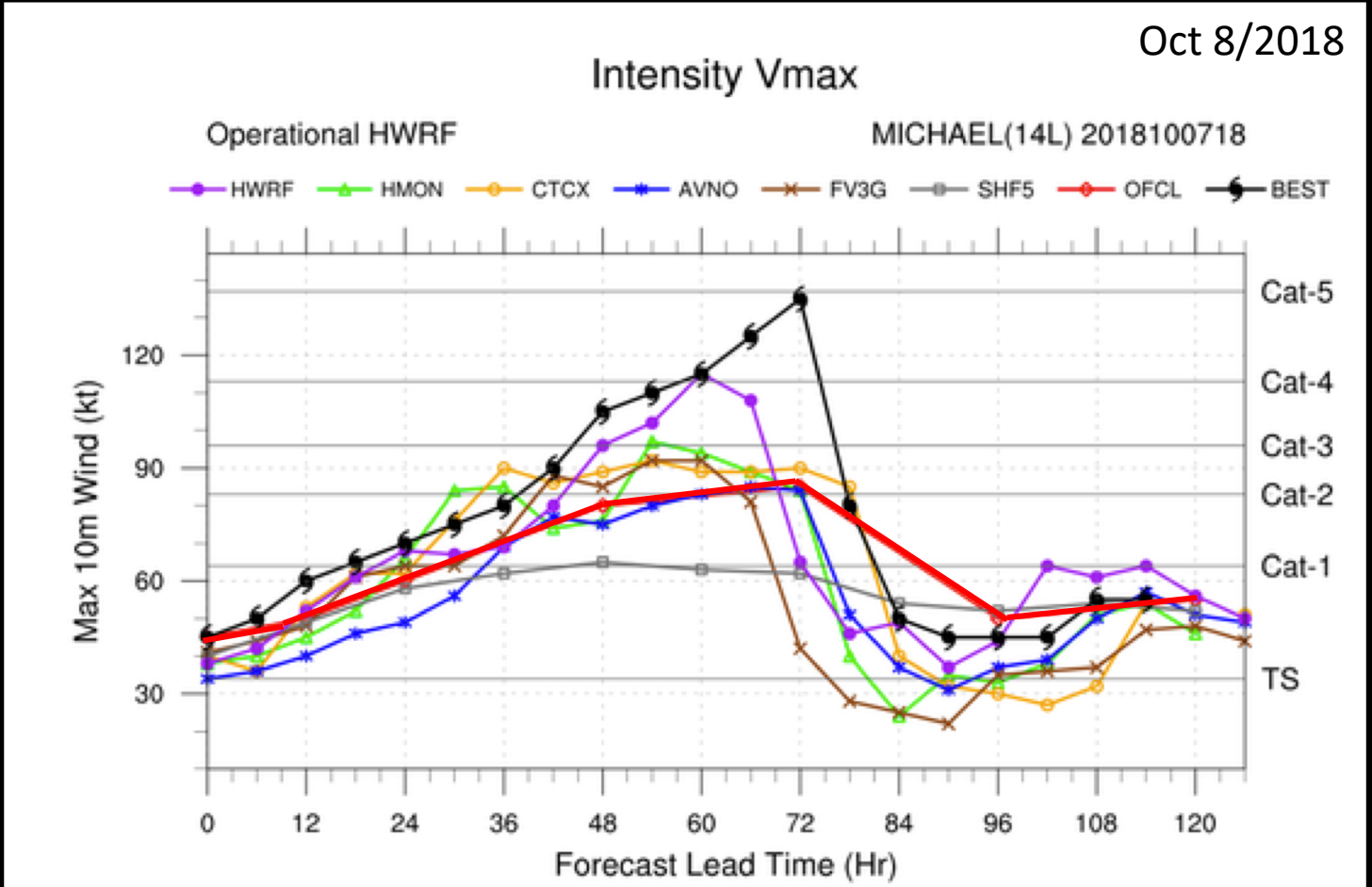


https://www.emc.ncep.noaa.gov/gc_wmb/vxt/HWRF/index.php

Mexico Beach
After Hurricane Michael

- Category 5 at landfall
- Storm surge 7.7 feet
- Total cost estimated as $25 billion

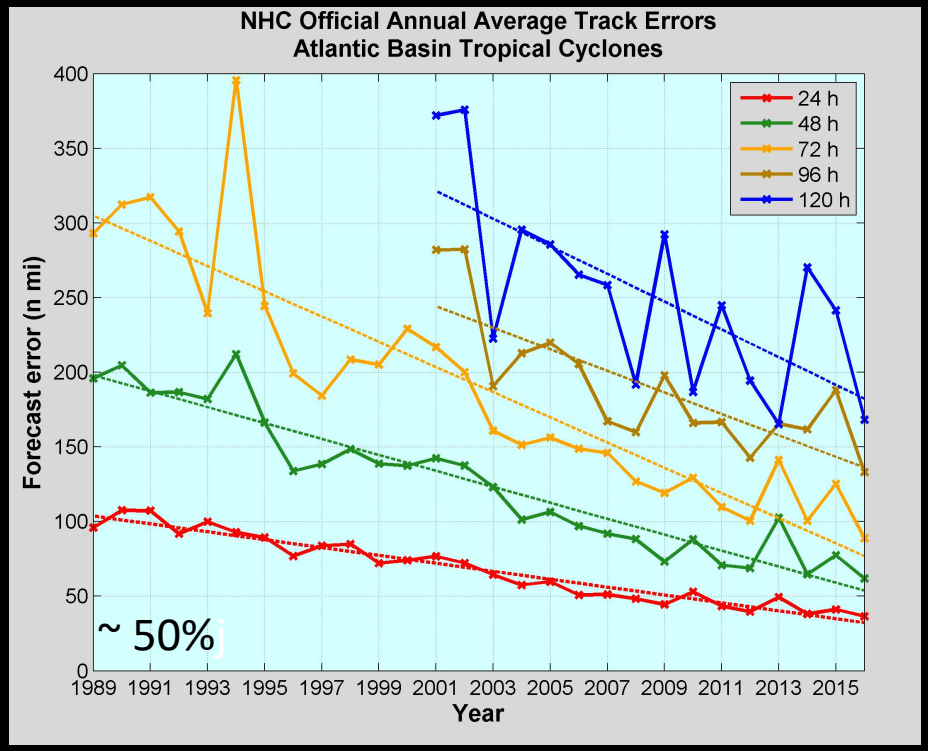
Forecast Guidance for Storm Michael

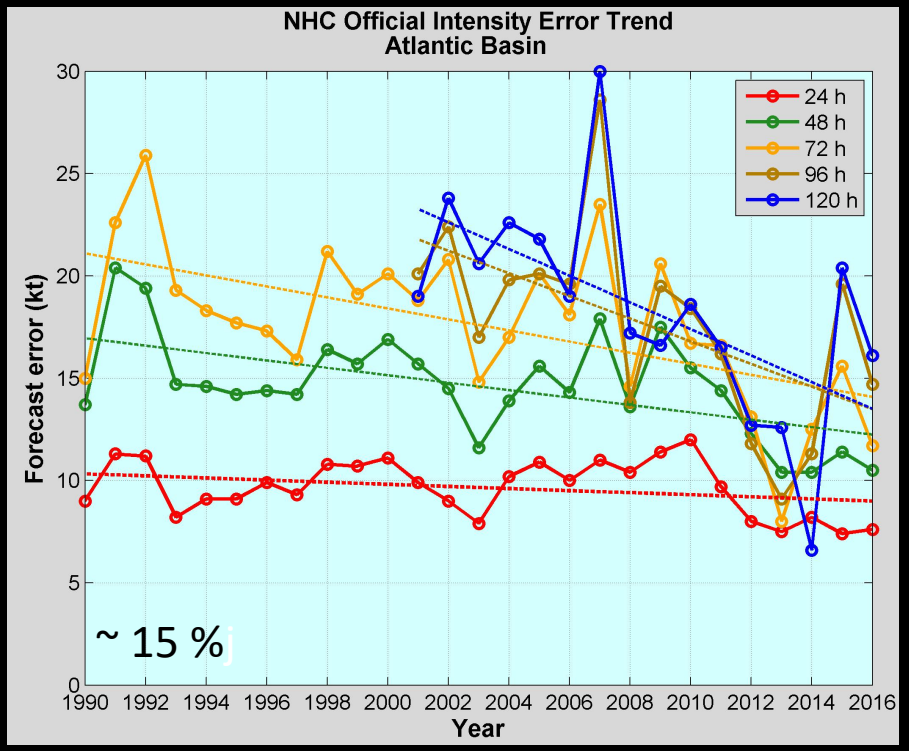


https://www.emc.ncep.noaa.gov/gc_wmb/vxt/HWRF/index.php

- None of the models forecasted the rapid intensification
- Official forecast predicted a cat 2 at landfall

NOAA Annual Operational Suite Review





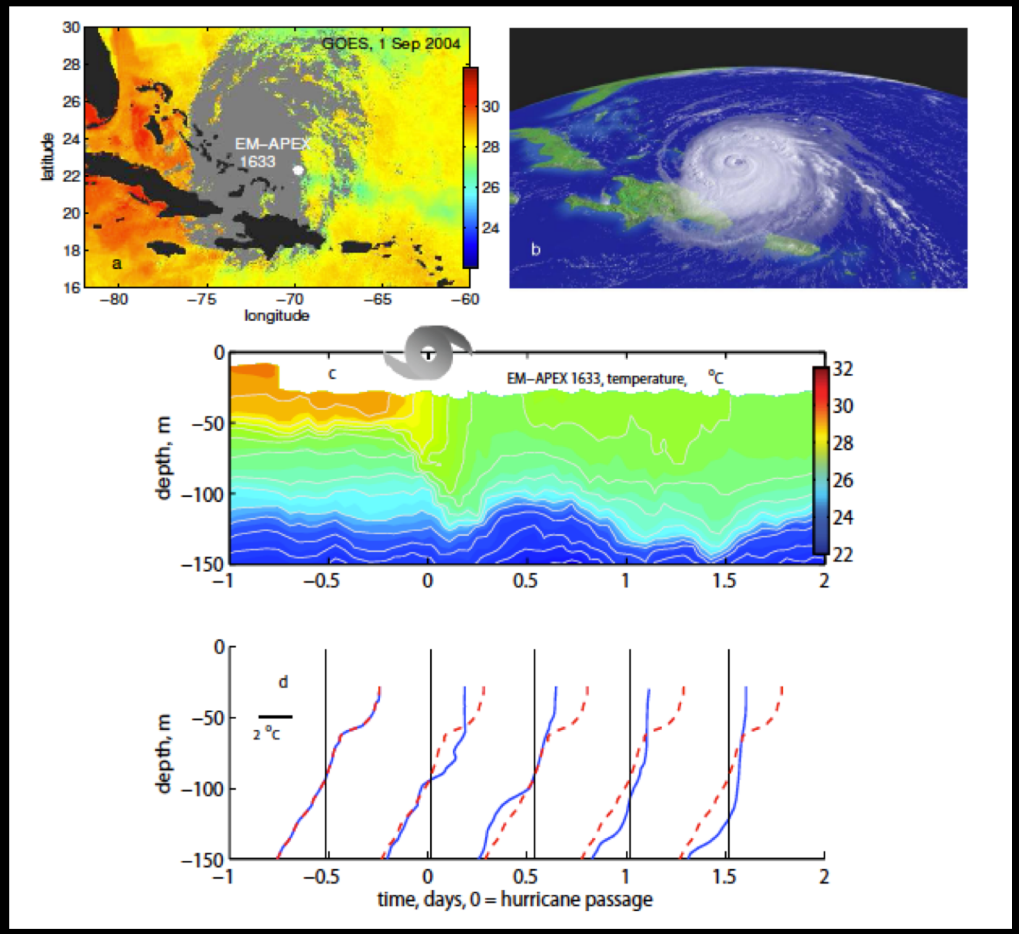
Limitations on Hurricane Intensity Improvement

- Computing resources and model resolution (Rotunno et al., 2009)
- Poor understanding of the atmospheric boundary layer (Nolan et al., 2009; Andreas et al., 2015)
- Difficulty in modeling the upper ocean response to storm forcing (Yablonsky and Ginis, 2009).

Upper Ocean Response

- Temperature and humidity differences at the air-sea interface control the heat fluxes. SST is a relevant ocean quantity
- During a storm, SST is manly controlled by the storm-induced vertical mixing and the strength of the vertical stratification

Hurricane Francis 2004 ⟶

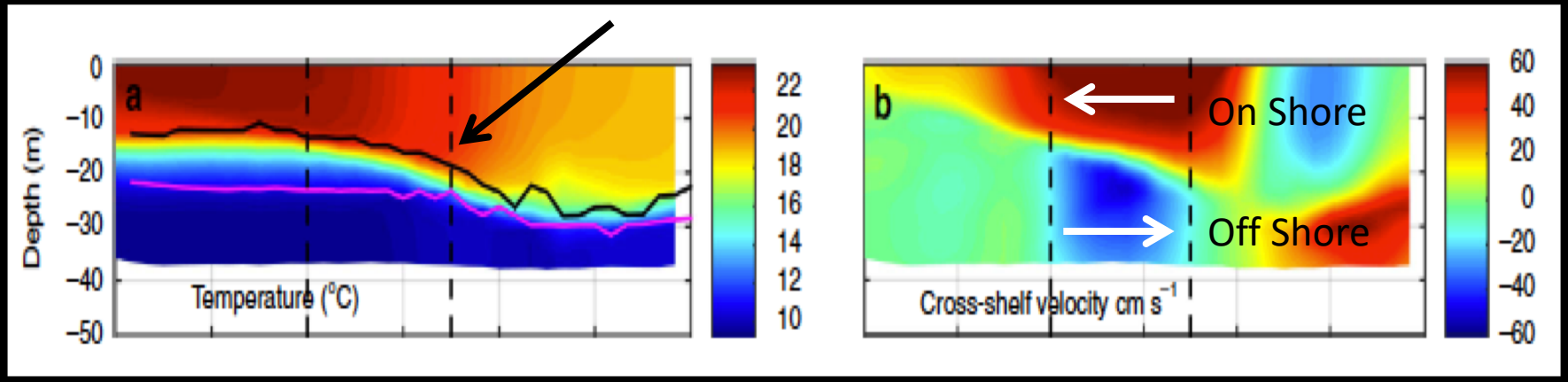


Price 2009

Upper Ocean Response

- In the continental shelf, there are other physical processes that control SST during storms: shear-induced vertical mixing due to wind-forced two-layer circulation (Glenn et al 2016), upwelling/downwelling circulation depending on the incident angle of the storm (Miles et al 2017)

Hurricane Irene (Glenn et al 2016)



To capture the upper ocean response in the shelf is critical because the SST at the shelf will determine if a hurricane will intensify or weaken before landfall

How to Improve the Modeling of the Upper Ocean Response During a Hurricane on the continental shelf?

Improve the subsurface initial conditions in the operational ocean models: right initial vertical stratification, better evolution of the SST during storms , better heat fluxes estimates

How to Improve the Modeling of the Upper Ocean Response During a Hurricane on the continental shelf?

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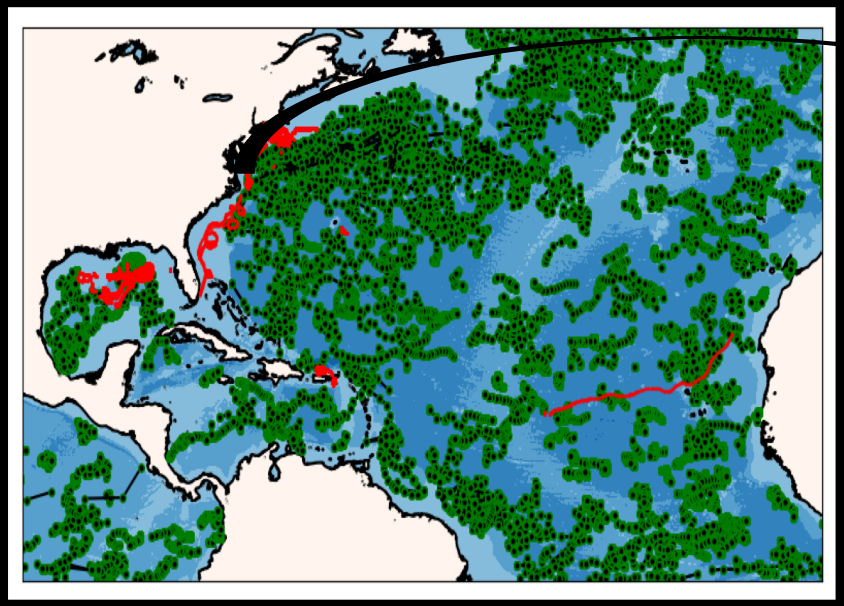
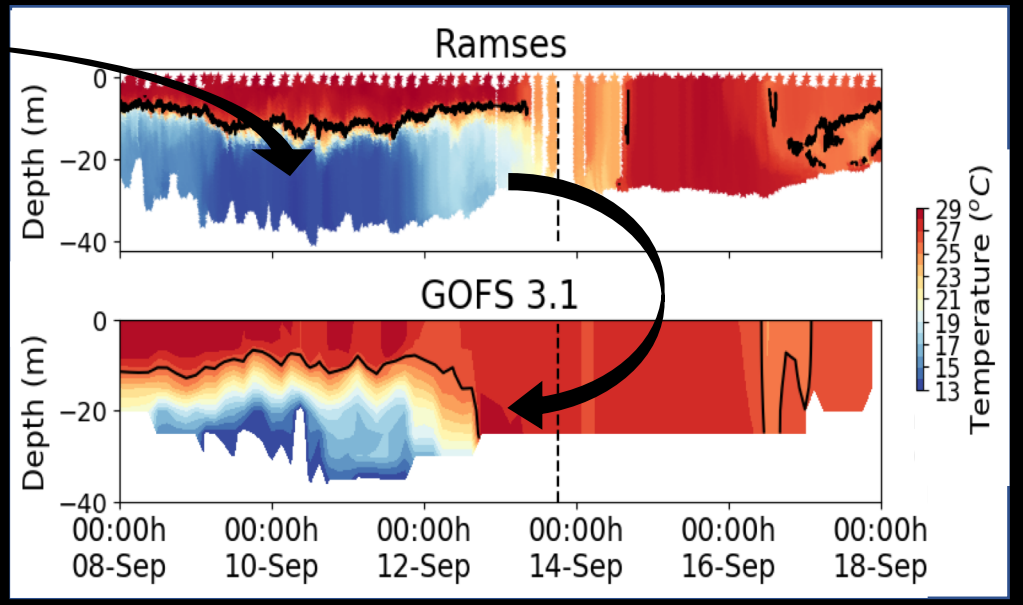
↓

Ocean Data Assimilation



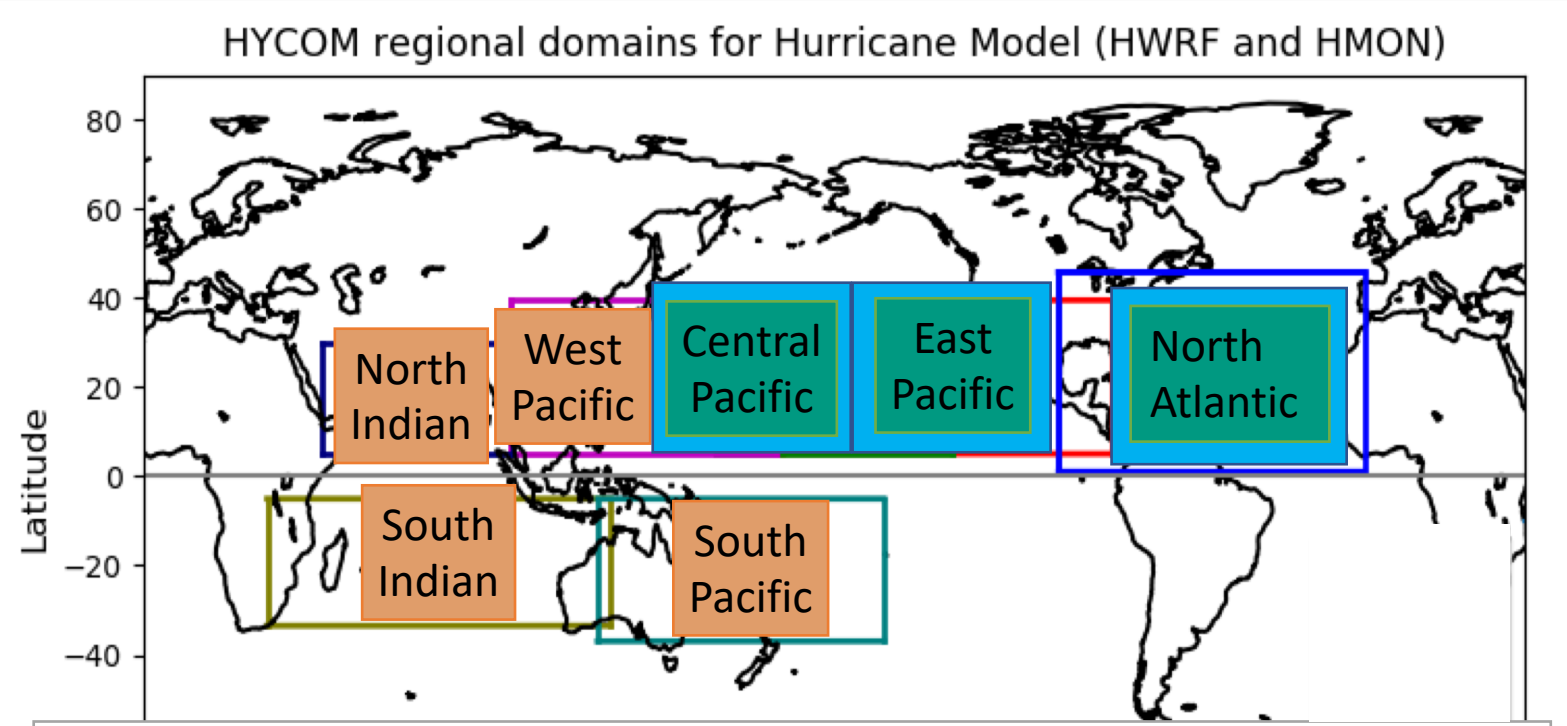


NOAA Hurricane Forecasting Models

HWRF/HYCOM

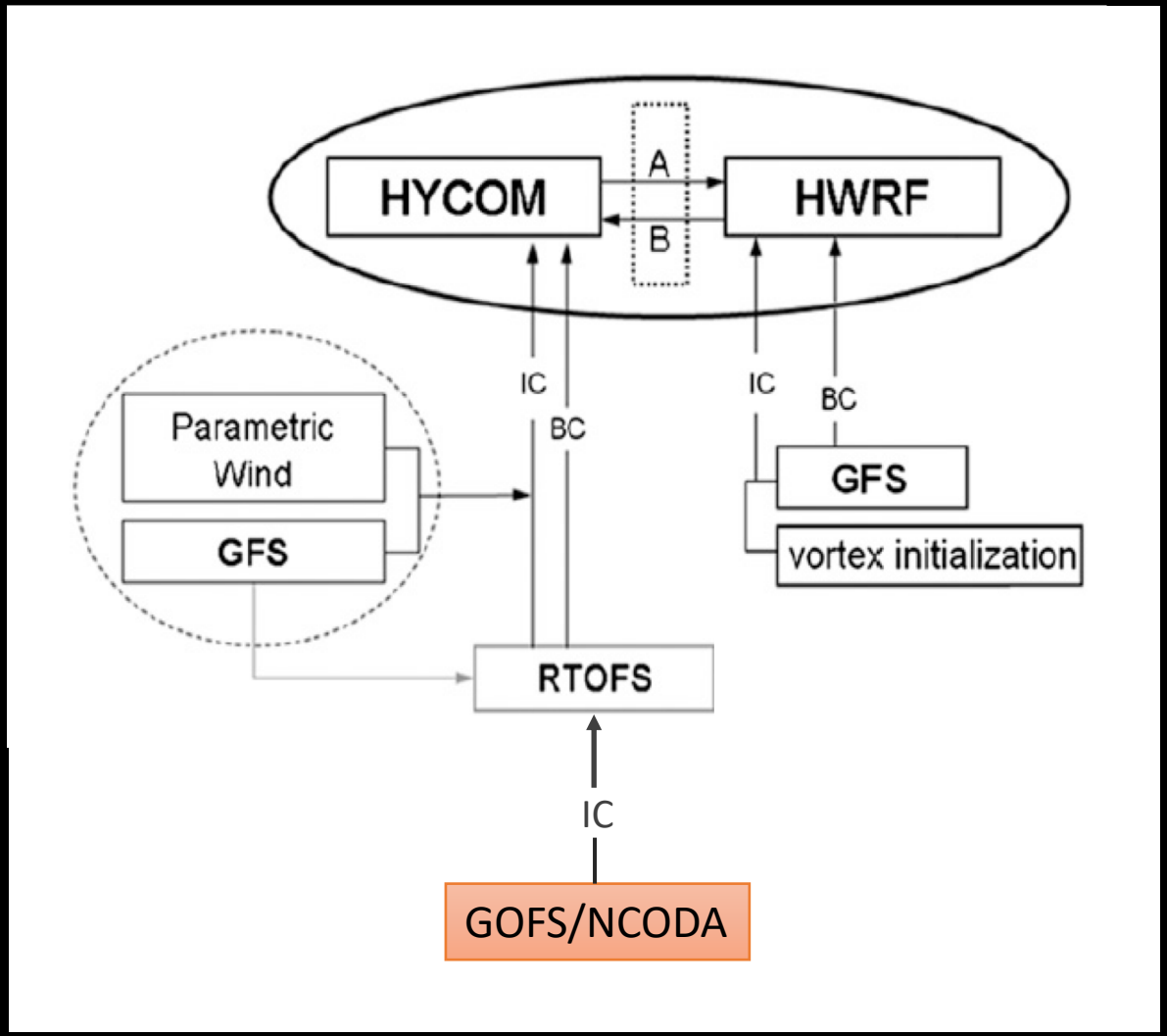
HMON/HYCOM

HWRF/POM



HWRF – Hurricane Weather Research Forecasting Model
HYCOM – Hybrid Coordinate Ocean Model
HMON - Hurricanes in a Multi-scale Ocean-coupled Non- hydrostatic model
POM – Princeton Ocean Model

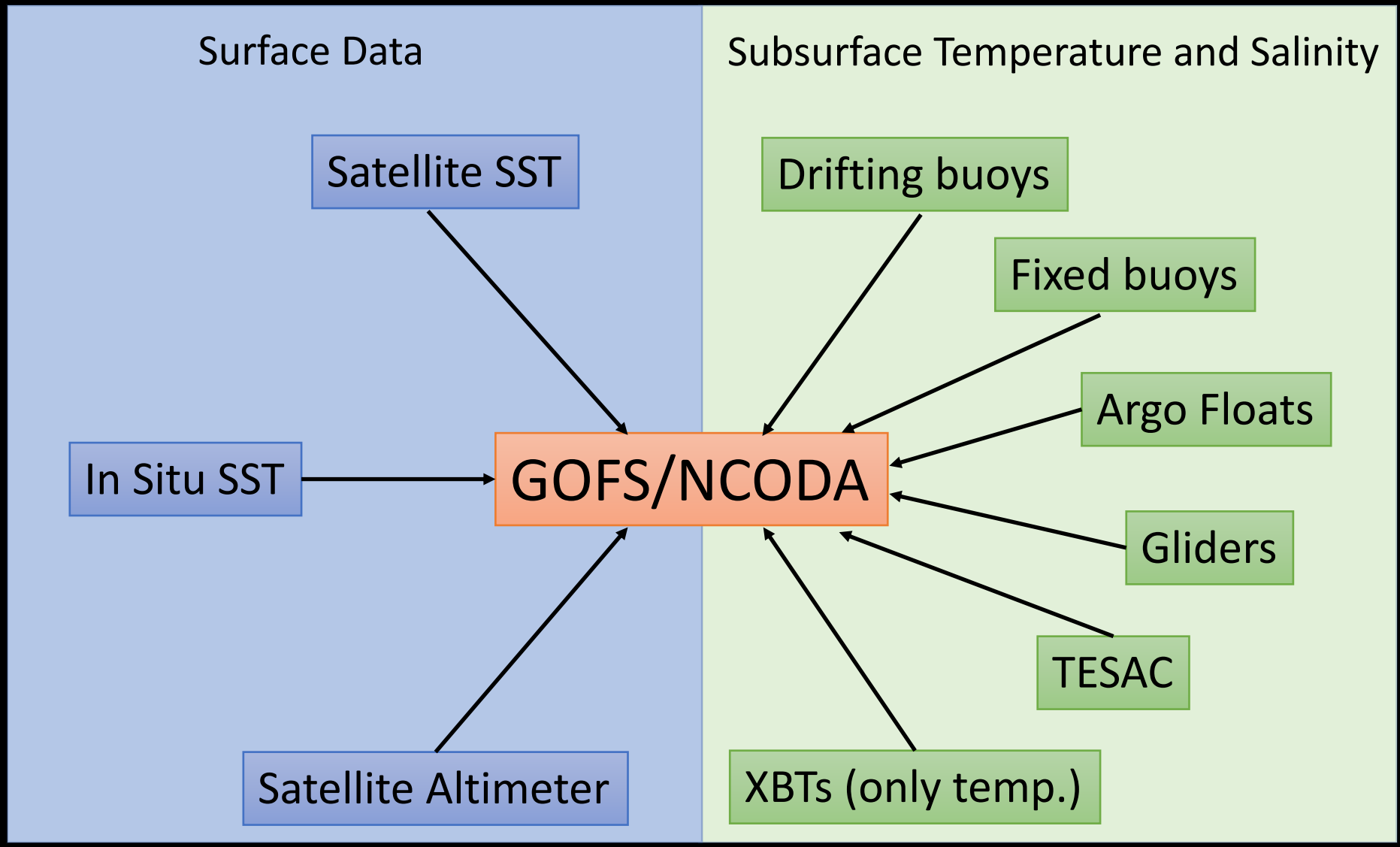
Hurricane Coupled Ocean-Atmosphere Forecasting Model: HWRF-HYCOM System



Kim et al. 2014

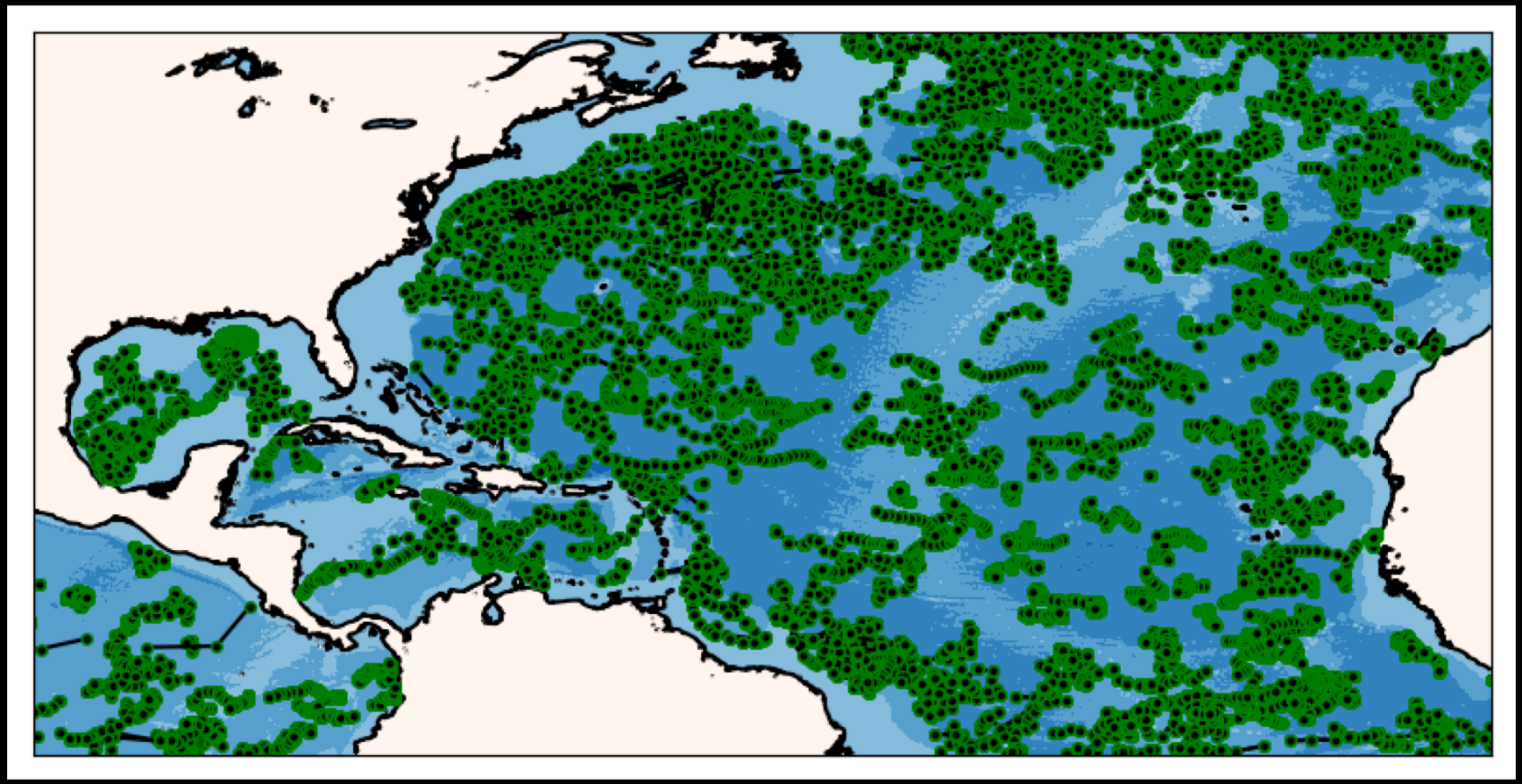
RTOFS – Real Time Ocean Forecasting System
GFS – Global Forecasting System

Global Ocean Forecasting System (GOFS) / Navy Coupled Ocean Data Assimilation System (NCODA)



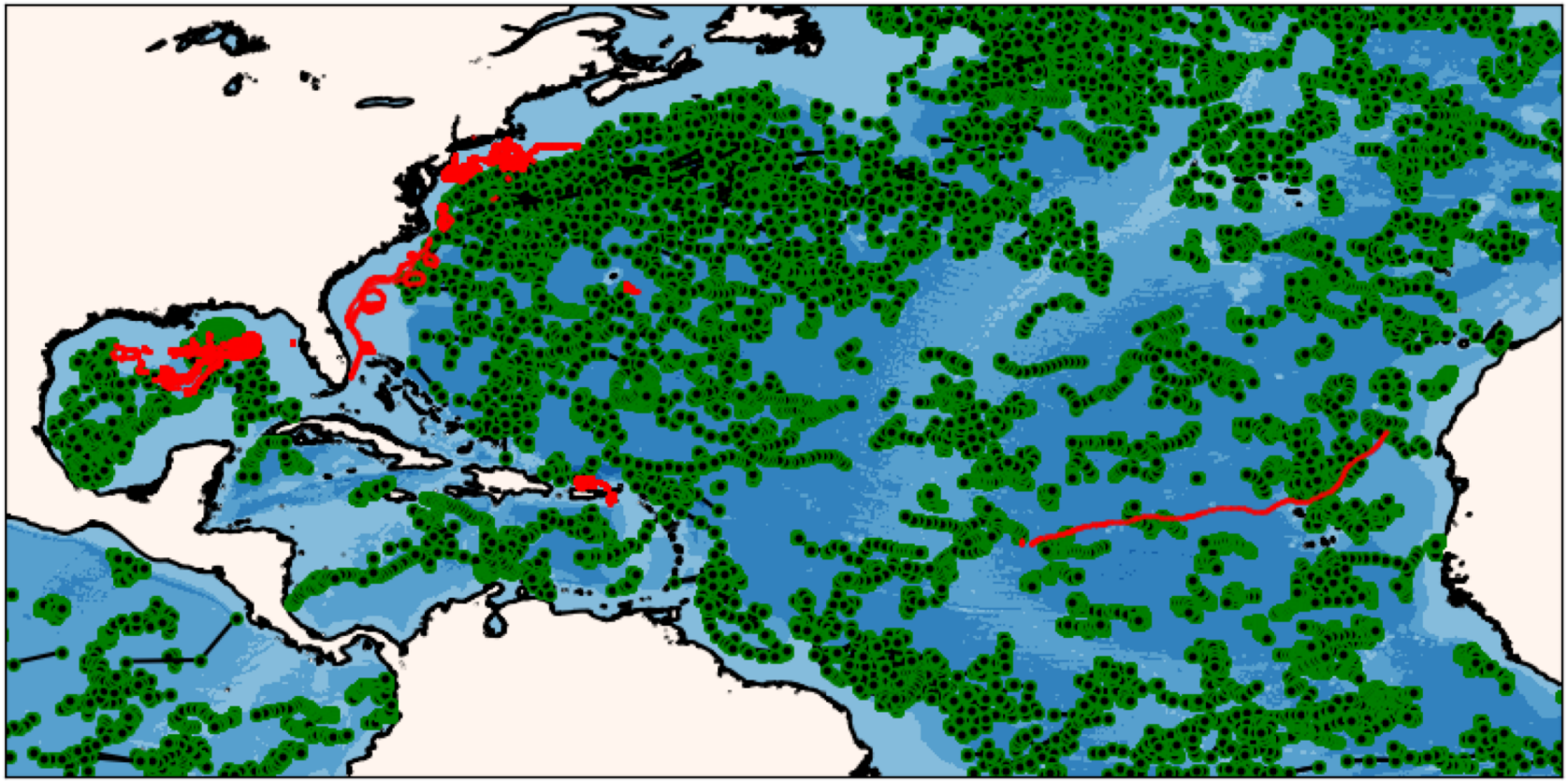
IOOS
Integrated Ocean Observing System

ARGO Floats
During the 2018 Hurricane Season



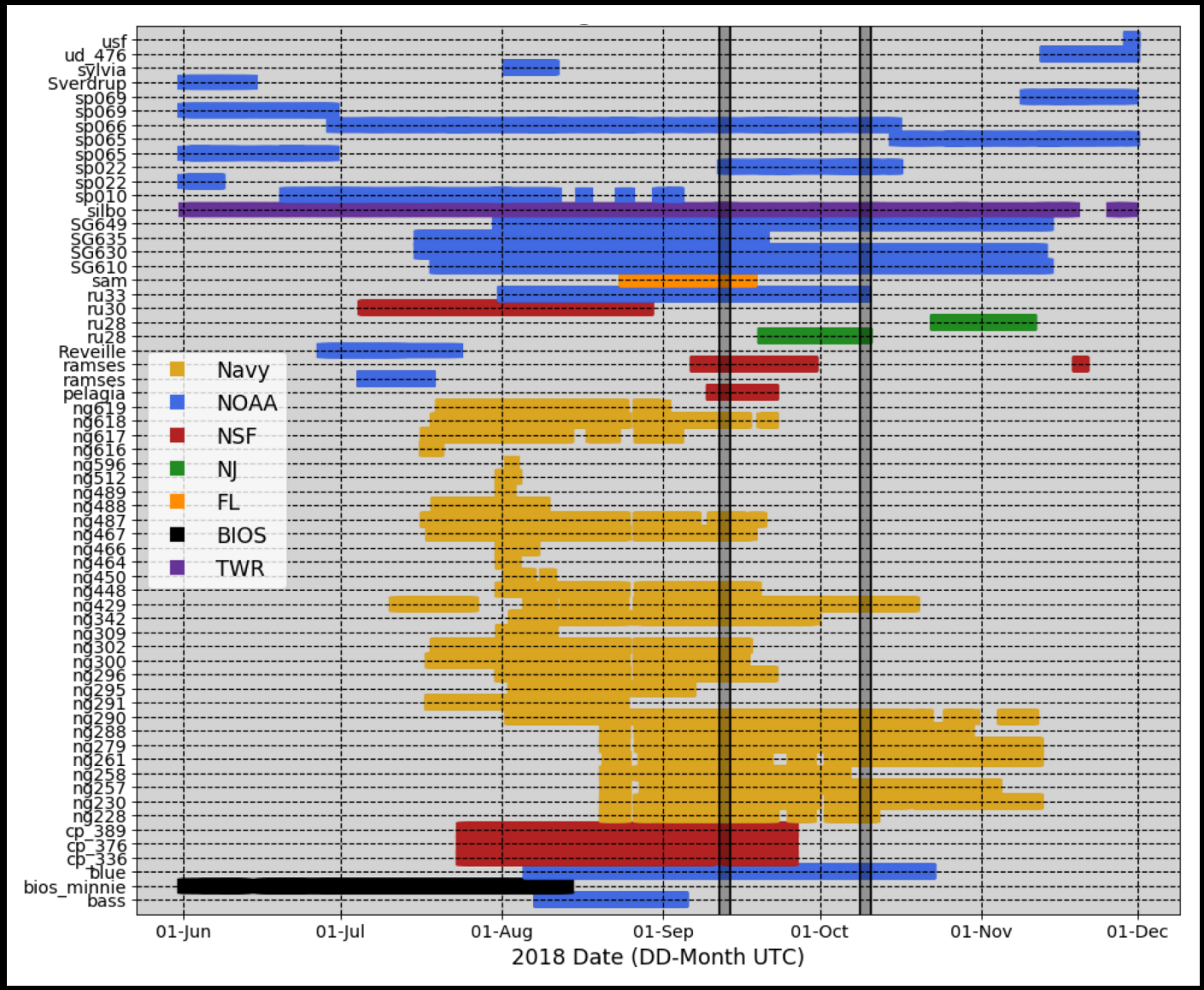
- Argo floats mostly occupy the open ocean
  - One vertical profile every ten days

ARGO Floats and Gliders During the 2018 Hurricane Season

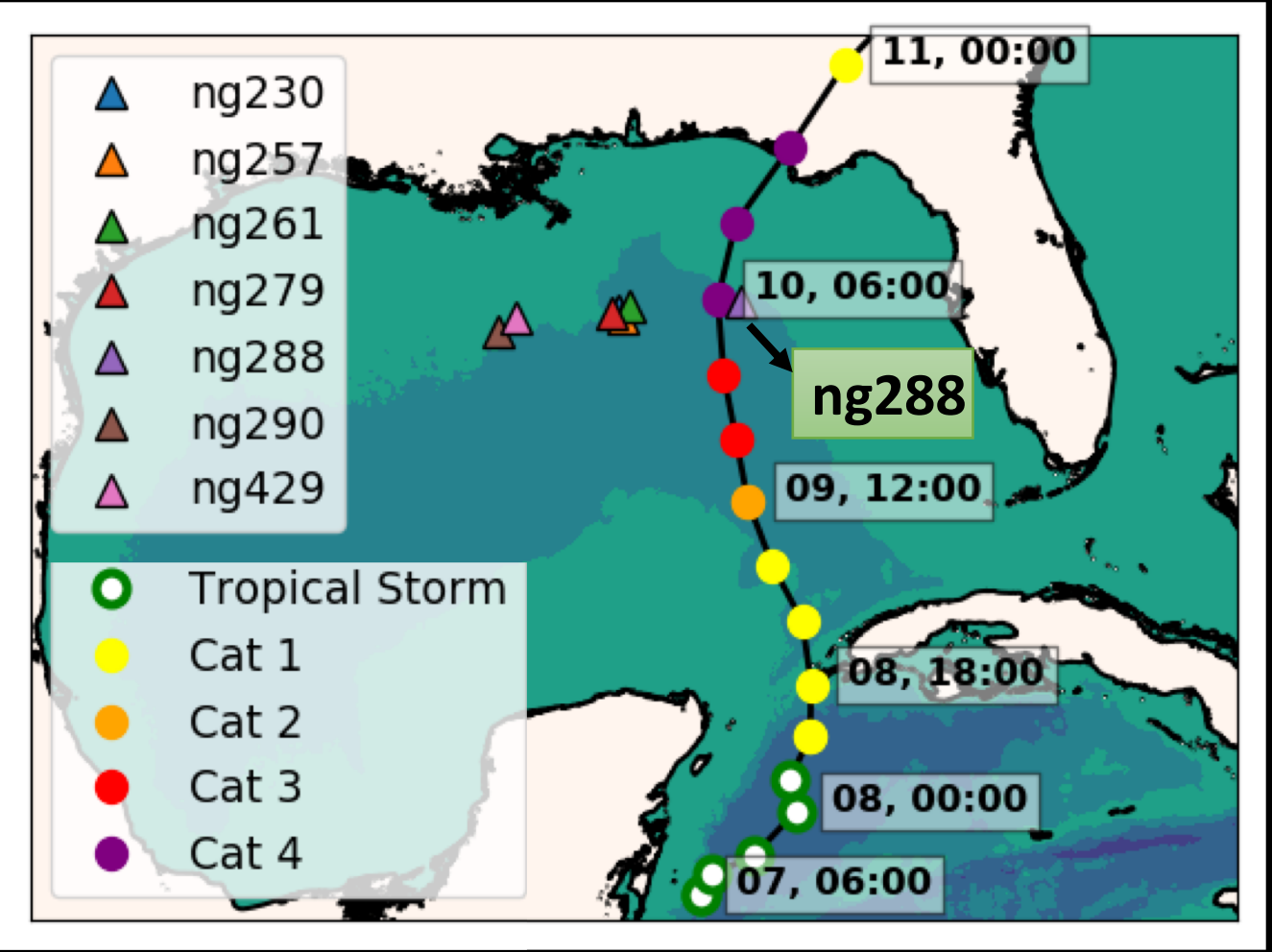


- Glider observations are mostly in the shelf
- Tens of profiles per day

62 Gliders in the IOOS Glider Data Assembly Center (DAC) During Hurricane Season 2018

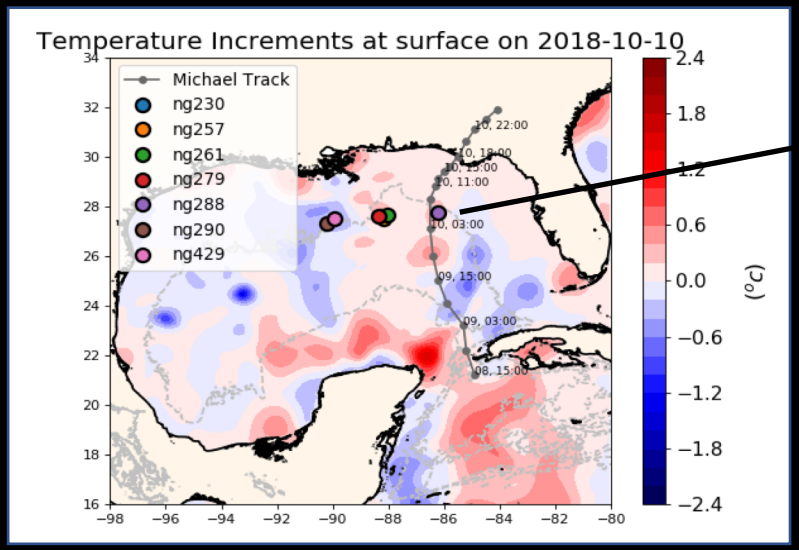


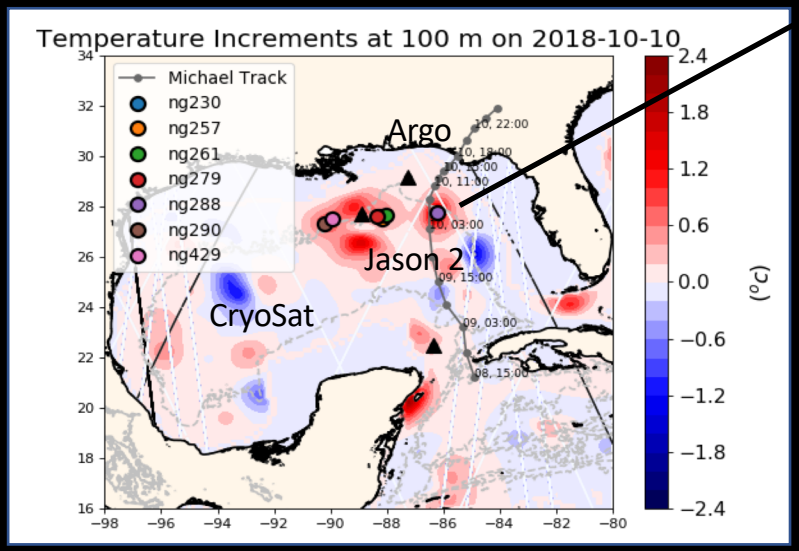
Hurricane Michael

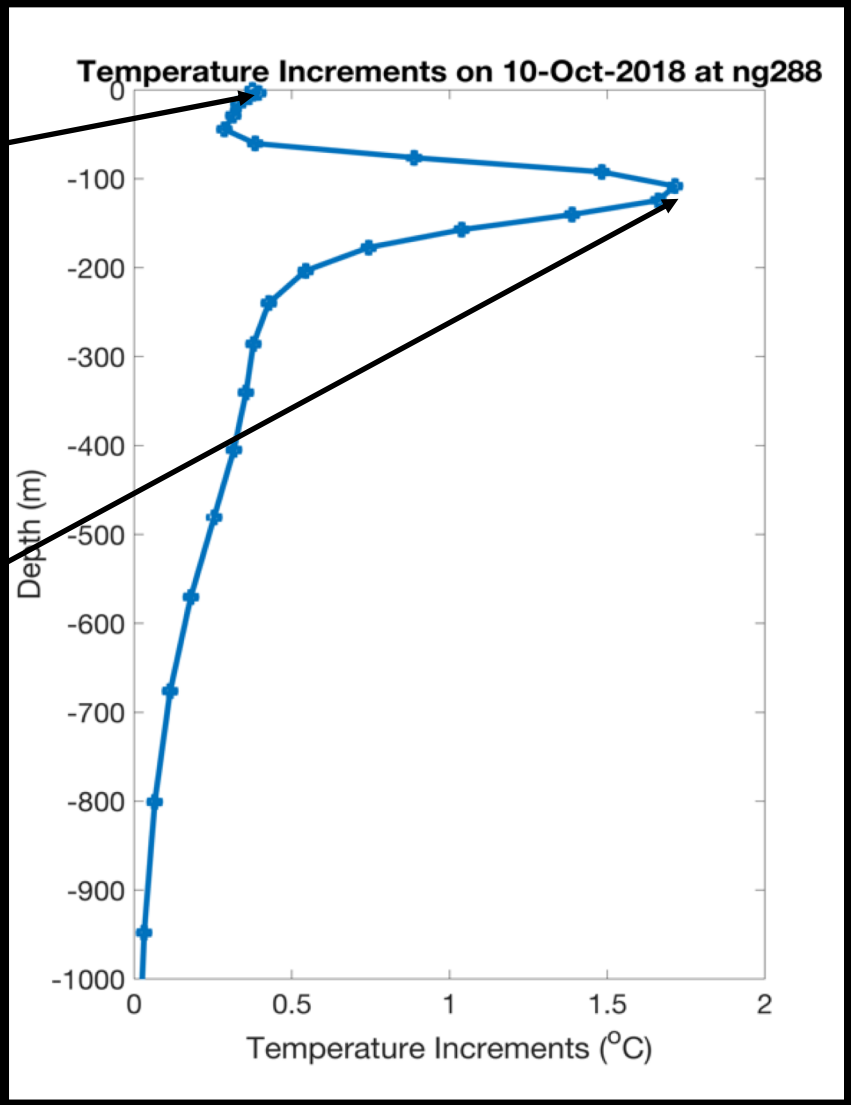


- Seven Navy gliders reporting to the glider DAC in the GoM during hurricane Michael
- Ng288 was at 36 km from the eye of hurricane Michael

NCODA Temperature Increments

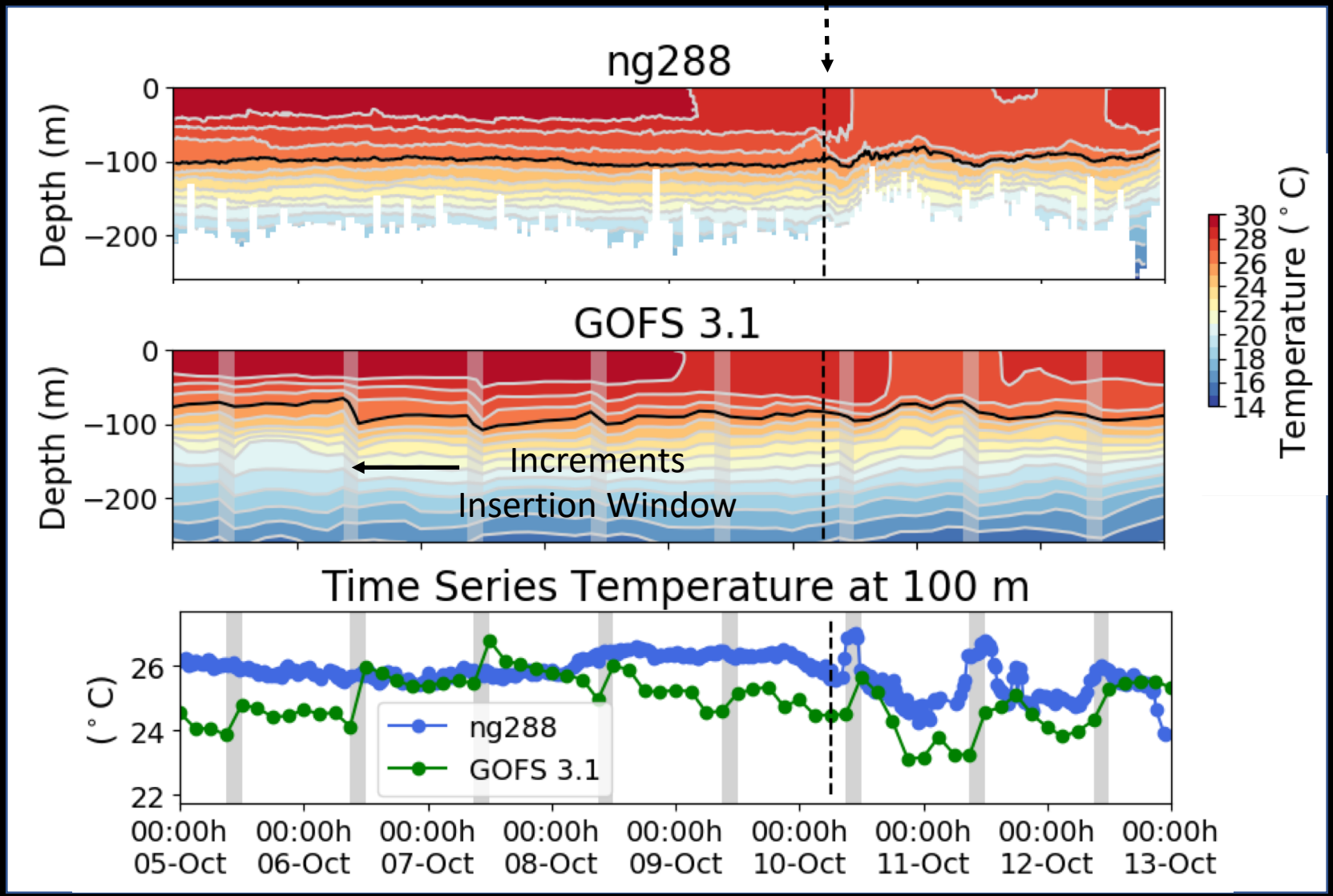






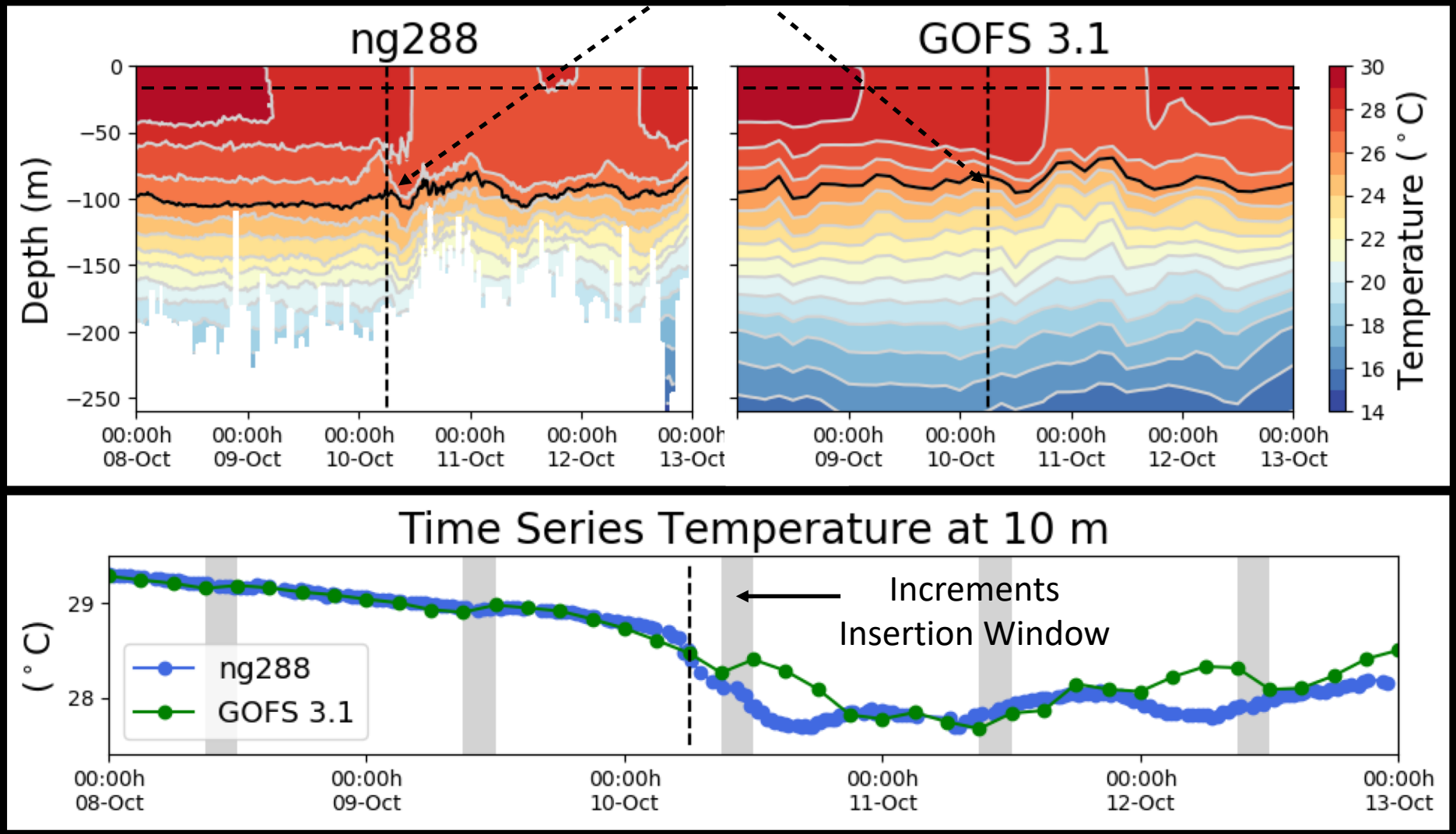
The increment is the change made to the model state at the end of the previous assimilation cycle

Hurricane Michael



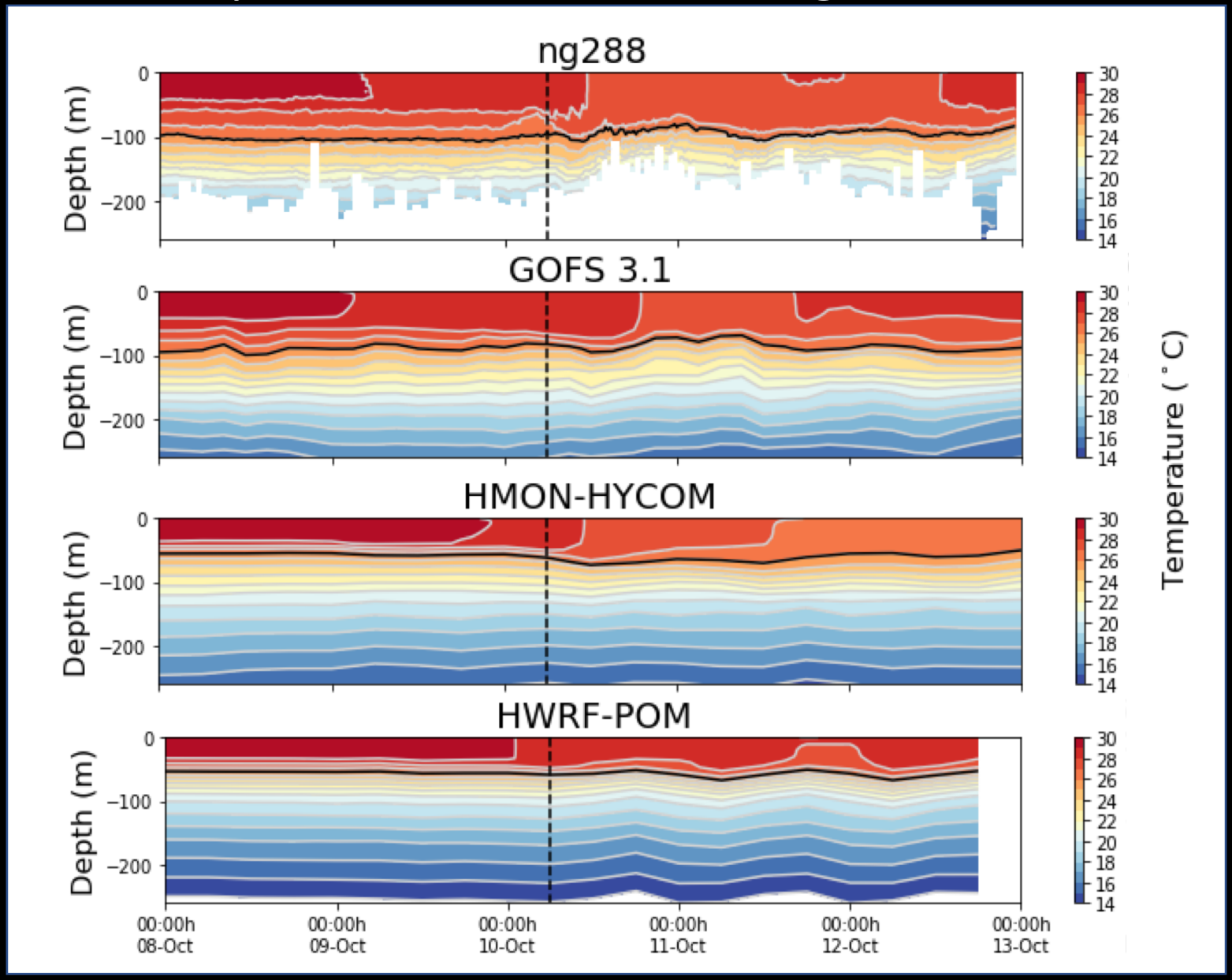
The assimilation of glider data days ahead of Michael corrected the position of the thermocline

Hurricane Michael

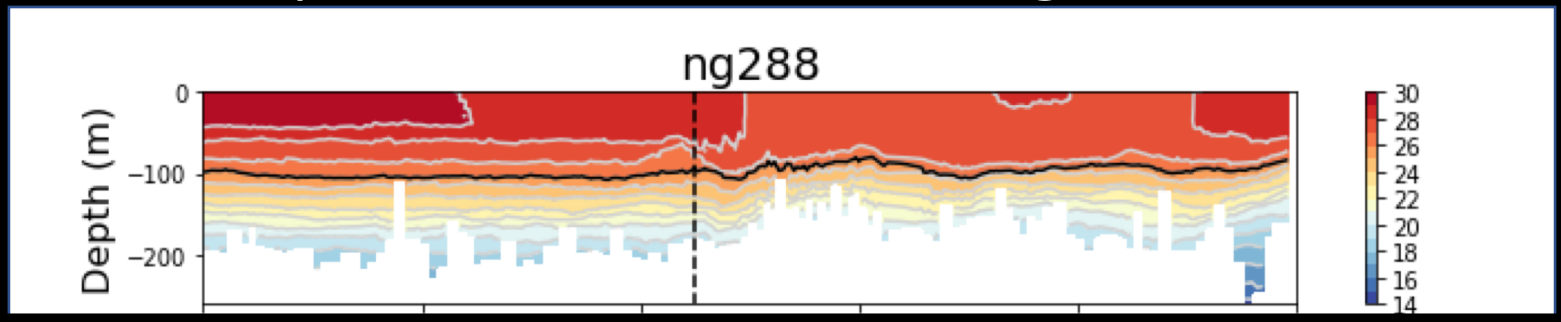


The modeled SST increased after the passage of Michael: the ocean response is faster than the 1-day assimilation cycle

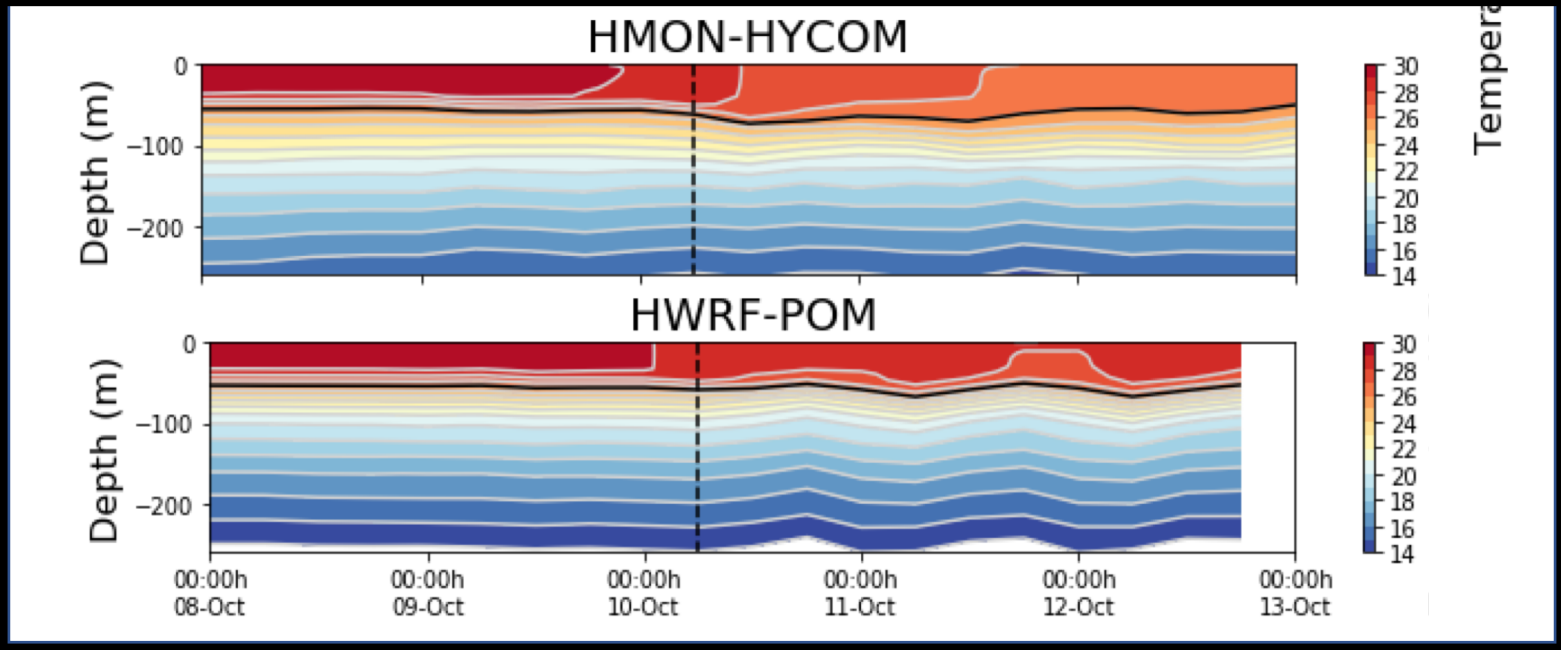
Glider Data vs Operational Models During Michael



Glider Data vs Operational Models During Michael



The ocean under the operational hurricane models have a thermocline that is too shallow and does not completely capture the magnitude and timing of cooling and subsequent mixing

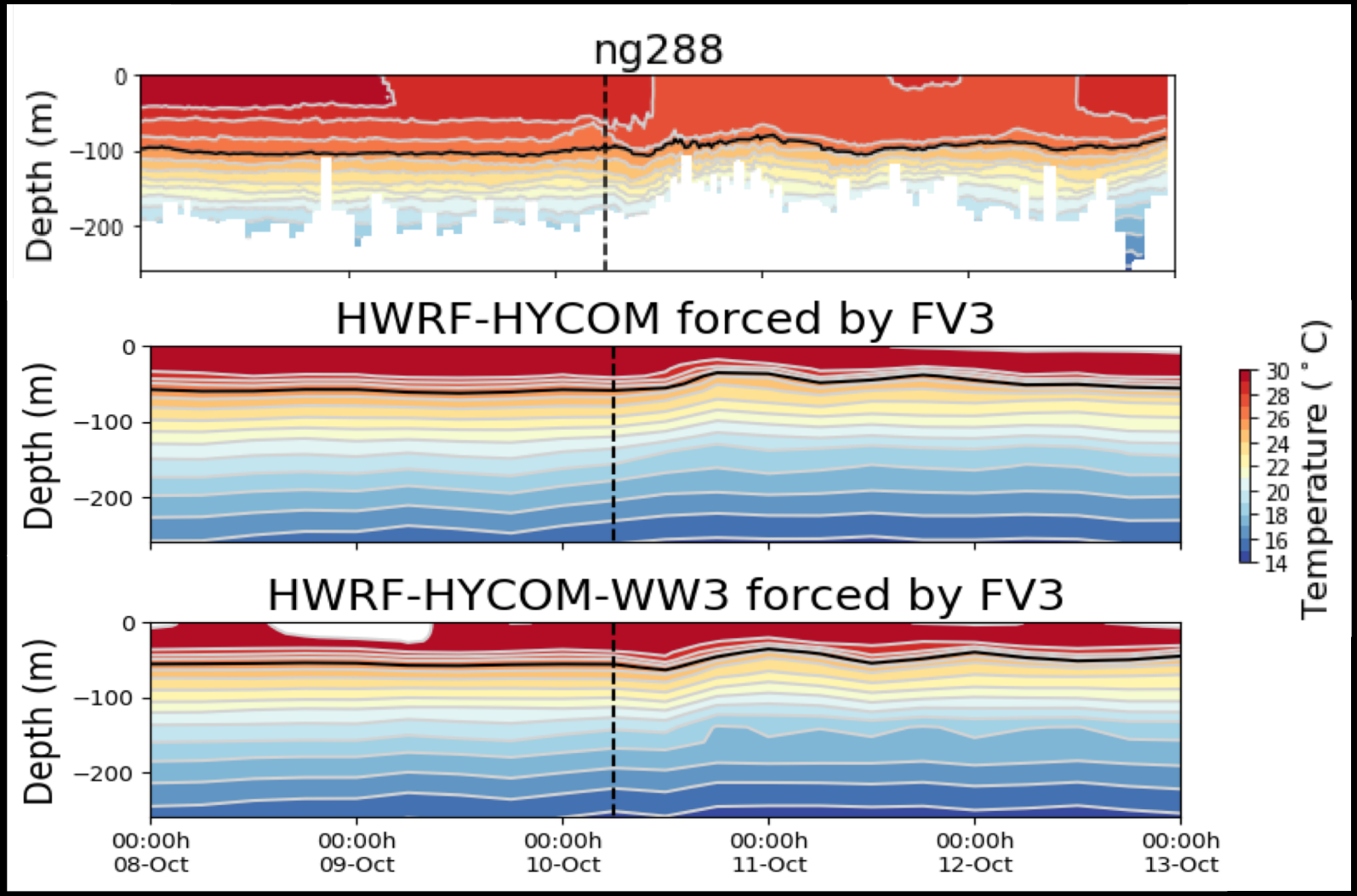


Ongoing and Future Work

- Ongoing collaboration with NCEP

Avichal Mehra
Hyun-Sook Kim

2018100718 Forecast



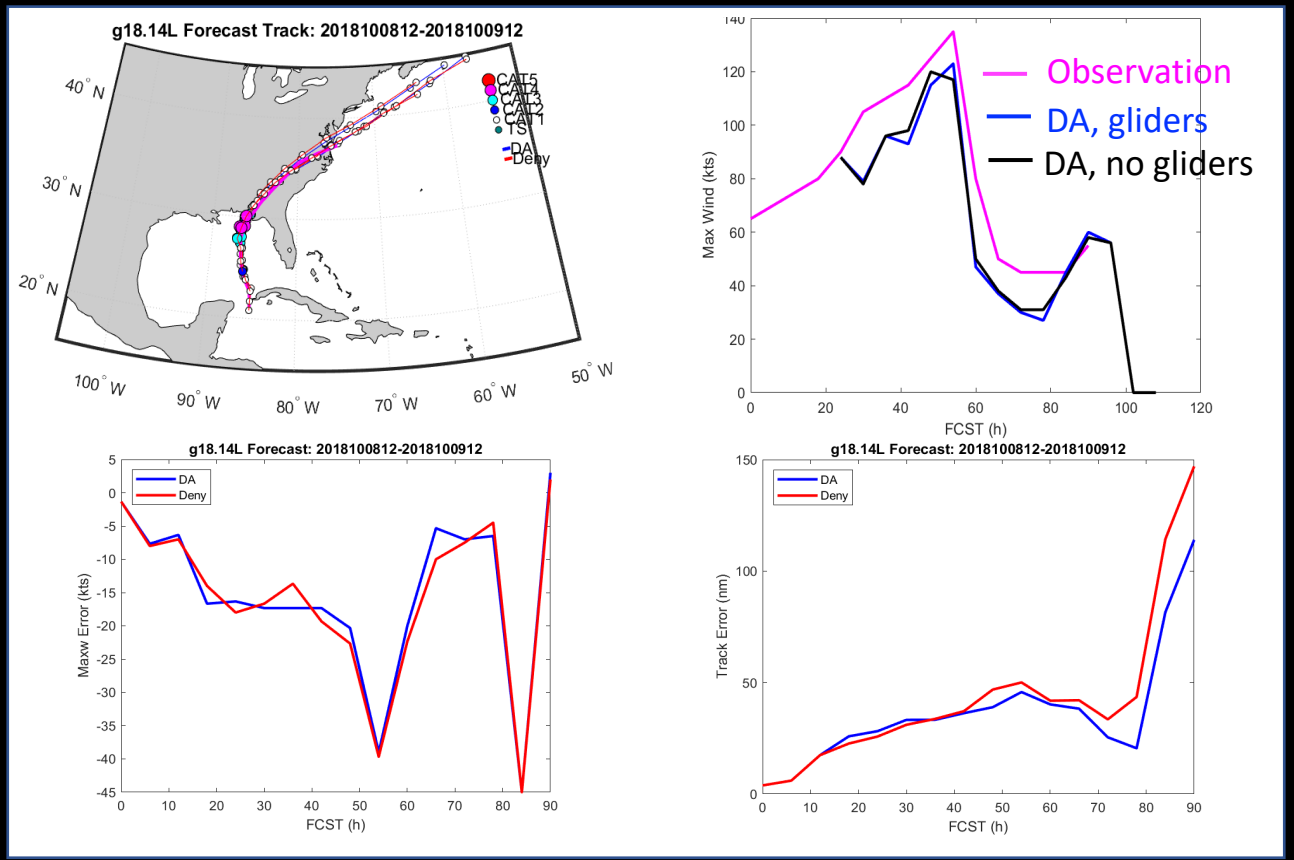
Ongoing and Future Work

- Quantify Impact of glider observations on operational hurricane models

COAMPS-TC Forecast of Hurricane Michael

Sue Chen, NRL Monterey

2018100912 forecast



- COAMPS-TC forecast intensity was weaker than the real-time best track
- Assimilating the gliders improved the Hurricane Michael's track forecast

Conclusions

- The data assimilation ahead of a storm is critical to ensure that the models have the right initial vertical stratification
- The length of the assimilation cycle in NCODA needs to be short enough to be able to capture the rapid ocean response during a hurricane
- The ocean models underneath the NOAA hurricane forecasting models are not getting the benefit of DA though GOFS/NCODA
- We will continue collaborating with NCEP and NRL during the 2019 hurricane season