# Integration of Ocean Data Assimilation System In the NOAA UFS R2O Project

National Weather Service


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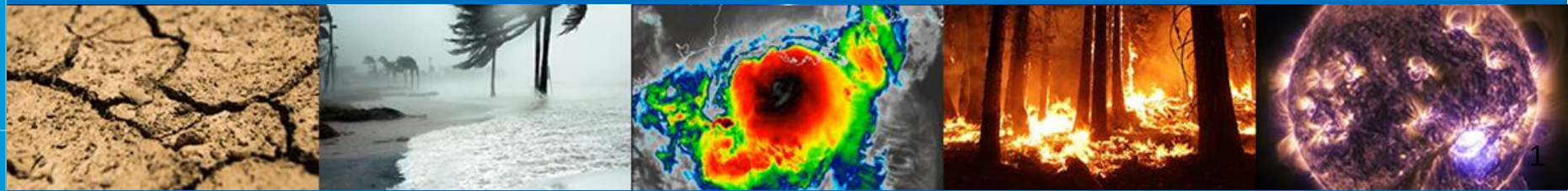
**Joint ECMWF/OceanPredict workshop on Advances in Ocean Data Assimilation**
**May 18, 2021**

# Motivation: UFS-R2O Framework at NCEP/EMC

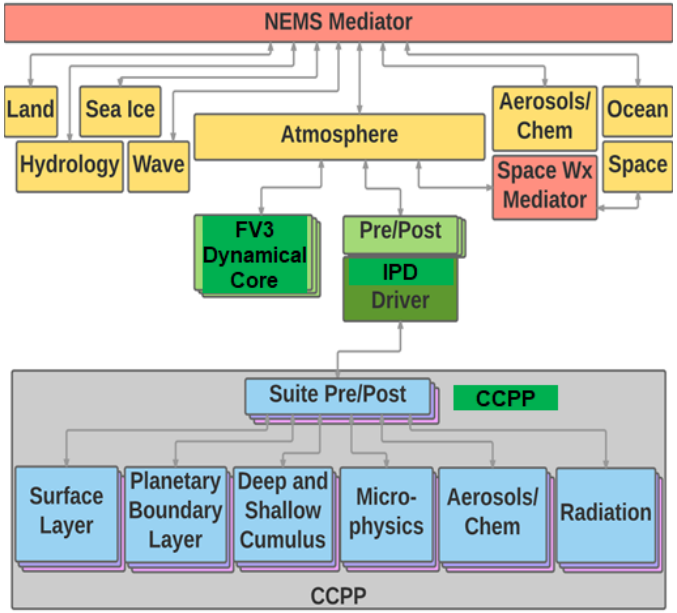
- Synchronization of NWS forecasting system in UFS R2O project: **“One System Many Applications”**
- UFS coupled model for Atm-Ocean-Ice-[…]: FV3-MOM6-CICE6-WW3
- **Unification** of the DA under **JEDI** projects
- Modernization and unification of common utilities: Pre- & Post-processing, observational data archiving, DA workflow, etc.
- Interface for Observation Data Access (IODA) component of **JEDI**
- **Community-based development and software integration**

# Overview

- Unified Forecast System
- Operational Targets for UFS R20
- Global Ocean Data Assimilation System
- Towards Coupled DA
- Ocean color and biogeochemistry
- Regional Ocean Data Assimilation

# Unified Forecast System

- NWS UFS system consists of the following community components
  - NEMS for infrastructure
  - CMEPS mediator
  - FV3 dycore with CCPP Physics driver
  - MOM6 ocean model (S2S scales)
  - HYCOM ocean model (weather scales)
  - WW3 wave model
  - CICE5/CICE6 ice model
  - GOCART aerosol model
  - NOAH-MP Land model
- Each component has its own authoritative repository. NEMS infrastructure allows flexibility to connect instantiations of the repositories together to create a coupled model.
- *https://ufscommunity.org*



# Operational Target – FY 2024

- **Global Forecast System (GFS) v17**
- **Global Ensemble Forecast System (GEFS) v13:**
  - First **fully coupled system** from weather to sub-seasonal scales
  - Integrated GFS and GEFS systems
  - FV3 + MOM6 + CICE6 + WW3 + NOAH-MP
  - **JEDI-based Weakly/Quasi-strongly coupled DA**
  - 30+ ensemble members

# Current UFS-based Coupled Applications

GFS v17

**FV3 – WW3**
Effects of waves on atmospheric stress at ocean surface

**FV3 – CHEM**
Atmosphere, aerosols interaction

**ADCIRC – WW3**
Wave and surge coupling (COASTAL ACT)

**FV3 – HYCOM**
**H**urricane **A**nalysis and **F**orecast **S**ystem

HAFS

**MOM6 – CICE6**
Data Atmosphere, Ocean Ice coupled model for **G**lobal **O**cean **DA S**ystem with **JEDI-SOCA**

NG-GODAS

**FV3 – MOM6 – CICE6 – WW3**
**S2S** scales (25 km atm, ¼ deg ocean and ice, ½ deg waves)

GFS v18 / GEFS v13

# Latest Configuration of UFS S2S

## Atmosphere

- FV3 dynamical core
- GFS Physics with GFDL microphysics
- CCPP physics driver
- C384 (~25km), 64/127 levels

## Ocean

- MOM6 Modular Ocean Model
- ¼ degree tripolar grid, 75 hybrid levels
- OM4 Set up [Adcroft, 2019]

## Waves

- WAVEWATCH III
- ½ degree regular lat/lon grid
- ST4 Physics [Ardhuin, 2010]

## Ice

- CICE6  Los Alamos Sea Ice Model
- ¼ degree tripolar grid (same as ocean)
- 5 thickness categories

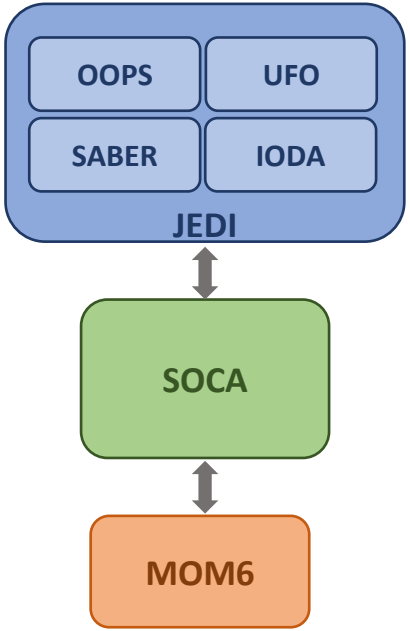
## Driver/Mediator

- NEMS driver
- CMEPS mediator

https://github.com/ufs-community/ufs-weather-model

# Sea-ice Ocean & Coupled Assimilation [SOCA]: JEDI Encapsulation of MOM6 (& Sea-ice)

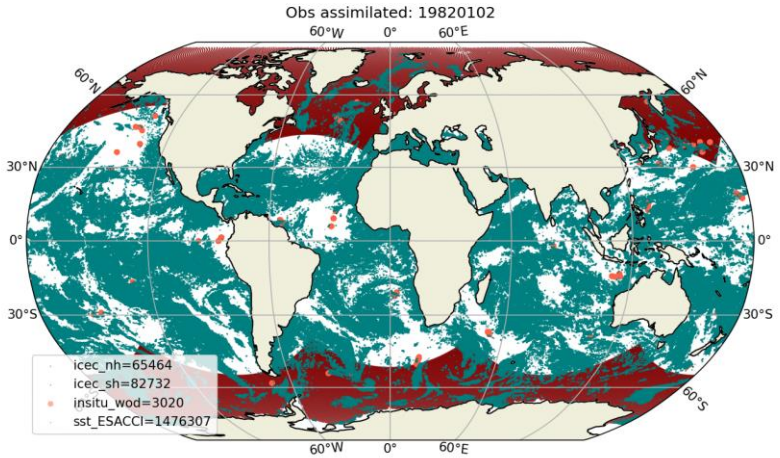
- **SOCA** is the **JEDI** encapsulation of **MOM6** and Sea-ice
- **SOCA** **implements** the *interfaces*, *methods*, *applications* and *configuration* that the **abstract** components of **JEDI** need specifically for models using the **MOM6**.
- **SOCA** provides objects for *Geometry*, *State* and *Increment*, *IO* access, *Variable Changes*, Interpolation to observation locations, the Tangent Linear and Adjoint and the ability to advance the model.
- **SOCA** also provides framework for *unit testing* of the interface as well as *regression testing*, example configuration scripts to run various applications (e.g. 3DVar, Forecast, etc.)



# NG-GODAS Scout Run (J. Kim et. al)

- DATM-MOM6-CICE6: 1-degree in JEDI-SOCA 3DVar framework
- 30 year ocean reanalysis at ¼ degree
- Provide ocean ice benchmarks for UFS S2S GEFS v13

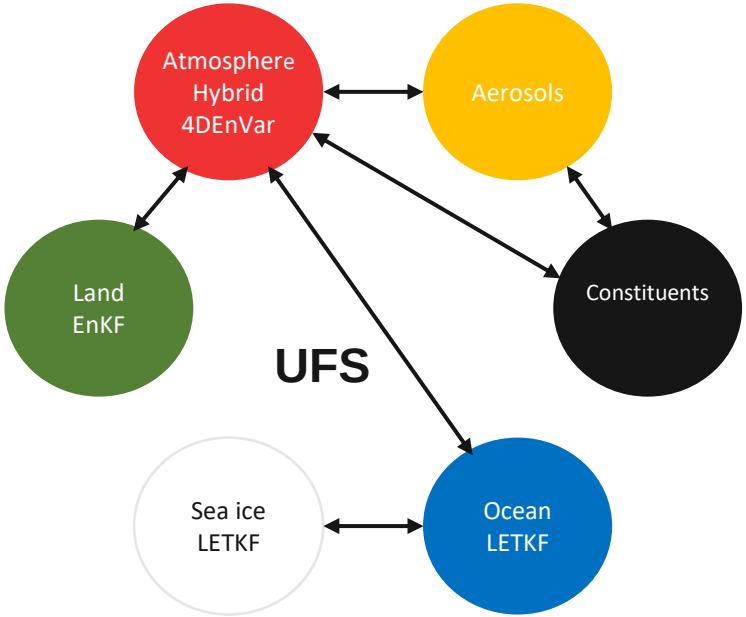
| Obs type | Date |
|---|---|
| ADT | 1993-2020 (NESDIS) |
| Satellite SST (AVHRR) | 1981-200208 (ESACCI L3U), 200208-201811 (NESDIS L3U) |
| Insitu (T&S) | 1979-2020 (WOD) |
| SSS | SMOS ESA L2 (2010-2020), SMAP RSS/JPL L2 (2015-2020) |
| Sea ice Conc | NSIDC L3 SSMR, SSMI (1979-200305), EMC L2 (200306-2020 SSMI, SSMIS) |

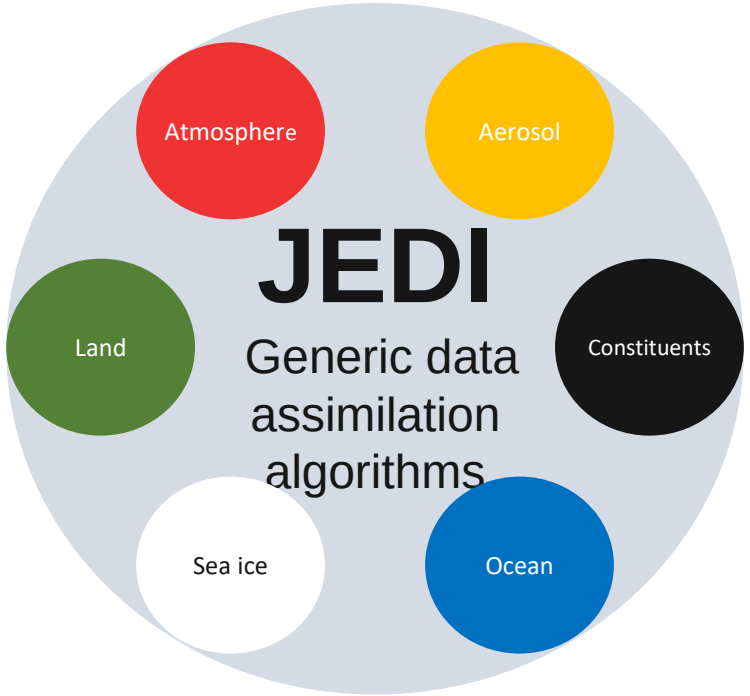



**Over 1 Million Observations per day**

# Towards Coupled Data Assimilation

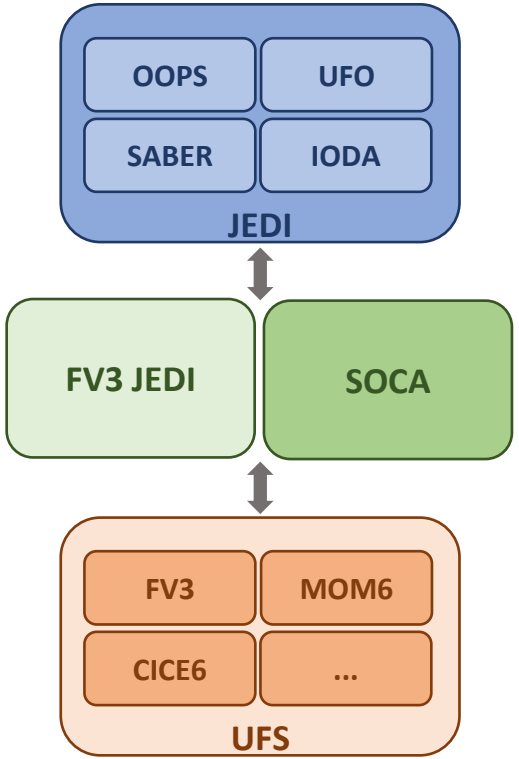
Up to now data assimilation systems have been developed in parallel for the different models, with various levels and approaches for coupling between data assimilation and model components.



# Coupled DA Design

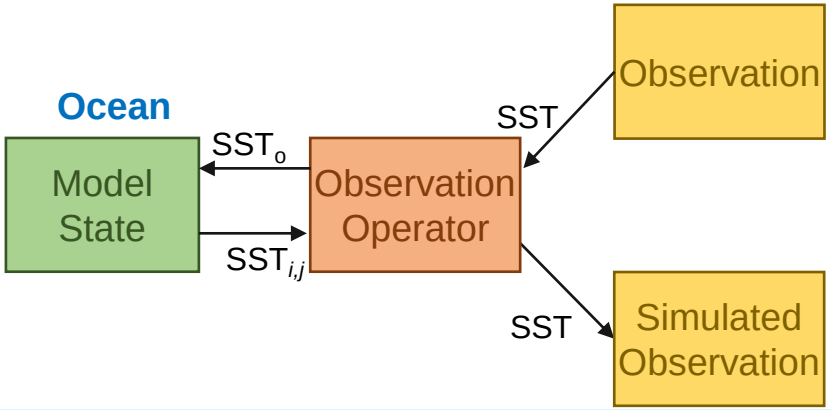
- By design the **JEDI generic** components know nothing about the **specific model** (grid or variables) so an **interface** is needed to sit between the JEDI core components and the models themselves.
- Develop **separate interfaces** specific to a model component (atmosphere, ocean, sea-ice, etc.)
- Behavior of the interfaces are controlled through the configurations, with no hardwired variables.



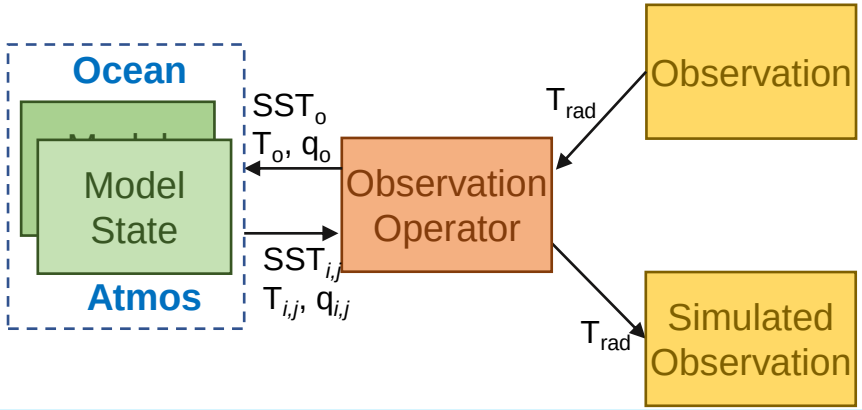
# Coupled Observation Operators

- The Unified Forward Operator (UFO) in JEDI introduces standard interfaces between the model and observation world.
- Observation operators are independent of the model, ease sharing, and are easily configurable for coupled data assimilation.

## Uncoupled Ocean Only



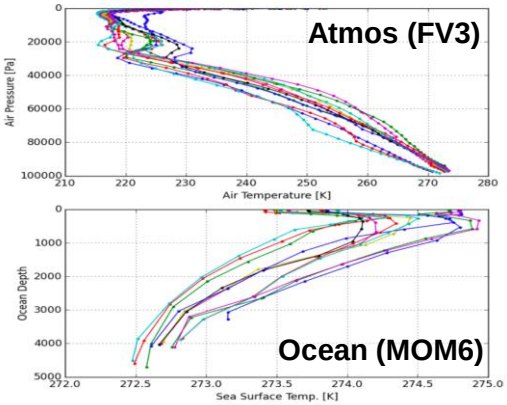

## Coupled Ocean-Atmosphere



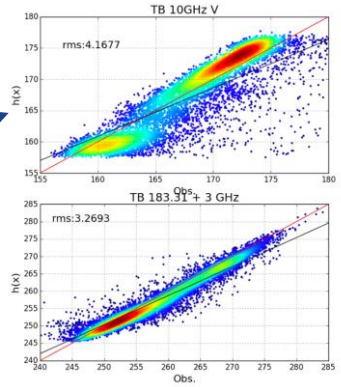
# Coupled Observation Operators

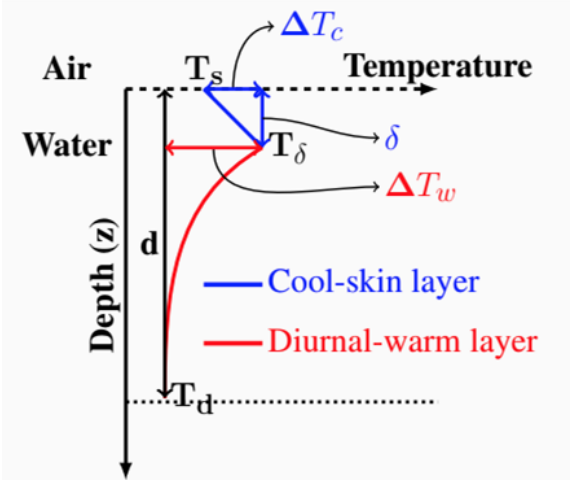
## (Examples courtesy Hamideh Ebrahimi/JCSDA)

- NCEP/EMC (NSST) and NASA GMAO (Akella et. al) have both developed radiance-driven SST through GSI. Multi-domain UFO development is already underway in JEDI (Ebrahimi, JCSDA).
- For MW channels, there is sensitivity of the observation to the temperature at some sub-skin depth (*1-30 mm*)
- IR channels are are generally sensitive to skin temperature (*~15 μm*)




**CRTM UFO for GMI**




Schematic of the details of near-surface $T(z)$ variation,

$$T(z) = T_d + \Delta T_w(z) - \Delta T_c(z).$$

# NG-GODAS + BLING BioGeoChemistry

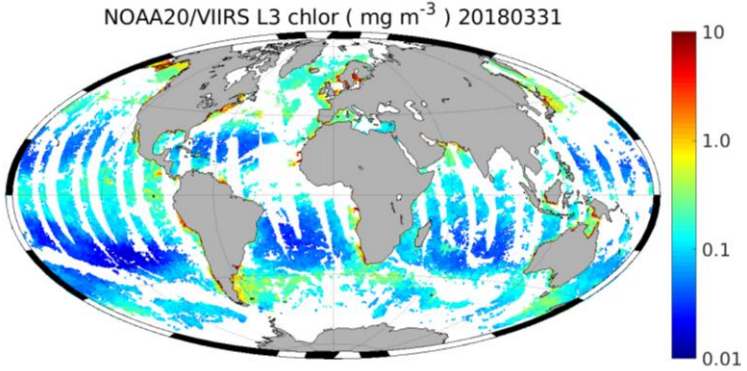
**Goals:**

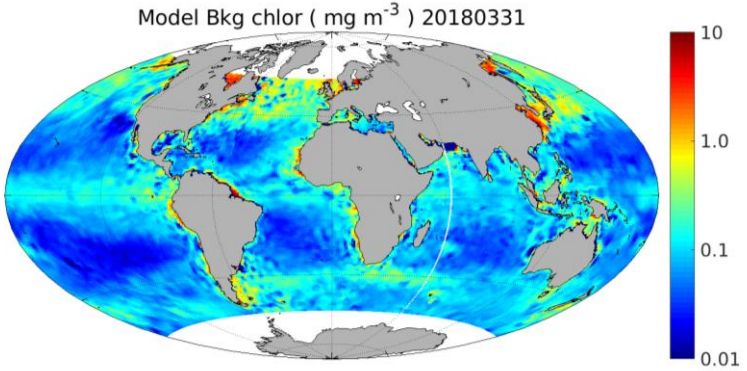
1. To exploit data-driven and data-assimilating techniques for more-accurate biogeochemical modeling of coastal and open ocean environments
2. Support NOAA/NCEP's operational weather forecasts by improving ocean state initialization in the UFS through the ingestion of ocean color data and integration of ocean biophysical feedback
3. Build NCEP's ecological forecast capabilities for monitoring critical changes and "tipping points" in coastal ecosystems

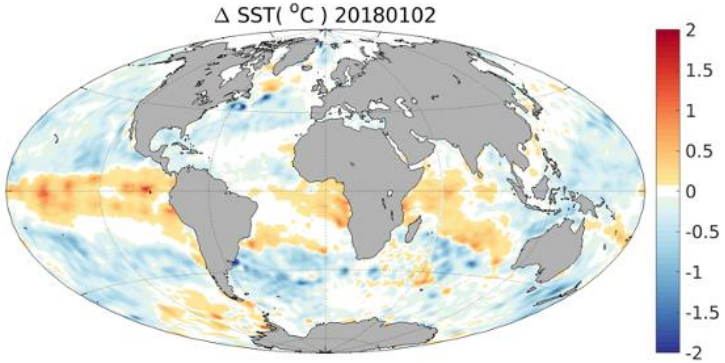
**Approach:**

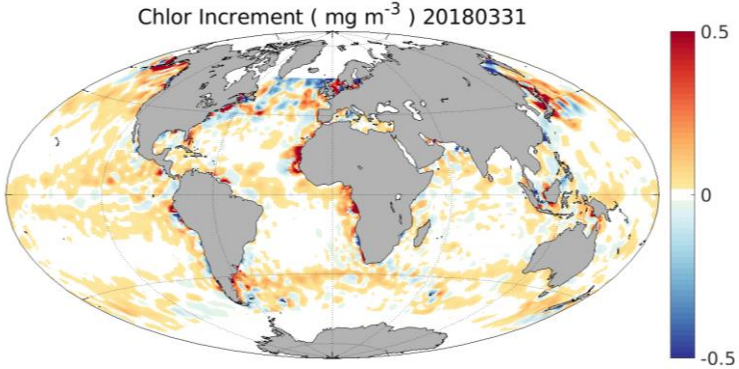
1. Include *chlorophyll a* and *Ocean Color* products from VIIRS platforms in the **JEDI/*UFO*** and **JEDI/SOCA**
2. Include BGC (BLING) modules in Modular Ocean Model 6 (MOM6);
3. Evaluate the model's ecological forecast skills and feedback to ocean physics.

# JEDI/SOCA with UFS + BLING



# UFS Regional Ocean DA for HAFS

## Goals:

1. Build Hybrid Ocean DA for HAFS in UFS-GODAS and JEDI/SOCA framework to replace RTOFS
2. Ingest high resolution ocean observations e.g. Gliders and HF-Radar
3. High resolution global model spin-up for downscaling nesting applications

## Approach:

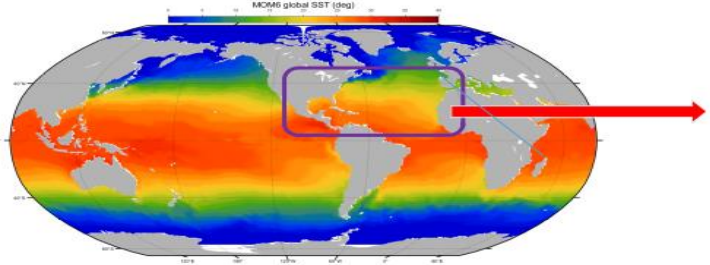
1. Leverage Regional MOM6 ocean capabilities from JEDI/SOCA
2. Configure and populate JEDI/IODA observation database with glider and HF-Radar
3. M6 HAT10 model and experiment

# MOM6 Regional ODA Configuration

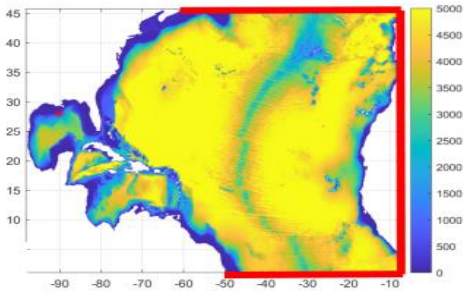
**HAT10 domain and input configuration**

- **MOM6 restart files: Climatology from SODA3**
- **Model resolution: 1/12 degree (1135x633x50 grid cells)**
- **Boundary Condition: Rutgers-developed OBC options**
- **Forcing files: GFS**

**Global MOM6**




**Regional MOM6 (HAT10)**

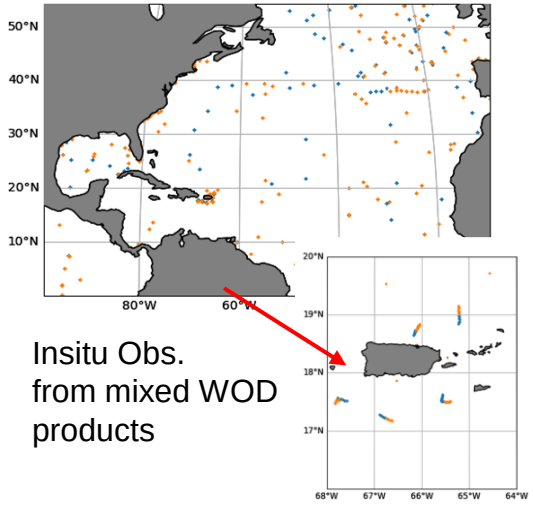



**Goal:**
**provide best estimate ocean IC & BC for coupled Hurricane forecast system**

**Current Experiment configuration: 1/12-degree resolution**
**Forcing: CORE/JRA55**
**IC & BC: Climatology from SODA3, Rutgers-developed OBC options**

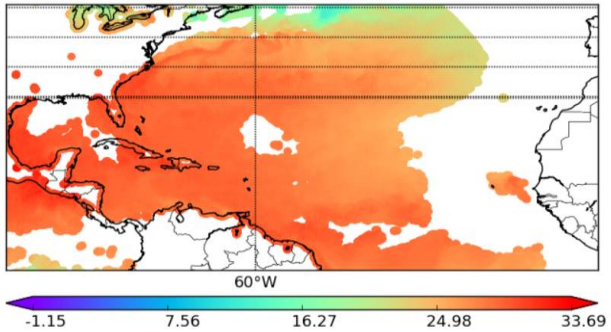
# Regional ODA Experiment: Current Obs

- In addition to glider data

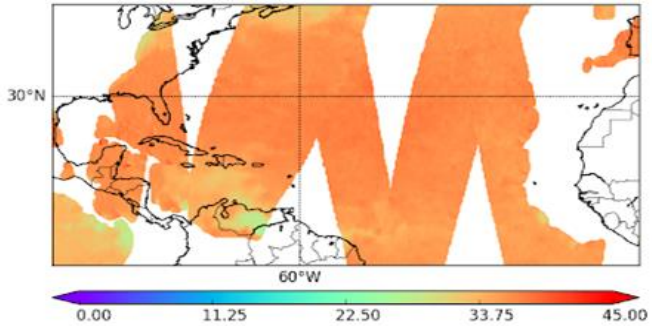



Insitu Obs.
from mixed WOD
products

GOES-16/17 ABI SST product



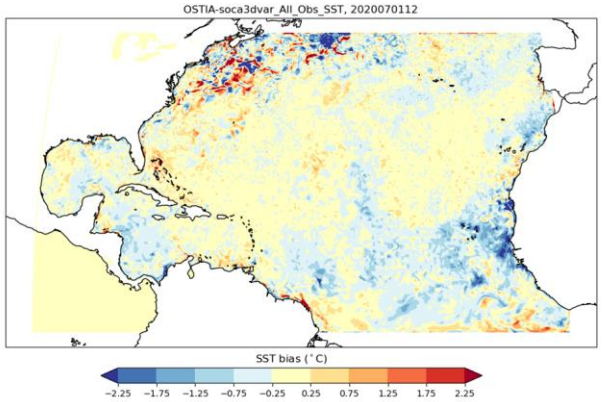

SSS Obs. Coverage from SMAP LC2

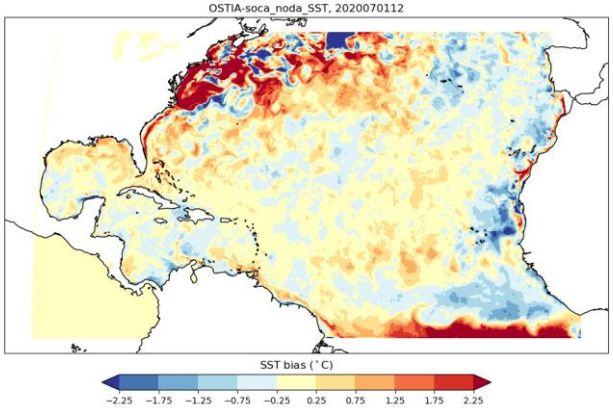



- currently assimilating ~ 300,000 insitu obs. &
~20,000 glider obs. per cycle
- thinning & binning work in progress

# JEDI/SOCA 3DVar: SST Validation v/s OSTIA

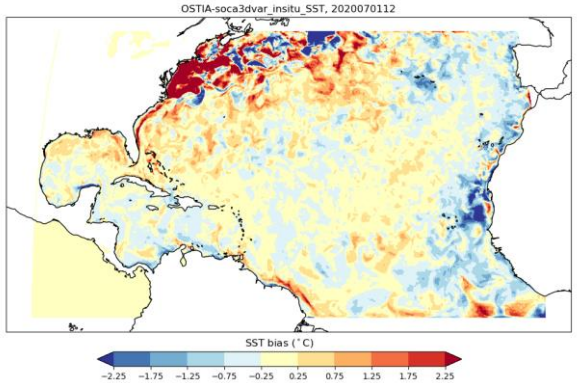
all obs




no DA

PRELIMINARY




Insitu Obs only

# Concluding Remarks

- UFS and JEDI provide an opportunity to unify the modeling and data assimilation frameworks in support of NOAA missions

- Leveraging several efforts within the coupled modeling community and JEDI for coupled data assimilation