# Coupling Strategy for Hurricane Analysis and Forecast (HAFS)

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**HFIP Annual Review Meeting, November 19, 2020**

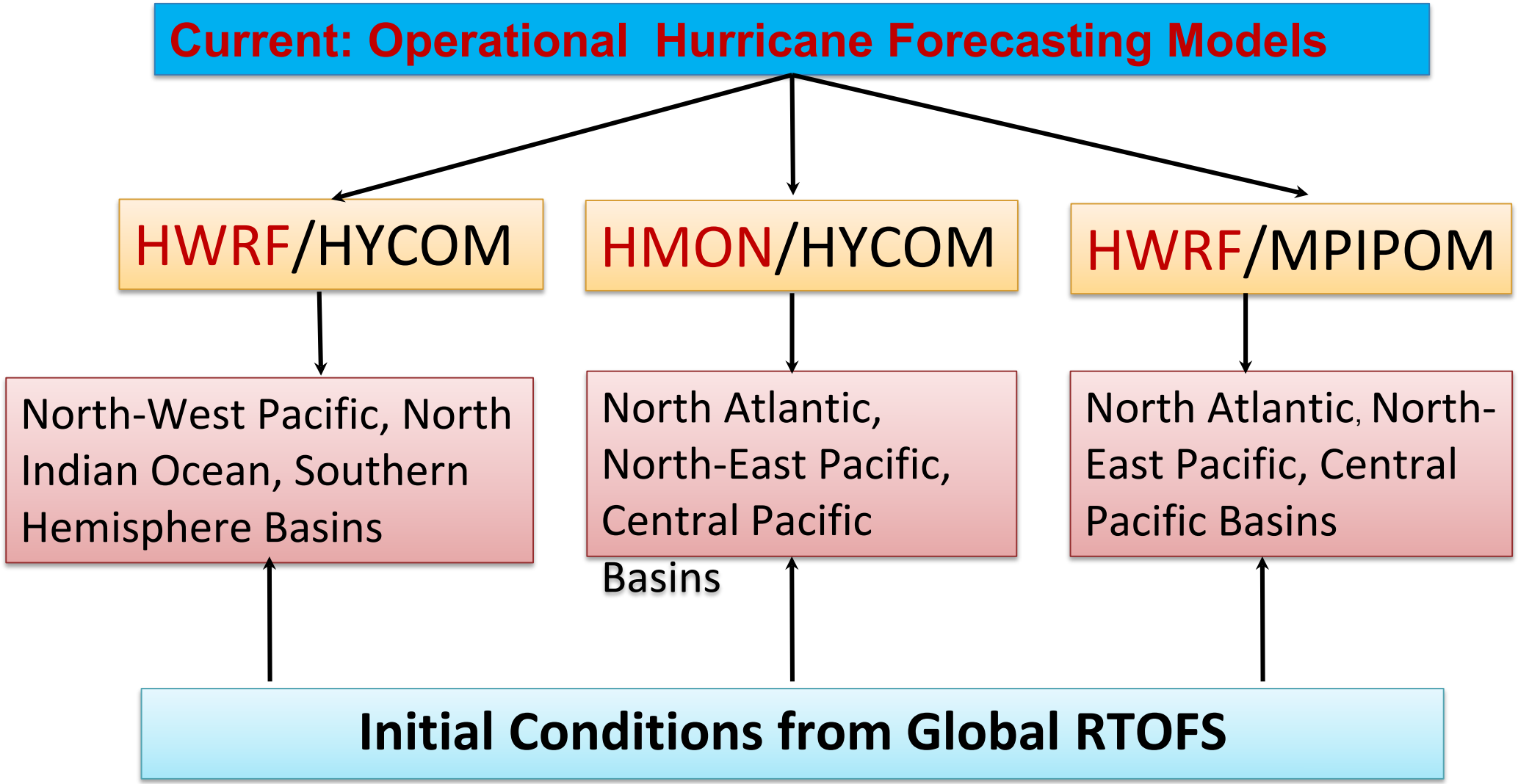
# Outline

- Coupled Operational Hurricane Systems
- Current Coupled HAFS configuration
- Future Coupled HAFS Configuration
- Future Coupled HAFS Data Assimilation

# Coupled Operational Hurricane Models at NCEP

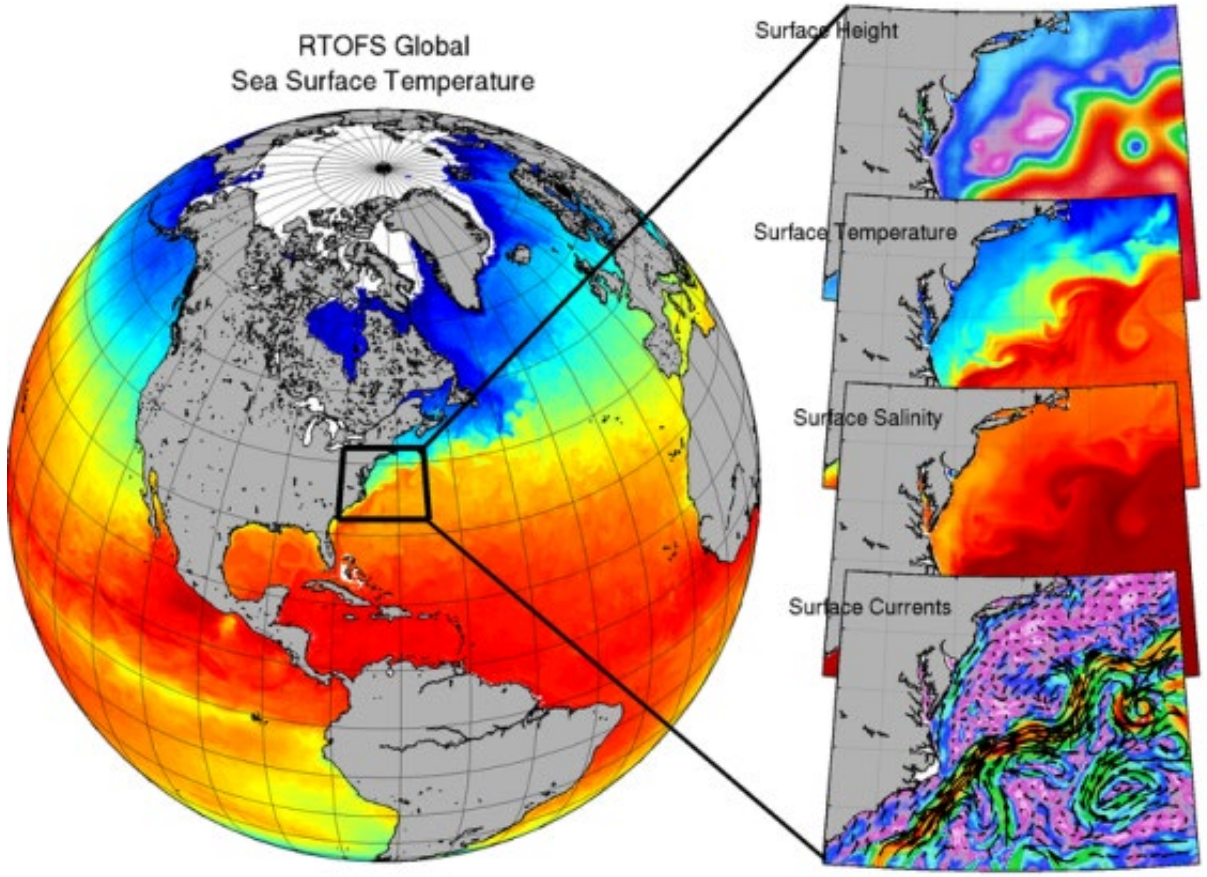
## Configurations:

- **HWRF:**
  - ❖ MPIPOM (2-way) at 1/12° and WW3 (1-way) at 1/10° (NATL, EPAC and CPAC)
  - ❖ HYCOM (2-way)  at 1/12° (WPAC, NIO and SH)
- **HMON:**
  - ❖ HYCOM (2-way) at 1/12° (NATL, EPAC and CPAC)




Adapted from Maria Vargas (Rutgers Univ)

# Current: Real Time Ocean Forecast System (RTOFS) at NWS/NCEP




- Eddy Resolving Ocean Modeling and Initialization
- Coupled Modeling for Hurricanes (Air- Sea- Wave flux interactions, mixing)
- Inputs to operational Global (GFS v16) and Coastal (NWPS) wave models to allow for wave-current interactions.
- Coupled Ecosystem Forecasting (Biogeochemical, NPZD, tracers)
- RTOFS presently based on **HYCOM**

Strong collaboration with US Navy, leveraging core HYCOM and ocean data assimilation developments at NRL.

# New: Q1FY21 RTOFS-DA Implementation Timeline

| Dates | Milestone |
|---|---|
| May 1, 2020 | Retrospective T&E at EMC |
| July 20, 2020 | Real time T&E at EMC |
| July 23, 2020 | External Evaluation |
| July 24, 2020 | Approval from EMC Director |
| August 7, 2020 | Approval from NCEP Director's Office |
| August 31, 2020 | Submission of Codes to NCO |
| October-November 2020 | NCO IT Testing completed |
| December 3rd, 2020 (scheduled) | IT briefing to NCEP Director's Office |
| December 8th, 2020 (tentative) | Operational implementation by NCO |

# Hurricane Analysis and Forecast System (HAFS): A collaborative Project in UFS Framework

07 NCAR/DTC

06 OFCM/AOC

05 ESRL/NESII

04 ESRL/GSD

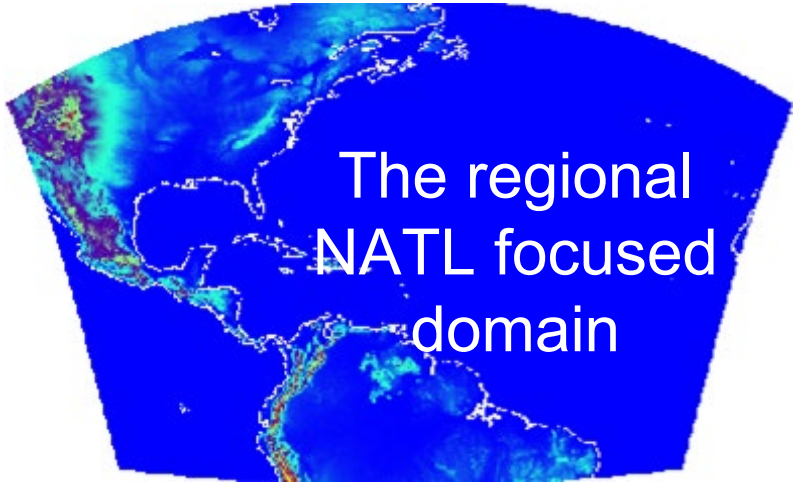
NCEP/EMC 01

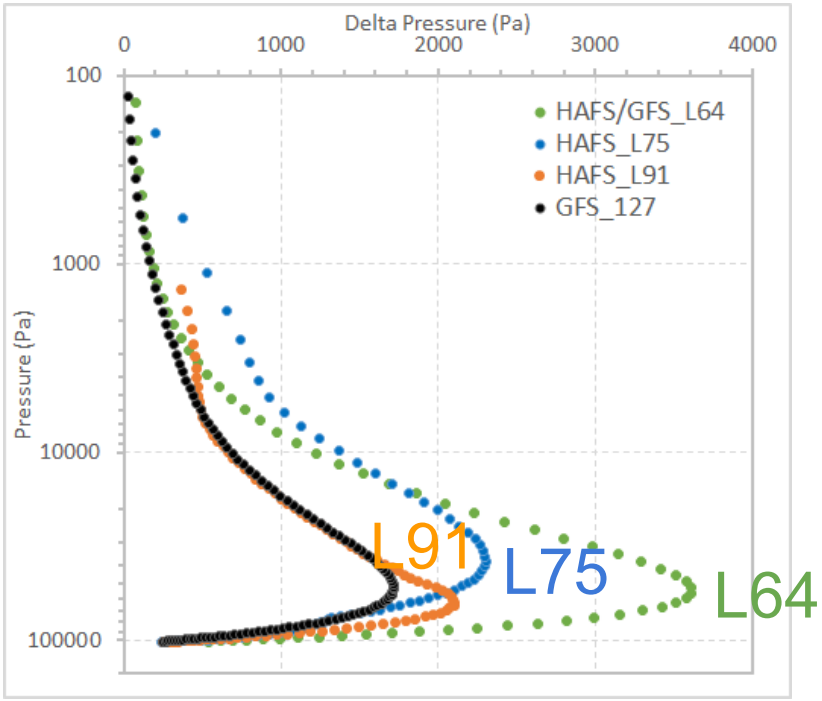
AOML/HRD 02

GFDL 03

# HAFS v0.1A Baseline Configuration

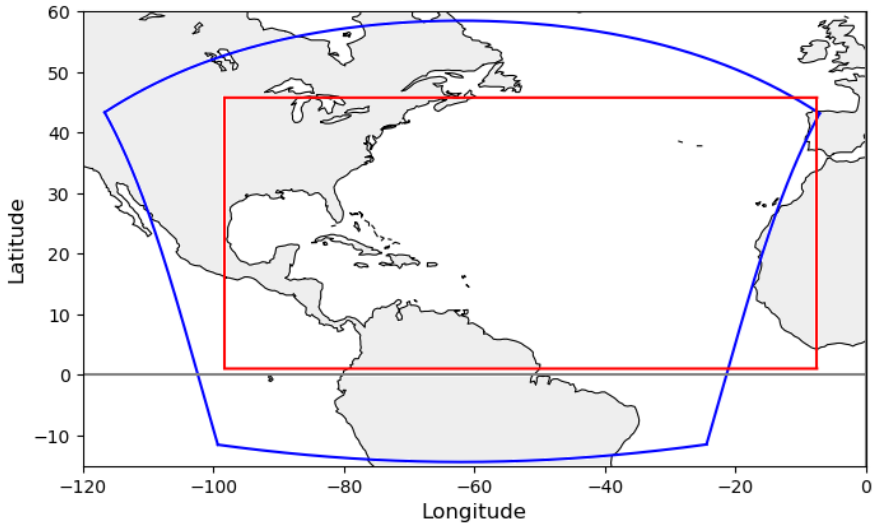
- The HAFS.v0.1a baseline configurations on top of the 2019 HAFS.v0.0a real-time experiment
  - Modeling infrastructure, dynamics, and physics advancement (FV3dycore, CCPP, UFS_UTILS, etc.)
  - Slightly increased domain size in the 3-km resolution
    - from ~85x55 deg to ~85x63 deg
  - Increased vertical levels from L64 to L75
  - Lateral boundary condition blending (nrows_blend=10)
  - Both convective and orographic GWD are turned off
  - Reduced radiation scheme time step from 3600s to 900s
- Same dynamics and physics options as HAFS v0.0A
  - Time step of 90s, advection scheme hord=6
  - GFDL microphysic; RRTMG radiation; No CP; Noah LSM
  - GFS surface layer with HWRF exchange coefficients
  - GFS EDMF PBL with HWRF modification
  - NSST on; Convective GWD off; orographic GWD on



# The HAFS v0.1A Coupled Configuration

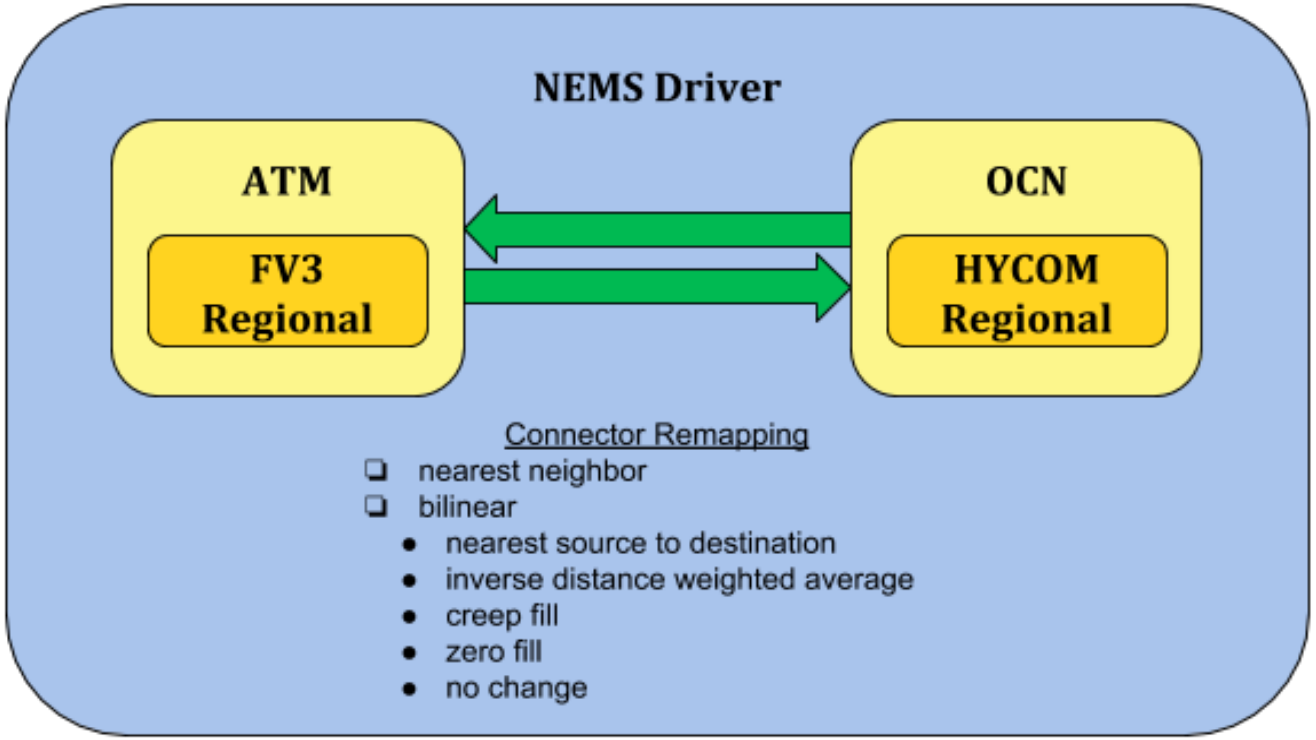
- The FV3 atmospheric model component
  - Further increased model domain (~85x72 deg)
  - Further increase the vertical leves from L75 to L91
  - Use the HAFS_v0_gfdlmp_nocpnsstugwd physics suite
    - GFDL microphysic; RRTMG radiation; No CP; Noah LSM; GFS surface layer with HWRF exchange coefficients; GFS EDMF PBL with HWRF modification; Both convective and orographic GWD are turned off; Turning off the NSST component
    - Radiation scheme time step 1800s
  - GFS NEMSIO file for IC; 3-hrly GFS grib2 files for LBC
- The HYCOM ocean model component
  - Cover NATL basin (1-45.78N, 261.8-352.5E) at a 1/12-degree resolution with 41 vertical layers
  - Ocean IC from RTOFS nowcast and/or forecasts
  - Use persistent oceanic LBC
  - Atmospheric forcing from 0.25-degree GFS grib2 files to cover non-overlapped area




Blue: FV3 domain
Red: HYCOM domain

# ESMF/NUOPC Based HAFS-HYCOM Coupling

## Direct coupling through the bilinear regridding method with the data merging for non-overlapped areas



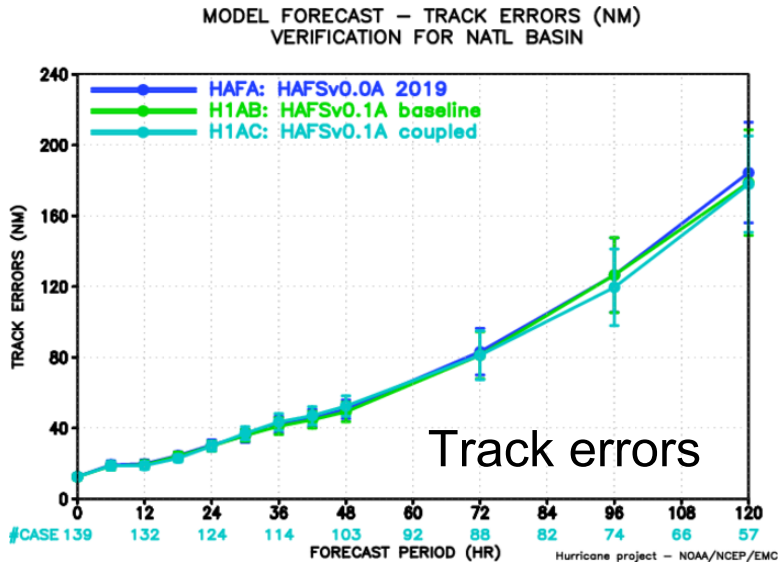

| Shapes | |
|---|---|
| ▭ | Component |
| ⇨ | Connector |

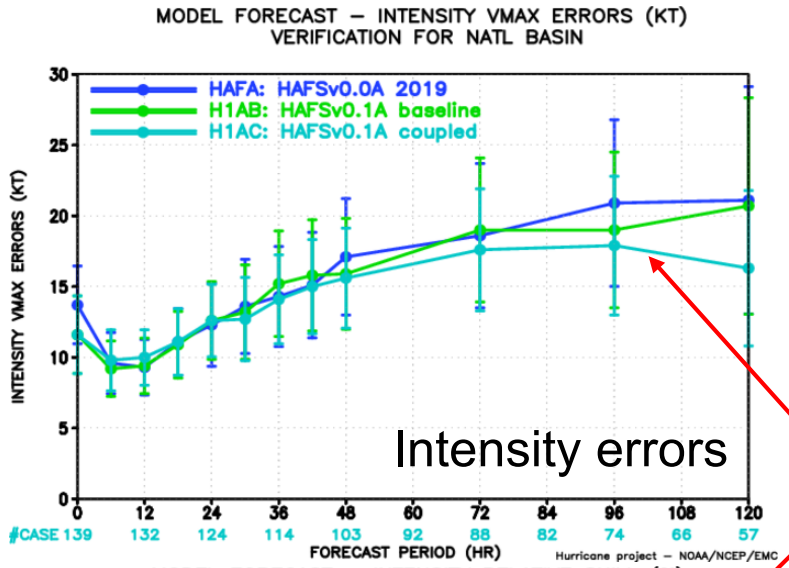
| Color Code | | |
|---|---|---|
| | Blue | Driver |
| | Yellow | Model |
| | Green | Connector |
| | Orange | Mediator |
| | Gray | Off |

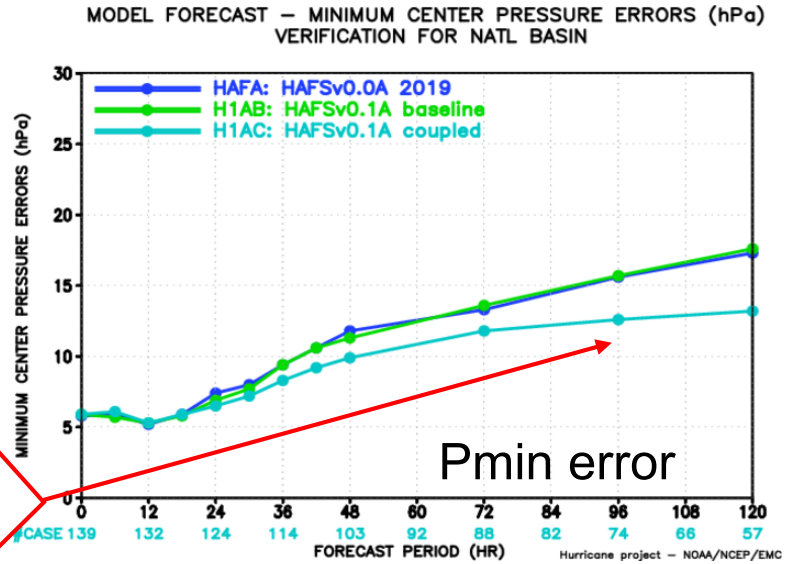
**From ATM to OCN:** 10-m wind, air-sea momentum flux, 2-m temperature, 2-m humidity, net short-wave and long-wave radiation fluxes, precipitation, surface pressure

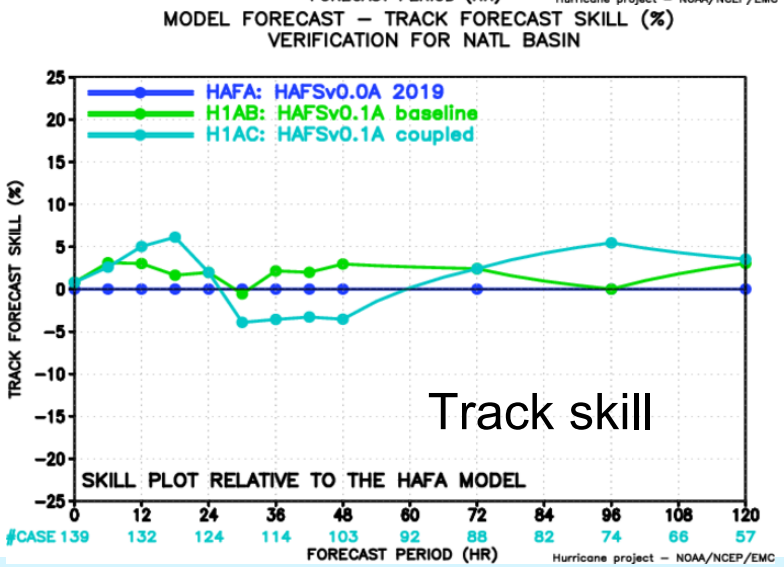
**From OCN to ATM:** sea surface temperature

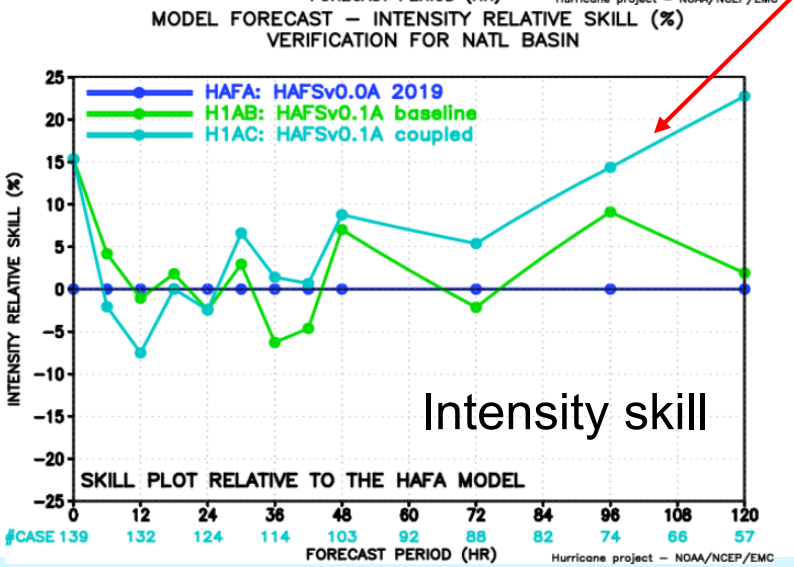
# Performance of the HAFS V0.1A Coupling Configuration
# (For selected 2019 NATL storms 05-13L)

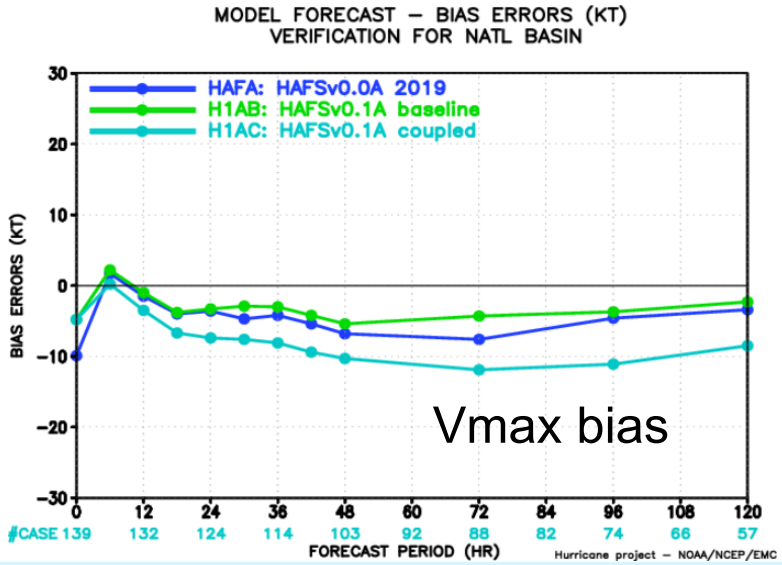


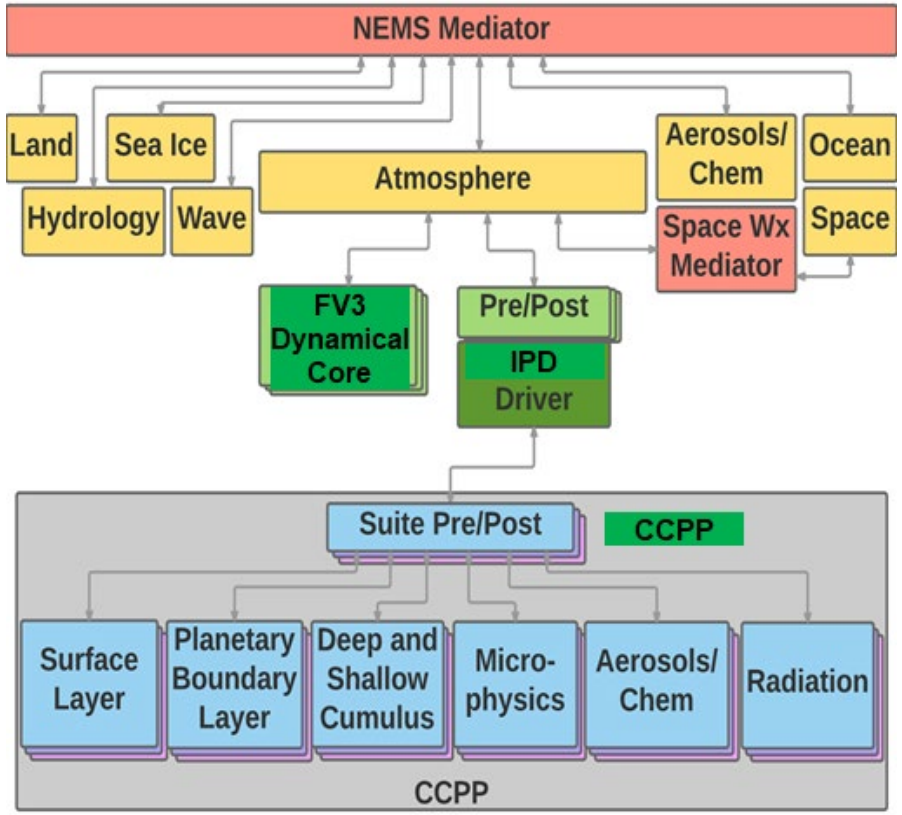



# Future Coupled HAFS: HWRF/HWRF-B provides Blueprints

- Coupler can exchange data with multiple moving concurrent nests and the static parent domain
- Efficient and accurate treatment of moving grid interpolations
- Use of real*8 for grid-to-grid interpolation while allowing real*4 execution of component models
- 3-way coupled
- Scalable

# 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
  - CICE ice model
  - GOCART aerosol model
  - 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*



# Current UFS Coupled Model Developments

## Each of these is a working coupled application which is actively being tested and developed

### UFS - weather

Atmosphere and one-way wave coupling.

### UFS – CHEM

Atmosphere, aerosols interaction (prototype with GSDCHEM, moving to GOCART)

### ADCIRC – WW3

Wave and surge coupling (COASTAL ACT)

### UFS - marine DA

Ocean-Ice coupled model with a Data Atmosphere, used for ocean and sea ice DA

### UFS - HAFS

Hurricane Analysis and Forecast System

### UFS - S2S

Fully coupled atmosphere - ocean - ice - wave model (25 km atm, ¼ deg ocean and ice, ½ deg waves)

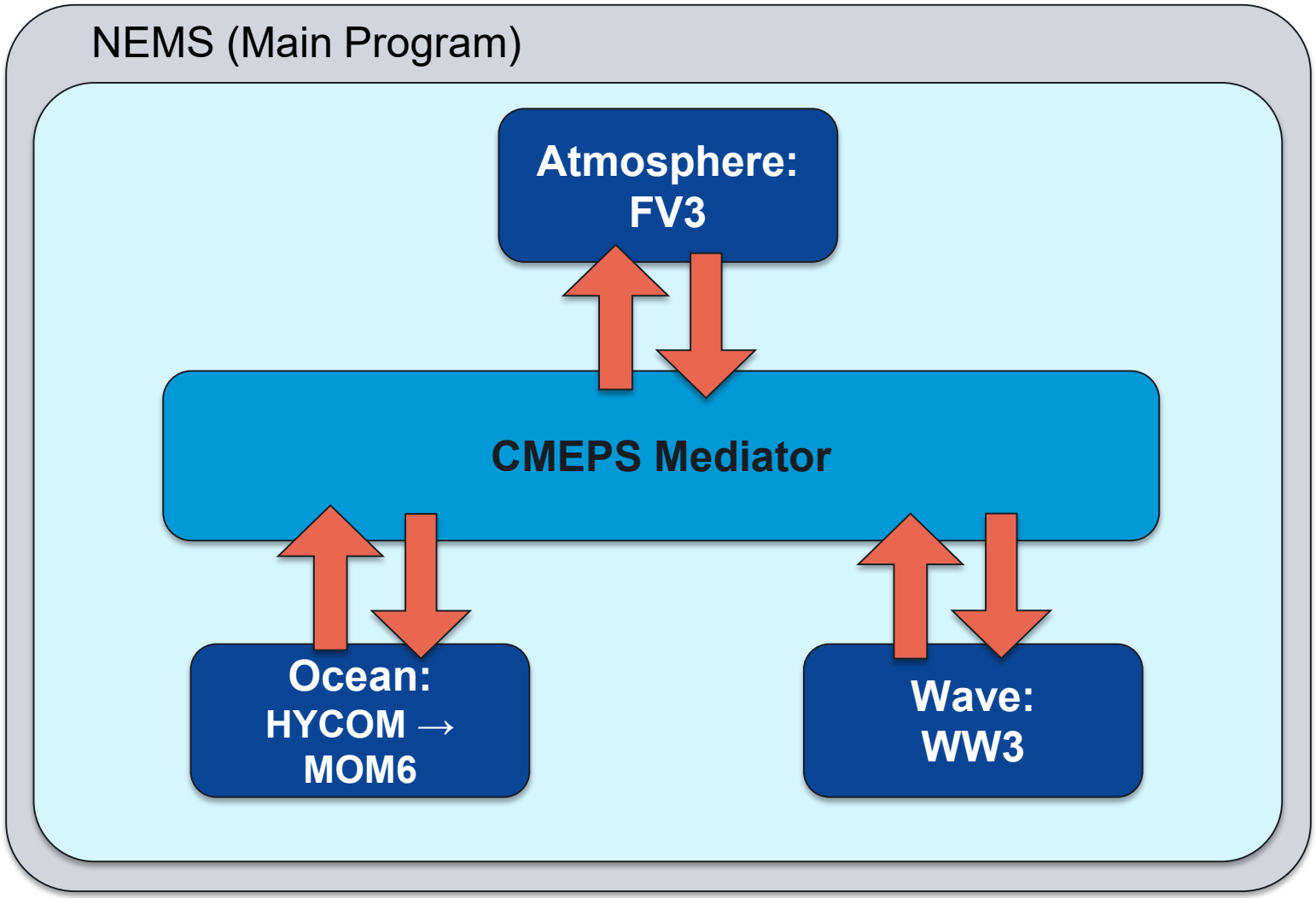
# Future Coupled Developments at NCEP/EMC

- NCEP/EMC developments transitioning to Community Mediator for Earth Prediction Systems (CMEPS) which also uses NUOPC layer

- Advantages of CMEPS over NEMS

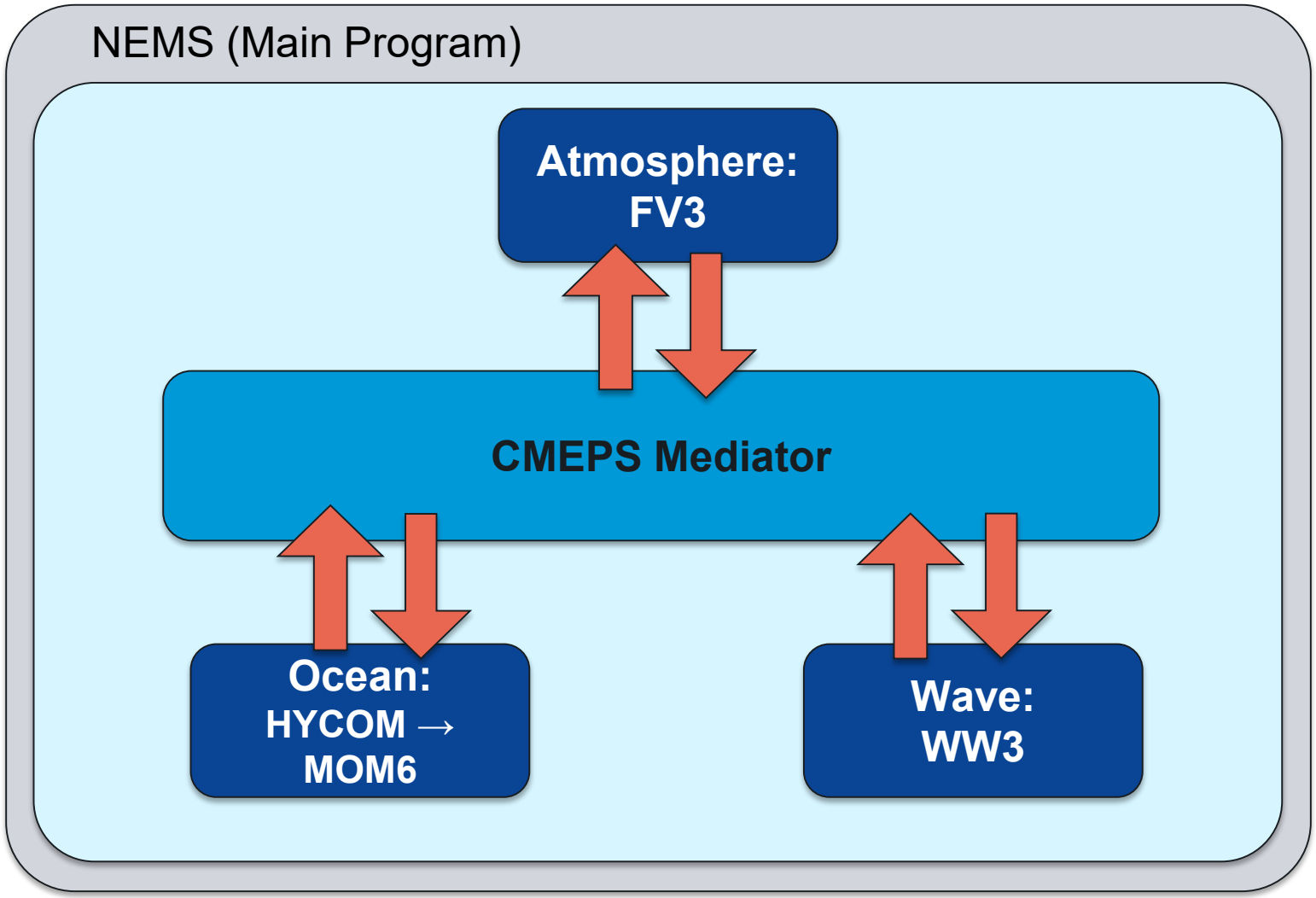
  - Community development in close collaboration with NCAR
  - Modular design; ease of use
  - Advanced “Geometric Structure” which can handle both structured and unstructured grids
  - Multiple options for handling flux computations
  - Remap and Merge defined in a single file for field exchanges
  - Use of YAML external file for NUOPC field dictionary

# Future Coupled HAFS Configuration




- Atm/Ocn fluxes are computed by atm model
- Atm/Ocn land/sea masks do not match
- SST is interpolated from ocean→atm using conservative interpolation followed by nearest neighbor fill

# Future Coupled HAFS Configuration




- Wave model sends z0 roughness length to atm
- Ocean sends surface currents to Waves
- Wave sends Stokes Drift (u,v) to ocean for sea-state dependent Langmuir mixing

# Project HSUP-2/DRA-2: FL-4

**Title: Advance ocean data assimilation and coupling of air-sea models in the NOAA UFS in support of improved flood and inundation forecasting through coordination with NWS and NOS**

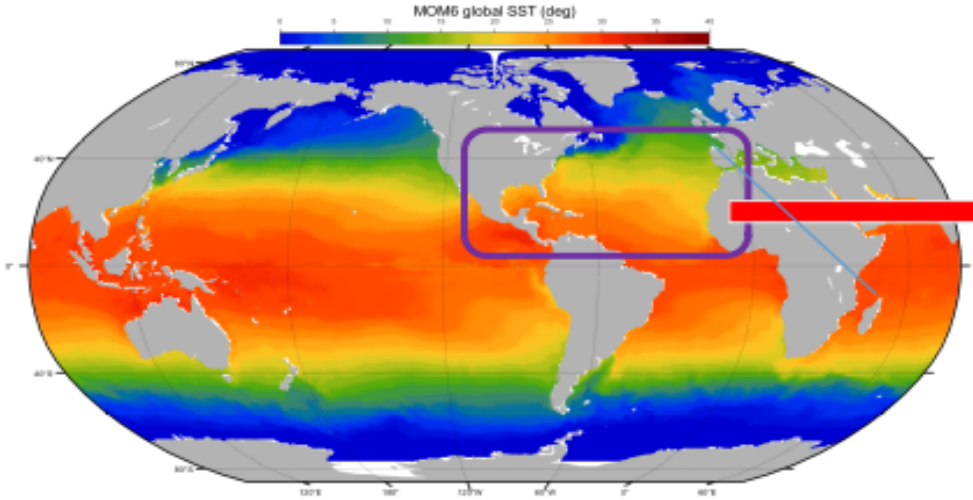
## Objectives:

- Coupled model development within the UFS framework with regional FV3
- Transition NWS and NOS ocean data assimilation efforts toward a common infrastructure (JEDI) and incorporate currently unused high-resolution ocean observations
- Enable comparison of ocean models and DA methods, and future leveraging of research activities for improved coupled Hurricane forecasts
- Establish capabilities of air-sea interface modeling and gaps that must be addressed for future coupled DA and explore strongly coupled DA for Hurricane applications

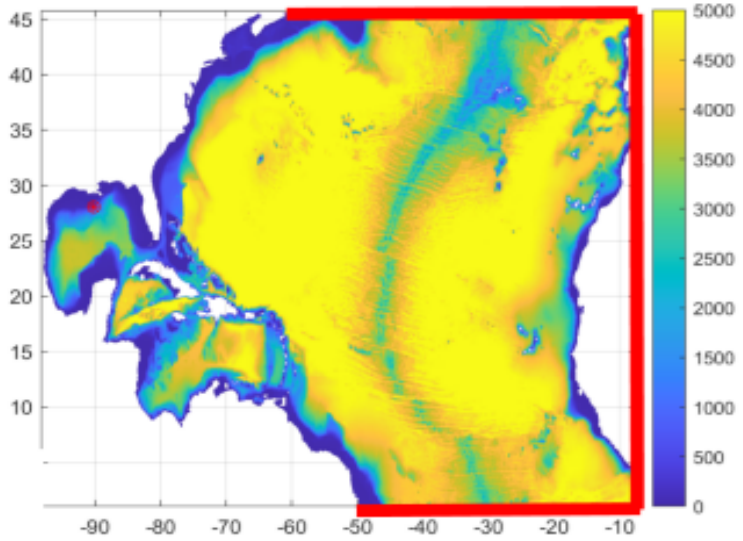
# Regional ODA Implementation

- Established regional ODA capability in the UFS-GODAS/JEDI-SOCA system
  - Implemented global-to-regional state converter and linked to DA workflow

**Global MOM6**




**Regional MOM6 (HAT10)**

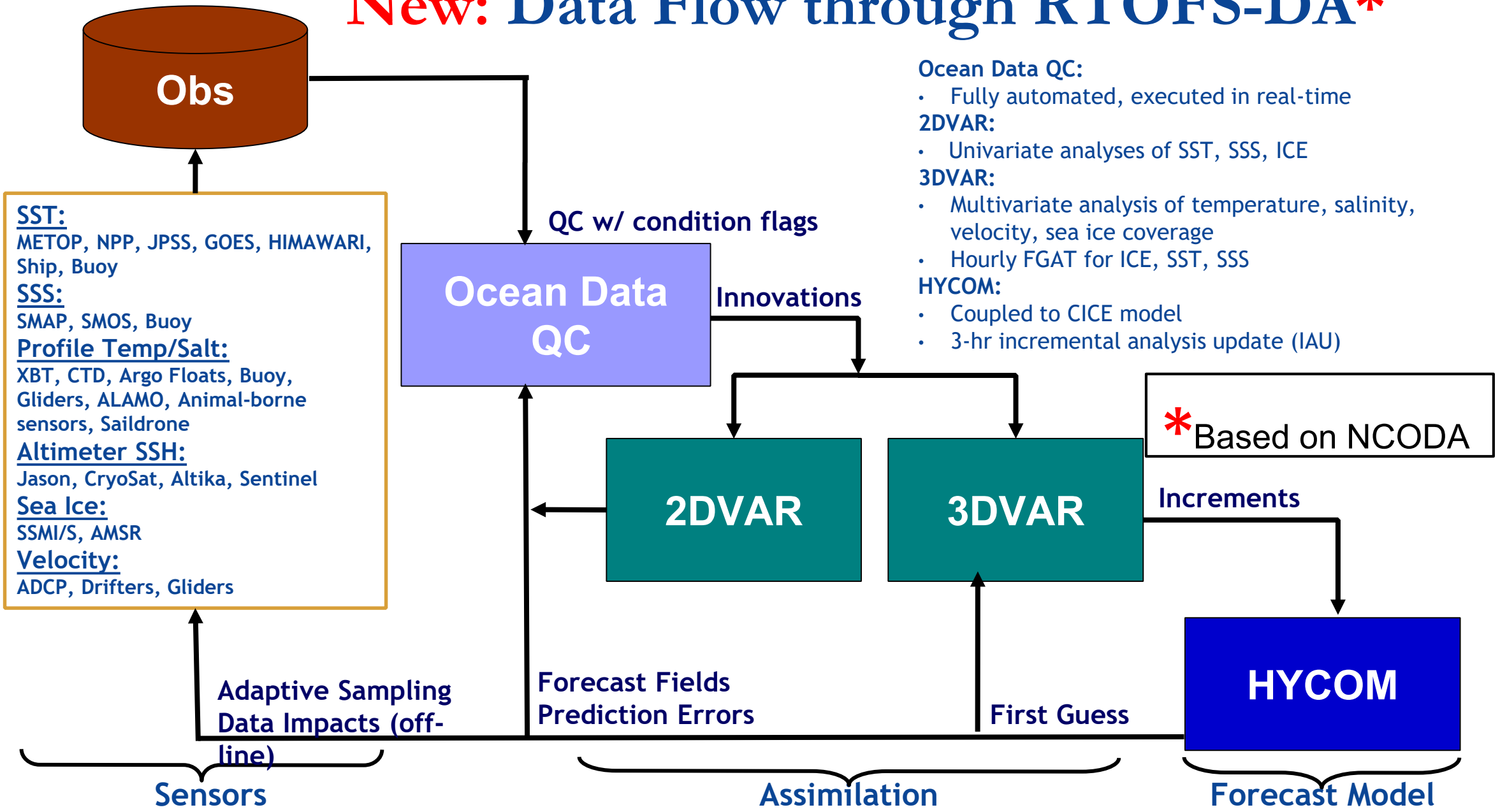



**Goal:**
**provide best estimate ocean IC & BC for coupled Hurricane forecast system**

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

# Thank You!

# New: Data Flow through RTOFS-DA*




**Ocean Data QC:**
- Fully automated, executed in real-time

**2DVAR:**
- Univariate analyses of SST, SSS, ICE

**3DVAR:**
- Multivariate analysis of temperature, salinity, velocity, sea ice coverage
- Hourly FGAT for ICE, SST, SSS

**HYCOM:**
- Coupled to CICE model
- 3-hr incremental analysis update (IAU)

*Based on NCODA

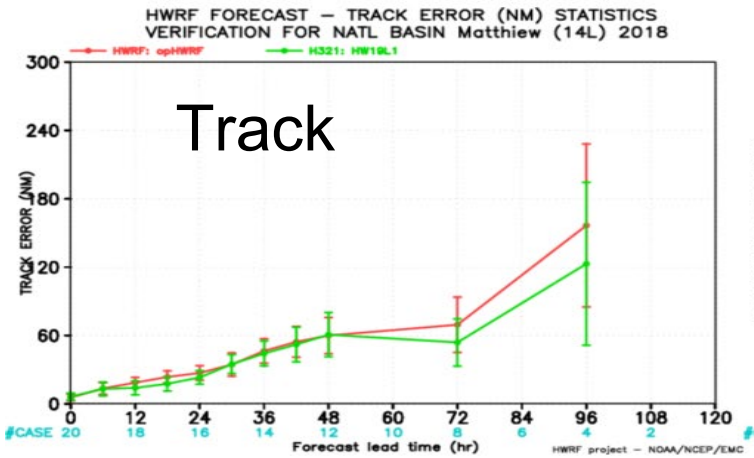
# Coupled Experimental Hurricane Models at NCEP

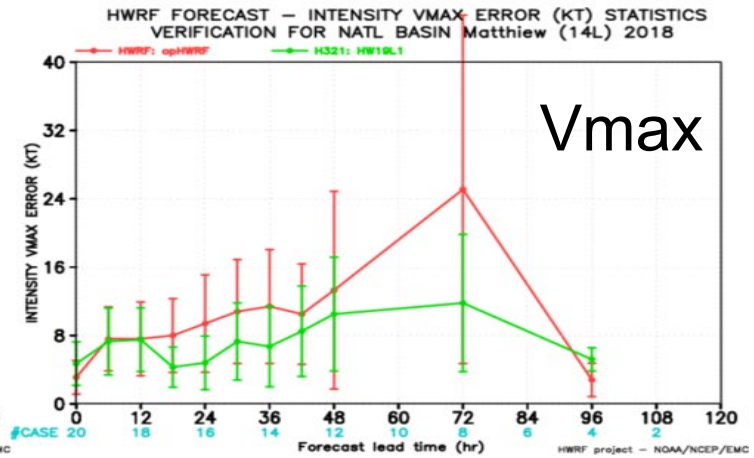
## Configurations:

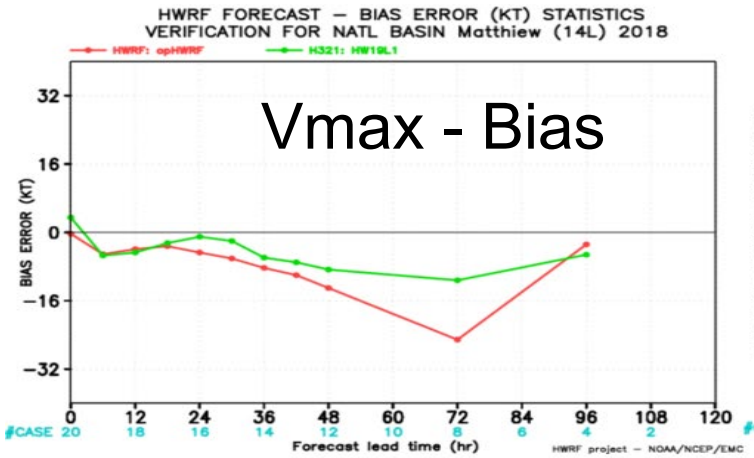
- **HWRF:**
  - MPIPOM and WW3 (3-way) (NATL and EPAC)
  - HYCOM and WW3 (3-way) (NATL, EPAC and WPAC)
- **HMON:**
  - HYCOM and WW3 (3-way) (NATL and EPAC)

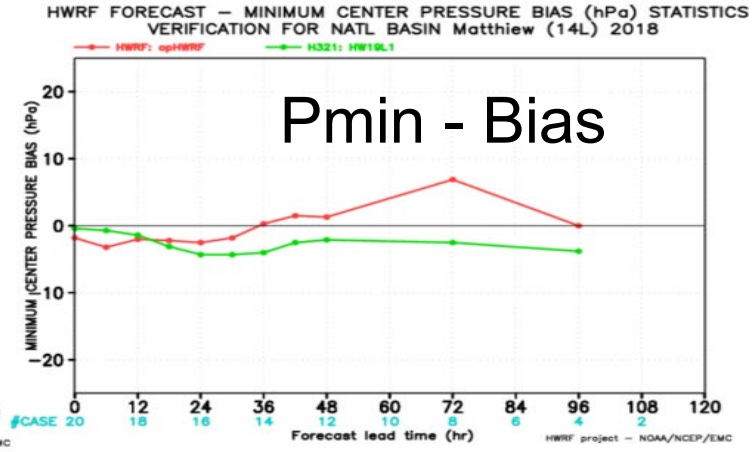
# Verification Statistics for Michael (14L) 2018

**H218 – 2018 operational HWRF; H321 – 3-way coupled (H219 + WW3)**




Courtesy: H-S Kim

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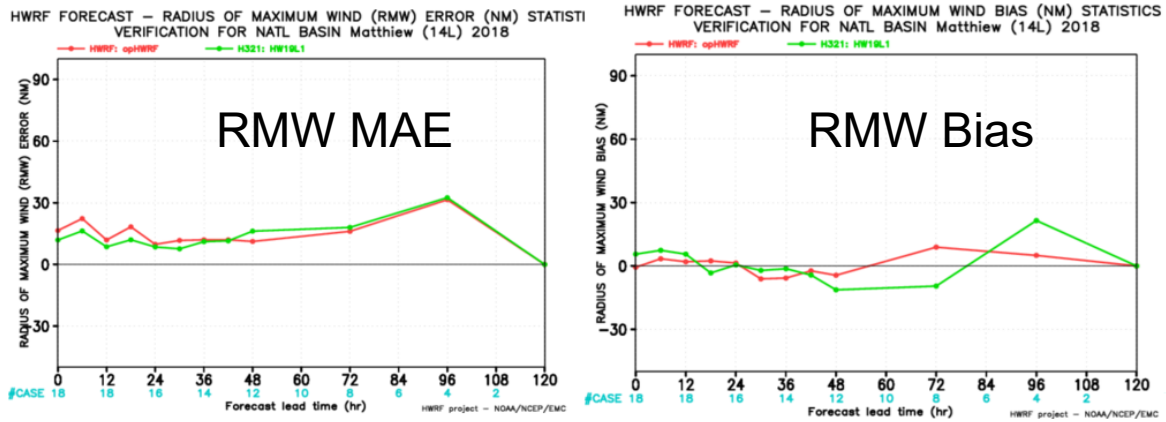


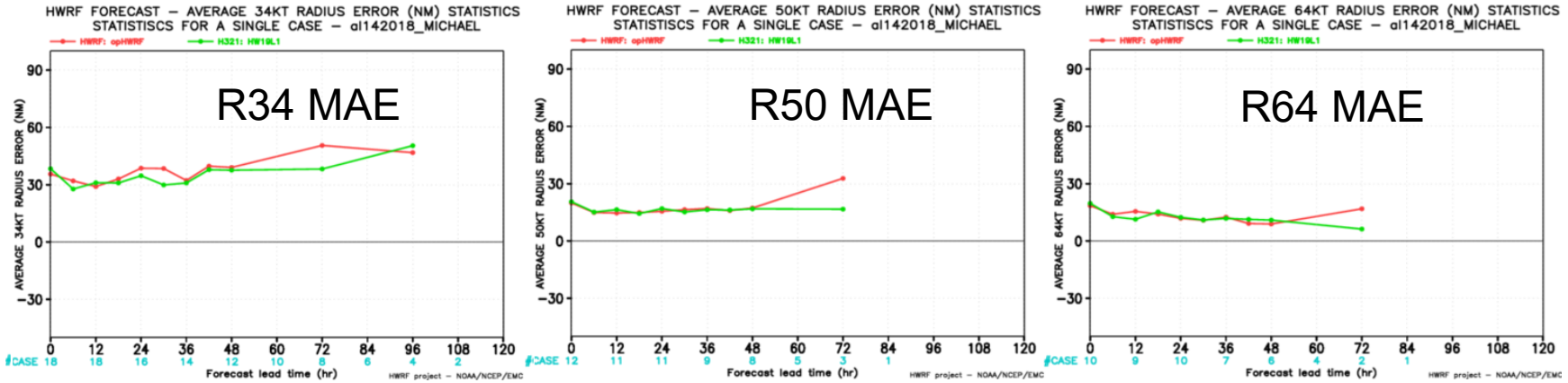


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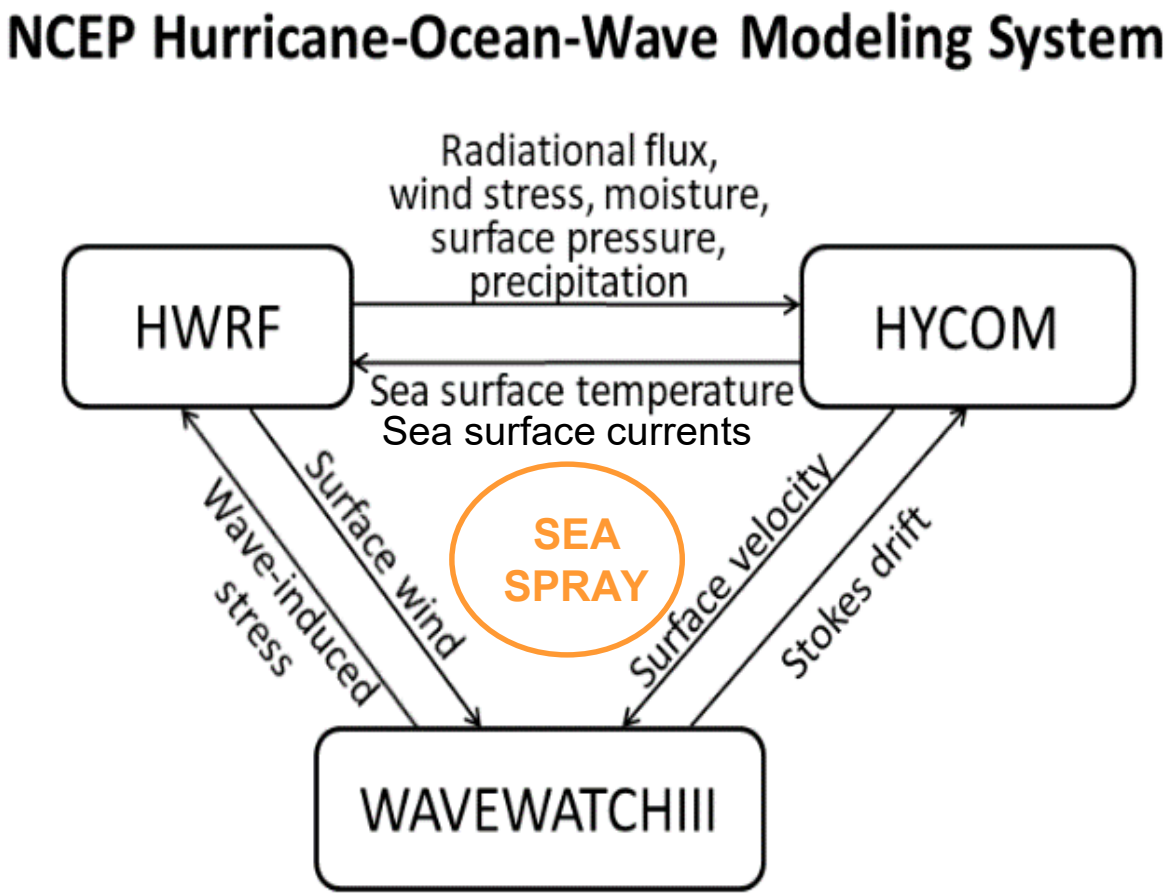
# Coupled Experimental Hurricane Models at NCEP




Ongoing Developments:

- Include sea-spray impacts
- Data assimilation for Ocean & Wave components
- Improve mixing physics, especially shear instability and entrainment
- Improve representation of Stokes Drift forcing
- Conduct a large sample size experiment with the 3-way coupled system

Courtesy: H-S Kim