Use of Ocean Observations for Operational Hurricane Forecast Systems at NWS/NCEP

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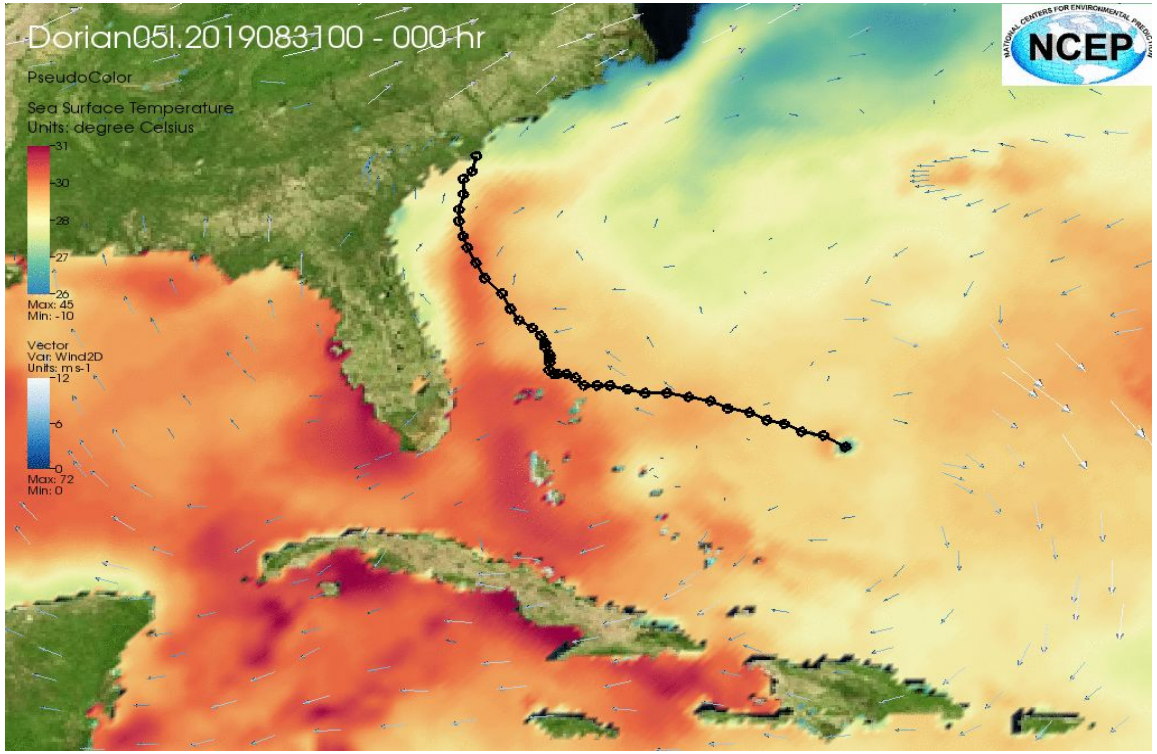
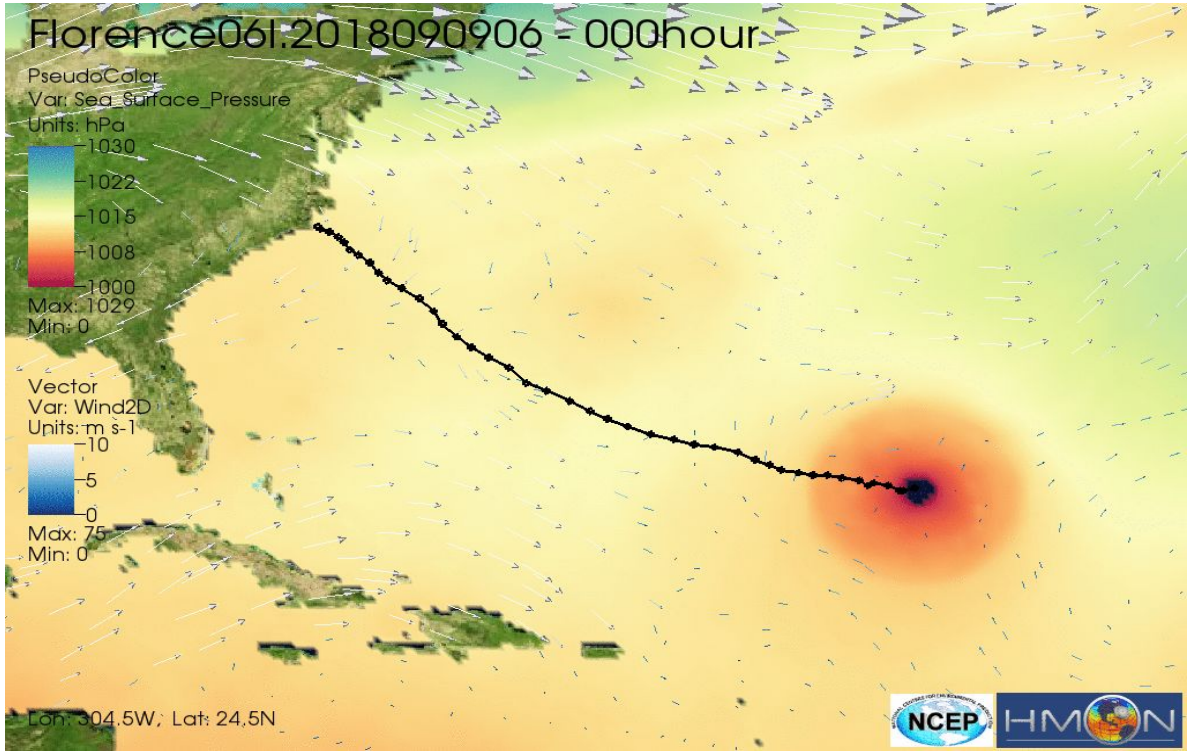
Current Operational Regional Hurricane Models at NWS/NCEP: HWRF & HMON





HWRF:

- WRF-NMM+MPIPOM/HYCOM+WWIII Coupled System
- Triply nested 13.5/4.5/1.5 km resolution w/91 levels
- 4D Hybrid EnVar DA System with Vortex Initialization, RTOFS for Ocean Initialization
- Advanced Physics
- All Global Basins (NHC and JTWC), max. 7 storms on-demand

HMON:

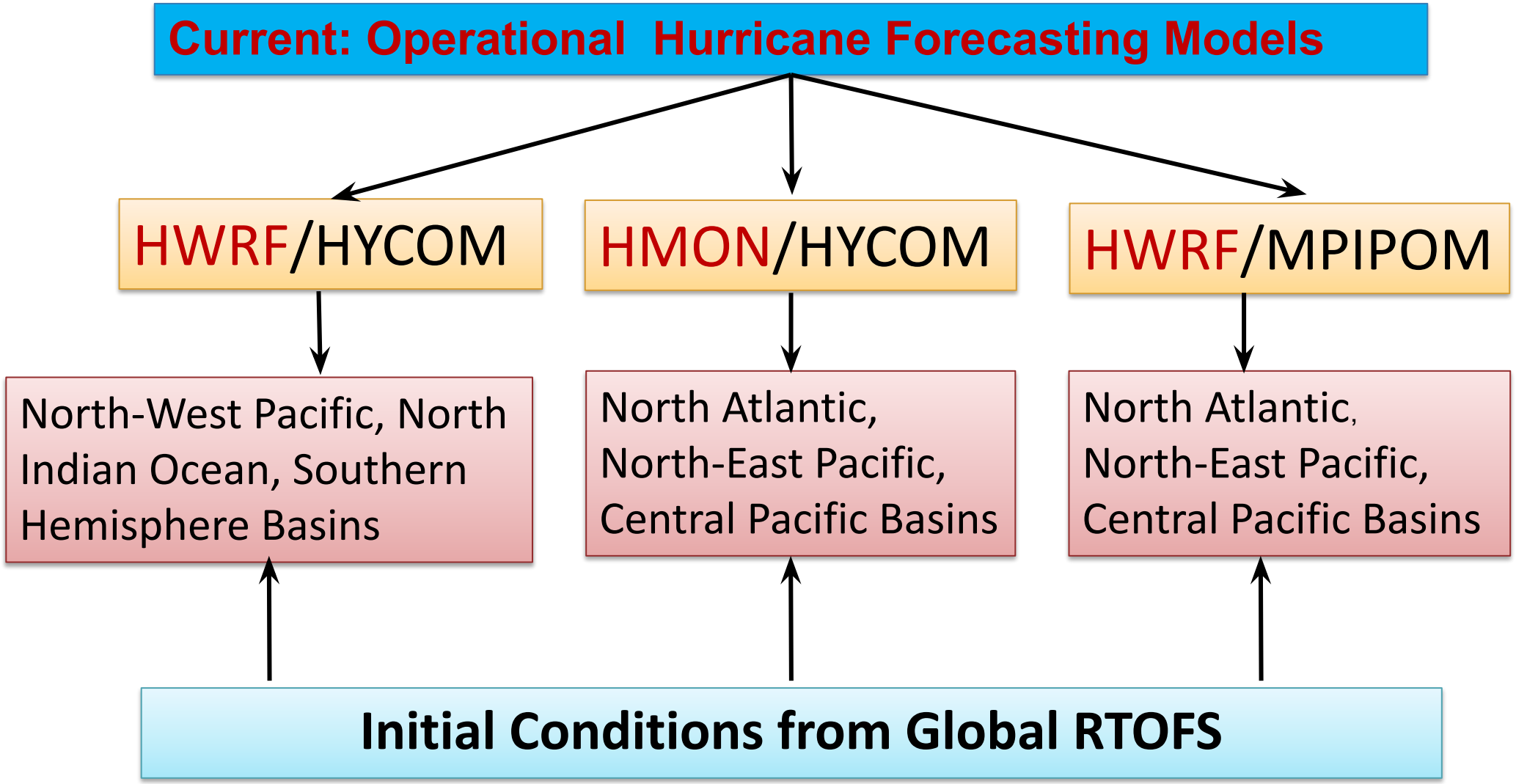
- NMMB+HYCOM Coupled System
- 18/6/2 km resolution w/71 vertical levels
- Advanced Vortex Initialization, Advanced Physics
- RTOFS for Ocean Initialization
- NHC Basins, max. 5 storms on-demand

Coupled Operational Hurricane Models at NCEP

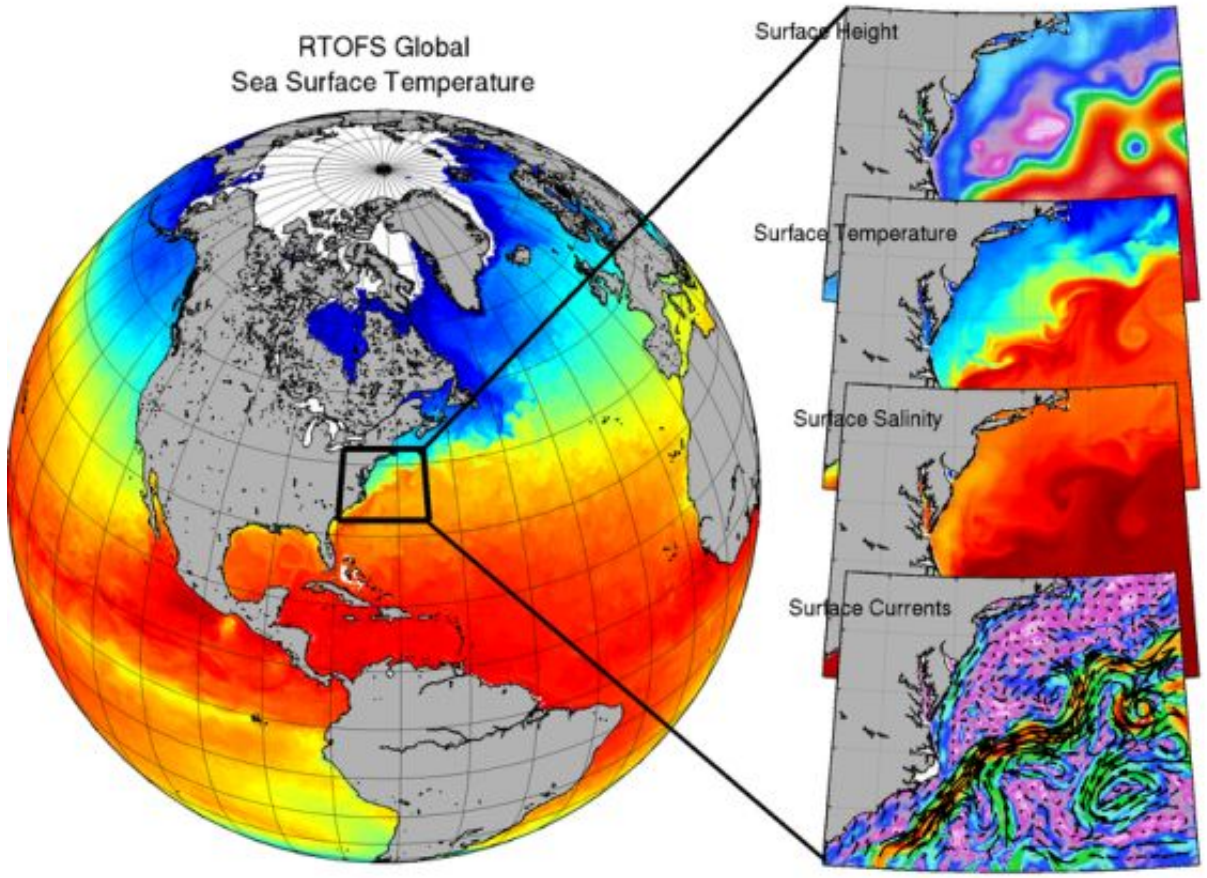
Ocean Model Configurations:

- **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)


Current: Operational Hurricane Forecasting Models
HWRF/HYCOM
HMON/HYCOM
HWRF/MPIPOM
North-West Pacific, North Indian Ocean, Southern Hemisphere Basins
North Atlantic, North-East Pacific, Central Pacific Basins
North Atlantic, North-East Pacific, Central Pacific Basins
Initial Conditions from Global RTOFS

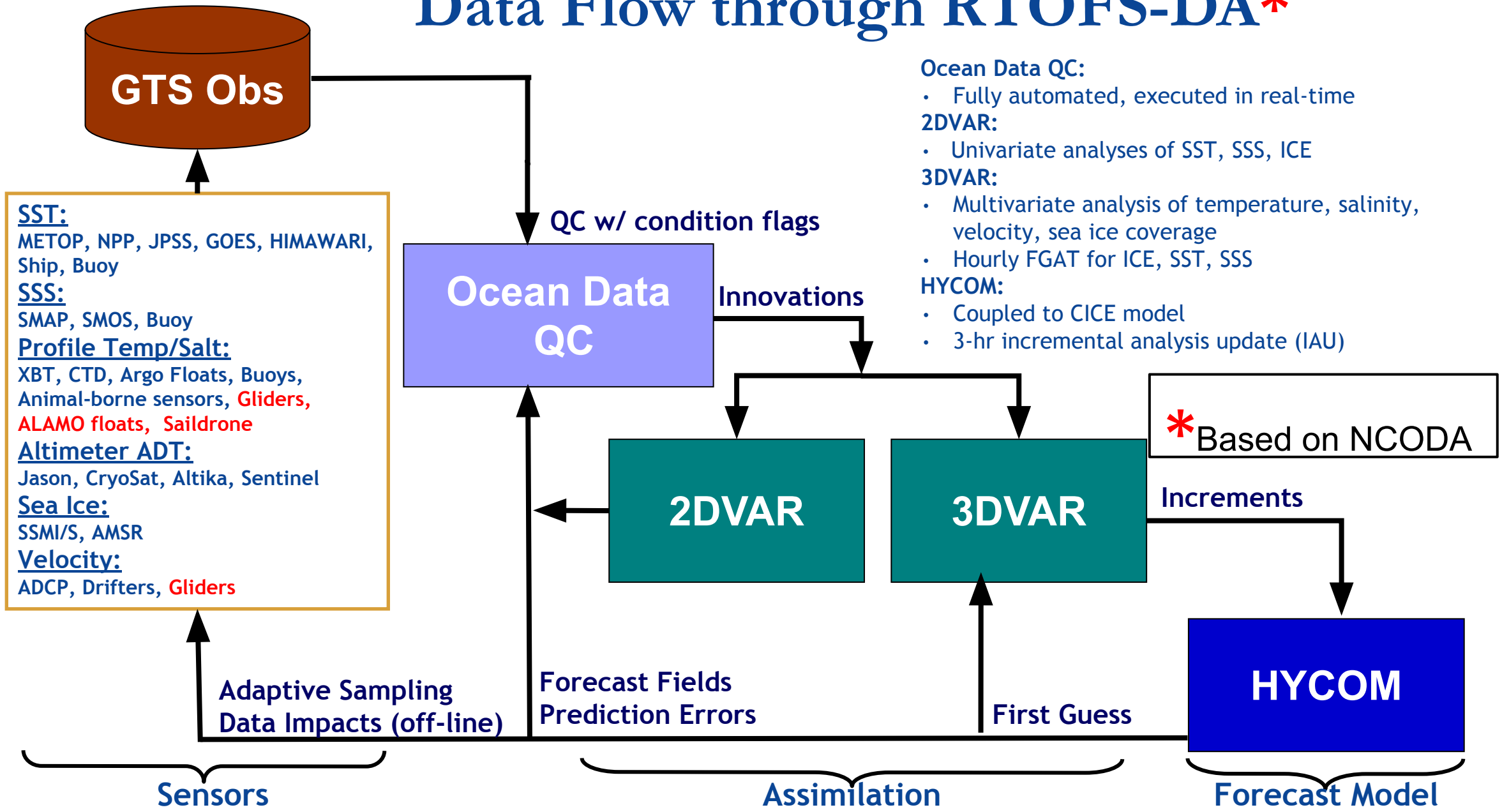
Real Time Ocean Forecast System (RTOFS) at NWS/NCEP



- 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.
- **RTOFS-DA: First operational Mesoscale Global Data Assimilation System at NWS/NCEP**
- RTOFS presently based on HYCOM

Collaboration with US Navy, leveraging core HYCOM and ocean data assimilation developments at NRL

Data Flow through RTOFS-DA*



Future UFS-based Operational Ocean Forecasts at NCEP

Global Models:

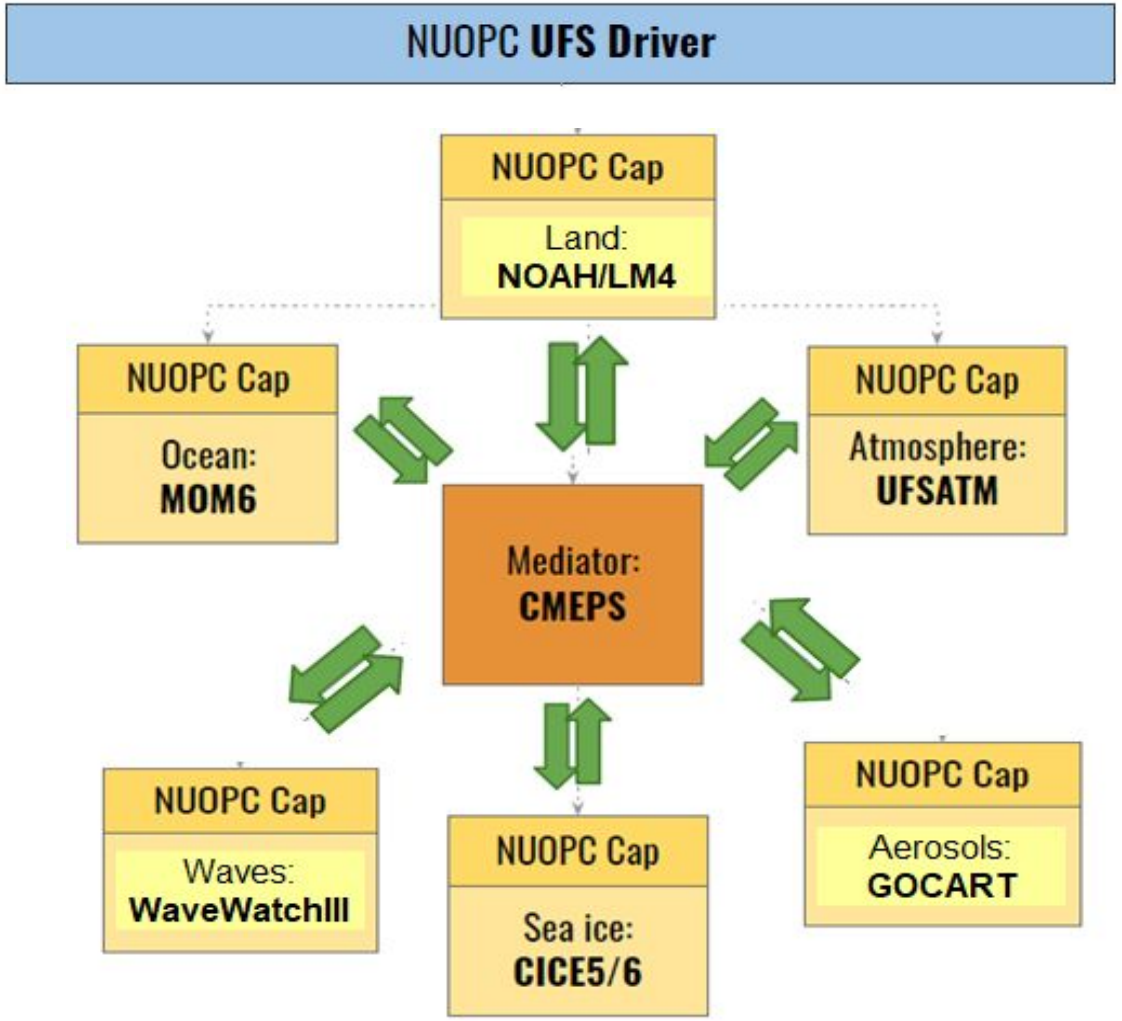
- Unified Forecast System (UFS) with MOM6 coupled to FV3 and CICE6, initially for sub-seasonal to seasonal applications.
- Replace HYCOM with MOM6 for RTOFS.

Regional (Hurricane) Models:

- Hurricane Analysis and Forecast System (HAFS) with FV3 based Hurricane model coupled to HYCOM (initially) and MOM6 when available.
- HAFS operational in all global ocean basins (NATL, EPAC, CPAC, WPAC, NIO, SH).

Unified Forecast System

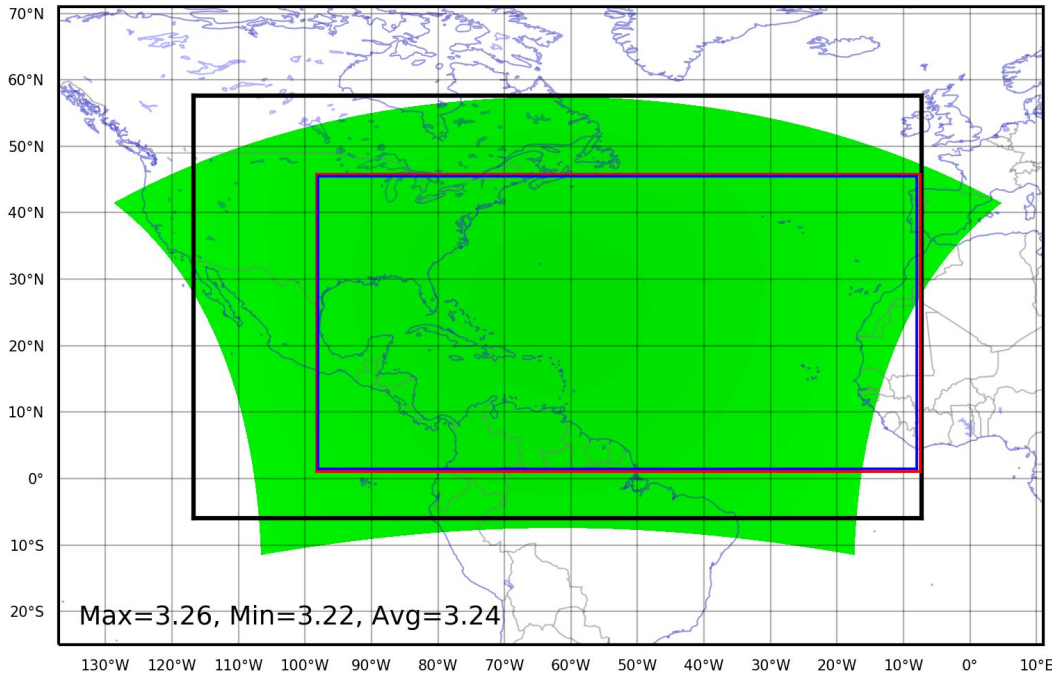
- NWS UFS system consists of the following community components
  - NUOPC for infrastructure
  - CMEPS mediator
  - FV3 dycore for atmosphere
  - MOM6 ocean model (S2S scales)
  - HYCOM ocean model (weather scales)
  - WW3 wave model
  - CICE6 ice model
  - GOCART aerosol model
  - NOAH-MP land surface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



The HAFS v0.2A Configuration

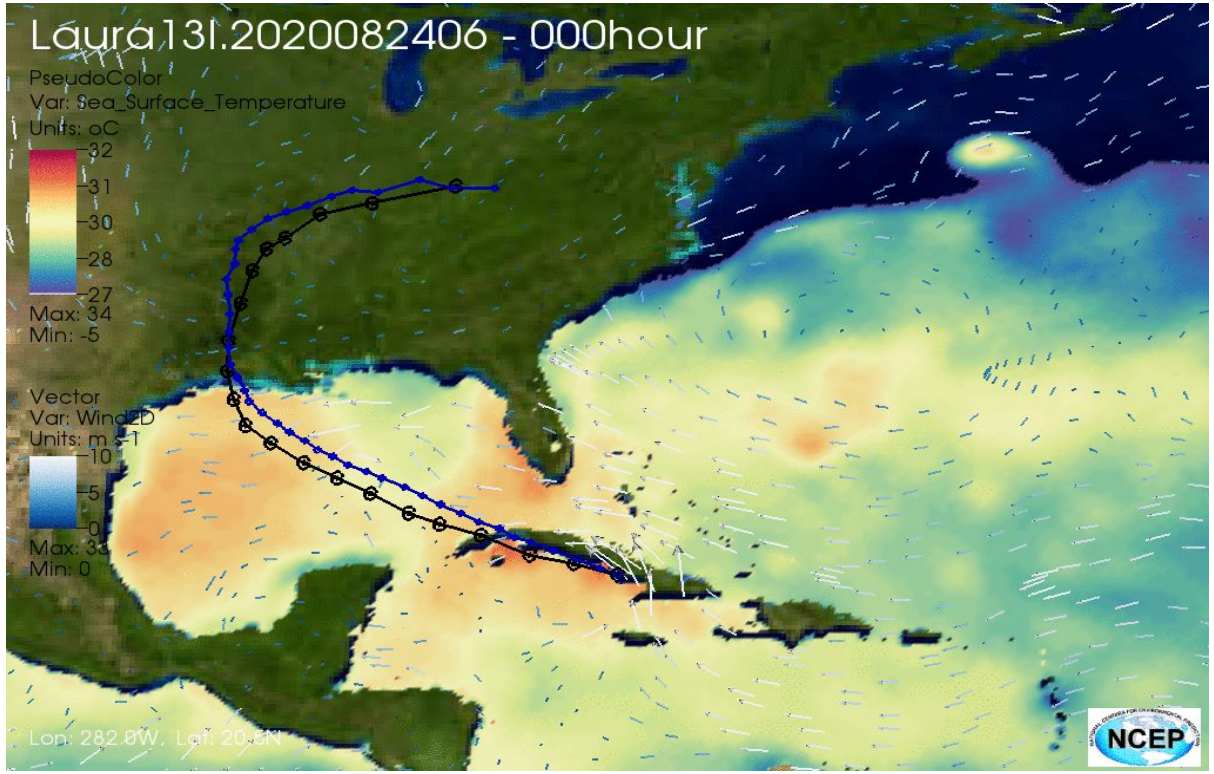
- The FV3ATM component
  - Regional ESG C3089 grid (~3-km) with L91 levels
  - GFSv16 netcdf files for IC; 3-hrly GFSv16 grib2 files for LBC
  - dt_atmos=90s; k_split=3; n_split=5; radiation time step: 1800s; LBC blending with nrows_blend=10
  - GFDL microphysic; RRTMG radiation; Scale-aware SAS convection; Noah LSM; GFS surface layer with HWRF exchange coefficients; Modified GFSv16 scale-aware TKE-EDMF PBL scheme (with sfc_rlm=1); Turn on orographic GWD but keep convective GWD off

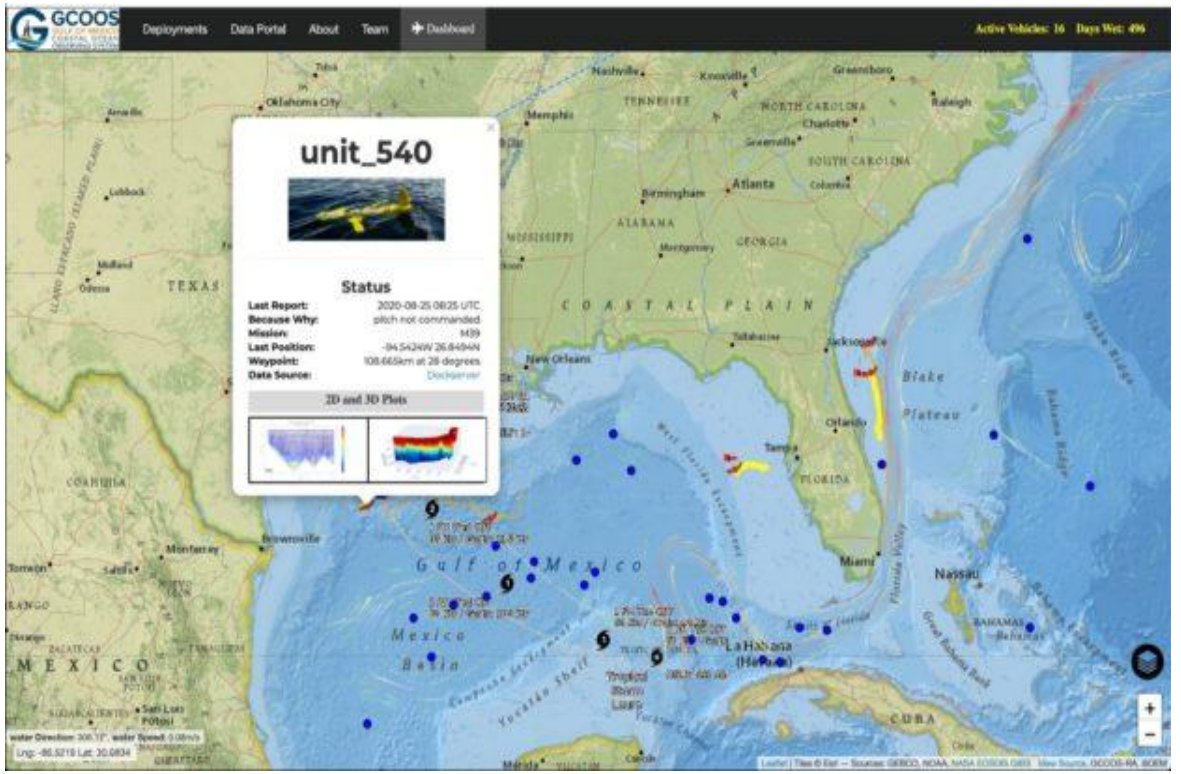
- The HYCOM component
  - CMEPS based ocean coupling 1/12-degree NATL domain (1-45.78N, 261.8-352.5E) L41
  - Ocean IC from RTOFSv2 and persistent oceanic LBC
  - Atmospheric forcing from GFSv16 grib2 files for non-overlap area



FV3ATM model domain
FV3ATM output domain
HYCOM ocean domain

Hurricane Analysis and Forecast System (HAFS): Hurricane Laura in August 2020





Marine JEDI: Future Operational Ocean Data Assimilation Systems

Global Applications:

- Next Generation -Global Ocean data Assimilation System (NG-GODAS; 1deg; ¼ deg; 1/12 deg)

Regional (Hurricane) Applications:

- Coupled Hurricane Analysis and Forecast System (HAFS; 1/12 deg)

* from daily analysis run at NAVOCEANO

Future: Unified DA Effort - JEDI

- The Joint Effort for Data assimilation Integration (JEDI) is a collaborative development spearheaded by the JCSDA:

  - Next generation unified data assimilation system

    - For research and operations (including R2O/O2R)
    - For various components of the earth system, including coupled
    - Mutualize as much as possible without imposing single approach
      - Open-development software –model: in addition to supported releases, community, developers can obtain and collaborate on latest development branches

  - Collaborative teams – NOAA, NASA, US NAVY,

Courtesy of JCSDA

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

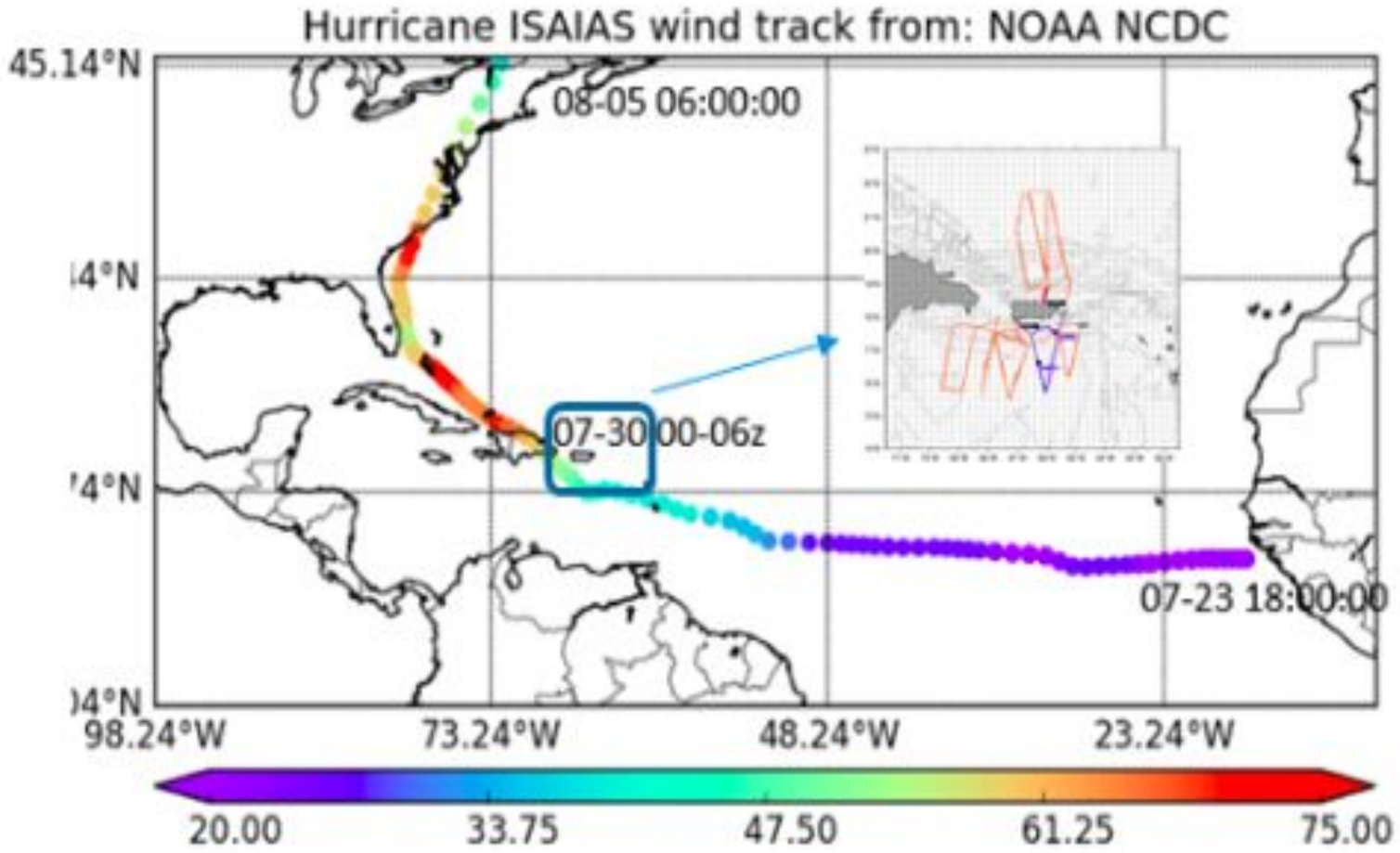
Title: Advance ocean data assimilation and coupling of air-sea models in the NOAA UFS in support of improved flood and inundation forecasting through coordination with NWS and NOS.

Common Strategies:

- **Marine Coupling:** use common (UFS-based) infrastructure/tools for coupling models
  - NEMS (Driver, Model Caps, Connectors)
  - NUOPC (ESMF based layer)
  - CMEPS (Community Mediator for Earth Prediction Systems)
  - CDEPS (Community Data models for Earth Prediction Systems)

- **Marine Data Assimilation:** use common (JEDI-based) tools/algorithms for use with common observations
  - Inputs -- IODA (Interface for Observational Data Access)
  - Compute innovations/residuals -- UFO (Unified Forward Operator)
  - Algorithms -- OOPS (Object Oriented Prediction System)
  - Workflows -- SOCA Science

Regional ODA Experiment: Isaias (2020)



- Marine JEDI DA experiment with North Atlantic Basin
  - Hurricane Isaias (July 23 ~ August 05, 2020)
  - Analysis window and hurricane track with a view of glider data location
  - Gliders encountered Isaias approx. July 30

Challenges related to Ocean Observations for Hurricane Forecasting

- Dearth of subsurface ocean observations (< 1000 profiles/day for assimilation globally)
- Multiple steps from collection of observations to availability for real-time operations (models, products)
- Research challenges for coupled modeling systems (flux representation, coupling strategy)
- Research challenges for coupled data assimilation (observing system design)

Thank You!

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

Future: Benefits of Using JEDI

Reduce duplication of effort between JCSDA partners

✔ Adding new observations (UFO and IODA)
✔ Implementation of new DA algorithms (OOPS)

Bring all components of Earth-system in one DA system

✔ Develop DA once for all components (OOPS)
✔ Enable future coupled DA developments (OOPS)

Modern DA systems are too complex for one person to grasp

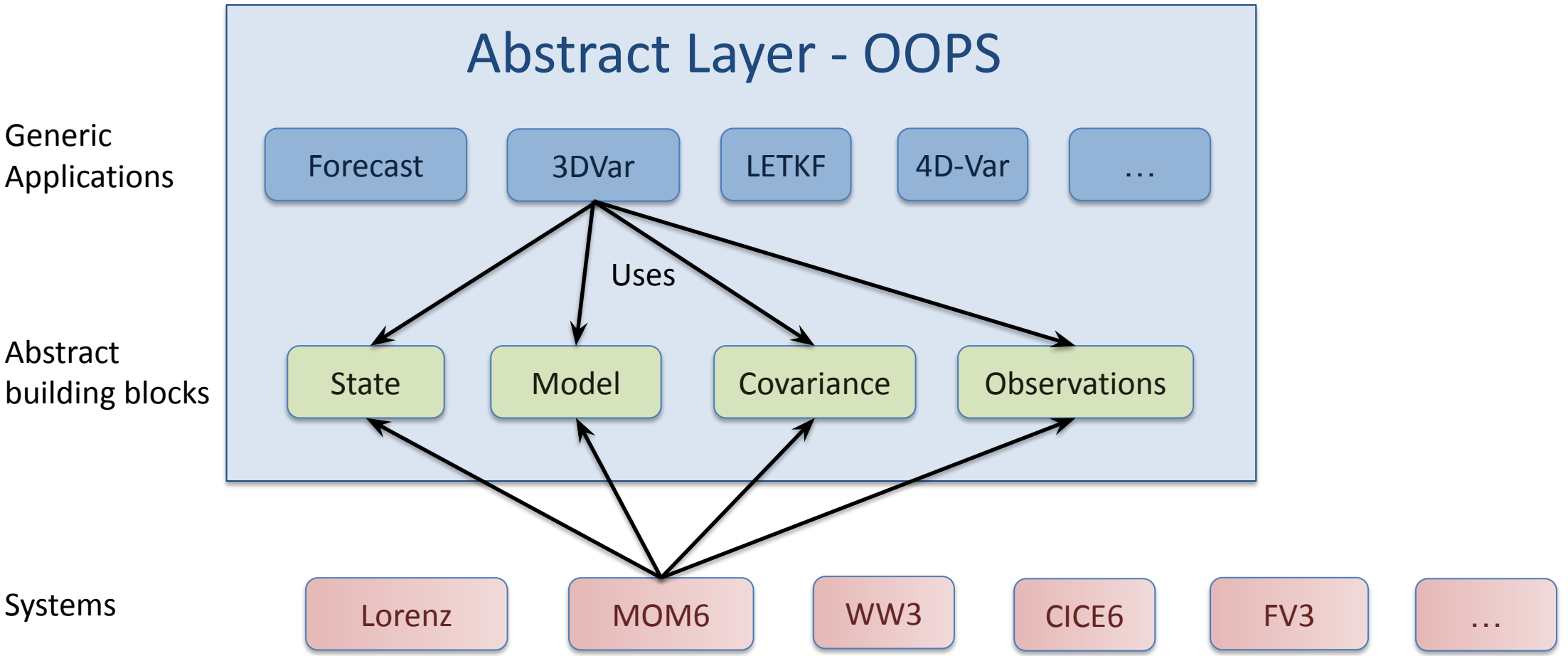
✔ Collaborative developments
✔ Separation of concerns

Modernize software

✔ Speed-up future developments
✔ Ease maintenance
✔ Increase portability and efficiency

Courtesy of JCSDA

Future: Unified DA Effort - JEDI



Abstract interfaces are the most important aspect of the design

Courtesy of JCSDA