EuroSea/OceanPredict workshop on "Ocean Prediction and Observing System Design"

Sensitivity of the Hurricane Analysis and Forecast System (HAFS) to Ocean Initialization from the Modular Ocean Model (MOM6) Analysis fields

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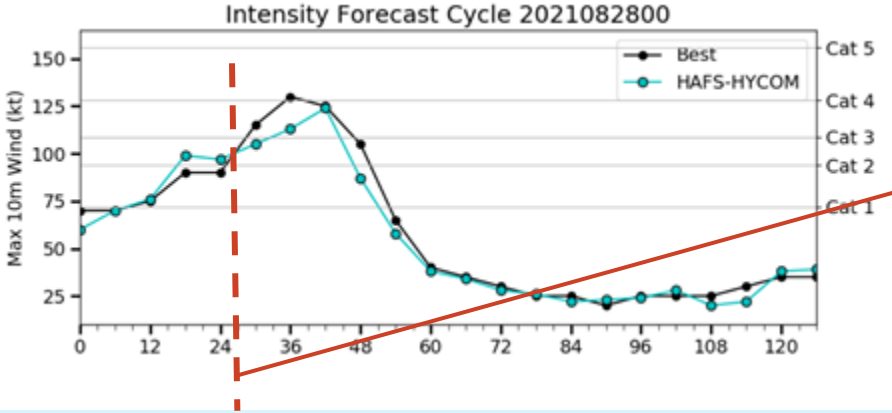
NATIONAL WEATHER SERVICE

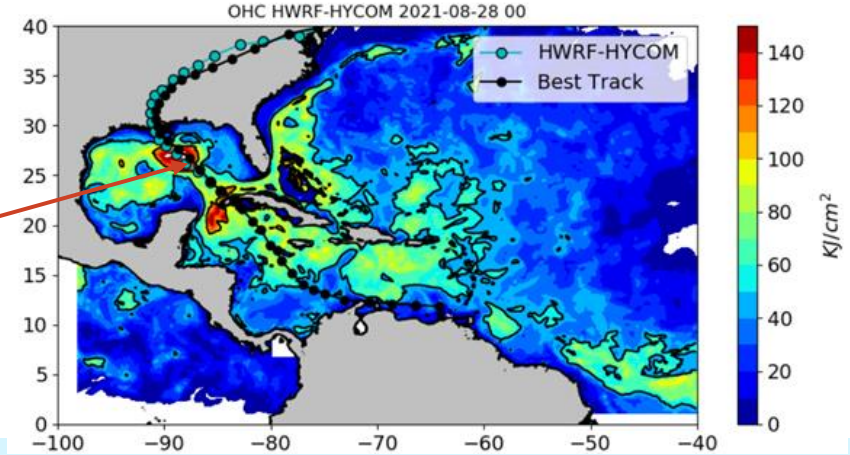
Outline

1. Introduction
1. MOM6 3DVAR data assimilation cycles
1. HAFS-CDEPS-MOM6 coupling
1. Interpolation from MOM6 3DVAR analysis to HAFS-HYCOM IC
1. Summary

Motivation

- Upper ocean thermal structure plays a very important role in the intensification of storms (Emanuel 1999).
- Tropical cyclones intensify when they pass over warm oceanic features (e.g. Leipper and Volgenau 1972, Jaimes and Shay 2015)
- Reduced inner-core sea surface temperature cooling is correlated with storm intensification (Cione and Uhlhorn 2003).
- Accurate ocean initial conditions are necessary for an accurate tropical cyclone intensity forecast (Halliwell et al. 2008, Le Hénaff et al. 2021)





Objective

Investigate the sensitivity of upper-ocean conditions and intensity of tropical cyclones in the Hurricane and Analysis Forecast System (HAFS) to ocean initialization from the Modular Ocean Model (MOM6) data assimilation system

Introduction

1. RTOFS: The global operational Real-Time Ocean Forecast System at NOAA/NCEP/EMC
2. 3DVAR

- JCSDA: Joint Center for Satellite Data Assimilation
- JEDI: Joint Effort for Data assimilation Integration
- SOCA: Sea-ice, Ocean, and Coupled Assimilation (Marine DA: 3dvar, letkf, 3dhyb)

1. MOM6: The Modular Ocean Model (MOM) version 6 (Github GFDL repository) at NOAA/GFDL, NCEP, NCAR, Rutgers, FSU, ANU, et al
2. HAFS-CDEPS

- Hurricane Analysis and Forecast System (HAFS)
- Community Data Models for Earth Prediction Systems (CDEPS)

1. HAFS-HYCOM

- Hybrid Coordinate Ocean Model (HYCOM)

Introduction

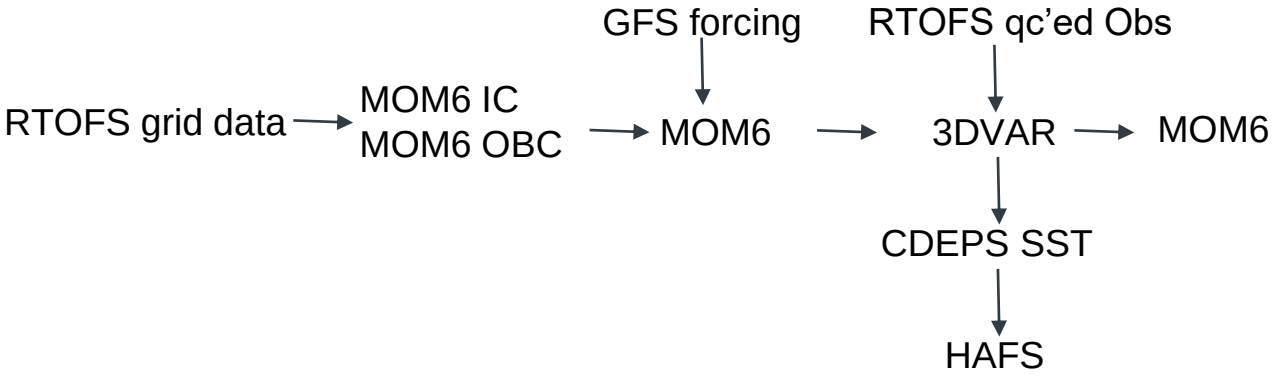


Diagram of RTOFS - MOM6-3DVAR - CDEPS - HAFS systems
* OBC: open boundary conditions

Introduction

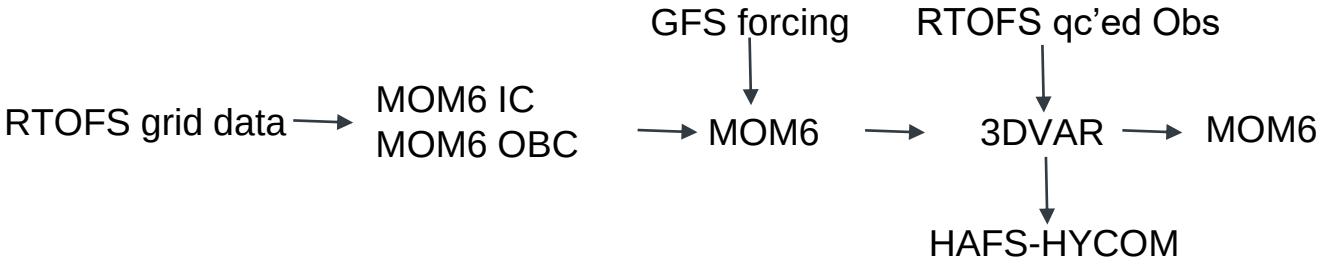


Diagram of RTOFS - MOM6-3DVAR - HAFS-HYCOM systems
* OBC: open boundary conditions

Introduction

MOM6 3DVAR configuration

- Satellite observations: VIIRS JPSS SST, METOP SST, ADT
- 3DVAR: Static covariance based on BUMP (Background error on Unstructured Mesh Package). Rossby radius based correlation scale
- MOM6: Grid points 1135(lon)X633(lat)X50(Layer)
  Horizontal grid size 1/12 degree, Staggered Arakawa C-grid
  Vertical flat Layer (meter) = 5.05, 15.15, 25.25, ……, 5185.15, 5895.05;
- GFS: 0.25 degree atmosphere forcing (U10, V10, T2, Q2, PRATE Precipitation rate, DLWRF Downward long-wave radiation flux, DSWRF Downward short-wave radiation flux, SLP)
- DA cycles: Every 6 hours

Introduction

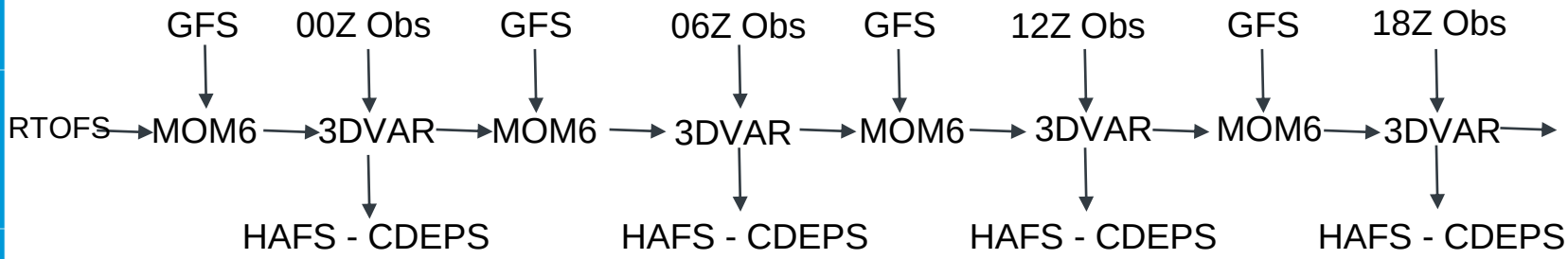


Diagram of RTOFS - MOM6-3DVAR - HAFS-CDEPS flow chart

Introduction

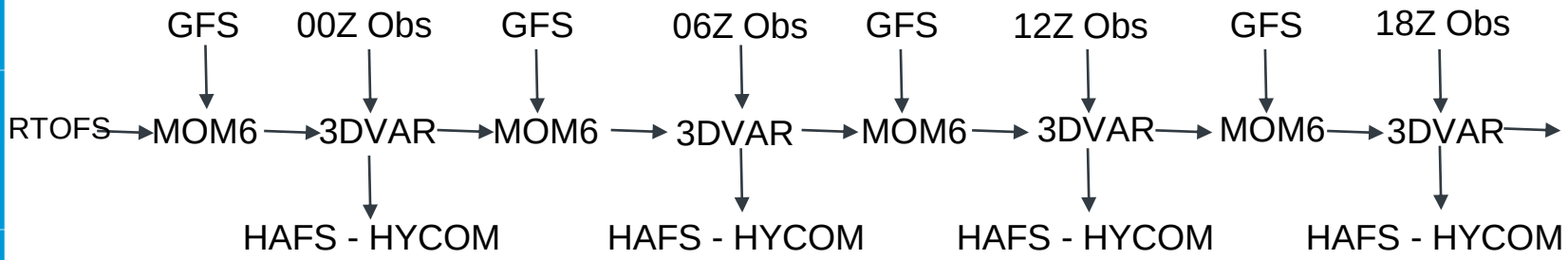
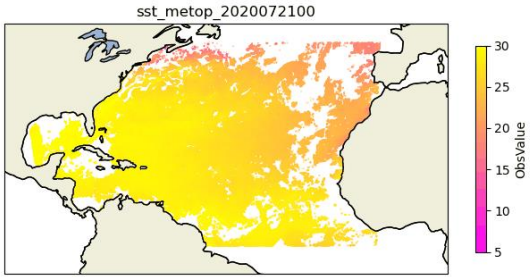


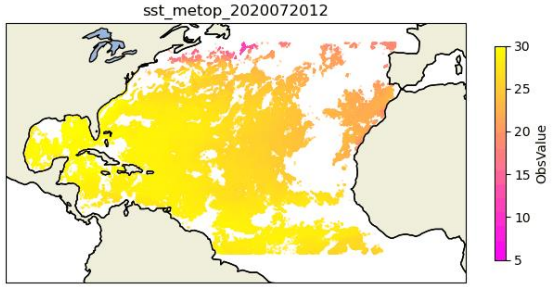
Diagram of RTOFS - MOM6-3DVAR - HAFS-HYCOM flow chart

MOM6 3DVAR data assimilation cycles 7/20/2020 - 8/6/2020

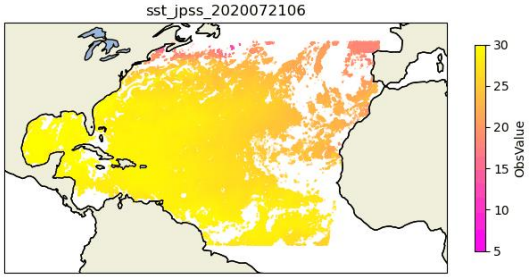
METOP 00Z



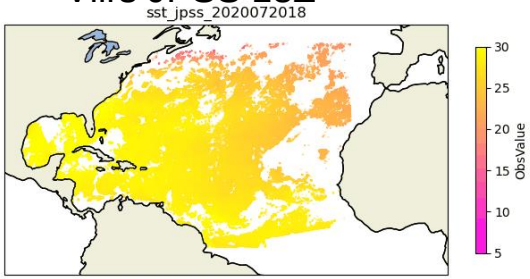
METOP 12Z



Viirs JPSS 06Z



Viirs JPSS 18Z



RTOFS SST obs for 6 hour DA window, e.g., 03Z - 09Z obs for 06Z

metop obs for 00Z and 12Z jpss obs for 06Z and 18Z mainly cover HAT10 respectively

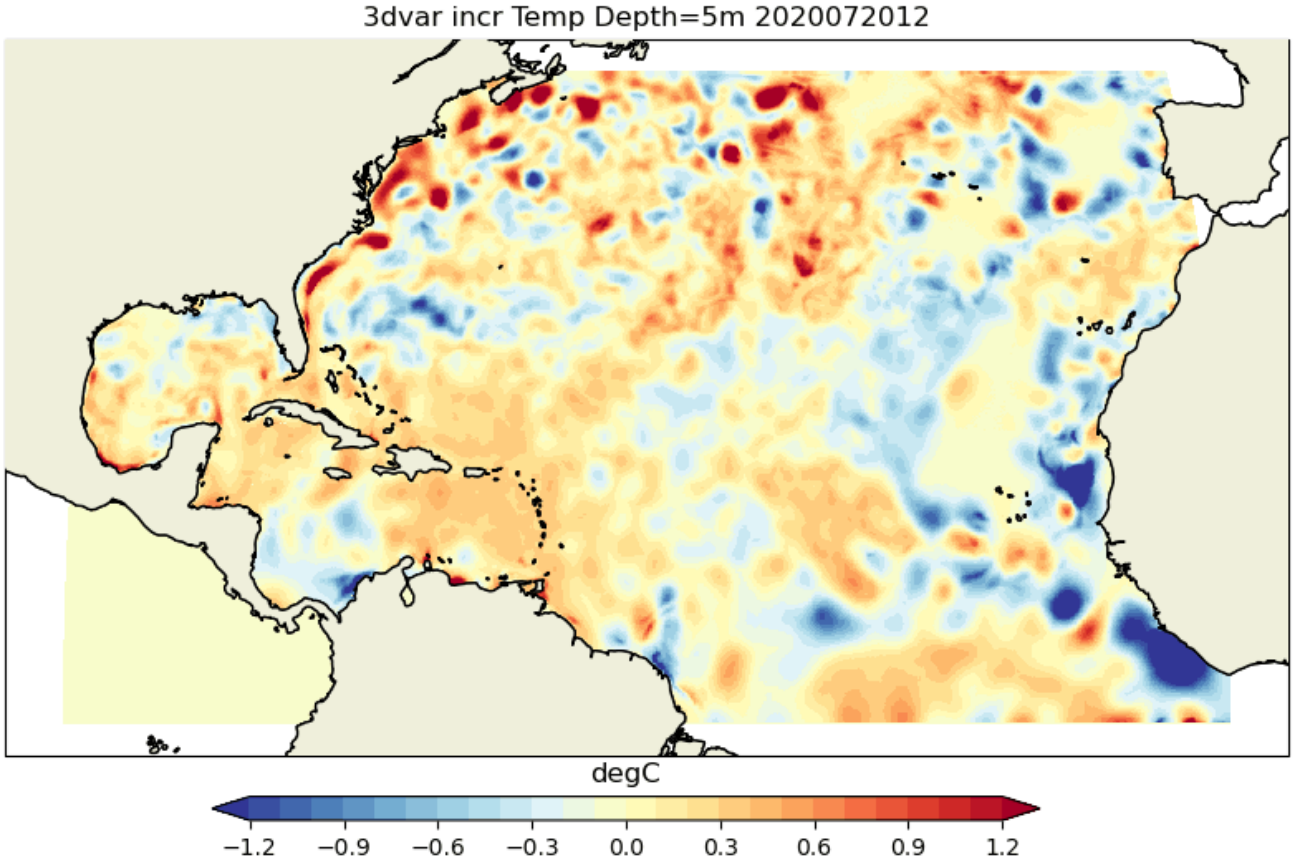
MOM6 3DVAR assimilates metop and jpss SST at 00, 06, 12, and 18Z.

Background check threshold is 1.5 C

All these shown are of good quality and assimilated

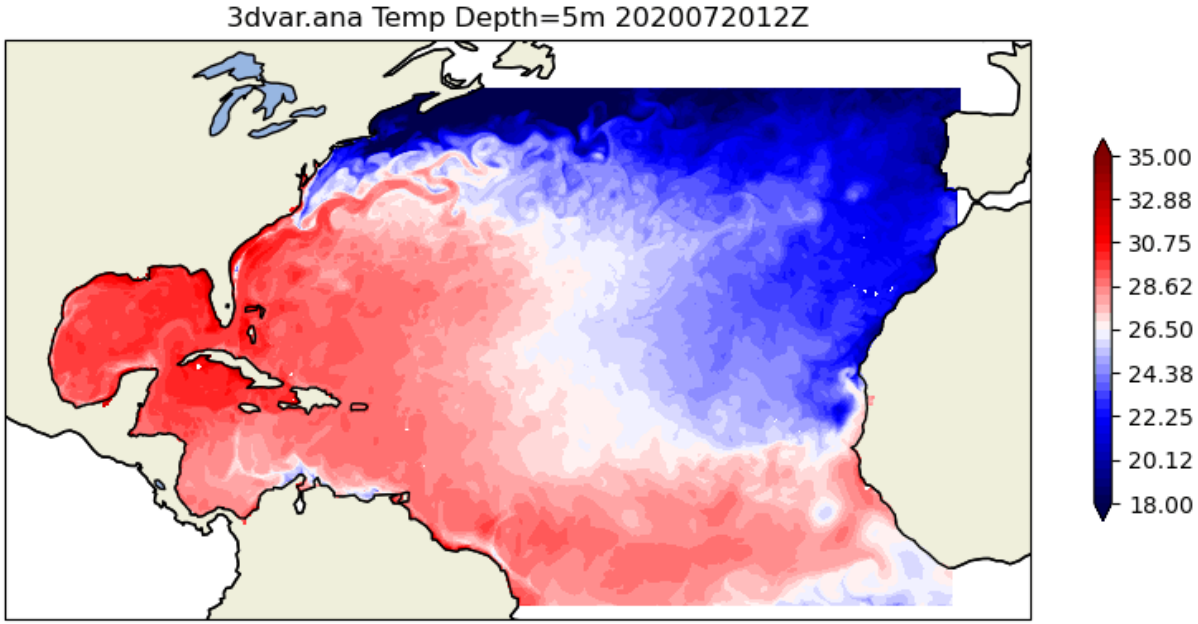
MOM6 3DVAR data assimilation cycles 7/20/2020 - 8/6/2020

1/12 degree MOM6 3DVAR increment SST

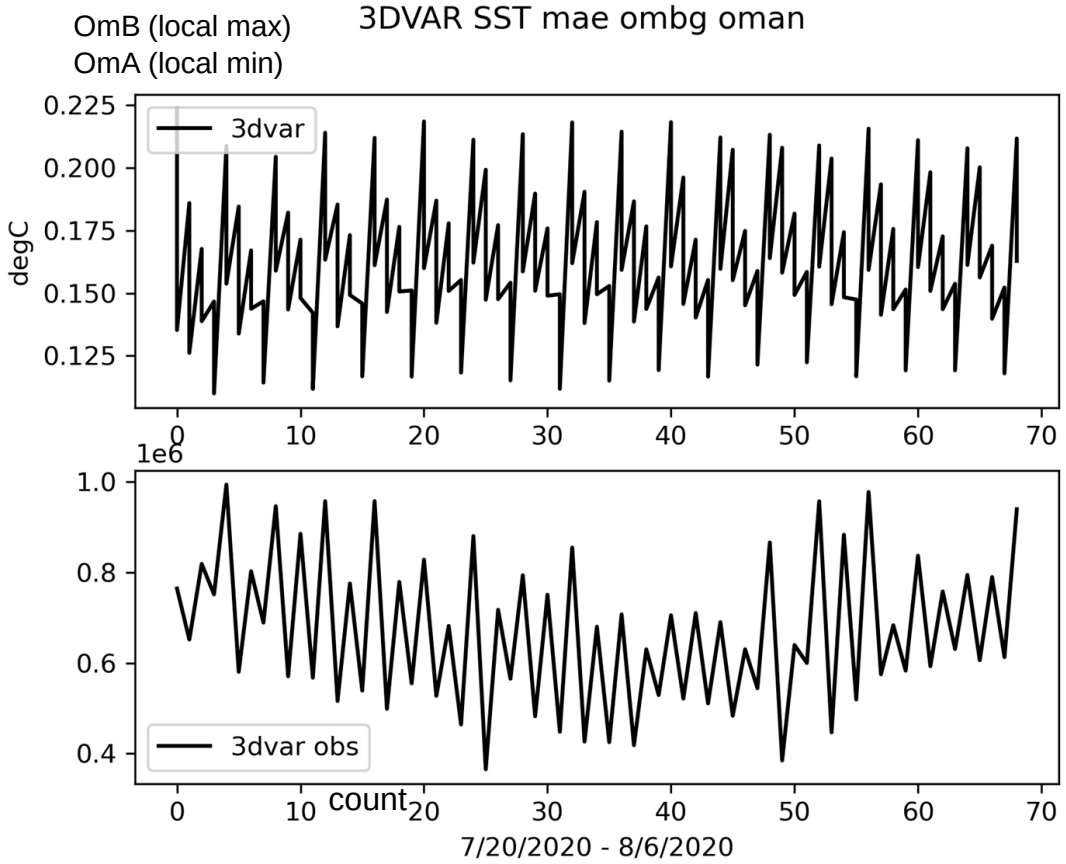


MOM6 3DVAR data assimilation cycles 7/20/2020 - 8/6/2020

1/12 degree MOM6 3DVAR analysis SST



MOM6 3DVAR data assimilation cycles 7/20/2020 - 8/6/2020



Sawtooth pattern time series of mean absolute error

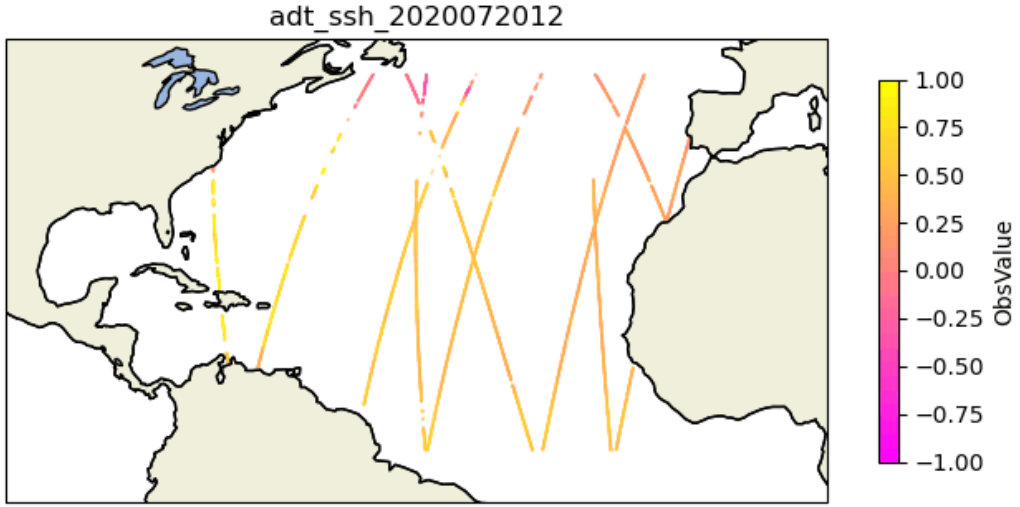
Ombg, obs minus background
Oman obs minus analysis

Both ombg and oman are relatively small

Ombg is larger than oman

MOM6 3DVAR data assimilation cycles 7/20/2020 - 8/6/2020

RTOFS SSH/adt observations



MOM6 3DVAR assimilates RTOFS SSH/adt at 00, 06, 12, and 18Z.

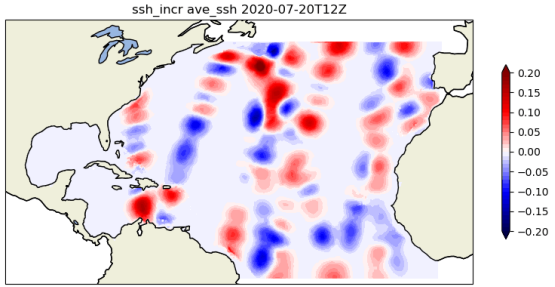
Background check absolute threshold is 0.2 meter. It has always been 0.2 meter.

All these shown are of good quality and assimilated

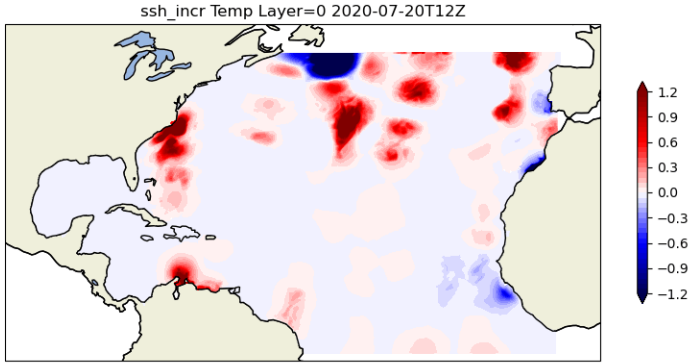
MOM6 3DVAR data assimilation cycles 7/20/2020 - 8/6/2020

1/12 degree MOM6 3DVAR increment SSH, SST, and SSS

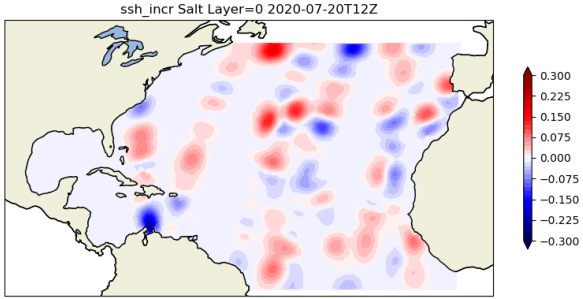
SSH



SST



SSS



All SSH, SST, and SSS increments are caused by RTOFS SSH/adt observations only

ocn.var.iter1.incr.2020-07-20T12:00:00Z.nc

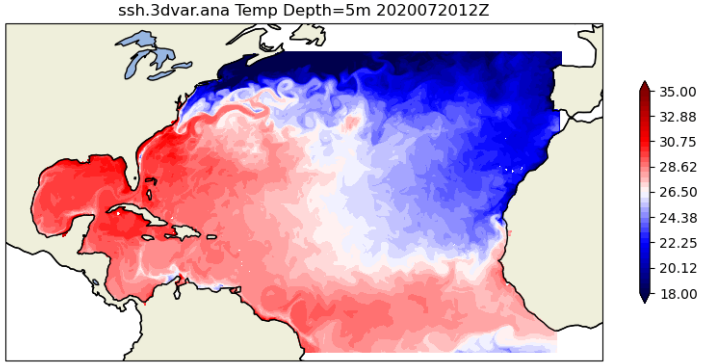
……

ocn.var.iter1.incr.2020-08-06T12:00:00Z.nc

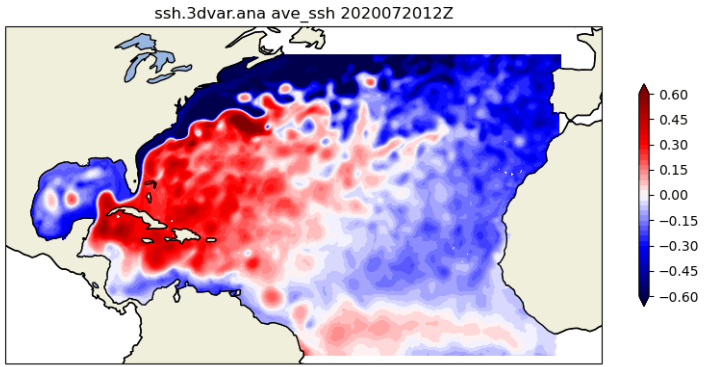
MOM6 3DVAR data assimilation cycles 7/20/2020 - 8/6/2020

1/12 degree MOM6 3DVAR analysis SST and SSH

SST

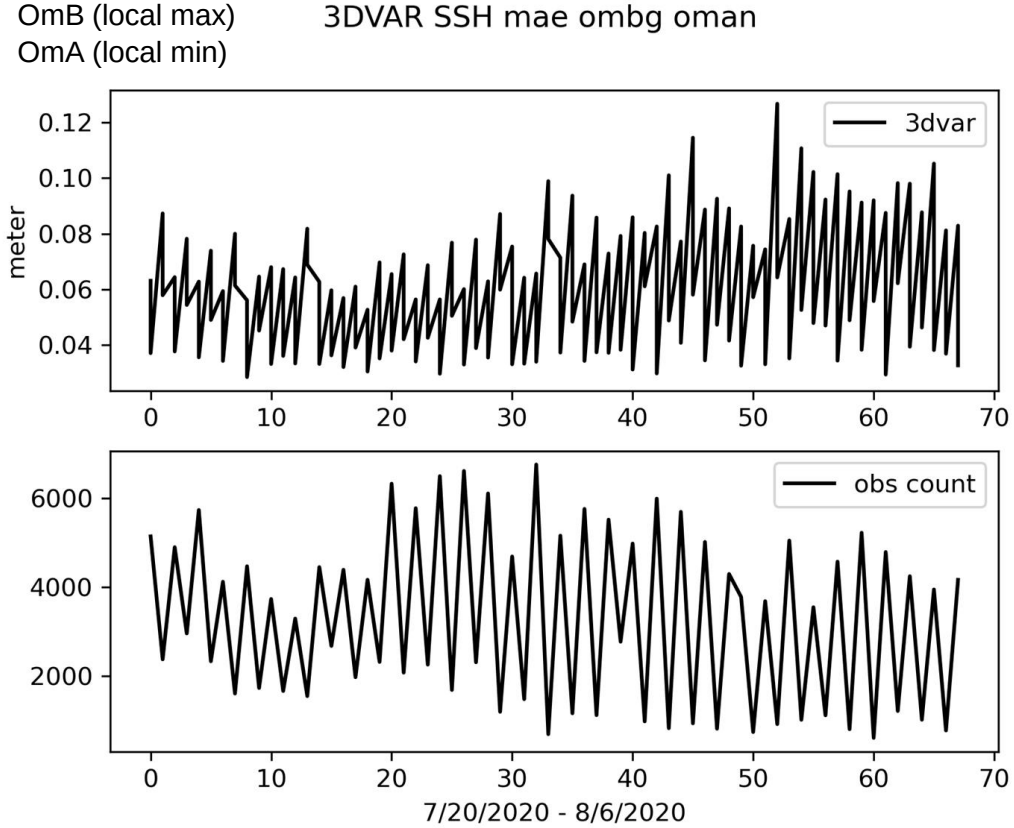


SSH



MOM6 3DVAR data assimilation cycles 7/20/2020 - 8/6/2020

OmB (local max)
OmA (local min)



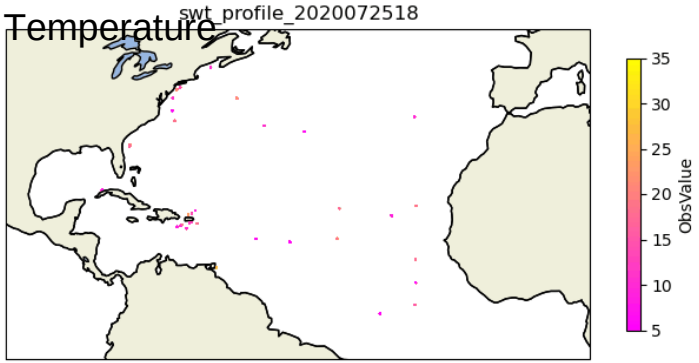
Sawtooth pattern

Time series of SSH mean absolute error
Ombg, obs minus background
Oman, obs minus analysis

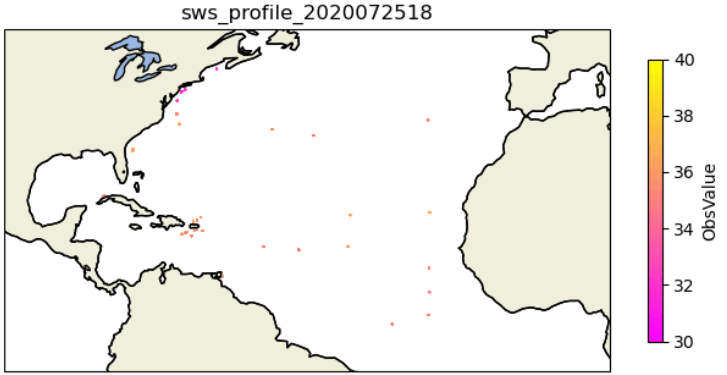
MOM6 3DVAR data assimilation cycles 7/20/2020 - 8/6/2020

RTOFS T/S profile observations

Sea Water Temperature



Sea Water Salinity

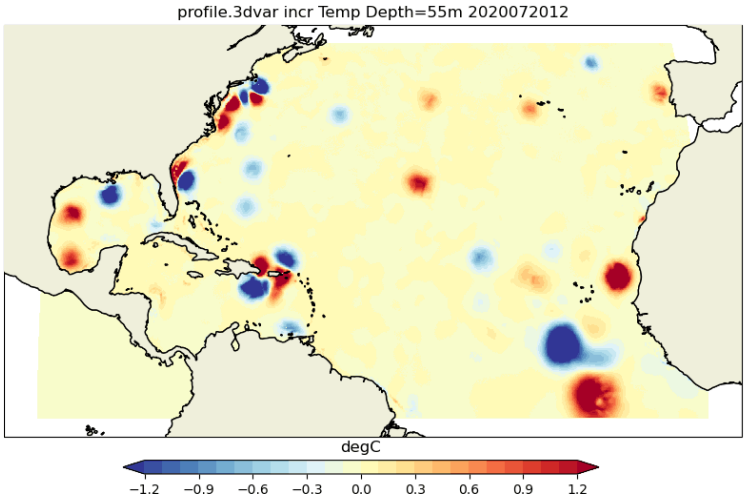


MOM6 3DVAR assimilates RTOFS T/S profile at 00, 06, 12, and 18Z. All these observations shown are of good quality and assimilated

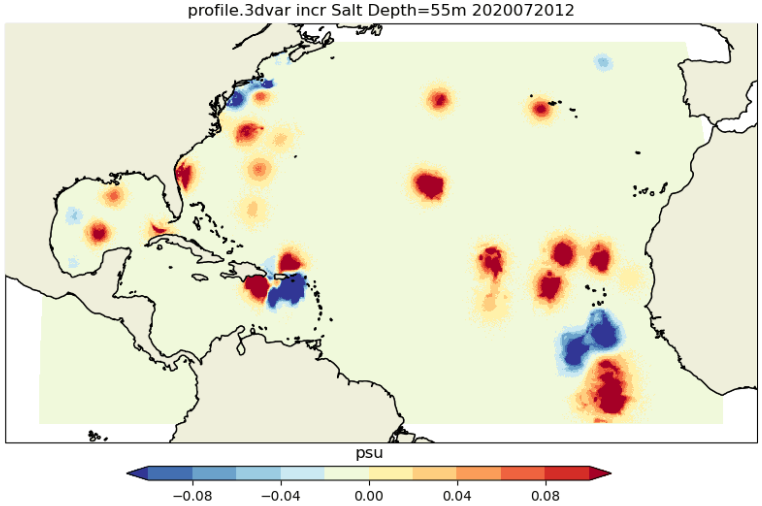
MOM6 3DVAR data assimilation cycles 7/20/2020 - 8/6/2020

1/12 degree MOM6 3DVAR increment SST and SSS

SST incr



SSS incr

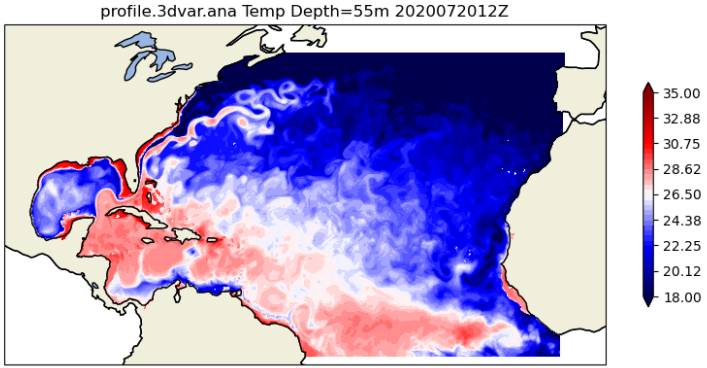


SST and SSS increments are caused by RTOFS profile observations

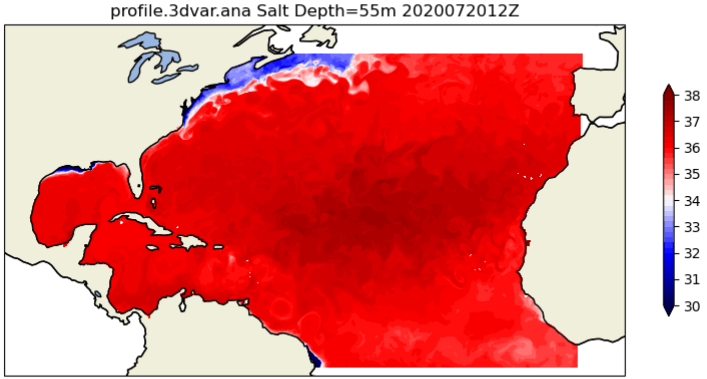
MOM6 3DVAR data assimilation cycles 7/20/2020 - 8/6/2020

1/12 degree MOM6 3DVAR analysis SST and SSS

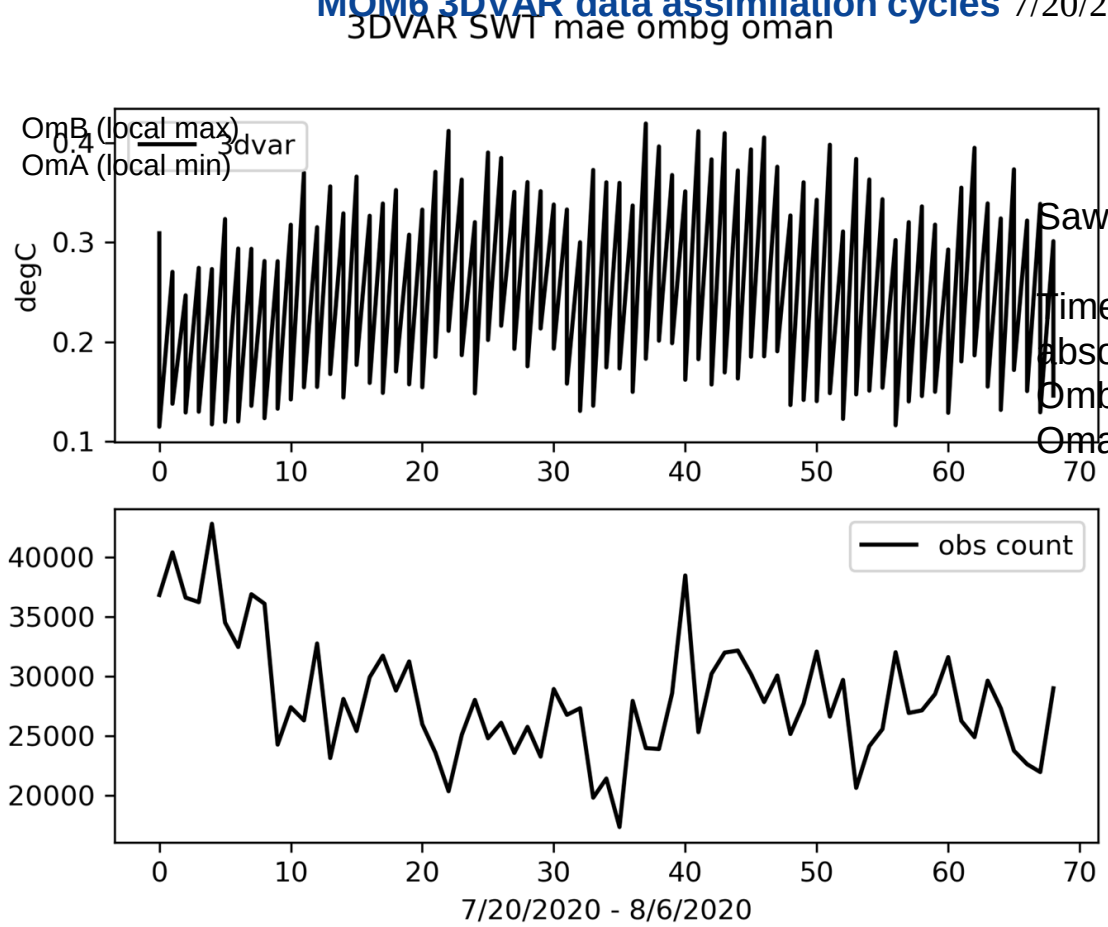
SST



SSS



MOM6 3DVAR data assimilation cycles 7/20/2020 - 8/6/2020

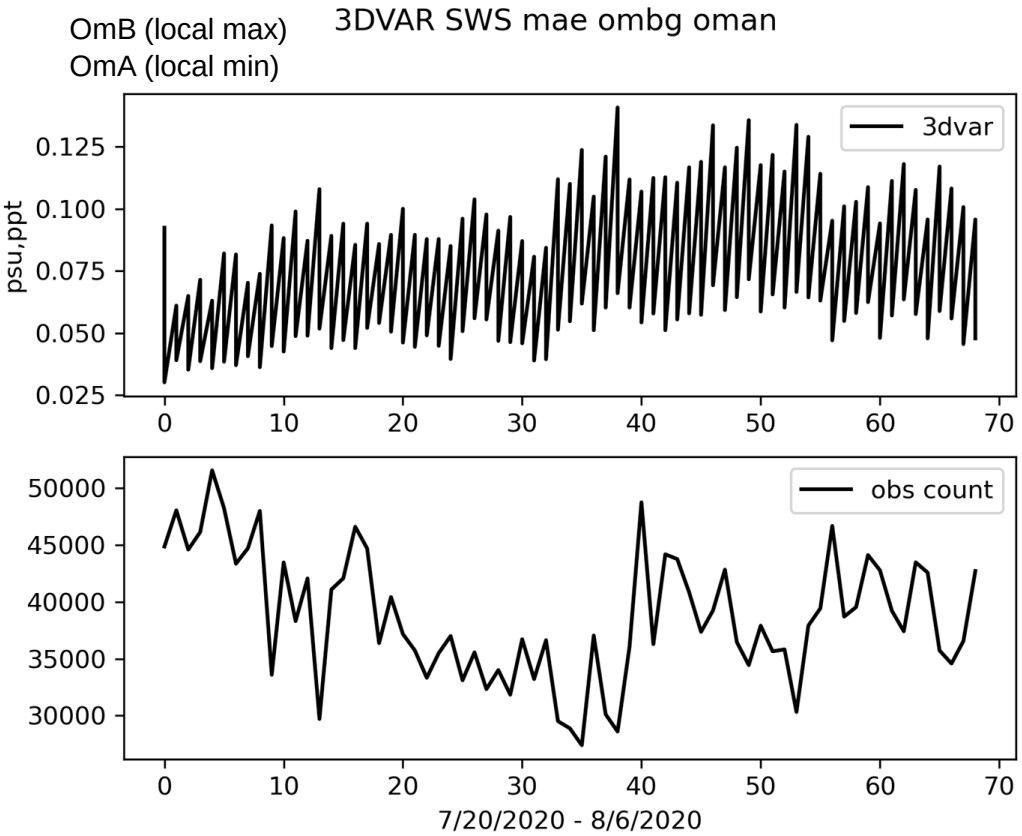


Sawtooth pattern

Time series of sea water temperature mean absolute error
Ombg, obs minus background
Oman, obs minus analysis

MOM6 3DVAR data assimilation cycles 7/20/2020 - 8/6/2020

OmB (local max)
OmA (local min)



Sawtooth pattern

Time series of sea water salinity mean absolute error
Ombg, obs minus background
Oman, obs minus analysis

Hurricane Isaias (2020) forecast by HAFS using MOM6 SST and HYCOM SST

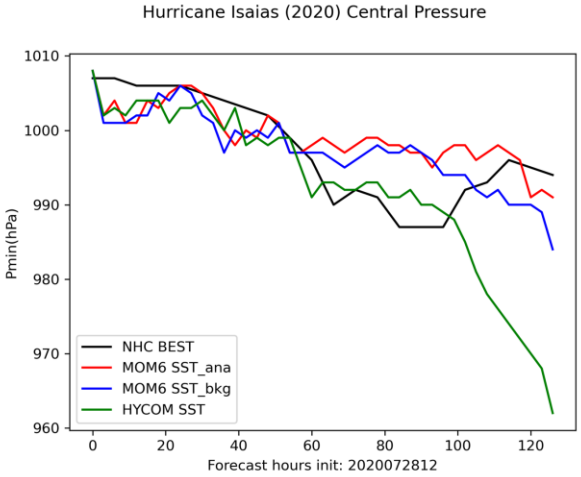
2020072812 - 2020080212

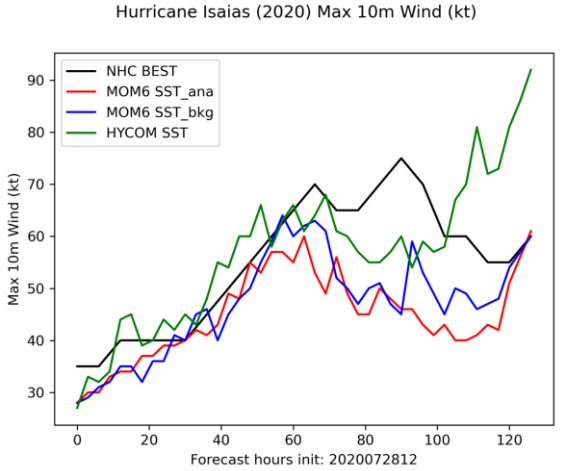
HC BEST: NHC Best track

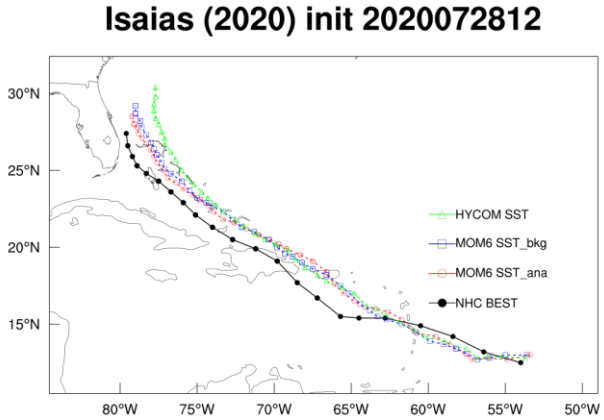
MOM6 SST_ana: MOM6 provides SST analysis to HAFS every 6 hours

MOM6 SST_bkg: MOM6 provides SST forecast to HAFS every 6 hours initialized at 2020072812

HYCOM SST: HYCOM provides SST forecast to HAFS every 6 minutes initialized at 2020072812







Hurricane Isaias (2020) forecast by HAFS using MOM6 SST and HYCOM SST

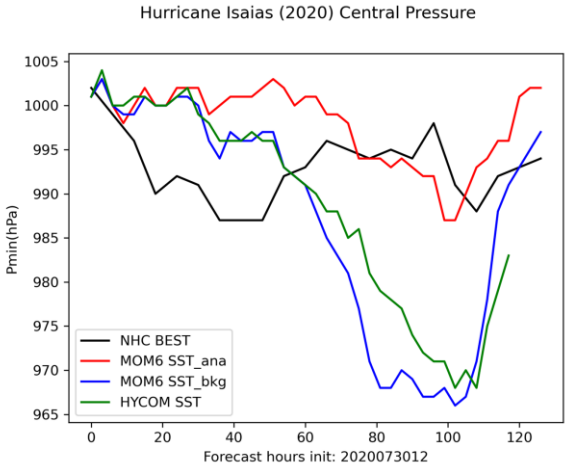
2020073012 - 2020080412

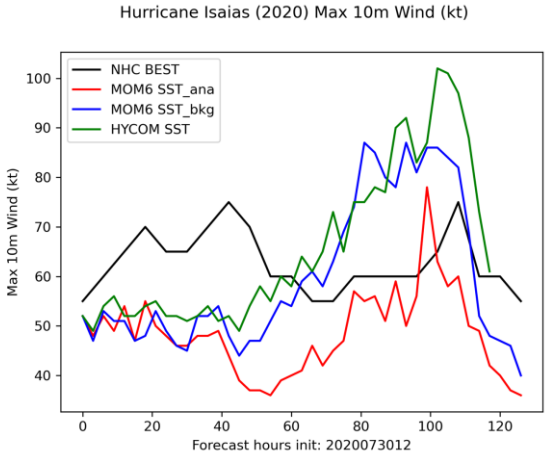
NHC BEST: NHC Best track

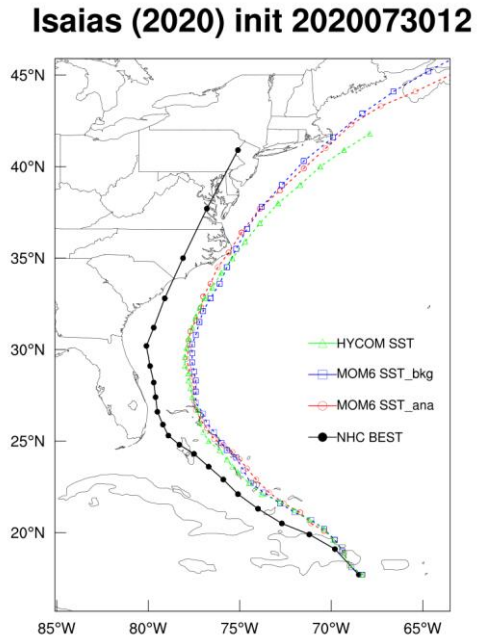
MOM6 SST_ana: MOM6 provides SST analysis to HAFS every 6 hours

MOM6 SST_bkg: MOM6 provides SST forecast to HAFS every 6 hours initialized at 2020073012

HYCOM SST: HYCOM provides SST forecast to HAFS every 6 minutes initialized at 2020073012







Summary

1. RTOFS grid data are interpolated to MOM6 IC and OBC

2. GFS 0.25 degree fields are used as MOM6 atmospheric forcing

3. Ran MOM6 3DVAR 6 hourly DA cycles assimilating RTOFS qc'ed SST, ADT, and profile obs

4. Compared HAFS Hurricane Isaias (2020) forecast between using MOM6 SST and HYCOM SST

5. In-progress:

- Run HAFS-HYCOM cycles using MOM6 3DVAR analysis interpolated as HYCOM IC.