Preliminary results:
The development of regional high-resolution MOM6 and data assimilation for HAFS

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1. PhoD/AOML,
2. IMSG/EMC Marine JEDI
3. IMSG/EMC Hurricane
4. EMC

HFIP meeting October 27, 2021

outline

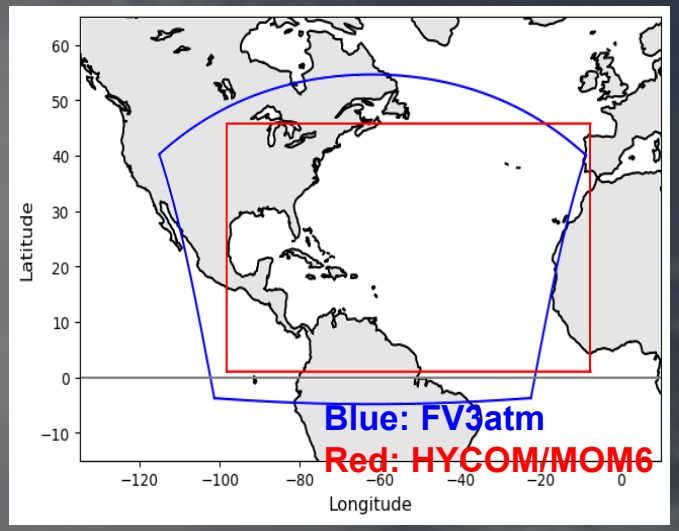
1. regional high-resolution MOM6 & baseline
   a. Open Boundary Conditions (OBCs) experiments
   b. Vertical mixing test
2. ocean data assimilation (DA) with marine JEDI for a Hurricane Isaias (2020) case
3. HAFS-CDEPS tests w/ 2D MOM6 SST analysis

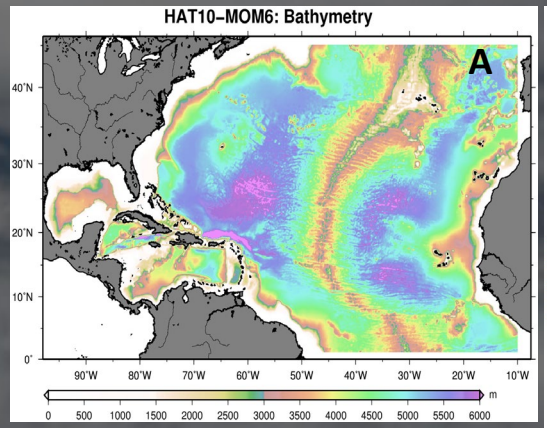
MOM6 North Atlantic (HAT10)

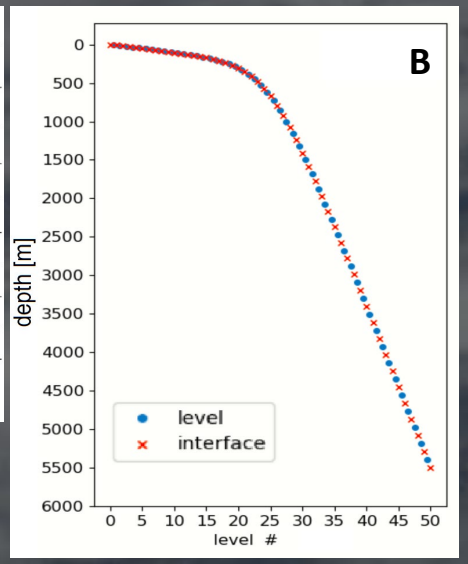
Regional MOM6 configuration for HAFS

- domain
  - horizontal: 1135x633 at 1/12-d
    (261.7 - 352.5E, 1.0 - 45.8N)
  - Vertical: 50-layer (z*) with min. depth 5.5 m
- IC and OBC
  - global RTOFS nowcasts & forecasts
- forcing
  - 0.25-degree GFS forcing:
    SLP, U10/V10, T2, Q2,
    DSWRF, DLWRF, PRATE
  - runoff - off
  - tides - off

HAFS-A







OBC experiments

1. OBC (hereafter OBC3)
    a. Flather, Orlanski, Nudged, Orlanski_tan, Nudged_tan
    b. Nudging time scale for velocity = 0.3 [d], 360 [d]
    c. freeslip vorticity=True

state variables: T/S/U/V/SSH

1. nest

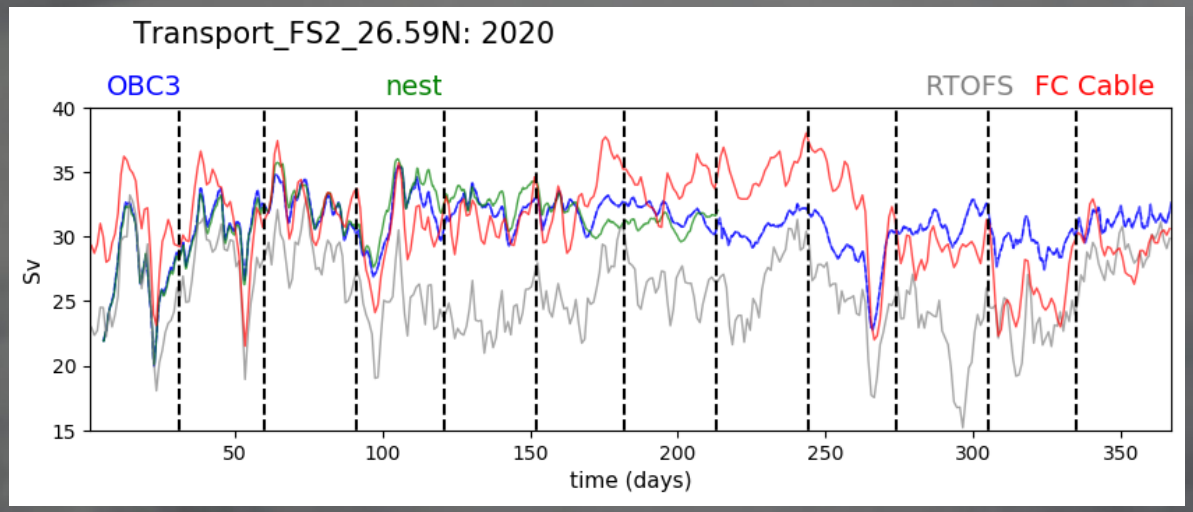
    OBC3 + sponge zone at 12-grids with 1-day e-folding w/ daily state

state variables: T/S

expensive!

OBC experiment results

Validation - the FC cable transport

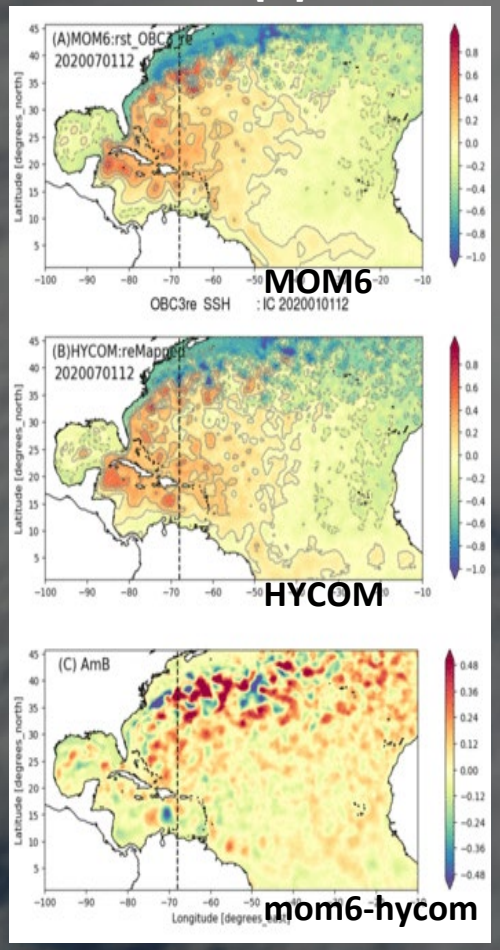


- OBC3 and nest both estimate similar magnitude (note: the nest run is stopped at July 31).
- OBC3 is agreed well with the observations and better than the global RTOFS estimates
- OBC3 under-estimates in Summer (JJAS) by ~7 Sv, followed by overestimation in Fall (ND) w/ ~7 Sv.

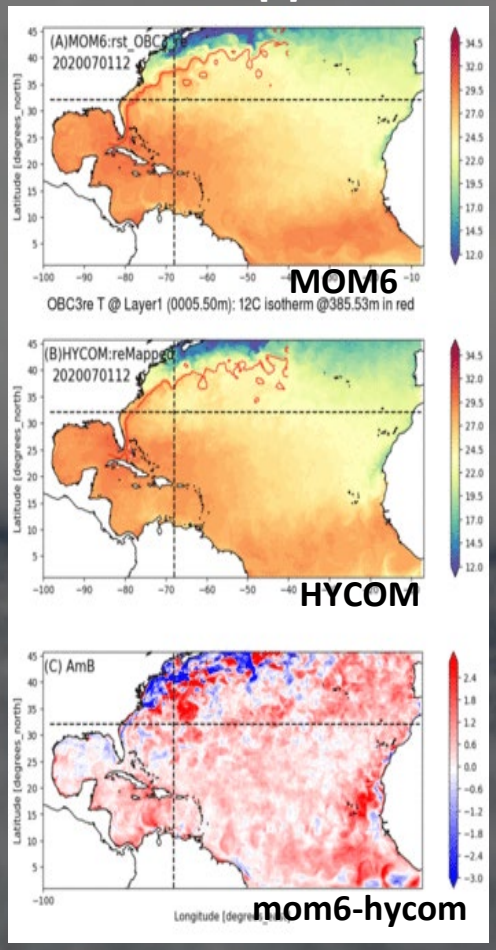
Baseline

July 1-month animation of daily SSH and SST

SSH [m]



SST [C]



Comparable with HYCOM

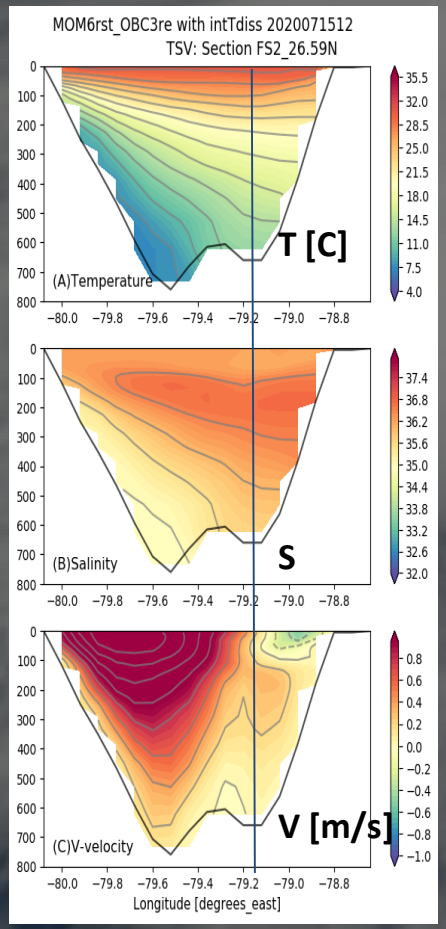
- Mesoscale variabilities, esp. the western boundary currents.
- the Gulf Stream (12°C isotherm/390 m) in red (in SST).
- the Loop Current and WCEs in the GOM.
- area of high SSH.

Different w/ HYCOM

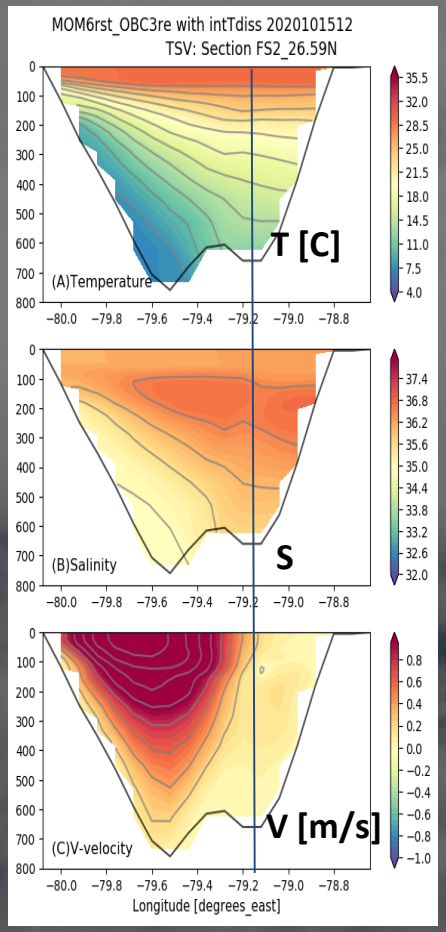
- relatively colder Slope water.
- southward the GS and separation of the GS
- weaker upwelling off Africa
- relatively warmer Tropics <O(2°C) and higher SSH setup <O(0.25 m)
- increase trend in time and depth, primarily in the upper thermocline.

The FC transect

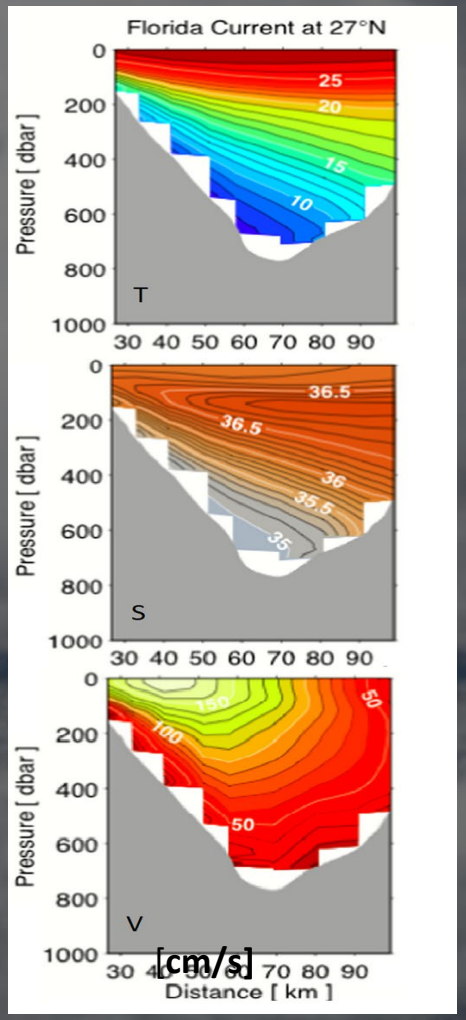
mid-july



mid-October



obs. mean T/S/V
(Meinin and Luther, DSR 2016)

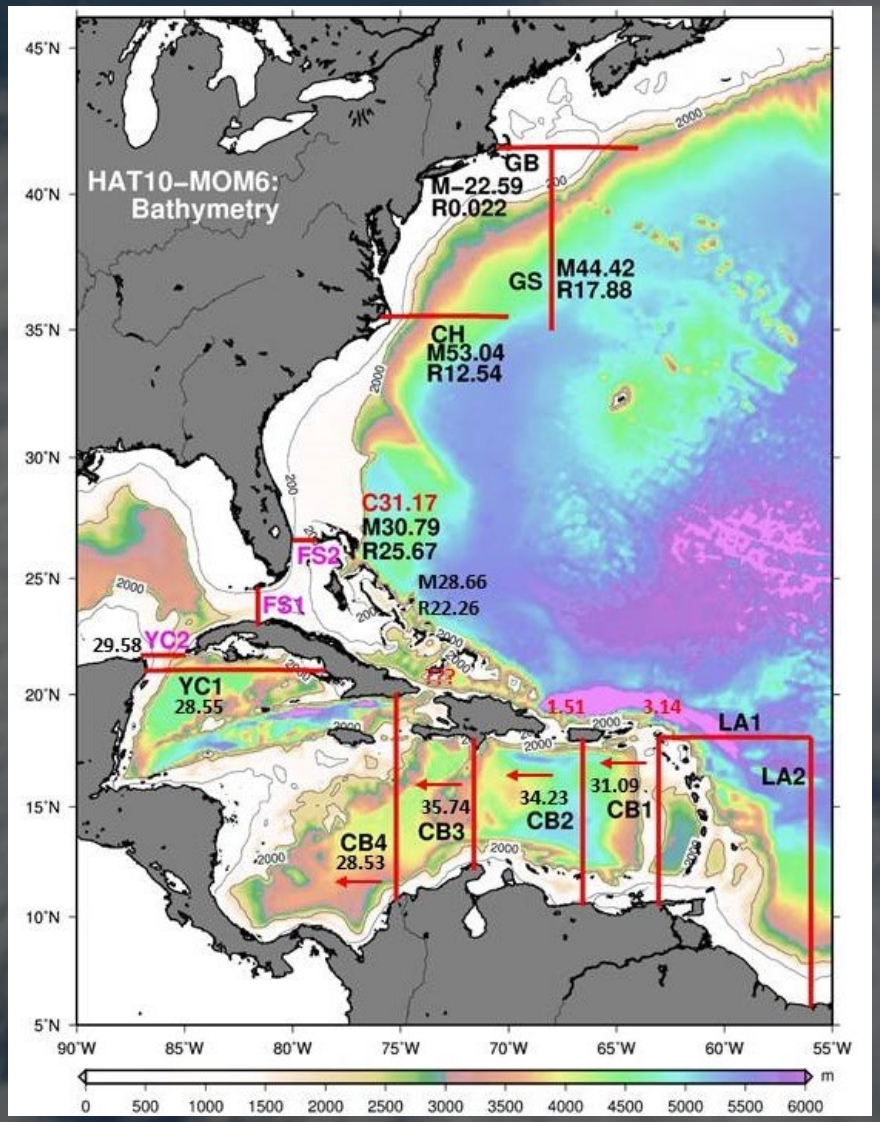


<u>Temperature:</u>
Obs 7 - 27ºC
MOM6 6 - 31ºC

<u>Salinity:</u>
Obs 34.9 - 36.8
MOM6 34.4 - 36.3

<u>Velocity:</u>
Obs < 170 cm/s
MOM6 < 170 cm/s

Transport check points



MOM6 ("M"/# in black) simulates volume transport, agreeing with observations (red) Baringer and Larsen 2001; Candela et al. 2019; Hamilton et al. 2005; Meinen et al. 2010)

Over the SW marginal sea:

1. in the eastern Caribbean Sea: inflow/outflow among the islands, eps, O(7 Sv) between CB3 and CB4
2. O(1 Sv) loss between YC1 and YC2: due to return flow in the Caribbean Sea
3. O(1 Sv) loss between YC2 and FS1: may be recirculation in the GOM or leaks along the continental shelf.
4. O(2 Sv) gain between FS1 and FS2: may be the flow through the Old Bahama channel to FS2.

In the GS system and the Slope Sea:
Large differences from HYCOM

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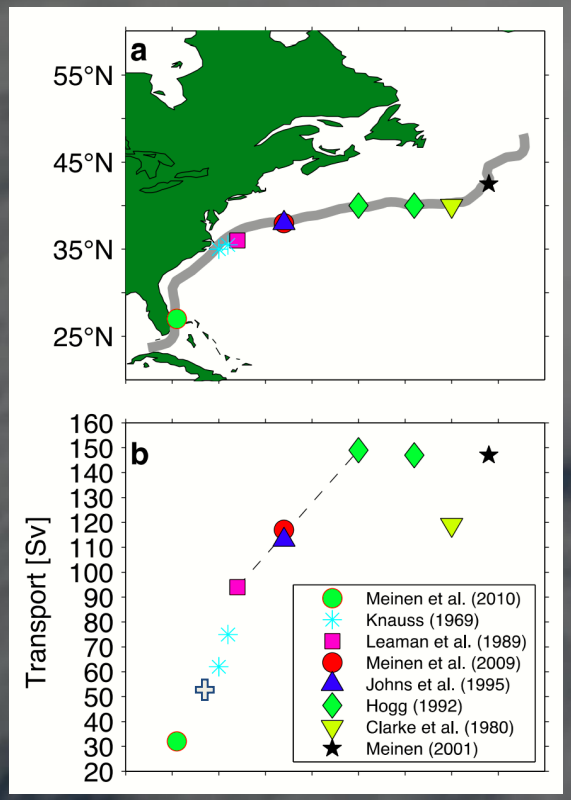
Transport check points

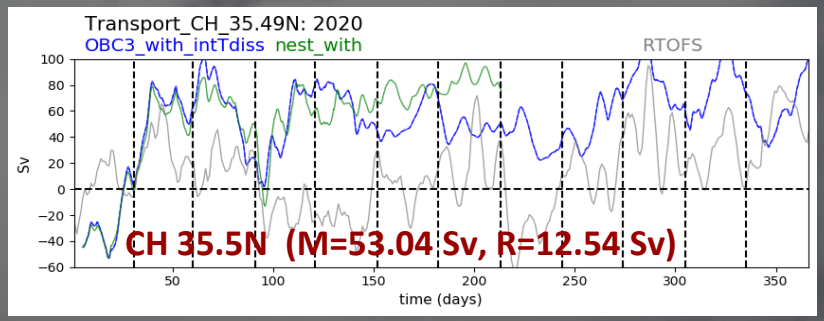
Large differences in the GS system and the Slope Sea with HYCOM. However, the MOM6 transport estimates consistent with observations from various studies..

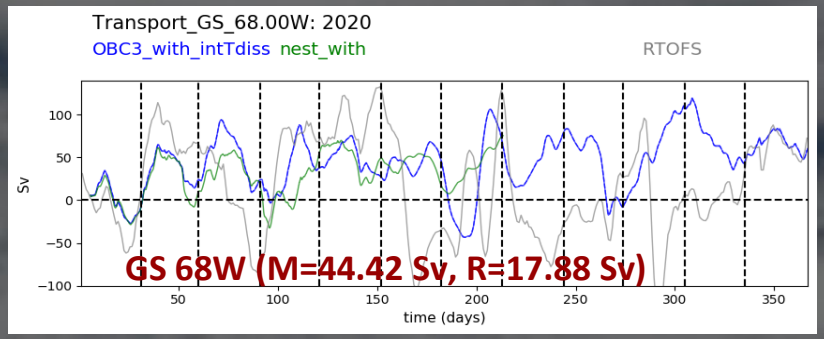


Meinin and Luther (DSR 2016)

CH O(57 Sv) in Heiderich and Todd JPO(2020)

Comparisons with global RTOFS





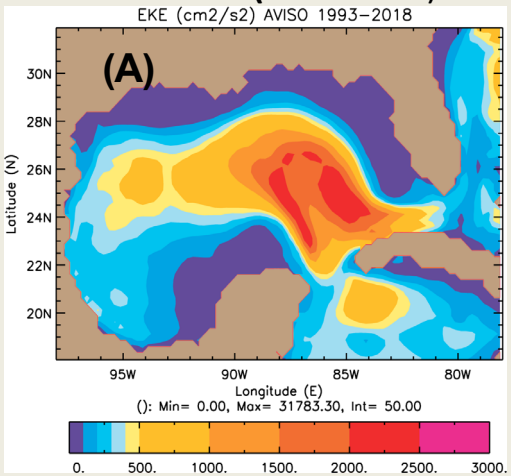
Discrepancies in the transport estimates @CH 35.5N and @GS 68W are due to large temporal variation with global RTOFS, whereas MOM6 has a persistently northeastward flow.

However, the underprediction of MOM6 estimates at 68W is due to the transect extent (including the shelf flow)

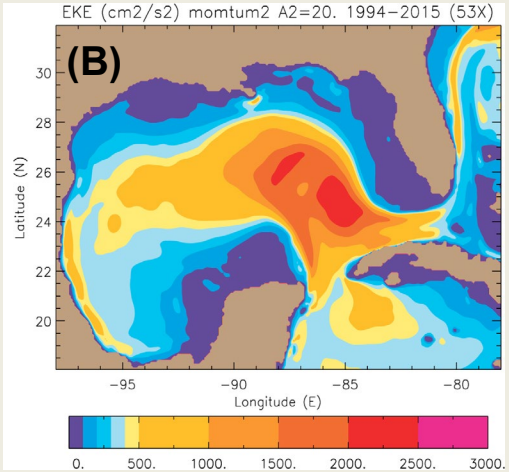
Mixing comparison: ePBL vs. KPP

courtesy of Bozec of FSU

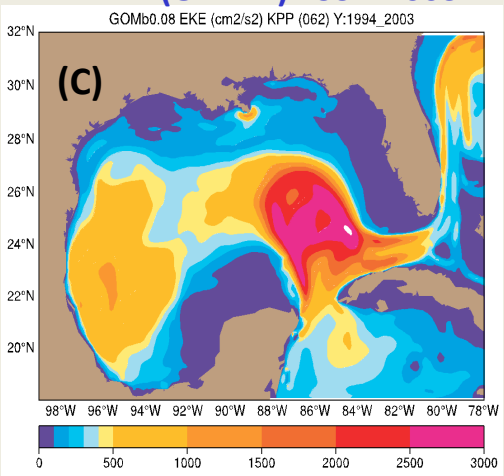
AVISO (1993-2018)



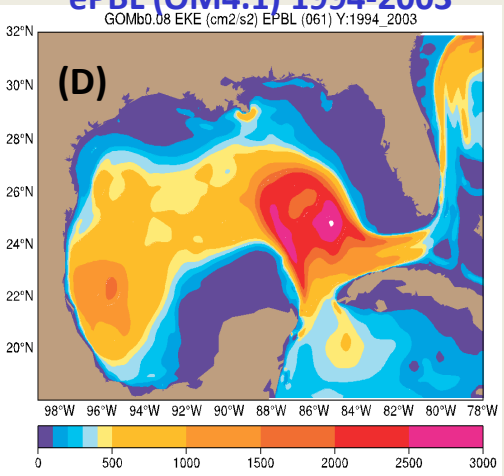
REANALYSIS 1994-2015



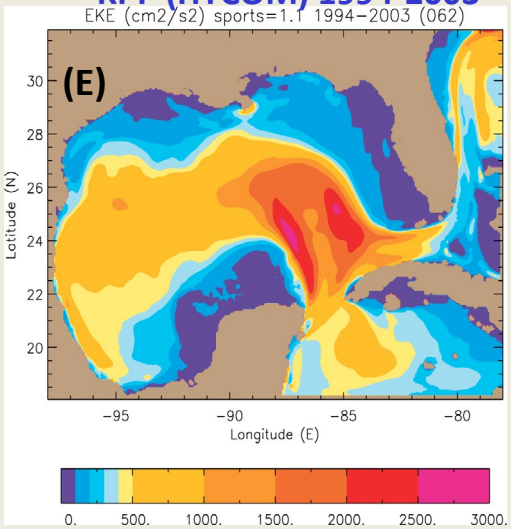
KPP (OM4.1) 1994-2003



ePBL (OM4.1) 1994-2003

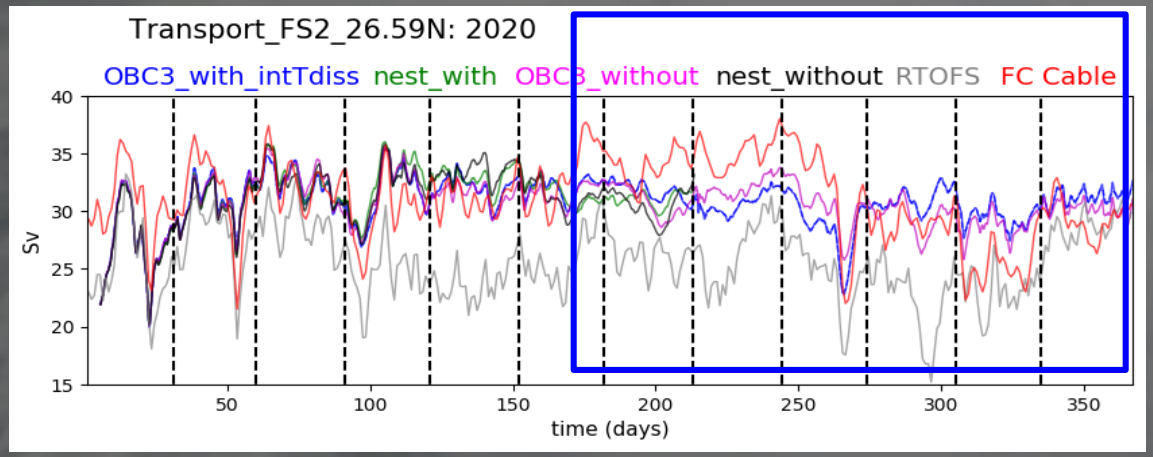


KPP (HYCOM) 1994-2003



Tests for ePBL mixing
(+ internal tidal dissipation)

Transport validation



FS2	mean	STD	RMSE
cable	31.17	3.46	-
RTOFS	25.67	3.13	6.29
OBC3_w/	30.79	2.15	3.04
OBC3_w/o	30.63	2.15	2.75

better estimates w/o additional mixing, but the differences from OBS3 w/ is not statistically significant.

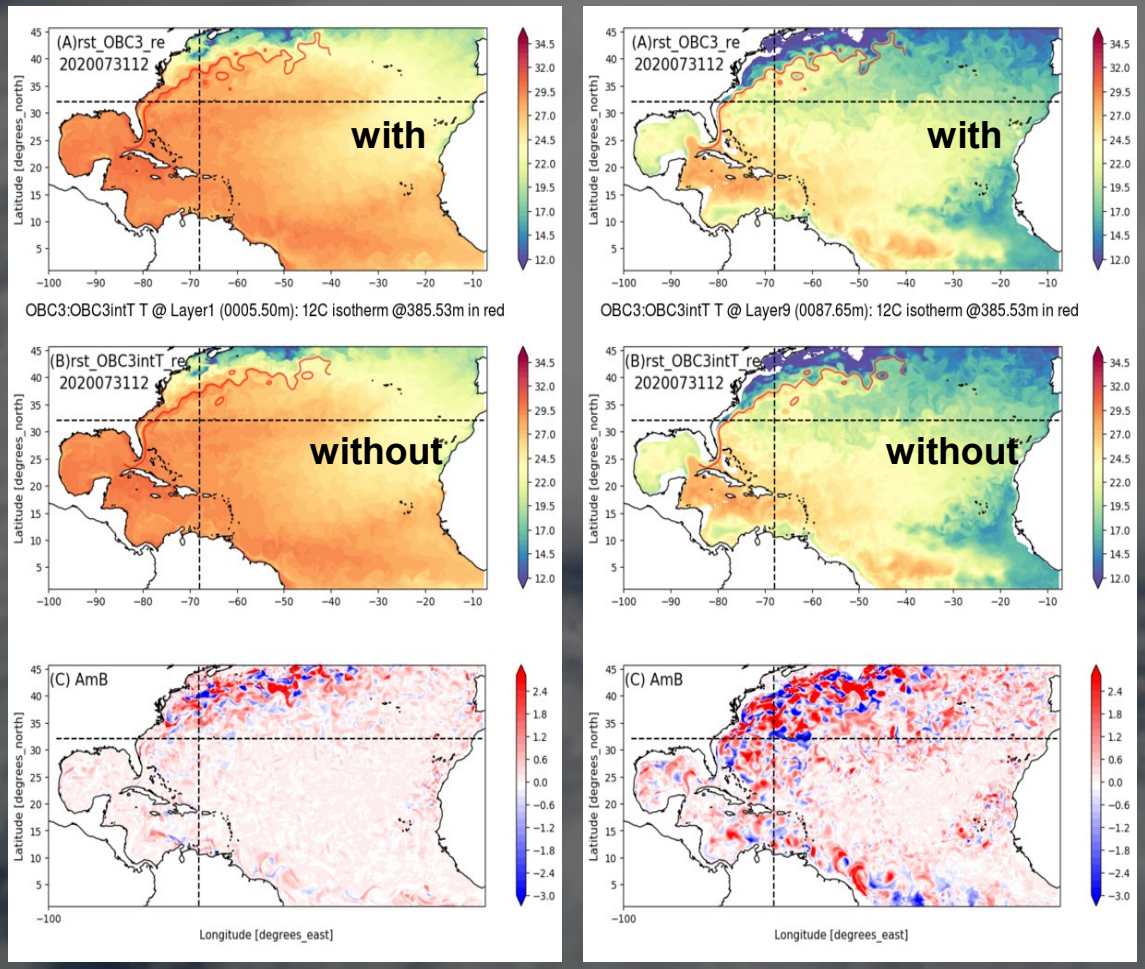
Still
large gaps in Summer and late Fall (blue box) exist

But, the difference for the period might be due to remote forcing, or budget imbalance,...

Mixing tests
(+ internal tidal dissipation)

valid 12Z July 31, 2020

SST [C] | layer 9 (87.65 m) T [C]



Higher eddy activities with the thermal frontal currents in horizontal.

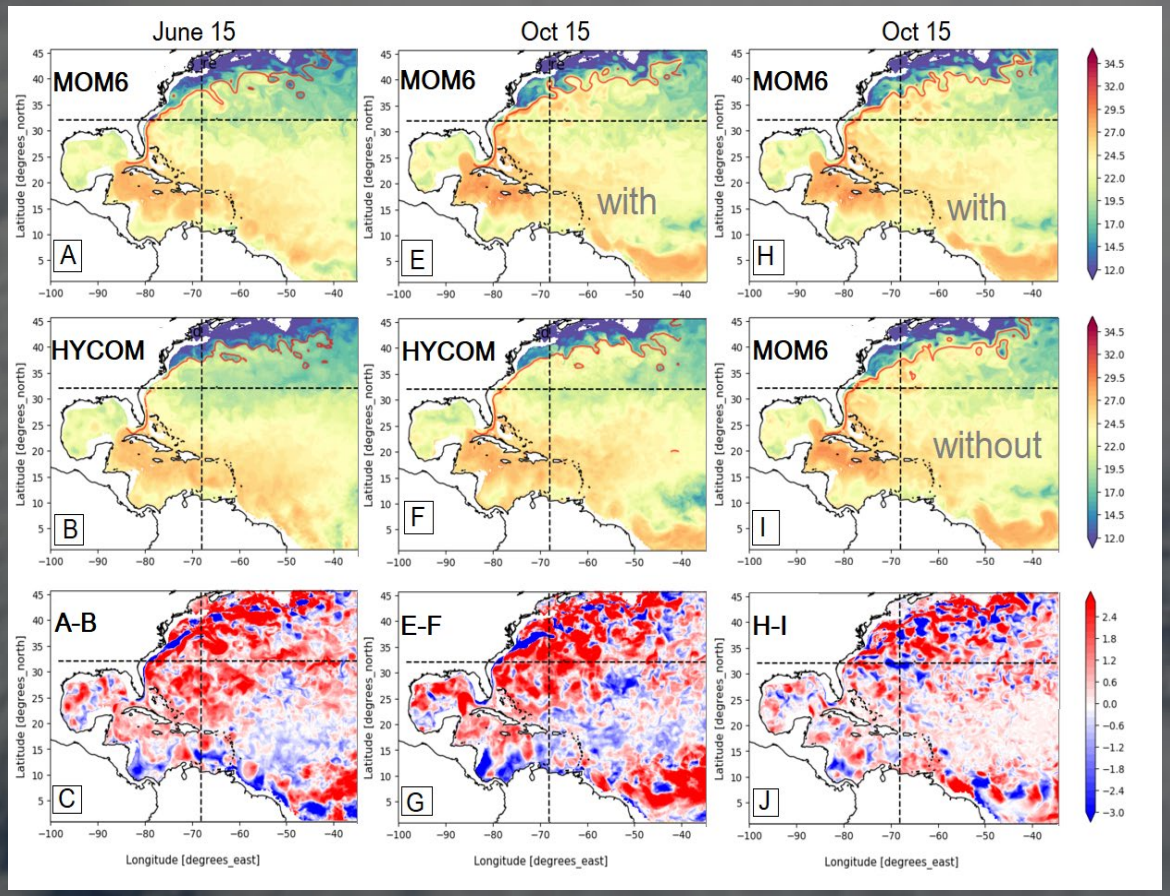
Associated T is enhanced with depth.

w/ additional mixing
Warmer !

GOM simulations

differences in the LC simulations for the Summer & Fall period

87.65-m T



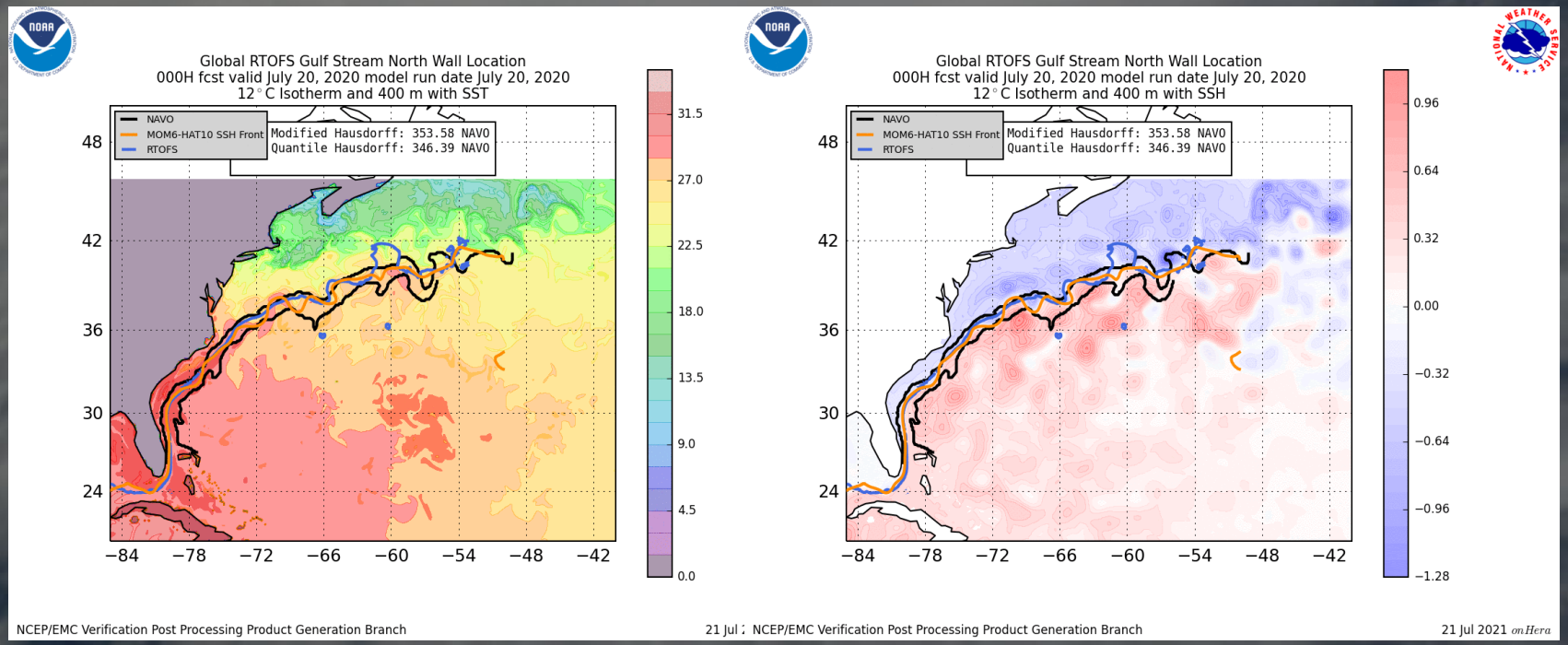
Baseline:
Warmer, Northward & laterally extended LC with time

w/o additional mixing mitigate T overprediction of the baseline

Marine JEDI - 3DVar
Preliminary results

Model validation: North Wall Gulf Stream
July 20 - Aug 5 (Hurricane Isaias)

Better positions of the GS north Wall via Data Assimilation

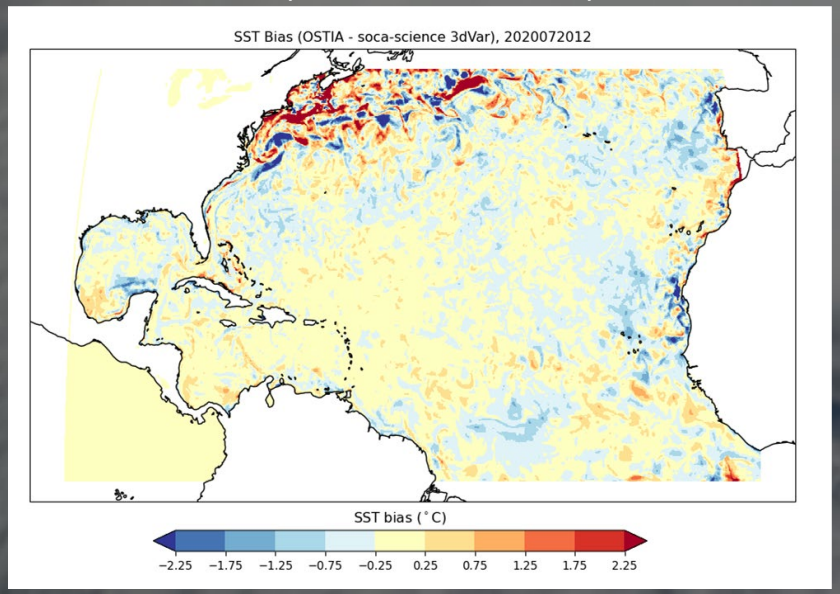


Marine JEDI - 3DVar

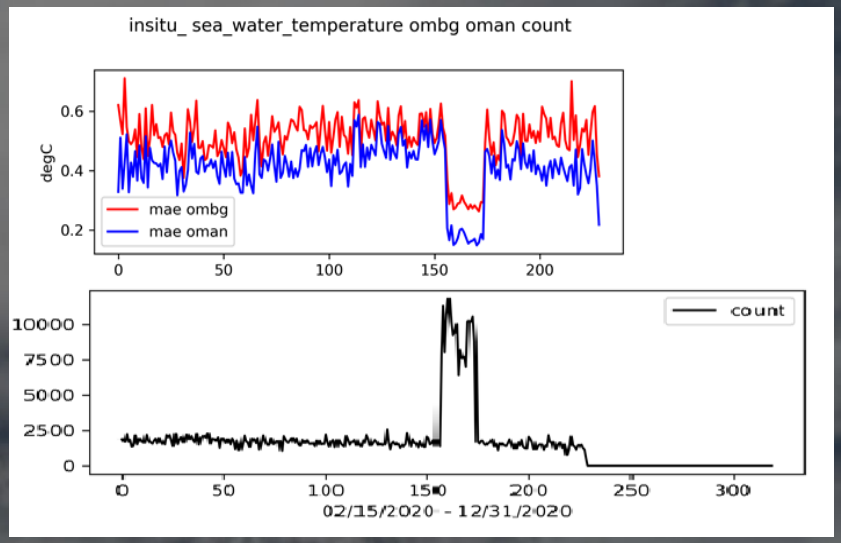
Preliminary results

Hurricane Isaias period
2020-07-20:12Z to 2020-08-05:12Z

SST Bias (=OSTIA - 3DVar)



OMB, OMA & Obs. Count (insitu)



Obs. Assimilated:
AOML gliders, WOD MRB/PFL,
SST (GHRSST), ADT (NESDIS)

regional MOM6 - warm bias even after DA:
need to improve.

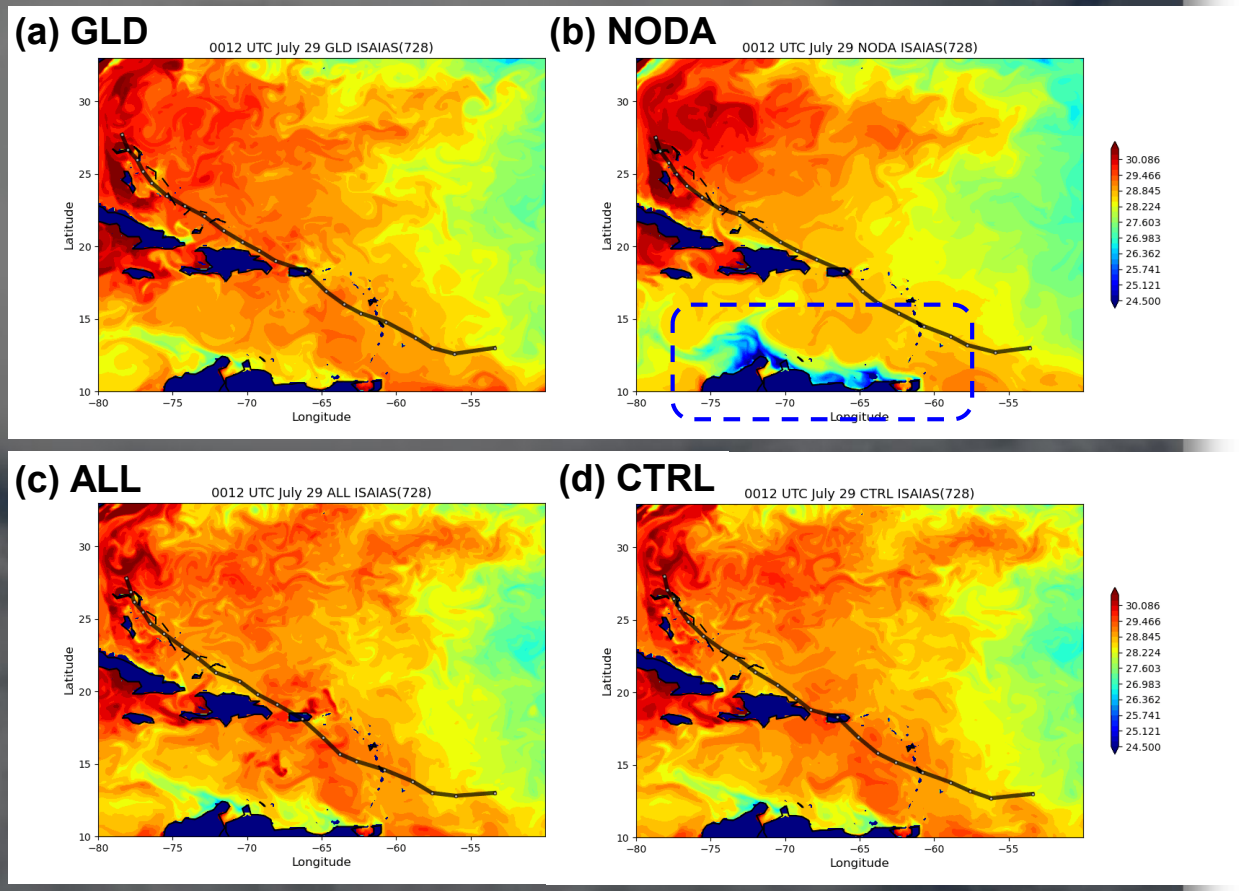
Marine JEDI - 3DVar

Data Impact Study - preliminary

(a) **GLD**: only gliders
(b) **NODA**: no DA
(c) **ALL**: CTRL product and AOML gliders (10 m thinning box applied)
(d) **CTRL**: satellite and in situ observations:

- NESDIS and GHRSST
- Insitu (MRB,CTD,float)
- SMAP
- NESDIS ADT

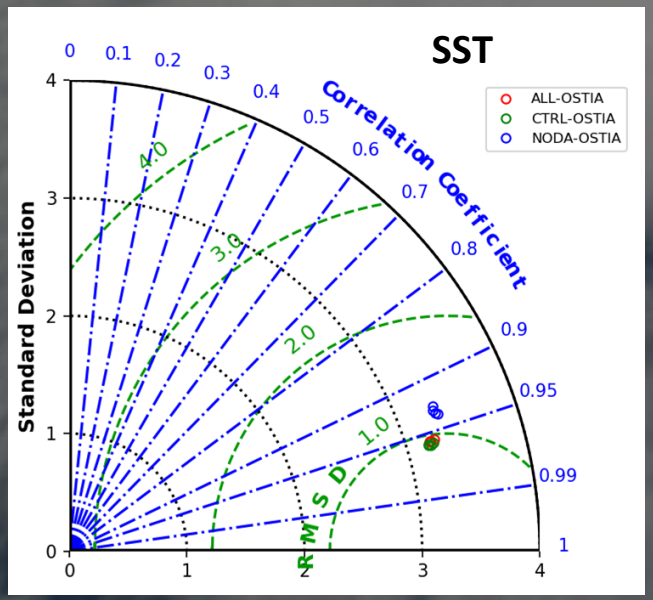
SST corrections apparent in the Caribbean Sea and in the Bahama Shallows.

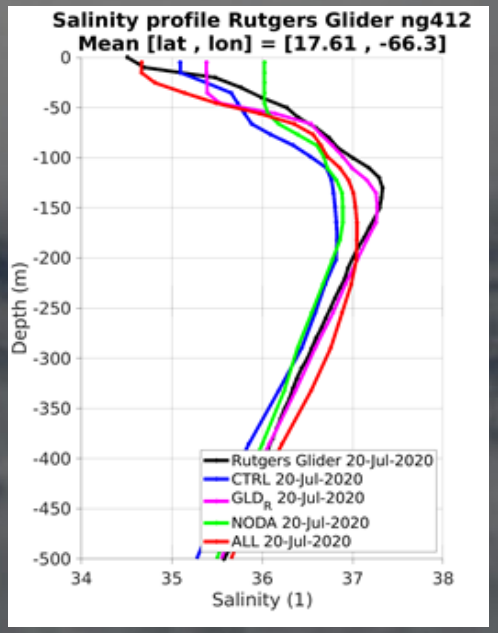


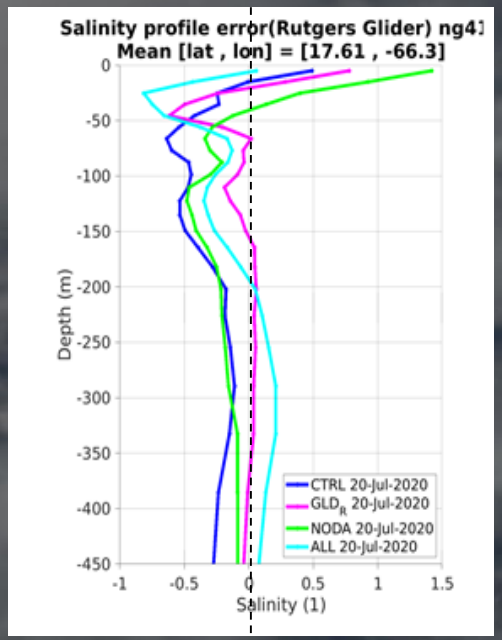
Marine JEDI - 3DVar

SST and S profiles

Experiment	Details
CTRL	assimilate satellite data: SST, ADT and in-situ obs
ALL	assimilate CTRL product and marine glider obs
NODA	free run
GLD	gliders only

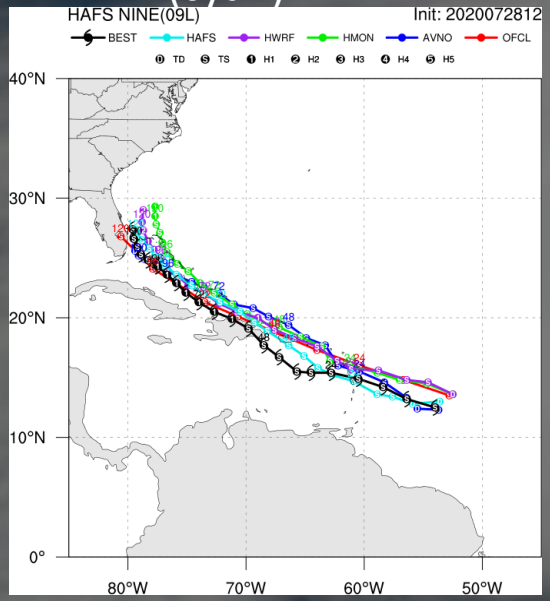




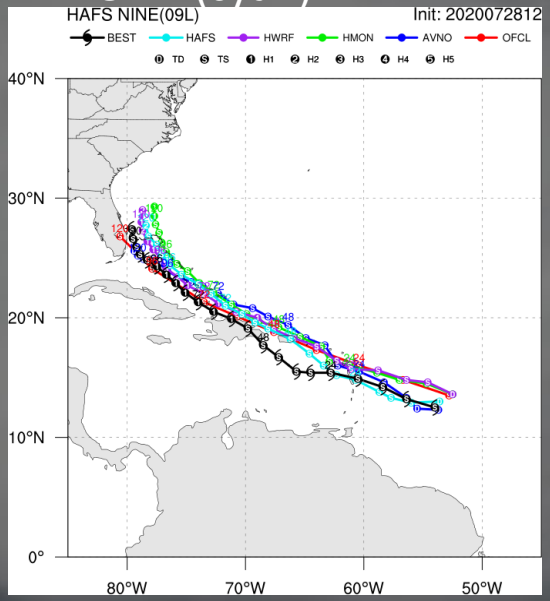


HAFS-CDEPS demonstration

ALL (cyan)

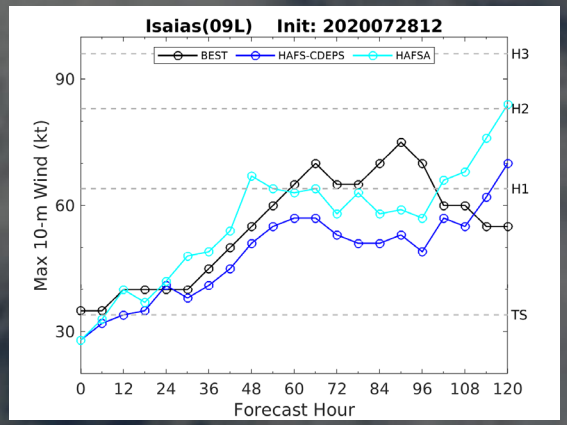


NODA (cyan)



Changes in the track forecasts:

Track is improved w/ ALL



Different colors!

Final remarks

1. Summary and conclusions
   a. reasonable simulations (based on the transport analysis), using the global RTOFS HYCOM nowcasts as ICs/BCs, but degrading with time.
   b. relatively warm water simulation in the upper thermocline
   c. enhanced the LC (the 2nd half of 2020)
   d. the GS separation caused by stronger southward shelf currents from the Slope Sea and probably stronger recirculation of the Slope water
   e. Comments for operational setting:
      i. expensive to run, e.g. *O*(15 min) for 240PEs for 24-d simulation (vs. 90PEs for HYCOM)
      ii. more expensive w/ sponge & OBC
2. To improve regional MOM6
   a. test & experiments for vertical mixing
   b. forcings -
      i. tides
      ii. runoff
      iii. winds, e.g. using relative winds
      iv. radiational fluxes (e.g. adding outgoing blackbody radiation)
      v. SW flux penetration
   c. tools for analysis and validation

1. Future work
   a. integrating MOM6 to the UFS/HAFS for a unified tool
   b. marine JEDI DA - tuning and improve 3DVar DA