EuroSea/OceanPredict workshop, June 29 - July 1, 2022

Numerical study of the upper ocean response to Hurricane Laura (13L)

Part II: TC-Wave-Current Interactions

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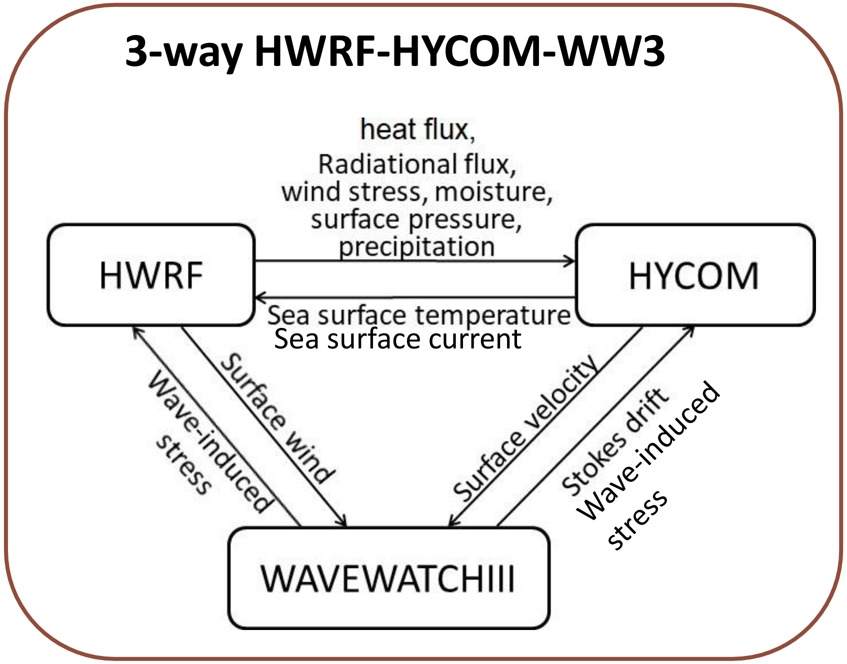
16:25 – 16:45 BST

1. Modeling system

Kim et al. (2022)

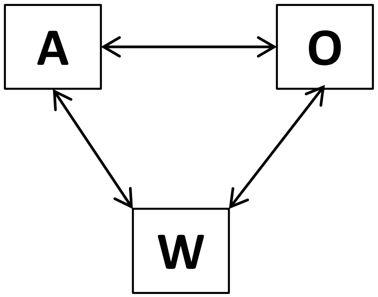


(A) 3-way coupling:

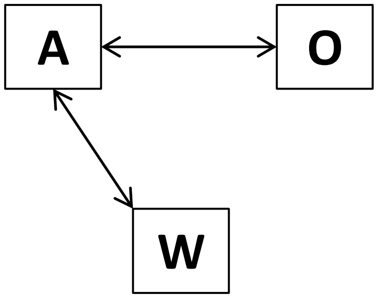
1) Atmosphere (A)
   Hurricane Weather Forecast and Research (HWRF)
2) Ocean (O)
   Hybrid Coordinate Ocean Model (HYCOM)
3) Wave (W)
   WAVEWATCH III (WW3)

(2) Cases:

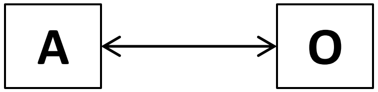
case 1: 3-way



case 2: 3-way w/o OW



case 3: 2-way



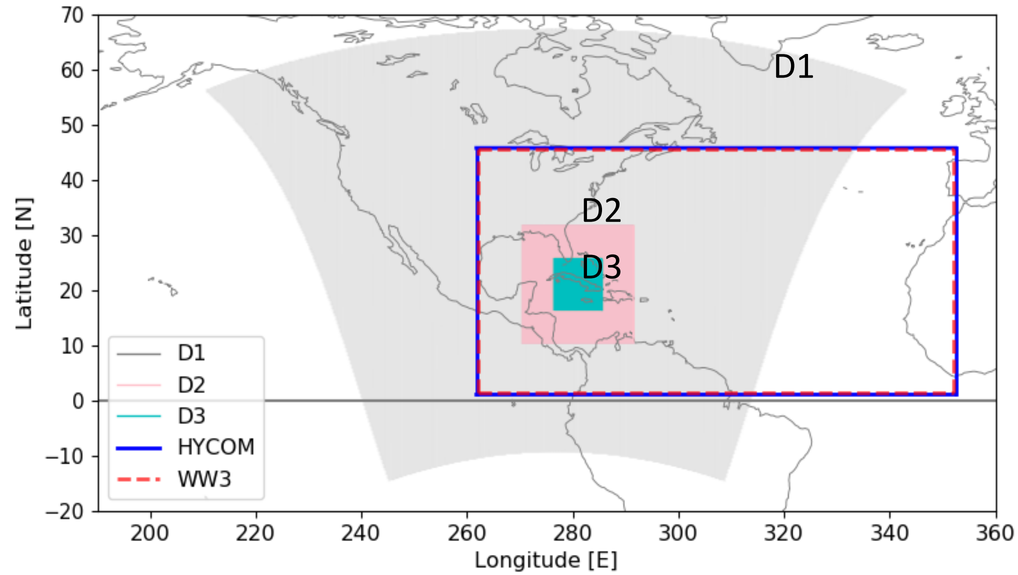
2. Domain configurations

HWRF
- triple-nested, storm following (D2 and D2) and quasi-stationary (D1)
- IC/BC: GFS analysis and forecast & warm start

HYCOM:
- stationary
- IC/BC: global RTOFS (Real-Time Ocean Forecast System) nowcast and forecast & warm start

WW3:
- stationary
- IC/BC: global WW3 nowcast and forecast

North Atlantic NHC domain



Horizontal resolution [km]

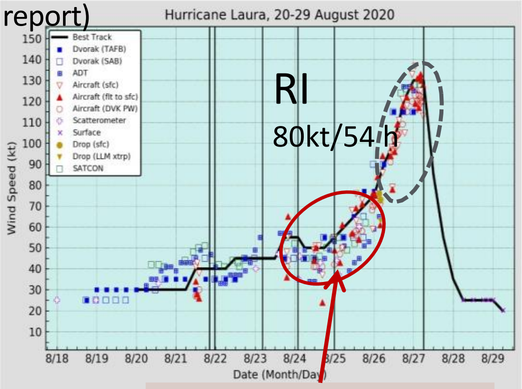
D1	D2	D3	HYCOM	WW3
13.5	4.5	1.5	~9	~10

Vertical layer

HWRF	HYCOM
75 hybrid pressure-sigma	41 hybrid z-sigma

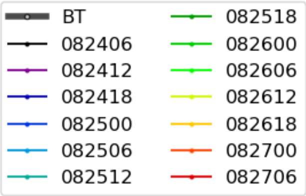
3-1. Results: Track and Intensity

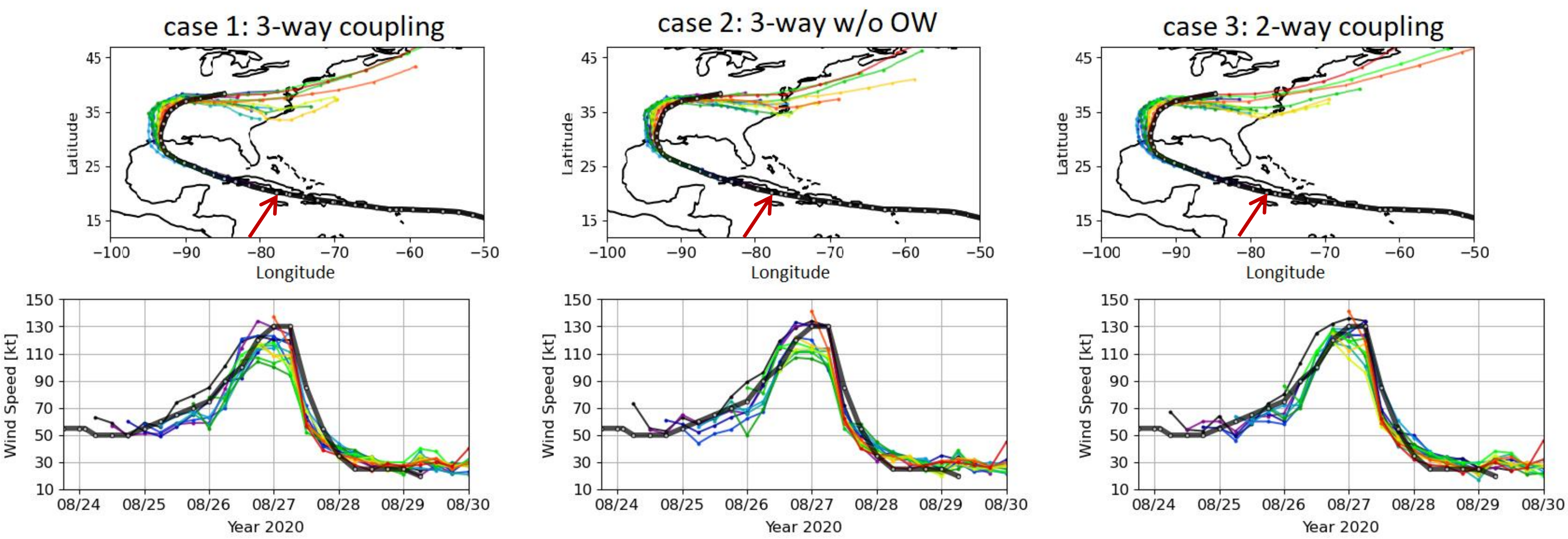
Laura (13L) underwent RI (55kt/24h) ending Vmax=130 kt 00Z August 27 (NHC report)



High uncertainty in Obs.

13 cases for a period that Laura transited the GOM



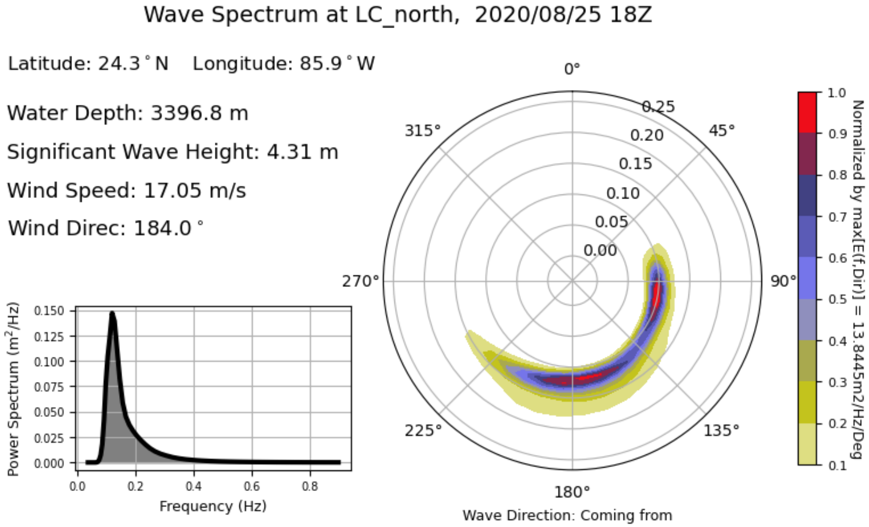


↗ Initial location at 2020082406

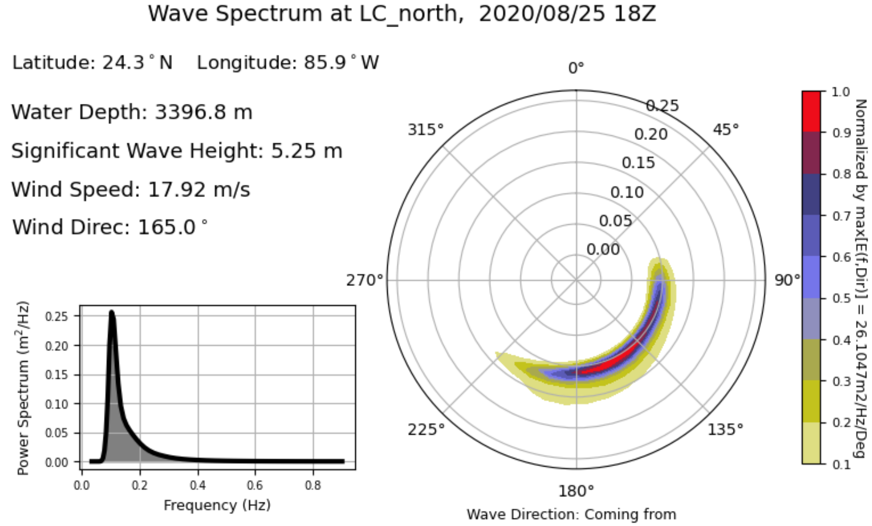
3-2. Results: Wave simulations

Comparisons between case 1 and case 2

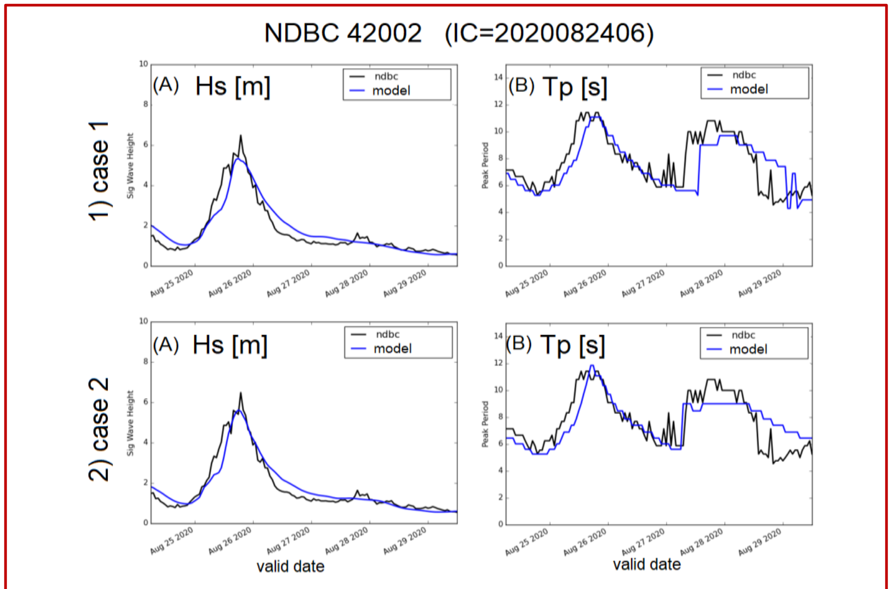
1) case 1



2) case 2



validation



4. Mixed Layer (ML) Heat Budget

Jacob et al. (2000)

$$\frac{\Delta T_m}{\Delta t} = \overbrace{\underbrace{-\vec{U} \bullet \nabla T_m}_{\text{Adv}} \underbrace{- \frac{Q_o}{\rho_0 C_p h}}_{\text{HeatFlux}} \underbrace{- \frac{w_e \Delta T_m}{h}}_{\text{EntFlux}}}^{\text{RHS}},$$

where T_m is the bulk mixed layer temperature (K),

$\vec{U}$ is the velocity in the MLD (m/s),

Q_o is the surface heat flux (J/m2),

ρ_0 is the water density (1023 kg/m3),

C_p is the heat capacity (3985 J/kg/K),

T is the temperature difference ML and thermocline

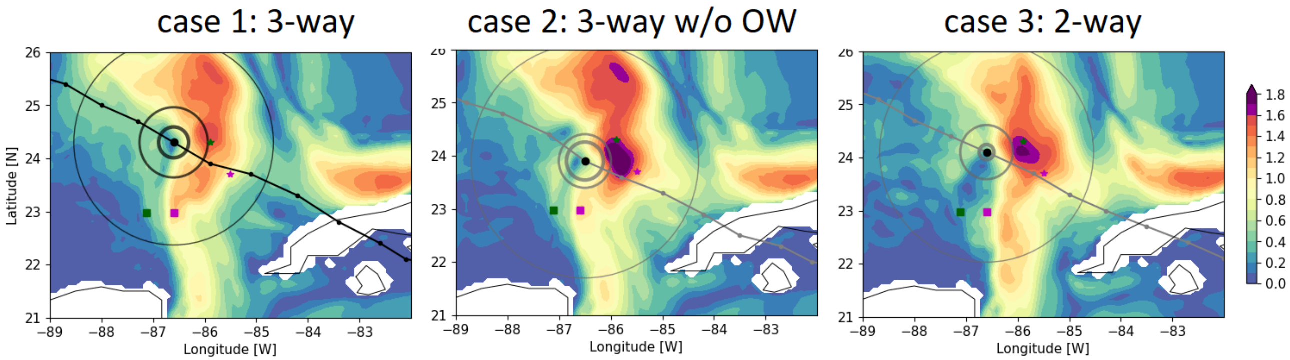
Entrainment velocity, w_e:

$$w_e = w_m - \frac{\partial h}{\partial t},$$

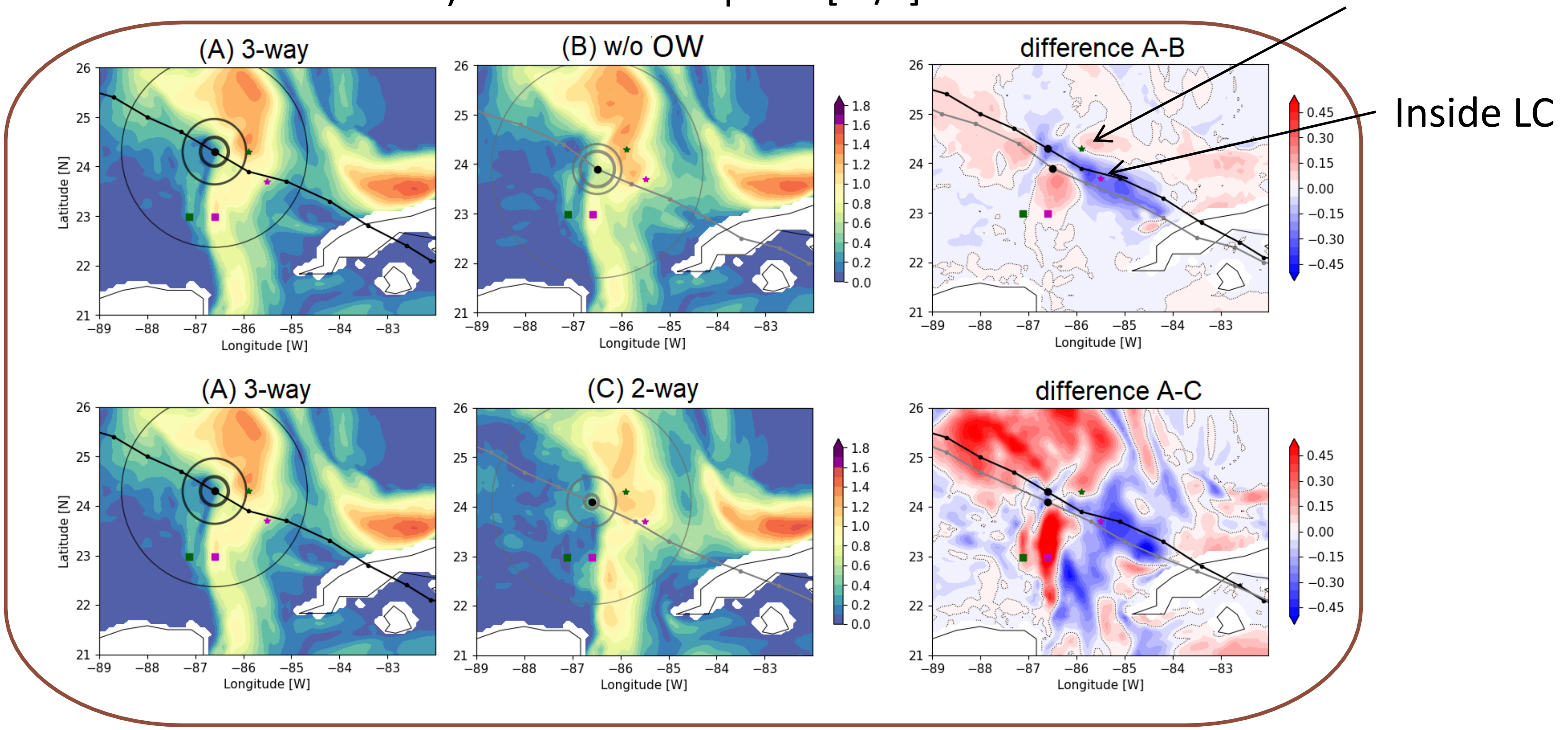
where w_m is the vertical velocity at the depth of the ML base .

4-1. Results: Ocean currents

1) 33-h surface current speed [m/s]



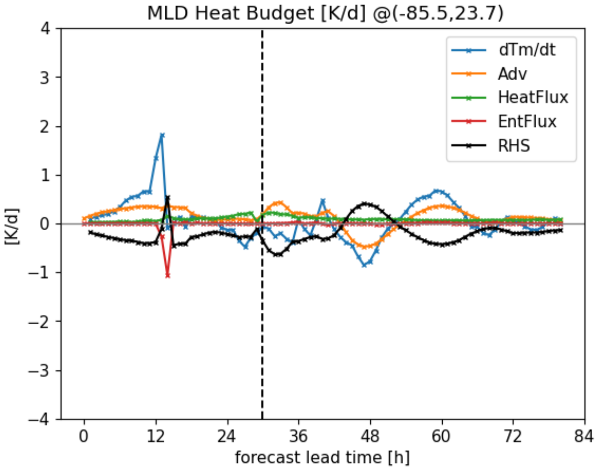
2) 33-h current speed [m/s] at MLD



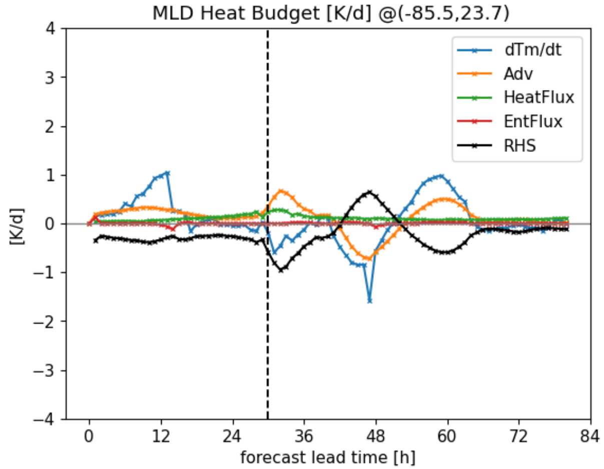
4-2. Results

Inside the LC region (and the TC track)

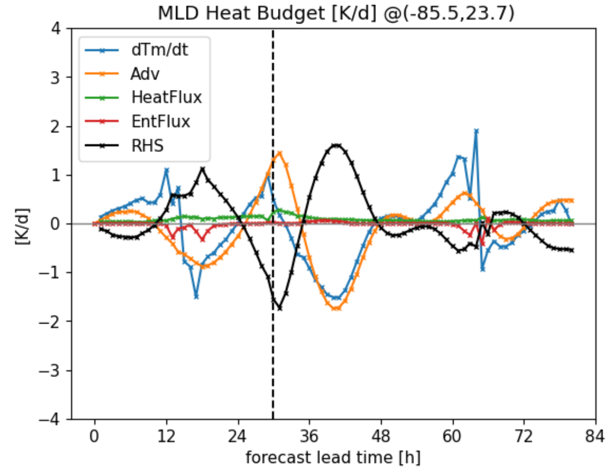
A) case 1



B) case 2



C) case 3

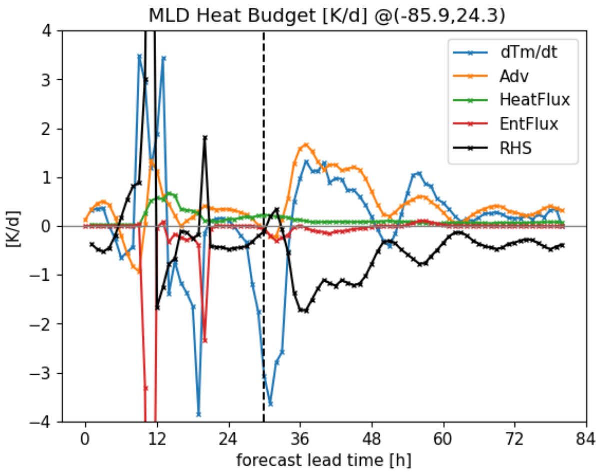


a) Tendency and advection terms are dominant; relatively large variations with case 3 in general, compared to cases 1 and 2.
b) Pre-storm period: Rather large variations in the tendency for all 3 cases (cases 1-3), but relatively large variations including advection for 2-way coupling (case 3)
c) Post-storm period: Significant variations, partially due to the storm-induced inertial waves

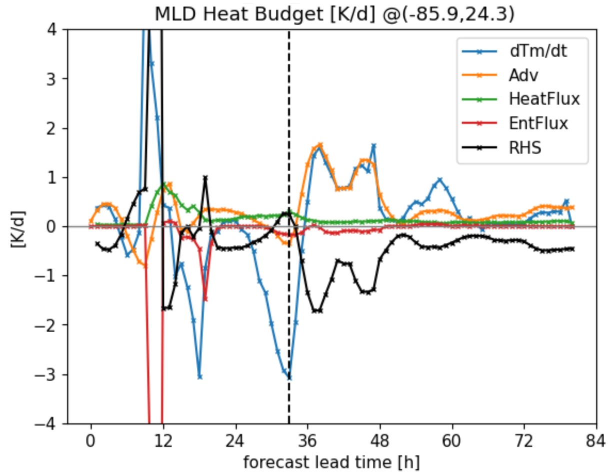
4-2. Results

at the northern flank of LC (and the TC right quadrant)

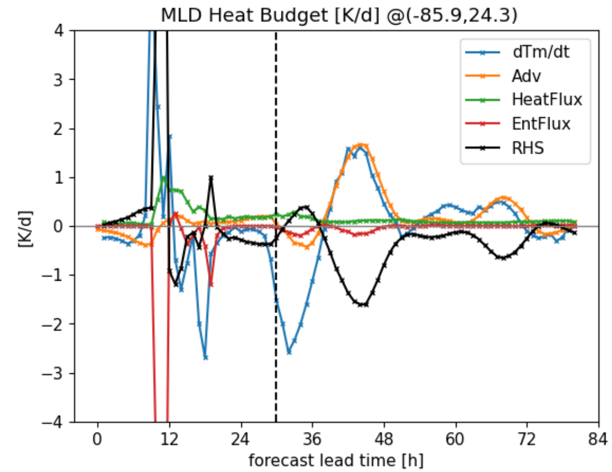
A) case 1



B) case 2



C) case 3



a) Unlike the LC inside, magnitude of each terms are comparable for all cases
b) In general, tendency and advection terms are dominant, except a pre-storm period where the tendency and entrainment flux are dominant.
c) Post-storm period: relatively high temporal variations for cases 1-2, compared to case 3 (remote forcing other than inertial waves?)

5. Summary and conclusions

1. 3-way coupling induces higher SST/MLT cooling by *O*(<2C), compared to one w/o Ocean-wave coupling and 2 way-coupling (no tuning) 🡐 not shown

2. 3- vs. 2-way coupling: Wave-current interactions reduce the magnitudes of tendency and advection term in the ML heat budget balance

3. In general, tendency and advection terms dominate the ML heat budget for 3-way and 2-way coupling, except dominant tendency and entrainment flux for a pre-storm period at the LC front.

4. Wave-current interactions shift and split wave spectrum (refraction and trapped?)