Joint Hurricane Testbed Semi-annual Progress Report
Project: Evaluation of Upper Ocean Mixing Parameterizations
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Introduction:

Past observational, theoretical and numerical studies have substantiated the fact that tropical cyclone intensity is sensitive to the upper ocean heat potential in the directly forced region of the storm. Observational and numerical investigation of ocean response during hurricane Gilbert in the western Gulf of Mexico suggested that the upper ocean heat and mass budgets have a strong dependence on the entrainment mixing scheme. Thus, one of the major uncertainties in a coupled hurricane ocean forecasting model is the choice of mixing scheme as significant oceanic mixed layer cooling and deepening during a storm passage is due to mixing. As part of this Joint Hurricane Testbed (JHT) funded project, using the Hybrid Coordinate Ocean Model (HYCOM) configured with different entrainment mixing schemes, this issue is investigated in detail. Available high-resolution oceanic observations during the passage of three tropical cyclones (Gilbert 1988, Isidore 2002 and Lili 2002) in the Atlantic provide the data set to evaluate model results. Overall, 702 temperature, 102 salinity and 210 current profiles acquired during these storms are directly compared to simulated results to identify the best mixing schemes for different forcing characteristics and background oceanographic conditions that can be used in the coupled intensity prediction models. In this report, the progress so far on the project in deriving the initial conditions and forcing data is presented.

Objectives:

Our principal objectives are:

- Configuration of the numerical model based on suitability of geographic coverage and vertical structure representation for Gilbert, Isidore and Lili cases;
- Derivation of realistic initial conditions for hurricanes Gilbert and Isidore using a combination of in situ and remotely sensed data; and
- Derivation of realistic boundary layer forcing by blending in situ and aircraft derived quantities with the large scale model fields.
- Simulation of ocean response for all the three storms and comparison with the observed profiler data.
- Identification and recommendation of better oceanic vertical mixing parameterizations for use in coupled intensity prediction models.

These objectives have been achieved for the Gilbert case. Simulations have been completed for the Isidore and Lili cases and now we are focusing on performing the comparisons. Further refinement and dependence of the simulated results on the vertical resolution is also being investigated as part of the project. Results will be presented in the IHC and a final report with recommendations will be prepared in the next six months.

Model Configurations:

Two configurations of HYCOM are set up to perform the numerical simulations for the different mixing schemes. As most of the observations are in the western Gulf of Mexico during hurricane Gilbert, the model domain extends from 80 to 98° W longitude and from 14 to 31° N latitude. With a horizontal grid resolution of 0.07°, the model has 250×242 horizontal points. Ocean response simulations are performed for three cases with 20/22/50 layers in the vertical. The bathymetry used in the model is derived from ETOPO 5 topography and the boundaries along Florida Straits and the Caribbean Sea are closed by vertical sidewalls as the area of interest is in the Western Gulf of Mexico. We also performed many numerical simulations using open boundary conditions and found that the model results are not sensitive to these boundary conditions here.

With the occurrence of hurricanes Isidore and Lili in the same general geographic region, ocean response simulations are combined into a single continuous case spanning 30 days. The model domain extends from 65º to 98º W and 9º to 31º N with a resolution of 0.08°. The model has 22 vertical layers on a 413×296 horizontal grid and the boundary conditions are provided from basin-scale Atlantic Ocean HYCOM simulations driven by realistic atmospheric forcing. While the profiler acquired data are at very high resolution in the vertical (~ 1 *m*), the model is configured with a 3 *m* resolution near surface until it transitions into the isopycnic domain. Additional simulations are being performed with much higher resolution, the results from which we plan to show at the IHC conference.

Simulations and Results:

Gilbert Case: As proposed, the model was forced with the analyzed wind fields starting from 14 Sept 1988, 0 UTC to 20 Sept 1988 and the simulated fields examined and compared with observed profiles. Simulated mixed layer temperature response for 06 UTC on 16 Sept 1988 corresponding to the in-storm experiment is shown in Fig.1 for the five vertical mixing schemes. While generally the simulated fields have similar patterns of surface temperature reduction, the magnitude remains very different. In particular, the KT mixing scheme (Kraus and Turner 1967; Gaspar 1988) simulates warmer temperature and the PWP scheme (Price, Weller and Pinkel 1986) simulates much colder temperatures that are almost 1.5° C cooler than the three higher order schemes. Simulated profiles were extracted for comparison to the actual profiles and a full comparison is performed using linear regression analyses. Results indicate that the KPP (Large et al. 1994) and MY (Mellor and Yamada 1972) schemes compare best to observations followed closely by the GISS scheme (Canuto et al. 2001). Comparison of results from bulk KT and quasi-bulk PWP schemes are not as satisfactory as indicated by Fig.2 and regression statistics shown in Table 1. However, the model mixed layer is not well resolved due to the vertical resolution limitations so the vertical resolution is being increased to investigate any sensitivity to such limitation.

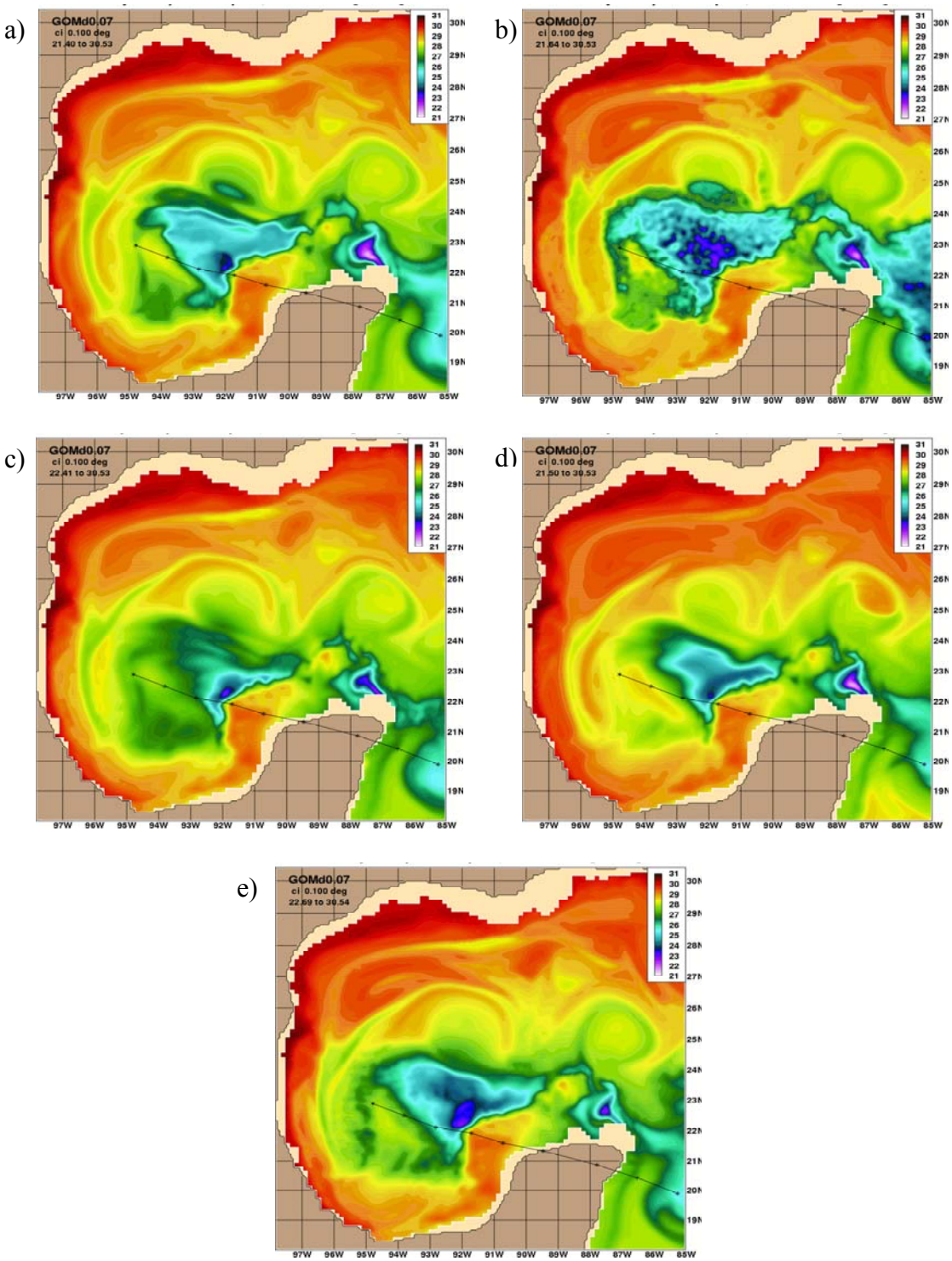

Figure 1: Simulated mixed layer temperatures during hurricane Gilbert for a) KPP, b) KT, c) PWP, d) MY, and e) GISS mixing schemes. Differences between the cases are clearly visible with PWP being the coolest and KT being the warmest. Black line indicates track of the Storm till 06 UTC 16 September 1988.

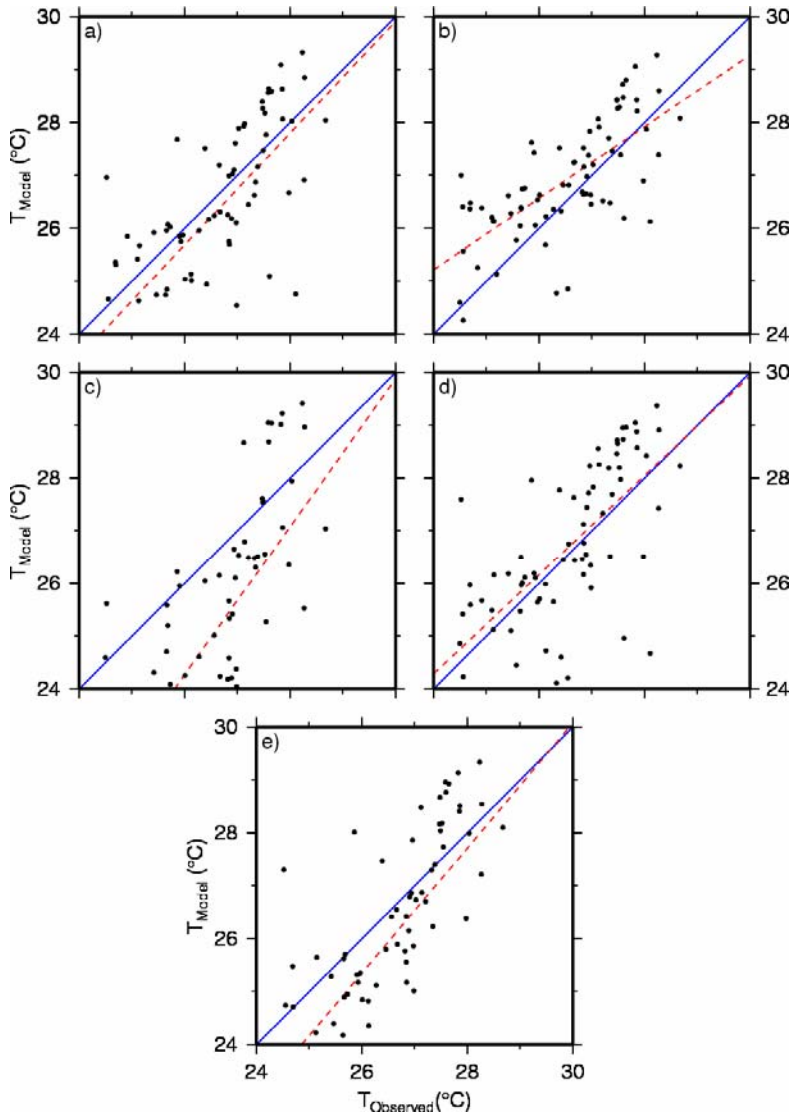

Figure 2: Comparison of observed and simulated mixed layer temperatures for a) KPP, b) KT, c) PWP, d) MY and e) GISS mixing schemes. The solid blue line represents perfect comparison with the dashed red line indicating the linear regression fit. KPP and MY schemes show a better comparison to data.

	KPP	KT	PWP	MY	GISS
Slope	1.05	0.68	1.40	0.94	1.18
Bias	-1.75	9.00	-12.18	1.68	-5.40
Mean diff.	0.28	-0.40	1.52	-0.14	0.56
σ diff.	1.19	0.85	1.76	1.12	1.38
RMS diff.	1.21	0.94	2.30	1.12	1.48

Table 1: Linear regression statistics and parameters that quantify differences between simulated mixed layer temperatures from the model and the observed profiler data. Units are in degrees Celsius except the non-dimensional slope of the regression line.

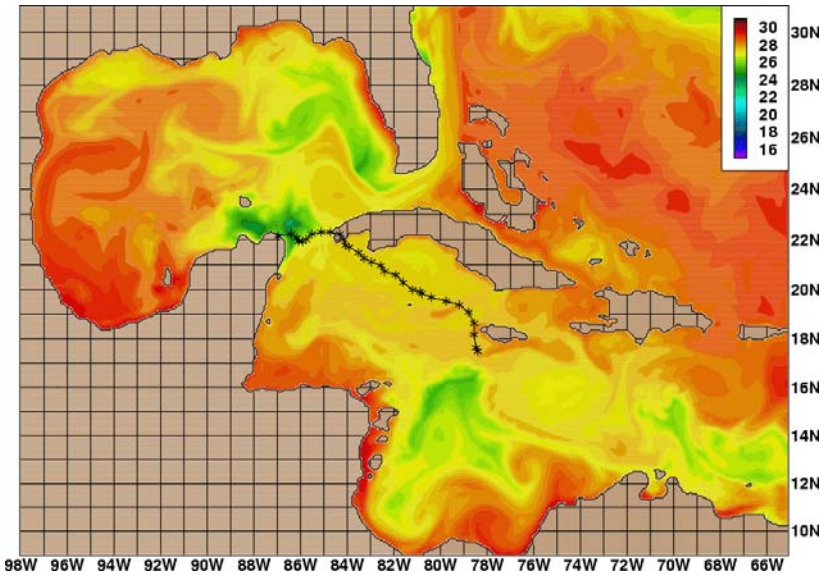

Figure 3: Mixed layer temperature response during Isidore for the KPP mixing scheme in the combined cases of Isidore and Lili. Cooling of about 4°C is seen to the right of the storm center. While the cooling is reduced over the loop current and in the Caribbean, it is up to 0.5°C more than what is observed.

Isidore and Lili Cases: In contrast to the Gilbert case of 6 day integration, Isidore and Lili cases are combined in to a single simulation spanning 20 days. Starting form 0 UTC 14 Sept 2002, integrations are performed up to 0 UTC 4 Oct 2002 to compare the profiler observations to the simulated results. Due to problems with the initial conditions as indicated in the first year report, these conditions were revised twice and the simulations are performed for the different vertical mixing schemes. On careful examination, there are still some minor problems with the initial conditions. This leads to somewhat higher cooling in the Loop Current region and we have identified a methodology to fix these problems. Therefore detailed comparisons are not performed with the profiles. Mixed layer response using the KPP scheme during Isidore is shown in Fig.3. As with the Gilbert case, we are planning to increase the vertical resolution and the updated results are planned to be presented at the IHC.

Summary:

As proposed originally, simulations of upper ocean response to hurricanes Gilbert, Isidore and Lili are performed for the different upper ocean mixing schemes. Initial comparison of the simulated results to observations in the Gilbert case indicates higher order KPP and MY mixing schemes compare better with data. It is planned to re-run the simulations with higher vertical resolution to identify any dependency on this for this Gilbert case. Initial simulations have been completed for the Isidore and Lili cases. We are further refining the initial conditions and investigating the vertical resolution issues. Results from these experiments will be compiled and presented at the IHC.

Funding:

Due to administrative difficulties, we are yet to receive the additional funding of ~$15K for the second year approved by the JHT steering committee. We would very much appreciate receiving this soon to cover the time needed to be spent on the project.

References:

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