17A.6 OCEAN DATA ASSIMILATION AND INITIALIZATION PROCEDURE FOR THE COUPLED GFDL/URI HURRICANE PREDICTION SYSTEM

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1. INTRODUCTION

A new data ocean assimilation and initialization procedure has been developed to simulate a realistic structure of the Gulf Stream (GS) and Loop Current (LC) in GFDL/URI coupled hurricane prediction system used operationally at the NCEP. This procedure is based on feature modeling approach and consists of cross-frontal "sharpening" of the background temperature and salinity fields, according to data obtained in specialized field experiments in the GS. After that, the ocean model is integrated for 2 days to create strong currents in the GS and LC. A new feature modeling approach was also developed for initializing a multi-current system in the Caribbean Sea.

2. THE 2002 OCEAN INITIALIZATION AND DATA ASSIMILATION PROCEDURE IN THE GFDL/URI MODEL

The ocean initialization and data assimilation procedure implemented to operations at NCEP in 2002 (OP02) included four phases (Bender and Ginis, 2000). During Phase 1, the Princeton Ocean Model (POM) was integrated in a diagnostic mode for two weeks using the GDEM monthly temperature and salinity fields. It was followed by a two-month integration in a prognostic mode (Phase 2). In Phase 3, the daily NCEP SST is assimilated within the mixed layer and the POM is then integrated for 2 days for dynamic adjustment, keeping SST fixed in time. In Phase 4, the sea surface cold wake is generated 3 days prior to the beginning of coupled model forecast, using forcing by the observed hurricane winds. In OP02, the Atlantic basin was divided into three small regions: the Gulf of Mexico, Western Atlantic and Eastern Atlantic. This resulted in the occasional loss of ocean coupling when a hurricane moved from one region to another during a forecast.

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In the new 2003 version (OPO3), the Gulf of Mexico and Western Atlantic regions are combined into one "united" computational domain to rectify this problem.

3. NEW INITIALIZATION AND DATA ASSIMILATION PROCEDURE

The new initialization and data assimilation procedure is based on a feature-modeling approach which we apply to initialize the GS and LC in the GFDL/URI model. The essence of this approach is to simulate the GS and LC paths and their cross-frontal structures as realistically as possible at the time of the hurricane model forecast. The main assumption in this approach is that the cross-frontal temperature, salinity and velocity structures in the upper and main thermocline do not change significantly along a strong oceanic front such as the GS. This assumption is well supported by data obtained in specialized field experiments (Halkin and Rossby 1985).

The first step in the initialization procedure is to specify continuous paths for the GS and LC in the united ocean domain (Fig. 1). West of Cape Hatteras (from 82°W to 75°W) where the GS is typically very stable, its path is specified using long-term averaged data, as in Leaman et al. (1989). East of Cape Hatteras, from 75°W to 50°W, we use satellite-derived monthly North Wall data provided by P. Cornillon (private communication). In the Gulf of Mexico, we determine the LC path using the maximum temperature gradients in the main thermocline in the GDEM data. As the LC source, we also initialize a weak current along the 12°C isotherms at z=400m in the GDEM data (from 50°W to 70°W) in the southern part of the region (15-16°N) and connect it with the LC near the Yucatan Strait. After the GS and LC paths are defined, normal cross-sections are constructed with 0.1° increments along the paths. The GDEM temperature and salinity fields are then interpolated at each z-level (also with 0.1° increments) onto these cross-sections. In the next step, the temperature and salinity gradients are sharpened in each cross-section according to the observational data obtained in field experiments (Leaman et al. 1989). Sharpening is done within 0.8° from each side of a current. A similar procedure is applied to create the LC in the Gulf of Mexico. For sharpening in the LC area, we use the same gradients of temperature and salinity as in the GS, but multiplied by a coefficient which increases along the LC path from 0.2 at 50°W (the LC source) to 1.0 at 82°W where the LC turns into the GS.

After sharpening, the temperature and salinity fields are interpolated back from the cross-sections onto the model grid system. The initial baroclinic velocities are calculated from the geostrophic balance equations assuming zero elevation. Starting with these fields and assuming zero barotropic velocities, the ocean currents are spun up by integrating of the POM equations for 2 days. That was sufficient for the velocity fields to adjust to the strong gradients of temperature and salinity in the main thermocline in the GS and LC. Phase 1 and Phase 2 of OP02 are eliminated. Phases 3 and 4 of OP02 become Phases 1 and 2 of OP03. This initialization procedure has been extensively tested for hurricanes during previous hurricane seasons and was implemented into the 2003 operational version of the GFDL/URI coupled hurricane-ocean model.

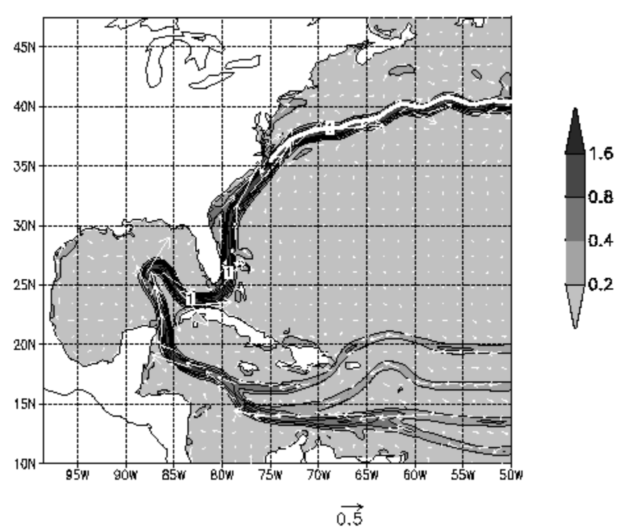

Fig. 1 Surface current after Phase 1 of the MCS ocean model initialization during Hurricane Isidore forecast (initial time: 12 UTC, September 19, 2002). White line indicates the GS North Wall in September.

4. INITIALIZATION OF A MULTI-CURRENT SYSTEM

To specify positions of the currents in the MCS we used a schematic representation of the circulation in the Caribbean Sea created by Johns et al. (1999), who processed ship observation data for the passages between the Atlantic Ocean and the Intra-Americas Sea. After the current paths corresponding to the MCS are specified, cross-sections normal to the paths are constructed, as in OP03. We then identify lines that separate neighboring currents at equal distances from the current centers. At each z-level in a cross-section perpendicular to the path, we find the maximum from the right (minimum from the left) temperature between the current center and the separation line and sharpen the gradient using the difference between this maximum (minimum) values and the temperature at the current center. The sharpening at each level is guided by the gradients derived from observed GS cross-sections.

Fig. 1 shows the surface ocean currents after a 2-day integration in Phase 1 of the MCS initialization, during the forecast of Hurricane Isidore initiated at 12 UTC, September 19, 2002. We see that a stable continuous multi-current system has developed that resembles the schematic representation of the circulation obtained in Johns et al. (1999). This example demonstrates that the new procedure can successfully initialize a complex multi-current system in the ocean. Presently available data do not allow a more accurate specification of synoptic variability in the position and intensity of each current. As more observational data become available in the future, it will allow the detection of fronts in real-time, and the new data can be assimilated using the present methodology without difficulty.

It is known that hurricane-induced cooling is very sensitive to the depth of the mixed layer. Since the LC separates two very different water masses (the Gulf of Mexico has a much shallower mixed layer than the Caribbean Sea), it is reasonable to assume that its location may be affect hurricane intensity when a hurricane crosses LC and moves slowly. The present methodology allows an LC initialized with any given path in the GFDL/URI hurricane model. In order to take advantage of this technology, satellite-retrieved sea surface height (SSH) data can be used in future. For example, the SSH data can help to determine how far the northern boundary of the LC penetrates into the Gulf of Mexico at the time of a hurricane forecast.

5. REFERENCES

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