Baroclinic topographic waves on the Nicaragua Shelf generated by tropical cyclones

Dmitry S. Dukhovskoy, Steven L. Morey, and James J. O'Brien
Center for Ocean-Atmospheric Prediction Studies
Florida State University
Tallahassee, Florida, USA, 32306-2840
ddmitry@coaps.fsu.edu

1. Introduction

The present study is focused on the dynamic response of a stratified low-latitude ocean to tropical storms. In particular, cases of baroclinic coastally trapped waves generated by hurricanes passing over the Nicaragua Shelf are discussed. Tropical cyclones have a great impact on the ocean dynamics. Characterized by large wavelengths (O(10^3 km), strong wind-stress fluctuations, and long periods (weeks), these atmospheric systems influence the ocean dynamics on the scales from gravity waves to long waves which depend crucially upon the earth's rotation. The Caribbean Sea is strongly affected by tropical storms during the hurricane season. Since 1985 there were only two years (1992 and 1997) when the storms did not pass over the region.

2. Description of the region

In the Gulf of Mexico, hurricanes can generate barotropic shelf waves (e.g., *Morey et al.*, 2006). In the Caribbean Sea, due to very small Coriolis parameter (*f*), barotropic topographic shelf waves can be supported only over a very broad shelf due to large external Rossby radius of deformation ($R_e = f^{-1}\sqrt{gH}$, where *H* is the average depth). The shelf region near Honduras and Nicaragua, the Nicaragua Shelf, is the only wide shelf in the basin (~300 km in the widest place). However, the external Rossby radius for this location is ~ 700 km. Thus, barotoropic topographic waves can not be supported on this shelf. The presence of a sloping shelf break allows one to assume that internal topographic waves can exist in this region. The escarpment goes very shallow which permits one to suggest that atmospheric forcing can generate baroclinic waves along the shelf. Highly energetic positive wind stress curl imposed on the sea surface initiates isopycnal rise in the upper ocean through Ekman pumping. If the forcing moves towards the shelf break, the density anomaly follows it encroaching on the continental rise. This could produce strong baroclinic trapped motions. The typical slope of the shelf is ~10^{-2}. The range of stratification ($S = Nf^{-1}$) in the upper 50 m is ~200-300 which satisfies $\alpha > S^{-1}$. This allows trapped waves of type II, strongly trapped waves, following the classification of *Rhines* [1970].

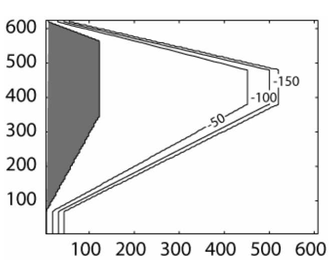

Figure 1. Model domain and bathymetry. Depth is in meters. The axes are distances (km).

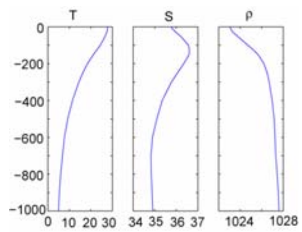

Figure 2. Temperature, salinity, and density profiles in the model.

3. Model experiment

To reproduce the mechanism described above, an idealized domain representative of the Nicaragua Shelf has been configured (Figure 1). The ocean is baroclinic and initialized with long-term average temperature and salinity profiles (Figure 2) (http://dss.ucar.edu). For simulation, the Navy Coastal Ocean Model (NCOM) is used with 10 σ-

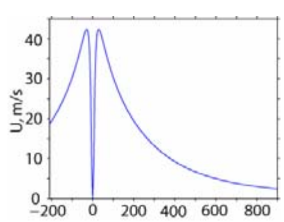

Figure 3. Wind speed profile in the hurricane used to force the model. The abscissa is distance from the hurricane center, km. The ordinate is

levels (Martin, 2000). The horizontal resolution is 4 km. The model is forced with a cyclonic wind stress from an analytical pressure wind field (Figure 3). The hurricane moves from the southeastern corner of the domain (lower right corner in Figure 1) to the northwestern corner (upper left) with a translation speed of 30 km h^{-1}.

The model results show (Figure 4) that when the density anomaly initiated by the moving hurricane hits the shelf break a baroclinic slope-trapped motion is produced. The wave phase moves with the shallow water to its right. Another type of wave is seen along the northern edge of the shelf (upper part of the domain). Since the coast in the model is approximated as a wall and not a sloping bottom, this is an interior Kevlin wave.

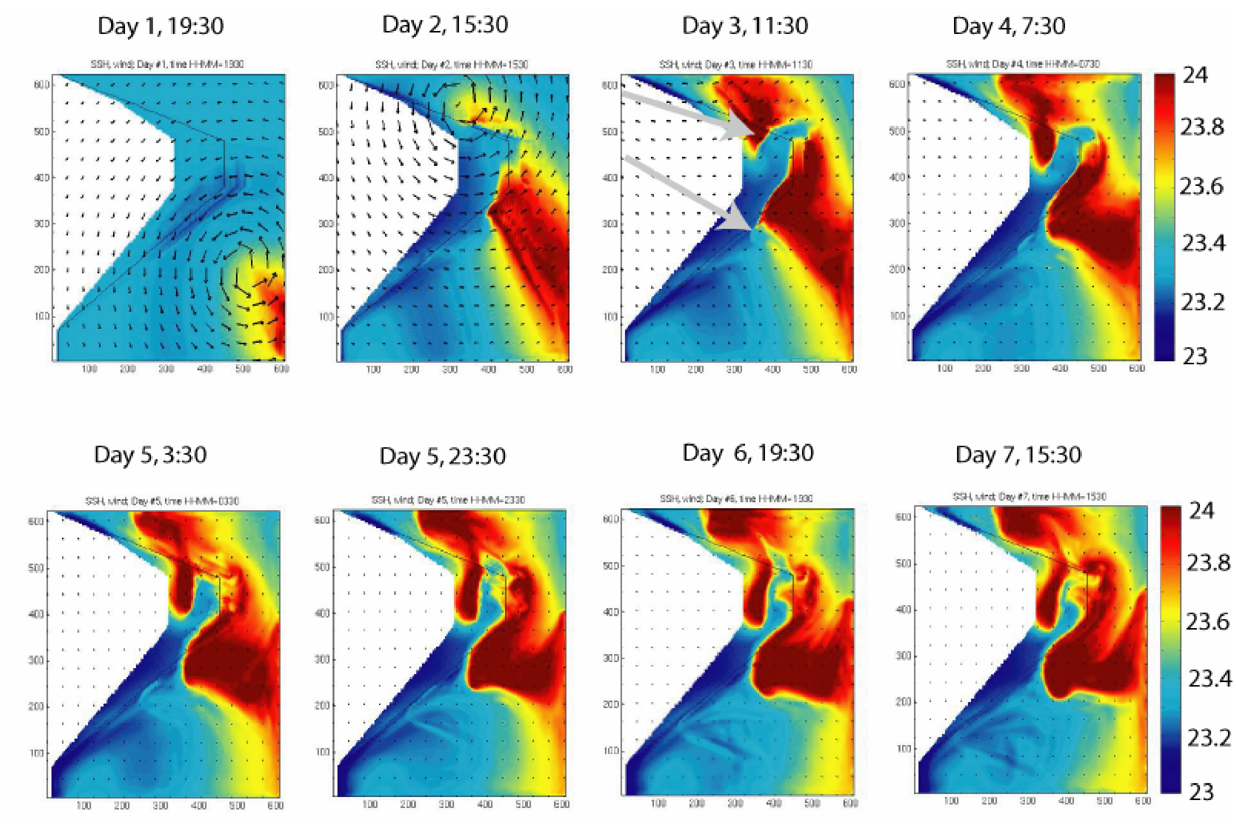

Figure 4. Simulated σ-density field at z = 30 m. Black arrows are wind vectors. Gray arrows in the panel "Day 3" indicate two baroclinic waves trapped along the topography. The upper wave is an interior Kelvin wave and the lower wave is a baroclinic topographic wave.

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References

Morey, S.L., M. Bourassa, J.J. O'Brien, and D.S. Dukhovskoy, Modeling the impacts of remote forcing on hurricane storm surge, *Research Activities in Atmospheric and Ocean Modeling*, World Meteorological Organization, Submitted, 2006.

Martin, P.J., A description of the Navy Coastal Ocean Model Version 1.0. NRL Report: NRL/FR/7322-009962, pp. 39, Naval Research Laboratory, Stennis Space Center, MS, 2000.

Rhines, P.B., Edge-, bottom-, and Rossby waves in a rotating stratified fluid, *Geophys. Fluid. Dyn.*, *1*, 273-302, 1970.