16A.6 MODULATIONS OF SURFACE WAVE ENERGY OVER NEAR-INERTIAL TIME SCALES

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1 INTRODUCTION

The ocean response to tropical cyclone (TC) surface forcing is a complex interaction between baroclinic and barotropic motions that re-distribute energy in the ocean during and after these strong forcing events. Shay and Chang (1997; hereafter SC) describe the ocean response to TC forcing as a combination of both energetic baroclinic and weak barotropic modes within the near-inertial wave band. It is the weak barotropic mode which acts to relax the sea surface depression, a barotropic trough resulting from the direct wind stress forcing and surface Ekman divergence, back to its quiescent state. Here, observed surface wave measurements in the Gulf of Mexico during and subsequent to the passage of Lili (2002) are used to illustrate the modulation in the surface wave energies over near-inertial time scales in the barotropic trough after TC passage.

2 SURFACE WAVE MEASUREMENTS

NOAA operates and maintains an array of moored 3-, 10- and 12-m discus buoys, each having a 5-digit World Meteorological Organization station identifier. NOAA buoy 42001 is a 10-m discus buoy located at 25^{0} $55.2^{'}$ N 89^{0} $40.8^{'}$ W (180 nm south of Southwest Pass, LA) and moored at a depth of 3,246 m. In addition to the meteorological and oceanographic data routinely measured, these buoys are capable of providing the necessary information to derive both the non-directional (m^2 Hz^{-1}) and directional (m^2 Hz^{-1} deg^{-1}) surface wave density spectrum. The non-directional (directional) wave density spectrum is a measure of the wave elevation variance per frequency interval (and per unit direction interval) and is commonly referred to as the wave spectral energy.

These moored pitch-roll buoys are capable of measuring the accelerations to derive the wave spectral energy magnitude between 0-999 m^2 Hz^{-1}, where each frequency interval is between 0.02-0.4 Hz with a resolution of 0.01Hz. Hourly wind speeds, significant wave heights and wave spectral energies that experienced infrequent data dropouts have been linearly interpolated and the wave spectral energies were filtered using a running mean to highlight the observed variability.

TC Lili approached NOAA buoy 42001 from a south-southwest direction after crossing the western tip of Cuba. She reached her maximum intensity, passing within one radius of maximum winds (R_{max}) to the west of NOAA buoy 42001 at 1950 UTC 2 October 2002 while translating at slightly greater than 5 m s^{-1} on a predominately poleward track (Fig. 1).

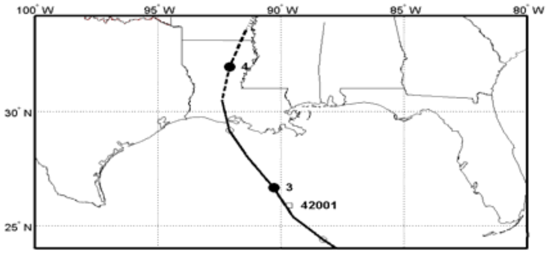

Figure 1. The National Hurricane Center's best track for tropical cyclone Lili (2002). Black circles represent the position at 0000 UTC along with a date, open circles represent the position at 1200 UTC and NOAA buoy 42001 is represented by a square (data courtesy of NOAA).

As Lili made her closest approach to the buoy, her surface winds exceeded 50 m s^{-1}, significant wave heights peaked above 10 m and wave spectral energies exceeded 220 m^2 Hz^{-1} which were largely contained in the swell part of the spectrum that decayed rapidly, within hours, after Lili's passage (Fig. 2). These wave spectral energies contained in the lower-frequency intervals (0.05-0.1 Hz) began several hours prior to, peaked during and decayed within several inertial periods (IP~27 hrs) of Lili's closest approach to the buoy.

By contrast, notice the smaller amplitudes of the wave spectral energy and significant wave heights in the higher frequency intervals that are modulated at near-inertial periods and persist beyond several IPs. Similar near-inertial oscillations have been observed from buoys after passage of TCs in the past (Johnson and Withee 1978; Faber et al. 1997).

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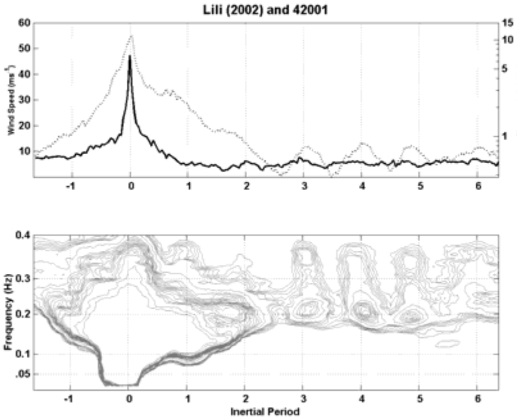

Figure 2. Time series of a) wind speed (solid) and significant wave height (dashed), and b) contoured (0.05 to 1 m^2 Hz^{-1}) wave spectral energy from NOAA buoy 42001 prior to, during and subsequent to Lili's passage. The time is scaled by inertial period, 1.13 d (data courtesy of NOAA).

3 DISCUSSION

The modulations of the surface wave energies over near-inertial time scales induced by TC Lili have similarities to the surface height changes due to the vertically-integrated mass divergence as suggested in numerical simulations from a 17-level model with a free surface boundary condition (SC). By including a free-surface in a 3-dimensional model where both barotropic and baroclinic modes exist, SC found in a rotating, stratified shear-flow, that there is an interaction between the barotropic trough and the baroclinic response which induces surface elevation changes over near-inertial periods. SC showed near-inertial motions resulted from the geostrophic adjustment of the barotropic trough and that the time-scale associated with the baroclinic motions are short-lived in comparison with the weak barotropic motions. That is, the observed persistence of near-inertial modulations of surface wave energy associated with the geostrophic adjustment process related to the barotropic trough is consistent with the slow decay of the the barotropic trough (Chang 1985).

4 SUMMARY

Data buoy measurements indicate modulation of sea surface wave energy over near-inertial time scales in the barotropic trough due to the wind stress and surface Ekman divergence. Within $\pm 2R_{\max}$ from the storm track, there is a clear signal of persistent oscillation over near-inertial time scales primarily due to the interactions between baroclinic and barotropic modes excited by the TC. In the context of air-sea exchanges, the modulation of these surface waves may thus impact the air-sea fluxes by altering the roughness length scale at the interface. These measurements may prove to be a useful diagnostic tool in understanding coupled atmosphere ocean simulations, ultimately aimed at predictability.

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