16D.7 THE ROLE OF WAVES, SEA SPRAY AND THE UPPER OCEAN IN MIDLATITUDE STORM DEVELOPMENT

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1. INTRODUCTION

A coupled atmosphere-wave-sea spray-ocean model system is used to study North Atlantic extratropical hurricanes to evaluate the combined impacts of wave drag, sea spray, and upper ocean sea surface temperature (SST) on storm development. Our focus is on storm intensity and development. We consider the role of air-sea fluxes and boundary layer/atmosphere implications.

The composite model system consists of a well-tested mesoscale atmospheric model, a modern operational wave model, a recent parameterization for heat and momentum fluxes due to sea spray, and an advanced ocean circulation model. The atmospheric model is the Canadian MC2 (Benoit et al., 1997) model, the wave model is the NCEP model WaveWatchIII (WW3), the sea spray parameterization follows Andreas (2003) Andreas and DeCosmo (2002), and Andreas and Emanuel (2001) and the ocean model is POM (Princeton Ocean Model). Sea spray enhances latent and sensible heat fluxes, and show their wind speed dominance in the formulation implemented here. On the other hand, wind-generated waves produce enhanced sea surface roughness, and following the empirical HEXOS relations, or the wave-induced stress formulation of Janssen (1991), reduces the storm's energy.

2. CASE STUDIES

Storm case studies are extratropical hurricanes Earl (1998), Gustav (2002), Juan (2003) and two intense winter bombs from January 2000 and 2002. All follow typical Northwest Atlantic storm patterns, veering towards the Northeast as they develop. As an example, Figure 1 gives the sensitivity of the storm track of the January 2002 winter bomb to simulations with waves and spray (denoted, fully-coupled) compared to the Canadian Meteorological Centre track analysis.

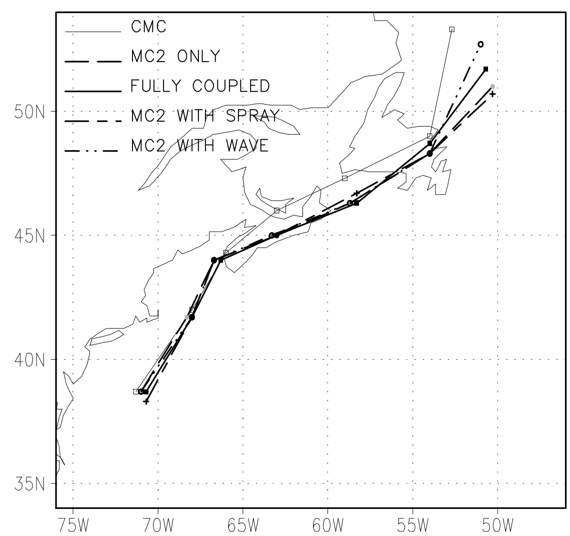

Figure 1. Comparison of the storm tracks of January 2002 'bomb' using MC2 with and without spray and waves, as well as analyses. Storm center locations are plotted every 6-h, beginning 12 UTC 12 Jan. 2002.

Overall this shows that the simulations capture the evolution of the storm reasonably well, and the storm tracks are not too sensitive to spray or waves. Although the simulated bomb tracks are biased slightly to the right of the analysis tracks, storm propagation speeds are in overall agreement with the analysis.

The intensifying impacts of spray and waves on the spatial patterns of U_{10} and SLP

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are given in Figs. 2a-2b, at the peak of the January 2002 bomb. The spatial distributions of differences ΔU_{10} are quite asymmetric, whether mediated by spray (Figs. 2a), or by waves (Figs. 2b). The competition between spray and waves is also qualitatively clear, to intensify or reduce storm intensity. For the storm presented in the figure, the maximum spray-mediated deepening is about 3 hPa, whereas maximum wave-mediated filling is about 2 hPa, respectively.

3. CONCLUSIONS

Spray and wave drag impacts differ greatly from the point of view of their generating mechanisms. Maximum spray impacts tend to occur in small local areas near a storm's center, where winds are maximum, whereas maximum wave impacts are widespread, in the areas dominated by rapidly-varying winds, with roughened sea surfaces and enhanced Charnock parameters. For example, maximum Charnock parameters tend to occur in the right spiral bands, where winds have the same direction as the storm propagation, producing increased effective fetch and duration,

While the impacts of sea spray and wave drag on storm tracks tend to be small, impacts on air-sea fluxes can be large. By itself, spray can increase latent and sensible heat fluxes, for example by as much as about 30% for a local-area average (250^2 km^2) area following the January 2000 'bomb' storm track, tending to intensify the storms. Spray-enhanced winds can increase by as much as 7.5 ms^{-1}, and deepening of the minimum SLP by about 5 hPa. By comparison, the corresponding de-intensifying wave drag effects are on the order of 4 ms^{-1}, tending to cancel the spray effects.

ACKNOWLEDGMENTS

Partial funding is from the Panel on Energy Research and Development (PERD, Canada) project on Severe Storms and Waves.

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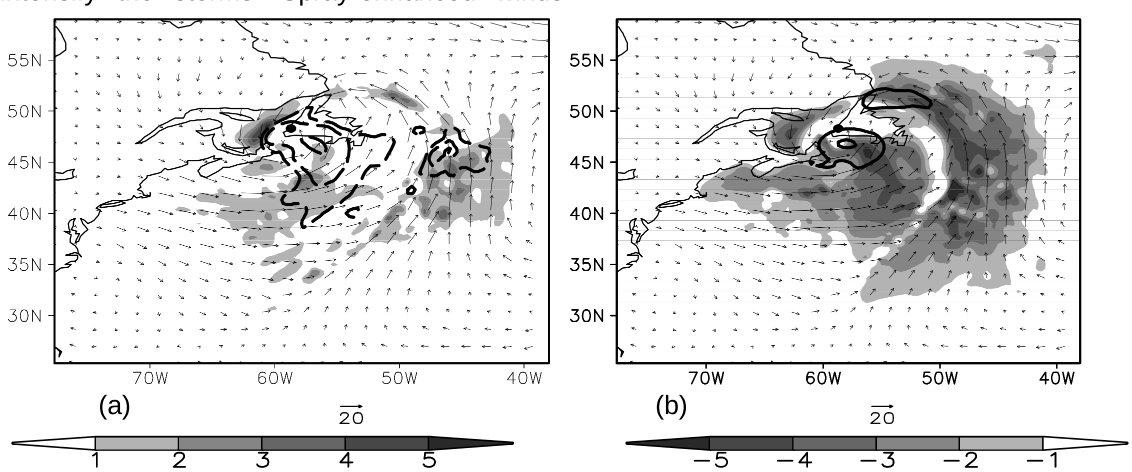

Figure 2. Differences ΔSLP (hPa) (contour) and ΔU_{10} (m s^{-1}) (shaded) at bomb's peak for (a) MC2-spray minus control, (b) MC2-wave minus control. In (a) [(b)] ΔSLP contours start at –1 [+1] mb, with ΔSLP intervals at –1 [+1] mb. Control winds U_{10} superimposed. Storm centers are •.