Effect of Surface Waves on Air-Sea Momentum Flux

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LONG-TERM GOALS

The long-term goal of this study is to clarify the detailed physical mechanism of the interaction between surface gravity waves and near surface atmospheric turbulence, and to improve our predictive capability of the momentum and energy transfer between the atmosphere and the ocean.

OBJECTIVES

The main objective of this program is to continue and extend the study of the effect of surface waves on air-sea momentum flux by investigating detailed wave fields, wave-induced pressure fields, and wave-induced velocity signals. In particular, we address the directionality and the nonlinearity of the coupled wind-wave systems. We suspect that these two are among the major reasons why our linear analysis of the wave-induced pressure/velocity yields very different results over an open ocean compared with those in the coastal area.

APPROACH

We continue to analyze the field data from the two ONR-sponsored experiments (RASEX, MBL West Coast) by employing the similarity analysis of wind-wave coupling [Hare et al., 1997], and the estimation of directional frequency-wavenumber surface wave spectra, using the extended version of the algorithm developed by Hanson et al. [1997]. By combining these two approaches, we are able to improve our estimates of the momentum flux supported by gravity waves, in both coastal conditions and in open ocean conditions, without relying on empirical parameterizations. Specific tasks to be conducted include:

- Analysis of nonlinear/directional wave spectra using RASEX data and MBL West Coast data
- Similarity analysis of wave-induced signals using RASEX data and MBL West Coast data

Based on these analyses we are able to ask the following questions:

- What is the major difference of wind-wave coupled systems between coastal conditions and open ocean conditions?
- Can we explain this difference in terms of the different directional/nonlinear characteristics of surface wave fields?
- What is the implication of these results on the estimation of wave-induced momentum flux?

WORK COMPLETED

We completed the data analysis of the wave-induced pressure/velocity field from the RASEX, and

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published the results [Hare et al., 1997]. We have completed investigation of the directional and nonlinear characteristics of surface wave fields from the RASEX and the MBL West Coast data. The results have been published in Karachintsev [1998], and will be submitted for publication in a refereed journal. We have initiated the similarity analysis of the wave-induced pressure/velocity field using the open ocean data from the MBL West Coast Experiment.

RESULTS

Our similarity analyses of the RASEX data demonstrate that, when compared to theory, simple extrapolation of measurements of the wave-induced pressure field from a fixed height above the surface may contribute to the uncertainty of measured momentum fluxes. In addition, our similarity relationship for the wave-induced vertical velocity field yields results that are consistent with previous laboratory studies. This suggests that the similarity hypothesis may be valid over a reasonably wide range of wind and wave conditions, as long as waves are not too steep and are aligned with wind.

In order to address the directionality and the nonlinearity of the wind-wave coupling processes, we have developed an algorithm of estimating the frequency-wavenumber wave height spectrum, by extending the Data Adaptive Spectral Estimator developed by our group [Hanson et al., 1997]. Our original algorithm assumes that all waves propagate at their own phase speeds determined by the dispersion relation, and seeks the most likely direction in which waves propagate. With our revised algorithm, waves are allowed to propagate at all speeds, and estimations are made for both the most likely propagation direction and the most likely propagation speed. This allows us to study the detailed dispersion characteristics of wave components. In Figures 1 we show an example of the frequency-wavenumber spectrum along the mean wind direction obtained from the MBL West Coast Experiment. Except near the dominant wave peak, the spectral peak at a given frequency is observed at lower wavenumbers than the dispersion relation throughout the observed frequency range. The bicoherence analysis of the same wave field is shown in Figure 2. The wave components from the peak frequency up to about 2 Hz are seen to be strongly phase-coupled with the dominant wave component. These results suggest that frequency wave spectra may be dominated by steep dominant waves and their bound harmonics, as predicted by Belcher and Vassilicos [1997], hence, they do not contain any information of shorter freely propagating waves.

IMPACT/APPLICATION

If the ocean wave frequency spectra are strongly influenced by the dominant waves and their bound harmonics, as demonstrated by our data analyses and also predicted by the theory of Belcher and Vassilicos [1997], our linear study of the coupled air-sea systems, as well as any linear analyses based on the temporal wave height data, requires caution in interpreting the results.

TRANSITIONS

Our directional wave spectral analyses have been incorporated by other MBL/ARI investigators for the study of atmospheric turbulence in the wave boundary layer.

RELATED PROJECTS

We have been participating in the Coastal Ocean Processes (CoOP) Air-Sea Gas Exchange Program of NSF. The first CoOP field experiment took place in conjunction with the MBL West Coast Experiment in 1995. The objective of our CoOP program is to study the effect of physical and chemical processes near the air-sea interface on the air-sea gas exchange in coastal waters.

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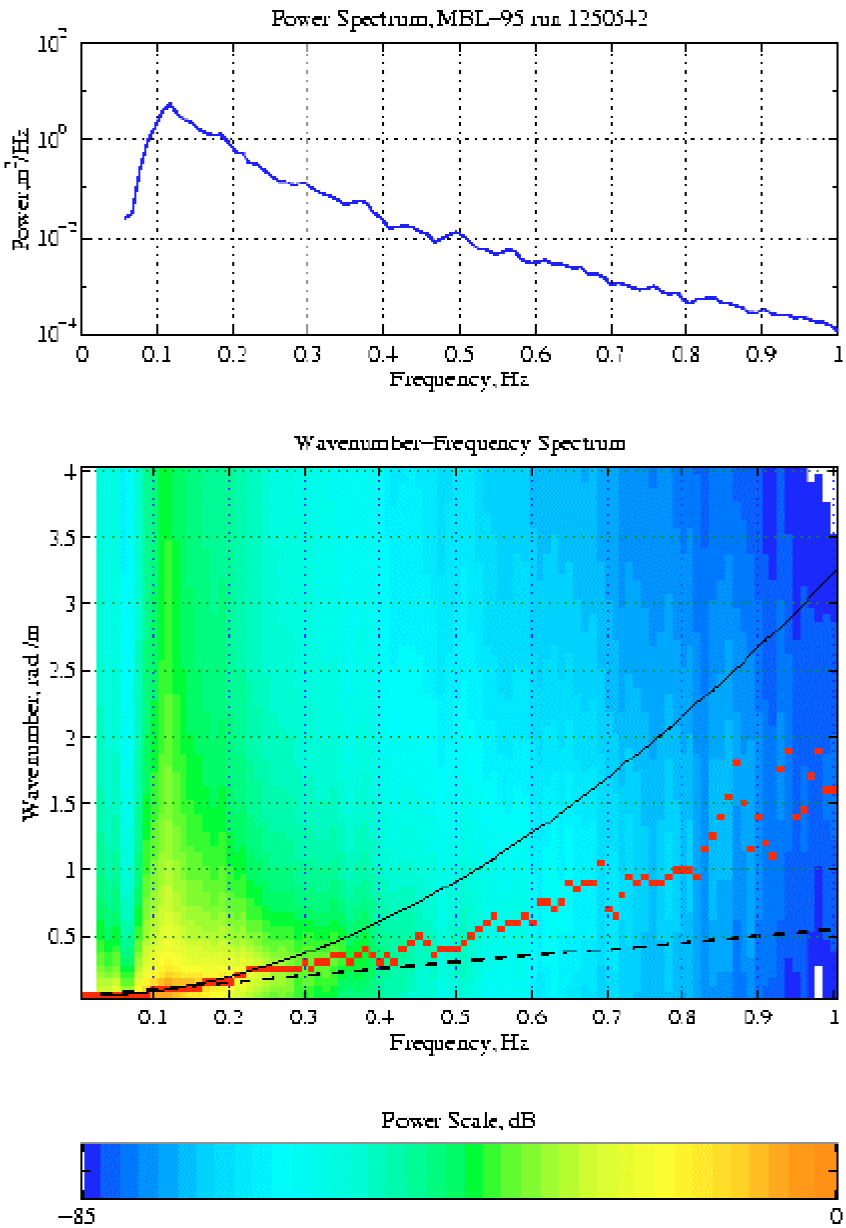

Figure 1. Frequency power spectrum (top) and wavenumber-frequency spectrum (bottom) from the MBL experiment. Run 1250542. Solid line corresponds to the linear dispersion relation. Dashed line corresponds to the propagation speed of dominant waves. Red squares indicate the spectral peak in wavenumber.

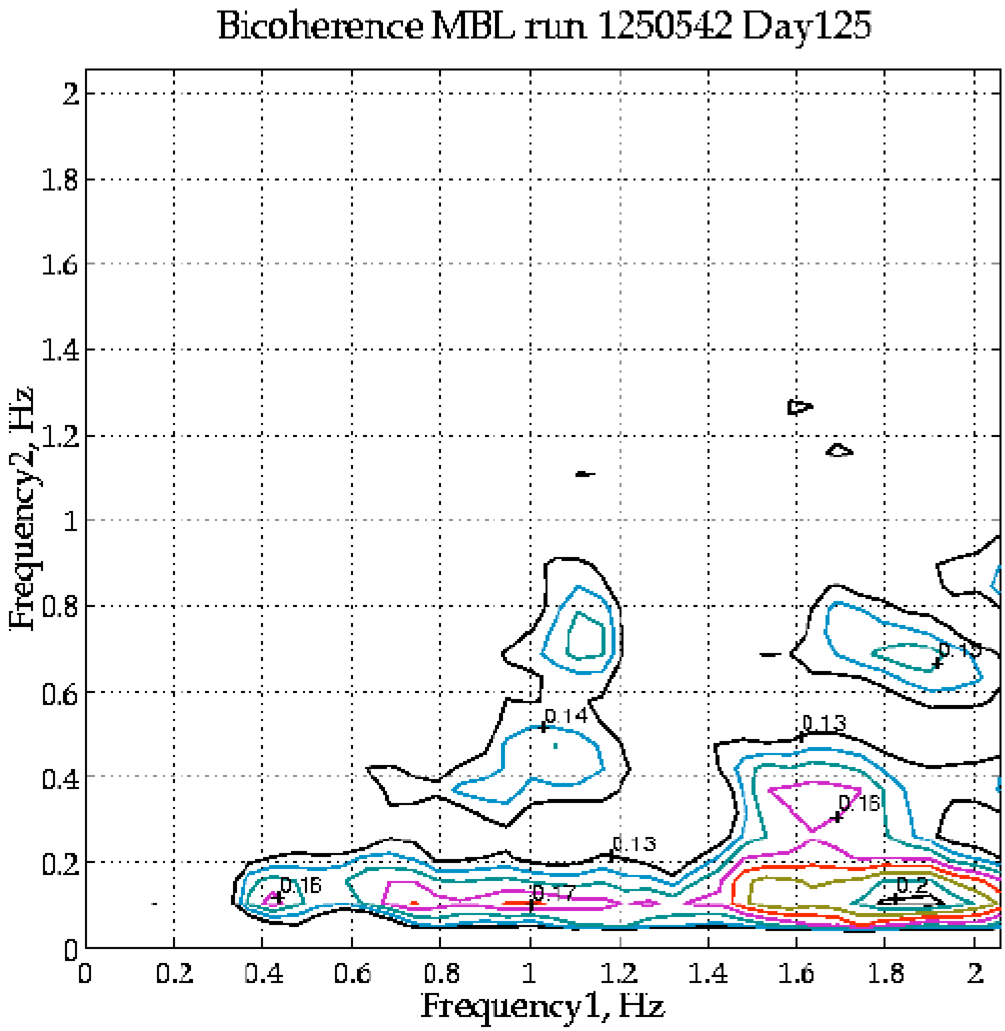

Figure 2. Bicoherence function from the MBL experiment. Run 1250542. Contour levels are every 0.02 of the bicoherence value.