P4.12 HOW DO WIND WAVES GROW?

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1. INTRODUCTION

The wind and waves measurements in the SWADE program introduced a new data collection practice, namely, that wind and waves were measured at the same resolution simultaneously. Previously, wind data were merely collected as hourly averages. The availability of simultaneous high-resolution wind and wave data has provided an unparalleled opportunity to directly examine detailed wind action on waves, especially during wave growth.

2. BACKGROUND

How do wind waves grow? It is a question that several generations of scientists have addressed. In addition to the early work of Jeffreys (1925) and Ursell's (1956) famous "nothing very satisfying" summary, modern conceptual perceptions of wind waves primarily stem from the theoretical conjectures of Phillips (1957), Miles (1957), and Hasselmann (1962). The current proliferation of numerical wave models is basically developed from these early theories. Numerous measurements of wave energy spectra with average wind speeds have been conducted for the validation and possible enhancement of the available models. Now with the latest SWADE measurements and the advancement of wavelet transforms, we are able to examine wind wave processes from new perspectives.

3. ANALYSIS AND RESULTS

One way of analyzing simultaneously recorded wind and wave measurements is through cross wavelet spectrum analysis (Liu, 1994). Figures 1 and 2 show a segment of the simultaneous wind speeds and wave time series data and their corresponding wavelet spectra. There is no obvious relationship between the two time series that can be readily deduced. However, if we consider the wavelet spectrum, a tract of high energy density contours appears in both spectra over the same frequency ranges and during the time when highest wave heights occurred in the wave time series. Qualitatively we might infer that wind and waves interact immediately during wave growth.

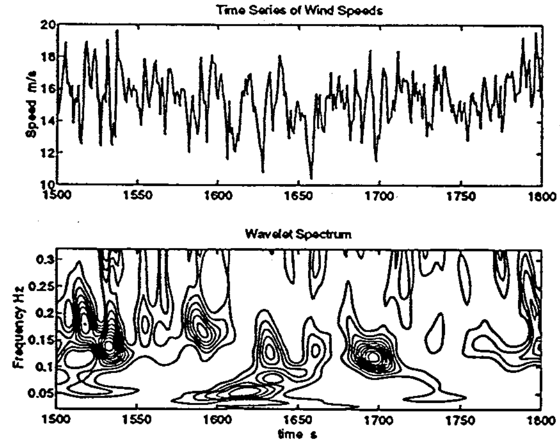

Figure 1. The time series of wind speeds and its respective wavelet spectrum.

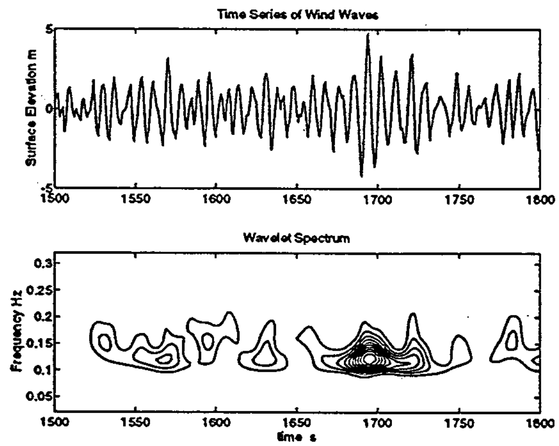

Figure 2. The time series of wind waves corresponding to the wind data of Figure 1 and its respective wavelet spectrum.

To see if we can verify this inference quantitatively, we calculate the cross wavelet spectrum and their corresponding wavelet coherence for the simultaneous wind and wave data. The results, expressed either in contour or three-dimensional plots, are rather intricate and perplexing. It is not at all clear what we can meanfully deduce. If, however, we plot the results for individual frequencies, we can see some interesting results. Figure 3, corresponding to the same data of Figures 1 and 2, is an example of what these plots can tell us. The five separate graphs in Figure 3 display, respectively from top down, the wavelet spectrum for wind, the wavelet spectrum for waves, the real part, the imaginary part, and the phase of wavelet coherence. All of the plots contain the three frequency components of 0.1131, 0.1199, and 0.127 hz for which the energy density is highest.

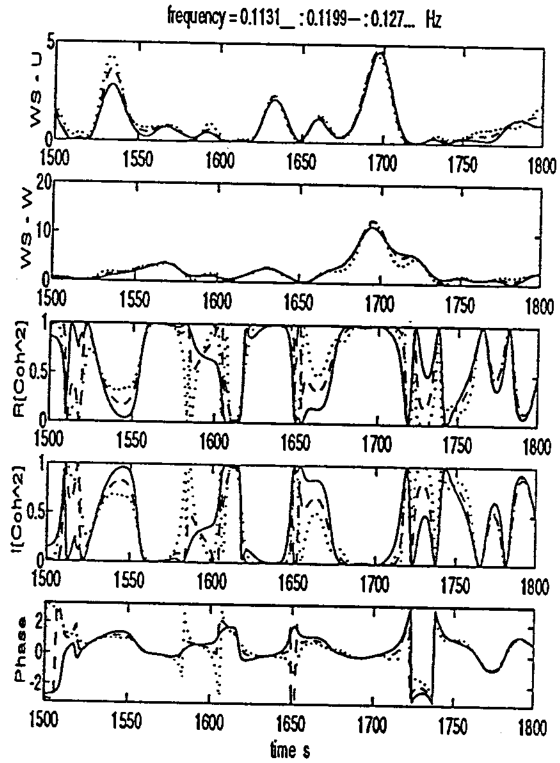

Figure 3. Plots of three peak-energy frequency components versus time. The five subgraphs from top down are, respectively, wavelet spectrum for wind speeds, wavelet spectrum for waves, the real part, the imaginary, and the phase of coherence.

Note that in Figure 2 there are five groups of waves that can be identified from the wavelet spectrum. In the second graph of Figure 3 in which energy densities increase and decrease with respect to time, only three stronger groups (i.e., at time marks 1570, 1630, and 1695) are reflected from the fluctations of these frequency components. The top graph of Figure 3 shows that the wavelet spectrum components for wind speeds exhibit similar, but more, energy fluctations with time. Some of the fluctuations correspond closely to those of the waves. By examining the bottom three graphs of Figure 3, it shows quite clearly that for the three wave groups identified with appreciable energy contents, the real part of their coherence is close to 1, their imaginary part close to 0, and their phase is also close to 0. Therefore, during wave growth, the frequency components for peak wave energy between wind and waves are inherently *in phase*. Wave groups constitute the basic elements of wind wave processes, and the wave growth are primarily taking place within the wave group.

4. CONCLUDING REMARKS

As the growth of wind waves is an extremely complicated process, the above results contribute still qualitatively toward an understanding of the nature of how do waves grow. While we are accustomed to correlate wave growth with "average" wind speeds, the results presented here clearly show that waves are in fact responding to wind speeds instantly. Further detailed studies may challenge or counter more familiar notions of wind waves. Using cross wavelet spectrum analysis not only introduces new data analysis techniques, it may also leads to new courses of exploration.

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GLERL Contribution No. 920.

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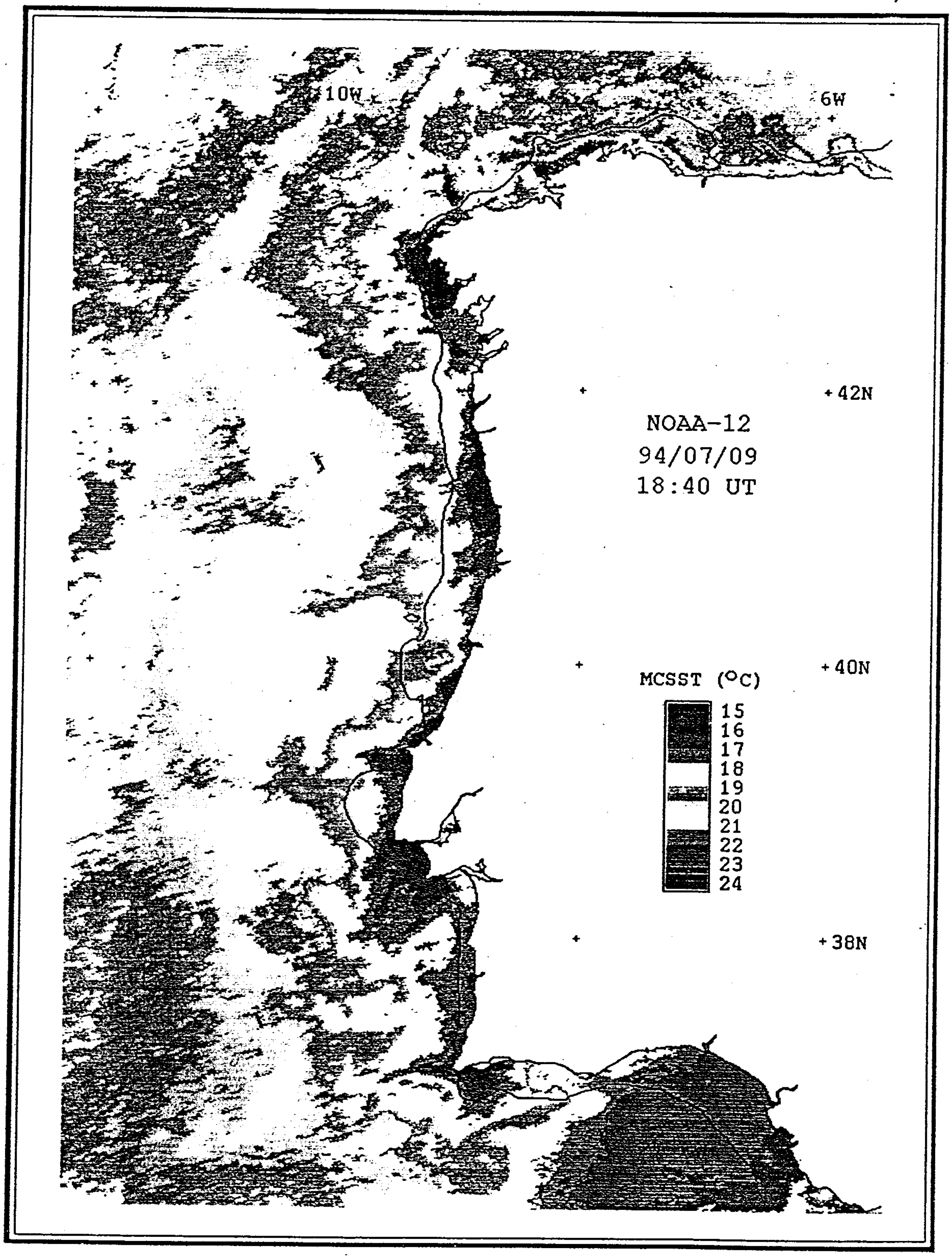

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