

On the Contribution of Swell to Sea Surface Phenomena—Part 2

Hisashi Mitsuyasu
Professor Emeritus, Kyushu University, Fukuoka, Japan

Yuichi Maeda
Saitama Prefectural Government, Saitama, Japan

ABSTRACT

This paper is a sequel to our previous paper of the same title (Mitsuyasu, 1997). In that paper we made a comprehensive review of our studies on the coexistent system of wind waves and swell, e.g., growth and decay of swell by wind, effects of swell on the attenuation of wind waves, the surface drift current and the microwave backscattering from the wind-wave surface. In this paper, on the basis of our recent new study (Maeda, 1990), we present more detailed discussions on 2 topics: The attenuation of wind waves by the following swell, and the growth of swell by the following wind. It is shown that the attenuation of wind waves by the following swell depends not only on the swell's steepness, but also on the ratio of the frequency of the swell to the spectral peak frequency of the wind waves. The attenuation mechanism proposed by Phillips and Banner (1974) and that by Masson (1993) show similar properties, but the observed effect of the frequency ratio is much stronger than the effects of those theoretical predictions. It is also shown that the measured growth rate of swell in the following wind is in good agreement with the empirical formula of Mitsuyasu and Honda (1982) in a region of large inverse wave age, while it approaches the empirical formula of Hsiao and Shemdin (1983) in a region of small inverse wave age. The measured growth rate in a region of large inverse wave age is roughly 2 times the theoretical value of Al-Zanaidi and Hui (1984) and half of the value determined recently by Donelan (1999). Finally we discuss the so-called u_s , similarity for the wind-induced growth of water waves.

INTRODUCTION

Recently the effect of swell on air-sea interaction phenomena has become a controversial issue; many studies are concerned with the attenuation of wind waves by swell, growth or decay of swell by wind, and the effect of swell on sea-surface roughness (Donelan, 1987; Mitsuyasu and Yoshida, 1991; Mason, 1993; Donelan, 1999; Drennan et al., 1999; Donelan and Dobson, 2001). The problem is important not only as it relates to dynamical processes at the air-sea boundary, but also for practical applications, such as wave forecasting.

As regards the attenuation of wind waves by swell, the phenomenon itself was found many years ago (Mitsuyasu, 1966), and the famous theory to explain the phenomenon was presented by Phillips and Banner (1974). However, several studies done later (e.g., Wright, 1976; Hatori et al., 1981; Sakai et al., 1994) presented results that did not support the theory of Phillips and Banner (1974). Recently, we also found a curious phenomenon: The wind waves did not attenuate by opposing swell (Mitsuyasu and Yoshida, 1989, 1991), while the Phillips and Banner theory (1974) predicts the attenuation of wind waves. On the other hand, Masson (1993) made a numerical computation of nonlinear coupling between swell and wind waves and showed that the nonlinear coupling causes the swell to grow at the expense of the short waves, but the coupling is negligible unless the frequencies of swell and wind waves are very close.

In order to make clear the controversial problem, in the present study, we first test the attenuation mechanisms proposed by Phillips and Banner (1974) and Masson (1993) by using the Maeda (1990) laboratory data for the following-wind case. Second, we study the growth of swell by following wind. In a sense, this problem is nothing but the problem of wind-induced growth of water waves, which has been studied, for example, by Mitsuyasu and Honda (1982) and recently by Kato et al. (2000). In these studies, however, the measurements were limited to the growth of relatively short waves (waves of large inverse wave ages) due to the small wind-wave tanks. On the other hand, Maeda (1990) measured the growth rate of longer waves by using a much larger wave tank, and his data contain the growth rate of waves in relatively small inverse wave ages. Thus the present data on the growth of water waves by wind will shed light on the wind-induced growth of water waves for relatively small or moderate inverse wave age as well as for large inverse wave age.

WIND AND WAVE DATA

In this study, we mainly use the wind and wave data presented by Maeda (1990). This paper is his master's thesis at Kyushu University, which concerns the dynamic process in the water surface where wind waves coexist with swell propagating in the direction of the wind. Since the paper is not commonly available, detailed descriptions of the experimental conditions appear below.

The experiment was carried out in a large wind-wave flume 2 m high (water depth: 1.2 m), 1.5 m wide and 54 m long. Kusaba and Masuda (1988) have given a detailed description of the flume. Waves were measured at fetches of 1 m, 5 m, 10 m, 20 m, 25 m, 30 m and 35 m by using capacitance-type wave gauges. Vertical wind profiles over the water surface, $U(z)$, were measured at fetches of 10 m, 20 m and 30 m by using a Pitot static tube.

Received July 5, 2002; revised manuscript received by the editors October 16, 2002. The original version (prior to the final revised manuscript) was presented at the Twelfth International Offshore and Polar Engineering Conference (ISOPE-2002), Kyushu, Japan, May 26–31, 2002.

KEY WORDS: Ocean wave, wind waves, swell, interaction between wind waves and swell, growth of water waves by wind.