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Reply*

Jin Wu

Department of Hydraulics and Ocean Engineering, National Cheng Kung University, Tainan, Taiwan

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ABSTRACT

1. Introduction

From data collected throughout the years, Monahan (2001) attempted to show that bubbles produced by breaking waves in saltwater were smaller in size but greater in number and had about the same total (air) volume as in freshwater. Our analyses (Wu 2000) indicated that both the bubble number and air volume were greater in saltwater but no apparent differences were found in bubble sizes. In other words, the debate is more concisely on the bubble size and void ratio; the latter is the total air content per unit water volume. Let us then look into quantitative results cited by Monahan on these two aspects.

a. Bubble size

As indicated by Monahan (2001), the measurement technique of bubbles had been improved with the passage of years from Monahan (1966) to Monahan et al. (1994). A comparison between size spectra of fresh- and saltwater bubbles was presented in Monahan and Zietlow (1969); see Fig. 1a, the data of which are actually from Monahan (1966). Another comparison is reproduced in Fig. 1b from Wang and Monahan (1995); these data are from Carey et al. (1993). Original presentations of these two comparisons cited by Monahan (2001) are preserved in Fig. 1 and later in Fig. 2. Differences are seen between fresh- and saltwater data presented in Fig. 1 over the small-radius side of the peak. This is primarily due to that particular data point masked with parentheses by Monahan and Zietlow at the bubble radius of about 83 μm. A sampling range of 152 μm was used by Monahan (1966) for the data presented in Fig. 1a. Such a large range is obviously too wide for the masked data point at the radius of 83 μm for saltwater bubbles, as well as the data point at the radius of 76 μm for freshwater bubbles. In other words, the data shown in Fig. 1a indicate that more bubbles were produced in saltwater; as for their sizes, let us move along.

Monahan (2001) continued to state, on the basis of data presented in Fig. 1b, that the mean bubble radius in freshwater was found by Wang and Monahan (1995) to be 2480 μm, and was reduced to 1132 μm in water with a salinity of 6 ‰, and to 320 μm with a salinity of 20 ‰. We see, however, quite distinctly in the figure that for all five cases with different salinities, size distributions of bubbles have their peaks at about the same radius. Moreover, even from a simple inspection of two curves in Fig. 1b for salinities of 0 and 6 ‰, their average radii can not have the above values stated by Monahan in his discussion. Furthermore, we question the size distribution curve for freshwater shown in Fig. 1b to have a second peak near the radius of about 225 μm. Such a feature was not observed in other studies (Wu 1981; Cartmill and Su 1993; Loewen et al. 1996), including also the set of data discussed by Monahan (2001) and shown in Fig. 1a. This then questions the freshwater data over large radii presented in Fig. 1b. All of these tend to indicate, as suggested in Wu (2000), that bubbles produced in water of different salinities appear to peak at, and to have the average size of, nearly the same radius as illustrated in Fig. 1b.

b. Void ratio

Monahan (2001) went further to state that Monahan et al. (1994) and Wang and Monahan (1995) had found that the peak void fractions in fresh- and saltwaters were remarkably similar just beneath the water surface in the bubble plume. Both studies actually derived their conclusions from the same set of data reproduced in Fig. 2 from Wang and Monahan (1995). The interest here is, of course, on the production phase represented by the initial rise and peak of data shown in the figure. As discussed in the previous section, we questioned the results for freshwater over large radii in Fig. 1b, and tend to accept the comparison over large radii shown in Fig. 1a. We see now that it is quite impossible to have nearly the same void ratio between 0 and 20 ‰ salinities over the production phase shown in Fig. 2 from their respective size distributions shown in Fig. 1. Again, inasmuch as we trust more the data trends shown in Figs. 1a and 1b for respectively small and large radii, we suspect the accuracy of Wang and Monahan's measurements of void ratio. Their instrument was extensively described in both papers (Monahan et al. 1994; Wang and Monahan 1995); its calibration, however, was not reported.

In summary, we agree with Monahan (2001) that further studies are needed to improve our understanding of the generation of bubble clouds during wave breaking, and welcome the opportunity in the commenting studies of Monahan et al. (1994) and Wang and Monahan (1995). Nonetheless, our earlier conclusion stands.

Finally, I am very grateful to Professor Edward Monahan for sharing with me throughout the years his extensive knowledge on whitecaps, bubbles, and spray, and for providing me the timely conference publications discussed herein.

REFERENCES

Carey W. M., J. W. Fitzgerald, E. C. Monahan, and Q. Wang, 1993: Measurements of the sound produced by a tipping trough with fresh and salt water. *J. Acoust. Soc. Amer.*, **93**, 3178–3192. Find this article online

Cartmill J. W., and M. Y. Su, 1993: Bubble size distribution under saltwater and freshwater breaking waves. *Dyn. Atmos. Oceans*, **20**, 25–31. Find this article online

Loewen M. R., M. A. O'Dor, and M. G. Skafel, 1996: Bubbles entrained by mechanically generated breaking waves. *J. Geophys. Res.*, **101**, 20759–20769. Find this article online

Monahan E. C., 1966: Sea spray and its relationship to low elevation wind speed. Ph.D. thesis, Massachusetts Institute of Technology, 175 pp.

Monahan E. C., 2001: Comments on “Bubbles produced by breaking waves in fresh and salt water.”. *J. Phys. Oceanogr.*, **31**, 1931–1932. Find this article online

Monahan E. C., and C. R. Zietlow, 1969: Laboratory comparisons of freshwater and salt-water whitecaps. *J. Geophys. Res.*, **74**, 6961–6966. Find this article online

Monahan E. C., Q. Wang, X. Wang, and M. B. Wilson, 1994: Air entrainment by breaking waves: A laboratory assessment. *Aeration Technol., ASME Fluids Eng. Div.*, **187**, 21–26.

Wang Q., and E. C. Monahan, 1995: The influence of salinity on the spectra of bubbles formed in breaking wave simulations. *Sea Surface Sound '94*, M. J. Buckingham and J. R. Potter, Eds., World Scientific, 312–319.

Wu J., 1981: Bubble populations and spectra in near-surface ocean: Summary and review of field measurements. *J. Geophys. Res.*, **86**, 457–463. Find this article online

Wu J., 2000: Bubbles produced by breaking waves in fresh and salt waters. *J. Phys. Oceanogr.*, **30**, 1809–1813. Find this article online

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Figures

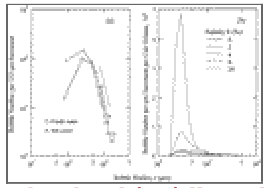

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FIG. 1. Bubble size spectra: (a) from Monahan (1966), reproduced from Monahan and Zietlow (1969), and (b) from Carey et al. (1993), reproduced from Wang and Monahan (1995).

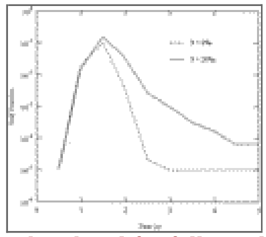

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FIG. 2. Evolution of integrated void fraction. This figure is reproduced from Wang and Monahan (1995)

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Corresponding author address: Dr. Jin Wu, Department of Hydraulics and Ocean Engineering, National Cheng Kung University, No. 1 Ta-Hsueh Rd., Tainan 701, Taiwan. E-mail: jinwu@mail.ncku.edu.tw

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