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Disturbance in the Air-Temperature Field Due to Persistent Bubble Bursting on the Water Surface

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Extended Abstract

Extreme ocean climate such as storm surge and high waves in winter is often caused by an intensive extratropical cyclone called ‘explosive cyclone’. Although an explosive cyclone is formed by the effects of the atmospheric baroclinicity, it is recently found that the heat supply from the ocean surface is essential for the rapid development [1]. The numerous bubbles are entrained in the ocean due to wave breaking. These bubbles rise to the sea surface and eventually burst to generate tiny sea spray, called film droplets. The film droplets fly and evaporate in the air to contribute to the air-sea heat transfer [2]. This study investigates how the bursting of the surface bubbles affects the air-temperature field above the water surface. We introduced the Background Oriented Schlieren (BOS) technique [3] for visualizing spatial distribution of the air temperature as well as refractive index of the air. The basic features of the temperature field disturbed by the bursting bubbles will be shown through the visual experiment.

The BOS technique enabled us to measure air-temperature distribution above the water surface where bubbles continuously burst. The water temperature was maintained at 30°C by a thermostat, and air bubbles were generated by an air-stone, to reproduce a mid-latitude ocean in a small tank. This experiment was conducted both on the still water surface without bubbles and on the water surface with bubbles, and the results were compared to examine the contribution of bubble bursting to heat transfer from the water surface to the air and a vertical profile of the temperature distribution was obtained by traversing a vertical shooting range from 6 cm to 30 cm from the water surface in 2 cm increments.

Process of heat transfer from water surface to the air was successfully visualized both areal and dynamic by BOS technique. While the refraction angle distribution is almost uniform in without bubble water surface case, the significant complex refraction angle distribution was observed in bubbling water case. It implies that the air near the water surface is greatly disturbed by the bursting of bubbles and that the air near the water surface is frequently renewed. Such air turbulence is caused by the air inside the bubble compressed by surface tension and released into the atmosphere when the bubble bursts, thereby disrupting the air at the water surface, and at same time, by the large amount of water droplets generated when the bubble bursts stirring the air. Thus, in still water surface condition, heat transfer is conducted slowly only by natural convection, but in bubbling water surface condition, forced convection is added and heat transfer is accelerated. Additionally, numerous water droplets cool the air by latent heat as they evaporate in the air. We successfully visualized a decrease in temperature of about 0.3°C around an evaporating levitating water droplet too. Thus, bubble bursting has a significant direct and indirect effect on heat transfer from water surface to the air. This effect appears permanently at very close to the water's surface, but becomes less frequent as distance increases, and is almost non-existent at 30 cm from the water's surface. Thus, bubbles accelerate heat transport near the water surface and alter thermal boundary conditions and are a factor in meteorological phenomena.

References

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