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A Comparison between Sea Surface Temperature Measured by an Infrared Radiation Thermometer and that by the Bucket Method*

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Abstract: As a part of the micro-meteorological observation over the sea, measurement was made of the vertical distributions of temperature in the atmosphere and water near the sea surface from an anchored buoy and the research vessel *Tansei-Maru*. The sea surface temperature measured by the bucket method was compared with that by a sea-borne infrared radiation thermometer. The result indicates no significant difference between them in average. In a few cases, however, the difference of several tenth of degree in centigrade were observed. The standard deviation of the temperature difference is found to be 0.31°C.

1. Introduction

Acurate measurements of temperature at the air-earth interface are required in the study of the vertical heat transport in the atmospheric boundary layer. This is particularly true for the study of heat exchange between air and sea because in general the vertical temperature gradient in the atmosphere near the sea surface is smaller than that near the ground surface.

One of the "standard" methods of measuring the sea surface temperature is to take a sample of water from the sea surface by means of a bucket and to measure its temperature with a thermometer. Obviously, it is not possible to obtain the real skin temperature of the sea surface by this method since the sample taken by the bucket will contain water from lower parts, too. We shall refer to the temperature measured by the bucket method as the bucket temperature. Recently an air-borne radiation thermometer has become widely used for quick serveys of sea surface temperature. In contrast to the bucket temperature, the temperature measured by an infrared radiation thermometer represents the temperature of the upper water layer of 20 microns thick, because 99% of the incident radiation is emitted by this layer (HINZPETER, 1967). In 1960, EWING and MCALISTER measured the long-wave infrared radiation from the top 0.1 mm of the evaporating ocean. They demonstrated the existence of a cool surface layer characterized by departures of as much as 0.6°C from the "surface temperature" found by conventional methods. Since then, several authors discussed the difference between the temperature at the ocean-air interface and that measured by conventional methods in conjunction with the thermal stratification in the uppermost layer of the sea (see, for example, HASSE, 1963 and SAUNDERS, 1967a).

This article reports the result of comparison of the bucket temperature with the temperature measured by a radiation thermometer. The measurement was made as a part of the programme of micrometeorological observations over the sea by the R. V. *Tansei-Maru* of the University of Tokyo (KT-67-17 cruise). The period of observation was from August 28 to August 31, 1967 and the site of observation was 4 km off the coast of the Sagami-Bay. The sea was approximately 100 meters deep and the ship was anchored at that location.

During the period of observation, the weather was mostly cloudy, with occasional light rain. Wind speed was 2~6.5 m/s at height of 4.4 meters above the sea surface with the direction of NNE~NW. There was swell of roughly 1

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meter high during the most of the time.

2. Measurement of bucket temperature

During the period of observation, the bucket temperature was measured with the standard procedure at several points along the shipside every hour except several hours in night time. Fig. 1 shows some examples of the distribution of temperature thus measured. The arrow in the figure indicates the direction of the current relative to the anchored ship. Fig. 1 (A) shows the only case where warm water used for cooling the engine was pouring from the outlets of the ship. The temperature of warm water at the right-side outlet was 35.3°C and that at the left-side was 28.0°C. This warm water was mixed rather quickly with the surrounding water and the temperature measured at a location separated about 8 meters from the outlet apeared to be the same as that of the ambient water.

In most cases, the distribution of bucket temperature along the shipside was uniform, with the departure of less than 0.1°C. Fig. 1(B) shows a typical example. In several occasions on August 29, however, relatively low temperature was observed at the downstream side of the ship (Fig. 1 (C)). The same tendency may be observed also in Fig. 1 (A).

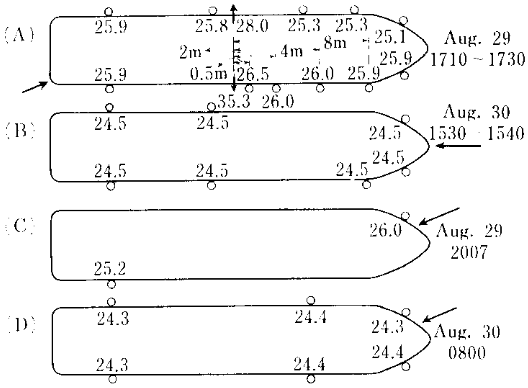

Fig. 1. Distributions of sea surface temperature along the shipside.

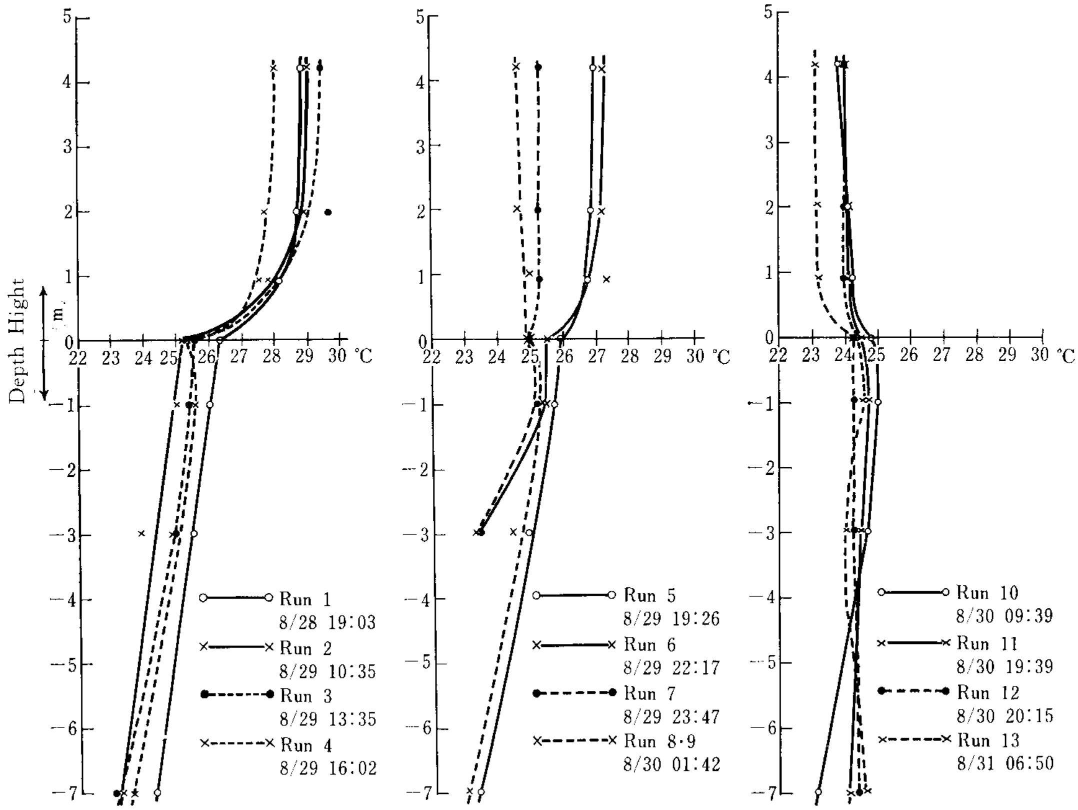

Fig. 2. Vertical distributions of temperature in the atmosphere and ocean near the interface.

This distribution was observed when the direction of the strong ocean current was not parallel to that of the ship*. However, it was not observed in a few cases on August 30 where apparently similar situations were present as far as the direction of the current relative to the ship was concerned [Fig. 1 (D)]. It is interesting to note that, as will be shown in Fig. 2, water temperature decreases with depth on August 29, while the vertical temperature gradient in the upper layer of the ocean vanished on August 30. It was speculated that the flow of water around the anchored ship was such that cool water from lower parts upwelled to the surface at the downstream side of the ship. However, no further efforts were made to seek an explanation of the occurence of the low temperature.

During the period of observations, the vertical distributions of temperature in the air and water near the sea surface were measured (Fig. 2). The mean air temperature was measured at heights of 0.9, 2.0 and 4.2 meters above the sea surface by thermistor thermometers mounted on the mast of a simple buoy. The buoy was also anchored, separated from the ship by the distance of approximately 100 meters. Signals from the sensors were transmitted to recorders aboard the ship through electrical cables. The water temperature was measured at depths of 1, 3 and 7 meters by thermistor probes from the ship.

In Fig. 2, the bucket temperature were plotted as the sea surface temperature. We observe that the bucket temperature appears to be consistent with the extrapolation of temperature profiles both in the air and ocean within the degree of vertical resolution considered here.

3. Temperature measured with a radiation thermometer

The infrared radiation thermometer we used is the Model PRT 14-313 made by Barnes Engineering Company of U. S. A. The model uses a thermistor bolometer as a detector of infrared radiation intensity with optical filters that limit the incoming radiation to 8~14 microns. The absolute temperature of the target is measured by comparing radiation emitted from it to a "blackbody" of known temperature, 55°C in this case. The field of view is 2° at half energy points according to the catalogue.

The radiation thermometer was mounted at the top of the shipboom which was projecting from the bow over the sea surface, 4 meters long and 5 meters high above the surface. The line of sight of the radiation thermometer made an angle of 20° from the vertical. According to HINZPETER (1967), temperature indicated by a radiation thermometer is independent of the inclination angle as far as it is less than about 30°. He also estimated from the theoretical consideration that temperature indicated by a radiation thermometer was 0.8°C lower than the true value in cloudless condition and 0.1°C lower in cloudy conditions. SAUNDERS (1967b) estimated that the departure from the blackbody temperature ranges from 0.4°C to 0.75°C under clear skies and is negligibly small under an overcast of low clouds. In our observation, it was almost always cloudy and hence no correction was made to our records.

Fig. 3 shows the diurnal variations of sea surface temperature measured by the radiation thermometer and by the bucket method. Fig. 4 shows the frequency distribution of ΔT where ΔT= bucket temperature − temperature indicated by the radiation thermometer. We observe that the frequency distribution takes the maximum at zero temperature difference. However, the temperature difference as much as 0.7°C were

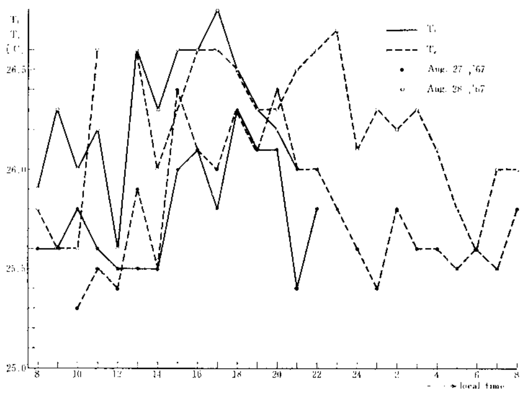

Fig. 3. Diurnal variations of sea surface temperature measured by the bucket method (T_b) and with a sea-borne infrared radiation thermometer (T_r).

* The direction and speed of the current was measured occasionally by tracking floating objects by a portable range finder.

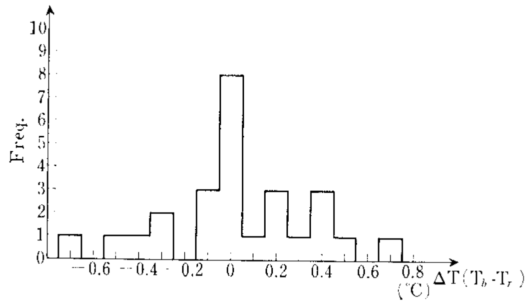

Fig. 4. Frequency distribution of difference between bucket temperature and temperature measured with a radiation thermometer.

observed during two days of observation. The standard deviation of ΔT is found to be 0.31°C. Furthermore, Fig. 4 indicates that the temperature measured by the radiation thermometer is not always lower than the bucket temperature.

An attempt was made to relate ΔT with various meteorological variables such as wind velocity or thermal stratification in the atmospheric boundary layer, wind stress estimated by the wind velocity profile or vertical heat flux estimated by the aerodynamic bulk method. We failed to find any significant correlations between them. After the present experiment, two of the co-authors of this paper made another observation from a marine tower, to extend the present study with an attempt to correlate the temperature difference with some meteorological and oceanographic conditions near the air-sea interface. The result will be published in a separate paper (KIMURA and MISAWA, 1969). The result of surveys of the distribution of sea surface temperature by sea-borne and air-borne radiation thermometers will also be published (OGURA, TAKEDA, KIMURA, TAIRA and NAKAI, 1969).

Acknowledgment

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赤外線放射温度計とバケツ法による表面水温の比較

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要旨　東京大学海洋研究所淡青丸による研究航海（KT-67-17）において，相模湾平塚沖約 4 km の地点（水深約 100 m）において，海面上の微気象観測が行なわれた．その一環として，特に赤外線放射温度計（バーンズ社，モデル PRT 14-313）による厚さ約 20 ミクロン程度の表面水層の温度と，いわゆるバケツ採水法による表面水温との比較を行なった．その結果によると，両者には平均として差は認められなかったが，時には 0.7°C の差が観測された．同時にブイにつけたサーミスター温度計により海面から 0.9，2.0 及び 4.2 m の高さの気温及び船の舷側から 1，3，7 m の深さの水温を測定し，この両者それぞれを外挿した表面水温とバケツ法によるそれとの比較も行なった．