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Wind-Swept Water Surface in Laboratory Cooled by Applying Heat

Allen H. Schooley
U.S. Naval Research Laboratory
Washington, D.C. 20390

This experiment was performed in a 40-cm x 45-cm x 20-cm basin containing 16 cm of water. Wind was directed toward the water at one corner by means of a 16-cm-diameter blower 12 cm above the surface. Near the center of the basin, a 0.25-mm-diameter thermistor bead with 0.025-mm-diameter leads was held at a depth of about 0.3 mm to 2 mm below the short-fetch wind waves, where the mean near-surface temperature, $T_s$, was measured and fed to a recorder. Air and bulkwater temperatures, $T_a$ and $T_w$, were read from digital thermometers about 15 cm above and 15 cm below the interface. The horizontal component of wind 5 cm above the interface was found to be 4.3 m sec$^{-1}$, which extrapolates to an equivalent of about $U_a = 7.1$ m sec$^{-1}$ at 10 m. Heat from a 215-watt lamp was directed down 27 cm from above the water surface. A Sauberer-Dirmhirn (Schooley 1969) radiation-balance probe was used to measure the net radiation (0.3µ to 60µ) entering and leaving the water, $Q_n$, in ly min$^{-1}$ (cal cm$^{-2}$ min$^{-1}$). Relative humidity, 36%, was measured near the water surface using a psychrometer.

In Fig. 1, $Q_n$ is shown to reach a maximum of $+1.45$ ly min$^{-1}$ (into the water) when the heat lamp was on for one minute. With everything else held constant, $T_s$ reached a mean minimum of 21.1°C. When the lamp was turned off, $Q_n = +0.12$ ly min$^{-1}$ and $T_s$ reached a mean maximum of 21.9°C. This unexpected result must have been caused by the interaction of $Q_n$, loss of heat by evaporation, $Q_e$, turbulent heat exchange and molecular conduction in air near and at the water surface, $Q_a$, and turbulent conduction and molecular heat exchange in the water near the surface, $Q_w$. For a steady state, the sum of these four $Q$'s, with direction of heat flow of each considered, should equal essentially zero.

At the upper left in Fig. 1 is the result of a simple test to directly check the polarity of the mean near-surface temperature sensor. A warm finger, com-

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Figure 1. Response of near-surface water temperature ($T_s$) in a wind-swept laboratory basin when heat from a lamp is turned on and off at minute intervals. $T_s$ decreases when the heat is on and increases when it is off. $Q_n$ is net visible and infrared radiation impinging on the surface when the heat is turned on and off.

pared to the water, was placed underneath and near the sensor. The temperature recorder immediately went offscale positive to the right. When the first finger skin began to cool, a second finger was used, and finally a third finger. These show in the record. When all fingers were removed, the normal temperature pattern was re-established. For practical reasons, the $Q_n$ sensor was not held in place during this last operation.

A check was made of changes in the near-surface temperature difference, $\Delta T_s$, when the heat lamp was turned on and off at one-minute intervals. This was done by devising a delicate thermopile with a 2-mm vertical separation. It was placed as near to the wind-driven surface as was possible without breaking the water surface. This experiment also indicated that the near-surface temperature was lower when the heat lamp was on and higher when it was turned off.

These experiments imply that there may be conditions on the sea where the surface may be warmer under a cloud shadow than when it is in direct sunlight.
REFERENCE

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1969. Radiation measurements at sea. J. geophys. Res., 74(4): 958–961. (This reference gives a brief description of the commercially available Sauberer-Dirmhirn Radiation Balance Probe. In recent personal correspondence, Professor Inge Dirmhirn has indicated that the untimely death of Dr. Sauberer resulted in an indefinite delay in producing a publication about their instrument, which has been widely used for several years.)