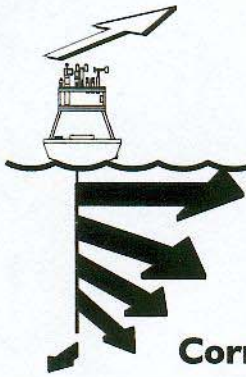


Woods Hole Oceanographic Institution
Upper Ocean Processes Group
Technical Note



Correcting Air Temperature for Solar Radiative Heating of Radiation Shields

Accurate measurements of air temperature above the sea surface are vital to the accurate estimation of sensible and latent heat fluxes between the ocean and atmosphere. One of the difficulties in measuring air temperature is the heating of the thermometer due to exposure to solar radiation. A simple solution to this problem is to mount a radiation shield around the thermometer to shade it from the sun. This approach is ineffective in low winds, however, since the radiation shield is also heated and without high winds to sufficiently cool the shield, the thermometer will measure the temperature of the heated shield and not the true air temperature. Another solution to this problem is to use a pump or fan to aspirate the thermometer, creating a cooling effect similar to the wind. This solution is preferable but in operational situations where power consumption must be kept low, such as on a mooring, the feasibility of this option depends on the duration of the deployment.

Both a shielded and an aspirated platinum resistance thermometer were deployed along with a suite of meteorological and oceanographic instrumentation on a 3m discus buoy at 15° 30'N, 61° 30'E during the Arabian Sea Mixed Layer Dynamics Experiment. The experiment was conducted in two sequential moorings at the same location, the first of which was deployed from 15 October 1994 to

20 April 1995 (Arab 1) and the second from 22 April to 20 October 1995 (Arab 2). The pump on the aspirated thermometer operated for 59 and 51 days during Arab 1 and Arab 2, respectively, before depleting its limited power supply. The aspirated thermometer was included in the design of this experiment to provide accurate air temperatures under expected low wind

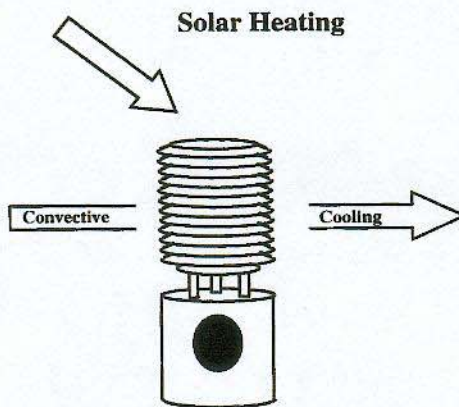


Figure 1: The two major processes of heating and cooling affecting the shielded thermometer.

conditions early in the deployment. Due to the availability of simultaneous aspirated and shielded temperature measurements, a correction for the shielded thermometer was sought to account for the heating and cooling of the radiation shield. A simple model which predicted the heating and cooling of the shielded thermometer was developed based on a comparison of the aspirated and non-aspirated temperature measurements. This model accounted for the major heating and cooling processes affecting the shielded thermometer

(depicted in Figure 1) based only on the incoming solar radiation, wind speed, wind direction relative to the buoy and sun angles.

Solar heating of the radiation shield was estimated as the product of the incoming shortwave radiation (measured on the mooring by a pyranometer) and the surface area exposed to the sun (a function of the sun's elevation angle and the shield geometry). Convective cooling is the rate at which the shield was cooled due to air flow over it and was estimated using the difference between the shielded and aspirated temperatures, the surface area of the shield and the convective heat transfer coefficient. Since the convective heat transfer coefficient is the only unknown in the model and since this coefficient is conceptually related to wind speed, a function for the convective heat transfer coefficient was determined based on the observed wind speed. Solar shading and wind blocking by other instruments on the buoy were incorporated in the model with reasonable success.

During the first 59 days of Arab 1, a correction based on the model reduced the average absolute difference between the shielded and aspirated thermometer by 0.20°C or 60%. The average absolute difference between the best available sensible heat flux measurement (the sensible heat flux computed using the aspirated temperature) and the sensible heat flux computed from the shielded air temperature was re-

duced by 1.65 W m^{-2} or 60% while the latent heat flux was reduced by 1.18 W m^{-2} or 35%. The air temperatures and corresponding sensible and latent heat fluxes for the uncorrected shielded, aspirated and corrected shielded time series are shown for a 3 day period during Arab 1 in Figure 2. This period was characterized by moderate winds

($4 - 6 \text{ m s}^{-1}$) and strong insolation.

While this correction seems to reduce large solar heating errors, there are a few factors or processes that are not taken into account. The correction depicted in Figure 2 does not incorporate the complex geometry of the shield, but simply assumes that heat transfer is occurring over a perfect cylinder. The ventilated design of the shield is difficult to simulate in a physical model and will certainly allow more convective cooling when compared to the perfect cylinder. Another difficult factor to correct

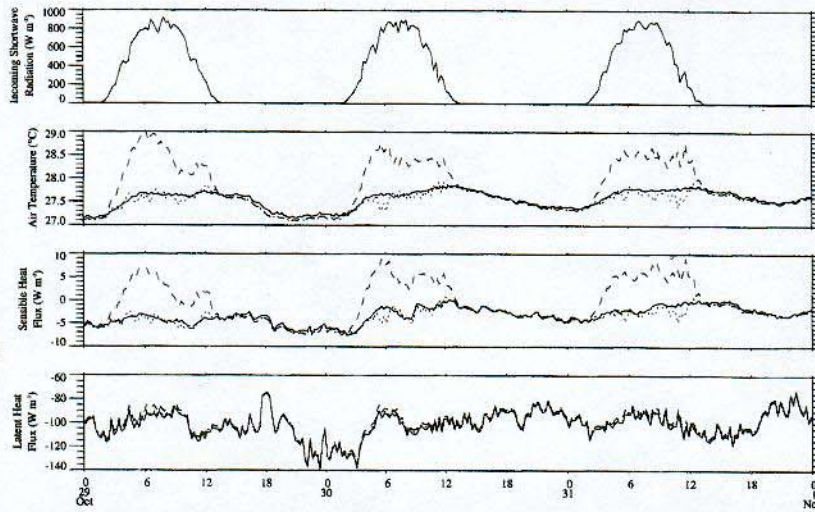


Figure 2. Incoming short-wave radiation (W m^{-2}), air temperatures ($^{\circ}\text{C}$), sensible and latent heat fluxes (W m^{-2}) for 29 - 31 October 1994 during the Arabian Sea Mixed Layer Dynamics Experiment. Aspirated (solid), uncorrected shielded (dashed) and corrected shielded (dotted) air temperatures and corresponding sensible and latent heat fluxes are shown.

is the shading of the shielded thermometer by objects around it. Shading is incorporated in the model only as a function of solar azimuth angle relative to the buoy while shading is clearly a function of both the solar azimuth and solar elevation. A correction based on these two sun angles is very difficult to determine and implement. The approach adopted in the model is only a partial solution. Directed experiments to measure the effects of the ventilated geometry and shading are possible,

however the preferred solution would be to develop a low power aspirated thermometer to replace the shielded thermometer for the entire duration of a mooring. Presently, the corrections applied to the shielded temperatures during the Arabian Sea experiment reduce the errors due to solar heating, thereby improving the estimation of sensible and latent heat fluxes.

ACKNOWLEDGMENTS:

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