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Humidity Effects and Sea Salt Contamination of Atmospheric Temperature Sensors

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ABSTRACT

Microthermal sensors contaminated by salt aerosol droplets are subject to erroneous temperature fluctuations caused by water vapor exchange in response to fluctuations in humidity. The effect was studied by comparing the values of mean-square temperature fluctuations indicated by contaminated and clean sensors. The effect was negligible for ambient relative humidities above 85%, primarily due to the lack of humidity fluctuations. The errors were significantly diminished by frequent washing of the sensors.

1. Introduction

Very fine resistance wires (called microthermal sensors) are often used to measure high-frequency temperature fluctuations in the atmosphere. In the atmospheric boundary layer over the ocean these measurements are degraded by the buildup of hydroscopic sea-salt aerosol droplets on the wires (Schacher and Fairall, 1977). One category of measurement degradation is caused by artificial temperature changes sensed by the wires due to the absorbing or releasing of water vapor by the salt droplets in response to fluctuations in relative humidity (Schmitt *et al.*, 1978). The buildup of salt droplets also causes a loss of sensor frequency response, a subject dealt with in another paper (Schacher and Fairall, 1979). This note is a quantification of the errors caused by the salt-humidity effect (based on shipboard measurements) and a partial solution to the problem. The methods used were an analysis of measured values of mean temperature fluctuations from clean and contaminated sensors.

2. Instrumentation

The sensors used in this experiment were Thermo-Systems Model 1210 probes with 2.5-μm diameter platinum wire. The wires are approximately 1.5 mm long with a nominal resistance of 50 Ω. The probes were employed in pairs using the two sensor (see Section 3) method where the temperature difference (ΔT) between the sensors was measured with an ac wheatstone bridge. The fluctuations in ΔT (sensed as changes in resistance) cause fluctuations in the bridge balance output voltage (V') given by

$$V' = \alpha GBR\Delta T, \qquad (1)$$

where R is the sensor resistance, B the bridge sensitivity (20 V Ω^{-1}), G the product of amplifier gains and α the resistance temperature coefficient of the platinum sensors (0.0036 K^{-1}). The voltage fluctuations are fed to an rms module with a time constant (or integration time) of 100 s and then output to a strip chart recorder. The strip chart records are usually reduced to half-hour average values. The rms voltage is then converted to ΔT_{rms} using Eq. 1.

3. Theoretical considerations

Given two temperature sensors a distance d apart, then the mean square temperature difference can be written (Lumley and Panofsky, 1964)

$$(\Delta T_{\mathrm{rms}})^2 = \langle \Delta T^2 \rangle = C_T{}^2 d^{\frac{2}{3}}, \qquad (2)$$

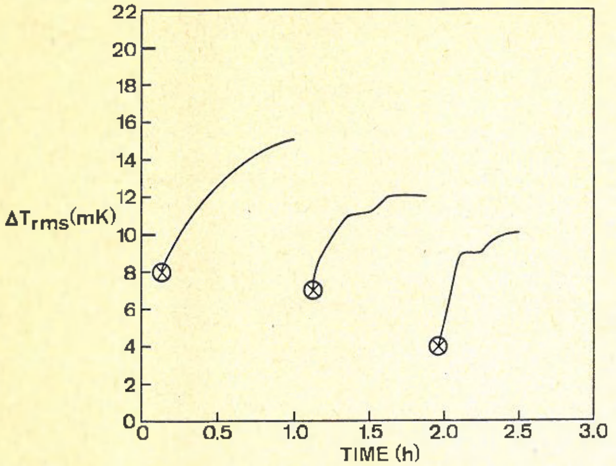

FIG. 1. Strip chart record of rms temperature difference fluctuations versus time. ⊗'s designate washing of the wires.

where d falls within the inertial subrange of isotropic turbulence and C_T^2 is the temperature structure function parameter. This quantity is related to the one-dimensional temperature Fourier power spectrum

$$\phi_{TT}(k)=0.25C_T^2k^{-5/3}, \tag{3}$$

where k is the one-dimensional wavenumber magnitude. Given the probe spacing (d = 0.3 m for this data) and the measurements described by Eq. (1) we can calculate C_T^2. However, the calculation of C_T^2 is subject to errors due to the influence of the sea-salt contamination on the measured values of ΔT_{rms}.

4. Results

In order to illustrate the magnitude of the salt effect and the time scales involved, we have reproduced a strip chart record (Fig. 1) of the rms temperature difference for a pair of wires washed clean of salt three times in a period of 2.5 h. Note that the signal increases steadily immediately after washing before gradually leveling off. Since the clean ΔT_{rms} values were about half the contaminated values we would expect the C_T^2 values calculated from the contaminated wires to be about four times the correct value.

In an effort to examine the salt effect, the resistance wires were systematically washed or changed at roughly 1 h intervals during a recent experiment (designated CEWCOM-78). The wires were washed by spraying with a fine mist of water followed by acetone or alcohol. Mean ratios of $(\Delta T_{\mathrm{rms}})^2$ immediately before and after washing versus relative humidity (RH) appear in Fig. 2. We observed that ΔT_{rms} values from contaminated wires are larger for an RH range from 60–85%, only. Presumably, the effect is diminished at RH above 85% because humidity fluctuations are less intense due to the small RH gradient. Their effect, as described, is within the system accuracy. Presumably, the effect is diminished at RH below 60% because the salt nuclei attached to the wires are not activated to form droplets (Fitzgerald, 1975); hence, humidity fluctuations cause less significant absorption or evaporation.

As a word of caution, it should be noted that these results apply to wires that have been washed at 1 h intervals and therefore are only lightly contaminated. An examination of earlier data from sensors exposed to marine aerosols for several days suggests that heavily contaminated wires are subject to erroneous readings in all humidity regions. Laboratory experiments (Schacher and Fairall, 1979) have shown that an aerosol droplet layer several wire diameters thick will lead to sufficient loss of frequency response to affect C_T measurements. Since the droplet size increases with relative humidity [Fitzgerald (1975) indicates

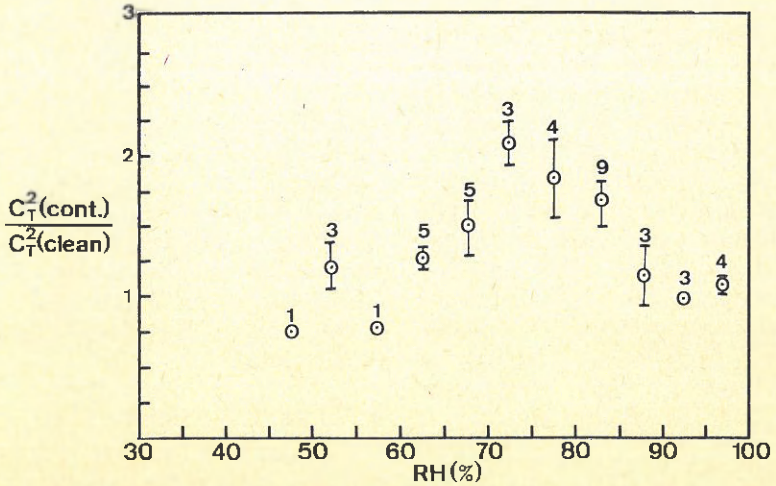

FIG. 2. The ratio of mean-square temperature difference measurements with contaminated sensors before and after cleaning or replacement versus ambient relative humidity.

that the majority of the increase occurs above a relative humidity of 95%], one anticipates that this effect will be most severe at high relative humidities.

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