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WHEN MEASUREMENTS MATTER

ClimaVUE™50—Correction of air temperature measurements from a radiation-exposed sensor

Introduction

Despite its seeming simplicity, air temperature is one of the most difficult environmental parameters to measure accurately. The current best practice involves housing the air temperature sensor in a radiation shield that is either passively ventilated or actively aspirated. Due to design constraints, the air temperature sensor in the ClimaVUE 50 all-in-one weather sensor cannot be fully shielded from solar radiation. However, since the ClimaVUE 50 measures wind speed and solar radiation, which are primary factors affecting the accuracy of the air temperature measurement, correction is possible.

Problem

The air temperature sensor on the ClimaVUE 50 is partially exposed to solar radiation, which may result in large air temperature (T_{air}) errors. Uncorrected measurements showed errors ranging to 3 °C when compared to measurements made in a state-of-the-art aspirated radiation shield.

Opportunity

The ClimaVUE 50 measures wind speed and solar radiation and uses those measurements in a simple energy balance calculation to correct the T_{air} measurement. After correction, error decreased to < 0.5 °C and yielded better accuracy than commonly used passive ventilation radiation shields.

Theory

The energy balance of the thermometer has been re-arranged below to correct for errors due to solar radiation.

$$T_{air} = T_{measured} - \left(\frac{\alpha_s S_t}{c_p \, k \sqrt{\frac{u}{d}}} \right) \quad \text{(Eq. 1)}$$

Where,

- α_s = absorptivity of temperature sensor to solar radiation (unitless)
- S_t = total incoming shortwave radiation (W m^{-2})
- c_p = specific heat of air (J mol^{-1} C^{-1})
- k = constant describing boundary layer heat conductance
- u = wind speed (m s^{-1})
- d = characteristic dimension of temperature sensor (m)

Experiment

An Apogee TS-100 aspirated air temperature sensor was chosen as the reference standard for T_{air}. The ClimaVUE 50 and Davis instruments air temperature sensor in non-aspirated, louvered radiation shield were co-located with the TS-100. A Davis sensor and radiation shield were included to compare ClimaVUE 50 performance to a typical T_{air} measurement. Five-minute averaged data was taken over a five day period of variably cloudy conditions in late summer 2015. The α_s and k from Equation 1 were used as fitting parameters to minimize error in T_{air} for the ClimaVUE 50 correction.

Results

The simple energy balance approach worked well to correct air temperature from a partially radiation exposed sensor (Figure 1).

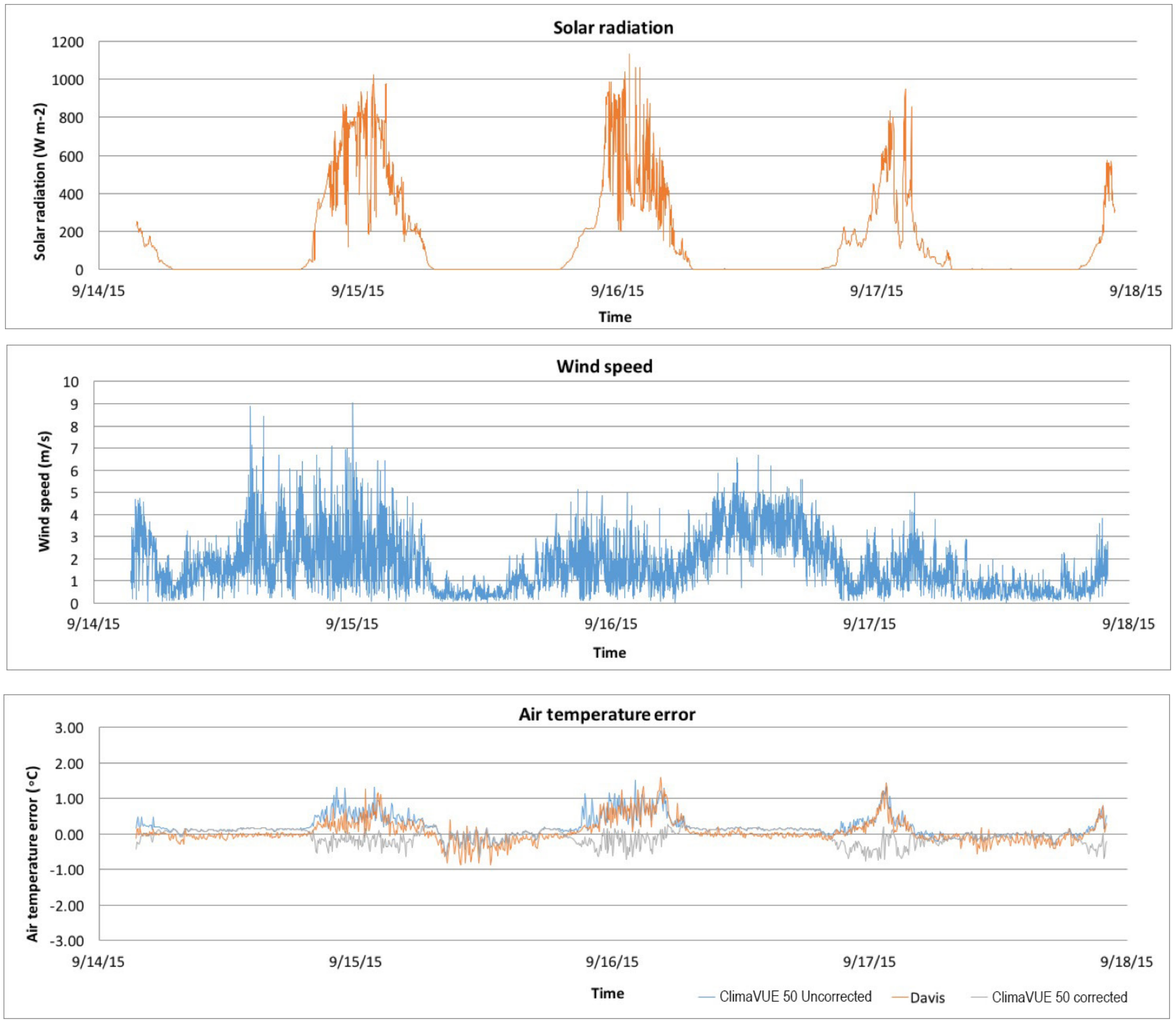

Figure 1. Environmental conditions and air temperature error ($T_{measured} – T_{TS-100}$) for the two air temperature sensors under evaluation

Discussion

The ClimaVUE 50 uses the wind and solar radiation measurements to correct its unshielded air temperature measurement with a resulting error of less than ±0.5 °C at the 95% confidence level. This is better than the typical radiation-shielded air temperature measurement error of ±0.7 °C (Table 1).

(All units °C)	ClimaVUE 50 uncorrected	Non-aspirated	ClimaVUE 50 corrected
Average error (bias)	0.20	0.07	–0.06
95% confidence interval	0.60	0.66	0.42
Maximum positive error	1.51	1.58	0.36
Maximum negative error	–0.66	–0.87	–0.77

Table 1. Summary statistics for air temperature measurements for two sensors under evaluation