REDUCTION OF AIR TEMPERATURE MEASUREMENT ERRORS BY A NEW MEASURING SYSTEM

Konrad Miegel * and Joachim Pätz **

* University of Rostock, Professorship Hydrology and Applied Meteorology
Universitätsplatz 1, 18051 Rostock, Germany
Phone: +49 381 / 498 3660
Fax: +49 381 / 498 3462
Email: konrad.miegel@uni-rostock.de and office.anemometerbau.de

** Anemometerbau GmbH Rostock
Drostenstraße 22 a, 18147 Rostock, Germany
Phone: +49 381 699152
Email: office@anenometerbau.de

ABSTRACT

The accuracy of temperature measurements suffers from the so-called radiation error. Strategies to minimize this error are reflecting equipment surfaces, ventilation and small size sensors. In spite of such measuring devices like radiation shield and forced ventilation the temperature measurement by modern systems remains problematical. Partly new error sources result from new technical solutions. Examples are imprecise sensors, disadvantageous positioning of sensors, influence of solar radiation at low sun elevation, ground-reflected radiation and long-wave surface radiation, warming by the ventilator motor, release of heat by condensation during clear nights and heat conduction through sensor cables or other elements. The aim of the contribution is to introduce in a new equipment to measure the temperature eliminating such error sources. By this system external influences of radiation are shielded. A novel ventilation system makes sure that the sensor temperature is equal to air temperature. Moreover, heat conduction through elements of the apparatus is avoided. This temperature measuring system is integrated in a climate station, which is energy self-sufficient. With respective specific modifications it can be used in several climate zones.

Figure 1:

Radiation protection enclosure (RPE)

After 150 years of climate record must be noted that climate data has still inaccuracies that complicate the detection of climate changes. This concern, inter alia, the measurement of air temperature, which accuracy suffers despite all the measures and improvements under the so-called radiation error suffers. Evidence of global warming is therefore fraught with uncertainty.

Strategies to reduce the radiation error are protective housing with reflective housing surface and the ventilation and small sizes of the sensor. Despite appropriate devices such as slats enclosures and active ventilation, the temperature measurement remains problematic even for newer measurement systems. Some of these have new sources of error. These include: inaccuracies and incorrect positioning of the sensors; radiation or thermal interference in sun is low, from the lower half space and the fan motor; release of heat of condensation at nocturnal cooling; heat conduction on component and sensor cable.

The reasons for inaccurate temperature records with ground-based stations are not only in the sensory or in some cases also the choice of the stations location, but also in an insufficient protection of the temperature sensors against radiation-induced effects. It is assumed that this is not a country-specific problem, but rather a worldwide cause for more or less erroneous temperature measurements.

This paper presents a novel radiation protection enclosure (RPE), which has been developed by the company Anemometerbau GmbH in collaboration with the University of Rostock and through which the fault effects can be largely eliminated. The Anemometerbau GmbH has been manufacturing innovative products for meteorology since 1875. Due to the RPE it is possible to largely shield temperature sensors in ground-based stations from external radiation effects. It is also combined with an innovative ventilation system. The measurement data of the high-precision temperature sensor can be recorded by a single-channel data logger, compared with the characteristic curve stored internally and will be sent to the central data logger.

The RPE consists of multiple interlocking positioned barrels which are aerodynamically completely separated. An air flow system with radiation protection chamber and aperture prevents the measuring chamber being penetrated by radiation and the flowing air from being swirled by the radiation protection elements. The radiation shield is positioned so that no side of entering (from above and below as well as laterally) radiation into the interior of the measuring system and influences the sensor in the measuring chamber. By shielding the sensor from nocturnal cooling and the resulting condensation of water vapor, thermal influence can be prevented.

The two outer profiles are equipped with a passive ventilation system that takes advantage of the so-called chimney effect. By an optimal-controlled, secondary aeration in the measuring chamber, it is also guaranteed that the sensor has the same temperature as the ambient air. This additional secondary forced ventilation is controlled by a flow sensor which is positioned in the measuring chamber and controls the air flow velocity therein. With sufficient passive circulation due to corresponding wind speeds the fan drive is not activated. If the air flow velocity in the housing is too low, the additional ventilation will be activated and controlled by the fan drive.

The use of this novel measurement system for the air temperature is in principle possible even in warm climates such as in tropical, subtropical and desert areas, as well at extremely low temperatures, such as in polar and sub-polar regions or high mountain regions. However, this requires further modifications of the radiation protective enclosure with which these special conditions will be taken into account in each case.

All the companies which new developments are to be compared structurally with the English weather shelter (EWS). This is also reflected in the measurement results (see Table 1). Our developed RPE is not comparable to the EWS and therefore represents a new approach and in combination with a highly accurate sensor (measurement precision 1/100 ° C) it goes far beyond the WMO requirements.

Table 1: Comparison of Stevenson hut with a modern round slats hut and the new RPE

Stevenson Hut	round slats hut	radiation protection enclosure (RPE)
can be made of wood, metal or plastic	can be made of wood, metal or plastic	consists of highly polished metal, insulation and plastic
ventilated or unventilated designs, uncontrolled flow to the sensor	ventilated or unventilated designs, uncontrolled flow to the sensor	Sensor is located in a measuring chamber with controlled flow velocity
Flow direction and flow velocity at the sensor is constantly influenced by the horizontal wind speed	Flow direction and flow velocity at the sensor is constantly influenced by the horizontal wind speed	Flow direction and flow velocity at the sensor are not influenced
the flowing gas can interact several times with the ribs of the cap, the fan motor and the sensor	the flowing gas can interact several times with the ribs of the cap, the fan motor and the sensor	driven by the secondary flow in the sewer system, the gas flows only once through the measuring chamber
a uniform vertical or horizontal flow velocity is not possible in the system	a uniform vertical or horizontal flow velocity is not possible in the system	a uniform vertical or horizontal flow velocity in the measuring chamber is given
Sensors are affected by the housing roof and the heat radiation of the motor	Sensors are affected by the housing roof and the heat radiation of the motor	Sensors can't be influenced by the heat radiation from the housing and of the motor
thermal separation of slats, roof and sensor is not possible	a thermal separation of the cap, slats, fan motor and sensor is not possible	thermal horizontal and vertical separation of the sensor is given
inadequate protection against indirect radiation	inadequate protection against indirect radiation	Radiation protection against direct and indirect radiation is given
Sensor is influenced by indirect and direct scatter radiation	Sensor is influenced by indirect and direct scatter radiation	Sensor can't be influenced by indirect and direct scatter radiation
The measurement result is influenced by the positioning of the sensor and the cable	The measurement result is influenced by the positioning of the sensor and the cable	any impact of this kind

management arm	management arm	
Sensor is influenced by the position of the sun in the enclosure	Sensor is influenced by the position of the sun in the enclosure	Sensor not be influenced by the horizontal and vertical radiation in the RPE
Sensor cable is not integrated in the system, thereby the cable can be heated by radiation and the sensor can be fed heat via the cable	Sensor cable is not integrated in the system, thereby the cable can be heated by radiation and the sensor can be fed heat via the cable	Besides the sensor, sufficient shares of the cable are integrated into the RPE
the sensor is influenced by the condensation heat at nocturnal cooling of the housing	the sensor is influenced by the condensation heat at nocturnal cooling of the housing partially	the sensor is not affected by condensation heat at nocturnal cooling of the housing
Measurement result is influenced by fixed precipitation (snow)	Measurement result is influenced by fixed precipitation (snow)	Measurement result can't be influenced by fixed precipitation (snow)

Figure 2:

Snow-cowered housing

18 months several prototypes have been successfully tested, the subject of our research is now to prove to be able to demonstrate an accurate temperature recording in the range of 1/100 °C.
Presently being studied extensive testing through field experiments with two monitoring stations at the University of Rostock. On the one hand, a comparison with conventional measuring instruments. The other hand, measurements are made to the interior of the measuring system, for which have been installed in different places temperature sensors. The comparison of measurement results is to show how effective the shielding from external radiation effects and the exchange with the ambient air through ventilation works. Possible deviations will are tested depending on the temporal resolution (hourly, daily and weekly values). Particular attention should next be placed on special meteorological conditions and influences, which include the comparison of weather conditions with little wind and storm, with and without clouds or the comparison of day and night clouds and wind poverty. Hours or days, with especially large deviations are to undergo a specific analysis.