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Meteorology — Radiosonde —

Part 3: **Laboratory test method for solar radiation error of temperature sensor in radiosonde**

Météorologie — Radiosonde —

Partie 3: Méthode d'essai en laboratoire pour les erreurs liées au rayonnement solaire du capteur de température dans la radiosonde

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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Foreword

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This document was prepared by Technical Committee ISO/TC 146, *Air quality*, Subcommittee SC 5, *Meteorology*.

A list of all parts in the ISO 8932 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Temperature and water vapour (i.e. humidity) are two of the basic atmospheric state variables and are important for developing weather and climate prediction models. To measure the temperature and humidity in upper-air, radiosondes are generally used. Radiosonde is an instrument intended to be carried by a balloon up through the atmosphere, equipped with devices to measure one or more meteorological variables such as pressure, temperature, humidity, and is provided with a radio transmitter for sending this information to an observing station.[1] Radiosonde observations are often used in concert with other measurement techniques such as remote sensing using satellites to provide comparative data. For radiosonde-derived data to be useful, the measurement accuracy of radiosoundings is needed. From a metrological perspective, this measurement accuracy should be expressed in terms of uncertainty that is traceable to the International System of Units (SI).

Correction for solar radiation effects is critical for precisely measuring the actual temperature in the upper air. Since the temperature sensor is exposed to the outside air, the temperature measured by the sensor will be different from the air temperature due to solar radiation impacting the sensor. During daytime soundings, solar radiation heats the sensor. Therefore, all radiosonde temperature measurements show positive value radiation-induced errors in daytime. This is one of the main errors decreasing the accuracy of temperature measurements; thus, the measured temperature in soundings requires correction based on an algorithm or look-up table supplied by manufacturers.

There are many parameters that affect the radiation correction in soundings such as radiation flux, air temperature, air pressure, ventilation speed, solar elevation angle, and radiosonde orientation and motion with respect to the sun. The radiative heating of sensors increases with a decrease in temperature (T), pressure (P) and ventilation speed (v), and, in general, the radiation correction increases as the radiosonde ascends. The decrease in these parameters (T, P, and v) results in a reduced heat transfer from the sensor to the air. With respect to the impact of ambient temperature on sensors, the reduction in thermal conductivity of air at low temperatures contributes to lowering the heat transfer coefficient, thereby resulting in an increased radiation correction at such temperatures.[2] The thermal conductivity of air plays a crucial role in influencing heat transfer at the boundary between the air and the sensor.

In radiosoundings, cloud cover and distribution as well as surface albedo also affect solar radiative heating. These conditions change in real time and are difficult to model in manufacturer's correction algorithms, thus introducing uncertainty. The radiation correction is a complicated process which depends on multiple factors and parameters as well as different radiation correction algorithm features as applied by various manufactures which are proprietary and rarely disclosed. This document provides a testing method for measuring the radiation error for integrated radiosonde temperature sensors, using a limited number of samples from a batch of mass produced sensors.

The Standing Committee on Measurements, Instrumentation and Traceability (SC-MINT), one of the Technical Commissions and Research Board at the World Meteorological Organization, offers advice, recommendations, and promotes studies on the effective and sustainable use of instruments, such as radiosondes as well as offering methods for upper air weather observations. The SC-MINT Guide recommends that for temperature correction, solar radiation correction should be applied using software during data processing.[1] Consideration of additional heating sources, the temperature sensor and supporting hardware are designed such that solar heating does not vary significantly as the radiosonde rotates in flight relative to the sun.

Despite recognising the importance of correcting sensor based meteorological temperature measurement, there is limited information in the SC-MINT Guide or other technical documents on test methods, procedures and related instrument details. Therefore, there is a need to publish a consensus procedure for evaluating radiosonde temperature error induced by solar radiation in an experimentally controlled way.

The procedure presented in this document provides laboratory setup technical requirements for conducting solar radiation test, test procedure for determining solar radiation error on radiosondes with various environmental and geometrical parameters, and a method for assessing uncertainties within test results. Temperature, pressure, ventilation and radiation flux, as well as geometric parameters including sensor boom tilt angle and light illumination angle are evaluated over ranges that are varied to mimic in-flight conditions as experienced by radiosondes.

Note that when considering uncertainty in soundings, other factors such as temperature spikes due to patches of warm air coming off the sensor housing and the balloon, time-lag, and albedo should also be considered, as summarized in Table 2 of Reference [3]. While all uncertainty terms affecting the results should be considered, this procedure specifically focuses on testing environmental and geometrical effects on the radiation correction.

The core procedure discussed in this document involves the SI-traceable generation of air ventilation speed in the test environment to simulate the ascendance speed of radiosondes. In addition, the solar irradiance, temperature, and pressure in the test cell should closely replicate those observed in upper air. To attain the required range variability of atmospheric parameters in the test setup, this testing method employs both an open suction-type wind tunnel and a closed-type wind tunnel as illustrative examples. These methods are chosen because of their traceability to the SI and validation by metrological and meteorological experts in testing radiosonde temperature sensors.[2,4]

Note that while the open suction-type wind tunnel using a combination of sonic nozzles and vacuum pump is based on Korean and US patents,[5,6] the patent holder has granted a license, free of charge, to an unlimited number of applicants globally, without discrimination, and under reasonable terms and conditions. This license allows for the creation, use, and sale of implementations based on this ISO document. However, it's crucial to clarify that this ISO document does not detail the patented technique and is not an endorsement for use of patented material. Alternative equivalent procedures, employing different types of wind tunnel systems, can also be used to determine air ventilation speed at varying temperatures and pressures if they are SI-traceable and meet the data quality objectives of the application.

In this document:

— the requirements for a climate chamber, wind-tunnel, a test cell, thermometers, pressure and vacuum gauges, a laser anemometer and a solar simulator are proposed;

— the test preparation, the procedure for installing a radiosonde in the test cell, the operation of the laboratory setup, the experimental range and sequence, and data processing are presented;

— a method to evaluate and report uncertainty of the determined radiation errors on the temperature using the uncertainty propagation law, based on a mathematical model, is proposed.

NOTE 1 Since the test method is limited by the use of ground-based facilities, radiative cooling effect of radiosonde temperature sensors observed in stratosphere cannot be reproduced and represented in the test result.

NOTE 2 The light source spectrum can be limited in the infrared (IR) region compared to that of the visible light solar spectrum. As recommended by the WMO guide by SC-MINT[1], the heat exchange in infrared radiation (IR) needs to be avoided by using sensor coatings that have low emissivity in the IR. Otherwise, the effect of IR can be underestimated in the test.

NOTE 3 Due to potential limitations in the number of test setups or laboratories capable of conducting this test, peer-reviewed reports or papers published online or offline resulting from research activities conducted by academia or meteorological institutes can be utilized as a test report when following this test procedure.

Meteorology — Radiosonde —

Part 3: Laboratory test method for solar radiation error of temperature sensor in radiosonde

1 Scope

This document specifies a test method for estimating the magnitude of radiosonde temperature sensor warming, induced by direct solar radiation, based on variations in air pressure, temperature, ventilation speed, tilt angle of its supporting sensor boom, and light illumination angle on the boom through a laboratory evaluation. This document provides the following:

a) technical requirements for a laboratory setup to measure the effect of direct solar radiation on radiosonde temperature measurement under simulated sounding conditions;

b) a test procedure for estimating radiosonde temperature measurement errors due to direct solar radiation in the air pressure range of 3 hPa to 1 000 hPa, temperature range[1)] of −70 °C to 50 °C, ventilation speed range of 3 $m \cdot s^{-1}$ to 7 $m \cdot s^{-1}$ at a specified irradiance (e.g. 1 000 $W \cdot m^{-2}$ or higher), sensor boom tilt range[2)] from 0° to 45° with respect to the air ventilation direction and the range of light illumination[3)] angle from 0° to 90° with respect to the sensor boom plane;

c) a method to evaluate uncertainty in the results under the test conditions.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC Guide 98-1, *Guide to the expression of uncertainty in measurement — Part 1: Introduction*

ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO/IEC Guide 99:2007, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*

IEC 60050-713:2021, *International Electrotechnical Vocabulary (IEV) - Part 713: Radiocommunications: transmitters, receivers, networks and operation*

IEC 60068-3-6:2018, *Environmental testing - Part 3-6: Supporting documentation and guidance - Confirmation of the performance of temperature/humidity chambers*

1) Currently, the lowest possible temperature of commercially-available climate chambers is approximately −75 °C. The temperature range can be adjusted base on the capability of the climate chamber used.

2) The tilt angle of the sensor boom can be adjusted depending on the space of the test cell. If tilting is not possible, a default angle of 0° can be used.

3) The light illumination angle can be adjusted depending on the ability of moving the light source or tilting the waveguide. If changing the illumination angle is not possible, a default angle of 90° can be used.