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Calibration and accuracy of non-catching precipitation measurement instruments

National foreword

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Étalonnage et précision des pluviomètres sans captage

Kalibrierung und Genauigkeit von nicht auffangenden Niederschlagsmessgeräten

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Contents

Page

European foreword ... **3**

Introduction ... **4**

1 Scope ... **6**

2 Normative references ... **6**

3 Terms and definitions ... **6**

4 Main characteristics of atmospheric precipitation ... **6**
4.1 Definitions ... **6**
4.2 Particle size distribution ... **7**
4.3 Shape of the rain drop ... **9**
4.4 Terminal fall velocity ... **10**

5 Non-catching precipitation measurement instruments ... **12**
5.1 General ... **12**
5.2 Optical gauges ... **12**
5.2.1 General ... **12**
5.2.2 Optical transmission ... **12**
5.2.3 Optical scattering ... **13**
5.2.4 Optical imaging ... **13**
5.3 Impact disdrometers ... **14**
5.3.1 General ... **14**
5.3.2 Electro-acoustic devices ... **15**
5.4 Microwave radar ... **15**

6 Existing calibration procedures ... **17**

7 Influence parameters ... **20**
7.1 Wind ... **20**
7.2 Contemporary particle crossings ... **20**
7.3 Drop shape ... **21**
7.4 Further sources of bias for optical instruments ... **21**
7.5 Further sources of bias for impact disdrometers ... **21**
7.6 Further sources of bias for radar disdrometers ... **21**

Bibliography ... **22**

European foreword

This document (CEN/TR 17993:2023) has been prepared by Technical Committee CEN/TC 318 “Hydrometry”, the secretariat of which is held by BSI.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

The document was prepared following a request for research development submitted by CEN/TC 318 in October 2017 to EURAMET, the European Association of National Metrology Institutes, through the cooperation programme between STAIR (the joint CEN-CENELEC strategic Working Group supporting standardization in research and innovation) and EMPIR (the European Metrology Programme for Innovation and Research of EURAMET).

This led to the approval and funding of the EURAMET pre-normative project 18NRM-03 "INCIPIT - Calibration and accuracy of non-catching instruments to measure liquid/solid atmospheric precipitation" (2019-2021). The project Deliverable D1, "Overview of existing models and working principles of non-catching precipitation gauges together with test/calibration schemes for different types of non-catching precipitation gauges" was provided as a supporting document to CEN/TC 318 and is the basis of the present CEN/TR draft.

Any feedback and questions on this document should be directed to the users’ national standards body. A complete listing of these bodies can be found on the CEN website.

Introduction

The development of highly accurate precipitation gauges for both liquid and solid precipitation is an increasingly relevant and pressing requirement in the environmental sciences and their applications (Lanza and Stagi, 2008). Non-catching instruments, which do not use a container to collect the hydrometeors when approaching the ground, are the emerging class of in-situ precipitation gauges (Cauteruccio et al., 2021). They detect the microphysical and dynamic characteristics of single or multiple hydrometeors while these cross a given section, or a volume, of the atmosphere (or directly impact the sensor) by employing optical, acoustic, and microwave principles.

National Meteorological and Hydrological Services (NMHS) and other organizations, in charge of the management of monitoring observation networks over large regions, increasingly look at such kind of instruments as a potential improvement over the more traditional catching-type gauges (typically tipping-bucket and weighing gauges), notwithstanding the higher lifecycle cost. The reasons are their potential in reducing the maintenance burden (by eliminating any moving part or containers to be periodically emptied and serviced), the high temporal resolution, the large number of parameters provided, and their suitability to be part of a fully automated monitoring observation network. Drawbacks can be easily identified in the higher complexity of the exploited technology, so that the capability of the user to correctly manipulate, maintain and calibrate the instrument might be limited.

Non-catching instruments are generally calibrated by the manufacturers, using internal procedures developed for the specific technology employed. No widely agreed procedure – nor any documentary standard – exists within national or international institutions. The adopted procedures are rarely traceable to the International System of Units (SI) and are often not even reproducible. Limited information is generally provided by the manufacturers about the methodology and instrumentation adopted for calibration purposes.

Having no funnel to collect the rainwater, traceable calibration and uncertainty evaluation for non-catching gauges are more difficult than for catching type gauges, and the use of an equivalent, reference flow rate (see e.g. Colli et al., 2014) is not possible. Rather, for an appropriate metrological characterization of non-catching instruments, reproducing the actual rain event characteristics is needed, including particle size distribution, shape, density and fall velocity. A considerable metrological effort is therefore needed to resolve traceability and uncertainty issues and to support new calibration methods including the development of standardized laboratory rainfall simulators.

As regards solid precipitation, non-catching instruments were included in the recent WMO SPICE (Solid Precipitation InterComparison Experiment) and compared with gauge measurements in a DFIR (Double Fence Intercomparison Reference) at various test sites (Nitu et al., 2018). The study concluded that further analysis is needed to better understand the behaviour of non-contact type measurement instruments, especially working with the raw data (drop size and fall speed distribution), and exploiting the full capacity of such devices, that can provide much more information than the precipitation accumulation (precipitation type, SYNOP and METAR codes, etc.). Field tests on SPICE reference sites have been continued in that sense after the official end of the project (Smith et al., 2020) to enhance the knowledge on the operational use of non-catching type instruments in winter conditions.

For liquid precipitation measurements, the evidence from the last WMO intercomparison of rainfall intensity gauges in the field (Vuerich et al, 2009) is that, due to calibration issues, caution should be posed in using the information obtained from non-catching instruments in any real-world application and in assessing the results of scientific investigations based on such measurements.

The main effort to develop standard procedures for the calibration of precipitation measurement instruments is presently being performed at the European level. The first experience was the development of the Italian national standard UNI 11452:2012, and the follow-up extension of such initiative at the European scale, leading to the publication of the recent standard EN 17277:2019. The scope of the standard is however limited to catching type gauges, which – due to the presence of the rain collector – can be calibrated using a known and constant flow rate generated in the laboratory as the reference (Santana et al., 2015). Traceable instrument calibration for non-catching gauges is the next step of the ongoing normative effort at the European scale under CEN/TC 318/WG12, but various scientific and methodological aspects are still open issues.

The project MeteoMet (Merlone et al., 2015), funded under the European Metrology Research Programme (EMRP), initiated a series of experimental activities in metrology for meteorology, with the MeteoMet2 specifically addressing the issue of atmospheric precipitation measurements from a metrological perspective. An associated research grant focused on rainfall measurements using catching and non-catching gauges. It is under this framework that, to support the ongoing normative effort, the INCIPIT project "Calibration and accuracy of non-catching instruments to measure liquid/solid atmospheric precipitation" was initiated in July 2019 (Merlone et al., 2020).

The project aimed at introducing metrological soundness, reproducibility, and standardization in the calibration of non-catching type instruments, so that an uncertainty budget can be determined, and measurements made traceable to the SI. A rigorous metrological approach based on modelling the measurement process and expressing the influence parameters in a model function was implemented, taking in account different types of rain-gauges and the different calibration schemes. By developing, characterizing, testing, and comparing different types of rain generators, test calibration of a representative number of different non-catching rain gauges was performed.

This document provides an overview of the existing models of non-catching instruments with a description of the working principle exploited and the calibration procedures currently adopted. The literature and technical manuals disclosed by manufactures are summarized and discussed. The report allows knowledge to be shared and provides consistent background information needed to advance the standardization activities towards the development of traceable procedures for the calibration of non-catching gauges and the associated calibration uncertainty assessment, as well as the evaluation of the accuracy of non-catching precipitation measurement instruments.

1 Scope

Non-catching type gauges are the emerging class of in situ precipitation measurement instruments. For these instruments, rigorous testing and calibration are more challenging than for traditional gauges. Hydrometeors' characteristics like particle size, shape, fall velocity and density need to be reproduced in a controlled environment to provide the reference precipitation, instead of the equivalent water flow used for catching-type gauges. They are generally calibrated by the manufacturers using internal procedures developed for the specific technology employed. No agreed methodology exists, and the adopted procedures are rarely traceable to internationally recognized standards. This document describes calibration and accuracy issues of non-catching instruments used for liquid/solid atmospheric precipitation measurement. An overview of the existing models of non-catching type instruments is included, together with an overview and a description of their working principles and the adopted calibration procedures. The literature and technical manuals disclosed by manufacturers are summarized and discussed, while current limitations and metrological requirements are identified.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp/

— IEC Electropedia: available at https://www.electropedia.org/

4 Main characteristics of atmospheric precipitation

4.1 Definitions

The World Meteorological Organization (WMO), in its Guide to Meteorological Instruments and Methods of Observation (WMO, 2014 updated 2017), defines atmospheric precipitation as "the liquid or solid products of the condensation of water vapour falling from clouds or deposited from air onto the ground".

Hydrometeors falling through the atmosphere can have different size, shape, velocity (magnitude and components) and density. The precipitation intensity (usually indicated as Snowfall Intensity – SI for solid and Rainfall Intensity – RI for liquid precipitation) and the associated Particle Size Distribution (PSD) are two main factors used to characterize a precipitation event. The precipitation intensity is defined by the WMO/CIMO guide as "the amount of precipitation collected per unit time interval" while the PSD, usually indicated with $N(d)$ and expressed in [L^{-3} L^{-1}], provides the number of particles (liquid or solid) per unit volume of air and unit size interval having a volume equal to the sphere of diameter d [L].

The most common types of rain are stratiform, that falls from nimbostratus, and convective that falls from cumulus and cumulonimbus.

Stratiform precipitation originates in high clouds, where small ice crystals are formed. In these clouds, the vertical wind is on average much smaller than the fall speed of the ice crystals, hence the wind cannot prevent them from falling. When they fall in a supersaturated air, they grow by vapor deposition. They can also grow by aggregation of ice particles. When the ice crystals reach an altitude where the air temperature (T) is above 0 °C they melt and can still grow by aggregation, but this phenomenon is of minor importance. This type of rain therefore tends to have small droplets (Rulfová and Kyselý, 2013).