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An American National Standard

Standard Practice for Determining the Operational Comparability of Meteorological Measurements[1]

This standard is issued under the fixed designation D 4430; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 Sensor systems used for making meteorological measurements may be tested for laboratory accuracy in environmental chambers or wind tunnels, but natural exposure cannot be fully simulated. Atmospheric quantities are continuously variable in time and space; therefore, repeated measurements of the same quantities as required by Practice E 177 to determine precision are not possible. This practice provides standard procedures for exposure, data sampling, and processing to be used with two measuring systems in determining their operational comparability **(1,2)**.[2]

1.2 The procedures provided produce measurement samples that can be used for statistical analysis. Comparability is defined in terms of specified statistical parameters. Other statistical parameters may be computed by methods described in other ASTM standards or statistics handbooks **(3)**.

1.3 Where the two measuring systems are identical, that is, same make, model, and manufacturer, the operational comparability is called functional precision.

1.4 Meteorological determinations frequently require simultaneous measurements to establish the spatial distribution of atmospheric quantities or periodically repeated measurement to determine the time distribution, or both. In some cases, a number of identical systems may be used, but in others a mixture of instrument systems may be employed. The procedures described herein are used to determine the variability of like or unlike systems for making the same measurement.

1.5 *This standard does not purport to address the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (See 8.1 for more specific safety precautionary information.)

2. Referenced Documents

2.1 *ASTM Standards:*

D 1356 Terminology Relating to Sampling and Analysis of Atmospheres[3]

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods[4]

3. Terminology

3.1 For additional definitions of terms, refer to Terminology D 1356.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *difference (D)*—the difference between the systematic difference (d) of a set of samples and the true mean (μ) of the population:

$$D = d - \mu \tag{1}$$

3.2.2 *systematic difference (d)*—the mean of the differences in the measurement by the two systems:

$$d = \frac{1}{N} \sum_{i=1}^{N} (X_{ai} - X_{bi}) \tag{2}$$

3.2.3 *operational comparability (C)*—the root mean square (rms) of the difference between simultaneous readings from two systems measuring the same quantity in the same environment:

$$C = \pm \sqrt{\frac{1}{N} \sum_{i=1}^{N} (X_{ai} - X_{bi})^2} \tag{3}$$

where:

X_{ai} = ith measurement made by one system,
X_{bi} = ith simultaneous measurement made by another system, and
N = number of samples used.

3.2.3.1 *functional precision*—the operational comparability of identical systems.

3.2.4 *estimated standard deviation of the difference (s)*—a measure of the dispersion of a series of differences around their mean.

$$s = \pm \sqrt{C^2 = d^2} \tag{4}$$

[1] This practice is under the jurisdiction of ASTM Committee D22 on Sampling and Analysis of Atmospheres and is the direct responsibility of Subcommittee D22.11on Meteorology.

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[2] The boldface numbers in parentheses refer to the list of references at the end of this practice.

[3] *Annual Book of ASTM Standards*, Vol 11.03.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

3.2.5 *skewness (M)*—the symmetry of the distribution (the third moment about the mean).

$$M = \frac{\sum_{i=1}^{N} ((X_{ai} - X_{bi}) - d)^3}{N^3} \quad (5)$$

$M = 0$ for normal distribution.

3.2.6 *kurtosis (K)*—the peakedness of the distribution (the fourth moment about the mean), $K = 3$ for normal distribution.

$$K = \frac{\sum_{i=1}^{N} ((X_{ai} - X_{bi}) - d)^4}{N^4} \quad (6)$$

3.2.7 *response time (T)*—the time required for the change in output of a measuring system to reach 63 % of a step function change in the variable being measured.

3.2.8 *identical systems*—systems of the same make and model produced by the same manufacturer.

3.2.9 *resolution (r)*—the smallest change in an atmospheric variable that is reported as a change in the measurement.

4. Summary of Practice

4.1 The systems to be compared must make measurements within a cylindrical volume of the ambient atmosphere not greater than 10 m in horizontal diameter. The vertical extent of the volume must be the lesser of 1 m or one-tenth *H*, where *H* is the height above the earth's surface of the base of the volume. The sample volume must be selected to ensure homogeneous distribution of the variable being measured.

4.2 For some measurements (for example, visibility) the horizontal distance or the height (for example, cloud height) may be the variable of interest. In the first case, one of the two dimensions of horizontal distance is minimized and may not exceed 10 m while all other criteria remain the same. In the second case, all criteria for position and sampling described in 4.1 remain unchanged and the measured height is treated as if it were an atmospheric variable. The physical dimension of some measuring systems may exceed the spatial limits of 4.1 (for example, a rotating beam ceilometer with a 200-m baseline). In those cases the systems must be installed so that the measurements are obtained from within the volume specified in 4.1.

4.3 Samples are taken in pairs and the time interval between the pairs of samples must be no less than four times the response time (4T) of the measuring systems **(4)**.

4.4 The time between members of a pair of measurements must be as small as possible, but must not exceed one tenth the response time.

4.5 The root mean square (rms) of the measurement differences is calculated to provide operational comparability or functional precision of the systems.

4.6 Measurement differences may change with the magnitude of the measurement (for example, the absolute value of the difference in the measurement of wind speed by two systems may be greater or smaller at high-wind speeds than at low-wind speeds). To test the data for such dependence, the range of measurements shall be divided into no less than three class intervals and each class shall have a sufficient number of samples to represent the class. The change in rms difference between classes indicates the dependence of the measurement difference on the magnitude of the measurement.

5. Significance and Use

5.1 This practice provides data needed for selection of instrument systems to measure meteorological quantities and to provide an estimate of the precision of measurements made by such systems.

5.2 This practice is based on the assumption that the repeated measurement of a meteorological quantity by a sensor system will vary randomly about the true value plus an unknowable systematic difference. Given infinite resolution, these measurements will have a Gaussian distribution about the systematic difference as defined by the Central Limit Theorem. If it is known or demonstrated that this assumption is invalid for a particular quantity, conclusions based on the characteristics of a normal distribution must be avoided.

6. Interferences

6.1 Exposure of the systems shall be such as to avoid interference from sources, structures, or other conditions that may produce a gradient in the measurement across the sample volume.

6.2 A mutual interference by systems may produce a systematic difference (*d*) or bias that would not occur if one system were used by itself. That bias is not a part of the comparability and must be reported separately.

6.3 A systematic difference greater than one increment of resolution must be investigated by interchanging the position of the sensors with an equal number of samples taken in each position. If the bias changes sign, it is due to the exposure and must be reported separately.

7. Apparatus

7.1 The apparatus used is the combination of sensor systems for which the operational comparability or functional precision is to be determined plus the data-processing equipment required to extract the data and calculate the statistical parameters.

8. Precautions

8.1 Safety precautions accompanying the sensor systems must be followed.

8.2 *Technical Precautions*:

8.2.1 Measurement-system mutual electrical interference must be minimized.

8.2.2 Use of this practice is based on a statistical analysis of the distribution of differences used to calculate operational comparability. Mean, standard deviation, skewness, and kurtosis of the distribution are reported to facilitate such analysis.

9. Sampling

9.1 Samples are collected in pairs from two sensors sampling the free ambient atmosphere.

9.2 Samples are collected from a cylindrical volume of the free atmosphere as defined in 4.1.

9.3 The distance between sensors should be the smallest distance that avoids sensor interaction but must meet 9.2.

9.4 The time between pairs of samples (X_{ai}, X_{bi}, and $X_{ai} + 1$, $X_{bi} + 1$) must be equal to or greater than four times the