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Meteorology 433

Precision, Error, and Sensor Performance

Spring 2022

Precision

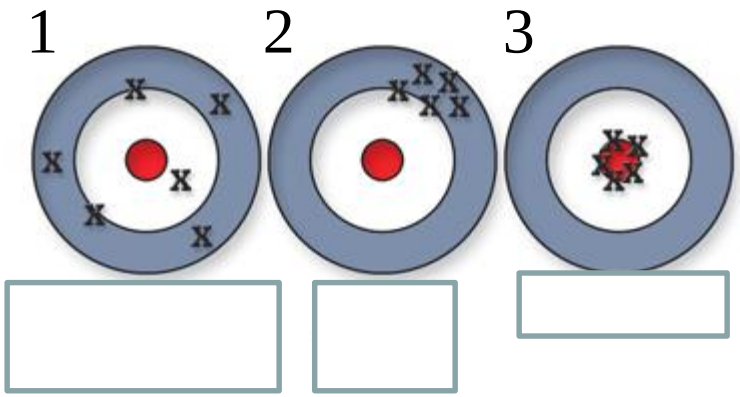
- Reliability or repeatability of a measurement.
  - How close together or how repeatable results are.
- Checked by repeating measurements.
  - Typically reported by using standard deviation.
- A precise instrument will give nearly the same reading every time.
- Poor precision results from poor technique.

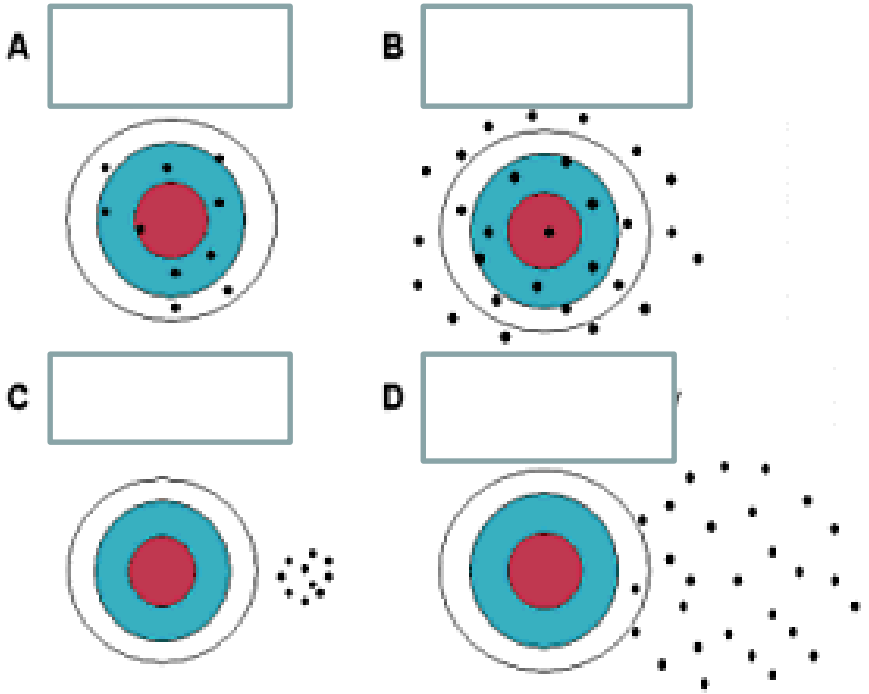
Accuracy

- Correctness.
  - How close a measurement is to the expected value.
- Checked by using different methods.
- Poor accuracy results from procedural or equipment flaws.

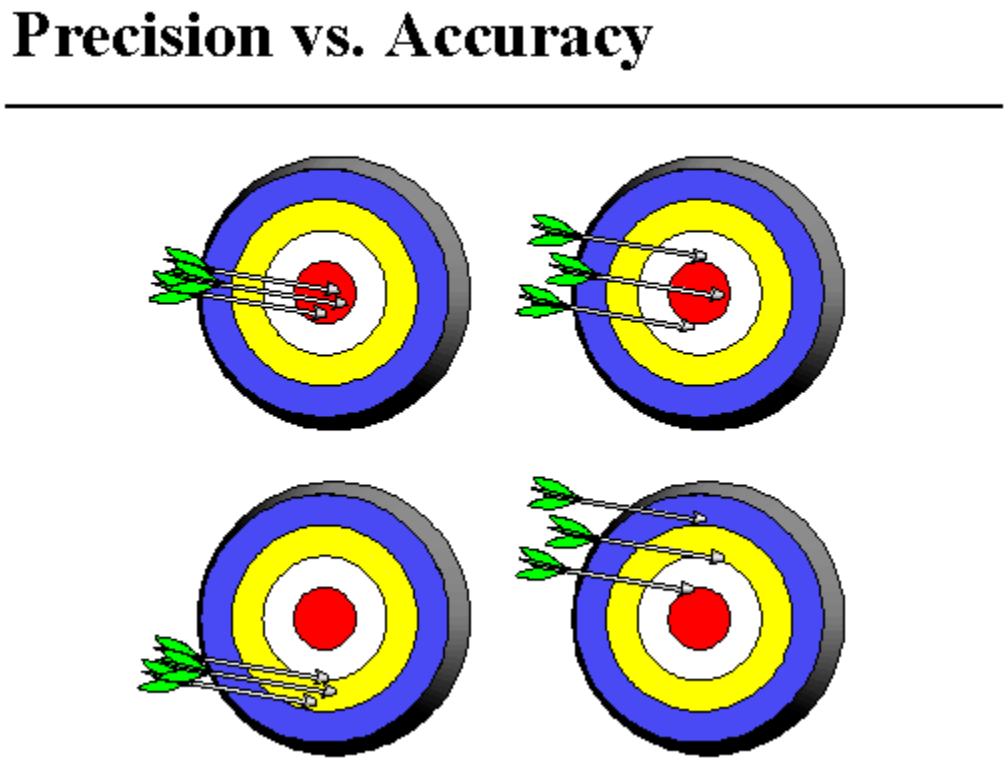
Accuracy vs. Precision

- “Accuracy is telling the truth…precision is telling the same story over and over again.” – Yiding Wang





Accuracy vs. Precision



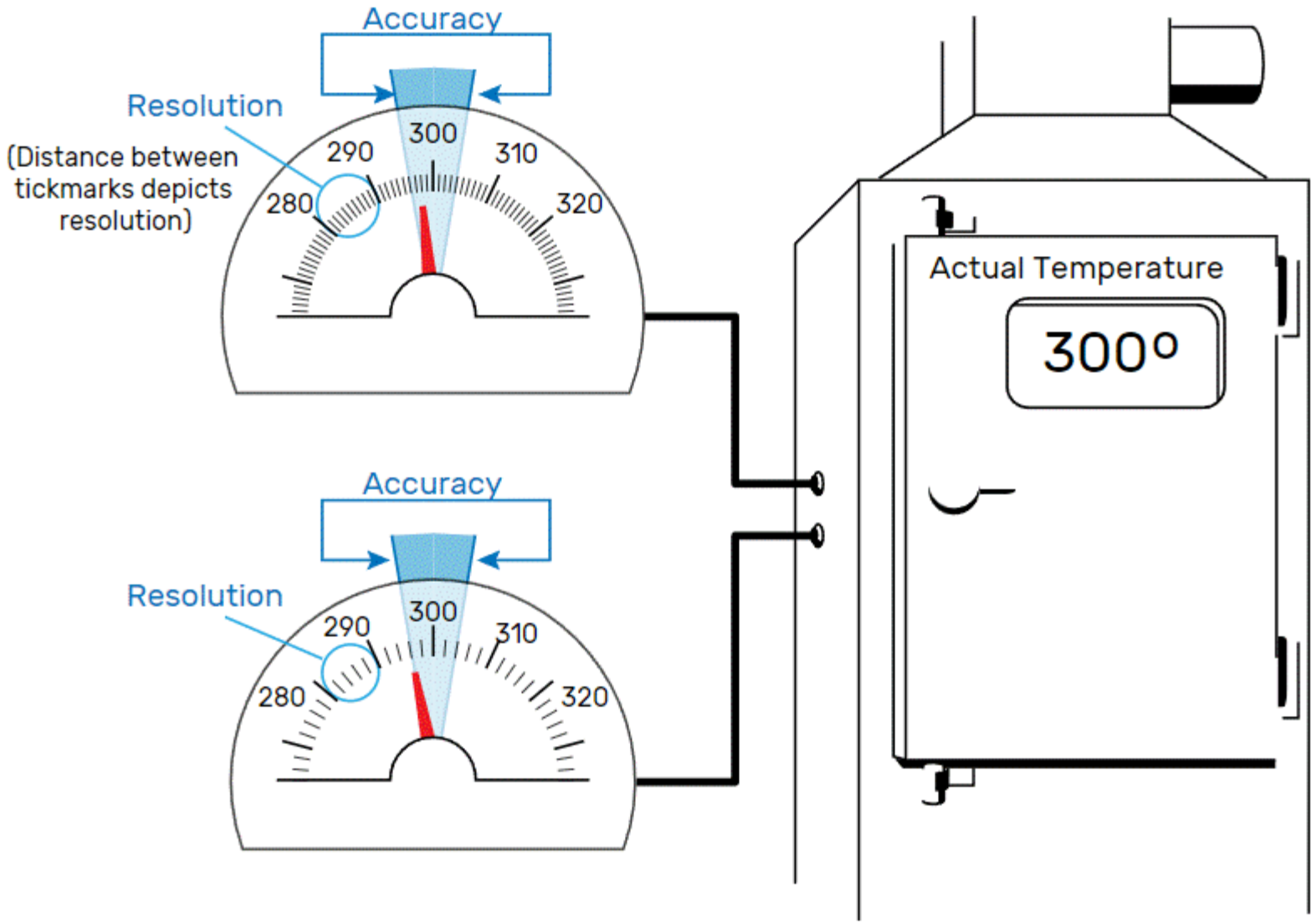
Sensor Nomenclature

- Accuracy: how close a senor can get to the actual value. The uncertainty in the measurement (also called uncertainty).

- Resolution: The smallest change in a quantity that the instrument can measure.

- Time Constant: Determines the response time of the instrument, or how long it takes to respond to a change in input.

- Static sensitivity: The change in output for a given change in input.


Accuracy
Resolution
(Distance between tickmarks depicts resolution)
280
290
300
310
320
Accuracy
Resolution
280
290
300
310
320
Actual Temperature
300°

Types of Error

- Systematic
  - Cause an instrument to be off by a similar magnitude.
  - Defective apparatus, incomplete working equations, human observers, etc.
- Random
  - Introduces errors that can result in slightly different measurements.
  - Present in all measurements.

Random Error

- Present in all measurements
- Arise from sudden or uncontrollable changes within the measured environment.
- Random act of carelessness by observer.
- Errors usually likely to be positive or negative.
- Minimized by taking a large number of measurements.

Sources of Error

- Static Errors
- Dynamic Errors
- Drift Errors
- Exposure Errors

Static Error

- Input is held steady or slowly varying.
- Errors remain after calibration.
- Deterministic or Random
  - Deterministic: Hysteresis, residual non-linearities, sensitivity to unwanted input.
  - Random: Noise.

Dynamic Error

- Errors due to changing input
  - Usually rapidly varying input.
- Disappear when input is constant long enough for output to stabilize.
- Usually assessed after static errors have been determined.

Drift Errors

- Physical changes that occur in a sensor over time.

- Can be reduced by frequent calibration.

Exposure

- Due to imperfect coupling between sensor and the atmosphere.

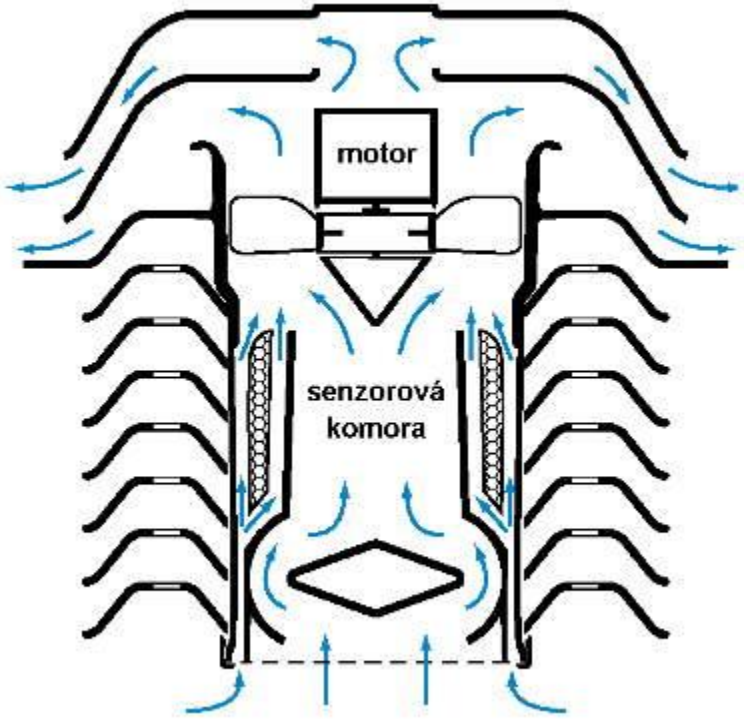
- Examples: Thermometer
  - Thermometer will never be exactly at the air temperature.
  - Thermometer interacts with its environment.

Thermometer Exposure Errors

- Radiation
- Conduction
- Static Conditions

Limiting Exposure

Model 41003-2 © 2003 Campbell Scientific (Canada) Corp.



More Exposure

- Cannot be accounted for during calibration.
- Statements about instrument accuracy and precision do not include exposure error.
- Exposure error can easily exceed all other error sources.
  - For a properly calibrated, well designed data acquisition system that is well maintained, exposure is the largest source of error.
- Instruments report their own state.
  - To some extent, any platform interacts with its environment.

Standards

- Calibration
- Performance
- Exposure
- Procedural

Calibration

- Standards maintained by NIST.
  - National Institute of Standards and Technology.
- Maintain standards for temperature, humidity, pressure, wind speed, etc.

Performance

- Standard method of testing sensors to determine their performance.

- Consists of definition of terms and methods of testing static and dynamic performance.

Exposure

- Where should instruments be placed?
  - Anemometers mounted on sides of buildings?
  - Roof?
  - Height of instruments?
- WMO Standards
  - World Meteorological Organization.

Procedural

- Selection of data sampling and averaging periods.