Semester Project

- Goal: Analyze weather data from a meteorological station or sensor, analyze the data, and draw conclusions.
  - Hypothesis based.
  - There are many options here: set up your own station, use an existing station, use or make a sensor/station of your own.
  - Analyze the data and make conclusions: do an advanced analysis and draw conclusions.
- Group project – two or three members to a group.

Meteorology 433

Static Calibration/Static Performance

Spring 2022

What is it?

- Characterize the static performance of a sensor
  - Performance of sensor when input is constant or slowly varying.
  - Varying one input, usually in a stepwise fashion, over a range of values while holding other inputs constant.

- Output is observed in steady-state conditions.
  - Input is held constant long enough for output to stabilize.

- Objective 1: Define instrument accuracy

- Objective 2: Develop input-output, or transfer equation.

- Dynamic Performance: The performance of a sensor when the input is rapidly varying.

Definitions

- Static Sensitivity: slope of the transfer curve
  - $S_s \equiv$ d(raw output)/ d(input)
    - Straight line: S_s = constant, linear sensor
    - Otherwise: non-linear sensor

- Range: Measured interval over which a sensor is designed to respond.

- What would you want out of an ideal instrument in terms of S_s and range?

  - Large, constant static sensitivity over the whole range and a wide range.

- A sensor with $S_s = 0$ is a useless sensor.
  - Using a brick for a pressure sensor, for example.

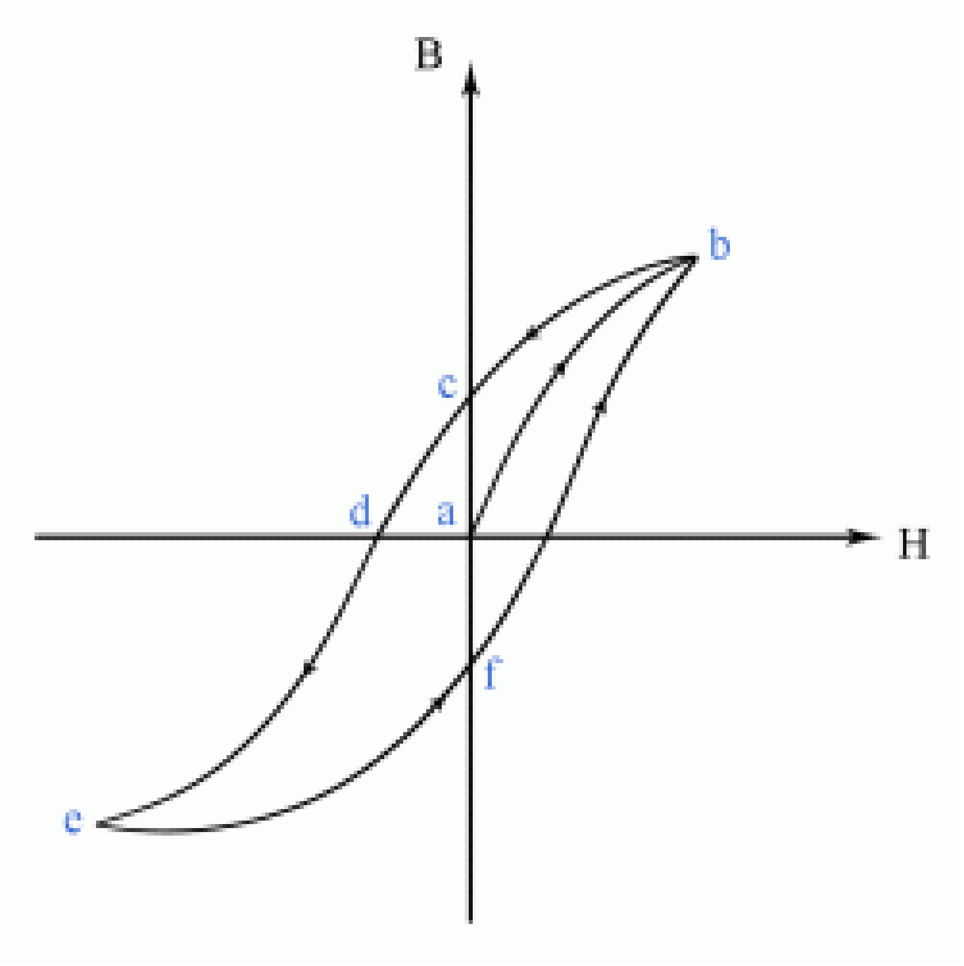
Definitions cont.

- Resolution: Smallest change in the input that produces a detectable change in the output.
  - Higher the sensitivity, the higher the resolution.
  - Resolution is not a function of sensitivity only.
    - Friction and noise can also reduce resolution.

- Hysteresis: Present when the sensor output for a given input depends upon whether the input was <u>increasing</u> or <u>decreasing</u>.

- Stability: An instrument is said to be stable and free from drift if repeated calculations over some period of time produce the same transfer curve.
  - Period can vary from days to years.

Hysteresis Graph



Calibration Procedure

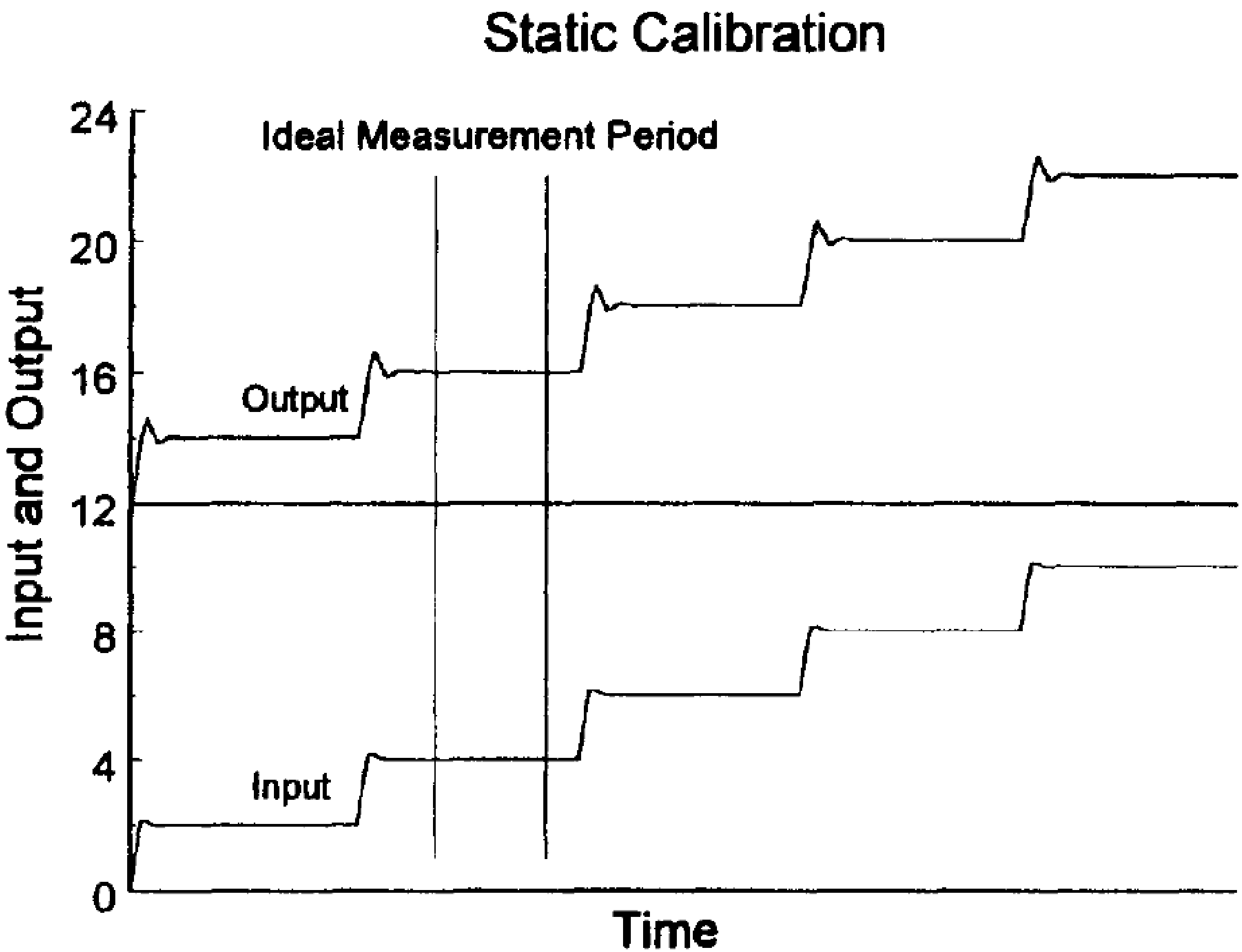
Objective: Develop a transfer equation that can be used to convert the observed output, Y_i , to an estimate of the known input X_i.

1. Development of transfer plot.
    - Accurate measurement of X_i, the primary input, and Y_i, the primary output, at N points over the design range of the sensor.

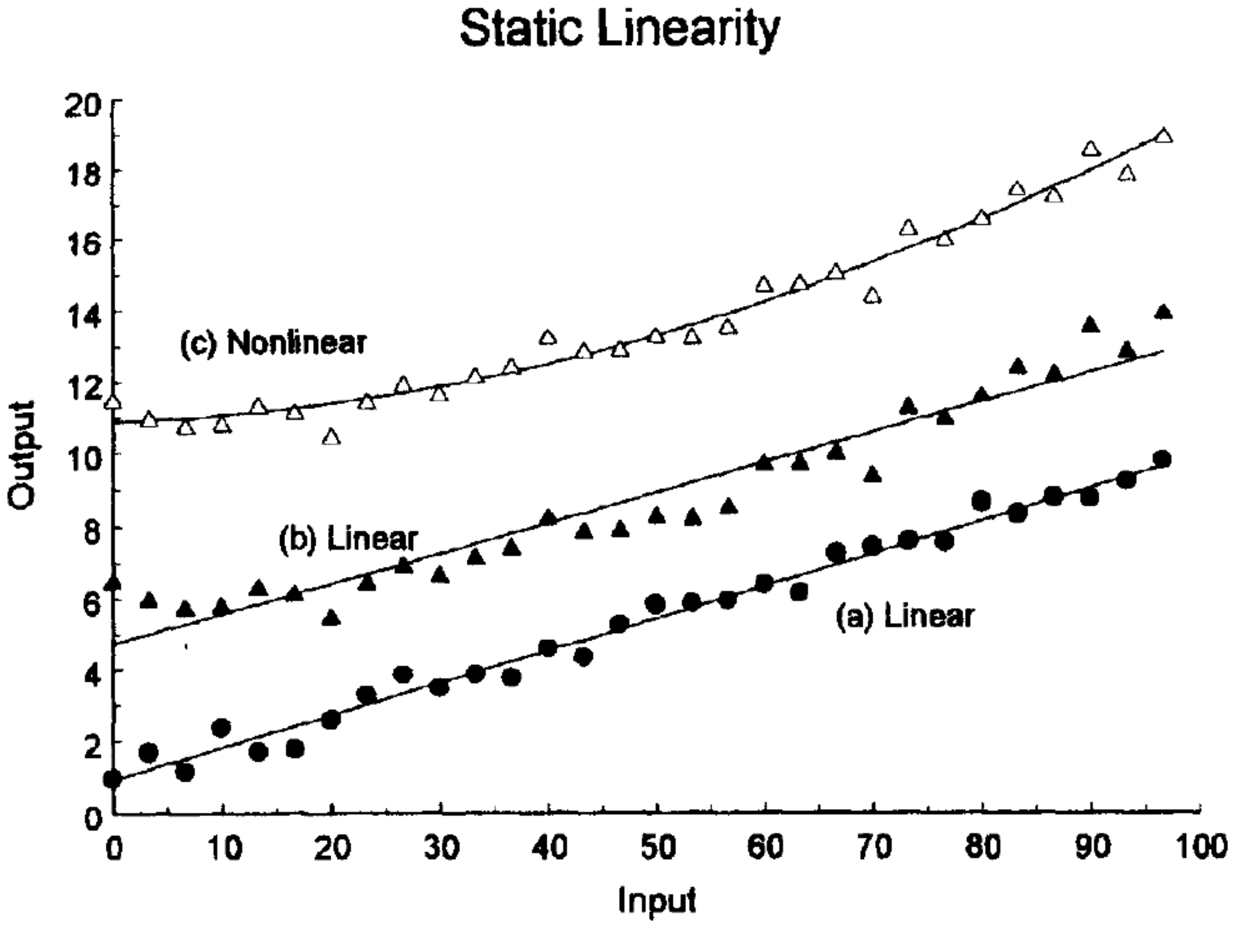
2. Development of a transfer equation.
    - Fit a straight line, or curve if necessary, to the data, using the least-squares procedure.
    - Objective: equation that can be used to convert output Y_i to an <u>ESTIMATE</u> of the observed input, X_i.

3. Development of a calibration equation.
    - Objective: equation that allows us to determine the observed quantity from the sensor output.

Transfer Plot



Transfer Plot

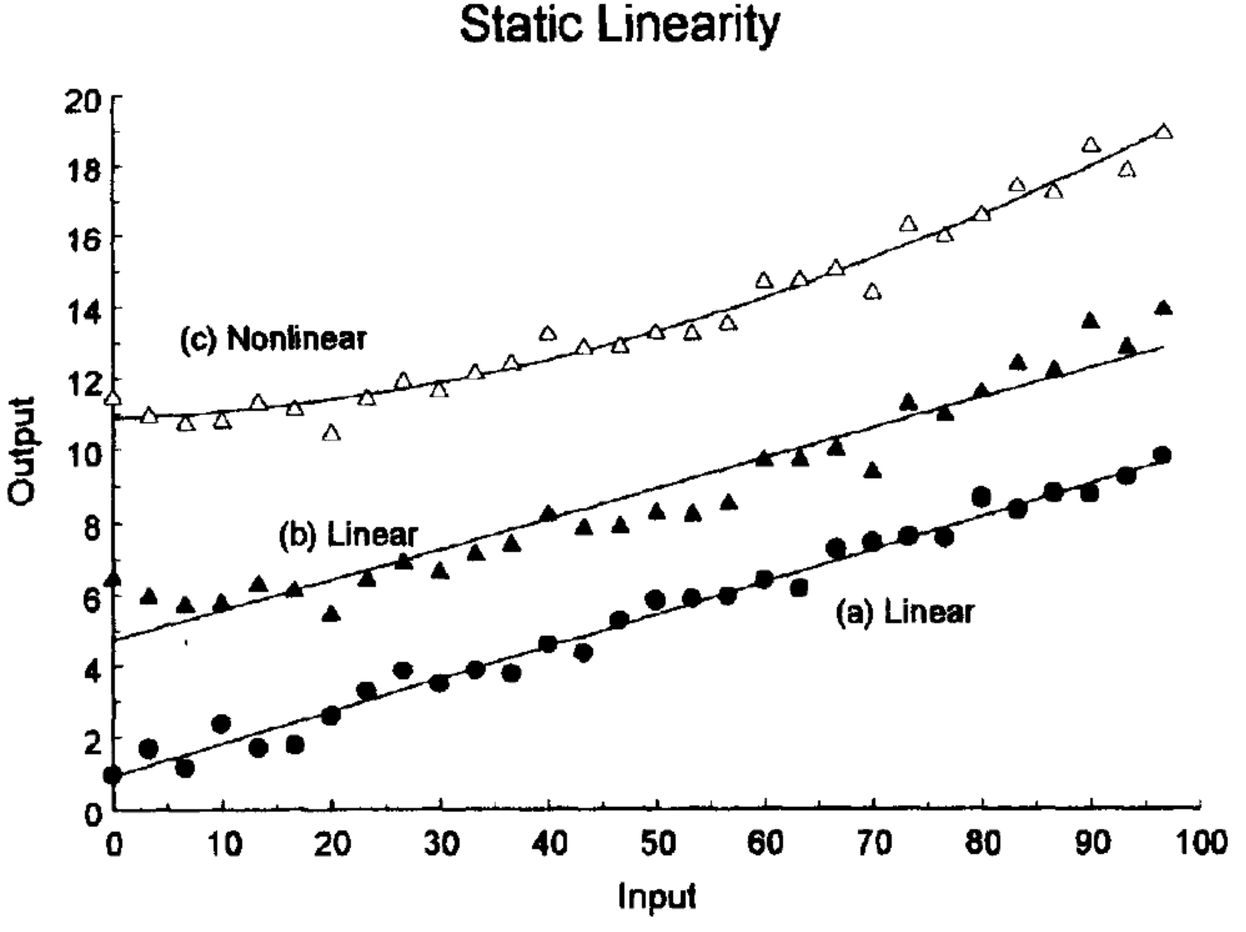


Transfer Equation

- $\hat{Y}_1 = a_0 + a_1 X_i + a_2 X_i^2 + a_3 X_i^3 + \ ...$
  - Y_1 is the output from the sensor for a known input, X_i.
  - $\hat{Y}_1$ is an approximation to Y_1 (Random Errors).
  - a_0, a_1, a_2, a_3 are coefficients

- $\hat{Y}_1 = a_0 + a_1 X_i$
  - For a linear sensor
  - The coefficients are determined by a least-squares fit to a straight line that minimizes the error function.

Transfer Plot



Error Function

- E = $\sum_{n=1}^{N}(a_0 + a_1 X_{in} - Y_{1n})^2$
  - N =number of data values
  - Remember: The first two terms are just the approximation to the output, Y.

- When you do this, you get
  - $D = N \sum X_{in}^2 - (\sum X_{in})^2$
  - $a_0 = (\sum Y_{1n} \sum X_{in}^2 - \sum X_{in} \sum X_{in} Y_{1n})/D$
  - $a_1 = (N \sum X_{in} \sum Y_{1n} - \sum X_{in} \sum Y_{1n})/D$

Calibration Equation

- Final result of the calibration procedure.

- Converts sensor readings into the measurable quantity we are interested in.

Calibration Equation

- $X_1 = c_0 + c_1 Y_1 + c_2 Y_1^2 + c_3 Y_1^3 + \ldots$
  - For a given output from the sensor, Y_1, the input was X_1.
  - For example, Y_1 could be a voltage from the sensor for a temperature, X_1

- $X_1 = c_0 + c_1 Y_1$
  - $c_0 = -a_0/a_1$
  - $c_1 = 1/a_1$

Bias and Imprecision

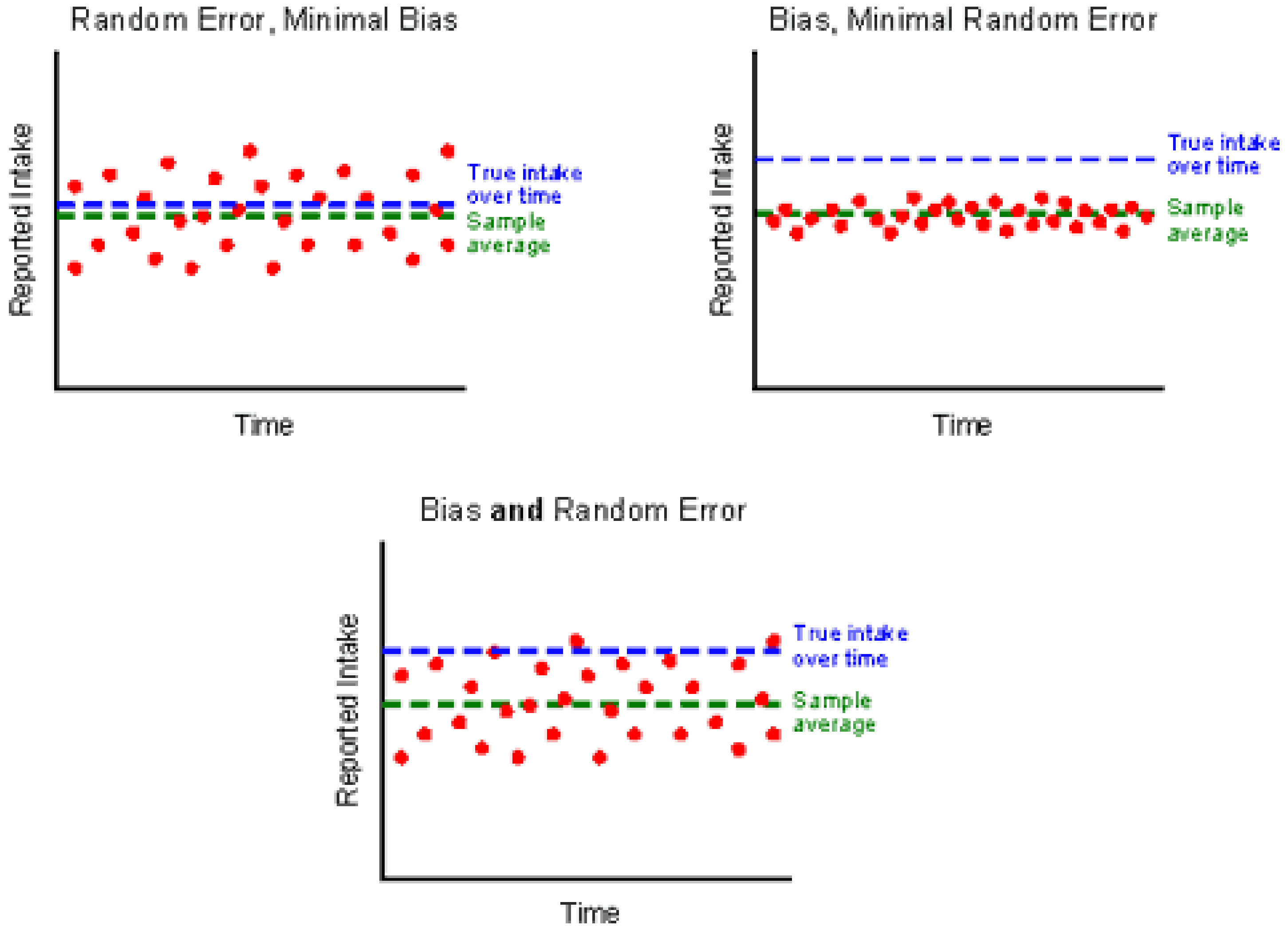
- Bias
  - Systematic error that can be corrected by calibration.
  - $\varepsilon = X_{1n} - X_{in}$
  - Output from calibration equation to true value.

- Imprecision: By convention, typically one or two standard deviations.
  - Uncertainty in a single measurement.

- The purpose of static calibration is to remove the bias and to numerically define the imprecision.
  - measure the quality of our calibration.

- After calibration:
  - Bias should be zero.
  - Drift could change this.

- Inaccuracy ≡ Bias ± imprecision


Random Error, Minimal Bias
Reported Intake
Time
True intake over time
Sample average
Bias, Minimal Random Error
Reported Intake
Time
True intake over time
Sample average
Bias **and** Random Error
Reported Intake
Time
True intake over time
Sample average