Lecture 8/17/22

Terminology

Transducer – A device that converts a nonelectrical quantity into an electrical signal and vice versa

- **Sensor** – A device that converts a nonelectrical quantity into an electrical signal
  - An input transducer
  - Examples: pressure sensor, accelerometer

- **Actuator** – A device that converts an electrical signal into a nonelectrical quantity
  - An output transducer
  - Examples: motor, light bulb, electric heater

Measurand – the quantity being measured by the sensor (such as pressure or temperature)

Size

Macro – 2mm and larger (us: 6’ = 1.8288m) – our world

Meso – 2mm down to 500μm (small fire ant is 2mm long) – her world

Micro – 500μm down to 0.5μm (paramecium is 100μm to 300μm long, human red blood cell has a 6μm to 8μm diameter)

Nano – 0.5μm down to 1nm (spherical influenza virus: 50nm to 120nm diameter with 10nm to 14nm spikes on surface)

Human Hair: ~100μm diameter

Modern Transistor: <100nm dimensions (TSMC has a 5 nm process)

MEMS: acronym for "Microelectromechanical Systems"

Definition: Any device or system partially or fully manufactured using microfabrication techniques

Microsensor: a sensor with at least one sub-mm physical dimension

MEMS Characteristics

(1) Typically based around a silicon substrate

(2) Typically use batch fabrication processing borrowed from microelectronics fabrication technology

Batch Fabrication: many devices fabricated in parallel

- Reduces Cost per Device

(3) Sometimes compatible with microelectronics fabrication

(4) But often not compatible with microelectronics fabrication

Sensor and Sensing Characteristics

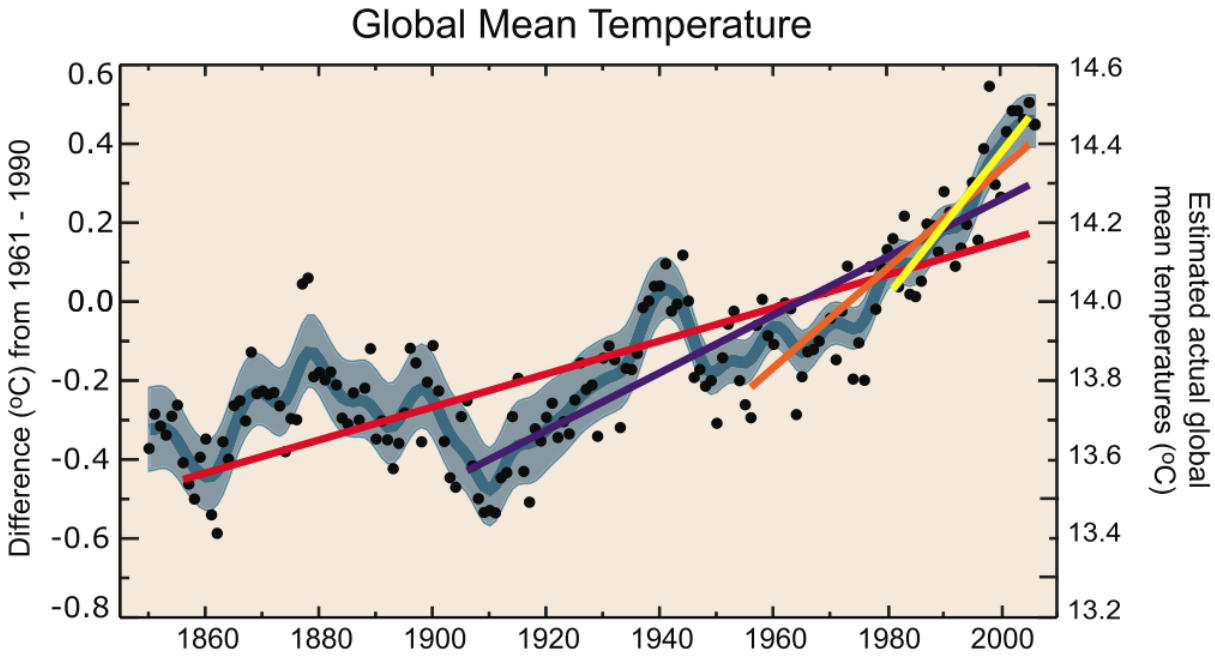
(1) Accuracy – how correct the sensor readings are

(2) Precision – the resolution of the sensor

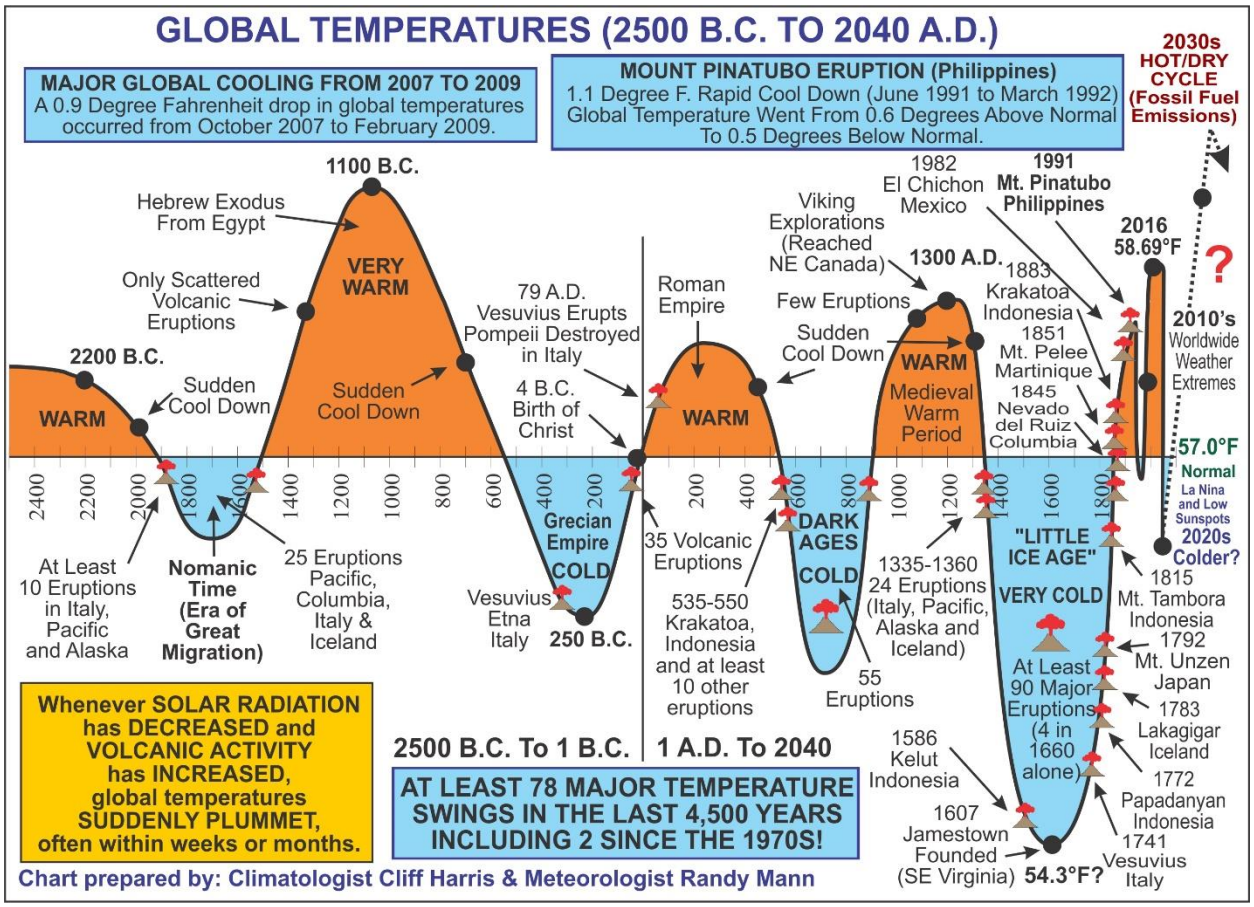
(3) Range – defines the minimum and maximum measurand levels that can be sensed

(4) Minimum sampling rate – must be at least twice the highest frequency present in the data to avoid aliasing

(5) Minimum sample collection period – must be long enough to capture any trends present in the data (see example on next page)



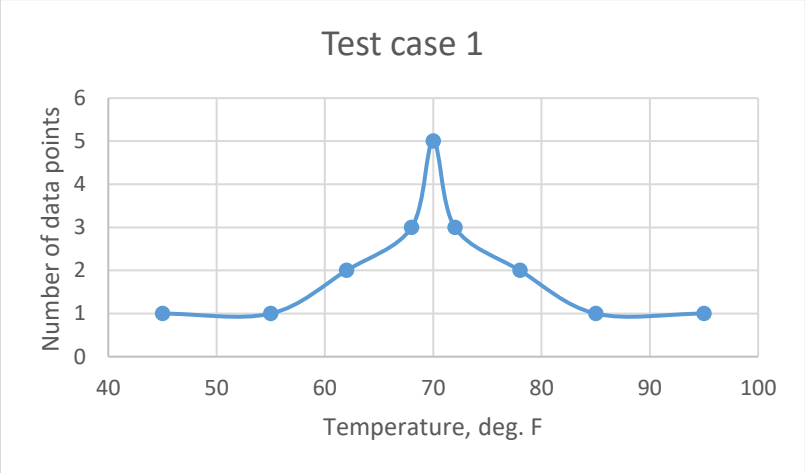
https://wg1.ipcc.ch/publications/wg1-ar4/faq/wg1_faq-3.1.html



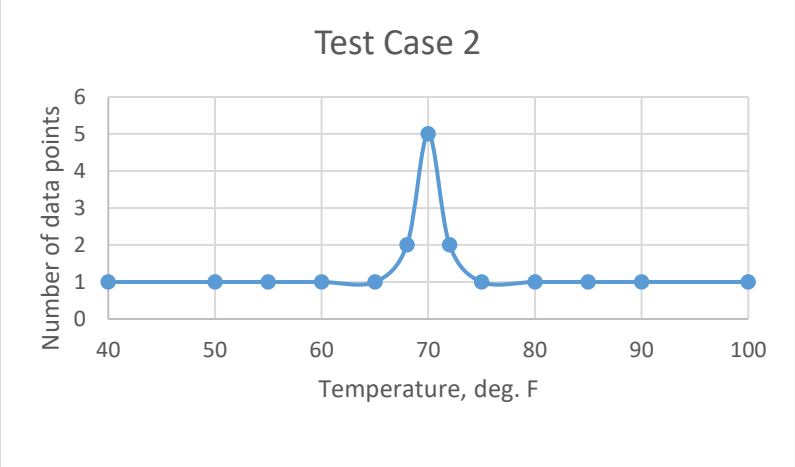
http://www.longrangeweather.com/global_temperatures.htm

Statistics of Sensor Data

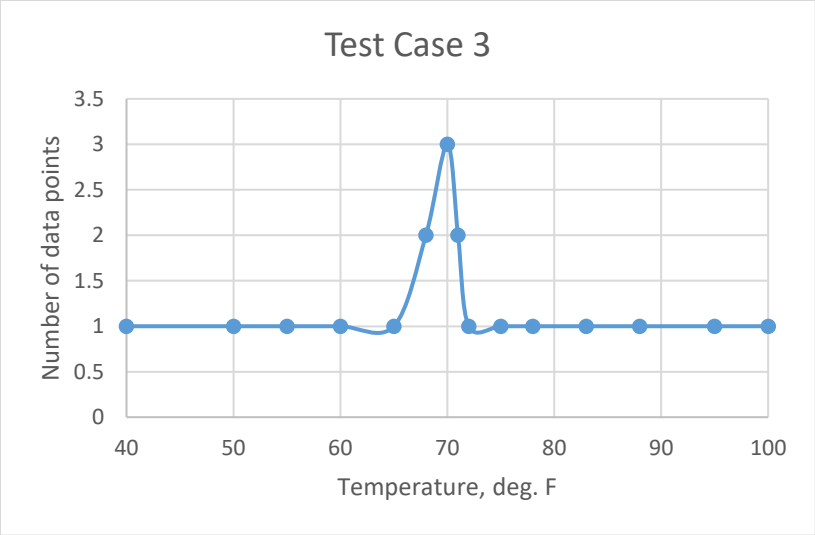
(1) Average (mean) – sum total of the values divided by the number of values of the data set
(2) Median – the middle value of the data set. Same number of data points above and below the median.
(3) Standard Deviation (σ) – a measure of the amount of variation in a set of data values. 68.27% of the data set lies within ± 1 σ. 95.4% within ± 2 σ.



Symmetrical Distribution
Average = 70 F
Median = 70 F
σ = 10.2 F



Average = 70 F
Median = 70 F
σ = 13.2 F



Skewed Distribution (most data points are below the average)
Average = 71 F
Median = 70 F
σ = 14.1 F

Note: in the case above, you are more likely to have data points below the average: this is then the "normal" case. But you wouldn't know that from just comparing data to the average value…

Scaling

The relative importance of physical quantities and forces varies with size

Dimensions:

- Length: $L \propto L$
- Surface area: $A \propto L^2$
- Volume: $V \propto L^3$

Therefore physical quantities proportional to volume decrease faster than quantities proportional to length as size is reduced

Example: a 50% reduction in x, y, z: $L_{new} = 1/2\ L_{old}$

$V_{new} = 1/8\ V_{old}$

Comparison of Macro and Micro Worlds:

Macro World

- Inertial forces important
- Electromagnetic actuators more efficient
- Responds slowly to environmental temp change
- Fluidic forces less important

Micro World

- Inertial forces less important
- Electrostatic actuators more efficient
- Responds quickly to environmental temp change
- Fluidic forces important
- Friction, Van der Waals forces, capillary action important

Examples of Microsensors:

Mechanical

- flow rate
- proximity
- stress/strain
- pressure
- acceleration
- angular rate (gyroscope)

Thermal

- PTAT
- thermistor
- thermocouple

Chemical

- humidity
- gas detection
- moisture content

Acoustic

- microphone

Radiation

- micro-antenna
- photodetectors
- photovoltaic
- x-ray
- magnetic field
- electric field

Biological

- DNA analysis
- contagion (E. coli, anthrax, Covid…)