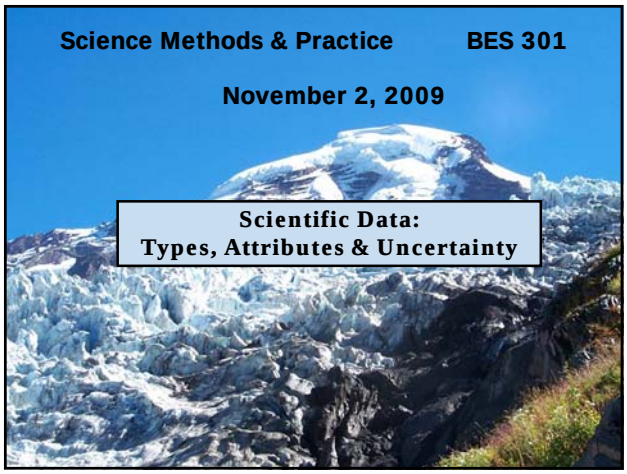
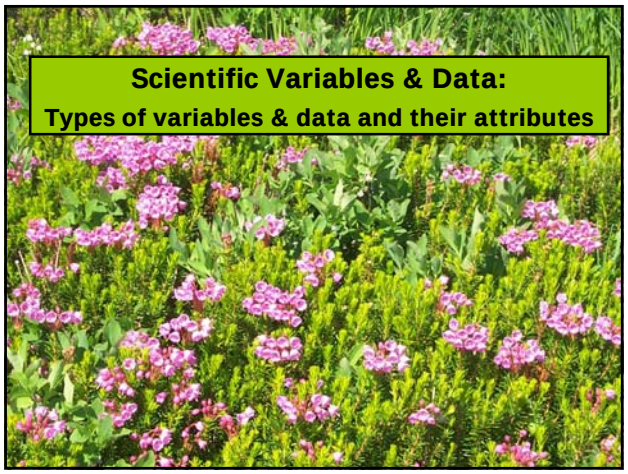
Science Methods & Practice BES 301

November 2, 2009



Scientific Data: Types, Attributes & Uncertainty



Scientific Variables & Data:
Types of variables & data and their attributes

Scientific Variables & Data

Variable:

Data:

Scientific Variables & Data

3 Main Types

Variable Type	Data Type
Categoric	Nominal
Ordered	Ordinal
Continuous	Interval

Scientific Variables & Data

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Variable Type	Data Type
Categoric	Nominal
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Scientific Variables & Data

Categoric Variables: Examples

Variables are categories of an attribute without ranking or numerical scale

Scientific Variables & Data

Nominal Data: information about categoric variables

Arctic Poppy (*Papaver radicatum*) can have yellow flowers or white flowers

Habitat	# Yellow flowers	# White flowers
Polar semi-desert	42	58
Polar desert	67	33

Statistical methods for such nominal data are unique – so it is important to recognize the kind of data.

Scientific Variables & Data

3 Main Types

Variable Type	Data Type
Categoric	Nominal
Ordered	Ordinal
Continuous	Interval

Scientific Variables & Data

Ordered Variables: Examples

Variables are categories of an attribute with a meaningful ordered ranking

Scientific Variables & Data

Ordinal Data: information using ordered variables

Observed order of germination of alpine plant seeds in the early summer

Order Germinating	Mount Rainier	Mount Baker	Mount Hood
First	*Aster alpigenus*	*Silene acualis*	*Aster alpigenus*
Second	*Epilobium alpina*	*Aster alpigenus*	*Smelowskia calycina*
Third	*Smelowskia calycina*	*Epilobium alpina*	*Epilobium alpina*
Fourth	*Silene acualis*	*Smelowskia calycina*	*P. davidsonii*
Five	*Penstemon davidsonii*	*Penstemon davidsonii*	*Silene acualis*

Data contains categories of an attribute with a meaningful ordered ranking

Scientific Variables & Data

3 Main Types

Variable Type	Data Type
Categoric	Nominal
Ordered	Ordinal
Continuous	Interval

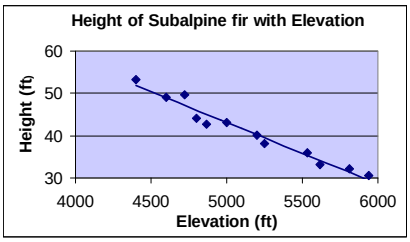
Scientific Variables & Data

Continuous Variables: examples

Continuous Variables:
- **values in numeric order**
- **size of the intervals between values is meaningful**

Scientific Variables & Data

Interval Data: information using continuous variables



Continuous Variables:
- values in numeric order
- size of the intervals between values is meaningful

Scientific Variables & Data

Moving beyond the textbook

Variable Type	Data Type
Categoric	Nominal
Ordered	Ordinal
Continuous	Interval
Discontinuous	

Variables are characterized by values in numeric order in discrete categories AND the size of the intervals between values is meaningful

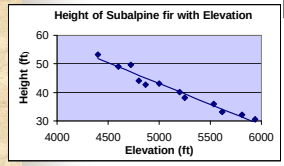
Scientific Variables & Data

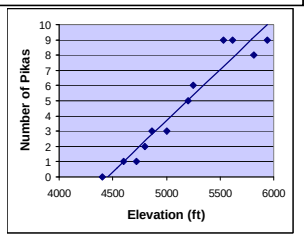
Interval Data

Continuous variables

Original data that can assume any numerical value along a scale

Discontinuous variables





Scientific Variables & Data

Moving beyond the textbook

Variable Type	Data Type
Categoric	Nominal
Ordered	Ordinal
Continuous	Interval
Discontinuous	
Derived	

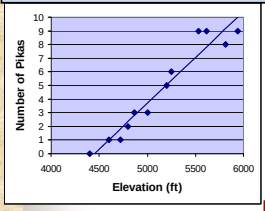
Interval data in which the original continuous or discontinuous variable is placed on a relative basis or derived from the combination of variables

Scientific Variables & Data

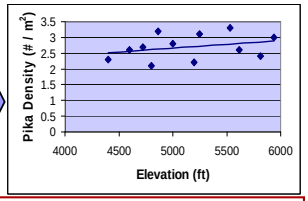
Derived Variables

Variables in which the original data are normalized to allow meaningful comparisons

Original, Discontinuous data



Derived, Continuous data



What if these sites were of different size?

Scientific Variables & Data

Derived Variables

Variables in which the original data are normalized to allow meaningful comparisons (per unit area, per unit time, etc.)

Bioregion	Number of grizzly bears	Density of grizzly bears (# / km²)
North Cascades	14	0.23
Northern Rockies	260	0.31

Original, Discontinuous data | **Derived, Continuous data**

BOTH types of data answer important, but they each address DIFFERENT questions AND require different statistical approaches

Scientific Variables & Data

Variable Type	Data Type
Categoric	Nominal
Ordered	Ordinal
Continuous	Interval
Discontinuous	
Derived	

Scientific Data: Attributes

Scientific Data: Attributes

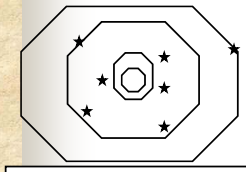
Accuracy & Precision

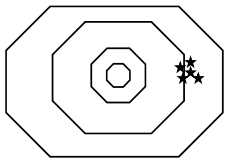
Accuracy

The degree to which measured values are close to the actual value

Precision

The degree to which measured values are close to each other (repeatability)





Scientific Data: Attributes

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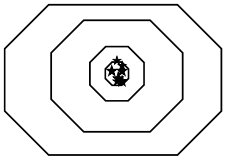


Accurate? Precise?

Scientific Data: Attributes

Accuracy & Precision

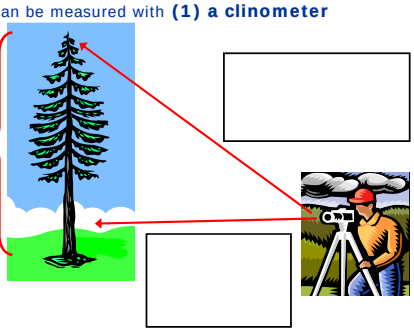
Is accuracy a good thing?

Is precision a good thing?

Scientific Data: Attributes

An Example to illustrate issues of precision & accuracy

Tree height can be measured with **(1) a clinometer**

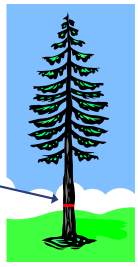


Scientific Data: Attributes

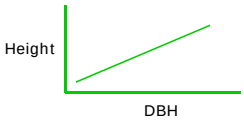
Precision & Accuracy Example

Tree height can be measured with (1) a clinometer or **(2) calculated from an established relationship with DBH**

(1) Measure Diameter at Breast Height (1.5 m) above the ground - DBH



(2) Establish DBH – height relationship from set of trees



(3) Calculate height of new trees from known DBH – height relationship

Scientific Data: Attributes

Precision & Accuracy

Results of a test of these two techniques using five forestry technicians measuring one tree

Technician	Clinometer	DBH Regression
Martha	26.2	32.2
John	27.1	28.1
Ed	26.8	26.4
Alicia	26.4	34.0
Barb	27.4	30.2
AVERAGE	26.78	30.18
STD DEV	0.49	3.05

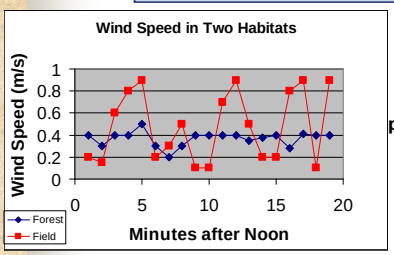
30.0 ft tall

Which is more accurate?

precise?

Scientific Data: Attributes

The nature of precision



Which measurements are more precise?

Real values of environmental parameters often vary in time & space

Variability does not always equate with precision!

Scientific Data: Error & Uncertainty

Factors that contribute to variation in measurements

I. Inherent variation in space and time

1. Sampling issues (next time)

II. Measurement Errors

1. Human Error - perception
2. Instrument & Process Errors

Scientific Data: Error & Uncertainty

Factors that contribute to Variation in Measurements

II. Measurement Errors

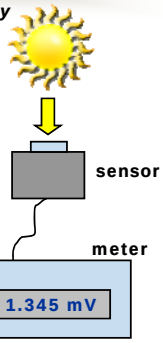
1. **Human Error - perception**
   - **Variation from care in measurements**
     - ✓ Parallax
     - ✓ Scale resolution
2. **Instrument & process errors:** *3 selected issues*
   - ✓ Instrument maintenance – calibration for accuracy
   - ✓ Instrument operation for accuracy
   - ✓ Instrument operation for precision

Instrument Calibration

What is CALIBRATION ?

Instrument Calibration

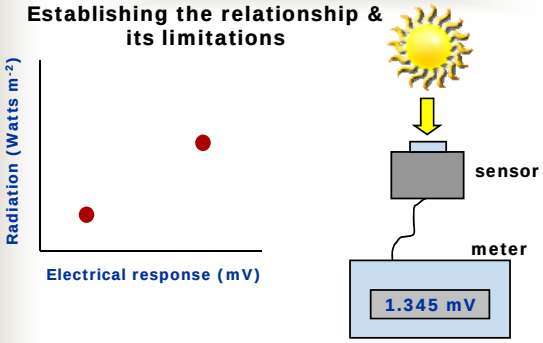
Measuring sunlight intensity



How do we get from electrical response to solar radiation intensity?

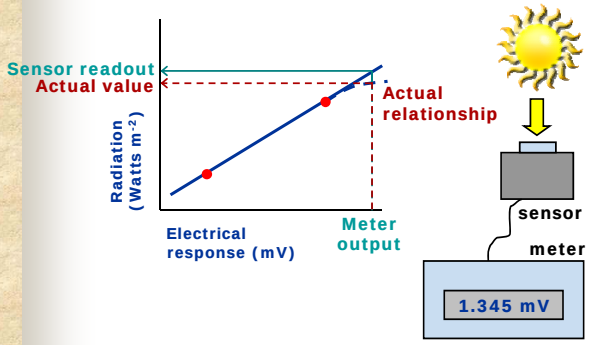
Instrument Calibration

Establishing the relationship & its limitations



Instrument Calibration

Danger of using an instrument outside of where it has been calibrated

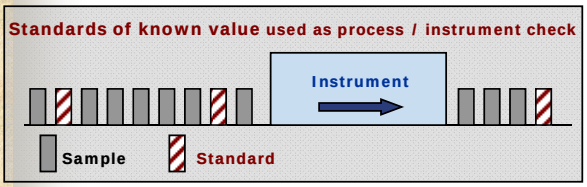


Scientific Data: Error & Uncertainty

Factors that contribute to Variation in Measurements

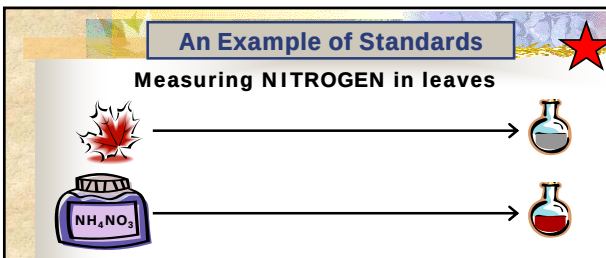
II. Measurement Errors

2. Instrument & Process Errors
   - Instrument maintenance: calibration for accuracy
   - Instrument operation: standards to verify accuracy



An Example of Standards

Measuring NITROGEN in leaves

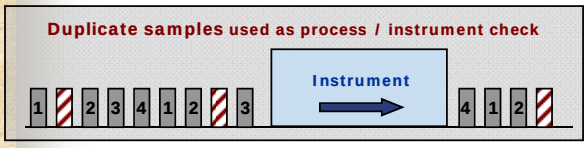


Scientific Data: Error & Uncertainty

Factors that contribute to Variation in Measurements

II. Measurement Errors

2. Instrument & Process Errors
   - Instrument maintenance: calibration for accuracy
   - Instrument operation: standards to verify accuracy
   - Instrument operation: duplicate samples for precision



Multiple leaves from same tree
Tissue samples from same leaf