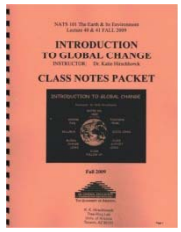
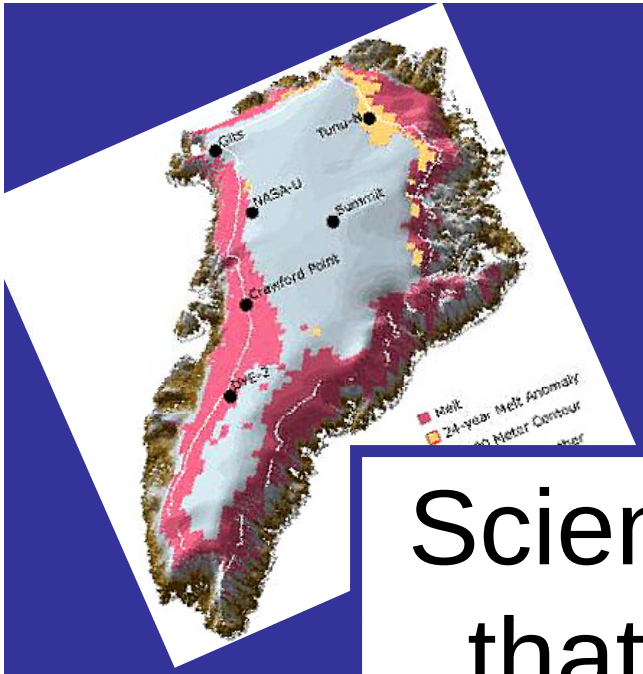
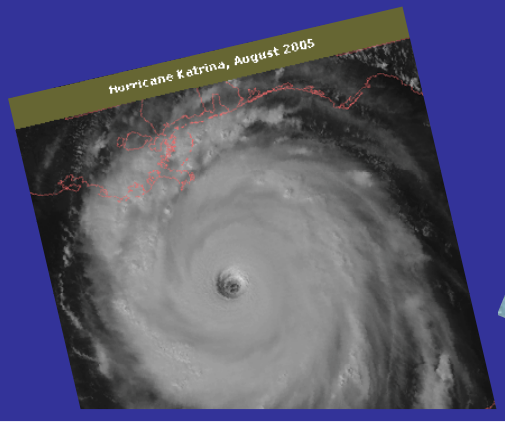
Topic #3:
GLOBAL CHANGE
&
THE CHALLENGE OF QUANTIFYING IT

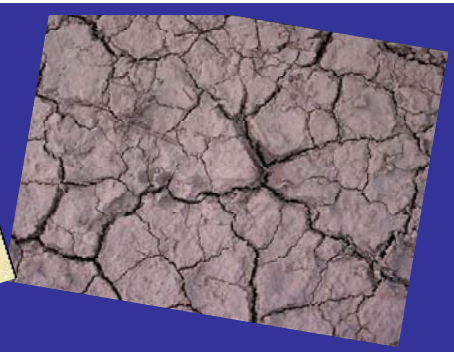






Science is demonstrating that this planet is more vulnerable than had previously been thought.

~ Richard Benedick



GLOBAL CHANGE SCIENCE

"The one universal ever-operating law throughout has been the law of change . . ." ***~ Laurence M. Gould***

Earth has always been changing in:

Atmosphere (gases – composition, abundance, vertical structure

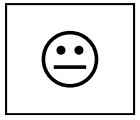
Solid Earth (core, mantle, crust, plate tectonics, volcanism, surface processes)

Hydrosphere (liquid, gaseous, solid)

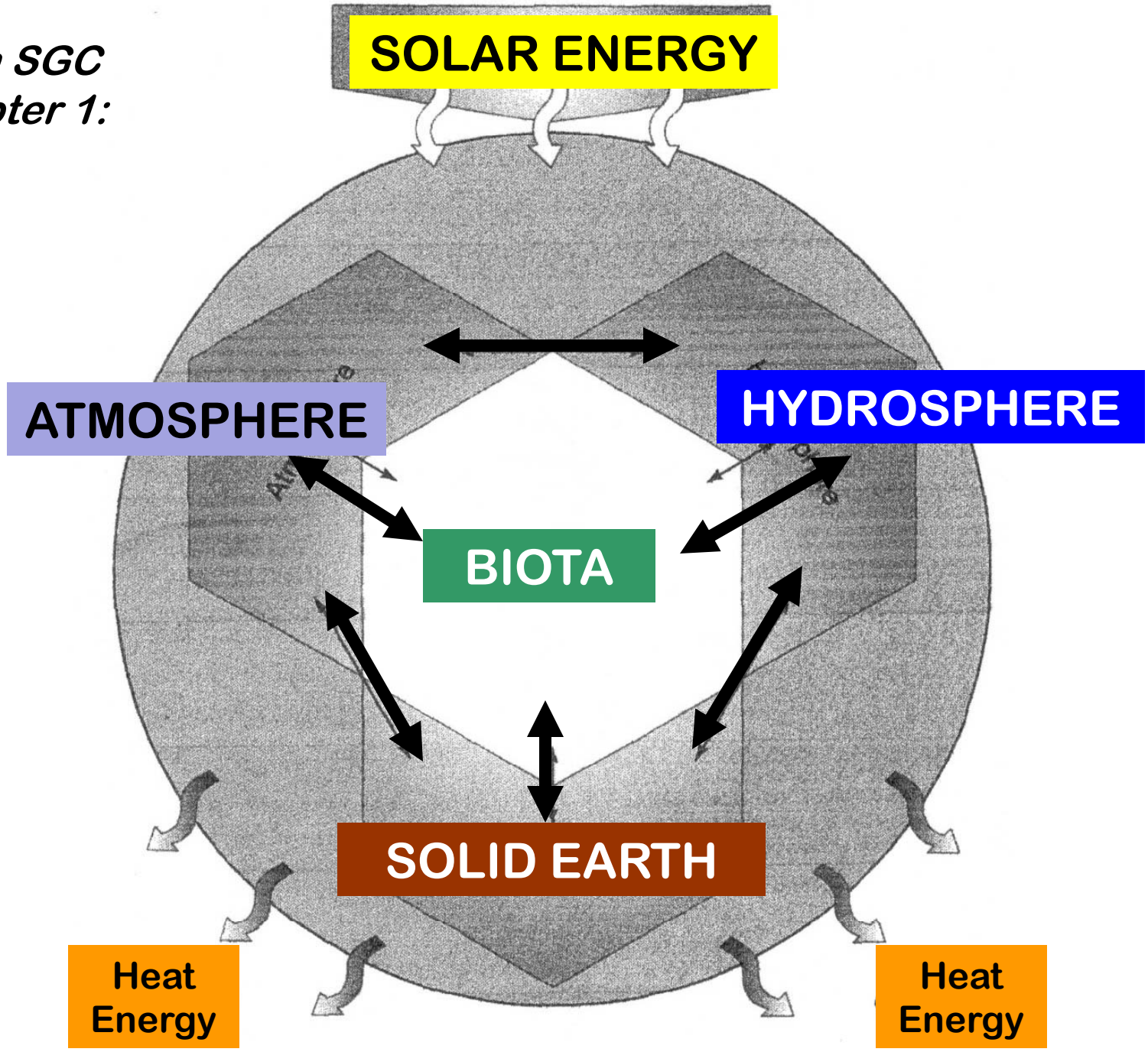
Biota (biosphere) (animal & plant life)

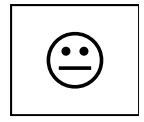
. . . .and in patterns and distribution of the above

Listen & think ➔
(not in Class Notes)

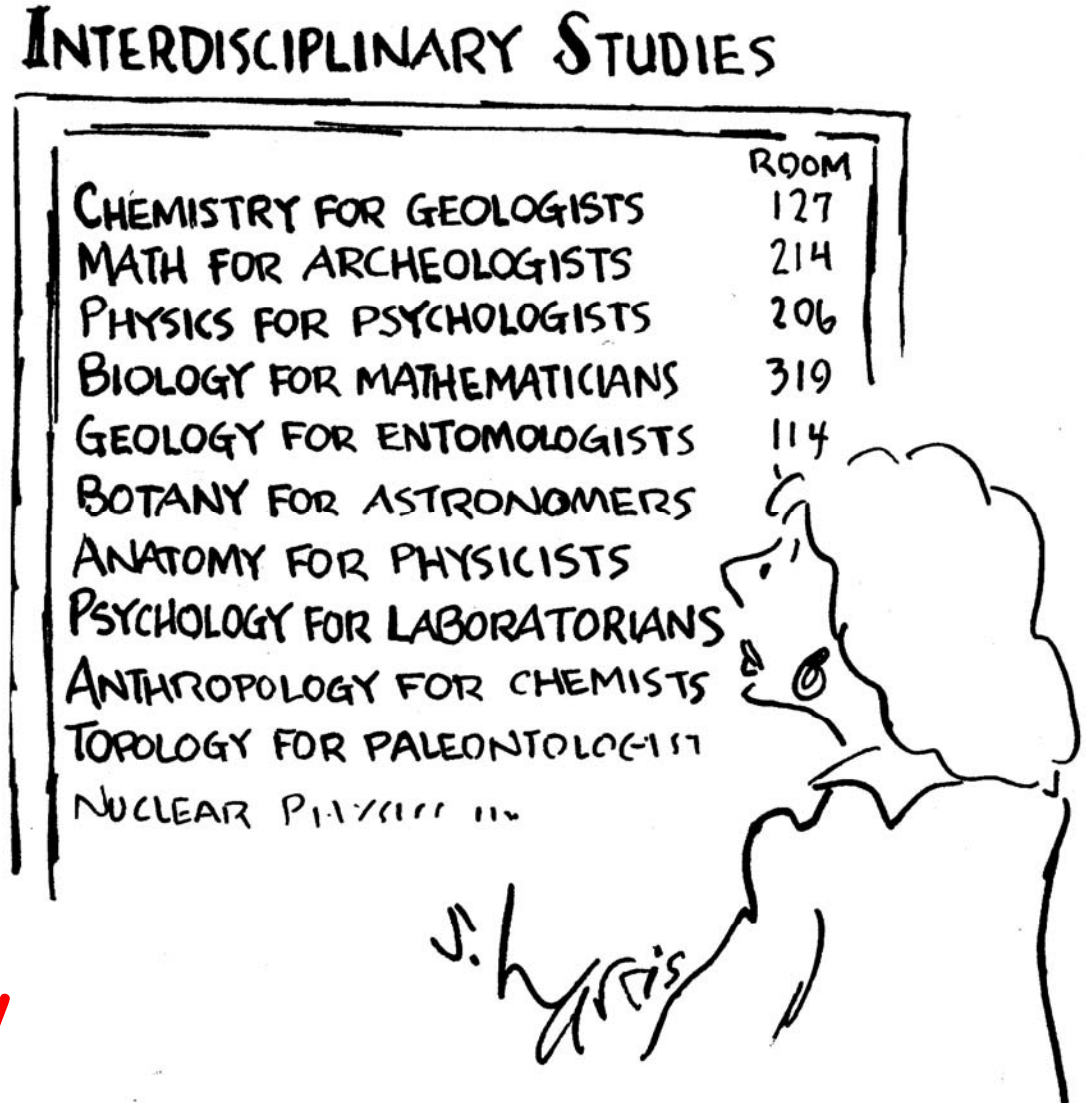


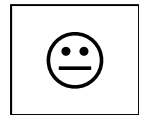
From SGC Chapter 1:

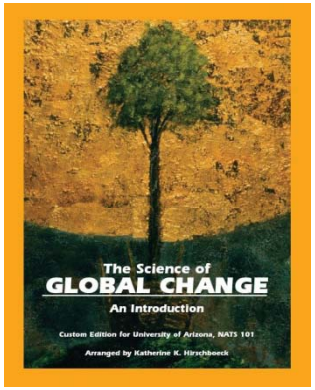




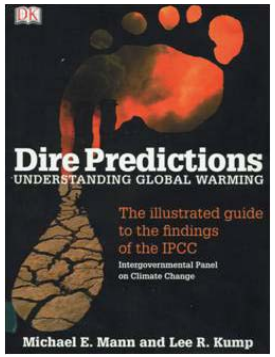
Hence studying global change requires an interdisciplinary approach







YOUR TEXTBOOKS:
EMPHASIZE
4 MAIN THEMES:



(a) Basics: Physical Science Background

(b) Basics: Energy Balance, Climate, & How They Change

(c) Observations of Climate Variability and Change

(d) Future Projections, Impacts, Vulnerability, Adaptation, Mitigation and Solutions

GC processes based on underlying physical science:

Matter **Thermodynamics**

Electromagnetism **Laws of Motion**

GLOBAL CHANGE SCIENCE IN ACTION

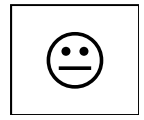
. . . at U of A
. . . Nationally
. . . Internationally

How Global Change Science is done:

Many disciplines involved, e.g., at U of A:

Geosciences
Hydrology & Water Resources
Atmospheric Sciences
Tree-Ring Laboratory
Plant Sciences
Renewable Natural Resources
Geography & Regional Development
Udall Center for Studies in Public Policy
Soil & Water Science
Arid Land Studies
Latin American Studies Center
Planetary Sciences
Optical Sciences Center
Electrical and Computer Engineering
Ecology & Evolutionary Biology

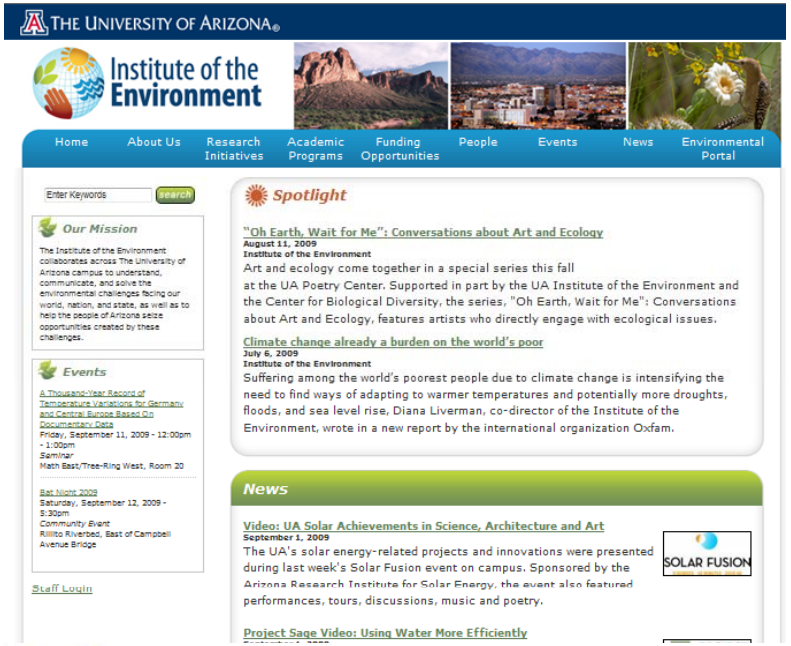
Economics & Agricultural Economics . . . etc. etc.



Institute of the Environment

Institute of the Environment (IE)

www.environment.arizona.edu



&

The University of AZ's Committee on Global Change

THE UNIVERSITY OF ARIZONA

Global Change PhD Minor Program

Our Mission

The Institute of the Environment collaborates across The University of Arizona campus to understand, communicate, and solve the environmental challenges facing our world, nation, and state, as well as to help the people of Arizona seize opportunities created by these challenges.

U.S. GLOBAL CHANGE RESEARCH PROGRAM

United States Global Change Research Program

Integrating federal research on climate and global change

http://www.globalchange.gov/

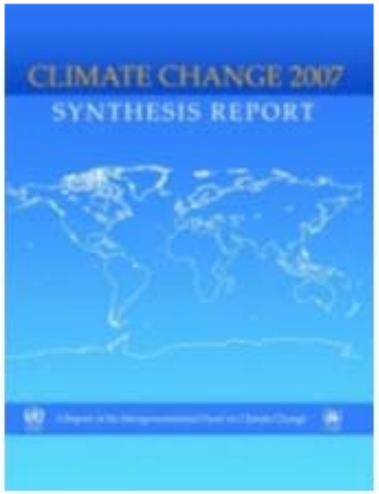
Reports and Assessments

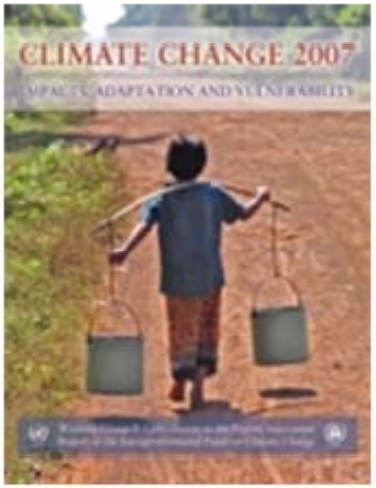
Annual Reporting to Congress

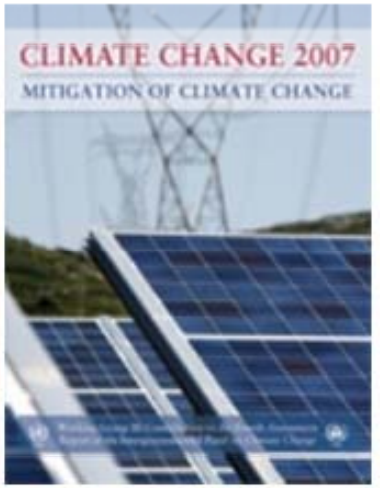
Intergovernmental Panel on Climate Change (IPCC)

http://www.ipcc.ch/

The AR4 Synthesis Report	WG I The Physical Science Basis	WG II Impacts, Adaptation and Vulnerability	WG III Mitigation of Climate Change







. . .which takes us to another "MODEL" ➔

OUR CLASS:

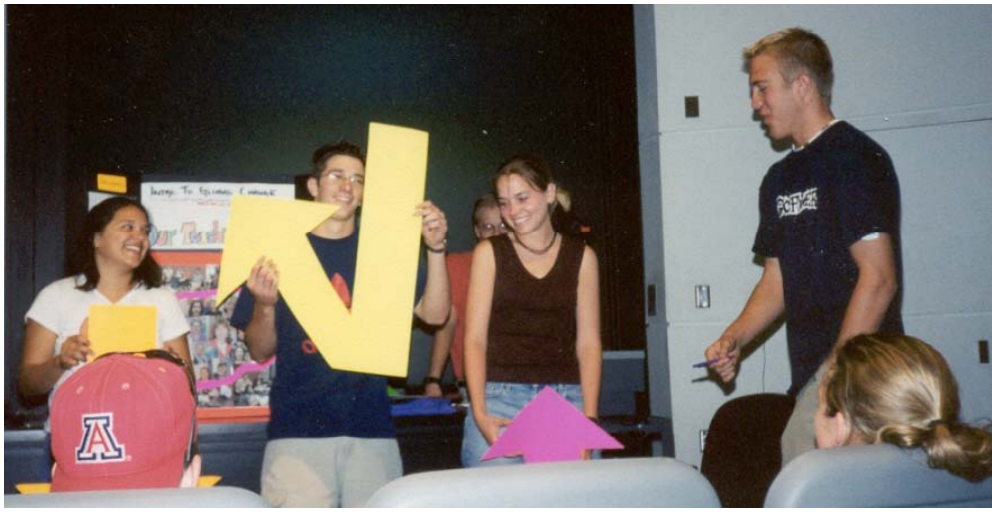
NATS 101-GC's Working Groups!

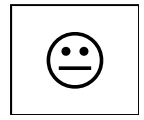
TEAMWORK!

A skill to develop for success in your future careers

What do employers want???

Why not consider being a preceptor???





METHODS USED IN GC SCIENCE

- Experiments
- Observations
- Modeling
- Standard “tools of science”-- hypotheses, prediction, testing, theories

Any unique to GC??

- Global Computer / Circulation Modeling: **GCMs**
- Determining Past Changes from “Natural Archives” (e.g. tree rings)
- Remote Sensing of the Environment

Concepts to think about as the semester progresses:

SUSTAINABILITY

Sustainability (ecological) = the ability to utilize natural resources without depleting their stocks or irrevocably damaging ecosystems. Maintaining resources in a way that they will be available for the benefit of future generations

Sustainability (economic) = growth in economic activity at such a rate that the economy keeps up with (or surpasses) the needs of a growing population.

We can estimate ecological sustainability via

THE ECOLOGICAL FOOTPRINT

The **Ecological Footprint** has emerged as the world's premier measure of humanity's demand on nature. It measures how much land and water area a human population requires to produce the resource it consumes and to absorb its wastes, using prevailing technology.

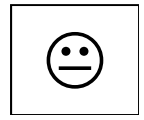
SOURCE: Global Footprint Network http://www.footprintnetwork.org/

We are currently overshooting the Earth's biological capacity by nearly 50%.

To sustain present levels of consumption, we would need:

MY ECOLOGICAL FOOTPRINT?

ON THURSDAY'S CLASS:
We'll get into WORKING GROUPS
& compare FOOTPRINTS!!
Check D2L and/or your email on Wed to find out your Group Assignment



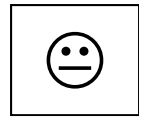
In the balance between resources, population, & human impact on the environment, 3 approaches are possible:

- **SUSTAINABILITY**
  use of resources now won't preclude their use in future
- **TECHNOLOGICAL INNOVATIONS**
  "we can fix the problem"
- **NATURE / HANDS OFF**
  "let Nature take its course"

"Humans have had a tremendous impact on our planet.
We have left our mark in many ways . . .

The damage can be reversed, but it will take years of cooperation by every individual and every nation." *

* *Pathways of Understanding: The Interactions of Humanity and Global Environmental Change," May 1992, CIESIN, p 40.*

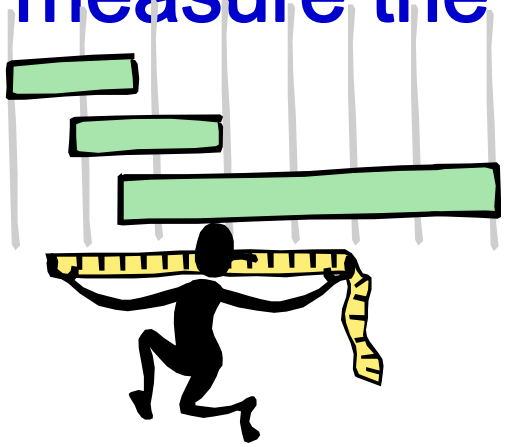


“The one universal ever-operating law throughout has been the law of change . . .”

~ Laurence M. Gould

On QUANTIFYING NATURE

- *Quantify* (def) = to make explicit the logical quantity of; to determine, express, or measure the quantity of



. . . On Quantifying Nature

PROBLEM: Scientists are faced with a major problem when they try to quantify nature:

- **Earth / global change phenomena and processes occur over an enormous RANGE of spatial and temporal SCALES.**

- **There is also an enormous range in the NUMBERS of things.**

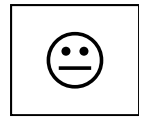
- **In addition, things in nature CHANGE in different ways and at different rates.**

. . .On Quantifying Nature

Without some way of expressing Earth and Global Change processes mathematically – how else can scientists measure, analyze and sort out the causes of global change?

Remember: Global change science is not a "LABORATORY SCIENCE" where we can conduct experiments to test hypotheses.

YOU & I ARE LIVING THE EXPERIMENT – one unrepeatable experiment!



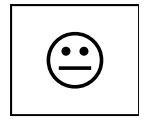
. . .On Quantifying Nature

Hence global change scientists use:

mathematical expressions
equations
symbols
models &

SCIENTIFIC NOTATION: e.g., 6.4×10^{-9}
to measure, analyze, and
"run experiments" on the Earth.

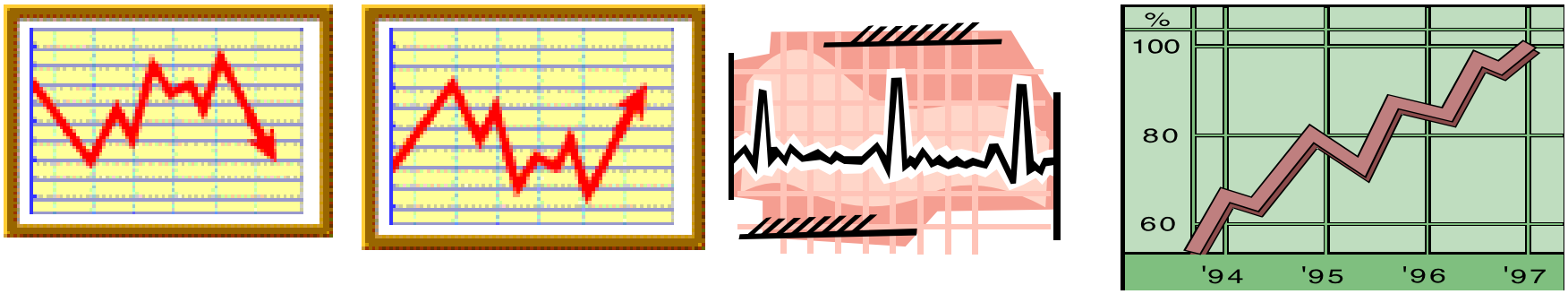
NOTE: Scientific Notation Review on p 18 of CLASS NOTES
– see also examples in SGC-II Chapter 2 on Atoms



Quantifying Change over TIME:

To quantify global change we examine TIME SERIES CHANGE:

A time series is a plot of value of some variable (x) at each point in time (t):



Quantifying Change over TIME:

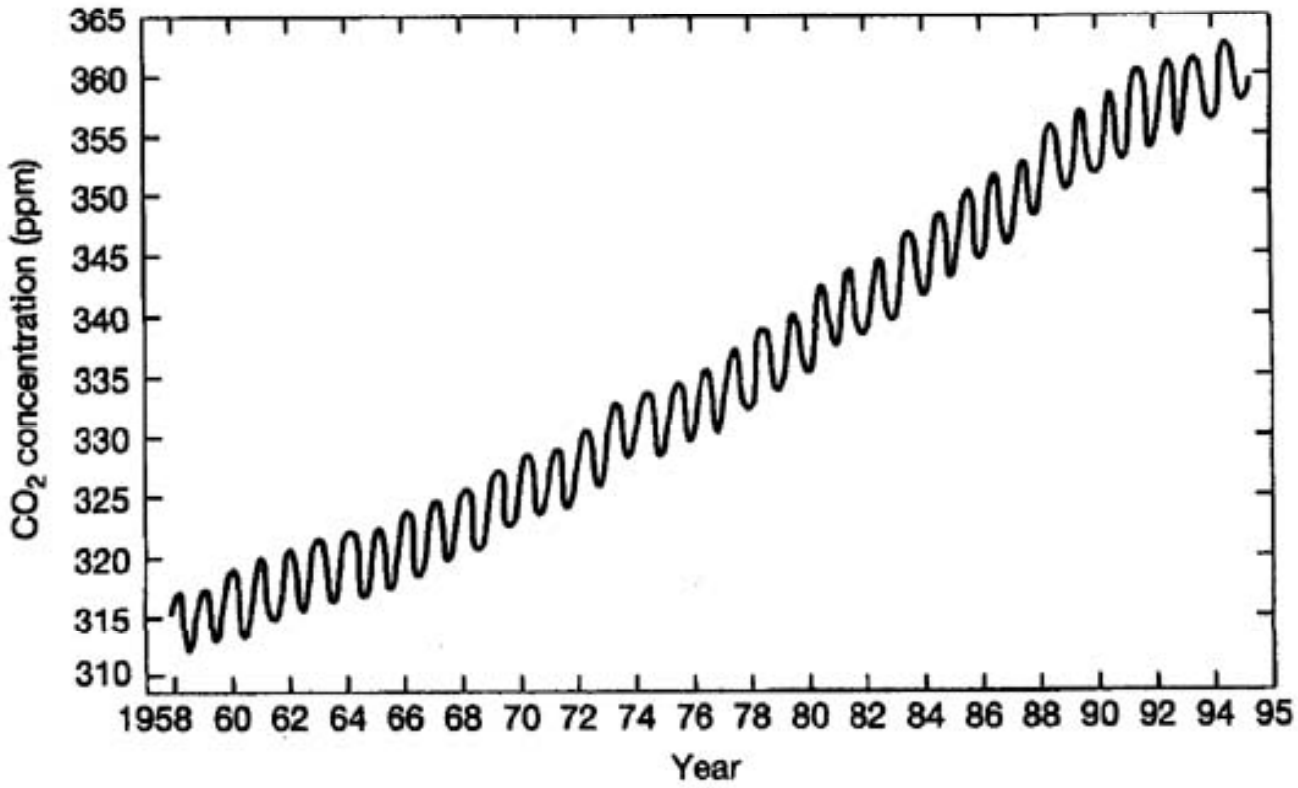
We also need to quantify
RATES OF CHANGE:

Change in some variable (x)
per change in time (t)

d(x) / d(t) where d = "change in,"

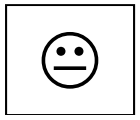
x = a variable, t = time

e.g. the "Keeling curve"



"the average rate of increase of CO^2 concentration since 1958 has been 43 ppm / 37 yr (or about 1.2 ppm/yr)"

ppm = parts per million

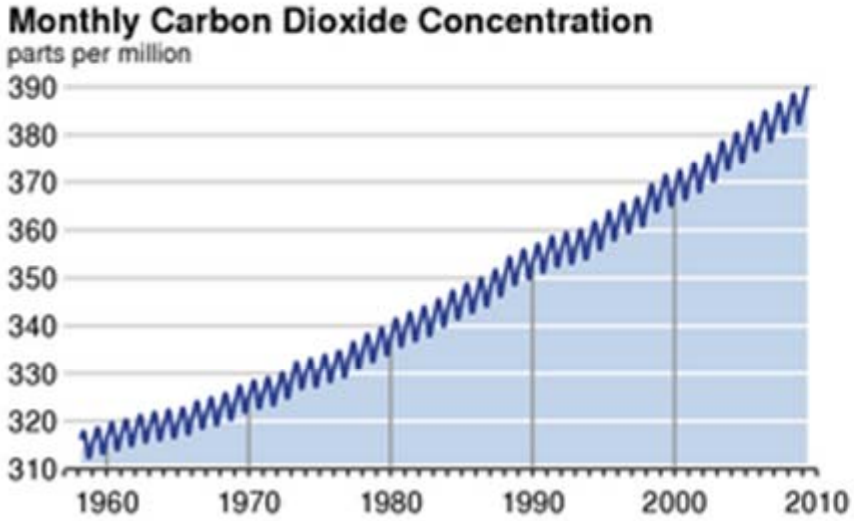


WELCOME TO SCRIPPS CO2

Welcome to the Home of the Keeling Curve

This site is dedicated to Dave Keeling, the first person to make high precision continuous measurements of carbon dioxide levels in the atmosphere.

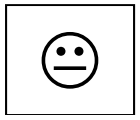
CO_2 Concentration at Mauna Loa Observatory, Hawaii

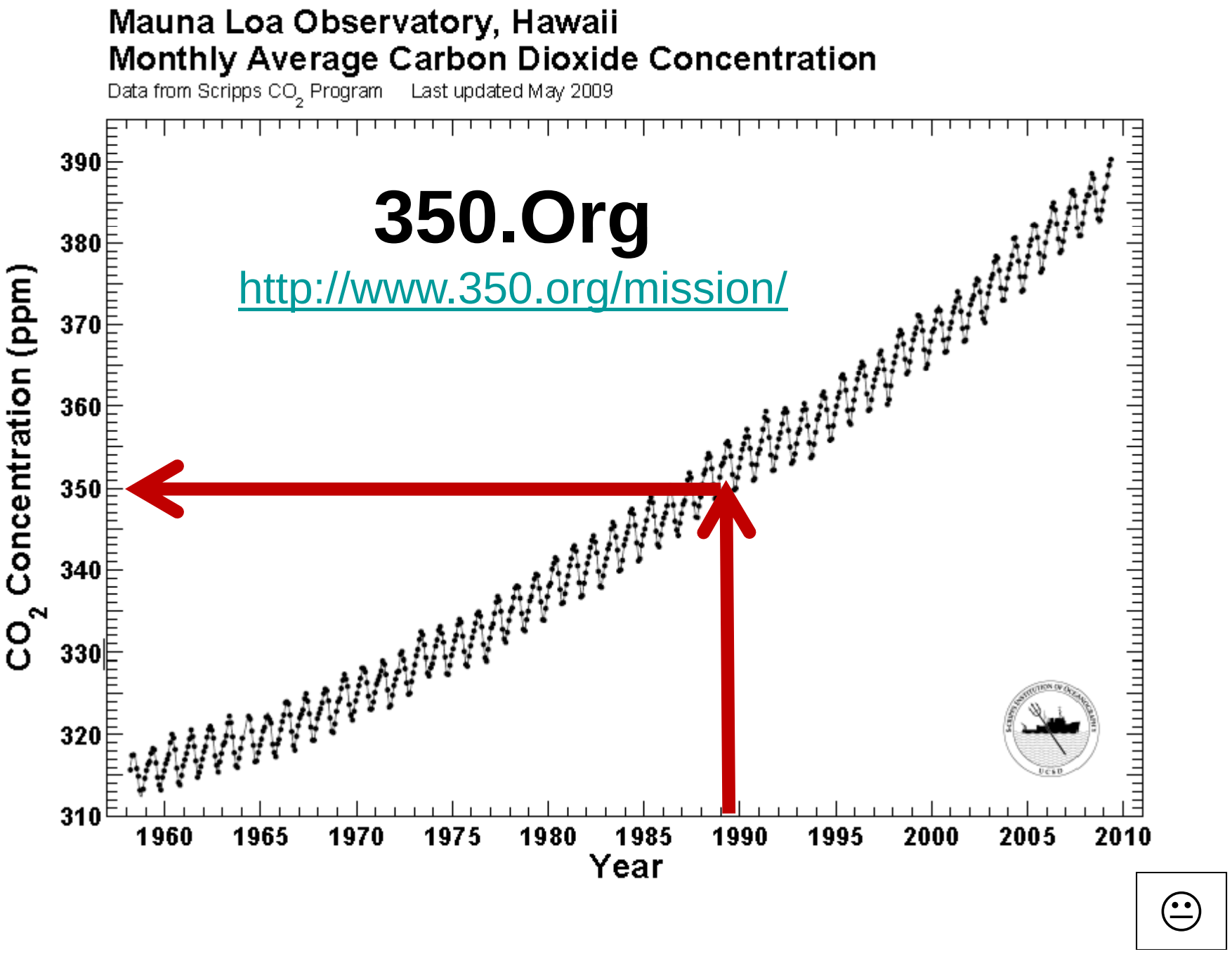


Keeling Curve

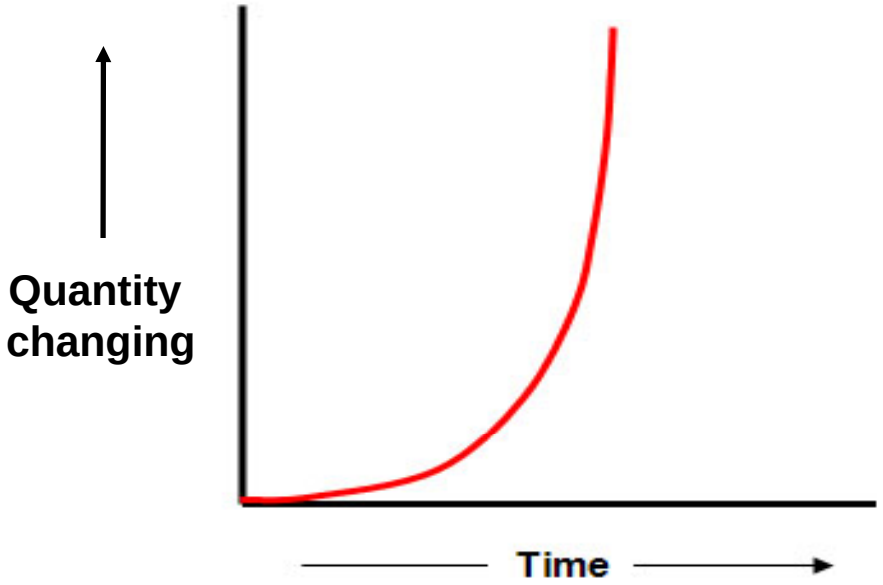
Mauna Loa Observatory

http://scrippsco2.ucsd.edu/




Mauna Loa Observatory, Hawaii
Monthly Average Carbon Dioxide Concentration
Data from Scripps CO2 Program Last updated May 2009
350.Org
http://www.350.org/mission/
CO2 Concentration (ppm)
390
380
370
360
350
340
330
320
310
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

Powers of 10 can be used to express exponential rates of change



A Classic Video on
The Relative Spatial Scale of Things:

"POWERS OF 10"

"In 1977, Charles and Ray Eames made a nine-minute film called Powers of Ten that still has the capacity today to expand the way we think and view our world. Over ten million people have since seen the film . . . ."

"Eventually, everything connects."—Charles Eames

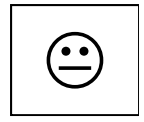
THINKING DEEPLY:
MORE ON "POWERS OF 10"
via WEBSITES:

Powers of 10 -- classic video

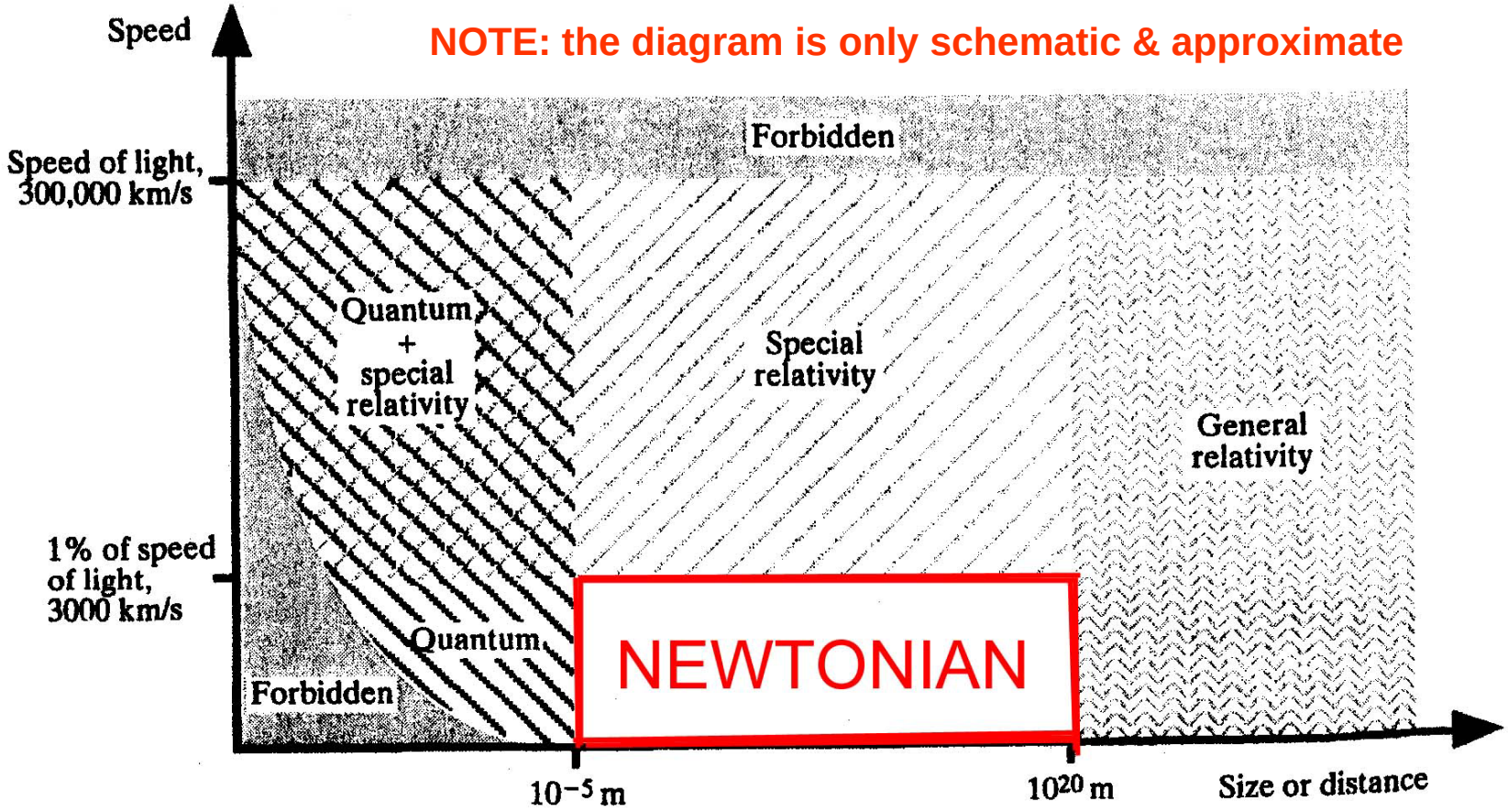
Powers of 10 website - updated website companion to the classic video by Charles & Ray Eames

Cosmic View: The Universe in 40 Jumps - online version of classic book by Kees Boeke

Powers of 10 Interactive Tutorial - an online Java journey -- similar to the video



The Relative Scale of Things



Newtonian physics breaks down for very SMALL objects, very LARGE objects, & very FAST objects.

Newton's laws of motion also break down for strong gravitational forces, such as those near a neutron star or black hole.

IN-CLASS ACTIVITY

"Think-Pair-Share"
Exercise on:
PLOTTING CHANGE OVER TIME

RECOGNIZING & DESCRIBING DIFFERENT TYPES OF CHANGE AS DEPICTED IN TIME SERIES PLOTS

Here are some terms that will help you describe time changes more precisely in fewer words:

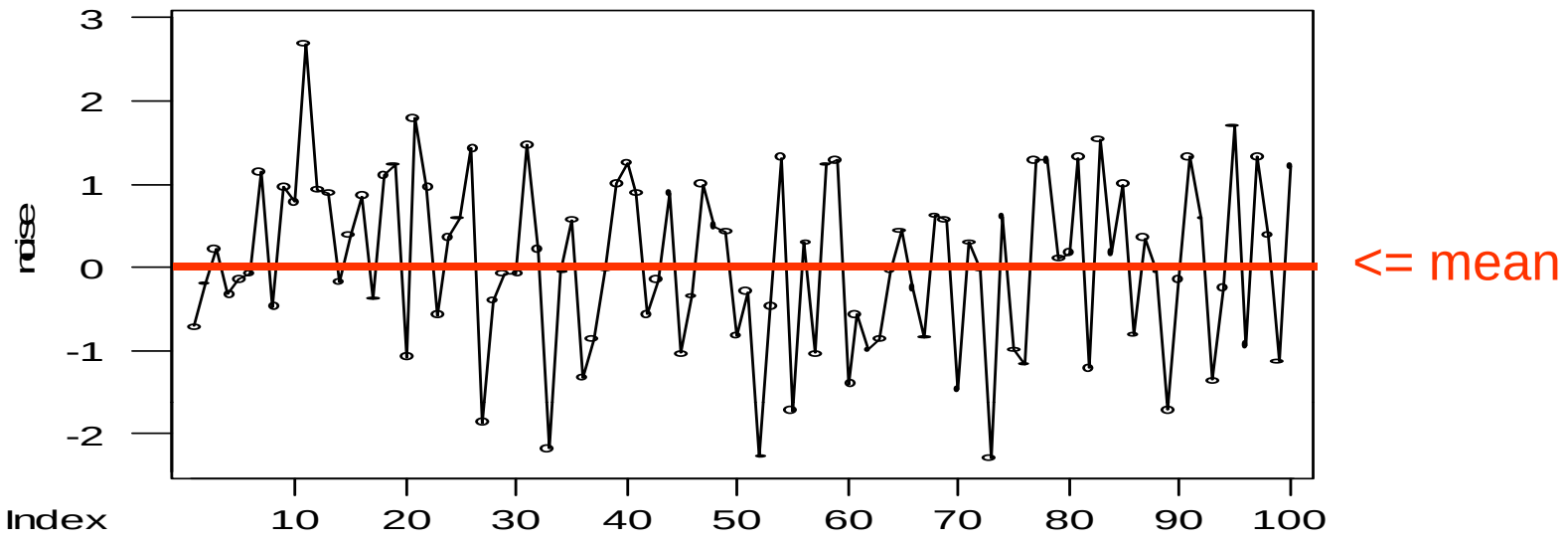
- **Mean** = average (a constant mean stays the same over time and looks like a horizontal line.)
- **Variance** = the range of fluctuations (wiggles) above and below the mean (statistically the variance is the square of the standard deviation about the mean)

Terms (cont.)

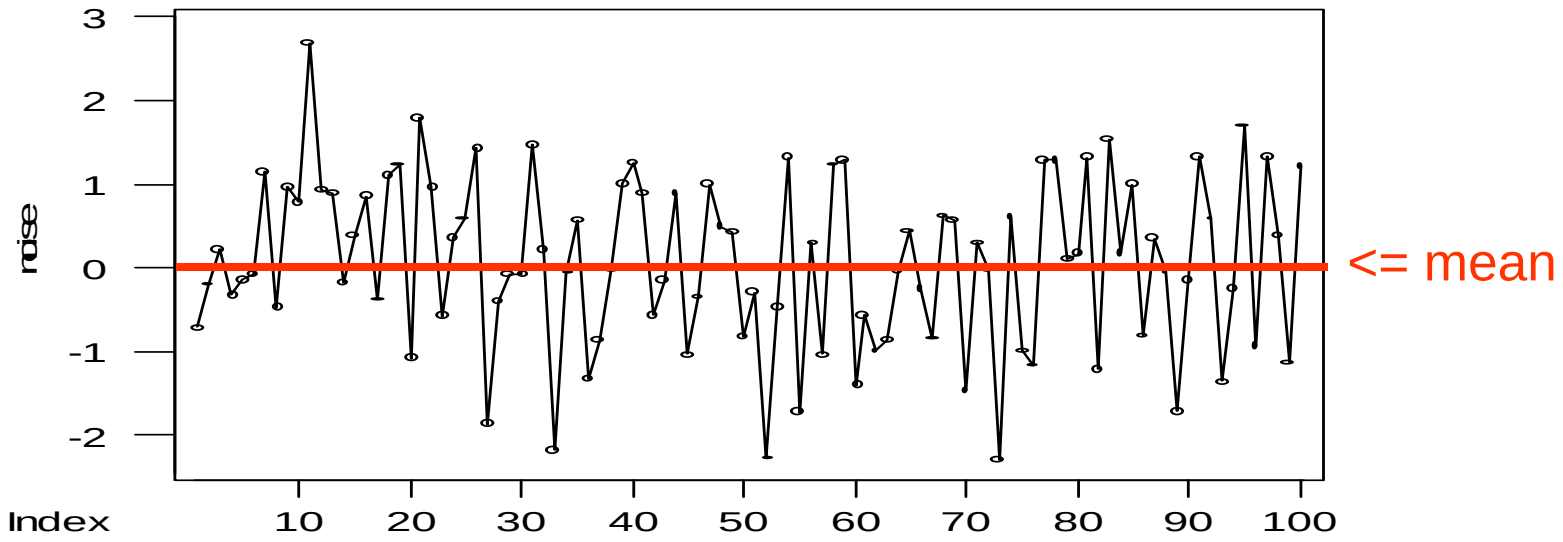
Periodic = perfect oscillations (fluctuations) (going up and down regularly or in a perfect wave-like motion)

- **Quasi-periodic** = almost regular oscillations (in nature things are quite often quasi-periodic rather than perfect oscillations)
- **Trend** = a line of general direction (increasing or decreasing)

Time Series Plot 1

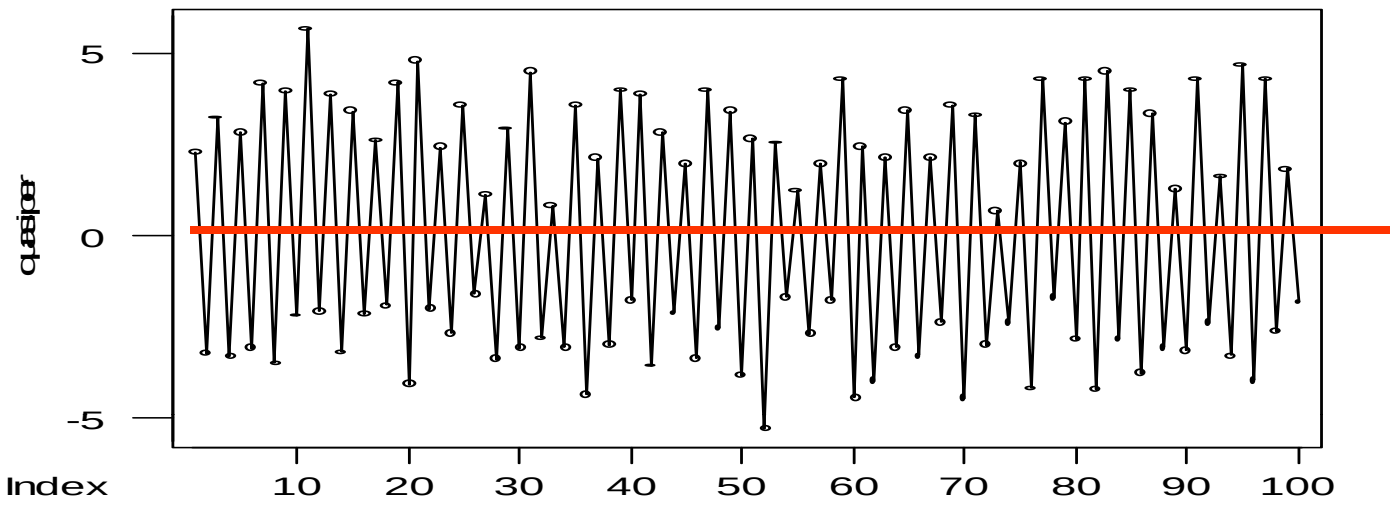


Draw in the MEAN line for this time series.



“White Noise” or “Random”plot -- This plot appears to go up and down without any regular pattern (e.g., randomly); there are about as many points above the CONSTANT time series mean (average) as below; and the range of wiggles (variance) above and below the mean seems to be about the same over time.

Time Series Plot 2

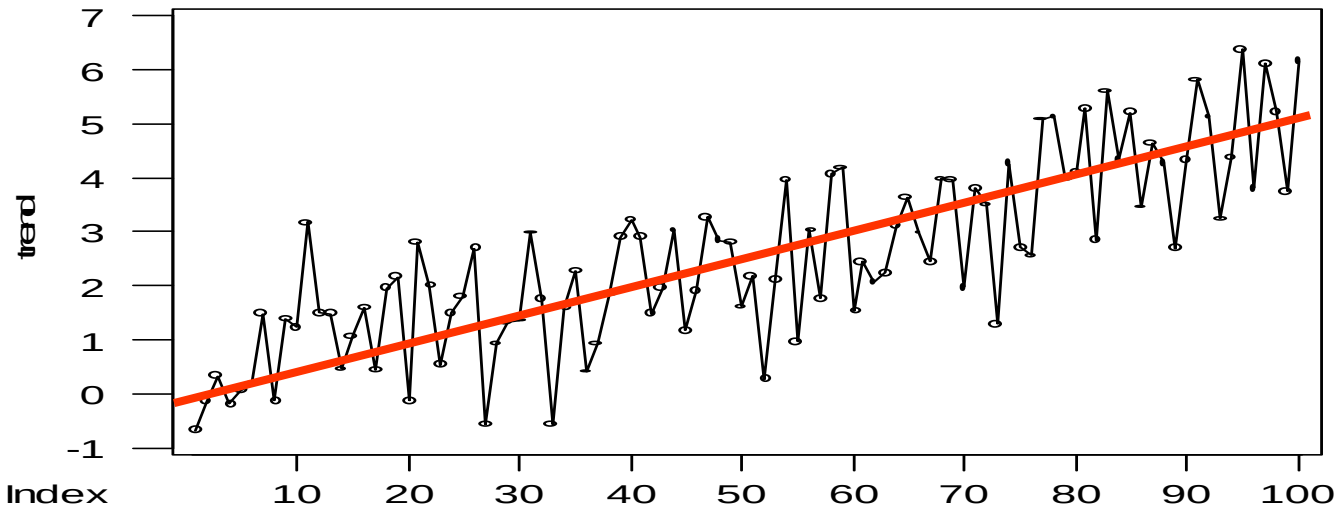


“Quasi-periodic plot”

Is the mean constant?

Is the variance constant?

Time Series Plot 3

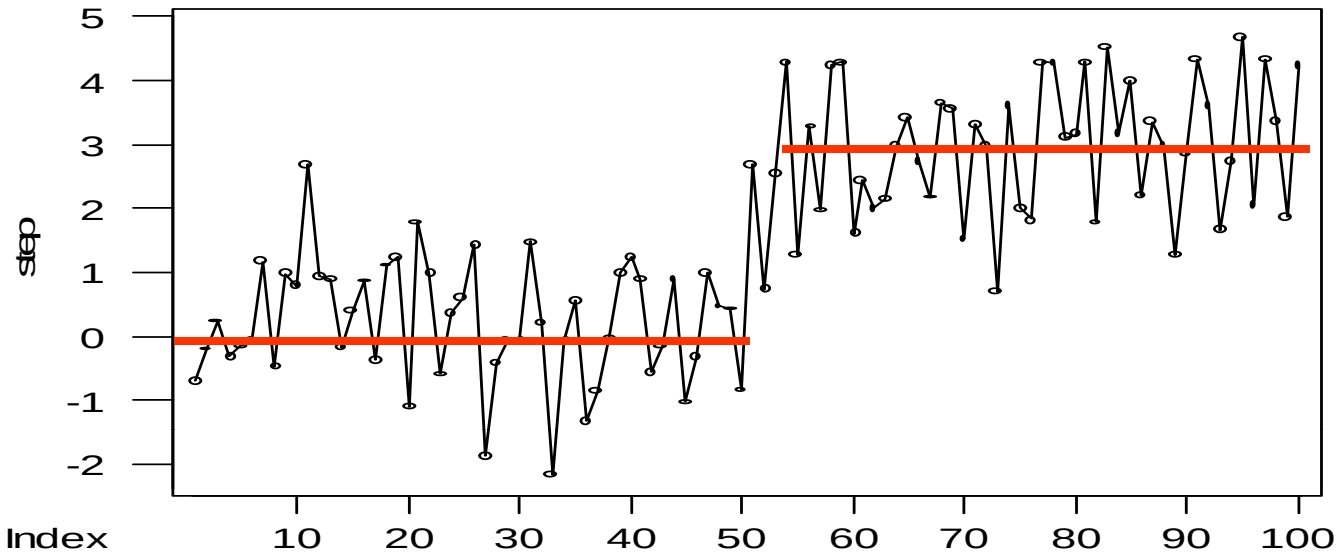


“Trend” plot

What’s happening to the mean?

Is the variance constant?

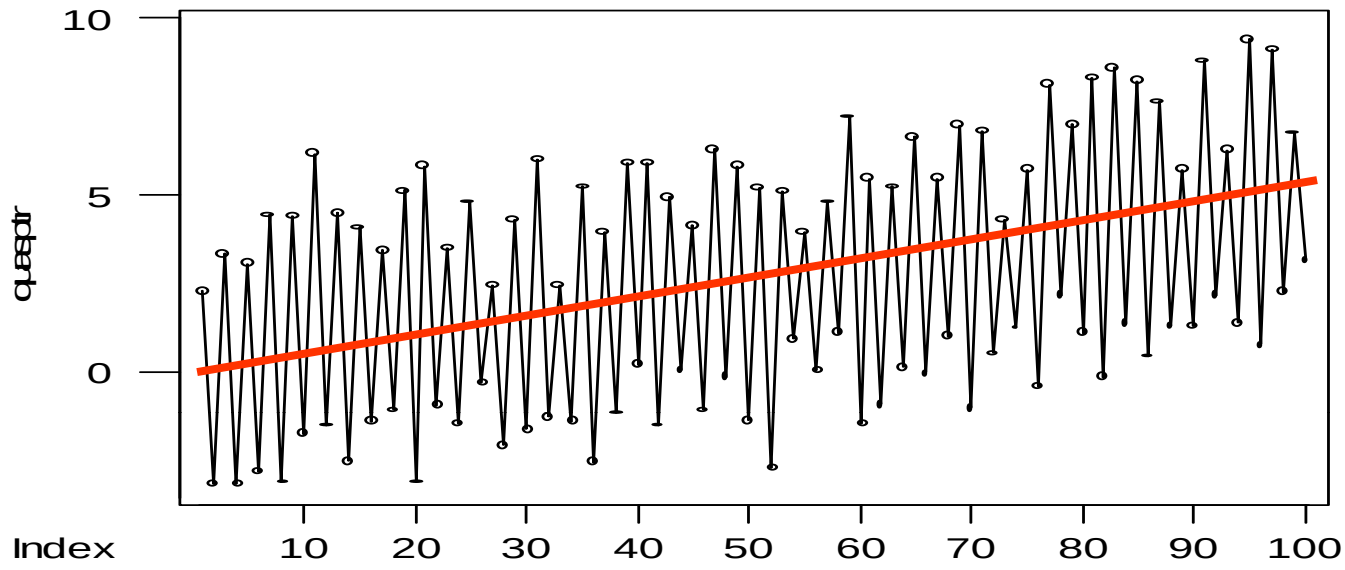
Time Series Plot 4



“Step change” plot

An abrupt jump between two series, each with a constant _____

Time Series Plot 5

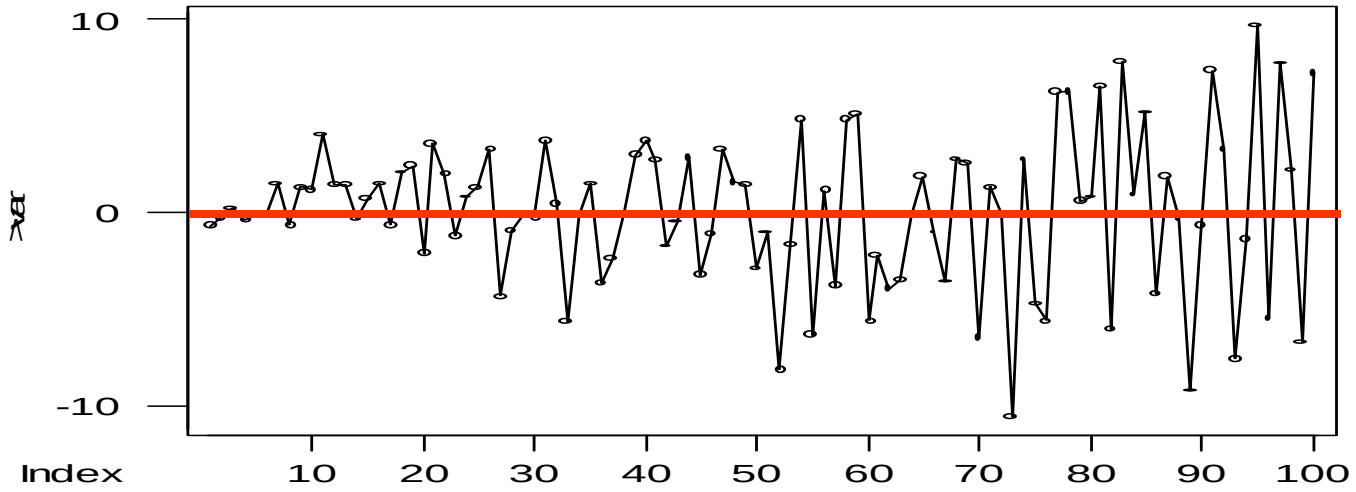


“Quasi-periodic with upward trend” plot

What’s going on with the mean?

The variance?

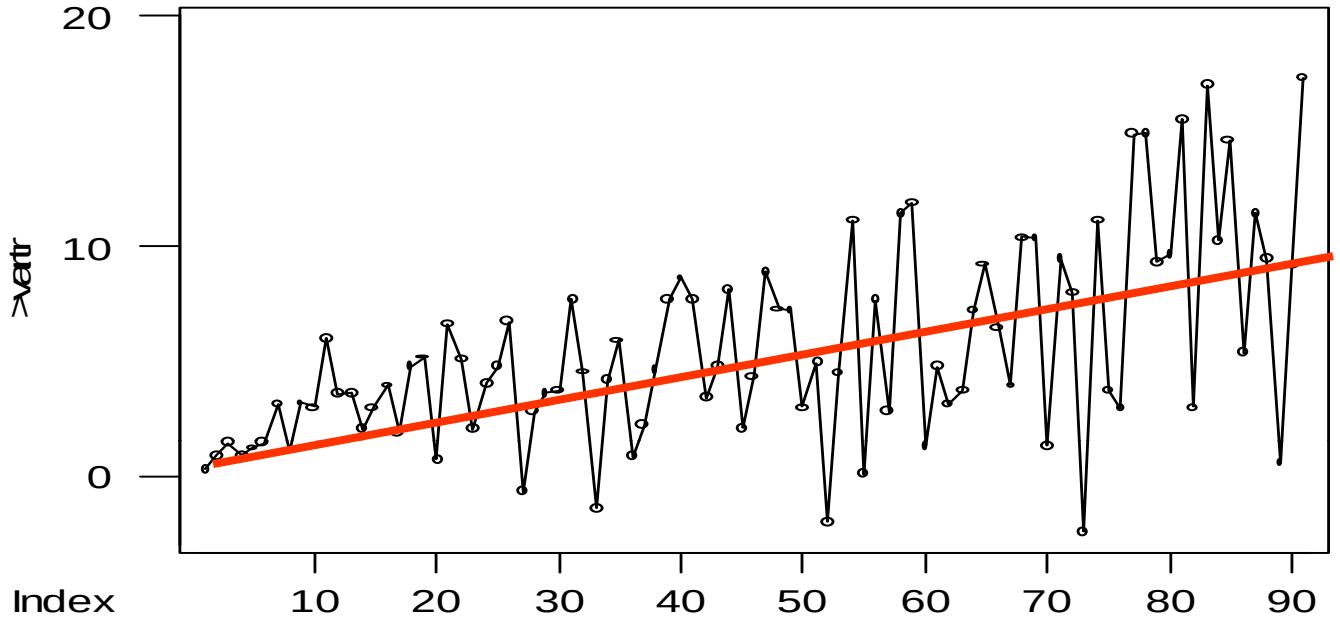
Time Series Plot 6



What's going on with the mean?

The variance?

Time Series Plot 7

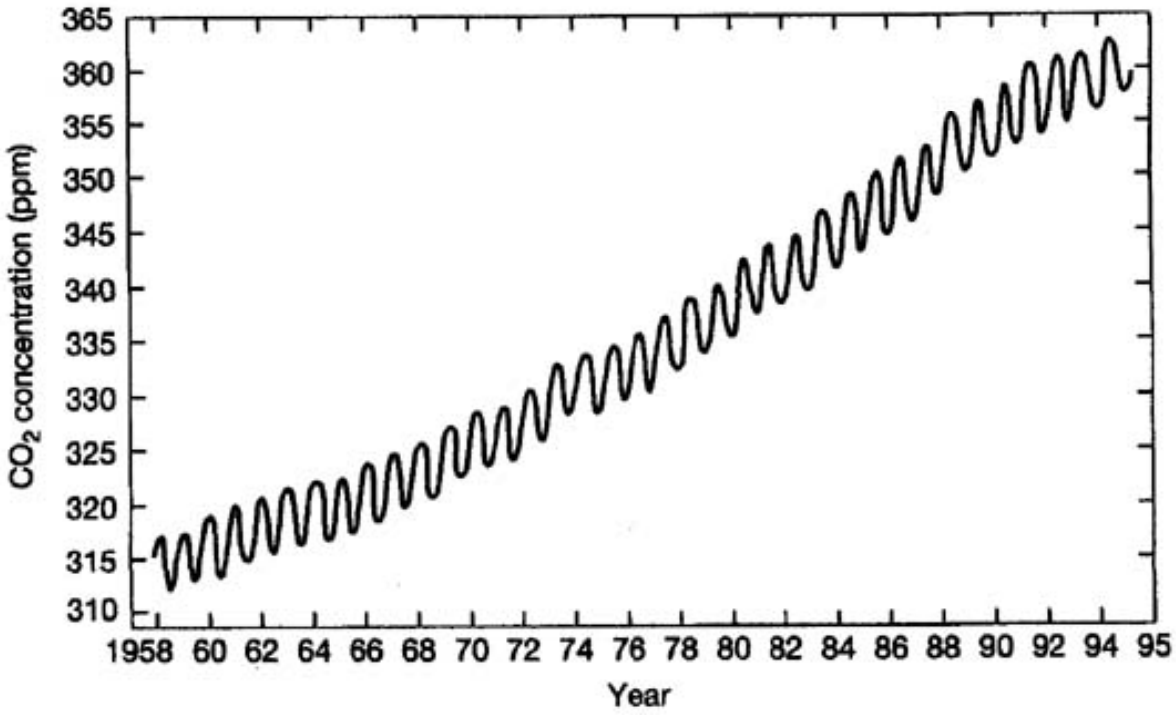


Is there a trend?

What's going on with the mean over time?

What's going on with the variance?

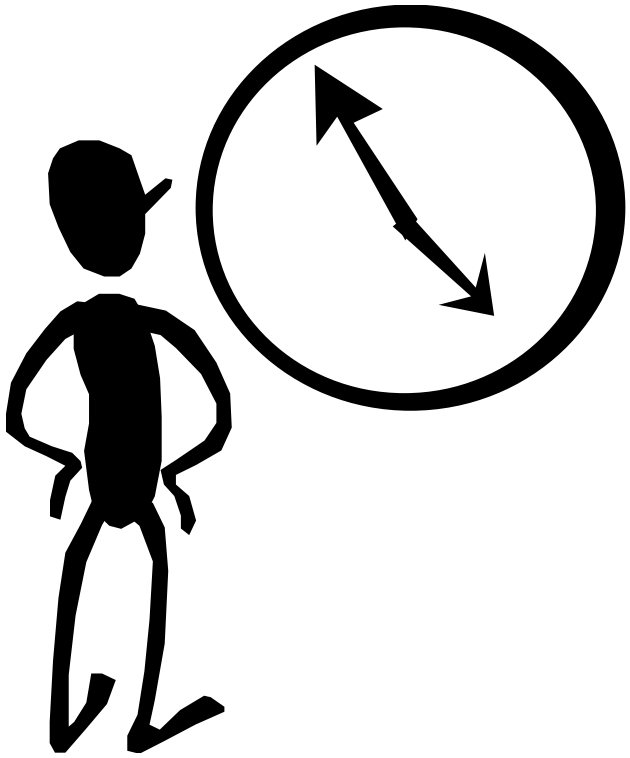
the “Keeling curve” is most like Plot # ____ ?



After you are done with the Time Plots

Go back to PART B
on the GREEN HANDOUT:

SOME QUOTES BY SCIENTISTS



IT'S TIME TO END YOUR DISCUSSION . . .

PLEASE WRAP IT UP AND QUIET DOWN.

PHRASES ABOUT SCIENCE FOR MATCHING:

__5___ Curiosity & self-discovery tend to motivate scientists
("Ask questions! . . " Paul Ehrenfest)

__4__ Dedicated & persistent research yields benefits
("No, it's a great life . . ." Steven Weinberg)

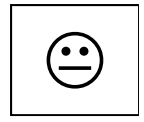
__2__ Scientists are attracted by the wonder, awe, & joy found in their research *("The joy of insight . . ." Victor Weisskopf)*

__1__ Inspiration emerges from a well-informed mind
("Newton's . . act of the prepared imagination" John Tyndall)

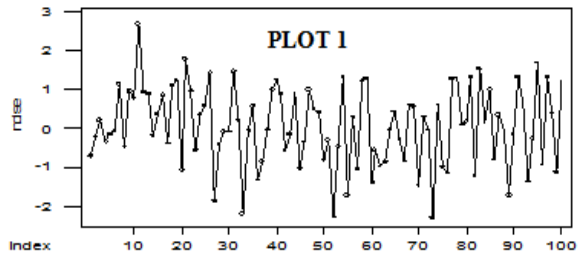
__7__ Theories cannot be verified, but they can be falsified
("No amount . . . can prove me right . . ." Albert Einstein)

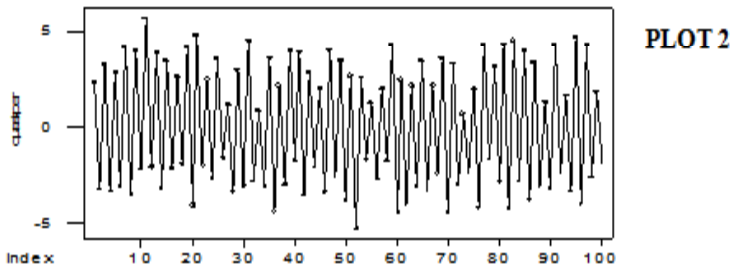
__3__ Self-deception can color an observation
(" ...art to be learned -- not to see what is not." Maria Mitchell)

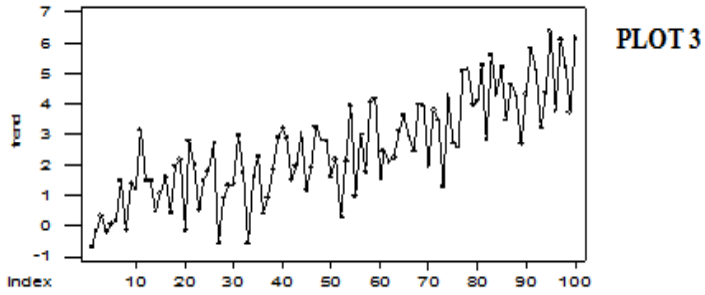
__6__ Knowledge is ever-changing
("law of change ...Nature never stands still ..." Laurence Gould)

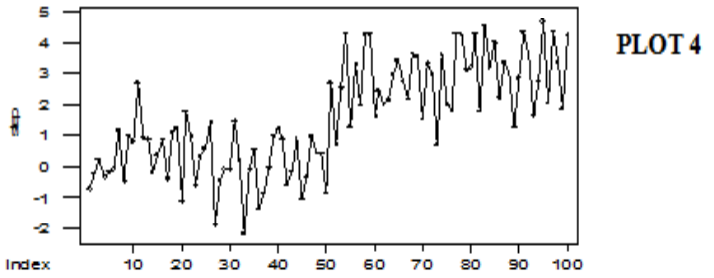


ANSWERS TO TIME SERIES GRAPHS







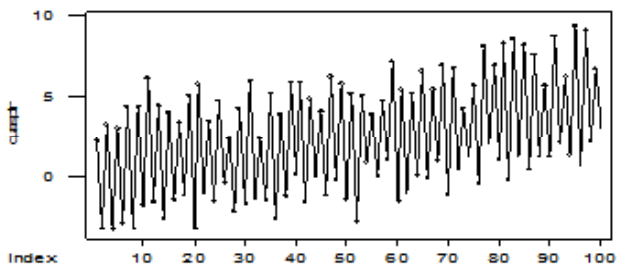


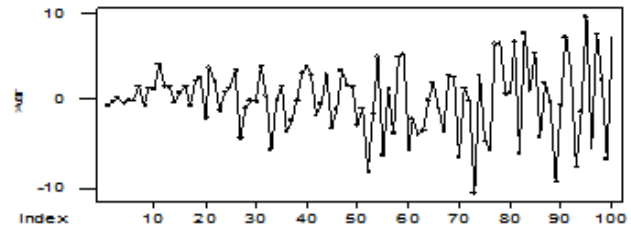
PLOT #1: "White noise" (random fluctuations) but with constant mean and variance [answer given for you]

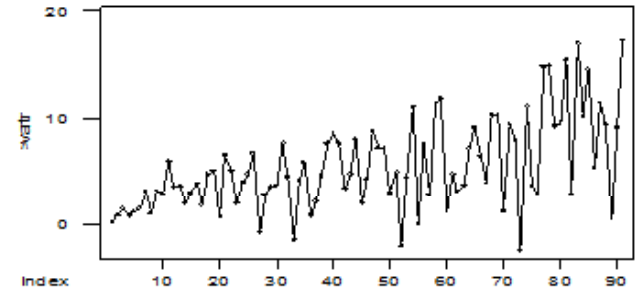
PLOT #2: **"**Quasi-periodic plot" with constant mean and variance. [Graph goes up and down very regularly (periodically); the mean stays the same, the range of fluctuations above and below the mean stays about the same over time.]

PLOT #3: "Trend" plot with the mean increasing over time, but a constant variance. [Graph shows trend of increasing values and increasing mean; the range of fluctuations is about the same.]

PLOT #4: "Step change" plot with an abrupt jump between two series like Plot 1. [Graph shows a "jump" or abrupt change between two different time series, each having a constant mean and variance]







PLOT #5: "Quasi-periodic with upward trend" plot [Graph shows an increasing trend and increasing mean, but has regular periodic ups and downs above and below the increasing mean.]

PLOT #6 "Increasing variance but constant mean" plot. [Graph's mean is constant but the range of fluctuations above and below the mean increases over time.]

PLOT #7 "Trend with increasing mean and increasing variance" plot [Graph had both an increasing mean and an increase in the range of fluctuations above and below the mean over time – the extremes are getting bigger!]

KEELING CURVE QUESTION:

Answer = Plot #5 WHY? The Keeling curve shows an increasing trend with a regular to quasi-periodic oscillation

Plot #3 is the second best answer.)