OBJECTIVES FOR TODAY'S CLASS:

COURSE TOPICS:

- **Review and wrap up science concepts from Friday's class**
- **Address the problems of QUANTIFYING NATURE in Global Change**
- **Learn what the KEELING CURVE is, why it is important, & why "350" is an important data point on the curve**
- **Review exponential relationships and the Powers of 10: important tools to express change and vast ranges of size, speed, time, etc.**
- **Learn terminology to describe changes depicted in TIME SERIES graphs**

COURSE LOGISTICS:

- **Look over the entire semester via the SEMESTER-ON-A-PAGE & TEXTBOOK /RQ SCHEDULE handout**
- **Learn about being a PRECEPTOR from a former student who was one!**

WRAP-UP & REVIEW:

Topic #2:
ON SCIENCE & BEING A SCIENTIST

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

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**

PART B: 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)

Topic #3: QUANTIFYING GLOBAL CHANGE:

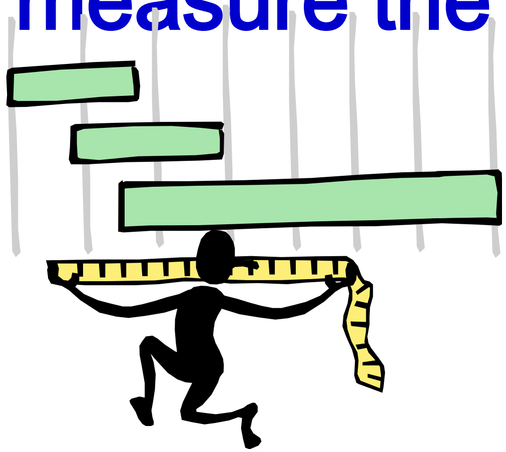
Scales, Rates & Time Series

“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 &

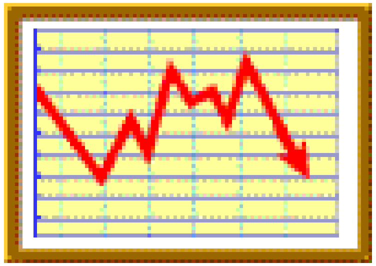
SCIENTIFIC NOTATION: e.g., 6.4×10^{-9}
to measure, analyze, and
"run experiments" on the Earth.

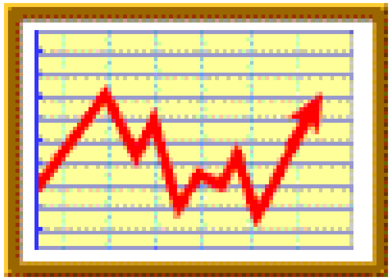
NOTE: This is a short Scientific Notation Review on p 18 of CLASS NOTES – see also examples in SGC E-text Chapter 2 on Atoms

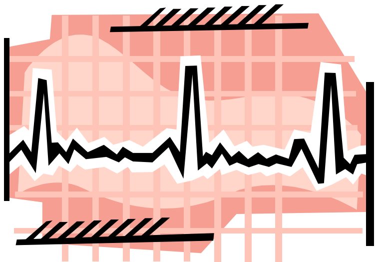
Quantifying Change over TIME:

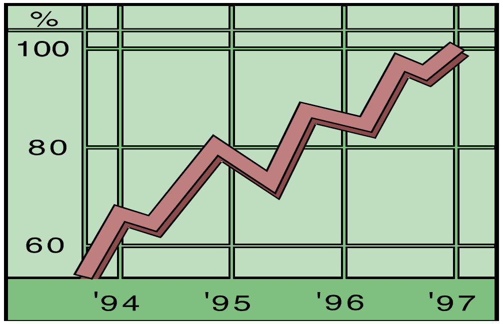
To quantify global change we examine TIME SERIES CHANGE:

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









Quantifying Change over TIME:

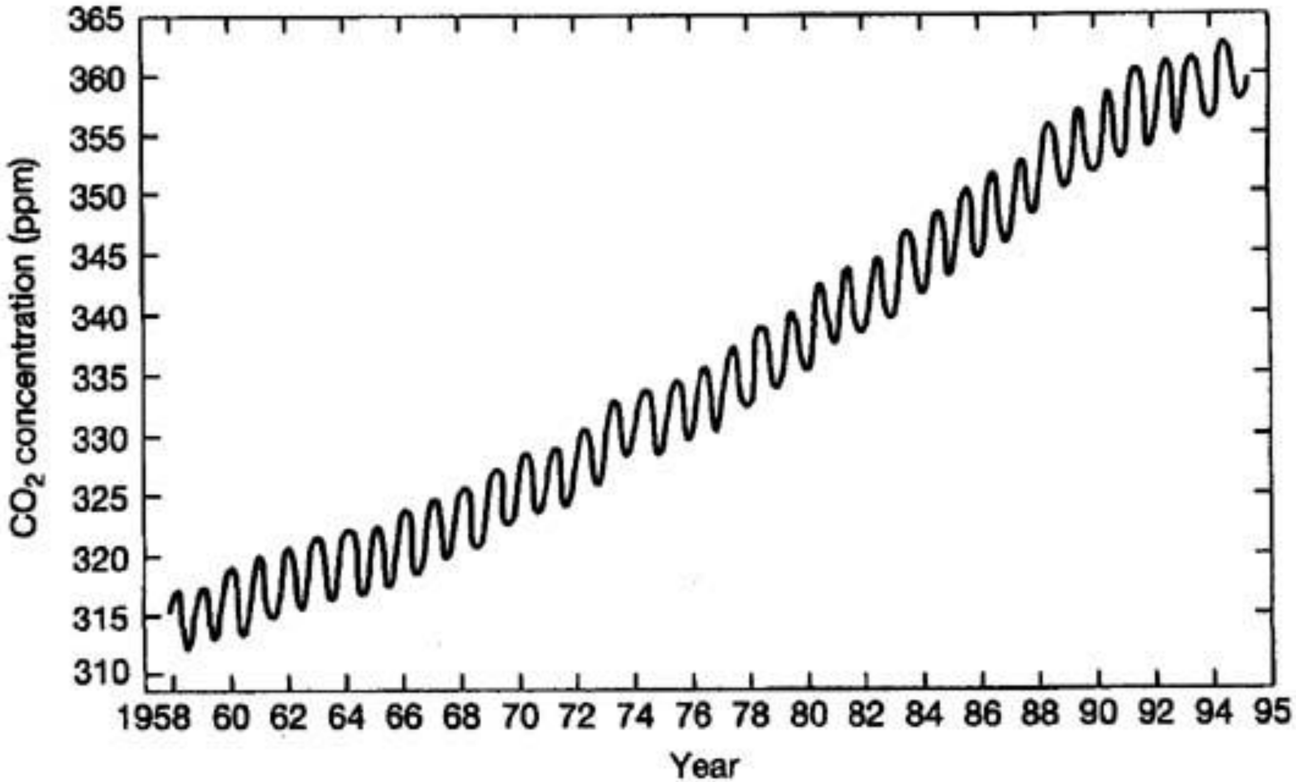
We also need to quantify
RATES OF CHANGE:

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)"

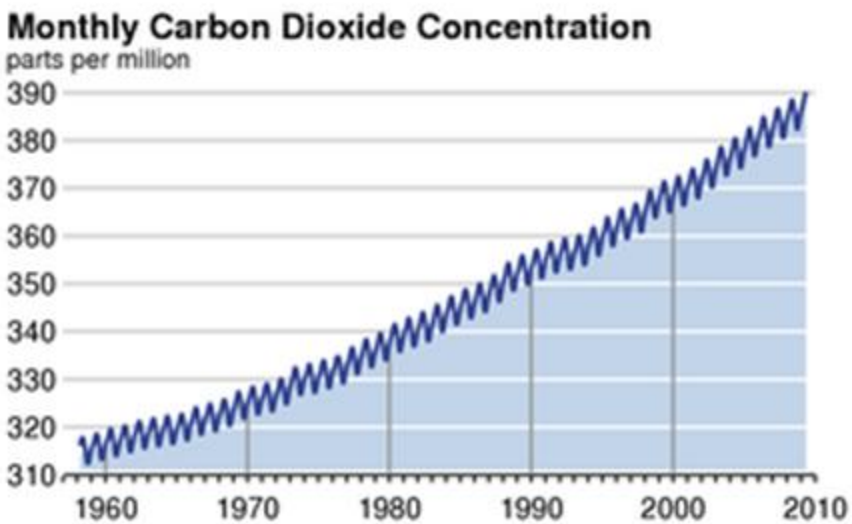
ppm = parts per million

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.

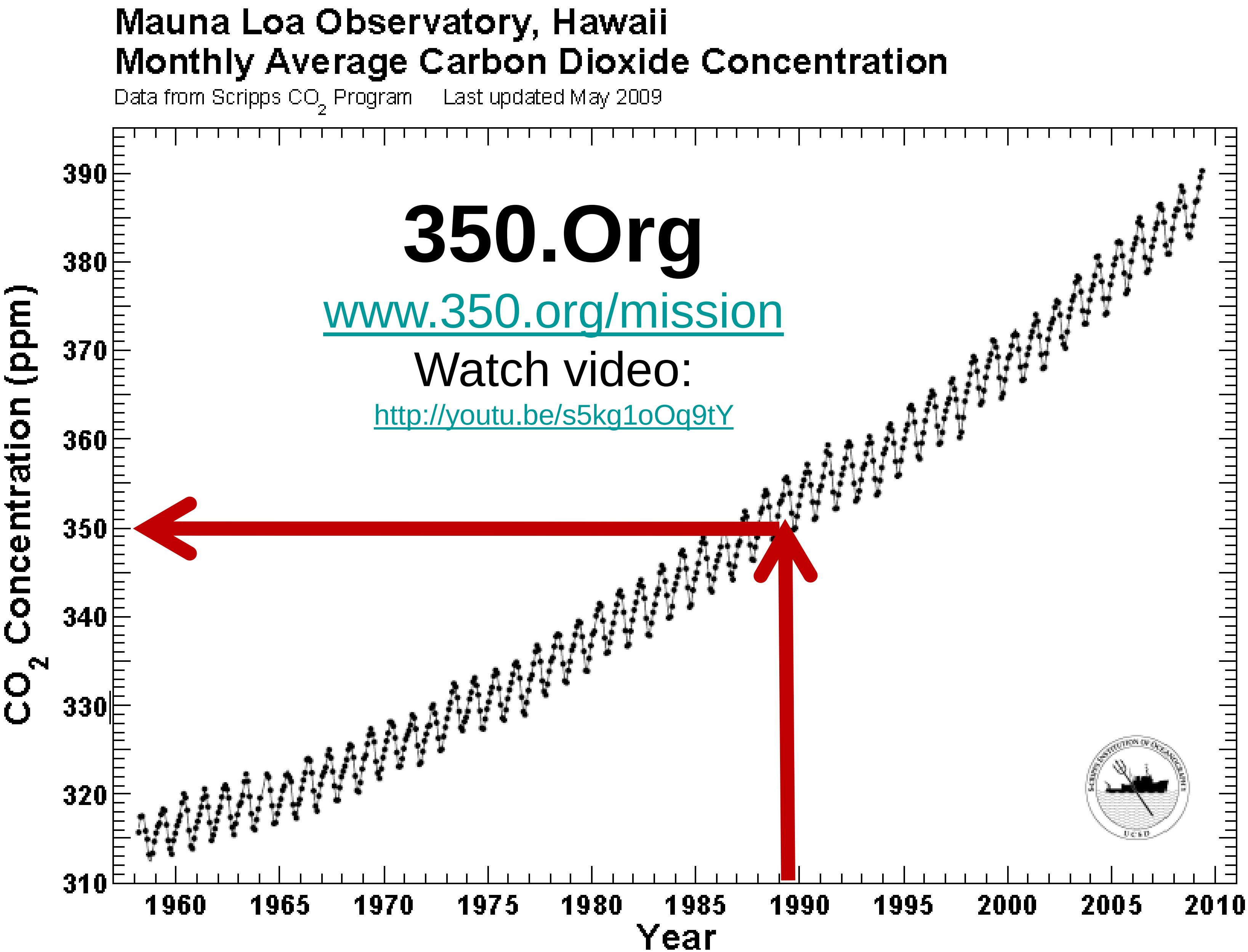
CO_2 Concentration at Mauna Loa Observatory, Hawaii



Keeling Curve

Mauna Loa Observatory

http://scrippsco2.ucsd.edu/



350.Org

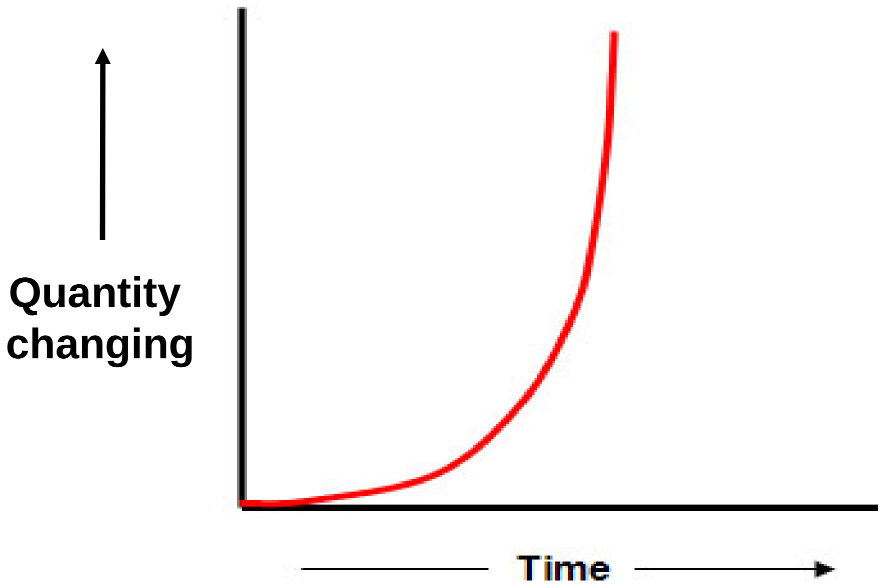
www.350.org/mission

Watch video:

http://youtu.be/s5kg1oOq9tY

Graph is from: http://www.esrl.noaa.gov/gmd/ccgg/trends/#mlo

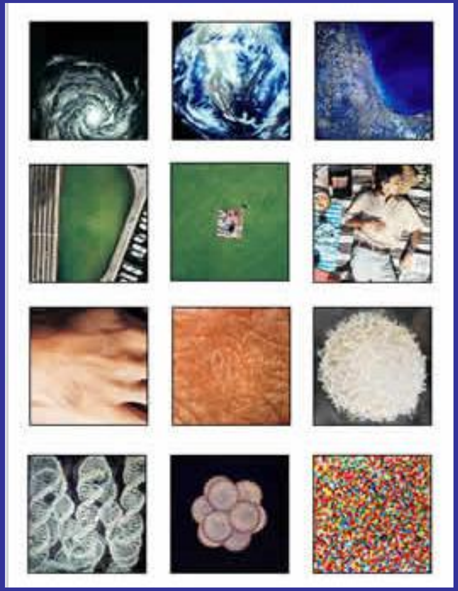
Powers of 10 can be used to express <u>exponential</u> rates of change



A Classic Video on The Relative Spatial Scale of Things:

"POWERS OF 10"

http://www.powersof10.com/film

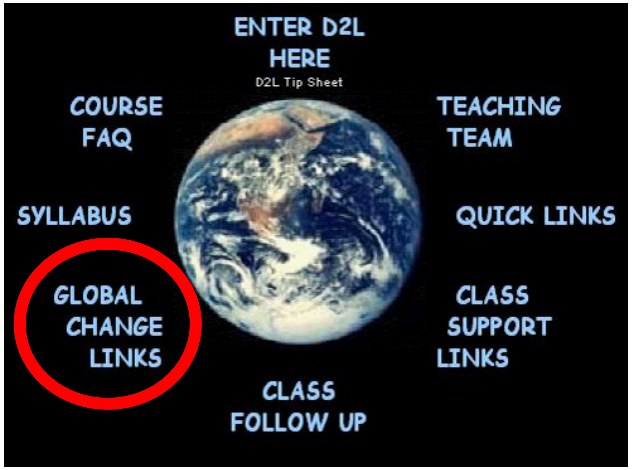


"In 1977, Charles and Ray Eames made a nine-minute film called Powers of Ten that still has the capacity today to expand the way we think and view our world. Over ten million people have since seen the film . . . ."

"Eventually, everything connects."

- Charles Eames

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



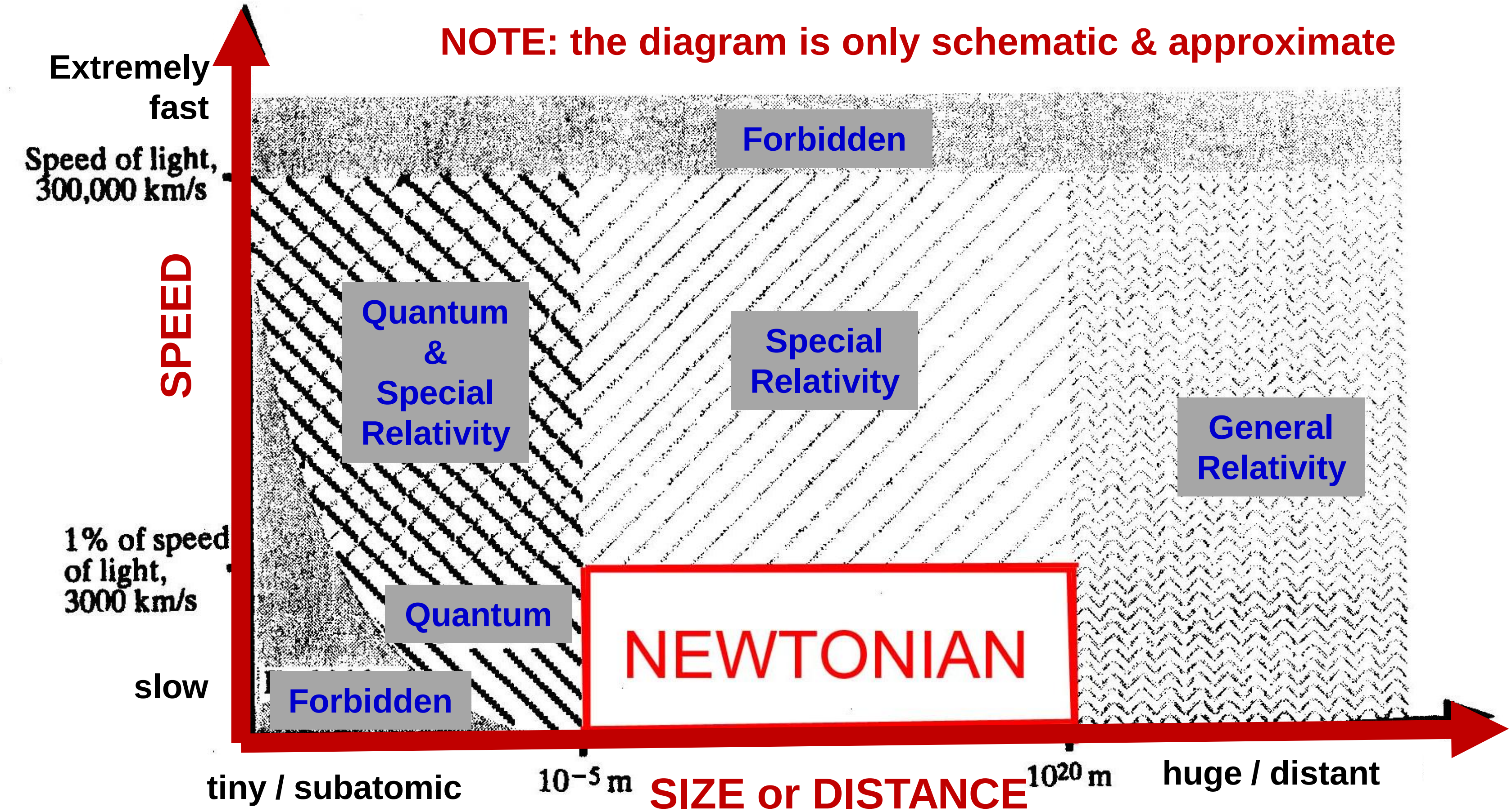
Powers of 10 -- classic video

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:

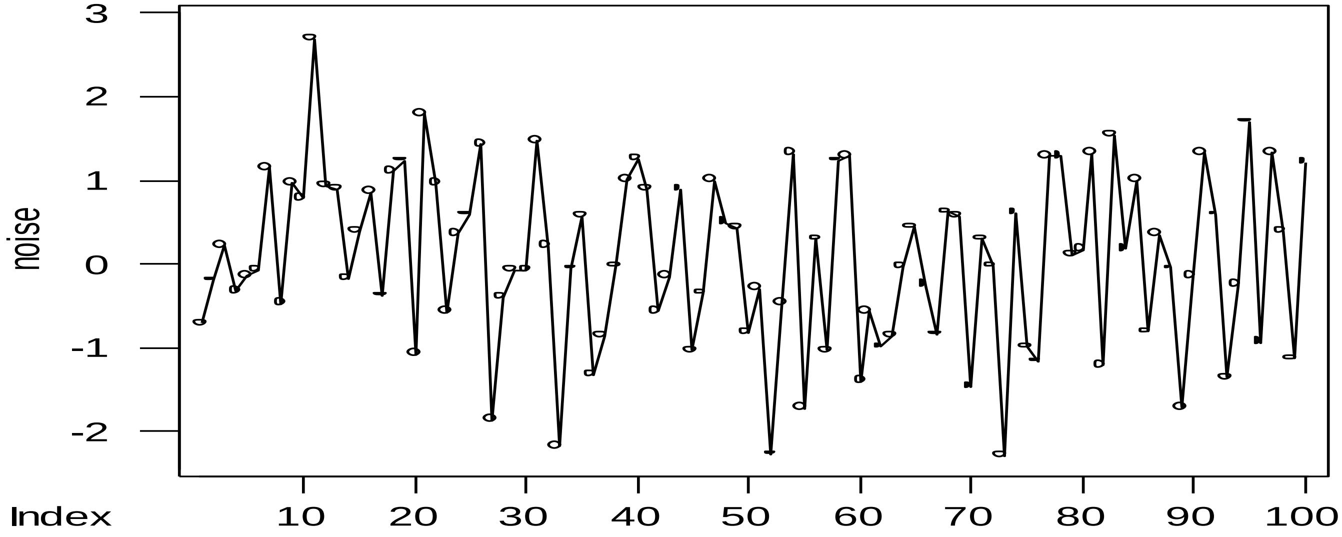
- **Mean** = average (a constant mean stays the same over time and looks like a horizontal line.)
- **Variance** = the range of fluctuations (wiggles) above and below the mean (statistically the variance is the square of the standard deviation about the mean)

Terms (cont.)

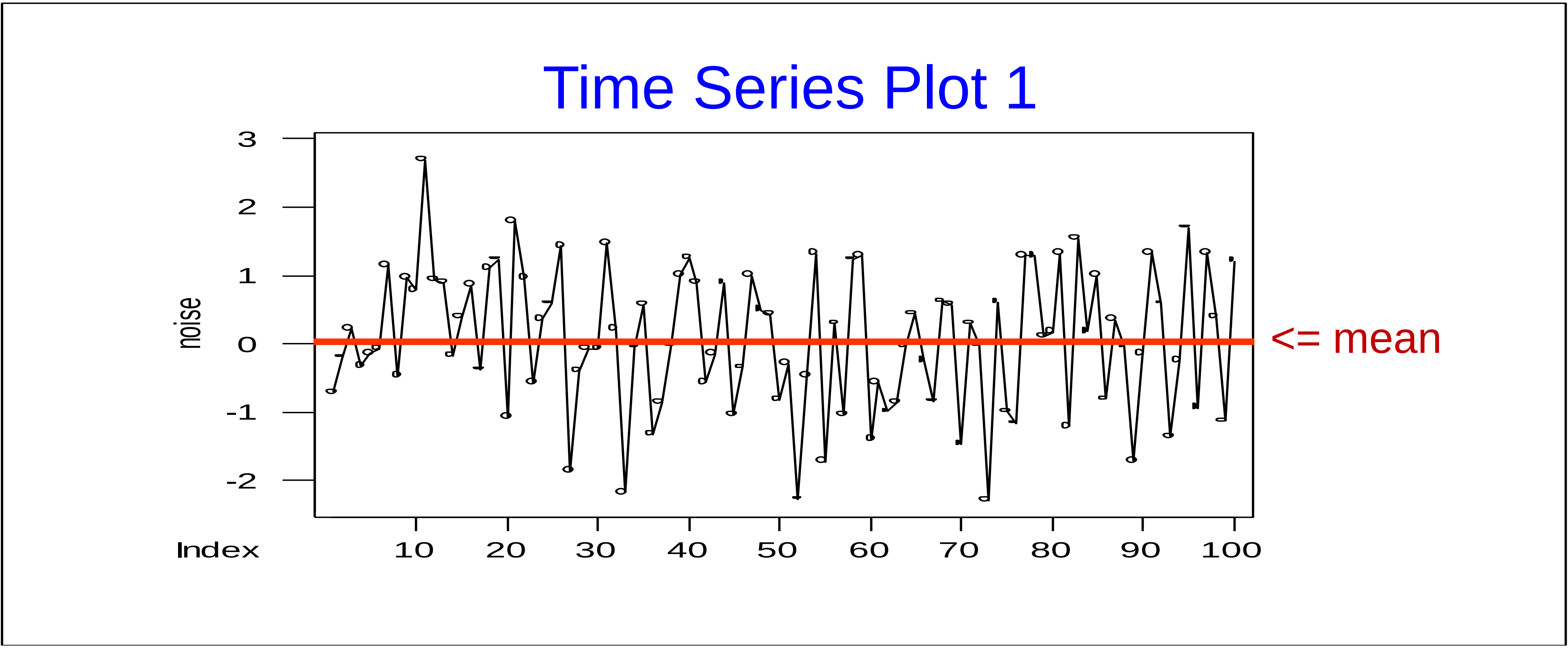
Periodic = perfect oscillations (fluctuations) (going up and down regularly or in a perfect wave-like motion)

- **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

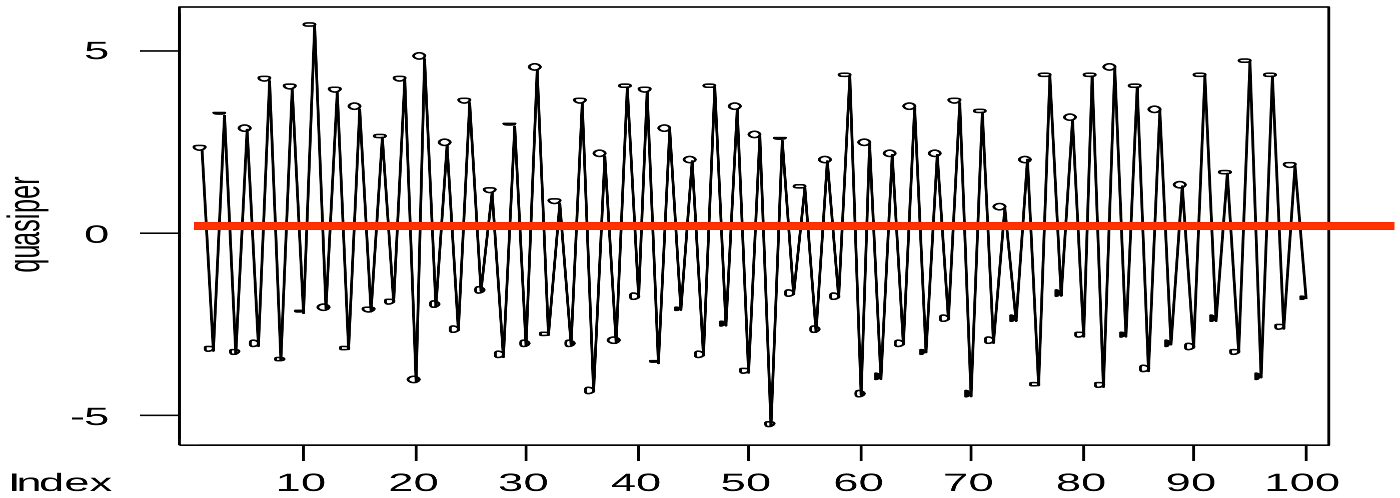


Draw in the MEAN line for this time series.



“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 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.

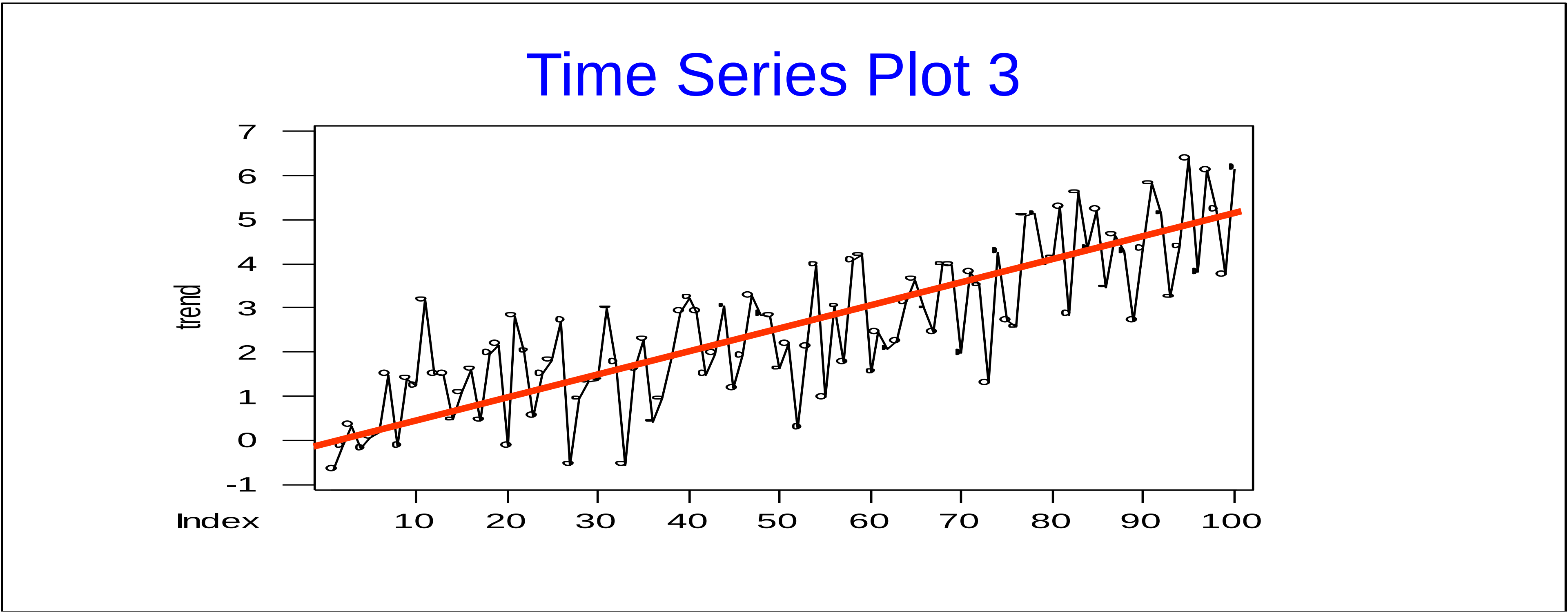
Time Series Plot 2



Regular ups and downs . . . but not perfect . .

Is the mean constant?

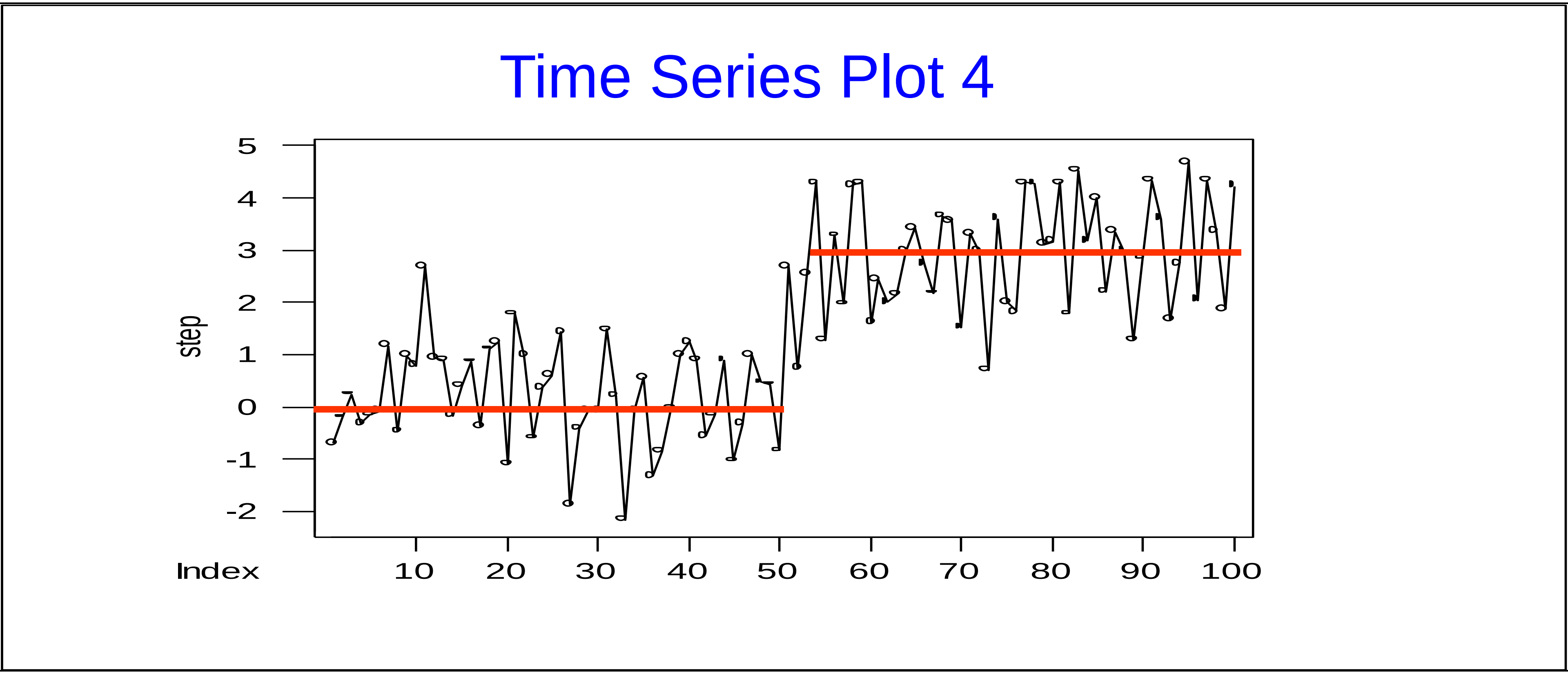
Is the variance constant?



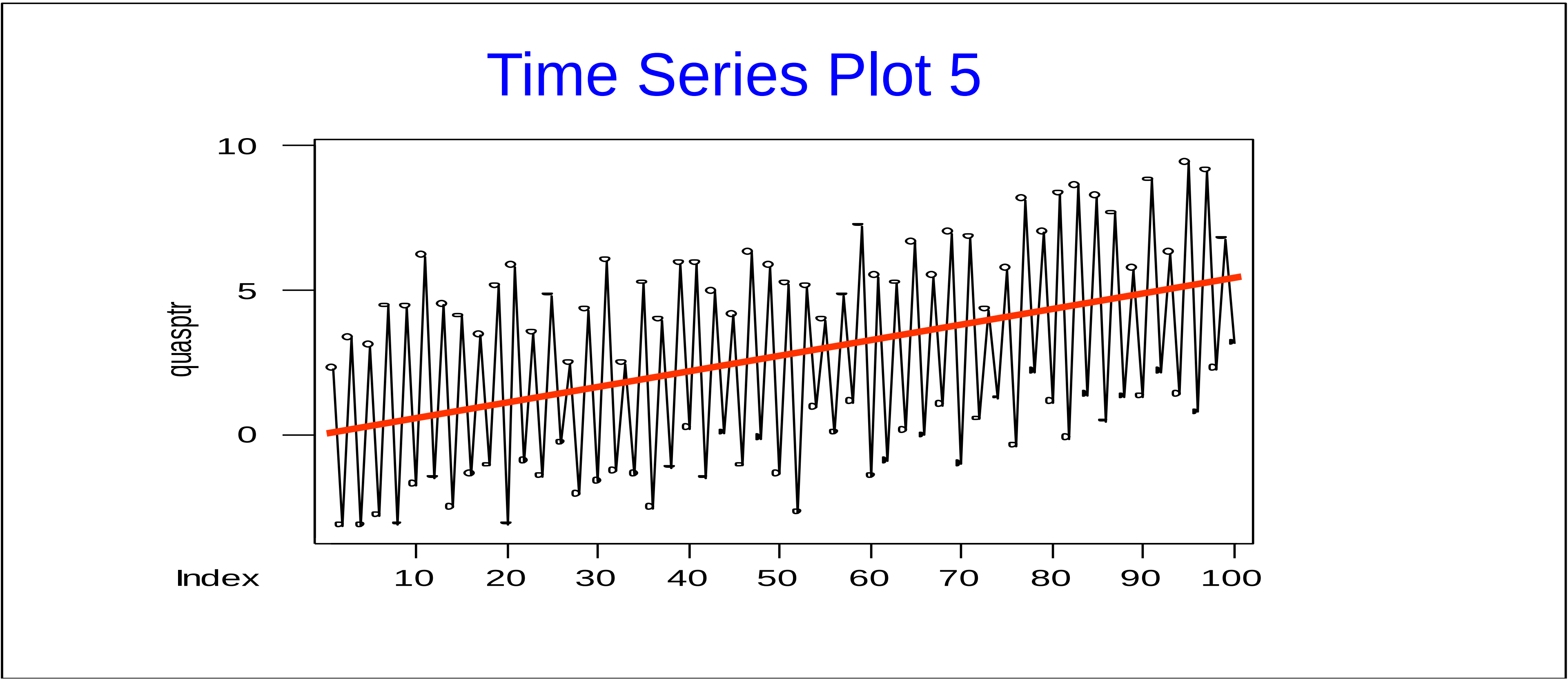
Hmmm, something is changing here . . .

What's happening to the mean?

Is the variance constant?



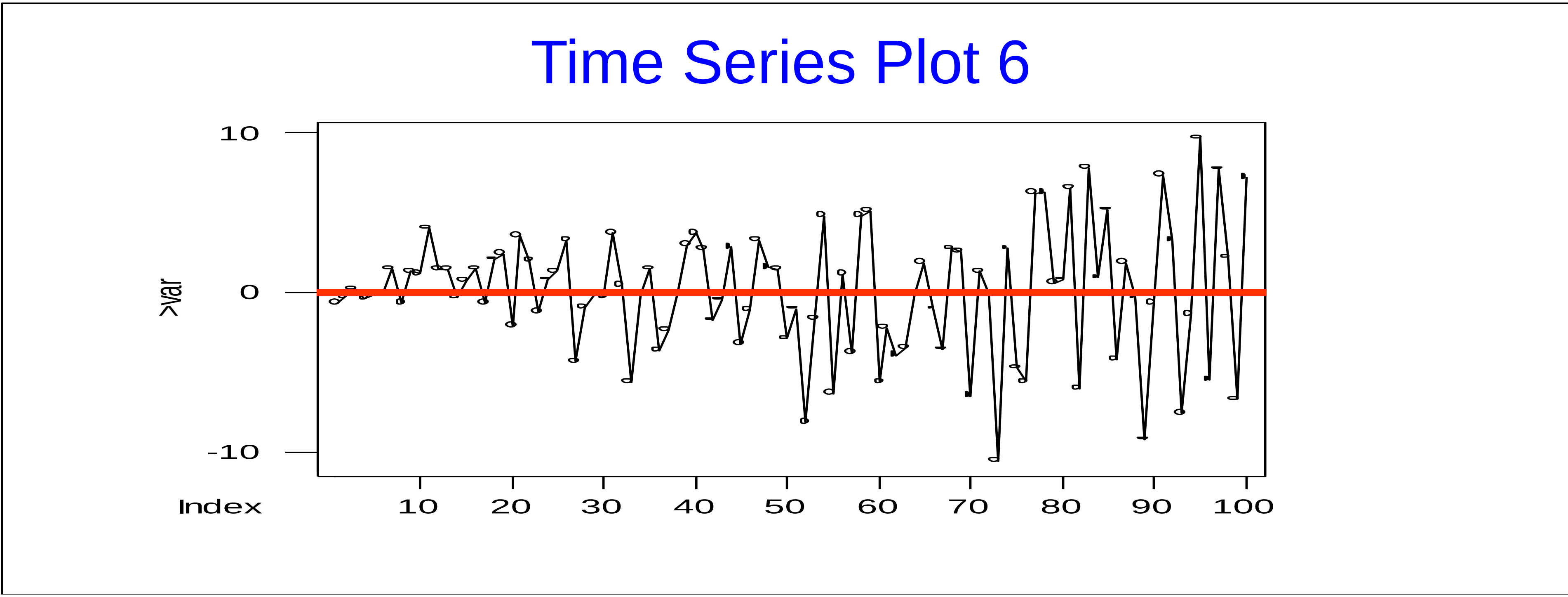
Looks a little like a "set of stairs" with an abrupt jump between two series, each with a constant __________



Looks like Plot #3, but it's different – in what way?

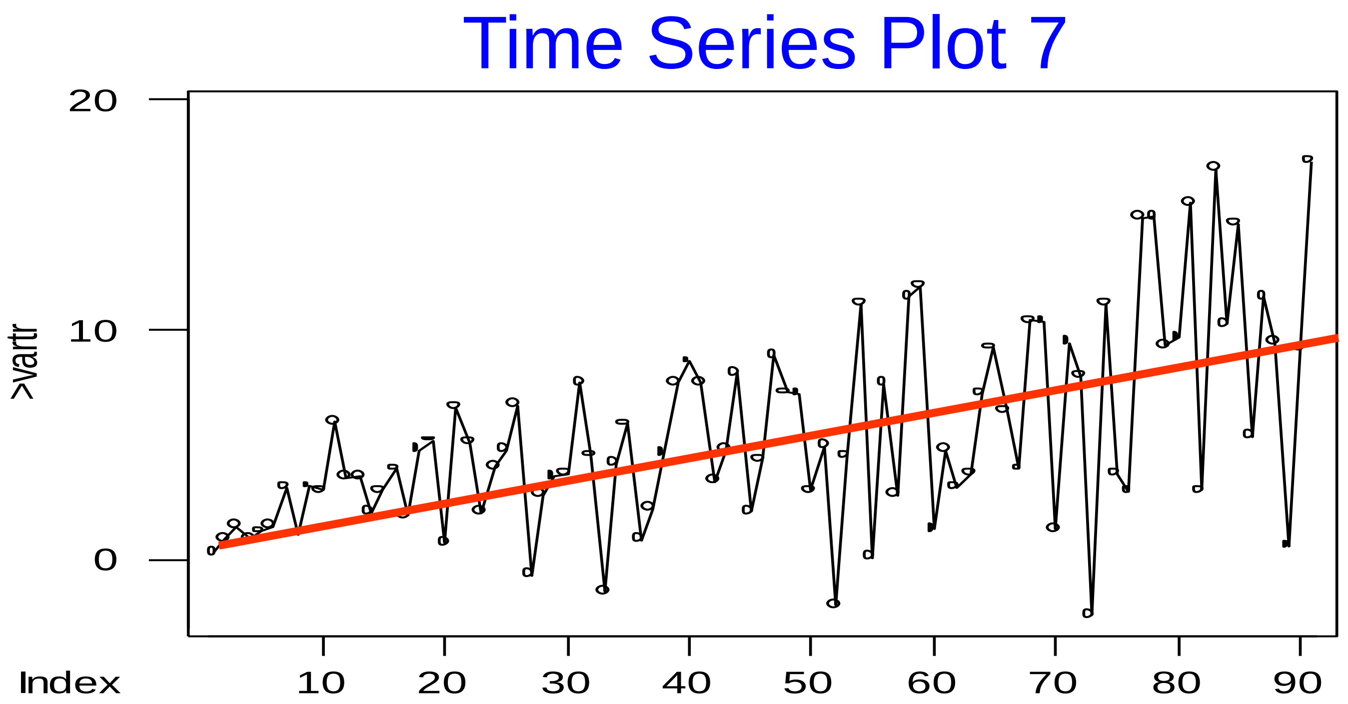
What's going on with the mean?

The variance?



What's going on with the mean?

The variance?

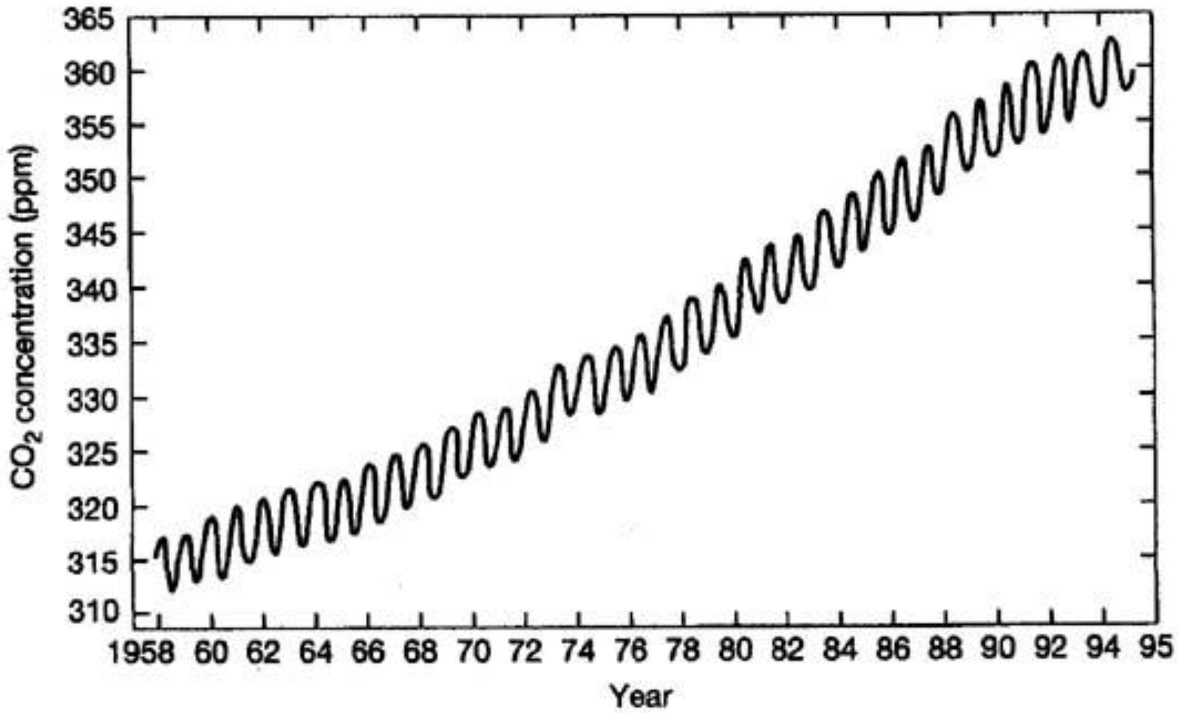


Is there a trend?

What’s going on with the mean over time?

What’s going on with the variance?

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



ANSWERS TO TIME SERIES GRAPHS
Will be given in our next CLASS . . .