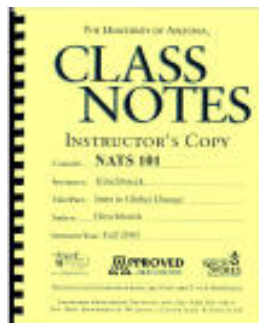
Topic #3:
INTRODUCTION TO KEY ISSUES OF GLOBAL CHANGE
(also: Quantifying Nature)

HINT: To find the page in the CLASS NOTES packet that corresponds with different parts of the lecture presentation, look for the box on each slide



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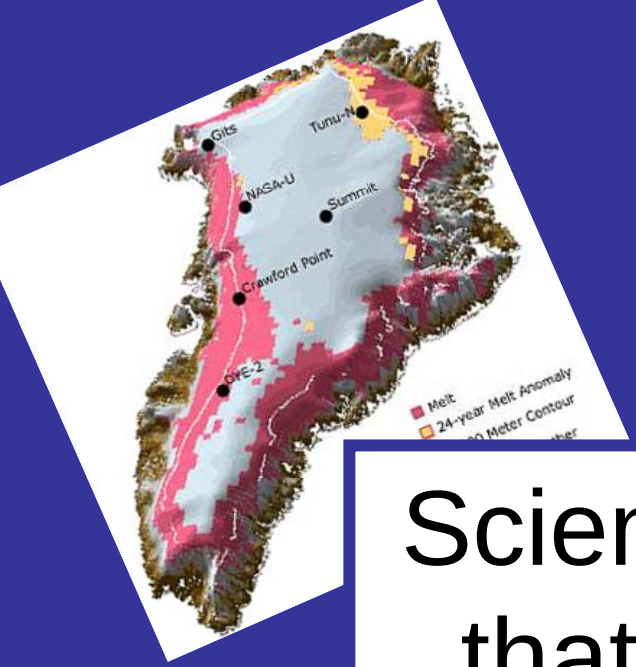
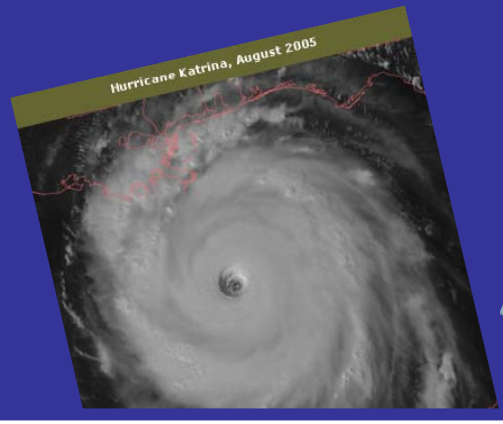
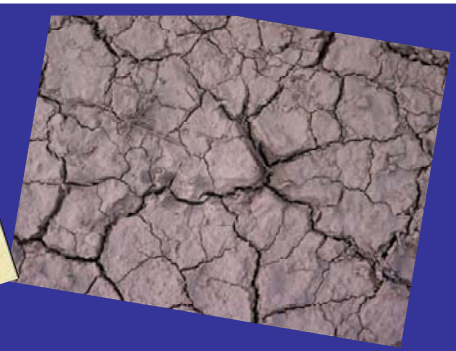




Science is demonstrating that this planet is more vulnerable than had previously been thought.

~ 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)

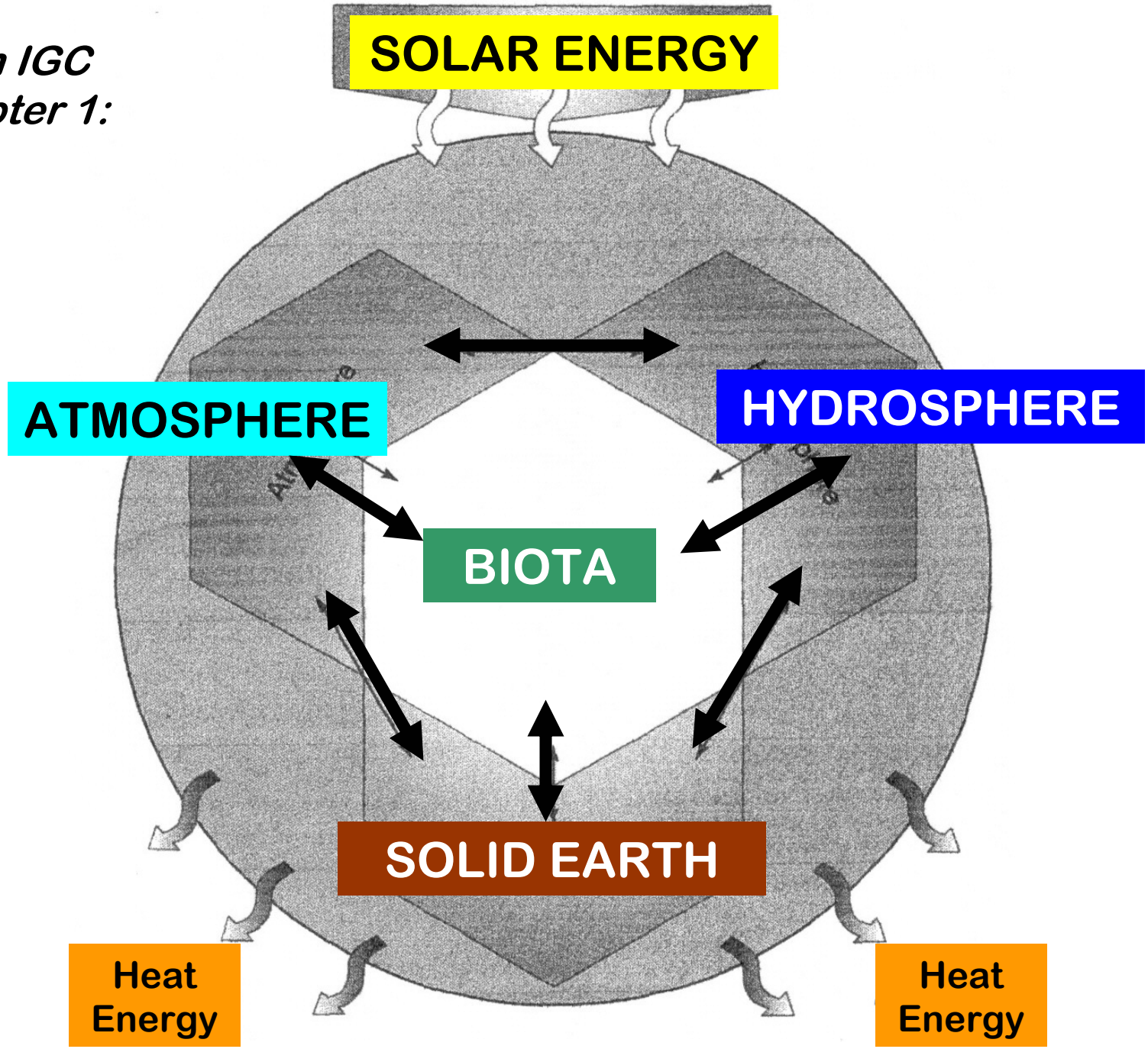
Hydrosphere (liquid, gaseous, solid)

Biota (biosphere) (animal & plant life)

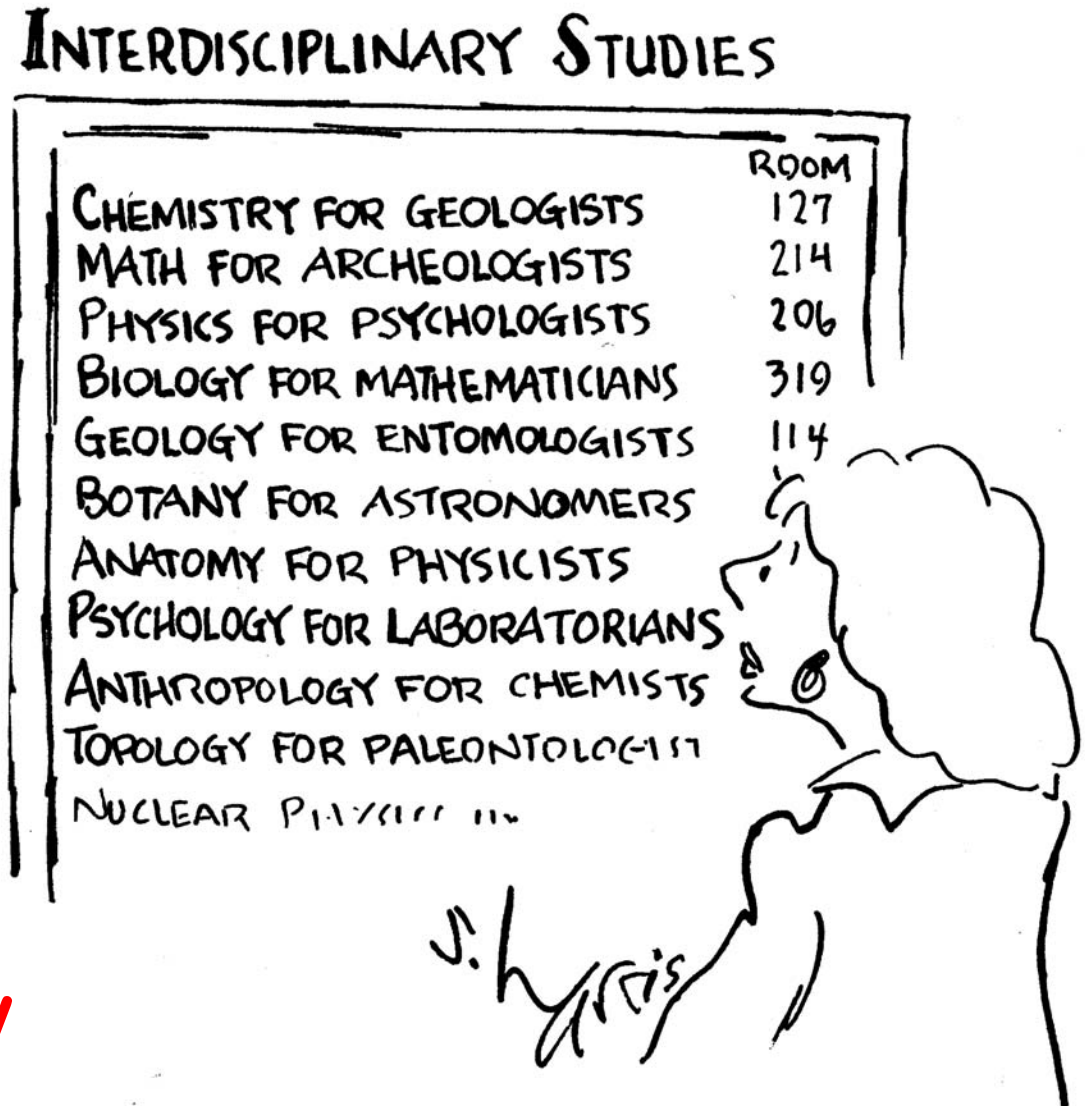
. . . .and in patterns and distribution of the above

Just listen ➔ ☺

From IGC Chapter 1:



Hence studying global change requires an interdisciplinary approach



YOUR TEXTBOOK:
INTRODUCTION TO GLOBAL CHANGE (IGC)
EMPHASIZES 3 MAIN THEMES:

The behavior of Earth's systems

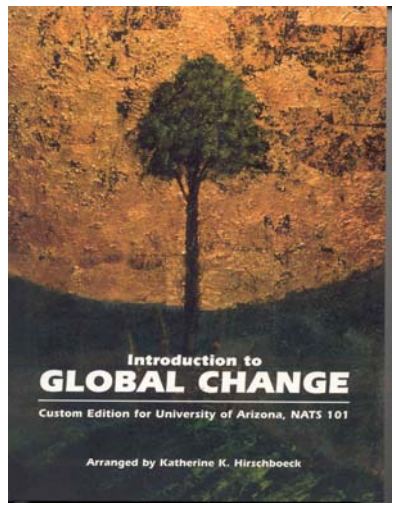
- * How systems operate
- * Global energy balance
- * Atmospheric circulation and climate
- * Atmospheric & oceanic interactions

Past global changes and how to detect them

- Ice ages
- * Short-term climatic variability

Modern global environmental issues

- *Global warming
- * Stratospheric ozone depletion
- * Deforestation / biodiversity
- Population and resources



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GLOBAL CHANGE SCIENCE IN ACTION

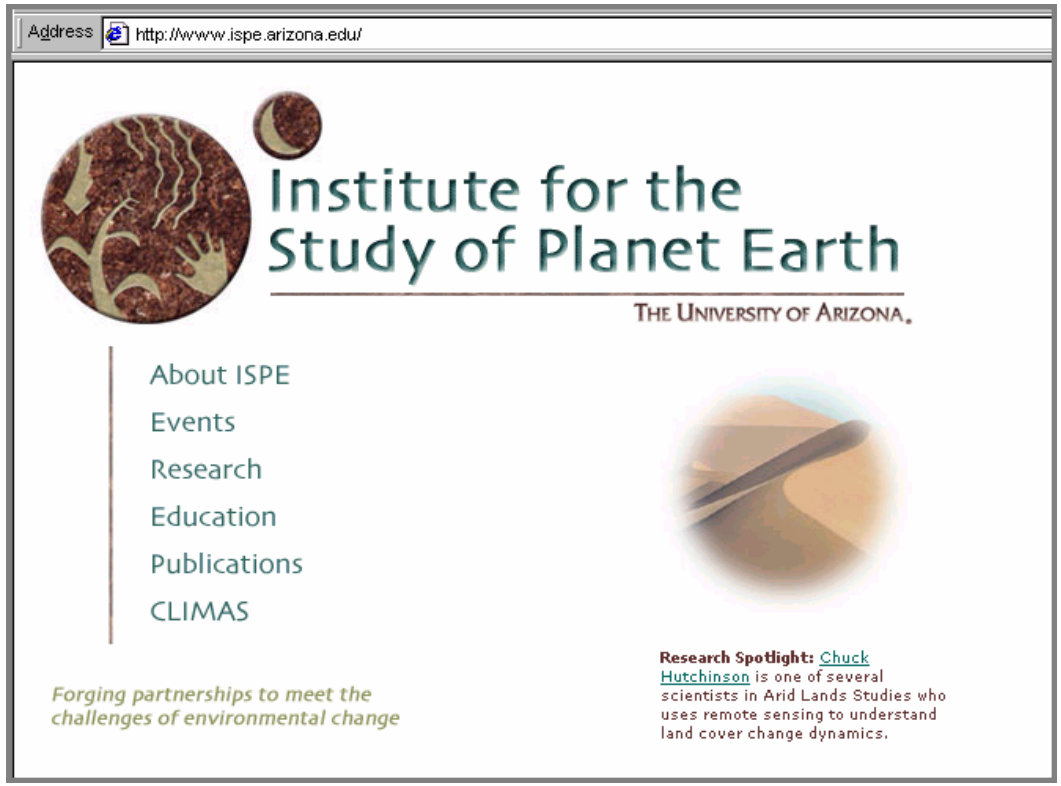
at U of A
Nationally
Internationally

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.

ISPE (Institute for the Study of Planet Earth) & the Univ of AZ's Committee on Global Change

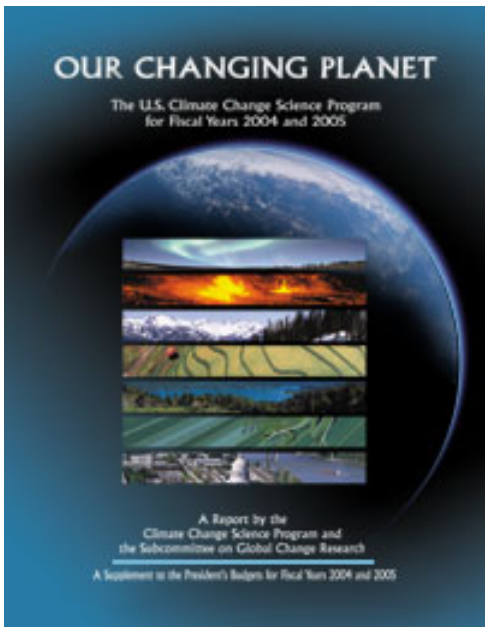


http://www.ispe.arizona.edu/

US GLOBAL CHANGE RESEARCH PROGRAM

US Global Change Research Program

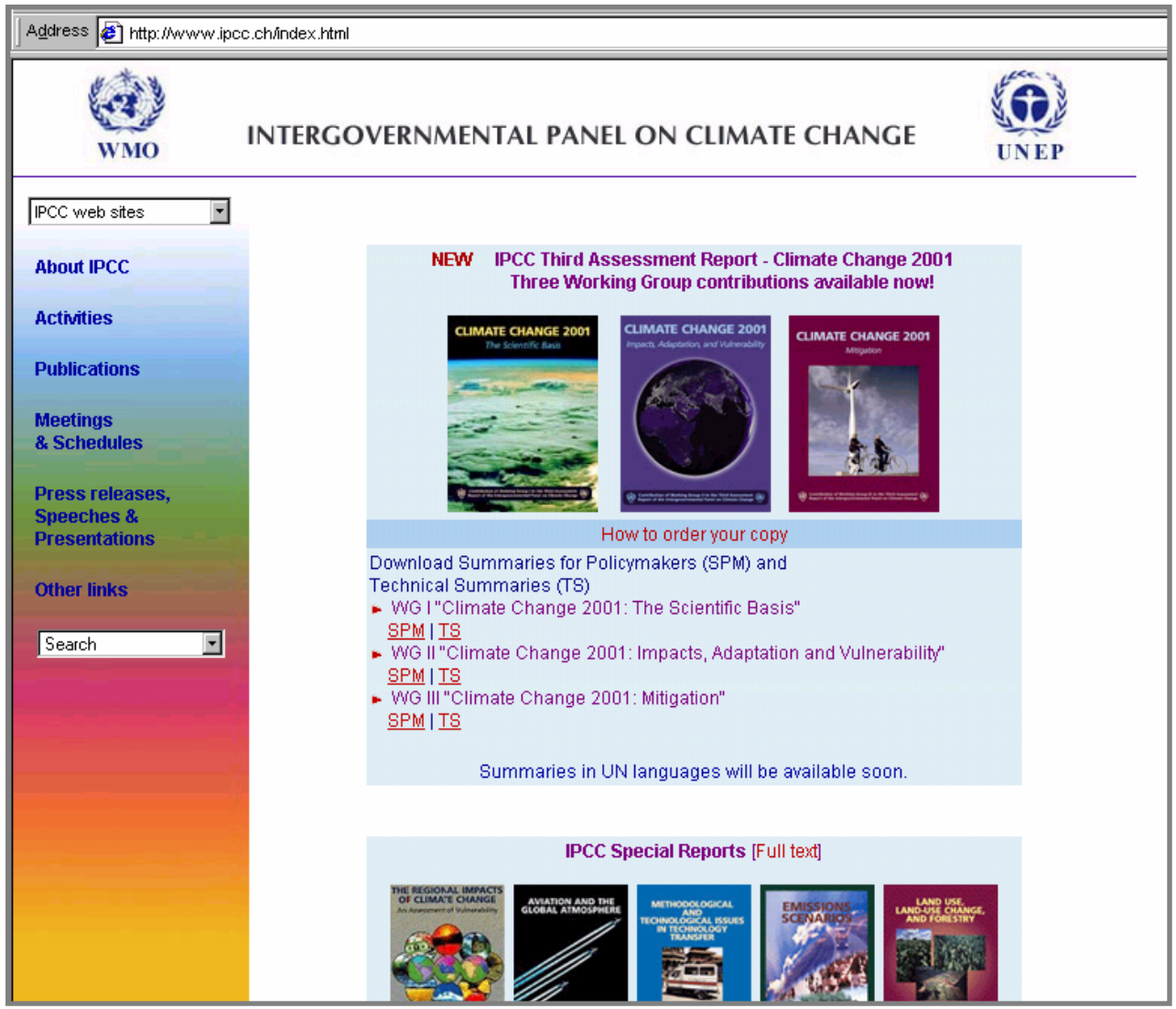
www.usgcrp.gov



http://www.usgcrp.gov

Intergovernmental Panel on Climate Change (IPCC)

http://www.ipcc.ch/



The IPCC (Intergovernmental Panel on Climate Change) has three working groups:

- **WG I (Working Group I) assesses the SCIENTIFIC aspects of the climate system and climate change**

- **WG II (Working Group II) addresses the VULNERABILITY of SOCIO-ECONOMIC and NATURAL systems to climate change, negative and positive consequences of climate change, and options for adapting to it.**

- **WG III (Working Group III) assesses options for LIMITING greenhouse gas EMISSIONS and otherwise MITIGATING 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???

TOOLS of GLOBAL CHANGE SCIENTISTS:

- Modeling
- 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.

One way to estimate ecological sustainability is by:

ECOLOGICAL FOOTPRINT ANALYSIS

TOTAL FOOTPRINT **31**

IN COMPARISON, THE AVERAGE ECOLOGICAL FOOTPRINT IN YOUR COUNTRY IS 24 ACRES PER PERSON.

WORLDWIDE, THERE EXIST 4.5 BIOLOGICALLY PRODUCTIVE ACRES PER PERSON.

IF EVERYONE LIVED LIKE YOU, WE WOULD NEED 7.1 PLANETS.

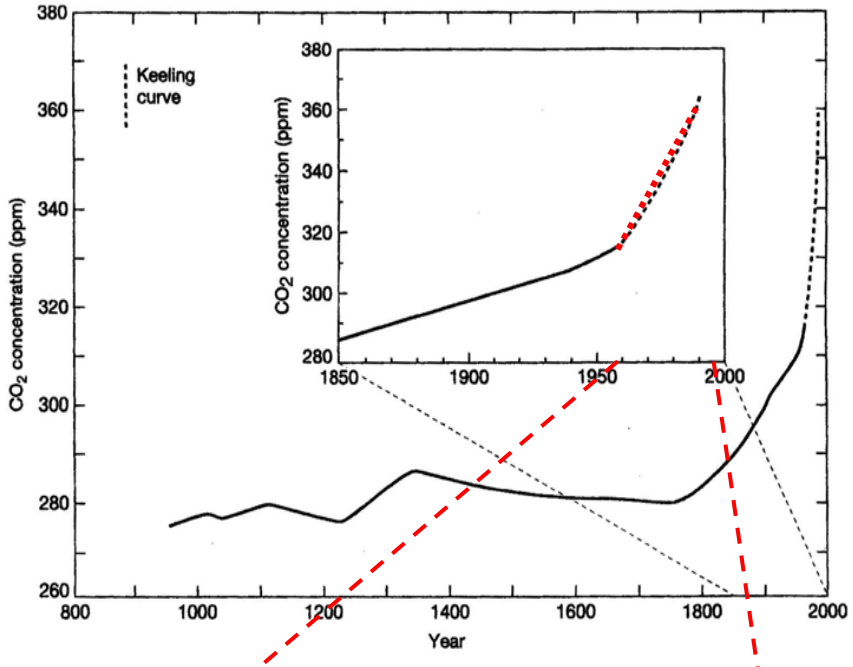
More on this later . . .

KEY ISSUES OF GLOBAL CHANGE

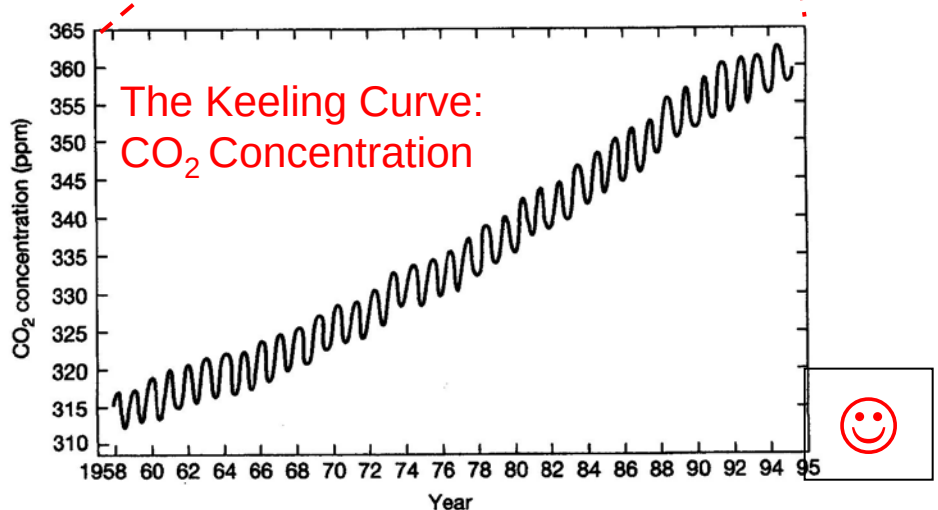
Why Study the Earth System & Global Change?

In the past 100 years, human actions have altered fundamental elements of the biogeochemical cycles of the Earth.

Since 1850, atmospheric carbon dioxide has increased by about 30 %, methane by more than 100 %.



Atmospheric CO_2 concentrations over the past 1000 years, as determined from ice cores and from direct atmospheric measurements. (The dashed line is the Keeling curve.) (After *Climate Change, 1994,* Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge)



Changes in:
-- land use management (e.g. deforestation) &
-- chemical / industrial inputs to the atmosphere have affected essential elements interactions within ecosystems, the atmosphere, and the hydrosphere.

At the same time, natural variability is occurring at all times in the:

- **atmosphere,**
- **geosphere (solid earth),**
- **hydrosphere, and**
- **biota of our planet.**

How and why are these changes occurring?

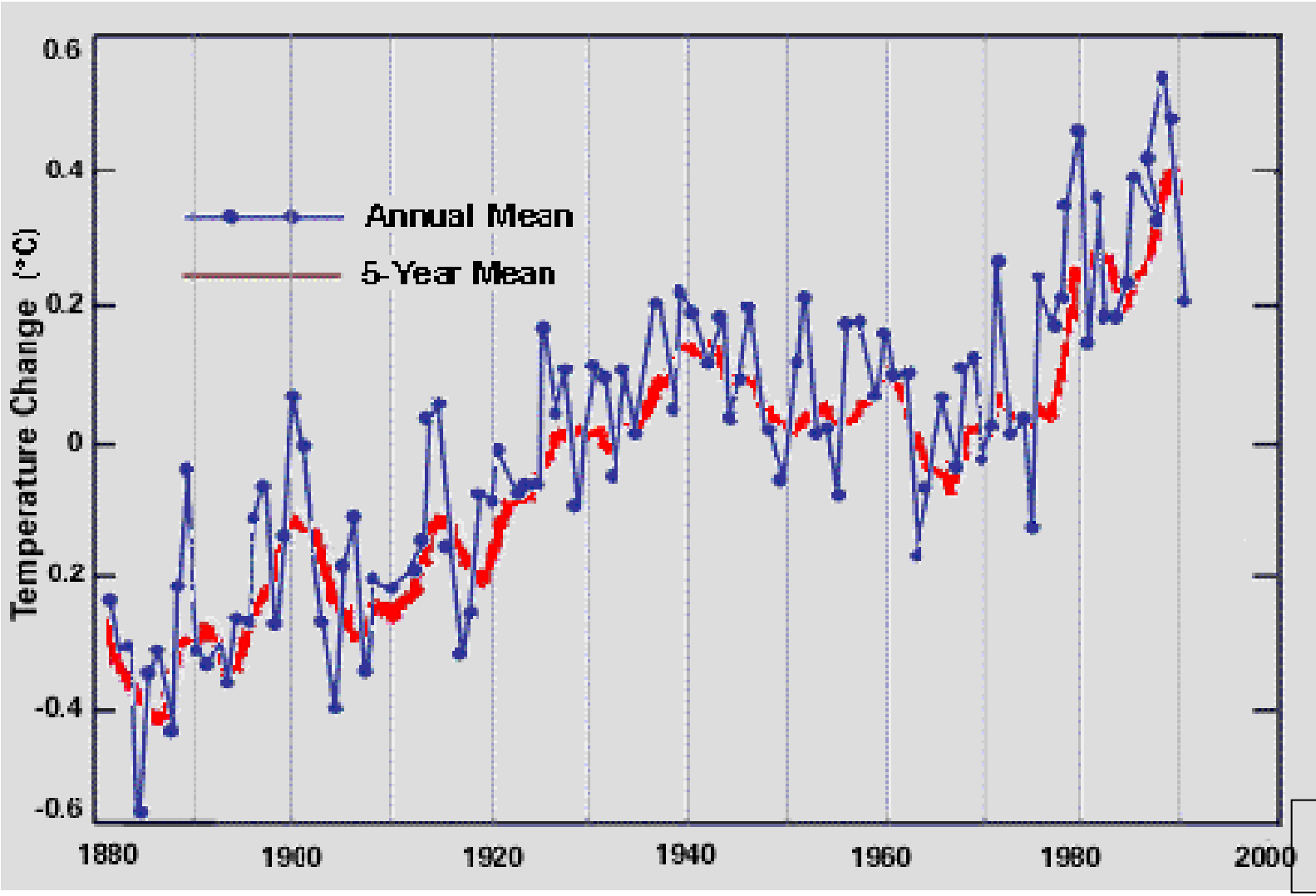
Are these changes good or bad for people?

Can human beings do anything to stop or reverse those changes that might be detrimental to the planet -- or are they part of natural variability that will happen no matter what we do?

These are the questions the GLOBAL CHANGE SCIENTISTS are asking and studying . . . .

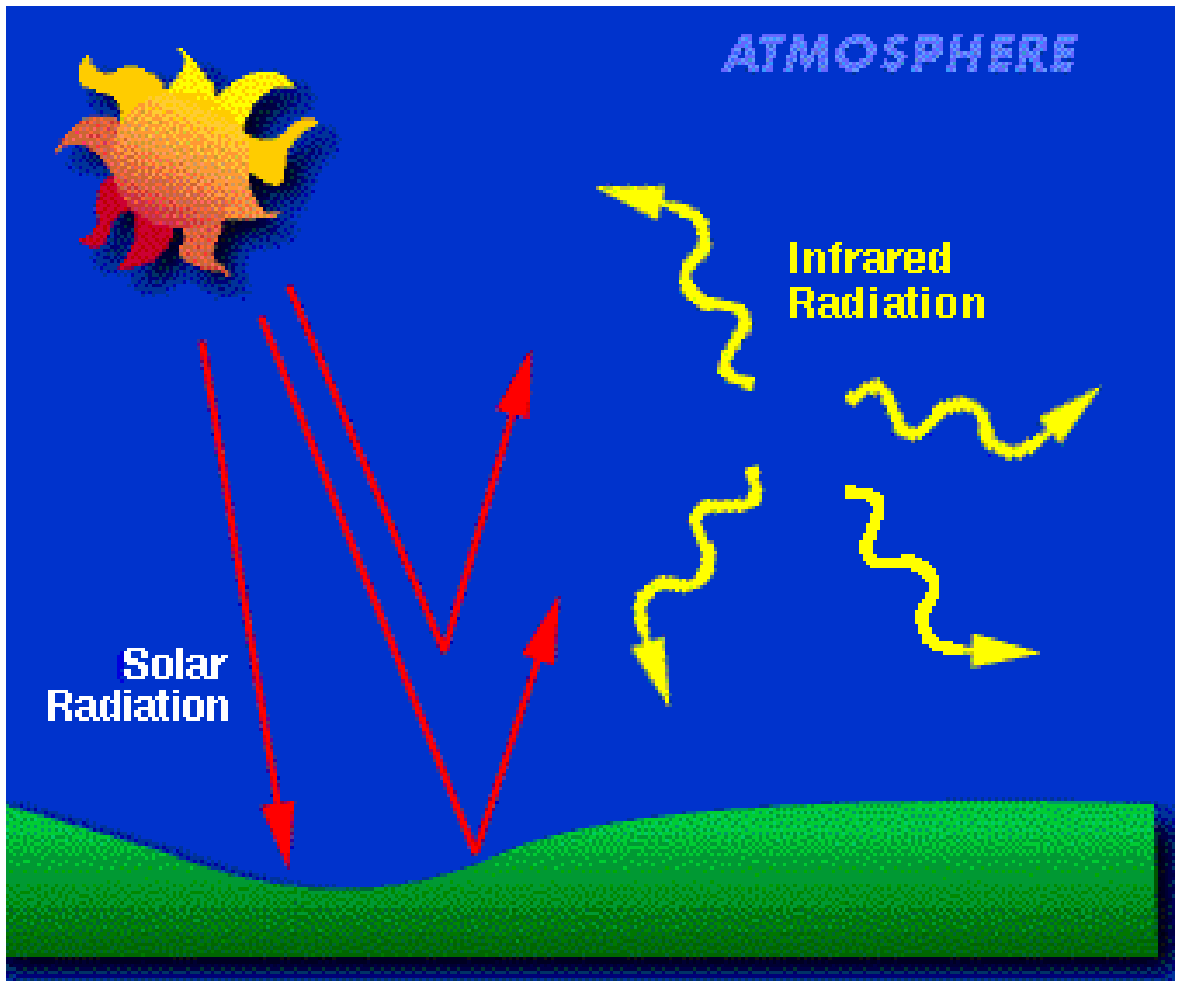
GLOBAL WARMING:

IS IT DUE TO NATURAL VARIABILITY OR HUMAN CAUSED ?



SUN-EARTH RADIATION BALANCE:

WHY IS IT IMPORTANT?
HAS THE BALANCE BEEN ALTERED?
IF SO, HOW AND IN WHAT WAYS?



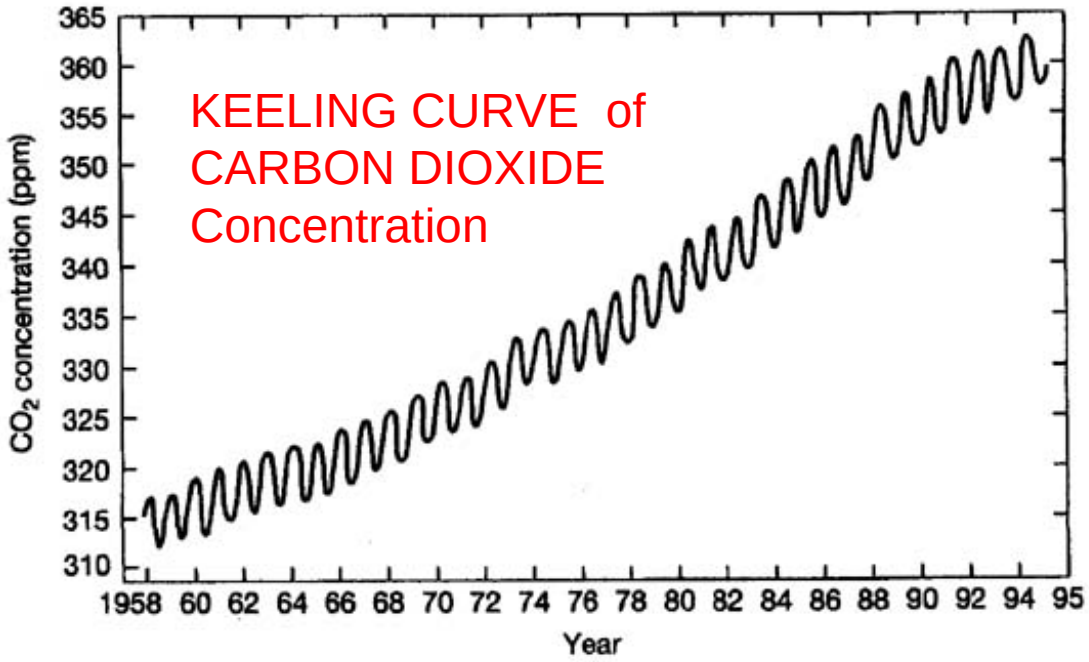
GREENHOUSE GASES & ATMOSPHERIC COMPOSTION

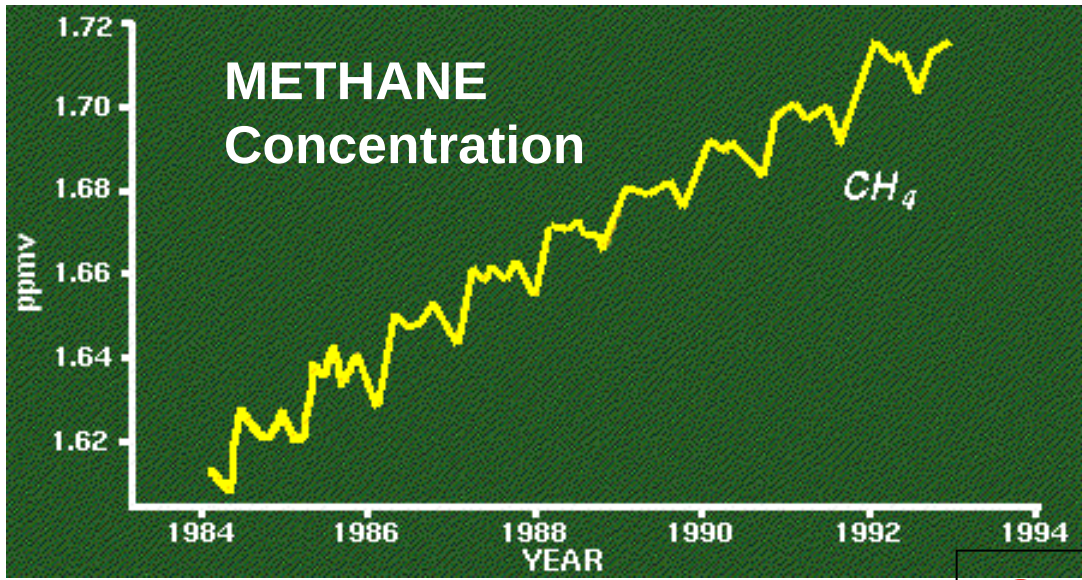
HOW DO GASES IN THE ATMOSPHERE INFLUENCE CLIMATE ?

HOW HAS THEIR CONCENTRATION CHANGED?

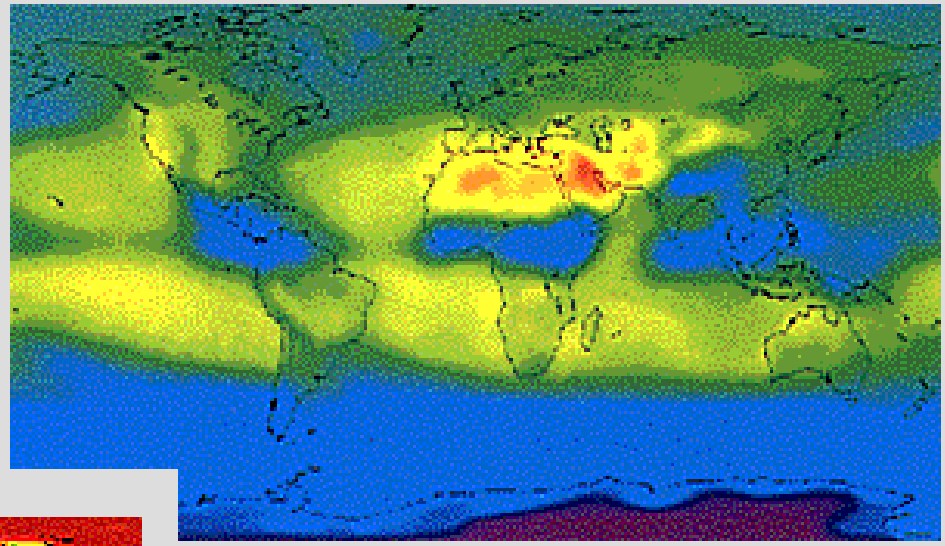
WHAT ARE THE CONSEQUENCES OF THIS CHANGE?

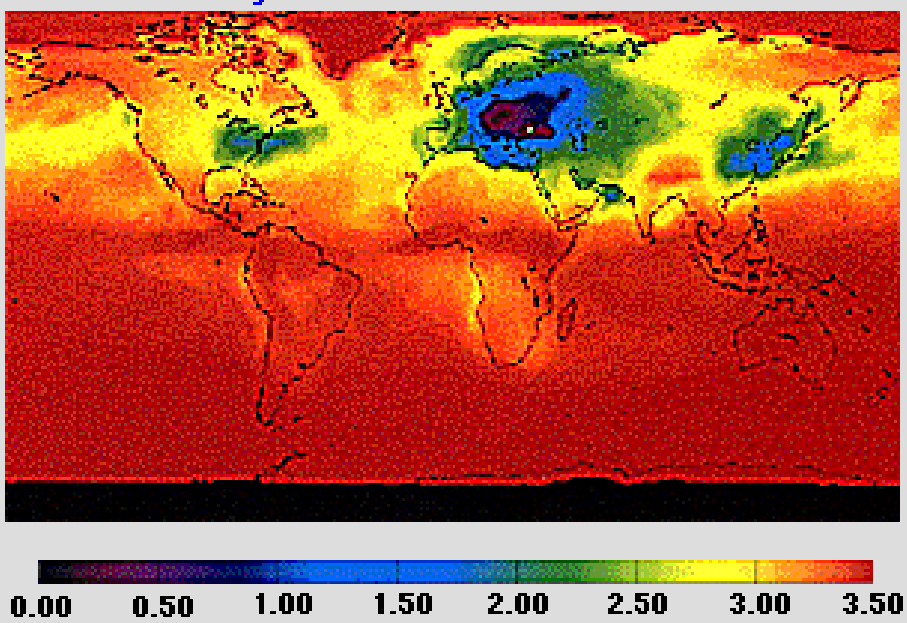
CAN IT BE SLOWED?





PATTERNS OF WARMING & COOLING -- observations & model results

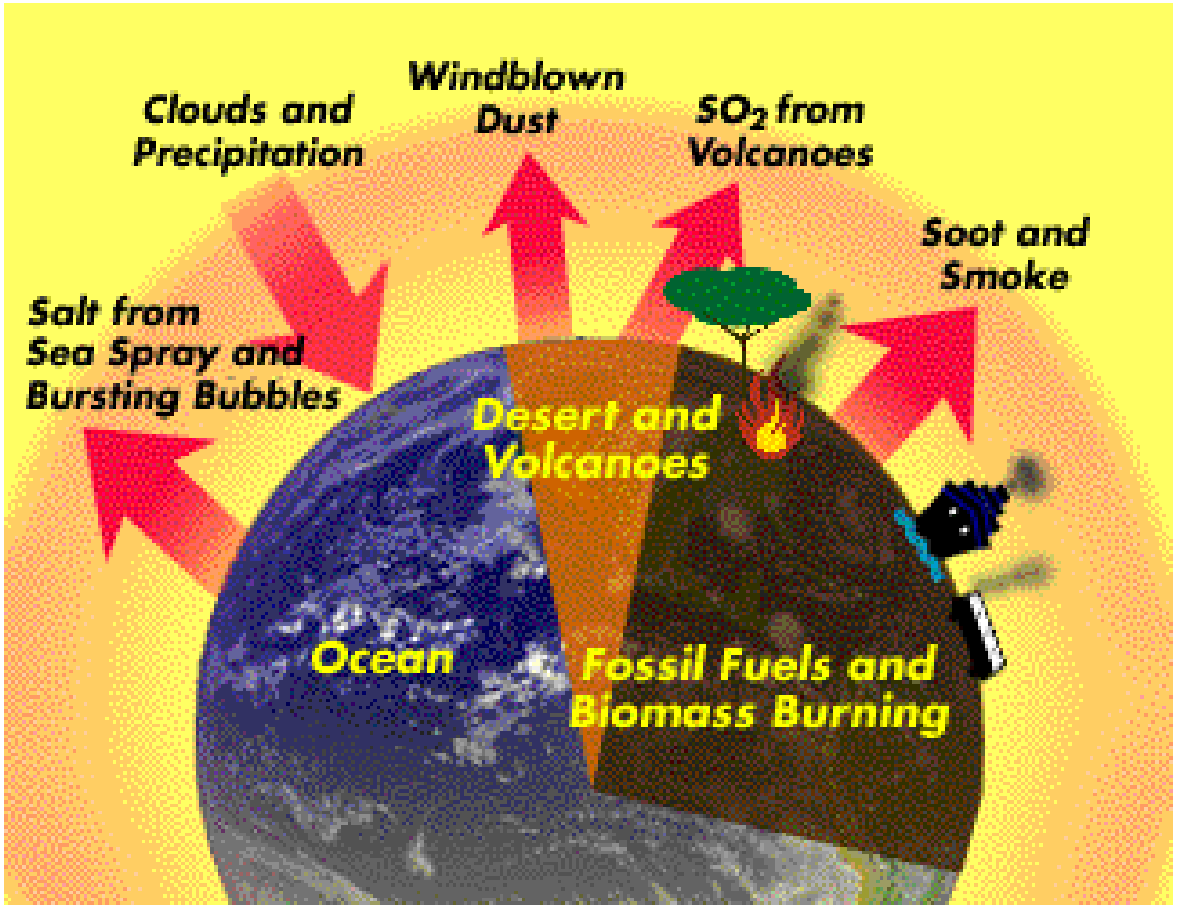




WHAT WILL THE FUTURE CLIMATE BE LIKE IN DIFFERENT PARTS OF THE WORLD?

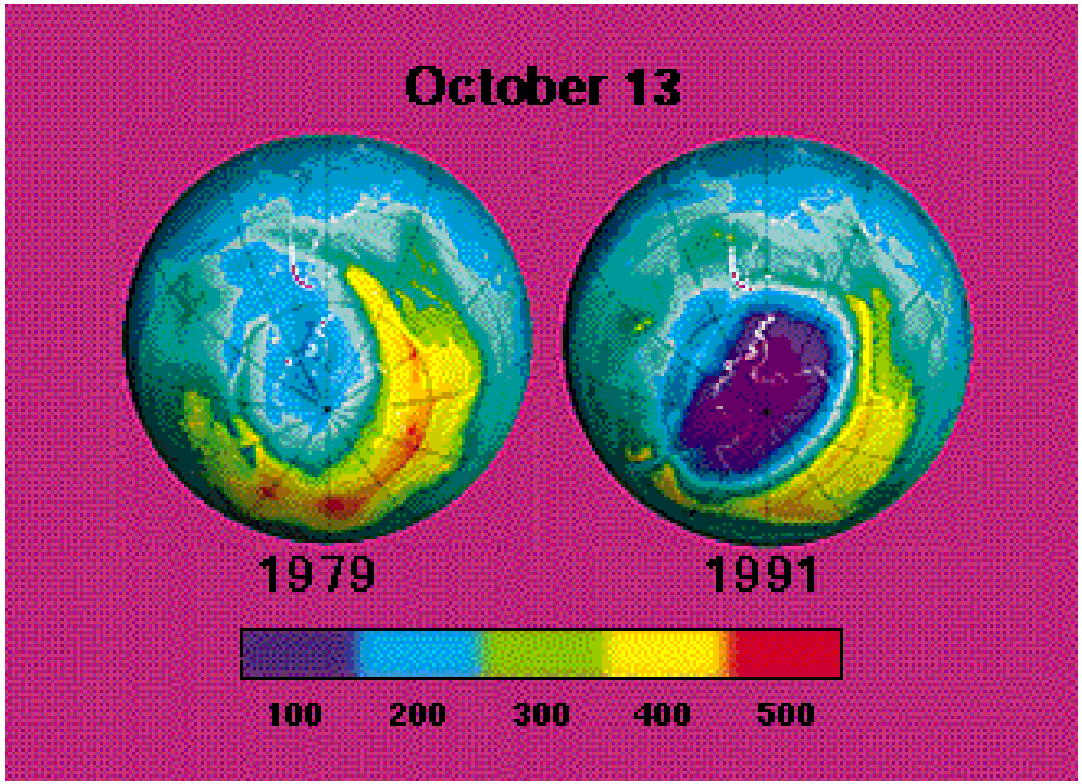
ARE THE EXPECTED CHANGES OBSERVABLE NOW??

NATURAL & ANTHROPOGENIC SOURCES OF ATMOSPHERIC CHANGE



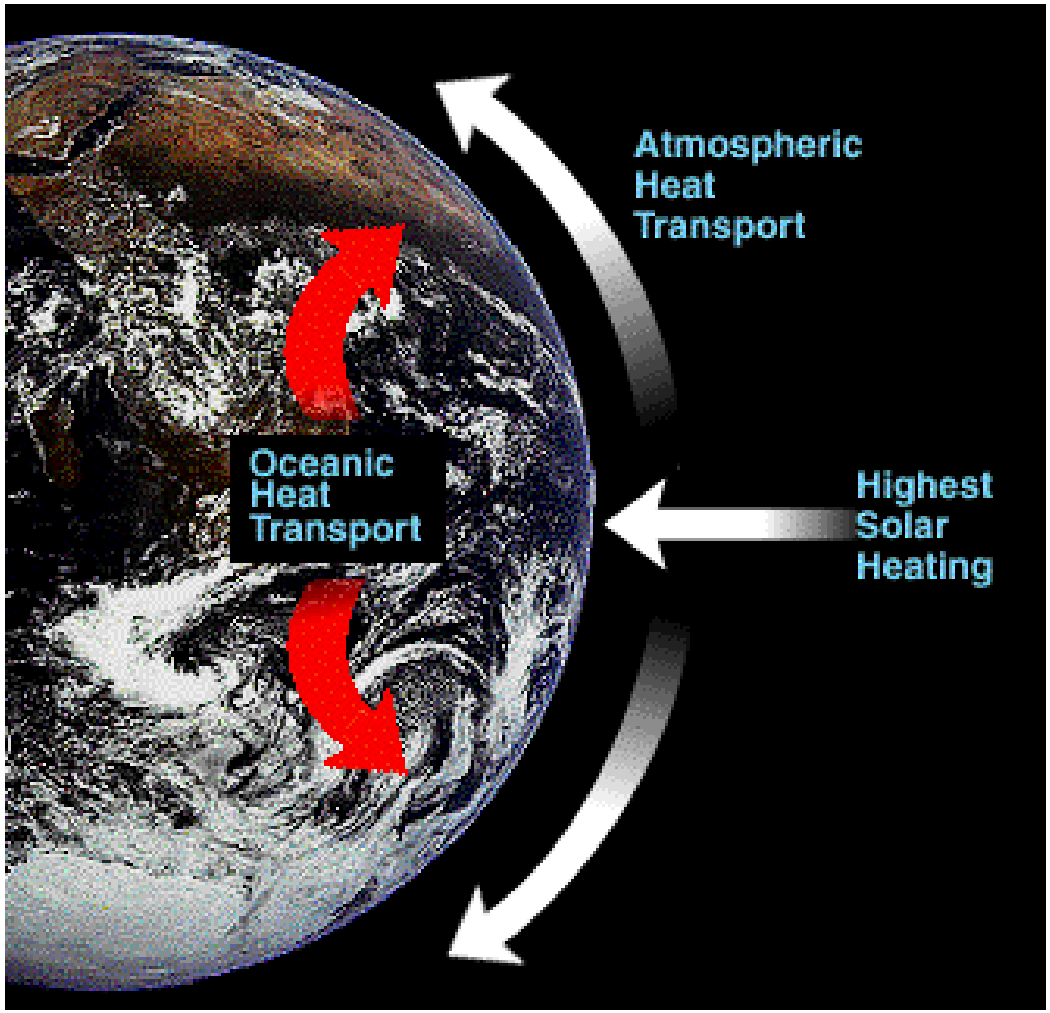
HOW DO WE DISTINGUISH BETWEEN CHANGE DRIVEN BY NATURAL VS ANTHROPOGENIC FORCINGS OR CAUSES?

STRATOSPHERIC OZONE DEPLETION



HOW HAVE HUMANS ALTERED THE EARTH'S PROTECTIVE OZONE LAYER?
IS THE OZONE HOLE PROBLEM SOLVABLE?

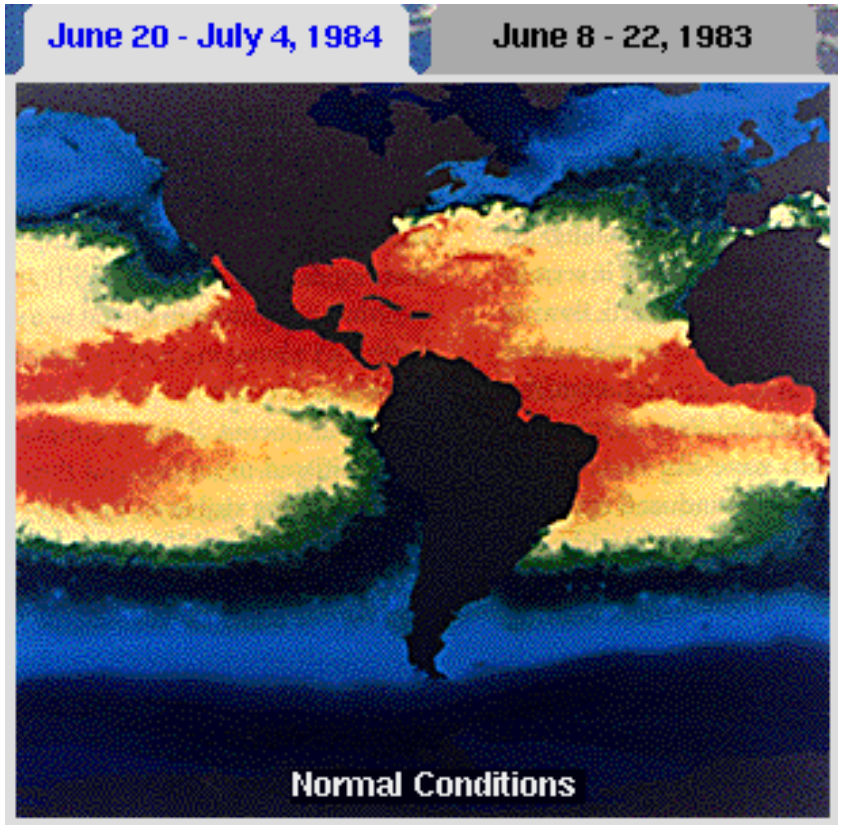
ATMOSPHERIC & OCEANIC CIRCULATION

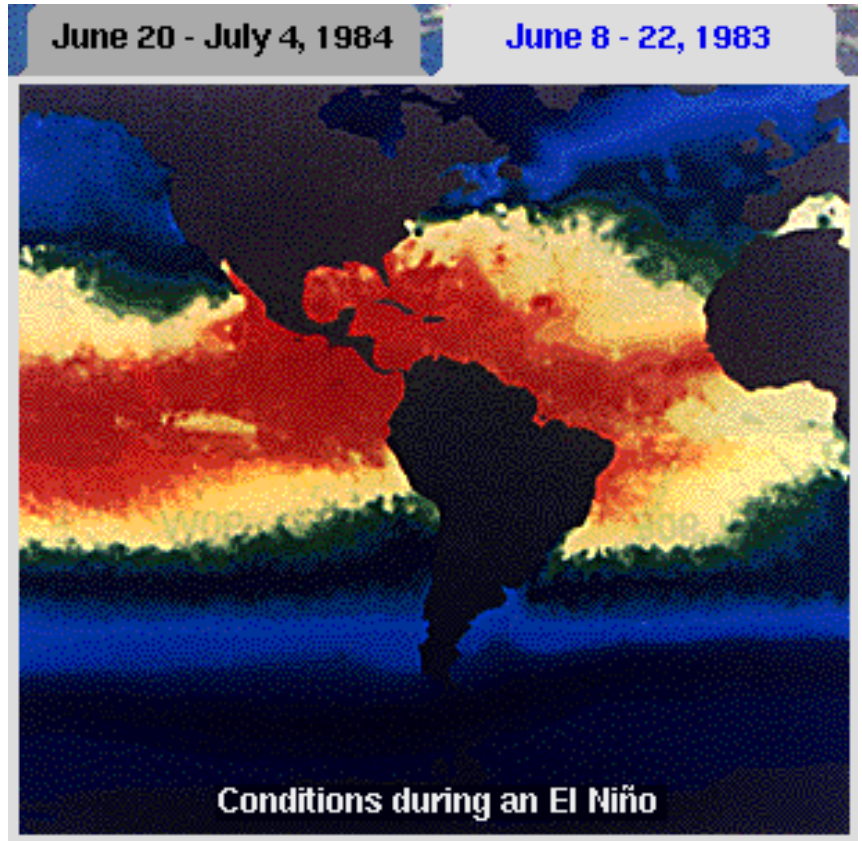


WHAT DRIVES THE ATMOSPHERE & OCEAN CIRCULATION ?

HOW DO THESE PROCESSES CHANGE ?

ROLE OF OCEANS





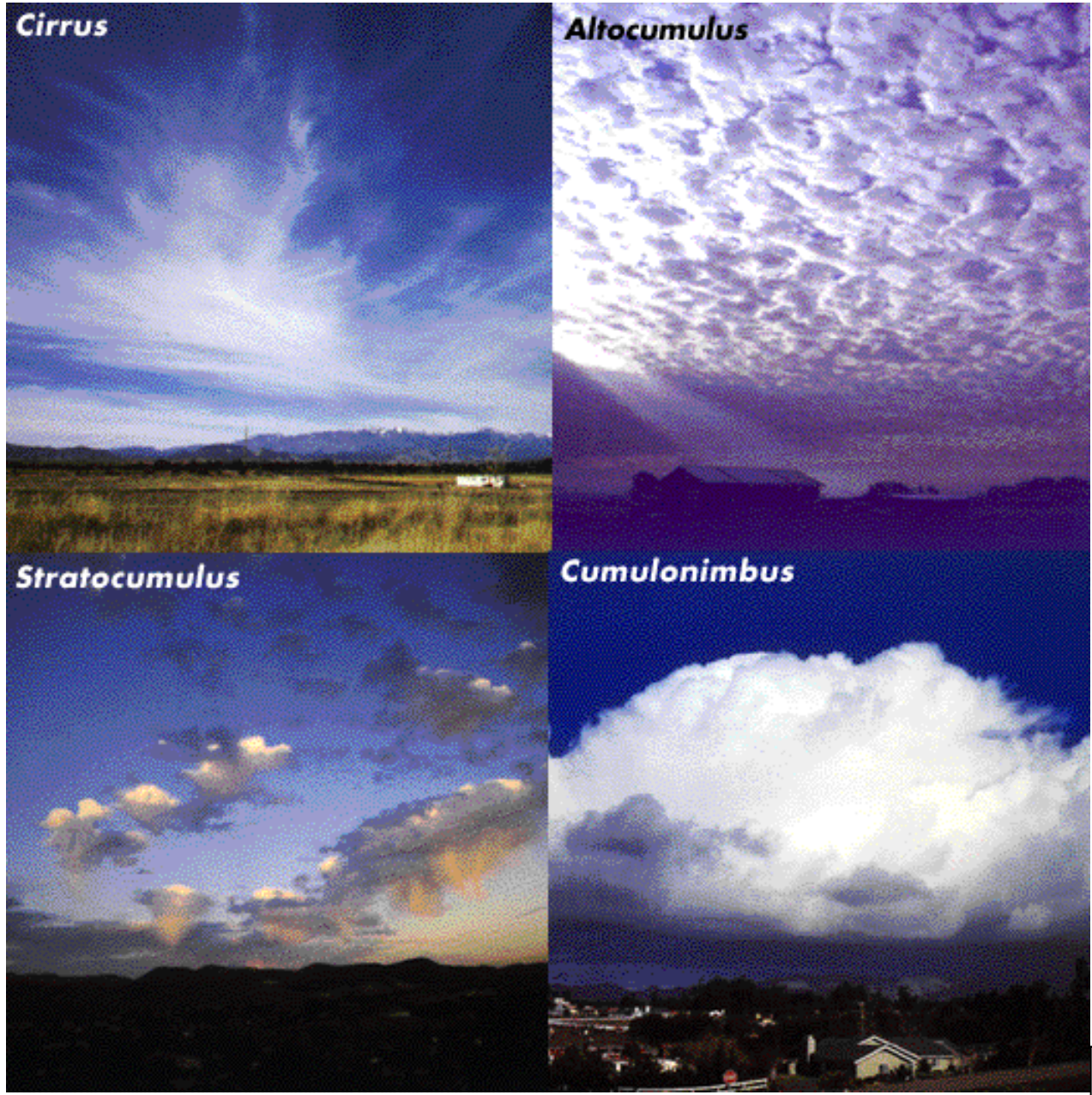
WHAT IS THE ROLE OF THE OCEANS IN CLIMATE VARIABILITY? CAN ABRUPT CLIMATE CHANGE HAPPEN?

. . . . as in “The Day After Tomorrow” movie

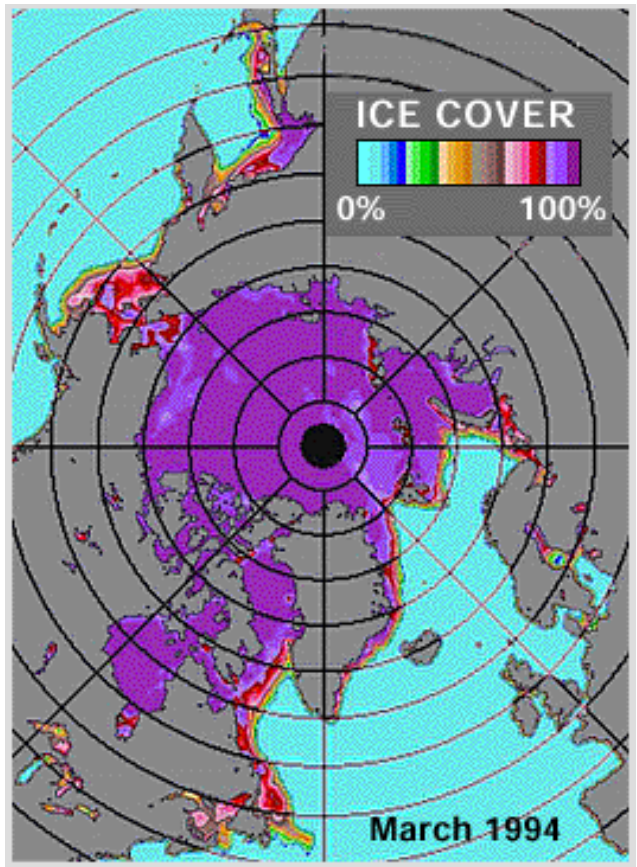
ROLE OF CLOUD FEEDBACKS

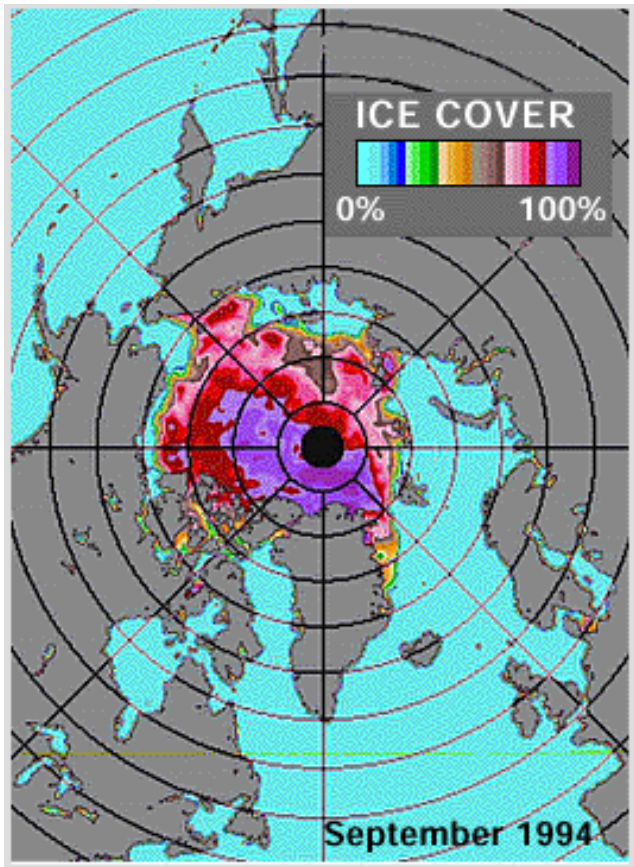
WHY IS IT SO DIFFICULT TO MODEL THE FUTURE (OR PAST) CLIMATE?

WHAT ROLE DO CLOUDS PLAY?



ROLE OF ICE FEEDBACKS

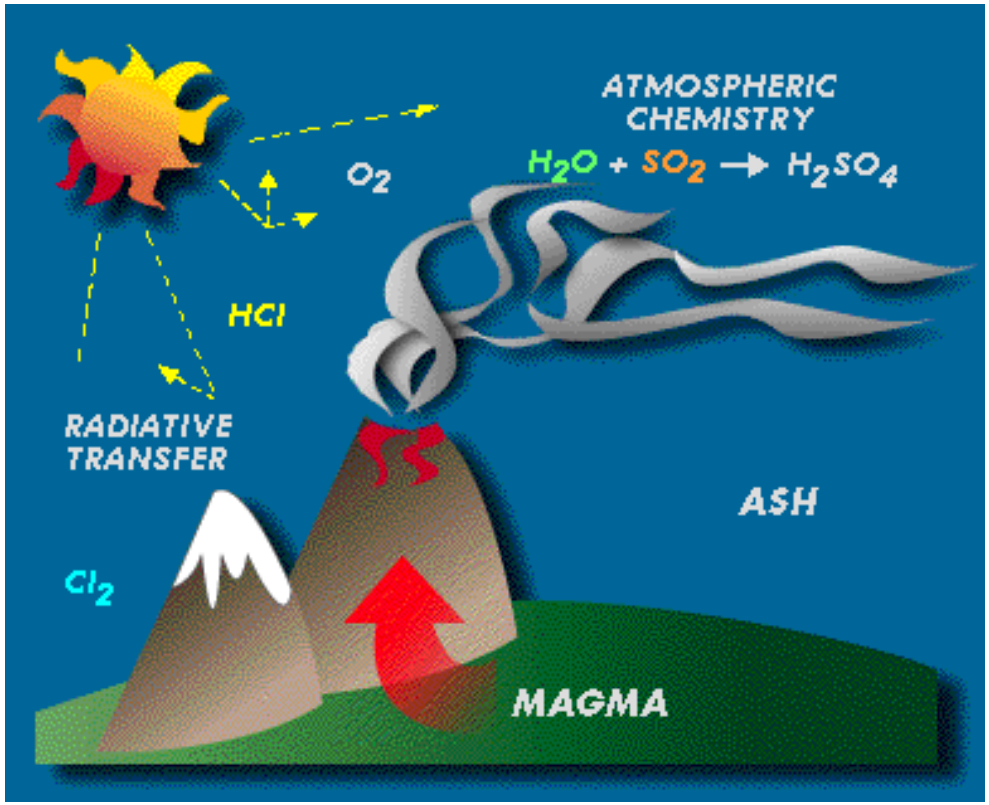




WHY SHOULD WE BE SO CONCERNED ABOUT POLAR ICECAPS MELTING?

HOW CAN PROCESSES IN THIS REMOTE PART OF THE GLOBE INFLUENCE OTHER LATITUDES?

CLIMATIC EFFECTS OF EXPLOSIVE VOLCANISM

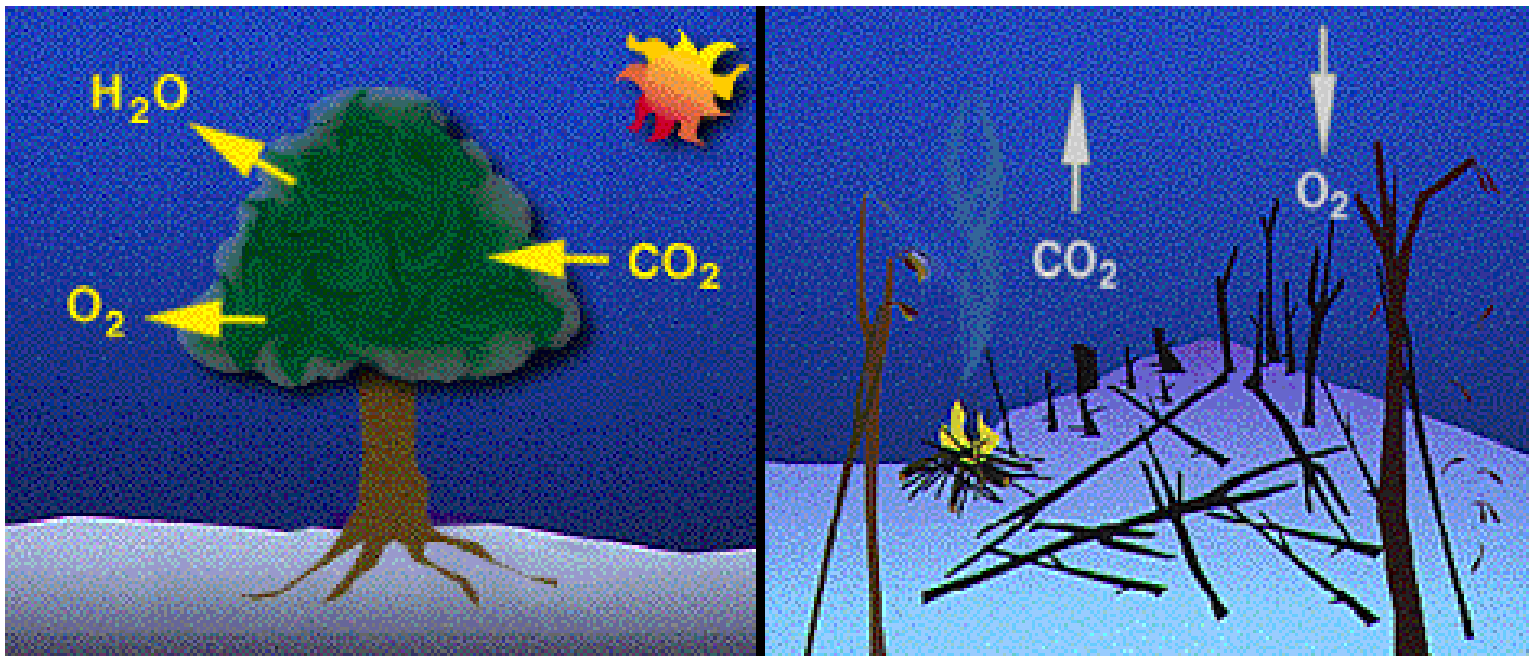


ARE THERE NATURAL PROCESSES THAT LEAD TO GLOBAL COOLING? HOW DOES THIS WORK?

GLOBAL CHANGES OF THE PAST & TREE RINGS

HOW CAN WE KNOW WHAT THE TEMPERATURE OR PRECIPITATION WAS LIKE IN THE PAST – BEFORE THE INSTRUMENTAL RECORD?

ROLE OF VEGETATON, BIODIVERSITY



HOW DOES THE CLIMATE AFFECT LIVING THINGS ON EARTH AND VICE VERSA?

WHAT DOES CLIMATE CHANGE MEAN FOR BIODIVERSITY?

DEFORESTATION

HOW ARE HUMANS IMPACTING BIODIVERSITY – AND DOES THIS AFFECT THE CLIMATE TOO?

PHOTO: U.S. Coast Guard, via European Press photo Agency

Is Greenhouse Gas Warming Causing an Increase in Global Hurricane Intensity?

ARTICLES

Mixing Politics and Science in Testing the Hypothesis That Greenhouse Warming Is Causing a Global Increase in Hurricane Intensity

BY J. A. CURRY, P. J. WEBSTER, AND G. J. HOLLAND

This complex hypothesis has been muddied frequently in recent public debate, yet can be clarified by laying bare the underlying causal chain and potential approach to verification.

"Science is what we have learned about how to keep from fooling ourselves."—RICHARD FEYNMAN

The incidence of seven major hurricanes threatening or directly affecting the United States during 2005, associated with warmer-than-average surface waters, has fueled the debate regarding the role of greenhouse warming in increasing hurricane intensity. The exceptional damage caused by Hurricane Katrina, estimated at exceeding $100 billion, and a death toll exceeding 1,300, has raised important policy issues on the vulnerability of the United States to the intense hurricanes and rising sea level associated with the emission of greenhouse gases.

Prior to the 2005 North Atlantic hurricane season, Trenberth (2005) published a commentary in *Science* raising the issue as to whether the increase in North Atlantic hurricane activity since 1995 could be attributed to global warming. This paper motivated us to begin looking at global hurricane data. In August, Emanuel (2005) published a paper in *Nature* associating the increase in sea surface temperature (SST) with an increase in maximum hurricane potential intensity and the destructive capacity of hurricanes, focusing on hurricanes in the North Atlantic and North Pacific. Webster et al. (2005; hereafter WHCC), in an article in *Science*, showed that since 1970 the total number of hurricanes has not increased globally, but the proportion of category-4 and -5 hurricanes had doubled, implying that the distribution of hurricane intensity has shifted toward being more intense. The timing of the publication of the Emanuel (2005) paper early in the 2005 North Atlantic hurricane season and the publication of WHCC between the landfalls of Hurricanes Katrina and Rita focused intense media attention on the topic of greenhouse warming and increasing hurricane intensity, although neither

AFFILIATIONS: CURRY AND WEBSTER—School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, Georgia; HOLLAND—National Center for Atmospheric Research, Boulder, Colorado
CORRESPONDING AUTHOR: Judith A. Curry, School of Earth and Atmospheric Sciences, Georgia Institute of Technology, 311 Ferst Drive, Atlanta, GA 30332-0340
E-mail: currya@eas.gatech.edu
DOI:10.1175/BAMS-87-8-1025
In final form 7 April 2006

Bulletin of the American Meteorological Society

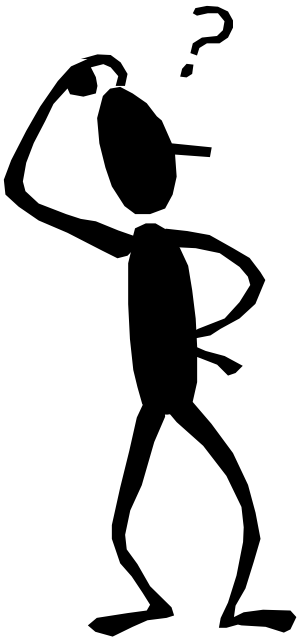
August 2006

"In summary, the central hypothesis . . . cannot be invalidated by the available evidence.

We anticipate that it may take a decade for the observations to clarify the situation as to whether the hypothesis has predictive ability. In short, time will tell."

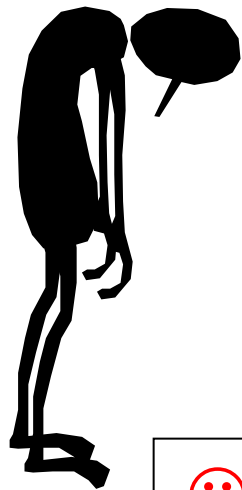
i.e., THE HYPOTHESIS/ CANNOT BE FALSIFIED WITH THE AVAILABLE EVIDENCE

RETURNING TO THE CONCEPT OF SUSTAINABILITY & A SUSTAINABLE EARTH . . . .



WHAT IF we use up nonrenewable resources to the extent that they are beyond extracting economically?

or WHAT IF some changes just mentioned are irreversible?



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"

SUMMARY QUOTE TO THINK ABOUT . . . .

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

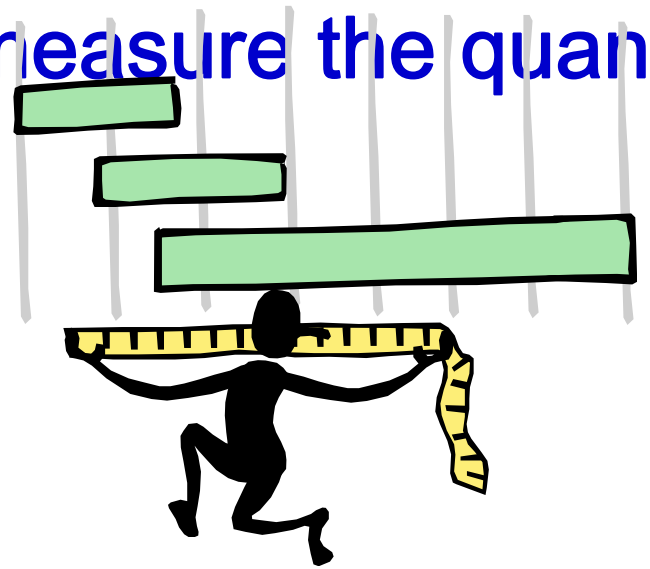
The damage can be reversed, but it will take years of cooperation by every individual and every nation." *

* *Pathways of Understanding: The Interactions of Humanity and Global Environmental Change," May 1992, CIESIN, p40.*

THINK GLOBALLY –
ACT LOCALLY

NEXT:
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:

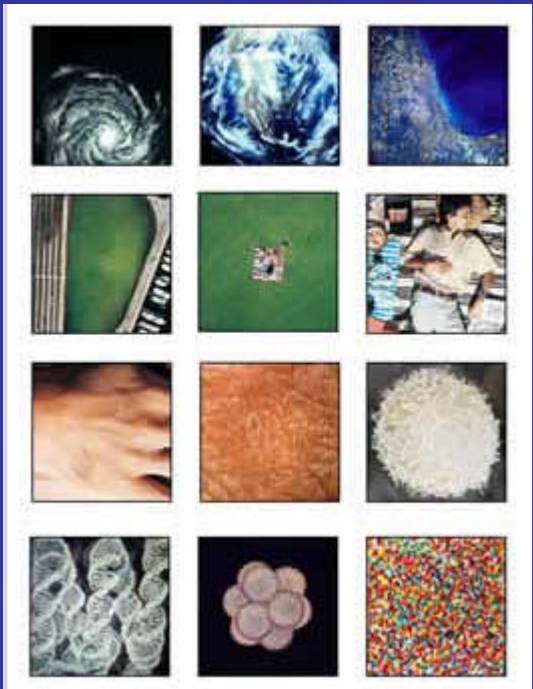
- Earth / global change phenomena and processes occur over an enormous RANGE of spatial and temporal SCALES.

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

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

A Classic Video on
The Relative Spatial Scale of Things:

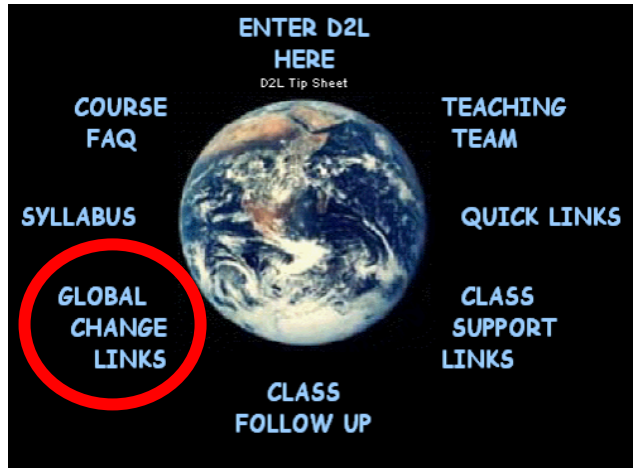
"POWERS OF 10"



"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

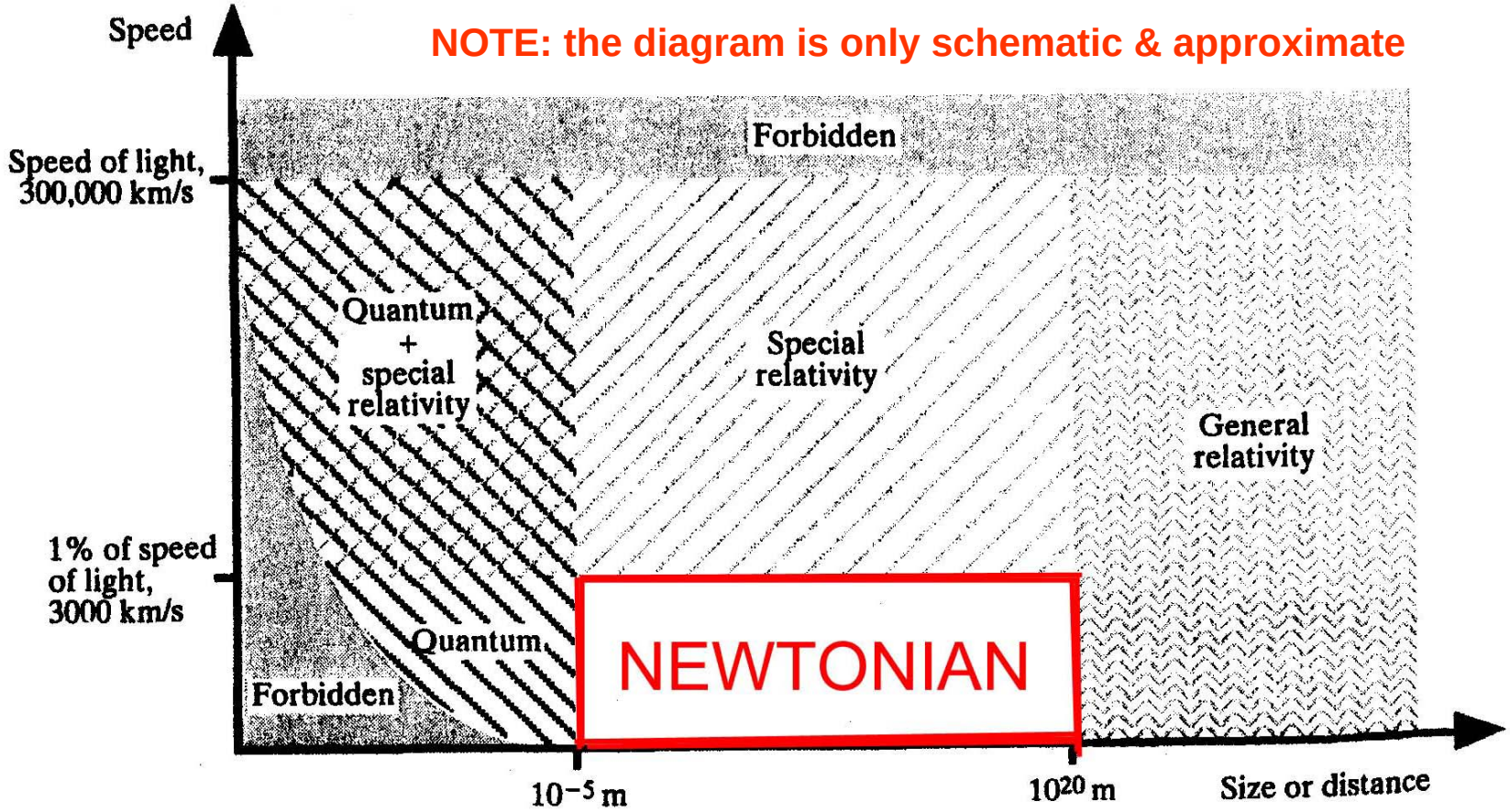
Powers of 10 website - updated website companion to the classic video by Charles & Ray Eames

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

CELEBRATE POWERS OF 10 DAY October 10, 2006

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.

. . .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

To address the KEY QUESTIONS, global change scientists use:

mathematical expressions
equations
symbols
models

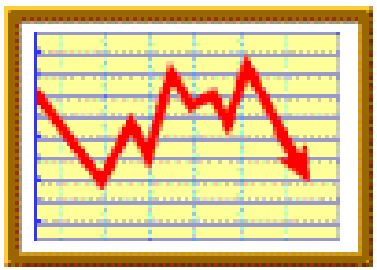
to measure, analyze, and "run experiments" on the Earth.

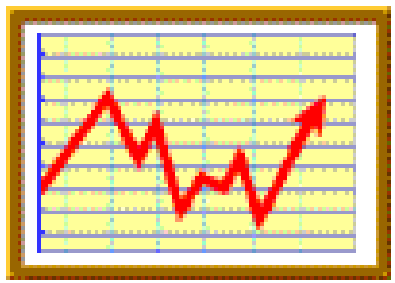
NOTE: Scientific Notation Review on p 21
– see also examples in IGC Hobson Chapter 2

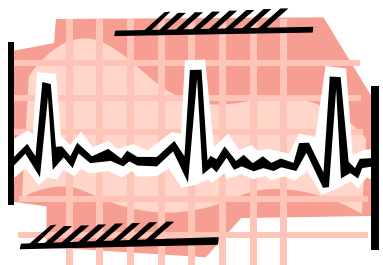
Quantifying Change over TIME:

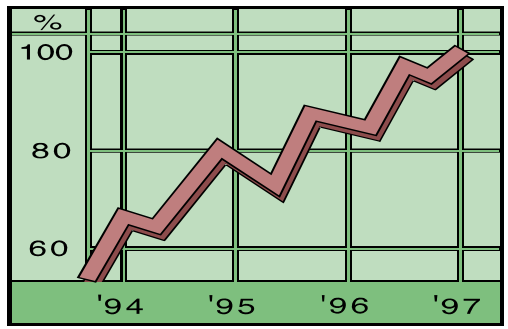
To quantify global change we examine TIME SERIES CHANGE:

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









RATES OF CHANGE

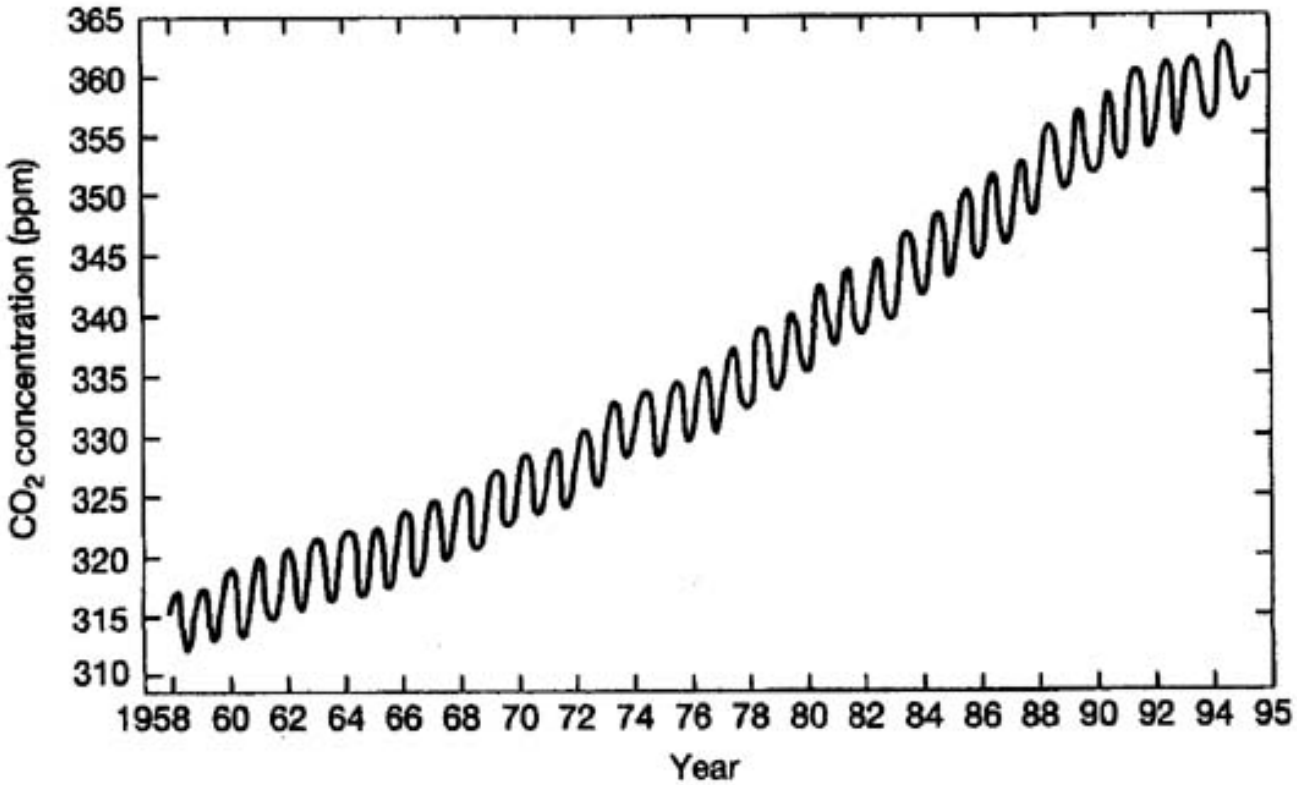
We also need to quantify RATES of change:

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

IN-CLASS ACTIVITY

Thought Exercise on:
PLOTTING CHANGE OVER TIME

(see pp 23-24 in Class Notes)

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

(see pp 23-24 in Class Notes)

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

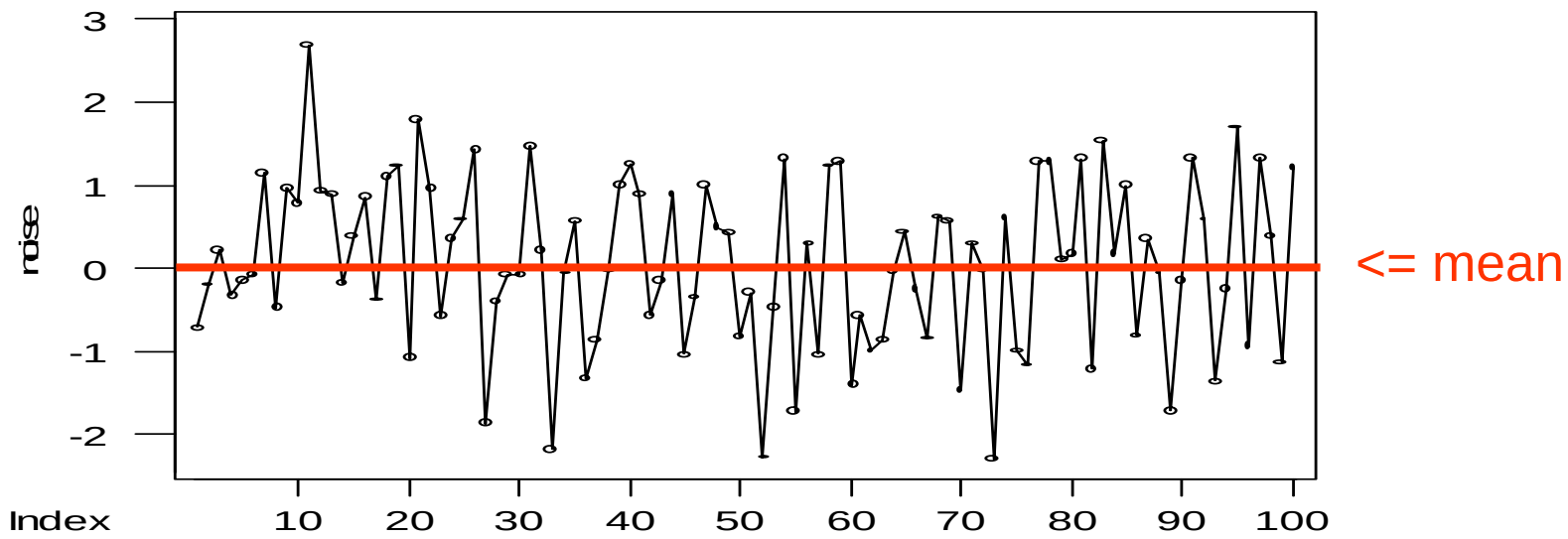
- **Mean** = average (a constant mean stays the same over time and looks like a horizontal line.)
- **Variance** = the range of fluctuations (wiggles) above and below the mean (statistically the variance is the square of the standard deviation about the mean)

Terms (cont.)

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

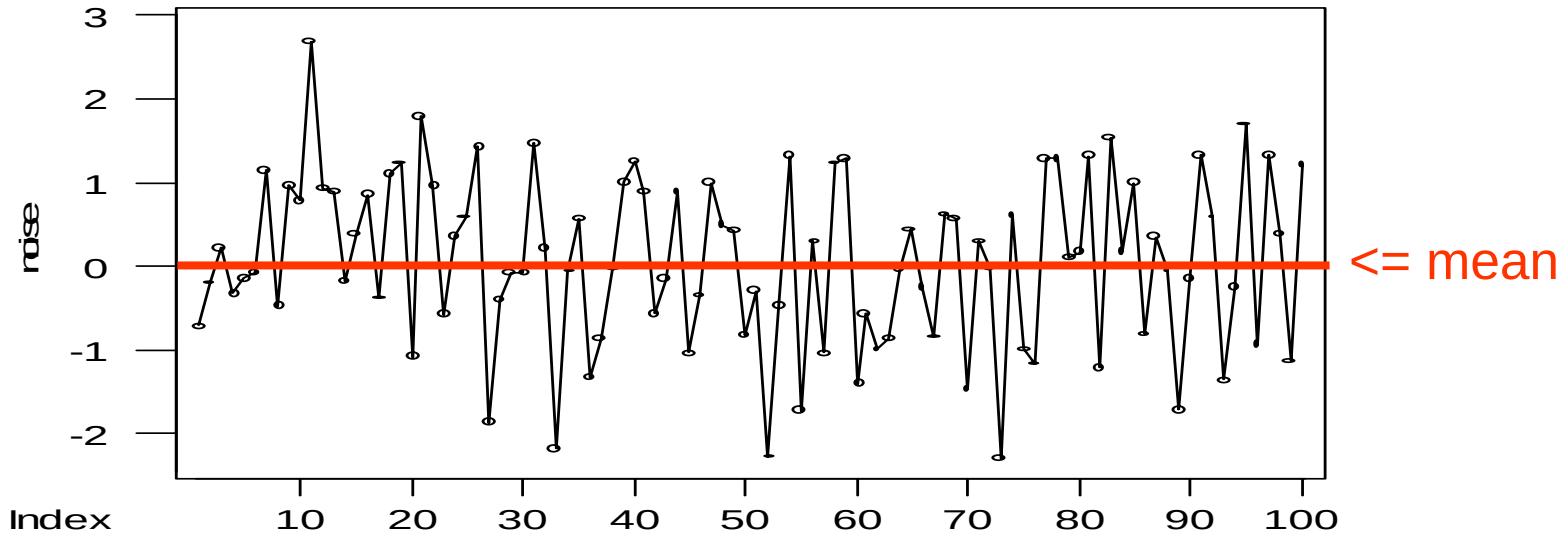
- **Quasi-periodic** = almost regular oscillations (in nature things are quite often quasi-periodic rather than perfect oscillations)
- **Trend** = a line of general direction (increasing or decreasing)

Time Series Plot 1



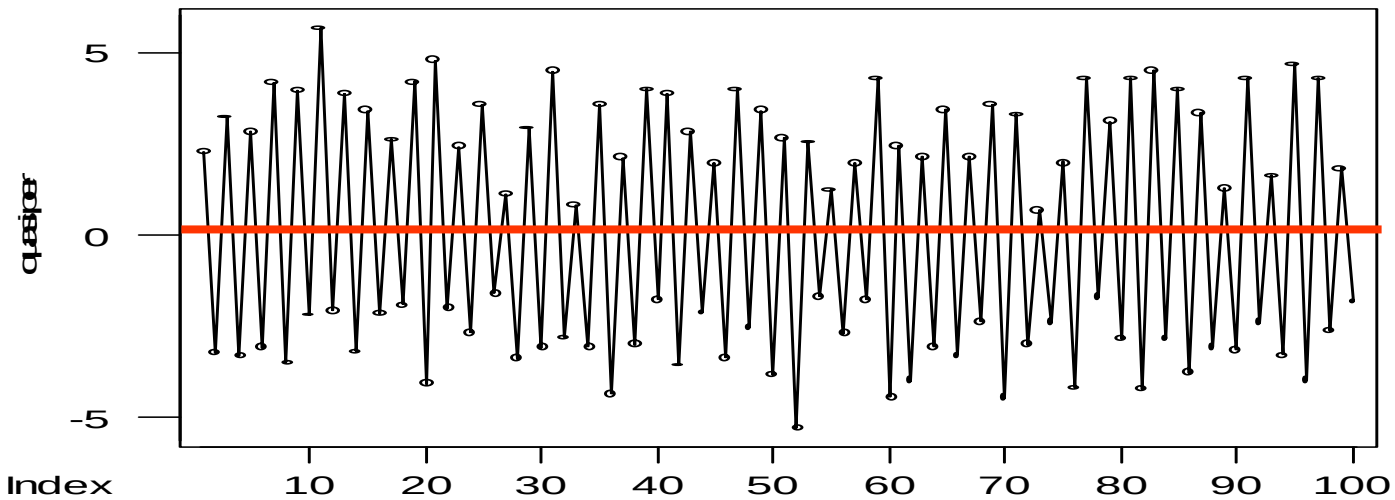
Draw in the MEAN line for this time series.

Time Series Plot 1



"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

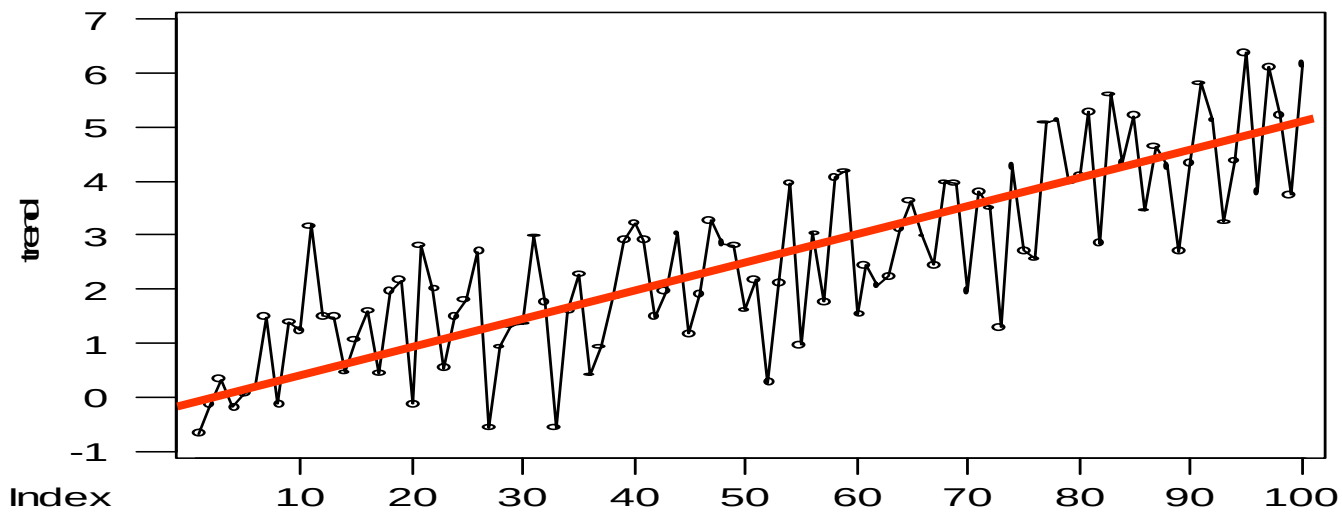


“Quasi-periodic plot”

Is the mean constant?

Is the variance constant?

Time Series Plot 3

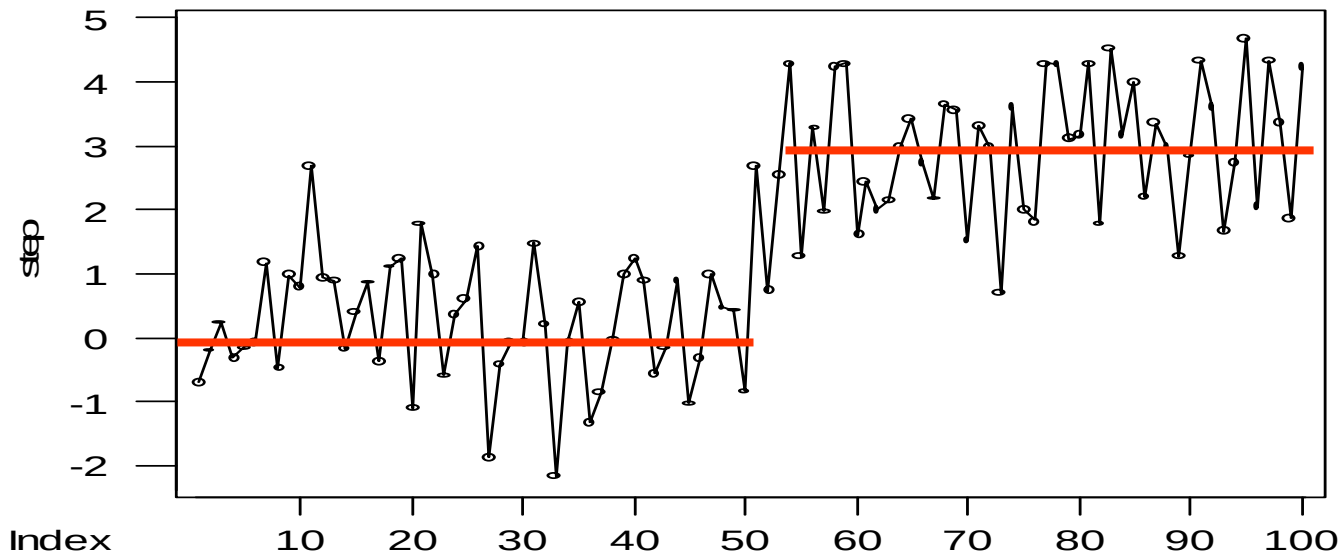


“Trend” plot

What’s happening to the mean?

Is the variance constant?

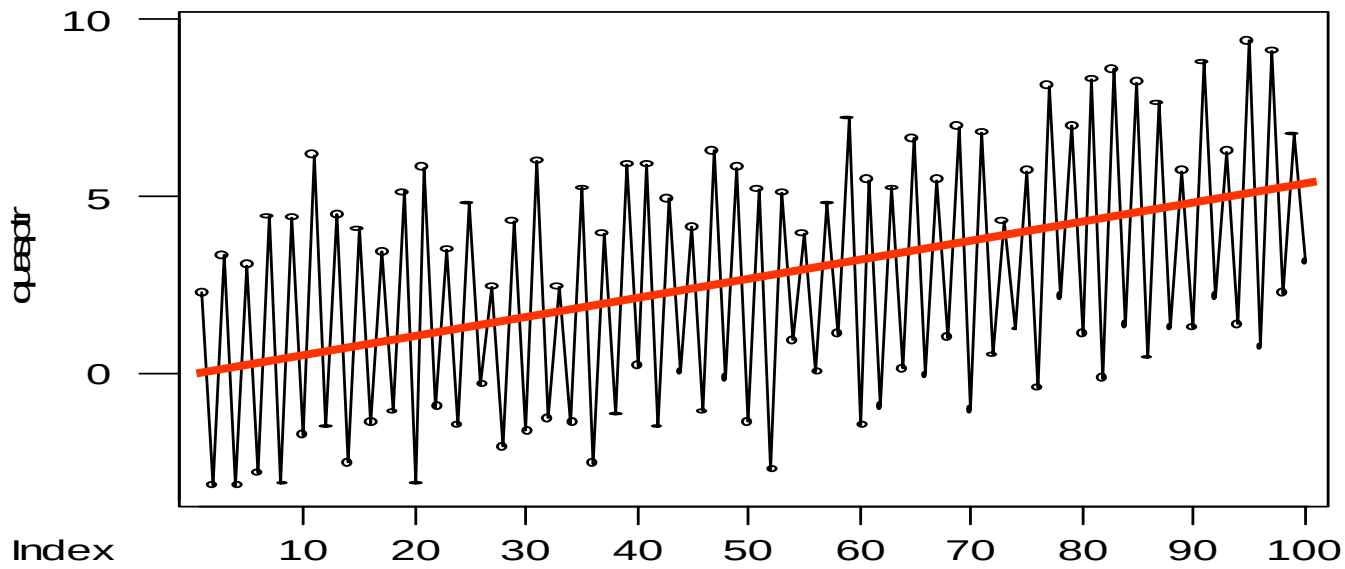
Time Series Plot 4



“Step change” plot

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

Time Series Plot 5

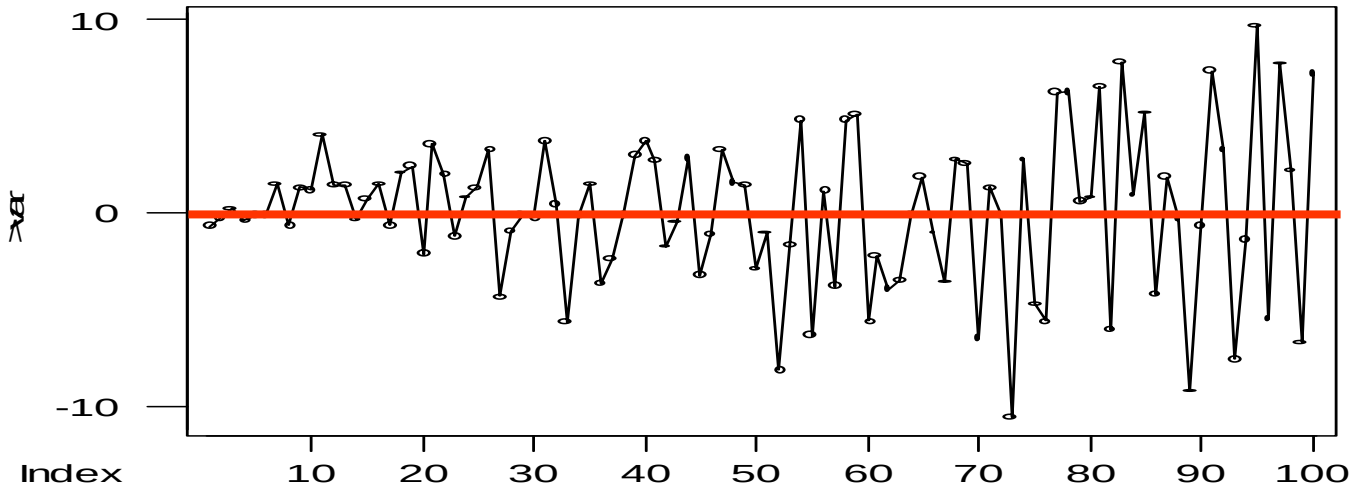


“Quasi-periodic with upward trend” plot

What’s going on with the mean?

The variance?

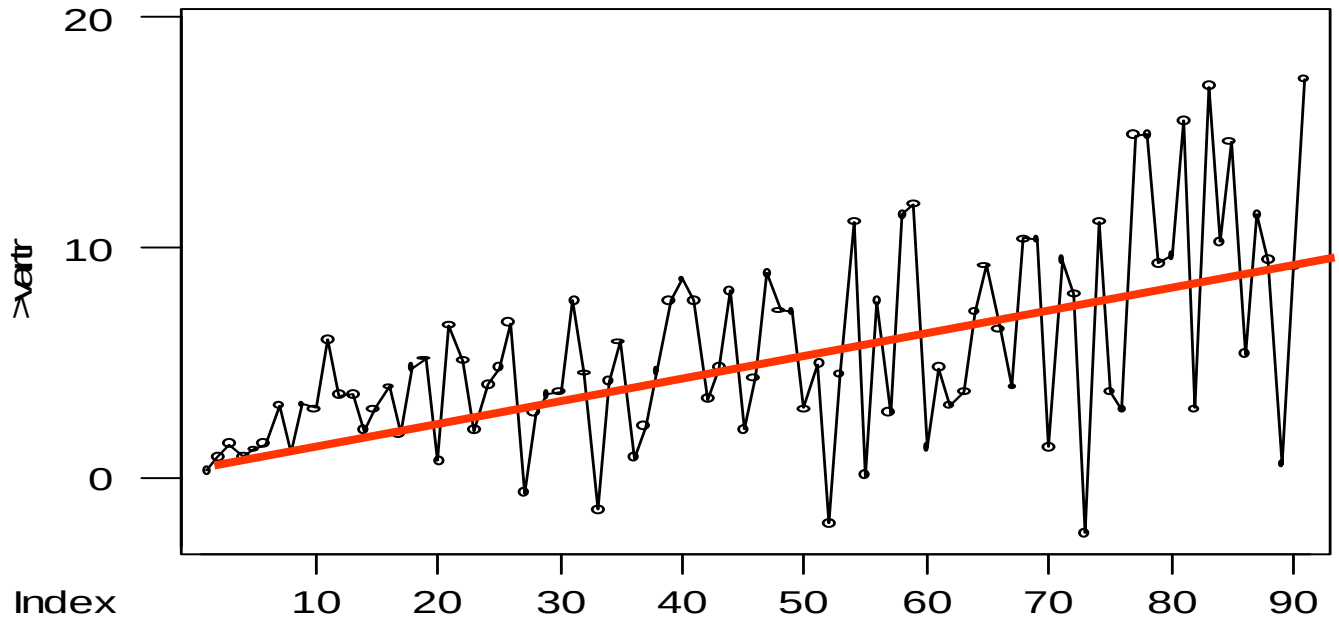
Time Series Plot 6



What's going on with the mean?

The variance?

Time Series Plot 7

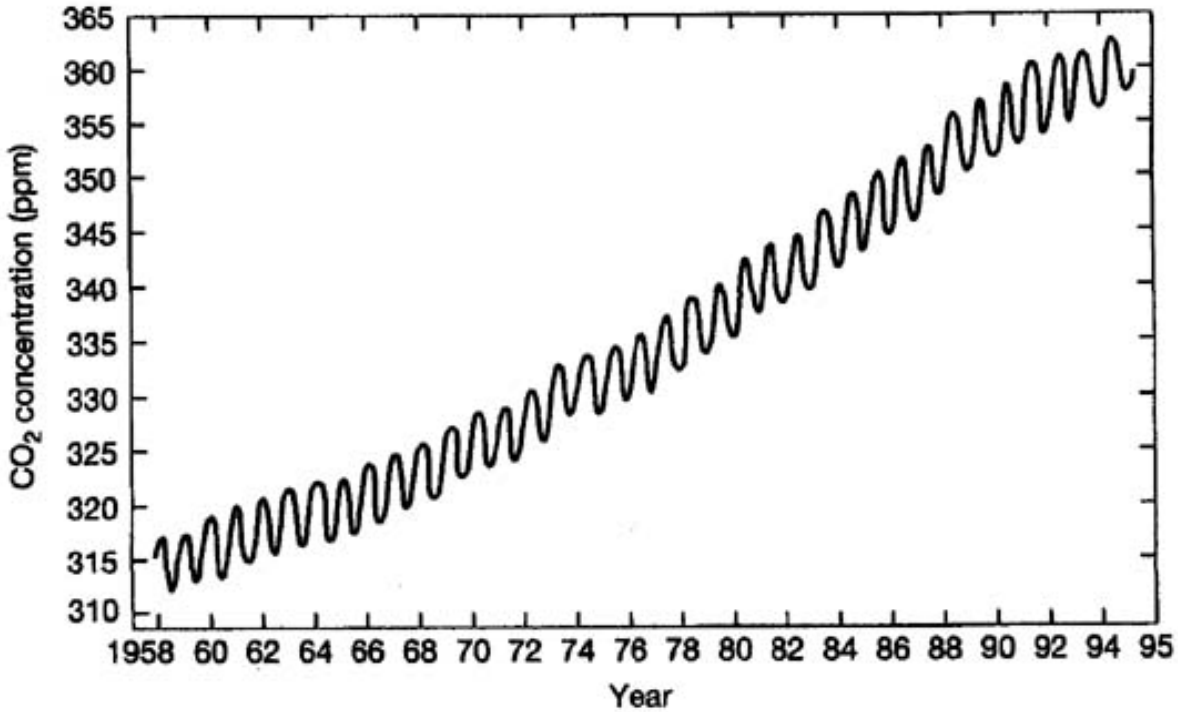


Is there a trend?

What's going on with the mean over time?

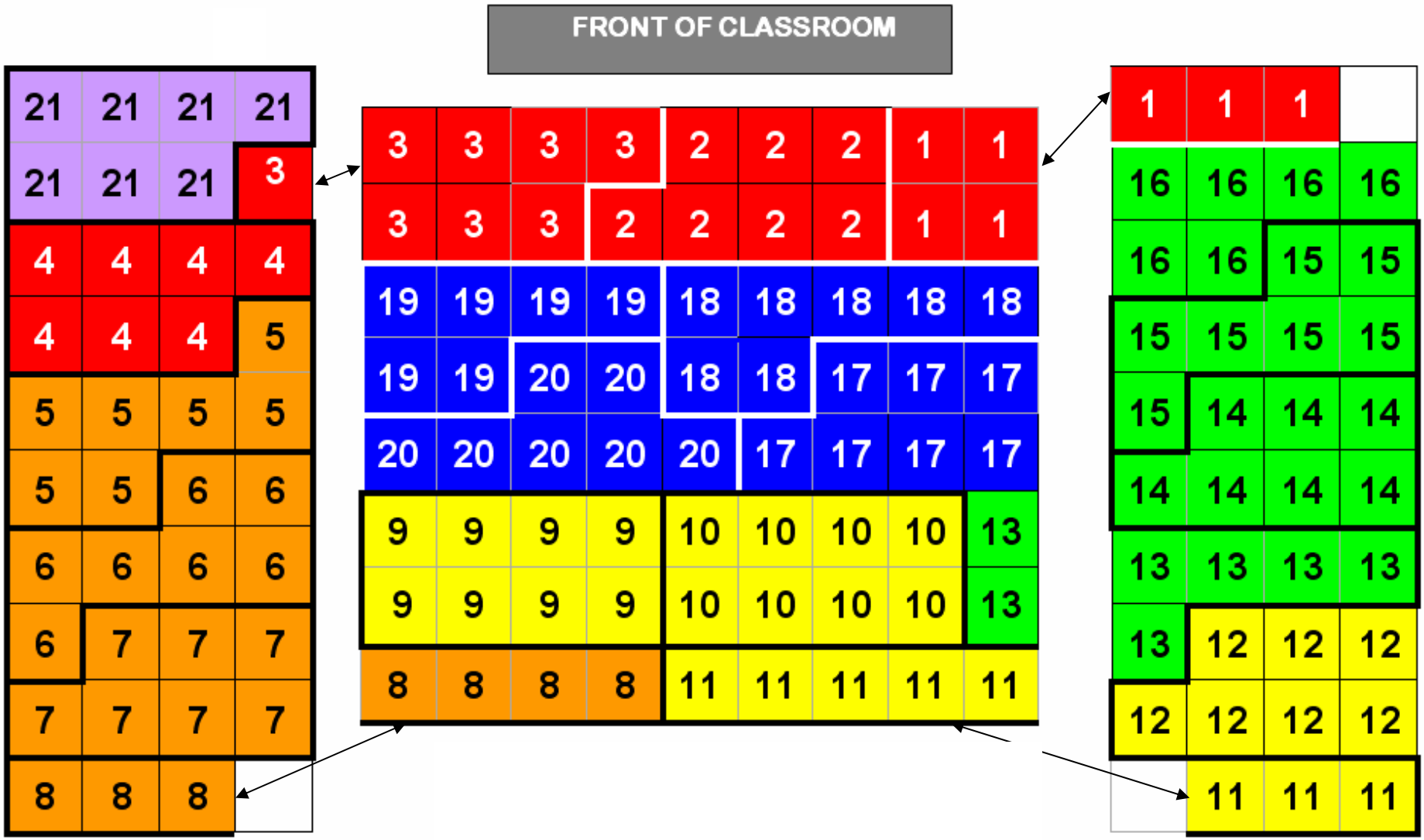
What's going on with the variance?

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



GROUP ACTIVITY

G-1 GROUP ECOLOGICAL FOOTPRINT


FRONT OF CLASSROOM
21 21 21 21
21 21 21 3
4 4 4 4
4 4 4 5
5 5 5 5
5 5 6 6
6 6 6 6
6 7 7 7
7 7 7 7
8 8 8
3 3 3 3 2 2 2 1 1
3 3 3 2 2 2 2 1 1
19 19 19 19 18 18 18 18 18
19 19 20 20 18 18 17 17 17
20 20 20 20 20 17 17 17 17
9 9 9 9 10 10 10 10 13
9 9 9 9 10 10 10 10 13
8 8 8 8 11 11 11 11 11
1 1 1
16 16 16 16
16 16 15 15
15 15 15 15
15 14 14 14
14 14 14 14
13 13 13 13
13 12 12 12
12 12 12 12
11 11 11

ASSIGNMENTS I-1 & G-1 on ECOLOGICAL FOOTPRINTS

- GET GROUP FOLDER (color coded)
- EVERYONE SIGN YOUR NAME in the GROUP FOLDER
- Pass out, fill in and put on Nametags
- First in alphabet in your group is TODAY's GROUP LEADER. Your job is to keep the discussion going and get assignment done!
- GO AROUND THE CIRCLE AND INTRODUCE YOURSELF:
  - where from
  - major
  - Ecological Footprint!
- WORK ON G-1 TOGETHER – GROUP LEADER appoints a RECORDER, who fills out the form.
- REPORT BACK TO CLASS ON GROUP'S TOTAL FOOTPRINT.
- NOTE: Submit your I-1 & G-1 by leaving it in your group folder.

ANNOUNCEMENTS

- Turn in ASSIGNMENT I-1 in your GROUP FOLDER before you leave.
- ONLINE QUIZ RQ-1 is due before NOON on THURSDAY Aug 31st.
- OFFICE HOURS are now posted under TEACHING TEAM