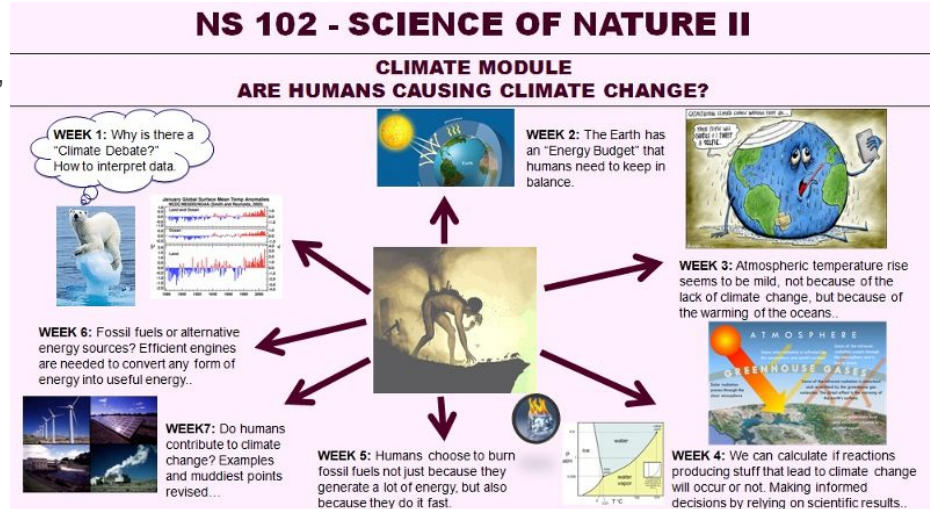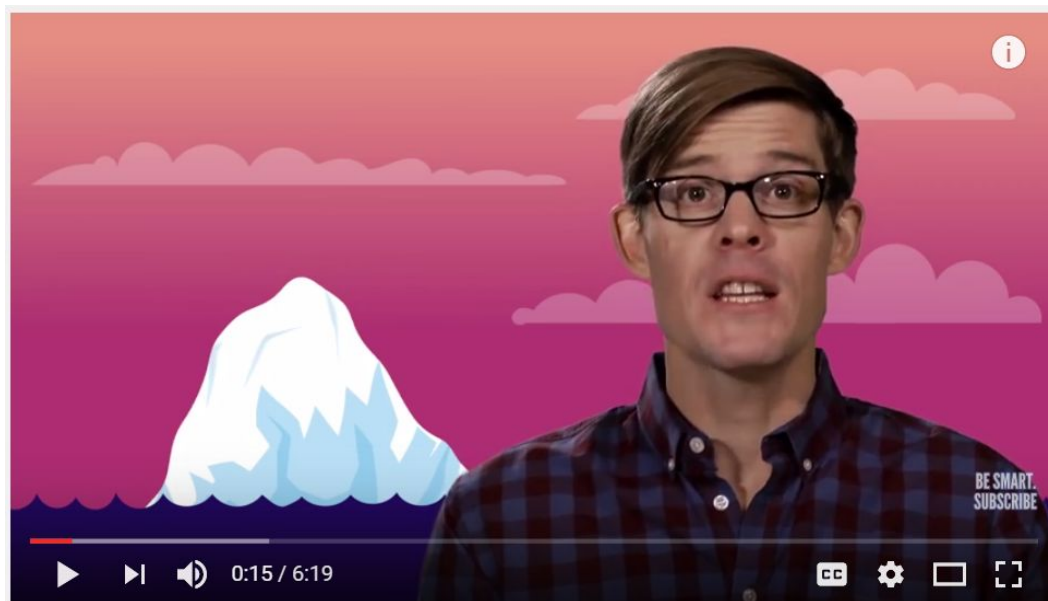# CLIMATE CHANGE IS REAL!

ARE HUMAN SINGLE-HANDEDLY CAUSING IT?

- learn why there is a "Climate Debate?"
- make informed decisions by interpreting raw data presented to us
- calculate the "energy budget" of Earth - and why humans are throwing it off-balance
- see data presented as contrary to the claim of climate change, and learn how to interpret these using science
- develop a molecular level understanding of what causes "the change"
- calculate the amount of energy produced by different fuels we use for civilized living using the first law of thermodynamics
- discuss the second law of thermodynamics, and interpret claims that the idea of climate change is against this law so it must be wrong
- discuss some existing and futuristic alternative energy sources, and calculate their efficiencies

NS 102 - SCIENCE OF NATURE II

CLIMATE MODULE
ARE HUMANS CAUSING CLIMATE CHANGE?

WEEK 1: Why is there a "Climate Debate?" How to interpret data.

WEEK 2: The Earth has an "Energy Budget" that humans need to keep in balance.

WEEK 3: Atmospheric temperature rise seems to be mild, not because of the lack of climate change, but because of the warming of the oceans..

WEEK 4: We can calculate if reactions producing stuff that lead to climate change will occur or not. Making informed decisions by relying on scientific results.

WEEK 5: Humans choose to burn fossil fuels not just because they generate a lot of energy, but also because they do it fast.

WEEK 6: Fossil fuels or alternative energy sources? Efficient engines are needed to convert any form of energy into useful energy..

WEEK7: Do humans contribute to climate change? Examples and muddiest points revised...

"Global Warming 101"

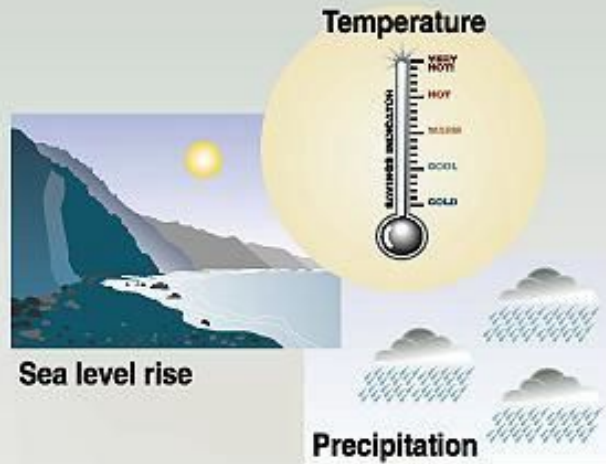Please watch the following video by clicking on the image.

Climate Science: What You Need To Know

POTENTIAL IMPACTS OF CLIMATE CHANGE

...why use Earth's temperature variations to assess if climate is changing

Potential climate changes impact

Temperature

Sea level rise

Precipitation

Impacts on...

Health	Agriculture	Forest	Water resources	coastal areas	Species and natural areas
Weather-related mortality	Crop yields	Forest composition	Water supply	Erosion of beaches	Loss of habitat and species
Infectious diseases	Irrigation demands	Geographic range of forest	Water quality	Inundation of coastal lands	Cryosphere: diminishing glaciers
Air-quality respiratory illnesses		Forest health and productivity	Competition for water	additional costs to protect coastal communities	

GRAPHIC DESIGN : PHILIPPE REKACEWICZ

Temperature Anomaly (°C)

-2.5   0   2.5

1885 - 1894

1945 - 1954

2005 -
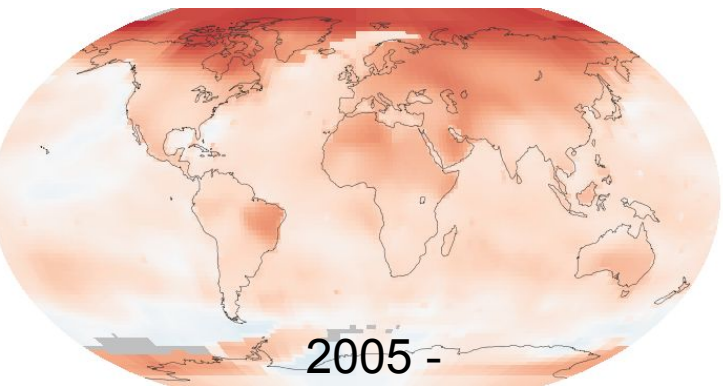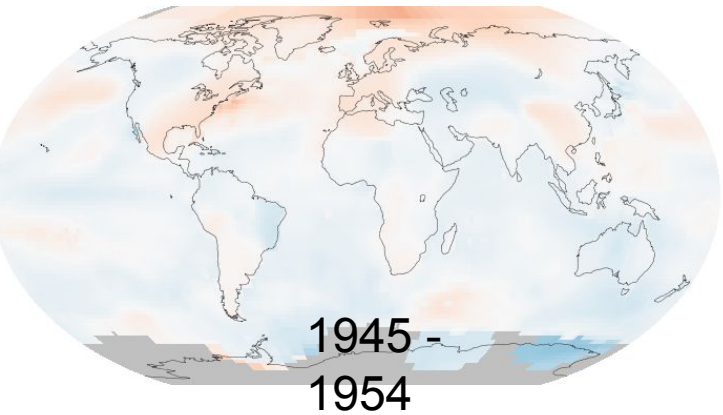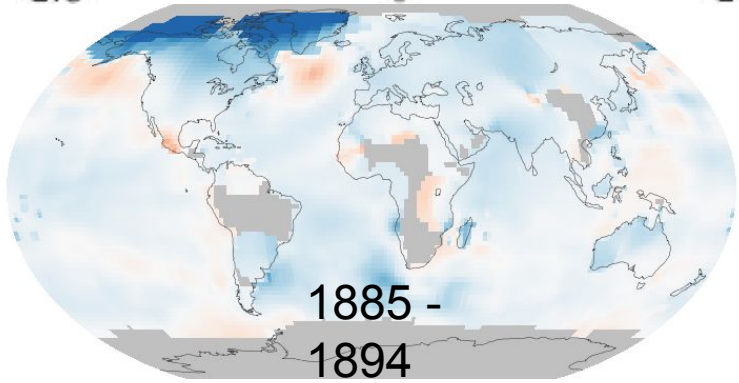
Projected Impacts of Climate Change

Global temperature change (relative to pre-industrial)

	0°C	1°C	2°C	3°C	4°C	5°C
Food		Falling crop yields in many areas, particularly developing regions				
		Possible rising yields in some high latitude regions			Falling yields in many developed regions	
Water	Small mountain glaciers disappear – water supplies threatened in several areas	Significant decreases in water availability in many areas, including Mediterranean and Southern Africa		Sea level rise threatens major cities		
Ecosystems	Extensive Damage to Coral Reefs	Rising number of species face extinction				
Extreme Weather Events	Rising intensity of storms, forest fires, droughts, flooding and heat waves					
Risk of Abrupt and Major Irreversible Changes	Increasing risk of dangerous feedbacks and abrupt, large-scale shifts in the climate system					

How large is the energy we are talking about?

The volume of the Atlantic Ocean is about 300 million km^3.

The heat required to raise the temperature of the Atlantic Ocean by **1°C is 10^{18} J = 1 Exajoule (EJ).**

If all the sun's energy is absorbed, it'd take **174 days** to raise the temperature of Atlantic Ocean 1°C.

The 2011 Tōhoku earthquake and tsunami in Japan had 1.41 EJ of energy.

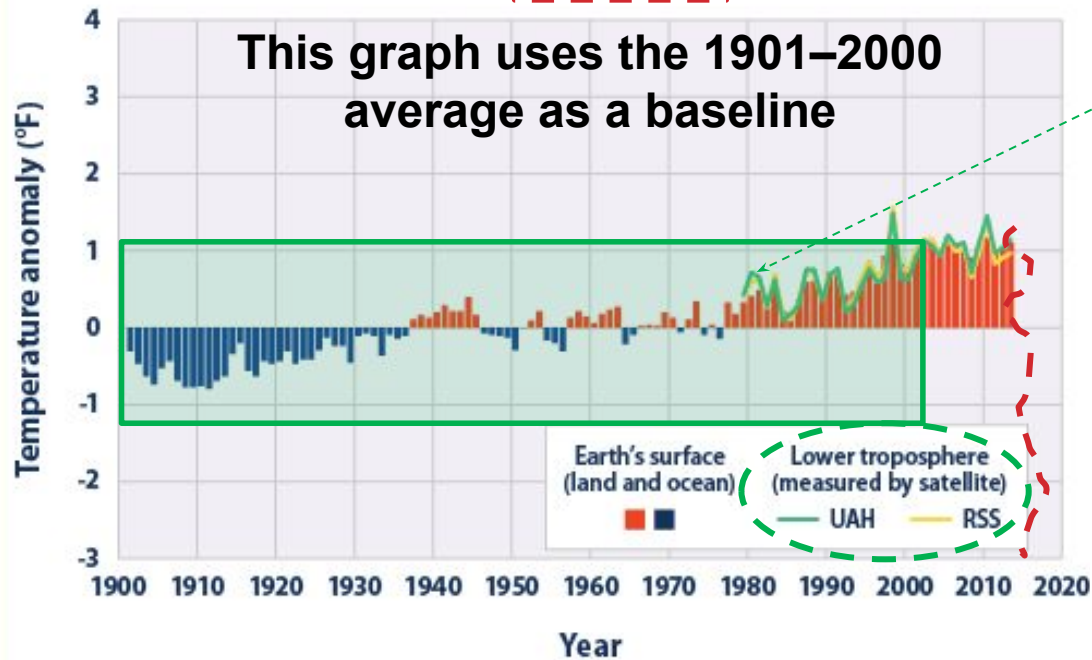Energy in the United States used per year is roughly 94 EJ.

IS THE CLIMATE REALLY CHANGING?

CAN WE DECIDE BY LOOKING AT THE DATA ON TEMPERATURE VARIATIONS?

...given time dependent data, draw the best fitting line and apply this analysis to published data on Earth's temperature variations to assess if climate is changing

Evidence 1: Changes in the average surface temperatures

Figure 2. Temperatures Worldwide, 1901–2013

This graph uses the 1901–2000 average as a baseline

Earth's surface (land and ocean) ■ ■
Lower troposphere (measured by satellite) — UAH — RSS

Temperature anomaly (°F) vs Year

Satellite data were analyzed by two independent groups—the Global Hydrology and Climate Center at the University of Alabama in Huntsville (UAH) and Remote Sensing Systems (RSS)

– confirmation of data

http://csep10.phys.utk.edu/astr161/lect/earth/atmosphere.htm
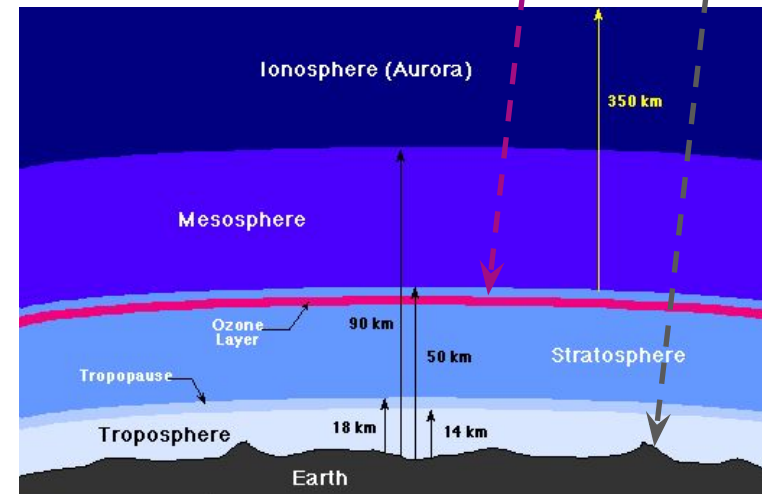
Opposing view: Global warming has stopped, according to average surface temperature data

No significant warming has been observed since 1990's???

NCDC Global Surface Temperature Anomalies
Jun 1997 to Apr 2013
- Update of David Rose's Graph -
Surface Temperatures Are Basically The Same Now As They Were
191 Months Ago in June 1997
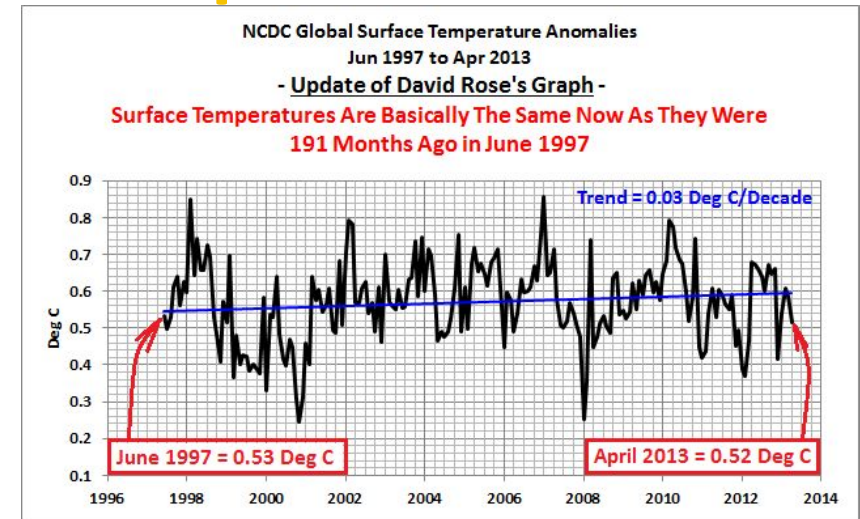
Bob Tisdale

Illustration From Dr. Trenberth's Article "Has Global Warming Stalled?"

http://www.rmets.org/weather-and-climate/climate/has-global-warming-stalled
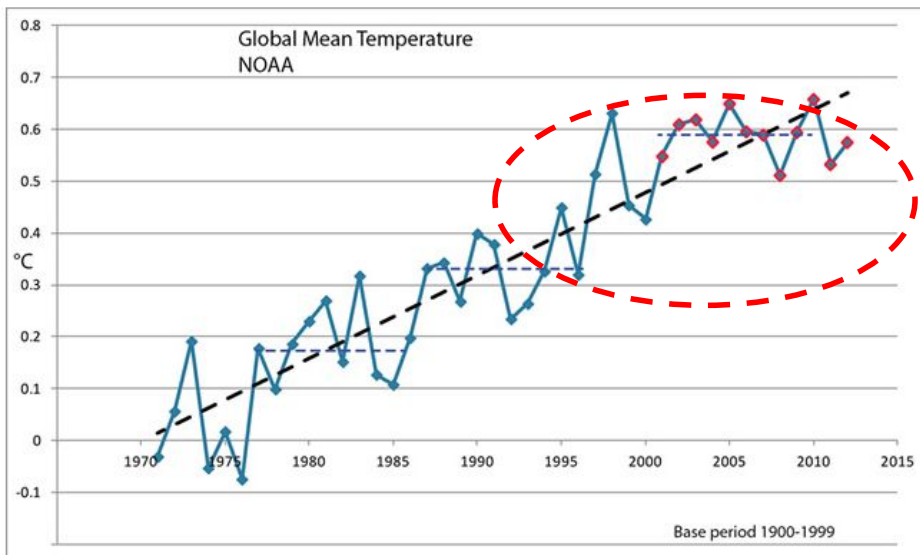
When dealing with real data, it is important to decide on...
 • how to fit the data (what functional form to use; i.e., what is your **model**?)
 • how to choose the data range to fit

So, how should one analyze data?

independent variable (*x*) vs. dependent variable (*y*)

Let's start with the simplest model that proposes *y* depends linearly on *x*:

$$y_i = a\, x_i + b + \text{(random deviation)}_i$$

Linear regression

Error: *y-y'*

Estimated line: *y' = a x + b*

Data: *y*
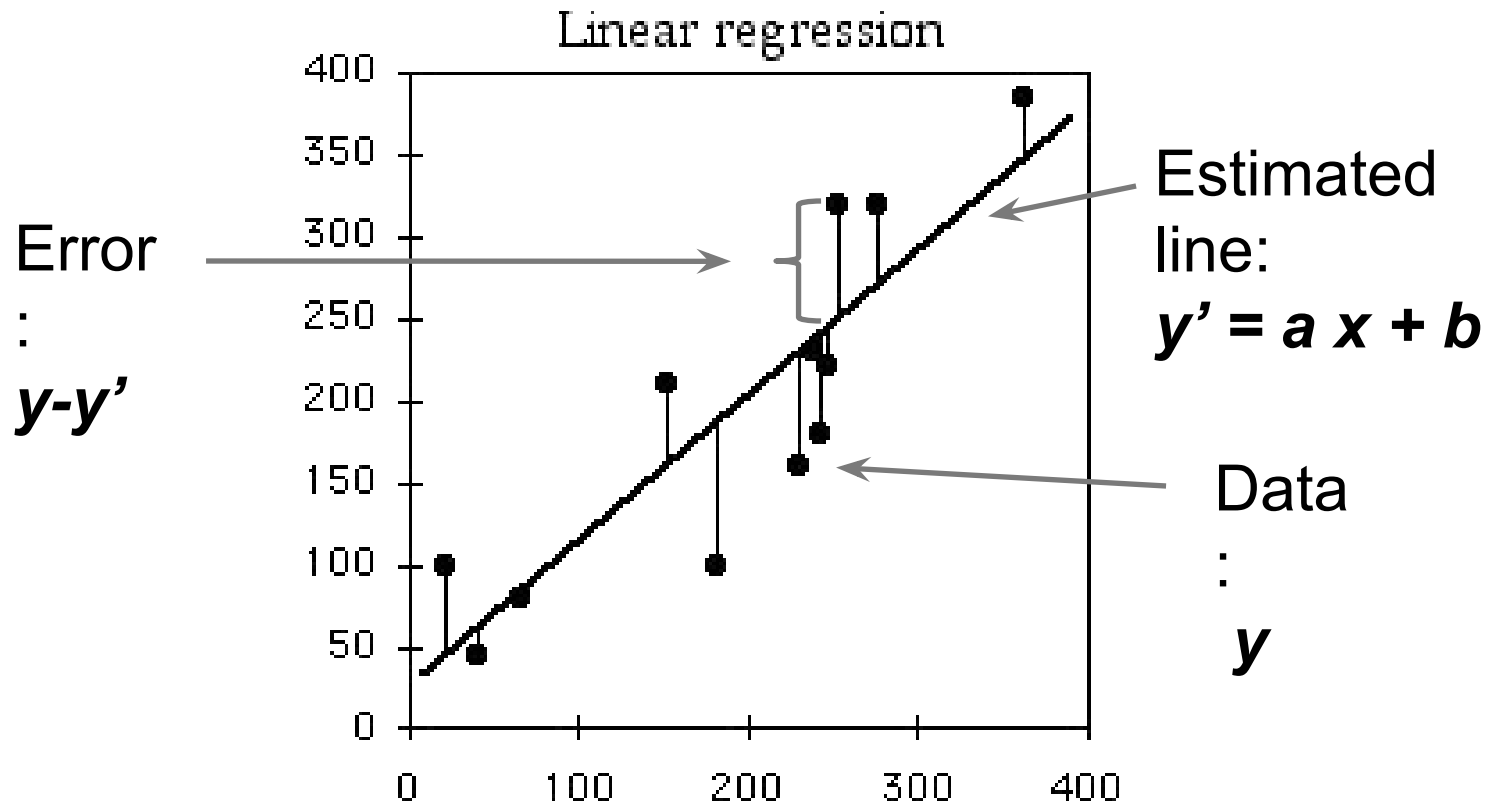
Evidence 2: Has climate change stopped?

NCDC Global Surface Temperature Anomalies
Jun 1997 to Apr 2013
- Update of David Rose's Graph -
Surface Temperatures Are Basically The Same Now As They Were
191 Months Ago in June 1997

Trend = 0.03 Deg C/Decade

June 1997 = 0.53 Deg C   April 2013 = 0.52 Deg C
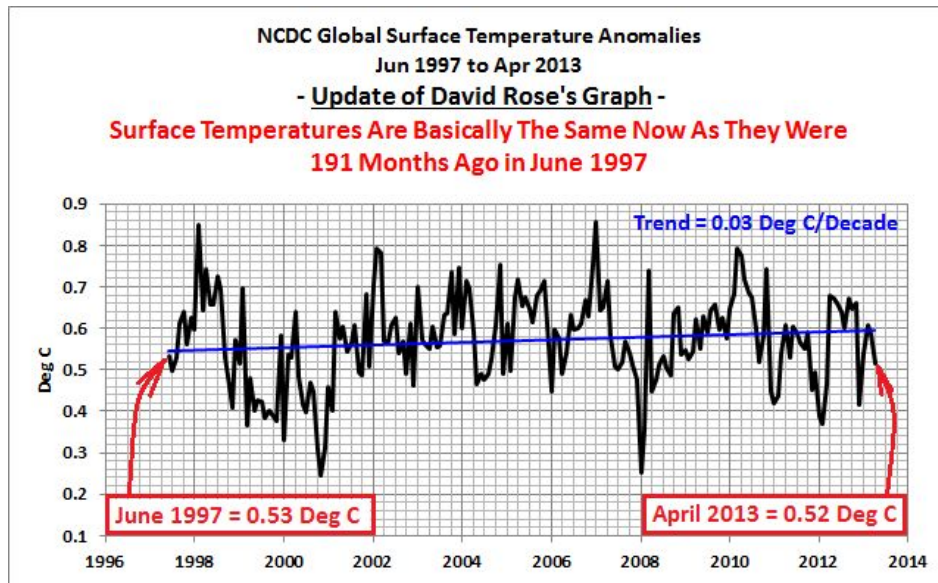
Bob Tisdale

No significant warming has been observed since 1990's.

Ok.. Even if surface temperatures are not changing significantly for the last 20 years, does it mean climate change has stopped?

Where does the extra heat accumulate?

Heat content: The amount of heat that is stored

Where is global warming going?

Earth's Total Heat Content anomaly

- Land & Atmosphere Heating
- Ocean Heating

Ocean Heating

Land + Atmosphere

Ocean 93.4%

Atmosphere 2.3%

Continents 2.1%

Glaciers & ice caps 0.9%

Arctic sea ice 0.8%

Greenland Ice Sheet 0.2%

Antarctic Ice Sheet 0.2%
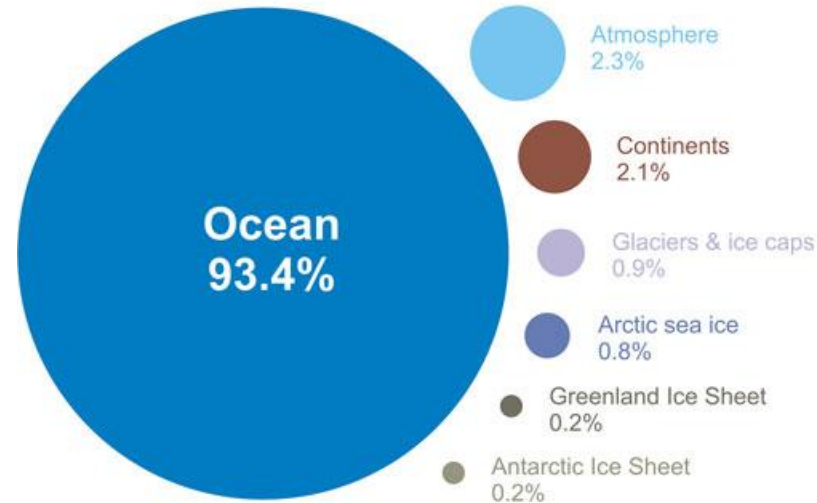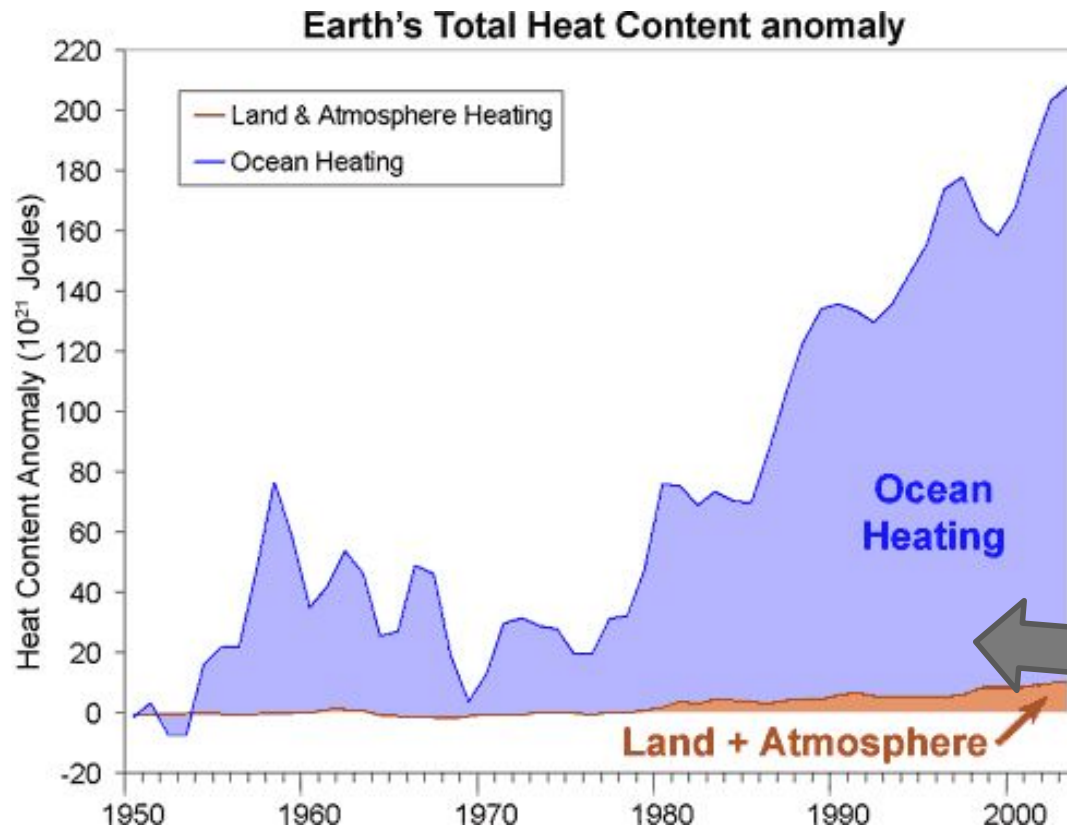
Which dependent variable has stronger dependence on time?

Sea level changes

Figure 1. Global Average Absolute Sea Level Change, 1880–2013
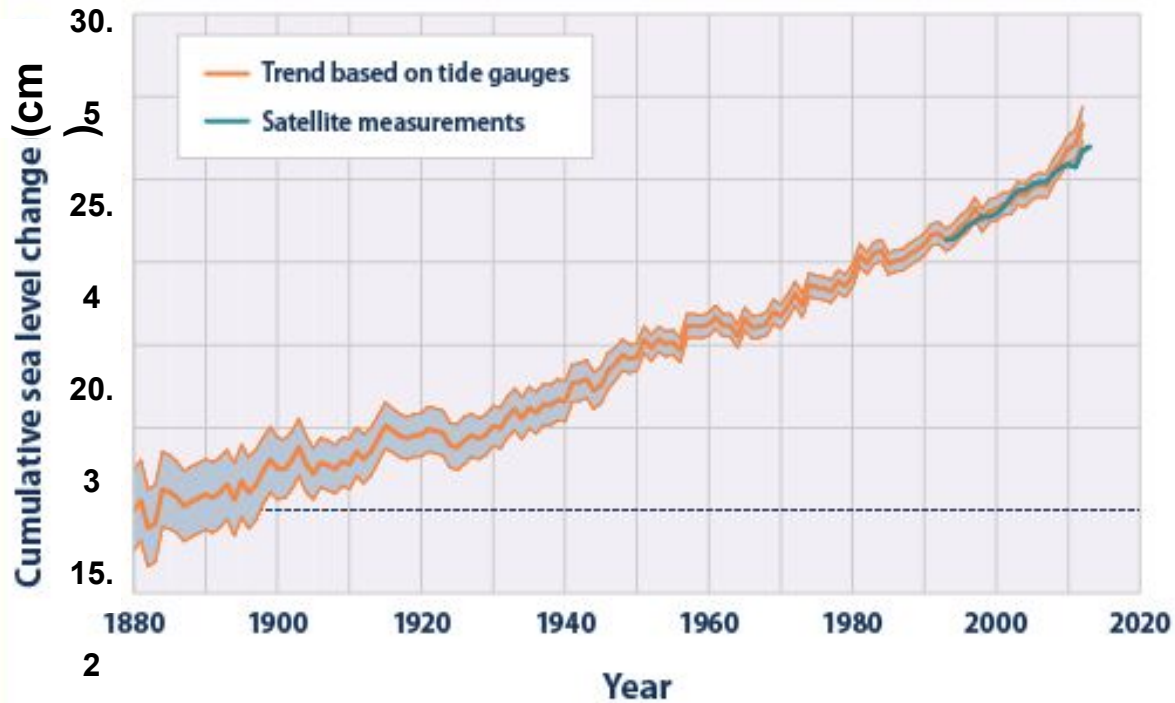
Absolute sea level change refers to the height of the ocean surface

IS THE CLIMATE REALLY CHANGING?

CAN WE DECIDE BY LOOKING AT THE DATA ON TEMPERATURE VARIATIONS? **PART 2**

... more evidence and data on Earth's temperature variations to assess if climate is changing

Evidence 3: We are losing arctic ice

Removing the lid from the top of the planet
Loss of reflective ice cooling 'albedo'
Replaced by dark ocean warming

100% 85% 7% 93%

Albedo: Fraction of solar energy reflected back into space

Arctic Sea Ice melt contributes to climate change by reducing the Earth's overall reflectivity
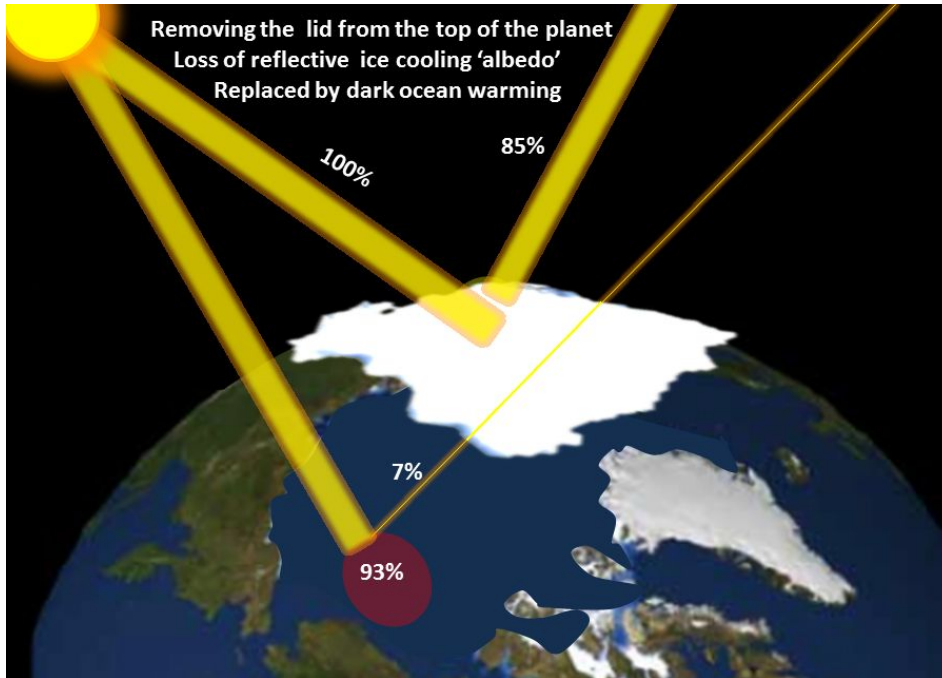
This figure shows Arctic sea ice extent from 1979 through 2013 using data from September of each year, which is when the minimum extent typically occurs.

Figure 1. September Monthly Average Arctic Sea Ice Extent, 1979–2013

Opposing View: Antarctica is gaining ice - Why?

Arctic and Antarctic Standardized Anomaly and Trend
Nov. 1978 - Oct. 2011

http://www.accuweather.com/en/weather-blogs/climatechange/is-antarctic-ice-melting-1/67365
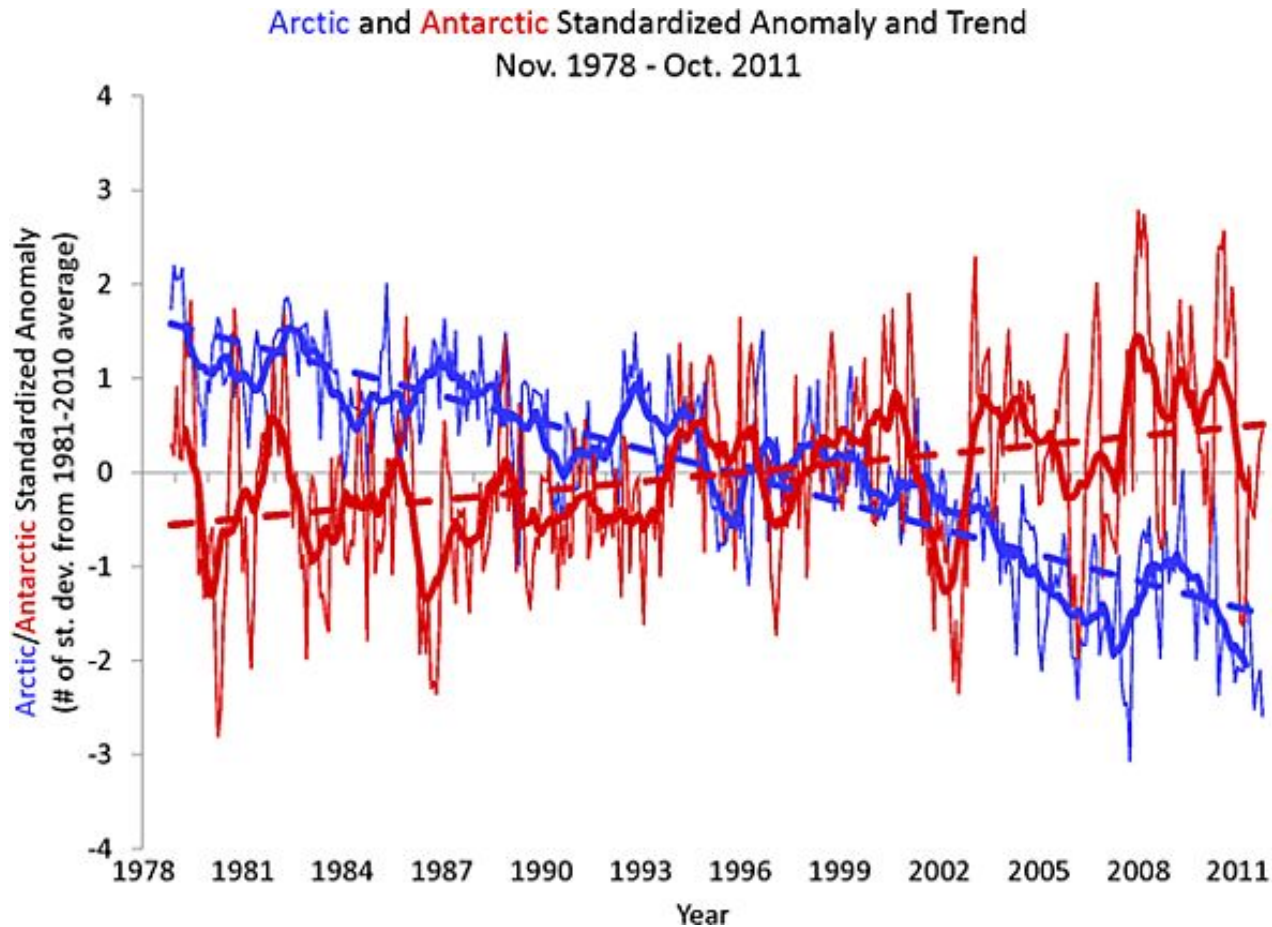
Satellites measure Antarctica is gaining sea ice, but it is losing land ice at an accelerating rate which has implications for sea level rise.

Land vs. Sea Ice

Sea Ice

Land Ice

Land vs. Sea Ice

http://www.yaleclimateconnections.org/2014/11/loss-of-land-ice-not-sea-ice-more-sea-level-rise/

Arctic

Antarctic

median extent

Russia

Greenland

Alaska

Canada

1000 km

Ice covering Antarctica

Ice 2,000 m thick (1.2 miles)

Continent with subglacial lakes, rivers

Lake Vostok

Lakes   Rivers   Below sea level
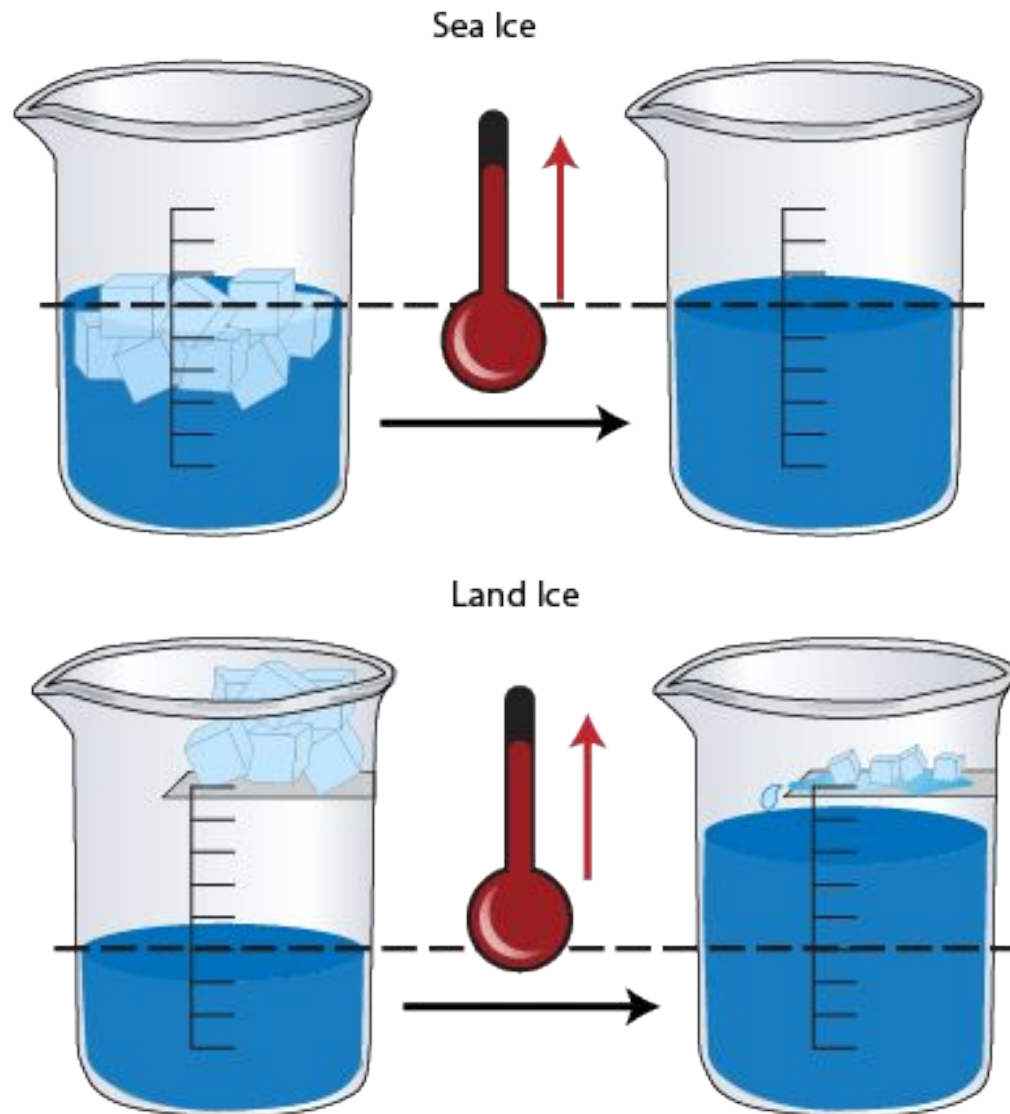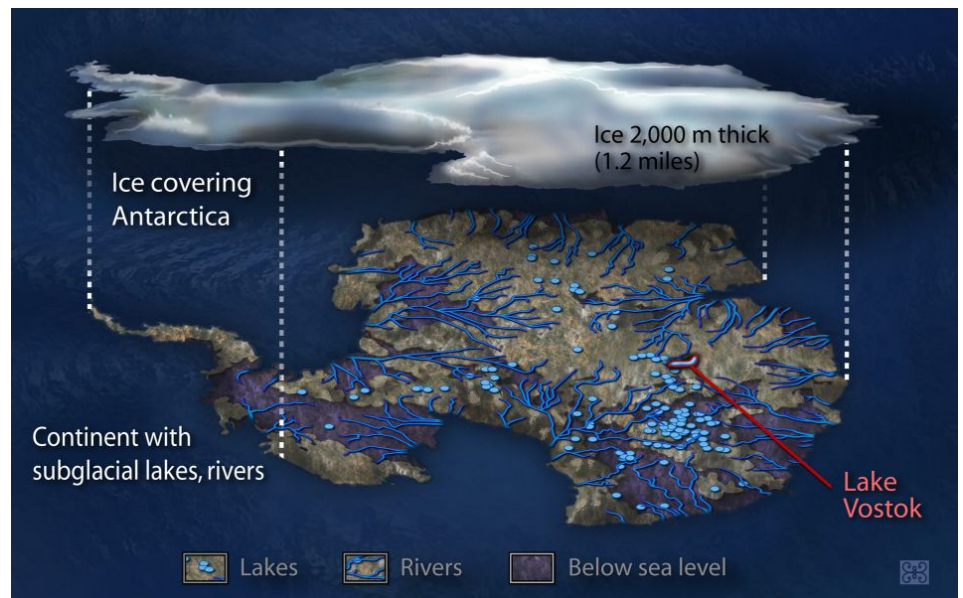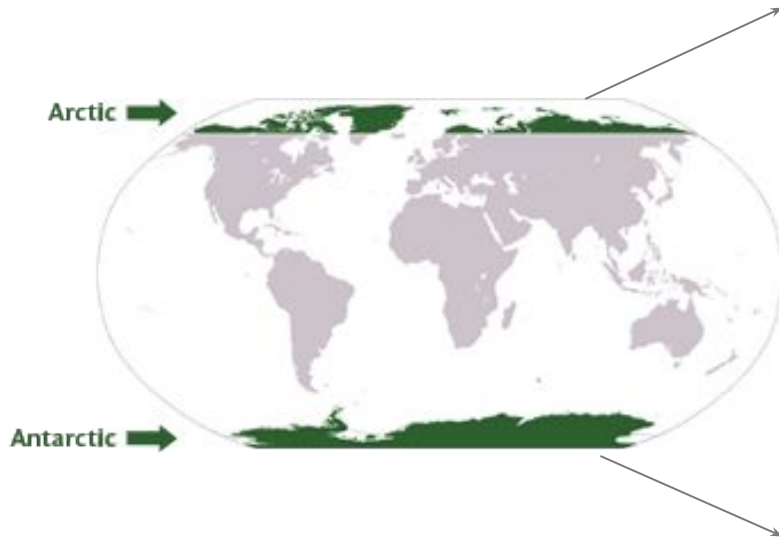
Evidence 4: Effect of carbon dioxide (CO$_2$)

Carbon Dioxide vs Temperature: past 400,000 years
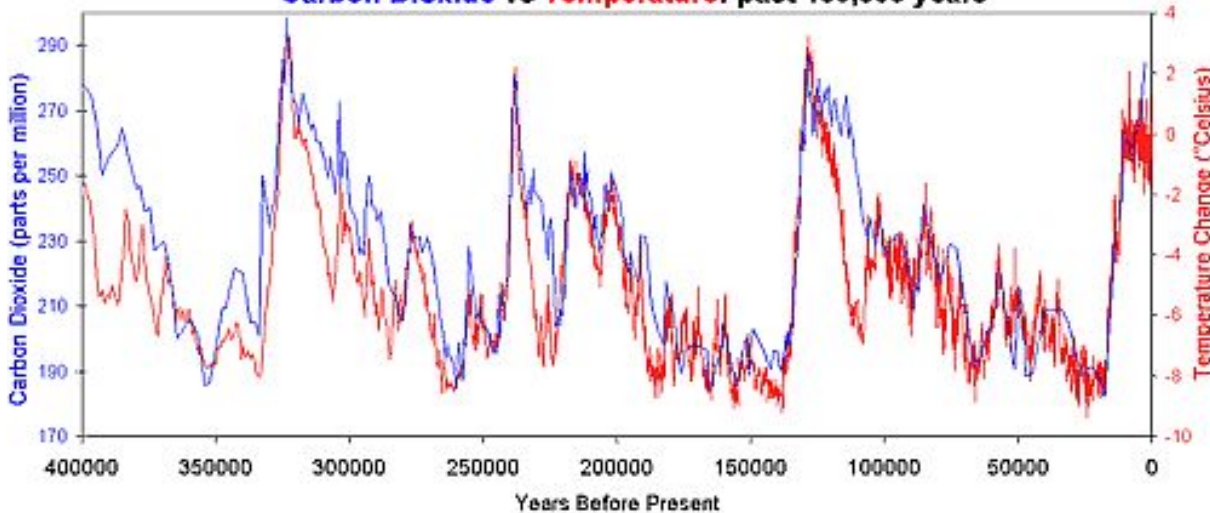
CO$_2$ levels and average temperatures on Earth have followed the same trend for 400000 years

Carbon Dioxide Variations

The Industrial Revolution Has Caused A Dramatic Rise in CO$_2$

Ice Age Cycles
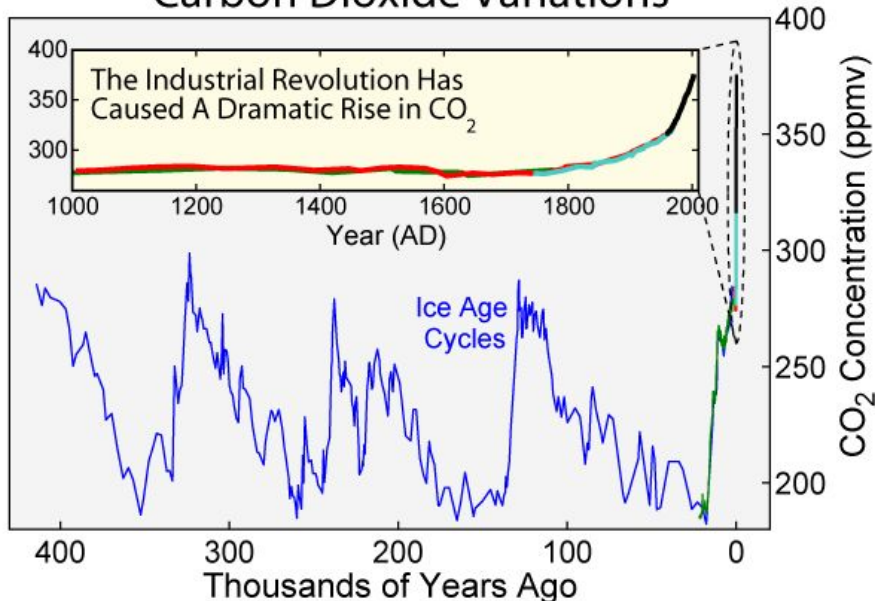
Humans have increased the amount of carbon dioxide (CO$_2$) in the atmosphere by about 40% over the past 150 years.

http://www.skepticalscience.com/empirical-evidence-for-co2-enhanced-greenhouse-effect-advanced.htm

Opposing View: Earth is in its cooling cycle

Carbon Dioxide Variations
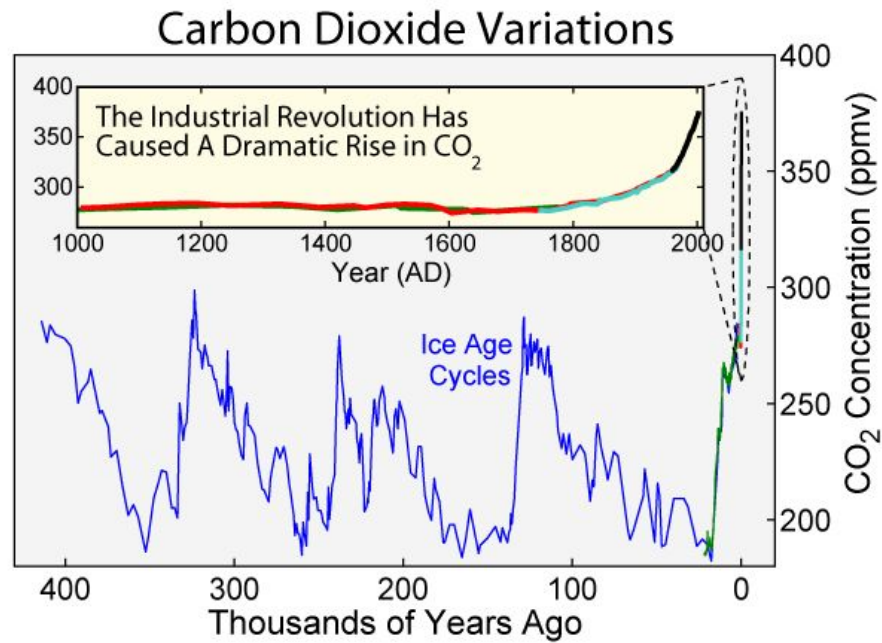
Models vs. Observations

Good scientific models have 'predictive power'. If the theory's any good, the predictions will come true. http://www.skepticalscience.com/empirical-evidence-for-co2-enhanced-greenhouse-effect-basic.htm

Here's an example: When the Table of Elements was proposed, many elements were yet to be discovered. Using the theory behind the Periodic Table, the Russian chemist Dmitri Mendeleev was able to predict the properties of germanium, gallium and scandium, despite the fact they hadn't been discovered.

Global mean temperature anomaly w.r.t. 1850–1900
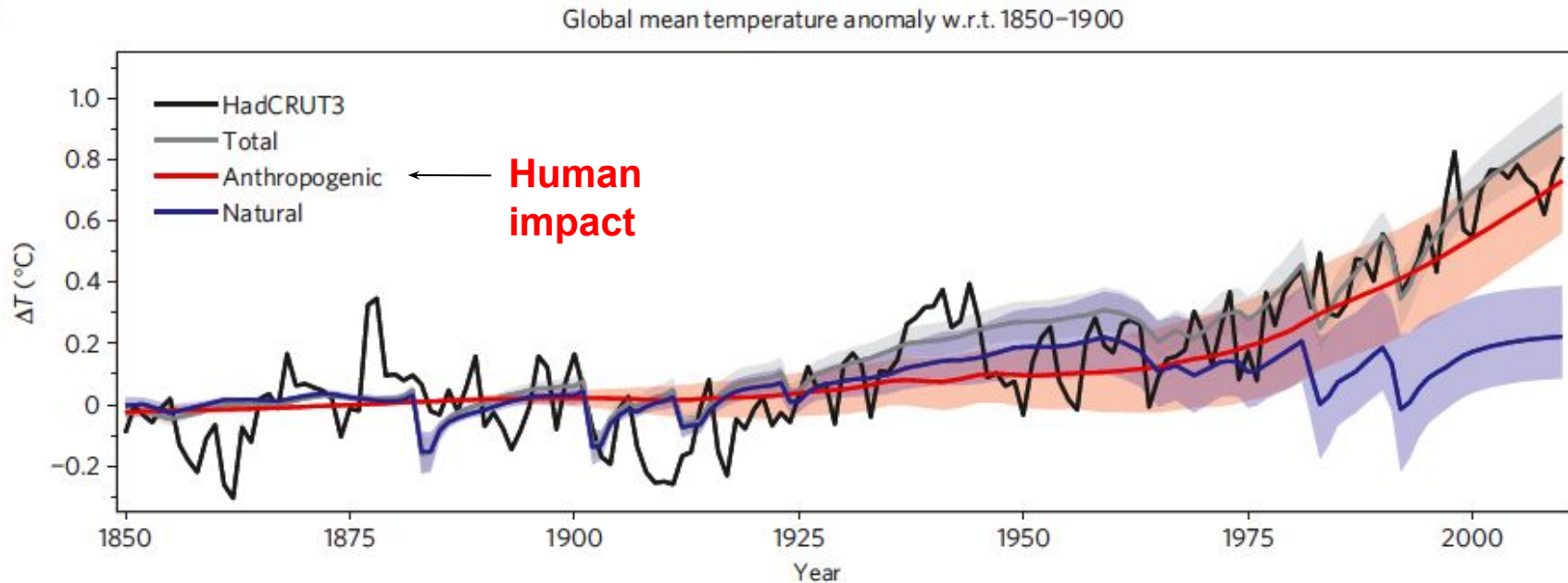
None of the successful models is able to predict recent warming without taking rising CO_2 levels into account!

CAUSATION VS. CORRELATION

DOES A DEFINITE CORRELATION BETWEEN TWO DATA SETS ALWAYS MEAN ONE CAUSES THE OTHER?

... given the effects of parameters on the outcome of an experiment, be able to determine the correlation or causation between two parameters and calculate the correlation coefficient to determine the correlation degree between these parameters.

THE DEADLY FACTS ABOUT
WATER!

FACT!
WATER CAN BE CHEMICALLY
SYNTHESIZED BY BURNING
ROCKET FUEL!!!

FACT!
WATER ONE OF THE PRIMARY INGRIDIENTS
IN HERBICIDES AND PESTICIDES!!!

FACT!
OVER CONSUMPTION CAN CAUSE
EXCESSIVE SWEATING, URINATION,
AND EVEN DEATH!!!

FACT!
WATER IS THE LEADING
CAUSE OF DROWNING!!!

FACT!
100%
OF ALL SERIAL KILLERS,
RAPIST AND DRUG DEALERS HAVE
ADMITTED TO DRINKING WATER!!!

FACT!
100 PERCENT OF ALL PEOPLE
EXPOSED TO WATER WILL *DIE!*

Please watch the following video that describes correlation and causation:

THE FAMILY CIRCUS

"I wish they didn't turn on that seatbelt sign so much! Every time they do, it gets bumpy."
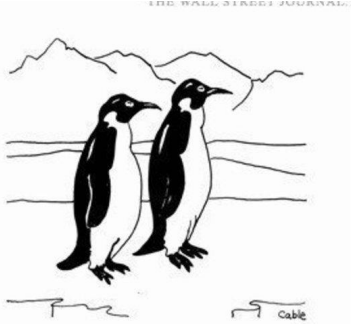
"Do you think all these film crews brought on global warming or did global warming bring on all these film crews?"


SOMEDAY, I WANT TO GET MARRIED BECAUSE STUDIES SHOW THAT MARRIED PEOPLE ARE HAPPIER.

A SMARTER INTERPRETATION IS THAT NO ONE WANTS TO MARRY AN UNHAPPY PERSON.

YOU'RE ANNOY-ING.

WITH ANY LUCK, YOUR SOUL MATE WON'T BE PERCEPTIVE.

CORRELATION

100% OF PEOPLE WHO BREATHE, DIE

CAUSATION

100% OF PEOPLE WHO DON'T BREATHE, DIE
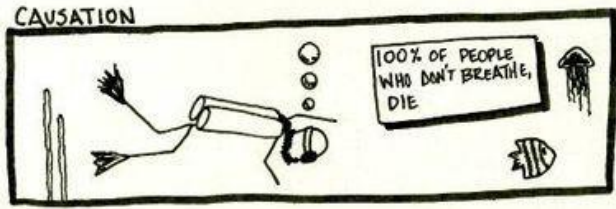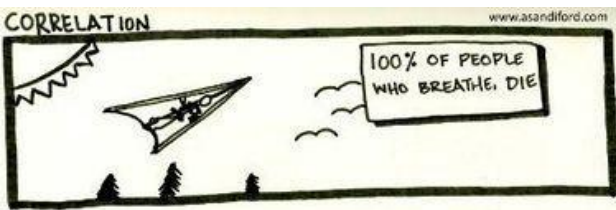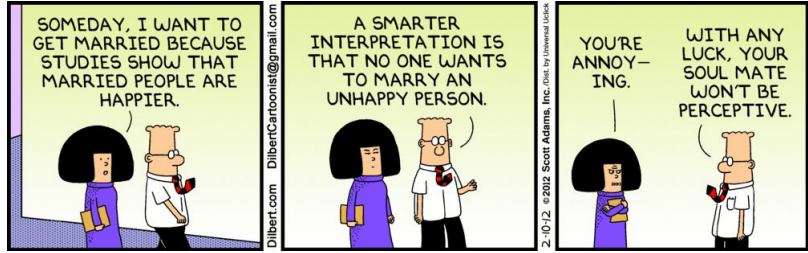
You can read more about correlation/causation here.

Is the correlation between data significant?
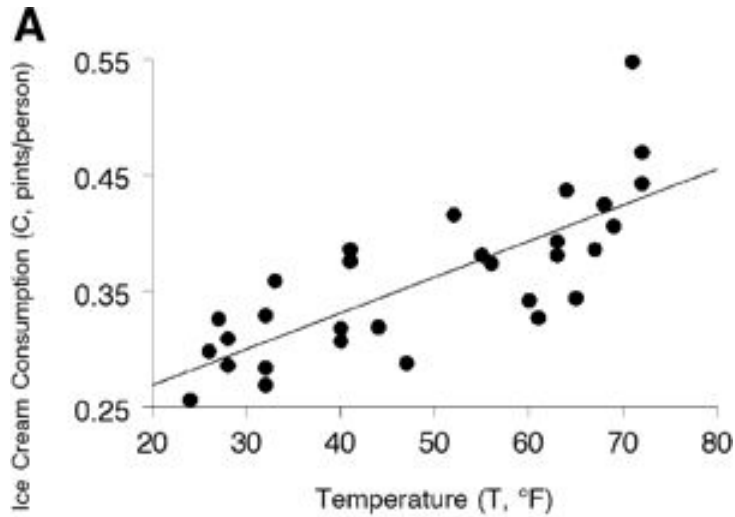
Fit implies <u>significant correlation</u>

Ice cream consumption is correlated with temperature.
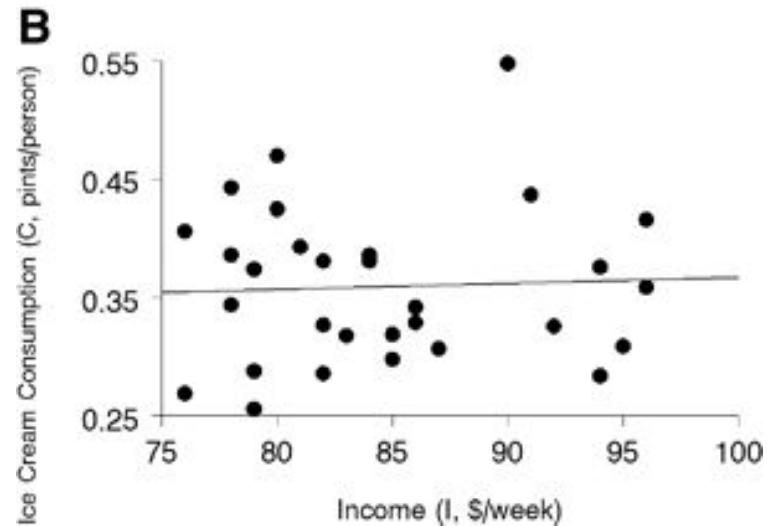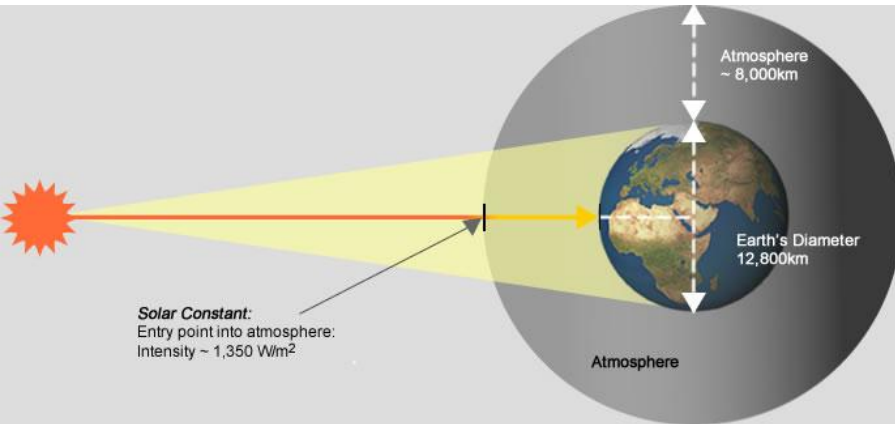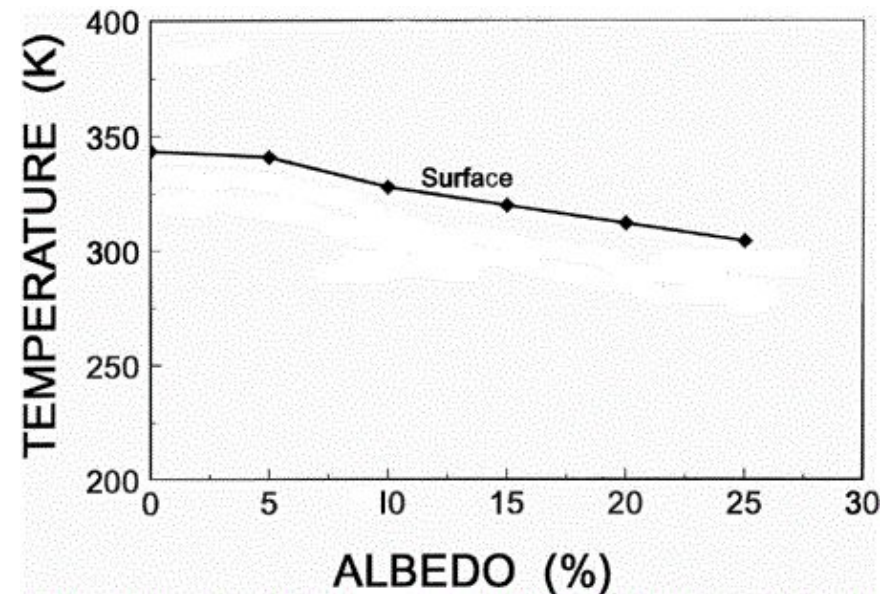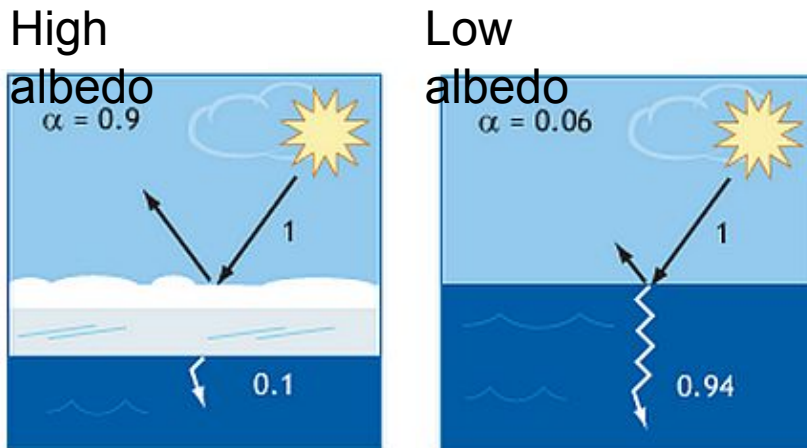
Fit implies <u>insignificant correlation</u>

Ice cream consumption is NOT correlated with income.

Correlations

Positive correlation:
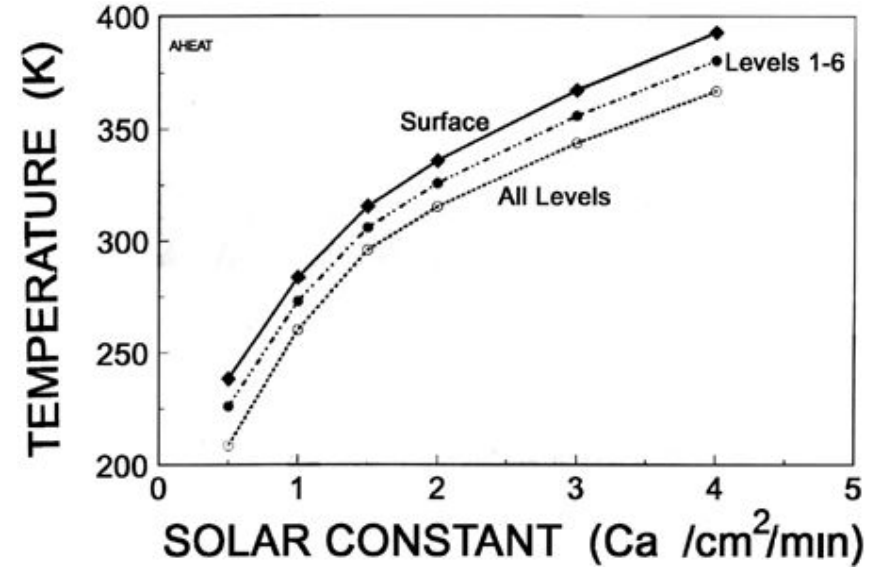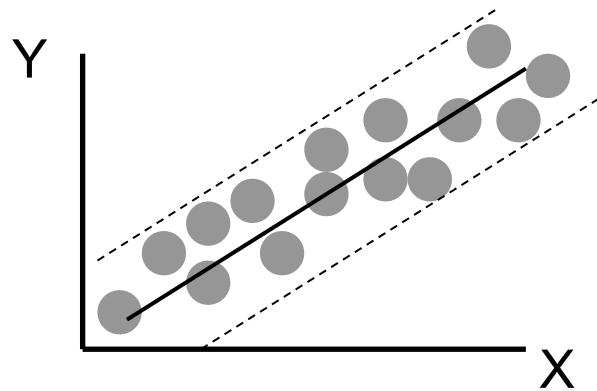

Negative correlation:

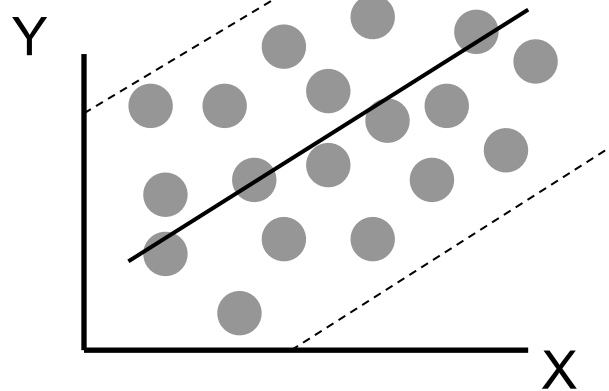High albedo

Low albedo

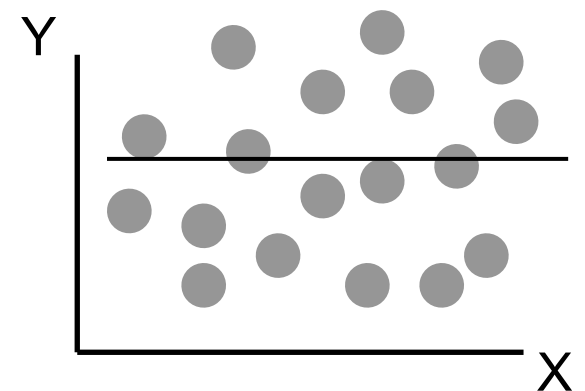# Degree of relationship

Strong relationships   Weak relationships   No relationship

How can we quantify correlation?