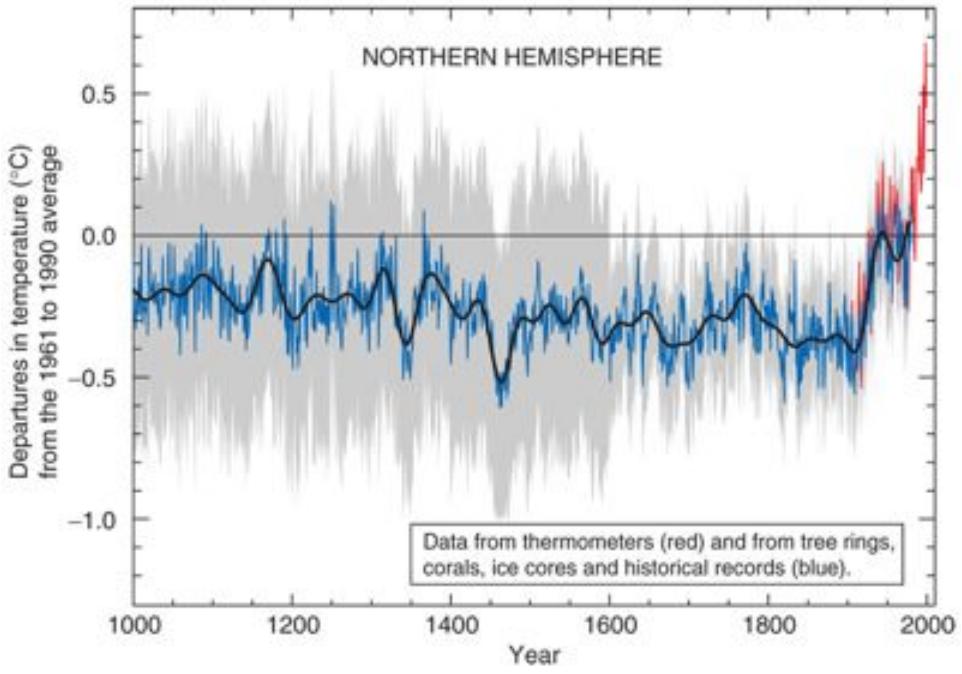
**FACT:**
**The Earth is getting warmer.**

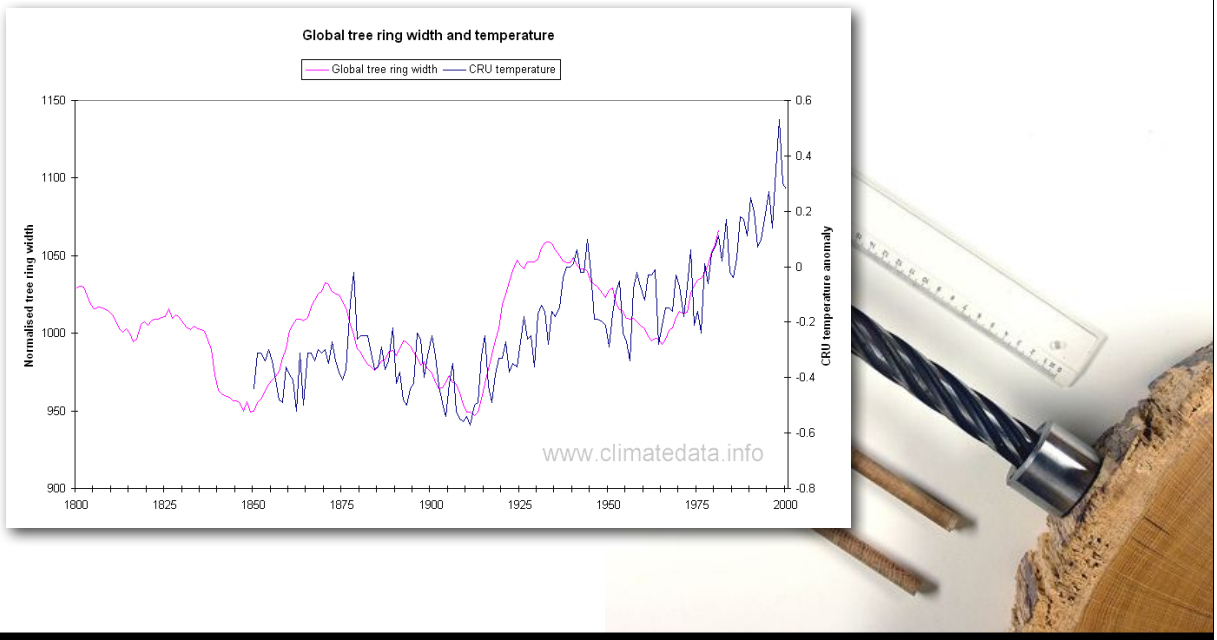
- Weather is the set of all extant phenomena in a given atmosphere at a given time.

- Climate is the average and variations of weather in a region over long periods of time.




Instrumental records: 1st example (1659) Quasi-global (~1850s)
International Meterorological Organization (1873)
World Meteorological Organization (1950)

Pre: 1800s rely on PROXY DATA




Tree Rings as example of Proxy Data

http://www.climatedata.info/Proxy/Proxy/treerings_introduction.html

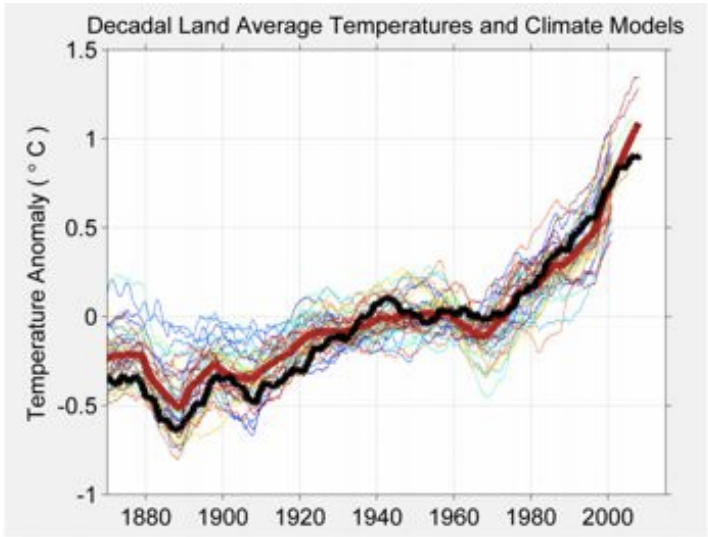
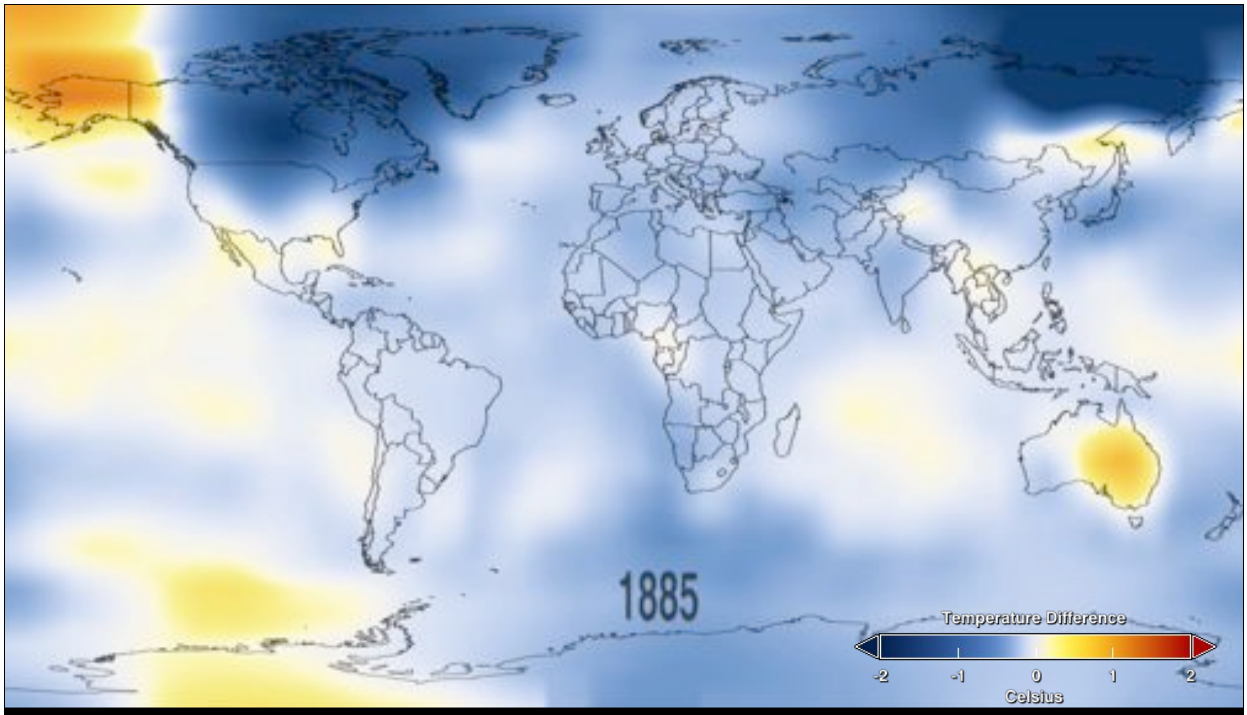



Figure 9. The above figure shows a comparison between Berkeley Earth Surface Air Temperature and a collection of GCM results from AR4. The GCM results are created by sampling the entire GCM field at the same locations and times as the Berkeley Earth average. The GCM average is shown in red and the Berkeley average is shown in black

Berkeley Earth Surface Temperature, 2012 still in progress (lead scientist: Richard Muller)

Fig 9. http://berkeleyearth.org/graphics/model-performance-against-berkeley-earth-data-set




NASA Goddard Institute for Space Studies analyzis of global temperature data.

http://svs.gsfc.nasa.gov/vis/a000000/a003600/a003674/index.html

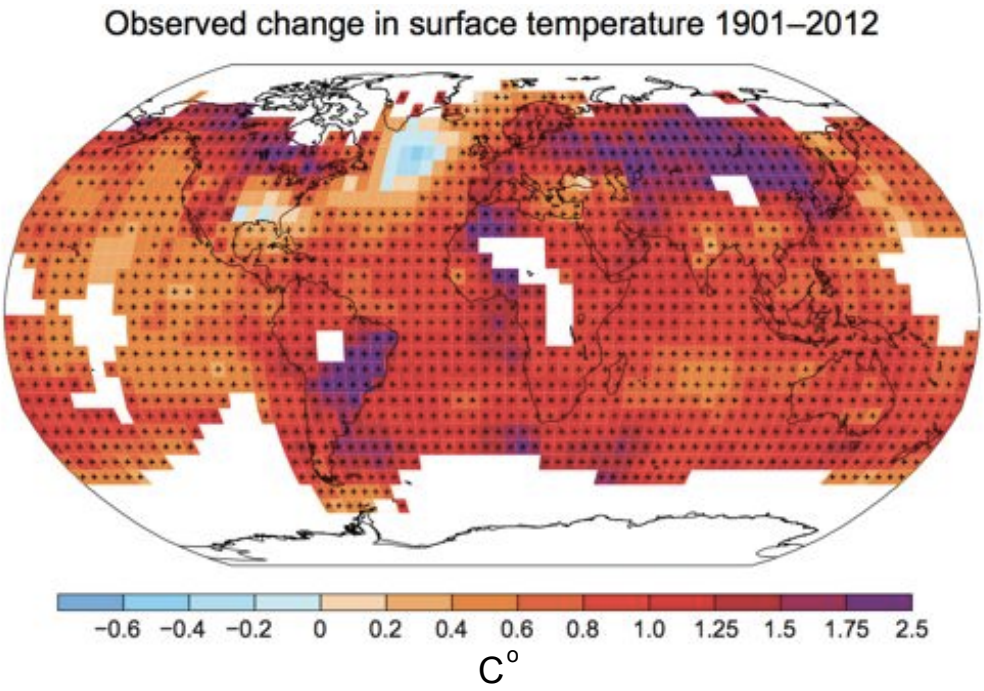
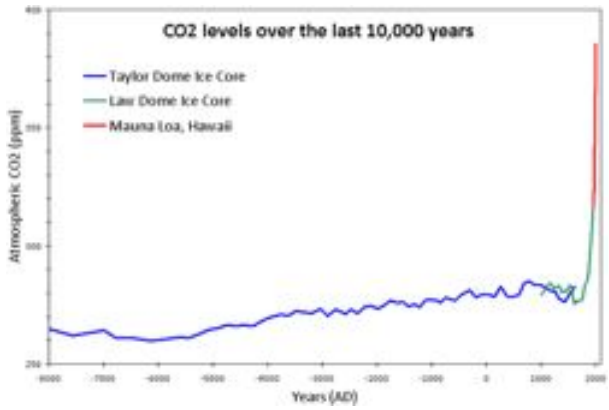
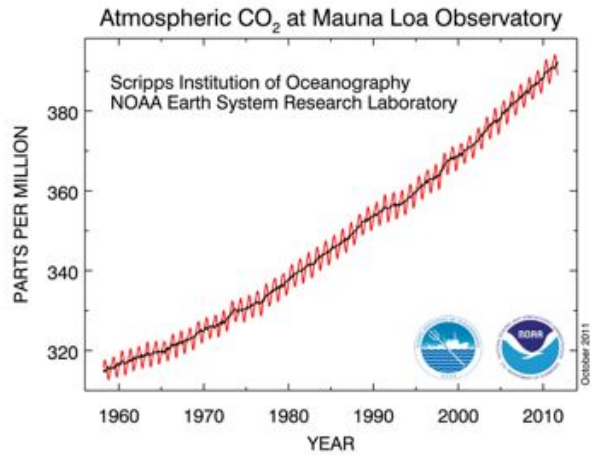



Figure SPM.1 (AR5)

**FACT:**
**The Earth is getting warmer.**

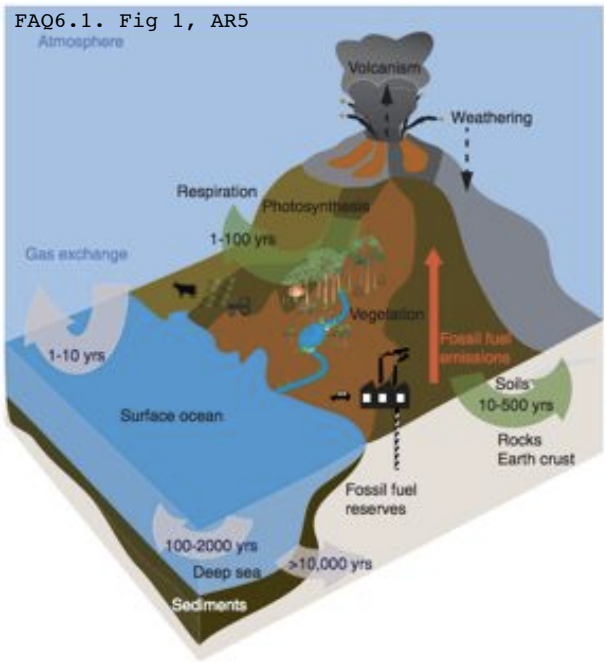
**FACT:**
**There is more CO2 in the Earth's atmosphere. Much of this is due to human activity.**

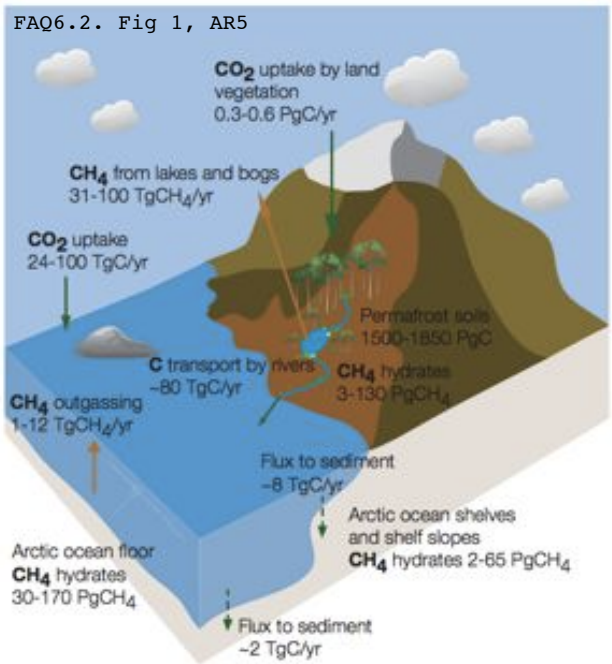



CO2 historical trends

Ice Cores as example of Proxy Data
http://www.climatedata.info/Proxy/Proxy/icecores.html



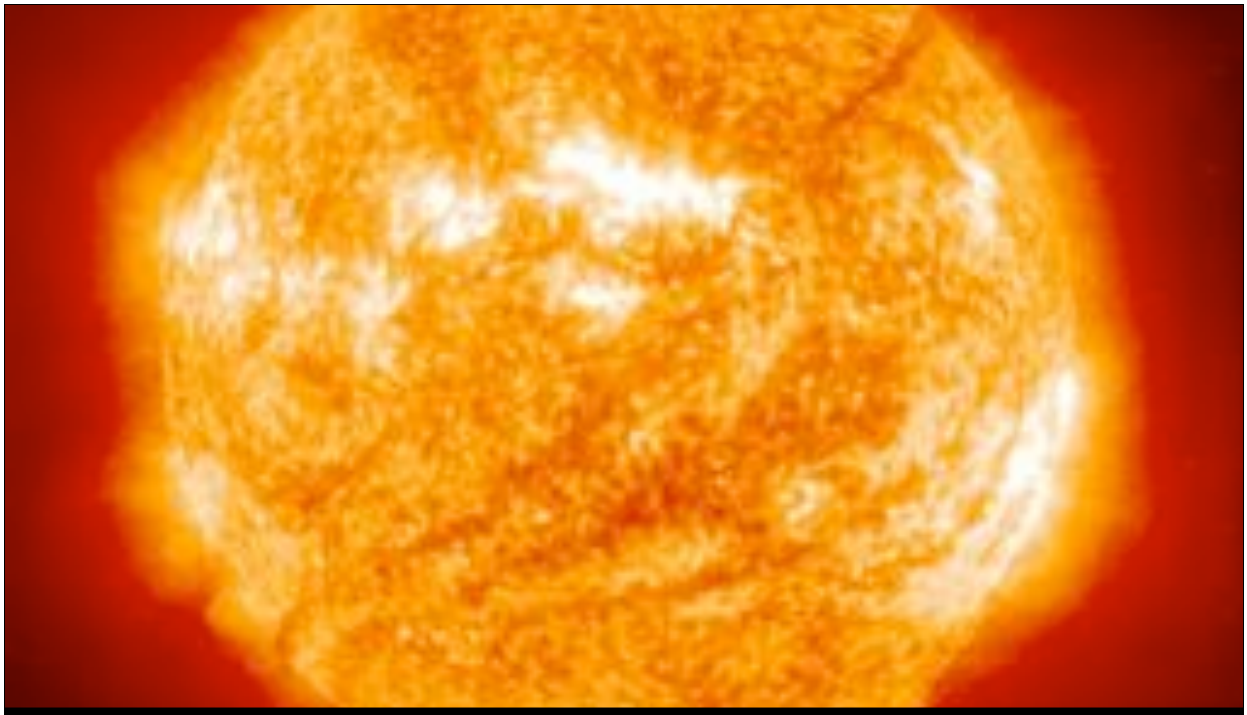

Carbon Cycle logistics.

Can track C from fossil fuel burning to see how much (or how quick) the cycle operates.

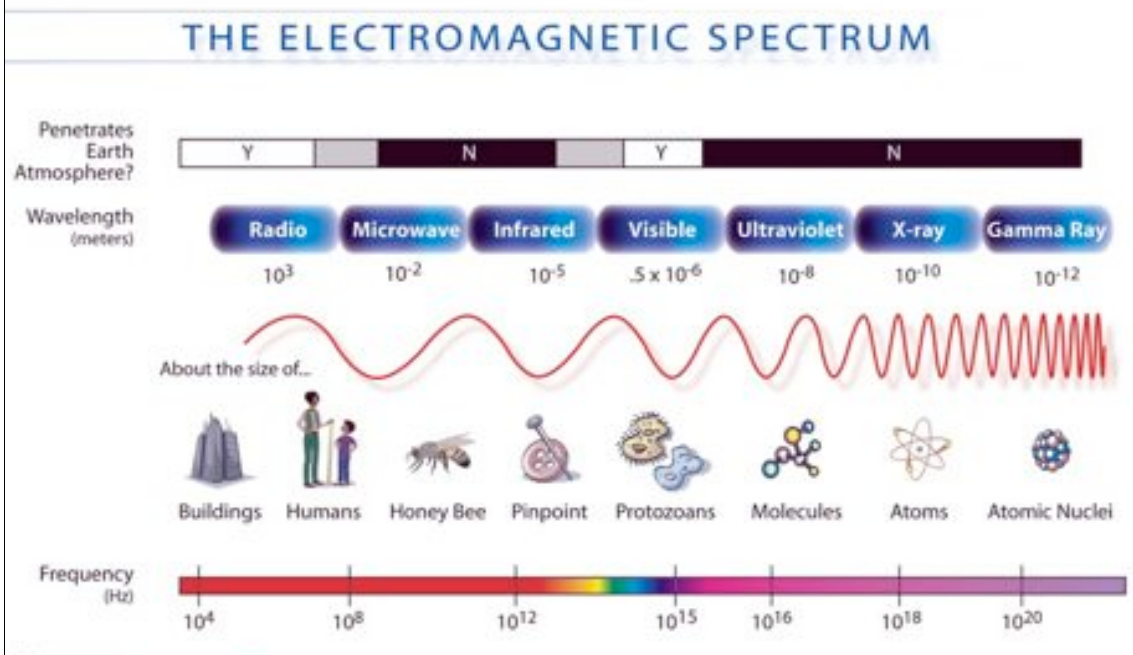
**FACT:**
**The Earth is getting warmer.**

**FACT:**
**There is more CO2 in the Earth's atmosphere. Much of this is due to human activity.**

**FACT:**
**CO2 is a greenhouse gas.**



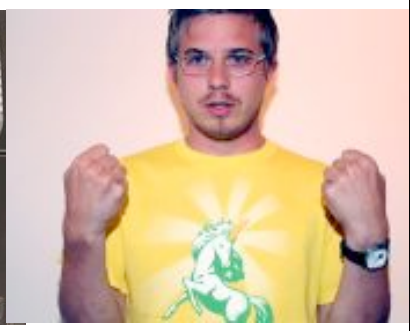
It all starts with the Sun




Different types of energy. Electromagnetic radiation basics.

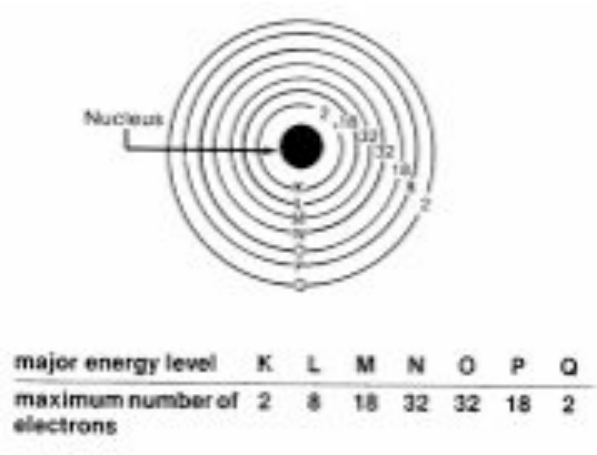
low energy
(thermal radiation)

(visible light)



high energy
(x-ray, ultraviolet)

Different types of energy. Electromagnetic radiation basics using t-shirts from threadless.com

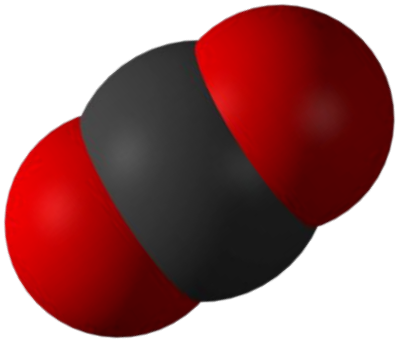


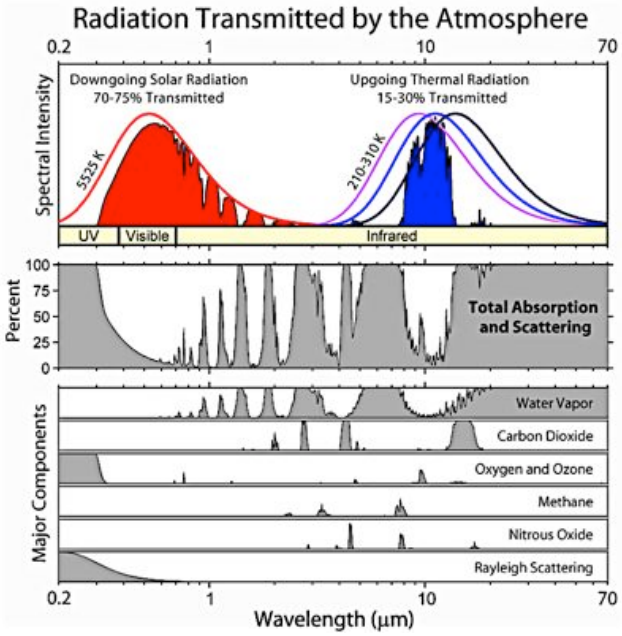

A little quantum stuff thrown in.

Key thing is that energy can be absorbed and re-emitted


Different types of energy. Electromagnetic radiation basics using t-shirts from threadless.com

Key thing is that energy can be absorbed and re-emitted






Carbon Dioxide is a Greenhouse Gas. This simply means that it can absorb energy at thermal radiation frequency.

**FACT:**
**The Earth is getting warmer.**

**FACT:**
**There is more CO2 in the Earth's atmosphere. Much of this is due to human activity.**

**FACT:**
**CO2 is a greenhouse gas.**

## HOW TO GET YOUR OWN SCIENTIFIC EPONYM

"Human nature is complex, fickle and strange. But there is one constant in people's mercurial ways: people like to have things named after themselves."

-Samuel Arbesman

| | |
|---|---|
| Law | Symbol |
| Dictum | Shift |
| Razor | Index |
| Principle | Formula |
| Rule | Measure |
| Scale | Postulate |
| Effect | [any Greek letter] |
| Score | Distance |
| Number | Curve |
| Test | Constant |
| Criterion | Phenomenon |
| Paradox | |

$$\text{Ng} = n^{-1}(f + 1)$$

*Ng's Score*

Where n = the number of cup holders a vehicle has.

Where f = the frequency per year where all cup holders are in use during vehicle use.

Examples:

My Honda Civic: Has two cup holders (n=2), and I would predict that both are in use during traveling at least 20 times each year (f=20). This means the Ng's Score for this particular '97 Civic calculates to a score of 11.5

A Ford Expedition: Apparently has 10 cup holders (n=10). Which I'm going to guess the vast majority of Ford Expedition owners have never had the opportunity to use all at once during the course of even owning the vehicle (f=0). Therefore, an Ng's Score here would calculate to 0.1

$$(1) \quad \frac{W_k\, S_{blaster} \cdot bmi_{opt} \cdot h_{opt}}{5.4^{(1 + b_p^o + b_w^o)}}$$

$$(2) \quad bmi_{opt} = \left[1 - \left(|(25 - mh^{-2})| \cdot 0.04\right)\right]$$

$$(3) \quad h_{opt} = \left[1 - \left(|(h - 1.8)| \cdot 1.112\right)\right]$$

$$(4) \quad \frac{W_k\, S_{blaster} \cdot \left[1 - \left(|(25 - mh^{-2})| \cdot 0.04\right)\right] \cdot \left[1 - \left(|(h - 1.8)| \cdot 1.112\right)\right]}{5.4^{(1 + b_p^o + b_w^o)}}$$

*Abram's Stormtrooper Axiom*

**FACTS:**

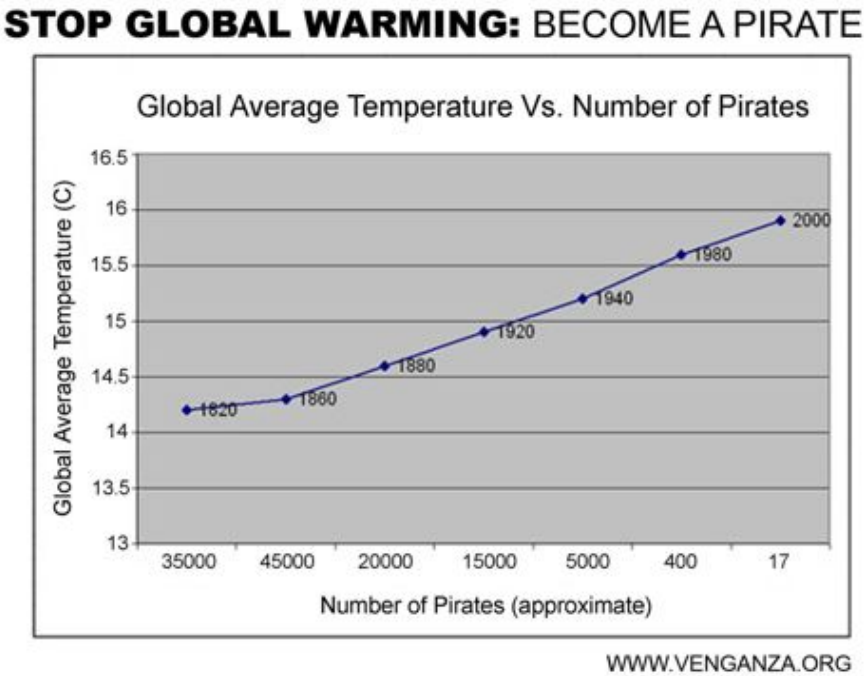
**The Earth is getting warmer.**

**There is more CO2 in the Earth's atmosphere. Much of this is due to human activity.**

**CO2 is a greenhouse gas.**

**HYPOTHESIS:**

**The increase in temperature is largely due to the anthropogenic production of CO2.**




HYPOTHESIS: The increase in temperature is largely due to the anthropogenic production of $CO_2$.

# Ask your phone (or google):

*What is the answer to life, the universe, and everything?*

HYPOTHESIS: The increase in temperature is largely due to the anthropogenic production of $CO_2$.

# THERMODYNAMICS

*A theory is the more impressive the greater the simplicity of its premises, the more different kinds of things it relates, and the more extended its area of applicability. Therefore the deep impression that classical thermodynamics made upon me. It is the only physical theory of universal content which I am convinced will never be overthrown, within the framework of applicability of its basic* concepts.

-A. Einstein.

*Lisa, get in here. In this house we obey the laws of thermodynamics!*

-Homer Simpson.

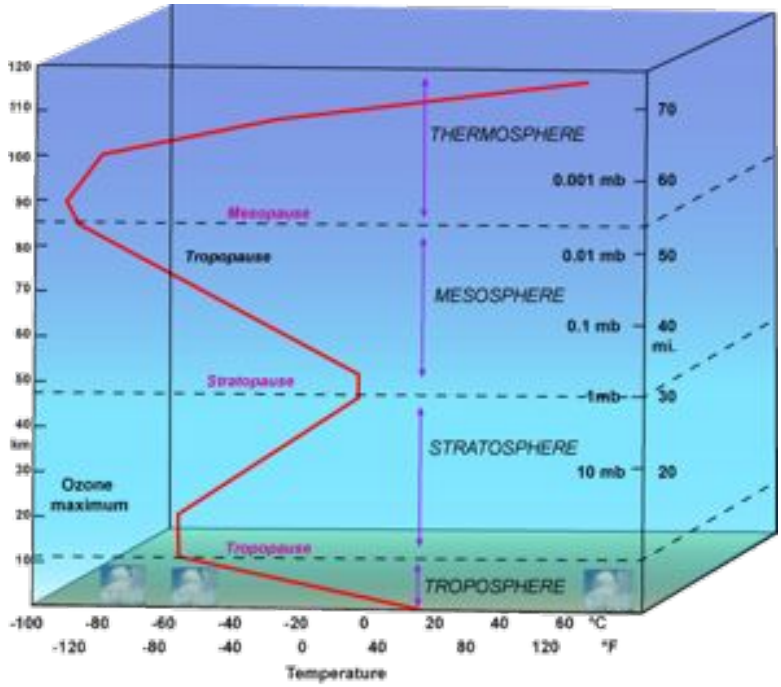
The laws of thermodynamics are to science what Shakespeare is to literature.

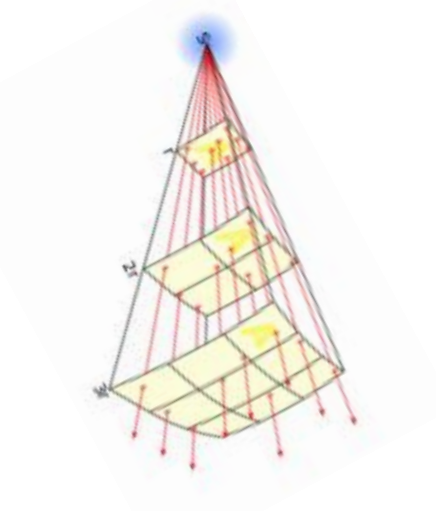
# FIRST LAW OF THERMODYNAMICS

FTW!

Also colloquially referred to as the "conservation of energy" rule.

It's about *book keeping*

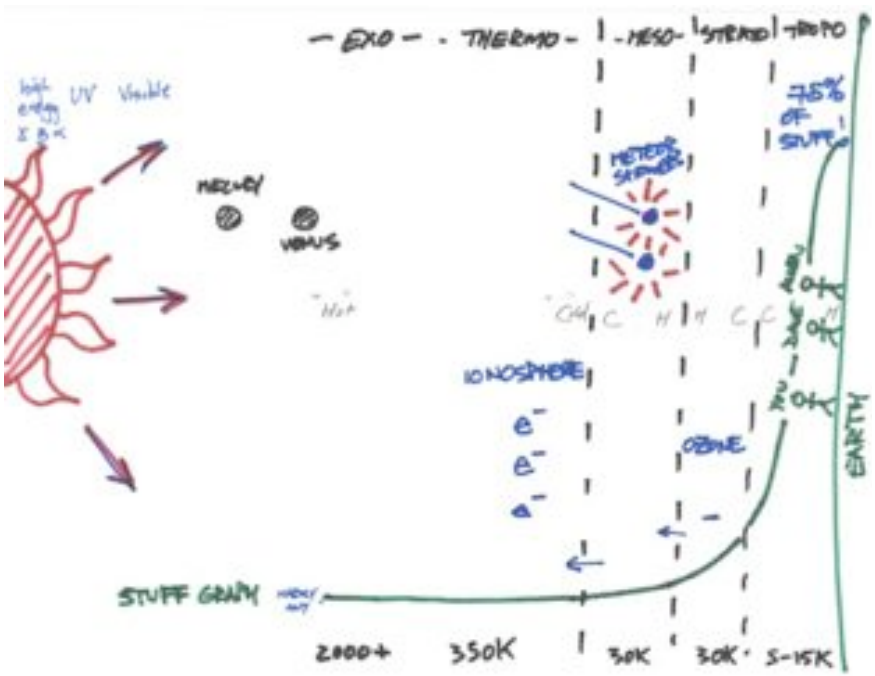


Thermodynamically, we also need to define our SYSTEM.

What is the troposphere? In a nutshell, the troposphere is the lowest portion of Earth's atmosphere comprising about 75% of the total mass of the atmosphere. It's here that almost all of its water vapor and aerosols are present.

TROPOPAUSE: This represents the place, where the temperature gradients do flip flop from the surface of the Earth (the top part of the troposphere)




What is the troposphere? In a nutshell, the troposphere is the lowest portion of Earth's atmosphere comprising about 75% of the total mass of the atmosphere. It's here that almost all of its water vapor and aerosols are present.

TROPOPAUSE: This represents the place, where the temperature gradients do flip flop from the surface of the Earth (the top part of the troposphere)

TIME FOR CHARADES!

I NEED TWO TEAMS OF 5 TO GO HEAD TO HEAD.

VOLUNTEERS?


Velocity = $v$ = m/$s$

Acceleration = $a = v/s$ = m/$s^2$

Force = $F = ma = kg \cdot$ m/$s^2$ **(Newton)**

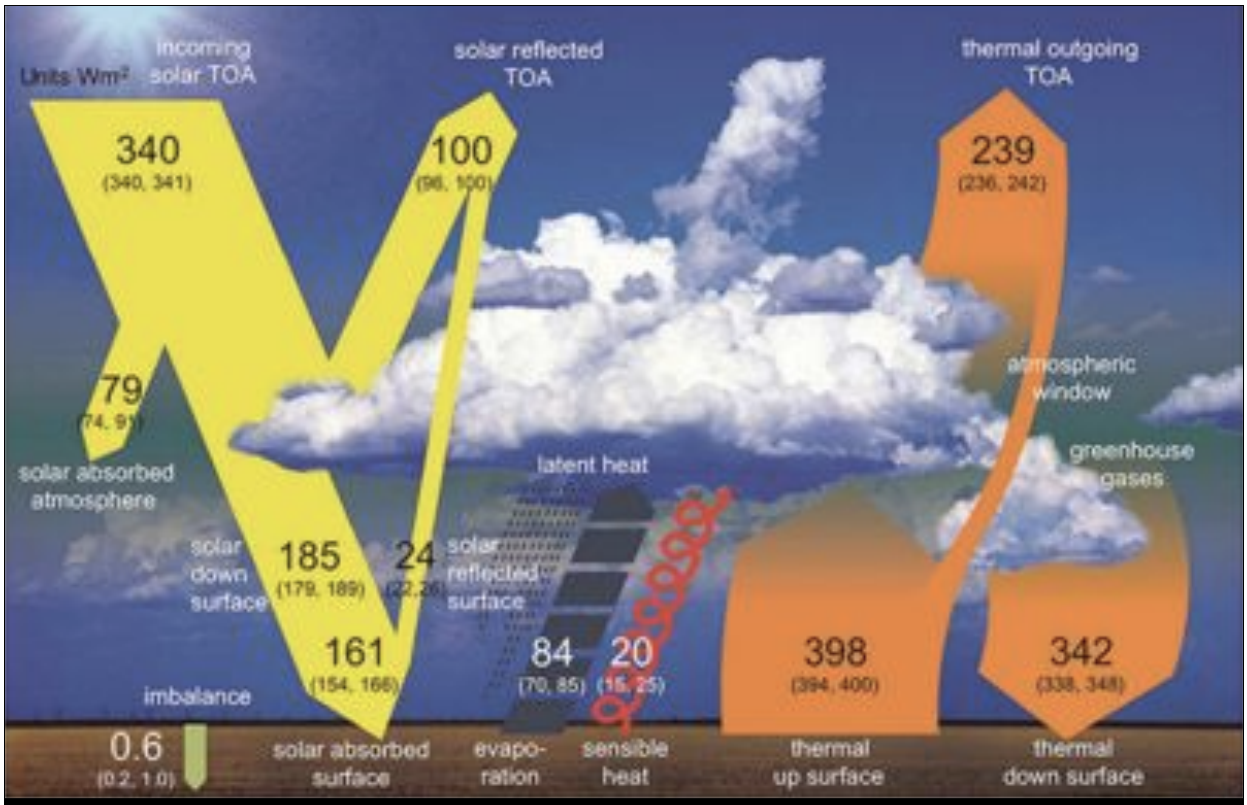
Work = $W = F \cdot d$ = kg·m·m/$s^2$ = kg·m$^2$/s$^2$ **(Joule - unit of Energy)**

Power = $P = W/s = kg \cdot m^2/s^2 \cdot s = kg \cdot m^2/s^3$ **(Watt)**

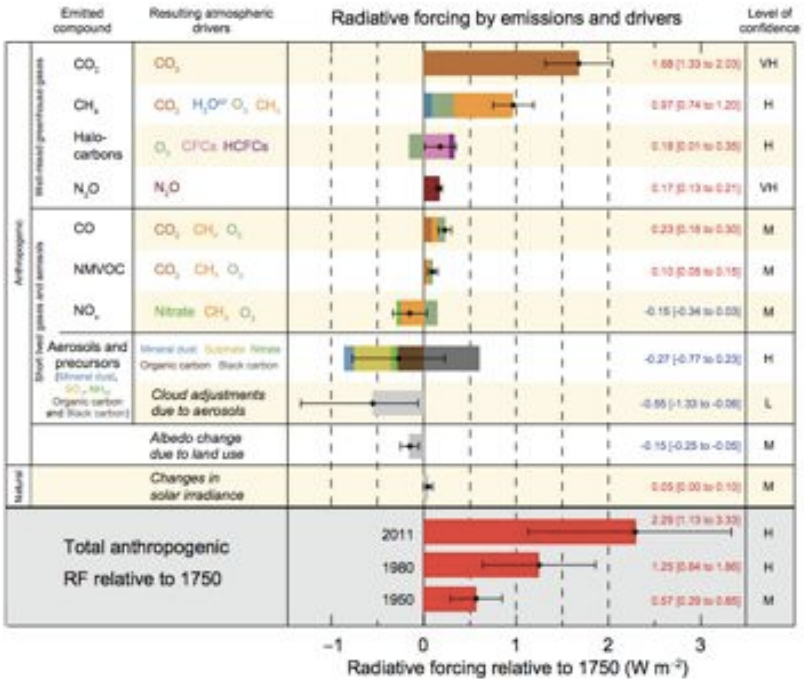
Some units of note:

**m = distance in metres**
**$s$ = time in seconds**
**kg = mass in kilograms**

Being able to book-keep energy infers being able to track and measure it too.




The flowchart…
(Fig 2.11 AR5, Chapter 2)




The radiative forcing of the surface-troposphere* system due to the perturbation in or the introduction of an agent (say, a change in greenhouse gas concentrations) is the change in net irradiance (solar plus long-wave; in $Wm^{-2}$) at the tropopause AFTER allowing for stratospheric temperatures to readjust to radiative equilibrium, but with surface and tropospheric temperatures and state held fixed at the unperturbed values.

nature geoscience

LETTERS

PUBLISHED ONLINE: 4 DECEMBER 2011 | DOI: 10.1038/NGEO1327

## Anthropogenic and natural warming inferred from changes in Earth's energy balance

Markus Huber and Reto Knutti*

**The Earth's energy balance is key to understanding climate and climate variations that are caused by natural and anthropogenic changes in the atmospheric composition. Despite abundant observational evidence for changes in the energy balance over the past decades[1–3], the formal detection of climate warming and its attribution to human influence has so far relied mostly on the difference between spatio-temporal warming patterns of natural and anthropogenic origin[4–6]. Here we present an alternative attribution method that relies on the principle of conservation of energy, without assumptions about spatial warming patterns. Based on a massive ensemble of simulations with an intermediate-complexity climate model we demonstrate that known changes in the global energy balance and in radiative forcing tightly constrain the magnitude of anthropogenic warming. We find that since the mid-twentieth century, greenhouse gases contributed 0.85 °C of warming (5–95% uncertainty: 0.6–1.1 °C), about half of which was offset by the cooling effects of aerosols, with a total observed change in global temperature of about 0.56 °C. The observed trends are extremely unlikely (<5%) to be caused by internal variability, even if current models were found to strongly underestimate it. Our method is complementary to optimal fingerprinting attribution and produces fully consistent results, thus suggesting an even higher confidence that human-induced causes dominate the observed warming.**

The optimal fingerprint detection and attribution framework provides a rigorous, statistical method to quantify the contributions

Owing to its large heat capacity, the ocean accounts for more than 85% of the energy content change $Q$ in the climate system[9]. A robust ocean warming trend is evident despite sparse data and uncertainties and biases in ocean observations[3,10]. The feedback parameter $\lambda$ is inversely related to climate sensitivity[11].

We use a massive ensemble of the Bern2.5D climate model of intermediate complexity[12,13], driven by bottom-up estimates of historic radiative forcing $F$, and constrained by a set of observations of the surface warming $T$ since 1850 and heat uptake $Q$ since the 1950s (see Methods). The Special Report on Emissions Scenarios (SRES) A2 (ref. 14) emission scenario is used as one illustration of a non-intervention scenario. The radiative forcing time series[15,16] are shown in Fig. 1 along with the probabilistic model output based on the constrained model parameters[17]. The energy balance model has no natural interannual variability but is able to reproduce the observed global trend of past temperature and ocean heat uptake. Uncertainties in surface warming, ocean heat uptake and in all individual radiative forcing components are considered (see Methods).

Figure 2a shows the contribution of different forcing species to the accumulated forcing since the year 1850. The partitioning of the net cumulative forcing into ocean heat uptake and outgoing longwave radiation is illustrated in Fig. 2b. Between 1850 and 2010, the climate system accumulated a total net forcing energy of $140 \times 10^{22}$ J with a 5–95% uncertainty range of $95–197 \times 10^{22}$ J, corresponding to an average net radiative forcing of roughly 0.54 (0.36–0.76) $W m^{-2}$. The additional energy input is balanced in

AR5 states "at least half of the Earth's temperature rise is 'very likely' attributed to human activity"

http://www.nature.com/news/at-least-three-quarters-of-climate-change-is-man-made-1.9538

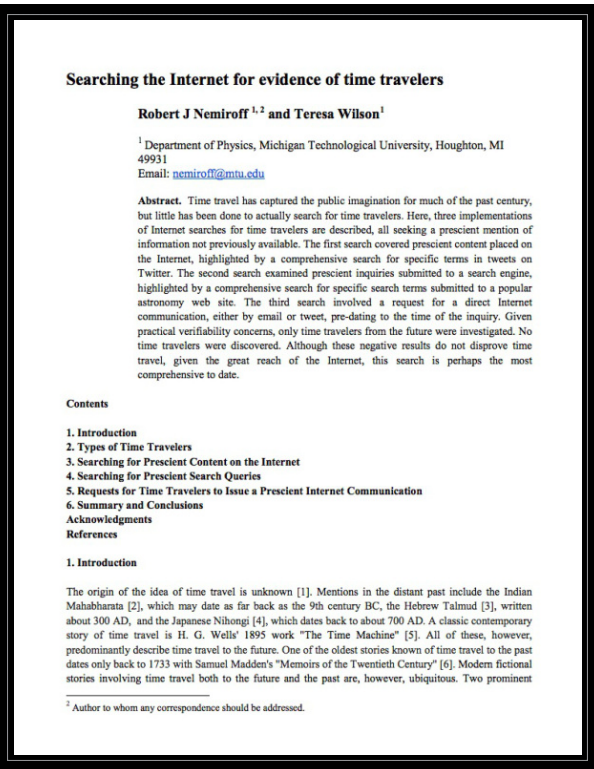
**FACTS:**
**The Earth is getting warmer.**

**There is more $CO_2$ in the Earth's atmosphere. Much of this is due to human activity.**

**$CO_2$ is a greenhouse gas.**

**HYPOTHESES:**
**The increase in temperature is largely due to the anthropogenic production of $CO_2$.**

**These greenhouse gas amounts and increases in temperature will lead to predictable (and bad) effects to the planet and its inhabitants.**



**Searching the Internet for evidence of time travelers**

**Robert J Nemiroff [1, 2] and Teresa Wilson [1]**

[1] Department of Physics, Michigan Technological University, Houghton, MI 49931
Email: nemiroff@mtu.edu

**Abstract.** Time travel has captured the public imagination for much of the past century, but little has been done to actually search for time travelers. Here, three implementations of Internet searches for time travelers are described, all seeking a prescient mention of information not previously available. The first search covered prescient content placed on the Internet, highlighted by a comprehensive search for specific terms in tweets on Twitter. The second search examined prescient inquiries submitted to a search engine, highlighted by a comprehensive search for specific search terms submitted to a popular astronomy web site. The third search involved a request for a direct Internet communication, either by email or tweet, pre-dating to the time of the inquiry. Given practical verifiability concerns, only time travelers from the future were investigated. No time travelers were discovered. Although these negative results do not disprove time travel, given the great reach of the Internet, this search is perhaps the most comprehensive to date.

**Contents**



**1. Introduction**

The origin of the idea of time travel is unknown [1]. Mentions in the distant past include the Indian Mahabharata [2], which may date as far back as the 9th century BC, the Hebrew Talmud [3], written about 300 AD, and the Japanese Nihongi [4], which dates back to about 700 AD. A classic contemporary story of time travel is H. G. Wells' 1895 work "The Time Machine" [5]. All of these, however, predominantly describe time travel to the future. One of the oldest stories known of time travel to the past dates only back to 1733 with Samuel Madden's "Memoirs of the Twentieth Century" [6]. Modern fictional stories involving time travel both to the future and the past are, however, ubiquitous. Two prominent

[2] Author to whom any correspondence should be addressed.

HYPOTHESIS: These greenhouse gas amounts and increases in temperature will lead to predictable (and bad) effects to the planet and its inhabitants.

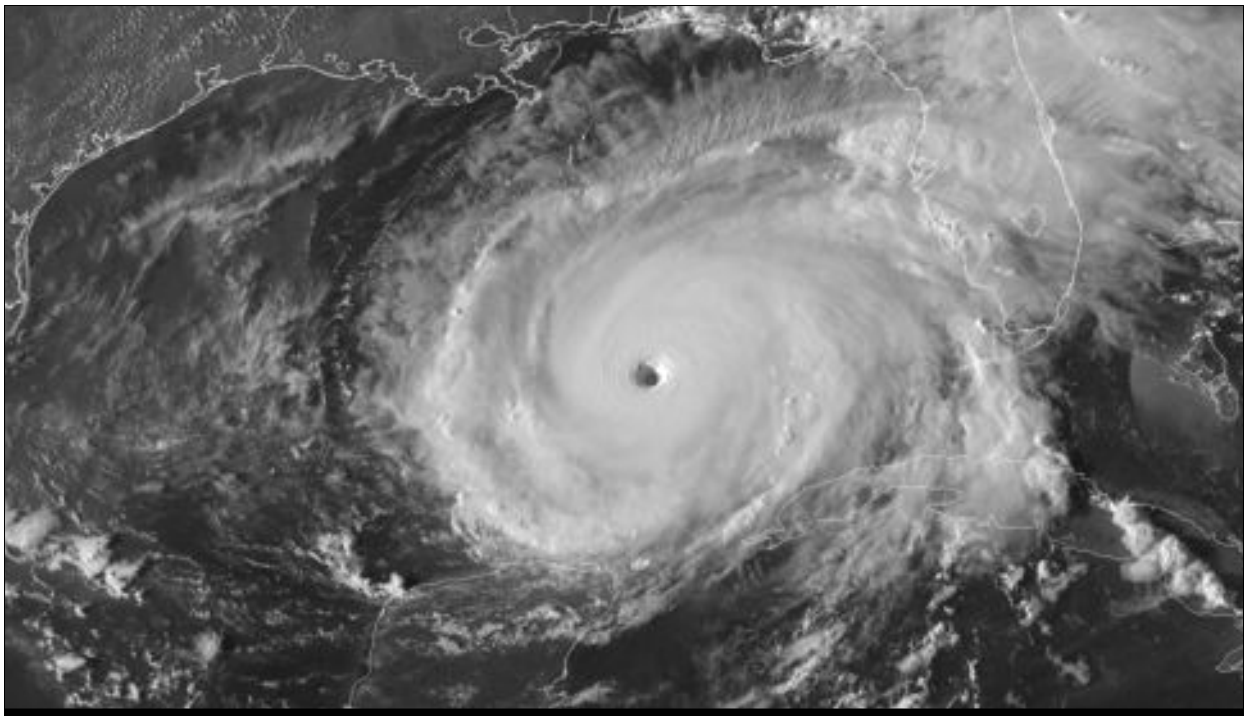
$$dU = dQ - dW$$

HYPOTHESIS: These greenhouse gas amounts and increases in temperature will lead to predictable (and bad) effects to the planet and its inhabitants.

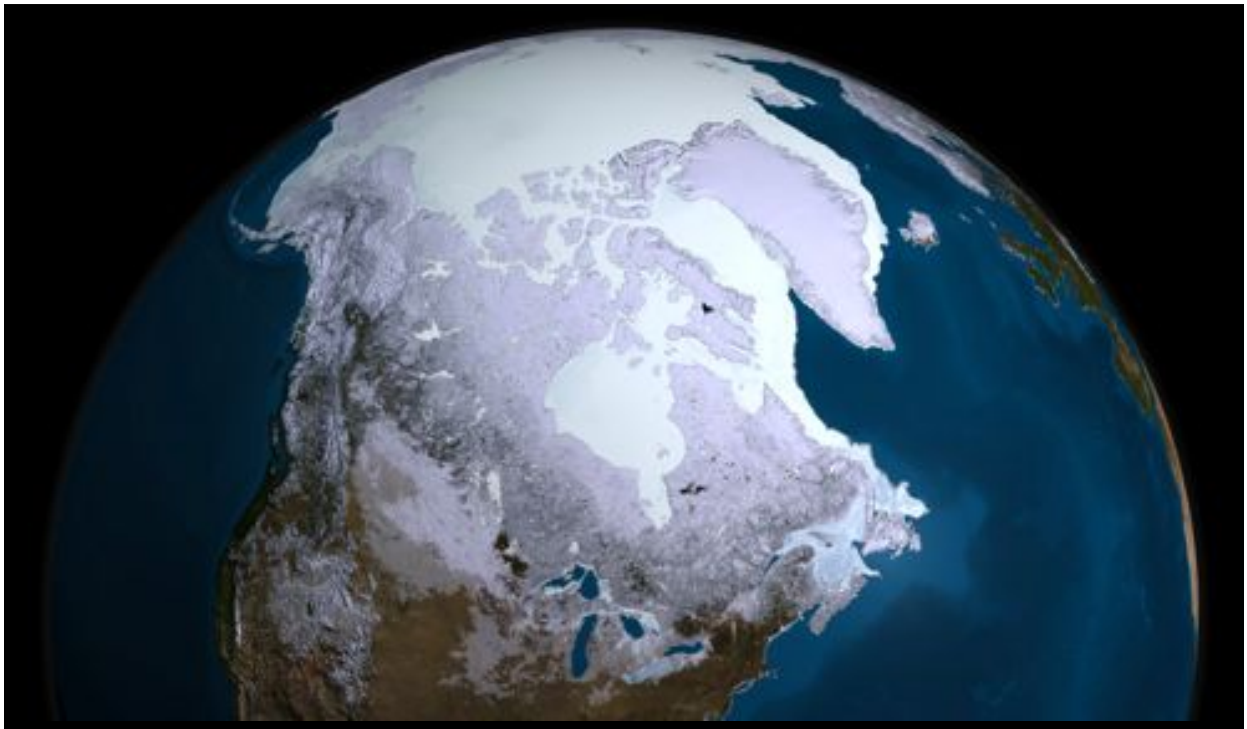
$$dU = dQ - dW$$

In short:

$dU$ = internal energy
$dQ$ = heat
$dW$ = work



ADJUSTING LEVELS OF WORK - AIR, WATER, EVEN LAND.

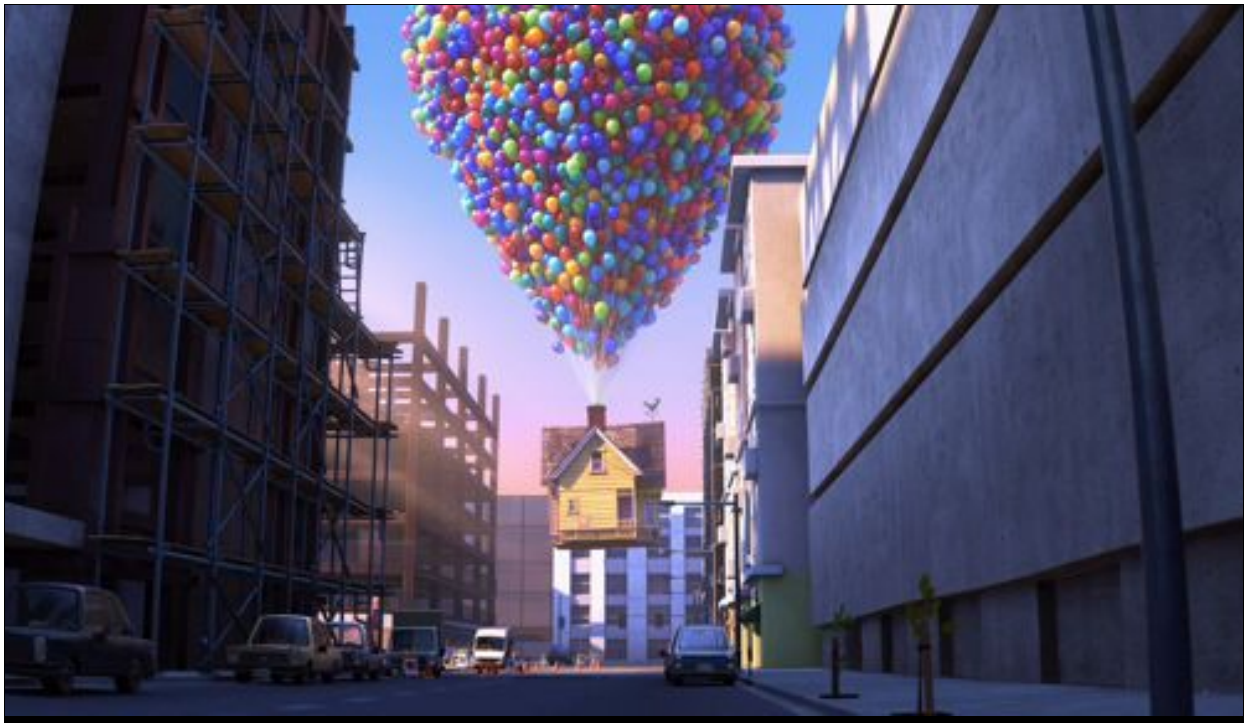


ADJUSTING LEVELS OF INTERNAL ENERGY.
ICE MELTING, SEA LEVELS, TROPIC BANDS
CHANGE IN CHEMICAL REACTIONS

# PV=NRT

demo

Boyles Law:
P = Pressure, V = Volume, N = number of molecules of gas
R = a constant to tie it all together (8.314472 $m^3 \cdot Pa \cdot K^{-1} \cdot mol^{-1}$)
T = Temperature



Boyles Law:
P = Pressure, V = Volume, N = number of molecules of gas
R = a constant to tie it all together (8.314472 $m^3 \cdot Pa \cdot K^{-1} \cdot mol^{-1}$)
T = Temperature

$$dq = c_{v,m}\, dT + \frac{Pa \cdot dV}{Ma}$$

This is what you get when you combine the First Law of Thermodynamics with Boyles Law. This is often referred to as a formal rendition of the the 1st Law for atmospheric considerations.

"The models used in climate research range from simple energy balance models to complex Earth System Models (ESMs) requiring state of the art high-performance computing. The choice of model depends directly on the scientific question being addressed (Held, 2005; Collins et al., 2006d). Applications include simulating palaeo or historical climate, sensitivity and process studies for attribution and physical understanding, predicting near-term climate variability and change on seasonal to decadal time scales, making projections of future climate change over the coming century or more, and downscaling such projections to provide more detail at the regional and local scale. "

*AR5, Chapter 9.*

Models are composed of algorithms (a step by step calculation), which in turn are based on processing mathematical expressions, which in turn may be derived from physical laws, which in turn are derived from the things people see and do and measure everyday and throughout history.

Figure 1.13, AR5

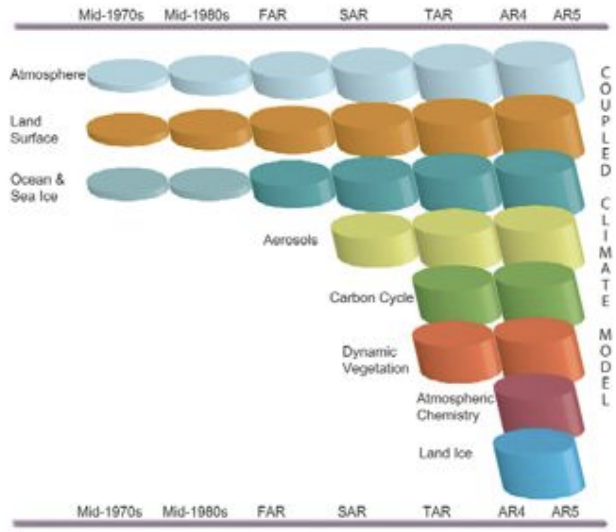
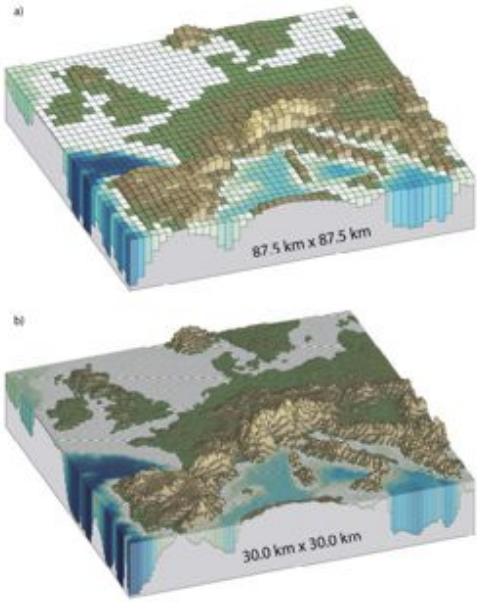



Figure 1.14, AR5




Models are composed of algorithms (a step by step calculation), which in turn are based on processing mathematical expressions, which in turn may be derived from physical laws, which in turn are derived from the things people see and do and measure everyday and throughout history.

For the Fifth Assessment Report of IPCC, the scientific community has defined a set of four new scenarios, denoted Representative Concentration Pathways (RCPs, see Glossary). They are identified by their approximate total radiative forcing in year 2100 relative to 1750: 2.6 W m$^{-2}$ for RCP2.6, 4.5 W m$^{-2}$ for RCP4.5, 6.0 W m$^{-2}$ for RCP6.0, and 8.5 W m$^{-2}$ for RCP8.5. For the Coupled Model Intercomparison Project Phase 5 (CMIP5) results, these values should be understood as indicative only, as the climate forcing resulting from all drivers varies between models due to specific model characteristics and treatment of short-lived climate forcers. These four RCPs include one mitigation scenario leading to a very low forcing level (RCP2.6), two stabilization scenarios (RCP4.5 and RCP6), and one scenario with very high greenhouse gas emissions (RCP8.5). The RCPs can thus represent a range of 21st century climate policies, as compared with the no-climate policy of the Special Report on Emissions Scenarios (SRES) used in the Third Assessment Report and the Fourth Assessment Report. For RCP6.0 and RCP8.5, radiative forcing does not peak by year 2100; for RCP2.6 it peaks and declines; and for RCP4.5 it stabilizes by 2100. Each RCP provides spatially resolved data sets of land use change and sector-based emissions of air pollutants, and it specifies annual greenhouse gas concentrations and anthropogenic emissions up to 2100. RCPs are based on a combination of integrated assessment models, simple climate models, atmospheric chemistry and global carbon cycle models. While the RCPs span a wide range of total forcing values, they do not cover the full range of emissions in the literature, particularly for aerosols.

IPCC SCENARIOS.

"**Firstly**, it can be run for a number of years over simulated time and the climate generated by the model compared in detail to the current climate."

Here, a valid model is one where average distribution and season variations of appropriate parameters such as surface pressure, temperature and rainfall compare well. As well, noted variability in the model should coincide well with variability in the observed situation as well.

"**Secondly**, models can be compared against simulations of past climates when distribution of key variables was substantially different than at present."

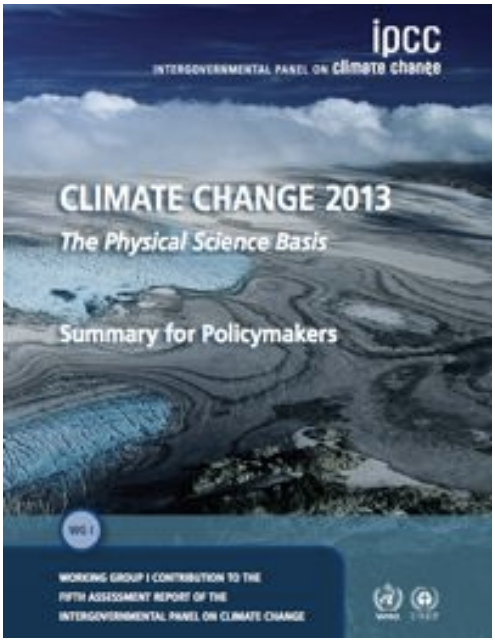
An example would be about 9000 years ago, where the Earth's orbit in relation to the sun was slightly different. The axis of rotation was basically tilted 24o rather than the current 23.5o. Enough, however, to obviously affect the distribution of solar energy to the surface of the planet. Now meteorological data is obviously weaker for those type of timescales but there is data that (ice core data, vegetation fossilization patterns, etc).

"**Thirdly**, a model can be validated by usage in predicting the effect of large perturbations on the climate."

i.e. El Nino, large volcanic eruptions... (like mount Pinatubo 1991 / second largest eruption in 20th century).

VALIDATING MODELS. (I.E. HOW DO YOU TRUST MODELS?)

SIMPLE VERSUS COMPLEX. BEST MODELS ARE THE ONES THAT FIT REALITY.




| Confidence Terminology | Degree of confidence in being correct |
|---|---|
| Very high confidence | At least 9 out of 10 chance |
| High confidence | About 8 out of 10 chance |
| Medium confidence | About 5 out of 10 chance |
| Low confidence | About 2 out of 10 chance |
| Very low confidence | Less than 1 out of 10 chance |

| Likelihood Terminology | Likelihood of the occurrence/ outcome |
|---|---|
| Virtually certain | > 99% probability |
| Extremely likely | > 95% probability |
| Very likely | > 90% probability |
| Likely | > 66% probability |
| More likely than not | > 50% probability |
| About as likely as not | 33 to 66% probability |
| Unlikely | < 33% probability |
| Very unlikely | < 10% probability |
| Extremely unlikely | < 5% probability |
| Exceptionally unlikely | < 1% probability |

SO WHAT DOES THE FUTURE HOLD?

# ANYWAY…

FACTS:
The Earth is getting warmer.

There is more CO2 in the Earth's atmosphere. Much of this is due to human activity.

CO2 is a greenhouse gas.

HYPOTHESES:
The increase in temperature is largely due to the anthropogenic production of $CO_2$.

These greenhouse gas amounts and increases in temperature will lead to predictable (and bad) effects to the planet and its inhabitants.

CONSEQUENCES:
Read the IPCC report AR5 (Summary for Policy Makers)