Meta-Analysis of Climate Change Data

VXPhysics.com

ABSTRACT

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I. Purpose

As a concerned Physicist, Researcher, Physics instructor, and citizen this work started as a private investigation into the factors related to Anthropogenic (that is, man-made) Global Warming (AGW). This analysis was started in 2002 with the creation of solar radiation balance and regression models of global temperature implemented in Mathcad. It has grown into an 99 page investigation into Atmospheric Physics with over one hundred separate climate factors.

The purpose of this investigation is to abstract Climate and AGW principles and evidence, **Organize the Evidence** it into 5 general categories A - E, examine the evidence, and then to draw conclusions based on the evidence.

Organization of Evidence To Be Investigated - See Detailed Table of Contents, pg 6

Five General Evidence Categories (A - E), Each consisting of a number of Sections:

A. SECTIONS 0 - III: TEMPERATURE, AVERAGED TEMP, HEAT OF OCEANS, CO_2, AND ENERGY PRODUCTION
B. SECTIONS IV to IX: SOLAR, PLANETARY, GALACTIC, ENSO, PDO CYCLES, SPECTRAL MODELS, SATURATION
C. SECTIONS X to XIII: ANALYSES CLIMATE MODELS - Atmospheric Physics, GHGs, Models, and Limitations
D. SECTIONS XIV to XXIII: ANALYSIS: Looking for Unique Fingerprints of Anthropogenic Global Warming, Extremes
E. SECTION XXIV: SOME BASICS OF METEOROLOGY

Sampling of Topics to be Covered

- Greenhouse Effect (GHE), Energy Balance, Lapse Rate Physics, Radiative Emission Altitude (pgs. 96 - 99)
- Proxies & Reconstructions of Temperature and CO_2 (ppm) for Different Geological Ages
- The nature of Greenhouse gases.
- Instrumental Records of Temperatures during Last 200 Hundred Yrs. Graph of Seasonal Temp 1880-2021
- **Plot of Seasonal Global Temperature Anomaly Over Eight - 20 Yr. Cycles from 1881 to 2021**
- CO_2 Concentration Records
- The Holocene Period: The last 10,000 years of climate stability or "normal" climate of temperature decline.
- Fossil Fuel Energy Production
- Solar Irradiance, GHG Radiation Bands, Band (CO_2) Broadening & Albedo
- Solar Magnetic and Sunspot Cycles
- Solar Variation - Cycles: Orbital, 70 Year, Milankovitch,
- Ocean Cycles: ENSO and PDO
- First Order 1D Latitudinal Energy Balance Model
- Regression Model: ENSO, Irradiance, Volcanic Aerosols, & Anthropogenic Effects. Correlation: 0.90 to ΔT.
- Model of the Transient Climate Response to Cumulative CO_2 Emissions and the remaining carbon budget.
- Diurnal, Regional, and Seasonal Air Temperature Asymmetries - See Section XIV - Test #6
- History, Basic Physics of Climate
- Global Temp Prediction by: Energy Balance, GCM, Cycles-Wavelets, Regression of Climate Models
- Search for Unique Anthropogenic Global Warming Signatures or Fingerprints
- Ocean Currents, Sea, Glacier, and Snow Levels
- Climate Extremes: Rainfall, Snow Coverage, Sea Level, Hurricanes, Destabilized Polar Vortex
- Review of Unique AGW Signatures/Fingerprints: 13 Tests, See Section XIV - Tests #0 to #12
- Anthropogenic Heat Flux - Urban Thermal Island Effect Heating

Purpose - Continued

A Meta-Analysis and Analysis of Physics and Models will then be done on these Sections and Topics and an assessment made base on the evidence of AGW.

On Page 4 the "III. Summary of Conclusions", summarizes the conclusions and gives a listing of conclusions. These summaries are based on the evidence given in Sections XIV to XXIII.

These analytic climate model scripts (Mathcad Version14) and data are accessible from **VXPhysics.com.**

http://www.VXPhysics.com/Climate_Analysis/Meta-Analysis_of_Climate_Change_Data.xmcd Rev March. 15, 2019

In the following Sections we will discuss the methodology to be used, division of topics, some technical considerations, and finally a summary of our conclusions.

II. Methodology - Evidence to be Investigated

The primary mechanism for potential global warming is the "Greenhouse Effect", GHE. The first few pages are a review of the Natural Greenhouse Effect, Greenhouse Gases, and some Critical Factors for Anthropogenic Global Warming. These factors are reviewed in the first few pages. The main effort is in the meta-analysis or the reviewing of the literature on climate change, organizing it, and then differentiating between the Natural and Anthropogenic Climate Change causes/correlations, as shown in what follows.

Differentiating Between Natural and Anthropogenic Climate Change Factors

Twenty two topics (**Table of Contents: Sections 0 to XXI)** were investigated.
Refer to Table of Contents - Investigation of Climate Change Data on pages 3 and 6. These topics are organized into:

Some Technical Consideration: Sections IIB and XX

One of the topics considers the question: "Is the concept of an averaged global temperature physically meaningful?" Temperature is an intensive quantity. It depends on the local state of a system. It is not extensive. Its average is not a meaningful concept of temperature, that is, it cannot be meaningfully averaged. The temperature field can be averaged or weighted in a number of ways. **However, there is no unique average value.**
What is a global meaningful concept is energy content of oceans. See Section IIB.

For anthropogenic global warming to be true, it must meet a number of critical tests or finger prints. These tests were applied. See Category D. The data passes the 10 tests given in Section XIV.
Increases in Extreme Weather are observed for about half of the factors. See Section XX.

The Main Evidence Given for Anthropogenic Global Warming, AGW

Greenhouse gas emissions, primarily carbon dioxide, CO_2, (which has a long lifetime in the earth's atmosphere) **and not natural climate variations,** are causing significant:

A. Increase in Global Temperature. The International Panel on Climate Change (IPCC) climate sensitivity is estimated @1.5C - 4.5C per doubling of CO_2 concentration.

B. Rising Sea level, Warming Oceans, Bleaching of Coral Reefs

C. Shrinking ice sheets, declining Arctic sea ice, glacial retreats, and decreased snow cover.

D. Increases in AGW sensitive extreme weather.

This Meta-Analysis will investigate this Evidence using the 10 tests or AGW signatures outlined in Sections XIV to XXIII

Distinguishing Between Known Physics and Climate Science Modeling of Complex Chaotic Behavior

The term Climate Change (CC) in the context of AGW, is nebulous and the cause of much confusion. The exact term needed for a coherent discussion is Climate Science. It has been my observation that many discussions of CC are really based on differing philosophies and often, based on self interests. Contemporary generations are highly concerned about their future, and rightly so, and often view CC as the product of the profligate, environmentally destructive lifestyle of earlier generations. Consequently, a discussion of CC is often less a discussion of science and more one of world view. The truth is reveled by the science and not by the world view du jour.

Nature of most discussions on CC and the need for Clarity
Those who engage in discussions of CC generally have a limited understanding of the mechanisms of climate change. Often, claims by the public of what the science shows are not well founded. Indeed, Climate Models, being untestable, cannot even meet the minimum requirements of the Scientific Method, that is, testability and falsifiability. Like politics, the pertinent effects of climate are local. How are local communities affected by CC. The effects could be catastrophic for one community, city, or nation, but highly beneficial to another. We do not possess the degree of detail and knowledge of forcers and feedbacks of climate needed to make local climate predictions. Winds are the primary movers of heat on the earth, however the discovery of Lorentz Attractors, the nature of fluid dynamics (Navier-Stokes Equation), and satellite data shows that the Physics of fluid flow is chaotic, that is, unpredictable.

A Larger Global Perspective
To fully understand the spectrum of climate trends, one must view it from the perspective of the history of the earth. Consider a time frame on the order of the life of the planet, such as the last billion years. The most salient historical feature of climate is the recurrence of Ice Ages. Section 0 shows the most common state of earth is to be in an ice age. We have spent the last 20,000 years coming out of the current Holocene Epoch Ice Age.

Over geological periods of time global freezing is the earth's biggest climate concern. Paleomagnetic and fossil evidence show that normally CC causes the earth to progress into a snowball. In the **geochemical carbon cycle**, chemical weathering transforms and captures atmospheric CO_2 into carbonates. (Natural Decline Rate of -20 ppm per 10 millennia.) Ice Albedo negative feedback then freezes the earth. See Section VI. To recover from the snowball, hyper greenhouse CO_2 concentrations of 20,000 Pa are needed. The current theory is that volcanoes spewing CO_2 and methane provide the mechanism to recover from ice ages.
AGW has saved us from the mass extinction events of global ice ages. Rising oceans from AGW are bad for coastal property values, but survivable. On the Earth, the IPCC states that "a 'runaway greenhouse effect" - analogous to that of Venus - appears to have virtually no chance of being induced by anthropogenic activities. Runaway greenhouse effects may have led to mass extinctions in the past, but they were triggered by global volcanism.

Climate Change Models

The earth's climate system is extremely detailed and complex for which there is no complete model. For example, models cannot resolve the detail within individual clouds. Feedbacks from clouds represent a significant source of error and uncertainty in total global feedbacks and these may also drive variations in local climate changes. Clouds remain one of the most-complex and most-studied of feedbacks under climate change. They are the single most important, but least understood feedback mechanisms. Cirrus clouds high in the atmosphere re-radiate heat back to the earth and give a positive feedback. Cumulus clouds reflect solar radiation back to space and give negative feedback. Climate models as they exist today cannot capture the nonlinearities and uncertainties in physical processes that are parametrized in climate models. Models are ad hoc approximations of initial conditions and past model past behavior. There is no consensus, but a large range of speculative values for feedback forcings.
There are unknown unknowns in climate factors and dynamics, particularly with regard to critical tipping points.

Dilemma: Assessment of AGW Risks: Benefits and Tradeoffs
Carbon is essential for life: Our bodies, plants, animals, food, plastics, wood, and plant food are composed of carbon. **Fuels** such as (renewable) wood and fossil fuels are all mostly carbon. Without fossil fuels we could not have crawled out of the Medieval Era. Fossil fuels provide energy, which powers the great engine of technical innovation that allowed us to get off the farms, live in cities, and freed us from common drudgery. Drudgery such as: traveling by foot, using beasts of burden, and working long hours to provides the basics of life, such as food, water, shelter, heating, cooking, transportation, information, and education. It allows us to pursue higher realms of human endeavor such as thought, art, science, technology, commerce, medicine, or philosophy.

What is important in assessment of AGW is keeping a balance between the improvement in human condition of developing nations enabled by fossil fuels versus rising atmospheric CO_2 levels, while transitioning to a Post Fossil Fuel era. It is a Reality that Developing Nations will continue to use increasing amounts of Fossil Fuels.
See Section XXIV.

Preview: Seasonal Global Temperatire Anomaly 8 - 20 Yr. Cycles since 1881

Use GISS Gobal Temp. Data: https://data.giss.nasa.gov/gistemp/

The basic Goddard Institute Space Studies (GISS) temperature analysis scheme was defined in the late 1970s by James Hansen when a method of estimating global temperature change was needed for comparison with one-dimensional global climate models. Derived from the MERRA2 reanalysis.
MERRA2: Advances made in the assimilation system that enable assimilation of modern hyperspectral radiance and microwave observations, along with GPS-Radio Occultation datasets.
Temperature anomalies indicate how much warmer or colder it is than normal for a particular place and time. For the GISS analysis, normal always means the average over the 30-year period 1951-1980 for that place and time of year. This base period is specific to GISS, not universal.

Extract Global Surface Temp. Anomaly Data for Seasonal Cycles over Eight 20 Year Periods from 1980

Global Temperature Data: GISSTemp := READPRN("GISS-NASA MONTHLY TEMP 1980 to 2022.txt")

Start the 20 Yr. Rows at: $\mathrm{Yr20}(n) := n \cdot 240 + 12$ **NOTE:** To use the latest 2021 data, the 20 Year Periods start at 1801.

$mn := 0, 1 .. 11 \quad Months_{mn} := mn \quad Month := Months + 1$

```
TempSeasons(M) := | TempM ← submatrix(M, 12, 23, 1, 1)
                  | for  yr ∈ 1 .. 7
                  |   TempM ← augment(TempM, submatrix(M, Yr20(yr), Yr20(yr) + 11, 1, 1))
TMS := TempSeasons(GISSTemp)  | TempM
```

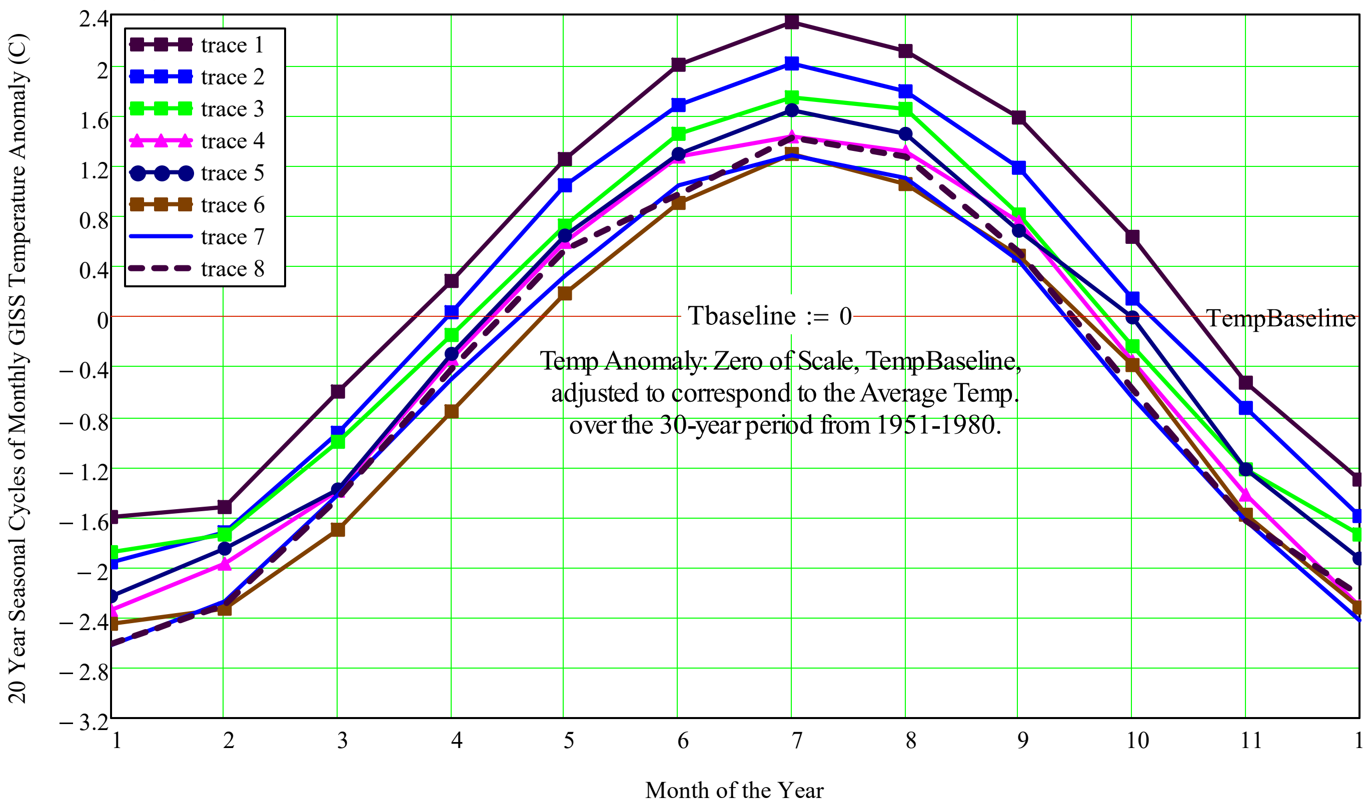
NOTE THE HUGE INCREASE IN TEMPERATURE RISE OVER THE LAST VICENNIAL!

2021 was sixth hottest year on record, despite cooling La Niña event, but top 8 warmest years have all since 2013

$\max\left(TMS^{\langle 7\rangle}\right) - \max\left(TMS^{\langle 6\rangle}\right) = 0.33 \qquad \mathrm{mean}\left(TMS^{\langle 7\rangle}\right) - \mathrm{mean}\left(TMS^{\langle 6\rangle}\right) = 0.30833$

Traces 1 - 8: Correspond to the 20 Year Cycle of Years: 2021, 2001, 1981, 1961, 1941, 1921, 1901, 1881, respectively.

Eight Seasons of 20 Year Cycles of GISS Temp Anomaly from 1881 to 2021. Top Trace 1 is Curve for 2021 Season



III. Summary of Conclusions

__Science__ is the systematic knowledge of the physical or material world gained through observation and experimentation.

Just as time only moves forward and entropy must always increase for a closed system, __change is inevitable__.

"Greenhouse Effect", Lapse Rate, and Radiative Emission Altitude (See Pages 97-98)

The way the temperature changes with altitude is important for the greenhouse effect. If it were a constant temperature then it would just look like an elevated surface. Most of the infrared radiation (IR) escaping the Earth to space comes from the surface or the troposphere, so the temperature variations in the troposphere are most important. The altitude at which IR is radiated into space (radiative alititude) is a critical factor in GHG.

Increasing the amount of GHG in the atmosphere causes the emission that makes it to space to come from higher in the troposphere, which reduces the amount of radiation reaching space since the higher air is colder. But, the emission must balance the energy received from the sun, so the entire atmosphere column below it, including the surface, has to warm up. This warming ensures that the effective radiating altitude can emit the necessary energy to balance the incoming solar radiation, given that the emission of infrared depends on its temperature. The effect on the surface will depend on the lapse rate, and the lapse rate depends on how the atmosphere moves heat around.
The essential factors for the Greenhouse Effect are given in Section XI.

Listing of Conclusions from the Examination of the Evidence. Refer to II. pages 9 - 10.

- **The Evidence for Anthropogenic Climate Change is Overwhelming**
- I have Climate Data for the last 20 Years. The new published data does not agree with the old. The Data is being manipulated.
- The data & Sec XXI, raise the concern that data can be easily manipulated (model biases) to predict false warming trends.
- We are currently in the Holocene Epoch of Ice Age Glacial Retreat. The last glacial maximum ended about 15,000 years ago.
- CO2 levels currently are 415 ppm and are rising at the rate of ~ 2.2 ppm per year. 100 - 200 faster than preindustrial periods.
- The satellite evidence shows that anthropogenic CO_2 production is causing a **significant increase in down welling long wave** radiation power density with resultant global warming and increased stratospheric cooling. See Section V-3.
- NOAA's USHCN early data has been consistently adjusted downward, so now century-long temp trend is higher.
- The Physics is known, but Models are incomplete & fail to predict the actual temperature behavior. See Section V.
- .Much is unknown. One of largest unknown factors are feedbacks from clouds. Uncertain parameters, calibrated single point.
- For increased CO2, factors are very complex and chaotic. We cannot know precisely what the long term effects may be.
- Climate Science strictly fails the criteria of the *Scientific Method.* Not measurable in real time, experimental, repeatable.
- It is sad to say, but the integrity of the work on Climate Change is questionable, e.g. self interests such as gov't contracts.
- Most warming not caused by 3.5 W/m^2 AGW GHG forcing directly, but feedbacks. Feedback estimates: 0.9 to 1.9X.
- The crucial amount of carbon dioxide **Band Broadening** with increasing concentration & height is uncertain.
- The Climate Models do not accurately track the temperature data & do not agree.
- Global temp of the earth is **inherently bistable**. It swings between Ice ages and Warm Interglacials. See Sections 0 and I.
- IPC assessment is that it is **very unlikely** that AGW can **trigger greenhouse runaway** like Venus. See Section X.8 - pg. 61
- 1979 - 2022 satellite data shows a global linear trend temperature anomaly of +0.12 C/decade. It is now
- What are **Tradeoffs** Between Improvement of Human Conditions from Energy Production and Climate Change?
- Only viable coal replacement: **nuclear power**. Solar: Wind, PV, Agro & Geothermal, lack the scale for replacement.
- Production fusion power **may be** available in 40-80 years. Too late to be relevant for a contemporary AGW solution.
- Needs of developing nations, e.g. India, means that **nothing significant** will be done about **fossil fuel burning**.

Potential Paths to Planetary Environmental Salvation

Double or triple the government funding for Nuclear Fission and Fusion Research Programs. Take it from NASA. Solve our problems on the earth first before we go off to the planets.
Allocate money for the establishment of research programs for the investigation of unconventional, **but theoretically sound** energy alternatives: e.g. cogeneration high temperature/efficiency generators with carbon sequestration, infrared radiators to cool earth to space, wind vortex, nondissipative terrestrial solar, extraction of extraterrestrial solar. These are **highly speculative**, but considering that we are dealing with a planetary wide problem with potential losses in the thousands of $trillions, it is a small price to pay. This should be an international program.

ORGANIZATION OF SECTION HEADINGS DETAILS

I. Investigation of Climate Change Data - 23 Specific Topics

II. Conclusions From Evaluation Of Evidence

III. GeoEngineering: Potential Solutions To Global Warming

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I. Investigation of Climate Change Data

B. SECTIONS IV to IX: SOLAR, PLANETARY, GALACTIC, ENSO, PDO CYCLES

SECTION IV. Solar Variation: Wolf Number, Sunspots, C14 SS Extreme, Irradiance, Wind

1. TCrut Temp, Solar Proxy: Changes C14 Concentration, Sunspot Extreme Periods, & #Sun Spots
   NGDC-Table of smoothed monthly sunspot numbers 1700-present
2. Sun Spot Epochs (910 to 2010) - Maunder Minimum
3. Extended C14 Data (Red) Smoothed Data, Detrended Data, & Hallstadzeit Cycles
3. Cycle #24 2018 - A 30 Year Minimum Cycle
3. PMOD Total Solar Irradiance-31 Day Median Fit
4. The Sun's Total Irradiance: Cycles, Trends & Related Climate Change Uncertainties -1978 - PMOD
5. Reconstruction of solar irradiance since 1610, Lean 1995 (1600-1995) - Correlates to Temperature
6. NASA OMNI2: Solar Wind Pressure and Decadal Trends
7. Solar Cycle Prediction - Solar Cycles # 24 and 25 -NASA - Influence of sun on climate
8. Wilcox Solar Observatory - Solar Polar (North-South) Magnetic Field vs Sunspot Cycles
9. Hathaway: Magnetic Conveyer Model - Sunspot Prediction
10. Zharkova: Irregular Heartbeat of Sun driven by dual dynamo-Accurate **Sunspots Prediction**

Predicts Lowest Sunspot Cycle Minimum in 370 Years, similar to Maunder Min - But AG Warming Continues

SECTION V. Solar Radiation and GHG Absorption Spectra and CO2 Band Broadening

1. Top of Atmosphere and Sea Level (Greenhouse Gas Absorption Bands)
2. Comparison of MODTRAN Model to Nimbus 3 IRIS instrument (ClimateModels.UChicago.edu)
3. **Test #00: Measurements of Radiative Surface Forcing of Climate - AGW Increase of 3.5 W/m^2**

SECTION VI. Project Earthshine - Measuring the Earth's Albedo

Earth's average albedo is not constant from one year to the next; it also changes over decadal timescales. The computer models currently used to study the climate system do not show such large decadal-scale variability of the albedo.

SECTION VII. 70 Year Warming Cycles

Analysis: Statistics of Climate Change -Temperature Rise is Not Monotonic - 70 Year Cycles

SECTION VIII. Milankovitch Astronomically Forced Glacial Insolation Cycles

1. Astronomical Insolation Forcing: Early Pleistocene Glacial Cycles - Huybers
2. Milankovitch radiation for different latitudes and time periods
3. Total Solar Irradiance - 31 Day Median
   See "Long-term numerical solution for the insolation quantities of the Earth.xmcd"

SECTION IX. Atmosphere-Ocean Effects: ENSO and PDO

ENSO - The Southern Oscillation: Consistently dominant influence on mean global temperature

1. ENSO Index - 1950 to 2014

PDO 1. PDO Index - 1900 to 2010

C. SECTIONS X to XIII: ANALYSES OF CLIMATE MODELS

SECTION X. Physics, Energy Balance Models, Wavelet Analysis of Global Temperature Anomaly

1. History of of Development of Climate Physics
2. Elementary Meteorology Atmospheric Physics, Lapse Rate
3. Stefan-Boltzmann Law of Radiation: Calculation of Effective Temp of Earth
4. S-B Law: Single Layer Radiative "Toy" Model of the Atmosphere - Modelling GHE
5. First Order 1D Latitudinal Energy Balance Model
6. References to More Complex Climate Models **VXPhysics.com/climate_analysis.htm**
7. CO2 Band Broadening-
8. How close are we to the edge of a runaway greenhouse effect? Habitable Zone

SECTION XI. Summary of Facts of GHE, GH Gases, Radiation, and Temp Rise

SECTION XII. Climate Cycle Analysis - Adaptive Hilbert-Huang Transformation

"Solar Forcing and Climate - A Multi-resolution Analysis.xmcd"
Empirical Analysis Mode Decomposition via Hilbert-Huang Transforms -> "EMD HHT.xmcd"

SECTION XIII. Regression Model: Global Temp Reproduced by CO_2 and Natural Forcing

Testing the Anthropogenic Greenhouse Gas Global Warming Model

D. ANALYSIS: Looking for Unique Fingerprints of Global Warming

SECTION X-3 **Test #00**: High Res Spectral Measurements give 3.5 W/m^2 increase to CO2 AGW **True**
Test #0: Use ENSO, Irradiance, Volcanic Aerosols, & AGW Effects to Create an Empirical Temp Model **True**

SECTION XIV. Finding the Unique Anthropogenic Greenhouse Gas (CO2) Fingerprints
Test #1: Spectral signatures of climate change in IR spectrum between 1970 - 2000 **True**
Test #2: Natural Forcing alone cannot account for global warming - IPCC - 2007 WG1-AR4 **True**
Test #3: Warming over land is greater than over oceans - IPCC - 2007 WG1-AR4 **True**
Test #4: GH Effect requires the lower and mid-troposphere to be warmer than the surface. **True**
Test #5: AGW requires the temperature of the stratosphere to decrease **True**
Test #6: Asymmetric diurnal temp change-Nights warming faster than days, summer/winter **True**
Test #7: Measure - Global Atmospheric Downward Longwave Radiation from 1973-2008 **True**
Test #8: Observational of surface radiative forcing (long wave downwelling IR) by CO_2 2000-10 **True**
Test #9: Constant Relative Humidity (RH) results in maximum climate sensitivity **True**

Effects Associated with Increased Temperatures in General

SECTION XV. Geologic and Current Nonlinear Trends and Multiyear Cycles Sea Levels
1. Geologic: Holocene Sea Level Rise - 8000: BP 360'/8000 yr = **0.54"/year**
2. Current Global Sea Level vs Time - 1800 to 2014 - Anomalous increased rate since 1990.
3. Sea Level and CO2 over 600 Million Years
4. Shutdown of thermohaline circulation

SECTION XVI. Glacier Records
1. Glacier Global Temp Reconstruction & Ts - 1600 to 2000 (169 Records)
2. Glacier Mass Balance and Regime: Data of Measurements and Analysis 1950-2000
3. Vostok Ice Core Data, Ratio $^{18}O/^{16}O$ (High-->Warm) ==> Continental Glaciers over past 10^6 years

SECTION XVII: Snow Coverage in the Northern Hemisphere
Snow cover, reflects 90% of sunlight. 1965 data shows snow coverage is decreasing by 13.7%

SECTION XVIII. Cryosphere - Sea Ice Extent - Northern and Southern Hemispheres
2.5% Loss of Global Sea Ice Extent since 1980

SECTION XIX. Model Predictions for Tropical Atmosphere Warming
www.climatechange.gov.au/en/climate-change/science.aspx, Spencer_EPW_Written_Testimony_7_18_2013
Test #10: Plots: All 73 climate models predict Too Much Tropical Atmospheric Warming During 1979 to 2012 **FAIL**

SECTION XX. Is Extreme Climate (> 30 Years) Getting Worse? **Evidence: Yes and No**
Test #11: Models/Snow Extent, Very Hot/Cold, Droughts, Wetness, Sea Level Rise Prediction **Fail**
1. Simulated annual time series of January NA-Continental Scale Snow Coverage - 1850 to present
2. N. Hemisphere Snow Cover Anomalies (December & January). Trend Line (Blue) - Arctic Ice decreased
3. US Percentage Area Very Warm, Very Cold
4. Extreme and Severe Drought Agricultural Land
6. IPCC Revisions: Sea Level Rise by 2100
5. NOAA: Rainfall/Wetness
7. **Hurricane Frequency, intensity, Intgtd KE** - 2017 Factors See **Section XXVI** for **Basics of Hurricanes**
8. US Tornadoes Frequency (Type)- Not increased.
9. US Extreme Weather Index
10. **Destabilized Polar Vortex (USA Frigid Winters of 2009-2013, 2016) - Cause: Arctic Sea Ice decrease**

SECTION XXI. Potential instability in Atlantic Ocean water circulation system
SECTION XXII. Thermal Dissipation: Anthropogenic Heat Flux
SECTION XXIII. Test 12-AGW Induced Rising Height of Atmospheric Boundary Layer

E. SECTION XXIV Some Basics of Meteorology - Clouds and Hurricanes

Met 1. GISS Temp Data Sources - Pg. 85 **Met 2. Clouds -Pg. 86** **Met 3. Basics of Hurricanes**
A Deadly Cycle Page 92 **Why do Hurricanes Require 80F?**
SECTION XXV. Mechanism of CO2 IR Absorption

E. SECTION XXVI. Tradeoff Between Improvement of Human Conditions & Climate Change

1. The Improvement in Human Conditions Via Fossil Fuels Dwarfs the Changes in CO2 Levels
   Humanity Unbound - Four Indicators of How Fossil Fuels Saved Humanity from Nature

II. CONCLUSION: EVALUATION OF EVIDENCE by SECTION

"*Science and skepticism are synonymous, it's okay to change your mind if the evidence changes.*" - Michael Shermer
"*The first principle is that you **must not fool yourself** and you are the easiest person to fool.*" - Richard Feymann

0. Section 0: We are currently coming out of the Holocene Ice Age. The earth is warming up from ice age.
1. Sections 0 & III-A: CO_2 levels are less than 1/10 of Cenozoic maximum of 6200 ppm.
2. The evidence shows "global" warming over the last 300 years. But, is a 400 yr climate or a 40 yr trend?
3. Section IIA. Warming over the last 100 years has been unusually rapid. Global +0.9 C for last 65 years.
4. Section IIB. Global (Average) Temperature is not a physically meaningful concept.
5. Section V #3: Test 00: High Res Spectral Measurements gives 3.5 W/m^2 increase to CO_2 AGW.
6. Section XIII: Test 0: Regressions reproduce both natural fluctuations & CO_2 trend line of global temp.
7. **Section XIV: Tests 0 through 12 show unique AGW fingerprints.**
8. Section XIV: T8- Measurements of downwelling long wave radiation vs time --> 0.2 W/m^2 per decade. Correlates with decadal 22 ppm CO_2 increase - 10% of the trend in long wave downwelling radiation.
9. Section XV shows anomalous increase in sea level rise starting in 1990, 1.7-3.25 mm/year~1in/decade.
10. Section XVI to XVIII show decreased glacier mass and decrease north sea ice.
11. Section XX - #10: 2009 - 2013 & 2016 US winters experienced destabilized polar vortex, resulting in extremes of winter temperatures
12. Section XXI: This 2017 analysis suggest that it is a possibility that the AMOC could collapses 300 years after the atmospheric CO2 concentration is abruptly doubled from the 1990 level
13. Section XXIII: Increased CO2 has raised the tropopause, ozone layer, & energy balance raises surface Temp

Environmental Concerns:

1. Increased CO_2 in the oceans causes increased carbonic acid, which attacks coral.
2. Increased Temperature causes thermal expansion and melting of ice, which results in sea level rise

Summary of the above Evidence:

We are in the Geologic Holocene Epoch. Coming out a an ice age. A Period of relative cold temperatures.
Climate is a complex phenomena. The Physics is known, but Models are incomplete & poor predictors.
There is definitely a spike in the recorded global temperature over the last 100 years. Data has verified eight unique fingerprints of AGW. The global temperature trend has been +0.9 C rise from 1950 to 2016.
Because of the chaotic nature of climate, climate models results must be presented as statistical ensembles. Therefore only probalistic conclusions are meaningful. Climate prediction is difficult because climate is chaotic and not all factors and interactions are known and quantifiable in convergent models.
The evidence implies that AGW contributes significantly to the total Global Warming in our industrial era.
Increased acidity of the oceans and rising seas are also a major anthropogenic concern.
There is still much we do not know about climate. We have a poor understanding of feedback factors. Factors are at best guesses. IPCC Assessment Report, AR 5, Chapter 9.8.3 "Unlike shorter lead forecasts, longer-term climate change projections push Models into conditions outside the range observed in the historical period used for evaluation." We also have limited data, e.g. volcanic, sun, and cosmic ray activity, 3D data on clouds, threshold for convection, and aerosols.
Because of the verified fingerprints of anthropomorphic greenhouse gas production, that is, tests #1 - 8 and the small variation in natural forcing, it is unlikely that natural global warming, occurring due to solar variation ($< \pm 1.5$ W/m^2) or other mechanisms (cosmic rays, ocean currents, or unknown feedback factors), could be the cause of recent global warming.

Therefore, considering all the above factors, the evidence shows that anthropogenic CO_2 production is causing a significant increase in downwelling long wave (IR) radiation power density with resultant global warming and increased stratospheric cooling.
The provisional evidence indicates that AGW is real, but of unknown magnitude. Satellite data Sec IIA-7A is 0.12 C/decade. By 2100, there is also much concern about reaching climate tipping points.

III. GeoEngineering: Potential Global Warming Solutions

The best way to reduce AGW is to reduce the production of CO_2 and other GHG. However, the improvement in human conditions by economic growth and increasing world population push the an increase in the consumption of energy. Alternative energy sources, at this time, are not economically or technically tenable.We must resort to other Climate Engineering solutions.

A. Alternative Energy Sources - Fission is Only Viable Alternative

Non-Carbon Energy Source. Ultimate Solution is Fusion- but Technology is not here yet.

See • Models: Other Energy Technology - Nuclear Fusion, e.g. MIT ARC

B. Climate Engineering Strategies- Mitigating Climate Change:

The observed spike in temperature carries risks such as increases in ocean heights. The outlook for mitigating the AGW component of warming by political change is very dim. Climate Engineering may target different areas of the climate system; possess varying mechanics, costs, and feasibility; have diverse environmental and societal impacts on varying scales; and create their own sets of risks, challenges, and unknowns.

The following are potential CO2 mitigation strategies:

- 1. **Carbon Dioxide Removal** (**CDR**) methods attempt to **absorb and store** carbon from the atmosphere; either by technological means, or by enhancing the ability of natural systems (e.g. oceans) to do so.
- 2. **Solar Radiation Management** (**SRM**) or Sunlight Reflection Methods aims to reduce the amount of heat trapped by GHG by **reflecting visible shortwave (0.3-3 µm) sunlight** back into space, either by reflectivity of the earth (albedo) or introduction of atmospheric aerosol particles.
- 3. **Earth Radiation Management** (**ERM**).

For details of some ERM Strategies: See **http://dx.doi.org/10.1016/j.rser.2013.12.032**
Fighting global warming by climate engineering: Is the Earth radiation management and the solar radiation management any option for fighting climate change?

Channel long wave radiation from the earth directly into space. Increase outgoing **longwave (4-25 µm) terrestrial** radiation. GHG are good "insulators" that re-radiate long wave IR back to the earth. However, there is a 8-13 µm atmospheric window that is transparent to GHG and allows IR to escape directly into space. Photonic Radiators(thin titanium or Silicon): high thermal emittance building coolers-assist A/C units.One advantage of **ERM**:earthside-not necessary go above earth.

Meteorological Reactors (**MR**) - de-carbonize energy production. Several companies are working on the development of a Solar Updraft Tower, a renewable-energy power plant that utilizes low temperature long wave solar heat. The convection from the updraft in a tower powers wind turbines from the chimney updraft to produce electrical power Solar Chimney Power Plant (**SCPP**). To be viable, tower diameters of 4.3 miles, heights of 1000 m, glazed collector, with an efficiency of 0.5%, cost of 7 cents per kWh, and outputs of 200 MW, have been proposed.

Comparison of Strategies: Mitigation of three trillion tons of CO_2 by 2100 is a major challenge.

Even a major mitiation program will result in substantial global warming. Thus a major increase in R&D resources is needed. Carbon dioxide removal (**CDR**) would need centuries before acting, but addresses the real problem as well as ocean acidification and other CO_2 induced problems.

Solar Radiation Management (**SRM**) and ERM do not deal with reducing production of GHG and attendant problems like ocean acidification. SRM could provide rapid cooling, in few months, but would require to be maintained at least for decades and presents **serious side-effects**.

SCPPs with large collectors will probably be more useful to produce renewable energy than to cool the Earth. None of these strategies by itself is sufficient to solve the problem of AGW.

A mix of Alternative Energy, Improved Efficiency, & Climate Engineering technologies are required.

General Overview of the Greenhouse Effect - See Section XI

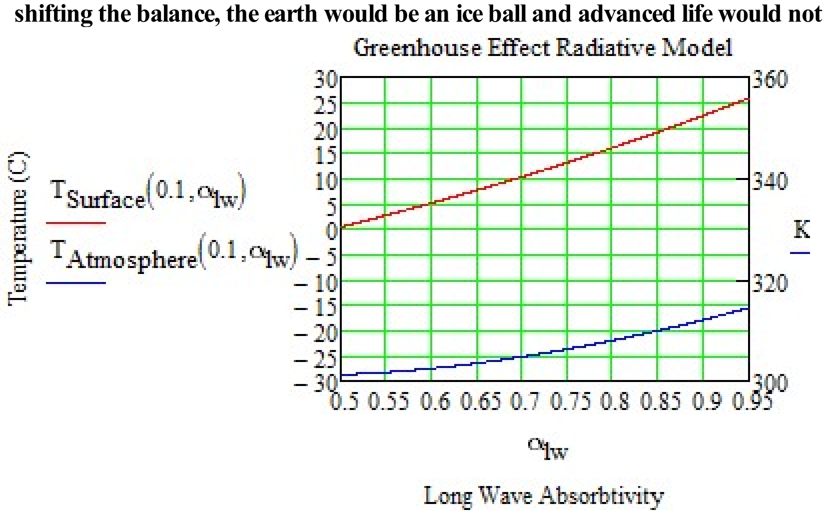
Thermal Equilibrium - First Law of Thermodynamics
The sun has a surface temperature of about 5800K. It radiates light with a peak wavelength of about 0.5 µm. Thus the earth receives mostly visible **shortwave** (**< 1µm**) energy from the **sun**, the majority of which passes through the atmosphere. This shortwave radiation heats the earth to a much lower temperature. The earth then radiates thermal energy at the lower temperature in the infrared, IR, back to space. (The mechanism for heat flow back to **vacuum** of space can **only occur by radiation.)** The temperature of the earth is established when thermal equilibrium is achieved, that is, when the energy re-radiated from earth in the IR equals the energy received from the sun in the short wavelengths.
See Section X. 3 for calculation of the resulting effective temperature given this balance.

Simplified Single Layer Model of Natural Greenhouse Effect (GHE)
The atmosphere serves to distribute the energy of solar radiation received by the Earth. Most of the radiant energy is converted into atmospheric heat energy before it is radiated back into space. Winds redistribute this energy, dissipating more of it in the process than by all other forces combined.

The earth is heated to a temperature of about 300K by the sun. It radiates IR radiation at a peak wavelength of 10 µm back to space. The atmosphere near the **surface** is largely **opaque to this mid IR, thermal radiation (5-15µm from water vapor and CO2)** (with important exceptions for "window" bands - See Section V. Solar Radiation Spectrum), and most heat loss from the surface is by a drop in temperature (sensible heat) and latent heat transport.

It is more realistic to think of greenhouse effect as applying to a **single layer "surface" in the mid-troposphere**, which is effectively coupled to the surface by a temperature **lapse rate** (Refer to Section X.2, XXIII) that is, where the temperature decreases from the surface up to the top of the **cooler troposphere**. Within the mid-troposphere region where **radiative effects are important**, the presentation of the Idealized Greenhouse Model becomes more reasonable: a layer of atmosphere with greenhouses gases will re-radiate heat in all directions, about equally upwards and downwards, thereby cooling (195 W/m^2) the mid-troposphere by transmitting heat to deep space which is at 2.7K. Increasing the concentration of these gases increases the amount of absorbed radiation, net loss of heat from the surface is slowed,and thereby further **cools the upper atmosphere** more. Therefore, **less energy is radiated into space.** To maintain energy balance with incoming solar radiation, the surface temp must increase. **GHE corresponds to IR emissivity of atmosphere**.

GHGs constitute only **1%** of the atmosphere, but they **shift the balance** between incoming shortwave solar radiation and long wave IR thermal radiation by 4W.m2. The net GHE increases the land & ocean temperature by about 20 C. See the results of a simple radiative model of the Greenhouse effect below (also refer to Section X. 4 for details), which calculates both the earths' surface and atmospheric temperatures shown below. **If it were not for this natural GHE shifting the balance, the earth would be an ice ball and advanced life would not be possible.**



Results of "Toy" GHE Model.
For details see Section X. 4 page 59.
This is a simple radiative model of the earth's Greenhouse Effect. The model uses an Albedo of 0.3 and uses visible light absorbtivities of 0.1. It plots the variation of the surface ($T_{surface}$) and atmosphere temperatures as the long wave infrared absorbtivities α_{lw} vary from 0.5 to 0.95.
Note that with an atmosphere this model gives a range of warming from 5C to 35C from the atmosphere to the surface. An average increase of 15C. The established value for the global greenhouse effect for the earth is about 16C.

Anthropogenic Global Warming (AGW) Mechanism and Concerns:
The Industrial Era has doubled the concentration of CO_2 . CO_2 is only 0.04% of the atmosphere, (its highest atmospheric concentration (400 ppm) in at least 650,000 years), but it modifies the balance of shortwave incoming and IR. (Note: High CO_2 concentration is not dangerous. We exhale 40,000 ppm.) It is a strong absorber of infrared wavelengths, so it **absorbs and then reradiates** (equally up and back down to the earth) energy that would otherwise escape to space & nudges upward (height) the temperature at which the radiation balance occurs. Another critical factor is that this added AGW CO_2 lingers for decades to centuries, while water vapor rains out. **The concern** is that AGW gases would change the balance and cause unwanted warming and effects such as **melting of polar ice caps (**resulting in a decrease in albedo)**, increased rate sea level rise, and severe weather.**

<u>For the following discussion refer to the "Energy Balance Intensities" figure on page 5.</u>
If we average the **incoming shortwave solar radiation** that is absorbed by the earth's climate over the surface of the earth we get around **235 W/m^2**.

If we average the **outgoing longwave** radiation from the **top of atmosphere** we get the same value: **235 W/m^2**.
If the atmosphere did not absorb any terrestrial radiation then the surface of earth must also be emitting 235 W/m^2. The only way that the surface of the earth could emit this amount is if the temperature of the earth was around **255K or -18°C. See Section IX-2.** And **yet we measure** an average **surface temperature** of the earth around **15°C** – which corresponds to an emission of radiation of 396 W/m^2 from the **surface of the earth**. If the atmosphere wasn't absorbing **and re-radiating longwave** then the surface of the earth would be -18°C. The actual warmer temperature of the earth results from **the "greenhouse" effect.** The name comes from a faulty analagy with a glass greenhouse.

In reality, of course, the situation is **more complicated**. Warmer air holds more water vapor, which is itself an important greenhouse gas. If we add carbon dioxide to the atmosphere, **water vapor becomes more abundant and amplifies the temperature increase** that would result from the carbon dioxide alone. Indeed, somewhat **more than half** of any AGW warming comes from this and other **positive feedback** processes.

Main Feedback Factors: We currently have a **limited understanding** of the effect and magnitude of feedbacks.
1. Evaporation increases water vapor content of the atmosphere (provides both cloud shading, but water vapor is a GHG). It causes both cooling from clouds reflecting sunlight and heating from the greenhouse effect.
2. Albedo is the ratio of reflected to absorbed sunlight. This is affected by the ratio of snow and ice to dark land (ice is reflective, while dark land absorbs sunlight). AGW causes increased heating and thus melting of polar ice.
3. Volcanic dust reflects sunlight and cools the planet. 4. Ocean currents/upwelling can change ocean heat flux.

<u>Is CO2 Absorption Saturated? Spectral Band Broadening of CO2 Bending Moment. See Sections V & X.</u>
Saturation is entirely true for a spectral interval of about one micron wide on either side of the center of the CO_2 band. However, this neglects the hundreds of spectral lines from CO_2 that are outside this interval of complete absorption. The change in absorption for a given variation in carbon dioxide amount is greatest for a spectral interval that is only partially opaque; the temperature variation at the surface of the Earth is determined by the change in absorption of such intervals. Upon **increasing CO_2 concentration**, the layer at which the absorption coefficient at each wavelength is low enough to **let the IR light escape** will be found **higher in the atmosphere**. The emitting layer will then have a **lower temperature** (and lower water vapor content), at least until the tropopause is reached, and hence a **lower emitting power.**

However, **CO_2 radiative effects** become **increasingly important higher in the atmosphere** as the higher levels become progressively more transparent to IR thermal radiation, largely because the **atmosphere is drier** and **water vapor -** an important greenhouse gas (**GHG**) - becomes **less**. GHG will absorb light only in a set of specific wavelengths, which show up as thin dark lines in a spectrum. In a gas at **sea-level** temperature and pressure, the countless molecules colliding with one another at different velocities each absorb at slightly different wavelengths, so the **lines are broadened and overlap** to a considerable extent.

High in the atmosphere, at **low pressure,** the spikes become much more **sharply defined,** like a picket fence. There are gaps between the H_2O lines where radiation can get through unless blocked by CO_2 lines. **Thus CO_2 absorption in the stratosphere does not saturate**. If the concentration of CO_2 is doubled, the GH effect **model** adds ~ 4 W/ m^2, which results in a global average temperature increase of ~ 2.8C.
See Section XI for Summary of GHE.

<u>The atmosphere also serves to distribute the energy of solar radiation received by the Earth from wind.</u>
Most of the radiant energy is converted into atmospheric heat energy before it is radiated back into space. Winds redistribute this energy, dissipating more of it in the process than by all other forces combined.

Air pressure is a measure of the density of air exerted on its surroundings. At sea level this is 14.7 lb/in^2. When air is heated, its density decreases and the air rises as it expands. Warm air up high, therefore, exerts a lower pressure than cold air at lower altitudes. When air is cooled it contracts, increases in density and sinks. Cold air exerts a higher pressure than warm air.

Air flows from high pressure areas to low pressure areas in an attempt to equalize pressure. At the equator the pressure is lower and at the poles it is higher. Therefore, other things being equal, **air should flow from the poles to the equator**. If the Earth did not rotate, wind would flow from the North to the South. Because of the rotation of the Earth (from the West to the East), the winds are deflected to the right of their normal path. That is, if you are at the North Pole the winds would blow due South; however, the rotation of the earth causes the winds to be deflected to the right. If you are at the South Pole the winds are deflected to the left. This is called the Coriolis effect. The wind circulation pattern on Earth is not that simple because of the imposition of **large convection cells** related to **solar heating.**

Mechanism of CO_2 IR Absorbtion

Additionally see SECTION III-B. CO_2 GHG Properties

Carbon Dioxide Absorbs IR from the earth and then Re-emits Infrared Radiation in All Directions

Adapted from: https://scied.ucar.edu/carbon-dioxide-absorbs-and-re-emits-infrared-radiation

Molecules of carbon dioxide (CO2) do not absorb visible light, but they're bonds are tuned in such a way that they absorb energy from infrared (IR) radiation frequencies. A molecule of CO2 can absorb an incoming infrared photon. The energy from the photon causes the CO2 molecule to vibrate. Shortly thereafter, the molecule gives up this extra energy by emitting another infrared photon. Once the extra energy has been removed by the emitted photon, the carbon dioxide stops vibrating.

This ability to absorb and re-emit infrared energy is what makes CO2 an effective heat-trapping greenhouse gas. Not all gas molecules are able to absorb IR radiation. For example, nitrogen (N2) and oxygen (O2), which make up more than 90% of Earth's atmosphere, do not absorb infrared photons. CO2 molecules can vibrate in ways that simpler nitrogen and oxygen molecules cannot, which allows CO2 molecules to capture the IR photons.

Greenhouse gases and the greenhouse effect play an important role in Earth's climate. Without greenhouse gases, our planet would be a frozen ball of ice.

There are those who say that the small amount of extra CO2 percentage wise cannot make much difference. Although it is a "small" amount percentage wise, it is a large amount in an absolute sense. During the ice ages, CO2 levels were around 200 parts per million (ppm), and during the warmer interglacial periods, they hovered around 280 ppm. Today, they have doubled to 400. Given 400 ppm of volume of CO2, If you have a **2,200 sq ft house**, and a roof the same size, then, in the column of air over your house, there is 931 **pounds of added CO2** . And there is the same amount all over the earth.

Added Weight of CO2 on 2200 sq ft Roof

$$\text{Added\_Weight}_{CO2} := \frac{14.7\text{psi}}{g} \cdot 2200\text{ft}^2 \cdot 200 \cdot 10^{-6} = 931.392 \cdot \text{lb}$$

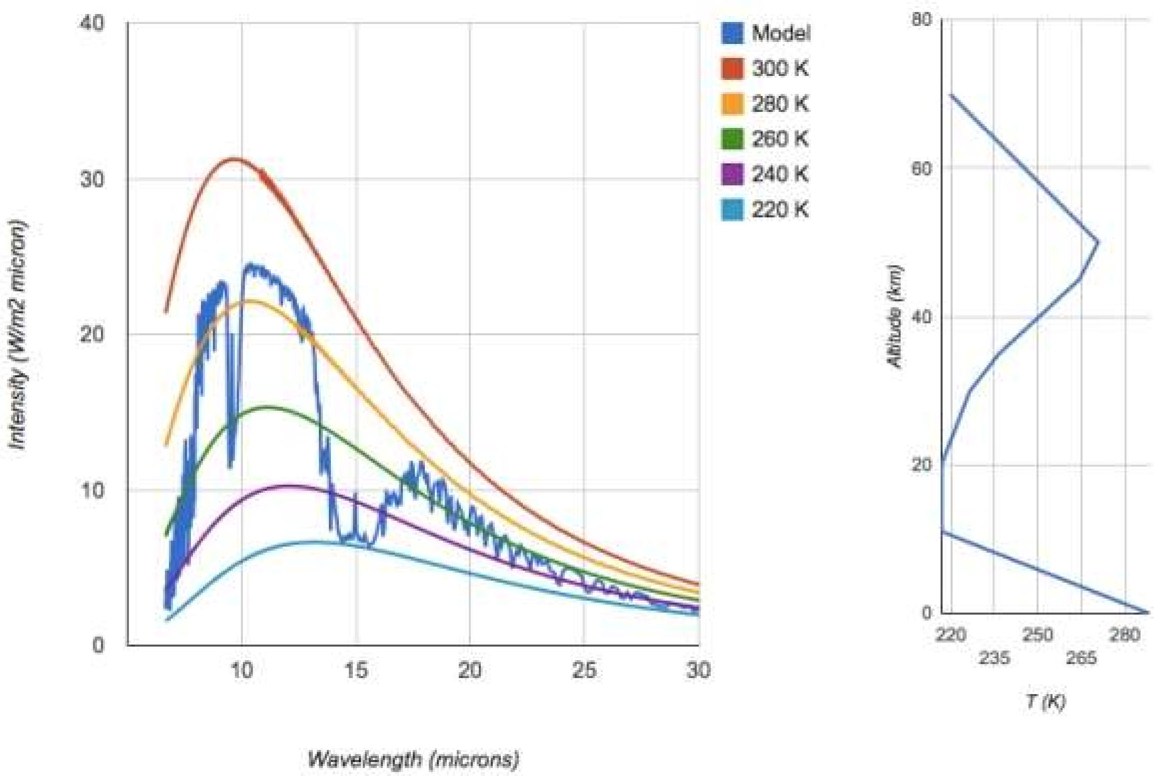
AGW Mechanism: Effective Radiative Emission Altitude

http://andthentheresphysics.wordpress.com/2014/03/05/effective-emission-height/

Dr. W. Kenneth M. Rice, Institute for Astronomy, University of Edinburgh

Consider the emission altitude influenced by the concentration of greenhouse gases. Recognizing that the temperature gradient in the troposphere (lapse rate) is **primarily determined by convection**, if you're aware of the temperature at a specific altitude, it's possible to trace back to the surface and ascertain the surface warming attributed to the greenhouse effect. That said, I haven't clearly elucidated what this emission altitude really means. When in balance, the Earth releases as much energy into space over a given time as it takes in from the Sun. By calculating the average energy radiated per square meter every second (about 240 W/m²), the Stefan-Boltzmann law ($F = \sigma T^4$) can be applied to find the temperature a perfect emitter would require to release this energy at the same rate. For Earth (with an albedo of 0.3), this temperature stands at approximately 255 K. The emission altitude refers to the atmospheric height where this temperature is observed. In the Earth's atmosphere it is at about 5 km.

In reality, however, the **actual emission is much more complicated**. Let's apply the **MODTRAN** radiation transfer code. If you use the 1976 U.S. Standard Atmosphere, set the CO_2 concentration to **400 ppm, and lookdown from 70 km**, you get the two plots:



The left-hand panel is the spectrum, and the right-panel is the temperature profile. The **outgoing flux is 258.58 W/m² which**, if you use the Stefan-Boltzmann law, corresponds to a blackbody temperature of **259.9 K**. Looking at the temperature profile, this would correspond to an **effective emission height of between 4 and 5 km.** However, the spectrum itself is clearly not a 259.9 K blackbody spectrum. *For wavelengths beyond 17 microns, the emission is coming from temperatures between 260K and 240K*

What does this mean?

(so heights around 5km in the troposphere). Between about 13 and 17 microns, the emission's coming from a region with temperatures close to 220K so, near the troposphere/stratosphere boundary. Between 7 and 13 microns, the emission is coming from a region with temperatures in excess of 280 K which, in this example, is actually the surface. So, there isn't a single emission region, but the emission is still equivalent to a blackbody with a temperature of 259.9 K.

Now, if you change the CO_2 concentration from **400 ppm to 800 ppm**, the **outgoing flux** drops to 255.75 Wm^{-2}, equivalent to a blackbody with a temperature of 259.1 K. If the system was in equilibrium at a CO_2 concentration of 400ppm, it would now be emitting less energy per square meter per second than it receives. **To retain equilibrium, it must warm**. Again using MODTRAN, this requires increasing the surface temperature by 0.9K (here I'm considering only the influence of changing CO_2 concentrations, and am not considering feedbacks). Since the temperature gradient in the troposphere is to a large extent set by convection, this means that if the surface warms by 0.9K, the temperature at all altitudes in the troposphere must increase by 0.9K (in this example I've, again, ignored water vapor feedback). Hence, once the system returns to equilibrium, the effective temperature will again be 259.9K, but this will now be at a higher altitude than when the CO_2 concentration was 400ppm. Therefore, a significant fraction of the outgoing emission will come from higher in the atmosphere when the CO_2 concentration is 800ppm, than when it is 400ppm.

So, I hope that's reasonable clear and basically correct. It's clear that there isn't a single emission height in the atmosphere, but it is clear that one can define such a height, and it's clear that increasing the greenhouse gas concentration increases the temperature at all altitudes in the troposphere and increases the height at which a significant fraction of the emission is coming from. That both illustrates the greenhouse effect and the consequences of increasing greenhouse gas concentrations. As usual corrections or comments welcome.

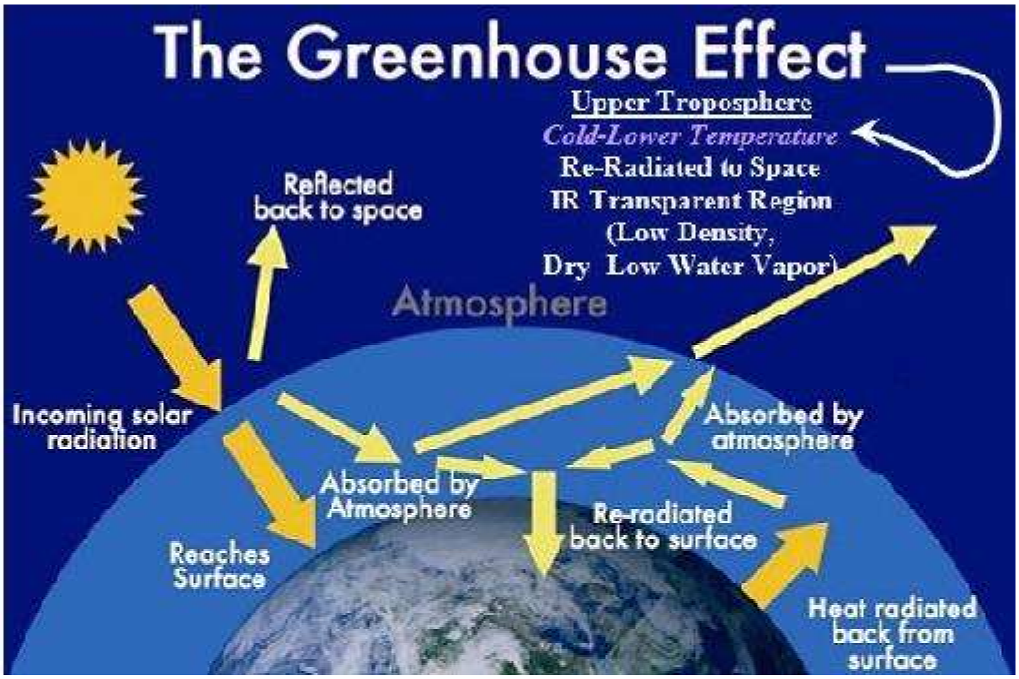
Air Pressure

Although the changes are usually too slow to observe directly, air pressure is almost always changing. This change in pressure is caused by changes in air density, and air density is related to temperature.

Warm air is less dense than cooler air because the gas molecules in warm air have a greater velocity and are farther apart than in cooler air. So, while the average altitude of the 500 millibar level is around 18,000 feet (5,600 meters) the actual elevation will be higher in warm air than in cold air.

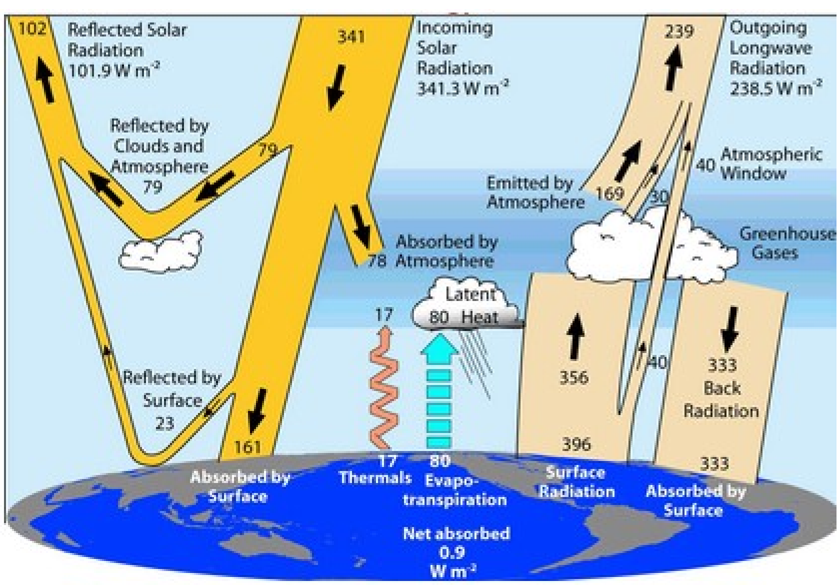
Graphic Illustrations for Single Layer Greenhouse Effect, GHE

The earth is an **isolated planet**, that is, it is surrounded by the vacuum of space. The energy-in (yllow) is by short wave solar radiation and the only energy-out must (red) also be by radiation (longwave). For Energy Balance, the shortwave solar heat coming in must equal the long wave IR re-radiated heat going out.
The energy out comes **only** from the **IR region in the upper Troposphere that is transparent**, which is at a lower temperature (on average, the temperature drops by 6.5 degrees C for every thousand meters of altitude you climb).
If **GHG** is added, then **more energy is absorbed in the lower atmosphere** which **cools the upper** troposphere. According to the Stefan-Boltzmann Law, the radiated power is proportional to T^4. Thus the GHG IR molecules **radiated less power to space** than they absorb from the surface. Thus the temperature of the lower atmosphere must rise to maintain energy balance. This rise in temperature at the surface is the greenhouse effect.
See Section XI for Summary of GHE.



In the graph below, more that the energy leaving the earth, 452 W/m^2, is much greater than the solar radiation absorbed from the sun, 235 W/m^2. The **absorption and re-radiation** by "greenhouse" gases in the atmosphere is responsible. This is another indication of the greenhouse effect. The earth system **recirculates the energy from long wave mid IR**

Energy Balance Intensities (Power Density) 0.9 W/m^2 Warming



Trenberth, K. E., Fasullo, J. T., and Kiehl, J. T., "Earth's Global Energy Budget," Bull. Amer. Meteor. Soc.

I. Investigation of Climate Change Data

A. SECTIONS 0 - III: TEMP, AVG TEMP, CO2, AND ENERGY

SECTION 0. History of Climate Change

The Nature of Ice Ages - 5 Major Ice Ages

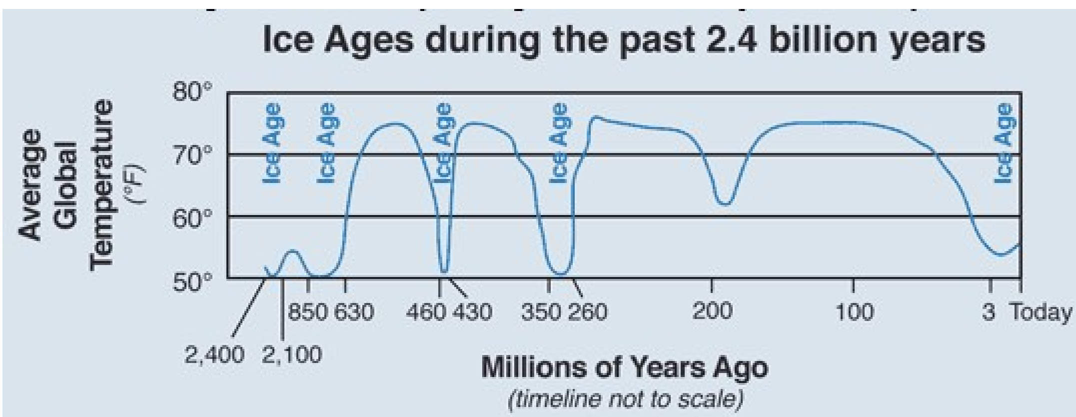
Ice ages are times when the entire Earth experiences notably colder climatic conditions. During an ice age, polar regions are cold, there are large differences in temperature from the equator to the pole, and large, continental-size glaciers can cover enormous regions of the Earth. **Solar luminosity was 30% dimmer 4.5B years ago.**

Ever since the Pre-Cambrian (600 million years ago), ice ages have occurred at widely spaced intervals of geologic time—approximately 200 million years—lasting for millions, or even tens of millions of years.

At least five major ice ages have occurred throughout Earth's history: the earliest was over 2 billion years ago, and the most recent one began approximately 3 million years ago and continues today (yes, we live in an ice age!). The most recent ice age was almost 10,000 years ago.

We are currently in the Holocene Epoch of Glacial Retreat and the Vostok Ice Core data in Section I. Plot 2-1 shows this more clearly.

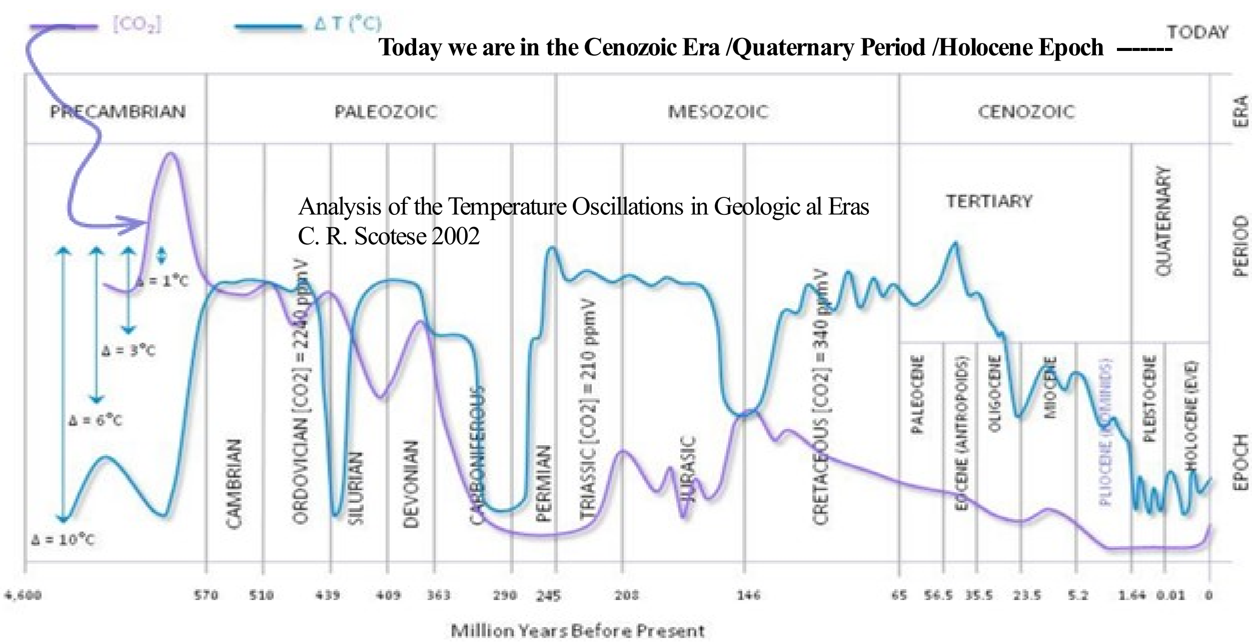
Simplified chart showing when the five major ice ages occurred in the past 2.4 billion yrs of Earth's history.



Era - a long period of time (intervals of hundreds of millions of years) which is marked by the definite beginning and end.
Period - a cycle of time (intervals of tens of millions of years long).
Epoch - a more recent period (intervals of tens of thousands to millions of years).

Today
Cenozoic
Quaternary
Holocene

The earth's temperature has oscillated between cold ice ages and hot "tropical" periods.



SECTION I. Paleological Isotopic Temp Record - the Vostok Ice Core - 1999

http://www.heartland.org/publications/NIPCC%20report/PDFs/Chapter%203.1.pdf
http://en.wikipedia.org/wiki/Ice_core
Petit, "Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica",
Nature 399: 429-436 CO2: Gas age CO2 (ppmv) File: co2vostokPetit.txt
Carbon Dioxide Information Analysis Center
http://cdiac.esd.ornl.gov/ftp/trends/temp/vostok/vostok.1999.temp.dat
Depth (m), Age of ice (yr BP), Deuterium content of the ice (D), Temperature Variation (deg C)

$Temp_{Vostok}$:= READPRN("vostok.1999.temp.txt' CO2Vostok := READPRN("CO2vostokPetit.txt")

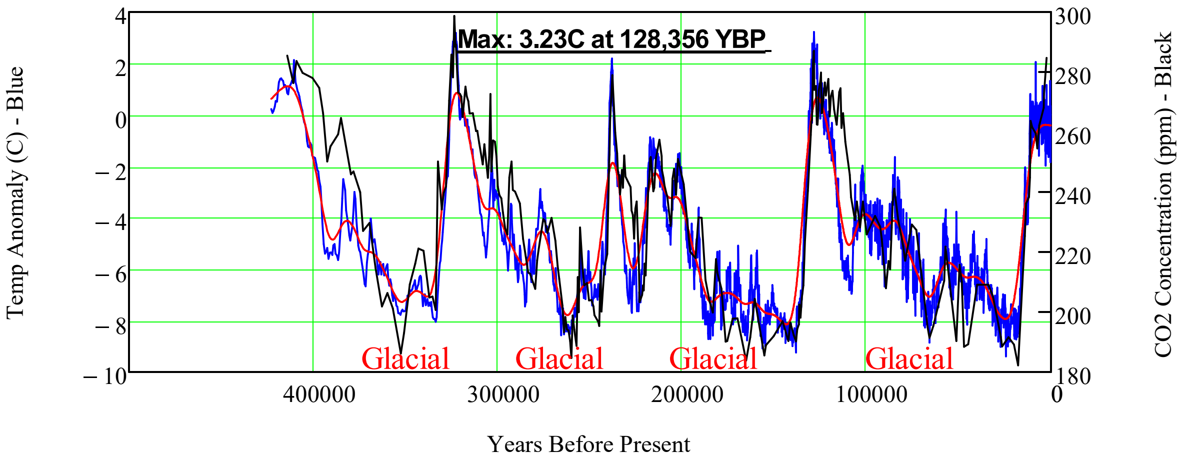
SECTION 1.2.1 Glacials/Ice Ages & their Temp Cycles over the Past 450,000 Yrs - Vostok Ice Core

Note: The 100,000 Year Cycle, which corresponds the the Earth's Orbital Variation

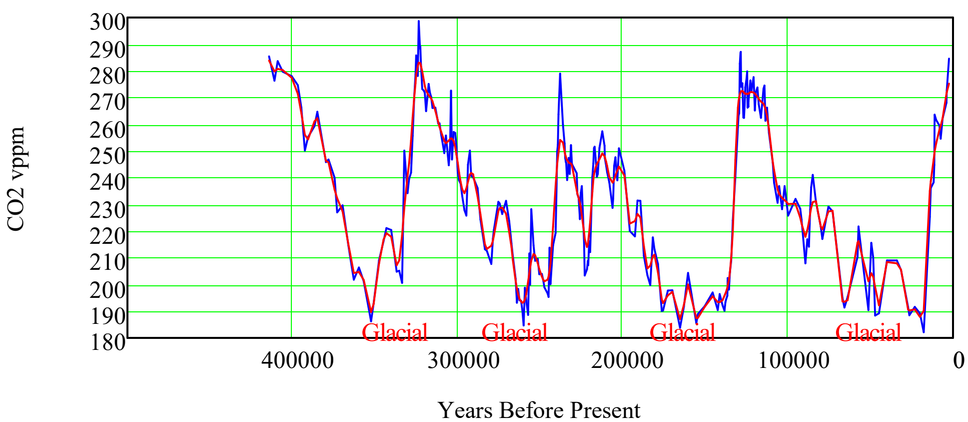
CO_2 actually lags temperature by around 1000 years.

IS CO_2 GHE SAVING US FROM ANOTHER GLACIAL?

2-1. Vostok Ice Temperature/Glacials (Blue) & CO2 (Black) over 420,000 Years

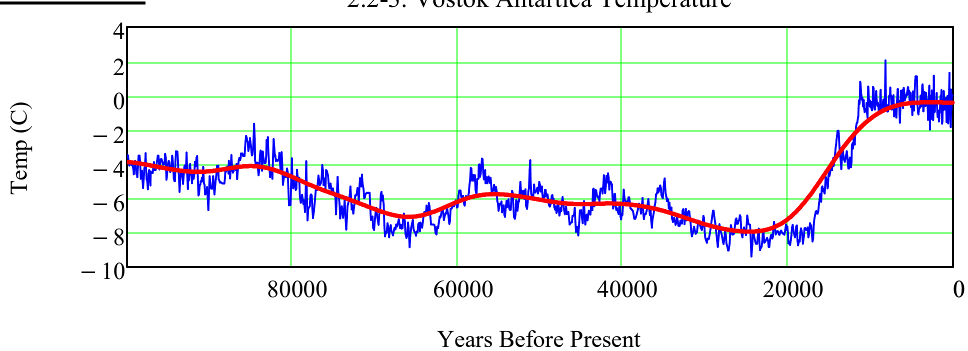


2-2. Vostok Antartica CO2 Concentration



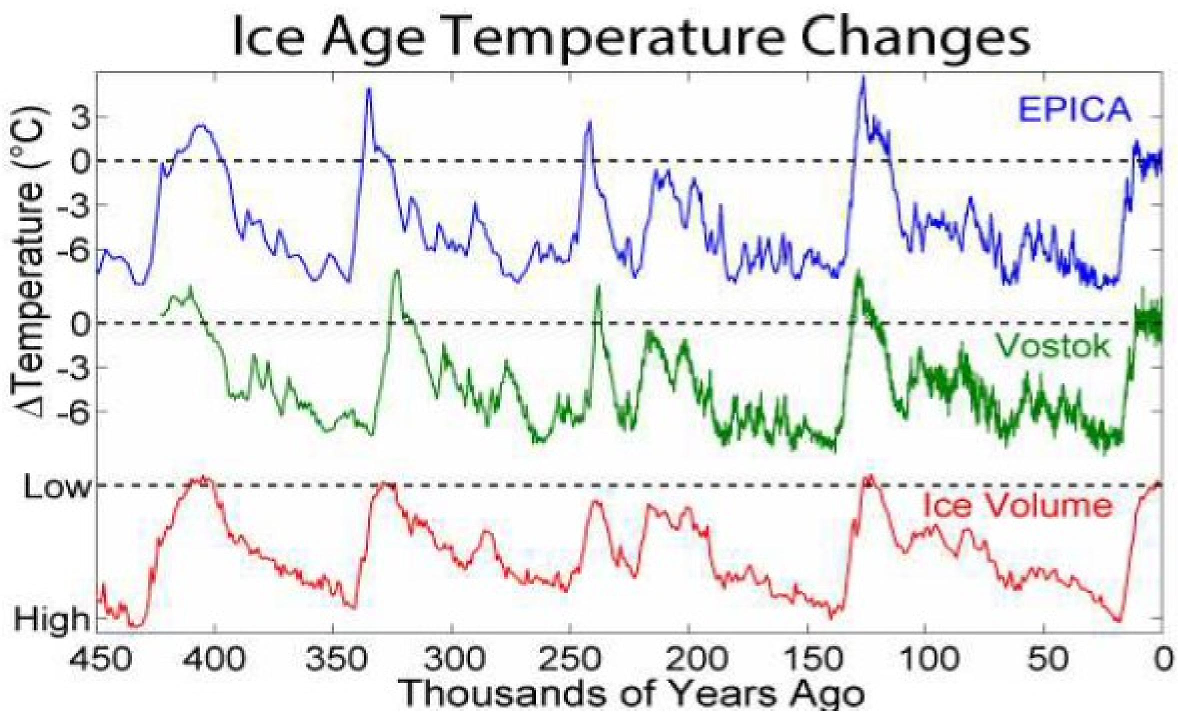
SECTION 1.2.3

2.2-3. Vostok Antartica Temperature



S I.3. The Global Temperature is inherently bistable. Intermediate Temps are unstable

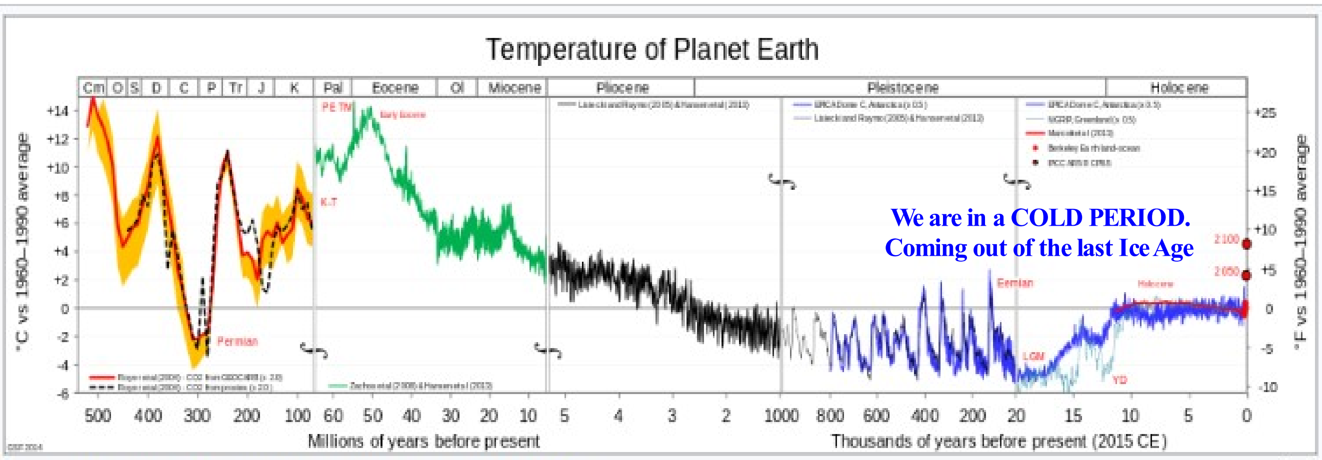
Paleo Climate Extremes - Bistable with rapid oscillation from ice age to warm Interglacials
Rapid 10,000 year increase in Global Temps followed by decline and long 100,000 year ice age.
Five Major Ice Ages in 1/10,000 Earth's History A Pedagogical "Toy" Bistable Climate Model, Katz
The sensitivity of IR opacity of water vapor pressure, combined with the sensitivity of equilibrium vapor pressures to temperature, qualitatively suggests a bistable system:
Plot Below: Ice Age Temperature Changes: https://en.wikipedia.org/wiki/File:Ice_Age_Temperature.png



What is the Normal Temperature of the Earth relative to the last 1/2 Billion Years?

Palaeotemperature graphs compressed together. Earth's Climate History for Last Half Billion Yrs:
Geologically, we are in a cold period, despite coming out of a glacial period.

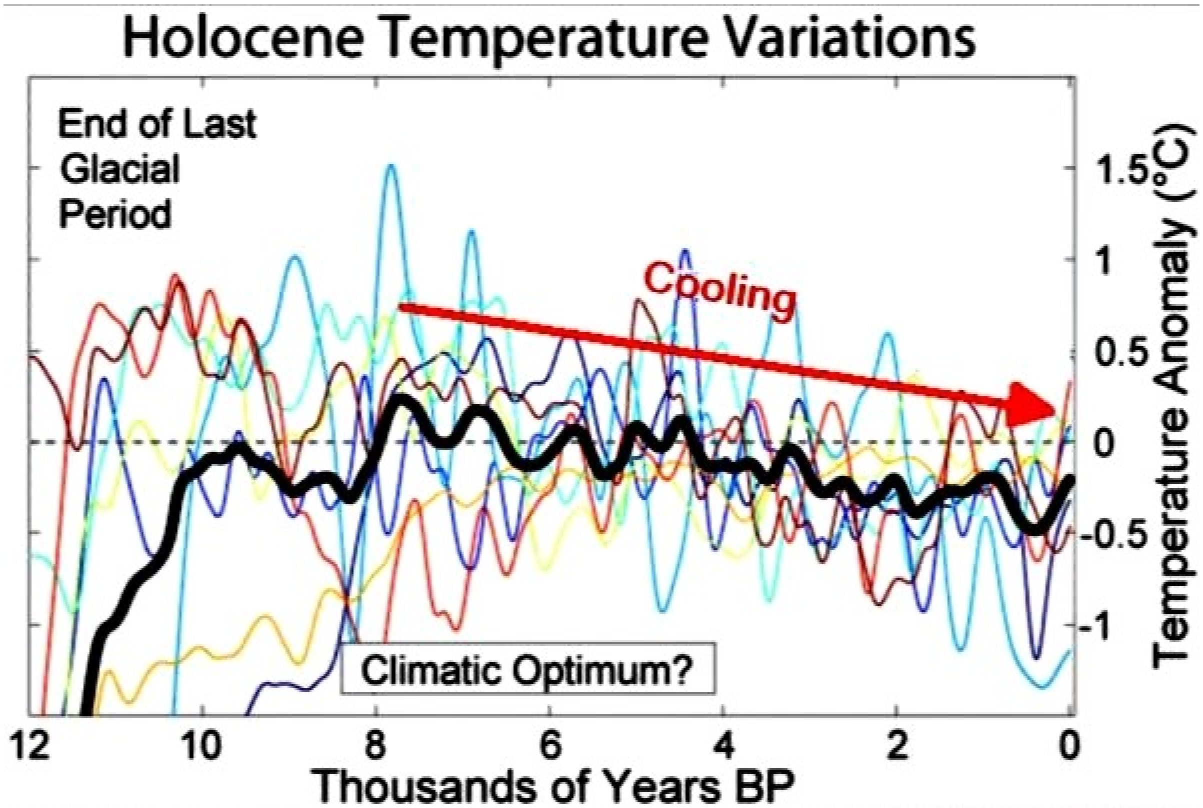
Paleoclimatology (in British spelling, palaeoclimatology) is the study of changes in climate taken on the **scale of the entire history of Earth**. It uses a variety of **proxy methods** from the Earth and life sciences to obtain data previously preserved within things such as rocks, sediments, ice sheets, tree rings, corals, shells, and microfossils. It then uses the records to determine the past states of the Earth's various climate regions and its atmospheric system. Studies of past changes in the environment and biodiversity often reflect on the current situation, specifically the impact of climate on mass extinctions and biotic recovery. https://en.wikipedia.org/wiki/Paleoclimatology#/media/File:Phanerozoic_Climate_Change.png



Palaeotemperature graphs compressed together

SECTION I.3. What is Normal Temp of Earth? Cenozoic IV - Holocene

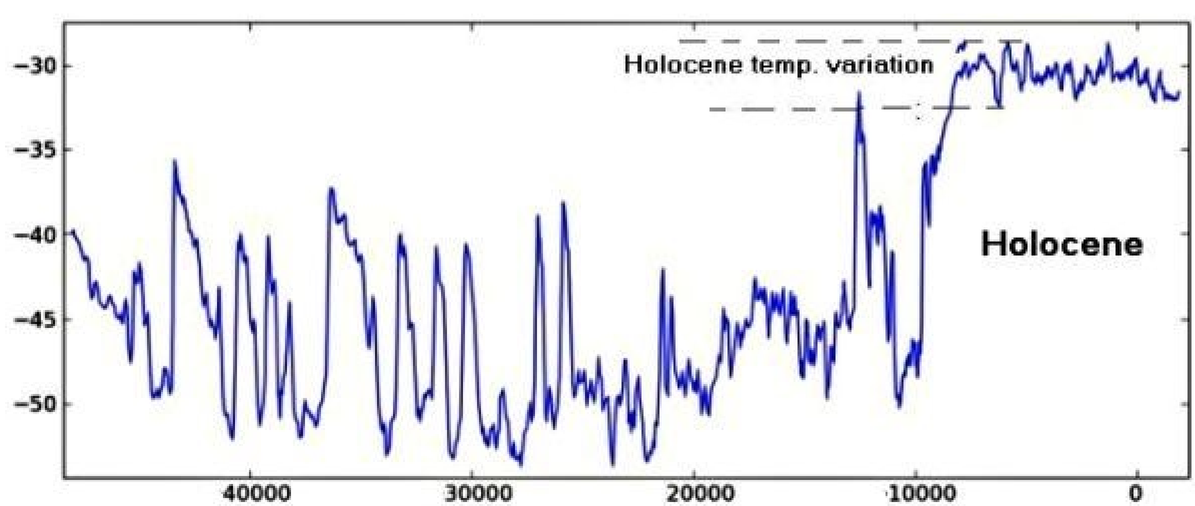
http://www.dandebat.dk/eng-klima7.htm#en



The Holocene Period

http://www.dandebat.dk/eng-klima7.htm#en

The interglacial Holocene has supported the development and growth of human civilizations, it has been the cradle of civilization. This unique climatic stability made the development of agriculture possible, it created the basis for the development of civilizations and enabled eventually the industrial revolution and consequently the modern world with its technique and myriads of people. Had we not had a window of about 10,000 years of stable climate with only small temperature variations, civilization would not have been nearly as developed, if at all existent, and Earth's population would have been only a fraction of the current.



4. The Little Ice Age and Medieval Warm Period in the Sargasso Sea (Local Area-May not be Typical)

Lloyd D. Keigwin

ftp://ftp.ncdc.noaa.gov/pub/data/paleo/contributions_by_author/keigwin1996/fig4bdata
http://lv-twk.oekosys.tu-berlin.de/project/lv-twk/002-Sargasso-Sea-surface-temperature.htm

This graph shows the Sargasso Sea surface temperature, which was derived from oxygen isotope ratios. This is an indicator of evaporation and, therefore, a proxy for sea-surface temperature. The Sargasso Sea is a two-million-mi2 body of water in the North Atlantic Ocean that lies roughly between the West Indies and the Azores from approximately 20-35oN. It is relatively static through its vertical column so that potential interference from mixing with other water masses and sediment sources is minimal. The isotopic ratios are derived from biotic debris that has precipitated onto the sea floor. Wide and abrupt variations in temperature are indicated. The relative temperature variations of the Little Ice Age (LIA) and the Medieval Warm Period (MWP) are prominently recorded in the data. Note that the temperature has been increasing since about 300 years before present (1700 A.D.) The horizontal line is the average temperature for this 3000-year period.

No indication of Error Bars. These are huge zig-zag changes, may be local shifts in currents, not global.

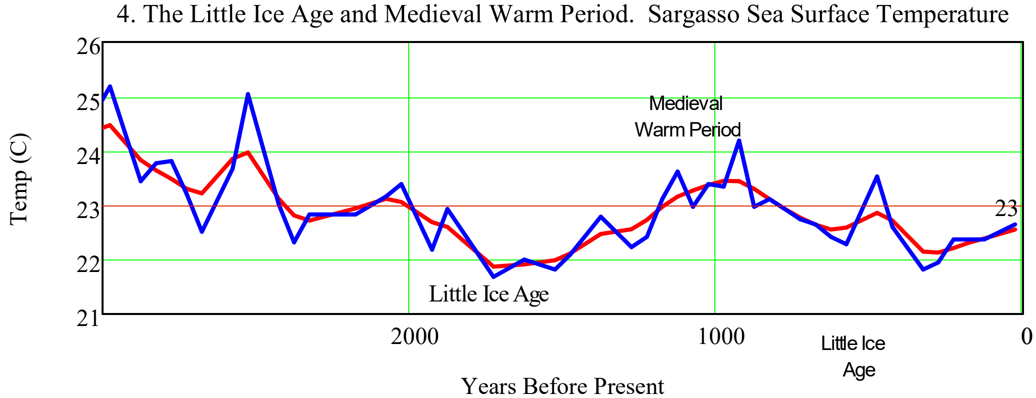
$Temp_{Paleo}$:= READPRN("Paleo Temp Keigwin 1996.TXT")

$Temp_{Recent}$:= READPRN("Paleo Temp Keigwin 1955-1995.TXT")

$Years := Temp_{Paleo}^{\langle 0 \rangle}$ $\quad$ $Temp := Temp_{Paleo}^{\langle 1 \rangle}$

TSmooth := ksmooth(Years, Temp, 200) $\quad$ WRITEPRN("TSmooth.txt") := TSmooth

TSmooth := READPRN("TSmooth.txt")

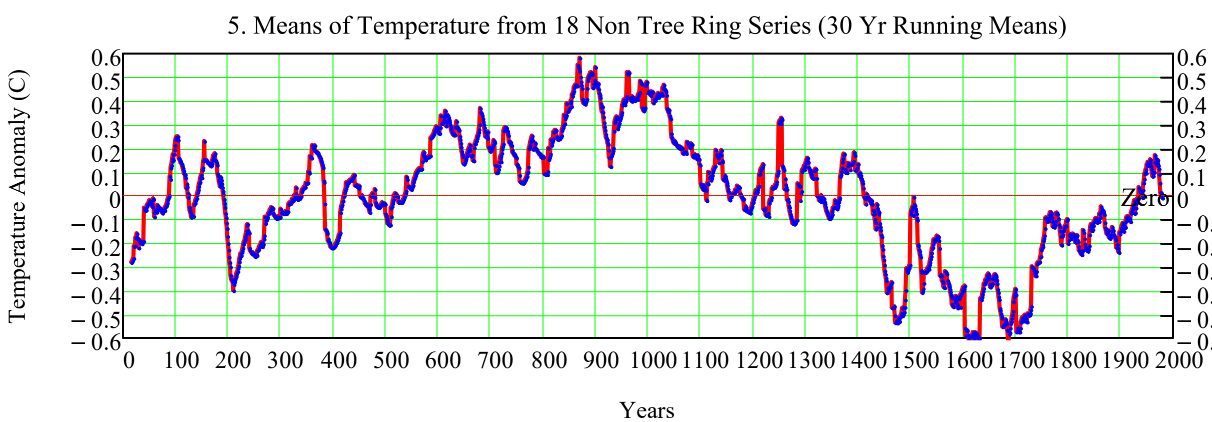


5. 2000-Year Global Temperature Reconstruction Based on Non-Tree Ring Proxies - Loehle - 2007

There are reasons to believe that tree ring data may not capture long-term climate changes (100+ years) because tree size, root/shoot ratio, genetic adaptation to climate, and forest density can all shift in response to prolonged climate changes, among other reasons Most seriously, typical reconstructions assume that tree ring width responds linearly to temperature, but trees can respond in an inverse parabolic manner to temperature, with ring width rising with temperature to some optimal level, and then decreasing with further temperature increases. Only 3 of the data sets is from Europe.

This reconstruction does not show the "hockey stick". **Thus the MWP and Little Ice Age were global.**

Loelhe := READPRN("LoehleE&E2007.csv") $\quad$ "Loehle, E&E Nov. 2007", calendar date,dev. deg C



6. Millennial (Yrs 1000 to 2000) temperature reconstruction intercomparison and evaluation

M. N. Juckes, M. R. Allen, K. R. Briffa

supplement: http://www.clim-past.net/3/591/2007/cp-3-591-2007-supplement.zip

mitrie_cited_reconstructions_v01.csv

Reconstructions; Name Date-Column (Color)

crowley_lowery 2000-4 Northern (Red) mann_jones 1999 -10 Global (Violet)
hegerl_etal 2006-6 " (Blue) oerlemans2005-12 " (Blue-Green)
huang_etal 1998-7 x 0 " (Green)

Observed "Instrument"

Supplement 2007 (Blue)
See SECTION II. 3: **Berkeley Land Surface (Not Land/Sea)** Temp Data - BerkTemp from 1800 to 2014 (Black)

BerkTemp := READPRN("BerkTemp3.txt") $BkYr := BerkTemp^{\langle 0\rangle} + \left(BerkTemp^{\langle 1\rangle} - 1\right)\cdot 0.08333$

BerkTempS := ksmooth(BkYr1800, BerkTemp1800, 10)

Mitrie_T2006 := READPRN("mitrie_instrumental_2006.txt")

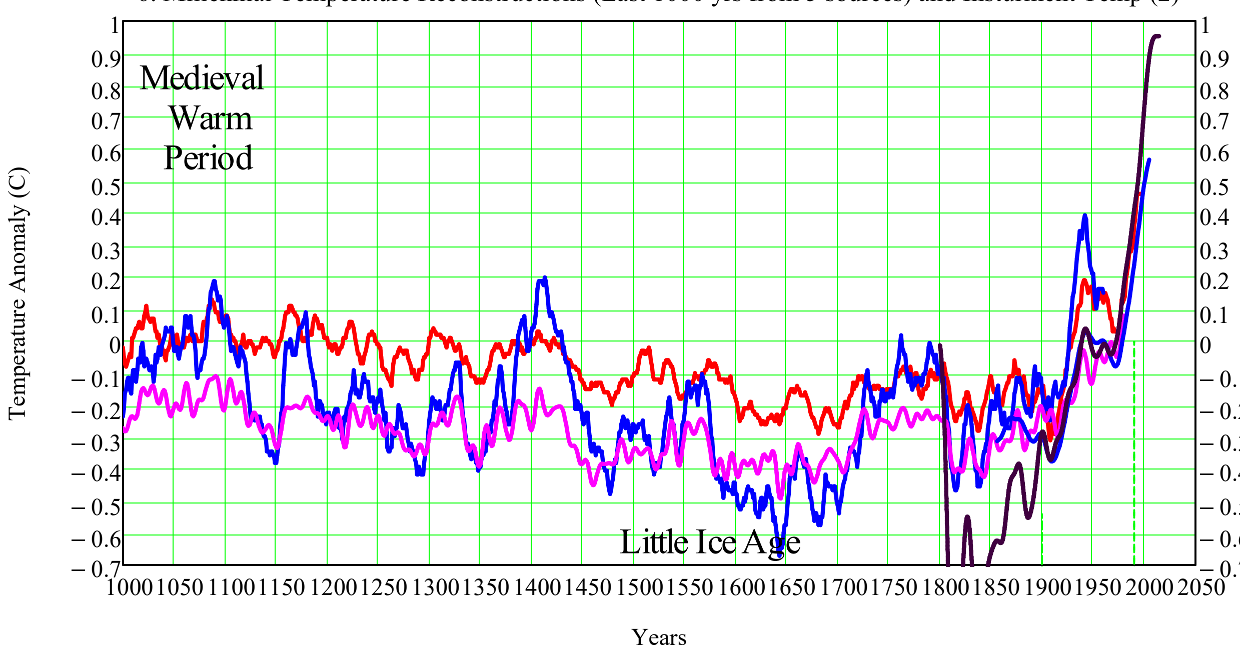
$Mitrie\_T2006S := ksmooth\left(Mitrie\_T2006^{\langle 0\rangle}, Mitrie\_T2006^{\langle 1\rangle}\right.$, Yr_{mr} := READPRN("YrMitrie.txt")

MitrieTempf := READPRN("mitrie reconstructions1.txt") MitrieTemp := MitrieTempf

cols(MitrieTempf) = 13 **Mann Hockey Puck Curve (Rose Color)**

Note that the rise within the last 100 years has been **much more rapid** than in the past.

6. Millennial Temperature Reconstructions (Last 1000 yrs from 5 sources) and Insturment Temp (2)



7. Temperature reconstructions and anomalies taken from the references listed below

ftp://ftp.ncdc.noaa.gov/pub/data/paleo/treering/reconstructions/n_hem_temp/briffa2001jgr3.txt

Re calibrations given in Briffa et al. (2001) J Geophysics Res 106, 2929-2941

Years: 1000 to 1997

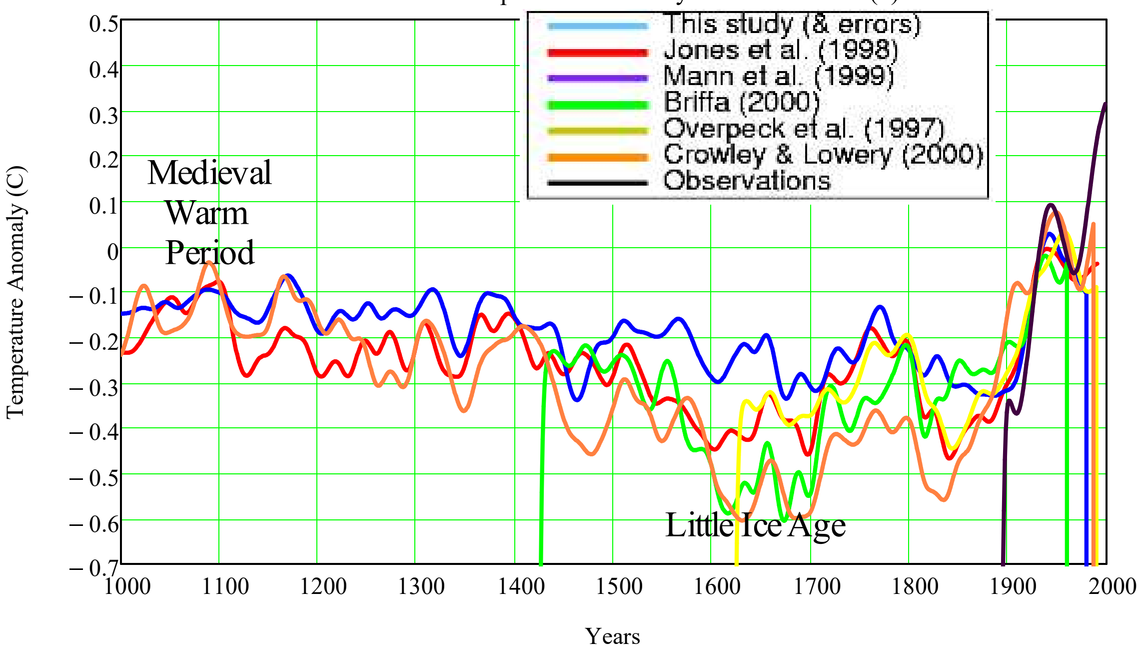
1: Jones et al. (1998) Holocene
2: Mann et al. (1999) Geophysics Res Lett
3: Briffa et al. (2001) J Geophysics Res
4: Briffa (2000) Quat Sci Rev
5: Overpeck et al. (1997) Science
6: Crowley & Lowery (2000) Ambio
7: Observed temperatures from Jones et al. (1999) Rev Geophys

TempMill7 := READPRN("Temp 7 Reconstructions-briffa.txt")

$YearMill := TempMill7^{\langle 0\rangle}$ TempS := MKSmooth(TempMill7)

MKSmooth is a Matrix ksmooth over 12 points

7. Millenial Temperature Anomaly Reconstructions (5)



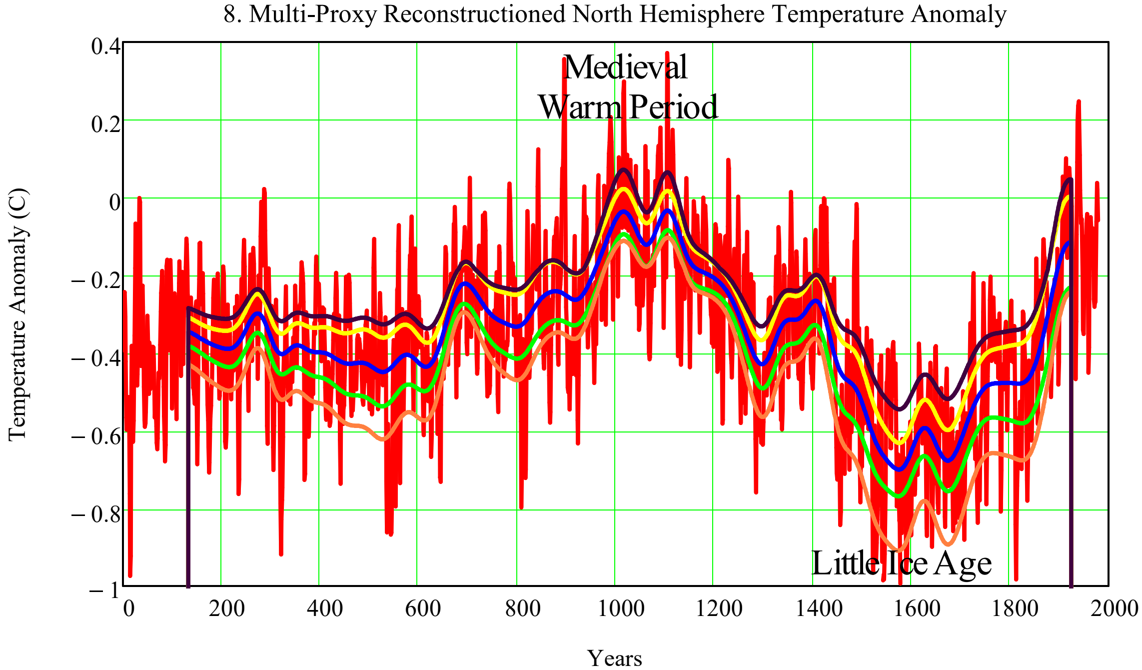
8. Highly variable Northern Hemisphere temperatures reconstructed from low- and high-resolution proxy data,

Anders Moberg1, Dmitry M. Sonechkin2, Karin Holmgren3, Nina M. Datsenko2, Nature 2005

NHTC := READPRN("Highly variable NH temps reconstructed-Moberg.TXT")

$NHTC_{yr} := NHTC^{\langle 0 \rangle}$ $NHTC_{Temp} := NHTC$ $cols(NHTC) = 9$

8. Multi-Proxy Reconstructioned North Hemisphere Temperature Anomaly



9. Roman, Medieval, and Modern Warm Periods - Modern same as Roman and Medieval

This reconstruction is the first to show a distinct Roman Warm Period c. AD 1-300, reaching up to the 1961-1990 mean temperature level, followed by the Dark Age Cold Period c. AD 300-800. The last 2,000 years of proxy reconstructed temperature variations for the Northern Hemisphere shows that the **Modern Warm Period (today) is not significantly different from the Medieval Warm Period of ~1,000 years ago,** or the Roman Warm Period of ~2,000 years ago (Ljungqvist, 2010):

Read Data from: Ljungqvist, F.C. 2009, N. Hemisphere Extra-Tropics 2,000yr Decadal Temperature Reconstruction
Source: ftp://ftp.ncdc.noaa.gov/pub/data/paleo/contributions_by_author/ljungqvist2010/ljungqvist2010.txt

	Line Color
Column 0: Begin Decade AD	
Column 1: End Decade AD	
Column 2: Reconstructed temperature anomaly in degrees C with respect to 1961–1990	Blue
Column 3: Upper Red Trace - 2 standard deviation error bar	Red
Column 4: Lower Red Tracde- 2 standard deviation error bar	Red
Column 5: Instrumental temperature data from the variance adjusted CRUTEM3+HadSST2 90–30°N	
Smoothed Data for Temp Anomaly	Heavy Green

Data Columns: Decade ReconT Up.err. Lo.err. Inst.Temp.

$$T_{LMillenial} := \mathrm{READPRN}(\text{"Temp NH 1 to 2000AD Ljungquist2010.txt"})$$

Smooth the Temp Anomaly Data, Green Line

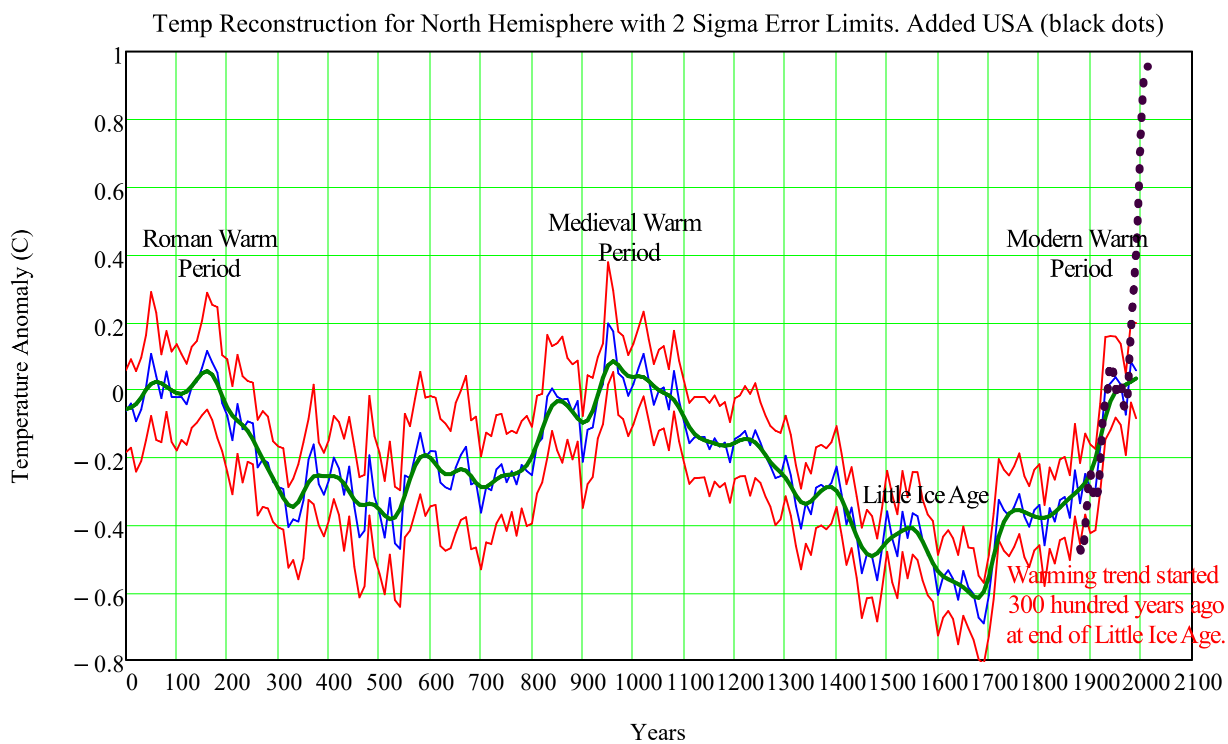
$$TLSmooth := \mathrm{ksmooth}\left(T_{LMillenial}^{\langle 0\rangle}, T_{LMillenial}^{\langle 2\rangle}, 50\right)$$

Lungquist Reconstruction data from year 0 to 2000. Added GISS USA 1880 to 2014 Data from Section II.2 below

$$USTemp := \mathrm{READPRN}(\text{"GISS NH TempC-2014.txt"})$$

$$USTS := \mathrm{ksmooth}\left(USTemp^{\langle 0\rangle}, USTemp^{\langle 13\rangle}\cdot 0.01, 10\right)$$

Units 0.01 Celsius,
J-D Mean in Col 13
Smooth for decadal
Black Dotted Trace



SECTION II A. Instrument Direct Temp: NOAA, NASA, Berkeley Earth Records

1. Global from 1880: 2006 & 2014 Datasets Direct Inst Temp Time Series Records

Latitude Range -90 to 90, Longitude Range -180 to 180
(from the Global Historical Climatology Network dataset)
http://www.co2science.org/cgi-bin/temperatures/ghcn.pl

BerkT := READPRN("BerkTemp2.txt")

$BYr := BerkT^{\langle 0 \rangle} + BerkT^{\langle 1 \rangle} \, 0.08333$

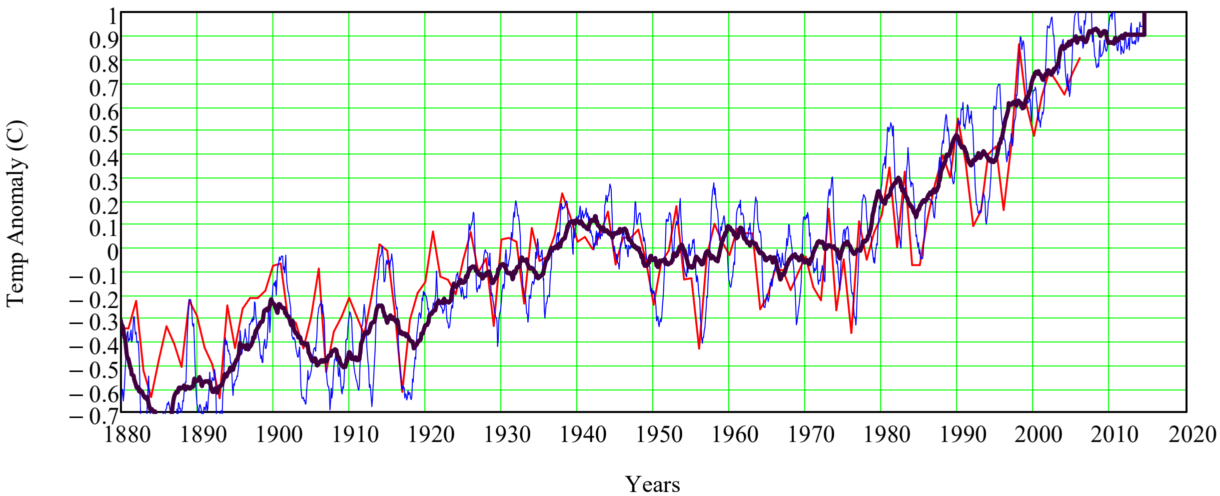
GHCN := READPRN("GHCN Temp Anomally 1880 - 2006.txt")

GHCN2 := READPRN("GHCN Temp Anomally 1880 - 2014.txt")

National Climatic Data Center's website: http://www.ncdc.noaa.gov/oa/climate/ghcn-monthly/index.php
Berkeley Earth Decadal Land-Surface Temperatures: http://berkeleyearth.org/summary-of-findings

$USATSmth := ksmooth\left(GHCN^{\langle 0 \rangle}, GHCN^{\langle 1 \rangle}, 5\right)$ WRITEPRN("USATSmth.txt") := USATSmth

1. Global Temp Anomaly: GHCN Dataset (Red) & Berkeley Land/Surface 1&5Yr Avg



2. NASA GISS Surface Temperature Analysis - US and Zonal 1880 - 2021

Goddard Institute Space Studies: Annual Mean US & Global Temperature Change

http://data.giss.nasa.gov/gistemp/graphs/Fig.D.txt - Blue & Red /Fig.A2.txt - Green
Annual and five-year running mean surface air temperature in the contiguous 48 United States (1.6% of the Earth's surface) relative to the 1951-1980 mean. 2014 http://data.giss.nasa.gov/gistemp/ Data in C.
This is an update of Figure 6 in Hansen et al. (1999). Fields: year Annual_Mean 5-year_Mean

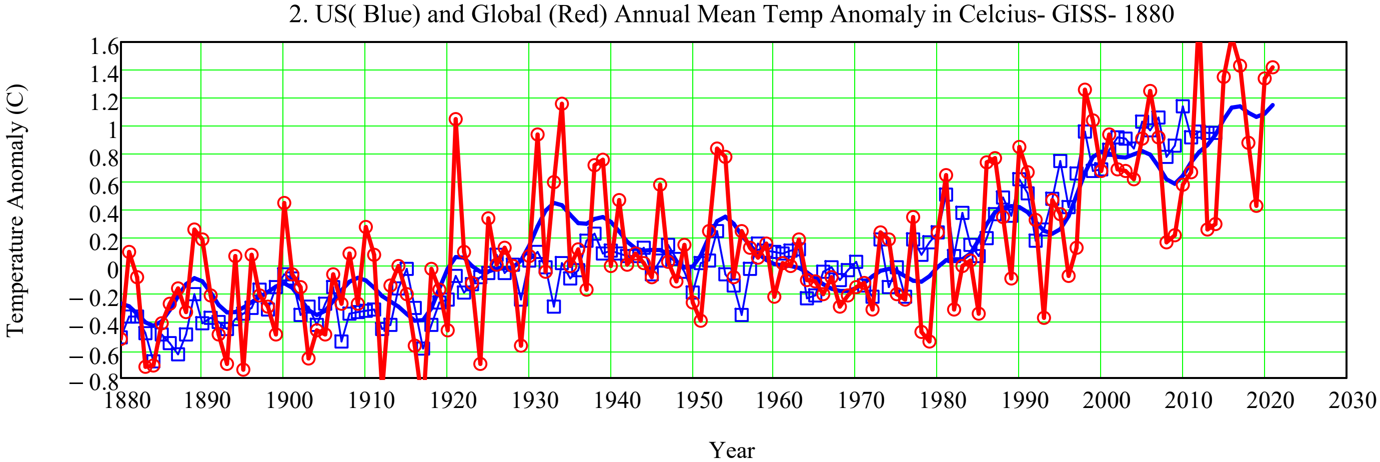
USTemp0 := READPRN("Contiguous 48 US Tempt Anomaly.TXT")
USTemp := READPRN("GISS NH TempC-2014.txt")
GTemp0 := READPRN("GISS NASA Global Temp Mean 1800-2021.TXT")
GTemp := READPRN("GISS GLB TempC-2014.TXT")

Red 2009 Averaging Method
Units 0.01 Celsius, J-D Mean in Col 13
reen 2013 Revised Method
Units 0.01 Celsius, J-D Mean in Col 13

$GTemp0S := ksmooth\left(GTemp0^{\langle 0 \rangle}, GTemp0^{\langle 1 \rangle}, 5\right)$

Note: Until 2008, the warmest year in the US was 1934. Currently 2020 is the hottest year

2. US(Blue) and Global (Red) Annual Mean Temp Anomaly in Celcius- GISS- 1880



2A. Seasonal Global Temp. Anomaly 8 - 20 Yr. Cycles since 1881

Use GISS Gobal Temp. Data: https://data.giss.nasa.gov/gistemp/

The basic Goddard Institute Space Studies (GISS) temperature analysis scheme was defined in the late 1970s by James Hansen when a method of estimating global temperature change was needed for comparison with one-dimensional global climate models. Derived from the MERRA2 reanalysis.
MERRA2: Advances made in the assimilation system that enable assimilation of modern hyperspectral radiance and microwave observations, along with GPS-Radio Occultation datasets.
Temperature anomalies indicate how much warmer or colder it is than normal for a particular place and time. For the GISS analysis, normal always means the average over the 30-year period 1951-1980 for that place and time of year. This base period is specific to GISS, not universal.

Extract Global Surface Temp. Anomaly Data for Seasonal Cycles over Eight 20 Year Periods from 1980

Global Temperature Data: GISSTemp := READPRN("GISS-NASA MONTHLY TEMP 1980 to 2022.txt")

Start the 20 Yr. Rows at: $Yr20(n) := n \cdot 240 + 12$ **NOTE:** To use the latest 2021 data, the 20 Year Periods start at 1801.

$mn := 0, 1 .. 11 \quad Months_{mn} := mn \quad Month := Months + 1$

$$TempSeasons(M) := \left| \begin{array}{l} TempM \leftarrow submatrix(M, 12, 23, 1, 1) \\ \text{for } yr \in 1 .. 7 \\ \quad TempM \leftarrow augment(TempM, submatrix(M, Yr20(yr), Yr20(yr) + 11, 1, 1)) \\ TempM \end{array} \right.$$

$TMS := TempSeasons(GISSTemp)$

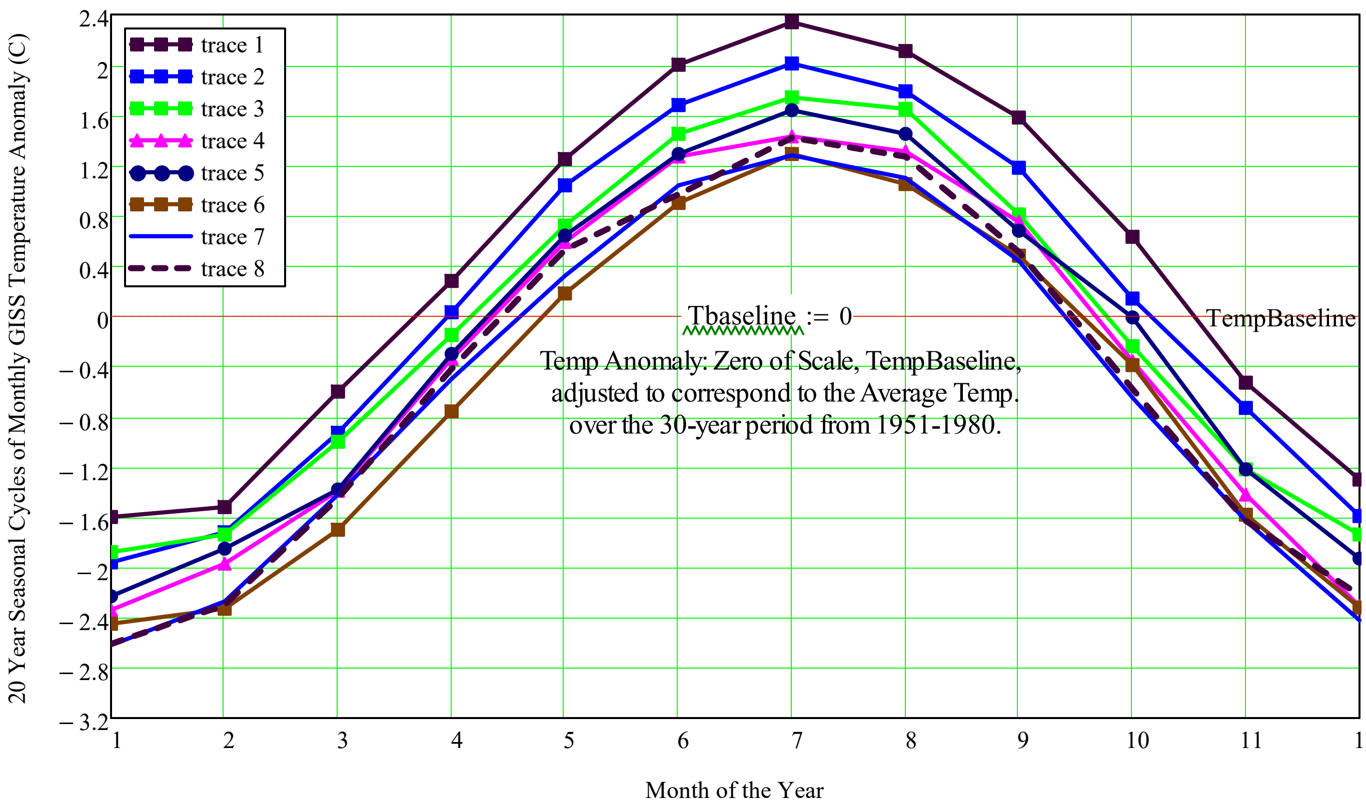
NOTE THE HUGE INCREASE IN TEMPERATURE RISE OVER THE LAST VICENNIAL!

2021 was sixth hottest year on record, despite cooling La Niña, and top 8 warmest years have all been since 2013.

$max\left(TMS^{\langle 7 \rangle}\right) - max\left(TMS^{\langle 6 \rangle}\right) = 0.33 \qquad mean\left(TMS^{\langle 7 \rangle}\right) - mean\left(TMS^{\langle 6 \rangle}\right) = 0.30833$

Traces 1 - 8: Correspond to the 20 Year Cycle of Years: 2021, 2001, 1981, 1961, 1941, 1921, 1901, 1881, respectively.

Eight Seasons of 20 Year Cycles of GISS Temp Anomaly from 1881 to 2021. Top Trace 1 is Curve for 2021 Season



3. Berkeley Earth Land Average Temp and Simple CO2 and Volcano Temperature Fit

Focused (Richard A. Muller) on land temperature data analysis. Berkeley Earth was founded in early 2010 with the goal of addressing the major concerns of "skeptics" regarding global warming and the instrumental temperature record. The project's stated aim was a "transparent approach, based on data analysis.

http://berkeleyearth.org/summary-of-findings

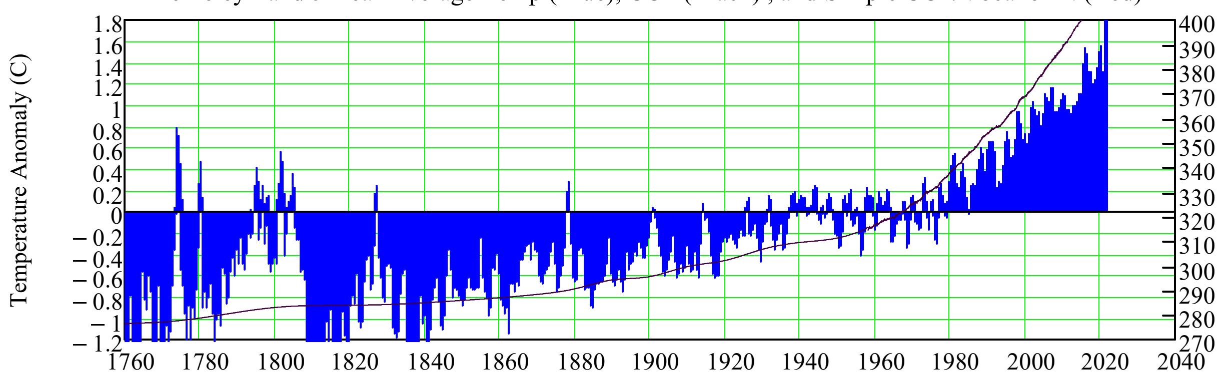
Yr , Month, TempAnom&Unc: 1Yr, 5 Yr, 10Yr, 20 Yr

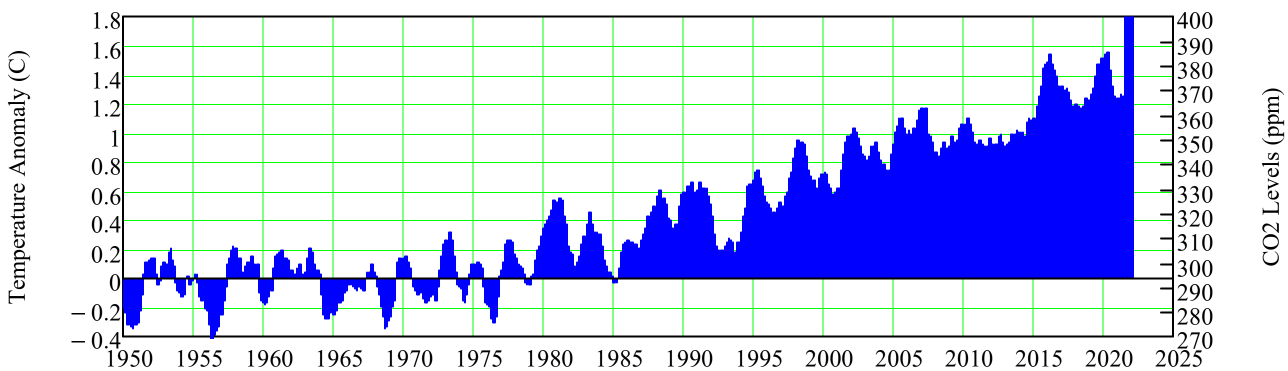
BCVFit := READPRN("forcing-comparison-data2.txt") ==> Year , CO2, Volcano, ln(), Volcano, T, Tfit

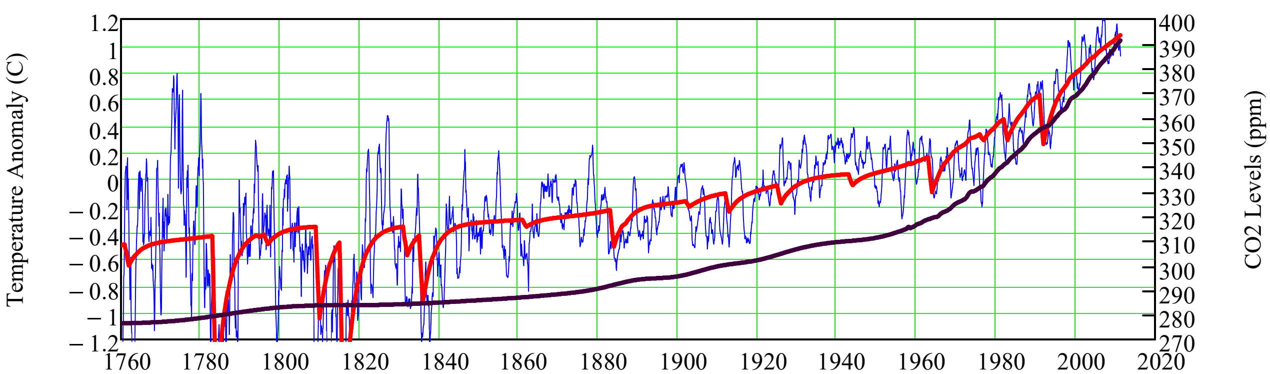
$\alpha := 8.342105 \quad \beta := 4.466369 \qquad \gamma := -0.01515 \qquad Fit := \alpha - 8.8 + \beta \cdot \ln\left(BCVFit^{\langle 1 \rangle} \cdot 277.3^{-1}\right) + \gamma \cdot BCVFit^{\langle 2 \rangle}$

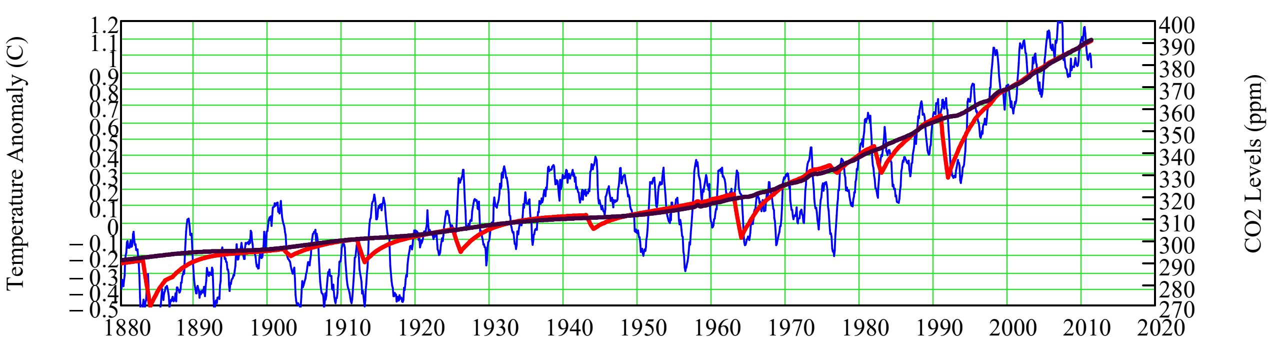
MLCO2 := READPRN("NOA_Mauna_Loa_Monthly_CO2_22.txt")

Berkeley Land 5 Year Average Temp (Blue), CO2 (Black) , and Simple CO2/Vocano Fit (Red)









4. Hadley Center- Climate Research Unit: HadCrut Global Land Air Data 1860 to 2015:
See Section III-A (CO2) - 5 for Plots of CO2 vs HadCrut Global Temp.

http://www.cru.uea.ac.uk/cru/data/temperature/CRUTEM4-gl.dat Monthly and Yearly Data

Read HadCrut Formatted File (Different Number of Cols/Row): HadCrutE4 = Insert File Input (HadCrutE4.dat)

Read every other row

5. GISS Zonal: Annual mean Land-Ocean Temperature - Selected zonal means 1880 - 2013

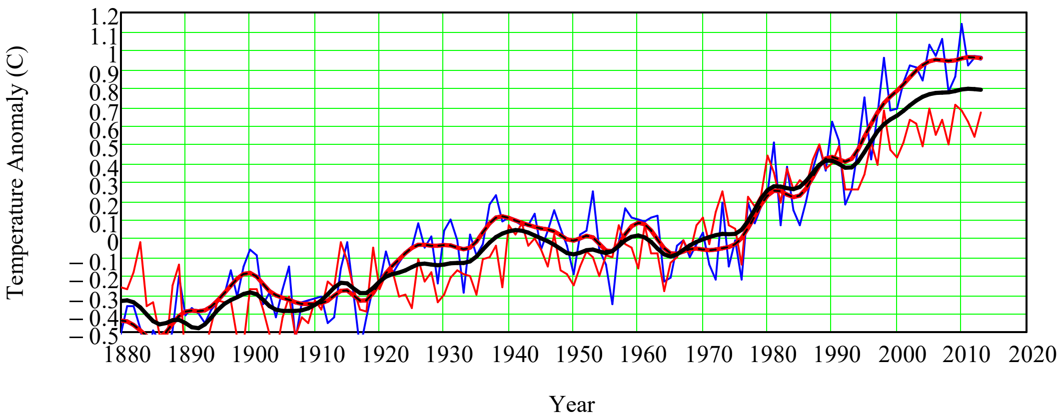
http://data.giss.nasa.gov/gistemp/tabledata_v3/ZonAnn.Ts.txt

Fields: Year Glob NHem SHem -90N -24N -24S -90N -64N -44N -24N -E

USTSmth := READPRN("USTSmth1.txt")

$USZTemp := READPRN("ZonAnnT1880-2013.txt")$ $NHTSmth := ksmooth\left(USZTemp^{\langle 0\rangle}, USZTemp^{\langle 2\rangle}\cdot 0.01, 5\right)$

$USZTSmth := ksmooth\left(USZTemp^{\langle 0\rangle}, USZTemp^{\langle 3\rangle}\cdot 0.01, 5\right)$ $GTSmth := ksmooth\left(USZTemp^{\langle 0\rangle}, USZTemp^{\langle 1\rangle}\cdot 0.01, 5\right)$



6. NOAA: No Slowdown in Global Warming

Science: Possible artifacts of data biases in the recent global surface warming hiatus - June 4, 2015

ftp://ftp.ncdc.noaa.gov/pub/data/scpub201506/NewAnalysis/NewAnalysis.aravg.mon.land_ocean.90S.90N.asc

ftp://ftp.ncdc.noaa.gov/pub/data/scpub201506/NewAnalysis/NewAnalysis.aravg.mon.land.90S.90N.asc

Global_New := READPRN("NewAnalysis.aravg.ann.land_ocean.90S.90N.asc")

Global_NewMon := READPRN("NewAnal.mon.global.txt")

$rd := rows(Global\_New)$ $Date_{1950} := submatrix\left(Global\_New^{\langle 0\rangle}, 70, rd-1, 0, 0\right)$

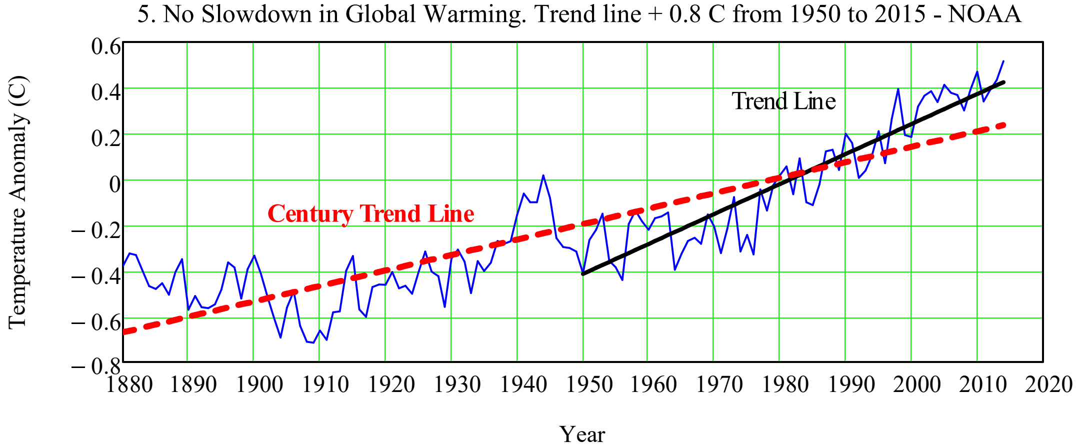
$L_{1950} := line\left(Date_{1950}, submatrix\left(Global\_New^{\langle 1\rangle}, 70, rd-1, 0, 0\right)\right)$

$Trend_{1950}(Year) := L_{1950_0} + L_{1950_1}\cdot Year$ $\Delta T1950 := L_{1950_1}\cdot 65 = 0.85271$

$L_{1880} := line\left(Global\_New^{\langle 0\rangle}, Global\_New^{\langle 1\rangle}\right)$ Last 65 Year: $\Delta T\_Century := L_{1950_1}\cdot 100 = 1.31186$

$Trend_{1880}(Year) := L_{1880_0} + L_{1880_1}\cdot Year$ $Temp\_Change\_Century := L_{1880_1}\cdot 100 = 0.67615$

Global Temperature Change per Century = +0.68 C. Increased to +



Contrary to much recent discussion, the latest corrected analysis shows that and there has been no slow down.

[7A. Satellite: University of Alabama Huntsville & 7B. http://www.drroyspencer.com/latest-global-temperatures]

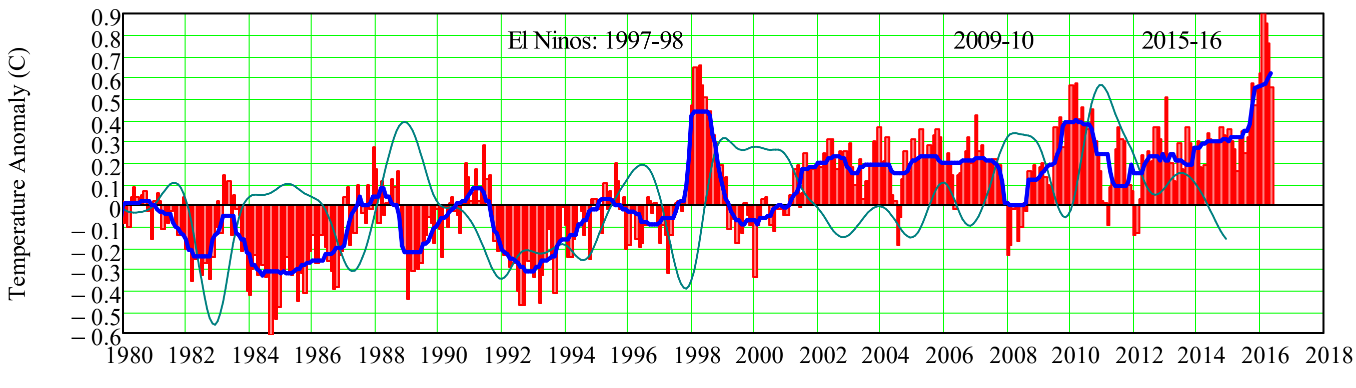
http://vortex.nsstc.uah.edu/data/msu/t2lt/uahncdc_lt_5.6.txt

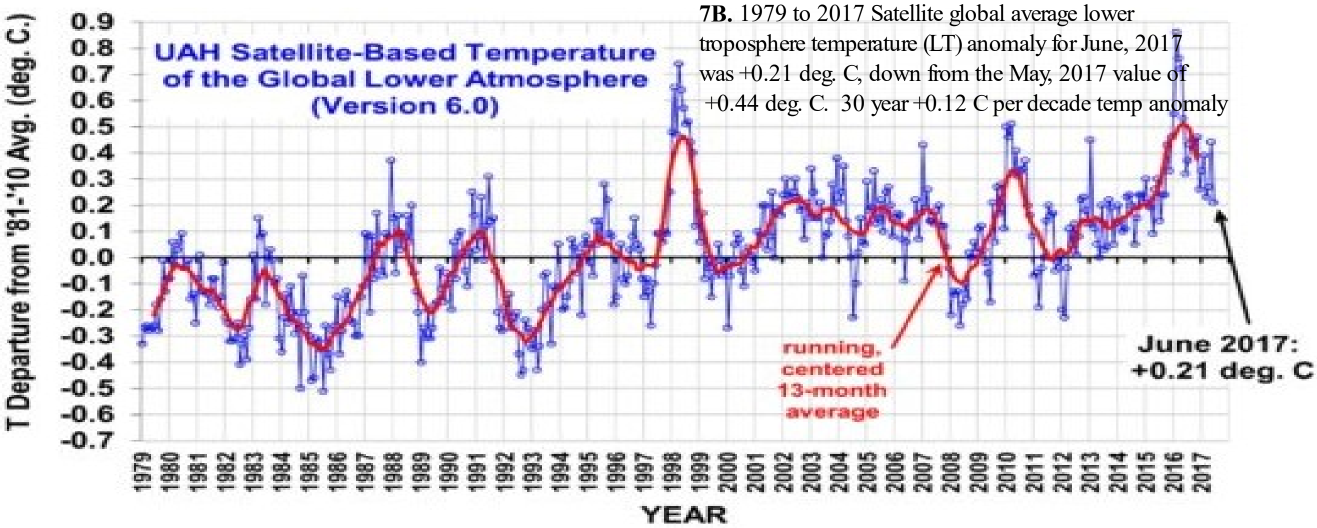
$$Tsat13 := READPRN("uahncdc\_lt\_5\text{-}6\text{-}x.txt")$$

$$Yrsat13 := Tsat13^{\langle 0 \rangle} + \left(Tsat13^{\langle 1 \rangle} - 1\right)\cdot\frac{1}{12}$$

Southern Oscillation Index (SOI): A standardized index based on the observed sea level pressure differences between Tahiti and Darwin.

Ice Ages and Interglacials - Page 219
SOI Data: http://www.cpc.ncep.noaa.gov/data/indices/soi



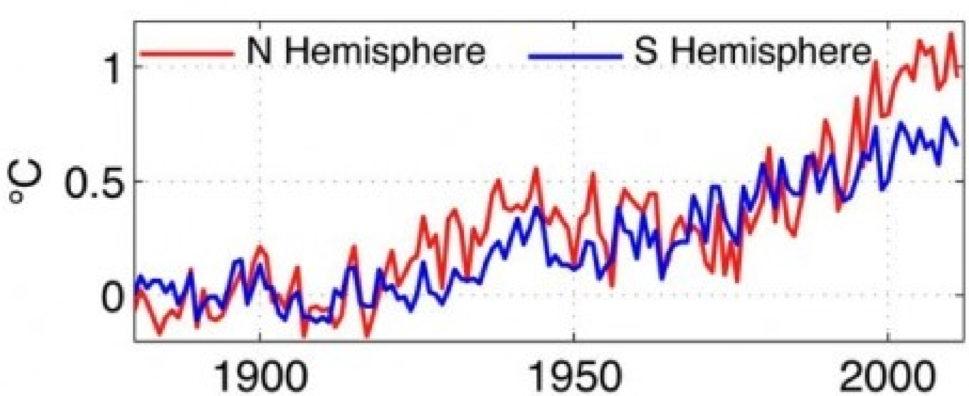


7B. 1979 to 2017 Satellite global average lower troposphere temperature (LT) anomaly for June, 2017 was +0.21 deg. C, down from the May, 2017 value of +0.44 deg. C. 30 year +0.12 C per decade temp anomaly

8. Greater Temperature Asymmetry of Northern versus Southern Hemisphere Since 2000

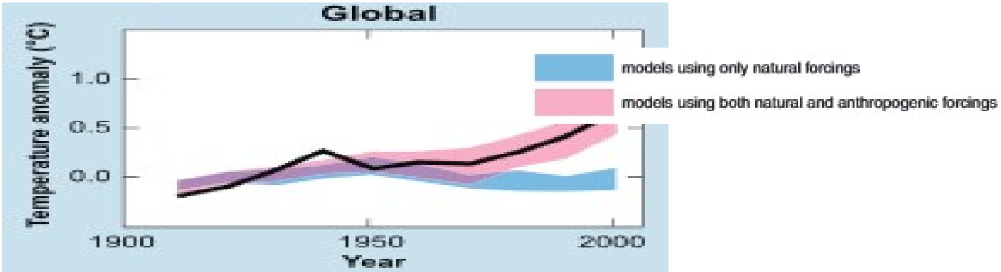
Interhemispheric Temperature Asymmetry over the Twentieth Century and in Future Projections - Andrew R. Friedman
Journal of Climate, Feb 2013

Northern Hemisphere has **more land and less ocean** than the Southern Hemisphere, and oceans warm relatively slowly. Prior to 1980, the long-term trend that would have been there from increased greenhouse gases during the 20th century was essentially canceled out by man-made stratospheric sulphate aerosol emissions, which mostly cooled the Northern Hemisphere, the study found. Anthropogenic aerosols are believed to have masked GHGs over the middle of the twentieth century.



10. IPCC Report "Climate Change 2007: "Synthesis Report - Summary for Policymakers.

Comparison of observed continental- and global-scale changes in surface temperature with results simulated by climate models using **either natural or both natural and anthropogenic forcings**. Decadal averages.



11. Analysis: Climate Change Stats - Mean Temp Rise is Non Monotonic - 70 Year Cycles

Reference: "ABRUPT GLOBAL TEMPERATURE CHANGE AND THE INSTRUMENTAL RECORD," Menne

Use GISS Global Temp Data: "GISS NASA Global Temp Mean Fig2A.TXT" from Above

Break into Four 35 Year Periods: 1880 to 1910, 1911 to 1945, 1946 to 1980 and 1981 to 2010

Use Analysis from: **http://www.leapcad.com/Climate_Analysis/Cycles_and_Trends_Average_Temp.xmcd**

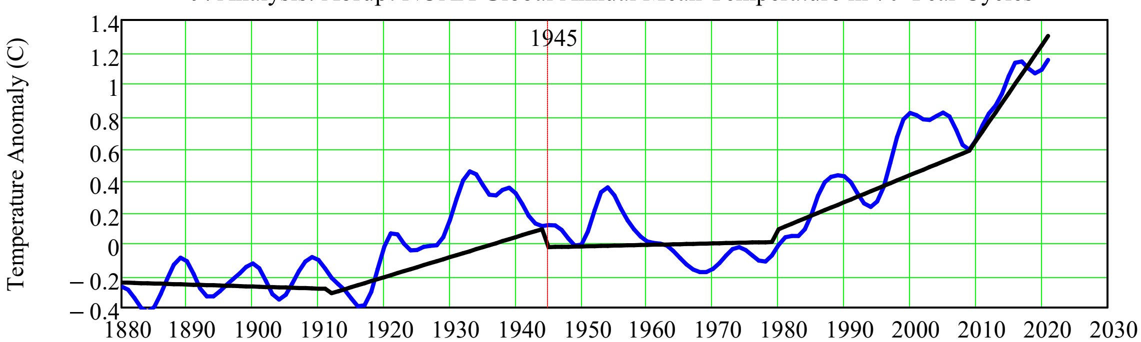
GTemp2010 := READPRN("GISS NASA Global Temp Mean Fig2A.TXT") T_{abrupt} := READPRN("GAbrupt.txt")

Note: Previously, Temperature Plateaus and then Climbs in 60 Year Cycles

"The solar system oscillates with a 60-year cycle due to the Jupiter/Saturn three-synodic cycle and to a Jupiter/Saturn beat tidal cycle" 9.1 year moon orbital cylce. See Scafetta "Empirical evidence for a celestial origin of .."

After 2010, Temperature Rise No Longer Plateaus.

9. Analysis: Abrupt NOAA Global Annual Mean Temperature in 70 Year Cycles



Correlation Coefficient: $\mathrm{corr}\left(GTemp2010^{\langle 2\rangle}\cdot 0.01, T_{abrupt}\right) = 0.98589$ $\mathrm{Stdev}\left(T_{abrupt}\right) = 0.23426$

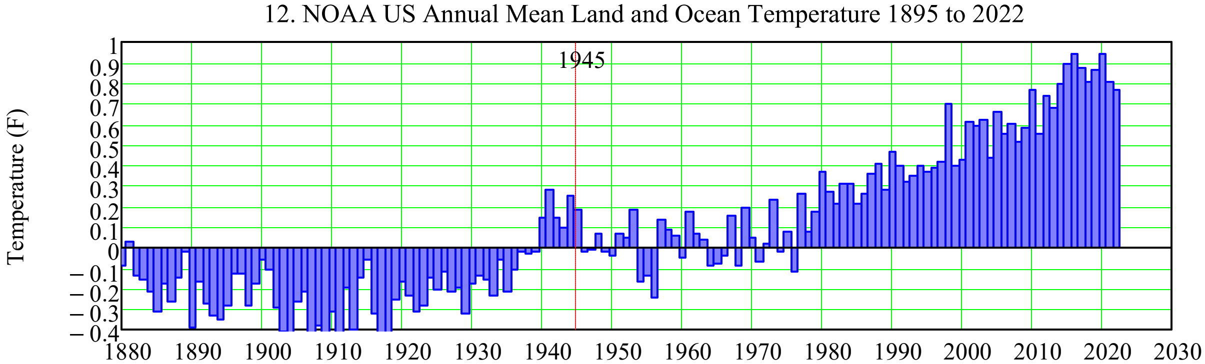
t Test: $t := \frac{0.98622}{0.23434} = 4.2085$ These 70 year cycles are statistically significant

12. NOAA Land and Ocean Mean Yearly Temperature

https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/global/time-series

TCF := READPRN("NOAA Mean Anomoly 1880-2022.txt")

12. NOAA US Annual Mean Land and Ocean Temperature 1895 to 2022



SECTION II B. Concerns about the Concept of Averaged Global Temperature

"Does a Global Temperature Exist?" - Essex, Ross McKitrick, and Bjarne Andresen -2006
We are all acquainted with the idea of an average. You may have a sequence of numbers and take the average. This particular example is a mathematical average, but it is not a physical meaningful one. You may take the average of heights or weights of a number of people in a room. This gives a number that has some physical meaning. These particular type of quantities, such as height and weight, are called **extensive**, that is, they vary with the size or volume of a quantity.

Temperature is an **intensive** quantity. It does not depend on the size. It is the state of a system. A sum over an intensive quantity has no physical meaning. For example, the temperature of the light of a laser pen is about 10^{11} K. Hotter than the interior of our sun. The average of the temperature of a laser pen, an oven, and a person has no physical meaning.

Radiation is a method of heat transfer due to emission of electromagnetic waves. The Stefan–Boltzmann law is a statistical law which states that the radiated EM energy per time from a blackbody in equilibrium, that is, at a common temperature, is proportional to T^4. A global temperature of the earth (from latent heat, kinetic convective heat transfer, scattering) $\propto$ to $E^{1/4}$ is not a meaningful quantity. Radiation temperature of a real body is determined by the ratio of absorptivity to emissivity and not the amount of available power. Cloud albedo varies with height & GHG condensation.

The temperature of the earth is a **temperature field.** Temperature varies with location, time, insolation, clouds, volcanic activity, air currents/pressure differences, land/city effects, GHG concentrations, measurement accuracy, and it is chaotic. Temperature T(x,t) can be mapping to each point x on the earth at a particular time, t. At a particular point, the temperature can fall and rise. It varies from night to day, summer to winter, and year to year. If we take an average of the temperature on the same day at three different points, say Paris, Nome Alaska, and Miami Florida, the average would be physically meaningless. There can be heating at one location and cooling at another. Thus the concept of warming is ill-posed. The temperatures are not in equilibrium. The average represent no unique physical variable. Different methods of averaging of a temperature field can give any value within that field. **There is no unique statistically meaningful -random fluctuation-average value**. The average of a temperature field is not a physical temperature. It does not represent a state of a physical object. Nor does it represent a proxy for a global energy. A single/local hot object does indicate internal energy, but there is an associated heat capacity and it is a local concept.

Weather is not driven by temperature, but temperature differences. A temperature difference results in a flow of heat. In the atmosphere it can result in a difference of pressure or wind. Temperature changes can result in different chemical and biological reaction rates.

The global "temperature" given by say, NOAA, is the result of applying complex formula to "average" different temperature at different points on the earth, each given a different weighting, taken at different times of day. The result does not have physical meaning. There is no NIST or international standards organization ISO that defines a global temp. Nor is there any way to define a meaningful proxy from the temperature field. It could be **used as an indicator**.

Essex et all state that there is no meaningful global temperature. Averages of temperatures are physically meaningless.

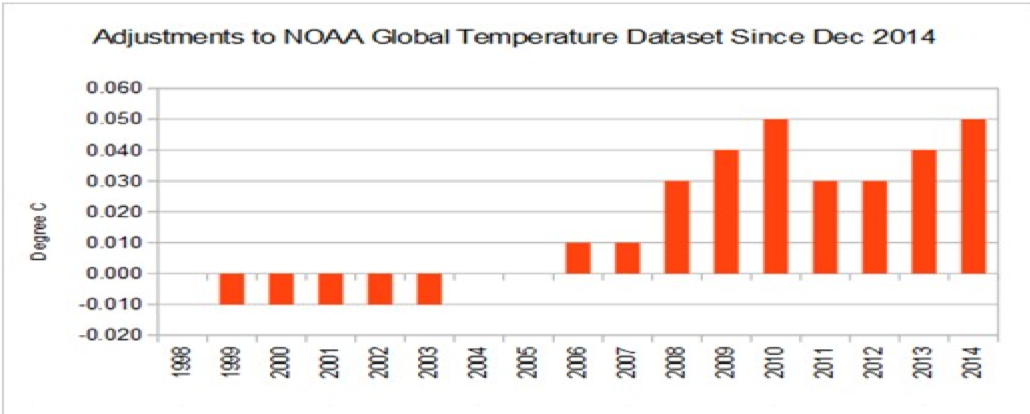
Alternative Point of View to Essex et all above
http://www.realclimate.org/index.php/archives/2007/03/does-a-global-temperature-exist/
The common arithmetic mean is just an estimate that provides a measure of the Center value of a batch of measurements (Center of a cloud of data points, and can be written more formally as the integral of x f(x) dx. The above argument is irrelevant in the context of a climate change because it missed a very central point. CO_2 affects all surface temperatures on Earth, and in order to **improve the signal-to-noise ratio**, an ordinary arithmetic mean will **enhance the common signal** in all the measurements and **suppress the internal variations** which are spatially incoherent (e.g. not caused by CO_2 or other external forcings). Thus the choice may not need a physical justification, but is part of a scientific test which enables us to get a clearer 'yes' or 'no'. One could choose to look at the global mean sea level instead, which does have a physical meaning because it represents an estimate for the volume of the water in the oceans, but the choice is not crucial as long as the indicator used really responds to the conditions under investigation. And **the global mean temperature is indeed a function of the temperature over the whole planetary surface.**

It is old and traditional knowledge that the **temperature measurements** made in meteorological and climatological studies are supposed to be **representative of a certain volume of air**, i.e. the arithmetic mean. In the above, Essex et al.,argue that it is not really physical, but surely the temperature measurements do have clear practical implications? **Temperature itself can be inferred** directly from **several physical laws, such as the ideal gas law, first law of thermodynamics and the Stefan-Boltzmann law, so it's not the tempera**ture itself which is 'unphysical'. Even though the final temperature of two bodies in contact may not be the arithmetic mean, it will still be a weighted arithmetic mean of the temperatures of the two initial temperatures if no heat is lost to the surroundings. Besides, grid-box sizes for numerical weather models often have a minimum spatial scale of 10-20km, and the temperature may be regarded as a mean for this scale. Numerical weather models usually provide useful forecasts.

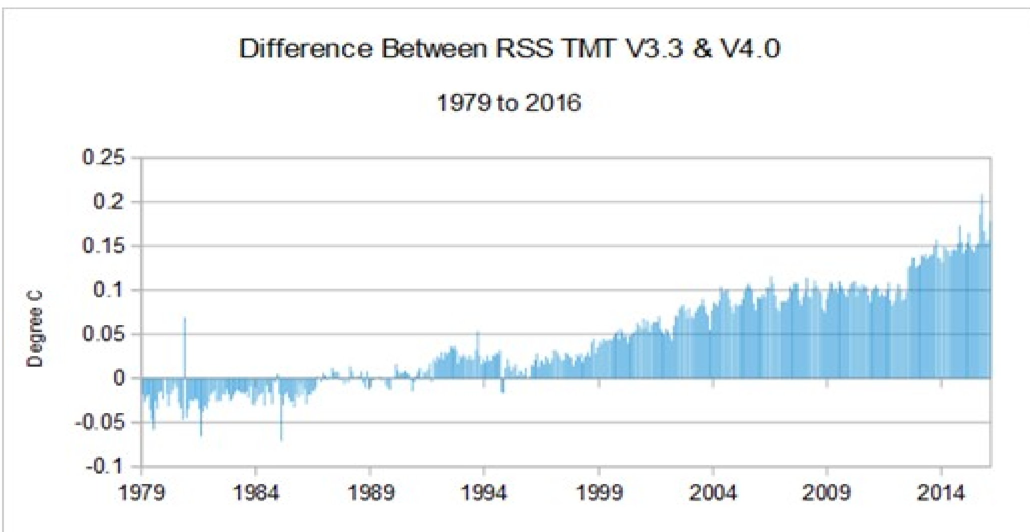
12. How The Pause Was Made To Disappear:

https://notalotofpeopleknowthat.wordpress.com/2016/03/09/how-the-pause-was-made-to-disappear/

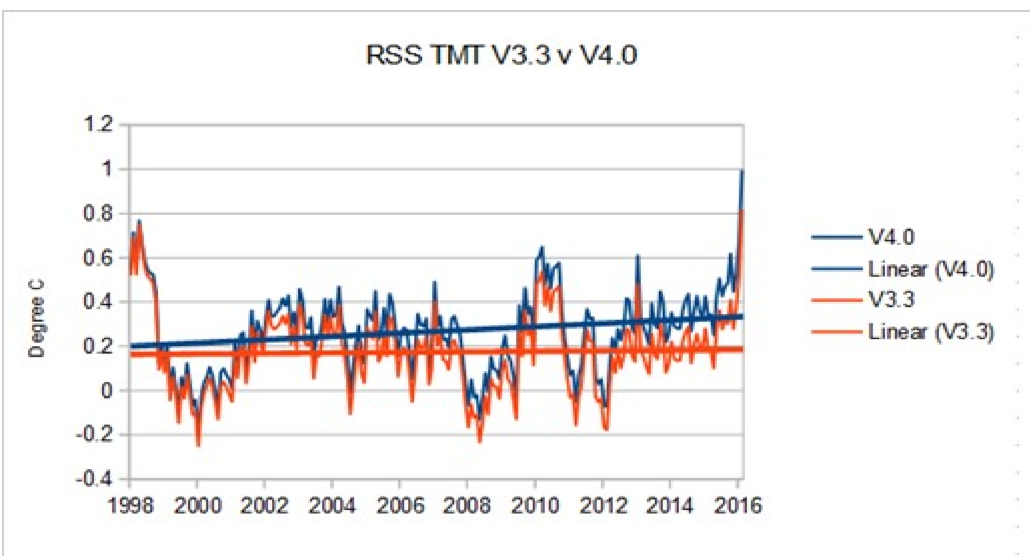
"Corrections" were made to NOAA and RSS data that lowered early and raised more recent temperatures data. As a result of these corrections to the data, the recent temperature pause was made to disappear. Not all experts agree concerning the illegitimacy of the criteria that was used to make these adjustments.



RSS Mid Troposphere temperatures, TMT, Satellite Data



The effect of the change since 1998 in particular is startling. An essentially flat trend has been replaced by 0.74C/C.

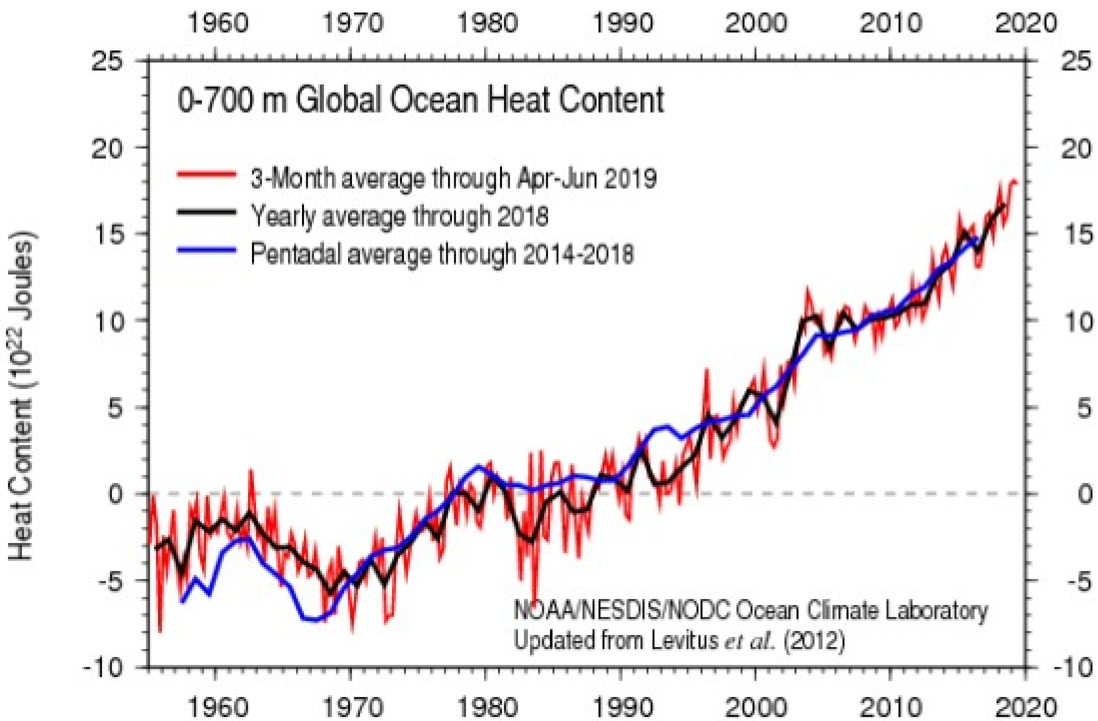


SECTION IIC. Heat Content of Oceans, Surface Temperature not Accurate, Recent Temp Hiatus

Heat of Oceans Global warming (or global cooling) can be more accurately quantified in terms of the accumulation (or loss) of heat in the Earth system as measured in joules. The 2007 IPCC report estimated that **global average total net anthropogenic radiative forcing in 2005 was 1.6 W/m²** from solar irradiance. This estimate corresponds to a heat accumulation in the climate system of 2.8×10^{22} joules per year.The ocean, of course, is the **largest reservoir (90%)** of this heat change. Thus, the Earth's heat budget observations,within the limits of their representativeness and accuracy, provide an observational constraint on the actual global average radiative forcing. The value of ocean heat content at any time documents the accumulated heat content and its change since the last assessment. Unlike temperature at some specific depth in the ocean or height in the atmosphere, where there is a time lag in its response to radiative forcing, no time lags are associated with heat changes, since the actual amount of heat present at any time is accounted for. Moreover, because the **surface temperature** is a **massless** two-dimensional global field while **heat content involves mass**, the use of **surface temperature as a monitor of climate change is not accurate for evaluating heat storage changes.** The temperature hiatus can be explained by **heat transfer absorbed below700 m** down to a depth of 2000 m

Heat Content of Oceans -Indisputable evidence of global warming, but ~ΔTavg = 0.025K

Levitus et al., Geophysical Research Letters 36 (2009): L07608.   Units of 10^22 J/year



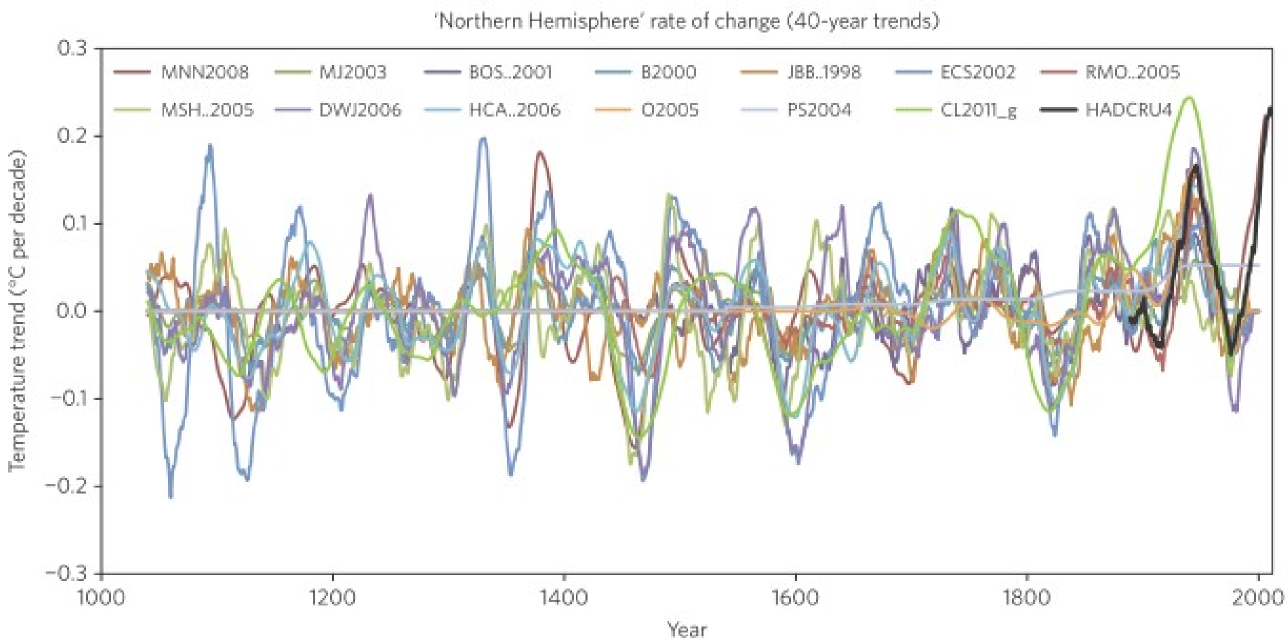
Mass_Ocean := $1.4 \cdot 10^{21}$ kg   **Ocean Temp Rise:**

$$14 \cdot 10^{22} J \cdot \left[\left[Mass\_Ocean \, 4000 J \cdot (kg \cdot K)^{-1} \right]^{-1} \right] = 0.25\,K$$

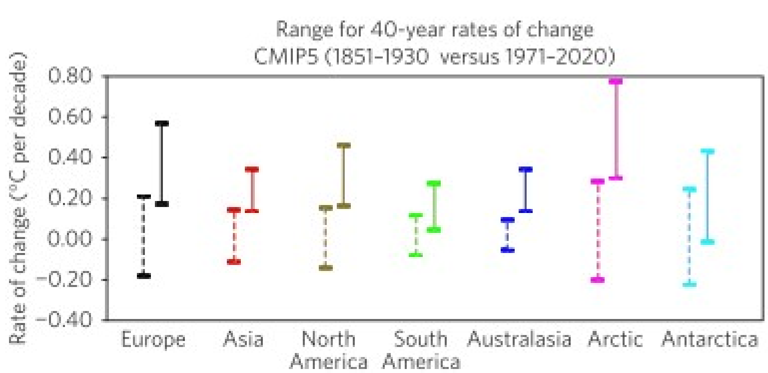
SECTION II D. Almost Every State in USA Has Warmed In The Past 100 Years

Temperature Change per Decade in US States											
1	Rhode Island	0.34	13	N. Dakota	0.208	25	Pennsylvania	0.142	37	N. Carolina	0.054
2	Massachusetts	0.3	14	Wyoming	0.197	26	Washington	0.129	38	Iowa	0.046
3	New Jersey	0.28	15	Nevada	0.196	27	Oregon	0.128	39	W. Virginia	0.035
4	Arizona	0.27	16	Wisconsin	0.189	28	Texas	0.114	40	Missouri	0.029
5	Maine	0.27	17	Montana	0.188	29	Virginia	0.107	41	S. Carolina	0.024
6	Connecticut	0.25	18	New York	0.181	30	Kansas	0.103	42	Tennessee	0.021
7	Michigan	0.25	19	New Mexico	0.177	31	Florida	0.081	43	Louisiana	0.019
8	Utah	0.23	20	Maryland	0.176	32	Ohio	0.077	44	Mississippi	0.014
9	Minnesota	0.23	21	Vermont	0.172	33	Illinois	0.076	45	Kentucky	0.008
10	Colorado	0.23	22	Idaho	0.166	34	Nebraska	0.072	46	Arkansas	0
11	New Hampshire	0.22	23	California	0.161	35	Oklahoma	0.072	47	Georgia	0.04
12	Delaware	0.21	24	S. Dakota	0.143	36	Indiana	0.059	48	Alabama	0.07
http://www.climatecentral.org/wgts/heat-is-on/HeatIsOnReport.pdf											

SECTION II E. Near-term acceleration in the rate of temperature change



Rates of temperature change over 40-year periods for a number of climate reconstructions that cover various Northern Hemisphere areas. Areas are land and ocean, land, and land 20 ◦ –90 ◦ , see Supplementary Information. The thick black line shows the corresponding rate of change of Northern Hemisphere temperature from the HADCRU4 data set13.



Impact of Increasing Rates of Change

The large shift over the coming decades relative to the historical period of both occurrences of high rates of change and the average rates of change indicates that the world is now entering a regime where background rates of climate change will be well above historical averages until at least mid-century. The impacts of an extended period of increasing rates of change are unclear.

Arctic Polar Amplification: Warming melts highly reflective white ice and snow, which is replaced by the dark blue sea or dark land, both of which absorb far more sunlight and hence far more solar energy. Because of Arctic amplification, the most northern latitudes warm two times faster (or more) than the globe as a whole does.

SECTION III-A. CO_2 Concentration Changes

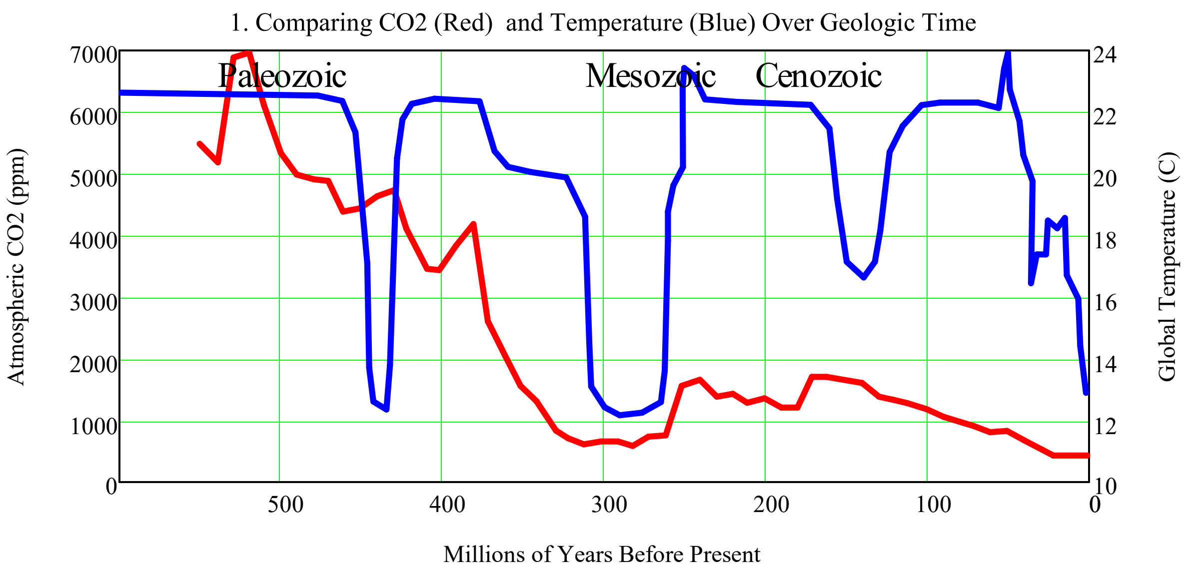
1. Global Temperature and Atmospheric CO_2 over Geologic Time

Paleozoic, Mesozoic, Cenozoic: 600 to 0 Million Years BPA
Temperature: http://www.scotese.com/climate.htm
"GEOCARB III: A REVISED MODEL OF ATMOSPHERIC CO2 OVER PHANEROZOIC TIME", R.A. Berner, 2001
See also: **http://www.geocraft.com/WVFossils/CO$_2$_Temp_O2.html**

Late Carboniferous to Early Permian time (315 mya -- 270 mya) is the only time period in the last 600 million years when both atmospheric CO_2 and temperatures were as low as they are today (Quaternary Period).

PaleoTemp := READPRN("Temp-Comparing CO2 -Temp over Geologic Time.txt")
RCO2 := READPRN("Effect of GCM Model Params - GEOCARB II.txt")
RCO2 = mass of atmos. CO2(t)/mass of CO2(0)   ppm = 300 ppm x RCO2 $PaleoCO2 := RCO2^{\langle 1 \rangle} \cdot 300 \cdot \frac{4}{3}$

NOTE: Current CO_2 levels are less than 1/10 of what they were in previous eras.



CO_2 and O_2 Concentration Monthly Plot

2. Keeling Curve: Mauna Loa Observation Hawaii Monthly CO2 & O2 Concentration Data

The carbon dioxide data, measured as the mole fraction in dry air, on Mauna Loa constitute the longest record of direct measurements of CO_2 in the atmosphere. This data is the gold standard in climate research. They were started by C. David Keeling of the Scripps Institution of Oceanography in March of 1958 at a facility of the National Oceanic and Atmospheric Administration (Keeling, 1979). NOAA started its own CO2 measurements in May of 1974. The moving average is for seven adjacent seasonal cycles centered on the month to be corrected, except for the first and last three and one-half years of the record, where the seasonal cycle has been averaged over the first and last seven years, respectively. The estimated uncertainty in the Mauna Loa annual mean growth rate is 0.11 ppm/yr. This estimate is based on the standard deviation of the differences between monthly mean values.

Keeling had perfected the measurement techniques and observed strong diurnal behavior with steady values of about 310 ppm in the afternoon at three locations (Big Sur near Monterey, the rain forests of Olympic Peninsula and high mountain forests in Arizona). By measuring the ratio of two isotopes of carbon, Keeling attributed the diurnal change to respiration from local plants and soils, with afternoon values representative of the "free atmosphere". By 1960, Keeling and his group established the measurement record that was long enough to see not just the **diurnal and seasonal variations/oscillations**, but also a year-on-year increase that roughly matched the amount of fossil fuels burned per year.

The Keeling Curve also shows a cyclic variation of about 5 ppmv in each year corresponding to the **seasonal change in uptake of CO_2 by the world's land vegetation**. Most of this vegetation is in the Northern hemisphere, since this is where most of the land is located. The level **decreases from northern spring** (May) onwards as new plant growth takes carbon dioxide out of the atmosphere through photosynthesis and rises again in the northern fall as plants and leaves die off and decay to release the gas back into the atmosphere.

Read data from http://www.esrl.noaa.gov/gmd/ccgg/trends/co2_data_mlo.

https://scrippsco2.ucsd.edu/data/atmospheric_co2/primary_mlo_co2_record.html

Year	Month	decimal date	average ppm	interpolated ppm	trend (season corr)	#days

$MLCO2 := READPRN("NOA\_Mauna\_Loa\_Monthly\_CO2\_23.txt")$ $MLO2 := READPRN("O2Monthlymlooav-2022.txt"$

$Date := MLCO2^{\langle 2\rangle}$ $CO2_{ML} := MLCO2^{\langle 3\rangle}$ $TrendCO2 := MLCO2^{\langle 3\rangle}$ $RD := rows(Date)$

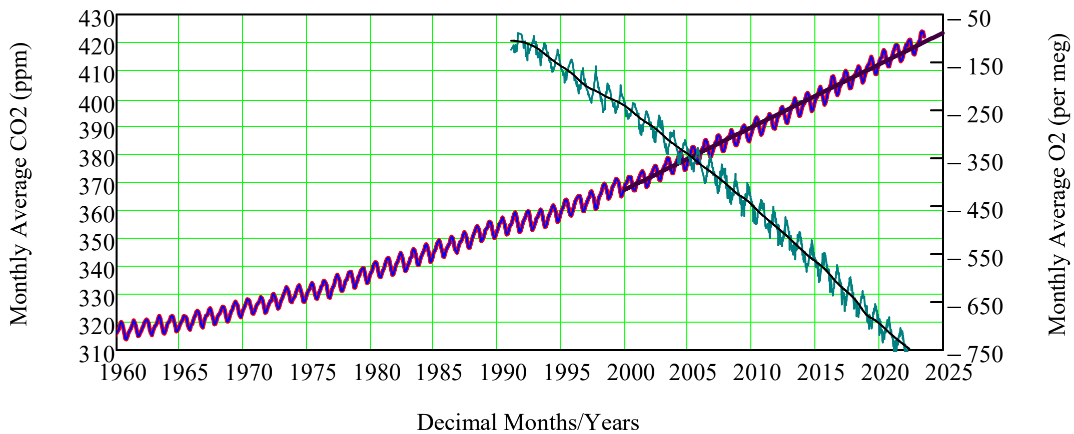
Get CO2 Trend Line from 1990 to 2023 $Yr_{1990} := 2000, 2000.05 .. 2025$

$Date_{2000} := submatrix(Date, 503, RD-1, 0, 0)$ $L_{co2} := line\left(Date_{2000}, submatrix(TrendCO2, 503, RD-1, 0, 0)\right)$

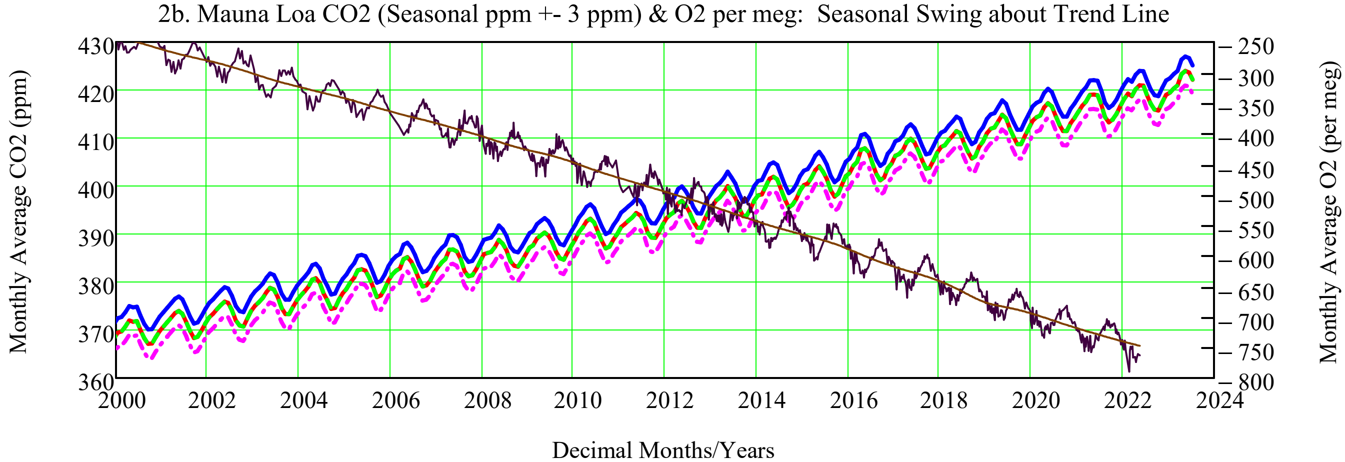
$Trend_{co2}(Year) := L_{co2_0} + L_{co2_1} \cdot Year$ $Keeling(yr) := 1.054 \cdot 10^{-2}(yr-1960)^2 + 9 \cdot 10^{-1} \cdot (yr-1960) + 315.5$

From 1960, CO_2 increased by 106 ppm, while O_2 from 1990 decreased by 440 per meg.
440 meg corresponds to a loss of 440 O_2 molecules out of each one million O_2 molecules in the atmosphere, or a loss of 0.044%.

Mauna Loa Increasing CO2 and Decreasing O2 (Green) Seasonal vs. Time



2b. Mauna Loa CO2 (Seasonal ppm +- 3 ppm) & O2 per meg: Seasonal Swing about Trend Line



3. Neftel Siple Ice Station - 1847 to 1953

http://cdiac.ornl.gov/ftp/trends/co2/siple2.013

Avg depth (m)	Gas (yr AD)	concentration (ppmv)

Increase per year (%)

$$\frac{(390-372)\cdot 100}{10\cdot 372} = 0.48387$$

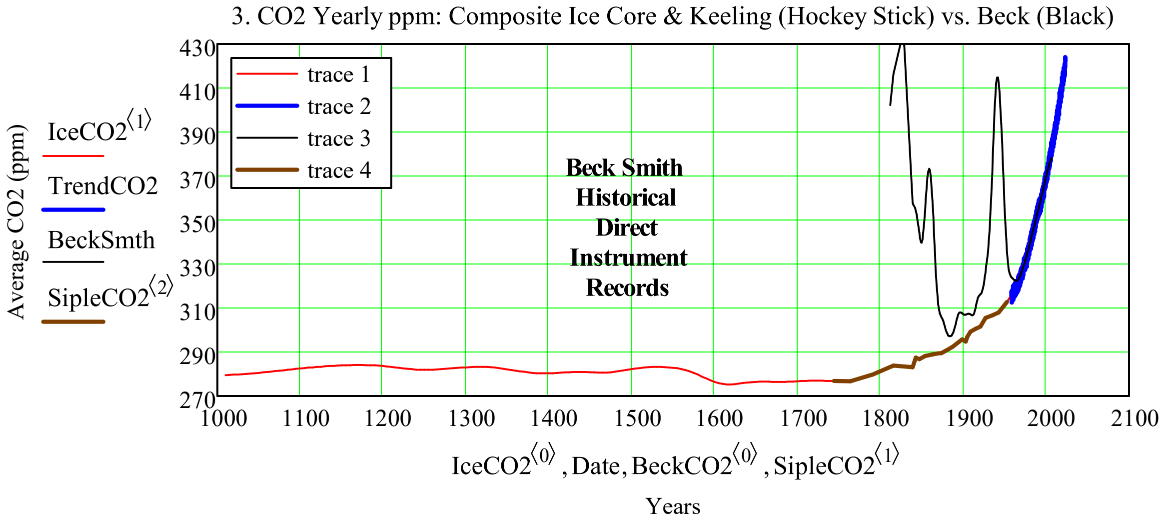
$SipleCO2 := READPRN("Friedli\ Siple\ CO2\ 1986.TXT")$ $IceCO2 := READPRN("CO2\ Ice\ Core\ Data.txt")$

http://www.wasserplanet.becsoft.de/180CO2/CO2tot1812-2007.txt
Column C: CO2 total 1812-1961 corrected. annual averages from raw data.

$BeckCO2 := READPRN("Beck\ CO2\ Corrected.TXT")$

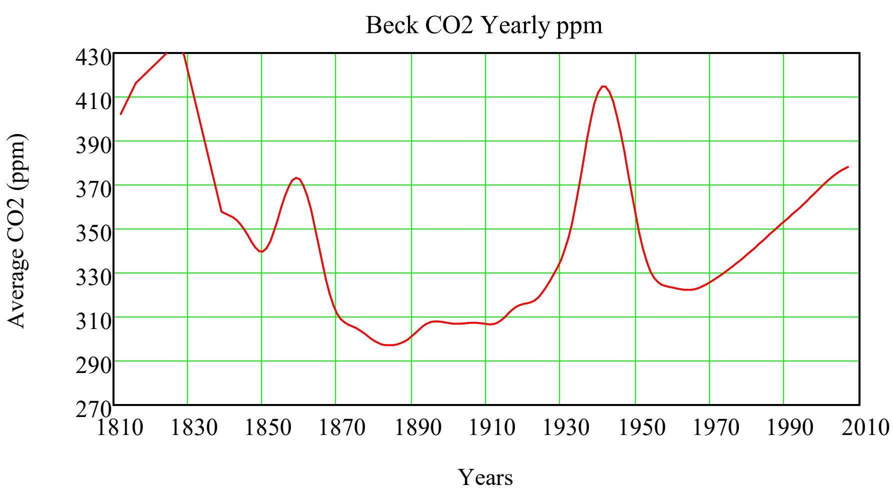
$BeckSmth := ksmooth\left(BeckCO2^{\langle 0\rangle}, BeckCO2^{\langle 1\rangle}, 10\right)$

Composite Plots of Ice, Trends, Beck Smith, and Siple CO_2 Data



E.G. Beck "180 years accurate CO_2 analysis in air by chemical methods", In press Energy&Environment

After a more thorough review of the old literature, E.G.Beck concluded that there were indications that **current CO_2 concentrations were considerably exceeded in the 1820s** and again in the 1940s



www.soest.hawaii.edu/GG/FACULTY/POPP/Lecture15.ppt

Measurements of CO_2 concentration - Core from rapidly accumulating ice

Merge well with instrumental data1763 - major improvements to the steam engine by the

Scottish engineer James Watt

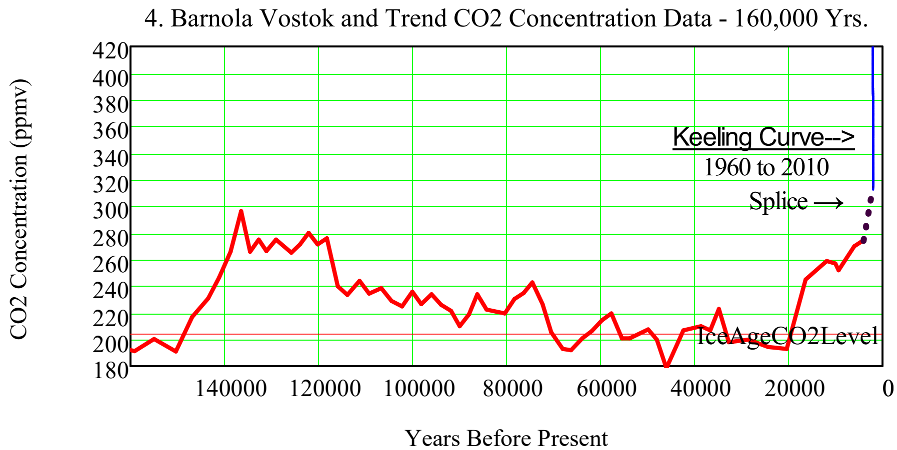
1769 – first self-powered road vehicle, built by French inventor Nicholas Cugnot
1780 - formulation of the Law of Combustion by the French scientist Antoine Lavoisier
1790 - invention of the electrical battery by the Italian scientist Luigi Galvani
1807 - development of commercial steamboats by the American inventor Robert Fulton
1816 – first U.S. energy utility company and natural gas is used to light streets of Baltimore
1851 - height of the New England whaling industry
1886 – German mechanical engineer Karl Benz first patent for gasoline-powered ICE car
1903 – first sustained powered air flight, at Kill Devil Hills, North Carolina

4. Vostok Ice Core CO_2 Data: Barnola et al, Nature, 329, 408-414 (1987)

Depth (m), Ice Age(yrs), Gaz age (Yrs), CO2 (ppmv), minimum, maximum

BarnolaCO2 := READPRN("Barnola Vostok CO2 1987.TXT") IceAgeCO2Level := 205

Vostok cores show that CO_2 concentrations are at the highest level in 160,000 years.



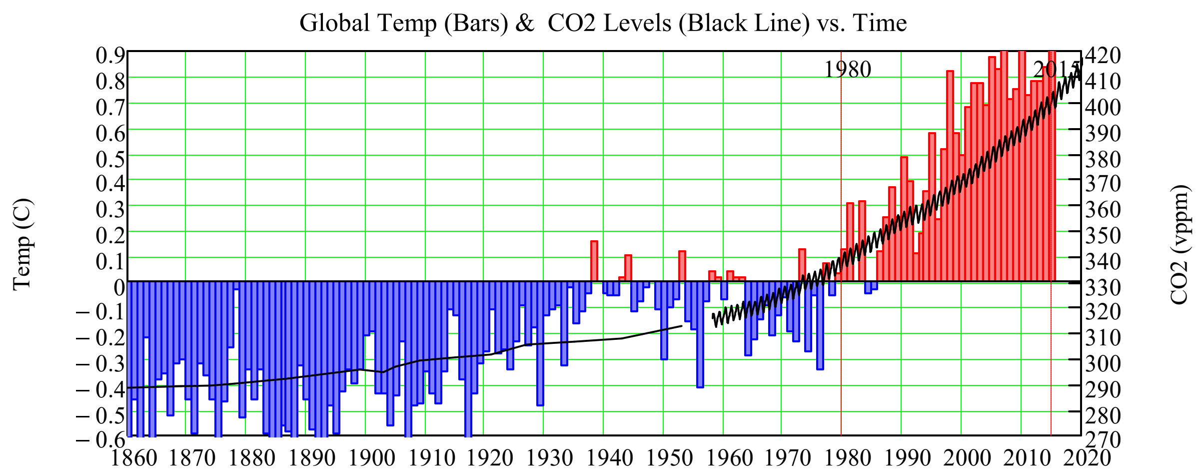
5. An imperative for climate change planning: tracking Earth's global energy - Kevin E Trenberth

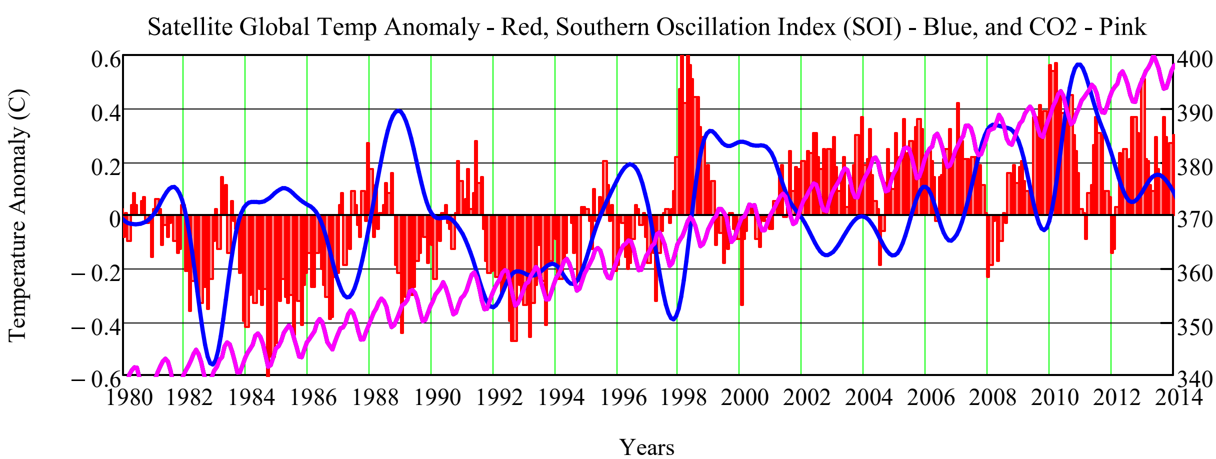
http://www.cgd.ucar.edu/cas/Trenberth/trenberth.papers/EnergyDiagnostics09final2.pdf

Plot data from above article for Fig 1

http://www.cru.uea.ac.uk/cru/data/temperature/CRUTEM4-gl.dat Column 13 has yearly Temp data to 5-2015.
http://www.cru.uea.ac.uk/cru/data/temperature/HadCRUT4-gl.dat Monthly Temp Data 1850 to **Feb 2013**
http://www.cru.uea.ac.uk/cru/data/temperature/CRUTEM4-gl.dat Monthly Temp Data 1850 to Oct 2014

Note: For this plot, years 1980 - 2014 show a solid plus warming.



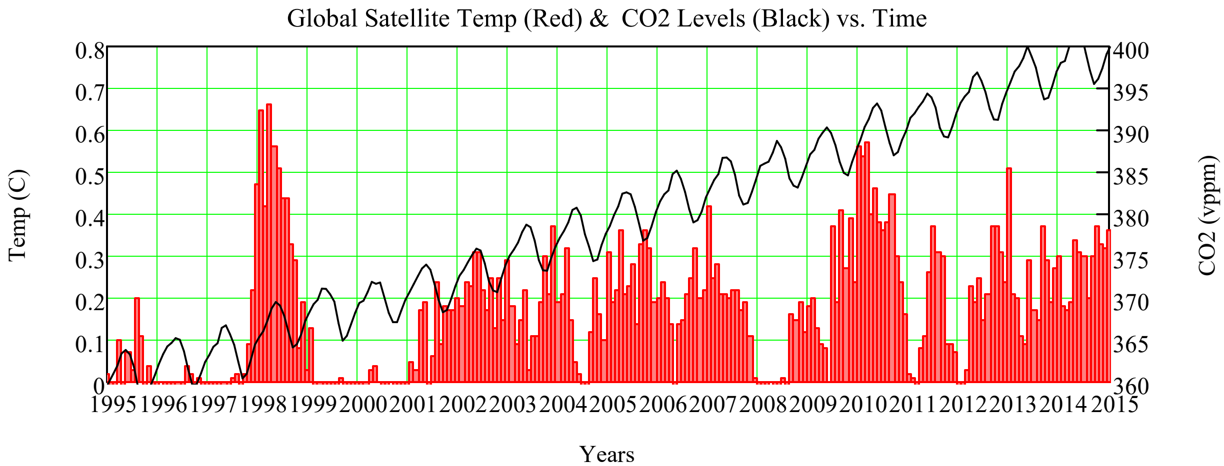


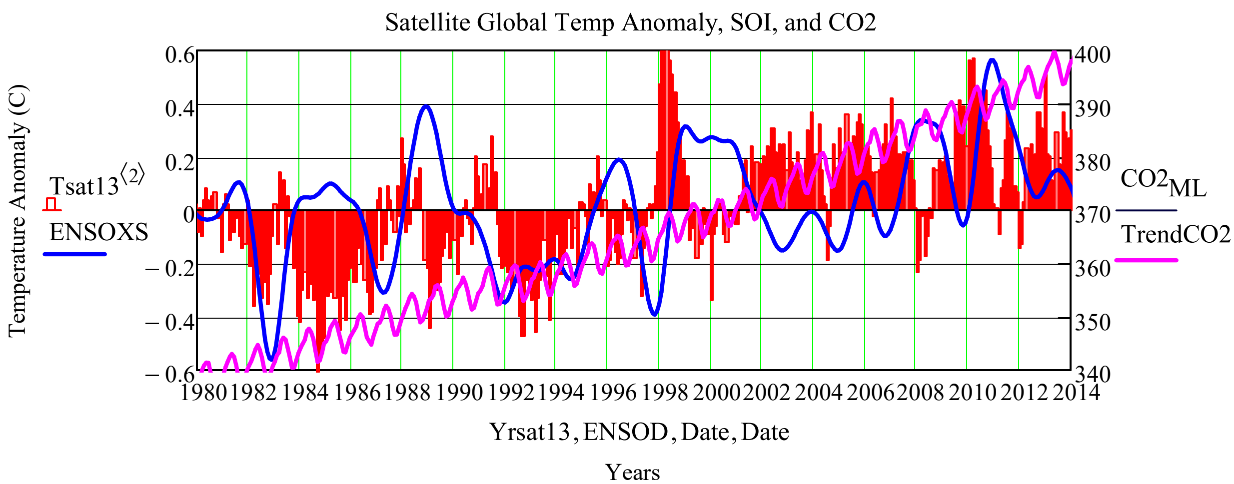
Does Temp track CO2? Fails Decadal Examination.

NO!

Doubling the amount of CO2 does not double the greenhouse effect. It has a logarithmic response. The way the climate reacts is complicated, and it is difficult to separate the effects of natural changes from man-made ones over short periods of time. Decadal forecasts are a known of weakness of generic numeric general circulation models.

Global Satellite Temperature Does NOT TRACK CO_2 During the Last 18 Years





Use Ice Core and NOA _Mauna_Loa_Trend_CO2.txt versus hadcrut3glx.txt in file Correlation_Yr_CO2_Temp.TXT.

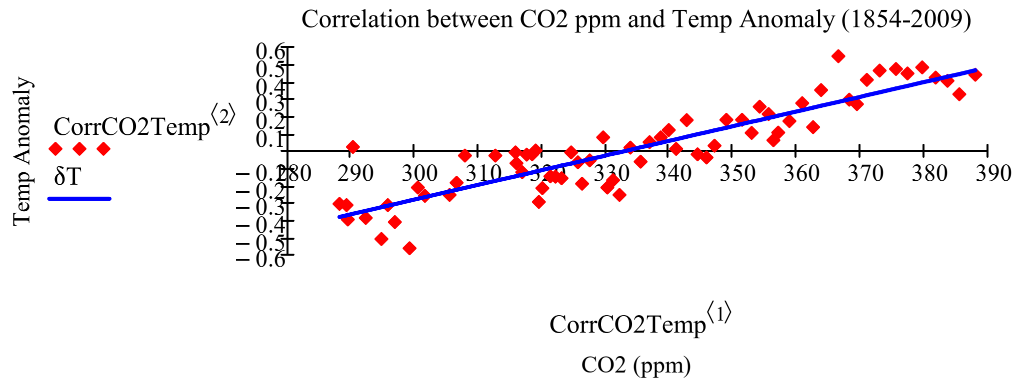
CorrCO2Temp := READPRN("Correlation_Yr_CO2_Temp.TXT")

$RSquare := corr\left(CorrCO2Temp^{\langle 1\rangle}, CorrCO2Temp^{\langle 2\rangle}\right)^2$ $RSquare = 0.80882$

$ss := slope\left(CorrCO2Temp^{\langle 1\rangle}, CorrCO2Temp^{\langle 2\rangle}\right) = 0.00847$

$int := intercept\left(CorrCO2Temp^{\langle 1\rangle}, CorrCO2Temp^{\langle 2\rangle}\right) = -2.82393$ $\delta T := int + ss\cdot CorrCO2Temp^{\langle 1\rangle}$

Correlation (1854 to 2009) between CO_2 and Temperature Anomaly



Covariation Between CO2 and δD (Change in Deuterium)

If the δD change reflects a proportional T drop, then more than ½ of the interglacial-to-glacial change occurred before significant removal of atmospheric CO2.

Values shown normalized to their mean values during the mid-Holocene (5–7 kya BP) and the last glacial (18–60 kya BP) Clearly visible are the disproportionately low deuterium values during the mid-glacial (60–80 Kya BP), the glacial inception (95–125 KyaBP), and the penultimate glacial maximum (140–150 Kya BP)
Covariation of carbon dioxide and temperature from the Vostok ice core after deuterium-excess correction" Kurt M. Cuffey & Françoise Vimeux

SECTION III-B. CO_2 Properties, Production, Scenarios, and Fossil Fuel Projections

1. Properties of Green House Gases - The Non Condensable Gases (CO2, methane, etc.)

Oxygen (O2), nitrogen (N2), and argon (AR), though they make up **~99%** of the atmosphere, are **almost entirely transparen**t to **solar and terrestrial radiation**. They have no dipole moment to interact with EM.

Most **diatomic** gases, such as water vapor (H2O), carbon dioxide (CO2), nitrous oxide (N2O), and a handful of other trace gases vibrate and absorb and re-radiate in the IR. CO2 and N20 have an oscillating dipole moment. H2O has a permanent dipole moment. They interact with EM waves, are consequently GHG, and make the lower atmosphere **nearly opaque to infrared** radiation, though still largely transparent to solar radiation (but clouds have strong effects on radiation at all wavelengths). Together, by the GHE, they increase the Earth's surface temperature from about **0° F to around 60° F**. **Only the vibration and rotation modes of a molecule can interact with IR radiation.** These interactions are governed by Quantum Mechanics and can only take place at discrete values of frequency. See pg. 95 for additional info on dipolar molecules.

Water Vapor, about **0.25% of the mass** of the atmosphere, is the strongest (60% of warming) GHG. However, it does not control the earth's temperature, but is controlled by the temperature. The temperature controls the max amount of water the atmosphere can contain. It condenses out on a timescale of ~2
Climate is therefore **strongly influenced** by **non condensable greenhouse gases** (e.g. CO2, CH4, N2O), which do not condense out and more can be packed into the atmosphere. Together these comprise about **0.04% of the mass** of the atmosphere. Concentration of CO2 has i**ncreased by 43%** since the dawn of the industrial revolution. It is important because it has a long lifetime in the earth's atmosphere. The addition of non-condensable gases causes the temperature to increase and this leads to an increase in water vapor that further increases the temperature. This is an example of a positive feedback effect.

2. Atmospheric Carbon Dioxide Concentration - 1850 to Present

The concentration of CO_2 in Earth's atmosphere has increased during the past century, as shown in Figure below. The magnitude of this atmospheric increase is currently about 4 **giga tons of carbon (Gt C)** per year. Total human **industrial CO_2 production**, primarily from use of coal, oil, and natural gas and the production of cement, is currently about **8 Gt C per year** (7,56,57). Humans also exhale about 0.6 Gt C per year, which has been sequestered by plants from atmospheric CO_2. Office air concentrations often exceed 1,000 ppm CO_2. To put these figures in perspective, it is estimated that the **atmosphere contains 780 Gt C**; the surface ocean contains 1,000 Gt C; vegetation, soils, and detritus contain 2,000 Gt C; and the intermediate and deep oceans contain 38,000 Gt C, as CO_2 or CO_2 hydration products.

Each year, the surface ocean and atmosphere exchange an estimated 90 Gt C; vegetation and the atmosphere, 100 Gt C; marine biota and the surface ocean, 50 Gt C; and the surface ocean and the intermediate and deep oceans, 40 Gt C (56,57). So great are the magnitudes of these reservoirs, the rates of exchange between them, and the uncertainties of these estimated numbers that the sources of the recent rise in atmospheric CO_2 have not been determined with certainty (58,59). Atmospheric concentrations of CO_2 are reported to have varied widely over geological time, with peaks, according to some estimates, some 20-fold higher than at present and lows at approximately 200 ppm (60-62).

% Industrial Production per Atmosphere

$$\frac{8 \cdot 100}{780} = 1.02564$$ The Climate Catastrophe - A Spectroscopic Artifact

Is the airborne fraction of anthropogenic CO2 emissions increasing? NO!

http://www.skepticalscience.com/Is-the-airborne-fraction-of-anthropogenic-CO2-emissions-increasing.html

Knorr finds that since 1850, the airborne fraction has remained relatively constant. When CO2 emissions were low, the amount of CO2 absorbed by natural carbon sinks was correspondingly low. As human CO2 sharply increased emissions in the 20th Century, the **amount absorbed by nature correspondingly increased**. **The remaining airborne (in the atmospheric) Fraction remained level at around 43%**. The Trend in the Fraction since 1850 is found to be 0.7 ± 1.4% per decade. Almost Zero. There are several differences in methodology between Knorr 2009and Le Quere 2009. Knorr's result does not include the filtering for ENSO and volcanic activity employed by Le Quéré. However, when filtering Knorr does include this in his analysis, he finds a trend of 1.2 ± 0.9% per decade. This is smaller than Le Quere's result but is statistically significant.

CDIAC - Carbon Dioxide Information Analysis Center - Global Anthropogenic CO2 Emissions

http://cdiac.ornl.gov/trends/emis/meth_reg.html

Year Total Gas Liquids Solids Cement_Production Gas_Flaring Per_Capita

Units of **Million Metric Tons of Carbon**. Per capita emission estimates in metric tons of carbon.

Emiss := READPRN("Global CO2 Emissions from Fossil-Fuel Burning-1751 2006.txt")

https://ourworldindata.org/co2-emissions Emiss2 := READPRN("global-co2-fossil-plus-land-use 1850-2020.txt")

Emiss2Yrs := stack(submatrix(Emiss , 0 , 97 , 0 , 1) , submatrix(Emiss2 , 0 , 170 , 0 , 1)) **Units: GT CO_2**

Calculate Change per Year - Note there are sources other than anthropogenic

GigaTonCarbon: $ppm := 2.1 \cdot 10^{9} \cdot ton$ $t := 0 .. rows(IceCO2) - 2$

Siple CO2 Data is from 1850 to 1956 **Ice Core Data:** $IceCO2Inc_t := \left(\frac{IceCO2_{t+1,1} - IceCO2_{t,1}}{IceCO2_{t+1,0} - IceCO2_{t,0}}\right) \cdot 2.1$

$rows(CO2_{ML}) = 785$ $d := 0 .. 50$ $td_d := 9 + d \cdot 12$ $dd := 0 .. 49$ $td_{50} = 609$

$IncCO2ML_{dd} := \left(TrendCO2_{td_{dd+1}} - TrendCO2_{td_{dd}}\right) \cdot 2.1$ $DateD_{dd} := Date_{td_{dd+1}}$ **Carbon to CO_2 Ratio**

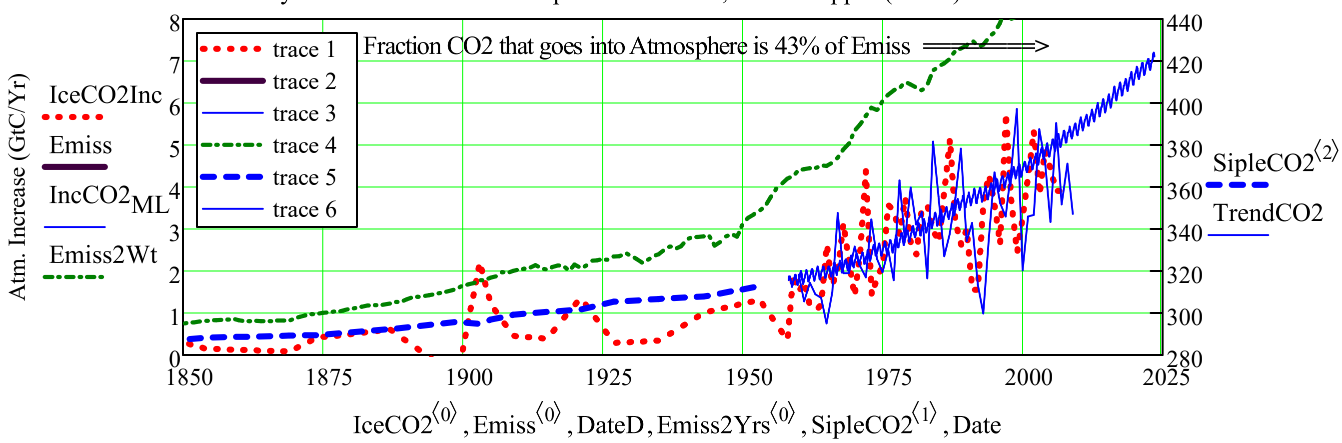
$Emiss := Emiss^{\langle 1 \rangle} \cdot \frac{1}{1000}$ EmissLevel := Emiss $Emiss2Wt := \frac{Emiss2Yrs^{\langle 1 \rangle}}{10^{9}} \cdot \frac{12}{44}$

$Emiss_{209,0} = 2.577$ $Emiss_{255,0} = 8.23$ $\frac{Emiss_{255} - Emiss_{209}}{2006 - 1960} = 0.12289$

CDIAC - Carbon Dioxide Information Analysis Center - Global Anthropogenic CO2 Emissions

Colors: Total Antro Emissions (Black Line), Emissions#2 (Green Dash), CO2 (Blue Lines), Siple (Dashed Blue), IceCoreCO2 (Red)

1. Yearly CO2 Emission & Atmospheric Increases, and Atm ppm (Black) - 1850 to Present



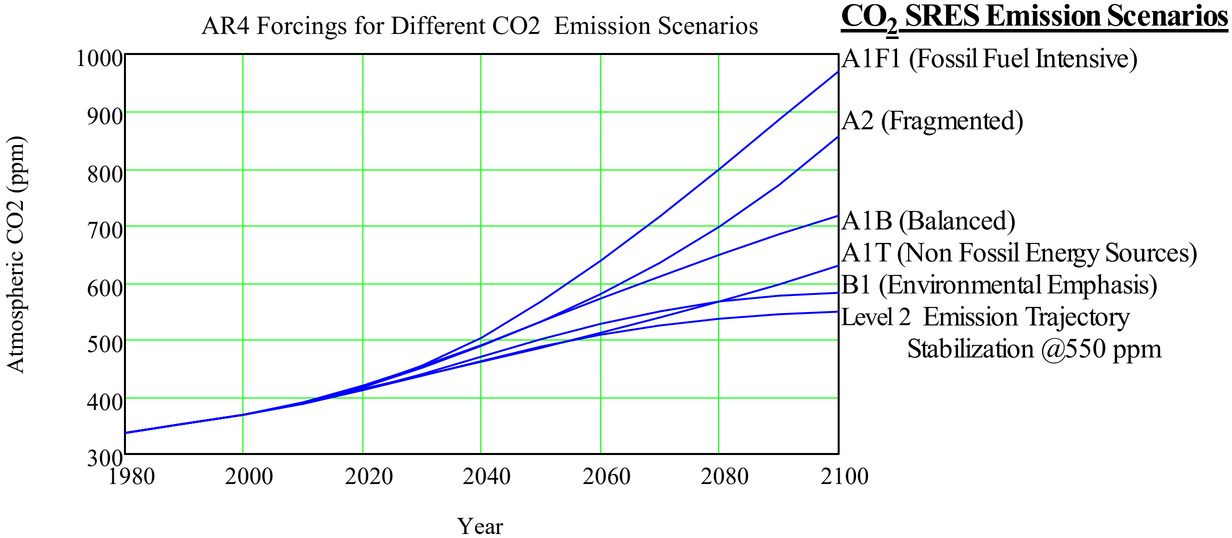
3. Global Atmospheric CO_2 Projections: IPCC Special Report Emission Scenarios (SRES)

http://www.ipcc-data.org/ancilliary/tar-isam.txt https://www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf

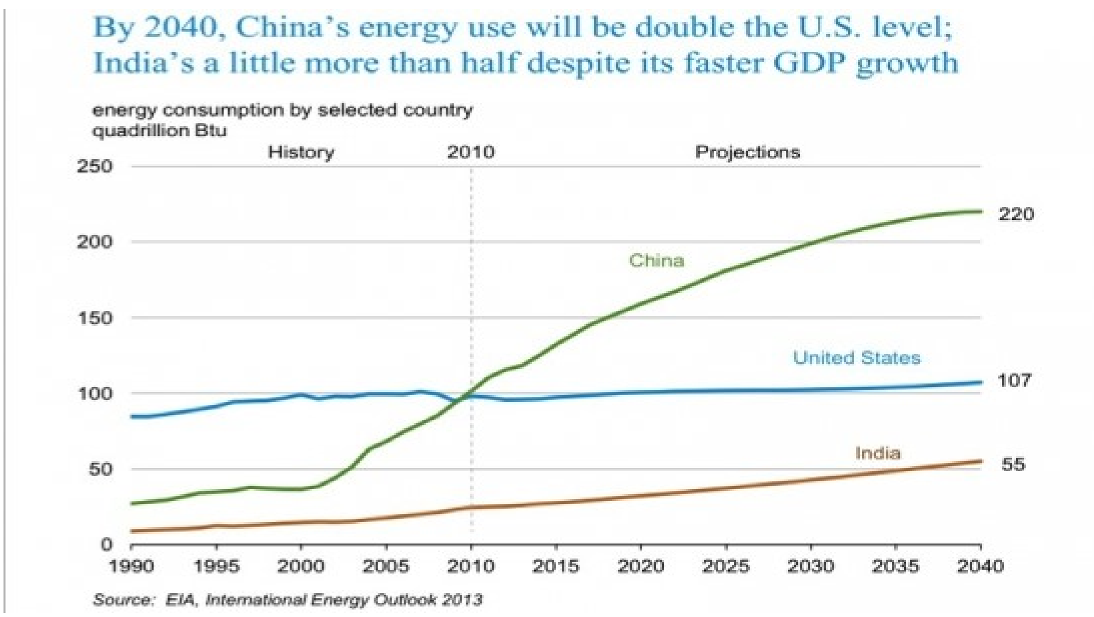
Year A1B A1T A1FI A2 B1 B2 A1p A2p B1p B2p IS92 IS92a/SAR

Years

ProjCO2 := READPRN("CO2 AR4 Emission Proj-Data.txt")



3. World Energy Production Projection



4. The Carbon Cycle

The carbon cycle involves huge natural fluxes among the oceans, atmosphere, and land biosphere. This very active natural cycle has been perturbed by the addition of large amounts of CO2 to the atmosphere due to combustion of fossil fuels and other human activities. Only about half of the anthropogenic CO2remains in the atmosphere, and the other half is removed by "sink" processes on land and in the oceans which are not adequately understood at present.

SECTION III-C. Fossil Fuel Energy Sources - CO_2 Emission Sources

1. Main Areas of Human Energy Consumption in the US

http://www.epa.gov/climatechange/ghgemissions/gases/co2.html

Electricity 38%, Transportation 32%, Industry 14%, Residential 9% and NonFossil Fuel 6%
Electricity is not a primary energy source. It is one of the most common energy carriers. generate 3 to 4 times more torque per unit energy input than all but the largest and most efficient house-sized diesel ship engines (50 percent efficient).

2. Human Contribution Relative to Other Sources of CO_2

The **burning of fossil fuels** sends **7 gigatons** (**3.27 %**) of carbon dioxide into the atmosphere each year, while the biosphere and oceans account for 440 (55.28 %) and 330 (41.46 %) gigatons, respectively—total human emissions have jumped sharply since the Industrial Revolution. Carbon is emitted naturally into the atmosphere but that the atmosphere also sends carbon back to the land and oceans and that these carbon flows have **canceled each other out** for millennia. Burning fossil fuels, in contrast, creates a new flow of carbon that, though small, is not canceled.

3. Coal Usage and Factors

Source: http://www.nationalreview.com/article/392167/social-justice-coal-robert-bryce
Coal is perfectly suited for electricity production, it's abundant, its reserves are geographically dispersed, prices are not affected by any canceled entities, and — above all — it's cheap. Coal-fired generators provide about 40 percent of all global electricity. Coal is the most carbon intensive fossil fuel.

Coal is the world's **fastest-growing form of energ**y and it has been since 1973. In 2013 alone, coal use grew by about 2 million barrels of oil equivalent per day (boe/d). That was about three times the growth seen in natural gas (which grew by about 700,000 boe/d), four times the rate of growth in wind (up by about 500,000 boe/d), and 13 times the growth in solar (which was up by about 150,000 boe/d).

China has led the rush toward coal and now accounts for fully half of global coal consumption.

Increased use of hydrocarbons results in **better living standards**. Indeed, per capita carbon dioxide emissions (like per capita electricity usage) are a reliable indicator of higher incomes.

4. Oil Production - US Drilling Rigs - December 2014

Why is the world market suddenly awash in oil? The answer: Over the past few years — thanks to rigs, rednecks, and rights — the U.S. has added the equivalent of one Kuwait and one Iran to its domestic oil and gas production.

Since 2004, **U.S. oil production is up 56 percent**, or about 3.1 million barrels a day, about the same volume as Kuwait produced last year. The dimensions of the boom in natural gas can be seen by looking solely at the Marcellus Shale in Pennsylvania, where output has jumped eight-fold since 2010 and is now about 16 billion cubic feet per day, a volume roughly equal to Iran's current natural-gas production.

U.S. oil and gas numbers are soaring because of an abundance of rigs. **More than half of all the drilling rigs on the planet are operating in the United States.** We have about 1,900 active rigs. The rest of the world combined has about 1,300.

Atmospheric Carbon Dioxide Levels vesus Carbon Emissions

https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide

Carbon dioxide concentrations are rising mostly because of the **fossil fuels that people are burning for energy**. Fossil fuels like coal and oil contain carbon that plants pulled out of the atmosphere through photosynthesis over many millions of years; we are returning that carbon to the atmosphere in just a few hundred. Since the middle of the 20th century, annual emissions from burning fossil fuels have increased every decade, from close to 11 billion tons of carbon dioxide per year in the 1960s to an estimated 36.6 billion tons in 2022 according to the Global Carbon Budget 2022.

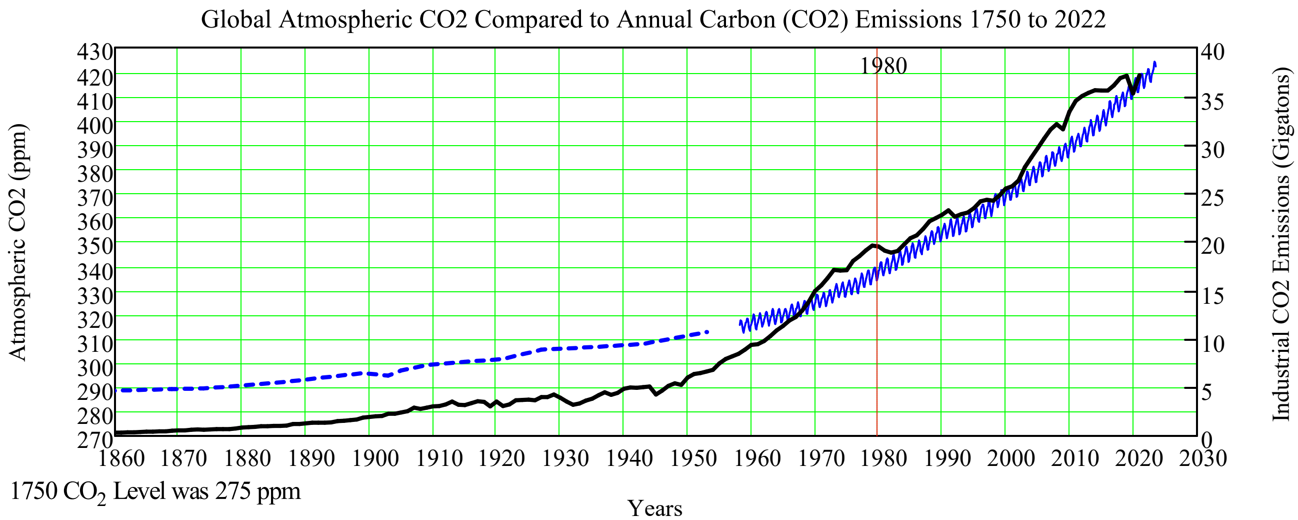
Carbon cycle experts estimate that natural "sinks"—processes that remove carbon from the atmosphere—on land and in the ocean absorbed the equivalent of about **half of the carbon dioxide we emitted** each year in the 2011-2020 decade. Because we **put more carbon dioxide into** the atmosphere than **natural sinks can remove**, the total amount of carbon dioxide in the **atmosphere increases every year**.

The more we overshoot what natural processes can remove in a given year, **the faster** the atmospheric concentration of carbon dioxide rises. In the **1960s**, the global growth rate of atmospheric carbon dioxide was roughly **0.8± 0.1 ppm per year**. Over the **next half century**, the annual growth rate **tripled, reaching 2.4 ppm** per year during the 2010s. The annual **rate of increase** in atmospheric carbon dioxide over the **past 60 years is about 100 times faster** than previous natural increases, such as those that occurred at the end of the last ice age 11,000-17,000 years ago.

Data Sources: https://www.icos-cp.eu/science-and-impact/global-carbon-budget/2022
https://gml.noaa.gov/webdata/ccgg/trends/co2/co2_mm_mlo.txt

For values in billion tonnes of carbon dioxide (CO2) per year, multiply Carbon Emissions by 3.664.

$$TotCarbEmit := READPRN("Total Carbon Emissions 1750 - 2020.txt") \qquad TotCO2Emit := 3.664 \cdot TotCarbEmit^{\langle 1 \rangle}$$



1750 CO_2 Level was 275 ppm

The amount of carbon dioxide in the atmosphere (blue line) has increased along with human emissions (gray line) since the start of the Industrial Revolution in 1750. Emissions rose slowly to about 5 gigatons—one gigaton is a billion metric tons—per year in the mid-20th century before skyrocketing to more than 35 billion tons per year by the end of the century. NOAA Climate.gov graph, adapted from original by Dr. Howard Diamond (NOAA ARL). Atmospheric CO2 data from NOAA and ETHZ. CO2 emissions data from Our World in Data and the Global Carbon Project.

C. SECTIONS IV-IX: SOLAR, PLANETARY, GALACTIC, ENSO, PDO CYCLES

- Diurnal (daily)
- Seasonal
- IV. Wolf Number, Sunspots - average sunspot cycle 11.2 years variation from 9 to 14 years
- Longer Cycles -
- In addition to the solar irradiance variation with the solar cycle (the (Schwabe) cycle), the solar activity varies with longer cycles, such as the Empirical 70 year warming cycle (Menne), proposed 88 year (Gleisberg cycle), 208 year (DeVries cycle), the 1,000 yr (Eddy cycle), 100,00 yr Milankovic, and motion in galaxy - galactic yr ~ 226 Million yr
- VI. Albedo Variations
- VII. Empirical 70 year warming cycle (Menne)
- VIII. Milankovitch Orbital: 21, 41, 54, 100 (corresponds to glacial cycles), 410 kyears
- IX Climate Cycle Analysis: Hilbert-Huang Transformation Analysis

IV. Solar Variation: Wolf Number, Sunspots, C14 SS Extrema, Irradiance, Wind

See Section XIIA for Solar Radiation Spectrum and XIIIB for Reflectance.

http://en.wikipedia.org/wiki/Solar_variation

The Sun and Climate **http://pubs.usgs.gov/fs/fs-0095-00/fs-0095-00.pdf**

Many geologic records of climatic and environmental change based on various proxy variables exhibit **distinct cyclicities that have been attributed to extraterrestrial forcing**. ... Another terrestrial observation was that the Maunder Minimum coincided with the coldest part of the Little Ice Age.

http://commons.wikimedia.org/wiki/File:Carbon-14_with_activity_labels.png http://www.radiocarbon.org/IntCal04%20files/intcal04.14c

Read Carbon 14 Atmospheric Concentration Data

\# CAL BP, 14C age, Error, Delta 14C, Sigma,
YR BP ,YR BP, per mil , per mil

$C14 := READPRN(\text{"Atmospheric C14 Concentration.TXT"})$ $\quad Yr := C14^{\langle 0 \rangle} + 40$

$SSSmooth := ksmooth\left(reverse(Yr), reverse\left(C14^{\langle 3 \rangle}\right), 2000\right)$

$Detrend := reverse\left(C14^{\langle 3 \rangle}\right) - SSSmooth$

$SSCycle := ksmooth(reverse(Yr), Detrend, 1000)$ $\quad Yr_{SS} := 2010 - Yr$

Wolf number

The Wolf number (also known as the International sunspot number, relative sunspot number, or Zürich number) is a quantity which measures the number of sunspots and groups of sunspots present on the surface of the sun.

http://en.wikipedia.org/wiki/Wolf_number

The Solar Physics Group at NASA's Marshall Space Flight Center

Royal Greenwich Observatory - USAF/NOAA Sunspot Data

http://solarscience.msfc.nasa.gov/greenwch/spot_num.txt

Sunspot Monthly Averages -2013.txt: Spliced above with Recent Indices.txt data from //www.swpc.noaa.gov/

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, SS2022: 1749 to 2022 Monthly Sunspot Data

Read Sunspot SP NASA Data - 2015

$SSpots := READPRN(\text{"sunspot\_num2015.txt"})$

$NumSS := SSpots^{\langle 2 \rangle}$

$YrDec := -\left(SSpots^{\langle 0 \rangle} + \frac{SSpots^{\langle 1 \rangle} - 1}{12} - 2014\right)$

$SSpotYrly := READPRN(\text{"SN\_y\_tot\_V2.0-1690.txt"})$

$SSSmth := ksmooth(-YrDec, NumSS, 11)$

Read Sunspot NOAA Data - 2022

$SSpots := READPRN(\text{"observed-solar-cycle-indices 1750-2022.txt"})$

$NumSS := SSpots^{\langle 3 \rangle}$

Yearly Average Data through 2017: 2017.5

$YrDec := SSpots^{\langle 0 \rangle} + \frac{-1\,SSpots^{\langle 1 \rangle} - 1}{12}$

Solar Influences Data Analysis Center - SIDC

http://www.sidc.be/sunspot-data/ https://www.swpc.noaa.gov/

YrMon, Year_Decimal, Monthly, Monthly Smoothed Sunspot Number, 1749 to 2014

$SSN := READPRN(\text{"monthssn201409.dat"})$ $\quad SSNYr := READPRN(\text{"yearssn2013.dat"})$

$SSNYrSmooth := ksmooth\left(SSNYr^{\langle 0 \rangle}, SSNYr^{\langle 1 \rangle}, 11\right)$

NGDC - Group Sunspot Numbers (Doug Hoyt re-evaluation) 1610-1995

http://www.ngdc.noaa.gov/stp/SOLAR/ftpsunspotnumber.html#hoyt - 4bb. monthrg.dat

$SSN\_Hoyt := READPRN(\text{"Grp SSN-monthrg-1610-1995.dat"}$ $\quad SSNS := ksmooth\left(SSNYr^{\langle 0 \rangle}, SSNYr^{\langle 1 \rangle}, 10\right)$

NGDC-Table of smoothed monthly sunspot numbers 1700-present

Year, SNN-Jan to SNN-Dec

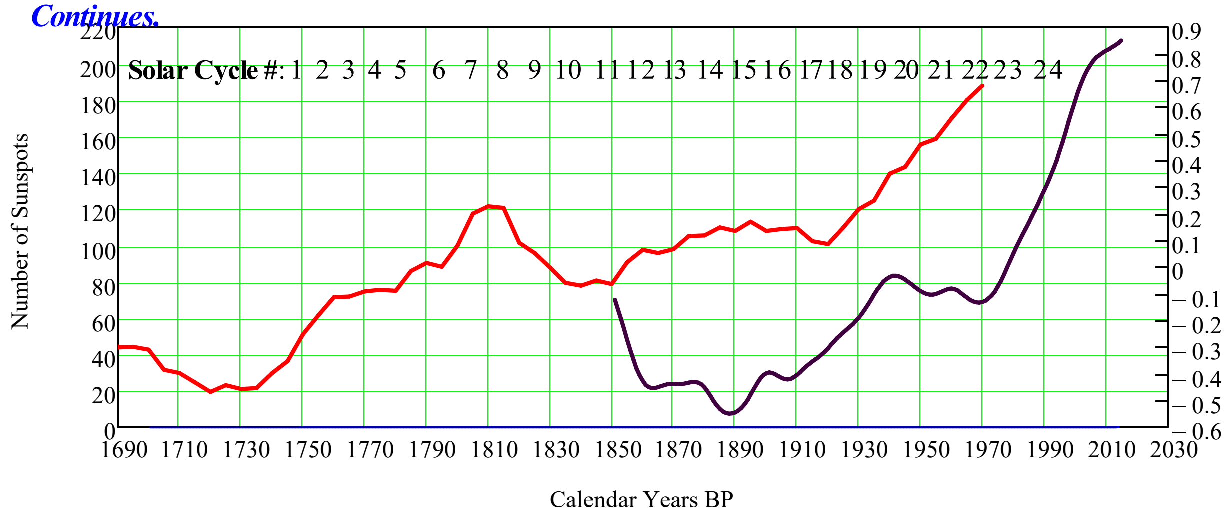
$SSNSm\_Hoyt := READPRN(\text{"SmoothMonthMeanHoyt-1749-2009.txt"})$ $\quad R := rows(SSNSm\_Hoyt)$

$r := 0..R-1 \quad SSH_r := \sum_{mm=1}^{12}\left(SSNSm\_Hoyt_{r,mm} \cdot \frac{1}{12}\right) \quad Year_H := SSNSm\_Hoyt^{\langle 0 \rangle}$

Smooth Hadcrut over 11 year cycle Sun Spots: $\quad TKSmooth := ksmooth\left(Time_{crut}, TCrutYr, 11\right)$

1. Black-TCrut Temp, Solar Proxy: Red-Changes C14 Concentration, Blue - Number of Yearly Sunspots ***Note that the Current Temperature Anomaly DOES NOT Track Sunspot Numbers. AGW***

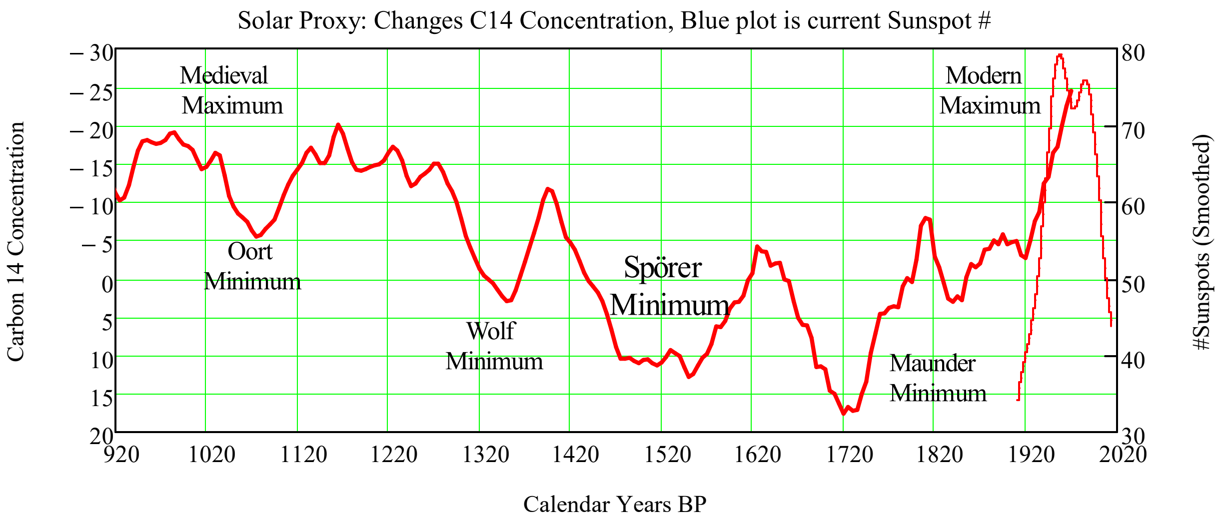
Continues.



$SubsetSSN := submatrix(SSNYr, 210, 313, 0, 1)$ $SSSSNDec := ksmooth\left(SubsetSSN^{\langle 0 \rangle}, SubsetSSN^{\langle 1 \rangle}, 24\right)$

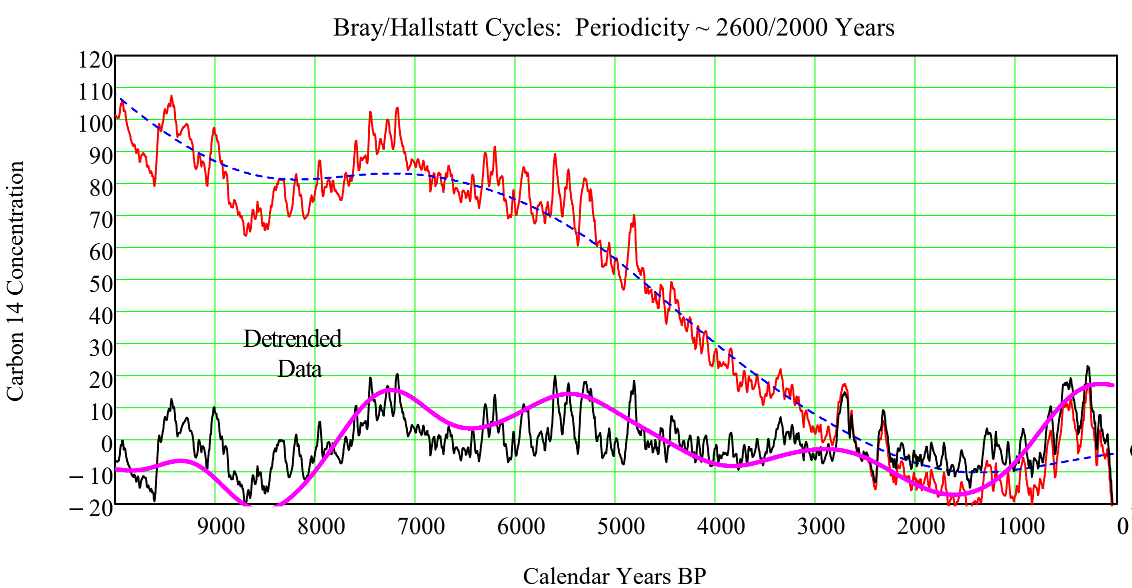
2. Solar Sun Spot Epochs (910 to 2010) from C^{14} Concentration - Maunder Minimum

Maunder Minimum: 70 year period from 1645 to 1710 when all solar activity stopped



3. Extended C14 Data (Red) Smoothed Data (Dotted Blue)

Detrended Data (Solid Black) Hallstadzeit Cycles (Heavy Magenta Curve)



Refer to Above Sun Spot Epochs

The Bray cycle appears to be closely tied to tight clusters of **grand solar maxima and minima**. The Little Ice Age Wolf, Spörer, Maunder and Dalton grand minima are the best example of a solar grand minima cluster and they fall in a Bray low. The Greek Dark Age and the Homer grand minimum also fall in a Bray low.

4: 1975 to 2023 Monthly Sun Spot Data - Cycle 24 was a 30 Year Minimum Solar Cycle

Solar Influences Data Analysis Center Royal Observatory of Belgium, 1749 to 2023

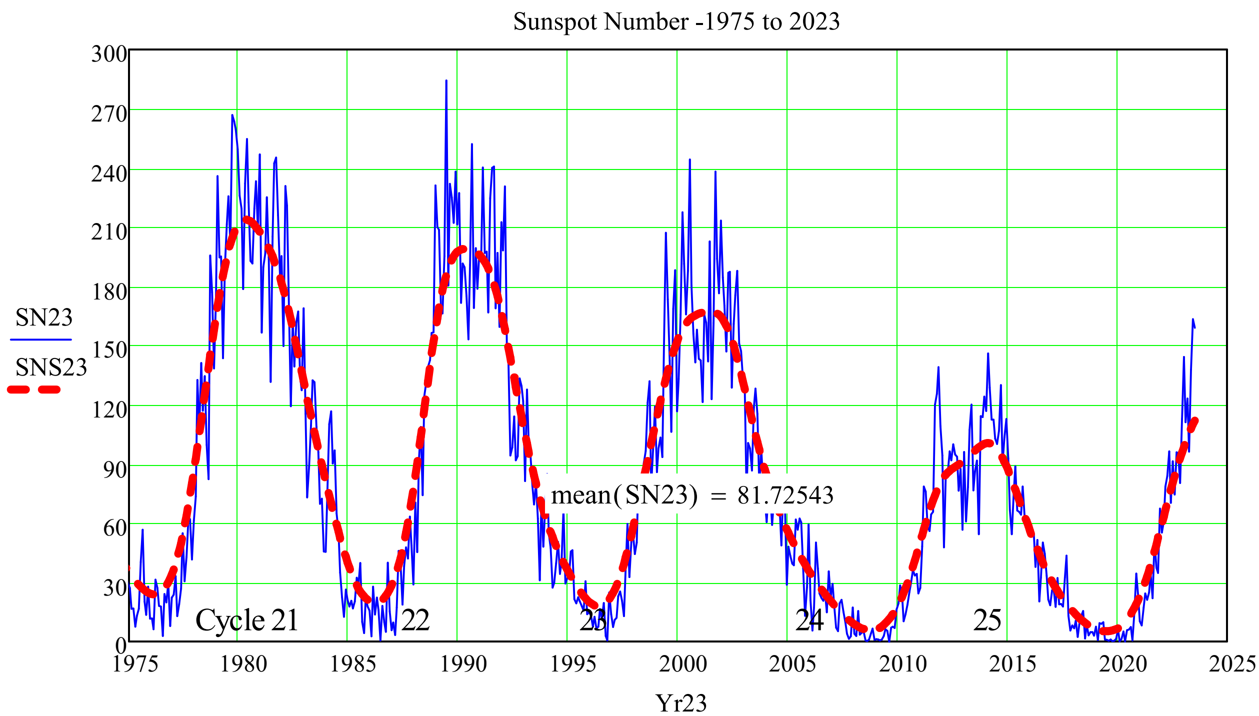
https://www.sidc.be/SILSO/datafiles

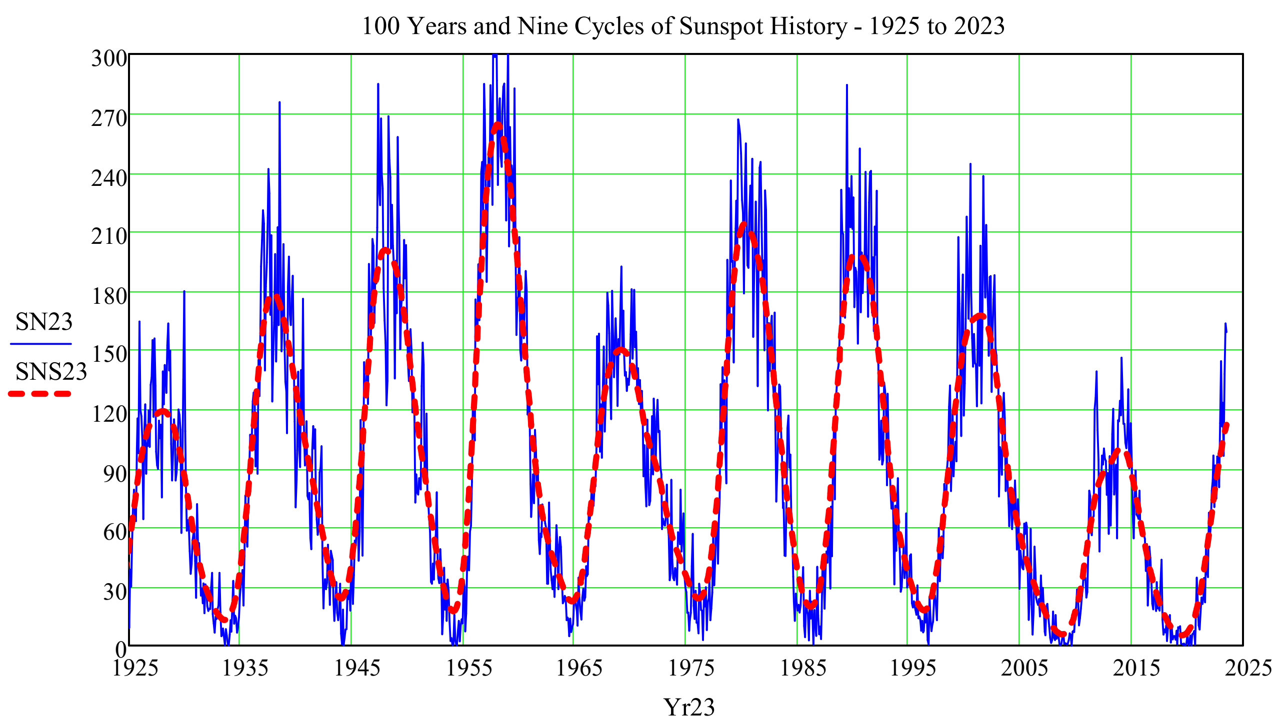
Data is from 1749 to July 2023

$SSN2023 := READPRN("SN\_m\_tot\_V2.0\text{-}2023.txt")$ $\quad Yr23 := SSN2023^{\langle 2 \rangle}$ $\quad SN23 := SSN2023^{\langle 3 \rangle}$

Smooth the Data: $SNS23 := ksmooth(Yr23, SN23, 2)$

Red Dashed Line is the Smoothed Curve





4. PMOD Total Solar Irradiance, TSI, Composite

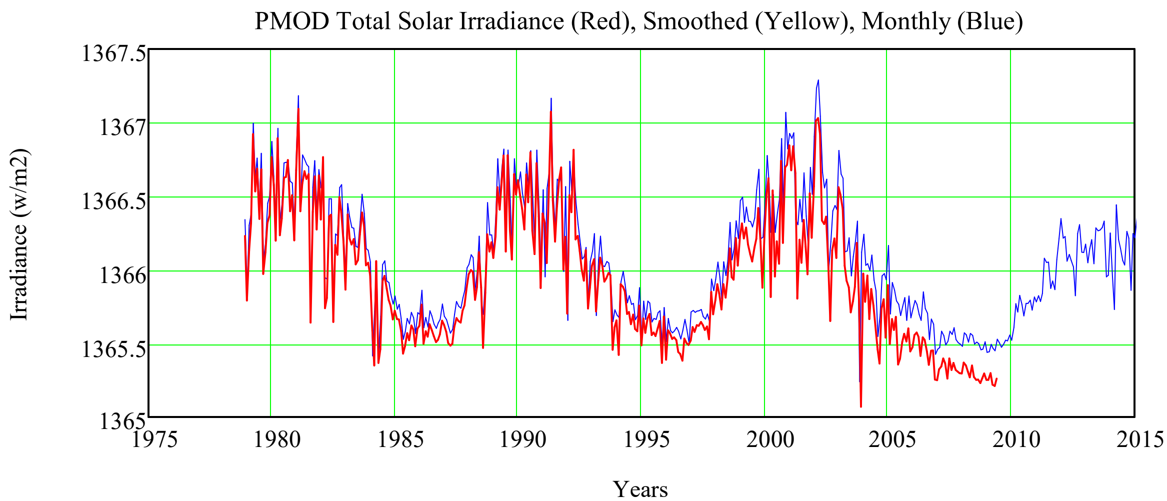
"The Suns Total Irradiance: Cycles, Trends and Related Climate Change Uncertainties since 1978"
PMOD/WRC, Davos, Switzerland, "Unpublished data from the VIRGO Experiment on the cooperative ESA/NASA Mission SoHO"
ftp://ftp.pmodwrc.ch/pub/data/irradiance/composite
YYMMDD, epoch (1 corresponds to 1-Jan-1980), average irradiance in W/m2

$TSI_{PMOD} := READPRN("TSI.PMODF\_15.TXT")$ $TSI_{PMOD_{410,0}} = 800101$

TAM, Convert Daily to Monthly Average **TSI 2014 is Yearly**

$TSIA06 := READPRN("TSIMonthAvg-2006Data.txt")$ $TSI_{smm} := READPRN("TSIsm8.txt")$

$TSIMon := DMAvg(TSI_{PMOD})$



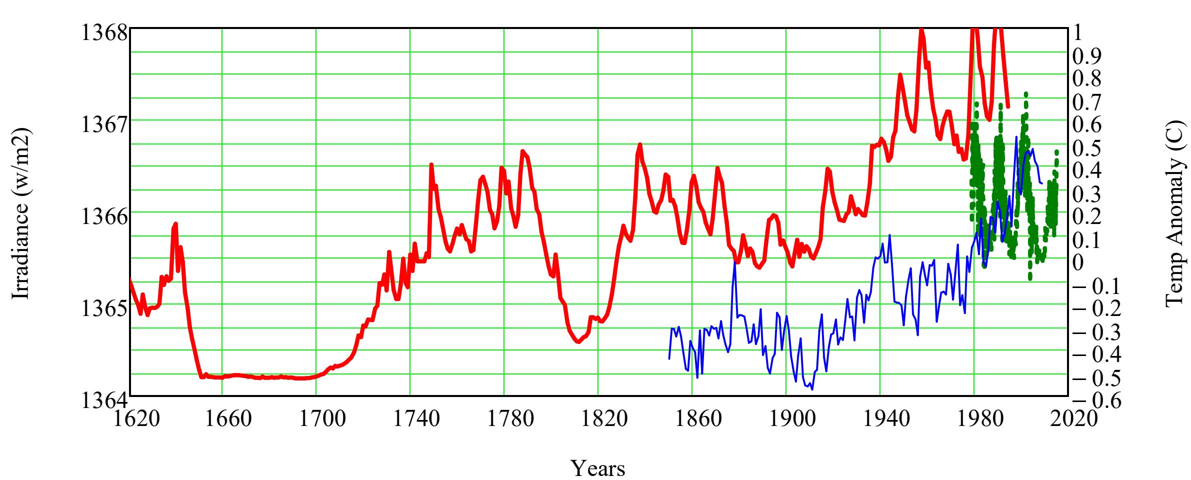
5. Reconstruction of solar irradiance since 1610, Lean 1995 (1600-1995) - Correlates to Temp

Solar Irradiance Correlates with U.S. Temp Anomaly

$HadCrutz := READPRN("hadcrut3vgl.txt")$ $rows(HadCrutz) = 32$ $cols(HadCrutz) = 14$ $nz := 0..159$

$DateTSIL := READPRN("TSIpmodDate.txt")$

$TSDF_{lean} := READPRN("lean1995data.txt")$ $Yr_{lean} := TSDF_{lean}^{\langle 0 \rangle}$ $TSD_{lean} := Fill\left(TSDF_{lean}^{\langle 1 \rangle}\right)$



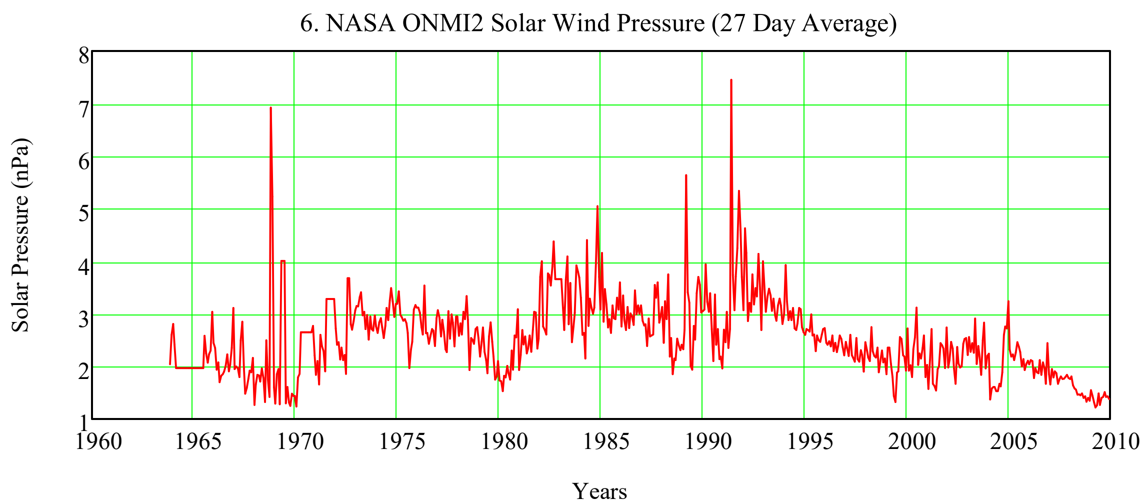
6. NASA OMNI2: Solar Wind Pressure and Decadal Trends

Solar Wind Pressure and Trends

http://omniweb.gsfc.nasa.gov/cgi/nx1.cgi
omni2_27day data from 19630130 to 20091230
Scalar B, nT, Flow pressure
YEAR DOY HR   1   2

SWPF := READPRN("OMNI_Solar_Wind_1963_27Day.dat")   SWP := Fillin(SWPF)

Note the downward trend in Solar Wind Pressure since 1993, a flattening, and then renewed fall in 2005 at an equal rate, dropping to 1970 levels. This hints that we will be seeing a period of reduced solar activity - See the next SECTION on Solar Prediction.



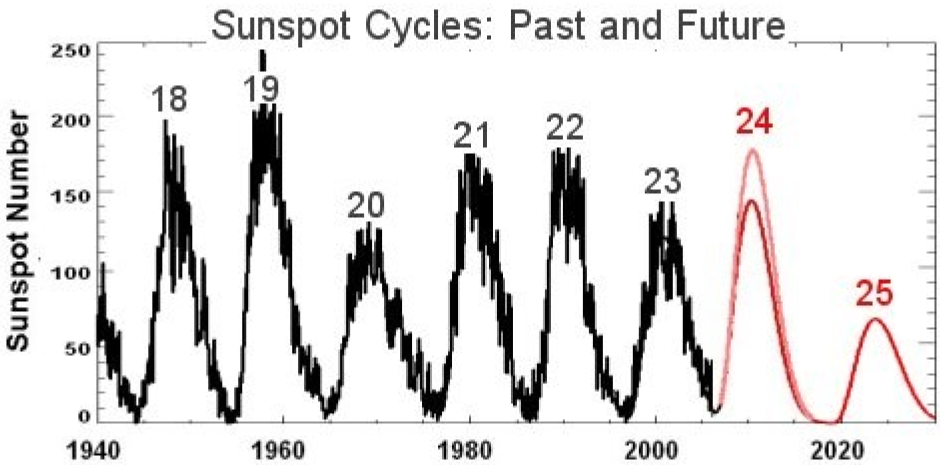
7. NASA: Solar Cycle Sunspot Prediction ==> Global Cooling - Added Cycle 24 Data

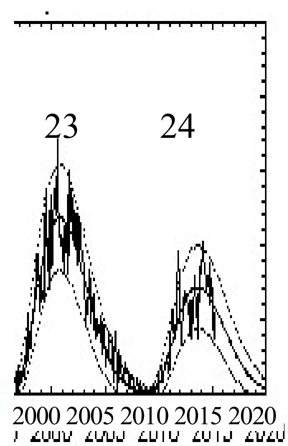
http://solarscience.msfc.nasa.gov/predict.shtml Data: HathawayMagSunspot_predict.txt

A historic low period of the Sun's activity is coming.

NASA: Solar Cycle 25 peaking around 2022 could be one of the weakest in centuries.

http://science.nasa.gov/headlines/y2006/10may_longrange.htm





What influence does the sun have on global climate? Solar Energy.

The Sun provides the energy that drives the climate system. **Long-term variations in the intensity of solar energy reaching the Earth are believed to cause climate change on geological time-scales.** New studies indicate that **changes in the Sun's magnetic field** may be responsible for shorter-term changes in climate, including much of the climate of the 20th century. Also, at least one indirect effect of solar variability, the effect that changes in the **amount of UV radiation** emitted by the Sun have on the warming effect of the ozone layer, has been established. A second indirect effect, the effect that changes in solar radiation have on **cosmic-ray induced cloudiness**, has been hypothesized, but not proven. This suggested effect is being studied both by observations and in laboratory simulations.

The strength of the Sun's magnetic field varies through the 11-year solar cycle. When the **Sun's magnetic field is** strong, it reduces the number of **cosmic rays** hitting the Earth. **Laboratory experiments have shown that cosmic rays are one of the factors causing the formation of water droplets and clouds** in the atmosphere. In 1997, two Danish researchers, Svensmark and Friis-Christiansen, showed that from **1983 to 1994, there was a high degree of correlation between total cloud cover and the number of cosmic rays striking the Earth**, which in turn is correlated with the intensity of the Sun's magnetic field. **The changes in cloud cover, 3-4 percent, were large enough to explain much of climate change.** Additional observational studies aimed at determining whether there is a correlation between solar intensity and cloudiness are underway, and CERN, the European Organization for Nuclear Research, will be conducting laboratory experiments to determine whether simulated cosmic rays can, in fact, create the conditions for cloud formation.

Svensmark, H. and E. Friis-Christiansen, 1997: Variation of cosmic ray flux and global cloud cover –'96 A missing link in solar-climate relationships. *Journal of Atmospheric, Solar and Terrestrial Physics,* 59: 1225-32.

Svensmark, H. and N. Calder, 2007, *op cit.*

Ibid., Pg. 562.

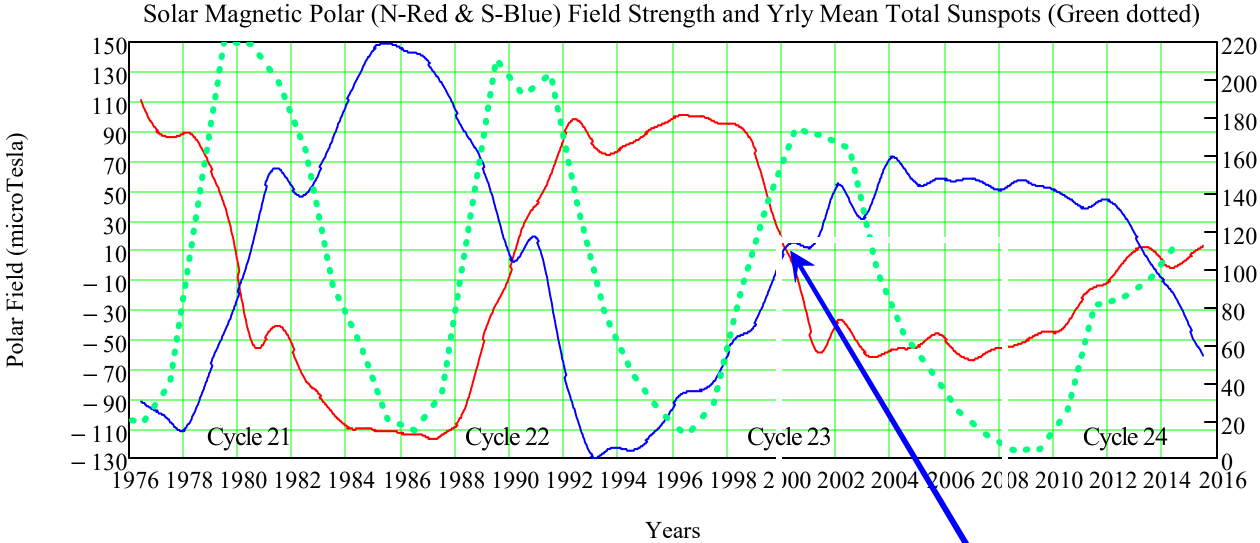
8. Wilcox Solar Observatory Polar Observations: Correlation Magnetic Field & Sunspots

Solar Mag: http://wso.stanford.edu/Polar.html#latest SunSpot# Data: http://www.sidc.be/silso/datafiles

Year, Month, Day, N, S, Avg, Filtered N, S, Avg

$$MagF := READPRN("SunNSPolarMagField-XClean.txt") \quad Date := \overrightarrow{\left(MagF^{\langle 0\rangle} + \frac{MagF^{\langle 1\rangle} - 1}{11} + \frac{MagF^{\langle 2\rangle}}{365}\right)}$$

A 20 nhz low pass filtered values eliminate **yearly geometric projection effects on Solar Mag Field Data**



The development of the solar polar Magnetic field strength throughout a solar sunspot cycle can be used to **predict** the magnitude of the next cycle and the peak of the current cycle. Polar field **reversal**s, where the North-Red and South-Blue curves **intersect**, typically occur within a year of **sunspot maximum**.

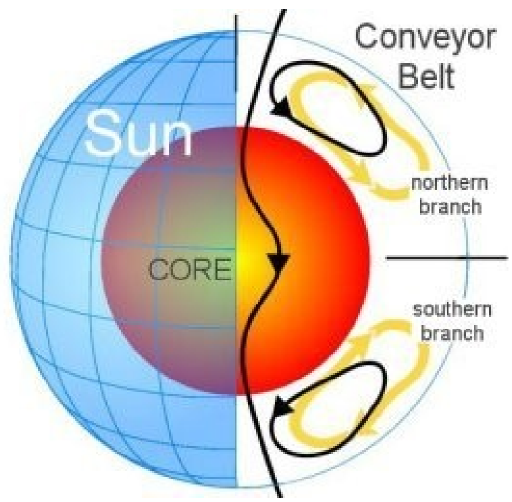
http://science.nasa.gov/science-news/science-at-nasa/2006/10may_longrange/

2006 Hathaway Model - Single Dynamo

The **Great Conveyor Belt** is a massive circulating current of hot plasma within the Sun. It has **two branches**, north and south, each taking about 40 years to perform one complete circuit. Researchers believe the turning of the belt controls the sunspot cycle, and that's why the slowdown is important.

Normally, the conveyor belt moves about **1 meter per second**—walking pace," says Hathaway. "That's how it has been since the late 19th century." In recent years, however, the belt has decelerated to 0.75 m/s in the north and 0.35 m/s in the south. "We've never seen speeds so low.

According to theory and observation, the **speed of the belt foretells the intensity of sunspot activity** ~ 20 years in the future. A slow belt means lower solar activity; a fast belt means stronger activity. The reasons for this are explained in the Science@NASA story Solar Storm Warning. "The **slowdown** we see now means that **Solar Cycle 25**, peaking around the year **2022**, could be one of the **weakest in centuries**," says Hathaway.



V. Zharkova Model - 2012, 2015 - Principal Component Analysis: Predicts Mini Ice Age during 2030s

Principal Component Analysis of Background and Sunspot Mag Field Variations During Solar 21-23

Note: Analysis is deemed simplistic by many other experts: only 35 yrs data, sun is stochastic, fails backwards

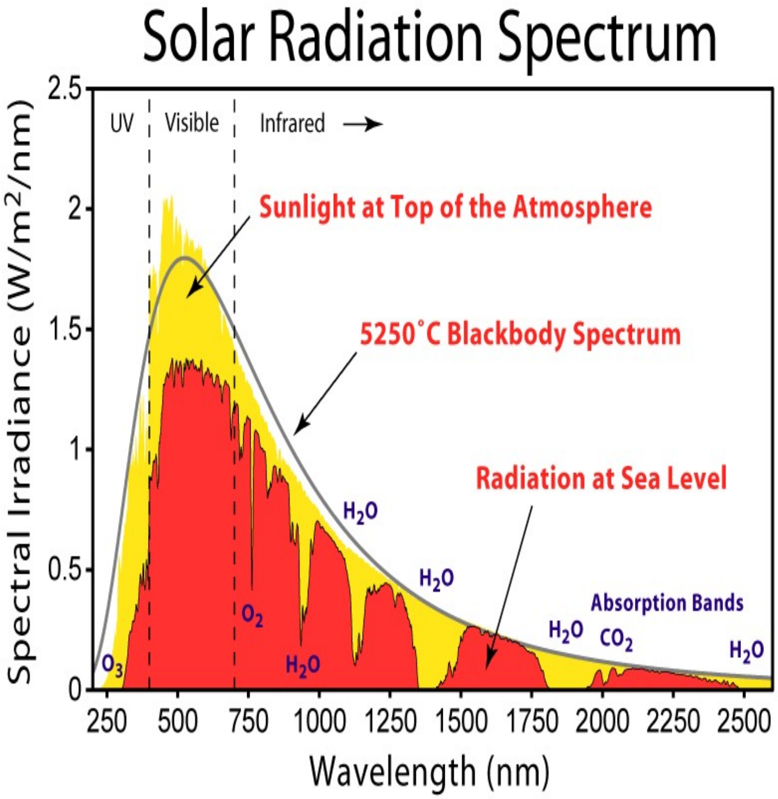
A new model of the Sun's solar cycle is producing **unprecedentedly accurate** predictions of irregularities within the Sun's 11-year heartbeat. The model draws on dynamo effects in two layers of the Sun, one close to the surface and one deep within its convection zone. The model predicts that the **magnetic wave pairs** will become **increasingly offset** during Cycle 25, which peaks in 2022. Thus, the solar activity will **fall by 60 per cent during the 2030s** to conditions last seen during the '**mini ice age**' that began in **1645**.

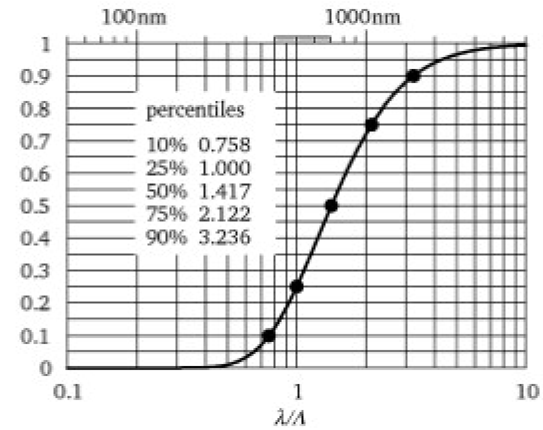
Zharkova and her colleagues have found that **adding a second dynamo, close to the surface**, completes the picture with surprising accuracy. Found **magnetic wave components appearing in pairs**, originating in **two different layers** in the Sun's interior. They **both** have a frequency of **approximately 11 years**, although this frequency is **slightly different**, and they are **offset in time**. Over the cycle, the waves fluctuate between the northern and southern hemispheres of the Sun. Combining both waves together and comparing to real data for the current solar cycle, we found that our predictions showed an accuracy of 97%. The prediction results indicate that the solar activity is defined mainly by the solar background magnetic fields (SBMF) while the sunspots and their magnetic fields seem to be derivatives of the SBMF variations.

SECTION V. Solar Radiation & GHG Absorption Spectra & CO2 Band Broadening

1. Top of Atmosphere and 2. Sea Level

Note: Relative Importance of Water Vapor versus CO_2 absorption. Greenhouse gases—including **most diatomic** gases with two different atoms (such as carbon monoxide, CO) and all gases with three or more atoms—are able to absorb and emit infrared radiation. Though more than 99% of the dry atmosphere is IR transparent (because the main constituents—**N_2, O_2, and Ar—are not able to directly absorb** or emit infrared radiation), intermolecular collisions cause the energy absorbed and emitted by the greenhouse gases to be shared with the other, non-IR-active, gases.

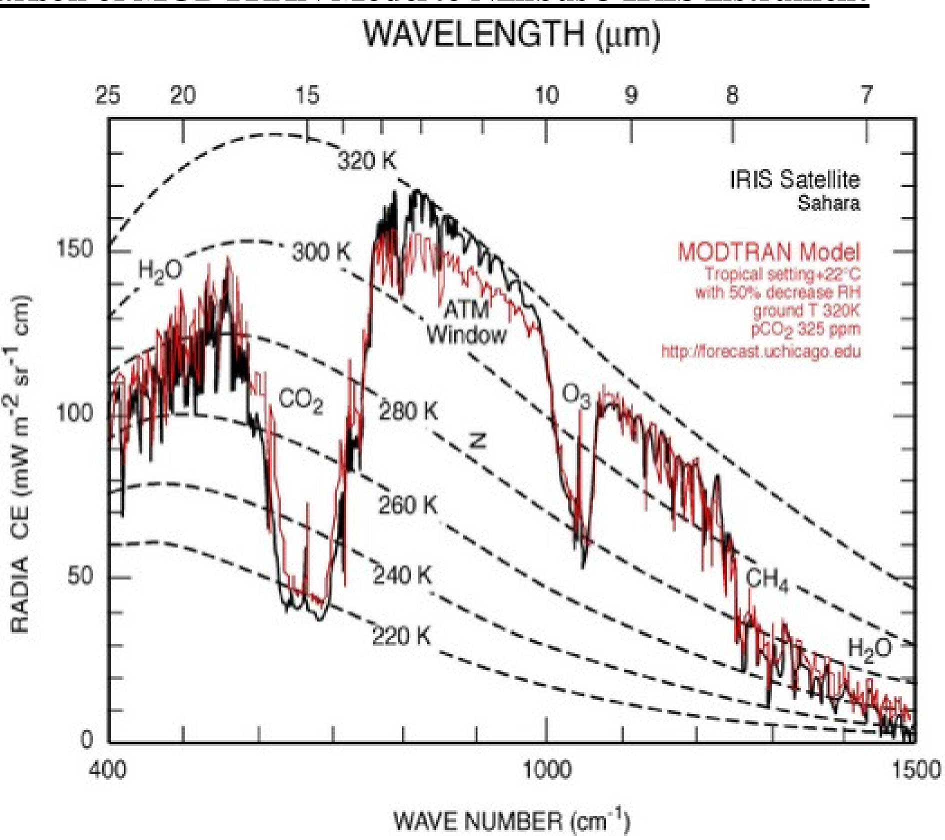




Cumulative fraction of solar black body emission as a function of wavelength λ and thermal wave length Γ (bottom scale) for radiation temperature of 5780 K. **Thermal IR** is long wavelength IR that does not originate from the sun. It is the mechanism used by the atmosphere and earth to shed energy to space.

http://climatemodels.uchicago.edu/modtran/modtran.doc.html

2. Comparison of MODTRAN Model to Nimbus 3 IRIS instrument



3. High Measurements of the Radiative Surface Forcing of Climate

W.F.J. Evans, North West Research Associates, Bellevue, WA; and E. Puckrin
https://ams.confex.com/ams/Annual2006/techprogram/paper_100737.htm

The earth's climate system is warmed by **35 C due** to the emission of **downward infrared radiation by greenhouse gases** in the atmosphere (surface radiative forcing) or by the absorption of upward infrared radiation (radiative trapping). **Increases in this emission/absorption are the driving force behind global warming.** Climate models predict that the release of greenhouse gases into the atmosphere has altered the radiative energy balance at the earth's surface by **several percent** by **increasing the greenhouse radiation from the atmosphere**. With **measurements at high spectral resolution**, this increase can be quantitatively attributed to each of several **anthropogenic gases.** Radiance spectra of the **greenhouse radiation from the atmosphere have been measured at ground level** from several Canadian sites using FTIR spectroscopy at high resolution. The forcing radiative fluxes from CFC11, CFC12, CCl_4, HNO_3, O_3, N_2O, CH_4, CO and CO_2 have been **quantitatively determined** over a range of seasons. The contributions from stratospheric ozone and tropospheric ozone are separated by our measurement techniques. A comparison between our measurements of surface forcing emission and measurements of radiative trapping absorption from the IMG satellite instrument shows reasonable agreement. The experimental fluxes are simulated well by the FASCOD3 radiation code. This code has been used to **calculate the model** predicted **increase in surface radiative forcing since 1850** to be **2.55 W/m^2**. In comparison, an ensemble summary of **our measurements indicates** that an energy flux **imbalance** of **3.5 W/m^2** has been created by anthropogenic emissions of greenhouse gases **since 1850**. This experimental data should effectively end the argument by skeptics that no experimental evidence exists for the connection between greenhouse gas increases in the atmosphere and global warming.

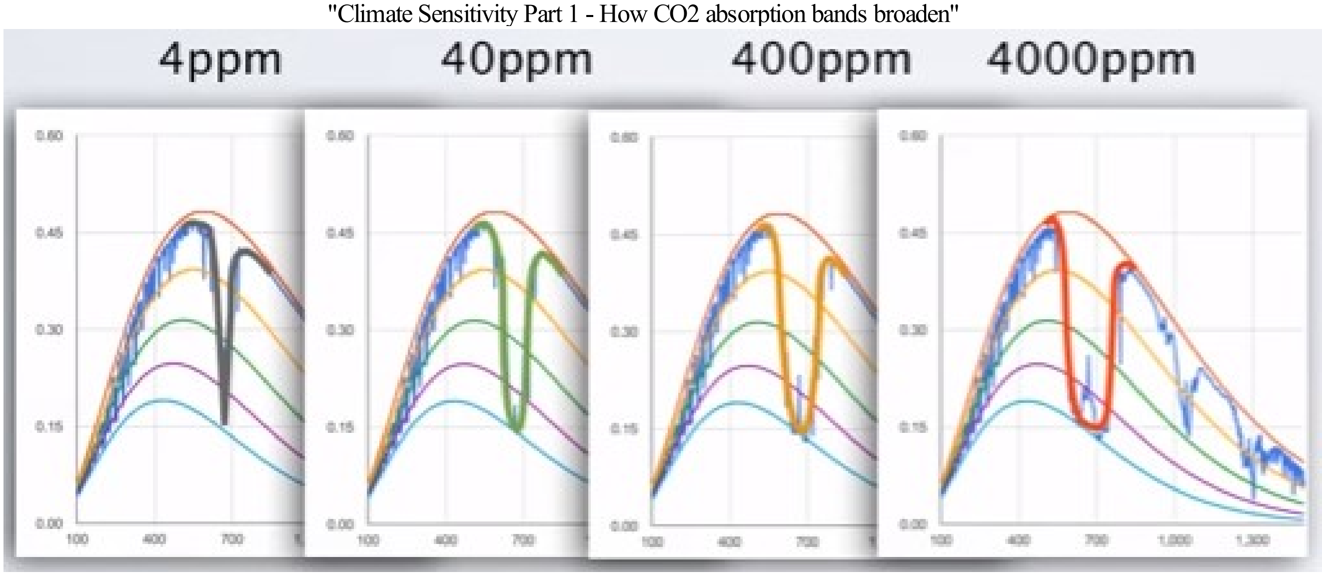
A typical winter spectrum of the downward radiance in the **5-16 µm** wavelength range is shown in the paper referenced below, with the emission from several greenhouse gases identified.
https://ams.confex.com/ams/Annual2006/techprogram/paper_100737.htm

CO2 Band Widening: @Peak 667 to wings@700 cm-1 wave number band of CO2 bending motion

Blackbody Curves with CO2 Absorption at Increasing Concentrations from Mod Tran Program
Top curve is warm air at bottom of atmosphere. Bottom curve is cold air at top of atmosphere. This is a result both of #1: increased photon mean-free path length and #2: % absorption - side band wave. The curves below show that CO2 infrared spectrum absorption causes less energy to be emitted into space. **This loss in upwelling emitted IR energy from increased CO2 band broadening absorption has to be compensated by increase in surface temperature.**
Note: This model does not consider the surface heat loss by convective currents. Radiative Convective (RC) models.

667 cm-1 wavenumber = 15 µm

But Energy In must equal Energy Out. Reducing the Energy out does not change the solar energy in. If you increase CO2 concentration there will be less energy going out to space. Therefore must increase. There will be a 1C increase for every 3W increase in emission.
See for example youtube.com George Mason University: GMU CLIM102 Video:
"Climate Sensitivity Part 1 - How CO2 absorption bands broaden"



Band Broadening

Doppler Broadening: Gas velocity has a Max-Boltzmann distribution. ∴ Spectral line shapes will have a M-B distribution.

Collision Broadening: As pressure of gas increases the collision rate increases and perturbs the energy states.

Stark Broadening: Occurs with strong electric fields, such as in ionized gases. Stark and Collision Broadening lumped into Pressure Broadening.

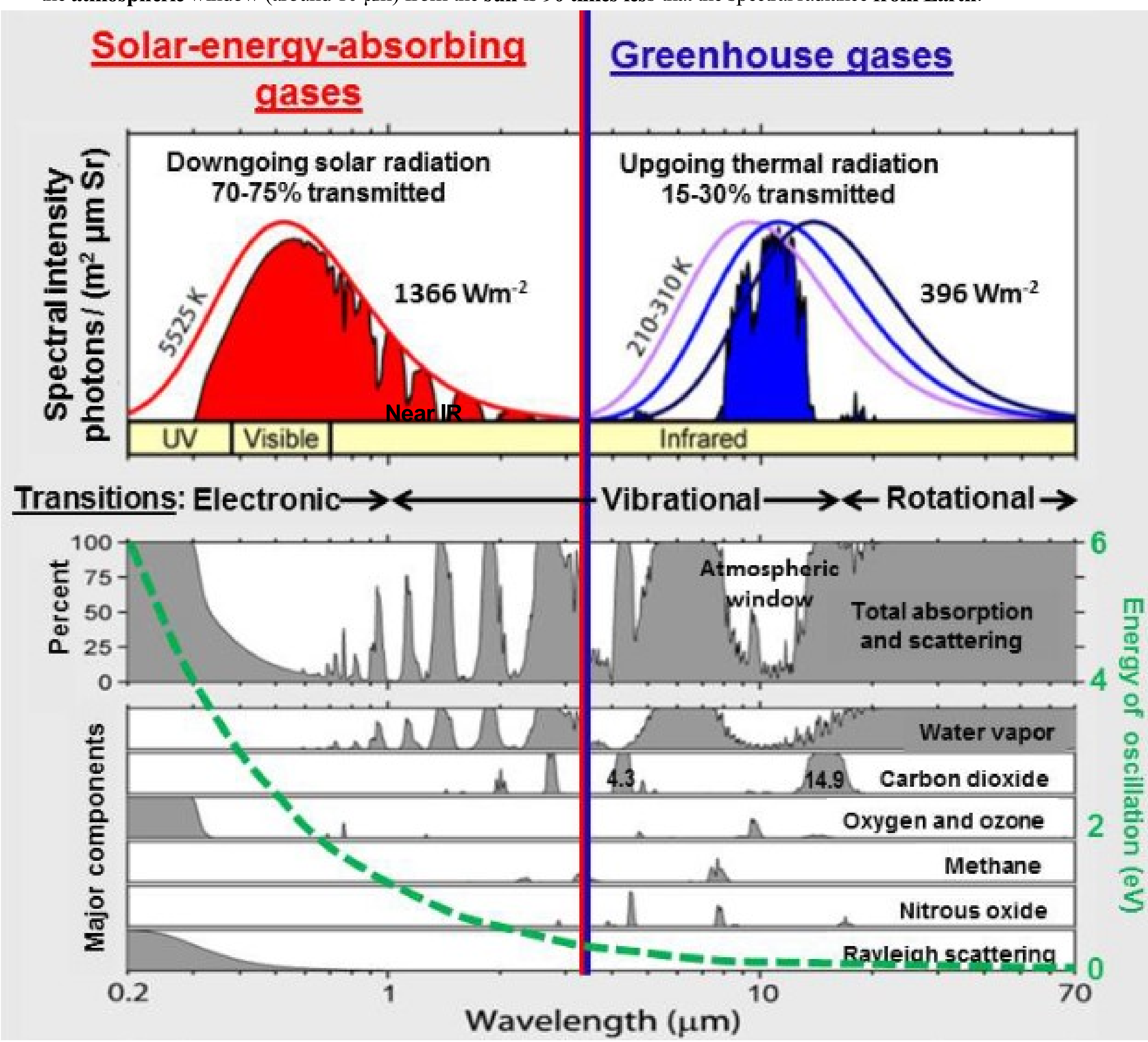
Absorption Bands of ozone, carbon dioxide, water vapor and total atmosphere

This graph explains why the wavelengths in the visible light range of the electromagnetic spectrum from the sun at 6000K are able to reach Earth's surface and why the wavelengths in the infrared radiation range are emitted to space from the earth at 300 K.

The relative importance of a greenhouse gas depends on its abundance in Earth's atmosphere and how much the gas can absorb specific wavelengths of energy.

An effective absorber of infrared radiation has a broader absorption profile, which means that it can absorb a wider spectrum of wavelengths. Water vapor, H_2O, and carbon dioxide CO_2 can absorb radiation wavelengths in the range of 4 μm to 80 μm, except those between 8 μm and 12 μm. CO_2 **is long lived** in the atmosphere. **Ozone** O_3 can absorb wavelengths between 9 μm and 10 μm, but it is found in **low concentrations**.

Note: The **peak spectral radiance** of **infrared** energy radiated by **Earth** is only **1.4%** of the peak spectral radiance of **solar** radiation at the **top** of the atmosphere (**69 times smaller**). The spectral radiance of **infrared** wavelengths reaching the **atmospheric** window (around 10 μm) from the **sun** is **90 times les**s that the spectral radiance **from Earth**.



SECTION VI. Project Earthshine - Measuring the Earth's Albedo

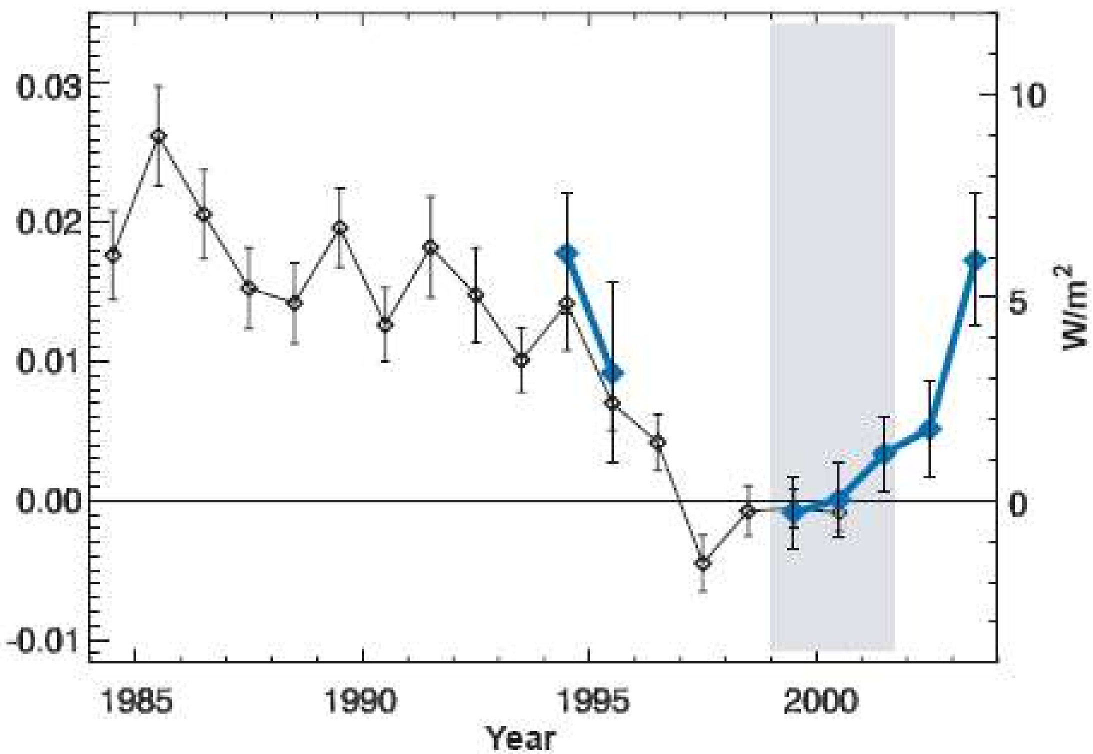
http://www.bbso.njit.edu/Research/EarthShine/

Earth's global albedo, or reflectance, is a critical component of the global climate as this parameter, together with the solar constant, determines the amount of energy coming to Earth. **Probably because of the lack of reliable data, traditionally the Earth's albedo has been considered to be roughly constant, or studied theoretically as a feedback mechanism in response to a change in climate.** Recently, however, several studies have shown large decadal variability in the Earth's reflectance. Variations in terrestrial reflectance derive primarily from changes in cloud amount, thickness and location, all of which seem to have changed over decadal and longer scales.

A global and absolutely calibrated albedo can be determined by measuring the amount of sunlight reflected from the Earth and, in turn, back to the Earth from the dark portion of the face of the Moon (the `earthshine' or `ashen light'). For more than a decade we have been measuring the Earth's large-scale reflectance from Big Bear Solar Observatory.

"Changes in the Earth's reflectance over the past two decades" Figure 3 - Below

E. Palle, P.R. Goode, P. Montanes-Rodriguez and S.E. Koonin, Science, 304, 1299-1301, 2004a
http://bbso.njit.edu/Research/EarthShine/literature/Palle_etal_2004_Science.pdf



1. Figure 3 - Reconstructed annual reflectance anomalies 1984 to 2000

Reconstructed annual reflectance anomalies, Δp* (black), with respect to the mean anomaly for the regression calibration period 1999–2001 (vertical gray band). The **large error bars** result from the **seasonal variability** of Earth's albedo, which can be **15 to 20%**. Also plotted (blue) are the Earth Shine, ES, -observed annual anomalies for 1999–2003 and 1994–1995. The right hand vertical scale shows the deficit in global lSW forcing relative to 1999–2001.

The decrease in Earth's reflectance from 1984 to 2000 suggested by ISCCP data in the Graph corresponds to a change in Δp* of some –0.02, which translates into a decrease of the Bond albedo by 0.02 (Δp*/p* = ΔA/A) and an additional SW absorption, R, of **6.8 W/m²** (R = ΔA x C/4, where C = 1368 W/m² is the solar constant). This is **climatologically very significant**. For example, the latest IPCC report argues for a **2.4 W/m2 increase in CO_2 longwave forcing since 1850**. Our observational ES data extend from 1999 to 2003 and indicate a clear reversal of the ISCCP-derived reflectance trend starting in 1999 up through 2003. The increasing trend in reflectance corresponds to approximately 5 W/m², bringing the mean reflectance anomaly back to its 1980s values. Only the ES data are currently available to signal this reversal; it will be interesting to see how the proxy behaves when ISCCP data are available beyond mid-2001.

These results are difficult to attribute to monotonically increasing atmospheric greenhouse gases.

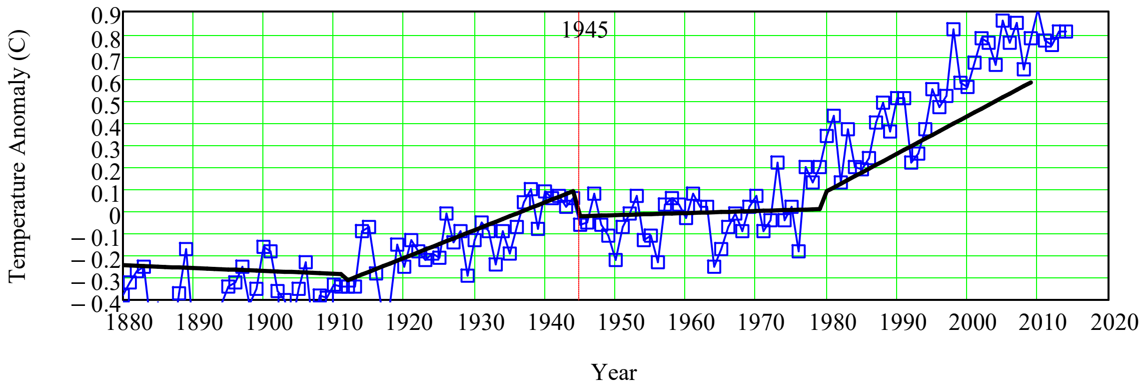
SECTION VII. 70 Year Warming Cycles (Menne)

1. Analysis: Statistics of Climate Change - Temp Rise is Non Monotonic - 70 Year Cycles
Ref: "ABRUPT GLOBAL TEMPERATURE CHANGE AND THE INSTRUMENTAL RECORD," Menne
Use GISS Global Temp Data: "GISS NASA Global Temp Mean Fig2A.TXT" from Above
Break into Four 35 Year Periods: 1880 to 1910, 1911 to 1945, 1946 to 1980 and 1981 to 2010
Uses Analysis from: **http://www.leapcad.com/Climate_Analysis/Cycles_and_Trends_Average_Temp.xmcd**

Note: Temperature Plateaus and then Climbs in 70 Year Cycles

$T_{abrupt} := \text{READPRN}(\text{"GAbrupt.txt"})$

1. Analysis: Abrupt NOAA Global Annual Mean Temperature in 70 Year Cycles



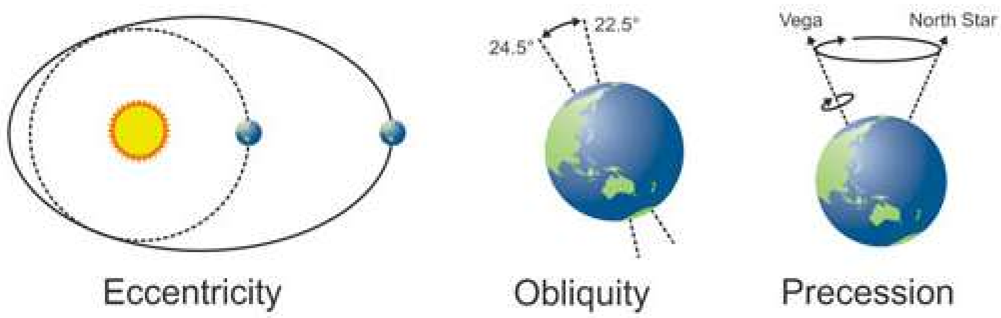
Correlation Coefficient and t Test:

$\text{Stdev}\left(T_{abrupt}\right) = 0.23426$

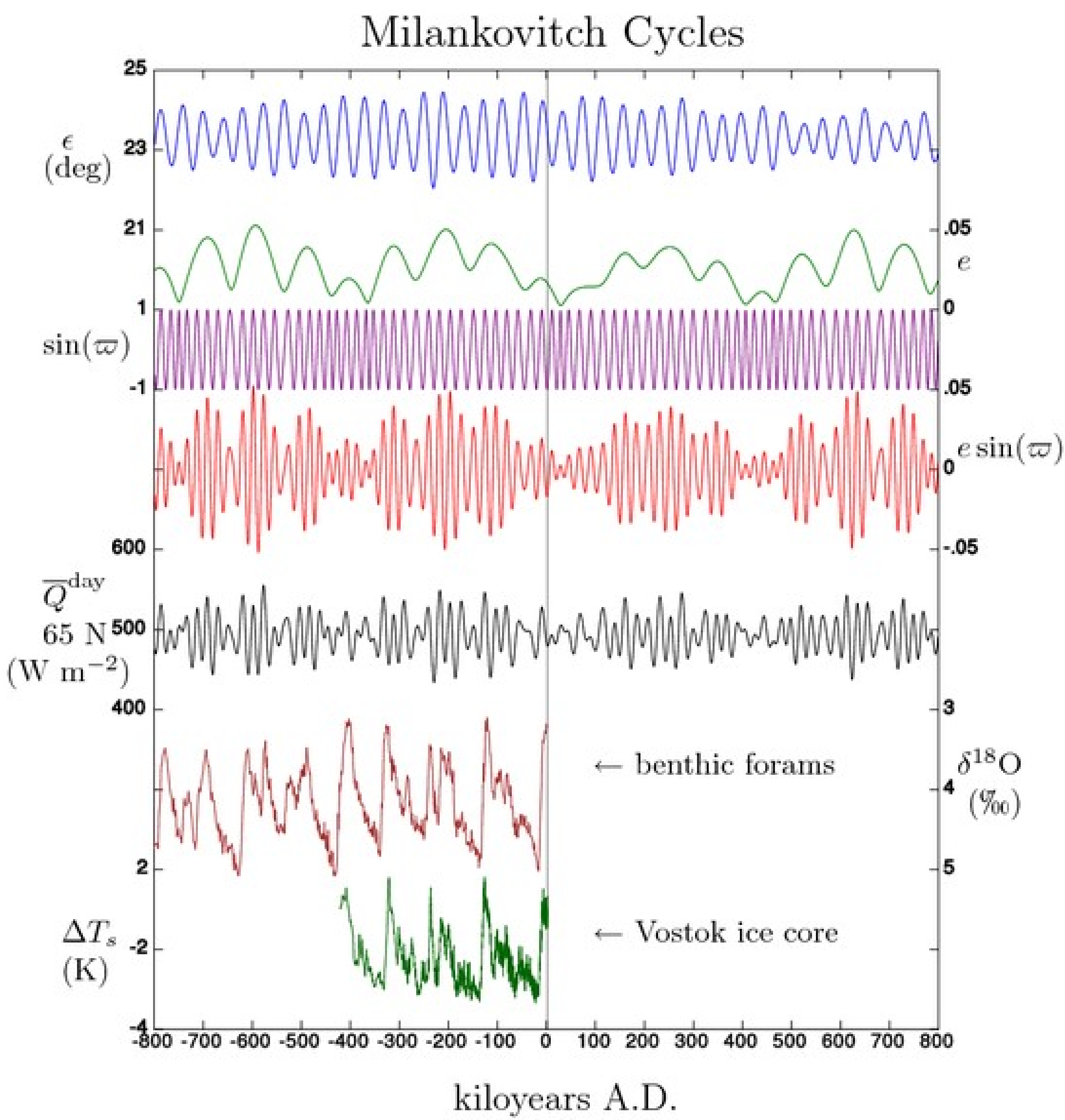
t Test: $t := 0.98622 \cdot 0.23434^{-1} = 4.2085$ These 70 year cycles are statistically significant

SECTION VIII. Milankovitch Cycles

Interglacials come along approximately every **100,000 years.** This is called the **Milankovitch cycle**, brought on by changes in the Earth's orbit. There are three main changes to the earth's orbit. The shape of the Earth's orbit around the sun (**eccentricity**) varies between an ellipse to a more circular shape. The earth's axis is tilted relative to the sun at around 23°. This tilt oscillates between 22.5° and 24.5° (**obliquity**). As the earth spins around it's axis, the axis wobbles from pointing towards the North Star to pointing at the star Vega (precession).



The three main orbital variations. **Eccentricity**: changes in the shape of the Earth's orbit.
Obliquity: changes in the tilt of the Earth's rotational axis. **Max 9% in Δ distance ~ 20% in Δ insolation.**
Precession: wobbles in the Earth's rotational axis.
http://www.skepticalscience.com/Why-does-CO2-lag-temperature.html



The astronomical theory of Paleoclimate after Milankovitch (1930, 1941)

http://en.wikipedia.org/wiki/Milankovitch_cycles

Milankovitch Cycles relate climatic change to variations of the amount of solar energy received by the Earth as a consequence of quasi-periodic changes in celestial geometry (see Imbrie & Imbrie, 1979, and Berger, 1988, for reviews). Of particular importance are variations in the eccentricity of the Earth's orbit (with dominant periods of roughly 400 kyr and 100 kyr), in the obliquity of the Earth's rotational axis relative to the orbital plane (with characteristic periods of 54 kyr and 41 kyr) and in the precession of the equinox or more exactly the eccentricity modulated precession expressed by the precessional index of Berger (1976, 1978b) (with periods of 23 kyr nd 19 kyr). The obliquity cycle is more effective in high latitudes, whereas the low latitudes are dominated by the precessional cycle.

See _Global Warming - Milankovitch.doc for list of articles
The next tipping point comes in ca. 50,000 years from now, when the Milankovich forcing almost certainly would be sufficient to start glaciation.

Solar System Orbital Simulation Data
The presence of chaos, moreover, severely limits the accuracy of orbital integrations on the time scale of **millions of years**. Chaos causes initial errors to grow exponentially in time, and so the simulated orbits diverge from the correct ones.
http://astrobiology.ucla.edu/OTHER/SSO/

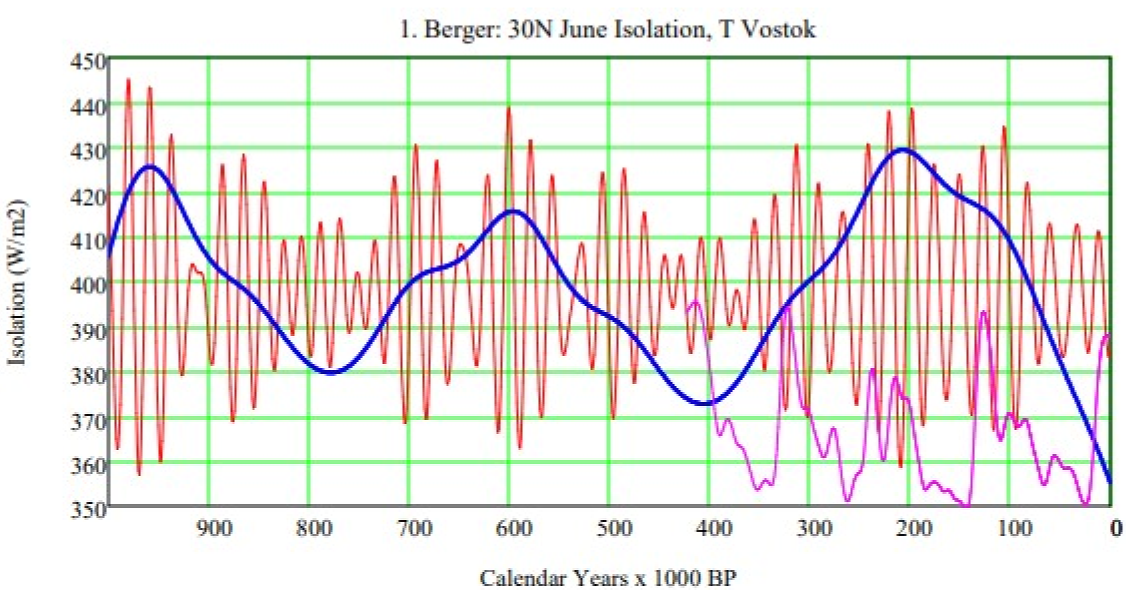
1. Astronomical Solar Insolation Forcing

Early Plesitocene Glacial Cycles - Huybers
Link between glacial extent and solar forcing (orbital configuration).
ftp://ftp.astr.ucl.ac.be/pub/loutre/QSR/
BergerFILE2_90.DAT
INSOLATION DEC
Year 90NDec 60NDec 30NDec 0 Dec 30SDec 60SDec 90SDec

$\text{InsDec} := \text{READPRN}(\text{"BergerFILE2\_90.DAT"})\quad \text{InsJun} := \text{READPRN}(\text{"BergerFILE3\_90.DAT"})$

$\text{MeanIns} := \text{mean}\left(\text{InsJun}^{\langle 4\rangle}\right)\qquad \text{MeanIns} = 398.33779$

$\text{InsSmooth} := 40\cdot\left(\text{ksmooth}\left(-\text{InsJun}^{\langle 0\rangle}, \text{InsJun}^{\langle 4\rangle}, 100\right) - \text{MeanIns}\right) + \text{MeanIns}$



2. Milankovitch radiation for different latitudes and time periods

www.climatedata.info Average of 60 and 70 N
BP, Months 7 to 7, Annual 65N, Annual global, Global cos-weighted

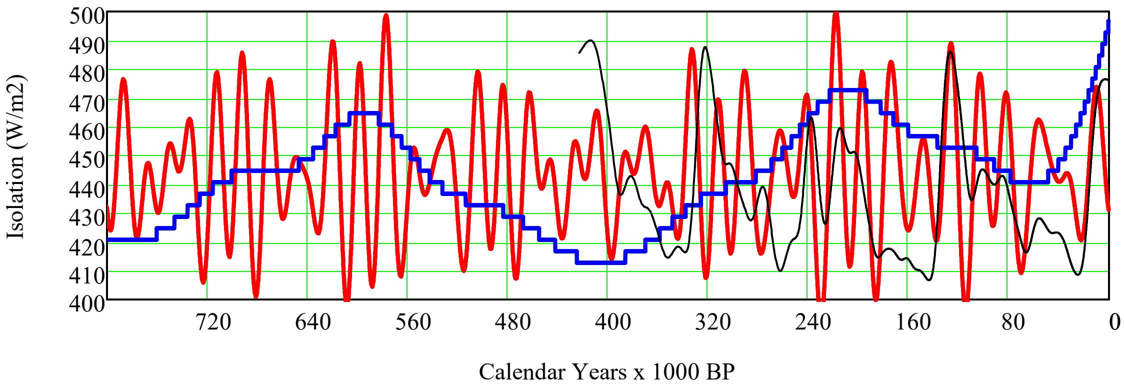
Mlnkvthh_Ins := READPRN("Milankovitch - Isolation - ClimateCom.txt")

$$MeanMkvh := mean\left(Mlnkvthh\_Ins^{\langle 1\rangle}\right) \qquad MeanMkvh = 444.08333$$

$$MkvhSmooth := ksmooth\left(\frac{Mlnkvthh\_Ins^{\langle 0\rangle}}{1000}, Mlnkvthh\_Ins^{\langle 1\rangle}, 100\right)$$

$$MkvhSmth := 40\cdot(MkvhSmooth - MeanMkvh) + MeanMkvh$$

2. Milankovitch Iso Annual 65N, T Vostok



NASA Earth Observing Systems (EOS) Solar Radiation and Climate Experiment (SORCE)

An imperative for climate change planning: tracking Earth's global energy

http://lasp.colorado.edu/sorce/tsi_data/daily/sorce_tsi_L3_c24h_m29_v10_20030225_20091223.txt
nominal_date_yyyymmdd R8 f12.3 (Column 1: Nominal Data Time, YYYYMMDD) ; ; tsi_1au R8 f10.4
(Column 5: Total Solar Irradiance (TSI) at 1-AU, W/m^2)

$TSI := READPRN(\text{"Total Solar Irradiance.txt"}) \qquad rows(TSI) = 2494 \qquad n := 0..2493$

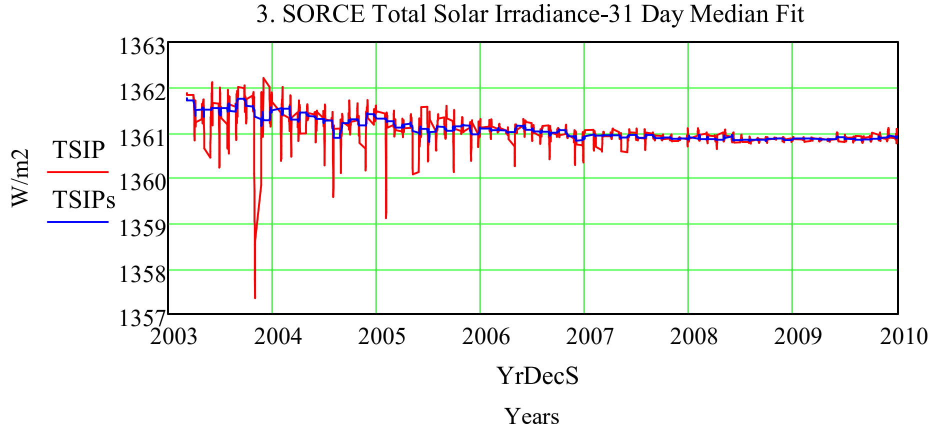
$TSIP := TSI^{\langle 4\rangle} \quad TSIP_n := if\left(TSIP_n = 0, TSIP_{n-1}, TSI\right. \quad mean(TSIP) = 1361.04 \quad Avg_n := 1361$

$$YrDecS_n := str2num\left(substr\left(num2str\left(TSI_{n,0}\right), 0, 4\right)\right) + \frac{str2num\left(substr\left(num2str\left(TSI_{n,0}\right), 4, 8\right)\right)}{1231}$$

$TSIPs := medsmooth(TSIP, 31)$

The sun has progressed from an active part of the sunspot cycle in 2003 to a very quiet phase in 2008 through 2010. The net change is a decrease in TSI of 0.5 W/m^2 - for an absorbed solar radiation, ASR, of 0.1 W/m2. For more studies and conclusions on recent solar effects see http://www.skepticalscience.com/solar-activity-sunspots-global-warming.htm

3. SORCE Total Solar Irradiance-31 Day Median Fit



SECTION IX. ENSO-2014 AND PDO (ENSO - The Southern Oscillation)

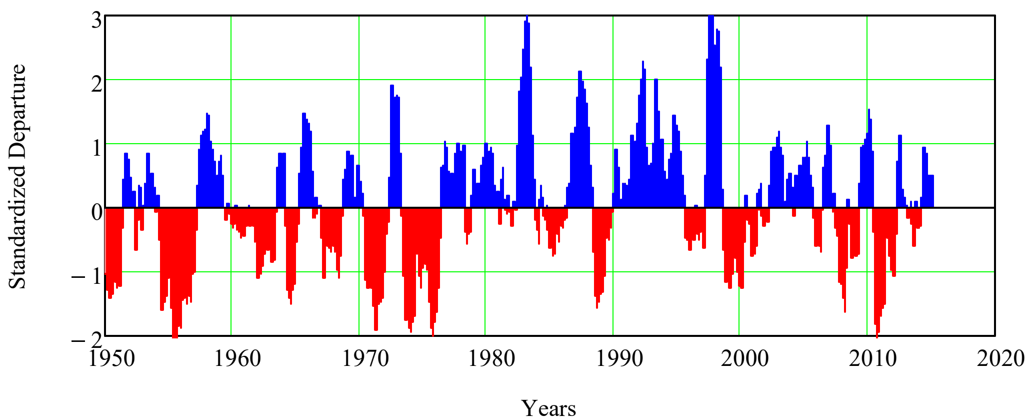
http://www.leapcad.com/Climate_Analysis/Empirical_Model_ENSO_Solar_VolcAero_Anthro.pdf

Multi Variate ENSO Index: http://www.esrl.noaa.gov/psd/people/klaus.wolter/MEI/mei.html

MV E I Data Format: Year, ENSO (Jan, Feb,...Dec)

El Niño/Southern Oscillation (ENSO) is the most important coupled ocean-atmosphere phenomenon to cause global climate variability on interannual time scales. Here we attempt to monitor ENSO by basing the **Multivariate ENSO Index (MEI)** on the six main observed variables over the tropical Pacific. These six variables are: sea-level pressure (P), zonal (U) and meridional (V) components of the surface wind, sea surface temperature (S), surface air temperature (A), and total cloudiness fraction of the sky (C).

MEIData := READPRN("MultiVariate ENSO Index.TXT")



Pacific Decadal Oscillation (PDOI) Index from 1900 to 2014

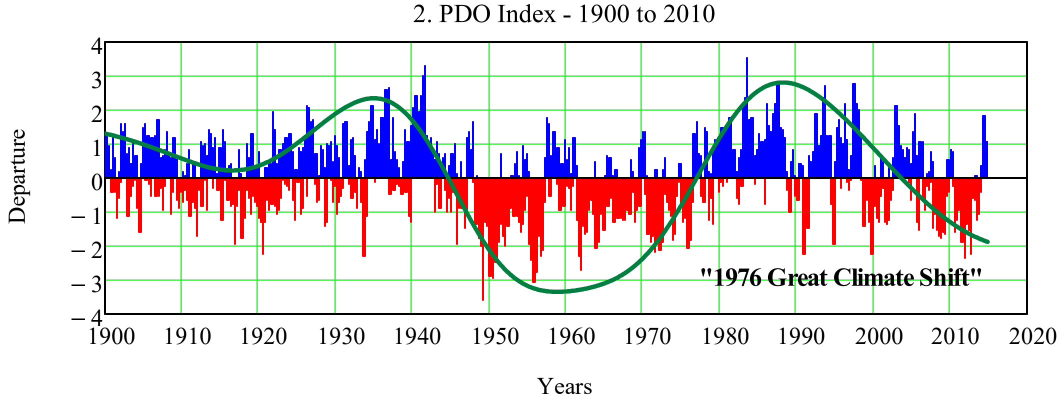
Note: ENSO and PDO are not statistically independent. They have a 47% correlation.

http://jisao.washington.edu/data/pdo/ Year, Jan to Dec

PDO := READPRN("PDO_Index2014.txt") $\quad$ R := rows(PDO) $\quad$ rr := 0 .. (R − 1)·12 + 11

PDOx := submatrix(PDO, 0, R − 1, 1, 12) $\quad$ $PDOYr_{rr} := \left(PDO^{\langle 0\rangle}\right)_{floor\left(\frac{rr}{12}\right)} + \frac{mod(rr,12)}{12}$

$PDOI_{rr} := PDOx_{floor\left(\frac{rr}{12}\right), mod(rr,12)}$ $\quad$ $PDOPlus := \overrightarrow{(\Phi(PDOI)\cdot PDOI}$ PDOSm := ksmooth(PDOYr, PDOI, 20)



C. SECTIONS X - XIII - Climate Model Analyses

SECTION X

History, Physics, Models, Band Broadening, HZ, CO2 Runaway, Summary

1. History of Climate and Atmospheric Physics and Models

1660 Boyle's Law
1738 Daniel Bernoulli: The first kinetic theory
1824 Fourier calculates that the Earth would be far colder if it lacked an atmosphere.
1847 Hermann Helmholtz law of conservation of energy. Thermal energy is form of mechanical E
1849 Faraday EM waves are coupled transverse E and M in mutually perpendicular directions
1861 Tyndall observes that greenhouse gases absorb narrow bands of infrared energy
1865 Maxwell hypothesizes from his E and M equations transverse EM waves that travel with velocity c.
1879 travel law
1876 Josiah Willard Gibbs. Foundations of Thermodynamics
1852 Beer-Lambert law linear relationship between absorbance and concentration of absorbing gas
1890 Wien's displacement law
1896 Arrhenius publishes calculation of global warming from human emissions of CO_2.
1900 Planck's Law for calculation of radiant flux as function of temperature. BB Electrons oscillate with
1900 Ångström field and lab experiments absorption does not appear to have much effect on air temperature
1901 PlanckEinstein relation $E = h\nu$. Photons carry discrete energy.
1902 De Bort's discovery of the tropopause, stratosphere, and temperature lapse rate by balloon
1919 Vilhelm Bjerknes identifies first differential equations of atmosphere dynamics
1922 Lewis Richardson does first numerical computation of 6 hour forecast (2 years work by hand)
1920-1925 Opening of Texas and Persian Gulf oil fields inaugurates era of cheap energy.
1929 Bureau coined the name "radiosonde" and flew the first instrument.
1930s Milankovitch proposes orbital changes as the cause of ice ages.
1938 Calendar argues CO2 levels rising -->greenhouse global warming is underway, reviving interest
1956 Ewing and Donn offer a feedback model for quick ice age onset
Phillips somewhat realistic Global Circulation Model computer model of the global atmosphere.
Plass calculates water vapor absorption lines did not block the CO_2 absorption spectrum
1958 Telescope studies show a run-away greenhouse effect raises temperature atmosphere of Venus
1960 Keeling accurately measures CO_2 in atmosphere and detects an annual rise
1960s NOAA Global Circulation Model, GCM combines ocean and atmospheric processes
1967 Manabe and Wetherald GCM calculation that 2X CO_2 would raise world temperatures ~ 2C.
1968 Studies suggest a possibility of collapse of Antarctic ice sheets, raise sea levels catastrophically.
1969 Budyko and Sellers present models of catastrophic ice-albedo feedbacks.
Nimbus III satellite provide comprehensive global atmospheric temperature measurement
Conrath verify that Modtran calculations match observed radiation using IRIS instrument on Nimbus III
1972 Ice cores and other evidence show big climate shifts 11,000 years ago.
1975 Manabe and Wetherald first 3D Global Circulation Model, GCM
1976 Deep-sea cores show a dominating influence from 100,000-year Milankovitch orbital changes,
Eddy - prolonged periods without sunspots in past centuries, corresponding to cold periods
1977 Scientific opinion tends to global warming, not cooling, as chief climate risk
1982 Greenland ice cores reveal drastic temperature oscillations in the space of a century
Antarctic ice cores -CO_2 and temp went up and down together through past ice ages
Broecker speculates that a reorganization of North Atlantic Ocean circulation can bring Change
1987 MODTRAN FORTRAN code to model transmission of EM in atmosp developed by USAF and Spectral Sciences
1990 First Intergovernmental Panel Climate Chge report says world warming and future warming seems likely.
1991 Mt. Pinatubo explodes; Hansen predicts cooling pattern, verifying by 1955 GCM
1995 16 modeling centers get together to compare projections of future climate change
2006 "Hockey stick" post-1980 global warming was unprecedented for centuries
2010 Coopersmith shows thermal energy is frequency that exists with certain amplitudes of oscillation
2015 Find collapse of West Antarctic ice sheet irreversible, meters of sea-level rise future centuries.

2. Elementary Atmospheric Physics: Radiation, Lapse Rate, GHE, Fluid Flow, 2nd Law

Planck's Law (Irradiance at particular wavelength)

$\mu := 10^{-6}$ Wavelengths for Color: $\lambda Green := 0.5$ $\lambda Red := 0.7$ $\lambda Earth := 11$

Boltzmann constant, kb

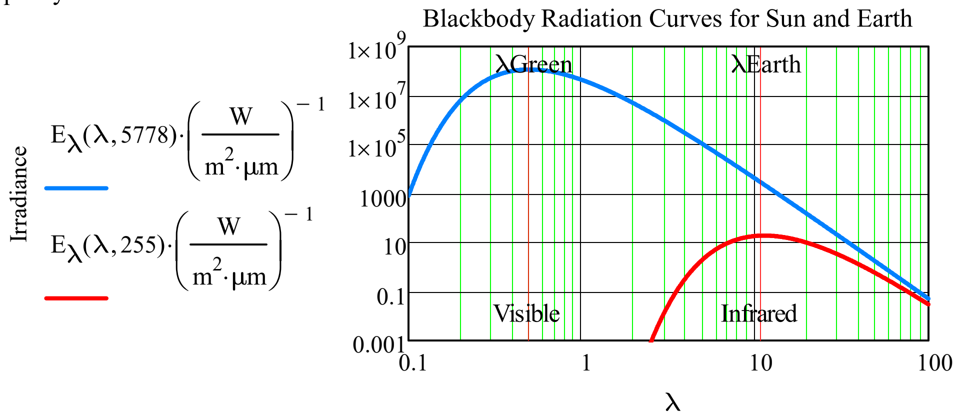
$h := 6.626069 \cdot 10^{-34} \cdot J \cdot s$ $k_b := 1.38 \cdot 10^{-23} \cdot m^2 \cdot kg \cdot s^{-2} K^{-1}$ Emissivity: $\varepsilon := 1$

Einstein-Planck Equation

$E = h \cdot \nu$

where h is Planck's constant
and ν is frequency of EM radiation.

$$E_\lambda(\lambda, T) := \frac{\varepsilon \cdot \pi \cdot h \cdot c^2}{(\lambda \cdot \mu m)^5} \cdot \frac{1}{e^{\frac{h \cdot c}{\lambda \cdot \mu m \cdot k_b \cdot T \cdot K}} - 1}$$



Wavelength, λ, is in units of μm

Stefan-Boltmann Law (E is Total Irradiance)

$\sigma_{SB} := 5.67 \cdot 10^{-8} \cdot W \cdot m^{-2} \cdot K^{-4}$

$E(T) := \sigma_{SB} \cdot T^4$

$E(255K) = 239.74181 \cdot \frac{W}{m^2}$

$P_{SB}(T) := 5.67 \cdot 10^{-8} \cdot A \cdot T^4$

Wien's Displacement Law

For a given BB temperature (K) gives the peak wavelength, λ_{peak}, for the BB spectrum in m.

$\lambda_{peak}(T) := \frac{0.00289m}{T}$

$\lambda_{peak}(5778) = 0.50017 \cdot \mu m$

$\lambda_{peak}(255) = 11.33333 \cdot \mu m$

Beer's Law

The Beer–Lambert law, also known as Beer's law, the Lambert–Beer law, or the Beer–Lambert–Bouguer law relates the attenuation of light to the properties of the material through which the light is traveling.
By definition, the transmittance of the material sample is related to its optical depth Δs as

$E_{transmitted} = E_{incident} \cdot e^{-n \cdot b \cdot \Delta s}$ or as $E_{transmitted} = E_{incident} \cdot e^{k \cdot \rho \cdot \Delta s}$

where n is the number density of absorbing particles and b is the absorption cross section
and k is the absorption coefficient and ρ is the density.

Beer's law is crucial to CO_2 AGW Physics and Modeling. All other things being equal, Beer's law states that if absorption occurs for a density ρ for a distance of Δs then if the density of CO2 doubles, the same absorption occurs in half the distance or Δs/2.

Navier-Stokes Equation for Fluid Flow

$$\rho \frac{D\vec{V}}{Dt} = -\nabla p + \rho \vec{g} + \mu \nabla^2 \vec{V}$$

This equation has nonlinearities, μ Del ^{2} V term. Biggest computers in world cannot solve this down to the scale of thunderstorms (supercells~ 25 km)- one of major heat transfer mechanism. Existing models resolution down to about 100 km.

where ρ is density, g is gravitational acceleration, p is pressure, μ is viscosity, and v is velocity

First Law of Thermodynamics for Meteorology - Lagrangian Description

The temperature of an air parcel of mass, m_{air}, changes by an amount ΔT when hear ΔQ_H is added, and changes when work is done on or by the parcel. If ρ is the density and C_p is the specific heat at constant pressure, then the First Law can be expressed as:

$$\frac{\Delta Q_H}{m_{air}} = C_p \cdot \Delta T - \frac{\Delta P}{\rho} \qquad Cp_{air} := 1005 \cdot \frac{J}{kg \cdot K}$$

The mass of air in a volume is: $m = \rho \cdot (A \cdot \Delta z)$

Pressure is: $\Delta P = \rho \cdot g \cdot \Delta z$ The weight is: $F = m \cdot g$

Then the **First Law** can be reformulated to give temperature change of a rising or sinking air parcel

Solving

$$\Delta T = \frac{-g}{C_p} \cdot \Delta z + \frac{\Delta Q_H}{m_{air} \cdot C_p}$$

For an adiabatic process ($\Delta Q = 0$) the **Temperature Lapse Rate** is:

$$\frac{\Delta T}{\Delta z} = \frac{-|g|}{C_p} = \frac{-9.8K}{km}$$

Ideal Gas Law

Equation of State
(Low densities)

$$P \cdot V = n \cdot R \cdot T$$

Lapse Rate - Convection (See Sec XXIII):

Without a source of radiation, such as the sun, a planet's temperature would approach absolute zero. Therefore by the Ideal Gas Law, there could be no atmospheric temperature, and thus no ΔT for a lapse rate. The effects of mostly convection, but also, evaporation, expansion and condensation processes results in the troposphere temperature profile or lapse rate.
Note the lapse rate on Venus is 10.5 K/km, but the atmospheric pressure/depth is 92X greater.

Rayleigh and Mie Scattering

Air molecules have diameters of 10^{-4} to 10^{-3} μm, much smaller than light 0.35 to 0.7 μm. These particles cause Rayleigh Scattering, which makes the sky blue. The ratio of $I_{scattering}$ to incident intensity I_0 is shown below.
Scattering of sunshine clouds: example Mie scattering.

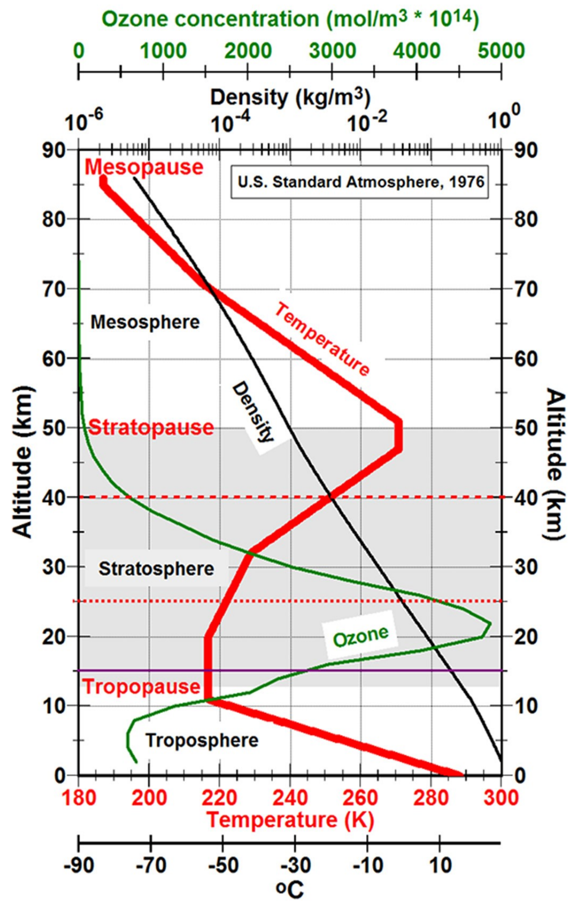
$$\frac{I_{scattering}}{I_0} = k_{scattering} \frac{1}{\rho_{air} \lambda^4}$$

Bernoulli's Equation

$$\frac{1}{2} v^2 + \frac{P}{\rho} + |g| \cdot z = C_B$$ Where C_B is a constant

US Standard Atmosphere

Lapse Rate, Density, Ozone vs. Altitude



Local Thermodynamic Equilibrium - Kirchoff's Law

At each point, a local temperature can be defined such that emission is given by Kirchhoff's law

$$j_\nu = k_\nu B_\nu(T)$$

where jv is emission, kv is absorption, and Bv is the brightness given by the Planck law. A system is not in local thermodynamic equilibrium (LTE) or **thermalized** if the local kinetic (Maxwellian) temperature is not equal to the Planckian temperature of the radiation field.
Real atmospheres are not in local thermodynamic equilibrium since their effective infrared, ultraviolet, and visible **brightness temperatures** are different. Also, they are not homogenous - separate parcels. Scattering is another non-local thermodynamic equilibrium effect.
LTE breaks down altitudes > 100km ->collisions are rare.

Absorption or Emission by a Spectral Line

From Beer's Law, by integrating the absorption coefficient, $i_\lambda(S)$, (over the entire spectrum, the total energy absorbed along a path S per unit solid angle and projected area can be found within a uniform gas.

$$i'_\lambda(S) = i'_\lambda(0)\ \exp\ (-a_\lambda S)$$

$$\frac{d^2 Q'_a}{dA_p d\omega} = \int_0^\infty i'_\Omega(0)\ [1 - \exp\ (-a_\Omega S)\ ]\ d\Omega$$

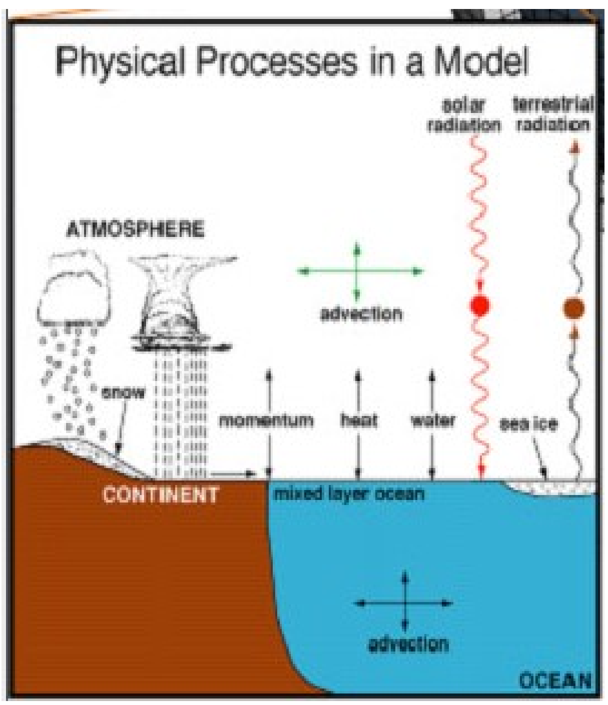
where $i_\Omega(0)$ is the incident spectral intensity at the origin of path S.

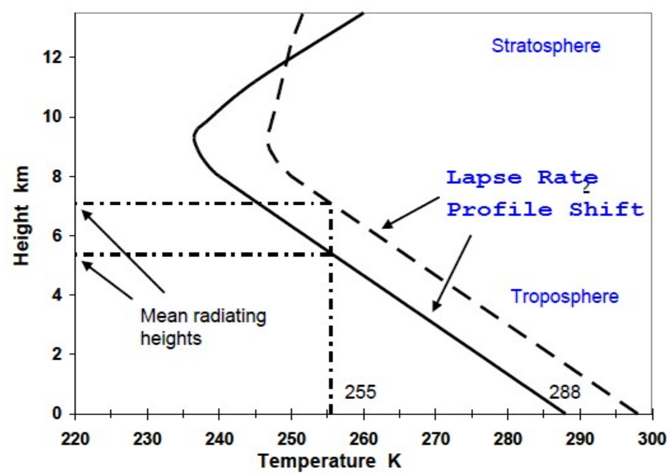
Refer to: *Meteorology for Scientists and Engineers*, Roland B. Stull, 2nd Ed. 2000, Brooks Cole
A First Course in Atmospheric Radiation, Grant W. Petty, 2nd Ed. , 2006, Sundog Publishing
Thermal Radiation Heat Transfer, Radiation Transfer With Absorbing, Emitting, and Scattering Media, NASA SP-164

Greenhouse Effect and Lapse Rate

The way the temperature changes with altitude is important for the greenhouse effect. If it were a constant temperature then it would just look like an elevated surface. Most of the radiation escaping the Earth to space comes from the surface or the troposphere, so the temperature variations in the troposphere are most important.

Increasing the amount of GHG in the atmosphere causes the emission that makes it to space to come from higher in the atmosphere, which reduces the amount of radiation reaching space since the higher air is colder. But, the emission must equal about 250 W/m^2, so the atmosphere will have to warm at that higher altitude. The effect on the surface will depend on the lapse rate, and the lapse rate depends on how the atmosphere moves heat around.





Energy Equilibrium and Lapse Rate, the Tropospheric Temp Gradient (Mostly due to Convection) determine Effective Emission Height and thus the GHE

The tropopause occurs at the altitude where regular convection stops, and thermodynamic gradient stratification begins. It is defined as the lowest level at which the lapse rate has a discontinuity or decreases to 2 °C/km or less. Nearly all clouds, dust, and water vapor, i.e., weather is in the troposphere.

Given that the tropospheric temperature gradient (lapse rate) **is largely set by convection**, if you know the temperature at some height in the atmosphere, then **one can work back down the lapse to the surface** in order to **determine the surface warming** due to greenhouse effect. *Effective emission height.* In **equilibrium**, the Earth radiates as much energy back into space per unit time as it receives from the Sun. If you determine the average amount of energy radiated per square met re per second (about 240 W/m^2) you can use the Stefan-Boltzmann law ($F=\sigma T4$) to determine the temperature a blackbody would need to have so as to radiate this amount of energy per square met re per second. For the Earth (with an albedo of 0.3) it is about 255 K. **The effective emission height is the height in the atmosphere at which the temperature matches this temperature**. In the Earth's atmosphere it is at about 5km. Raising the CO2 concentration raises tropopause, lowers effective temperature. Thus temp of surface must increase to restore balance.

Clausius Second Law of Thermodynamics

S is Entropy, F is Flux, A is Area

$$S = \frac{dQ}{dt} \qquad \dot{Q} = \int_A F_{in}\, dA - \int_A F_{out}\, dA \qquad \frac{d_e S}{dt} = -\int_A \frac{F_q \cdot \hat{n}}{T}\, dA$$

3. Stefan-Boltzmann Law of Radiation - Find Effective Temperature of Earth - No Atmosphere

$R_{orbit} := 1.5 \cdot 10^{11} m \quad R_{sun} := 7 \cdot 10^{8} m \quad T_{sun} := 5780K$

Transmittance $\alpha := 0.3$

Stefan-Boltzmann constant $\sigma := 5.6704 \cdot 10^{-8} \frac{watt}{m^2 \cdot K^4}$

$Power_{sun}$ is the Peak Total Power from Sun at Earth

$$Power_{sun} := \alpha \pi \cdot R_{earth}^{2} \cdot \sigma \cdot T_{sun}^{4} \left(\frac{R_{sun}}{R_{orbit}} \right)^{2} = \text{IR Power}_{Earth}$$

$Power_{sun} = 5.28391 \times 10^{16} W \qquad R_{earth} := 3963mi$

$A_{earth} := \frac{1}{2} 4 \cdot \pi \cdot R_{earth}^{2}$

$\frac{Power_{sun}}{0.5 \cdot A_{earth}} = 413.4851 \cdot \frac{W}{m^2}$

The flux of the solar radiation energy received by the Earth ~ 1370 W/m²

Find T_{earth}, The Effective Emitting Equilibrium Temperature of Earth

where the Earth's Emission Power equals the Sun's Input Power to Earth.

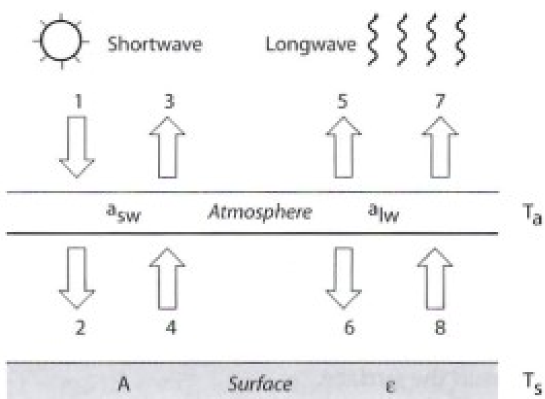
albedo of earth:
$\alpha_{earth} := 0.7$

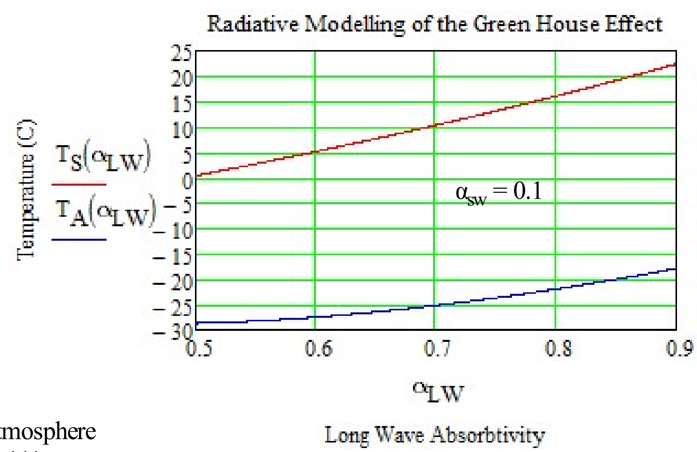
$$T_{earth} := \left[\frac{\alpha_{earth}}{4} \cdot \left(\frac{R_{sun}}{R_{orbit}} \right)^{2} \right]^{\frac{1}{4}} T_{sun} \qquad T_{earth} = 255.38227\,K$$

Temp in Celsius
$257 - 273 = -16$

The earth is warmer than -16C. This actual warmer temperature (~20C) results from the GHE.Further evidence is provided by the moon, which has no atmosphere. Moon has same sunlight, but temps range from -173C to 100C.

4. Single Layer Radiative Energy Balance "Toy" Model of Atmosphere: Modeling Greenhouse Effect





Equilibrium requires that the net sw and lw fluxes at the top of the atmosphere and between the surface and atmosphere are both zero. If not there would be a net gain. Therefore, at the top: F3 + F5+ F2 - F1 = 0. At the surface: F4 + F8 -F2 -F6 = 0. The above is based on the the **1st Order assumption** that Kirchoff's Law holds.

The atmosphere has Short wave and Long Wave Absorbtivities:

$\alpha_{sw} \qquad \alpha_{lw}$

Earth Surface Short Wave Albedo, A_e

30% of solar radiation is reflected back to space
20% by clouds, 5% by atmosphere, 5% by surface

Effective Albedo: $A_e := 0.3$

At the top of the atmosphere the globally averaged Flux S

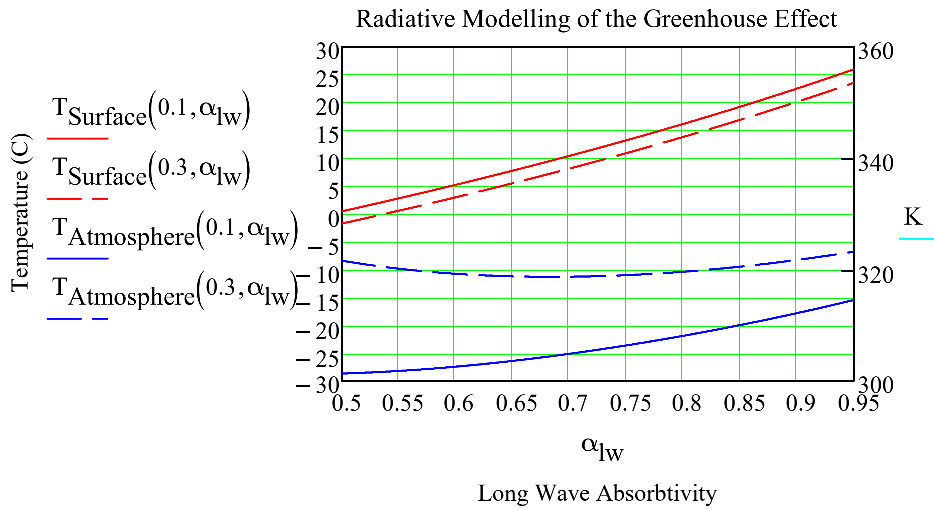
$S_0 := 1370 \frac{W}{m^2} \qquad S := \frac{S_0}{4}$

Then rearranging flux terms and using the Stefan-Boltzmann Law for temperatures for the surface and atmosphere fluxes gives:

$$T_{Surface}(\alpha_{sw}, \alpha_{lw}) := \left[\frac{S}{\sigma} \cdot \left[1 - (1 - \alpha_{sw}) A_e \right] \left(\frac{2 - \alpha_{sw}}{2 - \alpha_{lw}} \right) \right]^{0.25} - 273K$$

$$T_{Atmosphere}(\alpha_{sw}, \alpha_{lw}) := \left[\frac{S}{\sigma} \frac{\left[(1 - A_e) \cdot (1 - \alpha_{sw}) \cdot \alpha_{lw} + \left[1 + (1 - \alpha_{sw}) A_e \right] \cdot \alpha_{sw} \right]}{(2 - \alpha_{lw}) \cdot \alpha_{lw}} \right]^{0.25} - 273K$$

For the Above Model See: *A First Course in Atmospheric Radiation*, Grant Petty, 2nd Ed. , 2006, Sundog Publishing. Pg. 141
For MultiLayer Models see http://biocycle.atmos.colostate.edu/toy-models/ or www.acs.org/content/acs/en/climatescience/
Penn State, One-Layer Energy Balance Model: https://www.e-education.psu.edu/meteo469/node/198



This is a simple radiative model of the earth's Greenhouse Effect. The model uses an Albedo of 0.3 and uses visible light absorbtivities of 0.1 and 0.3. It plots the variation of the surface $T_{surface}$ and atmosphere temperatures as the long wave infrared absorbtivities α_{lw} vary from 0.5 to 0.95. Note that with an atmosphere this model gives a range of warming from 5C to 35C from the atmosphere to the surface. An average increase of 15C. The established global greenhouse effect for the earth is about 16C.

5. First Order 1D Latitudinal Energy Balance Model - From Climate Modelling Primer, McGuffe

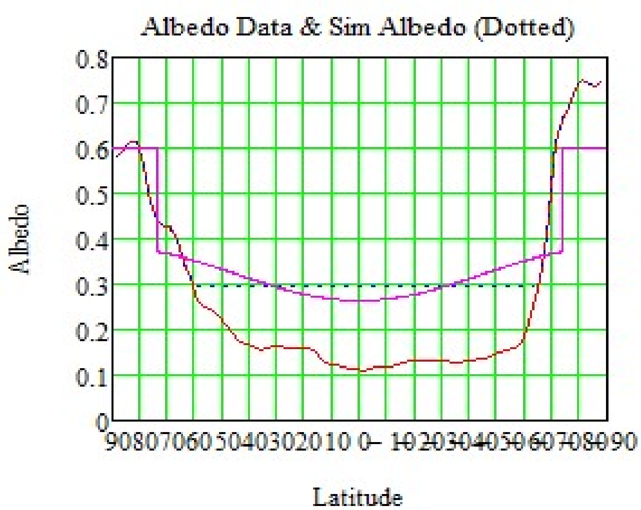
Model details are available at:
http://www.vxphysics.com/Climate_Analysis/1D_Zonal_Globall_Temperature-Energy_Balance_Model.pdf

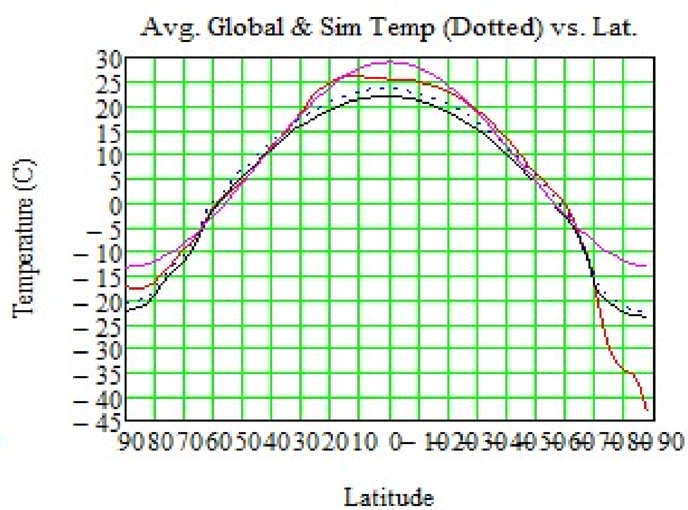
Details: http://leapcad.com/Climate_Analysis/1D_Zonal_Globall_Temperature-Energy_Balance_Model.xmcd

Energy flows into Earth through radiation from the Sun and out of Earth by reflection and radiation. There are latitudinal variations. The flow of energy into Earth and the flow of energy out of Earth must be equal if Earth is to maintain a stable temperature. H_0 is the extraterrestrial solar flux (w/m^2). In the zonal model, we need to be able to calculate the total energy received from the sun per unit time. This is given by $\pi R^2 H_0$. The average extraterrestrial solar flux over the entire surface can by calculated by $H_0/4$.

Mathcad Simulation Results: 1-D Effusive EBM Analytic Model (Magenta Plots) - Without GHE

To is the planetary, globally averaged temperature, T2 is 2/3 of the Temp difference from the poles to equator, Tpe. The ice sheet edge (T = -10C) is above 73.74^o, with ice albedo, α_{ice}. **The result is shown in the plot at right, below.**





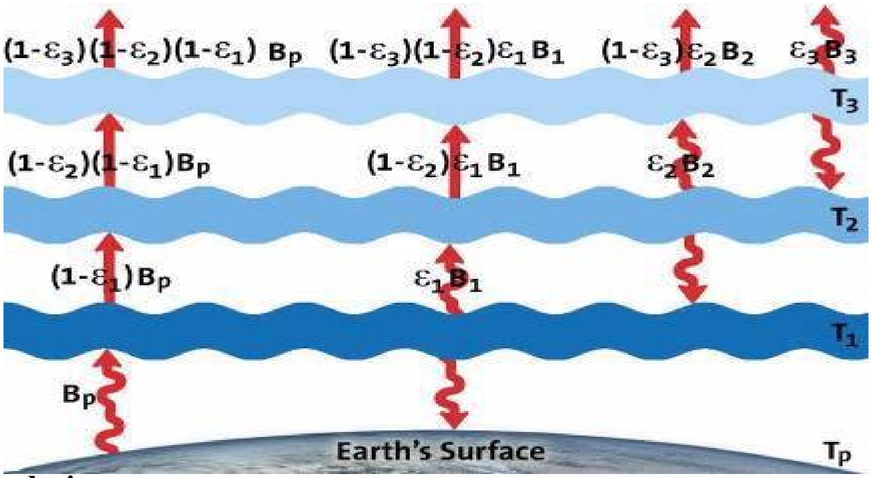
6. References to More Complex Models

Climate Model Papers: General Circulation Models (GCM) http://www.leapcad.com/Climate_Analysis.html

- GISS ModelE (See http://www.giss.nasa.gov/tools/modelE/)
- Efficient Three-D Global Model - GISS Model II
- Educational GISS Model II
- Climate Model vs. Satellite Data http://www.easterbrook.ca/steve/2014/02/climate-model-vs-satellite-data/

Multi Layer Model

Am Chemical Society. https://www.acs.org/content/acs/en/climatescience/atmosphericwarming/multilayermodel.html
The squiggly arrows represent radiation emitted by the body from which the arrow originates. The straight-line arrows represent radiation that has been transmitted without absorption through a layer. The temperature-dependent Planck black-body function for this wavelength is represented by B with a subscript denoting the temperature of the layer to which it applies. The emissivity of each layer is similarly labeled. The temperatures are TP at the surface and T1 > T2 > T3 for temperatures of the layers. Decreasing pressure and, hence density and partial pressure, of the atmospheric gases is represented by the decreasing depth of color of the layers.



7. CO2 Band Broadening

Is CO2 Absorption Saturated? Spectral Band Broadening of CO2 Bending Moment. See Section V.

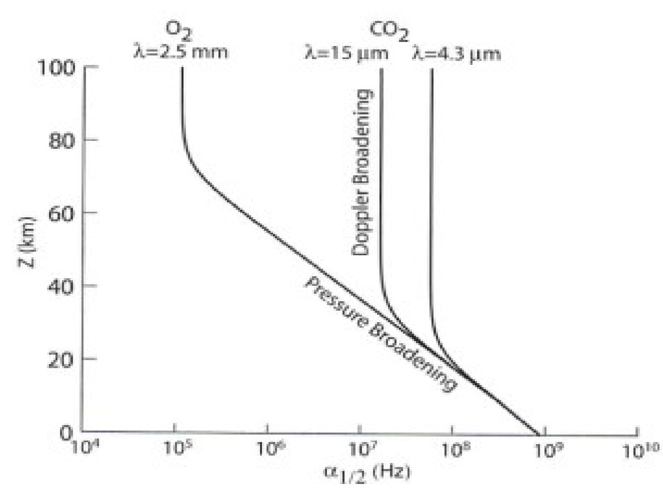
Saturation is entirely true for a spectral interval of about one micron wide on either side of the center of the CO2 band. However, this neglects the hundreds of spectral lines from CO2 that are outside this interval of complete absorption. The change in absorption for a given variation in carbon dioxide amount is greatest for a spectral interval that is only partially opaque; the temperature variation at the surface of the Earth is determined by the change in absorption of such intervals.
Upon increasing CO2 concentration, the layer at which the absorption coefficient at each wavelength is low enough to let the IR light escape will be found higher in the atmosphere. The emitting layer will then have a lower temperature (and lower water vapor content), at least until the tropopause is reached, and hence a lower emitting power.
The planet's temperature is **regulated by the thin upper layers** where radiation does **escape easily into space**.

Band Broadening - For a gas to absorb a particular wavelength there must be an allowed transition with the same energy: Rotational, Vibrational, Photodissociation. If no transitions then it passes through air-not absorb.
Types of Broadening: Doppler, Collision, and Stark Broadening
Doppler Broadening: Gas velocity has a Maxwell-Boltmann distribution. Therefor, spectal line shapes will have a Maxwell-Boltmann distribution.
Collision Broadening: As pressure of gas increases the collision rate increases and perturbs the energy states.
Stark Broadening: Occurs with strong electric fields, such as in ionized gases. Stark and Collision Broadening lumped into Pressure Broadening. See Section XXIII for AGW shift in Lapse Rate.

Diatomic molecules (N2, O2, etc) and monatomic molecules don't interact with longwave.
Greenhouse gases are all polyatomic (at least 3 atoms):
H2O, CO2, CH4, O3, N2O.
Vibration mode is the transition that absorbs the infrared
Absorption tends to be at a single wavelength ("line")
Lines are then broadened by various processes
.

Effect of Height & Lapse Rate on AGW

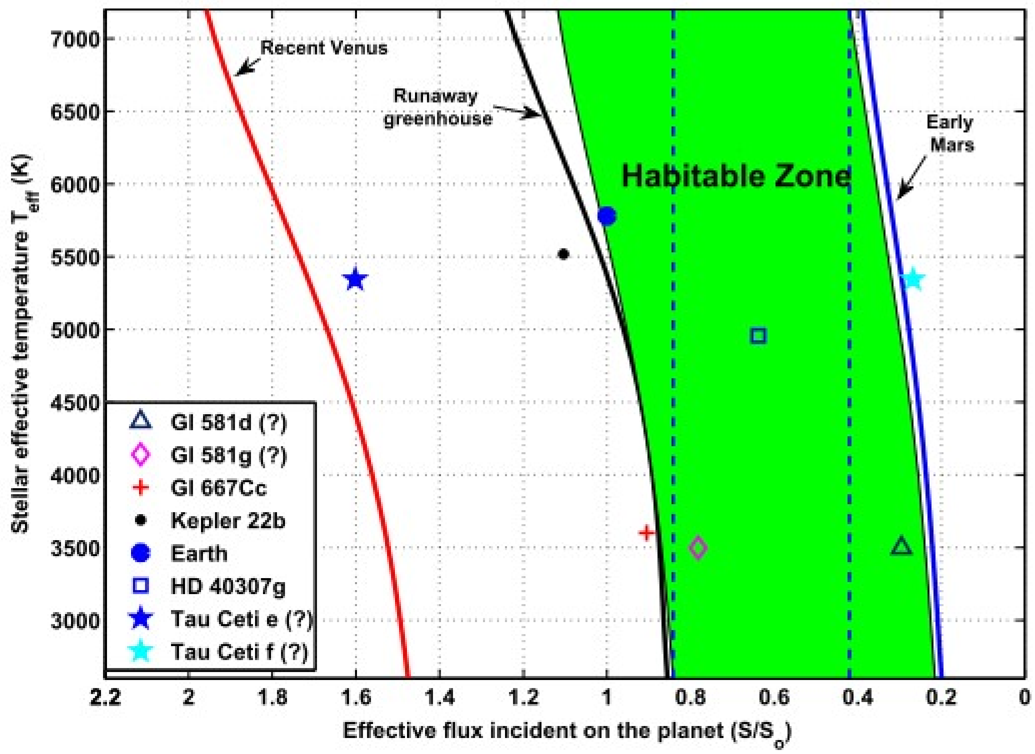
The atmosphere gets thinner as you go up.
So eventually greenhouse gases become less prevalent and radiation can escape more easily
Less GHG, emission is less. Because of Lapse Rate it's also colder up there. See Section XXIII. Colder affects Energy balance. Factoring in the vertical temperature profile is important for the AGW.



Line Width versus Altitude for O_2 and CO_2, where $\alpha_{1/2}$ is the half width

8. How close are we to the edge of a runaway greenhouse effect?

Calculation of Planetary Habital Zones (PHZ) - Planet Earth is on the Hot Edge of a PHZ
Habitable Zones Around Main-Sequence Stars: New Estimates,
Ravi kumar Kopparapu 1,2,3,4 , Ramses Ramirez 1,2,3,4 , James F. Kasting 1,2,3,4,
The Astrophysical Journal, 10 Aug 2017



Habital Zone For Planets in General:

An updated 1-D radiative-convective, cloud-free climate model is used to obtain new estimates for HZ widths around F, G, K and M stars. New H2O and CO2 absorption coeffiients, derived from the HITRAN 2008 and HITEMP 2010 line-by-line databases, are important improvements to the climate model. According to the new model, the evaporative water loss (inner HZ) and maximum greenhouse warming (outer HZ) limits for our Solar System are at 0.99 AU and 1.70 AU, respectively, suggesting that the present Earth lies near the inner edge of a runaway greenhouse effect.

The above model shows that in terms of Habital zones, the Earth is on the edge of Runaway GHE limits.

Planet Earth

However, based on 1 dimensional models, even if you **evaporated a big chunk of ocean it would just rain back out**, because the water vapor would radiate away more thermal energy than it absorbed through sunlight. An **estimate of how much carbon dioxide would be required to get this steamy atmosphere, and the answer is about** 30,000 ppm of atmospheric carbon dioxide, which is actually good news in terms of anthropogenic climate change. Thirty thousand ppm is about **10 times more** carbon dioxide than most experts estimate could be released from burning all available fossil fuels, although such high values could in theory be reached by releasing large amounts of carbon dioxide from the Earth's vast deposits of limestone and other carbonate rocks.

SECTION XI. Summary of Factors of GHE, GH Gases, Radiation, and Temp Rise

1. By the Wien's Displacement Law, the sun at 5800K radiates visible, short wavelengths (sw) in a window about 0.5 µm. Avg Incoming 341 W/m^2. The earth at 300K, radiates longwave (lw), in a window about 10 µn IR. A 1° drop in temperature results in a 1.2% to 1.8% drop in emission frequency. Radiation is absorbed in discrete quanta of energy (photons), given by $E = h\nu$, where h is Planck's constant and ν is the line frequency.
2. Radiative sw solar heat is easily let in through the atmosphere to earth, but some IR is "trapped" on the way out. See Figure at bottom of page 11. One result is thickening of the troposphere. The atmosphere is transparent to the light in the visible sw from the sun, but absorbs low wave IR from the earth. IR adds 4 W/m^2.
3. GHGs: For EM interaction, the Vibrational motions must change the dipole moment of molecule between the ground and excited states. Only molecules with at least 3 atoms can be greenhouse gases. Molecular vibrations (bending and asymmetric stretching) give rise to infrared active modes that are important for the greenhouse effect. **Only the vibration and rotation modes of a molecule can interact with IR radiation. See Pg. 95**
CO_2 is important because the bending mode is near the center of the earth's 10 µm thermal radiation distribution. H_2O is more important due to sheer abundance.The molecules that absorb and re-radiate lw IR radiation are the greenhouse gases, primarily water vapor and CO_2. They comprise only 1% of the atmosphere. Water vapor is the IR strongest absorber, but CO_2 has a longer lifetime and concentration is more constant in the atmosphere and is increasing from the burning of fossil fuels.
4. First Law of Thermodynamics requires that sw energy from sun equal or balances the lw from the earth.
5. View from space. Without an atmosphere, the surface temperature of the earth would be given by Stefan-Boltmann Law for Total Irradiance. Effective Blackbody Temp TBB = 255K See Section X #3.
*** 6**. The effective temp of the CO_2 emission into space (upper troposphere lapse rate) is **well below earth's** 255K black body temperature. End result: There is far less IR emissions into space in the CO_2 spectrum than one would expect based on either earth's surface temperature or black body temp. ∴ surface & tropopause T must increase.
7. There is a big transmission of energy of from GHGs like CO_2 that absorb IR to other gas molecules. Only a very small number of CO_2 molecules have the necessary kinetic energy to emit a photon. Mostly, they just bang around against other gas molecules and if they do capture a photon, that quickly turns into general kinetic energy and temperature rise in the surrounding gas. The surrounding gas acts as a big heat reservoir. It mediates and dampens the CO_2 emissions. But every once in a while, a CO_2 molecule will get a hard knock, and before it gets knocked again, it fires off a photon cooling off itself and the surrounding gas. The relaxation time for a CO_2 molecule after absorbing a 15µ photon is 10µs. But the time between collisions at atmospheric pressure is 0.27 ns. Accordingly a CO_2 molecule will get knocked on average 370,000 times before its mean emission time.
8 Collisions between molecules (average kinetic energy) of a gas are a measure of temperature. It's pretty much independent of the photon absorption and emission mechanism.
9. Photon emission is the only means of shedding photon absorption energy.
10. Typically collisions do not cause electron jumps. Specifically, if energy from a collision could be shed as a photon emission, then it would be relatively easy to get to colder and colder temperatures. Heat energy would be emitted as light (radio) waves, and the remaining materiel would be colder. That does not happen
12 Two keys to GHE. **Key #1**. The atmosphere gets colder as you go up to the boundary between the stratosphere and the troposphere. This boundary temperature is 218K. See Section X. 2 for Lapse Rate. Part of this is due to convection in the lower atmosphere, but a significant reason for this drop is the absorption and emissions of IR by GHGs CO_2 and H_2O.
13. **Key #2** to the GHE is that the atmosphere radiates both upward and downward. Shown by Heat Flux #5 in GHE Model Section X. 4 above. This cools the atmosphere which is the surface that radiates heat back to space. Thus by number 4 above, the net effective/earth surface temperature must rise to equal the sw heat flux in from the sun. See Section X. 3 GHE Model. Net loss of heat from surface is now slowed.
14 The atmosphere is not all at the same temperature and that it does not absorb and emit radiation as an ideal gray body with the same emissivity at all wavelengths. The atmosphere is best modeled as a MultiLayer.
15. There are feedbacks, such as increased evaporation of water vapor that further increase GHE Temp.
16. Radiative forcing F_{rad} for Increasing Concentration ppm CO_2 from C_0: $F_{rad} = (5.35\ W/m^2) \ln(C/C_0)$

Empirical Mode Decomposition HHT

This Work Uses the GISS Monthly Temperature Data from Above

Because the Array Origin for the rest of this Mathcad worksheet is set to the nominal value of 0
and the HHT works best with the Array Origin set to1,
the EMD HHT was computed in the separate Mathcad Worksheet: "EMD_HHT GISS.xmcd"
Below is a screen shot of this Mathcad Worksheet.

Reference:C:\Users\tom\Documents\$ VXP\www\Pure CSS Version\Climate_Analysis\EMD Extrema.xmcd(R)

Reference:C:\Users\tom\Documents\$ VXP\www\Pure CSS Version\Climate_Analysis\EMD HHT Function.xmcd(R)

Array Origin = 1 $GISST := READPRN(\text{"GISS-NASA MONTHLY TEMP 1980 to 2022.txt"})$ $rows(GISST) = 1709$

Extract Yearly Data from Monthly Data $TSpan := submatrix(GISST, 7, 1687, 1, 2)$ $r := 1, 2 .. 141$ $YR_r := 1 + 12(r - 1)$

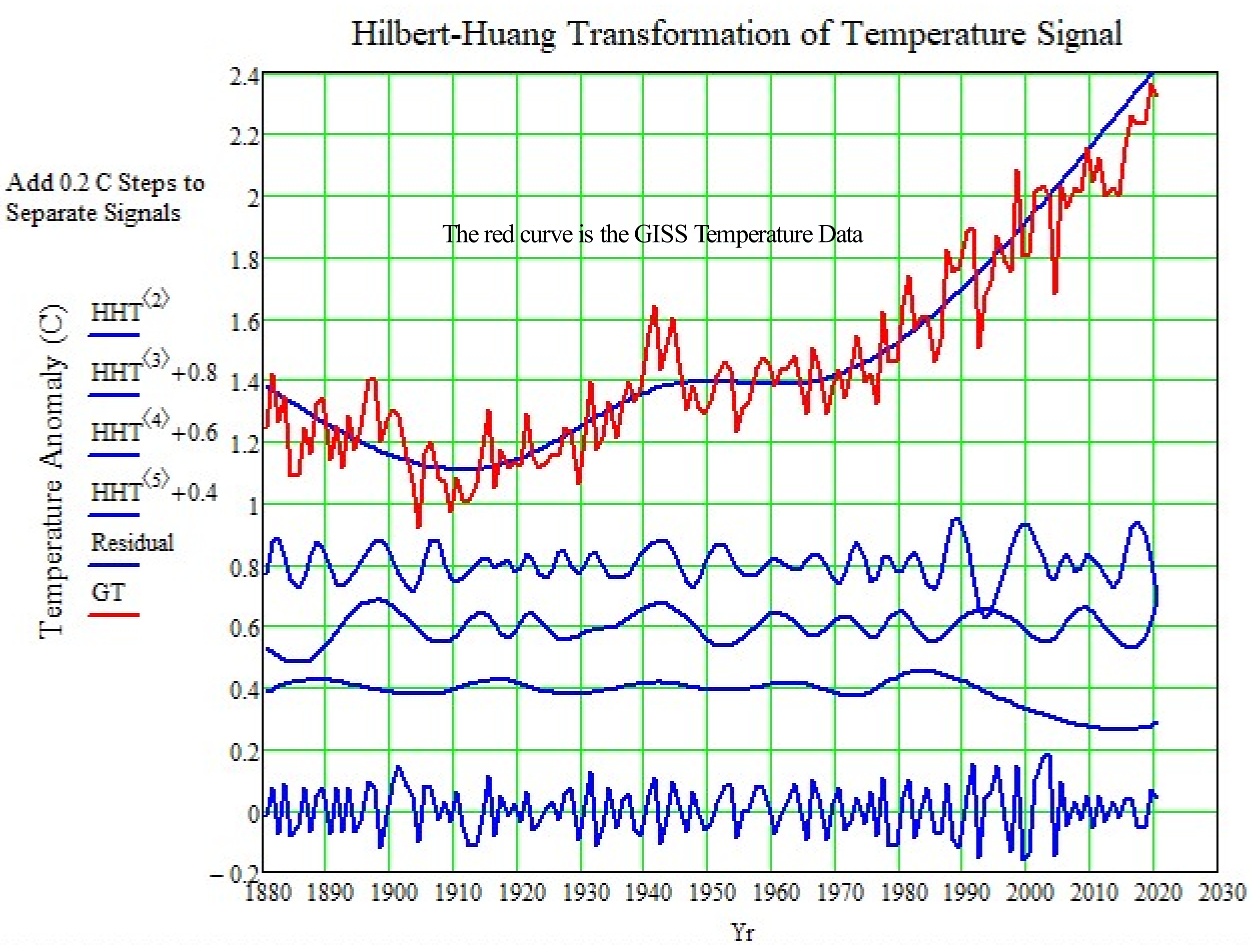
$Yr_r := TSpan_{YR_r, 1}$ $X_r := r$ $GT_r := TSpan_{YR_r, 2}$ $Ext := extrema(GT)$

$HHT := eemd(GT, 0, 1)$ $Residual := HHT^{\langle 6 \rangle} + HHT^{\langle 7 \rangle} + HHT^{\langle 8 \rangle}$ $RExt := rows(Ext)$

$spmax := submatrix(Ext, 1, Ext_{RExt, 2}, 1, 2)$ $spmin := submatrix(Ext, Ext_{RExt, 2} + 1, RExt - 2, 1, 2)$

$up_{sp} := cspline(spmax^{\langle 1 \rangle}, spmax^{\langle 2 \rangle})$ $upper := interp(up_{sp}, spmax^{\langle 1 \rangle}, spmax^{\langle 2 \rangle}, X)$

$low_{sp} := cspline(spmin^{\langle 1 \rangle}, spmin^{\langle 2 \rangle})$ $lower := interp(low_{sp}, spmin^{\langle 1 \rangle}, spmin^{\langle 2 \rangle}, X)$



Note the 140 year low frequency cycle. See also Section IIA. 11

D. Testing the Anthropogenic Greenhouse Gas Global Warming Model

Looking for Unique Fingerprints of AGW

SECTION XIII. Regression Model: Global Temp from CO2 and Natural Forcings

Test #0. Use ENSO, Irradiance, Volcanic Aerosols, & Anthropogenic Effects to Create an Empirical Temp Model

See **http://www.leapcad.com/Climate_Analysis/Empirical_Model_ENSO_Solar_VolcAero_Anthro.pdf**
Ref: "Some statistical aspects of anthropogenic and natural forced global temperature change", Schonwiese and Bayer, 1995.
Empirical Multivariate Regression Model by Combining ENSO (E), Irradiance (S), Volcanic Aerosols (V), CO_2 Anthropogenic Forcing Effects (A) to generate Multi-Variate regression coefficients of Global Temperature Anomaly data. The resulting model has an R^2 of 0.84, i.e. it **captures 84% of the variation of Global Temperature**. This model is then used to make decadal temperature projections based on predictions for these four climate variables.
Monthly mean surface temperature anomalies ΔT_{MS} are reconstructed as a **Linear Regression Equation**:

$$\Delta T_{MS}(t) = co + c_E \cdot E(t - \Delta t_E) + c_V \cdot V(t - \Delta t_V) + c_S \cdot S(t - t_S) + c_A \cdot A(t - t_A)$$

Where E, V, S and A are a AR(1) time series with **optimized lags** of $\Delta t_E = 7$, $\Delta t_V = 8$, and $\Delta t_S = 2$ months and $\Delta t_A = 17$ years. The lags are chosen to maximize the proportion of global variability that the statistical model captures and are spatially invariant. The fitted coefficients are obtained by multiple linear regression against the instrumental surface temperature record (HadCRUT4). The Temp data was median smooth within a 7 month period.

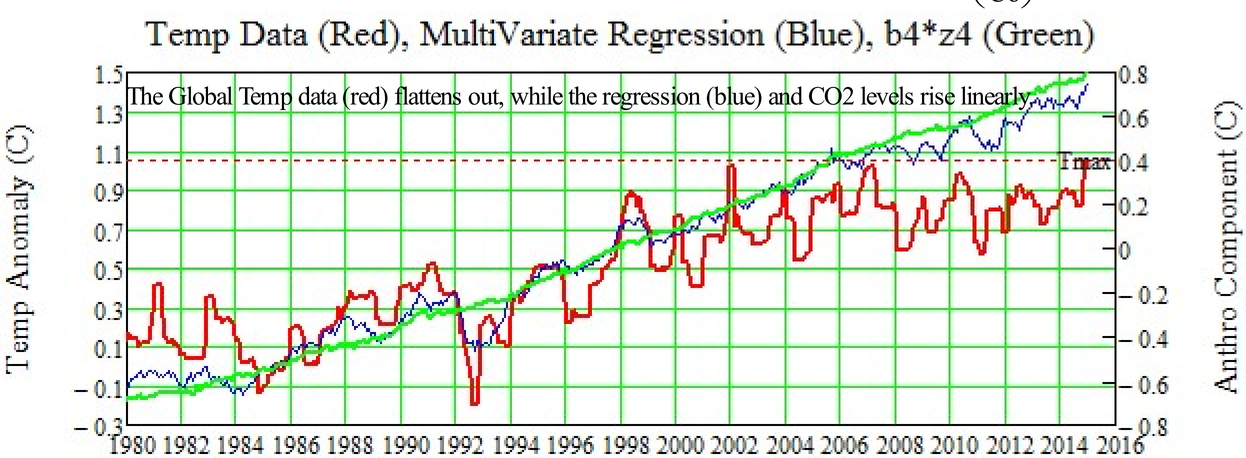
Multiforced regression models based on observational temperature data are able to **reproduce both a major part of natural fluctuations (decadal time scale) & a trend which may be due to GHG forcing**. Moreover, **future extrapolations** of the GHG forced temperature trend show a magnitude which is **similar to Global Climate Model** projections.

Compare Anthropogenic (CO2) Forcing Component - to Temp Data

b4*z4 (Green Line) is the Optimized Match of Effects of CO_2 Forcing to Global Temperature Data

IPCC CO_2 Log Forcing Function used in Regression Model. Co = 340 ppm.

$$Co := 340 \qquad \Delta F_{IPCC}(C) := 6.3 \ln\left(\frac{C}{Co}\right)$$



$\text{corr}(Y, \Delta T) = 0.9038$ $\qquad$ $RSquare := \text{corr}(Y, \Delta T)^2 = 0.81685$ $\qquad$ $\text{corr}(Y, \Delta Ts)^2 = 0.72544$

Correlation to Global Temp between:
Y (ΔTemp) and x1 (ENSO) = - 3.5%
Y (ΔTemp) and x2 (Volcanic Aero) = - 49%
Y (ΔTemp) and x3 (Solar) = - 8.5%
Y (ΔTemp) and x4 (Anthropogenic) = 87%

CO_2 has ten times the correlation than Solar

$$CORR = \begin{pmatrix} 1 & 0.35061 & -0.11702 & -0.23532 & -0.05022 \\ 0.35061 & 1 & 0.01393 & -0.3596 & -0.48887 \\ -0.11702 & 0.01393 & 1 & 0.12867 & 0.08534 \\ -0.23532 & -0.3596 & 0.12867 & 1 & 0.87369 \\ -0.05022 & -0.48887 & 0.08534 & 0.87369 & 1 \end{pmatrix} \begin{pmatrix} x1 \\ x2 \\ x3 \\ x4 \\ y \end{pmatrix} \begin{pmatrix} \text{ENSO} \\ \text{Aerosols} \\ \text{Solar} \\ \text{CO2} \\ \Delta\text{Temp} \end{pmatrix}$$

D. SECTIONS XIV to XX: ANALYSIS - Looking for Unique Fingerprints of Global Warming

SECTION XIV Testing the Anthropogenic Greenhouse Gas Model

Testing for Unique Fingerprints of AGW

Test #1. Spectral signatures of climate change in IR spectrum between 1970 and 2000

"Spectral signatures of climate change in the Earth's infrared spectrum between 1970 and 2006", Chen et al. (2007

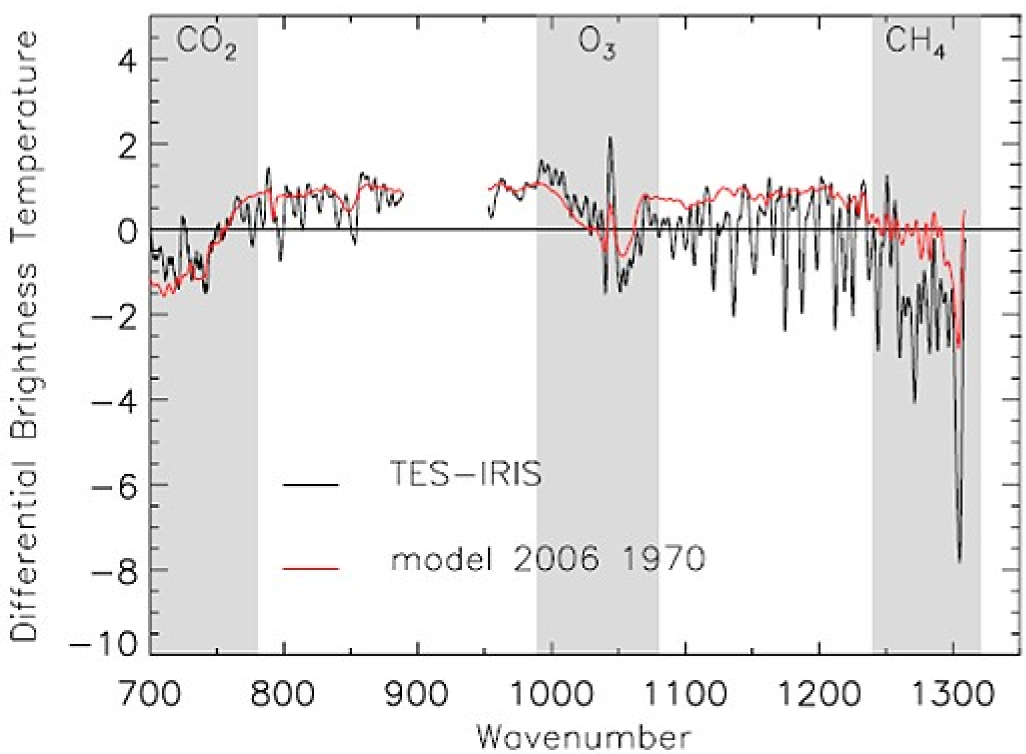
Chen et al. showed that increased CO2 is preventing LW radiation from escaping the atmosphere and this decreasing LW radiation is accurately being predicted by climate models.

The observed TES – IRIS and simulated 2006 – 1970 difference spectra are shown in Figure 3. The background offset in the lower wavenumber window discussed previously when comparing the observed and modeled brightness temperature spectra (Figure 1 and Figure 2) is not apparent when comparing the observed and modeled difference spectra. Instead the feature cancels out and the background is seen to match well over the wing of the 15 µm CO 2 band and in the window regions. This emphasizes the importance of looking at the raw spectra as well as the difference spectra. The modeled 2006 – 1970 difference in the methane signal is shallower than the observed case, which is due to the model calculating a deeper signal for 1970 than was observed.

CONCLUSIONS

The TES data compare very well with the IRIS data, suggesting successful normalization of the different instrument characteristics. The TES and IRIS difference spectrum covers the time range of 1970 – 2006, a period of 36 years. Simulated spectra represent the state of the HadGEM1 coupled model for 1970 and 2006. Changing spectral signatures in CH 4 , CO 2 , and H 2 O are observed, with the difference signal in the CO 2 matching well between observations and modeled spectra. The methane signal is deeper for the observed difference spectrum than the modeled difference spectrum, but this is likely due to incorrect methane concentrations or temperature profiles from 1970. In the future, we plan to extend the analysis to more spatial and temporal regions, other models, and to cloudy cases.

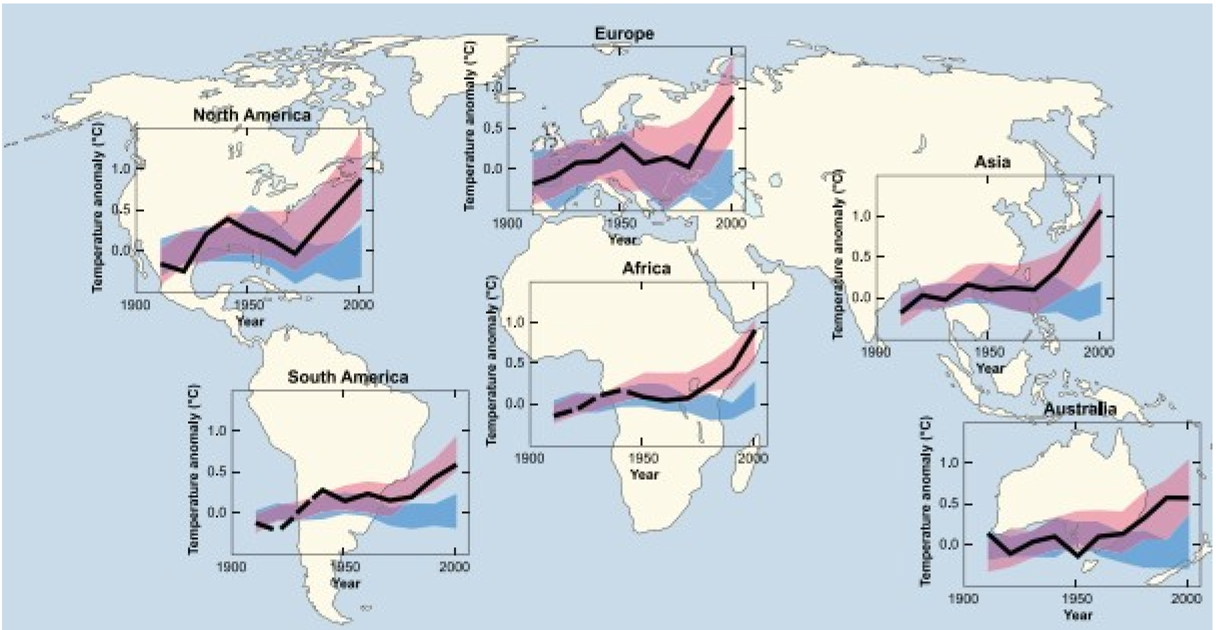
"This experimental data should effectively end the argument by skeptics that no experimental evidence exists for the connection between greenhouse gas increases in the atmosphere and global warming."



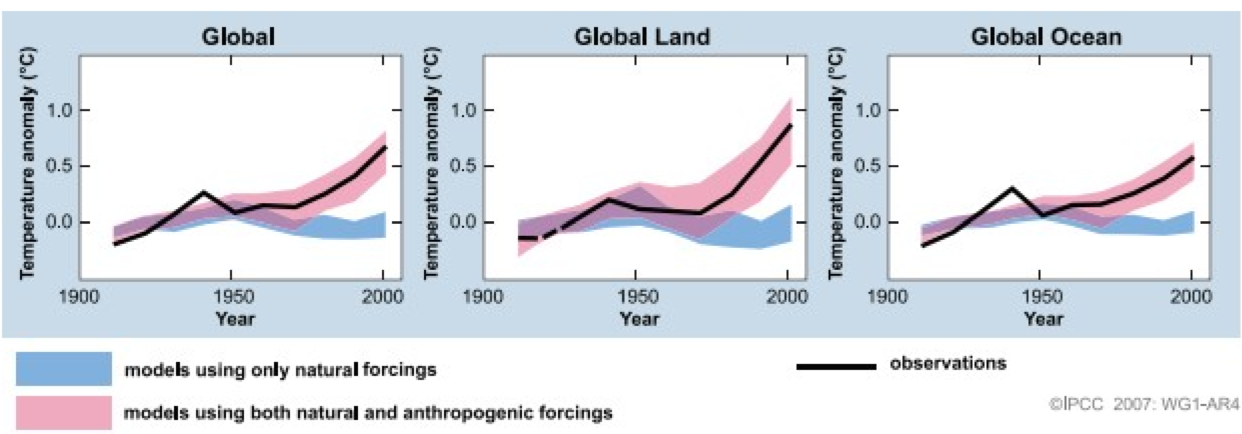
Observed difference spectrum (black line) between 2006 and 1970 (TES – IRIS) and the simulated difference spectrum (red line) for the same time interval.

Test #2. Natural Forcing alone cannot account for global warming - IPCC - 2007 WG1-AR4

Temperature changes relative to the corresponding average for 1901-1950 (°C) from decade to decade from 1906 to 2005 over the Earth's continents, as well as the entire globe, global land area and the global ocean (lower graphs). The black line indicates observed temperature change, while the colored bands show the
combined range covered by 90% of recent model simulations. Red indicates simulations that include natural and human factors, while blue indicates simulations that include only natural factors. Dashed black lines indicate decades and continental regions for which there are substantially fewer observations.



Test #3. Warming over land is greater than over oceans - IPCC - 2007 WG1-AR



Test #4.
GH Effect requires the lower and mid troposphere to be warmer than the surface.

Reconciling Observations of Global Temperature Change

Panel on Reconciling Temperature Observations, National Research Council, 2000

FINDINGS - 21

Based on current estimates, the lower to mid-troposphere has warmed less than the earth's surface during the past 20 years. For the time period from 1979 to 1998, it is estimated that on average, over the globe, surface temperature has increased by 0.25 to 0.4 °C and lower to mid-tropospheric temperature has increased by 0.0 to 0.2 °C.

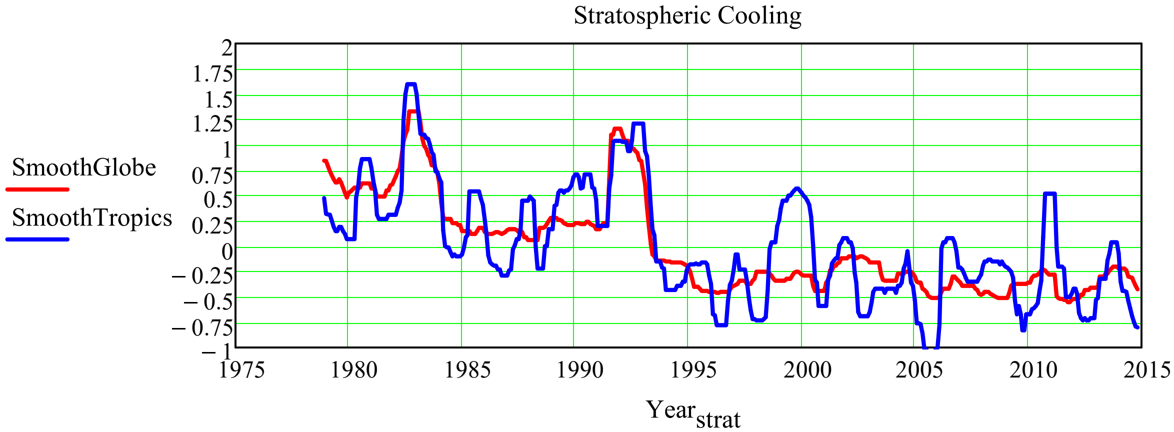
Test #5: AGW (GH Effect) requires the stratosphere to cool

Stratosphere Data: http://www.nsstc.uah.edu/data/msu/t4/uahncdc_ls_5.6.txt

Year Mo Globe Land Ocean NH Land Ocean SH Land Ocean Trpcs Land Ocean NoExt Land

$$StratTemp := READPRN("LowStrat - uahncdc\_ls\_5.6.dat") \qquad Year_{strat} := StratTemp^{\langle 0 \rangle} + \frac{StratTemp^{\langle 1 \rangle} - 1}{12}$$

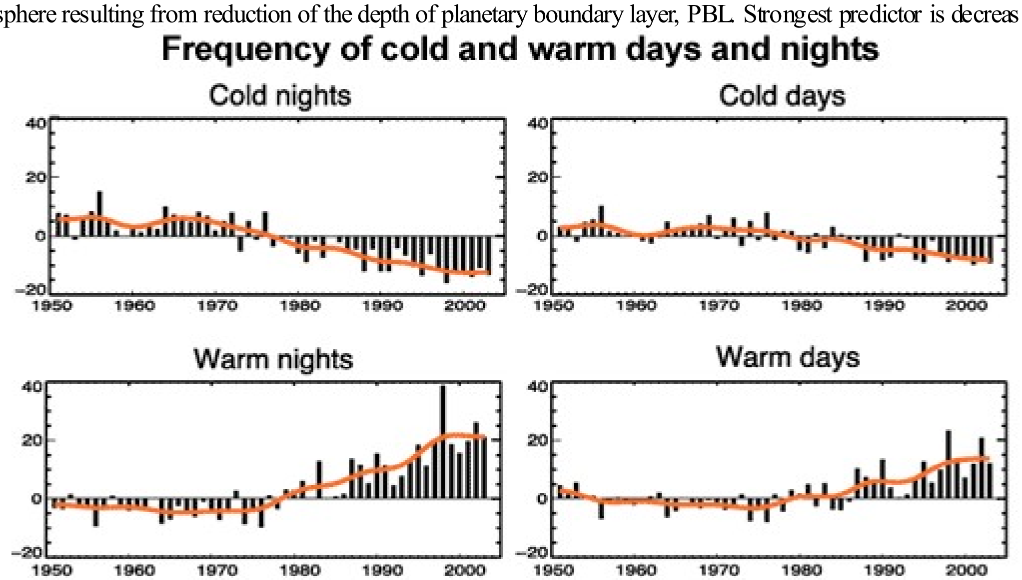
$$SmoothGlobe := medsmooth\left(StratTemp^{\langle 2 \rangle}, 11\right) \qquad SmoothTropics := medsmooth\left(StratTemp^{\langle 11 \rangle}, 11\right)$$



Test #6 Asymmetric diurnal temp change - Nights warming faster than days

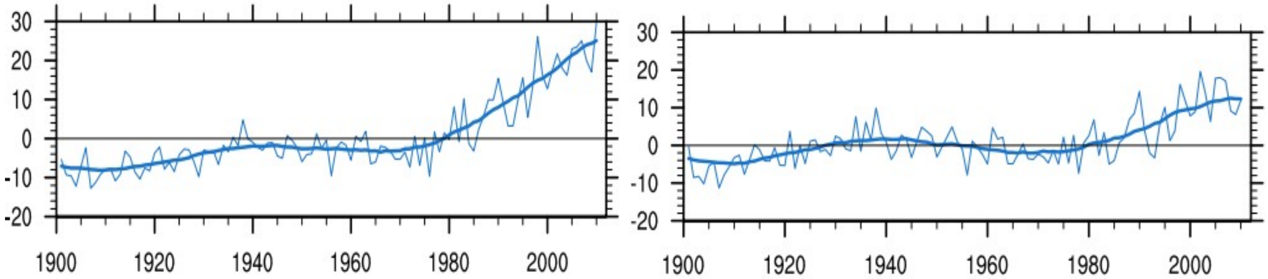
If an increased greenhouse effect was causing warming, we would **expect nights to warm faster** than days, winters faster than summers, and polar regions faster. If the cause **were solar, day** and summer temps would increase more. See: Diurnal asymmetry to the observed global warming - Int J of Climatrology - Davy, 24 Feb 2016

Possible causes are reduction in cloud cover, precipitation, soil moistures, and the reduction in heat capacity of atmosphere resulting from reduction of the depth of planetary boundary layer, PBL. Strongest predictor is decreased PBL.



Graph Above: Observed trends (days per decade) for 1951 to 2003 in the number of extreme cold and warm days and nights per year. Cold is defined as the bottom 10%. Warm is defined as the top 10%. Orange lines show decadal trend (IPCC AR4 FAQ 3.3 adapted from Alexander 2006).

Below: Updated: Warm nights/days, TN90p/TX90P www.metoffice.gov.uk/hadobs/hadex2/Donat_etal2013.pdf



Test #7 Measure - Global Atmospheric Downward Longwave Radiation 1973-2008

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 114, D19101, doi:10.1029/2009JD011800, 2009 Wang and Liang
Evaluation of two widely accepted methods to estimate global atmospheric **downward longwave radiation (L_d)** under **both clear and cloudy** conditions, using meteorological observations from 1996 to 2007 at 36 globally distributed sites, operated by the Surface Radiation Budget Network (SURFRAD),we applied them to globally available meteorological observations to estimate **decadal variation in L_d.** The decadal variations in global L_d under both clear and cloudy conditions at about 3200 stations from 1973 to 2008 are presented. We found that daily L_d **increased at an average rate of 2.2 W m^{-2} per decade from 1973 to 2008**. The rising trend results from increases in **air temperature, atmospheric water vapor, and CO_2 concentration.** The L_d is estimated by

$$L_d := (1 - f)\cdot L_{dc} + f\cdot \sigma T_a^{\ 4}$$

where f is the cloud fraction, L_{dc} clear-sky radiation, σ is the Stefan-Boltzmann constant, and T_a is air temp

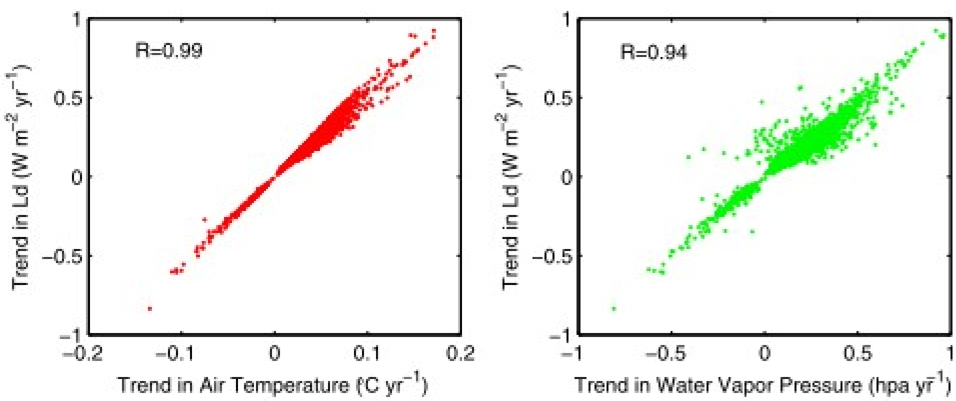
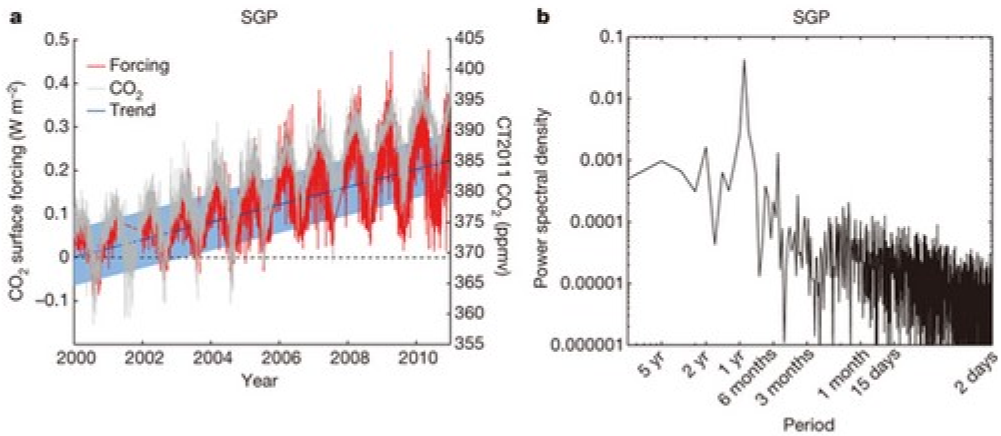


Figure 6. The scatterplots of linear trends in L_d as a function of trends in air temperature (red) and water vapor pressure (green) at the stations shown in Figure 5. One point in the figure represents one station. The correlations of the trends in air temperature, relative humidity, and water vapor pressure are also shown.

Test #8 Observational determination of surface radiative forcing by CO_2 2000 to 2010

Observational determination of surface radiative forcing by CO_2 from 2000 to 2010
D. R. Feldman, W. D. Collins, P. J. Gero, M. S. Torn, E. J. Mlawer & T Shippert, Nature 519, 339–343 (19 March 2015)

The climatic impact of CO2 and other greenhouse gases is usually quantified in terms of radiative forcing, calculated as the difference between estimates of the Earth's radiation field from pre-industrial and present-day concentrations of these gases. Radiative transfer **models** calculate that the increase in CO2 since 1750 corresponds to a global annual-mean radiative forcing at the tropopause of **1.82 ± 0.19 W m−2** (ref. 2). However, despite widespread scientific discussion and Modelling of the climate impacts of well-mixed greenhouse gases, there is l**ittle direct observational evidence** of the radiative impact of increasing atmospheric CO2. Here we present observationally based evidence of **clear-sky** CO2 surface radiative forcing that is **directly attributable** to the **increase**, between 2000 and 2010, of **22 parts per million atmospheric CO_2.**
The time series of this forcing at the **two locations**—the Southern Great Plains (SGP) and the North Slope of Alaska (NSA)—are derived from Atmospheric Emitted Radiance Interferometer spectra.The time series both show statistically significant trends of **0.2 W m−2 per decade** (with respective uncertainties of ±0.06 W m−2 per decade and ±0.07 W m−2 per decade) and have seasonal ranges of 0.1–0.2 W m−2. This is **only ten per cent of the trend in downwelling longwave radiation.** These results confirm theoretical predictions of the atmospheric greenhouse effect due to **anthropogenic** emissions, and provide **empirical evidence of how seasonal and rising CO_2 levels,** mediated by temporal variations due to photosynthesis and respiration, **are affecting the surface energy balance**.



Test #9. Constant Relative Humidity (RH) results in maximum climate sensitivity.

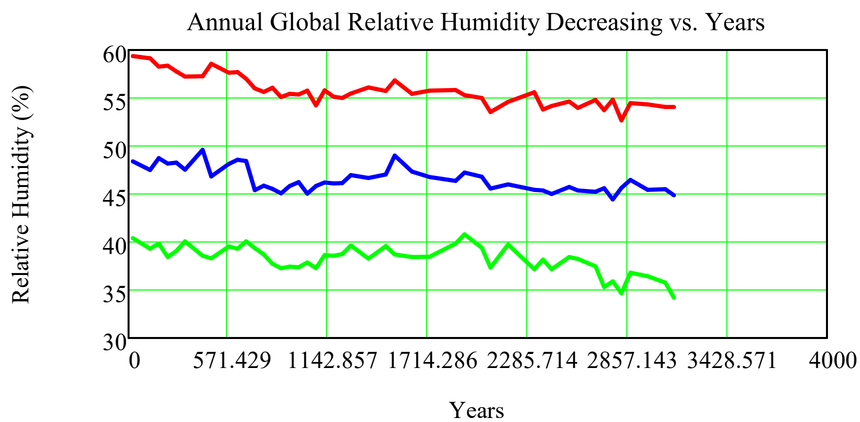
General Circulation Climate Models assume that RH is constant. The RH data shows this is false.
Evidence Reveals that Relative Humidity has been decreasing as CO2 has been rising
Data: http://www.esrl.noaa.gov/psd/cgi-bin/data/timeseries/timeseries1.pl

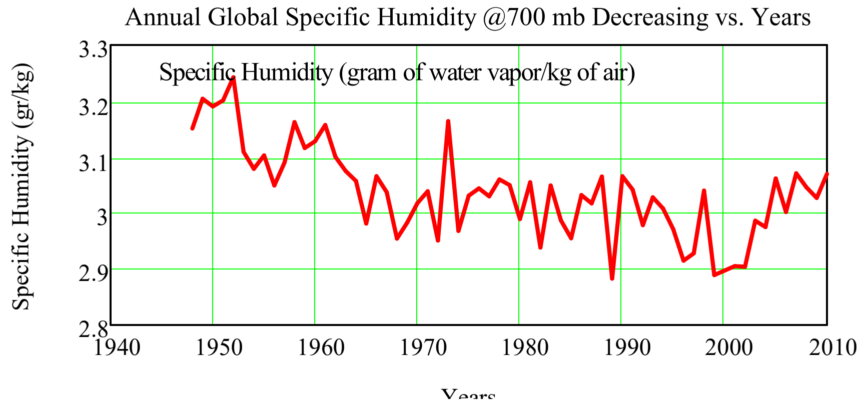
25 February 2015 (Nature) – a, Time series of observed spectrally integrated (520–1,800 cm−1) CO2 surface radiative forcing at SGP (in red) with overlaid CT2011 estimate of CO2 concentration from the surface to an altitude of 2 km (gray), and a least-squares trend of the forcing and its uncertainty (blue). b, Power spectral density of observed CO2 surface radiative forcing at SGP. c, As for a but for the NSA site. d, As for b but for the NSA site.

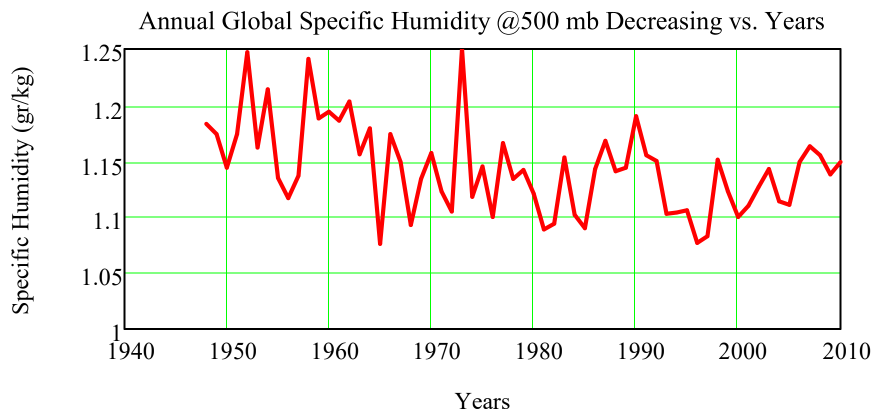
RH700 := READPRN("ESRL-NOAA-RH-GlobalAnnual700mb-1948-2010.txt")
RH500 := READPRN("ESRL-NOAA-RH-GlobalAnnual500mb-1948-2010.txt")
RH300 := READPRN("ESRL-NOAA-RH-GlobalAnnual300mb-1948-2010.txt")
SH700 := READPRN("ESRL-NOAA-SH-GlobalAnnual700mb-1948-2010.txt")
SH500 := READPRN("ESRL-NOAA-SH-GlobalAnnual500mb-1948-2010.txt")
SH300 := READPRN("ESRL-NOAA-SH-GlobalAnnual300mb-1948-2010.txt")

Higher Surface Levels (Decreasing Pressure): 700 Red, 500 Blue, and 300 Green mb

$\text{Years} := \text{RH700}^{\langle 0 \rangle}$




Annual Global Specific Humidity @700 mb Decreasing vs. Years
Specific Humidity (gram of water vapor/kg of air)
Specific Humidity (gr/kg)
3.3
3.2
3.1
3
2.9
2.8
1940
1950
1960
1970
1980
1990
2000
2010


Annual Global Specific Humidity @500 mb Decreasing vs. Years
Specific Humidity (gr/kg)
1.25
1.2
1.15
1.1
1.05
1
1940
1950
1960
1970
1980
1990
2000
2010
Years

SECTION XV. Geologic and current nonlinear multiyear cycles in sea level

Effects Associated with Increased Temperatures in General

1. Non Linear Trend: Holocene Sea Level Rise - 8000 BP

Variations in sea level during the Holocene
(10,000 BC, the time since the end of the last major glacial epoch).

Adjusted for glacial isostatic motion. See "Refining the eustatic sea-level curve since the Last Glacial Maximum using far- and intermediate-field sites", Fleming, Kevin (1998). Earth and Planetary Science Letters 163 (1-4): 327-342. "Modeling Holocene relative sea-level observations from the Caribbean and South America", Quaternary Science Reviews 24 (10-11): 1183-1202, Milne

$SLHol := READPRN("Holocene\_Sea\_Level.txt") \quad r := 0..rows(SLHol) - 1 \quad cc := 0..1$

$SLHolBP_{r,0} := -SLHol_{r,0} \quad SLHolBP_{r,1} := SLHol_{r,1}$

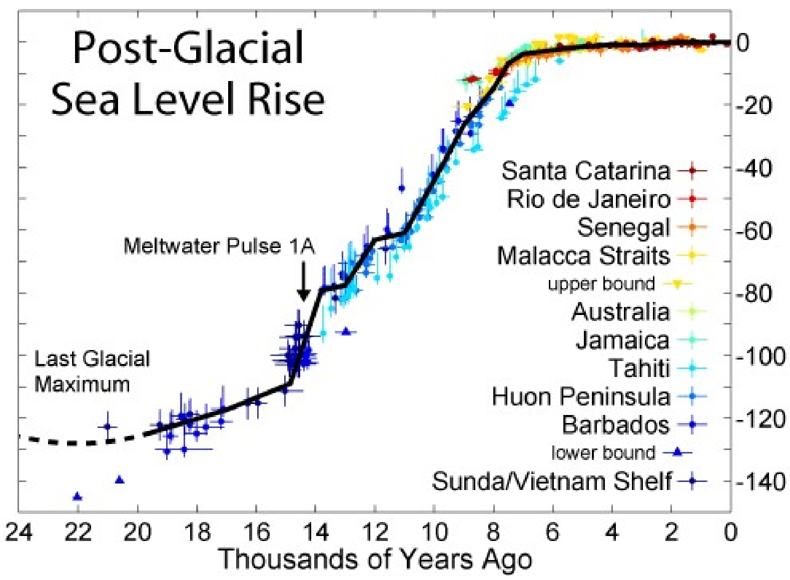
$SLHolC := READPRN("Holocene\_Sea\_Level4.txt") \quad r := 0..rows(SLHolC) - 1 \quad cc := 0..1$

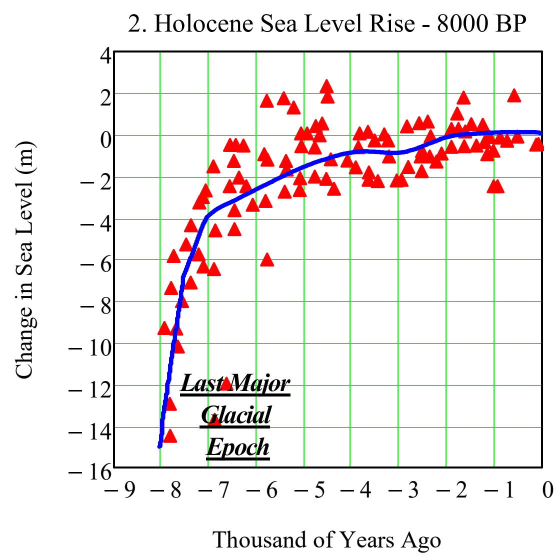
$SLHolBPC_{r,0} := -SLHolC_{r,0} \quad SLHolBPC_{r,1} := SLHolC_{r,1} \quad SSSHol := csort(SLHolBPC, 0)$

$X := SSSHol^{\langle 0 \rangle} \quad Y := SSSHol^{\langle 1 \rangle} \quad w := 33 \quad mm := \frac{w-1}{2} \quad n := rows(Y) \quad i := 0..n-1$

$$mvg\_avg_i := if\left[i < mm, \frac{\sum_{j=0}^{2 \cdot i} Y_j}{(2 \cdot i) + 1}, if\left(i > n - 1 - mm, \frac{\sum_{j=2 \cdot i - n + 1}^{n-1} Y_j}{2n - 1 - 2 \cdot i}, \frac{\sum_{j=i-mm}^{i+mm} Y_j}{w} \right) \right]$$

Post Glacial Sea Level Rise





1. Non Linear Trend: Global Sea Level vs Time - 1800 to 2022 - Anomalous increased rate since 1990

Jevrejeva, S., Grinsted, A., Moore, J. and S. Holgate. , J. Geophys. Res., 111, C09012, 2006
Global Sea Level Reconstruction Data http://www.pol.ac.uk/psmsl/author_archive/jevrejeva_etal_gsl/
%time, gsl_rate (mm), gsl_rate_error (mm), gsl (mm), gsl_error(mm)

Proudman Oceanographic Laboratory
http://www.pol.ac.uk/psmsl/author_archive/church_white/
church_white_grl_gmsl.txt
years, GMSL in millimeters, One-sigma error in millimeters.
Note: Data agrees with Global mean sea level from
TOPEX/Poseidon, Jason-1, and Jason-2

U of Colorado Sea Level Research Group Sat Data
http://sealevel.colorado.edu/files/2014_rel5/sl_ns_global.txt
SatSL: Sat 2015 Global Mean Sea Level Time Series
Seasonal signal removed.
Data Format: Years, mm

$NASA := READPRN(\text{"NASA Global Mean Sea Level to 1998-2022 OK1.txt"})$ $YrN := NASA^{\langle 0\rangle}$ $SLN := NASA^{\langle 6\rangle}$

$SeaLevel := READPRN(\text{"Global sea level data.txt"})$

$SL\_CWF := READPRN(\text{"church\_white\_gmsl.txt"})$

$SLI := submatrix(SeaLevel, 630, rows(SeaLevel) - 1, 0, 3)$

$Time := SeaLevel^{\langle 0\rangle}$ $Time2 := SL\_CWF^{\langle 0\rangle}$

$SL := SeaLevel^{\langle 3\rangle}$ $SL\_CW := SL\_CWF^{\langle 1\rangle}$

$SatSL := READPRN(\text{"sl\_ns\_global2015.txt"})$

The Proudman raw and regression data gives a reference level for 2007.5 of ~ 137 mm and U of Col of 36.5 mm.
Add 100 mm to U of Col data to match up.

$SatSLM := SatSL^{\langle 1\rangle} + 100$

$Sr := line\left(SLI^{\langle 0\rangle}, \overrightarrow{SLI^{\langle 3\rangle}}\right)$ $SL_{reg}(year) := Sr_0 + Sr_1 \cdot (year)$ $SL_{reg}(2007.5) = 136.58959$ $Sr_1 = 1.71045$

$SR := line\left(SatSL^{\langle 0\rangle}, SatSLM\right)$

$SR_1 = 3.24825$

http://www.psmsl.org/products/reconstructions/gslGPChange2014.txt
%time, gsl_rate (mm), gsl_rate_error (mm), gsl (mm), gsl_error(mm)
Jevrejeva et al 2014

$SLJ := READPRN(\text{"gslGPChange2014.dat"})$

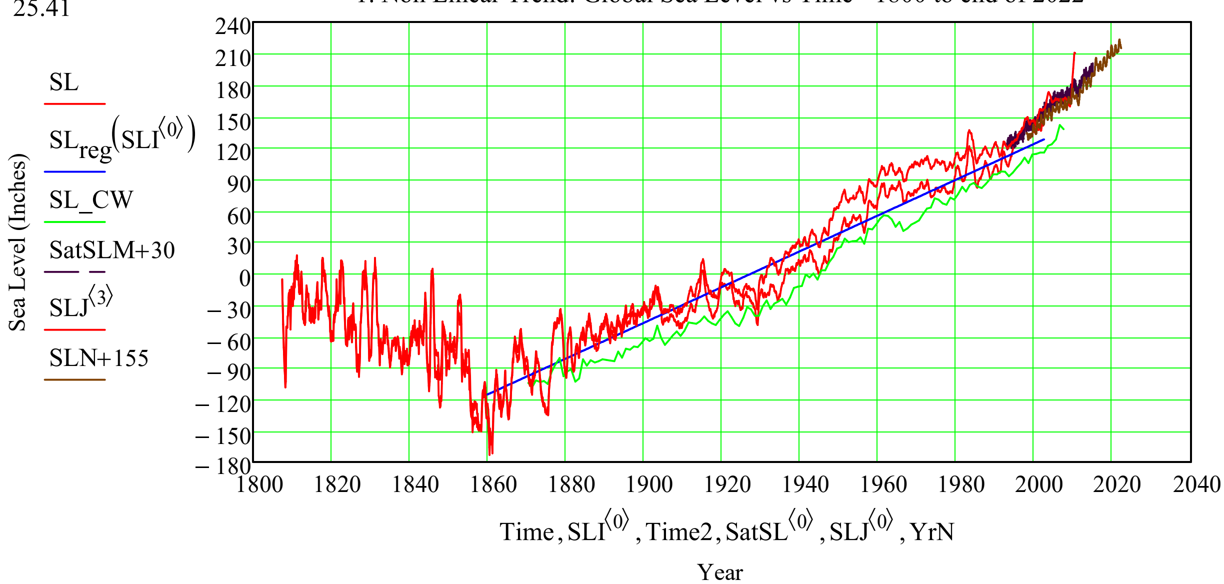
Sea level rise, Sr, of 1.7 mm/year began 1860, well before large scale CO_2 emissions

However, after 1990 the rate (SR) increased to 3.4 mm/year.

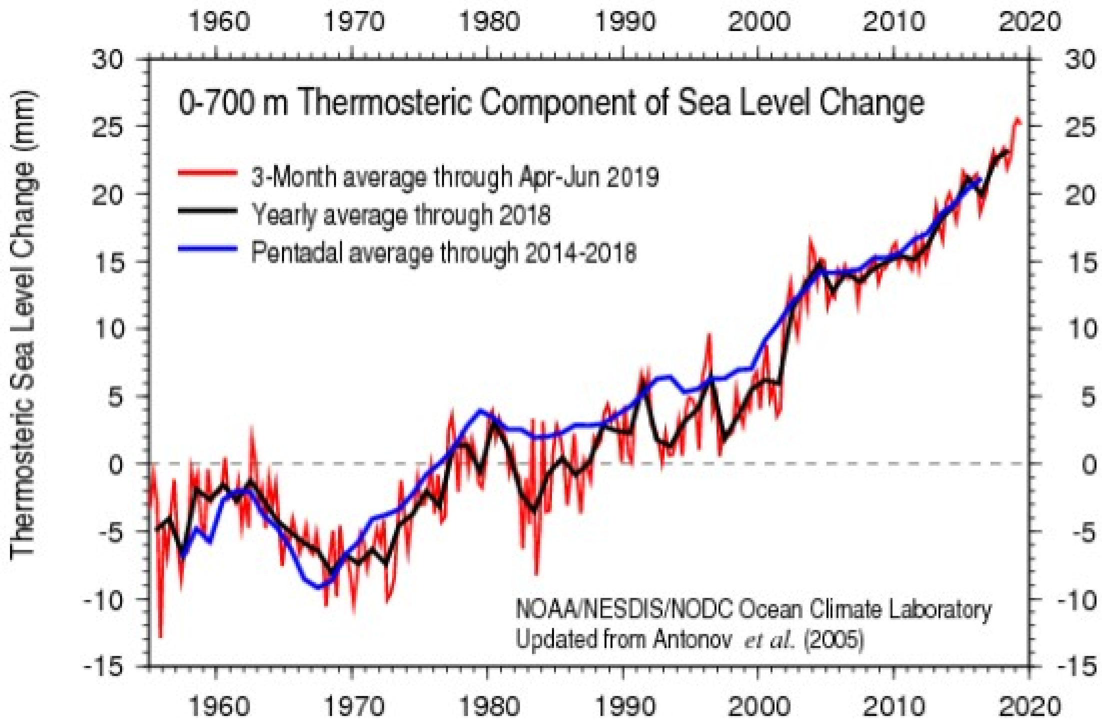
Convert mm to Inches

$\frac{240 + 180}{25.41} = 16.53$

1. Non Linear Trend: Global Sea Level vs Time - 1800 to end of 2022

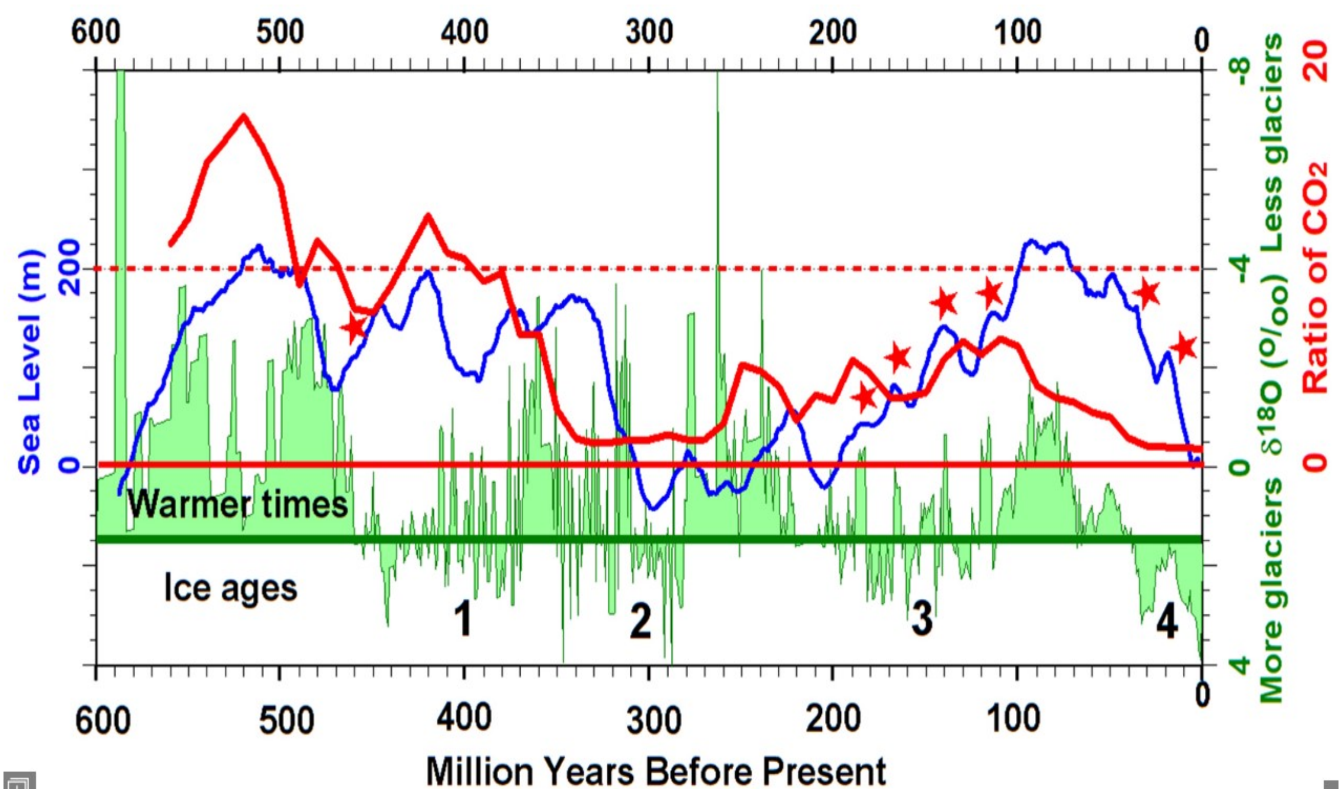


A mechanism for changing sea level is **thermosteric**, related to thermal expansion/contraction properties of water molecules themselves. As temperatures of the ocean increases, the volume of seawater increases and can produce a higher sea level.



http://ozonedepletiontheory.info/ImagePages/CO2-sealevel-glaciations-horizA.html

3. Sea Level Rise over the last 600 million years



4. Shutdown of thermohaline circulation

There is some speculation that global warming could, via a shutdown or slowdown of the thermohaline circulation, trigger localized cooling in the North Atlantic and lead to cooling, or lesser warming, in that region.[76] This would affect in particular areas like Scandinavia and Britain that are warmed by the North Atlantic drift

SECTION XVI "Extracting a Climate Signal from 169 Glacier Records", J. Oerlemans, 2005

Table S2. Global mean temperature reconstructed from glacier records compared to other temperature series. Glaciers Temp Reconstruction (Blue), Mann et al. Proxy (Red), Jones and Moberg Proxy (Green)

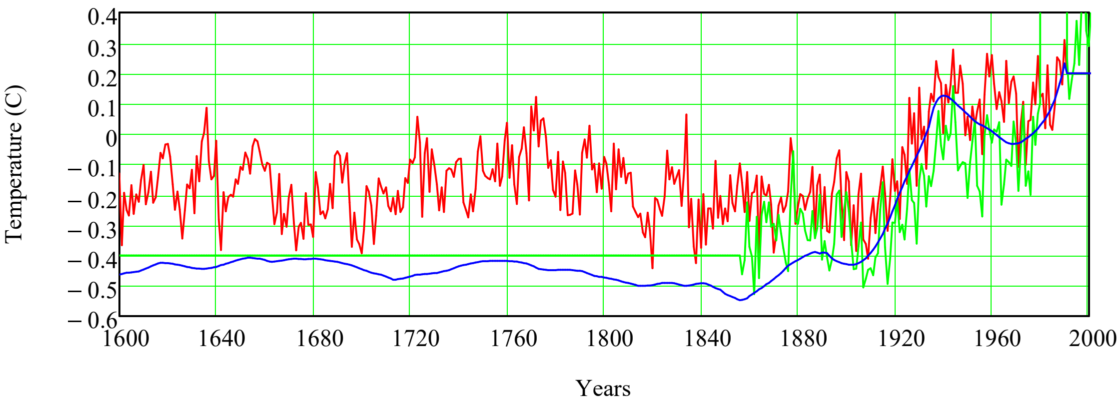
TempGlacier := READPRN("Extracting a Climate Signal from 169 Glacier Records Data.csv")

$$\frac{dL'(t)}{dt} = -\frac{1}{\tau}\left[cT'(t) + L'(t)\right] \qquad T'(t) = -\frac{1}{c}\left[L'(t) + \tau\frac{dL'(t)}{dt}\right]$$

Climate sensitivity depends in particular on the surface slope (a geometric effect) and the annual precipitation (a mass-balance effect). Glaciers in a wetter climate are more sensitive, and this is taken into account. Using a first-order theory of glacier dynamics, changes in glacier length were related to changes in temperature. Here, t is time, *L'* is the glacier length with respect to a reference state, and T is a temperature perturbation (annual mean) with respect to a reference state. As a result, in the sample of 169 glaciers, c varies by a factor of 10, from ~1 to ~10 km/K. Values of τ vary from about 10 years for the steepest glaciers to a few hundreds of years for the largest glaciers in the sample with a small slope (the glaciers in Svalbard). Most of the values are in the range of 40 to 100 years.

Glaciers Temp Reconstruction (Blue), Mann et al. Proxy (Red), Jones and Moberg Proxy (Green)

1. Glacier Global Temp Reconstruction & Ts - 1600 to 2000



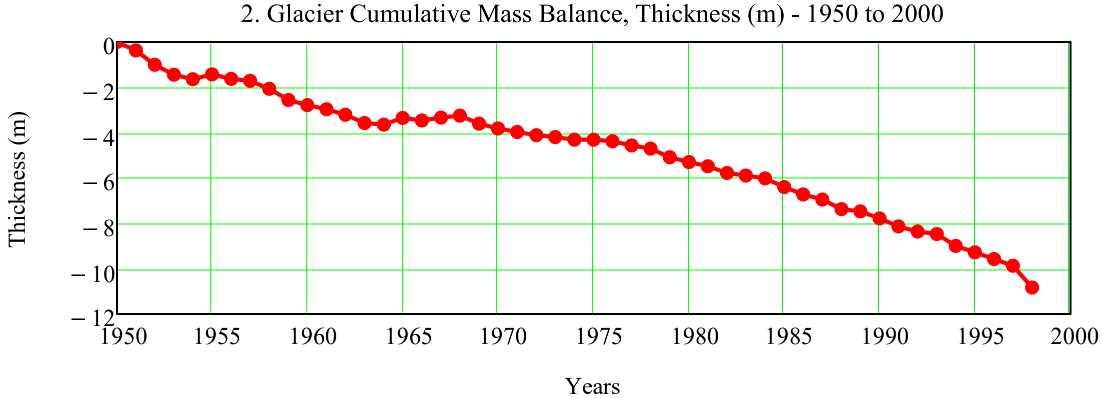
Glacier Mass Balance and Regime: Data of Measurements and Analysis OP55_glaciers.pdf
Institute of Arctic and Alpine Research, University of Colorado, Boulder, Colorado
http://instaar.colorado.edu/index.html

Appendix 3: Annual data on glacier regime - Averaged AAR calculations
Averaged annual or net mass balance calculations, pg. 79, <bn>, (mm)

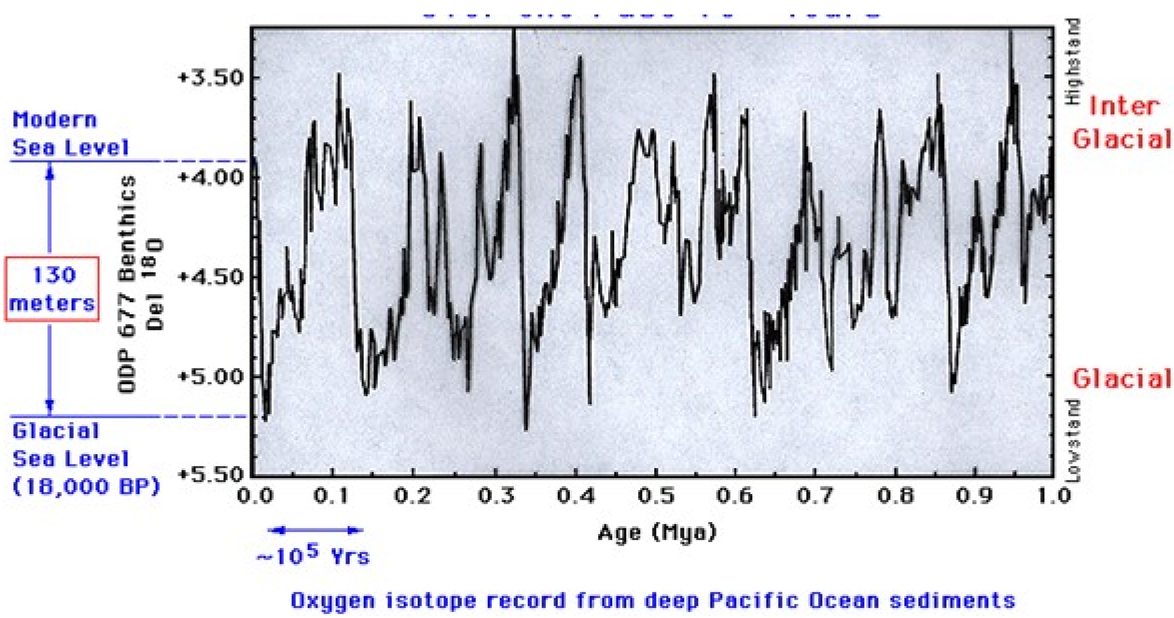
ANMB := READPRN("Averaged annual or net mass balance calculations OP55.TXT")

$$\text{CumNMB} := \left(\text{ANMB}^{\langle 3\rangle} - \text{ANMB}_{4,3}\right)\cdot 10^{-3}$$

2. Glacier Cumulative Mass Balance, Thickness (m) - 1950 to 2000



3. Vostok Ice Core Data, Ratio $^{18}O/^{16}O$ (High–>Warm) ==> Continental Glaciers over past 10^6 years

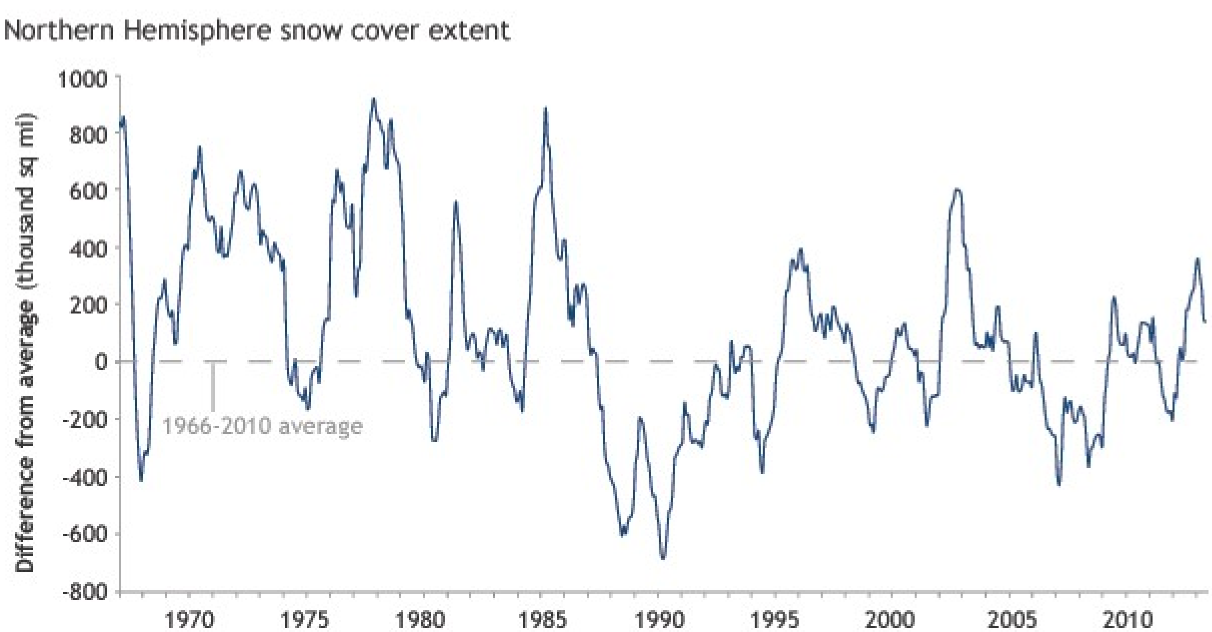


SECTION XVII. Snow Coverage in the Northern Hemisphere

Snow cover, the **whitest natural surface on the planet, reflects** roughly **90 percent of the sunlight** that reaches it. **Snow-free ground absorbs** anywhere from **four to six times more solar radiatio**n than snow-covered Earth. Though some snow cover occurs in the Southern Hemisphere or on Northern Hemisphere sea ice, **nearly all of the Earth's seasonal snow cover happens over land in the Northern Hemisphere.**

Changes over time

http://www.climate.gov/news-features/understanding-climate/2013-state-climate-snow-northern-hemisphere
From 1970 - Climate.gov



Rutgers Snow Coverage Data - From 1965

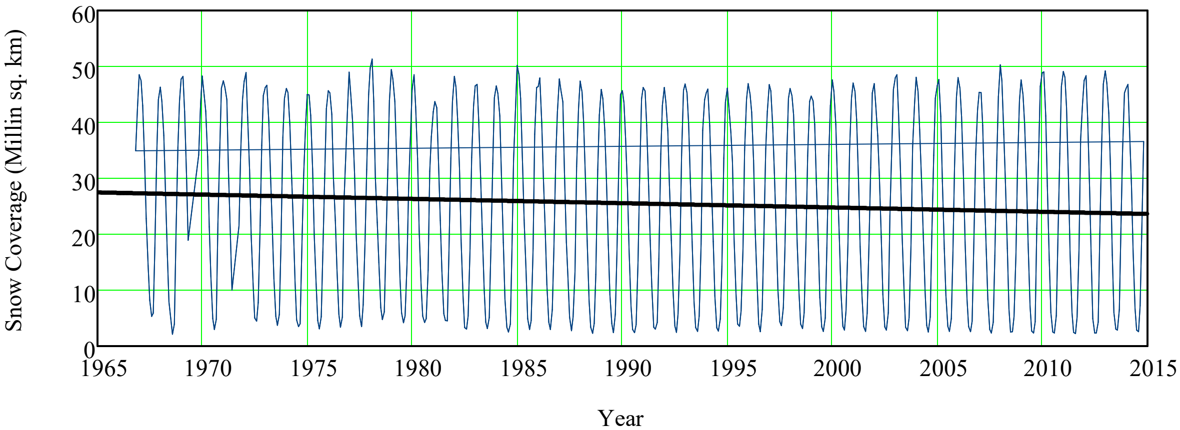
http://climate.rutgers.edu/snowcover/table_area.php?ui_set=1&ui_sort=0
Million sq. km
Row Year Month N. Hemisphere Eurasia N. America N. America (no Greenland)

$Snow := READPRN(\text{"gsl snow data.dat"})$ $\qquad Yr\_snow := Snow^{\langle 1 \rangle} + \frac{Snow^{\langle 2 \rangle} - 1}{12}$

$LSnow := line\left(Yr\_snow, Snow^{\langle 3 \rangle}\right)$ $\qquad Lin\left(Yr_{snow}\right) := LSnow_0 + LSnow_1 \cdot \left(Yr_{snow}\right)$

$PerCentSnowDecrease := \frac{Lin(2014) - Lin(1965)}{Lin(1965)} \cdot 100$ $\qquad PerCentSnowDecrease = -13.69749$

Rutgers Northern Hemispere Snow Coverage Data and Linear Fit (Solid Black)- 1965 to 2015

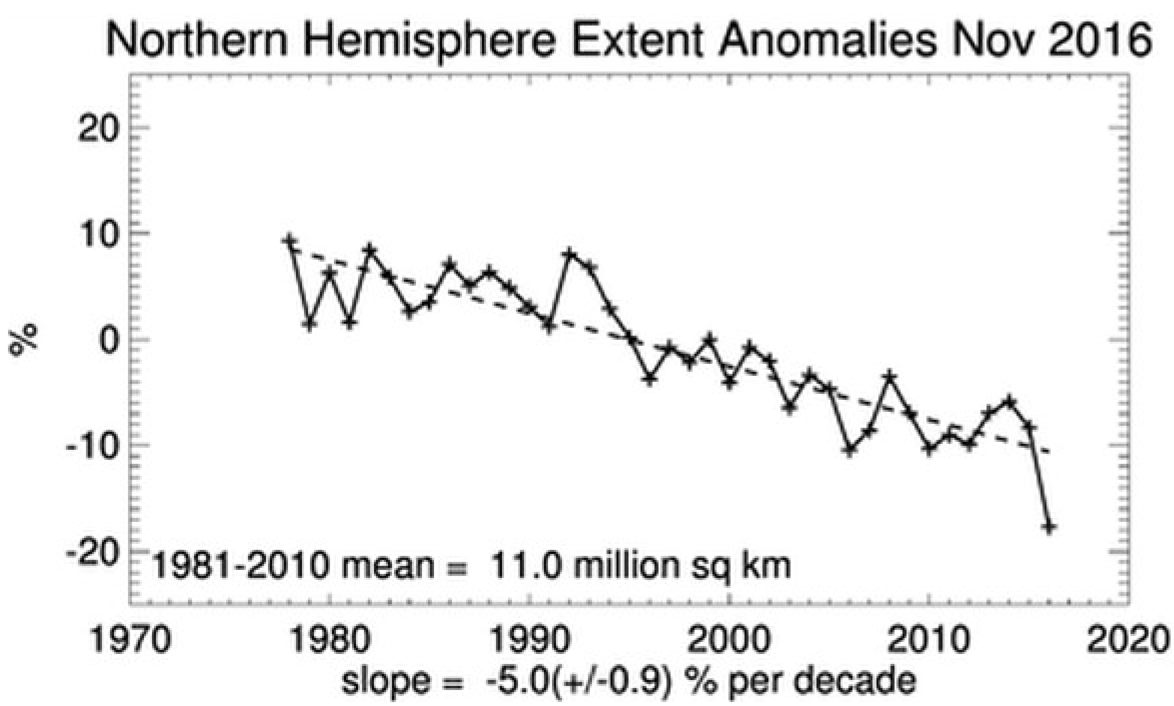


SECTION XVIII. Cryosphere -Sea Ice Extent -North & South Hemispheres

National Snow and Ice Data Center - North Year Month Day Extent (Millions sq km) Decimal Yr
ftp://sidads.colorado.edu/DATASETS/NOAA/G02135/north/ /south/daily/data/SH_seaice_extent_final.csv

Sea ice off the coast of Antarctica and the Arctic hit record lows.

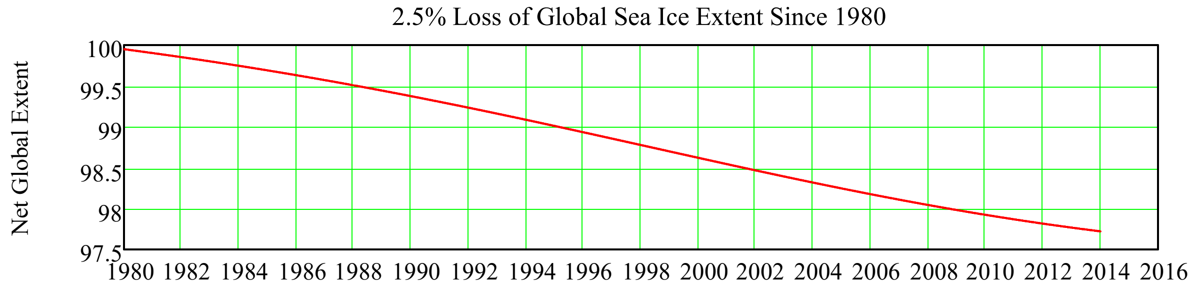
https://nsidc.org/data/seaice_index/



Calculate the Net Change:

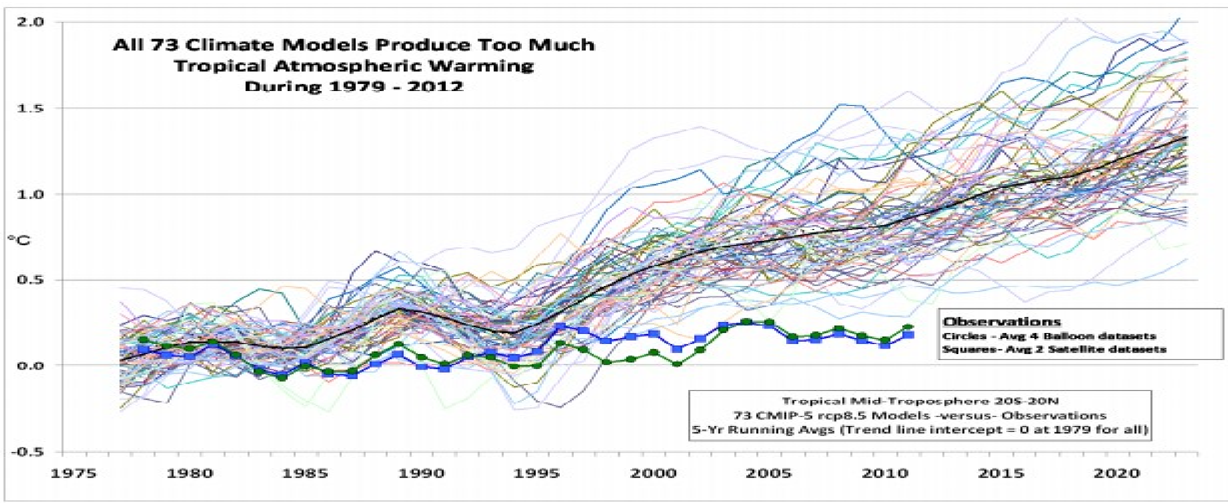
$$NetSeaIce := \frac{SeaIceSSmooth + SeaIceSmooth}{SeaIceSSmooth_0 + SeaIceSmooth_0} \cdot 100$$

2.5% Global Extent of Sea Ice Loss since 1980



SECTION XIX. Model Predictions for Tropical Atmospheric Warming-Test10

http://www.climatechange.gov.au/en/climate-change/science.aspx
http://www.drroyspencer.com/wp-content/uploads/Spencer_EPW_Written_Testimony_7_18_2013_updated.pdf



On IPCCs exaggerated climate sensitivity and the emperor's new clothes. From the first IPCC report until the previous IPCC report, climate predictions for future temperature increase where based on a climate sensitivity of 1.5 to 4.5°C per CO_2 doubling. The NCDC **ocean (blue) and global (brown)** monthly **temperature anomalies** (relative to the 1900-2000 average temperatures) since 1980.
Dr. Nir J. Shaviv Racah Institute of Physics in the Hebrew University of Jerusalem.

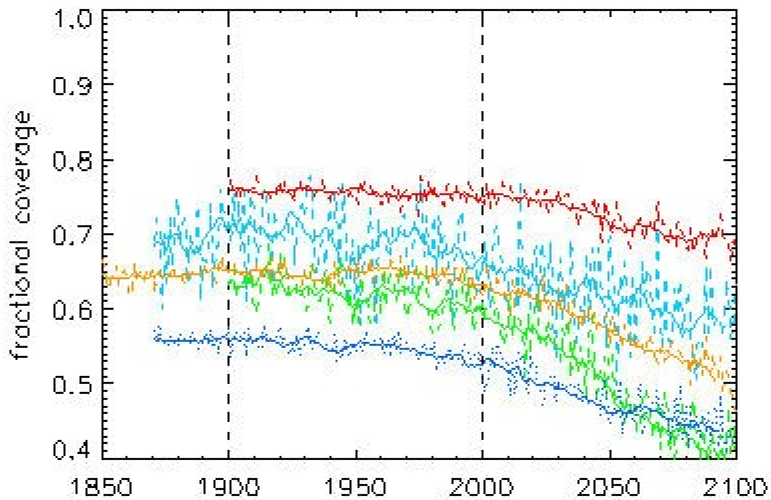
SECTION XX. Extreme Weather Getting Worse (NOAA Data)?

Decadal to Century Scale Trends in North American Snow Extent in Coupled Atmosphere-Ocean General Circulation Models - Columbia University, Geophysical Research Letters, 32:L18502, doi: 10.1029/2005GL023394.
http://www.eee.columbia.edu/research-projects/water_resources/climate-change-snow-cover/index.html

Continental-scale snow cover extent (SCE) is a potentially sensitive indicator of climate change, since it is an integrated measure of multiple hydroclimatological processes, and it is the most prominent seasonal land surface feature in the extratropical Northern Hemisphere. Conversely, feedback processes may cause SCE changes to in turn affect the direction and magnitude of other climate changes across the globe. In this study, current and future decadal trends in winter North American SCE (NA-SCE) are investigated, using 9 **general circulation models (GCMs)** of the global atmosphere-ocean system participating in the upcoming Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC-AR4).

Simulated annual time series of January NA-SCE spanning the 20th and 21st centuries are shown for all nine models in figure 1, based on a set of current and hypothesized future socioeconomic developments with associated greenhouse gas emissions, designated the 20C3M and SRESA1B scenarios, respectively. This exemplifies the considerable uncertainties that still plague GCM simulations. Nevertheless, all nine models exhibit a clear and statistically significant decreasing trend in 21st century NA-SCE, although the magnitude of the trend varies between models.

1. Simulated annual time series of January NA-Continental Scale Snow Coverage from 1850



2. Rutgers Snow Lab (Plot Only Jan & Feb Data):

http://climate.rutgers.edu/snowcover/files/moncov.nhland.txt

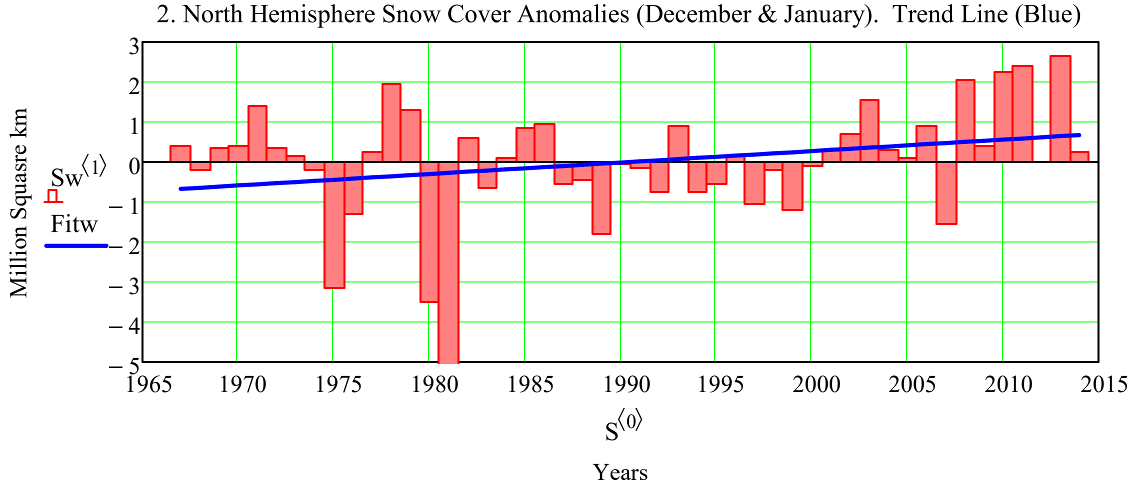
Snow := READPRN("Rutgers-moncov.nhland2014.t› S := SJan(Snow) Sw := SWin(Snow)

$S^{\langle 1 \rangle} := S^{\langle 1 \rangle} - \text{mean}\left(S^{\langle 1 \rangle}\right)$ $L := \text{line}\left(S^{\langle 0 \rangle}, S^{\langle 1 \rangle}\right)$ $Fit := L_0 + L_1 \cdot S^{\langle 0 \rangle}$

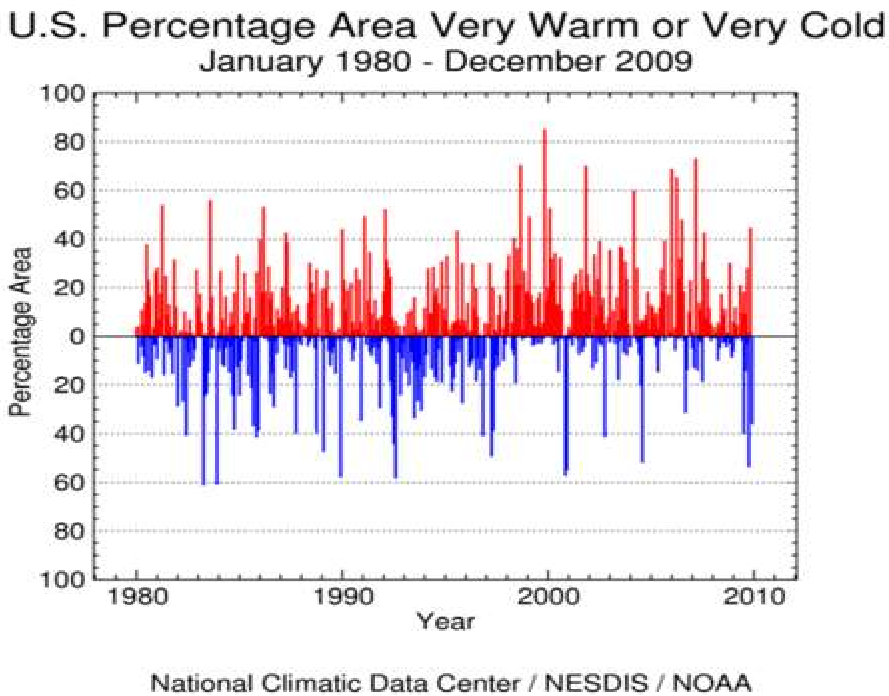
$Sw^{\langle 1 \rangle} := Sw^{\langle 1 \rangle} - \text{mean}\left(Sw^{\langle 1 \rangle}\right)$ $Lw := \text{line}\left(S^{\langle 0 \rangle}, Sw^{\langle 1 \rangle}\right)$ $Fitw := Lw_0 + Lw_1 \cdot S^{\langle 0 \rangle}$

Is slope of trend increasing(+) or decreasing (-)? $L_1 = 0.01255$ $Lw_1 = 0.02867$

2. North Hemisphere Snow Cover Anomalies (December & January). Trend Line (Blue)

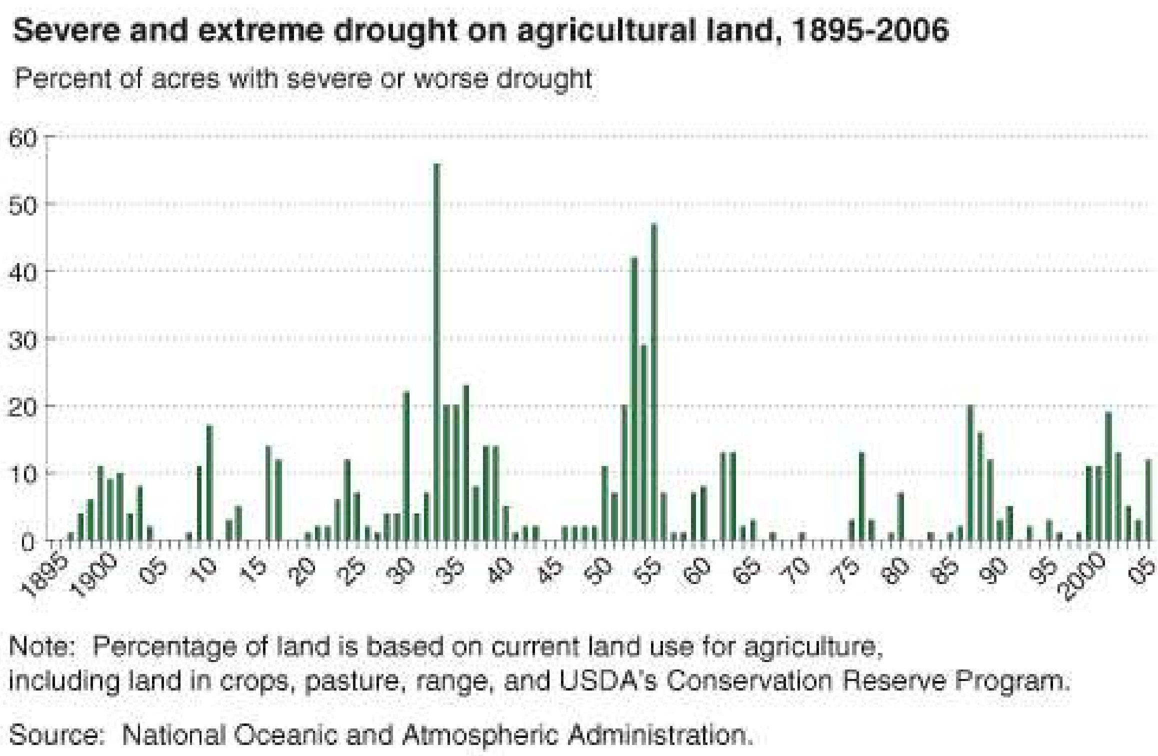


3. US Percentage Area Very Warm, Very Cold



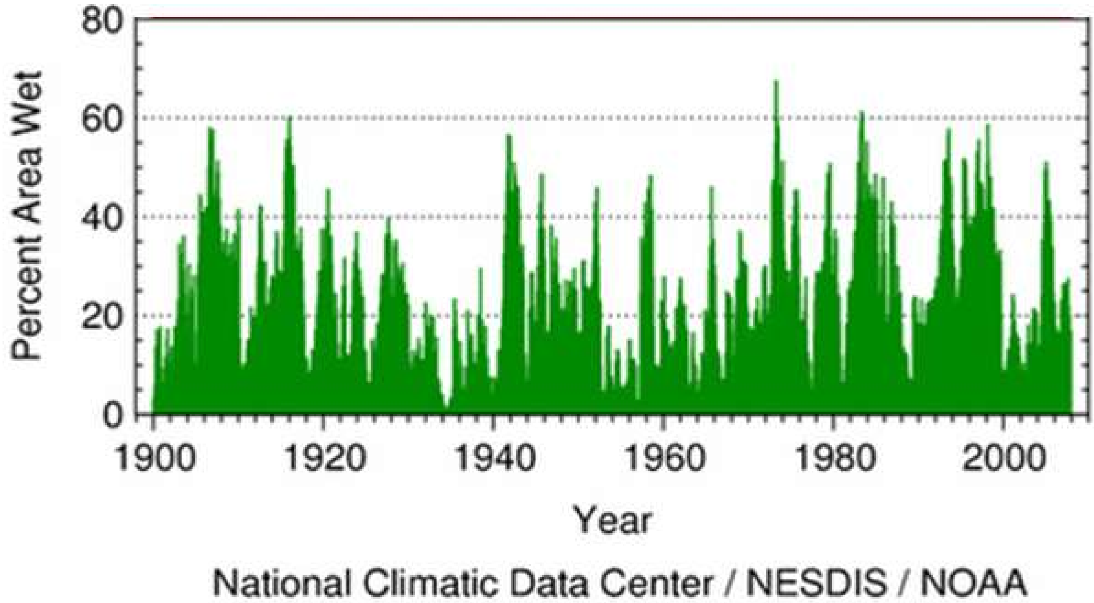
Red - Very Warm
Blue - Very Cold

4. USDA Economic Research Service: Worst Droughts 1930s



Amber Waves: US Department of Agriculture, Economic Research Service, May 2007

5. NOAA: Rainfall/Wetness Data



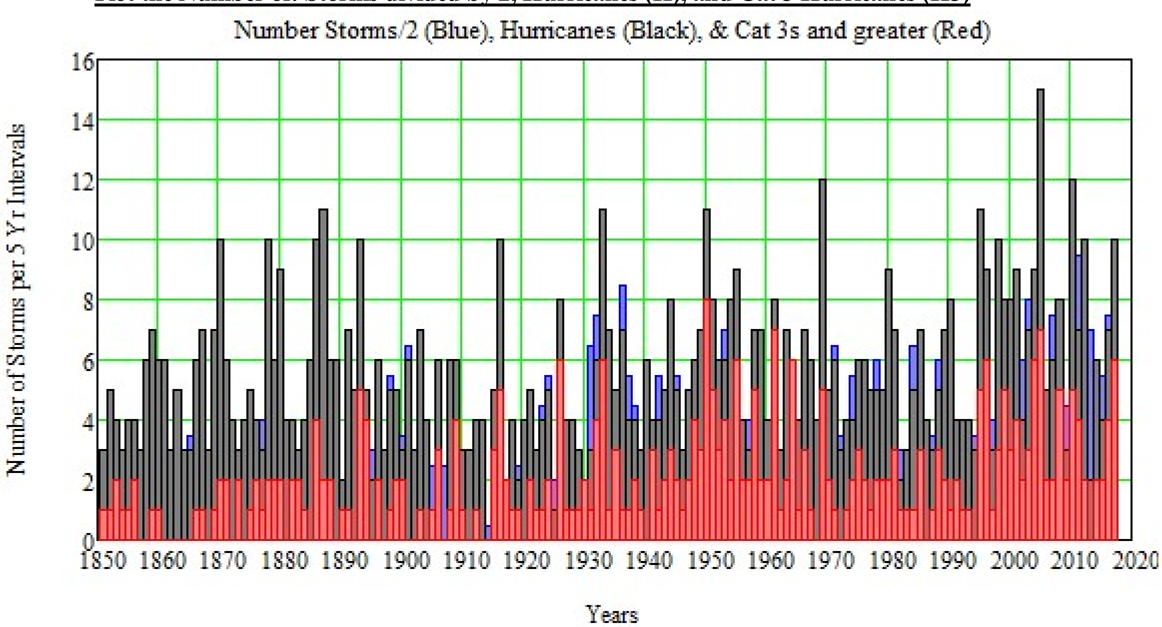
7. Hurricane Frequency - Getting Worse? No. See Met-3 at back of Study

For Analysis See: C:\Users\tom\Documents\$ VXP\www\Pure CSS Version\Climate_Analysis

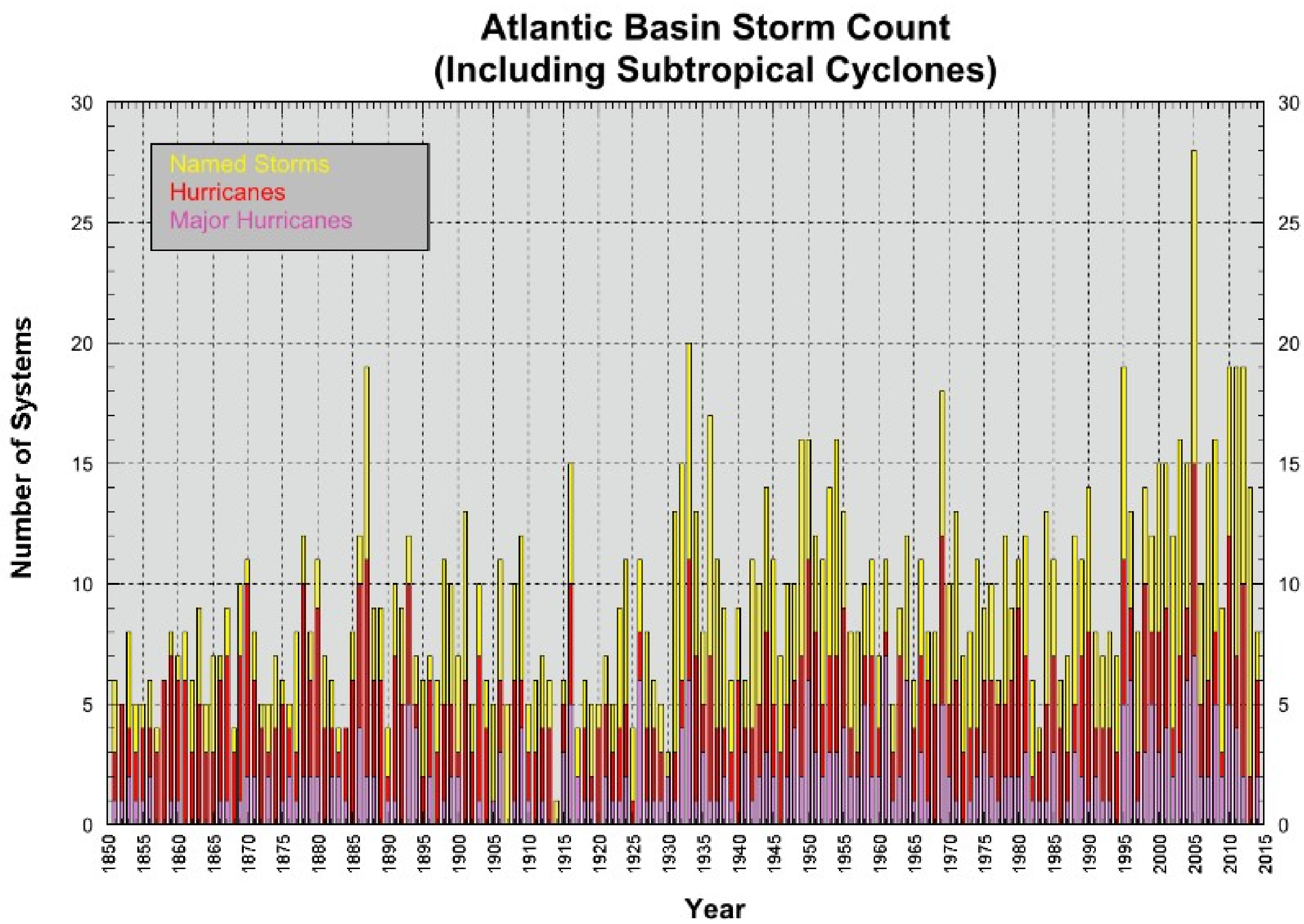
Data: Hurricane -Yr- Strm,Hurr,Major 1851-2017.txt

ttp://www.aoml.noaa.gov/hrd/tcfaq/TCFAQ_E.txt

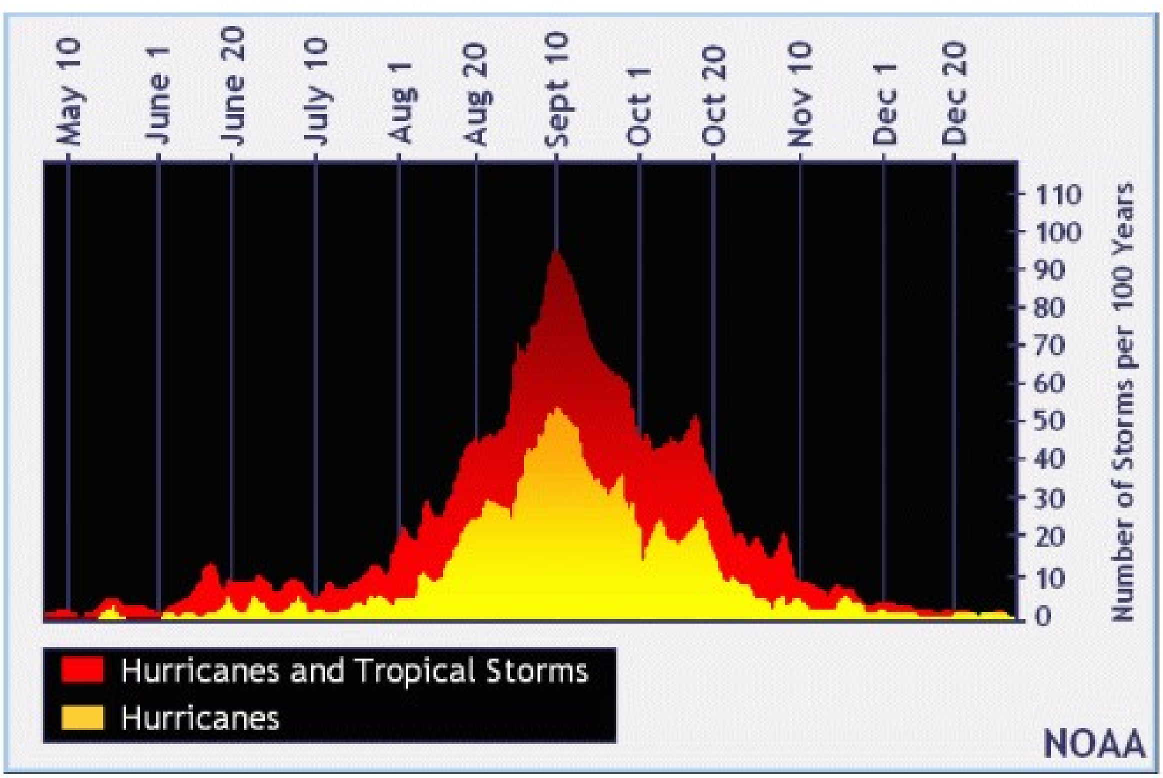
Plot the Number of: Storms divided by 2, Hurricanes (H), and Cat 3 Hurricanes (H3)



Anthropogenic warming by the end of the 21st century will likely cause tropical cyclones globally to be more intense on average (by 2 to 11% according to model projections for an IPCC A1B scenario). This change would imply an even larger percentage increase in the destructive potential per storm, assuming no reduction in storm size.
https://www.gfdl.noaa.gov/global-warming-and-hurricanes/

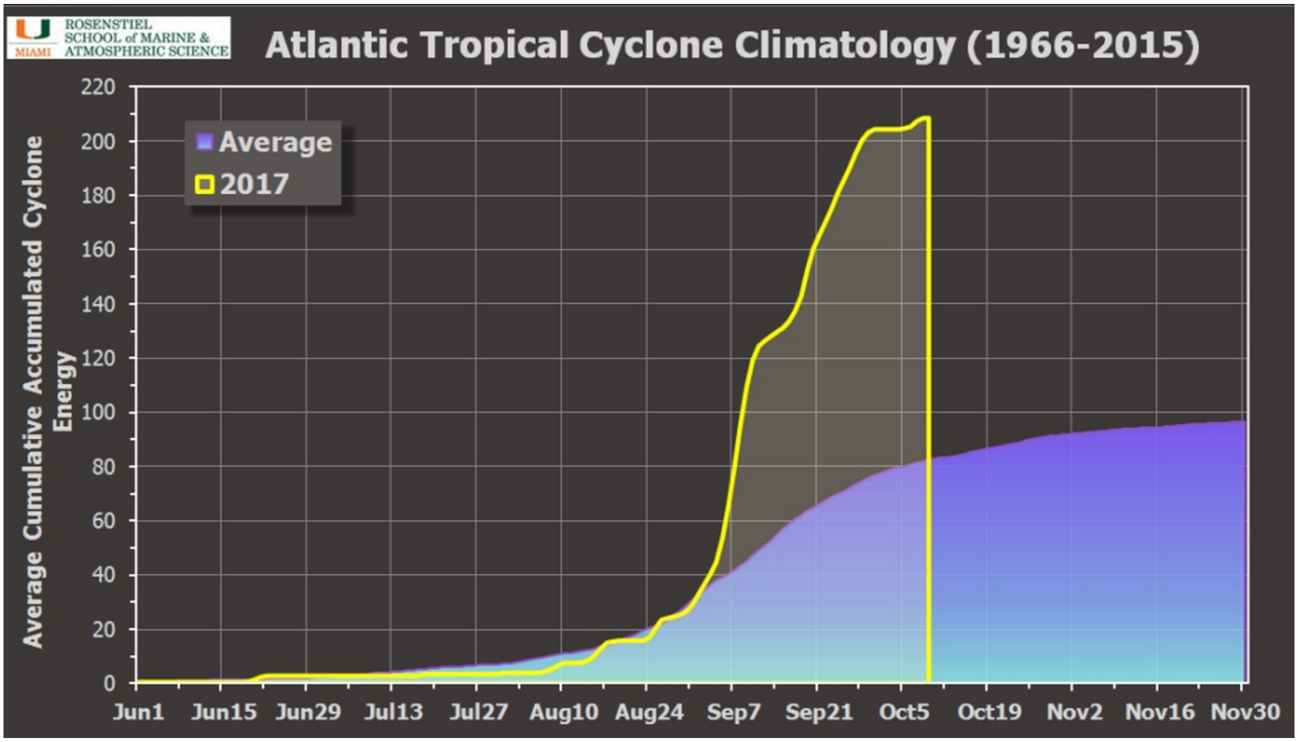


Hurricane Season Peak - Sept 10

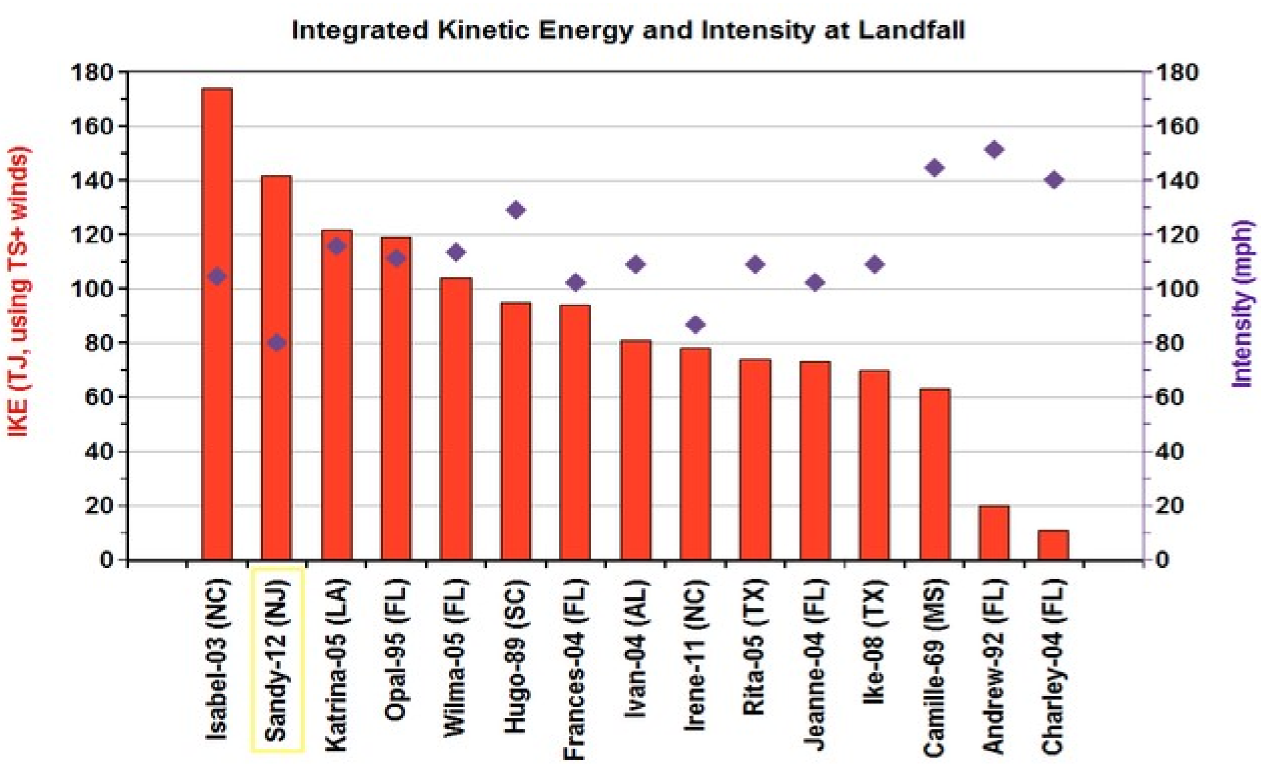


Accumulated Cyclone Energy - 2017 Hurricane Season

http://andrew.rsmas.miami.edu/

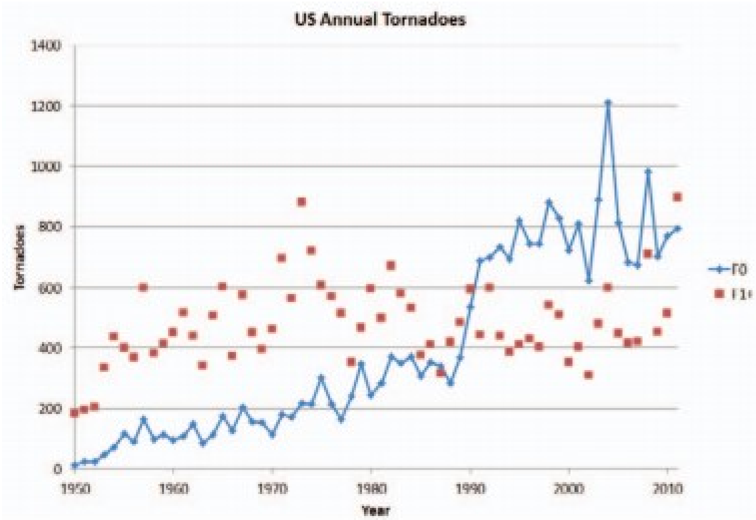


For 2017 the **accumulated cyclone energy** — a measure of the **intensity and longevity of storms** — is about **two and a half times higher than the average season**, according to University of Miami Rosenstiel School of Marine and Atmospheric Science hurricane researcher Brian McNoldy.



8. NWS US Tornadoes - Getting Worse

http://climate.rutgers.edu/stateclim_v1/robinson_pubs/refereed/Kunkel_et_al_2013.pdf



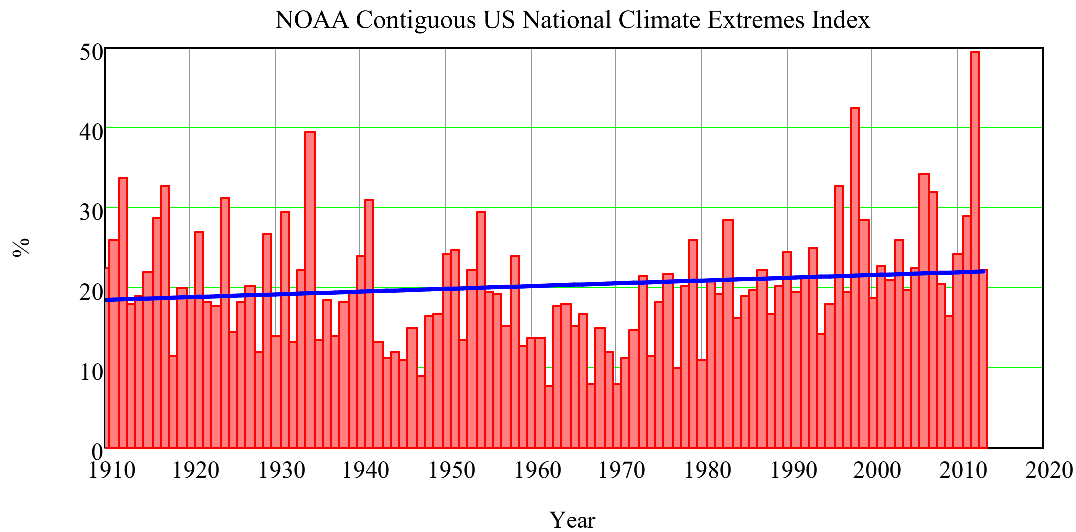
Reported tornadoes in NWS database from 1950 to 2011.

9. NOAA National Climate Extremes Index - Getting Worse

http://www.ncdc.noaa.gov/extremes/cei/graph

$CEI := READPRN(\text{"NOAANationalClimateExtremesIndex.txt"})$

$LX := line\left(CEI^{\langle 0\rangle}, CEI^{\langle 1\rangle}\right)$ $\qquad$ $FitX := LX_0 + LX_1 \cdot CEI^{\langle 0\rangle}$



10. Destabilized Polar Vortex (USA Frigid Winters of 2009-2013, 2016)

In the Arctic in the past, frigid air is typically trapped in a tight loop known as the polar vortex. This super-chilled air is not only **cold, it also tends to have low barometric pressure** compared to the air outside the vortex. The **surrounding high-pressure zones push in on the vortex** from all sides so the cold air is essentially "fenced in" above the Arctic, where it belongs.

As the Arctic region **warms faster** than most other places, **however**, the **Arctic sea ice melts more rapidly** and for longer periods each year, and is unable to replenish itself in the briefer, warmer winter season. This can **destabilize the polar vortex and raises the barometric pressure** within it. For several winter seasons (2009/2010, 2010/2011, and 2012/2013, 2016), the polar vortex was notably unstable. Correlation studies have implied that this vortex shift is "closely related" to **shrinking sea ice coverage in the Arctic** - particularly in the Barents-Kara seas - and increased snow cover over the Eurasian continent.

See **SECTION XVIII. Cryosphere -Sea Ice Extent -North & South Hemispheres**

This effect had not persisted long enough to be considered climate change, per se, but it is a recent trend.

SECTION XXI. Potential instability in the Atlantic Ocean water circulation system

Overlooked possibility of a collapsed Atlantic Meridional Overturning Circulation in warming climate Wei Liu,Shang-Ping Xie,Zhengyu Liu,Jiang Zhu, 2917

Changes in the Atlantic Meridional Overturning Circulation (AMOC) are moderate in most climate model projections under increasing greenhouse gas forcing. This intermodel consensus may be an artifact of common model biases that favor a stable AMOC. Observationally based freshwater budget analyses suggest that the AMOC is in an unstable regime susceptible for large changes in response to perturbations. By correcting the model biases, we show that the AMOC collapses 300 years after the atmospheric CO_2 concentration is abruptly doubled from the 1990 level. Compared to an uncorrected model, the AMOC collapse brings about large, markedly different climate responses: a prominent cooling over the northern North Atlantic and neighboring areas, sea ice increases over the Greenland-Iceland-Norwegian seas and to the south of Greenland, and a significant southward rain-belt migration over the tropical Atlantic. Our results highlight the need to develop dynamical metrics to constrain models and the importance of reducing model biases in long-term climate projection.

SECTION XXII. Thermal Dissipation: Anthropogenic Urban Heat Flux

Anthropogenic heat is heat generated by humans and human activity. **Nearly all energy used for human economy** is, at some point, **dissipated thermally within Earth's atmosphere** or land into Anthropogenic Heat. Only 1% is directly radiated into space. This is a consequence of the second law of thermodynamics - the tendency of energy towards higher entropy (more disordered) forms. Because the energy we derive from non-renewable sources (coal, petroleum, natural gas, and nuclear) would not otherwise have been introduced to the Earth System as heat (on relevant timescales), it can be considered a climate forcing term. Globally, in 2005, this **anthropogenic heat flux (AHF) was +0.028 W/m2**, or only about **1% of the energy flux being added to Earth** because of anthropogenic greenhouse gases.

Although small globally, the **spatial distribution** of current AHF averaged over the continental United States, western Europe, and China is, respectively, +0.39 and +0.68 W/m2, 0.22 W m−2 or up to **40% of the local forcing from carbon dioxide**. In the **densely populated** and economically vibrant urban areas, the AH fluxes have been reported to typically range from **20 to 70 W m−2**. AHF can increase turbulent fluxes to change meteorological conditions.

Based on the energy consumption and the gridded demographic data, the spatial distribution of AH emission over the **Yangtze River Delta (YRD)** region is estimated. AH fluxes over the YRD have been growing in recent decades. In 2010, the annual-mean values of AH over Shanghai, Jiangsu and Zhejiang are **14.46, 2.61 and 1.63 W m-2**, respectively, with the high value of **113.5 W m-2** occurring in the **urban areas of Shanghai**. These AH emissions can significantly change the urban heat island and urban-breeze circulations in the cities of the YRD region. In Shanghai, 2 m air temperature increases by **1.6 C in January and 1.4 C in July**, the PBLH (planetary boundary layer height) rises up by 140 m in January and 160 m in July, and 10 m wind speed is enhanced by 0.7 m/s in January and 0.5 m/s in July, with a higher increment at night. and average daytime metabolic rate M_d in urban areas is 175 W.

The largest proportions of total waste heat are from power stations and vehicle engines. The largest single sources are power stations and industrial plants such as oil refineries and steel making plants. In urban areas, it usually consists of the heat fluxes derived from energy consumption in buildings (QF,B), from the transportation sector (QF,T) and from human metabolism (QF,M). The sleeping metabolic rate Mn for a typical man is 75 W, and the and average daytime metabolic rate M_d in urban areas is 175 W.

Waste heat produced by human activities is one contributor to the **urban heat island (UHI)**. While this anthropogenic heat flux varies spatially and temporally (diurnally, seasonally and yearly) under certain conditions it can **exceed energy receipt from net all-wave radiation.** Typical values range from 20 and 70 W m−2 but values greater than 1000 W m−2 under extreme localized conditions have been calculated.

The UHI effect tends to exacerbate further such warming and temperatures in cities are predicted to rise even more resulting in increased energy demand for cooling systems in the warmest months in cities located in the low and mid-latitudes, although cities in high latitudes may need less heating energy during the cold periods (Taha, 1997). A model of the air-conditioning related heat flux in Tokyo estimated the air temperature already was raised by around 1 °C. As the vast majority of urban agglomerations are situated in the low and mid-latitudes (mostly in the Northern Hemisphere), overall a warmer climate will lead to increased energy consumption, more air pollution and greater risk of human mortality in cities. A positive feedback cycle has been created in many urban areas, where higher temperatures result in more energy being used for cooling, which in turn add to heat emissions into the atmosphere and raise temperatures further.

A 2% p.a. growth rate of waste heat resulted in a 3 degree increase as a lower limit for the year 2300.

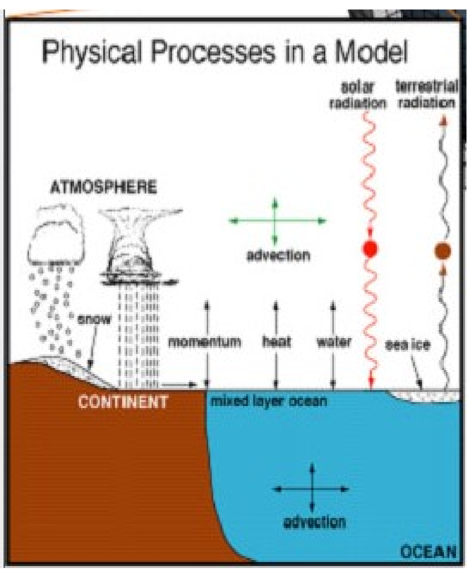
SECTION XXIII. Test 12- AGW Induced Rising Height of Atmos Boundary Layer

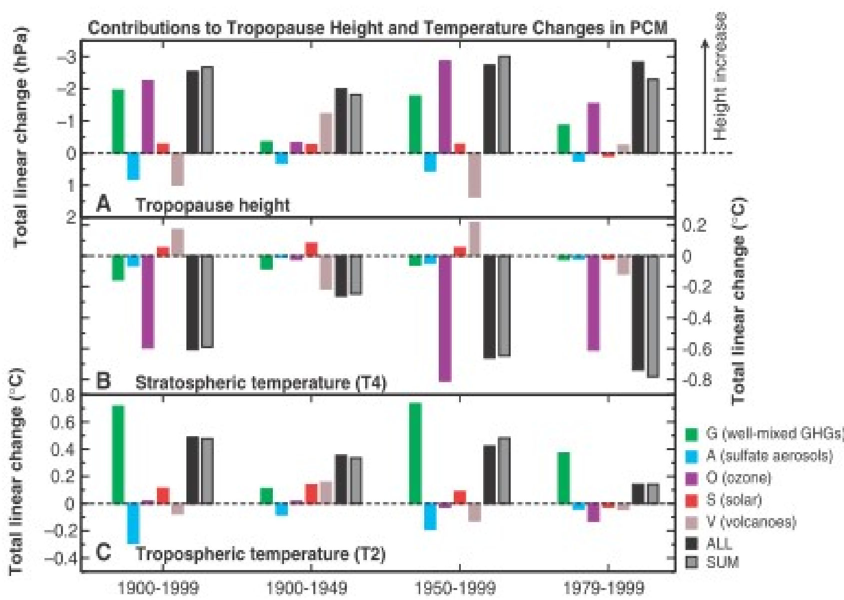
Contributions of Anthropogenic & Natural Forcing to Recent Tropopause Height Changes

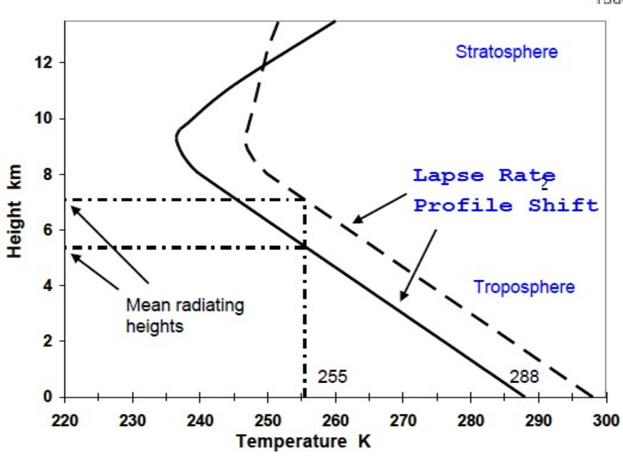
Observations indicate that the average height of the tropopause — the transition Zone between the stratosphere and troposphere — has increased by several hundred meters since 1979. Comparable increases are evident in climate model experiments. The latter show that human-induced changes in ozone and well-mixed greenhouse gases account for over 80% of the simulated rise in tropopause height over 1979-1999. Their primary contributions are through cooling of the stratosphere (ozone) and warming of the troposphere (well-mixed greenhouse gases). Tropopause height changes simulated over 1900-1949 are smaller than in recent decades, and are driven largely by variations in volcanic aerosols and solar irradiance. A model-predicted fingerprint of tropopause height changes is statistically detectable in two different observational ("reanalysis") datasets. This positive detection result allows us to attribute overall tropopause height changes to a combination of anthropogenic and natural forcings. Our study shows that the increase in tropopause height over the second half of the 20th century was predominantly due to human activity, and provides independent support for caims of recent tropospheric warming.

The tropopause is the transition zone between the troposphere and stratosphere, marked by large changes in the thermal, dynamical, and chemical structure of the atmosphere (1, 2). Increases in tropopause height over the last several decades have been identified in radiosonde data (2), in observationally-constrained numerical weather forecasts (re analyses) (3), and in climate models forced by combined natural and anthropogenic effects Model experiments suggest that this increase cannot be explained by natural climate variability alone. Its height is sensitive to the changes in atmospheric temperature caused by both natural and human factors

An important feature of the stratosphere is the ozone layer, which protects the Earth by absorbing much of the ultraviolet radiation from the Sun.







Total linear changes (32) in global mean, monthly mean tropopause height (A), stratospheric temperature (B), and tropospheric temperature (C) in PCM experiments with individual forcings (G,A, O, S, and V) and combined natural and anthropogenic forcings (ALL). Linear changes are computed over four different time intervals using the (unfiltered) ensemble-mean data from Fig.1. For each time period, anomalies were defined relative to climatological monthly means computed over 1900–1999. SUM denotes the sum of the linear changes in G, A, O, S, and V.

www.sciencemag.org SCIENCE VOL 301 25 JULY 2003

1. K. P. Hoinka, Mon. Weath. Rev. 126, 3303 (1998).
2. D. J. Seidel, R. J. Ross, J. K. Angell, C. C. Reid, J. Geophys. Res. 106, 7857 (2001)
3. W. J. Randel, F. Wu, D. J. Gaffen, J. Geophys. Res. 105, 15509 (2000).
4. B. D. Santer et al., J. Geophys. Res. 108(D1), 4002, doi:10.1029/2002JD002258 (2003)
Pu Lin*, Changes of the tropical tropopause layer under global warming, NOAA, 2016

SECTION XXIV Basics of Meteorology

Met-1. Types of GISS NASA Data Sources and New versus Old Differences:

GISTEMP Indices
Land-Ocean Temperature index (LOTI, i.e. the index that **includes weather station data and sea surface temperature** data to give a global anomaly index with wide spatial coverage) ("GLB.Ts+**dSST**.txt").

Met station index, which **only uses weather station data** ("GLB.Ts.txt") which doesn't't have as much coverage and has a substantially larger trend reflecting the relative predominance of faster-warming continental data in the average.

Old versus New differences are tiny, and mostly reflect slightly more data in the earlier years in the latest data and the different homogenization in GHCN v3 compared to GHCN v2 (which was used up to Dec 2011). The the biggest difference in trend (between 2006 and today), is a mere 0.05ºC/Century, and from 2008 to 2012 it is only 0.003ºC/Century.

HADCRUT - Climatic Research Unit (University of East Anglia) in conjunction with the Hadley Centre
http://www.cru.uea.ac.uk/cru/data/temperature/
CRUTEM4: Land air temperature anomalies
CRUTEM4v: Variance adjusted version of CRUTEM4
CRUTEM3: **Land air** temperature anomalies - superseded by CRUTEM4
CRUTEM3v: **Variance adjusted** version of CRUTEM3 (superseded by CRUTEM4v)
HadSST3: Sea Surface

VXPhysics.com

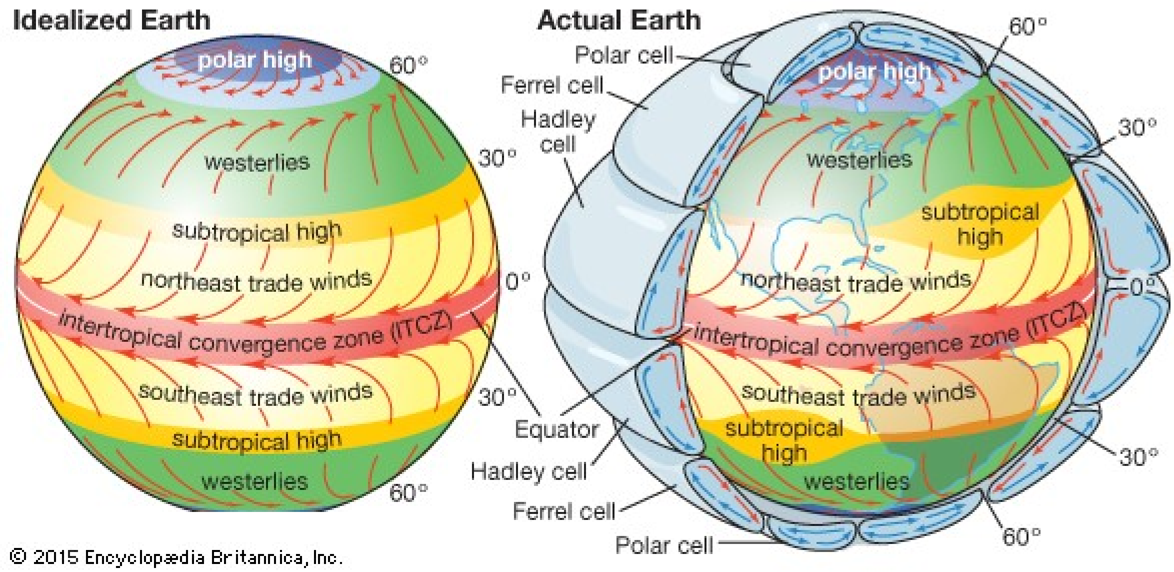
SECTION XXV - Met-2. Some Fundamentals of Atmospheric Convection Cells, Circulation, and Clouds

The atmosphere is a **cloud of gas and suspended solid**s extending from the Earth's surface out many thousands of miles, becoming **increasingly thinner** with distance but always **held by the Earth's gravitational pull.** It holds the air we breathe; it protects us from outer space; and **holds moisture (clouds)**, gases, and tiny particles. The atmosphere is rarely, if ever, dry. Chemical Makeup:Water vapor is nearly always present up to about 3%/4% (humid/tropical) of the total volume. CO_2 0.0400%

Hadley Cell
named after George Hadley, is a global scale **tropical atmospheric circulation** that features **air rising near the equator,** flowing poleward at **10–15 kilometers** above the surface, **descending in the subtropics**, and then returning equatorward near the surface. This circulation creates the **trade winds, tropical rain-belts and hurricanes**, subtropical deserts and the jet streams. Intertropical convergence zone. Known by sailors as the doldrums, is the area encircling Earth near the Equator, where the **northeast and southeast trade winds converge**.

In each hemisphere, there is one primary circulation cell known as a Hadley cell and **two secondary circulation cells at higher latitudes, between 30° and 60° latitude** known as the **Ferrel cell**, and beyond 60° as the **Polar cell.** Each Hadley cell operates between zero and 30 to 40 degrees north and south and is **mainly responsible** for the weather in the **equatorial** regions of the world.

Brewer-Dobson Circulation
is a model of atmospheric circulation, proposed by Alan Brewer in 1949 and Gordon Dobson in 1956, which attempts to explain **why tropical air has less ozone than polar air**, even though the tropical stratosphere is where most atmospheric ozone is produced. It is a simple circulation model that posits the existence of a slow current in the winter hemisphere which **redistributes air from the tropics** to the extratropics. The Brewer-Dobson circulation is **driven by atmospheric waves** and may be speeding up due to climate change.



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Cloud Atmospherics

http://www.srh.noaa.gov/jetstream

Cirrus Clouds: The most common form of high-level clouds are thin and often wispy cirrus clouds. Detached clouds in the form of white, delicate filaments, mostly white patches or narrow bands. They may have a fibrous (hair-like) and/or silky sheen appearance. Typically found at heights greater than 20,000 feet (6,000 meters), they are composed of ice crystals that originate from the freezing of supercooled water droplets.

Cumulus Clouds: Detached, generally dense clouds and with sharp outlines that develop vertically in the form of **rising mounds**, domes or towers with bulging upper parts often resembling a cauliflower. The sunlit parts of these clouds are mostly brilliant white while their bases are relatively dark and horizontal.

Virga: Shaft of precipitation. A mass of streaks of rain appearing to hang under a cloud and evaporating before reaching the ground. Evaporating rain.

Thunderstorms:
https://en.wikipedia.org/wiki/Thunderstorm
The first stage of a thunderstorm is the cumulus stage or developing stage. During this stage, masses of moisture are lifted upwards into the atmosphere. The trigger for this lift can be solar illumination, where the heating of the ground produces thermals, or where two winds converge forcing air upwards, or where winds blow over terrain of increasing elevation.
Thunderstorms result from the **rapid upward movement of warm, moist air,** sometimes along a front.
In the **dissipation stage**, the thunderstorm is dominated by the **downdraft**. If atmospheric conditions do not support super cellular development, this stage occurs rather quickly, approximately 20–30 minutes into the life of the thunderstorm. The downdraft will **push down out of the thunderstorm, hit the ground and spread out.** This phenomenon is known as a down burst.

There are four main types of thunderstorms: **single-cell, multi-cell, squall line (also called multi-cell line) and supercells.** Which type forms depends on the instability and relative wind conditions at different layers of the atmosphere ("wind shear"). Single-cell thunderstorms form in environments of low vertical wind shear and last only 20–30 minutes.

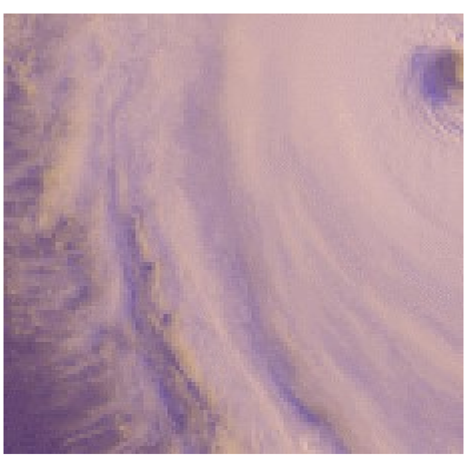
SECTION XXVI - Met-3. Hurricane Fundamentals

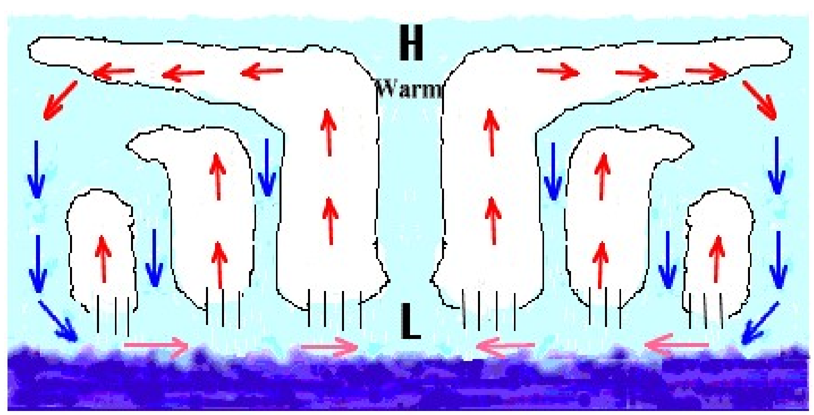
http://science.howstuffworks.com/nature/natural-disasters/hurricane.htm

The air closest to us is also the warmest, as the **atmosphere** is mostly heated by the **land and the sea**, **not by the sun.** When air heats up, its molecules move farther apart, making it less dense. This **air then rises** to higher altitudes where air molecules are less **compressed** by gravity. When warm, low-pressure air rises, **cool, high-pressure air** seizes the opportunity to move air seizes the opportunity to ***move in underneath*** it. This movement is called a ***pressure gradient*** force.
Warm, moist air from the **ocean's surface begins to rise rapidly**. As it rises, its -**water vapor condenses to form storm clouds and droplets of rain**. The **condensation *releases heat* called latent heat** of condensation. This latent heat **warms** the **cool air, causing it to *rise.*** This rising air is **replaced by more warm, humid air from the ocean below**. And the cycle continues, **drawing more warm, moist air into** the developing storm and **moving heat from the surface** to the atmosphere. This **exchange of heat creates a pattern of wind** that circulates around a center, like water going down a drain. **If** the high-altitude winds don't blow at the same speed at all levels -- if ***wind shears*** are present -- the storm becomes **disorganized** and weakens. The rotation of a hurricane is a product of the **Coriolis force,** a natural phenomenon that causes fluids and free-moving objects to **veer to the right** of their destination in the **Northern Hemisphere**.

Hurricanes are Earth's strongest tropical cyclones.
http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/hurr/stages/cane/home.rxml
A distinctive feature seen on many hurricanes and are unique to them is the dark spot found in the middle of the hurricane. This is called **the eye**. Surrounding the eye is the r**egion of most intense winds and rainfall** called the **eye wall.** Large bands of clouds and precipitation spiral from the eye wall and are thusly called **spiral rain bands**.They are found at the center and are between 20-50km in diameter. The eye is the focus of the hurricane. The most recognizable feature, which is free of clouds. It is the point about which the rest of the storm rotates and where the **lowest surface pressures** are found in the storm.
Skies are often clear above the eye and winds are relatively light. It is actually the calmest section of any hurricane.
The **eye is so calm** because the now **strong surface winds that converge towards the center never reach it**. Why? The **coriolis force** deflects the wind slightly away from the center, causing the wind to rotate around the center of the hurricane (the eye wall), leaving the exact center (the eye) calm.
Located just outside of the eye is the eye wall. This is the location within a hurricane where the most damaging winds and intense rainfall is found. The image below is of a hurricane (called cyclone in the Southern Hemisphere
Eye walls are called as such because oftentimes the eye is **surrounded by a vertical wall of clouds**. The eye wall can be seen in the picture above as the thick ring surrounding the eye.
At the surface, the winds are rushing towards the center of a hurricane -- forcing air upwards at the center. The coriolis force acts on these surface winds, and in the Northern Hemisphere, the deflection is to the right. The **convergence at the eye wall is so strong** here that the air is being lifted faster and with more force here than any other location of the hurricane. Thus, the **moisture transport from the ocean and subsequent latent heat production is maximized.** Radiating outward from the eye wall one can see a **banded structure** within the clouds. These clouds are called either **spiral rain bands** (or spiral bands). The image below is of a hurricane (called cyclone in the Southern Hemisphere).

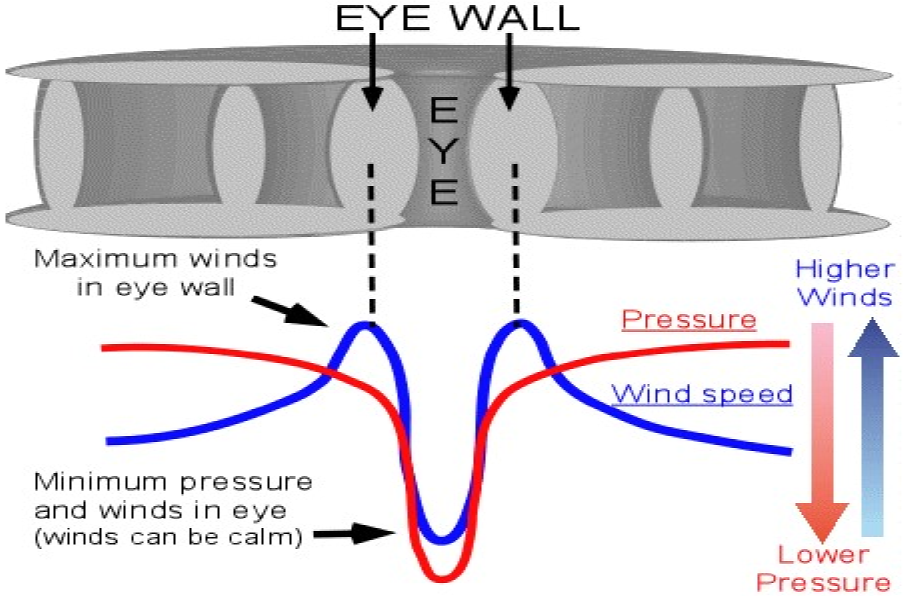
There are sometimes **gaps in between these bands** where **no rain** is found. In fact, if one were to travel between the outer edge of the hurricane to its center, one would normally progress from light rain to dry back to slightly more intense rain again over and over with each period of rainfall being more intense and lasting longer until reaching the eye. Upon exiting the eye and moving towards the edge of the hurricane, one would see the same events as in, but in opposite order.





http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/hurr/stages/cane/band.rxml
A schematic of this **banding feature** can be seen in the diagram above. The thunderstorms are now organized into regions of rising and sinking air. Most of the air is rising, but there is a small amount found in between the thunderstorms that is sinking.

Atmospheric pressure and wind speed change across the diameter of a hurricane. To demonstrate, the diagram below shows a rough profile of wind speed (blue) and surface pressure (red) across a hurricane. Between 100 and 200 kilometers from the eye, the winds are fast enough to qualify as tropical storm force. The atmospheric pressure here will still be relatively high compared to the storm's center at about 990 to 1010 millibars. However, the pressure gradually falls and the wind speed rises upon getting closer to the eye wall. At the Centre of the hurricane,the atmospheric pressure will be approximately **30 to 100 mb below** the normal sea level pressure. It is only over the last 50 to 100 kilometers that the large changes in pressure



The pressure begins to fall more rapidly while the wind speed simultaneously increases. Within the **eye wall, the wind speed** reaches its **maximum** but within the **eye**, the winds become **very light** - sometimes even calm. The surface pressure continues to drop through the eye wall and into the center of the eye, where the lowest pressure is found. Upon exiting the eye, the wind speed and pressure both increase rapidly. The wind speed again reaches a maximum in the opposite eye wall, and then quickly begins to decrease. The wind and pressure profiles inside a hurricane are roughly symmetrical, so a quick rise in winds and pressure through the eye wall followed by a slower increase in pressure and likewise decrease in wind speed would be expected.

Think of the atmosphere as a landscape of moving mountains and valleys. High pressure systems are mountains in the atmosphere. Low pressure systems are valleys. The air from the high pressure systems wants or tends to move toward the valleys

1086 mb (32.08 inches of mercury): Highest Ever Recorded
1030 mb (30.42 inches Hg): Strong High Pressure System
1013 mb (29.92 inches Hg): **Average Sea Level Pressure**
1000 mb (29.54 inches Hg): Typical Low Pressure System
980 mb (28.95 in): CAT 1 Hurr or a
Very intense mid-latitude cyclone978.7 28.5
978.7 to 965mb (28.5in to 28.93 in): CAT 2 Hurricane
950 mb (28.06 inches of mercury): CAT 3 Hurricane
870 mb (25.70 inches Hg): Lowest Ever Recorded

Wind Pressure of Moist Air, pw

$$\rho_{air} := 1.2\frac{kg}{m^3}$$

$$p_w(v) := \frac{1}{2}\cdot\rho_{air}\cdot v^2$$

$$p_w(120mph) = 36.06202\cdot\frac{lbf}{ft^2}$$

120 mph Force 8 x16 Garage Door = 4600 lbf

Total energy released through cloud/rain formation:

An average hurricane produces 1.5 cm/day (0.6 inches/day) of rain inside a circle of radius 665 km (360 n.mi) (Gray 1981). (More rain falls in the inner portion of hurricane around the eyewall, less in the outer rainbands.)

$$Heat_{Latent\_Water} := 2260\frac{k\cdot J}{kg} = 2.26\times10^6\frac{m^2}{s^2}$$

$$Volume_{Rain} := 1.5\frac{cm}{day}\cdot\pi\cdot(665km)^2 = 241196.32139\frac{m^3}{s}$$

$$D_{water} := 1000\frac{kg}{m^3}$$

Power of Hurricane:
$Power_{Hurr}$

$$Power_{Hurr} := Volume_{Rain}\cdot D_{water}\cdot Heat_{Latent\_Water} = 5.45104\times10^{14}\cdot W$$

The Little Boy atomic bomb dropped on Hiroshima had an energy (E.hab) of:

$$E_{Hab} := 63\times10^{12}\cdot J \qquad \frac{Power_{Hurr}}{E_{Hab}} = 8.65244\frac{1}{s}$$

A Typical Hurricane has an Energy: 8 Atomic Bombs per second

A Deadly Cycle

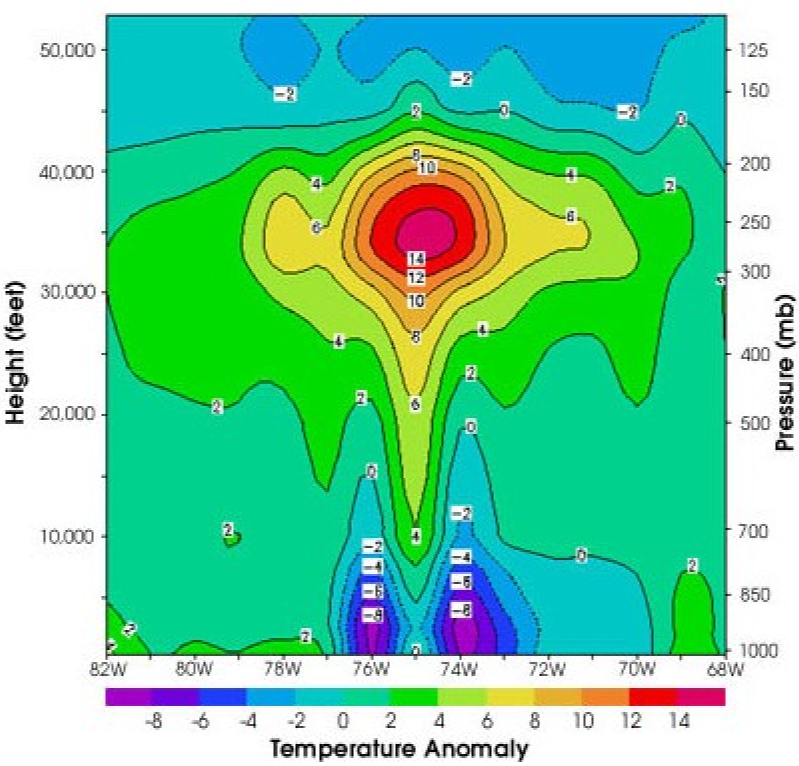
https://earthobservatory.nasa.gov/Features/HurricaneHeart/heart_2.php

The thing that makes hurricanes tick is the **warming** of the **upper atmosphere in the eye** of the storm. This heat comes from the condensation of water vapor into cloud droplet. Hurricanes are essentially a ring of thunderstorms swirling around the eye of the storm. To keep going, these thunderstorms need a continuous supply of water to replace what they lose in the form of raindrops. They are replenished by evaporated water that condenses in the air above the hurricane to form cloud droplets, which are then subsumed by the thunderclouds.

Though water vapor in the atmosphere may seem harmless, en mass it contains an enormous amount of energy. The energy comes from the **sun**, which initially excites the water molecules on the surface of the Earth and causes them to evaporate. Each time a little of this water vapor comes together in the air to form a cloud droplet, the process of evaporation is essentially put in reverse and a little energy is released into the atmosphere in the form of heat. While the release of heat to form one raindrop is miniscule, the amount of heat released to replenish the cloud droplets in a hurricane is massive.

It is this heat that drives a hurricane. "**The rapid spinning motion of the hurricane keeps this heat in the center** of the storm," says Halverson. The **heat** causes the air in the **upper reaches of the hurricane eye to warm and expand vertically** in the center of the hurricane, creating a **reduction in pressure near the surface**. To fill this void, air at the ocean surface streams inward toward the eye. Much like a **giant vacuum cleaner**, the hurricane's **eyewall sucks up air** from the ocean's **surface**, giving rise to the **spinning motion** of the hurricane and **drawing in even more evaporated water from the surface** of the ocean. The fresh **evaporated water** from the sea's surface then typically **travels up through the hurricane's eyewall** and **splays out at the top** where it cools and condenses. The **formation of ice particles** below freezing temperatures releases **more heat energy** and adds more water to the thunderclouds, often times causing them to grow even bigger.

The worst possible situation, is when hurricanes undergo what is known as a "**convective burst.**" In this instance a sort of **positive feedback loop** is triggered wherein the hurricane passes over a **large pool of warm water**, grows more intense, draws in more moist air, gets even nastier and so on until it reaches Category 4 or Category 5 strength. Once one of these convective bursts gets going it can last ten hours or more.



This graphic plots data from NOAA's Advanced Microwave Sounding Unit (AMSU) and shows a cross-section of Hurricane Bonnie to reveal its internal temperatures as a function of altitude and atmospheric pressure (both Y-axes), and as a function of **west longitude (X-axis).** The false colors represent temperature, with pink and red showing the highest values, greens and blues are intermediate values, and purples are the lowest values. Notice the **high temperatures toward the upper central part of the hurricane,** which are due to the **latent heat being released** from the water vapor being drawn upward from surface. The **colder areas** toward the **lower** central part of the storm are caused by the **relatively cold rain drops**. (Image courtesy Mitch Goldberg, NOAA [published in Kidder et al. 2000])

Why do tropical cyclones require 80°F (26.5°C) ocean temperatures to form ?

Tropical cyclones can be thought of as **engines that require warm, moist air as fuel**. This warm, moist **air cools as it rises** in **convective clouds (thunderstorms)** in the rainbands and eyewall of the hurricane The **water vapor** in the cloud **condenses** into water droplets r**eleasing the latent heat** which originally evaporated the water. This **latent hea**t provides the energy to **drive the tropical cyclone circulation**, though actually **very little** of the heat released is utilized by the storm to lower its surface pressure and increase the **wind speeds**.

In 1948 Erik Palmen observed that tropical cyclones required **ocean temperatures of at least 80°F (26.5°C)** for their **formation and growth**. Later work (e.g., Gray 1979) also pointed out the need for this warm water to be present through a **relatively deep layer (~150 ft, 50 m**) of the ocean. This **80°F** value is tied to the **instability of the atmosphere** in the tropical and subtropical latitudes. **Above this temperature deep convection** can occur, but **below** this value the atmosphere is **too stable** and little to no thunderstorm activity can be found (Graham and Barnett 1987).

On the validity of representing hurricanes as Carnot heat engine

https://www.atmos-chem-phys-discuss.net/8/17423/2008/acpd-8-17423-2008-print.pdf

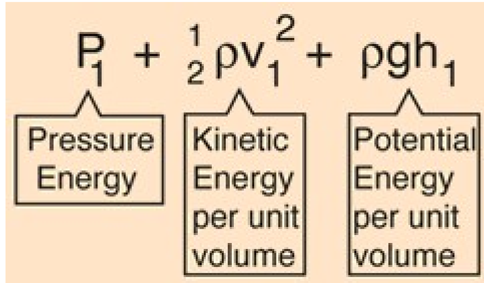
We have argued that representing hurricanes as Carnot **heat engine** is **not physically consistent.** We will now outline a perspective of a quantitative description of hurricanes as **adiabatic processes involving gas-liquid phase transitions**. Briefly, **during condensation, water vapor disappears from the gas phase**; in the result, **local air pressure drops**; this leads to the appearance of the **wind-inducing pressure gradient force proportional** in magnitude to the amount of **water vapor** in the atmosphere. The volume specific store of potential energy responsible for hurricane formation can be thus estimated as the value of **partial pressure p_v of saturated water vapor**. (Vertical distribution of water vapor partial pressure p_v departs significantly from the aerostatics equilibrium; at any height p_v is over five times larger than the weight of water vapor column above this height (Makarieva et al., 2006; Makarieva and Gorshkov, 2007). For this reason **practically all water vapor ascending in the hurricanes undergoes condensation**, so the condensational potential energy coincides with p_v to a good approximation.) According to Bernoulli's equation, potential energy p_v (J/m^3) is transformed to kinetic energy $p_V = KE = \frac{1}{2}\cdot\rho\cdot v_{max}^{2}$ of air masses having density ρ and moving at velocity u_{max}

u_{max} as $p_v=\rho u_{max}^2/2$. At $\gamma_v\equiv p_v/p=0.02$ at 15°C or $\gamma_v=0.05$ (at 30°C) and $\gamma_v=0.09$ (at 40°C on land), moist air pressure $p=10^5$ Pa and $\rho=1.2\ kg\ m^{-3}$ we have $u_{max}=50\ m\ s^{-1}$ or $u_{max}=90\ m\ s^{-1}$ and $u_{max}=120\ m\ s^{-1}$, respectively. These values agree with obser-

$$p := 10^5 Pa \quad \rho := 1.2\frac{kg}{m^3}$$

vations of maximum wind velocities observed in hurricanes and tornadoes (Zrnic and ´ Istok, 1980; Samsury and Zipser, 1995; Wurman et al., 1996; Businger and Businger, 2001). This approach also explains the **pronounced dependence of hurricane's intensity on surface temperature.** Hurricanes and tornadoes could be **compared to an explosion reversed** and prolonged in time. In the ordinary explosion potential energy concentrated in the explosion center is released in a burst, making local air pressure rise sharply and causing 5 dynamic air movement in the direction away from the explosion center. Conversely, **condensation of saturated water vapor** within the column of ascending air in hurricanes and tornadoes leads to a **sharp drop of local air pressure**. This further enhances the **ascending motion** of yet accelerating air masses, as well as the compensating radial fluxes of moist air incoming to the area where the process of condensation is most 10 intensive. **Water vapor contained in the incoming air undergoes condensation** in the same area; this sustains the pressure difference between the hurricane center and its environment. Hurricane could also be compared to a **black hole, which sucks the surrounding air** into the center, where it **partially "annihilates" due to condensation of water vapor** and its disappearance from the gas phase. Thus, hurricane is an "anti-explosion". While in explosion the gas phase appears from either liquid or solid phase, in hurricanes and tornadoes, conversely, the **gas phase of water vapor partially disappears from air due to condensation**. Unlike in explosion, the velocity of air masses in hurricanes and tornadoes is significantly lower than the velocity of thermal molecular motion. In consequence, all air 20 volumes are in thermodynamic equilibrium, so that air pressure, temperature and density within the hurricane conform to equilibrium thermodynamics. **The driving force of all hurricane processes is a rapid release, as in compressed spring, of potential energy** previously accumulated in the form of saturated water vapor in the atmospheric column during a prolonged period of water vapor evaporation under the action of the absorbed solar radiation. Since the power of the **practically instantaneous energy release** in the hurricane **greatly exceeds the power of energy exchange** with the environment, all hurricane processes can be described as **adiabatic**. The outlined approach predicts that high wind velocities can develop anywhere in the atmosphere (over land as well as over the ocean), where absolute humidity is high and the process of condensation is spatially non-homogeneous. It thus provides a unifying theoretical framework for understanding both hurricanes and tornadoes

$$Power_{Hurr} := Volume_{Rain}\cdot D_{water}\cdot Heat_{Latent\_Water} = 5.45104\times10^{14}\cdot W$$



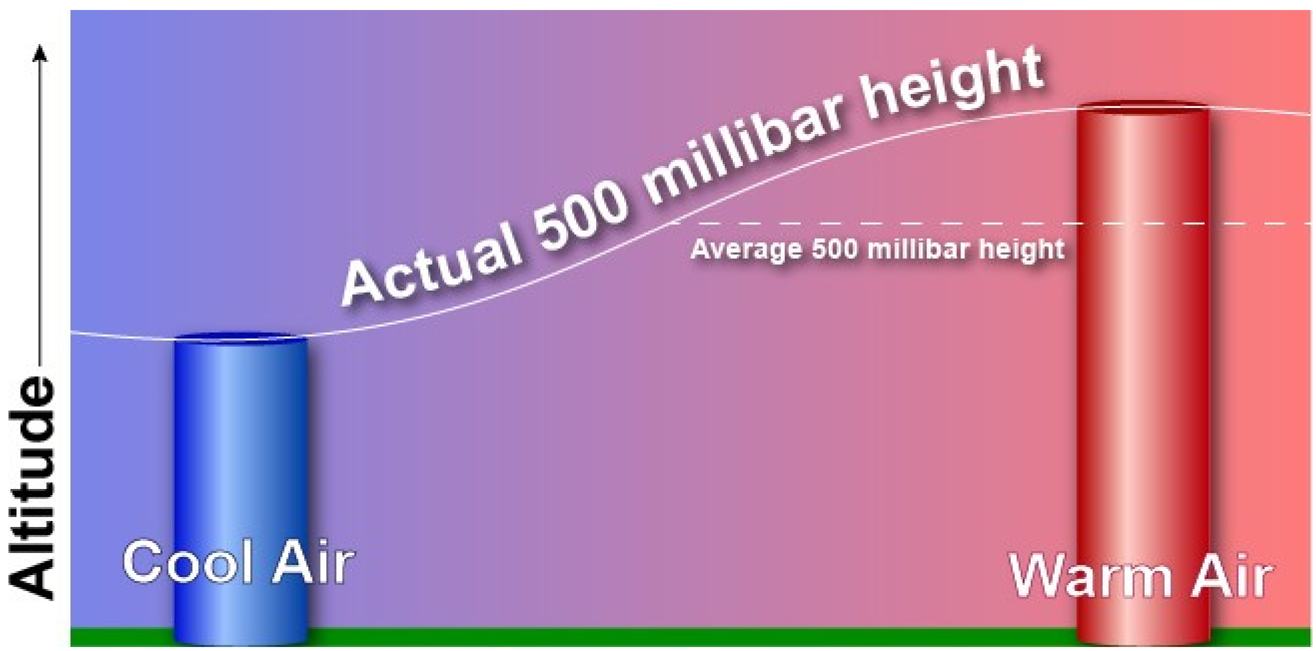
Water vapor is a relatively light gas when compared to diatomic Oxygen and diatomic Nitrogen. Thus, when water vapor increases, the amount of Oxygen and Nitrogen decrease per unit volume and thus density decreases because mass is decreasing.

$$v_{max} := \sqrt{\frac{2p}{\rho}}$$

Kinetic Energy per Unit Volume

$$\frac{1}{2}\cdot\rho\cdot\left(50\,\frac{m}{s}\right)^2 = 1500\cdot\frac{J}{m^3}$$

$$\gamma = \frac{c_p}{c_v}$$



The most basic change in pressure is the twice daily rise and fall in due to the heating from the sun. Each day, around 4 a.m./p.m. the pressure is at its lowest and near its peak around 10 a.m./p.m. The magnitude of the daily cycle is greatest near the equator decreasing toward the poles.

On top of the daily fluctuations are the larger pressure changes as a result of the **migrating weather systems.** These weather systems are identified by the blue H's and red L's seen on weather maps.