Lecture 1: Understanding the Greenhouse Effect and Anthropogenic Climate Change

Reading Assignment – Homework 1 Reading Assignments and Chapter 1 of PVCDROM (new name PVEducation.org)

Dr. Alan Doolittle*

Don’t Panic!!!!

Of late, some from your generation have expressed anxiety, fear and depression related to the “climate crisis”. There is no need for this.

The climate and mans understanding of its trends upward or downward have always been oscillating.

As we will see, the same data viewed with different statical analyses used to indicate the globe was cooling. For this reason, CFCs were banned.

https://www.youtube.com/watch?v=1kGB5MMIAVA

https://www.youtube.com/watch?v=yCzjSDwGSF8

Media and entertainers have commercial interests in getting you to watch their programs. Often, they create drama and/or fear in order to control behaviors for commercial gain. We need to base our discussions on the science.

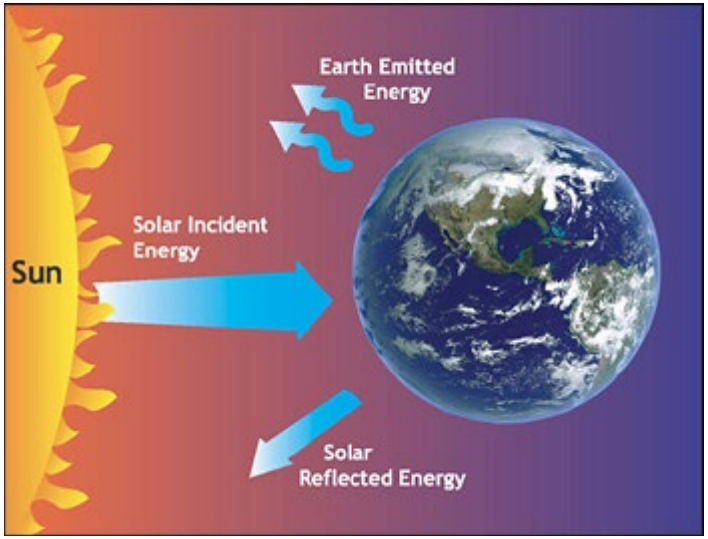
This slide is added as part of the Ga Tech initiative toward positive mental health.

Understanding the Green House Effect

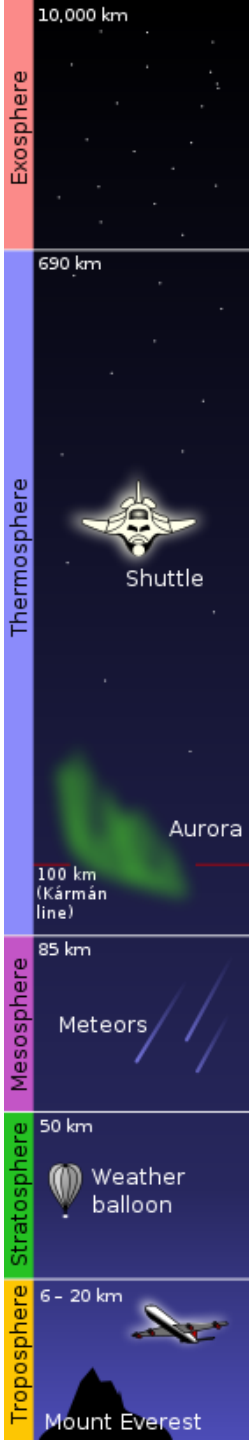
Dr. Alan Doolittle, Ga Tech

There is a difference between the Green House Effect, a known scientific phenomena , global warming and anthropogenic climate change. All are often used in the popular press as synonymous.

Anthropogenic climate change (sometimes called Anthropogenic Global Warming) is the “belief” that mans actions are causing the earths climate to change.



The following is from: http://www.esrl.noaa.gov/gmd/infodata/faq_cat-3.html
What is the greenhouse effect?
The Sun, which is the Earth's only external form of heat, emits solar radiation mainly in the form of shortwave visible and ultraviolet (UV) energy. As this radiation travels toward the Earth, the atmosphere absorbs about 25% of it, and about 25% is reflected by the clouds back into space. The remaining radiation travels unimpeded to the Earth and warms its surface. The Earth releases back to space the same amount of energy it has absorbed from the Sun. However, the Earth is much cooler than the Sun, so the energy re-emitted from the Earth's surface is much weaker, in the form of invisible longwave infrared (IR) radiation, sometimes called heat radiation. If you stand close to a hot object, but do not touch it, you can feel how the IR radiation heats your skin, although you cannot see the IR rays. Gases that absorb and trap this IR radiation, such as water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are known as "greenhouse gases". The atmosphere acts like the glass in a greenhouse, allowing much of the shortwave solar radiation to travel through unimpeded, but trapping a lot of the longwave heat energy trying to escape back to space. This process makes the temperature rise in the atmosphere just as it does in the greenhouse. This is the Earth's natural greenhouse effect and keeps the Earth 33 °C warmer than it would be without an atmosphere, at an average 15 °C (59° F).



Understanding the Green House Effect

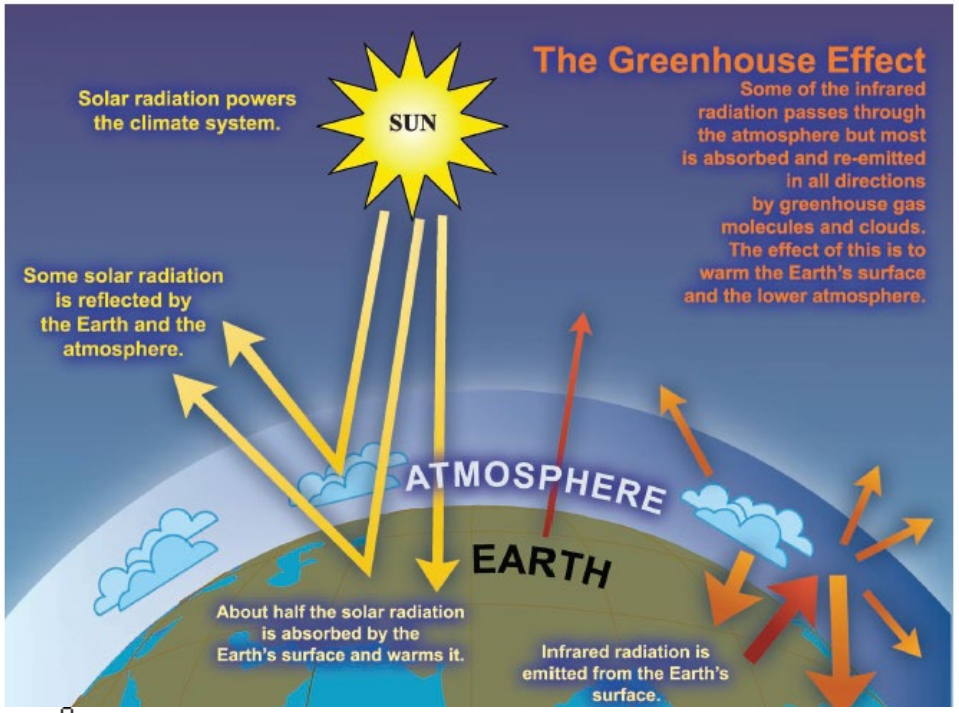
Dr. Alan Doolittle, Ga Tech

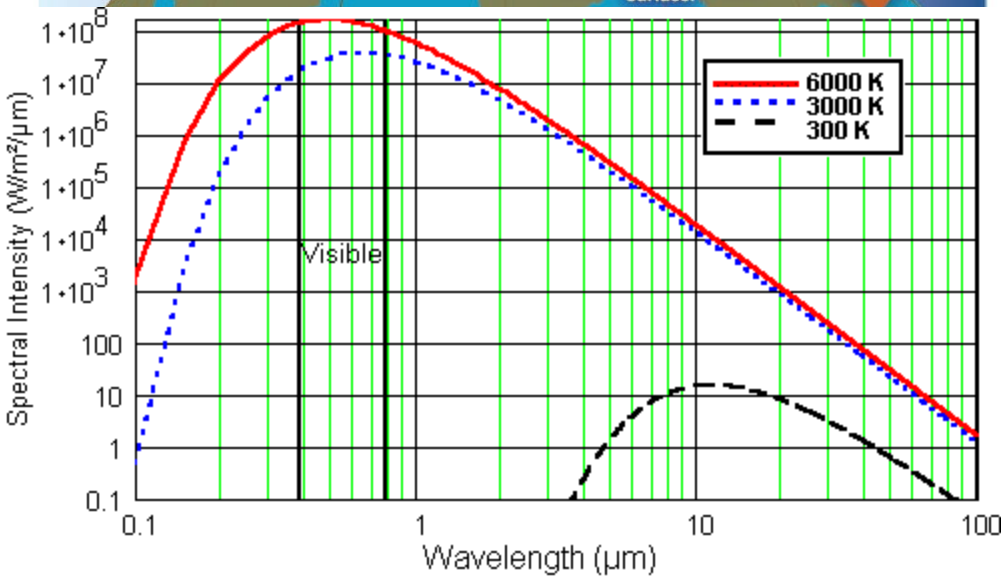
Is the Green House Effect Real? YES! The Green House effect is unquestionably real.

The average surface temperature of Earth is about 15 °C (59 °F)

Without an atmosphere but at the same approximate distance from the sun, , the moon averages ~ -23 °C (9 °F) but during the lunar day, the surface temperature averages 107 °C, and during the lunar night, it averages −153 °C

Since the incoming light is at different frequencies than the outgoing light, some outgoing light can be preferentially absorbed by various "Green House Gases".





Understanding the Green House Effect

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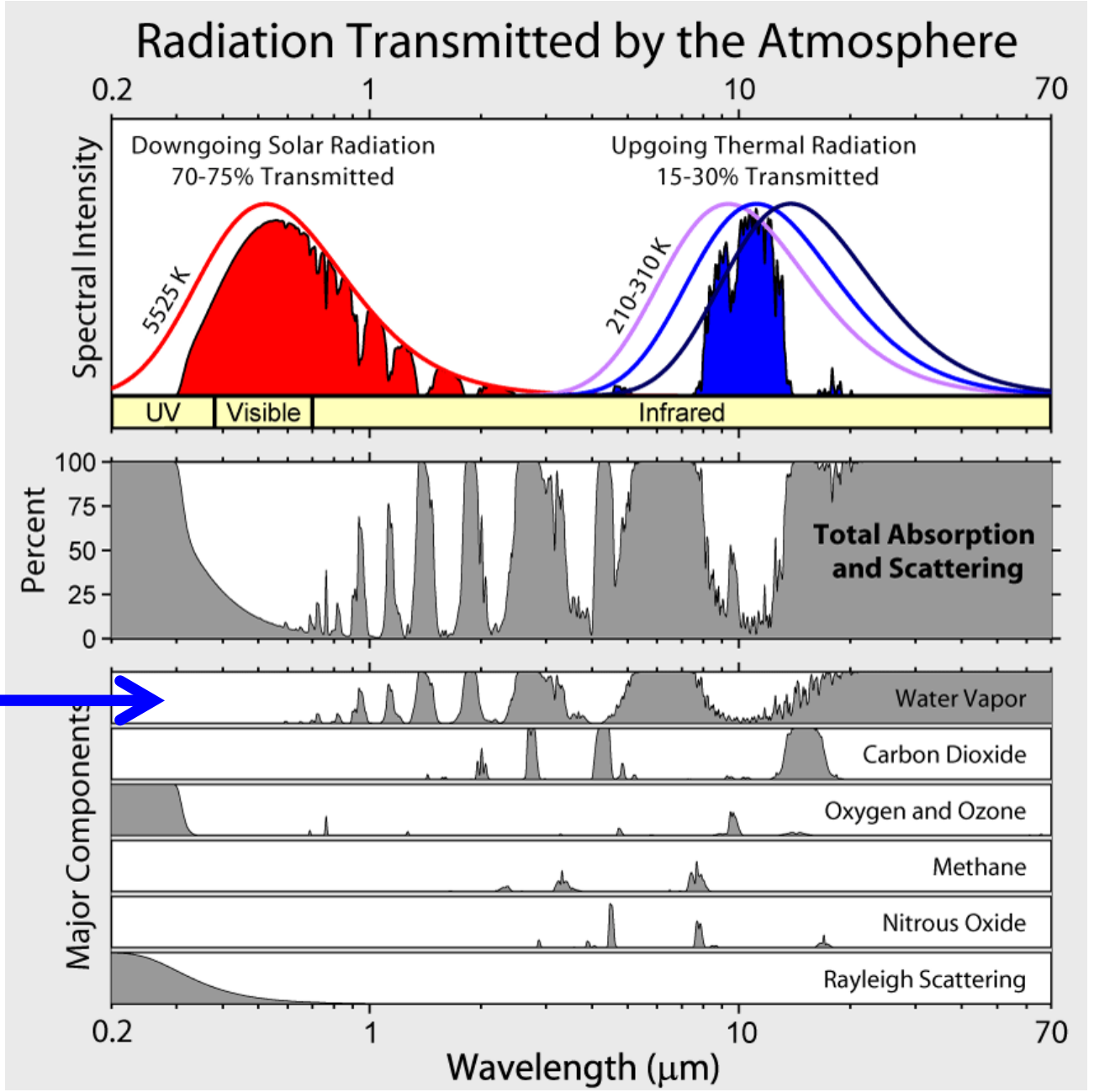
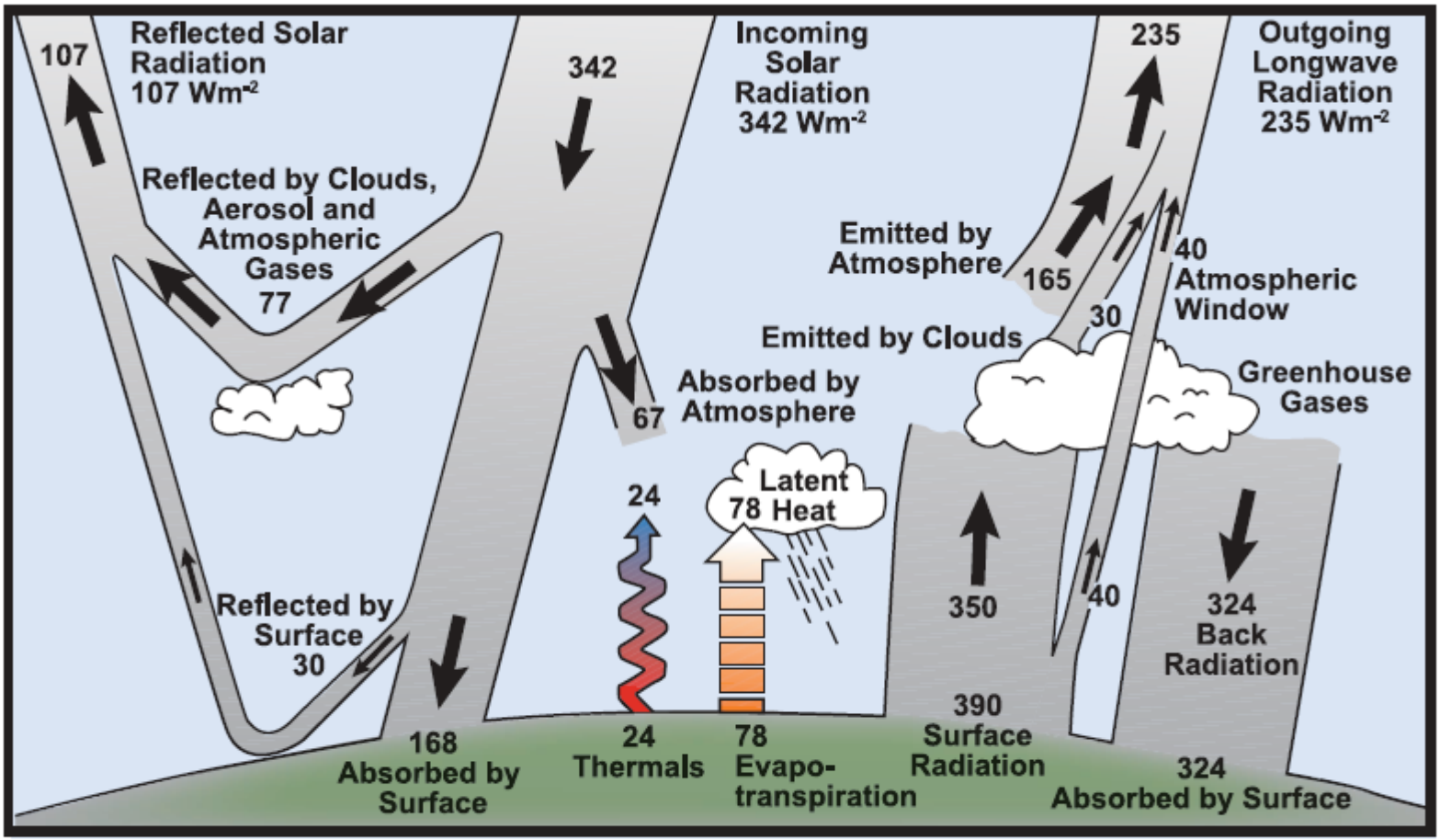
Since the incoming light is at different frequencies than the outgoing light, some outgoing light can be preferentially absorbed by various "Green House Gases".

Is anyone purposing to regulate rain?



Understanding the Green House AND other Effects

The Green House Effect is much more complex and only one of MANY radiative driving forces (measured in W/m^2). Climate predictions are required to take into account MANY complex and often poorly understood systems.



FAQ 1.1, Figure 1. *Estimate of the Earth's annual and global mean energy balance. Over the long term, the amount of incoming solar radiation absorbed by the Earth and atmosphere is balanced by the Earth and atmosphere releasing the same amount of outgoing longwave radiation. About half of the incoming solar radiation is absorbed by the Earth's surface. This energy is transferred to the atmosphere by warming the air in contact with the surface (thermals), by evapotranspiration and by longwave radiation that is absorbed by clouds and greenhouse gases. The atmosphere in turn radiates longwave energy back to Earth as well as out to space. Source: Kiehl and Trenberth (1997).*

From IPCC report 2007

Is Anthropogenic Climate Change Real?

Dr. Alan Doolittle, Ga Tech

Is Anthropogenic Climate Change Real?

Unlike the Green House Effect, the validity and more accurately, the magnitude of ACC is still in debate. Ardent environmentalists , some government officials and even the non-scientific press often state that the debate is over. However, there remains loud and clear dissenting voices. In this class, we will be open and considerate of all scientific opinions and attempt to present data and let each student decide.

Early IPCC findings suggested that man is "Very Likely" the cause of recent modest temperature increases. However, significant debate exists on this finding and on what to do about it and if anything substantive can be done. The latest IPCC reports have not presented any significant new data nor understanding but do conclude man is the cause for the recent climate change.

Is Anthropogenic Climate Change Real?

Dr. Alan Doolittle, Ga Tech

All debates should be open. Too many times this debate is driven by idealogs, environmentalists who want all fossil fuels to be eliminated and conservatives who want to deny there is any concern . To this end, I state my position clearly – I have none.

I am neither an environmentalist nor a ACC denier. I was trained in photovoltaics and am a huge supporter of PV but as an engineer, I also understand it's limited impact on the real problem. I am neither a democrat nor a republican.

My Opinion: The 20th century measured CO_2 atmospheric content has changed so drastically that proportionate steps should be taken to restore some balance or stem the increases. I am less convinced of the drastic temperature connection to CO_2 (specifically) often predicted . The models that suggest this connection are amazingly immature and do not trend with observations in the last decade. H_2O vapor absorbs more radiated power than CO_2 but no efforts are made to control "rain". Why? Clearly the actions proposed are full of political agendas. I view this to be somewhat fear mongering, albeit well intentioned, an attempt to motivate what is truly justified action. I also am concerned about the treatment of dissenting data and based on recent allegations dissenting voices within climatology. The magnitude of the climate problem seems to be a result of the magnitude of the earths population and our inherent need for energy. No realist will ever support a lower standard of living as many suggest we should. In the end, this dilemma is one of the costs for world peace, freedom from pandemic disease and thus an out of control population explosion.

Major “Political” Climate Conferences and Reports

Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change - TAR 2001

Intergovernmental Panel on Climate Change - IPCC 2007

Intergovernmental Panel on Climate Change - IPCC 2013

Several IPCC Assessment Reports (AR5, AR6, etc…)

Temperature Measurements – Easy, right?

Dr. Alan Doolittle, Ga Tech

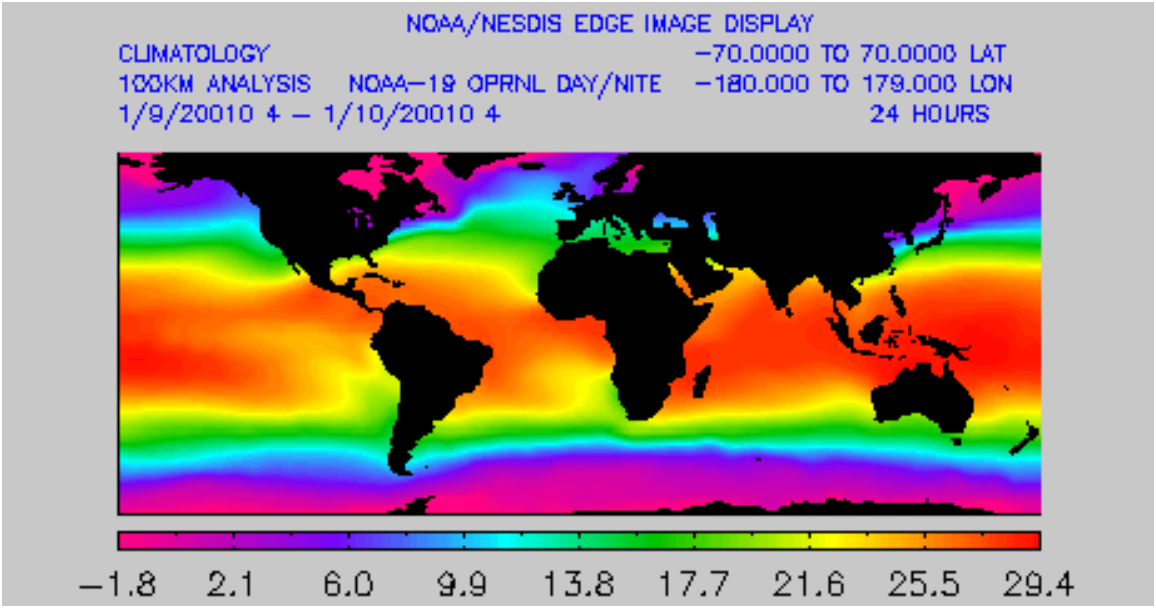
Since the temperature of the earth varies with date, time of day, latitude, longitude and elevation, monitoring "Global Temperature" is highly problematic.

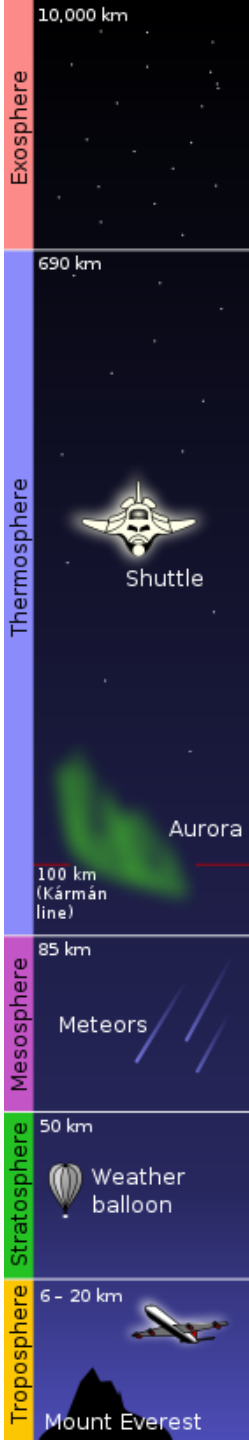
The National Oceanic and Atmospheric Administration performs this function for the US. See www.noaa.gov

Land, ship, buoy and satellite based sensors are used.

In general, land, buoy and ship data agree as collected (ship data shows ~0.1°C lower) with all indicating a recent increase in temperature whereas satellite data, as collected, indicates a slight decrease in temperatures until corrected by rather complex correction algorithms. Some reporting methods used by climatologists, sea temperatures compiled by the ERSST3b method for example, choose to eliminate the satellite data from their weighted averages because "it caused problems for some of it's users" (NOAA quote now removed from their website) whereas others give it less weight and "correct it" based on removing perceived offsets.

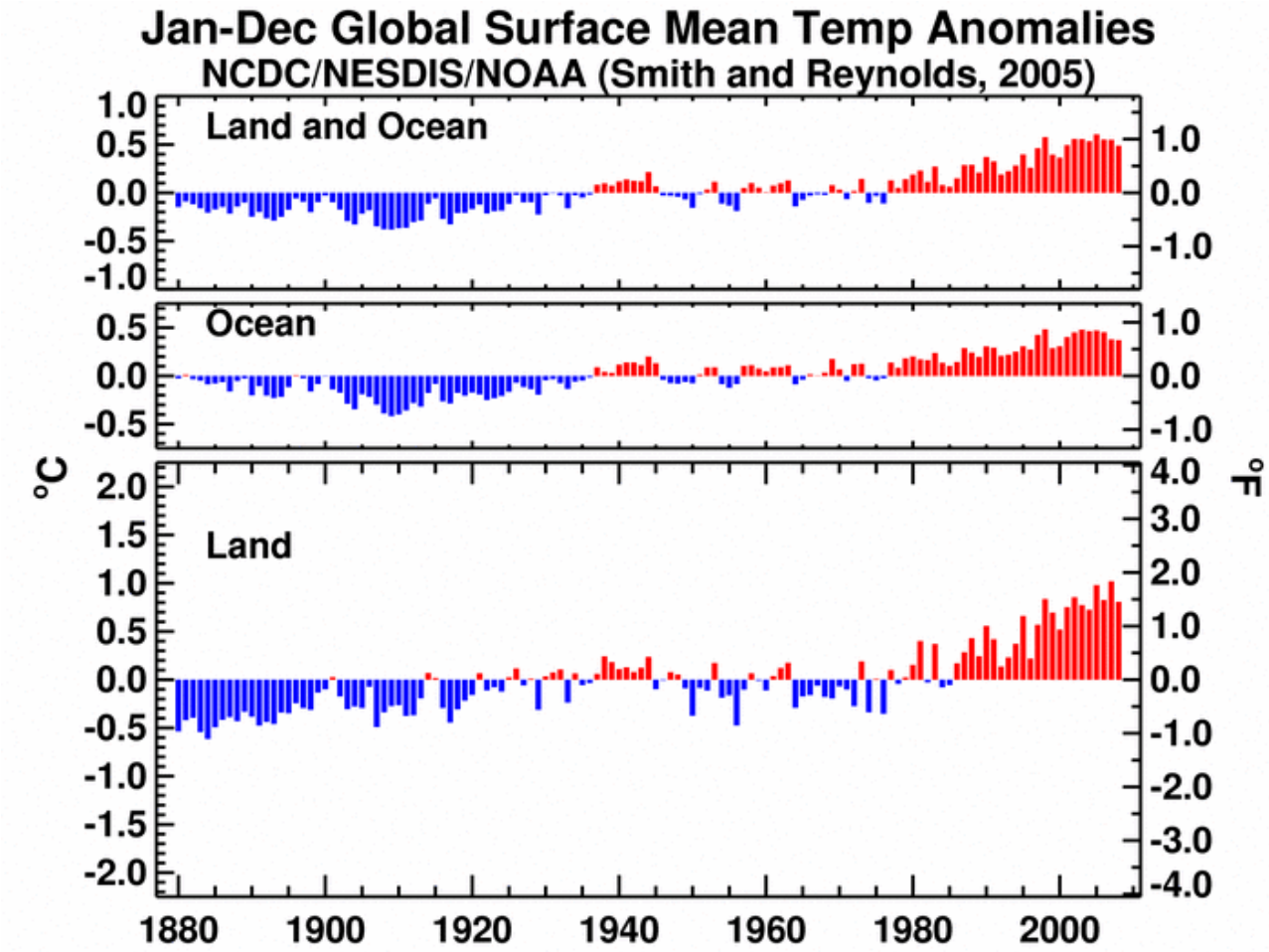
Update:
ERSST 4 was implemented in May/June 2015 and ignores satellite data entirely.





Differential Temperature Measurements – Easier

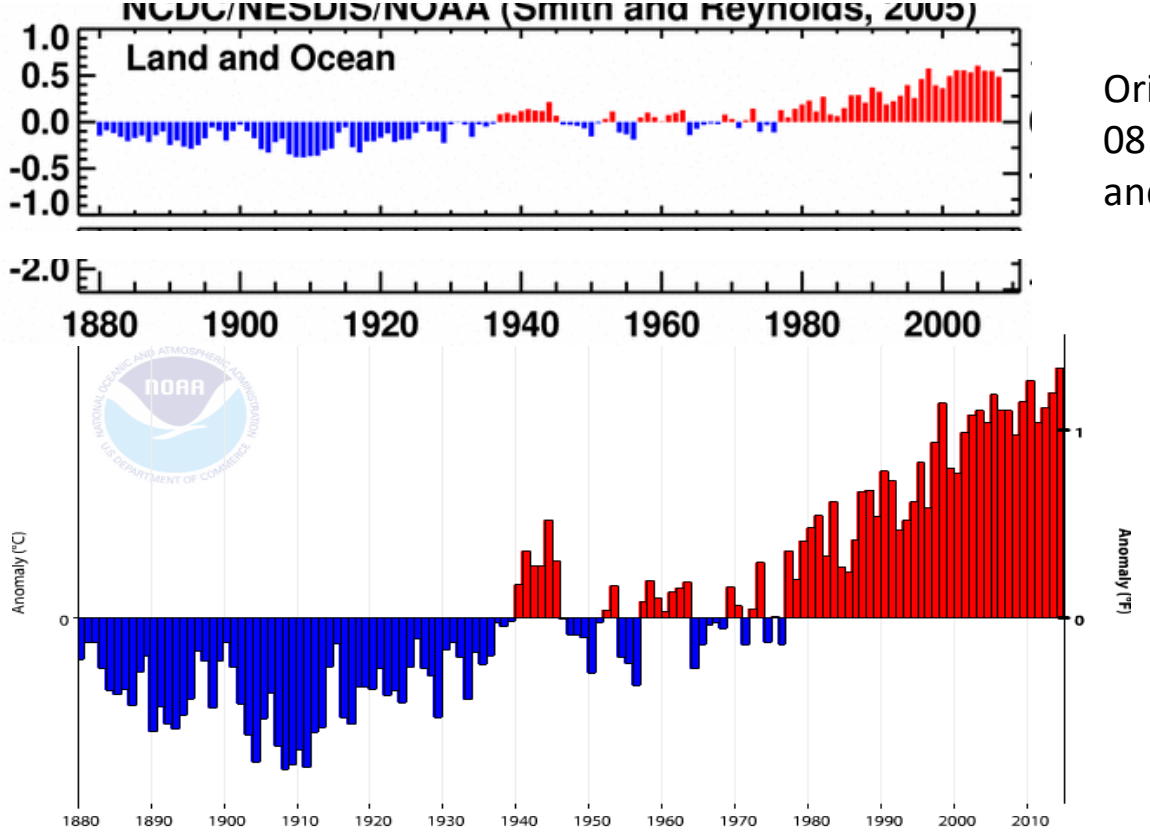
Since absolute temperature measurements are hard, Differences from an average are more often quoted. This comparison allows systematic error and uncertainties to be reduced. This temperature difference is referred to as a "Temperature Anomaly" (admittedly this name indicates a predetermined bias in that it is not simply a "deviation" but an "anomaly"). See www.noaa.gov



Things to note:

1) The total temperature rise is small but it is argued that this small amount is significant compared to ice age changes (~6 °)
2) Note that global temperatures have not increased since ~2002 (based on 2005 standard averaging)
3) The general trend extends back to ~1900

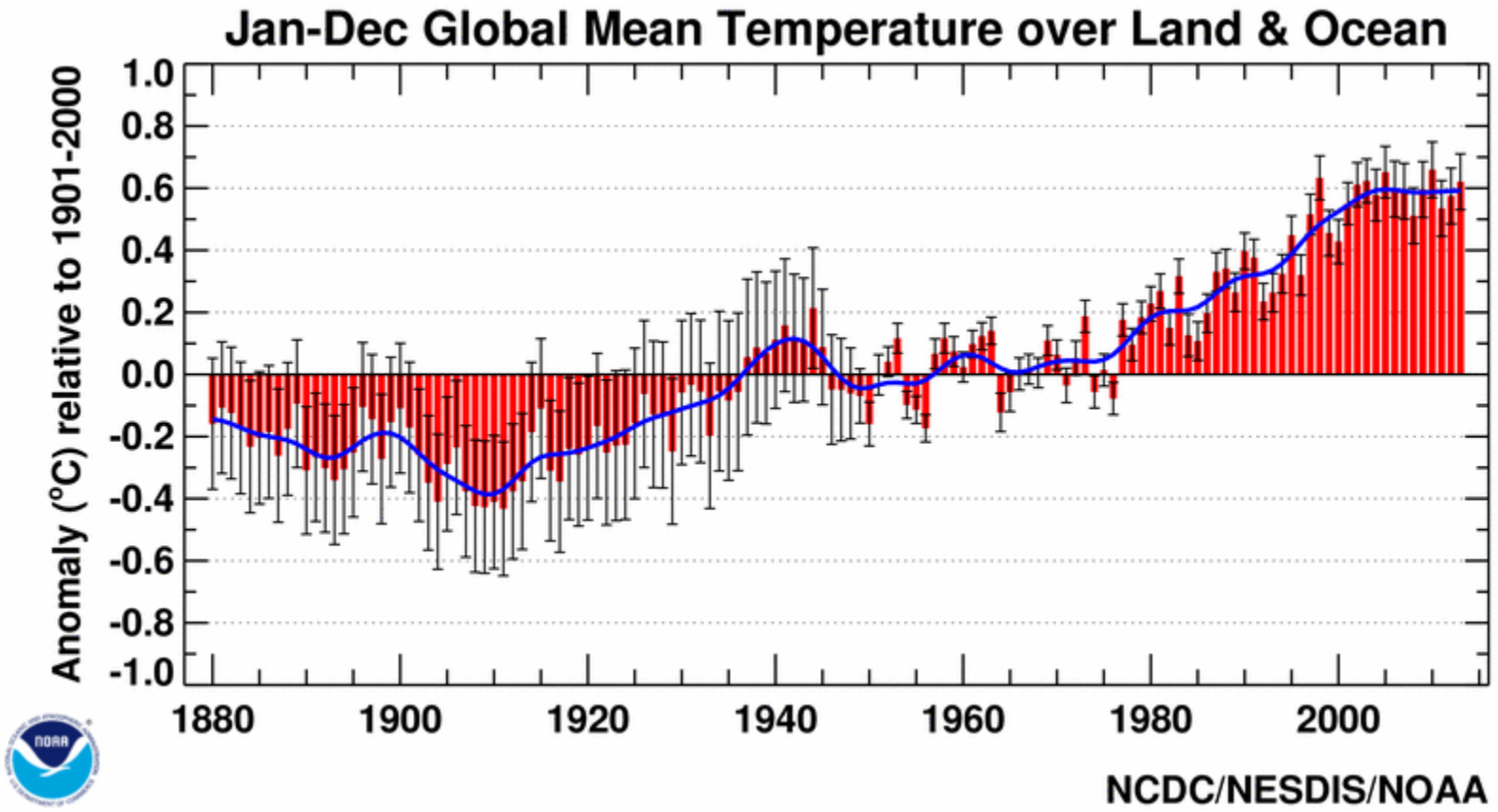
Differential Temperature Measurements – Depends on the way you take the data (which has changed in recent years)



Original NOAA graphs from 2005-08 time period shows a flattening and role over of recent years data.

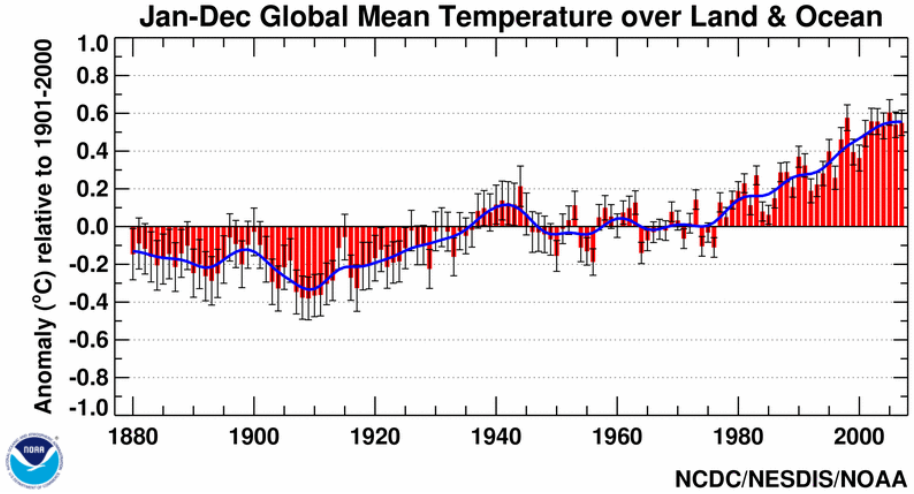
2015 NOAA graphs changed weighting methods and shows no flattening nor role over of recent years data.

Recent Differential Temperature Measurements

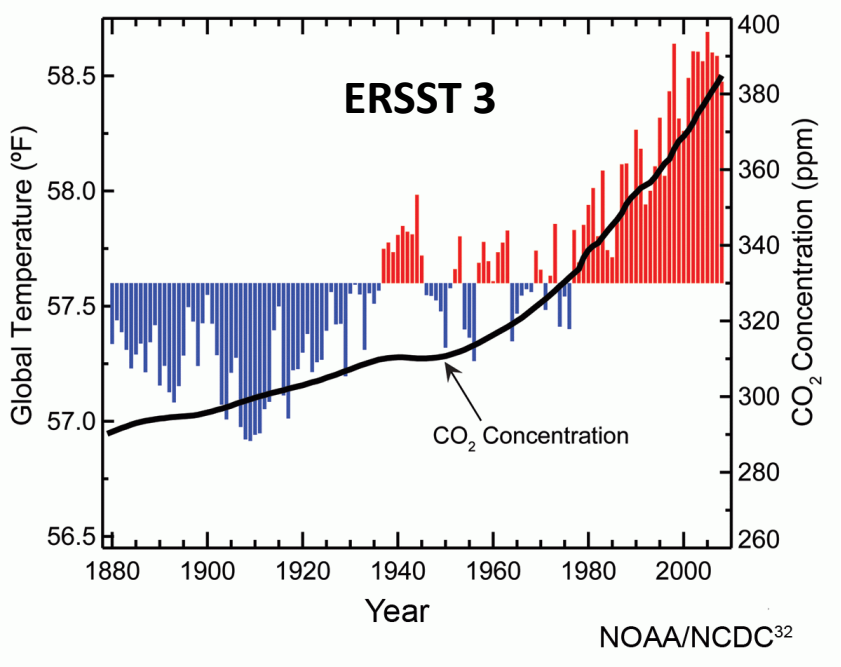


Not All "Data" are Created Equal…

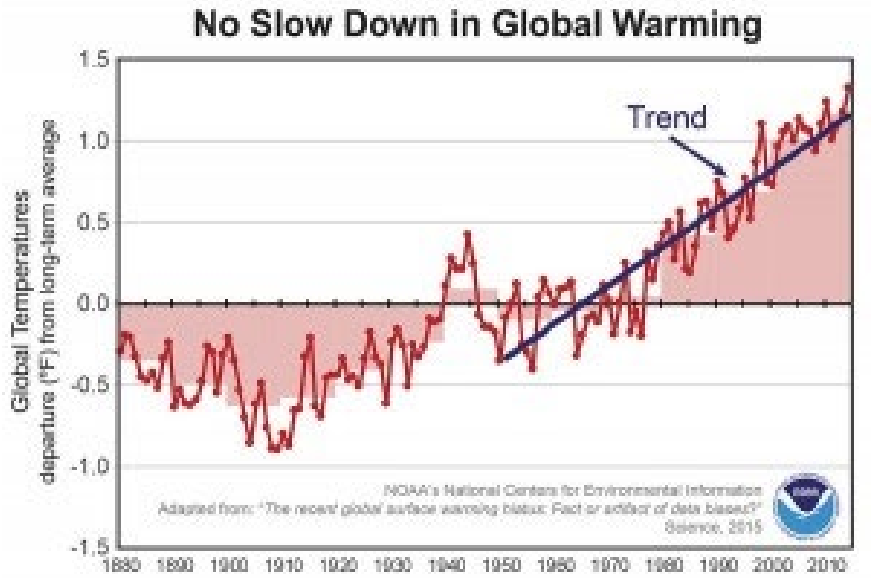
ERSST 3B



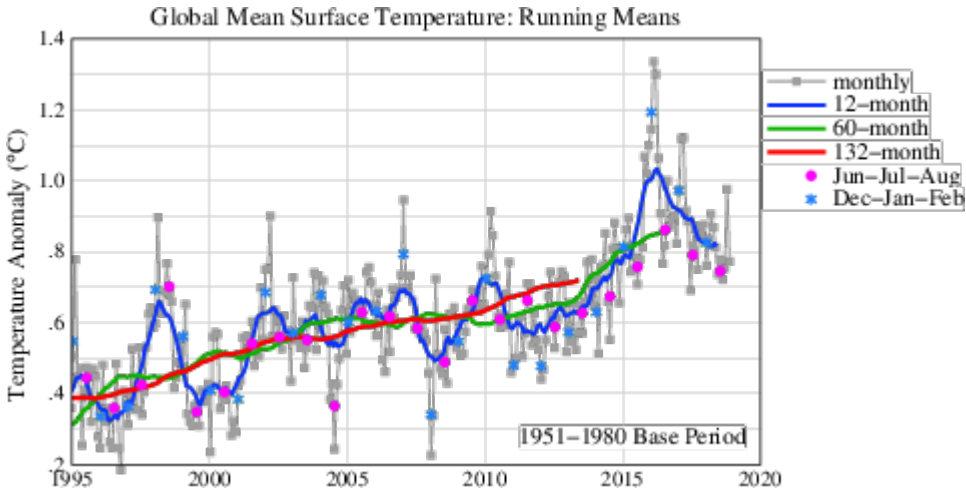
ERSST 3



NOAA Publically Disseminated Graph

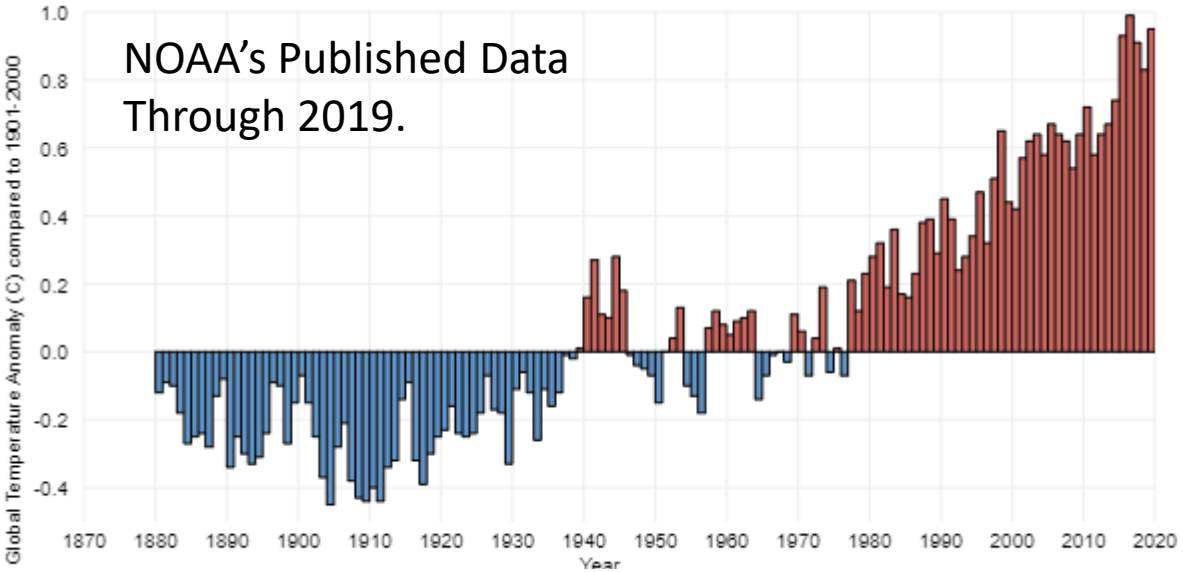


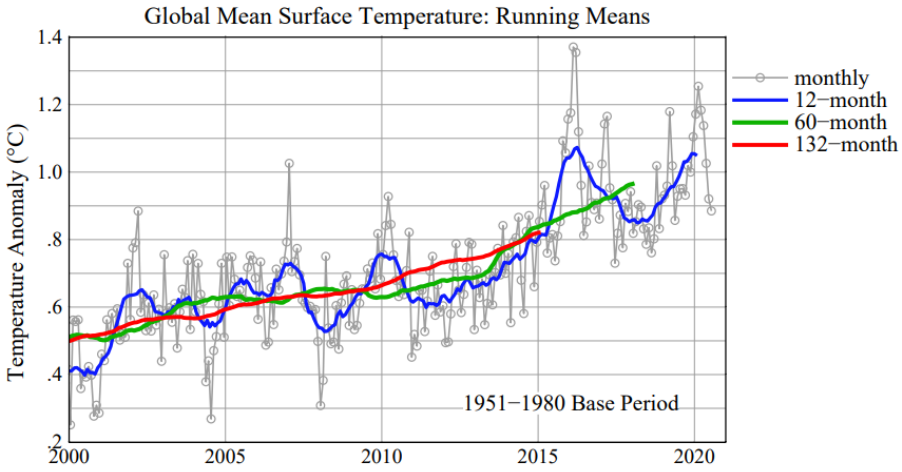
ERSST 5



Extended reconstructed sea surface temperature (ERSST)

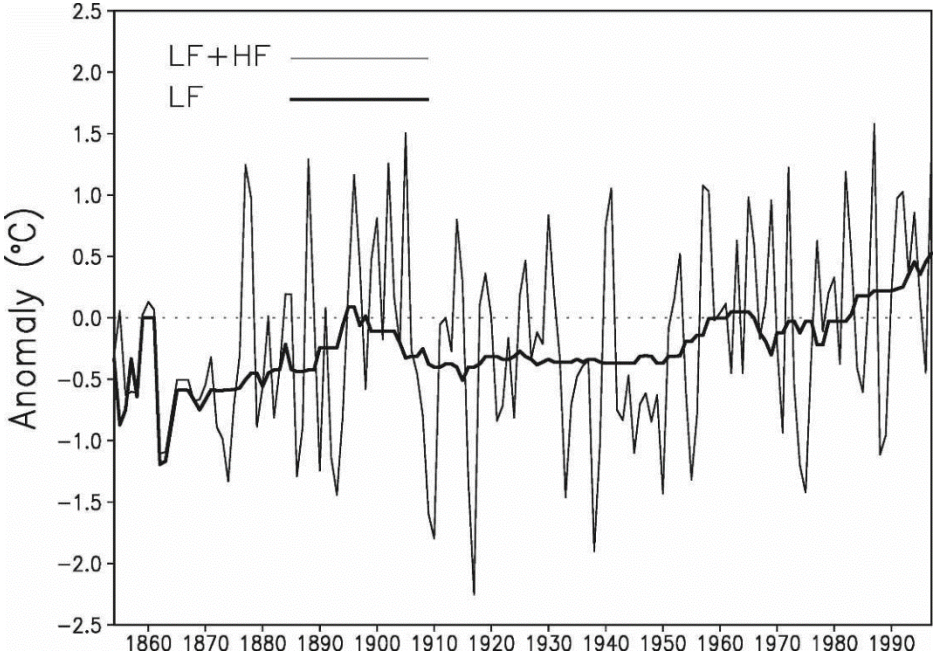
Most Recent Data





https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature

The data massaging matters…



Thousands of apples and oranges data points must be assimilated with human interpreted validations, relative weighting, and "bias correction". Land, ship, buoy and satellite data spanning various methods, accuracies and uncertainties must be factored in.

References (from NOAA): Dr. Alan Doolittle, Ga Tech

The following publications describe the processes and procedures for each version of the ERSST dataset.

ERSST v1

Smith, T.M., and R.W. Reynolds, 2003: Extended reconstruction of global sea surface temperatures based on COADS data (1854–1997). Journal of Climate, **16**, 1495–1510. doi:10.1175/1520-0442-16.10.1495.

ERSST v2

Smith, T.M., and R.W. Reynolds, 2004: Improved extended reconstruction of SST (1854–1997). Journal of Climate, **17**, 2466–2477. doi:10.1175/1520-0442(2004)017<2466:IEROS>2.0.CO;2.

ERRST v3

Smith, T.M., R.W. Reynolds, T.C. Peterson, and J. Lawrimore, 2008: Improvements to NOAA's historical merged land–ocean temperature analysis (1880–2006). Journal of Climate, **21**, 2283–2296. doi:10.1175/2007JCLI2100.1.

Xue, Y., T.M. Smith, and R.W. Reynolds, 2003: Interdecadal changes of 30-Yr SST normals during 1871–2000. Journal of Climate, **16**, 1601–1612. doi:10.1175/1520-0442-16.10.1601.

ERSST v4

Huang, B., V.F. Banzon, E. Freeman, J. Lawrimore, W. Liu, T.C. Peterson, T.M. Smith, P.W. Thorne, S.D. Woodruff, and H.-M. Zhang, 2014: Extended Reconstructed Sea Surface Temperature version 4 (ERSST.v4): Part I. Upgrades and intercomparisons. Journal of Climate, **28**, 911–930, doi:10.1175/JCLI-D-14-00006.1.

Liu, W., B. Huang, P.W. Thorne, et. al, 2014: Extended Reconstructed Sea Surface Temperature version 4 (ERSST.v4): Part II. Parametric and structural uncertainty estimations. Journal of Climate, **28**, 931–951, doi:10.1175/JCLI-D-14-00007.1.

Huang, B., P. Thorne, T. Smith, et. al, 2015: Further Exploring and Quantifying Uncertainties for Extended Reconstructed Sea Surface Temperature (ERSST) Version 4 (v4). Journal of Climate, **29**, 3119–3142, doi:10.1175/JCLI-D-15-0430.1.

ERSST v5

Huang, B., Peter W. Thorne, et. al, 2017: Extended Reconstructed Sea Surface Temperature version 5 (ERSSTv5), Upgrades, validations, and intercomparisons. J. Climate, doi: 10.1175/JCLI-D-16-0836.1

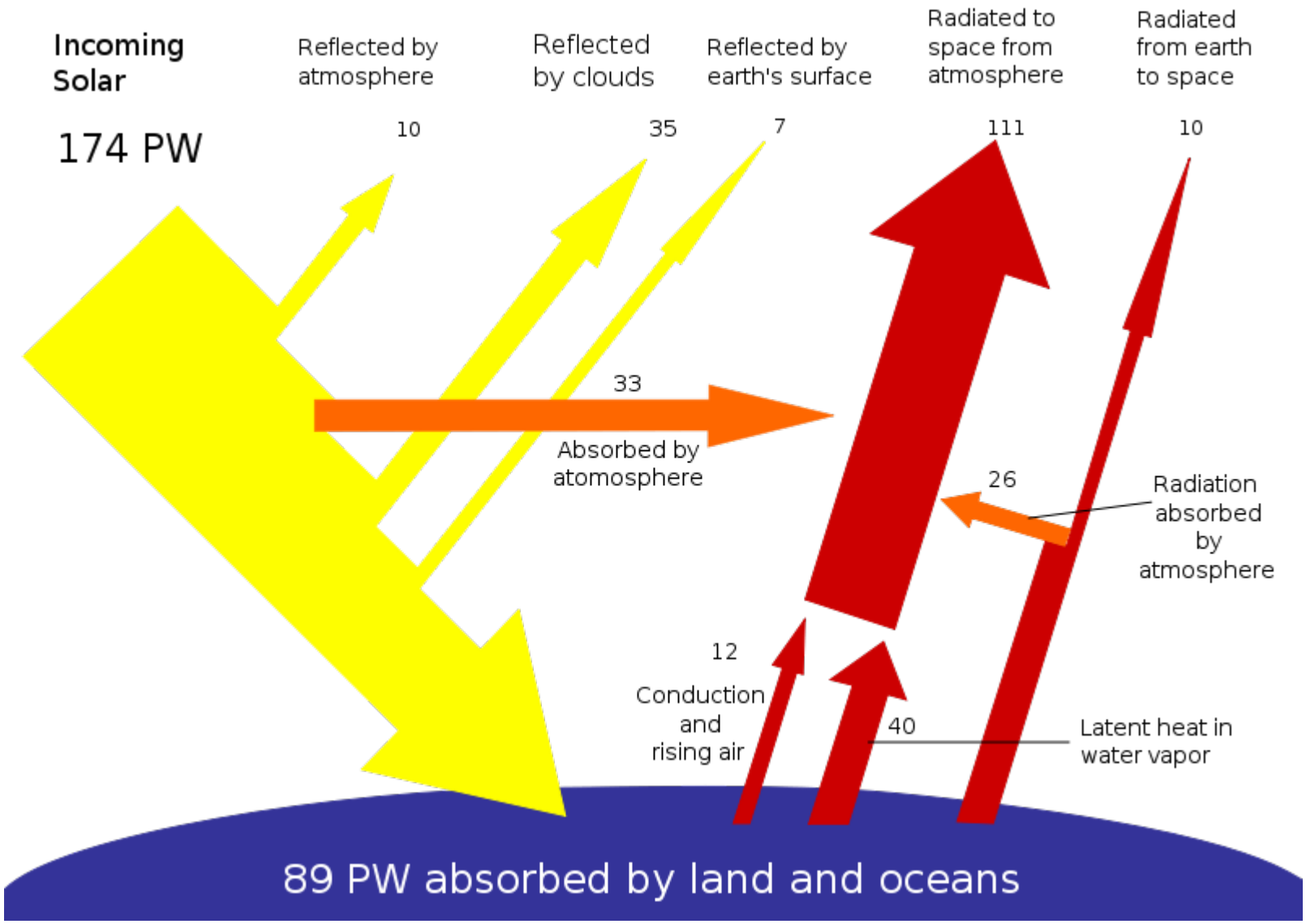
Huang, B., C. Liu, G. Ren, H.-M. Zhang, and L. Zhang, 2018: The role of buoy and Argo observations in two SST analyses in the global and tropical Pacific oceans. J. Climate, **32**, 2517-2535, doi:10.1175/JCLI-D-18-0368.1.

Huang, B., W. Angel, T. Boyer, L. Cheng, G. Chepurin, E. Freeman, C. Liu, and H.-M. Zhang, 2018: Evaluating SST analyses with independent ocean profile observations. J. Climate, **31**, 5015-5030, doi:10.1175/JCLI-D-17-0824.1.

Cite dataset when used as a source. See the dataset's DOI landing page for citation details at doi:10.7289/V5T72FNM.

Where does the energy go?

The power flows are enormous (a peta watts= 10^{15} W) as are the complexity of energy flow pathway.



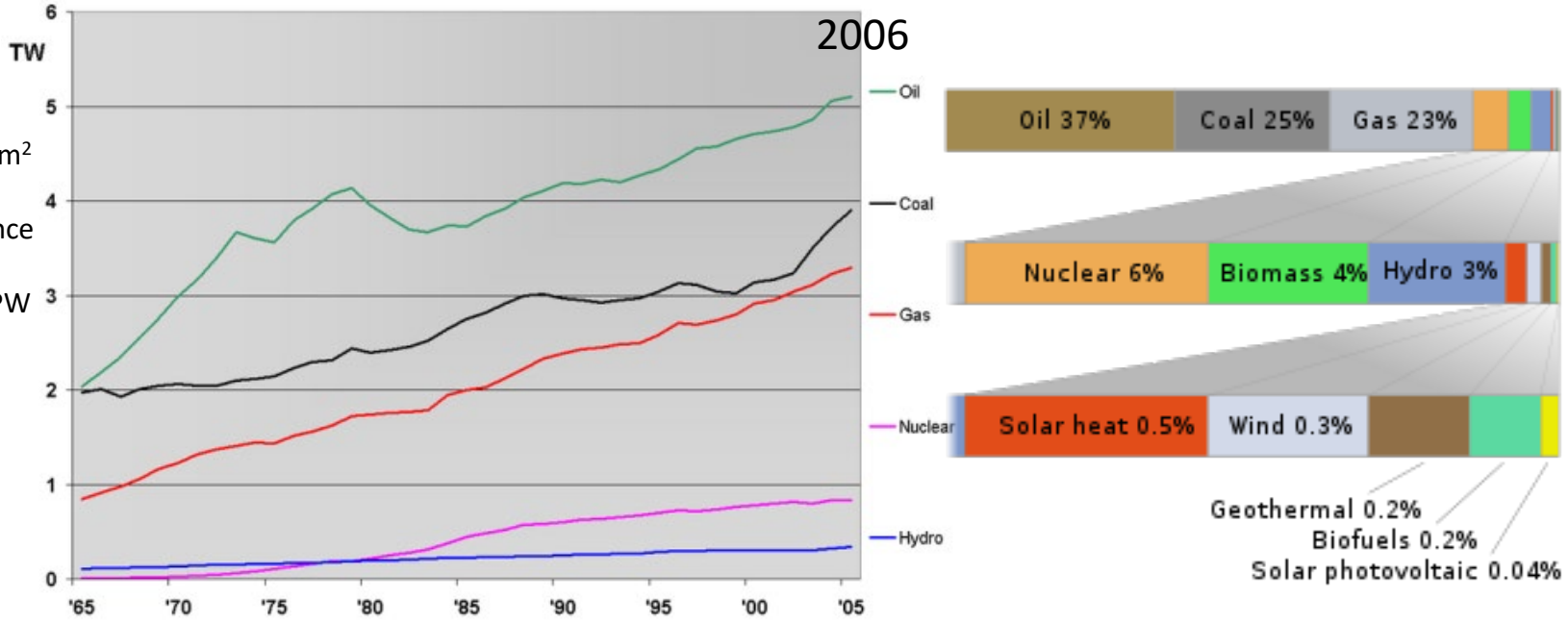
Where does the energy go?

While the solar induced power flows are 100's of peta watts (a petawatt= 10^{15} W) mans energy usage is estimated to be ~15.04 terawatts (a terawatt= 10^{12} W or ~0.005%), the majority of which comes from fossil fuels.

Compare this to a "large" nuclear power plant capacity of ~1 gigawatt (a gigawatt= 10^{9} W) and one sees the magnitude of the problem. As of 2005, there were 441 nuclear power plants producing only 367 GW (many less today due to the Fukushima Daiichi panic). To completely displace all fossil fuels would require more electric capacity from "clean technologies" than exists world wide or equal 10,000 new nuclear power plants . Unrealistic!

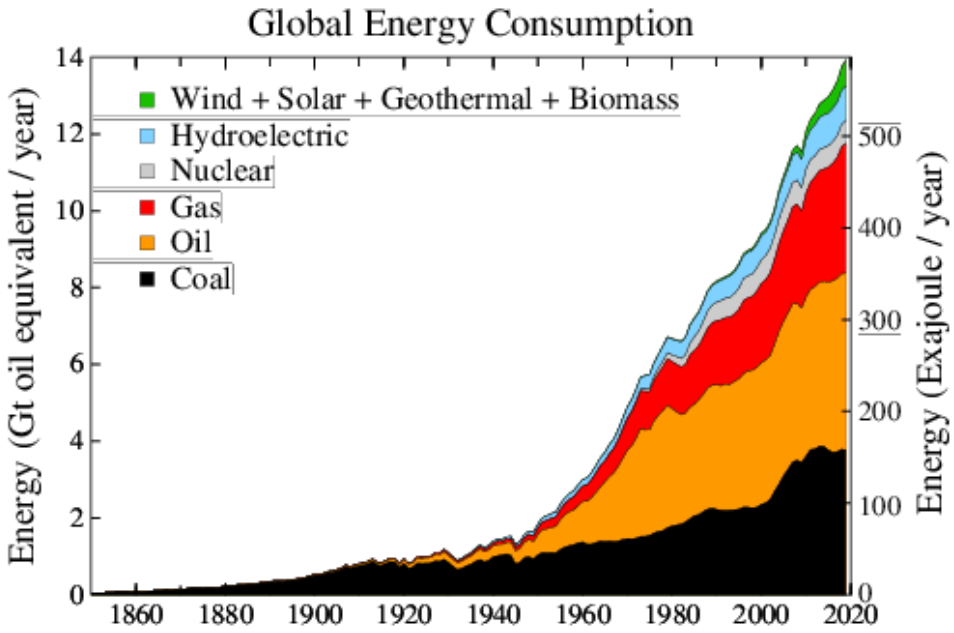
An aside, about the unintended consequences of government regulation: The International Atomic Energy Agency (IAEA) in 1974 forecast a capacity of 4.450TW for the year 2000 but cost overruns due to increased regulation raised plant costs by 15 times after the Three Mile Island accident.

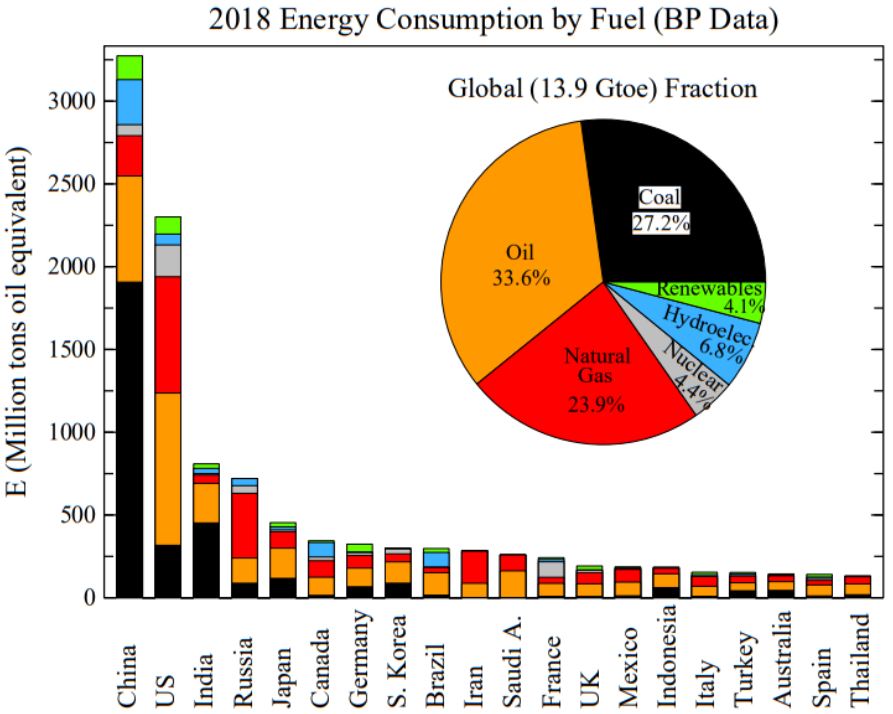
Earth has ~127,400,000 km^2 area.
The sun irradiance is 1366 W/m^2 delivering 174 PW

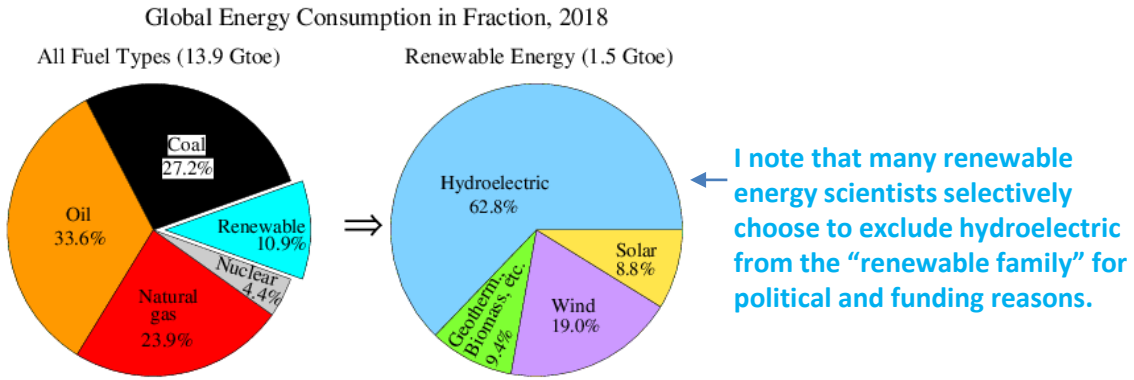


Sources: Figure, British Petroleum (overestimates nuclear capacity)
Nuclear capacity: Nuclear Engineering International, World Survey, "On the way out" 28 July 2005
Scott Henry, "Georgia Power takes a fresh look at nuclear power", Creative Loafing, 22 August 2007

Where does America and the world get its energy?





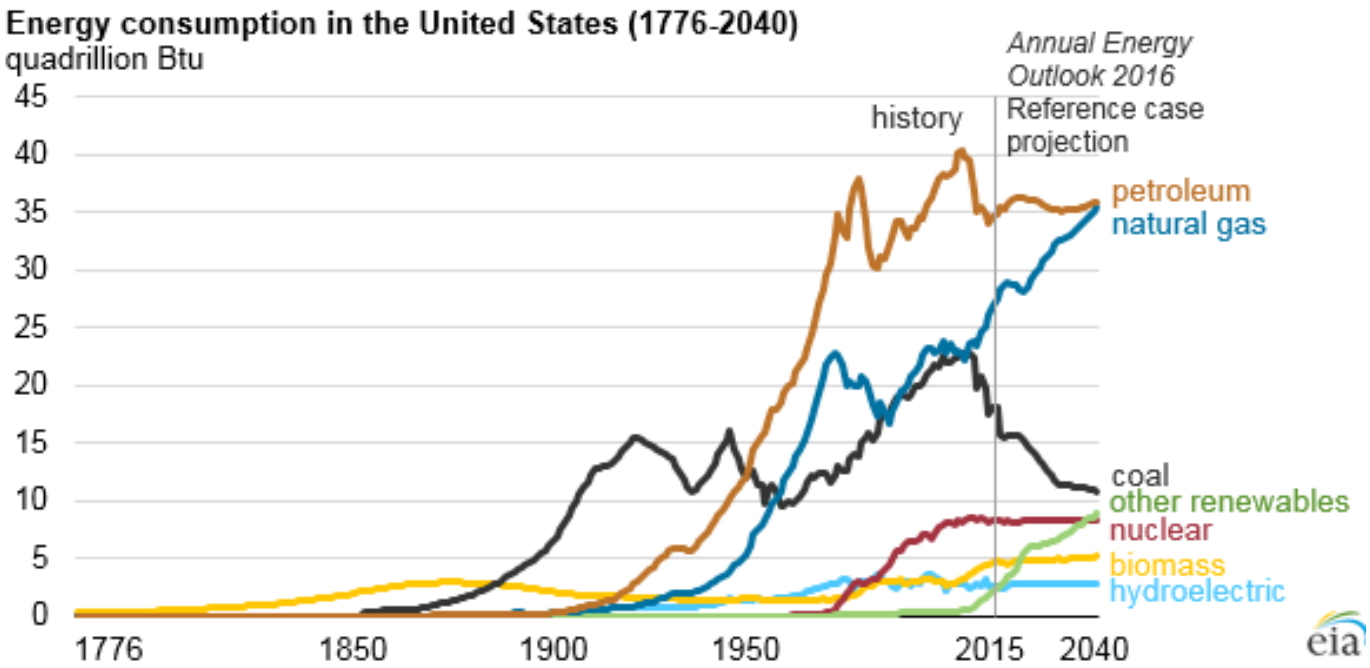


I note that many renewable energy scientists selectively choose to exclude hydroelectric from the "renewable family" for political and funding reasons.

http://www.columbia.edu/~mhs119/EnergyConsump/

Where does the energy go?
Strong Governmental Regulations and Taxes Effect Production

Under Obama (2008-2016) and likely again under Biden, Coal is slated to be taxed so heavily it will have to be phased out with no immediate replacement option.
This alone could triple energy prices.



Data shown was from 2015.
https://www.eia.gov/todayinenergy/detail.php?id=26912

Which fossil fuels does the USA use and how much CO_2 do they produce?

U.S. electric utility and independent power electricity generation and resulting CO2 emissions by fuel in 2019

	Electricity generation	CO2 emissions		
	million kWh	million metric tons	million short tons	pounds per kWh
Coal	947,891	952	1,049	2.21
Natural gas	1,358,047	560	617	0.91
Petroleum	15,471	15	17	2.13

Electricity generation is net electricity generation.
Includes electricity-only power plants. Combined heat and power plants are excluded because some of their CO2 emissions are from heat-related fuel consumption.

	Electricity Generated KWh	CO2 Emissions [million metric tons]	CO2 metric tons/KHh	% of Generation
Total Fossil Fuels Generation=	2.32E+12	1.53E+09		
Coal	9.48E+11	9.52E+08	1.004E-03	40.8%
Natural Gas	1.36E+12	5.60E+08	4.124E-04	58.5%
Petroleum	1.55E+10	1.50E+07	9.696E-04	0.7%
		Weighted CO2/KHh=	6.578E-04	

https://www.eia.gov/tools/faqs/faq.php?id=74&t=11

Transportation Fuels – a hard problem

"Average" USA Electric Car	"Average" USA Gasoline Car
(0.3KWh/Mile*) x (15,000Miles/Year) =	(1Gal/28 Miles) x (15,000Miles/Year)
4500 KWh x $0.12/KHW =	535 Gal/Year x $2.00/Gal =
$546/Year & **3.18 MT CO_2/Year**	$1071/Year & **4.75 MT CO_2/Year**
Average USA Electric Utility CO_2 Production	**CO_2 Production per Gallon Gasoline**
=7.07 × 10^{-4} metric tons CO_2/kWh (1,558.8 lbs CO_2/MWh × (4.536 × 10^{-4} metric tons/lb) × 0.001 MWh/kWh)	**= 8.887 × 10^{-3} metric tons CO_2/gallon of gasoline (8,887 grams of CO_2/gallon of gasoline)**

On average, electric cars are better than gasoline vehicles but that depends on the model and region of the country you are in.

- 42 MPG economy cars = 0.3KWh Electric Cars
- Coal rich electricity production regions (Atlanta) derate electric cars by 43% from the average used here. (3.18 MT → 4.6 MT)
- Natural Gas rich electricity production regions increase electric cars advantage by 42%. (3.18 MT → 2.24 MT)
- Energy distribution efficiencies also not factored in (10% for electricity and variable for gasoline).
- Much of electricity's advantage results from large scale power generation being almost double the efficiency of small-scale gasoline engines, making better use of raw materials.

U.S. electric utility and independent power electricity generation and resulting CO2 emissions by fuel in 2019

	Electricity generation	CO2 emissions		
	million kWh	million metric tons	million short tons	pounds per kWh
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Petroleum	15,471	15	17	2.13

*Hyundai Ionic 2019 and Tesla Model 3 2019 but ranging from 249 to 458 KWh/mile

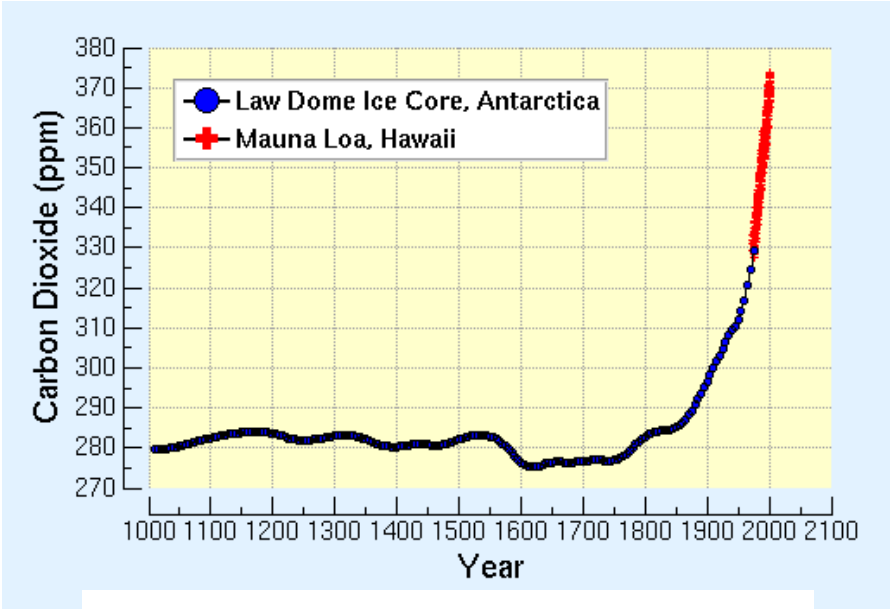
https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references
https://www.bts.gov/content/average-fuel-efficiency-us-light-duty-vehicles

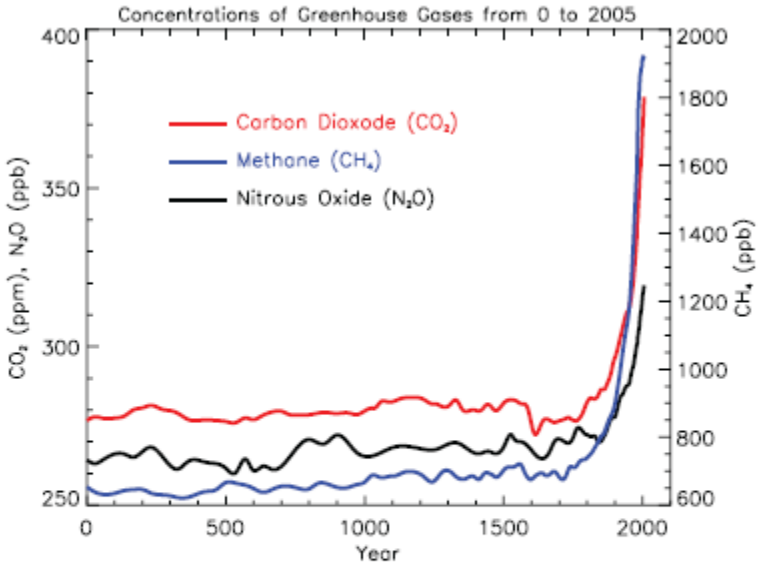
Why Is Man Sometimes Considered the Cause?

Ice core data has a time resolution of ~1000 years whereas recent direct IR absorption measurements are instantaneous values.

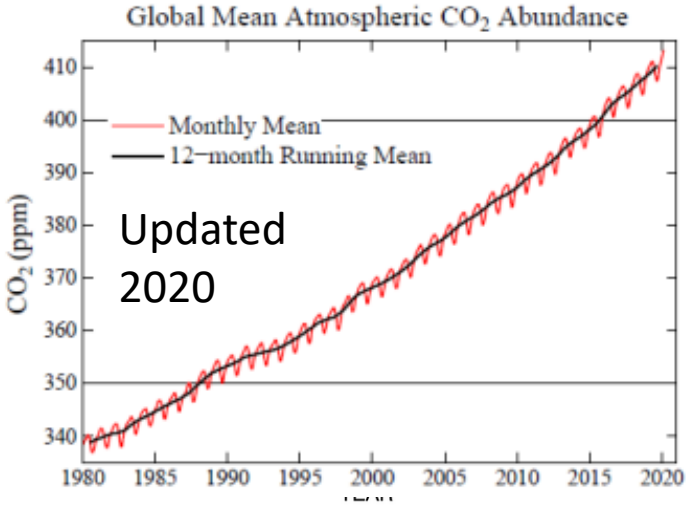
Both show increases in CO_2, Methane and Nitrous Oxide

CO_2 has increased by ~37% from it's middle ages value





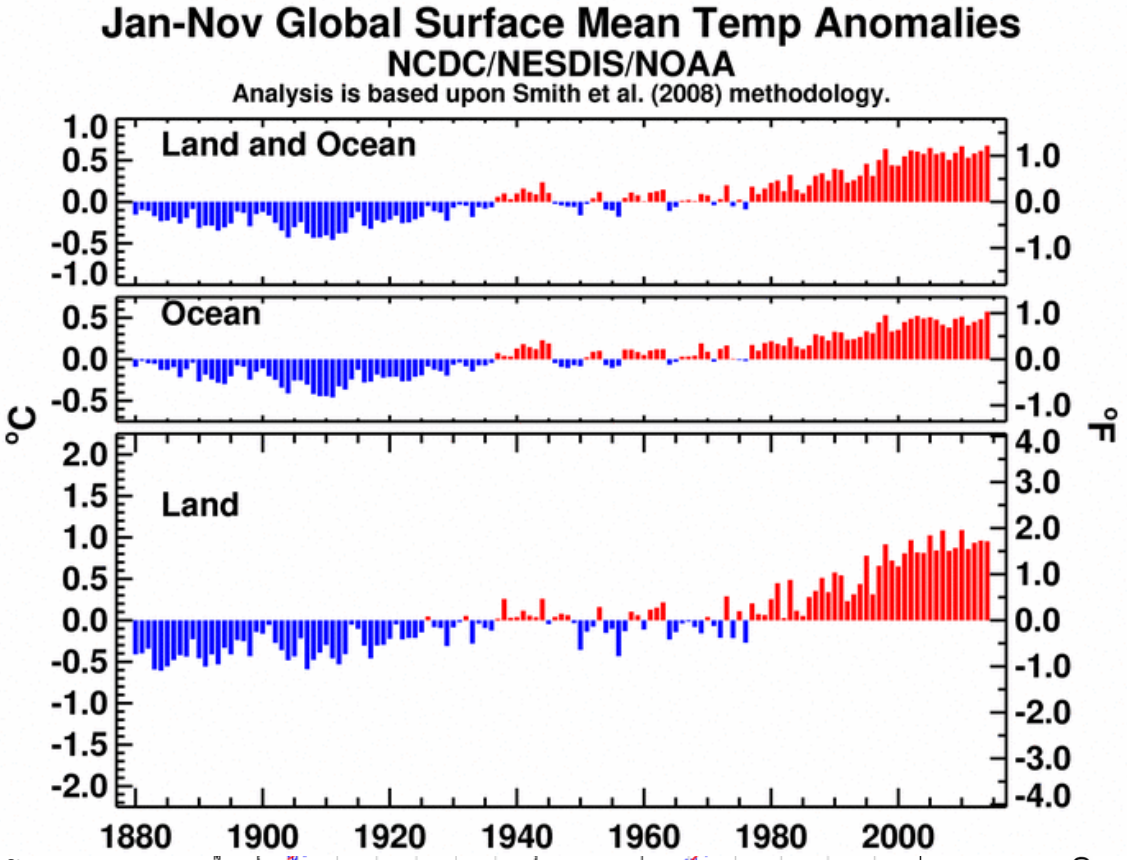
FAQ 2.1, Figure 1. *Atmospheric concentrations of important long-lived greenhouse gases over the last 2,000 years. Increases since about 1750 are attributed to human activities in the industrial era. Concentration units are parts per million (ppm) or parts per billion (ppb), indicating the number of molecules of the greenhouse gas per million or billion air molecules, respectively, in an atmospheric sample. (Data combined and simplified from Chapters 6 and 2 of this report.)*

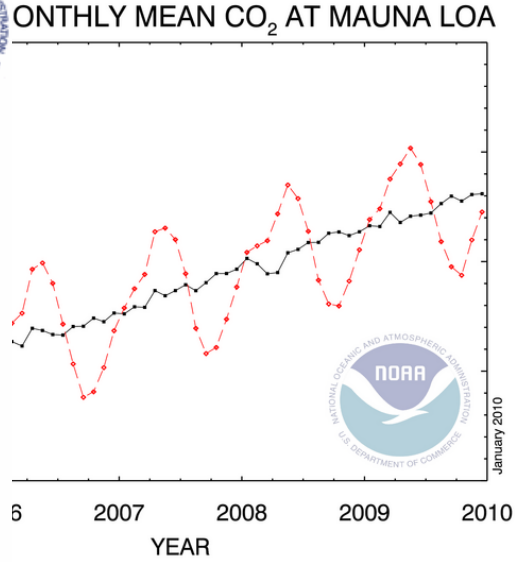


Why Is Man Sometimes Considered the Cause?

CO_2 has not tracked global temperature since 2002. CH_4 plateaued in 1998

This may be a "local variation" but needs to be tracked over longer times (recent data does not track GCM predictions).





Sc
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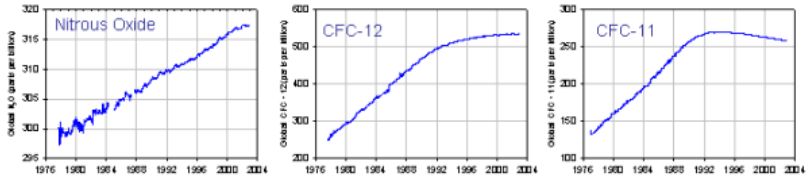
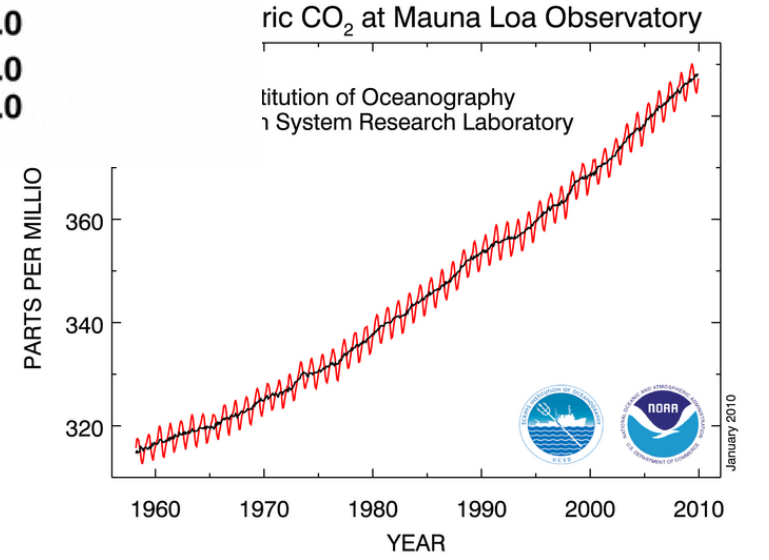
reports (CH_4)



Global trends in major long-lived greenhouse gases through the year 2002. These five gases account for about 97% of the direct climate forcing by long-lived greenhouse gas increases since 1750. The remaining 3% is contributed by an assortment of 10 minor halogen gases, mainly HCFC-22, CFC-113 and CCl_4.



What is the Roll of Solar Irradiance?

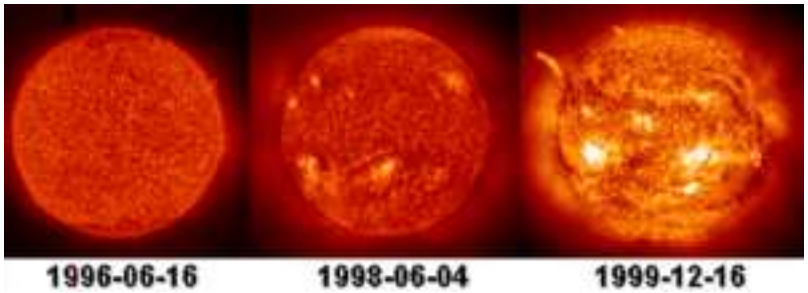
Dr. Alan Doolittle, Ga Tech

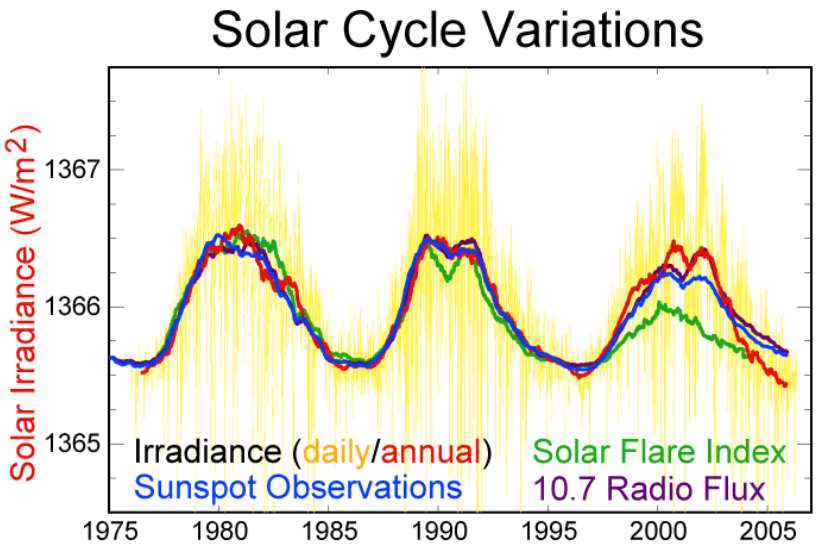
The suns output fluctuates in ~11 and 28 year cycles and is easily observed over relatively short times with dramatically different irradiances.

The spectrum of light can also vary making the Green House effect, which depends on differential frequency absorption very complex.

Significant controversy has recently been proposed based on Mars polar ice caps melting. Some indicate that this is evidence of the Sun's increased activity while others state the Mars environment is more complex and so no conclusion can be drawn.

The 2007 IPCC report ascribes ~10-30% of the total change to irradiance changes but goes on to state that very little is known about the effect of spectral and irradiance variations.



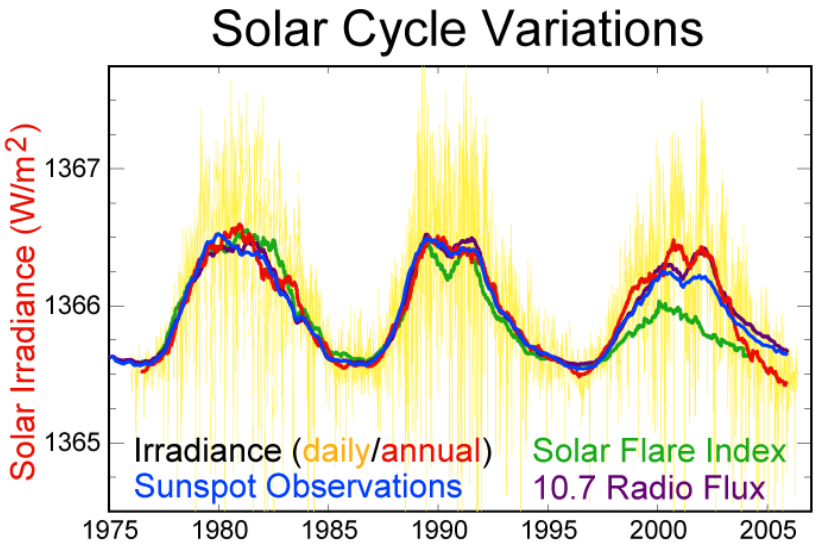


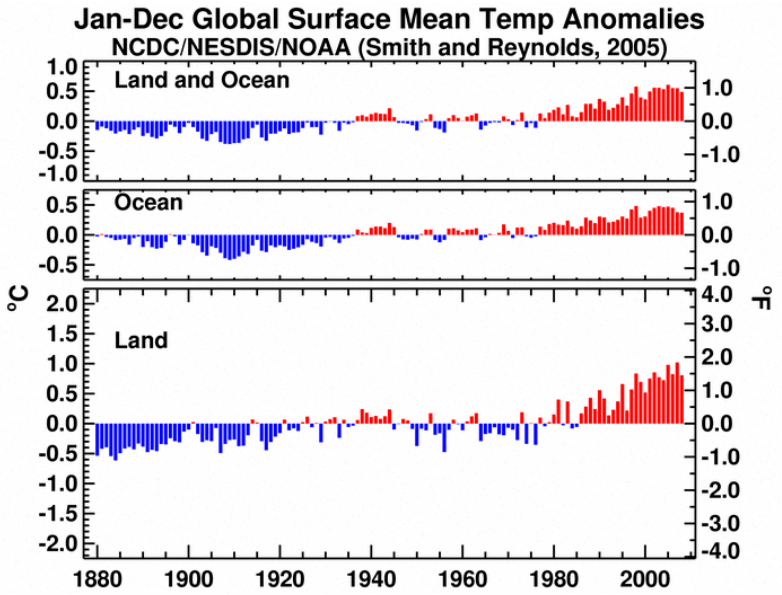
What is the Roll of Solar Irradiance?

Dr. Alan Doolittle, Ga Tech

Statement from IPCC report 2007 below. Curiously, it simply quotes the result from TAR 2001 despite significant increased understanding since then.

The TAR states that the changes in solar irradiance are not the major cause of the temperature changes in the second half of the 20th century unless those changes can induce unknown large feedbacks in the climate system. The effects of galactic cosmic rays on the atmosphere (via cloud nucleation) and those due to shifts in the solar spectrum towards the ultraviolet (UV) range, at times of high solar activity, are largely unknown. The latter may produce changes in tropospheric circulation via changes in static stability resulting from the interaction of the increased UV radiation with stratospheric ozone. More research to investigate the effects of solar behavior on climate is needed before the magnitude of solar effects on climate can be stated with certainty.





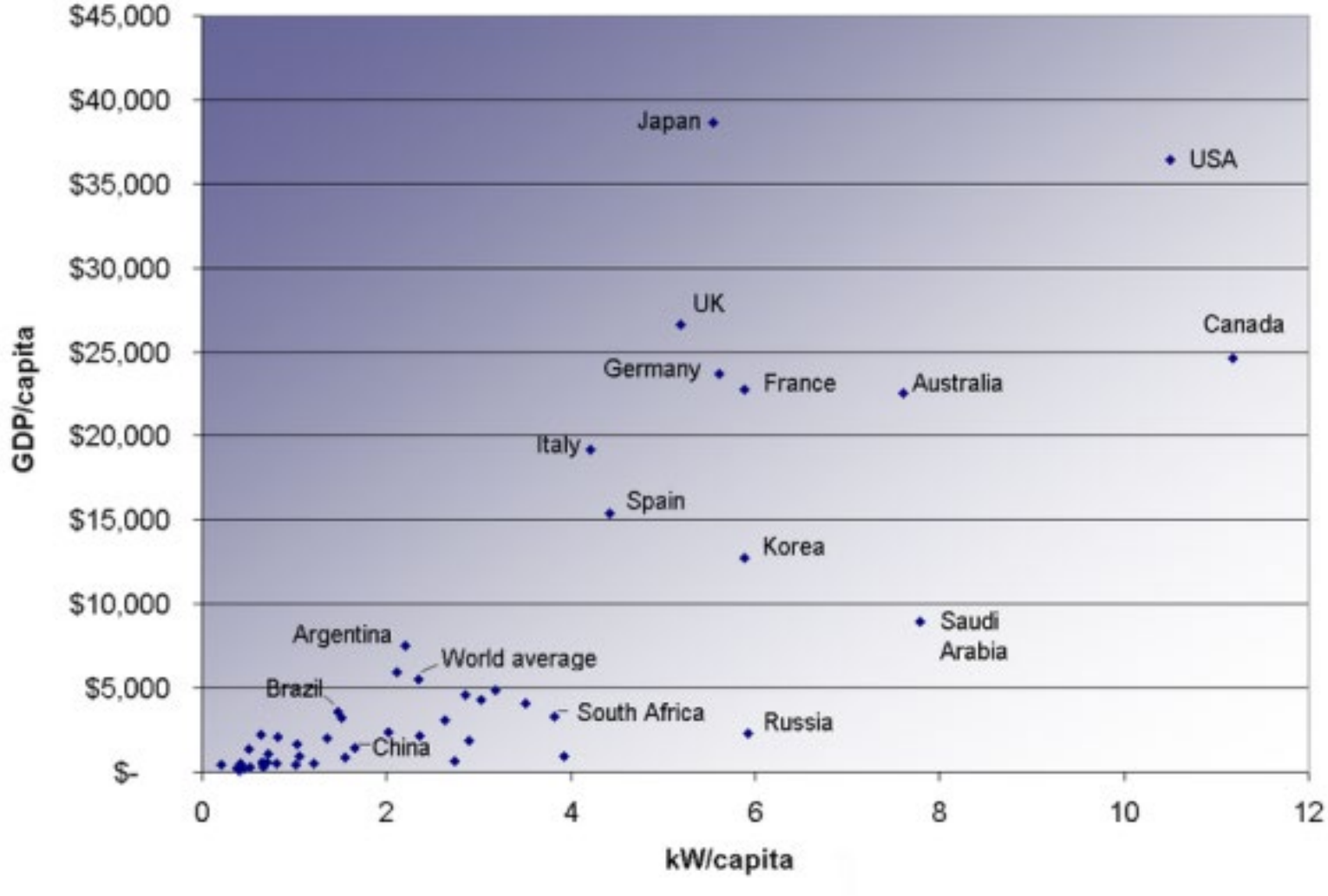
How bad will it get?

Dr. Alan Doolittle, Ga Tech

IPCC 2007 Report (if you choose to believe it)

All models assessed here, for all the non-mitigation scenarios considered, project increases in global mean surface air temperature (SAT) continuing over the 21st century, driven mainly by increases in anthropogenic greenhouse gas concentrations, with the warming proportional to the associated radiative forcing. There is close agreement of globally averaged SAT multi-model mean warming for the early 21st century for concentrations derived from the three non-mitigated IPCC Special Report on Emission Scenarios (SRES: B1, A1B and A2) scenarios (including only anthropogenic forcing) run by the AOGCMs (**warming averaged for 2011 to 2030 compared to 1980 to 1999 is between +0.64°C and +0.69°C**, with a range of only 0.05°C). Thus, this warming rate is affected little by different scenario assumptions or different model sensitivities, and is consistent with that observed for the past few decades (see Chapter 3). Possible future variations in natural forcings (e.g., a large volcanic eruption) could change those values somewhat, but **about half of the early 21st-century warming is committed in the sense that it would occur even if atmospheric concentrations were held fixed** at year 2000 values. **By mid-century (2046–2065),** the choice of scenario becomes more important for the magnitude of multi-model globally averaged SAT warming, **with values of +1.3°C, +1.8°C and +1.7°C** from the AOGCMs for B1, A1B and A2, respectively. About a third of that warming is projected to be due to climate change that is already committed. By late century (2090–2099), differences between scenarios are large, and only about 20% of that warming arises from climate change that is already committed.

Choosing to reduce energy consumption has standard of living consequences



"To care about the economy is to care about human life, since the economy is how life is sustained. It is a source of meaning, as well as sustenance, binding humans to each other in a web of voluntary exchange." Heather MacDonald

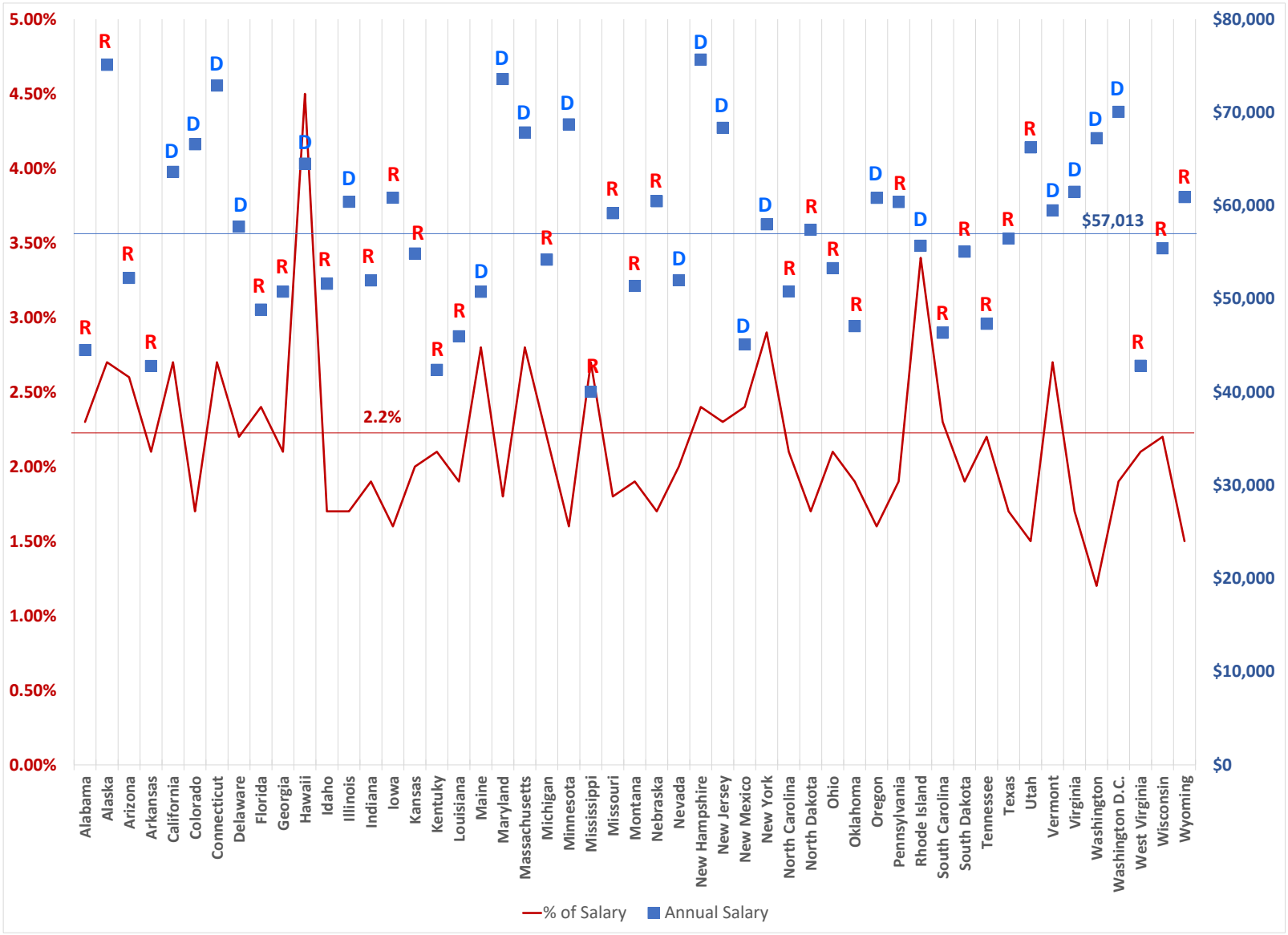
	Averages →	$57,013	10.9 Cents/KWH	$99.3/Month	$1193/Month	2.2%
State	Annual Salary	Electric Rate	Electric Costs	Annual Cost	% of Salary	
Alabama	$44,508	9.37	$85.00	$1,020	2.30%	
Alaska	$75,112	17.94	$163	$1,956	2.70%	
Arizona	$52,248	10.4	$94	$1,228	2.60%	
Arkansas	$42,798	8.15	$74	$888	2.10%	
California	$63,636	15.5	$141	$1,692	2.70%	
Colorado	$66,596	9.78	$89	$1,068	1.70%	
Connecticut	$72,889	17.76	$161	$1,932	2.70%	
Delaware	$57,756	11.21	$102	$1,224	2.20%	
Florida	$48,855	10.64	$96	$1,152	2.40%	
Georgia	$50,768	9.52	$86	$1,032	2.10%	
Hawaii	$64,514	26.17	$238	$2,856	4.50%	
Idaho	$51,624	8.12	$73	$876	1.70%	
Illinois	$60,413	9.28	$84	$1,008	1.70%	
Indiana	$51,983	8.79	$80	$960	1.90%	
Iowa	$60,855	8.47	$77	$924	1.60%	
Kansas	$54,865	10.06	$91	$1,092	2.00%	
Kentuky	$42,387	8.03	$73	$876	2.10%	
Louisiana	$45,992	7.64	$69	$828	1.90%	
Maine	$50,756	12.97	$118	$1,416	2.80%	
Maryland	$73,594	12.14	$110	$1,320	1.80%	
Massachusetts	$67,861	16.86	$153	$1,836	2.80%	
Michigan	$54,203	10.84	$98	$1,176	2.20%	
Minnesota	$68,730	9.69	$88	$1,056	1.60%	
Mississippi	$40,037	9.55	$87	$1,044	2.70%	
Missouri	$59,196	9.3	$84	$1,008	1.80%	
Montana	$51,395	8.93	$81	$972	1.90%	
Nebraska	$60,474	9.04	$82	$984	1.70%	
Nevada	$52,008	9.48	$86	$1,032	2.00%	
New Hampshire	$75,675	16.03	$146	$1,752	2.40%	
New Jersey	$68,357	13.93	$126	$1,512	2.30%	
New Mexico	$45,119	9.68	$88	$1,056	2.40%	
New York	$58,005	15.28	$139	$1,668	2.90%	
North Carolina	$50,797	9.36	$85	$1,020	2.10%	
North Dakota	$57,415	8.85	$80	$960	1.70%	
Ohio	$53,301	9.9	$90	$1,080	2.10%	
Oklahoma	$47,077	7.83	$71	$852	1.90%	
Oregon	$60,834	8.82	$80	$960	1.60%	
Pennsylvania	$60,389	10.41	$94	$1,128	1.90%	
Rhode Island	$55,701	17.05	$155	$1,860	3.40%	
South Carolina	$46,360	9.48	$86	$1,032	2.30%	
South Dakota	$55,065	9.31	$84	$1,008	1.90%	
Tennessee	$47,330	9.35	$85	$1,020	2.20%	
Texas	$56,473	8.63	$78	$936	1.70%	
Utah	$66,258	8.61	$78	$936	1.50%	
Vermont	$59,494	14.36	$130	$1,560	2.70%	
Virginia	$61,486	9.31	$84	$1,008	1.70%	
Washington	$67,243	7.41	$67	$804	1.20%	
Washington D.C.	$70,071	12.08	$110	$1,320	1.90%	
West Virginia	$42,824	8.12	$73	$876	2.10%	
Wisconsin	$55,425	10.93	$99	$1,188	2.20%	
Wyoming	$60,925	7.95	$72	$864	1.50%	

This data was collected from 2015. Also, keep in mind that it doesn't include any distribution related charges or miscellaneous fees that consumers might find on their electric bill increasing the overall amount they pay for electricity every month.
https://www.electricchoice.com/blog/percentage-income-electricity/

The politics of Energy

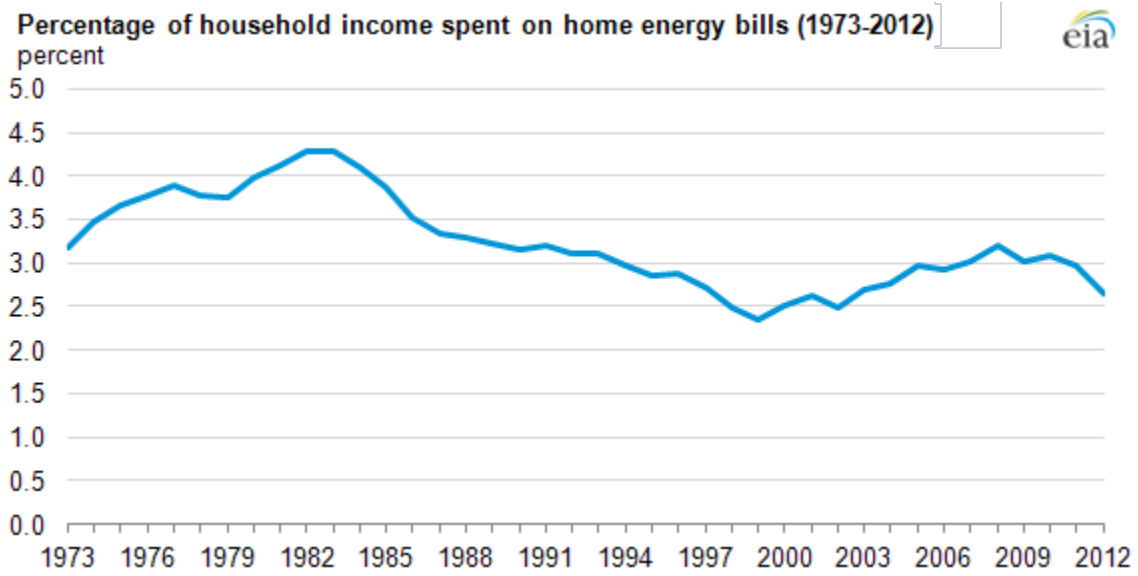
Dr. Alan Doolittle, Ga Tech

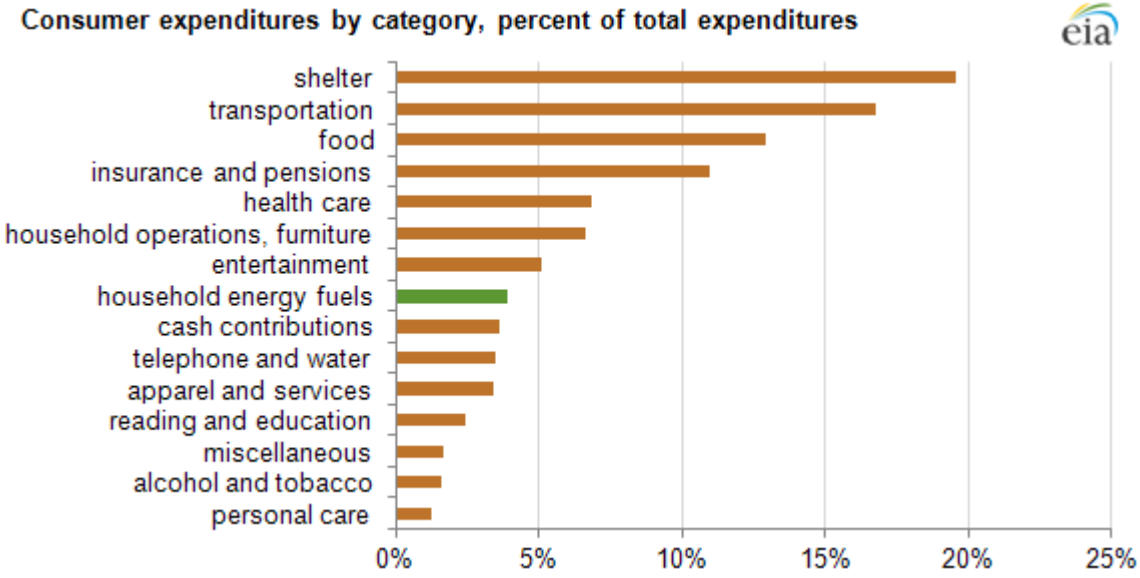
More liberal states have higher costs of living and higher salaries but tend to have on average the same % spent on energy. This leads to a feeling that "they can afford to spend more on energy".



Political leaning based on 2016 presidential vote

United States

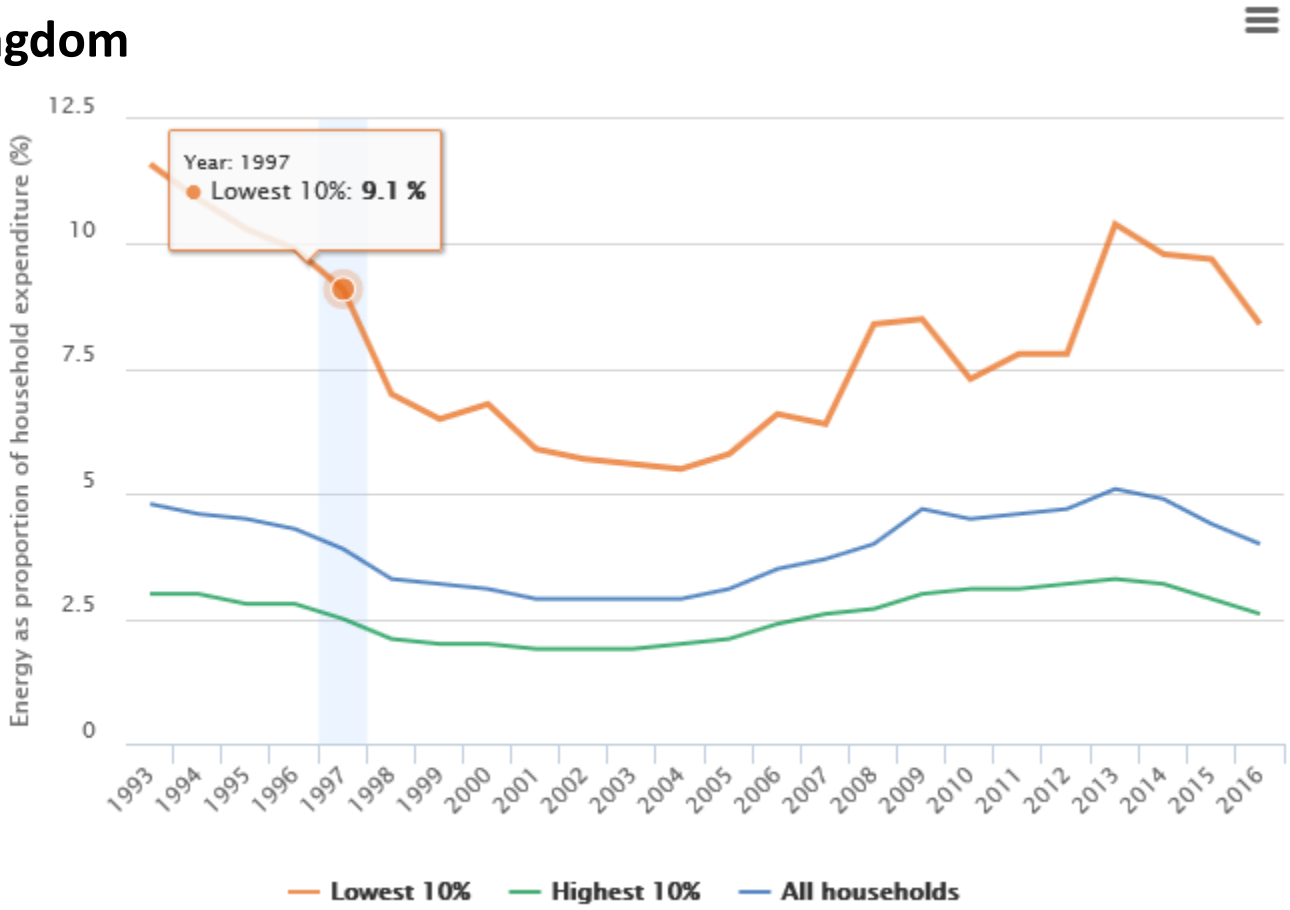




https://www.eia.gov/todayinenergy/detail.php?id=10891

Energy Cost % per Household is Generally much higher in other countries

United Kingdom



https://www.ofgem.gov.uk/data-portal/energy-spend-percentage-total-household-expenditure-uk

TABLE ES1. Median income, utility bill, energy burden, and unit size for households based on income type, building type, building ownership, and household race for groups across all metro areas

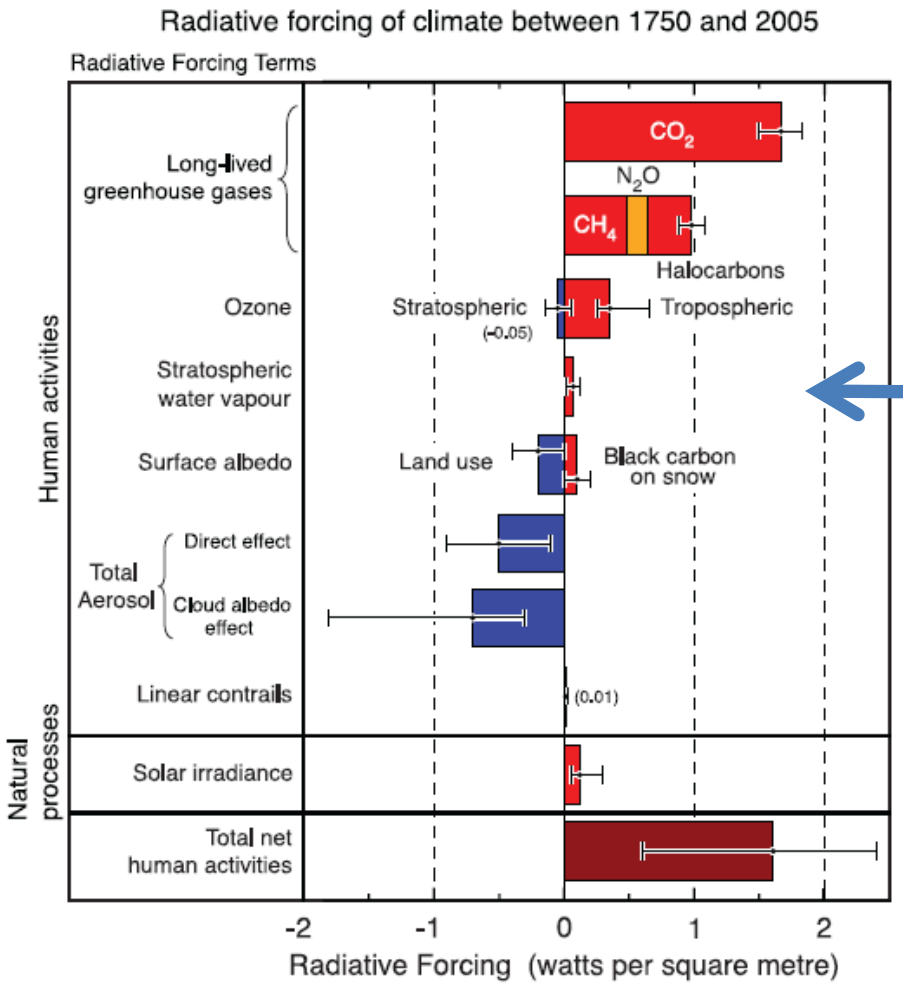
	Household type	Median annual income	Median size of unit (square feet)	Median annual utility spending	Median annual utility costs per square foot	Median energy burden[1]
Income type	Low-income[2] (≤80% AMI)[3]	$24,998	1,200	$1,692	$1.41	7.2%
	Non-low-income	$90,000	1,800	$2,112	$1.17	2.3%
	Low-income multifamily (≤80% AMI)	$21,996	800	$1,032	$1.29	5.0%
	Non-low-income multifamily	$71,982	950	$1,104	$1.16	1.5%
Building ownership	Renters	$34,972	1,000	$1,404	$1.40	4.0%
	Owners	$68,000	1,850	$2,172	$1.17	3.3%
Head of household race	White	$58,000	1,600	$1,956	$1.22	3.3%
	African-American	$34,494	1,290	$1,920	$1.49	5.4%
	Latino	$39,994	1,200	$1,704	$1.42	4.1%
All households	N/A	$53,988	1,573	$1,932	$1.23	3.5%

[1] Energy burden is the percentage of household income that is spent on energy bills. To calculate median energy burden, we calculated energy burden for all households and then took the median. This value differs from the median energy burden that is calculated using median annual utility spending and income.
[2] Low-income includes both single- and multifamily households. [3] Area median income (AMI) is the median dollar amount that divides the population into two equal parts.
Source: American Housing Survey (Census Bureau 2011 and 2013a).

ENERGY EFFICIENCY FOR ALL ACEEE

Which gases are thought to be bad?

Dr. Alan Doolittle, Ga Tech



Water vapor has an enormous absorbance but has minimal effect. Why?

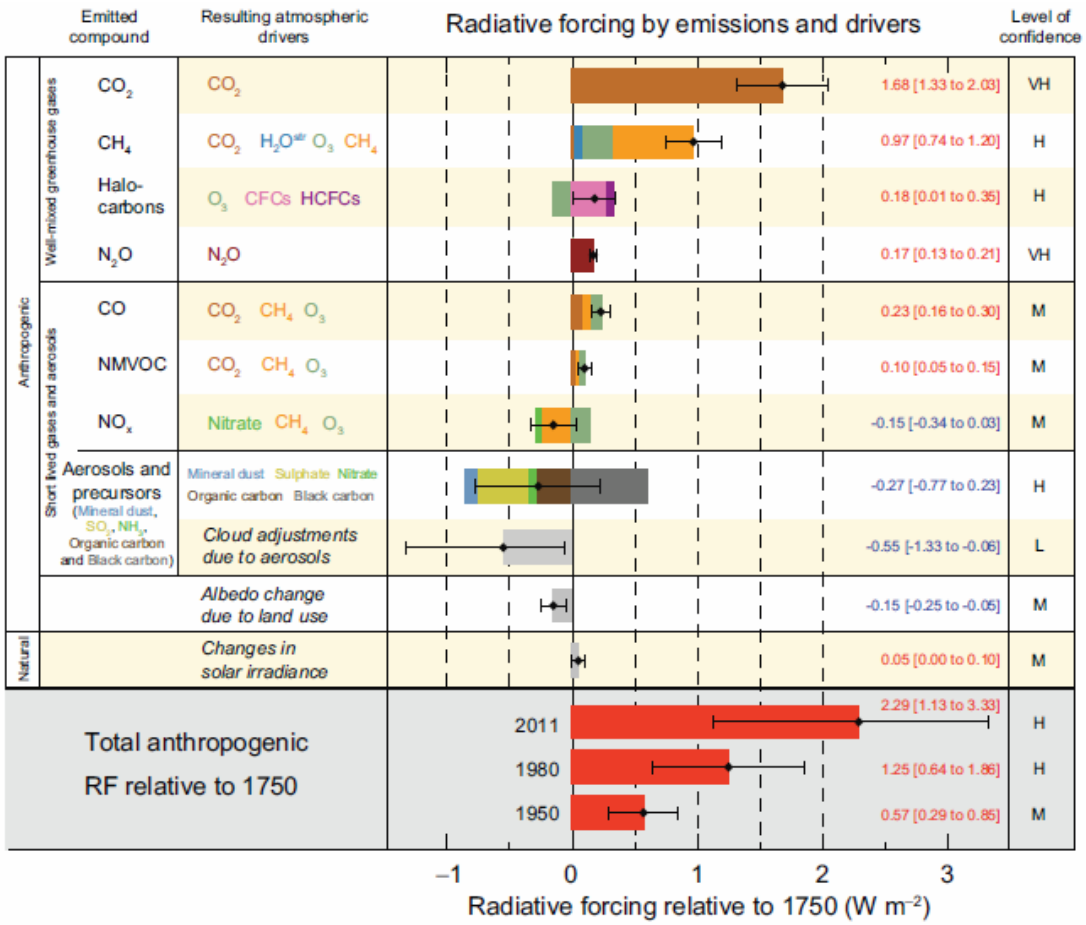
FAQ 2.1, Figure 2. *Summary of the principal components of the radiative forcing of climate change. All these radiative forcings result from one or more factors that affect climate and are associated with human activities or natural processes as discussed in the text. The values represent the forcings in 2005 relative to the start of the industrial era (about 1750). Human activities cause significant changes in long-lived gases, ozone, water vapour, surface albedo, aerosols and contrails. The only increase in natural forcing of any significance between 1750 and 2005 occurred in solar irradiance. Positive forcings lead to warming of climate and negative forcings lead to a cooling. The thin black line attached to each coloured bar represents the range of uncertainty for the respective value. (Figure adapted from Figure 2.20 of this report.)*

IPCC 2007 Report

Which gases are thought to be bad?

Dr. Alan Doolittle, Ga Tech

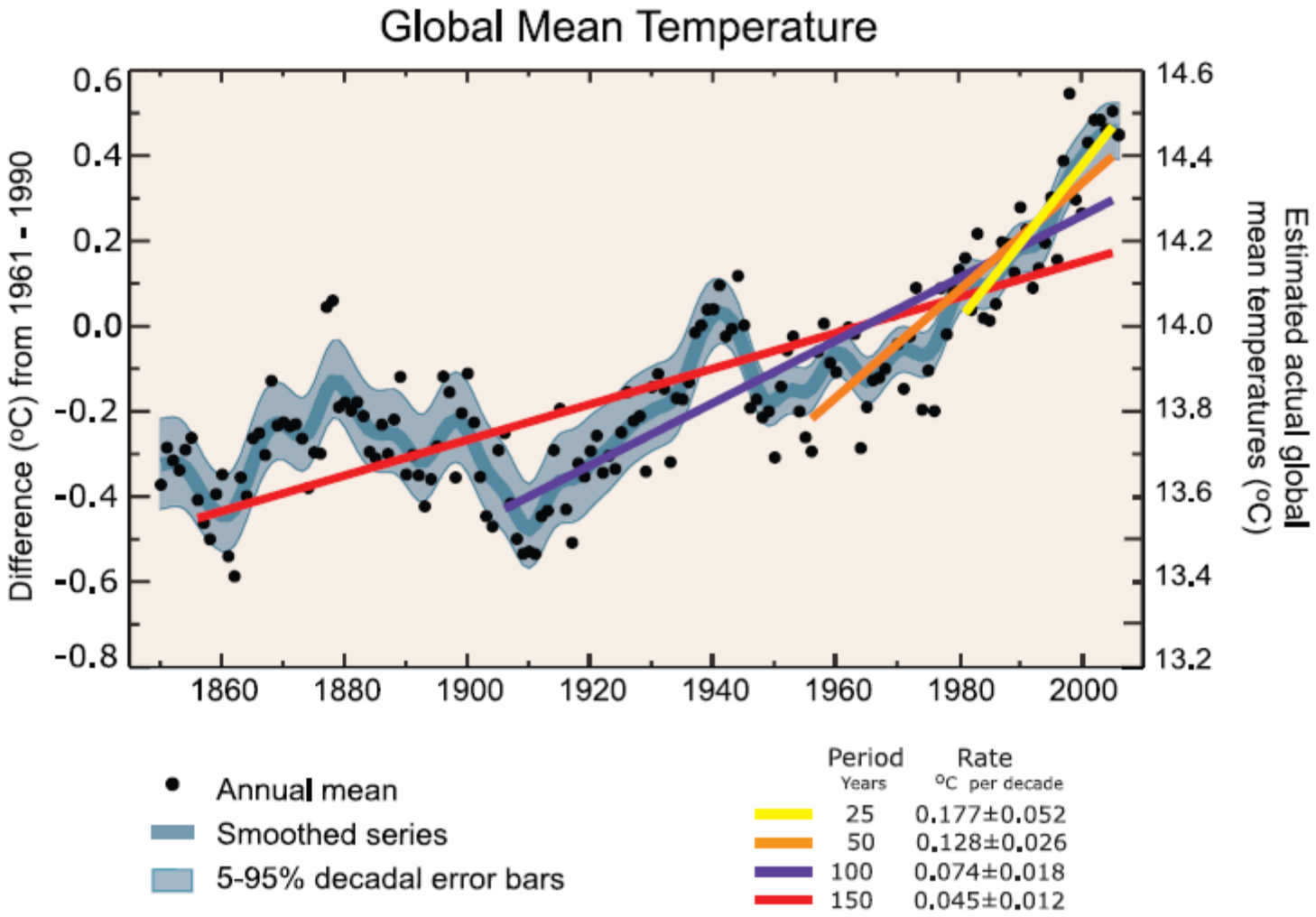
IPCC 2013 Report



Water vapor not present in newest report despite having overwhelming absorbance.

What are the currently most understood Temperatures?

Dr. Alan Doolittle, Ga Tech

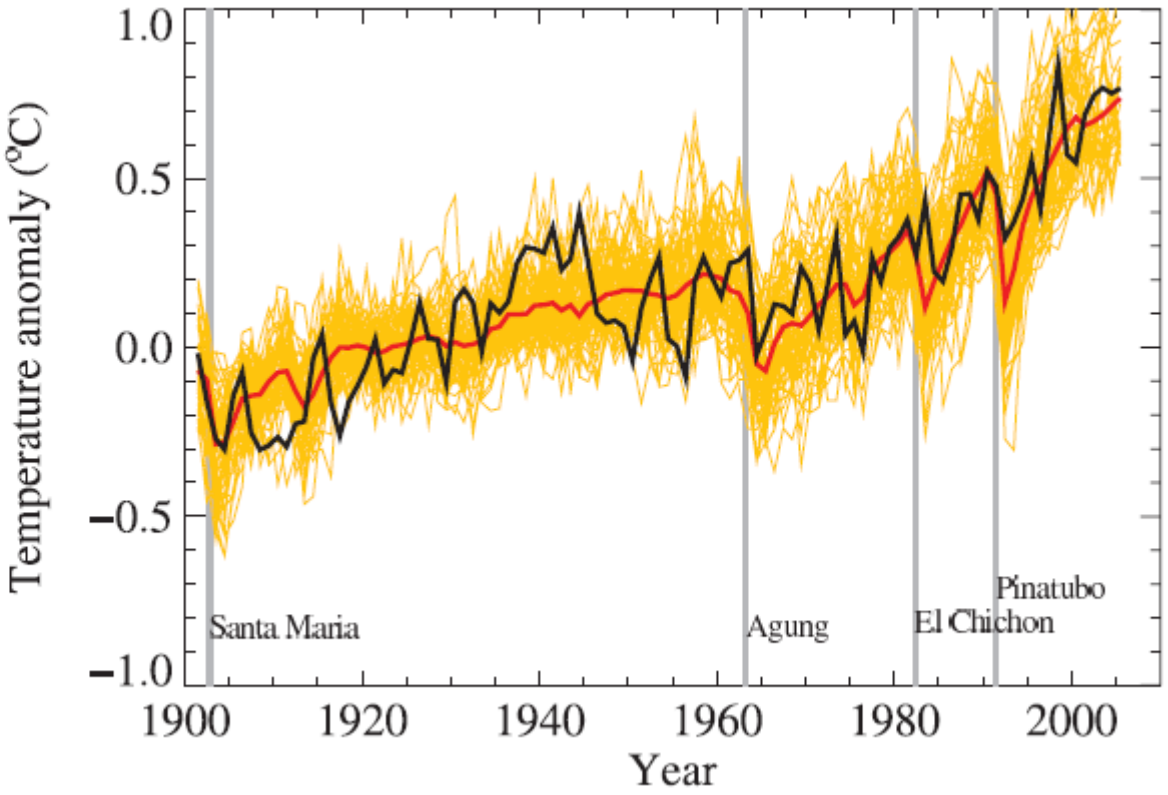


IPCC 2007 Report

What about natural disruptive events like volcanoes?

FAQ 8.1, Figure 1. *Global mean near-surface temperatures over the 20th century from observations (black) and as obtained from 58 simulations produced by 14 different climate models driven by both natural and human-caused factors that influence climate (yellow). The mean of all these runs is also shown (thick red line). Temperature anomalies are shown relative to the 1901 to 1950 mean. Vertical grey lines indicate the timing of major volcanic eruptions. (Figure adapted from Chapter 9, Figure 9.5. Refer to corresponding caption for further details.)*

IPCC 2007 Report



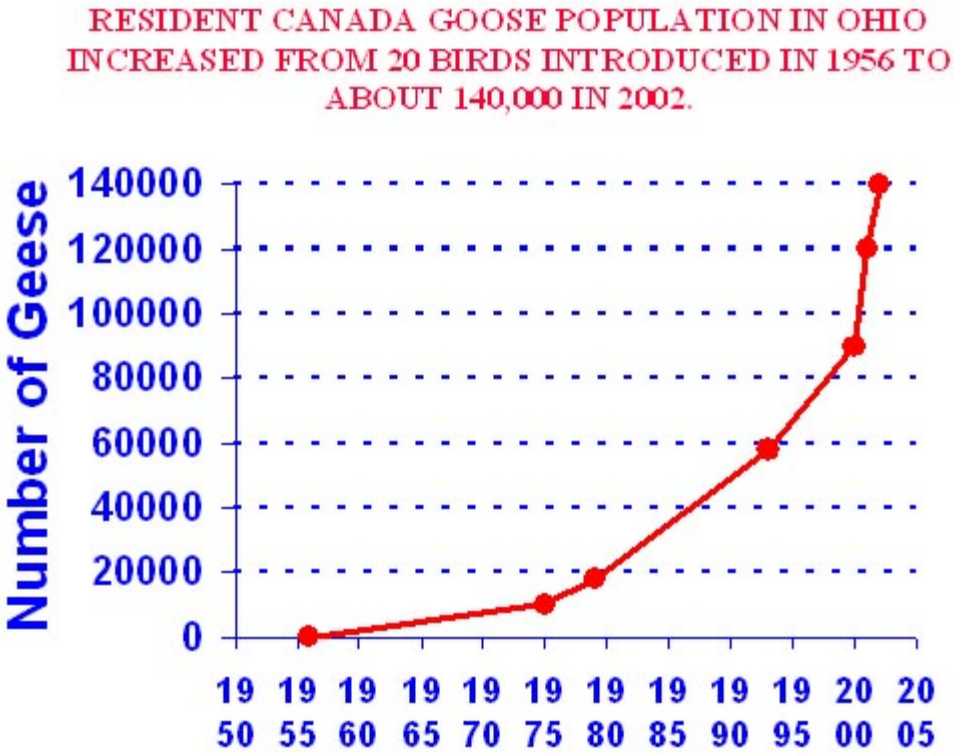
Volcanoes tend to cool the planet! Who would have "thunk" it.

The "Year Without a Summer" was 1816, in which severe summer climate abnormalities destroyed crops in much of the northern hemisphere. Was a result of historic low in solar activity and a series of major volcanic eruptions including Mount Tambora , Indonesia the winter of 1815, the largest known eruption in over 1,600 years. Enormous amounts of "greenhouse gases " and ash were released. Ash tends to cool through what is known as the aerosol effect.

Why do some people not believe ACC is real/a serious concern?

Some suggest caution about correlations without strict causal models . Causal models are extremely hard to have in climatology.

Did the CO_2 cause the temperature rise or did the temperature rise result in more CO_2? What do you do with your air conditioner on a hot day? Turning it up consumes more power



The number of Canadian Geese “invading” Ohio also correlates with Global Temperatures. Does that mean the geese are the cause of global warming?

Why do some people not believe ACC is real/a serious concern?

Other Reasons:

Lack of independent "blind" data sets. The US congress commissioned Wegmann report sited the concern that due to the problem of compiling such enormous amounts of data climatologists are using the same set of observations. This was further compounded by the perceived withholding of the raw data and the purging of dissenting voices from the climatology community as exemplified in the "climate gate" scandal.

Several very noted scientists including some on the National Academy of Science have had serious doubts (See writings of MIT's Sloane professor Lindzen and >30,000 signees of the petition project , including >9000 Ph.D's, as well as NAS past president Frederick Seitz).

The data feeding the models is so "massaged" and "corrected", sometimes without clear reason that outsiders from the climatology community (a community which derives significant financial gain from ACC) are suspicious.

Several noted public scandals: Climate gate, hockey puck model statistically proven erroneous , NOAA temperature station misplacements and Al Gore's movie/book loosing British legitimacy court battle among others

The IPCC report authors and most of the reviewers and editors are not established climatologists but are instead public policy specialists and environmentalists. Fewer than 10% of the climatologists present signed the 2001 report.

Errors compound quadratically so the more variables you have the greater the total error

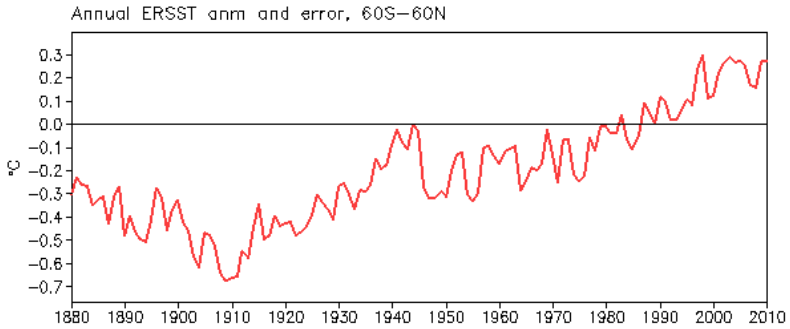
$$Total\ Error\ in\ F = \sqrt{\left(\frac{\partial F}{\partial \alpha}\Delta\alpha\right)^2 + \left(\frac{\partial F}{\partial \beta}\Delta\beta\right)^2 + ...\left(\frac{\partial F}{\partial \varpi}\Delta\varpi\right)^2} \text{ for independent values } \alpha, \beta, ...\varpi$$

$$Total\ Error\ in\ F = \sqrt{\left(\frac{\partial F}{\partial \alpha}\Delta\alpha\right)^2 + \left(\frac{\partial F}{\partial \beta}\Delta\beta\right)^2 + \left(\frac{\partial F}{\partial \alpha}\frac{\partial F}{\partial \beta}\Delta\alpha\Delta\beta\right) + ...} \text{ for interacting values } \alpha, \beta, ...\varpi$$

Did we start our averaging during a cold span and so now temperatures “are hotter” or is it okay to discard data that does not fit ones conclusion?

Extended Reconstructed Sea Surface Temperature (ERSST) v3b

The Extended Reconstructed Sea Surface Temperature (ERSST) dataset is a global monthly sea surface temperature analysis derived from the International Comprehensive Ocean–Atmosphere Dataset with missing data filled in by statistical methods. This monthly analysis begins in January 1854 continuing to the present and includes anomalies computed with respect to a 1971–2000 monthly climatology. The newest version of ERSST, version 3b, is optimally tuned to exclude under-sampled regions for global averages. In contrast to version 3, ERSST v3b does not include satellite data, which were found to cause a cold bias significant enough to change the rankings of months.



Annual ERSST v3b anomaly from 1880–2010 from 60°S and 60°N (red solid line). Note that the data are more reliable after the 1940s. The magnitude of the temperature increase in recent decades is much greater than the uncertainty in the data.

Background Information

The paper, "Improvements to NOAA's Historical Merged Land-Ocean Surface Temperature Analysis (1880–2006)," describes the update from ERSST v2 to ERSST v3, and both *in situ* and satellite Advanced Very High

Background Information

The paper, "Improvements to NOAA's Historical Merged Land-Ocean Surface Temperature Analysis (1880–2006)," describes the update from ERSST v2 to ERSST v3, and both *in situ* and satellite Advanced Very High Resolution Radiometer SST data are included. The current version (ERRST v3) has satellite SST data not included in previous versions. However, the addition of satellite data led to residual biases. The ERSST v3b analysis is exactly as described in the ERSST v3 paper with one exception: ERSST v3b does not use satellite SST data. The ERSST v3 improvements are justified by testing with simulated data.

ERSST v3 has improved low frequency tuning that reduces the SST anomaly damping before 1930 using the optimized parameters. However, the addition of satellite SSTs introduced a small residual cold bias (in the order of 0.01°C). The Advanced Very High Resolution Radiometer is an infrared-based instrument. There must be clear-sky conditions to obtain infrared measurements, and cloud contaminated data are often difficult to identify. This contamination leads to a cold SST bias in the retrievals. There were attempts to correct these biases as mentioned in "Improvements to NOAA's Historical Merged Land-Ocean Surface Temperature Analysis (1880–2006)," but the adjustment did not fully compensate for the cold bias. While this small difference did not strongly influence the long-term trend, it was sufficient to change the rankings of the warmest months in the time series. Therefore, use of satellite SST data was discontinued. Except for the removal of the satellite aspect, ERSST v3b processing is identical to version 3.

https://www.ncdc.noaa.gov/data-access/marineocean-data/extended-reconstructed-sea-surface-temperature-ersst-v3b

Academic Roasting of Highly Respected Anti-ACC Scientists

Richard S. Lindzen Until his retirement in 2013, he was Alfred P. Sloan Professor of Meteorology at the Massachusetts Institute of Technology. He was a lead author of Chapter 7, "Physical Climate Processes and Feedbacks," of the Intergovernmental Panel on Climate Change's Third Assessment Report on climate change. He has criticized the scientific consensus about climate change and what he has called "climate alarmism."

John Stewart Coleman (October 15, 1934 – January 20, 2018) was an American TV weatherman and co-founder of The Weather Channel

Judith A. Curry is an American climatologist and former chair of the School of Earth and Atmospheric Sciences at the Georgia Institute of Technology.

https://judithcurry.com/2017/01/03/jc-in-transition/

A deciding factor was that I no longer know what to say to students and postdocs regarding how to navigate the CRAZINESS in the field of climate science. Research and other professional activities are professionally rewarded only if they are channeled in certain directions approved by a politicized academic establishment — funding, ease of getting your papers published, getting hired in prestigious positions, appointments to prestigious committees and boards, professional recognition, etc.
How young scientists are to navigate all this is beyond me, and it often becomes a battle of scientific integrity versus career suicide (I have worked through these issues with a number of skeptical young scientists).

Vocal voice for change:

Richard Lindzen, the Alfred P. Sloan Professor of Meteorology at MIT and a member of the National Academy of Sciences who has long questioned climate change orthodoxy, is skeptical that a sunnier outlook is upon us.

“I actually doubt that,” he said. Even if some of the roughly $2.5 billion in taxpayer dollars currently spent on climate research across 13 different federal agencies now shifts to scientists less invested in the calamitous narrative, Lindzen believes groupthink has so corrupted the field that funding should be sharply curtailed rather than redirected.

“They should probably cut the funding by 80 to 90 percent until the field cleans up,” he said. “Climate science has been set back two generations, and they have destroyed its intellectual foundations.”

Vocal voice for change:

Judith Curry – Former Chair of Earth and Atmospheric Science at Ga Tech has written boldly and eloquently about the problems within climatology science community. These include lack of statistical error analysis and more disturbingly systematic efforts to silence dissenting voices. Examples of her writings are found on her blog, having retired out of frustration and tired of being attacked.

https://judithcurry.com/about/

https://judithcurry.com/2019/08/14/the-latest-travesty-in-consensus-enforcement/

https://judithcurry.com/2019/11/12/legacy-of-climategate-10-years-later/

Solution – Plant a Tree?

A "young" growing tree scrubs about 13 KG of CO_2/year
Older mature trees consume ~1/2 this CO_2

$5.7x10^{18}$ KG air * 100 ppb CO_2 reduction would require ~ 41 billion new trees to be planted.

The UN Billion Tree Campaign was launched in November 2006.

As of September 2009, 7 billion trees were purportedly planted (over 2.6 billion in China alone).

Few cheaper solutions can be found!

Brings a new meaning to "Tree Hugger".

What do you believe and why?

Home work 1: