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 man’s understanding of its trends upward or downward have always been oscillating.

As we will see, the same data viewed with different statistical 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

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 man’s actions are causing the earth’s 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$_2$O), carbon dioxide (CO$_2$), methane (CH$_4$) and nitrous oxide (N$_2$O) 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

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”.

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**Solar radiation powers the climate system.**

Some solar radiation is reflected by the Earth and the atmosphere.

About half the solar radiation is absorbed by the Earth's surface and warms it.

Infrared radiation is emitted from the Earth's surface.
Understanding the Green House Effect

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/m²). Climate predictions are required to take into account MANY complex and often poorly understood systems.

From IPCC report 2007
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?

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 CO₂ 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 CO₂ (specifically) often predicted. The models that suggest this connection are amazingly immature and do not trend with observations in the last decade. H₂O vapor absorbs more radiated power than CO₂ 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

- 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?

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

![Graph showing Jan-Dec Global Mean Temperature over Land & Ocean](Image)
Not All “Data” are Created Equal...

ERSST 3B
Jan-Dec Global Mean Temperature over Land & Ocean

ERSST 3

ERSST 5

No Slow Down in Global Warming

Extended reconstructed sea surface temperature (ERSST)
Most Recent Data

NOAA’s Published Data Through 2019.

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):

ERSST v1

ERSST v2

ERSST v3


ERSST v4


ERSST v5


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.

Sources: Figure, British Petroleum (overestimates nuclear capacity)
Scott Henry, “Georgia Power takes a fresh look at nuclear power”, Creative Loafing, 22 August 2007

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

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

https://www.eia.gov/tools/faqs/faq.php?id=74&t=11
Transportation Fuels – a hard problem

“Average” USA Electric Car

\[ (0.3\text{KWh/Mile}) \times (15,000\text{Miles/Year}) = \]
\[ 4500 \text{ KWh} \times \]
\[ $0.12/\text{KHW} = \]
\[ $546/\text{Year} & \]
\[ 3.18 \text{ MT CO}_2/\text{Year} \]

Average USA Electric Utility CO2 Production

\[ = 7.07 \times 10^{-4} \text{ metric tons CO}_2/\text{kWh} \]
\[ (1,558.8 \text{ lbs CO}_2/\text{MWh} \times (4.536 \times 10^4 \text{ metric tons/lb}) \times 0.001 \text{ MWh/kWh}) \]

“Average” USA Gasoline Car

\[ (1\text{Gal}/28\text{ Miles}) \times (15,000\text{Miles/Year}) = \]
\[ 535 \text{ Gal/Year} \times \]
\[ $2.00/\text{Gal} = \]
\[ $1071/\text{Year} & \]
\[ 4.75 \text{ MT CO}_2/\text{Year} \]

\[ \text{CO}_2 \text{ Production per Gallon Gasoline} = 8.887 \times 10^{-3} \text{ metric tons CO}_2/\text{gallon of gasoline} \]

\[ \text{8,887 grams of CO}_2/\text{gallon of gasoline} \]

\[ \text{7.07} \times 10^{-4} \text{ metric tons CO}_2/\text{kWh} \]

\[ (1,558.8 \text{ lbs CO}_2/\text{MWh} \times (4.536 \times 10^{-4} \text{ metric tons/lb}) \times 0.001 \text{ MWh/kWh}) \]

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.

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 CO₂, Methane and Nitrous Oxide

CO₂ has increased by ~37% from it’s middle ages value
CO₂ has not tracked global temperature since 2002. CH₄ plateaued in 1998. This may be a "local variation" but needs to be tracked over longer times (recent data does not track GCM predictions).

Scientific credibility is hampered by conflicting reports (CH₄).
What is the Roll of Solar Irradiance?

The sun’s 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?

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?

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
<table>
<thead>
<tr>
<th>State</th>
<th>Averages</th>
<th>Electric Rate</th>
<th>Electric Costs</th>
<th>Annual Cost</th>
<th>% of Salary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alabama</td>
<td>$44,508</td>
<td>9.37</td>
<td>$85.00</td>
<td>$1,020</td>
<td>2.30%</td>
</tr>
<tr>
<td>Alaska</td>
<td>$75,112</td>
<td>17.94</td>
<td>$163</td>
<td>$1,956</td>
<td>2.70%</td>
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<td>Arizona</td>
<td>$52,248</td>
<td>10.4</td>
<td>$94</td>
<td>$1,228</td>
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<tr>
<td>Arkansas</td>
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<td>8.15</td>
<td>$74</td>
<td>$888</td>
<td>2.10%</td>
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<tr>
<td>California</td>
<td>$63,636</td>
<td>15.5</td>
<td>$141</td>
<td>$1,692</td>
<td>2.70%</td>
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<tr>
<td>Colorado</td>
<td>$66,596</td>
<td>9.78</td>
<td>$89</td>
<td>$1,068</td>
<td>1.70%</td>
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<td>Connecticut</td>
<td>$72,889</td>
<td>17.76</td>
<td>$161</td>
<td>$1,932</td>
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<td>Delaware</td>
<td>$57,756</td>
<td>11.21</td>
<td>$92</td>
<td>$1,224</td>
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<td>Florida</td>
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<td>10.64</td>
<td>$96</td>
<td>$1,152</td>
<td>2.40%</td>
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<tr>
<td>Georgia</td>
<td>$50,768</td>
<td>9.52</td>
<td>$86</td>
<td>$1,032</td>
<td>2.10%</td>
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<td>Hawaii</td>
<td>$64,514</td>
<td>26.17</td>
<td>$238</td>
<td>$2,856</td>
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<td>8.12</td>
<td>$73</td>
<td>$876</td>
<td>1.70%</td>
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<tr>
<td>Illinois</td>
<td>$60,413</td>
<td>9.28</td>
<td>$84</td>
<td>$1,008</td>
<td>1.70%</td>
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<tr>
<td>Indiana</td>
<td>$51,983</td>
<td>8.79</td>
<td>$80</td>
<td>$960</td>
<td>1.90%</td>
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<tr>
<td>Iowa</td>
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<td>8.47</td>
<td>$77</td>
<td>$924</td>
<td>1.60%</td>
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<td>10.06</td>
<td>$91</td>
<td>$1,092</td>
<td>2.00%</td>
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<td>Louisiana</td>
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<td>7.64</td>
<td>$69</td>
<td>$828</td>
<td>1.90%</td>
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<td>Maine</td>
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<td>12.97</td>
<td>$118</td>
<td>$1,416</td>
<td>2.80%</td>
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<td>Maryland</td>
<td>$73,594</td>
<td>12.14</td>
<td>$110</td>
<td>$1,320</td>
<td>1.80%</td>
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<tr>
<td>Massachusetts</td>
<td>$67,861</td>
<td>16.86</td>
<td>$153</td>
<td>$1,836</td>
<td>2.80%</td>
</tr>
<tr>
<td>Michigan</td>
<td>$54,203</td>
<td>10.84</td>
<td>$98</td>
<td>$1,176</td>
<td>2.20%</td>
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<tr>
<td>Minnesota</td>
<td>$58,730</td>
<td>9.69</td>
<td>$88</td>
<td>$1,056</td>
<td>1.60%</td>
</tr>
<tr>
<td>Mississippi</td>
<td>$40,913</td>
<td>9.55</td>
<td>$87</td>
<td>$1,044</td>
<td>2.70%</td>
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<tr>
<td>Missouri</td>
<td>$59,196</td>
<td>9.3</td>
<td>$84</td>
<td>$1,008</td>
<td>1.80%</td>
</tr>
<tr>
<td>Montana</td>
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<td>8.93</td>
<td>$81</td>
<td>$972</td>
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<td>Nebraska</td>
<td>$60,474</td>
<td>9.04</td>
<td>$82</td>
<td>$984</td>
<td>1.70%</td>
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<tr>
<td>Nevada</td>
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<td>9.48</td>
<td>$86</td>
<td>$1,032</td>
<td>2.00%</td>
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<tr>
<td>New Hampshire</td>
<td>$75,675</td>
<td>16.03</td>
<td>$146</td>
<td>$1,752</td>
<td>2.40%</td>
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<td>New Jersey</td>
<td>$68,357</td>
<td>13.93</td>
<td>$126</td>
<td>$1,512</td>
<td>2.30%</td>
</tr>
<tr>
<td>New Mexico</td>
<td>$45,119</td>
<td>9.68</td>
<td>$88</td>
<td>$1,056</td>
<td>2.40%</td>
</tr>
<tr>
<td>New York</td>
<td>$58,055</td>
<td>15.28</td>
<td>$139</td>
<td>$1,668</td>
<td>2.90%</td>
</tr>
<tr>
<td>North Carolina</td>
<td>$50,797</td>
<td>9.36</td>
<td>$85</td>
<td>$1,020</td>
<td>2.10%</td>
</tr>
<tr>
<td>North Dakota</td>
<td>$57,415</td>
<td>8.85</td>
<td>$80</td>
<td>$960</td>
<td>1.70%</td>
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<tr>
<td>Ohio</td>
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<td>9.9</td>
<td>$90</td>
<td>$1,080</td>
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<td>Oklahoma</td>
<td>$47,077</td>
<td>7.83</td>
<td>$71</td>
<td>$852</td>
<td>1.90%</td>
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<tr>
<td>Oregon</td>
<td>$60,834</td>
<td>8.82</td>
<td>$80</td>
<td>$960</td>
<td>1.60%</td>
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<tr>
<td>Pennsylvania</td>
<td>$60,389</td>
<td>10.41</td>
<td>$94</td>
<td>$1,128</td>
<td>1.90%</td>
</tr>
<tr>
<td>Rhode Island</td>
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<td>17.05</td>
<td>$155</td>
<td>$1,860</td>
<td>3.40%</td>
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<tr>
<td>South Carolina</td>
<td>$46,360</td>
<td>9.48</td>
<td>$86</td>
<td>$1,012</td>
<td>2.30%</td>
</tr>
<tr>
<td>South Dakota</td>
<td>$55,065</td>
<td>9.31</td>
<td>$84</td>
<td>$1,008</td>
<td>1.90%</td>
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<tr>
<td>Tennessee</td>
<td>$47,330</td>
<td>9.35</td>
<td>$85</td>
<td>$1,020</td>
<td>2.20%</td>
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<tr>
<td>Texas</td>
<td>$56,473</td>
<td>8.63</td>
<td>$78</td>
<td>$936</td>
<td>1.70%</td>
</tr>
<tr>
<td>Utah</td>
<td>$66,258</td>
<td>8.61</td>
<td>$78</td>
<td>$936</td>
<td>1.50%</td>
</tr>
<tr>
<td>Vermont</td>
<td>$59,494</td>
<td>14.36</td>
<td>$130</td>
<td>$1,560</td>
<td>2.70%</td>
</tr>
<tr>
<td>Virginia</td>
<td>$61,486</td>
<td>9.31</td>
<td>$84</td>
<td>$1,008</td>
<td>1.70%</td>
</tr>
<tr>
<td>Washington</td>
<td>$67,243</td>
<td>7.41</td>
<td>$67</td>
<td>$804</td>
<td>1.50%</td>
</tr>
<tr>
<td>Washington D.C.</td>
<td>$70,071</td>
<td>12.08</td>
<td>$110</td>
<td>$1,320</td>
<td>1.90%</td>
</tr>
<tr>
<td>West Virginia</td>
<td>$42,824</td>
<td>8.12</td>
<td>$73</td>
<td>$876</td>
<td>2.10%</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>$55,425</td>
<td>10.93</td>
<td>$99</td>
<td>$1,188</td>
<td>2.20%</td>
</tr>
<tr>
<td>Wyoming</td>
<td>$60,925</td>
<td>7.95</td>
<td>$72</td>
<td>$864</td>
<td>1.50%</td>
</tr>
</tbody>
</table>

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

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

- % of Salary
- Annual Salary
United States

Percentage of household income spent on home energy bills (1973-2012)

Consumer expenditures by category, percent of total expenditures

https://www.eia.gov/todayinenergy/detail.php?id=10891
Energy Cost % per Household is Generally much higher in other countries

United Kingdom

**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

<table>
<thead>
<tr>
<th>Income type</th>
<th>Household type</th>
<th>Median annual income</th>
<th>Median size of unit (square feet)</th>
<th>Median annual utility spending</th>
<th>Median annual utility costs per square foot</th>
<th>Median energy burden¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low-income² (≤80% AMI)³</td>
<td>$24,998</td>
<td>1,200</td>
<td>$1,692</td>
<td>$1.41</td>
<td>7.2%</td>
</tr>
<tr>
<td></td>
<td>Non-low-income</td>
<td>$90,000</td>
<td>1,800</td>
<td>$2,112</td>
<td>$1.17</td>
<td>2.3%</td>
</tr>
<tr>
<td></td>
<td>Low-income multifamily (≤80% AMI)</td>
<td>$21,996</td>
<td>800</td>
<td>$1,032</td>
<td>$1.29</td>
<td>5.0%</td>
</tr>
<tr>
<td></td>
<td>Non-low-income multifamily</td>
<td>$71,982</td>
<td>950</td>
<td>$1,104</td>
<td>$1.16</td>
<td>1.5%</td>
</tr>
<tr>
<td>Building ownership</td>
<td>Renters</td>
<td>$34,972</td>
<td>1,000</td>
<td>$1,404</td>
<td>$1.40</td>
<td>4.0%</td>
</tr>
<tr>
<td></td>
<td>Owners</td>
<td>$68,000</td>
<td>1,850</td>
<td>$2,172</td>
<td>$1.17</td>
<td>3.3%</td>
</tr>
<tr>
<td>Head of household race</td>
<td>White</td>
<td>$58,000</td>
<td>1,600</td>
<td>$1,956</td>
<td>$1.22</td>
<td>3.3%</td>
</tr>
<tr>
<td></td>
<td>African-American</td>
<td>$34,494</td>
<td>1,290</td>
<td>$1,920</td>
<td>$1.49</td>
<td>5.4%</td>
</tr>
<tr>
<td></td>
<td>Latino</td>
<td>$39,994</td>
<td>1,200</td>
<td>$1,704</td>
<td>$1.42</td>
<td>4.1%</td>
</tr>
<tr>
<td>All households</td>
<td>N/A</td>
<td>$53,988</td>
<td>1,573</td>
<td>$1,932</td>
<td>$1.23</td>
<td>3.5%</td>
</tr>
</tbody>
</table>

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).
Which gases are thought to be bad?

Water vapor has an enormous absorbance but has minimal effect. Why?
### Which gases are thought to be bad?

**IPCC 2013 Report**

<table>
<thead>
<tr>
<th>Emitted compound</th>
<th>Resulting atmospheric drivers</th>
<th>Radiative forcing by emissions and drivers</th>
<th>Level of confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CO₂</strong></td>
<td>CO₂</td>
<td>1.68 [1.53 to 2.03]</td>
<td>VH</td>
</tr>
<tr>
<td><strong>CH₄</strong></td>
<td>CO₂ H₂O NH₃ O₃ CH₄</td>
<td>0.97 [0.74 to 1.20]</td>
<td>H</td>
</tr>
<tr>
<td><strong>Halocarbons</strong></td>
<td>O₃ CFCs HCFCs</td>
<td>0.18 [0.01 to 0.36]</td>
<td>H</td>
</tr>
<tr>
<td><strong>N₂O</strong></td>
<td>N₂O</td>
<td>0.17 [0.13 to 0.21]</td>
<td>VH</td>
</tr>
</tbody>
</table>

*Water vapor not present in newest report despite having overwhelming absorbance.*
What are the currently most understood Temperatures?

IPCC 2007 Report
What about natural disruptive events like volcanoes?

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 CO₂ cause the temperature rise or did the temperature rise result in more CO₂? 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

\[
Total\ Error\ in\ F = \sqrt{\left(\frac{\partial F}{\partial \alpha} \Delta \alpha\right)^2 + \left(\frac{\partial F}{\partial \beta} \Delta \beta\right)^2 + \ldots + \left(\frac{\partial F}{\partial \sigma} \Delta \sigma\right)^2} \quad \text{for independent values } \alpha, \beta, \ldots \sigma
\]

\[
Total\ Error\ in\ F = \sqrt{\left(\frac{\partial F}{\partial \alpha} \Delta \alpha\right)^2 + \left(\frac{\partial F}{\partial \beta} \Delta \beta\right)^2 + \left(\frac{\partial F}{\partial \alpha} \frac{\partial F}{\partial \beta} \Delta \alpha \Delta \beta\right) + \ldots} \quad \text{for interacting values } \alpha, \beta, \ldots \sigma
\]
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.

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 (ERSST 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.

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 CO₂/year
Older mature trees consume ~1/2 this CO₂

5.7x10^{18} KG air * 100 ppb CO₂ 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: