Lecture 1: Understanding the Greenhouse Effect and Anthropogenic Climate Change

Reading Assignment – Homework 1 Reading Assignments and Chapter 1 of PVCDROM

Dr. Alan Doolittle
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 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 (H₂O), carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O) 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”.
Understanding the Green House Effect

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Is anyone purposing to regulate rain?
Understanding the Green House Effect 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.

The IPCC findings suggest 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.
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. 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 of 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 very recent allegations dissenting voices within climatetology. 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.
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) whereas others give it less weight and “correct it” based on removing perceived offsets.
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

3) The general trend extends back to ~1900
Not All “Data” are Created Equal...

**ERNST 3B**

Jan-Dec Global Mean Temperature over Land & Ocean

Anomaly (°C) relative to 1901-2000

1880 1900 1920 1940 1960 1980 2000

**ERNST 3**

Global Temperature (°F)

Year

CO₂ Concentration

1880 1900 1920 1940 1960 1980 2000

NOAA/NCDC

**NOAA Publically Disseminated Graph**

No Slow Down in Global Warming

Global Mean Surface Temperature: Running Means

Temperature Anomaly (°C)


1951-1980 Base Period

**ERNST 5**
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 peta watts= $10^{15}$ W) mans energy usage is estimated to be $\sim 15.04$ terawatts (0.005%), the majority of which comes from fossil fuels.

Compare this to a “large” nuclear power plant capacity of $\sim 1$ gigawatt and one sees the magnitude of the problem. As of 2005, there were 441 nuclear power plans producing only 367 GW (many less today). 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
Where does the energy go?

Strong Governmental Regulations and Taxes Effect Production

https://www.eia.gov/todayinenergy/detail.php?id=26912
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.
Why Is Man Sometimes Considered the Cause?

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.

Scientific credibility is hampered by conflicting reports (CH₄).

Global Trends in Major Greenhouse Gases to 1/2003

Atmospheric CO₂ at Mauna Loa Observatory

Scripps Institution of Oceanography
NOAA Earth System Research Laboratory
Don’t Get Your Science from CNN 😊

No significant statistical increase since ~2002
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 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.
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
Which gases are thought to be bad?

Water vapor has an enormous absorbance but has minimal effect. Why? Feedback mechanisms.
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>
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<tr>
<td><strong>Well-mixed greenhouse gases</strong></td>
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<td>CO₂</td>
<td>CO₂</td>
<td>1.68 [1.53 to 2.03]</td>
<td>VH</td>
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<td>CH₄</td>
<td>CO₂, H₂O, O₃, CH₄</td>
<td>0.87 [0.74 to 1.20]</td>
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<td>Halo-carbons</td>
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<td>O₃, CF₄, HCFCs</td>
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<td>0.18 [0.01 to 0.35]</td>
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<td>N₂O</td>
<td>N₂O</td>
<td>0.17 [0.13 to 0.21]</td>
<td>VH</td>
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<td><strong>Atmospheric</strong></td>
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<td>CO</td>
<td>CO₂, CH₄, O₃</td>
<td>0.23 [0.16 to 0.30]</td>
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<td>NMVOC</td>
<td>CO₂, CH₄, O₃</td>
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<td>NOₓ</td>
<td>Nitrate, CH₄, O₃</td>
<td>-0.15 [-0.34 to 0.03]</td>
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<td><strong>Short-lived gases and aerosols</strong></td>
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<td>Aerosols and precursors</td>
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<td>-0.27 [-0.37 to 0.22]</td>
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<td>Black carbon</td>
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<td>-0.55 [-1.33 to -0.06]</td>
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<td>Cloud adjustments due to aerosols</td>
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<td>Albedo change due to land use</td>
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<td>-0.15 [-0.23 to -0.09]</td>
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<td><strong>Natural</strong></td>
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<td>Changes in solar irradiance</td>
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<td>0.05 [0.00 to 0.10]</td>
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<td><strong>Total anthropogenic RF relative to 1750</strong></td>
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<td>2011</td>
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<td>2.29 [1.13 to 3.03]</td>
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<td>1980</td>
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<td>1.25 [0.64 to 1.88]</td>
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<td>1950</td>
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<td>0.57 [0.29 to 0.85]</td>
<td>M</td>
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Water vapor not present in newest report despite having overwhelming absorbance.
What are the currently most understood Temperatures?

IPCC 2007 Report

IPCC 2013 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 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 recent 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)

What is the role of economic factors like the carbon credit economy?

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

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

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 quadratic ally so the more variables you have the greater the total error

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

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

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.

Lindzen was a dissenting voice on the IPCC 2007 report that counter proposed a water based stabilization of the earth’s temperatures.

“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.”
Solution – Plant a Tree?

A “young” growing tree scrubs about 13 KG of CO₂/year
Older mature trees consume ~1/2 this CO₂

\[ 5.7 \times 10^{18} \text{ KG air} \times 100 \text{ ppb CO}_2 \text{ reduction would require } \sim 41 \text{ billion new trees to be planted.} \]

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: