Central Coast Climate Science Education
Dr. Ray Weymann ray.climate@charter.net

Last edit: May 17, 2024

What's causing the current rapid rise in global temperatures: A little-discussed and strong piece of evidence

For whom this essay is intended: A general audience without an extensive science background.

Outline

I show the most recent data demonstrating the very rapid rise of global surface temperatures, the last year of which is the record-shattering year of 2023. I review a previous essay in which it was shown that there is nothing in the record of past climates going back 24,000 years showing such a rapid rise. This record, as well as from computer simulations, means that we cannot attribute this rise to natural variability.

I then review the concept of "forcings"--processes external to the earth's climate system which alter the energy balance of the earth's climate system. The two most important ones are: a) The increase in carbon dioxide caused by our combustion of fossil fuels and b) A change in the brightness of the sun.

A change in the brightness of the sun as a possible cause of the temperature rise, is contradicted by the satellite measurements of the sun's brightness covering this period.

But, in addition to this, there is a little-discussed but strong piece of evidence in *favor of* the *increase in carbon dioxide* in the atmosphere brought about by our combustion of fossil fuels as being responsible for this rapid warming and *against* a brightening of the sun being responsible, as some have argued.

I then present the results of a recent paper which analyses and compares the observation and calculations of the gradual change in temperature from 1985 to 2023 of three levels of the troposphere (the lower level of the atmosphere extending up to about 35,000 feet) and three levels of the stratosphere (the rarified region of the atmosphere at greater altitudes.) With increasing altitude of these six levels there is a trend. At the lowest level there is *strong warming.* At the 3rd level, at about the altitude where the troposphere ends and the stratosphere begins, there is neither a warming nor cooling trend. Then in the top three levels, there is *cooling* over these years, with the rate of this cooling *increasing* with increasing height of these three levels in the stratosphere.

The calculations incorporating the actual observed increase in carbon dioxide over this interval (and incorporating the actual observed *lack* of increase of solar brightness) agree very well with the observations. The observations disagree with what would be expected if a brightening sun were the main cause of the current rapid warming.

With this additional new evidence in mind, I conclude the main body of this Essay with my opinion that:
a) The increase in the rapid warming of the earth's surface is the result of adding carbon dioxide from fossil fuel combustion.
b) This evidence is now so strong that I believe this conclusion is ***incontrovertible,*** an opinion shared by the authors of the paper I discussed and by the vast majority of climate scientists.
c) The time has come when we need to focus our attention on the need to switch to the most economical and efficient clean energy sources as quickly as possible.
d) We must work hard to dispel the feeling of hopelessness and despair among many, especially our children and young adults, and dispel the belief that it is too late to avoid a climate catastrophe.

In the **Appendix** I give a simple non-mathematical explanation of why *cooling* of the *stratosphere* is expected with *increasing* amounts of atmospheric carbon dioxide, even though increasing levels of atmospheric carbon dioxide produce increased *heating* at the earth's surface and the *lower levels* of the atmosphere, as observed. In addition, I explain why a brightening of the sun would produce *heating* of **both** the troposphere and stratosphere, contrary to the observations.

End Outline

In a recent essay[1] I showed the historical record of global temperatures, dating from about 1880, when enough thermometers were distributed around the world that a global average temperature could be reasonably computed.

I addressed the question of whether the rate of increase of the global temperature over the last 5 decades is "unprecedented". The conclusion was that indeed it *is* unprecedented, at least for the past 24,000 years. Earlier than this there is little evidence having the necessary accuracy in time or temperature to address this question.

I then argued that *even if* there were--contrary to fact-- past episodes of equally rapid rise, that is not where our focus should be. The question that we should be focused on is: *what is the cause of our current rapid rise in temperature, since this rise, and the*

[1] (http://www.centralcoastclimatescience.org/uploads/5/3/8/1/53812733/unprecented_rise.pdf)

accompanying changes in our climate, are what affects <u>*us.*</u> If we cannot answer this question, then we cannot learn what actions, if any, can be taken to arrest this rise--and the increasingly damaging consequences from global warming we are already seeing. The purpose of the present essay is therefore to answer this question.

Many readers of this website will already know the answer to which the overwhelming amount of scientific evidence points: namely the increase in the amount of greenhouse gases in the atmosphere, especially carbon dioxide, resulting from our use of fossil fuels.

But I want to discuss a piece of evidence pointing to the same cause which is not often discussed outside of the professional literature.

As a point of reference for the present discussion I have reproduced Figure 1 from the previous essay and its legend:

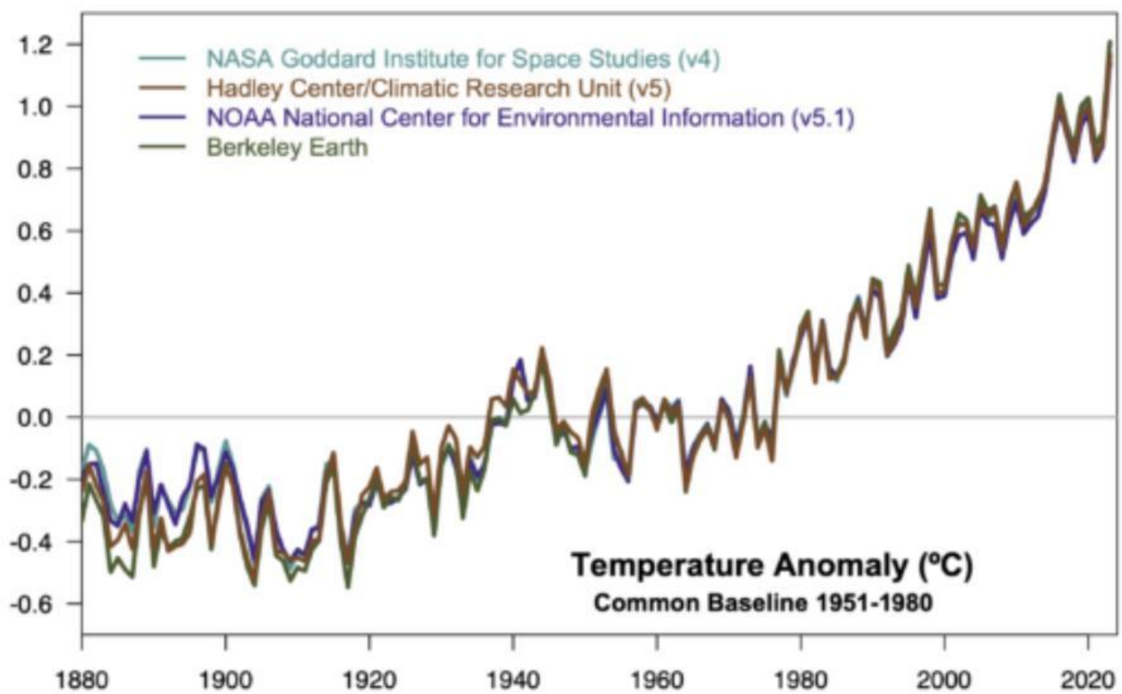

Figure 1. The plot of the global surface temperature averaged over the land and ocean surface[2]*. Note three things: First, the temperature is on the centigrade scale. (To convert the graph to the Fahrenheit scale multiply by 1.8.) Second, the graph shows, not the actual temperature, but the temperature* ***<u>compared to</u>*** *<u>the</u> <u>actual temperatures averaged over the years 1951 to 1980</u>. (To convert these relative temperatures to the approximate actual centigrade temperature, add 15*

[2] https://www.realclimate.org/index.php/archives/2024/01/not-just-another-dot-on-the-graph/

degrees.) Third, there are actually 4 different results plotted, which are determined independently by 4 different research groups, but they are barely distinguishable.

What can cause the global temperature to change: "Natural Variability" and "Forcings"

The global temperature, and the features of the climate associated with it, can change for various reasons. We can divide these changes into two types: "Natural Variability" and "Forcings".

Natural variability

Even without any externally induced changes in the climate system, as described below under the term "forcings", changes in the global temperature can, and do, occur. Such temperature changes, and associated climate events occur because semi-random fluctuations within the climate system itself can cause such changes, at least over periods of years or even decades. These fluctuations are best thought of as long term "weather" rather than long term changes in the climate.

The best known example of such natural variability is the change between the pattern of winds and ocean temperatures across the tropical Pacific ocean as it changes between what are termed "El Nino," "La Nina," and intermediate "Neutral" conditions. (See here[3] for a non-technical discussion of El Nino.)

Figure 2, below, shows the influence of these three conditions of the Pacific ocean upon the global temperature record. Note that for years where there are El Nino conditions (red dots) the temperature is usually (but not always) a little higher than the nearest Neutral (black squares) or La Nina ((blue circles) years, and conversely for La Nina years. Figure 2 demonstrates two important points: First, that *the El Nino/La Nina phenomenon has little effect on the trend of the overall current rapid rise in global temperature*.

[3] https://oceanservice.noaa.gov/facts/ninonina.html

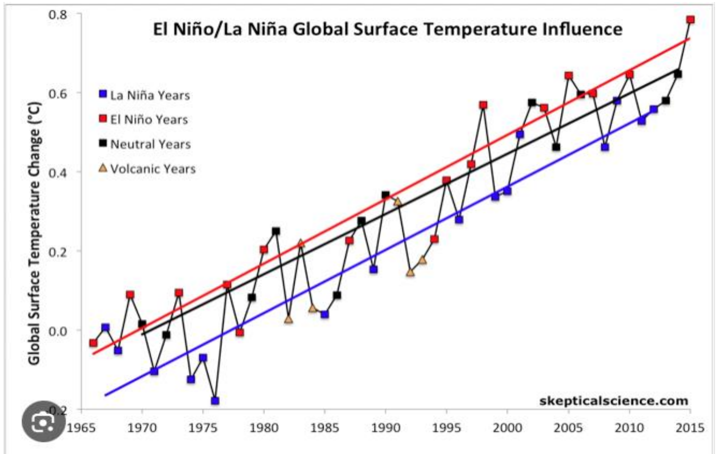

Figure 2: The global temperature through 2015[4] *with El Nino, Neutral, and La Nina years marked in red circles, black squares and blue circles, respectively. See the text for details. Note that this graph ends in 2015, whereas figure 1 runs through 2023.*

Second, that the excursions between El Nino and La Nina years are only about 0.2 degrees, *so they certainly cannot account for the current temperature rise of about 1.5 degrees* since 1880, shown in figure 1.

There are of course, other examples of natural variability with longer periods, and some "climate change deniers" have maintained that a significant portion of the entire 5 decades steep rise in global temperature is due to natural variability of some kind. Specifically, it is sometimes claimed that a longer period of natural variability, called the "Pacific Decadal Oscillation" (PDO) is responsible. But the evidence simply does not support this.[5] But in addition to the discussion in footnote 5, this can also be ruled out by the very same results already discussed in the previous essay on "Unprecedented rise..." referenced in footnote 1: *There are simply no instances of anything like the present rapid rise based on records over the past 24,000 years whether from natural variability or anything else.*

Therefore, the question to now focus on is whether the other class of causes for changes in climate, namely "forcings," could be responsible for the rise in temperature shown in Figure 1, and if so, which particular kind of forcing.

Forcings

A discussion of the concept of "forcings" was discussed in one of my climate science tutorials.[6] There, I suggested for a definition of a forcing *".... a process external to the climate system that ... changes the Earth's energy balance, but which is not itself*

---

[4] This figure is a "frozen" screen shot taken from the Figure 2 of: https://skepticalscience.com/record-hot-2015-glimpse-future-global-warming.html

[5] https://skepticalscience.com/Pacific-Decadal-Oscillation-basic.htm

[6] http://www.centralcoastclimatescience.org/uploads/5/3/8/1/53812733/topic2_forcings.pdf

affected by the change in the earth's energy balance, and the associated climate change, it induces."

An obvious example of a "forcing" is a change in the sun's brightness. A change in the amount of energy received from the sun certainly will affect the energy received by the earth. And this change in the earth's energy "budget" will cause changes in the earth's overall climate. But these changes in the earth's climate certainly do not react back on the sun itself in any way. So that is an example of a forcing.

A second example of a forcing is the change in the amount of greenhouse gases in the earth's atmosphere *due to combustion of fossil fuels by humans*. The warming caused by the greenhouse effect associated primarily with the carbon dioxide produced by this combustion has had a major impact on the energy balance of the earth's climate system. But this climate system itself does not react back on *us* to force *us* to change our use of fossil fuels. So this increase in the amount of greenhouse gases in the atmosphere caused by our use of fossil fuels is also a forcing.

These two forcings, a change in the sun's brightness and an increase in greenhouse gases by our use of fossil fuels, are the two main possibilities we need to discuss. The question then, is which of these two forcing is responsible for the current rapid rise in global temperature. As figure 1 shows, it is about 0.2 ^{o}C *per decade* over the past 50 years. The overwhelming number of research climate scientists agree that it is the increase in greenhouse gases in the atmosphere (especially carbon dioxide) resulting from burning fossil fuels that is the cause for this rapid rise, and not a change in the sun's brightness. But what is the evidence that leads to this consensus?

Could a change in the sun's brightness be the cause of the present rapid warming?

The data simply do not support this. See here[7] for a recent detailed discussion of the arguments. This is mostly simply illustrated by the following figure, which is figure 2 in the reference of footnote 7. It shows that *over the last 50 years*, while surface temperatures *increased* at the unprecedented rate we have been discussing, *as has the concentration of carbon dioxide*, the *energy received from the sun* has not *similarly increased*.

[7] https://skepticalscience.com/solar-activity-sunspots-global-warming.htm

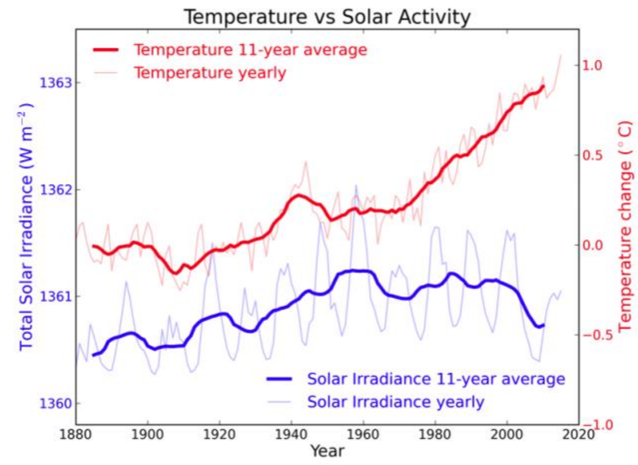

Figure 3. This plot is figure 2 in the reference in footnote 7.
The change in the brightness of the sun is shown by the ***blue*** *curve.*
Since 1979 direct satellite measures have been available; prior
to that, sunspot counts serve as a "proxy" for the sun's brightness.
The ***red*** *curve is the change in the earth's surface temperature.*

Changes in the sun's brightness likely <u>did</u> play a role in affecting the earth's surface temperature up to about 1940. But as the carbon dioxide levels rapidly grew, the greenhouse effect from carbon dioxide and other greenhouse gases *overwhelmed the influence of changes in solar brightness.*

<u>**Another powerful line of evidence for human-caused climate change: Stratospheric cooling**</u>

There is another very strong piece of evidence, which is not much mentioned outside of the professional literature. It demonstrates that an increase in the sun's brightness is <u>**not**</u> responsible for our current warming and that the increase in carbon dioxide <u>**is.**</u> Namely, the *<u>cooling</u>* of the **stratosphere** which has occurred concurrently with the *<u>warming</u>* of the earth's surface and the lower levels of the atmosphere.

The stratosphere is the region of our atmosphere above the lowest region (called the **troposphere**) and at earth's mid-latitudes it begins at about 6 or 7 miles in altitude and extends up to about 30 miles or even higher. Everything we call "weather" occurs in the troposphere. In the stratosphere, the air is very stable, and only a slight amount of carbon dioxide gets mixed from below into the stratosphere. But some does, and the amount of carbon dioxide has increased in the stratosphere as it has in the troposphere, though the actual amount of carbon dioxide is very much smaller in the stratosphere than in the troposphere.

Before describing this evidence, a comment about the *greenhouse effect* is in order.

One often hears the greenhouse effect described as resulting from "heat being trapped" in the atmosphere. A more accurate description is this: In the troposphere, the kinds of molecules responsible for the greenhouse effect (e.g. carbon dioxide) intercept and absorb a substantial fraction of the outgoing "heat radiation" (i.e. infrared radiation) emitted from the earth's surface. This absorbed energy is exchanged back and forth between the more common molecules making up the atmosphere (nitrogen and oxygen.) Ultimately, a large fraction of this energy that is re-emitted by the carbon dioxide molecules is *redirected* back to the earth's surface because there is so much overlying carbon dioxide blocking its escape. This redirected infrared energy enhances the direct warming from the sun. But at very high altitudes --in the stratosphere-- the overlying amount of carbon dioxide has dropped to such a low level that most of the infrared radiation emitted at these altitudes *can directly escape* into outer space.

See here[8] for my animated video showing how the greenhouse effect works. It tracks infrared radiation from its emission from the earth's surface to either its ultimate escape into outer space or its redirection back to the earth's surface. This redirected energy adds additional warming to that coming directly from the sun.

Returning to stratospheric cooling, back in 1967 in a couple of very influential papers, it was demonstrated that as a result of increased carbon dioxide, the stratosphere would *cool* while the earth's surface temperature *warmed*. (One of the authors, Syukuro Manabe, shared the 2021 Nobel Prize for his work in modeling the climate.) Subsequent computer models of the earth's entire climate system have become more and more sophisticated and confirm this. Likewise, increasingly accurate observations of temperature changes at all levels of the atmosphere, from the lowest couple of miles to the upper stratosphere, have become available. The observed trend of temperature changes, as increasing altitudes are considered , agree quite well with , albeit not perfectly with, the computer models.

This is shown below in figure 4 which is Figure 1 in a paper[9] which discussed in detail both the observations and the relevant calculations. The conclusion is unambiguous: these observations can only be explained by the *observed increase in carbon dioxide* and not by a change in the sun's brightness.

This figure clearly shows that the rate of *warming* is greatest for the lower part of the atmosphere (panel F) whereas in the upper reaches of the stratosphere the rate of cooling is greatest. (Panel A)

[8] https://www.youtube.com/watch?v=9DaohdBhbfQ&feature=youtu.be
[9] https://www.pnas.org/doi/10.1073/pnas.2300758120

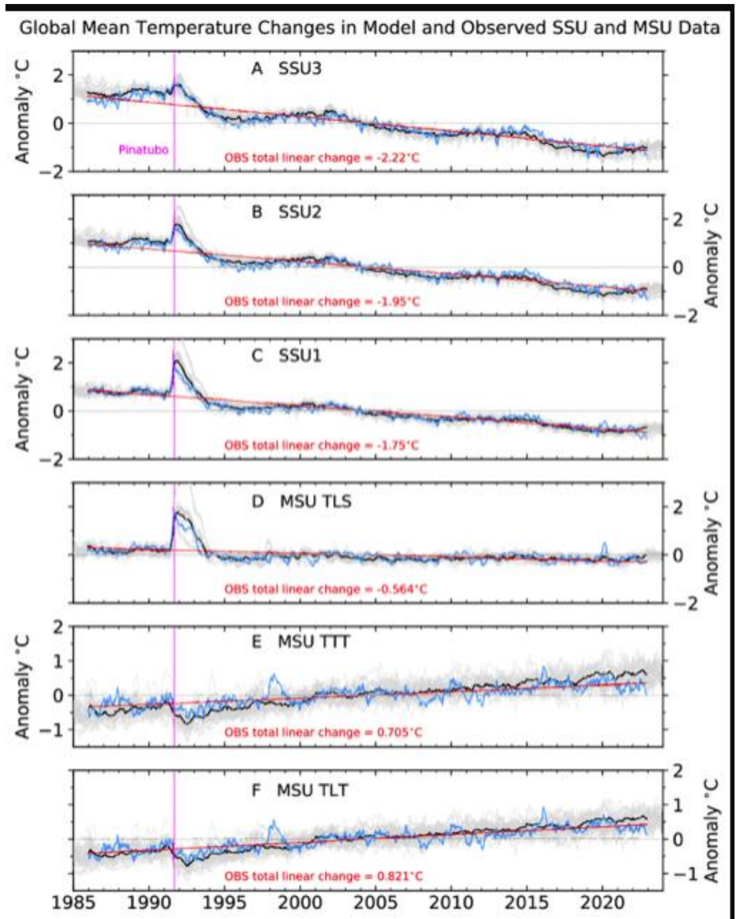

Figure 4. This is figure 1 in the paper cited in footnote 9. The black curves are the observed trends in temperature for 3 levels of the stratosphere (panels A, B, C with A the highest level) and 3 levels in the troposphere (panels D, E and F with F the lowest level.) The blue curves are calculations based upon the known laws of physics which underlie computer models. See the text for discussion and the caption in figure 1 of the paper cited in footnote 9 for a more detailed explanation of this figure.

The analysis in the paper cited in footnote 9, called "vertical fingerprinting", provides a powerful piece of additional evidence that our consumption of fossil fuels is responsible for the unprecedented rate of global warming we have been discussing. As the authors of the paper in footnote 9 conclude: *"Extending the reach of "vertical fingerprinting" from the lower troposphere to the upper stratosphere provides* ***incontrovertible*** *evidence of the anthropogenic impact on Earth's climate."*

In the Appendix, I give a simple non-mathematical explanation of why the upper stratosphere should cool even though the lower troposphere warms when the amount of carbon dioxide in the atmosphere has increased. By contrast, this is not what is expected if the carbon dioxide were kept constant but the sun increased in brightness. But it is important to keep in mind that the "proof of the pudding" is not such a simple explanation but rather the impressive agreement between the calculations shown by the blue curves in figure 4 and the observations shown in black. Bear in mind also that the calculations were carried out with the *observed increase* in carbon dioxide from about 1986 to about 2023 and the *observed lack of increase* in solar brightness over the same interval, (as shown in figure 3.)

Concluding remarks: Where should our focus now be?

I have gone through this long and detailed discussion to show readers why I believe

that:

When the evidence about stratospheric cooling is added to the vast amount of other evidence (e.g., rising sea levels, melting ice sheets, the increase in heat energy deposited in the ocean etc.)

then:

The conclusion that it is the increase in carbon dioxide produced by our combustion of fossil fuels which is responsible for our rapidly changing climate is *inescapable*,

and moreover that:

Those who do not acknowledge this do not understand the basic science, **or**, if they do understand it , are so influenced by ideological world views that they cannot accept it,

and therefore that:

It is futile to try to persuade those who do not accept this conclusion unless they are truly interested in having the science explained to them as clearly as possible,

and finally, that:

We should now spend less of our time and energy devoted to the question of *whether* humans are responsible for the rapidly changing climate and start devoting most of our time and energy to *developing the best path forward* to achieve net zero emission energy sources. This must be done with, at the very least, **"all deliberate speed"** in the memorable words of "Brown vs. Board of Education."

This will mean utilizing all current low emission energy sources and developing new and even more economical energy technologies to drive down the cost of energy to well below the cost of energy derived from fossil fuels. This does not mean we should ignore environmental considerations in deploying these low emission energy sources, but the reality is that there will be some difficult choices to be made in terms of the impacts on humans and the environment.

In pursuing this effort, we will have to deal with the understandable resistance to change and for the tendency to say "I am in favor of dealing with climate change, but put that new project somewhere else."

We will also have to dispel attitudes that "it is too late", or "nothing can be done about it" and other negative attitudes that new polling research[10] suggests are now shared by a disturbingly large fraction of children and young adults. It is the younger generation that must provide the political pressure for political leaders in this country and around the world to take the actions necessary to avoid much more severe impacts than from those we are now already experiencing and the human suffering and ecological impacts that will accompany them.

In light of all the foregoing, my next Essay will be about the Morro Bay Offshore Wind Farm.

For the Appendix, please see the next page.

---

[10] https://skepticalscience.com/ccdh-the-new-climate-denial.html?utm-source=email&utm-campaign=daily

APPENDIX

A simple non-mathematical description of why the stratosphere is cooling

It may seem contrary to expectations that as carbon dioxide in the atmosphere increases, the stratosphere is *cooling.* After all, adding additional CO_2 in the atmosphere results in surface *warming* along with *warming* of the *lower atmosphere*, as expected from basic physics and confirmed by observations.

In this short appendix I give a simple non-mathematical explanation of why the upper stratosphere has been *cooling* as carbon dioxide has been added to the atmosphere.

The energy balance of the upper stratosphere is governed mainly by two processes:

1) It is ***heated*** by ultraviolet sunlight striking ozone (O_3) molecules, breaking the molecule into O_2 and O. When O_2 and O molecules recombine to form another O_3 molecule they release energy which is shared among the more common molecules, air molecules N_2 and O_2 , thus acting to raise the temperature of the gas. (This is similar to the electrolysis of water in which an external electrical voltage splits water into hydrogen and oxygen molecules, which, when they combine, produce heat which can do useful work.)

2) It is ***cooled*** by the common air molecules, N_2 and O_2 giving up some of their energy when colliding with CO_2 molecules and sending them into more energetic vibrations.

The vibrational energy of such energetically vibrating CO_2 molecule is then released in the form of infrared radiation which can freely escape upwards into space or downwards into the troposphere. This is because the air in the stratosphere is so thin. This loss of radiation thus results in cooling process. *The free escape of this radiation in the stratosphere is in marked contrast to that at the earth's surface and the lower levels of the atmosphere*.

See the animation in my YouTube video which describes these processes in the context of the troposphere: https://www.youtube.com/watch?v=9DaohdBhbfQ&feature=youtu.be

The rate at which stratospheric *cooling* occurs is controlled by two factors:

a) The *temperature of the gas in the stratosphere*

The *higher the temperature* the more *rapid the cooling*. This might seem counter-intuitive as we associate higher temperatures with heating. But as the temperature gets higher, the N_2 and O_2 molecules have more energy, and are moving faster. This means that those collisions with the CO_2 molecules which take place with enough energy to excite the CO_2 molecules to energetic vibrations are more frequent. As explained above, this energy is radiated away and the gas cools. **Conversely, as the temperature is lowered the rate at which cooling occurs is decreased.**

b) The more numerous the CO_2 molecules, the more rapid the cooling.

This makes sense--if there are more CO_2 molecules for the common air molecules to collide with there will be more energy lost by escaping radiation, as described above.

These heating and cooling processes operate continuously but it is convenient to think of them as taking place in a few separate steps.

With these preliminary comments, consider two different hypotheses about what the dominant forcing mechanism is and how the temperature of the stratosphere will be affected.

FIRST hypothesis: Suppose there is *no change* in the sun's brightness. but there *is an increase* in the amount of CO_2 molecules in the stratosphere.

Imagine that the gas in the stratosphere is initially in energy balance[11], with heating balancing cooling. The heating from the sunlight acting on the ozone proceeds at a fixed rate (by our supposition, since it is the amount of ultraviolet light acting on the ozone that determines the heating rate.

Step1: suppose more CO_2 molecules are added to the air. This results in additional *cooling* as described above. This additional cooling upsets the energy balance since the heating rate has not changed so:
Step 2: the temperature of the gas in the stratosphere will drop. But then:

Step 3: this *drop in temperature* **reduces** the cooling rate, as described above, and will continue until energy balance is restored,

The net result is thus that at this new energy balance, **the stratosphere is now cooler than initially**.

SECOND hypothesis: Now suppose (for the sake of argument, but contrary to observations) the number of CO_2 molecules is held fixed, but:

Step 1: the solar ultraviolet brightness is *increased*. This would again result in an energy imbalance with the gas now *warming*. So:

---

[11] The heating and cooling processes are each so strong that at the very low density of air in the upper stratosphere, it will never be far from energy balance. If the heating rate is slightly greater than the cooling rate, the cooling rate will quickly act to restore energy balance. Conversely if the cooling rate is slightly greater than the heating rate.

Step 2: The temperature of the gas increases. But then:

Step 3: At this new higher temperature there is *increased cooling* which *brings about a new energy balance* offsetting the increased solar heating.

The net result is thus at this new energy balance, **the stratosphere is now *warmer* than initially**, contrary to what is observed.