

**Why do I agree with the conclusion that climate change is happening and that human activity is responsible for the majority of the change? (By Nick Strobel)**

- 1) The greenhouse effect is now a well-understood process that is caused by the presence of certain molecules. The first realization that the atmosphere can affect the surface temperature of a planet goes back to Joseph Fourier, who in an 1824 edition of the *Annales de Chime et de Physique*, wrote about the regulating effect of our atmosphere keeps the Earth from becoming an icy planet. Without an atmosphere, basic physics described at [www.astronomynotes.com/solarsys/s3c.htm](http://www.astronomynotes.com/solarsys/s3c.htm) shows that the expected surface temperature for Earth should be 254K or 19 degrees Celsius below the freezing point of water. Earth should be frozen over. We're not frozen over because of a natural greenhouse effect. Also, without an atmosphere, we'd go through the extreme swings between day and night seen in the other large object at the same distance from the sun as the Earth, the moon.

Nineteenth-century work by John Tyndall (1862) and Svante Arrhenius (1895) gave us a deeper understanding of how gases such as carbon dioxide and water vapor can trap infrared energy radiating from a warm sunlit surface. Twentieth-century developments in quantum mechanics and chemistry further explained how the structure and bonds of certain gases enable the gases to absorb infrared energy. Modern instrumentation has enabled us to measure quite precisely the infrared absorption bands of carbon dioxide and water vapor. Upper-division undergraduate meteorology labs have included experiments measuring the infrared absorbing properties of these gases for decades. There are other types of greenhouse gases, of course, such as methane and ozone but their effect on Earth and other planets is less significant than carbon dioxide and water vapor.

Being an astronomer I look to our neighboring planets, Venus and Mars, for further understanding of how the effects of an atmosphere's thickness and composition can affect the surface temperature—to understand why Venus is so hellishly hot and Mars is so darn cold. Without an atmosphere, basic physics described at [www.astronomynotes.com/solarsys/s3c.htm](http://www.astronomynotes.com/solarsys/s3c.htm) shows that any planet's atmosphere will affect a planet's surface temperature. Atmospheric physicists are now employing the well-understood greenhouse effect along with other gas physics to make estimates of plausible surface temperatures of exoplanets.

- 2) Measured atmospheric carbon dioxide concentration levels have increased almost 30% since the late 1950s when Charles Keeling began collecting data on Mauna Loa and the South Pole. Measurements of carbon dioxide from air bubbles trapped in ice cores tell us that the concentration of carbon dioxide in the atmosphere is the highest it has been for the past 800,000 years.
- 3) While the ice core data do show that there have been ups and downs of the carbon dioxide levels over the past 800,000 years tied to the ice ages, the decreasing ratio of carbon-13 to carbon-12 isotopes over time show that the recent increase in carbon dioxide this past century is due to fossil fuel burning and not some natural fluctuation cycle. Other signals such as decreasing oxygen content, decreasing carbon-14 to carbon ratios, and diverging concentrations between the northern and southern hemisphere due to more industrialization in the northern hemisphere also point to the rise in carbon dioxide being caused by fossil fuel burning. There are also increases in methane levels and nitrous oxide with the same north-south hemisphere divergence as well.
- 4) Increases in greenhouse gases that remain up in the atmosphere for years, such as carbon dioxide, methane, ozone, nitrous oxide, etc., should increase the temperature through the well-understood greenhouse effect. When looking at temperature trends, one needs to look at averages over at least 20 year timespans, so one doesn't get fooled by the "down the up escalator" cherry-picking of data and short-term trends. The global temperature trend has increased over the past almost 140 years with the most significant increase in the past 40 years.

- 5) The cause-effect relationship of increased carbon dioxide causing increased temperature seems clear (and smaller contributions due to increasing methane and other greenhouse gases). However, there are other possible ways to change a planet's temperature as outlined at [www.astronomynotes.com/solarsys/s4c.htm#A31](http://www.astronomynotes.com/solarsys/s4c.htm#A31). The sun and volcanoes are the top two natural causes with the greatest effects. When considering only the fluctuations in the sun's energy output, changing solar insolation due to the Milankovich cycle, and effects of gases and aerosols spewed out by volcanoes in the last century or so and ignoring the effect of the human-added carbon dioxide, the global temperature trend should have remained *flat* or perhaps even slightly decreased. The gap or discrepancy between what the temperature effect from just natural causes (e.g., sun and volcanoes) and the actual observed temperature trend has grown over the past 40 years.
- 6) Other indicators besides temperature show us that the climate is changing. They include decreases in Arctic sea ice, decreases in the mass of land ice on Antarctica and Greenland as measured by the GRACE mission, rising mean sea level and the rate of the sea level rise is increasing, and other lines of evidence noted by the National Research Council (not IPCC). One recent local example in Kern County is given in a report for the "Valley Edition" radio show about the decrease in number of cold winter days/nights needed for good pistachio, almond, and peach crops. The trees need more than 700 hours of sleep (i.e., frigid temperatures) every winter but for the past four years, they've had less than 500 hours. One of the grower's interviewed is taking a non-political business pragmatic approach when he says "I know that there are people that think that global warming is not man-made, but regardless we have to deal with it. I think that making plans around it are necessary." (See <http://kvpr.org/post/too-warm-grow-tree-crops-farmers-work-temper-climate-change-effects> for the report.)
- 7) Past climate changes such as ice ages/interglacials have been triggered by changing solar insolation (the amount of solar energy reaching a given area) from changes in the Earth's axis tilt and orbit shape (Milankovich cycle effect). In those cases carbon dioxide/greenhouse effect and albedo changes have acted as feedback agents to enhance the solar insolation effect of the axis tilt/orbit changes. Although the pre-historic climate records may show that greenhouse heating sometimes lagged behind temperature changes, the physics of the greenhouse effect has been well understood for well over a century now, so we do know what an increase in atmospheric carbon dioxide can do. Those lag times were feedbacks. Now we are adding carbon dioxide independently of any *natural* temperature changes and that extra carbon dioxide will be the triggering, forcing agent to cause a change in the global temperature via the well-understood greenhouse effect (i.e., instead of feedback).

The following last comment is about energy production. We need A LOT of energy to keep our standard of living and keep our economy growing. I recognize the great contribution of fossil fuels to supplying our energy, a fact I'm very aware of here in Kern County. However, fossil fuels are a finite resource and they will run out eventually. Non-nuclear renewable energy sources are coming down in price and they don't cause health problems or environmental pollution problems. Basic economics argues for switching over to renewable clean energy and we need to make the investments in it now to reap the rewards of it later in this century. If we don't, some other country will and we'll be left behind. On my own home front, I have been smarter about my energy usage, so my energy consumption has decreased while still enjoying all of the entertainment, work, food, and comforts of home. Less money going to my power company means more money for other things.