This is the print version of the Skeptical Science article 'The science isn't settled', which can be found at http://sks.to/settled.

Is the science settled?

What The Science Says:
Science is never 100% settled - science is about narrowing uncertainty. Different areas of science are understood with varying degrees of certainty. For example, we have a lower understanding of the effect of aerosols while we have a high understanding of the warming effect of carbon dioxide. Poorly understood aspects of climate change do not change the fact that a great deal of climate science is well understood.

Climate Myth: The science isn't settled
"Many people think the science of climate change is settled. It isn't. And the issue is not whether there has been an overall warming during the past century. There has, although it was not uniform and none was observed during the past decade. The geologic record provides us with abundant evidence for such perpetual natural climate variability, from icecaps reaching almost to the equator to none at all, even at the poles.

The climate debate is, in reality, about a 1.6 watts per square metre or 0.5 per cent discrepancy in the poorly known planetary energy balance." (Jan Veizer)

A common skeptic refrain is that "the science isn't settled", meaning there are still uncertainties in climate science and therefore action to cut CO_2 emissions is premature. This line of argument betrays a fundamental misunderstanding of the nature of science. Firstly, it presumes science exists in a binary state - that science isn't settled until it crosses some imaginary line after which it's finally settled. On the contrary, science by its very nature is never 100% settled. Secondly, it presumes that poor understanding in one area invalidates good understanding in other areas. This is not the case. To properly answer the question, "is the science settled?", an understanding of how science works is first required.

Science is not about absolute proofs. It never reaches 100% certainty. This is the domain of mathematics and logic. Science is about improving our understanding by narrowing uncertainty. Different areas of science are understood with varying degrees of confidence. For example, while some areas of climate science are understood with high confidence, there are some areas understood with lower confidence, such as the effect on climate from atmospheric aerosols (liquid or solid particles suspended in the air). Aerosols cool climate by blocking sunlight. But they also serve as nuclei for condensation which leads to cloud formation. The question of the net effect of aerosols is one of the greater sources of uncertainty in climate science.

What do we know with high confidence? We have a high degree of confidence that humans are raising carbon dioxide levels in the atmosphere. The amount of CO_2 emissions can be accurately calculated using international energy statistics (CDIAC). This is double checked using measurements of carbon isotopes in the atmosphere (Ghosh & Brand 2003). We can also triple check these results using observations of falling oxygen levels due to the burning of fossil fuels (Manning & Keeling 2006). Multiple lines of empirical evidence increase our confidence that humans are responsible for rising CO_2 levels.

We also have a high degree of confidence in the amount of heat trapped by increased carbon dioxide and other greenhouse gases. This is otherwise known as radiative forcing, a disturbance in the planet's energy balance. We can calculate with relatively high accuracy how much heat is trapped by greenhouse gases using line-by-line models which determine infrared radiation absorption at each wavelength of the infrared spectrum. The model results can then

be directly compared to satellite observations which measure the change in infrared radiation escaping to space. What we find in Figure 1 is the observed increased greenhouse effect (black line) is consistent with theoretical expectations (red line) (Chen et al. 2007). These results can also be double checked by surface measurements that observe more infrared radiation returning to Earth at greenhouse gas wavelengths (Evans & Puckrin 2006). Again, independent observations raise our confidence in the increased greenhouse effect.

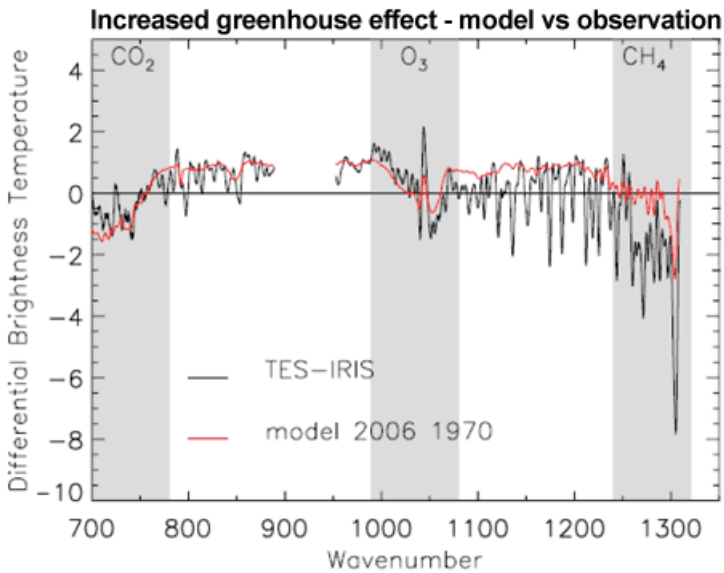

Figure 1: Increased greenhouse effect from 1970 to 2006. Black line is satellite observations. Red line is modelled results (Chen et al. 2007).

So we have a lower understanding of aerosol forcing and a higher understanding of greenhouse gas forcing. This contrast is reflected in Figure 2 which displays the probability of the radiative forcing from greenhouse gases (dashed red line) and aerosol forcing (dashed blue line). Greenhouse gas forcing has a much higher probability constrained to a narrow uncertainty range. Conversely, the aerosol forcing has a lower probability and is spread over a broader uncertainty range.

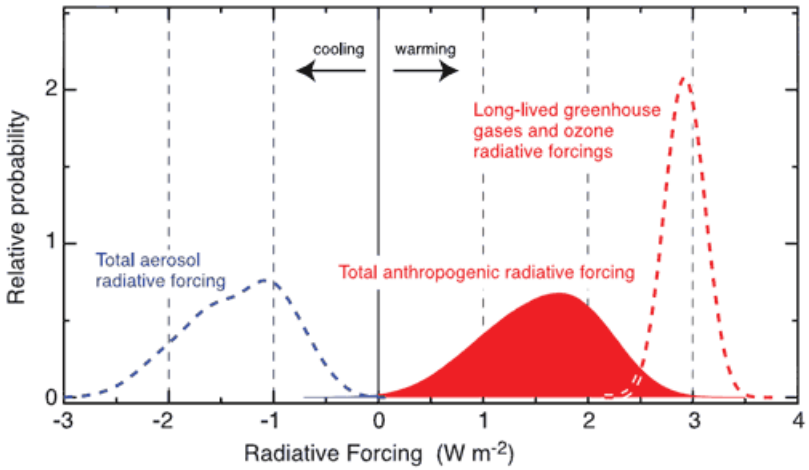

Figure 2: Probability distribution functions (PDFs) from man-made forcings. Greenhouse gases are the dashed red curve. Aerosol forcings (direct and indirect cloud albedo) are the blue dashed curve. The total man-made forcing is the solid red curve (IPCC AR4 Figure 2.20b)

The important point to make here is that a lower understanding of aerosols doesn't invalidate our higher understanding of the warming effect of increased greenhouse gases. Poorly understood aspects of climate change do not change the fact that a great deal of climate science is well understood. To argue that the 5% that is poorly understood disproves the 95% that is well understood betrays an incorrect understanding of the nature of science.

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Skeptical Science explains the science of global warming and examines climate misinformation through the lens of peer-reviewed research. The website won the Australian Museum 2011 Eureka Prize for the Advancement of Climate Change Knowledge. Members of the Skeptical Science team have authored peer-reviewed papers, a college textbook on climate change and the book Climate Change Denial: Heads in the Sand. Skeptical Science content has been used in university courses, textbooks, government reports on climate change, television documentaries and numerous books.

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