How sensitive is our climate?

What The Science Says:
Climate sensitivity can be calculated empirically by comparing past temperature change to natural forcings at the time. Various periods of Earth's past have been examined in this manner and find broad agreement of a climate sensitivity of around 3°C.

Climate Myth: Climate sensitivity is low
"His [Dr Spencer's] latest research demonstrates that – in the short term, at any rate – the temperature feedbacks that the IPCC imagines will greatly amplify any initial warming caused by CO2 are net-negative, attenuating the warming they are supposed to enhance. His best estimate is that the warming in response to a doubling of CO2 concentration, which may happen this century unless the usual suspects get away with shutting down the economies of the West, will be a harmless 1 Fahrenheit degree, not the 6 F predicted by the IPCC." (Christopher Monckton)

Climate sensitivity is expressed as the global temperature change for a particular forcing (eg - °C change per W/m^2 forcing). More commonly, it's given as the warming for doubled CO2 (i.e. from 280 ppm to 560 ppm).

Climate sensitivity from models

The first estimates of climate sensitivity came from climate models.

- In the 1979 Charney report, two models from Suki Manabe and Jim Hansen estimated a sensitivity range between 1.5 to 4.5°C.
- Forest 2002 uses a fingerprinting approach on modern temperature records and finds a range 1.4 to 7.7°C.
- Knutti et al. 2006 uses modelling (entering different sensitivities then comparing to seasonal responses) to find a climate sensitivity range 1.5 to 6.5°C - with 3 to 3.5 most likely
- Hegerl 2006 looks at paleontological data over the past 6 centuries to calculates a range 1.5 to 6.2°C.
- Annan 2006 combines results from a variety of independent methods to narrow climate sensitivity to around 2.5 to 3.5°C.
- Royer et al. 2007 examines temperature response to CO2 over the past 420 million years and determines climate sensitivity cannot be lower than 1.5°C (with a best fit of 2.8°C).

Climate sensitivity from empirical observations

There have been a number of studies that calculate climate sensitivity directly from empirical observations, independent of models.

- Lorius 1990 examined Vostok ice core data and calculates a range of 3 to 4°C.
- Hoffert 1992 reconstructs two paleoclimate records (one colder, one warmer) to yield a range 1.4 to 3.2°C.
- Hansen et al. 1993 looks at the last 20,000 years when the last ice age ended and empirically calculates a climate sensitivity of 3 ± 1°C.
- Gregory et al. 2002 used observations of ocean heat uptake to calculate a minimum climate sensitivity of 1.5.
- Chylek & Lohmann 2007 examines the period from the Last Glacial Maximum to Holocene transition. They calculate a climate sensitivy range of 1.3°C and 2.3°C.
- Tung & Camp 2007 performs statistical analysis on 20th century temperature response to the solar cycle to calculate a range 2.3 to 4.1°C.
- Bender et al. 2010 looks at the climate response to the 1991 Mount Pinatubo eruption to constrain

climate sensitivity to 1.7 to 4.1°C.

Stephen Schwartz climate sensitivity of 1.1°C

A recent paper Heat capacity, time constant and sensitivity of Earth's climate systemdetermines a climate sensitivity of 1.1 ± 0.5°C (Schwartz 2007). Sensitivity is calculated as the quotient of the climate's "time constant" and global heat capacity. The "time constant", the time for the climate system to return to equilibrium after a perturbation, is a key aspect of his paper. Schwartz examines results from various time series analyses and estimates a time constant of 5 years.

However, as Schwartz points out in his study, climate recovers at different rates depending on the nature of the forcing causing the perturbation. A short term change such as a volcanic eruption results in a short time constant of a few years. A long term increase in CO2 levels results in a recovery spanning decades. Schwartz rightly points out "as the duration of volcanic forcing is short, the response time may not be reflective of that which would characterize a sustained forcing such as that from increased greenhouse gases because of lack of penetration of the thermal signal into the deep ocean."

Nevertheless, Schwartz filters out long term changes by detrending the time series data which has the effect of biasing the result towards a shorter time constant. The time constant for non-detrended data yields a time constant of 15 to 17 years. Consequently, the estimated time constant of 5 years is questionable - a value the final result hinges on.

UPDATE 11 Feb 2010: Schwartz subsequently updated his climate sensitivity estimate in response to comments on his paper (Schwartz 2008). He now uses a time constant of 8.5 years leading to a climate sensitivity of 1.9 ± 1.0°C.

Intermediate rebuttal written by John Cook

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.