This is the print version of the Skeptical Science article 'Water vapor is the most powerful greenhouse gas', which can be found at http://sks.to/vapor.

Explaining how the water vapor greenhouse effect works

What The Science Says:
Water vapour is the most dominant greenhouse gas. Water vapour is also the dominant positive feedback in our climate system and amplifies any warming caused by changes in atmospheric CO2. This positive feedback is why climate is so sensitive to CO2 warming.

Climate Myth: Water vapor is the most powerful greenhouse gas
"Water vapour is the most important greenhouse gas. This is part of the difficulty with the public and the media in understanding that 95% of greenhouse gases are water vapour. The public understand it, in that if you get a fall evening or spring evening and the sky is clear the heat will escape and the temperature will drop and you get frost. If there is a cloud cover, the heat is trapped by water vapour as a greenhouse gas and the temperature stays quite warm. If you go to In Salah in southern Algeria, they recorded at one point a daytime or noon high of 52 degrees Celsius – by midnight that night it was -3.6 degree Celsius. […] That was caused because there is no, or very little, water vapour in the atmosphere and it is a demonstration of water vapour as the most important greenhouse gas." (Tim Ball)

Water vapour is the most dominant greenhouse gas. The greenhouse effect or radiative flux for water is around 75 W/m^2 while carbon dioxide contributes 32 W/m^2 (Kiehl & Trenberth 1997). These proportions are confirmed by measurements of infrared radiation returning to the Earth's surface (Evans & Puckrin 2006). Water vapour is also the dominant positive feedback in our climate system and a major reason why temperature is so sensitive to changes in CO2.

Unlike external forcings such as CO2 which can be added to the atmosphere, the level of water vapour in the atmosphere is a function of temperature. Water vapour is brought into the atmosphere via evaporation - the rate depends on the temperature of the ocean and air, being governed by the Clausius-Clapeyron relation. If extra water is added to the atmosphere, it condenses and falls as rain or snow within a week or two. Similarly, if somehow moisture was sucked out of the atmosphere, evaporation would restore water vapour levels to 'normal levels' in short time.

Water Vapour as a positive feedback

As water vapour is directly related to temperature, it's also a positive feedback - in fact, the largest positive feedback in the climate system (Soden & Held 2005). As temperature rises, evaporation increases and more water vapour accumulates in the atmosphere. As a greenhouse gas, the water absorbs more heat, further warming the air and causing more evaporation. When CO2 is added to the atmosphere, as a greenhouse gas it has a warming effect. This causes more water to evaporate and warm the air to a higher, stabilized level. So the warming from CO2 has an amplified effect.

How much does water vapour amplify CO2 warming? Without any feedbacks, a doubling of CO2 would warm the globe around 1°C. Taken on its own, water vapour feedback roughly doubles the amount of CO2 warming. When other feedbacks are included (eg - loss of albedo due to melting ice), the total warming from a doubling of CO2 is around 3°C (Held & Soden 2000).

Empirical observations of water vapour feedback and climate

sensitivity

The amplifying effect of water vapor has been observed in the global cooling after the eruption of Mount Pinatubo (Soden et al. 2002). The cooling led to atmospheric drying which amplified the temperature drop. A climate sensitivity of around 3°C is also confirmed by numerous empirical studies examining how climate has responded to various forcings in the past (Knutti & Hegerl 2008).

Satellites have observed an increase in atmospheric water vapour by about 0.41 kg/m² per decade since 1988. A detection and attribution study, otherwise known as "fingerprinting", was employed to identify the cause of the rising water vapour levels (Santer et al. 2007). Fingerprinting involves rigorous statistical tests of the different possible explanations for a change in some property of the climate system. Results from 22 different climate models (virtually all of the world's major climate models) were pooled and found the recent increase in moisture content over the bulk of the world's oceans is not due to solar forcing or gradual recovery from the 1991 eruption of Mount Pinatubo. The primary driver of 'atmospheric moistening' was found to be the increase in CO2 caused by the burning of fossil fuels.

Theory, observations and climate models all show the increase in water vapor is around 6 to 7.5% per degree Celsius warming of the lower atmosphere. The observed changes in temperature, moisture, and atmospheric circulation fit together in an internally and physically consistent way. When skeptics cite water vapour as the most dominant greenhouse gas, they are actually invoking the positive feedback that makes our climate so sensitive to CO2 as well as another line of evidence for anthropogenic global warming.

Intermediate rebuttal written by John Cook

Update July 2015:

Here is a related lecture-video from Denial101x - Making Sense of Climate Science Denial

[*see video at **this link**.*]

Additional video from the MOOC

Expert interview with Steve Sherwood

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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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