CLIMATE SCIENCE FORUM

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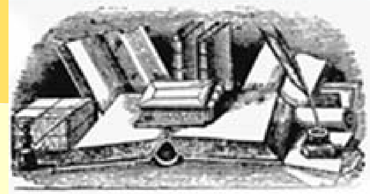


Large Part of Climate Change Deemed "Irreversible"

Temperatures remain elevated & stable even after carbon dioxide emissions cease

Some people assume that climate will revert to a less harmful state once humans stop putting greenhouse gases into the atmosphere, and that this can happen in our lifetimes or those of our children. Nothing could be further from the truth, says **Susan Solomon,** who published a paper this month on "Irreversible Climate Change due to Carbon Dioxide Emissions" (*see note 1*). Solomon is the coordinating lead author of "Climate Change 2007: the Physical Science Basis" (2) of the Intergovernmental Panel on Climate Change (IPCC), and discoverer of the ozone hole over Antarctica.

When carbon dioxide (CO_2) emissions stop, she explains, temperatures do not fall to earlier levels, but rather remain elevated and essentially the same for centuries. Solomon maintains that the climate change expected from CO_2 emissions in the first half of the 21st century is largely irreversible for 1000 years after emissions stop. In fact, sea level will continue to rise for many centuries after no more CO_2 is added to the atmosphere. The reason for this unhappy consequence is that the world's oceans have tremendous mass, and the extra heat in a warming climate and the extra carbon dioxide take a very long time to be mixed into the deep ocean.

The figure at right, from her paper, conveys the point succinctly. If CO_2 emissions grow by 2% per year, as they have since 2000, the concentration of the gas climbs rapidly in the atmosphere . For the sake of argument, she assumes all emissions of CO_2 cease when a "target" concentration is reached (such as 550 parts per million [ppm]). The level is now at 385 ppm, and was at 280 ppm before the industrial era. They want to see how the atmosphere will recover from the buildup of CO_2 from human activities if the activities stop: a "test case." They explore six different targets for atmospheric CO_2, getting six curves for the rise of CO_2 to a peak level, and a fall-off after emissions stop. Indeed, the level of CO_2 in the atmosphere starts to fall when emissions cease, quickly at first, then quite slowly (top graph). But the temperature of the Earth's surface, having climbed to a peak at the same time (lower graph),

(**Continues** ***on page 4***)

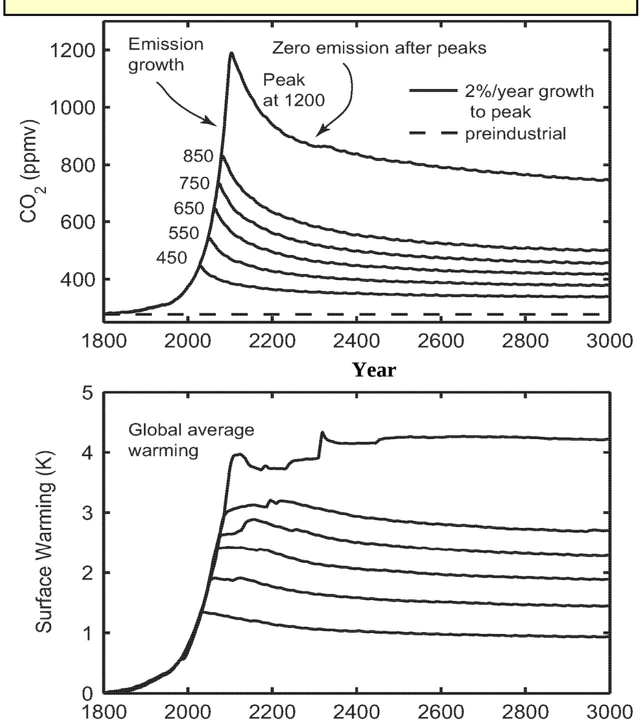
Physical and Biological Landscapes Impacted by Warming in Diverse Ways

FULL STORY, PAGE 2

Global Levels of Methane are Rising Once Again

PAGE 3

CONTENTS



(*Irreversible Climate Changes — Continued from page 1*)

remains essentially near the peak temperature, falling much less than one degree C for hundreds of years after emissions stop.

Using their knowledge of atmospheric chemistry, they calculated whether and how fast the level of CO_2 would drop as the ocean absorbs the gas from the air, and how fast temperatures would fall as a result.

Sea level would rise at least 0.4 to 1 meter if CO_2 concentrations are allowed to reach a fairly modest level of 600 ppm in this century. The seas could rise twice as much if the melting of ice sheets on land is considered.

Solomon and co-authors write, "It is sometimes imagined that slow processes such as climate changes pose small risks, on . . . the assumption that a choice can be made to quickly reduce emissions and thereby reverse any harm within a few years or decades. This . . . is incorrect for carbon dioxide emissions, because of the longevity of atmospheric CO_2 . . . and ocean warming."

How is this possible? First, CO_2 levels will **not fall** to pre-industrial levels. Because of the chemistry and the slow rate of mixing in the ocean, the levels fall and then plateau; in the long term the increase of CO_2 in the atmosphere above the pre-industrial level will stabilize at about 40% of the peak increase that will have occurred when emissions stop. This is shown in the top panel of the Figure on page 1. The CO_2 level in the atmosphere never falls to pre-industrial values, and it *never even falls to today's level.*

Then, why do temperatures not fall in the atmosphere while CO_2 concentrations are falling, after the magic day when emissions stop? As the ocean warms (at first) then cools, there is a lot of inertia. The Ocean is still warming while the atmosphere is cooling, so the rate that heat flows from the air to water drops off. As the atmosphere passes less and less heat to the ocean, CO_2 is still warming the atmosphere, but this warming by CO_2 decreases as the amount of the gas falls. The two effects are almost in balance, and the atmosphere remains warm, within ½°C of the peak temperature that was reached.

What does this portend for patterns of rainfall or drought? A "robust characteristic" of climate change in atmospheric models is an expansion of the so-called "Hadley cell," the predominant circulation in the tropics and subtropics. That implies that the belt of dry climates now running through the latitude of Mexico and the Sahara will shift north, which means the American Southwest and the Mediterranean basin can expect drier conditions. More frequent drought has already been documented in these regions. Solomon presents a map indicating many regions (North Africa, southern Europe, west Australia) can expect 10% less rainfall in the dry season *per degree of warming* – and many expect 2°C of warming by the year 2050. She reminds us, "The American dust bowl was associated with

(Continues in column two) ⟶

an average rainfall decrease of 10% over 10 to 20 years."

Rising sea level is an irrevocable result of carbon dioxide emitted in the past, even if the emissions are totally stopped, according to the paper. The next figure, illustrates a calculation of the lower limit to possible sea level rise, depending on the peak "target" CO_2 concentration. This shows the "lower limit" of sea level rise because melting of ice is not considered here. A one meter rise in sea level is a possible consequence of a target CO_2 level of 550 ppm (we are now at 385 ppm); a rise of 2 meters is possible from a target of 1000 ppm.

Solomon concludes that changes in the geography of the Earth's coastlines are irreversible as many coasts and islands will be submerged. The take-home message: if CO_2 emissions are stopped today, further warming and sea level rise are inevitable and irreversible. The CO_2 has already been released.

CITATIONS

1. "Irreversible climate change due to carbon dioxide emissions" by Susan Solomon, G.K. Plattner, R. Knutti, and P. Friedlingstein (2009). *Proceedings of the Nat. Academy of Sciences*, vol. 186, no. 6, 1704-1709, February 10, 2009. [http://www.pnas.org/cgi/doi/10.1073/pnas.0812721106]

2. "Climate Change 2007: the Physical Science Basis," Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (**IPCC).** Edited by S. Solomon *et al* (2007). Cambridge Univ. Press, Cambridge, UK, and New York, NY. [http://www.ipcc.ch/ipccreports/ar4-wg1.htm]

Top of page

RETURN TO MAIN PAGE

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