Climate and the Oceans: Global Warming and The Ocean

AOSC 680

Ross Salawitch

Class Web Sites:
http://www2.atmos.umd.edu/~rjs/class/fall2024
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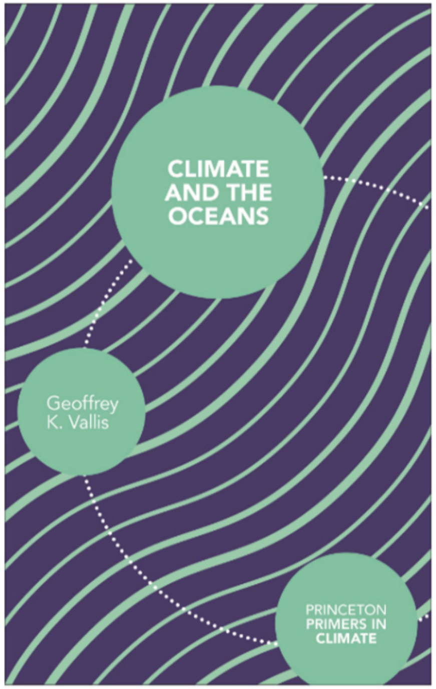

Lecture 17

31 October 2024

Transient Climate Response and Equilibrium Climate Response

What is the consequence of this picture for global warming? We are slowly but steadily putting greenhouse gases into the atmosphere; the mixed layer responds to this input, and its temperature increases in concert. However, the deep ocean is *far* from equilibrium, which means that, even if we were to stop adding greenhouse gases to the atmosphere and the levels of greenhouse gases were to stabilize at some level, the temperature of the ocean's mixed layer, and so of the atmosphere, would continue to rise for a long period after that. Let us suppose that we continue putting CO_2 into the atmosphere until its level has doubled from that in preindustrial times, and that this doubling occurs in the middle of the twenty-first century. We can expect the global averaged temperature to rise by between 1.3°C and 2.5°C, and probably around 1.8°C, from its preindustrial value by then.[10] Suppose that at that time the political and technological stars align and we are able to prevent greenhouse gas levels in the atmosphere from increasing any further. The average surface temperature of Earth will nevertheless *keep on increasing* until the deep ocean has finally equilibrated, which will take an additional few hundred years or more.

Must understand difference between transient climate response (TCR) and equilibrium climate sensitivity (ECS)

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Committed Warming

Irreversible climate change due to carbon dioxide emissions

Susan Solomon[a,1], Gian-Kasper Plattner[b], Reto Knutti[c], and Pierre Friedlingstein[d]

[a]Chemical Sciences Division, Earth System Research Laboratory, National Oceanic and Atmospheric Administration, Boulder, CO 80305; [b]Institute of Biogeochemistry and Pollutant Dynamics and [c]Institute for Atmospheric and Climate Science, ETH CH-8092, Zurich, Switzerland; and [d]Institut Pierre Simon Laplace/Laboratoire des Sciences du Climat et de l'Environnement, Unité Mixte de Recherche 1572 Commissariat à l'Energie Atomique–Centre National de la Recherche Scientifique–Université Versailles Saint-Quentin, Commissariat a l'Energie Atomique-Saclay, l'Orme des Merisiers, 91191 Gif sur Yvette, France

Contributed by Susan Solomon, December 16, 2008 (sent for review November 12, 2008)

The severity of damaging human-induced climate change depends not only on the magnitude of the change but also on the potential for irreversibility. This paper shows that the climate change that takes place due to increases in carbon dioxide concentration is largely irreversible for 1,000 years after emissions stop. Following cessation of emissions, removal of atmospheric carbon dioxide decreases radiative forcing, but is largely compensated by slower loss of heat to the ocean, so that atmospheric temperatures do not drop significantly for at least 1,000 years. Among illustrative irreversible impacts that should be expected if atmospheric carbon dioxide concentrations increase from current levels near 385 parts per million by volume (ppmv) to a peak of 450–600 ppmv over the coming century are irreversible dry-season rainfall reductions in several regions comparable to those of the "dust bowl" era and inexorable sea level rise. Thermal expansion of the warming ocean provides a conservative lower limit to irreversible global average sea level rise of at least 0.4–1.0 m if 21st century CO_2 concentrations exceed 600 ppmv and 0.6–1.9 m for peak CO_2 concentrations exceeding ≈1,000 ppmv. Additional contributions from glaciers and ice sheet contributions to future sea level rise are uncertain but may equal or exceed several meters over the next millennium or longer.

Solomon et al., PNAS, 2009: https://www.pnas.org/doi/epdf/10.1073/pnas.0812721106

Committed Warming

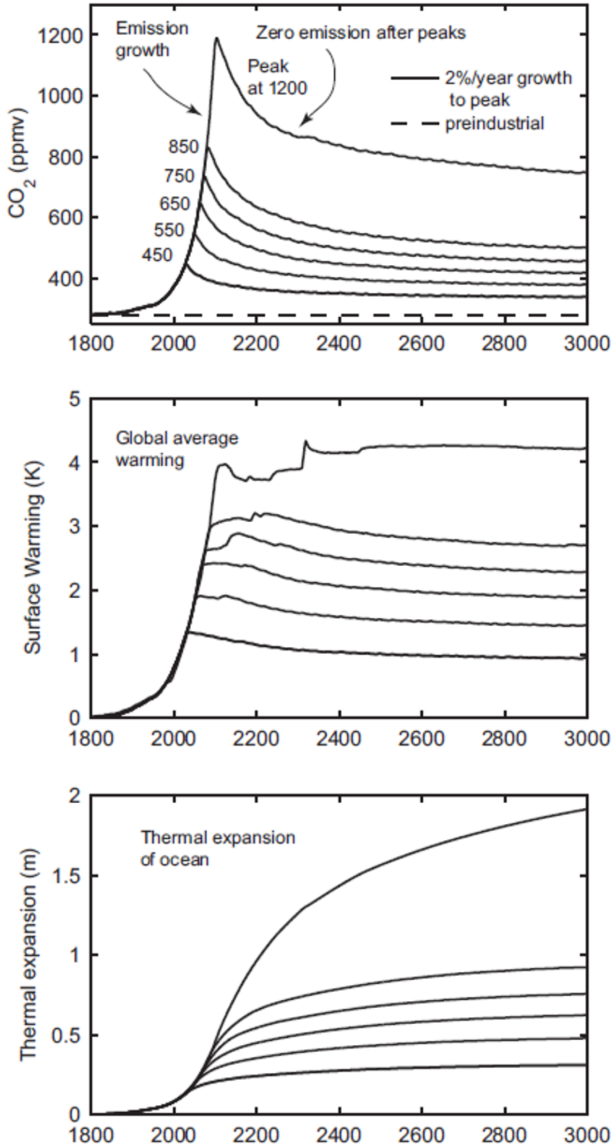

Fig. 1. Carbon dioxide and global mean climate system changes (relative to preindustrial conditions in 1765) from 1 illustrative model, the Bern 2.5CC EMIC, whose results are comparable to the suite of assessed EMICs (5, 7). Climate system responses are shown for a ramp of CO_2 emissions at a rate of 2%/year to peak CO_2 values of 450, 550, 650, 750, 850, and 1200 ppmv, followed by zero emissions. The rate of global fossil fuel CO_2 emission grew at ≈1%/year from 1980 to 2000 and >3%/year in the period from 2000 to 2005 (13). Results have been smoothed using an 11-year running mean. The 31-year variation seen in the carbon dioxide time series is introduced by the climatology used to force the terrestrial biosphere model (15). (*Top*) Falloff of CO_2 concentrations following zero emissions after the peak. (*Middle*) Globally averaged surface warming (degrees Celsius) for these cases (note that this model has an equilibrium climate sensitivity of 3.2 °C for carbon dioxide doubling). Warming over land is expected to be larger than these global averaged values, with the greatest warming expected in the Arctic (5). (*Bottom*) Sea level rise (meters) from thermal expansion only (not including loss of glaciers, ice caps, or ice sheets).

Solomon et al., PNAS, 2009: https://www.pnas.org/doi/epdf/10.1073/pnas.0812721106

Committed Warming

LETTERS
PUBLISHED ONLINE: 31 JULY 2017 | DOI: 10.1038/NCLIMATE3357

nature climate change

Committed warming inferred from observations

Thorsten Mauritsen[1*] and Robert Pincus[2,3]

Due to the lifetime of CO_2, the thermal inertia of the oceans[1,2], and the temporary impacts of short-lived aerosols[3-5] and reactive greenhouse gases[6], the Earth's climate is not equilibrated with anthropogenic forcing. As a result, even if fossil-fuel emissions were to suddenly cease, some level of committed warming is expected due to past emissions as studied previously using climate models[6-11]. Here, we provide an observational-based quantification of this committed warming using the instrument record of global-mean warming[12], recently improved estimates of Earth's energy imbalance[13], and estimates of radiative forcing from the Fifth Assessment Report of the Intergovernmental Panel on Climate Change[14]. Compared with pre-industrial levels, we find a committed warming of 1.5 K (0.9–3.6, 5th–95th percentile) at equilibrium, and of 1.3 K (0.9–2.3) within this century. However, when assuming that ocean carbon uptake cancels remnant greenhouse gas-induced warming on centennial timescales, committed warming is reduced to 1.1 K (0.7–1.8). In the latter case there is a 13% risk that committed warming already exceeds the 1.5 K target set in Paris[15]. Regular updates of these observationally constrained committed warming estimates, although simplistic, can provide transparent guidance as uncertainty regarding transient climate sensitivity inevitably narrows[16] and the understanding of the limitations of the framework[11,17-21] is advanced.

Mauritsen and Pincus, Nature Climate Change, 2017: https://www.nature.com/articles/nclimate3357

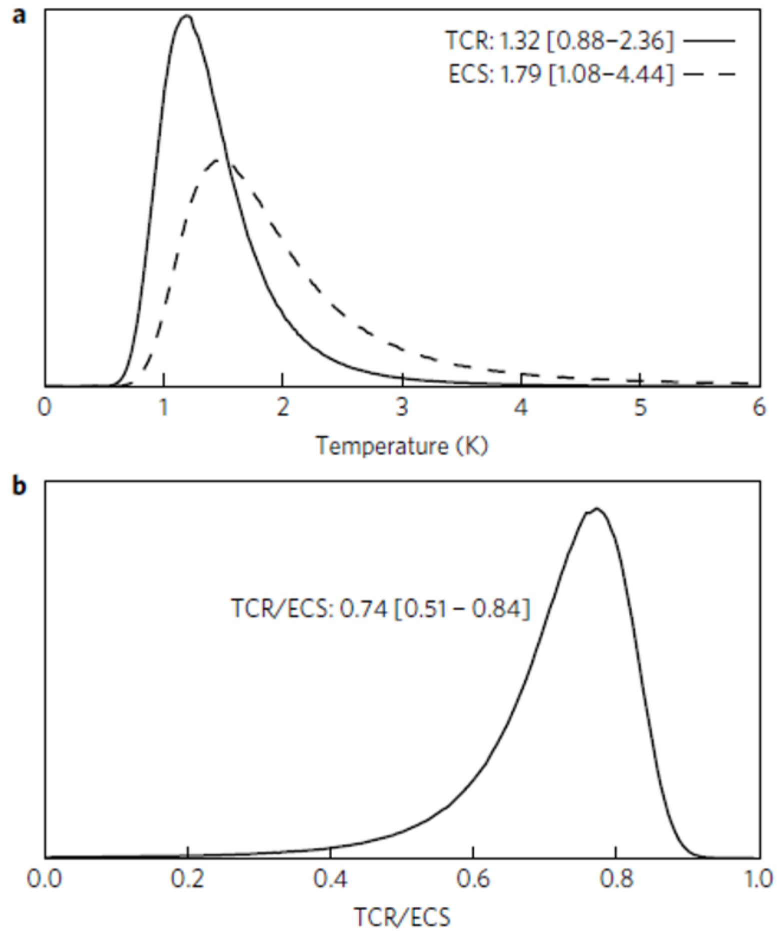

Figure 1 | Probabilities of transient climate response (TCR) and equilibrium climate sensitivity (ECS). a, Probabilities of TCR (solid) and ECS (dashed) inferred on the basis of observed warming, estimates of historical radiative forcing and observations of present-day energy imbalance. **b**, The ratio of the quantities in **a**, which is roughly equivalent t the proportion of long-term warming realized on centennial timescales. Displayed numbers are the median and 5th–95th percentiles of each distribution.

Mauritsen and Pincus, Nature Climate Change, 2017: https://www.nature.com/articles/nclimate3357

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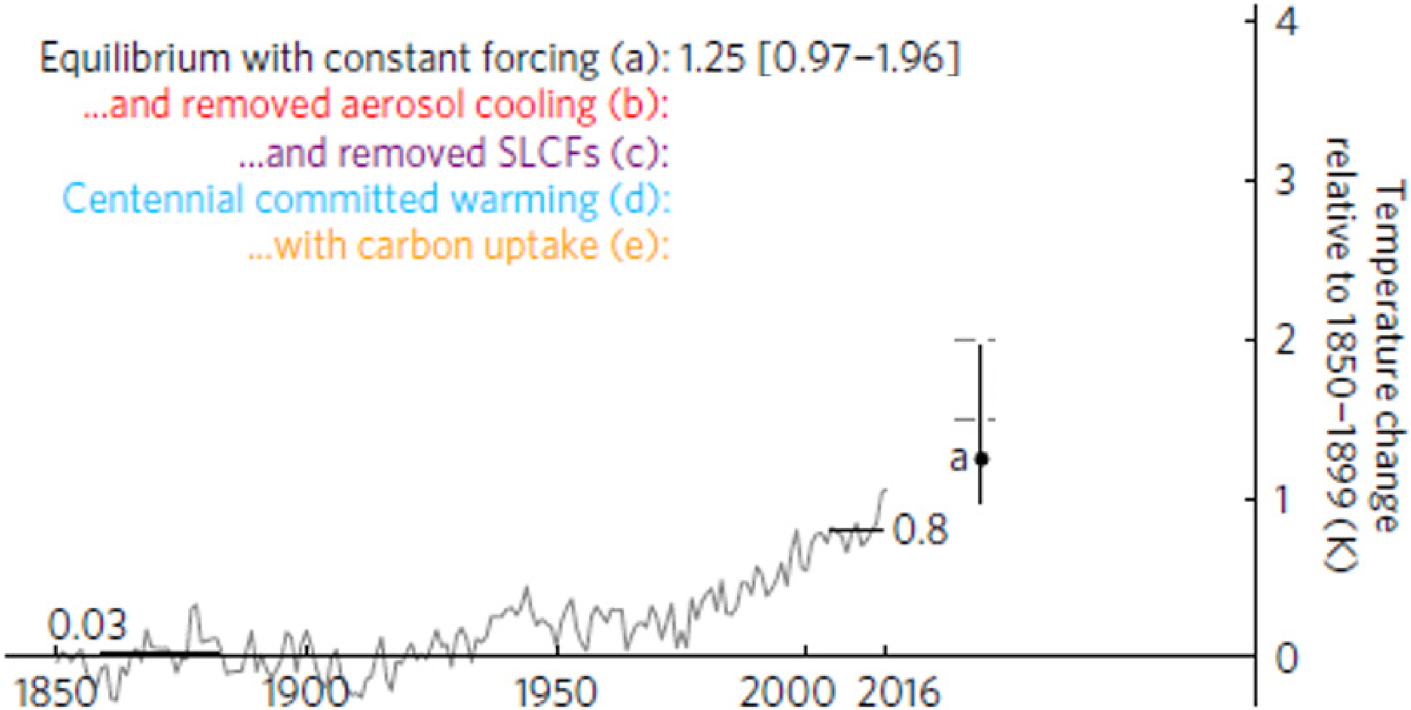

Figure 2 | Estimates of committed warming under five different sets of assumptions. Cases ***a*** (black) and ***b*** (red) are the equilibria with and without aerosol cooling, whereas case ***c*** (purple) includes the effect of removing short-lived climate forcers such as CH_4. Cases ***d*** (blue) and ***e*** (orange) are scaled with the transient climate response representative of warming within this century. Case ***d*** is otherwise equivalent to case ***c***.

In case ***e***, it is assumed that carbon uptake by the world's oceans continues on the centennial timescale.

Mauritsen and Pincus, Nature Climate Change, 2017: https://www.nature.com/articles/nclimate3357