Thoughts on Climate Sensitivity
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http://ccdatacenter.org/documents/CSThoughts.pdf

(This a very rough draft of my initial thoughts in response to " Explainer: How scientists estimate ‘climate sensitivity’ " - https://www.carbonbrief.org/explainer-how-scientists-estimate-climate-sensitivity)

The "conventional wisdom" is that there is a single value for climate sensitivity and all we need to do to forecast the future equilibrium temperature increase for a given anthropogenic emissions scenario is to get a better idea of what the value of climate sensitivity is and then use the formula "Equilibrium Temperature = Climate Sensitivity * ((Stabilized PPM/278)-1)" . For example, if atmospheric CO2 were to stabilize at 450 PPM and climate sensitivity were 3, the equilibrium temperature increase would be 3 *( (450/278)-1) or 1.86° C. (And for 556 PPM, a doubling of CO2, the increase would be 3.0° C). This is wrong on several fronts.

First, the formula assumes that there is a relatively linear relationship between the temperature increase contributions of CO2 and the three major feedbacks: water vapor, clouds, and surface albedo changes in the Arctic. But this is not the case with surface albedo changes, as the Arctic sea ice extent was relatively for at least the 1,400 year prior to 1980, when it started a precipitous decline (and the Arctic Ocean will likely be ice free by mid century). This means that the climate sensitivity will be different for an atmospheric concentration of CO2 that does not cause a significant decline in Arctic sea ice one that results in an ice free Arctic (see below for a "thought experiment"). Climate sensitivity therefore also depends on the stabilized atmospheric concentration of CO2.

Second, an equilibrium temperature does not depend on CO2 alone, but also depends on the "CO2 equivalent" of other greenhouse gases and aerosols.

Third, an anthropogenic CO2 emissions budget should not be set on an expected value for climate sensitivity alone, as natural feedbacks will likely contribute significantly to the total GHG emissions. Most of these emissions are dependent on temperature and some are already underway (from soils, peat, water surfaces, etc.). It is quite possible the emissions from feedbacks could use up the entire remaining "carbon budget".

Fourth, emissions from permafrost, once started, will continue even if the global average temperature is reduced, as the microbial process for creating these emissions warms up the permafrost.

Fifth, "conventional" climate sensitivity assumes that CO2 emissions eventually stop and that the atmospheric PPM CO2 stabilizes. This will not likely be the case because of natural emissions.

Sixth, emissions from methyl hydrates could start a serious feedback loop if the temperature increase exceeds a certain threshold (perhaps 5° C, but possibly lower) , driving the temperature up as much as an additional 5° C

And seventh, we are possibly past (or very near) the point where a value for climate sensitivity does not make any sense, as future anthropogenic emissions coupled with natural feedbacks will cause the temperature to increase enough to make most of the Earth uninhabitable unless we either capture and sequester many tens of gigatons of CO2 (at a cost that might be prohibitive) or start using solar radiation management.

Because of natural feedbacks, the concept of climate sensitivity needs to be significantly revised for it to become useful.

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As thought experiment, assume that a stabilized atmospheric CO2 concentration of 350 PPM would result in minimal Arctic sea ice loss and that climate sensitivity were 3.0. Then the equilibrium temperature increase would be 0.78° C. (Note that these numbers are not necessarily realistic but were just chosen to make a point.) Further assume that an atmospheric CO2 concentration of 420 PPM would result in the Arctic Ocean in September being ice-free for a month. According the formula, the equilibrium temperature would be 1.53° C.

Brian J. Soden and Isaac M. Held ("An Assessment of Climate Feedbacks in Coupled Ocean–Atmosphere Models", 2006; [http://journals.ametsoc.org/doi/full/10.1175/JCLI3799.1](http://journals.ametsoc.org/doi/full/10.1175/JCLI3799.1) ) estimated that the radiative forcing of the models they reviewed (roughly doubling in equivalent $CO_2$ between 2000 and 2100) was 4.3 W $m^{-2}$ and, "[o]n average, the strongest positive feedback is due to water vapor (1.8 W $m^{-2}$ $K^{-1}$), followed by clouds (0.68 W $m^{-2}$ $K^{-1}$), and surface albedo (0.26 W $m^{-2}$ $K^{-1}$), thus surface albedo changes (primarily Arctic sea ice and Northern Hemisphere snow cover extent) contribute about 6% of the total radiative forcing at the global tropopause. So the expected contribution of surface albedo changes in the Arctic for temperature increases of 0.78° C and 1.53° C would be 0.047° C and 0.092° C respectively, for an increase of 0.045° C. But according to Hudson ([http://www.npolar.no/npcms/export/sites/np/en/people/stephen.hudson/Hudson11_AlbedoFeedback.pdf](http://www.npolar.no/npcms/export/sites/np/en/people/stephen.hudson/Hudson11_AlbedoFeedback.pdf)), a realistic ice-free-summer scenario (no ice for one month, decreased ice at all other times of the year) results in a forcing of about 0.3 W m−2. And combine this with a similar albedo change for the decline in the Northern Hemisphere snow cover extent, the total albedo change would likely be closer to 0.6 W m-2, which would raise the equilibrium temperature about 0.35° C if climate sensitivity were 3. So the expected equilibrium temperature for 420 PPM would be closer to 1.84° C, which implies a climate sensitivity of 3.6.