EGU22-6540, updated on 06 Oct 2022
https://doi.org/10.5194/egusphere-egu22-6540
EGU General Assembly 2022

A discussion of Earth's climate sensitivity and its long term dynamics

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There is much current debate about the way in which the earth's climate and temperature are responding to anthropogenic and natural forcing. Current forecasts are dependent on the accuracy of how Equilibrium Climate Sensitivity (ECS) is evaluated. In the recent wide-ranging ECS sensitivity review and assessments of Sherwood et al (2020, *Rev. Geophys.* **58**, e2019RG000678), they report a baseline ECS 5%–95% with a range of 2.3 °C to 4.7 °C. While this is an important and much needed quantification – this wide ECS uncertainty range, based largely on uncertainty around total radiative forcing (TRF), is also problematic for our geophysical based community. The ECS value as viewed by policy and global strategy negotiators is currently only understood to a 70% (= 2.4 / 3.5) physically resolved level of resolution. An open question (to discuss in this talk) is it possible to resolve this physical measurement more accurately and what are the current main issues that need to be accommodated? As part of this discussion we present the work of Young, Allen and Bruun (2021): *a re-evaluation of the Earth's surface temperature response to radiative forcing* (2021, *ERL*, **16**, 054068). In that paper we have re-assessed the current evidence at the globally averaged level by adopting a generic 'data-based mechanistic' modelling strategy that incorporates statistically efficient parameter estimation. This identifies a low order, differential equation model that explains how the global average surface temperature variation responds to the influences of total radiative forcing. The model response includes a novel, stochastic oscillatory component with a period of about 55 years (range 51.6–60 years) that appears to be associated with heat energy interchange between the atmosphere and the ocean. These 'quasi-cycle' oscillations, which account for the observed pauses in global temperature increase around 1880, 1940 and 2001, appear to be related to ocean dynamic responses, particularly the Atlantic multidecadal oscillation. The model explains 90% of the variance in the global average surface temperature anomaly and yields estimates of the equilibrium climate sensitivity (ECS) (2.29 °C with 5%–95% range 2.11 °C to 2.49 °C) and the transient climate response (TCR) (1.56 °C with 5%–95% range 1.43 °C to 1.68 °C), both of which are smaller than most previous estimates. When a high level of uncertainty in the TRF is taken into account, the ECS and TCR estimates are unchanged but the ranges are increased to 1.43 °C to 3.14 °C and 0.99 °C to 2.16 °C, respectively. This then gives the 70% physical resolution limit in ECS mentioned above. Current work is in progress to test this ECS re-evaluation approach using the CMIP6 models. We will

discuss some on-going findings of these model signal assessments which include a specific focus on resolution of Atlantic and Pacific Ocean pentedecadal modes.

Peter C Young, P Geoffrey Allen and John T Bruun (2021). A re-evaluation of the Earth's surface temperature response to radiative forcing, *Environ. Res. Lett.* **16** 054068, https://iopscience.iop.org/article/10.1088/1748-9326/abfa50.