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How useful is equilibrium climate sensitivity in characterizing the global temperature response?

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Quantifying global temperature response to radiative forcing is central to assessments of climate change. In the simplest climate models, the magnitude of the temperature response is determined by a single number; the equilibrium climate sensitivity. In reality, such a simple characterization is problematic. The equilibrium climate sensitivity is only valuable if used to address questions about temperature change on time scales comparable to the longest time scales in temperature response. Due to the slow response of the deep ocean, these time scales are much longer than those of interest in most analyses of anthropogenic climate change. Moreover, the multi-scale (and approximately scale-invariant) structure of the temporal variability in global temperature makes it difficult to define consistent measures of short-scale climate sensitivity. A second obstacle is that climate sensitivity is state dependent whenever non-linear effects become important, and sensitivity may differ between distinct climate regimes. In addition to these fundamental challenges, it is questionable whether we have sufficiently long and reliable Holocene temperature records to make unbiased estimates of climate sensitivity. In this work, we will propose an alternative approach where the global climate response is measured as a function of scale and state. The ideas are illustrated with analysis of both simple and complex climate models, as well as using observational data.