

## **Climate Sensitivity: What is it? What is involved? How can it be measured? When is it relevant?**

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While there is little question that anthropogenic greenhouse emissions can lead to some warming, the practical importance of this depends on how large the effect is. This brings one to the question of climate sensitivity. The usual approach to this is basically one-dimensional in the hope that such an approach can be applied to horizontal averages of relevant thermodynamic quantities. Such a hope may not always be justified. In focusing on greenhouse warming, we will ignore this. However, in considering natural climate changes as analogues to anthropogenic warming, we will see that the assumption is often unlikely to be warranted. This is particularly germane when one attempts to consider paleoclimate variations as analogues of anthropogenic greenhouse warming.

We will, in this talk, define radiative forcing, and show how it is estimated for increasing greenhouse gas concentrations. Sensitivity is the equilibrated response of global mean temperature to this forcing. By convention, it is usually taken to be the response to the radiative forcing produced by a doubling of carbon dioxide. We will show how this can be estimated, and go on to the issue of how this response is affected by feedbacks involving water vapor and clouds. We will also briefly discuss the impact of albedo changes due to changes in surface snow and ice. Our approach here will be to consider what changes in clouds, water vapor and surface albedo can produce changes in radiative forcing comparable to what would be produced by a doubling of carbon dioxide. One result that will immediately become clear is feedbacks due to various changes cannot be independent of each other.

The explicit determination of feedbacks is a complex matter and there are many approaches – each with particular strengths and shortcomings. We will review a variety of such approaches ranging from the explicit observation of feedback mechanisms, to the observation of outgoing radiation, and including comparisons of response times and the explicit consideration temperature time series.

The comparison of greenhouse induced climate change with paleoclimatic climate change forces us to consider the relevance of the concept of climate sensitivity. In particular, we will show that the major glaciations cycles of the past 700,000 years do not actually depend on global mean forcing, and that the feedback processes, we have discussed, can become the mechanisms whereby the earth establishes mean balance in the presence of inhomogeneous seasonal forcing.