2024_61_Physics_PC: Why does climate sensitivity depend on the type of forcing?

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Background:

A key topic of current research is to understand the global temperature response to a given climate forcing, a metric known as climate sensitivity. Since atmospheric CO_2 concentrations are well-observed, the climate sensitivity to CO_2 could in principle be estimated from historical observations of temperature and CO_2. A difficulty in doing this, however, is that climate forcing agents other than CO_2 – for example aerosols and volcanic eruptions – have played a role in historical climate change. Climate modelling evidence shows that different forcing agents cause different climate sensitivities, and this is because of varying climate feedbacks. It has been demonstrated that the strength of climate feedbacks depends on the spatial pattern of surface warming. However, it remains unclear how different forcing agents result in different warming patterns, and whether climate models are able to correctly represent the mechanisms responsible for the formation of temperature patterns in response to forcings.

Aims and methodology:

The aim of the project is to understand the interactions between radiative forcing and warming pattern, and how they account for differences in climate sensitivity among forcing agents. Specific questions to be addressed in the project could include:

- Following a radiative forcing, how does the atmosphere shape the pattern of surface energy forcing, which determines the initial warming pattern?
- How does the circulation of the ocean modify this warming pattern over longer timescales?
- How does the warming pattern feed back on the radiation budget? Does this feedback amplify or dampen the surface temperature changes?

To address these questions, the student will run and analyse climate model simulations in which a variety of forcing agents are applied. We will develop a theoretical framework to interpret differences in climate sensitivity among forcing agents. The experiments will include both simplified and realistic representations of the ocean; comparing these simulations will make it possible to assess the relative importance of atmospheric and ocean processes in the formation of warming patterns. The generality of the mechanisms identified in these experiments will then be tested by analysing the experiments submitted for the last report of the Intergovernmental Panel on Climate Change (IPCC), which were produced a wide set of climate models.

Finally, since IPCC models are known to represent the interactions between surface temperature and radiation in different ways, observations will also be examined. This analysis will attempt to provide an observational constraint on the behaviour of climate models