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Radiative feedbacks in a 1D radiative-convective equilibrium model

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Equilibrium climate sensitivity (ECS), the change in surface temperature in response to a doubling of atmospheric CO2, is arguably one of the most important quantities when discussing climate change. Despite major improvements in climate modelling over the last decades, ECS estimates lie within a rather constant range between 1.5-4 K. The cause of this spread is not obvious as the comparison of comprehensive climate models is difficult due to the complexity of their formulations.

We are revisiting one of the simplest climate models, one-dimensional radiative-convective equilibrium (RCE). Despite their simple and concise model formulation, RCE models include the most dominant clear-sky radiative feedbacks. In our study, we quantify the strength of the Planck, water-vapor, and lapse-rate feedback by turning them on or off using different model configurations. This method allows us to compare the effect of different model assumptions, e.g. the vertical distribution of water vapor, on the decomposed radiative feedbacks. We find that the interplay of the water-vapor and the lapse-rate feedback is especially affected by the relative humidity in the upper troposphere.

The RCE model is run with a state-of-the-art radiation scheme, that is also used in comprehensive Earth system models. A line-by-line radiative transfer model is used to both verify the performance of the fast radiation scheme, and to attribute changes in the radiative feedbacks to specific regions in the electromagnetic spectrum.

In a further step, conceptual rectangular clouds are added to investigate possible cloud masking effects on both the radiative forcing and feedback. A large Monte Carlo ensemble is used to tune the cloud optical parameters in a way that the resulting cloud radiative effect matches satellite observations. Preliminary results suggest a near zero long-wave feedback, in contrast to previous studies.