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Moist Greenhouse states with solar and CO_2-induced forcing

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Water-rich planets such as Earth are expected to become eventually uninhabitable, because liquid water does not remain stable at the surface as surface temperatures increase with the solar luminosity over time. It is conceivable that a large increase in atmospheric greenhouse-gas concentrations could also destroy the habitability of water-rich planets, but previous studies could not clearly establish this. Here we use for the first time a state-of-the-art atmospheric general circulation model, namely a modified version of ECHAM6, to compare the potential of both solar and CO_2-induced forcing to render a water-rich planet uninhabitable.

We find that CO_2-induced forcing as readily destabilizes a present-day Earth-like climate as does solar forcing. This climate instability is caused by a positive cloud feedback, which is in turn caused by the weakening large-scale circulation with increasing surface temperature. The climate does not run away, but instead attains a new steady state with global-mean sea-surface temperatures above 330 K. The upper atmosphere is considerably moister in this warm steady state than in the reference climate. The upper-atmospheric mixing ratio of water exceeds the so-called Moist-Greenhouse limit, which implies that the planet would be subject to substantial loss of water to space. For either a certain range of elevated CO_2 concentrations or solar irradiation, we find both cold and warm equilibrium states. Therefore the transition to the warm state may not simply be reversed by removing the additional forcing.