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Increased climate sensitivity under global warming

K. Meraner, A. Voigt, and T. Mauritsen
Germany (katharina.meraner@zmaw.de)

Climate sensitivity, defined as the increase in global-mean surface temperature with a doubling of atmospheric carbon dioxide concentration, represents our simplest description of climate change. In a linear approximation of the climate system, climate sensitivity is constant and does not depend on the reference climate. However, climate model simulations sometimes report an increase of climate sensitivity with increasing global-mean surface temperature. Here, we show that the atmosphere general circulation model ECHAM6, coupled to a mixed-layer ocean, exhibits an increase in climate sensitivity from 3 K for the first CO_2 doubling to 7 K for the third CO_2 doubling. Gregory plots show that the increase in climate sensitivity can not be attributed to an accelerated decrease in planetary albedo and thereby increase in the shortwave feedback. Rather, the increase in climate sensitivity is caused by a flattening of the clear-sky outgoing longwave radiation at higher temperatures, yielding a less negative clear-sky longwave feedback. This likely results from a non-perfect cancellation between opposite changes in the temperature and the water vapor feedback, with the positive water vapor feedback strengthening faster than the negative temperature feedback. Such a behavior is consistent with a radiative model with fixed relative humidity and atmospheric temperatures on the moist adiabatic curve. The tropopause strongly rises with increasing global-mean surface temperature and leads to an increase and upward shift of upper tropospheric water vapor, while the tropopause temperature stays at 200 K. The fixed tropopause temperature is in line with the fixed anvil temperature hypothesis. This suggests a link to tropical deep convection.