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Time dependence of climate sensitivity

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Climate sensitivity is a measure for the global mean temperature change of the earth in response to a given radiative forcing. In an experiment with an instantaneous forcing by e.g. a doubling of the atmospheric CO_2 content the radiative imbalance at the top of the atmosphere can be regarded as a function of the global mean temperature change. In such an experiment the climate sensitivity can be approximated by linearly extrapolating to zero the TOA imbalance where equilibrium is obtained. The thus derived value is usually referred to as effective climate sensitivity. It has been established however, that the effective climate sensitivity changes over time. While the reason for this change is not clear, most recent investigations of the abrupt4xCO2 experiments of multiple members of the CMIP5 archive point to a delay in warming of the eastern tropical Pacific region relative to the global average in the multi model mean. Due to high stability in this region the heat is trapped there close to the surface which reduces the local lower tropospheric stability. The trapping of the warming close to the surface implies that the longwave cooling is less efficient in this region and its delayed warming relative to the global average increases global climate sensitivity over time. The decrease in lower tropospheric stability furthermore reduces low cloud cover leading to less negative low cloud feedback which causes additional warming.

We investigate the delayed warming in the eastern Pacific region in more detail in terms of its effects on stability as well as clouds for individual members and multi model means of both the CMIP5 and CMIP6 archives. We find that in the multi model mean, the CMIP6 members show an even larger delayed warming than the CMIP5 members. Furthermore, the individual members of both archives generally exhibit the same pattern of delayed eastern tropical Pacific warming and a corresponding decrease in lower tropospheric stability in the same region, which indicates robustness of the earlier results based on the CMIP5 multi model mean. Additionally, there is a decrease in liquid water content in the lower atmospheric layers, confirming the influence of reduced lower tropospheric stability on low clouds. However, there are several further regions such as the Southern Ocean with a consistent delayed warming and reduced stability, which might influence climate sensitivity as well.