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Investigation of strongly enhanced methane Part II: Slow climate feedbacks.

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Methane (CH_4) is the second most important anthropogenic greenhouse gas and its atmospheric abundance is rising rapidly at the moment (e.g. Nisbet et al., 2019).

We assess the effects of doubled and fivefold present-day (2010) CH_4 lower boundary mixing ratios on the basis of sensitivity simulations with the
chemistry-climate model EMAC. As a follow-up on Winterstein et al. (2019) we investigate slow adjustments by applying a mixed layer ocean (MLO) model
instead of prescribed oceanic conditions. In the simulations with prescribed oceanic conditions, tropospheric temperature changes are largely suppressed,
while with MLO tropospheric temperatures adjust to the forcing. In the present study we compare the changes in the MLO sensitivity simulations to the
sensitivity simulations with prescribed oceanic conditions (Winterstein et al., 2019). Comparing the responses of these two sets of sensitivity simulations separates rapid adjustments and the effects of slow climate feedbacks associated with tropospheric warming.

The chemical interactions in the stratosphere in the MLO set-up (slow adjustments) compare in general well with the results of Winterstein et al. (2019) (rapid adjustments). The increase of stratospheric water vapor is albeit 5 % (15 %) points weaker in the MLO doubling (fivefolding) experiment compared to the doubling (fivefolding) experiment with prescribed oceanic conditions in line with a weaker increase of stratospheric OH. Stronger O_3 decrease and CH_4
increase in the lowermost tropical stratosphere in the MLO sensitivity simulations compared to the sensitivity simulations with prescribed oceanic conditions indicate a more distinct strengthening of tropical up-welling due to tropospheric warming in the MLO set-up. The MLO simulations also show evidence of a strengthening of the Brewer-Dobson Circulation. When separating the quasi-instantaneous chemically induced O_3 response from the O_3 response pattern in the MLO set-up, the O_3 response to slow climate feedbacks remains. This pattern is consistent with the O_3 response to slow climate feedbacks induced by increases of CO_2.

This first of its kind study shows the climatic impact of strongly enhanced CH_4 mixing ratios and how the slow climate response of tropospheric warming potentially damp instantaneous chemical feedbacks.