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Stratosphere-troposphere coupling: Controls by the zonal mean circulation on the stationary wave response to climate change

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The stationary wave field, which is the zonally asymmetric component of the time mean atmospheric circulation, exerts a strong control on regional climate and accounts for a significant fraction of the wave driving of the Northern Hemisphere extratropical zonal mean circulation. Climate models simulate a wide range of stationary wave responses to climate forcing, and previous work has debated whether the responses are dominated by changes in the zonal mean flow or in the zonally asymmetric forcing terms such as diabatic heating. This paper will describe efforts to understand the stationary wave response to climate change in chemistry-climate models (CCMs) with good stratospheric representation, using a recently developed stationary wave model (SWM) with enhanced stratospheric resolution. We first focus on the response of the Canadian Middle Atmosphere Model (CMAM) CCM to climate change. The SWM analysis shows that changes to the zonal mean basic state with diabatic heating held fixed explain much of the CMAM stationary wave response. In particular, the acceleration of the subtropical upper tropospheric zonal mean jet in climate change, which is a robust radiatively driven zonal mean climate change response, can by itself drive a large fraction of the stationary wave response. In addition, CMAM simulates an increase in stratospheric wave driving in response to greenhouse forcing, in common with many climate models. However, the SWM analysis suggests that this wave driving response is not dominated by the subtropical jet response but involves several aspects of the zonal-mean wind response and the diabatic heating response. All of these components contribute to enhanced stratospheric wave driving, likely through positive feedbacks. Sensitivity tests based on reanalysis data confirm these findings and are used to interpret the underlying dynamics. We then extend the analysis to a group of CCM simulations in support of the SPARC CCMVal Report and WMO Ozone Assessments. In these models, it is also found that changes to the zonal mean account for a significant fraction of the stationary wave response to climate change.