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Model assessment of the response of the tropical lower stratosphere to the 11-yr solar cycle

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Enhanced ultraviolet irradiance during the positive phase of the 11-yr solar cycle is expected to warm the upper stratosphere. Observations and numerical modelling indicate positive temperature changes in solar maxima. Yet, many modelling attempts failed to successfully reproduce the temperature response maximum in the tropical lower stratosphere (TLS), which has been detected in reanalysis products. The cause of this warming remains debated. To investigate whether and how the 11-yr solar cycle affects the TLS, we carry out ensemble simulations with the middle atmosphere version of ECHAM5 forced only with realistic solar irradiance and ozone changes from 1955 to 2006. A multiple regression model isolates temperature responses to the solar cycle forcing in three different model setups (without ocean coupling, coupled to a mixed layer ocean, coupled to a full dynamical ocean) and two different horizontal resolutions. Our simulations demonstrate a weak dependence of the simulated stratospheric solar cycle signals on ocean coupling. Furthermore, none of the experiments is characterized by a double-peak response profile in the tropical stratosphere when ensemble-mean annual time series are analyzed. Instead, the magnitude of the simulated temperature anomalies increases almost monotonically from the tropical upper troposphere to the upper stratosphere. Many individual ensemble members, however, do show a well-formed temperature maximum in the TLS, but we call for caution in interpreting these signals as of solar origin. This is because the solar cycle regression coefficients in individual ensemble members are biased by the collinearity between the solar cycle predictor and the predictor of the El Niño-Southern Oscillation. More specifically, we find a tendency for negative or less positive temperature anomalies in ensemble members that exhibit positive correlations and vice versa. The large number of ensemble simulations allows for the quantification of the bias induced by collinearity. Collinearity, therefore, could adversely affect the calculated TLS response to the solar cycle in any single short model realization (e.g spanning over 5 solar cycles only) analysed with a multiple regression model. The same may be true for the observed record.