QOS2016-357, 2016
Quadrennial Ozone Symposium of the International Ozone Commission

The role of ozone feedback in modulating the atmospheric response to the solar cycle forcing

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The irradiance changes between the 11-year solar cycle maximum and minimum lead to increased stratospheric temperatures via enhanced UV absorption by ozone. This direct radiative response is strengthened by increased photochemical ozone production. While in reality these two processes are closely coupled, not all global climate models include interactive chemistry and may not therefore represent the solar-ozone feedback in an internally consistent manner. This study investigates the role of the representation of ozone for the modelled solar cycle response.

We use a version of the UM-UKCA chemistry-climate model. We perform a 64-year perpetual solar minimum integration with non-interactive treatment of ozone, i.e. where ozone is externally prescribed for the radiative calculations. This is complemented with two analogous non-interactive solar maximum integrations that include an increase in solar irradiance, but which differ in their representation of the solar-ozone response. We show that the representation of the solar-ozone feedback has a first-order impact on the simulated yearly mean short wave heating rates and temperature responses to the 11-year solar cycle forcing, with important implications for modelling studies. However, despite the substantial differences in the tropical temperature changes, the Northern Hemisphere high latitude circulation responses are broadly similar in both experiments, and show strengthening of the polar vortex during winter and a weakening in March. Therefore, the representation of the solar-ozone response appears unlikely to explain the substantial spread in the solar cycle dynamical responses in different models.

Lastly, we compare these results with an analogous solar maximum/minimum pair in which ozone is calculated by the photochemical scheme in a self-consistent manner. We show that the use of interactive vs non-interactive treatment of ozone does not strongly affect the yearly mean tropical temperature response. However, the results suggest potential differences in the seasonality of the dynamical response in the Northern Hemisphere high latitudes. All in all, our results highlight the importance of the solar-ozone feedback in modulating the atmospheric response to the solar cycle forcing and the importance of properly representing this for future model studies of the impact of the solar cycle forcing on climate.