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SWIFT - An extremely fast semi-empirical module for including polar ozone loss in climate model systems

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Increasing evidence suggests that a robust representation of all aspects of climate change in global climate models requires the inclusion of stratospheric chemistry. E.g. understanding emerges that increases in the stratospheric southern annular mode, which result from the radiative feedback of the ozone hole on stratospheric dynamics, propagate down and have major consequences for the climate of the southern hemisphere. Predicting future climate change during the period of the disappearance of the ozone hole requires accounting for these effects in climate models. The radiative/dynamical feedback of the ozone hole on atmospheric dynamics is at least partly driven by the mutual interaction between atmospheric waves and the steep gradients of the radiatively active ozone at the edge of the ozone hole. Accounting for these processes in climate models requires the inclusion of an interactive ozone hole in the model that allows for these mutual interactions. Model simulations with a static, circular prescribed ozone hole, that does not interact with atmospheric waves, are a valuable first step but will always convey a very incomplete picture. Coupled Chemistry Climate Models (CCMs) are numerically very demanding. Due to the numerical expense of such models they can neither be used to explore a wide range of scenarios nor for ensemble simulations, which are key to account for the internal variability of the climate system. There is an urgent need for model approaches that allow the inclusion of key processes of stratospheric chemistry and of an interactive ozone hole with much less numerical overhead. We have developed SWIFT (Semi-empirical Weighted Iterative Fit Technique), an extremely fast semi empirical model for polar ozone loss that allows accounting for this process in Atmosphere/Ocean General Circulation Models with hardly any numerical overhead. The model solves the differential equations that describe the vortex average evolution of HCl, ClONO2, HNO3 (gas phase), HNO3 (liquid/solid phase), ClOx, and ozone. It is driven by daily values of the vortex average extent of PSC conditions and solar illumination, quantities that are easily calculated from the wind and temperature field of any climate model. The stiffness of the system of model equations is low and the model processes hundreds of years in a second. As time constants for the overall effect of the included mechanisms the model includes 5 to 8 empirical fit parameters which are trained on vortex averaged observations of HCl and HNO3(gas phase) by the Microwave Limb sounder on Aura, ClONO2 by ACE FTS and ozone loss rates from Match. The training of the model is done with data from one Arctic and one Antarctic winter. It is important to note that these time constants merely replace the universal chemical reaction kinetic constants that are part of any chemical model and do not depend on climatic conditions. Hence, although the model includes empirical elements, it is valid for a wide range of climatic conditions extending far beyond the range of conditions that were used to train it. We show that the model reproduces both the seasonal variation of the included trace species and the inter-annual variations of ozone loss very well.