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Simulations of preindustrial, present-day, and 2100 conditions in the NASA GISS composition and climate model G-PUCCINI

D. T. Shindell[1,2], G. Faluvegi[1,2], N. Unger[1,2], E. Aguilar[1,2], G. A. Schmidt[1,2], D. M. Koch[1,3], S. E. Bauer[1,2], and R. L. Miller[1,4]
[1]NASA Goddard Institute for Space Studies, New York, NY, USA
[2]Center for Climate Systems Research, Columbia University, NY, USA
[3]Dept. of Geophysics, Yale University, New Haven, USA
[4]Dept. of Applied Physics and Applied Math, Columbia University, NY, USA

Abstract. A model of atmospheric composition and climate has been developed at the NASA Goddard Institute for Space Studies (GISS) that includes composition seamlessly from the surface to the lower mesosphere. The model is able to capture many features of the observed magnitude, distribution, and seasonal cycle of trace species. The simulation is especially realistic in the troposphere. In the stratosphere, high latitude regions show substantial biases during period when transport governs the distribution as meridional mixing is too rapid in this model version. In other regions, including the extrapolar tropopause region that dominates radiative forcing (RF) by ozone, stratospheric gases are generally well-simulated. The model's stratosphere-troposphere exchange (STE) agrees well with values inferred from observations for both the global mean flux and the ratio of Northern (NH) to Southern Hemisphere (SH) downward fluxes.
Simulations of preindustrial (PI) to present-day (PD) changes show tropospheric ozone burden increases of 11% while the stratospheric burden decreases by 18%. The resulting tropopause RF values are −0.06 W/m^2 from stratospheric ozone and 0.40 W/m^2 from tropospheric ozone. Global mean mass-weighted OH decreases by 16% from the PI to the PD. STE of ozone also decreased substantially during this time, by 14%. Comparison of the PD with a simulation using 1979 pre-ozone hole conditions for the stratosphere shows a much larger downward flux of ozone into the troposphere in 1979, resulting in a substantially greater tropospheric ozone burden than that seen in the PD run. This implies that reduced STE due to stratospheric ozone depletion may have offset as much as 2/3 of the tropospheric ozone burden increase from PI to PD. However, the model overestimates the downward flux of ozone at high Southern latitudes, so this estimate is likely an upper limit.

In the future, the tropospheric ozone burden increases by 101% in 2100 for the A2 scenario including both emissions and climate changes. The primary reason is enhanced STE, which increases by 124% (168% in the SH extratropics, and 114% in the NH extratropics). Climate plays a minimal role in the SH increases, but contributes 38% in the NH. Chemistry and dry deposition both change so as to reduce tropospheric ozone, partially in compensation for the enhanced STE, but the increased ozone influx dominates the burden changes. The net RF due to projected ozone changes is 0.8 W/m^2 for A2. The influence of climate change alone is −0.2 W/m^2, making it a substantial contributor to the net RF. The tropospheric oxidation capacity increases seven percent in the full A2 simulation, and 36% due to A2 climate change alone.

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