Goldschmidt 2023 Abstract
https://doi.org/10.7185/gold2023.13774

Calculating the ozone column depth in Earth's early atmosphere

AOSHUANG JI AND JAMES KASTING

Penn State

Presenting Author: azj64@psu.edu

Understanding the trajectory of atmospheric O_2 through Earth's history is central to the study of its evolution from a lifeless world to an inhabited one. One key outcome from the O_2 buildup in Earth's atmosphere is the appearance of an ozone layer that acts as a UV shield for sustaining an inhabited world. Thus, different 1-D and 3-D models have been employed to calculate the ozone column depth as a function of atmospheric O_2 concentration (pO_2) over the past 40 years. However, discrepancies have been found when comparing our 1-D photochemical model with a 3-D coupled chemistry-climate model (WACCM6).

Both models yield nearly the same ozone column depth for today's atmosphere, but the 3-D model predicts only half as much ozone at lower pO_2 levels. During our investigation, we have found that multiple interacting factors could contribute to this discrepancy, including H_2O concentrations in the upper troposphere, lower boundary conditions on biogenic trace gases, vertical and meridional transport rates, and different chemical mechanisms, especially the treatment of O_2 photolysis in the O_2 Schumann-Runge (SR) bands (175-205 nm). We have already shown that the treatment of the SR bands in WACCM6 leads to too short of a lifetime for methane in that model. We believe that rigorous treatment of O_2 photolysis is critical to solving the ozone column depth discrepancy, as well.

Additionally, we suspect that no one, including our group, has done a rigorous job of parameterizing this process at low pO_2 because all models are closely tied to present atmosphere parameters. To correct this problem, we will derive correlated-k coefficients to calculate O_2 photolysis rates at four temperatures (150 K, 200 K, 250 K, and 300 K) and five pressures (1 bar, 0.1 bar, 0.01 bar, 0.001 bar, and 0.0001 bar). We will incorporate these coefficients in our 1-D model and then, when they have been tested, in WACCM6 and other ozone photochemistry models. We can then compare the improved calculations with our old results to determine how much difference this makes and to understand not only the evolution of Earth's ozone layer more precisely, but also Earth-like planets.