Reproducing Internal Variability in Chemical Transport Models using a Stochastic Surrogate Model

Emmie J Le Roy

Massachusetts Institute of Technology, Department of Earth, Atmospheric and Planetary Sciences, Cambridge, MA USA 02139, USA

Author list (excluding presenting author)

Sebastian D. Eastham, Noelle E. Selin

Abstract

Chemistry-climate models and chemical transport models driven by archived meteorology from future climate simulations are valuable tools for projecting future changes in atmospheric composition. However, these models are very computationally intensive because the chemical and physical processes that convert emissions into air pollutant concentrations require solving the coupled differential equations of 100s-1000s of chemical species. As a result, generating enough ensemble members to account for internal (unforced) variability requires prohibitive computational resources, on top of exploring different future scenarios as well as model structural uncertainty. Separating internal variability from model structural uncertainty and future scenario uncertainty is important for impact assessment and decision-making since internal variability contributes to the range of possible real-world outcomes and can confound the attribution of air quality trends under different emission control and climate scenarios. Thus, there is a need to develop alternatives to single model initial-condition large ensembles for estimating internal variability. Here, we develop a method of generating surrogate realizations of ozone (O_3) and particulate matter ($PM_{2.5}$) to specifically quantify internal variability using fewer ensemble members and shorter simulation lengths. We use a chemical transport model (GEOS-Chem High Performance; GCHPv12.8.0) driven by an ensemble of archived meteorological fields from a global climate model (Community Atmosphere Model; CAMv3.1) (GCHP-CAM) to relate unforced variability in seasonal-mean O_3 and $PM_{2.5}$ to meteorological variables using simple regression analysis. Since anthropogenic emissions are held constant in our GCHP-CAM framework, our simulations are uniquely suited for exploring the drivers of unforced O_3 and $PM_{2.5}$ variability. Our initial results confirm that summertime (JJA) climate-induced O_3 variability is a strong linear function of local temperature in certain regions, particularly over North America and Europe (median R^2=0.81). We then leverage this relationship to estimate the internal variability of surface O_3} as a function of a stochastic residual local temperature variability term.

Early Career Scientist

YES, I am an early career scientist.