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Impact of biomass burning inventory choice on simulated $PM_{2.5}$ and aerosol optical depth

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Chemical Transport Models (CTMs) are widely used to simulate aerosol concentrations, composition, and optical properties at regional to global scales and are fundamental tools for assessing aerosol impacts on climate and air quality. Despite continued advances in CTMs, their performance remains dependent on the accuracy of meteorological inputs, chemical mechanisms, and emission inventories. Differences among biomass burning emission inventories can arise from several factors, such as fire detection methods, fuel consumption estimates from fire radiative power (top-down) or burn area (bottom-up) approaches, assumptions regarding fuel type, combustion completeness, emission factors, and temporal allocation assumptions. Systematic evaluation of biomass burning emission datasets against ground-based observations is therefore essential for identifying region-specific improvements for CTMs. In this study, we use the GEOS-Chem chemical transport model to quantify the sensitivity of simulated Aerosol Optical Depth (AOD) to biomass burning emission inventories during the 2019 wildfire season over North America. Simulations driven by three commonly used global inventories: the Global Fire Emissions Database version 4 (GFED4), the Global Fire Assimilation System (GFAS), and the Quick Fire Emissions Dataset version 2 (QFED2), are compared with two recently developed biomass burning emission products from Environment and Climate Change Canada (ECCC): the Canadian Forest Fire Emissions Prediction System (CFFEPS) and the Global Forest Fire Emissions Prediction System (GFFEPS). Model output is evaluated against AOD observations from 138 NASA Aerosol Robotic Network (AERONET) stations across Canada and the United States. The evaluation reveals substantial regional variability in model performance across emission inventories. Over Canada, simulations driven by CFFEPS and GFFEPS exhibit the strongest agreement with observations, particularly in northern and western regions, where correlations reach values above 0.8 and normalized mean errors are as low as ~30%, while simulations using other global inventories generally show larger normalized errors. Across the United States, GFAS-driven simulations achieve correlations of approximately 0.6–0.7 in the western and eastern regions. Overall, these results demonstrate the strong sensitivity of simulated AOD to the chosen biomass burning emission inventory and emphasize the importance of regionally optimized fire emissions for accurately representing aerosols in chemical transport models.