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Feedbacks between Air-Quality, Meteorology, and the Forest Environment

Paul Makar (1), Ayodeji Akingunola (1), Craig Stroud (1), Junhua Zhang (1), Wanmin Gong (1), Michael Moran (1), Qiong Zheng (1), Jeffrey Brook (1,2), and David Sills (3)

(1) Air Quality Research Division, Atmospheric Science and Technology Directorate, Science and Technology Branch, Environment and Climate Change Canada, Toronto, Canada (paul.makar@canada.ca), (2) Dalla Lana School of Public Health, University of Toronto, Toronto, Canada, (3) Cloud Physics and Severe Weather Research, Environment and Climate Change Canada

The outcome of air quality forecasts depend in part on how the local environment surrounding the emissions regions influences chemical reaction rates and transport from those regions to the larger spatial scales. Forested areas alter atmospheric chemistry through reducing photolysis rates and vertical diffusivities within the forest canopy. The emitted pollutants, and their reaction products, are in turn capable of altering meteorology, through the well-known direct and indirect effects of particulate matter on radiative transfer. The combination of these factors was examined using version 2 of the Global Environmental Multiscale – Modelling Air-quality and CHemistry (GEM-MACH) on-line air pollution model. The model configuration used for this study included 12 aerosol size bins, eight aerosol species, homogeneous core Mie scattering, the Milbrandt-Yao two-moment cloud microphysics scheme with cloud condensation nuclei generated from model aerosols using the scheme of Abdul-Razzak and Ghan, and a new parameterization for forest canopy shading and turbulence. The model was nested to 2.5km resolution for a domain encompassing the lower Great Lakes, for simulations of a period in August of 2015 during the Pan American Games, held in Toronto, Canada. Four scenarios were carried out: (1) a “Base Case” scenario (the original model, in which coupling between chemistry and weather is not permitted; instead, the meteorological model’s internal climatologies for aerosol optical and cloud condensation properties are used for direct and indirect effect calculations); (2) a “Feedback” scenario (the aerosol properties were derived from the internally simulated chemistry, and coupled to the meteorological model’s radiative transfer and cloud formation modules); (3) a “Forest” scenario (canopy shading and turbulence were added to the Base Case); (4) a “Combined” scenario (including both direct and indirect effect coupling between meteorology and chemistry, as well as the forest canopy parameterization). The simulations suggest that the feedbacks between simulated aerosols and meteorology may strengthen the existing lake breeze circulation, modifying the resulting meteorological and air-quality forecasts, while the forest canopy’s influence may extend throughout the planetary boundary layer, and may also influence the weather. The simulations will be compared to available observations, in order to determine their relative impact on model performance.