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Forest Canopy Processes in a Regional Chemical Transport Model

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Forest canopies have typically been absent or highly parameterized in regional chemical transport models. Some forest-related processes are often considered – for example, biogenic emissions from the forests are included as a flux lower boundary condition on vertical diffusion, as is deposition to vegetation. However, real forest canopies comprise a much more complicated set of processes, at scales below the "transport model-resolved scale" of vertical levels usually employed in regional transport models. Advective and diffusive transport within the forest canopy typically scale with the height of the canopy, and the former process tends to dominate over the latter. Emissions of biogenic hydrocarbons arise from the foliage, which may be located tens of metres above the surface, while emissions of biogenic nitric oxide from decaying plant matter are located at the surface – in contrast to the surface flux boundary condition usually employed in chemical transport models. Deposition, similarly, is usually parameterized as a flux boundary condition, but may be differentiated between fluxes to vegetation and fluxes to the surface when the canopy scale is considered. The chemical environment also changes within forest canopies: shading, temperature, and relativity humidity changes with height within the canopy may influence chemical reaction rates. These processes have been observed in a host of measurement studies, and have been simulated using site-specific one-dimensional forest canopy models. Their influence on regional scale chemistry has been unknown, until now.

In this work, we describe the results of the first attempt to include complex canopy processes within a regional chemical transport model (GEM-MACH). The original model core was subdivided into "canopy" and "non-canopy" subdomains. In the former, three additional near-surface layers based on spatially and seasonally varying satellite-derived canopy height and leaf area index were added to the original model structure. Process methodology for deposition, biogenic emissions, shading, vertical diffusion, advection, chemical reactive environment and particle microphysics were modified to account for expected conditions within the forest canopy and the additional layers. The revised and original models were compared for a 10km resolution domain covering North America, for a one-month duration simulation.

The canopy processes were found to have a very significant impact on model results. We will present a comparison to network observations which suggests that forest canopy processes may account for previously unexplained local and regional biases in model ozone predictions noted in GEM-MACH and other models. The impact of the canopy processes on NO_2, PM2.5, and SO_2 performance will also be presented and discussed.