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Understanding mercury processes in the Arctic using modeling and multi-media observations

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Our ability to model (or predict) the changes in mercury (Hg) cycling in the Arctic under changing climate requires mechanistic understanding of processes. Gas-phase bromine radical chemistry is the main driver for the frequent and concurrent deposition of ozone and Hg in the coastal boundary layer during the spring, but uptake by vegetation is more important inland. Sea ice and its overlying snow cover are broadly understood as the key elements in the production of reactive bromine in polar spring. We extend Hg chemical mechanism in Environment and Climate Change Canada’s mercury model GEM-MACH-Hg to include bromine production, bromine-ozone-Hg chemistry, and the exchange of bromine, ozone and Hg species between air and frozen surfaces. We perform high resolution model simulations for the Arctic domain. The model captures the evolution of high BrO column densities associated with synoptic weather disturbances during polar sunrise as can be seen from satellite. Extensive model evaluation is performed using measured ambient concentrations of ozone and speciated Hg, total Hg in snow and the vertical column densities of BrO retrieved from ground stations and buoys floating on the ice-covered ocean at fine temporal scale. Using model simulations, we explain the mechanism for Hg cycling in coastal regions, including retention and drainage of Hg in the snowpack.

We perform a multi-year simulation from 2000 to 2020 to capture the impacts of changes in meteorology (such as temperature, winds, sea ice extent) on Hg cycling in the Arctic. We demonstrate and explain contrast in Hg deposition-snowmelt-reemission processes between different locations using observations of ice core record at a high elevation ice-field and a coastal site. Limited information exists on concentrations of Hg bioaccumulation in high latitude terrestrial carnivores. Spatial patterns of Hg in wolverine were assessed across the Arctic and boreal biomes of western Canada. We show that spatially distributed estimates of simulated atmospheric wet deposition are positively correlated with wolverine Hg concentrations. Finally, based on model-observation comparison, we suggest questions for further research on underlying processes.