Chapter 17
Global Mercury Modelling at Environment Canada

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Summary We describe the recent developments of Environment Canada’s atmospheric mercury model (GRAHM) and its application to the intercontinental source-receptor relationships of mercury. The model includes 2188 Mg yr\(^{-1}\) global anthropogenic emissions, 1600 Mg yr\(^{-1}\) terrestrial emissions and 2600 Mg yr\(^{-1}\) oceanic emissions. Transport, chemical transformation and deposition of Hg\(^0\), Hg\(^{II}\) and Hg(p) are simulated in GRAHM within a meteorological assimilation and forecasting system. Current version of the GRAHM includes GEM oxidation by ozone in the troposphere and halogen oxidation in the Polar and the marine boundary layers. It also includes dynamic exchange of mercury fluxes at air-snow/ice interface. The model simulates springtime atmospheric mercury depletion events (AMDEs) and the net accumulation of mercury in snow in the Polar Regions. We performed one reference simulation with emissions as above and four perturbation simulations with 20% reduced anthropogenic emissions over East Asia, South Asia, Europe and North Africa and North America. 20% reduction in anthropogenic emissions of mercury over East Asia, South Asia, Europe and North Africa and North America represent 7.7%, 1.6%, 2.5% and 1.3% reduction in global anthropogenic emissions respectively. The deposition over East Asia, South Asia, Europe and North America are reduced by 13.5%, 7.9%, 8.3% and 4.3% due to the emission reductions within the same regions. Deposition in North America is found to be most affected by the emission reductions in other regions and the deposition in East Asia is least affected by outside reductions. The deposition in the Arctic is nearly equally sensitive to the unit emission reductions in Europe and East Asia and is most sensitive in springtime due to the high deposition related to AMDEs.

17.1 Introduction

Hg is on the priority list of a large number of international agreements, conventions and national advisories aimed at the protection of the environment including all compartments, human health and wildlife (e.g. CLRTAP, AMAP, UN-ECE, HELCOM, OSPAR and many more). The mercury methylation process is shown to be strongly correlated with loadings of inorganic mercury to the aquatic system.
from the atmosphere (Hammerschmidt et al., 2004). Ambient measurements of mercury reveal a vast global pool of mercury in the atmosphere up to the tropopause revealing its global nature and yet at the same time, atmospheric measurements of mercury in polar regions, in marine boundary layer and in the upper troposphere have shown that elemental mercury can be rapidly oxidized to more hygroscopic forms and deposited at much shorter time scales. In the atmosphere, mercury is mainly present as gaseous elemental mercury (GEM), reactive gaseous mercury (RGM) and particulate mercury (Hg(p)). GEM is the most dominant form of mercury in the atmosphere with the longest life time (0.5 – 2 yr) and RGM and Hg(p) have a significantly shorter lifetime (few days - week) and are deposited rapidly via dry and wet deposition (Lin et al., 2006). Emissions of mercury from natural as well as anthropogenic sources, multiple time scales of mercury in the atmosphere and photochemically and biologically driven revolatilization of mercury at the surface render understanding of global cycling of mercury a challenging subject. The impact of confounding factors such as climate change and changes in other pollutants in the atmosphere add to the complexity of determining the impact of reducing emissions of mercury on deposition.

In this chapter, we briefly describe the Environment Canada’s global mercury model GRAHM and provide results on model simulations to assess the impact of reduced anthropogenic emissions from four main source regions of mercury in Northern Hemisphere.

17.2 Model Description

The Global/Regional Atmospheric Heavy Metals Model (GRAHM) is an Eulerian, multi-scale meterological and mercury simulation model which is developed by including atmospheric mercury dynamical, physical and chemical processes on-line into Canadian operational weather forecasting and data assimilation model GEM (Global Environmental Multiscale Model). Details of the model GRAHM are described in Dastoor and Larocque (2004), Ariya et al. (2004) and Dastoor et al. (2008). Transport, transformation and surface exchange of three mercury species, namely, gaseous elemental mercury (GEM), gaseous divalent mercury (RGM) and particulate mercury (Hg(p)) are simulated in the model. For this study, the anthropogenic mercury emissions were updated to year 2000 (Pacyna et al., 2006). Terrestrial and oceanic emissions of GEM from direct natural sources and from previously deposited mercury were introduced based on the global mercury budget study by Mason and Sheu (2002). Land based natural emissions were spatially distributed according to the natural enrichment of mercury and re-emissions were distributed according to the distribution of total deposition of mercury for historic years. Oceanic emissions in the model are spatially distributed according to the deposition and primary production distribution. Seasonal and diurnal dependence is added to both land and oceanic emissions as a function of solar irradiance.