Atmospheric mercury depletion and mercury photoreduction in snowpack at a mid-latitude coastal island

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During polar springtime, the atmospheric mercury depletion event (AMDE) is considered an important mechanism driving photo-oxidation of elemental mercury (Hg⁰) via halogens and subsequent deposition (Hg²⁺) and re-emission (Hg⁰) from snowpack. While this atmospheric-snowpack interaction for mercury has been extensively studied in the coastal regions of the Arctic and Antarctic, only a few studies have characterized Hg exchange at mid-latitude coastal regions. We collected surface snow and atmospheric total gaseous Hg (TGM) at Mountain Halla, located at a coastal island of Jeju, South Korea, to characterize sources and mechanisms responsible for atmospheric-snowpack Hg exchange at mid-latitudes. Our TGM exhibited a δ²⁰²Hg range of −2.33 to −0.80‰, consistent with TGM evaded from the oceanic surface [1]. The snow samples collected at multiple elevations exhibited surprisingly consistent Hg isotope ratios (δ²⁰²Hg = -0.26 ± 0.33‰, Δ¹⁹⁹Hg = -1.06 ± 0.74‰, 1SD) with fresh snowfall (δ²⁰²Hg = 0.25 ± 0.42‰, Δ¹⁹⁹Hg = -1.08 ± 0.18‰) and aged snow affected by the AMDE in the Arctic (δ²⁰²Hg = 0.04 ± 0.61‰, Δ¹⁹⁹Hg = -2.51 ± 0.11‰) (Figure 1). Our snow halogen concentrations (Br⁻ = 1.00 ± 0.72μM, Cl⁻ = 476 ± 559μM, Na⁺ = 547 ± 603μM, 1SD) reveal levels that are similar to snow collected over the first year ice in the Arctic Ocean (Br⁻ = 0.7 ± 0.5μM, Cl⁻ = 342 ± 159μM, Na⁺ = 194 ± 100μM), known to be heavily influenced by coastal halogens. Over the course of three days, we observed an increasing trend in Hg isotope ratios in the snow (3rd day; δ²⁰²Hg = 0.34 ± 0.03‰, Δ¹⁹⁹Hg = 0.03 ± 0.02‰). The slope of Δ¹⁹⁹Hg/Δ²⁰¹Hg, used to distinguish between Hg²⁺ photo-reduction and methylmercury photo-degradation, displayed a value (1.05 ± 0.15) reflecting aqueous Hg²⁺ photo-reduction caused by snow melting. Our study provides preliminary evidence that coastal halogen induced Hg⁰ photo-oxidation followed by deposition may be an important mechanism driving Hg deposition to snowpack in mid-latitude coastal mountains. The frequent melting of the snow, however, supplies photo-reduced Hg²⁺ to both the mountain ecosystem and the atmosphere.