Why is atmospheric mercury level decreasing even thought the emissions are increasing?

Mercury is a unique metal that is a liquid at room temperature, which enables it volatile to the air and diffuse ubiquitous at a global scale. It becomes an environmental problem because the consumption of mercury-containing food, especially fish and seafood, could cause harm to our neurological system. Mercury mainly exists as stable mineral ores in the lithosphere until it's released to the atmosphere during volcanoes eruption, burning coal that contains mercury, or mercury mining. Since the industrial revolution, mercury level in the environment has been increased by 3-5 times, as evidenced by lake sediment and ice core records. Despite this long-term increase, observations of mercury concentrations in the air and falling rain and snow in North America and Europe show large decreases (1–2% $y^{?1}$) from 1990 to present. This has become a longstanding conundrum because the global emissions of mercury are believed to have been increasing, especially in the recent couple of decades caused by the soaring coal combustion in Asian countries. Previous studies have speculated that the decreasing trend in atmospheric mercury could be caused by a reduction of mercury released from the land and/or ocean. However, there is no reliable evidence, especially long-term observations of land/ocean mercury level and release to support this hypothesis.

In this study, we reevaluate the trend of global mercury emissions and find that previous emission inventories have several major flaws: First, they do not account for the decline in atmospheric release of mercury from commercial products. Most of the previous inventories focused on the stacks of point sources such as power plants and mercury mines, but overlooked fugitive releases from the usage of mercury-containing products such as paints, batteries, thermometers, and dental fillings. These emissions have decreased significantly since the phase-out of mercury from these products in the developed countries since the 1970s. Second, previous emission inventories overestimated the increasing trend of artisanal and small-scale gold mining emissions, where mercury is used to subtract gold from ores in developing countries. The strong onset is largely driven by a more complete report of this illegal activity. We adopt a more consistent estimation based on the trend of global gold demand. Third, they do not properly account for the change emissions from coal-fired utilities. Flue-gas desulfurization and selective catalytic reactor have been installed in these utilities for control emissions of SO_2 and NOx, respectively, especially over North America, Western Europe, Japan, Australia, and now China. Along with the control of the targeted pollutants, a significant portion of the mercury emissions is reduced as a co-benefit.

With all these updates considered, we find the global mercury emissions have decreased for 30% during 1990-2010, contradicting with many previous estimates. We then implement our inventory in a global 3D atmospheric mercury model (GEOS-Chem), which divides the world into a series of grid boxes and simulates the transport of mercury emissions among these boxes along with winds, reactions with other atmospheric constituents, washed out by rain/snow, and removal by contacting with land and ocean. The model can thus simulates the atmospheric mercury concentrations of

each model grid box. With all other factors kept constant, the model results with decreasing mercury emissions suggested by our inventory reproduce the observed trends in atmospheric mercury levels, suggesting that the observed trends in the past 20 years could be solely explained by the decline of man-made emissions. This solves the mercury conundrum and implies that prior policy assessments underestimated the regional benefits of declines in mercury emissions from phase-out of mercury from products and coal-fired utilities.

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Observed decrease in atmospheric mercury explained by global decline in anthropogenic emissions.
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