nature india

NEWS FEATURE | 31 January 2025

Mercury pollution driven by stratospheric forces

Heavy metal movement to worsen under increased climate change

By Sahana Ghosh

Human activity, including coal combustion, is the main cause of mercury release. Credit: Jay.Jarosz/CC BY 4.0

New research[1] exposes the stratosphere as a major driver of mercury pollution, challenging long-held beliefs that the layer below it, the troposphere, dictates global spread of the heavy metal.

“Nearly 52% of the mercury transported from the Northern Hemisphere to the Southern Hemisphere occurs through the stratosphere,” says co-author and atmospheric scientist Alfonso Saiz-Lopez at the Institute of Physical Chemistry Rocasolano, CSIC, Madrid, Spain.

In the stratosphere, the atmospheric layer in which commercial jets fly, and air flows steadily over vast distances, working as a global conveyor belt through which large quantities of gaseous mercury are picked up from industrial regions in the northern hemisphere and dropped off in remote areas regions like such as the Arctic and Antarctic. This happens because air is drawn upward in the tropics, moves poleward, and eventually descends back into the troposphere.

Air circulation in the stratosphere, the atmospheric layer where commercial jets fly and air flows steadily over vast distances, works as a global conveyor belt in which large quantities of gaseous mercury are picked up from industrial regions in the Northern Hemisphere and dropped off in remote, areas like the Arctic and Antarctic. This happens because air is drawn upward in the tropics, moves poleward, and eventually descends back into the troposphere.

Saiz-Lopez and his colleagues warn that more mercury will move through this layer as the climate warms. Their geochemical model of the mercury cycle shows If greenhouse gas emissions are not reduced, mercury levels in the global stratosphere could rise by up to 12% by the end of the century due to climate change altering stratospheric circulation.

Though stark, the findings could refine future mercury assessment models. Integrating stratospheric cycling in models can improve deposition prediction accuracy as their research reveals that mercury traveling through the stratosphere settles in different regions than mercury transported via the troposphere.

“Using the new mechanism, we'll be able to give a much more accurate picture to the Minamata Convention, a global treaty to curb excess mercury, so that they can bring in policies for better regulation,” says co-author Anoop Mahajan, who looks at chemistry-climate interactions at the Indian Institute of Tropical Meteorology in Pune.

The trace element, naturally found in rocks, including coal deposits, becomes an environmental pollutant when released into the atmosphere and water. While natural

processes like volcanoes and weathering send mercury into the atmosphere, human activities—such as burning fossil fuels, gold mining, and waste burning—are the main sources of mercury pollution.

Mercury exposure mainly occurs when people consume contaminated seafood. However, the element must first be oxidized to become part of the food chain.

The mercury passed through the stratosphere is primarily deposited in remote areas such as the Southern Pacific, Atlantic, Indian Ocean, and the Arctic and Antarctic, putting Arctic Indigenous communities at particular risk of exposure due to the central role of seafood in their diet. Global sources, which are much further away from the Arctic, including India, do contribute a lot more than initially thought, says co-author Aryeh Feinberg.

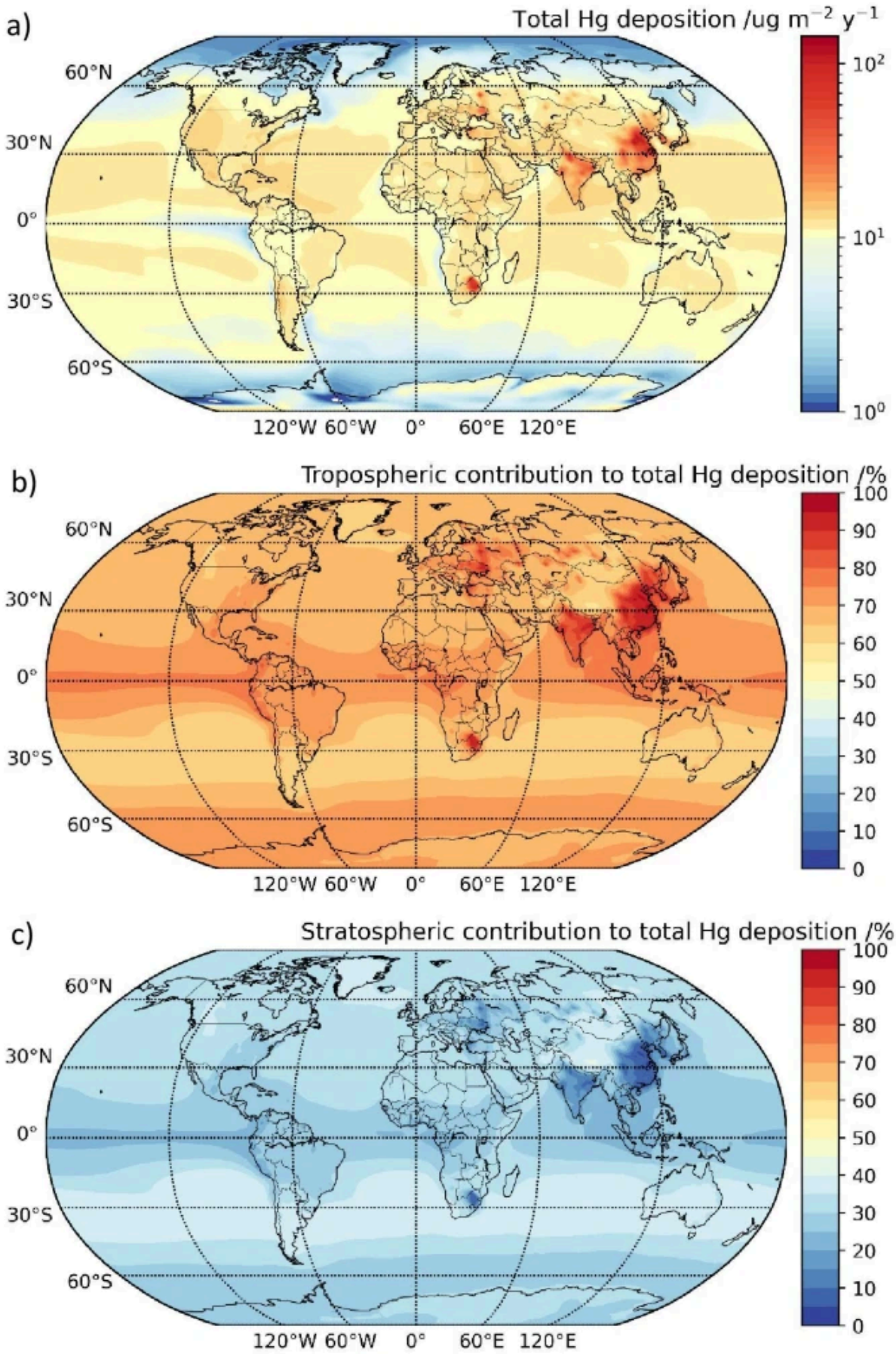
Lower stratosphere is a chemical factory of long-lasting mercury

The researchers launched their modeling study to fill a missing piece in the mercury movement puzzle: despite the Northern Hemisphere emitting 2.5 times more mercury, its concentrations – 1.5 ng/m^3 in the north and 1.0 ng/m^3 in the south show a weaker-than-expected difference between hemispheres. “Something was carrying it to the Southern Hemisphere which wasn't entirely explicable in the current models,” says Mahajan.

To quantitatively determine the stratosphere's role in mercury transport and its impact on ecosystem pollution, the research team incorporated mercury's chemical reactions and movement mechanisms in the upper and lower stratosphere into atmospheric circulation models – the Whole Atmosphere Community Climate Model (WACCM). They compared it with global mercury observations to verify the results.

The study estimates that between 5% and 50% of the mercury on the Earth's surface is oxidized into a stable form in the lower stratosphere. In this 5-km thick oxidation 'hot spot’, mercury reacts with chemicals and transforms into HgCl2 (mercury chloride), a highly stable oxidized form.

HgCl2 is resistant to breaking down by light (photolysis), so once it forms, it persists and deposits on Earth. Oxidation is more efficient in the stratosphere due to higher levels of UV radiation. Closer to the ground, in the troposphere, mercury remains in its elemental form longer because fewer factors are available to convert it into its reactive, oxidative form. “Mercury’s overall lifetime is extended by transport through the stratosphere because its removal occurs in the troposphere, by being washed out or depositing onto surfaces,” says Feinberg.



Role of troposphere and stratosphere in mercury deposition. Credit: Saiz-Lopez *et al.*

One of the team's next goals is to quantify how much stratospheric mercury originates from India, the second-largest mercury emitter after China and a signatory of the Convention.

“We are in a region where pollutants are pumped into the stratosphere quickly. So we are pretty sure that a large chunk of the oxidized mercury in the stratosphere will come from India and China,” adds Mahajan.

While some measurements of elemental mercury exist in India, data on oxidized mercury is rare, with only a few campaigns conducted and no long-term monitoring. “India must start measuring oxidized mercury, as it is the form that gets deposited and affects human health,” says Mahajan.

Sachin Gunthe who works on aerosol-climate interactions at the Indian Institute of Technology, Madras in Chennai (IIT-M) advocates for initiating steady mercury monitoring. “Observations are essential to verify models. For instance, they can help verify our simulations[2] which show that 65% of mercury deposition over the Indian subcontinent is in the monsoon season alone, over the Western Ghats and the Himalayas,” says Gunthe.

Long-term mercury monitoring would also help parse the anthropogenic and natural sources over India and validate hotspots, adds Chakradhar Reddy Malasani, a PhD student at IIT-M. “When we switched off Indian human-made mercury emissions from the model, mercury deposition dropped significantly (22–34%). This shows that human activities are probably the main source of mercury pollution in India but to be certain we need data,” he adds.

doi: https://doi.org/10.1038/d44151-025-00013-5

References

1. Saiz-Lopez, A. *et al. Sci. Adv.11,*eads1459(2025).

2. Malasani, C. R. *et al. Environ. Sci.: Processes Impacts.* **26**(11) (2024).

Nature India (*Nat India*) | ISSN 1755-3180 (online)