Name of research institute or organization:

Institute for Chemical and Bioengineering,
Swiss Federal Institute of Technology, ETH Zurich

Title of project:

Source regions of atmospheric mercury at the High Alpine Station Jungfraujoch

Project leader and team:

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Project description:

Mercury is a heavy metal of particular concern due to its ability to bioaccumulate in ecosystems, and its significant negative effects on human health and the environment. Long term human exposure to small amounts of mercury has been shown to result in serious neurological impairments [1]. Due to its long residence time in the atmosphere, mercury undergoes long-range atmospheric transport [2]. Thus, mercury can occur in regions far away from its initial emission sources. For an improved understanding of the atmospheric fate and transport of gaseous elemental mercury (GEM), we measured GEM from April 2011 to April 2012 in the Sphinx Observatory at the High Altitude Research Station Jungfraujoch (3580 m a.s.l.) and applied a Lagrangian particle dispersion model (LPDM) to analyze the experimental data. Measurements were performed with cold vapor atomic fluorescence spectroscopy, calibrated with an internal GEM permeation source and providing a high sensitivity (detection limit: 0.1 ng/m3) with a high temporal resolution (measurement frequency: 5 minutes). The observed concentrations of GEM are shown in Figure 1.

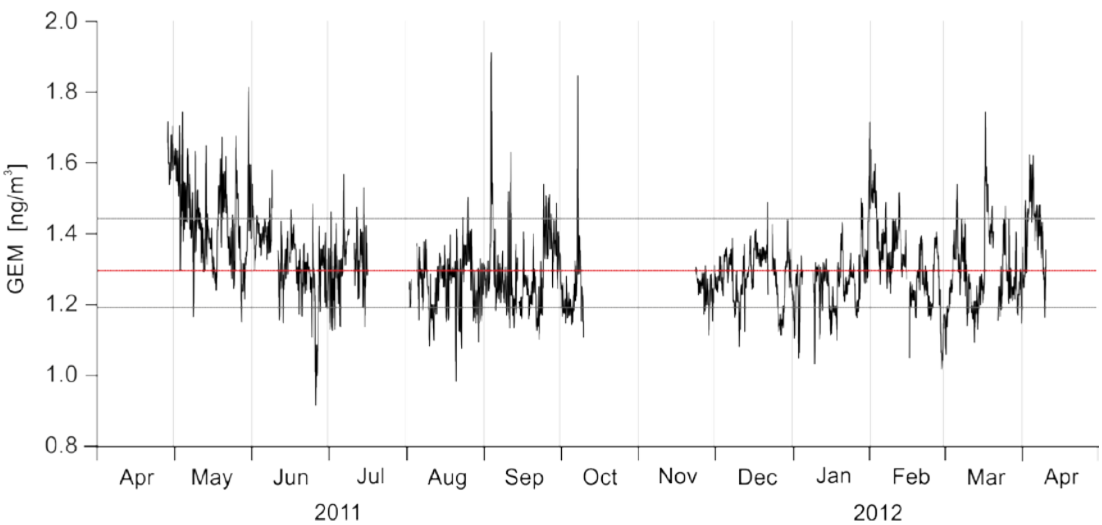

Figure 1. Gaseous elemental mercury (GEM) concentrations at Jungfraujoch averaged on a 3 hourly time scale, evolving around the median of 1.3 ng/m3 (red line). The light gray lines represent the 10% lowest (lower gray line) and the 10% highest (upper gray line) concentrations.

The GEM concentrations measured at Jungfraujoch are comparable to background levels measured worldwide [2]. The median over the whole sampling period is 1.3 ng/m^3 with a standard deviation of 0.14 ng/m^3. The GEM concentrations were slightly higher in winter and spring (median: 1.4 ng/m^3) compared to summer and autumn (median: 1.3 ng/m^3).

To identify potential source regions of GEM measured at Jungfraujoch, we used the LPDM FLEXPART. FLEXPART was run backward in time using ECMWF IFS wind fields with a global grid spacing of 1° by 1° degree [3]. During every 3-h interval, 50'000 particles were released at the measurement point and were followed backward in time for 10 days. In backward mode, FLEXPART calculates an emission sensitivity function [s·kg/m^3]. The emission sensitivity close to the surface (0 – 100 m) is called footprint and is of particular interest because most emissions occur near the ground. The footprints thus indicate where the air has resided near the ground and could take up pollutants before arriving at the monitoring station. We summed up the footprints for times when the measured GEM concentrations were above the 90% percentile (data points above the upper gray line in Figure 1) and below the 10% percentile (data points below the lower gray line in Figure 1). These footprints were then normalized by the average footprint resulting from the whole measurement period. Values above 0.1 in Figure 2 indicate that high measured GEM concentrations are preferentially associated with transport through this region. Figure 3 shows that for the period of low GEM concentrations, no value above 0.1 could be observed over GEM emission regions.

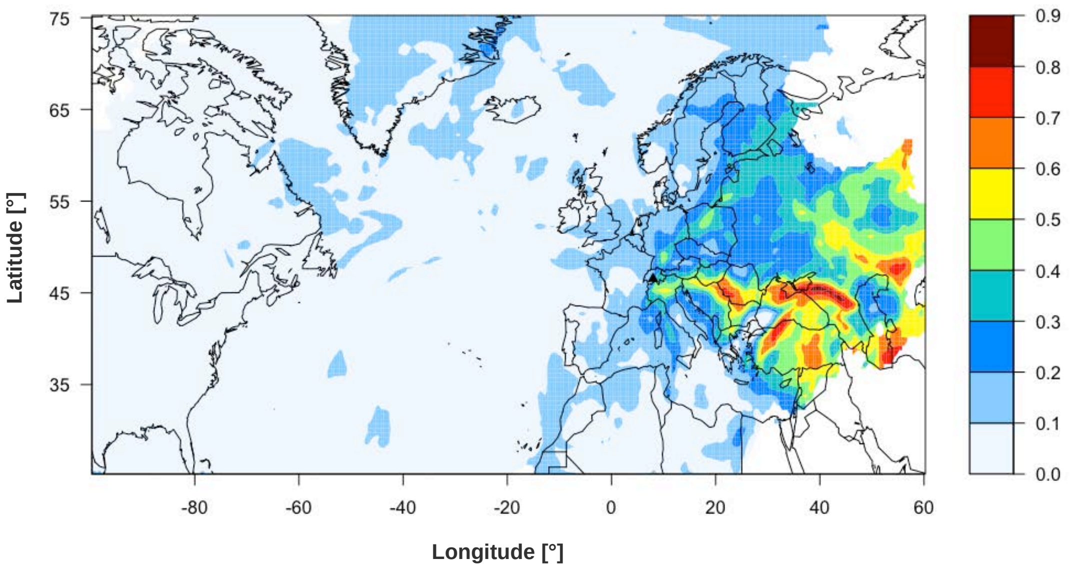

Figure 2. Potential source regions for ***high GEM concentrations*** *at Jungfraujoch indicated by values above 0.1.*

For times when the highest 10% of GEM were measured, the potential source regions were mainly located over Eastern and Central Europe. Possible anthropogenic sources of GEM from these regions are possibly the use of fossil fuel, particularly coal burning, for electrical power generation and heating, where GEM is unintentionally emitted [4]. Conversely, for periods when the lowest 10% of GEM concentrations were observed, the potential source regions were located west of Jungfraujoch.

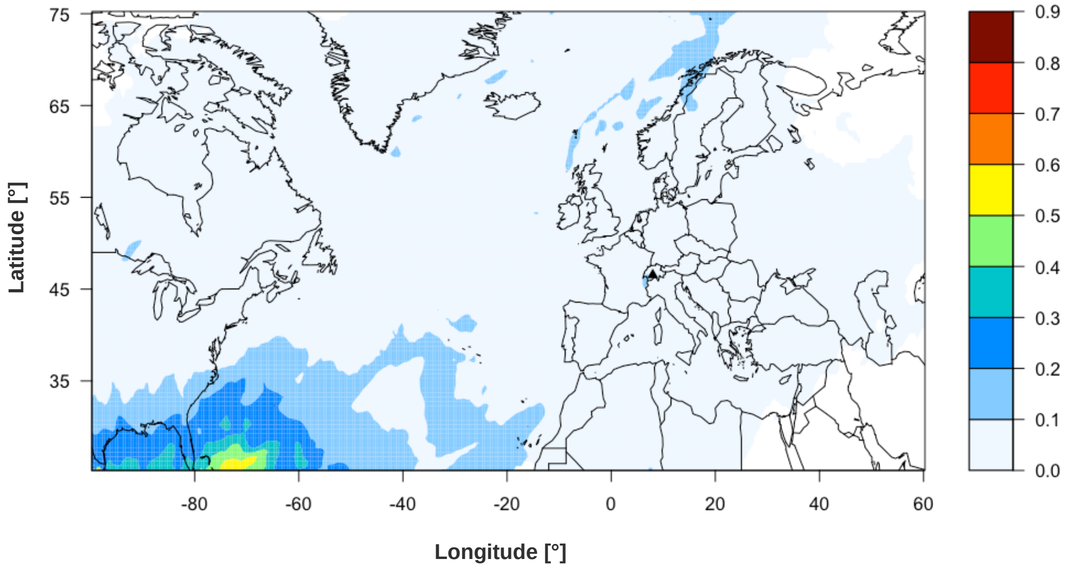

Figure 3. Potential source regions for ***low GEM concentrations*** *at Jungfraujoch indicated by values above 0.1.*

In this study, we showed that measurements of GEM at trace levels with a high temporal resolution combined with backward LPDM are an efficient tool enabling the identification of possible source regions of GEM. The observed source regions of GEM east of Jungfraujoch confirm the existing global GEM emission inventories predicting higher emissions of GEM in these countries as well [4].

The reported data set covers a period of almost one year with GEM pollution events occurring mainly in winter and spring. For a more robust identification of GEM source regions, a longer monitoring period of GEM concentrations is necessary. For more information about possible sources further east of the regions covered so far, particles in the FLEXPART model could be followed backward in time for longer than 10 days.

Our study on source apportionment of background concentrations of GEM provides an important contribution to the current process at the United Nations Environmental Programme (UNEP) to establish a global convention on mercury with the goal to reduce environmental contamination by mercury. To fulfill this goal, UNEP recommends that a global monitoring network on atmospheric mercury should be established to ensure that the required field data are available. Switzerland takes also part in the negotiations on global mercury regulations and strongly supports these international efforts.

Key words:

Mercury, gaseous elemental mercury, long-range transport, air monitoring, trajectory modeling, Lagrangian particle dispersion model

Collaborating partners/networks:

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LPDM modeling: Dr. Stephan Henne, EMPA, Dübendorf, Switzerland

Scientific publications and public outreach 2012:

Refereed journal articles and their internet access

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