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Air mercury monitoring in the Baikal area (2011-2021)

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ABSTRACT. We present long-term (2011 – 2021) data on air mercury monitoring that was started within the GMOS (Global Mercury Observation System) project (2011-2015) at the Listvyanka station located on the shore of Lake Baikal, Siberia. Monitoring shows an obvious seasonal variation in the background mercury concentration in the air, which increases in the cold season and decreases in the warm season. Short-term anomalies are associated with the wind carrying air from industrial areas where several large coal-fired power plants are located (Irkutsk and Angarsk). A positive correlation between mercury, SO_2 and NO_2 concentrations is observed both in short-term variations and in average monthly concentrations. The analysis of the forward and backward trajectories obtained with the HYSPLIT model demonstrates possible mercury emission sources. Concentration-weighted trajectory (CWT) analysis has revealed potential remote regions of mercury emissions from where mercury can be transported by air masses to the area of Lake Baikal, including the territories of Transbaikalia and Mongolia (Erdenet). During the 2018 cruise, the continuous air mercury survey above Lake Baikal covered 1800 km. The mean mercury concentration above Lake Baikal is significantly lower than the mean value obtained at the onshore Listvyanka station during the same days of the cruise. That can lead to the conclusion that Lake Baikal is a sink of atmospheric mercury.

Keywords: Lake Baikal, air mercury monitoring, seasonal and short-term variability, sources of emissions, coal-fired power plants

1. Introduction

Within the GMOS project, air mercury monitoring has been running since November 2011 at the Listvyanka station located on the SW shore of Lake Baikal (Sprovieri et al., 2016). In July 2018, for the first time, air mercury survey was carried out throughout the Baikal area during the cruise onboard the research vessel (RV) "Akademik Koptyug" (Mashyanov et al., 2021).

2. Materials and methods

Long-term air mercury measurements at the Listvyanka station were carried out using a Lumex RA-915AM air mercury monitor; air measurements during the RV cruise – with a RA-915M multifunctional portable analyzer. The principle of operation of both systems is based on differential atomic absorption spectroscopy with the Zeeman background correction (Sholupov et al., 2004) that provides continuous background GEM (gaseous elemental mercury) monitoring in compliance with EN 15852 standard. During the cruise around Lake Baikal, the air mercury survey was performed with two portable RA-915M mercury analyzers operating concurrently. Data were collected continuously with a response time of 1 s, averaging over 4 min, and zero control every 5 min; the detection limit was 0.6 ng/m^3. The RA-915M analyzer with the PYRO-915$^+$ attachment was also used for PBM (particulate bound mercury) determination. The following atmospheric gases were monitored together with GEM at a time resolution of 1–2 min: SO_2, NO, NO_2, CO, CO_2, O_3, and some others (Obolkin et al., 2014).

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3. Results and discussion

Continuous automatic monitoring of mercury at the Listvyanka monitoring station shows the mean GEM concentration of 1.59 ng/m^3 throughout the 2011-2021 observation years. PBM amounts to 0.7 % of GEM.

3.1. Seasonal variations

The obtained data show an obvious seasonal variation in the background mercury concentration in air (both GEM and PBM), increasing in the cold seasons (November – February) with the mean GEM of 1.74 (1.56 - 1.95) ng/m^3, and decreasing in warm seasons (June – September) averaging 1.43 (1.12 – 1.63) ng/m^3 (Fig. 1A); the same seasonal variation shows PBM since January 2016 to March 2017 (Fig. 1B).

Seasonal variations of both GEM and PBM types are obviously due to elevated mercury emissions from coal combustion during the cold season, giving rise to background mercury concentrations at regional and global levels.

3.2. Short-term variations

Short-term (minutes – hours) anomalies of the mercury concentration can reach values of 5-7, sometimes 15-20 ng/m^3. Long-term monitoring shows a positive correlation of GEM peaks with the local anomalies of acid gases typical of coal combustion emissions such as SO_2 and NO_2.

To assess the relationship between mercury and acid gas anomalies recorded at the Listvyanka station and the sources of industrial emissions, we used the HYSPLIT model (Cheng et al., 2013; 2015; Rolph et al., 2017) with air mass trajectory calculation at the three vertical levels of 50, 150 and 500 m. An example of long-distance transport of air pollutants is shown in Fig. 2. The correlated maxima of SO_2 and GEM concentrations at the Listvyanka monitoring station are observed during superposition of air masses carrying plumes of coal-fired power plants from the Angarsk, Irkutsk and Shelekhov cities (Mashyanov et al., 2021).

The monitoring data also indicate that forest fires could be a significant source of mercury and can contribute to the increase in the average monthly concentration, for example, 1.73 and 1.94 ng/m^3 in June 2019 and July 2020, respectively.

3.3. Mercury in the air above Lake Baikal

In July 2018, the air mercury survey was carried out throughout the Baikal area during the cruise onboard the RV “Akademik Koptyug”. The continuous air mercury survey above Lake Baikal covered 1800 km. During the cruise, there no significant anomalies of mercury concentration in the air above the lake (Fig. 3A). Concentration-weighted trajectory (CWT) method based on the backward trajectories of air masses (Cheng et al., 2015; Kalinchuk et al., 2021) revealed several potential areas of mercury emissions (Fig. 3B).

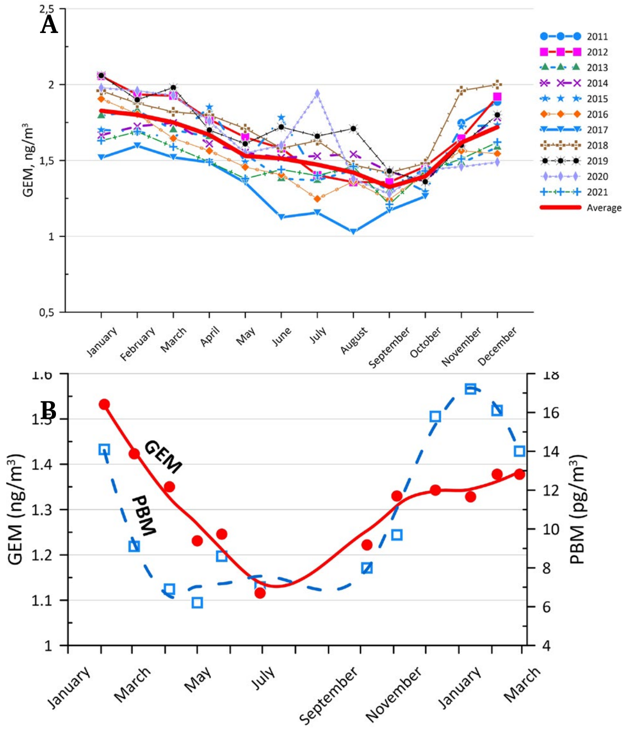

Fig.1. Seasonal variation in GEM between 2011 and 2021 (**A**) and PBM between 2016 and 2017 (**B**); average monthly value.

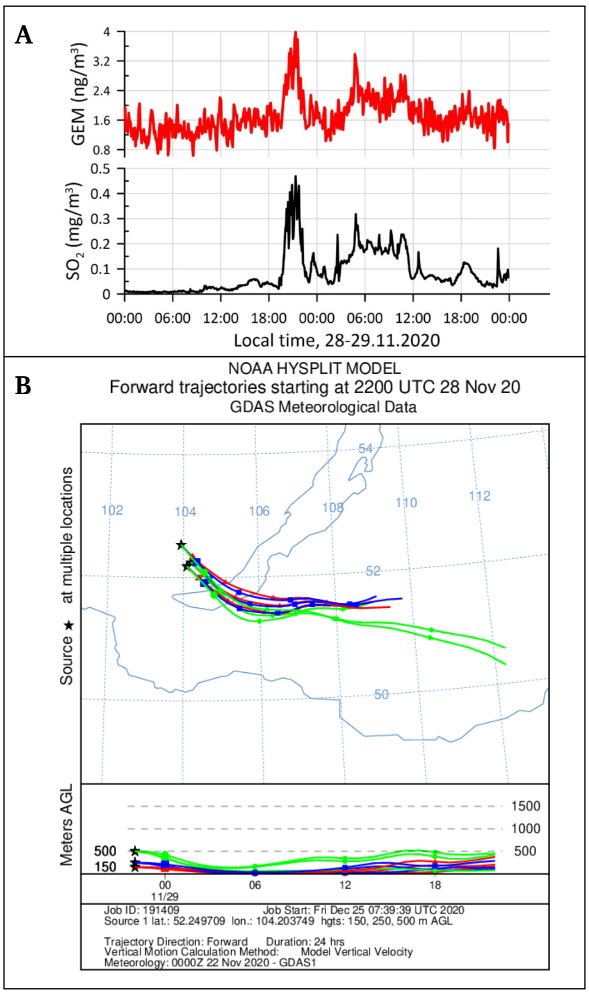

Fig.2. Superposition of the plumes from industrial emissions sources: SO_2 and Hg concentration (**A**); forward air trajectories modelling (**B**).

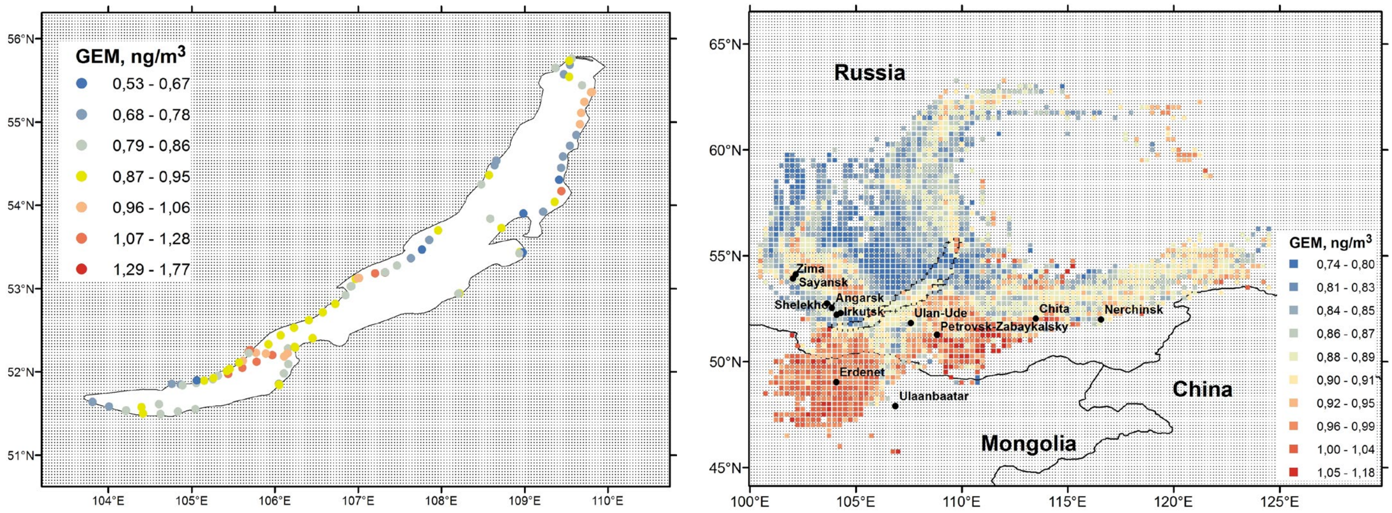

Fig.3. Local mercury anomalies in the air above Lake Baikal (**A**). Gridded (0.25° × 0.25°) concentration-weighted trajectory (CWT) values for GEM (**B**). Cruise onboard the RV "Akademik Koptyug", July 2018.

The cruise data confirmed the conclusion derived from stationary monitoring of the mercury air transport from industrial areas (Irkutsk, Angarsk, Shelekhov, and others) along the Angara River valley. Additionally, there were areas of mercury emissions on the southern side of Lake Baikal (Fig. 3B). The southwestern area is located on the territory of Mongolia and coincides with the position of the largest copper-molybdenum deposit and smelter (Erdenet). Sources of mercury located to the east, on the Ulan-Ude - Chita line, may be associated with the influence of cities and mining plants in Buryatia and Transbaikalia regions.

The mean mercury concentration of 1.10 ng/m^3 recorded above Lake Baikal is significantly lower than the mean value of 1.60 ng/m^3 obtained at the onshore Listvyanka monitoring station during the same days of cruise. The explanation for this phenomenon may be the specific air circulation over the Baikal water area in summer. An inverted layer is formed in the atmosphere above the cold lake surface, preventing the mixing of air above the surface with air masses coming from the continent. Under such conditions, Lake Baikal can be considered as a sink of atmospheric mercury.

Conclusions

The total mean (GEM) concentration at the Listvyanka station in 2011 to 2021 of the observation was 1.59 ng/m^3. PBM comprised about 0.7 % of GEM.

The average daily concentration of GEM ranged from 1.2 to 1.9 ng/m^3 and that of PBM from 7.8 to 15 pg/m^3 in the warm and cold seasons, respectively, indicating the elevated mercury emissions from coal combustion during the cold season.

The coal combustion plants are the main sources of the elevated mercury concentration at Listvyanka station, as confirmed by the clear correlation between the mean concentrations of Hg and SO_2, NOx, and O_3.

Wildfires can contribute to the increase in the average monthly GEM concentration.

The mean mercury concentration measured above Lake Baikal during the Baikal cruise was 1.10 ng/m^3, which is significantly lower than the mean value of 1.60 ng/m^3 obtained at the onshore Listvyanka GMOS station during the same days of the cruise. Thus, Lake Baikal can be a sink of atmospheric mercury due to air temperature inversion in the warm season.

CWT analysis of the 2018 cruise data revealed the areas where the sources of mercury anomalies were located: industrial areas along the Angara River (Irkutsk, Shelekhov, Angarsk, probably Usolye-Sibirskoye, Sayansk, and Zima), Mongolia (Erdenet), Buryatia and Transbaikalia.

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Conflict of Interest

The authors declare no conflict of interest.

References

Cheng I., Xu X., Zhang L. 2015. Overview of receptor-based source apportionment studies for speciated atmospheric mercury. Atmospheric Chemistry and Physics 15: 7877-7895. DOI: 10.5194/acp-15-7877-2015

Cheng I., Zhang L., Blanchard P. et al. 2013. Concentration-weighted trajectory approach to identifying potential sources of speciated atmospheric mercury at an urban coastal site in Nova Scotia, Canada. Atmospheric Chemistry and Physics 13: 6031-6048. DOI: 10.5194/acp-13-6031-2013

Kalinchuk V.V., Lopatnikov E.A., Astakhov A.S. et al. 2021. Distribution of atmospheric gaseous elemental mercury (Hg(0)) from the Sea of Japan to the Arctic, and Hg(0) evasion fluxes in the Eastern Arctic Seas: results from a joint Russian-Chinese cruise in fall 2018. Science of the Total Environment 753: 142003. DOI: 10.1016/j.scitotenv.2020.142003

Mashyanov N., Obolkin V., Pogarev S. et al. 2021. Air mercury monitoring at the Baikal area. Atmosphere 12(7): 807. DOI: 10.3390/atmos12070807

Obolkin V., Potemkin V., Makukhin V. et al. 2014. Low-level atmospheric jets as main mechanism of long-range transport of power plant plumes in the Lake Baikal region. International Journal of Environmental Studies 71(3): 391-397. DOI: 10.1080/00207233.2014.918396

Rolph G., Stein A., Stunder B. 2017. Real-time environmental applications and display system: READY. Environmental Modelling and Software 95: 210-228. DOI: 10.1016/j.envsoft.2017.06.025

Sholupov S., Pogarev S., Ryzhov V. et al. 2004. Zeeman atomic absorption spectrometer RA-915 for direct determination of mercury in air and complex matrix samples. Fuel Processing Technology 85: 473-485. DOI: 10.1016/j.fuproc.2003.11.003

Sprovieri F., Pirrone N., Bencardino M. et al. 2016. Atmospheric mercury concentrations observed at ground-based monitoring sites globally distributed in the framework of the GMOS network. Atmospheric Chemistry and Physics 16(18): 11915-11935. DOI: 10.5194/acp-16-11915-2016