E3S Web of Conferences **1**, 17007 (2013)
DOI: 10.1051/e3sconf/20130117007

Development of a Ground-Based Atmospheric Monitoring Network for the Global Mercury Observation System (GMOS)

F. Sprovieri[1], L. E. Gratz[1] and N. Pirrone[2]

[1] CNR Institute of Atmospheric Pollution Research, CNR-IIA, Rende, Italy; f.sprovieri@iia.cnr.it
[2] CNR Institute of Atmospheric Pollution Research, Rome, Italy

Abstract. Consistent, high-quality measurements of atmospheric mercury (Hg) are necessary in order to better understand Hg emissions, transport, and deposition on a global scale. Although the number of atmospheric Hg monitoring stations has increased in recent years, the available measurement database is limited and there are many regions of the world where measurements have not been extensively performed. Long-term atmospheric Hg monitoring and additional ground-based monitoring sites are needed in order to generate datasets that will offer new insight and information about the global scale trends of atmospheric Hg emissions and deposition. In the framework of the Global Mercury Observation System (GMOS) project, a coordinated global observational network for atmospheric Hg is being established. The overall research strategy of GMOS is to develop a state-of-the-art observation system able to provide information on the concentration of Hg species in ambient air and precipitation on the global scale. This network is being developed by integrating previously established ground-based atmospheric Hg monitoring stations with newly established GMOS sites that are located both at high altitude and sea level locations, as well as in climatically diverse regions. Through the collection of consistent, high-quality atmospheric Hg measurement data, we seek to create a comprehensive assessment of atmospheric Hg concentrations and their dependence on meteorology, long-range atmospheric transport and atmospheric emissions.

Key words: Atmospheric mercury, global transport, monitoring network, GMOS

Introduction

Mercury (Hg) is ubiquitous in the atmospheric boundary layer, as well as in the free troposphere and stratosphere. It has ground-level background concentrations that are nearly constant over hemispheric scales, with southern hemisphere concentrations slightly lower than those in the northern hemisphere (Sprovieri et al., 2005a,b; Hedgecock et al., 2008; Dommergue et al., 2010). In the troposphere, atmospheric Hg exists predominantly as gaseous elemental mercury (Hg^0; GEM), gaseous oxidized mercury (GOM), and fine particle-bound Hg ($PBM_{2.5}$). Conversions between different Hg forms add complexity to the ability to understand Hg chemistry and transport on the local, regional, and global scales (Lindberg et al., 2007; Sprovieri et al., 2010).

Mercury cycling between environmental compartments depends on the rate of different chemical and physical mechanisms (e.g., wet and dry deposition) and meteorological conditions, as well as on anthropogenic emissions and atmospheric forcing (Pirrone et al., 2010). Consequently, a complex mixture of chemical, physical and meteorological parameters control the fate of atmospheric Hg, and it is challenging to understand the global impact of Hg emissions, transport, and deposition (Lindberg et al., 2007).

A wide range of monitoring activities have been carried out in different regions of the world in order to assess the levels of mercury (Hg) in ambient air and precipitation, as well as its variation over time and with changing meteorological conditions (Ebinghaus et al., 2002; Pirrone and Mason, 2009; Sprovieri et al., 2010). In the past two decades a number of Hg monitoring sites have been established. These sites are located primarily in Europe, Canada and the USA, and a few are located in Asia. In contrast, very few Hg monitoring sites have been established in South and Central America, central and north Africa and other regions of the southern hemisphere.

In November 2010, under the auspices of the Global Mercury Observation System (GMOS) project, we began developing a global scale ground-based network of

atmospheric Hg monitoring sites. The objective of this monitoring network is to unify existing regional Hg measurement efforts with new monitoring stations in regions of the world where atmospheric Hg observational data is limited in order to improve our understanding of Hg transport and deposition the global scale.

A large volume of high-quality data has been generated over the past decade and beyond as part of on-going regional (i.e., EMEP, AMAP, CAMNet, NADP-MDN) and national (i.e., in Sweden, Italy, Japan, Korea, Taiwan, U.S.A. and Canada) programs and during focused EU projects (i.e., MAMCS, MOE, MERCYMS). The integration and synthesis of existing data sets will have high added value for the GMOS project.

Here, we provide a review of the current state of this new globally representative Hg monitoring network, including the principal characteristics and measurements being performed at the GMOS monitoring sites that are distributed across both the Northern and Southern Hemispheres.

Methods

At the GMOS monitoring sites, we aim to measure both ambient Hg and Hg in precipitation using high-quality, consistent measurement techniques. In this effort, a primary objective has been to harmonize the chosen measurement techniques with those being performed at existing monitoring stations around the world. At the start of the project, we performed a survey all new and existing GMOS sites to fully comprehend the measurements currently being collected and to determine an appropriate measurement scheme for atmospheric Hg measurements across this global scale network of sites. Based upon this information, we elected to measure speciated ambient Hg using the Tekran 2537/1130/1135 Hg speciation system. TGM measurements are being collected using either the Tekran 2537 or the Lumex RA-915-AM. Weekly precipitation samples are being collected primarily using wet-only collectors, such as the N-CON MDN or the Eigenbrodt NSA 171 wet-only samplers. Where necessary, due to site constraints or operator availability, some GMOS sites are alternatively collecting bulk precipitation samples. After selecting the measurement instrumentation, we developed Standard Operating Procedures, which are consistent with existing techniques in other regional networks, to be employed at all GMOS sites.

Results and Discussion

To date, there are 38 monitoring sites participating in the GMOS network. This includes existing sites that are already collecting atmospheric Hg measurements (ambient air and/or precipitation), new stations who are initiating Hg measurements for the first time through the GMOS project, and externally partnering sites who are contributing their measurement data to the GMOS database.

Fig. 1. Global map showing the locations of GMOS ground-based monitoring stations. Those in red are managed by external GMOS partners.

Figure 1 shows the location of the ground-based monitoring sites that are part of GMOS. Additionally, Table 1 provides information on the location, type, and affiliation of each site. Master Stations are those where Gaseous Elemental Mercury (GEM), Gaseous Oxidized Mercury (GOM), and fine particulate-bound Hg ($PBM_{2.5}$) as well as Hg in precipitation are, or will be, continuously measured. Secondary Stations are those where only Total Gaseous Mercury (TGM) and Hg in precipitation are, or will be, continuously measured. Table 2 summarizes the state of measurements to date at GMOS sites. While most new sites have purchased instrumentation, this process is still ongoing.

In addition to advising site operators on the purchase and installation of equipment, we have performed several training programs with the GMOS participants in order to inform the scientists and technicians on how to operate the instrumentation according to the GMOS SOPs. This has included one-on-one training sessions at the CNR-IIA in Rende, as well as a training meeting in Rome on measurements of Hg speciation in ambient air.

Furthermore, in the first two years of the GMOS project we have assisted with the installation of Hg monitoring equipment at a number of critical and challenging monitoring sites, such as the EvK2CNR Pyramid Laboratory in Nepal and the Dome C Laboratory in Antarctica. Sites such as these are providing new and valuable Hg data in areas where atmospheric Hg has not been thoroughly measured in the past. We have also established agreements with a number of external partners who are managing sites and networks outside of GMOS. Their support, collaboration, and data will greatly enhance the GMOS project and data record.

Conclusion

Within the GMOS project, we are continuing to establish new measurements of ambient Hg and Hg in precipitation at the GMOS sites to develop a full global

Table 1. Location, elevation, and affiliation of GMOS sites. (**M=Master, S=Secondary, MN=Master New, SN=Secondary New).*

Monitoring Site	Country	Elevation (m asl)	Lat	Lon	Type*	Institute	Affiliation
Alert	Canada	210	82.45	-62.52	M	EC	EC/GAW
Station Nord	Greenland	30	81.60	-16.67	S	AU	AMAP
Zeppelin (Ny Alesund)	Norway	474	78.91	11.88	M	NILU	GAW
Pallas	Finland	340	68.00	24.24	S	IVL	EMEP
Råö	Sweden	5	57.39	11.91	M	IVL	GAW
Auchencorth Moss	Scotland	260	55.79	-3.24	M	CEH	EMEP
Mace Head	Ireland	5	53.33	-9.91	S	HZG	GAW
Waldhof/Langenbrügge	Germany	74	52.80	10.75	M	HZG	EMEP
Listvyanka, Irkutsk	Russia	670	51.85	104.89	SN	SPBSU	GAW
Col Margherita	Italy	2545	46.37	11.79	SN	UNIVE	
Iskrba	Slovenia	520	45.56	14.86	MN	JSI	EMEP
Monte Cimone	Italy	2165	44.19	10.70	MN	CNR-IIA/ISAC	GAW
Mt. Bachelor, OR	USA	2743	43.98	-121.69	M	UofW	NOAA
Cap Ferrat	France	130	43.68	7.33	S	CNRS	
La Seyne-sur-Mer	France	10	43.11	5.89	S	IFREMER	
Mt.Waliguan-Changbaishan	China	741	42.40	128.11	S	IGCAS	GAW
Storm Peak, CO	USA	4086	40.45	-106.75	M	DRI	
Longobucco Station	Italy	1379	39.39	16.61	M	CNR-IIA	EMEP
Kanghwa Island	Korea	88	37.70	126.32	S	KNU	
Mt. Waliguan	China	3816	36.29	100.90	M	IGCAS	GAW
Minamata, Kyushu Islands	Japan	20	32.20	130.37	M	MoE	
Ev-K2-CNR	Nepal	5050	27.96	86.81	SN	CNR-IIA	GAW
Mt. Ailao	China	2503	24.54	101.03	SN	IGCAS	GAW
Cape Hedo, Okinawa	Japan	60	26.86	128.25	M	MoE	
Lulin Station (LABS)	Taiwan	2862	23.47	120.87	M	NCU	GAW
Mauna Loa, HI	USA	3397	19.54	-155.58	M	USEPA	NOAA/GAW
Celestún	Mexico	3	20.86	-90.38	SN	JRC	GAW
Calhau, Sao Vicente	Cape Verde	10	16.86	-24.87	SN	UofY/INMG	GAW
Kodaikanal	India	2343	10.23	77.46	MN	IOM-AUC	GAW
Nieuw Nickerie	Suriname	1	5.96	-57.04	SN	INTEC	GAW
Mahé Island	Seychelles	3	-4.67	55.17	MN	SBS/CNR-IIA	GAW
Rondonia Amazonia	Brazil	110	-8.69	-63.87	MN	USP	GAW
Cape Point	South Africa	230	-34.35	18.49	S	SAWS	GAW
Amsterdam Island	TAAF	70	-37.80	77.55	MN	LGGE-UJF	GAW
Bariloche	Argentina	801	-41.13	-71.42	MN	INIBIOMA	GAW
Cape Grim	Australia	94	-40.68	144.69	SN	IVL	GAW
Dumont d'Urville	Antarctica	40	-66.66	140.00	S	LGGE-UJF	GAW
Dome C	Antarctica	3220	-75.10	123.35	SN	LGGE-UJF/CNR	GAW

scale network of atmospheric Hg observations. This is an ongoing task, which will ultimately result in a global-scale network of monitoring sites where consistent and comparable atmospheric Hg measurements are being collected.

We anticipate that by the end of 2012, all instrumentation will be operational at the monitoring sites. We continue to provide support to site operators to manage the consistent collection of data, and to manage the quality assurance and quality control of the data being collected. Ultimately, we intend to provide this data to regional and global atmospheric modelers so that they can validate and improve their model results. This collaborative effort will advance our understanding of the global scale emissions, transport, chemistry and deposition of atmospheric Hg.

Acknowledgements

This work is being performed within Work Package 3 (WP3) of the European Union FP7 Global Mercury Observation System (GMOS) project.

References

Dommergue, A., Sprovieri, F., Pirrone, N., Ebinghaus, R., Brooks, S., Courteaud, J., and Ferrari, C. P.: Overview of mercury measurements in the Antarctic troposphere, Atmos. Chem. Phys., 10, 10(7), 3309 (2010)

Table 2. Existing measurements of Hg in ambient air and precipitation at GMOS monitoring sites (**M =Master, S=Secondary, MN=Master New, SN= Secondary New).*

SITE	TYPE*	TGM	GEM	$PBM_{2.5}$	GOM	Hg in Precipitation
Alert	M		X	X	X	
Station Nord	S		X			
Zeppelin	M	X				
Pallas	S	X				X
Råö	M		X	X	X	X
Auchencorth Moss	M		X	X	X	X
Mace Head	S	X				X
Waldhof/Langenbrügge	M		X	X	X	X
Listvyanka, Irkutsk district	SN	X				
Col Margherita	SN	X				
Iskrba	MN		X			X
Monte Cimone	MN					
Mt. Bachelor, OR	M		X	X	X	
Cap Ferrat	S	X		X		X
La Seyne-sur-Mer	S	X		X		X
Mt. Waliguan-Changbaishan	S	X				X
Storm Peak, CO	M					
Longobucco Station	M		X	X	X	
Kanghwa Island	S	X				
Mt. Waliguan	M		X	X	X	X
Minamata, Kyushu Islands	M		X	X	X	X
Ev-K2-CNR	SN	X				
Mt. Ailao	SN	X				X
Cape Hedo, Okinawa	M		X	X	X	X
Lulin Station	M		X	X	X	X
Mauna Loa, HI	M		X	X	X	
Celestún	SN	X				X
Calhau, Sao Vicente	SN	X				
Kodaikanal	MN		X			
Nieuw Nickerie	SN	X	X			X
Mahé Island	MN					
Rondonia, Amazonia	MN					
Cape Point	S		X			X
Amsterdam Island	MN		X	X	X	
Bariloche	MN		X			
Cape Grim	SN	X				
Dumont d'Urville	S	X				
Dome C	SN		X			

Ebinghaus, R., Kock, H. H., Coggins, A. M., Spain, T. G., Jennings, S. G., and Temme, Ch.: Long-term measurements of atmospheric mercury at Mace Head, Irish west coast, between 1995 and 2001, Atmos. Environ., 36, 5267–5276, 2002.

Fitzgerald, W. F.: Is mercury increasing in the atmosphere? The need for an atmospheric mercury network (AMNET), Water Air Soil Pollut., 80, 245–254, 1995.

Hedgecock IM, Pirrone N, Sprovieri F. Chasing quicksilver northward: mercury chemistry in the Arctic troposphere. Environ Chem 2008; 5:31-134.

Lindberg, S., Bullock, R., Ebinghaus, R., Engstrom, D., Feng, X. B., Fitzgerald, W., Pirrone, N., Prestbo, E., and Seigneur, C.: A synthesis of progress and uncertainties in attributing the sources of mercury in deposition, Ambio, 36(1), 19–32, 2007.

Pirrone, N., Mason, R.: Mercury fate and transport in the global atmosphere: Emissions, Measurements and Models. Springer, USA. ISBN: 978-0-387-93957-5, pp. 637, 2009.

Pirrone, N., Cinnirella, S., Feng, X., Finkelman, R. B., Friedli, H. R., Leaner, J., Mason, R., Mukherjee, A. B., Stracher, G. B., Streets, D. G., and Telmer, K.: Global mercury emissions to the atmosphere from

anthropogenic and natural sources, Atmos. Chem.Phys., 10, 5951–5964, doi:10.5194/acp-10-5951 - 2010, 2010.

Sprovieri, F., Pirrone, N., Ebinghaus, R., Kock, H., and Dommergue, A.: A review of worldwide atmospheric mercury measurements. Atmos. Chem. Phys. 10, 8245-8265, 2010.

Sprovieri, F., Pirrone, N., Landis, M., and Stevens, R. K.: Oxidation of gaseous elemental mercury to gaseous divalent mercury during 2003 polar sunrise at Ny-Alesund, Environ. Sci. Technol., 39, 9156–9165, 2005a.

Sprovieri, F., Pirrone, N., Landis, M., and Stevens, R. K.: Atmospheric mercury behaviour at different altitudes at Ny Alesund during Spring 2003, Atmos. Environ., 39, 7646–7656, 2005b.