Export of Atmospheric Hg from East and Southeast Asia Observed in Taiwan

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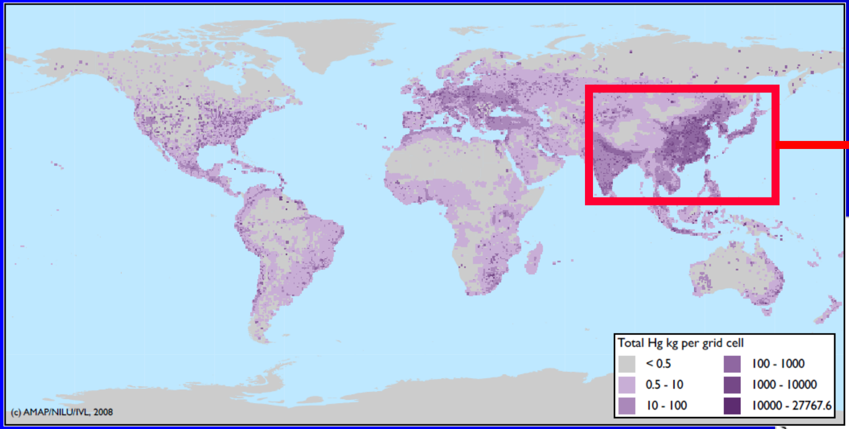
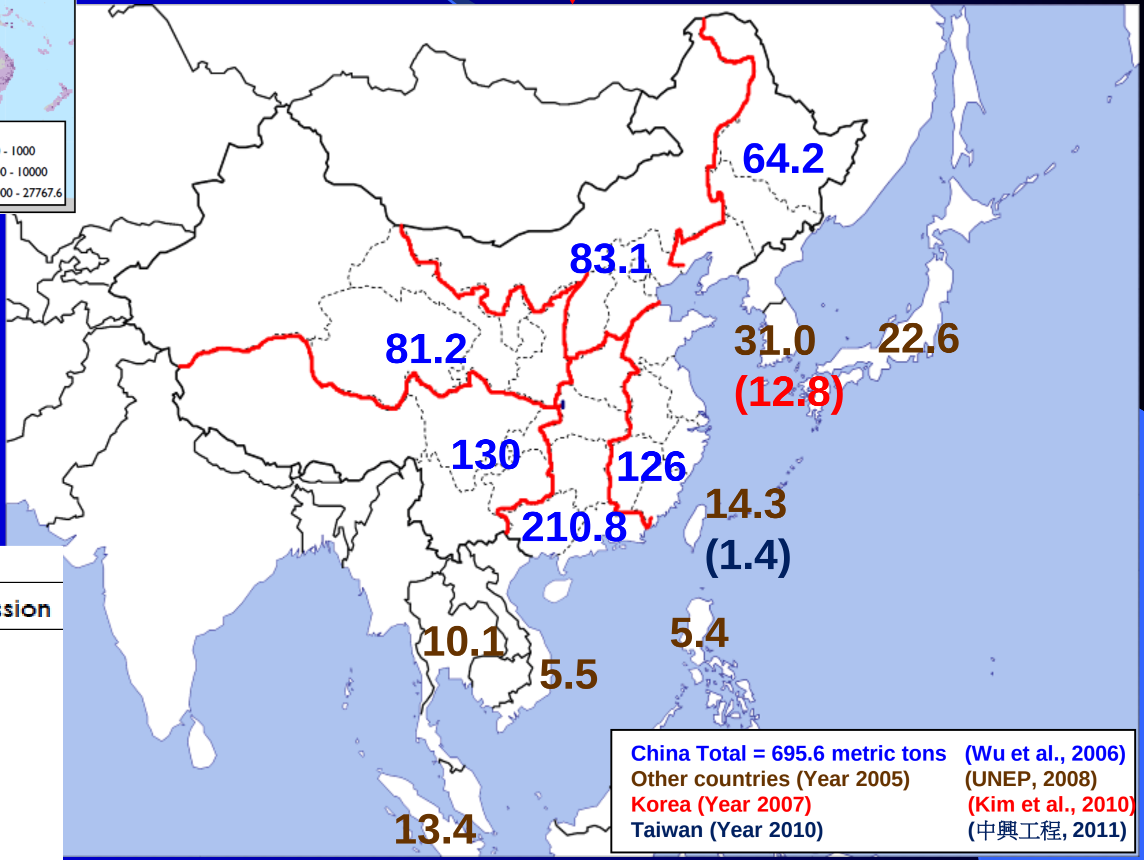
Global Anthropogenic Hg Emission in 2005



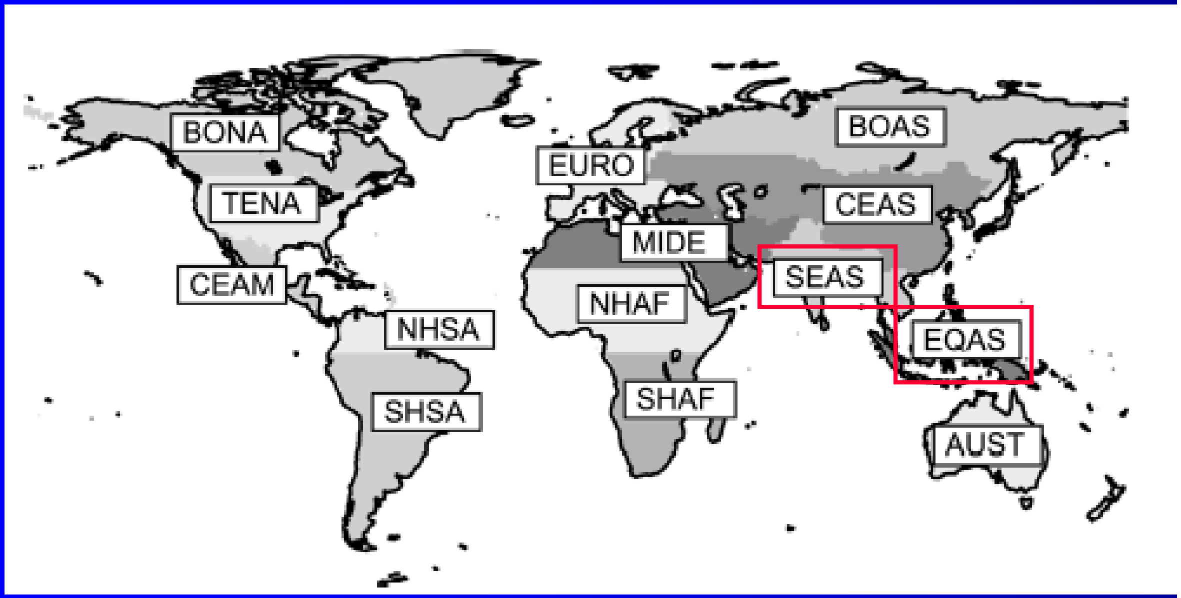


Global anthropogenic emissions to air in 2005 from different regions.

Continent	2005 emission, tonnes	% of 2005 emission
Africa	95	5.0
Asia	1281	66.5
Europe	150	7.8
North America	153	7.9
Oceania	39	2.0
Russia	74	3.9
South America	133	6.9
Total	1930	100

UNEP, 2008

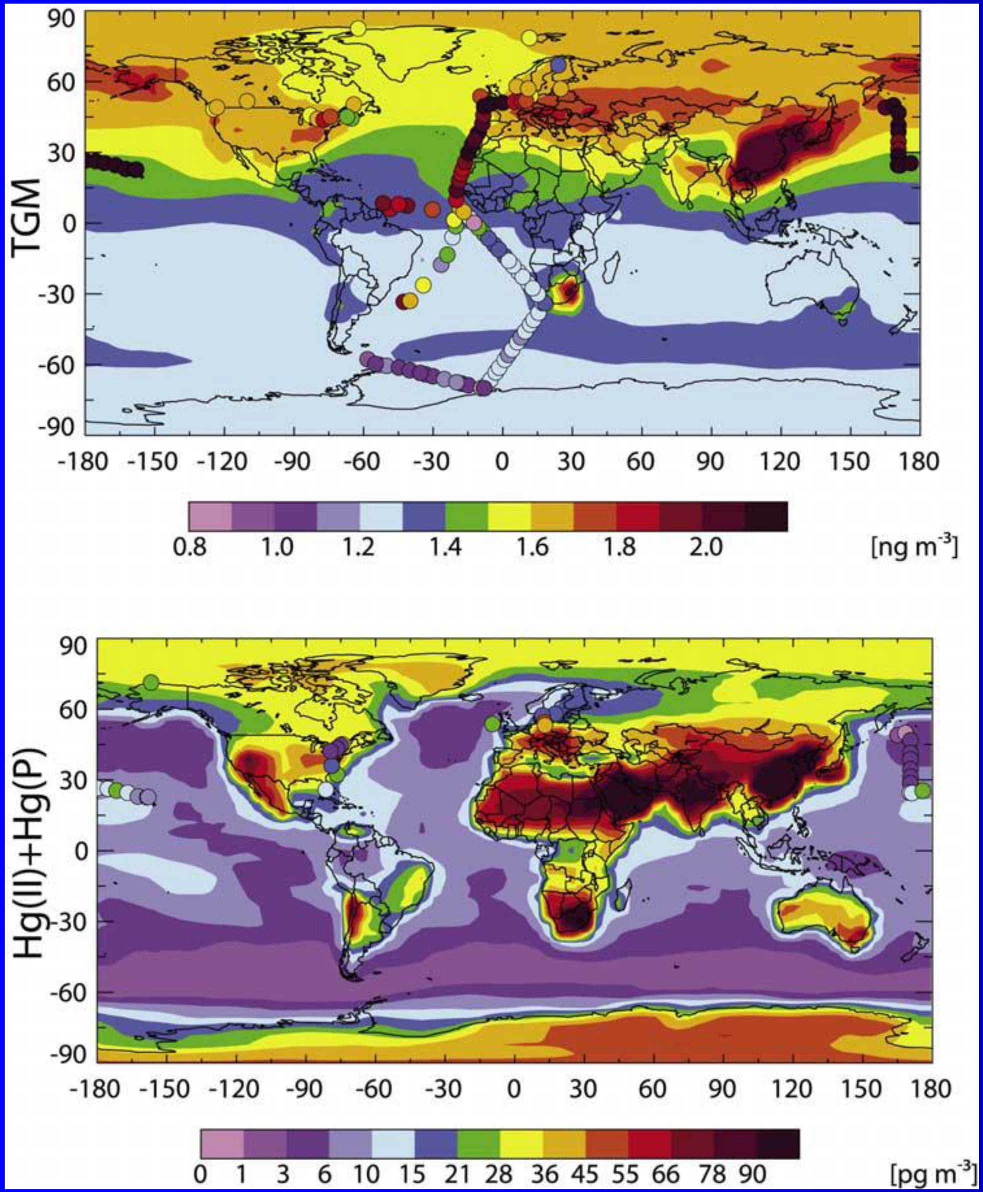
Biomass Burning Hg Emissions in 2005

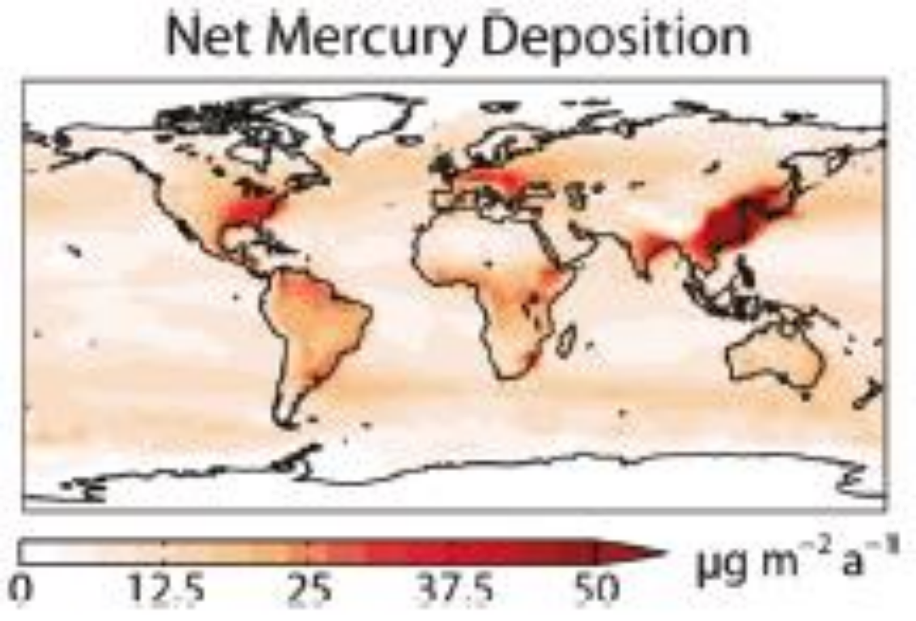


regions	Hg emissions Mg Hg/year mean	SD[a]
BONA	22	16
TENA	6	3
CEAM	22	25
NHSA	13	10
SHSA	95	39
EURO	2	1
MIDE	0	0
NHAF	83	13
SHAF	58	7
BOAS	99	83
CEAS	7	2
SEAS	57	35
EQAS	192	216
AUST	19	9
global	675	240
boreal[b]	121	85
temperate[c]	9	3
ROW[d]	545	224

Friedli et al., 2009

Distribution of Atmospheric Hg Concentrations and Deposition Fluxes: Modeling Results





Corbitt et al., 2011

Selin et al., 2007

Distribution of Atmospheric Hg at Lulin Atmospheric Background Station

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ATMOSPHERIC ENVIRONMENT

Temporal distribution and potential sources of atmospheric mercury measured at a high-elevation background station in Taiwan

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Atmospheric Hg Sampling at LABS

- Automated Sampling:
  - Since April 13, 2006
  - Tekran 2537A/1130/1135 CVAFS Speciation System
  - Speciation of atmospheric Hg: GEM/RGM/ PHg
  - Running in a 3-hr cycle: 2-hr sampling, 1-hr analysis

Tekran 2537A

Tekran 1130 pump unit

Tekran 1135

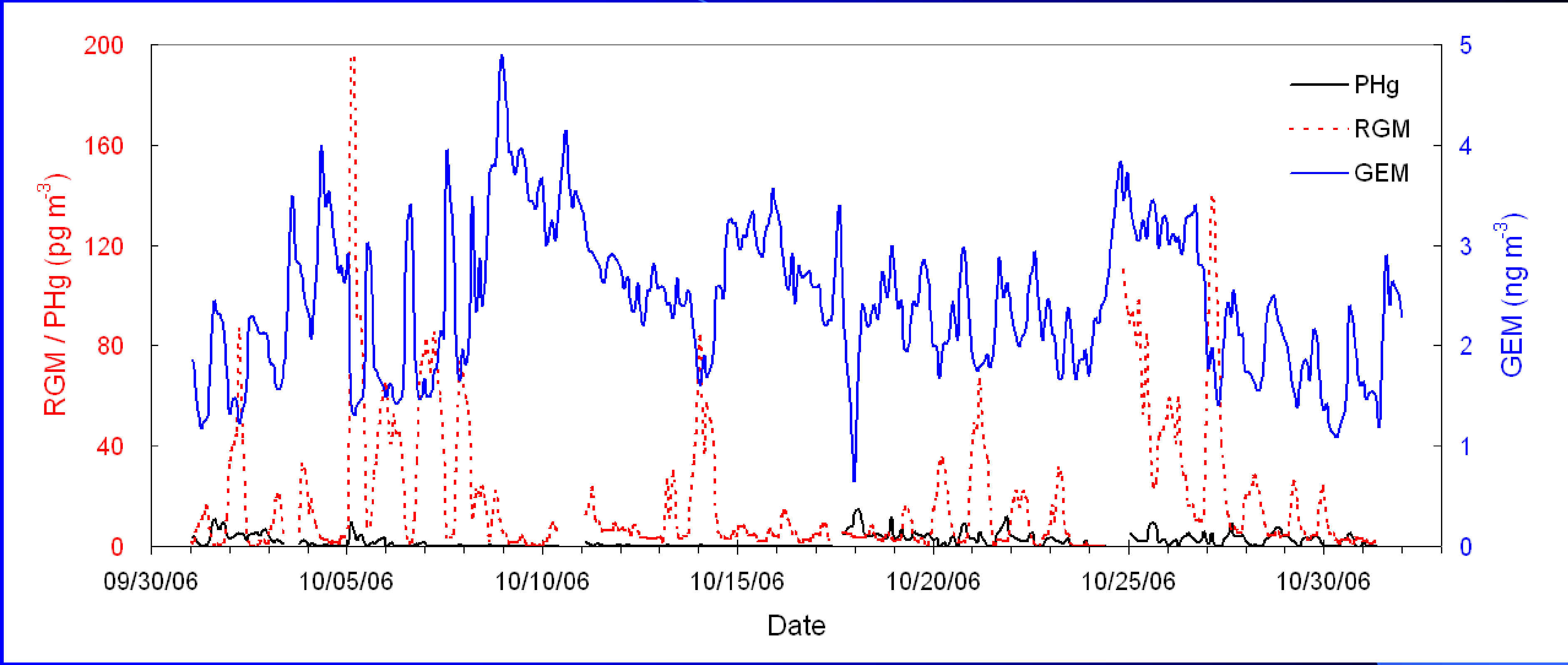
Tekran 1130

Summary of Atmospheric Hg in 2006/04-2012/04

	GEM ($ng\ m^{-3}$)	RGM ($pg\ m^{-3}$)	PHg ($pg\ m^{-3}$)
Mean	1.75	14.72	2.12
S.D.	0.80	27.73	5.86
Max.	7.86	395.75	369.55
Min.	0.57	<MDL	<MDL

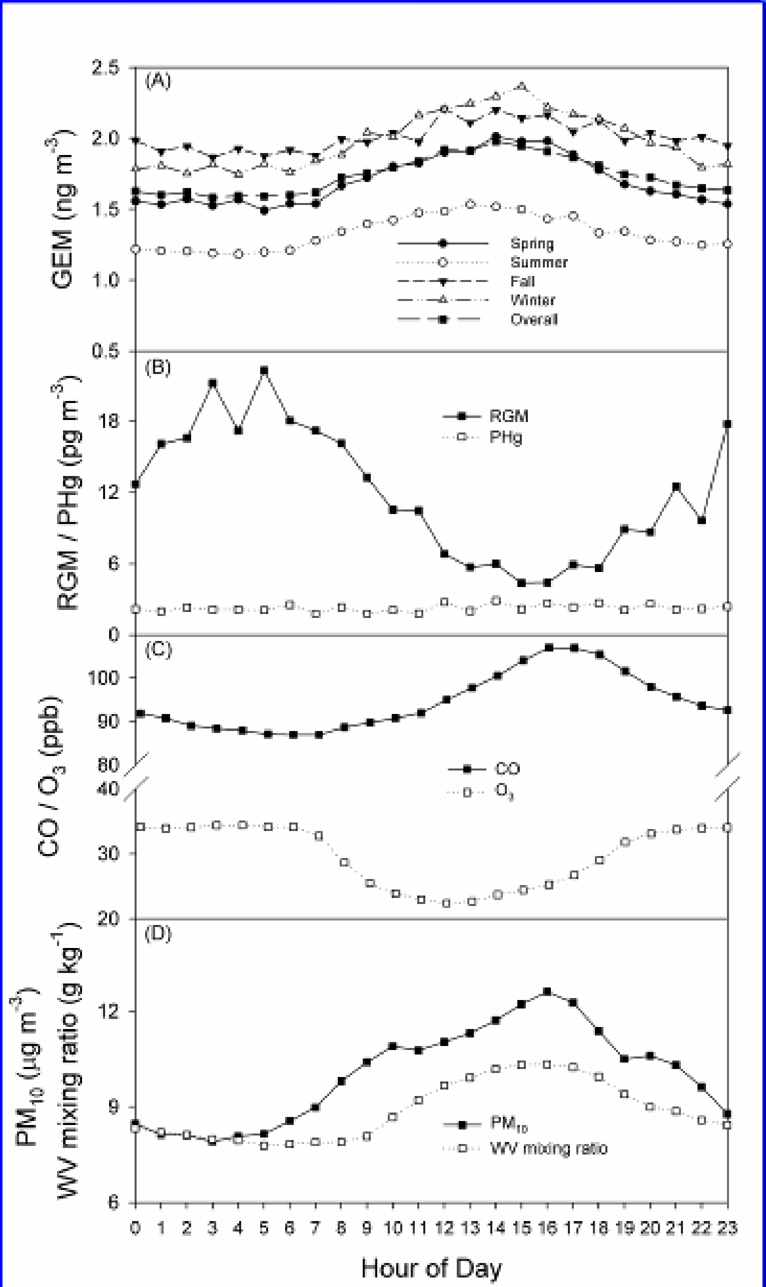
- GEM is the dominant atmospheric Hg species measured at LABS, constituting on average 99% of the total atmospheric Hg.
- Average GEM (1.75 ng m^{-3}) is slightly higher than the Northern Hemisphere background value of 1.5-1.7 ng m^{-3} at sea level.
- However, about 30% of the GEM is greater than 2 ng m^{-3}, suggesting sources other than the background atmosphere are influencing the background station.

Diurnal Distribution of Atmospheric Hg

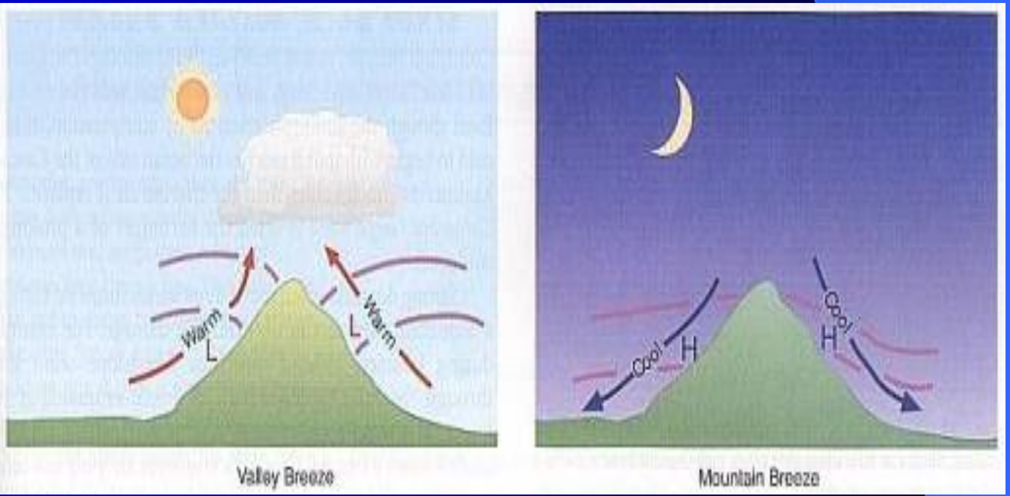


- A clear diurnal pattern was observed for GEM with afternoon peaks and nighttime lows.
- RGM often showed diurnal pattern opposite to that of GEM. Spikes of RGM were frequently observed between midnight and early morning with concurrent decreases in GEM.

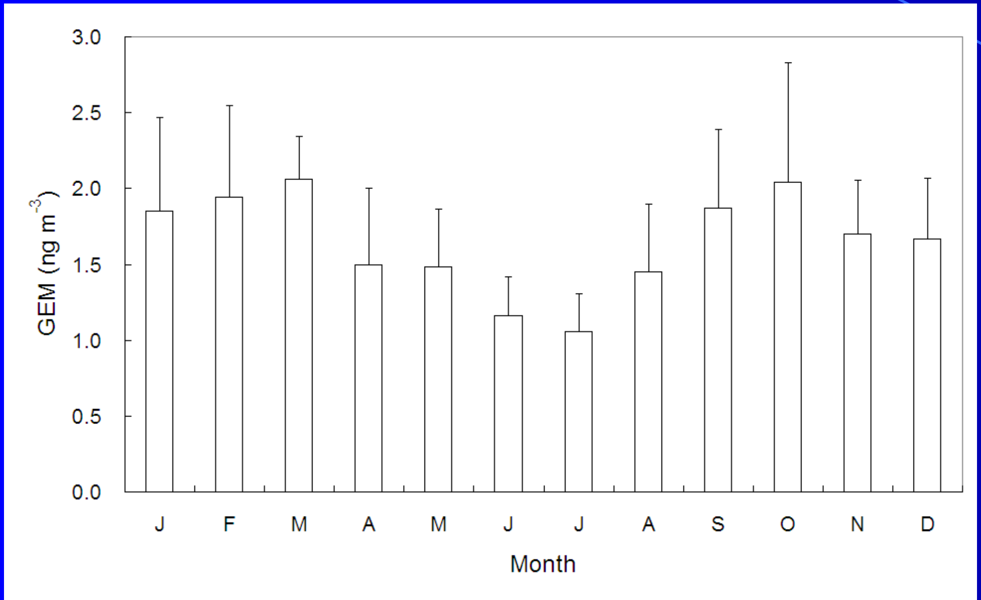
Diurnal Distribution of Hg and Other Chemicals



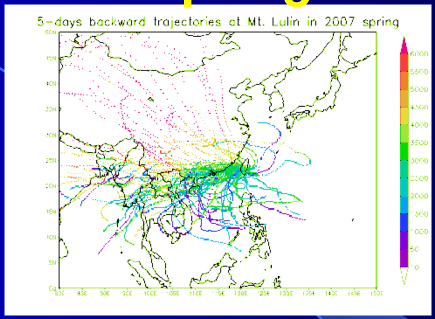
- Concentrations of CO, PM_{10} and WV mixing ratio all exhibited diurnal patterns similar to that of GEM.
- On the other hand, O_3 concentrations showed diurnal pattern similar to that of RGM.
- Upslope movement of boundary layer air in daytime and subsidence of free tropospheric air at night resulted in these diurnal patterns.



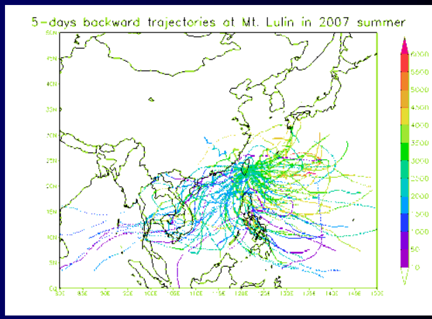
Seasonal Distribution of Nighttime GEM



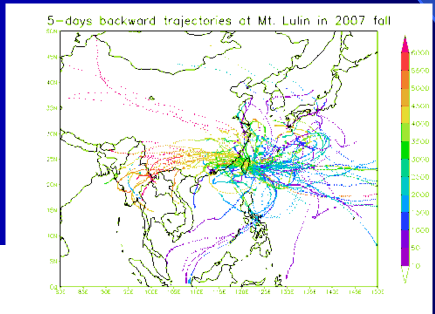
Spring



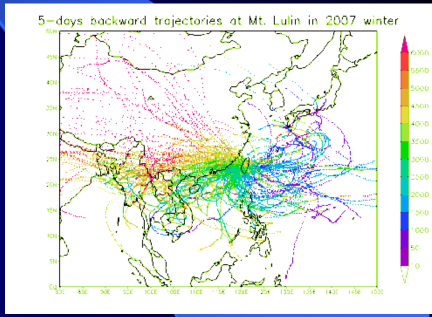
Summer

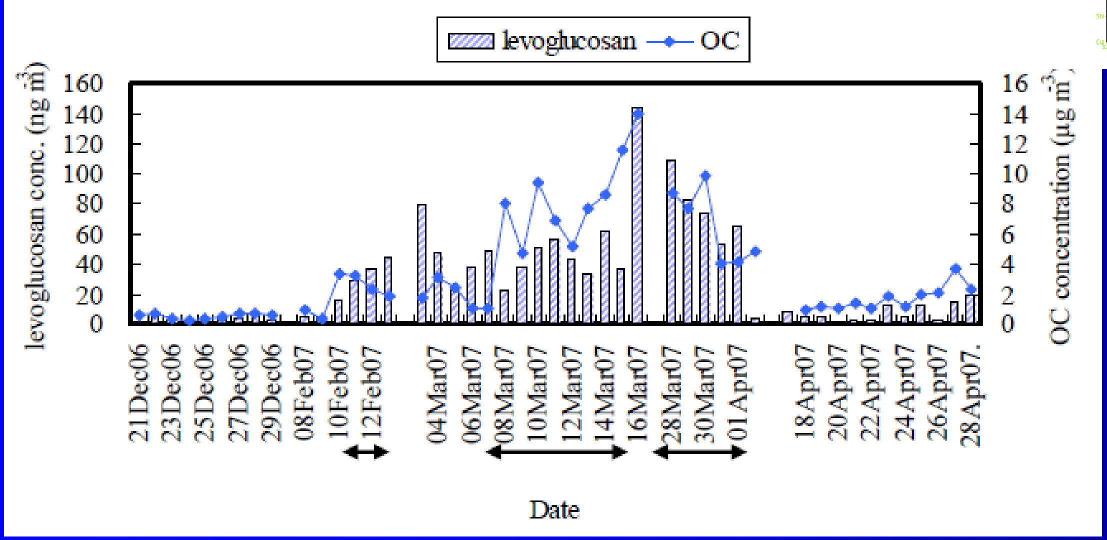


Fall

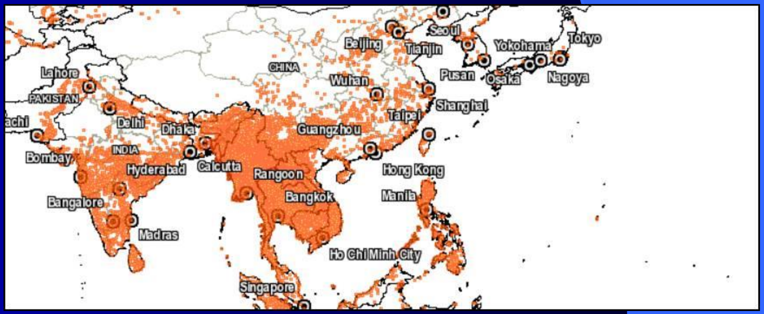


Winter

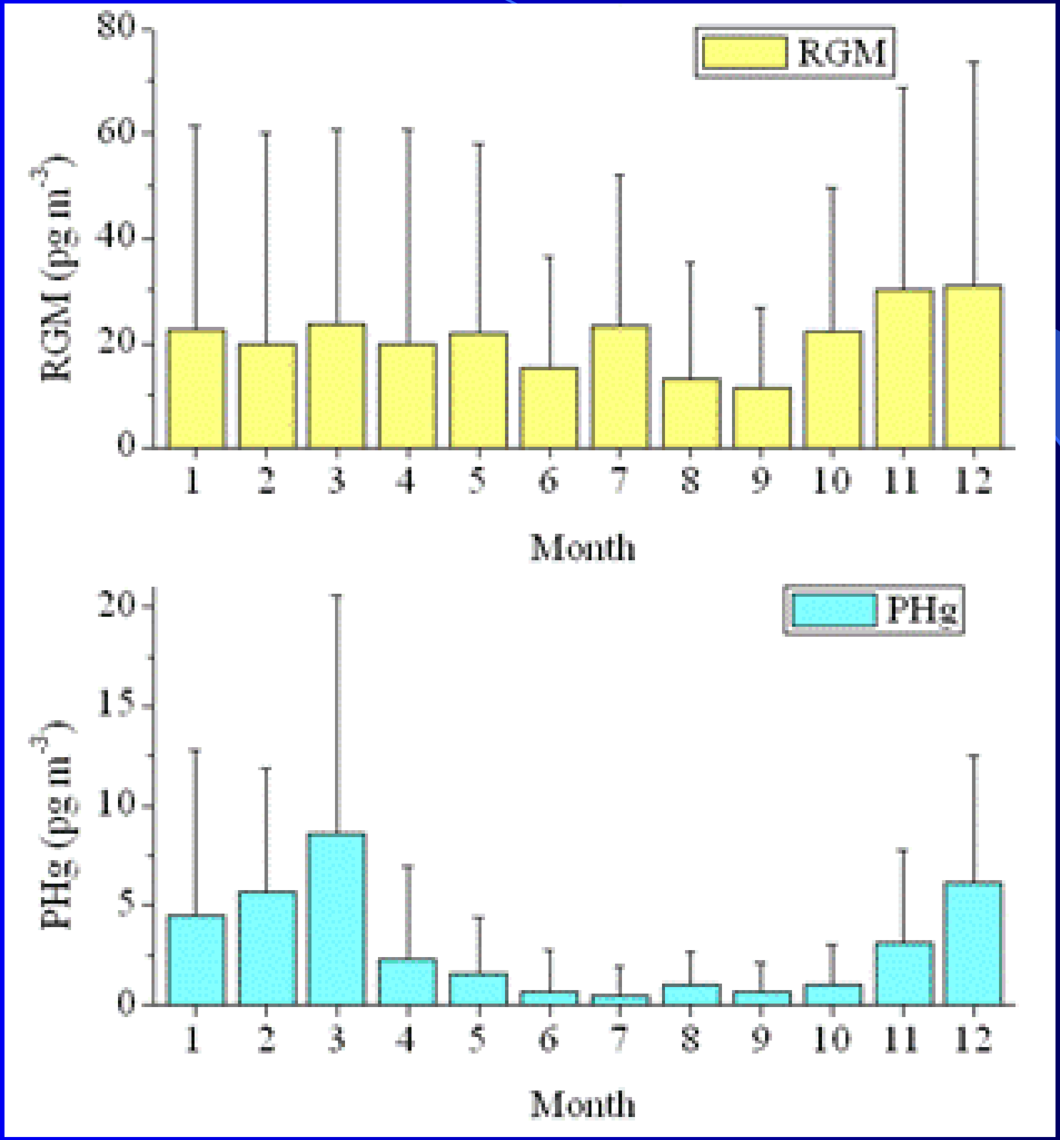




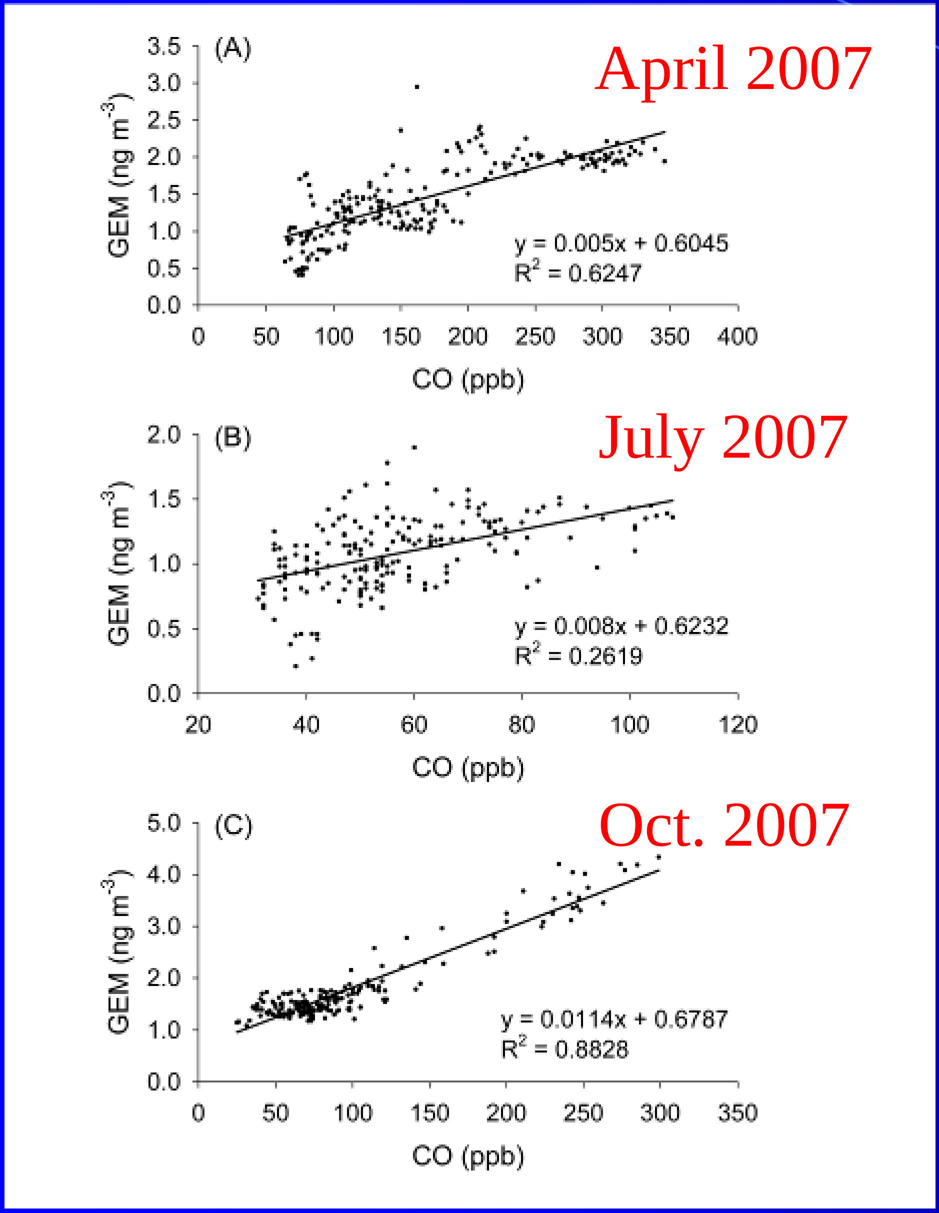
2007/03 MODIS fire detection



Seasonal Distribution of RGM and PHg

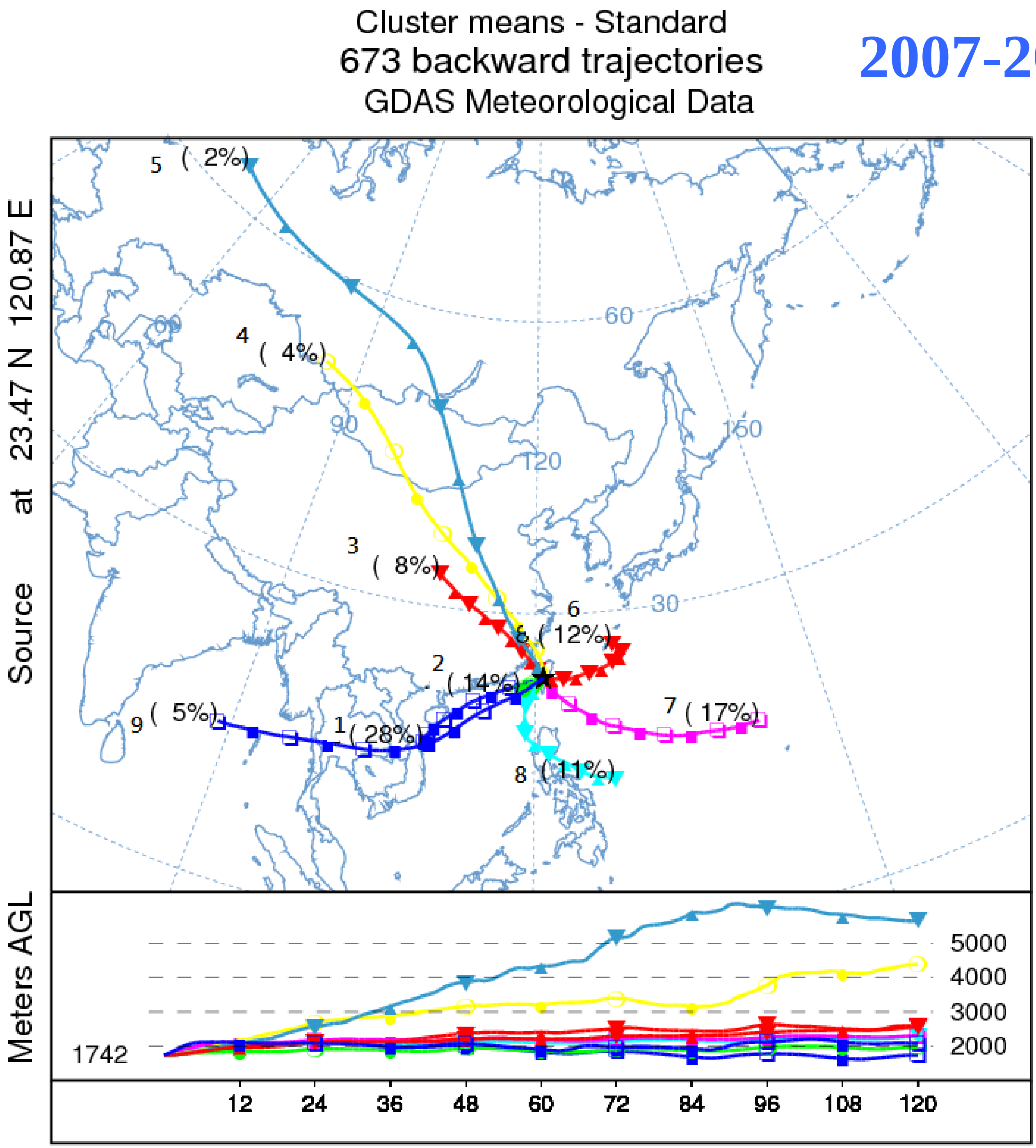


Correlation between GEM and CO



- Good GEM/CO correlations were observed in non-summer months, indicating influence of anthropogenic emission sources.
- GEM seasonal pattern, backward trajectory analysis and GEM/CO correlations indicated that air mass origins plays an important role in determining the GEM levels.
- These results also demonstrate the significance of East Asian Hg emissions and their long-range transport to downwind regions.
- Estimates of annual Hg^0 emission from the Chinese anthropogenic and the Southeast Asian biomass burning were 1536 and 128 metric tones, respectively.

2007-2008 data

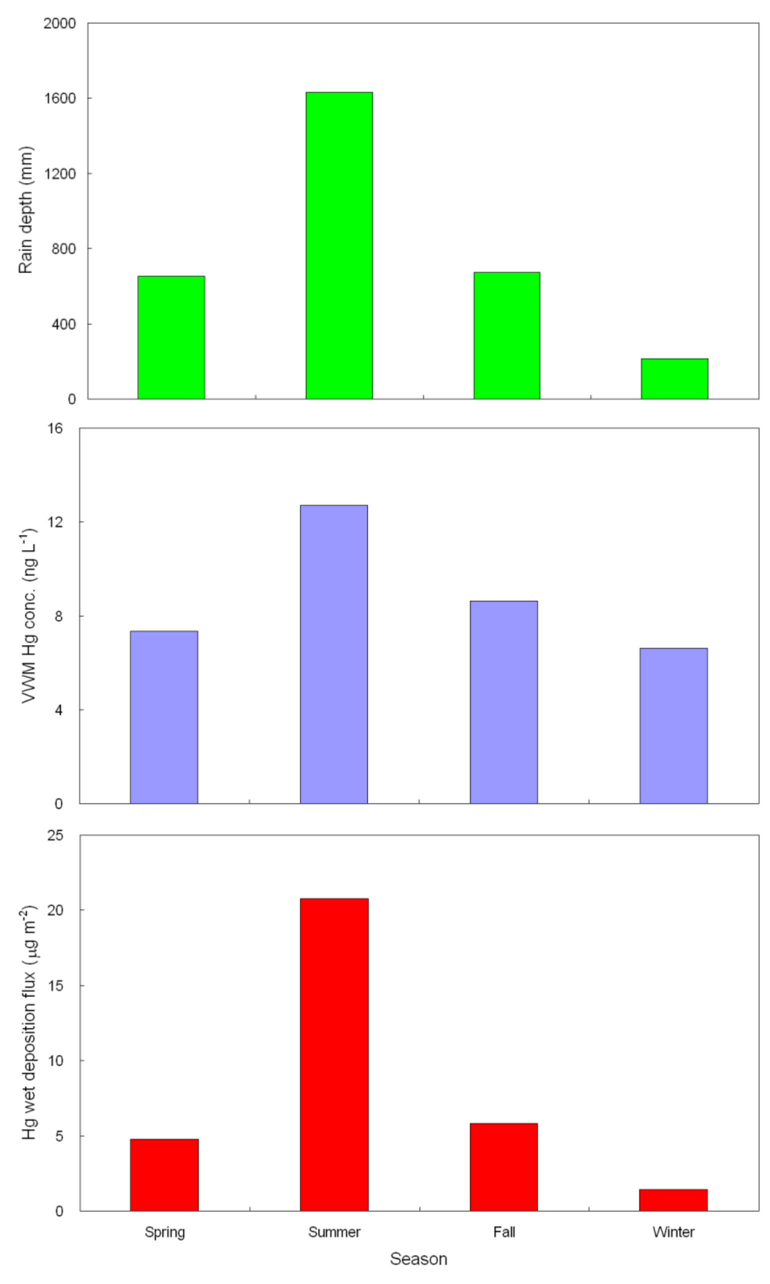


Cluster	Source Region
1	Indo-China Peninsula
2	Taiwan and SE China
3	China #1
4	China #2
5	High altitude
6	East China Sea
7	W. Pacific Ocean
8	South China Sea
9	Indian Ocean

Continental Air vs. Marine Air

Cluster	GEM	CO	O_3	PM_{10}	RGM	PHg
1 (Indo-China)	1.71	169.8	44.1	12.3	15.43	3.63
2 (Taiwan/SE China)	1.70	158.8	42.3	9.7	26.87	4.35
3 (China #1)	1.95	157.5	44.9	15.2	27.52	6.14
4 (China #2)	1.72	135.2	44.8	10.5	18.92	6.77
5 (High altitude)	1.69	150.9	48.1	14.1	18.72	5.38
6 (East China Sea)	1.59	112.6	32.6	5.6	22.80	2.30
7 (W. Pacific Ocean)	1.39	93.5	24.5	4.2	31.60	2.24
8 (South China sea)	1.38	101.9	29.1	5.3	24.71	1.54
9 (Indian Ocean)	1.40	102.7	29.2	6.0	4.46	1.06

Hg Wet Deposition at LABS in 2010



- Total Hg concentrations ranged between 4.08 and 24.93 ng L^{-1} with a VWM concentration of 9.62 ng L^{-1}, which is comparable to the 2010 values (3.8-23.1 ng L^{-1}) of NADP/MDN.
- The annual wet Hg deposition flux was 32.77 µg m^{-2}, which is significantly higher than the 2010 values (3.0-21.6 µg m^{-2}) of NADP/MDN.
- About 63% of the wet Hg deposition flux occurred in summer as a result of the high VWM concentration and rain depth.

Wet vs. Dry Depositions at LABS

	Spring	Summer	Fall	Winter	Total
Wet Deposition	4.78	20.75	5.82	1.42	32.77
Dry Deposition (RGM+PHg)	0.40-5.25	0.31-3.94	0.63-7.81	0.61-7.97	1.95-24.97
RGM	0.40-4.85	0.31-3.77	0.63-7.54	0.60-7.25	1.94-23.41
PHg	0.004-0.404	0.002-0.173	0.003-0.270	0.007-0.715	0.02-1.56

V_d of RGM: 0.5-6 cm s^{-1}; V_d of PHg: 0.1-0.4 cm s^{-1}

- Wet deposition flux is higher than dry deposition flux of RGM+PHg, mainly due to the extremely high summer wet flux.
- Dry RGM deposition is the major component of the total dry deposition.
- Dry deposition of GEM is not considered.

Summary

- Seasonal variation in GEM was evident in the free troposphere and marine boundary layer, with lower concentrations occurring in summer when marine air masses prevailed.
- Good GEM/CO correlations were observed in fall, winter, and spring, suggesting influence of anthropogenic emission sources.
- Monitoring results demonstrate the significance of East Asian Hg emissions, including both anthropogenic and biomass burning emissions, and their long-range transport in the BL and FT.

THANK YOU!

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