

Updates on Recent Mercury Monitoring Activities in Taiwan

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Atmospheric Hg Monitoring Activities Supported by Taiwan EPA

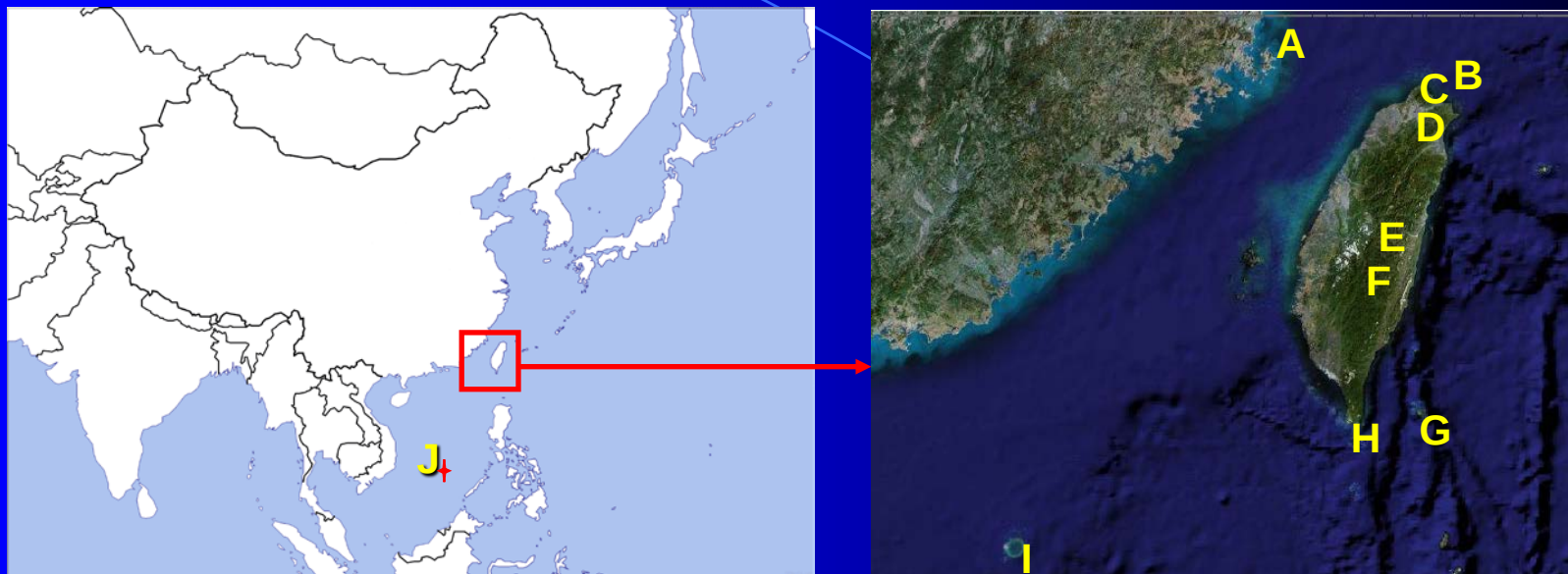
- Continuous speciated atmospheric Hg monitoring at Lulin Atmospheric Background Station (Dept. of Environmental Monitoring & Information Management)
- Intensive manual atmospheric Hg measurements at rural/remote sites (Dept. of Environmental Monitoring & Information Management)
- International collaboration in atmospheric Hg research (Dept. of Environmental Monitoring & Information Management)
- Mercury Wet Deposition Network in Taiwan (Dept. of Air Quality Protection & Noise Control)

Lulin Atmospheric Background Station (LABS)



- LABS is located atop Mt. Front Lulin in central Taiwan, with an elevation of 2862 m above sea level.
- GEM, RGM and PHg have been measured using Tekran 2537A/1130/1135 at the LABS since April 13, 2006.

Atmospheric Mercury Measurements at Background Sites



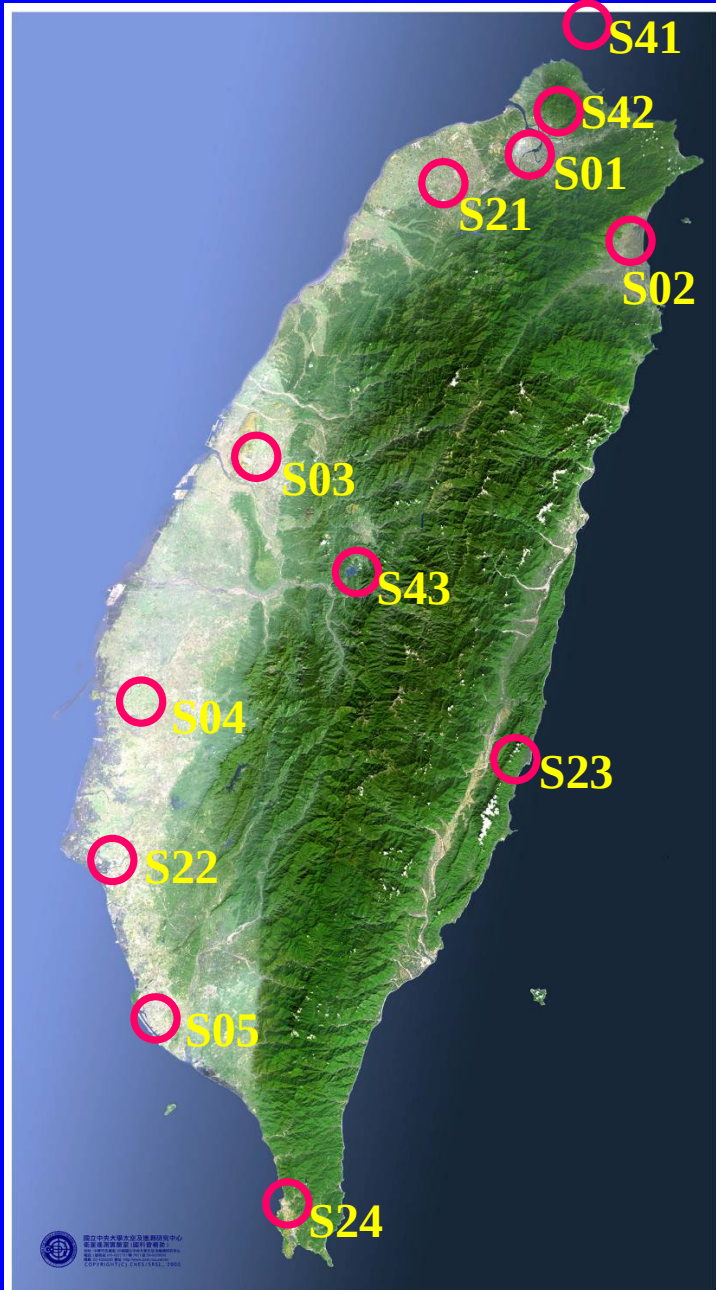
Symbol	Site	Characteristics	Latitude/Longitude	Altitude (m)
A	Matsu	Island	26.16°N, 119.95°E	50
B	Pengjiayu	Island	25.63°N, 122.07°E	102
C	Fugueijiao	Coastal/Rural	25.30°N, 121.54°E	-----
D	Mt. Bamboo	Mountain	25.19°N, 121.54°E	1025
E	Mt. Hehuan	Mountain	24.14°N, 121.28°E	3156
F	Mt. Lulin	Mountain	23.47°N, 120.87°E	2862
G	Lanyu	Island	22.02°N, 121.56°E	29
H	Hengchun	Coastal/Rural	21.96°N, 120.79°E	-----
I	Dongsha Island	Island	20.70°N, 116.73°E	6
J	Taiping Island	Island	10.38°N, 114.37°E	-----

Regional Atmospheric Hg Research

- 2008: Hg sampling at Mt. Fuji, Japan
- 2009: Hg sampling at Gosan, Korea
- 2010: 7-SEAS/Dongsha Experiment
- 2011: Son La Experiment (I)
- 2012: Son La Experiment (II)
- 2013: 2013 7-SEAS/BASELInE Campaign
- 2014: 2014 7-SEAS/BASELInE Campaign



Geographic Distribution of Sampling Sites



Mercury Wet Deposition Network:

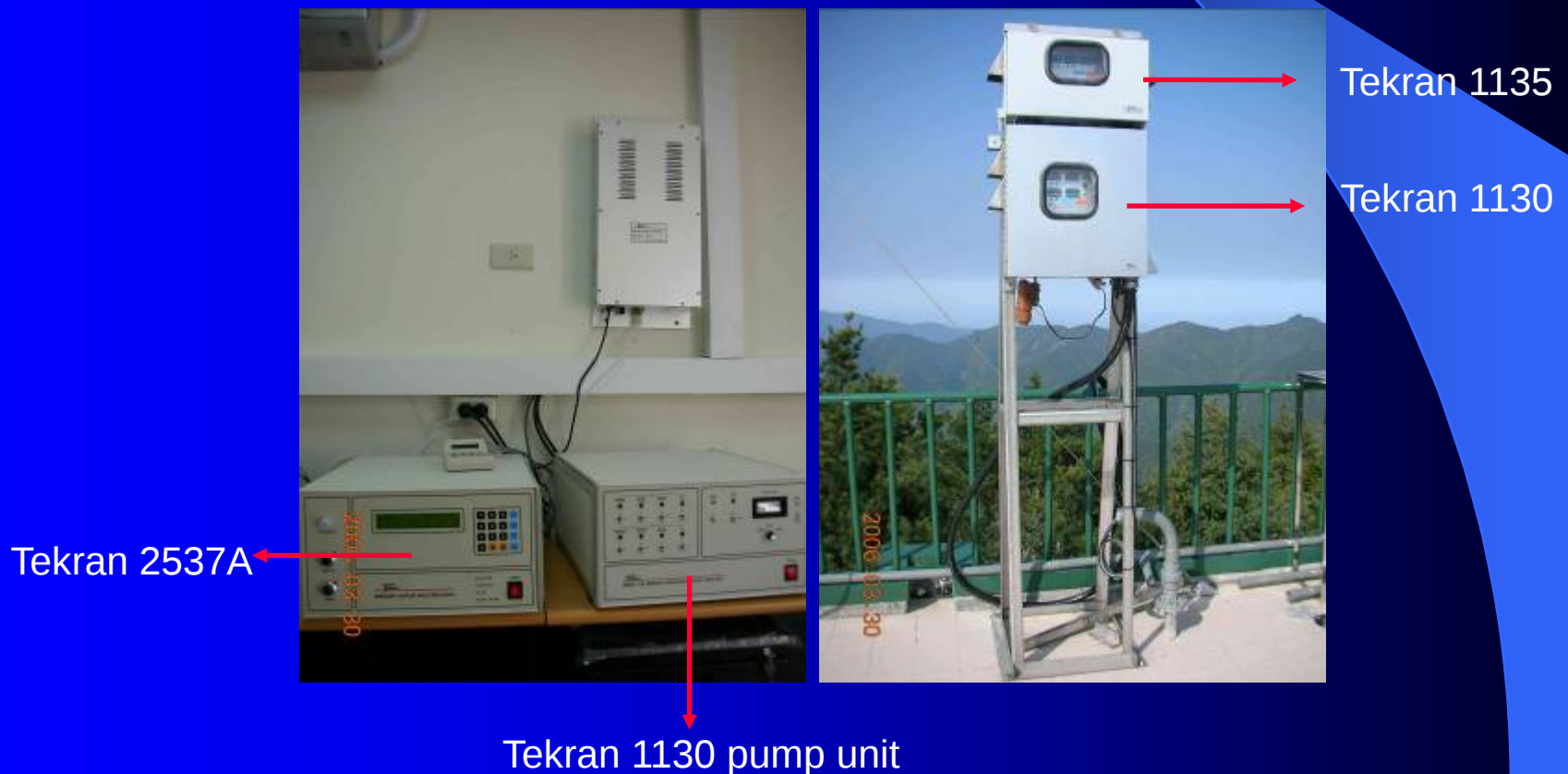
- 12 sampling sites
- Wet-only sampler
- Operation began since late 2008

Site No.	Site Name	Characteristics	Altitude (m above sea level)
S41	Pengjiayu	Remote/Island	101.7
S42	Anbu	Rural/Mountain	825.8
S01	Taipei	Urban	5.3
S02	Yilan	Suburb	7.2
S21	Jhongli	Urban/Industrial	125
S03	Taichung	Urban	173
S43	Sun Moon Lake	Rural/Mountain	1014.8
S04	Chiayi	Suburb/Agriculture	26.9
S22	Tainan	Suburb/Agriculture	25
S05	Kaohsiung	Urban/Coastal	15
S24	Hengchun	Rural/Coastal	22.1
S23	Chenggong	Rural/Coastal	33.5

Speciated Atmospheric Mercury Measurements at LABS

Atmospheric Hg Sampling and Analysis

- 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

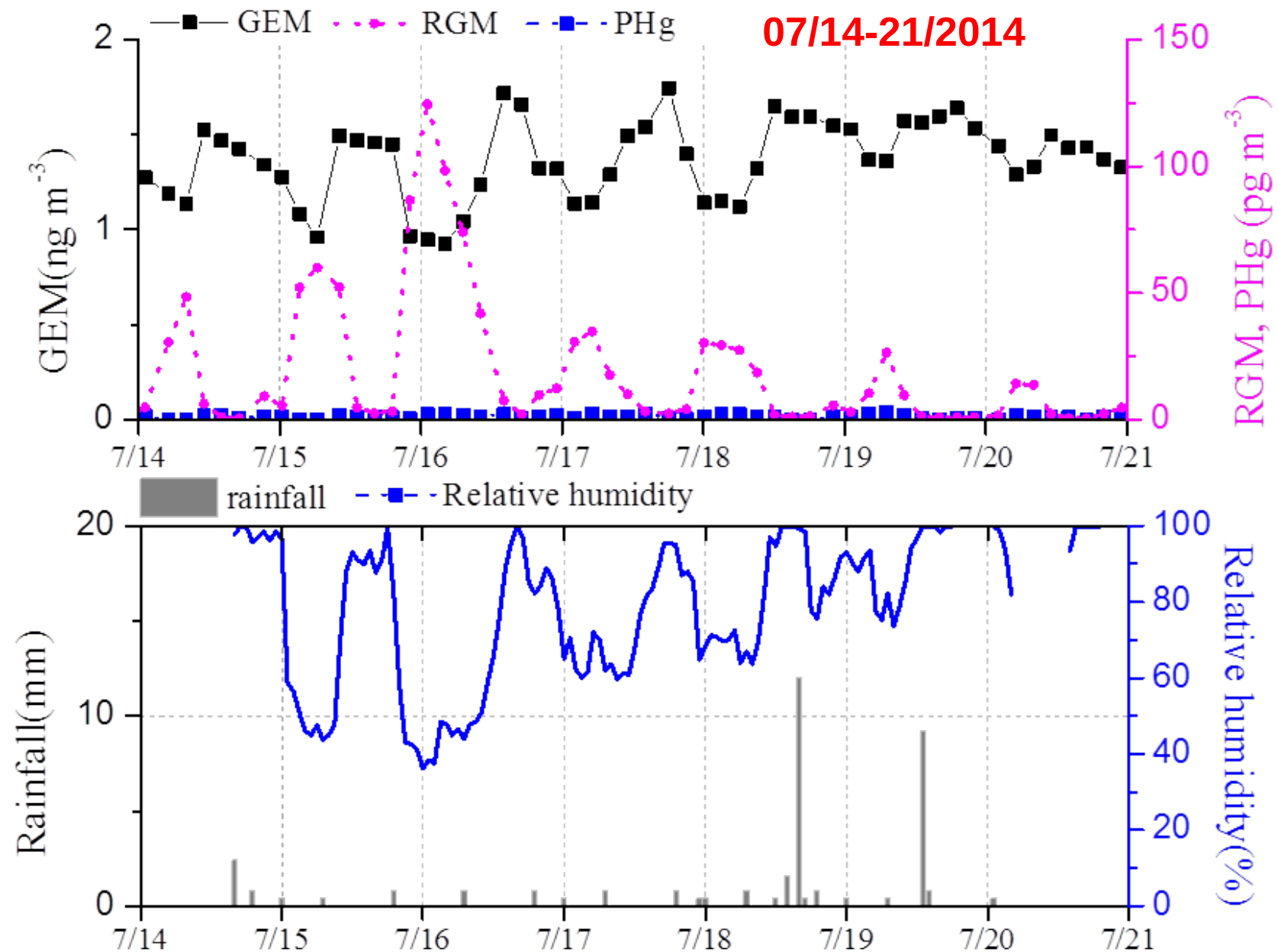


Summary of Atmospheric Hg in 2006/04/13-2014/06/30

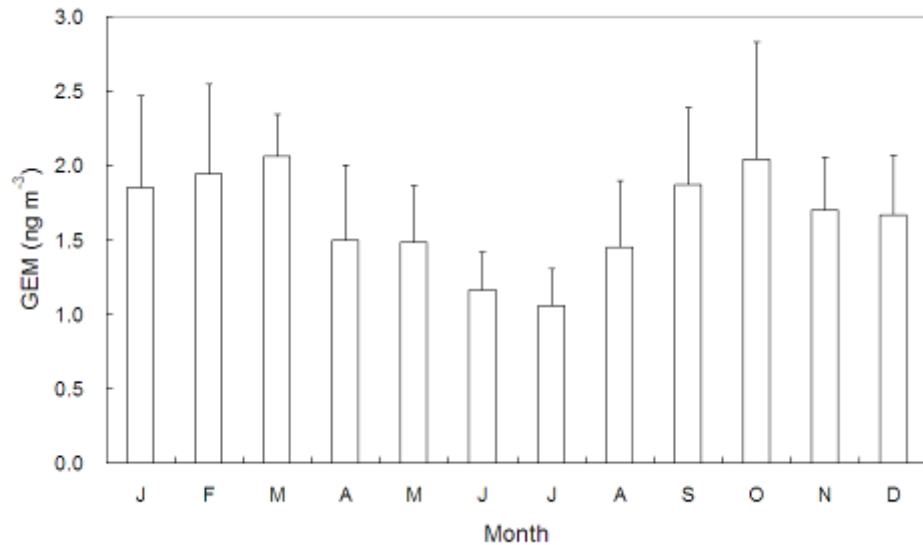
	GEM (ng m ⁻³)	RGM (pg m ⁻³)	PHg (pg m ⁻³)
Mean	1.6	17.6	2.8
S.D.	0.4	14.4	4.1

- GEM is the dominant atmospheric Hg species measured at LABS, constituting on average 98.7% of the total atmospheric Hg.
- Average GEM (1.74 ng m⁻³) is within 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.

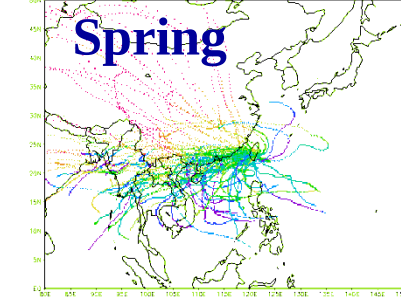
Diurnal Distribution of Hg and Humidity



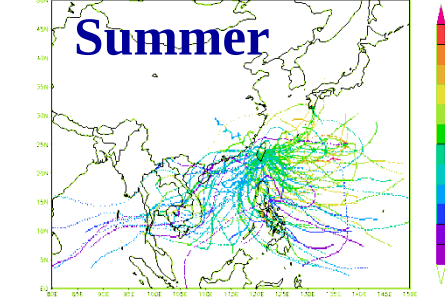
Seasonal Pattern of Nighttime GEM



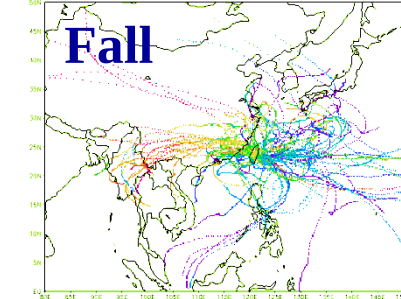
5-days backward trajectories at Mt. Lulin in 2007 spring



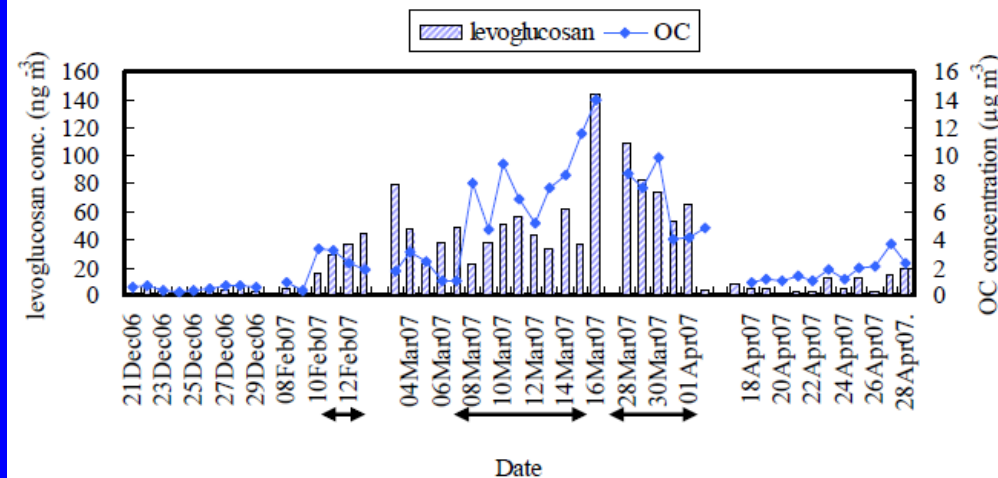
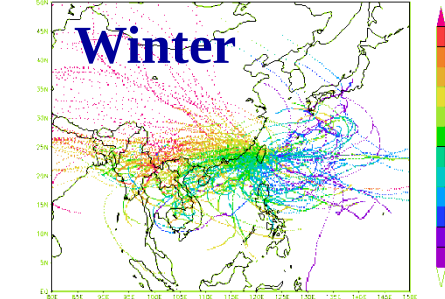
5-days backward trajectories at Mt. Lulin in 2007 summer



5-days backward trajectories at Mt. Lulin in 2007 fall



5-days backward trajectories at Mt. Lulin in 2007 winter



2007/03 MODIS fire detection

- LABS is the only site to observe Hg from anthropogenic emissions from China and biomass burning from Indochina Peninsula.

Correlation between Hg and Other Parameters

GEM related to anthropogenic events.
(Jaffe et al., 2005; Weiss-Penzias et al., 2007;
Sheu et al., 2010)

Positive correlation :
re-emission from soil.
(Gustin et al., 2002)

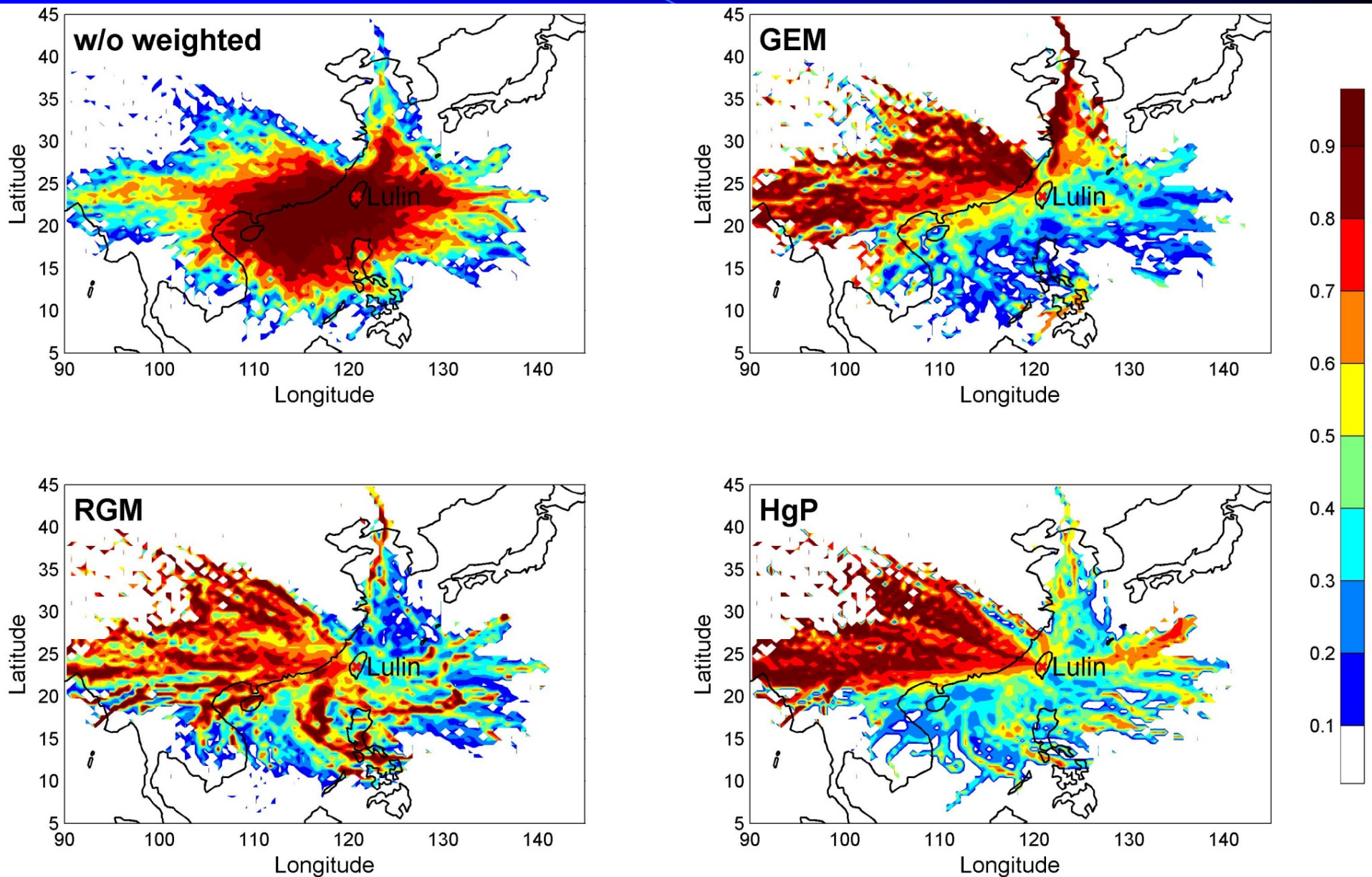
	RGM (pg m ⁻³)	PHg (pg m ⁻³)	CO (ppb)	O ₃ (ppb)	Wind speed (m/s)	RH (%)	Temperature (°C)
GEM	-0.30**	-0.10	0.78**	0.43**	0.02	0.14**	-0.43**
RGM		0.08	-0.24**	-0.01	0.08	-0.41**	0.02
PHg			-0.13	0.13**	-0.01	-0.39**	-0.37**

*: $p < 0.05$, **: $p < 0.01$

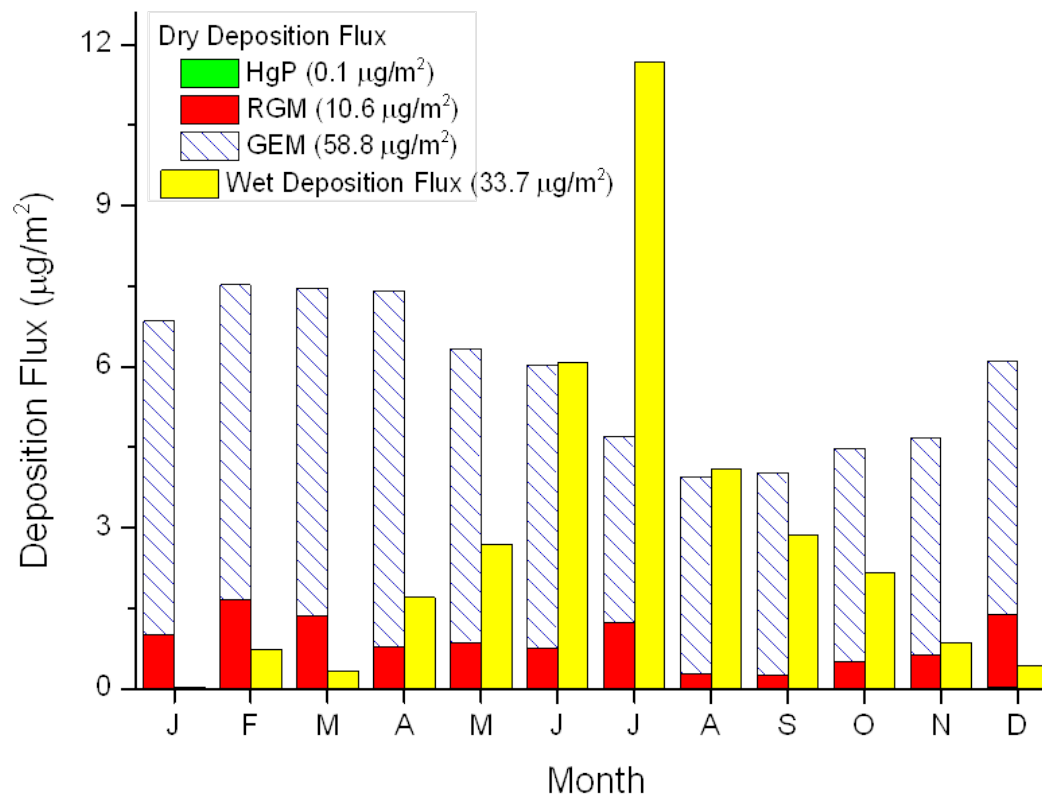
High solubility of RGM and PHg. (Faïn et al., 2009)

Oxidation reaction. (Swartzendruber et al., 2006, Faïn et al., 2009)

Source-Receptor Relationship: Concentration-Weighted Trajectory



Wet and Dry Deposition Fluxes in 2010



Location	Site Type	GEM	RGM	PHg	Wet	Reference
LABS, Taiwan	Mountain	58.8	10.6	0.1	33.7	This study
AMNet, USA	Rural/urban	13-35	0.3-7.8	0.1-0.8	6-12.6	Zhang et al. 2012

Unit: $\mu\text{g m}^{-2}$

Wet Mercury Deposition Monitoring Network in Taiwan

Sampling and Analysis

A



B



C



- **Weekly samples were collected** using automated wet-only precipitation collection systems.
- Sampling bottles and glassware were **changed every Tuesday morning**.
- Acid-cleaned glass funnels and 1L Teflon bottles were used for the Hg collections.
- Total Hg was quantified by dual amalgamation CVAFS after BrCl oxidation, $\text{NH}_2\text{OH}\cdot\text{HCl}$ neutralization, and SnCl_2 reduction (USEPA Method 1631, Revision E).



2009

2010

2011

2012

2013

VWM Hg Conc. (ng L⁻¹)

Higher rainwater
Hg concentrations
in western Taiwan.

7.6-17.2

7.7-21.8

6.8-16.7

7.1-18.9

5.6-14.0



Flux (μg m⁻²)

Higher wet
deposition flux of
Hg in northern
Taiwan.

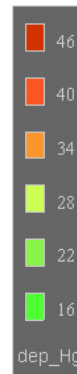
12.6-37.2

15.7-63.4

11.0-49.3

15.7-59.9

11.7-38.0



Rainfall (mm)

Higher rainfalls in
northern Taiwan.

1211-3861

1533-4915

1022-4879

1960-4912

1688-5206



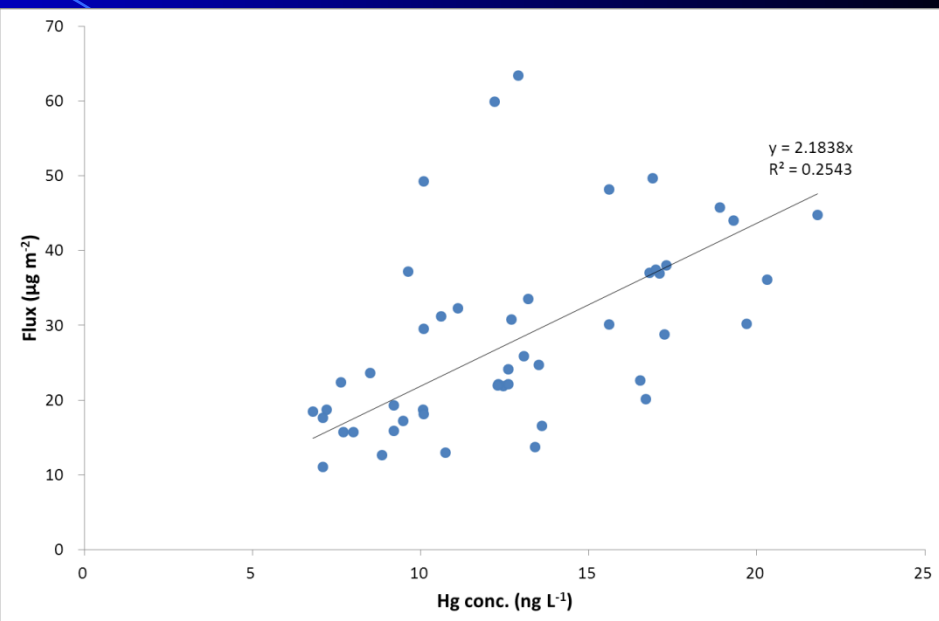
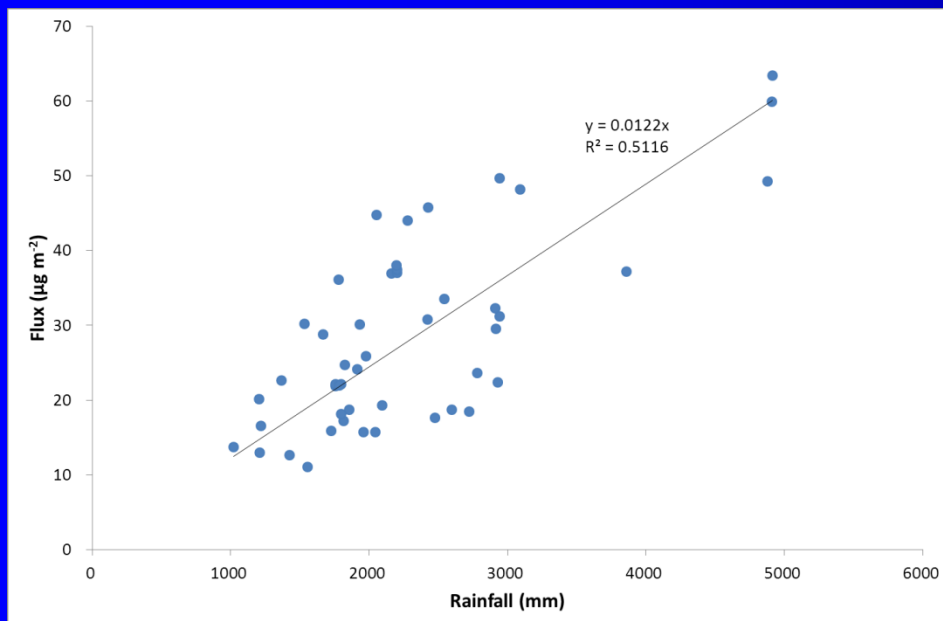
Comparison with Other Studies

Location	Site characteristic	Rainfall (mm)	VWM conc. (ng L ⁻¹)	Wet deposition Flux (μg m ⁻² yr ⁻¹)	Reference
12 sites in Taiwan	Various	1022-5206	5.6-21.8	11.0-63.4	This study
Equatorial Pacific Ocean	Open ocean	---	2.9	---	Mason et al., 1992
North Pacific Ocean	Open ocean	---	14.3	---	Laurier et al., 2003
Long Marine Lab, CA, USA	Coastal (Pacific)	---	6.0	4.0	Steding and Flegal, 2002
Monterey Bay, CA, USA	Coastal (Pacific)	---	5.8	4.16	Conaway et al., 2010
CBL, MD, USA	Coastal (Atlantic)	710-1170	11.4-15.0	8.2-17.2	Mason et al., 2000
Nam Co, China	High elevation	364.9	4.8	1.75	Huang et al., 2012
Mt. Leigong, China	Mountain	1533	4.0	6.1	Fu et al., 2010
Chuncheon, Korea	Rural	1061.9	8.8	9.4	Ahn et al., 2011
Pensacola, FL, USA	Urban/suburb	---	17.3	---	Landing et al., 2010
Seoul, Korea	Urban	1235-1645	10.1-16.3	16.8-20.2	Seo et al., 2012
Chongqing, China	Urban	921	30.67	---	Wang et al., 2012
Moffett Field, CA, USA	Urban	---	11.6	4.4	Steding and Flegal, 2002
110 sites in USA (MDN/NADP)	Various	---	1.5-26.1	2.4-20.2	NADP 2011 Annual Summary
10 sites in Japan	Various	882-2317	---	5.8-17.7	Sakata and Marumoto, 2005

Rainwater Hg concentrations in Taiwan are comparable to other countries. However, wet Hg deposition fluxes are much higher in Taiwan primarily due to higher rainfalls.

Flux vs. Rainfall

Flux vs. Conc.



Positive correlations between flux and rainfall and between flux and concentration. Nonetheless, the correlation between flux and rainfall is better, indicating that rainfall is more important in determining the magnitudes of wet flux.

Future Plans

- Estimation of dry Hg deposition flux at Mt. Lulin (Dr. Leiming Zhang of Environment Canada)
- Source-receptor relationship: quantify the contribution of trans-boundary transport to concentration and deposition
- Transformation, transport and fate of the deposited Hg
- Isotope studies
- Modeling
- International collaboration