

Mercury Monitoring in Taiwan and Southeast Asia

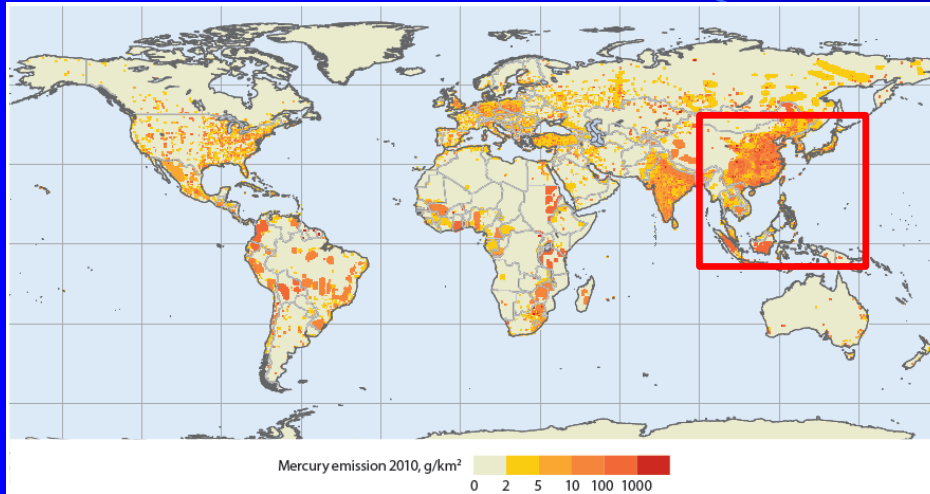
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²NADP Program Office, USA

³USEPA Office of Atmospheric Programs, USA

Anthropogenic Hg Emissions in 2010



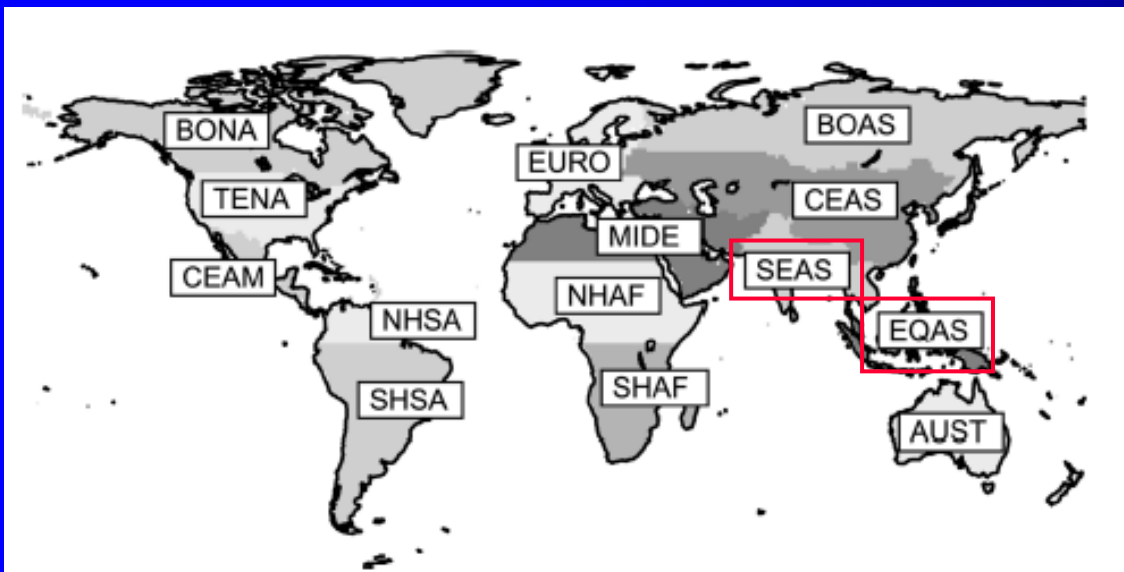
Global distribution of anthropogenic mercury emissions to air in 2010.

(UNEP, 2013)

Region*	Emission (range), tonnes**	%
Australia, New Zealand & Oceania	22.3 (5.4 - 52.7)	1.1
Central America and the Caribbean	47.2 (19.7 - 97.4)	2.4
CIS & other European countries	115 (42.6 - 289)	5.9
East and Southeast Asia	777 (395 - 1690)	39.7
European Union (EU27)	87.5 (44.5 - 226)	4.5
Middle Eastern States	37.0 (16.1 - 106)	1.9
North Africa	13.6 (4.8 - 41.2)	0.7
North America	60.7 (34.3 - 139)	3.1
South America	245 (128 - 465)	12.5
South Asia	154 (78.2 - 358)	7.9
Sub-Saharan Africa	316 (168 - 514)	16.1
Undefined (global total for emissions from contaminated sites)	82.5 (70.0 - 95.0)	4.2
Grand Total	1960 (1010 - 4070)	100

Country	Emission (tonnes)
Cambodia	3.9
China	575.2
Indonesia	78.2
Japan	17.2
Korea	7.1
Laos	1.3
Malaysia	6.1
Mongolia	6.9
Philippines	33.1
Singapore	0.9
Taiwan	5.5
Thailand	14.9
Vietnam	11.6

Biomass Burning Hg Emissions

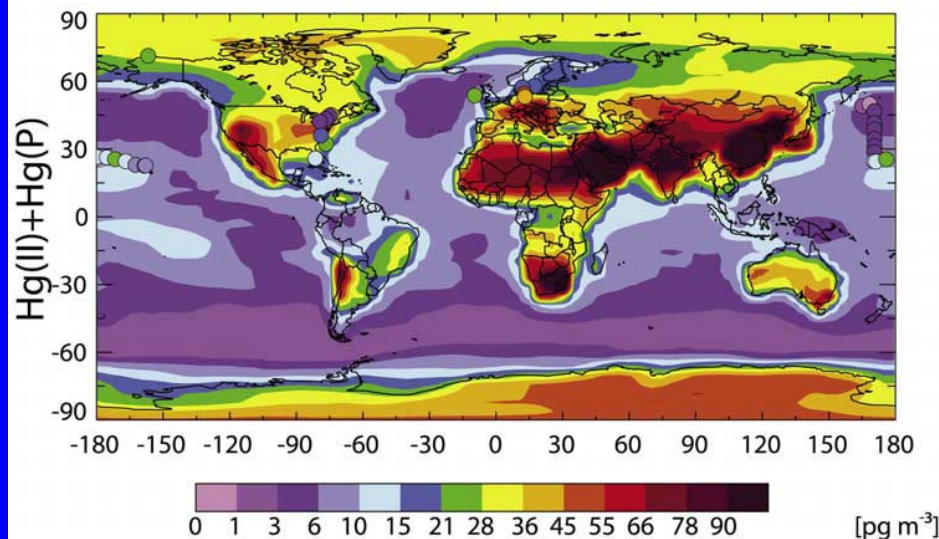
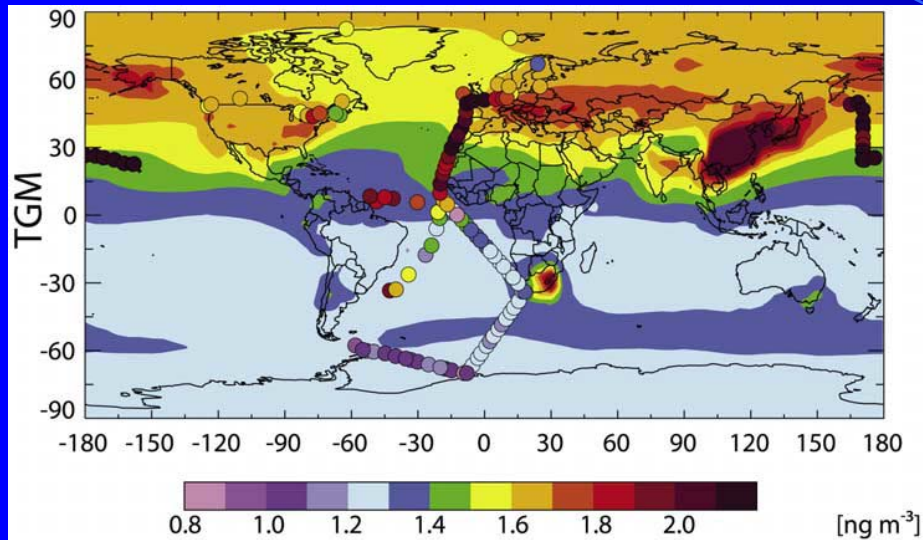


regions	Hg emissions Mg Hg/year	
	mean	SD ^a
BONA	22	16
TENA	6	3
CEAM	22	25
NHSA	13	10
SHSA	95	39
EURO	2	1
MIDE	0	0
NHAF	83	13
SHAF	58	7
BOAS	99	83
CEAS	7	2
SEAS	57	35
EQAS	192	216
AUST	19	9
global	675	240
boreal ^b	121	85
temperate ^c	9	3
ROW ^d	545	224

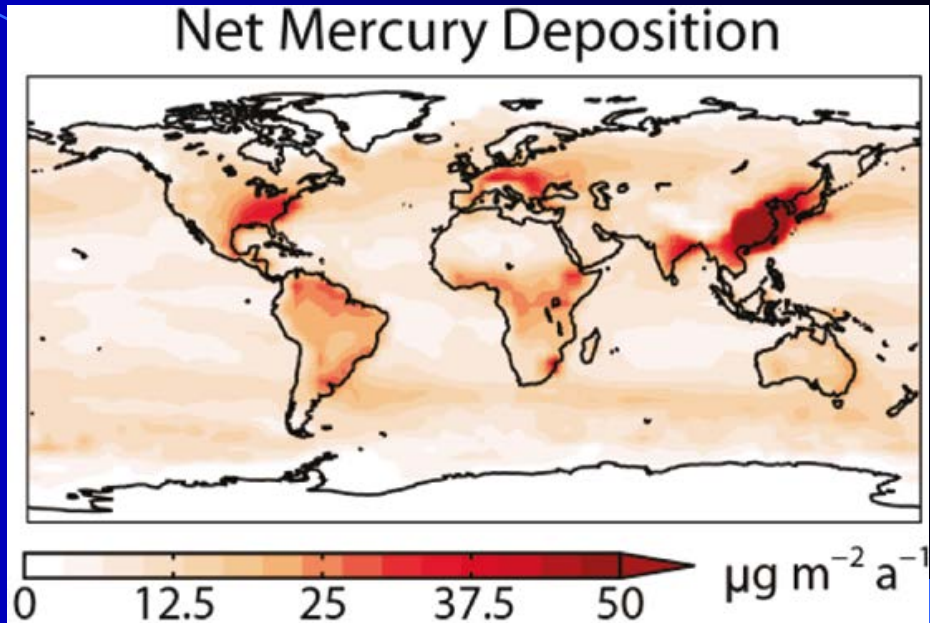
Friedli et al., 2009

SEAS + EQAS = 249 Mg Hg/year = 37% of global

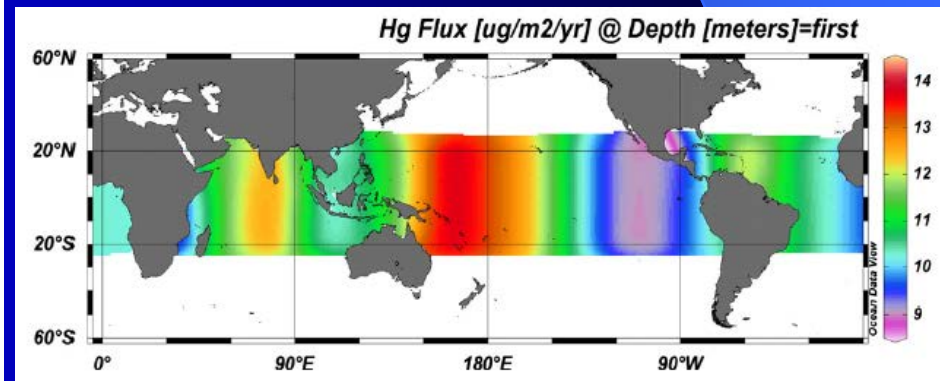
Distribution of Atmospheric Hg Concentrations and Deposition Fluxes: Modeling Results



Selin et al., 2007



Corbitt et al., 2011



Costa et al., 2012

Atmospheric Hg Monitoring Activities Supported by Taiwan EPA

- Continuous speciated atmospheric Hg monitoring at a mountaintop site, the Lulin Atmospheric Background Station

(Department of Environmental Monitoring & Information Management)

- Mercury Wet Deposition Network in Taiwan

(Department of Air Quality Protection & Noise Control)

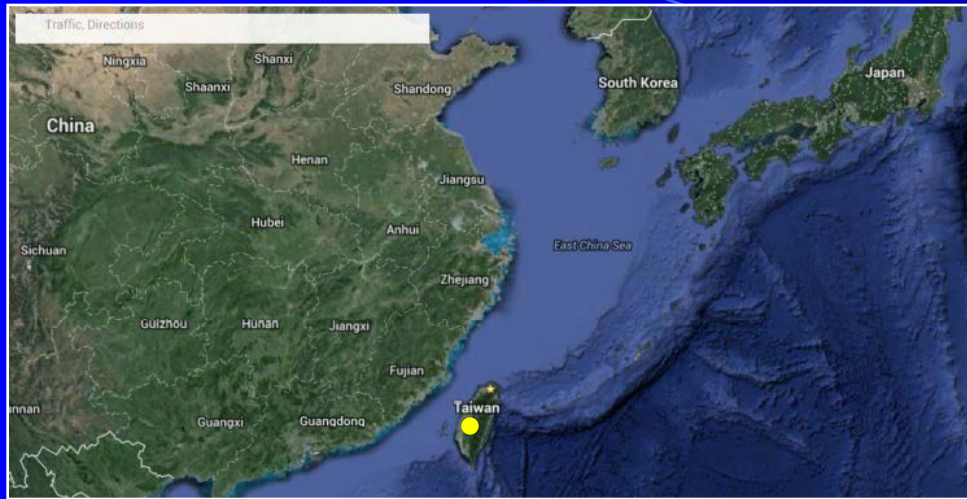
- Atmospheric Hg measurements at rural/remote sites in Taiwan

(Department of Environmental Monitoring & Information Management)

- International collaboration in atmospheric Hg research

(Dept. of Environmental Monitoring & Information Management)

Lulin Atmospheric Background Station (LABS)



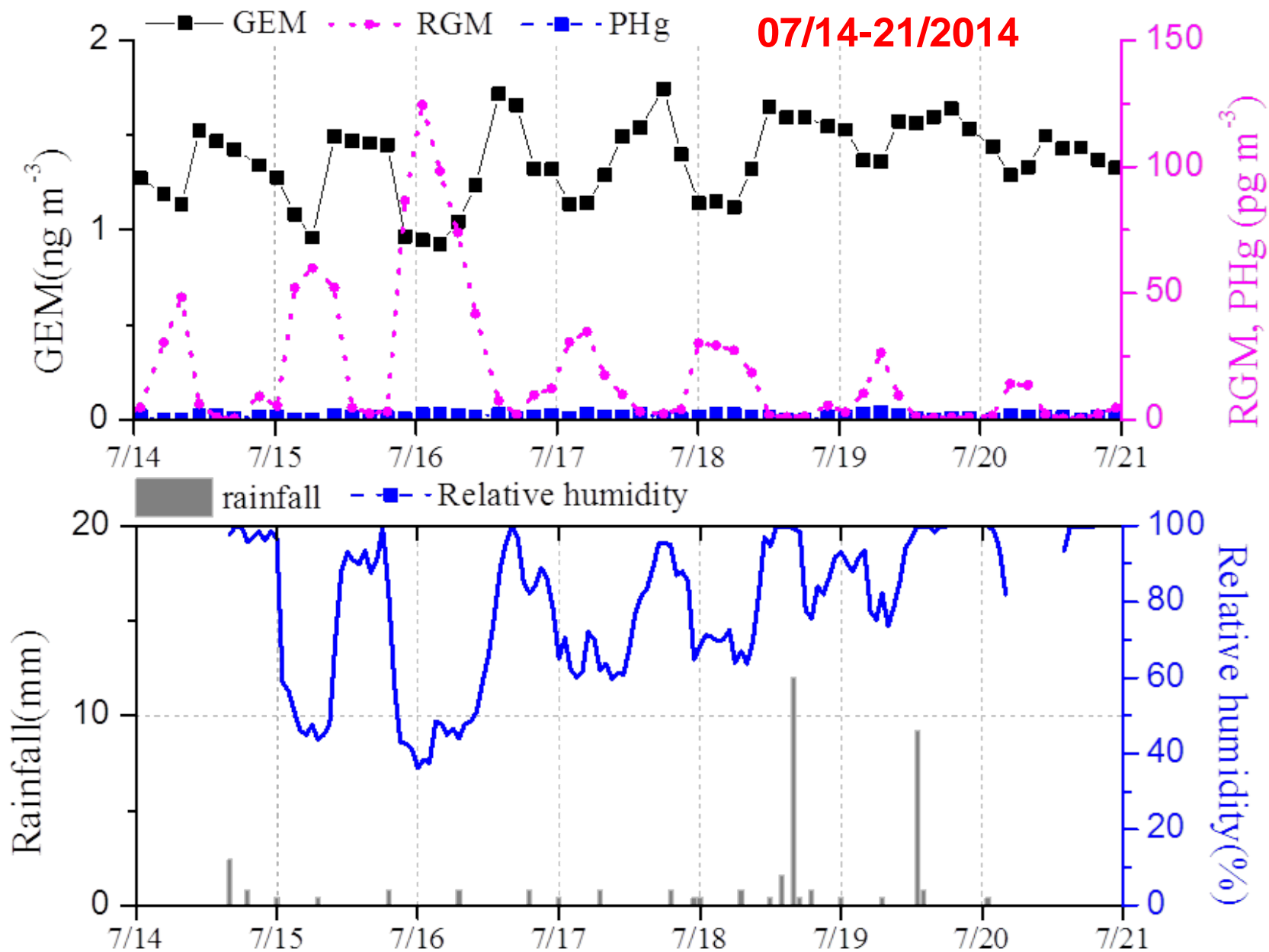
- LABS is located atop Mt. Front Lulin in central Taiwan, with an elevation of 2862 m above sea level.
- GEM, RGM and PHg have been measured using Tekran 2537A/1130/1135 at the LABS since April 13, 2006.

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

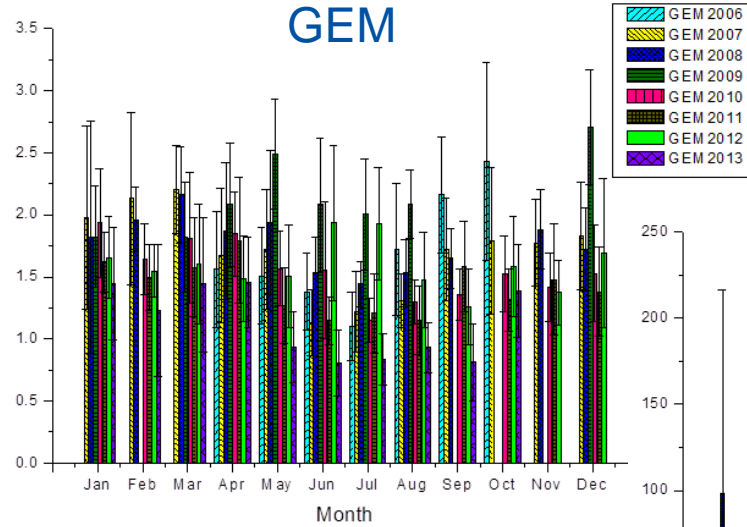
- GEM is the dominant atmospheric Hg species measured at LABS, constituting on average 98.7% of the total atmospheric Hg.
- Average GEM (1.6 ng m⁻³) is within the Northern Hemisphere background value of 1.5-1.7 ng m⁻³ at sea level.

Diurnal Distribution of Hg and Humidity

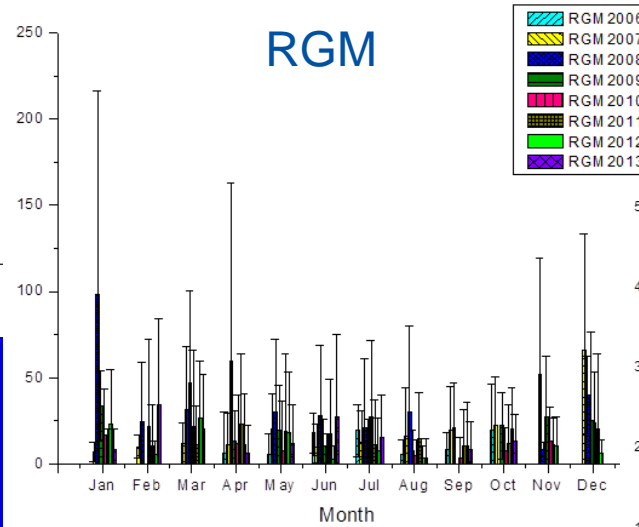


Monthly GEM, RGM and PHg in 2006-2013

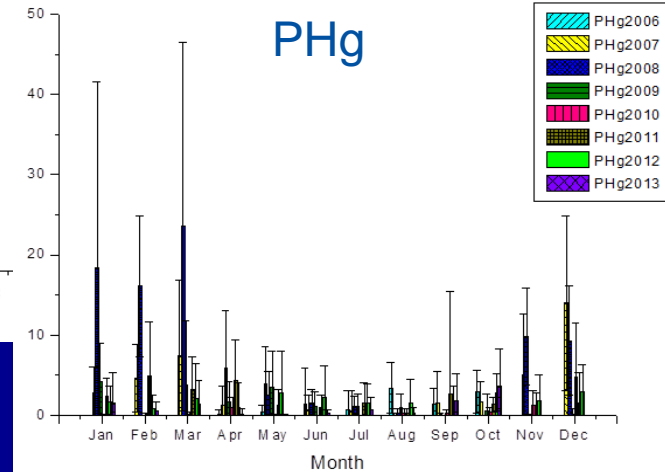
GEM



RGM



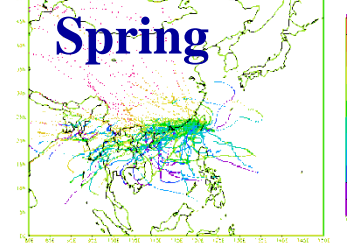
PHg



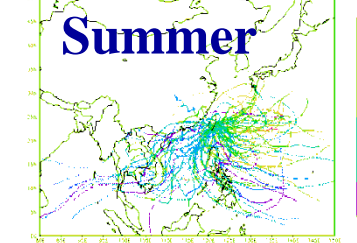
2007/03 MODIS fire detection



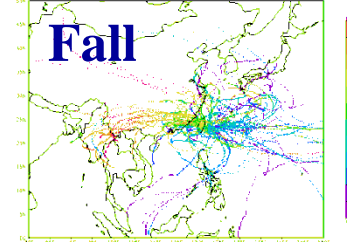
5-days backward trajectories at Mt. Lulin in 2007 spring



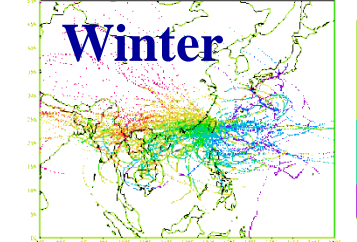
5-days backward trajectories at Mt. Lulin in 2007 summer



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

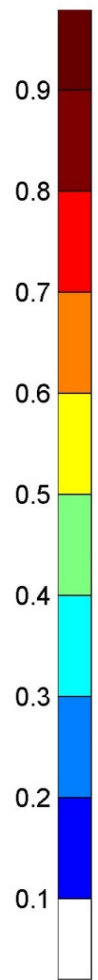
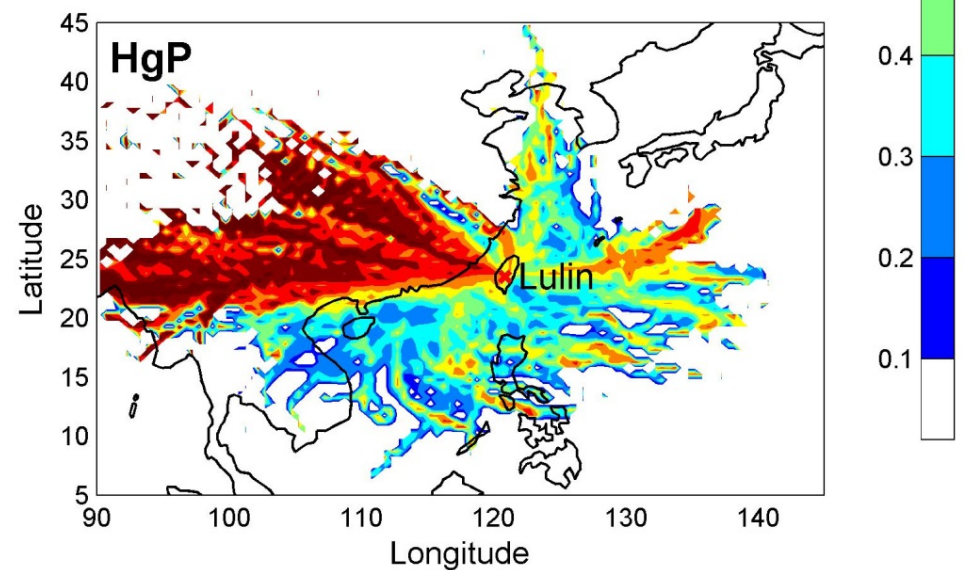
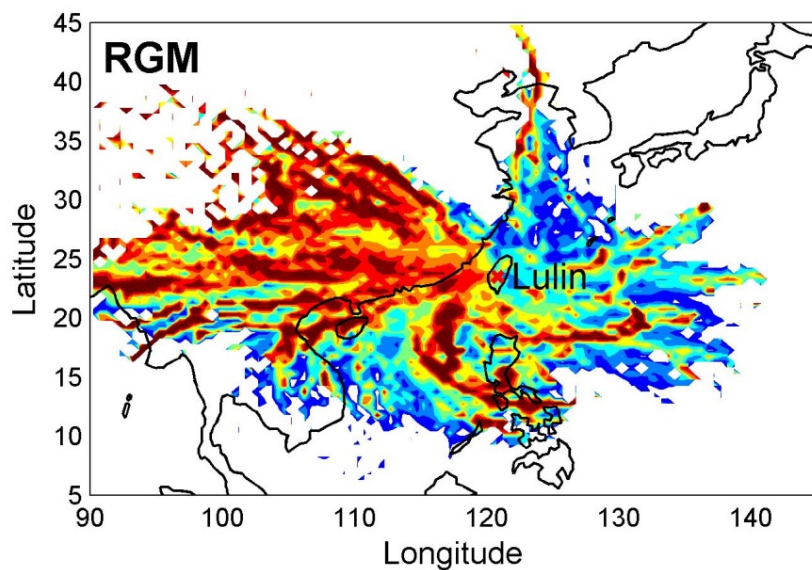
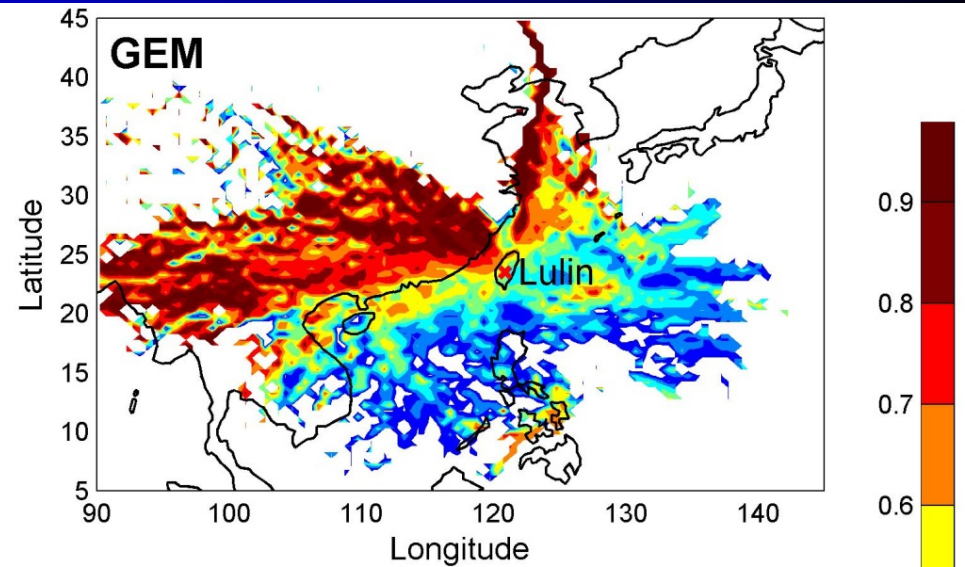
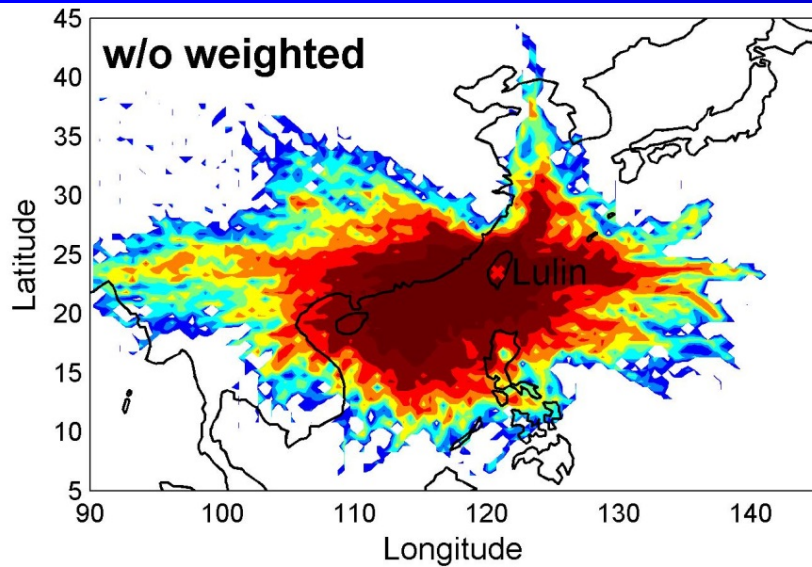


5-days backward trajectories at Mt. Lulin in 2007 winter



In general, higher GEM, RGM and PHg in winter and spring than in summer, but due to different reasons.

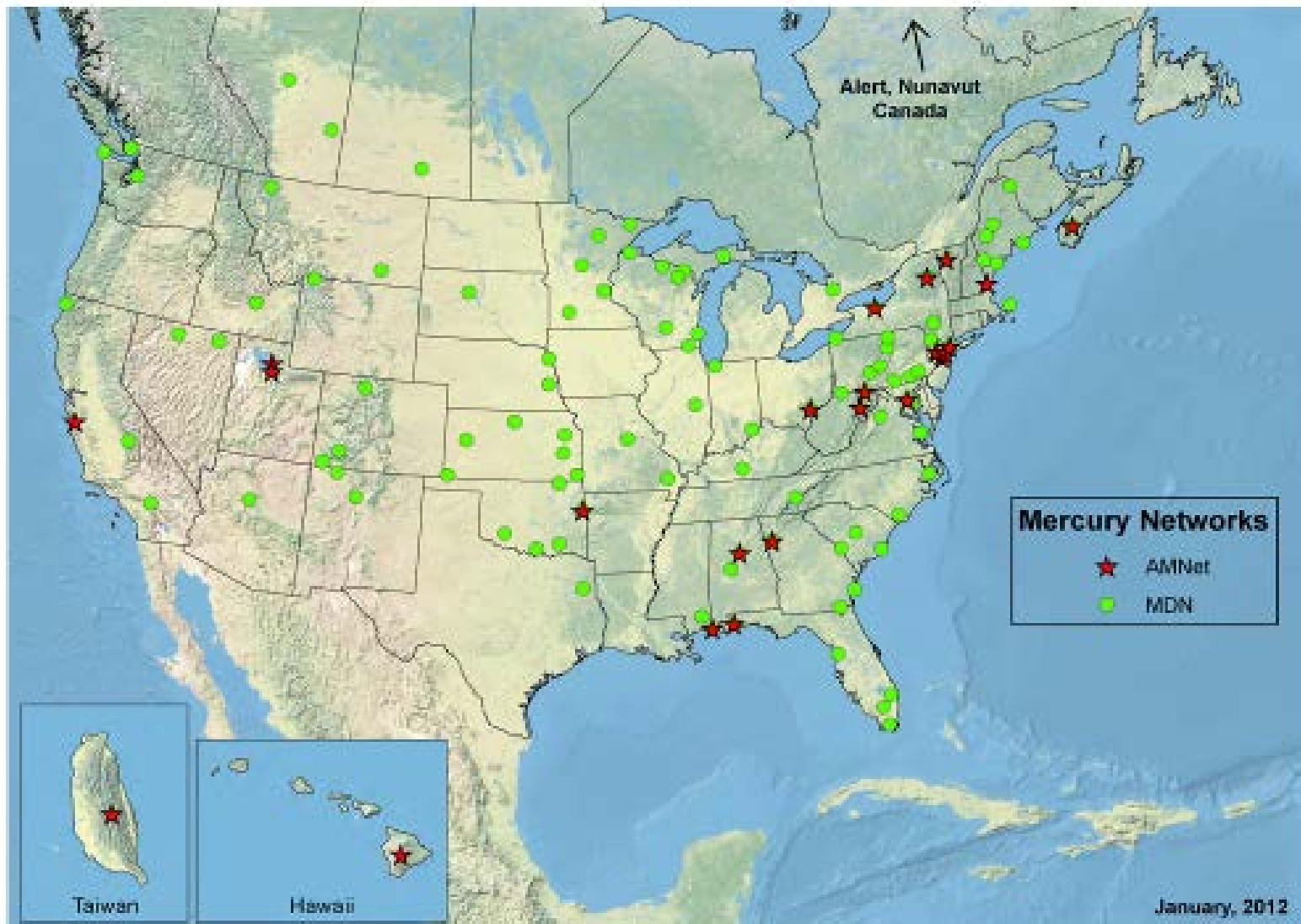
Source-Receptor Relationship: Concentration-Weighted Trajectory



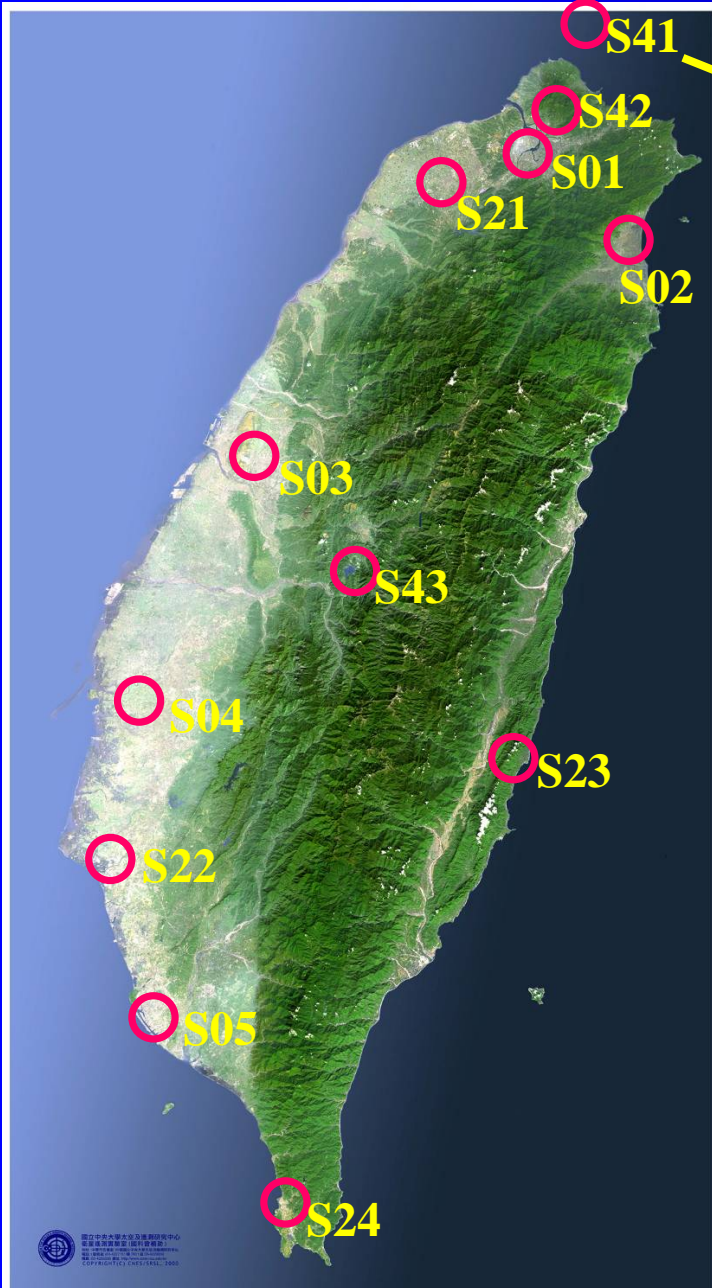
International Collaboration

US NADP/Atmospheric Mercury Network (AMNet)

NADP Mercury Networks



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

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

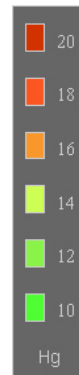
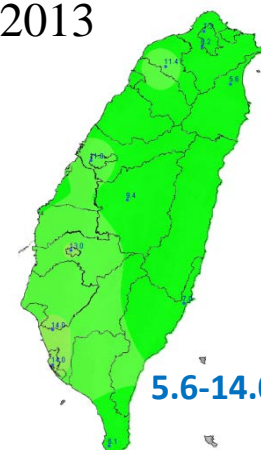
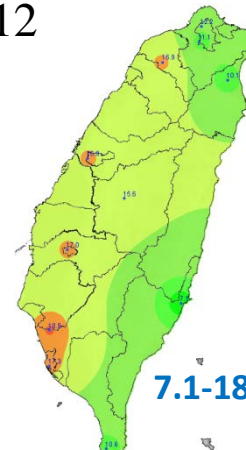
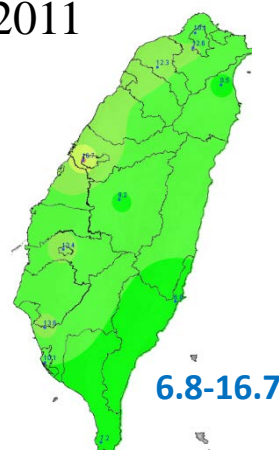
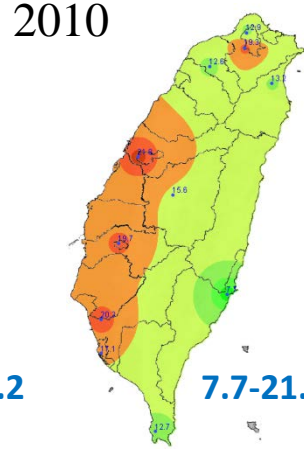
2011

2012

2013

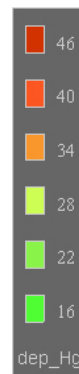
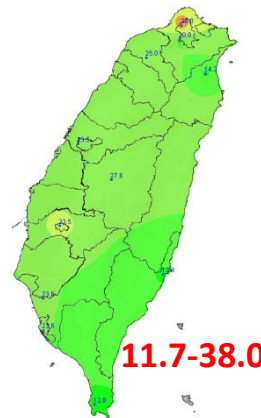
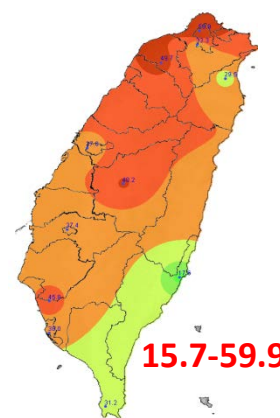
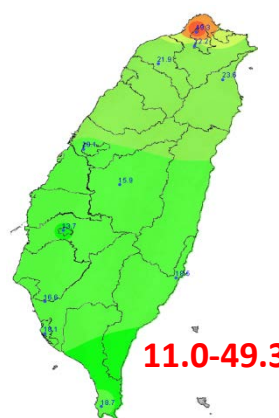
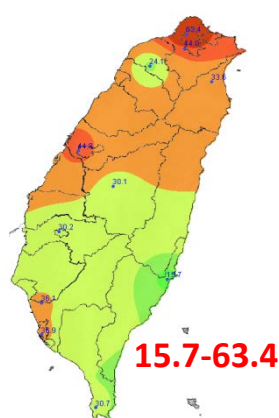
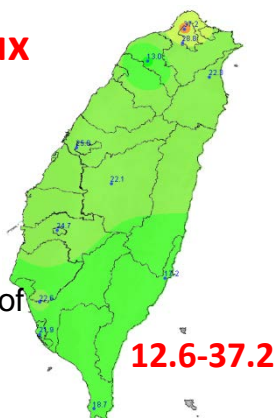
VWM Hg Conc. (ng L⁻¹)

Higher rainwater Hg concentrations in western Taiwan.



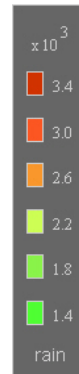
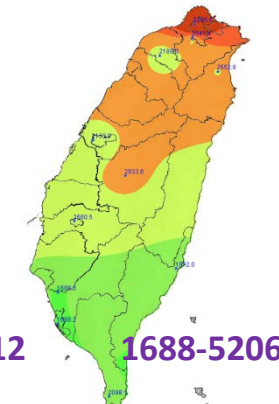
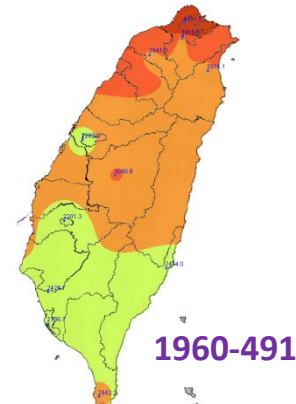
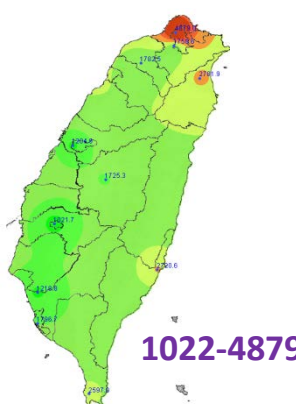
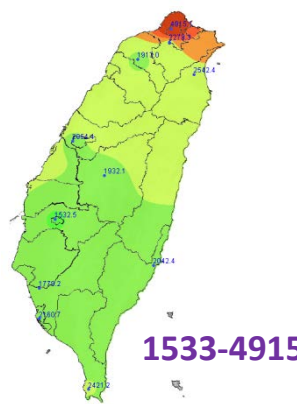
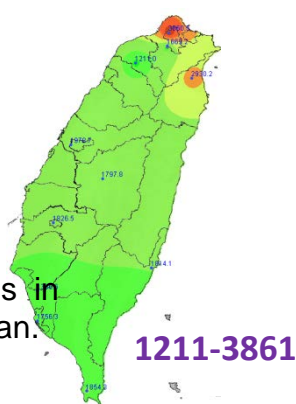
Annual Flux (μg m⁻²)

Higher wet deposition flux of Hg in northern Taiwan.



Annual Rainfall (mm)

Higher rainfalls in northern Taiwan.



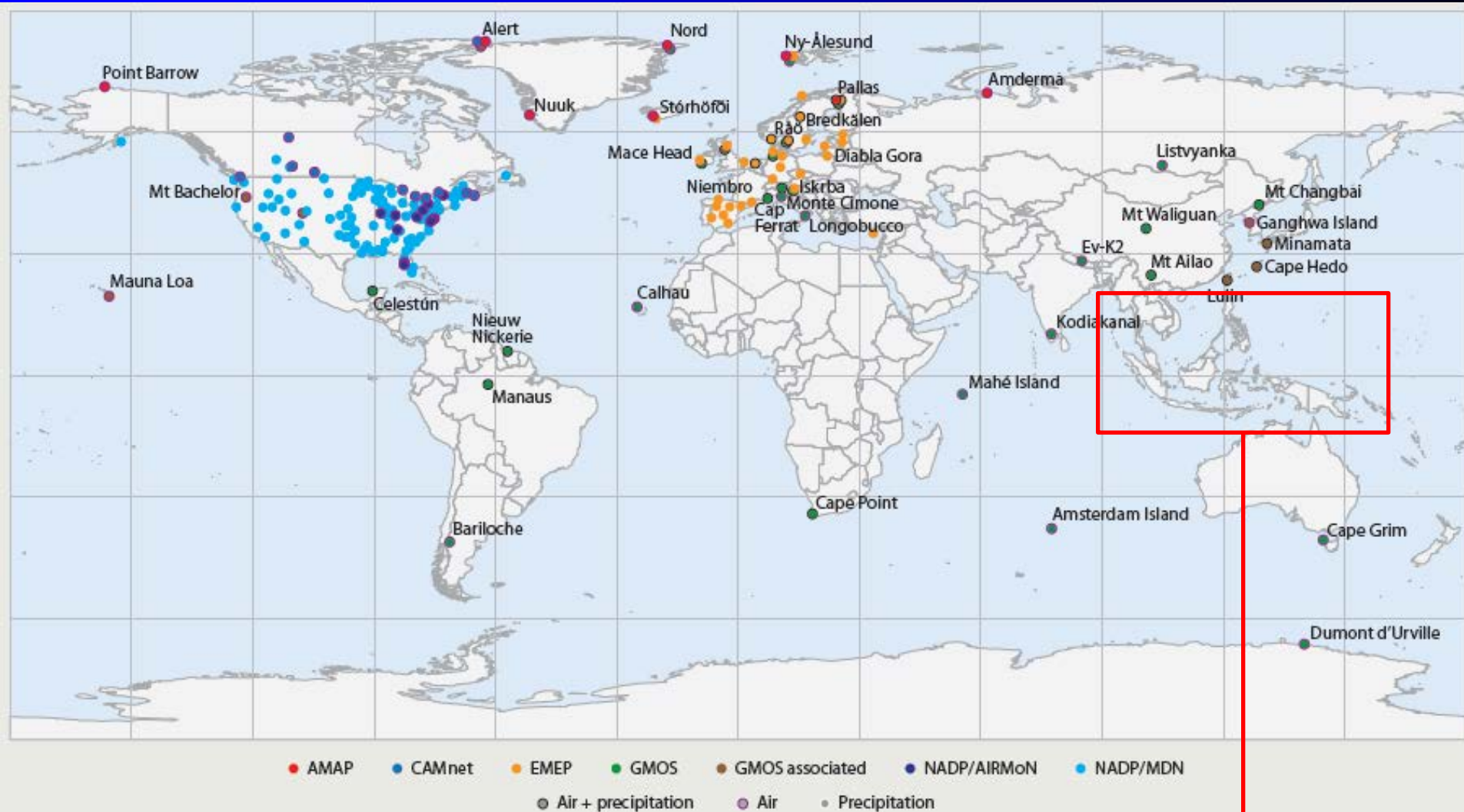
Comparison with Other Studies

Location	Rainfall (mm)	VWM conc. (ng L ⁻¹)	Wet deposition Flux (μg m ⁻² yr ⁻¹)	Reference
12 sites in Taiwan	1022-5206	5.6-21.8	11.0-63.4	This study
NADP/MDN in 2013	---	2.7-31.8	2.7-22.1	NADP 2013 Annual Summary
NADP/MDN in 2012	---	2.2-39.6	1.9-21.5	NADP 2012 Annual Summary
NADP/MDN in 2011	---	1.5-26.1	2.4-20.2	NADP 2011 Annual Summary
NADP/MDN in 2010	---	3.8-26.1	2.5-21.6	NADP 2010 Annual Summary
10 sites in Japan	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.

Asia-Pacific Mercury Monitoring Network (APMMN)

Atmospheric Hg Monitoring Worldwide



Currently, there is no long-term or background atmospheric Hg monitoring activity in SE Asia.

2012 Atmospheric Mercury Monitoring Workshop in Taipei, Taiwan

- Organized by Taiwan EPA, National Central University, U.S. EPA, and NADP, September 2012, Taipei, Taiwan
- Science and policy experts from Canada, Indonesia, Japan, Korea, Taiwan, Thailand, and the U.S.
- Exchanged information on programs in North America and Asia that monitor atmospheric mercury concentrations, wet/dry mercury deposition, and related atmospheric pollutants



2013 Asia-Pacific Mercury Monitoring Workshop in Washington, D.C.

- Share latest information from each partner agency
- Review proposal reach some agreement on monitoring objectives and major design elements for an operating (pilot) network for the region
- Devise a preliminary plan for deploying wet deposition collectors in Southeast Asia
- Establish a steering committee and plan for next steps and next meeting



2014 Asia-Pacific Mercury Monitoring Network Workshop in Hanoi, Vietnam

- A 3-year pilot network for wet Hg deposition monitoring, including sites in Indonesia, Thailand, and Vietnam
- Start collecting samples since September 30, 2014
- Samples will be shipped to National Central University of Taiwan for total Hg analysis
- Capacity building and personnel training



Current APMMN Pilot Sites



Increase participation in the pilot network to expand regional monitoring coverage

Future Plans

- MeHg in rainwater
- Isotope studies
- Measurement and estimate of dry Hg deposition flux
- Modeling
- Source-receptor relationship: quantify the contribution of trans-boundary transport to concentration and deposition
- Transformation, transport and fate of the deposited Hg
- International collaboration

**THANK
YOU!**



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