

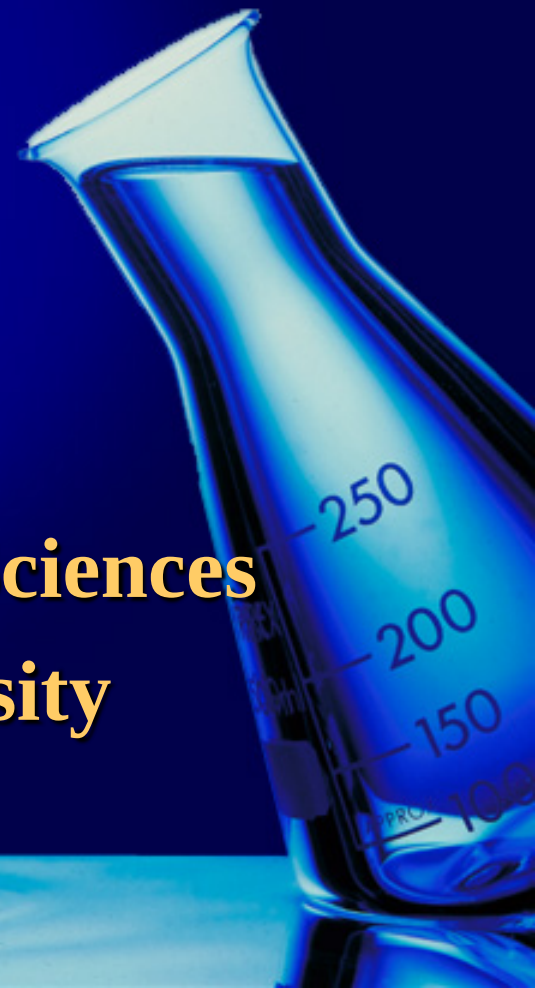
Mercury in East and Southeast Asia

Guey-Rong Sheu

Department of Atmospheric Sciences

National Central University

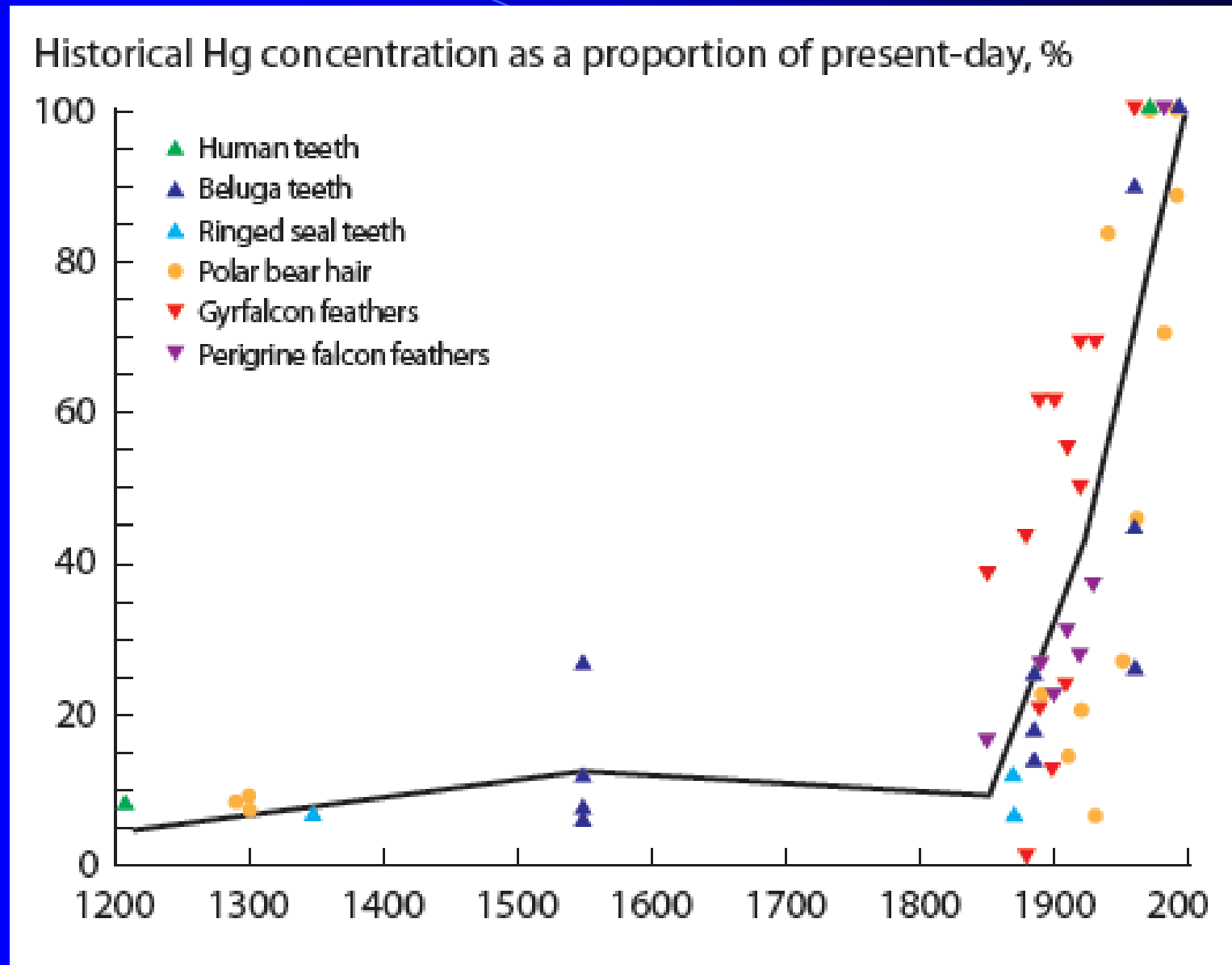
Jhong-Li, Taiwan



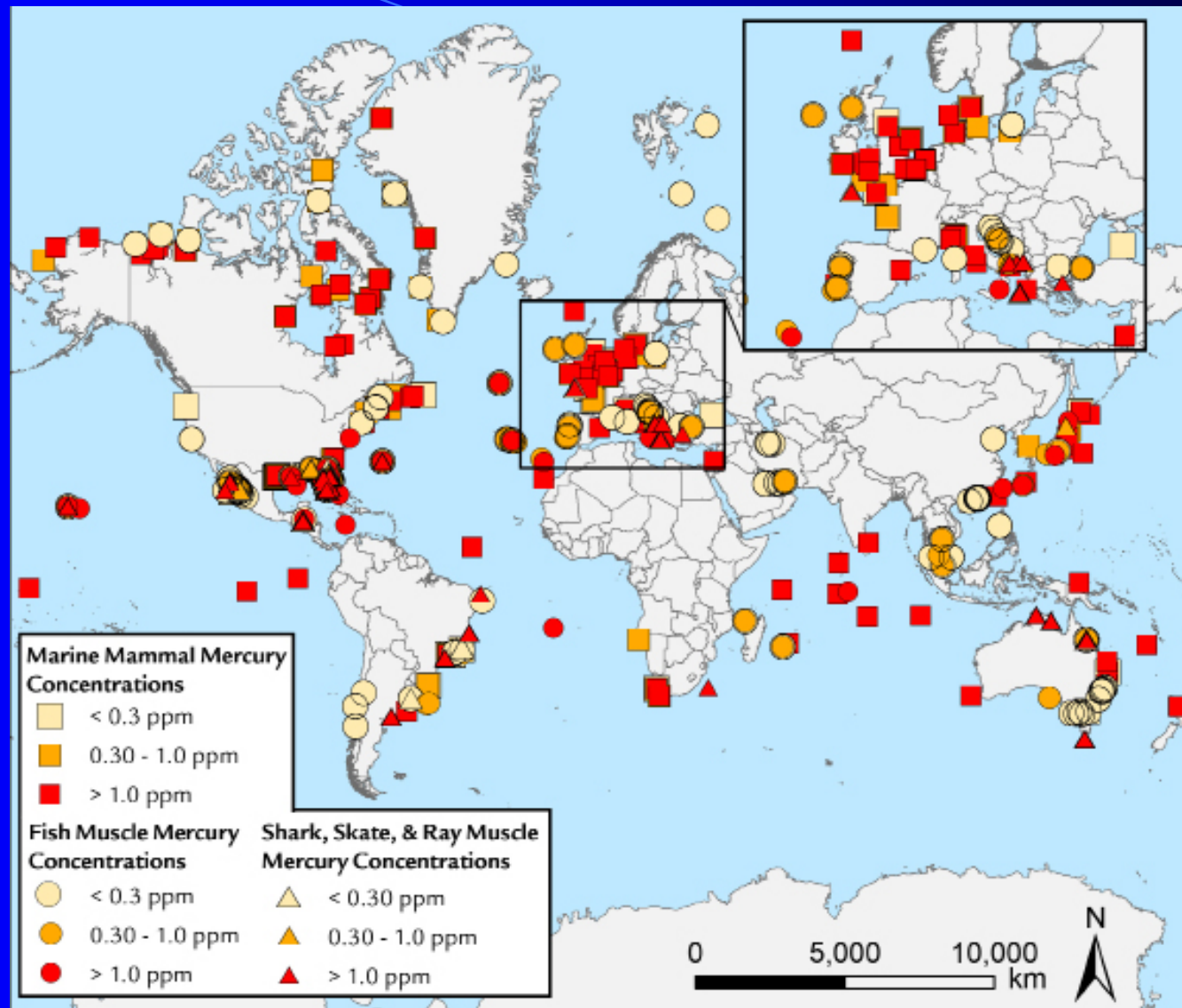
The background is a solid blue color. A thin, light blue curved line starts from the left edge and arcs downwards towards the bottom right. A larger, semi-transparent blue triangular shape is positioned in the lower right quadrant, pointing towards the bottom right corner.

Why Is Mercury Still A Concern?

Historical Hg Conc. in Biological Samples

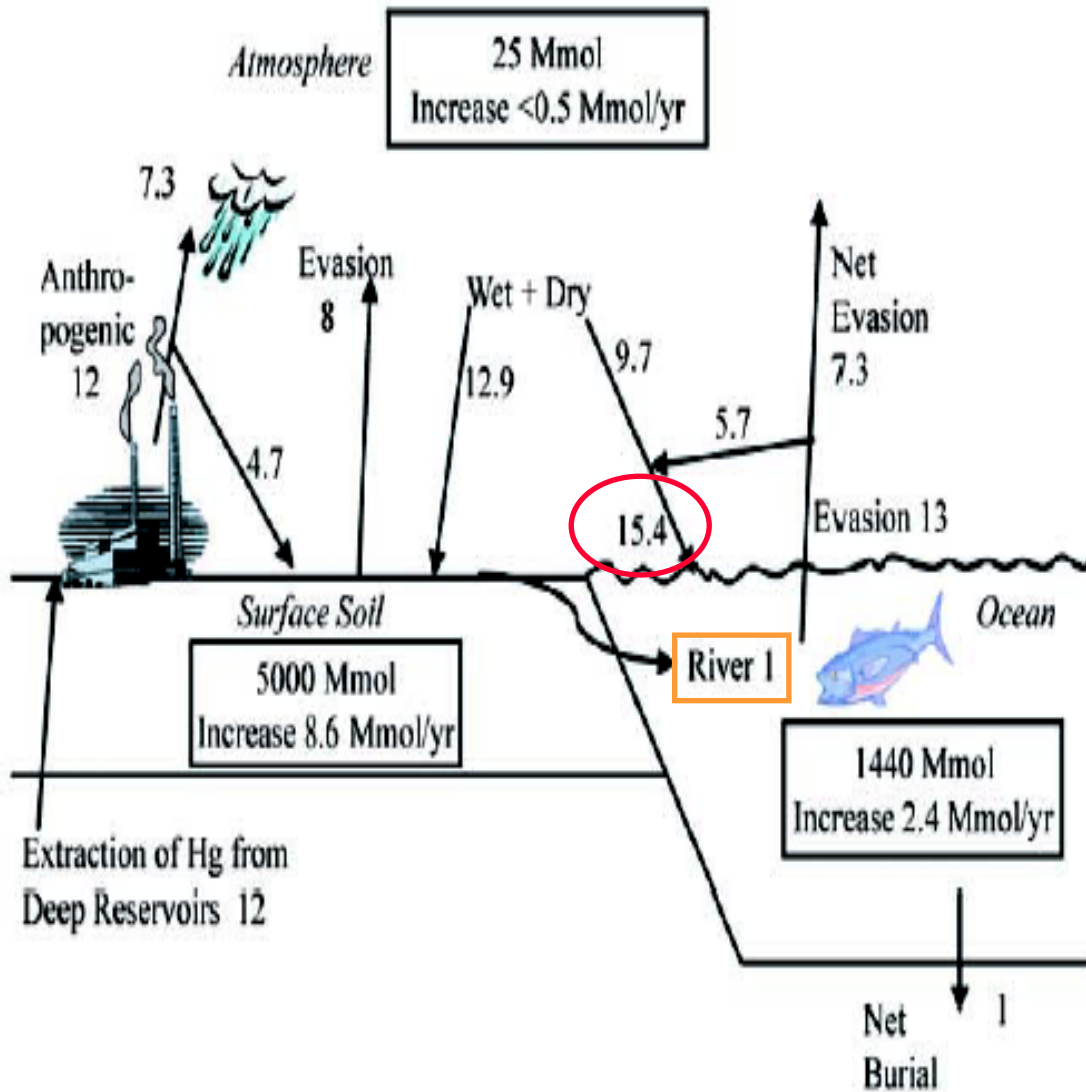


Marine Fish and Mammal Hg Conc. Worldwide



- 90% of the Hg content in fish is MeHg.
- USFDA standard is 1.0 ppm.

Current Global Hg Budget



Annual fluxes to oceans:

**Atmospheric deposition
= 15.4 Mmol yr⁻¹**

Riverine input
= 1 Mmol yr⁻¹

Atmospheric deposition >> Riverine input

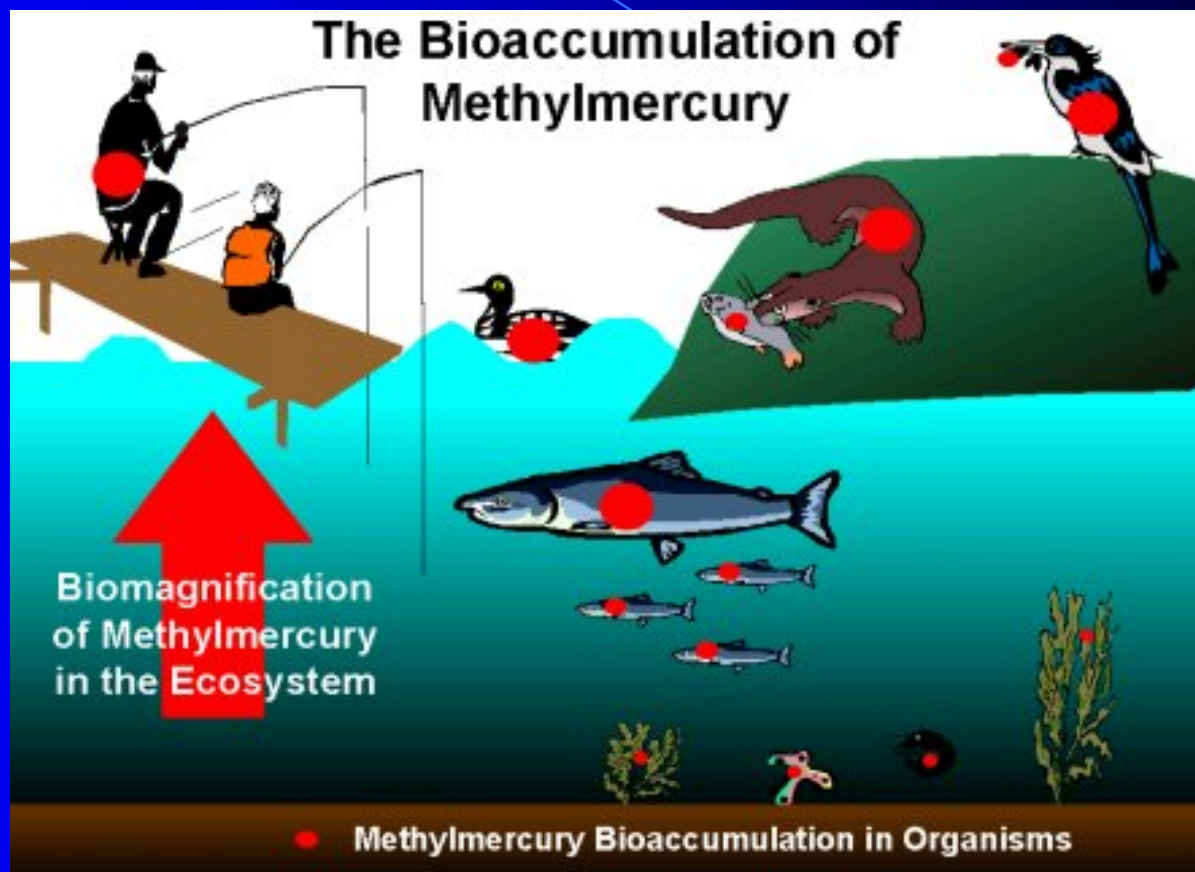
**** 1 Mmol = 200 metric tons**

Figure 3. The current global mercury cycle. All fluxes are in Mmol yr^{-1} .

Mason and Sheu, 2002

Bioaccumulation of MeHg

- Higher Hg concentrations in large long-lived predatory fish on the top of food chains. This poses a health risk to fish-eating populations.

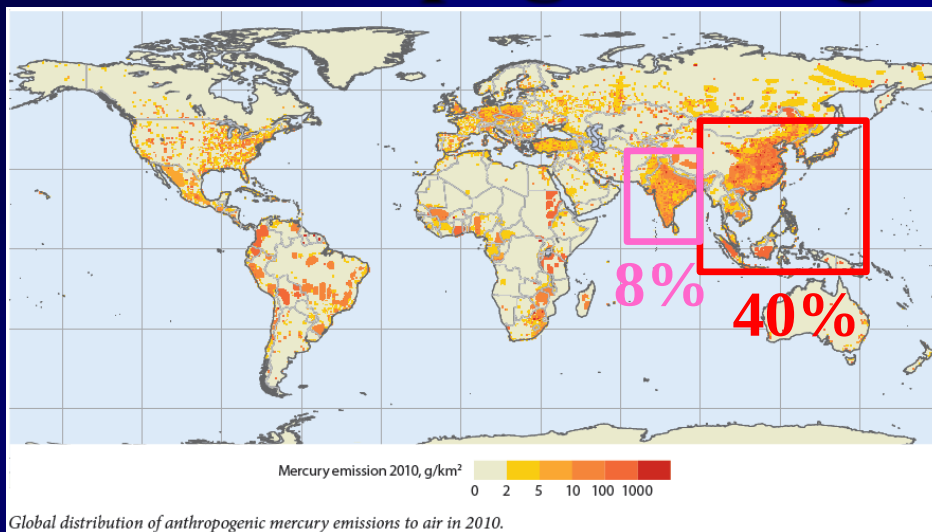


MeHg conc. in water = ppq or ppt = pg or ng/L = 10^{-15} - 10^{-12} .

MeHg conc. in fish = ppm = $\mu\text{g/g}$ = 10^{-6} .

Bioaccumulation factors of MeHg range between 10^5 and 10^7 .

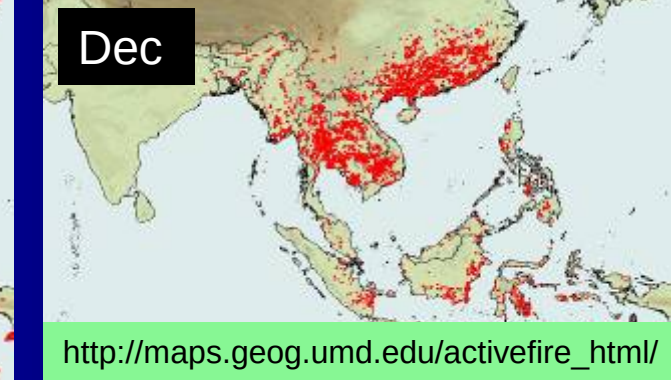
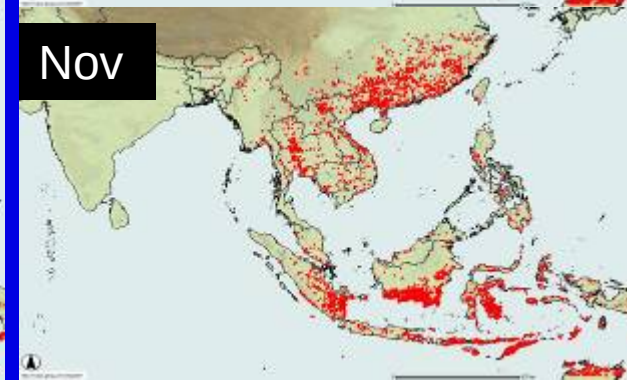
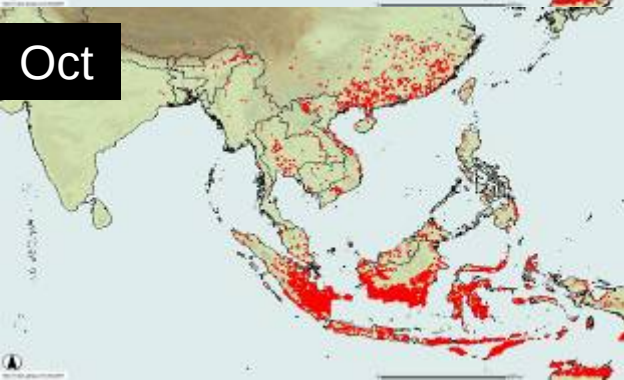
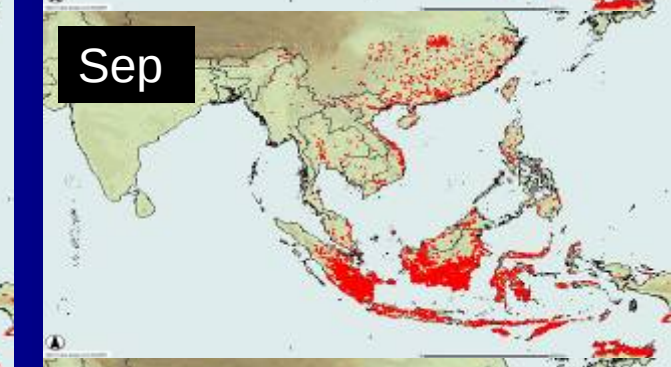
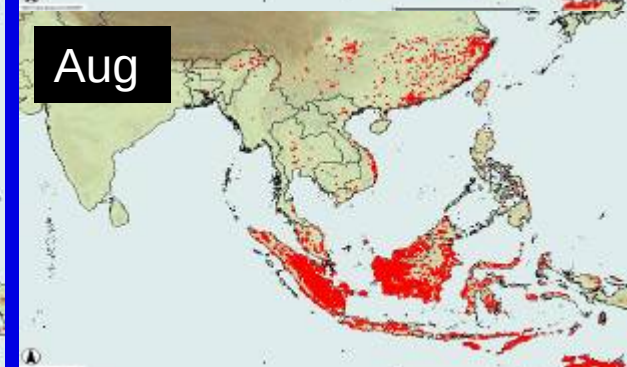
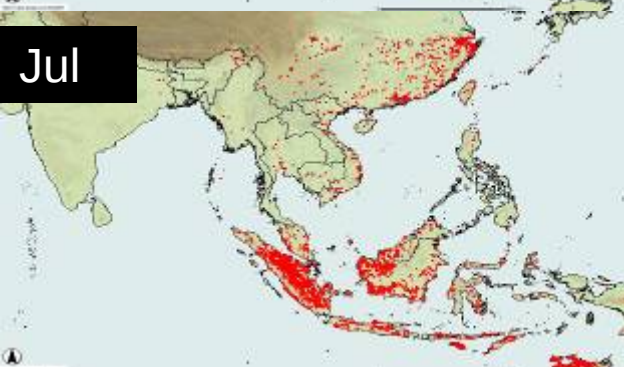
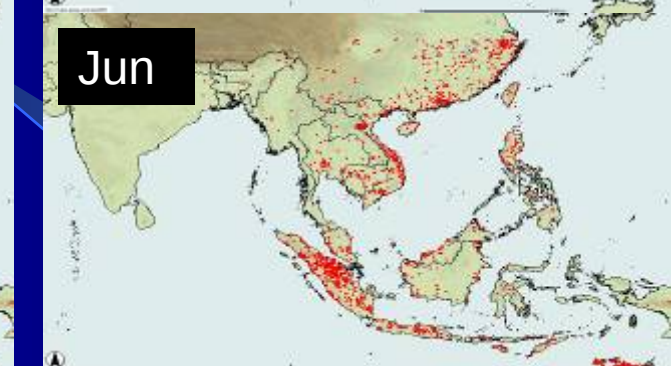
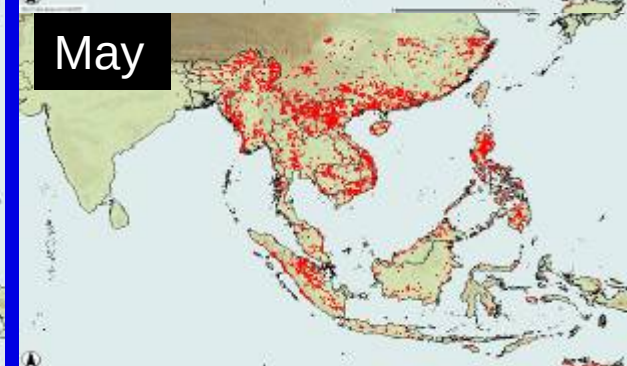
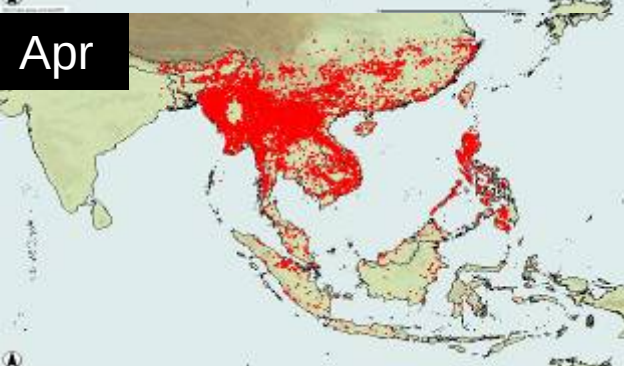
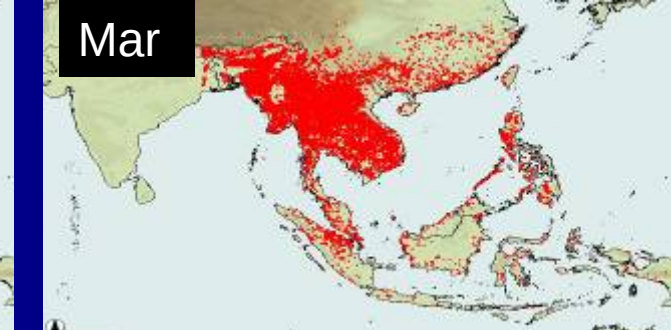
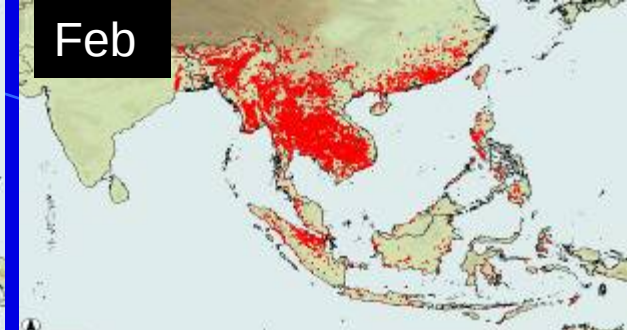
Anthropogenic Hg Emissions in 2010



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

(UNEP, 2013)



Biomass Burning Hg Emissions in 2005

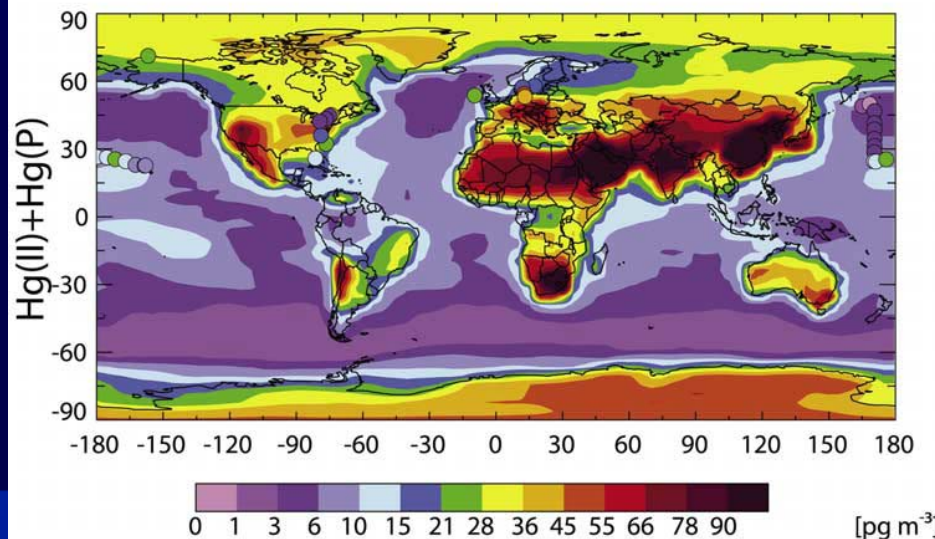
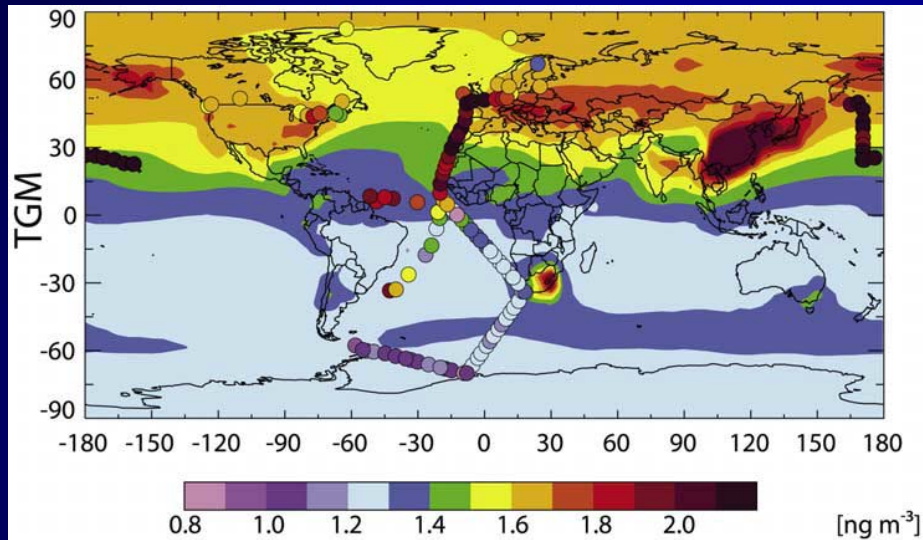


regions	Hg emissions Mg Hg/year	
	mean	SD ^a
BONA	22	16
TENA	6	3
CEAM	22	25
NHSA	13	10
SHSA	95	39
EURO	2	1
MIDE	0	0
NHAF	83	13
SHAF	58	7
BOAS	99	83
CEAS	7	2
SEAS	57	35
EQAS	192	216
AUST	19	9
global	675	240
boreal ^b	121	85
temperate ^c	9	3
ROW ^d	545	224

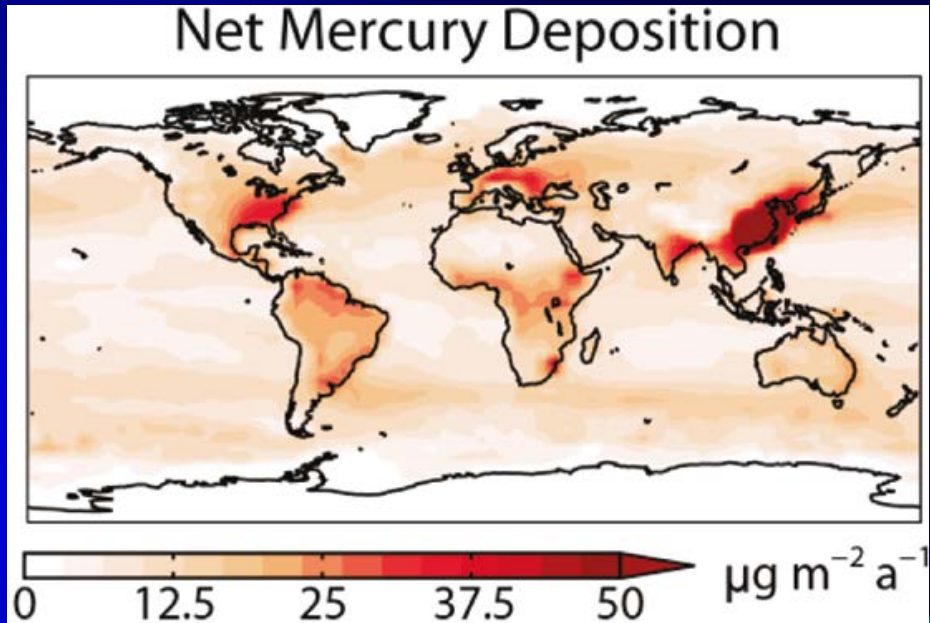
SEAS + EQAS = 249 Mg Hg/year

Friedli et al., 2009

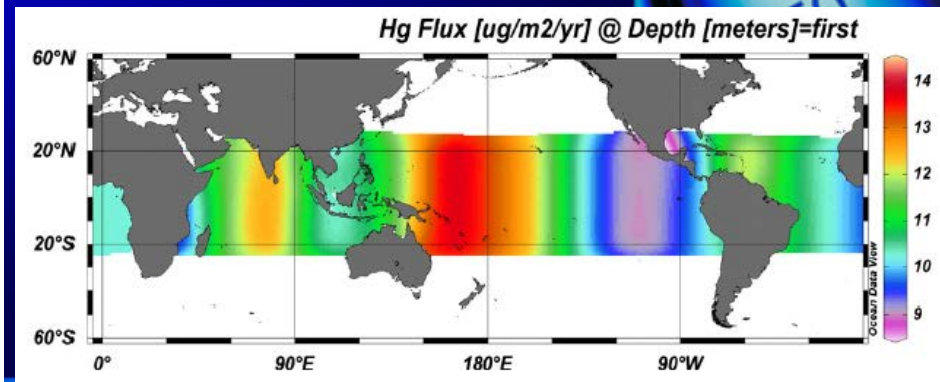
Distribution of Atmospheric Hg Concentrations and Deposition Fluxes: Modeling Results



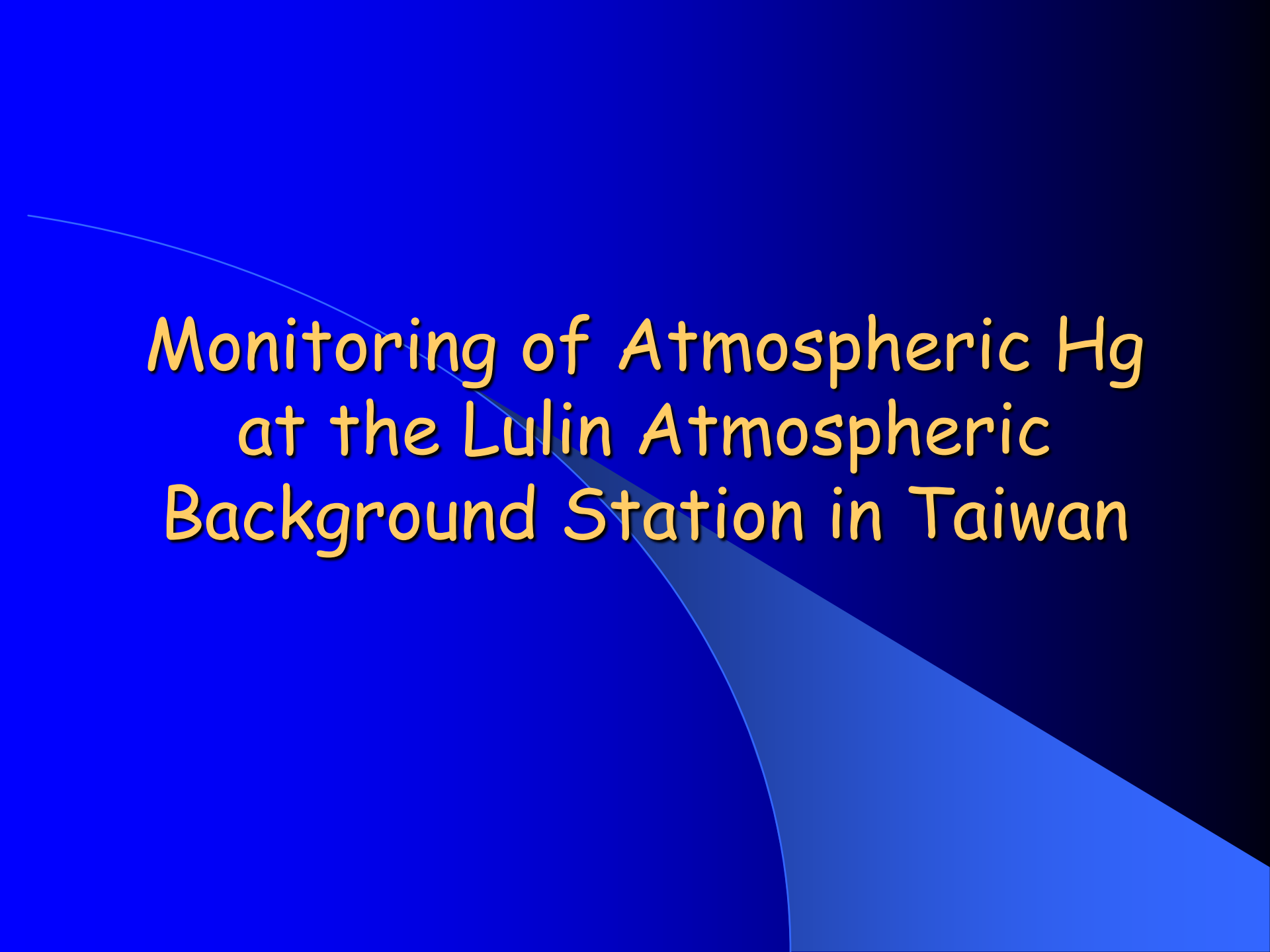
Selin et al., 2007



Corbitt et al., 2011

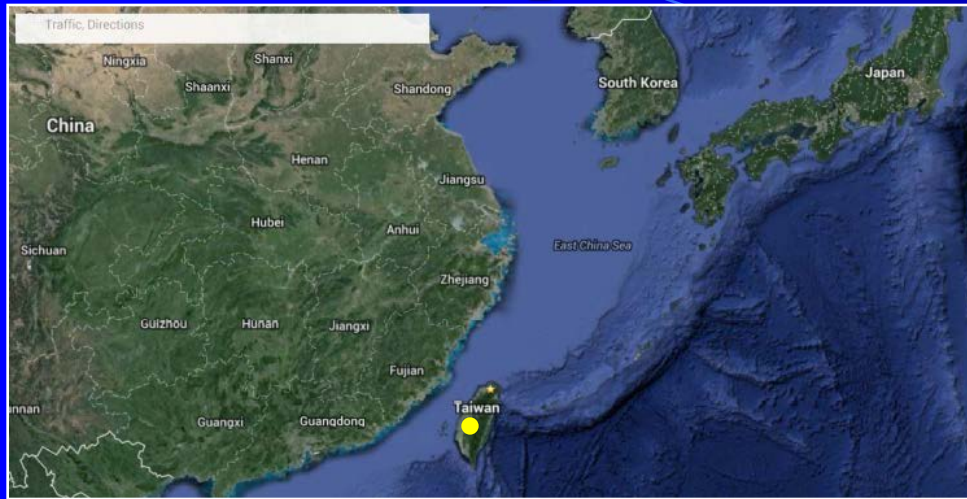


Costa et al., 2012



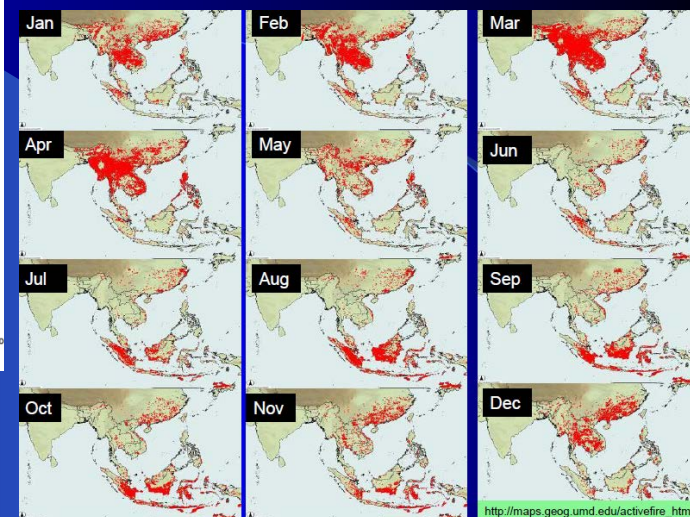
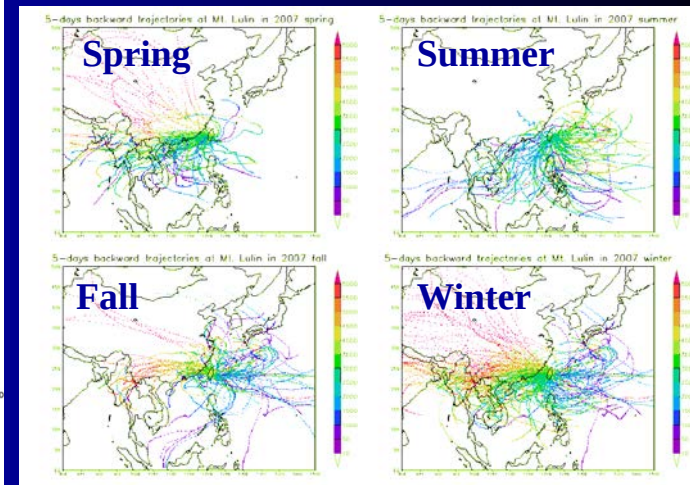
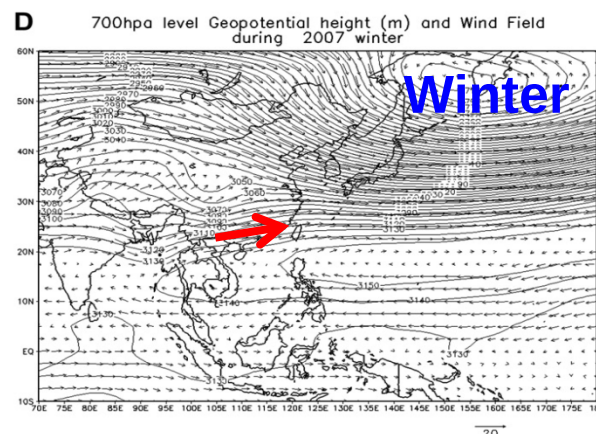
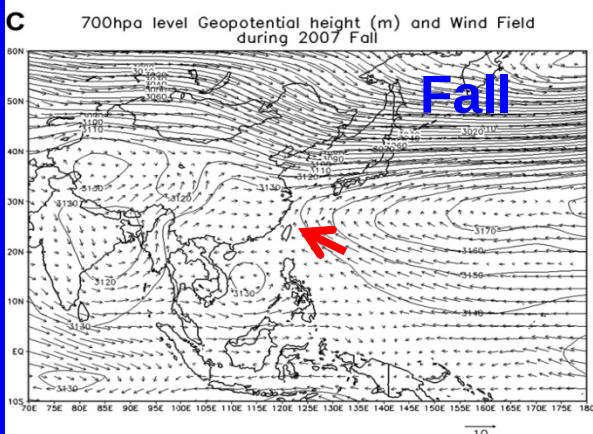
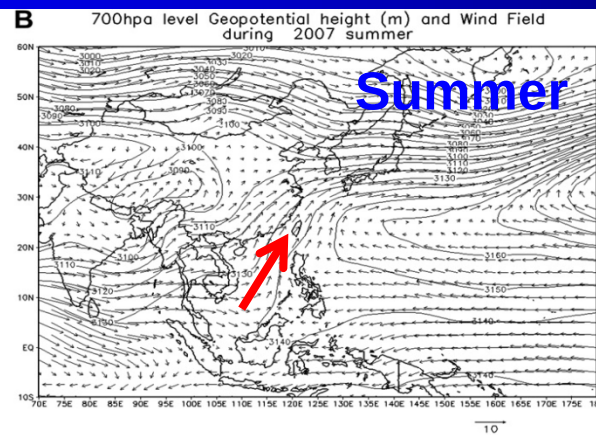
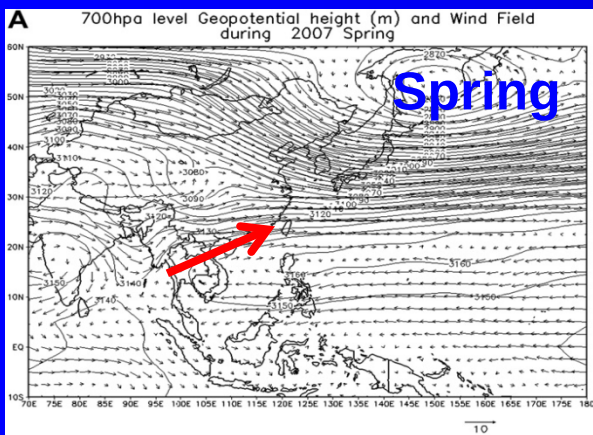
Monitoring of Atmospheric Hg at the Lulin Atmospheric Background Station in Taiwan

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.
- Wet deposition sampling and Hg analysis started since 2009.

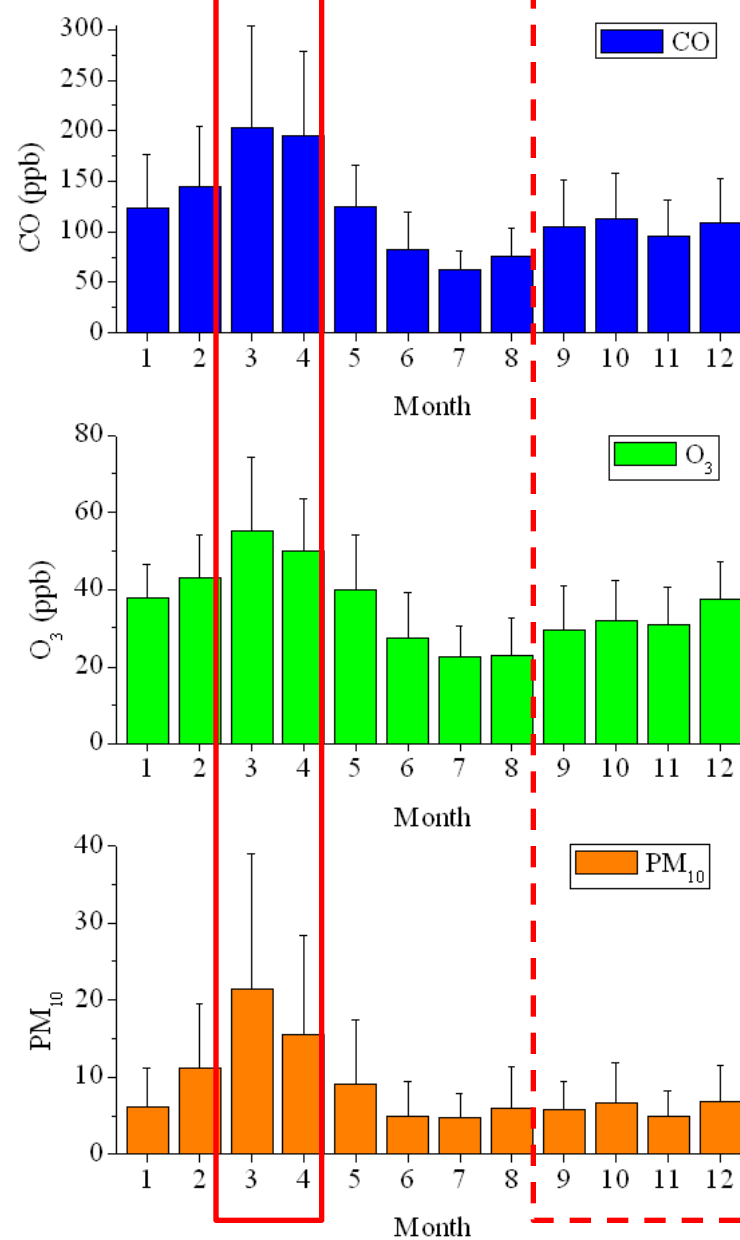
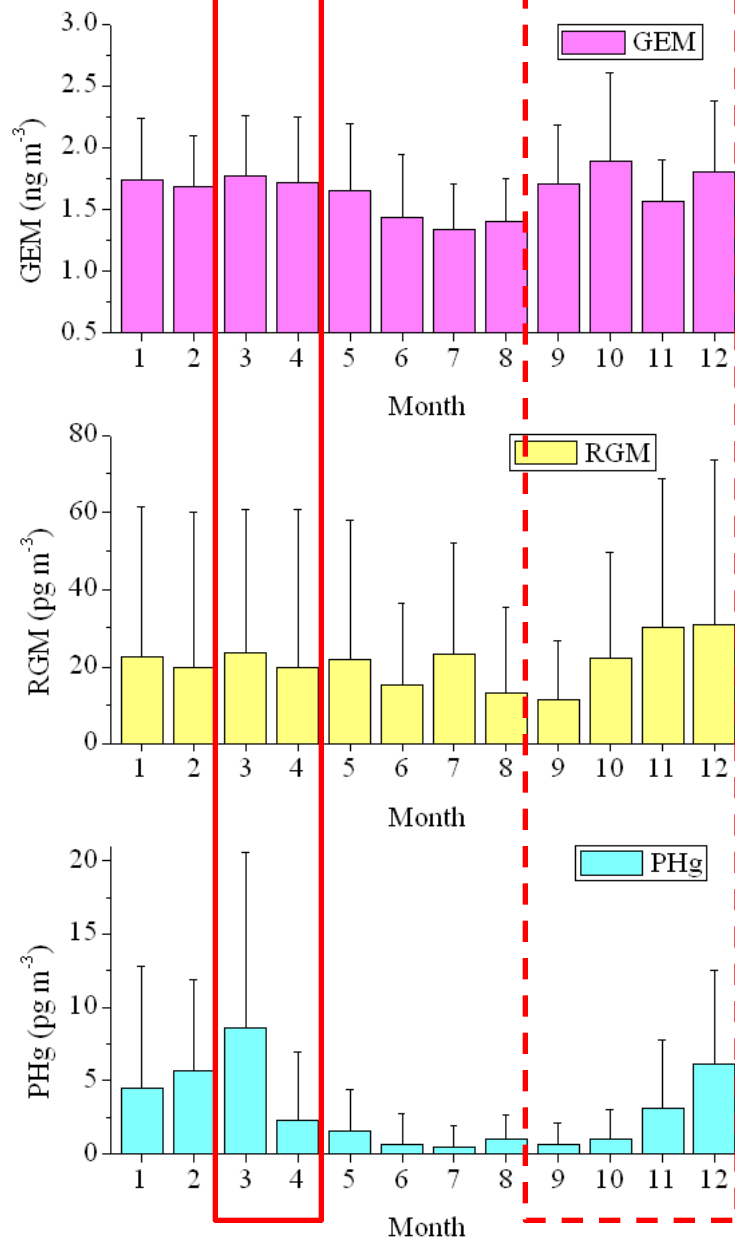
Seasonal Wind Field and Backward Trajectory at 700 hPa and Fire Activity in SE Asia



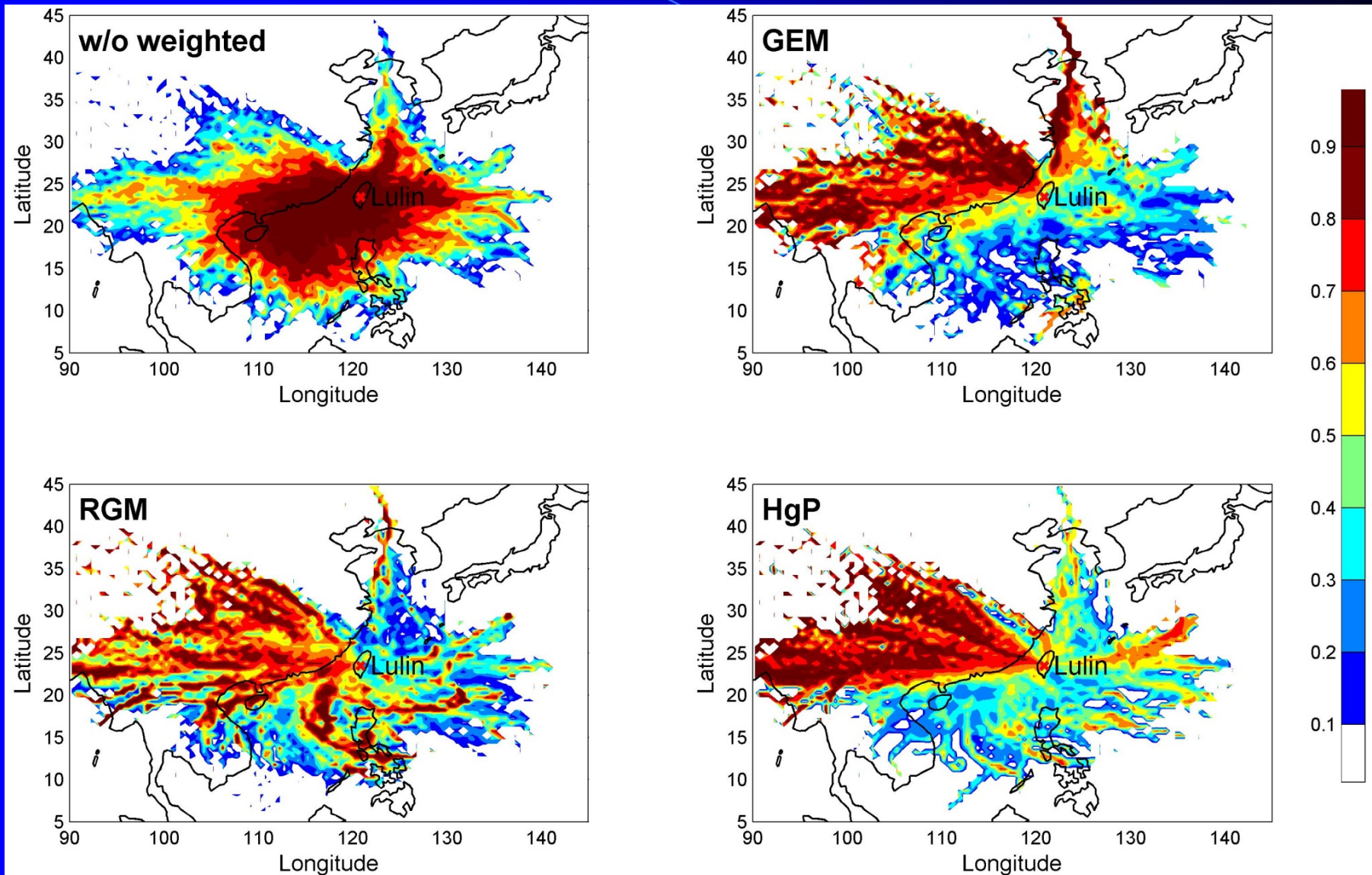
http://maps.geog.umd.edu/activefire_html/

(Sheu, 2010)

Seasonal Pattern of Hg, CO, O₃ and PM₁₀

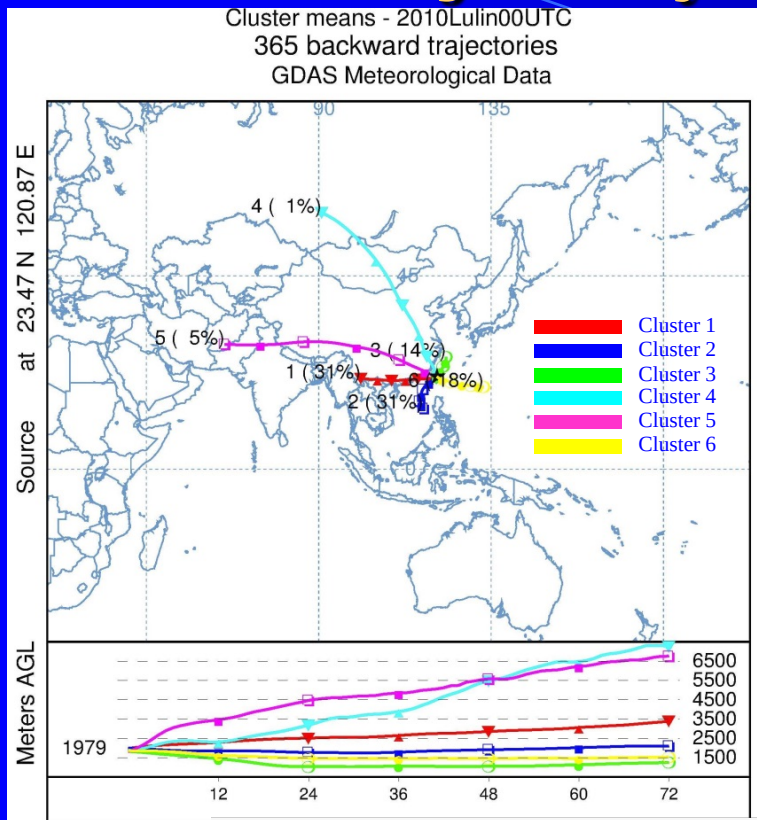


Source-Receptor Relationship: Concentration-Weighted Trajectory



(Cheng et al., 2013)

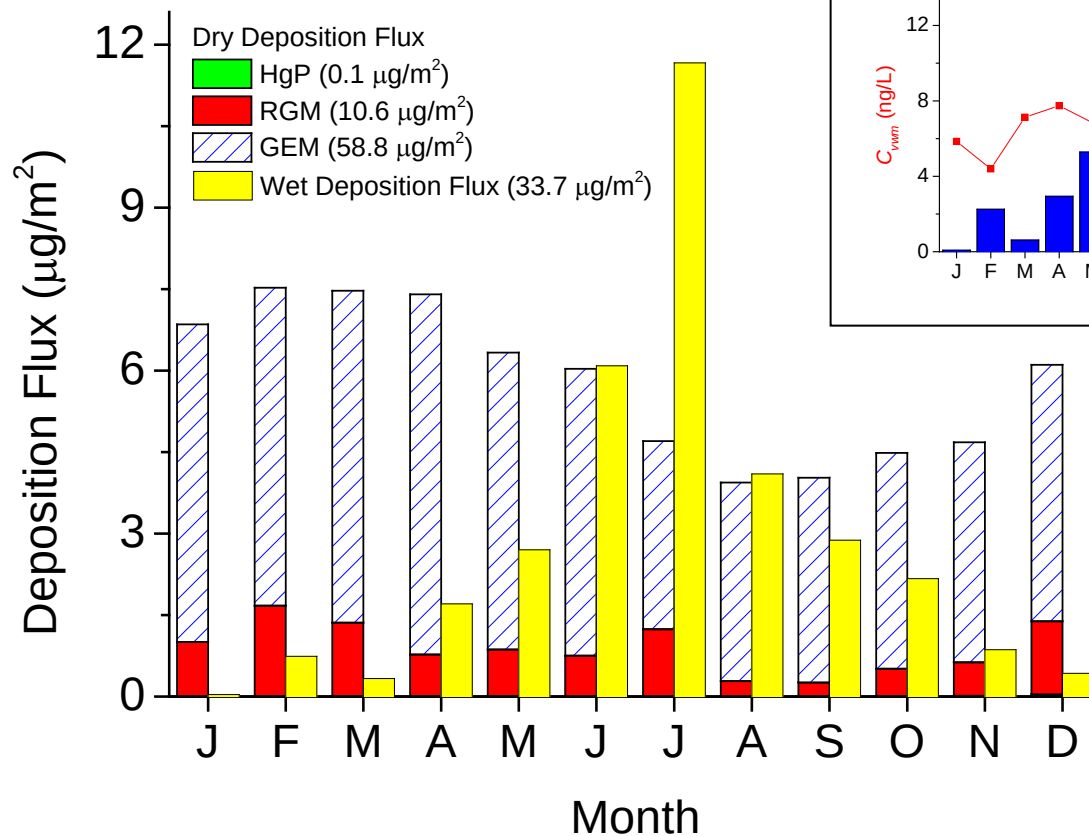
Trajectory Cluster Analysis



1. Indochina Peninsula and SW China
2. South China Sea
3. East China Sea
4. High altitude air mass from north
5. High altitude air mass from west
6. NW Pacific Ocean

Flow type	Cluster No.	Size	GEM (ng m ⁻³)	RGM (pg m ⁻³)	PHg (pg m ⁻³)	CO (ppb)	O ₃ (ppb)
Continental	1	113	1.7	17.0	0.7	175.0	41.9
	4	5	1.6	15.4	0.8	140.5	36.4
	5	17	1.7	15.8	5.7	148.9	39.1
Oceanic	2	114	1.4	17.8	0.2	131.2	32.5
	3	52	1.6	6.3	0.4	146.8	28.9
	6	64	1.4	8.3	0.3	103.1	21.2

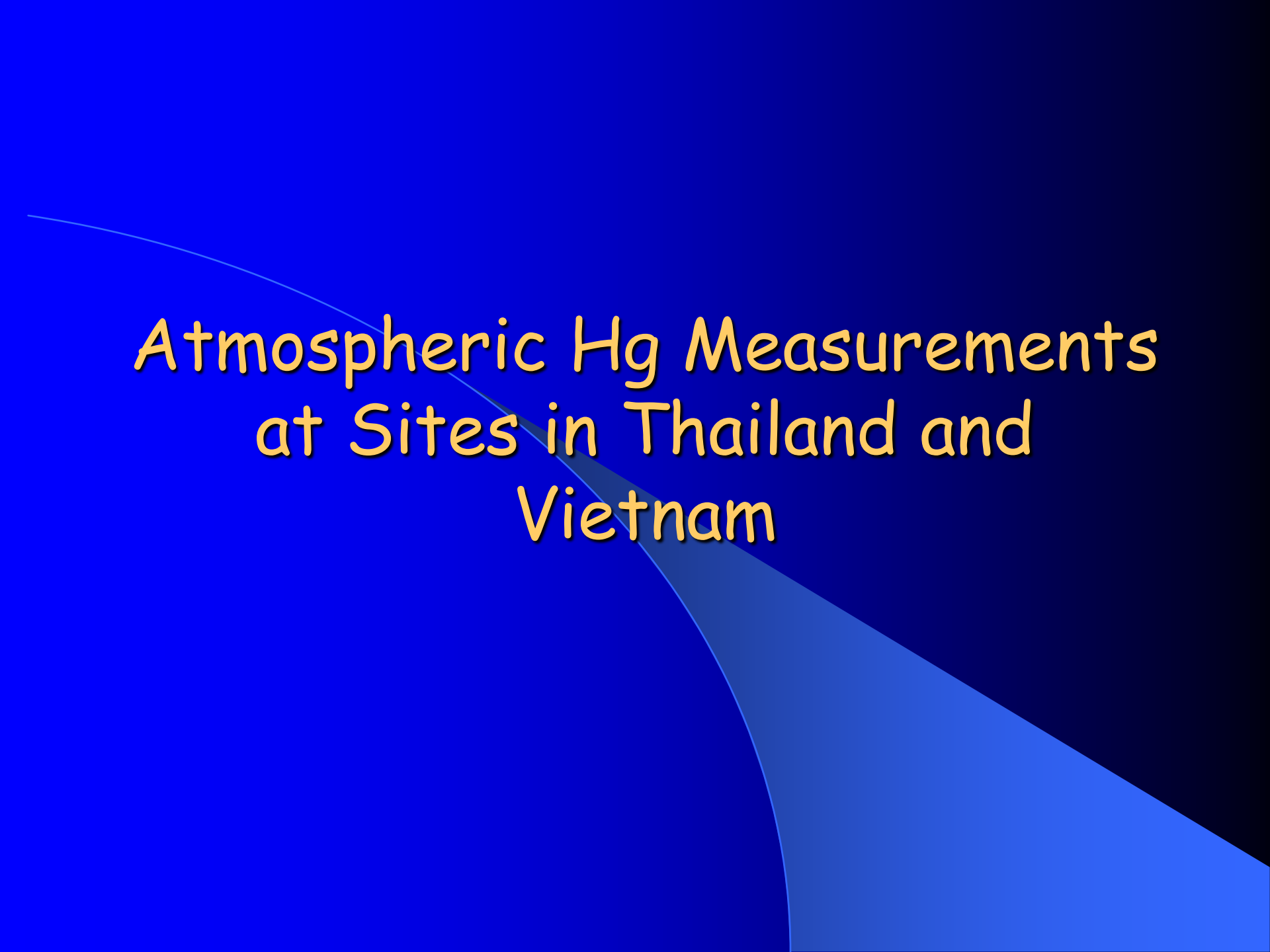
Wet and Dry Deposition Fluxes in 2010



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

(Zhang et al., 2003; 2009)

Unit: $\mu\text{g m}^{-2} \text{yr}^{-1}$



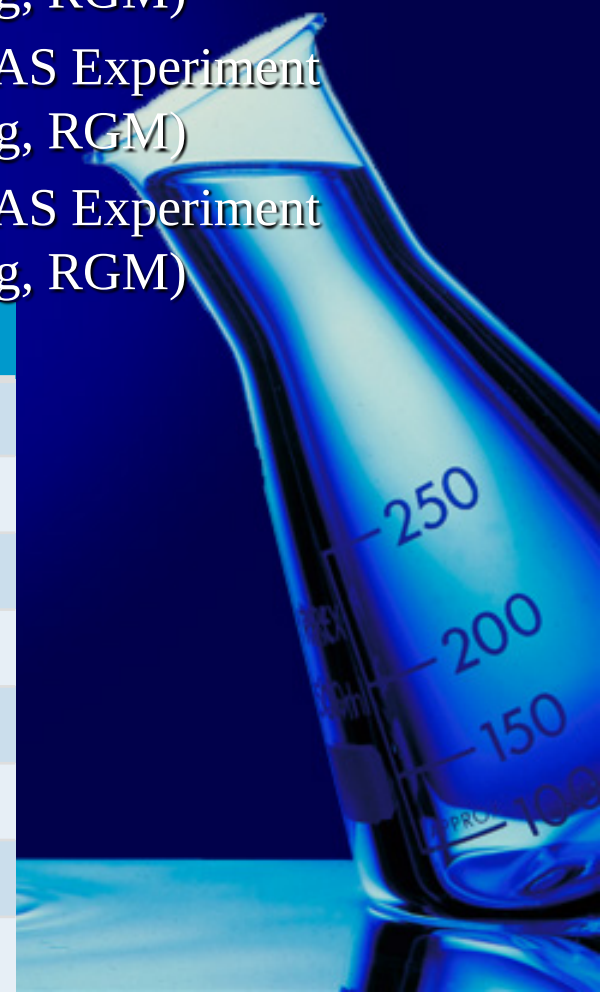
Atmospheric Hg Measurements at Sites in Thailand and Vietnam

Atmospheric Hg Measurements in SE Asia in Spring

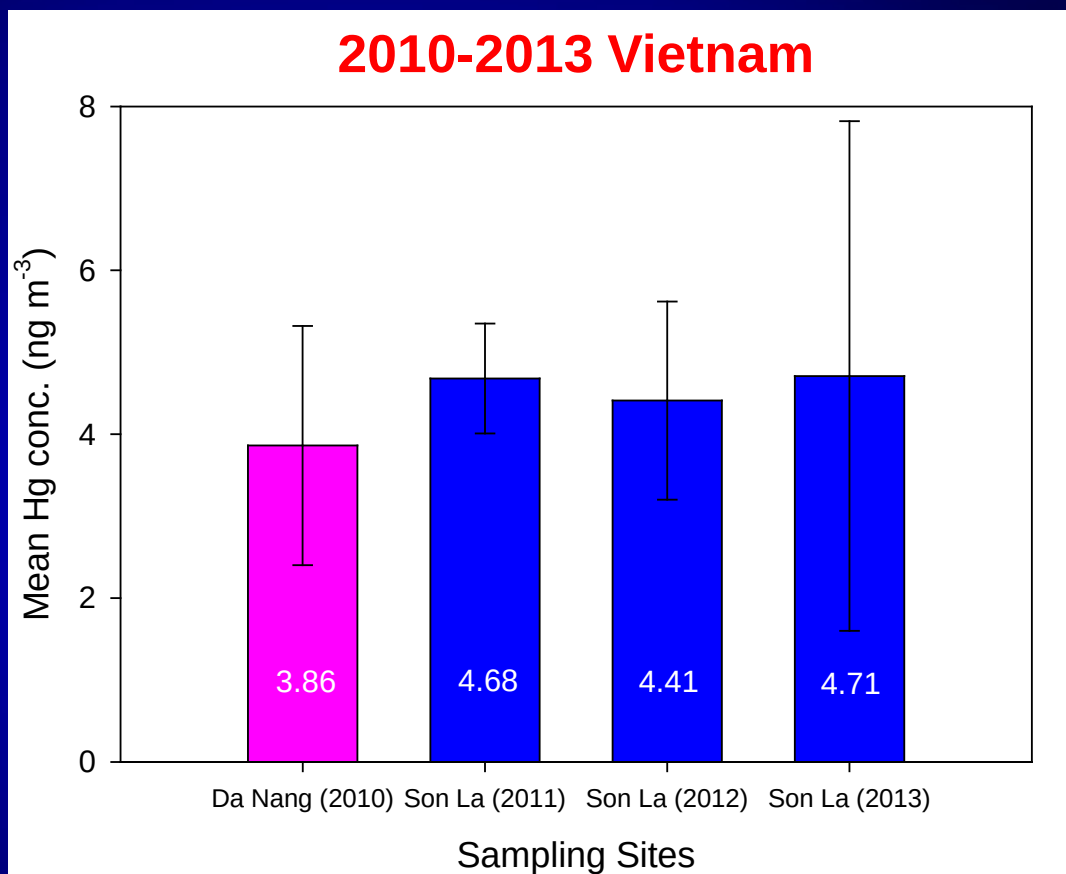


- 2010 Dongsha Experiment (GEM)
- 2011 Son La Experiment (GEM, PHg)
- 2012 Son La Experiment (GEM, PHg)
- 2013 7-SEAS Experiment (GEM, PHg, RGM)
- 2014 7-SEAS Experiment (GEM, PHg, RGM)
- 2015 7-SEAS Experiment (GEM, PHg, RGM)

	GEM	RGM	PHg
Fugueijiao	2014	2014	2014
Hengchun	2010, 2013, 2014	2013	2013
Dongsha	2010		
SCS	2010		
Da Nang	2010		
Son La	2011, 2012, 2013	2013	2011, 2012, 2013
Doi Suthep	2010		
Doi Ang Khang	2013, 2014, 2015	2013, 2014, 2015	2013, 2014, 2015

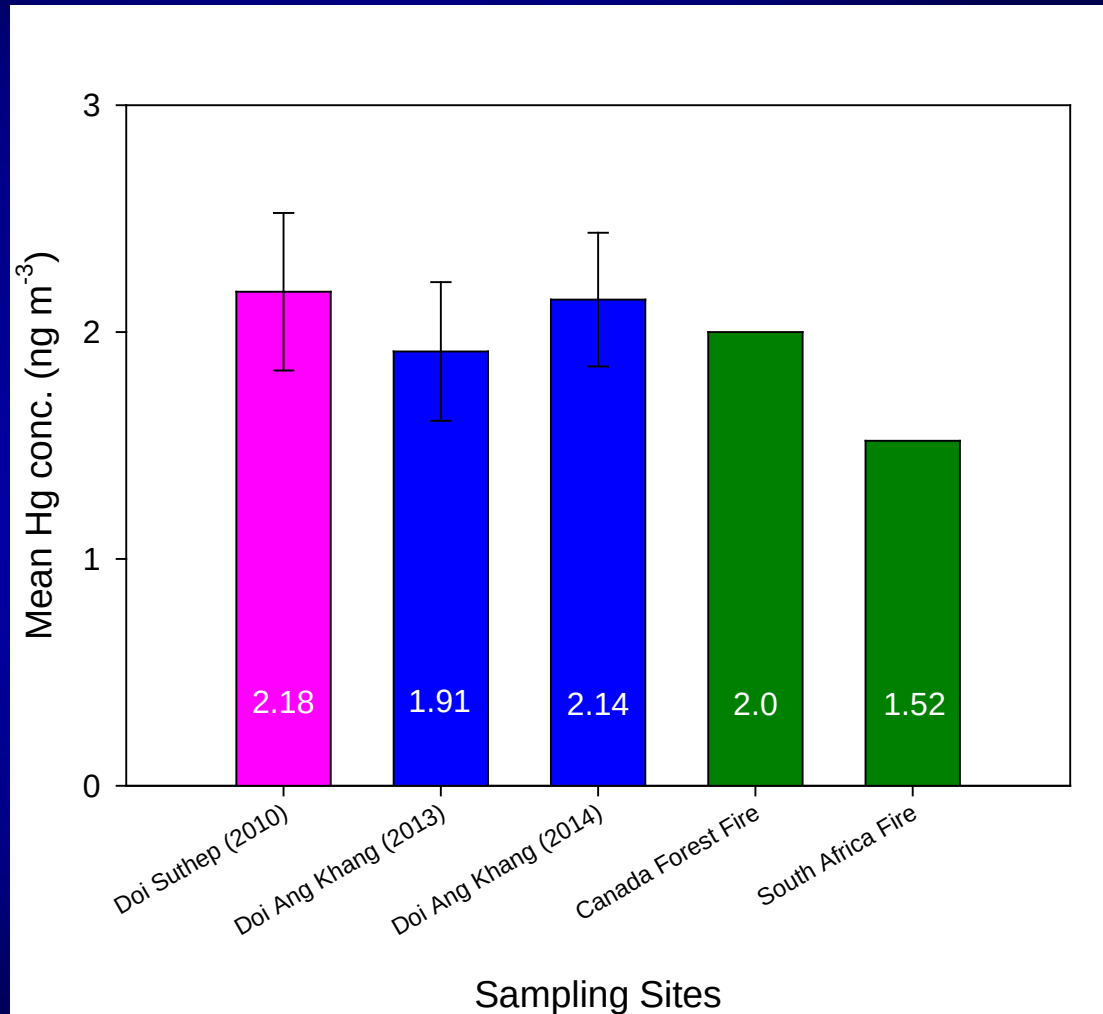


Atmospheric Hg in Vietnam in 2010-2013



Mean values of atmospheric Hg in Vietnam are about 2.3~2.8 times of the Northern Hemisphere background value (1.7 ng m⁻³), indicating sources other than the background air are influencing these sites.

Atmospheric Hg in Thailand in 2010-2014



Mean values of atmospheric Hg during biomass burning season in northern Thailand season are comparable to those of other regions.

Atmospheric Environment 78 (2013) 174–183

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Distribution of atmospheric mercury in northern Southeast Asia and South China Sea during Dongsha Experiment

Guey-Rong Sheu^{a,*}, Neng-Huei Lin^a, Chung-Te Lee^b, Jia-Lin Wang^c, Ming-Tung Chuang^b, Sheng-Hsiang Wang^a, Kai Hsine Chi^d, Chang-Feng Ou-Yang^c

^aDepartment of Atmospheric Sciences, National Central University, Jhongli 320, Taiwan
^bGraduate Institute of Environmental Engineering, National Central University, Jhongli 320, Taiwan
^cDepartment of Chemistry, National Central University, Jhongli 320, Taiwan
^dInstitute of Environmental and Occupational Health Sciences, National Yang Ming University, Taipei 112, Taiwan



Atmospheric Environment 44 (2010) 2393–2400

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

Guey-Rong Sheu^a, Neng-Huei Lin^{a,*}, Jia-Lin Wang^b, Chung-Te Lee^c, Chang-Feng Ou Yang^b, Sheng-Hsiang Wang^a

^aDepartment of Atmospheric Sciences, National Central University, Jhongli 320, Taiwan
^bDepartment of Chemistry, National Central University, Jhongli 320, Taiwan
^cGraduate Institute of Environmental Engineering, National Central University, Jhongli 320, Taiwan

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Atmospheric Environment 39 (2005) 3029–3038

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Export of atmospheric mercury from Asia

Daniel Jaffe^{a,*}, Eric Prestbo^b, Phil Swartzendruber^a, Peter Weiss-Penzias^a, Shungo Kato^c, Akinori Takami^d, Shiro Hatakeyama^d, Yoshizumi Kajii^e

^aInterdisciplinary Arts and Sciences, University of Washington-Bothell, Bothell, WA 98011 8246, USA
^bFrontier Geosciences Inc., Seattle, WA, USA
^cApplied Chemistry, Faculty of Engineering, Tokyo Metropolitan University, Tokyo, Japan
^dAtmospheric Environmental Division, National Institute of Environmental Studies, Tsukuba, Japan

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 108, NO. D17, 4529, doi:10.1029/2003JD003625, 2003

Reactive gaseous mercury formation in the North Pacific Ocean's marine boundary layer: A potential role of halogen chemistry

Fabien J. G. Laurier, Robert P. Mason, and Lindsay Whalin

Cheapeake Biological Laboratory, University of Maryland, Solomons, Maryland, USA

Shungo Kato

Department of Applied Chemistry, Tokyo Metropolitan University, Tokyo, Japan

Atmospheric Environment 77 (2013) 474–481

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Characterizations of wet mercury deposition to a remote islet (Pengjiayu) in the subtropical Northwest Pacific Ocean

Guey-Rong Sheu^a, Neng-Huei Lin^a

Department of Atmospheric Sciences, National Central University, 300 Jhongda Road, Jhongli 320, Taiwan



Atmospheric Environment 42 (2008) 7988–7996

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Reactive and particulate mercury in the Asian marine boundary layer

Duli Chand^{a,b,*}, Daniel Jaffe^{a,b}, Eric Prestbo^c, Philip C. Swartzendruber^{a,b}, William Hafner^a, Peter Weiss-Penzias^d, Shungo Kato^e, Akinori Takami^f, Shiro Hatakeyama^f, Yoshizumi Kajii^e

^aUniversity of Washington-Bothell, 1815 Campus Way NE, Bothell, WA 98011, USA
^bDepartment of Atmospheric Sciences, University of Washington, Seattle, WA, USA
^cFrontier Geosciences, 484 Pantaus Avenue N, Seattle, WA 98109, USA
^dDepartment of Environmental Toxicology, University of California, 1156 High Street, Santa Cruz, CA 95060, USA
^eApplied Chemistry, Faculty of Engineering, Tokyo Metropolitan University, Tokyo, Japan
^fAtmospheric Environmental Division, National Institute of Environmental Studies, Tsukuba, Japan

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 115, D06303, doi:10.1029/2009JD012958, 2010

Mercury in the marine boundary layer and seawater of the South China Sea: Concentrations, sea/air flux, and implication for land outflow

Xuewu Fu¹, Xinbin Feng¹, Gan Zhang², Weihai Xu^{3,4}, Xiangdong Li⁴, Hen Yao^{1,5}, Peng Liang^{1,5}, Jun Li², Jonas Sommar¹, Runsheng Yin^{1,5} and Na Liu^{1,5}



Atmospheric Environment 45 (2011) 4454–4462

Contents lists available at ScienceDirect

Atmospheric Environment

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Mercury in cloud water collected on Mt. Bamboo in northern Taiwan during the northeast monsoon season

Guey-Rong Sheu, Neng-Huei Lin^a

Department of Atmospheric Sciences, National Central University, 300 Jhongda Road, Jhongli 320, Taiwan

Atmospheric Environment 42 (2008) 7988–7996

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^aUniversity of Washington-Bothell, 1815 Campus Way NE, Bothell, WA 98011, USA
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^eApplied Chemistry, Faculty of Engineering, Tokyo Metropolitan University, Tokyo, Japan
^fAtmospheric Environmental Division, National Institute of Environmental Studies, Tsukuba, Japan

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 109, D19S25, doi:10.1029/2003JD004244, 2004

Mercury in the atmosphere around Japan, Korea, and China as observed during the 2001 ACE-Asia field campaign: Measurements, distributions, sources, and implications

Hans R. Friedli, Lawrence F. Radke, and Ryan Prescott

National Center for Atmospheric Research, Boulder, Colorado, USA

Pan Li, Jung-Hun Woo, and Gregory R. Carmichael

Center for Global and Regional Environmental Research, University of Iowa, Iowa City, Iowa, USA

Atmospheric Environment 43 (2009) 3267–3274

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Characteristics of atmospheric speciated mercury concentrations (TGM, Hg(II) and Hg(p)) in Seoul, Korea

Seung-Hee Kim^a, Young-Ji Han^b, Thomas M. Holsen^c, Seung-Muk Yi^{a,*}

^aDepartment of Environmental Health, School of Public Health, Seoul National University, Yongon-dong, Chongno-gu, Seoul 150-790, Republic of Korea
^bDepartment of Environmental Science, Kangwon National University, 192-1, Hyoja-2-dong, Chuncheon, Kangwon-do, 200-701, Republic of Korea
^cDepartment of Civil and Environmental Engineering, Box 5770, Clarkson University, Potsdam, NY 13699, United States

The Science of the Total Environment 259 (2000) 231–237

Background levels of atmospheric mercury in Kagoshima City, and influence of mercury emission from Sakurajima Volcano, Southern Kyushu, Japan

Takashi Tomiyasu^a, Ayako Nagano, Hayao Sakamoto, Norinobu Yonehara

Department of Earth and Environmental Sciences, Faculty of Science, Kagoshima University, Kagoshima 890-0065, Japan

Science of the Total Environment 408 (2010) 1295–1307

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Water Air Soil Pollut DOI 10.1007/s11270-007-9438-5

Monitoring of Atmospheric Mercury at a Global Atmospheric Watch (GAW) Site on An-Myun Island, Korea

Hang Thi Nguyen · Ki-Hyun Kim · Min-Young Kim · Sungmin Hong · Yong-Hoon Yoon · Zang-Ilo Shon · Jeong Soon Lee

Environmental Pollution 157 (2009) 816–822

Contents lists available at ScienceDirect

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The influence of long-range transport on atmospheric mercury on Jeju Island, Korea

Hang Thi Nguyen^a, Min-Young Kim^b, Ki-Hyun Kim^{a,*}

^aDept. of Earth & Environmental Sciences, Sejong University, Seoul, 143-747, Republic of Korea
^bSeoul Metropolitan Institute of Public Health and Environment, Seoul, 137-734, Republic of Korea

Monitoring of Atmospheric Mercury at a Global Atmospheric Watch (GAW) Site on An-Myun Island, Korea

Hang Thi Nguyen · Ki-Hyun Kim · Min-Young Kim · Sungmin Hong · Yong-Hoon Yoon · Zang-Ilo Shon · Jeong Soon Lee

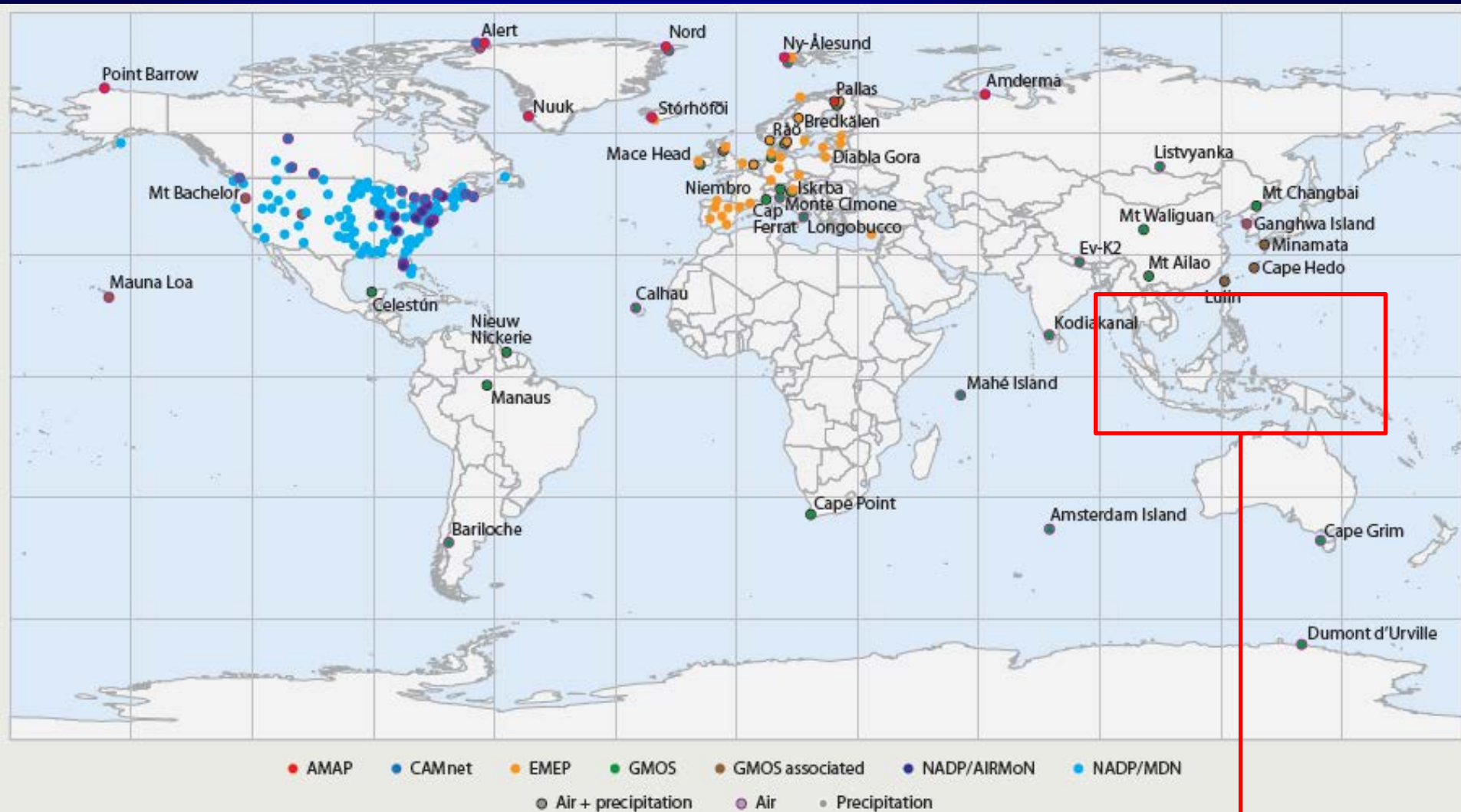
Total gaseous concentrations in mercury in Seoul, Korea: Local sources compared to long-range transport from China and Japan

Eun-Mi Choi^a, Seung-Hee Kim^a, Thomas M. Holsen^c, Seung-Muk Yi^{a,b,*}

^aGraduate School of Public Health, Department of Environmental Health, Seoul National University, Yongon-dong, Chongno-gu, Seoul 150-790, Republic of Korea
^bInstitute of Health and Environment, Graduate School of Public Health, Seoul National University, Yongon-dong, Chongno-gu, Seoul 150-790, Republic of Korea
^cDepartment of Civil and Environmental Engineering, Clarkson University, Potsdam, NY 13699, USA

This study identified long-range transport from China and local sources of elevated TGM concentrations in Seoul, Korea using the relationship between δTCM and δCO.

Atmospheric Hg Monitoring Worldwide



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

THANK you!



Contact:
grsheu@atm.ncu.edu.tw

