

Mercury in East and Southeast Asia

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Minamata Disease and Hg Pollution

- Minamata disease, a neurological disease caused by severe Hg poisoning due to consumption of contaminated fish, was first discovered in Minamata, Japan in **1956**.
- Hg-containing industrial wastewater discharge was the major Hg source to the fish in Minamata Bay.

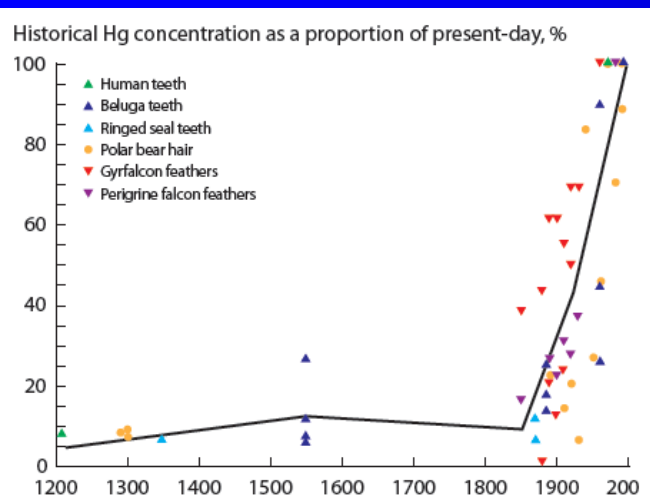


(Time, 2010)

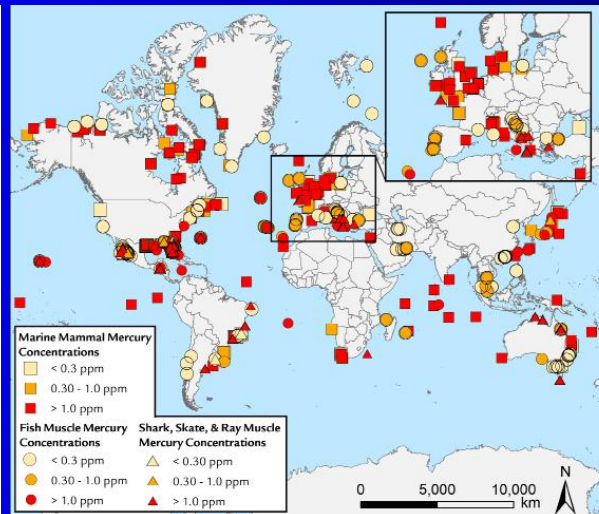


Global Hg Pollution

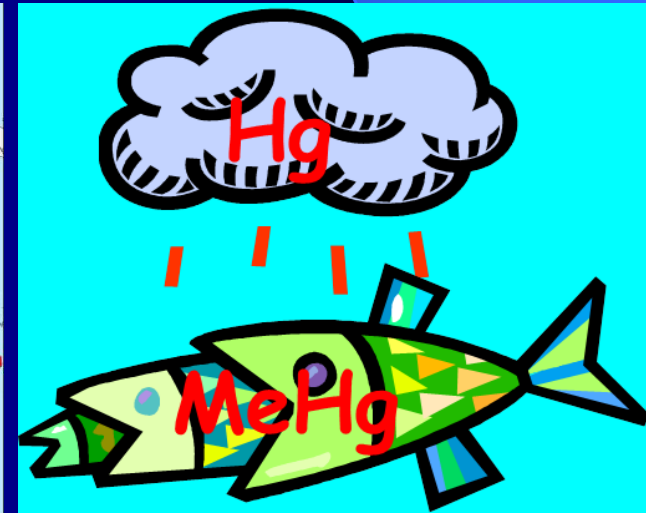
- Mercury is still a pollutant of global concern.
- Fish consumption is the major exposure route of Hg to many people worldwide.
- Atmospheric deposition is the major source of Hg to many aquatic ecosystems.
- Anthropogenic Hg emission is an important contributor to the Hg in the atmosphere.



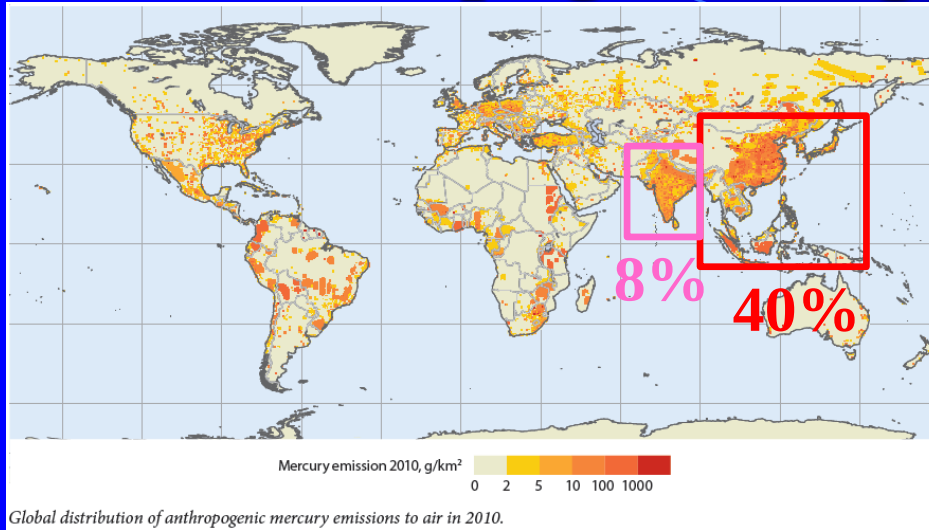
(UNEP, 2013)



(Evers et al., 2012)



Anthropogenic Hg Emissions in 2010

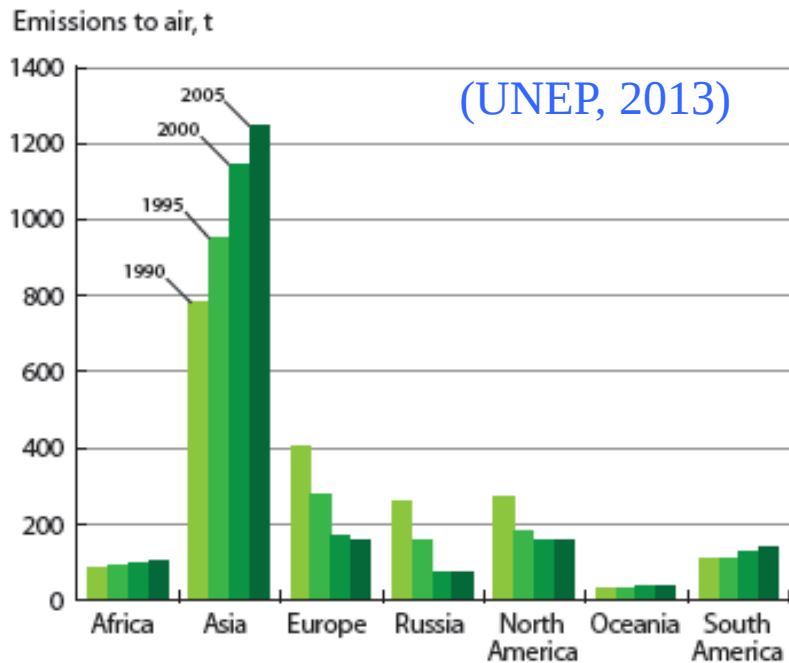


Region*	Emission (range), tonnes**	%
Australia, New Zealand & Oceania	22.3 (5.4 - 52.7)	1.1
Central America and the Caribbean	47.2 (19.7 - 97.4)	2.4
CIS & other European countries	115 (42.6 - 289)	5.9
East and Southeast Asia	777 (395 - 1690)	39.7
European Union (EU27)	87.5 (44.5 - 226)	4.5
Middle Eastern 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)
Bangladesh	1.4
Cambodia	3.9
China	575.2
India	144.7
Indonesia	78.2
Japan	17.2
Korea	7.1
Laos	1.3
Malaysia	6.1
Mongolia	6.9
Philippines	33.1
Singapore	0.9
Sri Lanka	0.6
Taiwan	5.5
Thailand	14.9
Vietnam	11.6

(UNEP, 2013)

Trends in Anthropogenic Hg Emissions



Estimates of annual anthropogenic mercury emissions from different continents/regions, 1990-2005.

Anthropogenic Hg emissions from Europe and North America are declining, whereas **emissions from Asia are increasing.**

Projections of Global Mercury Emissions in 2050 (Streets et al., 2009)

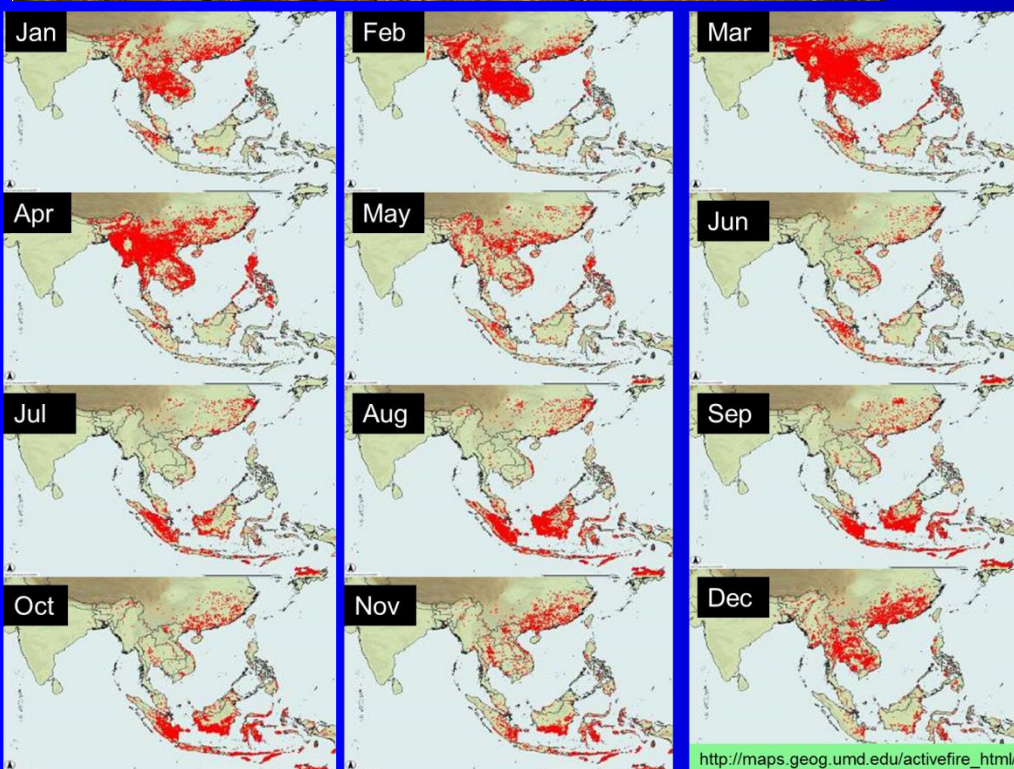
DAVID G. STREETS,^{*,†} QIANG ZHANG,[†] AND YE WU[‡]

TABLE 4. Mercury Emissions in 2050 by Scenario and World Region (Mg/yr)

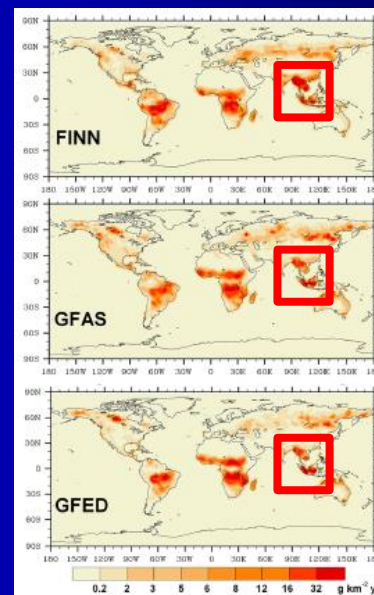
scenario	North America	Central and South America	Africa	Europe, Russia, Middle East	Asia and Oceania	world
2050 A1B	225.9	473.6	509.6	676.5	2970.0	4855.6
2050 A2	239.1	415.6	375.5	667.3	2208.5	3905.9
2050 B1	121.9	340.4	357.0	358.1	1208.9	2386.2
2050 B2	131.3	331.2	308.1	398.0	1461.4	2629.9

Projections under various IPCC scenarios of development. **It is likely that Hg emission will increase in the future.** The main driving force is the expansion of coal-burning electricity generation, especially in Asia.

Biomass Burning Hg Emissions



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



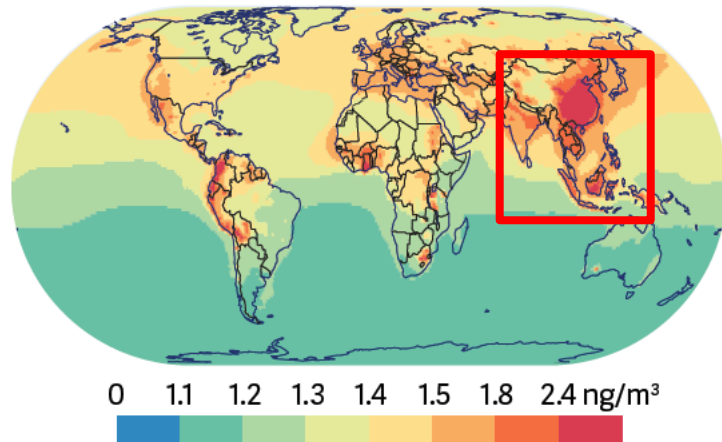
regions	Hg emissions Mg Hg/year	
	mean	SD ^a
BONA	22	16
TENA	6	3
CEAM	22	25
NHSA	13	10
SHSA	95	39
EURO	2	1
MIDE	0	0
NHAf	83	13
SHAF	58	7
BOAS	99	83
CEAS	7	2
SEAS	57	35
EQAS	192	216
AUST	19	9
global	675	240
boreal ^b	121	85
temperate ^c	9	3
ROW ^d	545	224

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

(Friedli et al., 2009; de Simone et al., 2015)

Distribution of Atmospheric Hg Concentrations and Deposition Fluxes: Modeling Results

a) **Mean annual GEM conc. In 2013**



b) **Annual total Hg deposition in 2013**

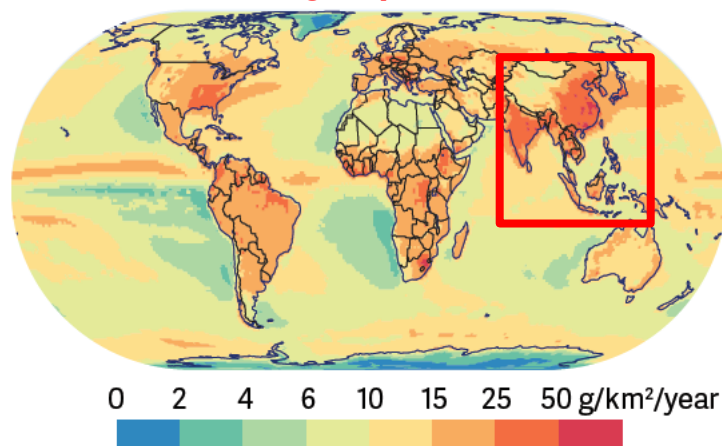
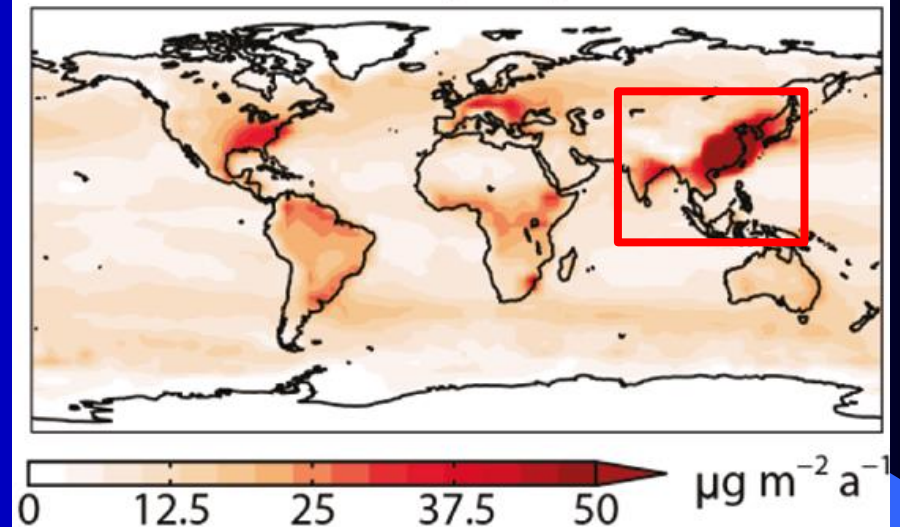


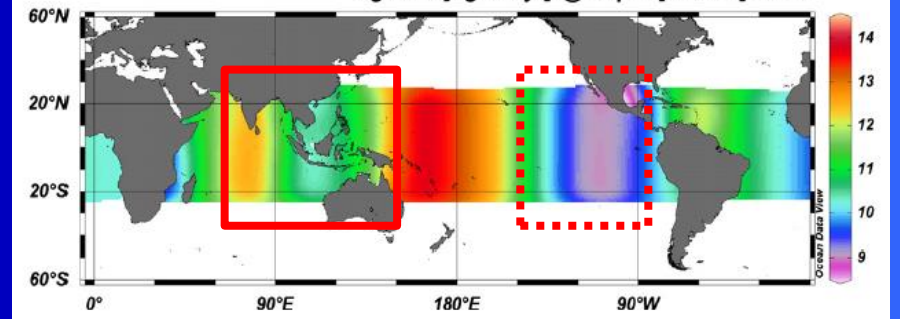
Figure 2. Global distribution of ensemble mean annual GEM concentration in ambient air (a) and annual total mercury deposition (b) in 2013.

Net Mercury Deposition



Corbitt et al., 2011

Hg Flux [ug/m2/yr] @ Depth [meters]=first

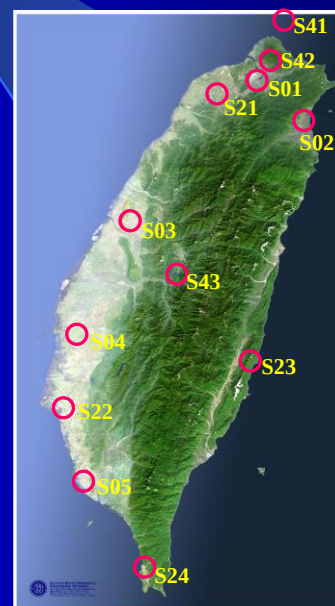
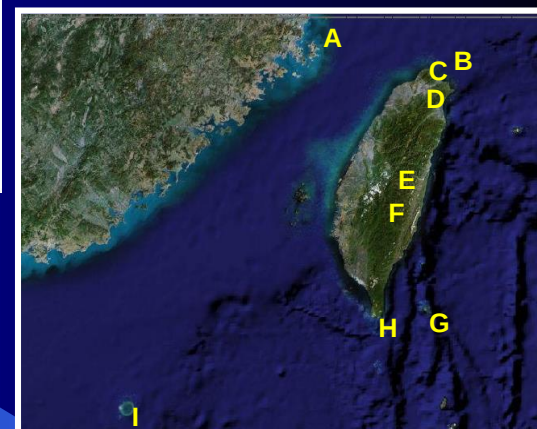


AMAP/UNEP, 2015

Costa et al., 2012

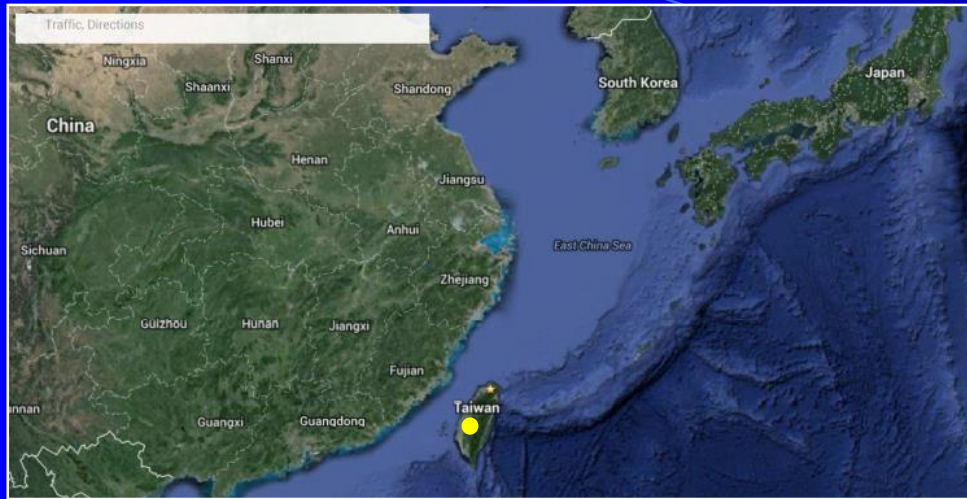
Atmospheric Hg Research in Taiwan

- Long-term continuous speciated atmospheric Hg monitoring at Lulin Atmospheric Background Station (LABS) since 2006
- Establishment and operation of a mercury wet deposition monitoring network since 2008
- Long-term cloudwater Hg monitoring at Mt. Bamboo in spring
- Atmospheric Hg measurements at background and remote sites
- Regional atmospheric Hg Research



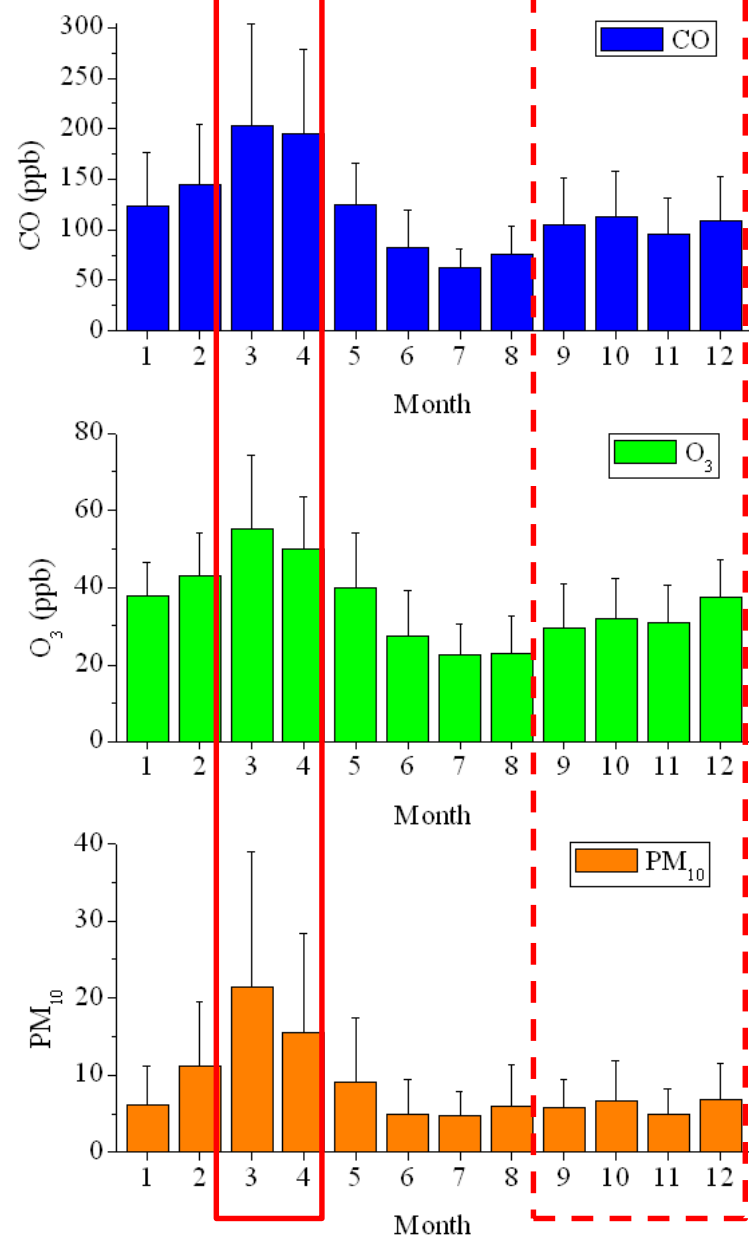
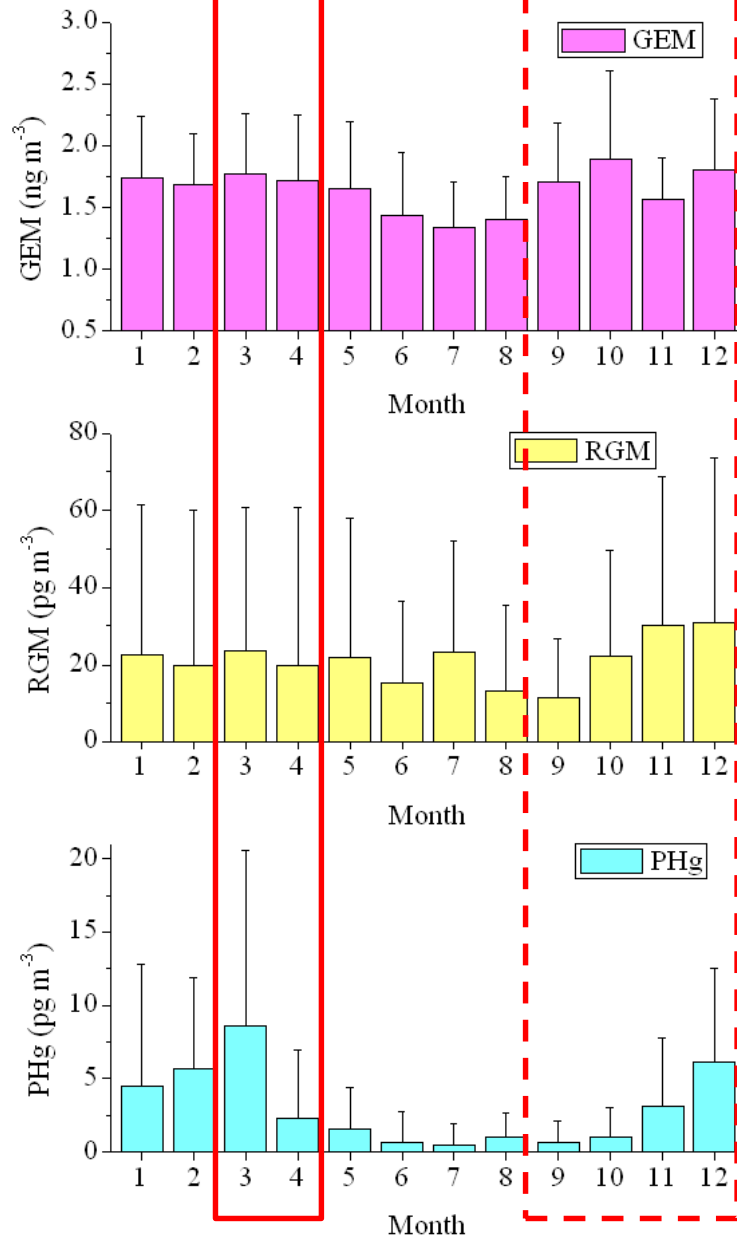
Trans-Boundary Transport of Hg Observed in Taiwan

Lulin Atmospheric Background Station (LABS)

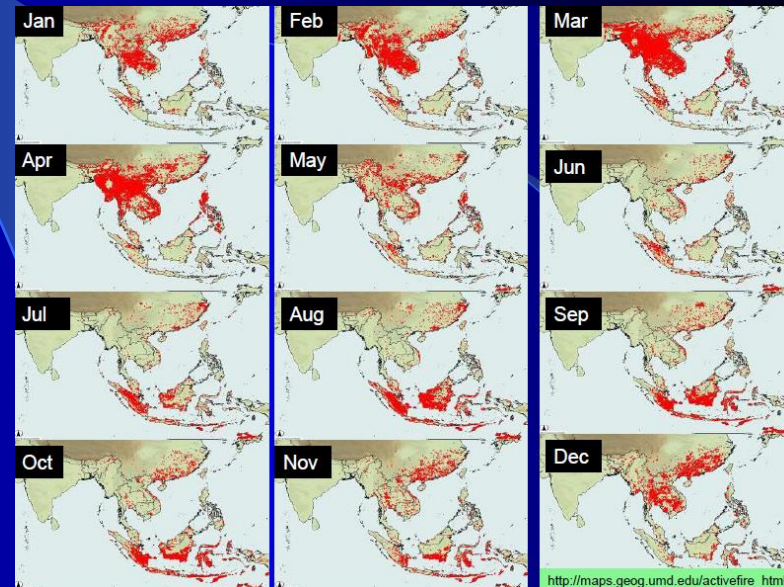
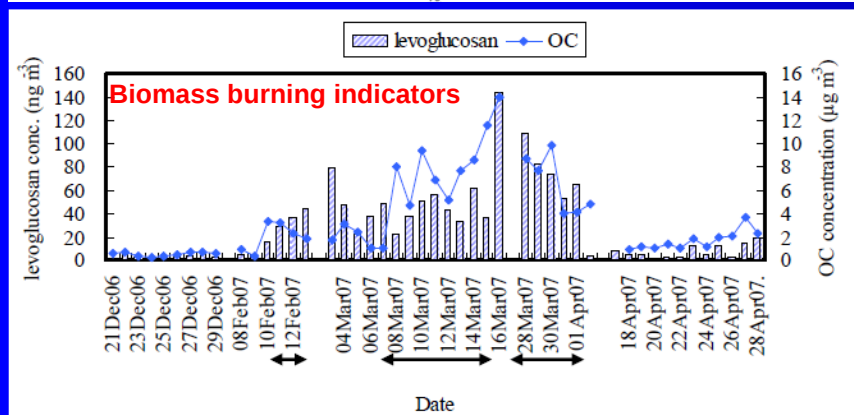
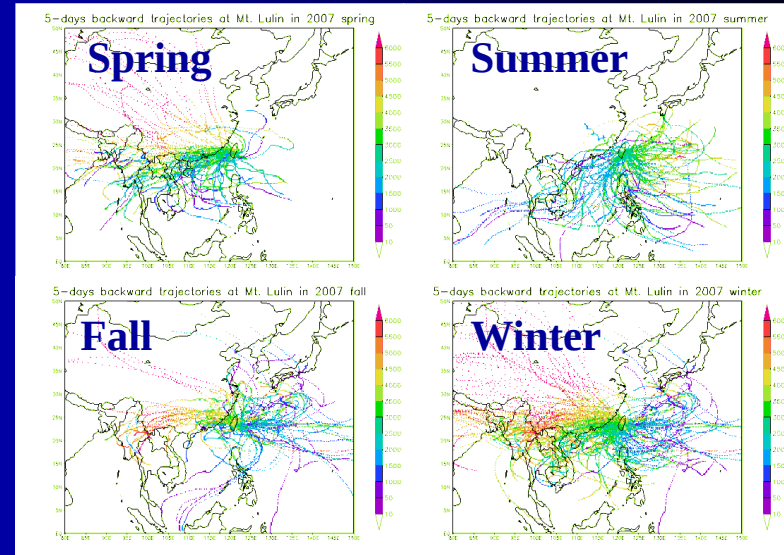
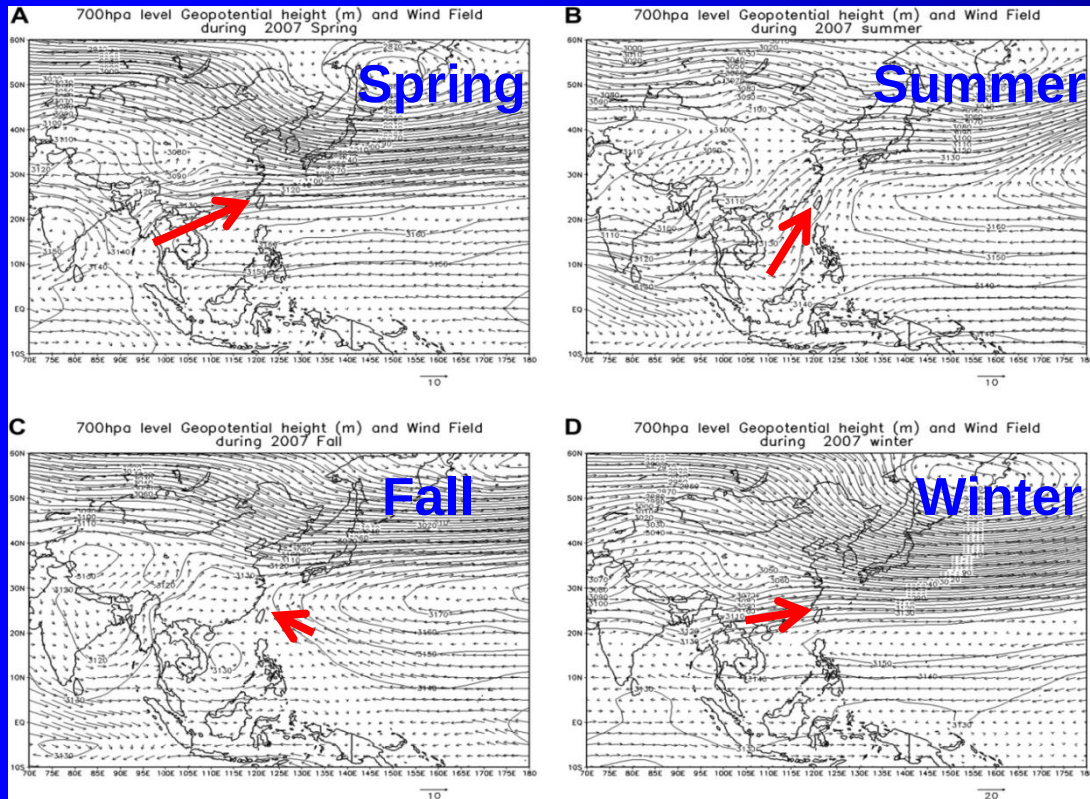


- LABS is located atop Mt. Front Lulin in central Taiwan, with an elevation of 2862 m above sea level.
- Gaseous Elemental Hg(GEM), Reactive Gaseous Hg(RGM) and Particulate Hg(PHg) have been measured using Tekran 2537X/1130/1135 at the LABS since April 13, 2006.

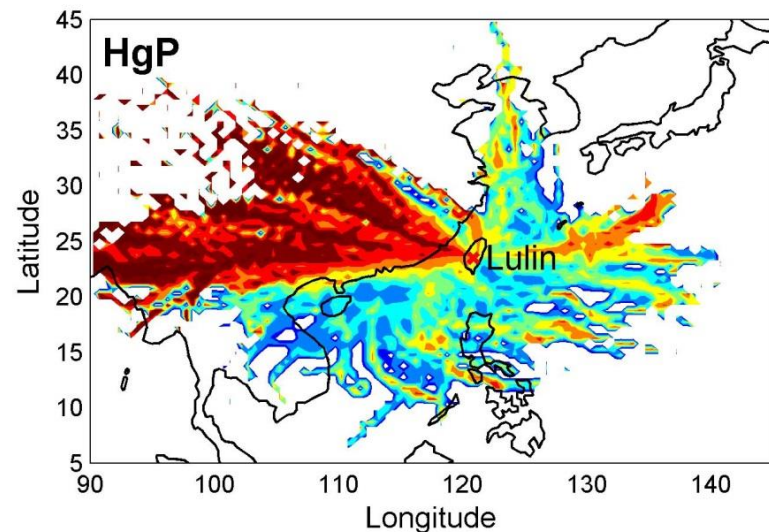
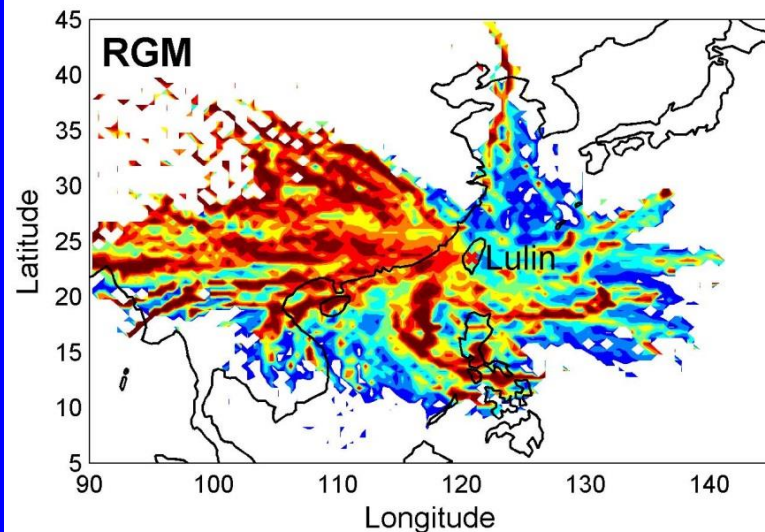
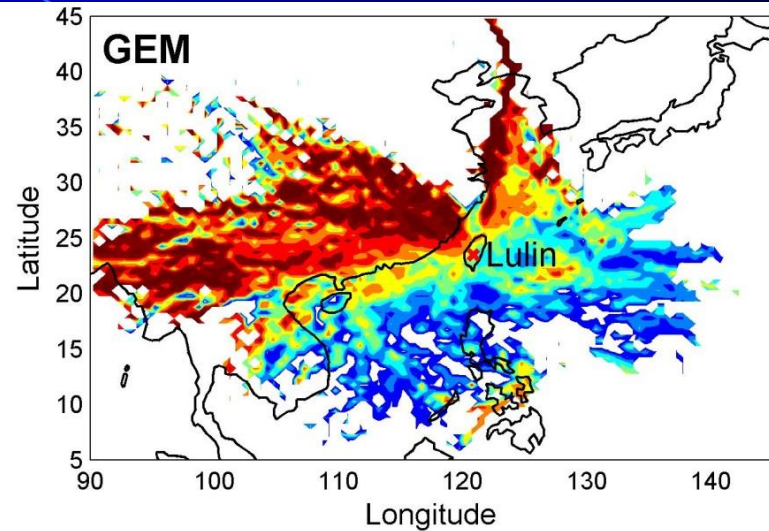
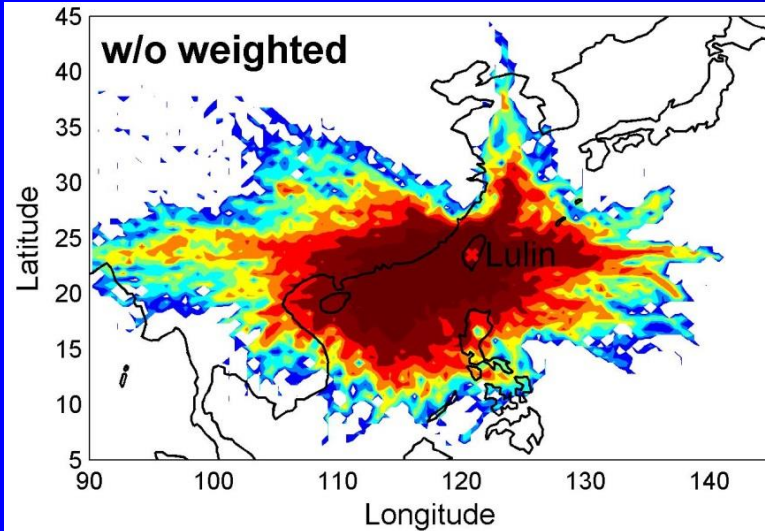
Seasonal Pattern of Hg, CO, O₃ and PM₁₀ at LABS



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

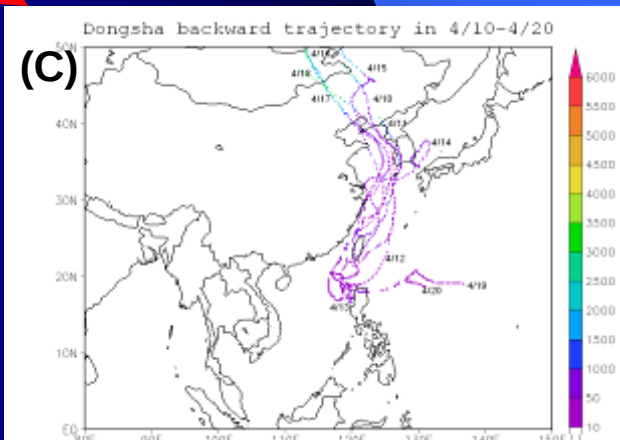
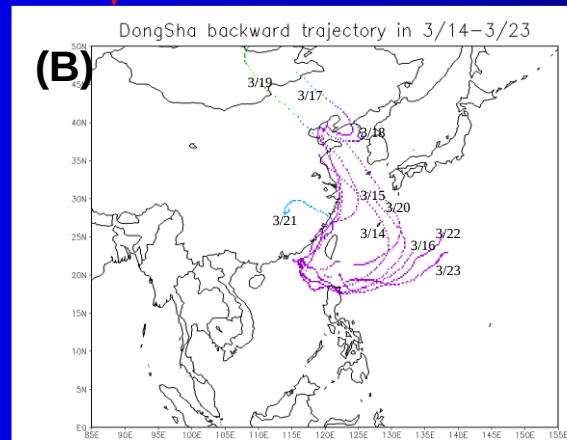
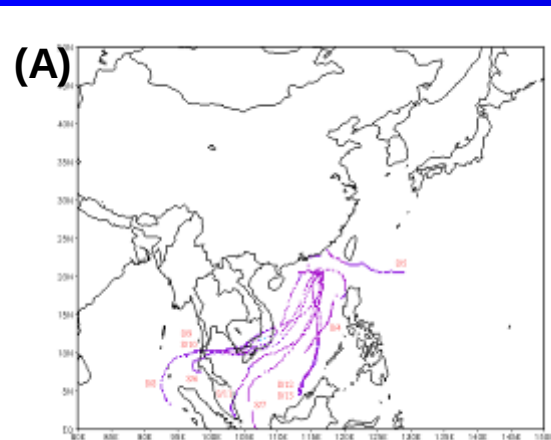
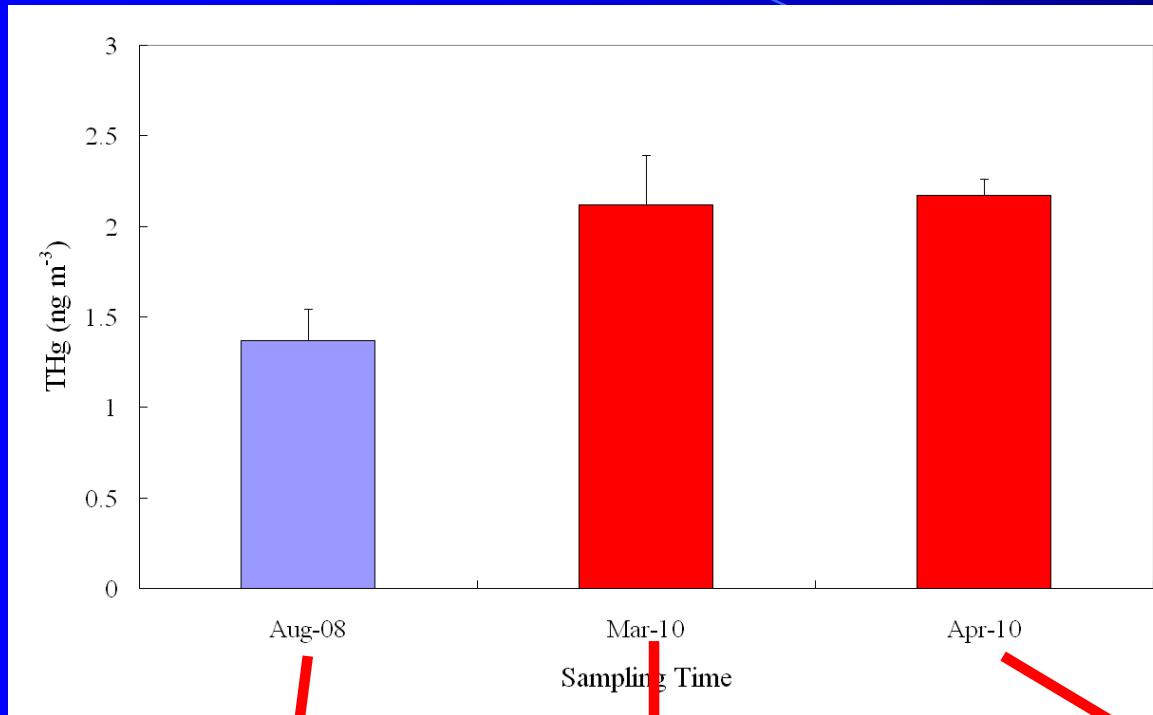


Source-Receptor Relationship: Concentration-Weighted Trajectory



0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

Seasonal Variation at Dongsha Island



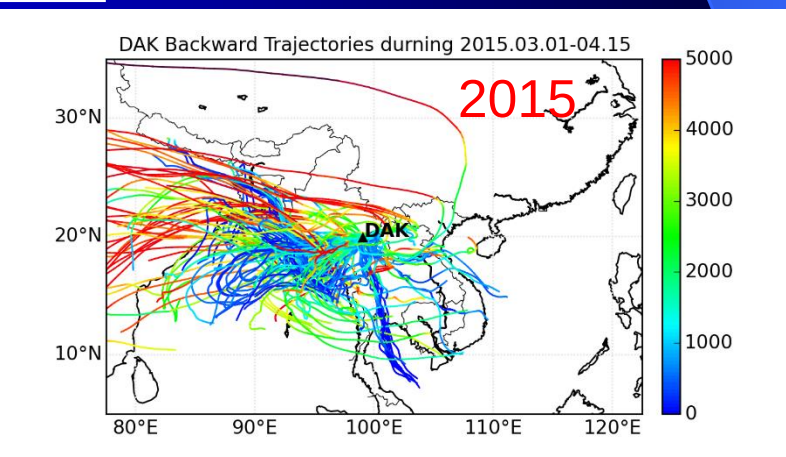
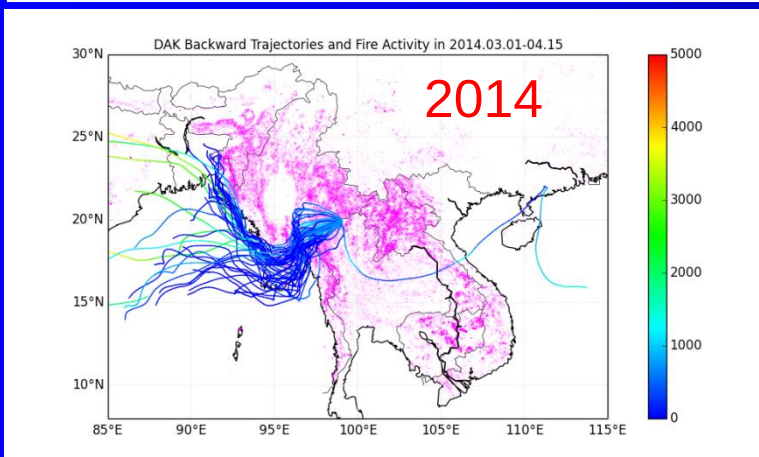
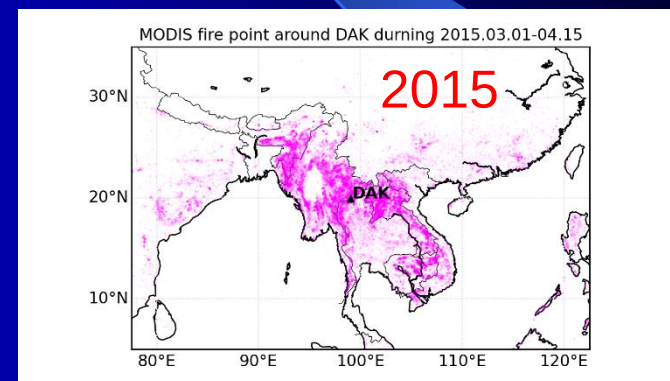
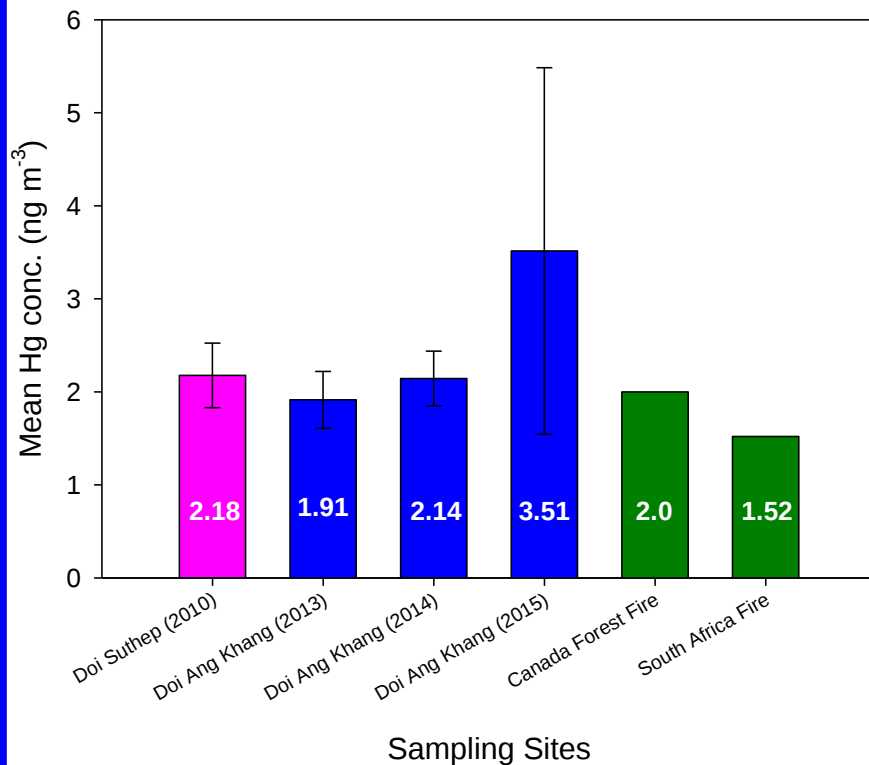
Atmospheric Hg Measurements in Thailand and Vietnam

Regional Atmospheric Hg Research

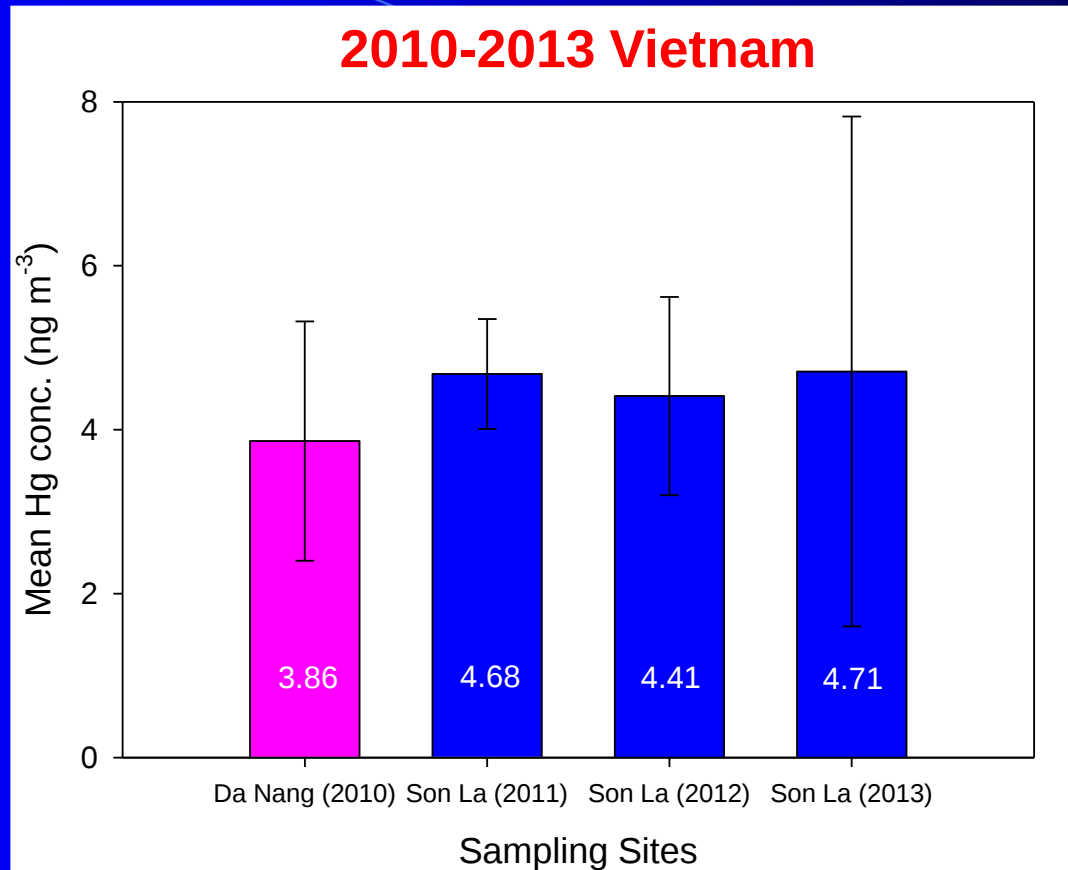
- **2008:** Hg sampling at Mt. Fuji, Japan
- **2009:** Hg sampling at Gosan, Korea
- **2010:** 7-SEAS/Dongsha Experiment
- **2011:** Son La Experiment (I)
- **2012:** Son La Experiment (II)
- **2013:** 2013 7-SEAS/BASELInE Campaign
- **2014:** 2014 7-SEAS/BASELInE Campaign
- **2015:** 2015 7-SEAS/BASELInE Campaign
- **2015:** Hg sampling at Mt. Fuji, Japan



Atmospheric Hg in Thailand in 2010-2015



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.

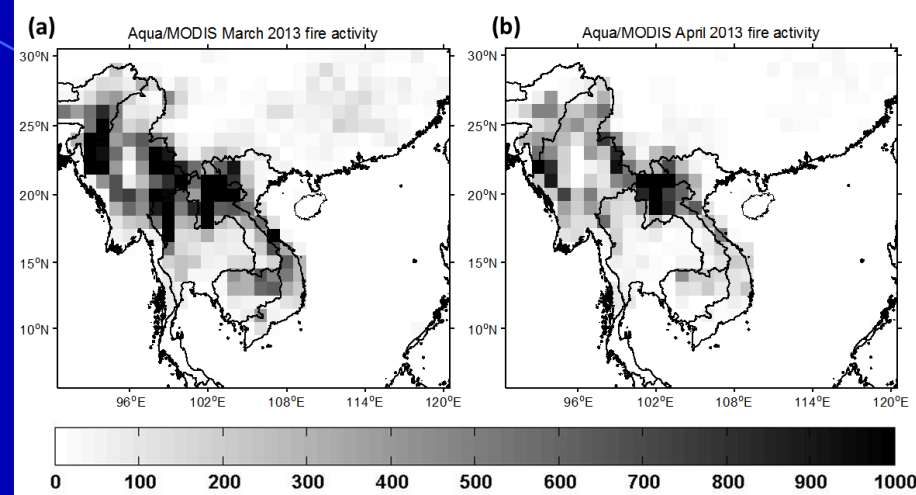
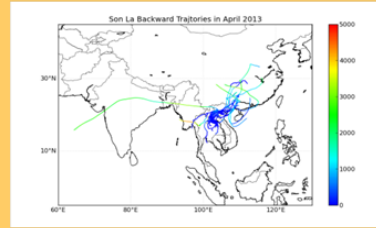
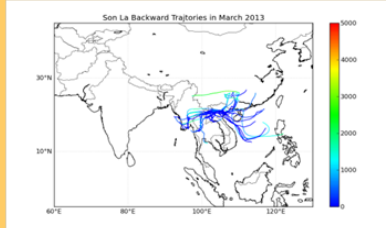
Potential Hg Emission Sources in Vietnam

Backward trajectories

Biomass burning activities

(A) 越南 Son La 3 月氣流後推軌跡

(B) 越南 Son La 4 月氣流後推軌跡



Possible Hg emission sources include biomass burning, cement production, and coal fire power plants.

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ATMOSPHERIC ENVIRONMENT

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

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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

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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

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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
 Chesapeake 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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ATMOSPHERIC ENVIRONMENT

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

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

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Atmospheric Environment 42 (2008) 7988–7996

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ATMOSPHERIC ENVIRONMENT

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

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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}

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

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the Science of the Total Environment

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

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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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ATMOSPHERIC ENVIRONMENT

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,*}

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^cDepartment of Civil and Environmental Engineering, Box 5770, Clarkson University, Potsdam, NY 13699, United States

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

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

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Science of the Total Environment

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 · Chang-Il Shon · Jeong Soon Lee

Environmental Pollution 157 (2009) 816–822

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ENVIRONMENTAL POLLUTION

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

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

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

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This study identified long-range transport from China and local sources of elevated TGM concentrations in Seoul, Korea using the relationship between δTGM and δC₁₃.



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

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Article

An Investigation of Atmospheric Mercury from Power Sector in Thailand

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Original Article

Mercury Contamination in the Atmosphere of Aceh Province, Indonesia

SERIKAWA Yuka*, ROSANA Elvince**, KAWAKAMI Tomonori†*,
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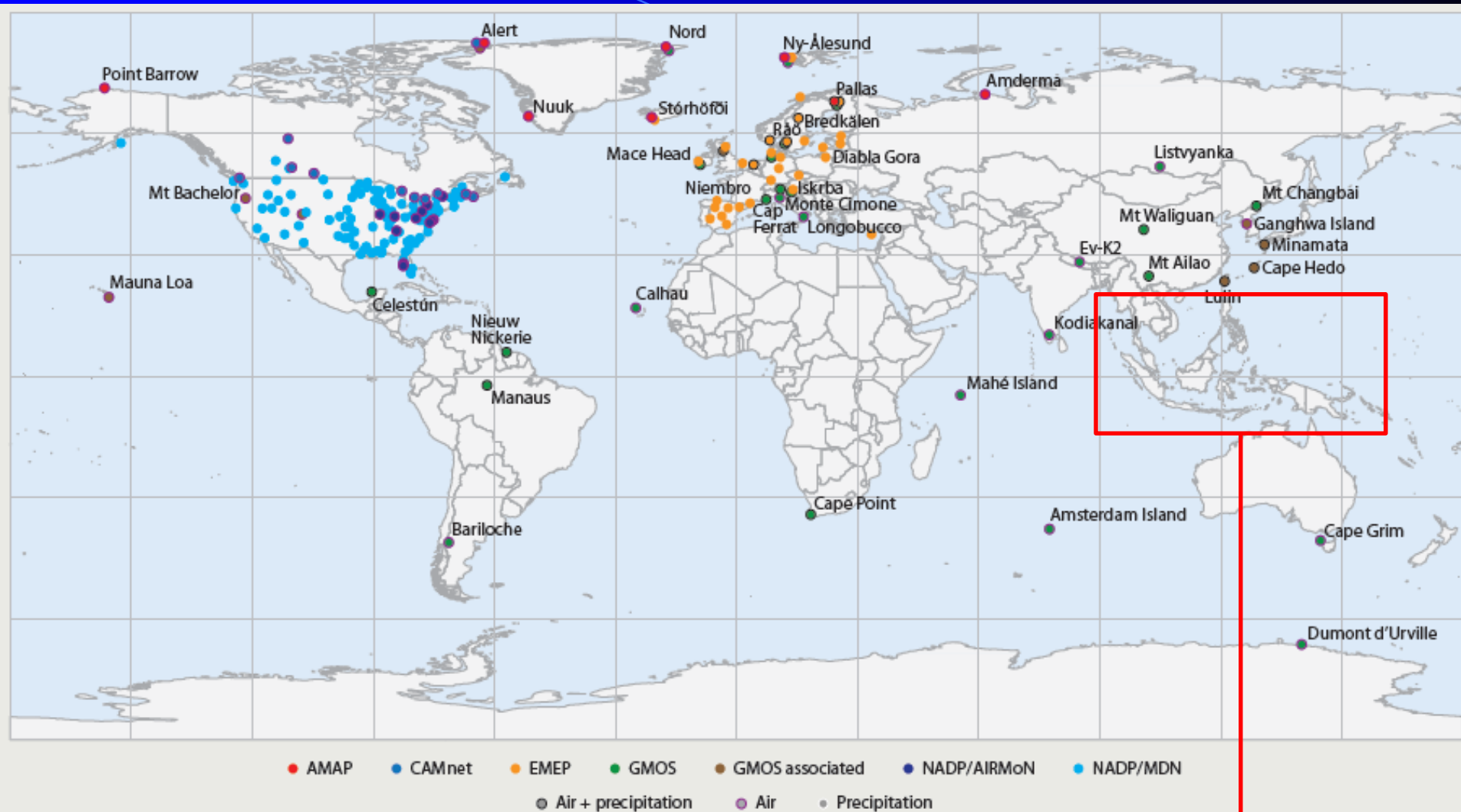
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Atmospheric Hg Monitoring Worldwide

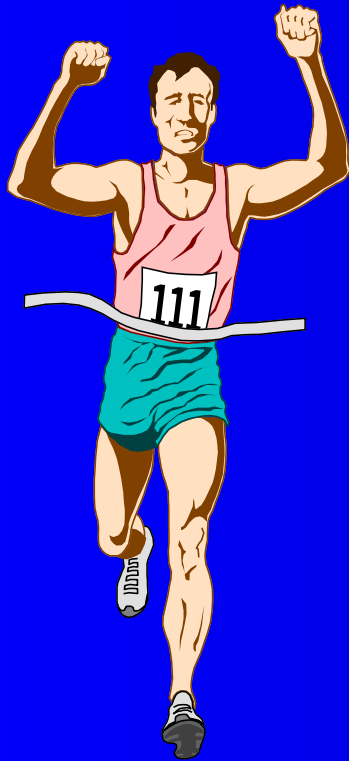


Currently, there is no long-term or background atmospheric Hg monitoring activity in SE Asia.



- Goal
 - Systematically monitor wet deposition and atmospheric concentrations of mercury in a network of stations throughout the Asia-Pacific region

THANK you!



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