Estimation of Trans-Boundary Mercury in Korea (from China) Using Emission DTA And CMAQ-Hg Model

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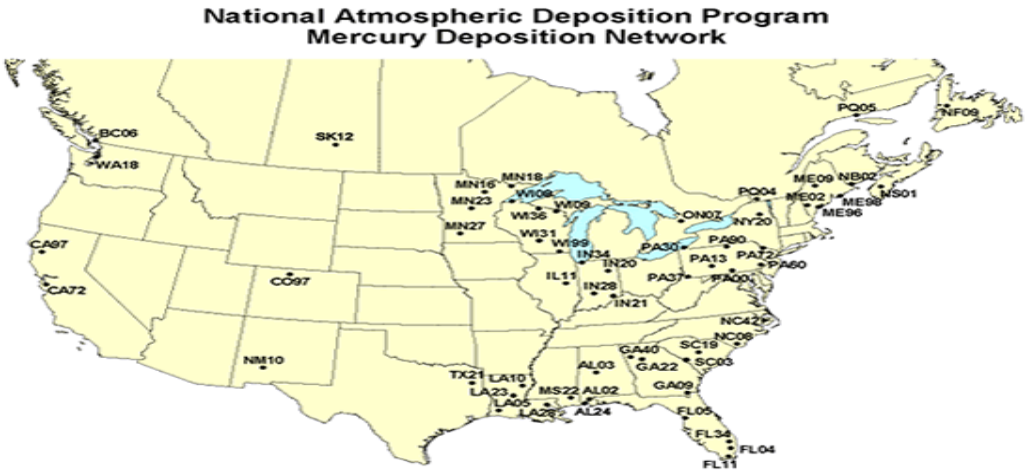
Background of the Study (1)

- Studies on mercury movement (U.S.A./EU)
  - In U.S.A., continuous updating mercury behavior(species) using CMAQ and HYSPLIT[1]
  - Since 1996, monitoring Hg concentration in rainfall / wet deposition using MDN in U.S.A. and Canada
  - METAALICUS (U.S.A. and Canada) : The relationship btw. atmospheric Hg deposition and bioaccumulation of Hg in ecosystem



- UNEP established-Hg observation system by operating GMOS

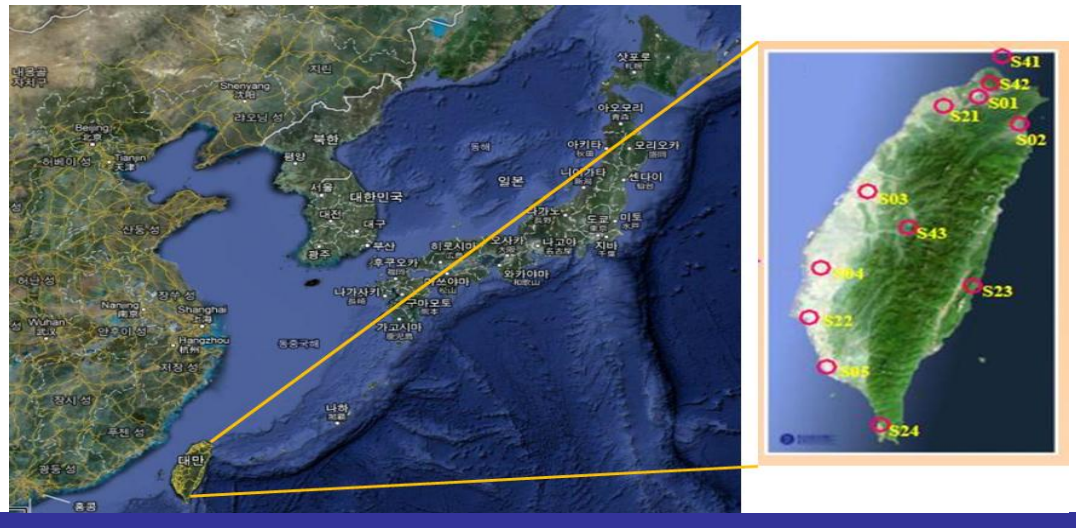
1) US EPA 'Air Quality Modeling Technical Support Document: EGU Mercury Analysis' (2011)
2) National Atmospheric Deposition Program homepage (http://nadp.sws.uiuc.edu)

Background of the Study (2)

- Japan : Cape Hedo Atmosphere and Aerosol Monitoring Station (CHAAMS) and Minamata Atmospheric Mercury Observation Site to identify the long-range transport Hg
- Taiwan : Collecting deposition data in various geological characteristics (urban, suburb, remote / industrial, mountain, agriculture, coastal, island)
- Korea : 12 monitoring stations for Hg deposition

  Chemical speciation by measurements in Seoul, Incheon, and Jeju Island

☞ Rapid increase of energy consumption in China promotes interactive Hg-researches btw. Northeast Asian countries



1) National Atmospheric Deposition Program homepage (http://nadp.sws.uluc.edu)

Objectives of the Study

✓ To estimate anthropogenic Hg emission in Korea

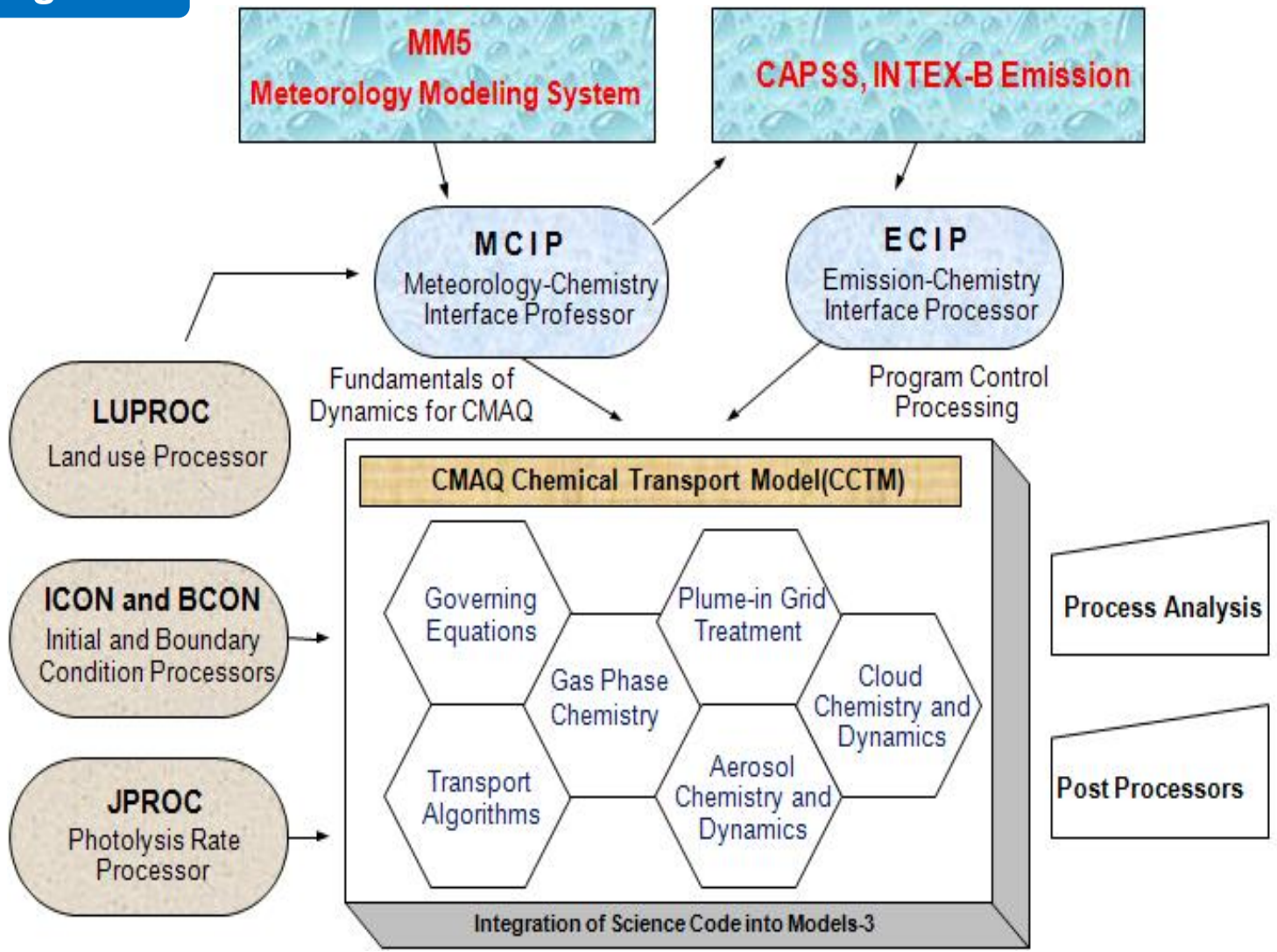
✓To investigate the contribution of trans-boundary Hg entering Korean Peninsula

✓ Measurement of Atmospheric concentration of Hg and speciation

☞ To provide informative result for international research

Research Approach(1)

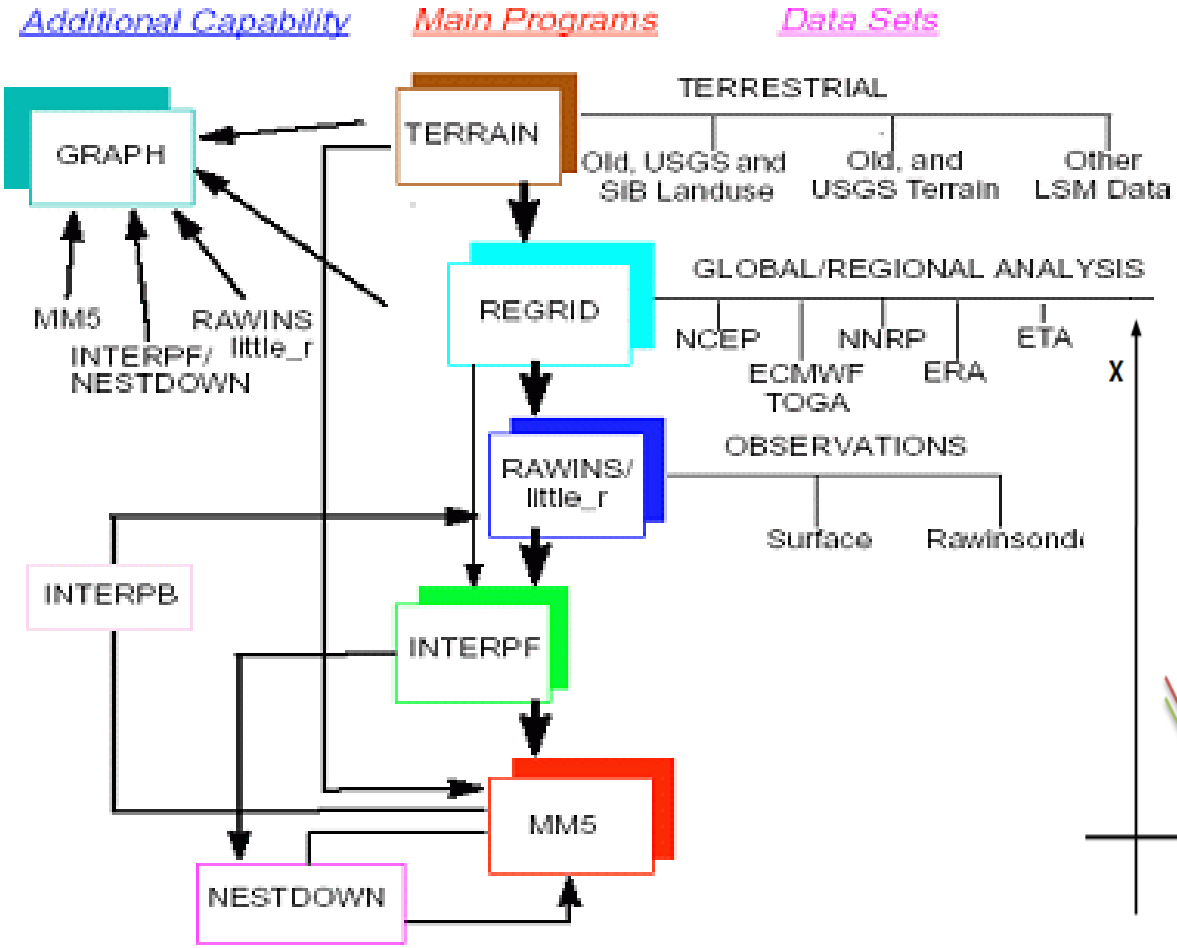
CMAQ-Hg

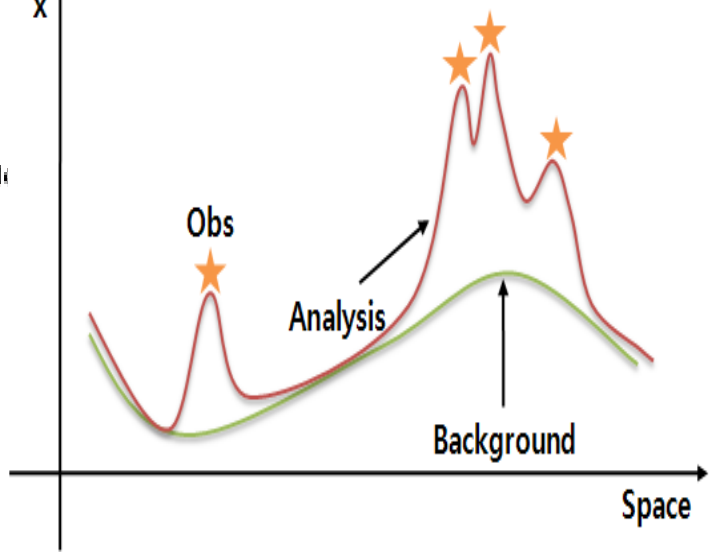


Research Approach (2)

MM5 data Synchronization

The MM5 Modeling System Flow Chart





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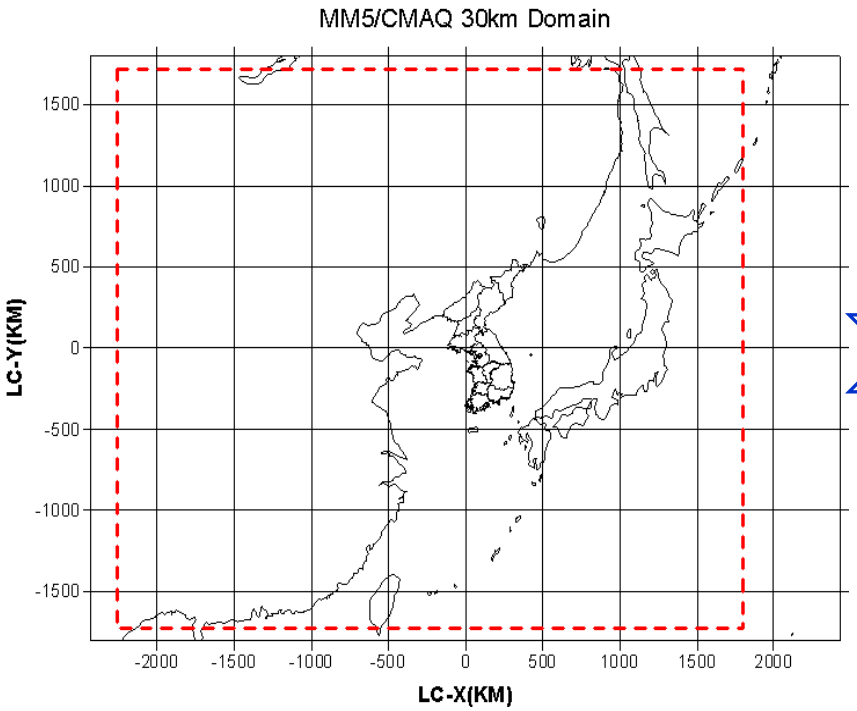
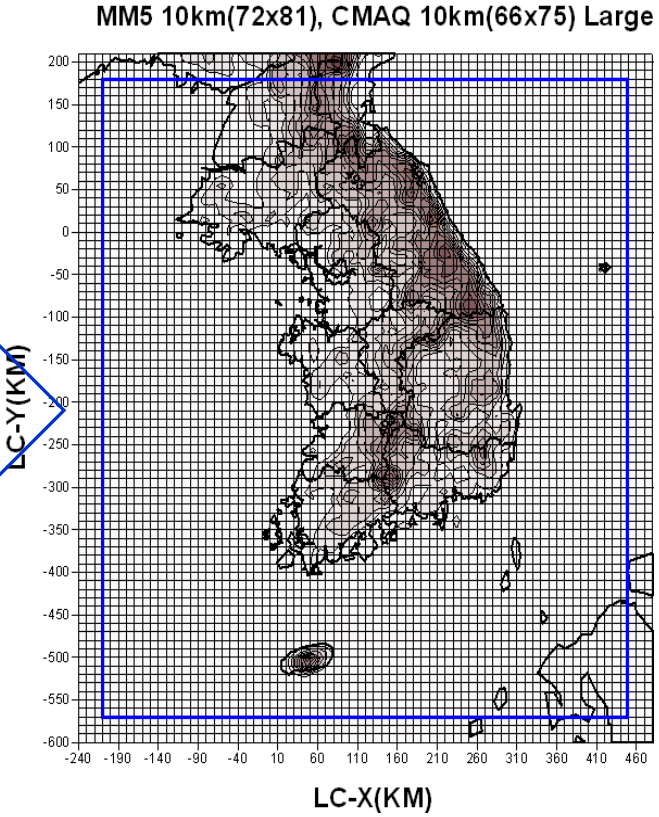
Research Approach (3)

Modeling Domain of MM5 & CMAQ



Nesting, 3:1



Method of the Study

Atmospheric Concentration of Hg

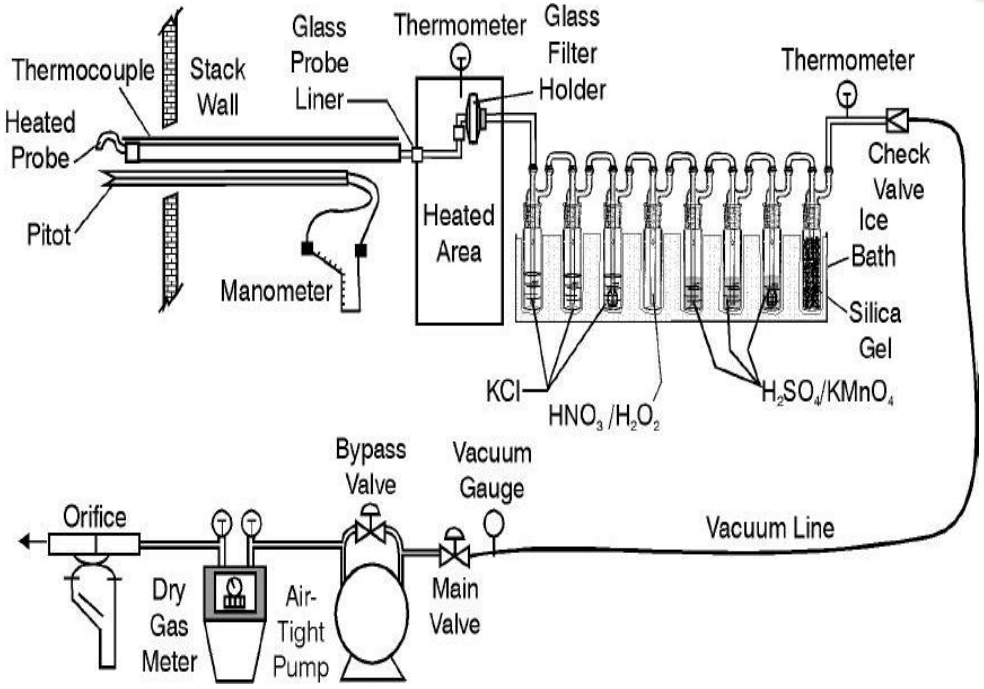
Site	Period	Target pollutants	Instrument
Seoul : urban	2007.02.01~present	TGM (Hg^0 + Hg^{2+}) Hg^{2+} Hg(p)	Tekran 2537A Denuder Quartz filter
Chuncheon : rural	2007.03.01~present	TGM (Hg^0 + Hg^{2+}) Hg^{2+} Hg(p)	Gold traps Denuder Glass fiber filter
Ganghwa Island : background	2008.02.20~present	TGM (Hg^0 + Hg^{2+})	Tekran 2537A

Experimental Method

Emission from Anthropogenic sources

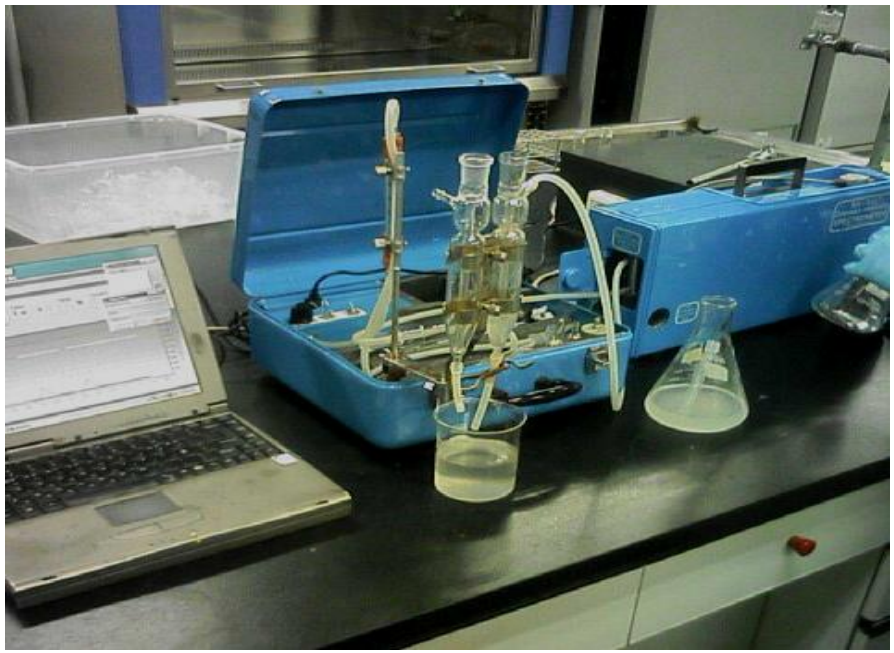
Sampling from Point sources

- Ontario Hydro Mtd. For speciation of Hg



Analysis of Hg

- Cold Vapor Atomic Absorption



Research Approach – Anthropogenic Emission in Korea

✓Determination of Emission Factor from the measured concentration

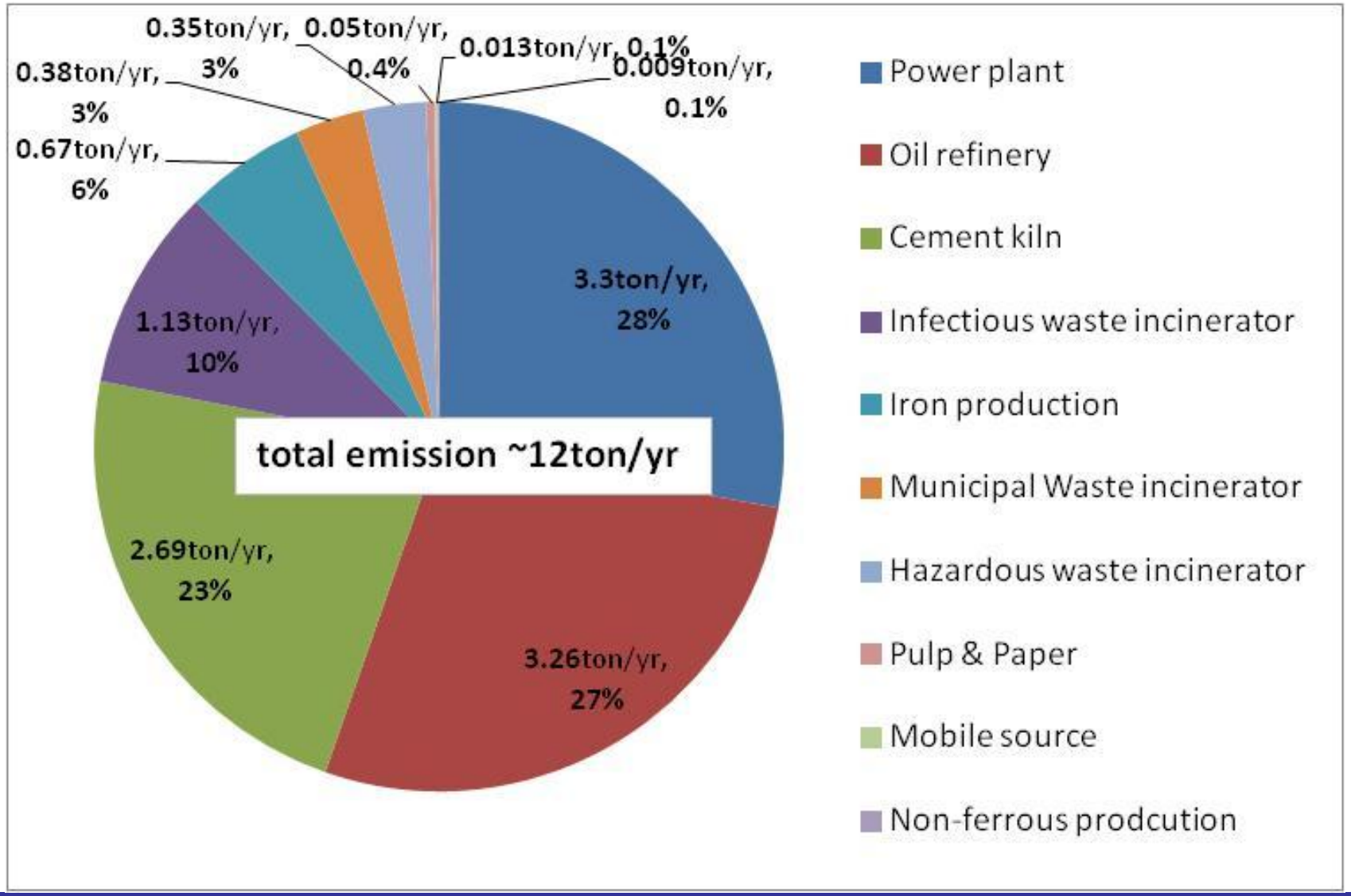
✓Estimates of yearly emission rate based on activity of the facilities

$$EF\ (mg-Hg/ton) = \frac{Hg\ conc.(mg/Sm^3) \times Exhaust\ gas(Sm^3/hr)}{Coal\ Fuel\ (ton/hr)}$$

$$Emission\ rate(mg-Hg/yr) = EF\,(mg-Hg/ton) \times Activity\,(ton/yr)$$

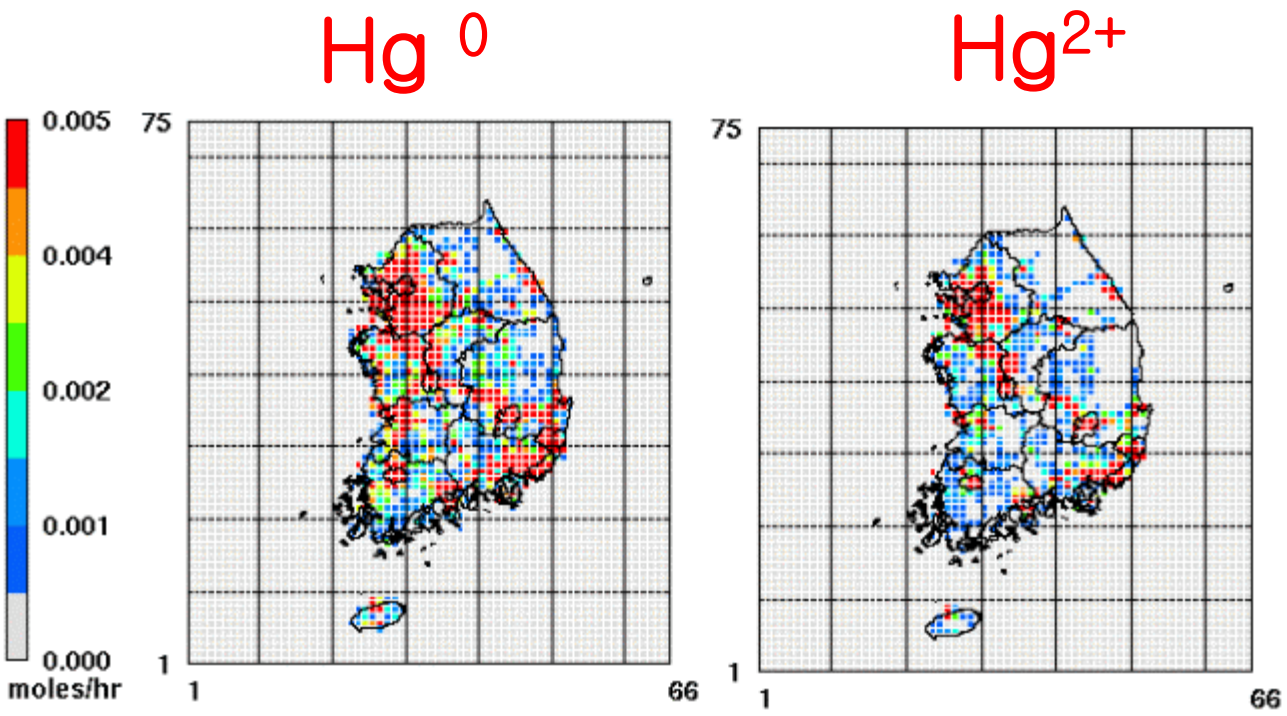
Result of the study (1)

Hg Emission from Anthropogenic Sources in Korea



Anthropogenic emission data(1)

Emission from Anthropogenic Sources in Korea

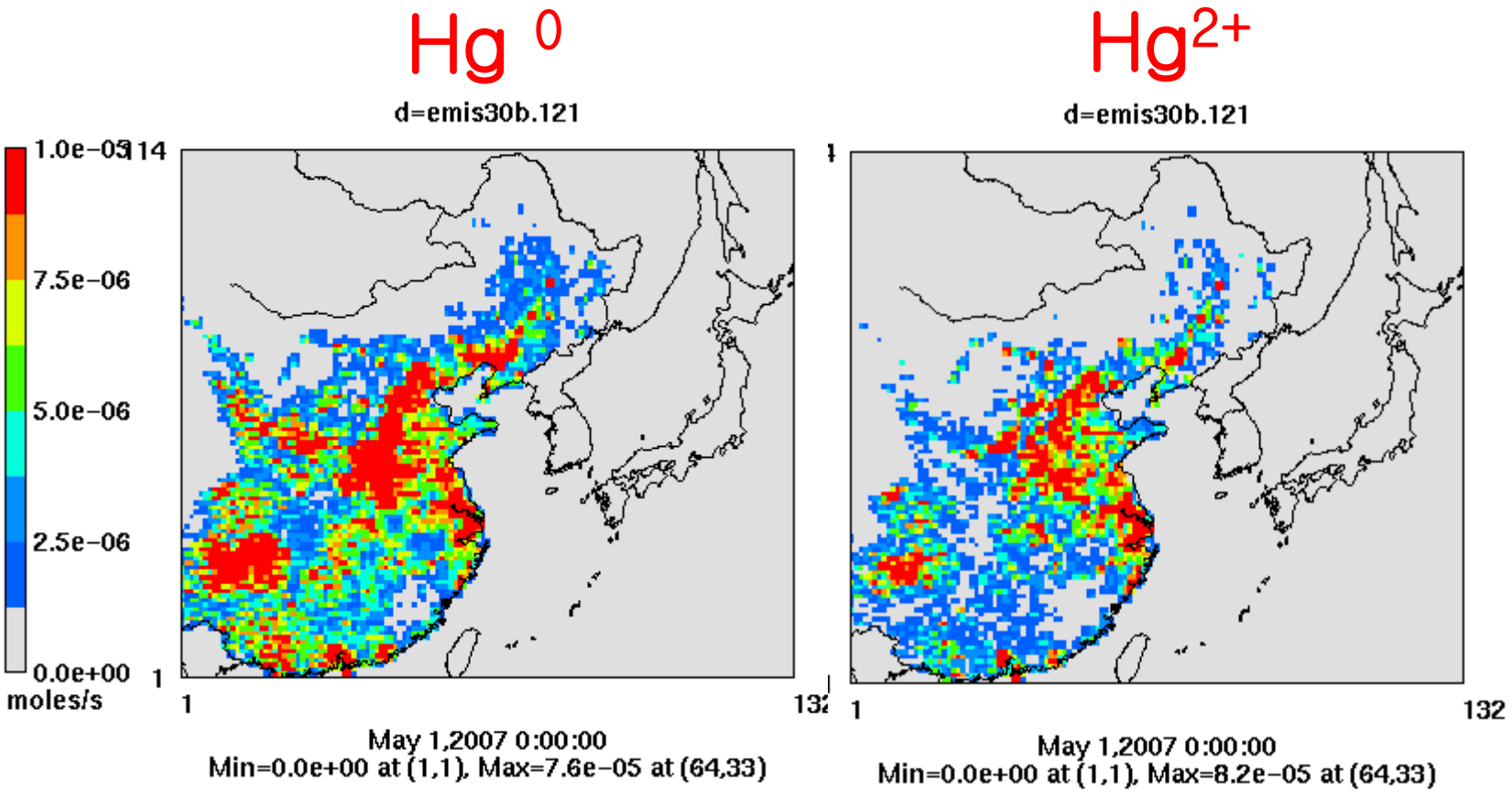


Distribution of Hg emission in Korea

Anthropogenic emission data(2)

Emission from Anthropogenic Sources in China

Emission distribution of Hg0 and Hg^{2+}in China (unit : moles/sec)



Asia inventory dataset by CGRER (Center for Global & Regional Environmental Research)

Estimates of Natural Emission

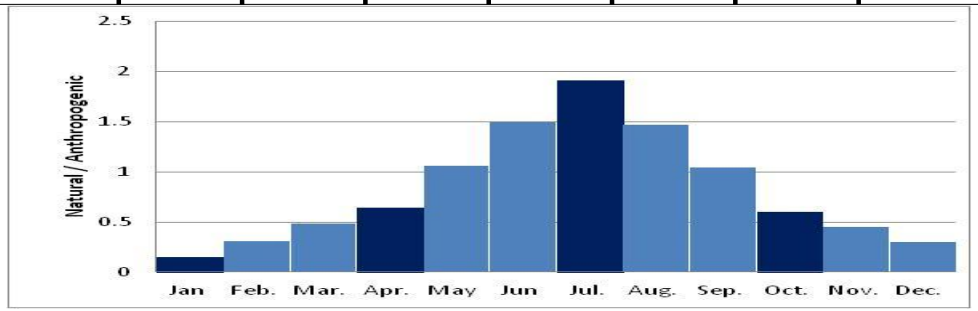
✓Natural emission proportional to Hg content in soil, which would be mainly determined by dry deposition

✓Natural emission in East Asia ~ 734 tons/yr, even larger than Anthropogenic emission*

✓ 30 tons in January; 61 tons in April; 126 tons in July; 61 tons in October*

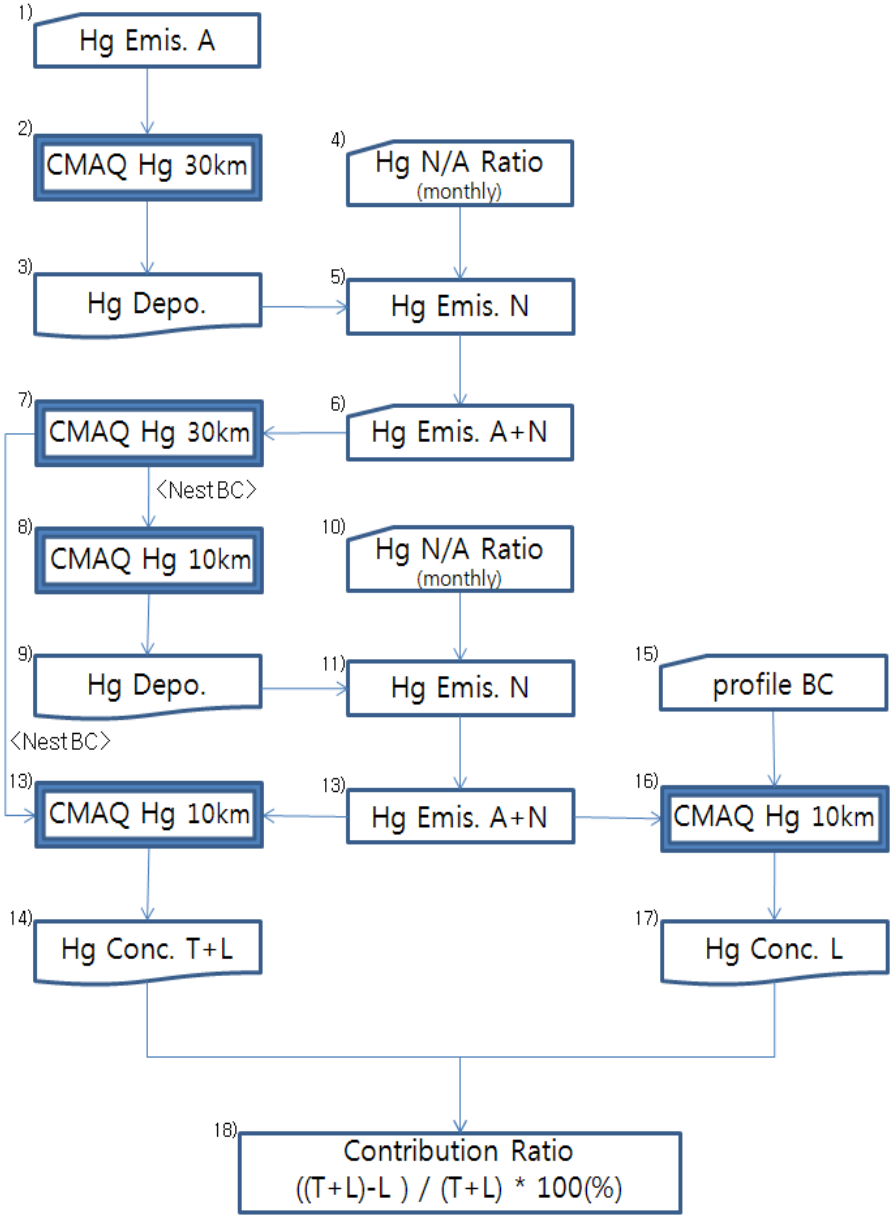
☞Monthly natural emission was estimated by interpolation from the reported ratio of natural to anthropogenic emission

Month	Jan	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Natural E. / Anthrop. E.	0.15	*0.31*	*0.48*	0.64	*1.06*	*1.49*	1.91	*1.47*	*1.04*	0.6	*0.45*	*0.3*



* Suraj et al. (2008)

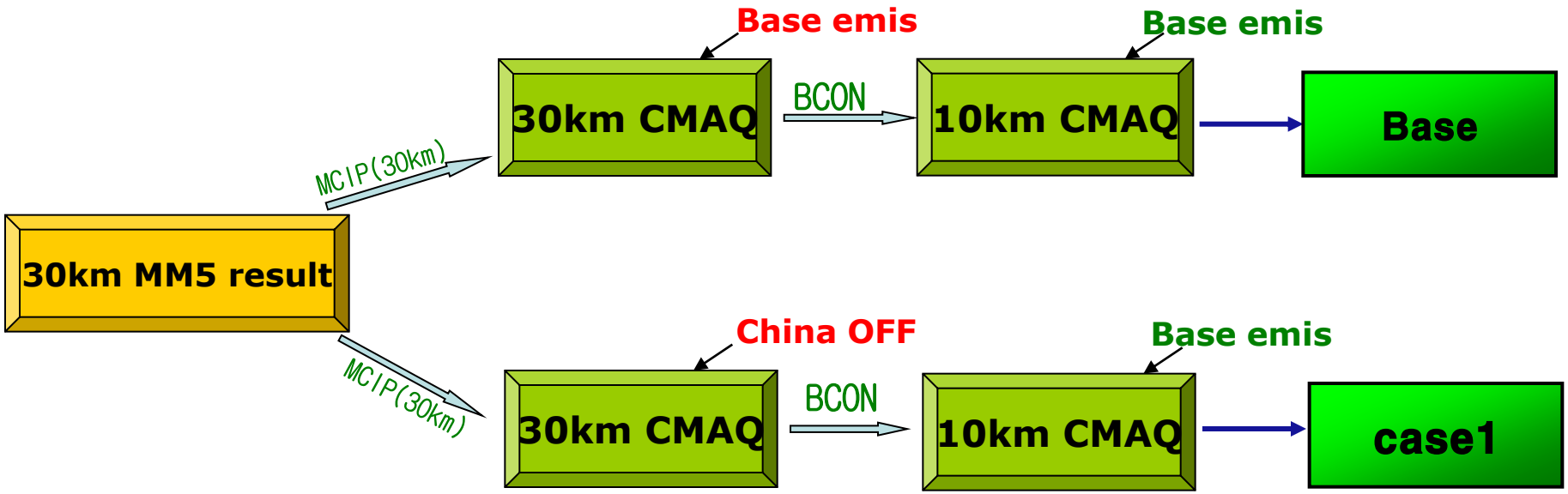
Research Approach



1) Anthropogenic Emission
2) CMAQ modeling 30km
3) Dry deposition 30km
4) Ratio of Natural to Anthropogenic emission
5) Natural emission 30km
6) Input of total emission (natural + anthropogenic)
7) CMAQ modeling 30km
8) Nesting of 30km CMAQ and 10km CMAQ Korea
9) Deposition in Korea 10km
10) Ratio of Natural to Anthropogenic emission
11) Natural emission 10km
12) Input of total emission (natural + anthropogenic)
13) CMAQ 10km Korea (Natural + anthropogenic)
14) CMAQ result (transported + domestic)
15) Profile of Troposphere Background (default)
16) CMAQ (only domestic emission)
17) CMAQ result (domestic only)
18) Calculation of Contribution ratio

Research Approach

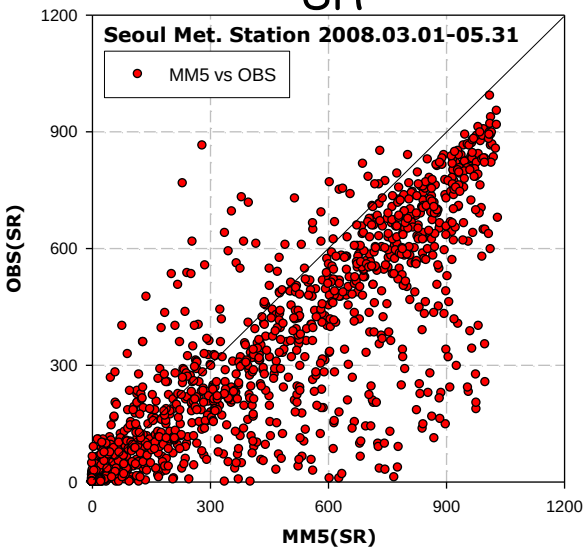
- 30, 10km CMAQ-Hg & 30km MM5
- Modeling period : 2008, 2009
- contribution ratio (CR) estimated



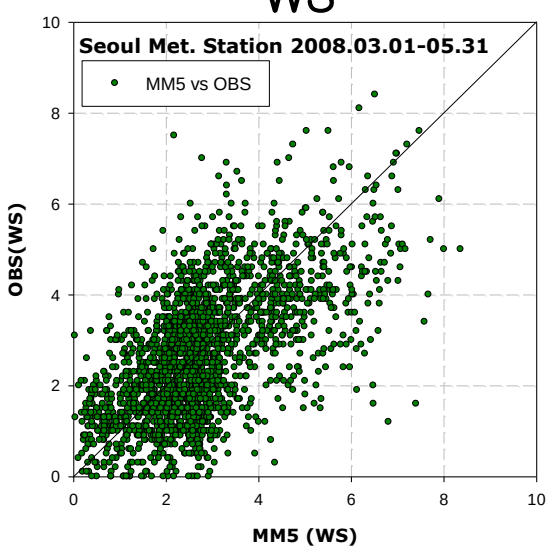
Evaluation of the model

Meteorological model

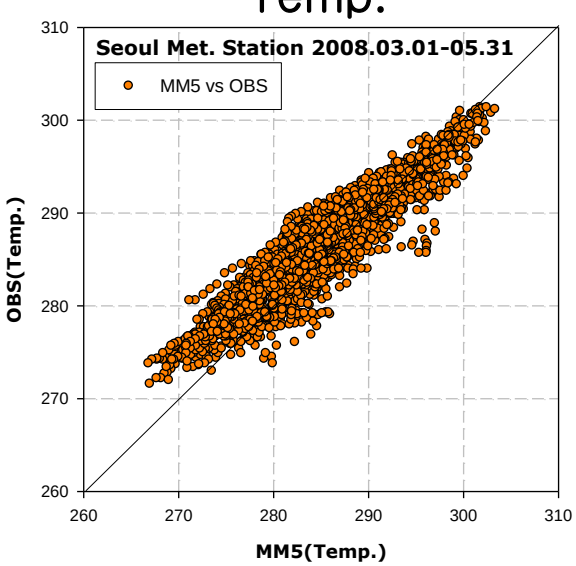
SR



WS



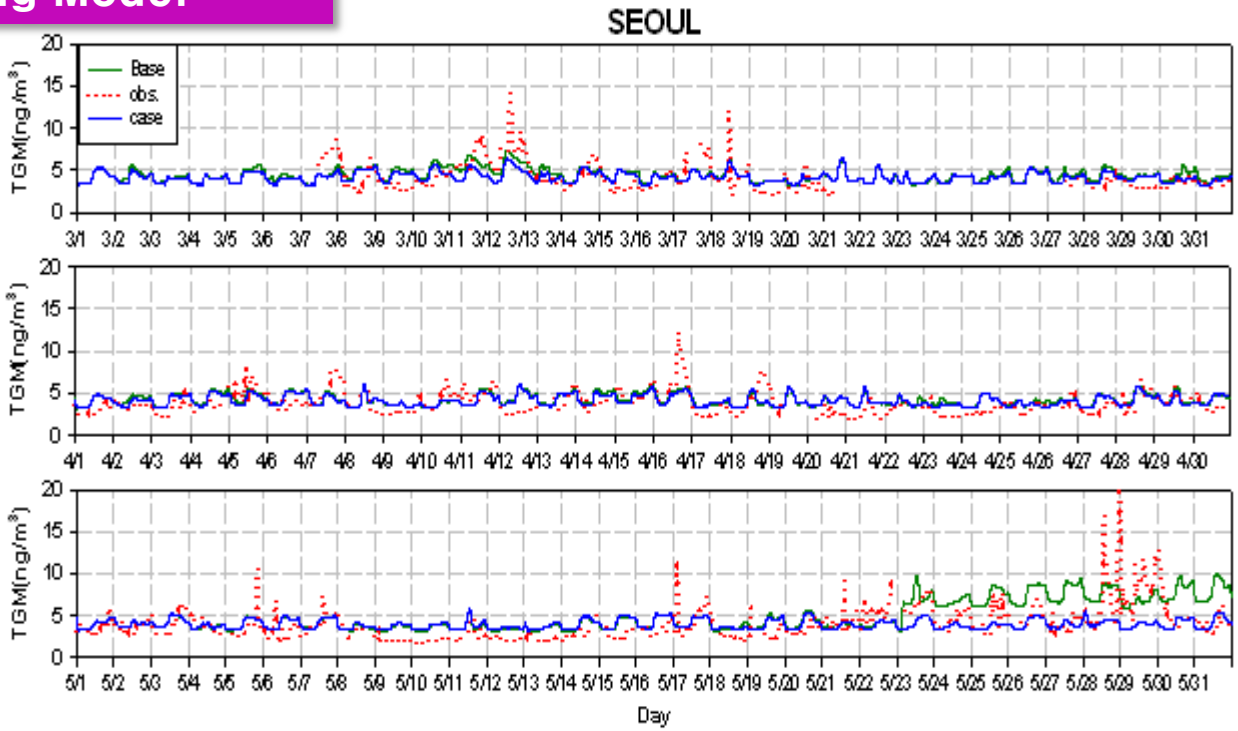
Temp.



- Scattering of hourly modeling data against observation
  - ✓ Solar radiations deviated under cloudy condition , r = 0.91
  - ✓ Wind speeds deviated at night, r = 0.61
  - ✓ Temperature is underestimated esp. for low value, r = 0.93

Evaluation of the model : ambient Hg level

CMAQ-Hg Model



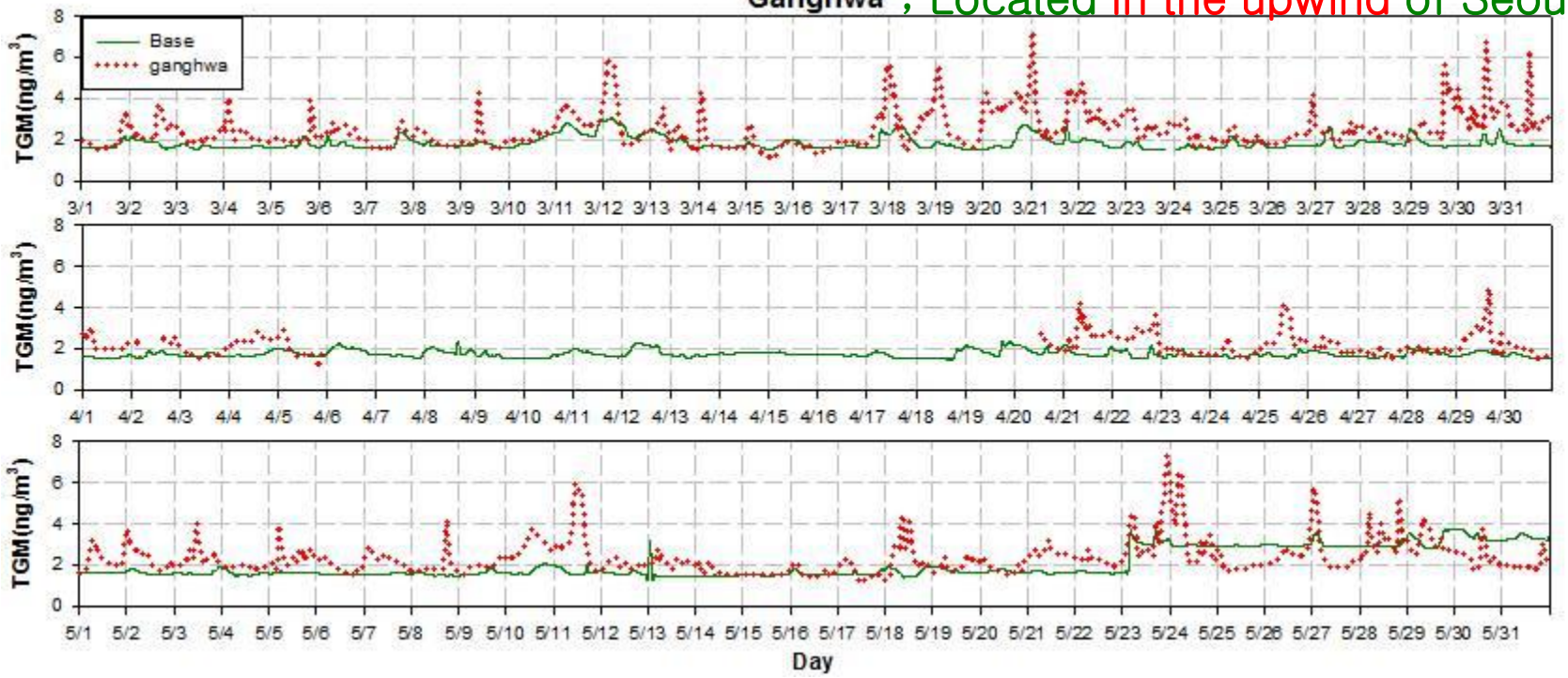
The comparison of Modeled vs. Observed hourly TGM at Seoul, March~May, 2008.

• **Generally similar pattern btw. Modeling & the observed, but not for high concentrations. (r = 0.48)**

Evaluation of the model : ambient Hg level

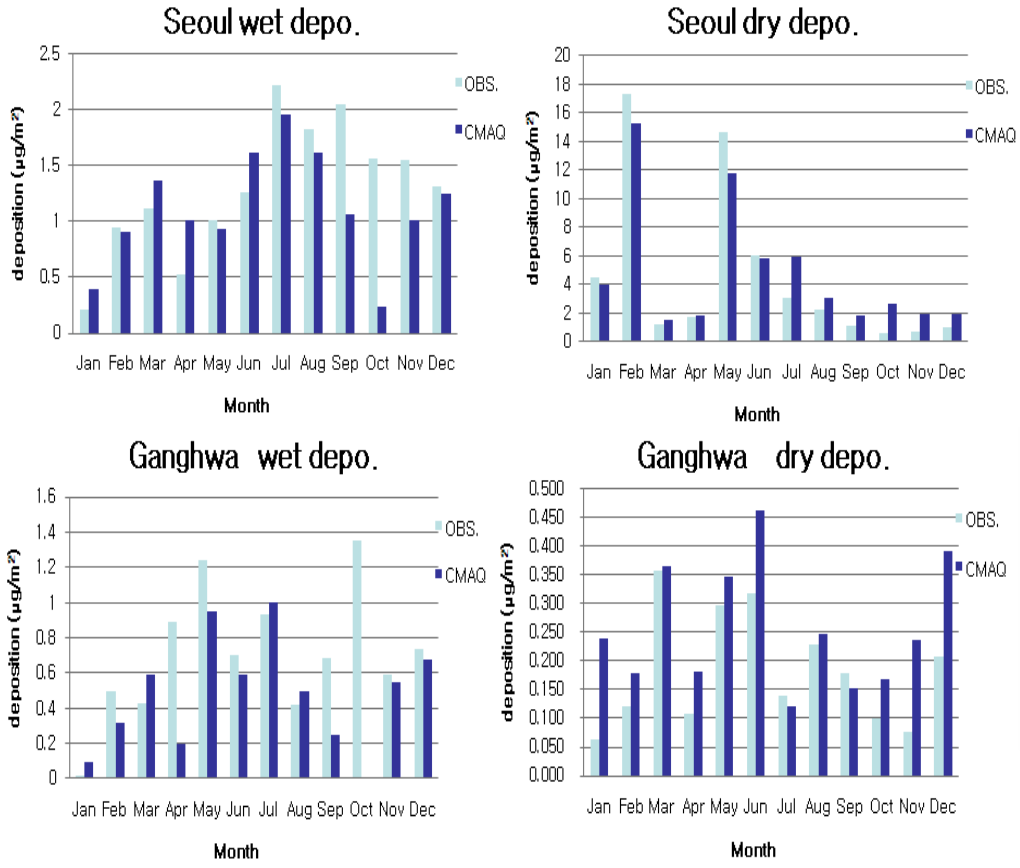
CMAQ-Hg Modeling

Ganghwa ; Located in the upwind of Seoul



- Time series of TGM at Ganghwa shows lower concentration than those at Seoul.
- Generally similar pattern btw. Modeling & the observed, but not for high concentrations. (r= 0.33)

Evaluation of the model : deposition



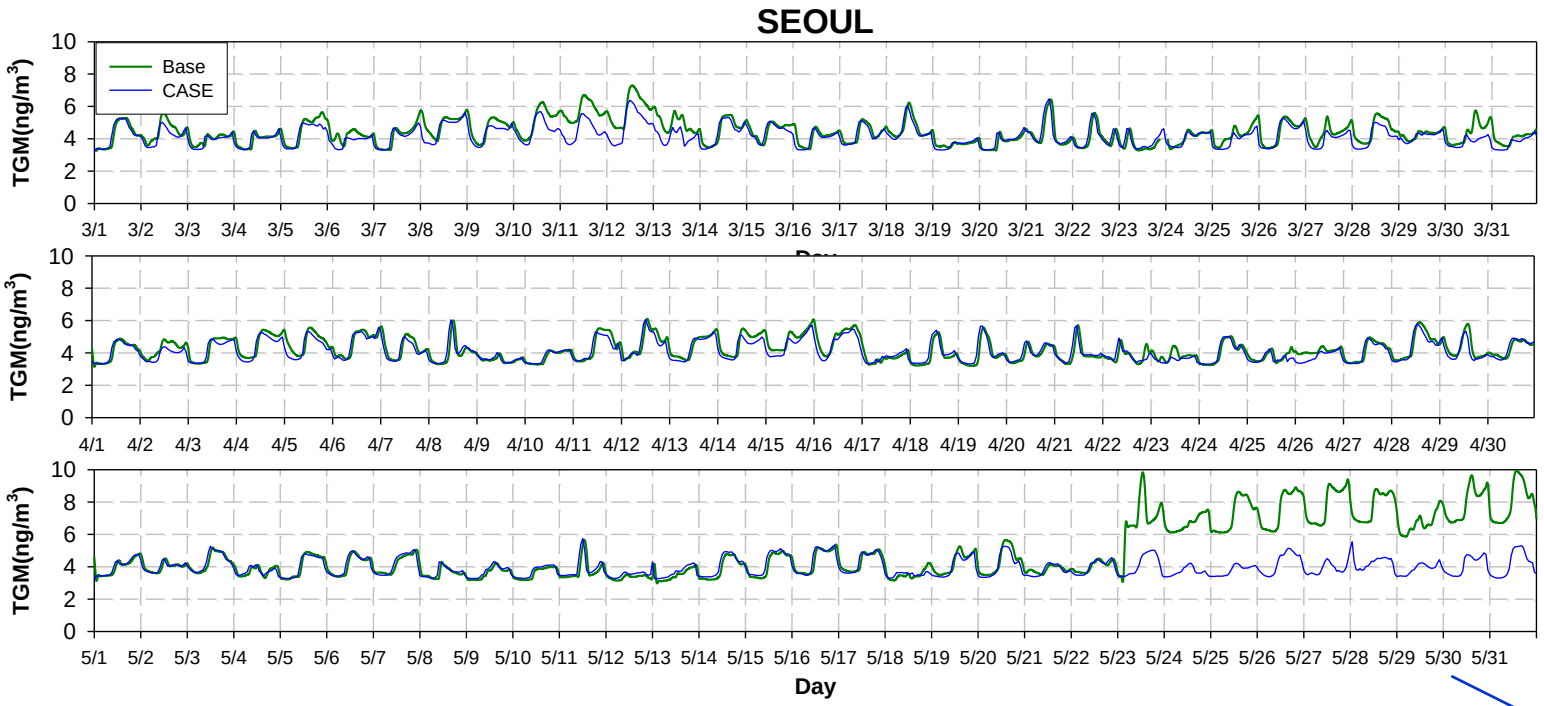
- Comparison of Modeled and Observed deposition

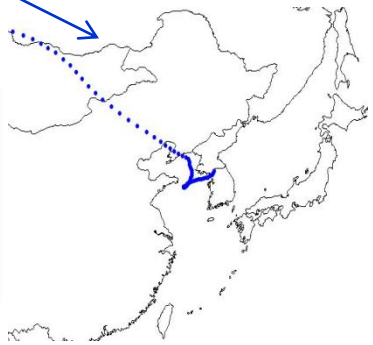
- Dry deposition fit well

- Underestimates wet–deposition in fall season (uncertainty of rainfall)

Results of the study

Long-range transport Cases





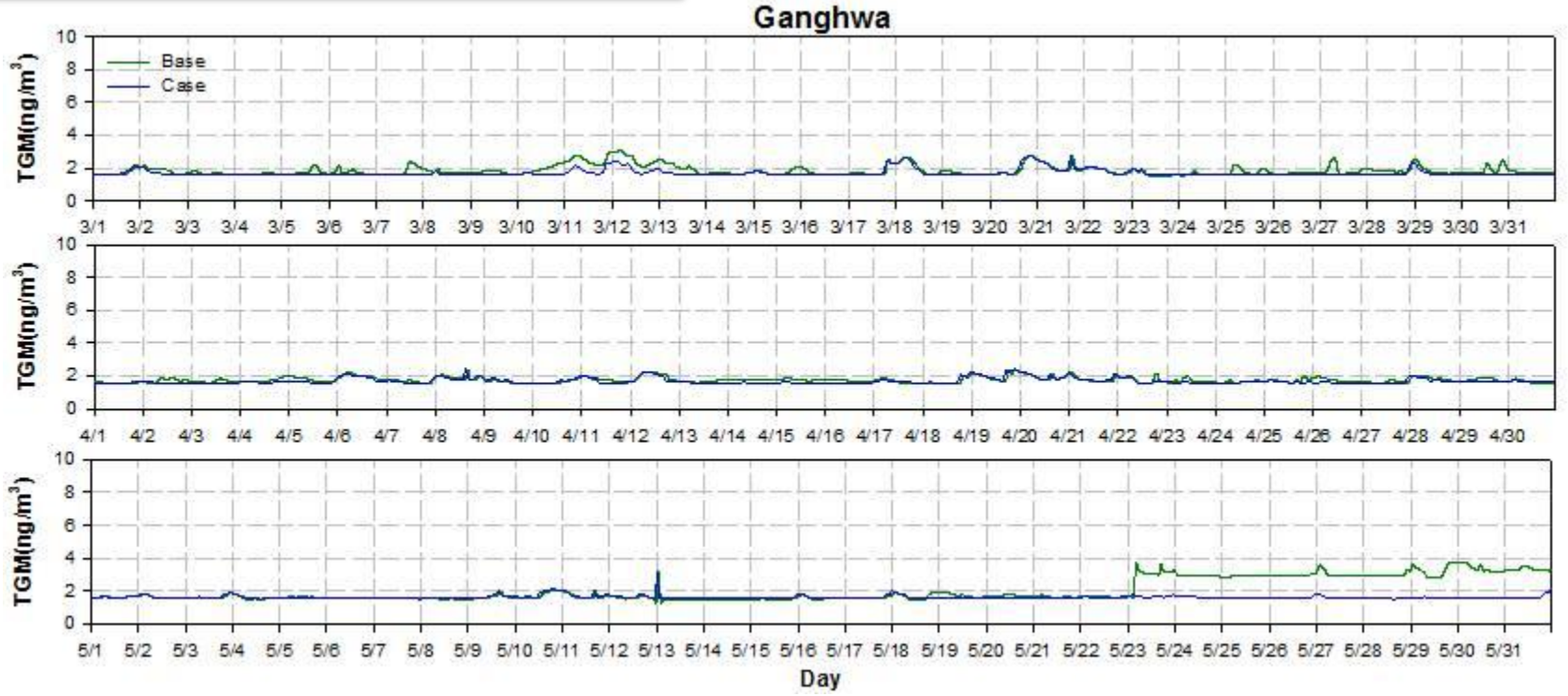
- Large effect on Seoul; March 10~14. and May 23~ 31

  => Long-range transport from China

Results of the study

Long-range transport Cases

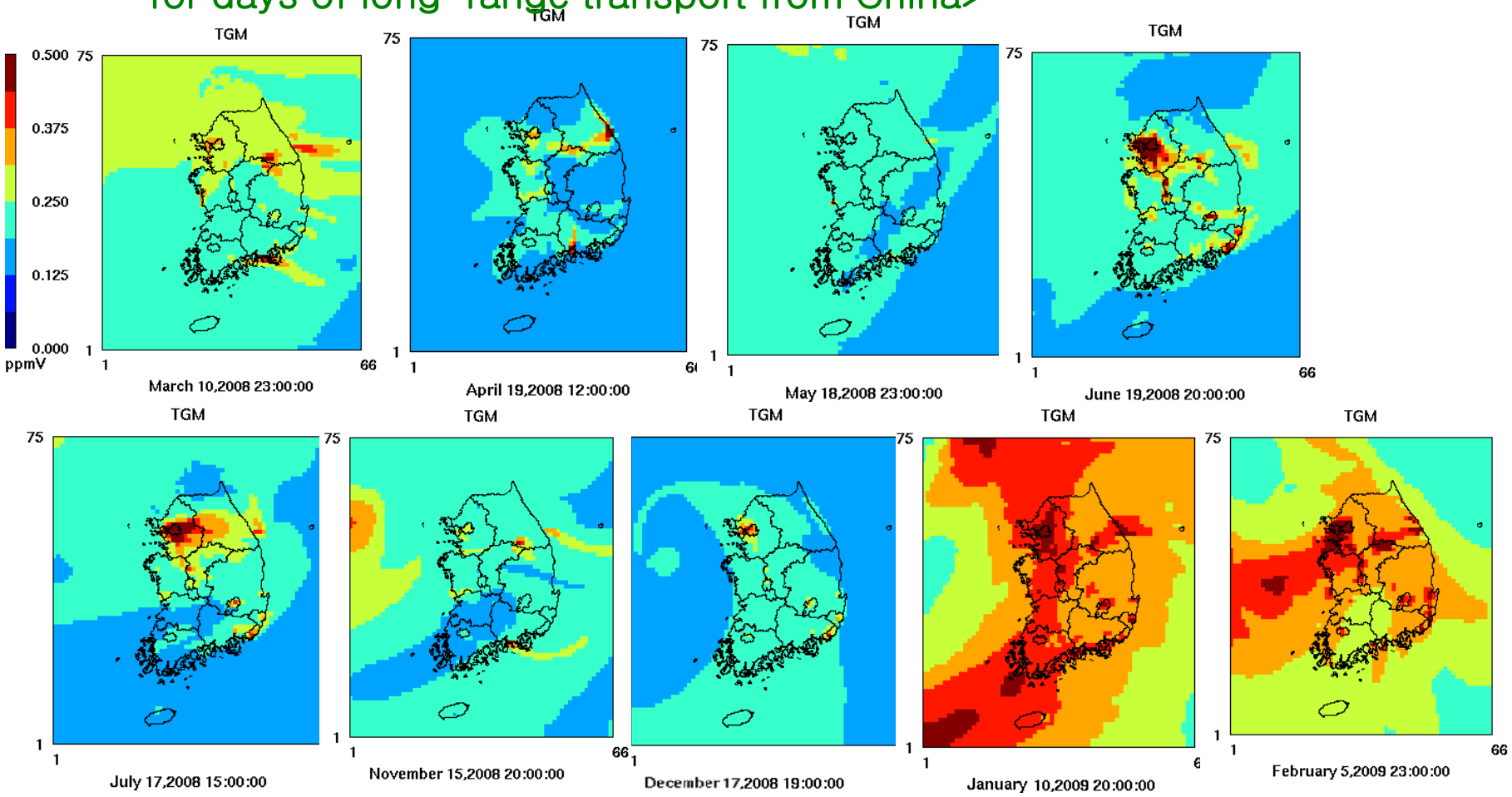
Effect of long-range transport



- Similar trend is observed at Ganghwa island(upwind of Seoul) during the same period.
- Without long ra nge transport from China, Hg concentration close to background level.

Results of the study

<Horizontal distribution of atmospheric Hg concentration for days of long-range transport from China>



- Westerly wind dominating except for April 19.
- High concentration above the West Sea, esp. in Jan.10 and Feb. 5.

Results of the study

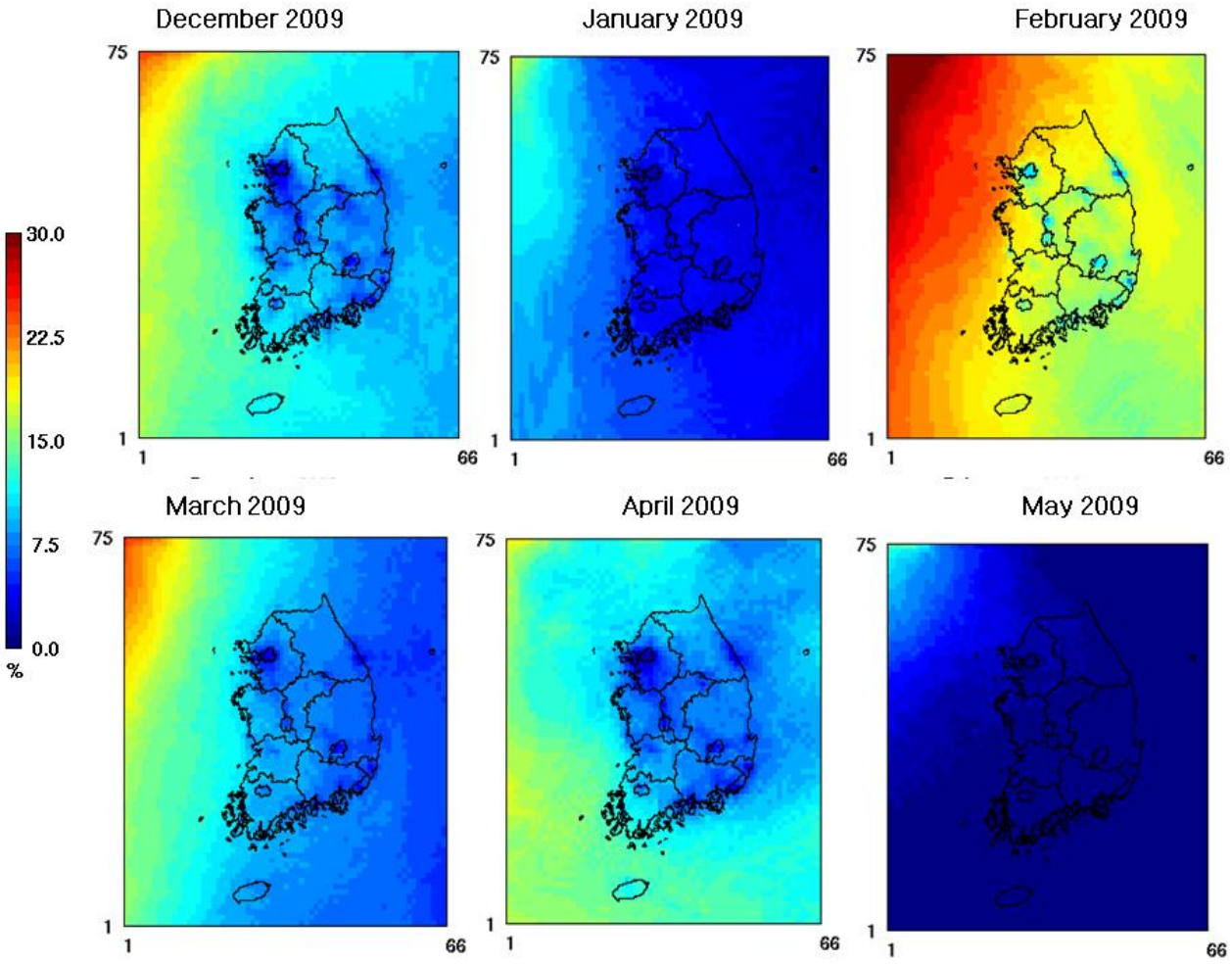
Case of long-range transport from China

2008	Frequency of long range transport case	
	2008	2009
Jan.	6	3
Feb.	5	7
Mar.	2	5
May	4	5
June	2	4
July	6	2
Aug.	1	1
Sep.	3	5
Oct.	1	5
Nov.	7	5
Dec.	8	4
Sum	45/yr	46/yr

- Frequency : based on horizontal distribution by CMAQ-Hg
- More frequent in winter when northwest wind was dominant.

Results of the study

Monthly Contribution Ratio(CR, %) of trans-boundary Hg in Winter and Spring, 2009

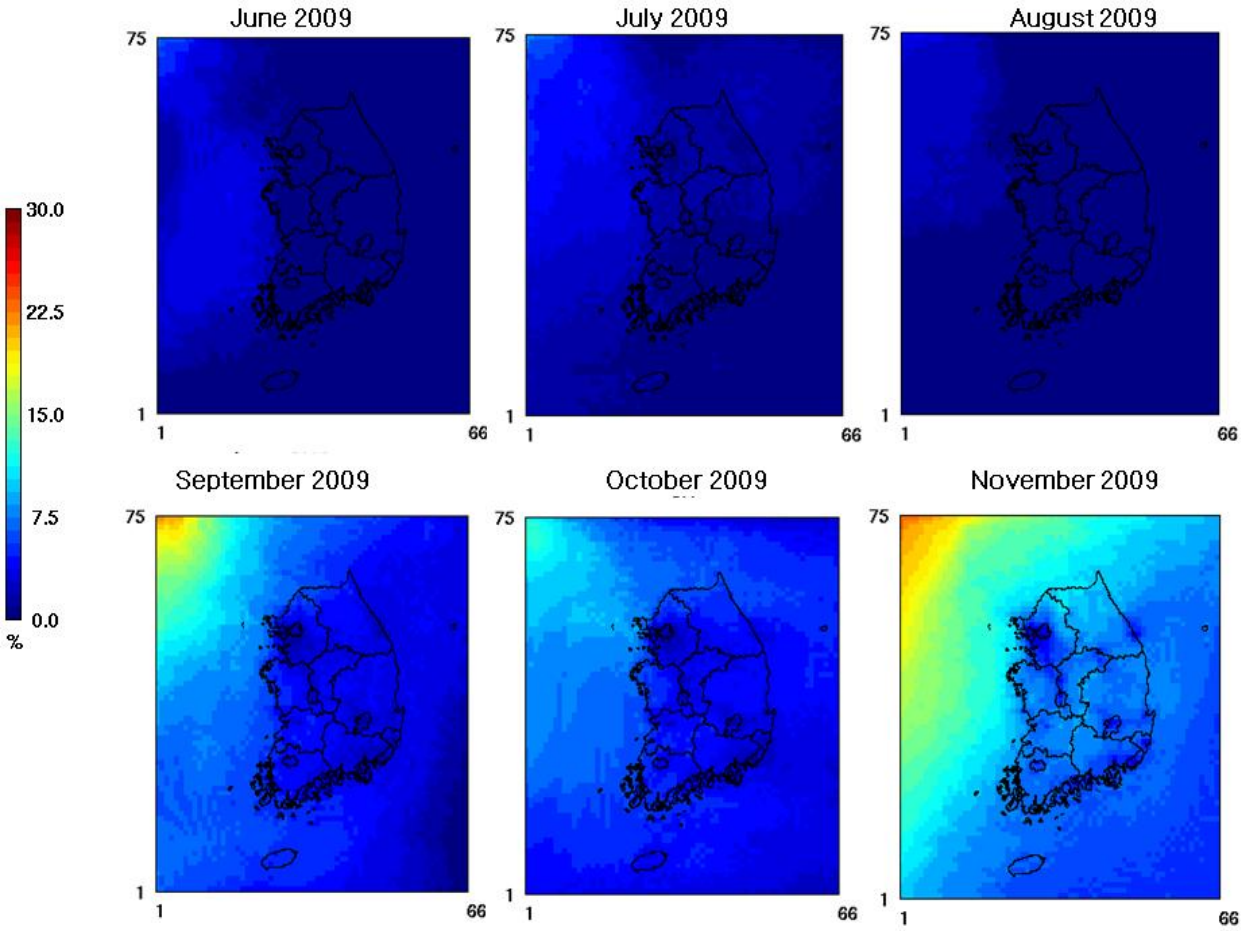


- February
  - ✓ 12~15% , Inland
  - ✓ 18%, West coast
  - ✓ 25% , West sea

$$CR = \frac{(T+L)-L}{(T+L)} \times 100(\%)$$

Results of the study

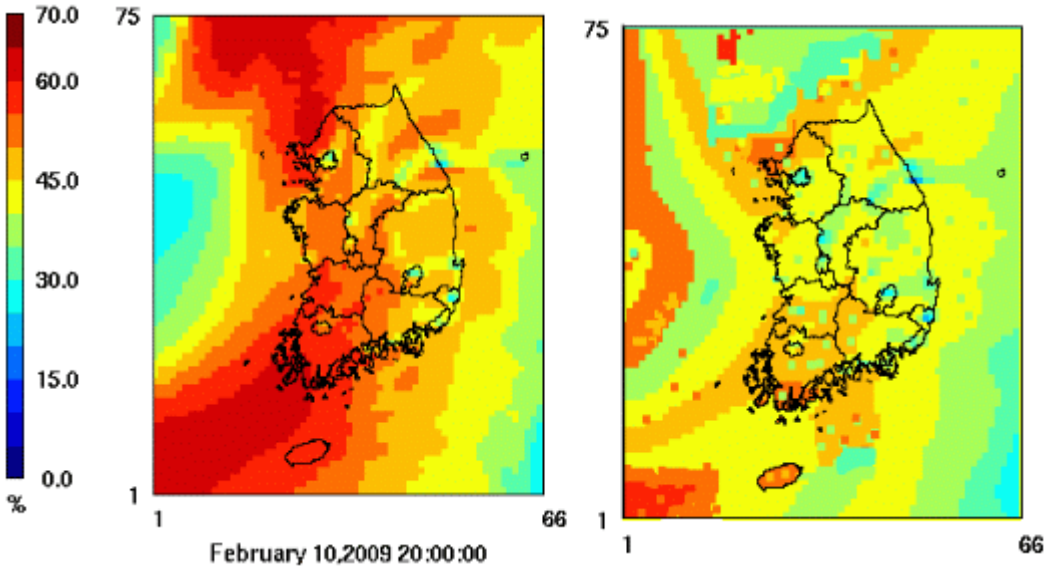
Monthly Contribution Ratio(CR, %) of trans-boundary Hg in Summer and Fall, 2009



- CR in summer & fall lower than that of winter

Results of the study

Contribution Ratio(CR, %) of trans-boundary Hg
on the highest day of the highest Month in 2009

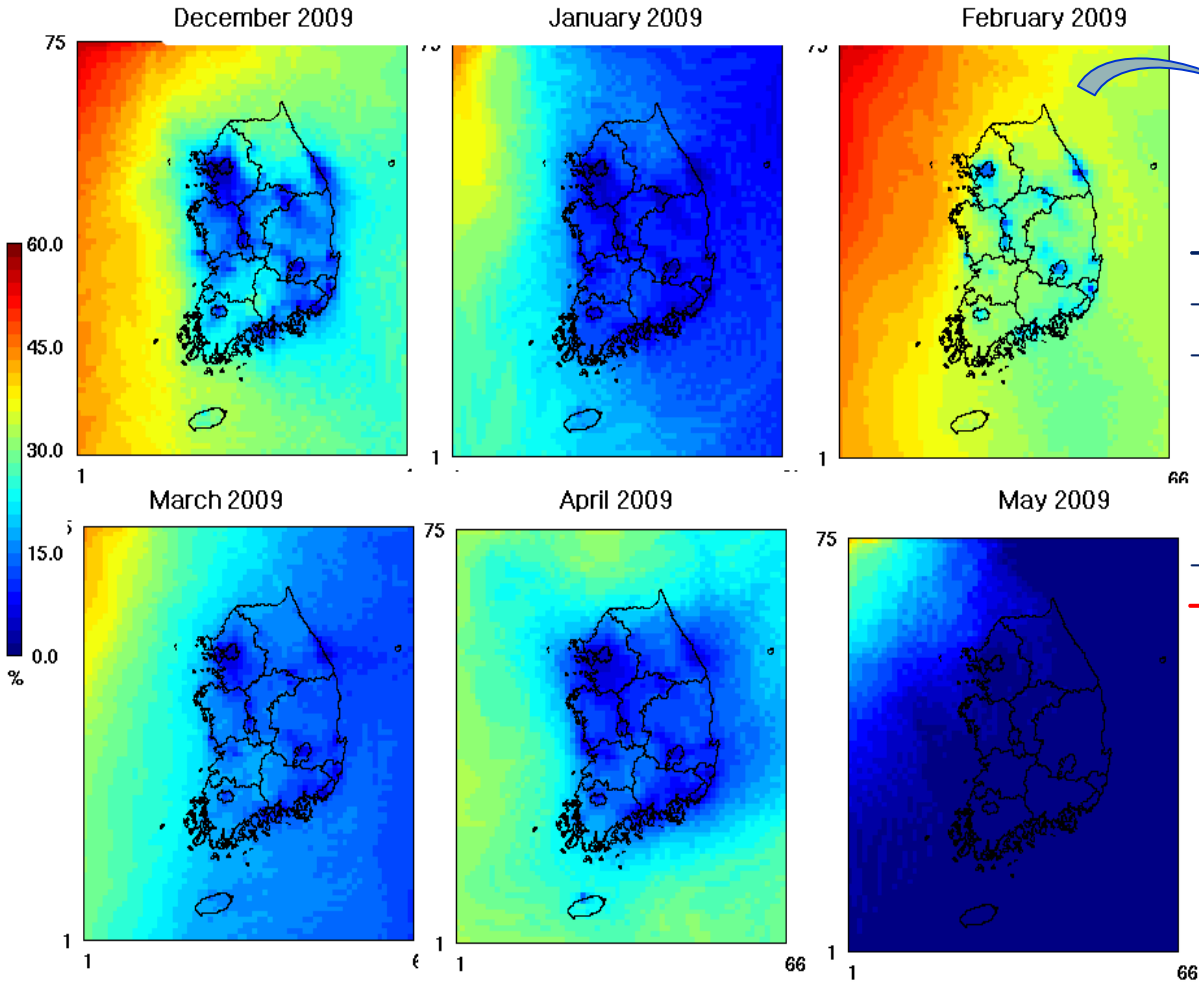


for 1 hr

for 1 day

Results of the study

Monthly Contribution Ratio(CR, %) of trans-boundary Hg with background Hg concentration excluded



- Western coast : > 60%
- Inland w/ local source: 20~30%
- Inland w/out source : ~40%

- without Background level in Troposphere ~1.5 ng/m^3

$$CR = \frac{(T+L-B)-(L-B)}{(T+L-B)} \times 100(\%)$$

Summary of the study

✓ **Total Anthropogenic Hg emission in Korea ~ 12.1 ton/yr**

: Power plants 3.3ton/yr (27.8%), Oil refinery 3.26/yr(27.5%), Cement Kiln 2.69ton/yr(22.7%), Infectious waste incinerator 1.13ton/yr (9.5%), Iron production 0.67 ton/yr(5.7%), Municipal waste incinerator 0.38ton/yr(3.2%), Hazardous waste incinerator 0.35ton/yr(3.0%), Pulp & paper 0.05ton/yr(0.4%), Mobile source 0.013ton/yr(0.1%), Non-ferrous production 0.009ton/yr(0.1%)

✓ **Frequency of long range transport from China based on horizontal distribution ~45 times in 2008, 40% of which occurred in winter,**

when Northwest wind from was dominating

✓**Monthly contribution ratio (CR, %) from China shows**

highest level in February

(west sea 25% > west coast 18% > Inland 12~15%

Limitation of the Present Study

✓ Emission from **North Korea?**

is not included

✓**Data synchronization?**

btw. Emission and Atmospheric concentration of Hg

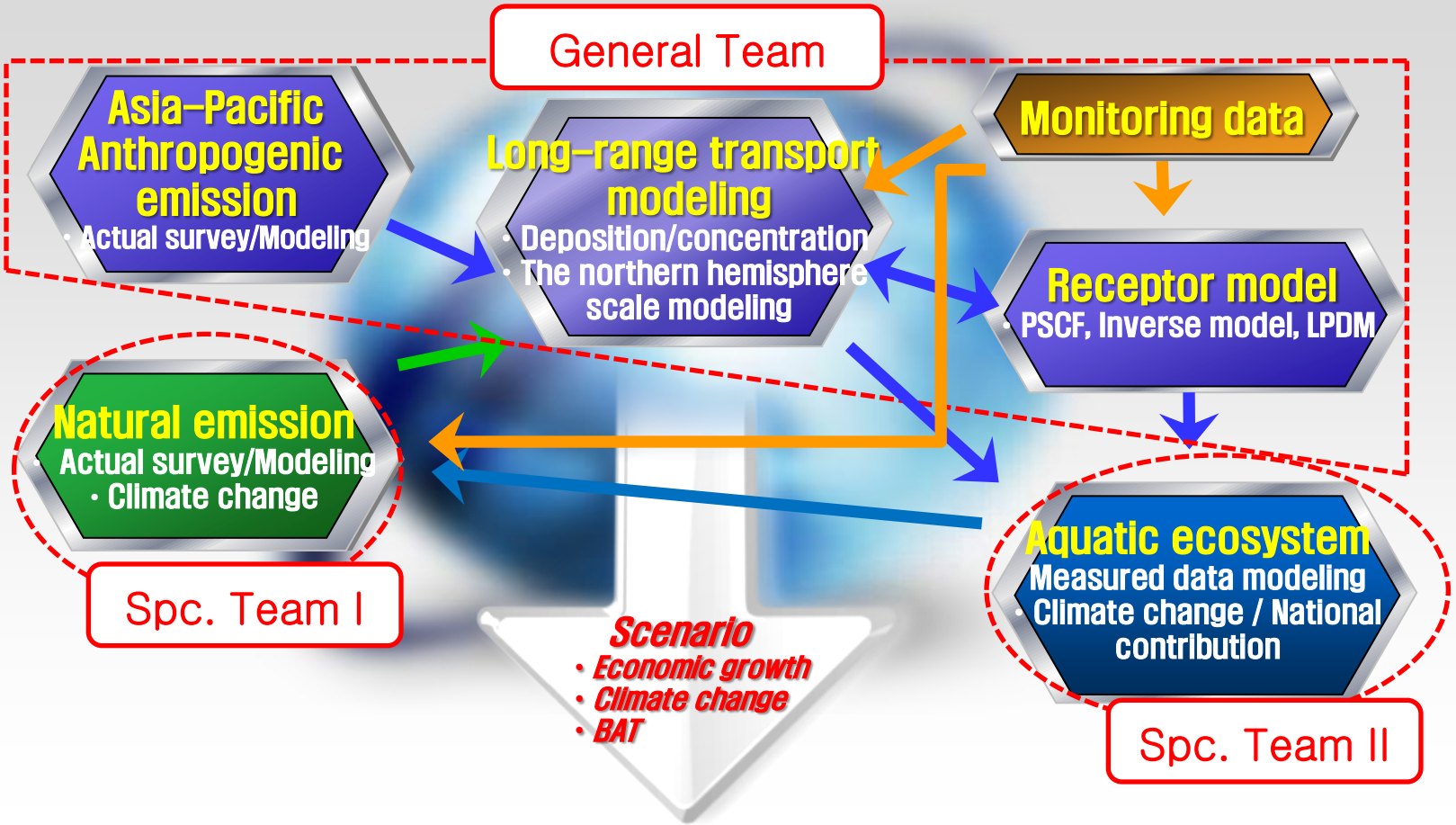
✓ detailed **Natural Emission?**

from actual Hg contents of different land use type is not enough

✓ Impact to the **Aquatic?** Ecosystem?

☞ Being addressed in the next stage of the project.

Further Study



Assessment of contributions between Northeast Asian countries and aquatic ecosystem behavior prediction of Hg

Thank you for your Attention!

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