Joint research Project on Long-range transboundary air pollutants

- progress, outcomes, and future plan -

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I Progress

Air quality in 1980s in ROK

Year	SO_2 (ppb)	CO_2 (ppm)	TSP ($\mu g/m^3$)	NO_2 (ppb)	O_3 (ppb)
1986	54	3.0	183	33	30
1987	56	3.0	175	33	10
1988	62	3.0	179	33	9
1989	56	3.2	149	27	8
Annual Standard	30	25(1hr)	150	50	100(1hr)

History of LTP Project

Sep. 1995

- Hosting a workshop on LTP in Seoul, Korea
- Launching a working group consisting of government officials and experts
- Establishing an interim secretariat of LTP Project at NIER, Korea

July 1996

- Agreements of the 1st LTP Expert Meeting
  - Conduct a joint research of modeling and monitoring on LTP
  - Upgrade the interim secretariat to an official secretariat to support the Working Group more efficiently
  - Adopt the operational principles of Working Group
  - Appoint Korea, China, and Japan as the member countries of the Working Group for LTP

Nov. 1997

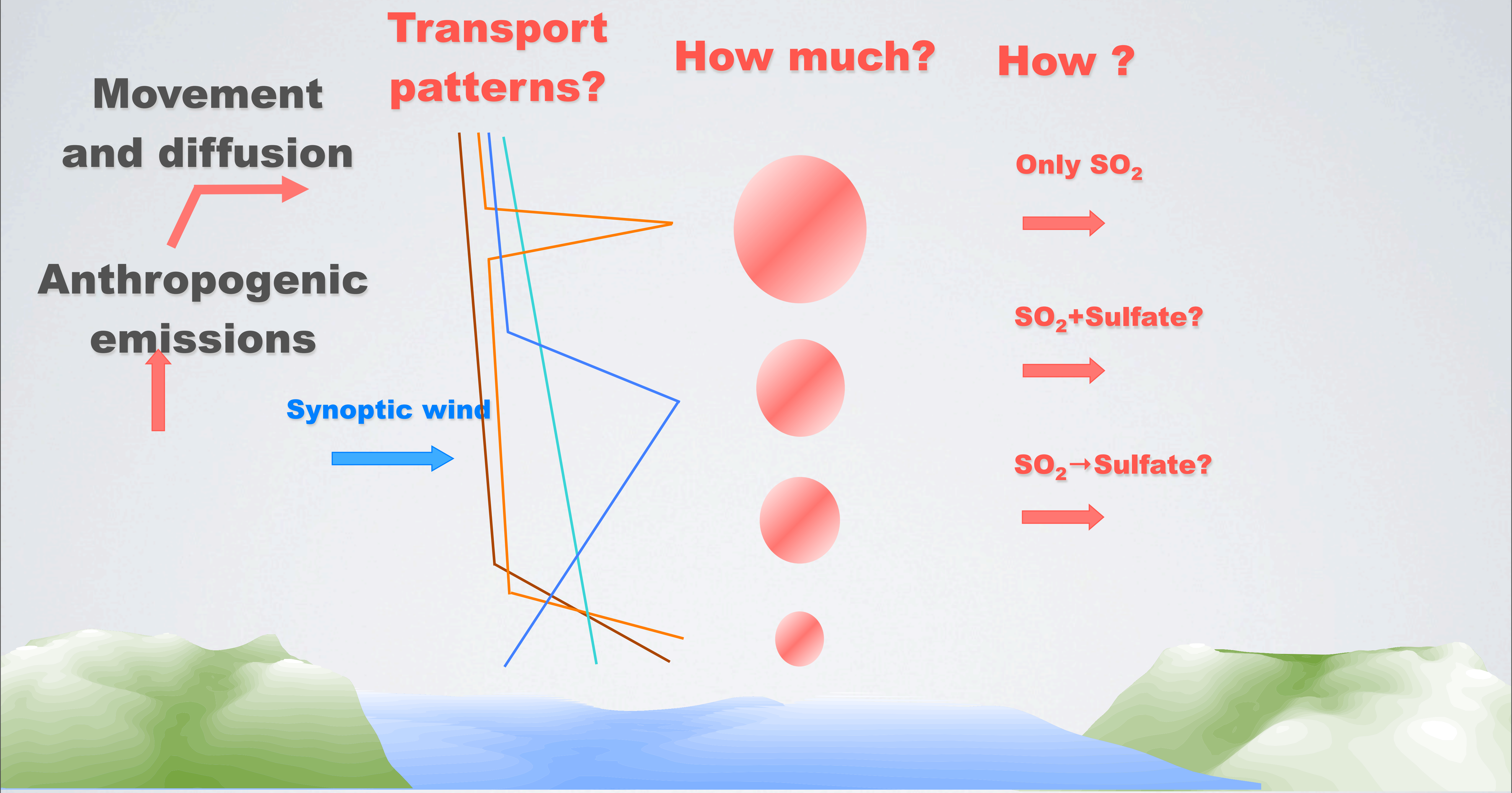
- The 2nd LTP Expert Meeting

  Launch sub-working groups for modeling and monitoring

2000 ~ 2004
2005 ~ 2007
2008 ~ present

- The 1st stage joint study
- The 2nd stage joint study
- The 3rd stage joint study

Questions in LTP project

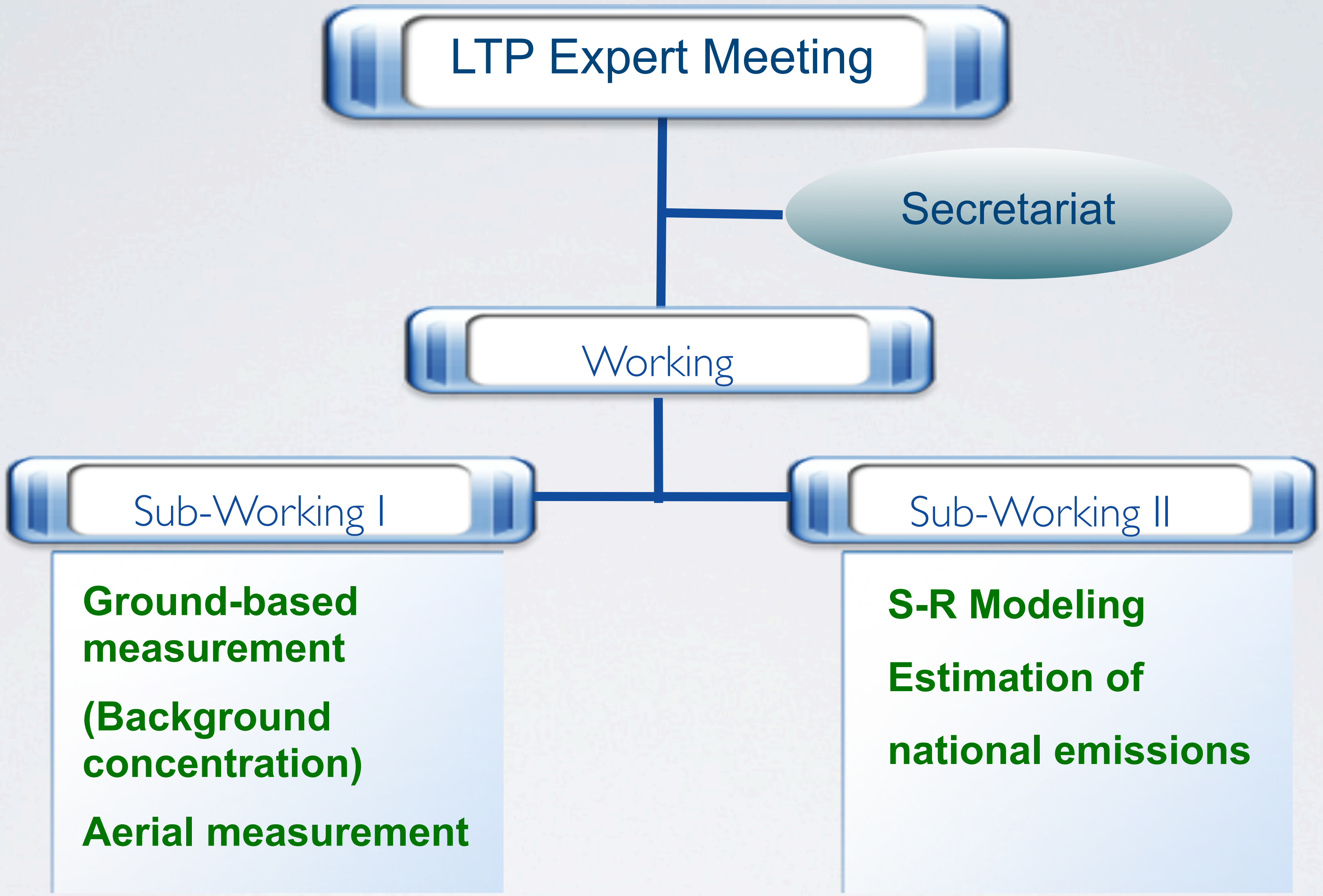


Outline of LTP Project

International cooperation for improving air quality in Northeast Asia

1st stage ('00~'04)	Establish a foundation for joint research Establish database on the concentration ,emissions of air pollutants and a modeling system
2nd stage ('05~'07)	Estimate emissions among three countries Research on monitoring and modeling Produce S-R relationships quantitatively among countries
3rd stage ('08~'12)	Research on the impacts of NOx, O3, and PM
Expected effects	Predict the impacts of long-range air pollutants on the air quality of Korea Predict the cross impacts of LTP Construct air pollutant monitoring system in Northeast Asia ***Make an emission reduction scenario in Northeast Asia***

Structure of Organization



➢ LTP has made many achievements in the fields of monitoring, modeling and emission inventory up until now. However, it still needs some systematic enhancement, for example, by restructuring the organization into Working Group and Task Force Team.

History of LTP

1996

1997

MOEK, NIER, KIST, Yunsei Univ, Konkuk Univ, GIST, MEP, CRAES, Pecking Univ, CNEMC, MOEJ, ACAP, Tokyo Univ and etc.

2000

2001

2002

2003

2004

2005

2006

2007

2008

2009

2010

2011

2012

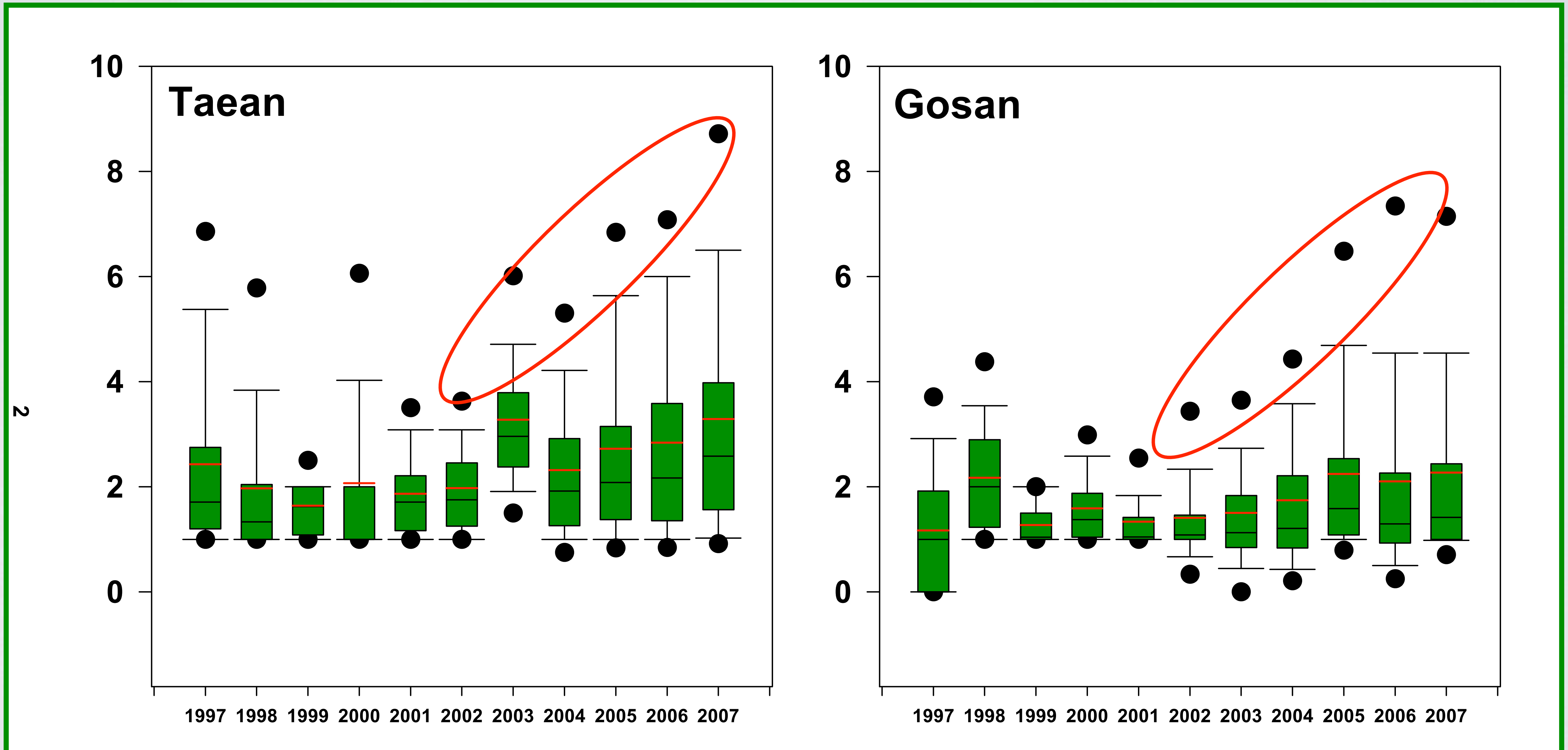
Ⅱ Outcomes

Surface measurement sites

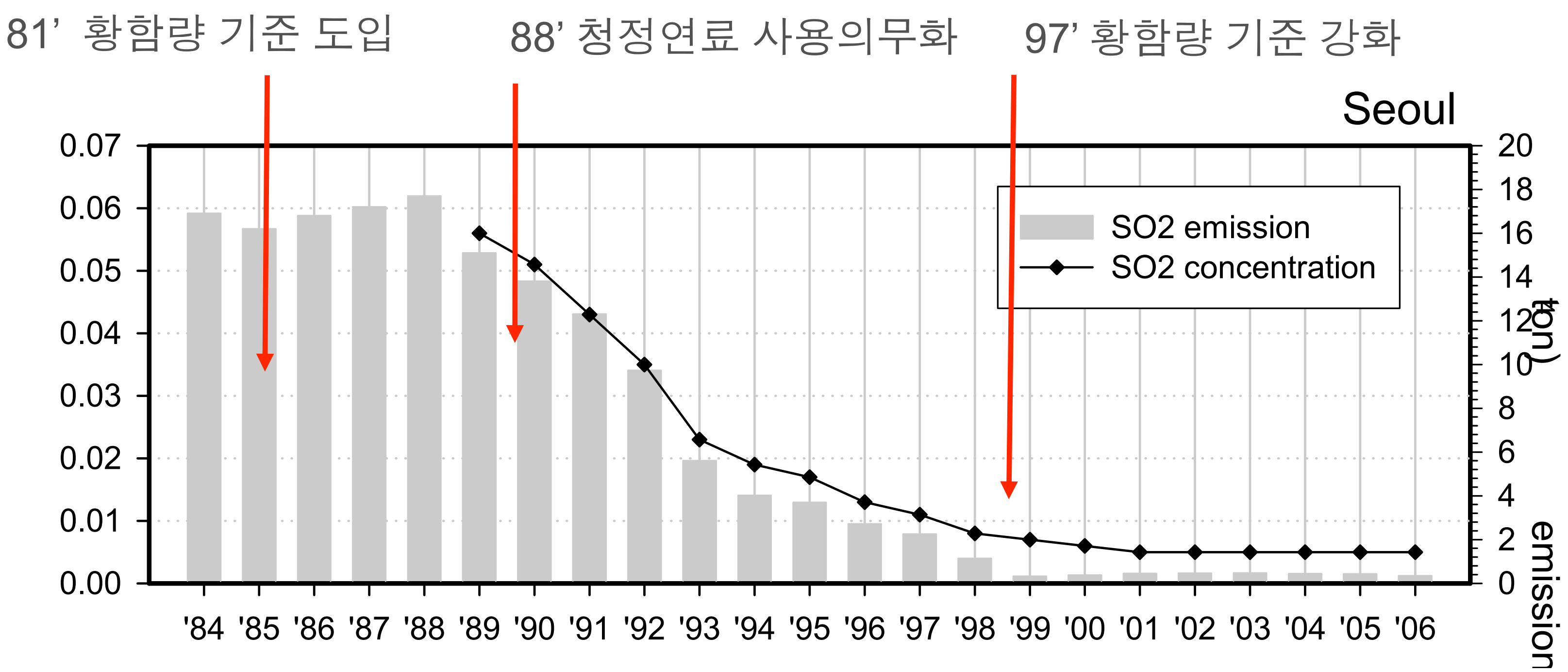
Measurement items

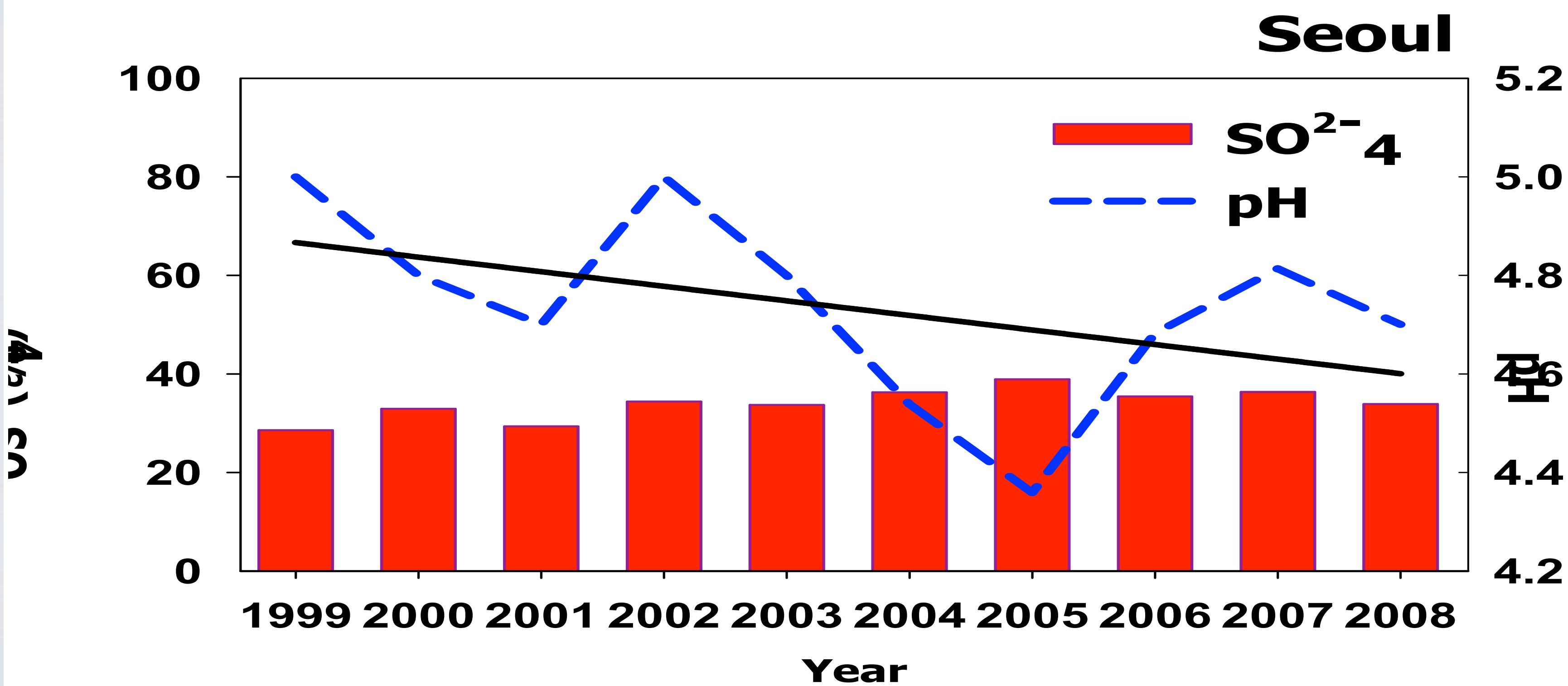
items	Size	Sampler	instruments
Mass concentrations	PM_{10}, $PM_{2.5}$	URG sampler	Microbalance (Sartorius AG, SC2)
	0.056~18 μm, 8 channel	MOUDI sampler	
Ion (SO_4^{2-}, NO_3^-, Cl-, Na^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+})	PM_{10}, $PM_{2.5}$	URG sampler	Ion chromatogrphy (Dionex, DX-120)
	0.056~18 μm, 8 channel	MOUDI sampler	
Gas (NH_3, HNO_3 etc)		URG sampler	Ion chromatogrphy (Dionex, DX-120)
Molecule (Al, Fe, Mg, Mn, Cu, Zn, Pb, Ni, Cd, Cr, Ba, Ti, S, Be, Co, Se, Sr, As)	PM_{10}, $PM_{2.5}$	URG sampler	PIXE
Carbon (OC, EC)	$PM_{2.5}$	URG sampler	OC/EC analyzer (Sunset, 3014)
Number concentrations	0.25~32 μm		Grimm aerosol spectrometer
VOCs	TO-14A (31)	Mini sampler	Gas chromatography
Gas species (SO2, O3, NOx, CO)			Mandatory
Meteorological variables (temp, relative humidity, wind speed/direction)			Mandatory

Annual mean [SO_2] trends in background sites in ROK (1997~2007)



Effect of LRT sulfur on acid rain





- Still acid rain in NE Asia

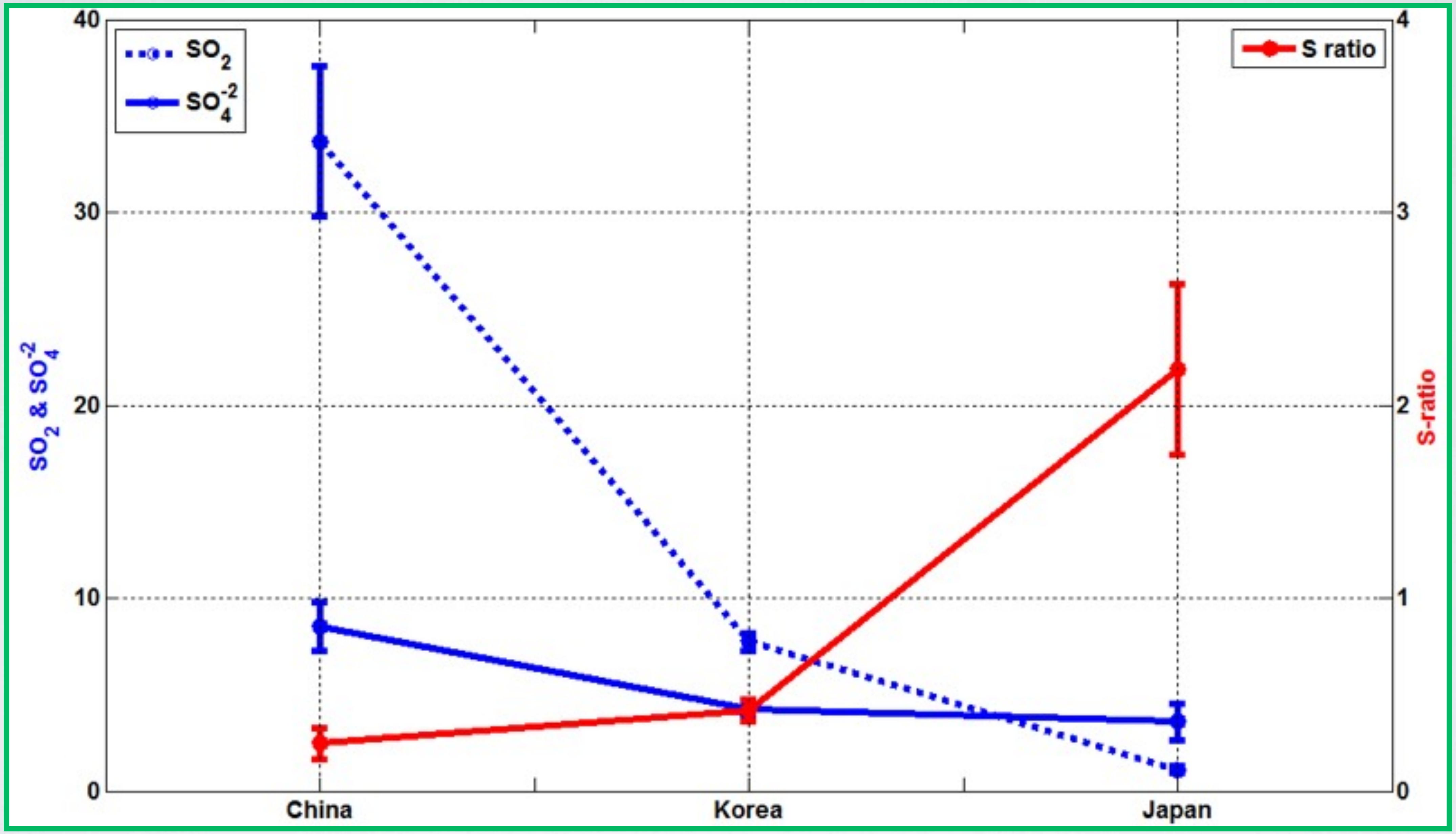
pH	China	Japan	ROK
2001	5.23	4.76	4.99
2002	5.17	4.78	4.99
2003	5.11	4.77	4.86
2004	5.16	4.79	4.75
2005	5.13	4.67	4.93
2006	5.13	4.78	4.74
2007	5.00	4.71	4.95

(EANET data report]

Tendency of F_S : China<Korea<Japan

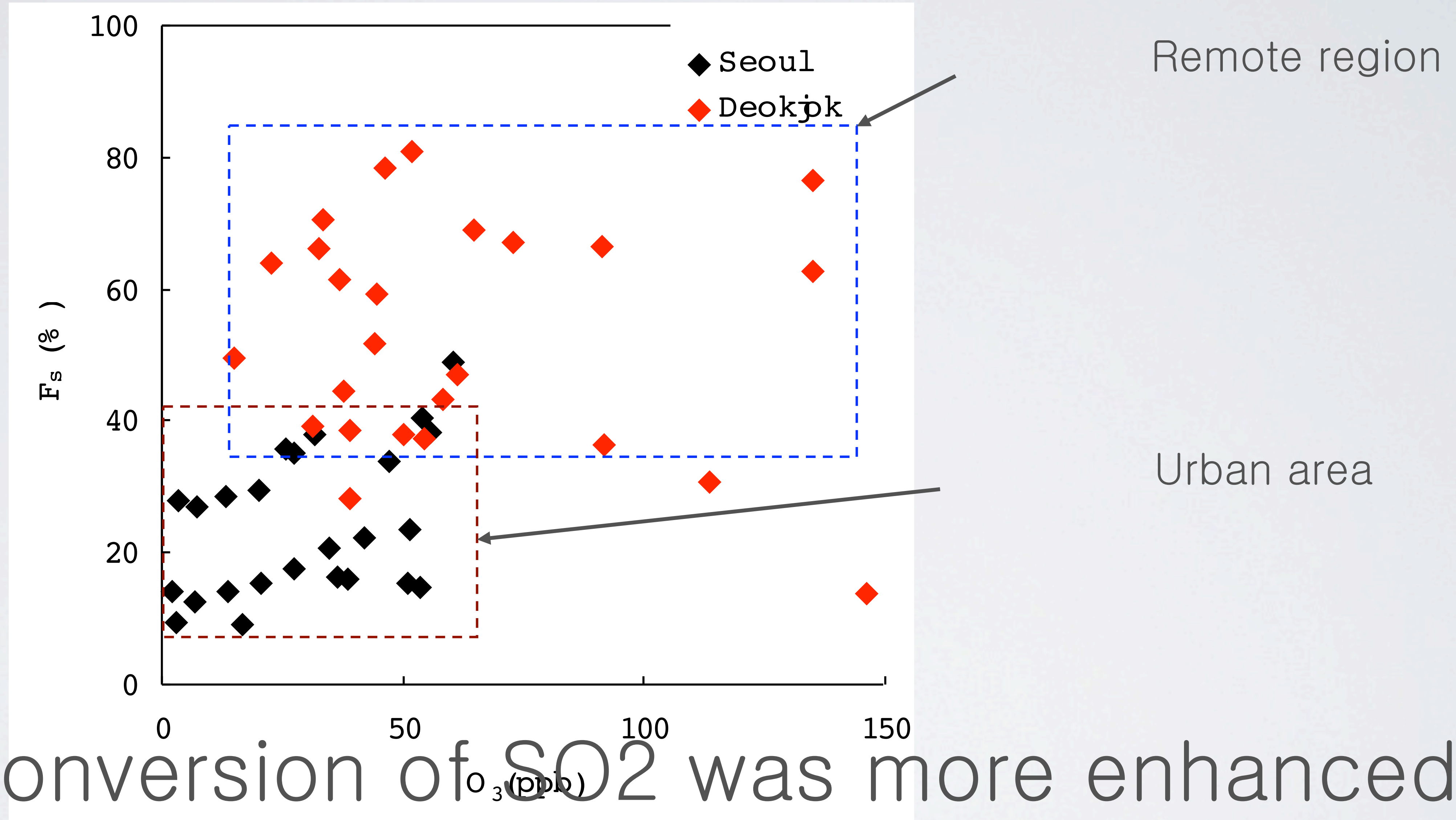
	China								Korea																Japan							
	Dalian				Xiaman				Gangwha				Taean				Gosan				Geoje				Rishiri				Oki			
	SO4	SO2		S-ratio	SO4	SO2		S-ratio	SO4	SO2		S-ratio	SO4	SO2		S-ratio	SO4	SO2		S-ratio	SO4	SO2		S-ratio	SO4	SO2		S-ratio	SO4	SO2		S-ratio
	μg/m3	ppb	μg/m3		μg/m3	ppb	μg/m3		μg/m3	ppb	μg/m3		μg/m3	ppb	μg/m3		μg/m3	ppb	μg/m3		μg/m3	ppb	μg/m3		μg/m3	ppb	μg/m3		μg/m3	ppb	μg/m3	
1995			55.00											3.00	8.57																	
1996			60.00											2.00	5.71																	
1997			47.00							3.00	8.57			3.00	8.57																	
1998			47.00							2.00	5.71			2.00	5.71			1.00	2.86													
1999			28.00							3.10	8.81			1.80	5.24			1.30	3.57			5.00	14.29									
2000		4.20	12.00			5.30	15.14		1.36	5.00	14.29	0.06	4.80	2.00	5.71	0.56	4.79	2.00	5.71	0.56	3.49	4.00	11.43	0.20		0.11	0.31			0.28	0.80	
2001		5.10	14.00			8.50	24.29		4.71	5.70	16.29	0.19	4.27	1.70	4.86	0.59	5.43	1.40	4.00	0.91	2.15	3.20	9.14	0.16		0.21	0.60			0.63	1.80	
2002		12.10	34.00			9.50	27.14		5.20	3.40	9.71	0.36	5.54	1.80	5.15	0.72	1.91	1.40	4.00	0.32	4.36	3.40	9.71	0.30		0.21	0.59			0.43	1.21	
2003	3.69				3.58				1.68	4.10	11.71	0.10	2.26	2.80	8.00	0.19	2.24	1.60	4.57	0.33	9.95	2.60	7.43	0.89		0.21	0.59			0.41	1.18	
2004	8.08	13.70	39.00	0.14	11.29	6.80	19.00	0.40	4.51	3.50	10.00	0.30	5.36	2.80	8.00	0.45	6.49	1.50	4.29	1.01	6.01	3.60	10.29	0.39	3.55	0.20	0.57	4.14	4.03	0.75	2.14	1.25
2005	8.59	16.00	46.00	0.12	16.09	7.70	22.00	0.49	3.10	3.00	8.57	0.24	3.10	2.60	7.43	0.28	4.60	2.10	6.00	0.51					1.78	0.18	0.51	2.30	5.35	0.74	2.11	1.69
2006	7.91	20.20	58.00	0.09		8.70	25.00			2.70	7.71			2.60	7.43			2.10	6.00						1.40	0.26	0.74	1.26	8.05	0.76	2.17	2.47
2007	8.14				9.23					3.00	8.57			3.20	9.14			2.20	6.29						1.10							
mean	7.28	11.88	40.00	0.12	10.05	7.75	22.10	0.44	3.43	3.50	10.00	0.21	4.22	2.41	6.89	0.46	4.24	1.66	4.73	0.60	5.19	3.63	10.38	0.39	1.96	0.20	0.56	2.57	5.81	0.57	1.63	1.80

Conversion ratio for sulfur F_S



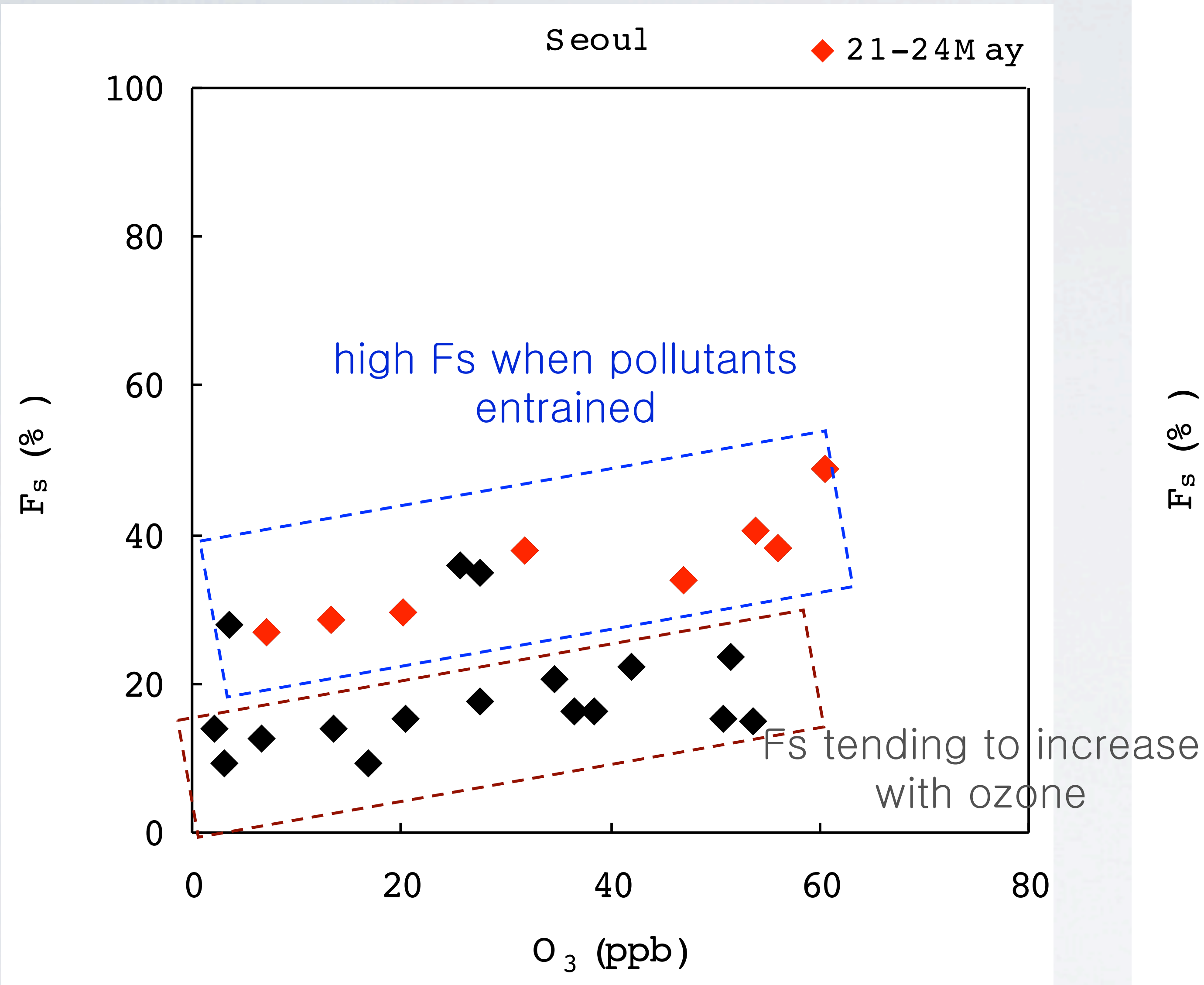
- China
  SO_2 : 1995 – 2006 (2003, 2007 excluded)
  SO_4^{-2} : 2003 – 2007
  S-ratio : 2004 – 2006
- Korea
  SO_2 : 2000년– 2005
  SO_4^{-2} : 1997 – 2007
  S-ratio : 2000년– 2005
- Japan
  SO_2 : 2004 – 2007
  SO_4^{-2} : 2000 – 2006
  S-ratio : 2004– 2006

Conversion ratio for sulfur F_S

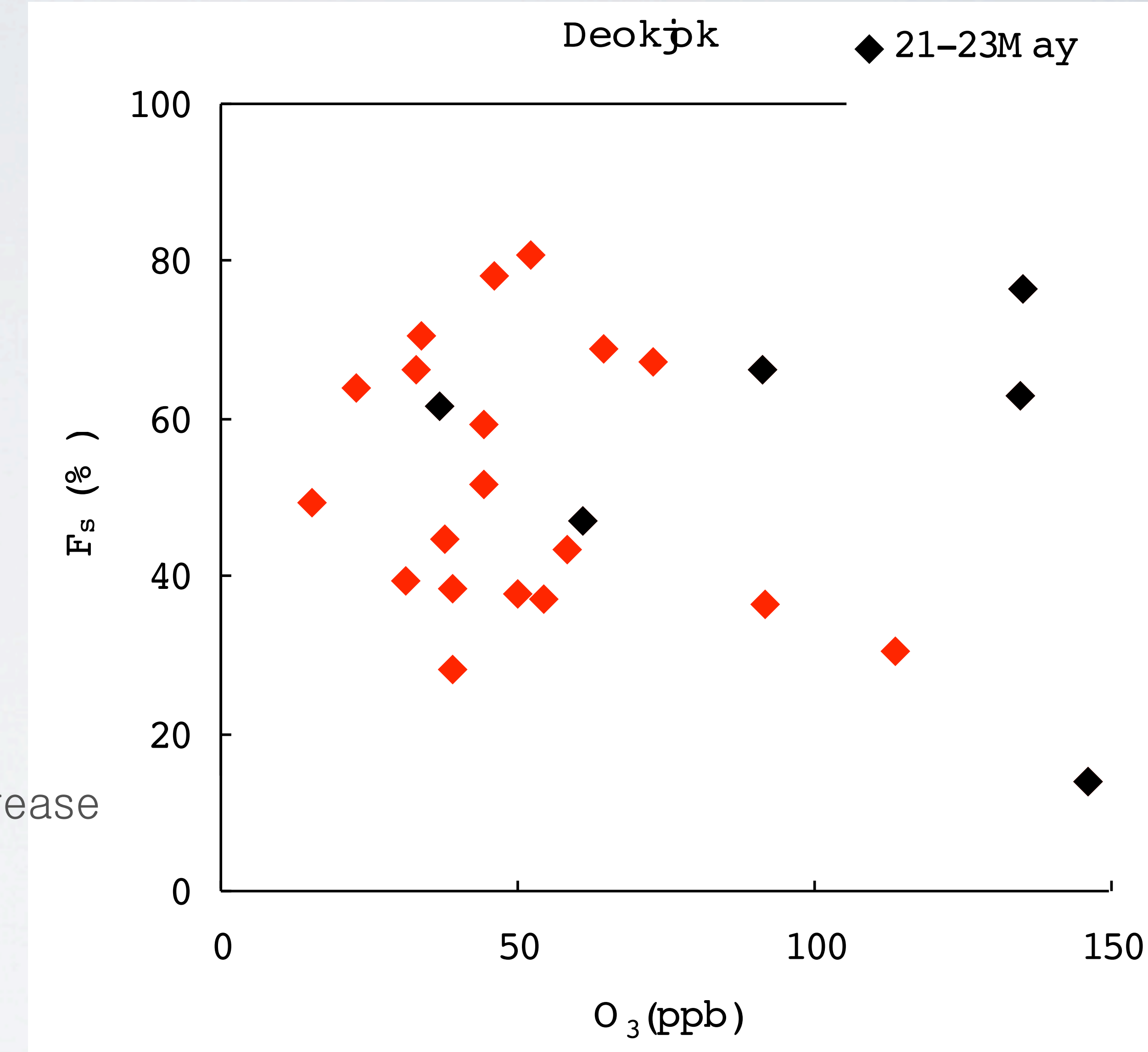


The conversion of SO2 was more enhanced in remote region than in rural region due to longer time for photochemical reaction

Conversion ratio for sulfur F_S

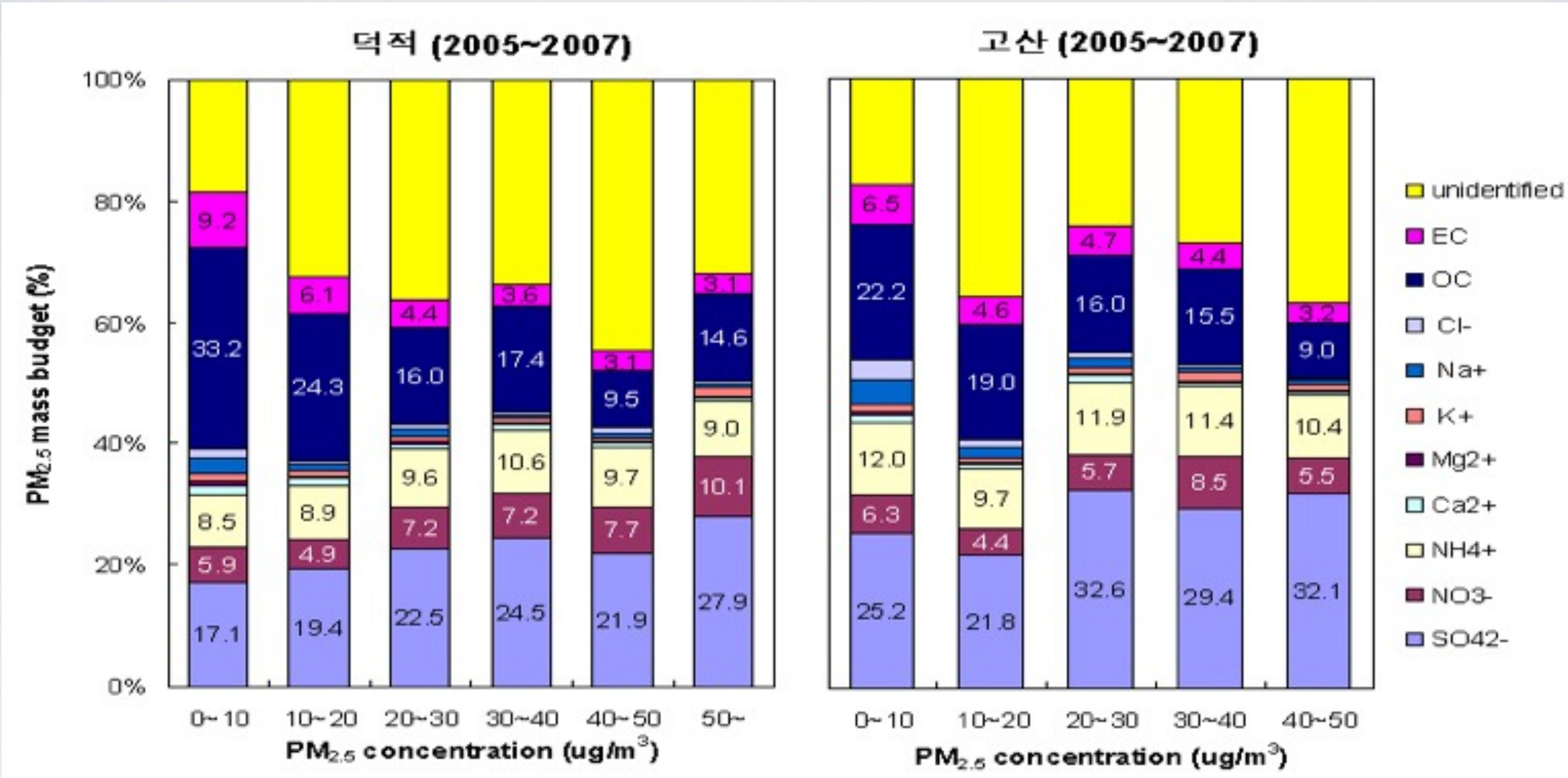


Indicating photochemical reaction is important for the oxidation of SO2 to sulfate.



No tendency

Characteristics of PM2.5 Mass in national background regions(2005-2007)



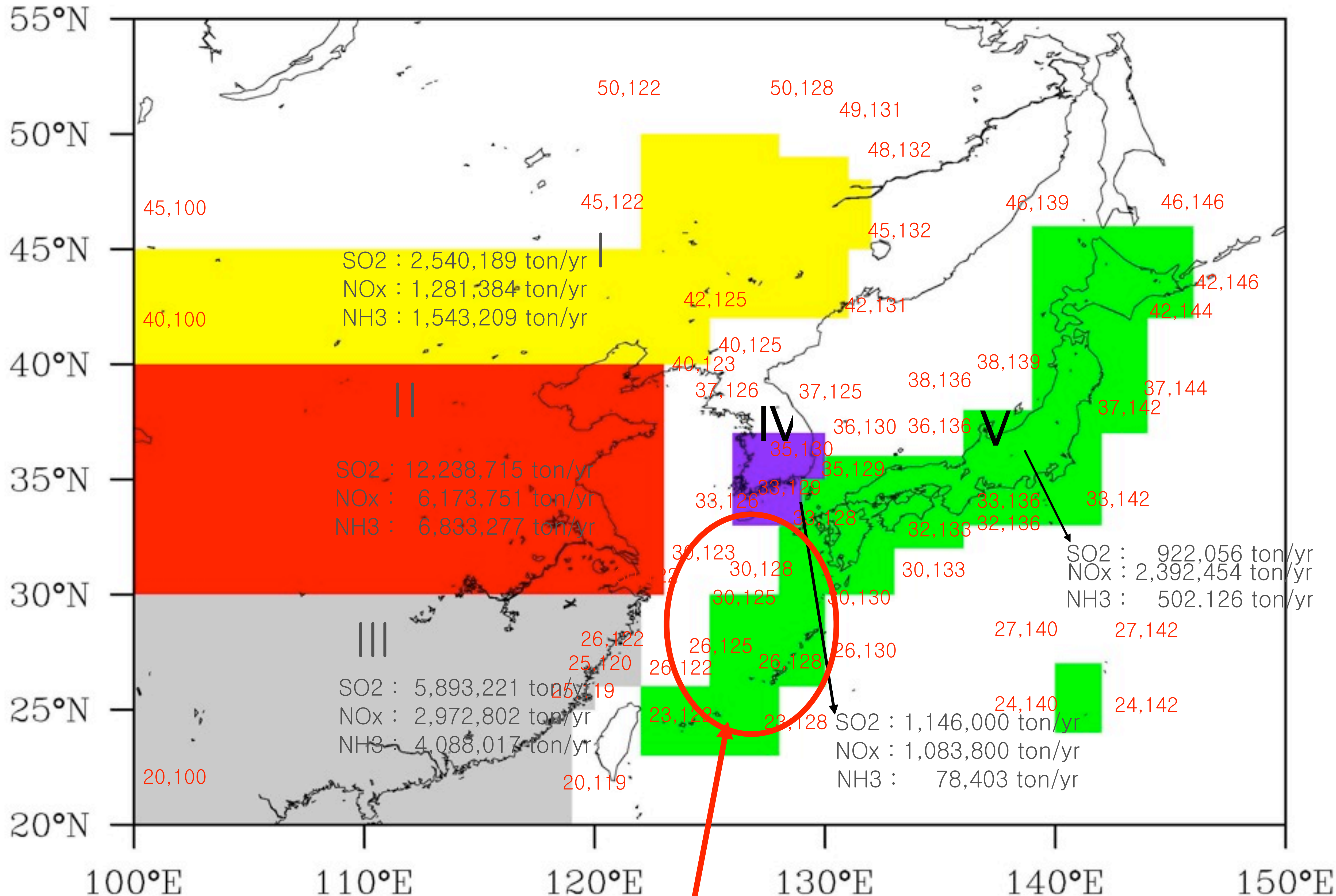
[SO_4^{2-}] increased greatly when affected by long-range transport

- In lower concentration, in Dukjeokdo, OC was the highest (~33.2%), while in Gosan, OC (~22.2%) and sulfate (~25.2%) showed the highest.
- In high concentration, in both Dukjeokdo and Gosan, sulfate showed the highest fractions (at ~ 27.9% in Dukjeokdo and ~32.1% in Gosan).

Modeling Method

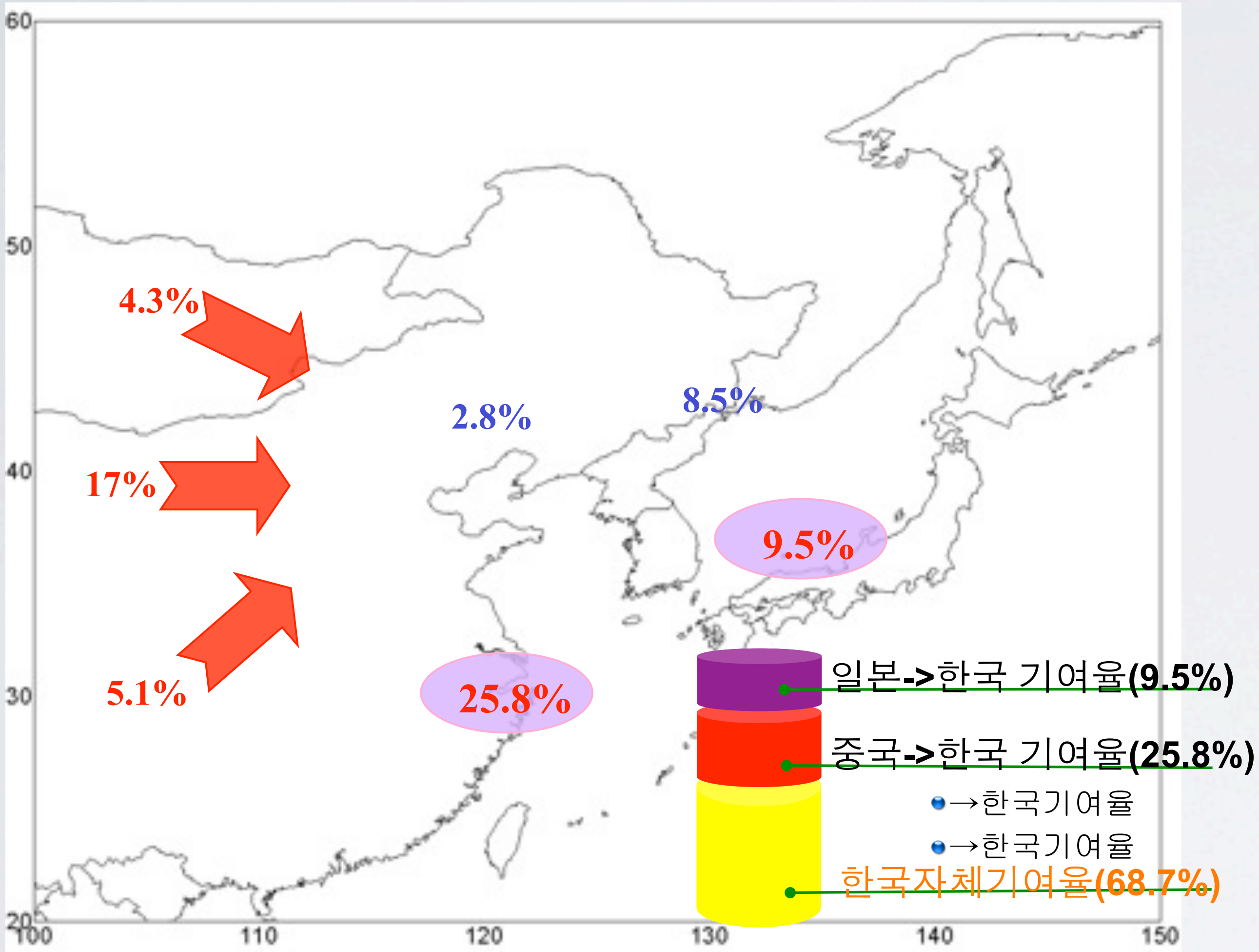
	China	Japan	Korea
Model system	Models-3 / CMAQ coordinate 14 layers, 70×66 grids, 60km resolution (Byun and Ching, 1999)	RAQM (Regional Air quality Model) terrain following coordinate 12 layers, 110×80 grids, 60km resolution (An et al.2002)	CADM (Comprehensive Acid Deposition Model) terrain following coordinates 12 layers, 110×80 grids, 60km resolution (Lee et al., 1998)
Domain	20～50N, 100～150E	20～50N, 100～150E	20～50N, 100～150E
Meteorological Model	MM5 34 layers with FDDA using NCEP reanalysis	MM5 125×95 (45km), 23 layers, FDDA using NCEP FNL reanalysis	CSU-RAMS 110×80, 29 vertical layer FDDA using NCEP FNL reanalysis
Chemical Mechanism	RADM Chemistry	CBM-IV mechanism	RADM Chemistry
Cloud Model Physical option	Diagnostic cloud model in RADM Simple explicit moisture scheme Grell cumulus schemes, MRF	Cloud model in MM5 Betts-Miller cumulus scheme, MRF RRTM	Cloud model in CSU-RAMS Anthes-Kuo cumulus scheme, MRF
Emission	SO_2, NOx, VOC, NH_3, CO, PM_{10}, biogenic VOC provided by LTP for the base year of 1998 (1°×1° resolution)	Same as China	Same as China
Dry deposition	Wesely's parameterization (Wesely, 1989)	Modified Wesely's parameterization (Walmsley & Wesely, 1996)	Dry deposition module in RADM (Lee et al, 1998)
Wet deposition	RADM Module (Chang et al, 1987)	RADM Module (Chang et al, 1987)	RADM Module (Chang et al, 1987)
Land use type	EPA/NOAA global ecosystem (11 categories)	DeFries & Townshend (1994)	EPA/NOAA global ecosystem (11 categories)

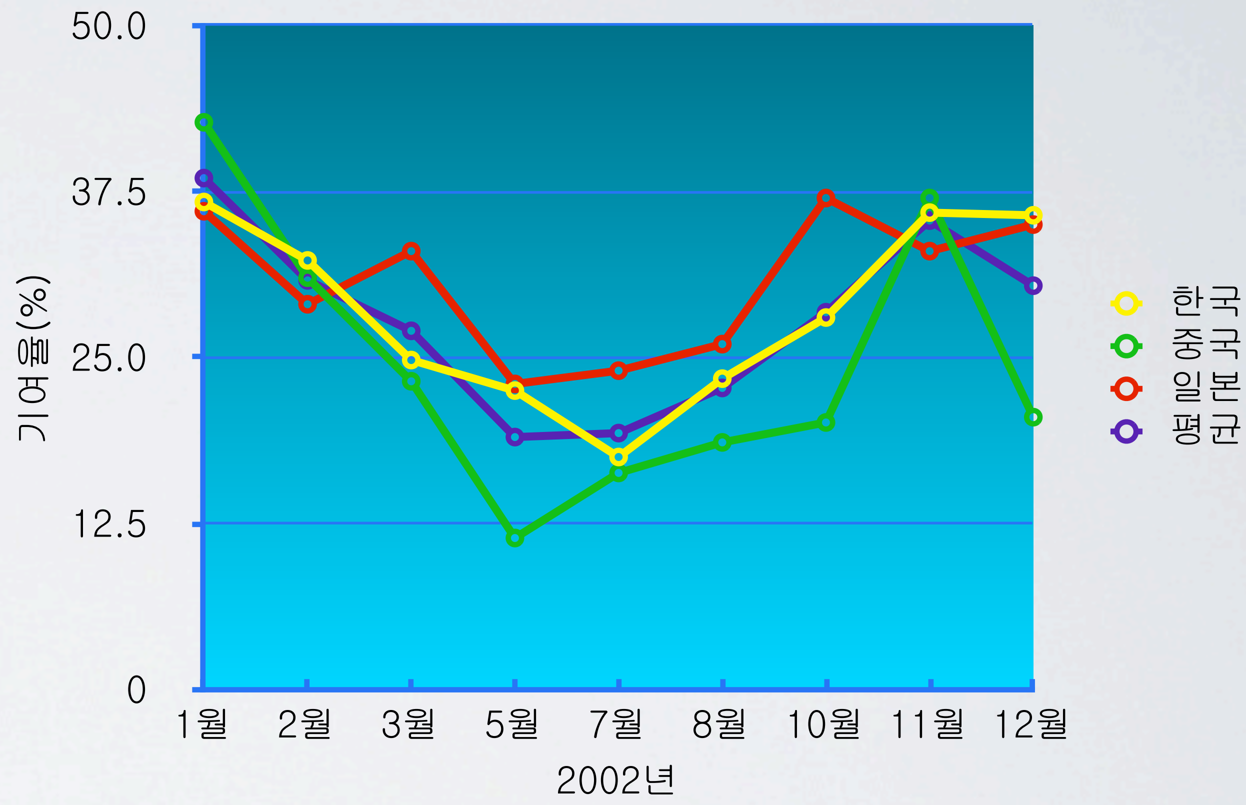
Regions for estimating S-R Relationship



China requests excluding ocean sector in Region V.

Source-Receptor Relationship in 2002 using emission data of 1996.





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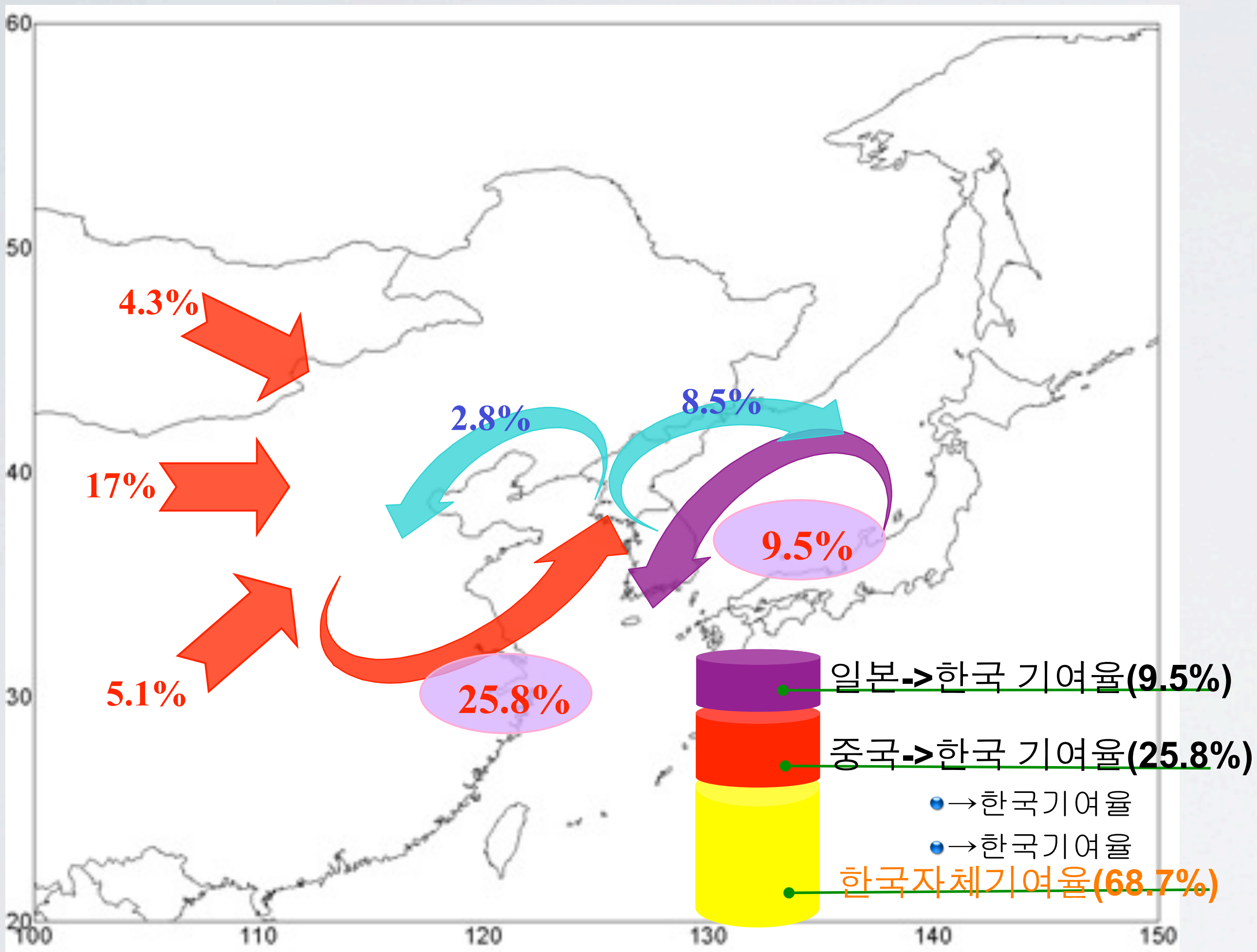
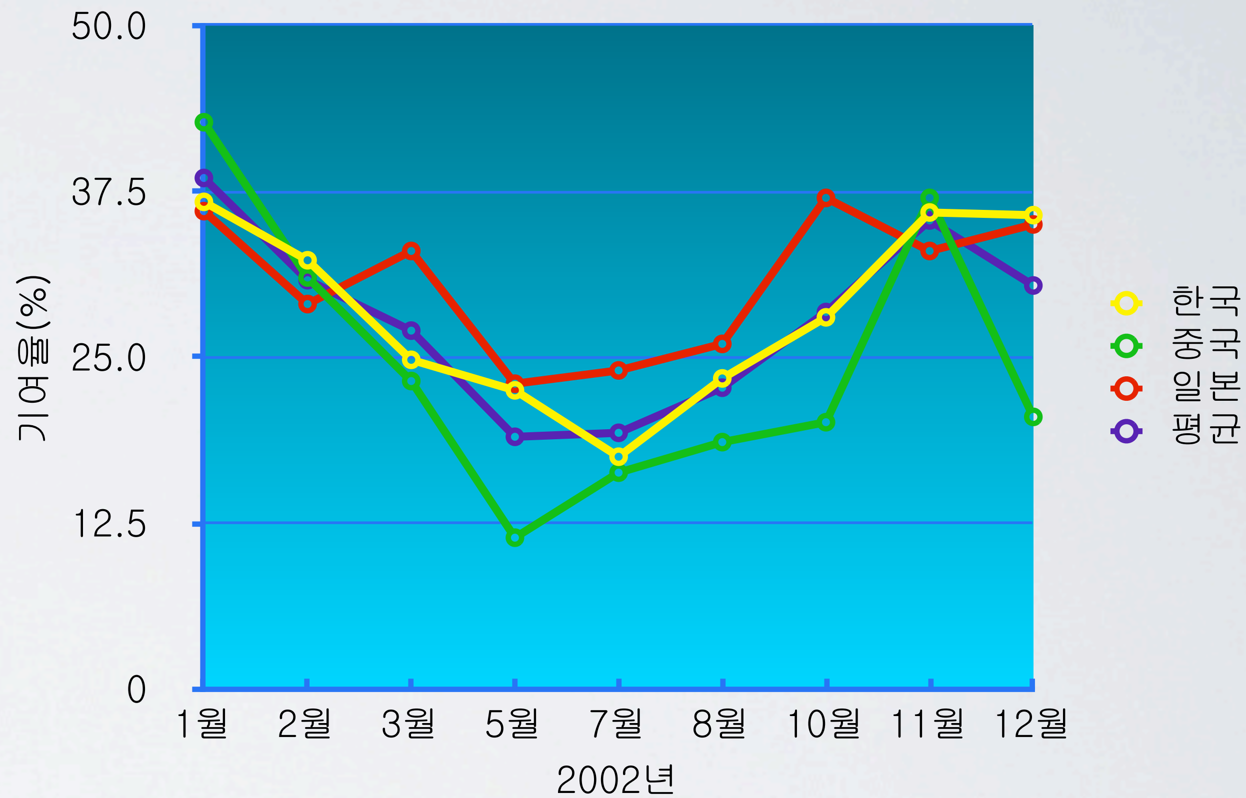


Seasonal variation of source contribution



Ⅲ Future plan

Teams and Roles for Post-2012 LTP Plan

1. Organizer

- **LTP Secretariat (incl. Dr. Jong-Choon Kim and Ms. Su-jin Heo**, *National Institute of Environmental Research*

2. Executive Authors

- **Dr. Shang Gyoo Shim**, *Korea Institute of Science and Technology*
- **Prof. Jung-Hun Woo**, *Dept. of Advanced Technology Fusion, Konkuk University*
- **Prof. Cheol-Hee KIM,** *Dept. of Atmospheric Sciences, Pusan National University*
- **Prof. Dong-Young Kim,** *KDI School of Public Policy and Management*

3. Advisory Committee (pool)

- **All LTP Participants**

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CONTENT

1. Background and Objectives

2. Suggested Topics for LTP Post-2012 Plan
   - Air Quality Forecast for Northeast Asia
   - Implementation of Advanced S-R Methodologies

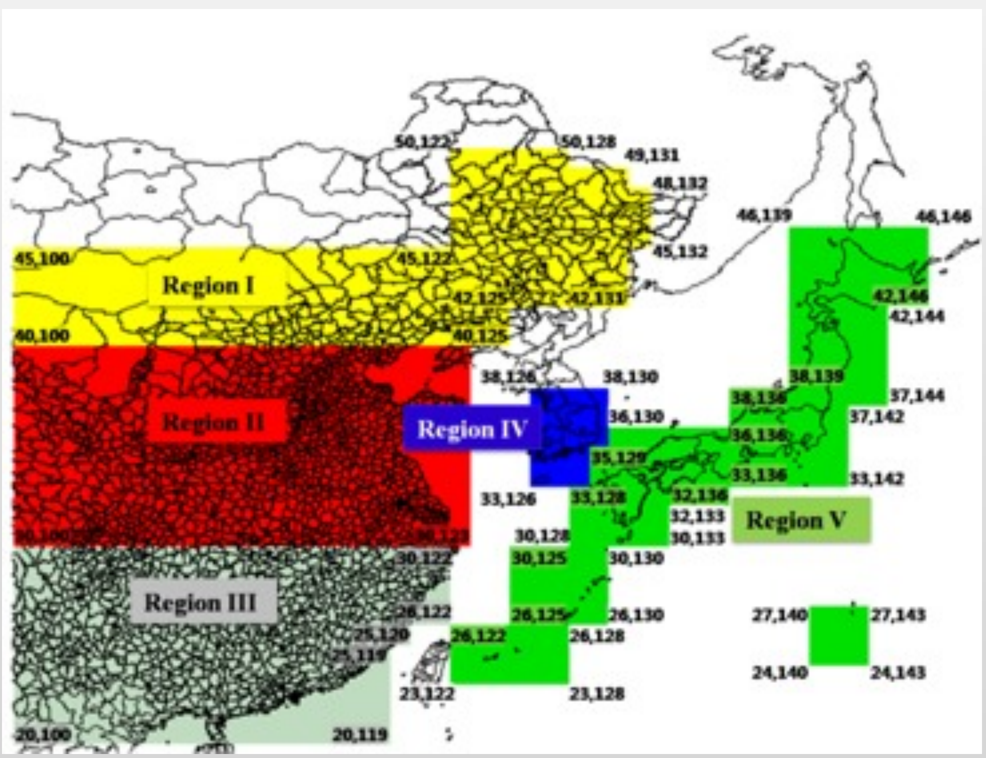
3. Post-Meeting Milestone

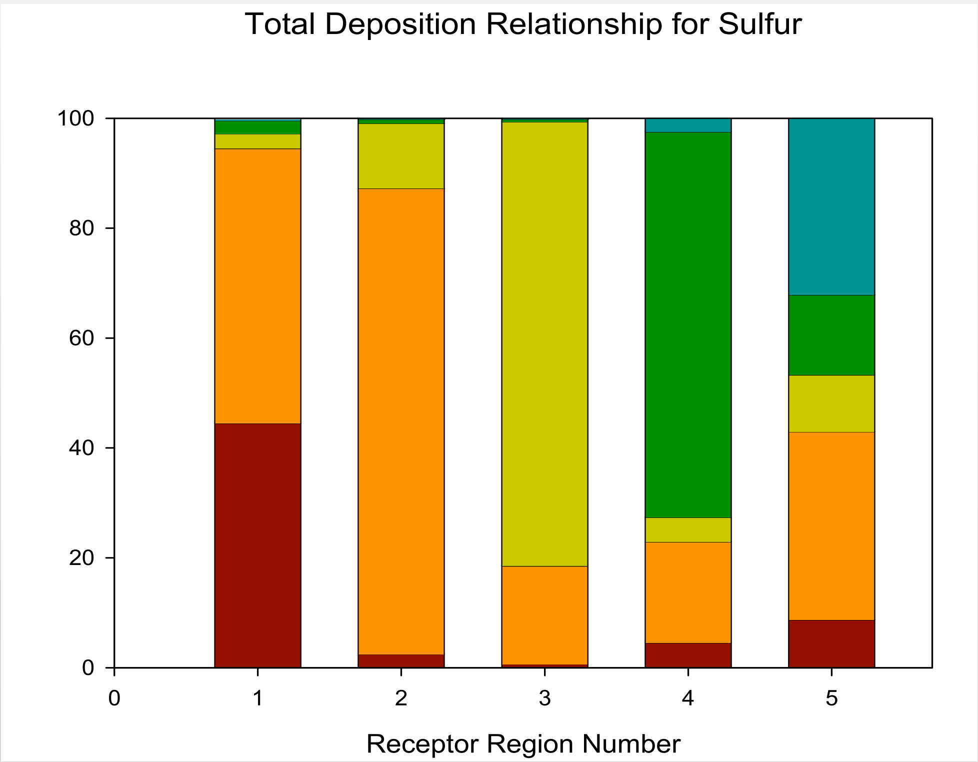
4. Discussion

1. Background and Objectives

Background

- LTP was started in year 2000 as a **government-based air pollution research framework** among China, Japan, and Korea
- LTP's activities have been mostly focusing on understanding **transboundary air pollution** and **S-R relationship among three countries**, using modeling and monitoring techniques
- Now LTP members are planning the **4th year of the 3rd Stage (2011)**





Similarities and uniqueness of LTP Framework to other activities

- **Similarity**
  - Air Quality Monitoring for Asia (to EANET)
  - Air Quality S-R Modeling for Asia (to MICS-Asia)
  - Target pollutants – Sulfur, Nitrogen, and others (EANET and MICS-Asia)
  - RAINS-Asia, GAINS-Asia, ABC, Global-Chem Modeling, and others…

- **Uniqueness**
  - Government-initiated scientific research collaboration framework in support of regional air quality issues
  - Both modeling and monitoring
  - Both pure science and policy supporting science
  - Strictly focus on East Asia(Three countries)
  - Long lasting geo-scientific collaboration in East Asia

New Challenges

- **Transboundary air pollution**
  - **- Long-term S-R**
  - **- Base-year modeling**
  - **- Periodic monitoring**

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New Challenges

- Transboundary air pollution
  - Long-term S-R
  - Base-year modeling
  - Periodic monitoring
- Climate change → -climate influence on air quality
  - future scenario
  - co-benefits
- Local and regional air pollution → - Inter- vs. intra- national S-R
  - Megacity impacts
- Category Integration → - CAPs + GHGs + HAPs
  - Impact study
- Understand pollution events → - Dust storm, wildfire, storms, heat
  - Air quality forecasting

New Challenges

- The LTP research framework has been working great, but the data and methodology for research are outdated from scientific viewpoint and research components are not complete in policy supporting viewpoint

- Climate change → -climate influence on air quality
  - future scenario
  - co-benefits
- Local and regional air pollution → - Inter- vs. intra- national S-R
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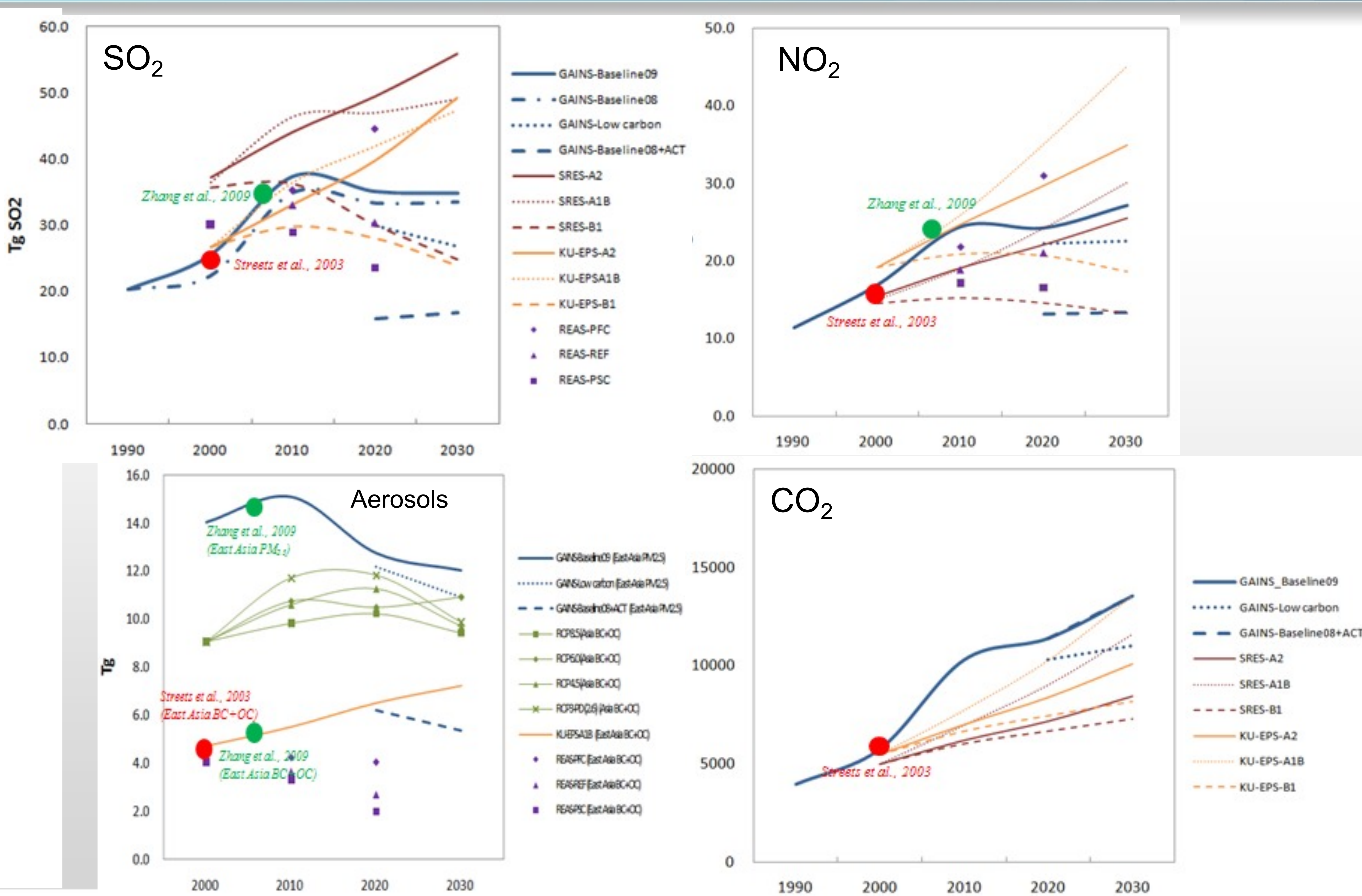
Time, LTP, and Emissions



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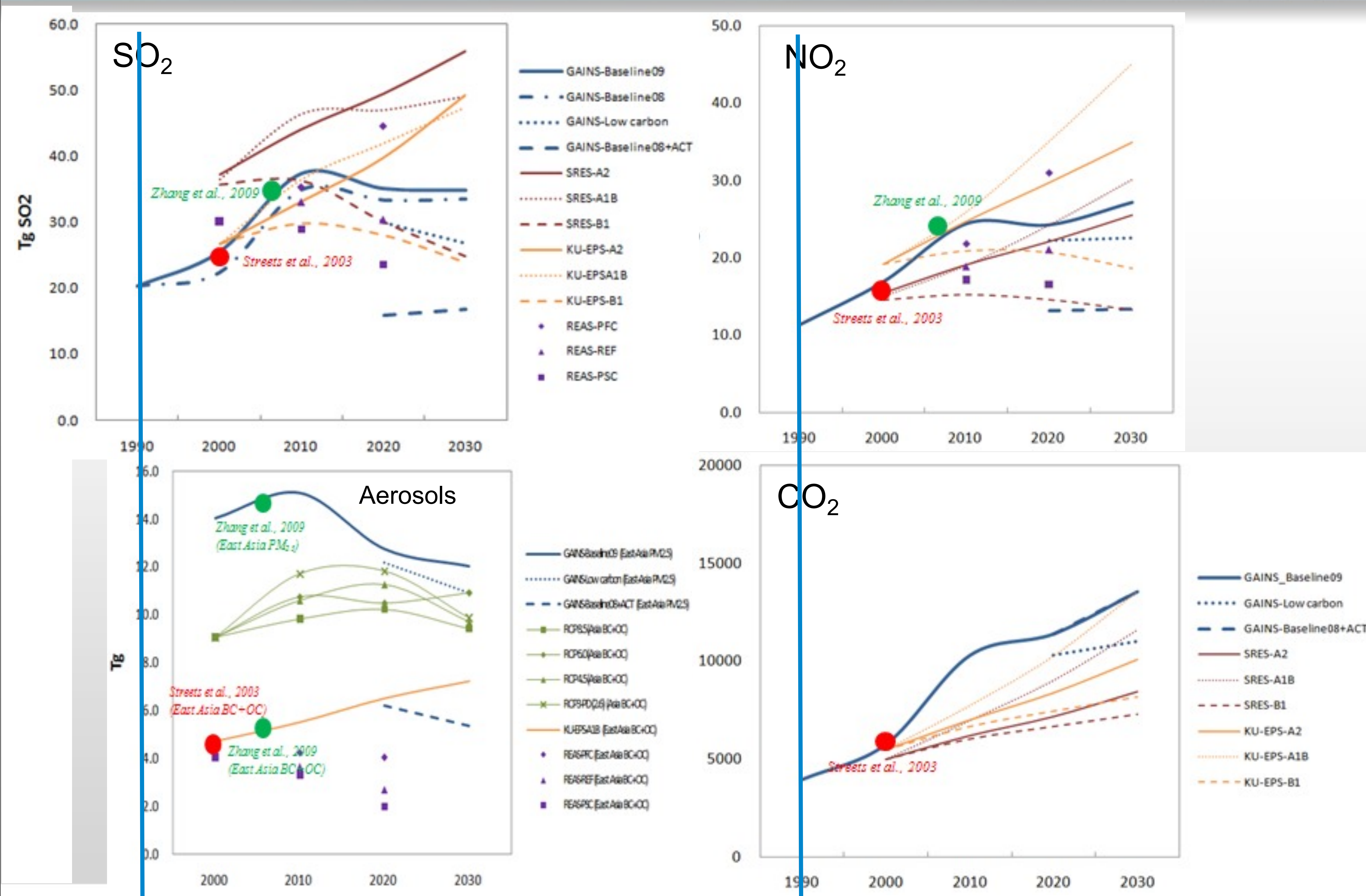
Time, LTP, and Emissions



Pre-historic

Pre-historic

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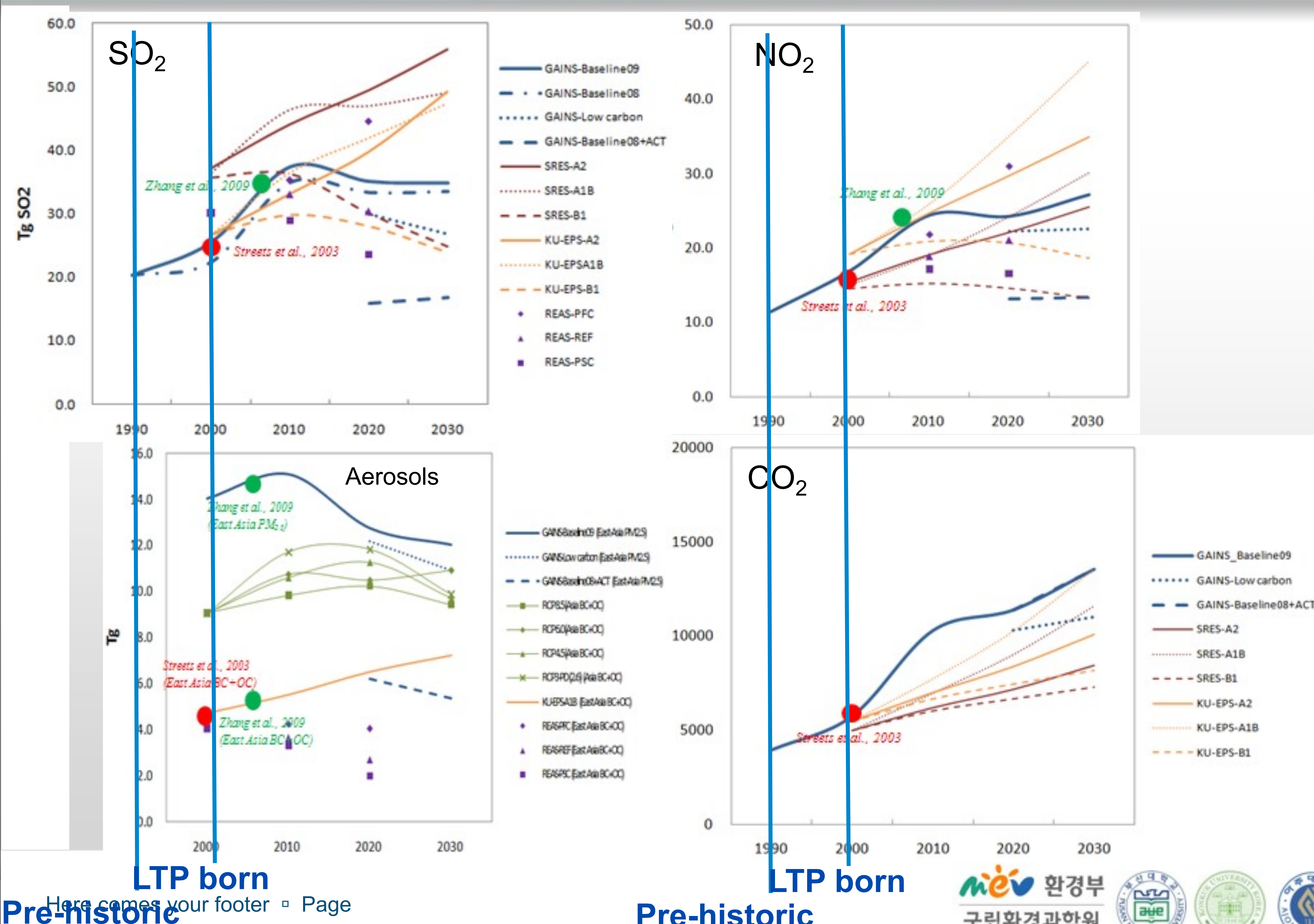
Time, LTP, and Emissions



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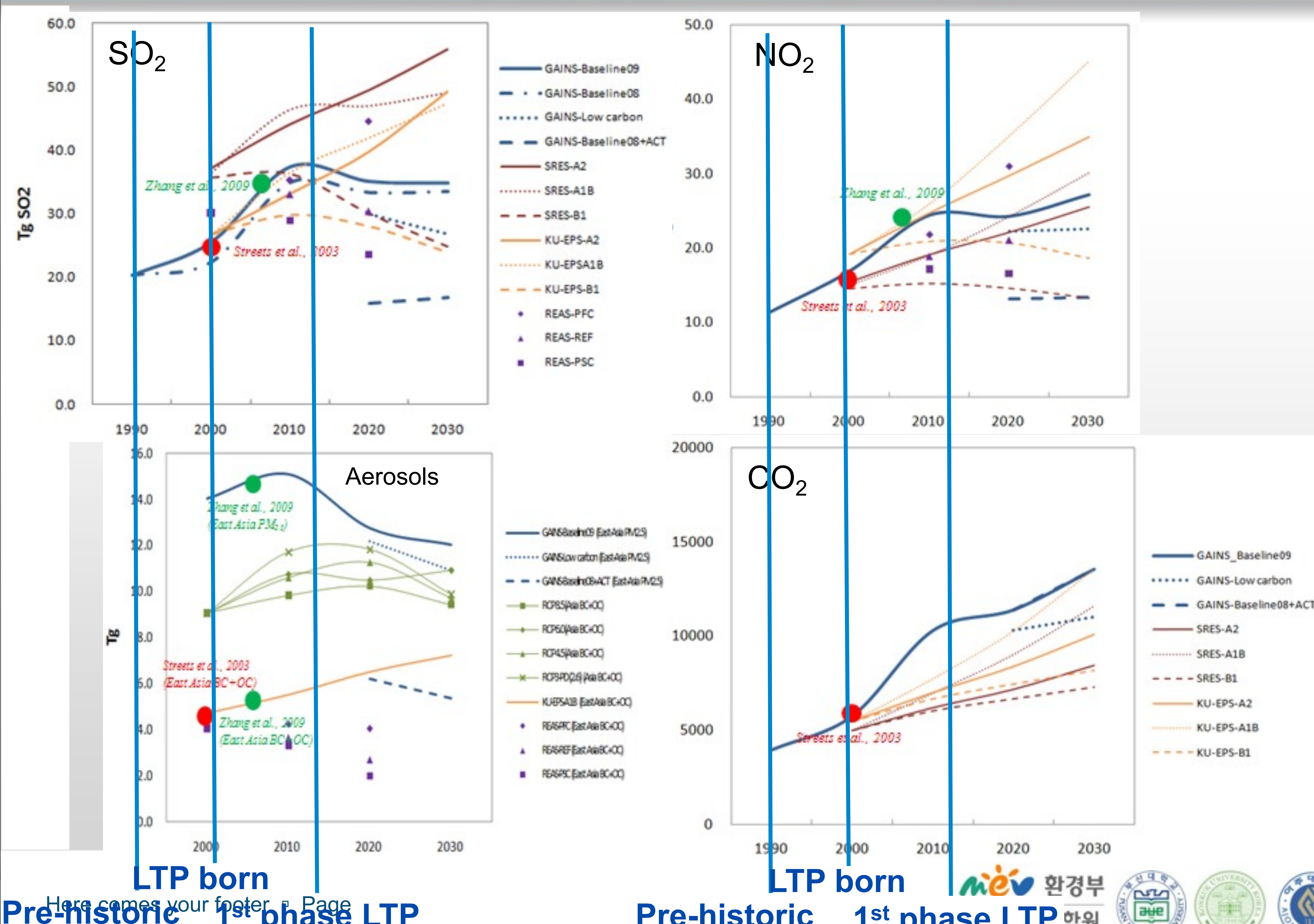
Time, LTP, and Emissions



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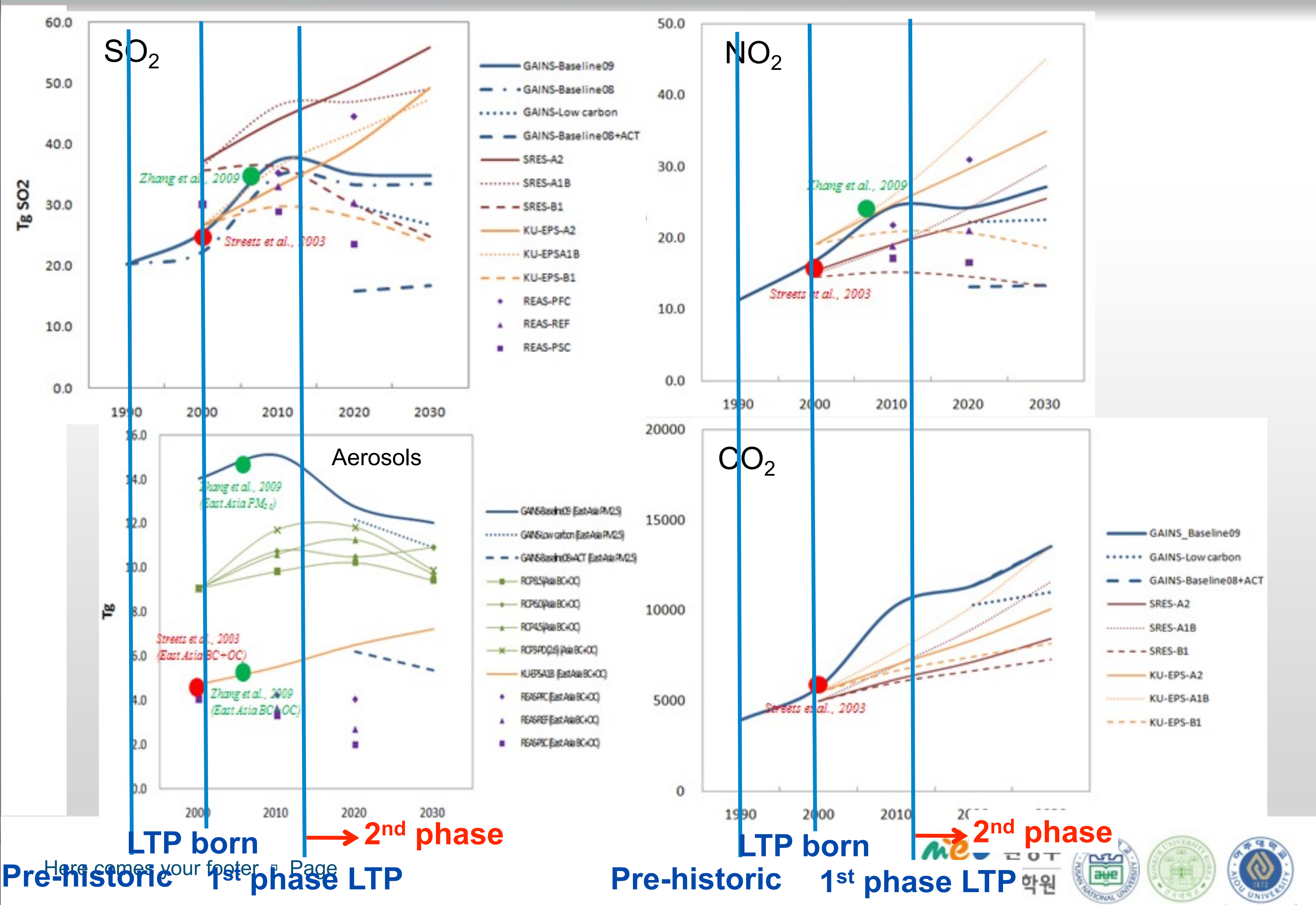

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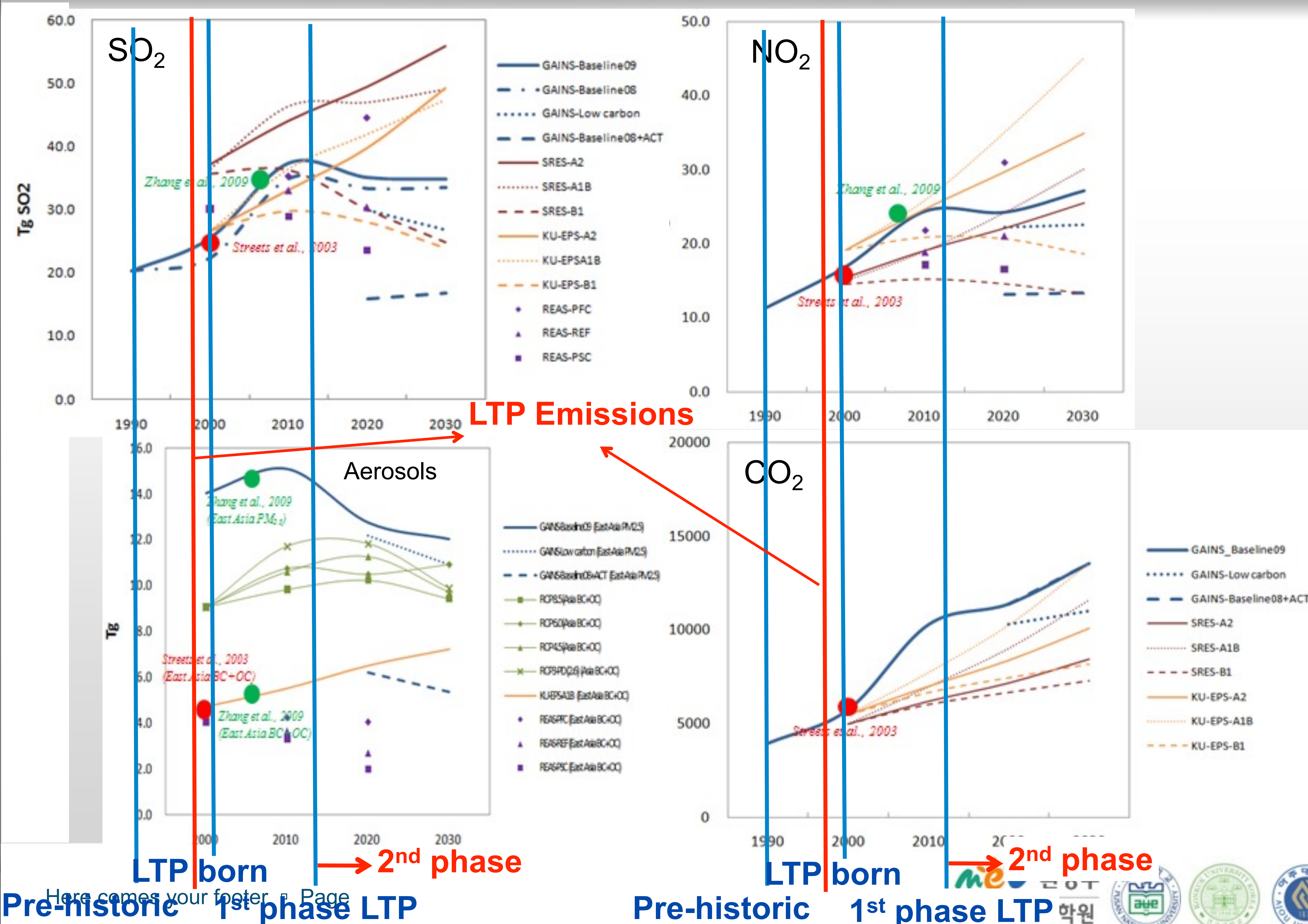

New Objectives

- Two major and one supplemental objectives

: Understand air quality issues in East Asia in consideration of new challenges, such as secondary pollutants, HAPs, climate change, and etc. Decide what we want to pursue and what we won't (State-of-art science)

: Use our understanding to prioritize our actions to mitigate adverse AQ effects for another decade. Health/ environmental impact and mitigation policy study need to be initiated (Policy supporting science)

: How can we improve our collaborative research framework to accomplish these objectives effectively?

2. Suggested Topics for LTP Post-2012 Plan

- Air Quality Forecast for Northeast Asia
- Implementation of Advanced S-R Methodologies
- Assessment of O_3 and PM for the future LTP Project
- Scenario-based Collaboration Simulation Approach

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2.1 Chemical Air Quality Forecast for Northeast Asia

Shang Gyoo Shim

Korea Institute of Science and Technology

Air Quality Forecast - Existing Efforts (examples)

- **Modeling Frameworks**

 - Meteorological Models : MM5, RAMS, WRF

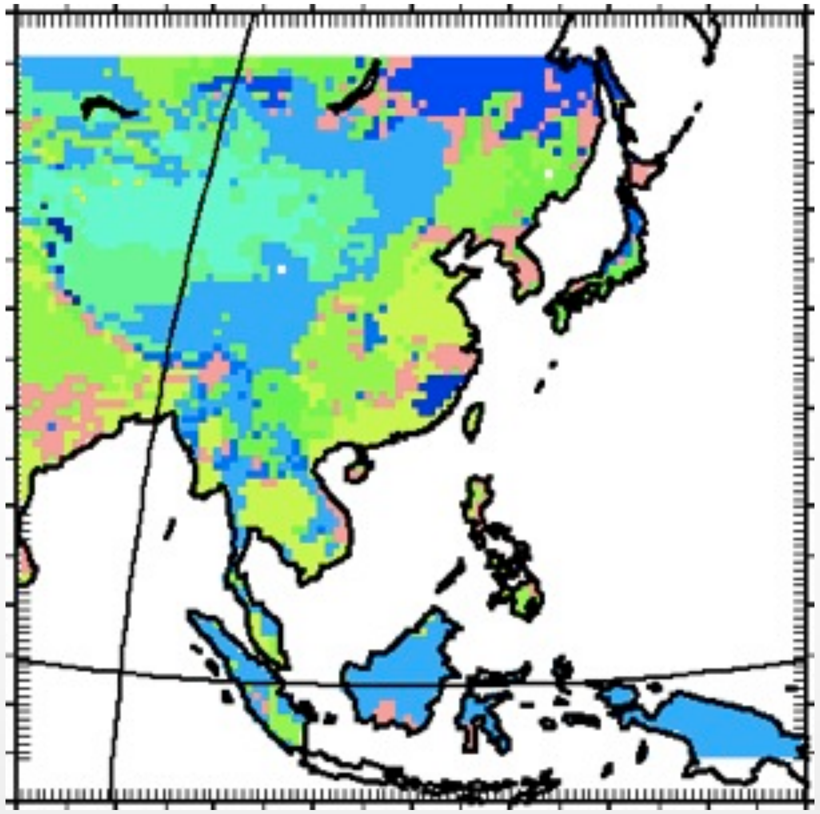
 - Chemical Models : CMAQ, CFORS, CAMx

 - Domian, Grid, and Emissions

✓China
 - Horizontal Grid Spacing:
 Asia: 36km, China and Korea:
 12km, Beijing Metropolitan Area: 4km
 - Vertical Layer : 14 layers
 - Emissions : Trace-P 2000 + Statistical Books

✓Japan
 - Horizontal Grid Spacing:
 Asia: 80km , 15 km (in preparation)
 - Vertical Layer : 23 layers to 20km
 - Emissions : Trace-P 2000 + dust, sea salt, lightening, volcano, radon, Biomass burning

✓Korea
 - Horizontal Grid Spacing:
 East Asia: 27km , Korea: 9km, SMA: 3 km
 - Vertical Layer : 11 layers to 14.7km
 - Emissions : INTEX-B 2006+ CAPSS 2007+ fugitive dust, biogenic, biomass burning



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Air Quality Forecast – a Framework (Draft)

- Three country generate the common metrological/emissions data for the simulation
- Each country uses its' own chemical model(s)
- Cooperation with other fields (ground and airborne monitoring, satellite data retrieval, LIDAR networks)

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- **Integrated performance testing during Intensive Monitoring Period (ex. forecast for 72 hours for the entire month of IMP)**
  - National Air Quality Index (API)
  - Concentration of air pollutants : O_3, PM_{10}, $PM_{2.5}$, SO_2, NO_2, sulfate, nitrate, ammonia, mercury etc.

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Need common /integrated modeling/monitoring framework and may need a modeling center

Air Quality Forecast – Necessary collaborations

For performance enhancement

- Input data update (Emission Inventory, Land Use, Terrain)
- More detailed emission Inventory (Fugitive dust, Sand storm, Forest fire, Biomass burning, Volcano, Biogenic emission)
- Emission inventory for North Korea
- Background, Boundary Conditions

For implementation - Arrangements

- Each country secures its' financial support from Government and/or International Organizations.
- Each country reports to the Environmental Minister and endeavors to bring this matter to the Tripartite Environment Ministers Meeting Among China, Japan, and Korea (TEMM)

2.2 Implementation of Advanced S-R Methodologies

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Why Do We Need Advanced S-R Methodologies?

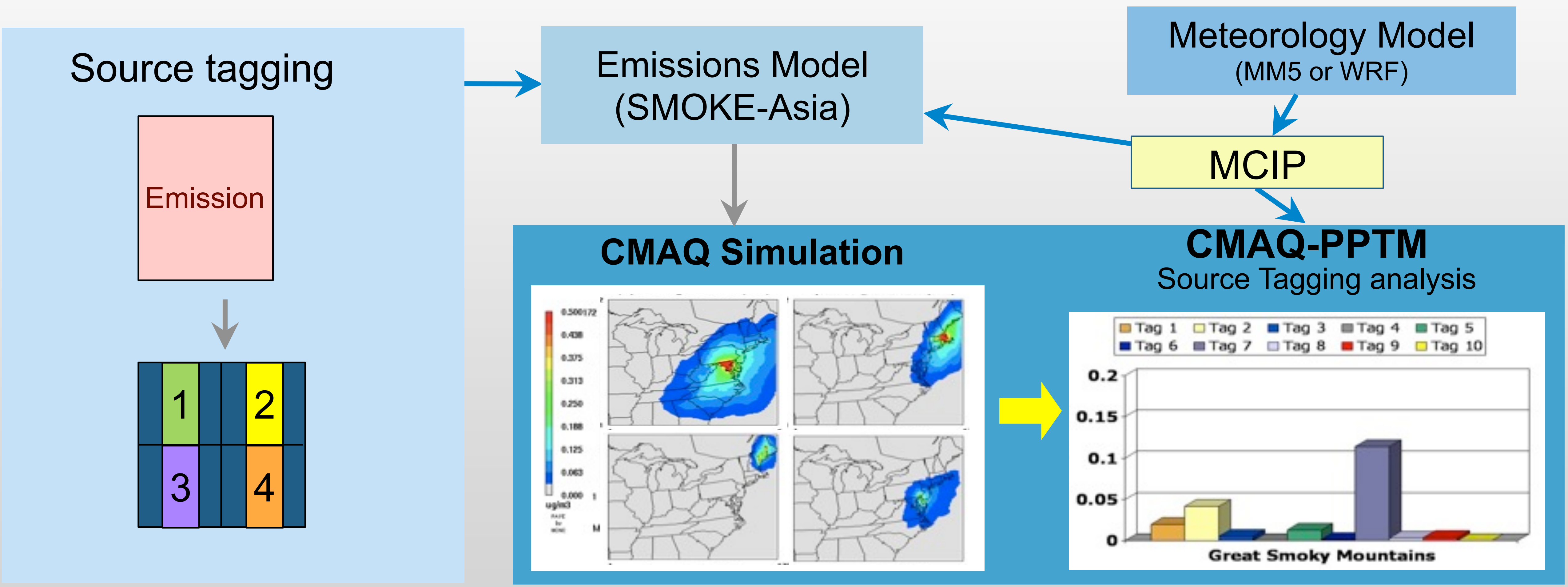
- **To conduct more sophisticate S-R research**
  - Simultaneous analysis for regions-sectors, ICs, BCs
  - Finer S-R(e.g. megacity impact study)
  - Control measure testing …
- **To understand various sensitivities**
  - Precursor to product sensitivity
  - Region to region sensitivities…
- **Benefits**
  - Save time, effort, and space(faster and simpler)
  - Avoid non-linearity

What's available?

- **Source tagging(REMSAD, CAMx-PSAT, CMAQ-PPTM)**
- **Forward Sensitivity(CMAQ-DDM)**
- **and more…**

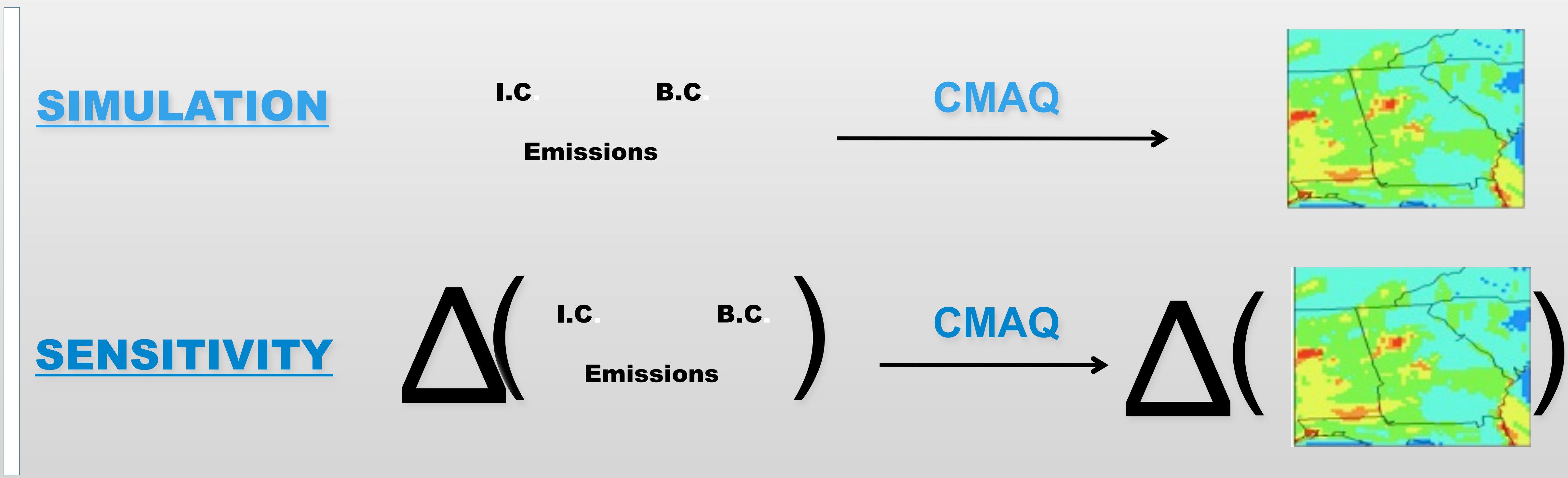
Source Tagging(CMAQ-PPTM)

- PPTM : Particle and Precursor Tagging Methodology
- Assessment of the source contribution by source tagging method
- Emissions from selected sources, source categories, or source regions are (numerically) tagged and then tracked throughout a simulation



Forward Sensitivity(CMAQ-DDM)

- Calculates sensitivity of concentrations to input parameters along with the concentrations themselves
- Can provide sensitivity to:
  - species
  - regions or individual sources
  - other model parameters (e.g. reaction rates)

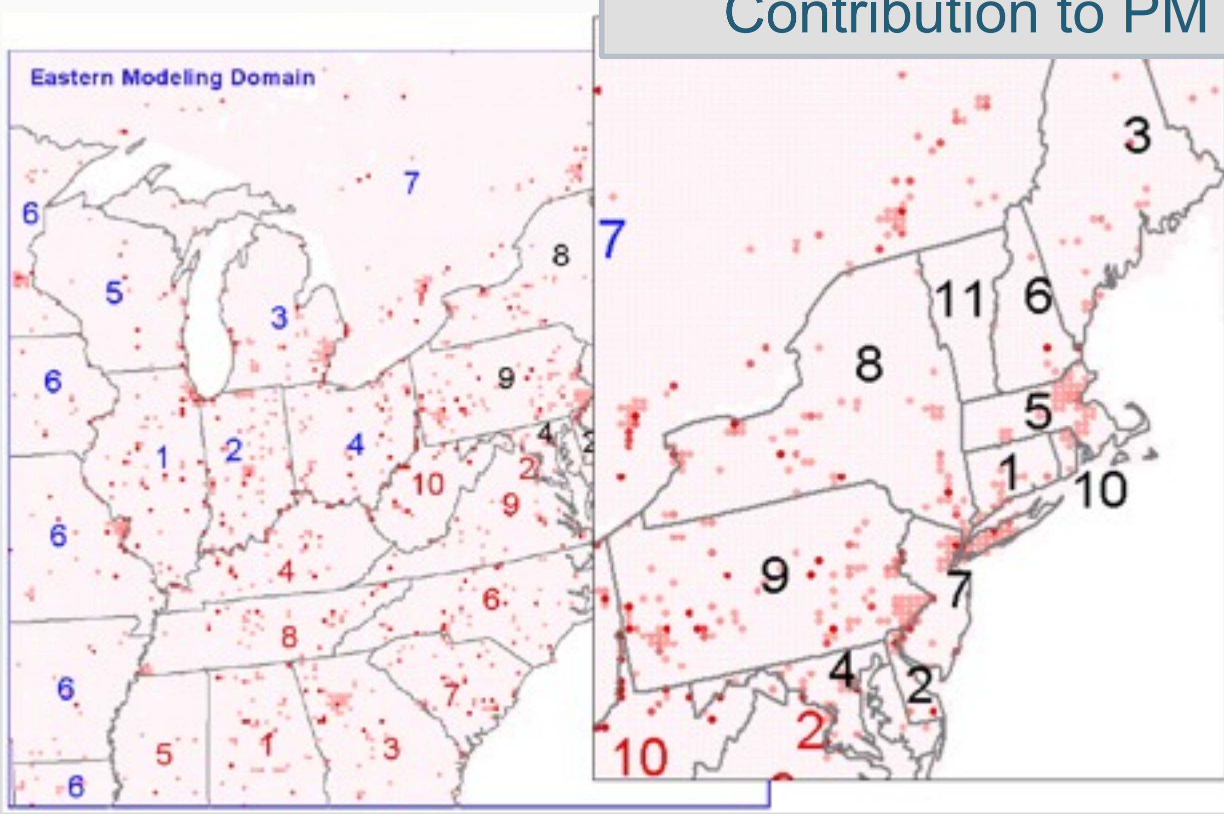


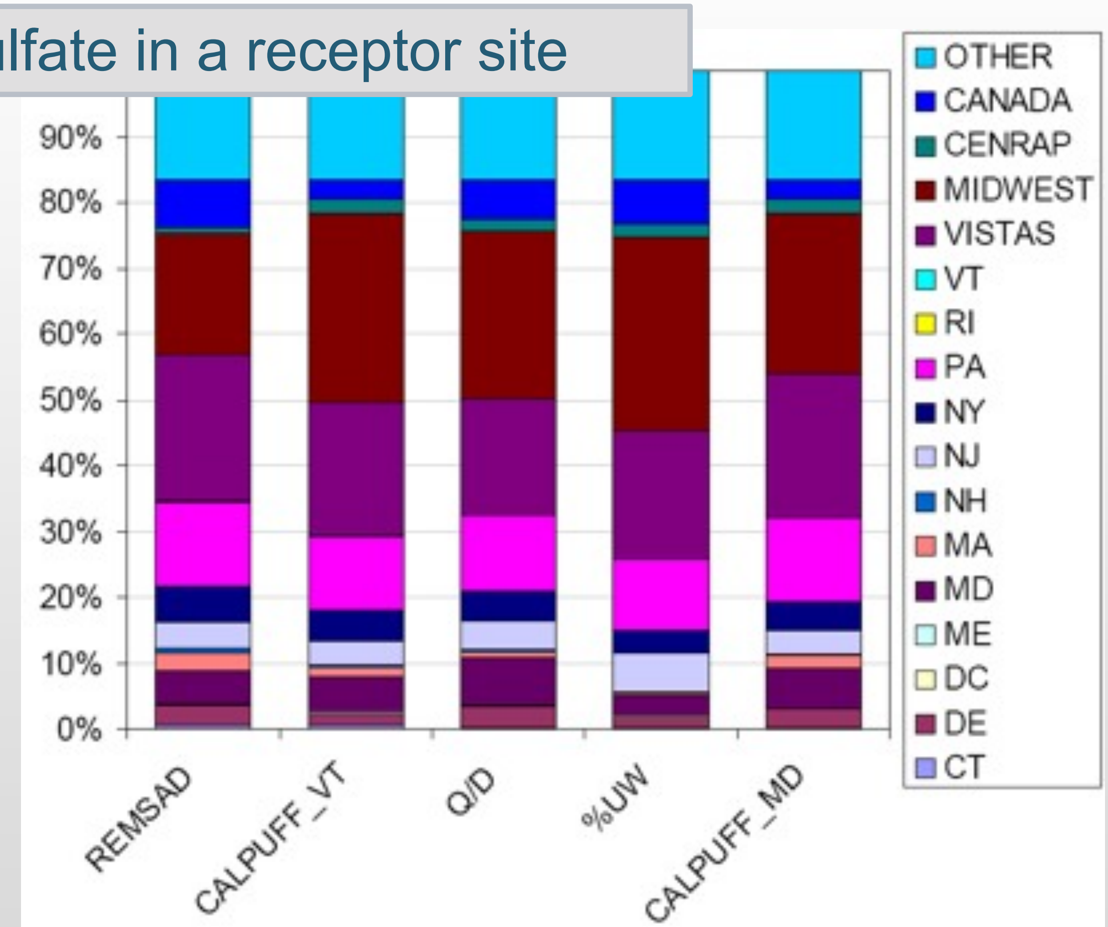
Source Tagging(REMSAD-tagging)

Woo et al.(2006)

- Use Tagging method based on REMSAD model for Northeast US

Contribution to PM sulfate in a receptor site





Woo et al., Development of REMSAD emissions tagging scheme in support of MANE-VU contribution assessment, 15th International Emission Inventory conference, 2006.

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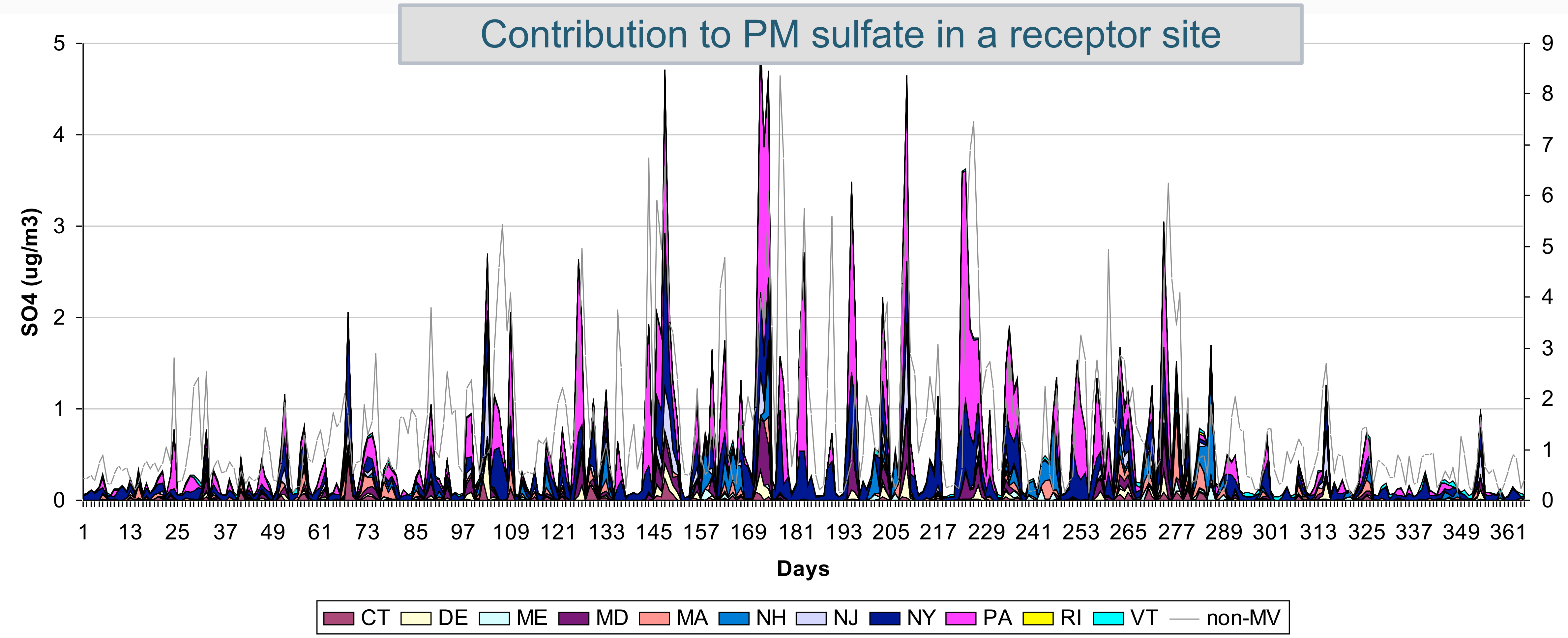

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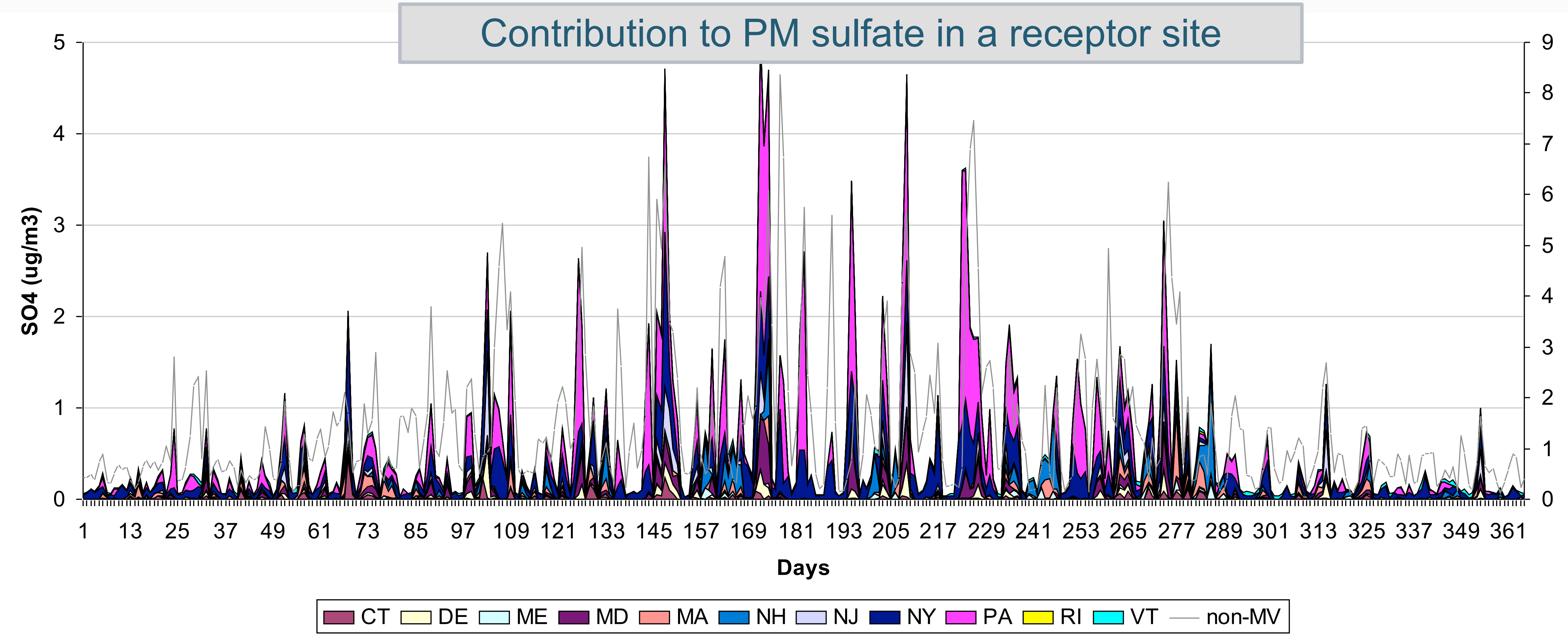

nt, 15th

Can be combined with AQF!

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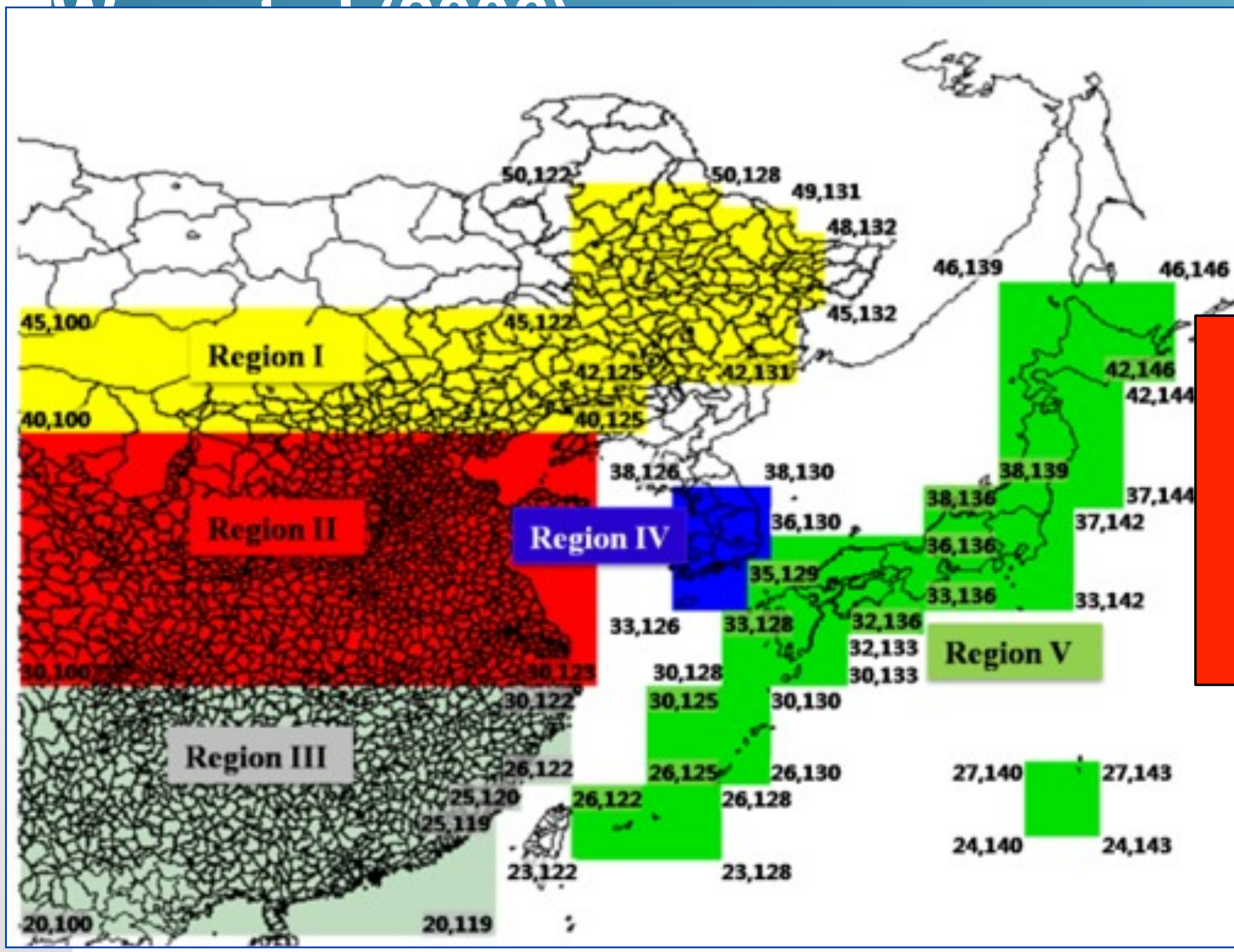
Source Tagging(REMSAD-tagging)



CT DE ME MD MA NH NJ NY PA RI VT non-MV

Assessment of megacity impacts

Can be combined with AQF!

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2.3 Assessment of O_3 and PM for the future LTP Project

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Key Findings of O3 Impacts (from TF-HTAP 2010)

(TF-HTAP :Task Force on Hemispheric Transport of Air Pollution)

O3 Impacts on Health Impacts

- One study based on the HTAP multi-model comparison estimated that O_3 resulting from emissions from foreign regions contributes 20% to >50% of O_3 mortalities, subject to large uncertainty
- Three studies estimate that reductions in O_3 precursor emissions may avoid more premature mortalities outside of some source regions than within, mainly because of larger populations outside of the source regions

O3 Impacts on Climate Change

- O3 contributes significantly to climate forcing,
  - Directly as a greenhouse gas that causes warming
  - and indirectly by damaging plants inhibiting their natural uptake of CO2.
- Among ozone precursors, widespread reductions in emissions of CH4, CO, and VOCs better reduce net climate forcing than reducing NOX, which may increase forcing over decadal time scales.

Key Findings of PM Impacts (from HTAP 2010)

PM Impacts on Health

- Contributions to PM from emissions within a region are much more important for health than emissions from foreign continents
- Intercontinental transport of PM can cause more mortalities than intercontinental transport of O3, due to the stronger PM-mortality relationship.
- Emissions from North America and Europe have much greater impacts on foreign regions than do emissions from East Asia and South Asia

Hundreds of annual avoided mortalities, threshold=5.8 μg/m³ in *italics*

Source Region	Receptor Region					Impact on foreign receptor regions:
	NA	EA	SA	EU	World	
NA	502 *125*	20 *19*	9 *8*	49 *38*	590 *190*	← 14.9%
EA	10 *5*	4348 *3330*	25 *23*	18 *14*	4433 *3376*	← 1.9%
SA	2 *1*	42 *39*	2105 *1099*	5 *3*	2168 *1142*	← 2.9%
EU	8 *4*	82 *78*	70 *57*	1769 *573*	2010 *71600*	← 12.0%

Key Findings of PM Impacts (from HTAP 2010)

PM Impacts on Climate Change

- Change of global annual average TOA all-sky aerosol direct RF in response to the 20% reduction of anthropogenic emissions
- BC activity under EMEP/CLRTAP: Focus country specific contribution to direct radiative forcing by BC aerosols

(unit: mW m^{-2}, mean ± std. dev)

Source Region	Sulfate	POM	BC	Sulfate+POM+BC
NA	16.1 ±5.6	1.6 ±1.0	-4.5 ±1.9	13.2 ±5.2
EU	26.7 ±9.5	1.9 ±1.2	-7.4 ±2.3	21.2 ±9.5
EA	19.6 ±7.2	3.2 ±1.8	-14.5 ±8.0	8.4 ±10.2
SA	6.1 ±1.9	2.5 ±1.3	-5.5 ±2.4	3.1 ±3.2
NA+EU+EA+SA	68.4 ±22.9	9.1 ±5.0	-31.9 ±13.7	45.9 ±24.6

2.4 Scenario-based Collaboration Simulation Approach

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KDI School of Public Policy and Management

Roadblocks for international environmental cooperation

- **Among countries**
  - Lack of trust, data sharing
  - Different (political and economic) interests
  - Lack of legitimacy of independent modeling
- **Among decision makers and scientists**
  - Lack of understanding
  - Different assumption, languages and interests

Conditions for effective collaboration

- Existence of on-going (effective and flexible) communication channels for domestic and international decisionmakers, key stakeholders, and scientists
- Joint Fact-finding mechanism
  - Shared assumptions in modelling
  - Shared data and research methods
- Shared roadmap from the beginning

Alternative approach to conventional ways

- **Conventional channels**
  - Government-initiated (established) meetings
  - Scientists-oriented meetings
- **Alternative channels**
  - Workshop environment where decisionmakers, key stakeholders, and scientists get together
  - More flexible and creative environment
  - For learning about the relationships between science and policies and politics

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Collaboration Simulation - Methods

Alternative approach to conventional ways

- **Conventional channels**
  - Government-initiated (established) meetings
  - Scientists-oriented meetings
- **Alternative channels**
  - Workshop environment where decisionmakers, key stakeholders, and scientists get together
  - More flexible and creative environment
  - For learning about the relationships between science and policies and politics

Scenario-based simulation method

- Construction of potential scenarios regarding transboundary air pollution (and/or) climate change with scenario development team among three countries (China, Japan, and Korea)
- Integration of Scenario with Modeling
- Utilization of scenario-based modeling with collaboration simulation exercise

Potential benefits of alternative approach

- Lower the tension among participants
- Promote comprehensive understanding about complex relationships on the issue
- Focus on future rather than the past
- Facilitate understanding of non-scientists on the model and its outcome
- Improve model design with inputs from other stakeholders and decisionmakers
- Maintain the communication among various actors
- Bridge the flexible communications with formal ones

Pre-requisite

- Acknowledgement of the potential benefits by key decision makers in three countries
- Identification of neutral convener or facilitators, experts on scenario-based planning in each country
- Knowledge on scientific, economic, political, policy factors

Milestone(tentative)

- Get other ideas, comments from all advisory committee members

- Hold a special task force meeting to prepare LTP Post-2012 draft

- First revision process (Summer, 2012)

- Finalize LTP Post-2012 plan at 15^{th} Expert Meeting

Thank you
and
let's start to think
for the future!

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