Current Status of IAM in Korea in Support of Transboundary Air Pollution Assessment Over Northeast Asia

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December 8, 2016

NEASPEC Transboundary Air Pollution Project
Expert Consultation Meeting, Seoul, Korea

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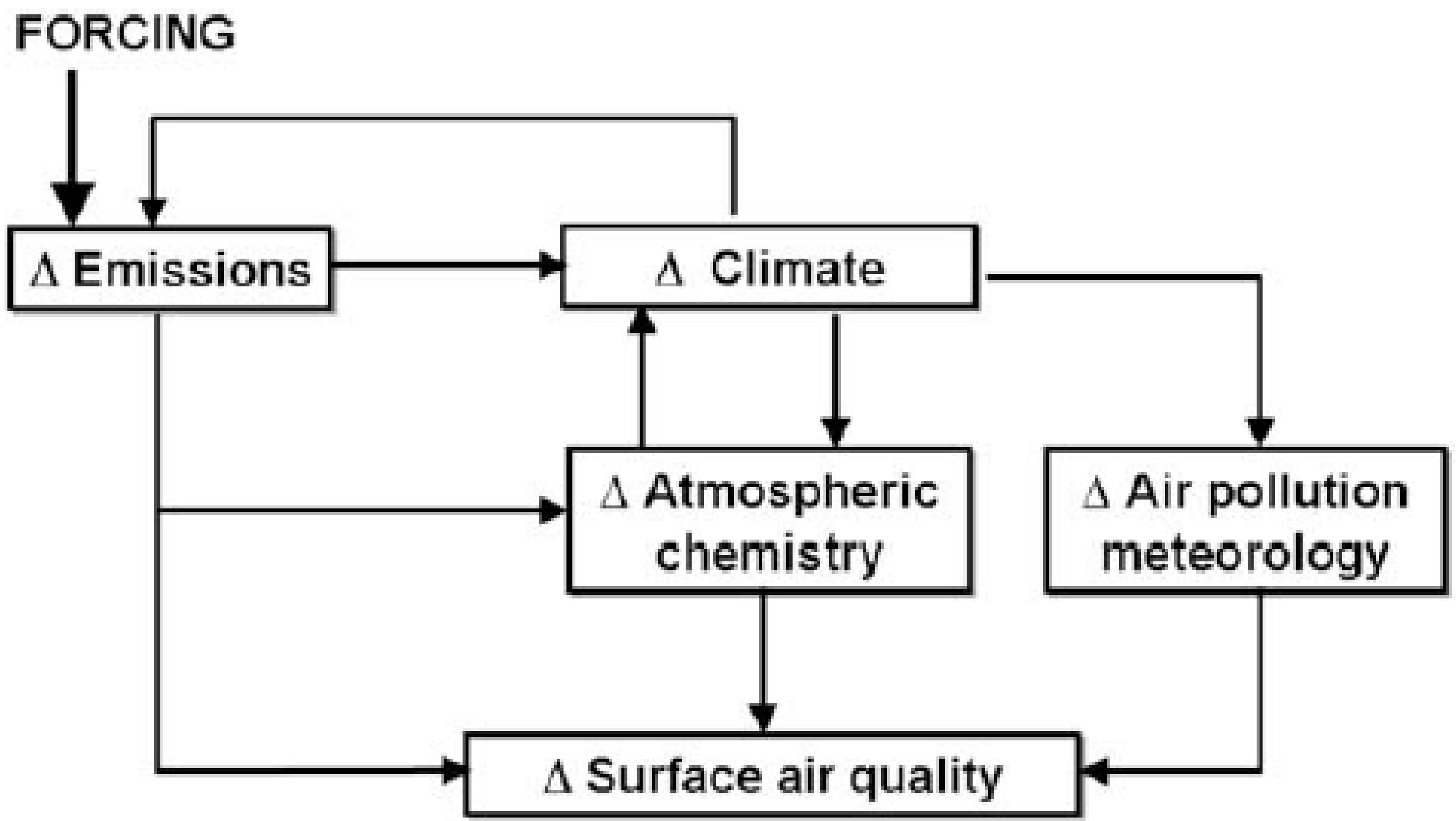
Content

1. **Present Status of TAP IAM-related work in Korea**

2. An idea on a possible collaborative framework on TAP IAM in NE Asia

Background

: Linkage between Climate Change and Air Quality



D. Jacob, 2009

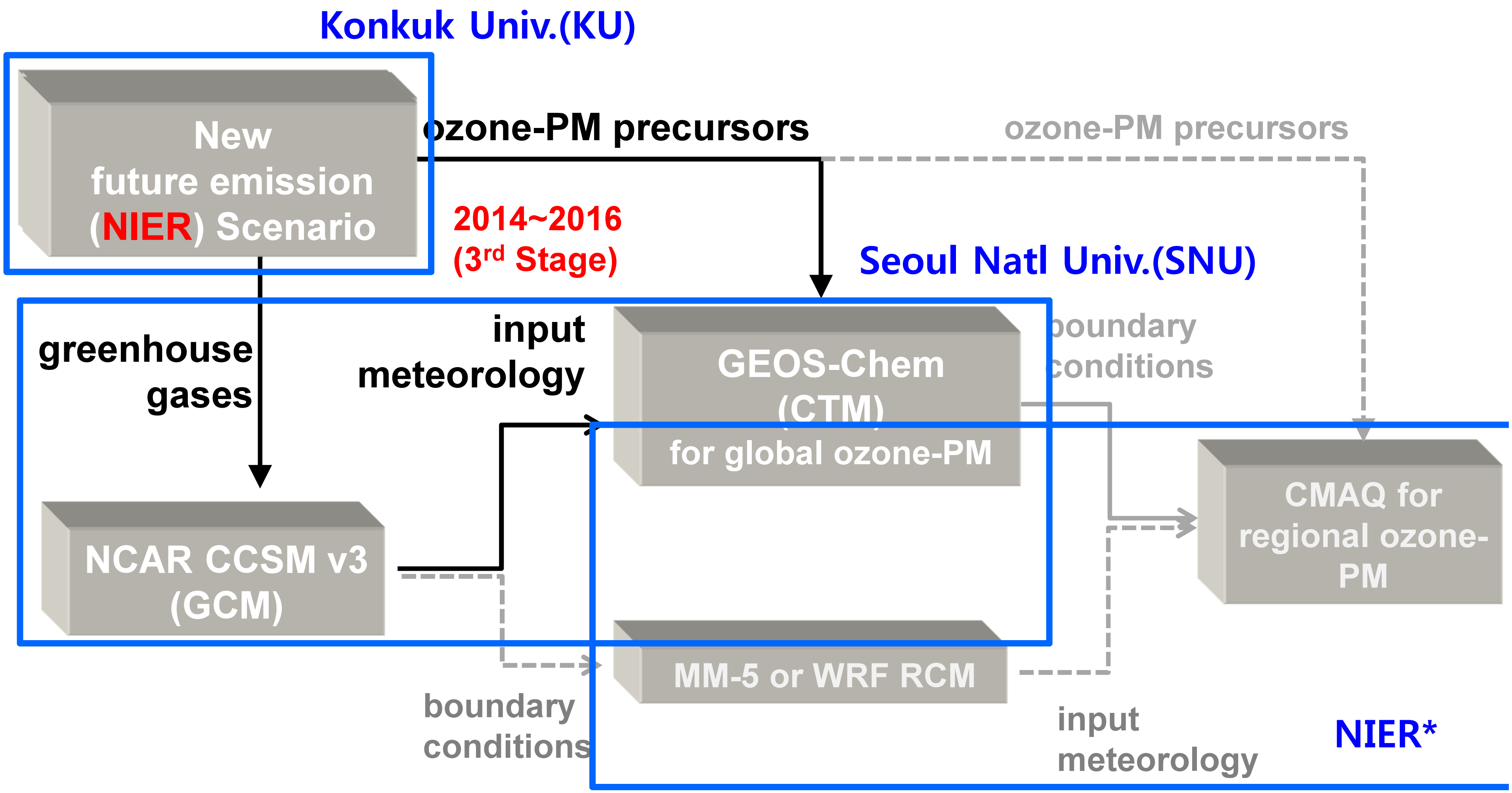
Integrated Assessment Model Development (Korea)

Title	Institute	Model	Characteristic
Integrated Environmental Strategy (IES)	• KEI-US EPA	• PAGE • CMAQ • BENMAP	• No energy model • Closed system • Optimization mode
Greenhouse Gases and Air pollutants Interaction and Synergy(GAINS)-Korea	• NIER/KU- IIASA	• GAINS - Emissions - Transport - Cost - Impact	• No energy model • Scenario mode • Linear air quality transport • Open system • Fast source apportionment • 1st admin level
Climate-Air Quality Integrated Modeling (ICAMS)	• NIER(SNU, KU) - NIES/IIASA	• MESSAGE/AIM • GEOSChem/CMAQ • BENMAP	• No policy feedback • Offline-linking (less integration) • Strong Science • Multi-domain(Global-National)

- **Pros** vs. **Cons**

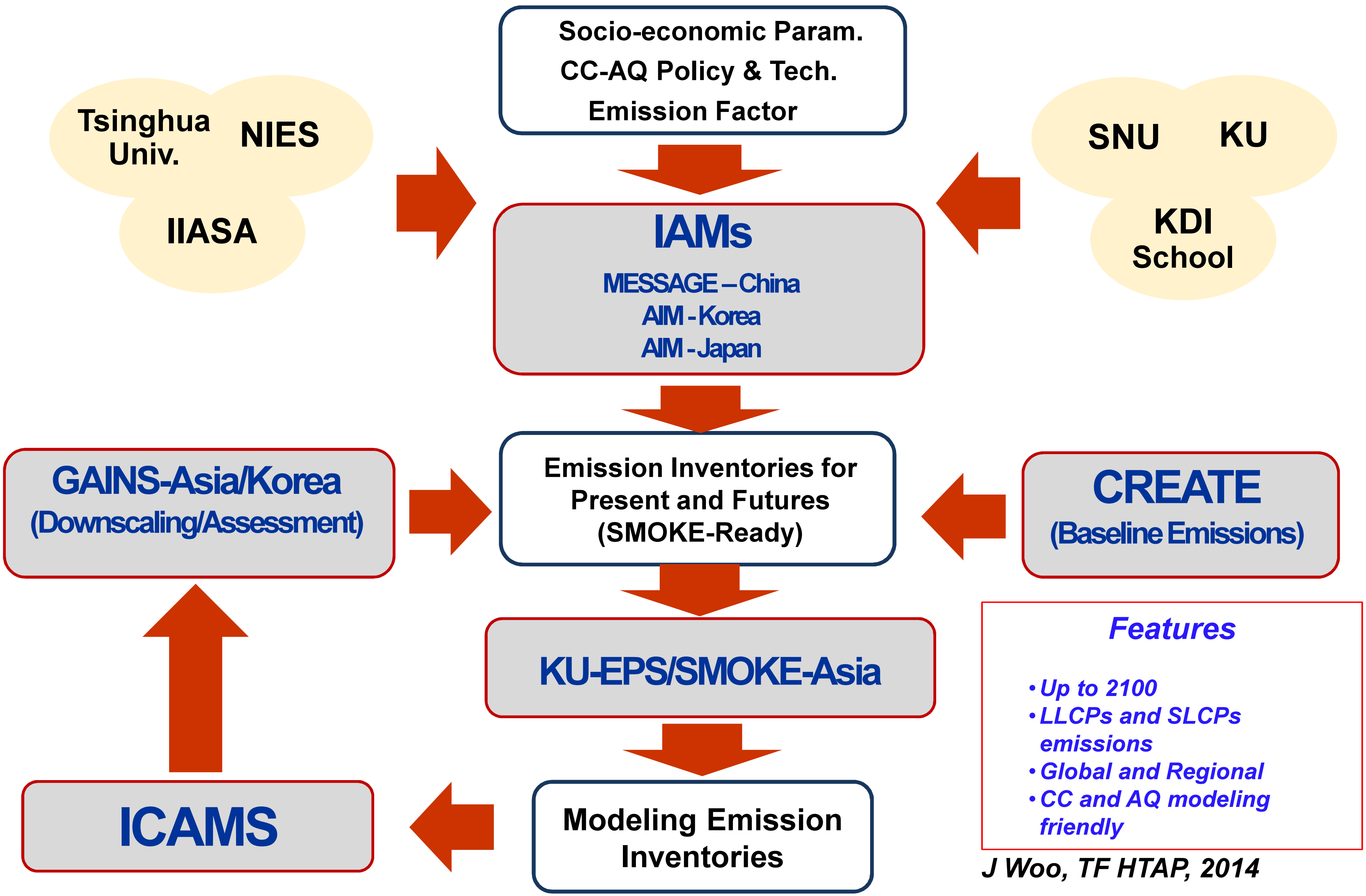
ICAMS

Climate Change and Air Quality Study using NIER/SNU-ICAMS



* National Institute of Environmental Research

New East Asia Future Emission Scenarios for ICAMS

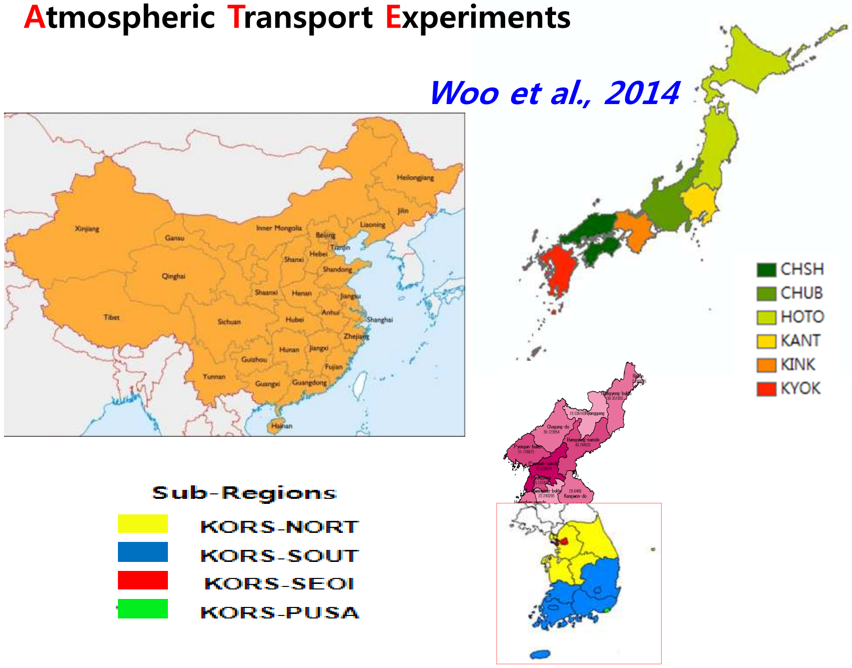


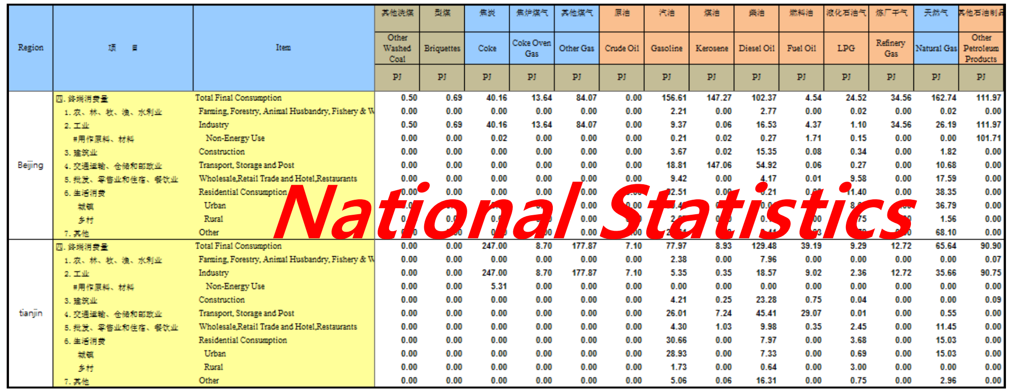
J Woo, TF HTAP, 2014

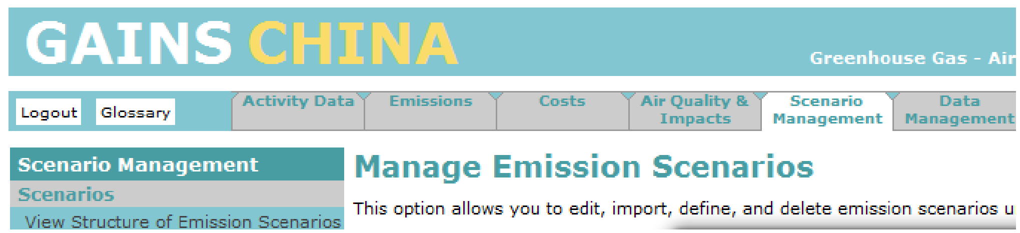
Baseline Emission Inventory : NIER/KU-CREATE*

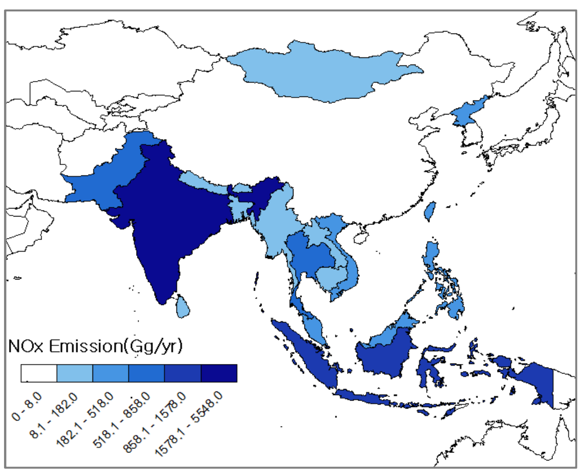
* Comprehensive Regional Emissions for Atmospheric Transport Experiments

Woo et al., 2014





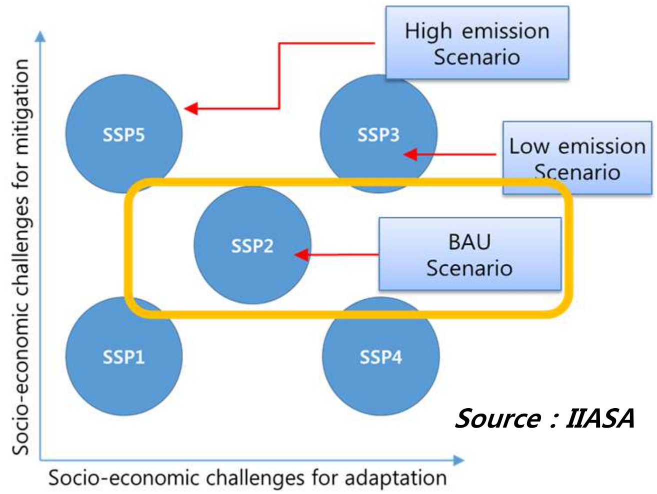


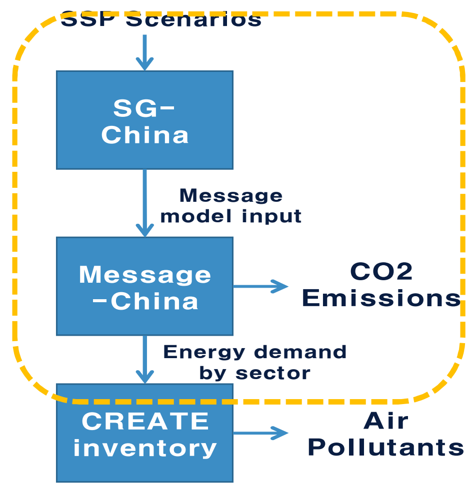


1. Emission Inventory : Improve GAINS-Asia emissions using updated national data, MEGAN/BlueSky emissions model
2. Year 2009/2010, Asia regions, ~300 source categories
3. Pollutants: CO_2, CH_4, NO_x, N_2O, PM_{10}, $PM_{2.5}$, SO_2, VOC, NH_3, CO, BC, OC, Mercury
4. Anthropogenic, Biogenic, Biomass burning
5. Emissions processing friendly

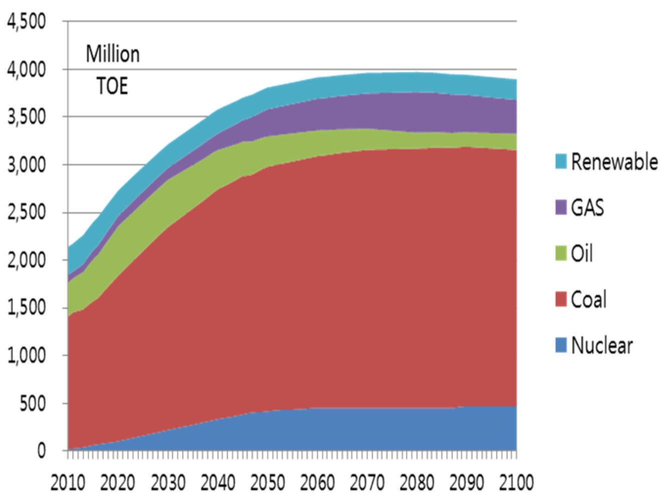
Energy Projection

Energy Demand of SSP Scenarios

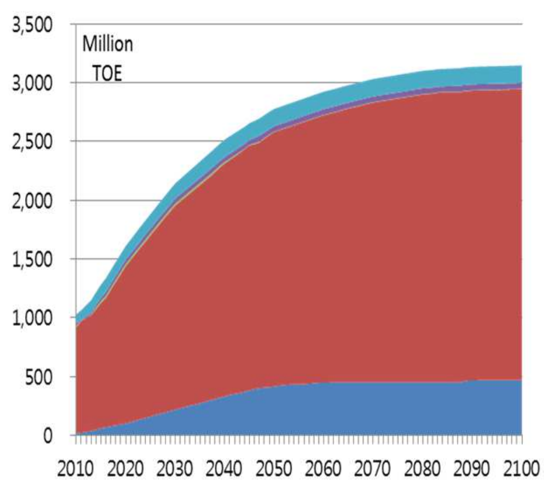




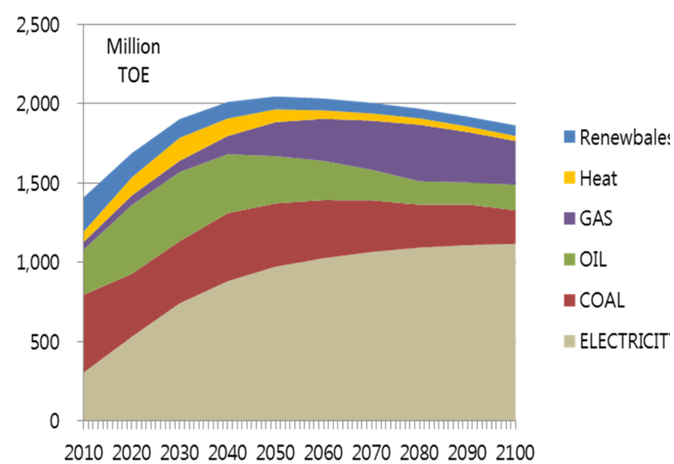
Energy projection using MESSAGE



Primary Energy

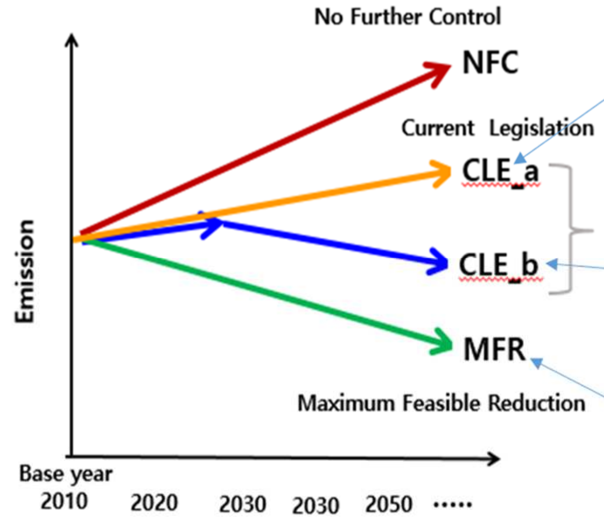


Fuel Mix in Power sector



Final Energy

Implementation of control policy



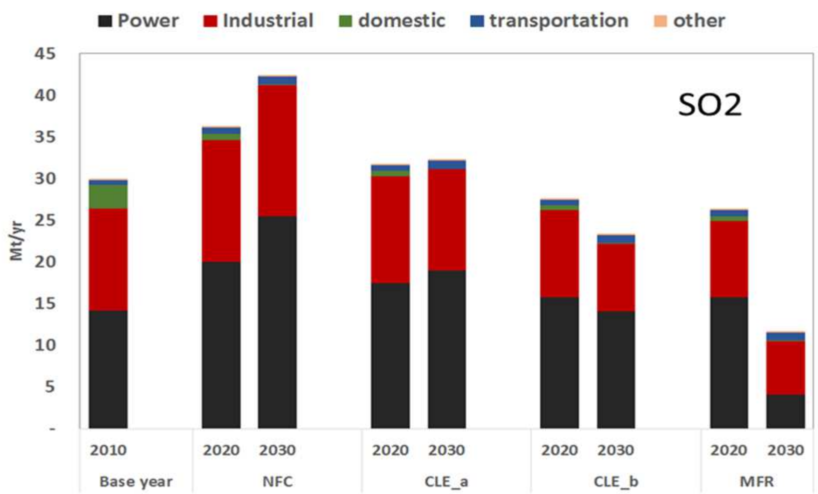
- 12th Action plan National action plan of air pollution prevention and control
- National emission standards

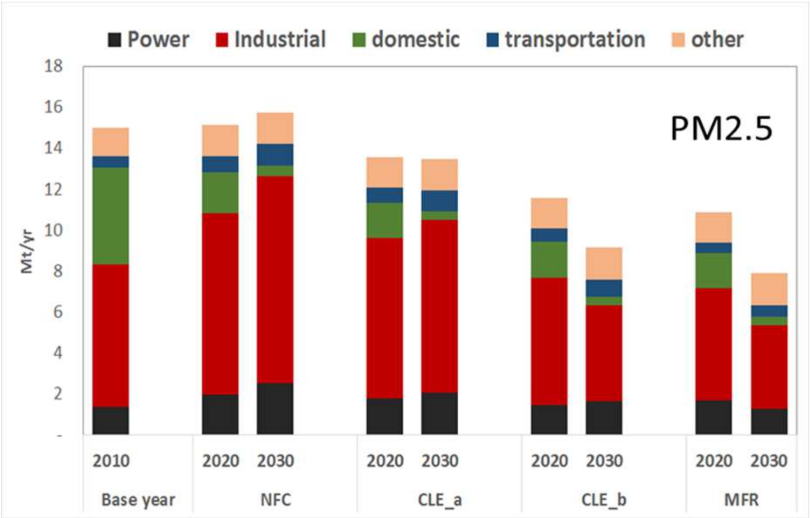
- 13th Action plan
- Medium and long term goals for control and prevention of air pollution
- Regional Action Plan (for JJJ /PRD /YRD)

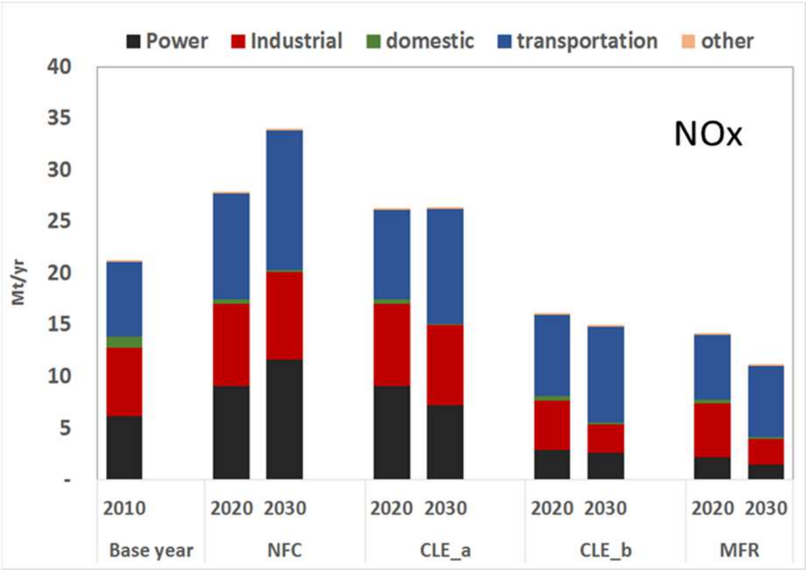
- CHINA' S INTENDED NATIONALLY DETERMINED
- CONTRIBUTIONS U.S.-China Joint Announcement on Climate Change

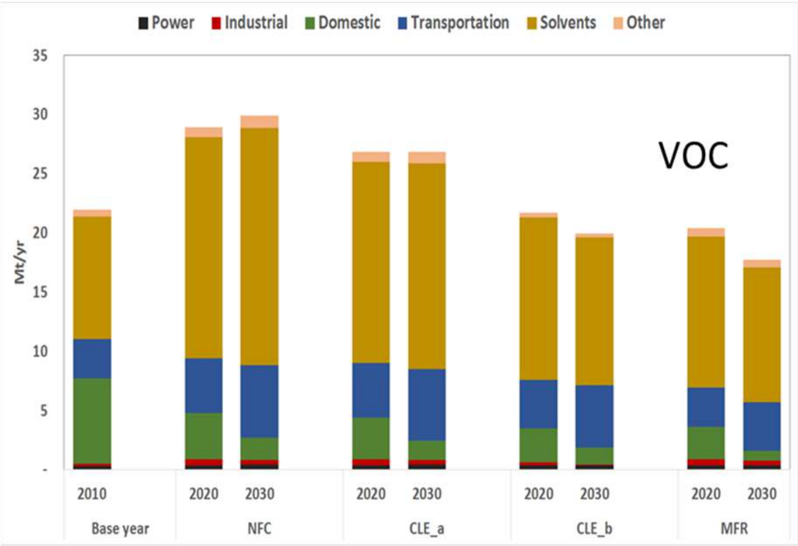
1. **NFC (No Further Control)** : No further control after 2010. All controls will be phased-out as their life time reaches
2. **CLE_a (Current LEgislation)** : Maintain 2010 level + Implement some planned national control policies(~ Yr 2013)
3. **CLE_b (Current LEgislation)** : CLE_a + Implement all planned control policies and technologies (with regional action plan)
4. **MFR (Maximum Feasible Reduction)** : Most stringent control technologies and reduction efforts will be introduced. (with INDC & Announcement on Climate Change)

Emission pathway for each scenario of China



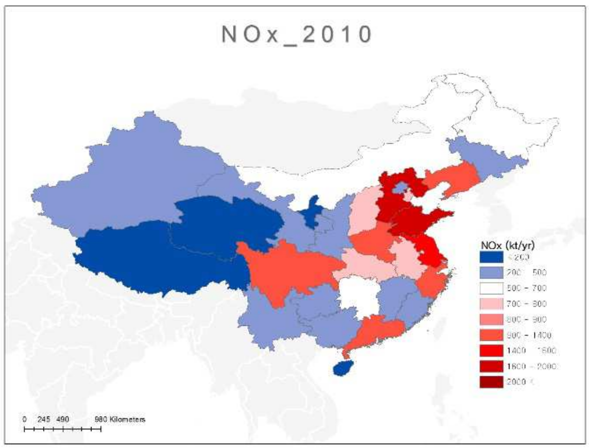




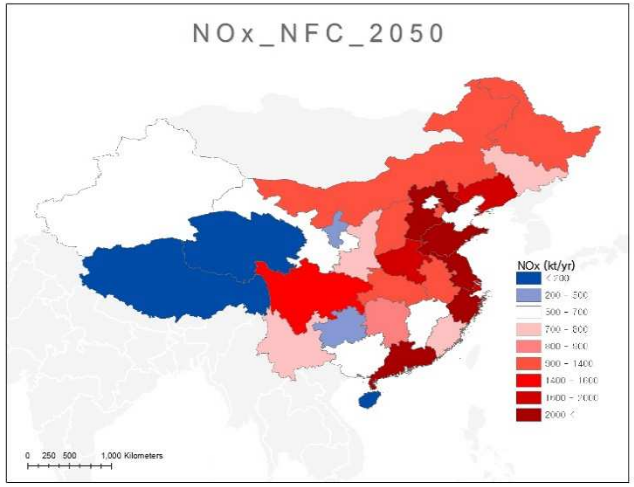


Province level emissions for each 2050 scenarios

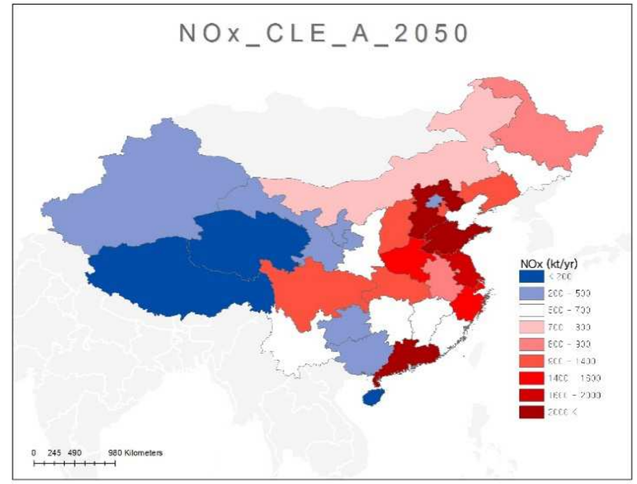
NOx



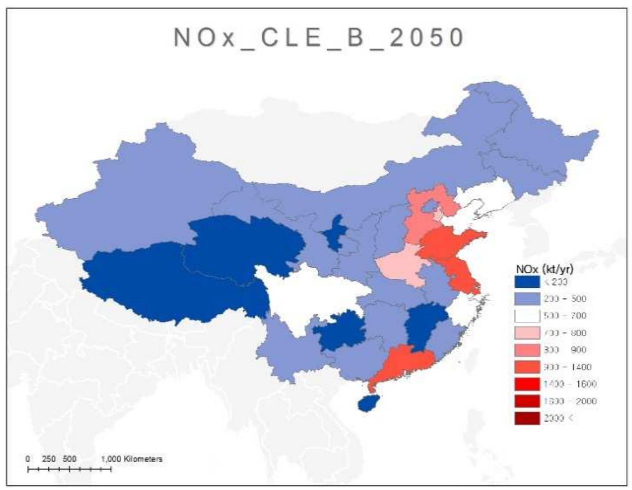
2010 Base year



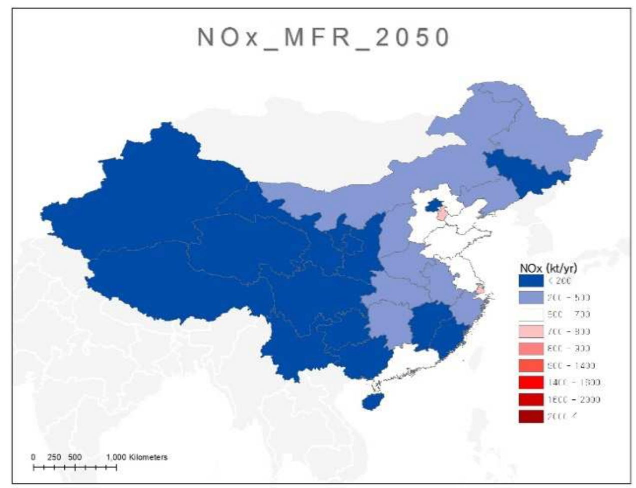
NFC



CLE_a



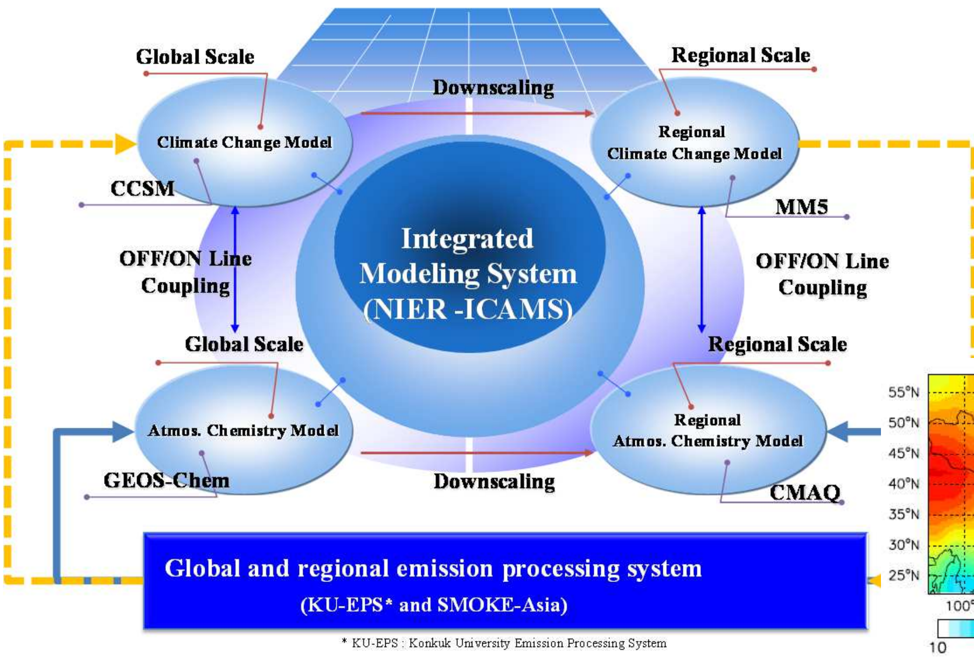
CLE_b

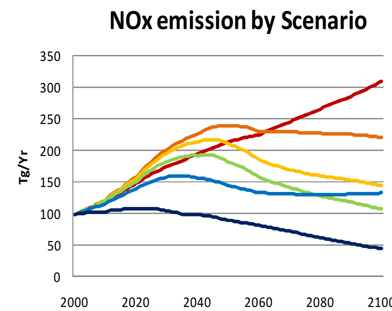


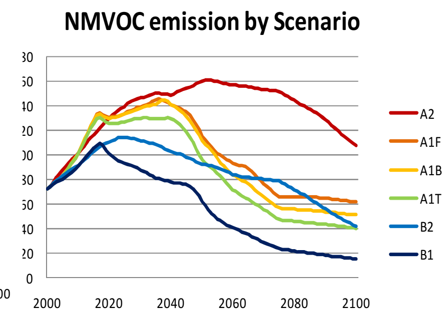
MFR

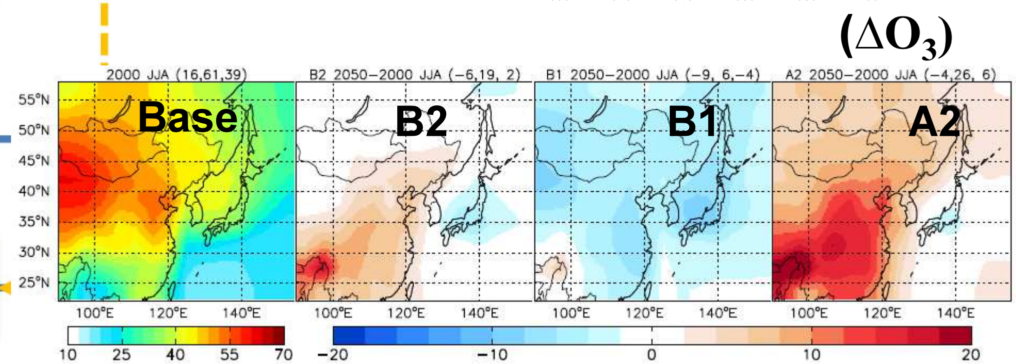
Impact of Climate Change on Regional Air Quality

Integrated Climate Change and Air Quality Modeling Framework (ICAMS, NIER 2011)

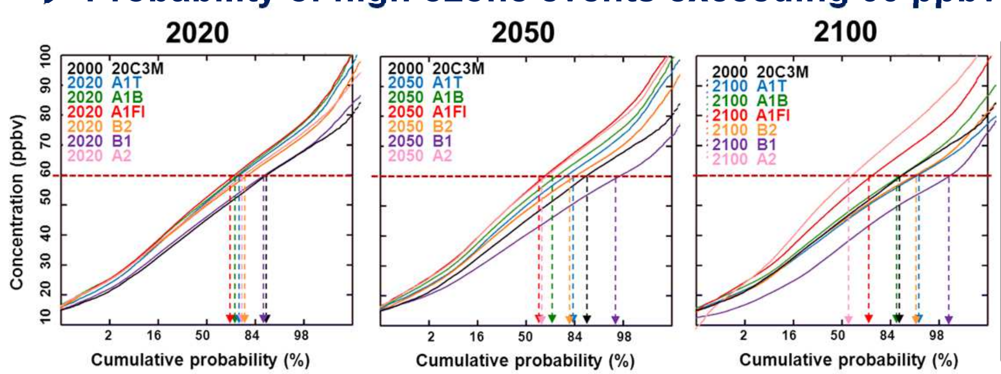








▶ **Probability of high ozone events exceeding 60 ppbv for summer maximum 8-h average over East Asia**



2000	10.8%					
IPCC SRES Scenarios	A1T	A1B	A1FI	B2	B1	A2
2020	24.9%	26.3%	28.3%	20.0%	11.6%	22.3%
2050	20.7%	26.5%	35.3%	15.5%	2.7%	33.5%
2100	6.1%	11.4%	26.7%	6.7%	1.3%	41.8%

Courtesy of R. Park

GAINS-Korea

GAINS-Korea : An CC-AQ Integrated Assessment Framework for Korea

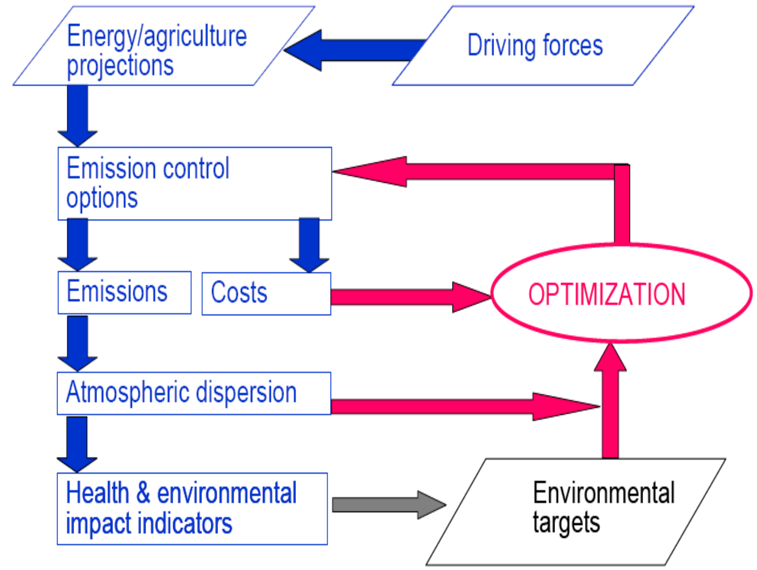
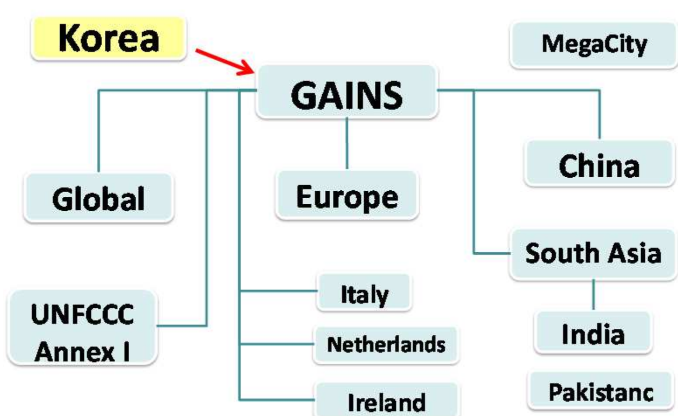


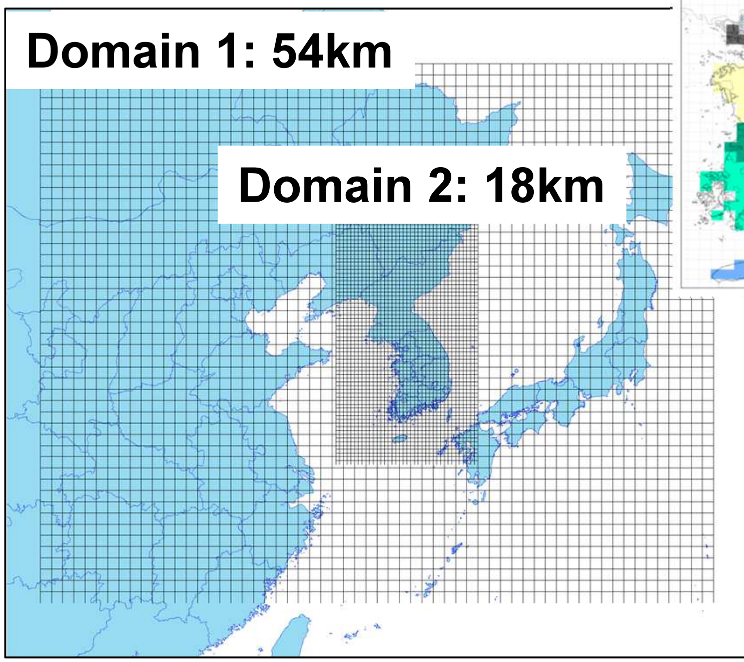
Figure 2.2: The iterative concept of the GAINS optimisation. Amann, 2011



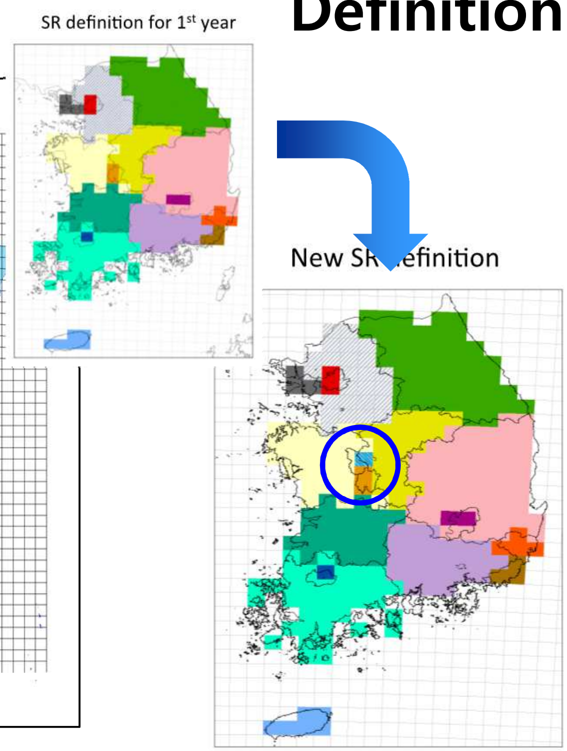
	PM	SO_2	NO_x	VOC	NH_3	CO_2	CH_4	N_2O	HFCs PFCs SF_6
Health impacts: PM	√	√	√	√	√				
O_3			√	√			√		
Vegetation damage: O_3			√	√			√		
Acidification		√	√		√				
Eutrophication			√		√				
Radiative forcing: - direct						√	√	√	√
- via aerosols	√	√	√	√	√				
- via OH			√	√			√		

CAMx Modeling for S-R Matrix

Modeling domain



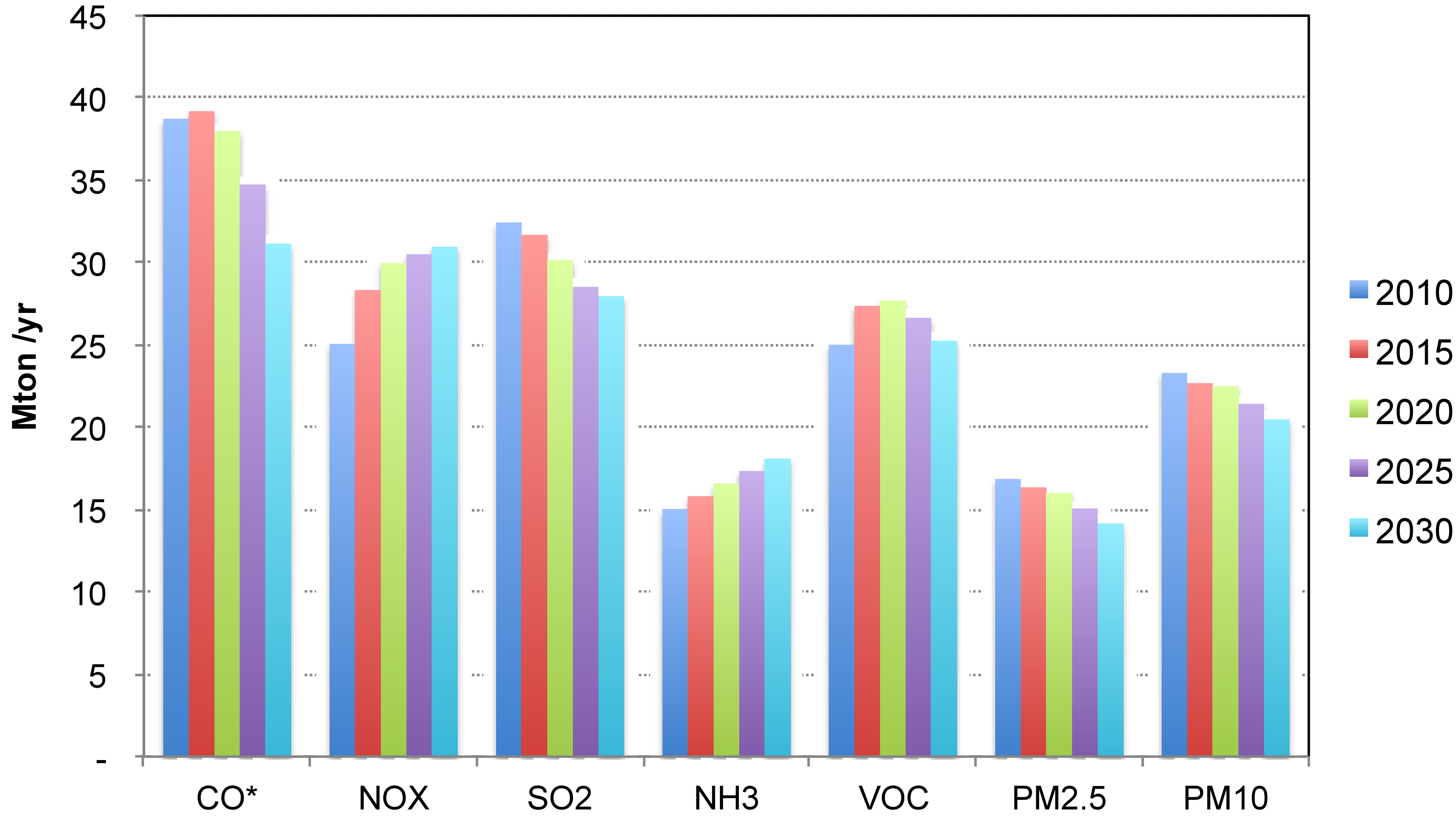
Definition of S-R region



- **Receptor (17 regions)**
Metropolitan cities (8 cities) and provinces (9 regions)
- **Source (19 regions)**
Same as receptor region s with outside of S. Kore a countries (China, N. Ko rea and Japan)

- Meteorological data : **MM5** (year **2005** from NIER)
- Emissions: GAINS-Korea (CAPSS2010), CREATE
- Emissions processing: **SMOKE-Asia** (Woo et al., 2012) linking with GAINS
- Air quality model : **CAMx** version 6.0 with **PSAT/OSAT** (Particulate/ozone Source Apportionment Technology)
  - Model option: EBI chemistry solver with CB05 mechanism, ACM2 diffusion, PPM advection scheme

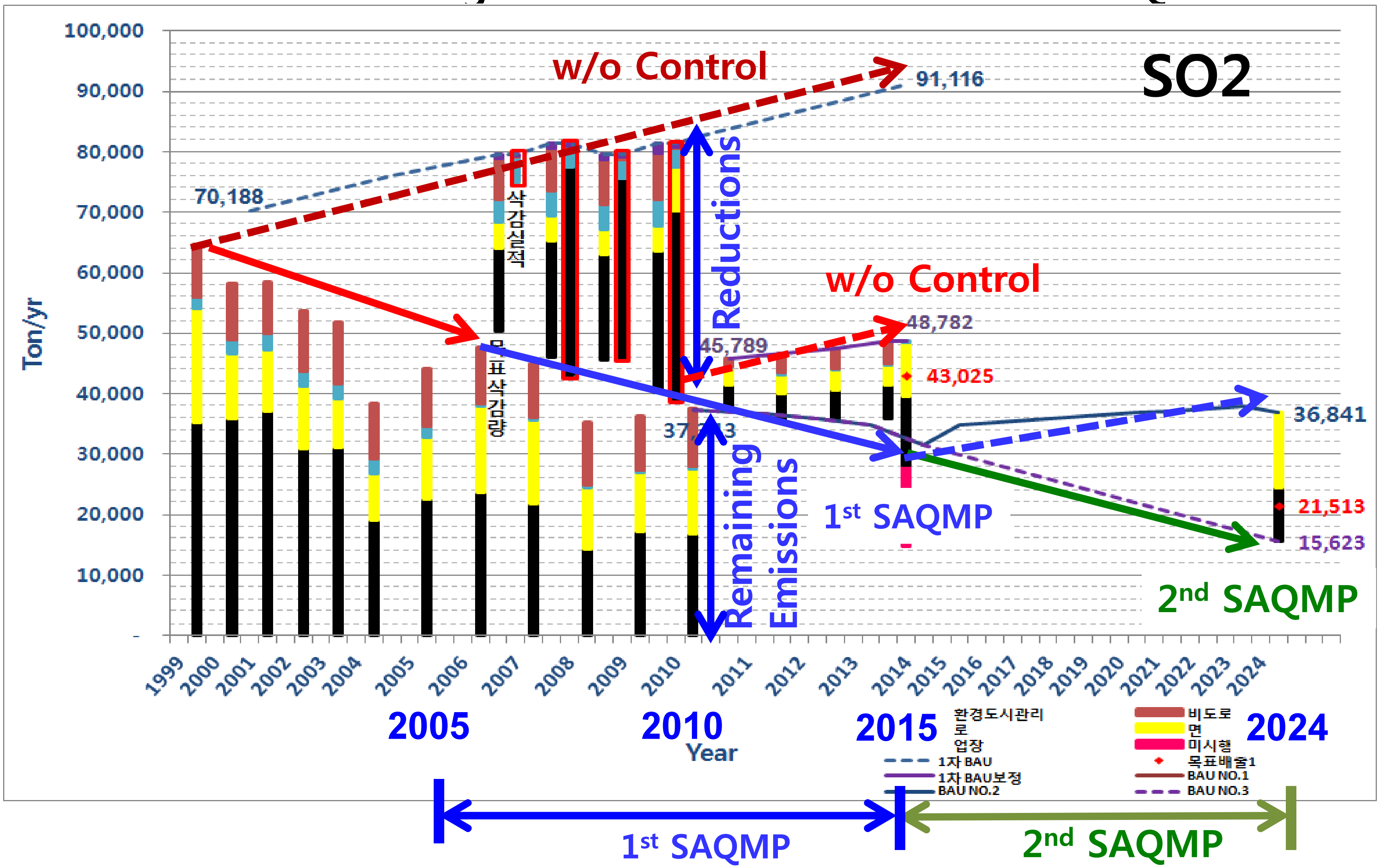
China Emission Scenario in GAINs-Korea S-R Matrix - ECLIPSE CLE



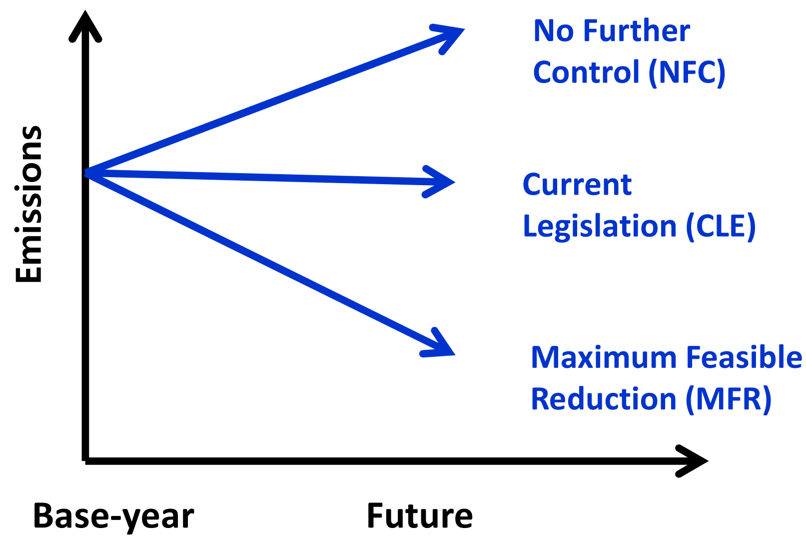
*CO emissions divided by factor of 5

Emission Trends for Pre/Post 2010 : Korea

- Emissions Change due to 1st and 2nd Phase of SAQMP

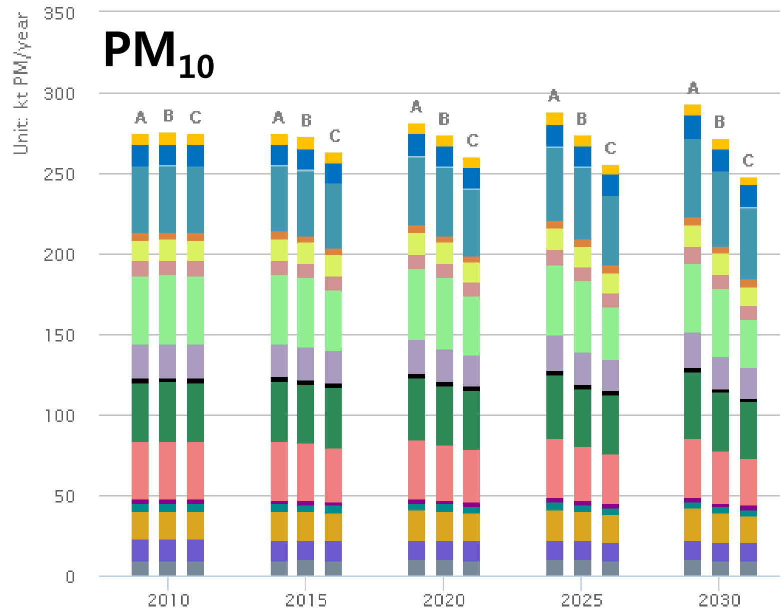


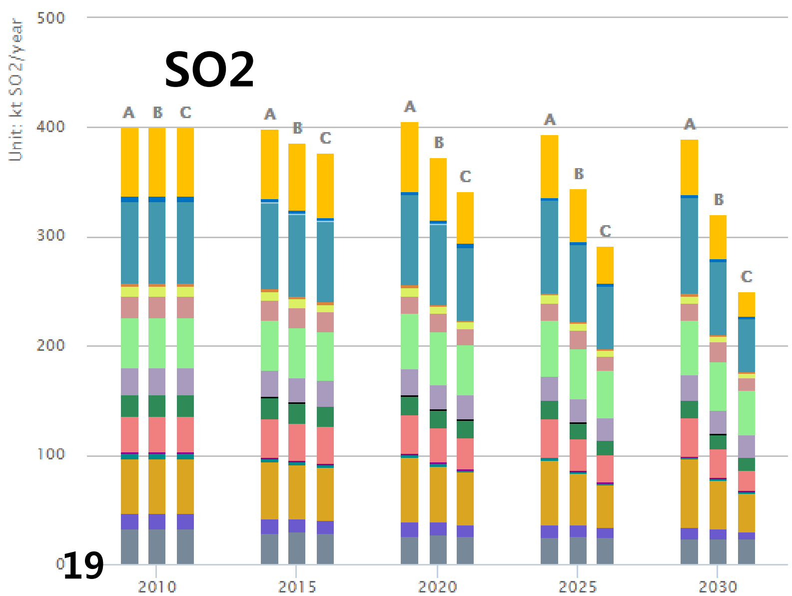
Future Emission Change under Three Scenarios

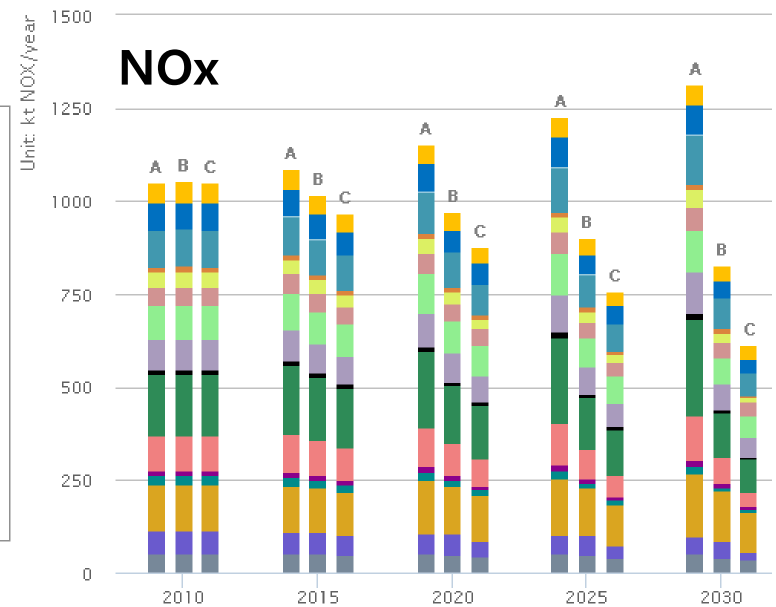


Scenario

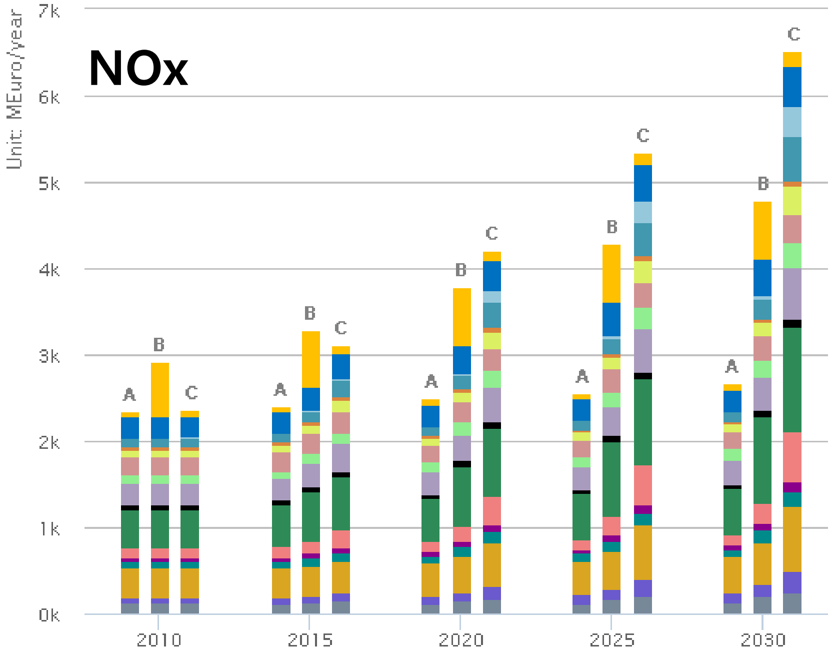
A : CLE (BAU)
B : AQ
C : MFR

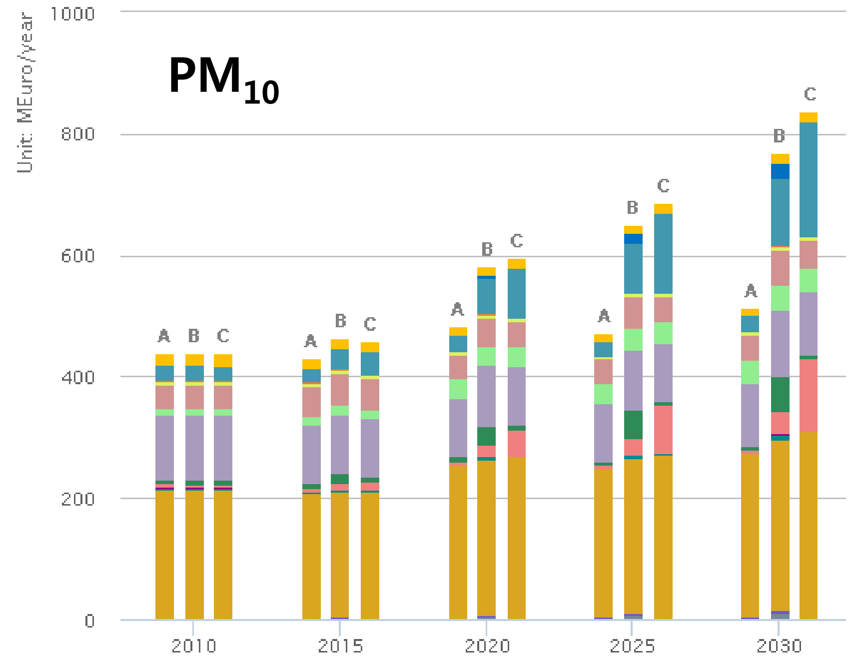


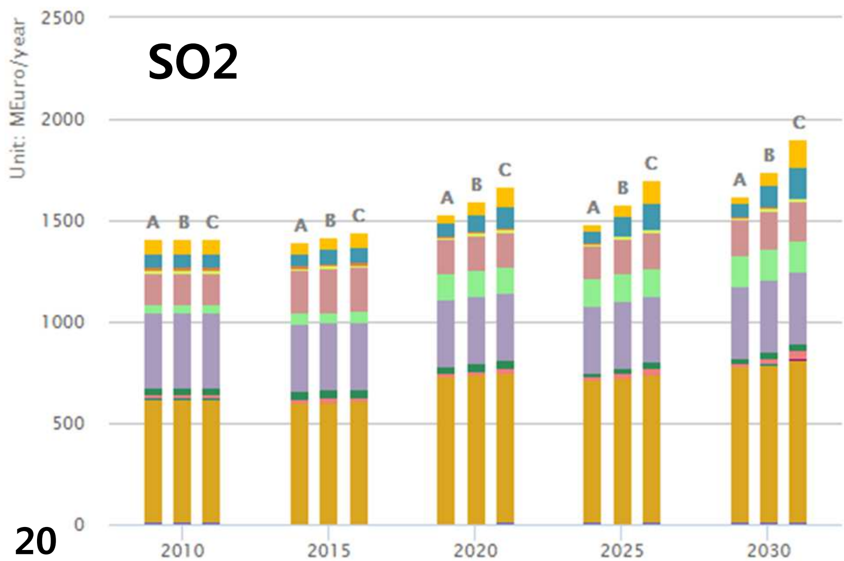




Control Cost under Three Scenarios



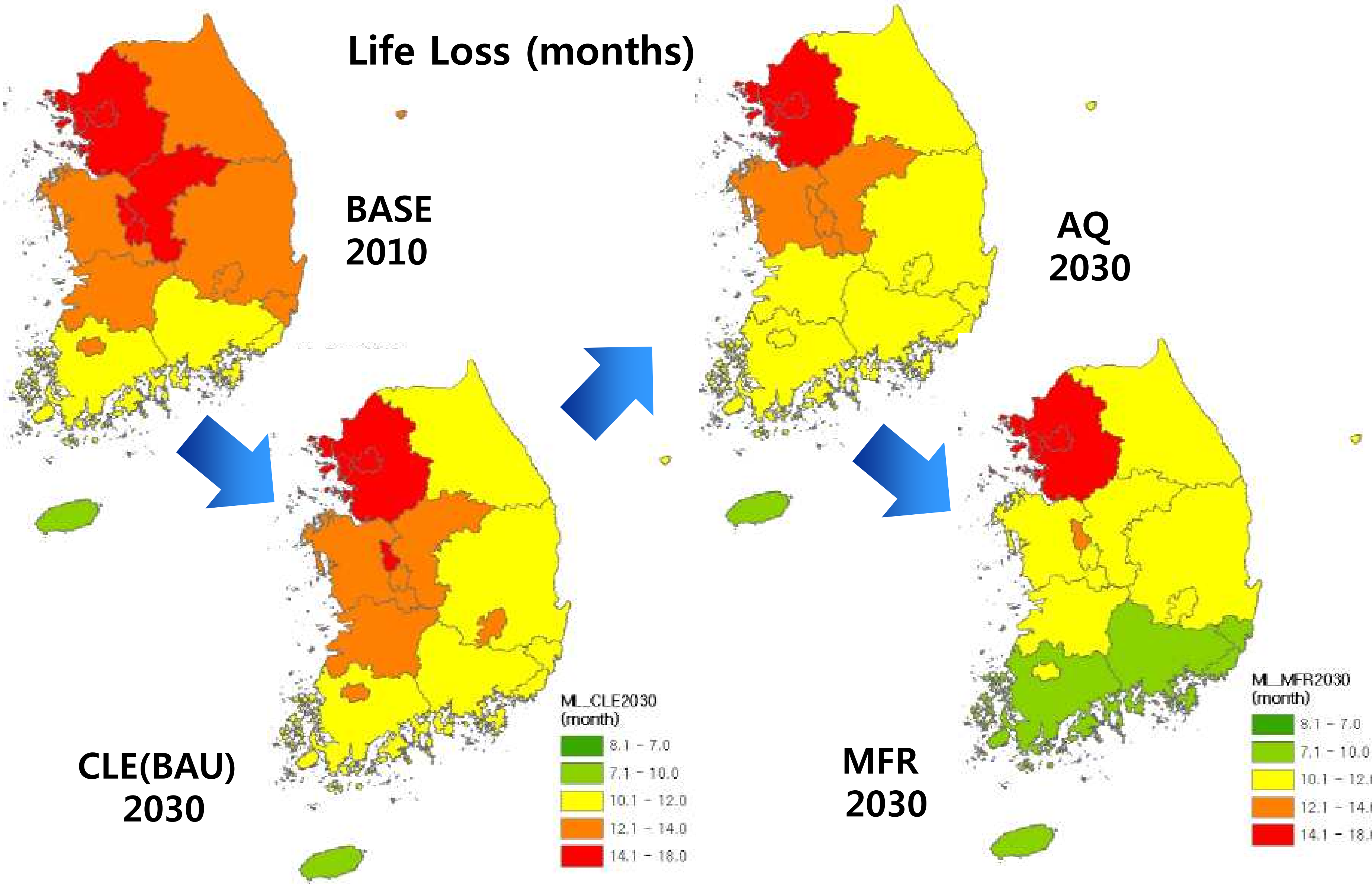




Scenario

A : CLE (BAU)
B : AQ
C : MFR

Future Health Loss under Different Scenarios



Content

1. Present Status of TAP IAM-related work in Korea

2. An idea on a possible collaborative framework on TAP IAM in NE Asia

Understanding Regional Air Quality

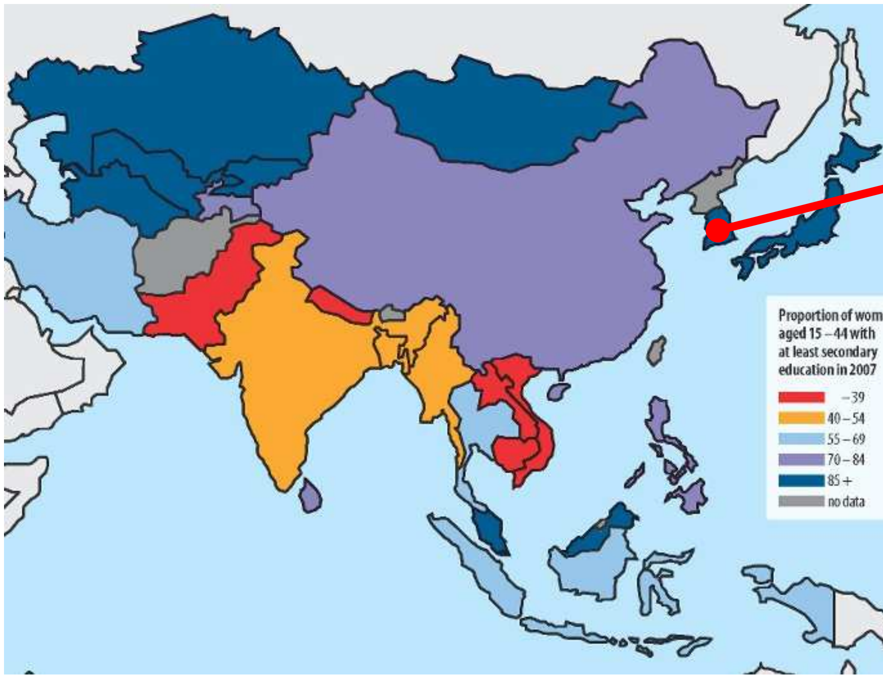
1. **Uncertainties of Emissions/Transport/Chemistry**

Science and Technology

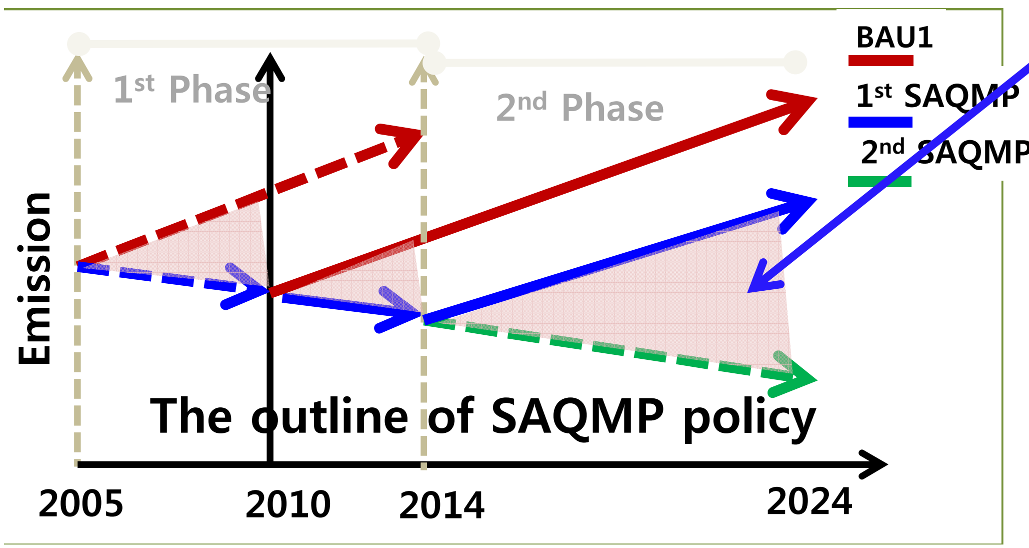
2. **Uncertainties of Emissions/Control/Contribution**

Control Emissions and Control Future

: Seoul Air Quality Management Plan (SAQMP)



Putting 8 billion dollars!

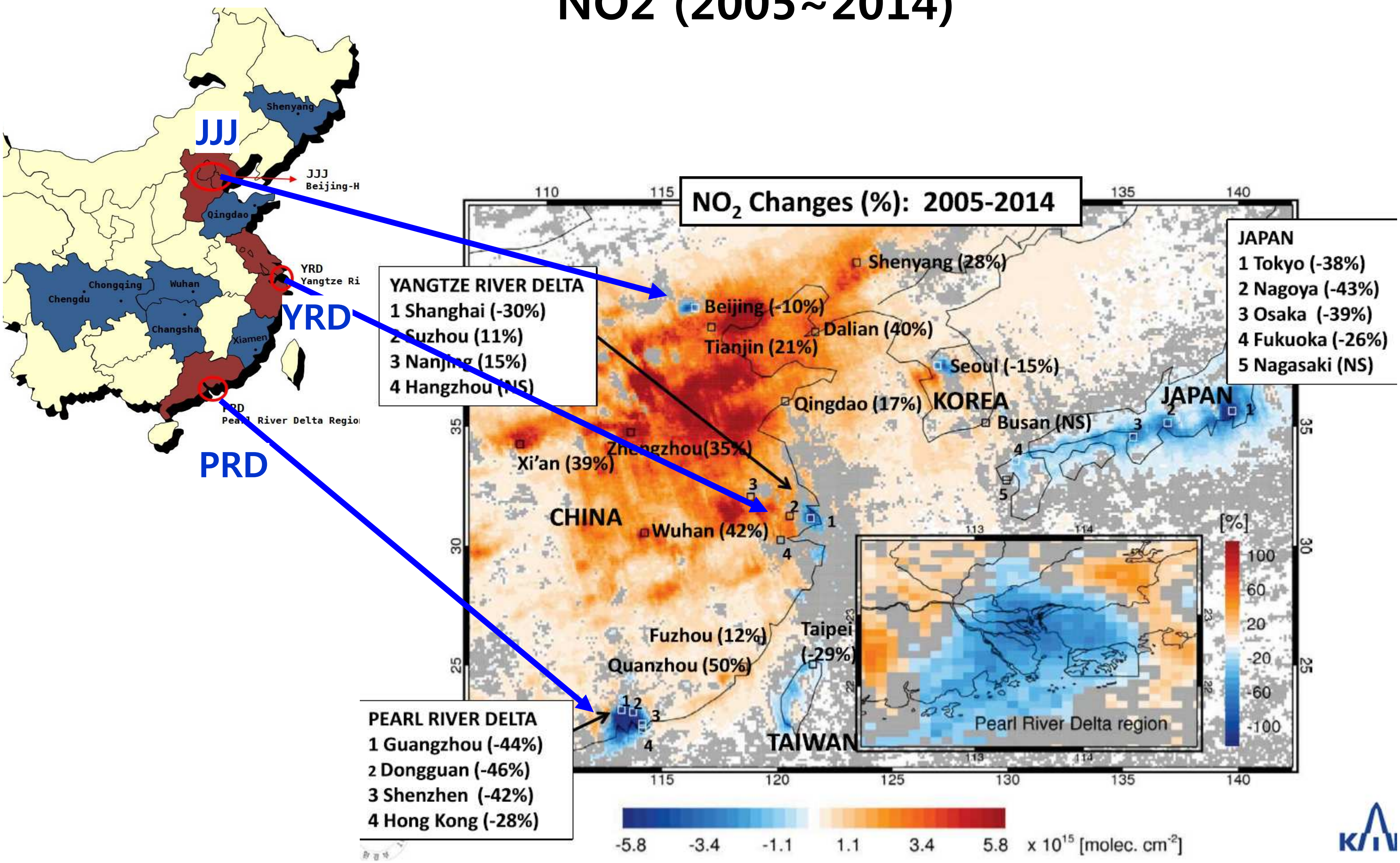


Target Air Quality

	$PM_{2.5}$ (new)	PM_{10}	NO_2	O_3 (new)
2024	*20㎍/㎥*	*30㎍/㎥*	*21ppb*	*60ppb*
2014	*-*	*40㎍/㎥*	*22ppb*	*-*
2010	-	47㎍/㎥	34ppb	-
2001	-	71㎍/㎥	37ppb	-

Air Quality Change on NE Asia

- NO2 (2005~2014)



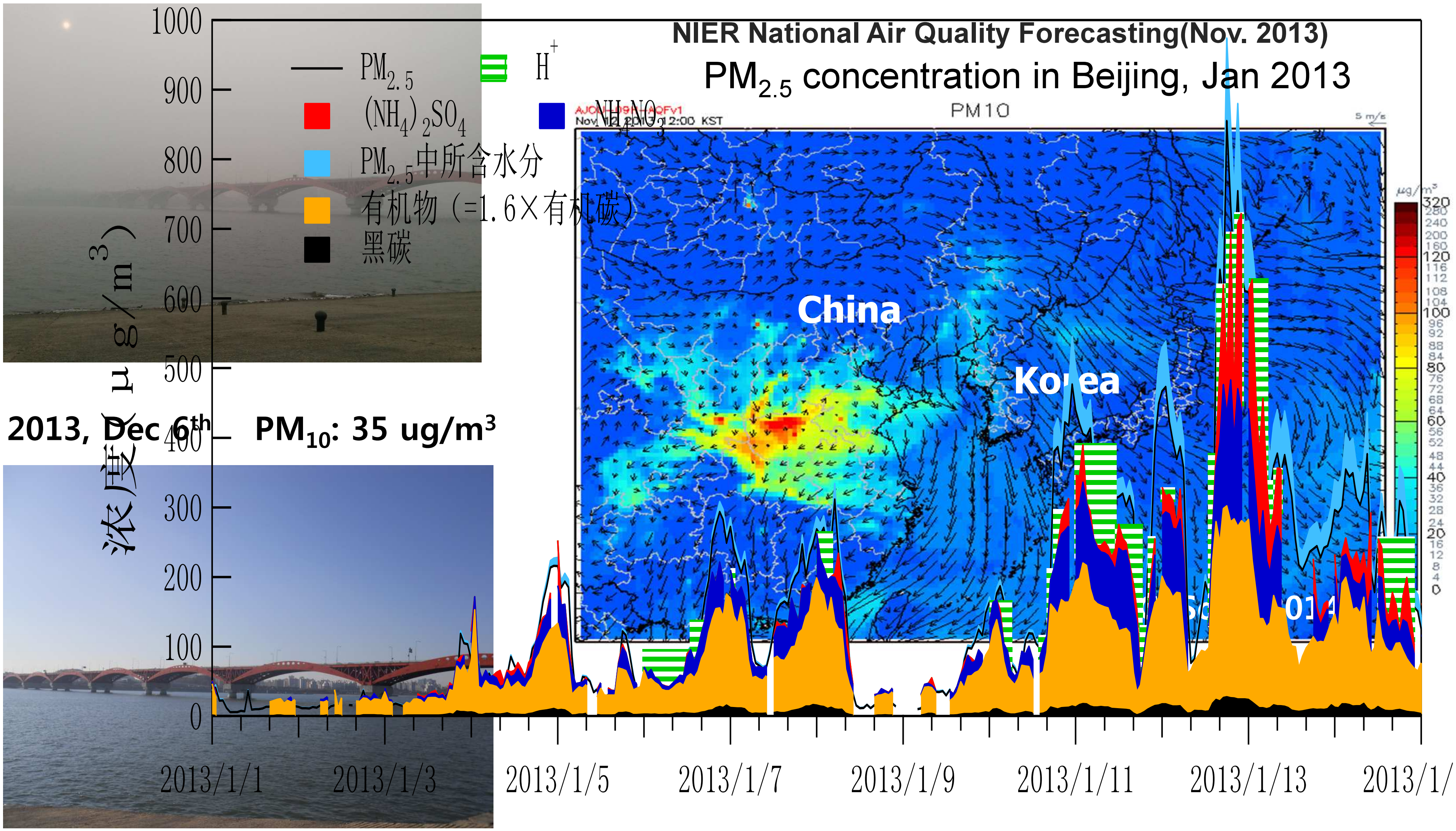
New Challenge for Emissions and Air Quality : Winter Haze

Fine particle pollution over Seoul

2013, Dec 5th PM_{10}: 166 ug/m³

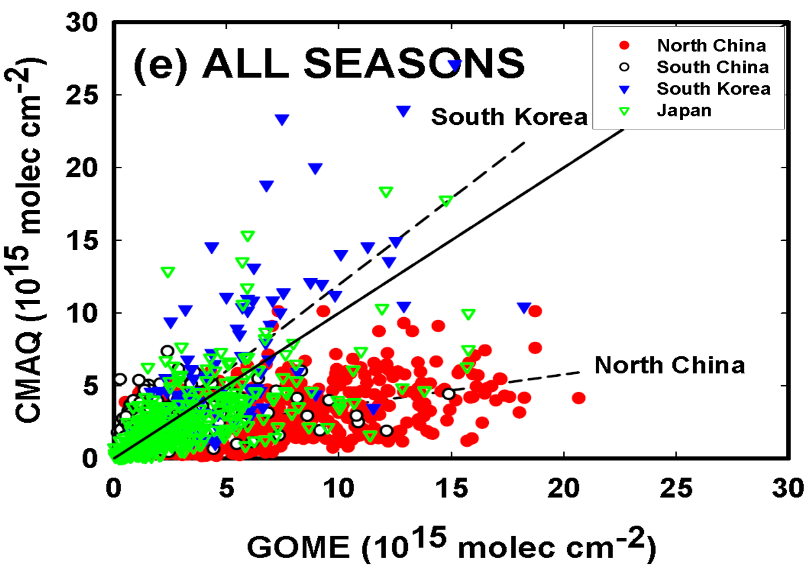
2013, Dec 6th PM_{10}: 35 ug/m³

Heavy pollution plume transport



Uncertainties Estimation of Emissions

CMAQ with 2001 ACE-ASIA emission inventory vs GOME-derived NO_2



Han et al., ACP 2009

Overall, it is estimated that the NOx emissions are underestimated by 57.3% in North China and overestimated by 46.1% in South Korea over an entire year

Overall Uncertainty in Anthropogenic Emission Estimates (±95% Confidence Intervals, Unit: %).

Region	SO_2	NO_x	CO_2	CO	CH_4	NMVOC	BC	OC	NH_3
China	13	23	16	156	71	59	484	495	53
Japan	9	19	7	34	52	35	83	181	29
Other East Asia	12	24	13	84	101	49	160	233	31
Southeast Asia	27	92	91	214	95	218	257	345	87
India	26	48	33	238	67	149	359	544	101
Other South Asia	35	63	44	291	109	148	379	531	101
International shipping	44	56	40	72	72	204	402	402	–
All Asia	16	37	31	185	65	130	364	450	72

Streets et al., JGR, (2003).

The overall uncertainties in 2006 INTEX-B Asian emission:
±16% (SO_2), ±37% (NOx),
±130% (NMVOC), ±185% (CO),
±360% (BC), ±450% (OC).

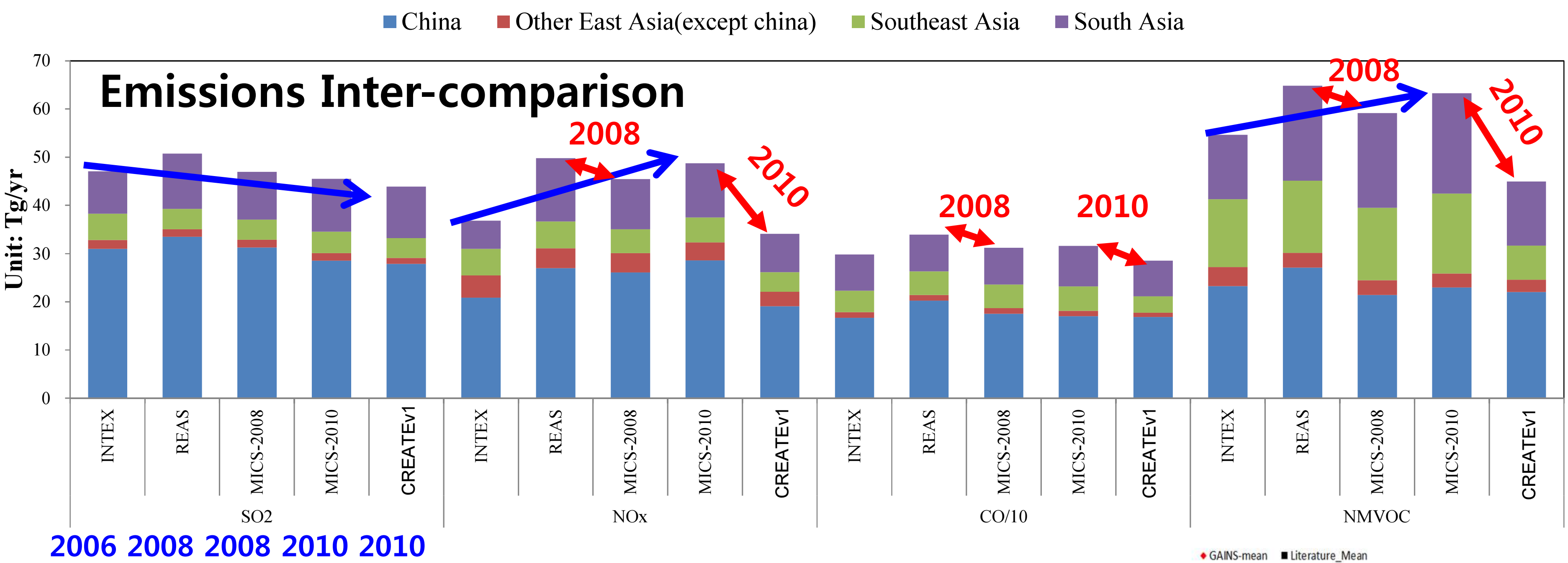
Zhang et al., ACP 2009

Uncertainties of REAS2.1 emissions in China/India/the rest of Asian countries :
±31/32/35% (SO_2), ±37/49/47% (NOx),
±78/137/111% (NMVOC), ±86/114/131% (CO),
±176/178/257% (BC), ±271/233/286% (OC)

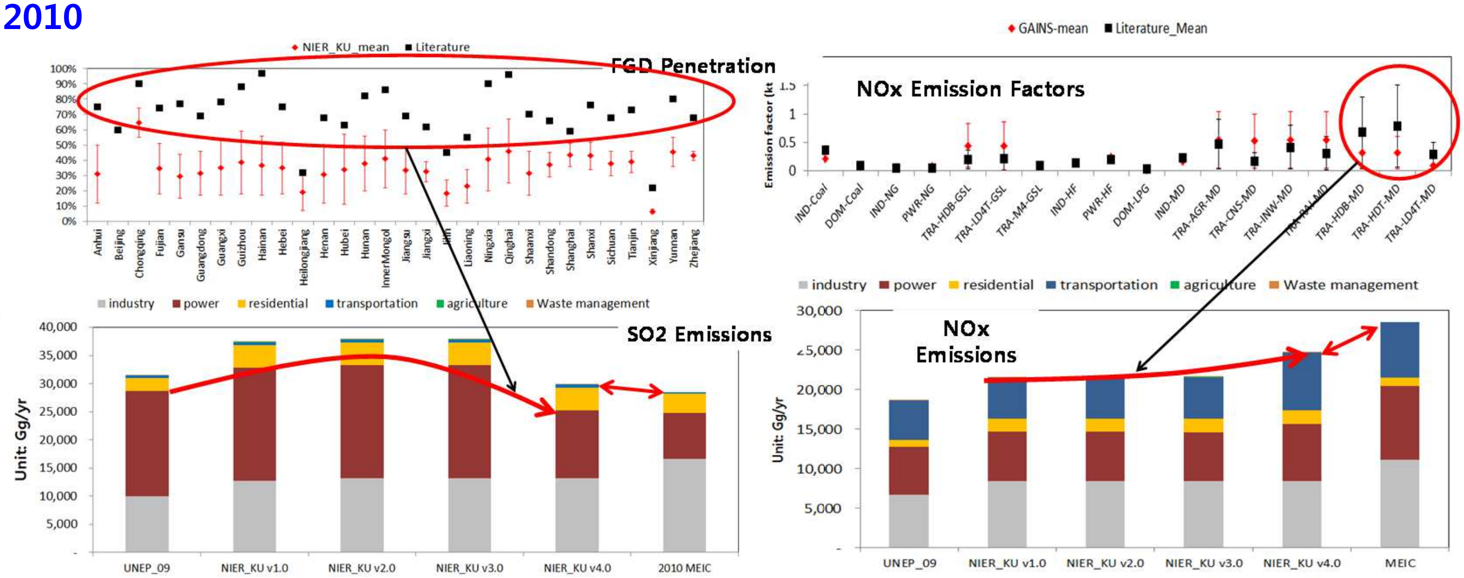
Kurokawa et al., ACP 2013

Some improvements except SO_2 over time, But still long way to go.

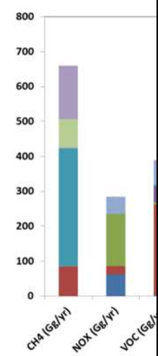
Uncertainties Emissions & Control

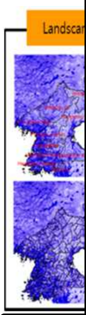


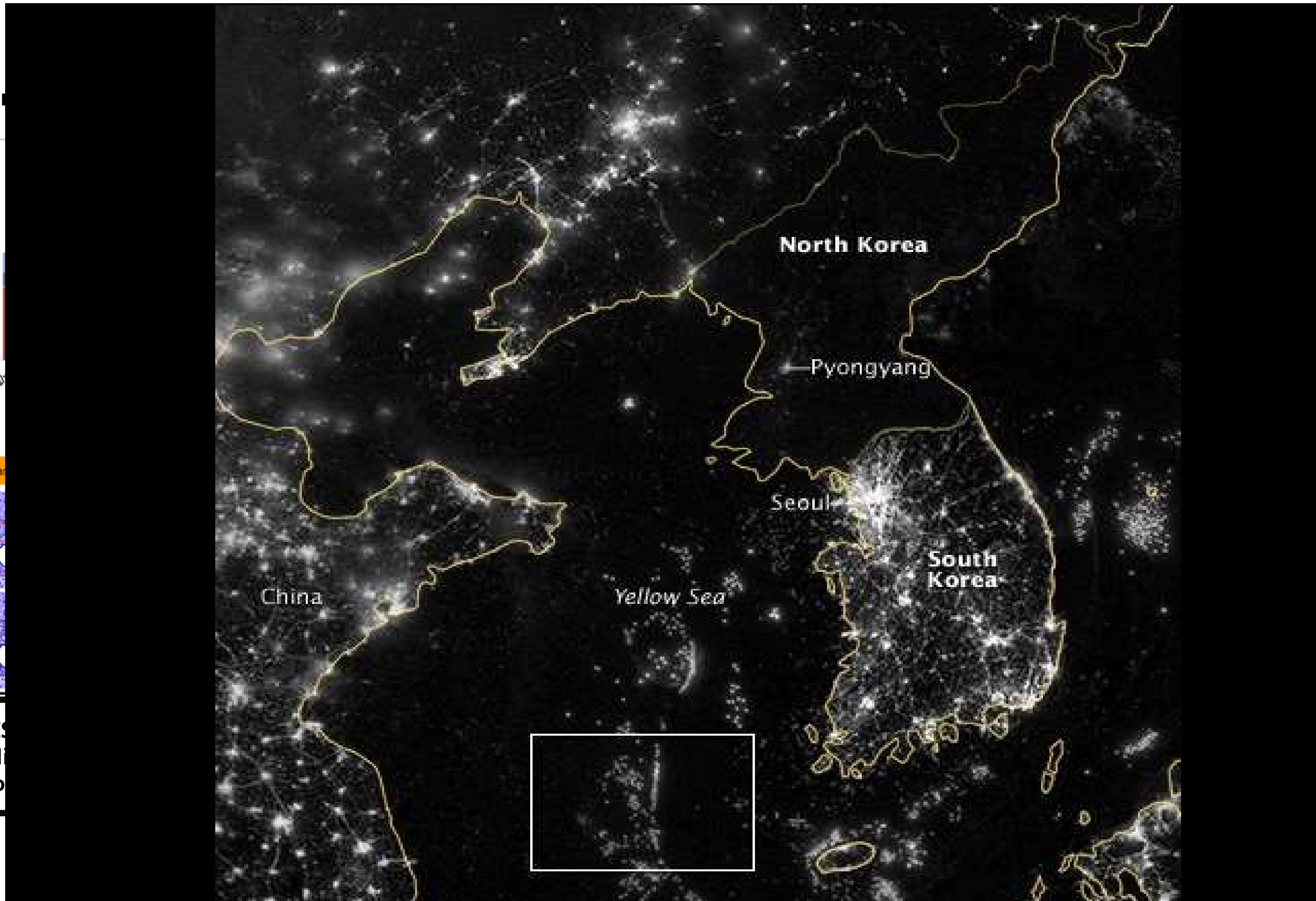
Update of emission factors and control measures for China



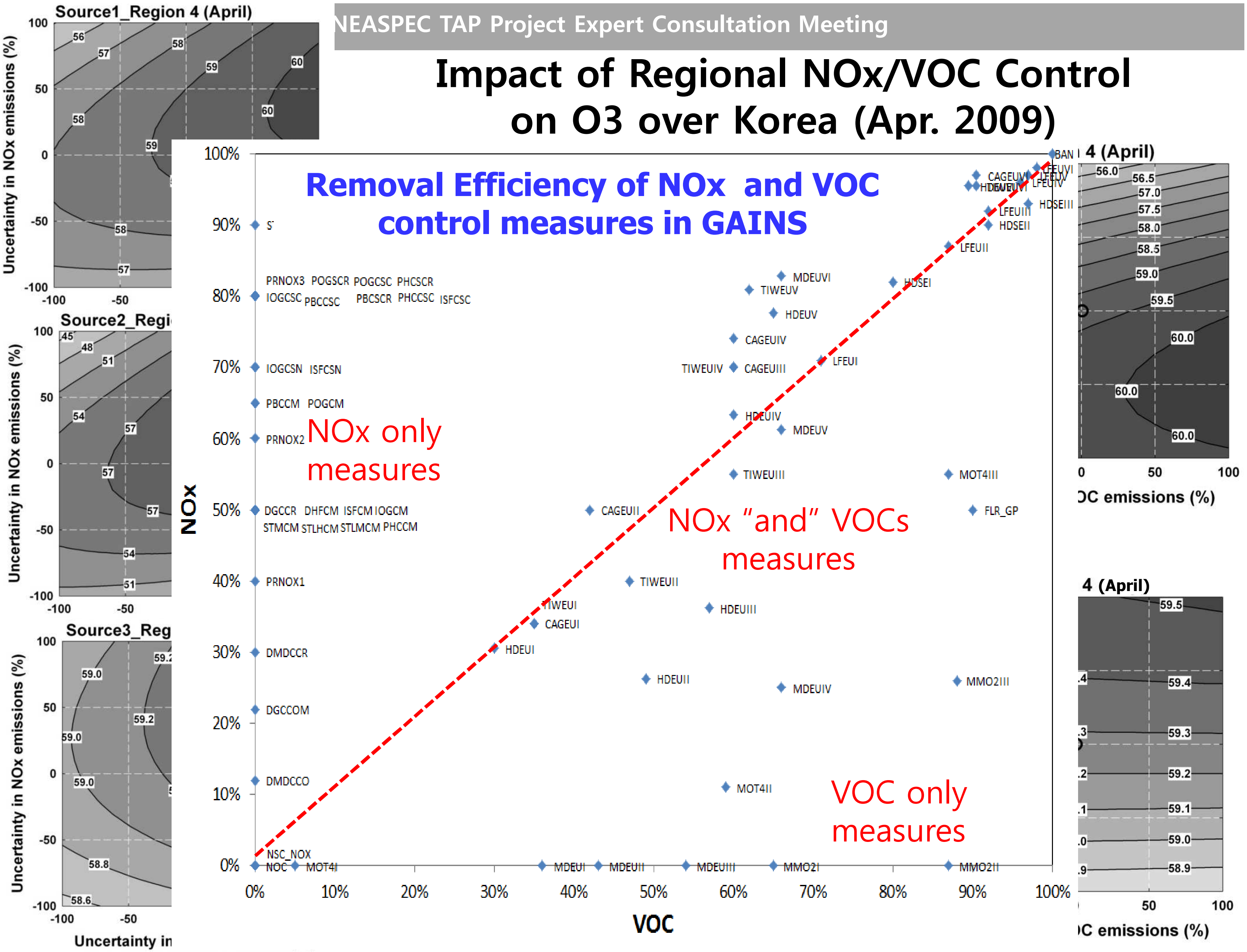
Factors Affecting Emission Uncertainties
- "Not-well Known" Emissions (North Korea)







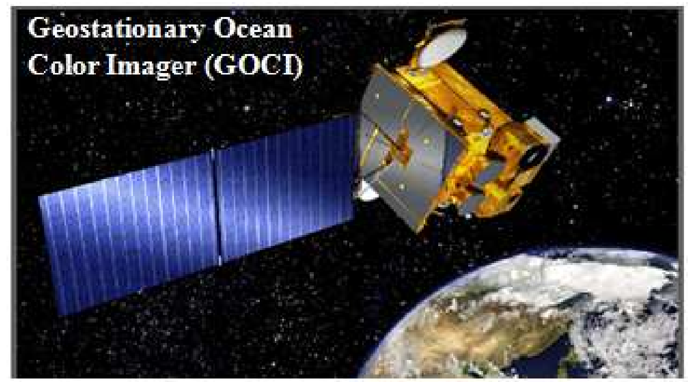
Impact of Regional NOx/VOC Control on O3 over Korea (Apr. 2009)



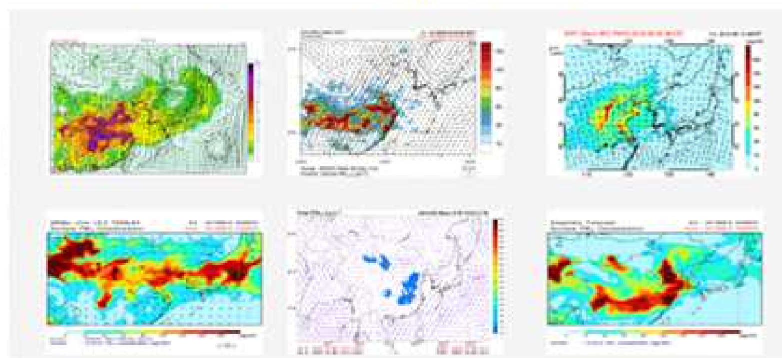
An International Cooperative Air Quality Field Study KORUS-AQ 2016 (1 May – 14 June)

KORUS-AQ

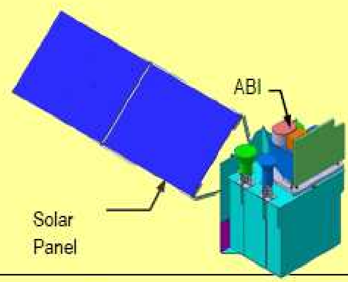
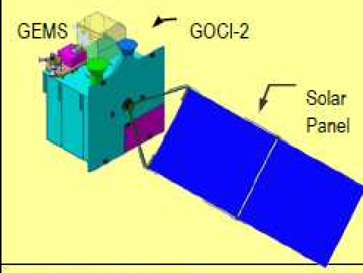
Ministry of Environment
National Institute of Environmental Research

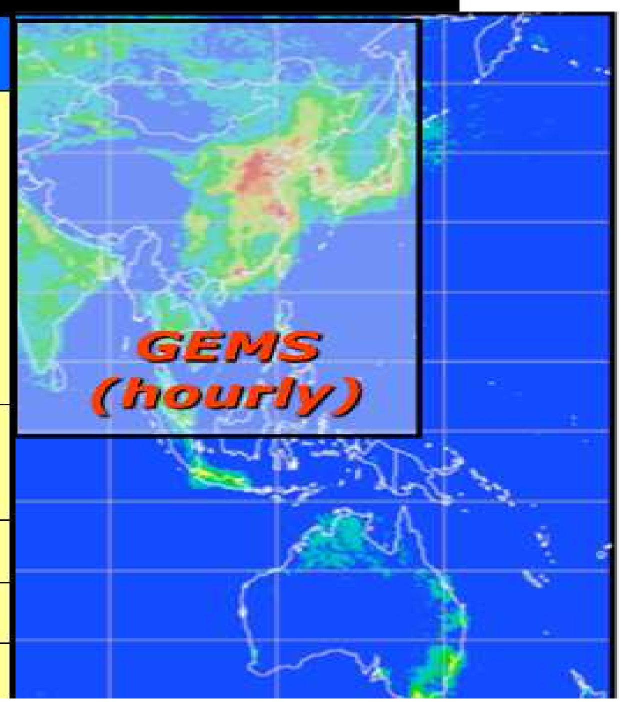


Korean and US Air Quality Model Forecasts



GEMS : Geostationary Environmental Monitoring Spectrometer

	2A	2B
Satellite configuration w/payloads		
Resolution	• 16 ch, Full size image < 15 min • 0.5, 1 km (Vis), 2 km (IR)	• GOCI-2 : 250 m • GEMS : 5 km x 5 km
Life time	10 years	10 years
Launch Mass	2849 kg	2550 kg
Power	2903 W	2903 W



Understanding Regional Air Quality

1. Uncertainties of Emissions/Transport/Chemistry

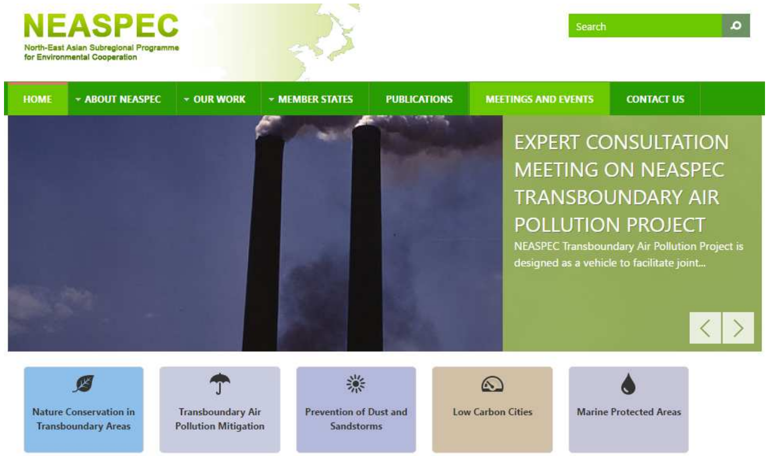
Science and Technology

2. Uncertainties of Emissions/Control/Contribution

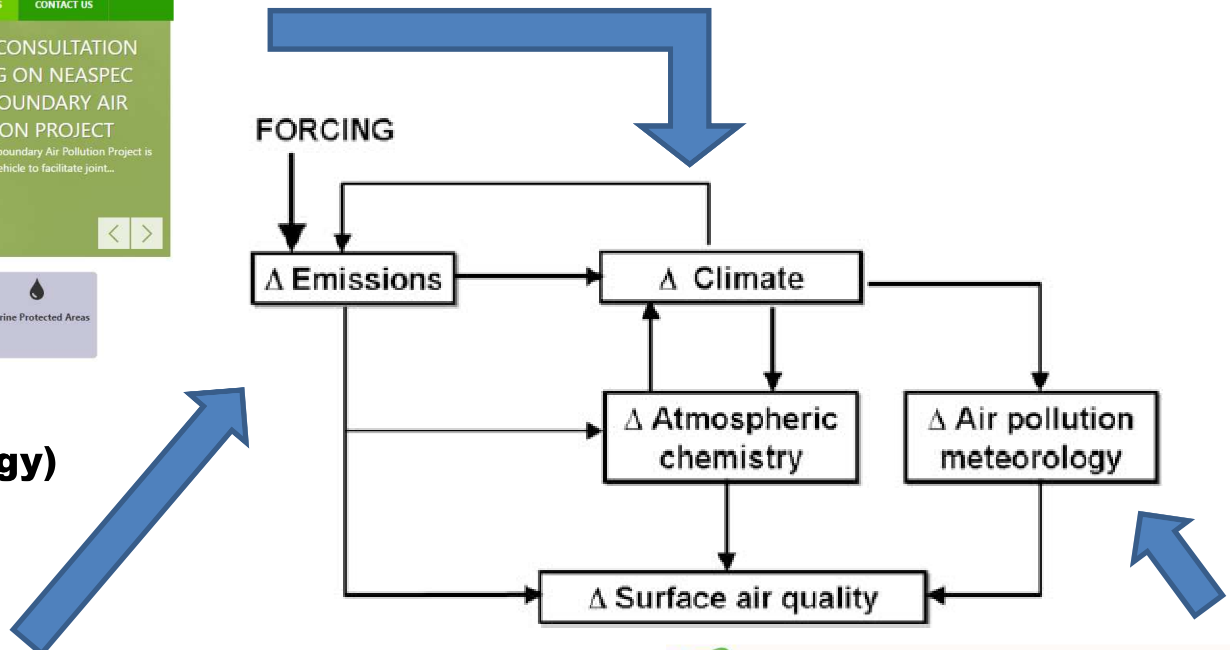
- Regional Collaboration beyond S & T

- From Understanding to Solution

Regional Collaboration beyond S & T



NEASPEC
(Integrated Future Strategy)

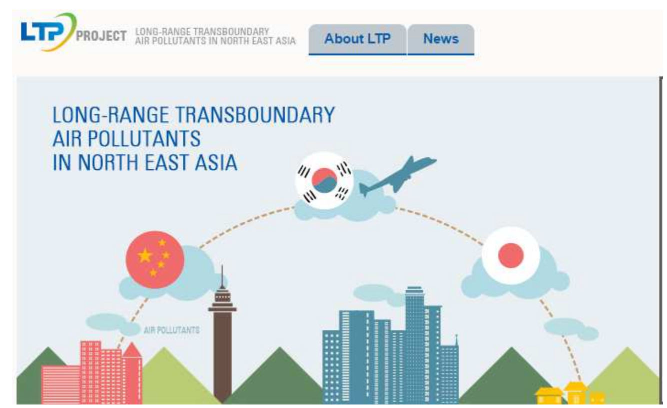


Policy Talk
(Control Measures)

Japan, China, S. Korea to cooperate on air pollution
May 6, 2013

A resident wears a mask as air pollution shrouds Beijing on May 6, 2013. Japan, China and South Korea agreed Monday to continue

LTP
(Transport and Chemistry)



Long-range Transport Project

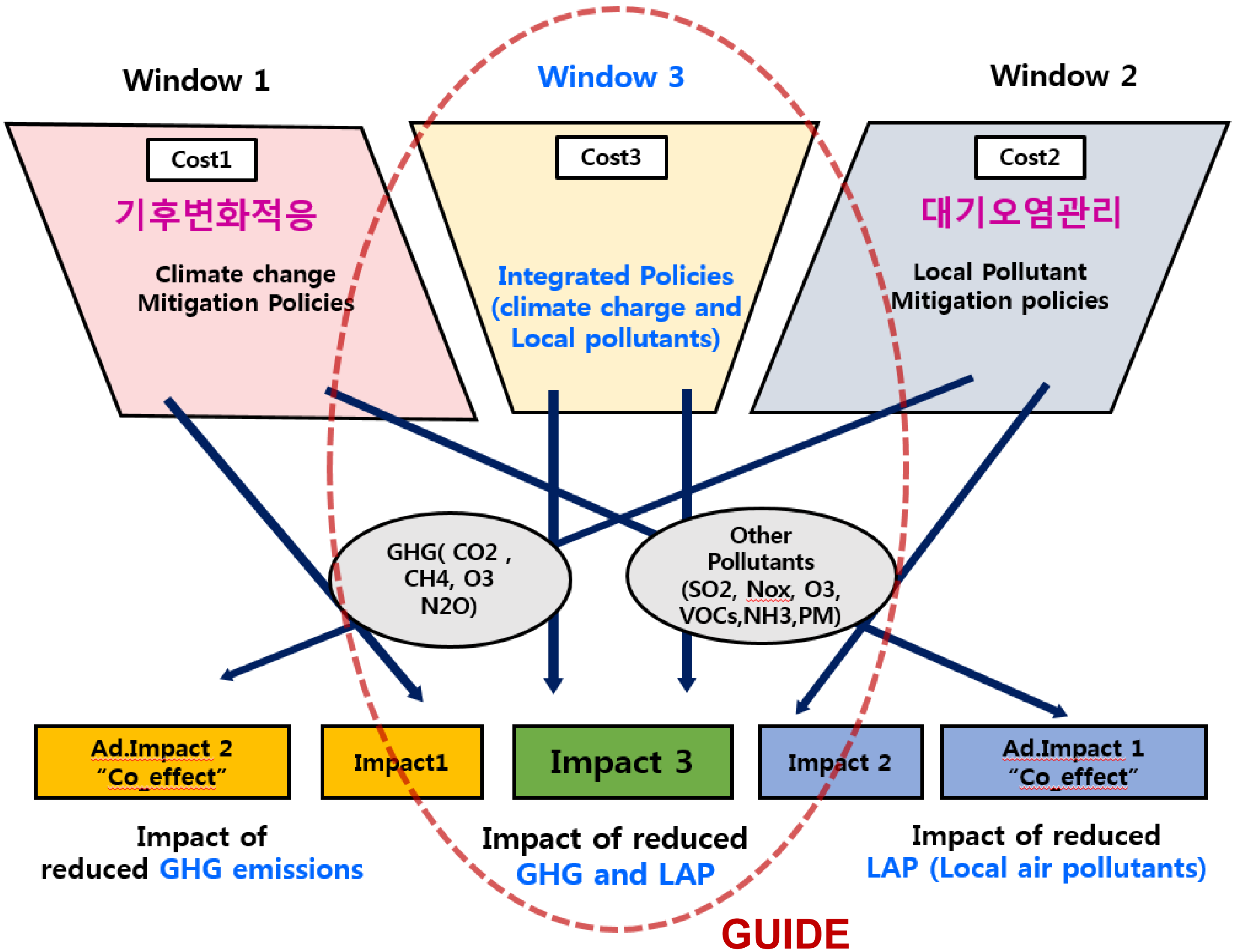
GUIDE

(A solution maker…)

2020 and beyond

* GHGs and Air pollutants Unified Information Design System for Environment(GUIDE)

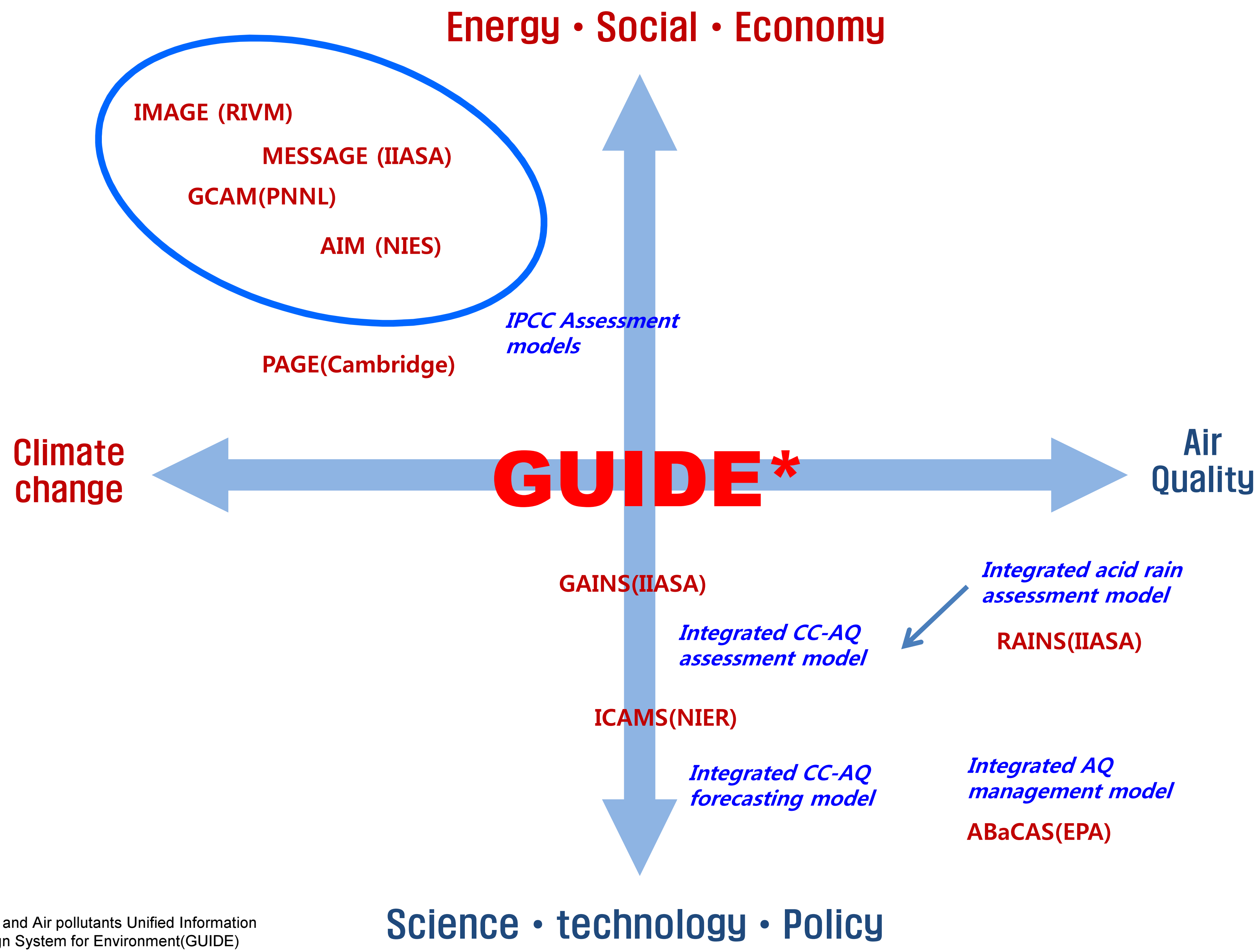
Integrated Management of Climate change and air quality



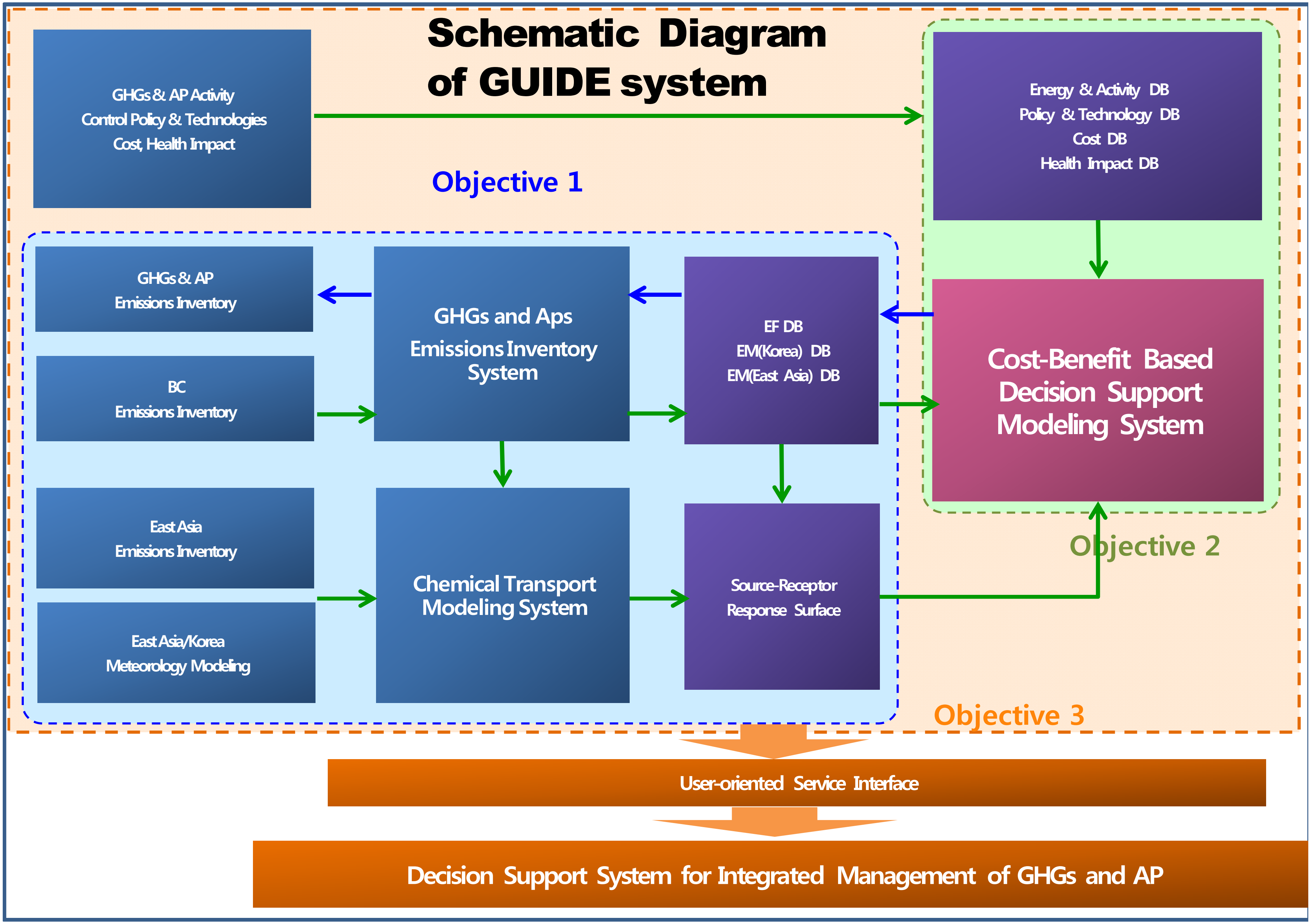
Integrated Assessment Model Development (International)

Title	Institute	Model	Characteristic
Greenhouse Gases and Air pollutants Interaction and Synergy(GAINS)	• IIASA	• GAINS - Global - China/Asia - Europe - Italy	• No energy modeling • Web-based service • Source-receptor based transport • Optimization mode • Applied in many international negotiations
North America climate-air quality assessment (US EPA STAR Grant)	• US EPA +Berkeley/Columbia/NERL/GNM/Illinois/WSU/Harvard /CMU	• CMAQ • AQM • GEOS-Chem • GISS	• No emissions inventory • Strong science-based • Climate-AQ interaction • 12 research consortium
ABaCAS: (Air Benefit and Cost and Attainment Assessment)	• US EPA-China	• CMAQ • SMAT • RSM-VAT • BenMAP	• No climate change • Strong science and technology • Real-time Source Apportionment • Applied for China

- Pros vs. Cons



* GHGs and Air pollutants Unified Information Design System for Environment(GUIDE)


Schematic Diagram of GUIDE system
GHGs & AP Activity
Control Policy & Technologies
Cost, Health Impact
Objective 1
Energy & Activity DB
Policy & Technology DB
Cost DB
Health Impact DB
GHGs & AP Emissions Inventory
BC Emissions Inventory
East Asia Emissions Inventory
East Asia/Korea Meteorology Modeling
GHGs and Aps Emissions Inventory System
Chemical Transport Modeling System
EF DB
EM(Korea) DB
EM(East Asia) DB
Source-Receptor Response Surface
Cost-Benefit Based Decision Support Modeling System
Objective 2
Objective 3
User-oriented Service Interface
Decision Support System for Integrated Management of GHGs and AP

GUIDE

: a smart decision making system to manage GHGs and APs simultaneously

1) The new macro economy-based Benefit-Cost(B-C) model for decision making

2) State-of-science source-receptor surface that can assess impacts of emissions control in realtime, even for non-linear chemical reactions

3) Implementation of integrated GHGs and Air Pollutants(APs) emissions inventory for Korea

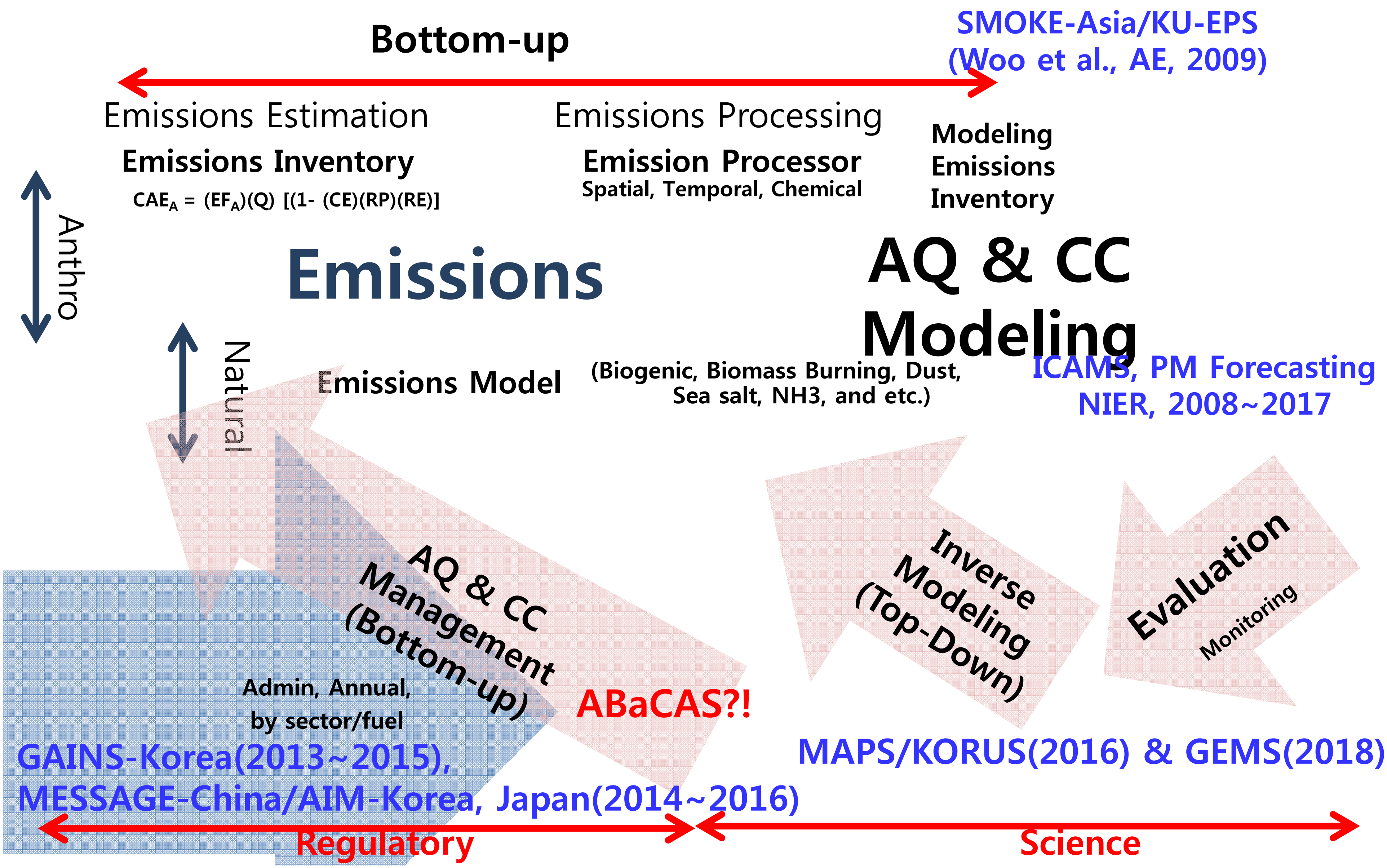
4) Incorporation of China and North Korea emission inventories to quantify out-of-region contribution

5) The simultaneous optimization for bi-directional co-control/co-benefits (i.e. co-benefits of APs and GHGs control)

Thank you for your attention!

Challenges and Opportunities

Supporting Filed Campaign and Improve Understanding of East Asia Emissions



KORUS-AQ Aircraft Field Campaign

Airborne sampling

- provides critical view for evaluation stra tegies in connecting ground-based and satellite observations
- Short term

Satellites

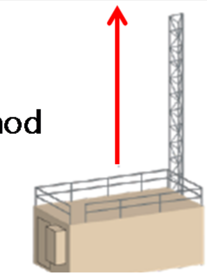
- provide broad coverage, continuity
- but it needs reliable information on near-surface exposure.

KORUS-AQ Goals

- **Improve capability for satellite remote sensing of air quality**
- **Better understanding of the factors co ntrolling air quality**
- **Test and improve model simulation of air quality**

Ground monitoring

- It will continue to be the primary method for monitoring exposure.
- Coverage is limited.

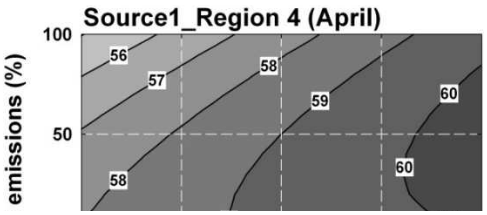


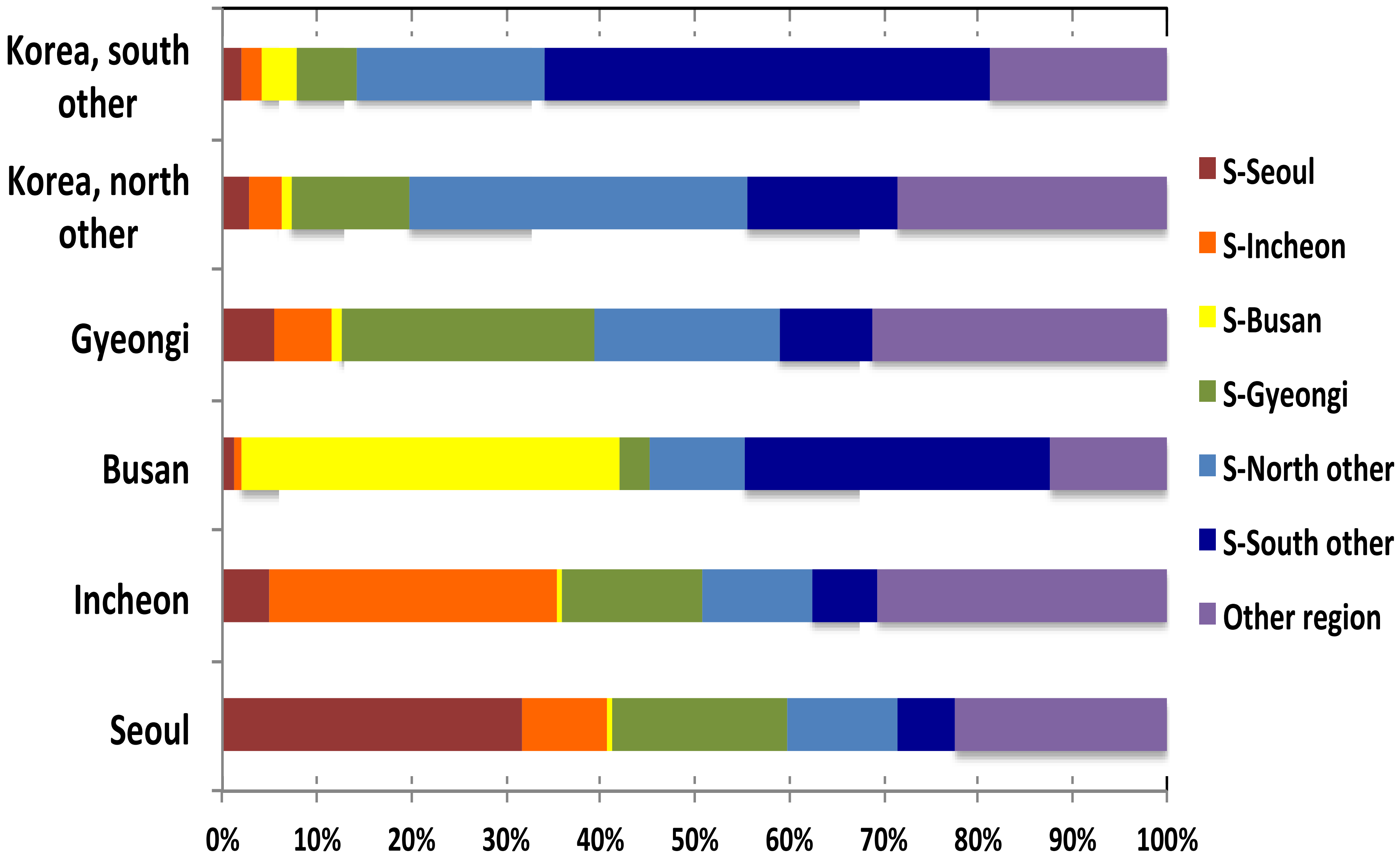
Modeling

- provide Air quality forecasting and warning service
- but it needs reliable information on emission inventory and so on.

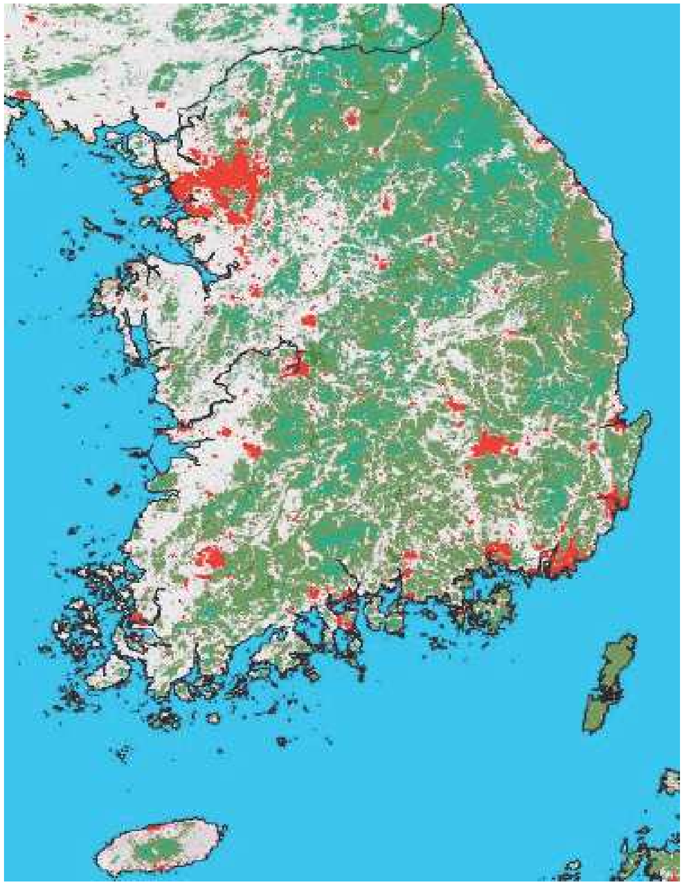
Obstacles to Understand Regional Air Quality

1. Uncertainties of Emissions/Transport/Chemistry
2. Uncertainties of Emissions/Control/Contribution


Source1_Region 4 (April)
emissions (%)
100
50
56
57
58
59
60
58
60

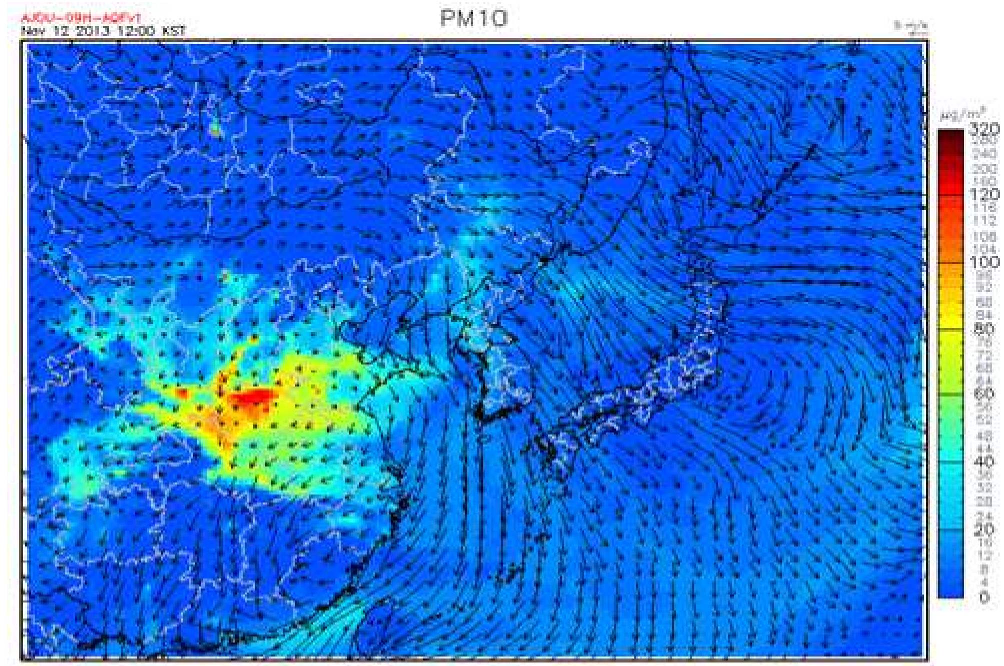

Korea, south other
Korea, north other
Gyeongi
Busan
Incheon
Seoul
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
S-Seoul
S-Incheon
S-Busan
S-Gyeongi
S-North other
S-South other
Other region

Why Korea?



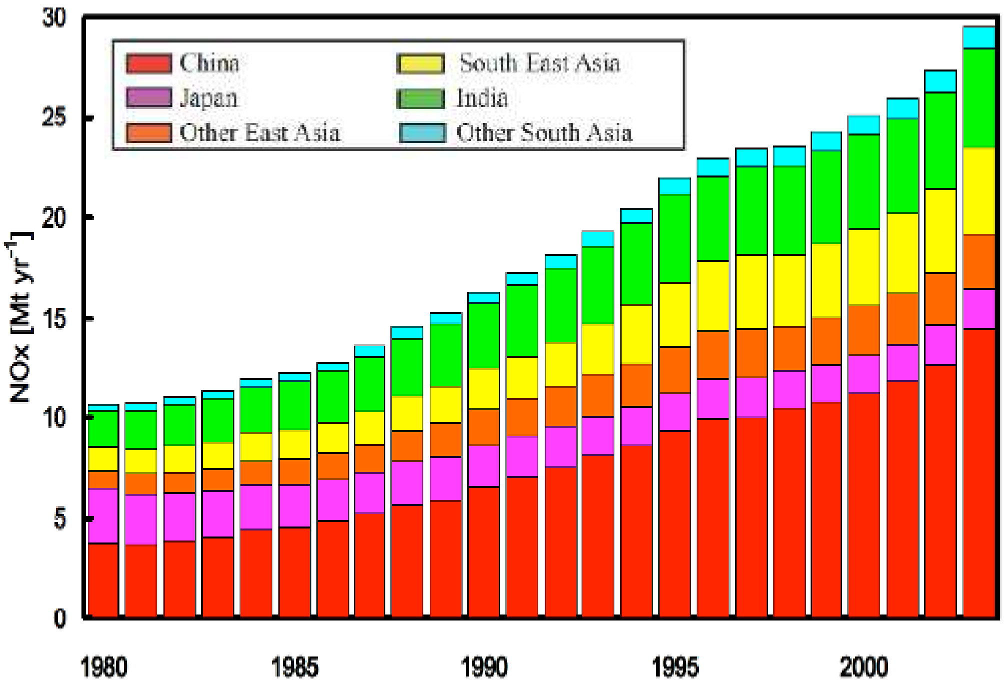
MODIS land cover map of South Korea.
Red colors-Urban & built up areas
Greens - forests, Gray - croplands
(courtesy Christine Wiedinmyer).

1. Korea's urban/rural sectors are distinct, providing an attractive setting for understanding the relativ e importance of human and natural emissions.



2. The Korean peninsula and its surrounding water s provide an advantageous experimental setting for distinguishing local and trans-boundary poll ution.

Why Korea?



Asian NO_2 emissions from 1980 -2003 based on activity data (Ohara et al., 2007)

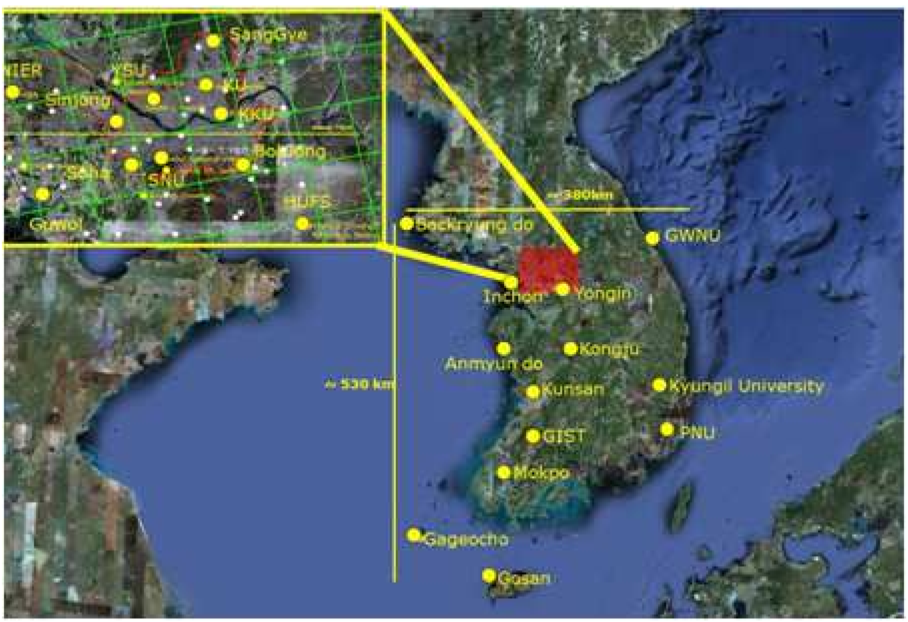
3. Korea is located in a region of rapid change with strong air quality gradie nts both in time and space.

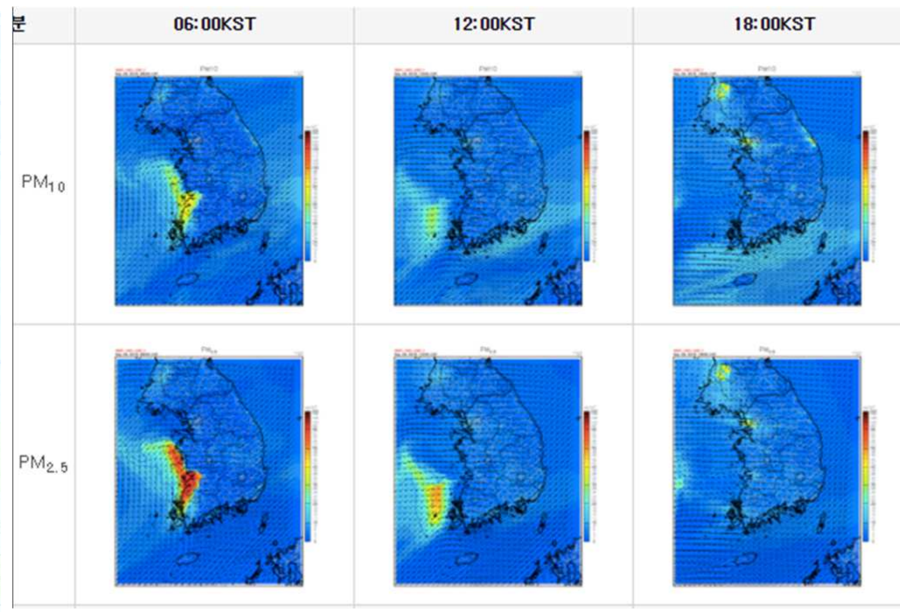
- PM_{10} concentration of Seoul areas has been changed day by day

Why Korea?

4. Korea provides a collaborative environment with strengths in air quality monitoring and ground-based measurements, geostationary satellite observations, and modeling.

- over 300 regular air quality monitoring, 40 wet & dry deposition, 20 PAMS
- 6 supersite, 47 $PM_{2.5}$ mass & composition monitoring site





DRAGON campaign(2012-2013)

- It was a concentrated observation with ground-based sun photometers over megacities for detecting local emissions and over costal sites for detecting long range transport.

Air Quality Forecasting

- PM_{10}, $PM_{2,5}$ and Ozone
- 4 times/day
- Ensemble model results used

Why Korea?

- Satellites in low Earth orbit (LEO) observations has been limited.
- Geostationary (GEO) observations as a vantage point for studying air quality can overcome limitation of LEO.
- The funded GEO atmospheric chemistry instruments expected to launch in 2019-2022 include GEMS by the Republic of Korea, TEMPO by the US, and Sentinel-4 by Europe (Figure).

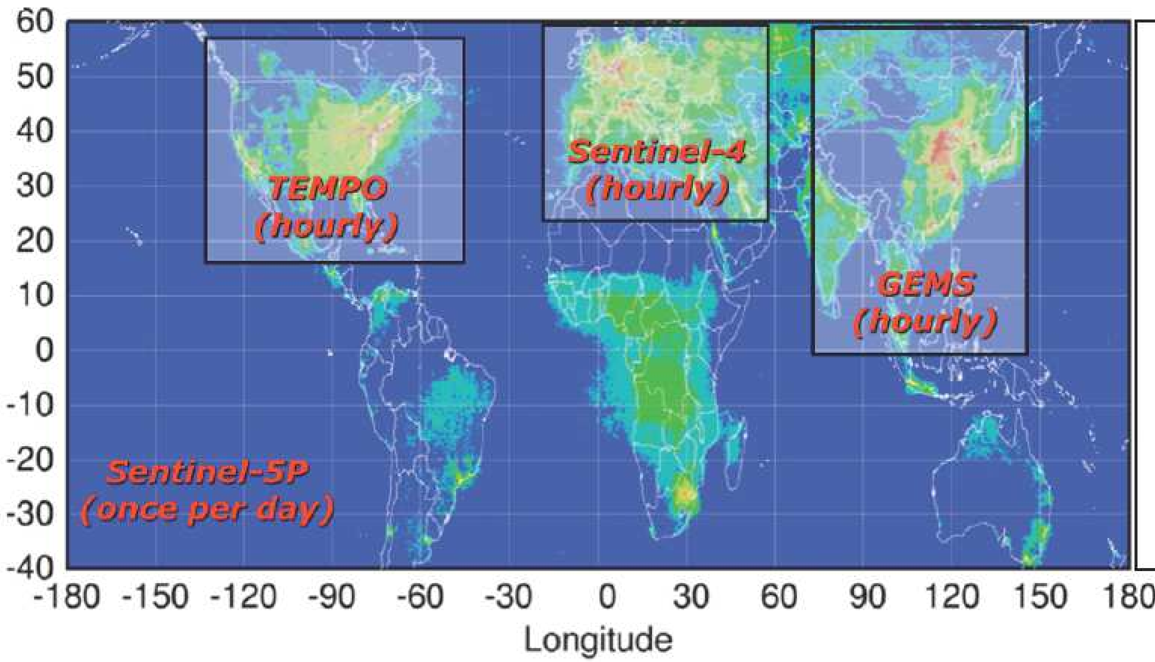


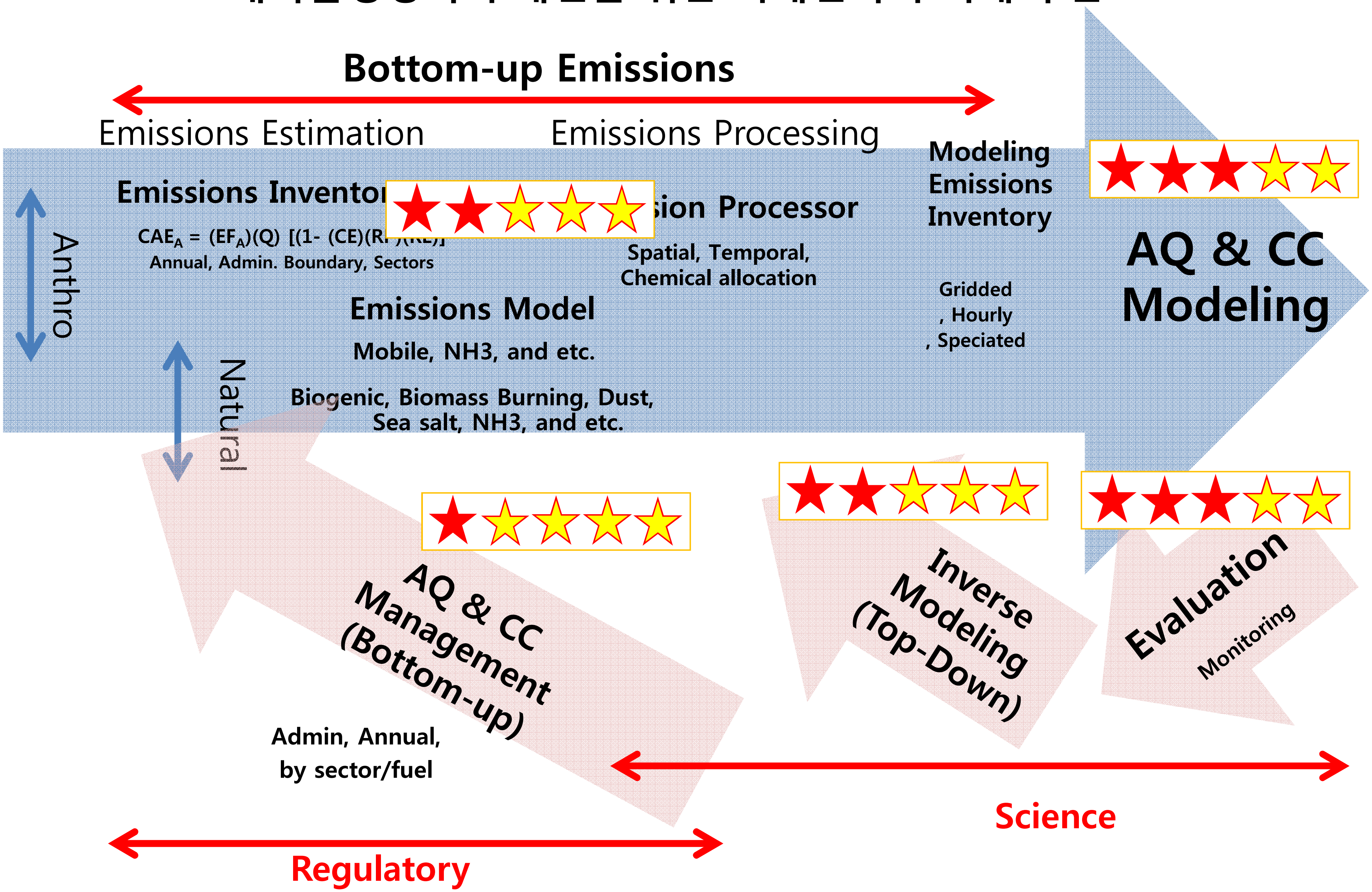
Figure. Global air quality satellite constellation showing expected fields of view for hourly geostationary observations from satellites positioned over North America (NASA-TEMPO), Europe (ESA-Sentinel-4), and Asia (KARI-GEMS). These observations will be supplemented by daily global views from TROPOMI onboard ESA's LEO satellite, Sentinel-5P. The background image is the global distribution of NO_2 as seen from space

5. KORUS-AQ would build relationships and strengthen future collaboration critical to the success of the constellation of geostationary air quality satellites to be launched by NASA, NIER, and ESA later this decade.

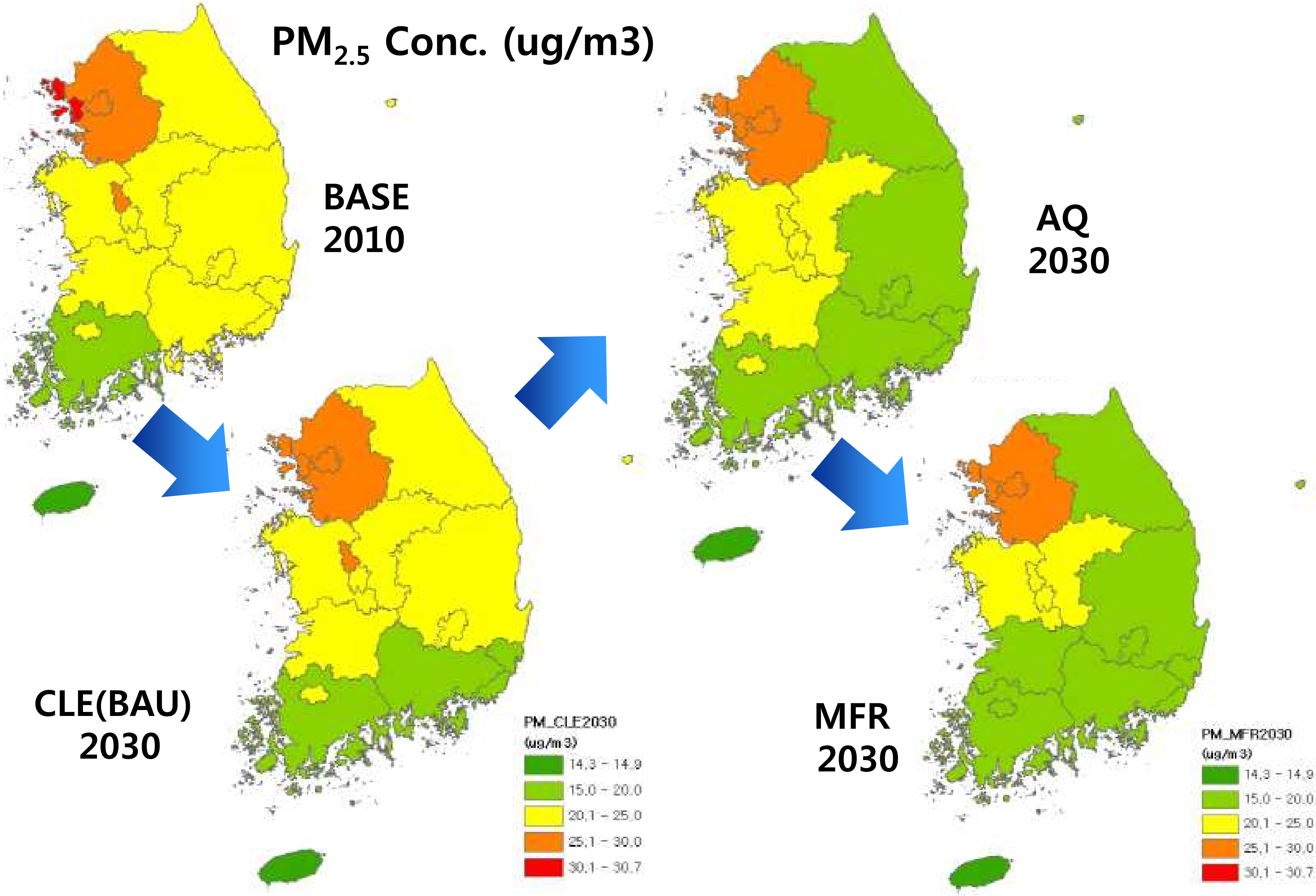
KORUS-AQ

수도권 대기환경(미세먼지) 관리

- 대기환경정책의 개선을 위한 미세먼지의 이해 수준



Future AQ under Different Scenarios



Emissions Change for Year 2010

- Update of emissions factors and control measures for Korea

: Seoul Air Quality Management Plan (SAQMP)

Source	Regulations	Source	Regulations
Point Source	Total amount regulation and Emissions Trading	Mobile	Stringent emission standards for new vehicles
	Expansion of areas using low-Sulfur fuel		Distribution of low emission vehicles
	Fuel switching, from Bituminous coal to LNG		Emission reduction plan for specified-diesel-vehicles: SCR/DPF installation
	Stricter Emission Allowance Standard		Emission reduction plan for specified-diesel-vehicles: DOC installation
	[illegible]		Emission r[illegible]sion
	[illegible]		[illegible]
	Increase of environment friendly firms		[illegible]
	Agreement on voluntary environmental agreement		Higher quality standards for engine oil
	Training of Manuel for Best Facility Management		Mandatory regular inspection program
	Financial support for facility investment		Higher quality standards for gasoline fuels
	Stricter management of facility for PM10 & VOC		Improvement of public transportation infrastructure
Area Source	Expansion of district air conditioning and heating system	Area Source	Stage II controls at gas stations
	Expansion of small-scale Community Energy System		Restriction of the use of cutback asphalt
	Expansion of Low-NOx boilers		Restriction of solvent for consumer products
	Better management of LNG facilities		Solvent Emissions Directive for paint in construction and
	[illegible]		Expansior[illegible]
	[illegible]		Installation[illegible]
	Eco- building standards and certification programs		Installation of the application for Charbroiling Restaurants
	Conversion of anthracite into natural gas		Clean Road
	Expansion of areas using low-Sulfur and clean fuels		Expansionof low tire wear
	Regulation of fugitive dust in Industrial Process		Ground to Green Infra

Point Source Control Measures

Mobile Source Control Measures

Area Source Control Measures

VOC Source Control Measures

Emissions Change for Year 2010
- Update of emissions factors and control measures for China

Power Sector
- All coal-fired units shall install install FGD, and the SO_2 removal efficiency increase to 90%.
- Coal-fired units except CFB boilers shall install denitration technologies.
- Upgrade the PM standard(from 50 mg/m^3 to 30mg/m^3), promote to use ESP+FGD or FAB.

Industrial Boilers
- Coal-fired boilers great than 20 t/h shall use desulfurization technologies.
- Upgrade the PM standard(50 mg/m^3 for new boilers), promote to use ESP or FAB.
- New boilers should install LNB.
- Phase out small boilers.

Transportation
- Accelerate implementation of fuel and emission standards: implement Euro5 vehicle standards.
- Scrap the yellow-labeled and old vehicles.
- Promote to use new energy vehicles.

Steel Industry
- Install desulfurization technologies on sintering operations.
- Upgrade the PM standard, promote to use high-efficiency dedustors (FAB).
- Eliminate outdated production capacity.

Cement Industry
- Install LNB and denitration technologies in precalciner cement kilns.
- Upgrade the PM standard, promote to use high-efficiency dedustors (ESP or FAB).
- Eliminate outdated production capacity.

Key VOC industries
- Promote comprehensive treatment of VOCs in petrochemical industry and chemical industry
- Promote leak detection and repair, online monitoring technology in the petrochemical, chemical and other key enterprises.
- Promote the use of water-based paint; encourage the production, sale and use of low toxicity, low volatile solvents.

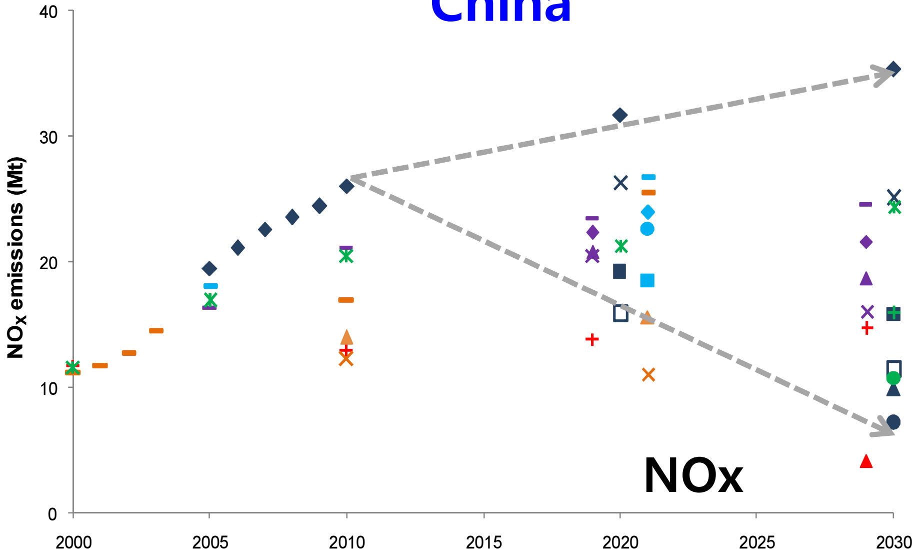
Residential Sector
- Promote to use clean coal.

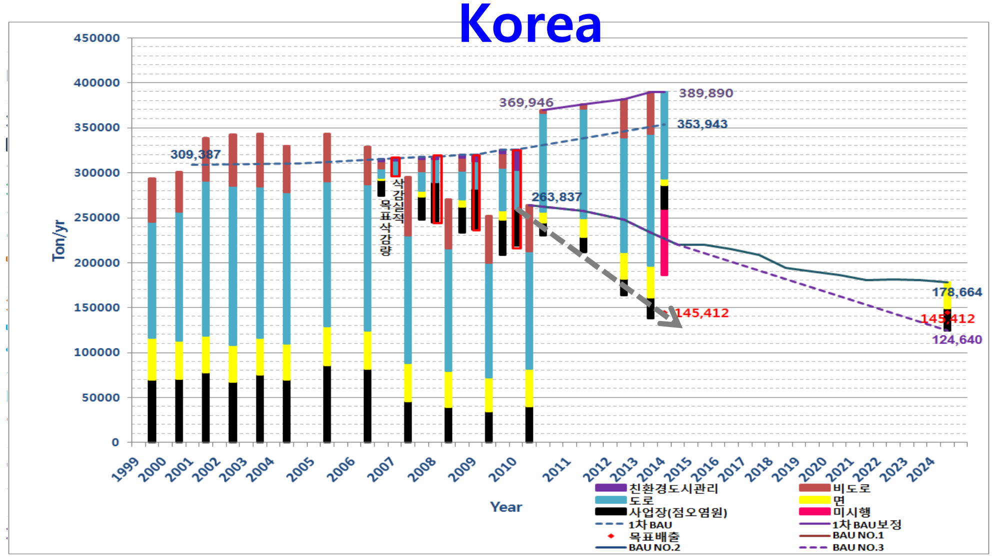
Industrial Kilns
- Upgrade de-dusting facilities

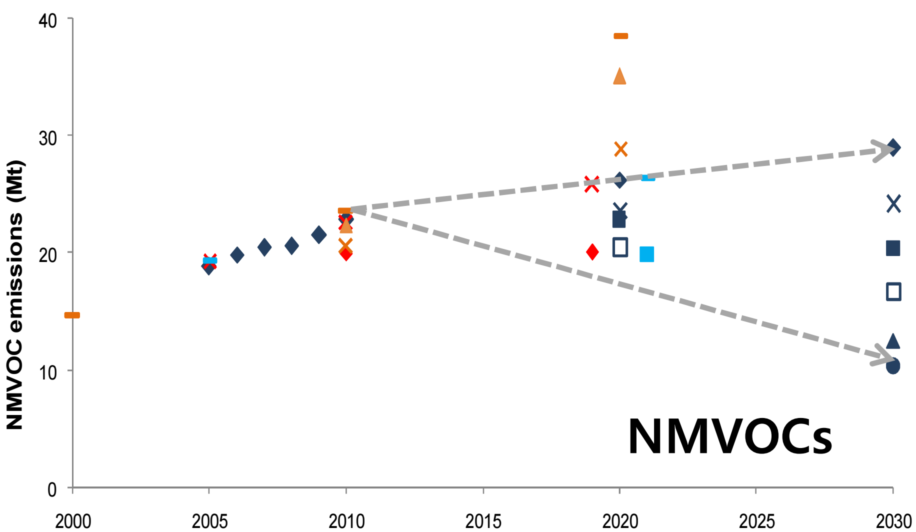
coal-fired power (2010)

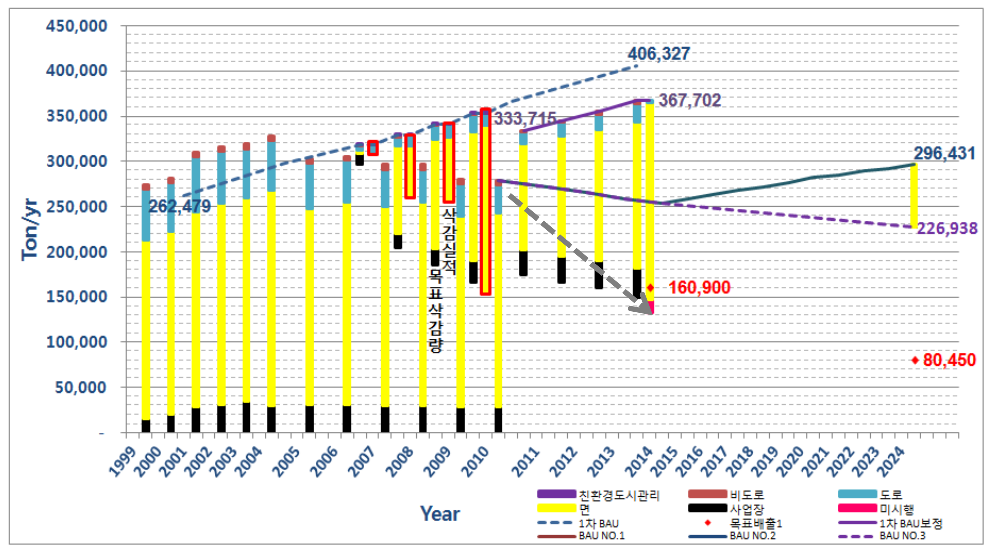
Emissions Evaluation over East Asia : China and Korea (2015)

China | **Korea**





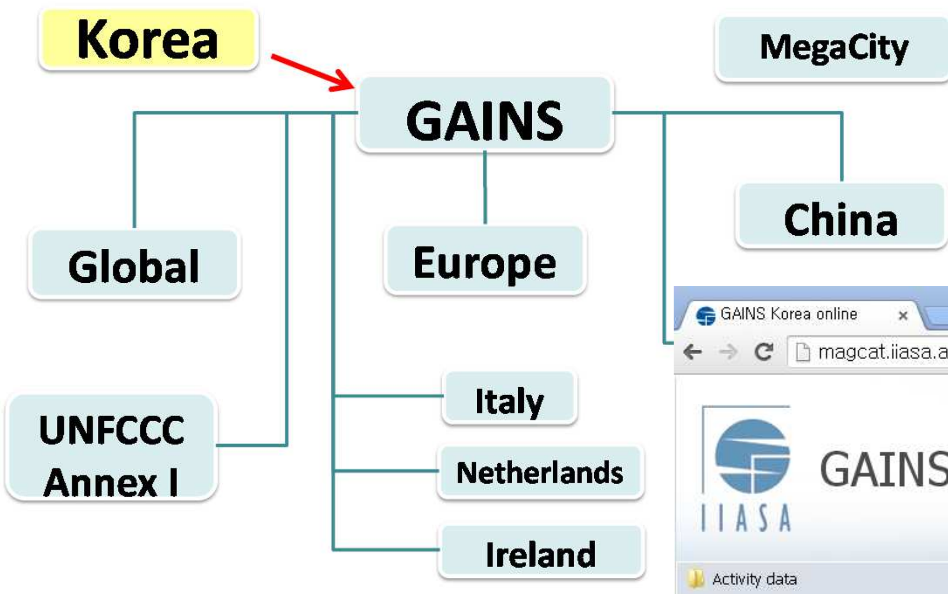




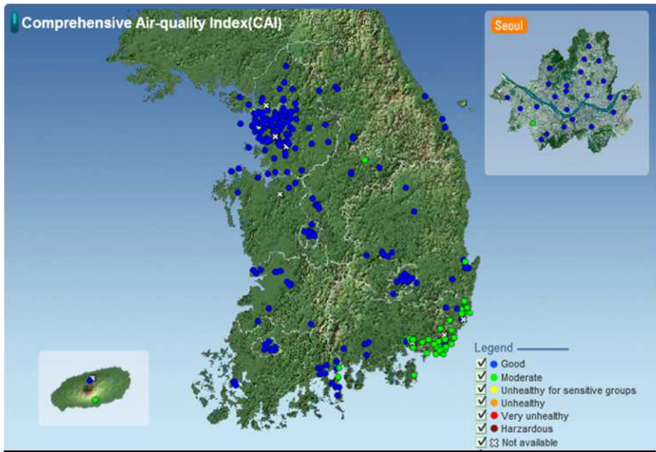
Wang et al., ACP, 2014

NIER, 2014

The GAINS Models Family



Air Quality Monitoring System for NIER/Korea



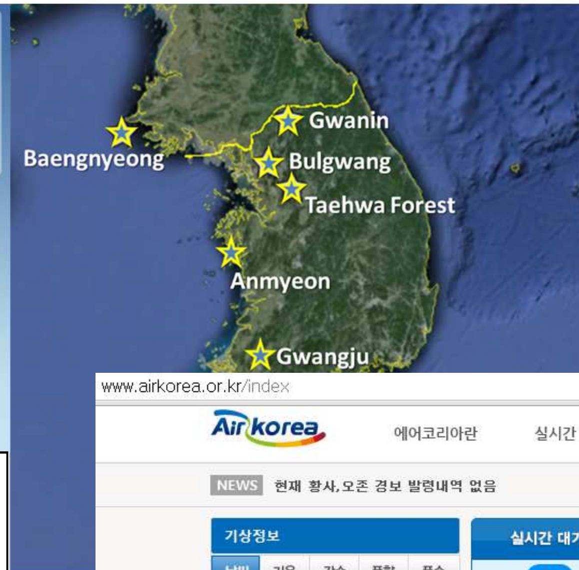


Figure 9. Air quality monitoring sites (above) and key research sites (right) for understanding internal and external influences on air quality across the Korean peninsula.

Air quality monitoring Stations: 350

- **AQ : PM_{10}, O_3, NO_2, SO_2, CO**
- **Met : T, RH, winds**

Roadside sites : 38

Rural sites : 19

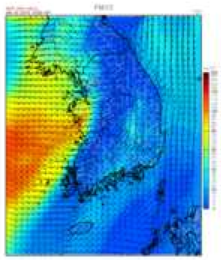
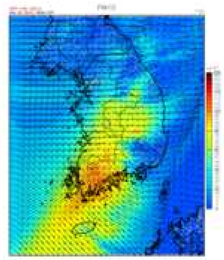
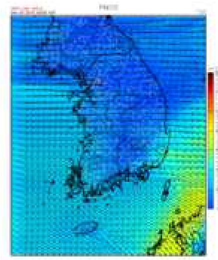
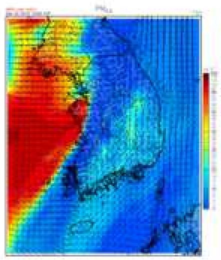
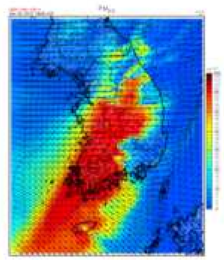
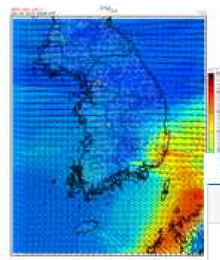
Background sites : 3

VOCs sites: 31

Air Forecasting (Modeling) System for NIER/Korea

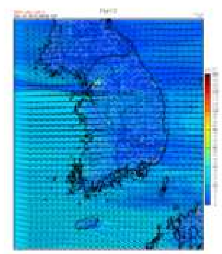
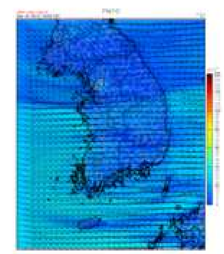
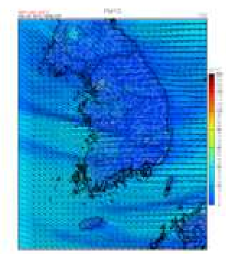
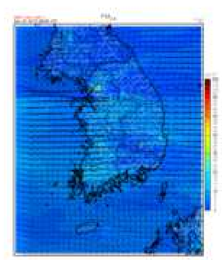
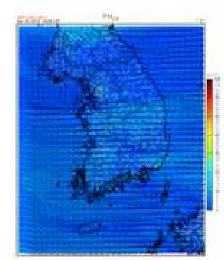
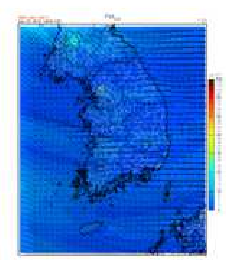
측모델결과

모델결과 오늘 [12월02일]

구분	12:00KST	18:00KST	24:00KST
PM_{10}			
$PM_{2.5}$			

Today (Dec 2, 2015)

모델결과 내일 [12월03일]

구분	06:00KST	12:00KST	18:00KST
PM_{10}			
$PM_{2.5}$			

Tomorrow (Dec 2, 2015)

New Opportunities
: Geo-Satellite and Aircraft Field Campaign

Megacity Air Pollution Studies–Seoul
(MAPS–Seoul)

Lead Investigators:

Gangwoong Lee (Hankuk University of Foreign Studies, HUFS)

Rokjin Park (Seoul National University, SNU)

Jhoon Kim (Yonsei University, YU)

Steering Committee at NIER:

You Deok Hong (Air Quality Research Division)

Joon Young Ahn (Air Quality Research Division)

Chang-Keun Song (Air Quality Forecasting Center)

Lim-Seok Chang (Air Quality Forecasting Center)

Jeong-Hoo Park (Air Quality Forecasting Center)

Sang-Kyun Kim (Global Environment Research Division)

Jaehyun Lim (Global Environment Research Division)

Ji Young Kim (Air Pollution Engineering Division)

NIER

(National Institute of Environmental Research)

- KORUS-AQ Home
- Mission Planning
- Science
- Participants

KORUS-AQ ESPO NASA

KORUS-AQ

KORUS-AQ: An International Cooperative Air Quality Field Study in Korea

US Steering Group: Jassim Al-Saadi, Gregory Carmichael, James Crawford, Louisa Emmons, and Saewung Kim

Korean Steering Group: Chang-Keun Song, Lim-Seok Chang, Gangwoong Lee, Jhoon Kim, and Rokjin Park

Introduction

Air Quality is an environmental concern of fundamental importance across the globe. The need to monitor and understand air quality requires continual effort as populations grow, energy use increases, and industrial activity evolves. Air quality goals have also evolved as improved understanding of health effects has demonstrated the added benefit of setting lower targets for exposure of humans and ecosystems to ozone, fine particles, and other toxic pollutants in the air. Long-term efforts have relied primarily on ground-based observations to diagnose regions of poor air quality and modeling to develop mitigation strategies. In recent years, satellites in low Earth orbit (LEO) have demonstrated the ability to observe the critical constituents affecting air quality. However, the impact of LEO observations has been limited by their infrequent nature and coarse resolution with respect to source distributions and timing (approximately once per day at horizontal scales of tens of km), insufficient to observe the details of air quality events that can develop over timescales of a single day. The promise of geostationary (GEO) observations as a vantage point for studying air quality can overcome these problems by providing observations many times throughout the day and at higher spatial resolution by taking advantage of longer viewing times. The drawback of GEO is the limited viewing domain, preventing global observations with a single satellite. This has led to an international effort to launch a constellation of satellite instruments focused on air quality over Asia, North America, and Europe. These instruments will provide hourly observations of those regions throughout the day at horizontal resolutions of better than 10 km. The funded GEO atmospheric chemistry instruments expected to launch in 2018-2019 include GEMS by the Republic of Korea, TEMPO by the US, and Sentinel-4 by Europe (Figure 1). Also, with its planned launch in 2016 the Sentinel-5 Precursor (S5P) mission will begin providing the next generation of once-daily global measurements from LEO at horizontal resolution similar to the GEO missions.

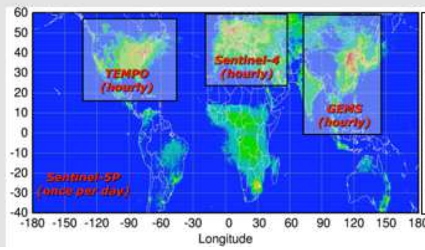


Figure 1. Global air quality satellite constellation showing expected fields of view for hourly geostationary observations from satellites positioned over North America (NASA-TEMPO), Europe (ESA-Sentinel-4), and Asia (KARI-GEMS). These observations will be supplemented by daily global views from TROPOMI onboard ESA's LEO satellite, Sentinel-5P. The background image is the global distribution of NO_2 as seen from space

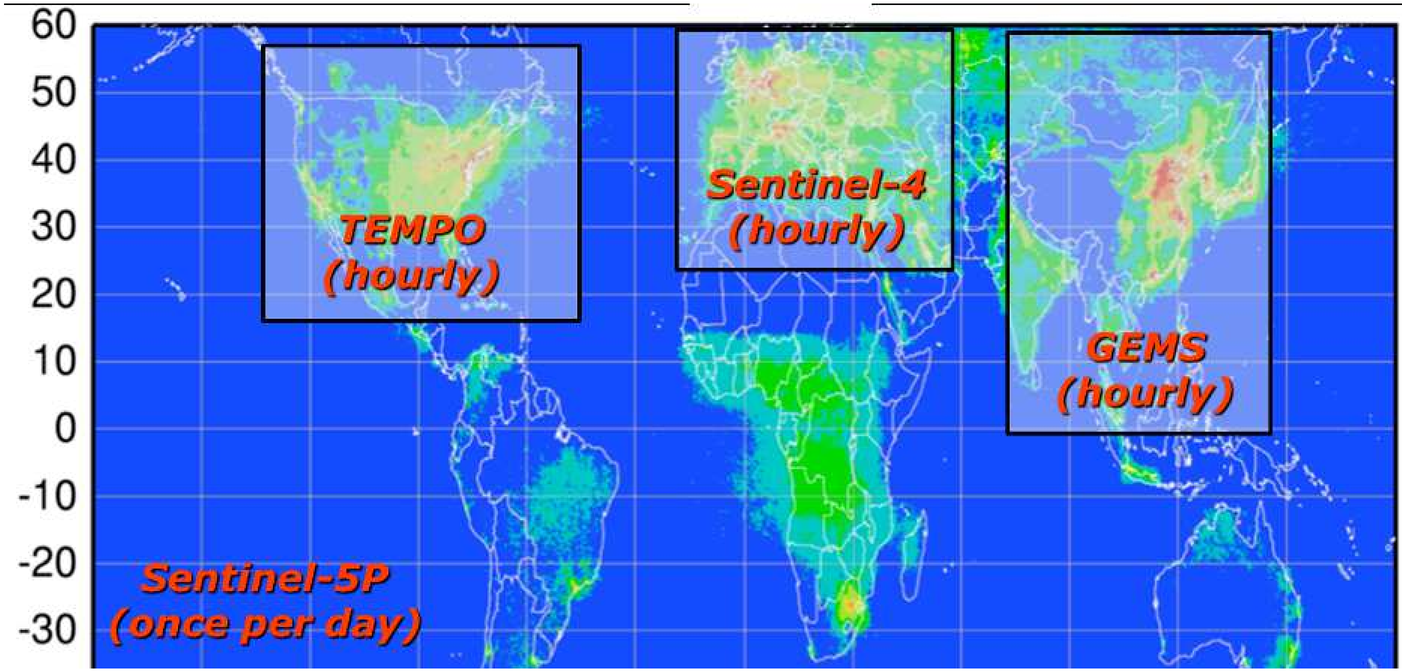
New Opportunity : Aircraft Field Campaign

1. NIER : Megacity Air Pollution Studies–Seoul (MAPS-Seoul)

- 2nd SAQMP policy should be based on scientific evidences!

2. NASA : An International Cooperative Air Quality Field Study in Korea(KORUS-AQ)

- *Use of GEO satellites information to improve air quality forecasts, models, and strategies for mitigating poor air quality*



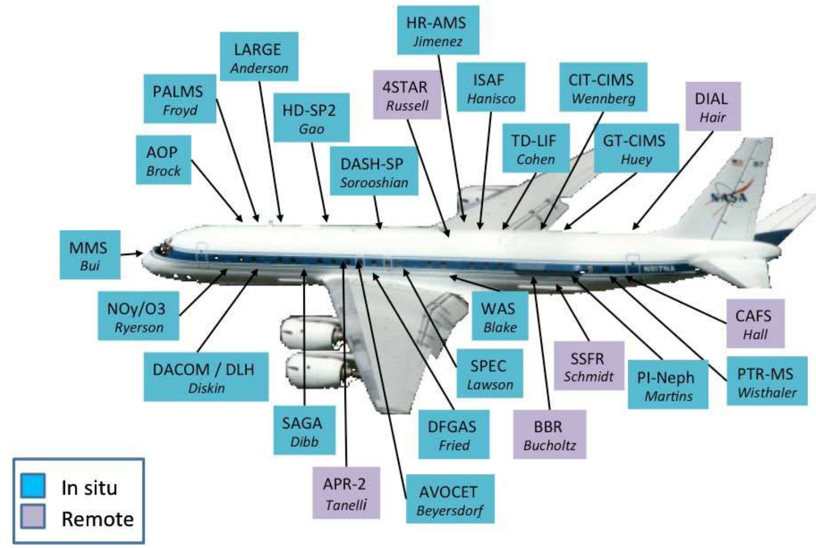
KORUS-AQ

NASA DC-8

NASA Dryden Flight Research Center Photo Collection
http://www.dfrc.nasa.gov/gallery/photo/index.html
NASA Photo: EC98-44444-7 Date: 25 Feb 1998 Photo by: Jim Ross

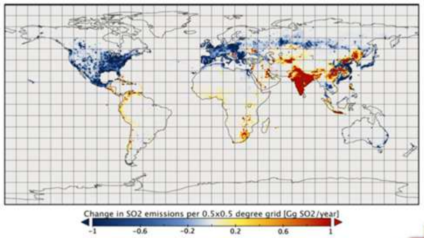
DC-8 Airborne Laboratory in flight over Mt. Whitney

SEAC4RS DC-8 Payload

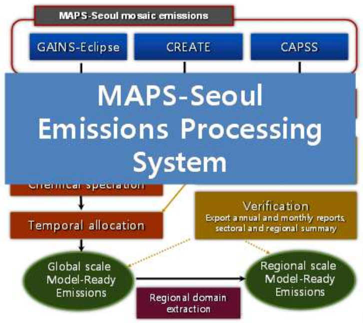


Role of Emissions for Field Campaigns (Improve through Feedback)

MAPS-Seoul/KORUS-AQ Field Campaigns

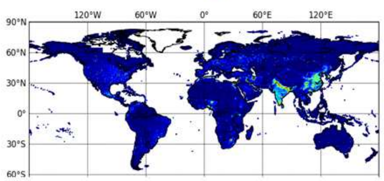


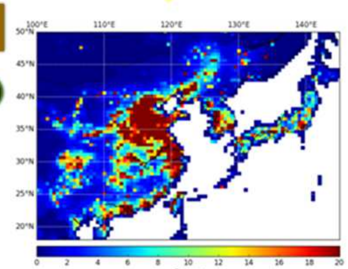
0.5 degree gridded, monthly emissions for year 2010



Konkuk Univ

27km gridded, hourly emissions for year 2010





AQ Forecasting Systems

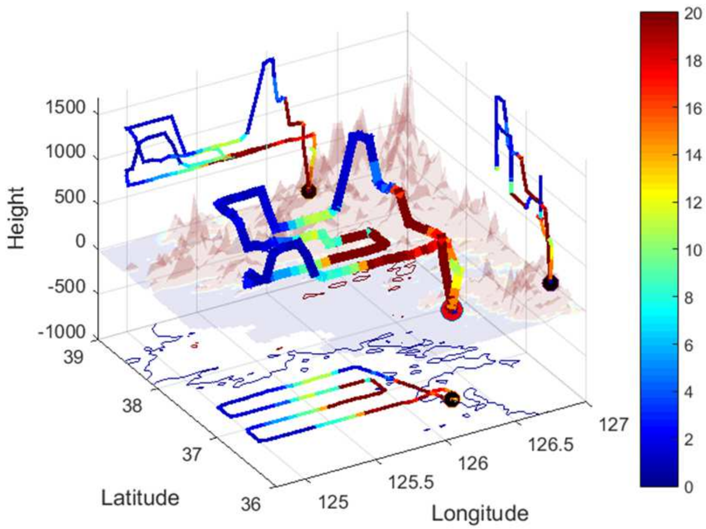
GEOS-Chem (SNU)

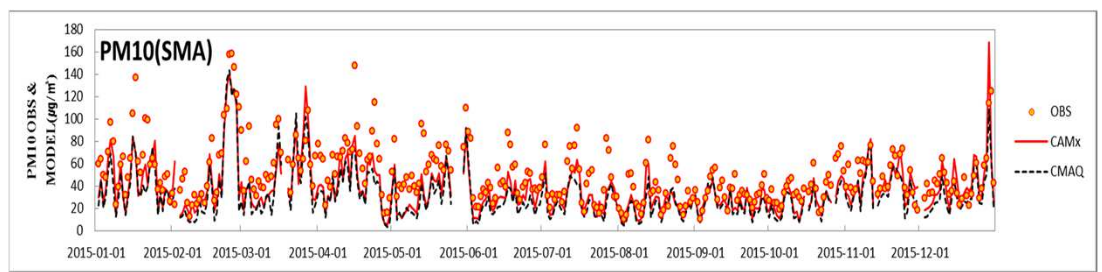
WRF-Chem (PNU)

CMAQ (GIST)

CAMx (AJU)

$$CAE_A = (EF_A)(Q)\ [(1- (CE)(RP)(RE)]$$



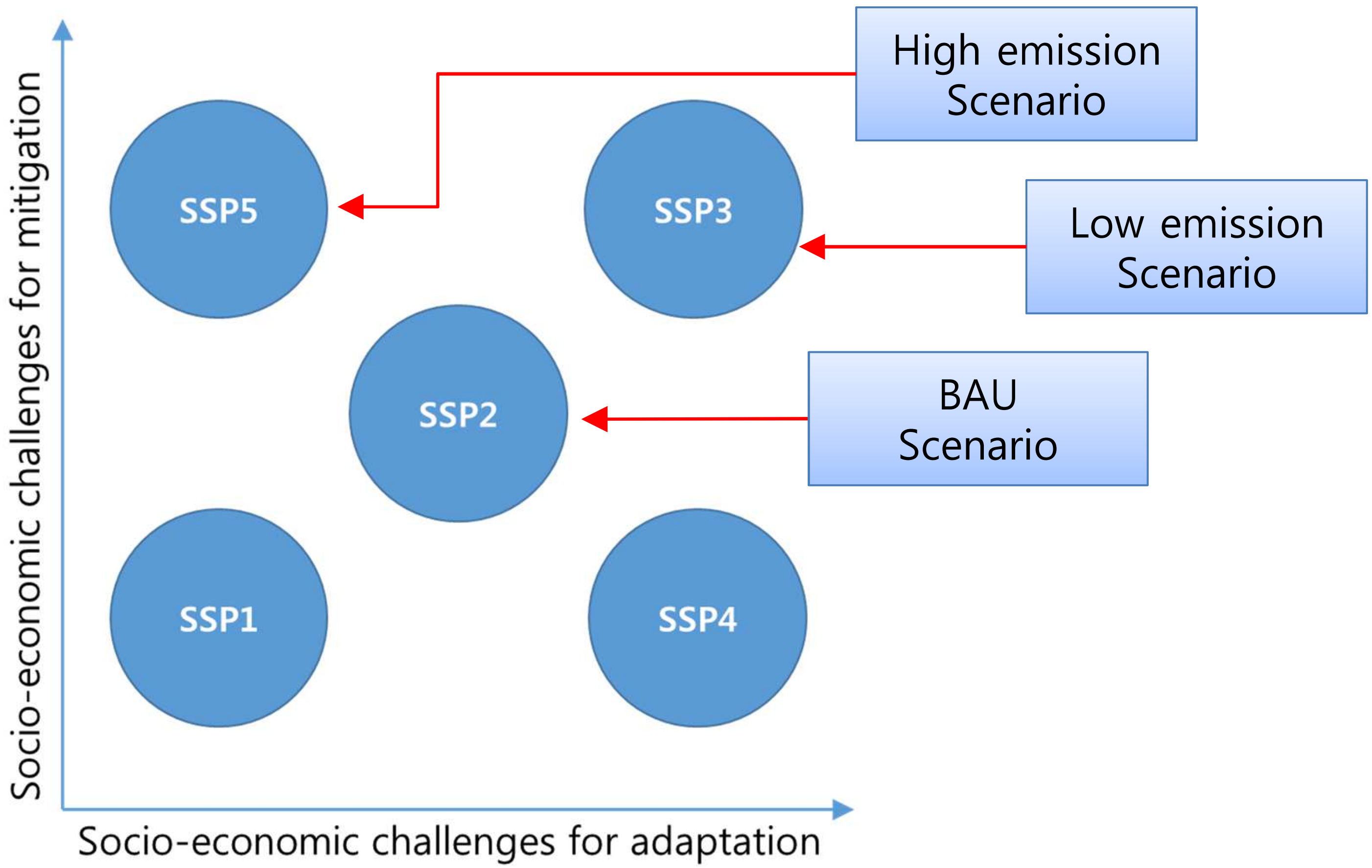


Summary

- A new regional emissions inventory, named NIER/KU-CREATE, was developed in support of various research/regulatory needs of Korea and East Asia
- The on-going(MAPS-Seoul) and up-coming(KORUS-AQ) aircraft field campaigns could be a good chance to apply and improve the inventory. For this purpose, it has being served as the modeling emissions inventory for several Air Quality Forecasting System(AQFS), based on GEOS-Chem, CMAQ, WRF-Chem, CMAx
- Initial MAPS-Seoul Campaign analysis revealed challenges and opportunities for the inventory and we are improving the information for upcoming field studies

Social-Economic Condition

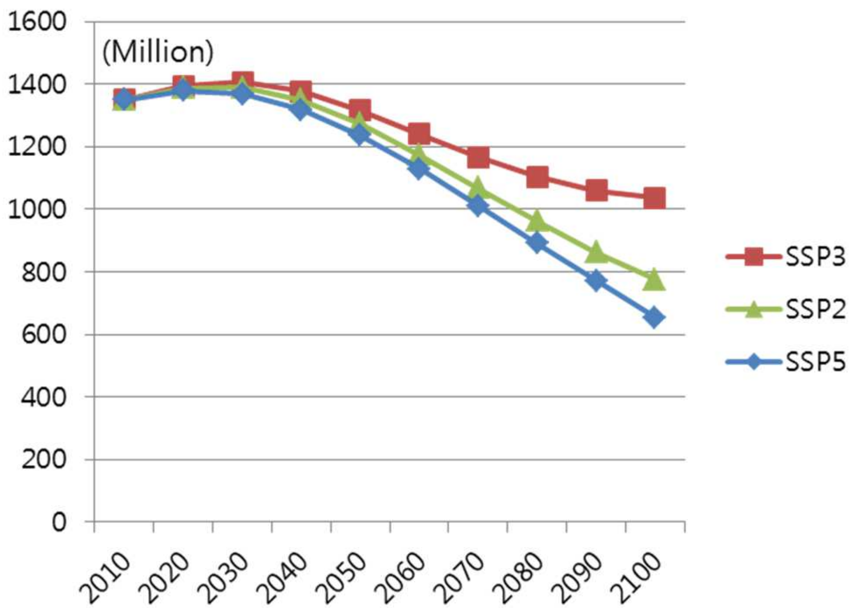
- Socio-economic scenarios are matched to SSP2, 3, 5



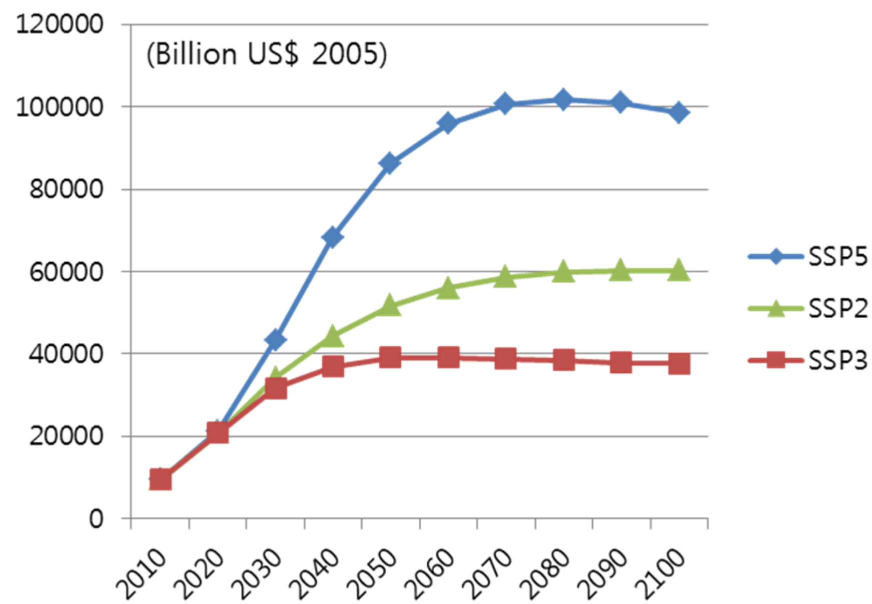
IIASA

Social economic condition by scenario

Population: IIASA-WiC POP

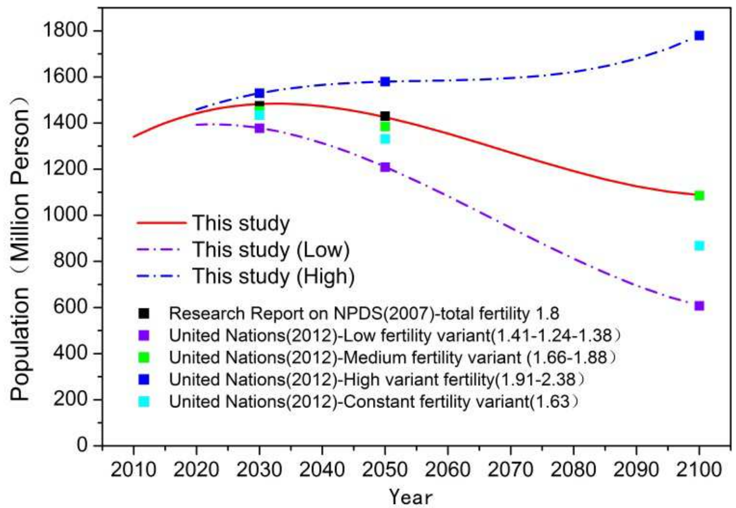


GDP|PPP: OECD Env.-Growth

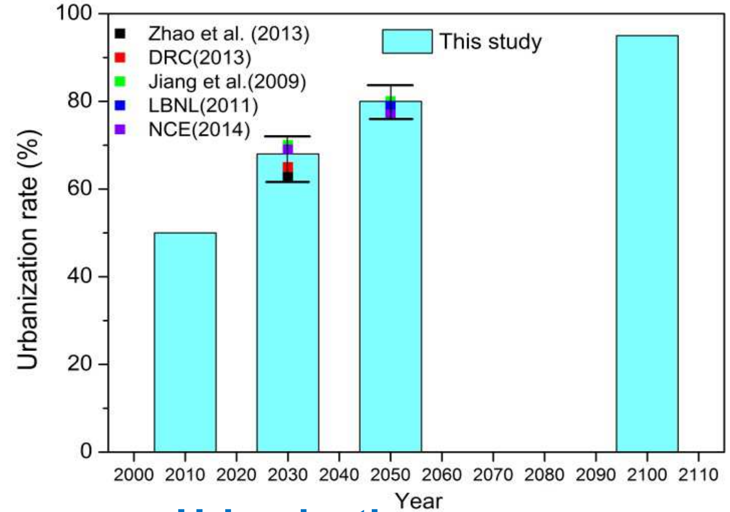


Source : IIASA

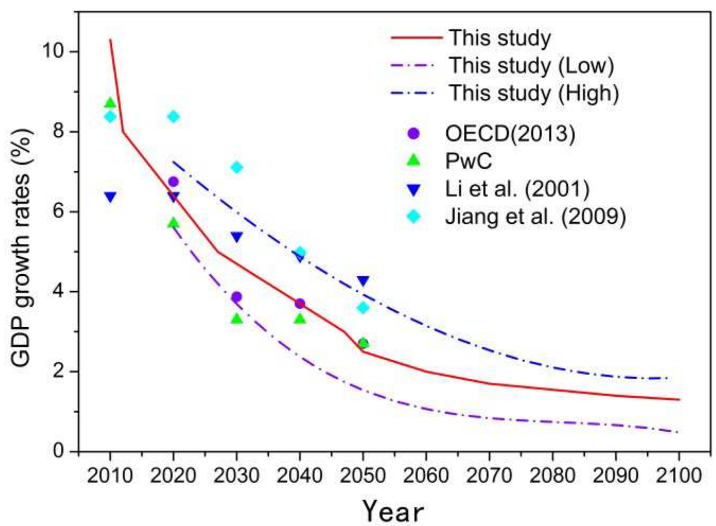
Social-Economic Parameter for China



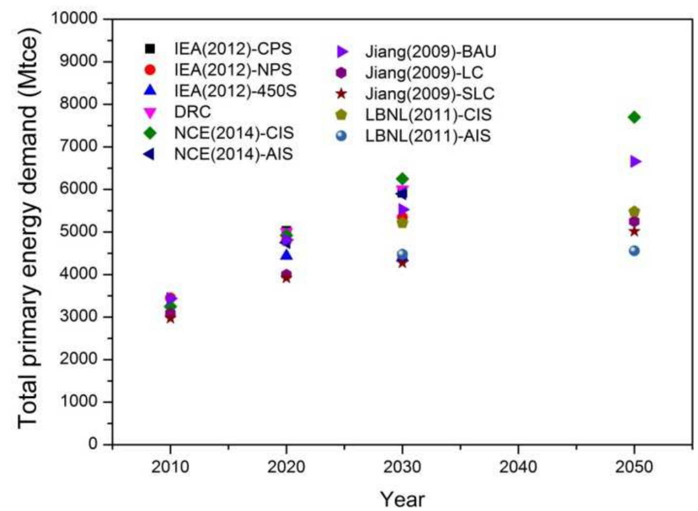
Population: Peak near 2030



Urbanization Rapid

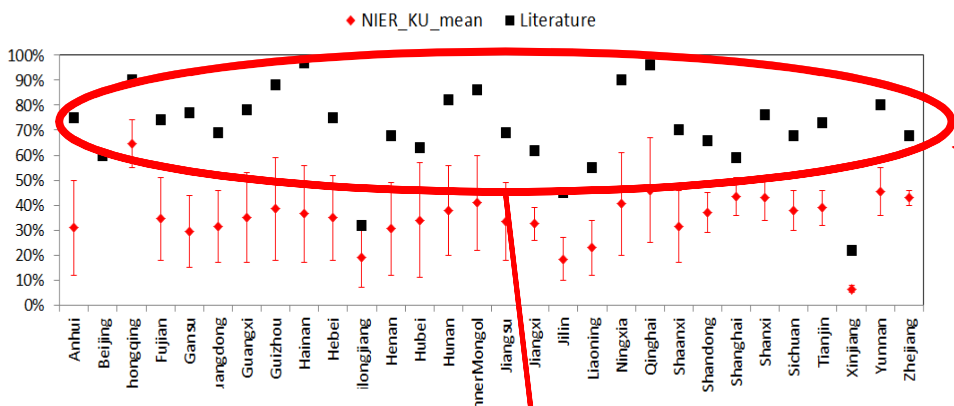


GDP growth Rates : Decreasing

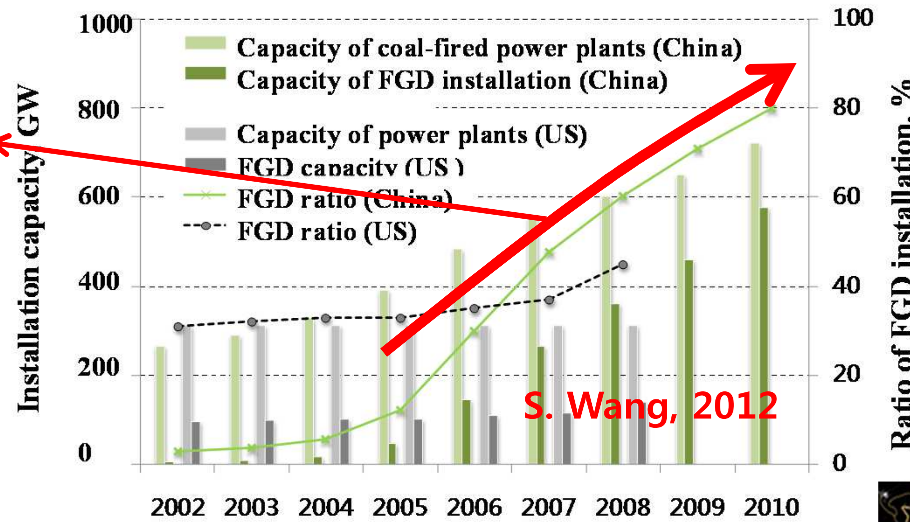


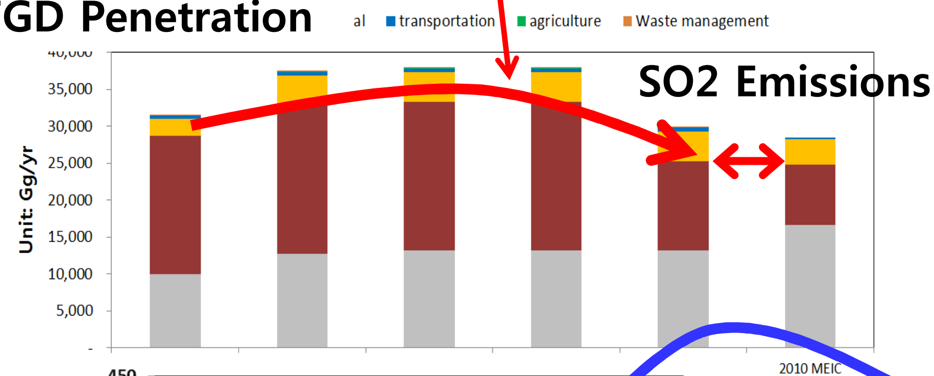
Energy demand : Increasing

NIER/KU-CREATE : Control Tech(China) and Emissions (North Korea)

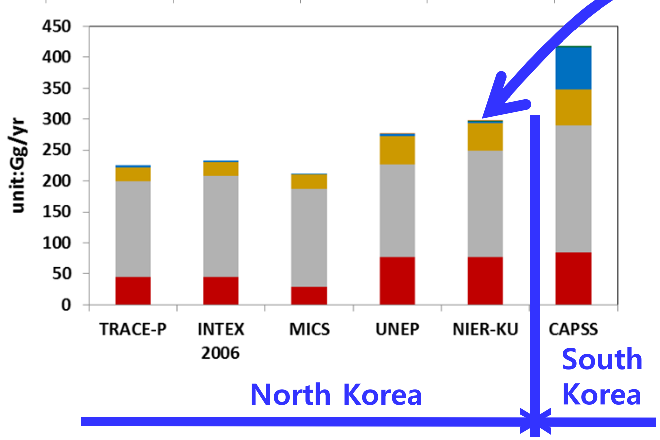


FGD Penetration

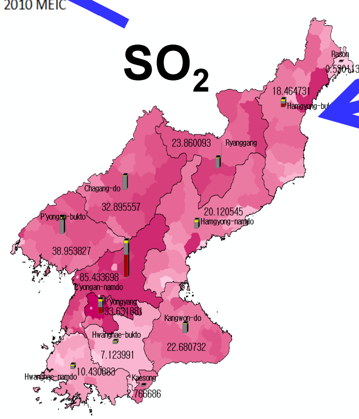


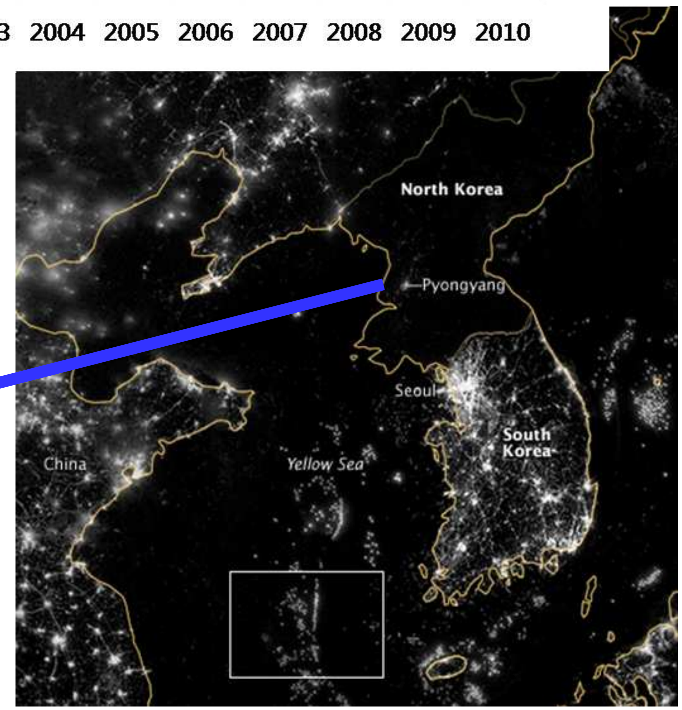


SO2 Emissions



SO_2





Social economic input data for MESSAGE

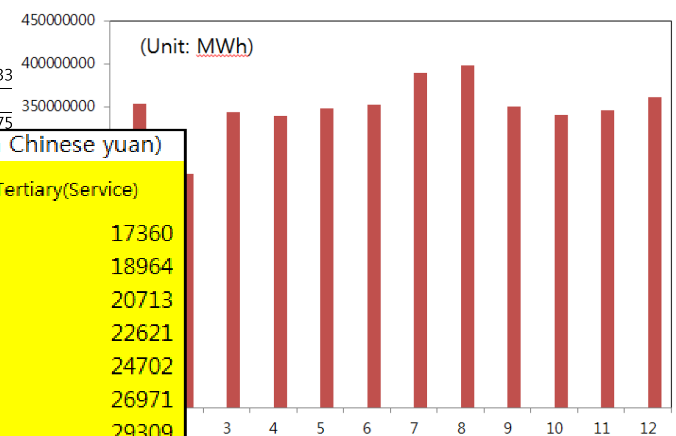
ENERGY BALANCE OF CHINA -2010 (STANDARD QUANTITY)
(10 000 tce)

	Energy Total(coal equivalent calculation)	Energy Total(calorific value calculation)	Coal Total	Raw Coal	Cleaned Coal	Other Washed Coal	Briquettes	Gangue
Total Primary Energy Supply	332703.3744	315747.304	224756.8373	226554.9418	-844.695	-948.017512	-5.391936	
Indigenous Production	296915.7193	279693.7331	227319.7678	227319.7678				
Hydro Power	23085.71034	8875.49388						
Nuclear Power	2361.72585	907.9852						
Wind Power	1426.433823	548.40438						
Recovery of Energy	5143.080619	5143.080619						
Import	54863.58577	54754.47652	11649.15474	11647.321			1.833744	
Domestic Airplanes&Ships Refueling in Abroad	932.612053	932.612053						
Export (-)	-7802.368829	-7427.343883	-1526.851982	-1522.376918			-4.475064	
Oversea Airplanes&Ships Refueling in China	-1042.788996	-1042.788996						
Stock Change	-16306.46548	-16306.46548	-12685.23327	-10889.77014	-844.695	-948.017512	-2.750616	
Input(-) & Output(+) of Transformation	-11072.8261	-76635.34878	-157863.9583	-167129.1645	3737.07522	4867.796663	660.3343718	-0.016
Thermal Power	-2.16573E-11	-65562.52267	-100049.3288	-98348.34415	-4.221	-1696.76364		-445.308
Heating Supply	-3580.182992	-3580.182992	-11143.01838	-10777.93896	-9.477	-355.602416		-94.192
				947.87025	41354.289	7523.291895		539.484
				02.284096	-37126.59678	-29.668548		
				-81.64449	-83.907	-3.093428		
				30.981238	-393.012			
				40.101326		-570.3672	660.33	
				340.03515	2287.598363	3626.743833	630.75	

technology	investment cost(US$)	fixed operation cost
Nuclear	2000/kw	1-2%
Hydro General	750/kw	1-2%
Hydro Micro	2000/kw	1-2%
Solar CSP	3500/kw	1.50%
Solar PV	3000/kw	0.5-1%
Wind Onshore	1300/kw	2
Wind Offshore	2400/kw	3
Biomass	1150/kw	6
Biogas	650/kw	1
Geothermal	1600/kw	1
Tidal	6500/kw	1
Fuel Cell	1000/kw	1
Coal Anthracite Steam	700/kw	4
Coal Bituminous Steam	700/kw	4
Coal Bituminous CCS	3000/kw	6
Heavy Oil	800/kw	4
LNG Steam	550/kw	4
Combined Cycle	1500/kw	4
Internal Combustion	1000/kw	4

Price of technology

generation efficiencies		Efficiency (Unit:%)
2010	Nuclear	40
2010	Hydro General	85
2010	Hydro Micro	80
2010	Solar CSP	30
2010	Solar PV	20
2010	Wind Onshore	30
2010	Wind Offshore	30
2010	Biomass	25
2010	Biogas	20
2010	Geothermal	10
2010	Tidal	15
2010	Fuel Cell	55
2010	Coal Anthracite Steam	35
2010	Coal Bituminous Steam	35
2010	Coal Bituminous CCS	50
2010	Heavy Oil	40
2010	LNG Steam	55
2010	Combined Cycle	47



Monthly load cycle

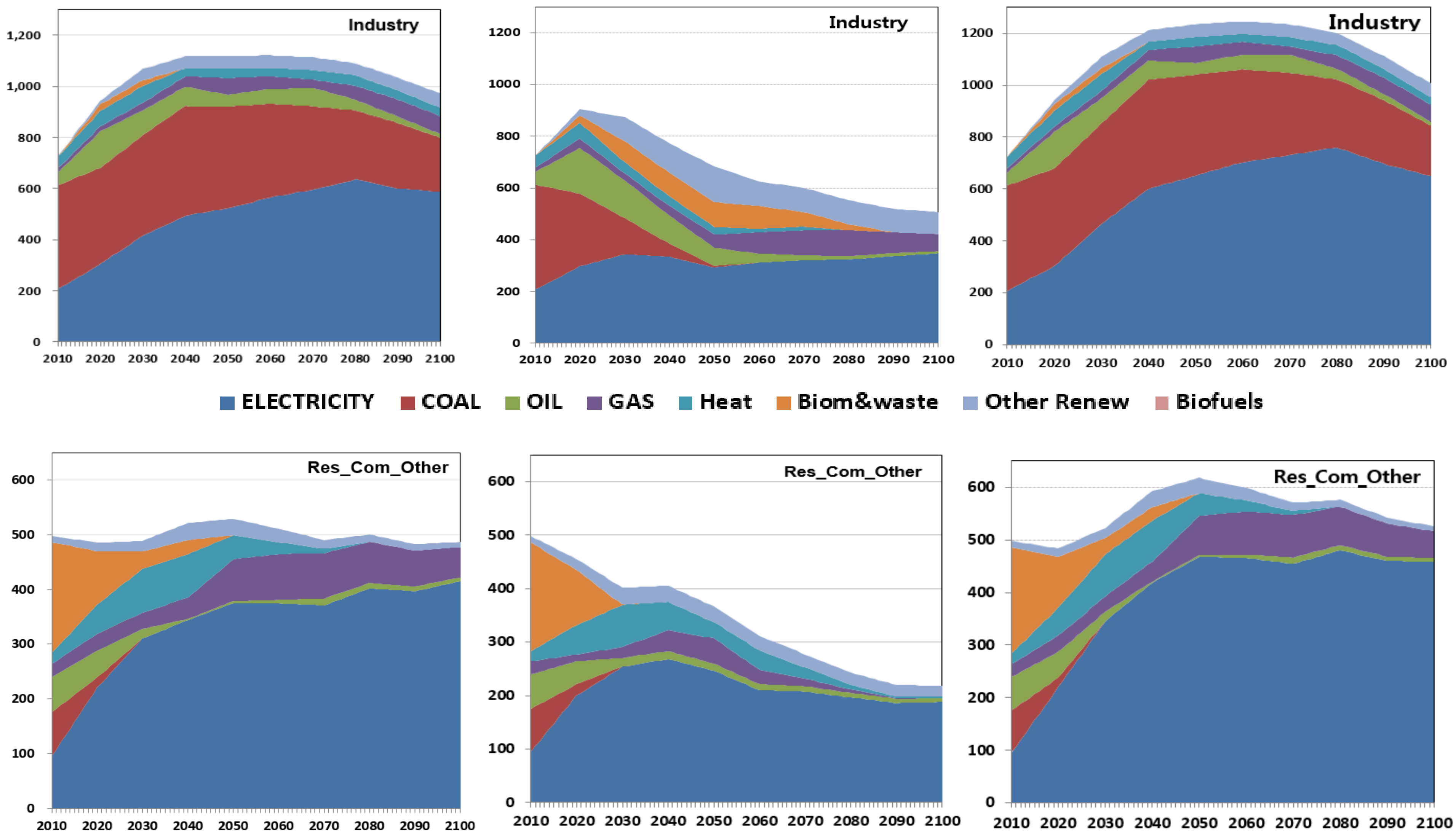
Value Added in economic sectors (Unit: Billion Chinese yuan)

year	Primary (Agri, Fishery, Mining, etc)	Secondary (Manufacturing)	Tertiary(Service)
2010	4053	18738	17360
2011	4235	20165	18964
2012	4419	21700	20713
2013	4606	23352	22621
2014	4795	25129	24702
2015	4984	27040	26971
2016	5148	28962	29309
2017	5310	31021	31846
2018	5467	33225	34598
2019	5617	35585	37584
2020	5759	38113	40823
2021	5908	40365	43928

Energy Projection by scenario

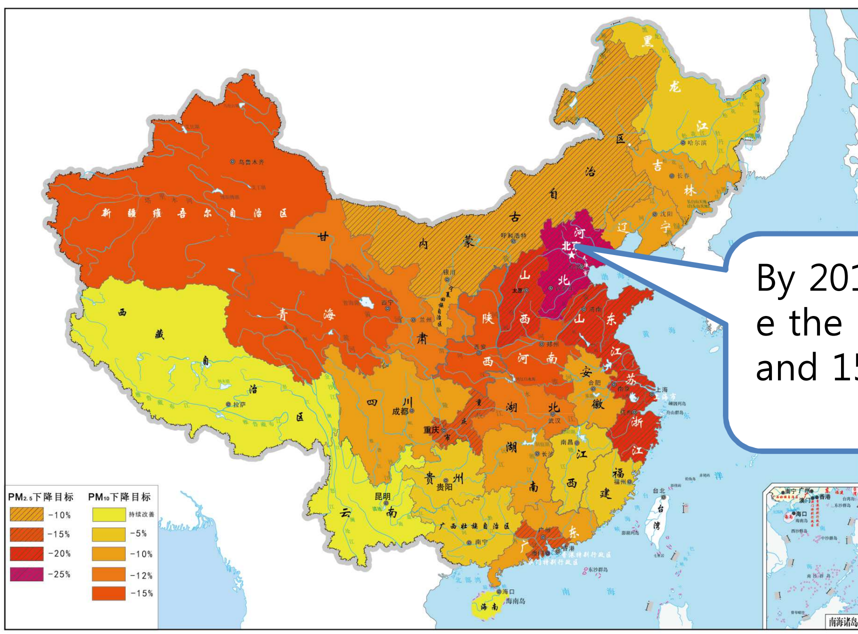
Unit : millon TOE

SSP2 (BAU) | SSP3 (Low) | SSP5 (High)



National action plan and emission standard for China

National action plan of air pollution prevention and control(2012-2017)

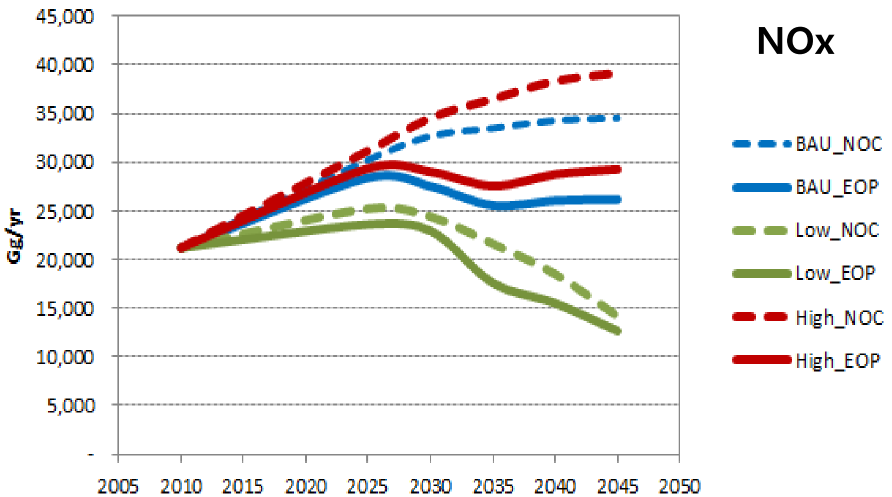


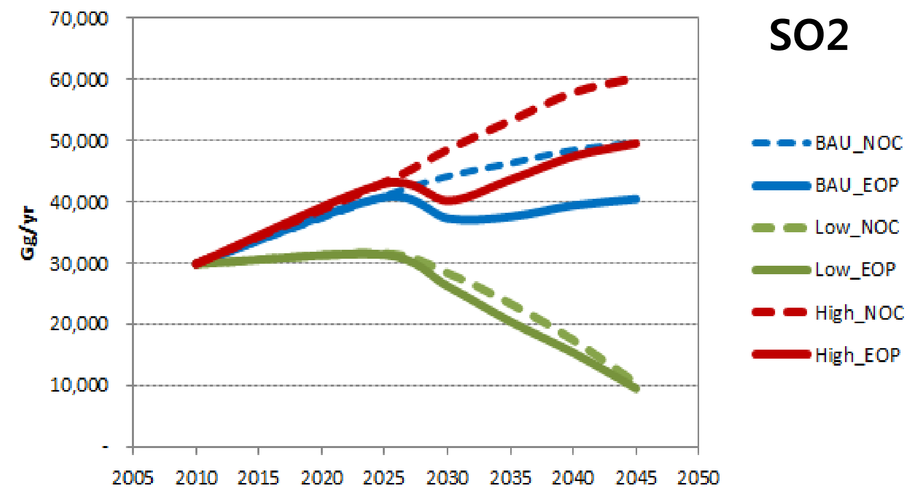
National emission standards
Power plant
Cement
Steel
……

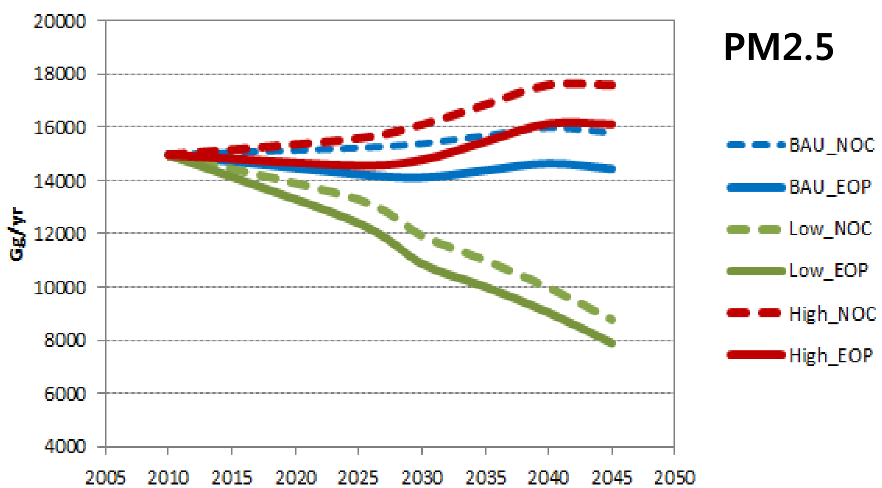
By 2017, the government aims to reduc e the $PM_{2.5}$ concentration by 25%, 20% and 15% in BTH, YRD and PRD.

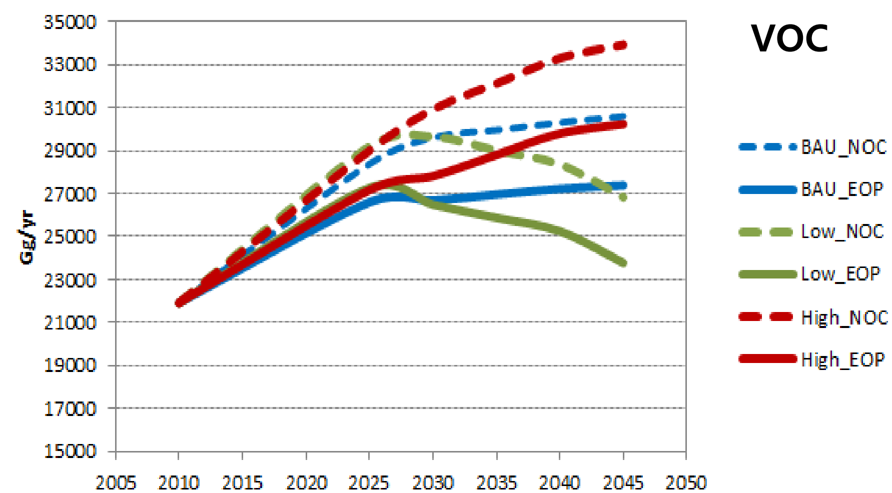
http://kjs.mep.gov.cn/hjbhbz/bzwb/

Implementation of Control technology



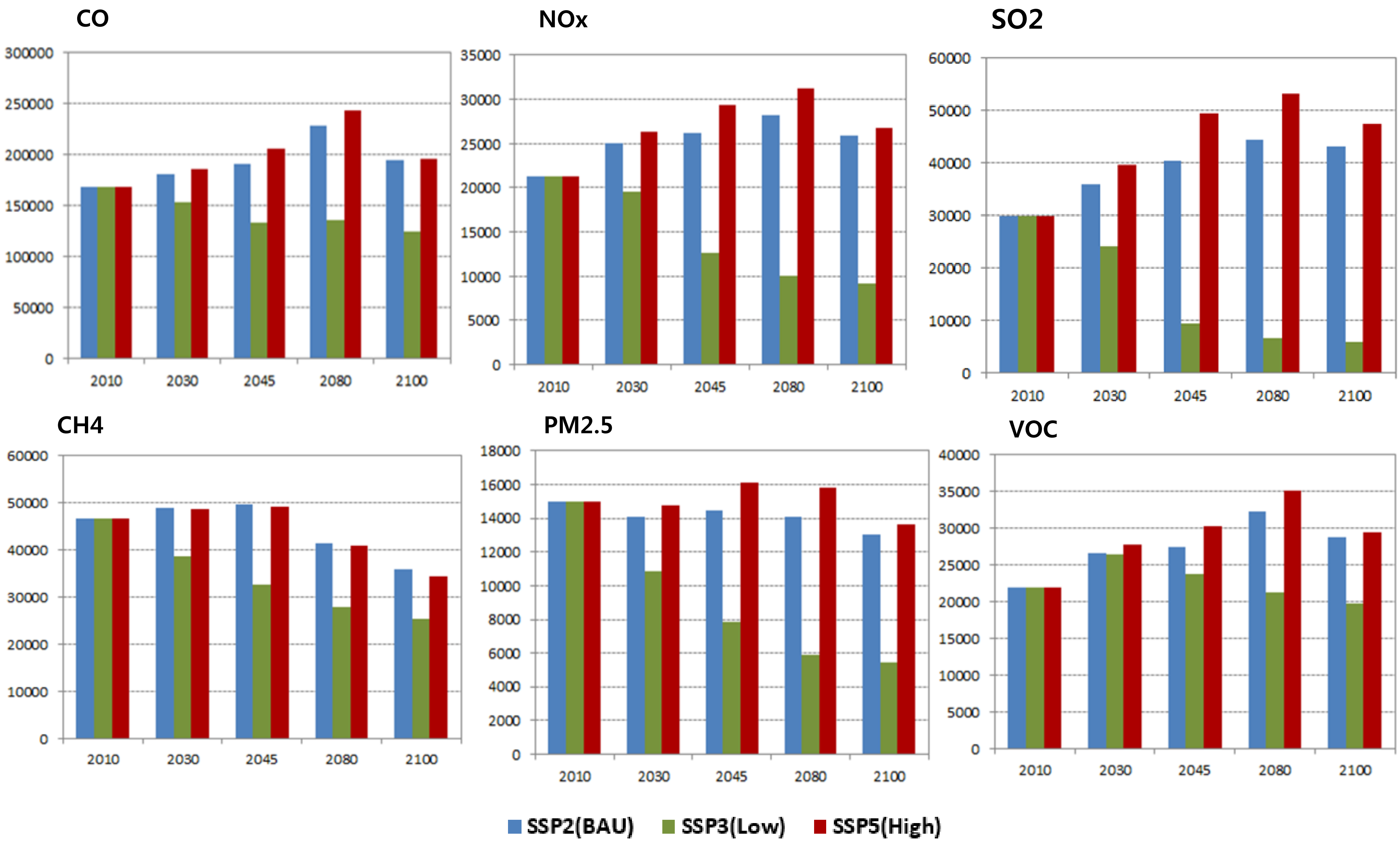




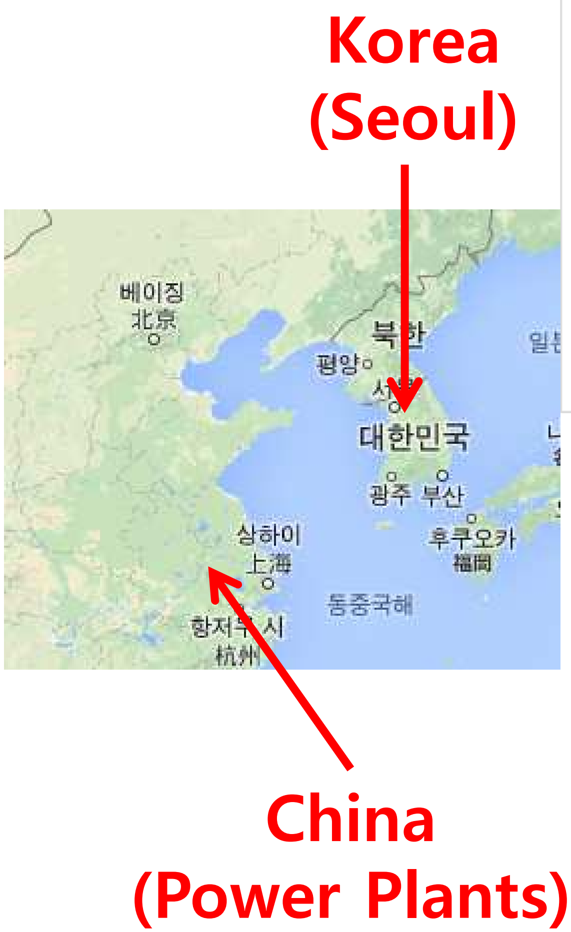


Future Projection of emission by scenario

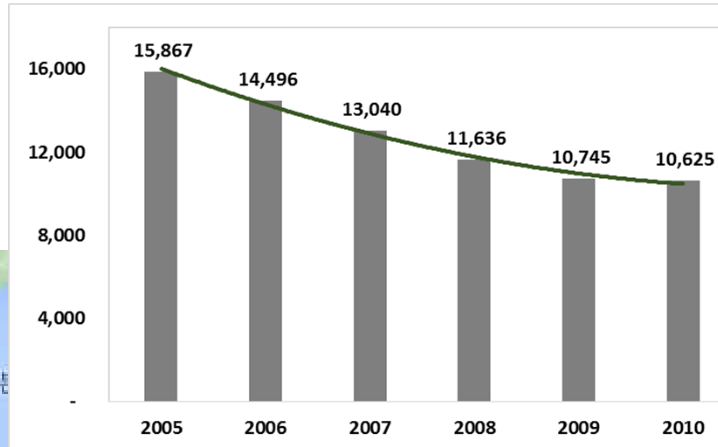
Gg/yr



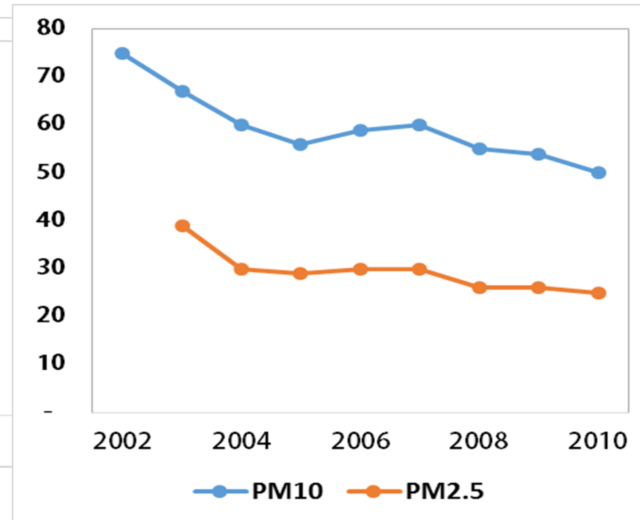
배출저감과 대기환경개선

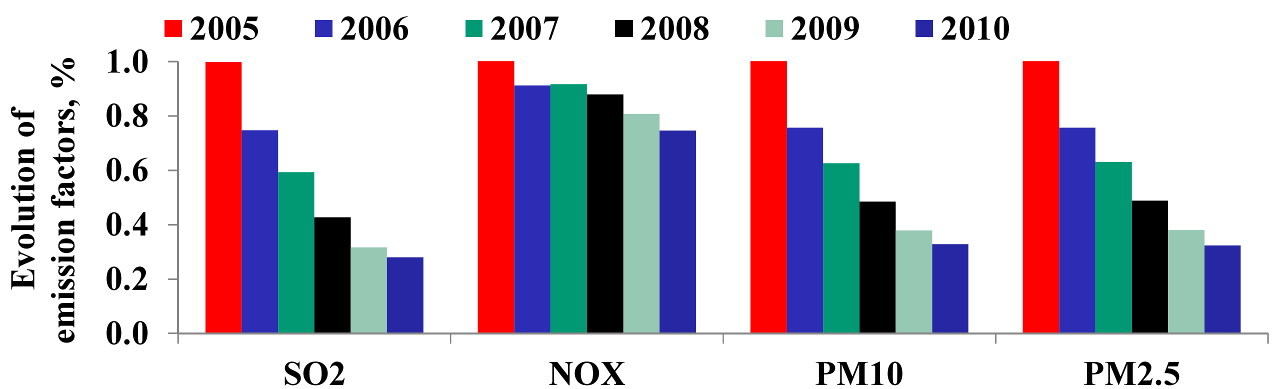


Emission trend
of PM10 (ton/yr)



Air Quality trend
of PM10, PM2.5 (㎍/㎥)



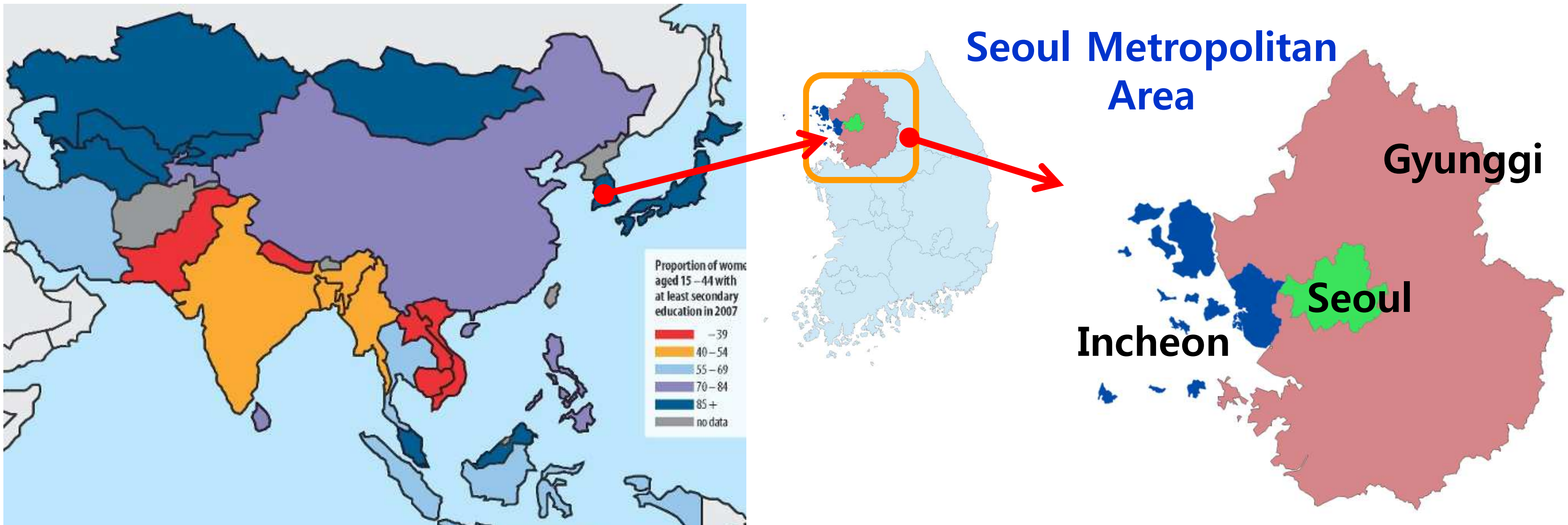


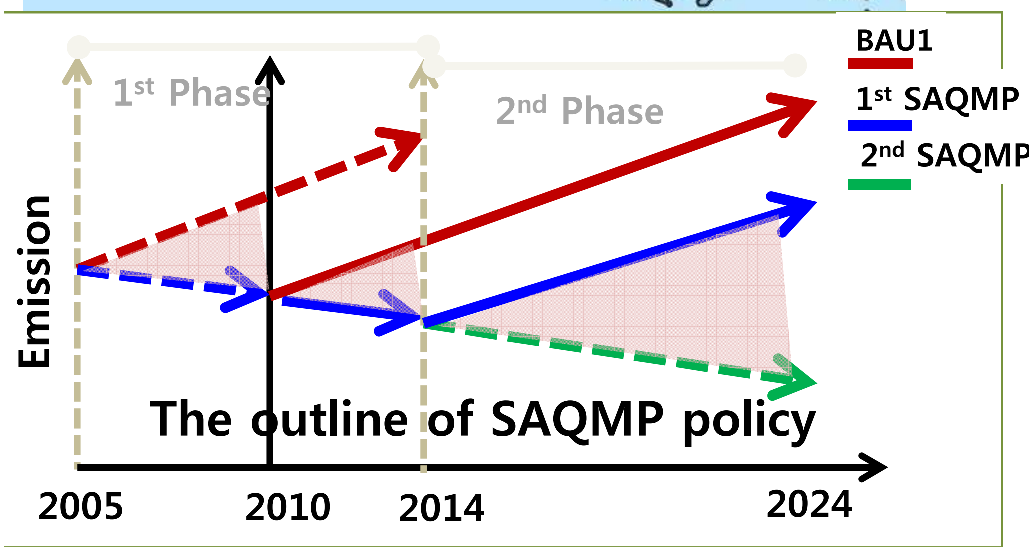
Ministry of Environment
National Institute of
Environmental Research

Multiplatform Observation of Air Quality in Korea :

An International Cooperative Air Quality Field Study
KORUS-AQ 2016 (1 May – 14 June)

Korea AQ Policy : Seoul Air Quality Management Plan (SAQMP)





Target Air Quality

	$PM_{2.5}$ (new)	PM_{10}	NO_2	O_3(new)
2024	***20㎍/㎥***	***30㎍/㎥***	***21ppb***	***60ppb***
2014	***-***	***40㎍/㎥***	***22ppb***	***-***
2010	-	47㎍/㎥	34ppb	-
2001	-	71㎍/㎥	37ppb	-

Society, Energy, Emissions and Future in terms of Air Quality and Climate Change

- **Global climate change potentially impacts regional air quality**

- **Future Climate Change(CC) and Air Quality(AQ) should be understood together,**

require understandings of

- Present CC & AQ status : f(Emissions, Meteorology, Reaction,…)
- Future changes : f(growth, control)
growth : f(socio-economic par., energy pathways,…)
control : f(policy, technology, economy,…)

Result : Shortest-term(Daily Chemical Weather Forecasting)
Mid-term(Decadal Prediction for Policy Analysis)
Long-term (Half/full Century Prediction for CC-AQ Works)

- **Present status and future research efforts of Korea**

(an overview based on my viewpoint)