Understanding Northeast Asia Emissions in Support of NEACAP

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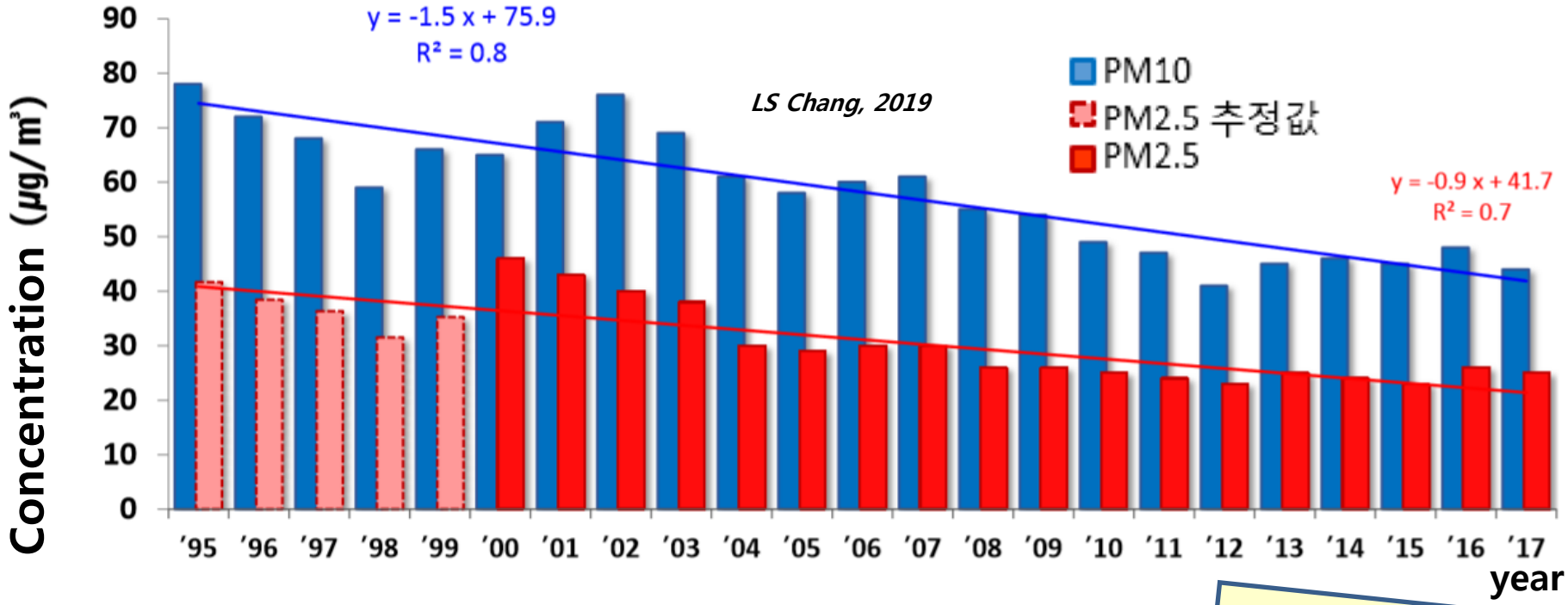
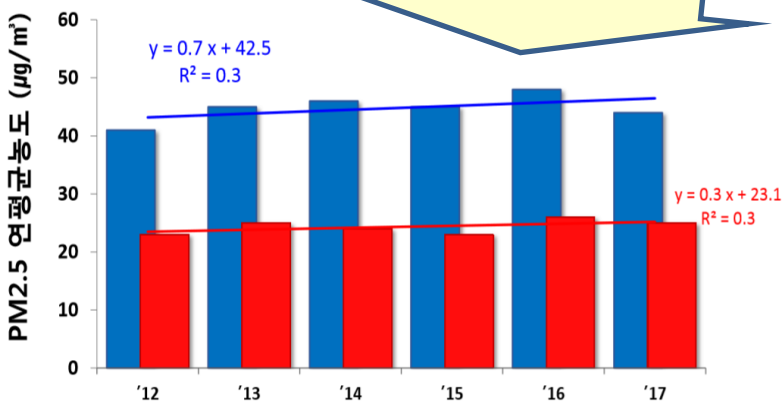
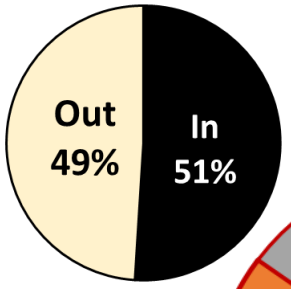
Atmospheric Information Systems Research Group

PM Concentration changes in Seoul, Korea

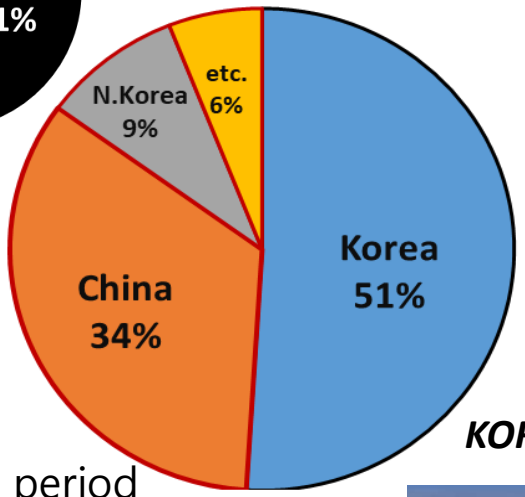


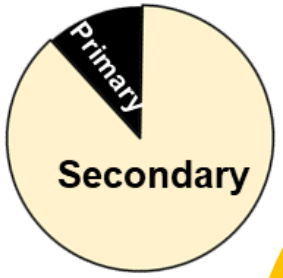


Contribution Assessment on Air Quality in Korea

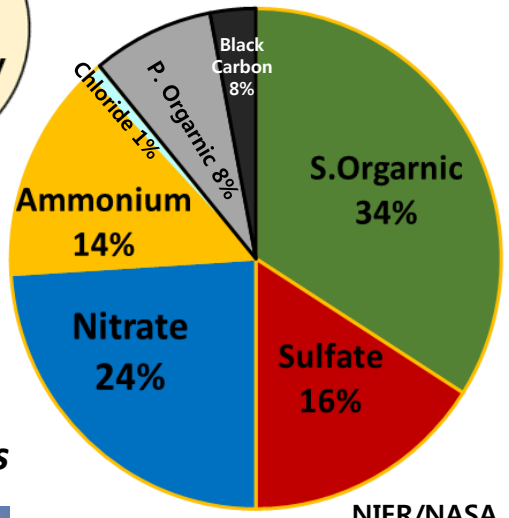


Local vs. Transboundary
Contribution





Primary vs. Secondary
Composition

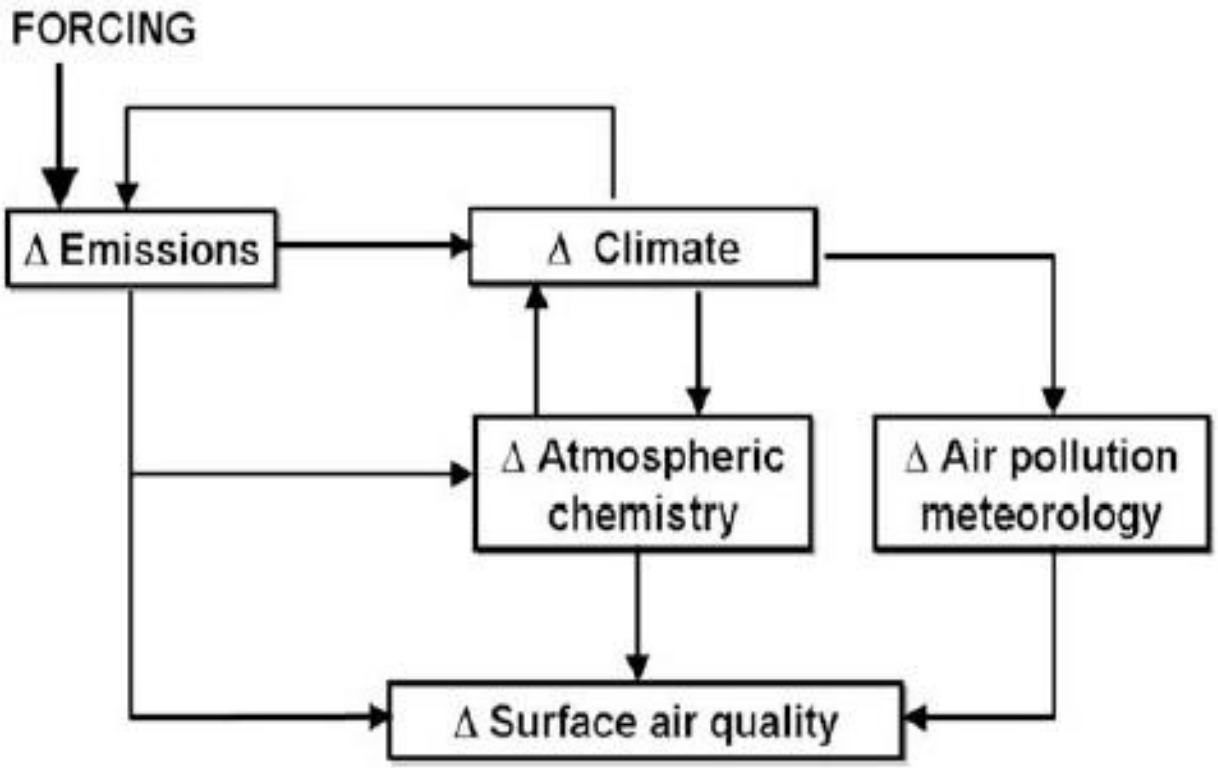


for
2016 May~Jun period

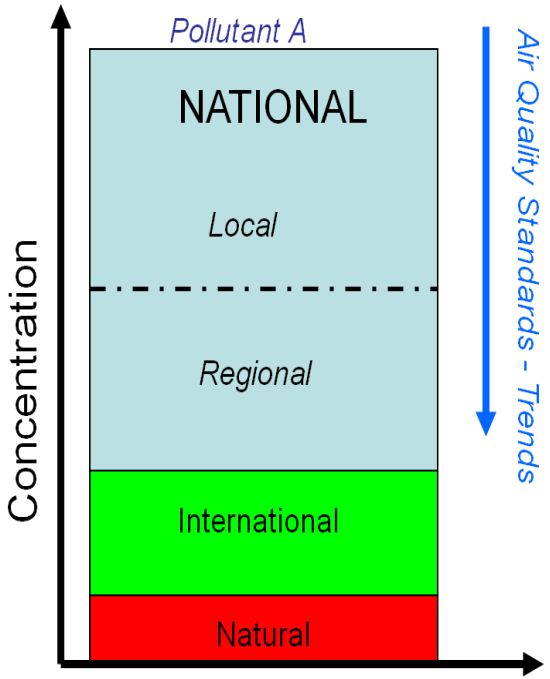
Seoul Metro
KORUS AQ, DC-8 flights

NIER/NASA, 2017

Concentration and Emissions



Daniel J. 2009



Concentration = f (Emission / Diffusion)

plus...

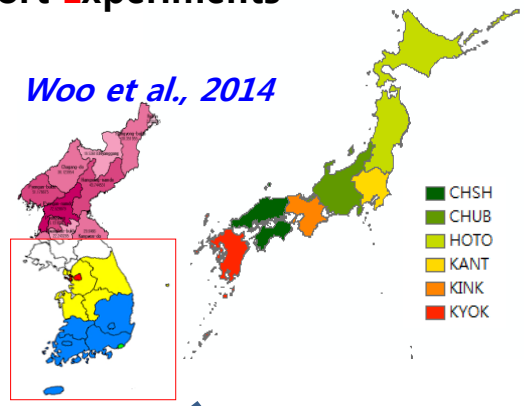
Chemistry and Deposition

Emission Inventories

Inventory	Inventory Domain	Spatial resolution	Temporal resolution	years	Sector / chemical
EDGARv4.2	Globe	0.1x0.1	Annual	1970~2008	Anthropogenic / Biomass burning / International shipping / Aviation CO_2,CH_4,N_2O,F-gas, CO, NOx, SO2, NH3,VOCs,PM_{10}
RCPs EI	Globe	0.5x0.5	Monthly (1 decade interval)	2000 – 2100 (Base year 2000)	Anthropogenic / Biomass burning / International shipping / Aviation CO_2,CH_4,N_2O,F-gas, BC, OC, CO, NOx, SO2, CH4, NH3, VOC
TRACE-P 2000	Latitude : -10 ~ 50 Longitude : 60 ~ 150	0.5x0.5	Annual	2000	Anthropogenic/Biomass burning/International shipping SO_2, NOx, CO, NMVOC, NH3, OC, BC, CO_2, CH_4
INTEX 2006	Latitude : -10 ~ 50 Longitude : 60 ~ 150	0.5x0.5	Annual	2006	Anthropogenic : SO_2, NOx, CO, NMVOC, OC, BC, PM_{10}, $PM_{2.5}$
REAS v1	Latitude : -10 ~ 50 Longitude : 60 ~ 150	0.5x0.5	Annual	Historical : 1980-2003 Base :2000 Prediction : 2004-2009 Project : 2010, 2020	Anthropogenic : SO_2, NOx, CO, NMVOC, NH_3, OC, BC, CO_2, CH_4, N_2O
REAS v2	Asia + Middleeast + Asian part of Russia	0.25x0.25	Monthly	2000-2008	Anthropogenic: SO2, NOx, CO, NMVOC, PM10, PM2.5, BC, OC, NH3, CH4, N2O, and CO2 Soil NOx and others
NIER/KU -CREATE	Asia	Grid on-demand (SMOKE/MEGAN/BlueSky-Asia)	Annual	2010/2015	Anthropogenic/Biomass Burning/Biogenic CO2, CH4, N2O, CO, NOx, NMVOC, NH3, PM10, PM 2.5, SO2
MEIC	China	0.25x0.25	Monthly	2008, 2010	Anthropogenic: SO2, NOx, CO, NMVOC, NH3, CO2, PM2.5, PM coarse, BC, and OC
CAPSS	South Korea	1km	Annual	1999-2011	Anthropogenic: CO, NOx, NMVOC, NH3, TSP, PM10, PM2.5, SO2
ECLIPSE	Globe	0.1x0.1	Annual/ Monthly	1990-2050	Anthropogenic (All GHGs, APs) CO2, CH4, N2O, CO, NOx, NMVOC, NH3, PM10, PM2.5, SO2

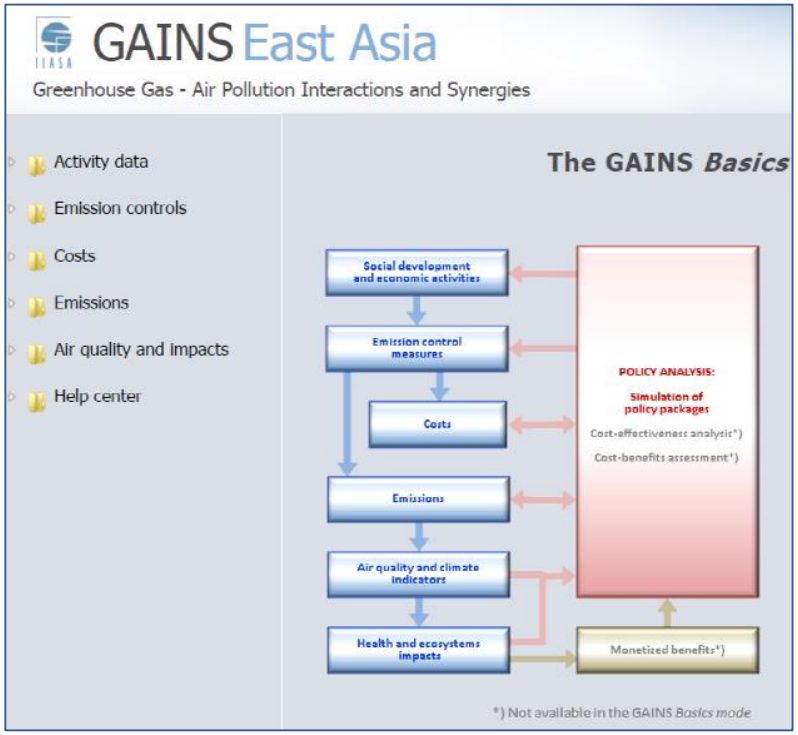
Emissions Inventory : NIER/KU-CREATE*

* Comprehensive Regional Emissions for Atmospheric Transport Experiments

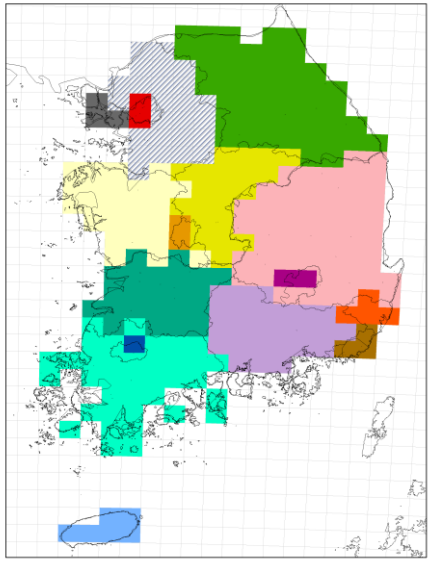


GAINS-Asia :4regions

GAINS-Korea 17regions



GAINS Korea
Greenhouse Gas - Air Pollution Interactions and Synergies

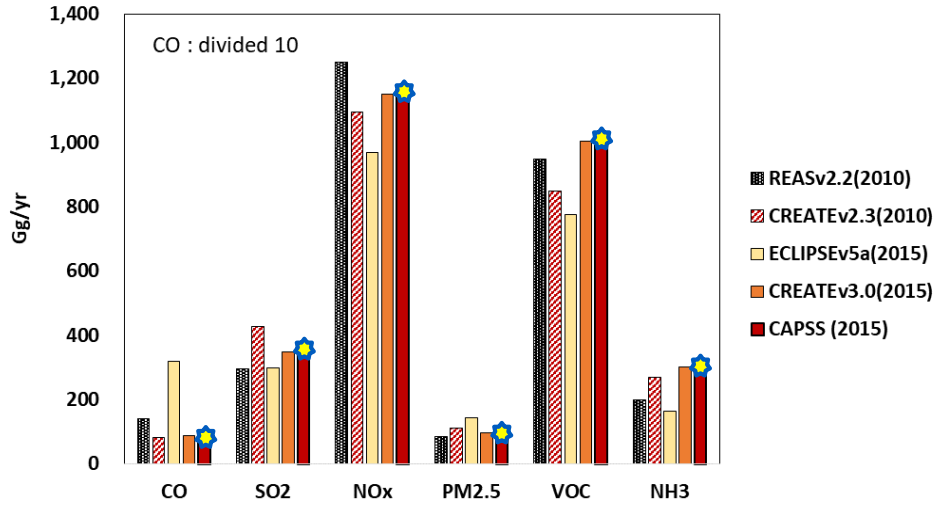


- 17 regions, Y 2010~2050
- Pollutants: CO2, CO, NOx, SO2, VOC, NH3, PM10, PM2.5, BC, OC
- Sectors: Energy, Mobile, Industrial Process, VOCs, Agriculture
- Transfer : CAMx & SMOKE

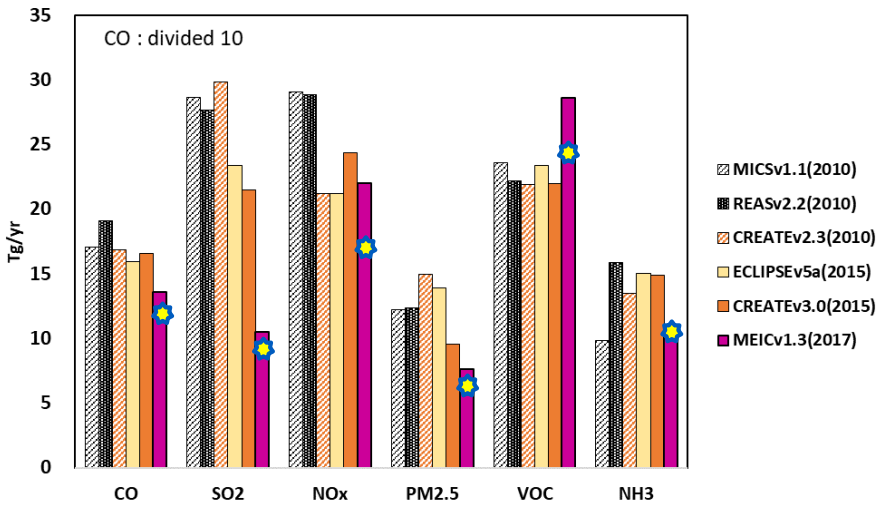
1. Anthropogenic Emissions Inventory : Improved GAINS-Asia and GAINS-Korea emissions using national info.
2. Year 2010, Asia regions, ~300 SCCs
3. Pols.: CO_2, NO_x, PM_{10}, $PM_{2.5}$, SO_2, VOC, NH_3, CO
4. Biogenic(MEGAN), Biomass burning(BlueSky)
5. Emissions projection and processing friendly

Comparison of Emissions Inventories

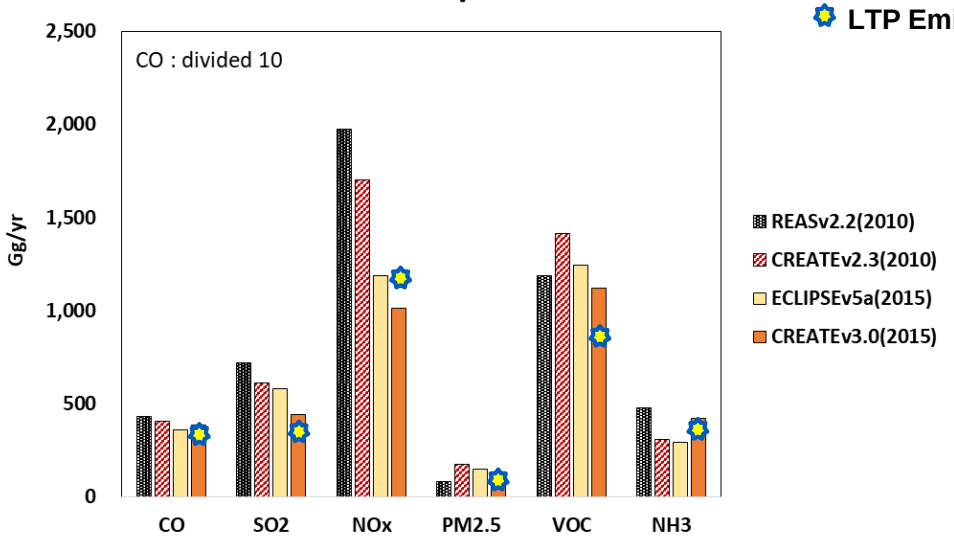
South Korea



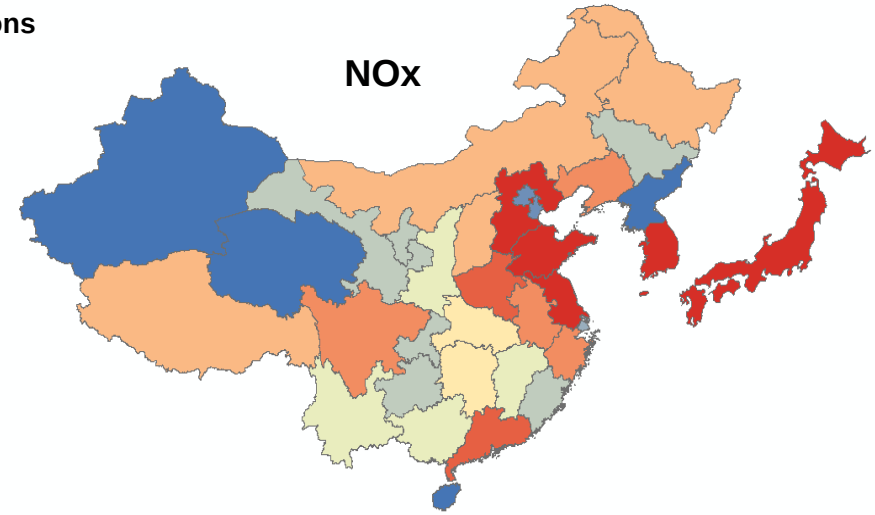
China



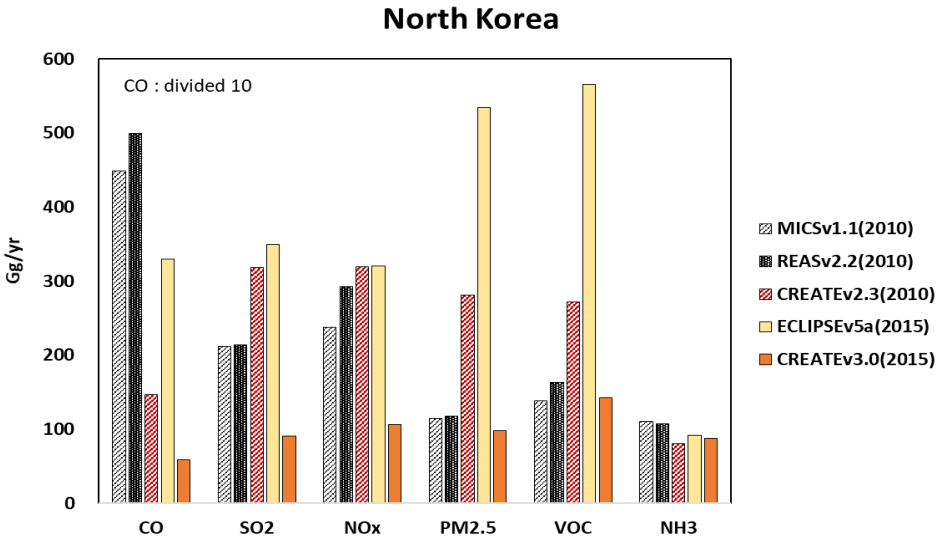
Japan

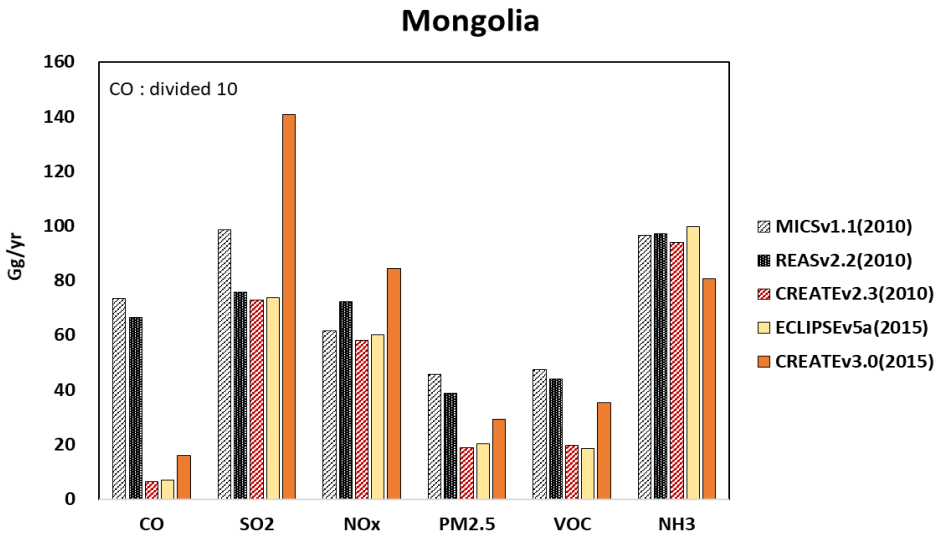


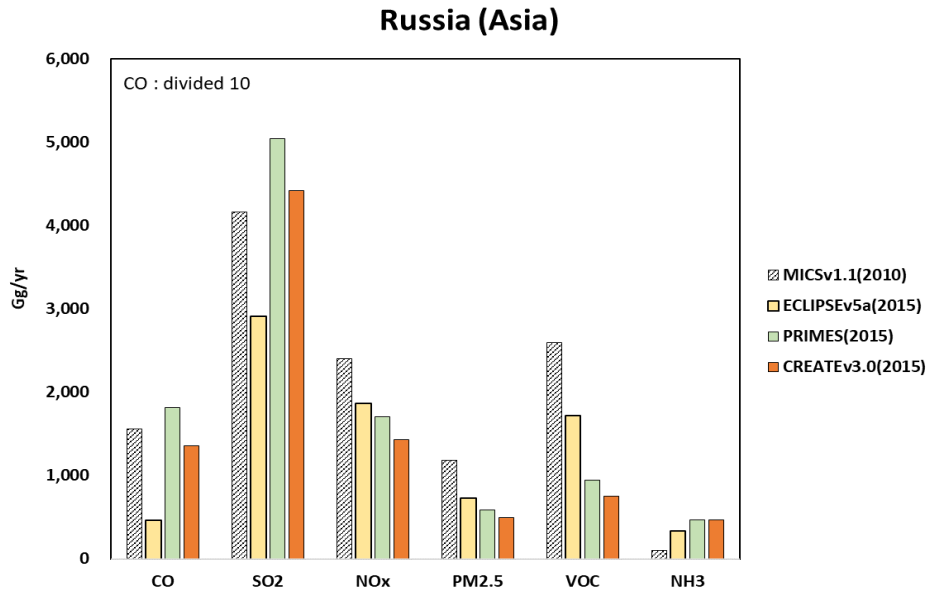
LTP Emissions

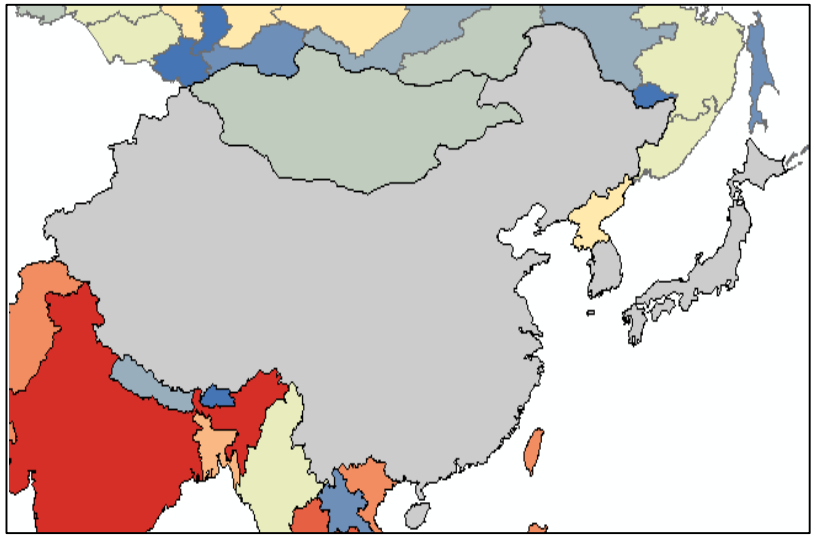


Comparison of Emissions Inventories



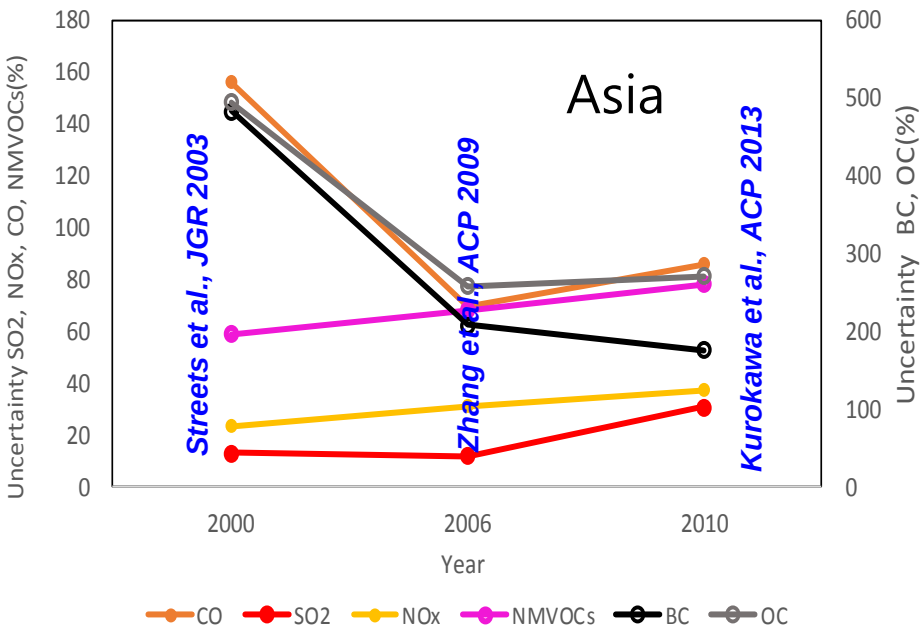


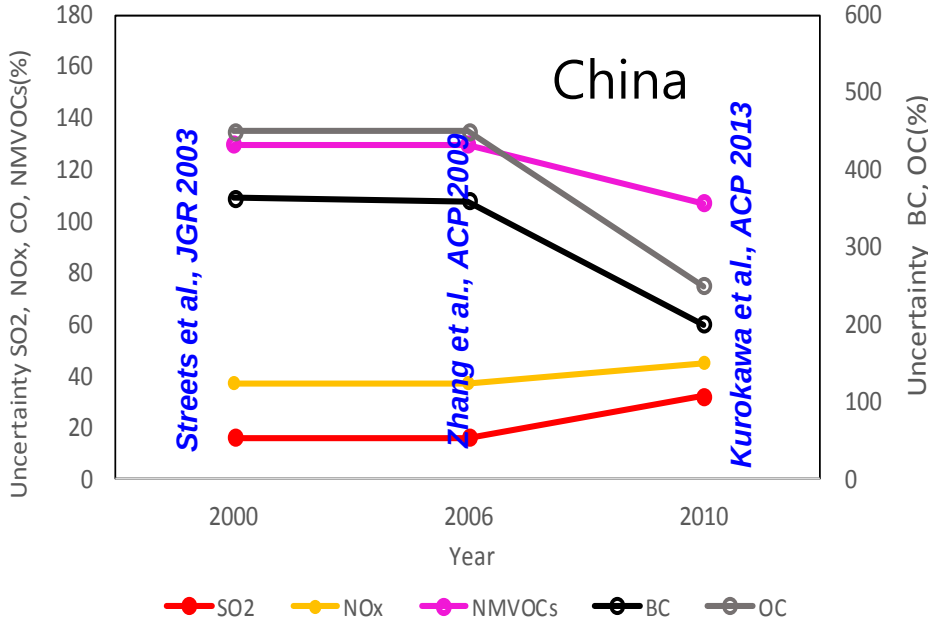




Uncertainty of Bottom-up Emission Inventories

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





M. Li et al. 2017

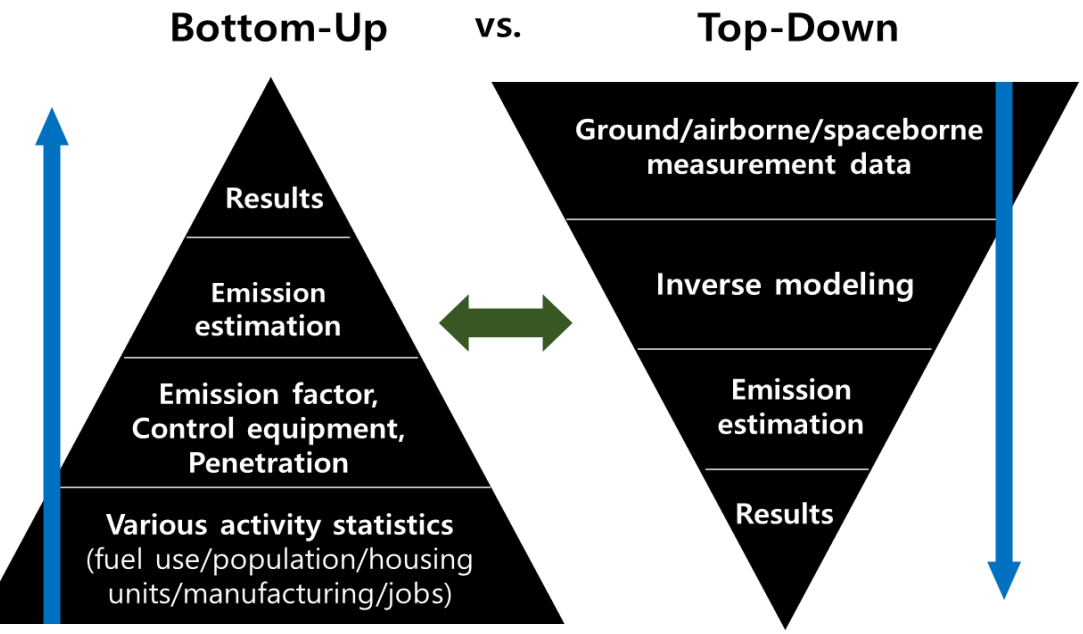
Regions	SO_2	NO_x	CO	NMVOC	NH_3	PM_{10}	$PM_{2.5}$	BC	OC	CO_2	References
China	±12	±31	±70	±68		±132	±130	±208	±258		Zhang et al. (2009)
						±91	±107	±187	±229		Lei et al. (2011)
	−14–13	−13–37				−14–45	−17–54	−25–136	−40–121		Zhao et al. (2011)
	−16–17							−43–93	−43–80		Lu et al. (2011)
	±31	±37	±86	±78	±153	±114	±133	±176	±271	±31	Kurokawa et al. (2013)
India	−15–16							−41–87	−44–92		Lu et al. (2011)
	±32	±49	±114	±137	±144	±120	±145	±178	±233	±49	Kurokawa et al. (2013)
Others	±35	±47	±131	±111	±148	±194	±208	±257	±286	±44	Kurokawa et al. (2013)

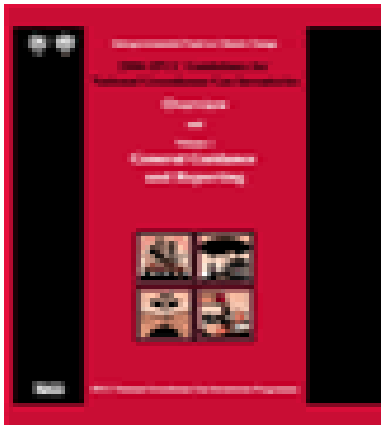
CREATE 2010 (China)

Woo, 2013

±28% (SO_2), ±39% (NOx), ±68 (NMVOC), ±60% (CO), ±101% (NH_3), ±50% (PM_{10}), ±54% ($PM_{2.5}$)

Emission Verification using Inverse Modeling Method





The 2019 Refinement to the IPCC Guidelines on National GHGs Inventories

(2019 Refinement)

CHAPTER 6

QUALITY ASSURANCE/QUALITY CONTROL AND VERIFICATION

Authors

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Contributing Authors

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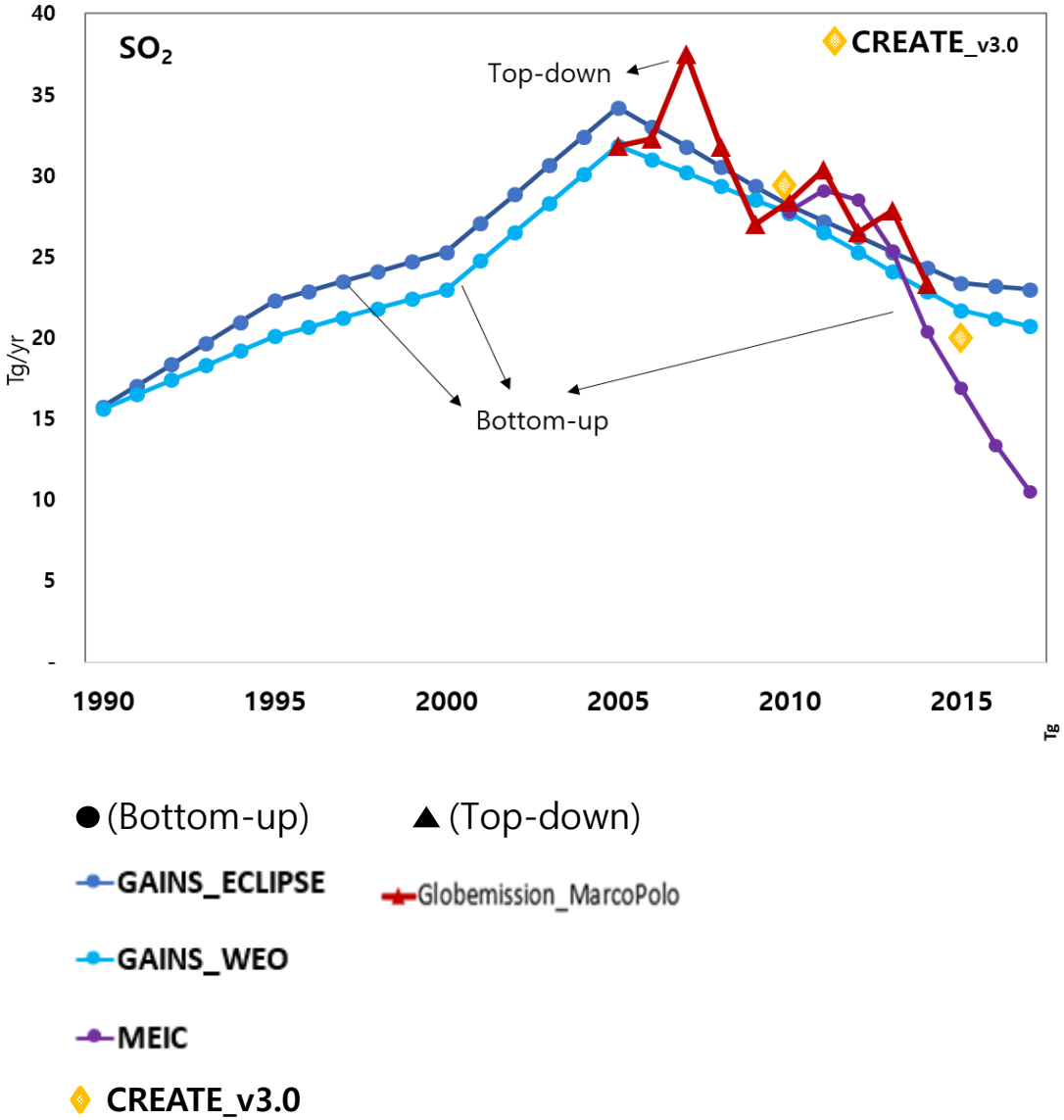
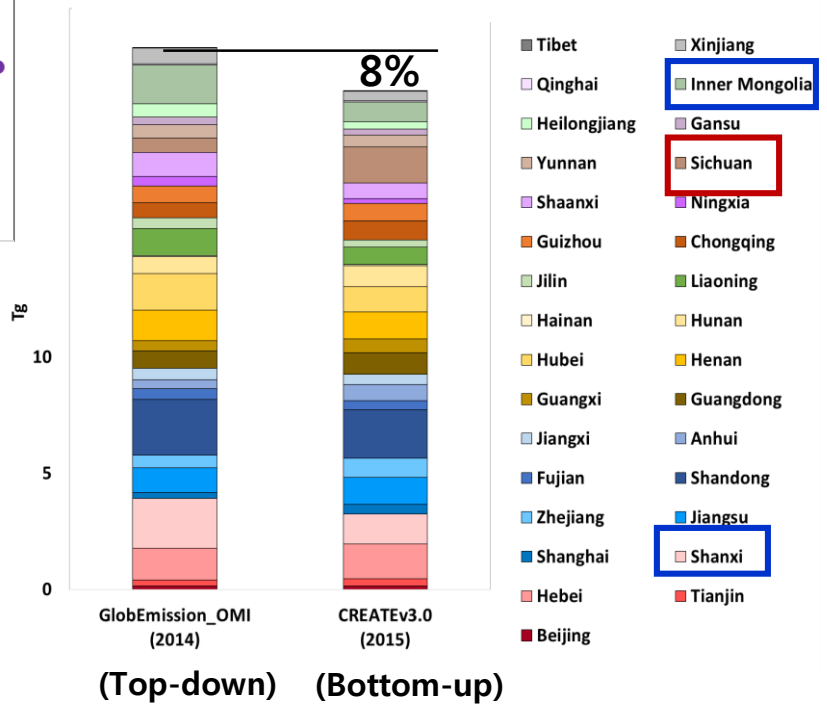
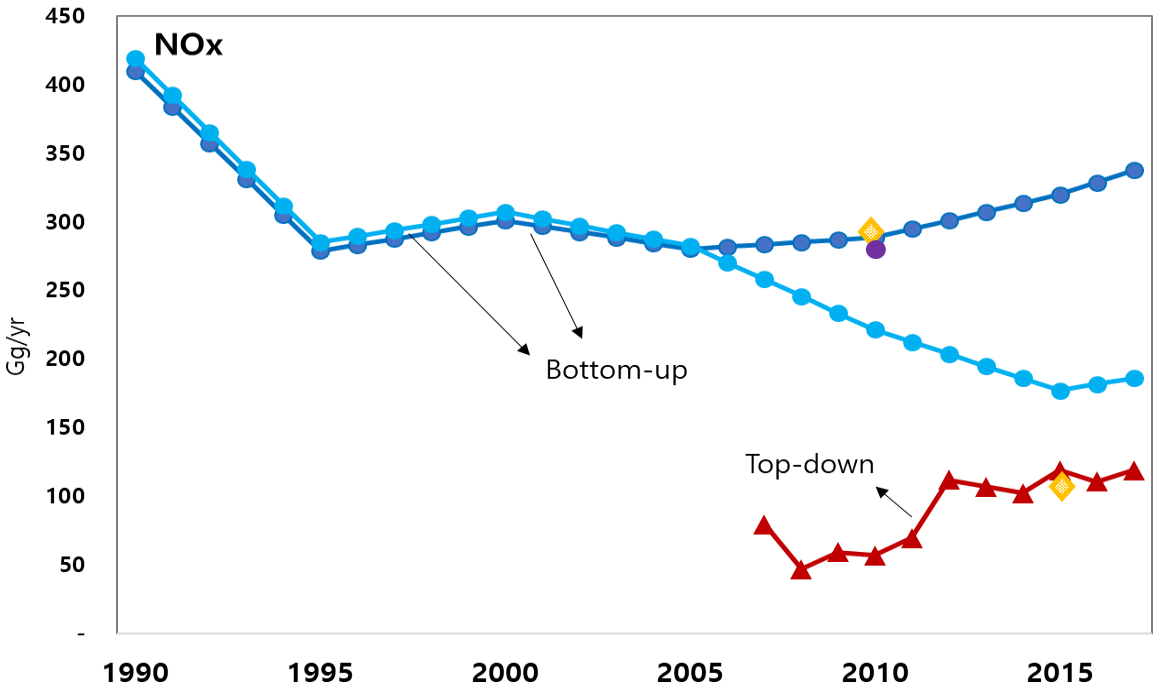
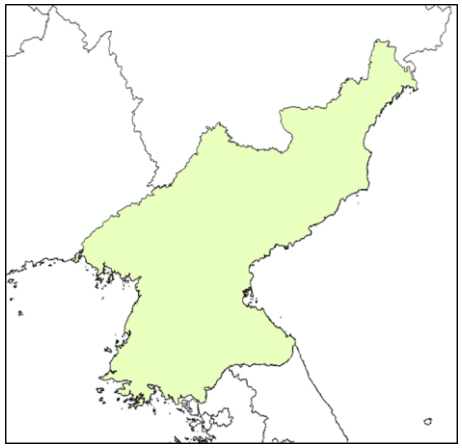
B-U vs. T-D comparison (SO_2, China)

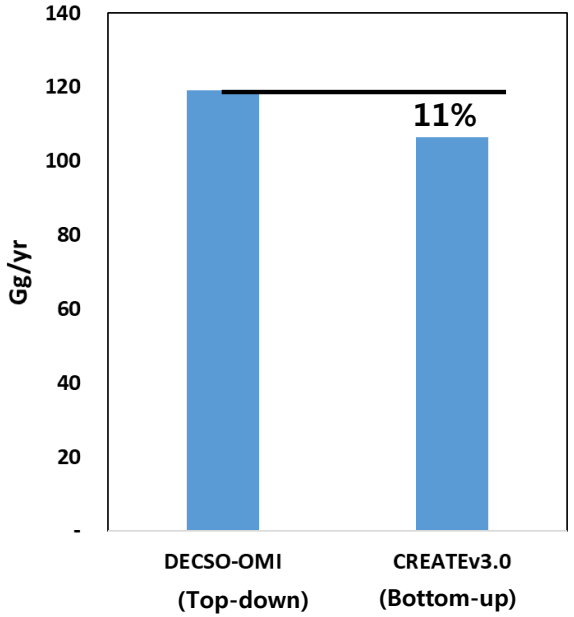




B-U vs. T-D comparison (NO_x North Korea)







● (Bottom-up) ▲ (Top-down)

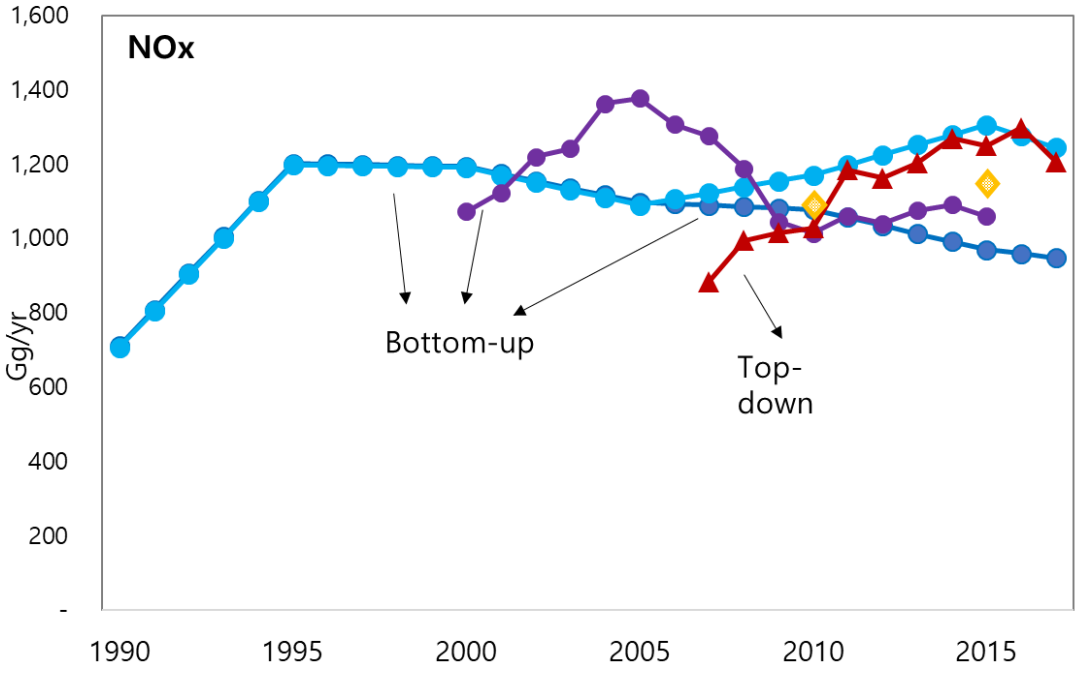
GAINS_ECLIPSE DECSO

GAINS_WEO

REAS

CREATE_v3.0

B-U vs. T-D comparison (NO_x South Korea)



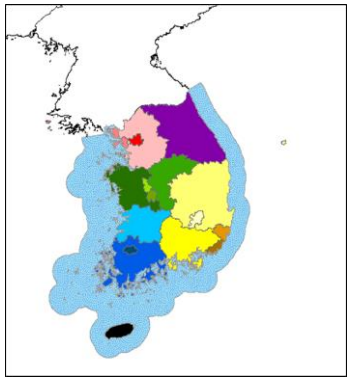
(Bottom-up) (Top-down)

GAINS_ECLIPSE DECSO

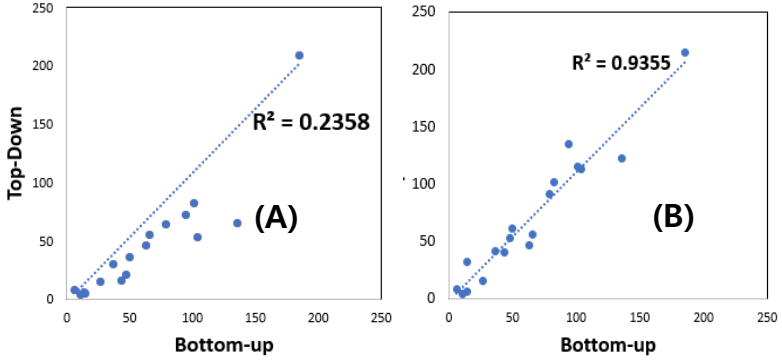
GAINS_WEO

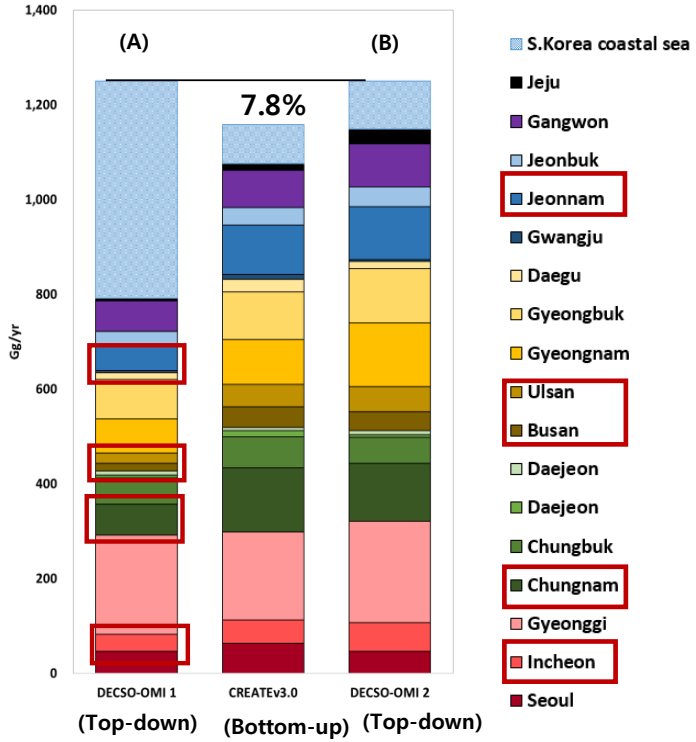
CAPSS

CREATE_v3.0



T-D vs. B-U





Understanding Emissions From an Aircraft Field Campaign : NASA KORUS-AQ

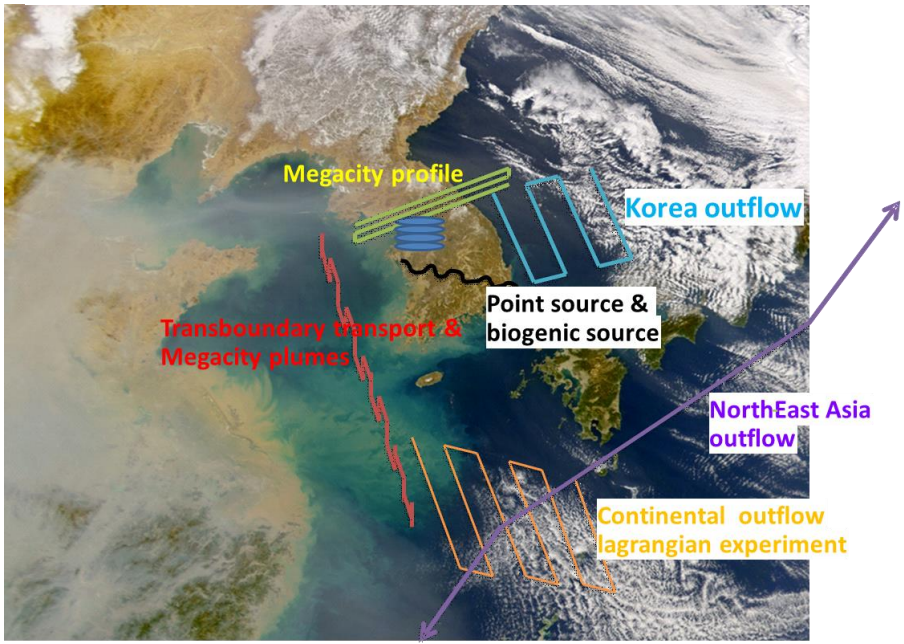
KORUS-AQ

Science

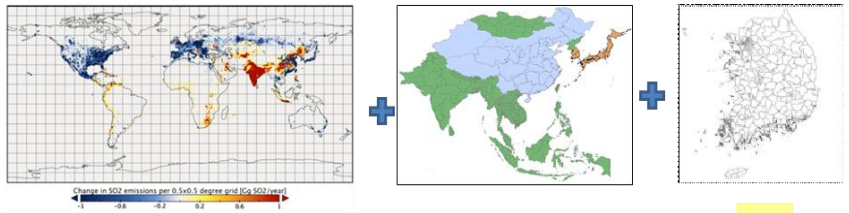
- Better understanding of the factors controlling air quality
- Test and improve model simulations of air quality

Societal Impact

- Provide guidance on measures to improve air quality in Korea



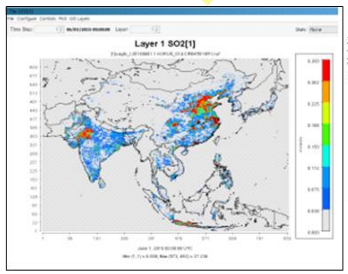
EMISSION INVENTORY : KORUS(CREATE)

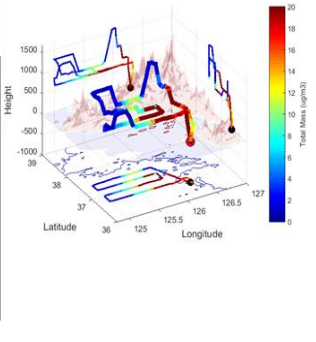


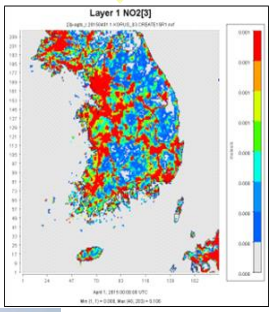
Monthly emissions with 0.1 deg. gridded resolutions over entire Asia

GRIMS-Chem, WRF-Chem, CMAQ,CAMx, and others

Monthly emissions with 3km gridded resolution over S. Korea



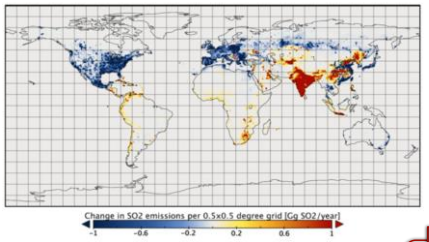


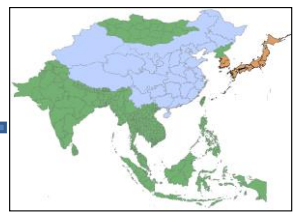


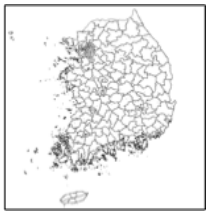
DC-8 Airborne Laboratory

NASA Dryden Flight Research Center Photo Collection
http://www.dfrc.nasa.gov/Gallery/Photo/index.html

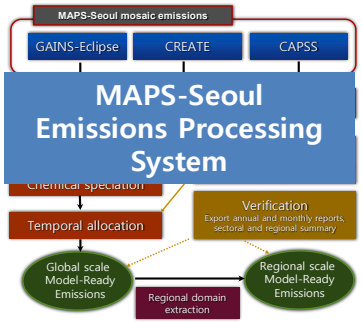
Providing Emissions Information in support of KORUS-AQ





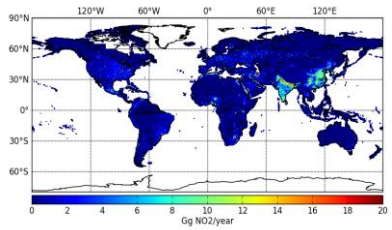


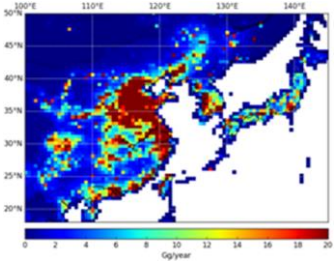
0.5 degree gridded, monthly emissions for year 2010



Konkuk Univ

27km gridded, hourly emissions for year 2010





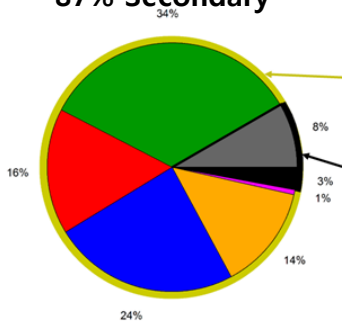
AQ Forecasting Systems

- GEOS-Chem (SNU)
- WRF-Chem (PNU)
- CMAQ (GIST)
- CAMx (AJU)

PM Concentration

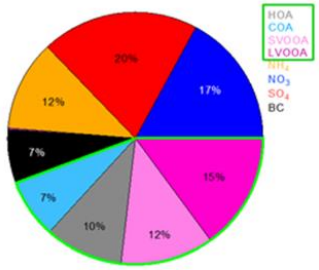
Aircraft

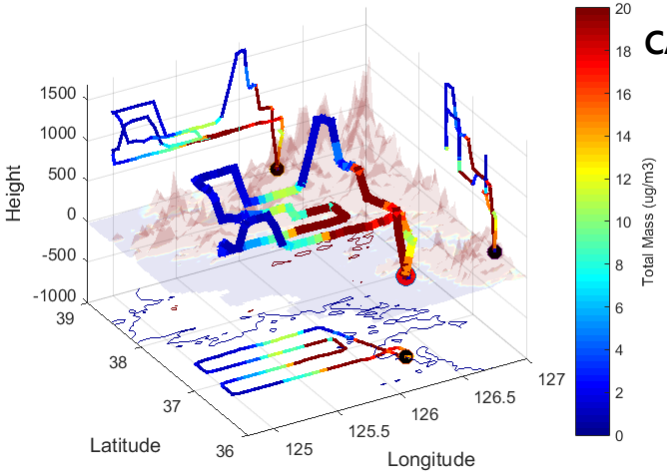
PM_1 : 31.1ug/m³
13% Primary
87% Secondary



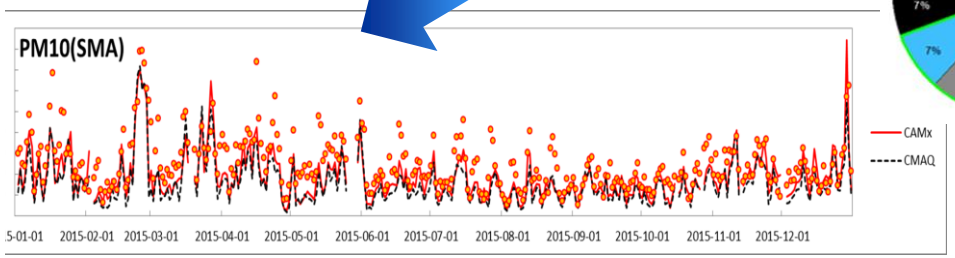
Surface

PM_1 : 22.1ug/m³
24% Primary
76% Secondary



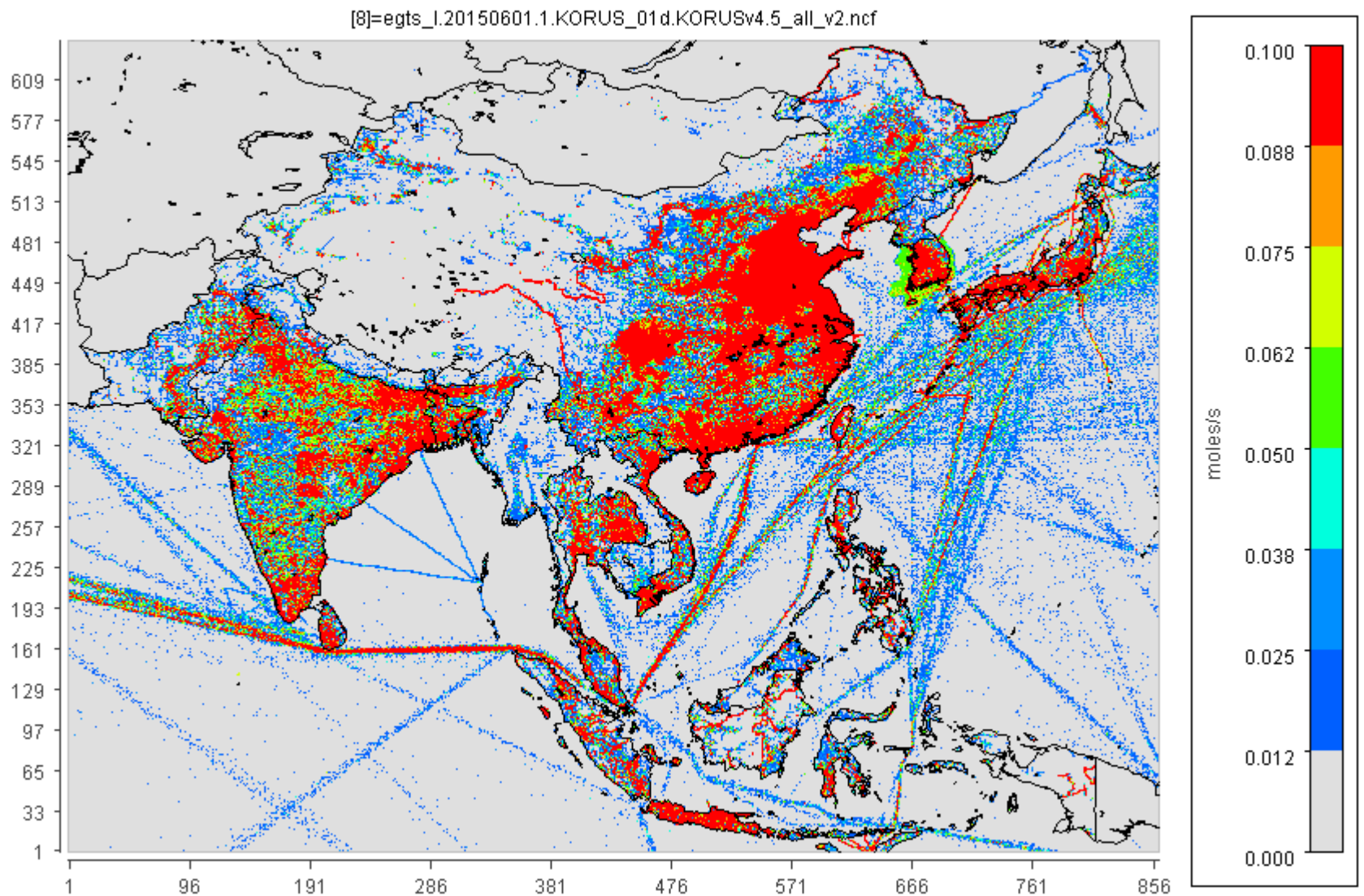


$CAE_A = (EF_A)(Q)\ [(1- (CE)(RP)(RE)]$



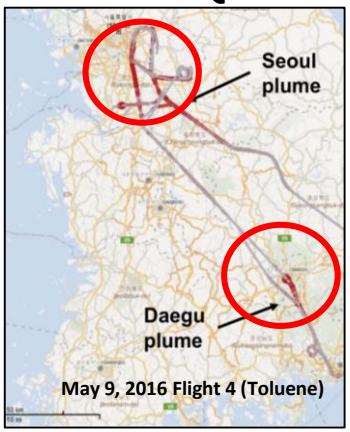
KORUS RSSR

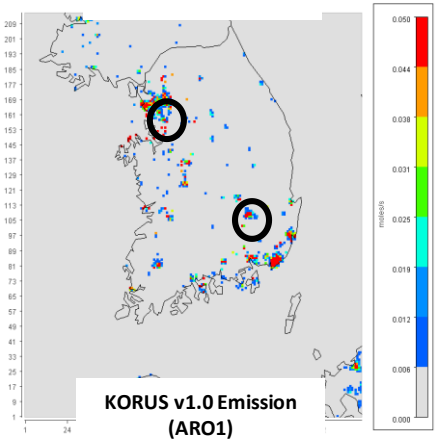
Standard KORUS-AQ Emissions (0.1 degree)



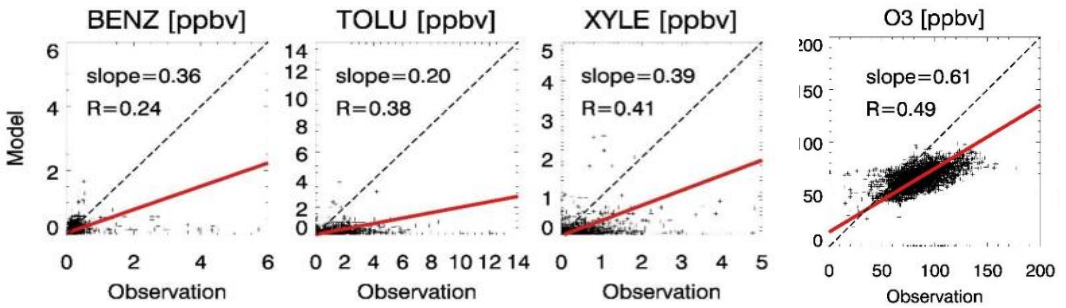
Effect of VOC Emission Improvements : 3D CTM

KORUS-AQ DC-8



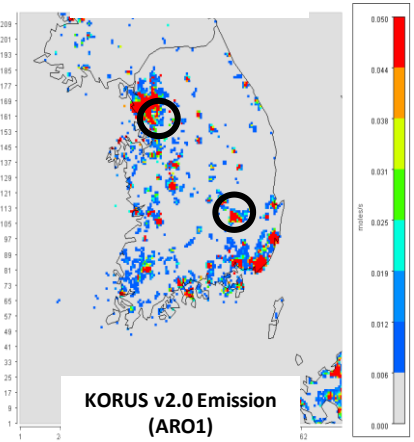


OLD (GRIMS-Chem vs. DC-8)

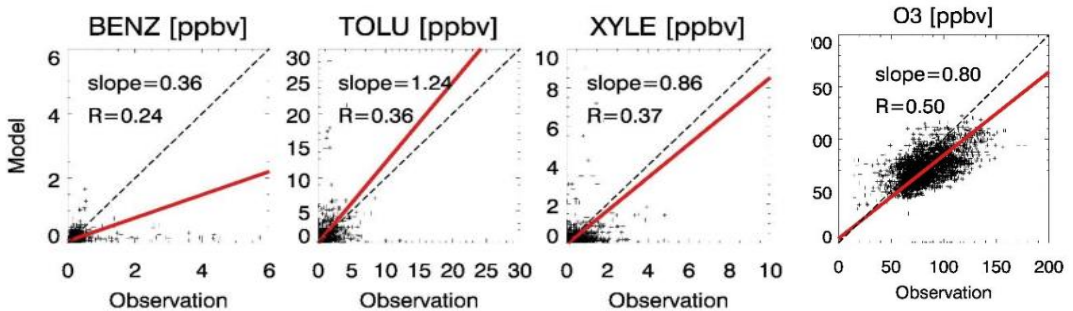


Source : R. Park, SNU

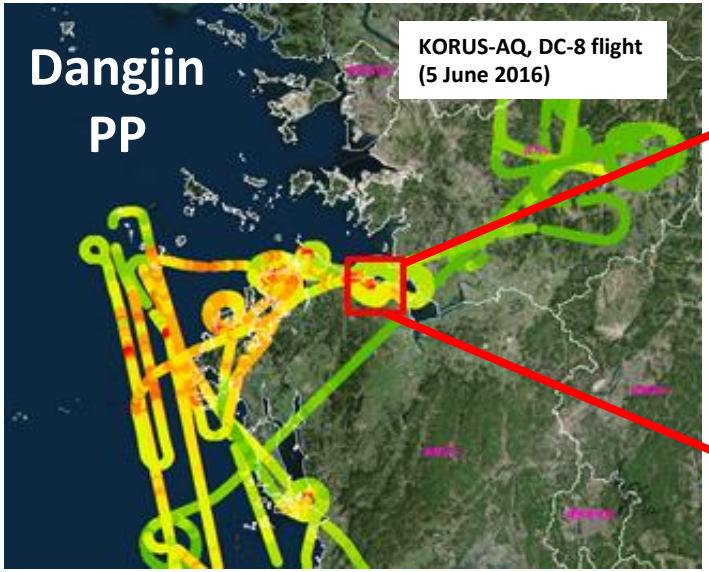
Whole flight track (<2km)



UPDATED (GRIMS-Chem vs. DC-8)

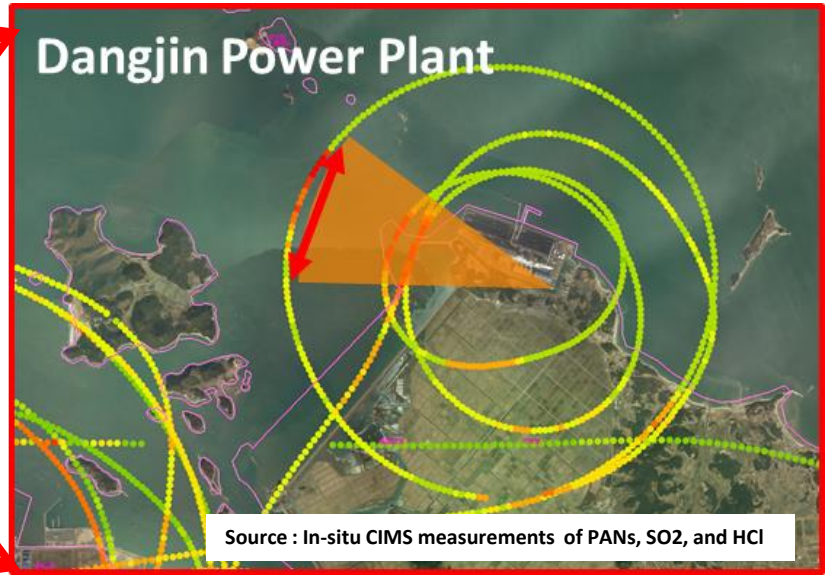


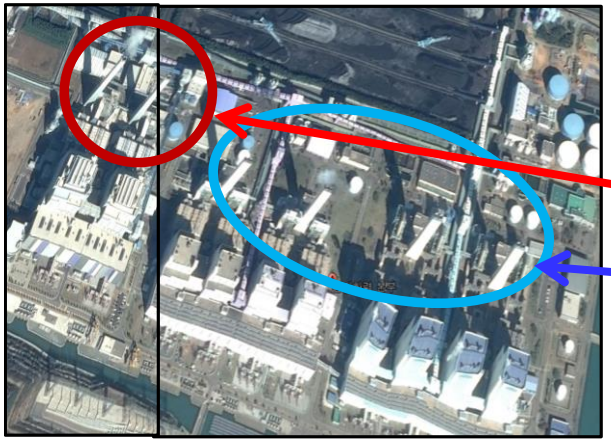
Understanding LPSs Emissions



SO2_GTCIMS (unit : ppbv)

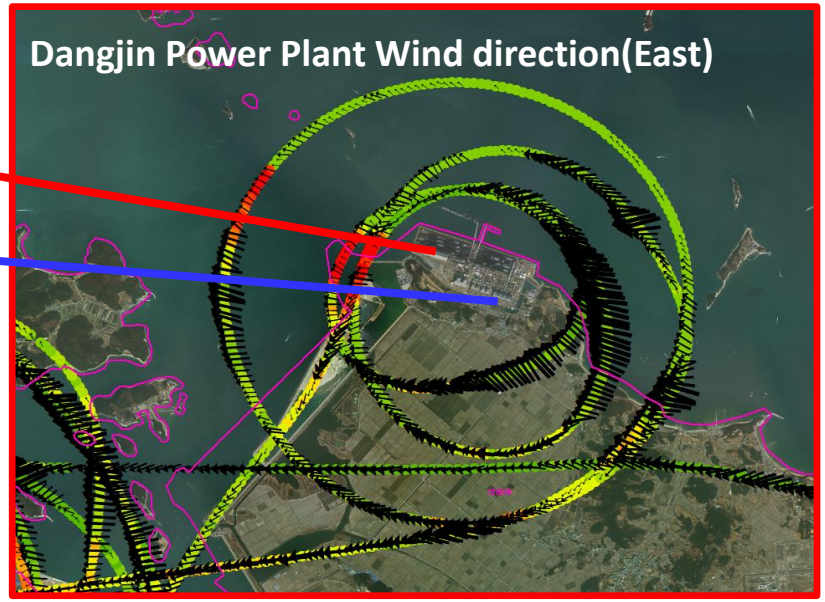
- 0.0 – 0.438
- 0.438 – 1.244
- 1.244 – 2.258
- 2.258 – 3.876
- 3.876 – 6.469
- 6.469 – 9.717
- 9.717 – 18.488
- 18.488 – 34.219
- 34.219 – 69.026
- 69.026 – 112.343





CAPSS 2013 : 4 Large Point Source Stacks

Updated CAPSS : 4 stacks plus 2 New Stacks



Ratio ($\frac{\text{Model}}{\text{Measurement}}$)	CAPSS 2013	Updated CAPSS
SO_2	0.37	0.71

Emission Inventories for 2019 LTP

<Overall Database>

- **CREATE**(Comprehensive Regional Emissions inventory for Atmospheric Transport Experiment) inventory provide the DB structure

<China>

- **CRAES** (Chinese Research Academy of Environmental Sciences) provided year 2017 (19provinces and 26+2 cities)
- **MEIC** (Multi-resolution Emission Inventory model) used for the rest of provinces in China

<Rest of Asia>

- **CREATE** inventory was used

<International Shipping>

- **Liu et al.,** inventory is being used

<South Korea>

- **CAPSS (**Clean Air Policy Support System) used for year 2015

<Japan>

- **ACAP** (Asia Center for Air Pollution Research) provided year 2015 EI

<Volcano>

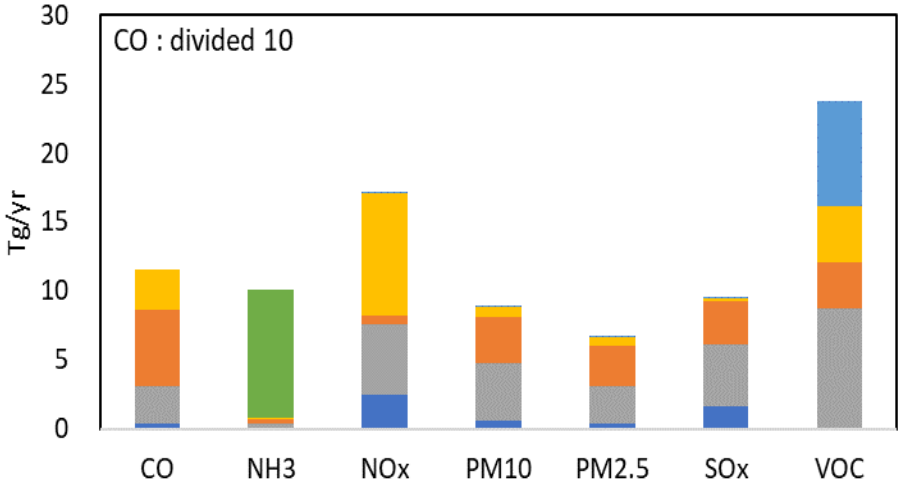
- **ACAP** inventory will be used

<Mosaic Emission Inventories and Modeling>

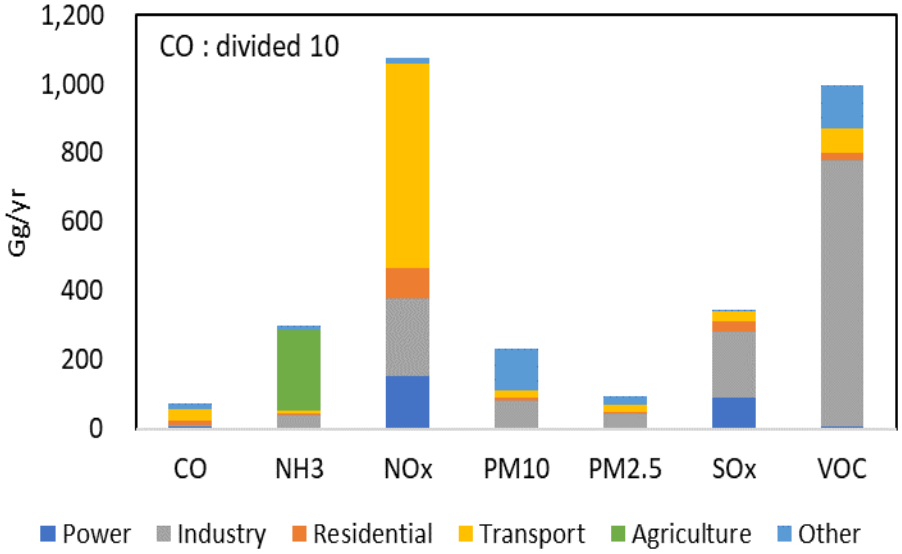
- **Inventory Mosaic : National, Rest of Asia, Shipping, Volcano**
- **Emissions Modeling : SMOKE-Asia**

Summary of LTP Emissions Inventory

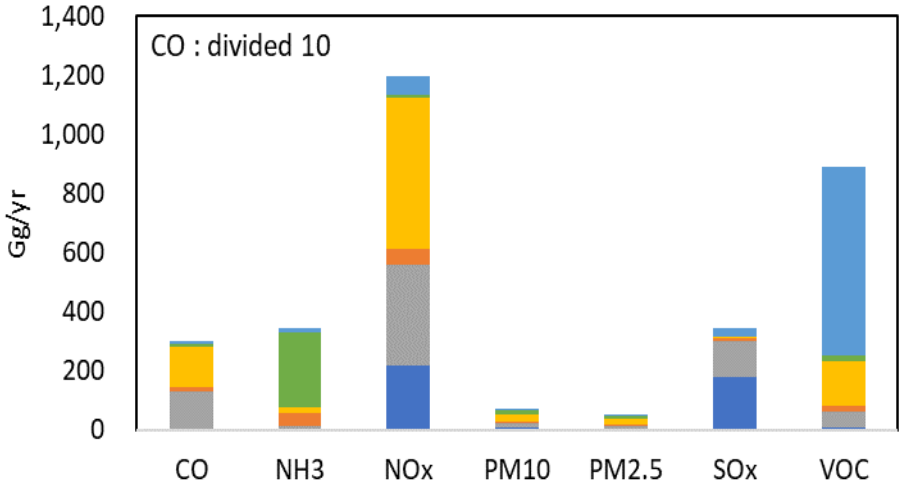
China



Korea



Japan



Integrated Assessment of Air Quality

Socio-economy Energy-Emissions

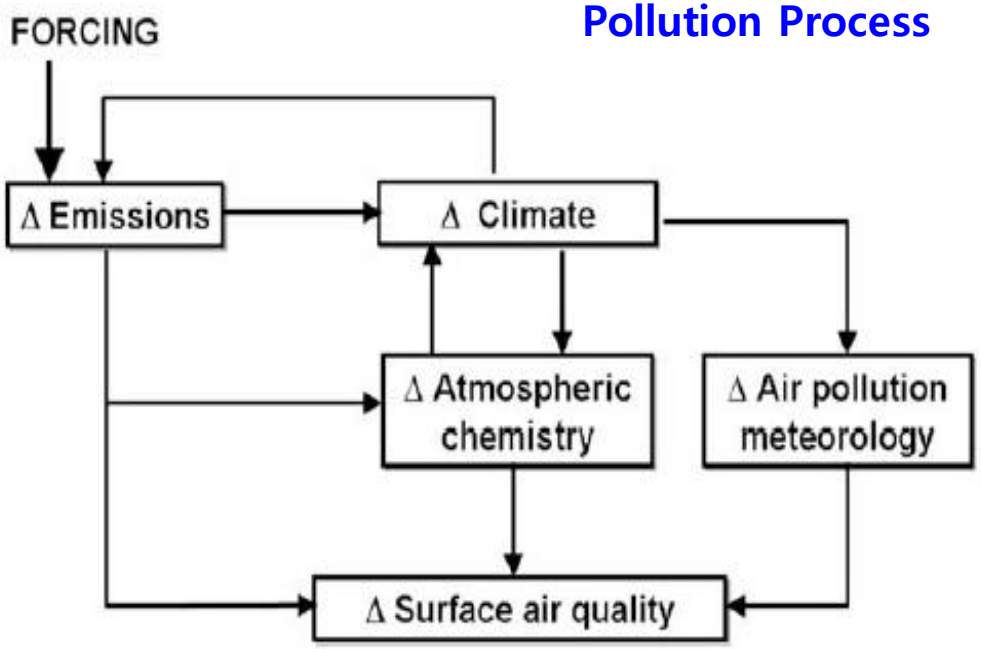
ΔPopulation
ΔGDP
ΔPolicy
ΔEnergy
Δnon-Fuel Activity
ΔFuel Activity
Δcombustion Equipment
Δcontrol Technology

Emissions Inventory

$$Em_A = (EF_A)(Act)\ [(1-(CE)(RP)(RE)]$$

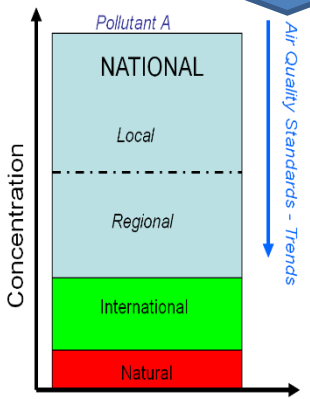
Em_A = Controlled point/area source emissions of pollutant A
EF_A = Uncontrolled emission factor for pollutant A
Act = Category activity
CE = % Control efficiency/100
RE = % Rule effectiveness
RP = % Rule penetration/100

Pollution Process

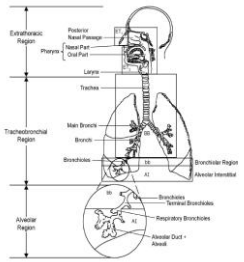


Jacob et al.,(2007)

Pollution Level

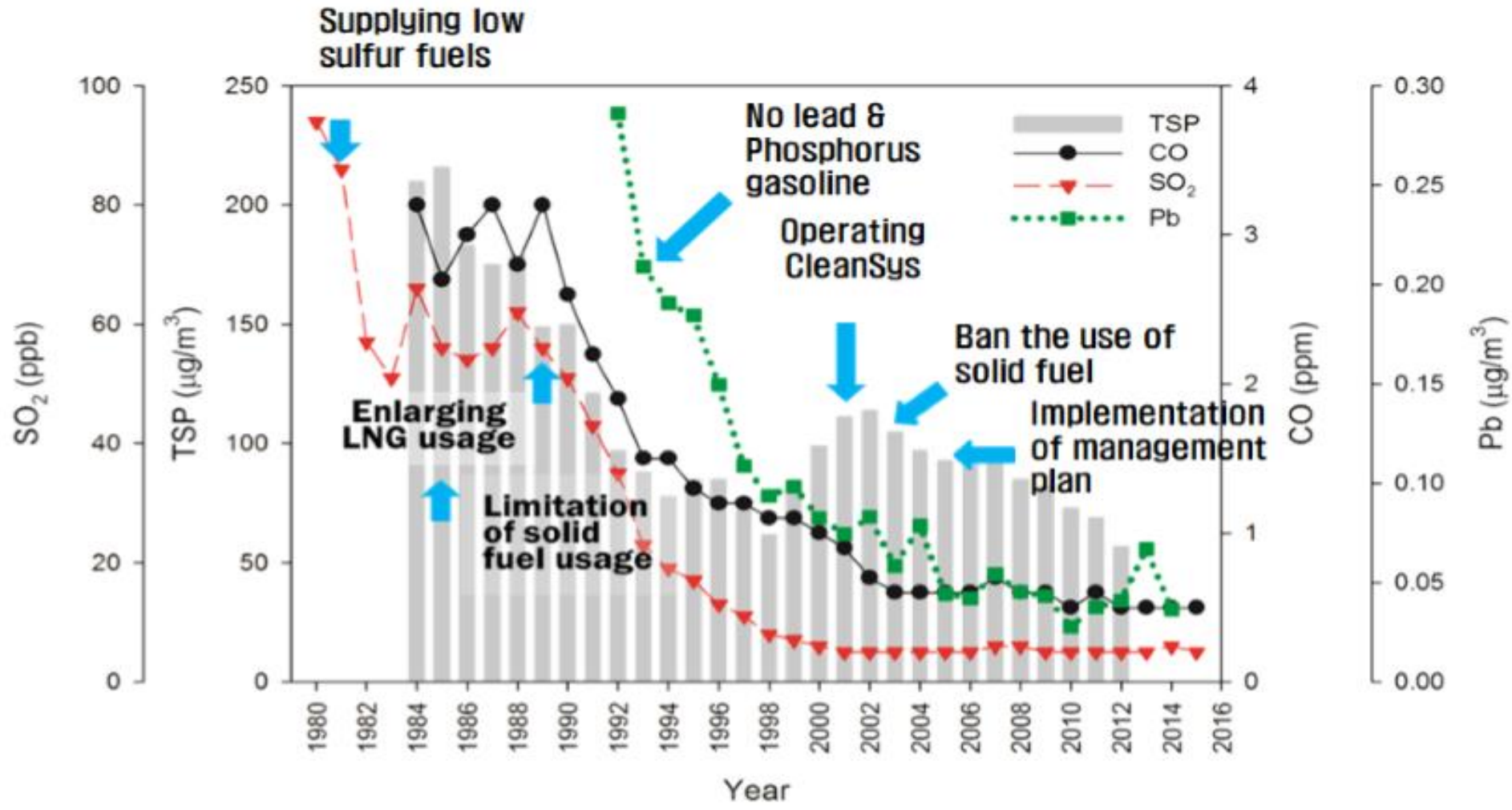


Health Impact



Health Impact = Concentration x Intake

Air Quality Policy and Concentration Changes in Korea

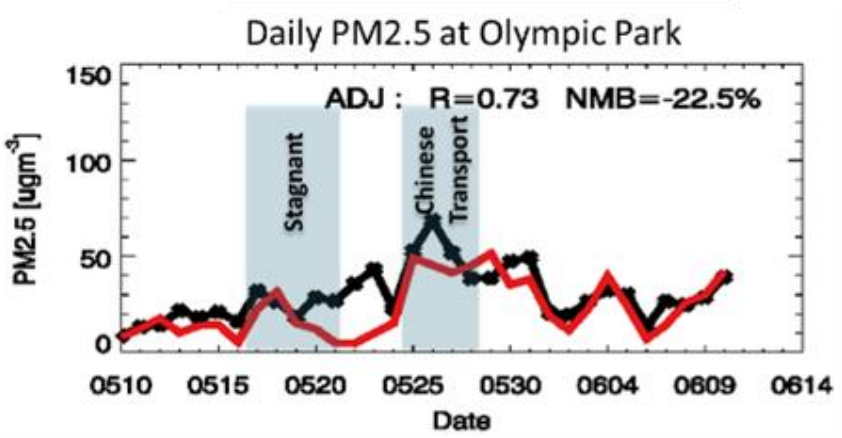


Moon et al, 2018

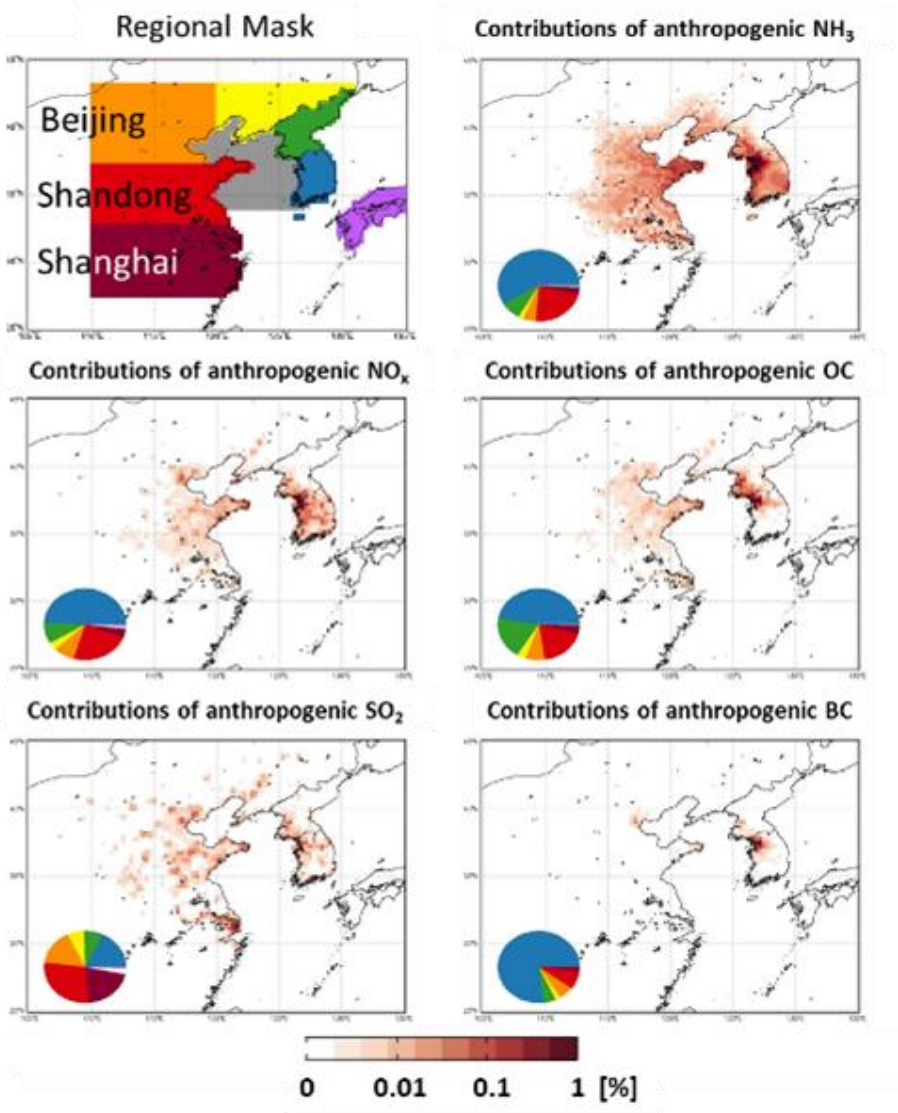
Primary and Secondary PM Contribution

During the KORUS-AQ

05/10 – 06/10 (not counting 05/20-05/23)



Regional Contributions	
South Korea	52
North Korea	9
Beijing Region	7
Shandong Region	22
Shanghai Region	5
Liaoning, Japan, Yellow Sea, etc	5

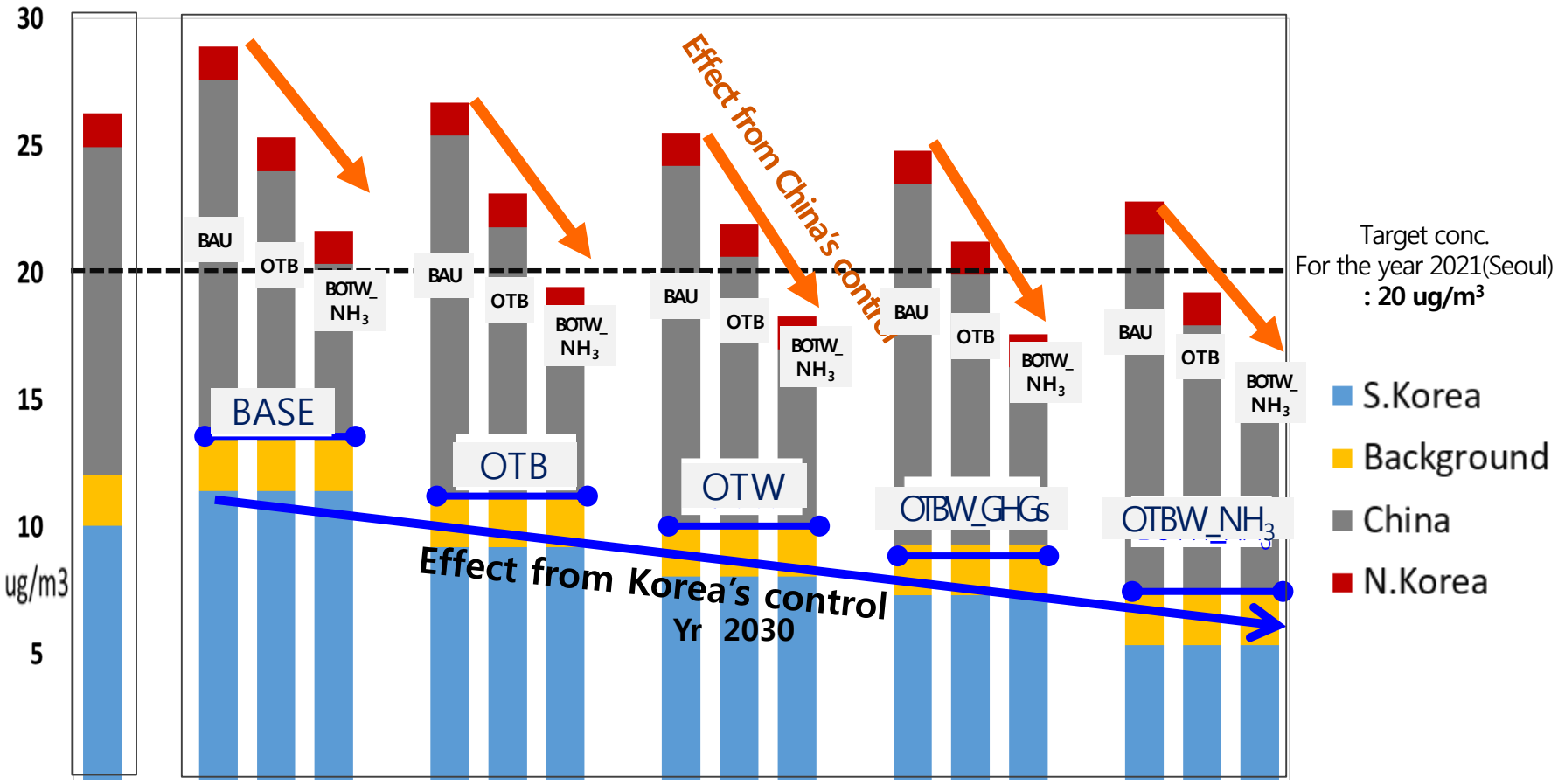


Choi, Park, Woo et al., 2019

Assessment of Transboundary Benefits

$PM_{2.5}$ concentration (year 2030, Korea)

➢ **Assessment of Control Policy Impacts by Korea-China linked scenario**

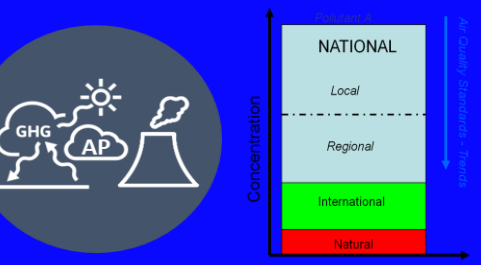


- **3.6~7.2ug/m³ of additional PM2.5 concentration improvement can be achieved from China's reduction**

New IAM in Korea

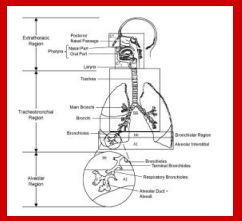
GHGs and Air pollutants Unified Information Design System for Environment(GUIDE)

Socio-economic & Energy Model



Emission Inventory & Air Quality Model

Cost-Benefit Analysis



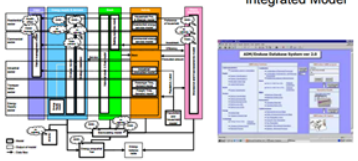
Health Impact

*GUIDE : GHGs and air pollutants Unified Information Design system for Environment

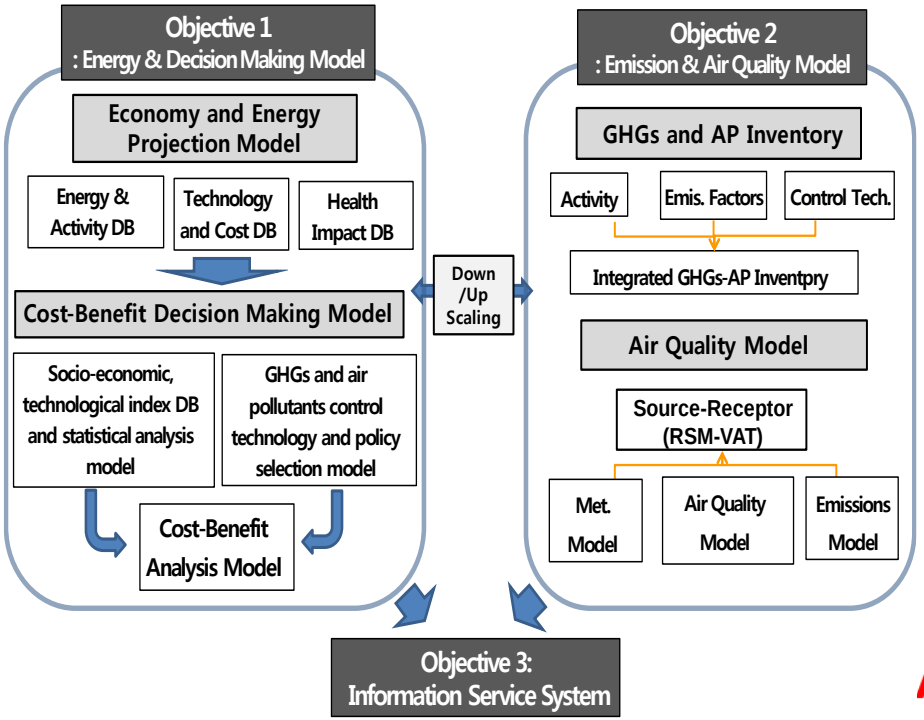
Benchmark Models for the GUIDE System

MESSAGE(IIASA)

Asia-Pacific AIM Integrated Model

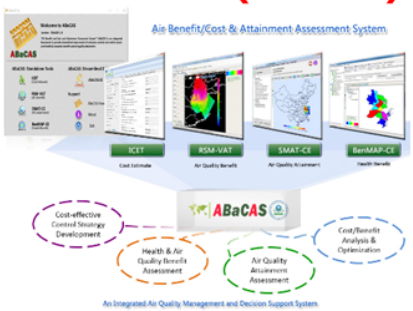


AIM(NIES)

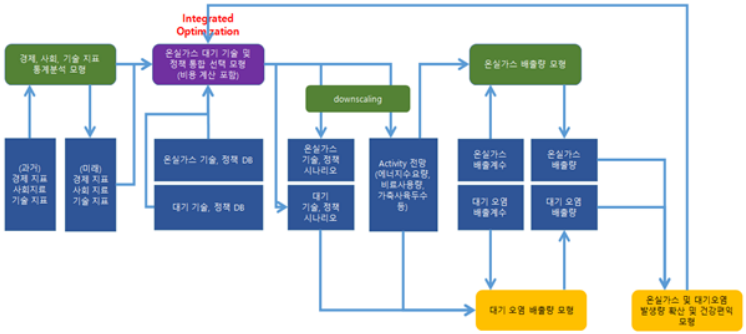


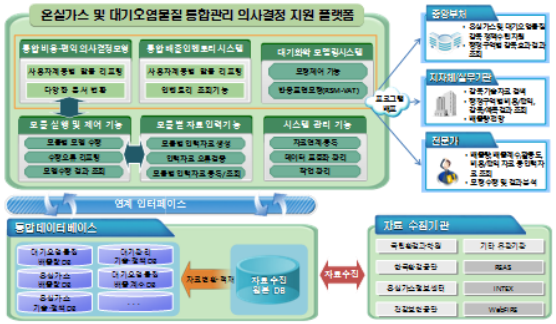
GUIDE

GAINS(IIASA)



AbaCAS(EPA-China)





GUIDE Model Software

Summary

- Long-term air quality in Korea has been improved but fine particle pollution is one of the remaining issues
- Understand air pollution in Korea and Northeast Asia includes many challenging issues such as climate change, transboundary transport, aging effects
- Needs for integrated management as a regional community is increasing. Not only international but inter-disciplinary collaboration as a community is essential
- Common understanding of baseline emissions provides very important ground toward cooperative solution on regional air quality of Northeast Asia
- Many recent activities with emission groups would provide good basis on this collaboration

Thank you!

감사합니다!

GUIDE - 통합관리 의사결정 지원 시스템 시나리오 모드

시나리오
· 실행모드 선택
· 시나리오 설정

정책 및 기술
· 정책 설정
· 기술 설정

에너지 전망
· 전망변수 설정
· 에너지전망 결과

통합 인벤토리

대기모델
· 통제요소 설정
· 대기모델 결과

건강피해
· 건강피해 설정
· 건강피해 결과

저감비용
· 저감비용 설정
· 저감비용 결과

의사결정

GHGs and air pollutants Unified Information Design system for Environment

에너지전망 옵션 데이터 불러오기... 에너지전망 결과 저장...

1. 에너지전망 옵션 설정

▶ 에너지전망 모형의 옵션을 설정합니다.

인구, 유가, GDP에 대한 설정이 가능합니다.

■ 인구

년도	인구수(단위: 만명)
2015	5000
2016	4900
2017	4800
2018	4700
2019	4600
2020	4500
2021	4500
2022	4500
2023	4500

■ 유가

년도	유가(단위: $/bbl)
2015	5
2016	6
2017	7
2018	6
2019	6
2020	6
2021	5
2022	4
2023	3

■ GDP

년도	성장률(단위: %)
2015	8
2016	6
2017	5
2018	1
2019	1
2020	0
2021	0
2022	0
2023	0

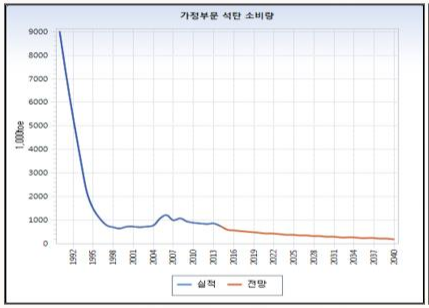
2. 에너지전망 결과

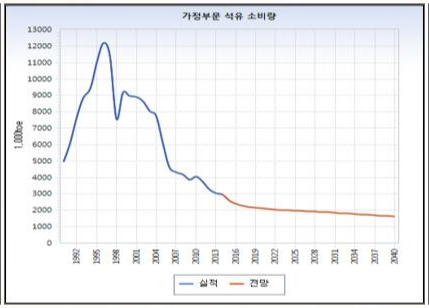
▶ 분야별 에너지전망 모형 결과를 보실 수 있습니다.

산출된 에너지전망 결과에 따라 온실가스 배출량이 산정됩니다.

▶ 아래의 콤보상자에서 원하시는 부문을 선택하신 후 [적용]버튼을 눌러주십시요.

■ 부문 선택 가정 적용





KEITI

GUIDE - 통합관리 의사결정 지원 시스템

시나리오 모드

X

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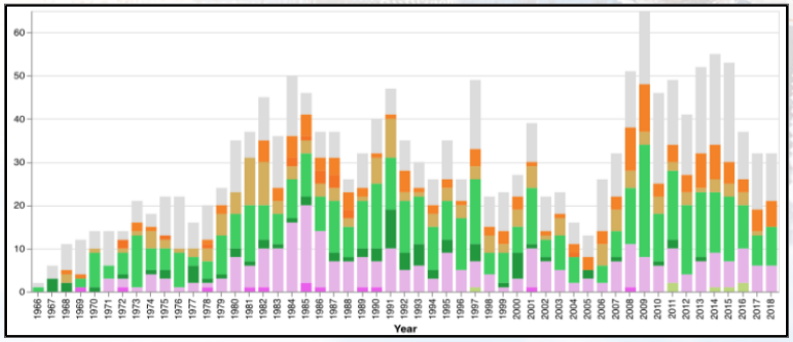
GHGs and air pollutants Unified Information Design system for Environment

불러오기... 내보내기... 삭제하기 수정사항 적용...

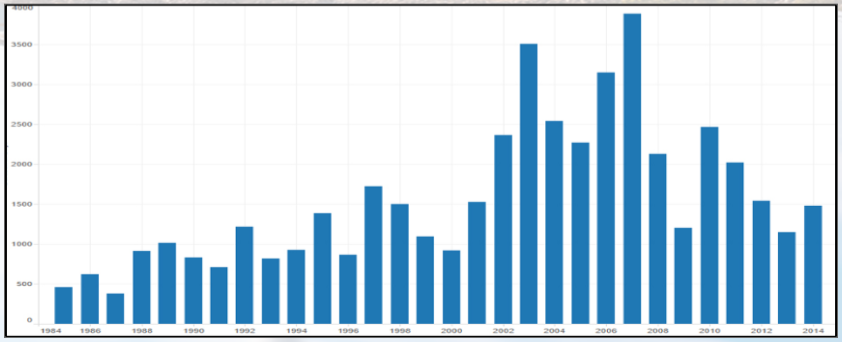
기준년도 2015 지역 선택 물질명 선택 분야 선택 연료 선택 기술 선택 검색 하기

Pollutant	Region	Sector	Fuel	Measure	Unit	Activity	actor_unabtc	rem_ef	factor_abtd	nversion_fact	factor_impl	perc	emiss	factor_RE	factor_GF	factor_CF	factor
CH4	BANG_DH...	DOM_STO...	HC2	NOC	[PJ]	0.01319	0.03	0	0.03	1.49	44.7	100	0.0004	1	0	0	
CH4	BANG_DH...	IN_BO_OTH	OS1	NOC	[PJ]	19.42749	0.011	0	0.011	2.86	31.46	100	0.2137	1	0	0	
CH4	BANG_DH...	IN_OC	GAS	NOC	[PJ]	74.57692	0.0471	0	0.0471	3.17	149.307	100	3.51257	1	0	0	
CH4	BANG_DH...	IN_OC	GSL	NOC	[PJ]	0.43531	0.003	0	0.003	3.17	9.51	100	0.00131	1	0	0	
CH4	BANG_DH...	IN_OC	HF	NOC	[PJ]	3.2486	0.003	0	0.003	3.17	9.51	100	0.00975	1	0	0	
CH4	BANG_DH...	IN_OC	MD	NOC	[PJ]	0.2209	0.003	0	0.003	3.17	9.51	100	0.00066	1	0	0	
CH4	BANG_DH...	IND_FOOD...	NOF	NOC	[kt COD (...	6.71705	0.125	0	0.125			100	0.83963	1	0	0	
CH4	BANG_DH...	IND_OCH_...	NOF	NOC	[kt COD (...	3.51	0.125	0	0.125			100	0.43875	1	0	0	
CH4	BANG_DH...	IND_PAP_...	NOF	NOC	[kt COD (...	1.56786	0.125	0	0.125			100	0.19598	1	0	0	
CH4	BANG_DH...	INW_FOOD	10YR_BP	NOC	[Mt waste]	0.05312	18	0	18			100	0.9562	1	0	0	
CH4	BANG_DH...	INW_OTH	20YR_BP	NOC	[Mt waste]	0.59813	0	0	0			100	0	1	0	0	
CH4	BANG_DH...	INW_PAP	20YR_BP	NOC	[Mt waste]	0.00415	4.8	0	4.8			100	0.01992	1	0	0	
CH4	BANG_DH...	INW_RUB	20YR_BP	NOC	[Mt waste]	7e-005	0	0	0			100	0	1	0	0	
CH4	BANG_DH...	INW_TEX	20YR_BP	NOC	[Mt waste]	0.01145	28.8	0	28.8			100	0.32967	1	0	0	
CH4	BANG_DH...	INW_WOOD	20YR_BP	NOC	[Mt waste]	0.00131	51.6	0	51.6			100	0.06744	1	0	0	
CH4	BANG_DH...	MSW_FOOD	10YR_BP	NOC	[Mt waste]	0.69183	18	0	18			100	12.45302	1	0	0	
CH4	BANG_DH...	MSW_OTH	20YR_BP	NOC	[Mt waste]	0.5637	0	0	0			100	0	1	0	0	
CH4	BANG_DH...	MSW_PAP	20YR_BP	NOC	[Mt waste]	0.15728	48	0	48			100	7.54944	1	0	0	
CH4	BANG_DH...	MSW_WO...	20YR_BP	MSW_WO...	[Mt waste]	0.10996	51.6	99.96124	0.02			50	0.0011	1	0	0	
CH4	BANG_DH...	MSW_WO...	20YR_BP	NOC	[Mt waste]	0.10996	51.6	0	51.6			50	2.83689	1	0	0	
CH4	BANG_DH...	PP_ENG	GAS	NOC	[PJ]	0.0368	0.9	0	0.9			100	0.03312	1	0	0	

■ 전체 배출량 변화



■ 부문별 배출량 변화 에너지산업 적용



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GUIDE - 통합관리 의사결정 지원 시스템

시나리오 모드

시나리오
· 실행모드 선택
· 시나리오 설정

정책 및 기술
· 정책 설정
· 기술 설정

에너지 전망
· 전망변수 설정
· 에너지전망 결과

통합 인벤토리

대기모델
· 통제요소 설정
· 대기모델 결과

건강피해
· 건강피해 설정
· 건강피해 결과

저감비용
· 저감비용 설정
· 저감비용 결과

의사결정

GHGs and air pollutants Unified Information Design system for Environment

모든값을 동일하게 1.0 | 다른 이름으로 저장... | 대기모델 결과 전체보기...

1. 대기모델 설정

▶ 대기모델(RSM)의 옵션을 설정합니다.
숫자를 입력하거나 Bar 조정을 통해
변수들을 설정합니다.

POW 1.0

IND 1.0

MOB 1.0

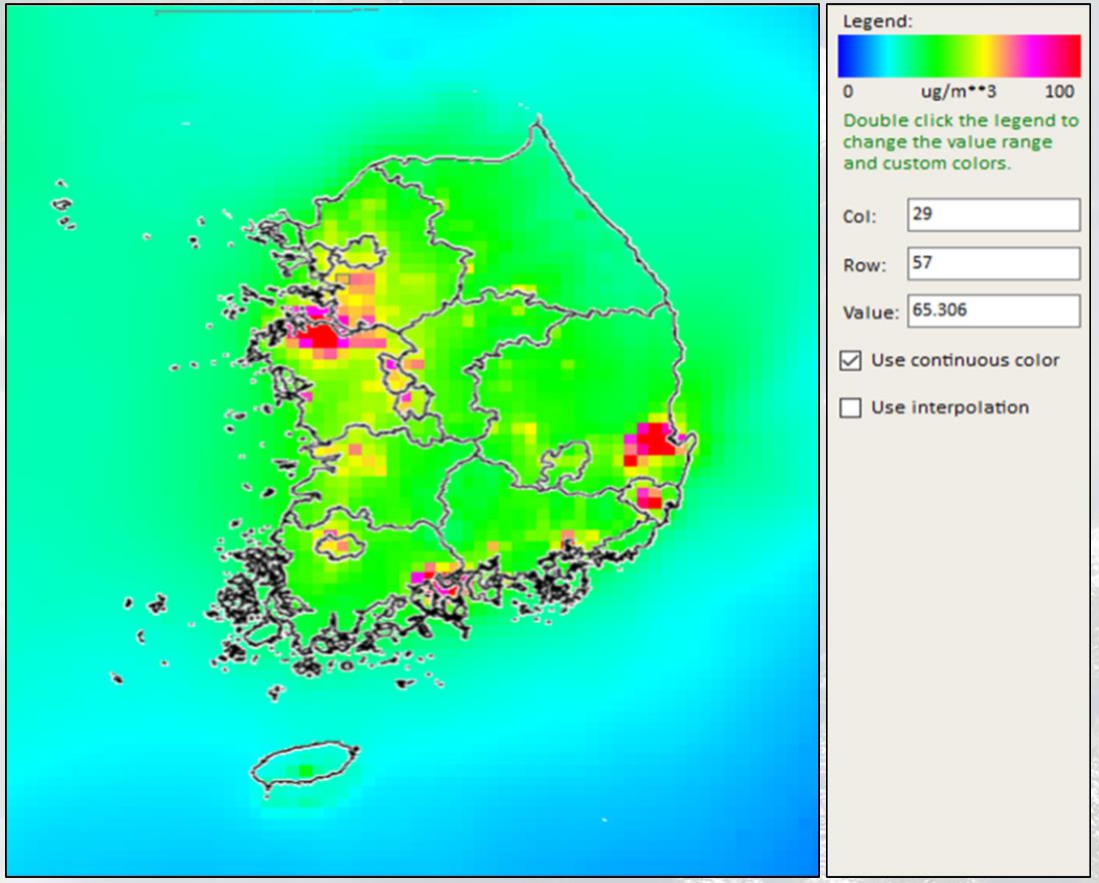
RES 1.0

AGR 1.0

SLV 1.0

OTH 1.0

2. 대기모델 결과 PM 2.5 적용



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