GEMS

SIJAQ/ASIA-AQ

Satellite Integrated Joint Monitoring for Air Quality study (SIJAQ)

Airborne and Satellite Investigation of Asian Air Quality (ASIA-AQ)

National Institute of Environmental Research

Environmental Satellite Center, SIJAQ team

GMAP & SIJAQ overview

SIJAQ : Satellite Integrated Joint monitoring (Studies) of Air Quality
Pre-SIJAQ(GMAP): GEMS Map of Air Pollution

Background

•Succession of KORUS-AQ (2016.5~6)
•In depth analysis on high PM pollution in winterValidaiton of Geostationary Environment Monitoring Spectrometer (GEMS), the world's first Geostationary Earth Orbit (GEO) environmental satellite

Time schedule for SIJAQ and GMAP

Pre-GMAP	1st GMAP	2nd GMAP	SIJAQ (Main campaign)
~~2020. 4~5~~ +	2020.10.12~11.27	2021.10~11	2022.10~2023.06 → 2022.5~8, 2024.2~3

SIJAQ background

- 2016 vs 2021

PM_{10} -21% ↘

$PM_{2.5}$ -24% ↘

NO_2 -22 % ↘

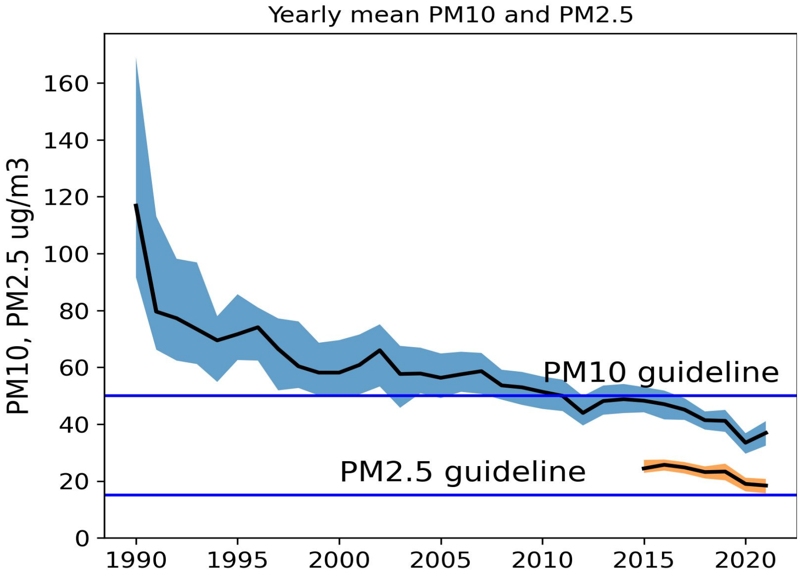
SO_2 -42% ↘

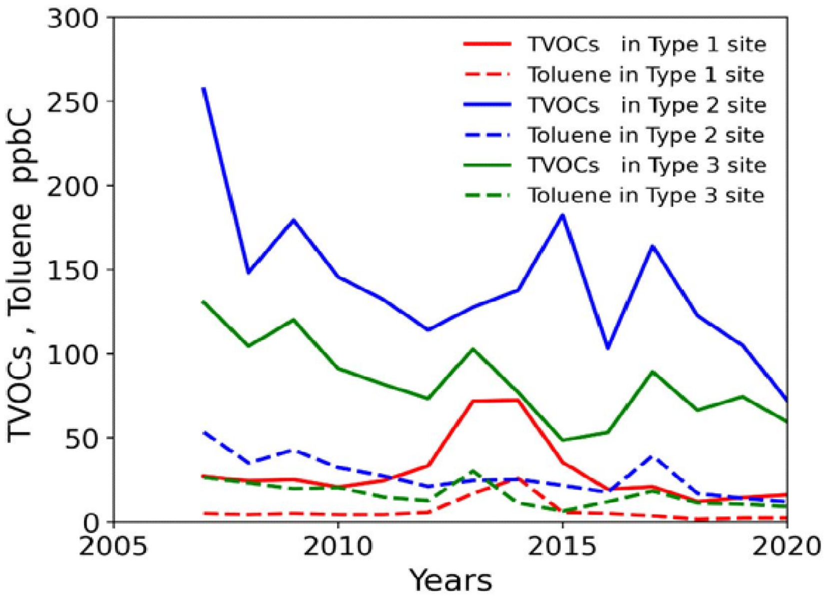
- VOCs

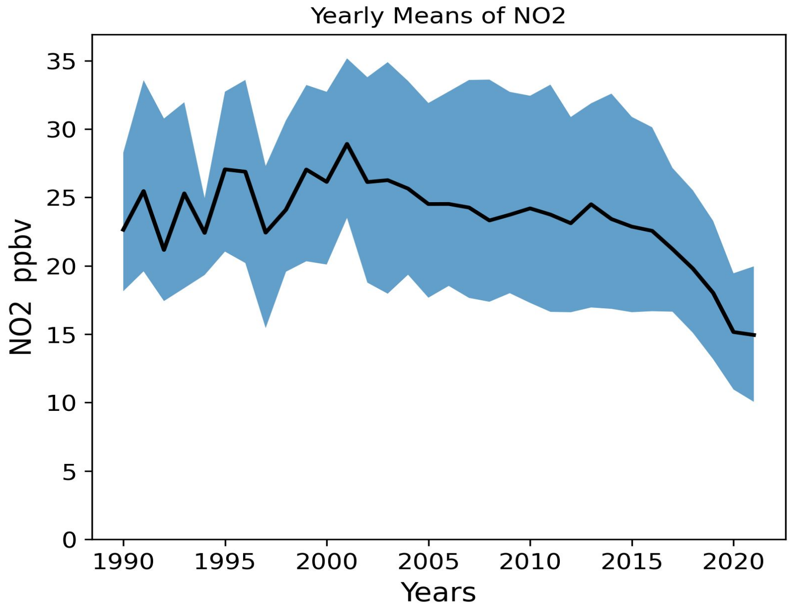
TVOCs, Toluene ↘ (PAMS type2)

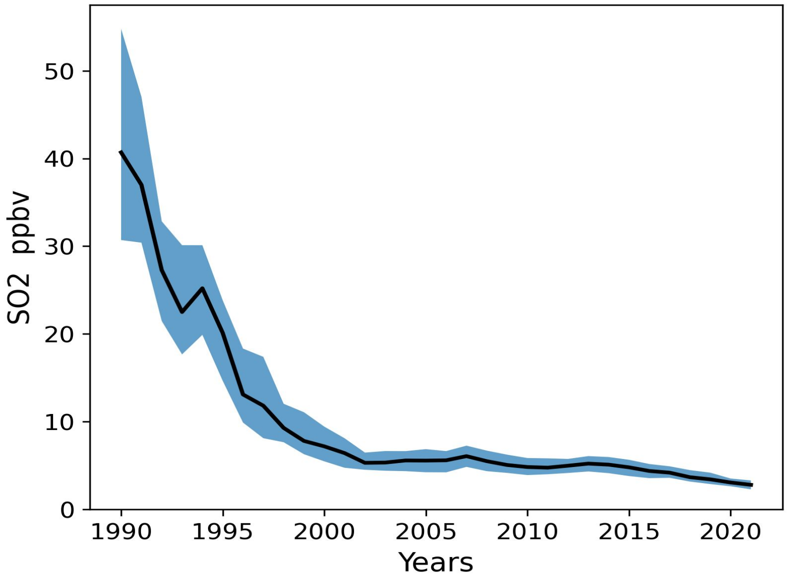
TVOCs, Toluene → (PAMS type 1 and 3)

Source: SIJAQ2022 RSSR

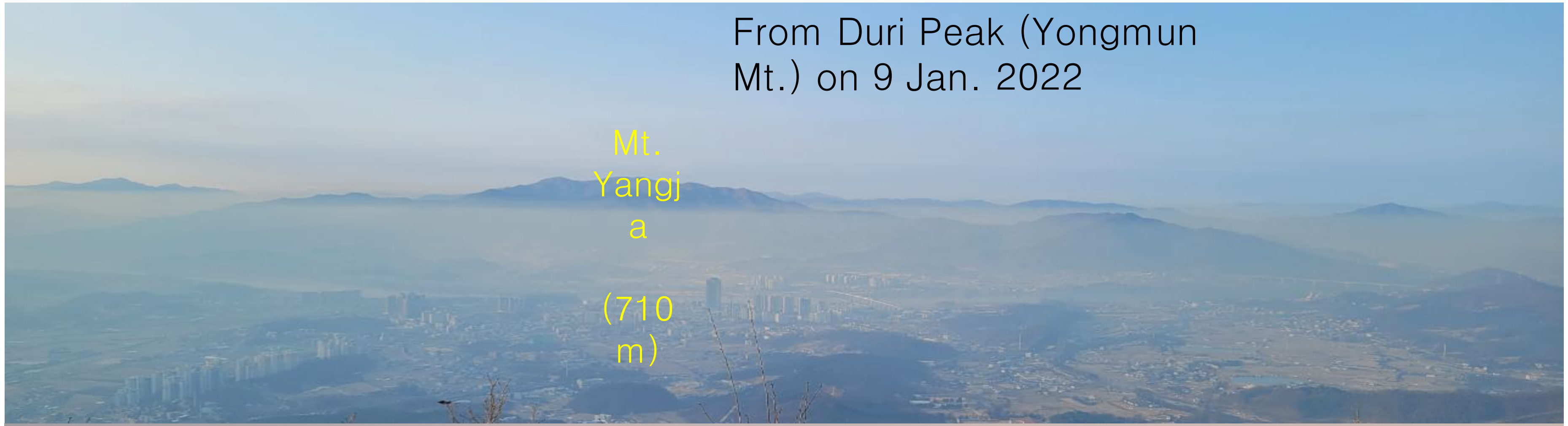


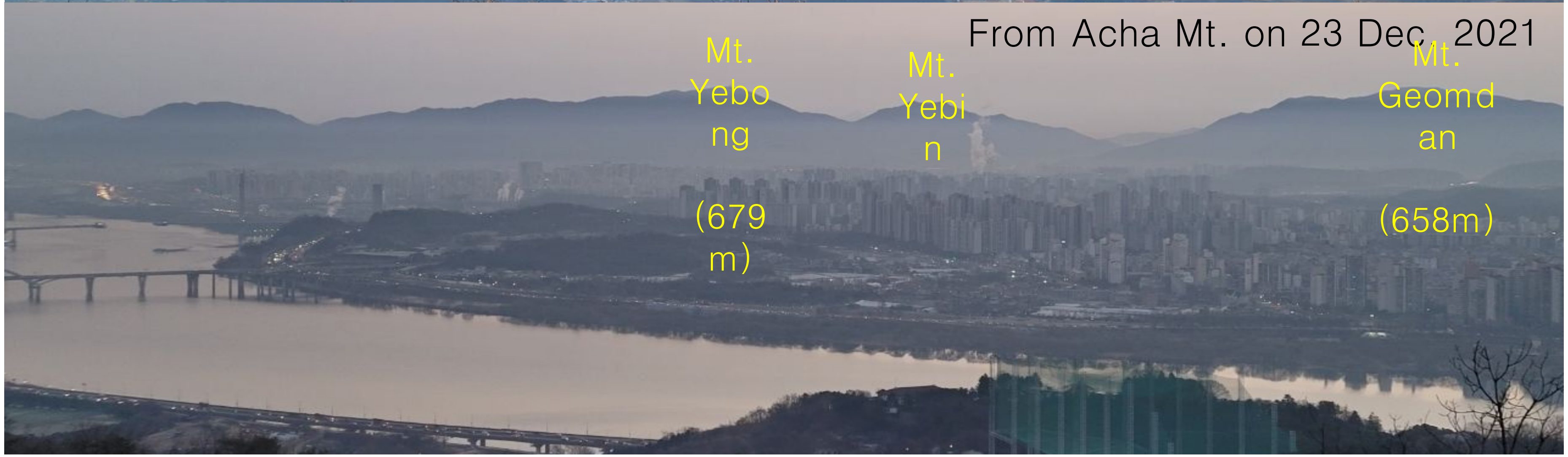






Winter smog in stable boundary layer





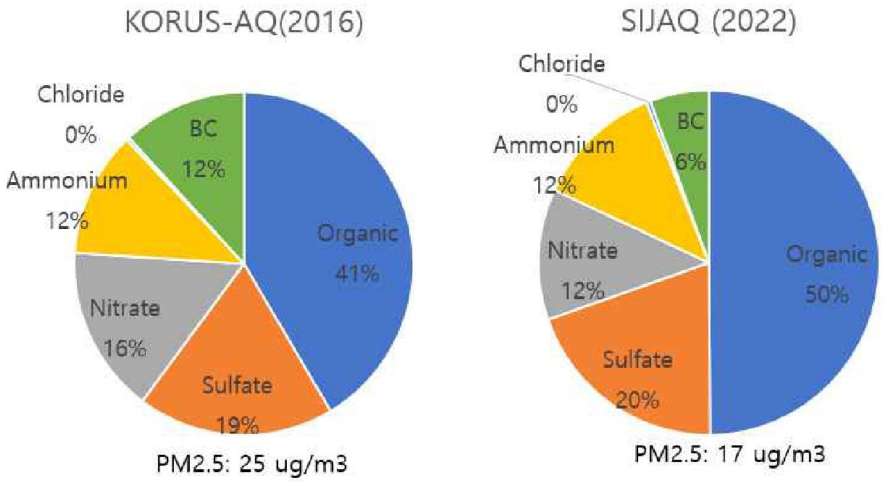
Source: Prof. Moonsoo Park(Sejong Univ.)

Spring smog in boundary layer

DoiSuthep
as an index to
measure the intensity
of PM

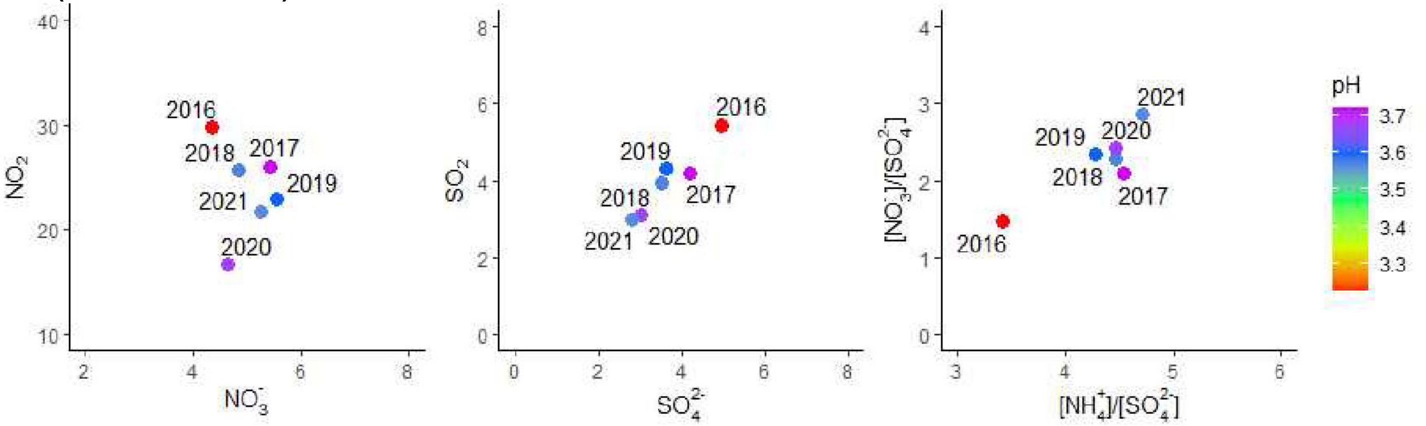
Source: AiroTEC :
Asian Air Quality
Operations Center by
Space Technology,
Geo-informatics &
Environmental
Engineering, 2023

SIJAQ background



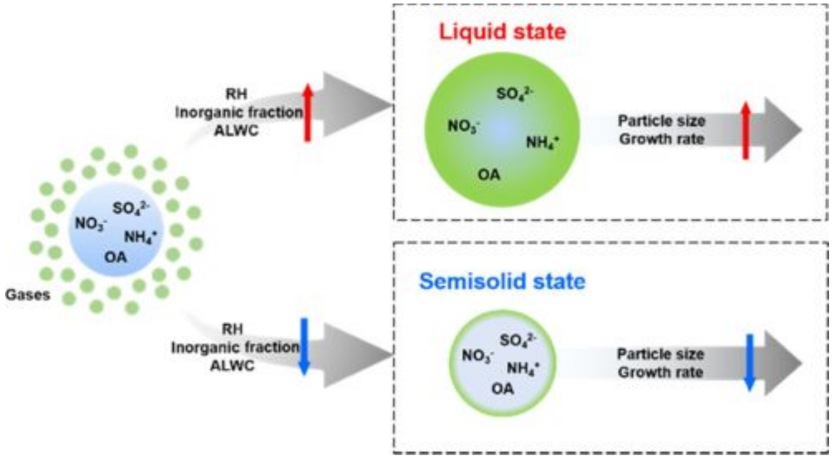
2016 vs 2022
Nitrate ↘
OC ↗

No linear relationship between NO_2 and Nitrate for last 6 years (2016~2021)



Nitrate production depends on photochemical oxidation during the day as well as heterogeneous reactions at the aerosol surface. (Lim et al., 2022).

When high PM occurs, aerosols are in a liquid state and have a larger volume mean diameter
(Song et al., 2022)
The physical state of aerosols affects the reaction with gaseous pollutants and heterogeneous reaction

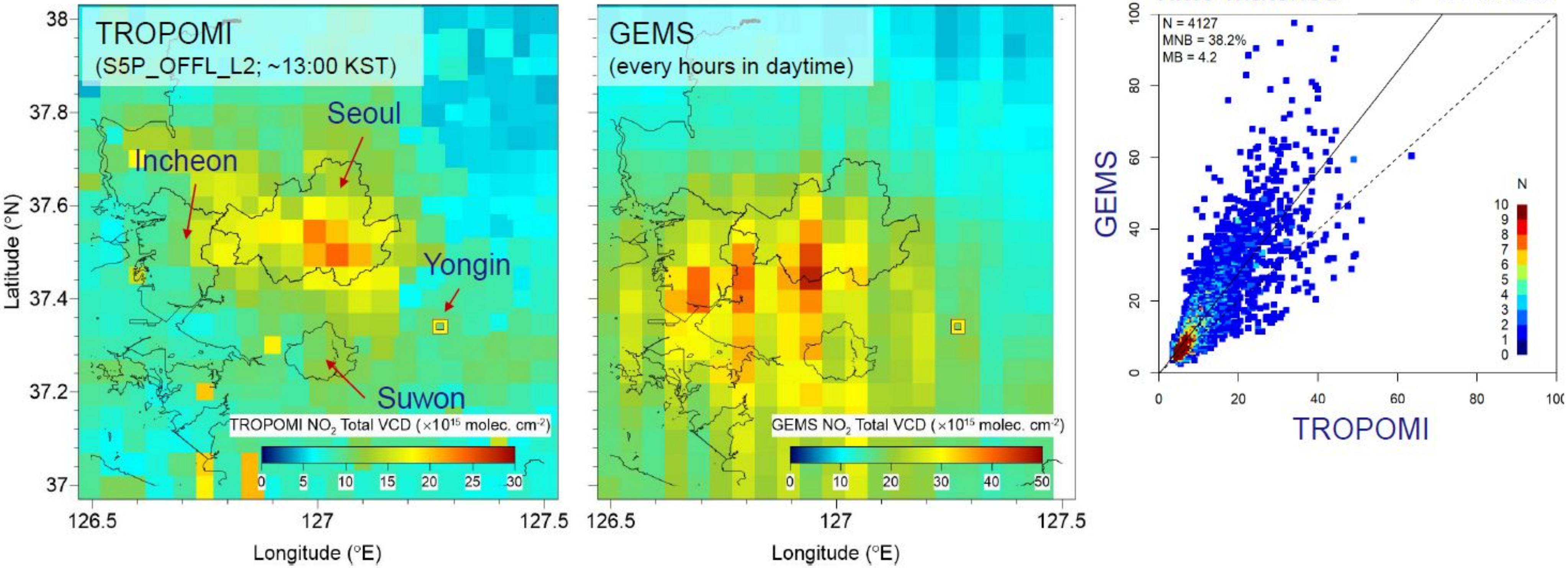


Source: SIJAQ2022 RSSR

Results

Spatial distribution of NO_2 Total VCD over SMA region

October 2021, Lon & Lat by 0.05°, CF <0.3, QAflag and SZA <85°

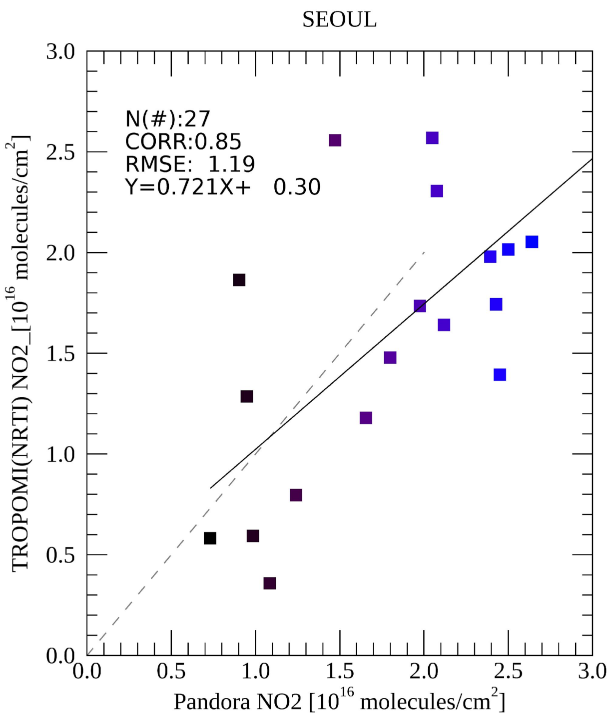


- Slightly different spatial distribution pattern of NO_2 Total VCD between TROPOMI and GEMS, due to different sampling time.
- Time-matched GEMS NO_2 Total VCD > TROPOMI NO_2 Total VCD

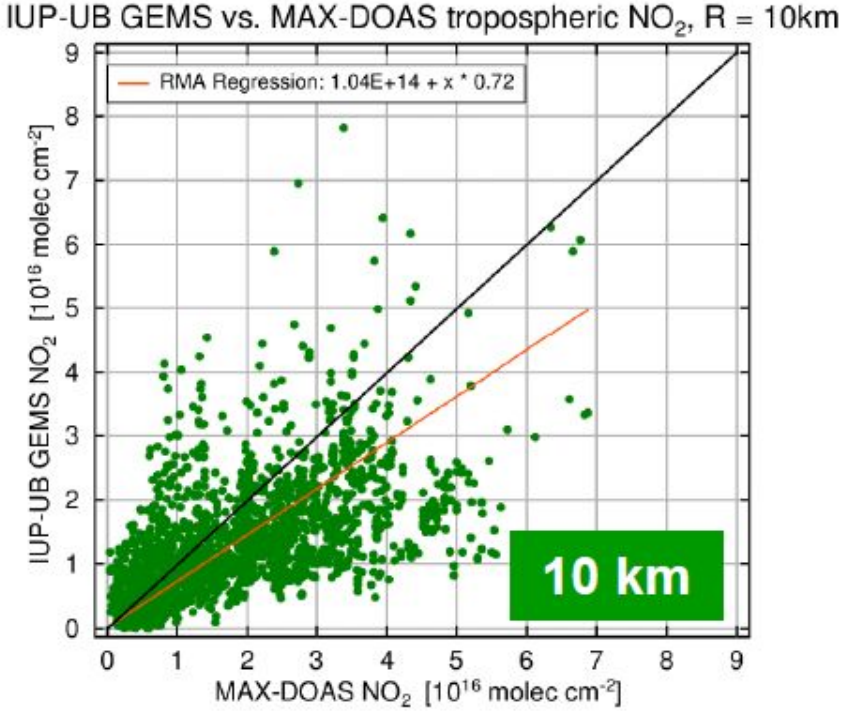
GMAP 2021

- High correlation, low bias, and high scatter (or rmse) for NO_2 VCD

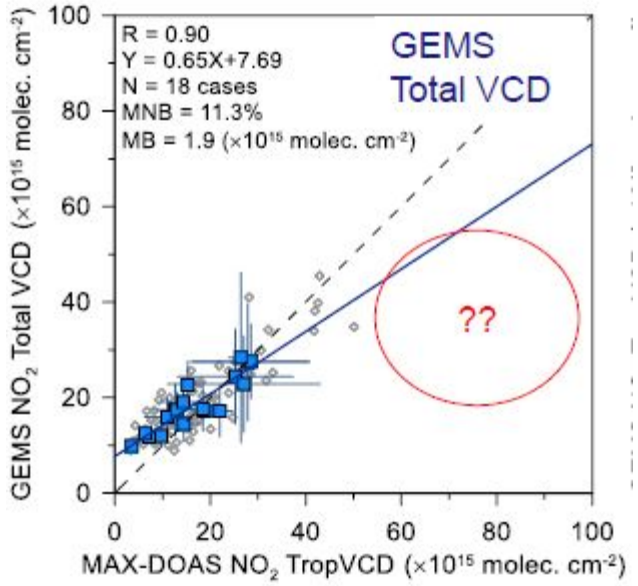
±30 mins, Lon & Lat < 5 km, CF <0.3, and SZA <85°



Source: Sangwoo Kim

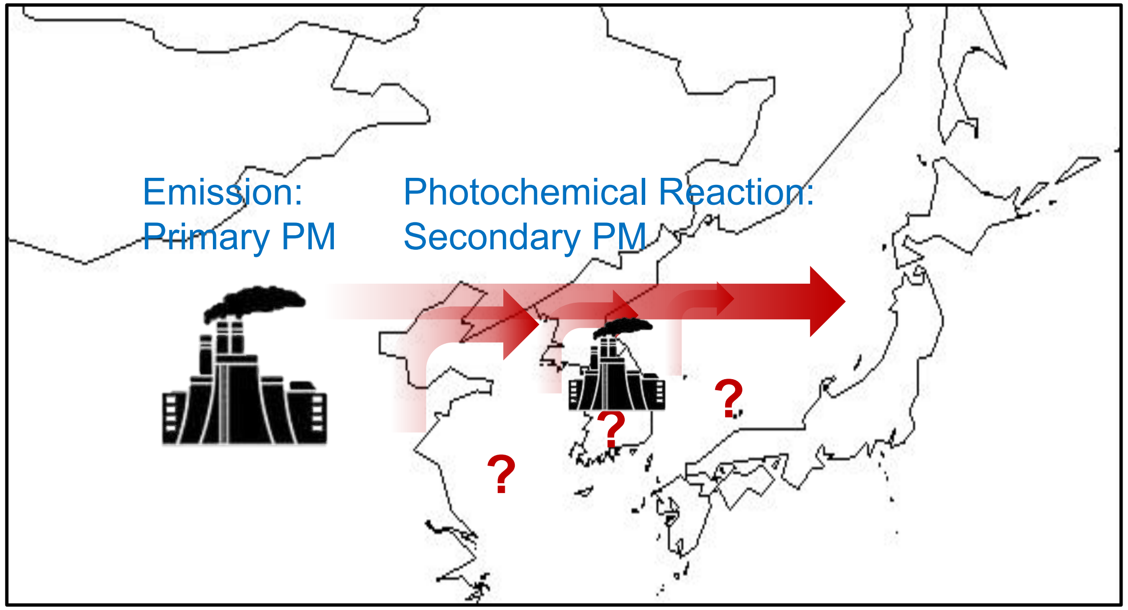


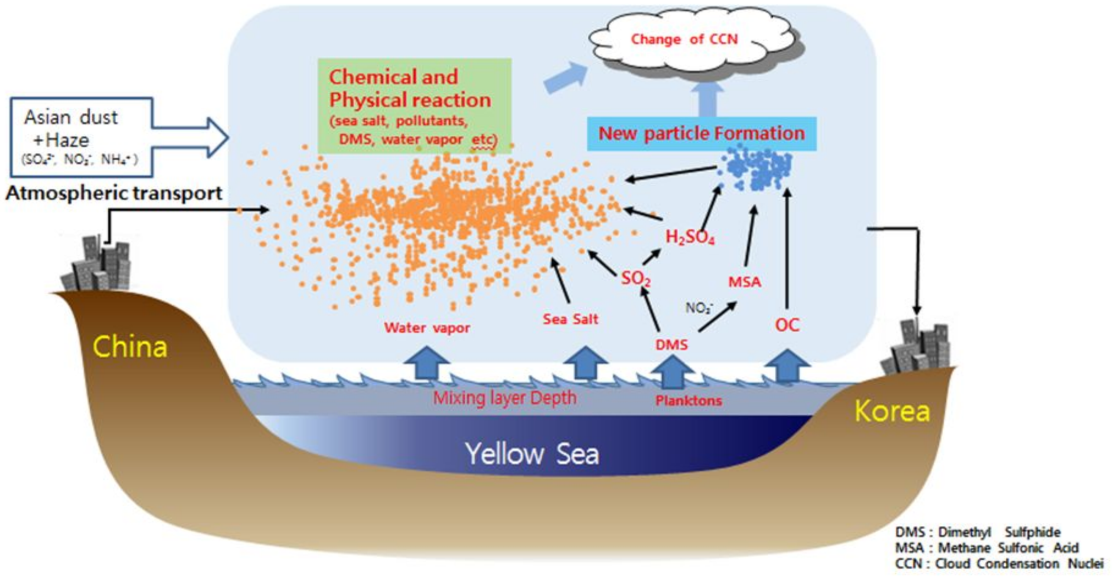
Source: Andreas Richter



Source: Yongjoo Choi

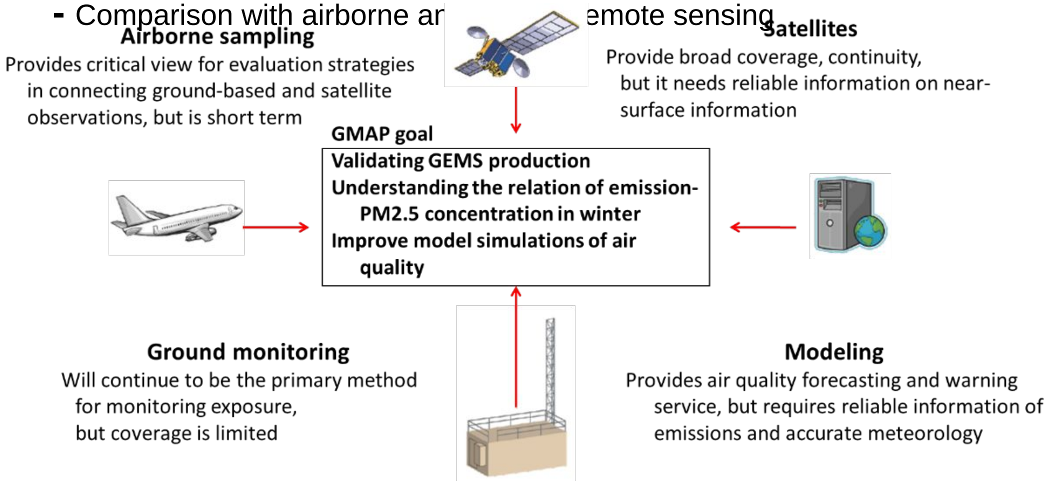
Satellite Integrated Joint Monitoring for Air Quality study (SIJAQ)





Purpose

- **Characterizing hot spots in East Asia**
  - Urban pollution, industrial complex, coal-fire power plant, biomass burning, volcanic eruption, wild fire, etc.
- **Investigating processes controlling high PM2.5 events in winter**
  - Unidentified aerosol formation mechanism (heterogeneous reaction, nighttime chemistry, meidum-range transport, etc.
- **Analyzing the impact of emission change**
  - Recent change in energy-related and agricultural emissions in East Asia
- **Validating GEMS performance beyond Korea**
  - Comparison with airborne ar emote sensing



SIJAQ/ASIA–AQ in preparation

SIJAQ/ASIA-AQ 1900D flight

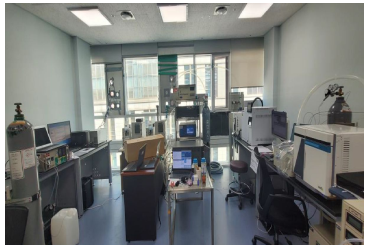
Instrument	Measuring item
HR-ToF-AMS	Organics, Nitrate, Sulfate, Ammonium, Chloride
SP2	rBC, Black carbon (50-500nm)
PCASP	Number concentration
PTR-ToF-MS	VOCs
CIMS	SO_2
LGR NH_3	NH_3
LGR CO	CO, CO_2, CH_4
Teledyne NO_2	NO_2
Teledyne O_3	O_3
TILDAS	HCHO
AIMMS-30	GPS, Temp. Hum., Pres. Widn

Instrument	Measuring item
Picarro/CRDS-2401m	CO_2, CH_4, CO, H_2O
Flask sampling	$\delta^{13}C$-CO_2, $\delta^{14}C$-CO_2, $\delta^{13}C$-CH_4

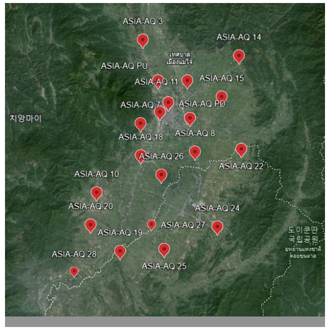
Instrument	Measuring item
Teledyne T500U	NO_2
HUFS	NO_2 (fast)
BrechtelTAP	Black carbon
Thermo43iQTL	SO_2
Thermo49iQ	O_3
LGR EAA-911	NH_3
LGR MCEA1-911	CO, CO_2, CH_4
OPC	$PM_{2.5}$
AIMMS-30	3-D wind

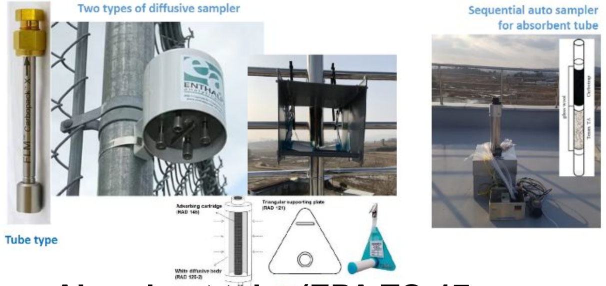
Instrument	Measuring item
EMSA	Trace gas column densities of NO2 and CH2O

SIJAQ/ASIA-AQ ground measurement

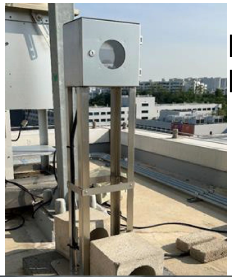


Chemical species/(Instrument)	Korea Univ.	Anmyundo	Ansan	Backryungdo
VOCs(PTR)	◎	◎	◎	
VOCs(PAMs)	◎			◎
O_3 CO SO_2	◎	◎	◎	◎
NO NOx	◎	◎	◎	◎
NOy	◎	◎	◎	◎
N_2O_5	◎	◎		
HNO_3	◎			
NH_3	◎	◎	◎	◎
Inorganic & organic composition(AMS)	◎	◎	◎	◎
Inorganic composition	◎	◎	◎	◎
Number concentration	◎	◎	◎	◎
BC	◎	◎	◎	◎
PBL height	◎			



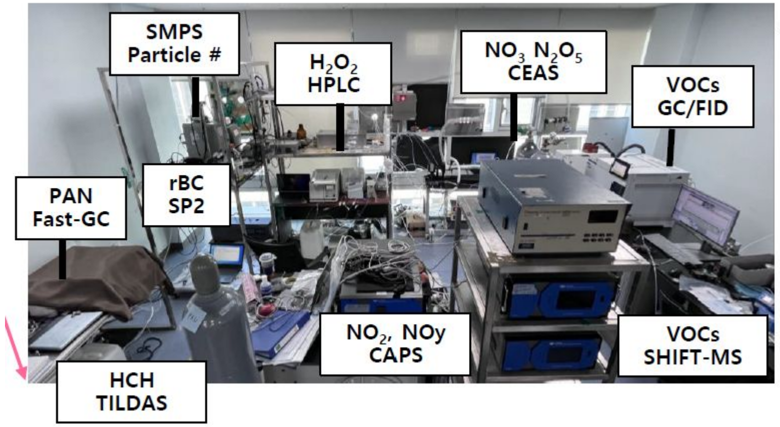


Absorbent tube (EPA TO-17 method, TenaxTA and Carbotrap (AirToxictube))

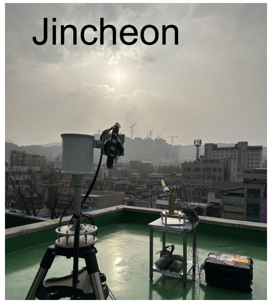


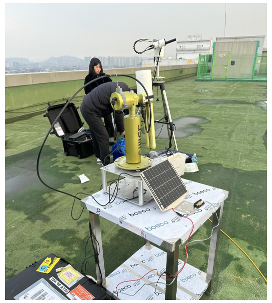
PM sensor
$PM_1 PM_{2.5} PM_4 PM_{10}$

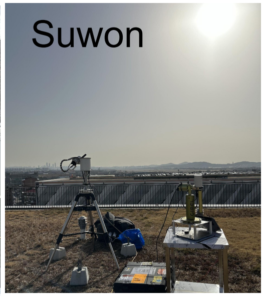
NO_3
LP−DOAS

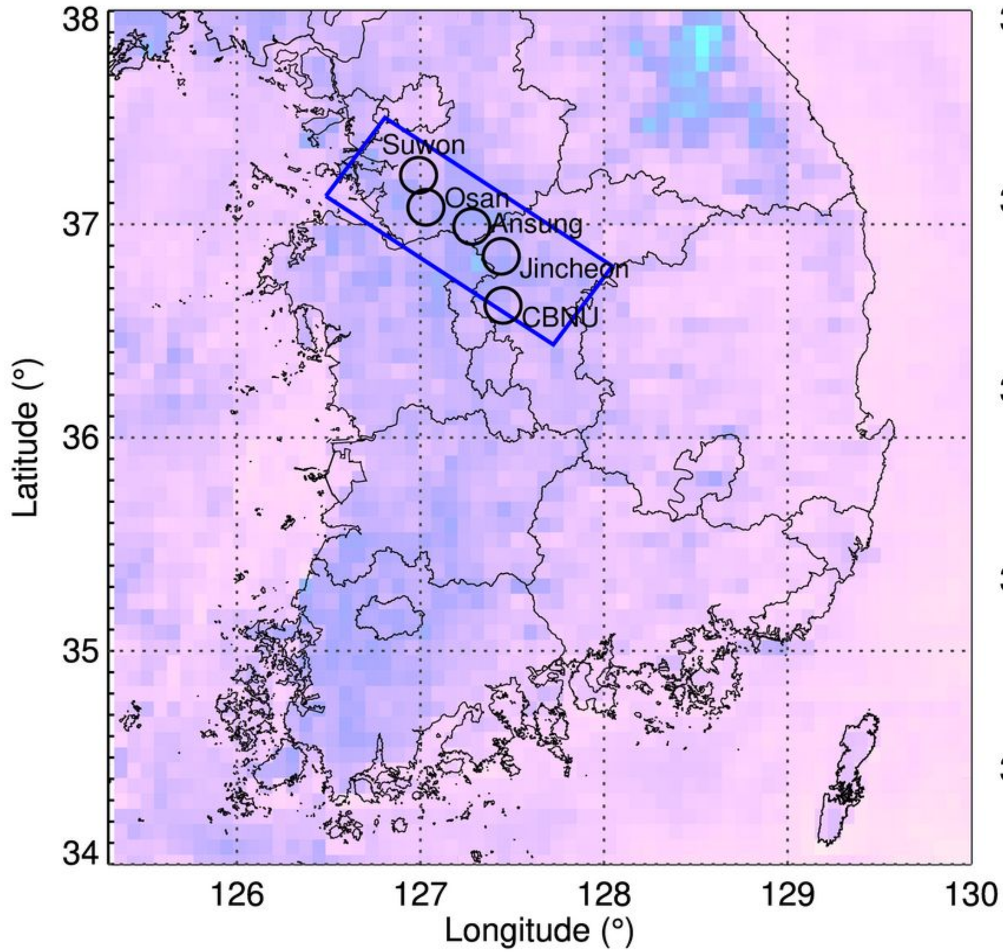


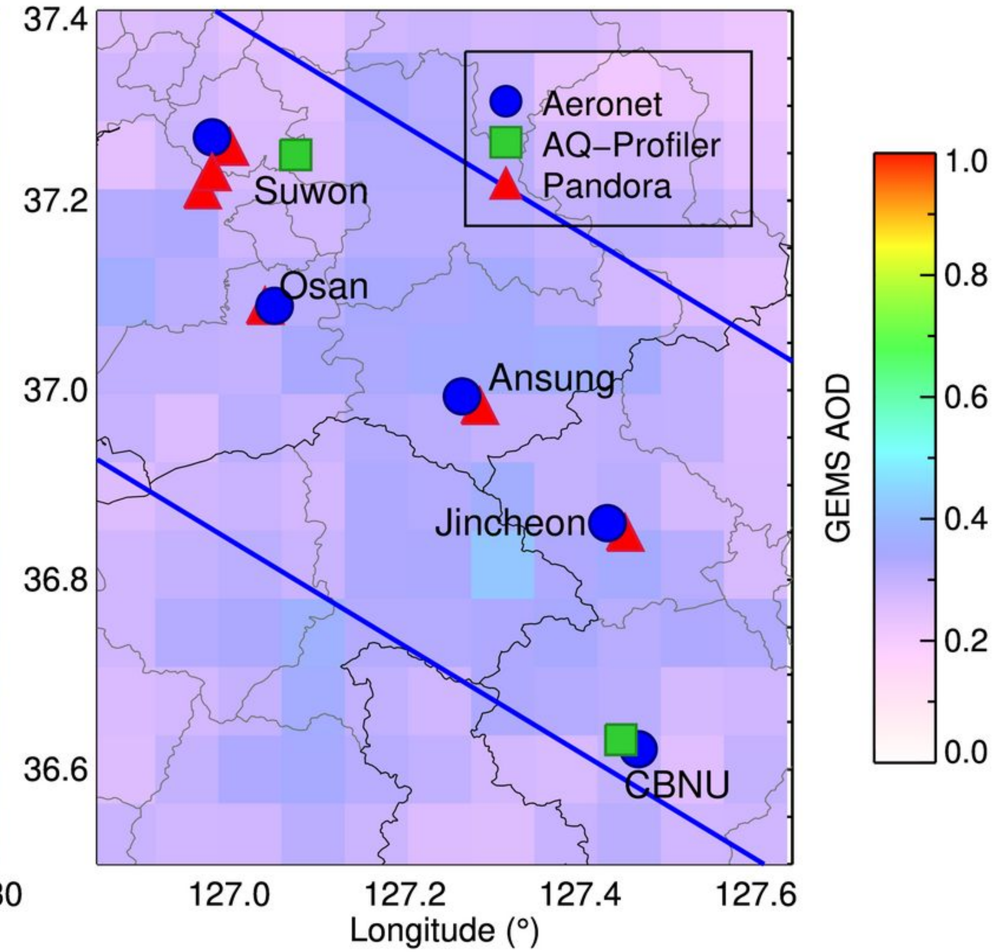
SIJAQ/ASIA-AQ ground remote sensing





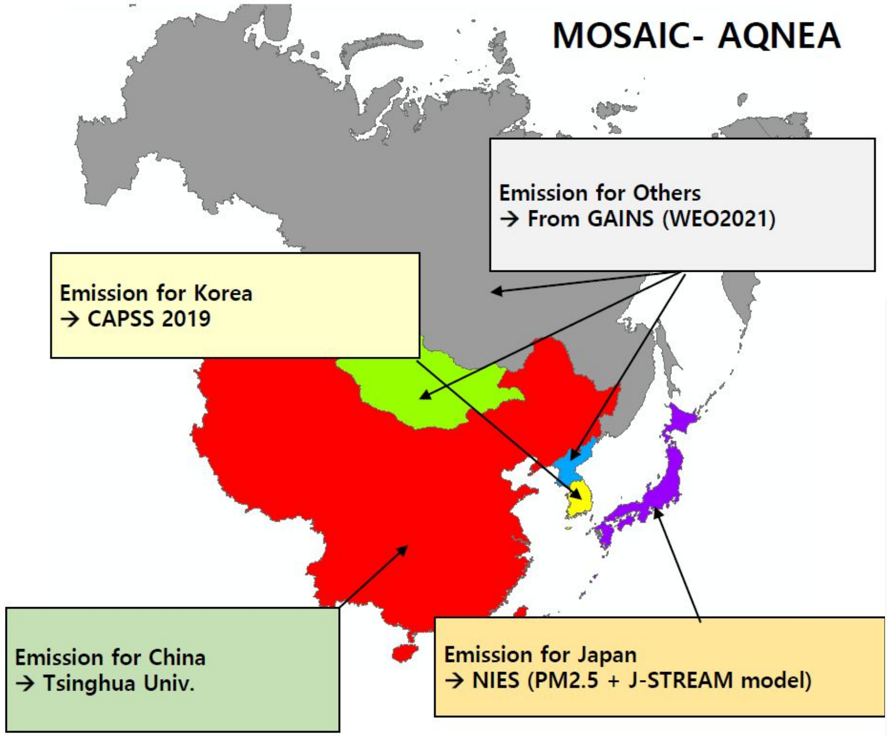






SIJAQ/ASIA-AQ emission inventory ⇒ AQNEA v3

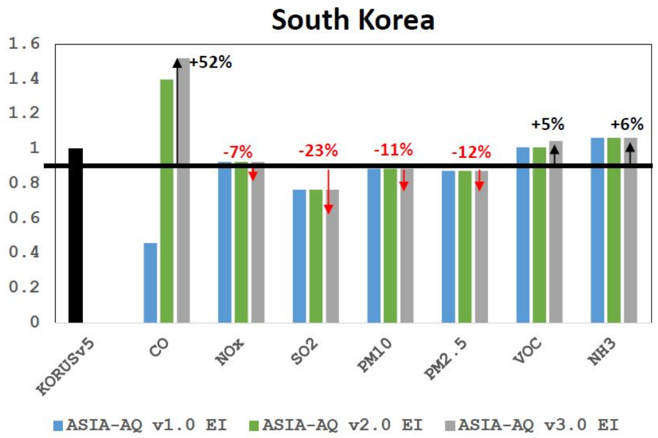
*AQNEA - Air Quality in NorthEast Asia   * ASIA-AQv1 = MOSAIC- AQNEA v1

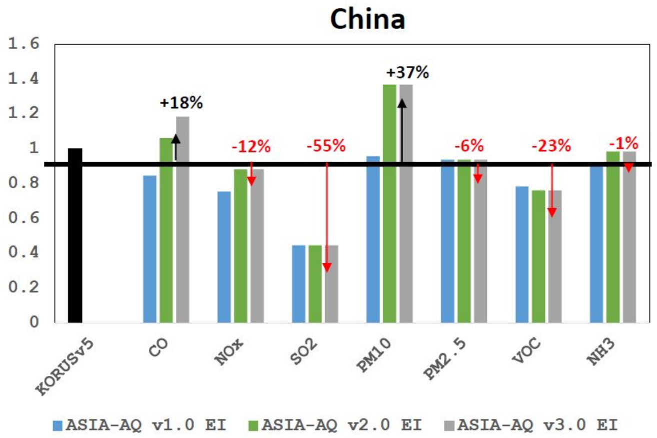


<AQNEA v1 Emission Inventory Sectors>

Tier 1	Tier 2
Power	Power, Energy
Industry	Industrial (Combustion + Process), Fugitive (incl. refinery and gas stations)
Residential	Residential + Commercial
On-road	Road transport
Non-road	Off-road vehicles and other machinery + Railways
Agriculture	Agriculture
Solvents	Solvent use + Paint use + ...
Other	Waste (incl. incineration facility) + etc.

ASIA-AQ v1.0 vs. v2.0 vs. v3.0

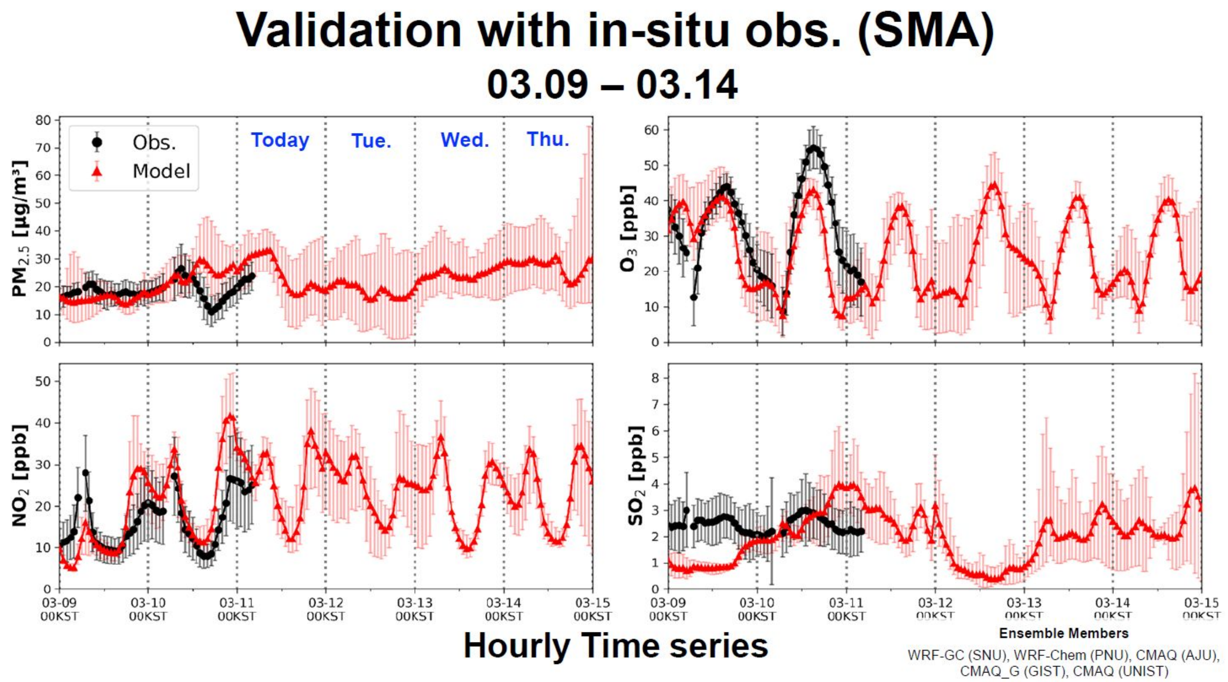


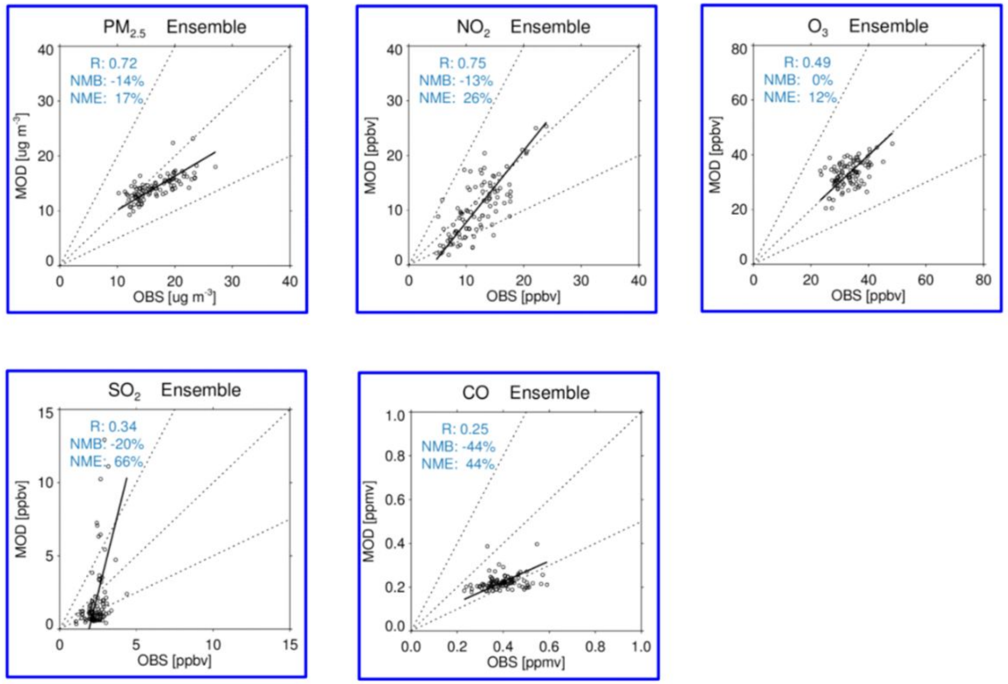


S. Korea (Gg/yr)	CO	NO_x	SO_2	PM_{10}	$PM_{2.5}$	VOC	NH_3
KORUSv5	1,549	1,076	342	230	96	996	297
ASIA-AQ v1.0 EI	711	997	262	204	84	1,005	316
ASIA-AQ v2.0 EI	2,167	997	262	204	84	1005	316
ASIA-AQ v3.0 EI	2,358	997	262	204	84	1,042	316

China (Gg/yr)	CO	NO_x	SO_2	PM_{10}	$PM_{2.5}$	VOC	NH_3
KORUSv5	141,937	22,514	13,374	10,798	8,115	28,356	10,327
ASIA-AQ v1.0 EI	120,180	17,004	5,983	10,341	7,617	22,260	9,341
ASIA-AQ v2.0 EI	150,838	19,894	5,983	14,787	7,617	21,592	10,182
ASIA-AQ v3.0 EI	168,135	19,894	5,983	14,787	7,617	21,592	10,182

SIJAQ/ASIA–AQ emission inventory ⇒ Forward validation

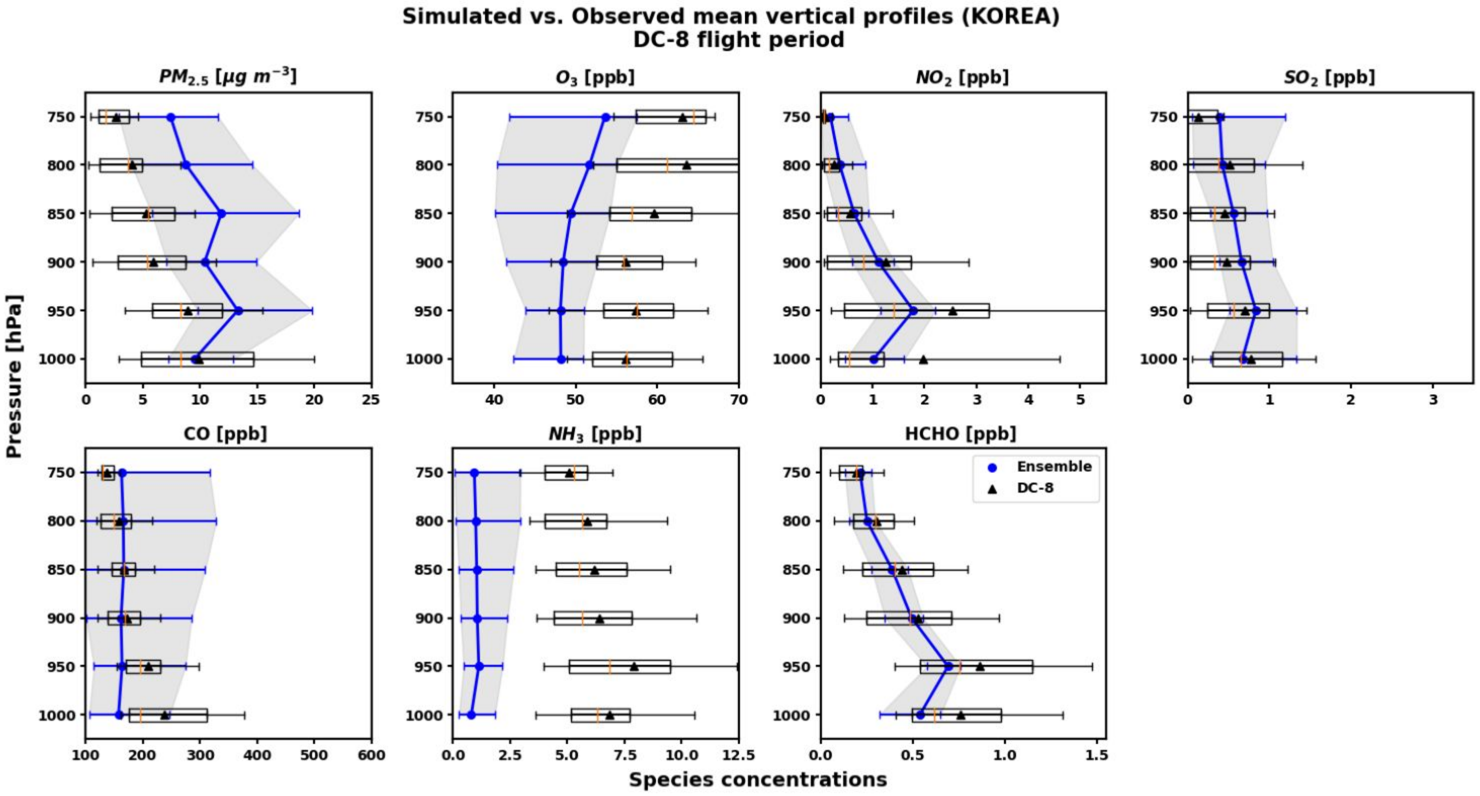




The scatter plots of the ensemble (MOD) and observations (OBS) are consistent, but MOD tends to underestimate OBS at specific high concentrations.

Note that looking at the individual model results for NO2 simulation, the correlation coefficients are high at 0.57 to 0.75, indicating that the most models simulate the high NO2 concentrations in the Seoul metropolitan area quite well

SIJAQ/ASIA-AQ emission inventory ⇒ Forward validation



In the case of PM2.5, the observed and predicted values showed a clear difference depending on the altitude. The predicted values of the ensemble model were higher than the observed values at all altitudes. The difference between them was greater in the lower and middle layers of the atmosphere than at the ground surface.

In the case of O3, the ensemble model showed a tendency to under-simulate the observed concentration by about 10 ppbv at all altitudes.

In the case of NO2, the observed values and the predicted values of the model were similar at all altitude. In particular, the observed values were the highest at an altitude of 950 hPa, and the ensemble model also showed the highest concentration.

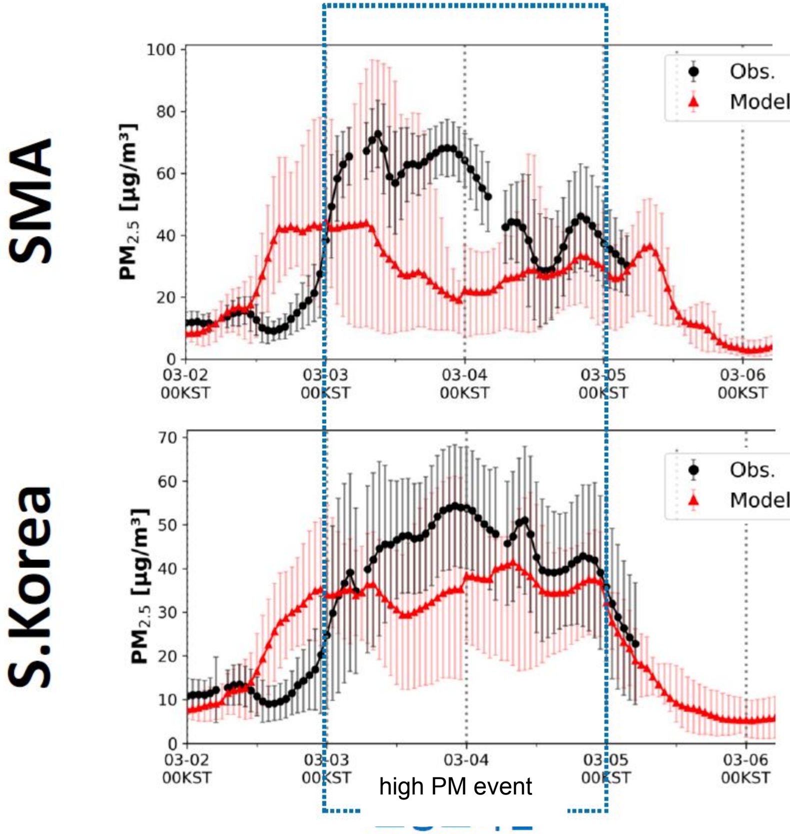
In the case of CO, the ensemble model showed similar values to the observed values at all altitudes.

In the case of NH3, the vertical concentration distribution showed the largest difference between the observed values and the predicted values of the model. The NH3 concentrations observed at DC-8 were outside the range of the ensemble model predictions as well as the inter-model range at all altitudes(NMB: -77%).

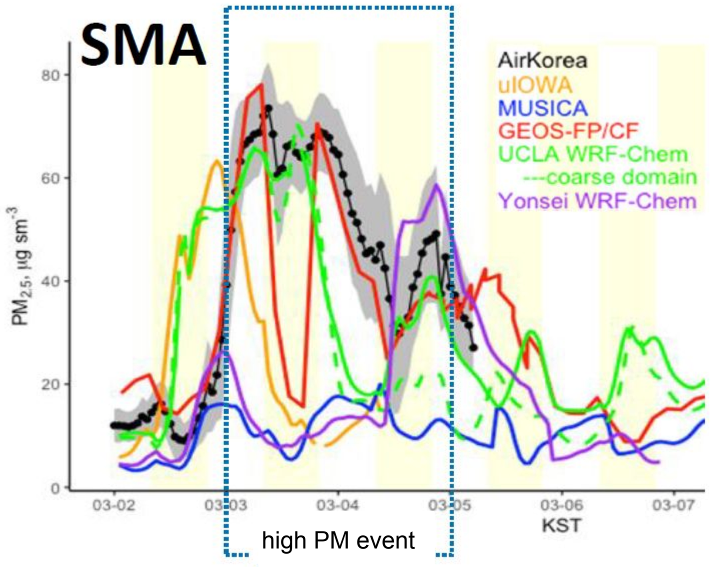
For HCHO, the observations and the model were in fairly good agreement at most altitudes.

For SO2, there was a high degree of agreement between the observed and predicted values at most altitudes.

SIJAQ/ASIA-AQ emission inventory ⇒ Forward validation



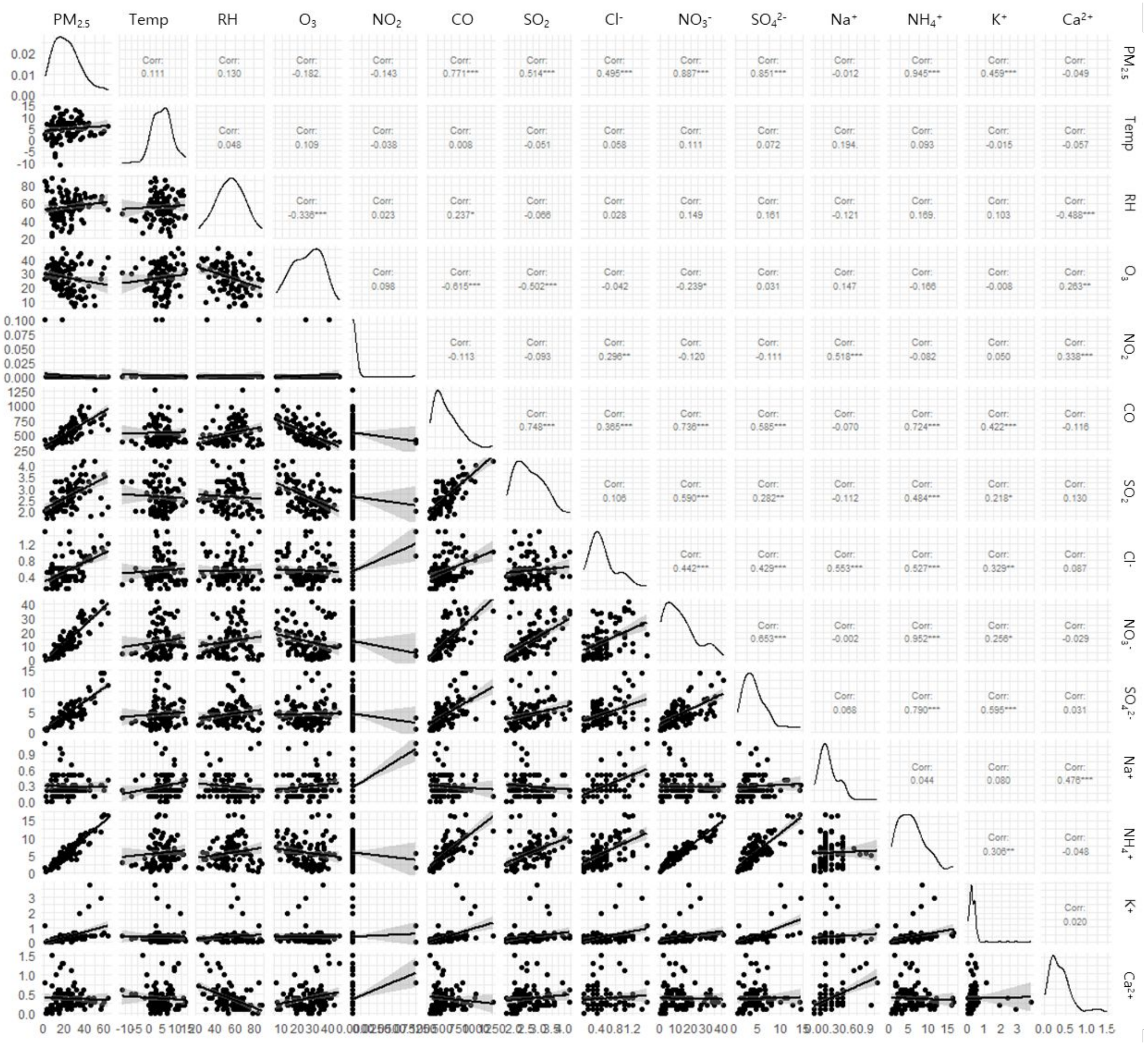
High PM event (3~4 March, 2024)
Model comparison with AirKorea



During the period of high concentration of particulate matter, the GEOS-FP/CF model simulated the highest concentrations similar to the observations, but the simulated PM2.5 concentrations showed large variability even during the high concentration period. In addition, in the case of UCLA WRF-Chem, the onset and end of the high concentration particulate matter phenomenon appeared faster than the observations, suggesting that the uncertainty of the synoptic meteorological field was large. Other models did not simulate the high concentration particulate matter phenomenon at all, or the high concentration ended in a short period (uIOWA model).

The ensemble model predictions showed under-simulation compared to the observations. In the case of the ensemble predictions, both the metropolitan area and South Korea showed a maximum concentration of about 40 µg m^{-3}, showing a large difference from the observations.

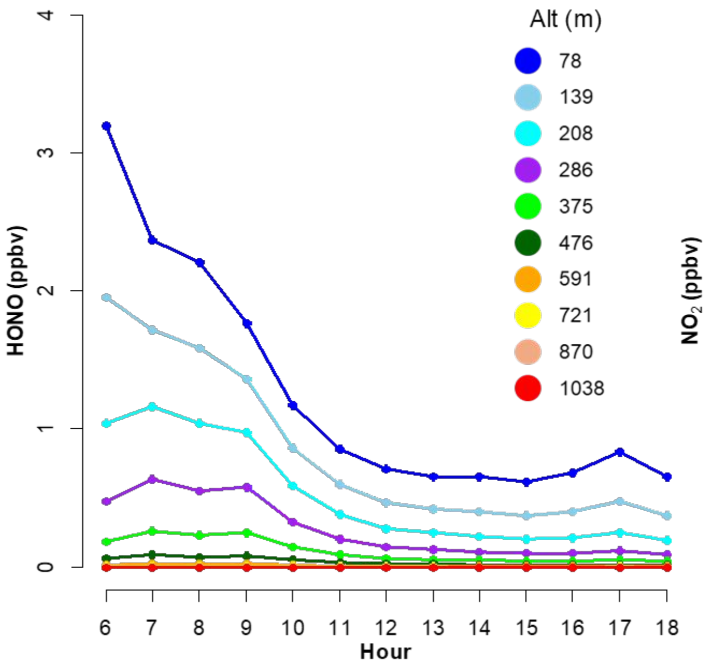
Nitrate production mechanism in low temperature and high humidity environment

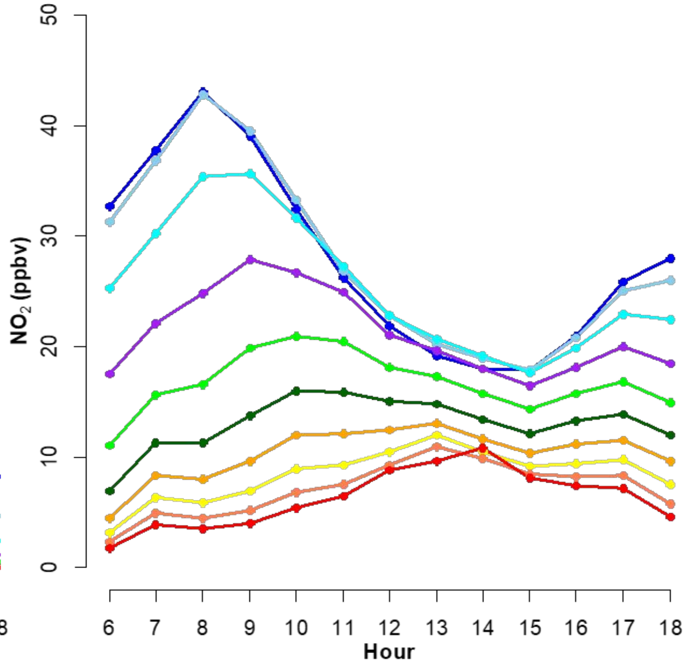


$PM_{2.5}$ 0~35 μg/m^3 vs $PM_{2.5}$ 35 μg/m^3

	Mean	
$PM_{2.5}$ (μg/m^3)	0 ~ 35	>35
Temp (℃)	4.5	4.5
RH (%)	54.6	58.9
WS (m/s)	1.7	1.4
NO^{3-} (μg/m^3)	9.4	30.1
SO_4^{2-} (μg/m^3)	3.6	8.1
NH_4^+ (μg/m^3)	4.4	11.4
Cl^- (μg/m^3)	0.5	0.9
Na^+ (μg/m^3)	0.3	0.3
K^+ (μg/m^3)	0.3	0.8
Ca^{2+} (μg/m^3)	0.4	0.3
Mg^{2+} (μg/m^3)	0.1	0.1

Vertical profiles of HONO and NO_2



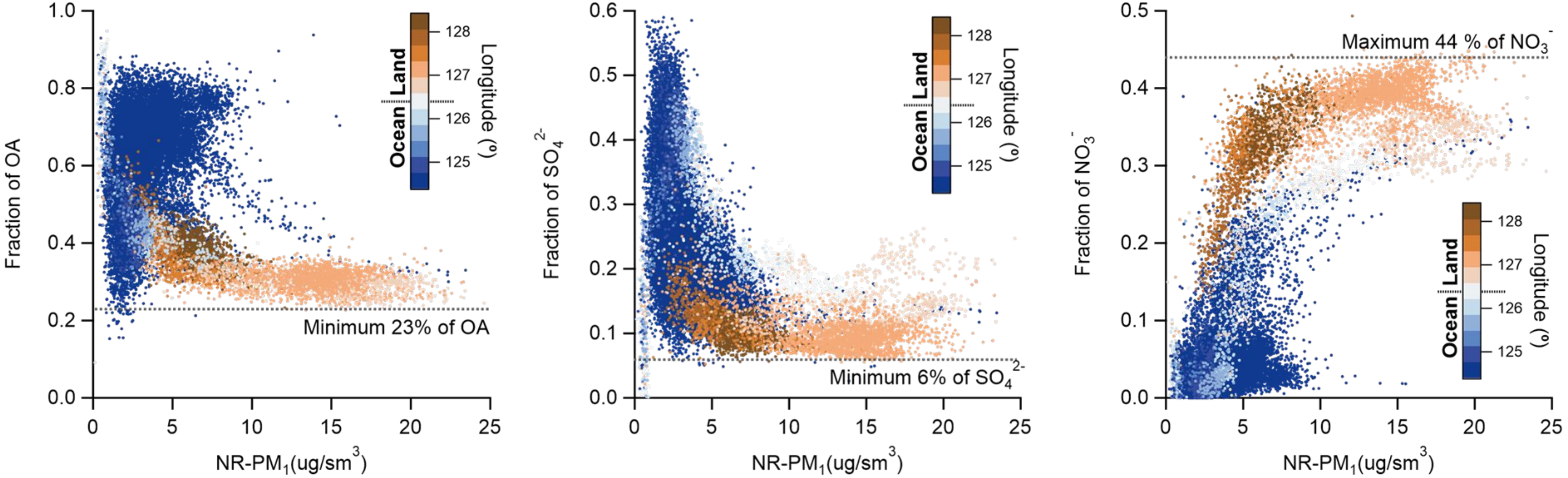


In the case of NO_2, the concentrations increased at low altitudes during the morning rush hour and decreased as the PBL grew during the day, whereas concentrations at high altitudes increased progressively, suggesting that diurnal variations in ground-level air pollutants may differ from those in the upper atmosphere.

In the case of HONO, the concentrations were highest at night regardless of altitude and showed a pattern of decreasing during the day due to photolysis

SIJAQ/ASIA-AQ

Analysis of chemical composition characteristics below 1 km altitude among airborne observations during the ASIA-AQ period.



In Korea, **OA** showed a clear boundary between the sea and the inland. In the West Sea, OA was distributed higher as PM1.0 increased, reaching a composition ratio of OA in PM1.0 of approximately 80%. In the inland, OA decreased as PM1.0 increased, and especially in the area near Seoul (126.7~127°E), which is the city center, it decreased to approximately 23%.

Sulfate was observed to have a higher composition ratio as PM1.0 decreased, and there was no particular difference between the land and the sea.

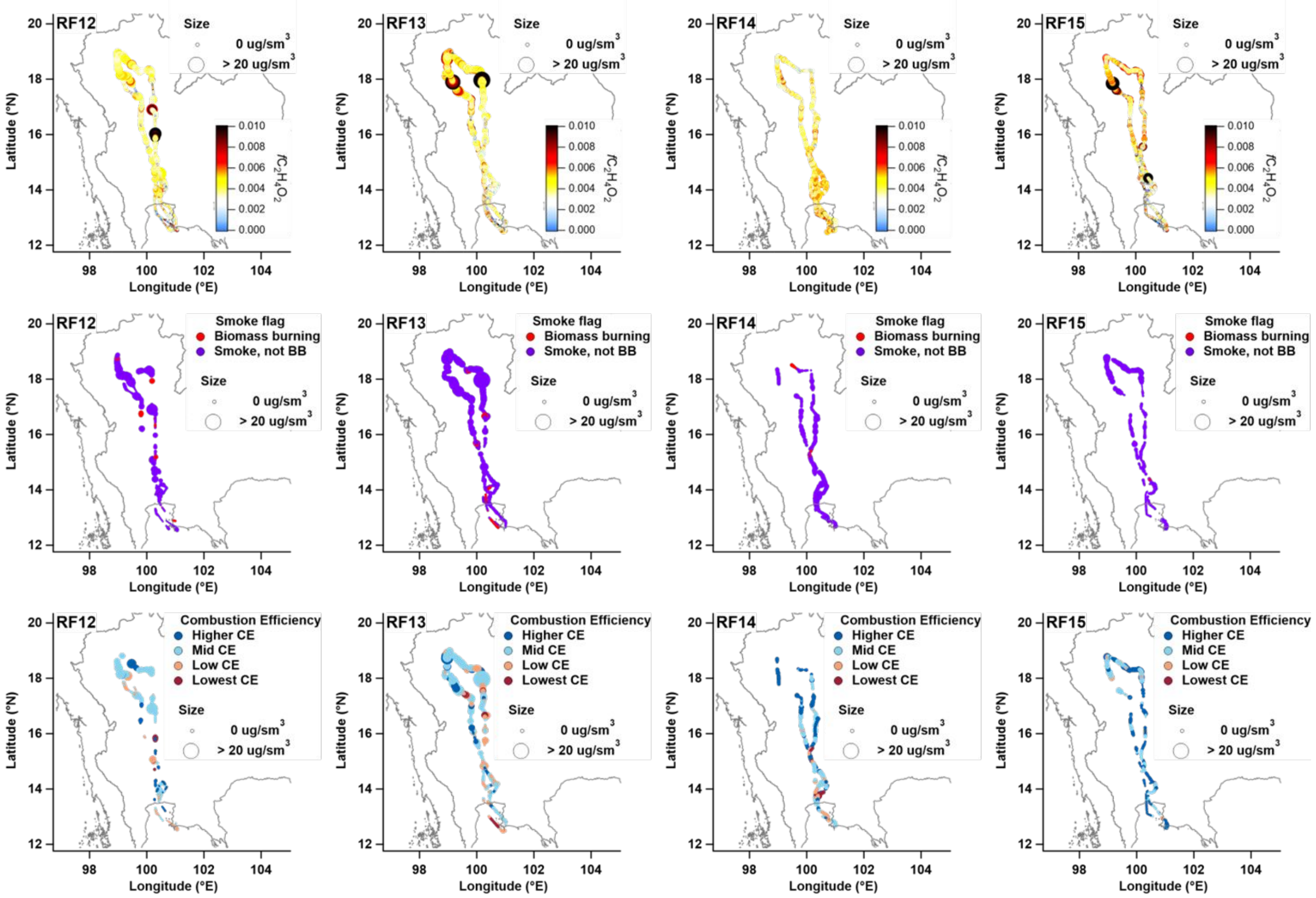
Nitrate showed a composition ratio opposite to OA and sulfate. Nitrate existed very limitedly in PM1.0 when the concentration was low, and was observed to have a lower composition ratio in the sea than in the inland. Nitrate increased its chemical composition ratio to about 44% along with the increase in PM1.0 concentration. This means that nitrate is a major chemical component that has a greater impact on the increase in PM1.0 inland in Korea than OA and sulfate, and

SIJAQ/ASIA–AQ

Levoglucosan:OA

Smoke flag

Combustion efficiency



The levoglucosan:OA ratios measured by HR-ToF-AMS were above 0.003 in most areas, indicating the influence of **biomass burning**.

In the smoke flags, most areas of Thailand, including Chiang Mai, were analyzed as **simple smoke, not biomass burning**, and the combustion efficiency was also analyzed as high or medium combustion efficiency, not the lowest combustion efficiency, which is the influence of biomass burning

The smoke flags were classified into three types: non-combustion influence, smoke influence, and biomass burning, respectively, through 60-s correlation analysis of the increase ratios of CO:CO2 and CH4:CO. Combustion efficiency was classified into five levels: high combustion efficiency, medium combustion efficiency, low combustion efficiency, and the lowest combustion efficiency (biological combustion), respectively, through 60-s correlation analysis of the increase ratio of CO:CO2.

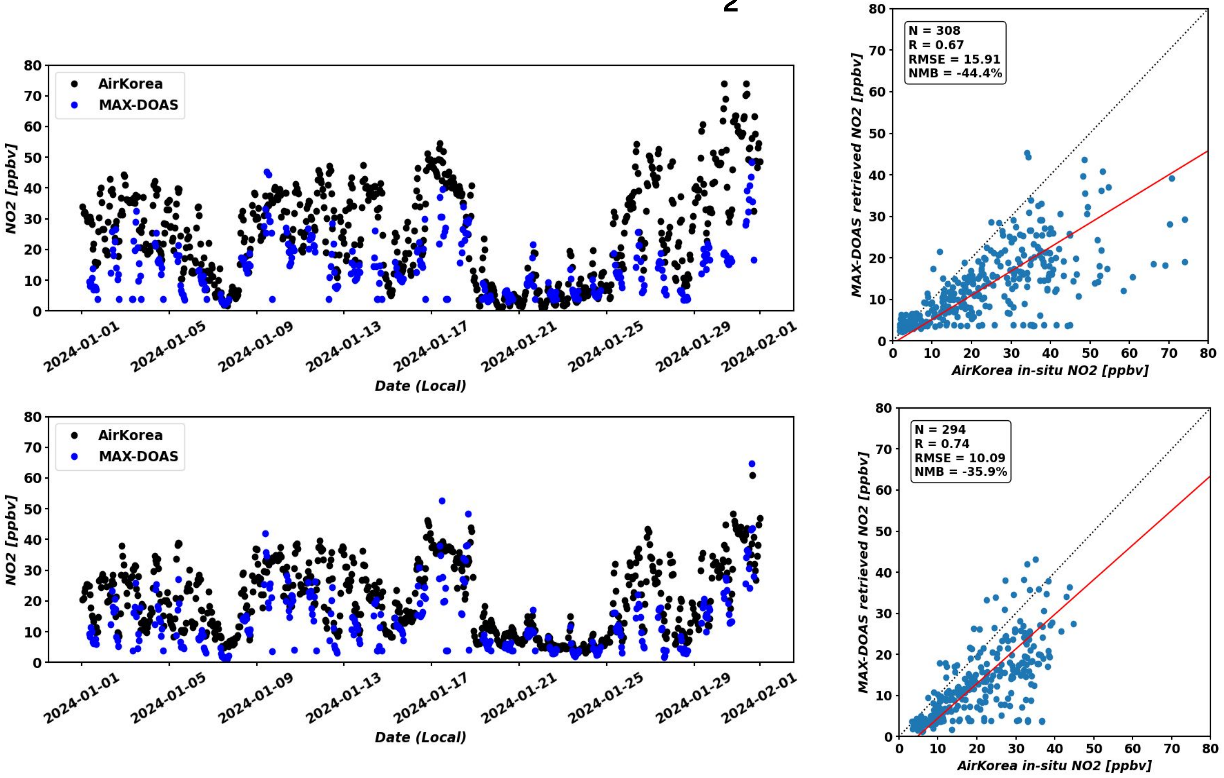
DOAS NO_2 profile validation

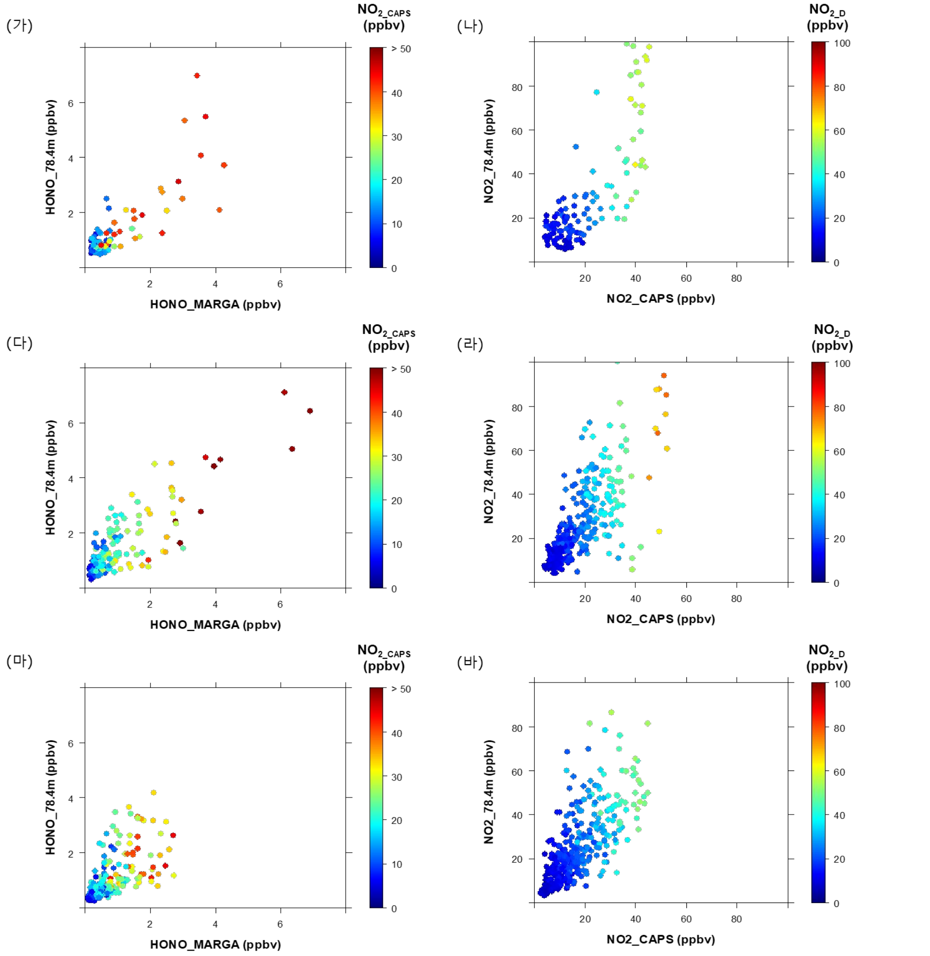
NO2, HCHO, O3, vertical profiles and aerosol characteristics (aerosol optical thickness, single-scattering albedo, particle size distribution, etc.) during the SIJAQ period

Suwon MAXDOAS vs AirKorea NO_2

North (Suwon)

South (Hwaseong & Osan)

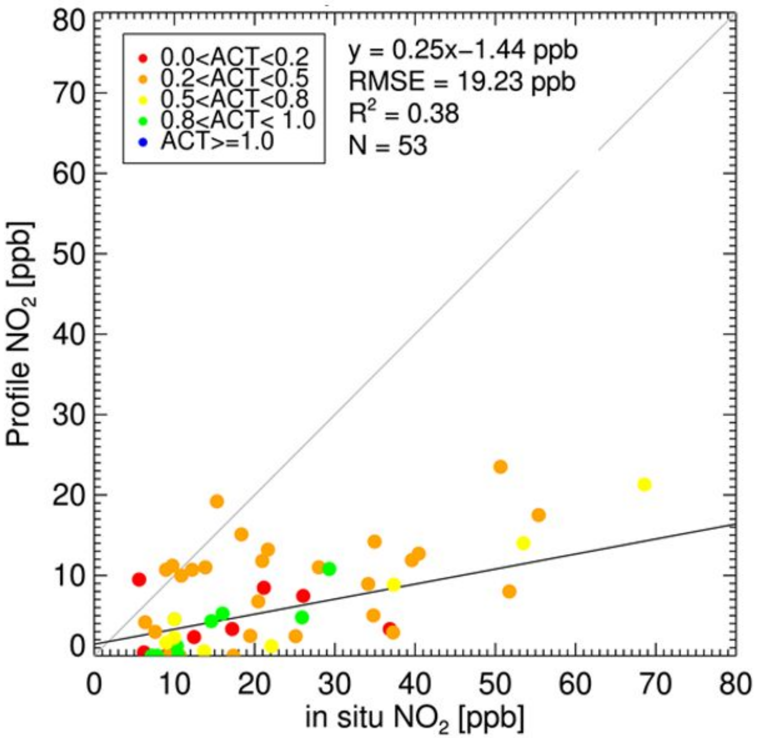


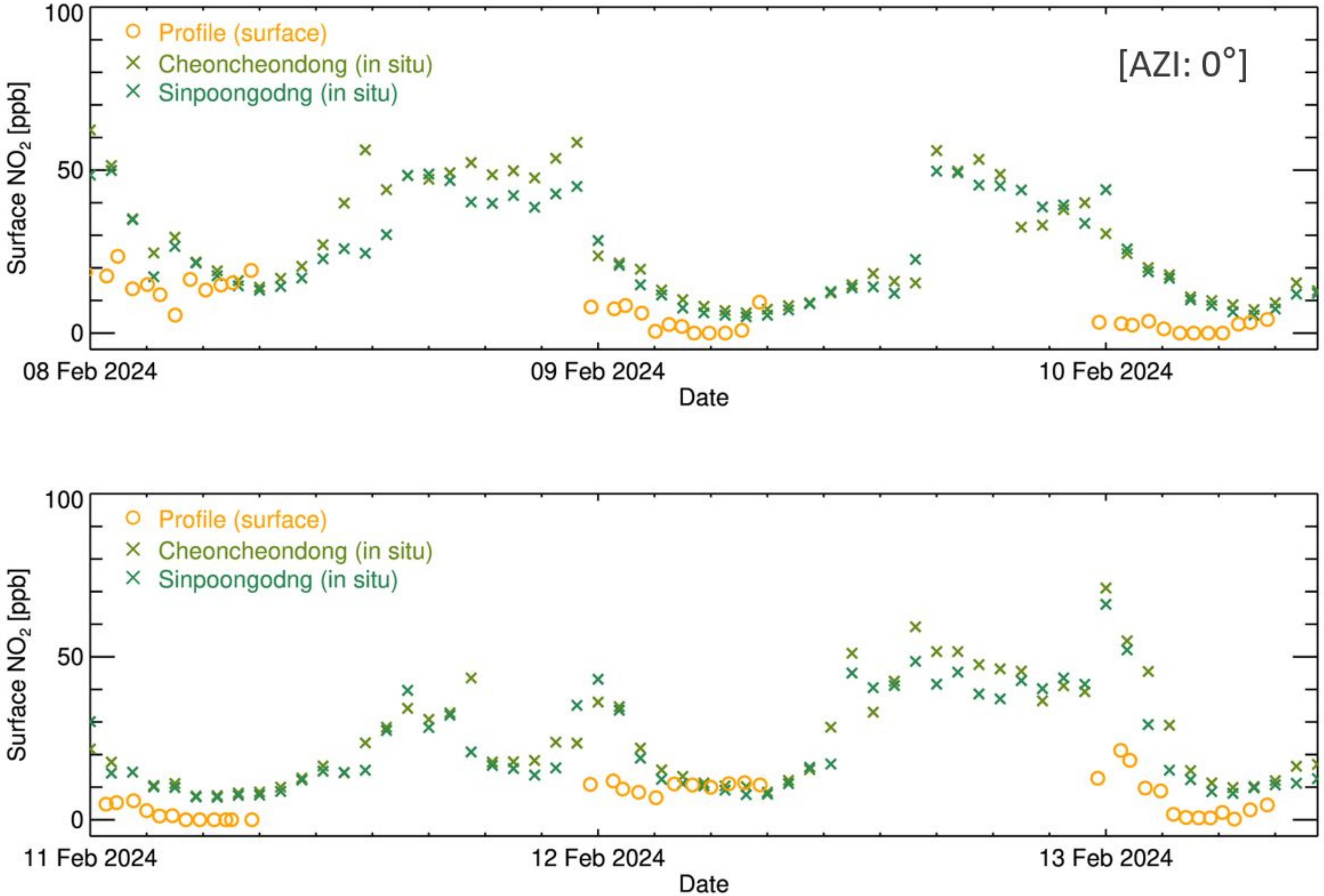


Comparison of surface HONO and NO2 concentrations observed by DOAS and MARGA(CL) in (가) January, (나) February, and (다) March

GEMS NO_2 profile validation

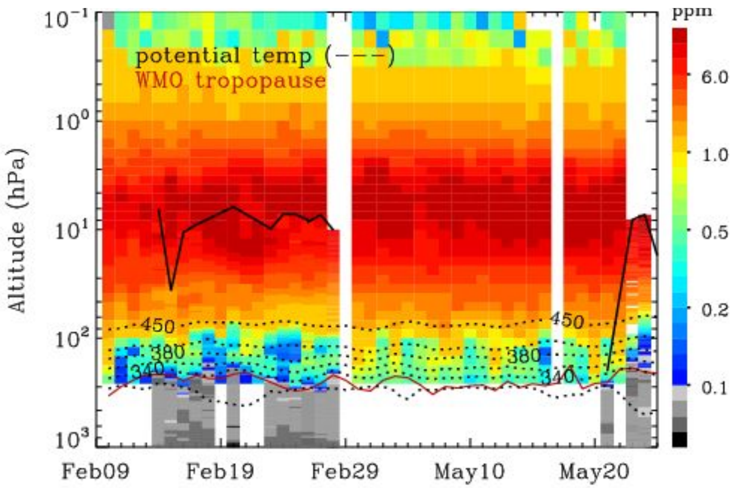
Pandora version	P191 (Extended version)
Location	Suwon
Latitude, Longitude	37.26, 126.99



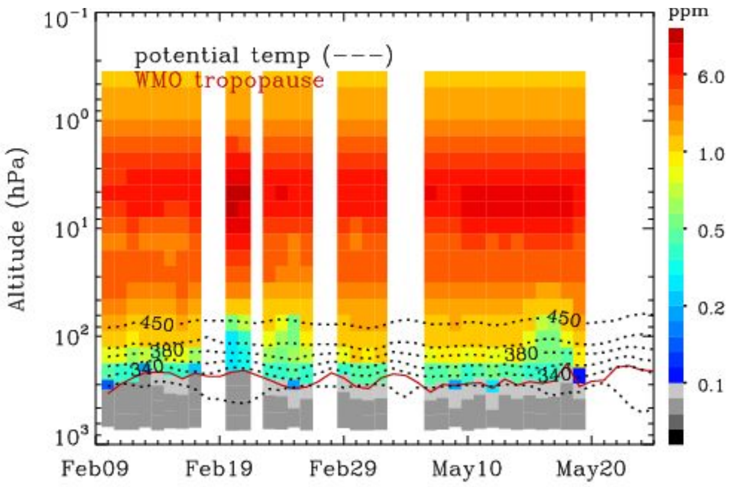


SEMS O_3 profile validation

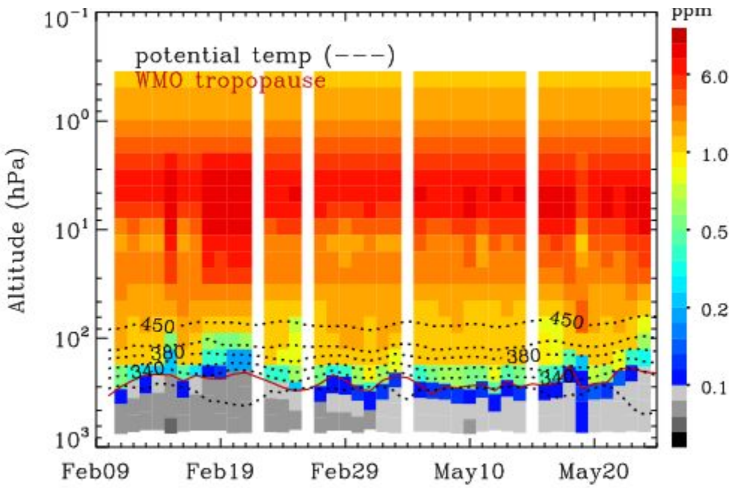
- MLS + ozone sonde



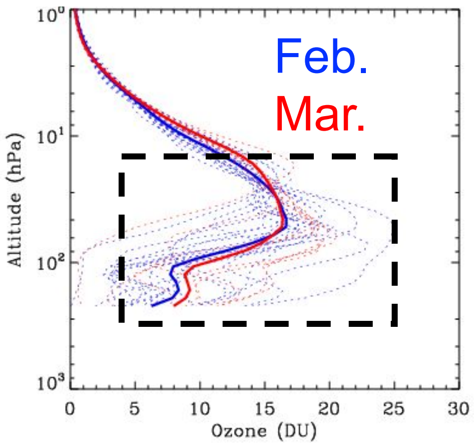
- GEMS v3.0



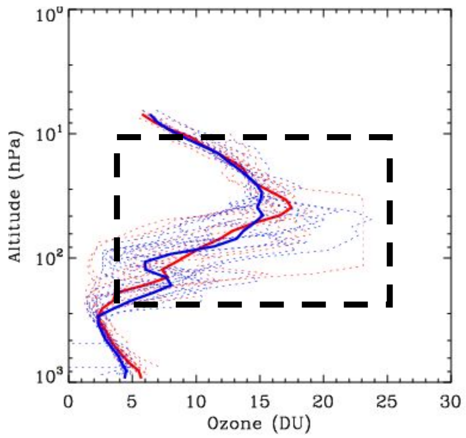
- GEMS v2.0



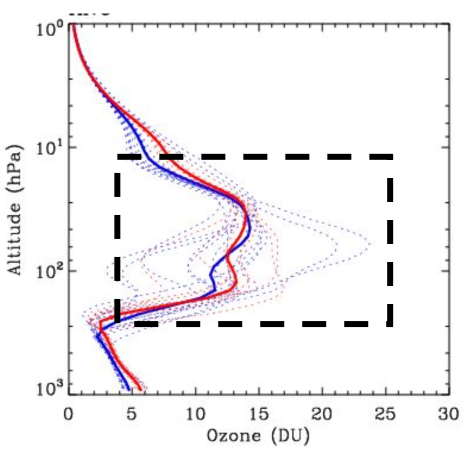
MLS



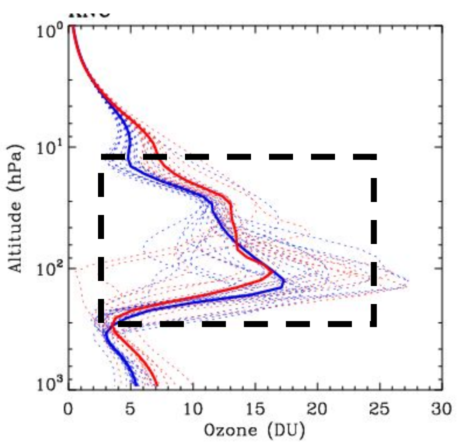
Ozone sonde



GEMS V3.0



GEMS V2.0



GEMS v3.0 Ozone is mostly underestimated around the tropopause, and tends to be overestimated in the middle stratosphere.

Summary

- SIJAQ data is being thoroughly validated and is expected to be released by November this year.

- In-depth analysis of ground/airborne/remote/modeling data is being conducted for winter PM formation and GEMS validation.

- The Korean RSSR team has been formed and will begin work in earnest in September.

Thank you

Terima kasih

cảm ơn bạn

谢谢

நன்றி

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감사합니다

Salamat

баярлалаа

ありがとうございました

ขอบคุณ