Pandora observations in the Korean Peninsula

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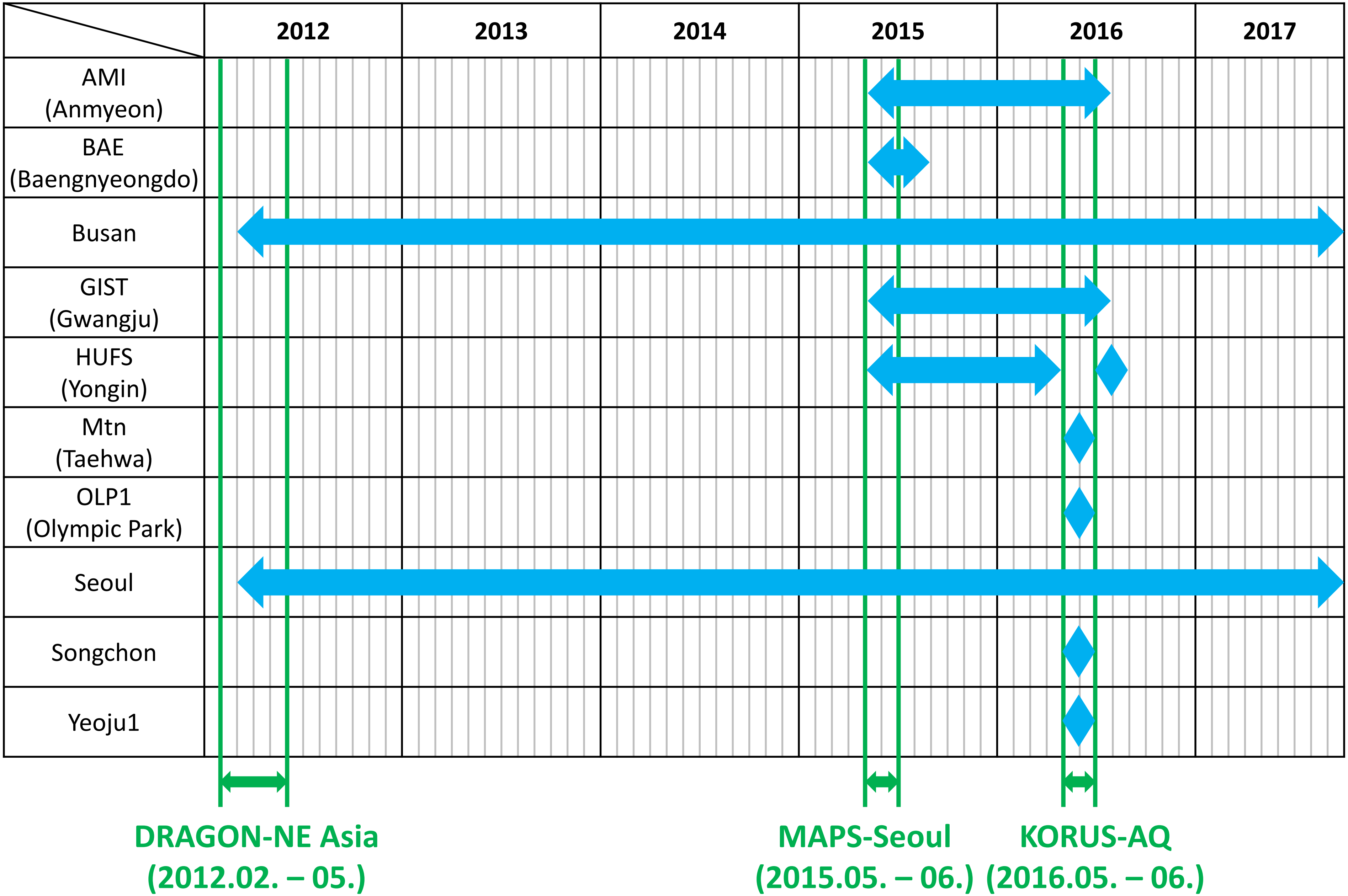
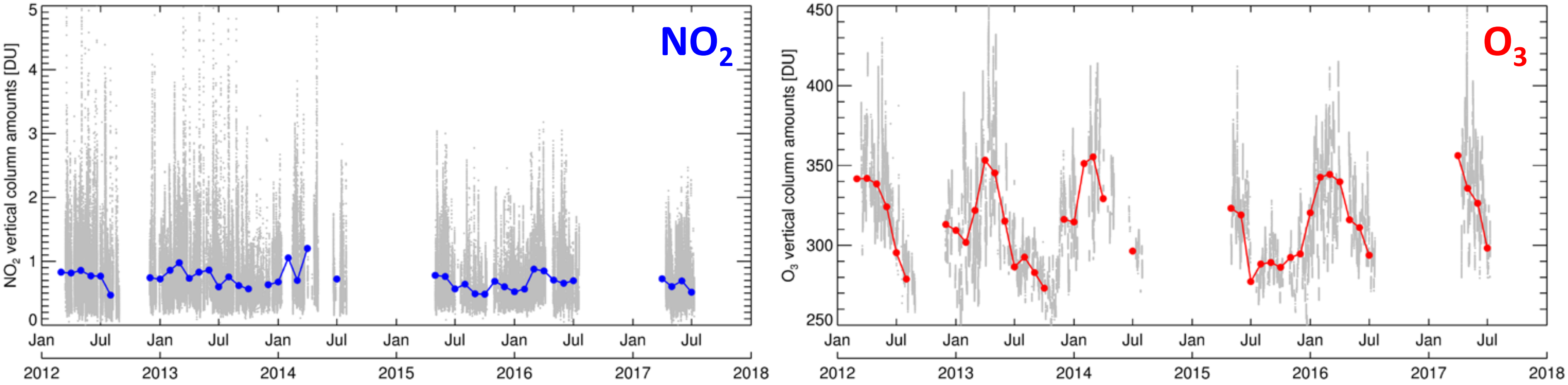
Pandora observations in the Korean Peninsula

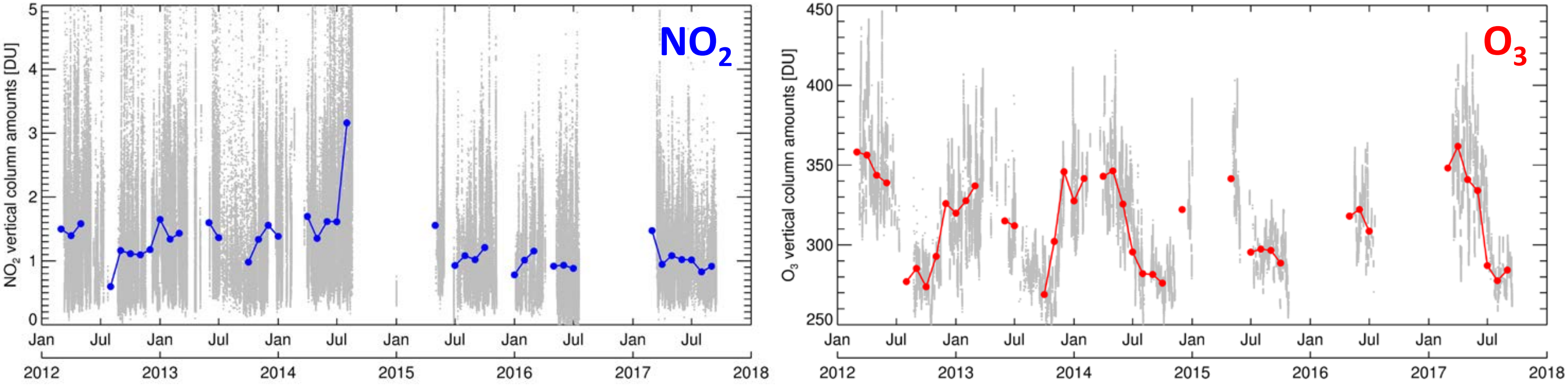


Long-term Pandora data: since DRAGON-NE Asia campaign

Busan

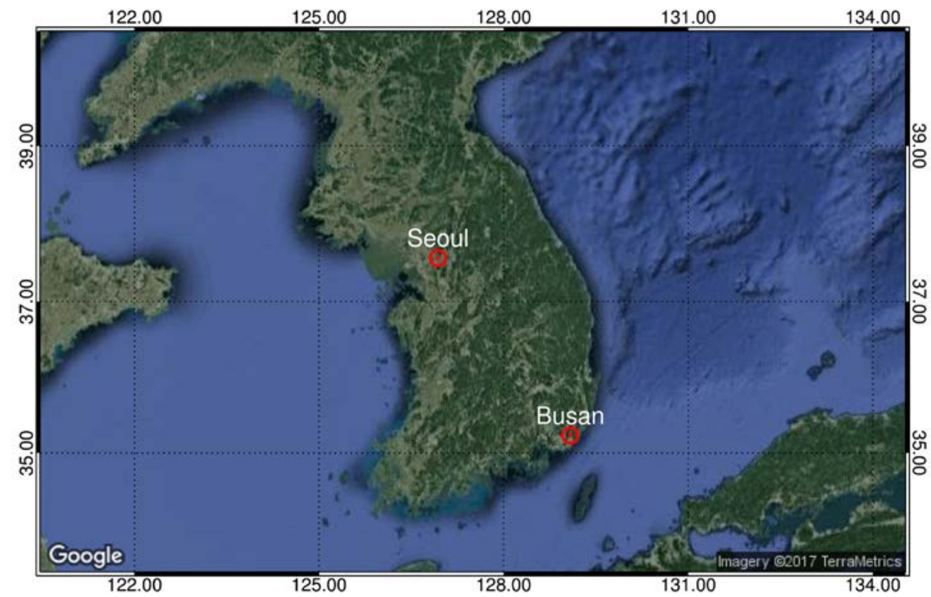


Seoul

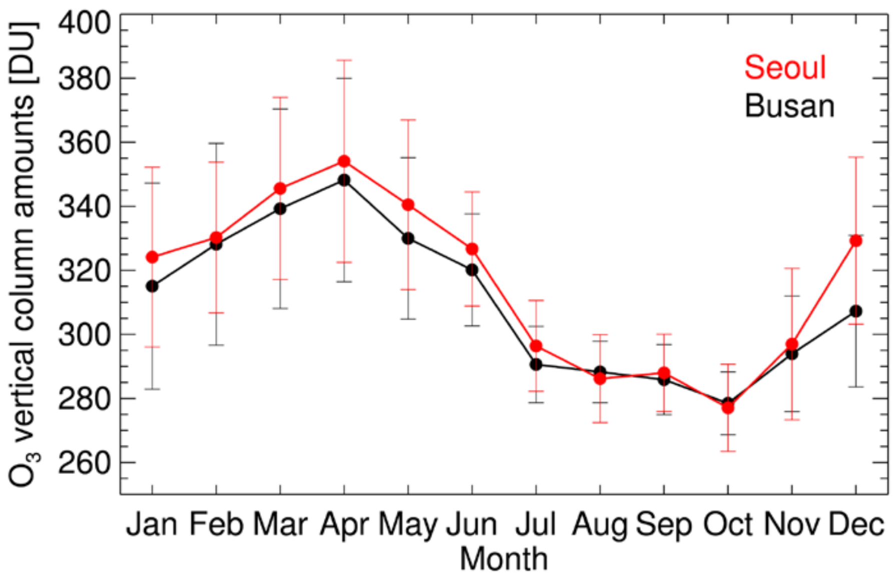


Long-term Pandora data

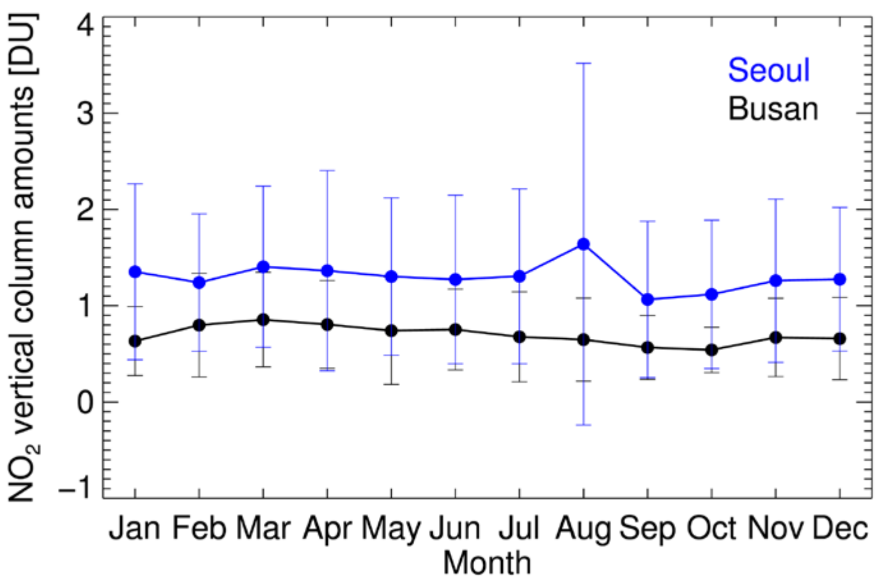
- **Seoul** & **Busan** sites (2012.03.~)
- Total column O_3 shows clear monthly variations. (max. on April & min. on Oct.)
- Monthly variations of total column NO_2 are small.



Monthly variations of total column O_3



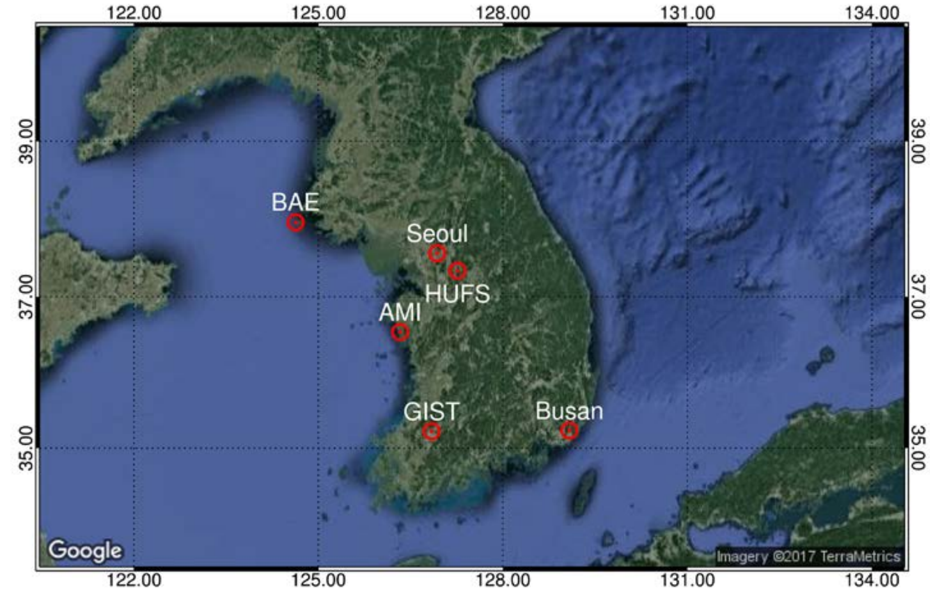
Monthly variations of total column NO_2



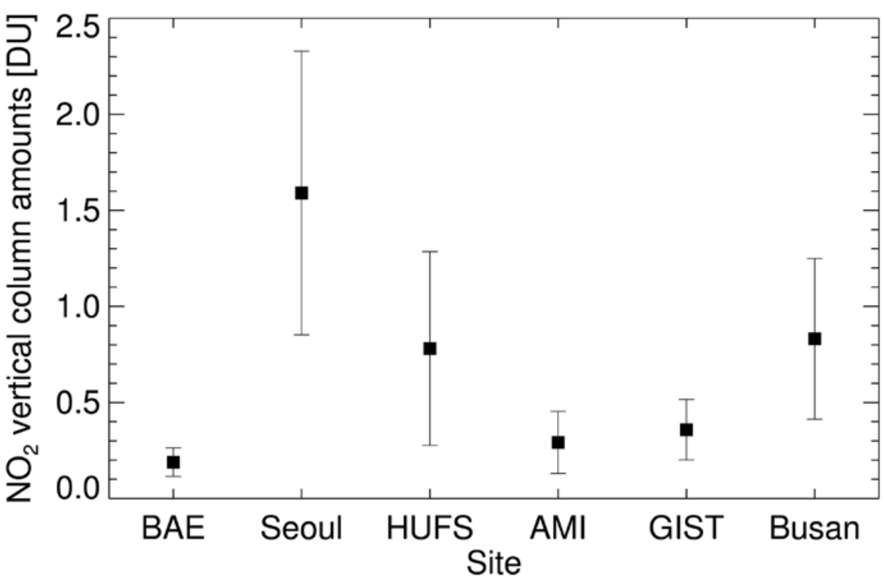
MAPS-Seoul campaign

- Megacity Air Pollution Studies-Seoul (MAPS-Seoul) campaign
- Preliminary campaign of KORUS-AQ
- 2015.05.18. – 2015.06.14.
- Rural sites: **BAE** and **AMI**
- Urban sites: **Seoul**, **HUFS**, and **Busan**
- Urban but low NO_2: **GIST**

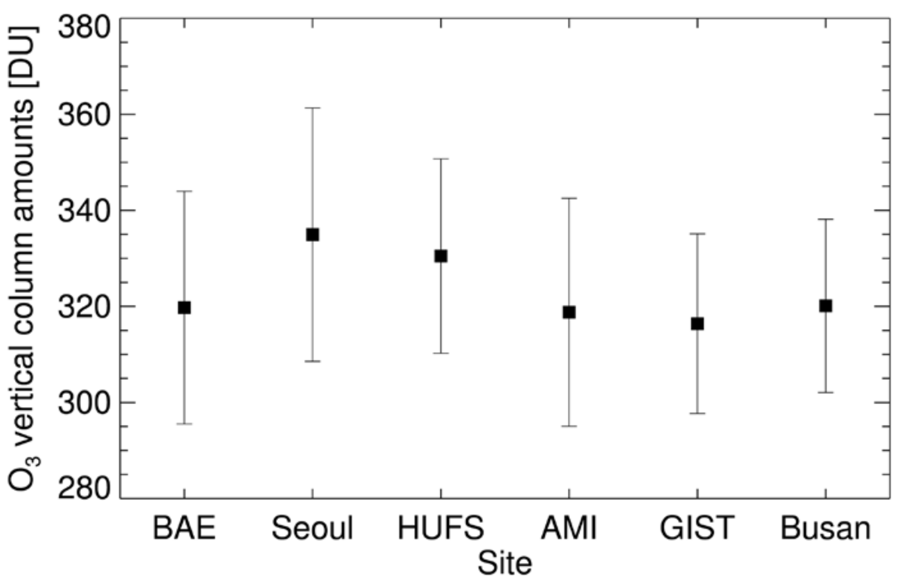
Pandora sites during MAPS-Seoul



Mean total column NO_2 during MAPS-Seoul



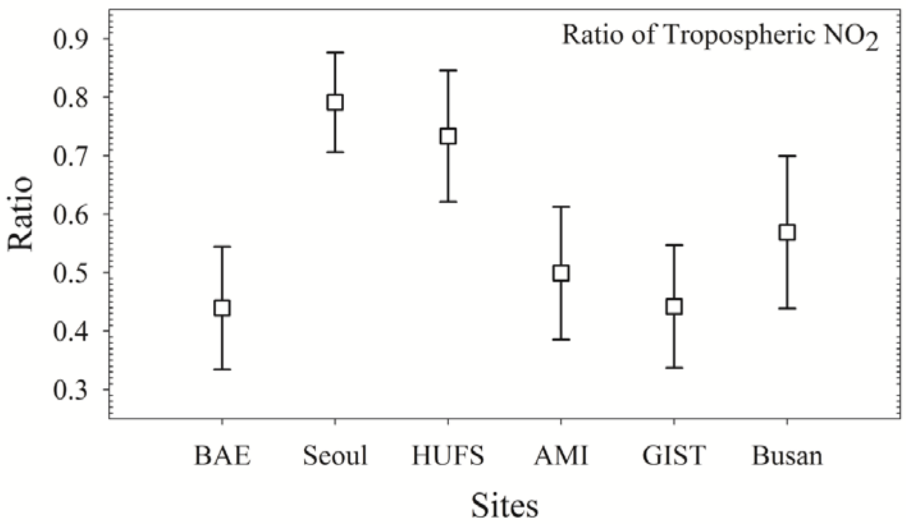
Mean total column O_3 during MAPS-Seoul



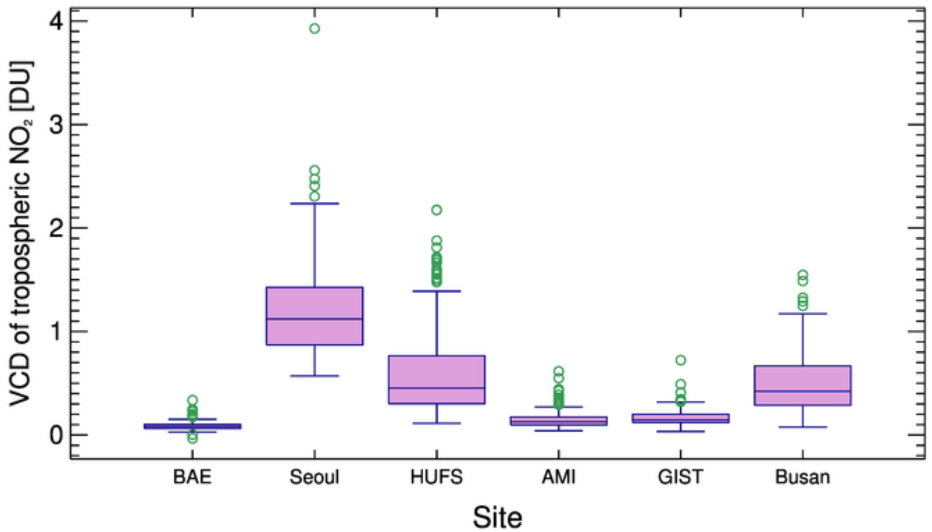
MAPS-Seoul campaign: Tropospheric NO_2 column

- (Pandora trop. NO_2 column) = (Pandora total NO_2 column) × (OMI trop.-to-total NO_2 ratio)

Ratio of trop. NO_2 during MAPS-Seoul



Mean trop. NO_2 during MAPS-Seoul

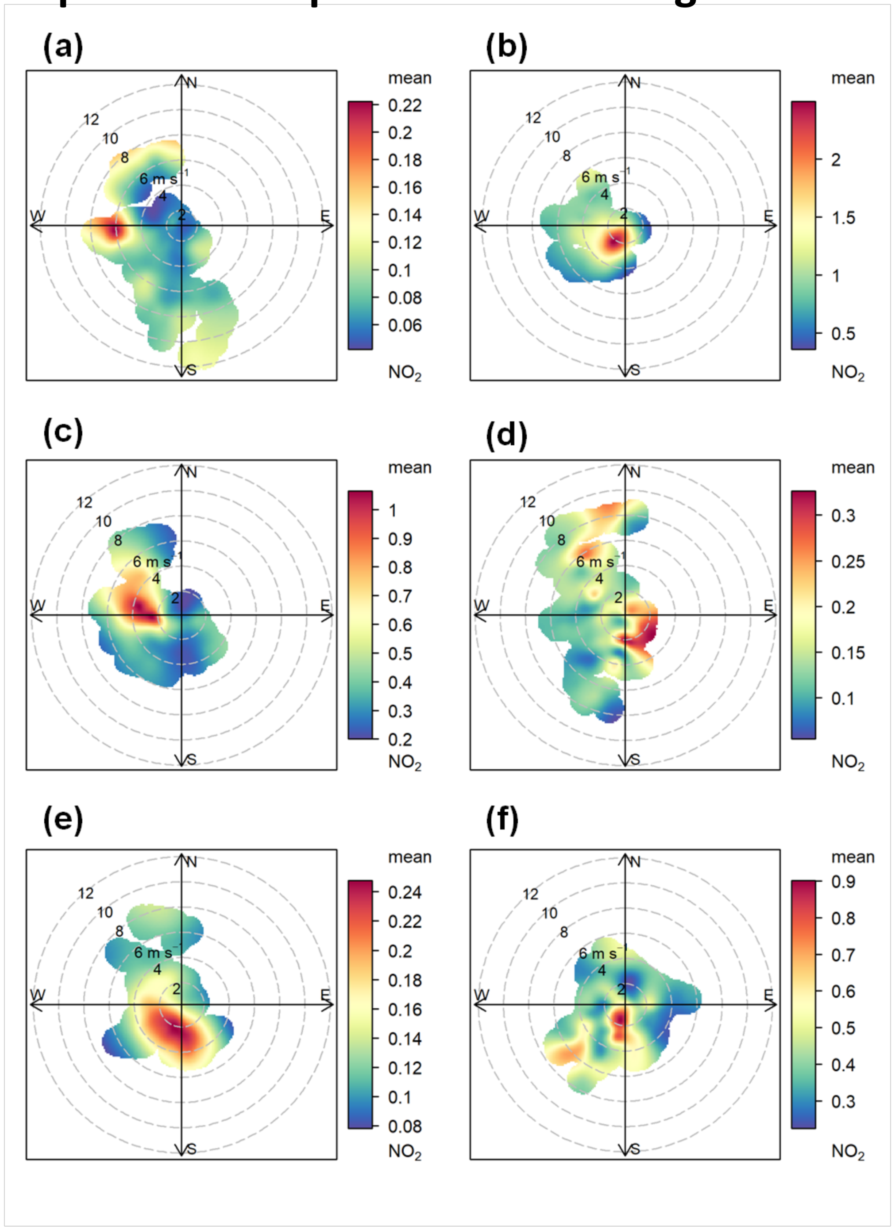


- Tropospheric NO_2 dominates total NO_2 VCD around the urban area (Seoul, HUFS, and Busan)

- Largest: Seoul / Smallest: BAE
- Urban (Seoul, HUFS, and Busan): large median & gap between 1st and 3rd quartiles
- Rural (BAE, and AMI): small median & gap between 1st and 3rd quartiles

MAPS-Seoul campaign: Regional characteristics of column densities

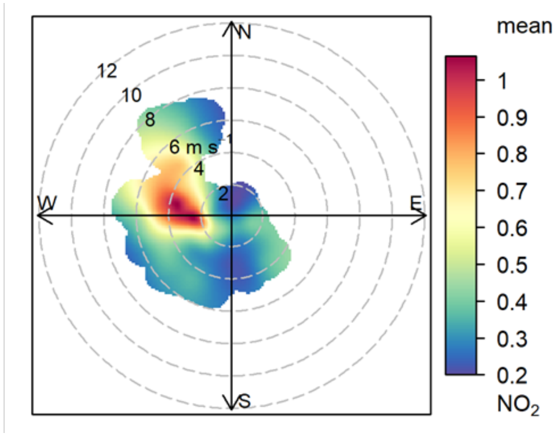
Polar plot with respect to wind during MAPS-Seoul



- **(a) BAE**
  - Effects of trans-boundary transport
- **(b) Seoul**
  - High concentrations with the condition of stagnant air
- **(c) HUFS**
  - Clearly affected by transport from Seoul
- **(d) AMI**
  - Attributed to domestic emissions
- **(e) GIST**
  - Emissions from city, but relatively lower than Seoul and Busan
- **(f) Busan**
  - High values with low wind speed

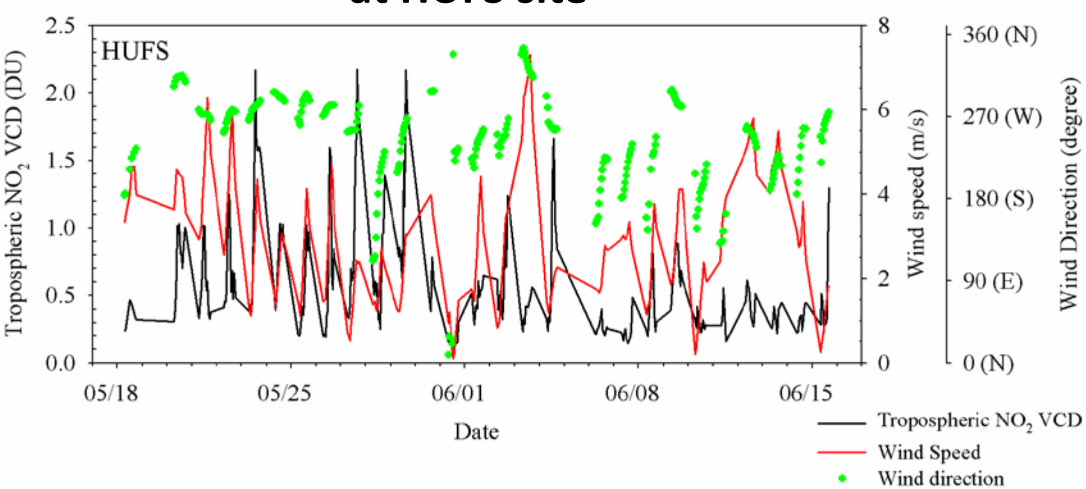
MAPS-Seoul campaign: Effects of transport from Seoul on HUFS NO_2

Polar plot of HUFS site

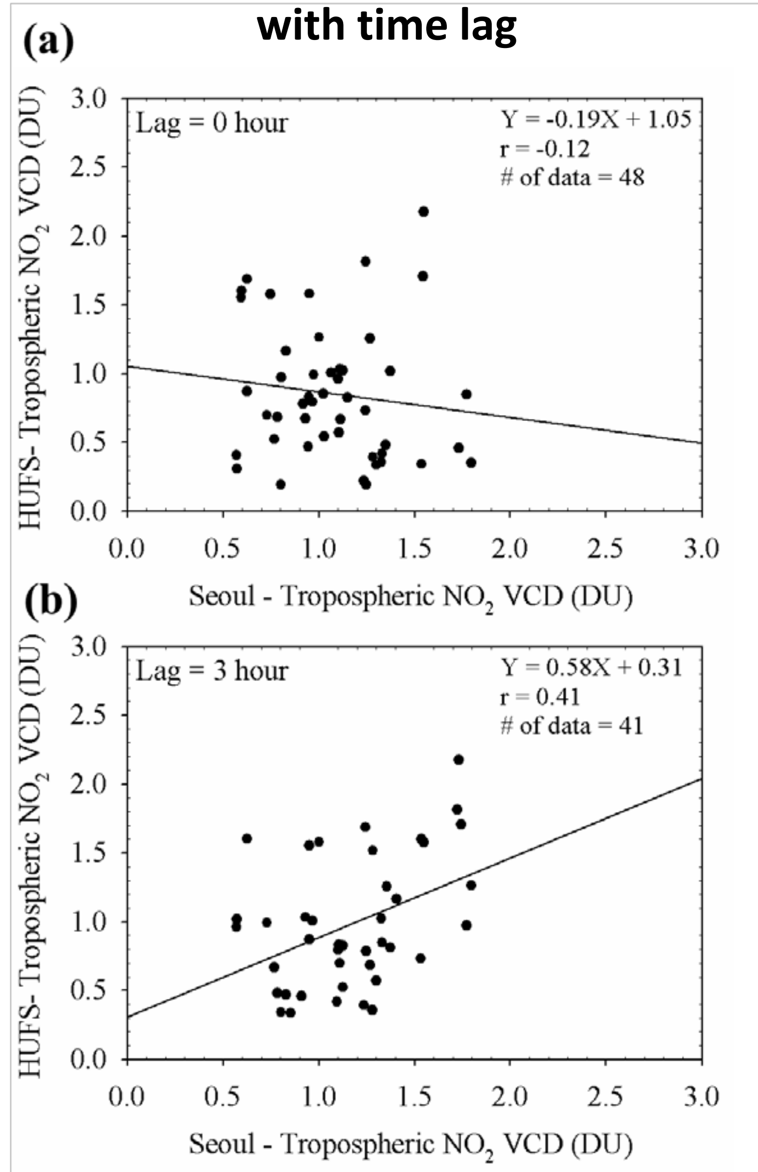


- NO_2 concentrations increase with westerly wind conditions
- Effects of transport from Seoul

Relationship between trop. NO_2 and wind at HUFS site

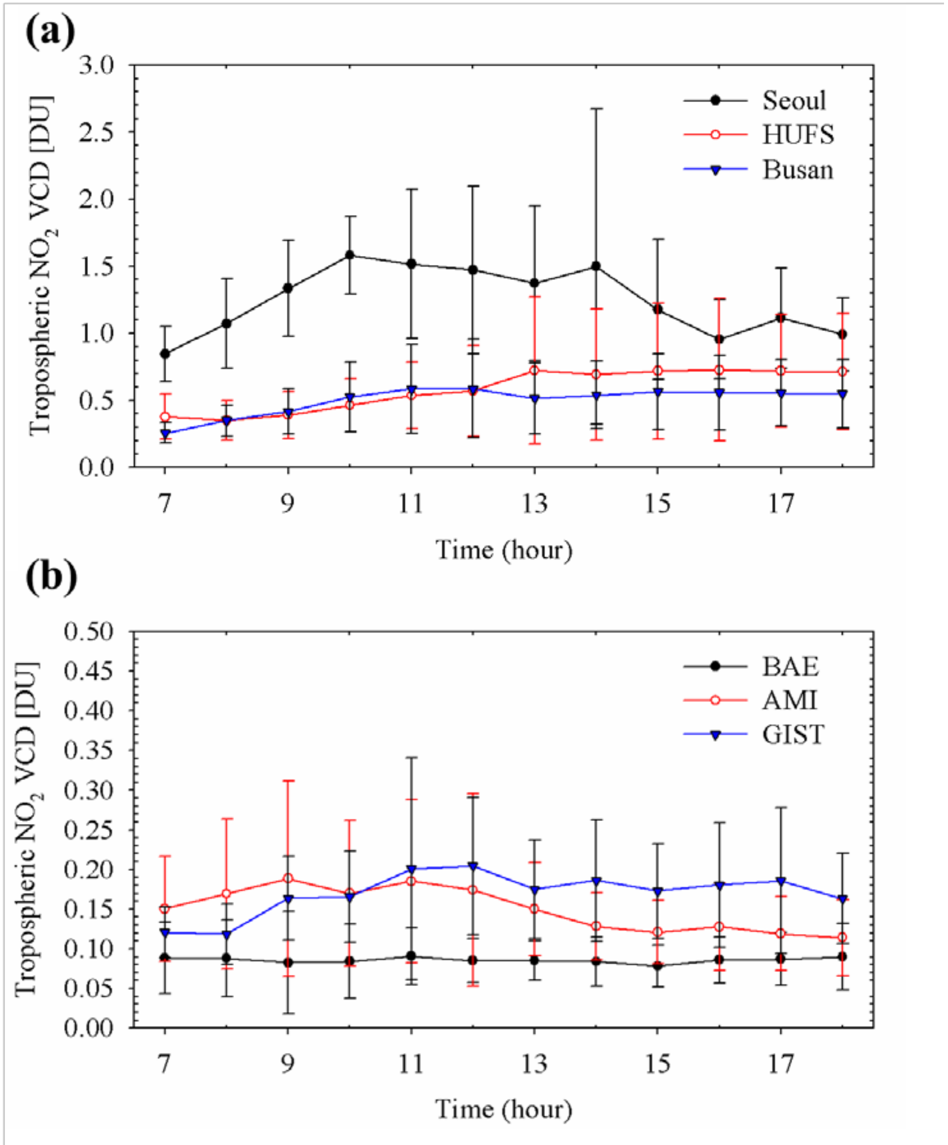


Scatter plot between Seoul and HUFS with time lag



MAPS-Seoul campaign: Diurnal variations of tropospheric NO_2

Diurnal variations of trop. NO_2 during MAPS-Seoul



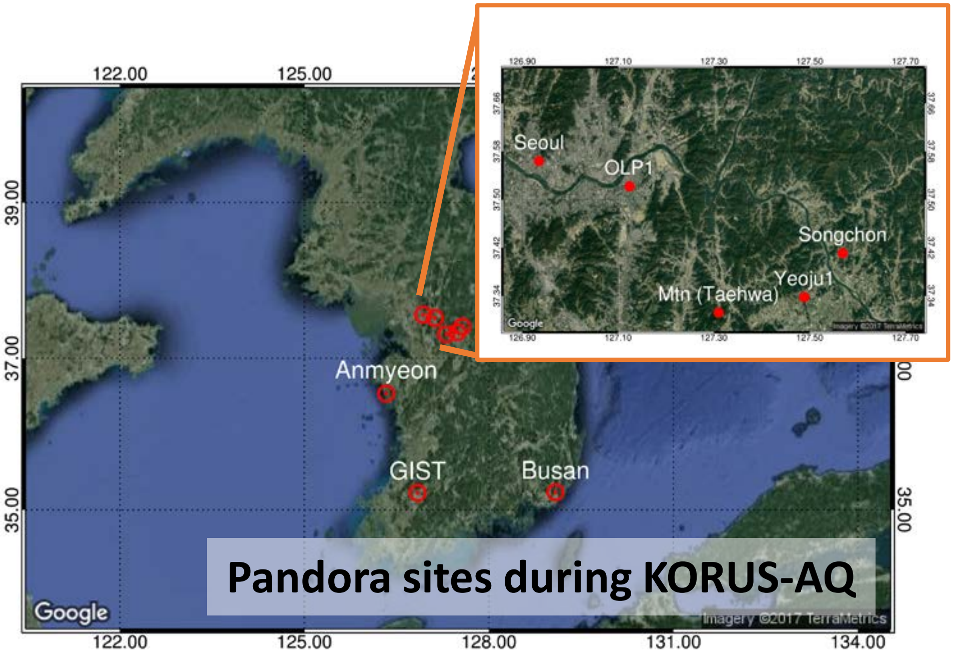
- **Urban sites**
- Peak at 10 AM in Seoul
- NO_2 VCD increases from 1 PM in HUFS site, which is 3 hours later than the peak in Seoul.

- **Rural sites (and GIST)**
- Attributed to emissions and transport from local sources
- Less clear diurnal variations than urban sites

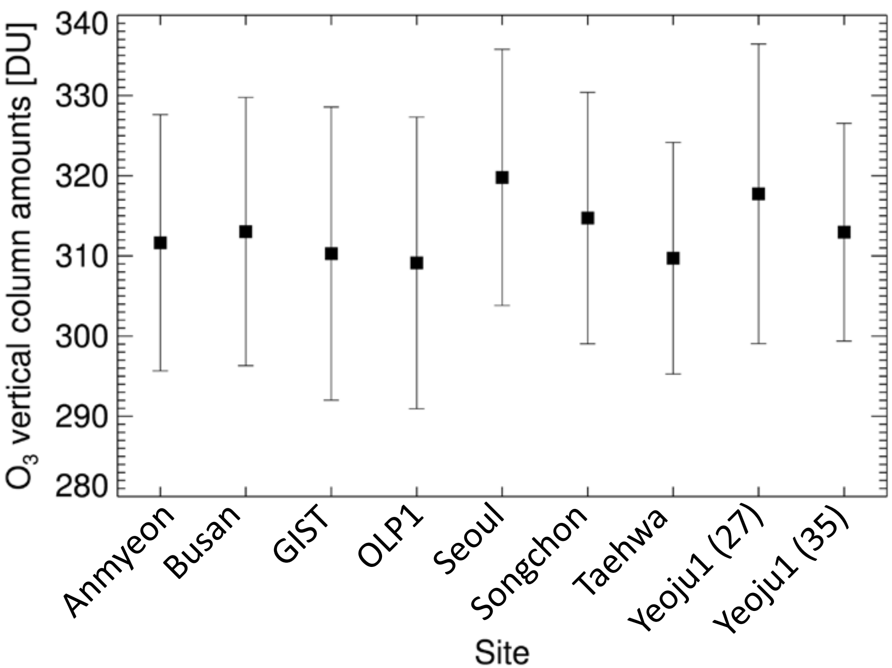
KORUS-AQ campaign

- Korea-United States Air Quality (KORUS-AQ) campaign
- 2016.05.02. – 2016.06.12.

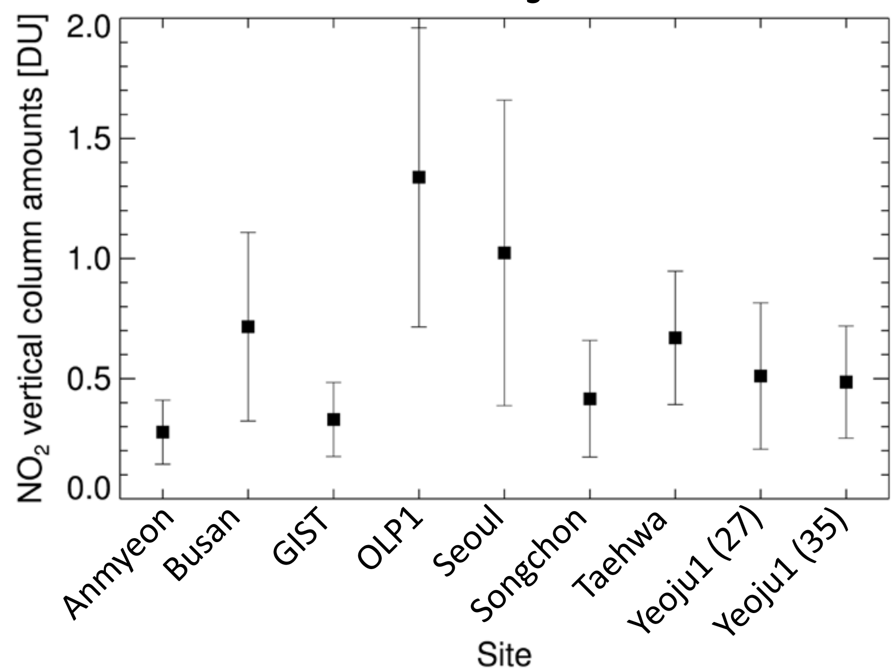
- O_3 shows larger spatial variation than NO_2.



Mean total column NO_2 during KORUS-AQ

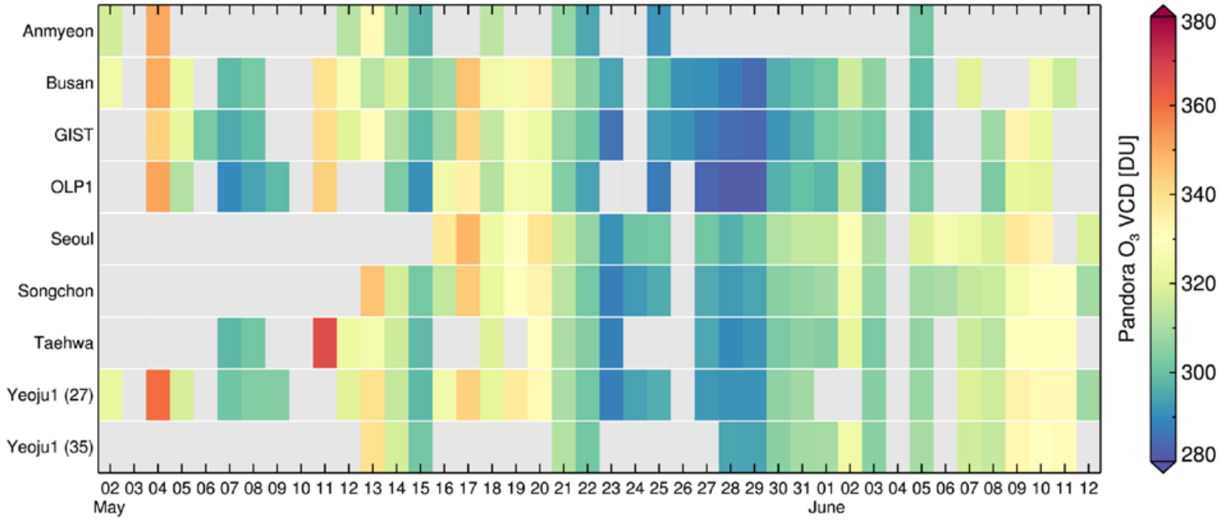


Mean total column O_3 during KORUS-AQ



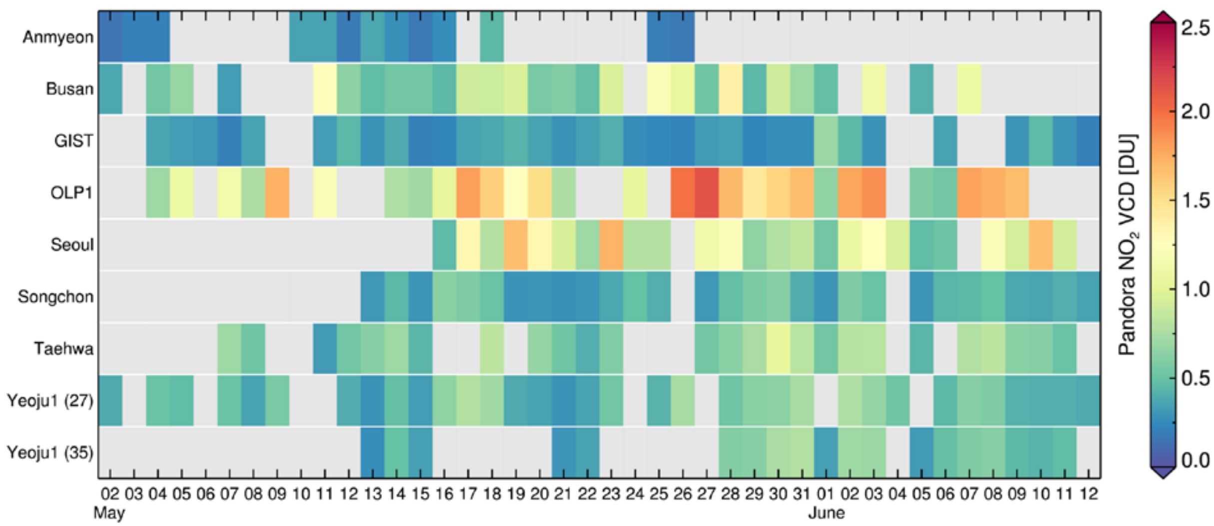
KORUS-AQ campaign

Daily variation of total column O_3 at each Pandora site



- Similar daily variations are found among the Pandora sites.
- Total column O_3 shows its minimum value in the middle of the campaign (around May 23 – May 29)

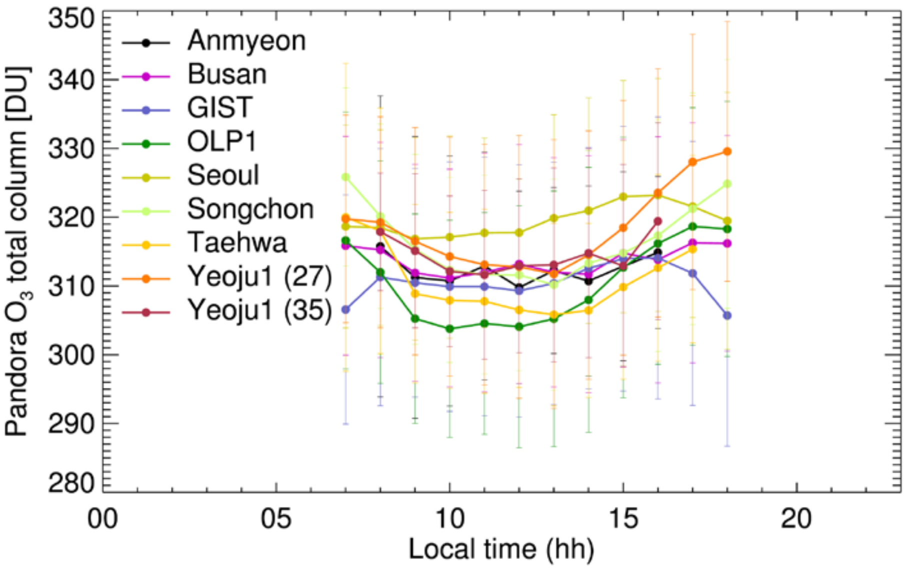
Daily variation of total column NO_2 at each Pandora site



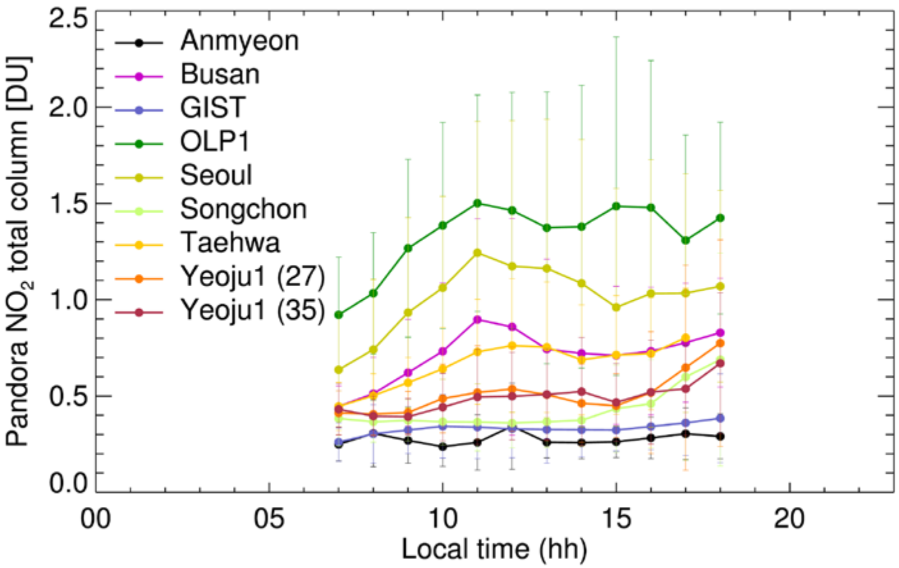
- Olympic Park (OLP1) site, which is located in Seoul, shows the highest NO_2 level, revealing the influence of local emissions to the total column NO_2

KORUS-AQ campaign

Mean diurnal variation of O_3 at each Pandora site



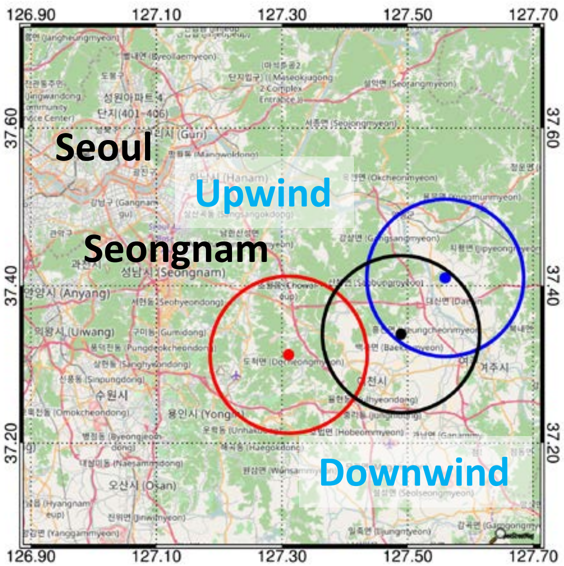
Mean diurnal variation of NO_2 at each Pandora site



- Diurnal variations are found, probably reflecting the effect of solar zenith angle difference.

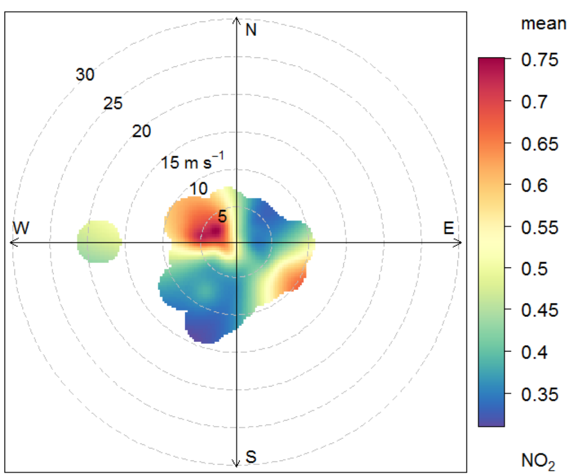
- High NO_2 concentrations are found in Seoul (Seoul and OLP1).
- Diurnal variability is stronger in urban sites (OLP1, Seoul, and Busan) than rural sites (GIST and Anmyeon) due to traffic.

KORUS-AQ campaign
: Variation of Pandora tropospheric NO_2 due to wind during KORUS-AQ

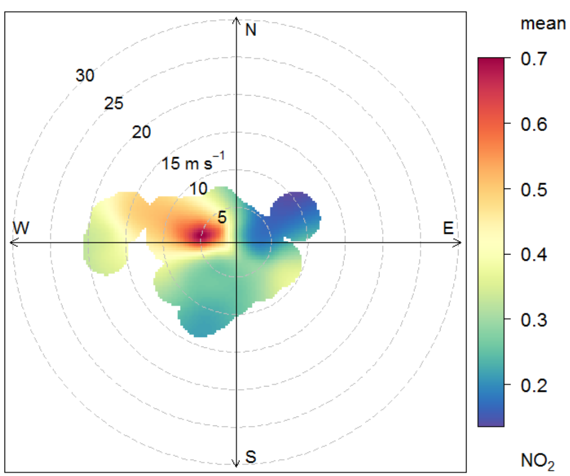


- There was not a Pandora at HUFS during KORUS-AQ, but four instruments (two at Yeoju1) had observed NO_2 in the downwind region of Seoul.
- NO_2 levels at Taehwa, Yeoju1, and Songchon sites consistently increased with westerly wind conditions.

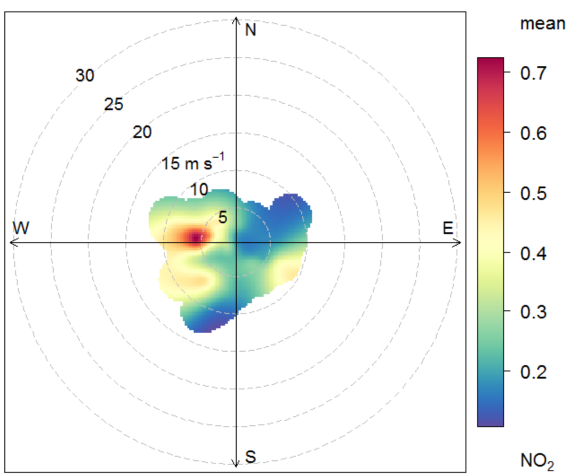
Taehwa



Yeoju1 (27)

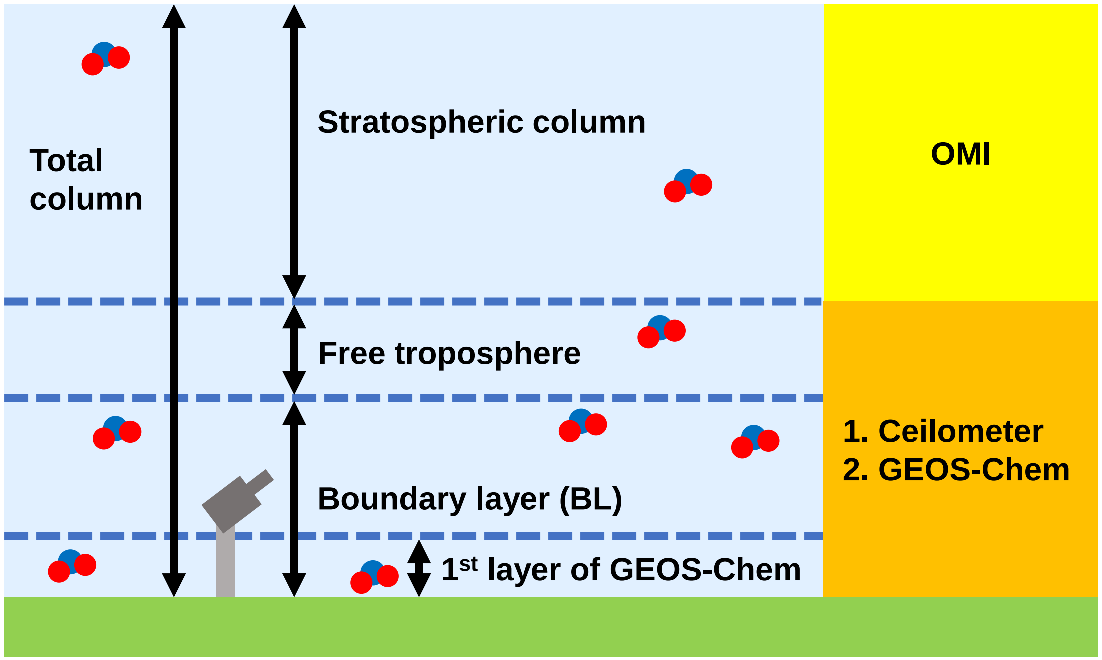


Songchon



KORUS-AQ campaign: Estimation of surface NO_2 mixing ratio

How to estimate surface mixing ratio from Pandora total column



Pandora tropospheric NO_2 ($PtrNO_2$)
= Pandora total NO_2 ($PtoNO_2$) –
OMI stratospheric NO_2 ($OstNO_2$)

1. Ceilometer

- Assume negligible NO_2 conc. in the free troposphere.
- Assume homogeneity of NO_2 conc. over the BL.

2. GEOS-Chem

- Consider vertical gradient of NO_2 conc. over the troposphere.

[Courtesy of Seungun Lee and Rokjin Park]

1. Using ceilometer BL height

$$Surface\,VMR = \frac{PtrNO_2}{BLH \times AD\_P}$$

[Knepp et al. (2013)]

BLH: BL height
AD_B: Air number density in the BL

2. Using GEOS-Chem NO_2 vertical profile

$$Surface\,VMR = \frac{PtrNO_2 \times \frac{GfNO_2}{GTrNO_2}}{FLH \times AD\_F}$$

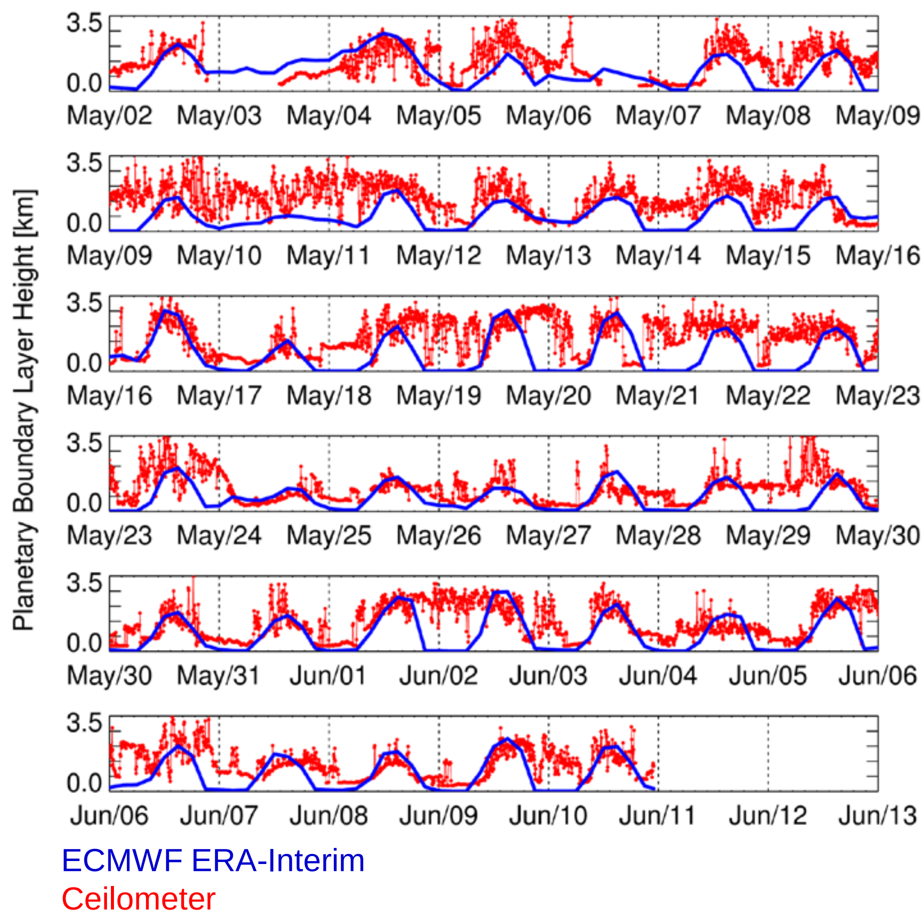
$GTrNO_2$: Integrated NO_2 VMR from GEOS-Chem over the troposphere
$GfNO_2$: NO_2 VMR from the first layer of GEOS-Chem
FLH: height of the first layer of GEOS-Chem
AD_F: Air number density in the first layer of GEOS-Chem

KORUS-AQ campaign: Estimation of surface NO_2 mixing ratio

- Two boundary layer data show different temporal variations. $Surface\,VMR = \dfrac{PtrNO_2}{BLH \times AD\_P}$

PBLH datasets

Dataset	Temporal resolution	Spatial resolution
ERA-Interim from ECMWF	3 hours	0.125° × 0.125°
Ceilometer (in Seoul site)	5 min	–

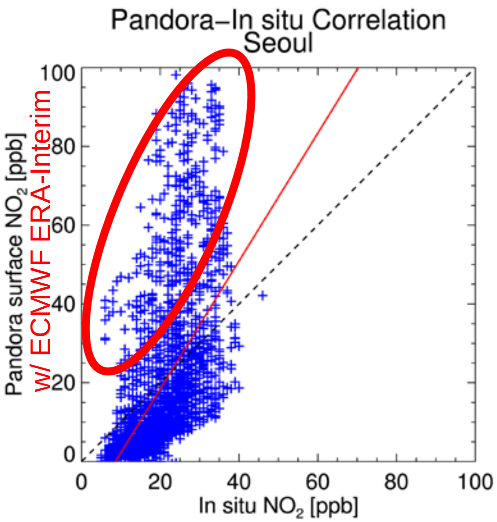


[Courtesy of Junhong Lee and Jinkyu Hong]

KORUS-AQ campaign: Evaluation of Pandora NO_2 surface mixing ratio

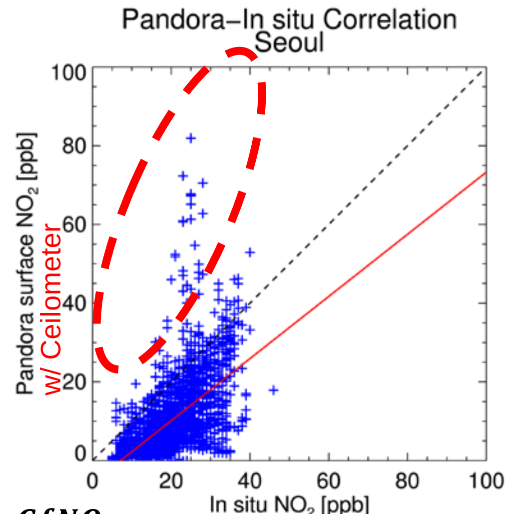
$$Surface\,VMR = \frac{PtrNO_2}{BLH \times AD\_P}$$

Boundary layer height from ECMWF ERA-Interim



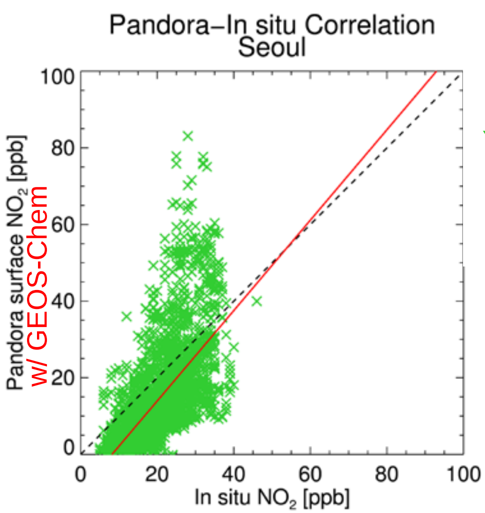
N=2863
Y=1.62x-13.95
R=0.57
RMSE=17.48

Boundary layer height from Ceilometer

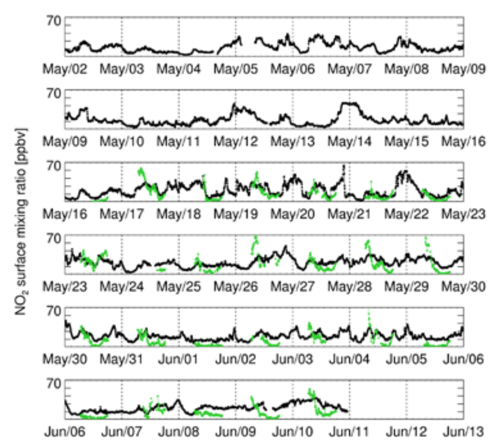


N=2804
Y=0.79x-5.64
R=0.61
RMSE=12.36

$$Surface\,VMR = \frac{PtrNO_2 \times \frac{GfNO_2}{GTrNO_2}}{FLH \times AD\_F}$$



N=2863
Y=1.18x-9.67
R=0.66
RMSE=11.51



AirKorea (in-situ)
Estimated from Pandora

Good agreement
→ but occasional peak
in the morning

Thank You!