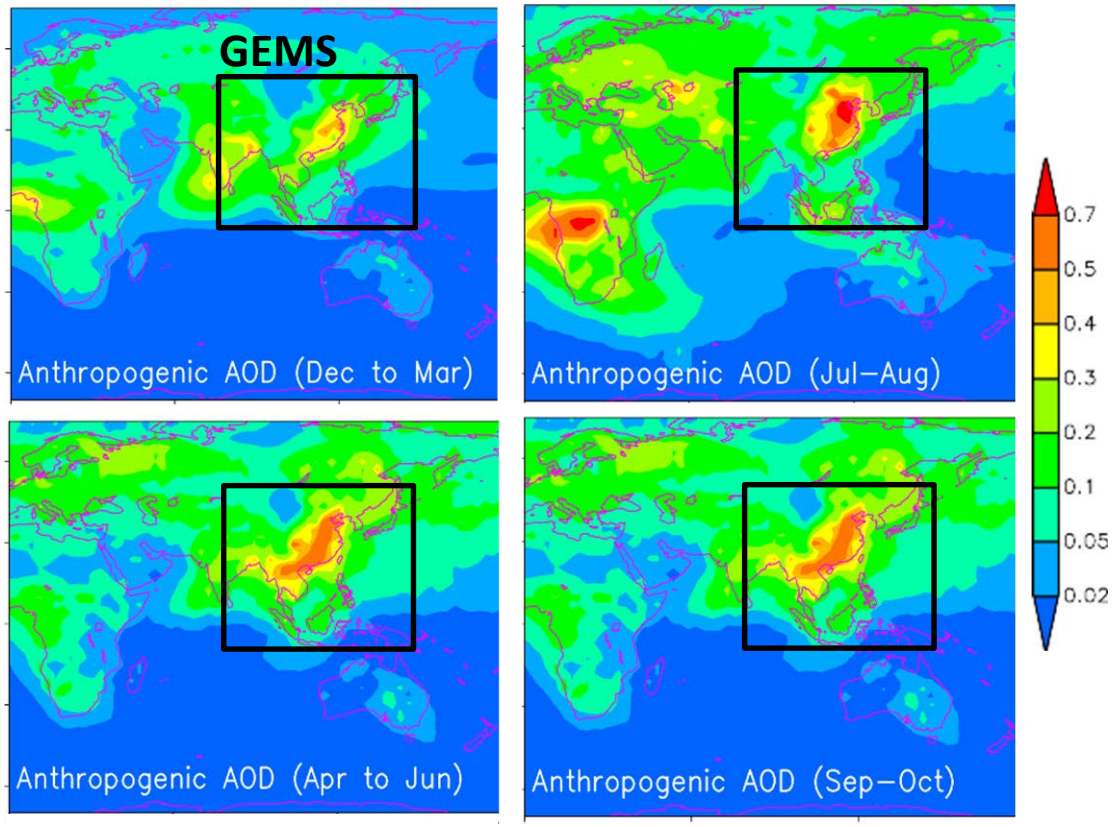
Ground Networks for Trace Gases and Aerosols in Asia



	Korea GEMS
Orbit	Geostationary
Domain	Asia-Pacific
Revisit	1 hour
Status	Instrument delivery 2017
Launch	2019
Payload	UV-Vis 300-500 nm
Products	O_3, NO_2, SO_2, HCHO, AOD
Spatial Sampling	3.5 km N/S x 8 km E/W @38N
Nominal product resolution	7 km N/S x 8 km E/W @38N (gas), 3.5 km N/S x 8 km E/W @38N (aerosol)

Sang-Woo Kim[1], Jhoon Kim[2] , Chang Keun Song[3], Heesung Chong[2] and contributed by many experts
Seoul National University (sangwookim@snu.ac.kr), [2]Yonsei University, [3]UNIST

Baseline GEMS products (16)

Product	Importance	Min (cm^{-2})	Max (cm^{-2})	Nominal (cm^{-2})	Accuracy	Window (nm)	Spatial Resolution (km^2) @S eoul	SZA (deg)	Algorithm
NO_2	O_3 precursor	$3x10^{13}$	$1x10^{17}$	$1x10^{14}$	$1x10^{15}$ cm^{-2}	425-450	7 x 8 x 2 pixels	< 70	BOAS DOAS
SO_2	Aerosol precursor Volcano	$6x10^{8}$	$1x10^{17}$	$6x10^{14}$	$1x10^{16}$ cm^{-2}	310-330	7 x 8 x 4 pixels x 3 hours	< 50 (60*)	
HCHO	VOC proxy	$1x10^{15}$	$3x10^{16}$	$3x10^{15}$	$1x10^{16}$ cm^{-2}	327-357	7 x 8 x 4 pixels	< 50 (60*)	
CHOCHO							7 x 8 x 4 px	< 50	
TropLO3 TropUO3 StratO3 TotalO3	Oxidant Pollutant O_3 layer	$4x10^{17}$	$2x10^{18}$	$1x10^{18}$	3%(TOz) 5%(Stra) 20(Trop)	300-340	7 x 8	< 70	OE TOMS
AOD AI SSA AEH	Air quality Climate	0 (AOD)	5 (AOD)	0.2 (AOD)	20% or 0.1@ 400nm	300-500	3.5 x 8	< 70	Multi-l O_2O_2 Ring
[Clouds] ECF CCP	Retrieval Climate	0 (COD)	50 (COD)	17 (COD)		300-500	7 x 8	< 70	O_2O_2 RRS
Surface Property	Environ- ment	0	1	-		300-500	3.5 x 8	< 70	Multi-l
UVI Solar Irad.	Public health	0	12	-			7 x 8	< 70	

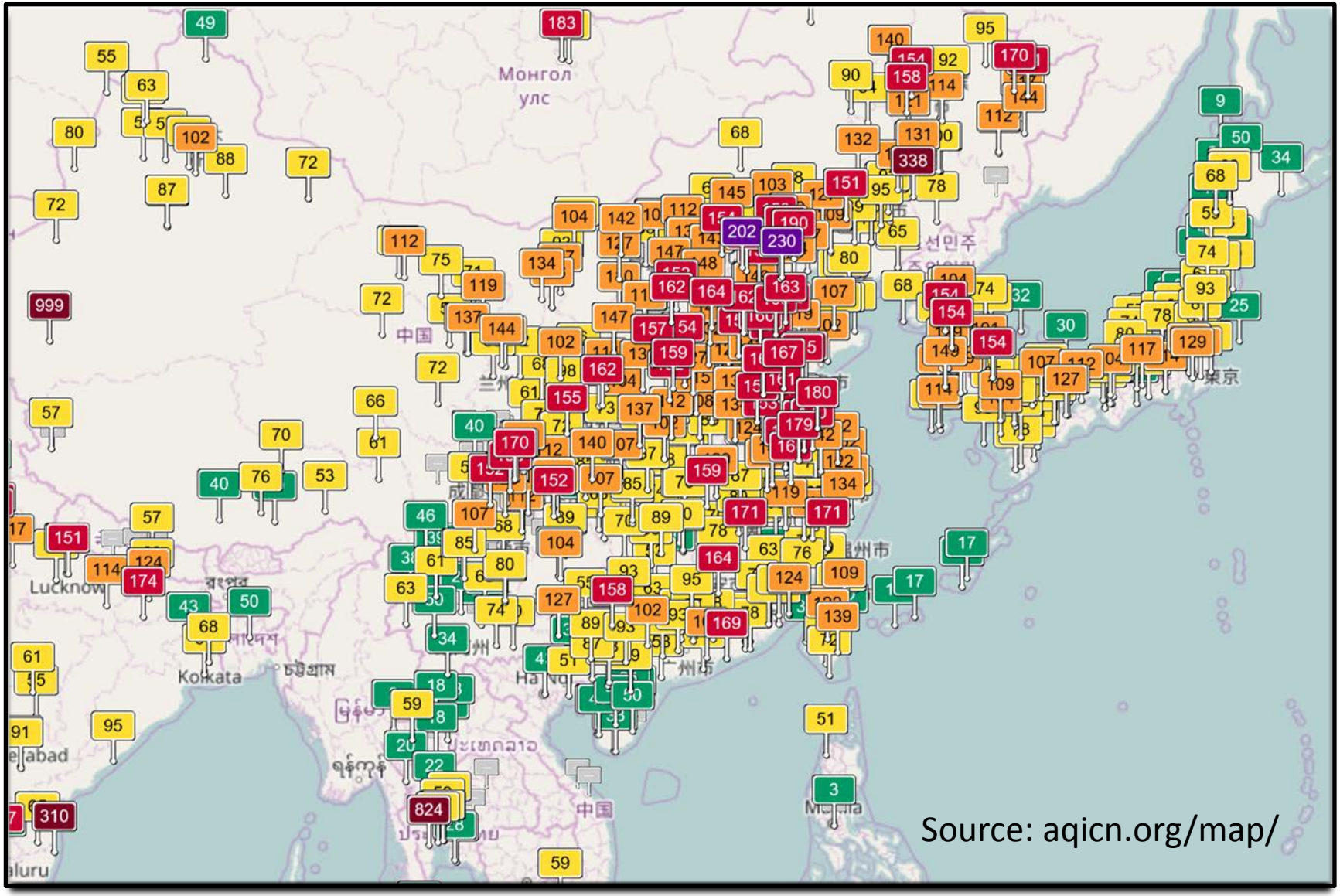
- **Networking Ground-based Measurements for validation**: Comparisons with in situ and remotely sensed data collected over a distributed network of ground validation sites

→ **Trace gases**: PANDORA, MAX-DOAS, Brewer, near-surface in-situ… (not well established yet)

→ **Aerosol**: Sky radiometer, Lidar, near-surface in-situ…

Air Quality Index over East Asia

(estimated from near-surface air quality measurements)

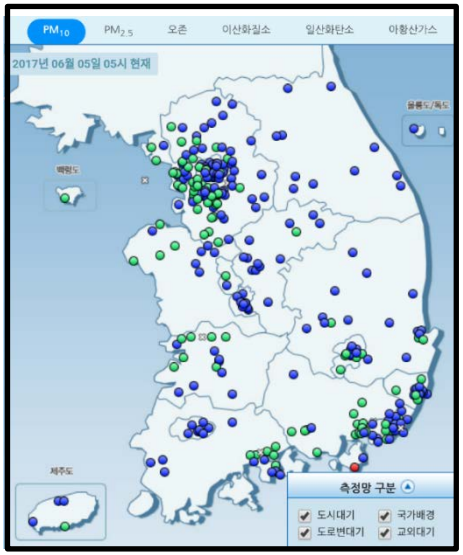


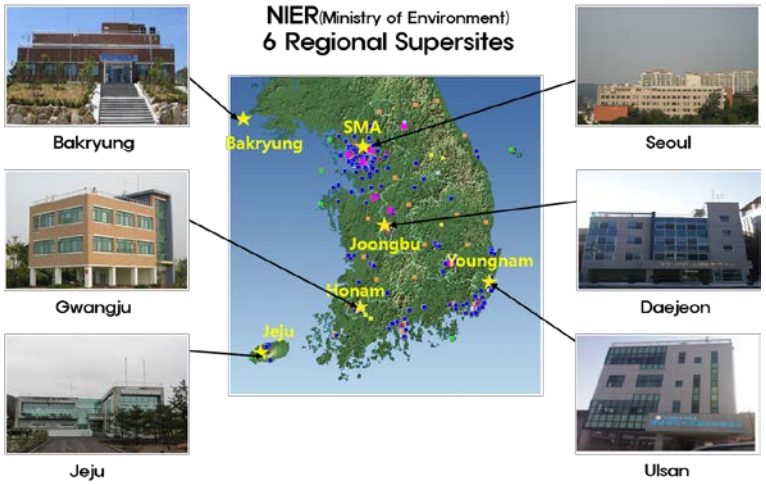
Comparisons with national air quality monitoring sites

Korea (NIER)

Urban (>300 sites), Others(>200 sites), Supersite(6 sites)

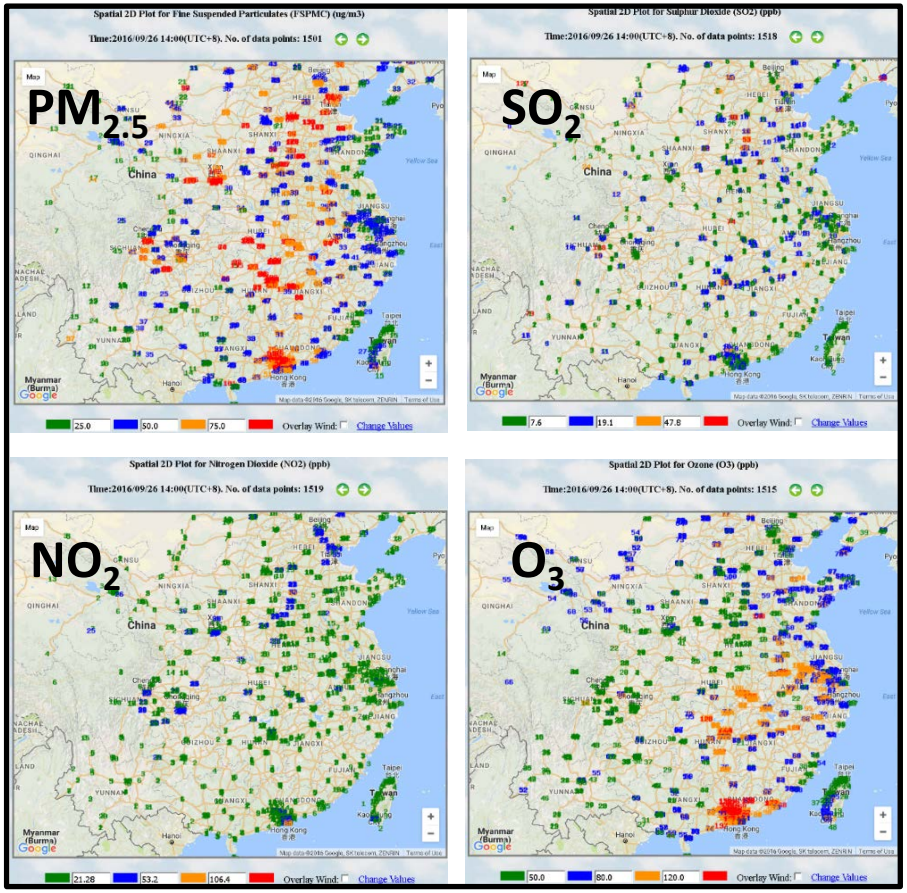
NO_2, SO_2, O_3, PM_{10}, $PM_{2.5}$ (>350 sites) and VOCs(>50 sites), PAHs, etc.



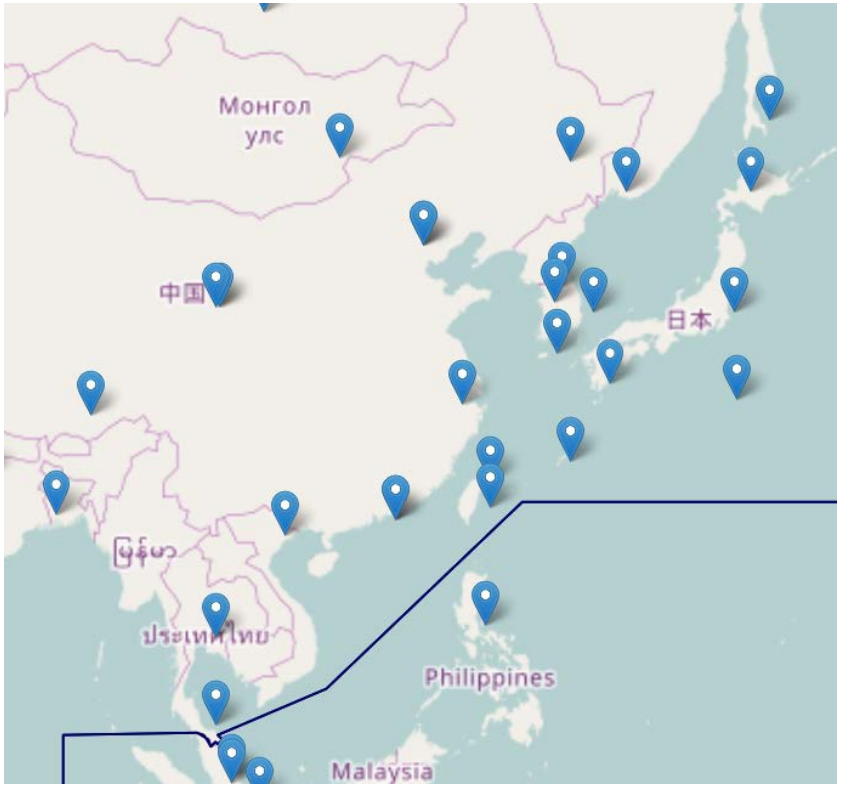


China (CNEMC)

1500 stations (as of Sept. 2016)



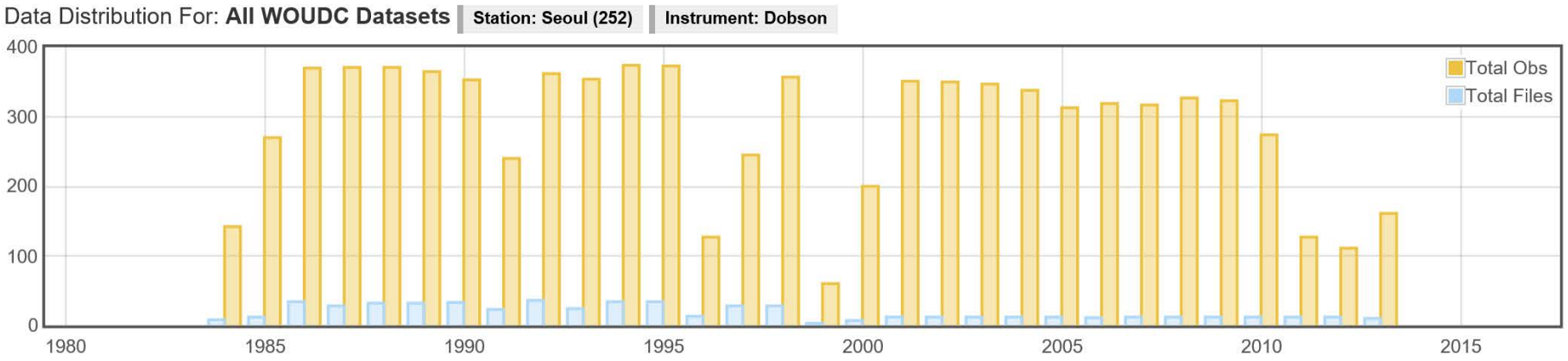
Courtesy of Changqing Lin (7th GEMS Science Meeting, 2016)
http://envf.ust.hk/dataview/gts/current/

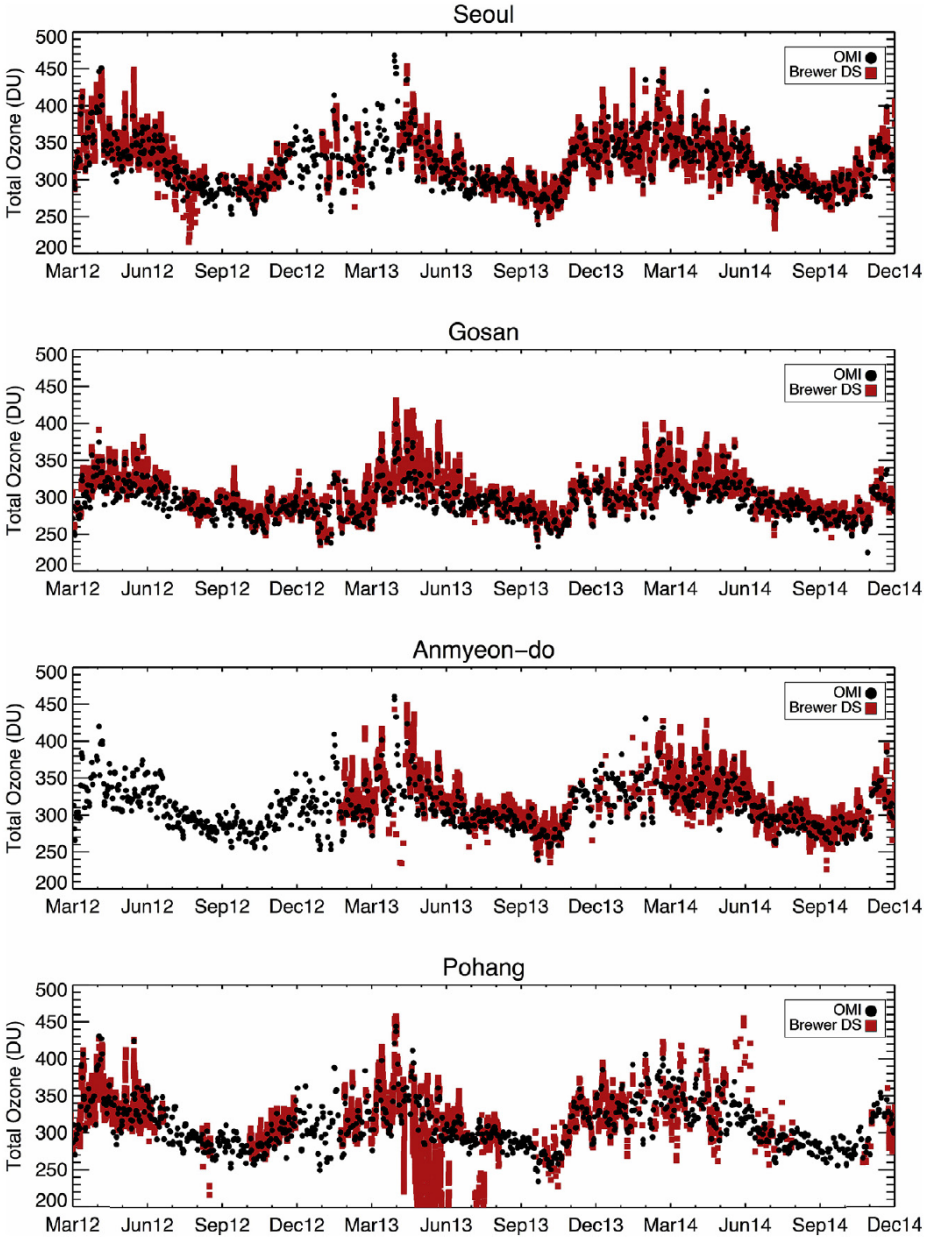


WMO/GAW

World Ozone and Ultraviolet Radiation Data Centre (WOUDC)

http://www.woudc.org/home.php





Time series of OMI (Black) and Brewer direct sun (DS) total ozone measurements over four stations in Korea during the DRAGON campaign.

Contents lists available at ScienceDirect
Atmospheric Environment
2017
journal homepage: www.elsevier.com/locate/atmosenv

Validation of Brewer and Pandora measurements using OMI total ozone

Kanghyun Baek [a], Jae H. Kim [a, *], Jay R. Herman [b], David P. Haffner [c], Jhoon Kim [d]

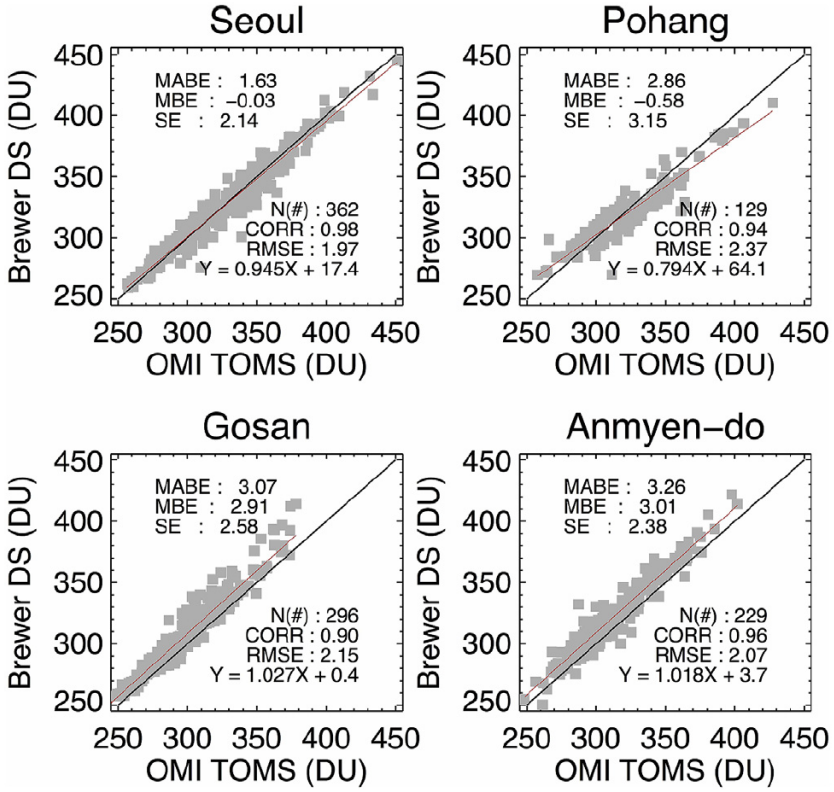
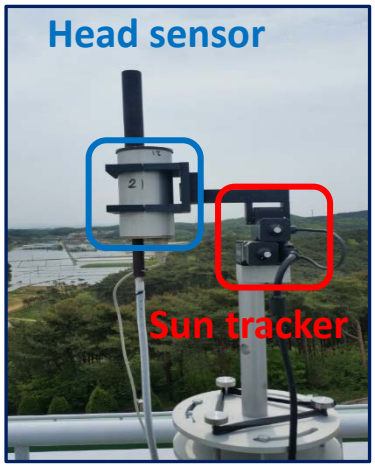
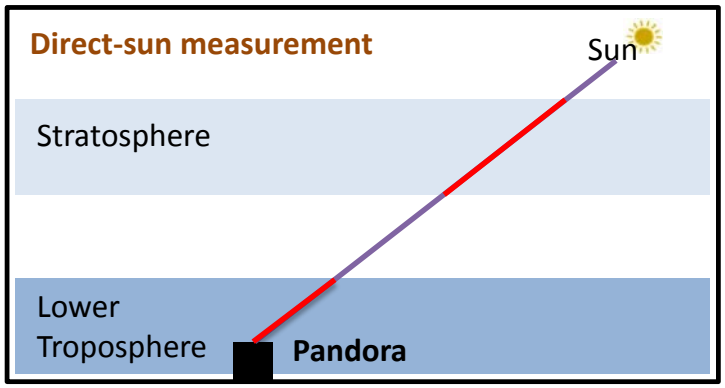


Fig. 3. Scatter plots of Brewer and OMI total ozone data over South Korea. The red and black lines represent the regression and unit line, respectively. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Pandora measurements in Korea

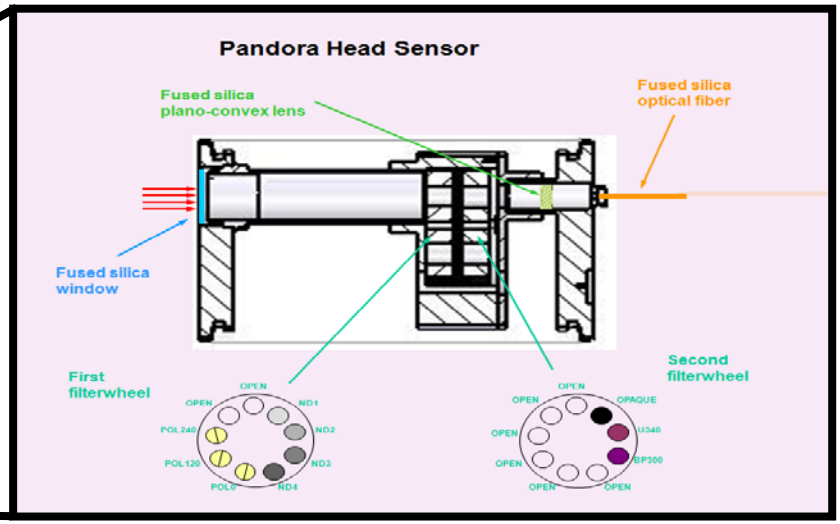


FOV	1.6°
FWHM	0.6nm
Wavelength range	280-525nm
Correction of Stray light	BP300 Filter (280-320nm) U340 Filter (280-380nm)
Products	Total column of O_3, NO_2, and HCHO

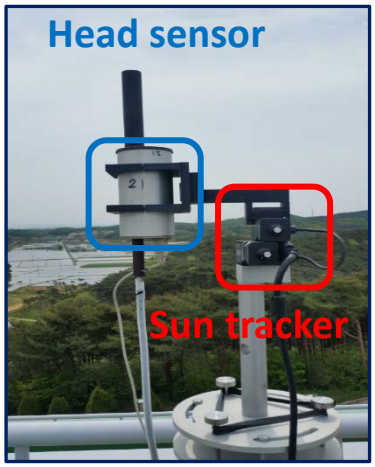


Courtesy of Prof. H.-L. Lee

Pandora Head Sensor



Pandora measurements in Korea



DRAGON Campaign (spring 2012)

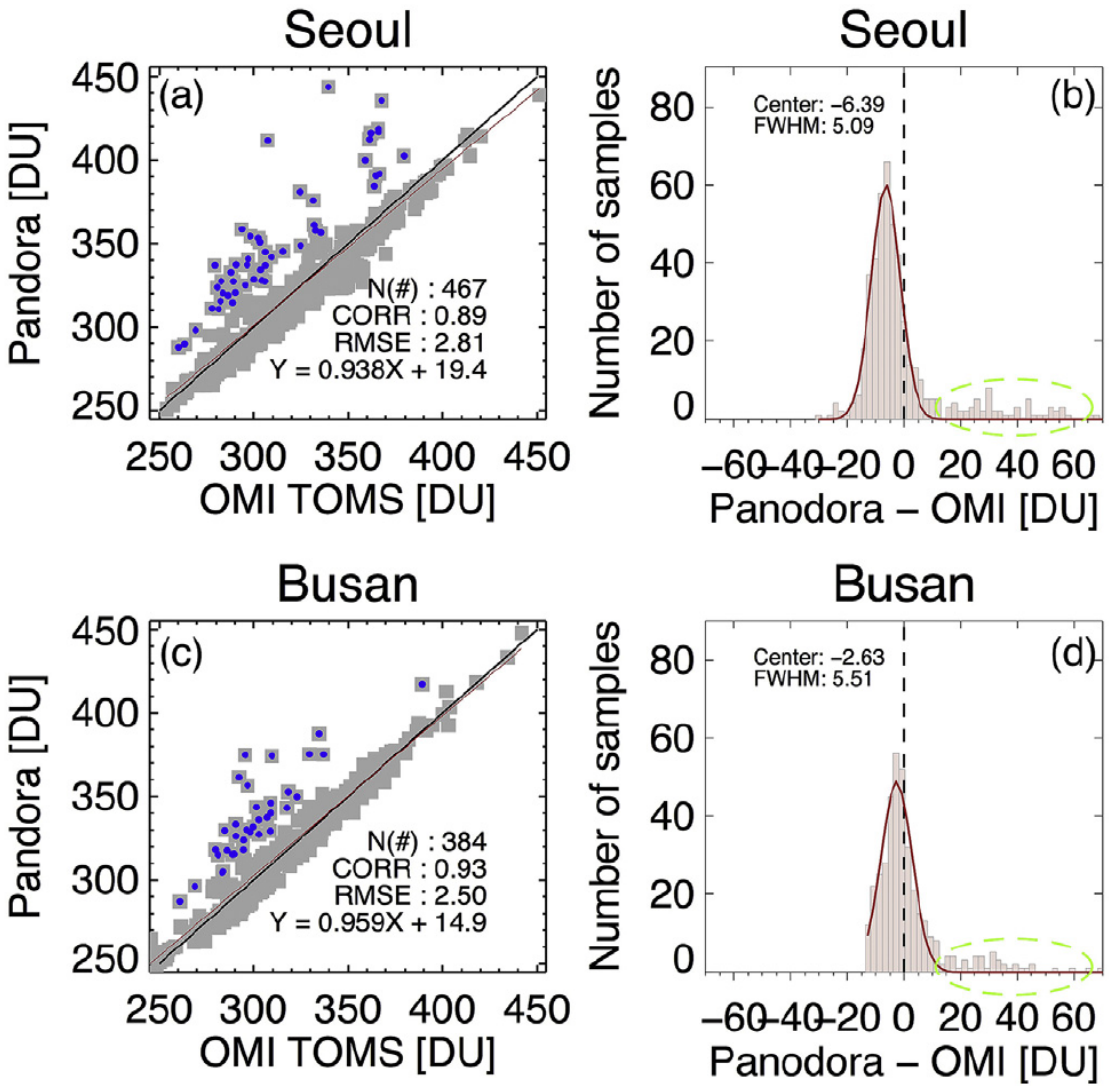
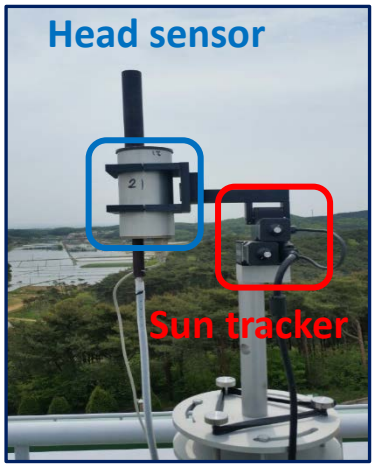


Fig. 6. Left: A comparison of the Pandora with OMI at Seoul and Busan. The black and red lines represent the unit and linear fitting lines, respectively. Right: Histogram of difference between Pandora and OMI TOMS TCO. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

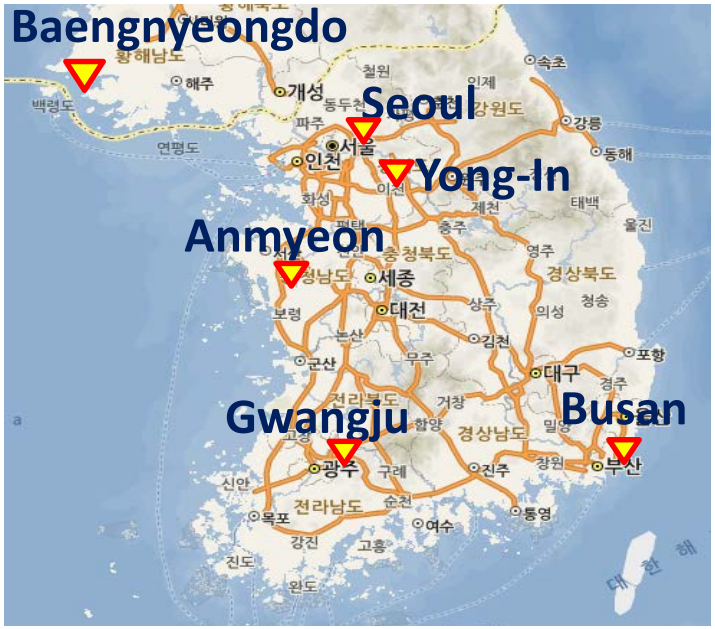
Baek et al. (2017)

Pandora measurements in Korea

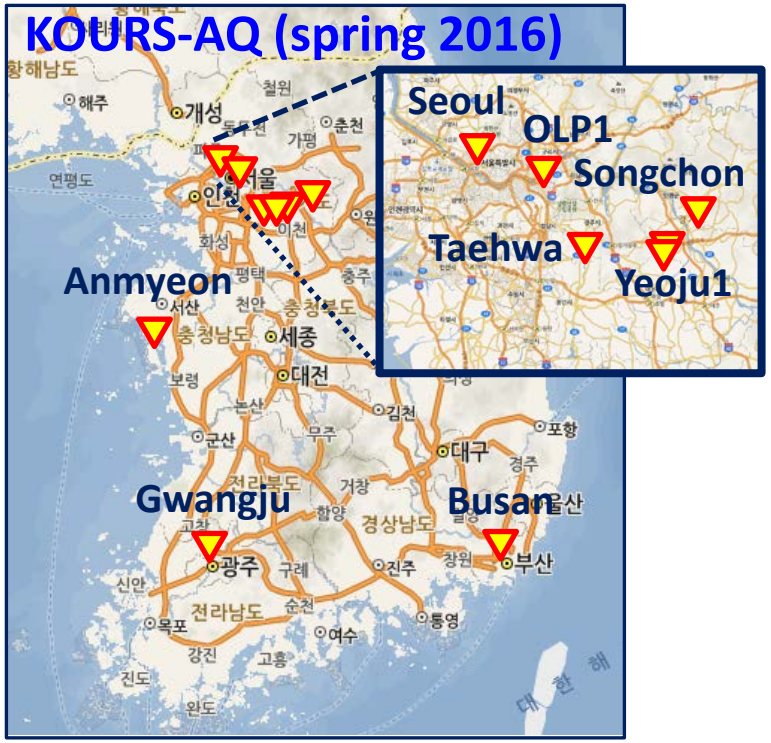


FOV	1.6°
FWHM	0.6nm
Wavelength range	280-525nm
Correction of Stray light	BP300 Filter (280-320nm) U340 Filter (280-380nm)
Products	Total column of O_3, NO_2, and HCHO

MAPS-Seoul campaign (spring 2015)

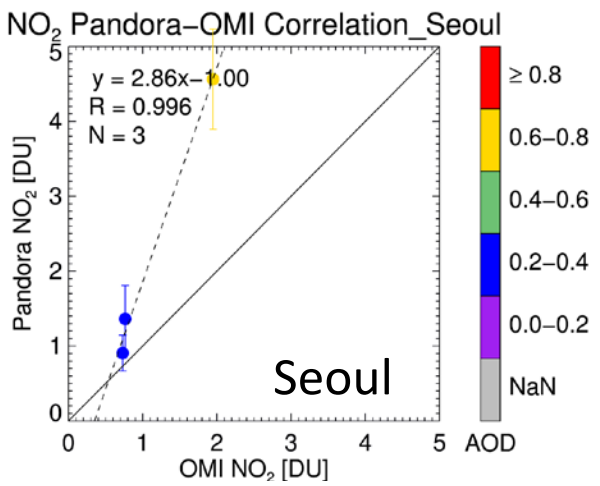


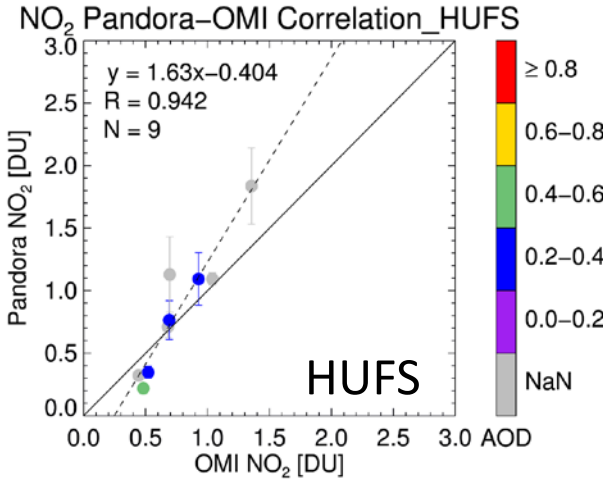
KOURS-AQ (spring 2016)

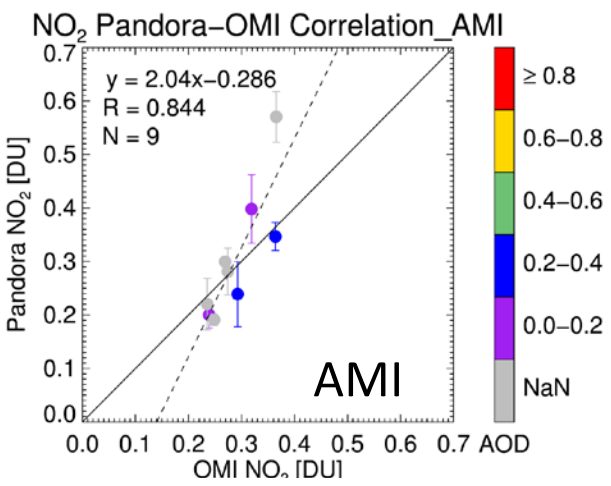


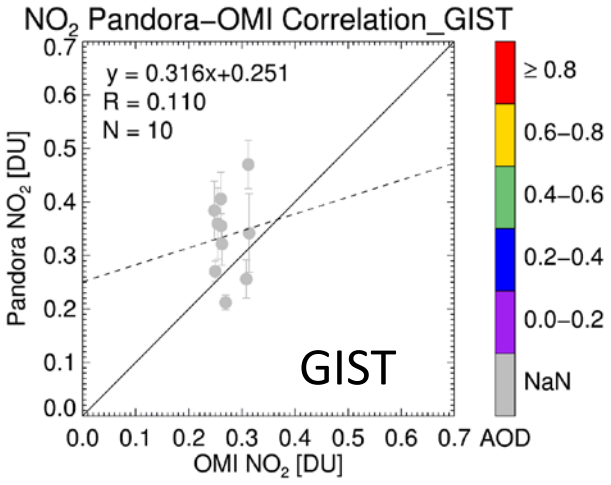
Pandora measurements during the MAPS-Seoul campaign (May- June 2015)

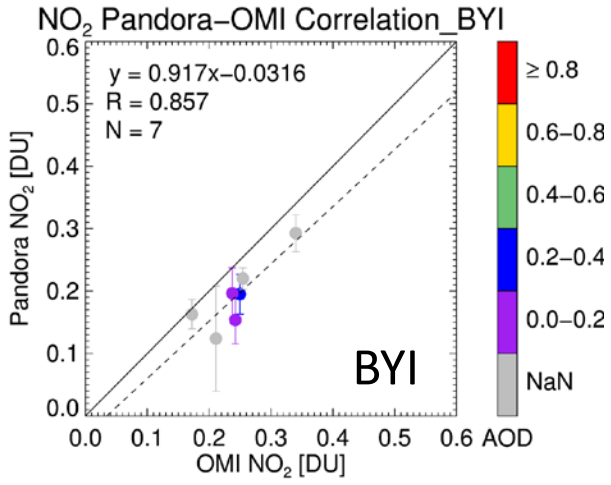
NO_2 : Pandora vs. OMI

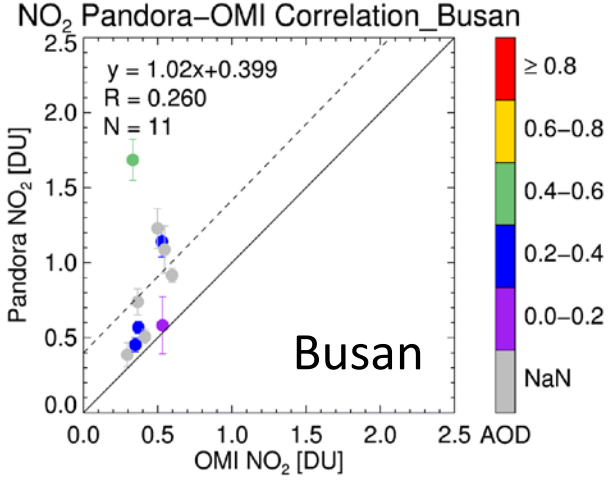








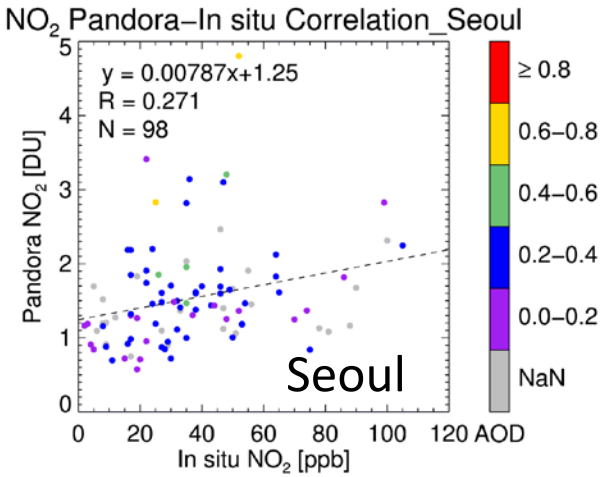


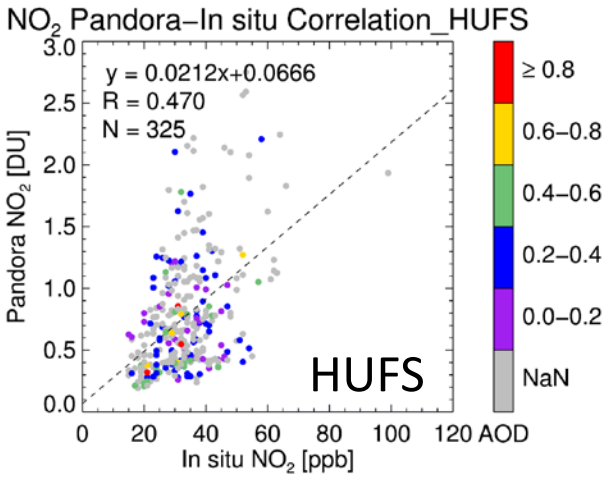


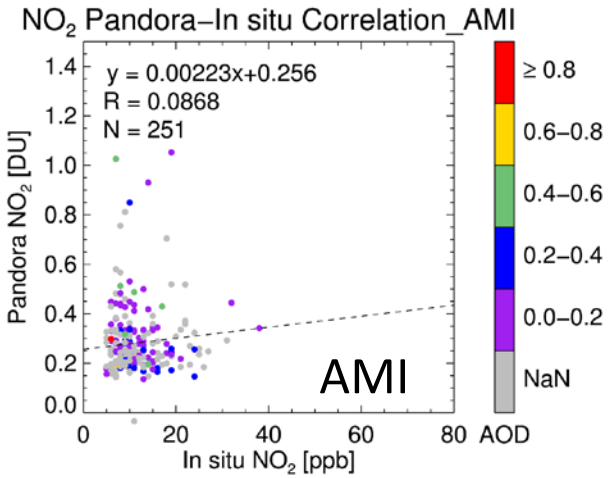
Courtesy of Prof. J. Kim

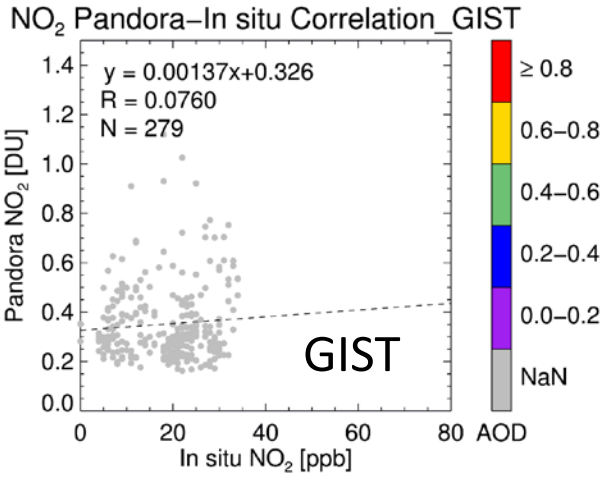
Pandora measurements during the MAPS-Seoul campaign (May- June 2015)

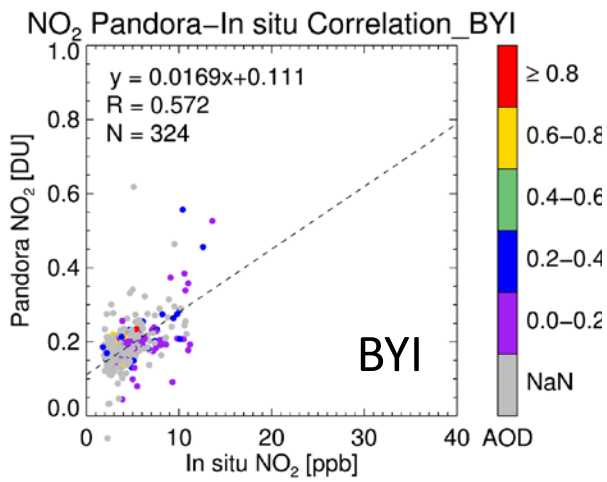
NO_2 : Pandora vs. surface in-situ

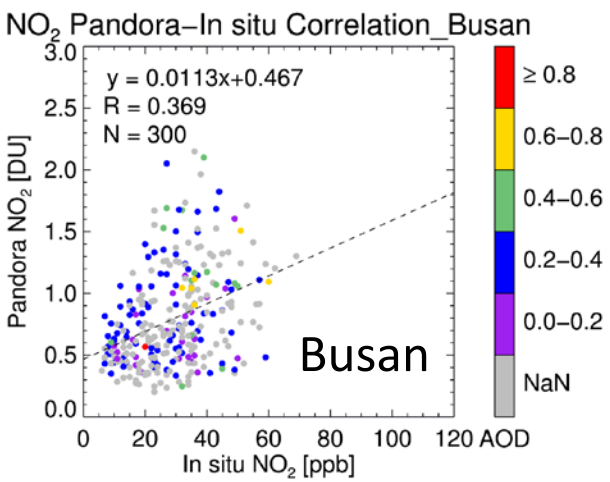








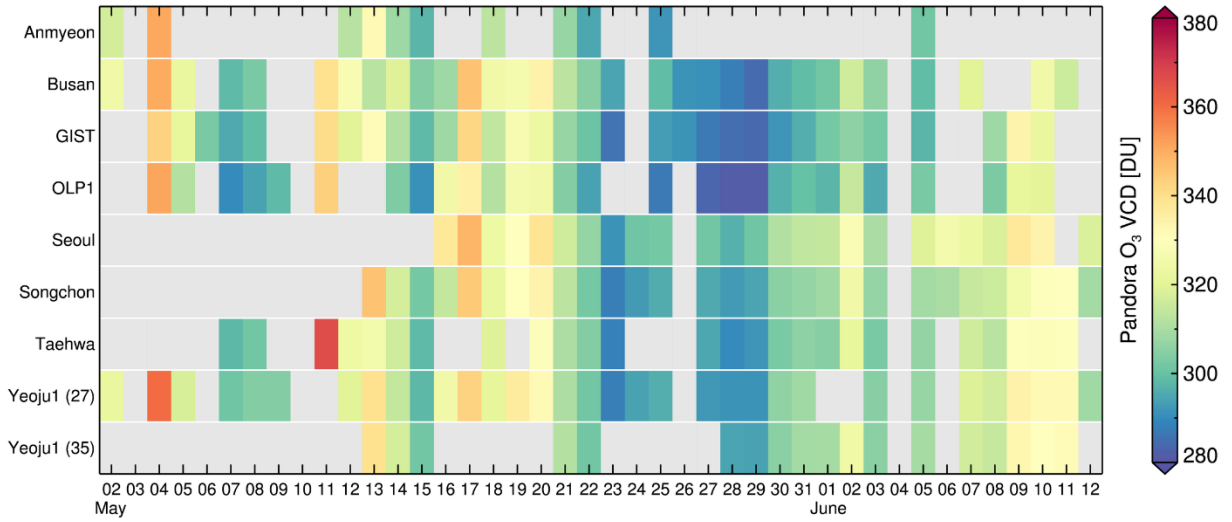




Courtesy of Prof. J. Kim

Daily variations of total column O_3 and NO_2 during KORUS-AQ

Daily variation of total column O_3 at each Pandora site

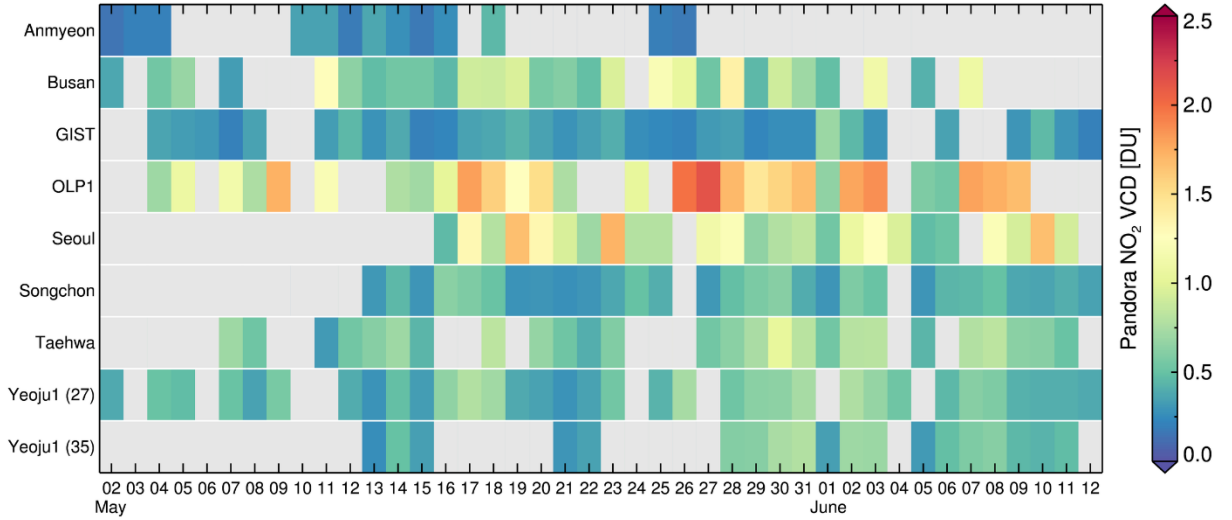


- Color indicates daily mean total column O_3.

✓ 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



- Color indicates daily mean total column NO_2.

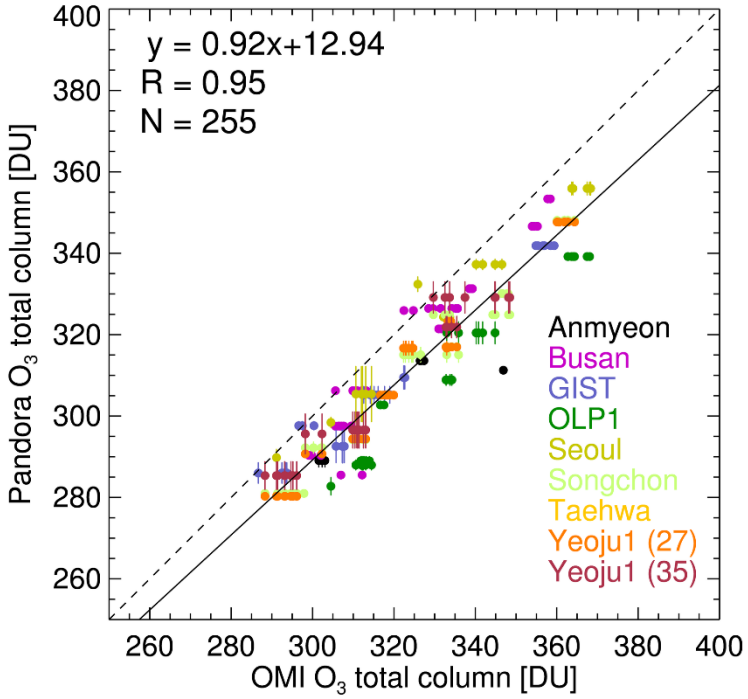
✓ There exists a larger horizontal spatial gradient than O_3.

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

Comparison between Pandora and other instruments during KORUS-AQ

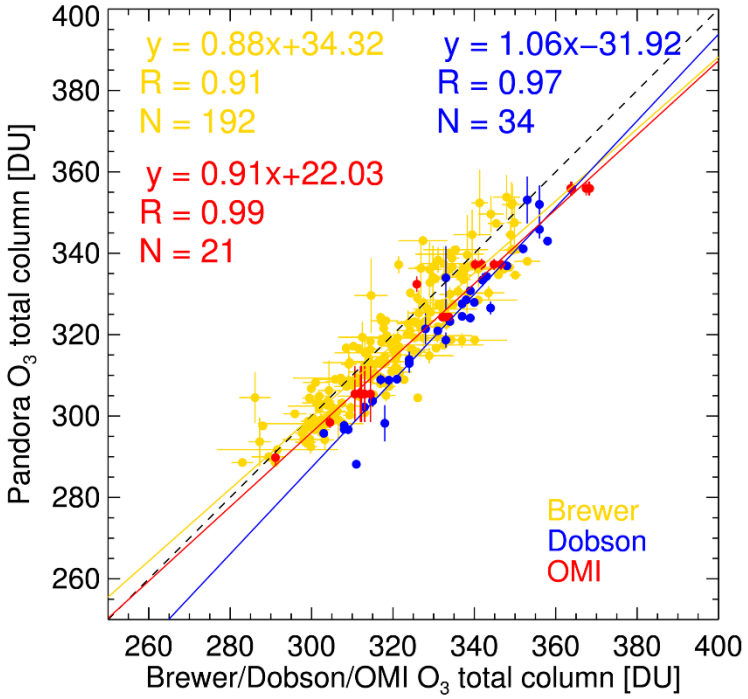
O_3 comparison

[Pandora vs. OMI at all sites]



- **Temporal co-location**: Average Pandora O_3 within ±30 min from OMI overpass time
- **Spatial co-location**: OMI pixels within 30 km from each Pandora site
- **Error bar**: standard deviation (1-σ)

[Pandora vs. Brewer/Dobson/OMI at Seoul site]



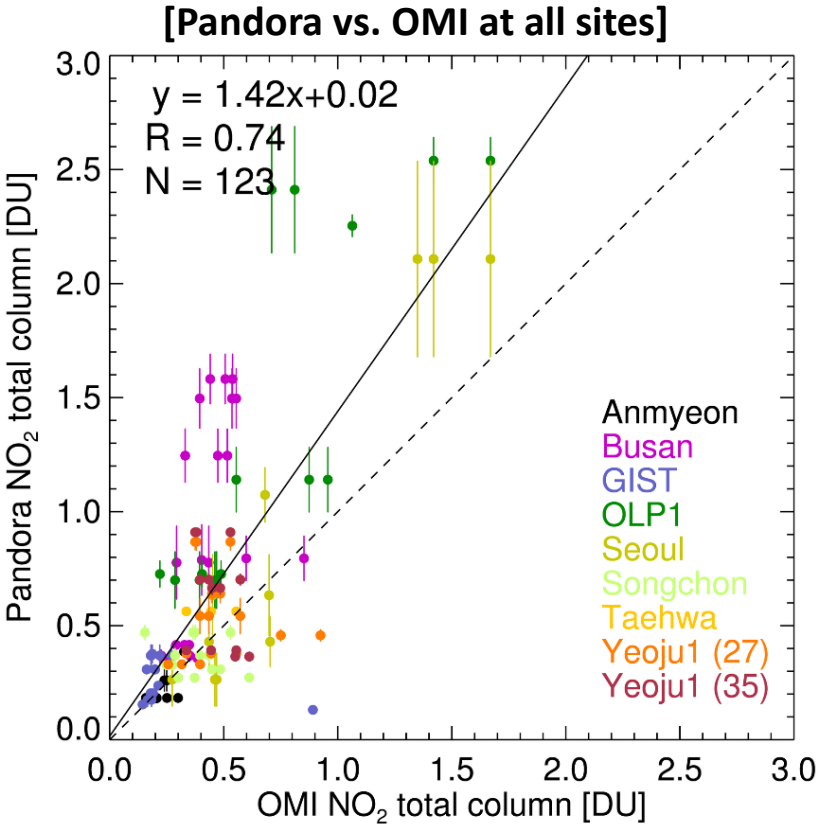
- **Dobson temporal co-location**: Average Pandora O_3 within ±30 min from Dobson observation time
- **Brewer temporal co-location**: hourly mean
- **Error bar**: standard deviation (1-σ)

✓ Pandora and other instruments show high correlations (R > 0.9), however Pandora tends to slightly underestimate O_3.

Courtesy of Prof. J. Kim

Comparison between Pandora and other instruments during KORUS-AQ

NO_2 comparison



- **Temporal co-location**: Average Pandora O_3 within $\pm$15 min from OMI overpass time
- **Spatial co-location**: OMI pixels within 20 km from each Pandora site
- **Error bar**: standard deviation (1-σ)

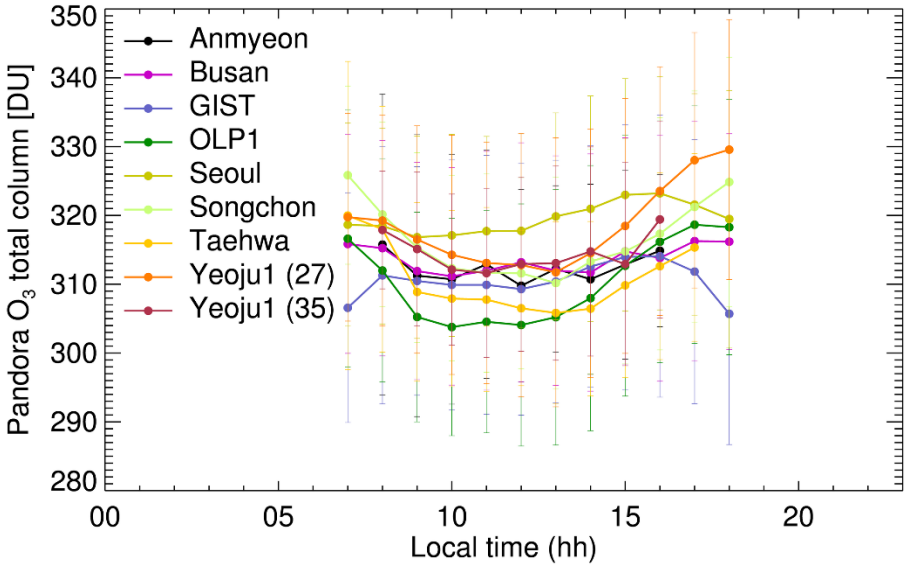
✓ OMI underestimates at high values of NO_2.

✓ Underestimation of OMI is partly due to coarse horizontal resolution of OMI pixel and chemical transport model grid used for computing AMF of operational products.

Courtesy of Prof. J. Kim

Diurnal variations of total column O_3 and NO_2 during KORUS-AQ

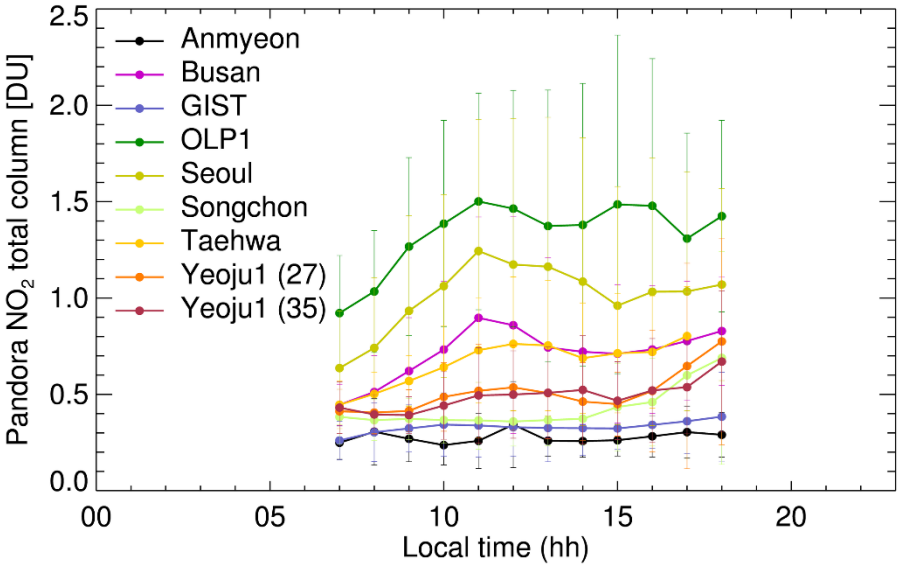
Mean diurnal variation of O_3 at each Pandora site



- **Error bar**: standard deviation (1-σ)

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

Mean diurnal variation of NO_2 at each Pandora site



- **Error bar**: standard deviation (1-σ)

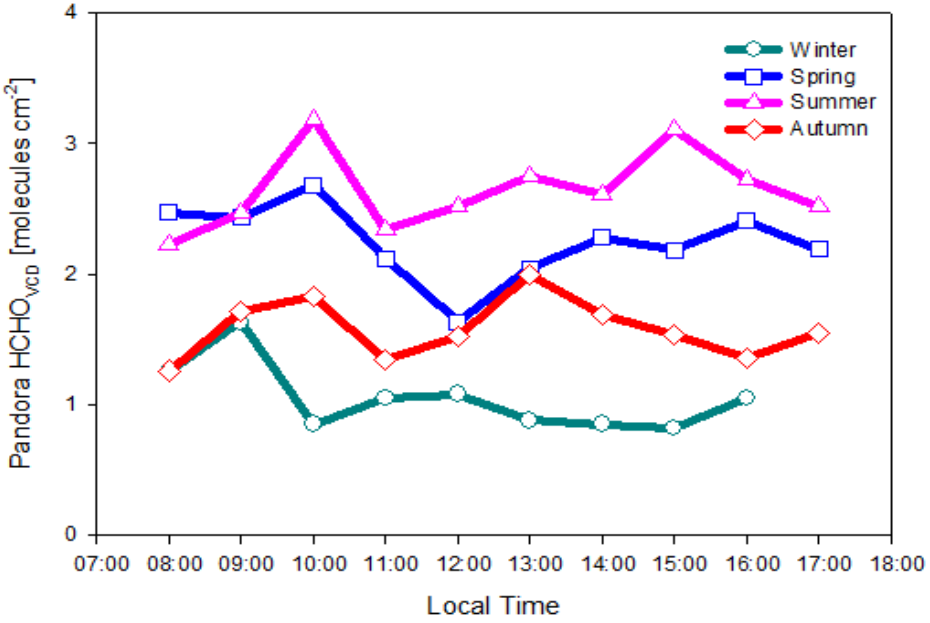
✓ High NO_2 concentrations are found in Seoul (Seoul and OLP1).

✓ Diurnal variability is more distinct in urban sites (OLP1, Seoul, and Busan) than rural sites (GIST and Anmyeon) due to traffic.

Courtesy of Prof. J. Kim

HCHO retrieval from Pandora measurements in Seoul, Korea

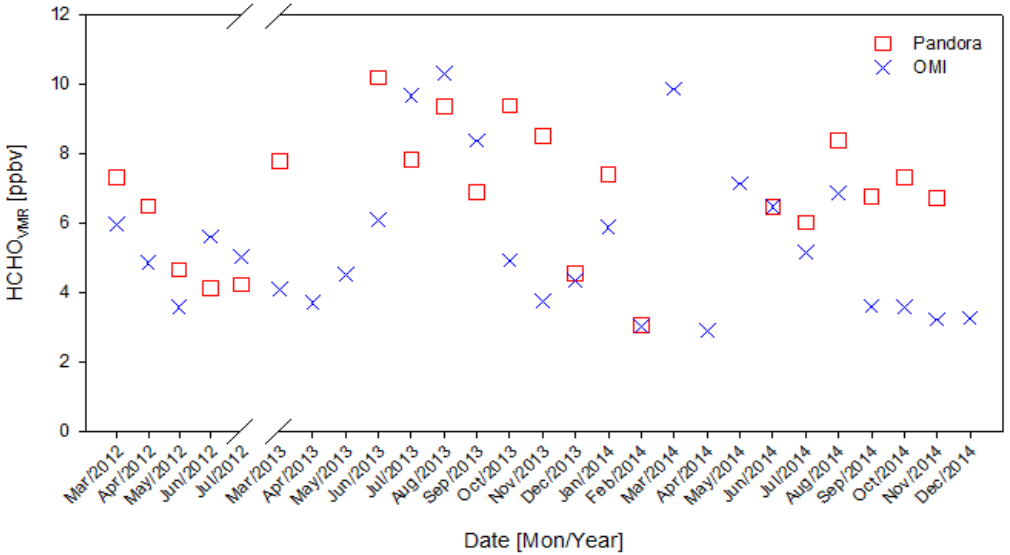
Diurnal Variation



- Seasonal characteristics of HCHO column diurnal variation between 2012 and 2014 in Korea.
- Traffic emission leads to a peak in the morning

[*Park et al.,* submitted to JGR]

Monthly Variation

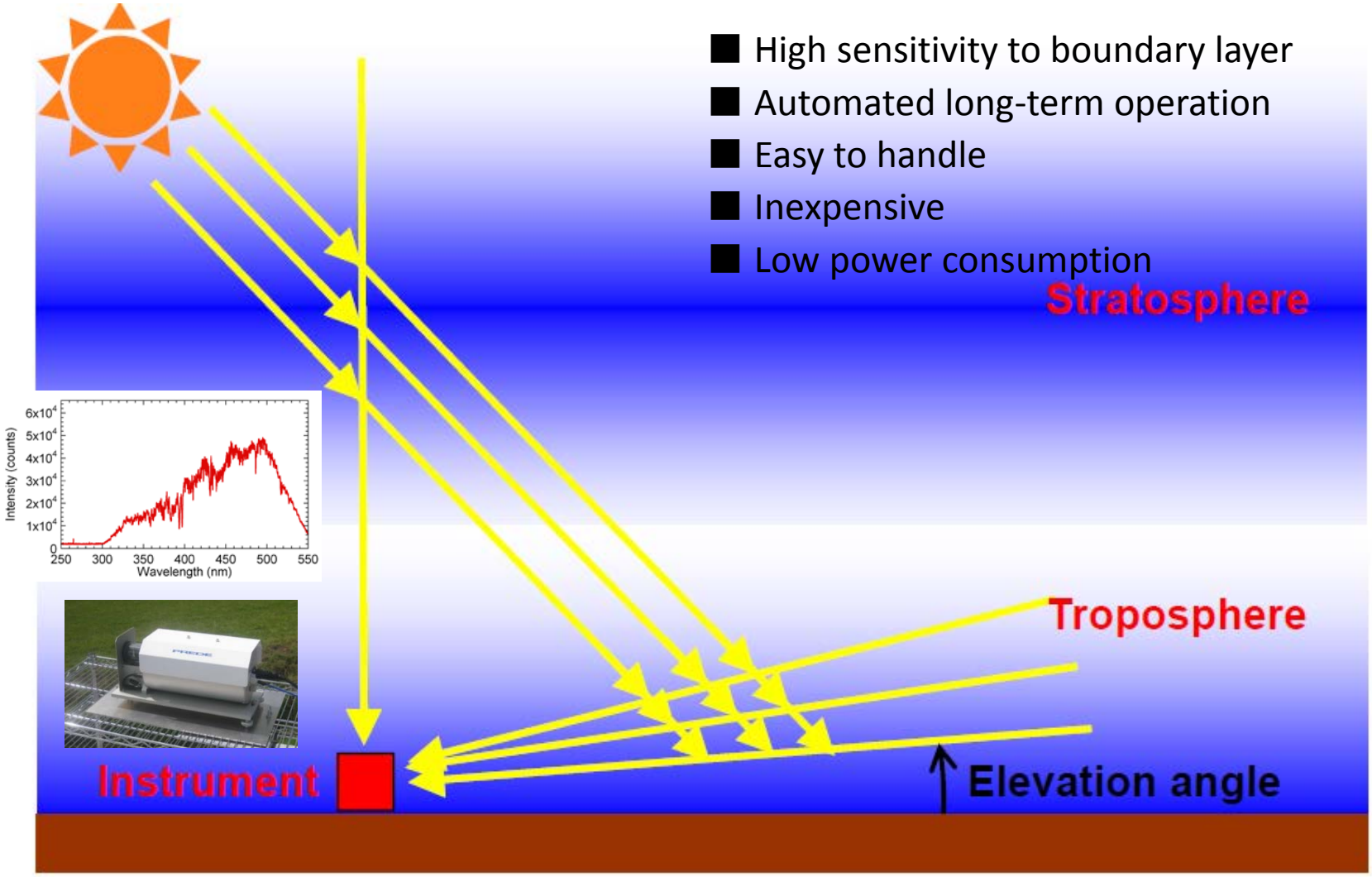


- Monthly variation of HCHO mixing ratio in PBL.
- Photo-oxidation plays a dominant role which leads to high level of HCHO in summer

Courtesy of Prof. H.-L. Lee

MAX-DOAS

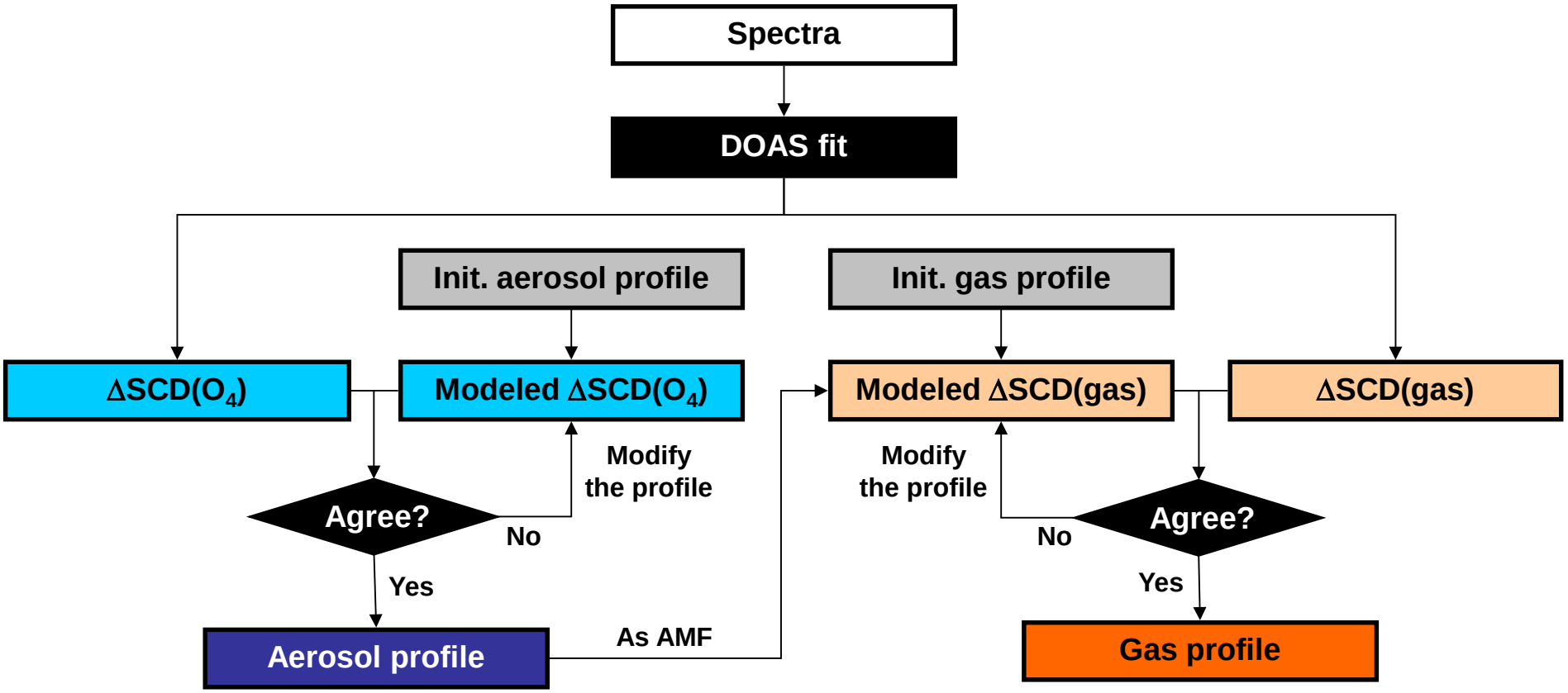
(Multi-Axis Differential Optical Absorption Spectroscopy)



Courtesy of Prof. H. Irie

Retrieval algorithm

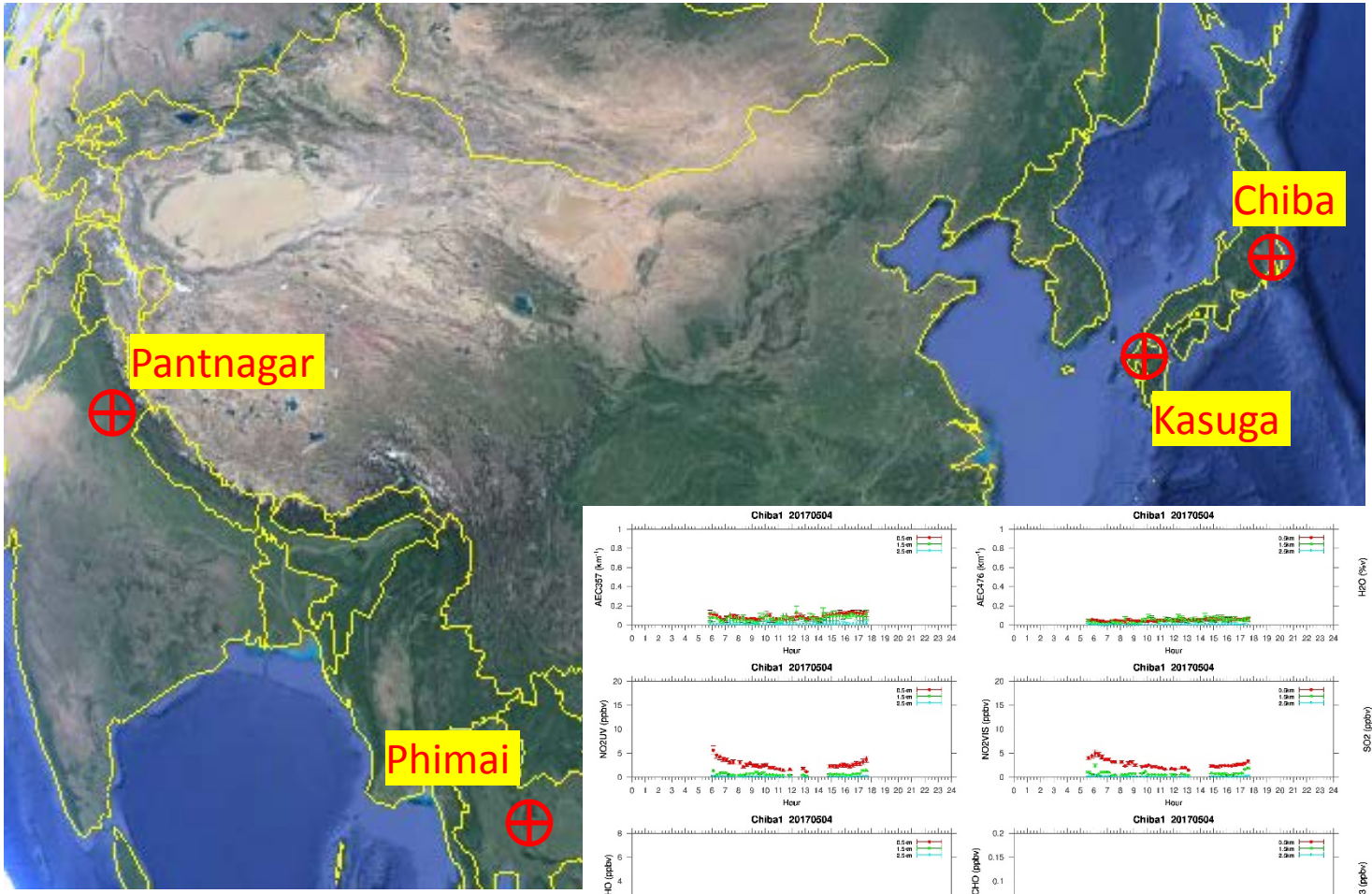
Japanese MAX-DOAS profile retrieval algorithm version 2 (JM2) (Irie et al., 2015)

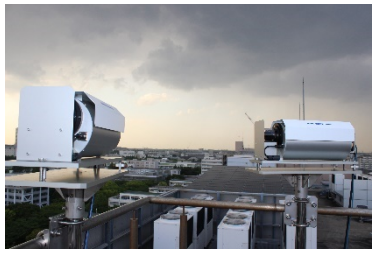


Courtesy of Prof. H. Irie

MAX-DOAS sites as part of SKYNET

http://atmos2.cr.chiba-u.jp/skynet/

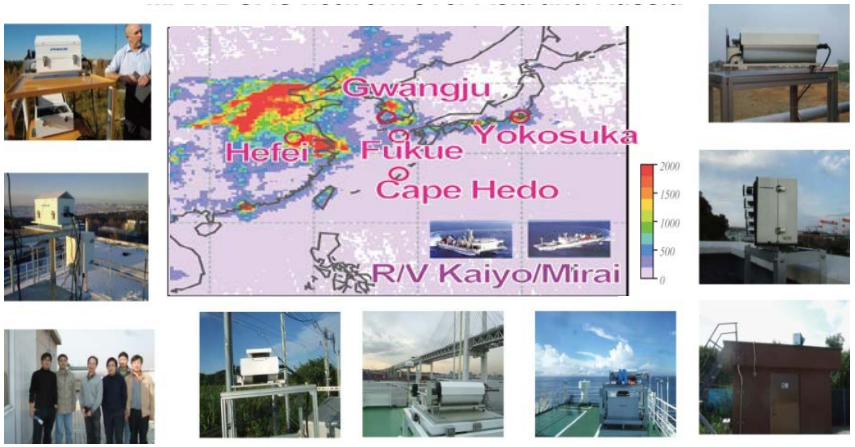




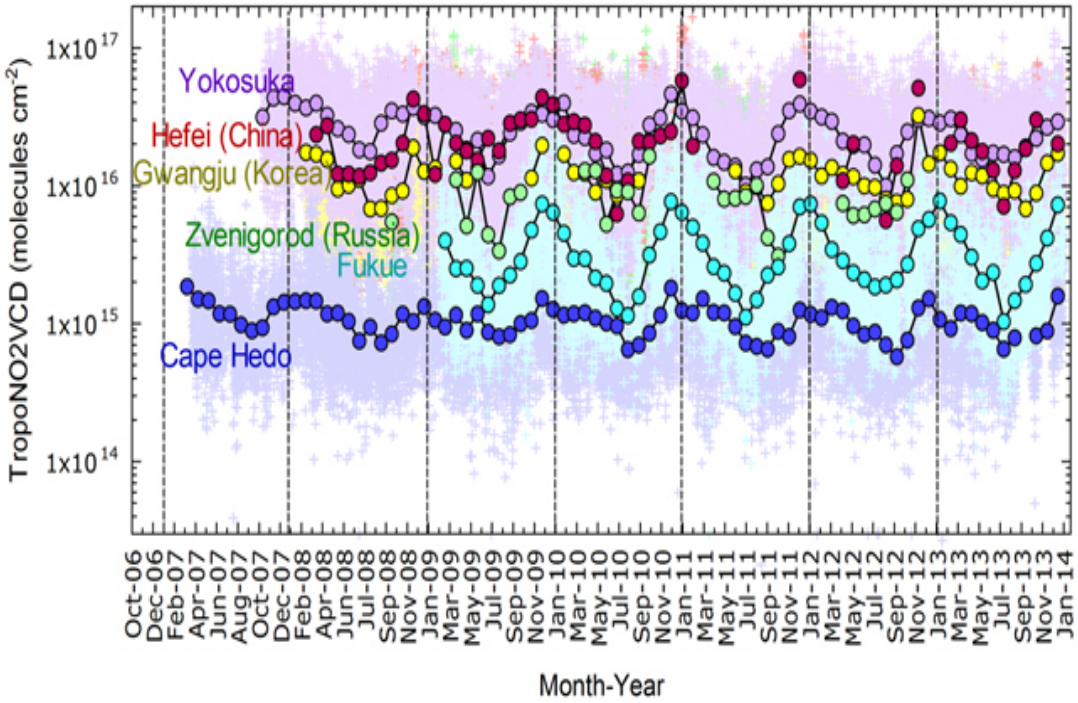
NRT multi-component retrieval with JM2 (Irie at al., 2015)

MAX-DOAS sites

East Asian part of MADRAS: MAX-DOAS network observations in Russia and Asia



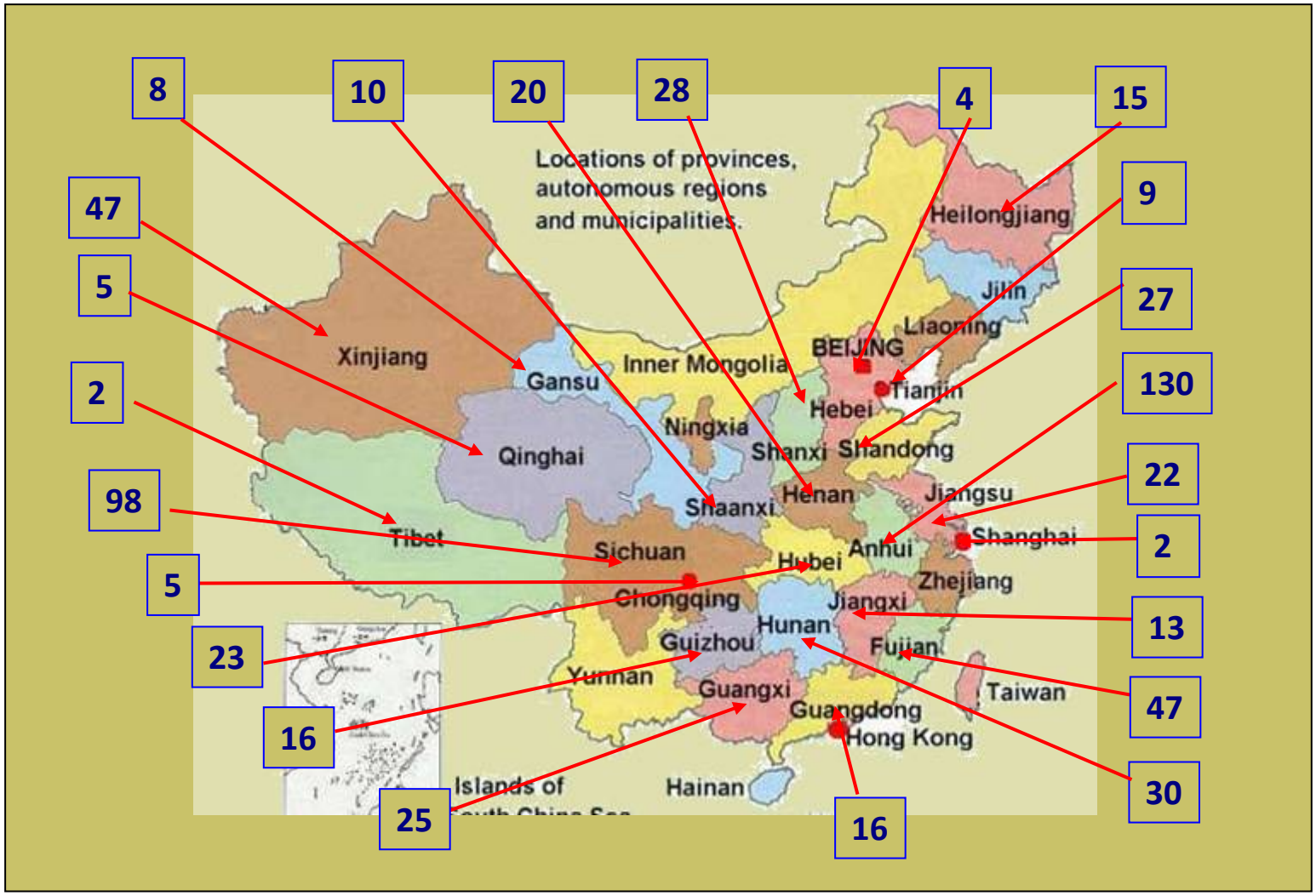
- Major products: TropoNO2VCD, AOD, their vertical profiles
- Aims: Evaluate satellite obs. (**OMI**, GOME2, Tropomi, GEMS, uvSCOPE etc) & Chemical Transport Models, Elucidate diurnal variations & vertical distributions, currently missed from satellite obs.
- Since 2007: Trends & seasonal to diurnal variations



More info & numerical data available at
http://ebcrpa.jamstec.go.jp/maxdoashp/index.html

Courtesy of Yugo Kanaya (JAMSTEC)

About 600 air quality monitoring sites using active DOAS system in China

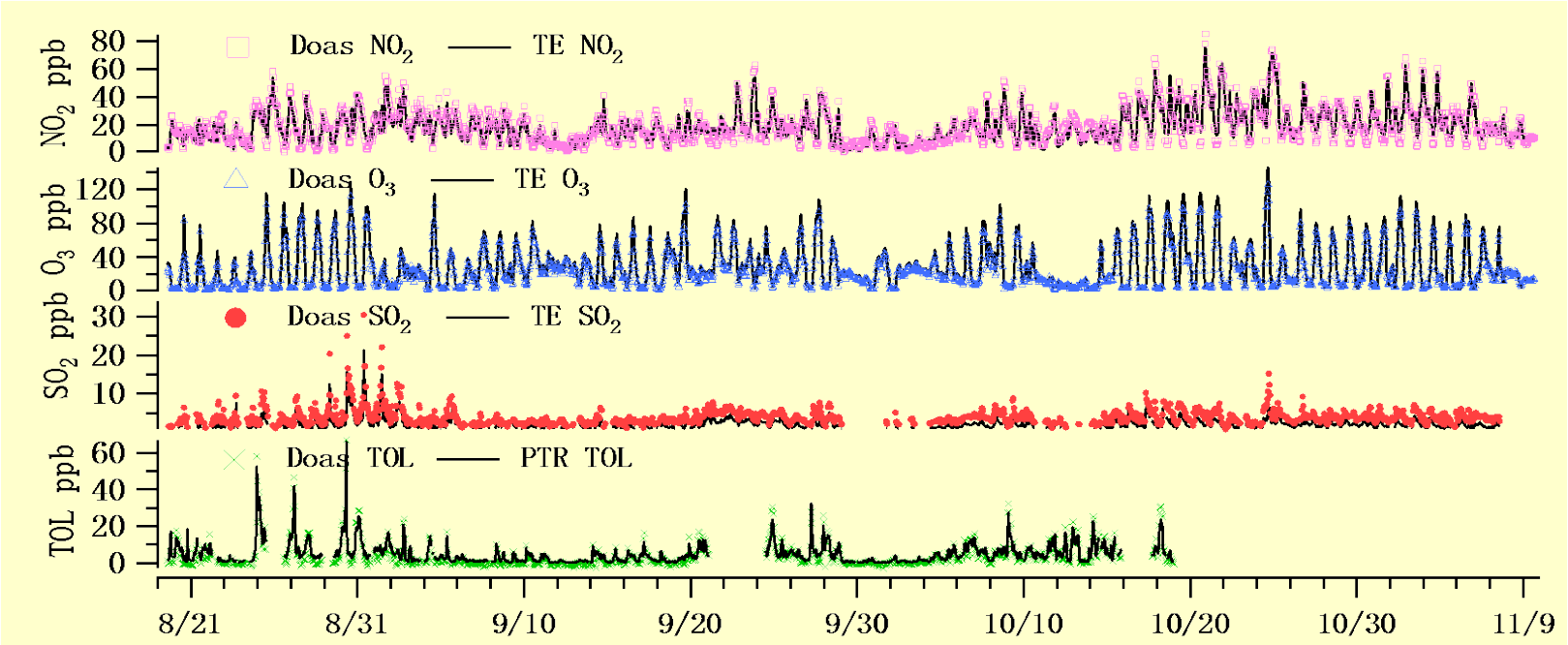


Courtesy of W. Q. Liu (CAS)

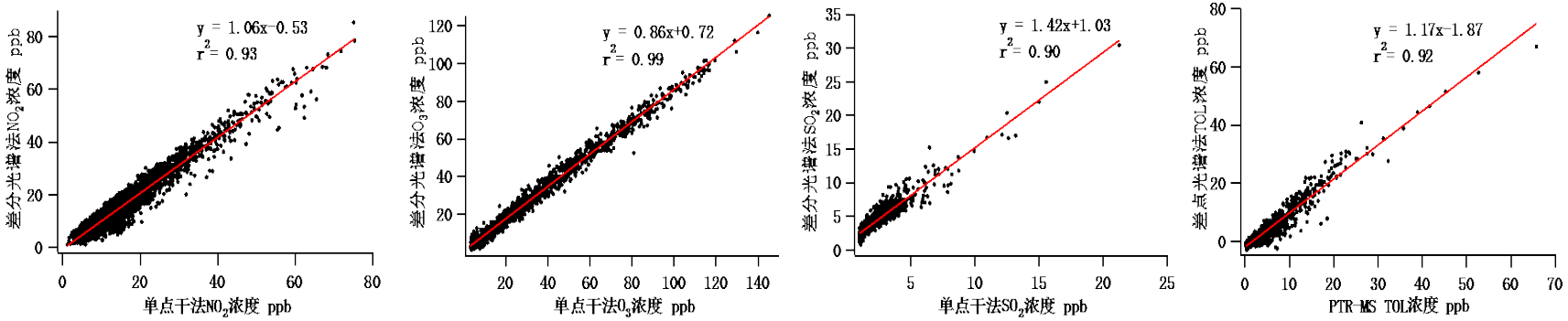
Comparison of active DOAS and point analyzer

- NO_2, SO_2, O_3 and toluene

Courtesy of W. Q. Liu (CAS)



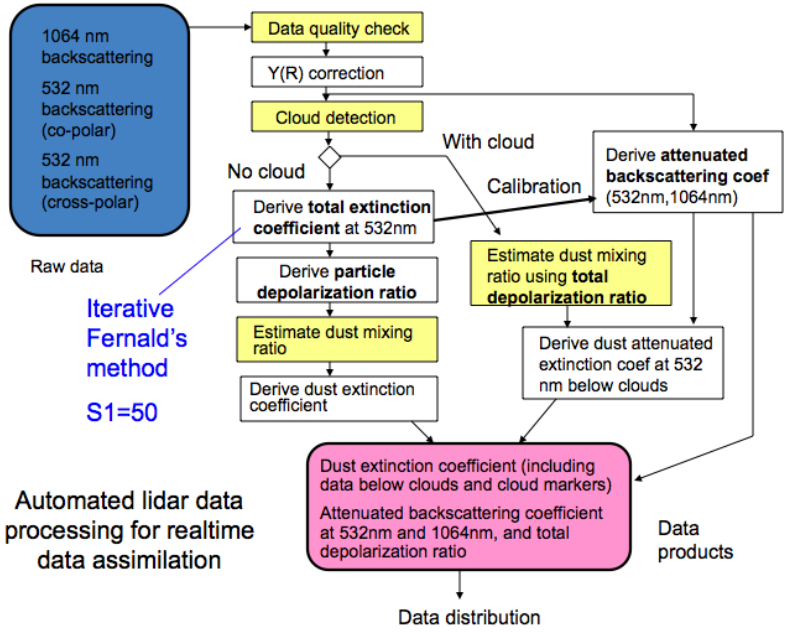
- Correlation of NO_2, O_3, SO_2 and toluene measured by DOAS and point analyzer

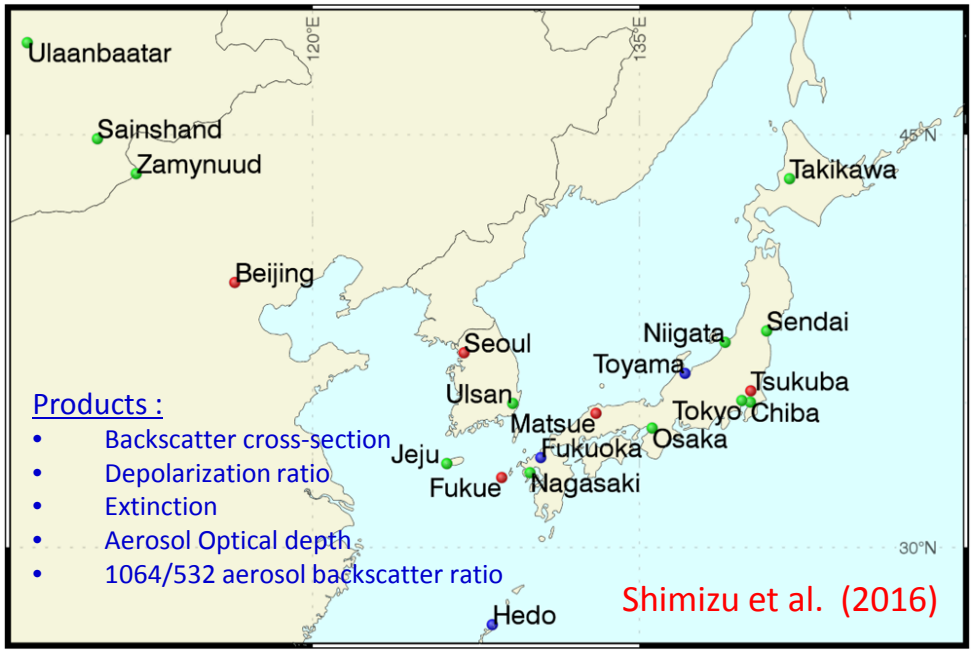


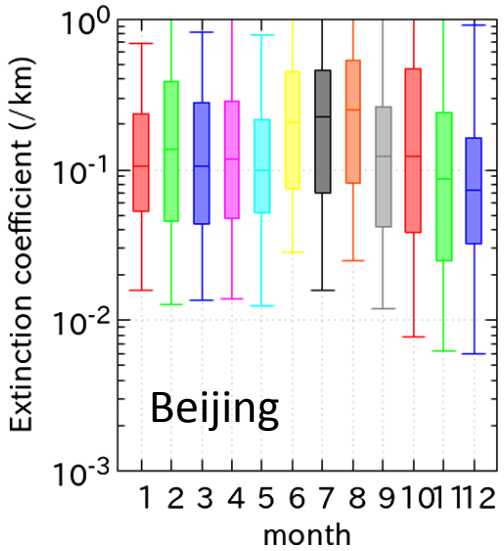
AD-Net

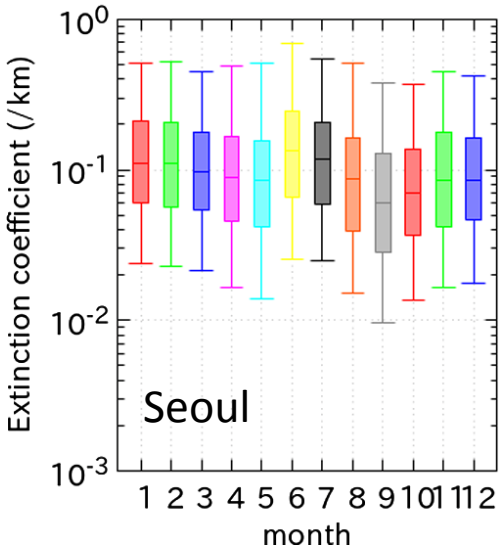
Asian dust and aerosol lidar observation network

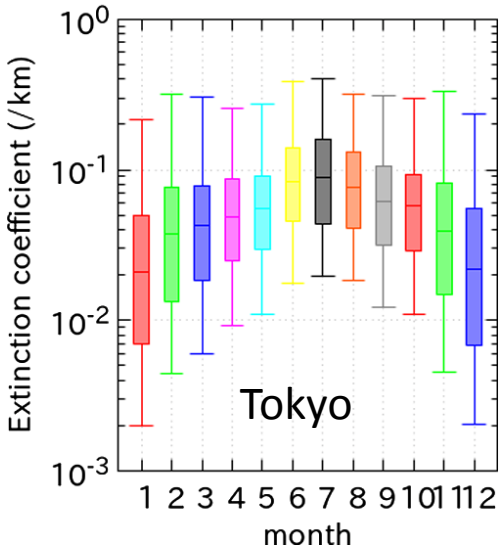
NRT Data Processing





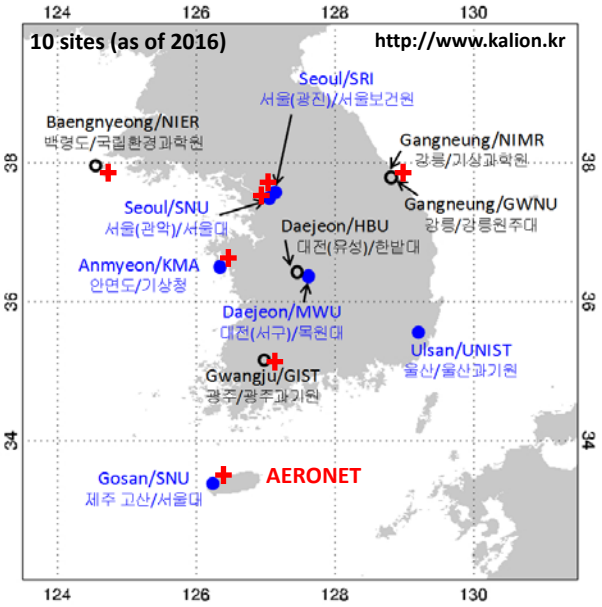


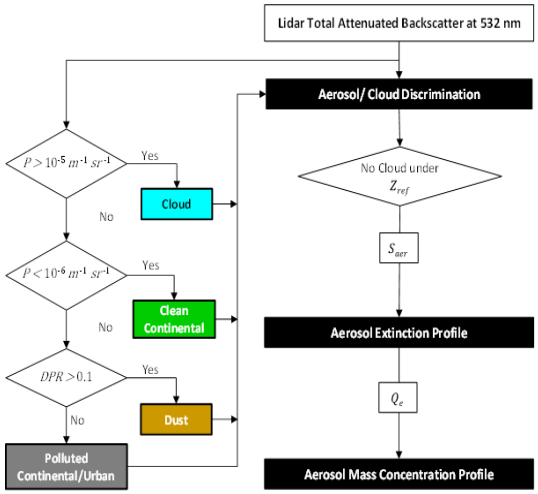




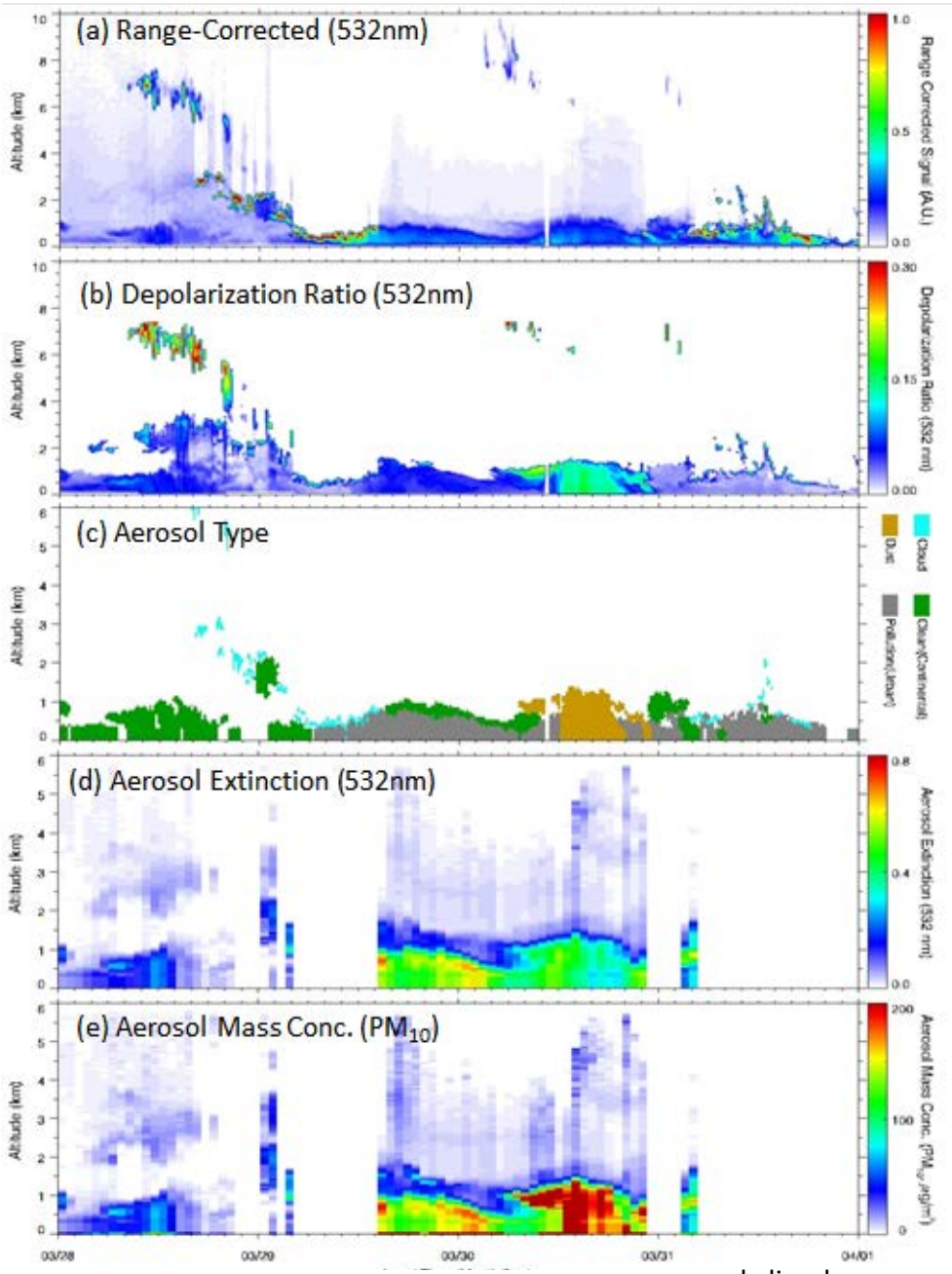
KALION

Korea aerosol lidar observation network





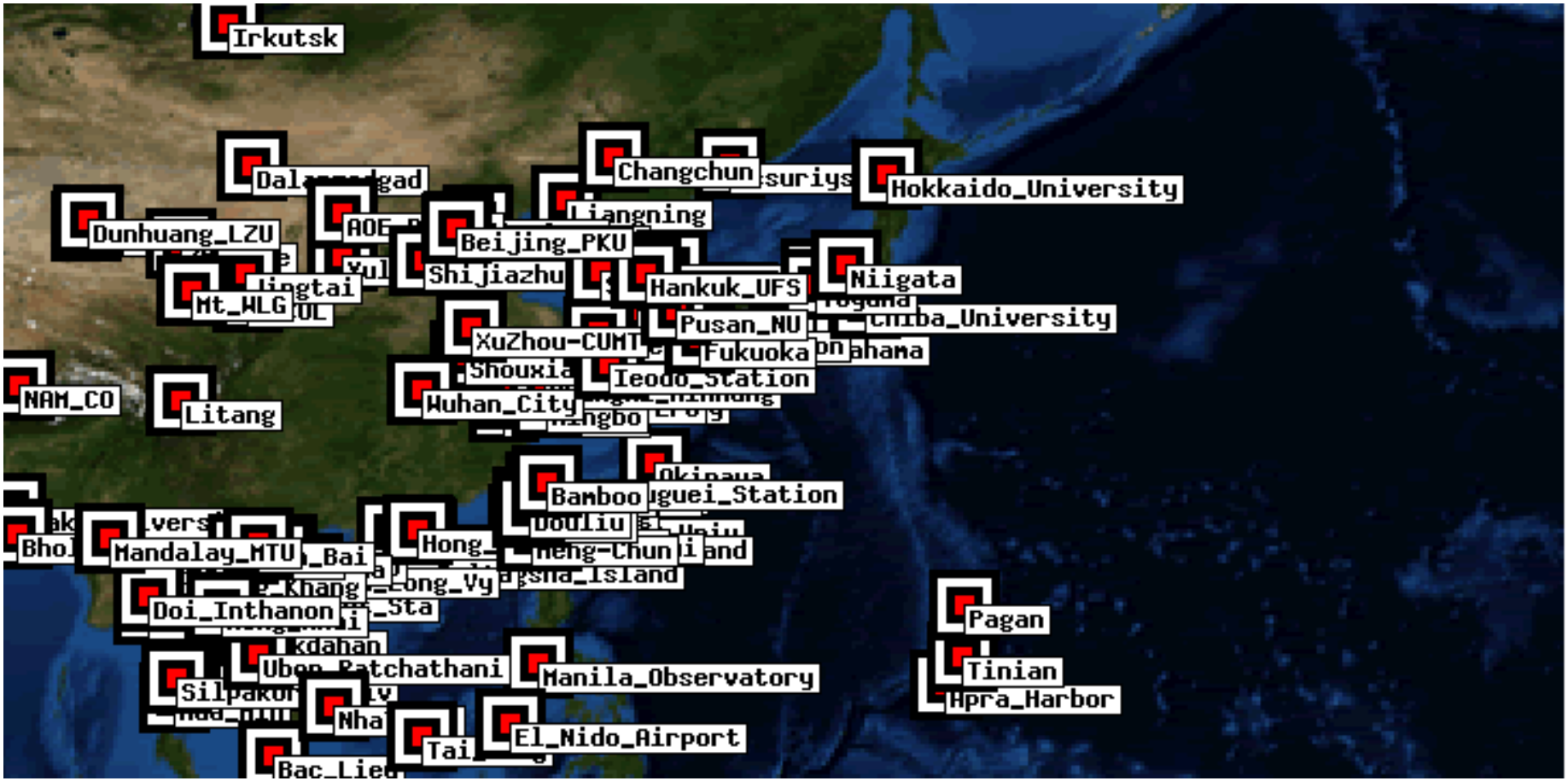
P = Attenuated backscatter
DPR = Depolarization ratio
Z_{ref} = Reference Height
S_{aer} = Lidar Ratio
Q_e = Mass Extinction Efficiency



www.kalion.kr

Aerosol Robotic Network (AERONET)

https://aeronet.gsfc.nasa.gov/



SKYNET

GAW Contributing Network

April 2016

Red : Data available (38)
Yellow: Data available in the future (28)
Black: Data can not be published (7)

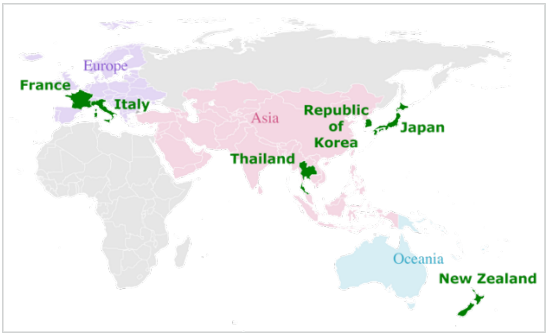
Skyradiometer

Skyradiometer, pyranometer, Lidar, microwave

http://atmos2.cr.chiba-u.jp/skynet/
http://www-lidar.nies.go.jp/skynet/index.php

Courtesy of Prof. Terry Nakajima

Okinawa



SKYNET international committee

- China
- Korea
- Japan
- South East Asia
- Europe
- India
- Mongolia

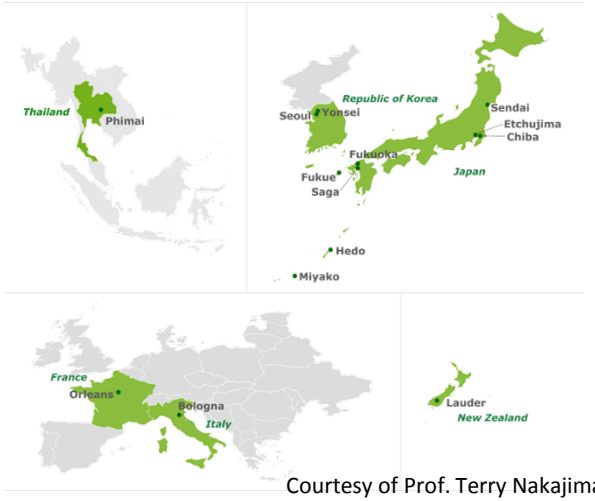
Sub-network

- Network Coordinator
- ISDC*1
- Mirroring
- RSDC*2
- WG*3
  - •Algorithm
  - •Calibration

*1 ISDC: International SKYNET Data Center *2 RSDC: Regional SKYNET Data Center *3 WG: Working Group

Chair: T. Nakajima
Vice: M. Campanelli, G. Pandithurai
China: H. Che, L. Dong
Korea (KSNET): S.-W. Kim, J. Kim
Japan: H. Irie, T. Nishizawa
South East: B. Thana
Europe (ESR): M. Campanelli, V. Estelles
India: V.K. Soni, G. Pandithurai
Mongolia: T. Nas-urt

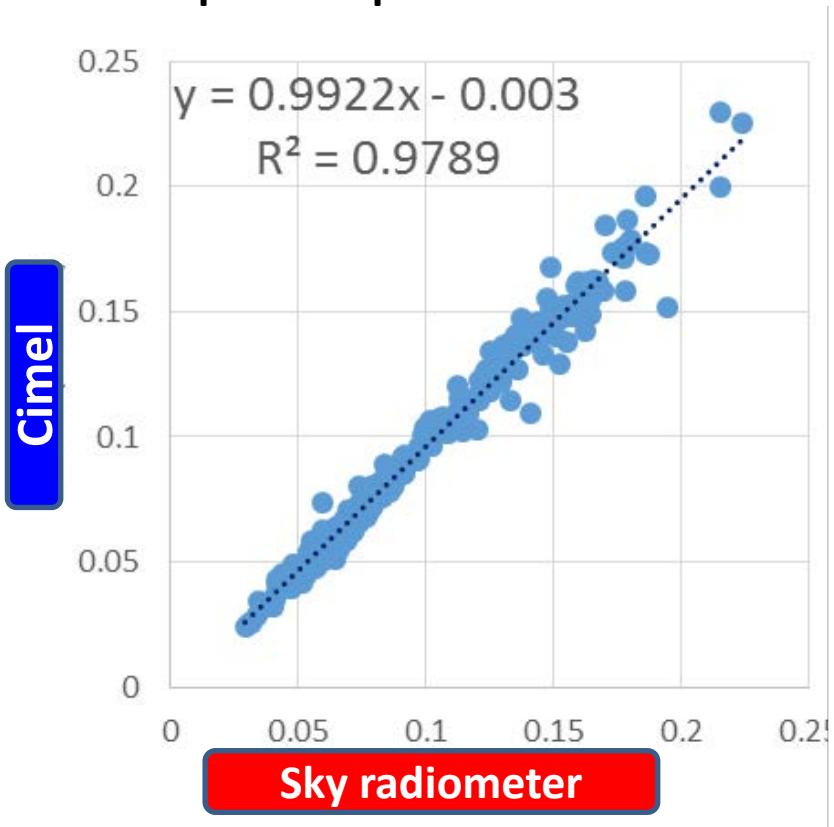
Network Coordinator: K. Aoki
ISDC: Nisizawa@NIES
Calibration WG: Che
Algorithm WG: Irie

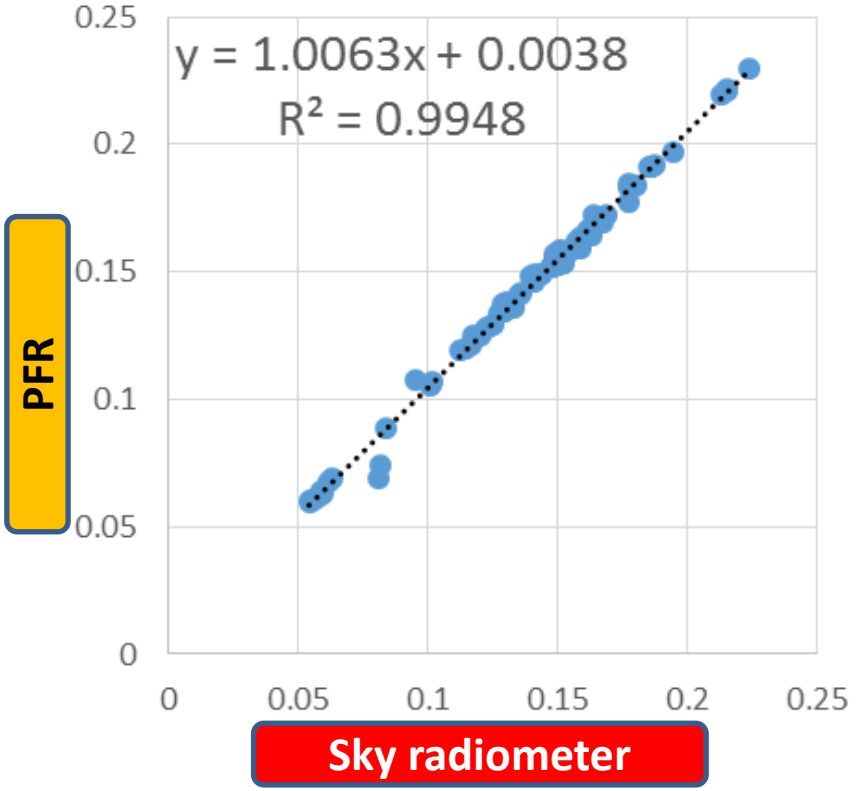


Courtesy of Prof. Terry Nakajima

Correlation analysis

Aerosol Optical Depth at 500 nm





PFR > Sky radiometer > Cimel

※Difference is less than **0.01** and small enough for applied researches.

※F0 calibration by Imporved Langley method for skyradiometer.

Courtesy of Prof. Terry Nakajima

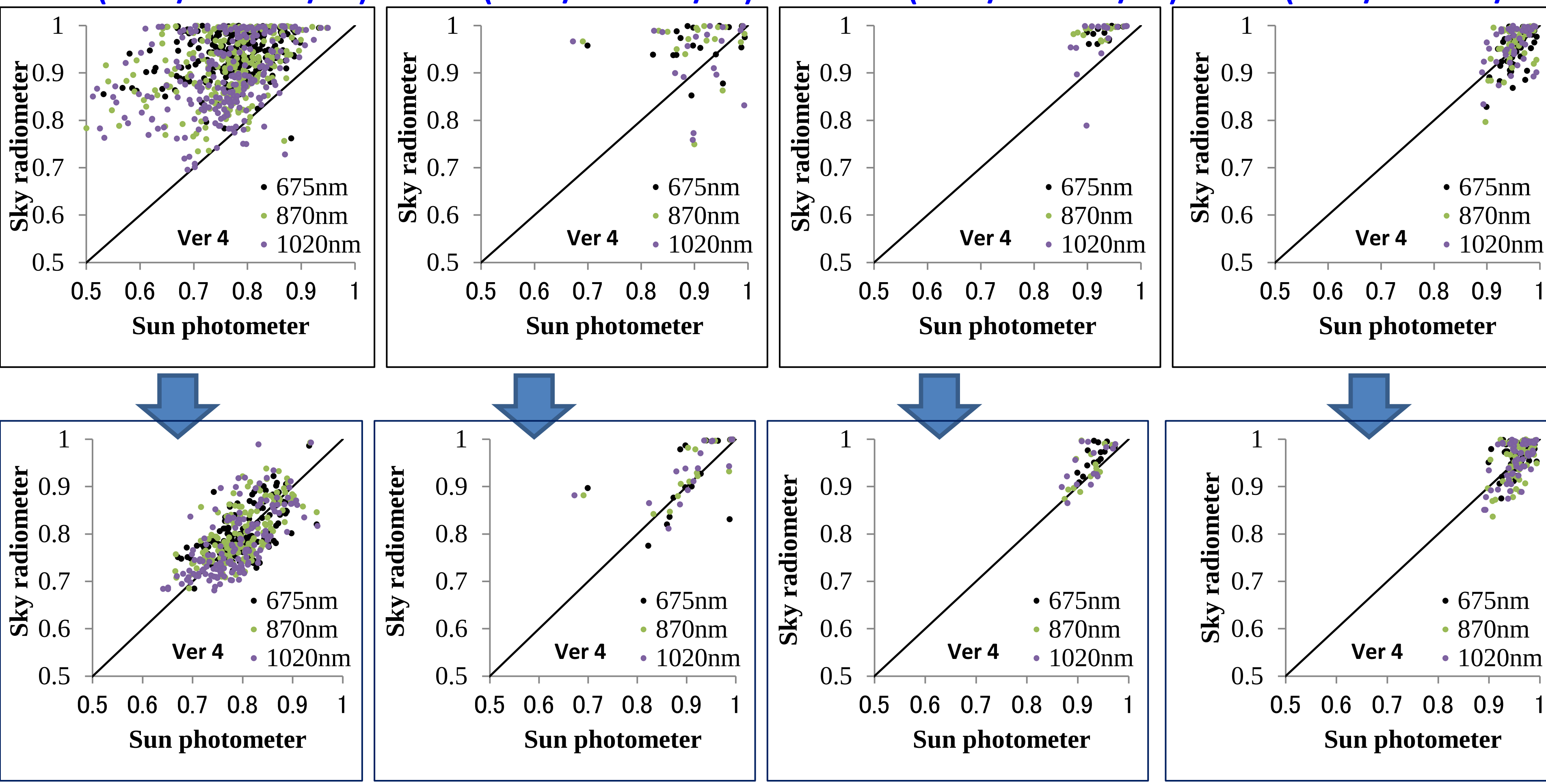
Comparison of SSA with AERONET values

- Cloud screening
- SVA(solid view angles)
- Skyrad.pack v4, 5

P. Khatri (JGR'15)

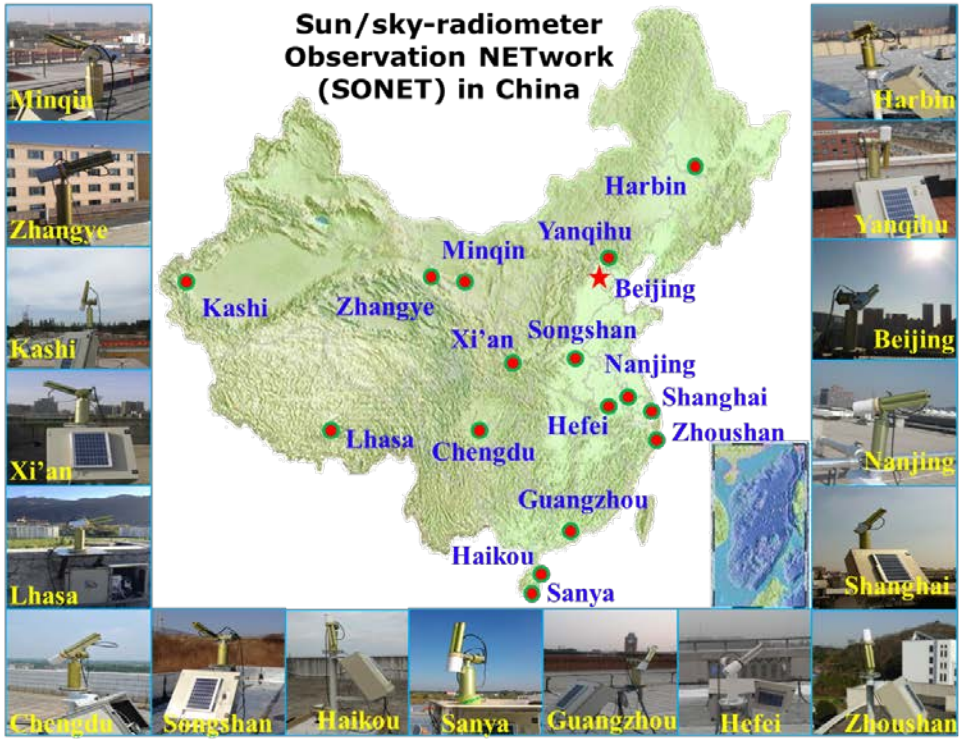
F0, SVA (angle not significant) SVA (angle not significant)

Pune (2004/10-2005/12) Chiba(2011/12-2012/10) Valencia (2008/04-2009/08) Seoul(2012/03-2012/05)



Courtesy of Prof. Terry Nakajima

Chinese Sun/sky-radiometer observation network (SONET)

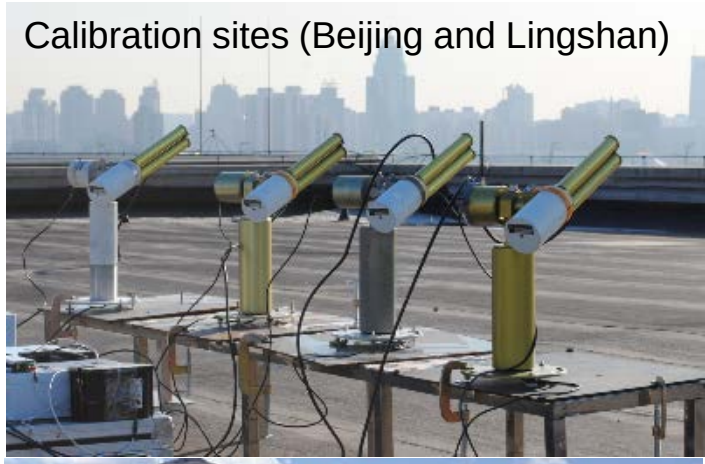


- Total 17 permanent sites since 2010 over China

Site types:
- ☐ Urban
- ☐ Rural
- ☐ Coastal
- ☐ Mountain
- ☐ Basin
- ☐ Plateau
- ☐ Dust
- ☐ Haze
- ...

Courtesy to Zhengqiang LI , 7th GEMS Science Meeting, 2016

Calibration sites (Beijing and Lingshan)

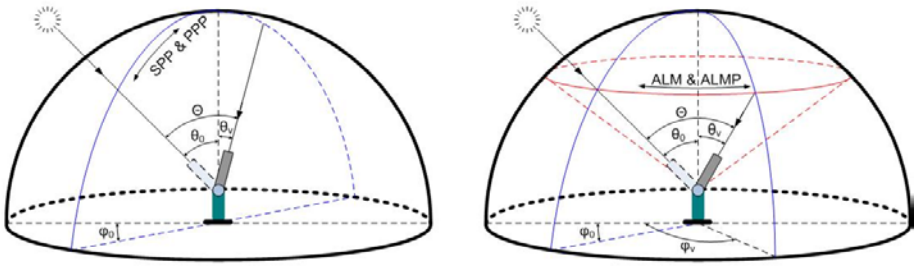


- Official homepage: http://www.sonet.ac.cn/en/index.php (figures and tables are from here)
- PI: Prof. Zhengqiang Li (lizq@radi.ac.cn), RADI/CAS, China
- Reference paper: Li et al. (2015)

Chinese Sun/sky-radiometer observation network (SONET)

The sun/sky radiometer (CE318-NE/DP)

Scanning angle of sky measurements
SSP: solar principal plane, ALM: almucantar



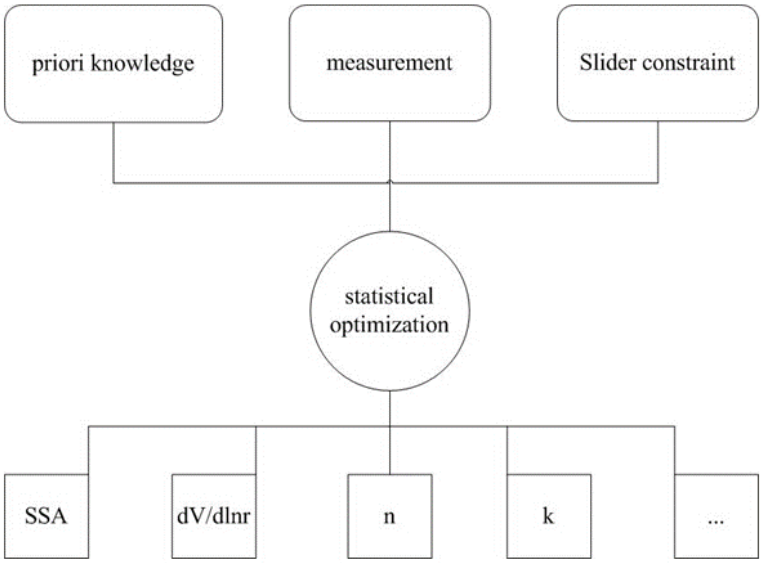
Without polarization (CE318-NE)

Mode		Scanning type	Scanning angle (°)
SPP		Scanning angle [-180°,180°]	-6,-5,-4,-3.5,-3,-2.5,-2,- 0,2,2.5,3,3.5,4,5,6,8,10,12,14,16,20, 25,30,35,40,45,50,55,60,65,70,80,90,100,110,120,130,140,150
ALM	ALR	Viewing azimuth angle [0°,360°]	0,3,3.5,4,5,6,6,7,8,10,12,14,16,18,20,25,30,35,40,45,50, 60,70,80,90,100,120,140,160,180
	ALL		360,357,356,355,354,353,352,350,348,346,344,342,340, 335,330,325,320,315,310,300,290,280,270,260,240,220,200,180

With polarization (CE318-DP)

Mode		Scanning type	Scanning angle(°)
PPP		Viewing Zenith angle [-90°,90°]	-85,-80,-75,-70,-65,-60,-55,-50,-45,-40,-35,-30,-25,-20,-15,-10,-5, 0.5,10,15,20,25,30,35,40,45,50,55,60,65,70,75,80,85
ALMP	APD	Viewing azimuth angle [0°,360°]	30,35,40,45,50,60,70,80,90,100,120,140,160,180
	APG		330,325,320,315,310,300,290,280,270,260,240,220,200,180

Inversion flowchart (statistical optimization)



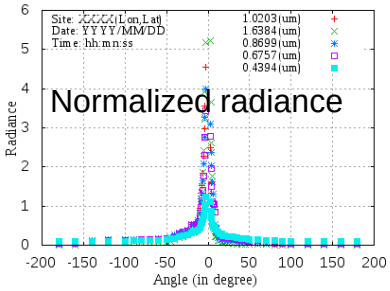
Level of SONET products

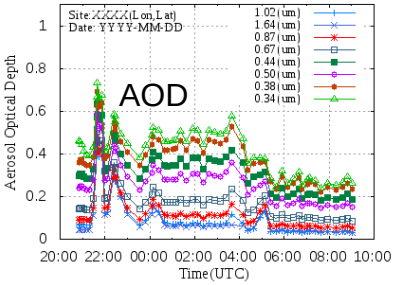
level	Description
Lev 1.0	direct processing the origin data
Lev 1.5	after cloud recognition processing and removing cloud processing
Lev 1.6	proceeds interpolation of calibration coefficient and reintegrates data based on lev1.5 data
Lev 2.0	Lev2.0 based on Lev 1.6 data, further process through expertise recognition which data has a higher quality level.

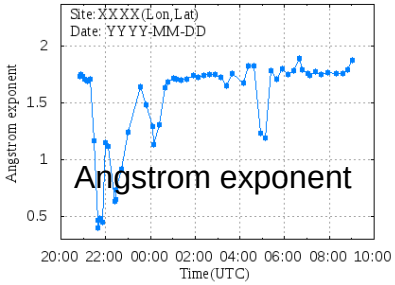
Chinese Sun/sky-radiometer observation network (SONET)

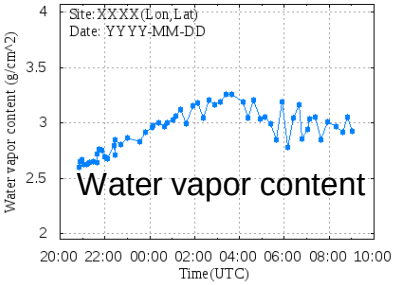
SONET products and frequency

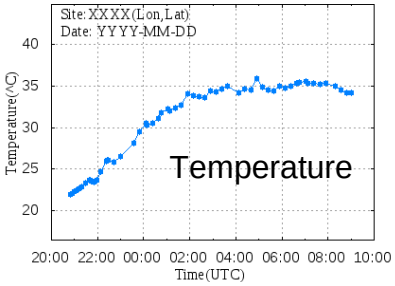
Products	Description	Frequency
AOD(λ)	*Aerosol optical depth (bands from 4 to 8)*	10-30 min
H_2O	*The water content of the atmospheric column*	10-30 min
α	*Ångström Index*	10-30 min
SSA(λ)	*Single scattering albedo (4 bands)*	About 60 min
$F_u(\lambda)$	*Scattering phase function (4 bands)*	About 60 min
$-F_{12}(\lambda)$	*Polarization phase function (4 bands)*	About 60 min
n(λ)	*Particle spectrum distribution (4 bands)*	About 60 min
$m_r(\lambda)$	*Real part of complex refractive index (4 bands)*	About 60 min
$m_i(\lambda)$	*Imaginary part of complex refractive index (4 bands)*	About 60 min
S(λ)	*Lidar ratio (4 bands)*	About 60 min
g(λ)	*Asymmetry factor (4 bands)*	About 60 min
AMF	*The proportion of the particles*	About 60 min
r_{eff}	*Effective radius (total, fine mode, crude mode)*	About 60 min
V	*Particle volume (total, fine mode, coarse mode)*	About 60 min
F_{down}	*Atmospheric downward radiation flux*	About 60 min
F_{up}	*Atmospheric upward radiation flux*	About 60 min
$F_{diffuse}$	*Atmospheric scattering radiation flux*	About 60 min
NS (%)	*Proportion of non-spherical particles*	About 60 min
BC (%)	*Proportion of black carbon aerosol composition*	About 60 min
AS (%)	*Proportion of sulfate aerosol composition*	About 60 min
DU (%)	*Proportion of mineral dust aerosol composition*	About 60 min
B_rC (%)	*Proportion of organic carbon aerosol composition*	About 60 min
H_2O (%)	*Proportion of aqueous composition*	About 60 min

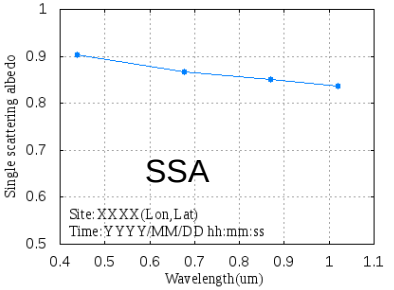


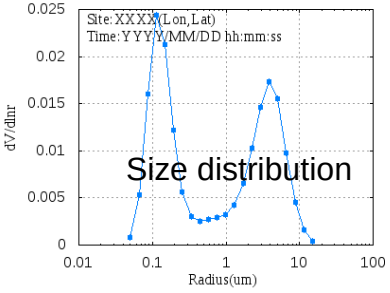


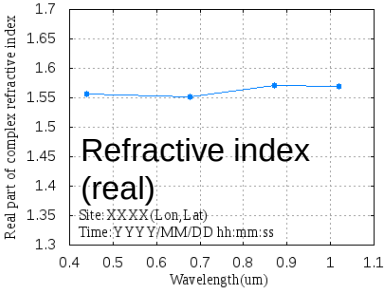


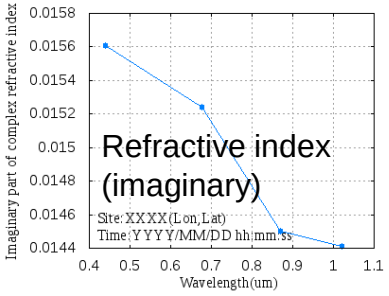


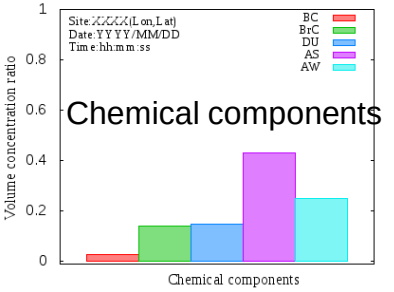






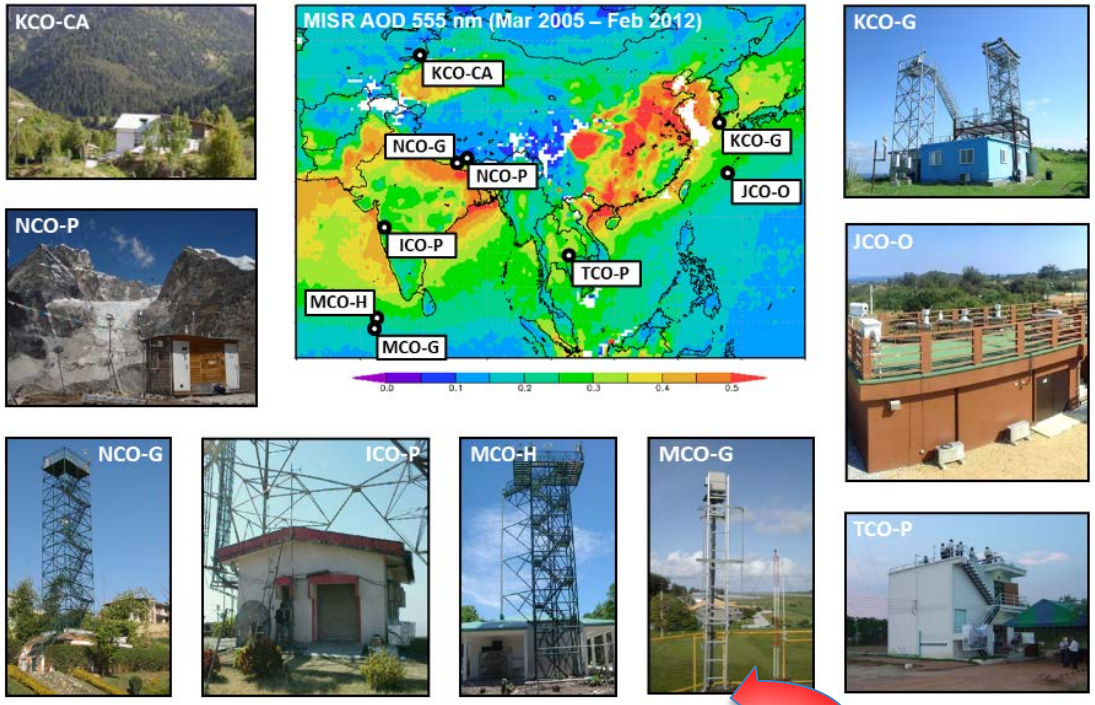


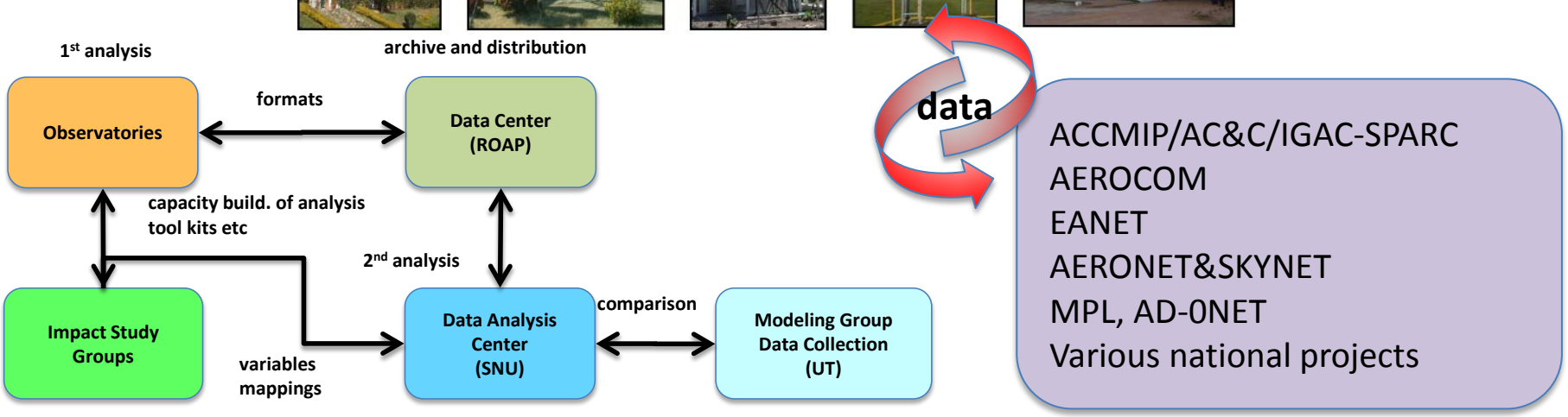




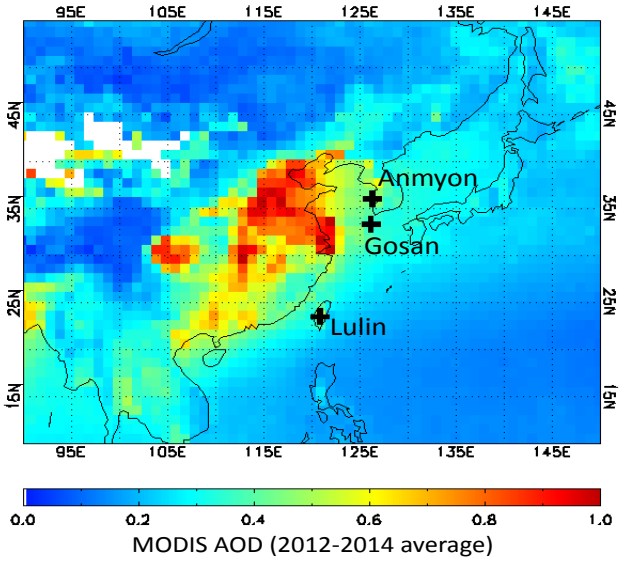
UNEP/ABC- (Asia) Climate Observatories

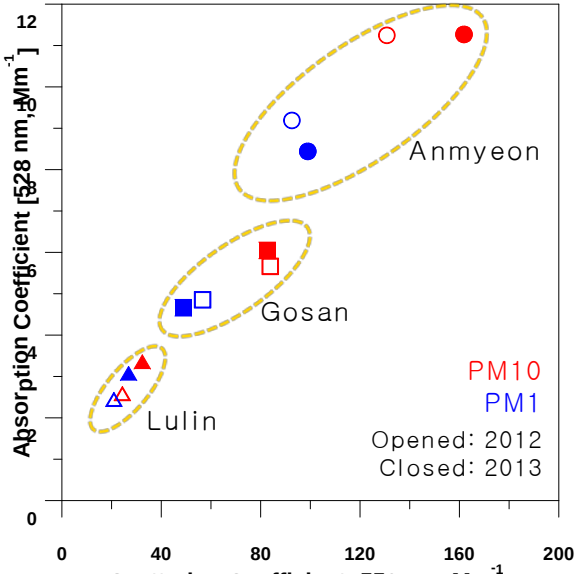
- Intensive Analysis Period (2011-)
- Data archives @ SNU (2011-)

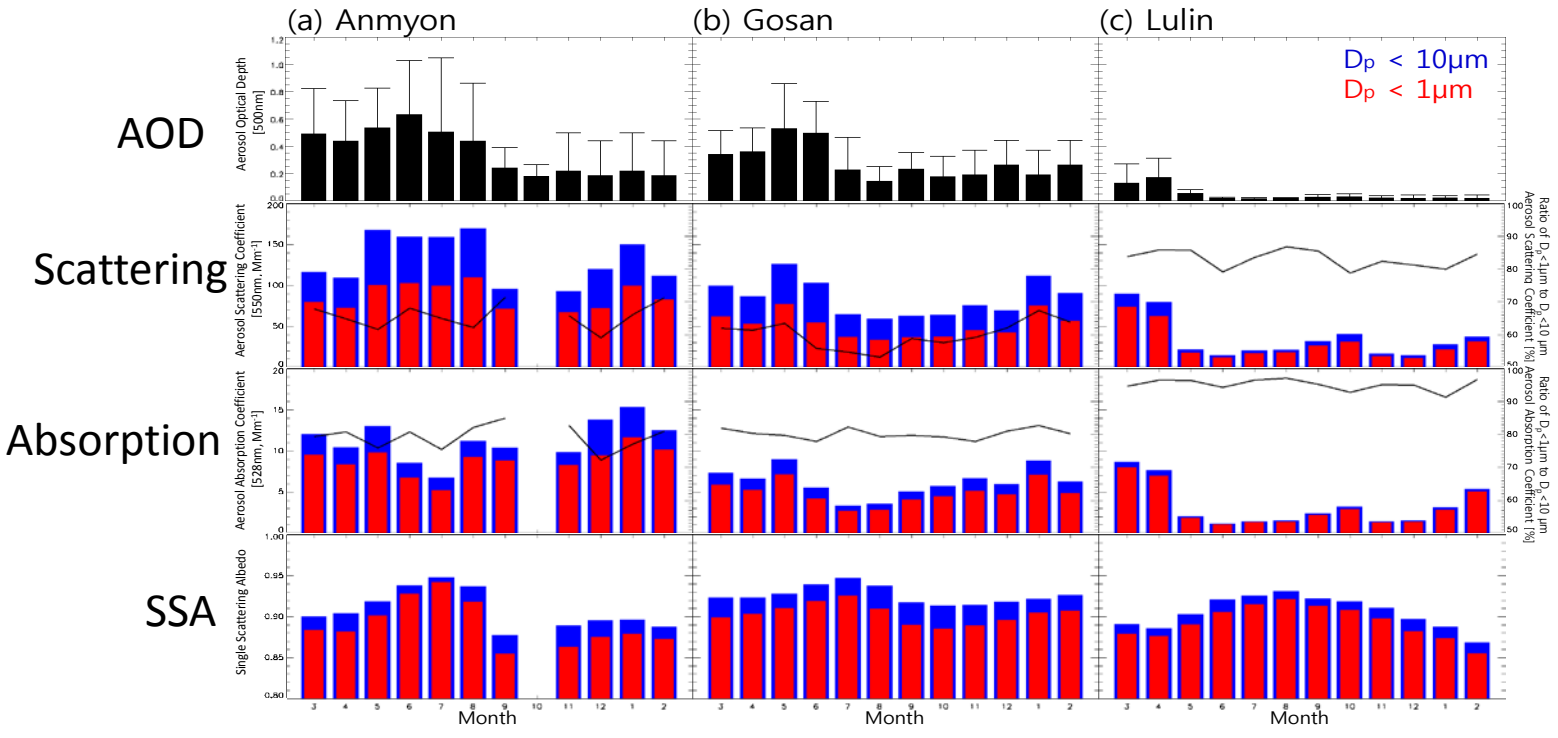




NOAA/ESRL Federal Aerosol Network







Networking Ground-based Measurements for validation

Trace gases: PANDORA, MAX-DOAS, Brewer, near-surface in-situ…

- Significant progresses were made in recent years, but establishing network in cooperation with existing networks are necessary.

Aerosol: Sky radiometer, Lidar, near-surface in-situ…

- Ground-based aerosol network is now relatively well established.

Thank you for your attention