Ministry of Environment
National Institute of Environmental Research

KORUS-AQ campaign results as a validation

Presenter: Ara Cho (NIER)

NIER, NASA, GEMS Algorithm science team, KARI

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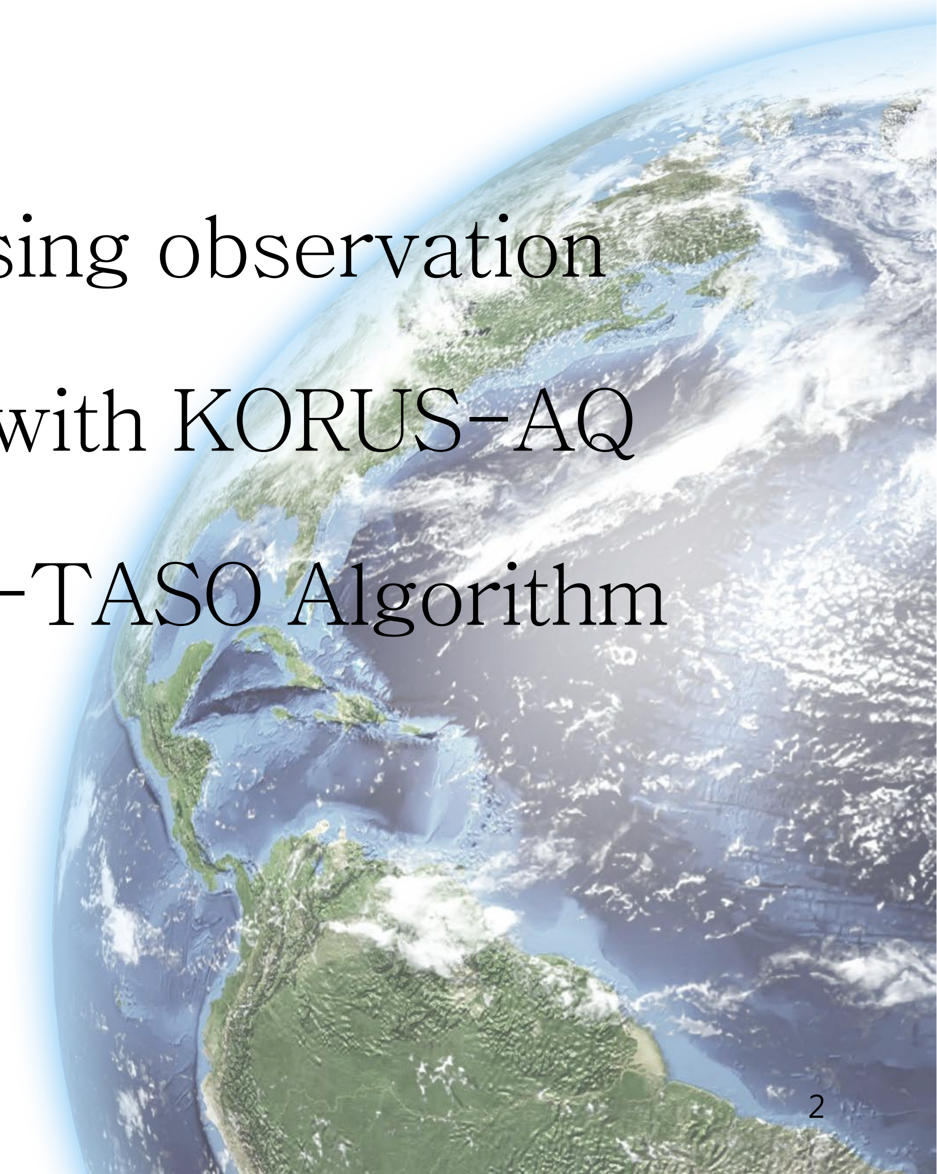

Credit : Geoeye

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INTRODUCTION

Introduction

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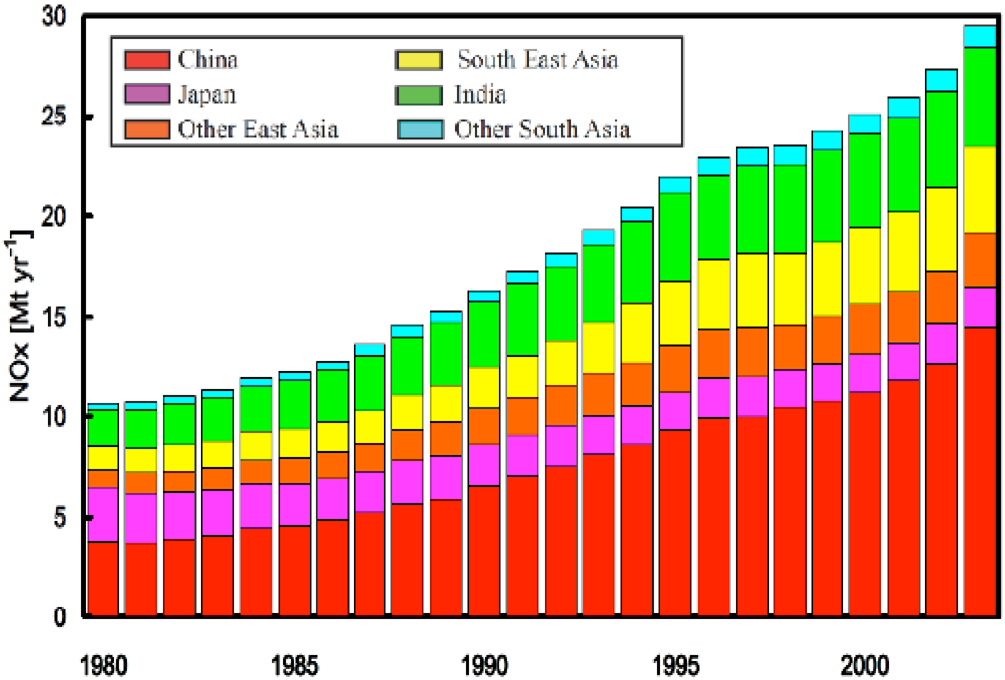
Korea is located in a region of **rapid change** with **strong air quality gradients** both in time and space.

➔ Started surface observation and forecasting air quality

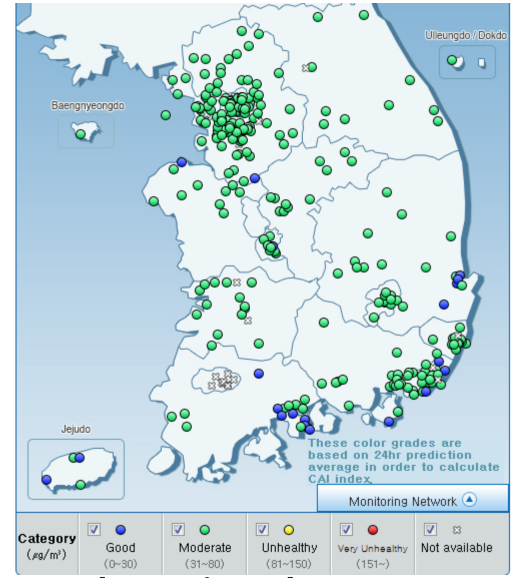


Asian NO_2 emissions from 1980 -2003 based on activity data (Ohara et al., 2007)

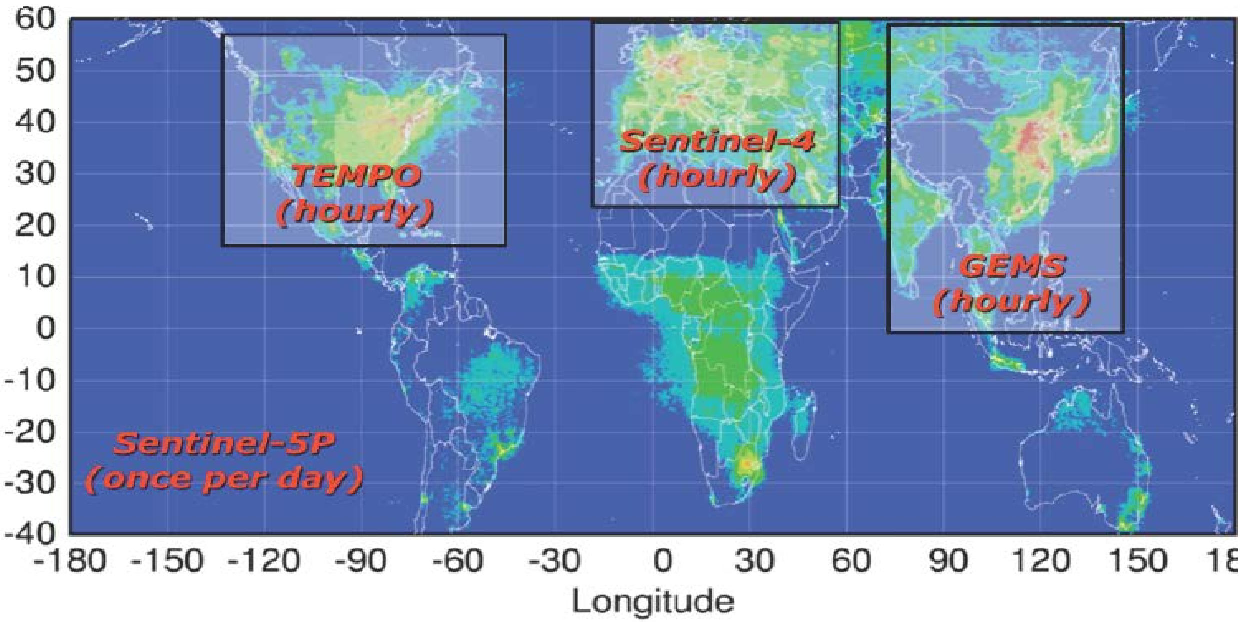
Introduction

- There are **temporal** and **spatial limitations** of the data to investigate climate change and air pollution (surface monitoring, LEO, …)

➔ Geostationary Environmental Monitoring Spectrometer(GEMS) will be launched in 2019.



dense in urban area



GEMS

Goal of KORUS-AQ campaign

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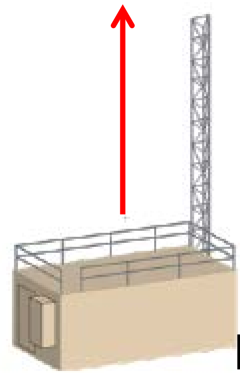
KORUS-AQ (Korean and U.S.) to implement
an **integrated observing system** for improving understanding of Air Quality

Airborne sampling
- connecting ground-based and satellite observations
- Short term

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

KORUS-AQ Goals
- **Improve capability for satellite remote sensing of air quality**
- **Better understanding of the factors controlling air quality**
- **Test and improve model simulation of air quality**

Ground monitoring
- The primary method for monitoring exposure.
- limited coverage.



Modeling
- Air quality forecasting and warning service
- it needs reliable information such as emission inventory

[Courtesy of James Crawford and Joon-young Ahn]

Observation platform

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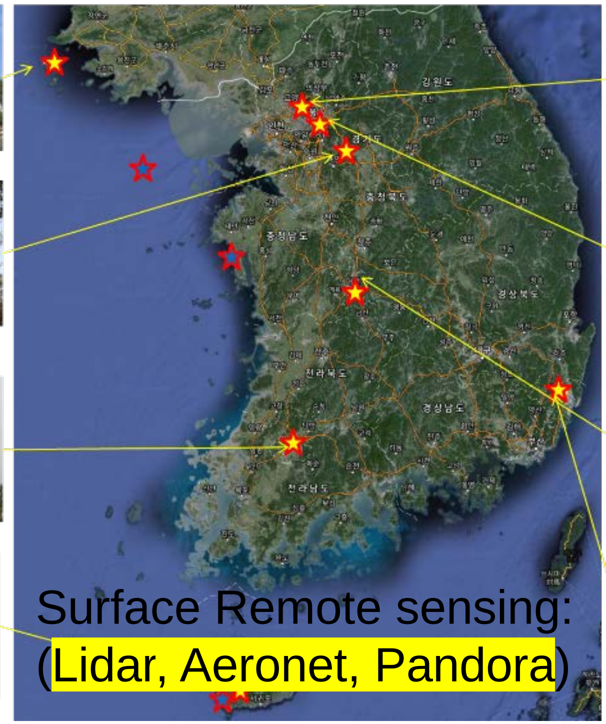
Mt. Taehwa

Gwangju

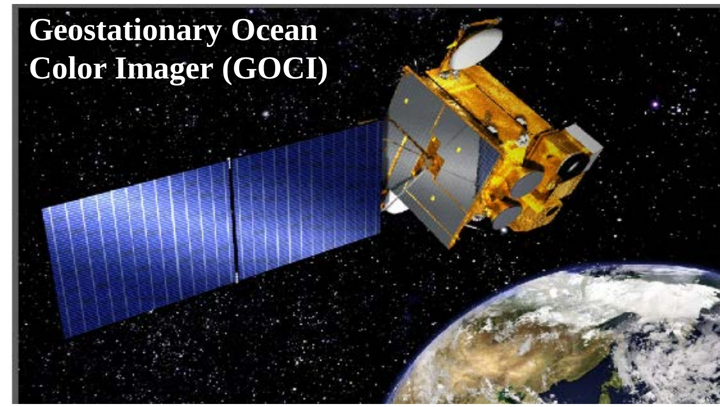
Jeju



Olympic Park

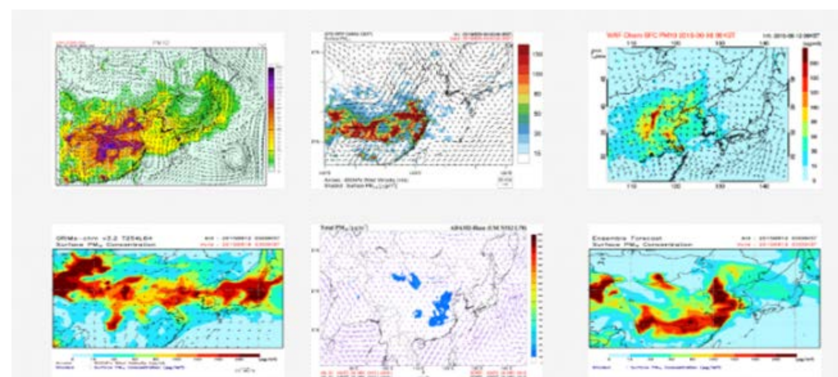
Daejeon

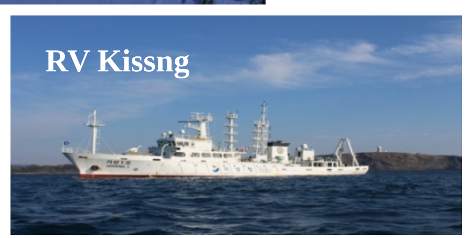
Ulsan



GOCI, OMI, MODIS, CALIPSO, IASI, etc

Korean and US Air Quality Model Forecasts





Observation platform

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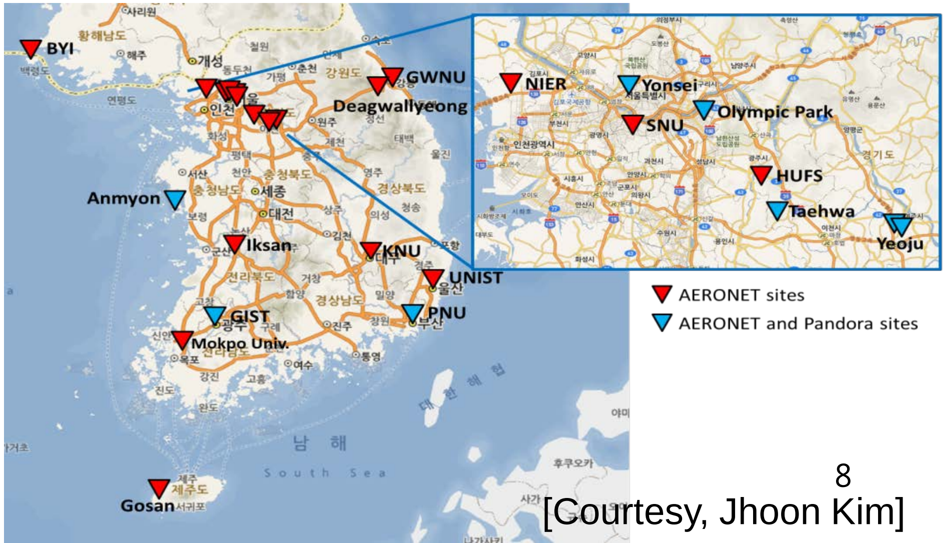
Surface remote sensing observation

- AERONET
  : Aerosol optical properties
  (AOD, SSA, FMF, AE, refractive index, etc.)

- Pandora
  : Total column trace gases (O3 and NO2)

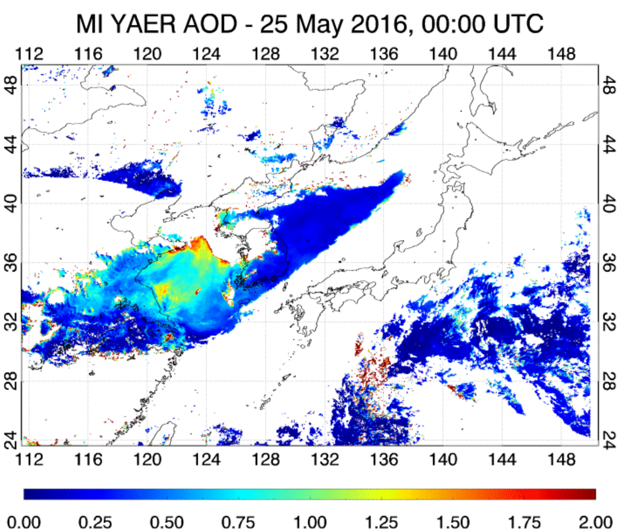
38 AERONET and SONET sites within GOCI domain
http://aeronet.gsfc.nasa.gov/new_web/DRAGON-KORUS-AQ_2016.html

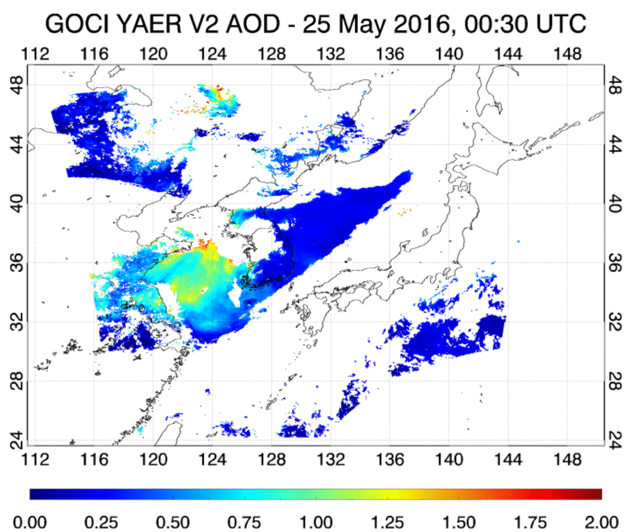
Korea AERONET & Pandora sites

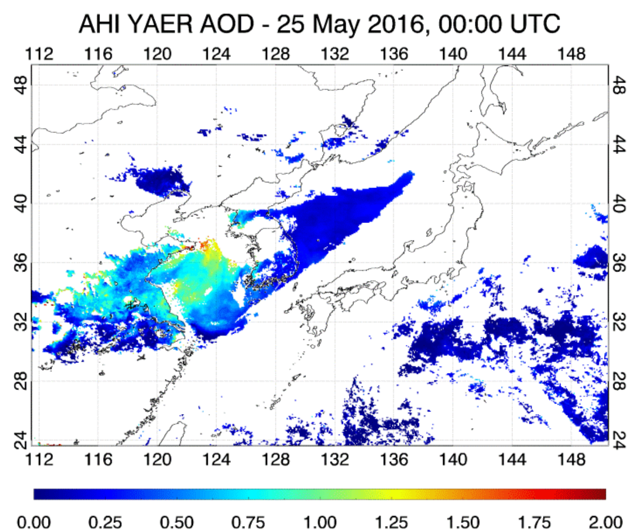


[Courtesy, Jhoon Kim]

Geostationary satellites aerosol observation







MI/COMS (NMSC/KMA, Korea)	GOCI/COMS (KOSC/KIOST, Korea)	AHI/Himawari-8 (JMA, Japan)
15-min interval for East Asia 3-hour interval for Full Disk (day and night)	1-hour interval for East Asia (total 8 times in daytime)	10-min interval for Full Disk (day and night)
1 bands in VIS (1 km) 4 bands in IR (4 km)	8 bands in VIS-NIR (0.5 km)	4 bands in VIS-NIR (0.5/1.0 km) 12 bands in IR (2 km)
Aerosol products (Yonsei) AOD (4km) *Mijin Kim et al. (2014, 2016)*	Aerosol products (Yonsei) AOD, FMF, AE (6 km) *Myungje Choi et al. (2016)*	Aerosol products (Yonsei) AOD, FMF, AE (6 km) *Hyunkwang Lim et al. (2016)*

[Courtesy, Jhoon Kim]

SURFACE REMOTE SENSING IN KORUS-AQ

Observation result of Remote sensing

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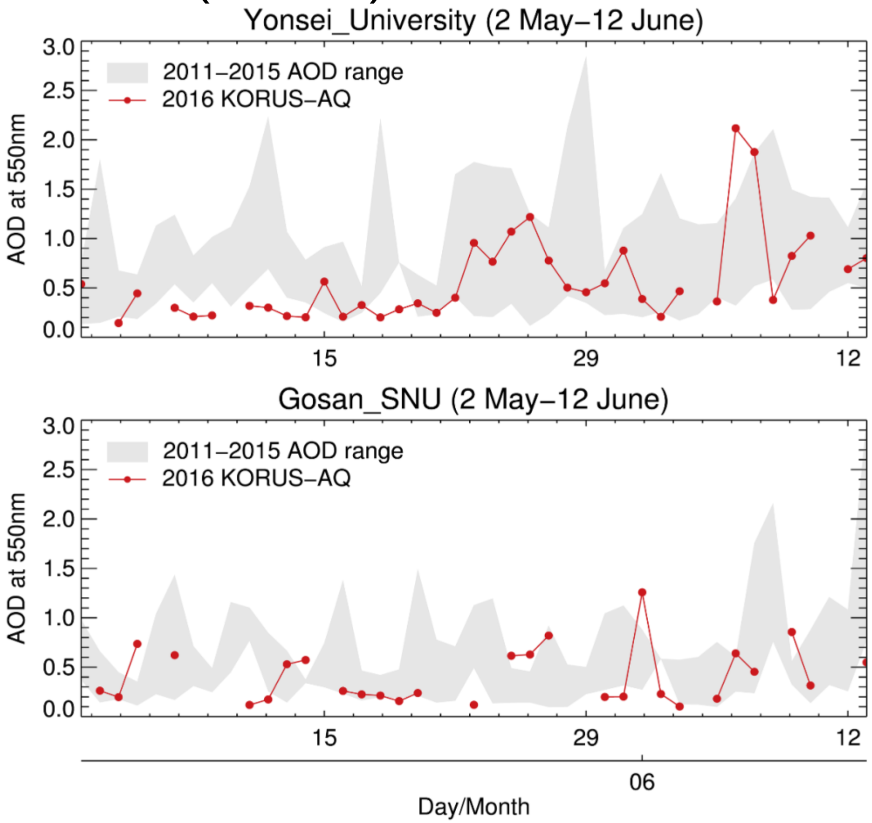
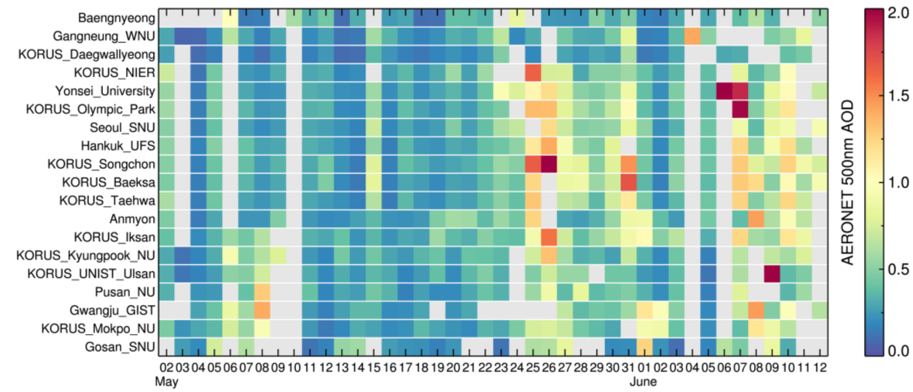
Time series of AOD and AE during KORUS-AQ

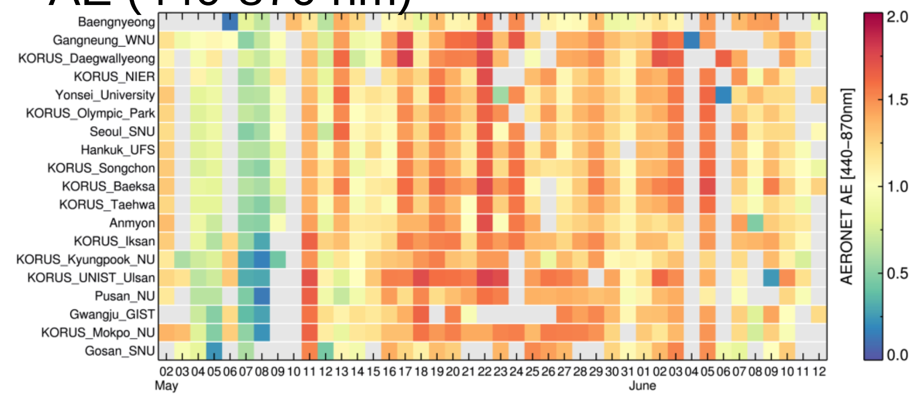
AOD (550 nm)



AOD (550 nm)



AE (440-870 nm)



- AERONET AOD at Seoul (megacity region) and Gosan (coastal region) have lower values compare to other recent years (2011 to 2015).

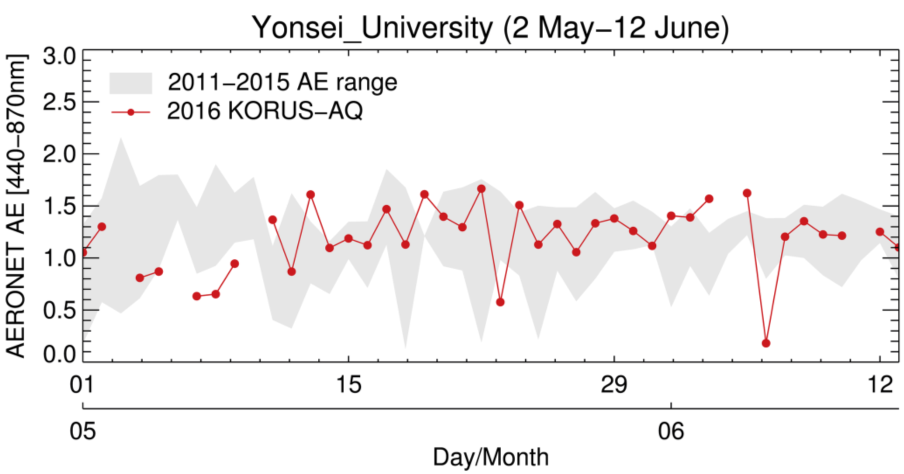
- AERONET AOD in the latter part of the campaign shows higher values than in the former part and fine particles are usually observed over the Korea peninsula during KORUS-AQ campaign.

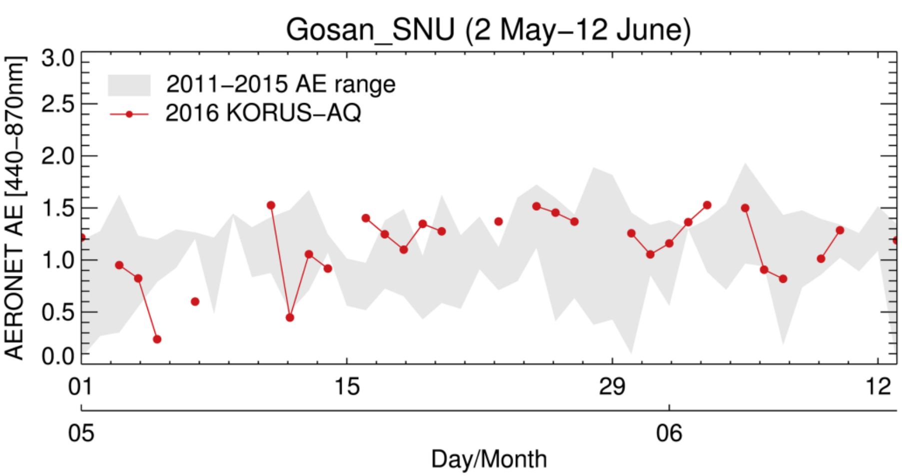
[Courtesy, Jhoon Kim]

Observation result of Remote sensing

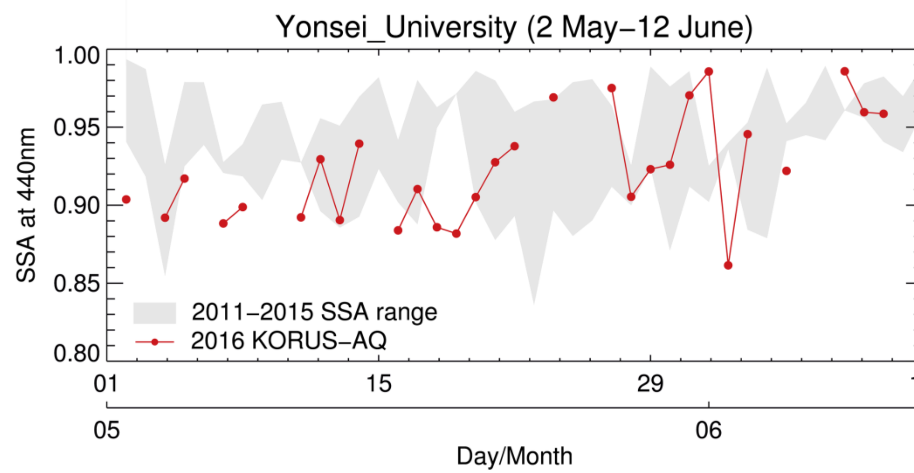
Time series of AE and SSA during KORUS-AQ

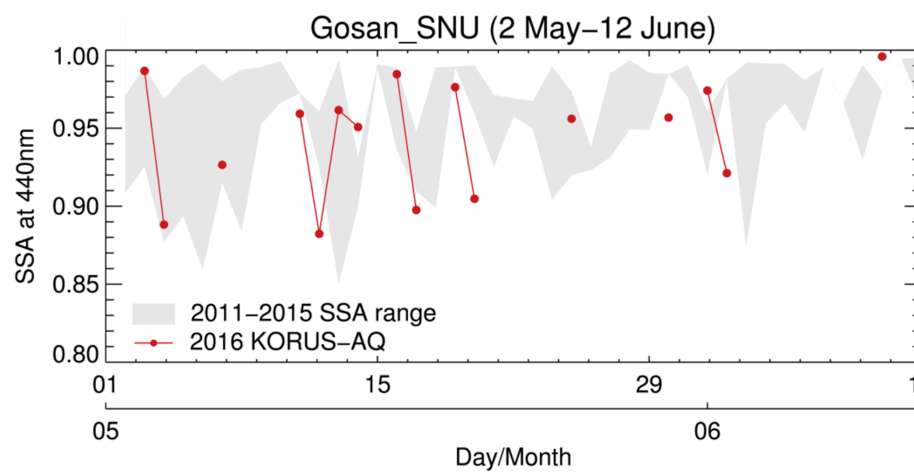
AE (440-870nm)





SSA (440nm)





[Courtesy, Jhoon Kim]

Observation result of Remote sensing

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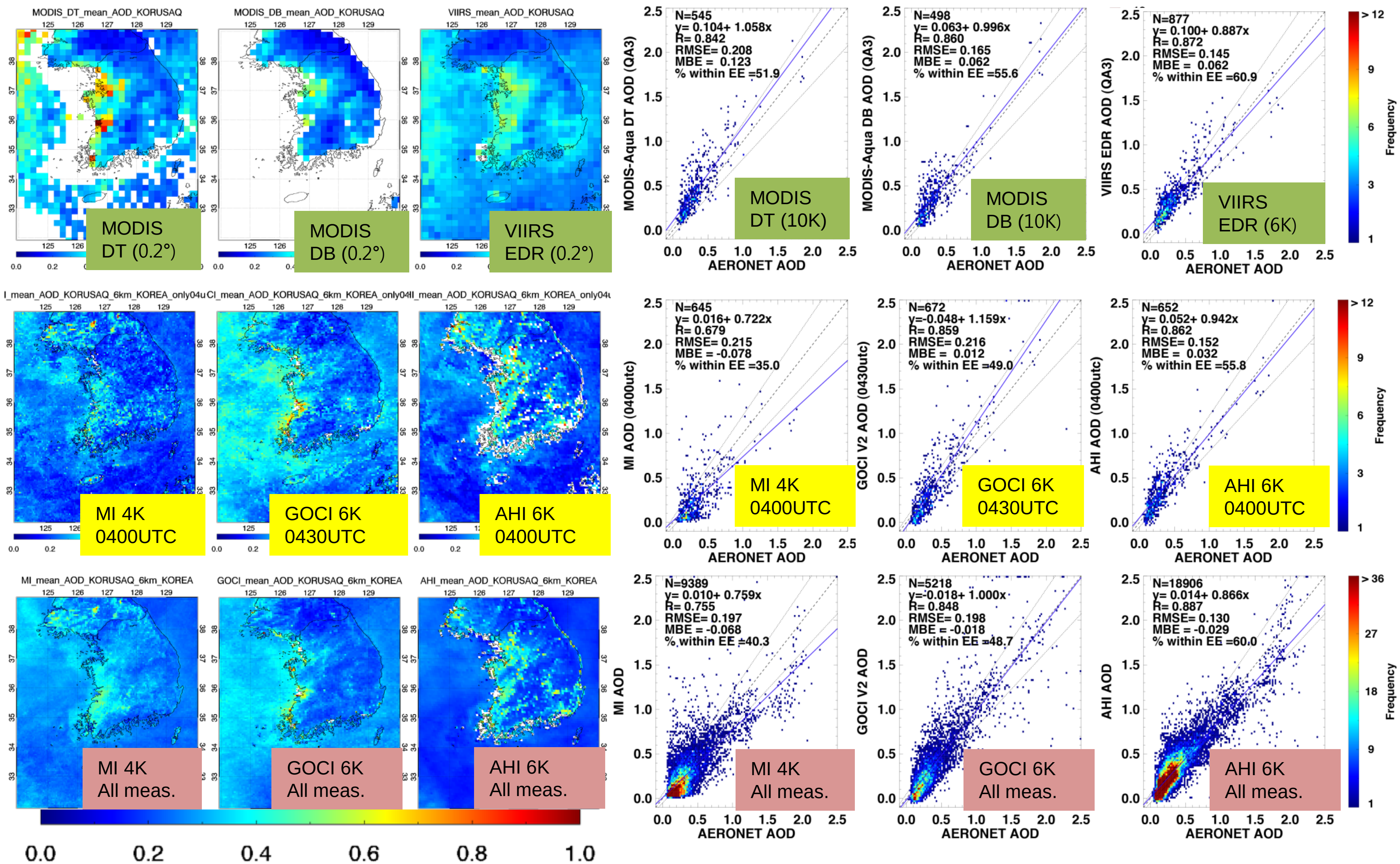

High AOD over Western part of Korea

- More frequent GEO measurement
  → 10-30 times higher in No. of collocated data
- Similar accuracy with LEO

[Courtesy, Jhoon Kim]

Observation result of Remote sensing

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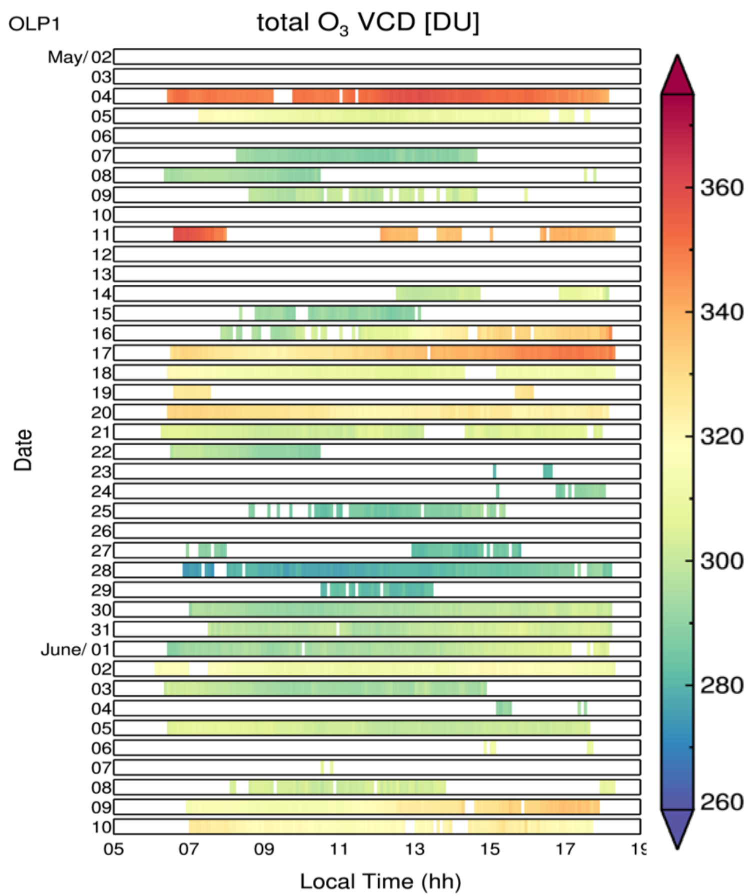
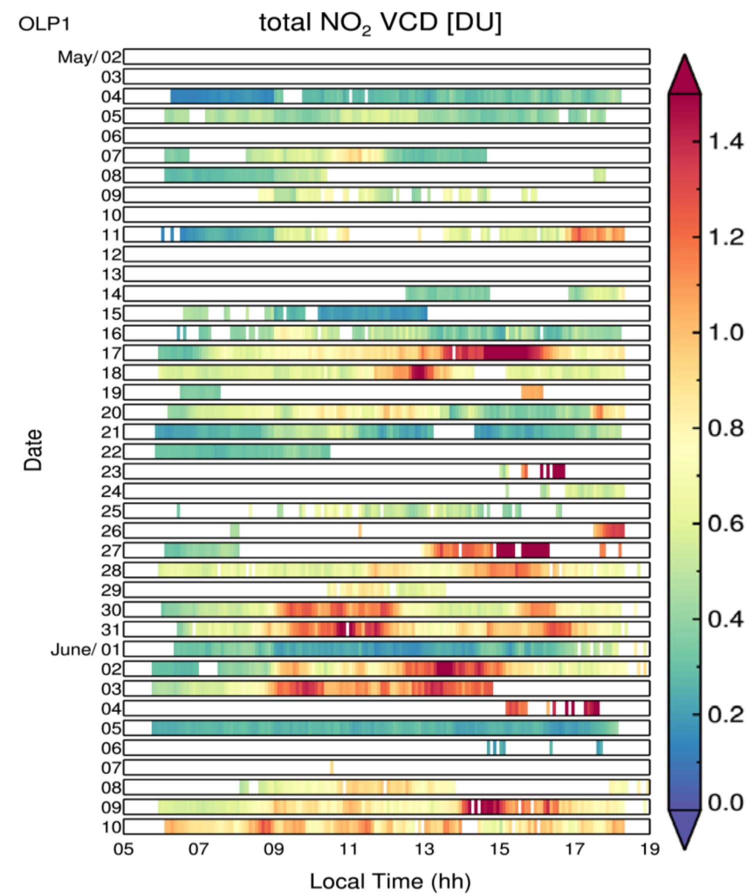
Pandora column amounts (Olympic Park time series)

[Courtesy, Jhoon Kim]





Pandora Ozone and NO2 measurements have low and high variability, respectively ➔ Olympic Park at urban area

Observation result of Remote sensing

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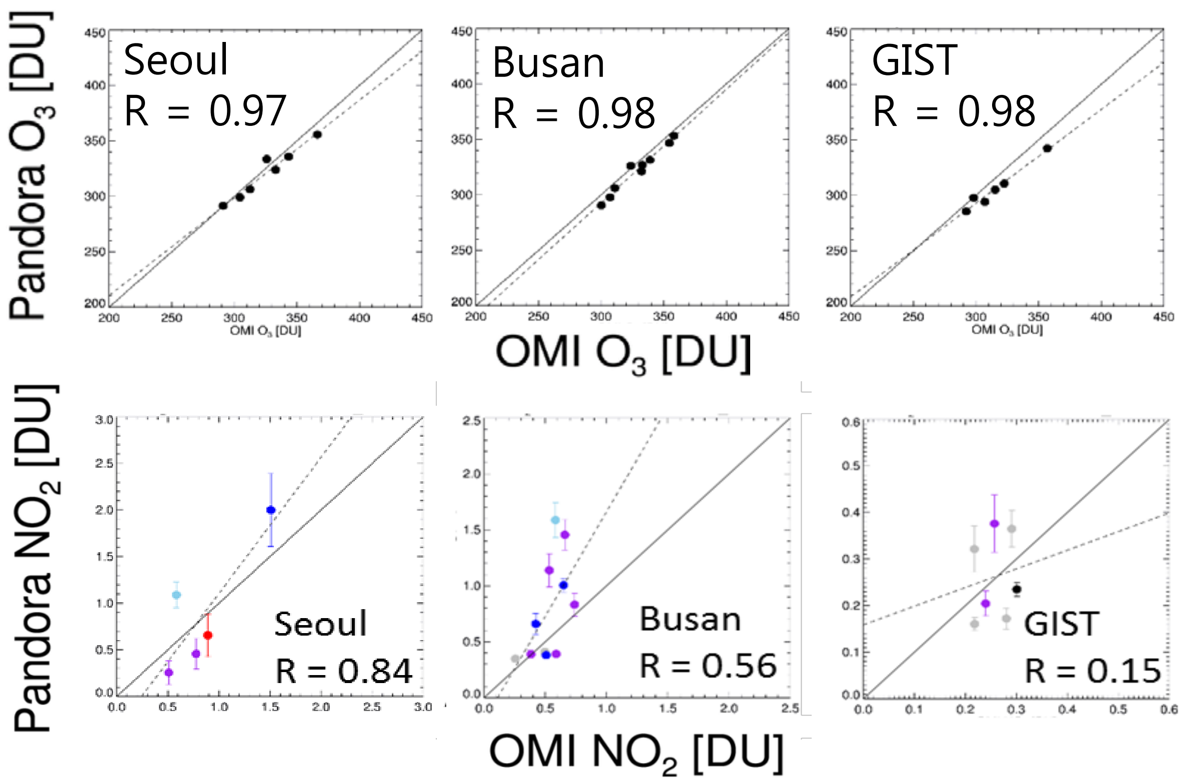
Validation of Pandora O_3, NO_2 using OMI

[Courtesy, Jhoon Kim]



- ***Temporal collocation***: Averaging Pandora NO2 within ±30 minute from OMI overpass time
- ***Spatial collocation***: Selecting OMI pixels within 30 km from each Pandora site

- For O_3, which has smaller spatial and temporal variability than NO_2, it was found that Pandora total VCD has high correlation with OMI (R>0.9).
- Pandora NO_2 has lower correlation with OMI data than O_3 because OMI has coarse spatial resolution and restricted observation time to measure NO_2 which has large spatial and temporal variability.

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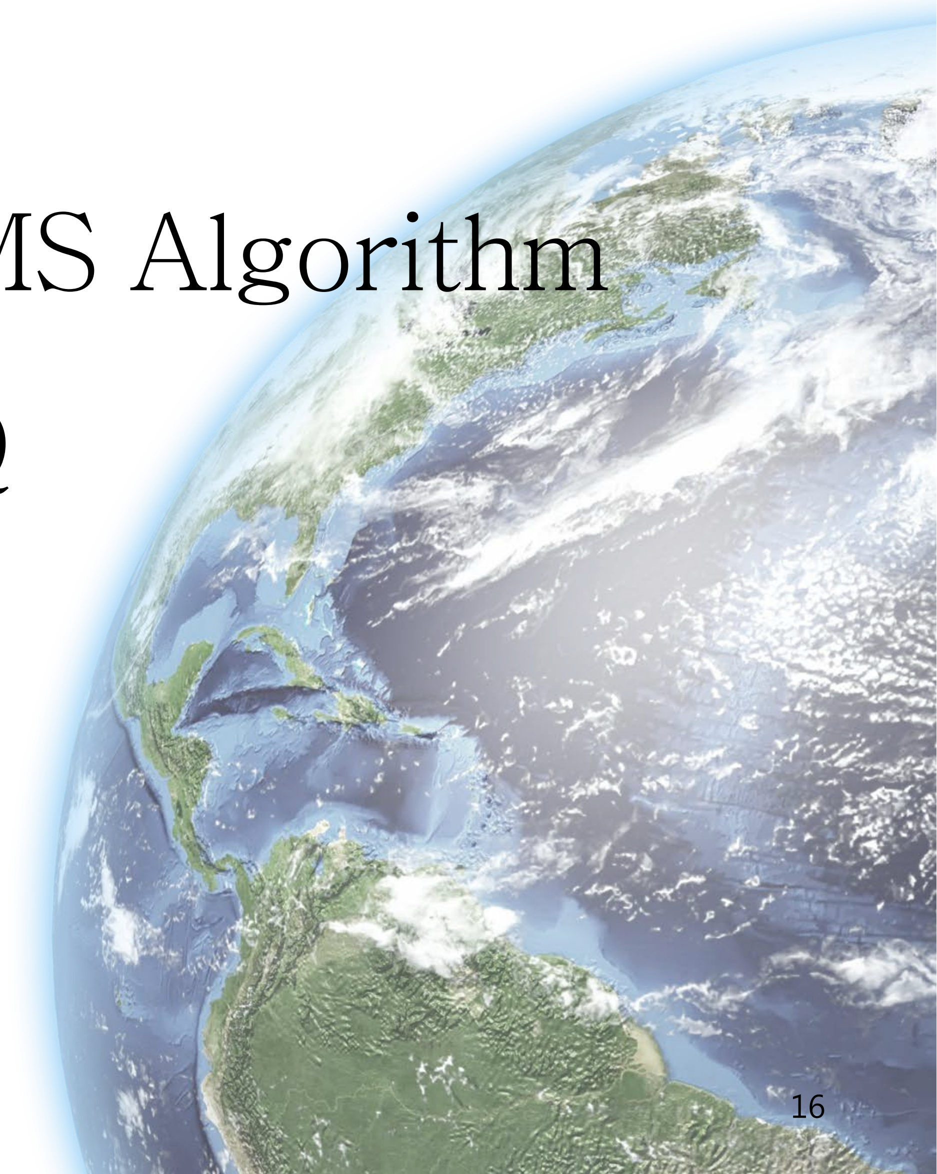
Evaluation of GEMS Algorithm with KORUS-AQ



Method

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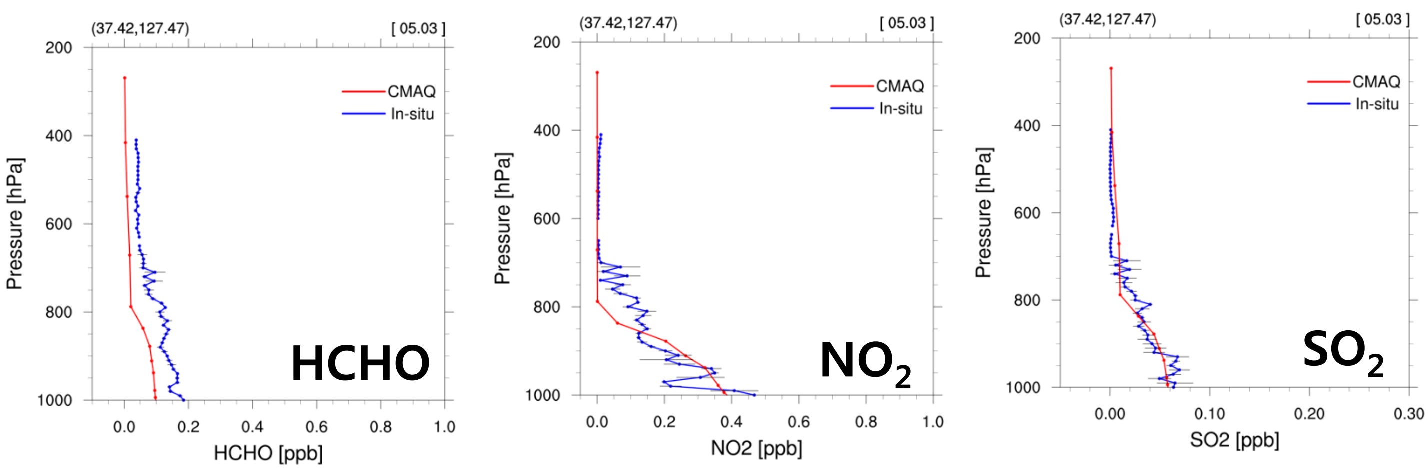
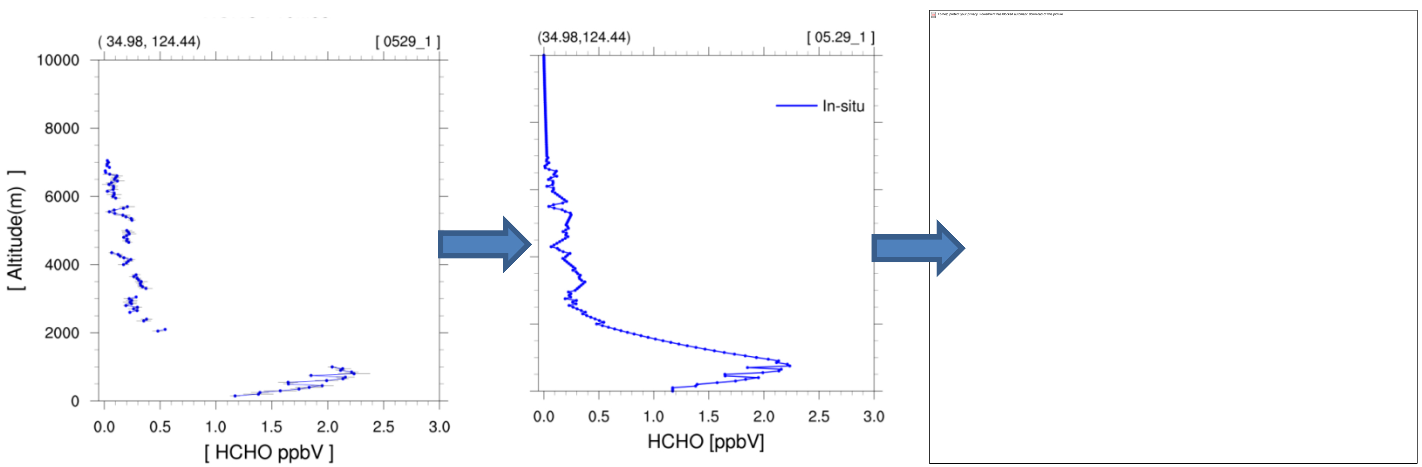
➢ Airborne profile data collection and analysis

- Airborne and CMAQ profiles during KORUS-AQ ➔ Airborne data is more detail!



- Retrieval Column data using interpolation and integration



Evaluation result

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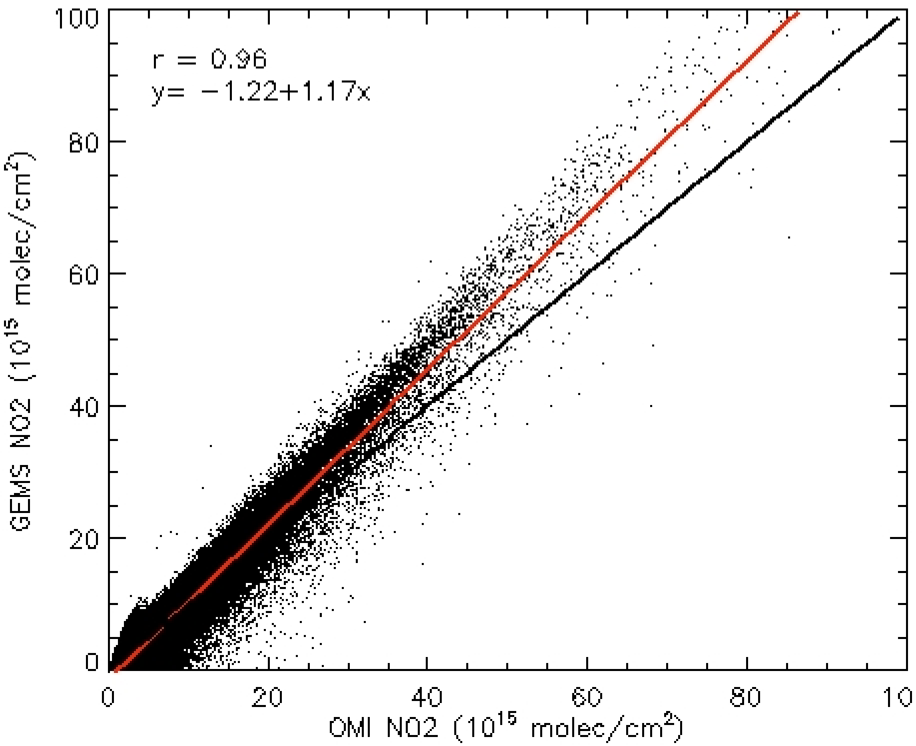
➢ NO2 Algorithm Evaluation

1. Comparison with OMI satellite

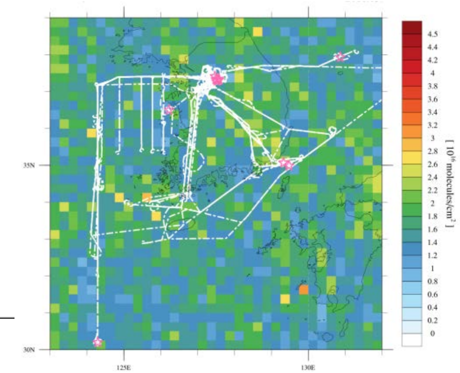
- OMI Level 2 NO_2
- 2005. 03
- Lat: -5˚~ 45˚, Lon: 75˚~145˚

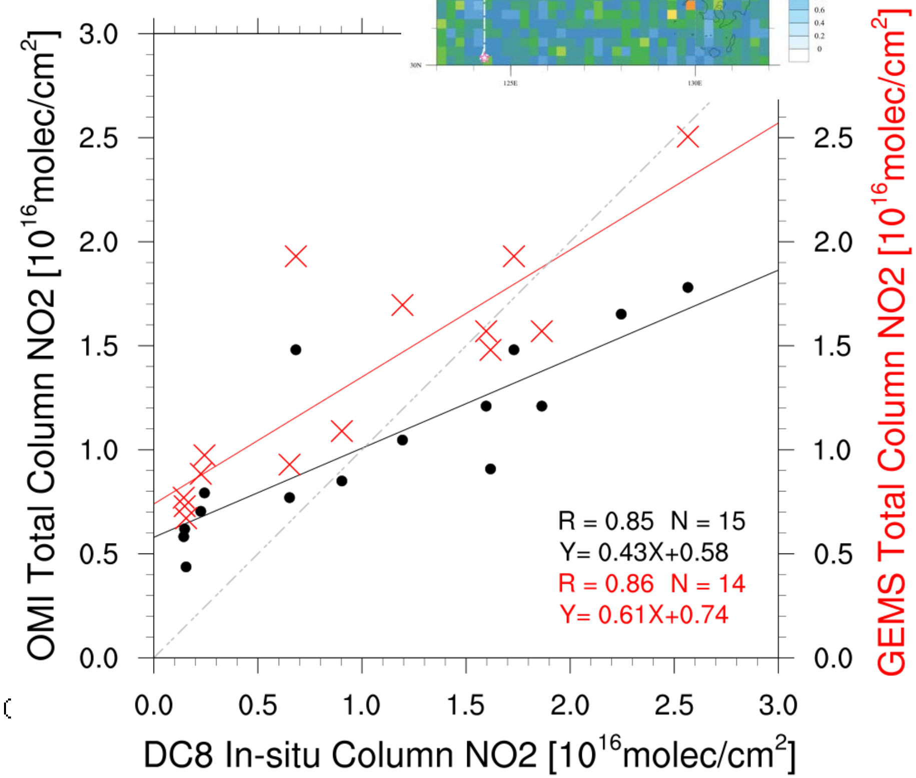
GEMS vs OMI



2. Airborne , 2016.05, 12:00~15:00 LST

DC-8 Spiral and track





Evaluation result

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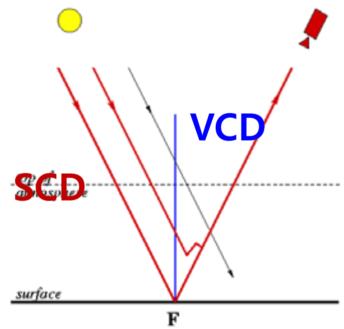
➢ HCHO Algorithm Evaluation

1. Comparison with OMI satellite

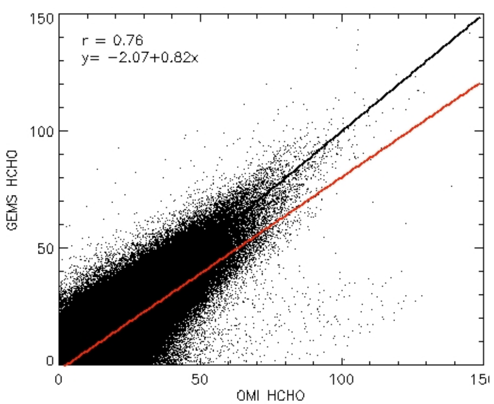
· OMI Level 2 HCHO

· 2005, Lat: -5˚~ 45˚, Lon: 75˚~145˚

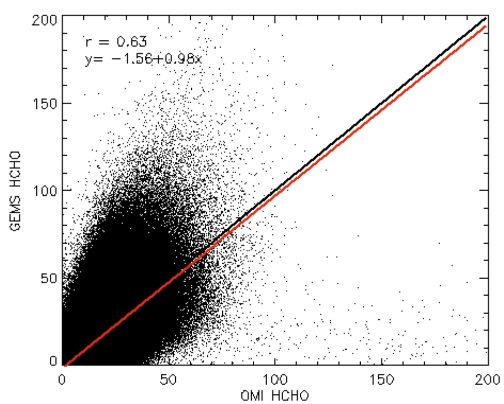


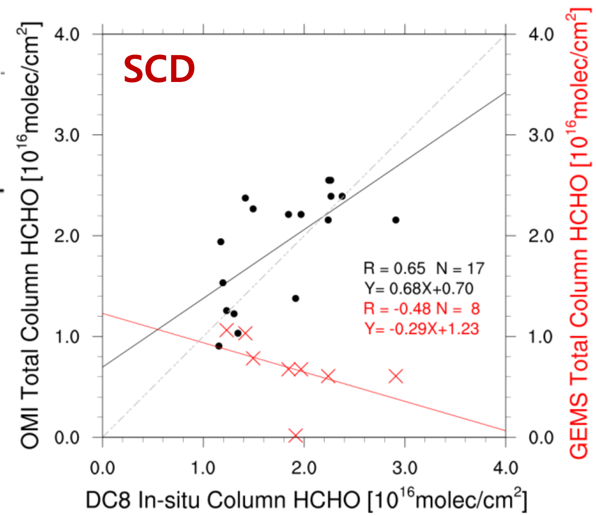
2. Airborne, 2016.05(KORUS-AQ),

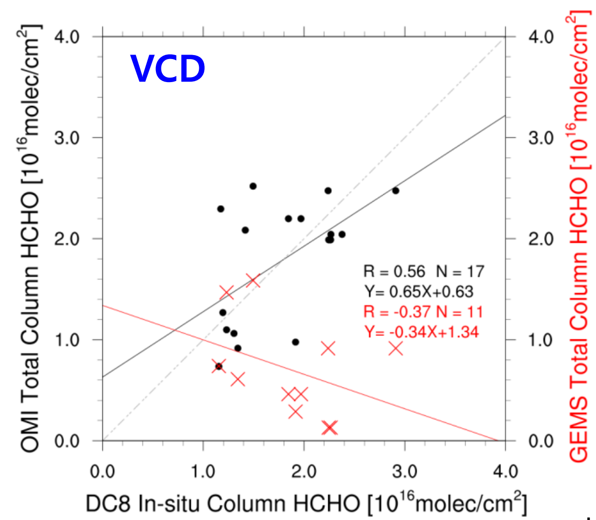
GEMS SCD vs OMI SCD



GEMS VCD vs OMI VCD







- Slant Column Density(SCD) is **similar** with OMI, Vertical Column Density(VCD) has **lower level of significance** than SCD

➔ be required retrieve **Air Mass Factor precisely**

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DEVELOPMENT OF GEO-TASO ALGORITHM

Introduction of Geo-TASO

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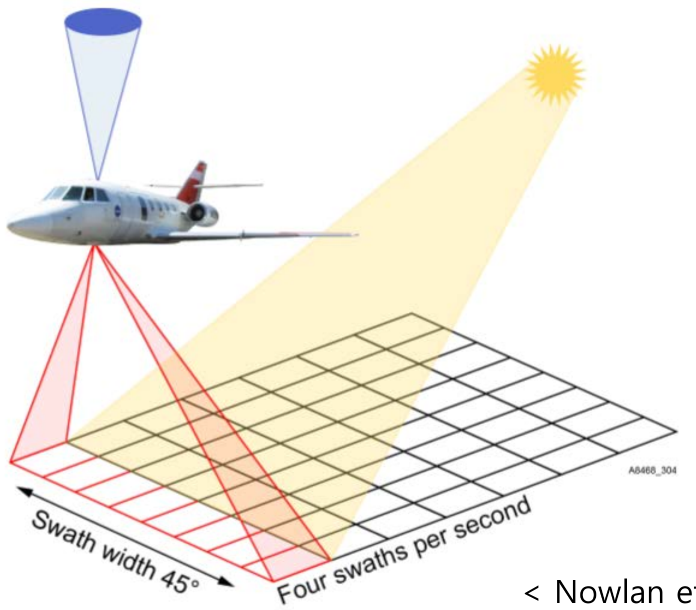
- Geo-TASO (Geostationary Trace gas and Aerosol Sensor Optimization)
  - Payload for aircraft to test algorithms performance of GEMS
- Retrieval of trace gas from Earth radiation intensity with UV-Vis hyper-spectrometer



< Nowlan et al. >

System Parameter	Value
Dispersion	UV: 0.14 nm/pix; Vis: 0.28 nm/pix
Spectral Passband	**UV: 280-490 nm; Vis: 560-980 nm**
Spectral Sampling	2 - 3.5 samples/FWHM
Spatial images/sampling (at 32 kft AGL)	40 by 80m IFOVs; 8 by 50m sampling
Cross-track swath (at 32 kft AGL)	8 km

< Leitch et al. >

Introduction of Geo-TASO

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- To improve GEMS Level2 Algorithms,
  GeoTASO and Sunphotometer are utilized as a test-bed

  * GeoTASO : the Airborne payload in KORUS-AQ campaign,
  * Sunphotometer : an aerosol ground observation

- Special feature of GeoTASO
  - Higher spatial resolution
  - Observations are not guaranteed to see temporal change at specific points.

  ➔ Development of airborne algorithm is needed.

Geo-TASO Algorithm

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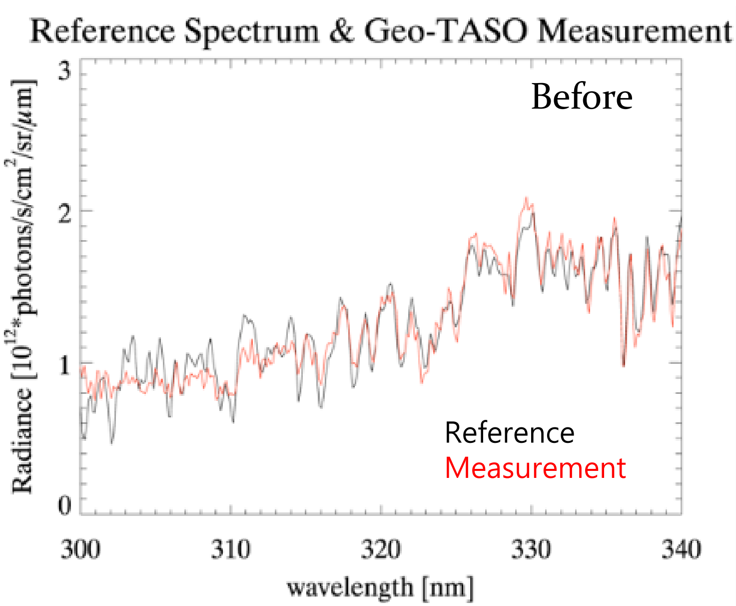
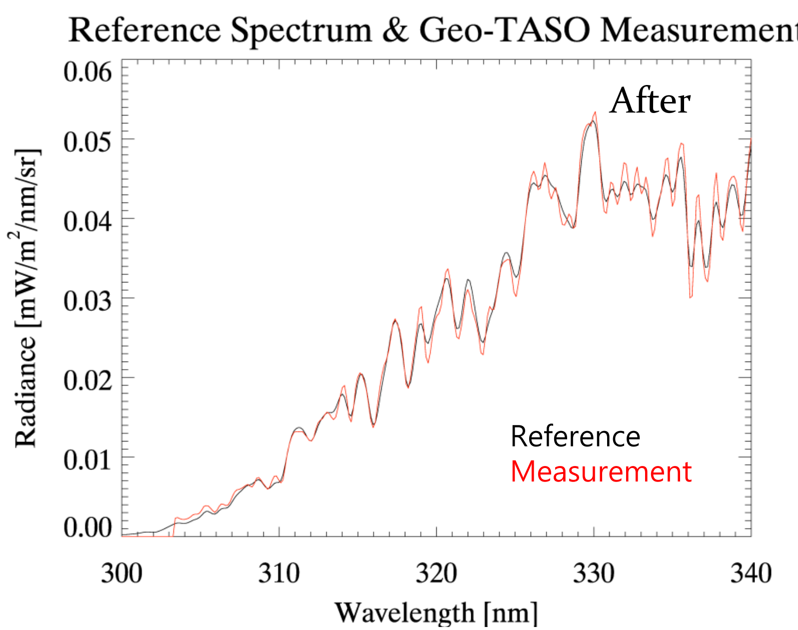
Wavelength Cal/Val Algorithm

- Develop wavelength cal/val algorithm for Geo-TASO with addition of Ozone and ring effect
- Sensitivity to UV area and cloud is reduced compared with previous algorithm



Correlaiton: 0.9236
RMSE: 0.6738



Correlation: 0.9978
RMSE: 0.1463

[Courtesy, Myoung-hwan Ahn]

Geo-TASO Algorithm

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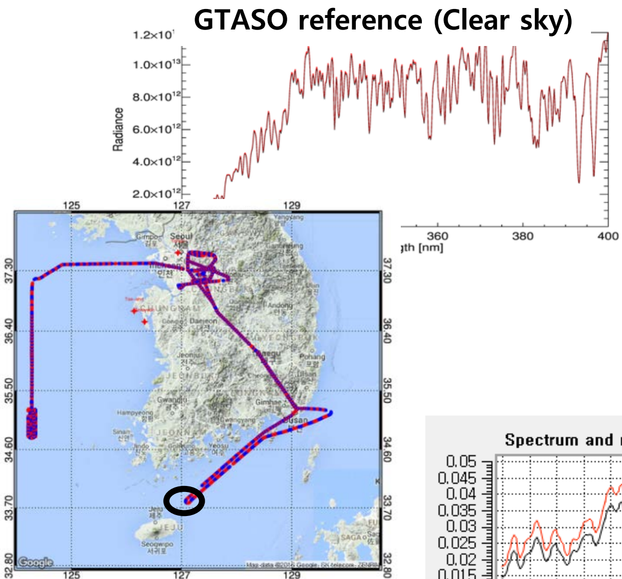
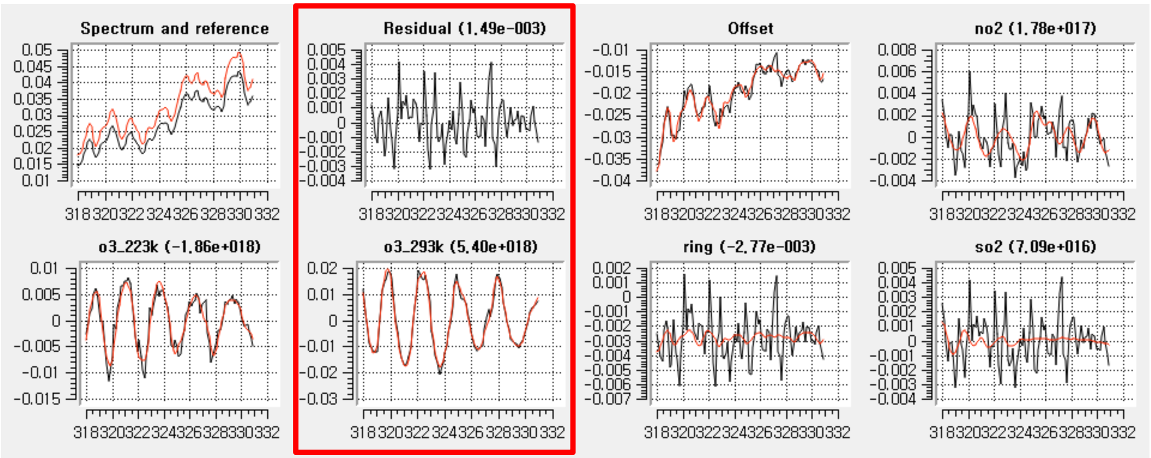
Ozone Algorithm

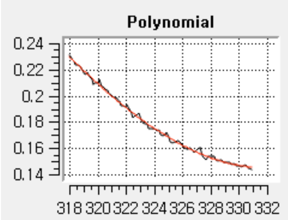


LEAST SQUARES FITTING

REFERENCE SPECTRA (SAO)
+
TEMPERATURE DEPENDENCE
+
Used Xsec
(O_3 243K, O_3 293K ring, SO_2, NO_2)

DOAS Fitting result (318 – 331 nm)





Residual is fitted as “1e-03 order”

[Courtesy, Jae-hwan Kim]

Geo-TASO Algorithm

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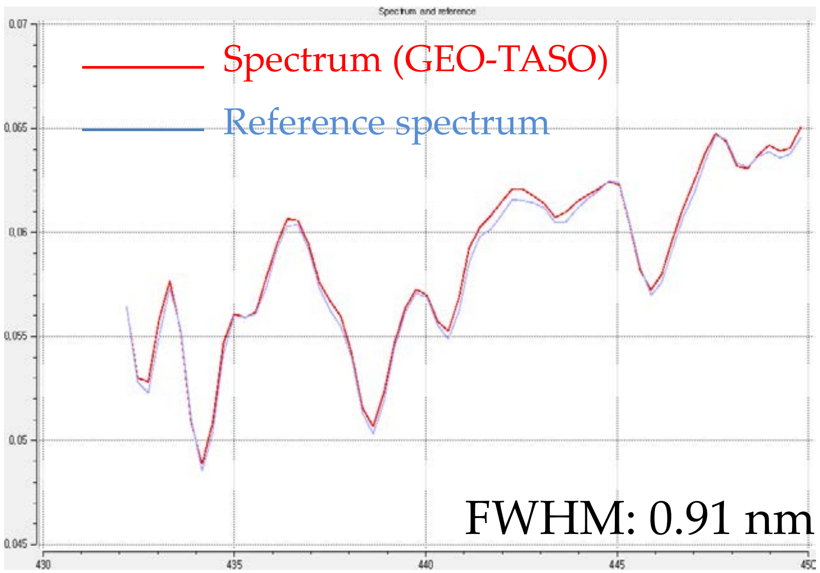
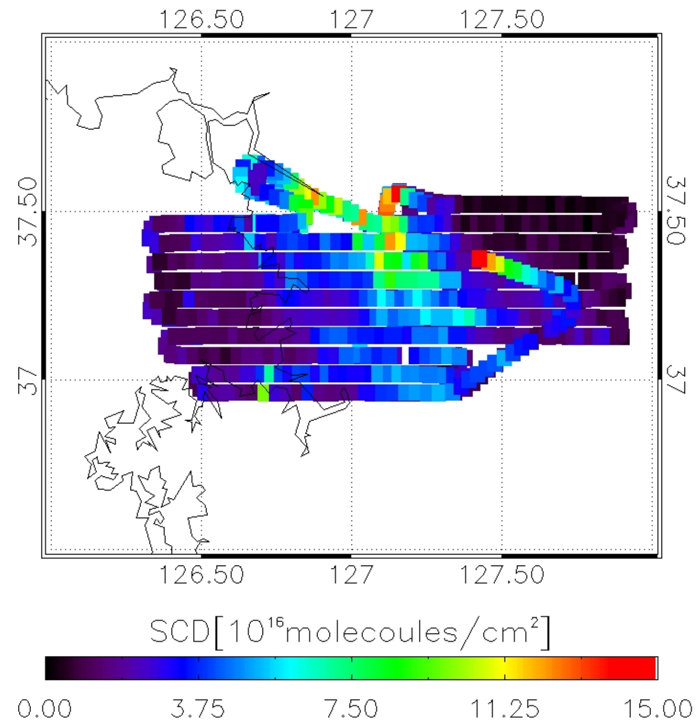
NO2 Algorithm



NO_2 SCD (May, 17,2016)



QDOAS spectral fitting software
(developed at the Royal Belgian institute for Space Aeronomy (BIRA-IASB)).

Fitting window: 432 ~ 450 nm

Cross section: NO_2_294K (Vandaele et al., 1998) , ozone_273K (Bogumil et al., 2000), ring (Chance and Spurr 1997)

[Courtesy, Hyunkee Hong]

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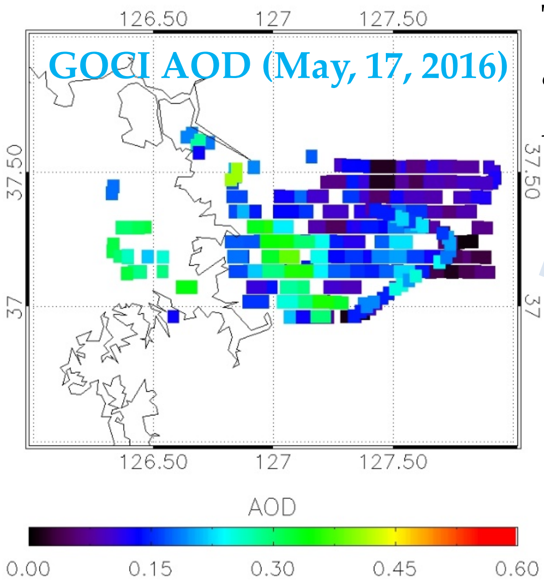
NO_2 AMF calculation

[Courtesy, Hyunkee Hong]

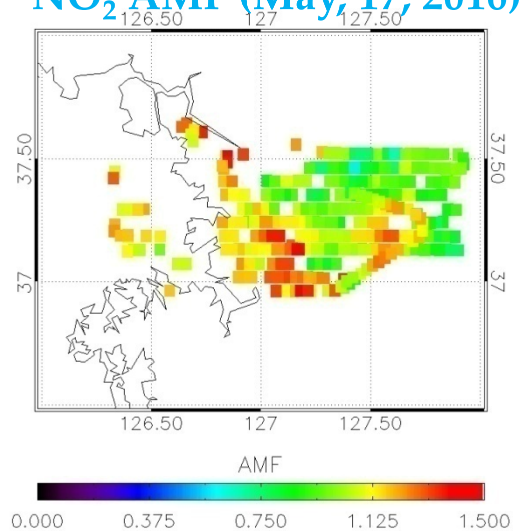
The aerosol vertical distribution is based on a Gaussian distribution function (GDF) and Aerosol peak height is assumed as 1 km.

GOCI AOD (May, 17, 2016)

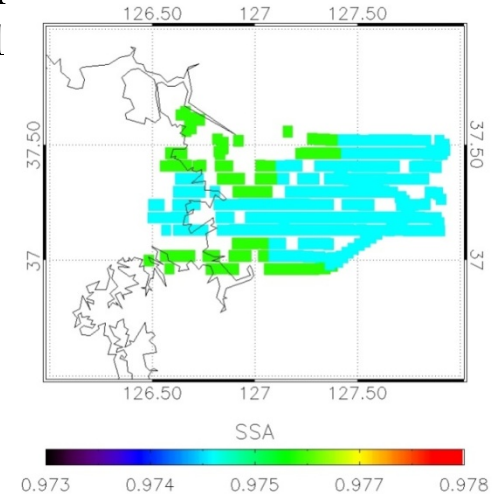


Courtesy of Jhoon Kim and Myeong Jae Choi

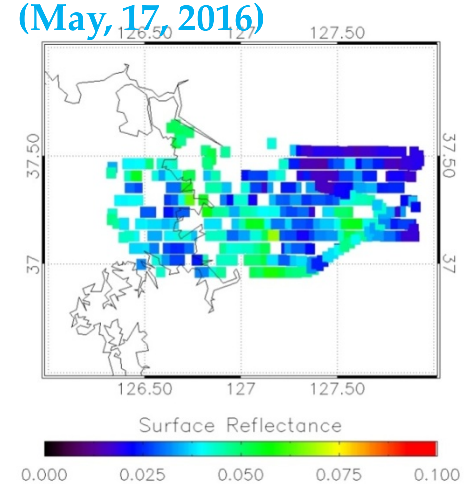
NO_2 AMF (May, 17, 2016)



MODIS SSA (May, 17, 2016)



MODIS surface reflectance (May, 17, 2016)



B200

SZA, VZA, RAA, Height

Geo-TASO Algorithm

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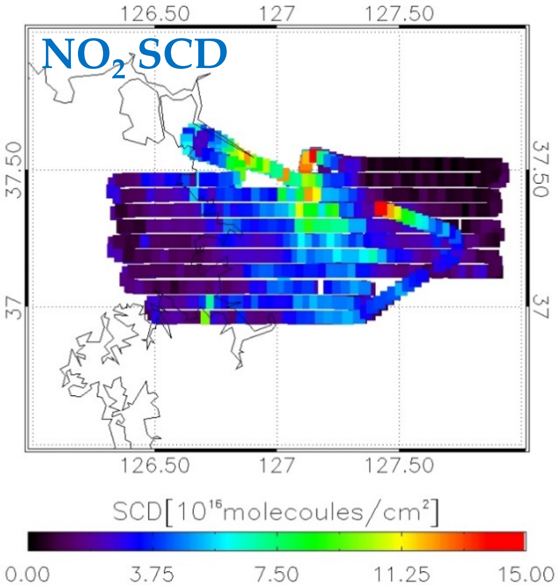
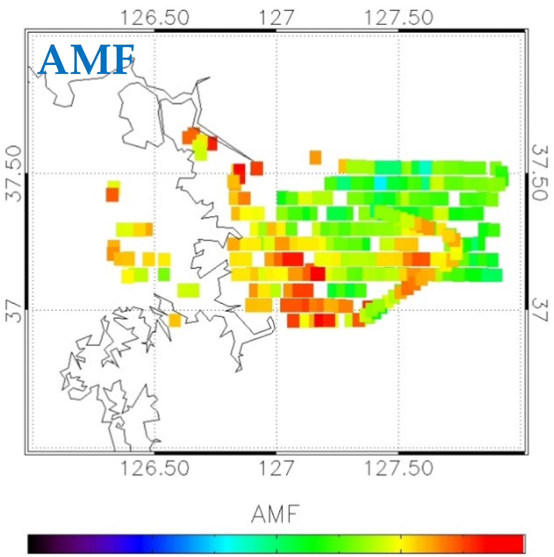
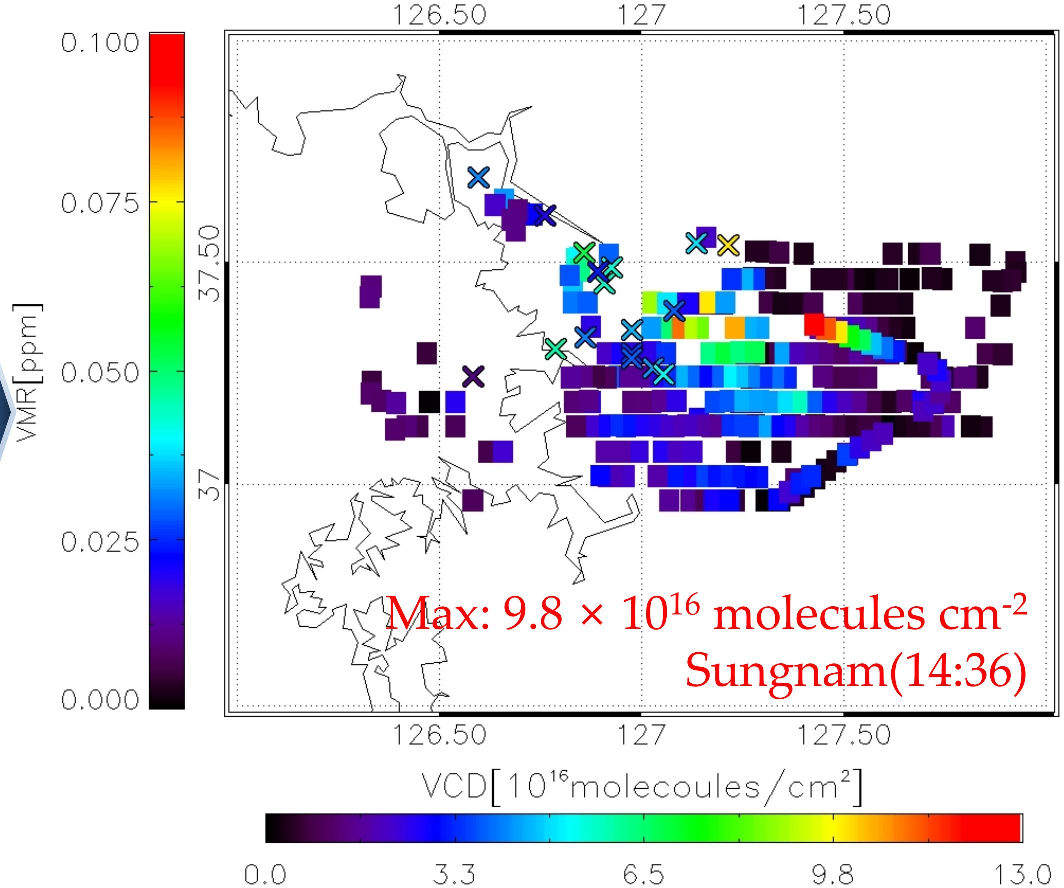
Tropospheric NO_2 VCD retrieval





<May, 17, 2016>

Tropospheric NO_2 VCD & in-situ NO_2 VMR at the same time



[Courtesy, Hyunkee Hong]

Summary

- During KORUS-AQ, it is used for observation such as ground-based remote sensing, airborne, satellite, and modeling.
- The result of surface remote sensing is matched well with last 5 years.
- In GEMS evaluation, the results of Ozone compared with DC-8 or OMI were significant, but we found that formaldehyde requires AMF improvement.
- To understand GEO-TASO observation result, we develop GEO-TASO algorithm and it is undergoing improvement.
- We will evaluate GEMS algorithm more with KORUS-AQ results so that GEMS will offer products with significant quality.

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THANK YOU FOR YOUR ATTENTION!

Retrieval Algorithm

Differential Optical Absorption Spectroscopy (DOAS)

The beer-Lambert law

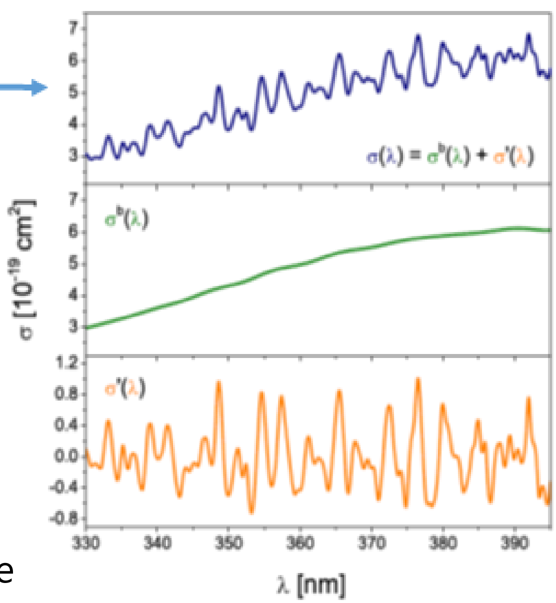
$$I(\lambda) = I_o(\lambda)\exp(-\sum_{j=1}^{n} S^j(\lambda)c_j)$$

➔ Optical thickness (density)

$$\tau \equiv \ln(\frac{I(\lambda)}{I_0(\lambda)}) = \sum_{j=1}^{n} S^j(\lambda)c_j$$

$$\ln\left(\frac{I(\lambda + \Delta(\lambda)) - offset(\lambda)}{I_0(\lambda)}\right) - \{\sum_{j=1}^{n} S^j(\lambda)C_j + P(\lambda)\} = 0$$

Measured optical thickness (MOT) Model equation (ME)



Broad spectral structure

➔ due to Rayleigh & Mie scattering
➔ Calculated from Polynomial models

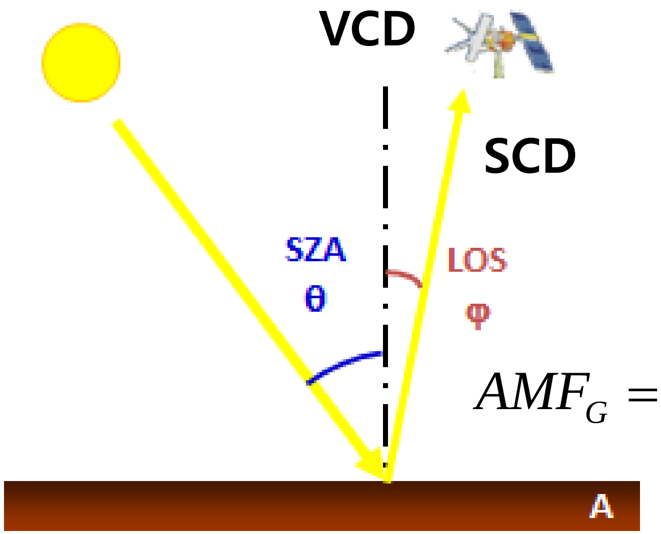
Narrow spectral structure

➔ Slant columns (SCD) calculated from a fitting method

Credit: H. L. Lee

Retrieval Algorithm

National Institute of Environmental Research



$$AMF_G = \frac{1}{\cos(\theta)} + \frac{1}{\cos(\varphi)}$$

The AMF is defined as **the ratio of the measured slant column to the vertical column in the atmosphere**:

$$AMF = \frac{SCD(\lambda, \Theta, \ldots)}{\boxed{VCD}}$$ *From Satellite*

The AMF_i are also often called "Scattering Weights"

The AMF expresses the sensitivity of the measurement, and depends on a variety of parameters such as:

- wavelength
- geometry
- vertical distribution of the species
- clouds
- aerosol loading
- surface albedo

➔ *Calculate AMF with RTM*

Credit: aeronomie.be