GESC
Global Environment Satellite research Center

Status of GEMS

Jhoon Kim[1], U. Jeong[2], M. Kim[2], S. Go[2],, X. Liu[3], Kelly Chance[3]
[1]P.I., GEMS; [2] Yonsei Univ., [3]Harvard Smithonian CfA

GEMS Science Team

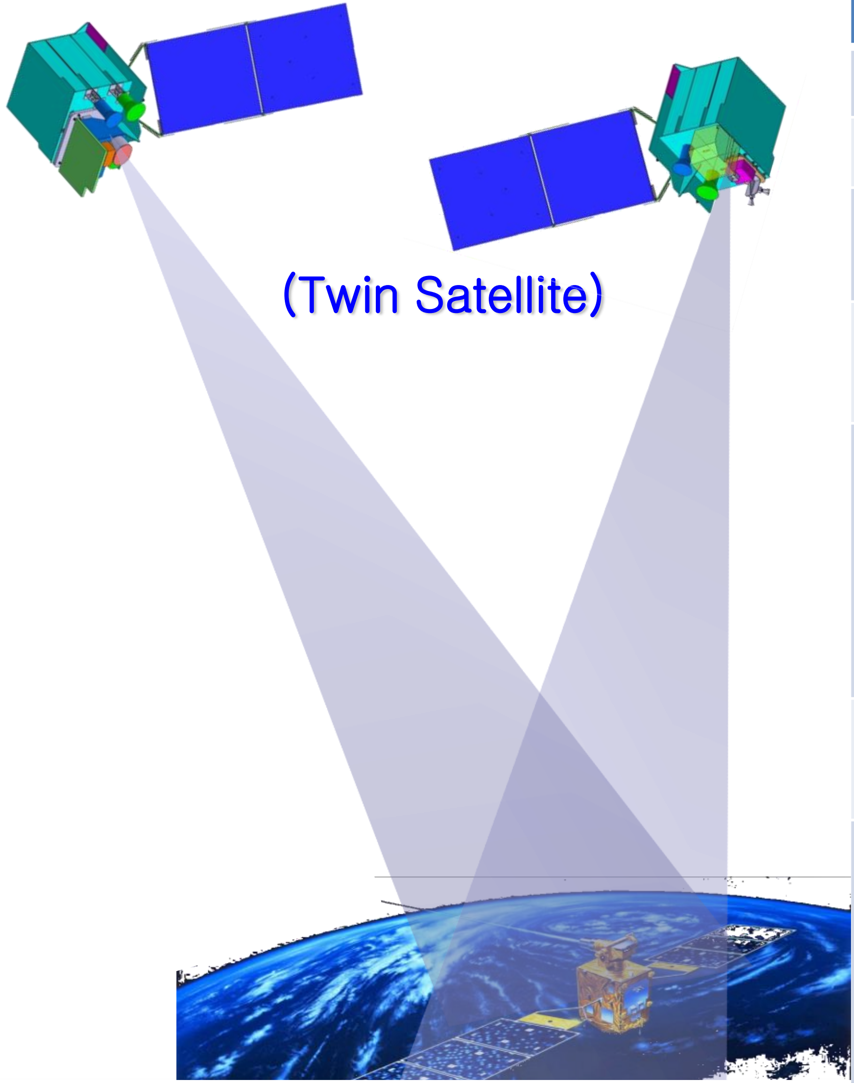
[1] Department of Atmospheric Sciences, Yonsei University, Seoul, Korea
[2] National Institute of Environmental Research

MINISTRY OF ENVIRONMENT

GEO-KOMPSAT 2

2A Sat. : AMI
Launch : 5/2018

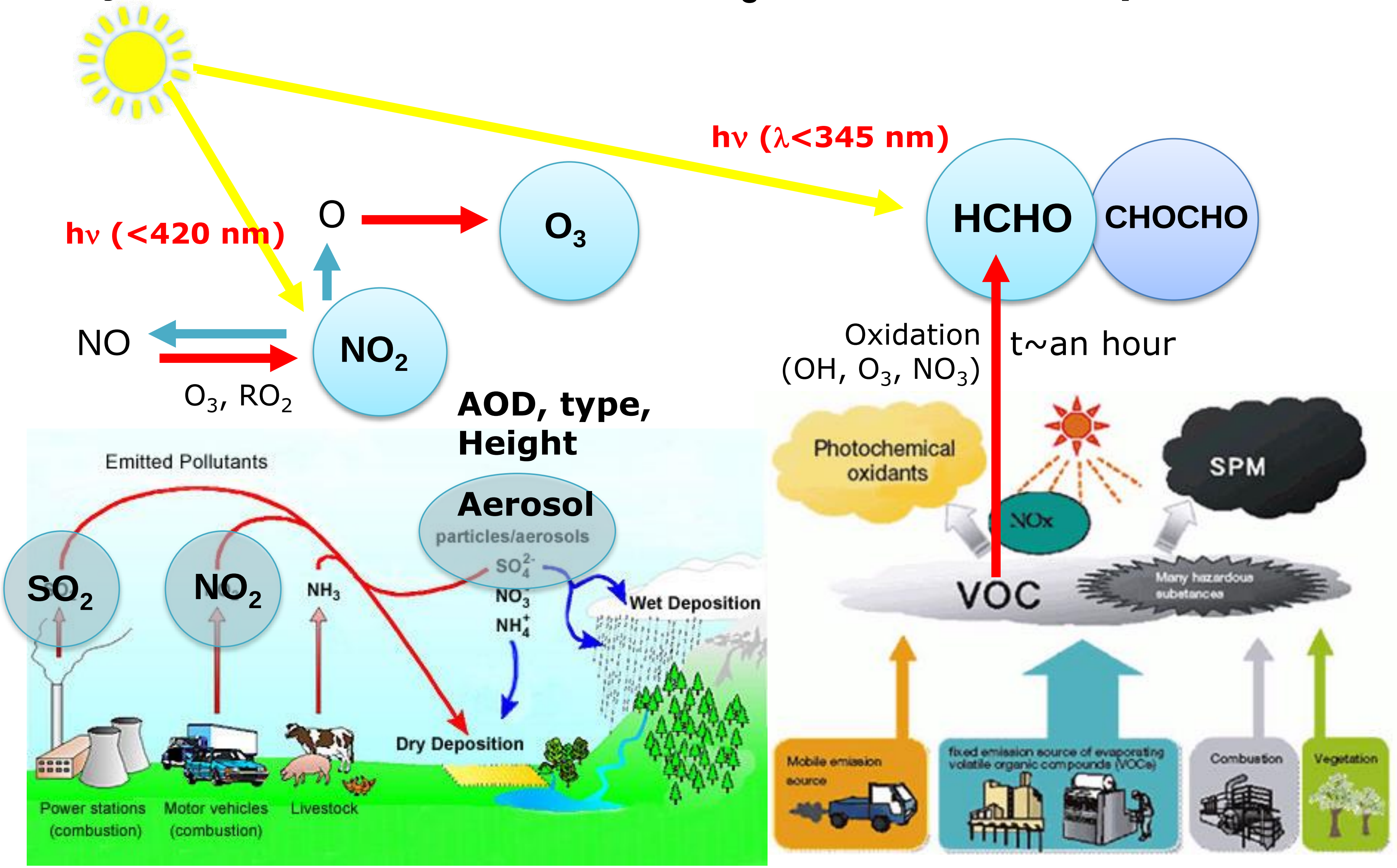
2B Sat. : GEMS, GOCI-2
Launch : 3/2019



Specification

	2A	2B	
Payload	AMI	GOCI-2	GEMS
Lifetime		10 years	
Channels	16	13	1000
Wavelength range	0.4 - 13 µm	375 - 860 nm	300-500 nm
Spatial resolution	0.5 / 1 km (Vis) 2 km (IR)	250 m@ eq 1 km (FD)	7 x 8 km^2 @ Seoul 3.5x8 km^2 (aerosol)
Temporal resolution	10 min (FD)	1 hour	1 hour
Major Products	CTP, CTT, CF, AOD, FMF, OLR, SI, CSR, SST, LST, AMV, … (56)	Ocn. current, chloryphyl, DOM, Phytoplankton, …	AOD, AI, SSA, ACH, CCH, CRF, NO_2, O_3, SO_2, UVI, HCHO, CHOCHO

Objective: Measurements of O_3 & aerosol with precursors

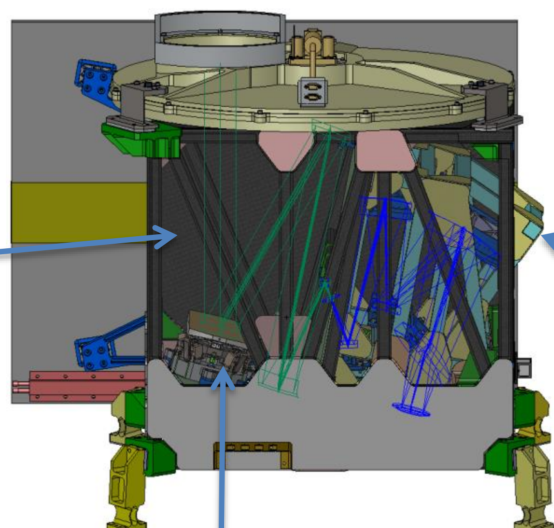


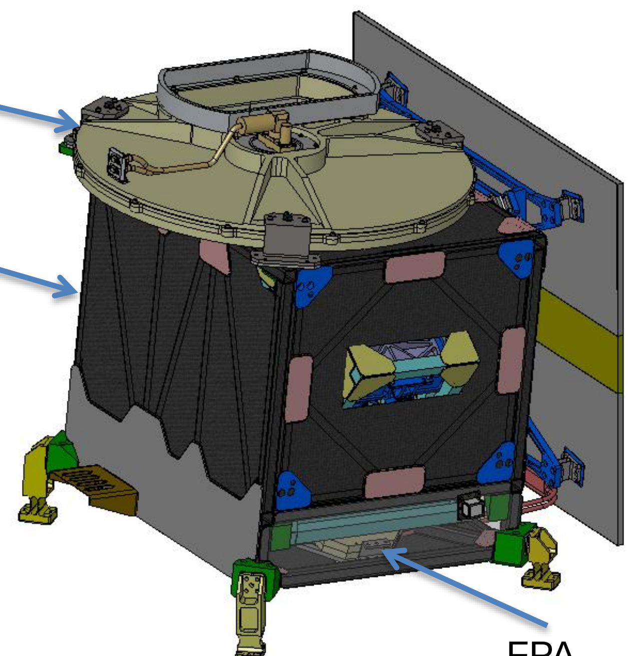
GEMS Instrument

- Step-and-stare UV-Vis imaging spectrometer scanning at least 8/day in 30 min
- Daily solar and dark calibration
- Images coadded at each position + mirror move back < 30 minutes
- Diffusers for on-orbit solar calibration and onboard LED light source
- 2-axis scan mechanism with gyro feed capability
- Redundant electronics for 10-year lifetime

✓ Hot pixel issues in southern part of the GEMS domain.

✓ Solar calibration time with GOCI-2 within 29-31 deg with the GEMS BTDF characterized at 30 deg.





Courtesy, KARI / BATC

Status of GEMS

- **GEMS Development**
  - SDR in Oct., 2013, PDR in Mar., 2014, CDR in Feb., 2015
  - GEMS Telescope shall be assembled, aligned, and tested at KARI in 2015 (JDAK)
  - GEMS System integration and test shall be performed in 2016
  - TRR in Aug. 2016, PSR in 2017 Q1
  - Delivery to KARI from BATC 2017 Q2 for S/C integration

- **GEO-KOMPSAT-2 Program**
  - SRR in Apr., 2012; SDR in Feb. 2014, PDR in Jul., 2014,
  - CDR planned in Sep. 2015 for GK-2A, and Jan. 2016 for GK-2B

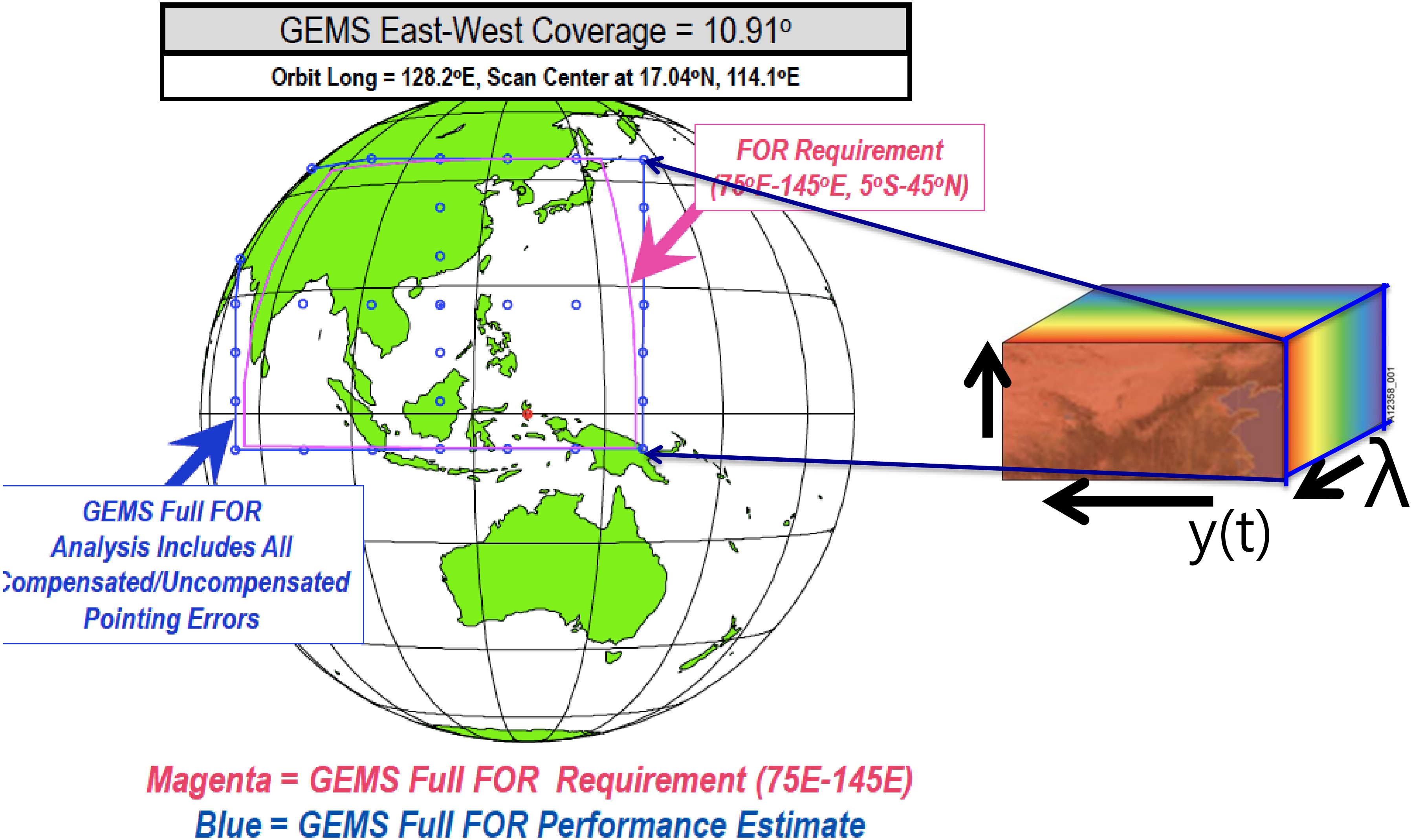
- **Launch**
  - Launch : Mar., 2019 by Arianespace (2A launch : May, 2018)

- **Related activities**
  - Air quality forecast in operation since 2013 by NIER/ME

    → GEMS to be an operational sat. (e.g. data assimilation of model with sat. data)
  - 'KORUS-AQ' airborne campaign in 2016 (with GEOTASO and MOS)

- **Cal/val network**
  - MaxDOAS, Pandora Network, AERONET, SONET, SKYNET, LIDARnetwork etc.

Spatial coverage



Baseline products (16)

Product	Importance	Min (cm^{-2})	Max (cm^{-2})	Nominal (cm^{-2})	Accuracy	Window (nm)	Spat Resol (km^2)@Seoul	SZA (deg)	Algorithm
NO_2	O3 precursor	$3x10^{13}$	$1x10^{17}$	$1x10^{14}$	$1x10^{15}$ cm^{-2}	432-450	7 x 8 x 2 pixels	< 70	BOAS DOAS
SO_2	Aerosol precursor Volcano	$6x10^{8}$	$1x10^{17}$	$6x10^{14}$	$1x10^{16}$ cm^{-2}	312-326	7 x 8 x 4 pixels x 3 hours	< 50 (60*)	
HCHO	VOC proxy	$1x10^{15}$	$3x10^{16}$	$3x10^{15}$	$1x10^{16}$ cm^{-2}	327-356	7 x 8 x 4 pixels	< 50 (60*)	
CHOCHO					$1x10^{16}$ cm^{-2}	437-452	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-λ OE O_2O_2
[Clouds] ECF CCP	Retrieval Climate	0 (COD)	50 (COD)	17 (COD)		460-490	7 x 8	< 70	O_2O_2 RRS
Surface Property	Environ-ment	0	1	-		300-500	3.5 x 8	< 70	Multi-λ
UVI	Public	0	12	-			7 x 8	< 70	

Performance Prediction

Error analysis Using the Optimal Estimation Method

$$\hat{\mathbf{x}} - \mathbf{x} = (\mathbf{A} - \mathbf{I}_n)(\mathbf{x} - \mathbf{x}_a)$$ → Smoothing error

$$+ \mathbf{G}_y \mathbf{K}_b (\mathbf{b} - \hat{\mathbf{b}})$$ → Model parameter error

$$+ \mathbf{G}_y \Delta f(\mathbf{x}, \mathbf{b}, \mathbf{b}')$$ → Forward model error

$$+ \mathbf{G}_y\, e$$ → Retrieval noise

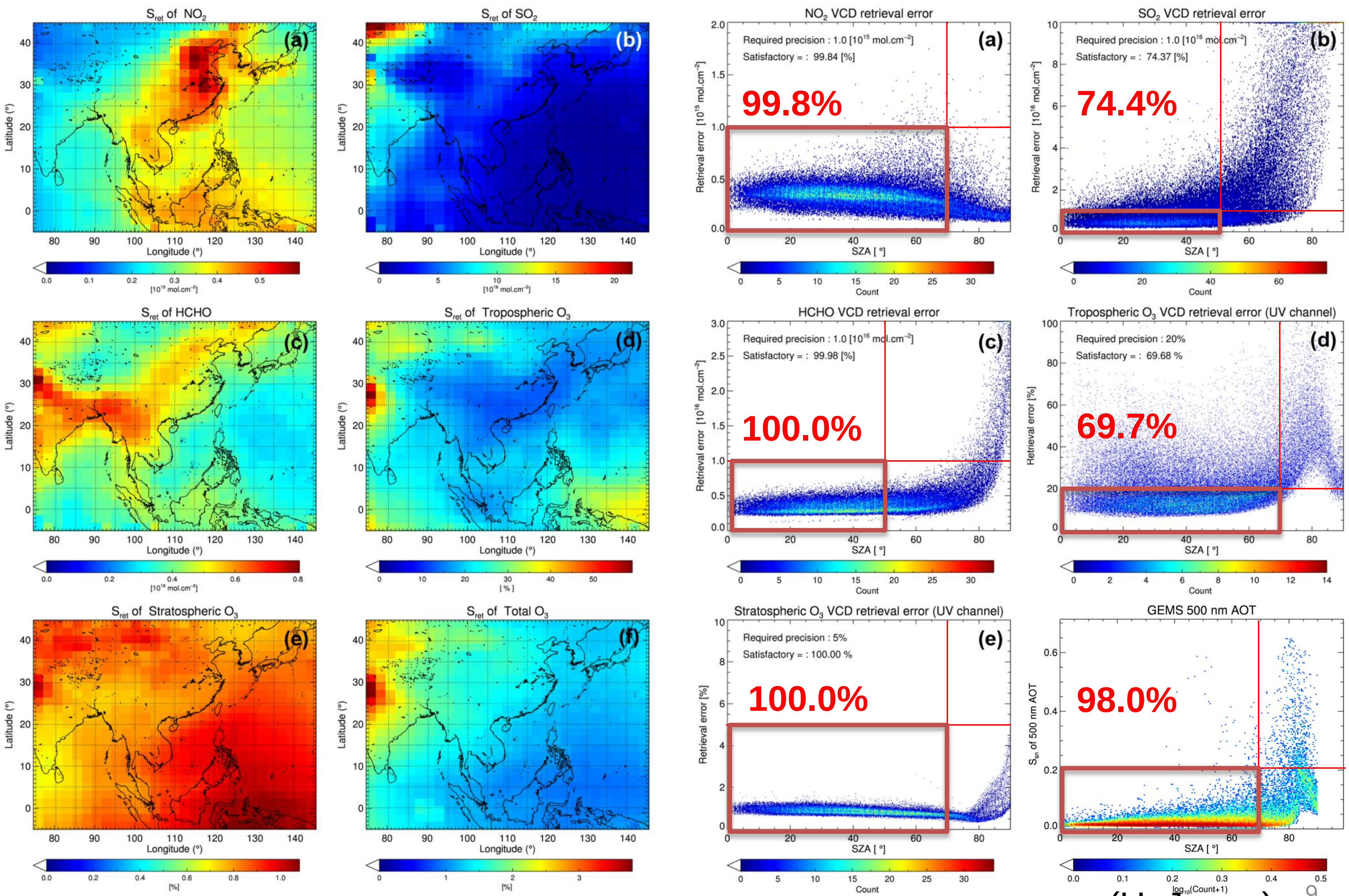
Solution error (S_{sn}) : square-root-sum of the diagonal elements of smoothing error and retrieval noise covariance matrices

- $\hat{\mathbf{x}}$: retrieved value
- **x** : true value
- **A** : averaging kernel
- $\mathbf{I}_n$: identity matrix
- $\mathbf{X}_a$: a priori estimates of x
- **G** : contribution function (generalized inverse of K)
- **K** : Jacobian matrix
- **b** : true model parameter

- $\hat{\mathbf{b}}$: best estimate of model parameters
- $\Delta\mathbf{f}$: forward model error
- **b′** : unknown forward model parameters
- ε : measurement error

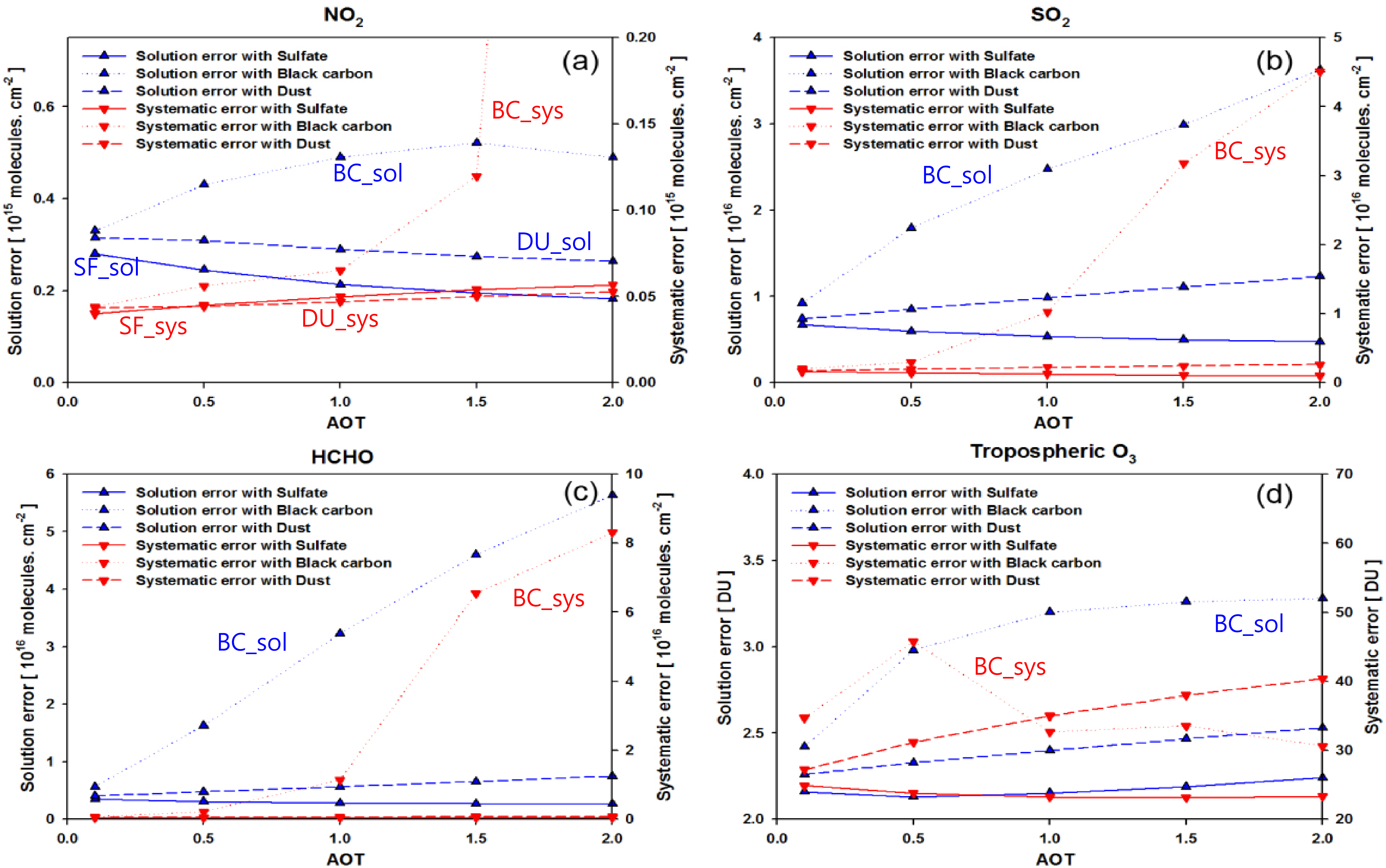
(Rogers, 2000)

Results



(U. Jeong)

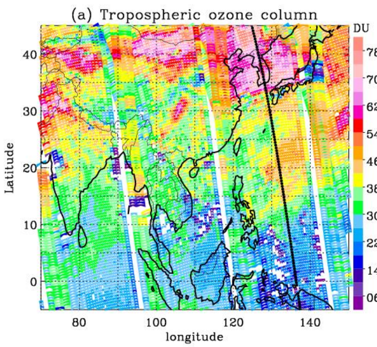
Effect of aerosol on retrieved gas column density



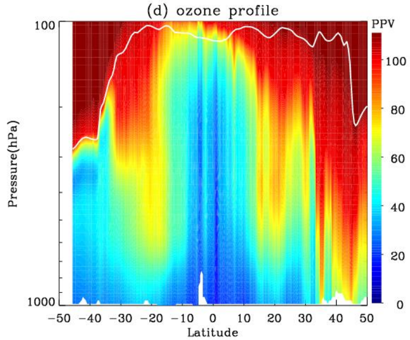
(U. Jeong)

Examples of retrieved products using OMI

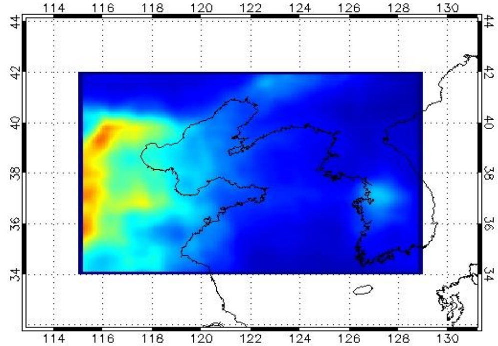
Troposp. O_3



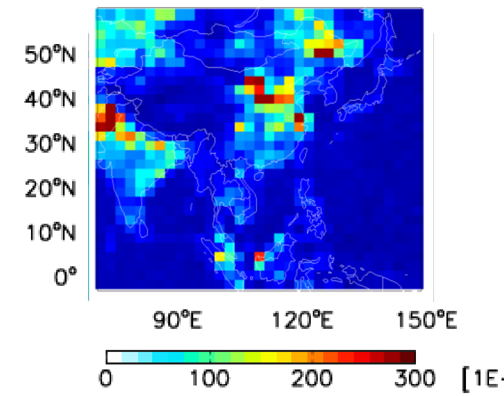
O_3 profile

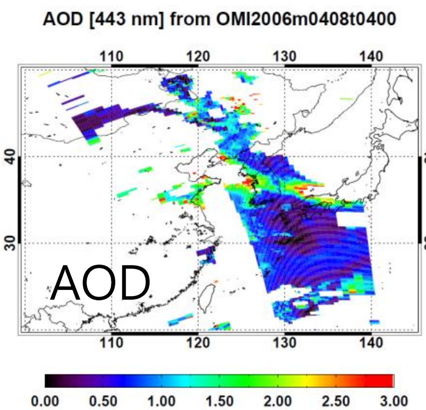


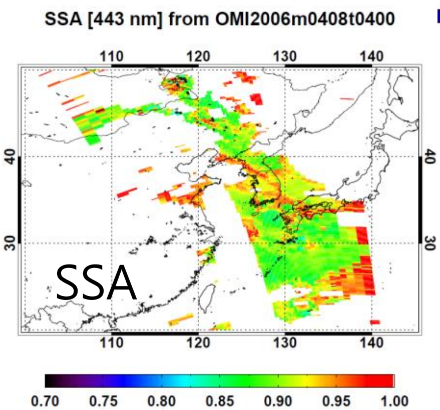
NO_2

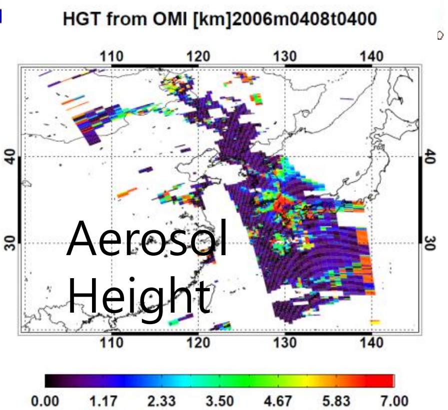


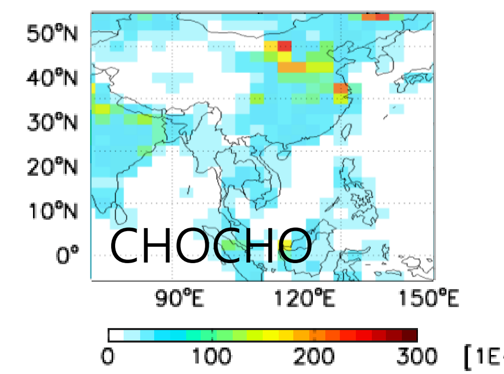
HCHO

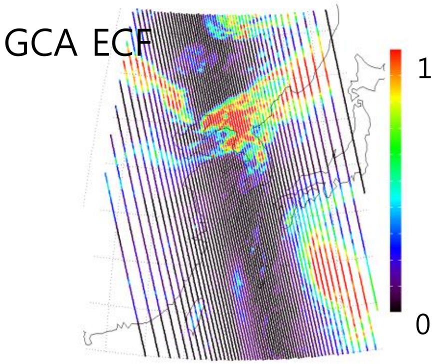


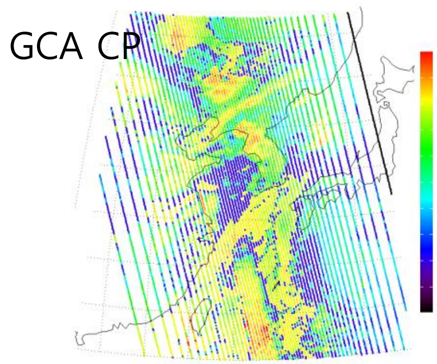












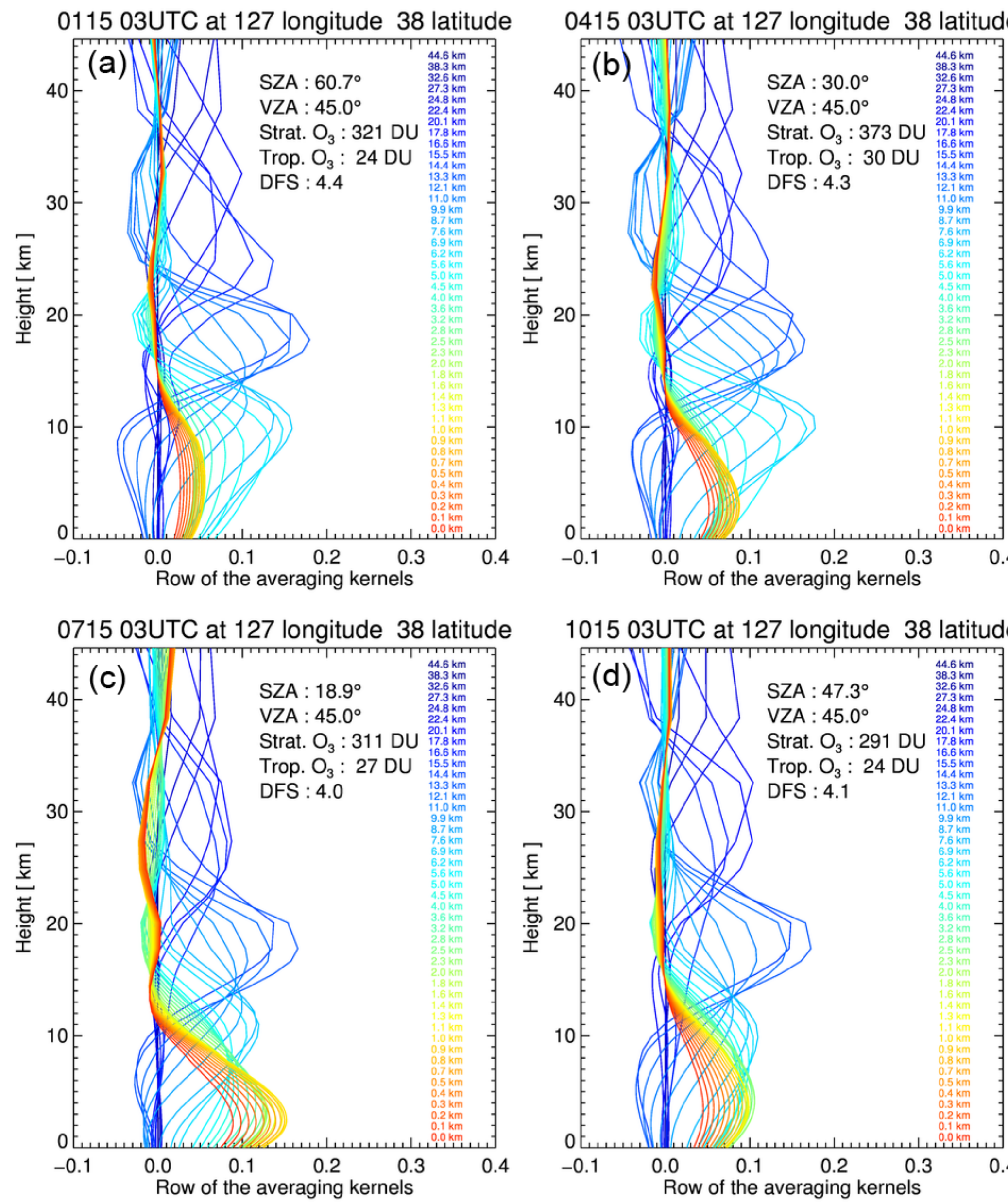
Credit :

Mijin Kim (Yonsei U) – Aerosol
Y.S. Choi (EWU) - Cloud
Jae H. Kim (Busan NU) – O_3
Hanlim Lee (Pukyung NU) - NO_2
Rokjin Park (SNU) – HCHO, CHOCHO
Y.J. Kim (GIST) –SO_2
J.M. Yoo(EWU), M.J. Jeong(GWNU) – Sfc p
M.H. Ahn (EWU) - calibration

Averaging kernel for O_3 retrieval

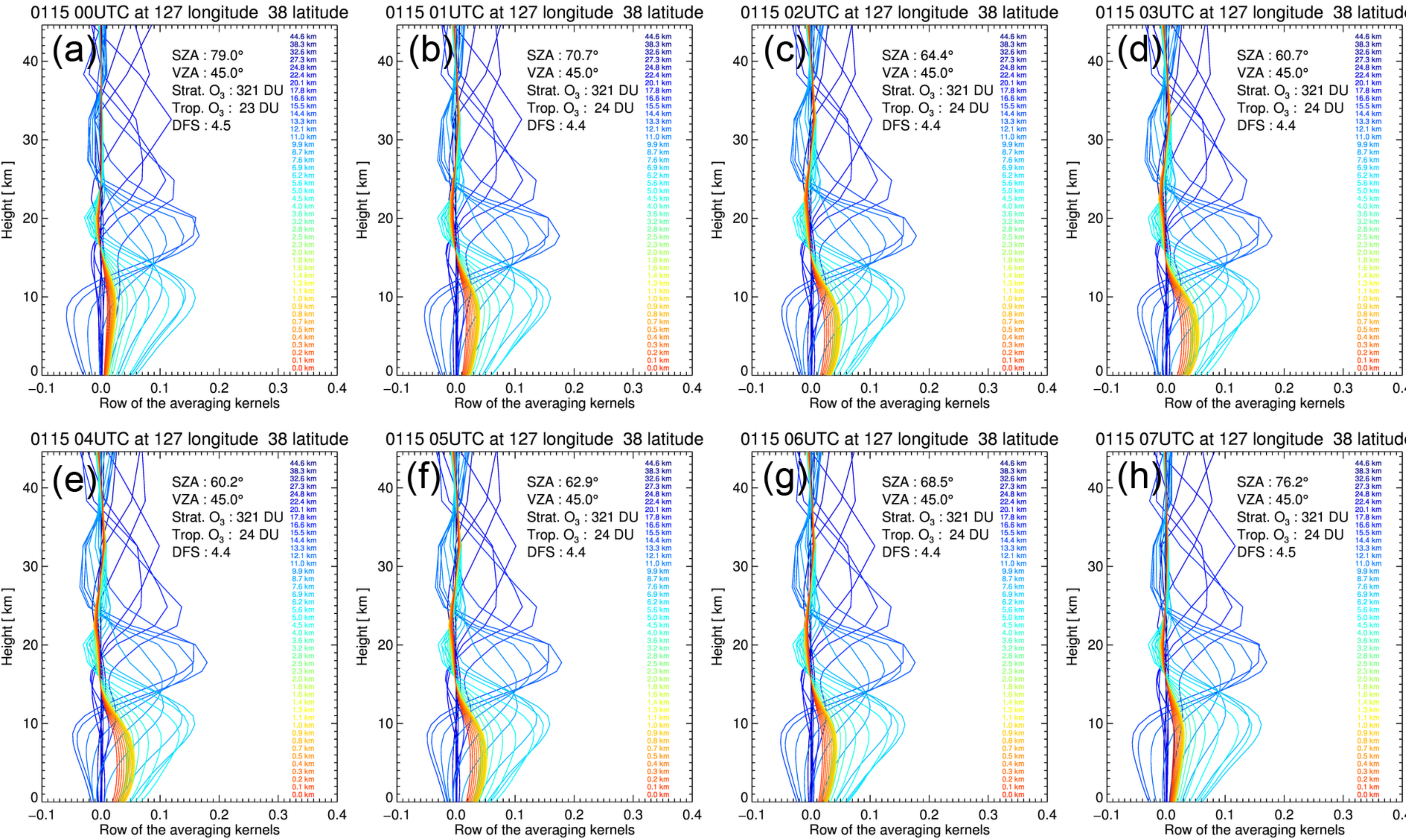
Retrieval sensitivity of tropospheric O_3 is high when SZA and VZA is low, or the amount of stratospheric O_3 is small.

Profile	Degrees of Freedom of O_3	
	Mean ± σ	Median
Troposphere	0.8 ± 0.2	0.9
Stratosphere	2.9 ± 0.5	2.8
Total	3.8 ± 0.4	3.7



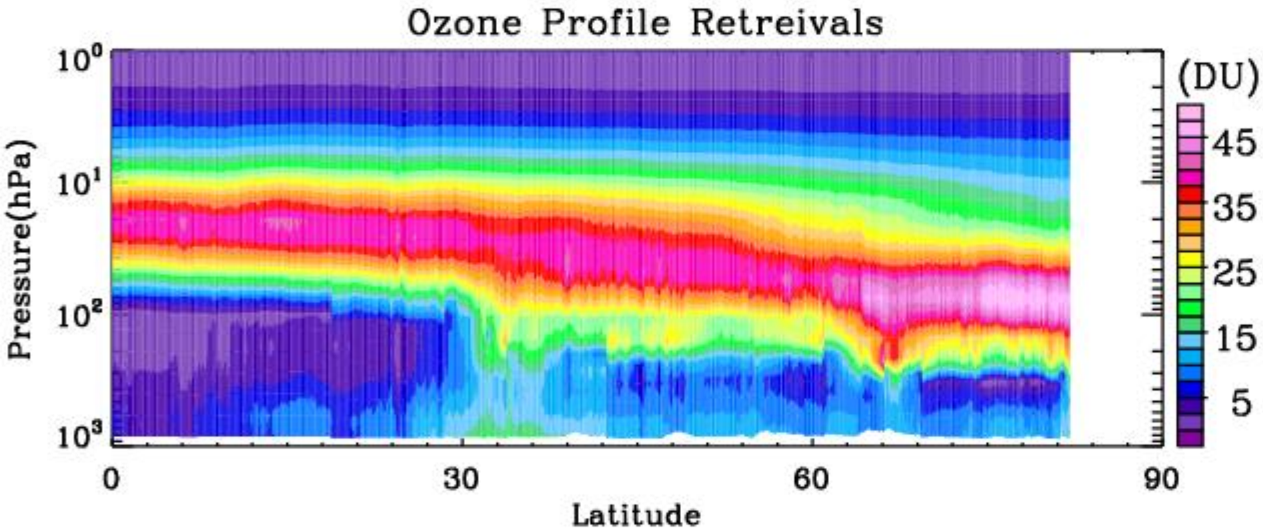
(U. Jeong)

Diurnal variations of *averaging kernel* of O_3

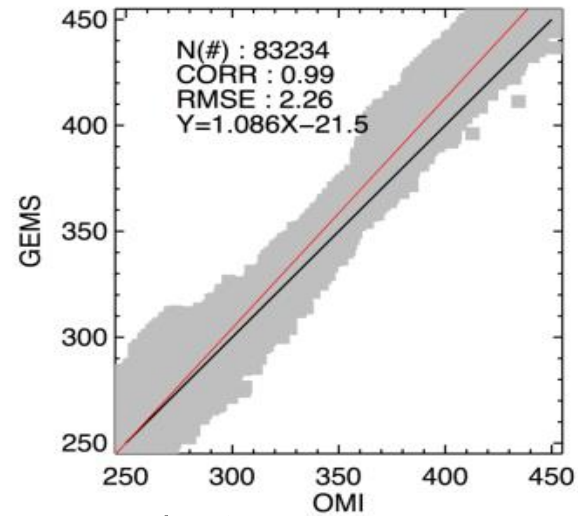


(U. Jeong)

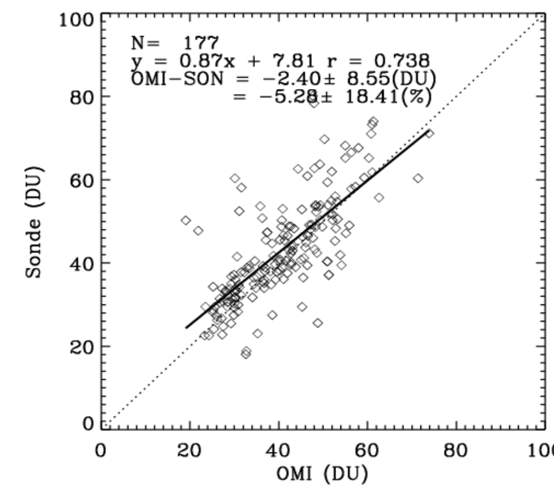
Retrieval of O_3



Total Ozone



Tropospheric Ozone

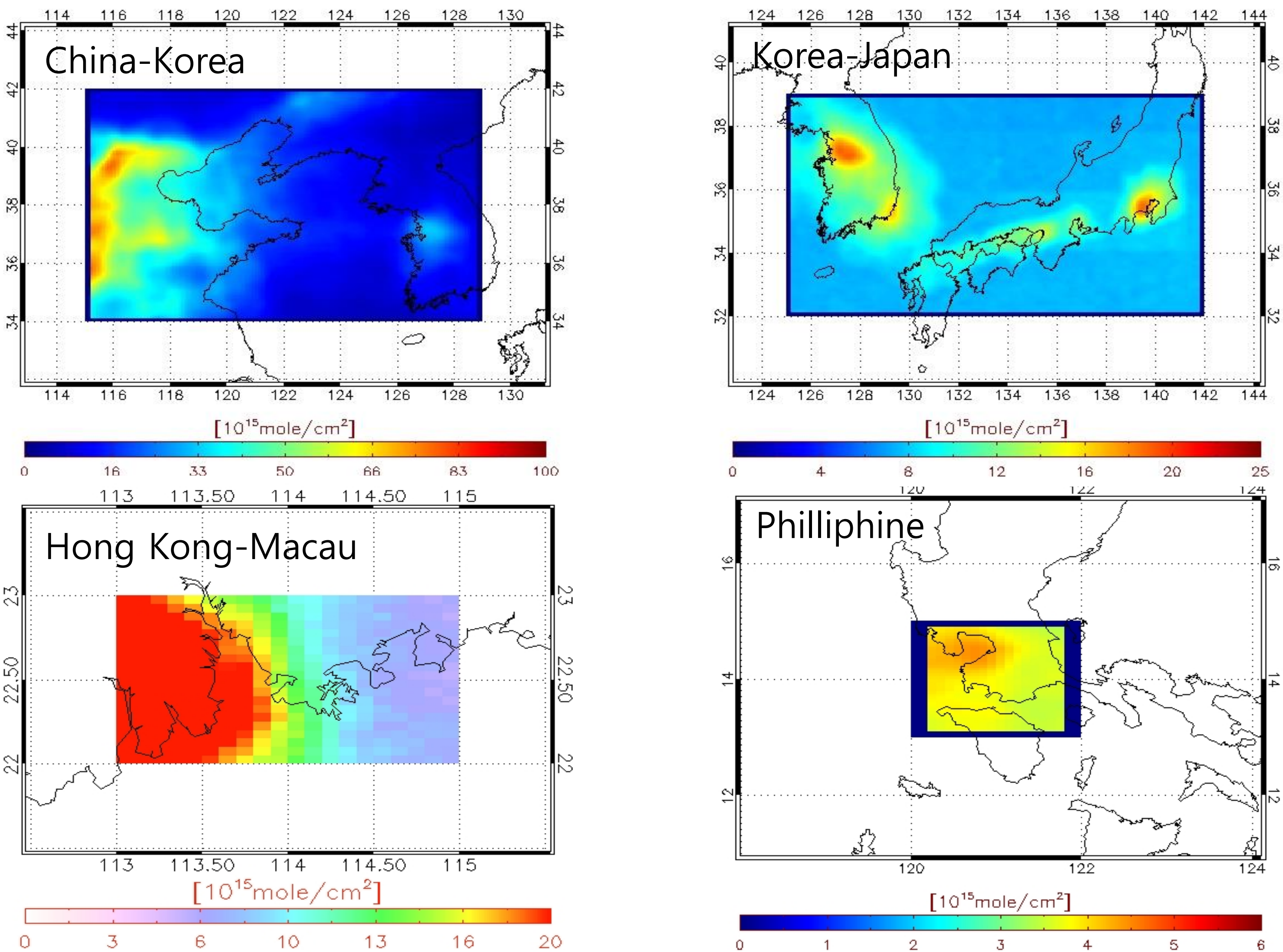


		Goal	Performance
O3 (Total)	R	0.57-0.68	0.99
	A, Slope	0.58-0.68	1.086
	B, Intercept	45.5 DU	21.5 DU
	RMSE	9.1	2.26
O3 (Trop)	R	0.35-0.56	0.74
	A, Slope	0.35-0.64	0.87
	B, Intercept	19.5 DU	8.55 DU
	RMSE	6.5-13DU (13-26%)	8.55 DU (18.41 %)

(Courtesy, J.S. Park, K.H. Paik, Jae H. Kim)

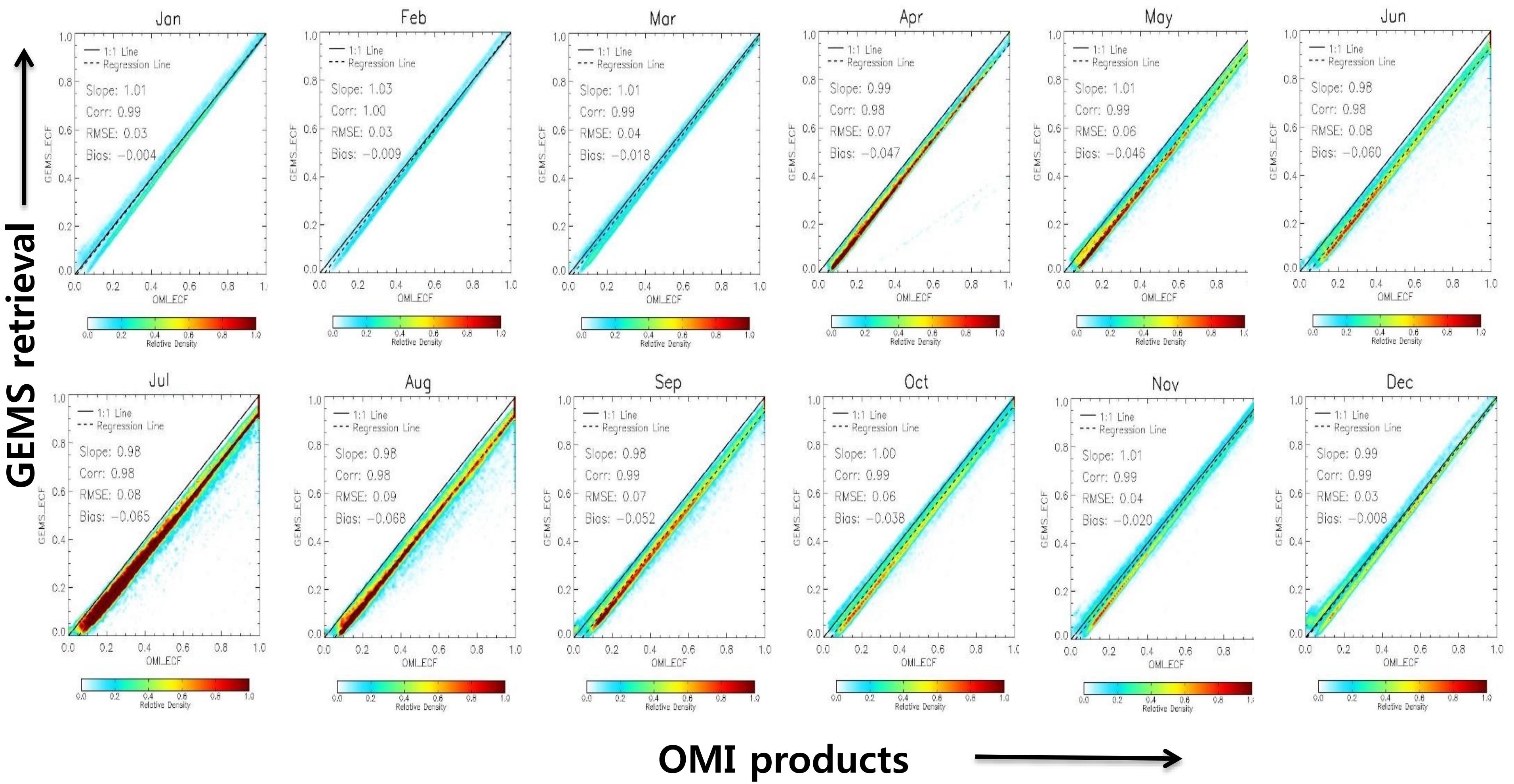
NO_2 Retrieval using OMI L1B data

(Courtesy, H.K. Hong, H. Lee)



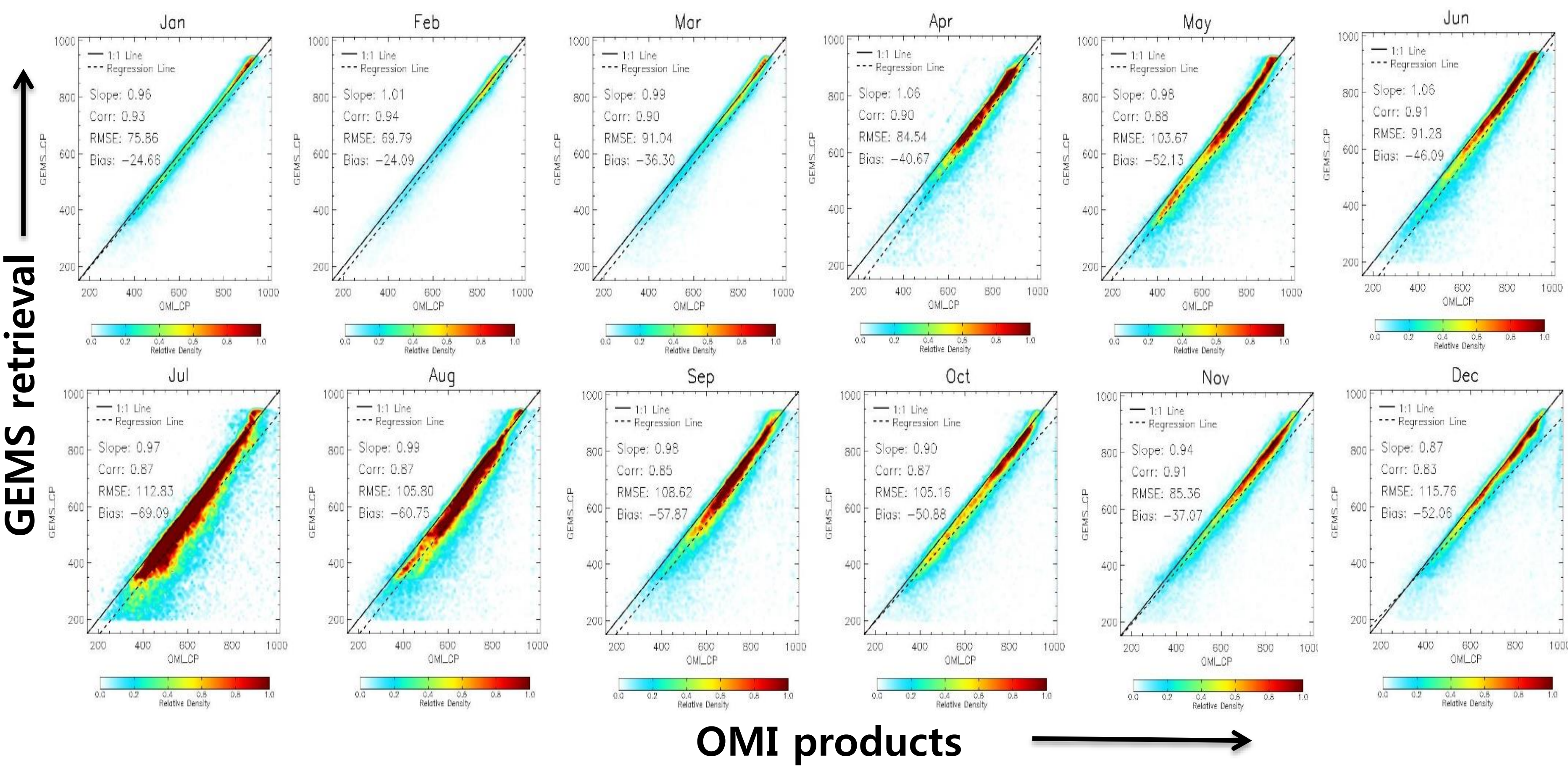
Cloud RF retrieval : Validation Results
(ECF, every 1st day of each month, 2007)

(Courtesy, B.R. Lee, Y.S. Choi)



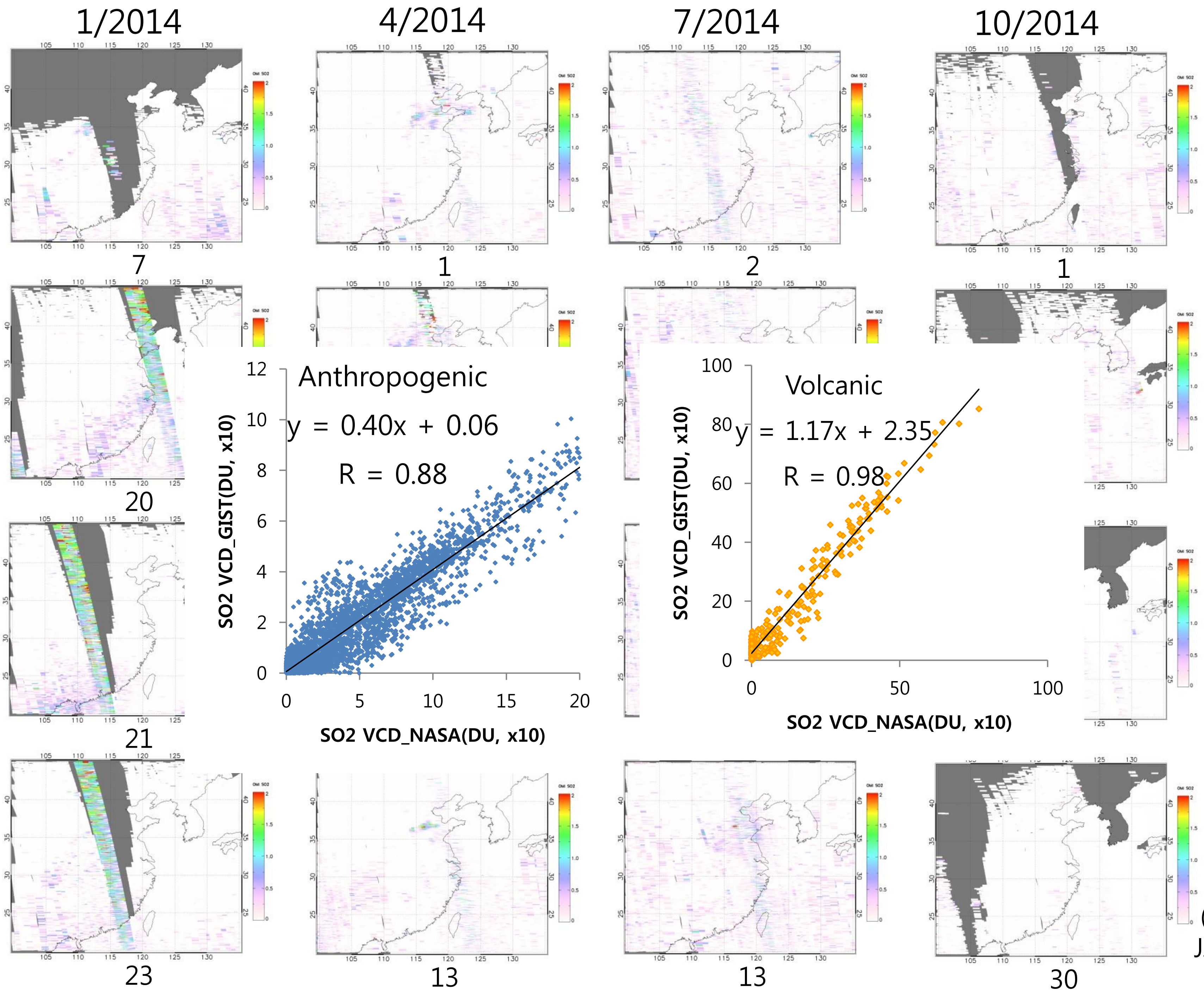
Cloud pressure retrieval : Validation Results
(CP, every 1st day of each month, 2007)

(Courtesy, B.R. Lee, Y.S. Choi)



✓ More underestimated data in CP especially in summer.

SO_2

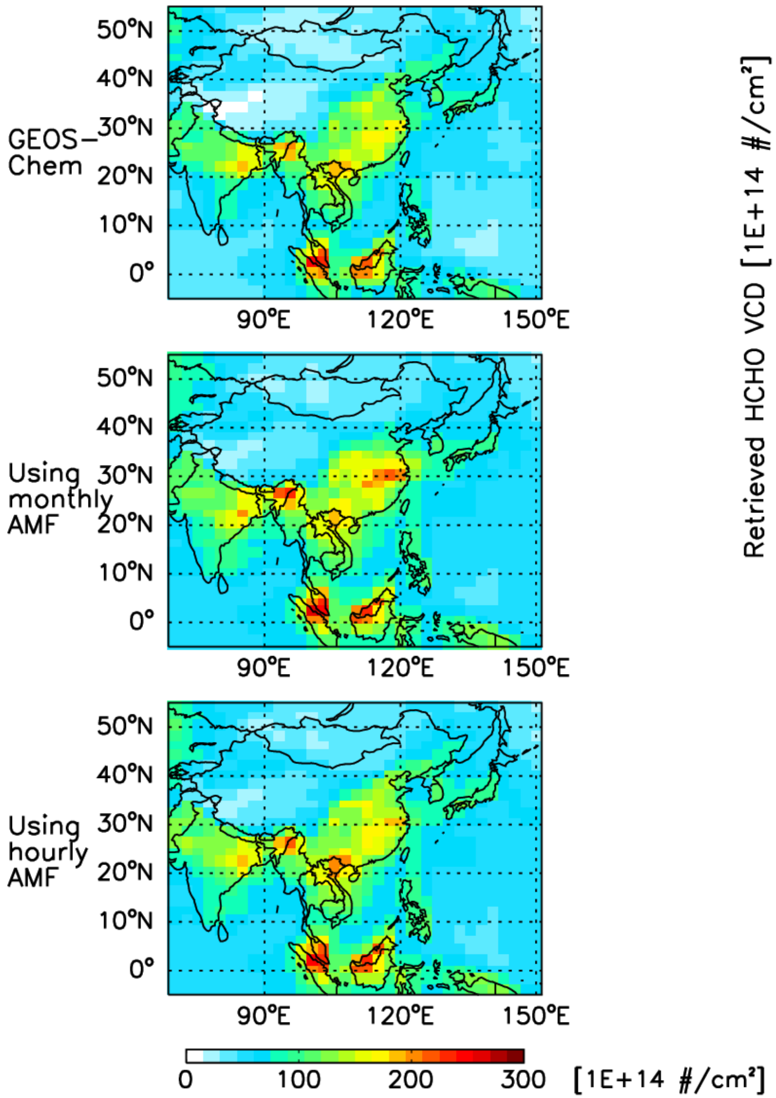


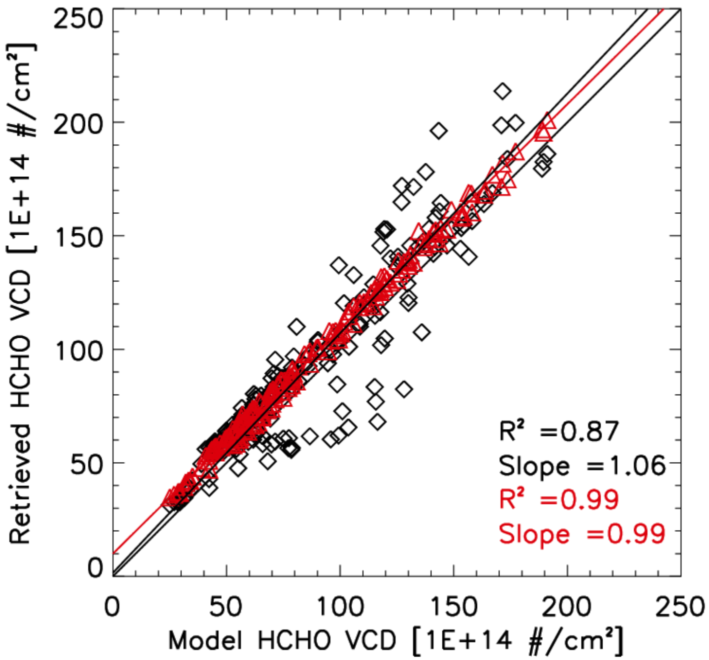
(Courtesy, J.H. Jeong, Y.J. Kim)

HCHO retrieval

(Courtesy, H.A. Kwon, R. Park)

HCHO VCDs mean for 11-13 LST (June 21, 2009)





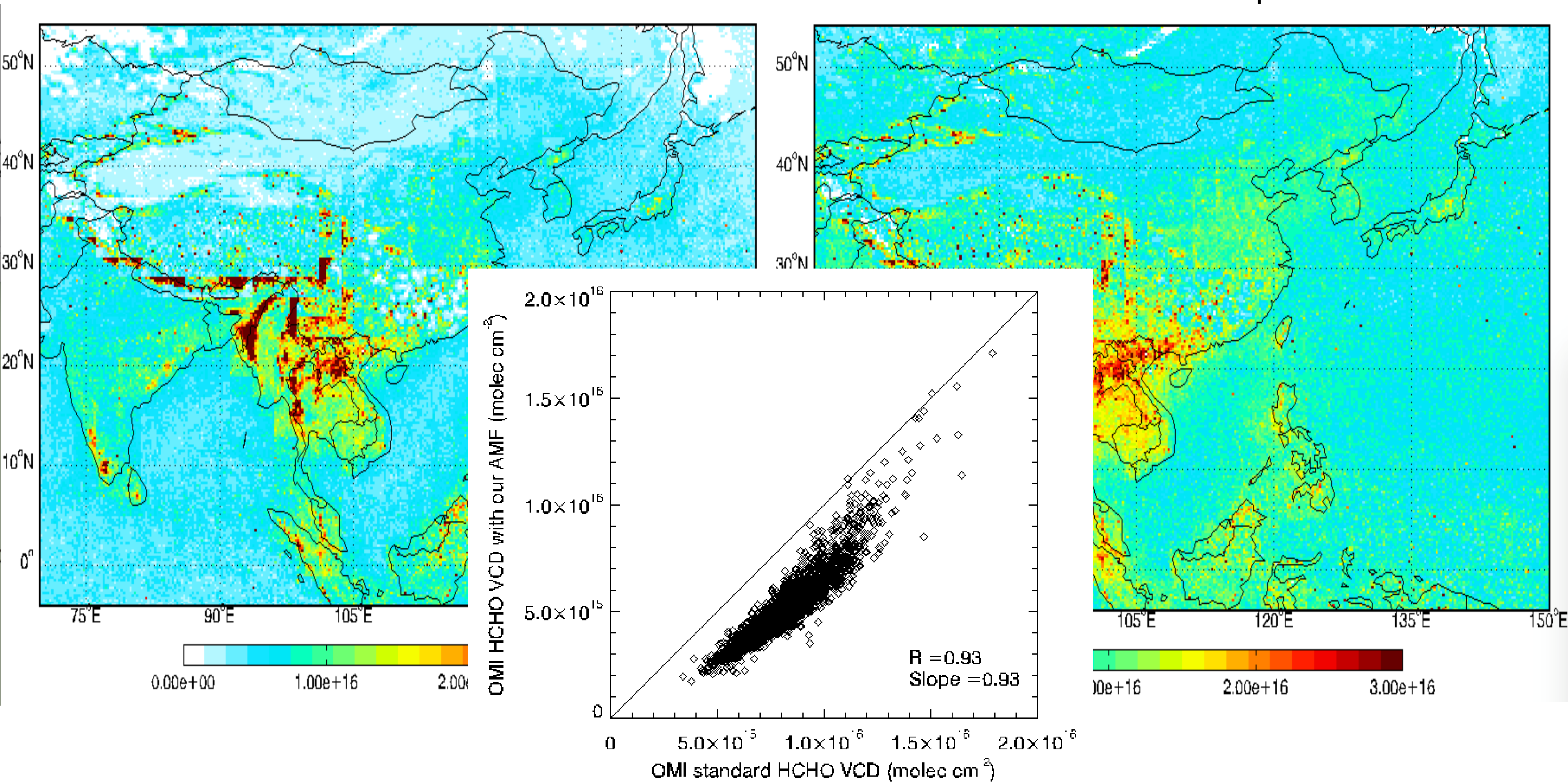
- Hourly AMF
- w/o consideration of noises

HCHO retrieval with aerosol (March, 2006)

(Courtesy, H.A. Kwon, R. Park)

HCHO VCD with aerosols

OMI standard product

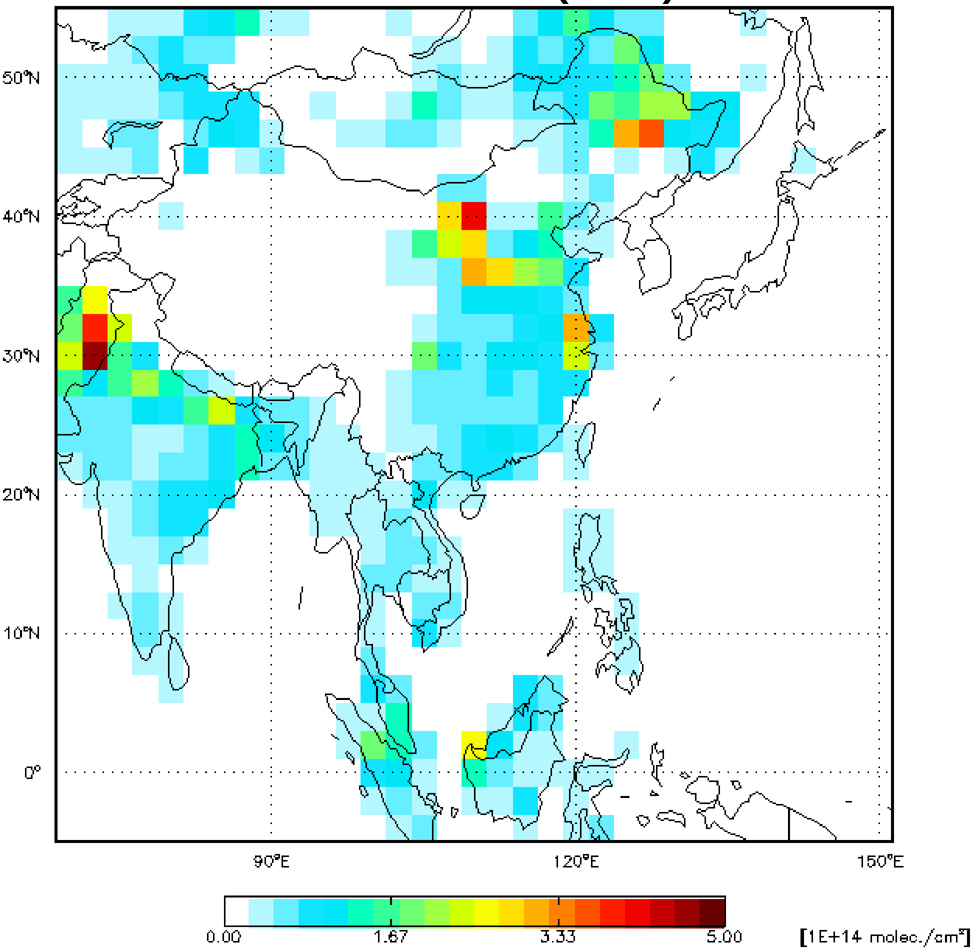


✓ Systematic underestmation of HCHO VCD is largely due to AMF.

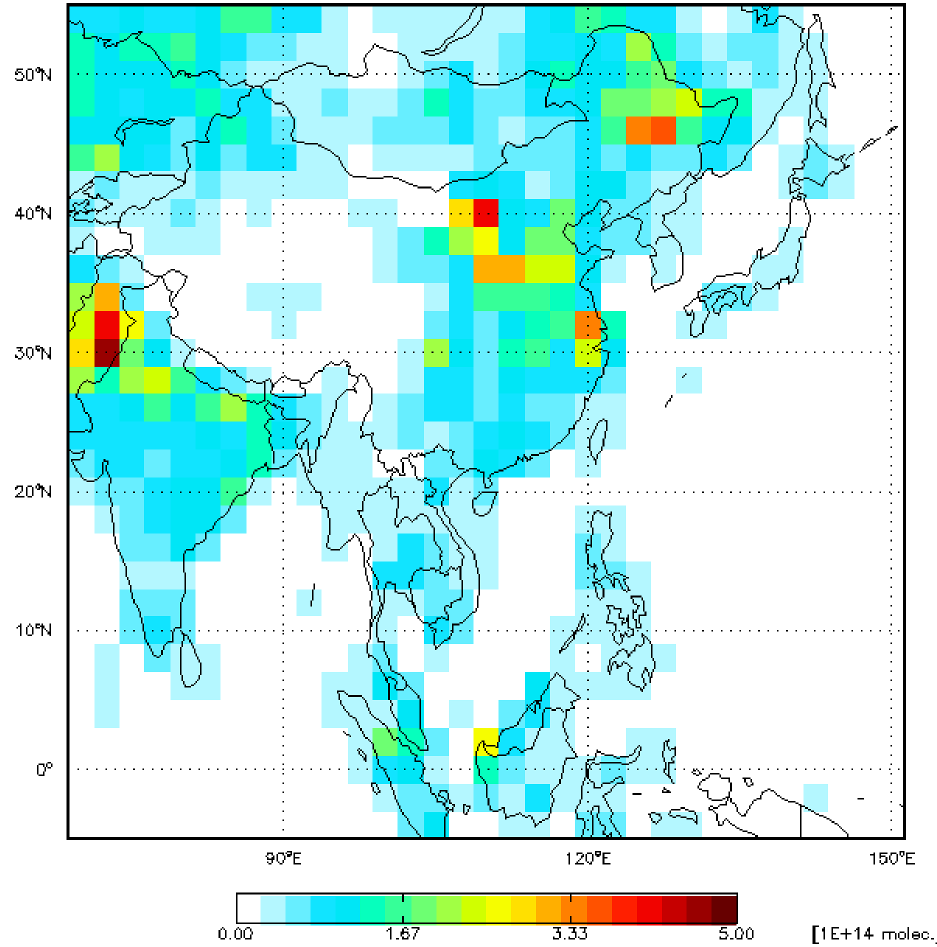
CHOCHO retrieval (437-452.2nm at 13 KST in July 1, 2006)

(Courtesy, H.A. Kwon, R. Park)

GEOS-Chem (true)

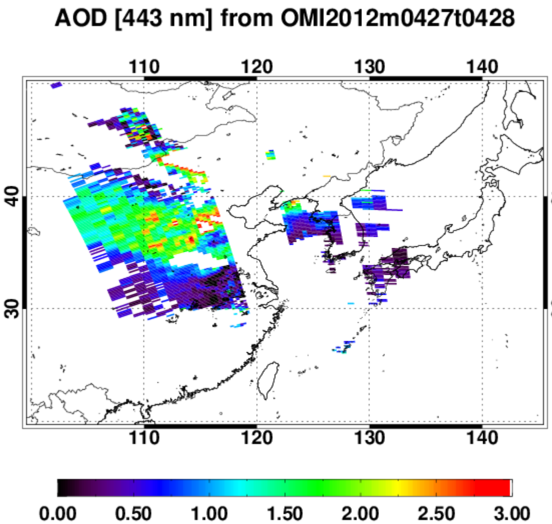


Retrieved VCD

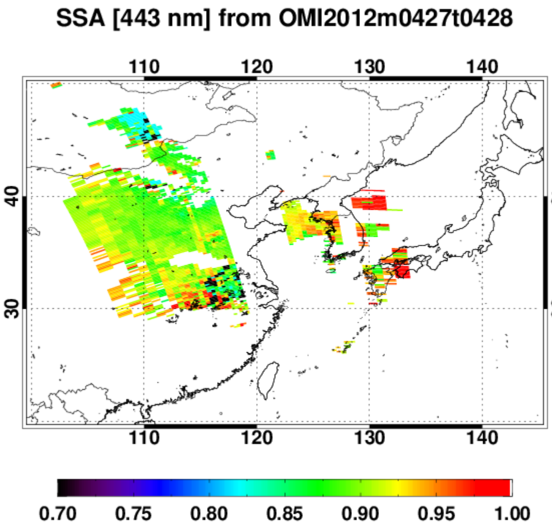


Retrieval of AOD, SSA, and HGT

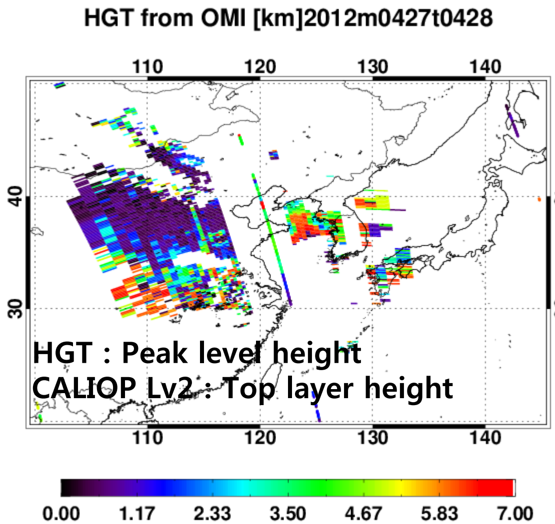
Retrieved AOD [443



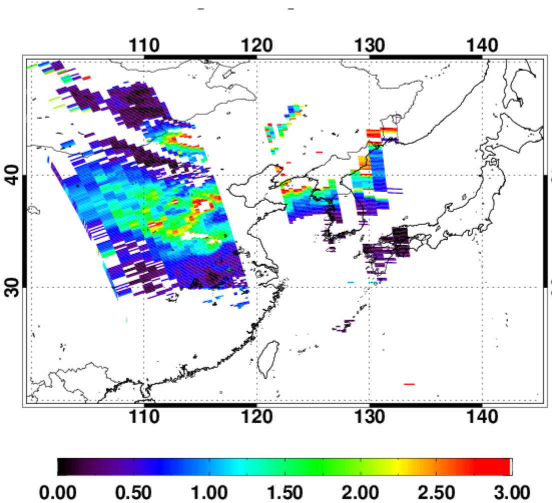
Retrieved SSA [443 nm]



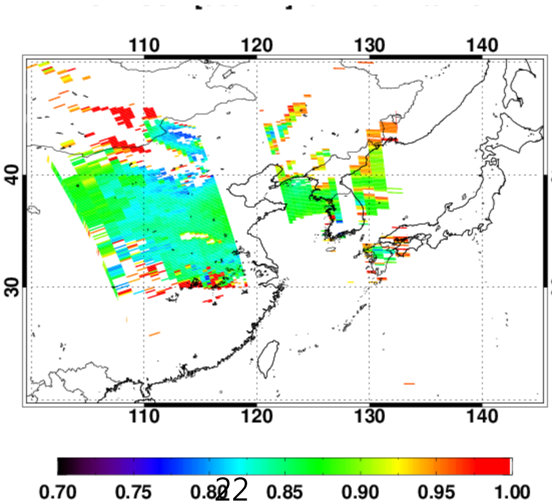
Fitted HGT [km]



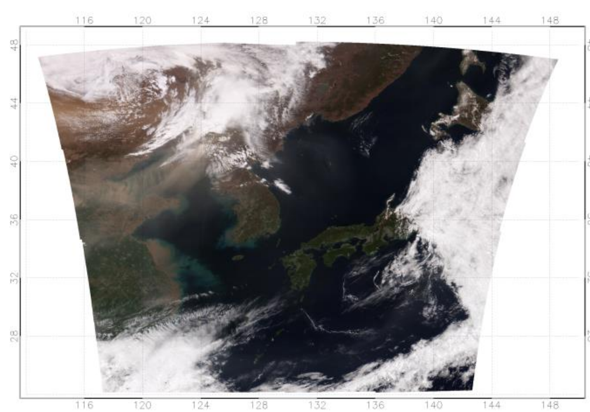
OMI AOD [388 nm]



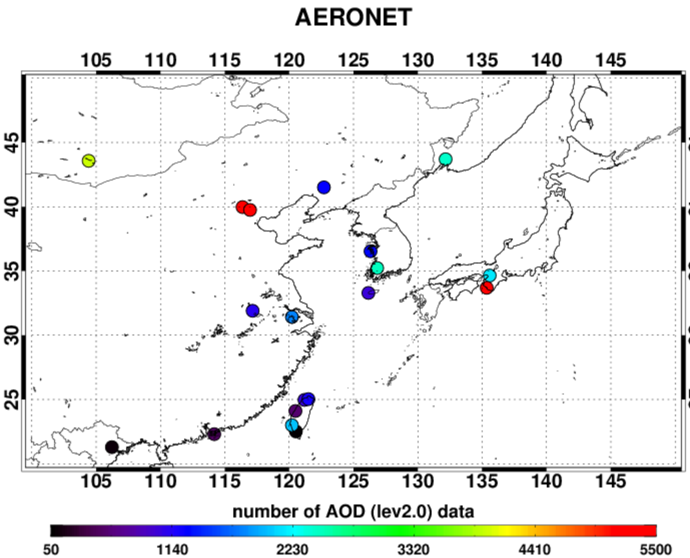
OMI SSA [388 nm]



MODIS RGB :2012/04/27

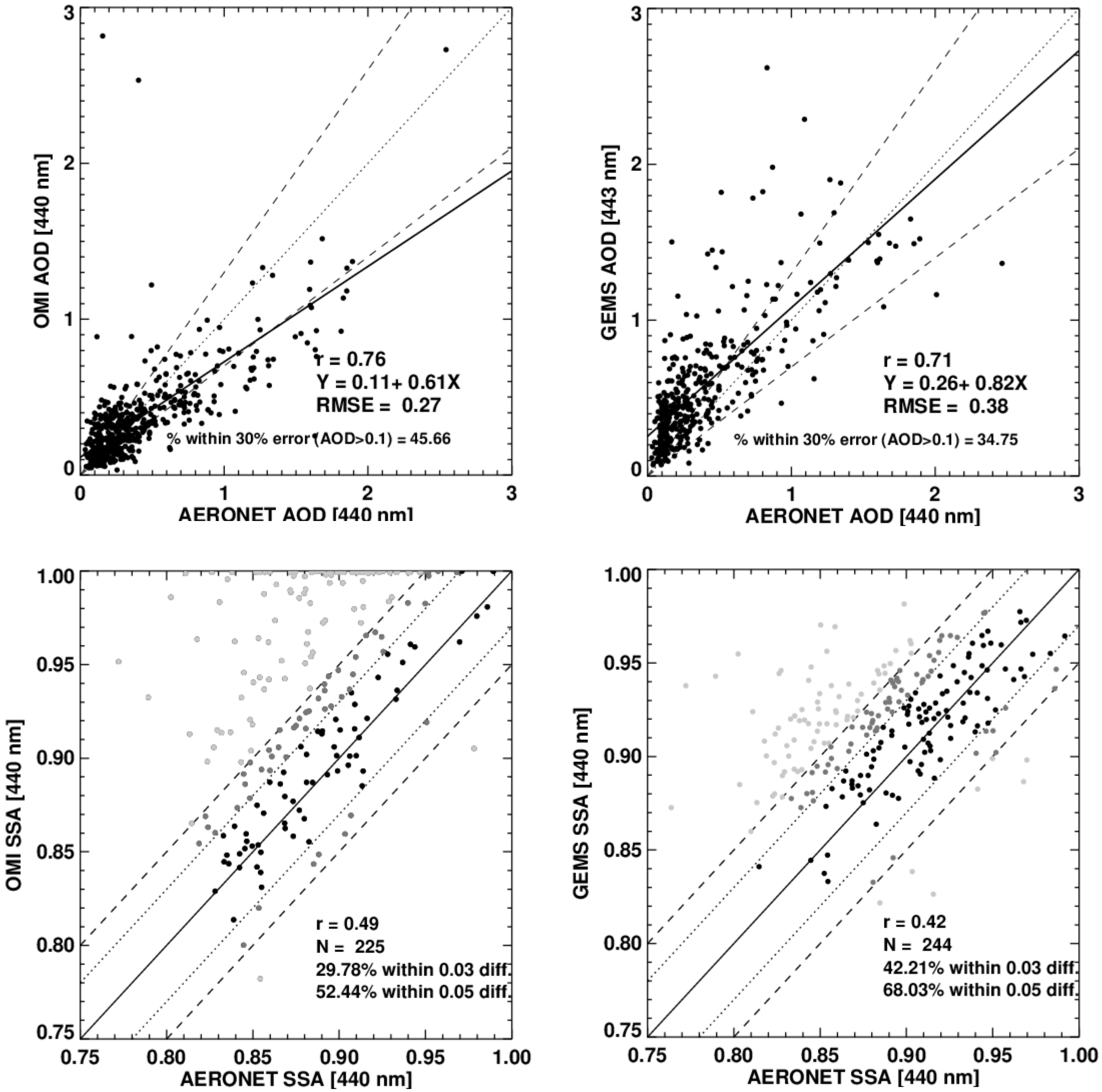


Validation of AOD and SSA



Operated Algorithm

Developed Algorithm



AOD validation

AERONET direct measurement(lev2.0)
2005. 01 ~ 12,
Within ±10 min., 0.4˚ x 0.4˚

SSA validation

AERONET inversion data(lev2.0)
2005. 01 ~ 12,
Within ±4 hr, 0.4˚ x 0.4˚

Prelaunch Test and Characterization

- Spectral Tests (spectrometer+focal plane)
  - Spectral Bandpass
  - Spectral Range
  - Smile & Keystone
- Stray Light Tests for Stray Light Model Validation (spectrometer+focal plane)
  - Diffuser can be placed in the light path
  - Various light source (tunable laser, spectral line source, Xenon arc lamp, Quartz-tungsten-halogen lamp)
- Spatial Characterization
  - MTF, Field of View
- Boresight and Spectral Stability
- Diffuser BTDF
  - On selected wavelengths and spatial positions
- NIST Traceable Radiometric Calibration
  - GEMS in ambient or thermal condition
  - Large Spherical Source(LSS) integrating sphere illumination
- Polarization Sensitivity
  - Rotatable polarizer

Validation Network

- Ground-based network for gas measurements
  - PANDORA network
  - MaxDOAS
  - AirKOREA and nation-wide network in Asian countries
  - EANET
- Aerosol network
  - AERONET
  - SKYNET (Japanese lead, Asia wide)
  - SONET (China)
- LIDAR network
  - KALION
  - NIES LIDAR network
- Airborne Campaigns
  - KORUS-AQ etc.
- Collaboration under discussion
  - China (Hong Kong), Vietnam,

KORUS-AQ Campaign(May-Jun 2016) : VAL activities

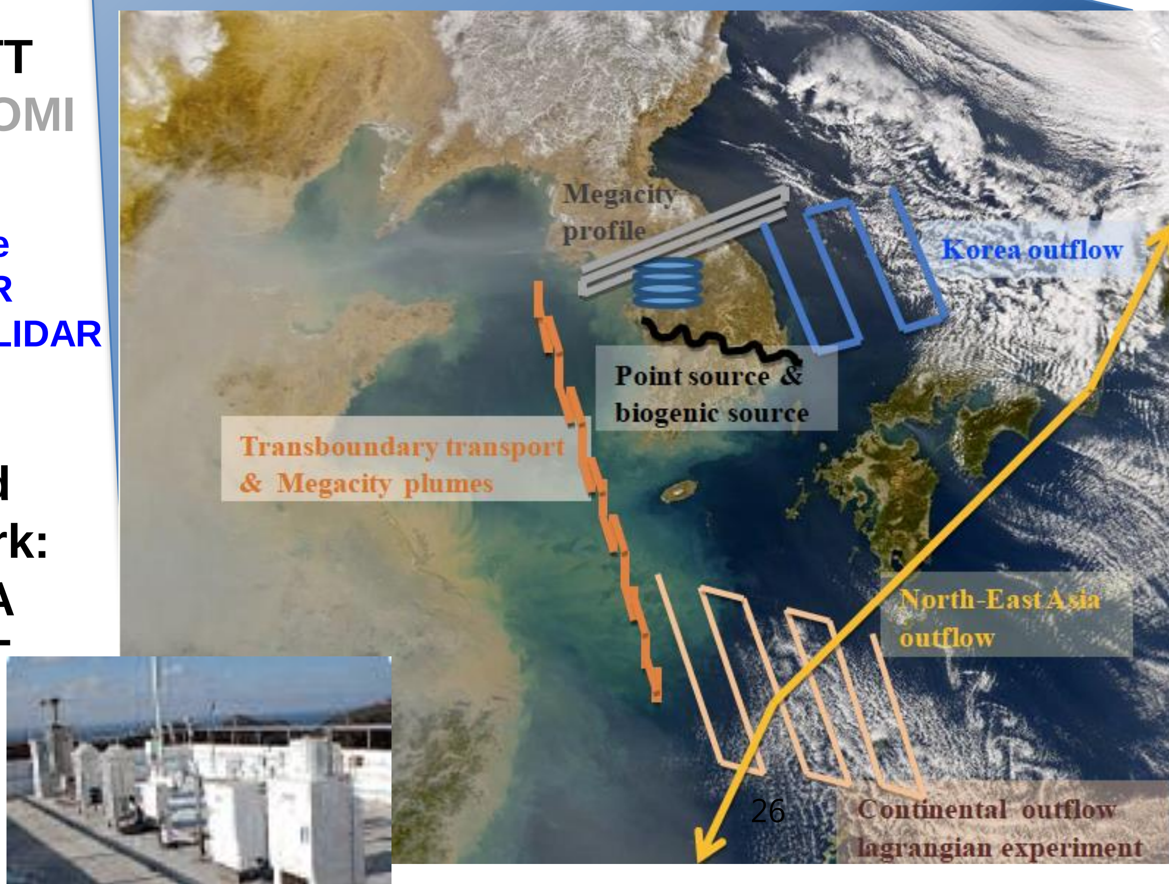
GOCI
VIIRS
OMPS
OMI
MOPITT
TROPOMI
GEMS

- O3 sonde
- O3 LIDAR
- Aerosol LIDAR

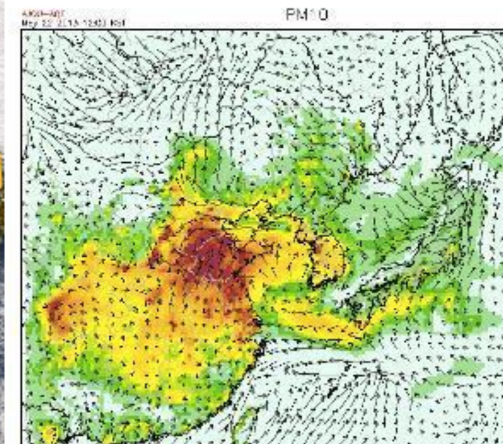
- Ground Network:

PANDORA
AERONET
SKYNET
EANET
Air Korea

Airborne
GEOTASO / B200
Aerosol LIDAR / DC8
Gas / King Air
MOS / B200

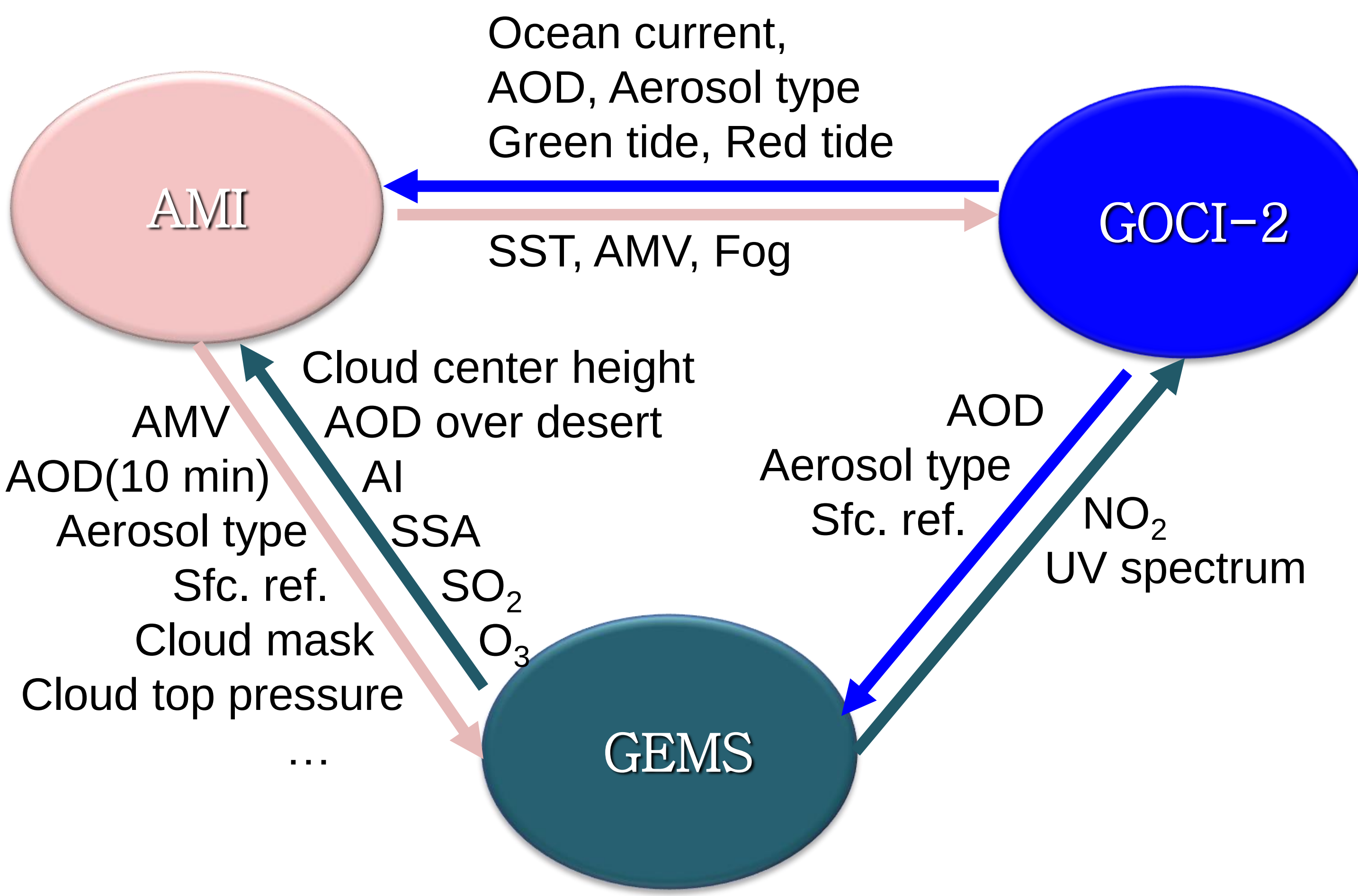


Air quality forecast



Shipborne

Synergistic products



- ✓ 24 hr Asian dust monitoring over dark and bright surface
- ✓ Cloud morphology (thickness, fraction, type …)

Summary

- GEMS onboard the Geo-KOMPSAT-2B is expected to provide information on aerosol and O_3 together with their precursors in high spatial and temporal resolution
  - O_3 NO_2 HCHO SO_2 AOD/AI/AEH CHOCHO
  - Clouds (CP, CRF), surface reflectance, UVI
- The predicted performance for the retrieval of trace gas column densities from the current design of GEMS satisfies the product accuracy requirements of NO_2, HCHO, stratospheric O_3, but partially satisfy for SO_2 and tropospheric O_3. Meanwhile, the performance is expected to be poor in winter near Korea in particular.
- Careful consideration of aerosol is required to retrieve trace gas concentration from geostationary satellite remote sensing, especially for absorbing aerosols in particular.
- Preflight tests to characterize stray light, polarization, spectral accuracy, diffuser BTDF etc can provide more accurate analysis on the GEMS performance .
- Synergy with AMI and GOCI-2 will provide more reliable products of aerosol and cloud products, which eventually improve the accuracy of trace gas column density.

Acknowledgement

GEMS Science Team

Ministry of Environment (MoE)
NIER, MoE
KEITI, MoE

Korea Meteorological Administration (KMA)

Korea Ocean R&D Institute (KORDI)

Ministry of Science, ICT & future Planning (MSIP)
KARI

GEMS Science Team

Changwoo Ahn
Jay Al-Saadi
P.K. Bhartia
Kevin Bowman
Greg Carmichael
Kelly Chance
Mian Chin
Yunsoo Choi
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