GEMS O3P/O3T Algorithm

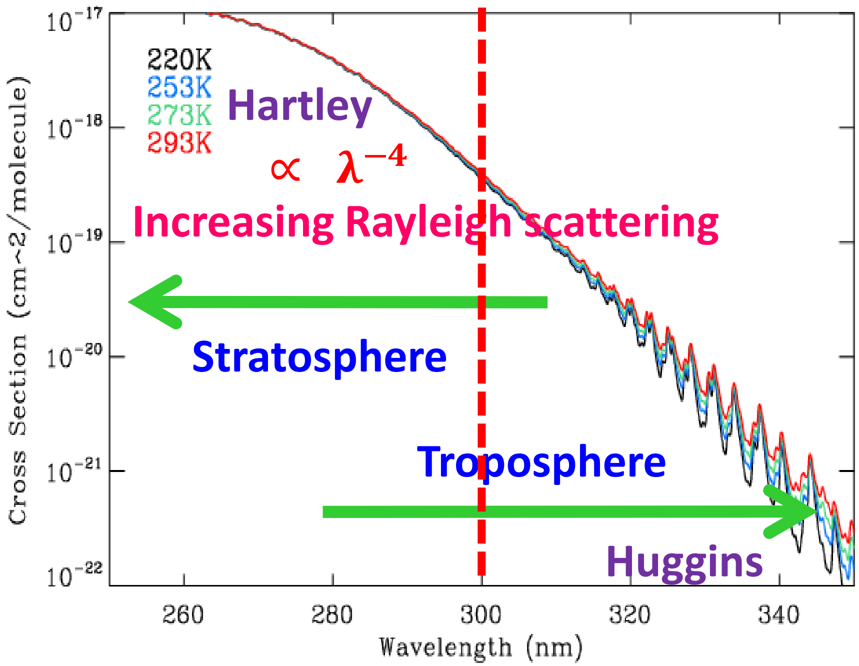
Ground Ozonestation Validation

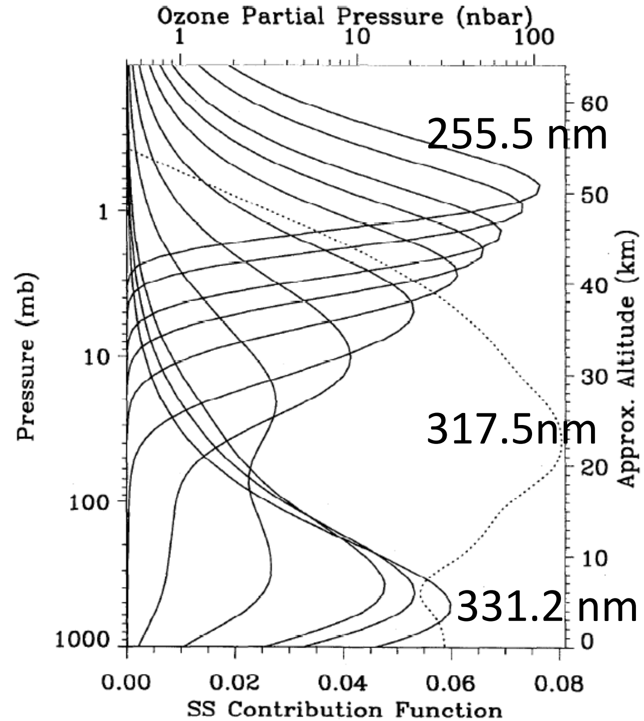
Jae H. Kim, Kanghyun Baek, Daegeun Shin, Juseon Bak

Pusan National Univ.

[2017 GEMS meeting]

Physics of Ozone retrieval

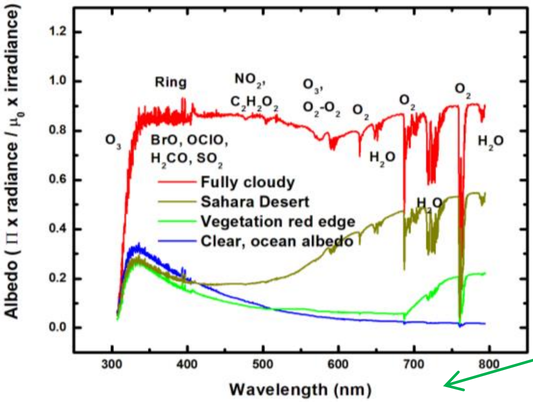




UV photons backscattered to space is attenuated by Rayleigh scattering & O3 absorption.

- The magnitude of O3 absorption cross section decrease by 5 orders from 270 to 340 nm
- Temperature-dependent ozone absorption in the Huggins bands
- Rayleigh Scattering varies inversely with wavelength ($\propto \lambda^{-4}$)

Physics of Ozone retrieval



- O3 & Rayleigh Scattering
- Cloud/Aerosol Mie Scattering, Raman Scattering, Surface Reflection
- Other trace-Gases absorption

$$Y = F(X, b) + \varepsilon$$

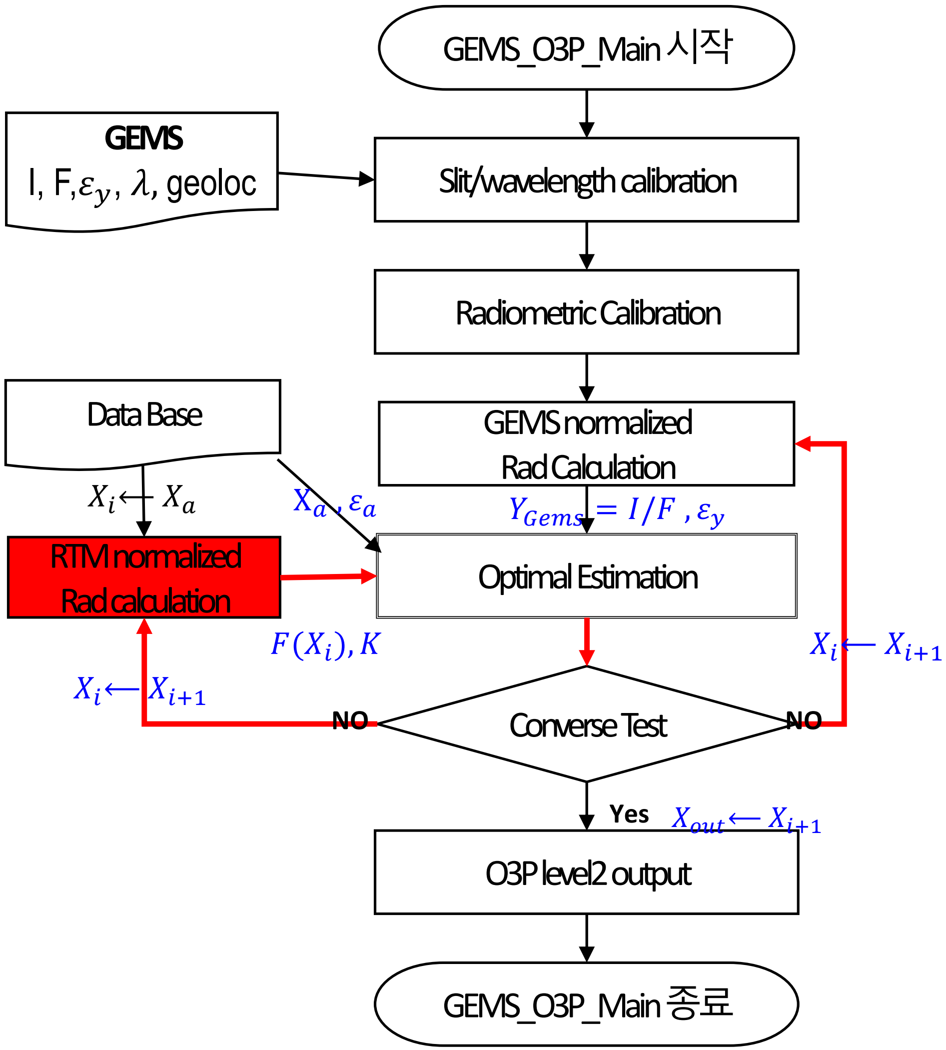
- Y: Measurement vector of m (e.g. radiation)
- F: Radiative Transfer Model
- X: State Vector of n (e.g. O3 profile)
- b: Complemetary Parameter, not fitted
- ε: Errors

Well-posed
Forward model Calculation

Atmospheric Composition (X) ⇄ Measurements (Y)

Inverse Problem
Ill-posed

Flow Chart (O3P) based on OEM



- VLIDORT calculation
  $F(X_i), K(X_i)$: $X_i = X_a$ (i = 1)

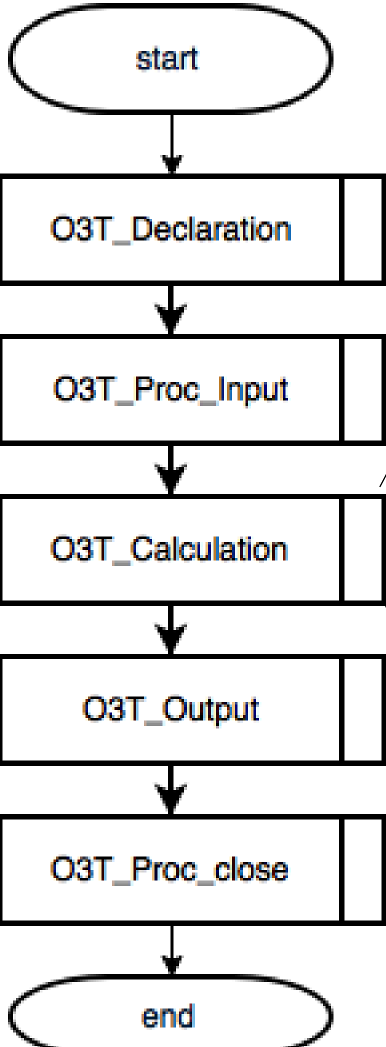
- Optimal Estimation

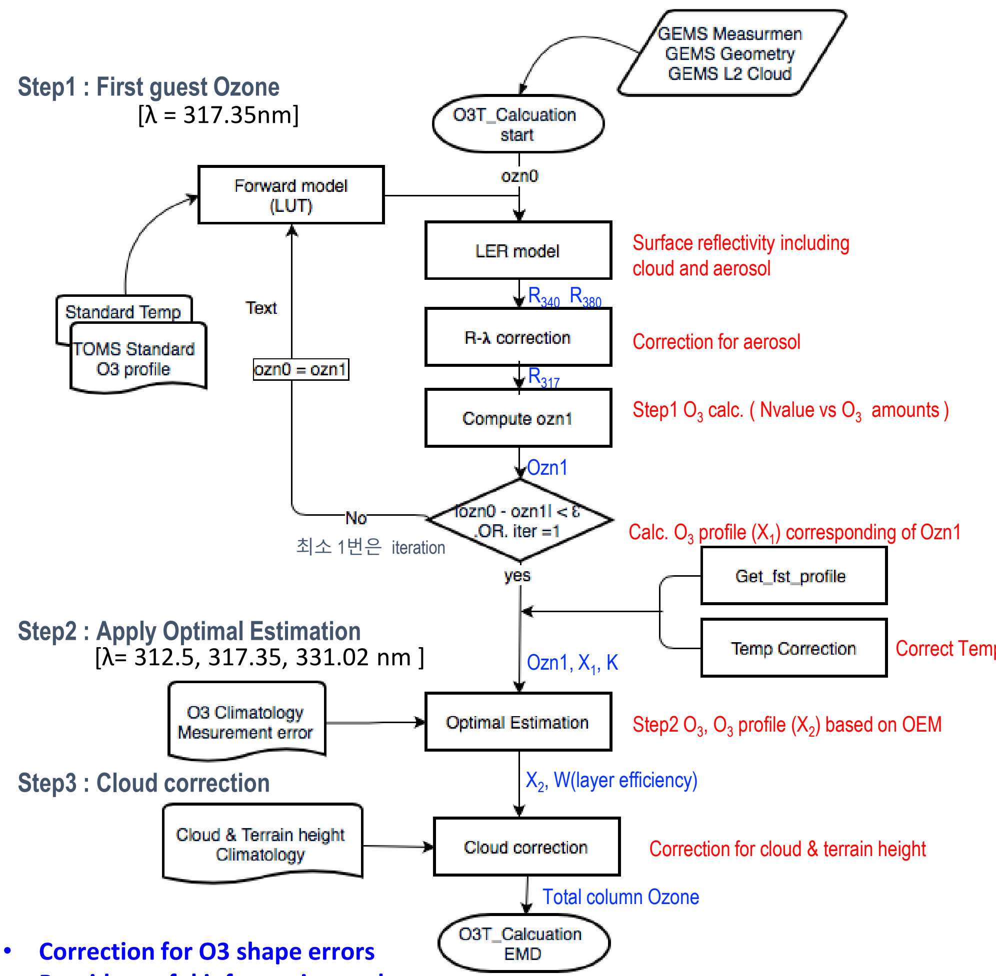
$$\mathbf{X}_{i+1} = \mathbf{X}_i + (\mathbf{K}_i^T \mathbf{S}_y^{-1} \mathbf{K}_i + \mathbf{S}_a^{-1})^{-1} \{\mathbf{K}_i^T \mathbf{S}_y^{-1} [\mathbf{Y} - \mathbf{R}(\mathbf{X}_i)] - \mathbf{S}_a^{-1} (\mathbf{X}_i - \mathbf{X}_a)\}$$

- Converse Test

$$\chi^2 = \left\| \mathbf{S}_y^{-\frac{1}{2}} \{\mathbf{K}_i (\mathbf{X}_{i+1} - \mathbf{X}_i) - [\mathbf{Y} - \mathbf{R}(\mathbf{X}_i)]\} \right\|_2^2 + \left\| \mathbf{S}_a^{-\frac{1}{2}} (\mathbf{X}_{i+1} - \mathbf{X}_a) \right\|_2^2$$

Flow Chart (O3T) based on TOMS

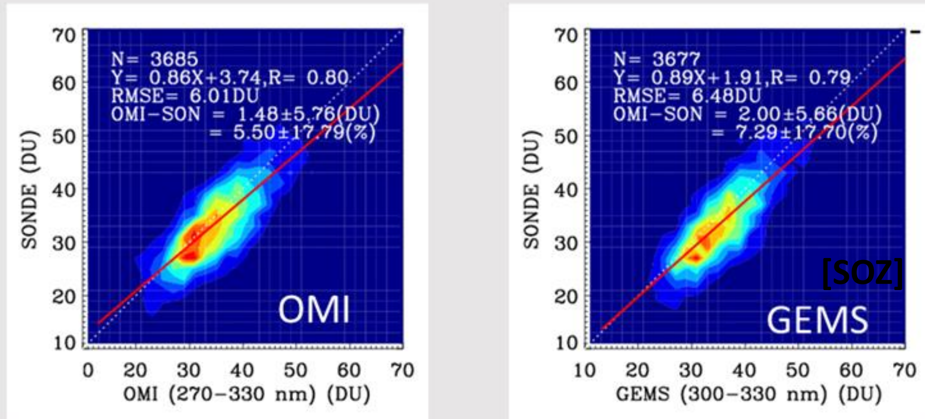




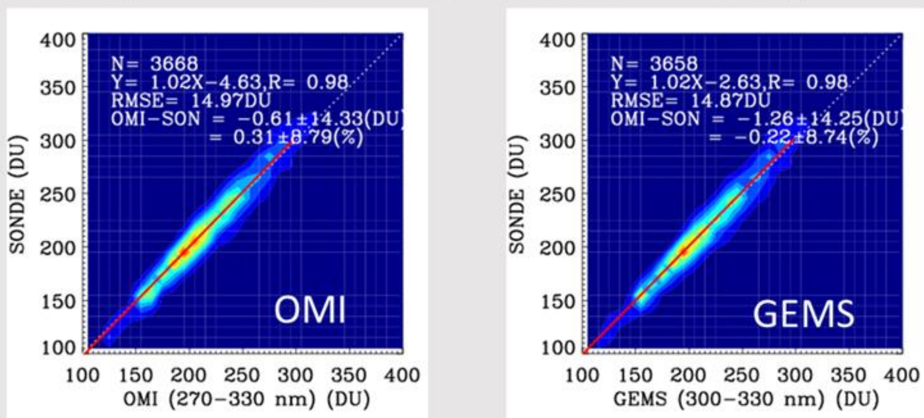
- **Correction for O3 shape errors**
- **Provide useful information such as retrieval error, AK, DFS, etc.**

Retrieval Examples : O3P-Tropospheric[TOZ] Ozone (TOZ)

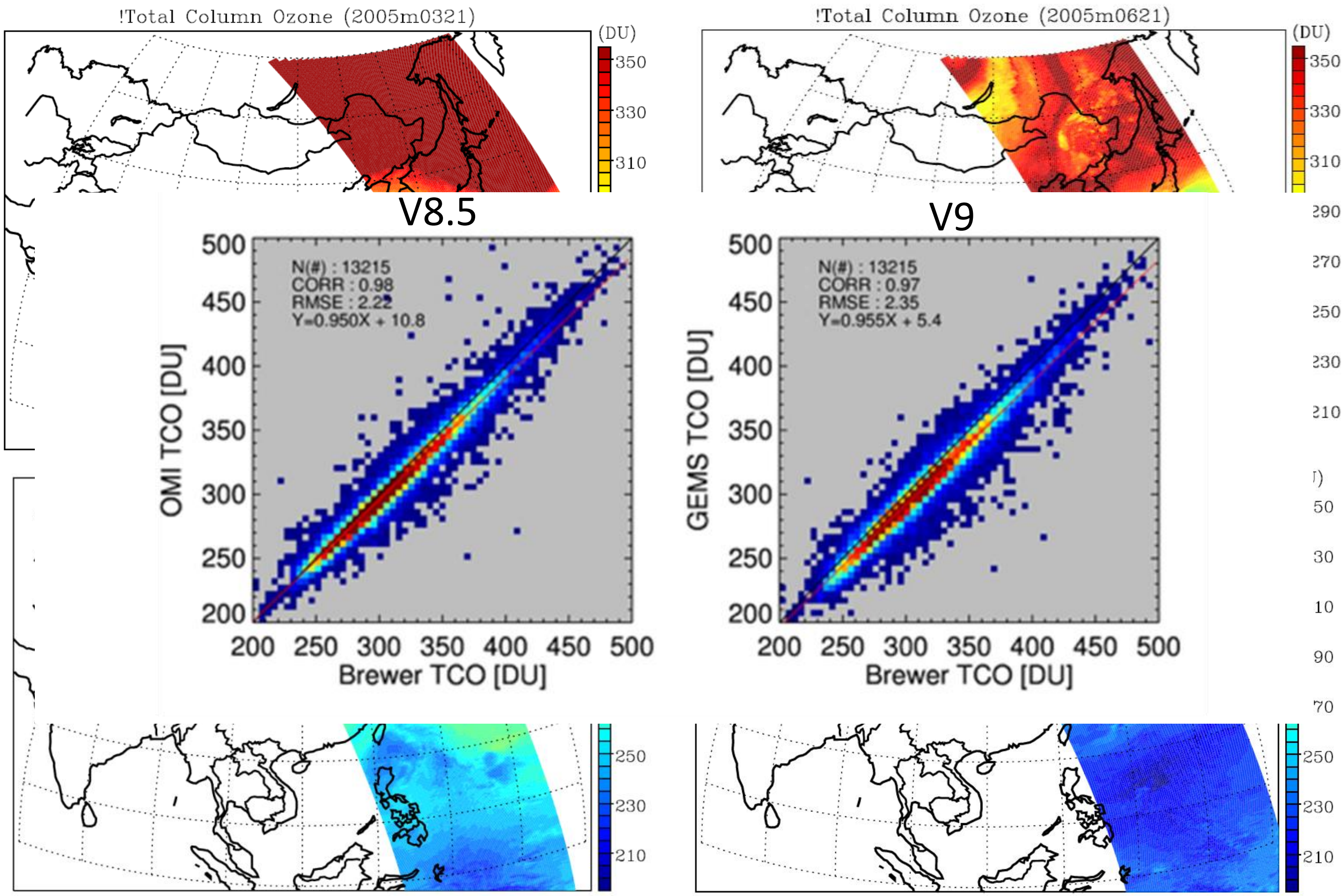
- Tropospheric Column Ozone [surface to tropopause]



- Stratospheric Column Ozone [tropopause to ~ 35 km]



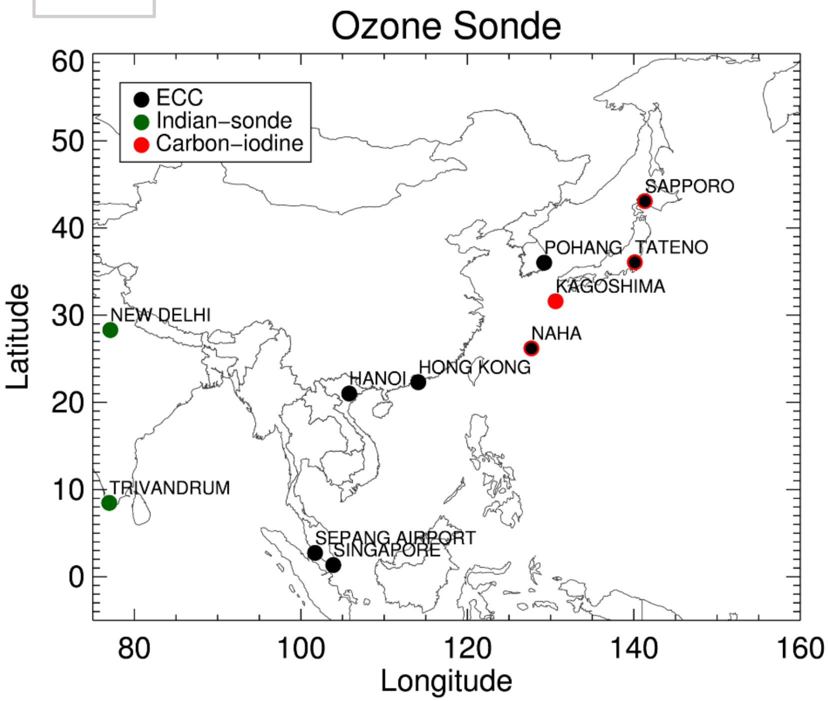
Retrieval Examples : O3T-Total Column Ozone (TCO)



Our Retrievals well capture the dynamically induced ozone variability

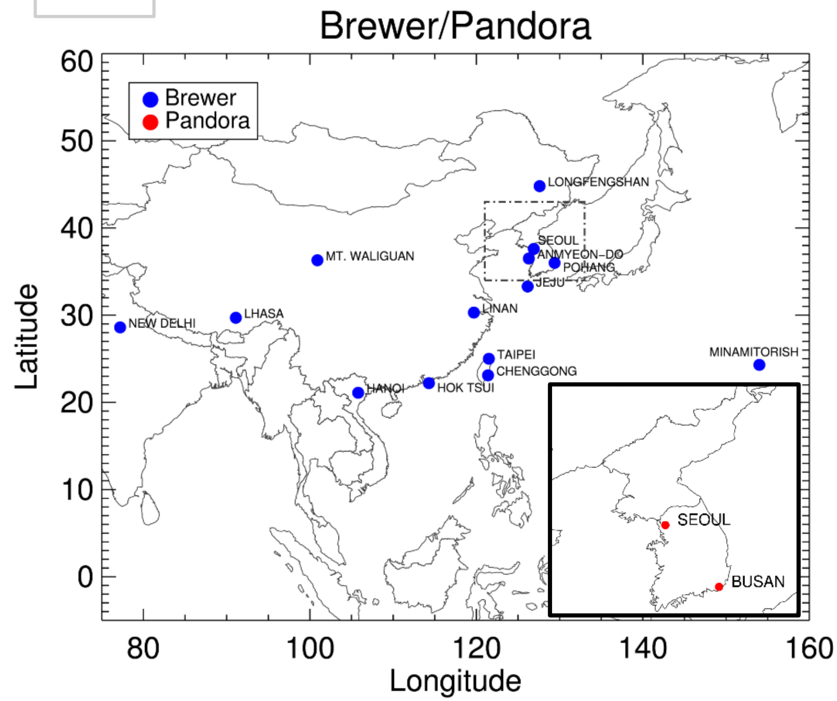
Validation System

O3P



There are 11 ozonesonde stations

O3T



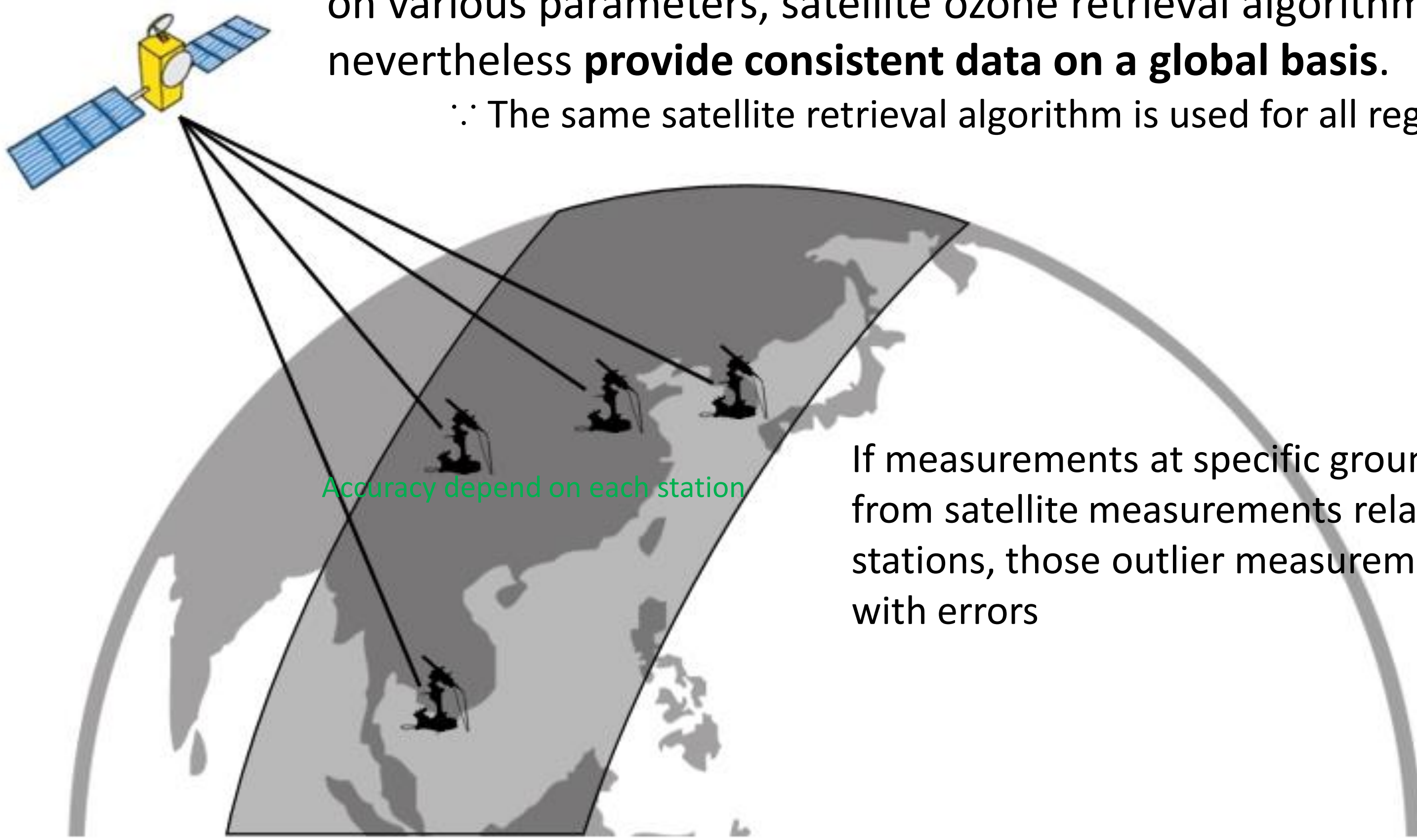
- 13 Brewer stations
- Two Pandora stations

In order to evaluate products retrieved from GEMS and to improve them, the high quality of ground-based measurements are required.

Evaluation of Ground-based O_3 measurements using OMI O_3

- Although the accuracy of satellite ozone measurements may depend on various parameters, satellite ozone retrieval algorithms nevertheless **provide consistent data on a global basis**.

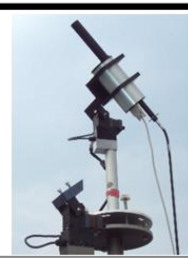
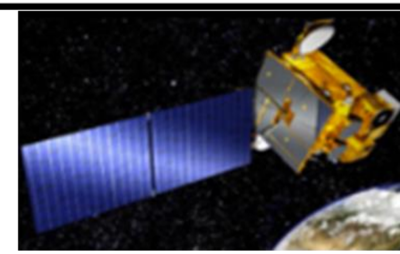
∵ The same satellite retrieval algorithm is used for all regions and times.



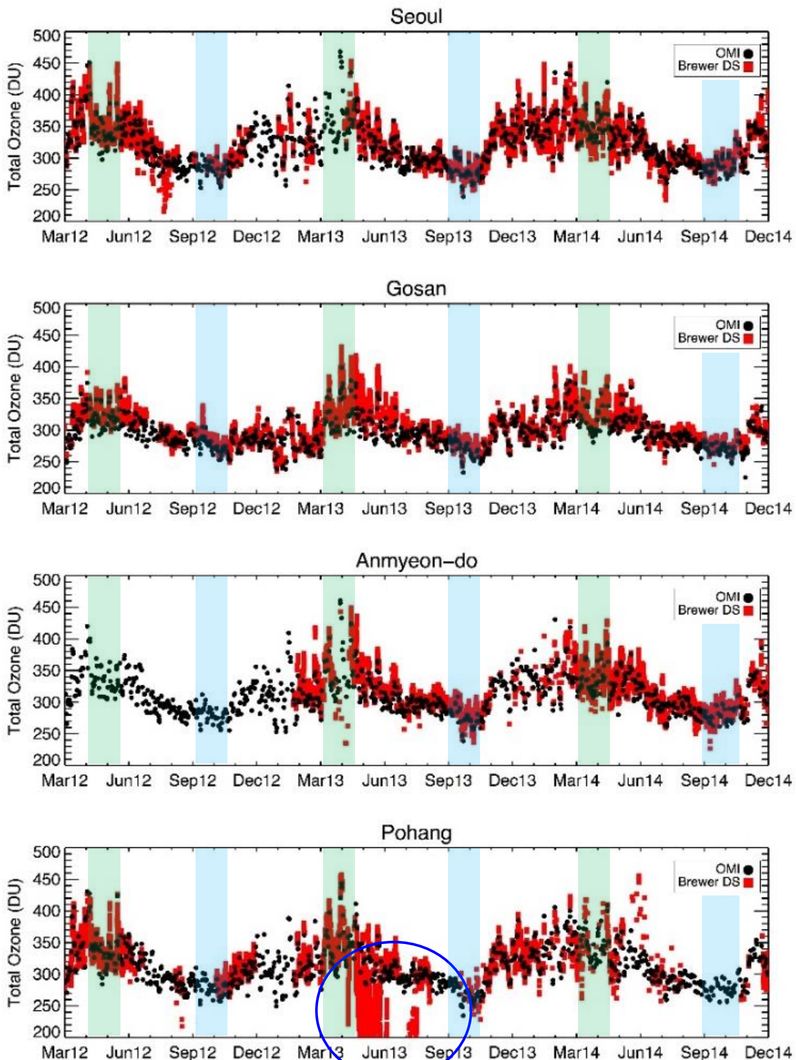
If measurements at specific ground stations deviate from satellite measurements relative to other stations, those outlier measurements can be judged with errors

Can be used to estimate the performance of the ground-based measurement station as well as to identify potential problems at individual stations.

Data information

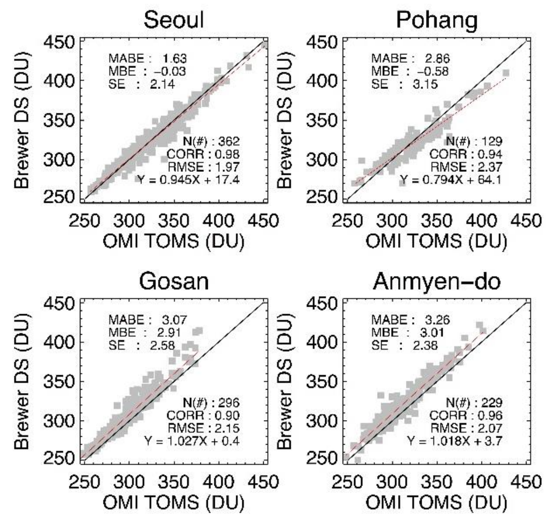
	Brewer	Pandora	Sonde	OMI-TO3	OMI-O3PROF
					
Method	Differential measurement method	Modified DOAS	Electrochemical Condensation Cell (ECC)	OMI TOMS V8.5	OMI SAO profile algorithm
Period	2012/3 ~ 2014/12		2005/1 ~ 2016/12	2012/3 ~ 2014/12	2005/1 ~ 2016/12
Station	Seoul, Pohang, Gosan, Anmyeon	Seoul, Busan	Above map	East Asia	East Asia
Quality control	Std err. < 2DU AOS < 1DU (Balis et al., 2007)	RMS < 0.05 Estimate err < 2DU (Tzourisou et al., 2012)	< 200 hPa (TOZ) < 12 hPa (SOZ) TOZ < 80 DU SOZ > 100 DU	Quality flag = 0 Exclude low anomaly	Quality flag = 0 @ SZA<60, fitting residual < 3
Precision	0.1%	0.05%	3-5%	2% error @ Low SZA 5% error @ High SZA	

Comparison of Brewer and OMI Total Column Ozone (TCO)

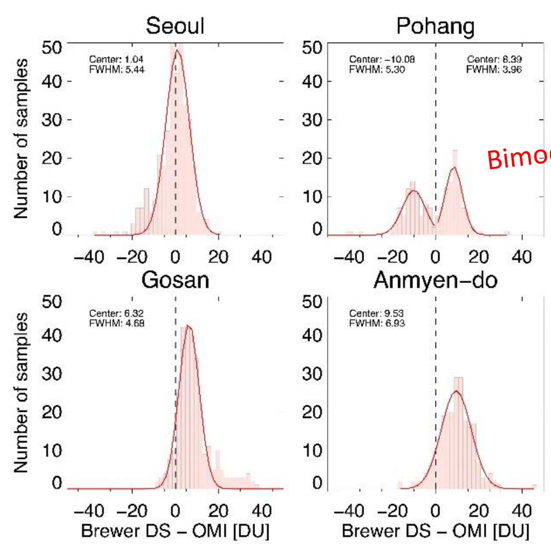


- Distinct annual cycle with maxima between March and May and minima between September and October
- A significant difference in the TCO time series is observed at **Pohang** between April and July 2013

R : 0.96-0.98, RMSE : < ~2.5 ,MB : < ~3%

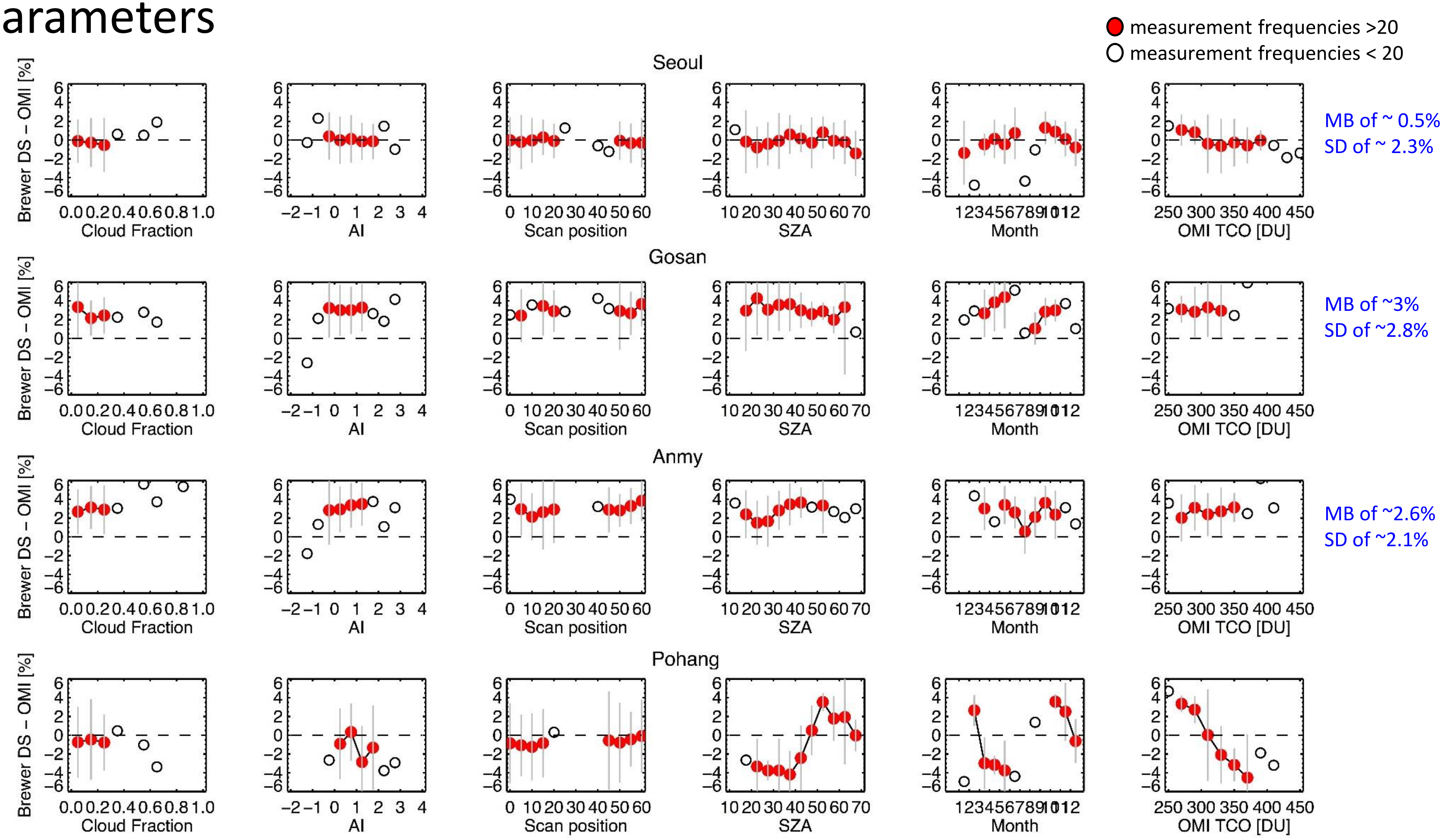


Slope of 0.79 at Pohang significantly below the range at other stations



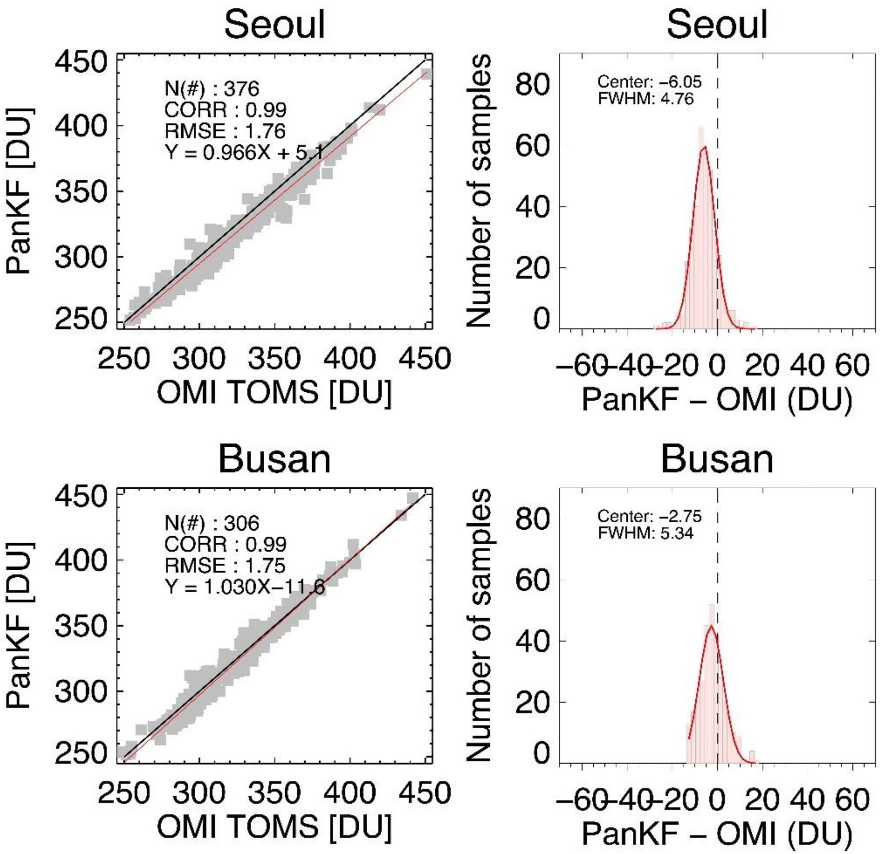
Bimodal distribution

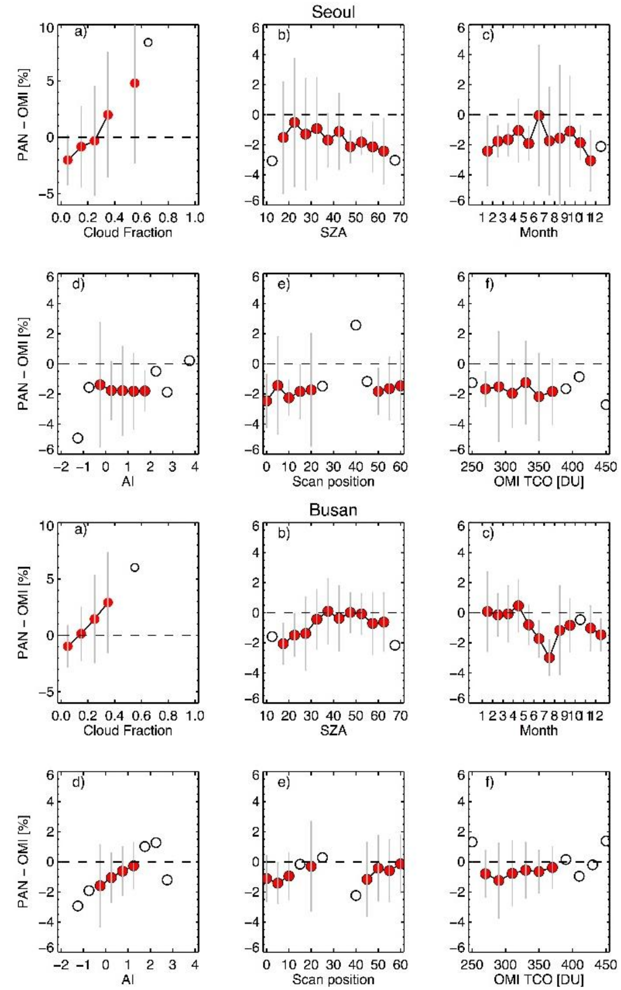
The Dependence of Satellite-to-ground Differences on various Parameters



- The bias at Pohang varies from ~ 4% at low to ~4% at high SZA, from ~ 4% in spring to ~4% in winter, and from 4% to 5% as TCO increases.
- Brewer instrument at Pohang suffered from TCO measurement problems during the study period

Comparison of Pandora and OMI TCO





- **To filter out** these cloud-contaminated data, we applied a **Kalman filter** to the Pandora measurements (Baek et al., 2017).
- The correlation of Kalman-filtered Pandora data with OMI-TOMS TCO is significantly improved.

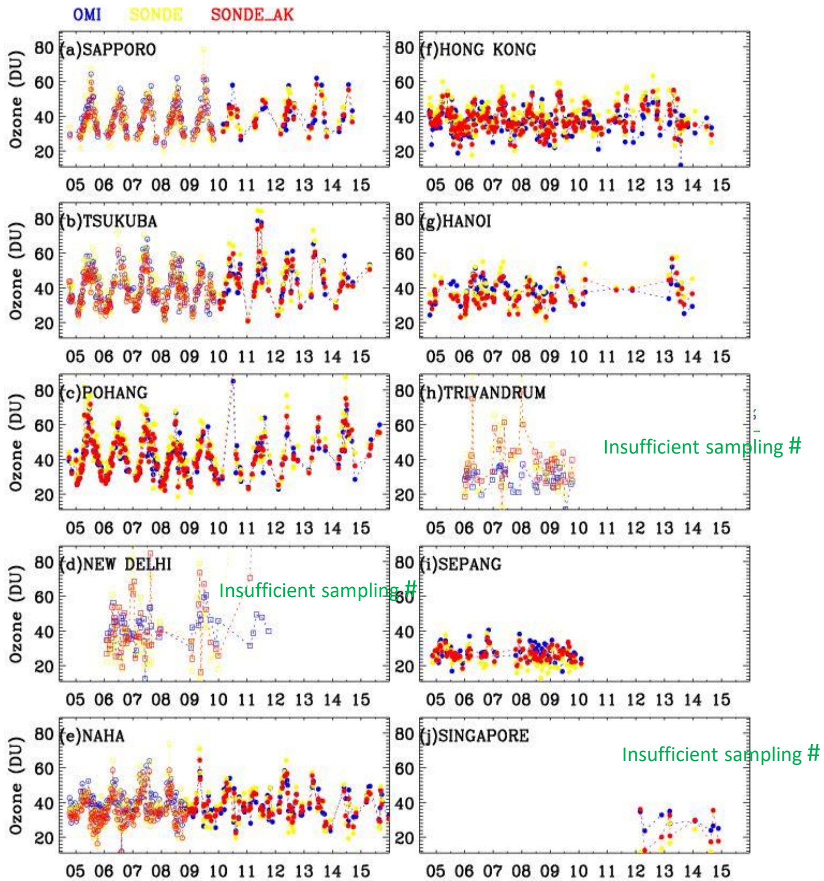
Large difference obtained with increasing cloud fraction

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]

[a] Department of Atmospheric Science, Pusan National University, South Korea
[b] Joint Center for Earth Systems Technology, University of Maryland, Baltimore, USA
[c] Science Systems and Applications, Lanham, MD, USA
[d] Department of Atmospheric Science, Yonsei National University, South Korea

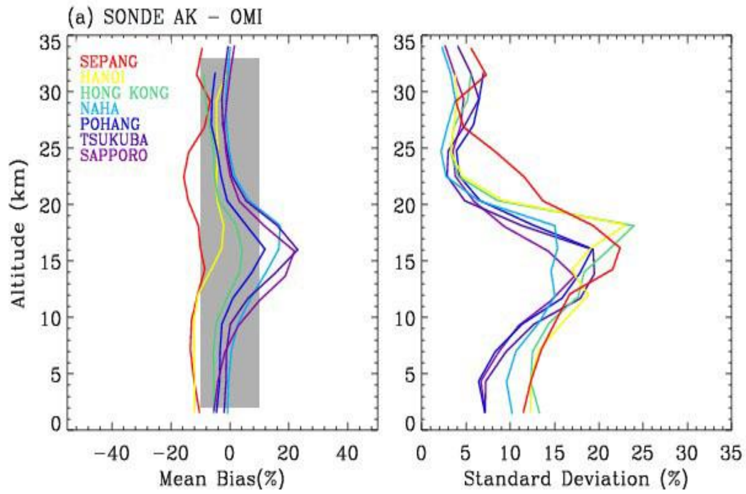
Comparison of Sonde and OMI Tropospheric Ozone at 10 sites



Station	Lon (°N)	Sonde Type	SONDE AK – GEMS		
			#	Mean Bias + 1σ	R
Sapporo, Japan	43.08	CI	114	-3.36 ± 2.29	0.93
		ECC	100	-0.63 ± 3.08	0.91
Tsukuba, Japan	36.07	CI	148	-2.75 ± 3.68	0.91
		ECC	140	0.21 ± 3.57	0.94
Pohang, Korea	36.02	ECC	264	0.91 ± 3.13	0.94
New Delhi, India	28.3	M B-M	50	3.95 ± 12.79	0.25
Naha, Japan	26.2	CI	140	-4.43 ± 4.07	0.84
		ECC	163	-0.62 ± 3.49	0.89
Hong Kong, China	22.31	ECC	249	-1.39 ± 4.52	0.75
Hanoi, Vietnam	21.01	ECC	91	-3.76 ± 4.78	0.68
Trivandrum, India	8.47	M B-M	38	7.38 ± 14.84	0.13
Sepang, Malaysia	2.73	ECC	86	-3.46 ± 3.71	0.47
Singapore	**1.34**	**ECC**	**18**	**-14.11 ± 9.77**	**-0.15**

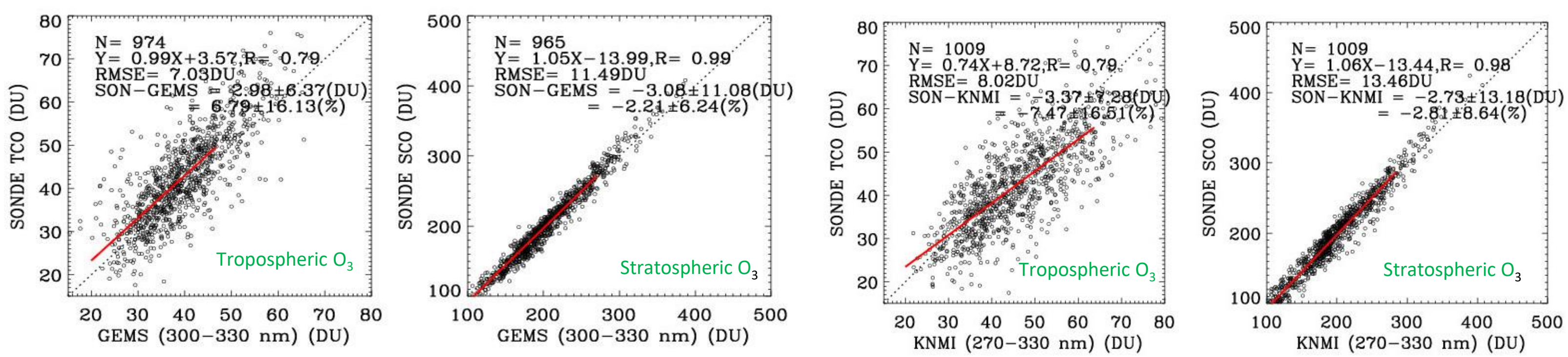
- Simulate GEMS retrievals from OMI measurements with 300-330 nm fitting window
- Demonstrate the high precision of ECC sonde measurements compared to CI and M B-M

Quality of GEMS ozone profile retrievals



- Fitting window [300-330 nm] to simulate GEMS spectrum
- Similar agreements between GEMS Ozone retrievals and ECC ozonesonde collected over GEMS Domain.

Quality comparison between GEMS and KNMI ozone from OMI



Our GEMS algorithm show similar performance for SCO with KNMI, but much Better quality for Tropospheric ozone.

Summary

- We developed ozone profile algorithm based on OEM and total column ozone based on TOMS.
- The performance of GEMS-O3 retrievals agree well with ground-based measurements.
- Satellite measurements can be used to estimate the performance of the ground-based measurement network as well as to identify potential problems at individual stations.
- Brewer instrument at Pohang suffered from TCO measurement problems during the study period.
- Pandora TCO measurements are unusually high relative to OMI-TOMS in the presence of clouds
- Demonstrate the high precision of ECC sonde measurements compared to CI and M B-M

Thank you

감사합니다