Intercomparison of total column ozone from Pandora over Seoul, Korea

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Introduction

- The Pandora spectrophotometer was developed at NASA in 2006, and was installed since 2012 in Korea (YonU & PNU).

- Total ozone observation was executed since 1985 in YonU, which is first observation site in South Korea. Furthermore, YonU site operated both Dobson and Brewer spectrophotometers for 20 years.

- Intercomparison of total ozone between Brewer and Dobson was studied based on the observation data (at Seoul).

Ground station for ozone observation in Korea

84	85-94	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16

Dobson Spectrophotometer
WMO/GO3OS Stn. No.252
Yonsei University/KMA
Seoul

Brewer #148
Yonsei Univ.
Seoul

Pandora
Yonsei Univ.,Seoul
Pusan National Univ., Busan
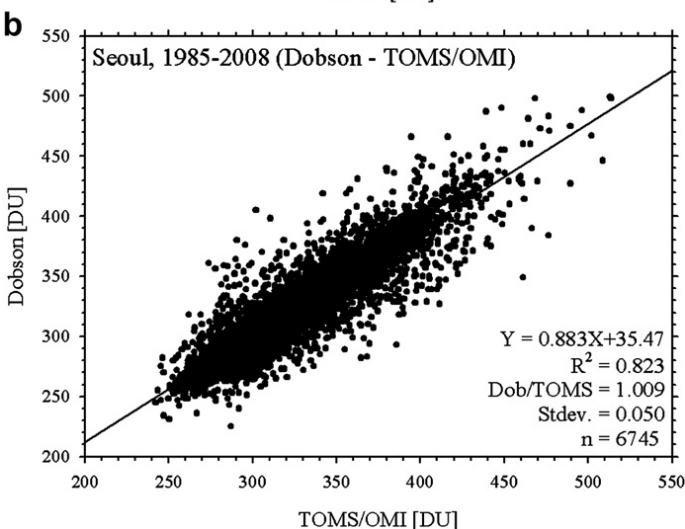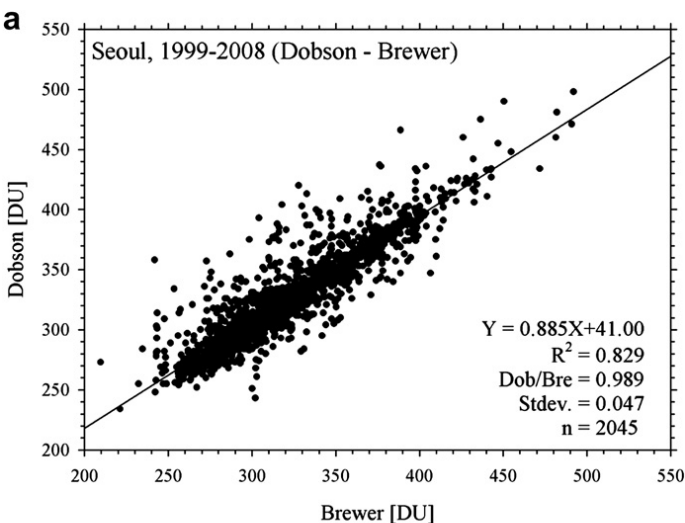
Brewer #095
WMO/GO3OS Stn No. 332.
KMA, Pohang

Ozonesonde
Model 5A ECC
KMA, Pohang

LIDAR
Anmyeon
KGAW

Brewer
KMA,
Gosan

Previous Intercomparison

Y = 0.885X+41.00
R^2 = 0.829
Dob/Bre = 0.989
Stdev. = 0.047
n = 2045

Seoul, 1999-2008 (Dobson - Brewer)

Y = 0.883X+35.47
R^2 = 0.823
Dob/TOMS = 1.009
Stdev. = 0.050
n = 6745

Seoul, 1985-2008 (Dobson - TOMS/OMI)

(Park et al., 2012, AE)

- Seoul site : Simultaneously operated to the Brewer and Dobson
- Intercomparison studies have been executed based on daily representative data.
  - Dobson vs Brewer
  - Dobson vs TOMS/OMI (daily-based data)

Dobson spectrophotometer

Brewer spectrophotometer
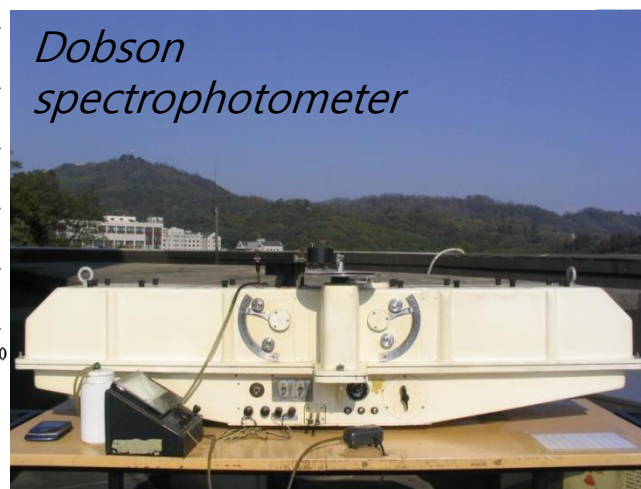
Ground-based observation network

Geographical Distributions of WOUDC stations

GEMS FOI
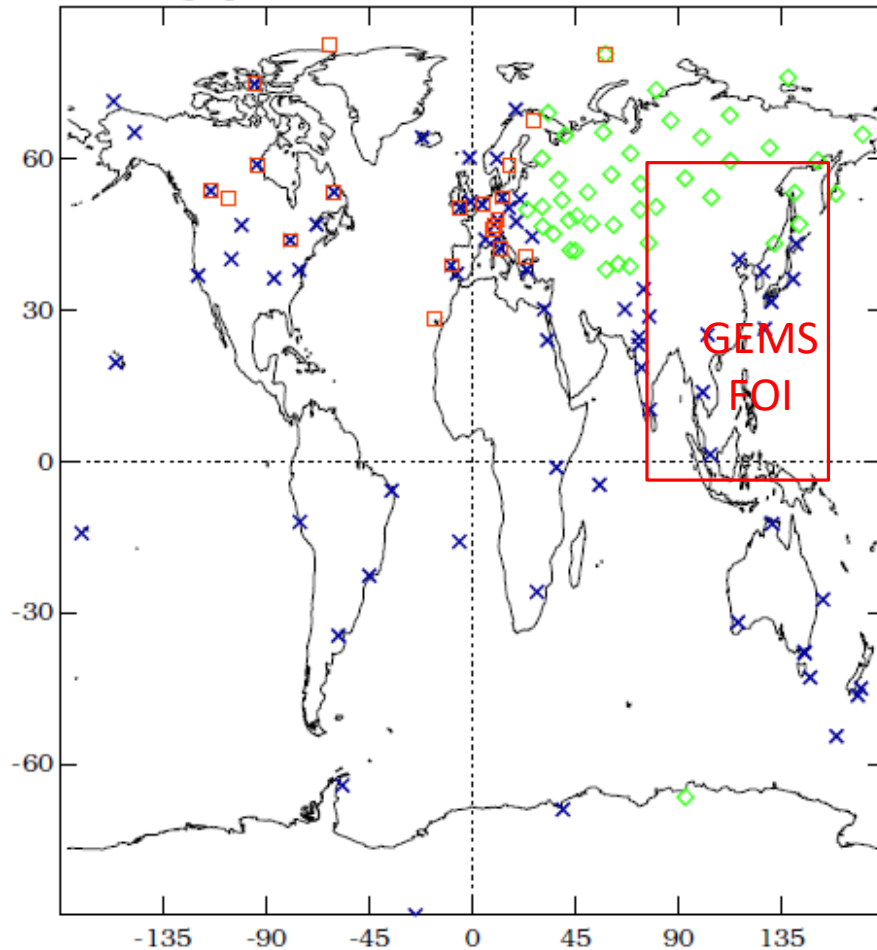
(Chiou et al., 2014, AMT)

Dobson Stations
Brewer Stations
Filter Instrument Stations

- The ground-based observation network is helpful for validation studies of satellite measurements including GEMS.

- The Pandora spectrometer was purposed on validation for GEMS missions.

- Continuous observation data in daily-scale is also essential to the validation study, because GEMS continuously retrieved the total ozone amount every hour.

Data Selection

Instrument	Observation Interval	Daily Data	Data selection
Pandora	2 minutes	Averaged	$SZA < 75$ $RMS < 0.05$ $dO_3 < 2$ DU
Dobson	3-times per day	Representative (lowest SZA)	$Mu < 2.6$
Brewer	Tens of minutes	Averaged	$SZA < 75$
OMI-TOMS	1-time per day	-	Level-3 (0.25deg.)
OMI-DOAS	1-time per day	-	Level-3 (0.25deg.)

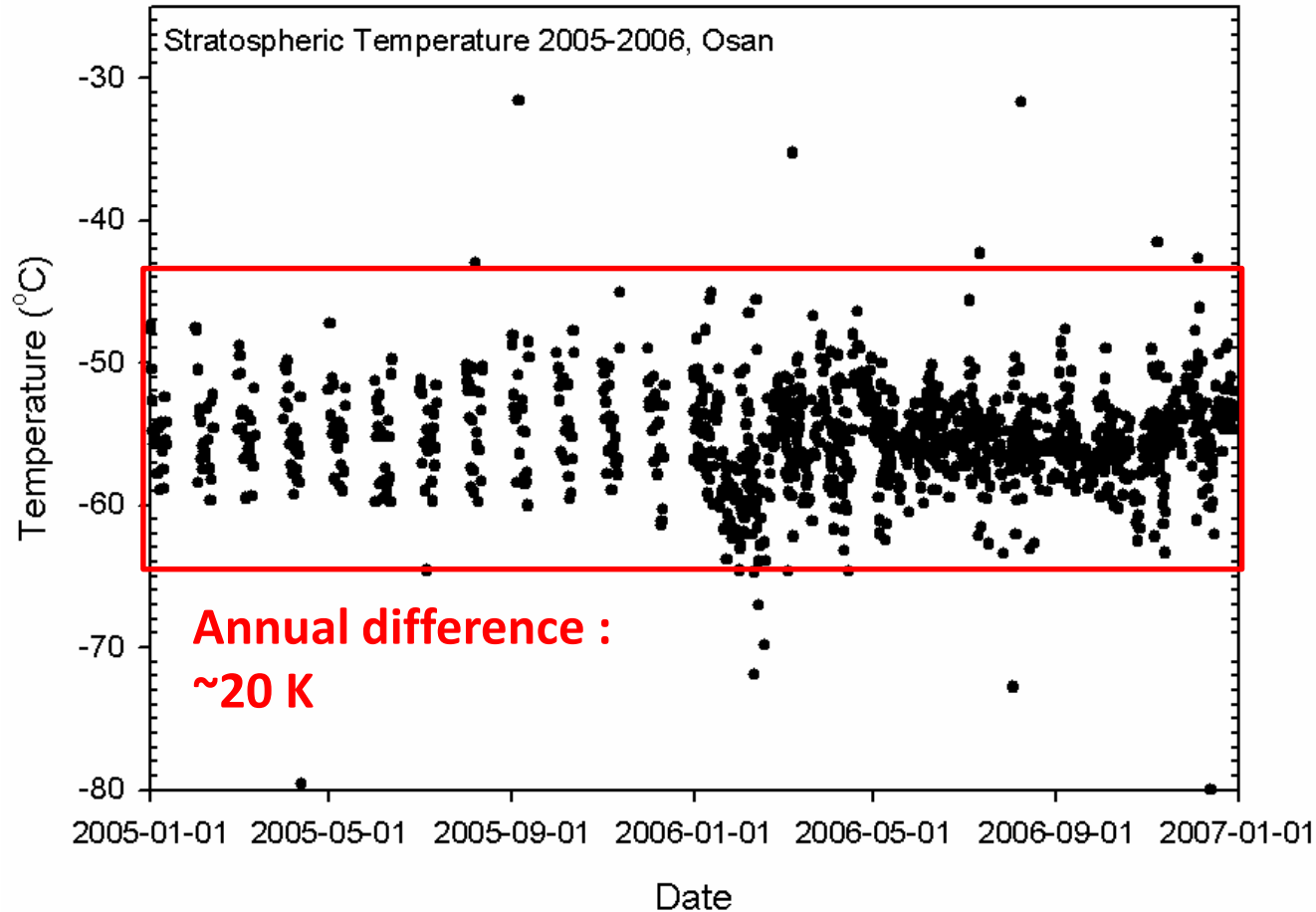Only Direct-sun data were used (Ground-based measurements)

TCO retrieval methods

Instrument	Retrieval Method	Cross section Database	T_{O3} (K)	Data frequency	Key Reference
Pandora	Spectral fitting (310-330 nm)	Brion et al. (1993, 1998) and Malicet et al. (1995)	225	2 minutes	Herman et al. (2015)
Dobson	4-wavelength (305.5, 317.5, 325.0, and 339.9 nm)	Bass and Paur (1985)	226.8	3-times per day	Evans and Komhyr (2008)
Brewer	5-wavelength (306.3, 310.1, 313.5, 316.7, 320.0 nm)	Daumont et al. (1992)	228	Tens of minutes	Kerr (2002)
OMI-TOMS	2-wavelength (317.5 and 331.2 nm)	Bass and Paur (1985)	Varied	1-time per day	Bhartia and Wellemeyer (2002)
OMI-DOAS	DOAS (331.1 – 336.6 nm)	Bass and Paur (1985)	Varied	1-time per day	Veefkind et al. (2006)

• This study : Ignore temperature correction
(Temperature effect : -0.13~0.33 %/K from Herman et al., 2015)

Kim et al. (2017, AMT)

Effective Ozone Temperature

Stratospheric Temperature 2005-2006, Osan
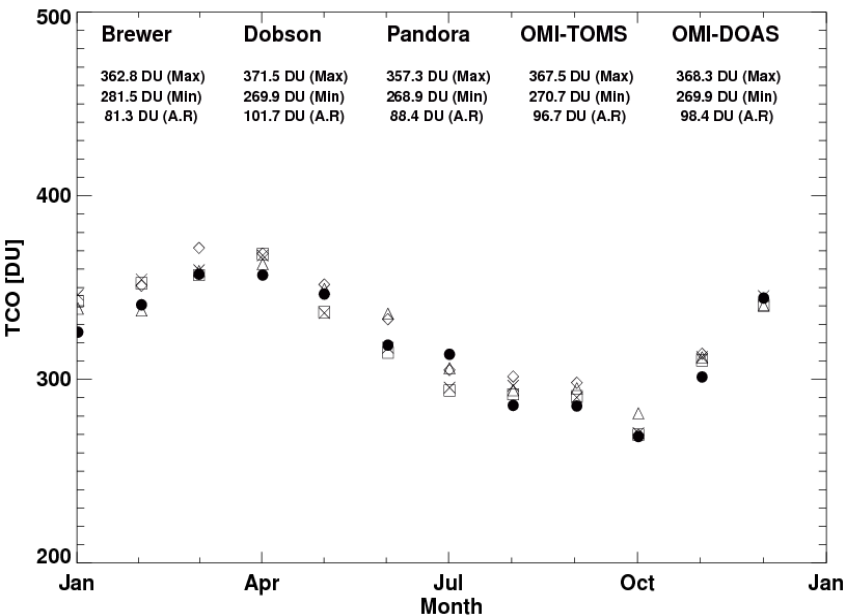
Annual difference : ~20 K

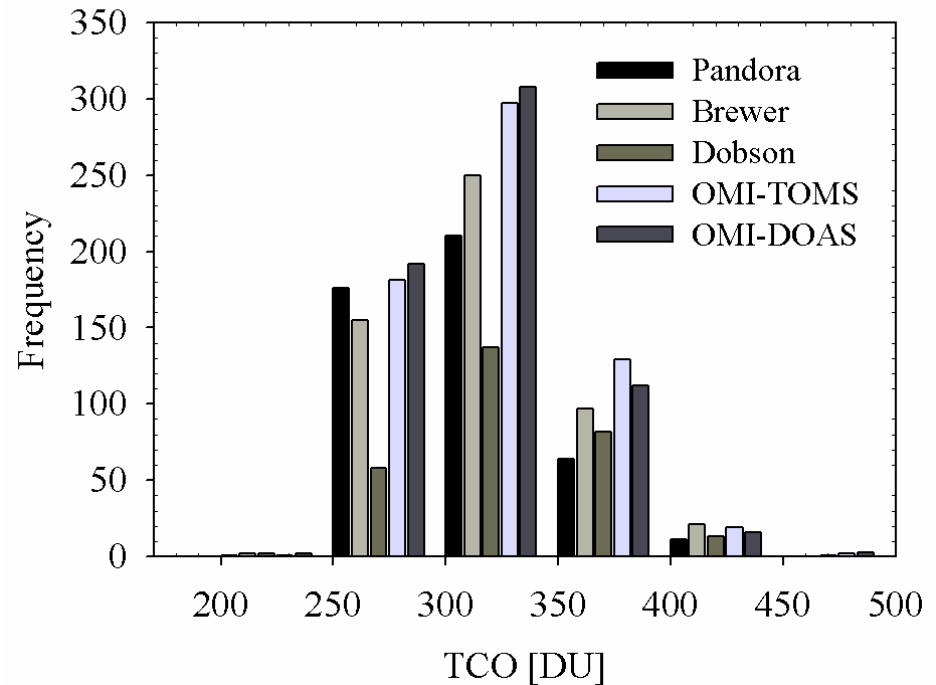**Kim et al. (2007, 10th Brewer Meeting)**

Monthly Variation

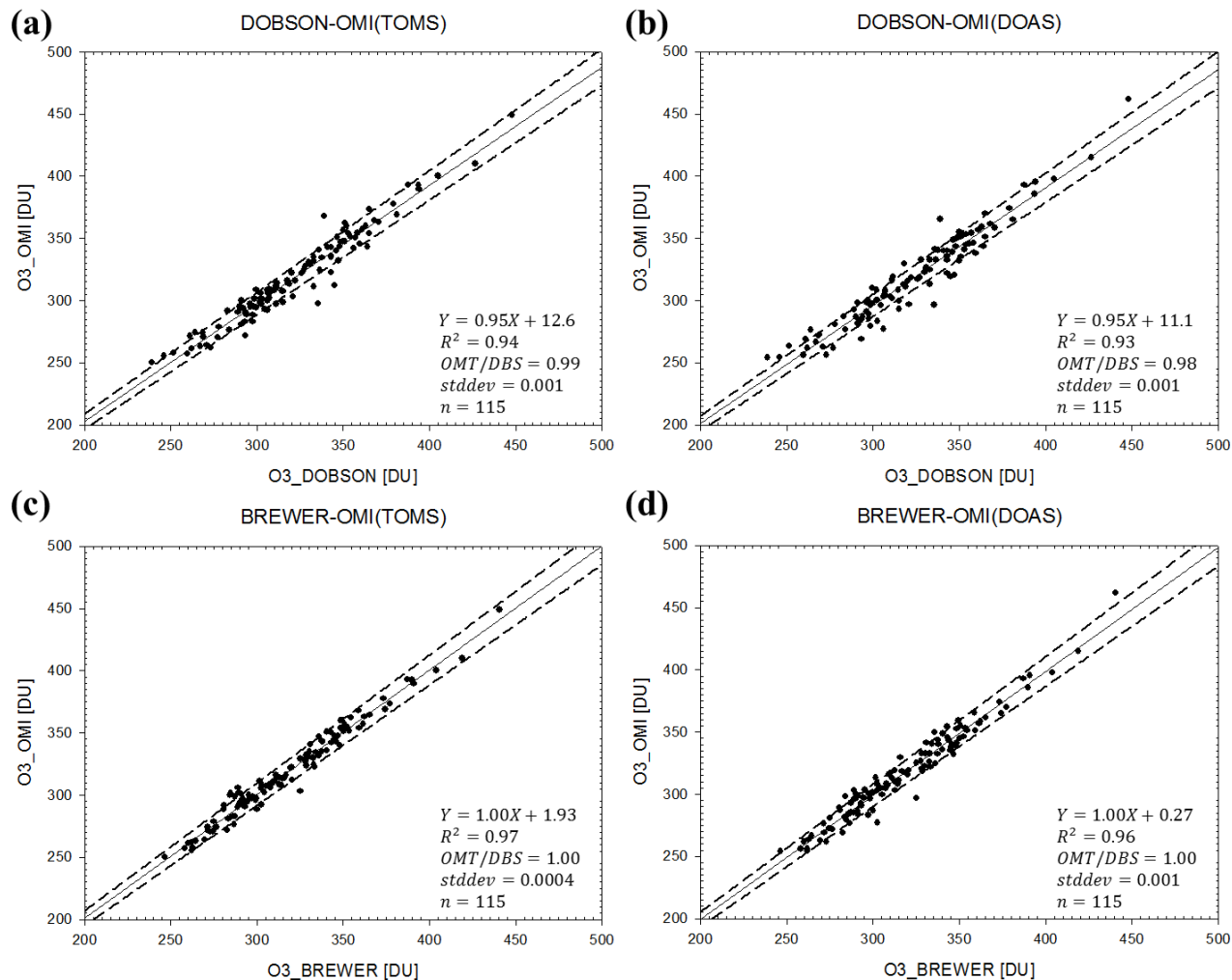Period : 2012/03 ~2014/12

Monthly Average

Frequency Histogram

- Total Ozone (TCO) Differences between instruments are caused by the difference method for daily data calculation.
- TCOs from Brewer and Pandora show similar patterns for monthly mean and annual difference of TCO.
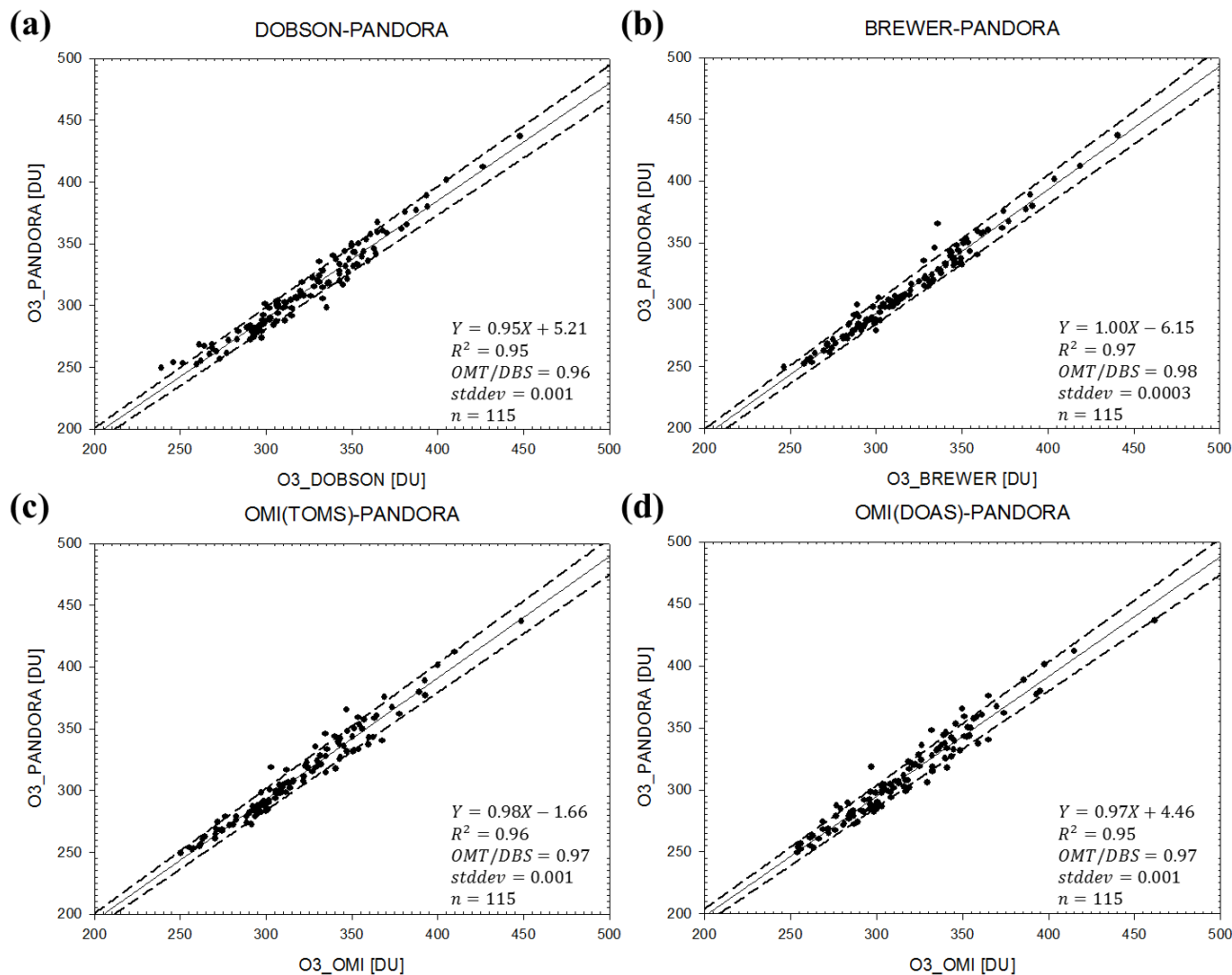
Kim et al. (2017, AMT)

Inter-comparison (Daily)

(a) DOBSON-OMI(TOMS)

$Y = 0.95X + 12.6$
$R^2 = 0.94$
$OMT/DBS = 0.99$
$stddev = 0.001$
$n = 115$

(b) DOBSON-OMI(DOAS)

$Y = 0.95X + 11.1$
$R^2 = 0.93$
$OMT/DBS = 0.98$
$stddev = 0.001$
$n = 115$

(c) BREWER-OMI(TOMS)

$Y = 1.00X + 1.93$
$R^2 = 0.97$
$OMT/DBS = 1.00$
$stddev = 0.0004$
$n = 115$

(d) BREWER-OMI(DOAS)

$Y = 1.00X + 0.27$
$R^2 = 0.96$
$OMT/DBS = 1.00$
$stddev = 0.001$
$n = 115$

- Results for intercomparison between ground and satellite
  - Slope : 0.95~1.00
  - R^2 : 0.93~0.97

Kim et al. (2017, AMT)

Inter-comparison (Daily)

(a) DOBSON-PANDORA

$Y = 0.95X + 5.21$
$R^2 = 0.95$
$OMT/DBS = 0.96$
$stddev = 0.001$
$n = 115$

(b) BREWER-PANDORA

$Y = 1.00X - 6.15$
$R^2 = 0.97$
$OMT/DBS = 0.98$
$stddev = 0.0003$
$n = 115$

(c) OMI(TOMS)-PANDORA

$Y = 0.98X - 1.66$
$R^2 = 0.96$
$OMT/DBS = 0.97$
$stddev = 0.001$
$n = 115$

(d) OMI(DOAS)-PANDORA

$Y = 0.97X + 4.46$
$R^2 = 0.95$
$OMT/DBS = 0.97$
$stddev = 0.001$
$n = 115$

- Intercomparison for Pandora
  - 2~4% underestimation
  - High correlation coefficients (0.95~0.97)

Kim et al. (2017, AMT)

Simultaneous comparison
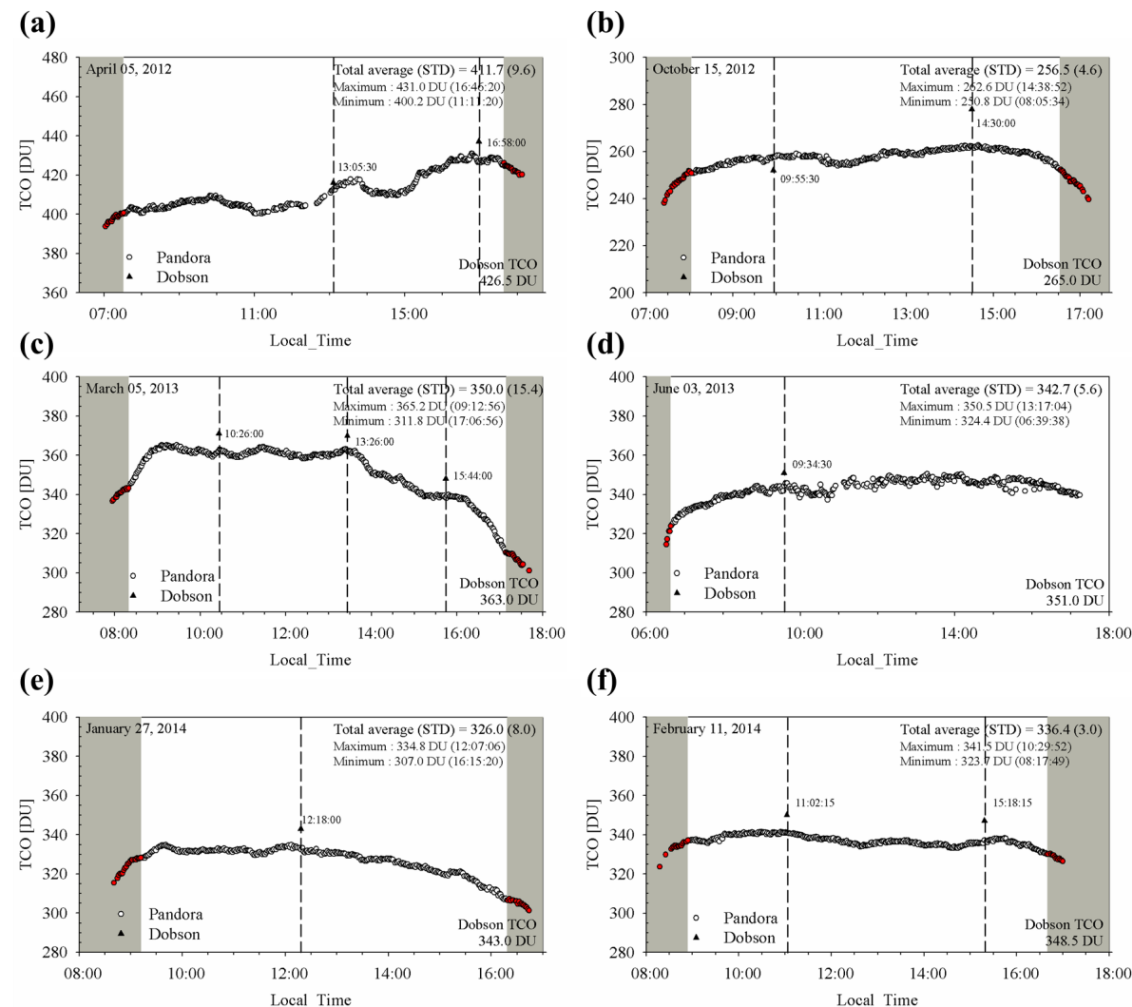
- Previous studies for comparison
  - Daily-based data
  - Assumed to be less variable (due to stable stratosphere condition)
- However, diurnal variation of total ozone is sometimes large.
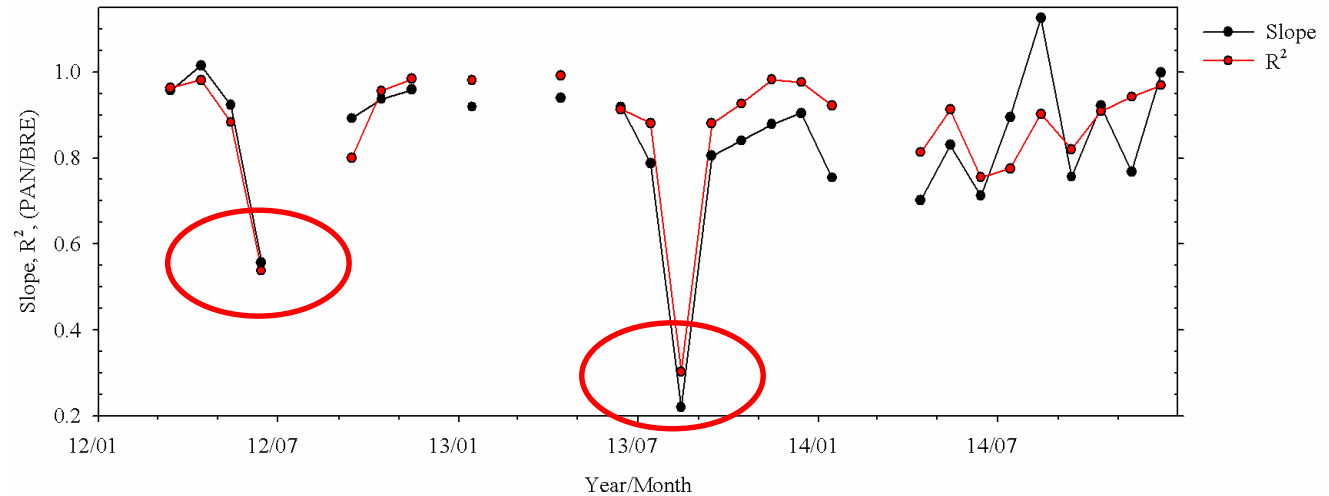- Simultaneous comparison
  - Brewer vs Pandora

Kim et al. (2017, AMT)

Simultaneous comparison

(a) Scatter plot of O_3 Pandora [DU] vs O_3 Brewer [DU]:
$Y = 0.98 X - 0.23$
$R^2 = 0.94$
$PAN/BRE = 0.98$
$stddev = 0.03$
$n = 12208$

(b) Histogram of Frequency vs Relative Difference (%), Mean: -2.3%
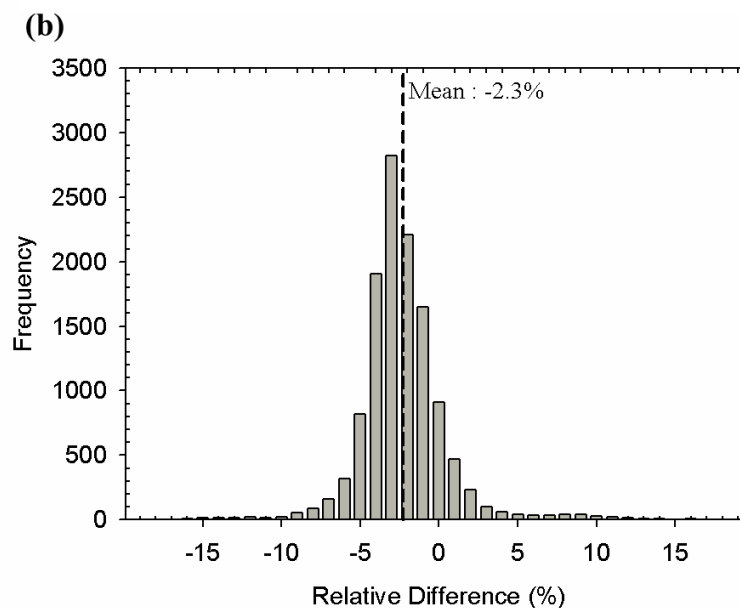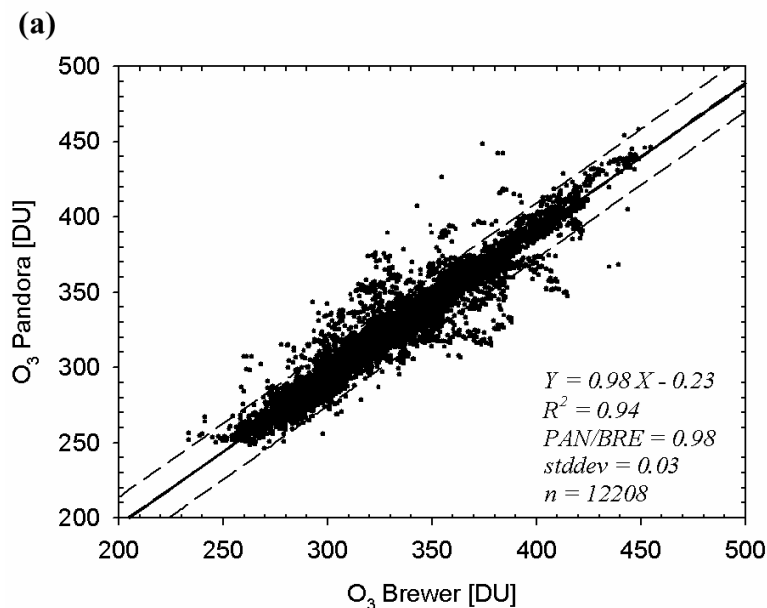
- Time difference < 5 minutes
- Total ozone from Pandora were averaged over all data for which the time difference between Brewer and Pandora was less than 5 minutes.
- Mean difference : TCO from Pandora is 2.3% lower than TCO from Brewer.
  [Insignificant bias]
- Mostly, Pandora TCO is lower than Brewer TCO.
- Precise analysis is required with consideration of temperature dependence.
- 89.2% (57.1%) of data has the difference within 5% (3%).

Kim et al. (2017, AMT)

Timeseries (Brewer vs Pandora)
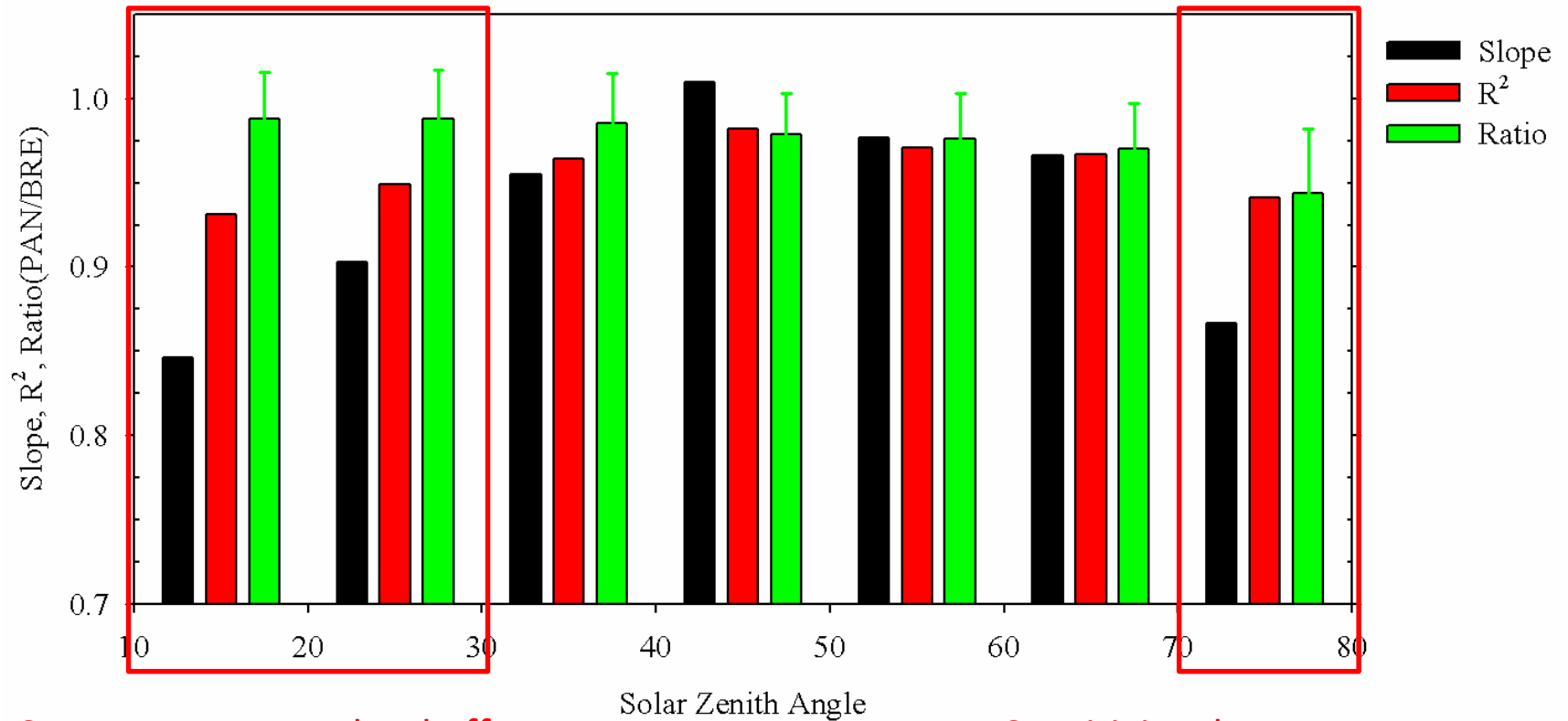
Slope and R²

Ratio (PAN/BRE)
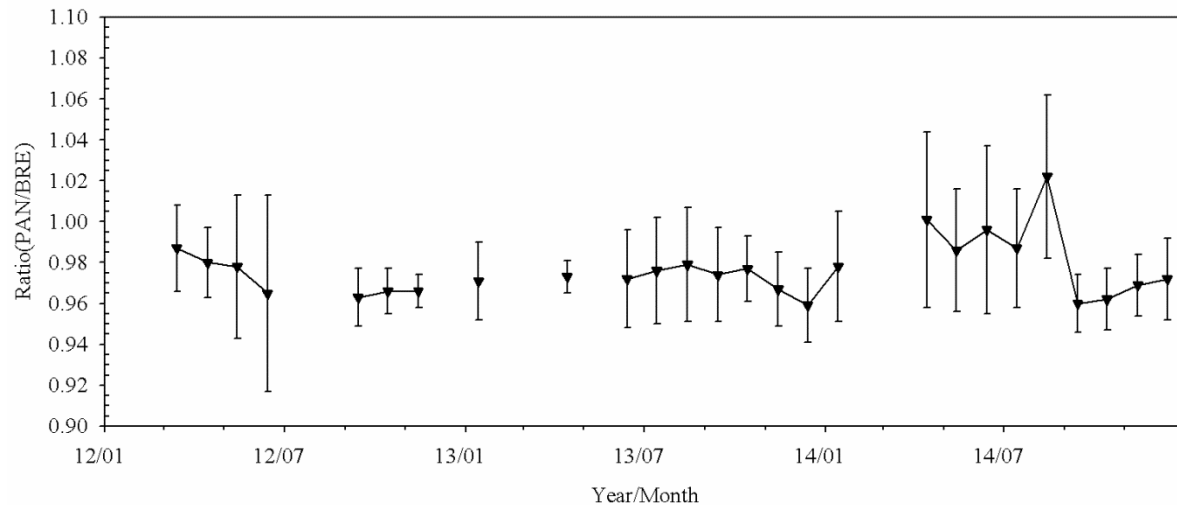
- The PAN/BRE is mostly less than 1.0 for all periods.
- Seasonal dependence of regression results (due to inaccurate cloud screening).

Simultaneous comparison

Summer season : cloud effect

Sensitivity change
(long optical path length)

Kim et al. (2017, AMT)

Summary

- Daily total ozone data measured by the Pandora spectrophotometer were compared using ground-based and satellite measurements.

- The Pandora total ozone show high agreement with other instruments, with slopes close to 1 and R^2 greater than 0.95.

- The underestimation of TCO from Pandora in long-optical path-length cases in Seoul can be attributed to the enhancement of aerosol scattering compared to the Brewer (Simultaneous observation).

- Further study
  - SZA dependence
  - Extend the comparison period
  - Checking consistency due to the Pandora instrument change
  - Seasonal Effect due to effective temperature for ozone, and vertical distribution change.