Analyzing the contribution of NO_2 to Aerosol amount using Pandora measurements over major cities in Asia

Seongyoung Kim, Ukkyo Jeong

Division of Earth and Environmental System Sciences Major of Geomatics Engineering, Pukyong National University, Busan, Republic of Korea

Email: seongyoung.kim98@gmail.com

PUKYONG NATIONAL UNIVERSITY

Abstract

1. A well-maintained Pandora spectrometer can be effectively utilized for satellite Aerosol optical depth (AOD) product validation **(see Fig 2)**.
2. A qualitative comparative analysis between the NO_2 VCD/AOD ratio derived from satellite data and Pandora showed discrepancies, mainly due to the underestimation of NO_2 vertical column density by satellites in heavily polluted urban areas **(see Fig 3)**.
3. Water vapor and temperature factors promote photochemical reactions, which negatively impact daily coefficient of determination (R^2) between NO_2 vertical column density (VCD) and AOD **(see Fig 4)**.
4. NO_2 makes a significant contribution to explaining variation in AOD in regions with high NO_2 VCD **(see Fig 5)**.

Objective

- Attempt to retrieve Aerosol optical depth (AOD) using Pandora spectrometer and compare it with AERONET data to verify accuracy and assess whether Pandora can provide reliable AOD data for satellite validation.
- Analyze the daily coefficient of determination (R^2) between NO_2 Vertical Column Density (VCD) and AOD to understand the features of their daily variations in regions across Asia with diverse meteorological conditions and pollutant emission patterns.

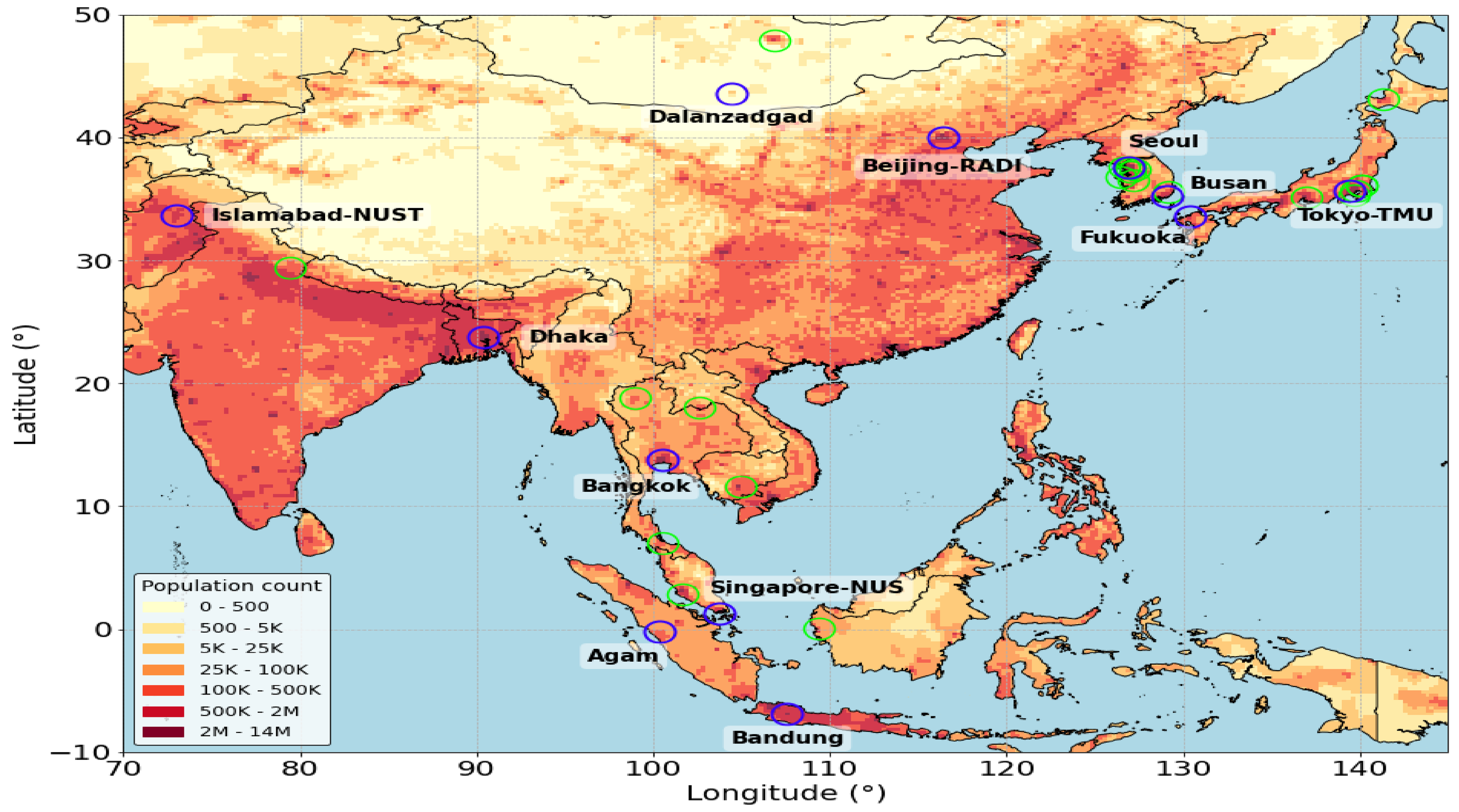

Fig 1. Map of Pandora instruments across Asia. Background colors show population counts. Blue circles: sites used to analyze daily R^2 between NO_2 VCD and AOD.

Methodology

AOD and NO_2 VCD Data

- **NO_2 VCD**: Used total NO_2 VCD data from the Pandora Global Network, with a precision of 0.01 DU and accuracy of 0.1DU under clear atmospheric conditions (Herman et al., 2009).
- **AOD**: Retrieved in this study utilizing the method proposed by Jeong et al. (2018) in the visible wavelength

Retrieved AOD Validation

- Validated the retrieved AOD by comparing it with AERONET AOD Level 1.5 to ensure measurement accuracy.

NO_2 to AOD Ratio

- The ratio of NO_2 VCD from TROPOMI to AOD from VIIRS was calculated to assess the relative influence of NO_2-related pollution on AOD (JP Veefkind et al., 2011), with the purpose of validating against ground-based Pandora measurements

Linear Regression Analysis

- Performed linear regression analysis on the daily R^2 between NO_2 VCD and AOD, using water vapor VCD derived from Pandora and temperature at 2m from MERRA-2 as independent variables.

Calculation of Corrected DV-R^2

- Calculated the corrected Daily R^2 between NO_2 VCD and AOD by considering water vapor VCD to account for regional photochemical effects

Trend Analysis

- Conducted a trend analysis using the corrected R^2 values to evaluate the contribution of NO_2 to the diurnal variability of AOD across different regions.

Pandora AOD Validation with AERONET

- AOD in the visible range was retrieved using the Pandora spectrometer. The analysis with AERONET at various sites showed high correlation coefficients (R = 0.85~0.98) and root mean square errors (RMSE) ranging from 0.023 to 0.106.
- Missing AOD observation data from AERONET can be supplemented with data from nearby Pandora sites, ensuring continuous AOD data availability for specific locations

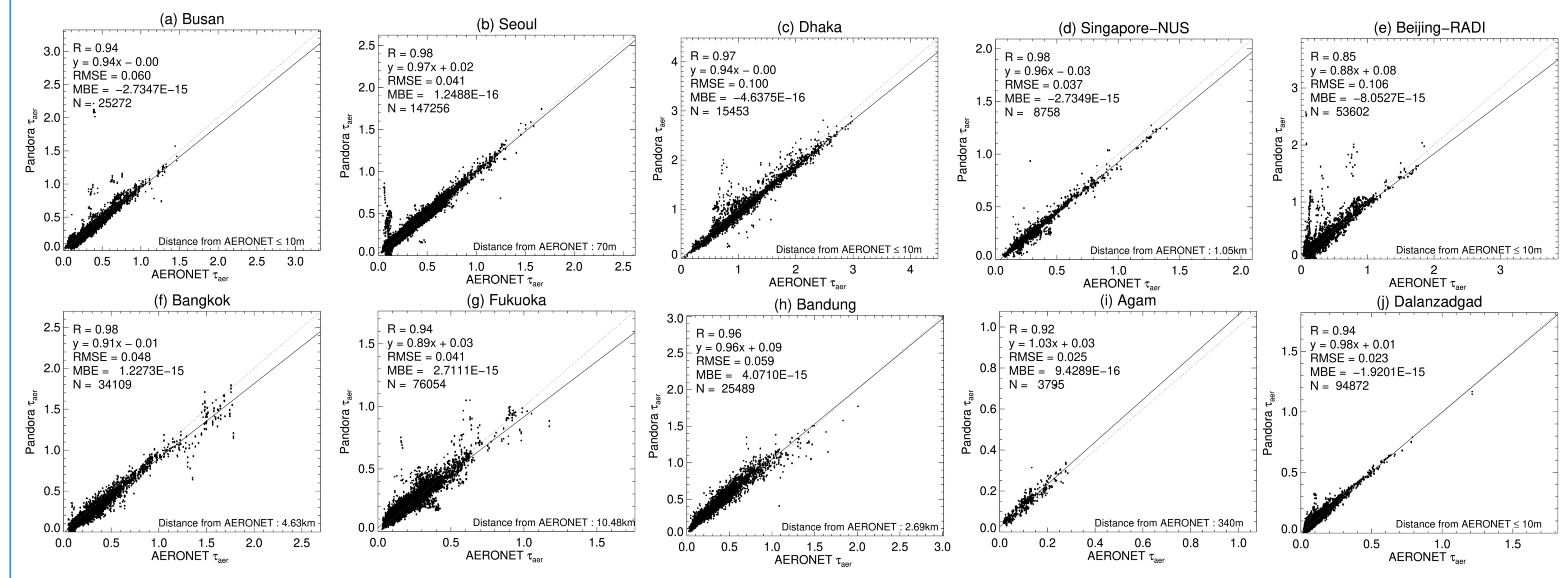

Fig 2. Scatter plot comparing AERONET and Pandora AOD measurements at 500 nm

Ground and Satellite-Derived NO_2 to AOD

- The NO_2 to AOD ratio serves as an indicator for assessing the relative impact of NO_2 on AOD.
- Based on the calculation using TROPOMI NO_2 VCD and VIIRS AOD, discrepancies have emerged when compared to ground-based measurements.
- TROPOMI tends to underestimate NO_2 VCD in highly polluted urban areas, leading to discrepancies in the NO_2 VCD to AOD ratio.

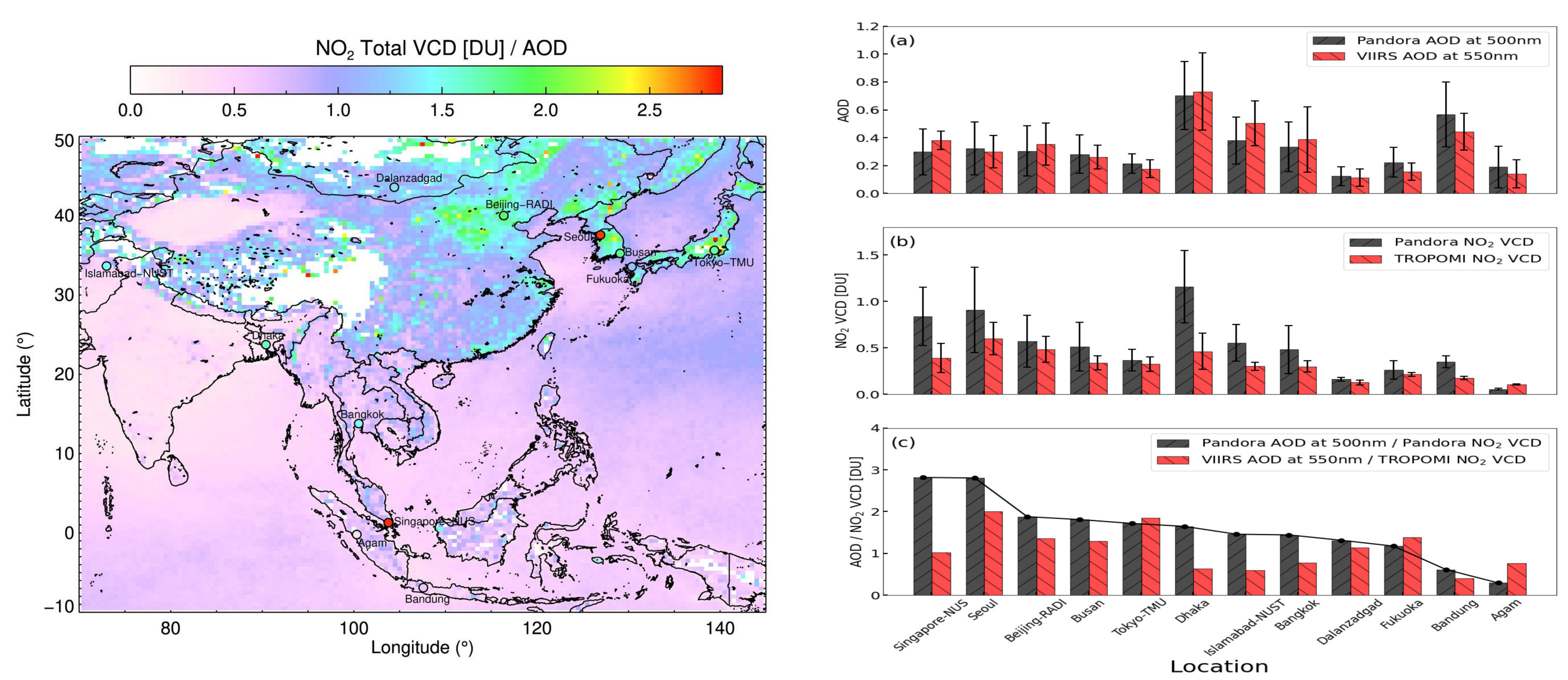

Fig 3. (Left) Spatial distribution of the monthly mean NO_2 to AOD ratio, using TROPOMI NO_2 VCD and VIIRS AOD, resampled at a 0.5° resolution for the year 2022. (Right) Comparison of NO_2 to AOD ratios derived from ground-based observations (depicted as circles on the map) with those calculated from TROPOMI and VIIRS across various Pandora sites.

Meteorological Impact on daily R^2 (NO_2 and AOD)

- A regression analysis using water vapor and temperature data from various regions in Asia as independent variables revealed a negative correlation between each of these factors and the Daily R^2 between NO_2 VCD and AOD.
- Both water vapor and temperature showed negative correlations.

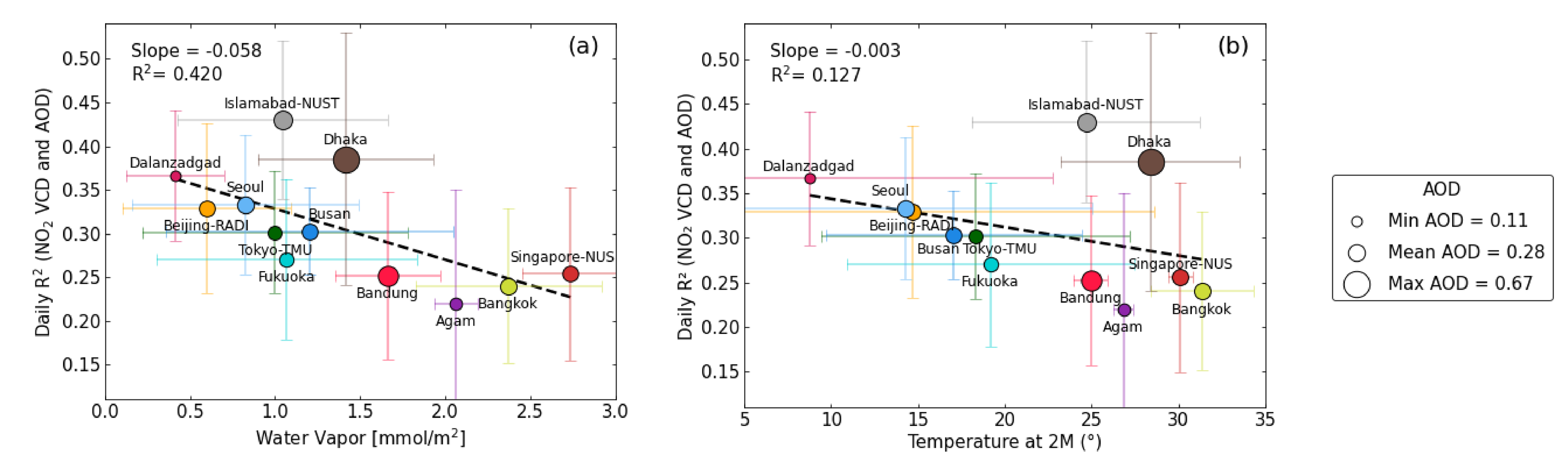

Fig 4. Monthly mean daily R^2 between NO_2 VCD and AOD across sites. (a) Relationship between monthly mean Daily R^2 and water vapor, and (b) relationship between monthly mean daily R^2 and temperature at 2m. Point size corresponds to the monthly mean AOD at 500 nm.

NO_2 VCD Impact on daily R^2 (NO_2 and AOD)

- By applying the correction for the effect of water vapor, the relationship between NO_2 VCD and the corrected daily R^2 between NO_2 VCD and AOD was analyzed.
- The result in Fig 5 suggests that high NO_2 column concentrations are strongly correlated with diurnal variations in AOD

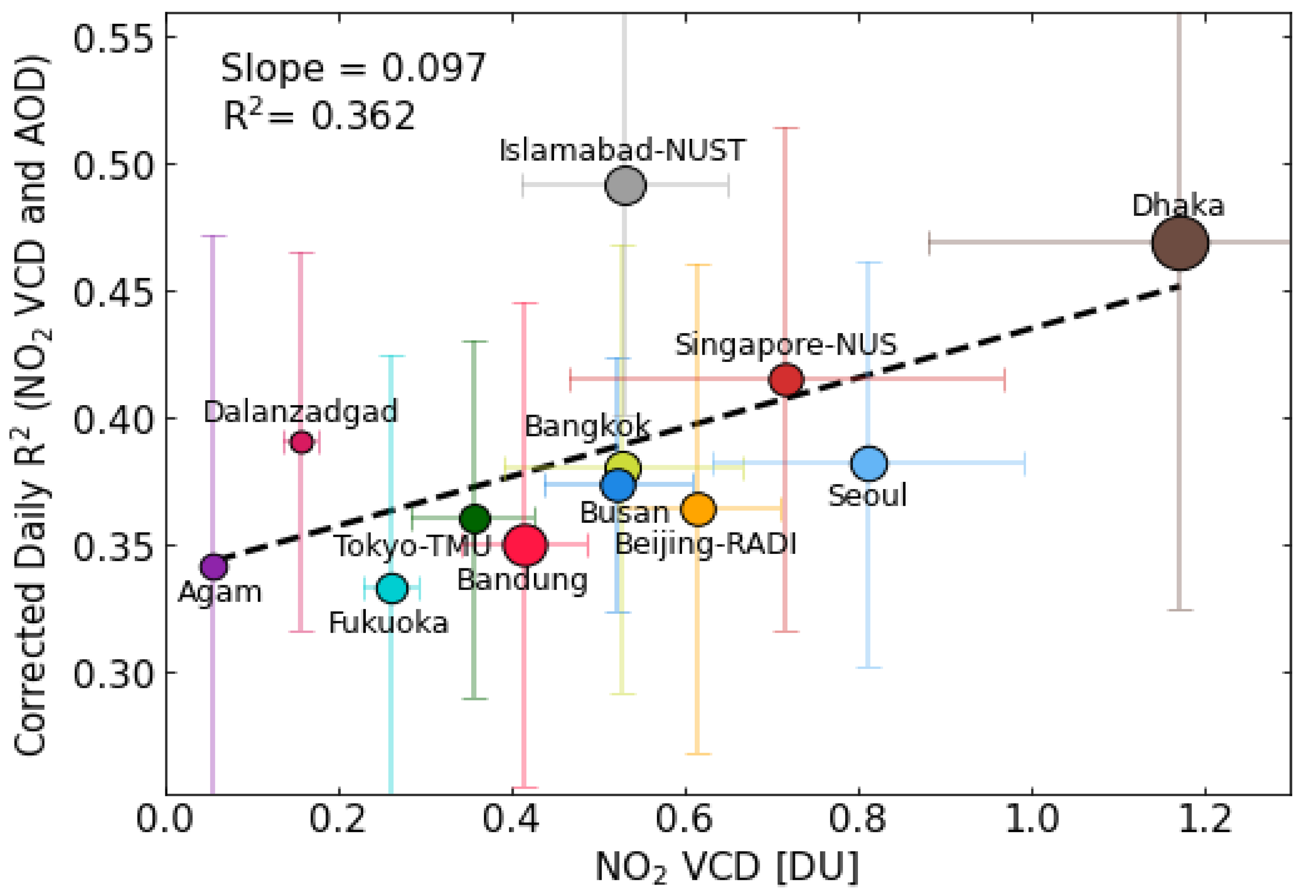

Fig 5. Relationship between NO_2 VCD and monthly mean corrected daily R^2 (adjusted for water vapor effects). point sizes are the same as in Fig 4.

Location	Main sources of pollutants
Dalanzadgad (Mongolia)	Desert dust
Beijing-RADI (China)	Industry, Transportation
Seoul (South Korea)	**Transportation**, Power plant
Busan (South Korea)	Industry, Transportation
Fukuoka (Japan)	Transportation
Tokyo-TMU (Japan)	Transportation
Islamabad-NUST (Pakistan)	**Industry**, Transportation
Dhaka (Bangladesh)	Industry, Transportation, **Resident**
Bangkok (Thailand)	Industry, Transportation, Power plant
Singapore-NUS (Singapore)	**Shipping**, Industry, Power plant
Agam (Indonesia)	Biomass burning, Biogenic
Bandung (Indonesia)	Transportation, Industry, Biomass burning

Table 1. Main sources of pollutants near each location. Dominant pollutant sources near the instrument are emphasized in red.

References

- Herman, J., A. using the direct-sun DOAS technique: Intercomparison Cede, E. Spinei, G. Mount, M. Tzortziou, and N. Abuhassan (2009), NO_2 column amounts from ground-based Pandora and MFDOAS spectrometers s and application to OMI validation, J. Geophys. Res., 114, D13307, doi:10.1029/2009JD011848.
- Jeong, U., Tsay, S.-C., Pantina, P., Butler, J. J., Loftus, A. M., Abuhassan, N., et al. (2018). Langley calibration analysis of solar spectroradiometric measurements: Spectral aerosol optical thickness retrievals. Journal of Geophysical Research: Atmospheres, 123, 4221–4238. https://doi.org/10.1002/2017JD028262
- Veefkind, J. P., Boersma, K. F., Wang, J., Kurosu, T. P., Krotkov, N., Chance, K., and Levelt, P. F.: Global satellite analysis of the relation between aerosols and short-lived trace gases, Atmos. Chem. Phys., 11, 1255–1267, doi:https://doi.org/10.5194/acp-11-1255-2011

Acknowledgments

- This work was supported by the National Institute of Environmental Research (NIER)