MAX-DOAS air quality observations at Phimai, Thailand, conducted in the framework of SKYNET

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SKYNET

- An observation network dedicated for aerosol-cloud-radiation interaction researches.
  (e.g., Takamura et al., 2004; Nakajima et al., 2007)

- Initiated under the WCRP/GAME project and expanded focusing on East Asia as ADEOS/GLI validation activity.

- A growing network linking more than 100 sites (as of 2015) all over the world. Still expanding with one main focus on satellite validations (GCOM-C, EarthCARE, GOSAT, GOSAT-2, Himawari-8, GEMS, ...).

In recent years, we are trying to enhance more the capability of SKYNET by adding the viewpoint of atmosphereic chemistry.

http://atmos2.cr.chiba-u.jp/skynet/
http://atmos.cr.chiba-u.ac.jp/
Air quality research under SKYNET

The idea to enhance the capability of SKYNET

SKYNET International network

Atmospheric chemistry

- trace gases (inorganic/organic)

Atmospheric physics

- aerosols
- clouds
- radiation

MAX-DOAS
(AOD, NO₂, SO₂, H₂O, O₃, HCHO, ...)

Sky radiometer
(AOD, SSA, COD, O₃, H₂O, ...)
Phimai site as part of growing network SKYNET
We introduced the MAX-DOAS system at Phimai on September 18, 2014.
Principle of MAX-DOAS observations

(Multi-AXis Differential Optical Absorption Spectroscopy)

- High sensitivity to trace gases in the boundary layer
- Long-term operation
- Easy to handle
- Inexpensive
- Low power consumption

UV/Vis. spectrum

Stratosphere

Troposphere

Instrument

~10-20 km

Elevation angle
MAX-DOAS instrument

- Outdoor unit (telescope, etc.)
- Indoor unit (spectrometer, etc.)

- Field of view < 1 deg
- Elevation angles = 2, 3, 4, 6, 8, 70 deg
- Maya2000Pro (Ocean Optics)
- FWHM: about 0.3 nm
- Wavelength: 310-520nm
- Temperature kept at 40°C
- Integ. time constant throughout the day
Retrieval algorithm development

- **DOAS method:** raw spectra → slant column density (extraction of conc. info.)
- **Radiative transfer model:** ray trace simulation for various conditions
  ※validated under an international framework [Wagner et al., 2007]
- **Inversion #1:** Retrieving a vertical profile of aerosols
- **Inversion #2:** Retrieving a vertical profile of NO₂

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First retrieval of tropospheric aerosol profiles using MAX-DOAS and comparison with lidar and sky radiometer measurements

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Abstract. Ground-based Multi-Axis Differential Optical Absorption Spectroscopy (MAX-DOAS) measurements were performed at Tsukuba, Japan (36.1°N, 140.1°E), in November–December 2006. By analyzing the measured spectra of scattered sunlight with DOAS and optimal estimation methods, we first retrieve the aerosol optical depth (τ) and the vertical profiles of the aerosol extinction coefficient (κ) at 476 nm in the lower troposphere. These retrieved quantities are characterized through comparisons with coincident lidar and sky radiometer measurements. The retrieved κ values for layers of 0–1 and 1–2 km agree with lidar data to within 30% and 60%, respectively, for most cases, including partly cloudy conditions. Results similar to κ at 0–1 km are obtained for the retrieved τ values, demonstrating that MAX-DOAS provides a new, unique aerosol dataset in the lower troposphere.

The measurements can be performed with a relatively simple setup and very low power consumption. The optical properties that are potentially measurable by MAX-DOAS include the aerosol optical depth (τ) as well as the vertical profile of the aerosol extinction coefficient (κ), while the well-established Sun photometer measurement technique can only retrieve optical properties of the total atmospheric column. The MAX-DOAS technique basically utilizes the differential absorption structures of the oxygen collision complex (O₂+O₂ or O₃) in the visible wavelength region to derive aerosol information. Because no absolute radiometric calibrations are generally needed, MAX-DOAS is suitable for conducting long-term automated measurements in a consistent manner, even at remote sites. In addition, MAX-DOAS measurements can yield significant information about several important trace gases, such as nitrogen dioxide (NO₂), formaldehyde, and glyoxal (e.g., Honninger et al., 2006).
Explored the potential for multi-component observations (Irie et al., 2011, 2015)

Aerosols at 357 & 476 nm
- NO\textsubscript{2}, SO\textsubscript{2}, O\textsubscript{3}, H\textsubscript{2}O
- HCHO, CHOCHO

Lower-tropospheric vertical profile information for 8 quantities:
- Aerosols
- NO\textsubscript{2}, SO\textsubscript{2}, O\textsubscript{3}, H\textsubscript{2}O
- HCHO, CHOCHO
Results: Diurnal variations (the first 3 days)

- Rapid diurnal variation in NO₂ and SO₂ VMRs.
  → can models reproduce these features as well as VMR levels?

- HCHO VMR is much larger than NO₂ VMR.
  → significant biogenic contributions
From the late wet season through the dry season, aerosols and NO$_2$, SO$_2$, and O$_3$ VMRs were enhanced.
Seasonal variations for VOCs

- HCHO and CHOCHO VMRs were also enhanced.
- $R_{GF}$ was at a moderate level of 0.03.
  $\rightarrow$ mixed contributions from BVOC and BB emissions

We hope that SKYNET will contribute to various ACAM activities through our unique observations.
**Summary**

- **SKYNET** is expanding, with one of main focuses on satellite validations (GCOM-C, EarthCARE, GOSAT-2, GEMS, ...).

- As an option for AQ study, we introduced the **MAX-DOAS** system at **SKYNET/Phimai** site in September 2014.

- We found that from the late wet season through the dry season, aerosols, NO$_2$, SO$_2$, O$_3$, HCHO, and CHOCHO VMRs were all enhanced.

- $R_{GF}$, defined as $[\text{CHOCHO}]/[\text{HCHO}]$, was at a moderate level of 0.03, suggesting mixed contributions from BVOC and BB emissions in the dry season.

- Including this unique observation at Phimai, **SKYNET** will provide very useful data for various **ACAM** activities, such as the evaluation of climate models.