Review of Air Quality Assessment with Ground and Satellite Monitoring

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Outline

• Introduction
• Aerosol and PM
  – Ground-based PM
  – Satellite-based AODs
  – PM 2.5 estimation from Satellite
• Gas Concentrations from Satellites
  – TROPOMI for Next Generation (2018-present)
  – GEMS
• SAR
• Summary
# NEACAP Target Pollutants

<table>
<thead>
<tr>
<th>Pollutant Type</th>
<th>Ground-based</th>
<th>Satellite</th>
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<td>PM2.5 and PM10</td>
<td>National data</td>
<td>GOCI, AHI, AMI, GEMS + ML (PM)</td>
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<tr>
<td>Black Carbon (BC)</td>
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<td>GOCI, AHI, AMI, GEMS (AOD) + ML (PM)</td>
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<td>Sulfur Oxides (SOx)</td>
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<td>GEMS TROPOMI</td>
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<tr>
<td>Nitrogen Oxides (NOx)</td>
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<td>GEMS TROPOMI</td>
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<tr>
<td>Volatile Organic Compounds (VOCs)</td>
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<td>GEMS (HCHO, CHOCHO) TROPOMI</td>
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<td>Ammonia (NH3)</td>
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<td>IASI</td>
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Aerosols and PM
<table>
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<tr>
<th>Network Name</th>
<th>Network Full-name</th>
<th>Instrument</th>
<th>Observation</th>
<th>Reference, (homepage)</th>
<th>GEMS Product</th>
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<tr>
<td>WOUDC</td>
<td>World Ozone and Ultraviolet Radiation Data Centre</td>
<td>Dobson spectrophotometer, Brewer spectrophotometer</td>
<td>TO$_3$, O$_3$ umkehr, TO$_3$, O$_3$ umkehr, AOD, SO$_2$ total column density, UV irradiance, UV index</td>
<td>Fioletov et al. (1999), (<a href="https://woudc.org">https://woudc.org</a>), Herman et al. (2009), (<a href="https://woudc.org">https://woudc.org</a>), Fioletov et al. (1999), (<a href="https://woudc.org">https://woudc.org</a>)</td>
<td>TO$_3$, O$_3$ profile, TO$_3$, SO$_2$, AOD, UV index</td>
<td>TO$_3$, SO$_2$, AOD, UV index</td>
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<tr>
<td>Pandora network</td>
<td>Pandora network</td>
<td>Pandora spectrometer</td>
<td>Total columns of O$_3$, NO$_2$, HCHO, their vertical profiles</td>
<td>Sugimoto and Uno (2009), (<a href="http://pandonia.net">http://pandonia.net</a>), Sugimoto and Uno (2009), (<a href="http://www.eanet.asia">http://www.eanet.asia</a>)</td>
<td>TO$_3$, NO$_2$, HCHO</td>
<td>SO$_2$, NO$_2$, Tropospheric O$_3$</td>
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<td>EANET</td>
<td>Acid Deposition Monitoring Network in East Asia</td>
<td>Wet and dry sampler</td>
<td>Wet deposition (sulfate), dry deposition (concentrations of SO$_2$, NO$_2$, and O$_3$)</td>
<td>Sugimoto and Uno (2009), (<a href="http://www.eanet.asia">http://www.eanet.asia</a>)</td>
<td>Tropospheric NO$_2$, AOD</td>
<td>Tropospheric NO$_2$, AOD</td>
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<td>KALION</td>
<td>Korea aerosol LIDAR observation network</td>
<td>LIDAR</td>
<td>Attenuated backscatter coefficient, aerosol extinction coefficient</td>
<td>Kim et al. (2015), (<a href="http://www.kalion.kr">http://www.kalion.kr</a>)</td>
<td>AOD, AEH</td>
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<tr>
<td>SPARTAN</td>
<td>Surface PARTICulate mAtter Network</td>
<td>Air Photon</td>
<td>Mass concentration; Chemical components (e.g. BC, SO$_2$, O$_3$, NO$_2$, NH$_4$)</td>
<td>Snider et al. (2015), (<a href="https://www.spartan-network.org/">https://www.spartan-network.org/</a>)</td>
<td>AOD, SSA, AI</td>
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<tr>
<td>Ceilometer network</td>
<td>Ceilometer network</td>
<td>Lidar</td>
<td>Cloud bottom height, cloud fraction</td>
<td>Münkel et al. (2010) (<a href="https://data.kma.go.kr/data/">https://data.kma.go.kr/data/</a>)</td>
<td>Cloud fraction</td>
<td></td>
</tr>
</tbody>
</table>

*Only available at AERONET observation times

Kim et al.(BAMS, revised)
Development of Satellite RS for Aerosols & Gases

Temporal Resolution

Spatial Resolution (km)

week
day
hr
min

0.1
1
10
100
1000

Purple : UV-Vis
Gray : single Vis
Yellow : Vis/NIR

Aerosol
Trace Gases
Red : IR
White : UV - IR

Italic & dashed line : to be launched

Kim et al.(revised, BAMS)

Kim et al. (2017) with update

0.40 - 0.02

0.48 - 0.03

0.54 - 0.04

0.34 - 0.03

0.27 - 0.02

0.26 - 0.02

0.28 - 0.02

0.37 - 0.02

0.39 - 0.02

0.20 - 0.01

0.21 - 0.02

0.21 - 0.01

0.21 - 0.01

0.37 - 0.02

0.37 - 0.02

0.30 - 0.02

0.25 - 0.02

0.20 - 0.01

0.21 - 0.01

0.21 - 0.01

0.21 - 0.01

0.33 - 0.02

0.37 - 0.02

0.37 - 0.02

0.37 - 0.02

0.37 - 0.02

0.37 - 0.02

0.37 - 0.02

0.37 - 0.02

0.37 - 0.02

0.37 - 0.02

0.37 - 0.02

Kim et al. (2017) with update
Estimated monthly mean PM$_{2.5}$ from AHI AOPs using Machine Learning
POLLUTANT GASES
\[ \text{NO}_2 \ & \ \text{SO}_2 \text{ from OMI} \]

(Long term Monitoring, 2005-2018)
OMI mean tropospheric NO$_2$ & SO$_2$ VCDs (2005–2018)

**NO$_2$**
- Mongolia
- Russia
- South Korea
- Japan
- Eastern China
- India
- Hong Kong

**SO$_2$**
- Norilsk, Russia
- Kuchinoerabujima volcano
- Anatahan Volcano
- Akatahan Volcano

![Map of NO$_2$ and SO$_2$ VCDs](image-url)
OMI mean tropospheric NO$_2$ VCDs & trends (2005–2018)

Mean: 20.137
Trend: -0.426
($10^{15}$ molecules/cm$^2$)

Mean: 3.417
Trend: +0.040
($10^{15}$ molecules/cm$^2$)

Mean: 16.914
Trend: -0.252
($10^{15}$ molecules/cm$^2$)

Mean: 9.476
Trend: -0.260
($10^{15}$ molecules/cm$^2$)

Mean: 13.454
Trend: -0.683
($10^{15}$ molecules/cm$^2$)

- All cities here but Pyongyang show decreasing trends of NO$_2$. 
OMI mean tropospheric NO$_2$ VCDs & trends (2005–2018): Russia and Mongolia

*Note that the color bar scale is 0 to 3. (It was 0 to 20 for previous slides.)
OMI mean tropospheric SO$_2$ VCDs & trends (2005–2018)

- **Jinan**
  - Mean: 16.664
  - Trend: -1.959
  - (10$^{15}$ molecules/cm$^2$)

- **Gaecheon**
  - Mean: 3.493
  - Trend: -0.289
  - (10$^{15}$ molecules/cm$^2$)

- **Hong Kong**
  - Mean: 1.677
  - Trend: -0.260
  - (10$^{15}$ molecules/cm$^2$)

- **Dangjin**
  - Mean: 3.818
  - Trend: -0.402
  - (10$^{15}$ molecules/cm$^2$)

- **Nabro volcano eruption (2011.06.13)**

- All four cities show decreasing trends of SO$_2$. 
OMI mean tropospheric SO₂ VCDs & trends (2005–2018): Russia and Mongolia

Mean: 53.134
Trend: -2.237
(10^{15} \text{ molecules/cm}^2)

*Note that the upper limit of the y-axis is 300, while it was 20 in previous slides.

- Tremendous amounts of SO₂ have been emitted from the Norilsk smelting facility (but showing a decreasing trend).
NO$_2$, SO$_2$, and CO from TROPOMI (2018-present)
Major cities and roads in Korea and Japan can be seen from the mean NO$_2$ map.
Oversampled TROPOMI tropospheric SO$_2$ and CO VCDs

May 2019

August 2018
AMI onboard GK-2A launched last week
GEMS onboard GK-2B launch in a year

OMI mean NO₂ (from 2005 to 2014) over GEMS FOR

Target species:
O₃,
aerosols,
NO₂
SO₂
HCHO

Launch schedule: Feb. 2020
Scientific Assessment Report

• The key goals of NEACAP:
  – to support information exchange and promote knowledge on the impact and trend of air pollution at the subregional level.

• This progress could be further strengthened with an open and institutionalized platform for interdisciplinary studies that supports
  – (a) building consensual knowledge among wider groups of experts, policy makers and other stakeholders, and
  – (b) serving as a key reference for policy and technical cooperation.

• Development of a scientific assessment report on the state, trend and impact of air pollution, as well as policy responses prepared by:
  – the analysis of the existing studies,
  – evaluation of monitoring and modelling data, and
  – policy review and formulation by multidisciplinary expert panels.
Data Sources

- Expanding networks of monitoring stations

- New generation of integrated air quality monitoring with the high density of particular matter (PM) monitoring sensors

- Satellites:
  - GEO Satellites:
    - Geostationary Ocean Color Imager (GOCI),
    - Advanced Meteorological Imager (AMI),
    - Advanced Himawari Imager (AHI)
  - LEO Satellites:
    - Moderate Resolution Imaging Spectroradiometer (MODIS)
    - Ozone Monitoring Instrument (OMI)
    - Visible Infrared Imaging Radiometer Suite (VIIRS)
    - TROPOspheric Monitoring Instrument (TROPOMI)

- Utilize satellite-derived data from GOCI, AMI, AHI, MODIS, VIIRS and TROPOMI
KORUS-AQ Daily Merged AOD product (0.5°×0.5° grid)

- Purpose: finding daily representative AOD from multiple LEO and GEO AOD products
- Study domain: 110-150°E, 20-50°N (0.5°×0.5° lon-lat grid resolution)
- Order of calculation
  1) Spatiotemporal mean for each product within each day
     - Spatial gridding for each scene, and temporal averaging for daily mean.
     - Additional filtering based on Hyer et al. (2011) to reduce cloud contamination
  2) For each grid, select median value AOD product as daily representative AOD
     (only when at least two products are available)
  3) Average of daily fused AOD during the Campaign period (5/1-6/12)
Data Sources

China:
1. Chinese Meterological Administration Atmosphere Watch Network (CAWNET)
2. A Global Community Building The First Open, Real-Time Air Quality Data Hub for the World (Open AQ) ([https://openaq.org](https://openaq.org))
3. The U.S. Department of State air quality (Stateair) – U.S. Embassy

DPRK:

Japan:
2. Atmospheric Environmental Regional Observation System

Mongolia:
1. The U.S. Department of State air quality (Stateair) - U.S. Embassy

ROK:
1. Airkorea ([https://www.airkorea.or.kr/](https://www.airkorea.or.kr/))
2. Seoul Research Institute of Public Health and Environment

Russia:
Summary

• The contents of Scientific Assessment Report include:
  – the impact and trend of air pollution at the subregional level
  – with an open and institutionalized platform
  – by the analysis of the existing studies, evaluation of monitoring and modelling data, and policy review and formulation by multidisciplinary expert panels.

• Data source include:
  – National ground-based monitoring results
  – Satellite dataset

• The report is to be prepared:
  – by lead authors and contributors
  – through the operation of the Working Group on Scientific Assessment Report (WGSAR)
  – with scoping and review meetings