UN ESCAP Expert Consultation Meeting of NEACAP, July 4, 2019

Review of Air Quality Assessment with Ground and Satellite Monitoring

Jhoon Kim

Yonsei University, Seoul, Korea

UNITED NATIONS ESCAP
Economic and Social Commission for Asia and the Pacific
EAST AND NORTH-EAST ASIA OFFICE

NEASPEC North-East Asian Subregional Programme for Environmental Cooperation

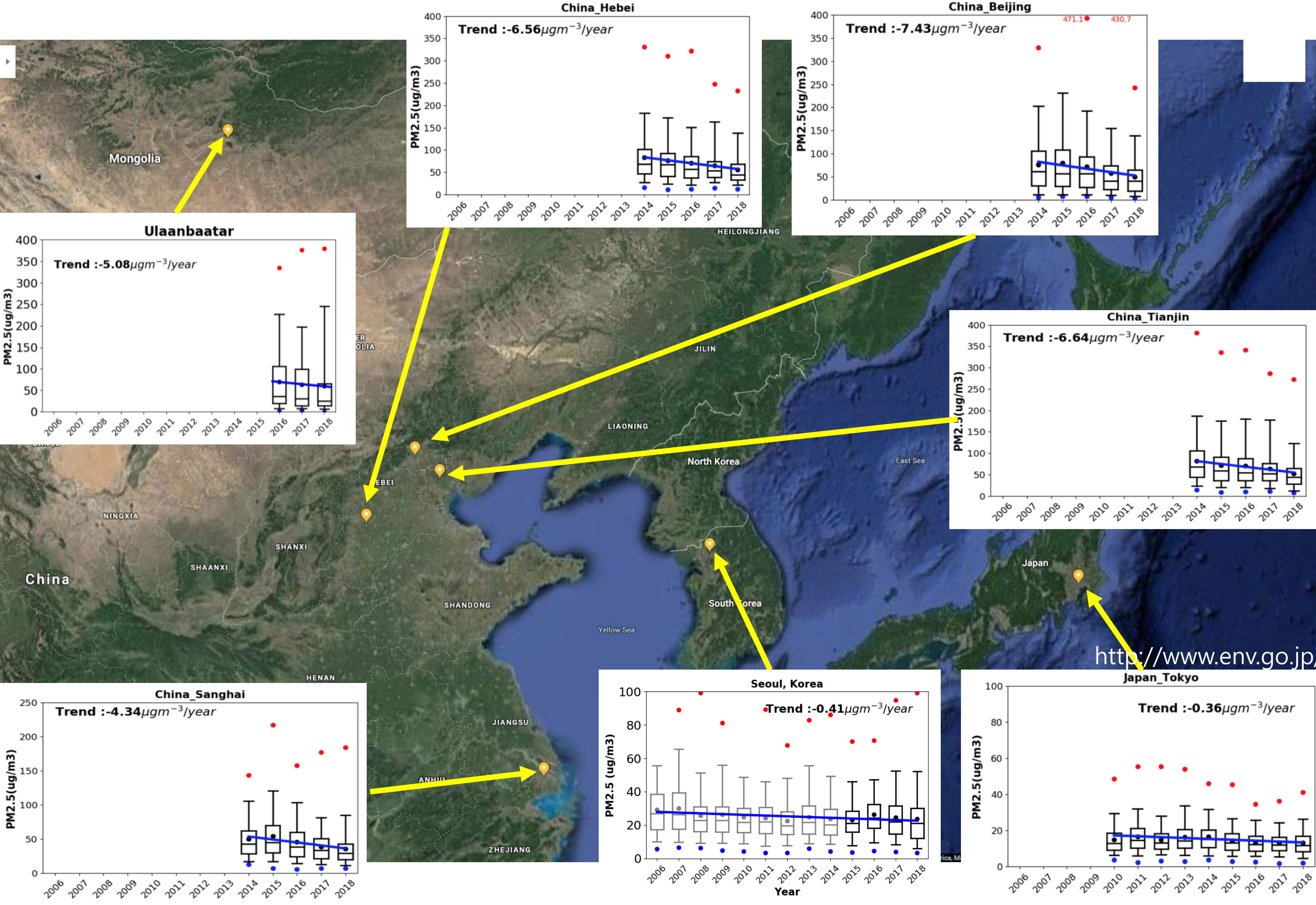
Outline

- Introduction
- Aerosol and PM
  - Ground-based PM
  - Satellite-based AODs
  - PM 2.5 estimation from Satellite
- Gas Concentrations from Satellites
  - OMI for Long-term (2005-2018)
  - TROPOMI for Next Generation (2018-present)
  - GEMS
- SAR
- Summary

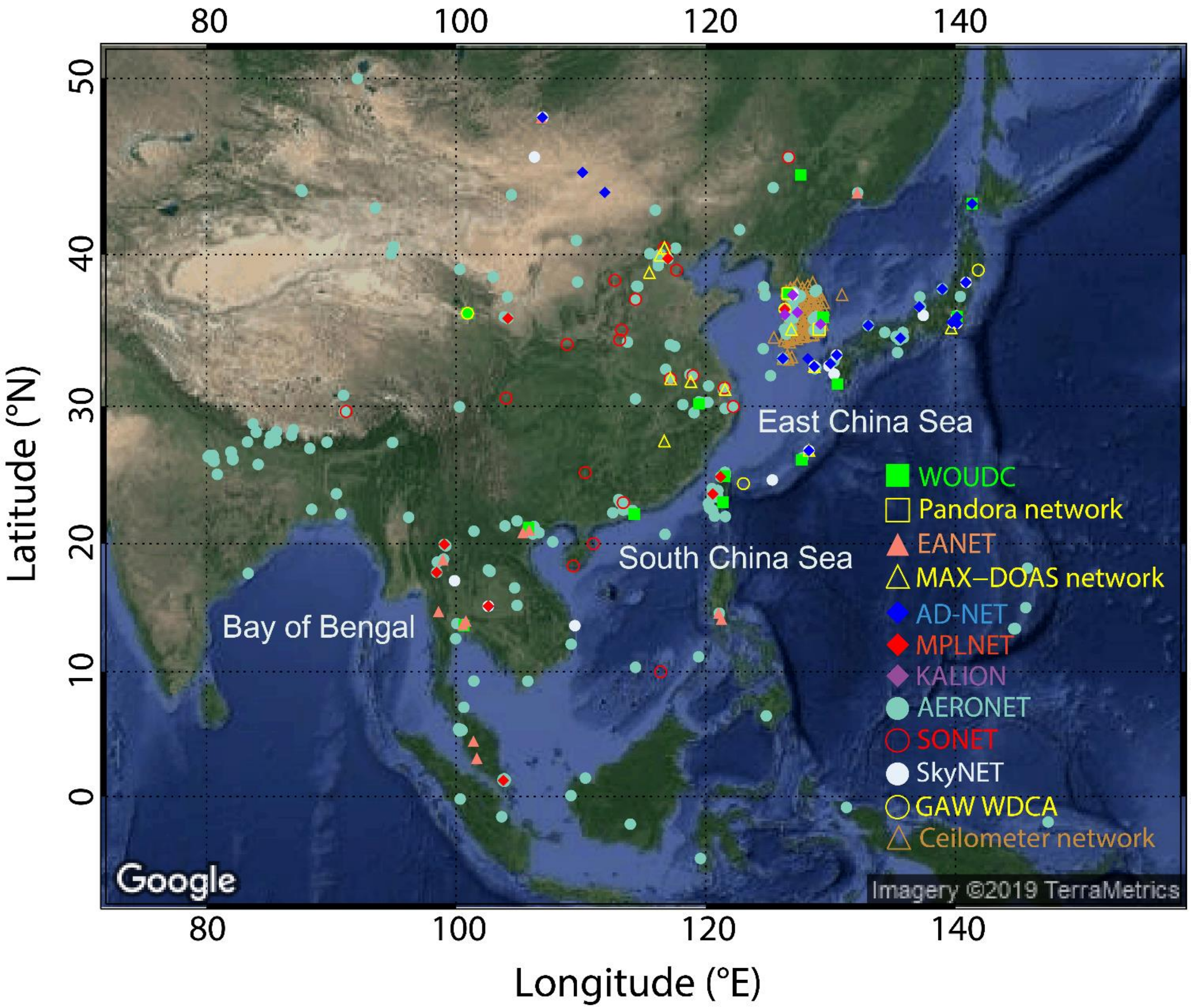
NEACAP Target Pollutants

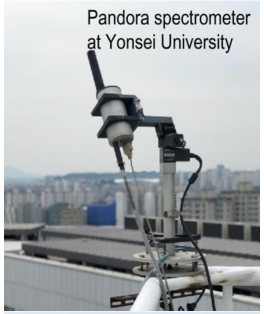
	Ground-based	Satellite
PM2.5 and PM10	National data	GOCI, AHI, AMI, GEMS + ML (PM)
Black Carbon (BC)		GOCI, AHI, AMI, GEMS (AOD) + ML (PM)
Sulfur Oxides (SOx)		GEMS TROPOMI
Nitrogen Oxides (NOx)		GEMS TROPOMI
Volatile Organic Compounds (VOCs)		GEMS (HCHO, CHOCHO) TROPOMI
Ammonia (NH3)		IASI

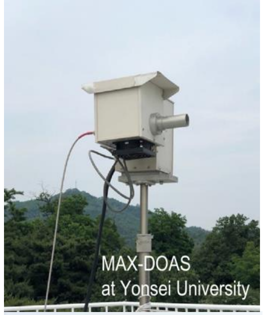
Aerosols and PM

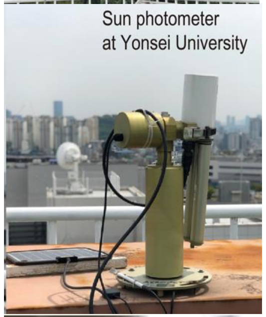

China_Hebei
Trend :-6.56$\mu gm^{-3}/year$
China_Beijing
Trend :-7.43$\mu gm^{-3}/year$
471.1
430.7
Ulaanbaatar
Trend :-5.08$\mu gm^{-3}/year$
China_Tianjin
Trend :-6.64$\mu gm^{-3}/year$
China_Sanghai
Trend :-4.34$\mu gm^{-3}/year$
Seoul, Korea
Trend :-0.41$\mu gm^{-3}/year$
Japan_Tokyo
Trend :-0.36$\mu gm^{-3}/year$
PM2.5(ug/m3)
PM2.5 (ug/m3)
Year
Mongolia
China
North Korea
South Korea
Japan
HEILONGJIANG
JILIN
LIAONING
NINGXIA
SHANXI
SHAANXI
SHANDONG
HENAN
JIANGSU
ANHUI
ZHEJIANG
Yellow Sea
East Sea
http://www.env.go.jp/

AQ Monitoring Network









Kim et al.(BAMS, revised)

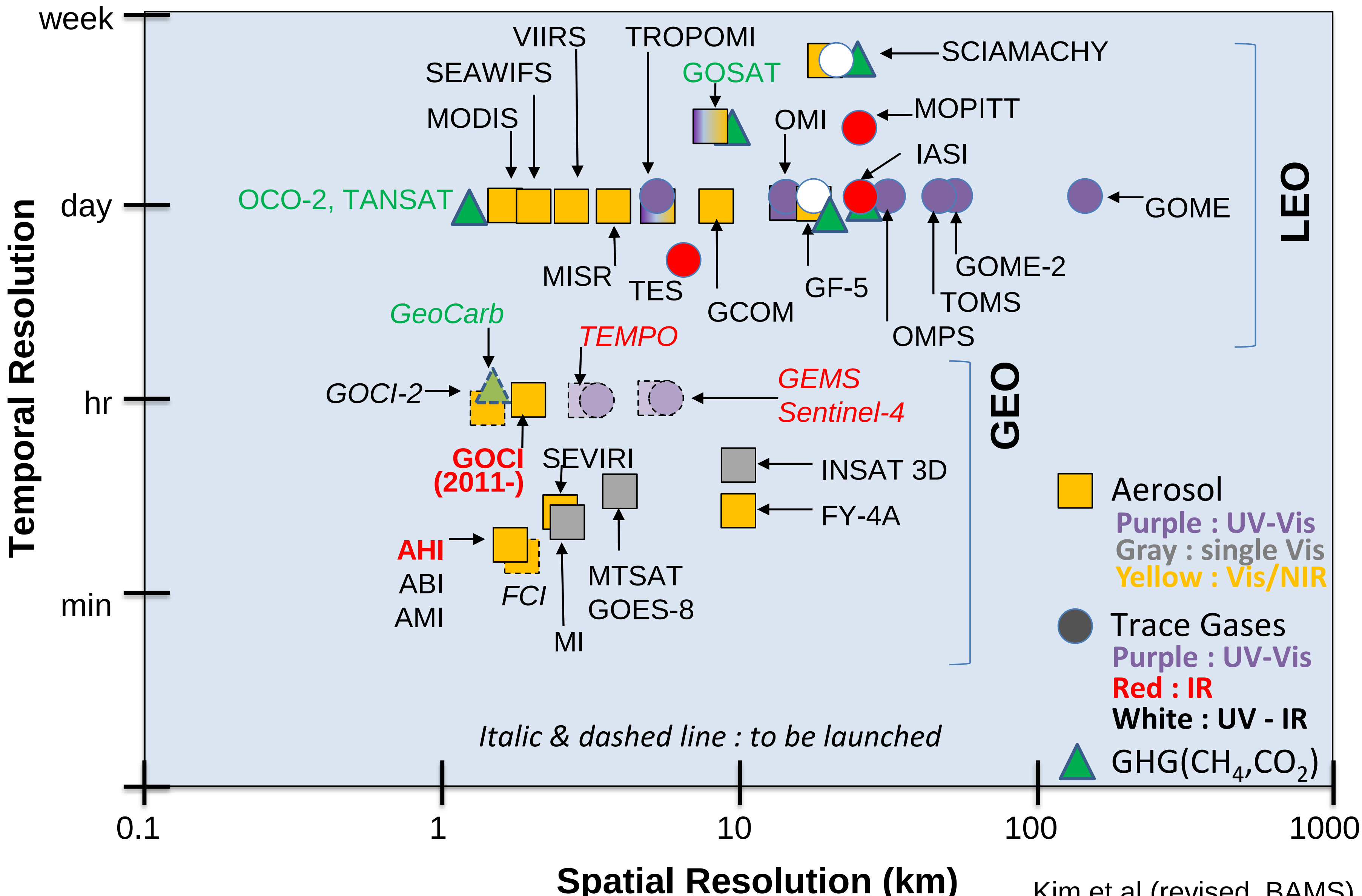
Ground-based Monitoring Network

Network Name	Network Full-name	Instrument	Observation	Reference, (homepage)	GEMS Product	Remark
WOUDC	World Ozone and Ultraviolet Radiation Data Centre	Dobson spectrophotometer	TO_3, O_3 umkehr	Fioletov et al. (1999), (https://woudc.org)	TO_3, O_3 profile	
		Brewer spectrophotometer	TO_3, O_3 umkehr, AOD, SO_2 total column density, UV irradiance, UV index		TO_3, SO_2, AOD, UV index	
Pandora network	Pandora network	Pandora spectrometer	Total columns of O_3, NO_2, HCHO, their vertical profiles	Herman et al. (2009), (https://pandora.gsfc.nasa.gov, http://pandonia.net)	TO_3, NO_2, HCHO	
EANET	Acid Deposition Monitoring Network in East Asia	Wet and dry sampler	Wet deposition (sulfate), dry deposition (concentrations of SO_2, NO_2, and O_3)	Sugimoto and Uno (2009), (http://www.eanet.asia)	SO_2, NO_2, Tropospheric O_3	
MAX-DOAS network	Multi-Axis Differential Optical Absorption Spectroscopy network	MAX-DOAS	Tropospheric NO_2, AOD	Kanaya et al. (2014) (https://ebcrpa.jamstec.go.jp/maxdoashp)	Tropospheric NO_2, AOD	
AD-NET	Asian dust and aerosol LIDAR observation network	LIDAR	Extinction coefficients of attenuated backscatter, aerosol, dust, spherical particle	Sugimoto and Uno (2001), (http://www-lidar.nies.go.jp/AD-Net)	AOD, AEH	
KALION	Korea aerosol LIDAR observation network		Attenuated backscatter coefficient, aerosol extinction coefficient	Kim et al. (2015), (http://www.kalion.kr)		
MPLNET	NASA Micro-Pulse LIDAR Network		Cloud heights, thin cloud extinction optical depths, cloud phase, aerosol height*, aerosol depolarization ratio profiles*	Welton et al. (2001) (https://mplnet.gsfc.nasa.gov)		
AERONET	Aerosol Robotic Network	Sun photometer	Size distribution, refractive index, phase functions, water vapor, Angstrom exponent, fine mode fraction, AOD, SSA	Holben et al. (1998), (https://aeronet.gsfc.nasa.gov)	AOD, SSA	
SONET	Sun–sky Radiometer Observation Network	Sun photometer		Li et al. (2018), (https://aeronet.gsfc.nasa.gov)		
SKYNET	Sky radiometer network	Sky radiometer	AOD, SSA	Takamura (2004), (https://www.skynet-isdc.org)		
SPARTAN	Surface PARTiculate mAtter Network	Air Photon	Mass concentration; Chemical components (e.g. BC, SO_4^{2-}, NO_3^-, NH_4^+)	Snider et al. (2015), (https://www.spartan-network.org/)	AOD, SSA, AI,	
GAW WDCA	Global Atmosphere Watch World Data Centre for Aerosols	Aerosol sampler	Aerosol particle number concentration, size distribution, light scattering coefficient, AOD	WMO/GAW report No. 153 (2003), (https://www.gaw-wdca.org)	AOD	
Ceilometer network	Ceilometer network	Lidar	Cloud bottom height, cloud fraction	Münkel et al. (2010) (https://data.kma.go.kr/data/)	Cloud fraction	

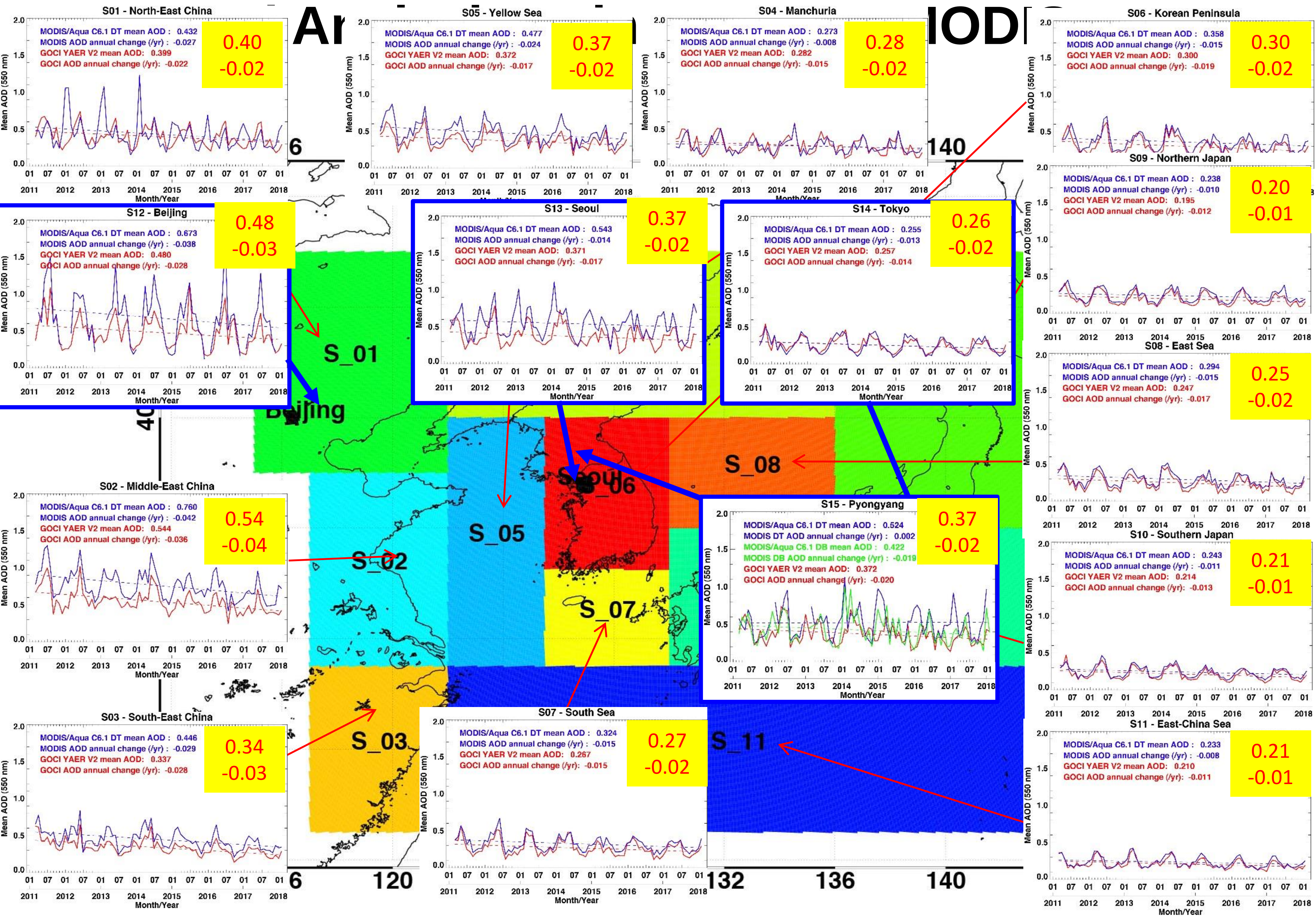
*Only available at AERONET observation times

Kim et al.(BAMS, revised)

Development of Satellite RS for Aerosols & Gases

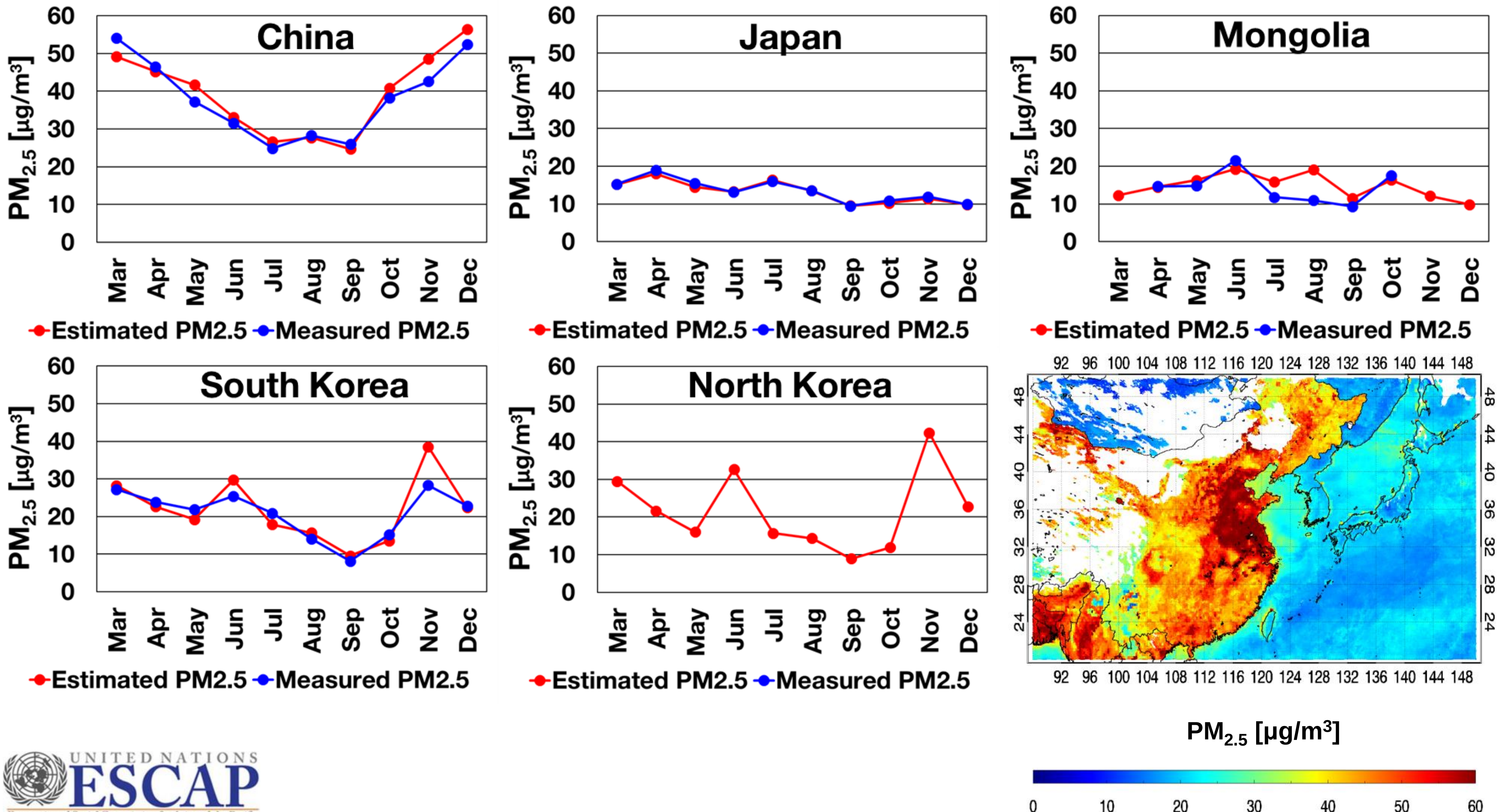


Kim et al.(revised, BAMS)



Kim et al. (2017) with update

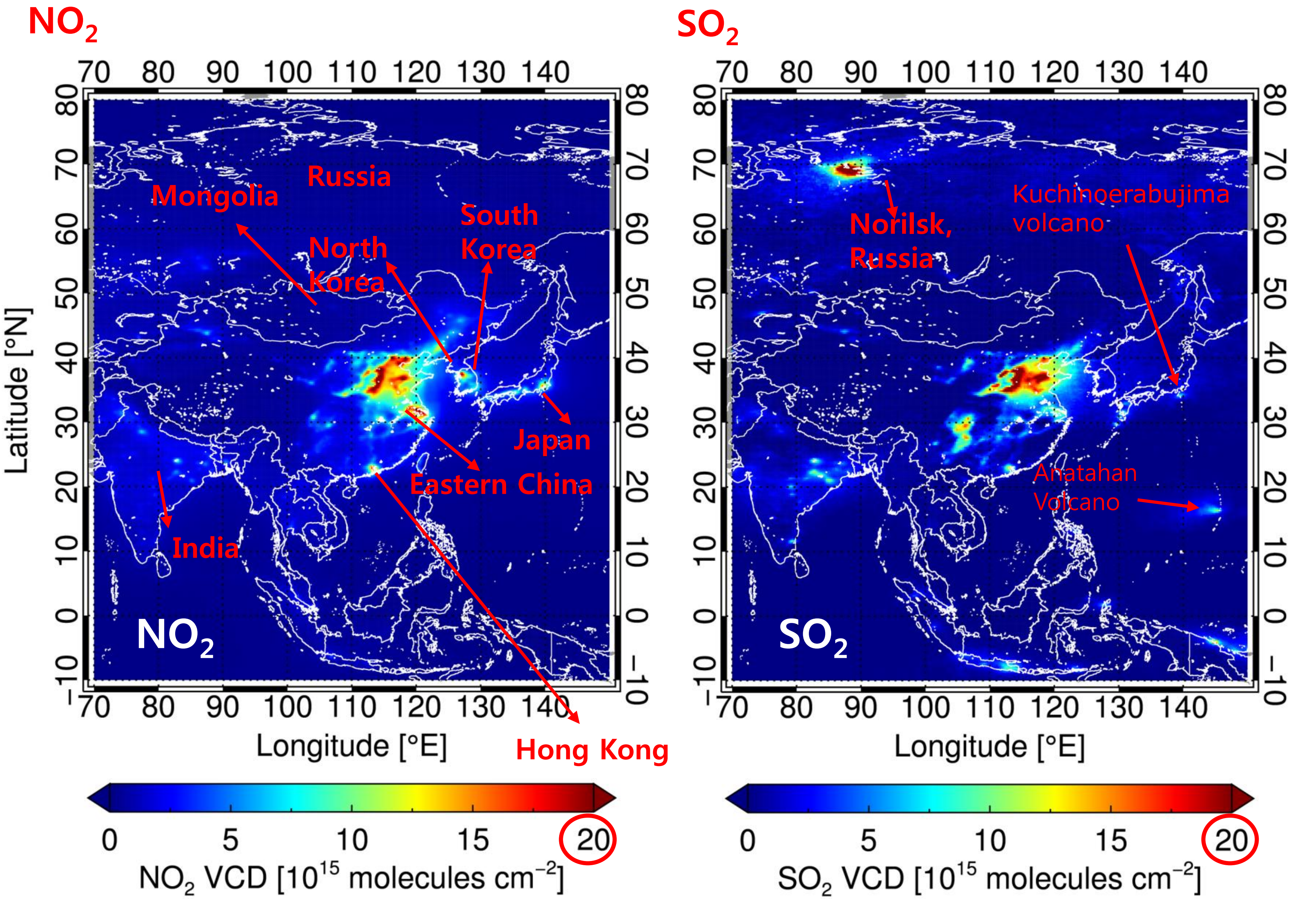
Estimated monthly mean $PM_{2.5}$ from AHI AOPs using Machine Learning



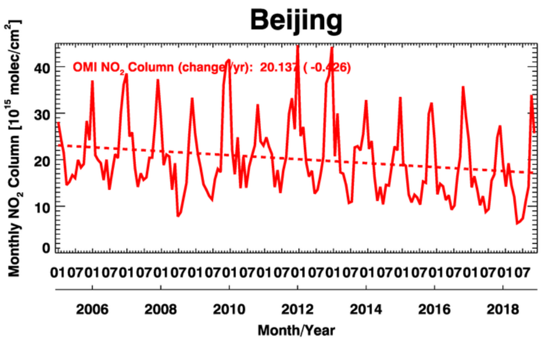
POLLUTANT GASES

NO_2 & SO_2 from OMI
(Long term Monitoring, 2005-2018)

OMI mean tropospheric NO_2 & SO_2 VCDs (2005–2018)

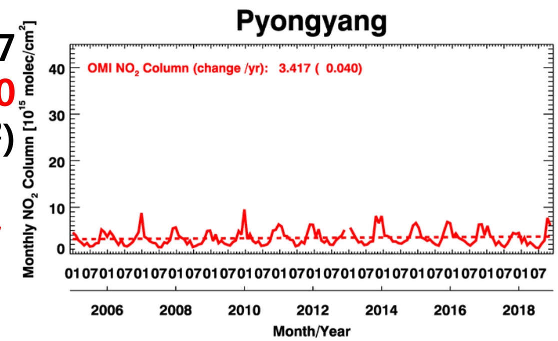


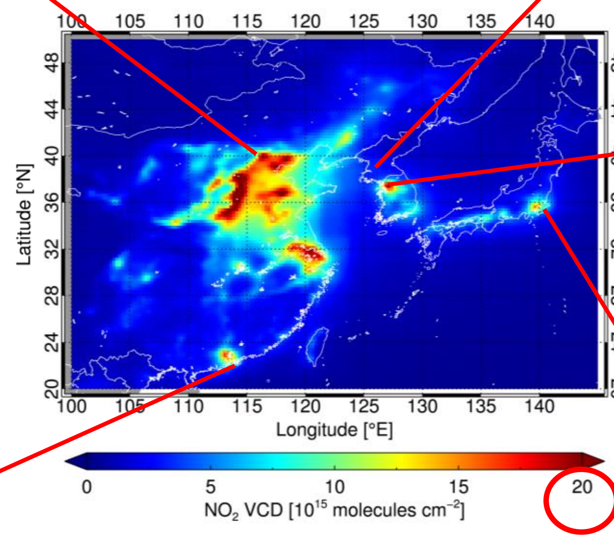
OMI mean tropospheric NO_2 VCDs & trends (2005–2018)

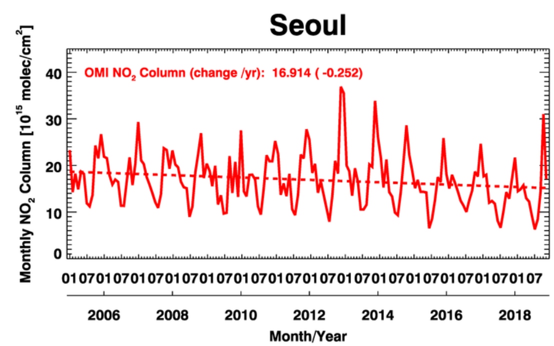


Mean: 20.137
Trend: -0.426
(10^{15} molecules/cm^2)

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

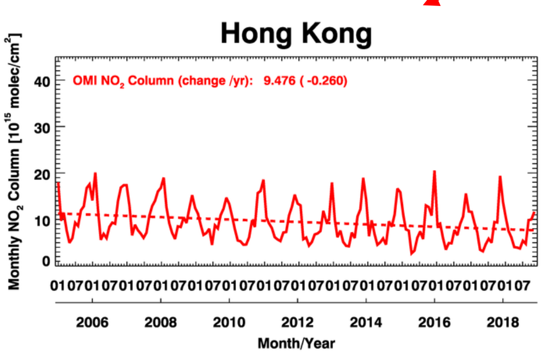




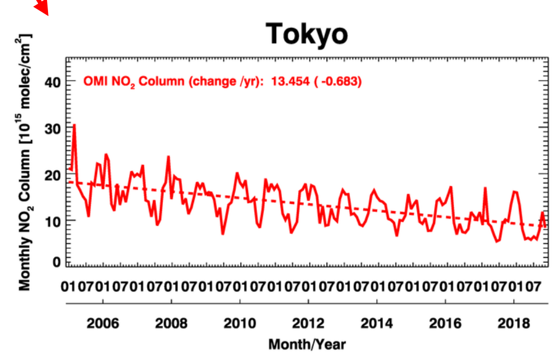


Mean: 16.914
Trend: -0.252
(10^{15} molecules/cm^2)

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

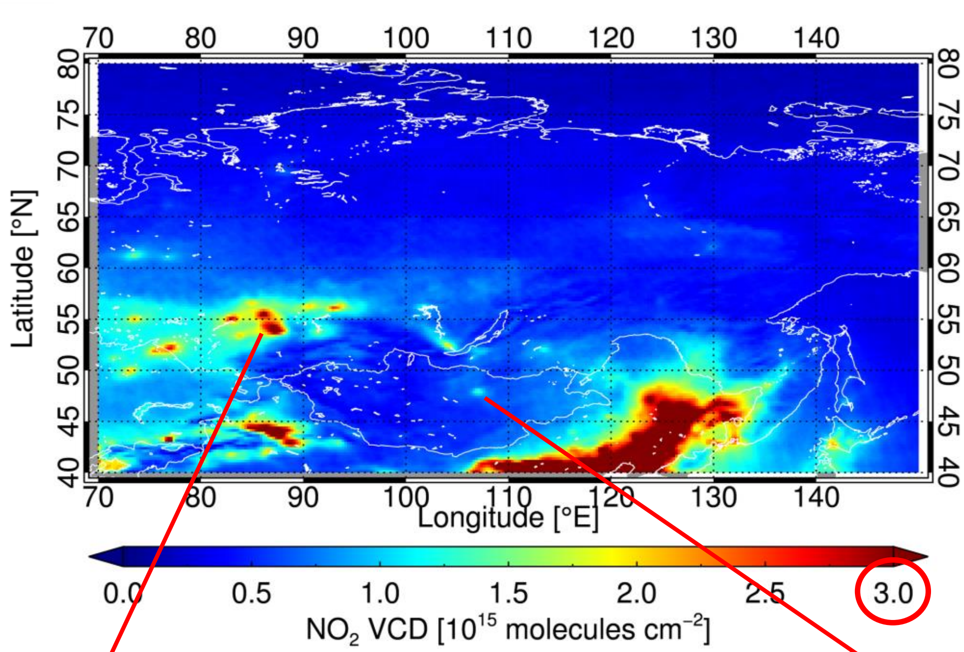


Mean: 13.454
Trend: -0.683
(10^{15} molecules/cm^2)

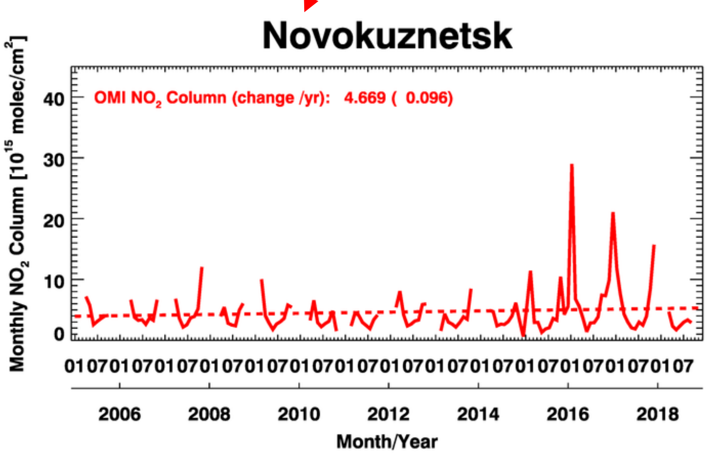


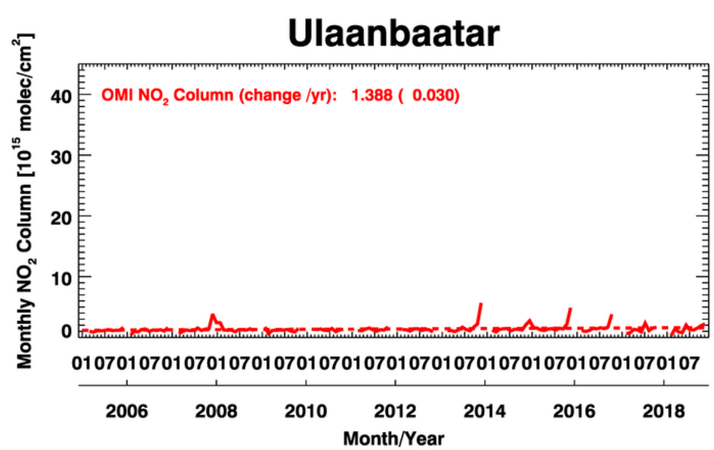
- All cities here but Pyongyang show decreasing trends of NO_2.

OMI mean tropospheric NO_2 VCDs & trends (2005–2018): Russia and Mongolia

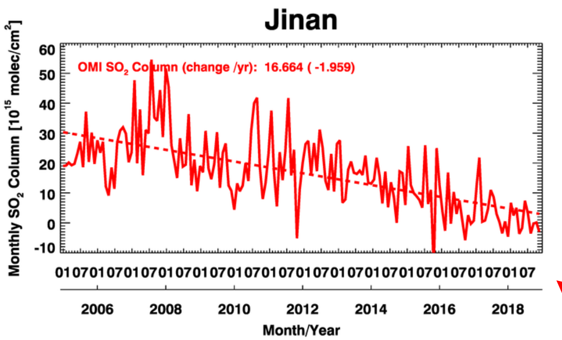


*Note that the color bar scale is 0 to 3.
(It was 0 to 20 for previous slides.)

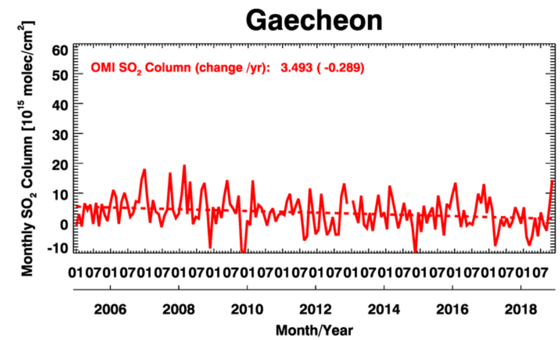




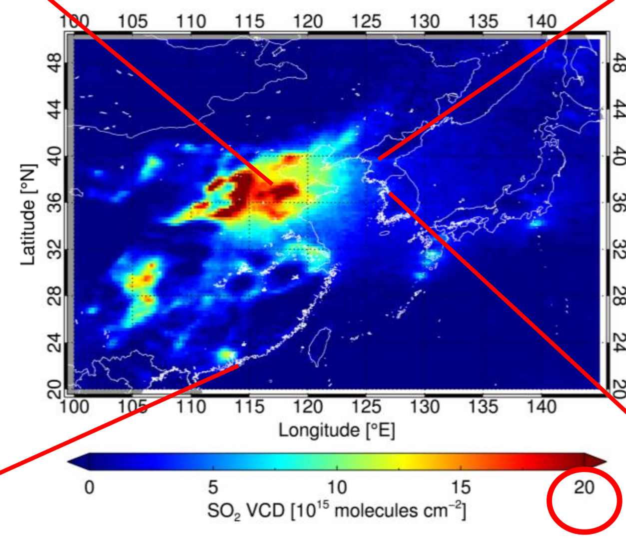
OMI mean tropospheric SO_2 VCDs & trends (2005–2018)



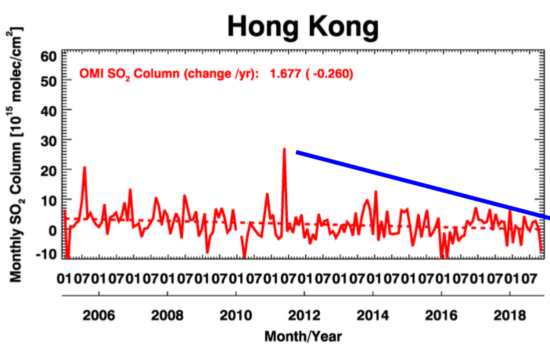
Mean: 16.664
Trend: -1.959
(10^{15} molecules/cm^2)

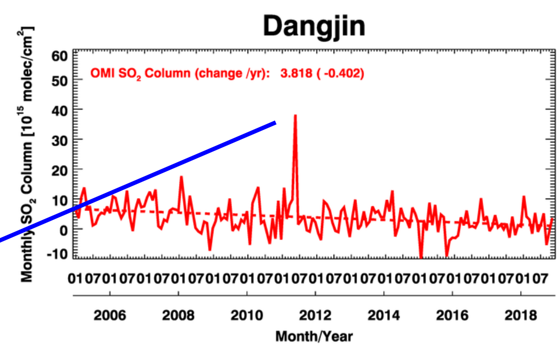


Mean: 3.493
Trend: -0.289
(10^{15} molecules/cm^2)



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



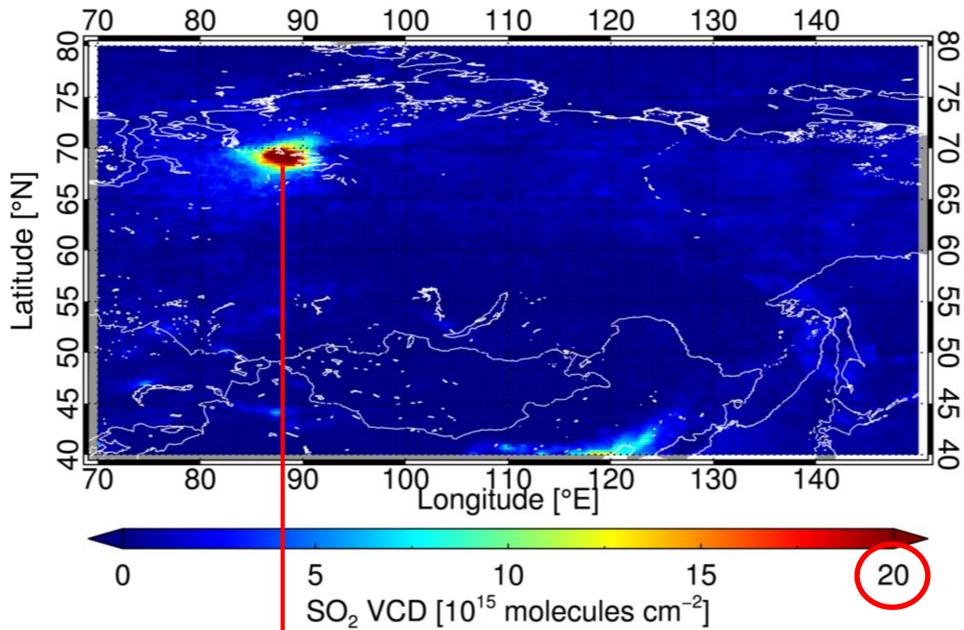


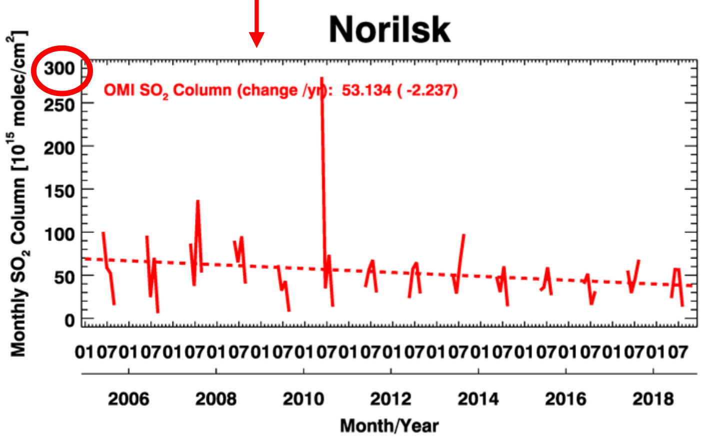
Nabro volcano eruption (2011.06.13)

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

- All four cities show decreasing trends of SO_2.

OMI mean tropospheric SO_2 VCDs & trends (2005–2018): Russia and Mongolia





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

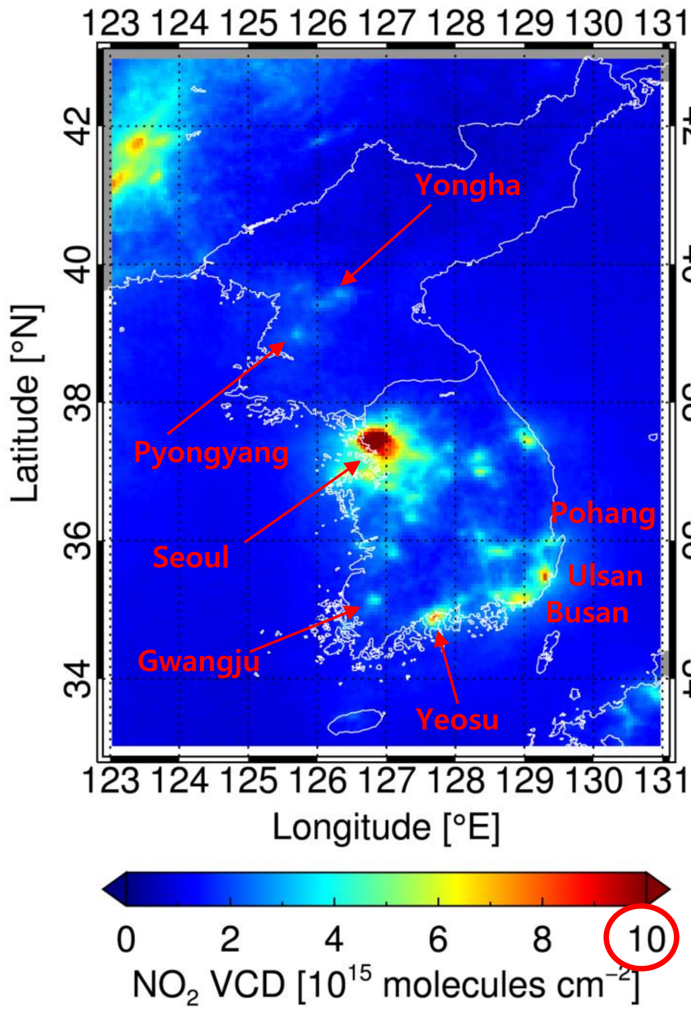
*Note that the upper limit of the y-axis is 300, while it was 20 in previous slides.

- Tremendous amounts of SO_2 have been emitted from the Norilsk smelting facility (but showing a decreasing trend).

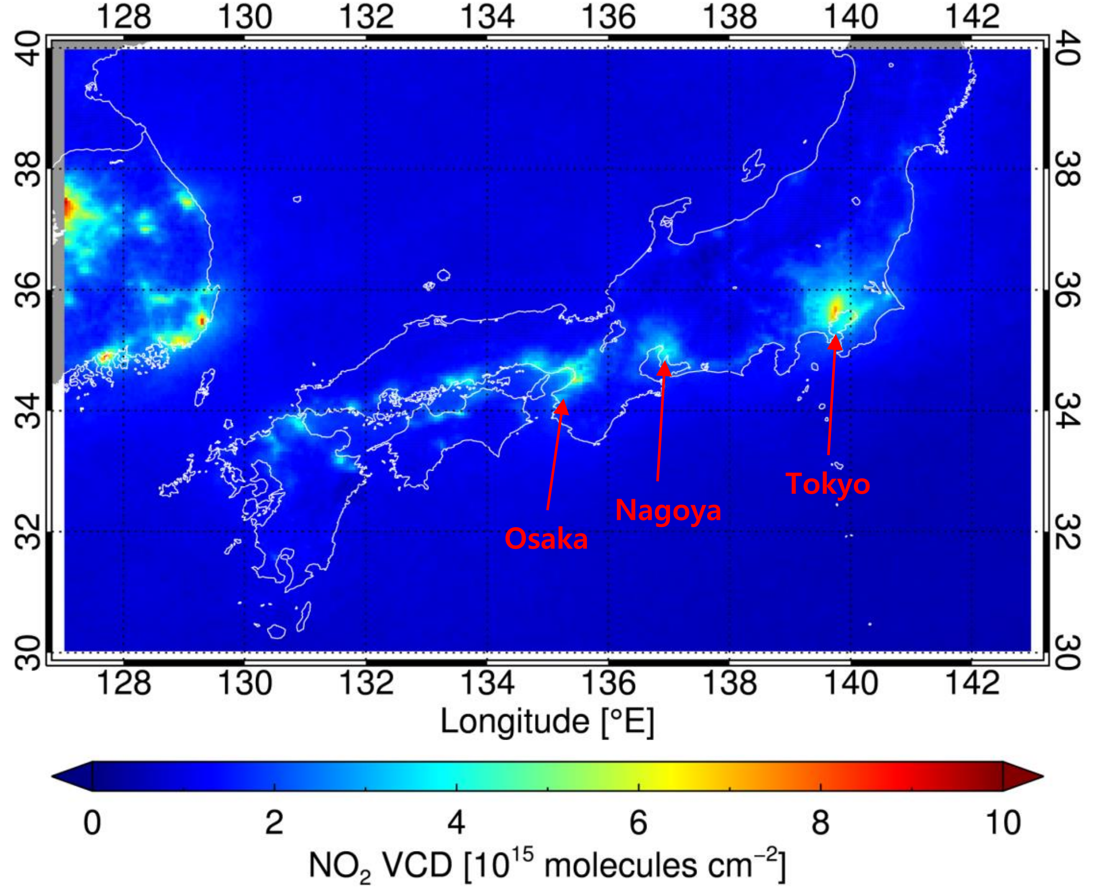
NO_2, SO_2, and CO from TROPOMI
(2018-present)

Oversampled TROPOMI tropospheric NO_2 VCDs in August 2018

South and North Korea

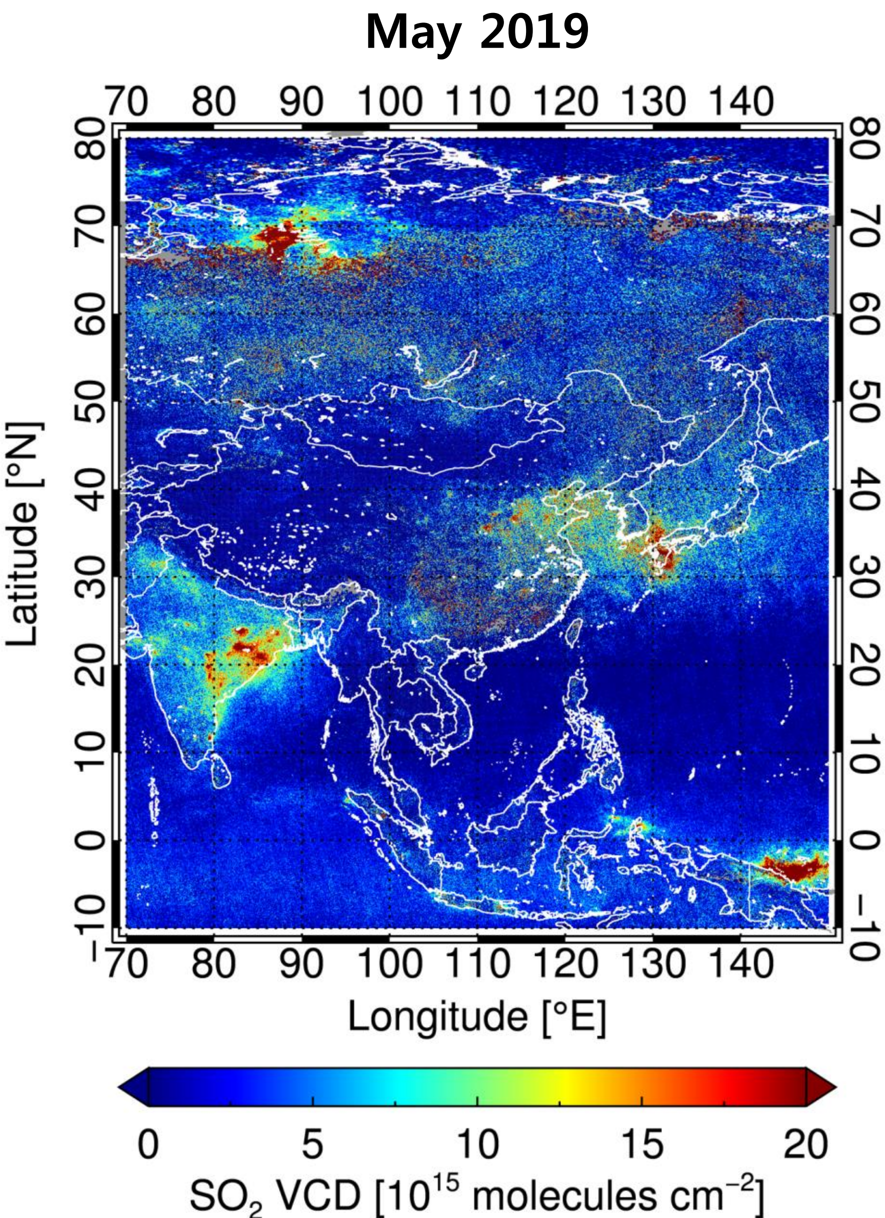


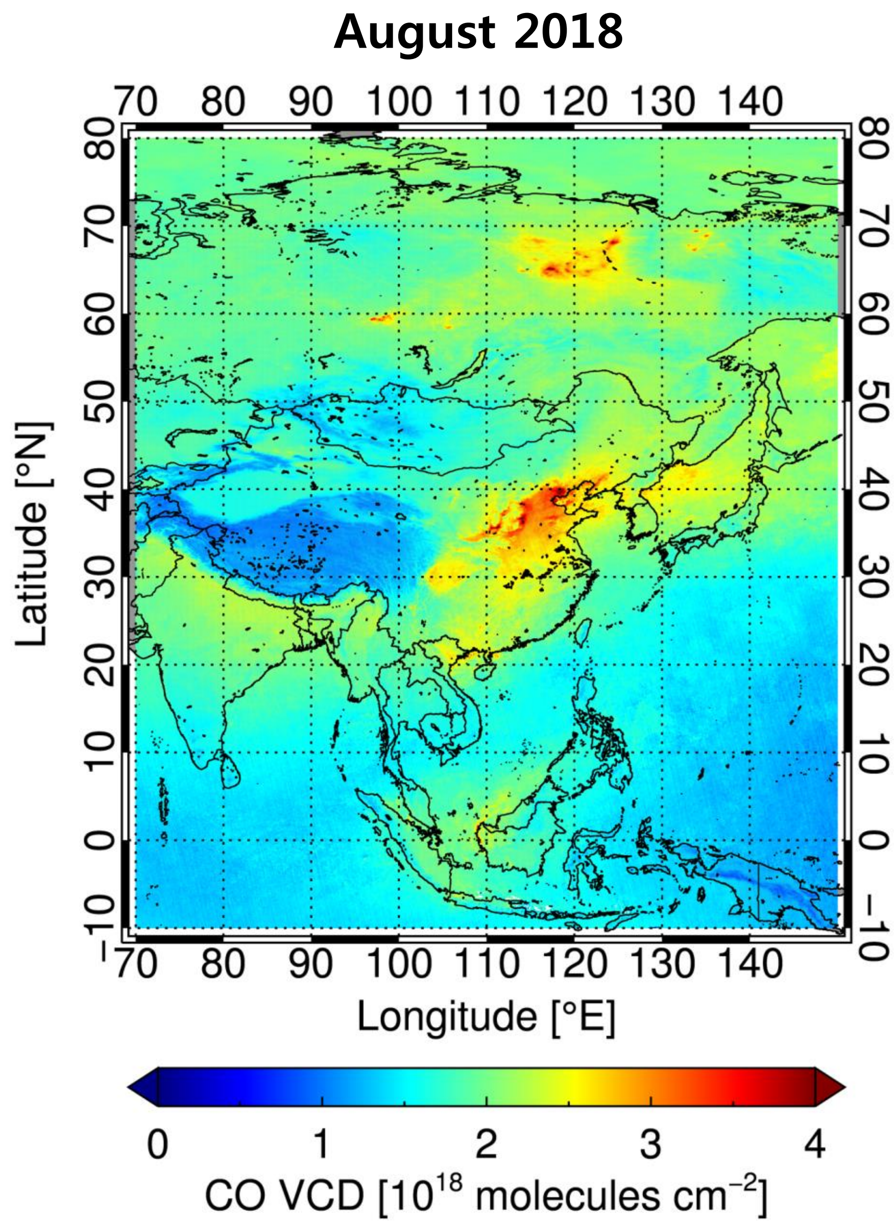
Japan



- Major cities and roads in Korea and Japan can be seen from the mean NO_2 map.

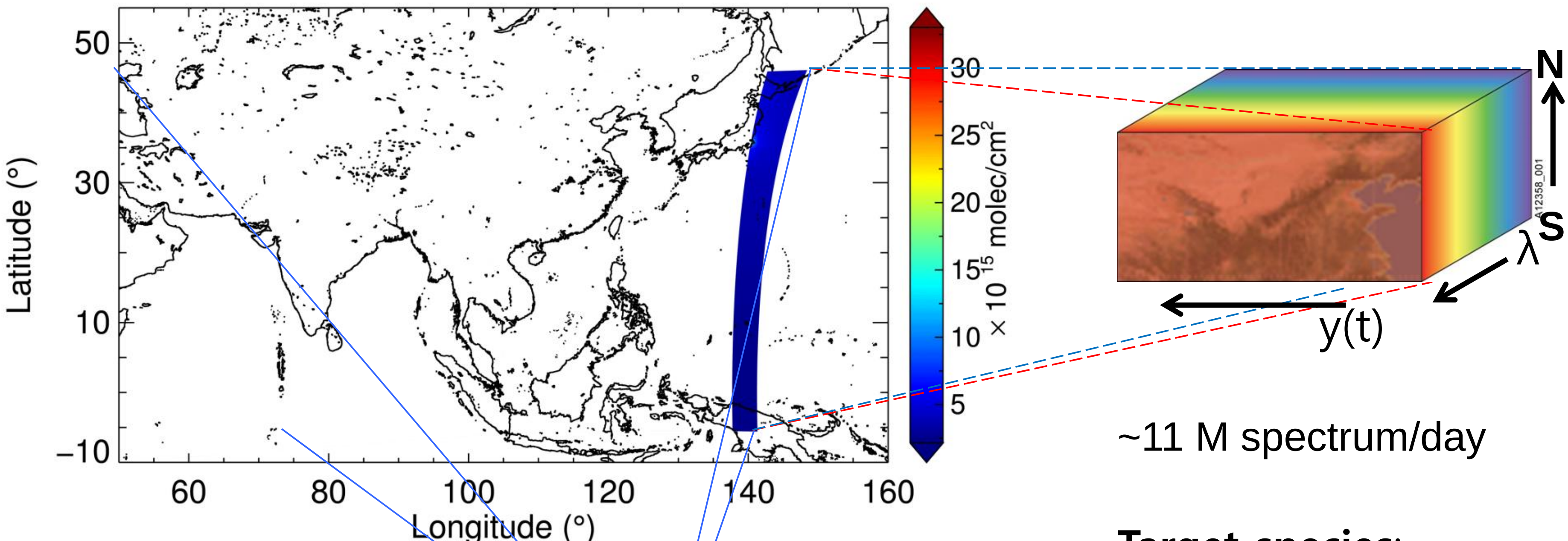
Oversampled TROPOMI tropospheric SO_2 and CO VCDs





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

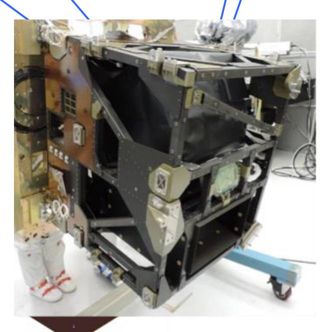
OMI mean NO_2 (from 2005 to 2014) over GEMS FOR



~11 M spectrum/day

<u>**Target species**</u>:

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.

(Discussion paper)

Data Sources

- Expanding networks of monitoring stations

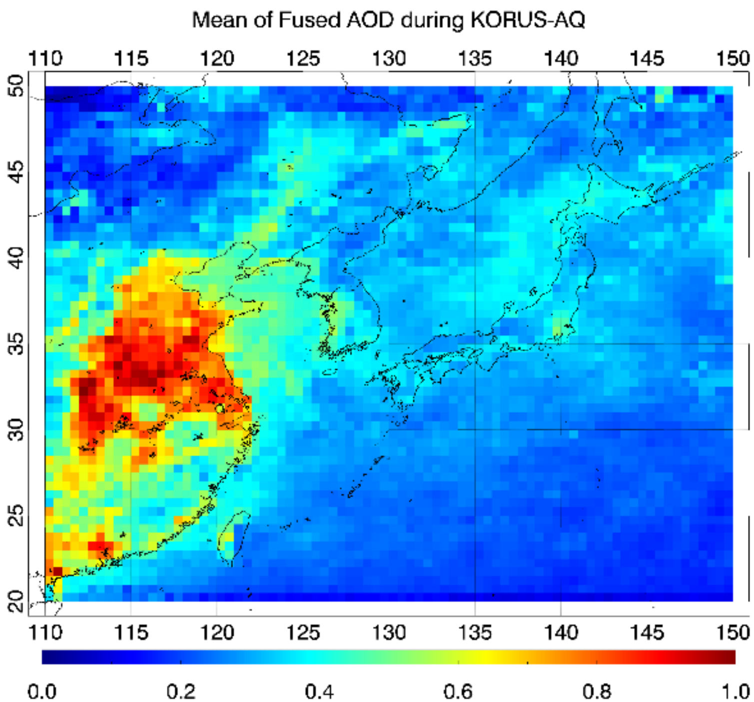
- New generation of integrated air quality monitoring with the high density of particular matter (PM) monitoring sensors

- 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

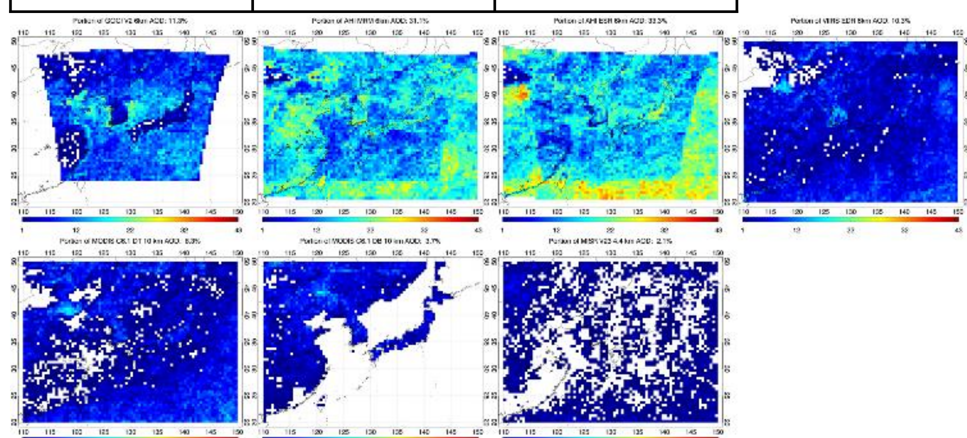
KORUS-AQ Daily Merged AOD product (0.5°×0.5° grid)

- 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)



Portion for Fused AOD

GOCI	AHI MRM	AHI ESR	VIIRS EDR
11.3%	31.1%	33.3%	10.3%
MODIS DT	MODIS DB	MISR	
8.3%	3.7%	2.1%	



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)
3. The U.S. Department of State air quality (Stateair) – U.S. Embassy

DPRK :

Japan :

1. Ministry of the Environment (http://www.env.go.jp/)
2. Atmospheric Environmental Regional Observation System

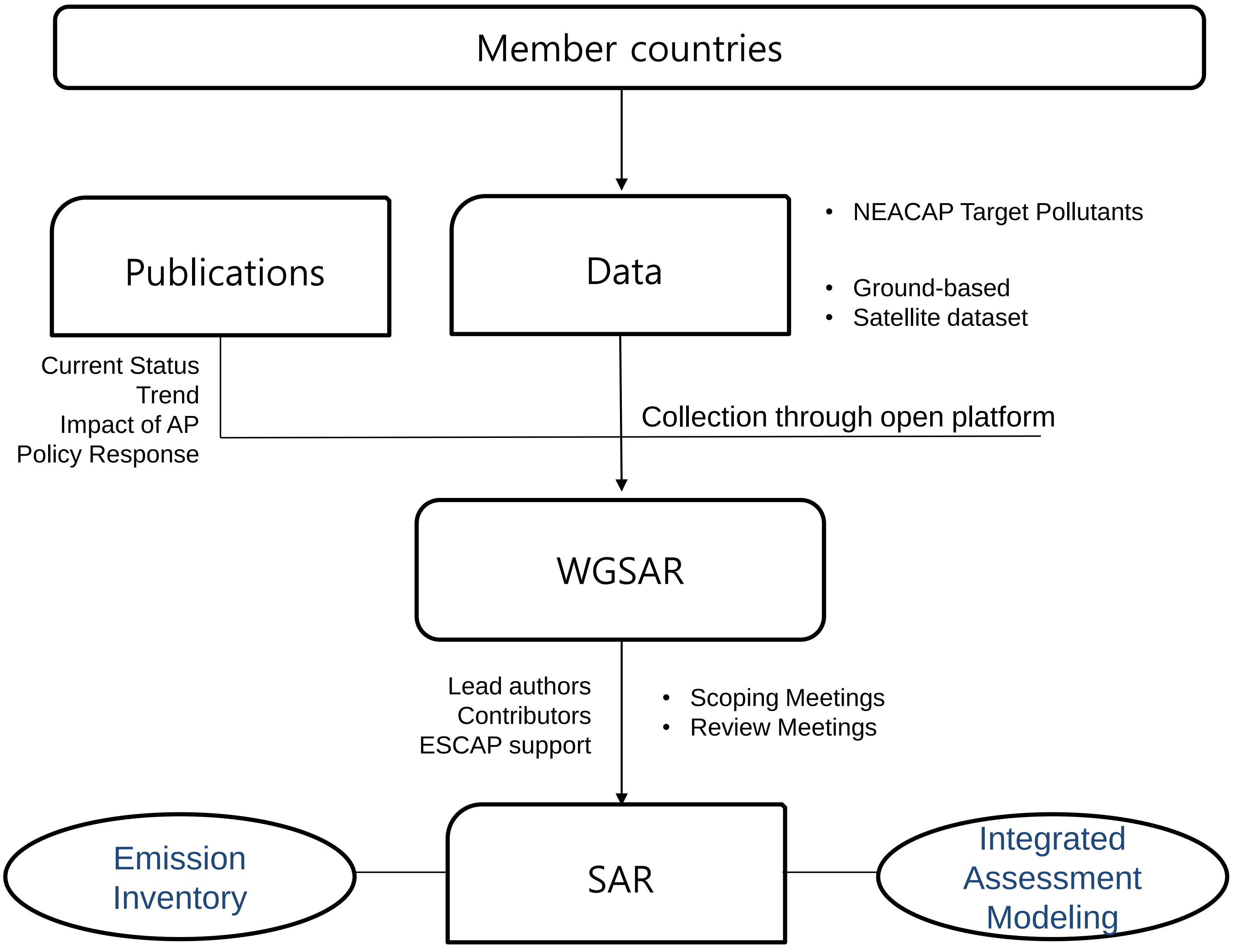
Mongolia:

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

ROK :

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

Russia :


Member countries
Publications
Data
• NEACAP Target Pollutants
• Ground-based
• Satellite dataset
Current Status
Trend
Impact of AP
Policy Response
Collection through open platform
WGSAR
Lead authors
Contributors
ESCAP support
• Scoping Meetings
• Review Meetings
Emission Inventory
SAR
Integrated Assessment Modeling

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