

National Aeronautics and Space Administration



Accessing and Analyzing Air Quality Data from Geostationary Satellites

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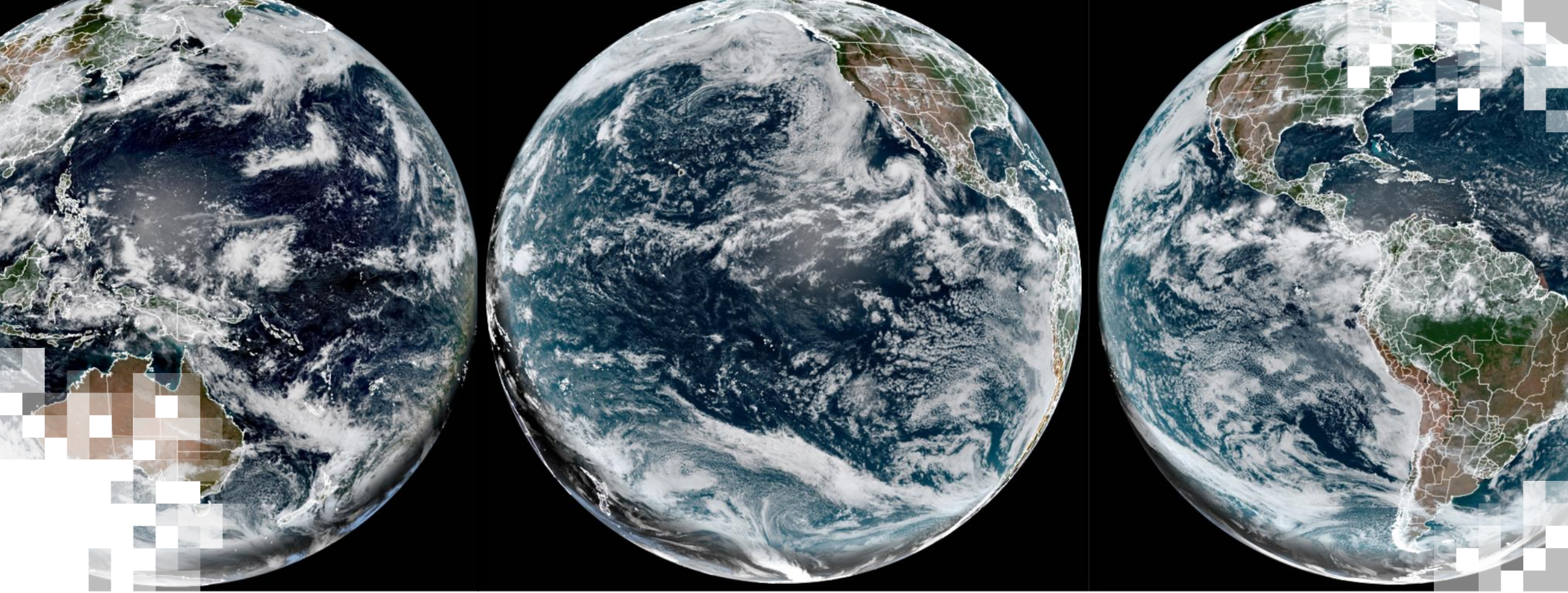
Air Quality Products from GEMS – October 25, 2022

Learning Objectives

By the end of this session, participants will:

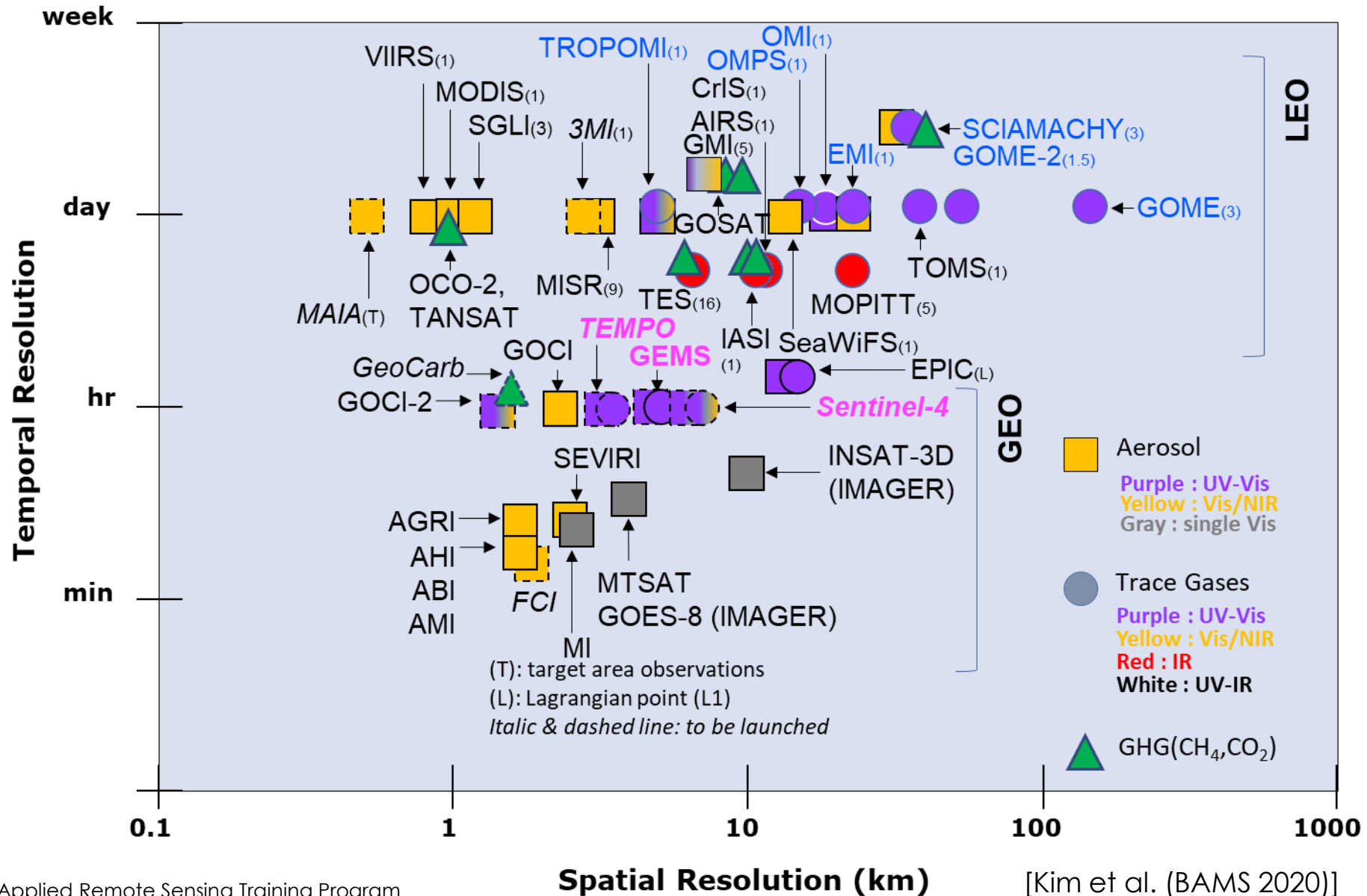
- Understand Air Quality Mission GEMS
- Understand the GEMS air quality datasets, retrieval algorithms, validation
- Locate and access GEMS air quality datasets
- Have sample python Jupyter Notebooks to read, map and extract GEMS datasets



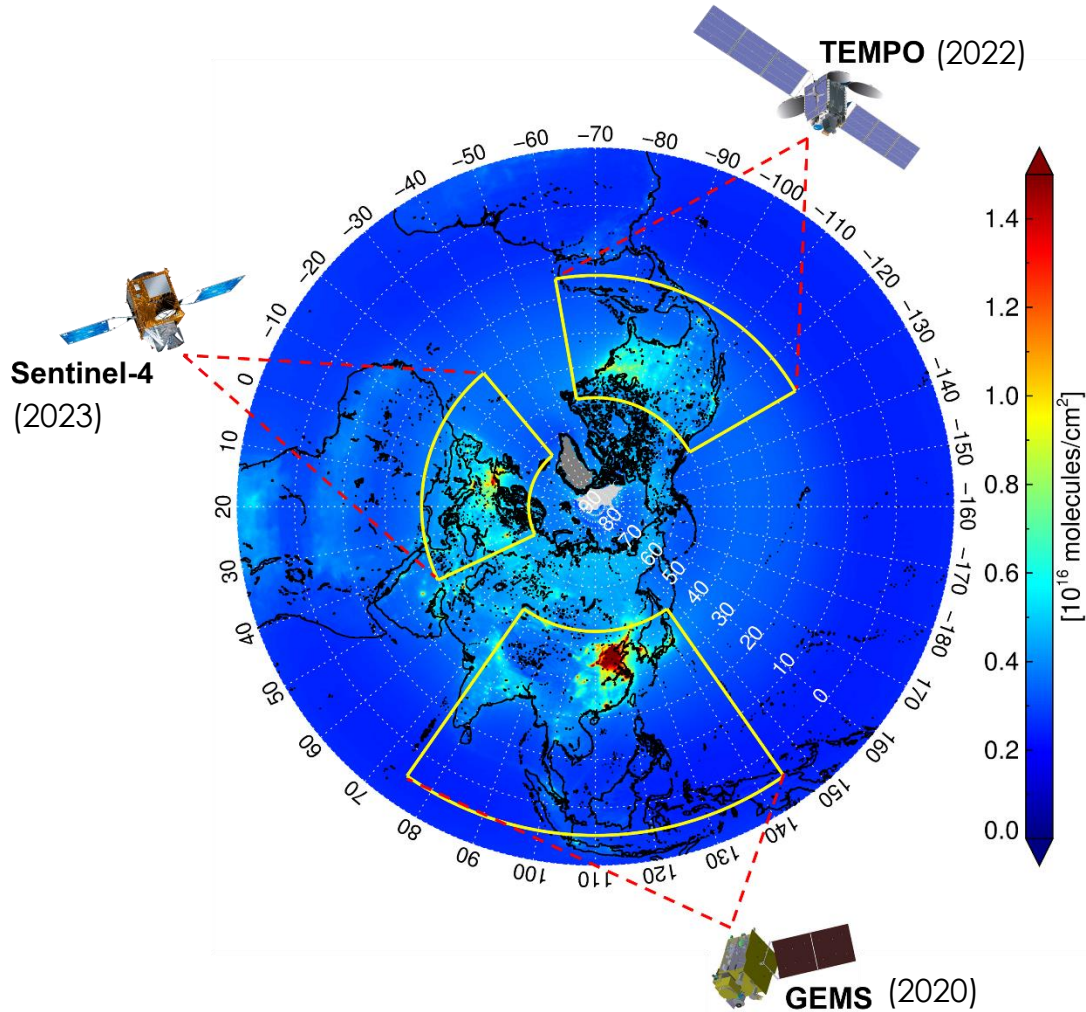


1. Introduction to the GEMS Mission

Satellite Remote Sensing for Aerosols & Gases



Geostationary Air Quality Constellation

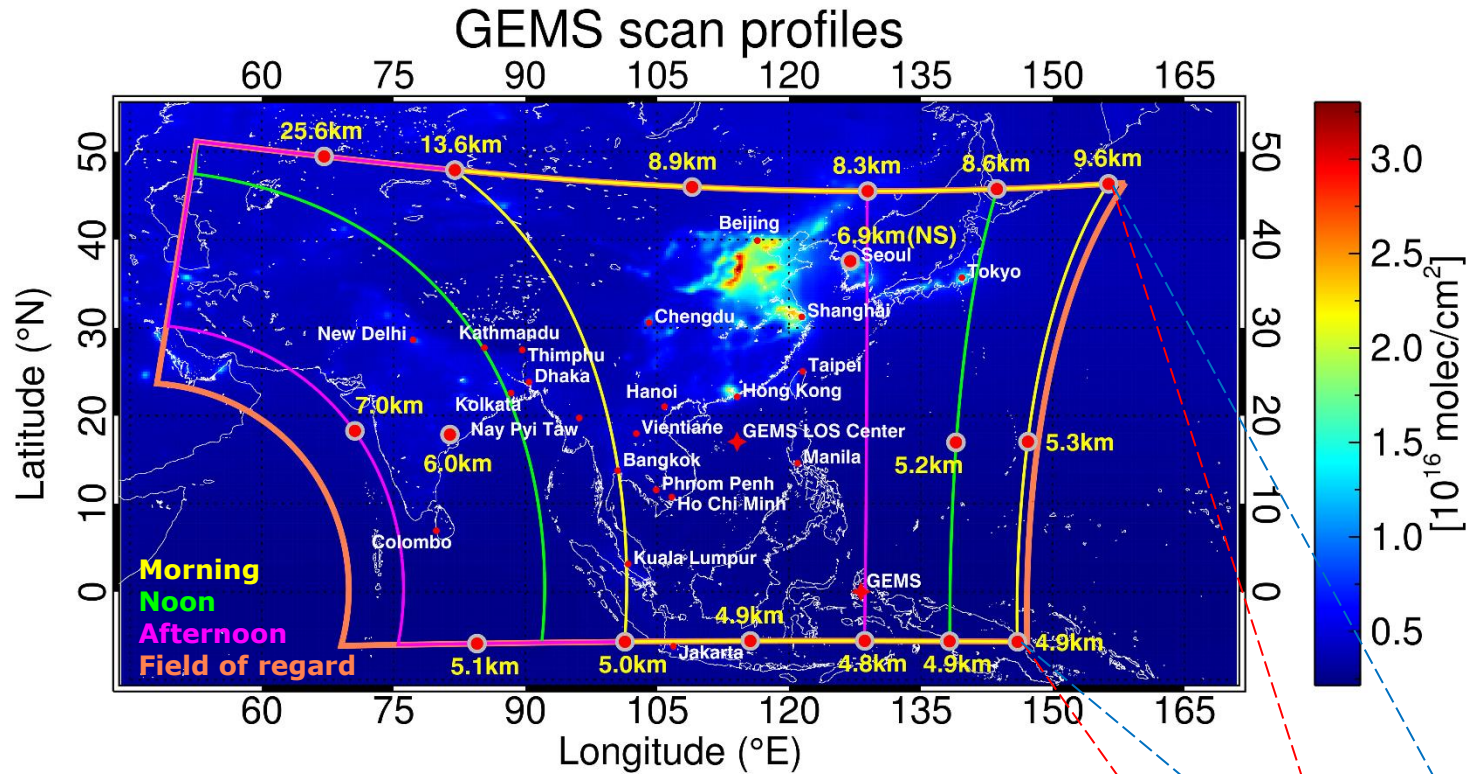


	Sentinel-4	TEMPO	GEMS
Domain	Europe	North America	Asia-Pacific
Revisit	1 hour	1 hour	1 hour
(Planned) Launch	~2023	2022	2020
Payload	UV-Vis-NIR 305–500 nm 750–775 nm	UV-Vis 290–490 nm 540–740 nm	UV-Vis 300–500 nm
Products	O ₃ , trop. O ₃ , NO ₂ , SO ₂ , HCHO, AAI, AOD, height-resolved aerosol	O ₃ , trop. O ₃ , 0-2km O ₃ , NO ₂ , HCHO, SO ₂ , CHOCHO, BrO, IO, HONO, AOD, AAI	O ₃ , trop O ₃ , NO ₂ , SO ₂ , HCHO, CHOCHO, AOD, AAI, AEH, (BrO, IO ..)
Spatial sampling	8 km x 8 km at 45°N	≤ 2.2 km N/S x 5.2 km E/W @36.5°N	3.5 km N/S x 8 km E/W @38°N
Nominal product resolution	8.9 km N/S x 11.7 km E/W @40°N	≤ 8.88 km N/S x 5.15 km E/W @35°N	7 km N/S x 8 km E/W @38°N (gas), 3.5 km N/S x 8 km E/W @38N (aerosol)
Accompanied instruments	MTG-S, MTG-I	GOES-R/S ABI	AMI, GOCI-2

[Kim et al. (BAMS 2020)]

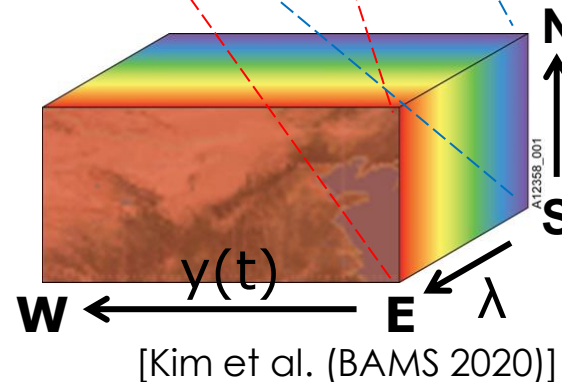


GEMS: Geostationary Environment Monitoring Spectrometer



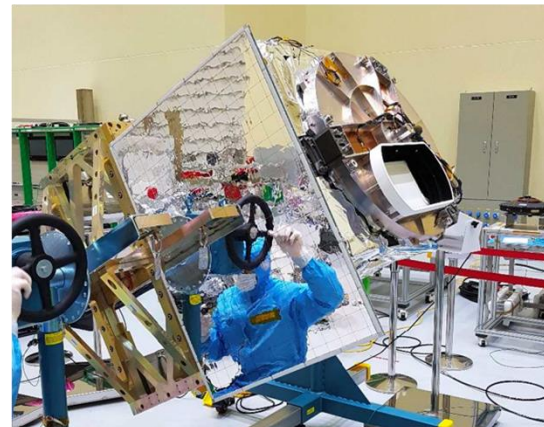
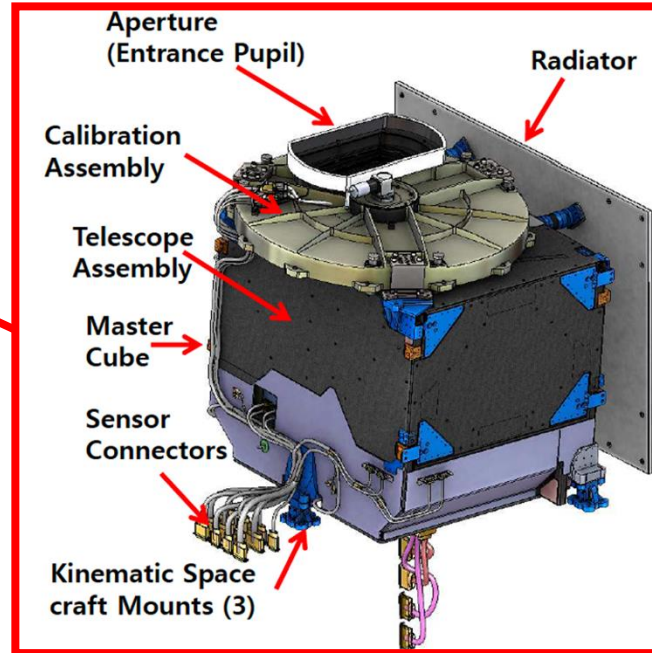
- GEMS (Geostationary Environment Monitoring Spectrometer), on board the GEO-KOMPSAT2B (Geostationary Korea Multi-Purpose Satellite), is a geostationary, scanning, ultraviolet-visible spectrometer.
- It is designed to monitor trans-boundary pollution events for the Korean peninsula and the Asia-Pacific region.

2048 N-S x 695 E-W x 8 times/day
 = 11,386,880 spectra/day
 = 227,737,600 data/day



UV – VIS	
Wavelength Range	300 – 500 nm
FWHM	< 0.6 nm
Temporal Resolution	1 hour
Spatial Sampling @ Seoul [km ²]	3.5 x 8 km ² (Aerosol) 7 x 8 km ² (Trace-gas)

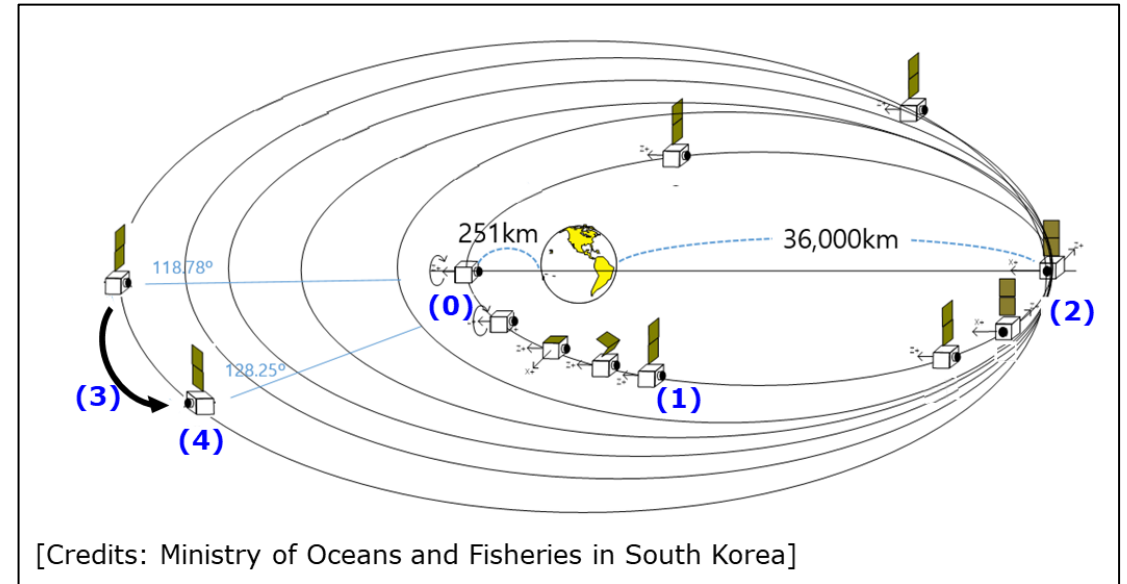
GEMS Instrument Specification



System Attributes	Requirements
Lifetime	>10 years
Reliability	> 0.85 at end of life
Field of regard	> 5000 km (N/S) × 5000 km (E/W) N/S range: 45°N–5°S E/W range: selectable between 75°E and 145°E Orbital position: 116.2°E < position < 128.2°E
Duty cycle/imaging time	Eight images during the daytime (30 min imaging + 30 min rest) × 8 times day ⁻¹
Ground sampling distance	< 7 km (N/S) at Seoul GSD area < 56 km ² at Seoul (Aspect Ratio less than 1:3)
Spectral range	300 to 500 nm
Spectral resolution	< 0.6 nm
Spectral sampling	< 0.2 nm
Signal-to-noise ratio	> 720 at 320nm > 1500 at 430nm
Data quantization	≥ 12 bits
MTF (instrument level)	> 0.3 in N/S direction at Nyquist frequency > 0.3 in E/W direction at Nyquist frequency
Imaging navigation	1 pixel
Pointing stability	48 μrad ² s ⁻¹
Pointing accuracy	0.02°
Radiometric calibration accuracy	< 4% (including standard lamp uncertainty)
Spectral calibration accuracy	< 0.02 nm
Spectral calibration stability	< 0.02 nm (within daytime observations)
Polarization factor	< 2% (310-500nm) No inflection point within 20 nm for all the wavelength range
Spectral feature	<0.05% (within 3 nm)
Stray light	<2% (310–350 nm)

Timeline Since Launch

No.	Date (KST)	Activity
0	2020.02.19	Transfer orbit injection (GK-2B launch)
1	2020.02.19	Solar array deployment
2	2020.02.20 – 2020.02.26	Liquid apogee engine firing
3	2020.02.26 – 2020.03.06	Moving from 118.78°E to 128.25°E
4	2020.03.06	GK-2B arrived successfully in orbit
5	2020.03.10	GEMS initial operation monitoring
6	2020.03.23	GEMS power on
7	2020.03.31	GEMS outgassing
8	2020.04.07	GEMS outgassing monitoring
9	2020.04.21	First GEMS measurements for Sun/Earth/LED
10	2020.04.23~	Daily operation (in-orbit test)
11	2020.04.28	Solar measurements with reference diffuser



[Courtesy of KARI & NIER]

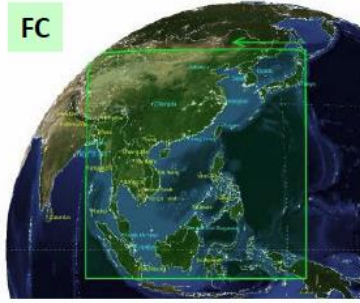
No.	Date (KST)	Activity
12	2020.08.31	GEMS power reset
13	2020.09.22	Solar measurements with reference diffuser
14	2020.12.20	Solar measurements with reference diffuser



GEMS E-W Scan Operation Scenario



Obs. No.	1	2	3	4	5	6	7	8	9	10	11	Total Obs. No.
UTC	23:00	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	
KST	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	
Jan	X	X	HE	HK	FC	FW	FW	FW	X	X	X	6
Feb	X	X	HE	HK	FC	FW	FW	FW	FW	X	X	7
Mar	X	HE	HK	FC	FC	FW	FW	FW	FW	X	X	8
Apr	HE	HK	FC	FC	FC	FW	FW	FW	FW	FW	X	10
May	HE	HK	FC	FC	FW	FW	FW	FW	FW	FW	X	10
Jun	HE	HK	FC	FC	FW	FW	FW	FW	FW	FW	X	10
Jul	HE	HK	FC	FC	FW	FW	FW	FW	FW	FW	X	10
Aug	HE	HK	FC	FC	FW	FW	FW	FW	FW	FW	X	10
Sep	HE	HK	FC	FC	FW	FW	FW	FW	FW	FW	X	10
Oct	X	HE	HK	FC	FC	FW	FW	FW	FW	X	X	8
Nov	X	X	HE	HK	FC	FW	FW	FW	X	X	X	6
Dec	X	X	HE	HK	FC	FW	FW	FW	X	X	X	6



		Longitude	Scan Width
HE	Half East	152.000	3.80500
HK	Half Korea	142.000	3.80500
FC	Full Central	142.000	7.61000
FW	Full West	133.000	7.61000
X	No observation		

[Source: <https://nesc.nier.go.kr/satellite/operation?page=1&limit=10>]

Baseline Level-2 Products of GEMS

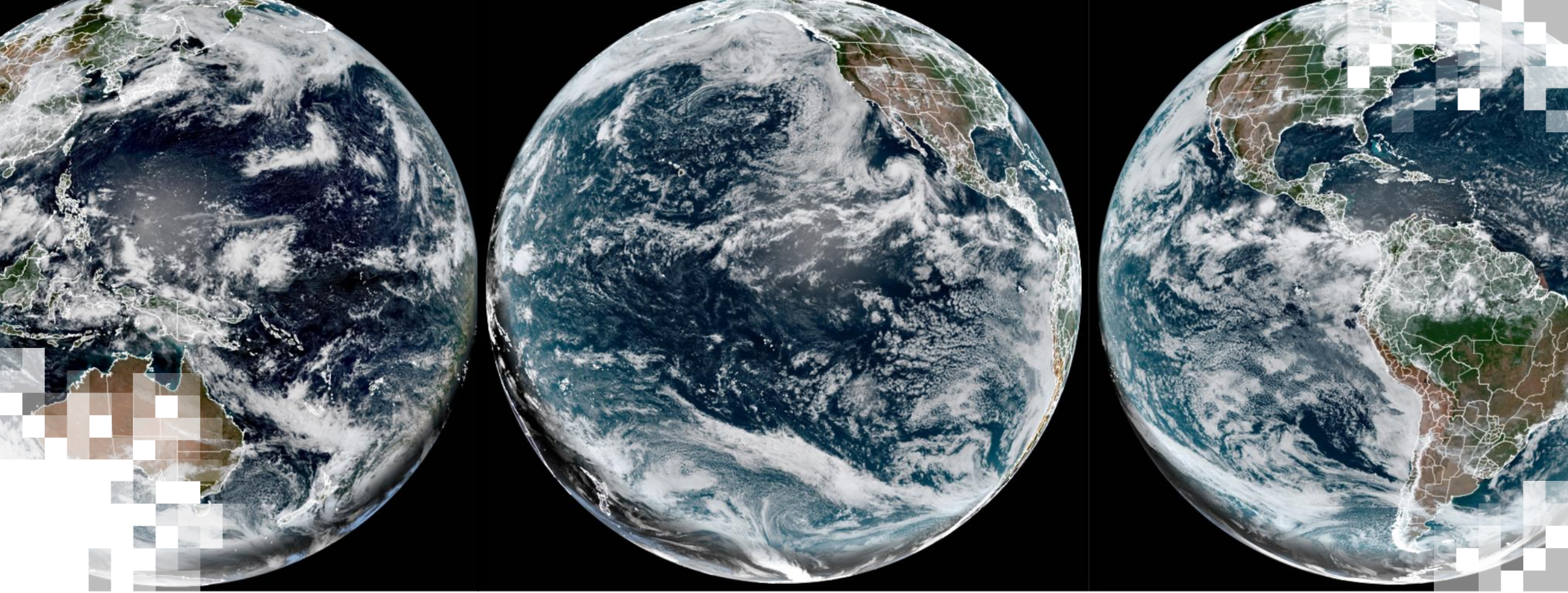
Product Group	Product	Importance
Aerosol	1) Aerosol Optical Depth	Air Quality Climate Public Health
	2) Single Scattering Albedo	
	3) UV-VIS Aerosol Index	
AEH	4) Aerosol Effective Height	
Cloud	5) Effective Cloud Fraction	Retrieval Climate
	6) Effective Cloud Pressure	
	7) Cloud Radiance Fraction	
SFC	8) Surface Reflectance	Retrieval Environment
O3T	9) Total Ozone	Oxidant Pollutant O ₃ layer
O3P	10) Tropospheric Ozone Profile	
	11) Stratospheric Ozone Profile	

Product Group	Product	Importance
HCHO	12) Formaldehyde	VOC Proxy
CHOCHO	13) Glyoxal	
NO ₂	14) Tropospheric Nitrogen dioxide	O ₃ & Aerosol Precursor
	15) Stratospheric Nitrogen dioxide	
SO ₂	16) Sulfur dioxide	Aerosol Precursor Volcano
UVI	17) UV Index	Public Health
	18) Plant Response Index	
	19) DNA Damage Index	
	20) Vitamin D Synthesis Index	

*Additional products of H₂O, BrO, HONO under development.

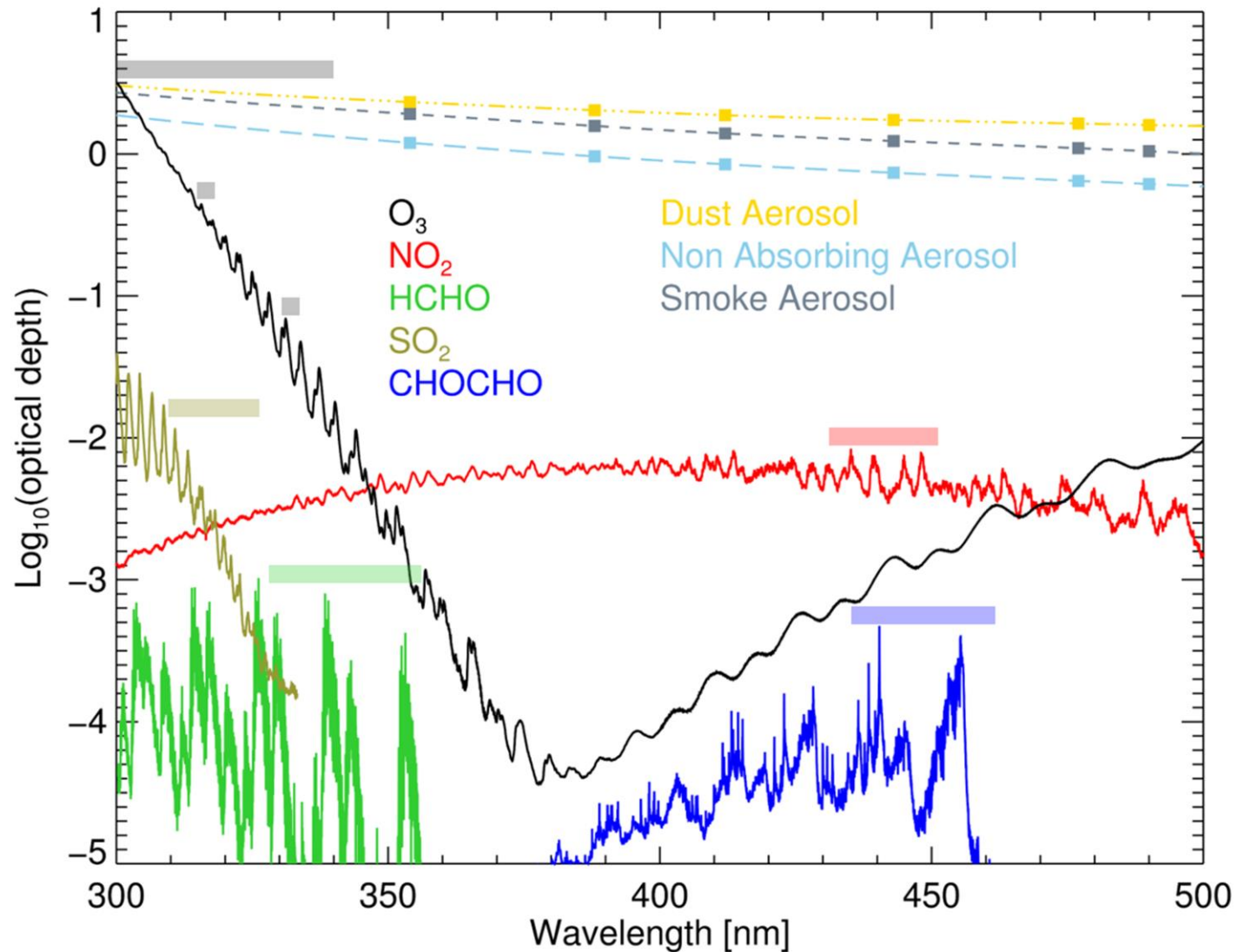
Data released as of September 2022





2. GEMS Air Quality Datasets – Algorithms & Validation

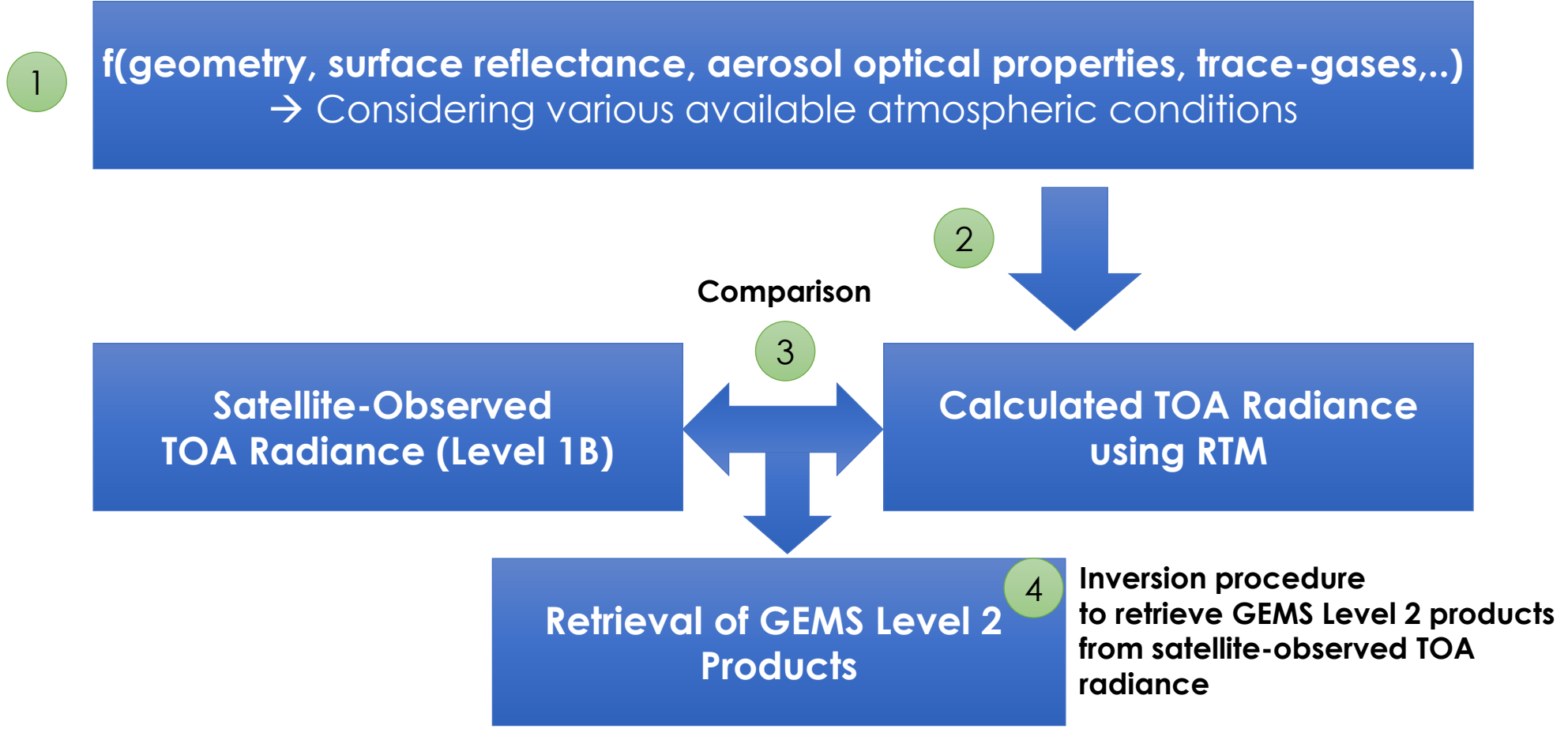
Optical Depths of Air Pollutants



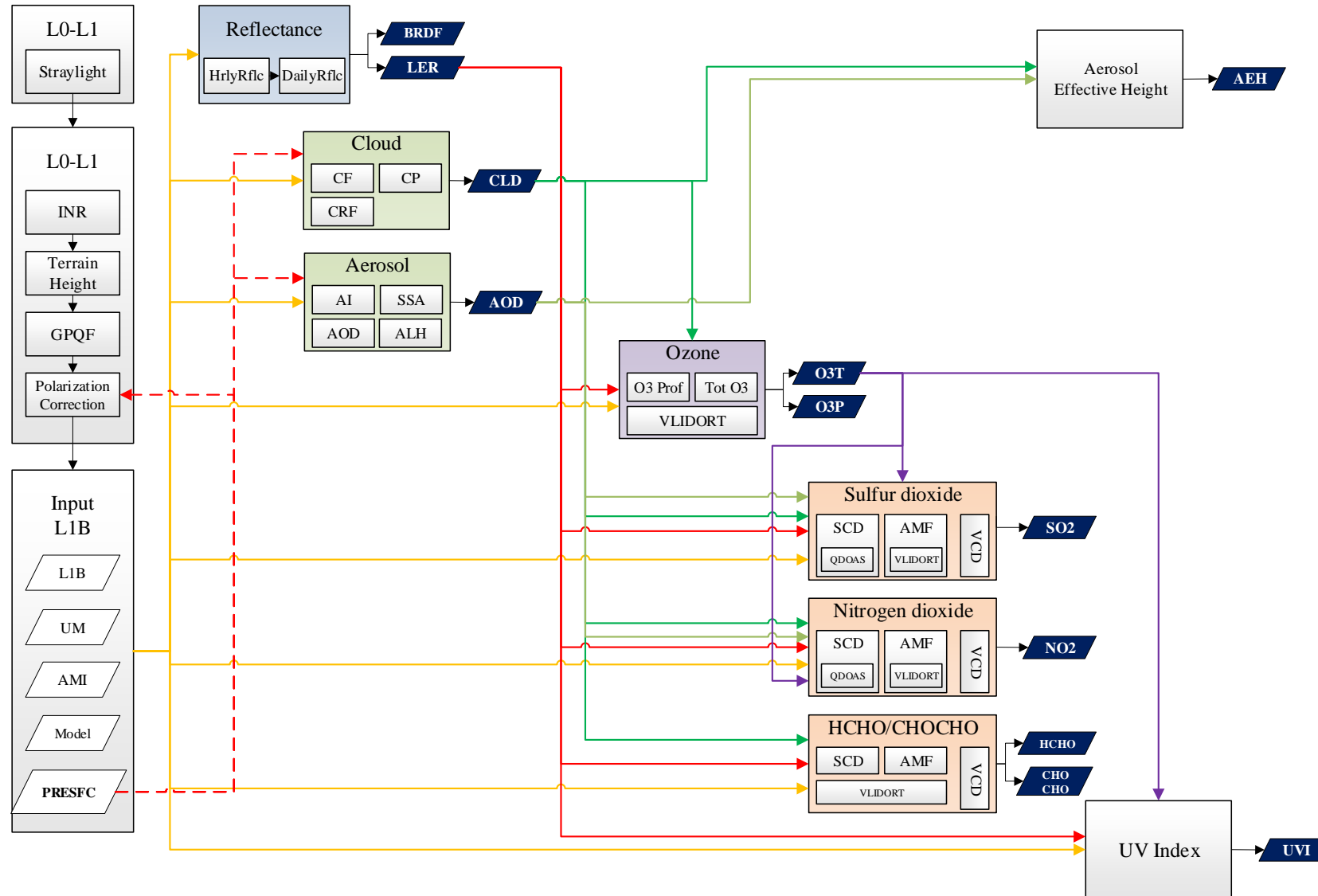
[Kim et al. (BAMS 2020)]



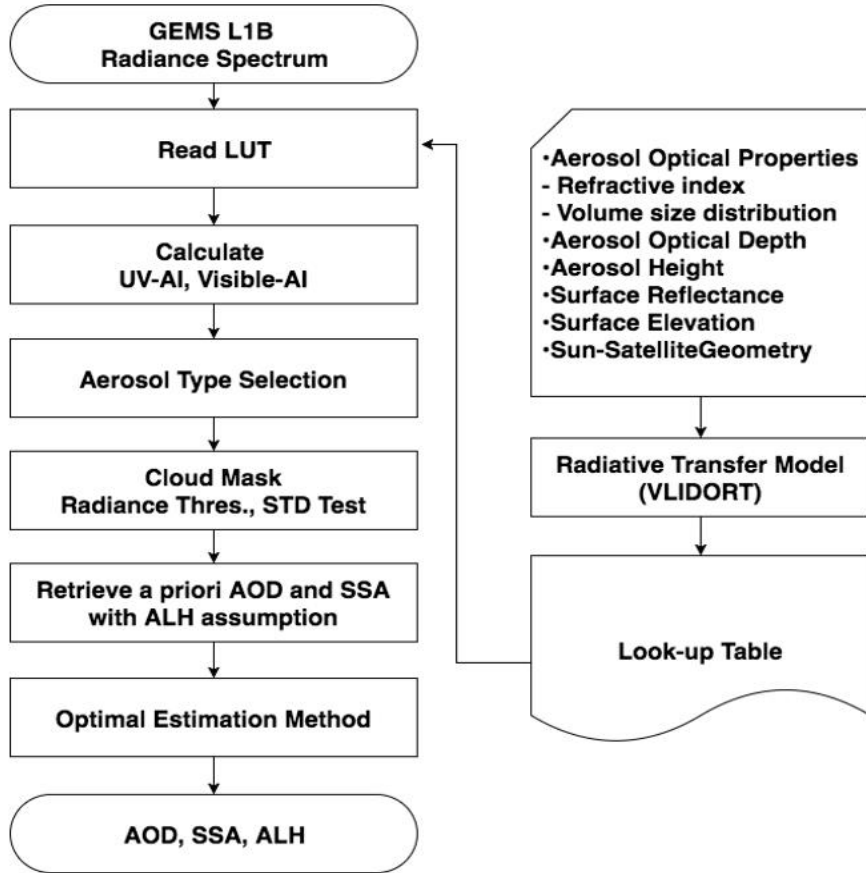
General Concept of Retrieving Level 2 Products from Satellite Measurement Datasets



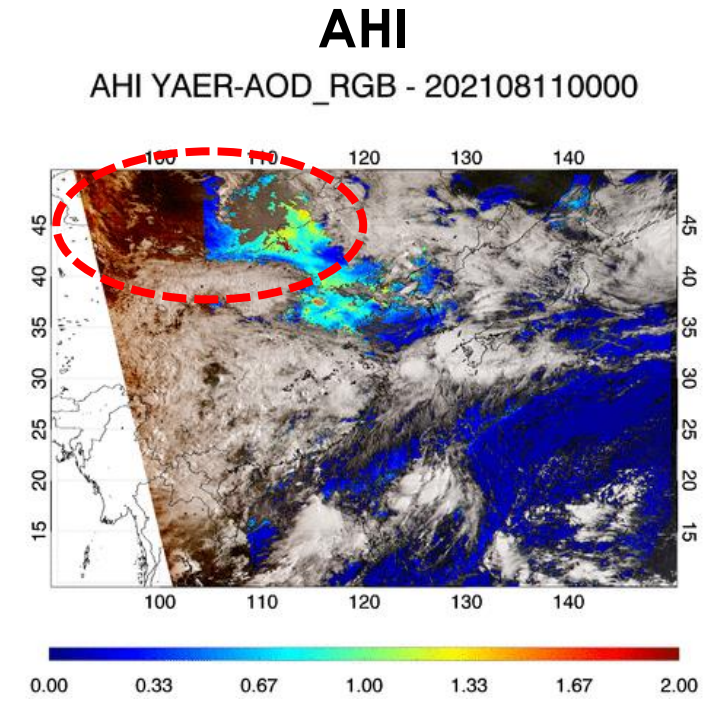
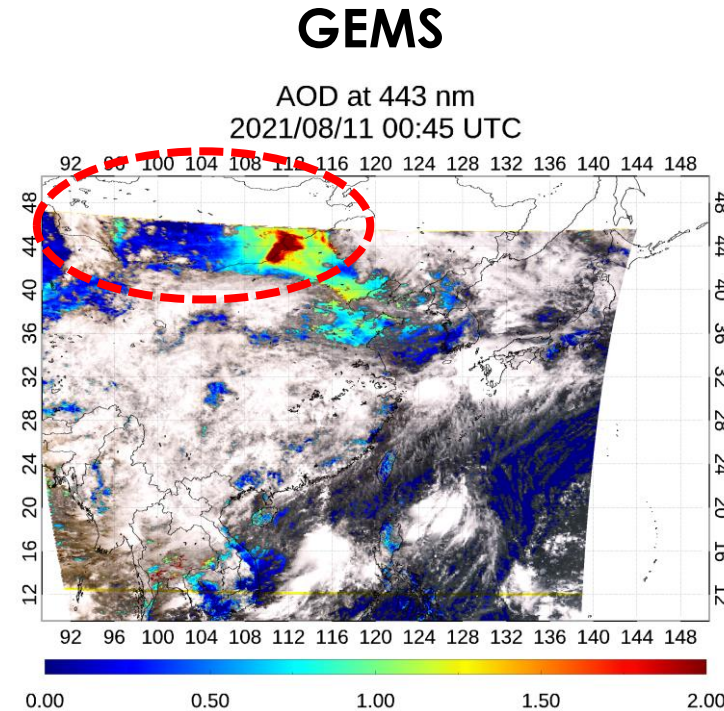
GEMS Algorithm Flow Chart



Aerosol Product- AOD (Aerosol Optical Depth)



- Major Products: AOD, SSA, and ALH
- Channels: 354, 388, 412, 443, 477, 490 nm
- Methods: 2-channel method + Optimal Estimation (Torres et al., 2013; Kim et al., 2018; Go et al., 2020a,b)

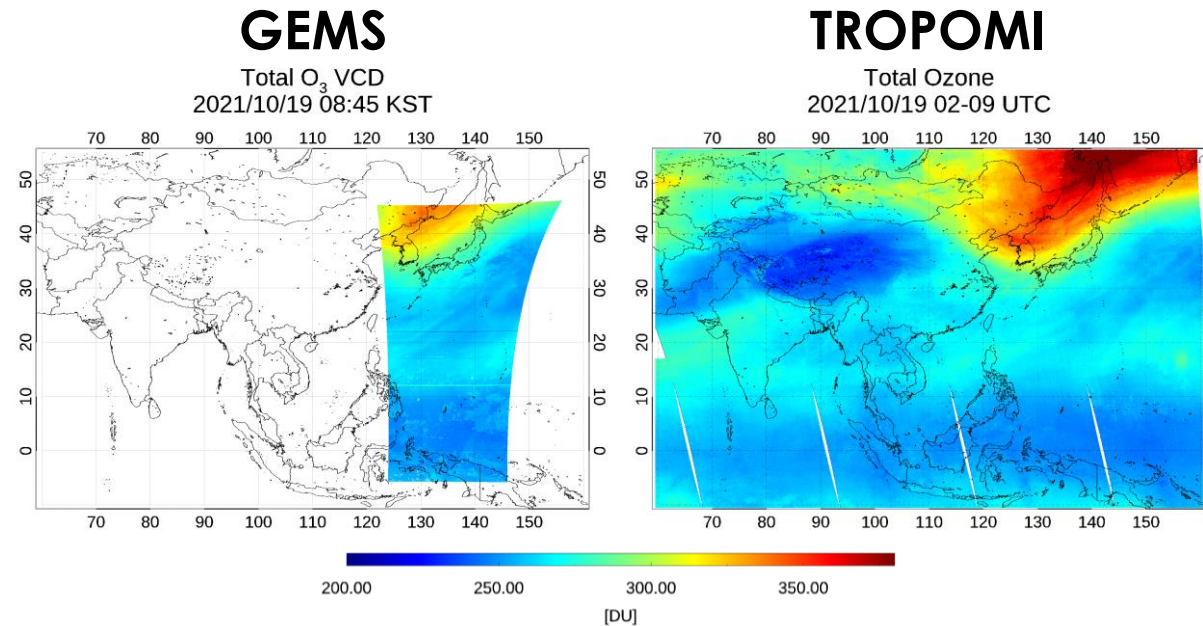
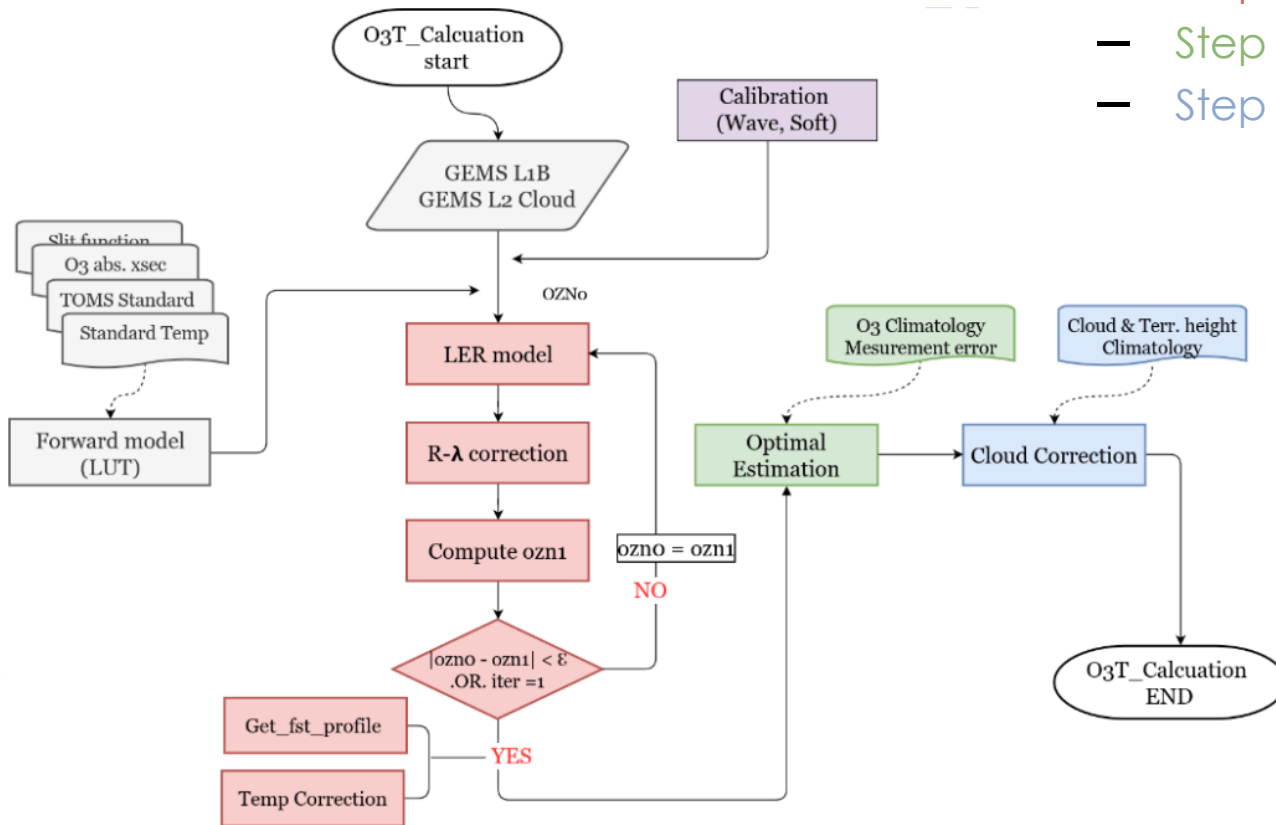


Lim et al. (RS 2018, AMT 2021)

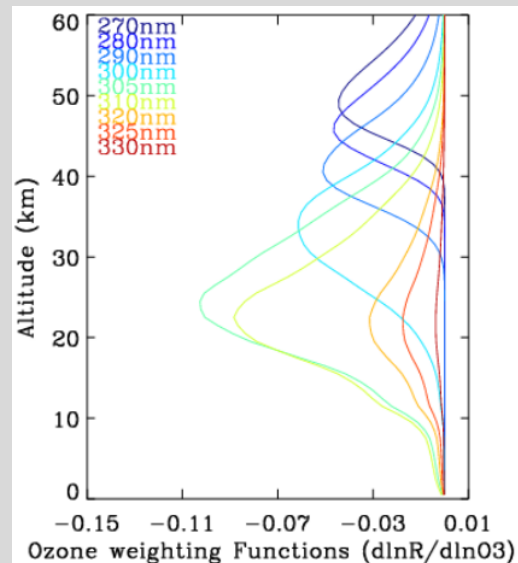
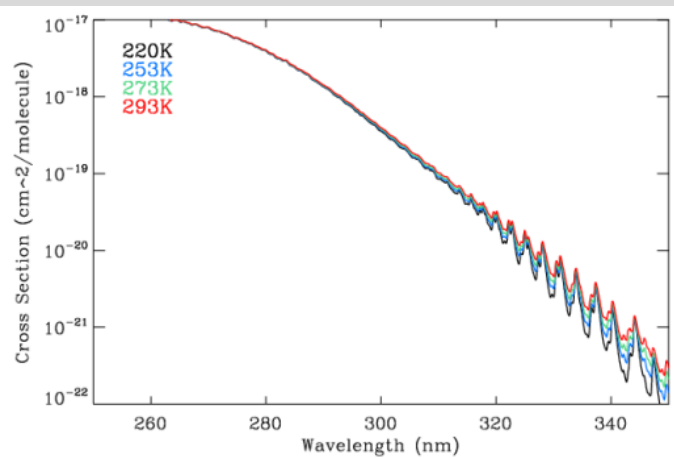
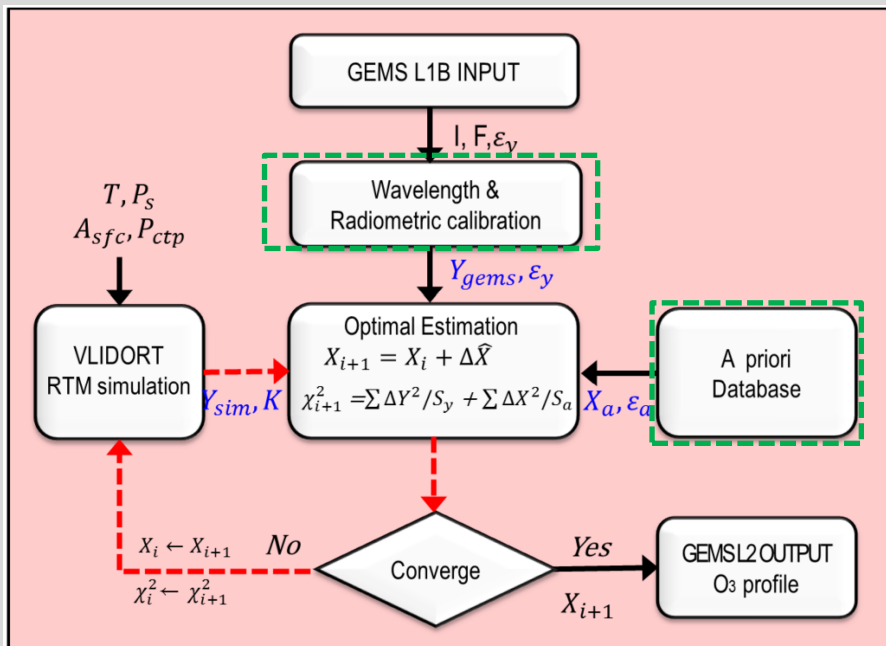


Ozone Product- O3T (Total Ozone)

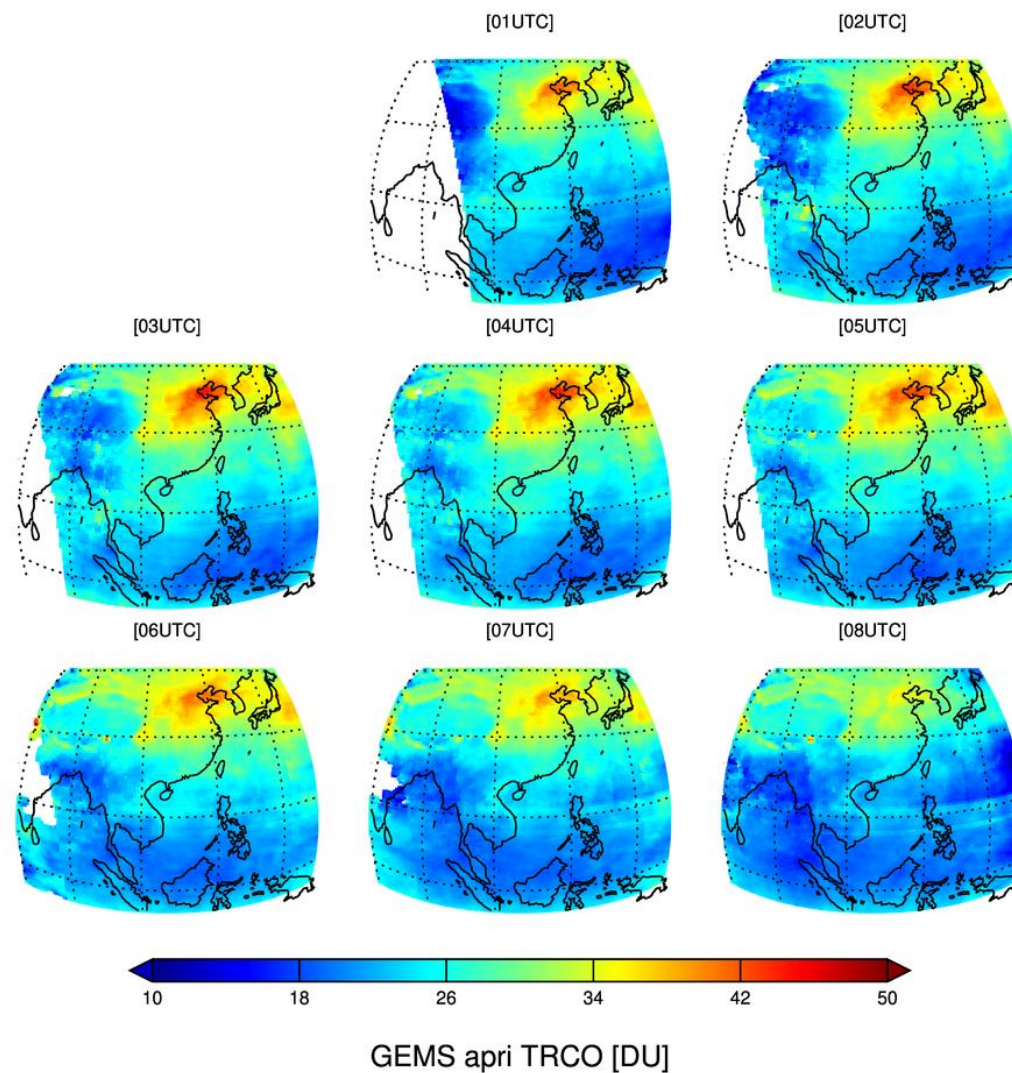
- Inversion Methods:
 - Step 1) TOMS Algorithm (Dave and Mateer (1967), Dave (1977))
 - Step 2) Optimal Estimation (Rodgers (2000))
 - Step 3) Effects of Clouds and Terrain Height Correction



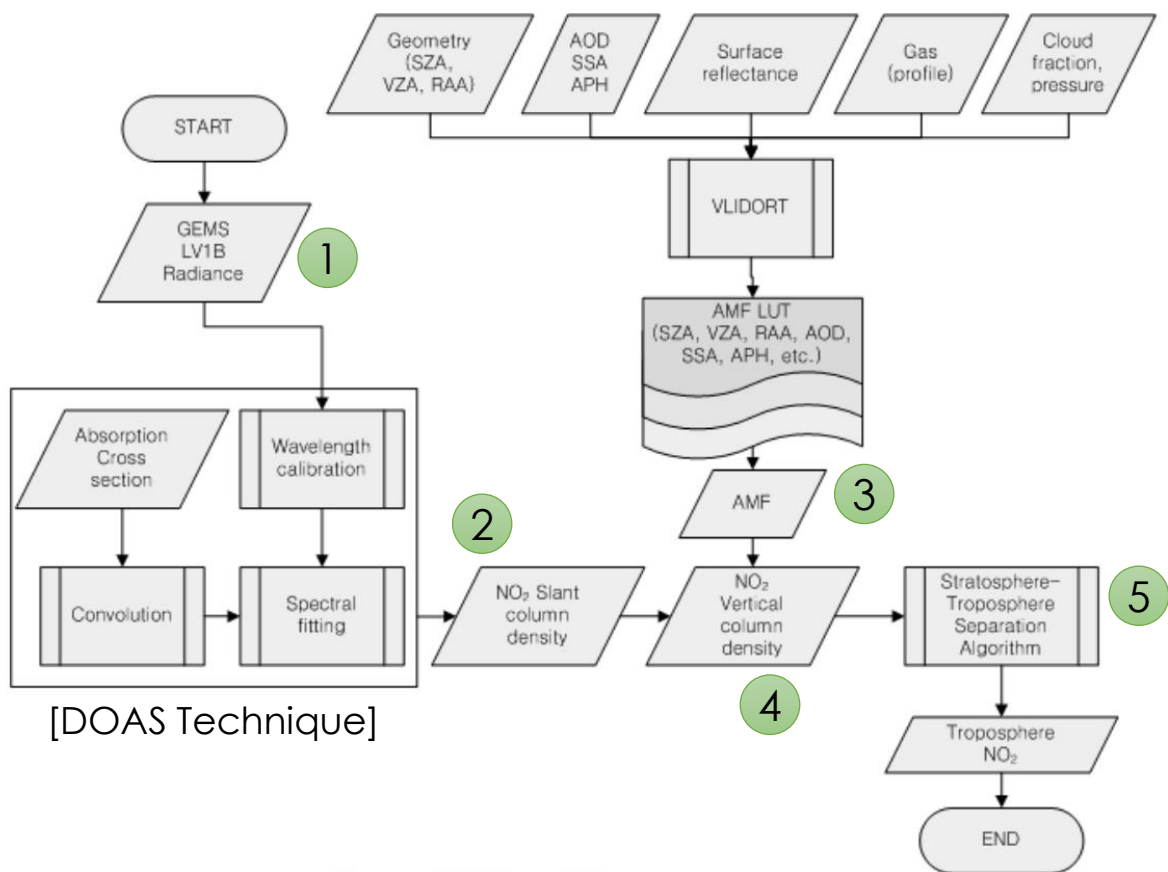
Ozone Product - O3P (Ozone Profile)



- Huggins Ozone Bands (300-340nm)



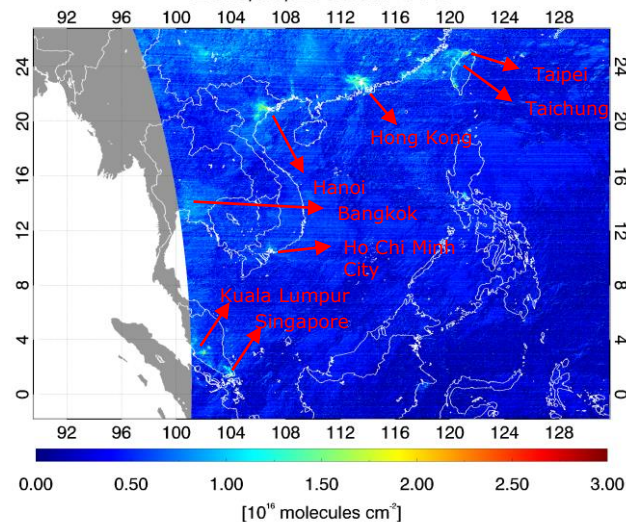
Nitrate Product - NO₂ (Nitrogen Dioxide)



- Fitting Windows: 432-450 nm
- Inversion Algorithms (NO₂, SO₂, HCHO):
 - 1) Spectral Radiance Measurements from GEMS
 - 2) Spectral Fitting of Slant Column Density (SCD)
 - 3) Air Mass Factor (AMF) Correction
 - 4) Calculate Vertical Column Density (VCD)
 - 5) NO₂: Stratosphere-Troposphere Separation (Based on Bucsela et al., 2013)

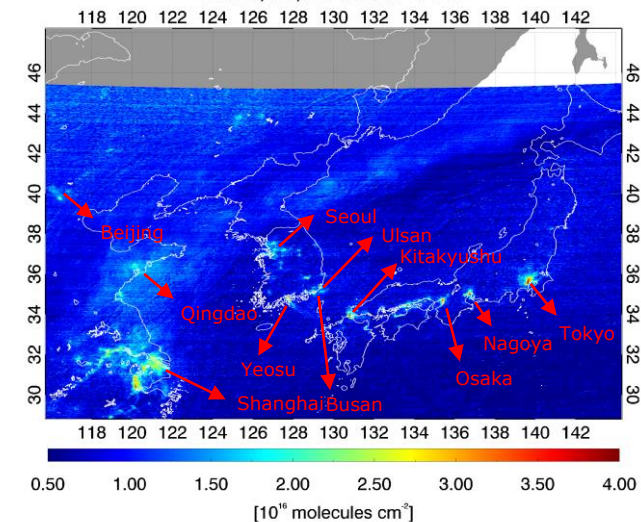
GEMS SCD

NO₂ total SCD
2020/08/20 00:45 UTC



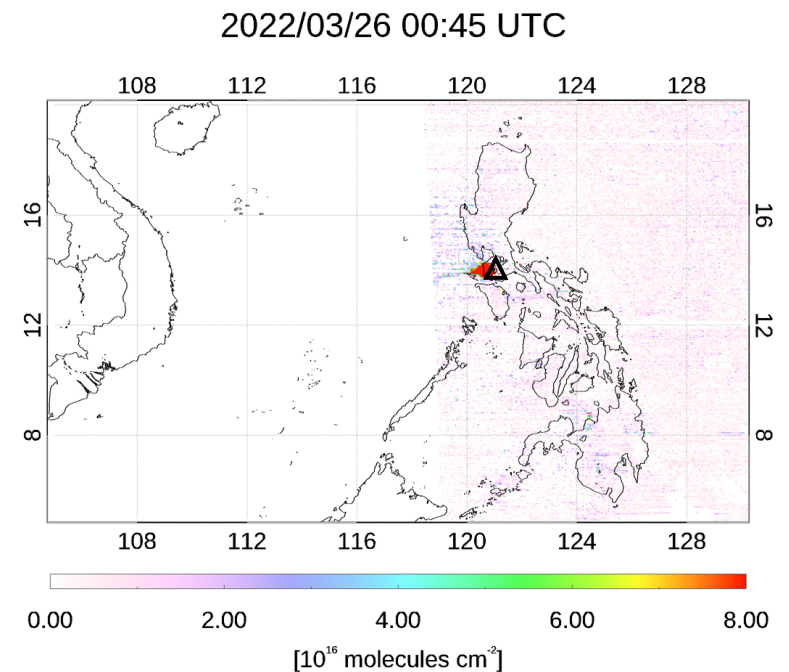
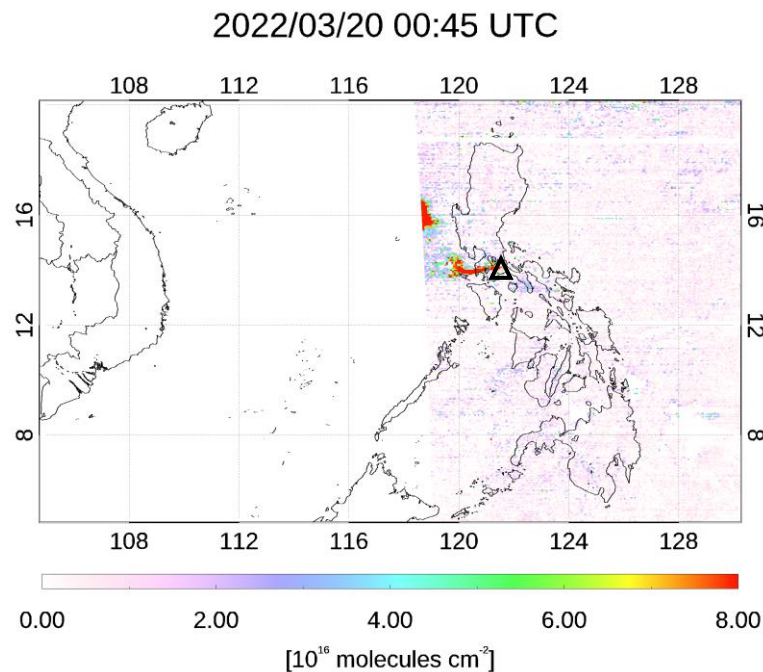
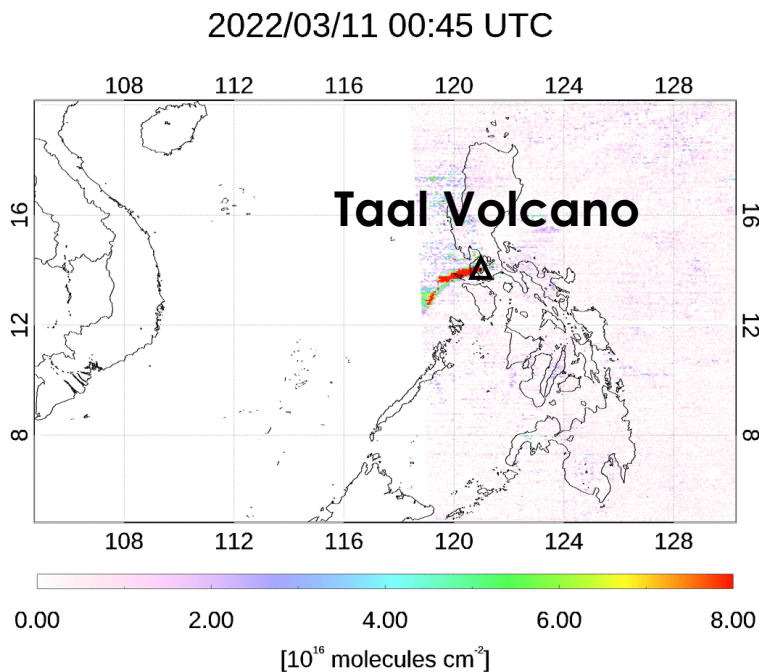
GEMS SCD

NO₂ total SCD
2020/08/20 00:45 UTC



Sulfate Product - SO₂

- Slant Column Retrieval: PCA (Li et al., 2013) and DOAS Method (Platt, 1994).
- Fitting Windows: 308-324nm
- Taal Volcano is located ~65 km south of Manila. A large-scale volcanic eruption occurred on March 26, 2022.
- GEMS captured SO₂ emitted from Taal volcano spreading to the Indochina Peninsula through the western coastal region of the Philippines.

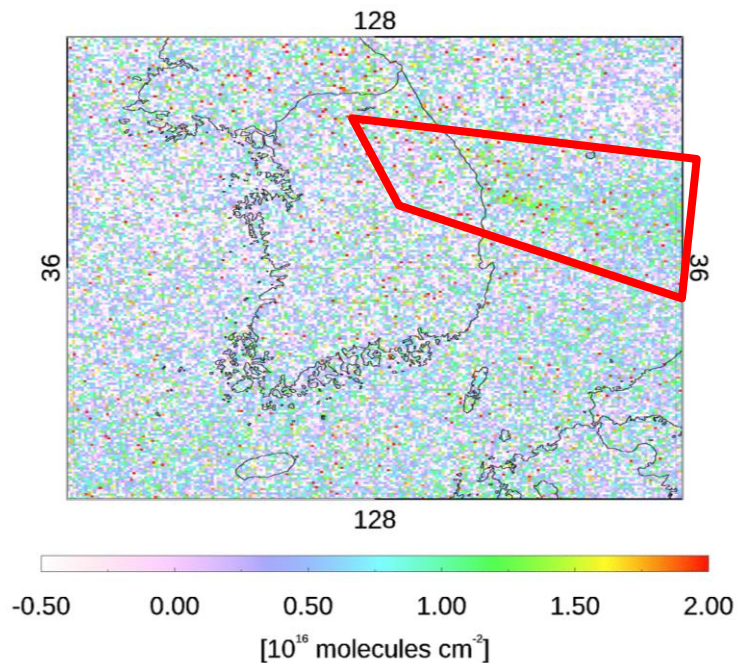


VOC Products - Formaldehyde (HCHO) and Glyoxal (CHOCHO)

- Slant Column Retrieval: Basic Optical Absorption Spectroscopy (BOAS)
- Fitting (calibration) Window of HCHO : 328.5–356.5 nm (325.5–358.5 nm)
- Fitting (calibration) Window of CHOCHO : 435.0–461.0 nm (433.0–463.0 nm)
- Large wildfires in Uljin and Gangnueng, South Korea on March 5, 2022

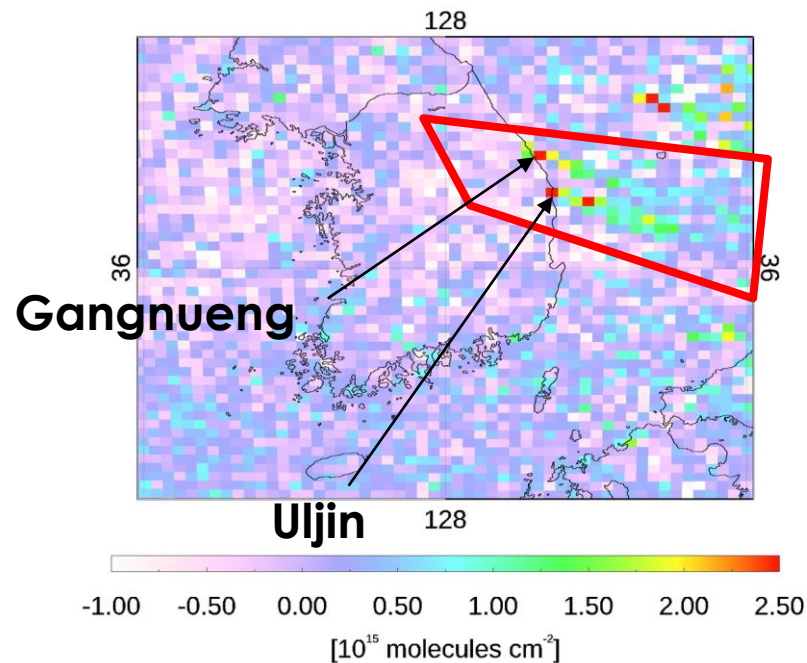
GEMS HCHO

2022/03/05 00:45 UTC

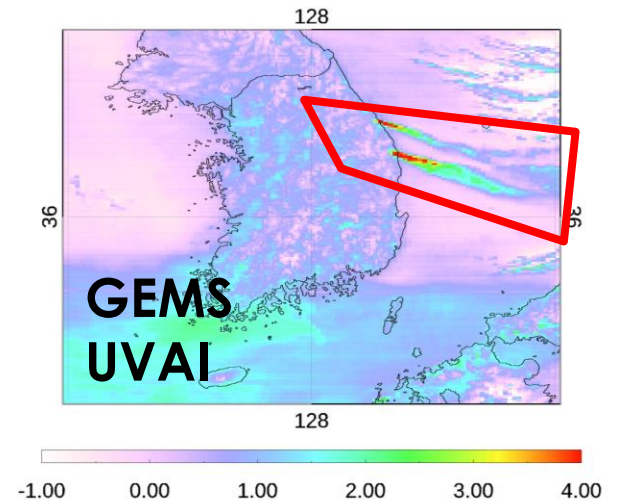


GEMS CHOCHO

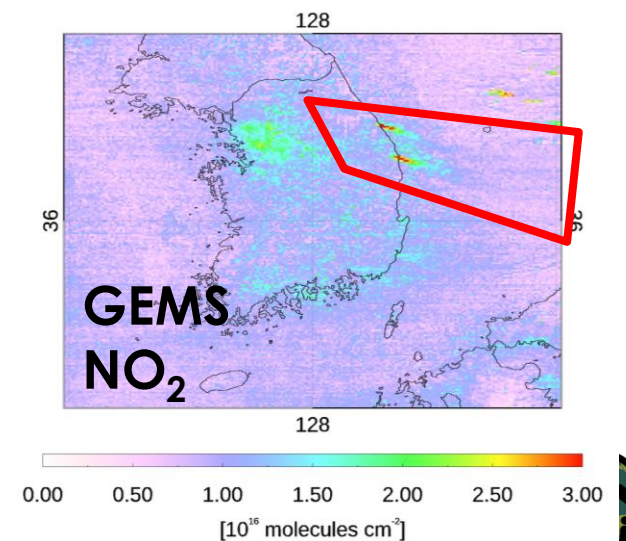
2022/03/05 00:45 UTC



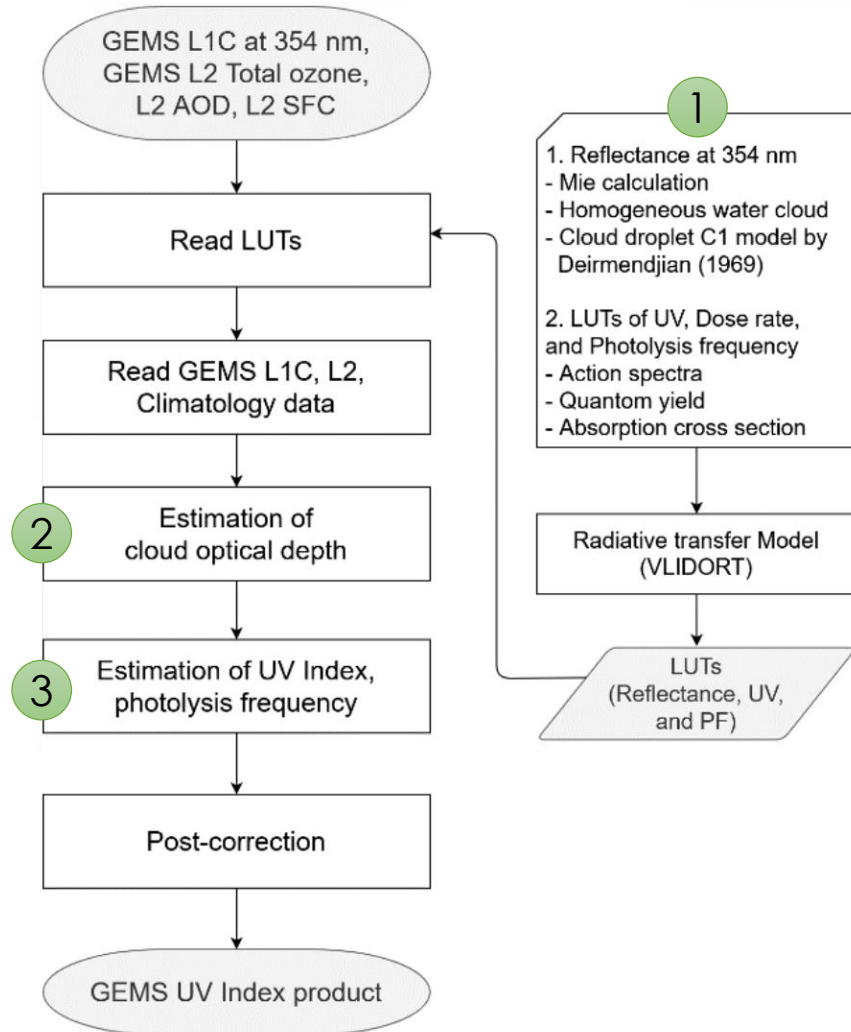
2022/03/05 00:45 UTC



2022/03/05 00:45 UTC

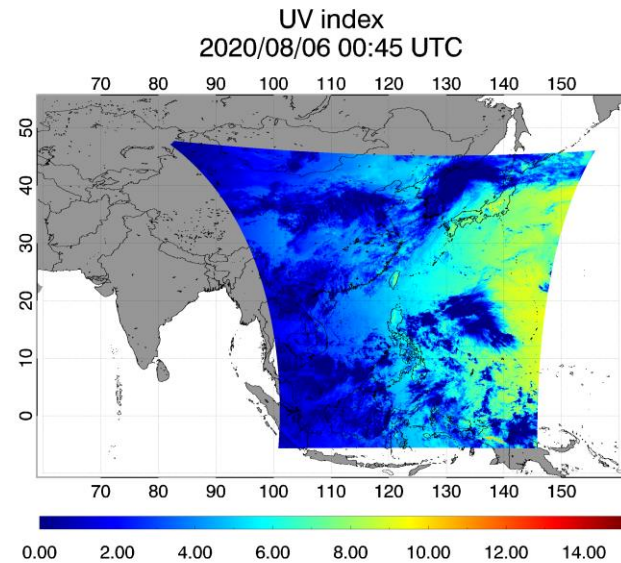


UV Index Product



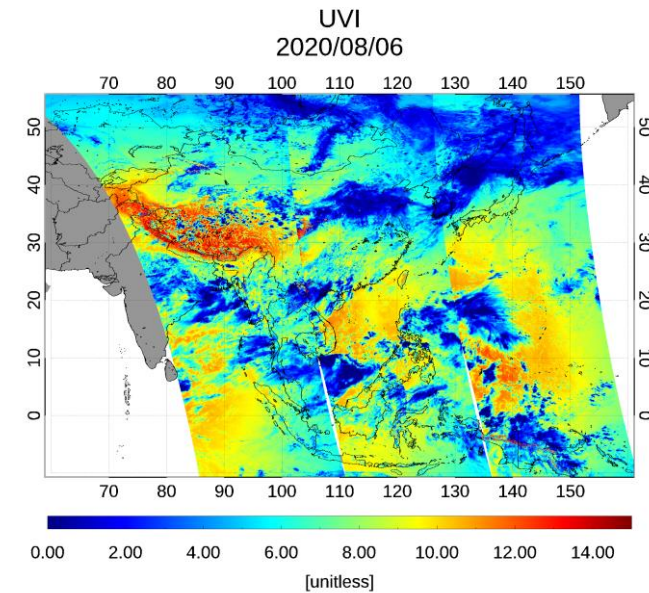
- Major Products:
 - UV Index
 - Plant Response Index
 - DNA Damage Index
 - Vitamin D Synthesis Index

GEMS UV Index



[unitless]

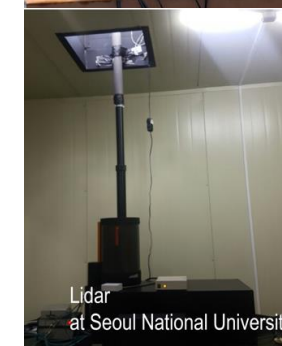
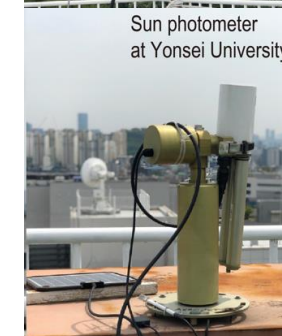
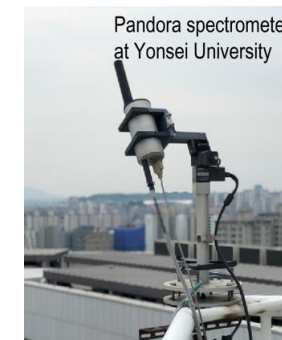
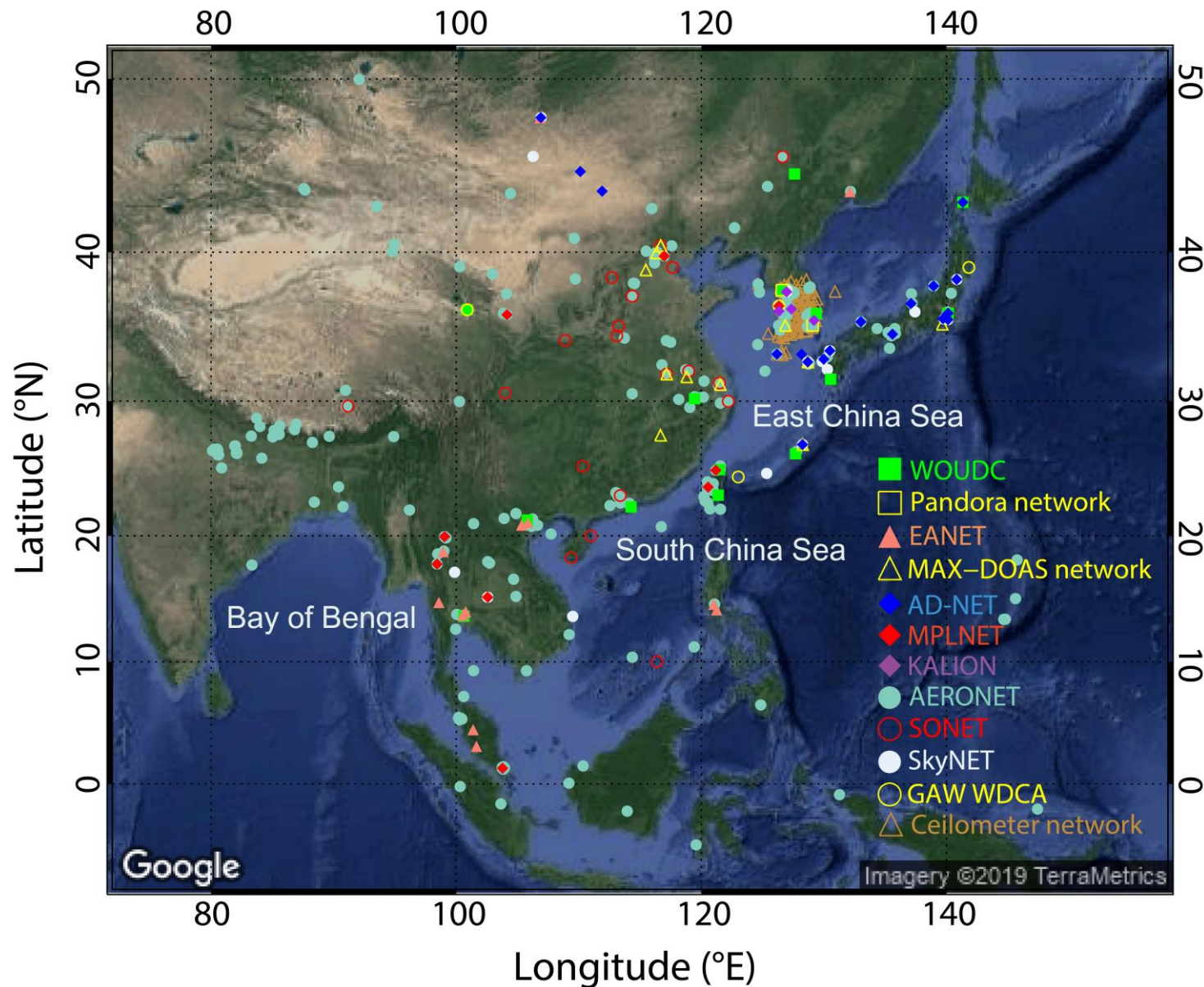
TROPOMI UV Index



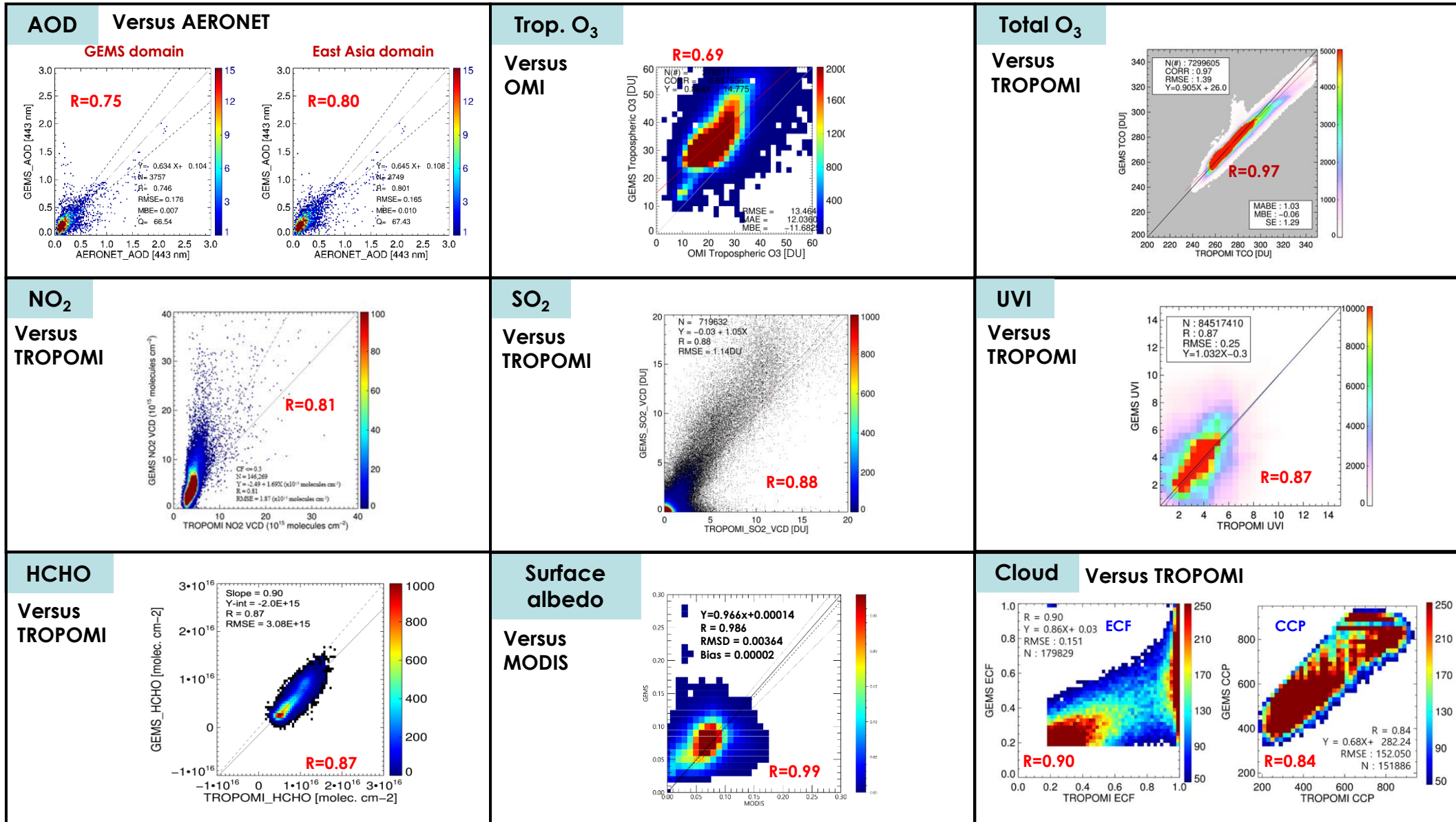
[unitless]



Validation Results of GEMS Level-2 Products

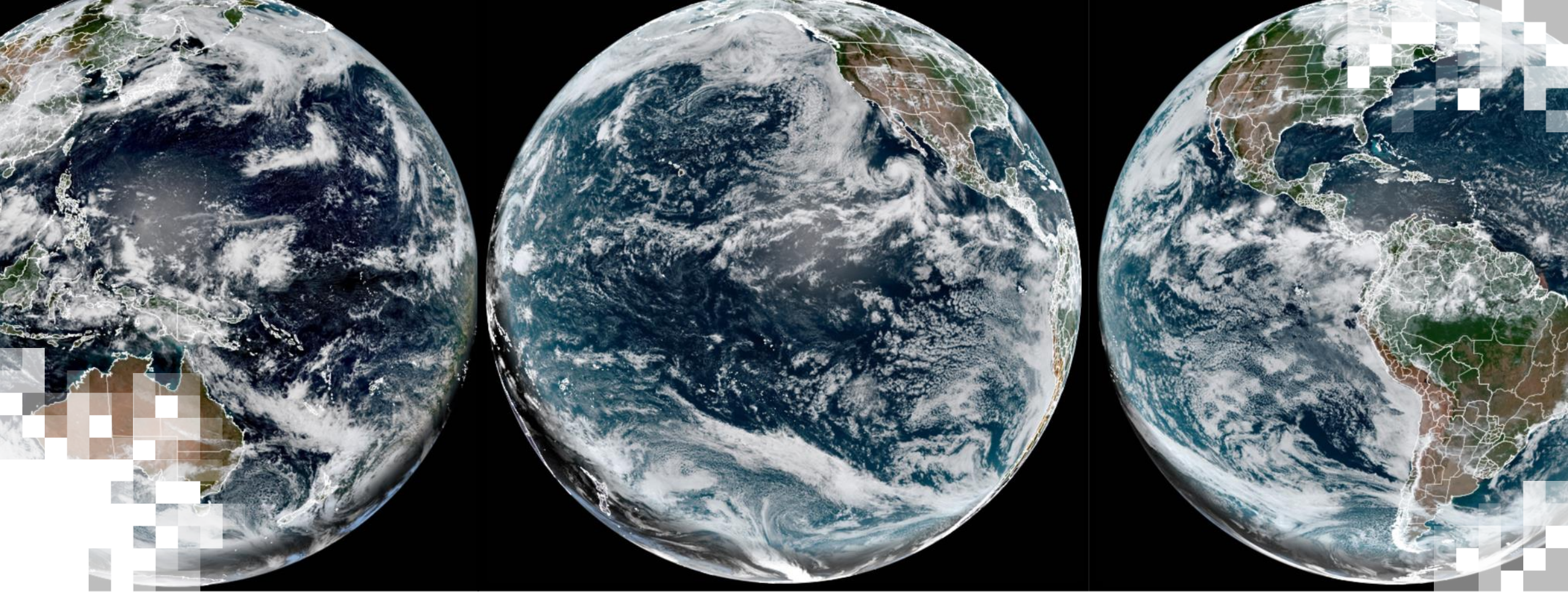


Validation Results of GEMS Level-2 Products Period: August–October 2020



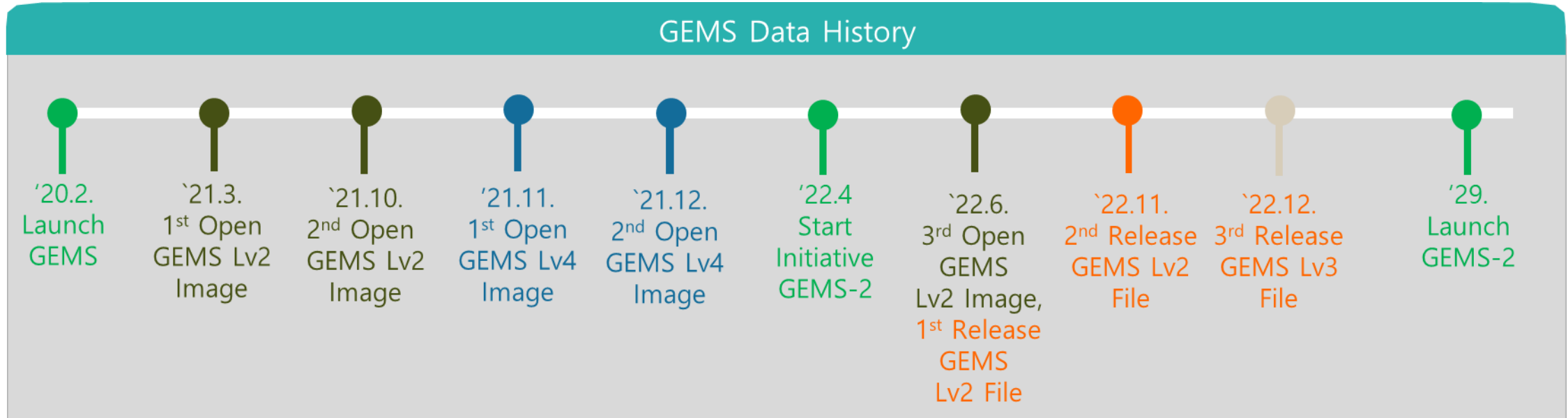
Validation Results of GEMS Level-2 Products

Parameter	Goal correlation (R)	Achieved correlation (R)	Slope (a)	Intercept (b)	RMSE	Reference	Region
O ₃ (Trop.)	0.5–0.8	0.69	0.86	14.78 DU	13.46 DU	OMI	East Asia
O ₃ (Total)	0.82–0.97	0.89	0.94	24 DU	1.83 DU	Pandora	Busan & Ulsan
NO ₂	0.80	0.81	1.69	-2.49×10^{15} molec. cm ⁻²	1.87×10^{15} molec.cm ⁻²	TROPOMI	GEMS domain
SO ₂	0.70	0.88	1.05	-0.03 DU	1.14 DU	TROPOMI	GEMS domain
HCHO	0.81	0.87	0.90	-2.0×10^{15} molec. cm ⁻²	3.08×10^{15} molec. cm ⁻²	TROPOMI	East Asia
AOD	0.70	0.75	0.63	0.10	0.18	AERONET	GEMS domain
UVI	0.86–0.96	0.87	1.03	-0.30	0.25	TROPOMI	GEMS domain
ECF	0.90	0.90	0.86	0.03	0.15	TROPOMI	GEMS domain
CCP	0.80	0.84	0.68	282.24 hPa	152 hPa	TROPOMI	GEMS domain
SFC	0.70–0.91	0.99	0.97	0.0001	0.0036	MODIS	GEMS domain



3. GEMS Air Quality Data Access

GEMS Data Release Plan



Credit: NIER

- ✓ 1st Release ('22.6.) Lv2 file product: Cloud, AOD, O3T, UVI, SO2
- ✓ 2nd Release ('22.11.) Lv2 file product: AEH, O3P, SFC, HCHO, Glyoxal, NO₂ (troposphere, total)
- ✓ 3rd Release ('22.12.) Lv3 file product: NO₂ (around the Korea Peninsula)

✘ Data will be downloadable from the ESC website: <https://nesc.nier.go.kr>

✘ L1C: Only offline (HDD) distribution (due to the large file size of ~8Gb per one hourly scan)

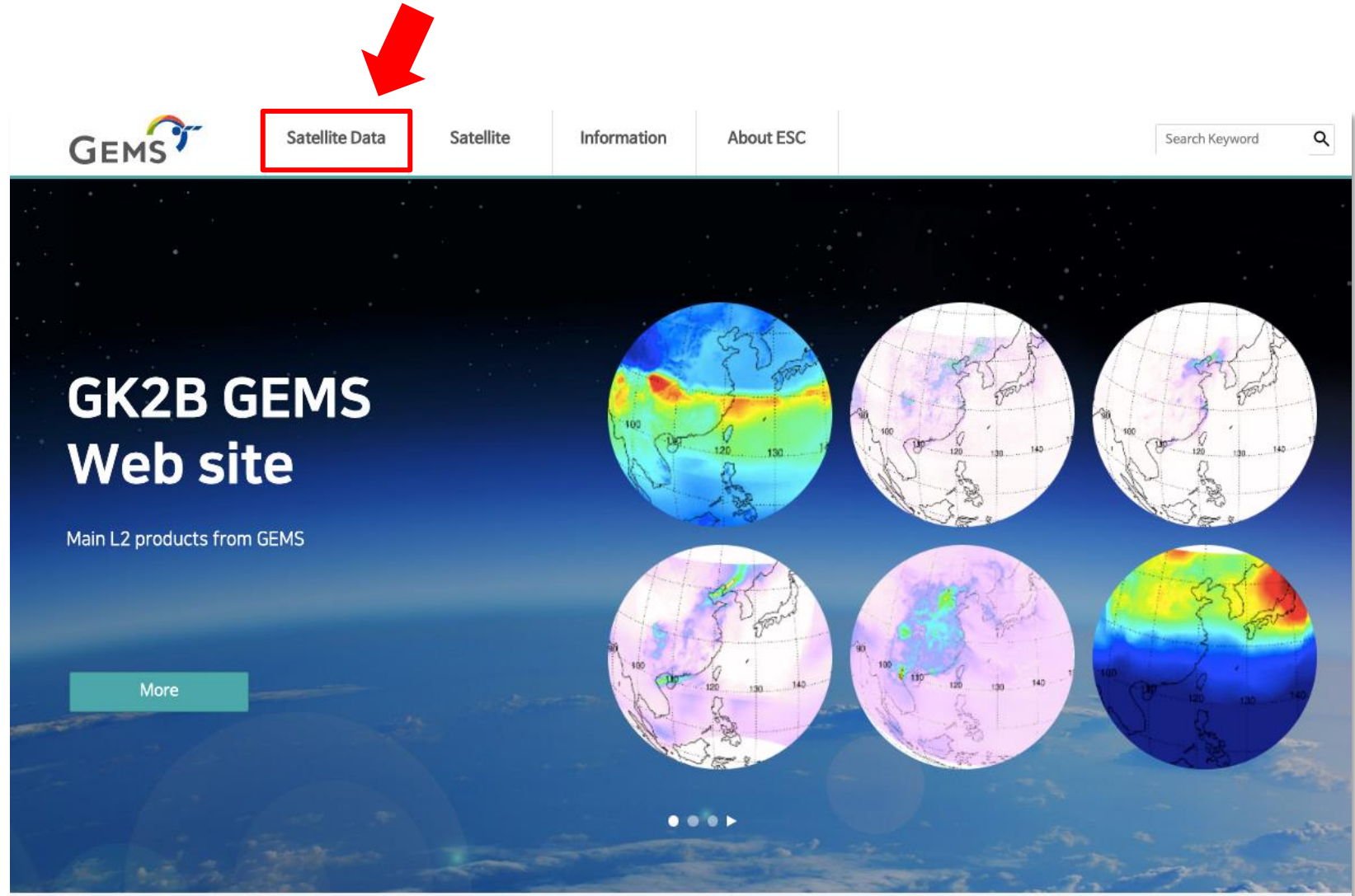


How to Access GEMS Data (1)

Step 1. Go to the National Institute of Environmental Research (NIER)- Environmental Satellite Center website: <https://nesc.nier.go.kr/>

Step 2. Click the 'Satellite Data' tab.

Note: You can find the instrument detail and products for GEMS on the 'Satellite' tab.



The screenshot shows the GEMS website interface. At the top left is the GEMS logo. To its right is a navigation menu with four tabs: 'Satellite Data' (highlighted with a red box and a red arrow pointing to it), 'Satellite', 'Information', and 'About ESC'. Further right is a search bar labeled 'Search Keyword' with a magnifying glass icon. The main content area features the text 'GK2B GEMS Web site' in large white font, followed by 'Main L2 products from GEMS' in smaller white font. Below this is a 'More' button. The background of the main content area is a dark blue space-themed image with six circular satellite data maps arranged in a 2x3 grid. At the bottom center of the main content area, there are three small white dots and a right-pointing arrow, indicating a carousel of images.



How to Access GEMS Data (2)



Satellite Data

Satellite

Information

About ESC

Search Keyword



Home / Satellite Data / Image View

Image View

Search Keyword Aerosol Optical Depth (443nm)

Level End Date

Product Select

Observation Mode All

Search

Period 2022-08-14 ~ 2022-08-16

UTC / KST UTC

Time 00:00 ~ 24:00

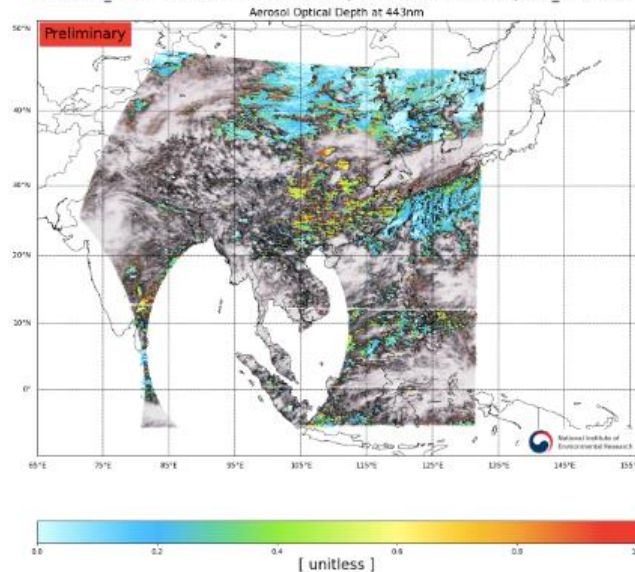
Interval 0.5s Result : [28/28]

All

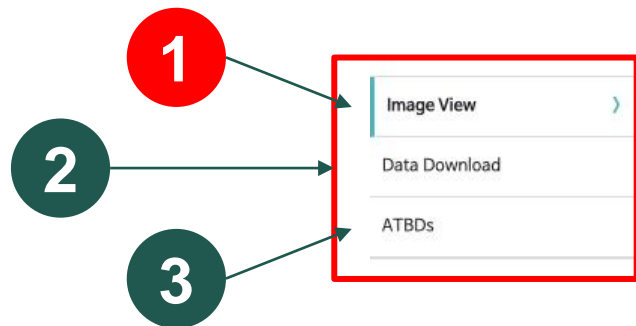
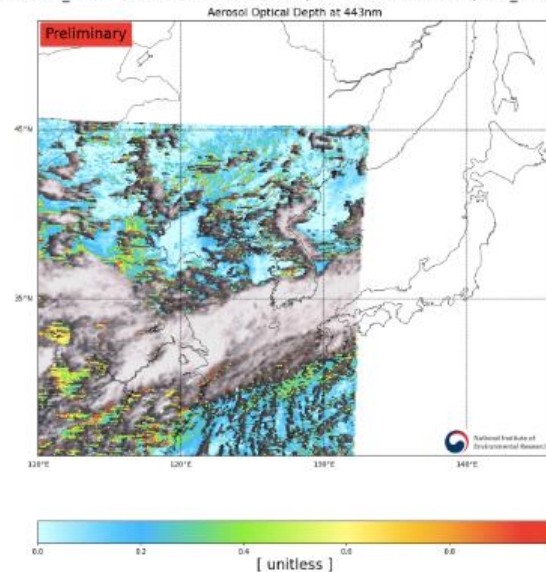
All Download

Download

GEMS L2_AERAOD 2022-08-16-07:45 UTC (2022-08-16-16:45 KST) FW_DPRO ESC



GEMS L2_AERAOD 2022-08-16-07:45 UTC (2022-08-16-16:45 KST) FW_DPRO ESC



1. View GEMS Imagery

- Begin by selecting the product of interest from the search bar, such as AOD, SSA, O3T, etc.
- Use the temporal search options to filter the data by time and date.
- You can see the image of the field of regards of GEMS and the zoomed-in area around the Korean Peninsula.

2. Download GEMS Data

3. Download ATBDs for GEMS

How to Access GEMS Data (3)



Satellite Data

Satellite

Information

About ESC

Search Keyword



Home / Satellite Data / [Data Download](#)

Data Download

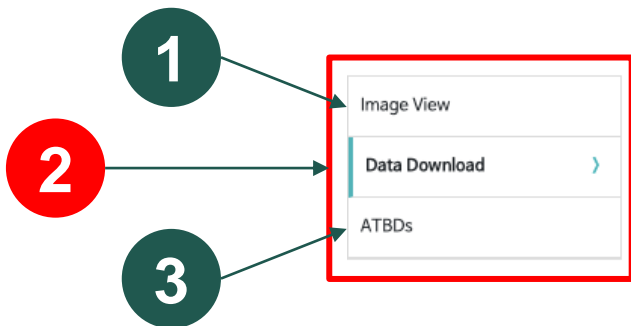
Search Keyword Level Product Observation Mode

Period UTC / KST Time

Total 100 item

<input type="checkbox"/>	No	File Name	Level	Product	File Size	Date (UTC)	Download
<input type="checkbox"/>	1	GK2_GEMS_L2_20220816_2345_UVI_HK_DPRO_ORI.nc	L2	UVI,UVI_Plant,UVI_DNA,UVI_VitaminD	84.1MB	2022-08-16 23:45:00	↓
<input type="checkbox"/>	2	GK2_GEMS_L2_20220816_2345_AERAOD_HK_DPRO_ORI.nc	L2	AERAOD354,AERAOD443,AERAOD550,AERTYPE,SS A443,UVAI,VISAI	154.6MB	2022-08-16 23:45:00	↓
<input type="checkbox"/>	3	GK2_GEMS_L2_20220816_2345_O3T_HK_DPRO_ORI.nc	L2	O3T	878.4MB	2022-08-16 23:45:00	↓
<input type="checkbox"/>	4	GK2_GEMS_L2_20220816_2345_CLOUD_HK_DPRO_ORI.nc	L2	ECF,CRF,CCP	84.1MB	2022-08-16 23:45:00	↓
<input type="checkbox"/>	5	GK2_GEMS_L2_20220816_2345_SO2_HK_DPRO_BIN2x2.nc	L2	SO2	181.7MB	2022-08-16 23:45:00	↓
<input type="checkbox"/>	6	GK2_GEMS_L2_20220816_2245_AERAOD_HE_DPRO_ORI.nc	L2	AERAOD354,AERAOD443,AERAOD550,AERTYPE,SS A443,UVAI,VISAI	154.6MB	2022-08-16 22:45:00	↓
<input type="checkbox"/>	7	GK2_GEMS_L2_20220816_2245_O3T_HE_DPRO_ORI.nc	L2	O3T	878.4MB	2022-08-16 22:45:00	↓
<input type="checkbox"/>	8	GK2_GEMS_L2_20220816_2245_SO2_HE_DPRO_BIN2x2.nc	L2	SO2	181.7MB	2022-08-16 22:45:00	↓
<input type="checkbox"/>	9	GK2_GEMS_L2_20220816_2245_CLOUD_HE_DPRO_ORI.nc	L2	ECF,CRF,CCP	84.1MB	2022-08-16 22:45:00	↓
<input type="checkbox"/>	10	GK2_GEMS_L2_20220816_2245_UVI_HE_DPRO_ORI.nc	L2	UVI,UVI_Plant,UVI_DNA,UVI_VitaminD	84.1MB	2022-08-16 22:45:00	↓

10 2 3 ... 10



1. View GEMS Imagery
2. Download GEMS Data
 - Use the temporal search options to filter the data by time and date.
 - Click the Download button to begin downloading GEMS data.
 - You can download multiple files using checkboxes.

3. Download ATBDs for GEMS



GEMS NetCDF4 File Naming Conventions

- **SAT_Instrument_Level_Date_Time_ALG_Area_ProcessType.Extension**
- i.e., **GK2_GEMS_L2_20210705_2245_AERAOD_HE_DPRO_ORI.nc**
 - SAT: Satellite name, GK2B (GEO-KOMPSAT 2B: Geostationary Korea Multi-Purpose Satellite)
 - Instrument: Instrument name, GEMS
 - Level: Data processing level, L2
 - Date: Observation date
 - Time: Start time of GEMS observation
 - ALG: Algorithm name
 - Area: GEMS scan area
 - Process Type: L2, including (DPRO: Daytime processing, NPRO: Night-time processing, RPRO: Re-processing)
 - Extension: File format, NC (NetCDF4 file)



GEMS AERAOD (Aerosol) Data Description

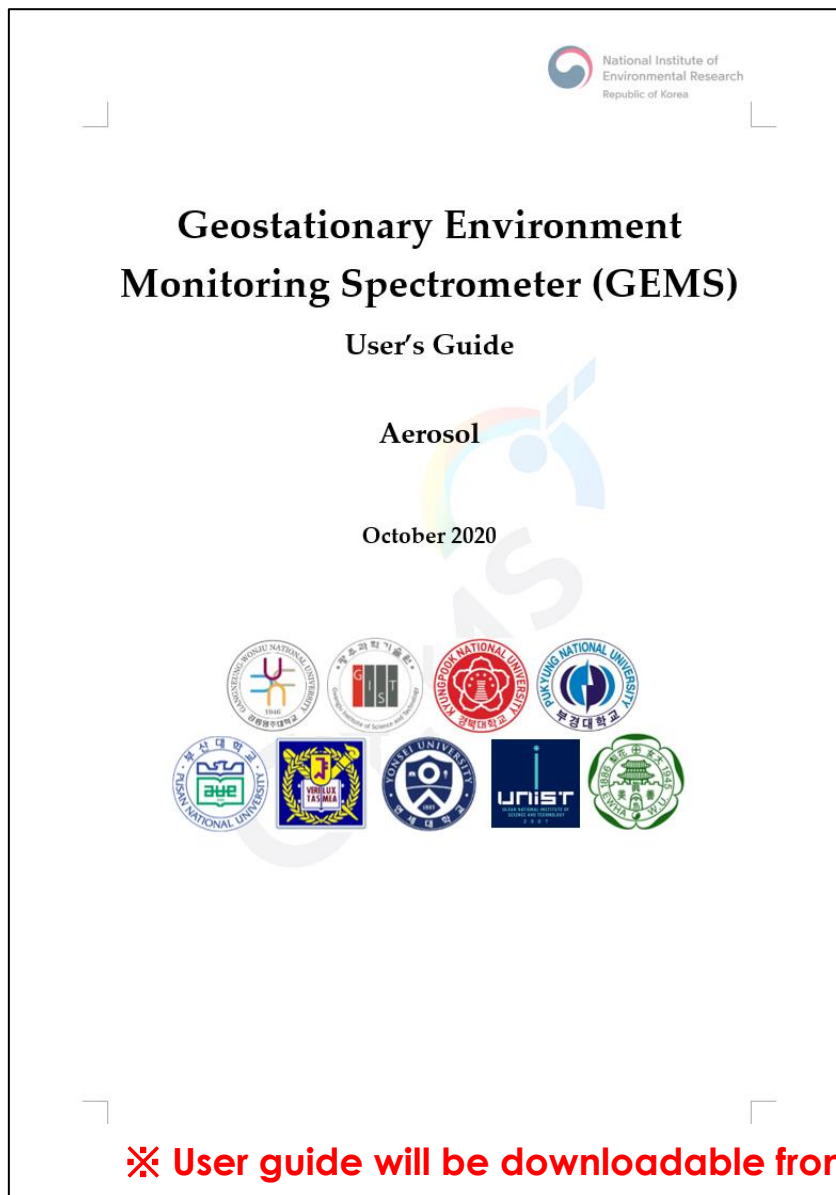
Satellite Variables

Name	Long Name	Type
▼ GK2_GEMS_L2_20210705_2245_AERAOD_HE_DPRO...	GK2_GEMS_L2_20210705_2245_AERAOD_HE_DPRO_ORI.nc	Local File
▼ Data_Fields	Data_Fields	—
AbsAerosolOpticalDepth	AbsAerosolOpticalDepth	2D
AerosolType	AerosolType	Geo2D
AprAerosolOpticalDepth	AprAerosolOpticalDepth	Geo2D
AprAerosolSingleScattAlb	AprAerosolSingleScattAlb	Geo2D
FinalAerosolLayerHeight	FinalAerosolLayerHeight	Geo2D
FinalAerosolOpticalDepth	FinalAerosolOpticalDepth	2D
FinalAerosolSingleScattAlb	FinalAerosolSingleScattAlb	2D
FinalAlgorithmFlags	FinalAlgorithmFlags	Geo2D
NormalizedRadiance	NormalizedRadiance	2D
UVAerosolIndex	UVAerosolIndex	Geo2D
VISAerosolIndex	VISAerosolIndex	Geo2D
▼ Geolocation_Fields	Geolocation_Fields	—
GroundPixelQualityFlags	GroundPixelQualityFlags	Geo2D
Latitude	Latitude	2D
Longitude	Longitude	2D
RelativeAzimuthAngle	RelativeAzimuthAngle	Geo2D
SolarZenithAngle	SolarZenithAngle	Geo2D
TerrainHeight	TerrainHeight	Geo2D
Time	Time	1D
ViewingZenithAngle	ViewingZenithAngle	Geo2D
▼ METADATA	METADATA	—
▼ ALGORITHM_SETTINGS	METADATA/ALGORITHM_SETTINGS	—

GEMS Aerosol L2 file structure

```
File "GK2_GEMS_L2_20210705_2245_AERAOD_HE_DPRO_ORI.nc"
File type: Hierarchical Data Format, version 5
netcdf file:/C:/Users/yes1/Desktop/GK2_GEMS_L2_20210705_2245_AERAOD_HE_DPRO_ORI.nc {
dimensions:
  nwave1 = 3;
  image = 347;
  spatial = 2048;
  nwave17 = 4;
  nwave16 = 6;
group: METADATA {
group: ALGORITHM_SETTINGS {
  // group attributes:
  :product_version = "v1.0.3";
  :nwave17 = 3.1E-5f, 3.54E-5f, 4.43E-5f, 5.5E-5f; // float
  :UVAerosolIndex_Wavelength_Pair = "354/368 nm";
  :VISAerosolIndex_Wavelength_Pair = "477/490 nm";
  :AprAerosolOpticalDepth_Wavelength = 4.43E-5f; // float
  :AprAerosolSingleScattAlb_Wavelength = 4.43E-5f; // float
  :AerosolType = "1: High absorbing fine,2: Dust,3: Non-absorbing";
  :UVAerosolIndex_Unit = "Unitless";
  :VISAerosolIndex_Unit = "Unitless";
  :FinalAerosolOpticalDepth_Unit = "Unitless";
  :FinalAerosolSingleScattAlb_Unit = "Unitless";
  :FinalAerosolLayerHeight_Unit = "km";
  :AbsAerosolOpticalDepth_Unit = "Unitless";
  :AprAerosolOpticalDepth_Unit = "Unitless";
  :AprAerosolSingleScattAlb_Unit = "Unitless";
  :FinalAlgorithmFlags_Unit = "Unitless";
  :AerosolType_Unit = "Unitless";
  :NormalizedRadiance_Unit = "Unitless";
  :GroundPixelQualityFlags_Unit = "Unitless";
  :Latitude_Unit = "Degree";
  :Longitude_Unit = "Degree";
  :SolarZenithAngle_Unit = "Degree";
  :RelativeAzimuthAngle_Unit = "Degree";
  :ViewingZenithAngle_Unit = "Degree";
  :Time_Unit = "Seconds since 1 January 2000 12:00:00 UTC";
  :SFC_file_name = "GK2_GEMS_20160115_030000_sfc_no_L2_ysu_QFlagInt16_new.nc";
  :Radiance_file_name = "GK2_GEMS_L1C_20210705_2245_CAO_NOR_693_ORI.nc";
  :Irradiance_file_name = "GK2_GEMS_IRR_20210705_ORI.nc";
```

GEMS AERAOD (Aerosol) Data Description – Quality Flag



quality of retrieval is reliable. If bits are 1, 10, 11, or 12, the quality of retrieval is less reliable.

Table 2. Quality flags for the GEMS Aerosol L2 file.

Bits	Definition	Note	Description
0	Reliable (AOD, SSA, ALH)	Good	(0, Good; 1 : have issue) AOD > 0.2 & ALH AK > 0.2
1	Less reliable (AOD, SSA, ALH)	Suspect	AOD < 0.2 or ALH AK < 0.2
2	Out-of-bounds SSA or AOD at 443 nm.	Bad	AOD < -0.05 or AOD > 3.6 or SSA < 0.82 or SSA > 1.0
3	OE fitting error	Bad	Fitting error during optimal estimation.
4	Normalized radiance above threshold	Bad	High normalized radiance
5	Surface albedo above threshold	Bad	High surface albedo
6	Cloud masking	Cloud	Presence of clouds
7	Solar zenith angle above threshold (69°) or viewing zenith angle above threshold (69°).	Bad	SZA > 69° or VZA > 69°
8	Sun-glint angle below threshold over water	Bad	Sun glint angle < 30°
9	Terrain height high	Suspect	Terrain height > 2 km
10	Previous L2 SFC (-5day) are used	Suspect	Absence of L2 SFC information
11	OMI climatology used for surface albedo	Suspect	Absence of L2 SFC information
12	Previous irradiance used	Suspect	Absence of L1C irradiance
13	AMI cloud-masking used	Cloud	Cloud masking using AMI L2 Cloud product.

Table 3. The example of a quality flag of 2561.

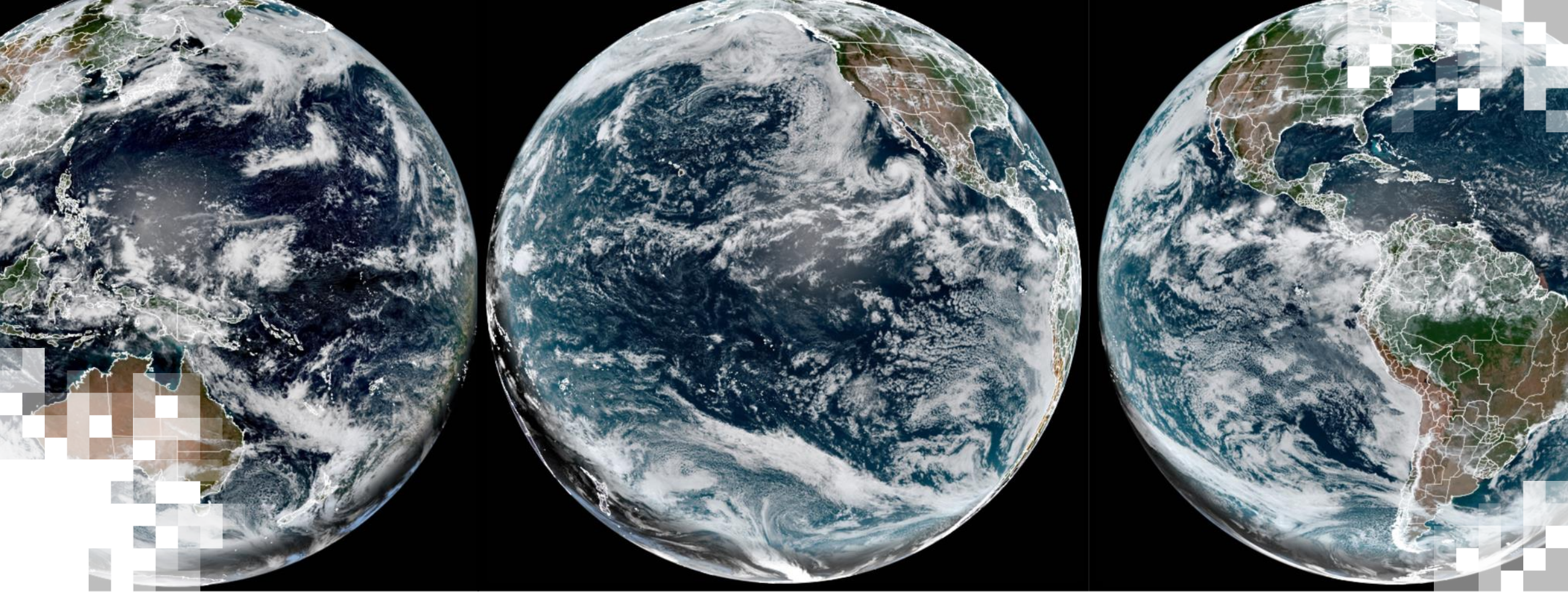
Bits	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	0	0	1	0	1	0	0	0	0	0	0	0	0	1
	$2^0 + 2^9 + 2^{11} = 1 + 512 + 2048 = 2561$													

2.2.9 NormalizedRadiance
Normalized radiance [steradian⁻¹]

8

※ User guide will be downloadable from the ESC website: <https://nesc.nier.go.kr>





4. Python Jupyter Notebooks Exercise to Read, Map, and Analyze GEMS Data



Thank You!

