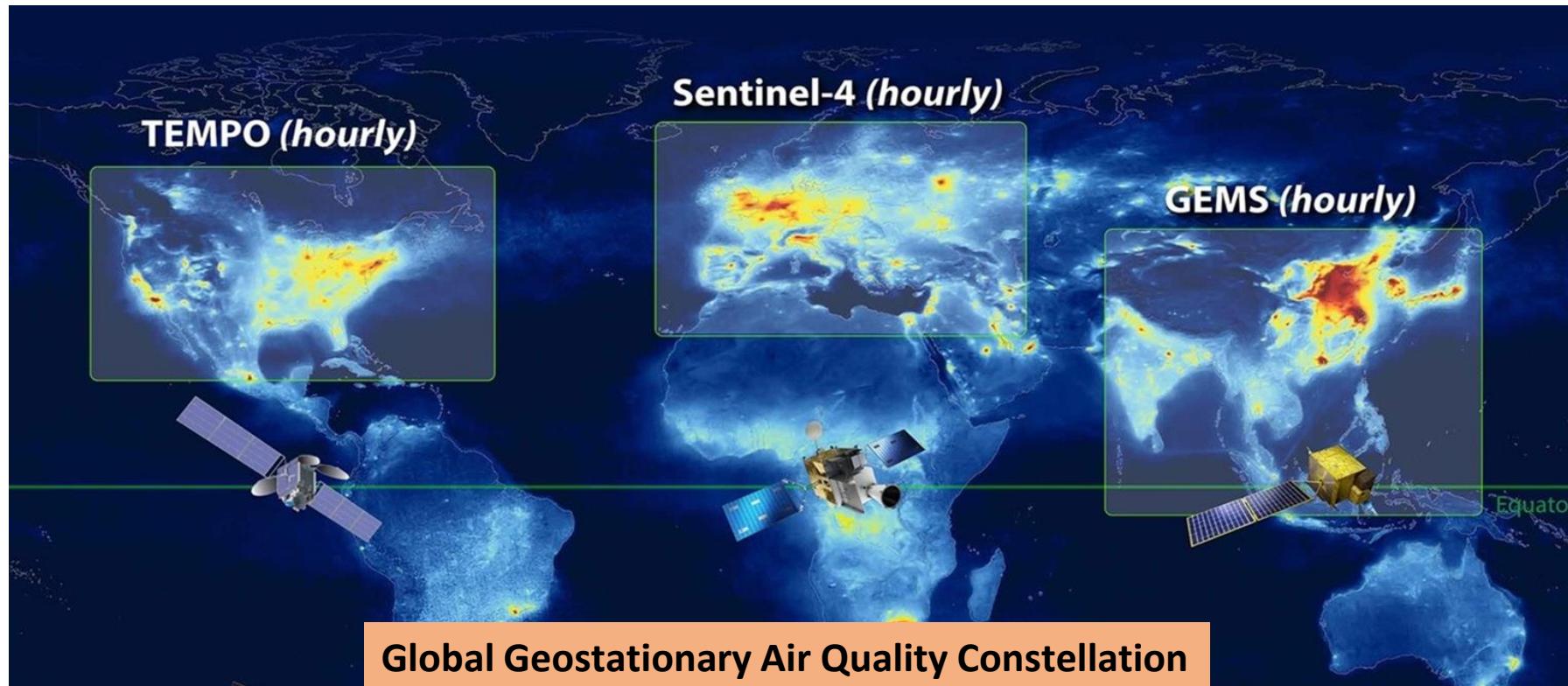


Assessment of GEMS Aerosol Product Suite

Pubu Ciren¹ and Shobha Kondragunta²

1 IMSG@NOAA 2 NOAA/NESDIS/STAR



Approach:

- Time period: 01/01/2021-09/30/2022 Version: 1.0 Resolution: ORI
- Evaluation strategy:
 - a) Aerosol Layer Height (ALH)
 - Collocated GEMS observations with CALIPSO observations
 - Temporal: ± 30 minutes
 - Spatial: within a box of 4 by 8 km centered with CALIPSO profile
 - CALIPSO Aerosol/Cloud Layer/Aerosol Profile 5 km products are used.
 - Compared GEMS ALH with CALIPSO ALH
 - For different range of GEMS AODs:
Low: $AOD < 0.4$; Medium: $0.4 \leq AOD < 0.8$; High: $AOD \geq 0.8$
 - For different number of aerosol layers identified by CALIPSO
Single layer; Multi-layers
 - For different aerosol types identified by GEMS aerosol product
High absorbing Fine; Dust; Non Absorbing
 - For different range of SSA from GEMS aerosol product
 $SSA < 0.9$; $SSA > 0.95$

Approach:

b) Aerosol Optical Depth

- Collocated GEMS observations with AERONET (Version 3) observations
 - Temporal: ± 30 minutes
 - Spatial: with a radius of 25 km and centered on AERONET stations
- Regional performances are analyzed.

c) UVAl, Aerosol Type etc.

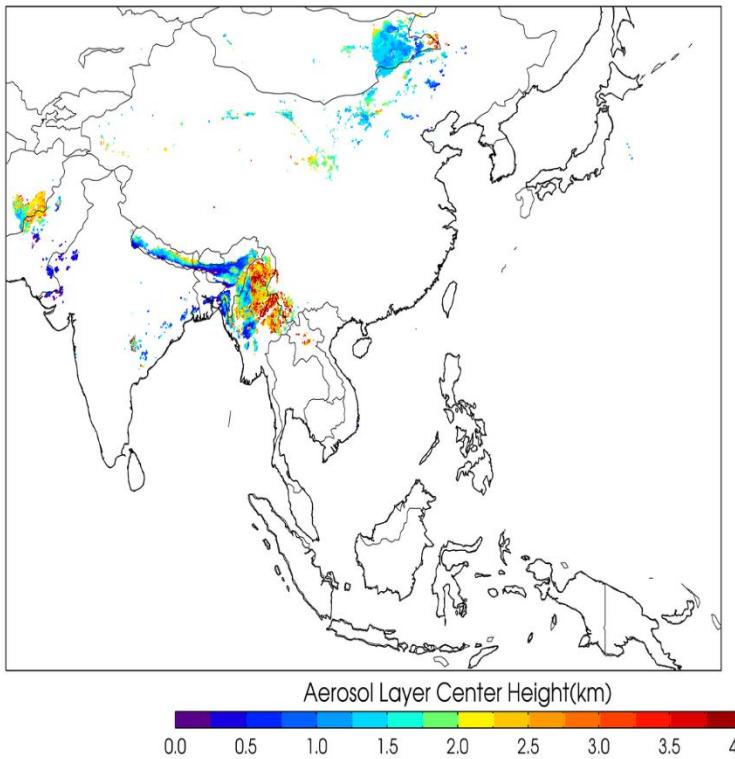
- Qualitative evaluations are carried out for aerosol events including both large and small smoke plumes, dust outbreaks, and smog events.
- Comparisons between GEMS aerosol product with products from other satellite instruments, such as TROPOMI and VIIRS.

Dust storm event: 03/27~03/29/2021

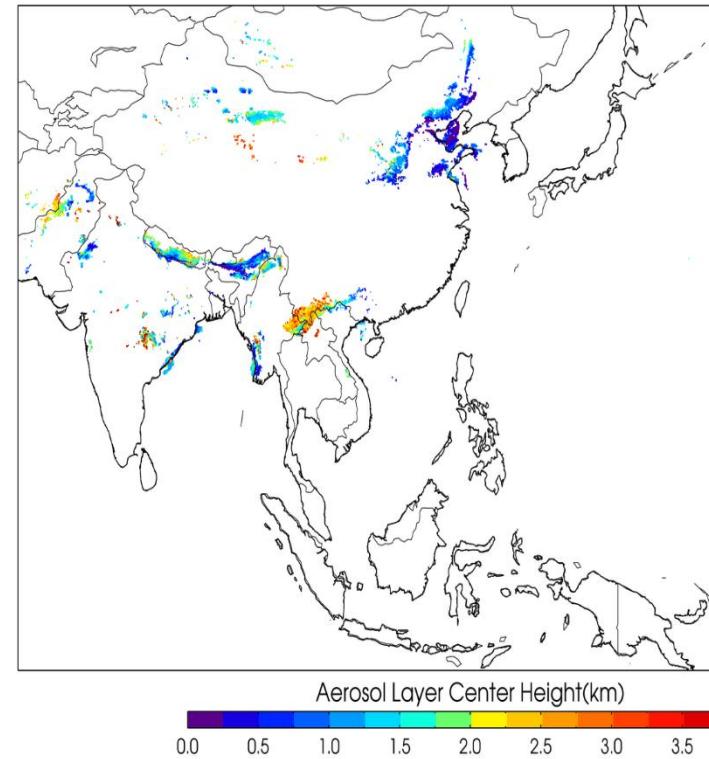
Hourly vs. Daily

S5P TROPOMI ALH

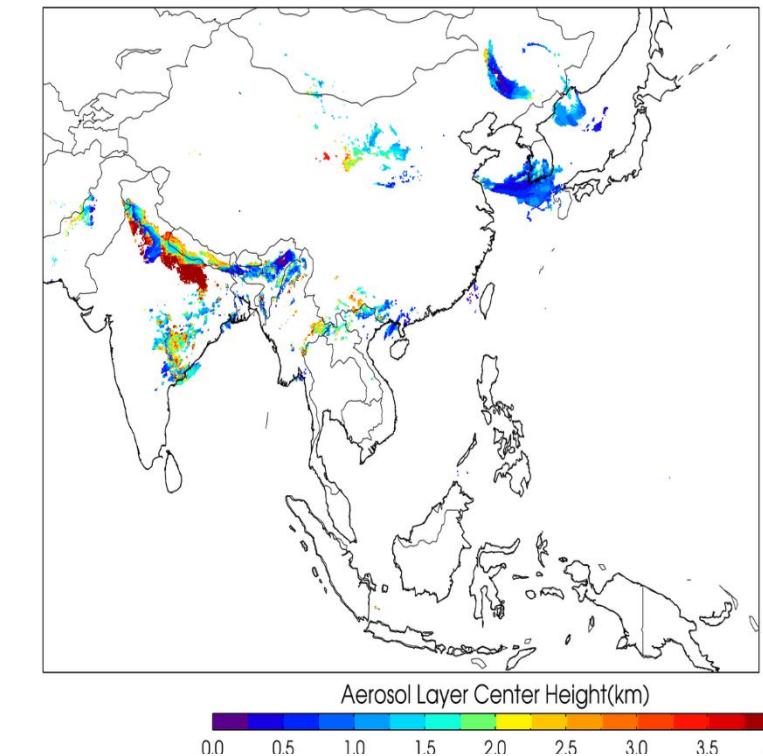
20210327



20210328



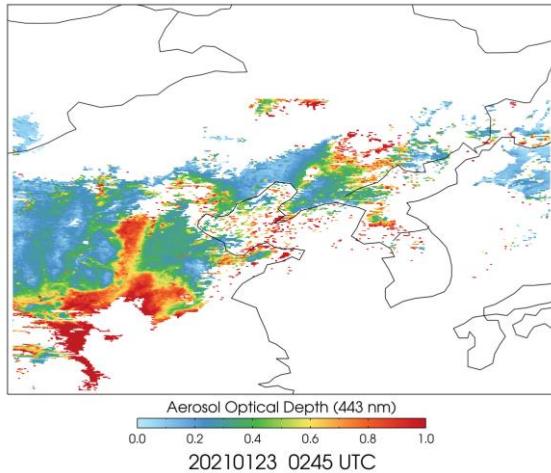
20210329



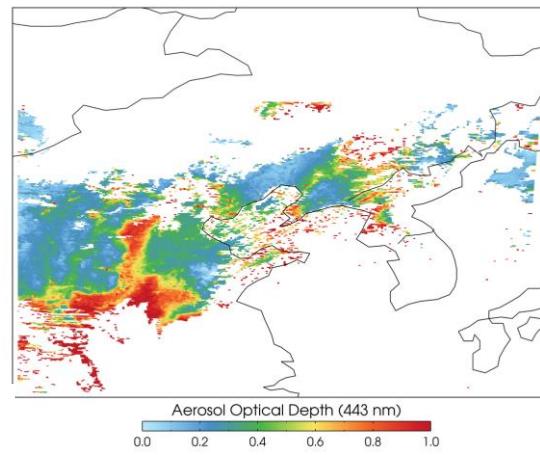
Once a day, and much less spatial coverage than GEMS ALH.

Smog over China : 01/23/2021

20210123 0245 UTC

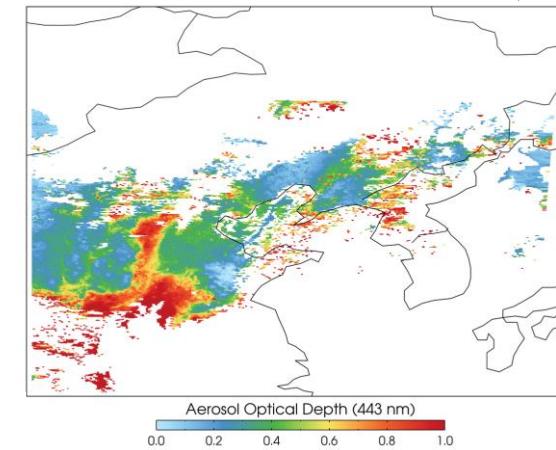


20210123 0345 UTC

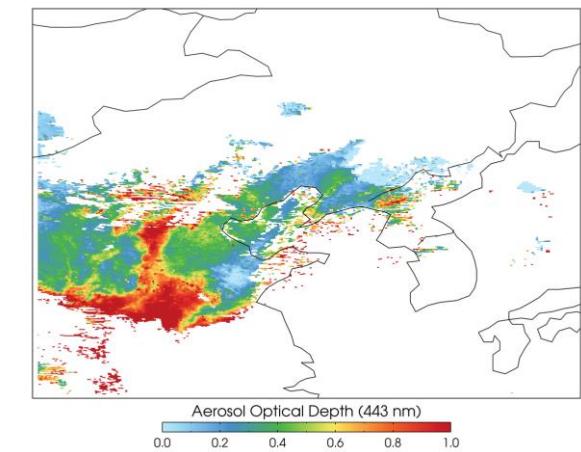


Growing plumes !

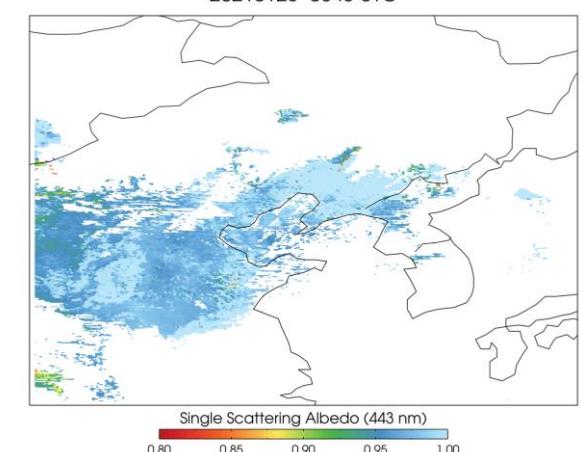
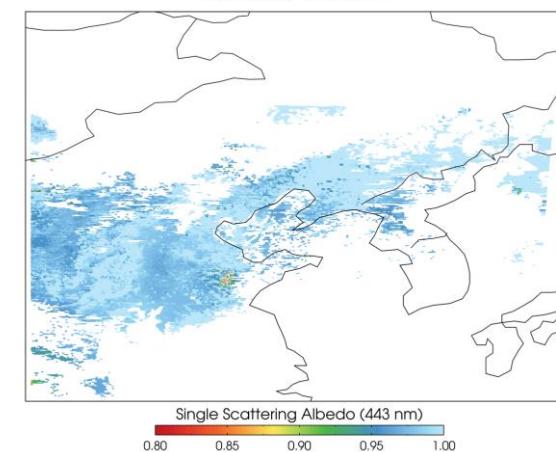
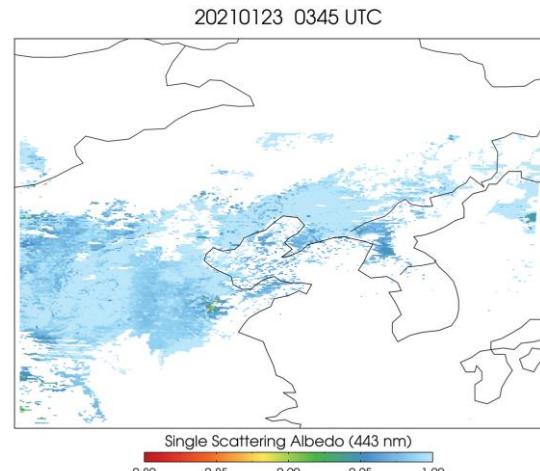
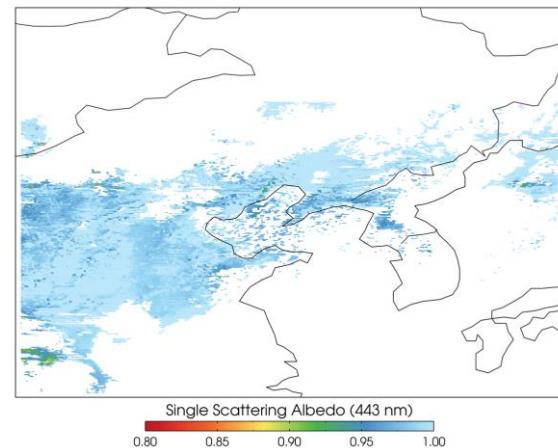
20210123 0445 UTC



20210123 0545 UTC

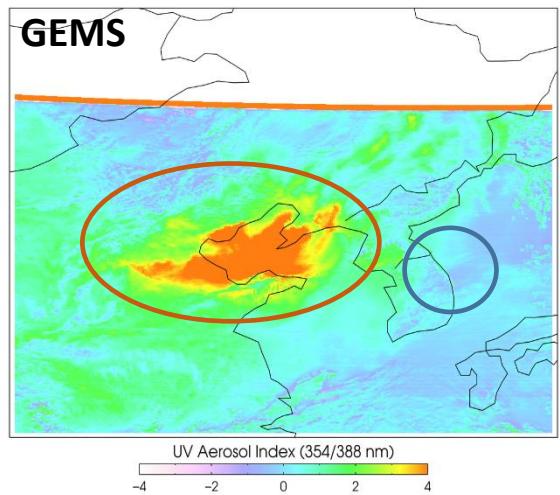


Non-absorbing plumes !

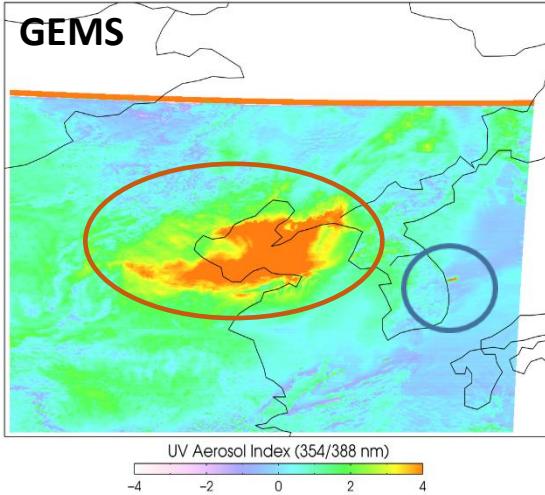


UV Aerosol Index: dust and smoke (03/04/2022)

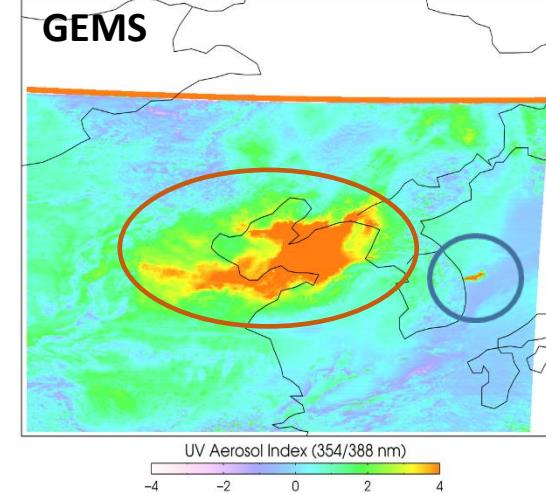
20220304 0245 UTC



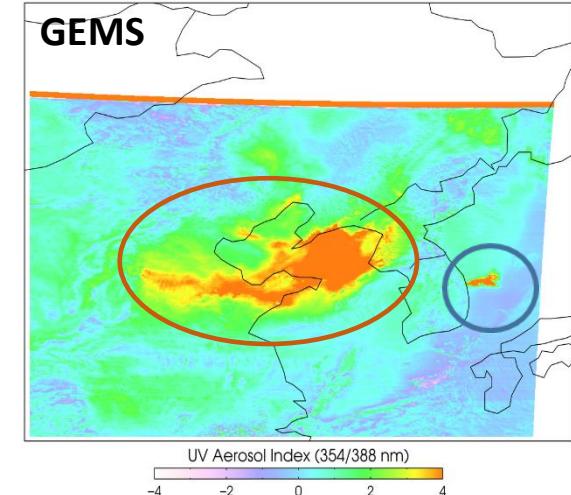
20220304 0345 UTC



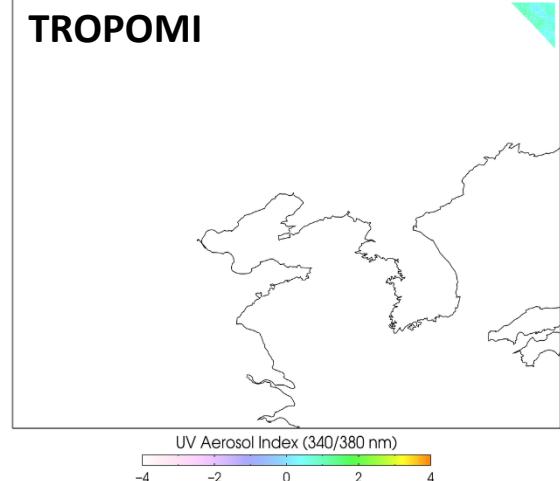
20220304 0445 UTC



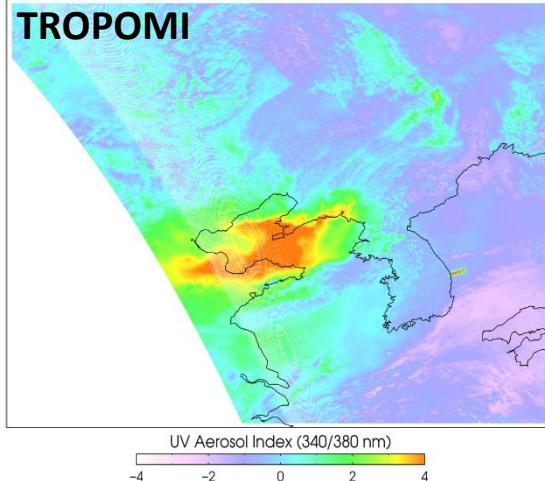
20220304 0545 UTC



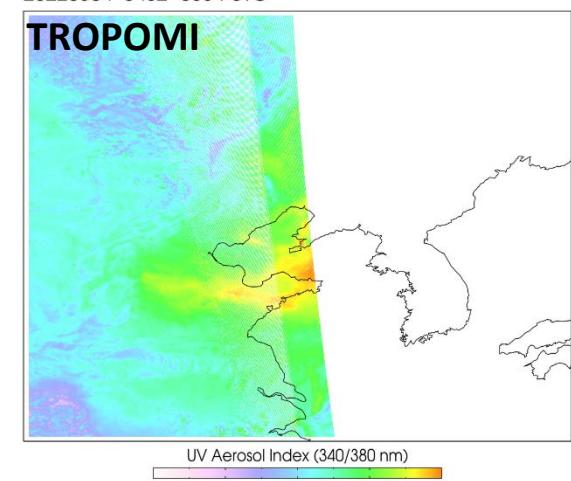
20220304 0129–0311 UTC



20220304 0311–0452 UTC



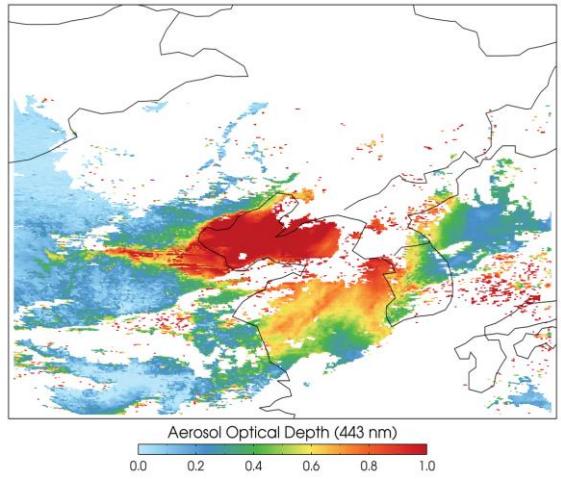
20220304 0452–0634 UTC



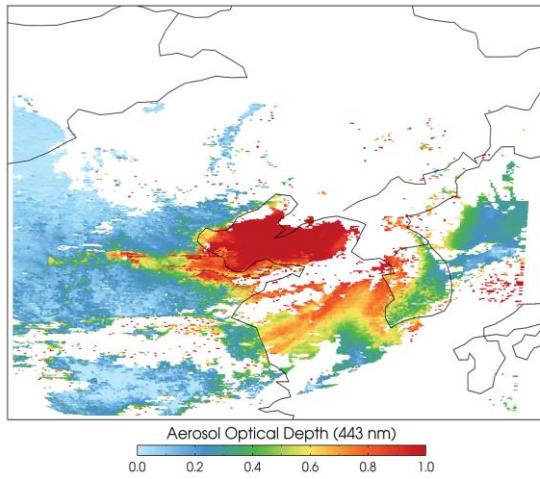
- **GEMS UVAI is able to capture absorbing aerosol plumes, such as a large dust plume and also a small scale smoke plume very well. The advantage of GEMS hourly observations is clearly seen by comparing to the similar UVAI from TROPOMI.**

Aerosol Type: dust and smoke (03/04/2022)

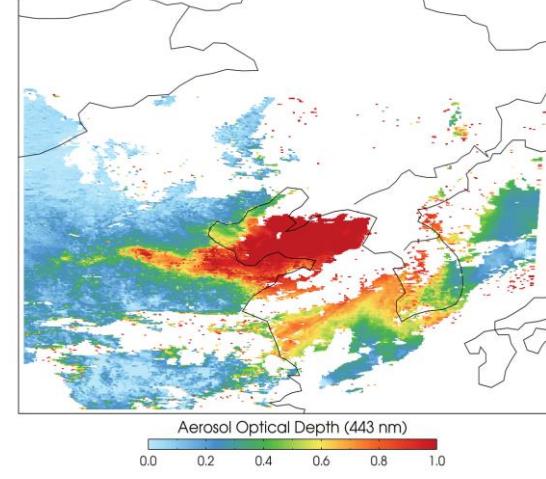
20220304 0245 UTC



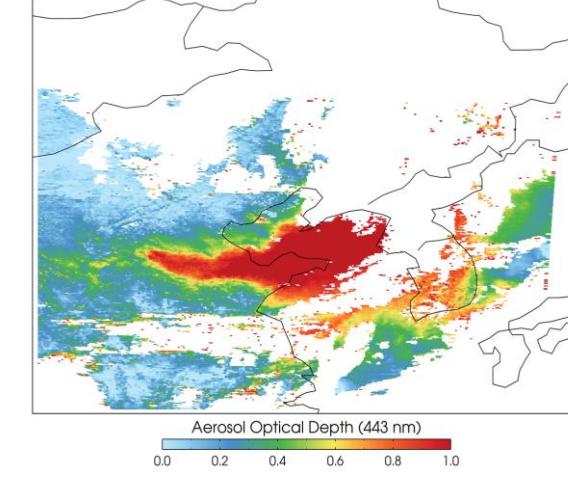
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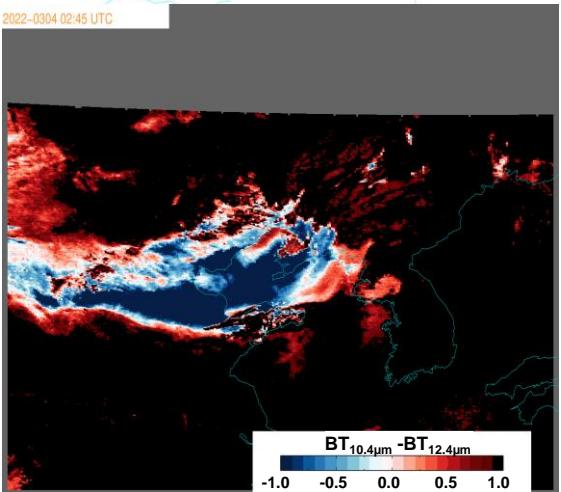
20220304 0445 UTC



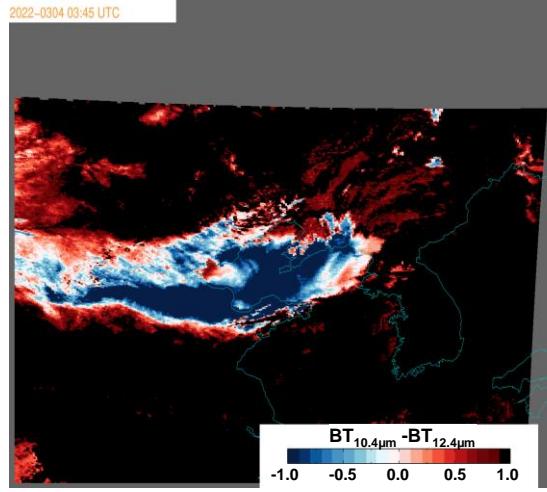
20220304 0545 UTC



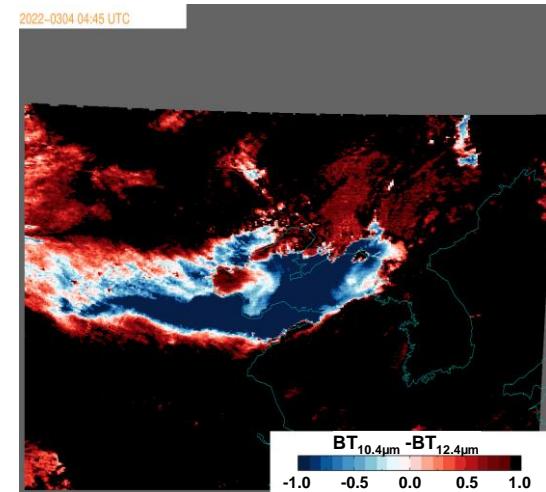
2022-0304 02:45 UTC



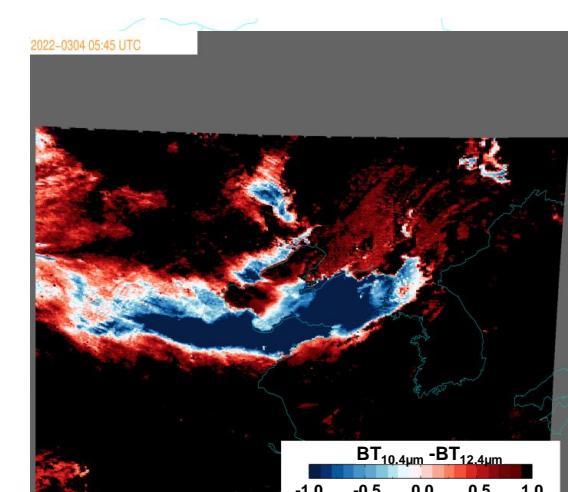
2022-0304 03:45 UTC



2022-0304 04:45 UTC



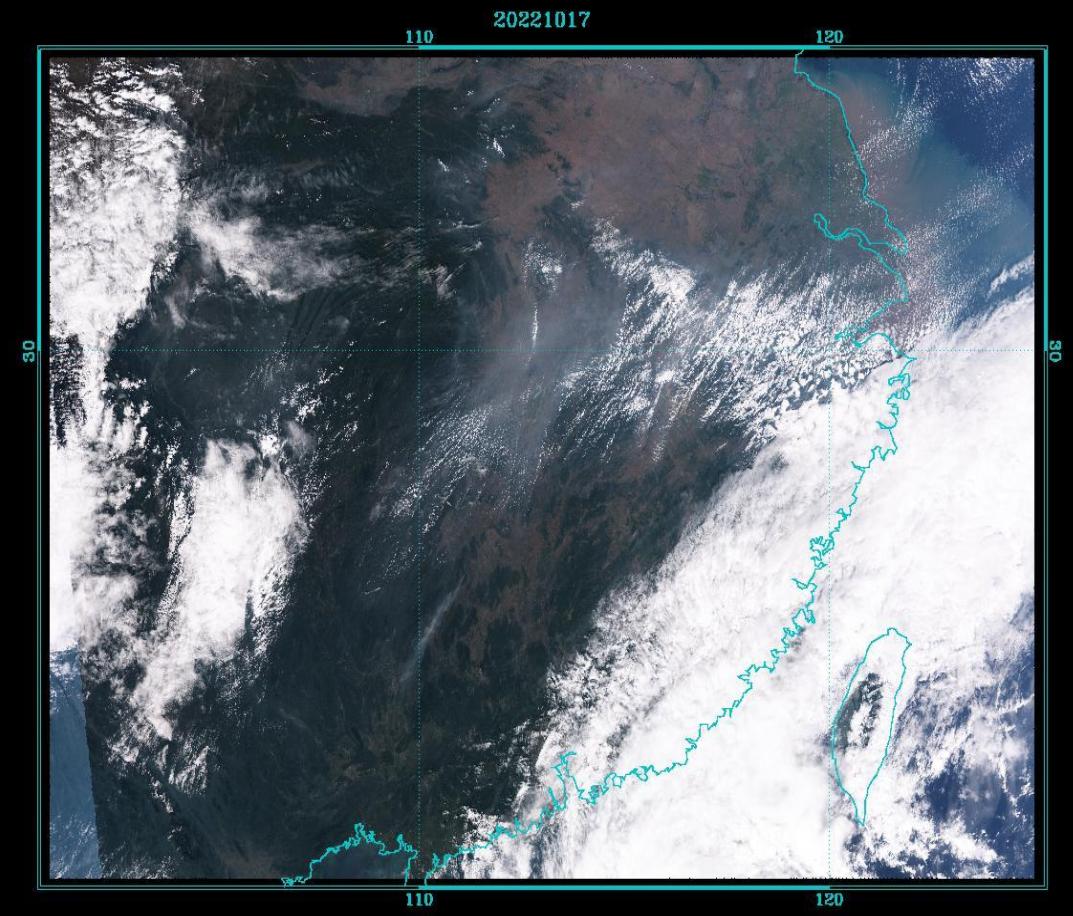
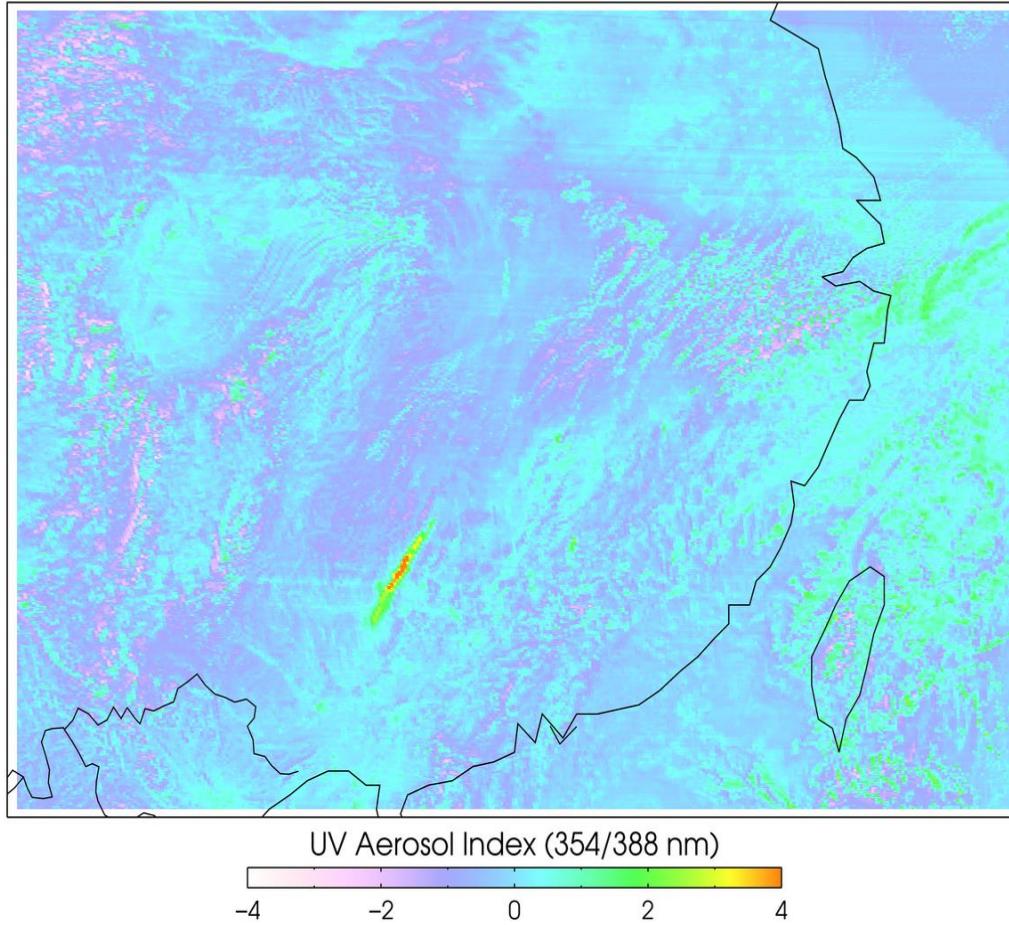
2022-0304 05:45 UTC



- Aerosol type in GEMS AOD product is able to identify dust plumes as dust aerosol, however, coverage is smaller than that seen in the AHI RGB images, other part of dust plumes is identified as “High Absorbing Fine mode” aerosol.
- GEMS AOD shows a consistent coverage of high AOD with dust plumes seen in AHI RGB images.

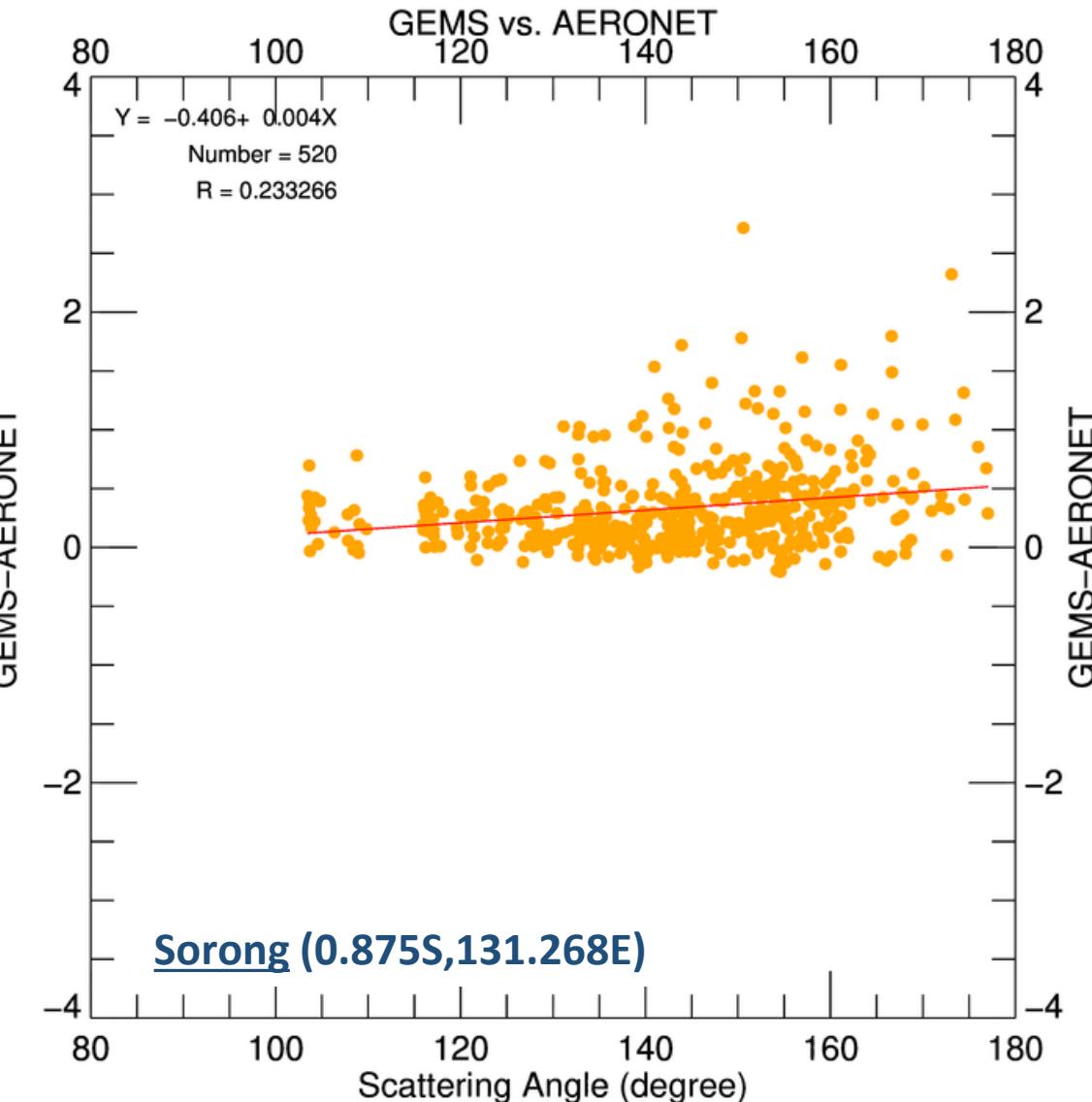
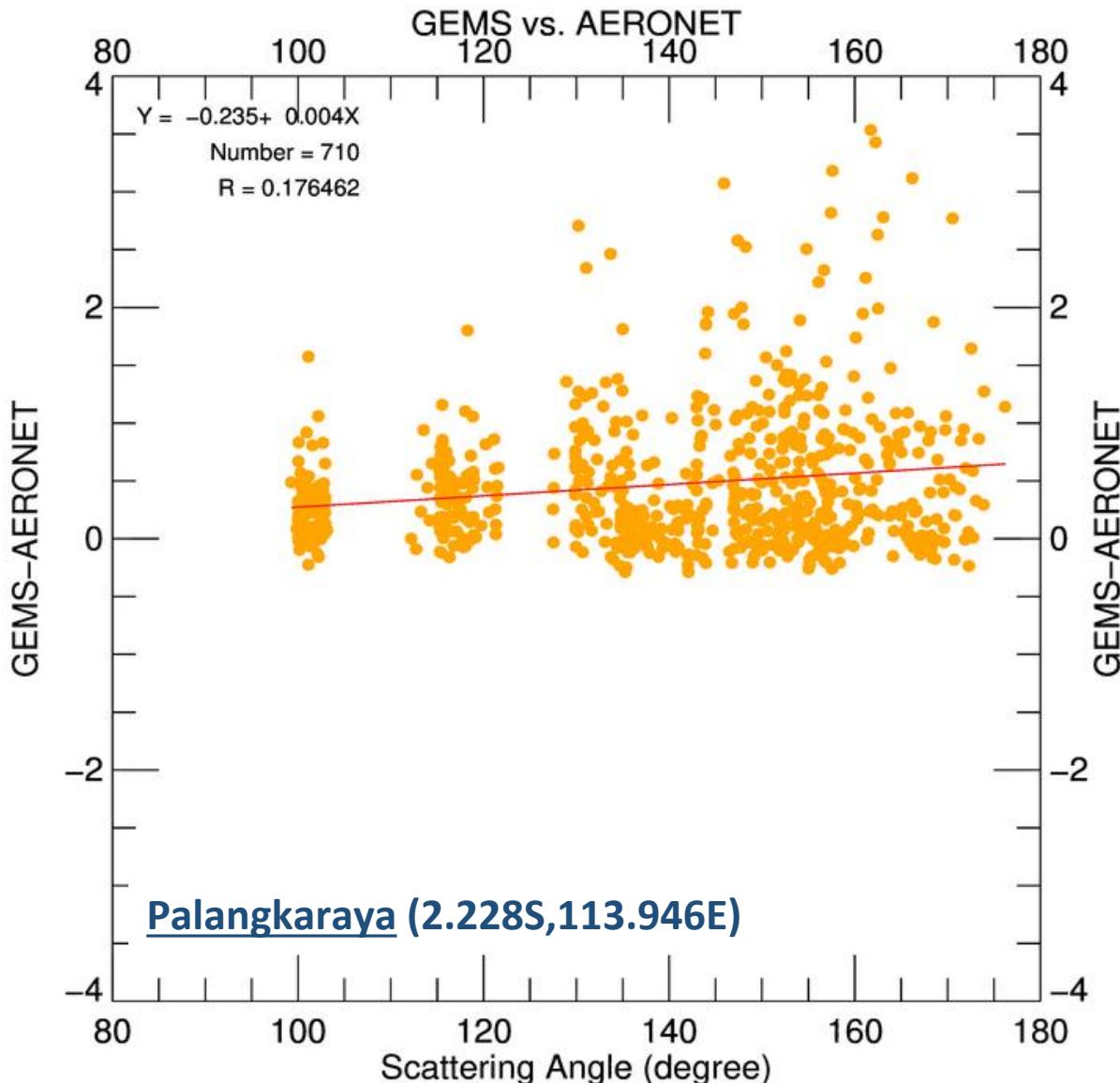
Smoke over Southern China: 10/17/2022

20221017 0545 UTC



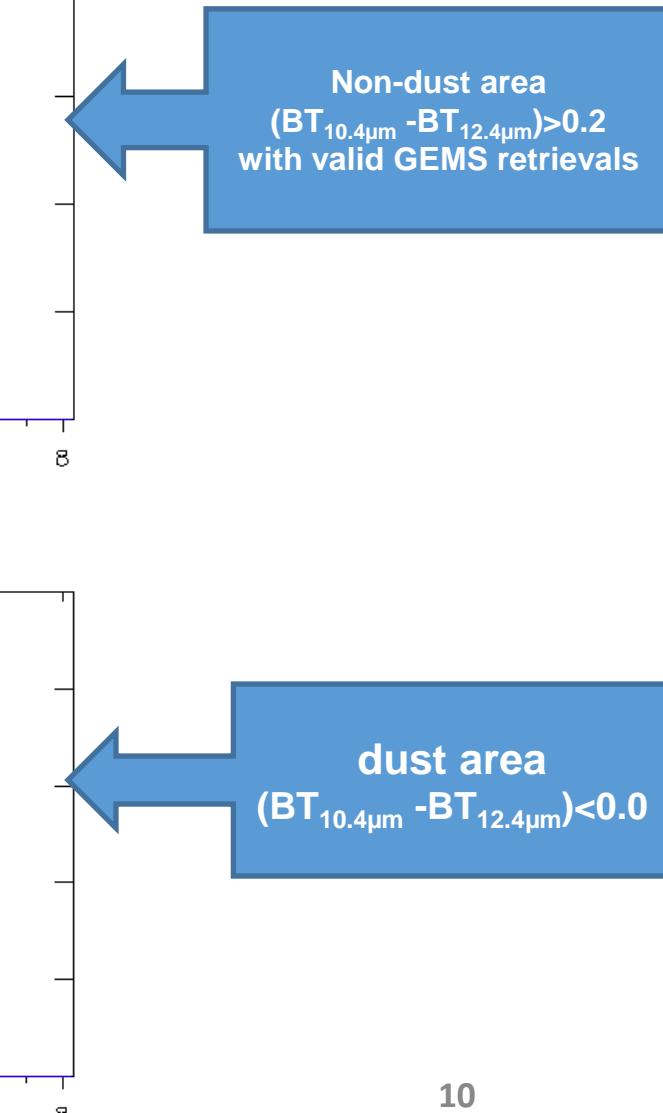
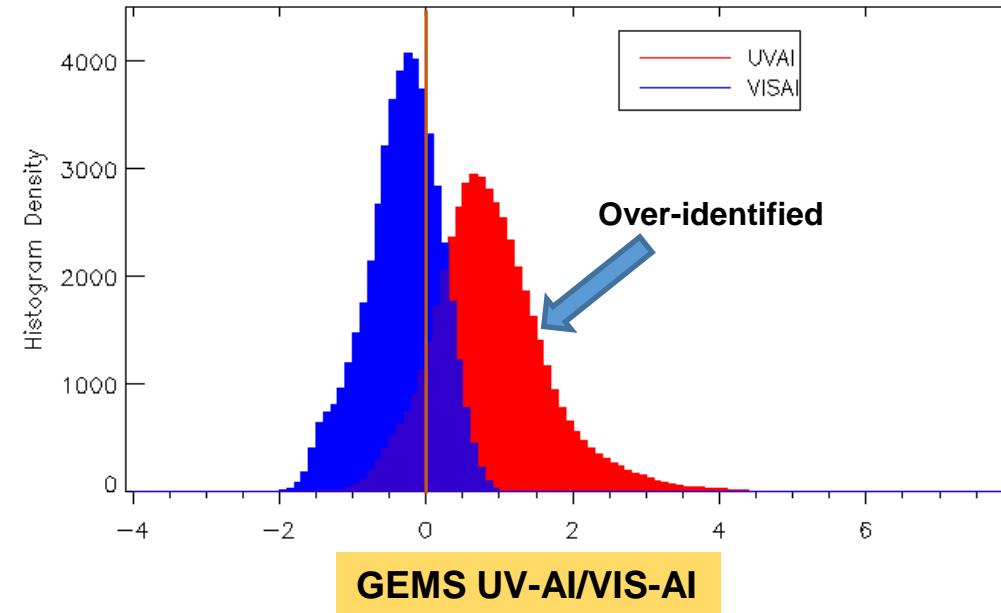
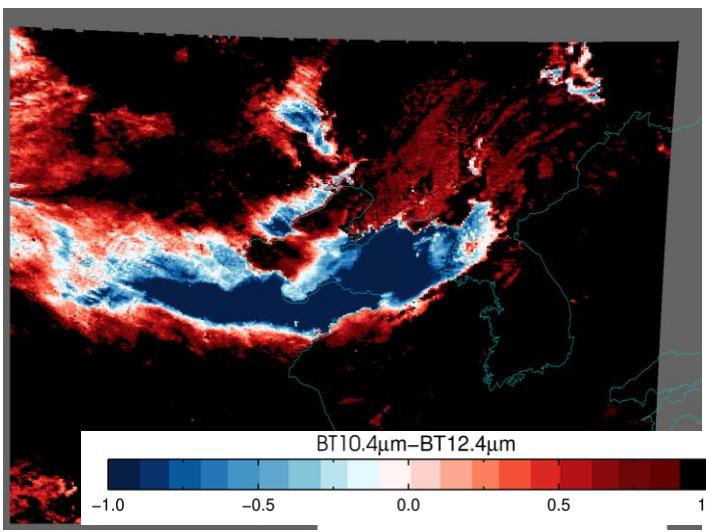
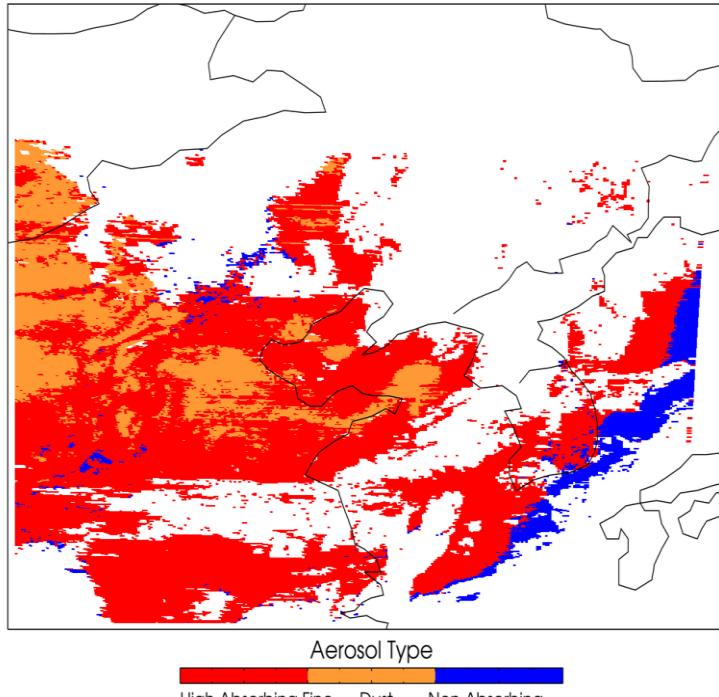
- GEMS AOD shows a very similar spatial pattern as NOAA 20 VIIRS AOD, even for the small scale plumes from forest fire.
- However, Striping and noisy pixels are seen in GEMS AOD, which may be related to calibration issues and cloud contamination.

Evaluation of GEMS AOD: Regional performance



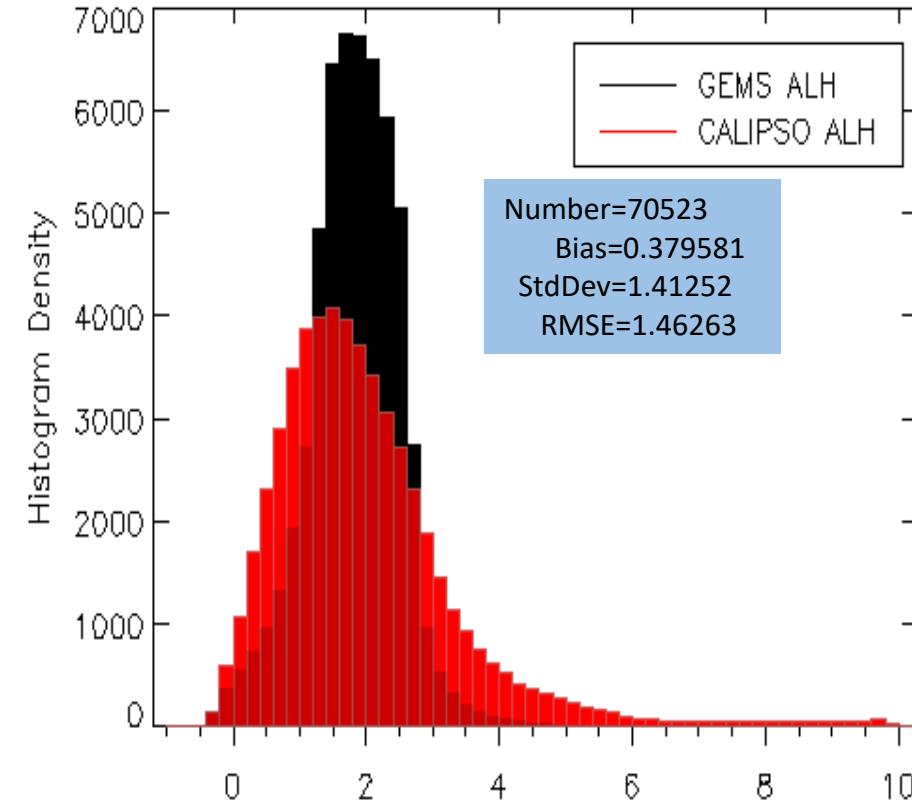
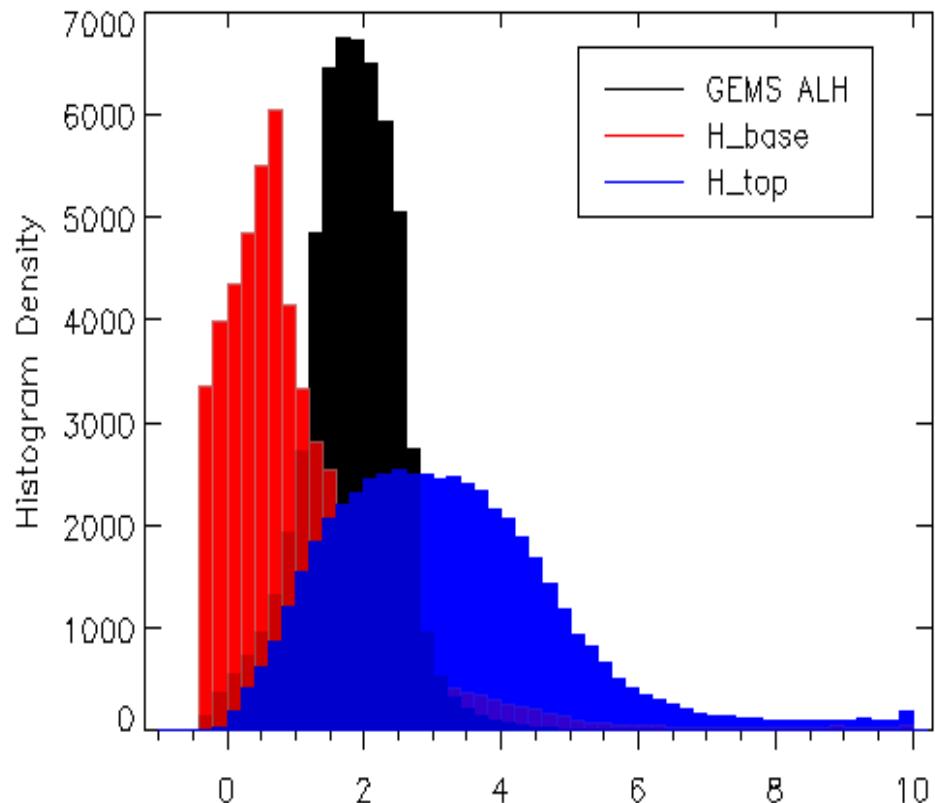
Evaluation of Aerosol Type Selection

20220304 0545 UTC



GEMS ALH

Time period: 01/01/2021-09/30/2022



- GEMS ALH is shown as sitting in the middle between top and base height of aerosol layer from CALIPSO.
- For some thin and sporadic layer of aerosol identified in CALIPSO, GEMS gives higher ALH. Cloud contaminations?
- In general, GEMS ALH has a slight overestimation, with a mean bias of 0.38 km, but a relatively large RMSE of ~1.5 km.

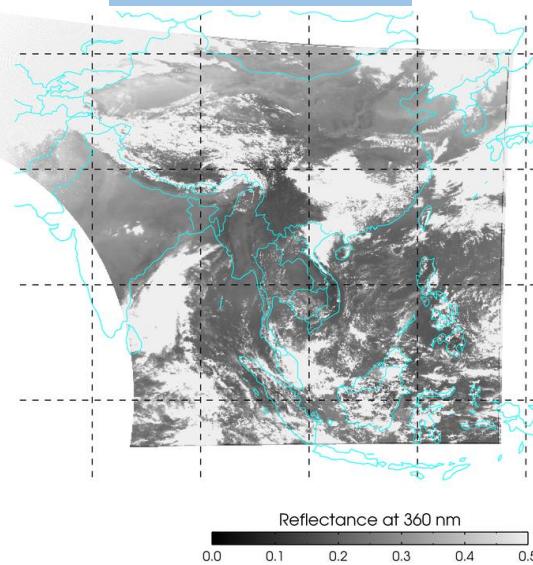
Different Categories

Time period: 01/01/2021-09/30/2022

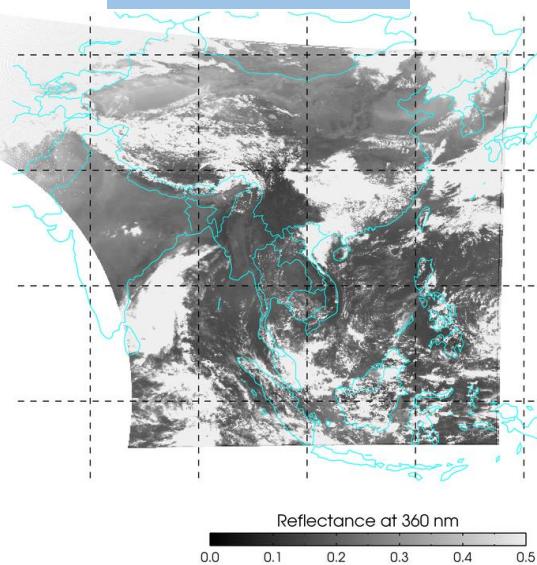
	Mean Bias	Standard deviation	RMSE
Different AOD ranges			
Low:AOD _{443nm} <0.4	0.48	1.424	1.504
Med:0.4<AOD _{443nm} <0.8	0.11	1.319	1.319
High: AOD _{443nm} >0.8	-0.33	1.320	1.320
Single layer vs. multi-layers			
Single Layer	0.07	1.339	1.341
Multi-Layers	0.77	1.405	1.603
Land vs. Ocean			
Land	1.013	1.113	1.505
Ocean	-0.213	1.405	1.421
Absorbing vs. Non-absorbing aerosol			
SSA<0.90	-0.021	1.669	1.669
SSA>0.95	0.544	1.201	1.327
Different aerosol type			
Non-Absorbing	0.624	1.117	1.329
High-absorbing Fine	0.287	1.511	1.538
Dust	-0.97	1.402	1.709

GEMS and AHI Synergy: Aerosol Detection

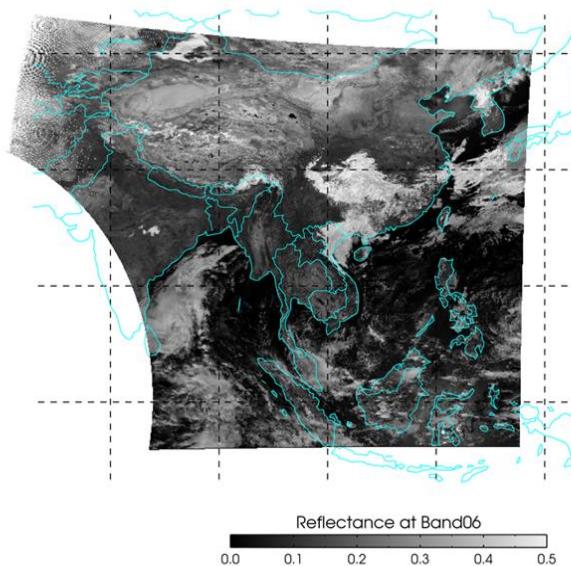
GEMS: 412 nm



GEMS: 440 nm



AHI (remapped): 2225 nm



Temporally coincide

- AHI: every 10 mins
- GEMS: hourly at 45 mins

Spectrally complement

- AHI: Vis-IR 16 bands
- GEMS: UV/Vis 300-500 nm

Spatially overlapping

- AHI: 0.5, 1 and 2 km resolution
- GEMS: 3.5 X8 km

JPSS EPS Aerosol Detection Algorithm

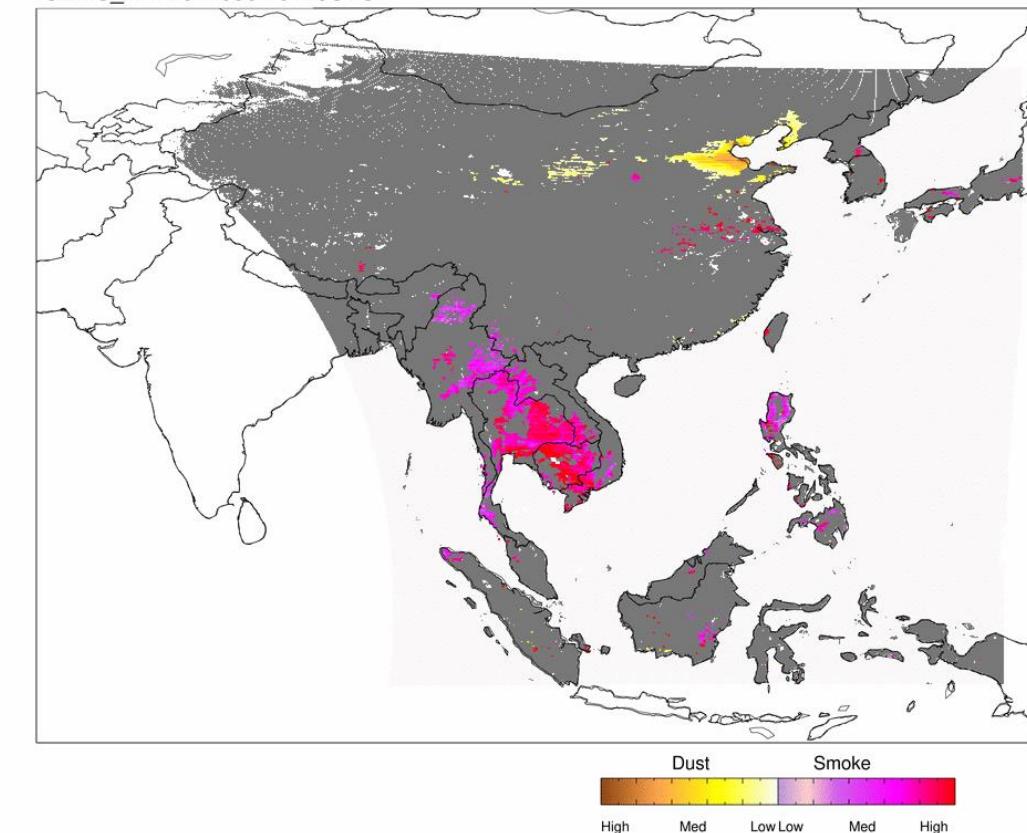
Absorbing Aerosol Index

$$\text{AAI} = -100[\log_{10}(R_{412}/R_{440}) - \log_{10}(R'_{412}/R'_{440})]$$

Dust Smoke Discrimination Index

$$\text{DSDI} = -10[\log_{10}(R_{412}/R_{2250})]$$

GEMS_AHI 20220304 0140UTC



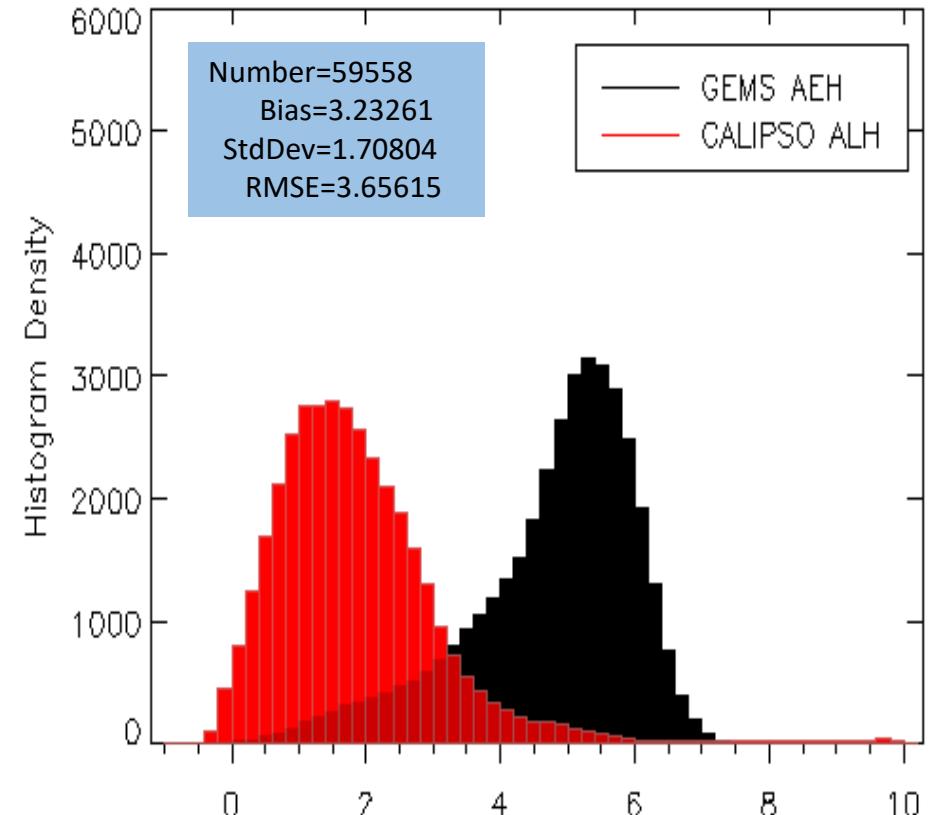
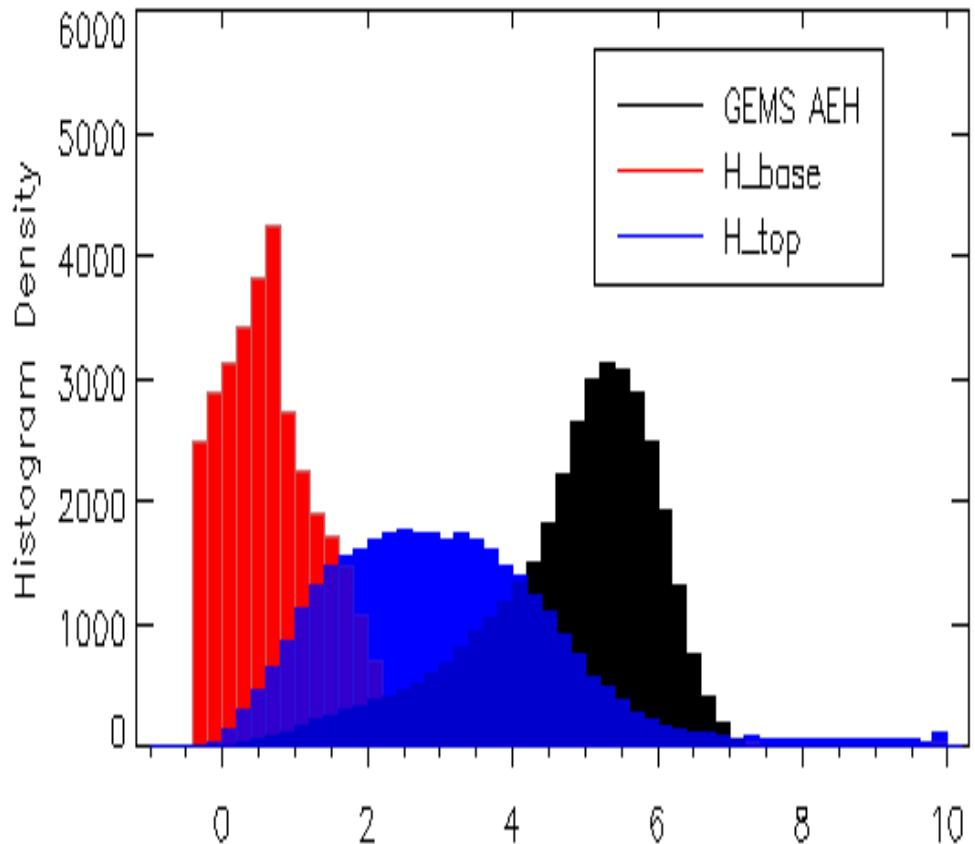
Summary

- GEMS aerosol product is able to capture the evolvement of episodic aerosol events with a great spatial coverage and reasonably good performance.
 - Compared to other UVAl products, GEMS UVAl is able to capture both a large and small scale absorbing aerosol events, with a better temporal coverage and no obvious angular dependence.
 - Underestimation and good correlation are seen in GEMS AOD for most area, but poor correlation and a large overestimation existed for stations close to the equator.
 - GEMS ALH performs generally well, compared with base and top height of aerosol layer, and centroid aerosol layer height from CALIPSO, with a positive bias of about 0.38 km, but a relatively large RMSE and standard deviation.
 - GEMS ALH performs better for layers with a moderate AOD, single layer aerosol and over ocean

□ Issues:

- Striping - the signature of calibration issues, and noisiness - the signature of cloud contamination is seen in AOD and also in other variables.
- Over-selecting of High Absorbing Fine mode (HAF) aerosol and under-selecting of DUST aerosol model are seen in the GEMS retrieval.

Backup slides



- **GEMS AEH has a large overestimation, shown as sitting well above the top height of aerosol layer from CALIPSO**
- **GEMS AEH has much less retrievals than GEMS ALH, ~20% less.**
- **In general, GEMS AEH has a very high bias, ~3.23 km, and also a larger standard deviation and RMSE.**

L2 Product overview: Total 10 products

Products	Parameters	Description
AERAOD	1) AOD	1) Aerosol Optical Depth (at 354,443 and 500 nm)
	2) SSA	2) Sing Scattering Albedo (at 354,443 and 500 nm)
	3) UVAl/VISAI	3) UV/Visible Aerosol Index (354/388 nm, 477/490 nm)
	3) ALH	3) Aerosol Layer Height
AEH	4) AEH	4) Aerosol Effective Height
CLOUD	5) ECF	5) Effective Cloud Fraction
	6) ECP	6) Effective Cloud Pressure
	7) CRF	7) Cloud Radiance Fraction
SFC	8) SFC	8) Spectral Surface Reflectance (311,317,340,354,388...490 nm)
O ₃ P/T	9) O3T	9) Total column ozone (DU)
	10) O3P_Trop	10) Tropospheric ozone amount (DU)
	11) O3P_Start	11) Stratospheric ozone amount (DU)
HCHO	12) HCHO	12) Formaldehyde VCD
CHOCHO	13) CHOCHO	13) Glyoxal VCD
NO ₂	14) NO ₂ _Total	14) Total column nitrogen dioxide density (SCD, VCD)
	15) NO ₂ _Trop	14) Tropospheric nitrogen dioxide density (SCD, VCD)
	16) NO ₂ _Strat	15) Stratospheric nitrogen dioxide density (SCD, VCD)
SO ₂	17) SO ₂	16) Column amount of SO ₂ (SCD, VCD)
UVI	18) UVI	17) UV Index

ALH vs. AEH

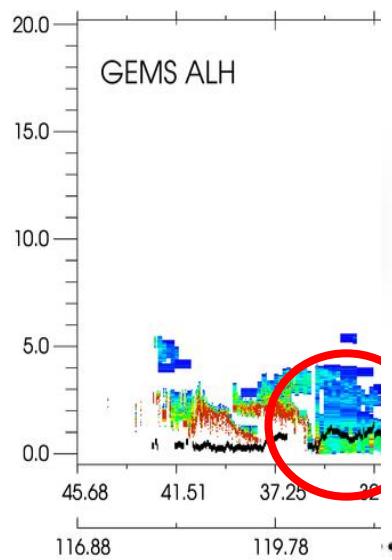
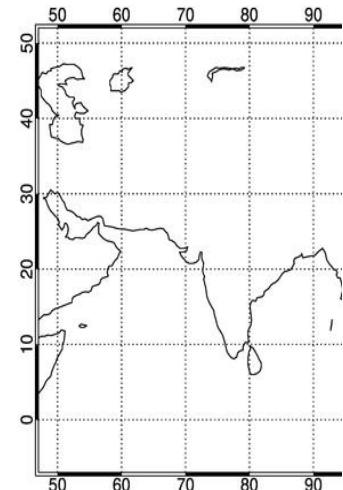
- Same definition:
➤ the peak height of Gaussian distribution (Km)
- Different algorithm:
ALH
Optimal estimation method
-Spectral fitting
@354, 388, 412, 443, 477, 490 nm

AEH

- O₄ SCD estimation technique
@477 nm

03/28/2021 GEN
GK2_GEMS_L2_20210328
CAL_LID_L2_05kmALay-P

CALIPSO VFM



North ←

← Tweet



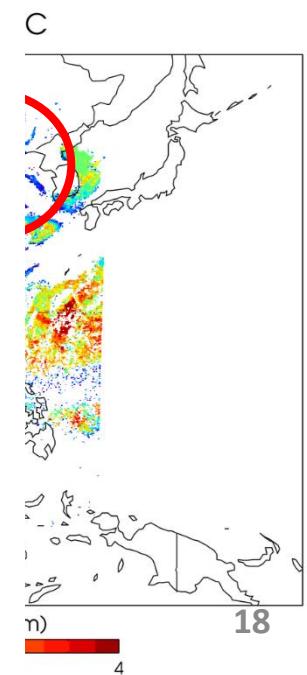
Zhou Lei
@ZhouLeiArt

...

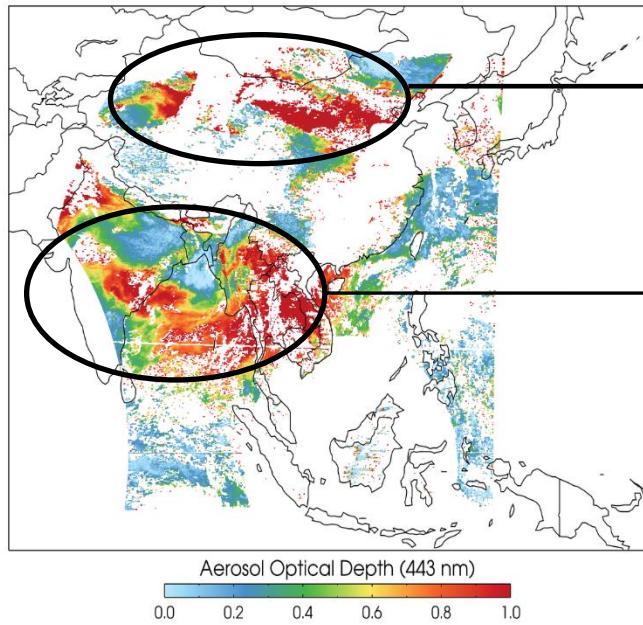
Blue sun in Beijing's sand storm today. The left pic is the Forbidden City and the right pic is CBD



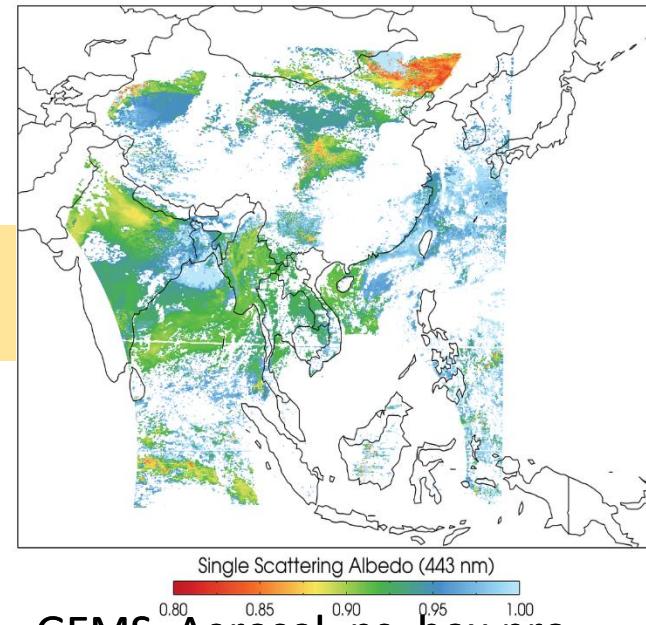
3:20 AM · Mar 28, 2021 · Twitter for iPhone



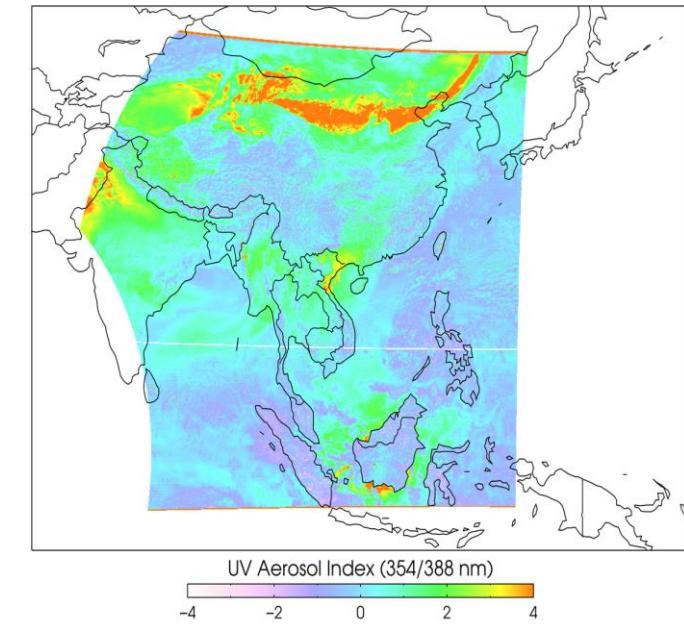
GEMS AOD



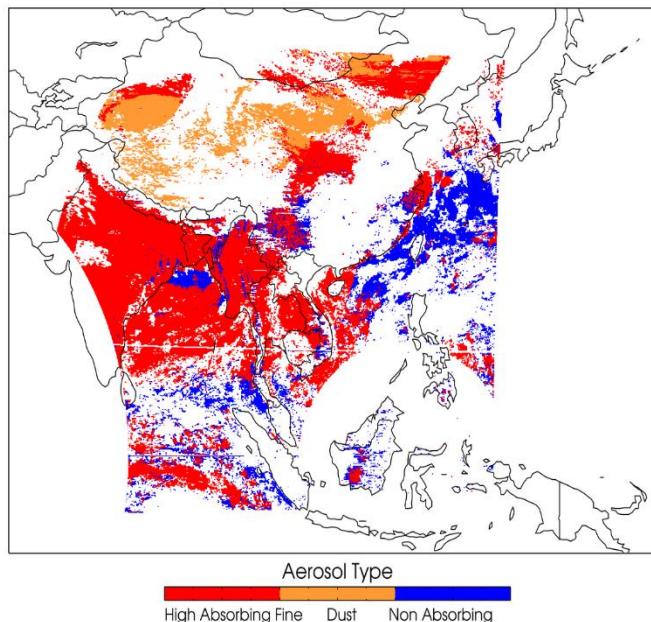
GEMS SSA



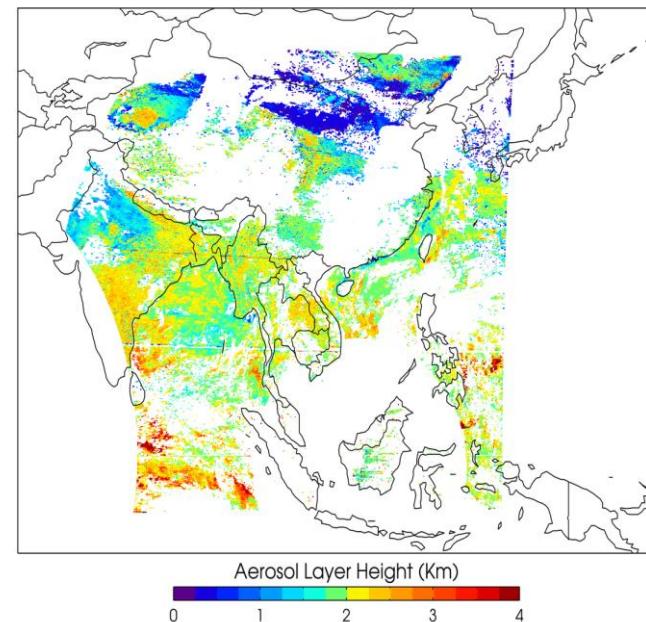
GEMS UVAI



GEMS Aerosol Type



GEMS_Aerosol_ps_box.pro
GEMS ALH



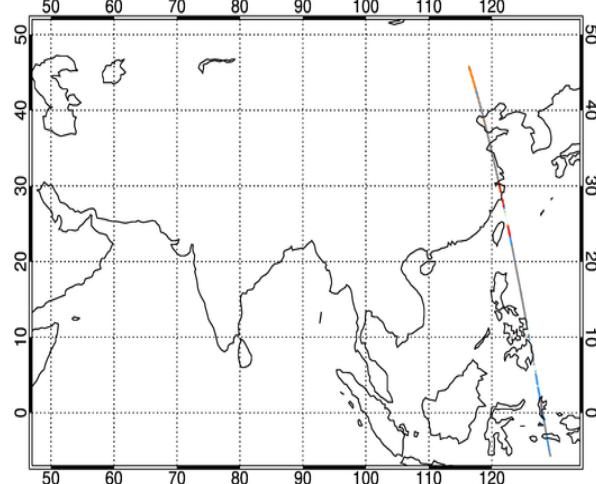
03/15/2021 05:45 UTC

Example of GEMS aerosol product

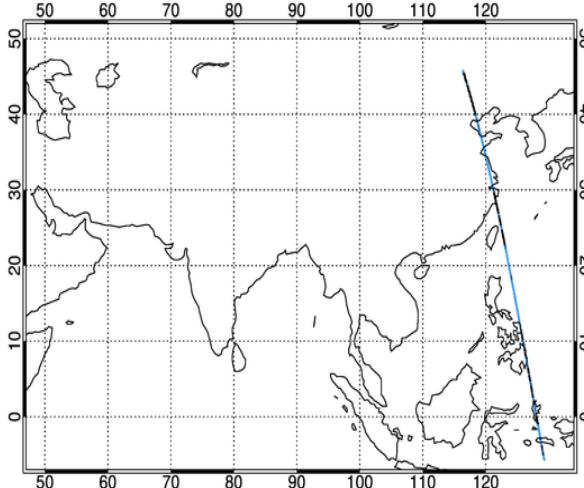
03/15/2021 GEMS: 05:45 UTC CALIPSO: 05:17 UTC

GK2_GEMS_L2_20210315_0545_AERAOD_FW_DPRO
CAL_LID_L2_05kmALay-Prov-V3-41.2021-03-15T05-17-27ZD

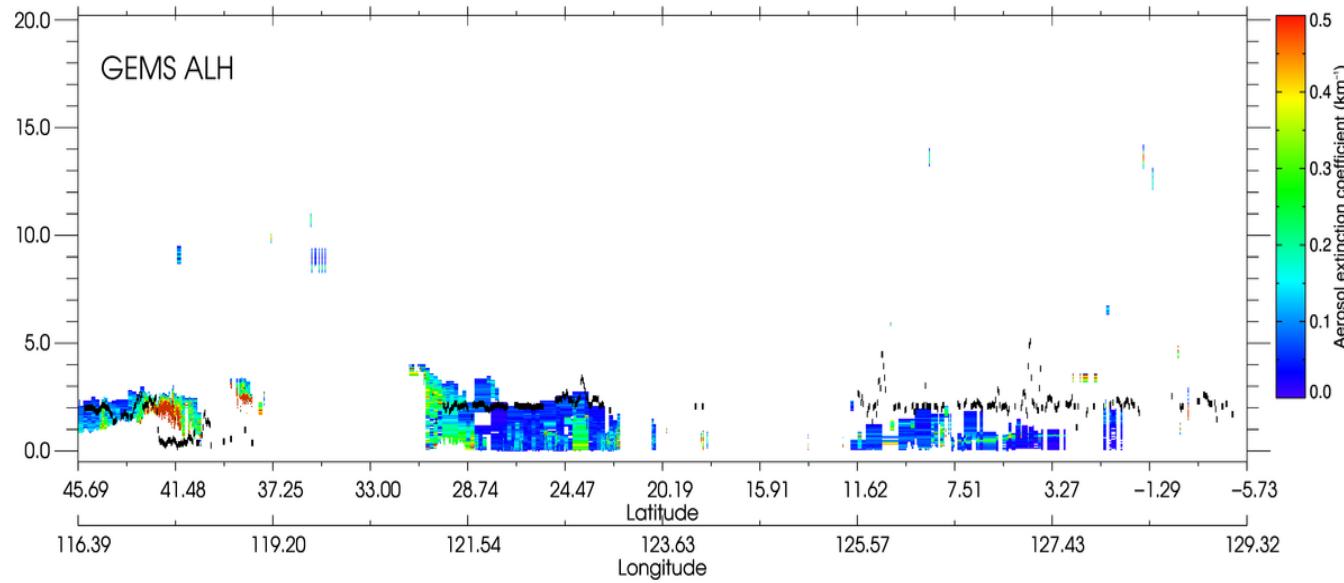
CALIPSO VFM



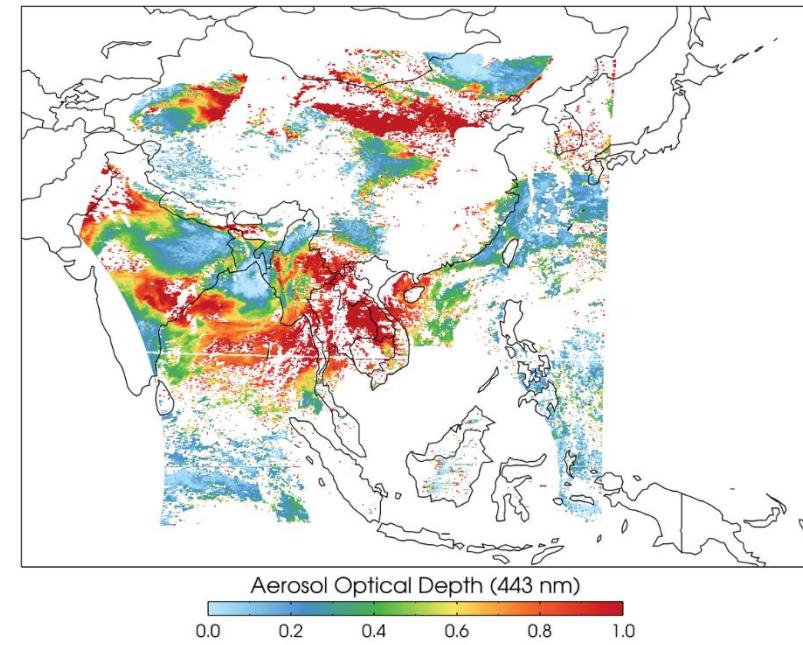
GEMS ALH



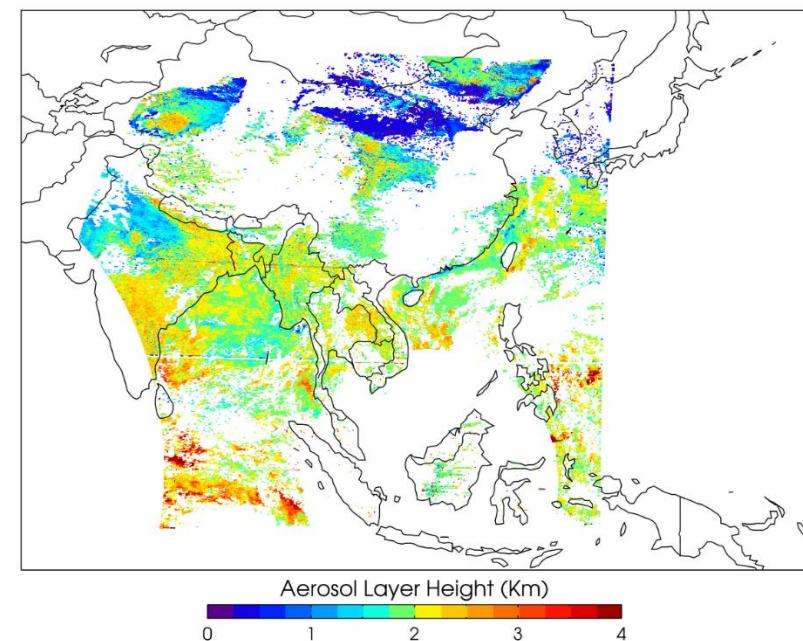
GEMS ALH



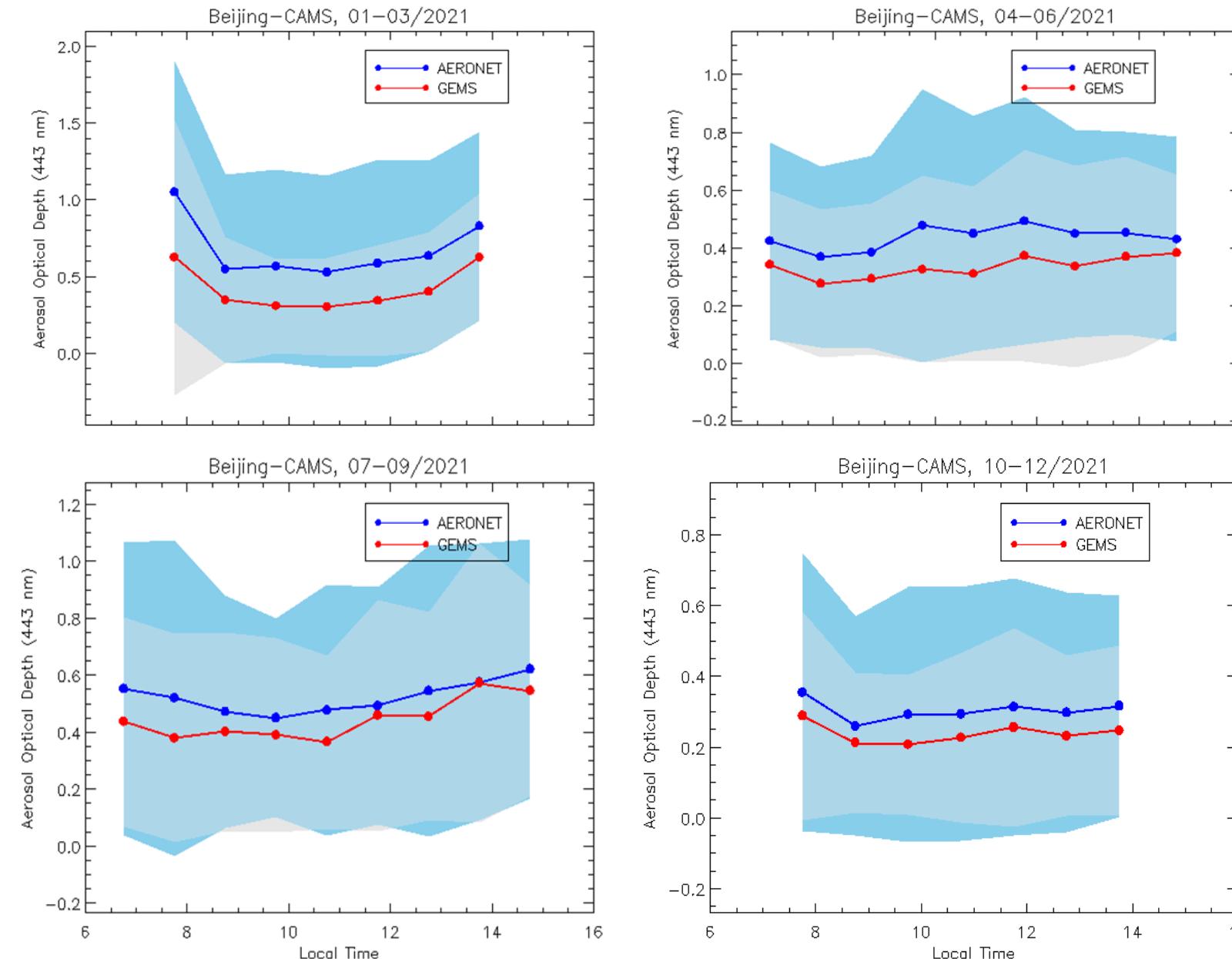
20210315 0545 UTC



20210315 0545 UTC

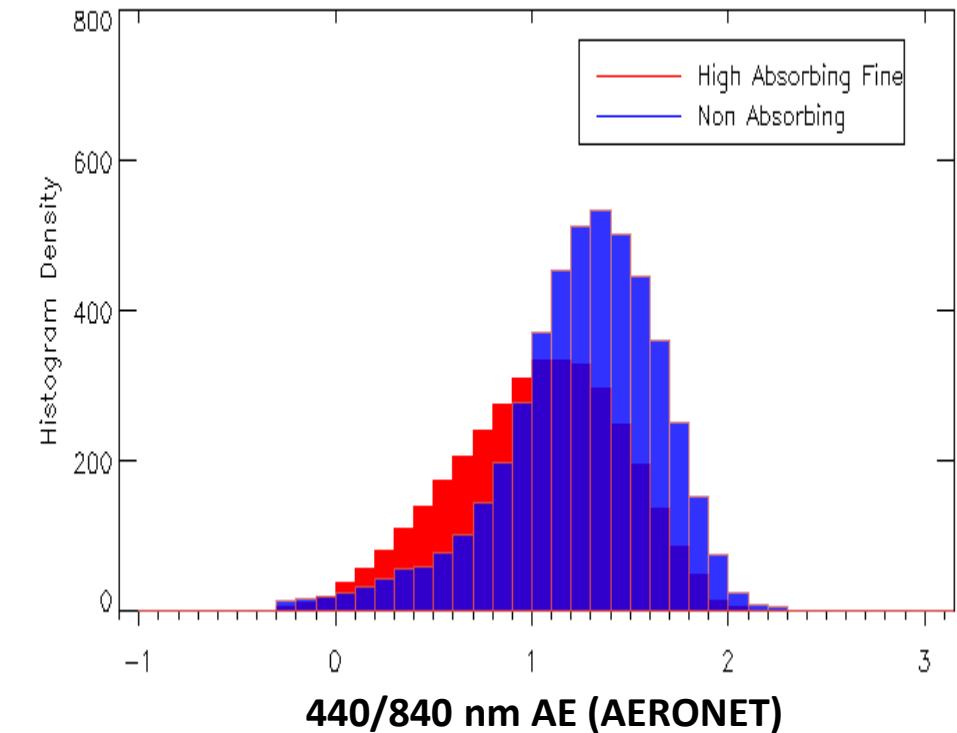
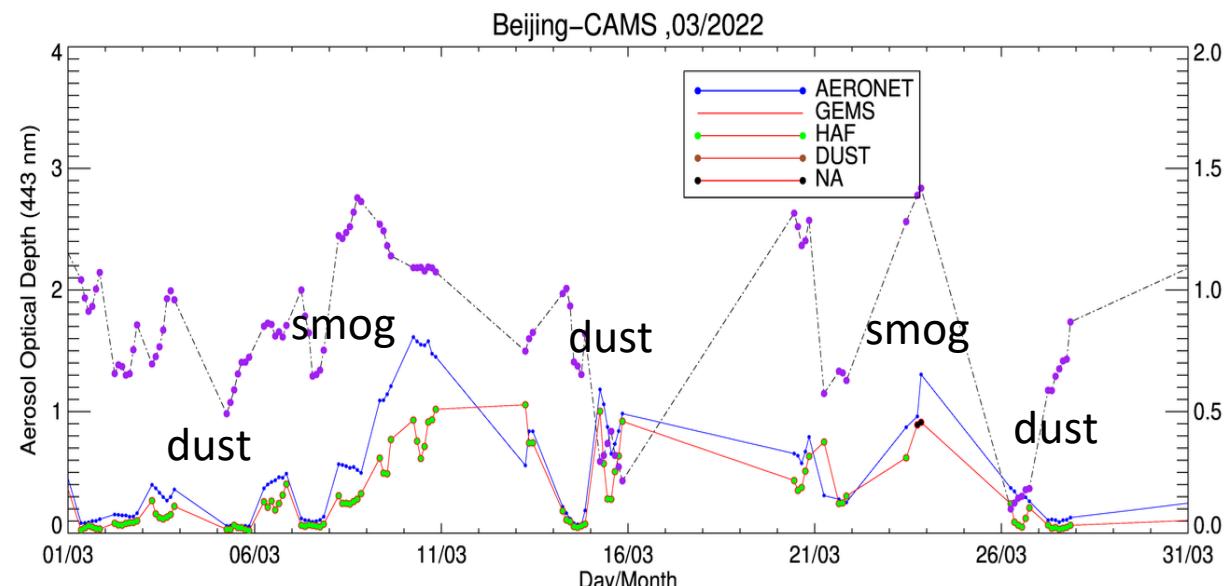
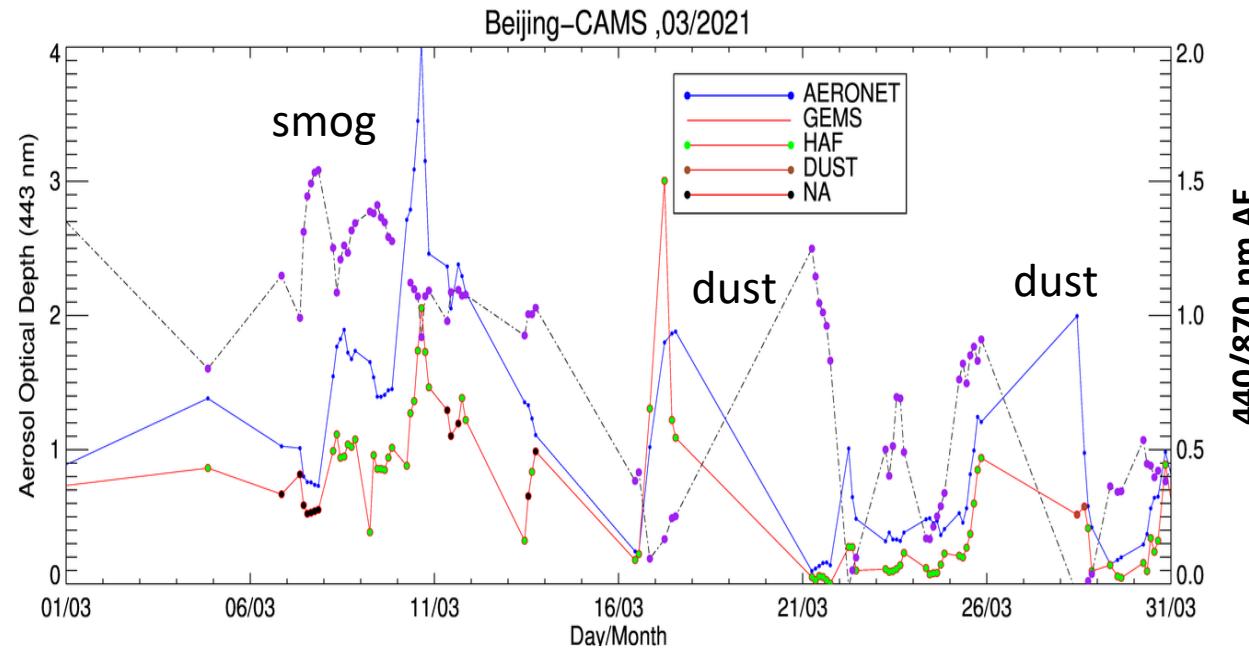


Evaluation of GEMS AOD: Diurnal Performance



- Four seasons (3 month average), GEMS AOD shows a similar diurnal variation as AERONET AOD, but with a clear underestimation.

Evaluation of GEMS AOD: Diurnal Performance

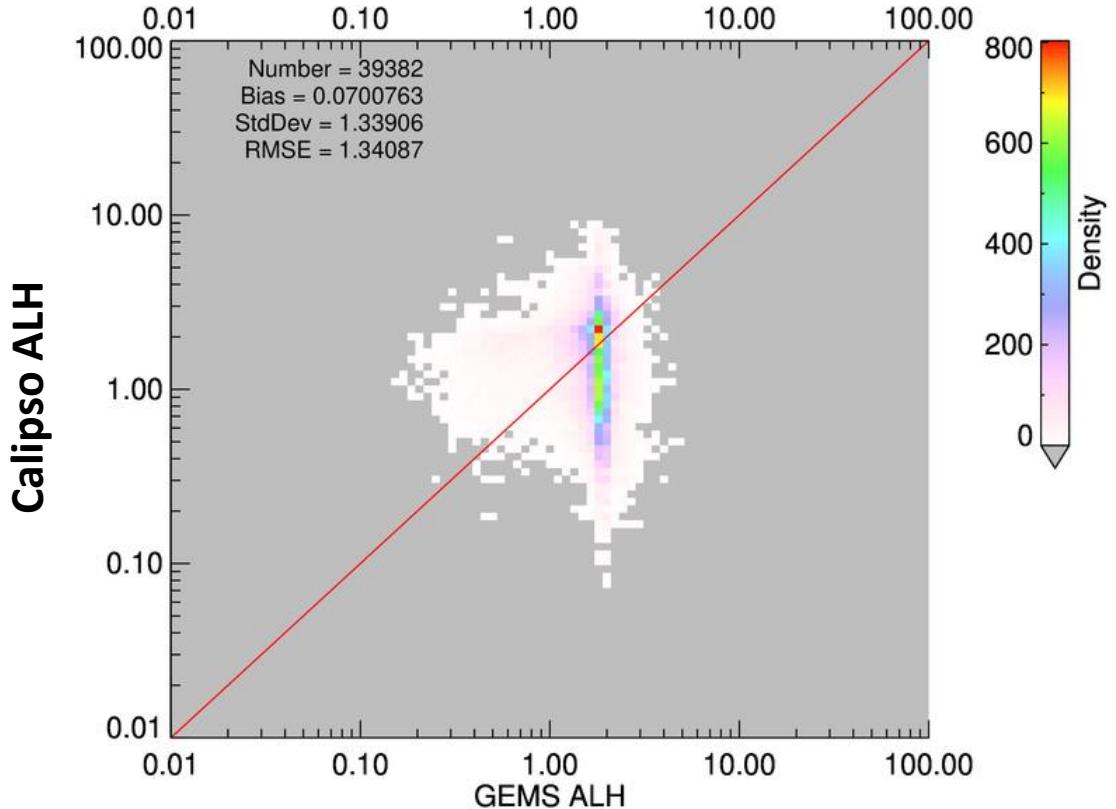


- ☐ Aerosol type classified as “HAF” in GEMS AOD retrievals do include aerosols with a large particle size as indicated by AERONET AE.

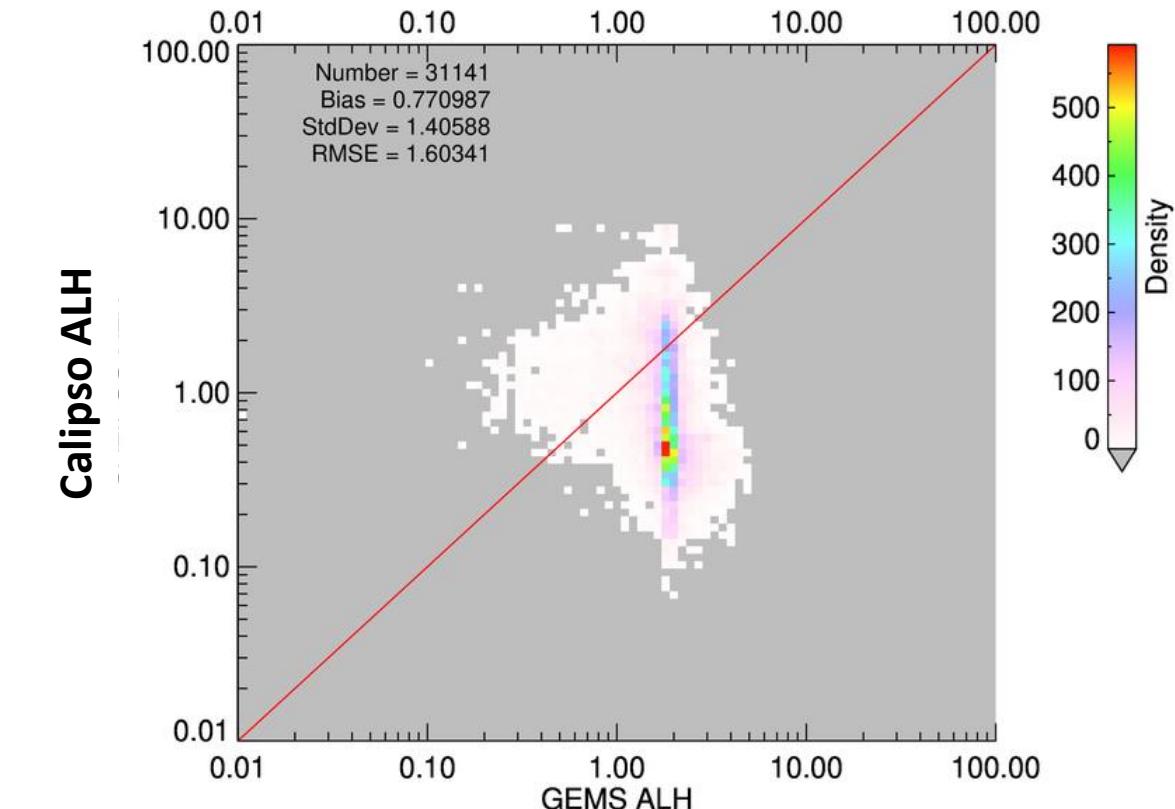
Single layer vs. multi-layers

Time period: 01/01/2021-06/30/2022

Single continued layer



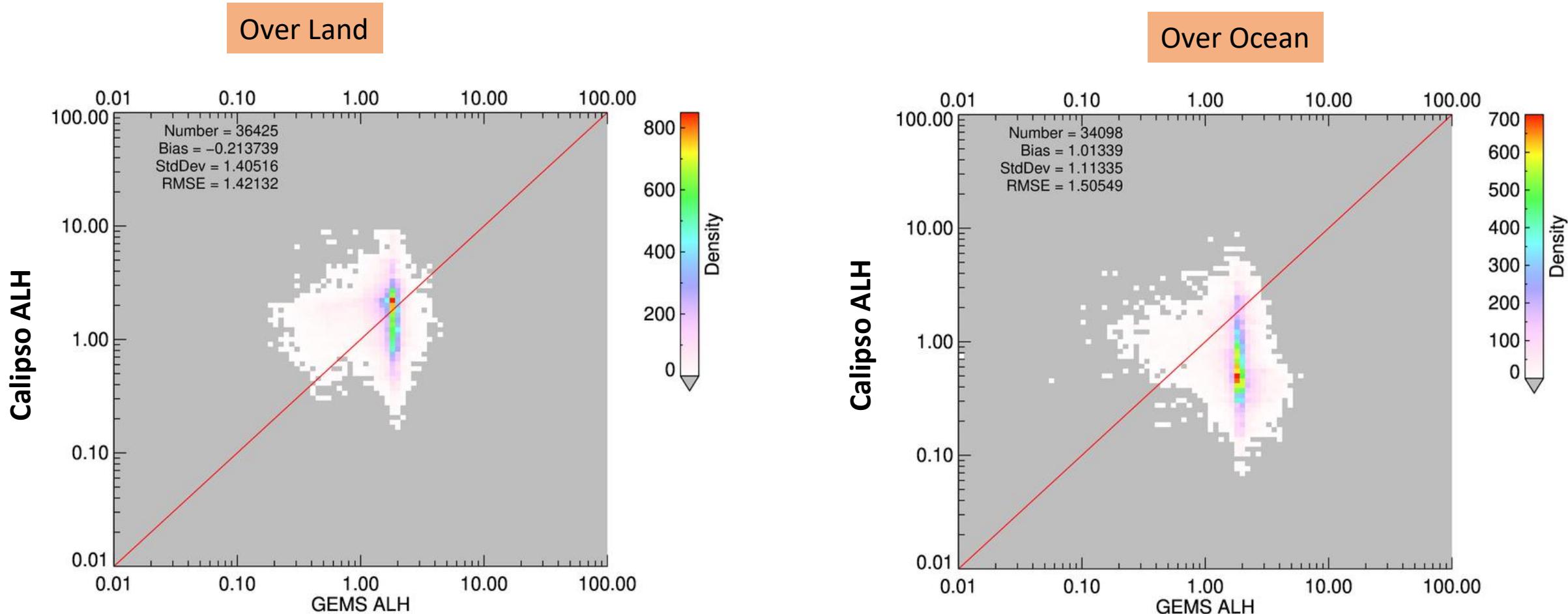
Multiple discontinued layers



- GEMS ALH seems perform much better for single layer aerosols, compared to aerosols with multiple layers.
- Bias, Standard deviation and RMSE of the GMES ALH are lower for aerosol extended as a single continued layer than those for aerosols with multiple discontinued layers.
- This is due to the single layer aerosol assumption in the algorithm.

Land vs. Ocean

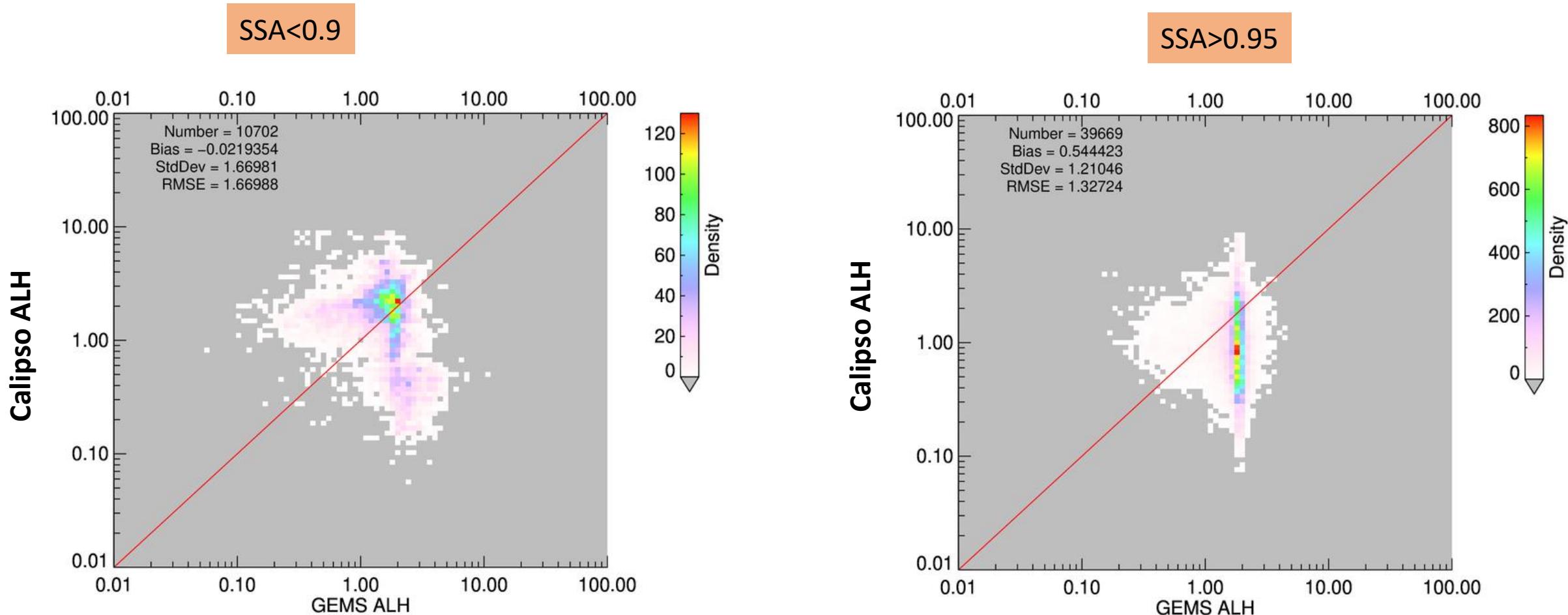
Time period: 01/01/2021-06/30/2022



- **GEMS ALH seems perform better over land than that over ocean.**
- **Overestimation is seen over ocean, with a bias of ~1.0 km.**
- **Slight underestimation is shown for over land, with a bias of ~-0.2 km.**

Absorbing vs. Non-absorbing aerosol

Time period: 01/01/2021-06/30/2022



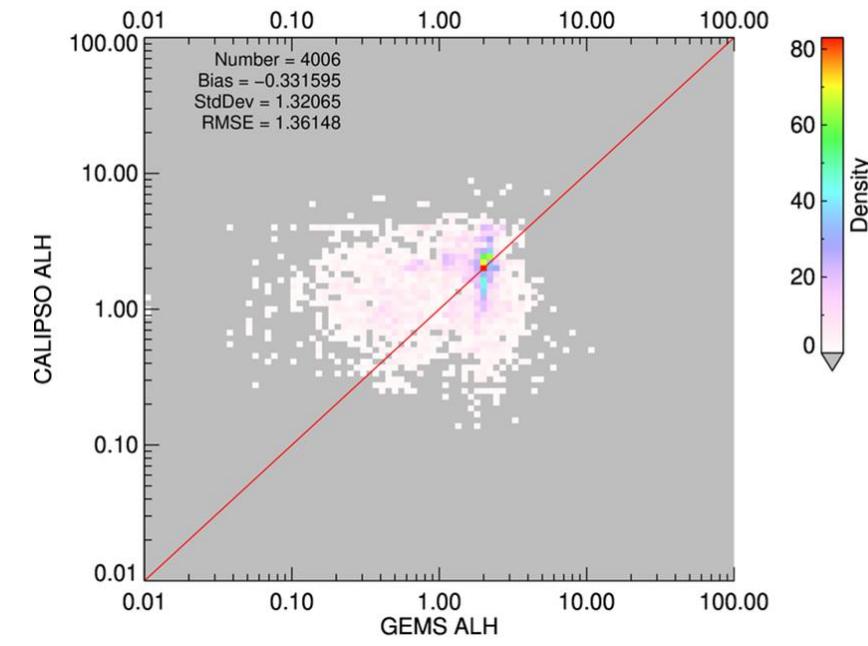
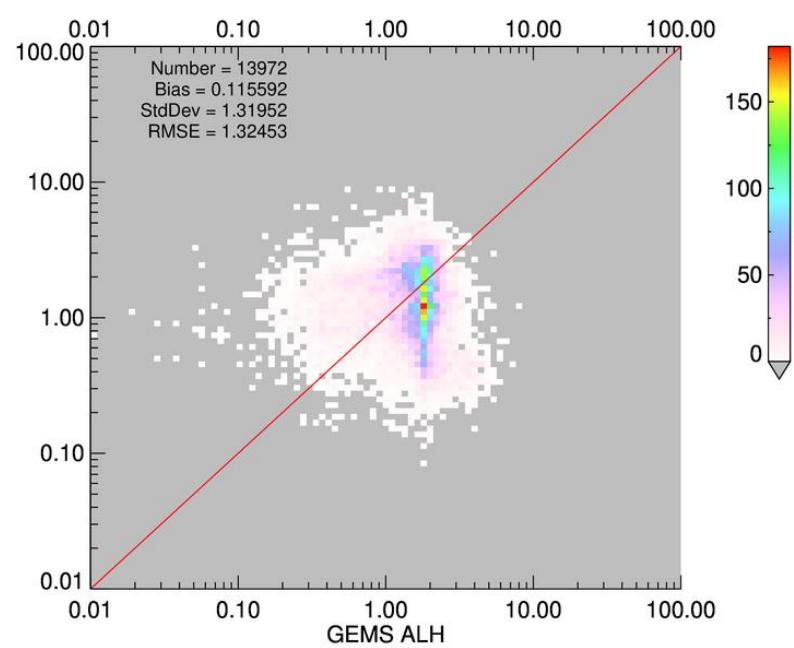
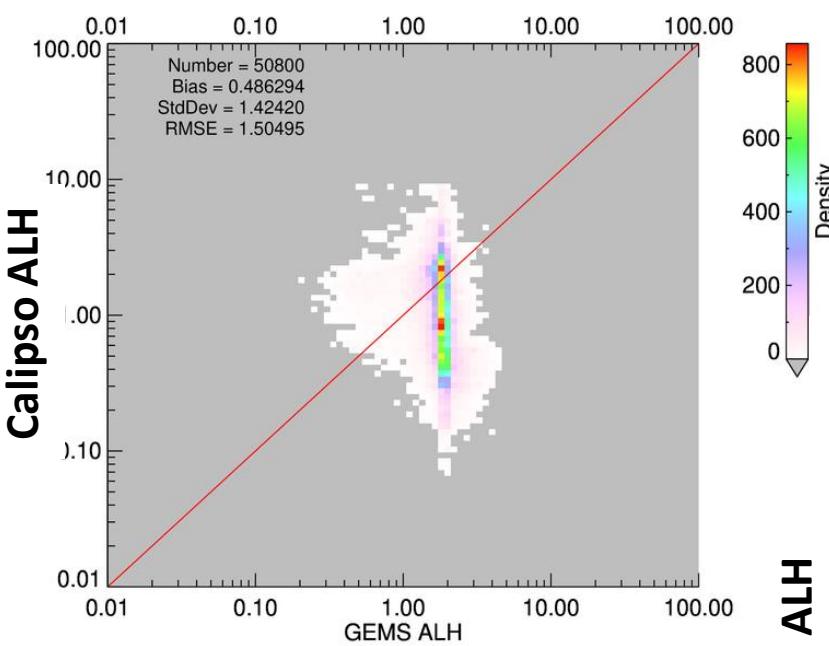
- GEMS ALH seems perform better for more absorbing aerosol than that for non-absorbing, as defined by GEMS SSA.
- For aerosol with SSA<0.90, GEMS ALH has very small bias of ~0.02 km.
- For aerosol with SSA>0.95 underestimation is seen, with a bias of 0.54 Km.

$AOD_{443nm} < 0.4$

Different AOD ranges

Time period: 01/01/2021-06/30/2022

$AOD_{443nm} > 0.8$



- There is a tendency that GEMS ALH performs better for moderate AOD
- Overestimation with a bias of 0.48 for thin aerosol layer ($AOD < 0.4$)
- Underestimation with a bias of -0.33 for thick aerosol layers ($AOD > 0.8$)

GEMS: Geostationary Environment Monitoring Spectrometer

-Developed and operated by Korean National Institute of Environmental Research (NIER)

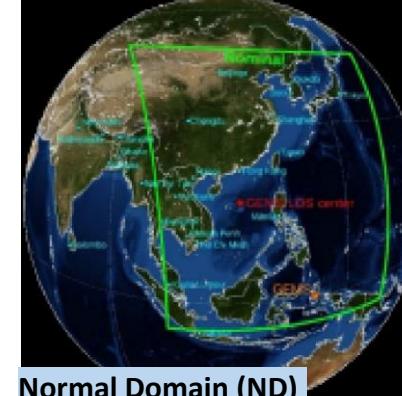
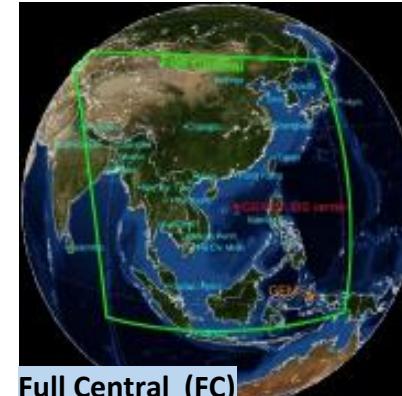
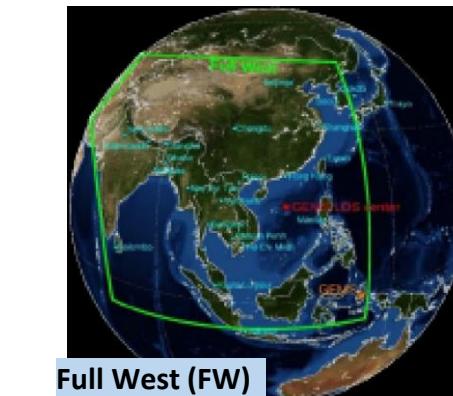
- Launched on Feb 19, 2020
- First UV-Visible Spectrometer on-board geostationary platform (GEO-KOMPSAT-2B)
- First satellite instrument to provide diurnal (hourly) variation of the atmospheric pollutants. Monitoring air pollution from space every hour becomes a reality!

GEMS observation Domain coverage

Specification of GEMS

Monitoring items	Ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), formaldehyde (HCHO), aerosols, etc.
Mission duration	10 years
Field of Regard (FOR)	5,000km x 5,000km(5°S - 45°N, 75°E - 145°E, covering 27 countries in East Asia)
Spatial resolution	Gaseous : 7 km x 8 km / Aerosol : 3.5km x 8 km
Observation cycle	8 times during daytime
Spectrum / Spectral resolution	UV-Visible (300 ~ 500 nm) / 0.6nm
Orbit / altitude / longitude	Geostationary orbit / 36,000km / 128°E

evening



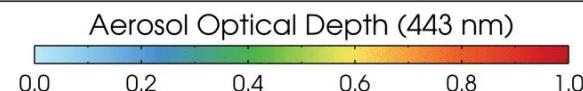
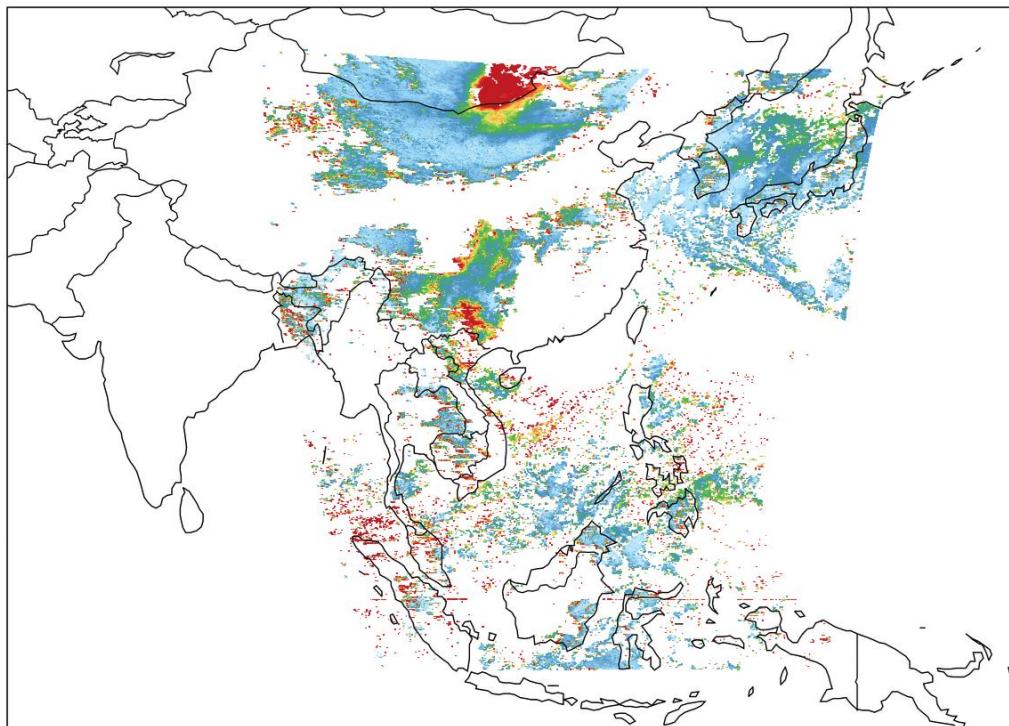
earlier morning



Smoke from Siberia fires: 08/05~08/07/2021

GEMS AOD

20210805 0045 UTC



GEMS ALH

20210805 0045 UTC

