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Aerosol layer height (ALH) retrievals from oxygen absorption bands: intercomparison and validation among different satellite platforms, GEMS, EPIC, and TROPOMI

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Table S1. AERONET sites used in this study.

Site_Name	Latitude	Longitude	Site_Name	Latitude	Longitude
Amity_Univ_Gurgaon	28.31733	76.91603	Hankuk_UFS	37.33883	127.2658
Anmyon	36.53854	126.3302	Heng-Chun	22.05474	120.6995
AOE_Baotou	40.8517	109.6288	Hong_Kong_PolyU	22.30333	114.1797
ARIAKE_TOWER	33.10362	130.272	Hong_Kong_Sheung	22.4833	114.1166
Bac_Lieu	9.28	105.73	IAOCA-KRSU	42.46383	78.52895
Baengnyeong	37.96611	124.6303	ICIMOD	27.64665	85.32327
Bangkok	13.7491	100.5177	Ieodo_Station	32.12295	125.1824
Beijing	39.97689	116.3814	IIT_Delhi	28.545	77.1926
Beijing_PKU	39.992	116.3102	Incheon	37.56882	126.6372
Beijing_RADI	40.0048	116.3786	Issyk-Kul	42.62278	76.98306
Beijing-CAMS	39.93333	116.3167	Jaipur	26.90582	75.80622
Bhola	22.22668	90.75642	Kanpur	26.51278	80.23164
Bidur	27.8955	85.1401	Kaohsiung	22.67562	120.2922
Cape_Fuguei_Station	25.29745	121.5379	Karunya_University	10.9353	76.7441
Chachoengsao	13.5	101.45	KORUS_UNIST_Ulsan	35.5819	129.1897
Chen-Kung_Univ	22.99342	120.2047	Lahore	31.47987	74.26406
Chiang_Dao	19.45472	98.9609	Luang_Namtha	20.9311	101.4162
Chiang_Mai_Met_Sta	18.77113	98.97247	Lulin	23.46861	120.8736
Dalanzadgad	43.57722	104.4192	Manila_Observatory	14.63525	121.0778
Dhaka_University	23.72839	90.39819	NAM_CO	30.77252	90.96245
Dibrugarh_Univ	27.45085	94.89689	ND_Marbel_Univ	6.496011	124.8425
Doi_Ang_Khang	19.93245	99.0454	NGHIA_DO	21.04778	105.7996
Dongsha_Island	20.69856	116.7288	Niigata	37.846	138.942
Douliu	23.7117	120.5448	Nong_Khai	17.8772	102.7167
DRAGON_Hakuba	36.70056	137.8641	Noto	37.33444	137.1369
DRAGON_Iida	35.51667	137.8422	Okinawa_Hedo	26.867	128.249
DRAGON_Ina	35.8475	137.9613	Osaka	34.65093	135.5906

DRAGON_Kofu	35.67889	138.5715	Pokhara	28.18664	83.97518
DRAGON_Matsumoto	36.25139	137.9778	Pune	18.53726	73.80549
DRAGON_Minowa	35.915	137.9807	QOMS_CAS	28.365	86.94806
DRAGON_Mt_Happo	36.69694	137.7981	Seoul_SNU	37.45806	126.9511
DRAGON_Mt_Haruna	36.47556	138.8778	Shirahama	33.69345	135.3569
DRAGON_Mt_Krigamine	36.09806	138.1683	Silpakorn_Univ	13.81931	100.0412
DRAGON_Omachi	36.50306	137.8514	Socheongcho	37.42313	124.738
DRAGON_Suwa	36.04556	138.1088	Songkhla_Met_Sta	7.184387	100.6046
DRAGON_Takayama	36.25278	137.3045	Sra_Kaeo	13.6889	102.5043
EPA-NCU	24.96753	121.1855	Tai_Ping	10.3755	114.362
Erlin	23.9253	120.4096	Taipei_CWB	25.01468	121.5384
Fukue	32.752	128.682	Ubon_Ratchathani	15.24552	104.871
Fukuoka	33.524	130.475	USM_Penang	5.35838	100.3023
Gandhi_College	25.871	84.12794	Ussuriysk	43.7004	132.1635
Gangneung_WNU	37.771	128.867	XiangHe	39.7536	116.9615
Gosan_NIMS_SNU	33.3001	126.2058	Xitun	24.1622	120.6169
Gosan_SNU	33.29222	126.1617	Yonsei_University	37.56443	126.9348
Gwangju_GIST	35.22828	126.8431			

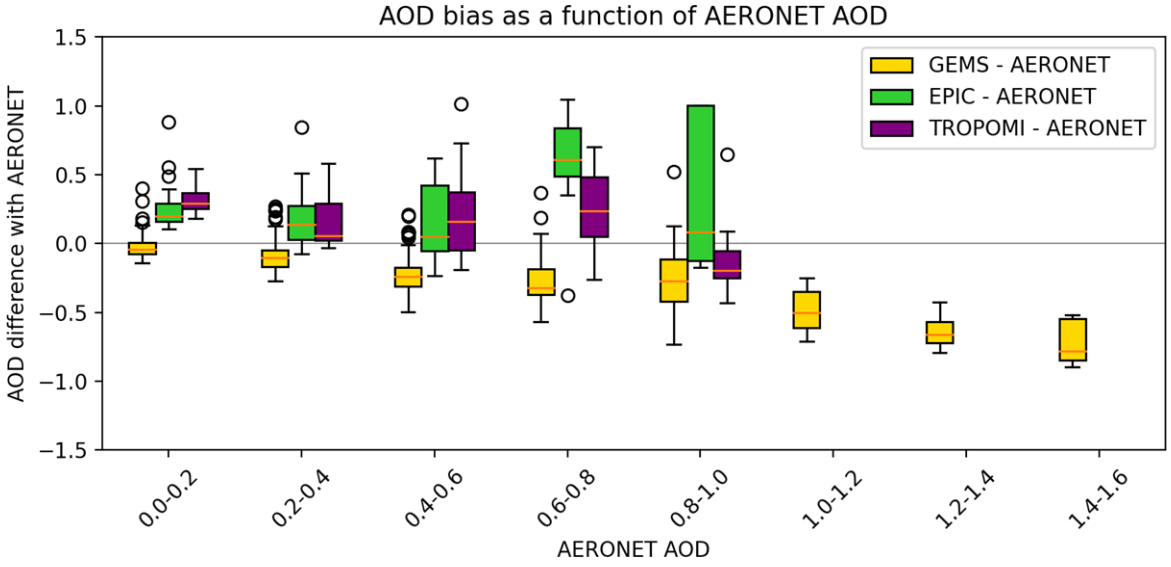


Figure S1. AOD bias as a function of AERONET AOD in box plots. Yellow, green, and purple indicates GEMS, EPIC, and TROPOMI bias with AERONET AOD.

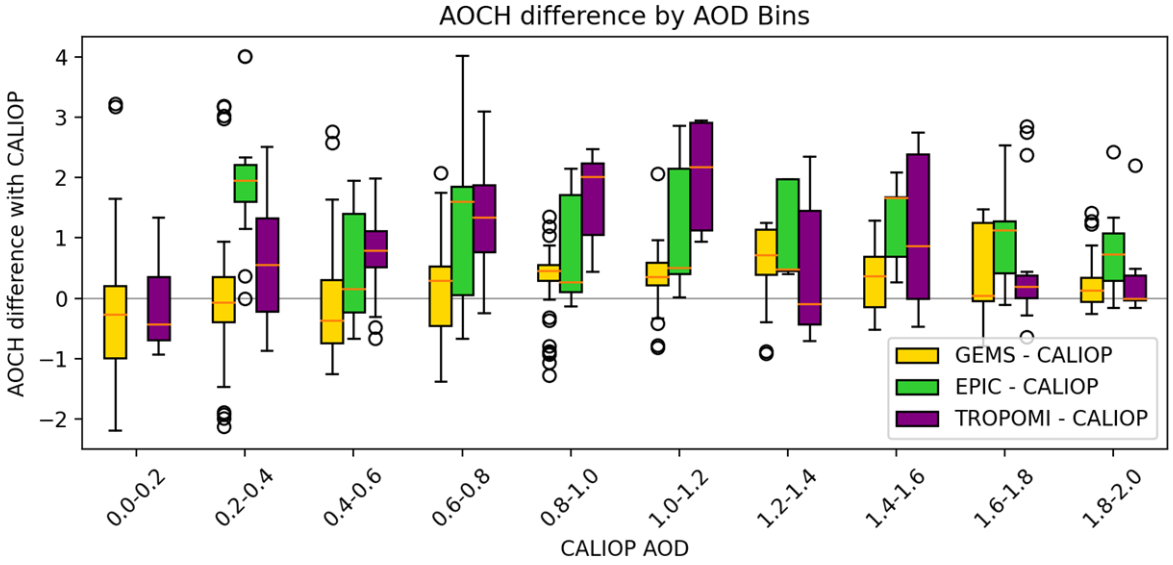


Figure S2. AOCH bias as a function of CALIOP AOD in box plots. Yellow, green, and purple indicates GEMS, EPIC, and TROPOMI bias with CALIOP AOCH.

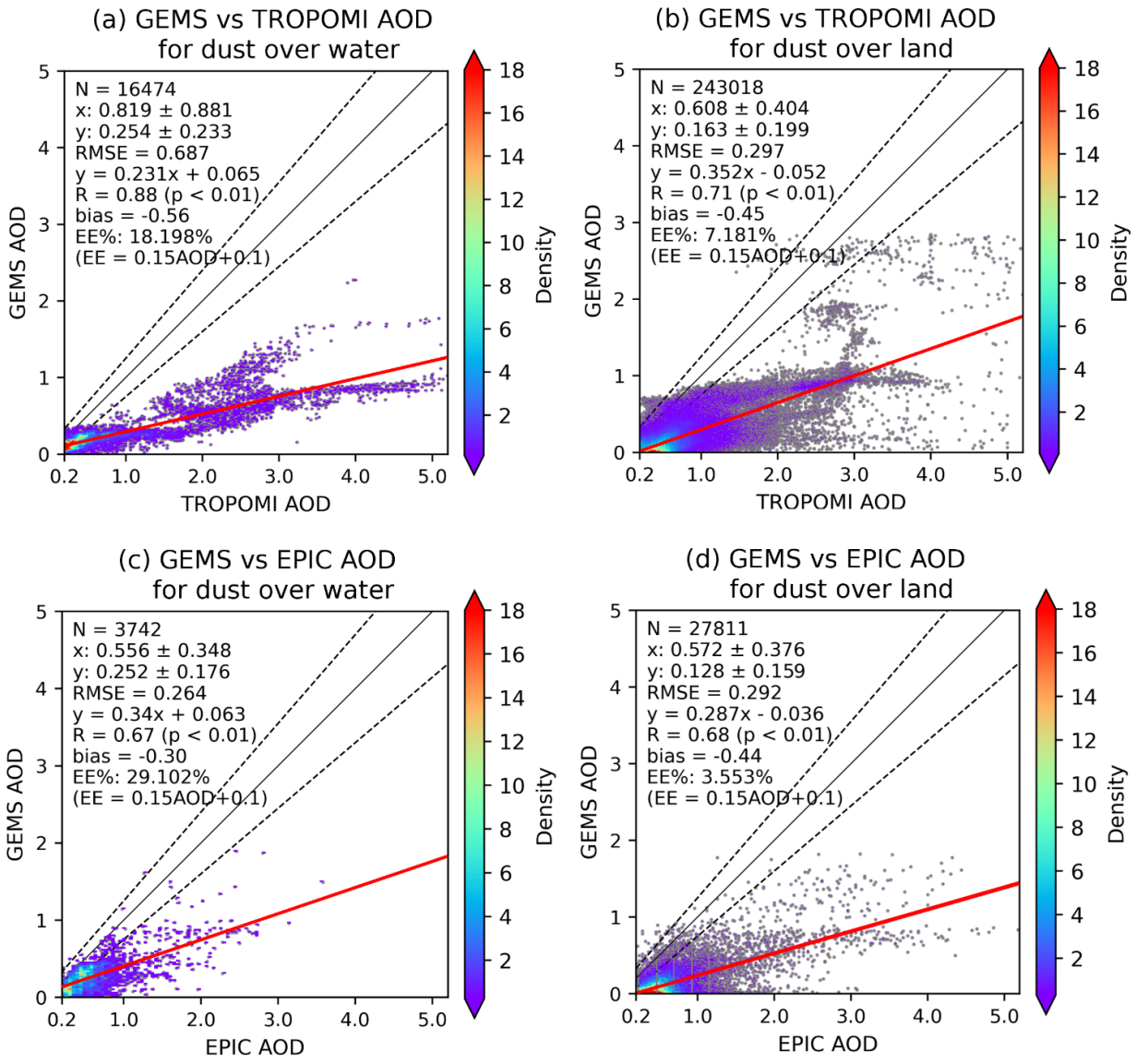
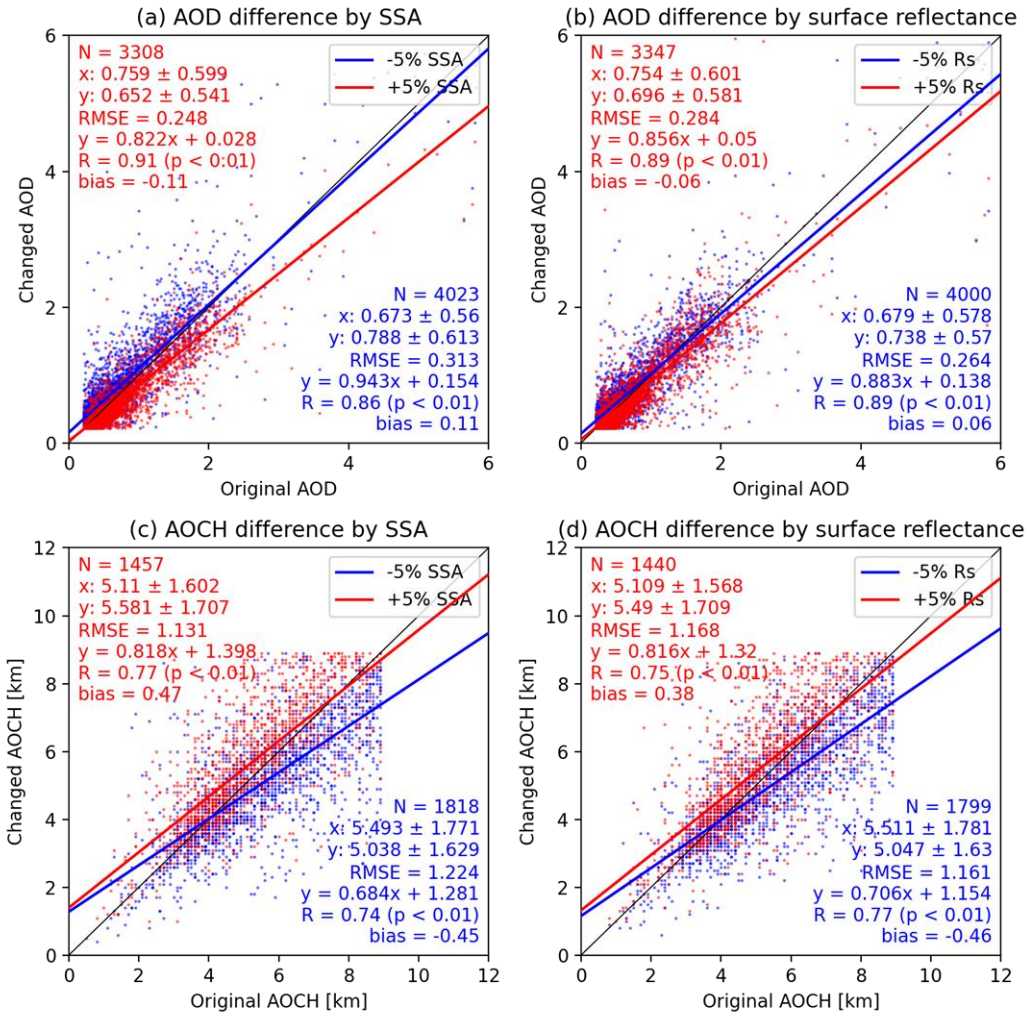


Figure S3. GEMS AOD compared with the corresponding TROPOMI and EPIC products for dust cases. Scatter density plots of (a) GEMS AOD versus TROPOMI AOD over water, (b) same as (a) but for land, (c) GEMS AOD versus EPIC AOD for water, and (d) same as (c) but for land. Black solid line is the one-to-one line, and the red solid line is the regression line. The dotted lines indicate error envelops (EE = ± 0.15 AOD + 0.1). TROPOMI and EPIC AOD does not have retrieval for less than 0.2, therefore, the figures axis start from where the data exists.



20 **Figure S4. Sensitivity test for AOD and AOCH on SSA and surface reflectance.**

Table S2. Aerosol model comparison used in AOD/ALH retrievals for GEMS and TROPOMI/EPIC

		GEMS AEH			EPIC/TROPOMI AOCH	
		HAF	Dust	NA	Dust	Smoke
mr		1.46	1.48	1.41	0.00428 ln τ + 1.55 (675 nm)	0.026τ+1.513 (680 nm)
mi		0.02044	0.00414	0.00401	0.00197 ln τ + 0.00268 (675 nm)	0.00857 (680 nm)
Reff	Fine mode	0.0854	0.0644	0.1013	0.0152τ+0.122	0.017τ+0.178

	Coarse mode	1.4115	1.0392	0.8176	-	0.579τ+2.477
Veff	Fine mode	1.5421	1.4420	1.5870	0.156τ+0.227	1.26
	Coarse mode	1.7630	1.6436	1.9371	-	0.278
fmf		0.99994	0.99823	0.99980	-0.0696 ln τ + 0.37	0.162τ+0.532
SSA		Retrieved together with AOD from AERONET inversion dataset			Coarse mode: 0.0214 ln τ + 0.949 (675 nm)	
Phase function		Mie			Fine: Mie Coarse: Dynamic AERONET climatology	Mie

τ is the AOD at 680 nm.

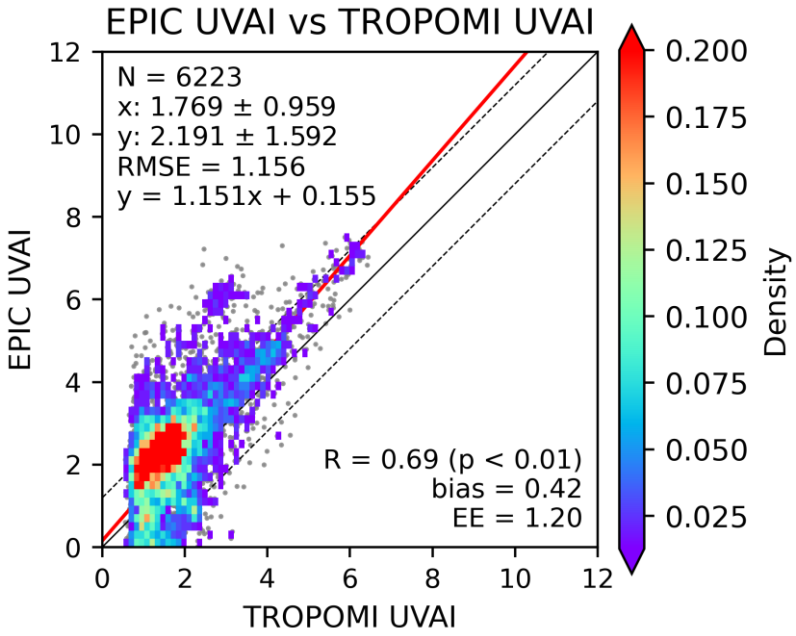


Figure S5. Comparison of EPIC with TROPOMI UVAI. The one-to-one line is represented by a black solid line, while the regression line is shown in red.

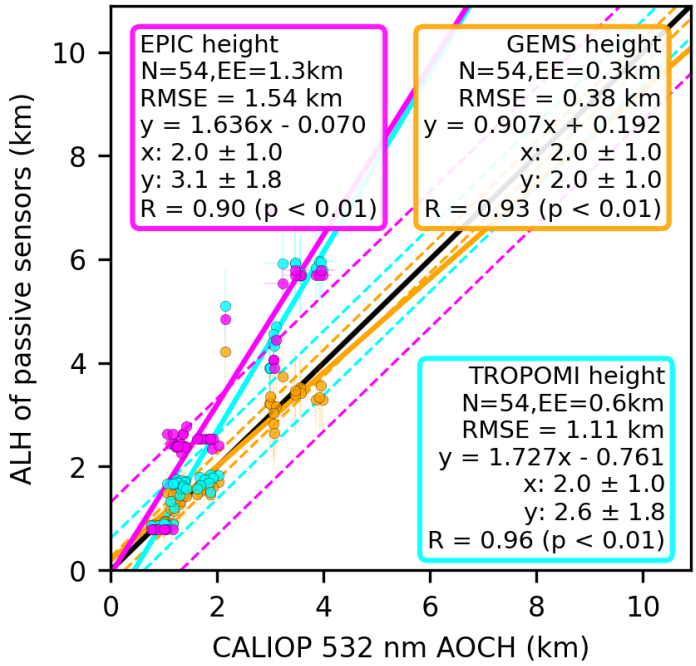


Figure S6. Comparison of GEMS, TROPOMI, and EPIC AOCH with CALIOP measurements for all cases when data are available from all retrievals. Scatterplot of GEMS (orange), TROPOMI (cyan), and EPIC (magenta) AOCH versus CALIOP AOCH. The black solid line indicates one-to-one line, and the dotted lines represent error envelop within which data points for each passive satellite product fall within one standard deviation.

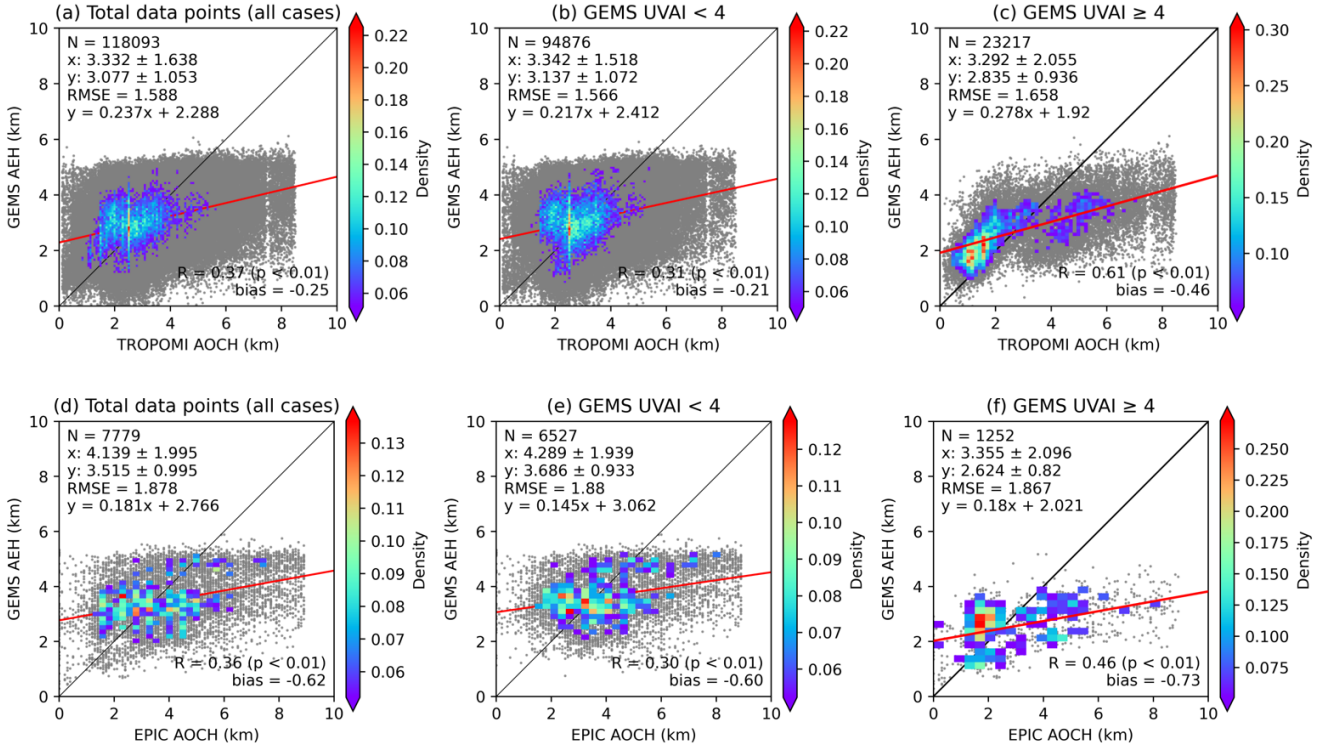


Figure S7. Intercomparison of AOCH values from GEMS, TROPOMI and EPIC for al cases (dust and smoke cases combined) as a function of UVAI. The density scatter plots show the AOCH comparison between GEMS and TROPOMI (a – c), and between GEMS and EPIC (d – f). (b) and (e) represent GEMS data for UVAI < 4, while (e) and (f) represent data for UVAI ≥ 4. GEMS AEH values have been converted to align with the AOCH definitions used by EPIC and TROPOMI.

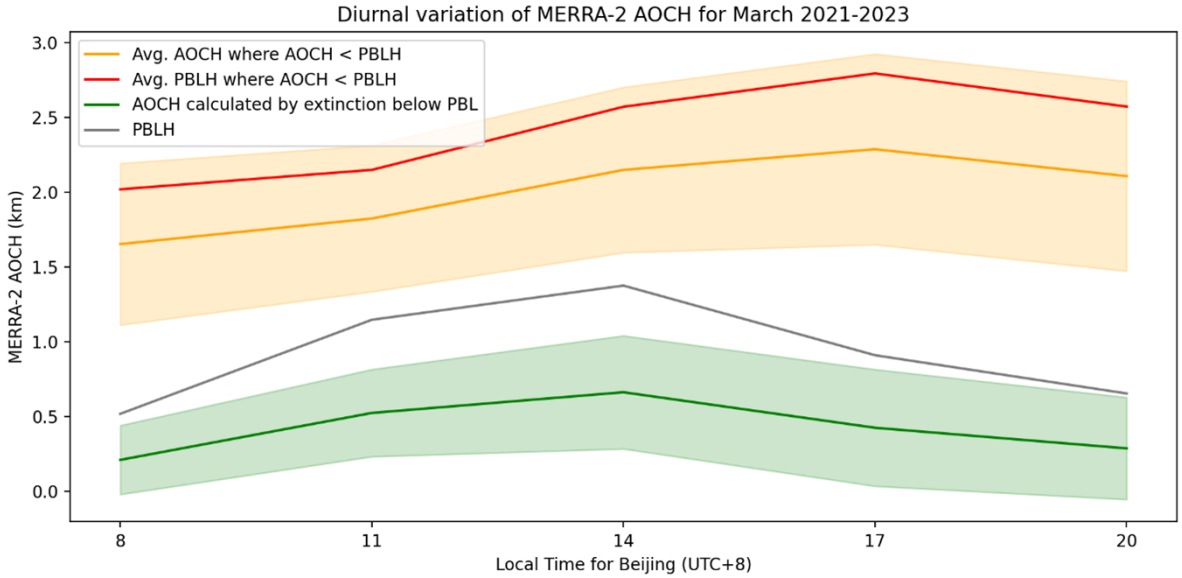


Figure S8. The diurnal variation of MERRA-2 AOCH and PBLH. The orange line and shadow indicate the mean and standard deviation of AOCH where AOCH is lower than the PBLH, and the red represents the average of those PBLH values. The green line and shadow indicate the mean and the standard deviation of MERRA-2 AOCH calculated considering the aerosol extinction only below the PBLH and the grey line indicates the average PBLH from MERRA-2.

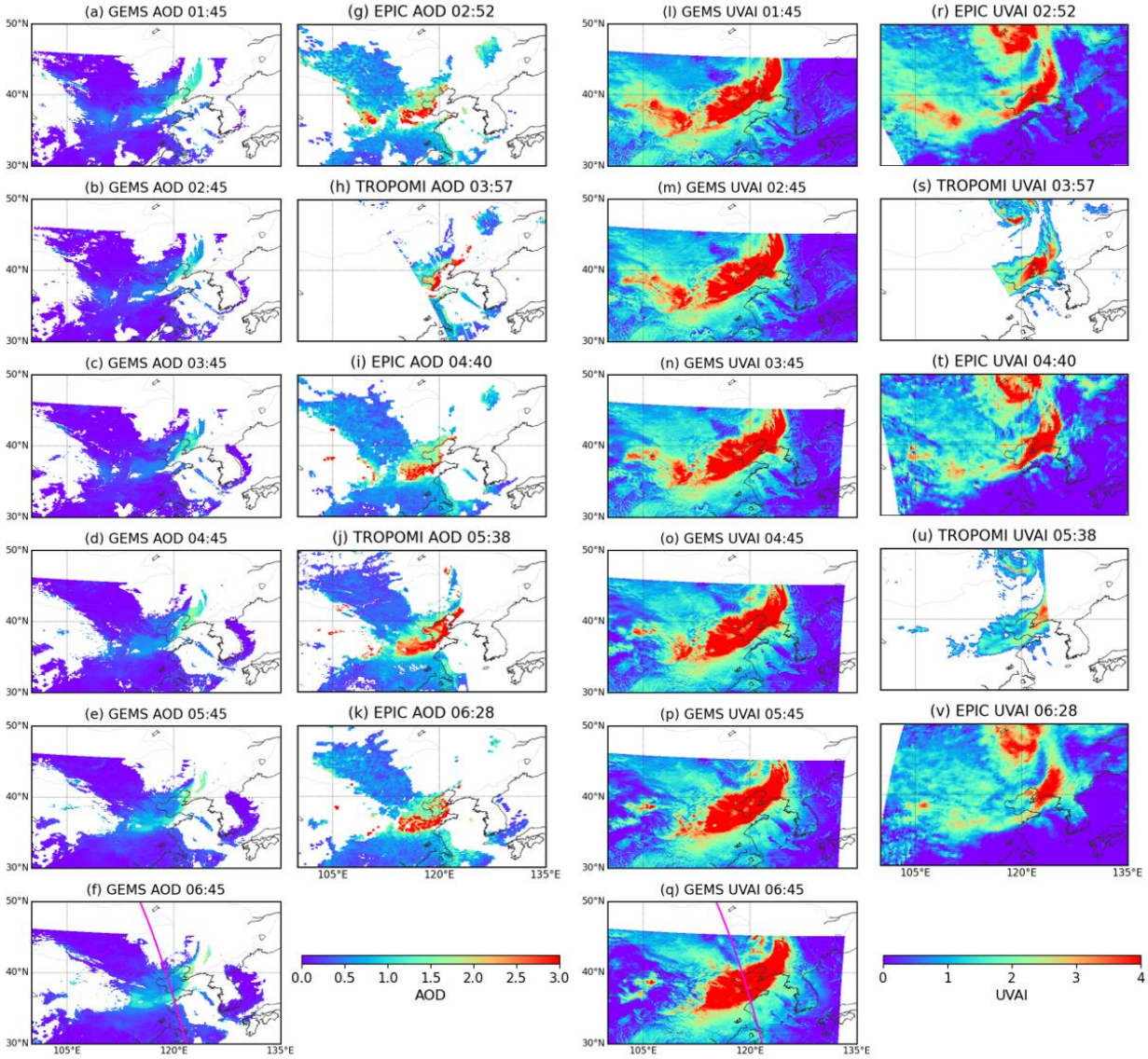


Figure S9. First column (a – f) shows hourly GEMS AOD products presented in timely order from (a) 01:45 to (f) 06:45 (UTC). Second column (g – k) EPIC and TROPOMI ALH aligned with the nearest time of GEMS measurement time for a dust plume case on 28 March 2021. Third column (l – q) shows GEMS UVAI and fourth column (r – v) shows EPIC and TROPOMI UVAI similar to the first and second columns. CALIOP ground tracks are shown as magenta lines on the first and third columns where it has the closest observation time with GEMS.

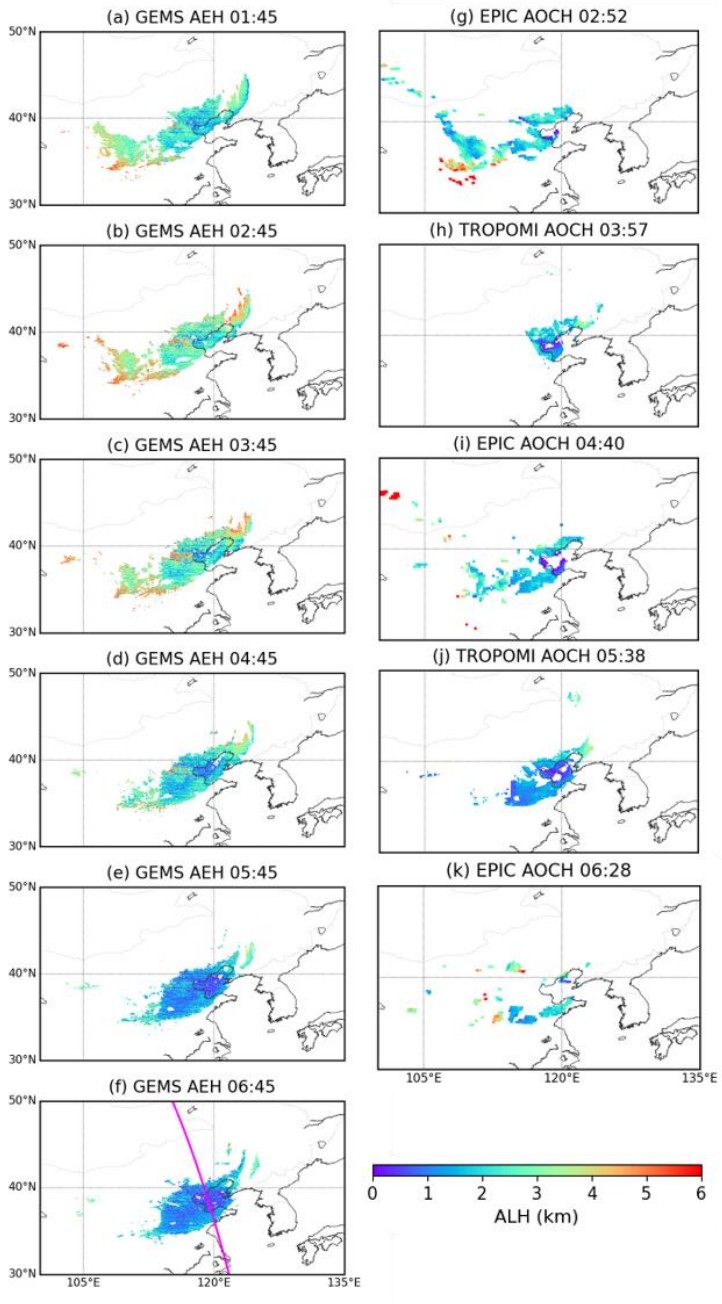


Figure S10. Regional coverage for absorbing aerosols screened by UVAI thresholds as 3, 1, 2, for GEMS, TROPOMI, and EPIC, respectively. First column (a – f) shows hourly GEMS ALH products presented in timely order from (a) 01:45 to (f) 06:45 (UTC). Second column (g – k) EPIC and TROPOMI ALH aligned with the nearest time of GEMS measurement time for a dust plume case on 28 March 2021. CALIOP ground tracks are shown as the magenta line on the GEMS ALH map (first column) where it has the closest observation time with GEMS.

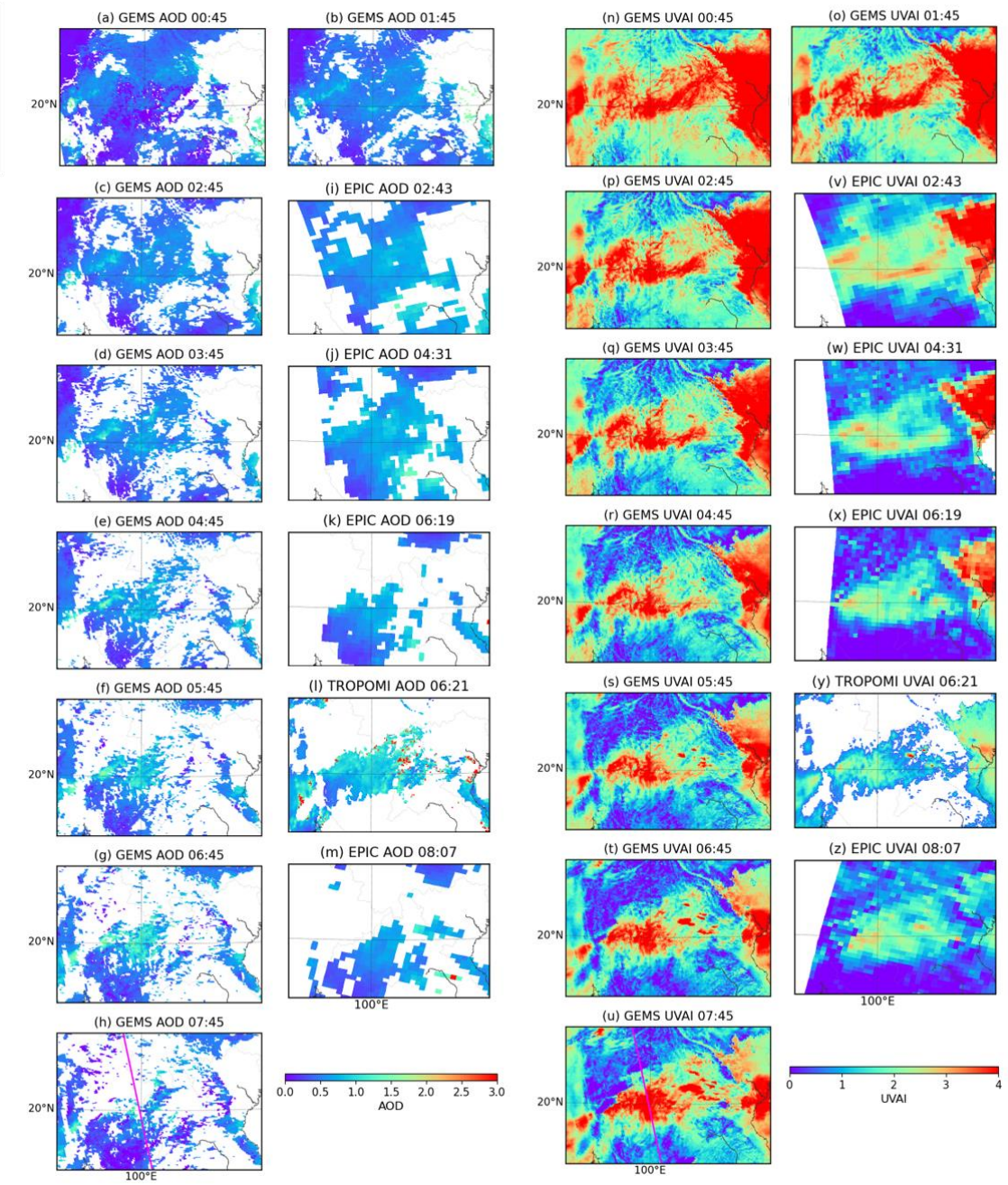


Figure S11. Figures (a – h) show hourly GEMS AOD products presented in timely order from (a) 00:45 to (f) 07:45 (UTC). Figures (i – m) EPIC and TROPOMI ALH aligned with the nearest time of GEMS measurement time for a dust plume case on 17 April 2023. Figures (n – u) show GEMS UVAI and (o – z) show EPIC and TROPOMI UVAI similar to the AOD figures. CALIOP ground tracks are shown as magenta lines on the first and third columns where it has the closest observation time with GEMS.

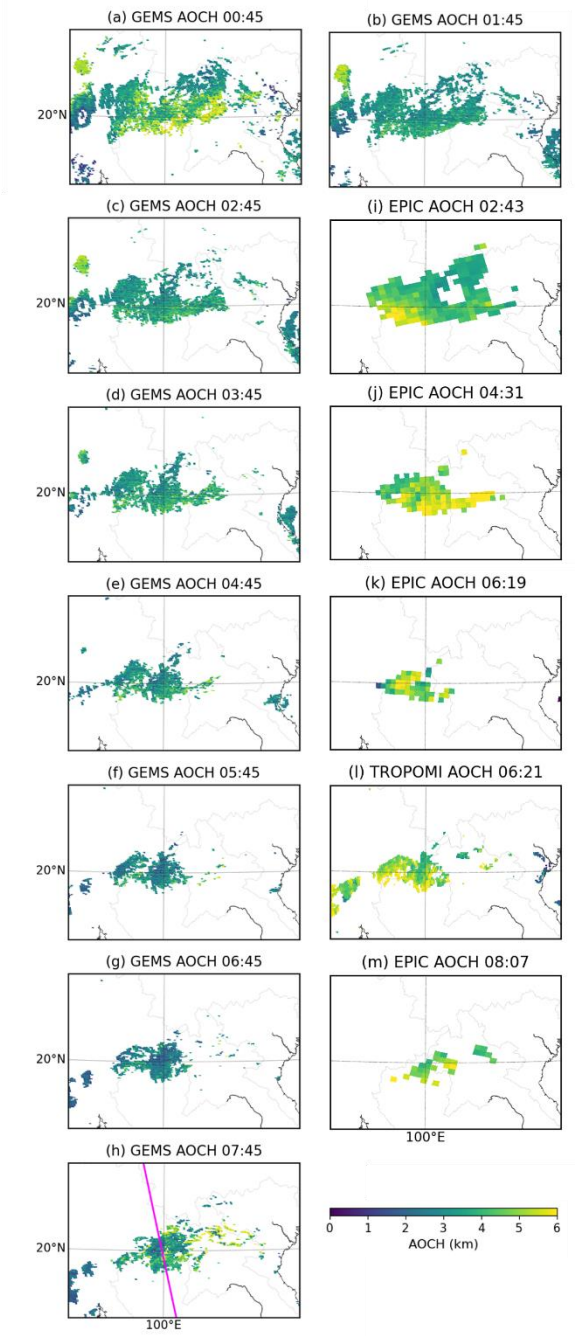


Figure S12. Regional coverage for absorbing aerosols screened by UVAI thresholds as 3, 1.5, 2, for GEMS, TROPOMI, and EPIC, respectively. Figures (a – h) show hourly GEMS ALH products presented in timely order from (a) 00:45 to (f) 07:45 (UTC). Figures (i – m) show EPIC and TROPOMI ALH aligned with the nearest time of GEMS measurement time for a smoke plume case on 17 April 2021. CALIOP ground tracks are shown as the magenta line on the GEMS ALH map (first column) where it has the closest observation time with GEMS.