Retrieval of Aerosol optical properties and PM from geostationary satellites in Asia

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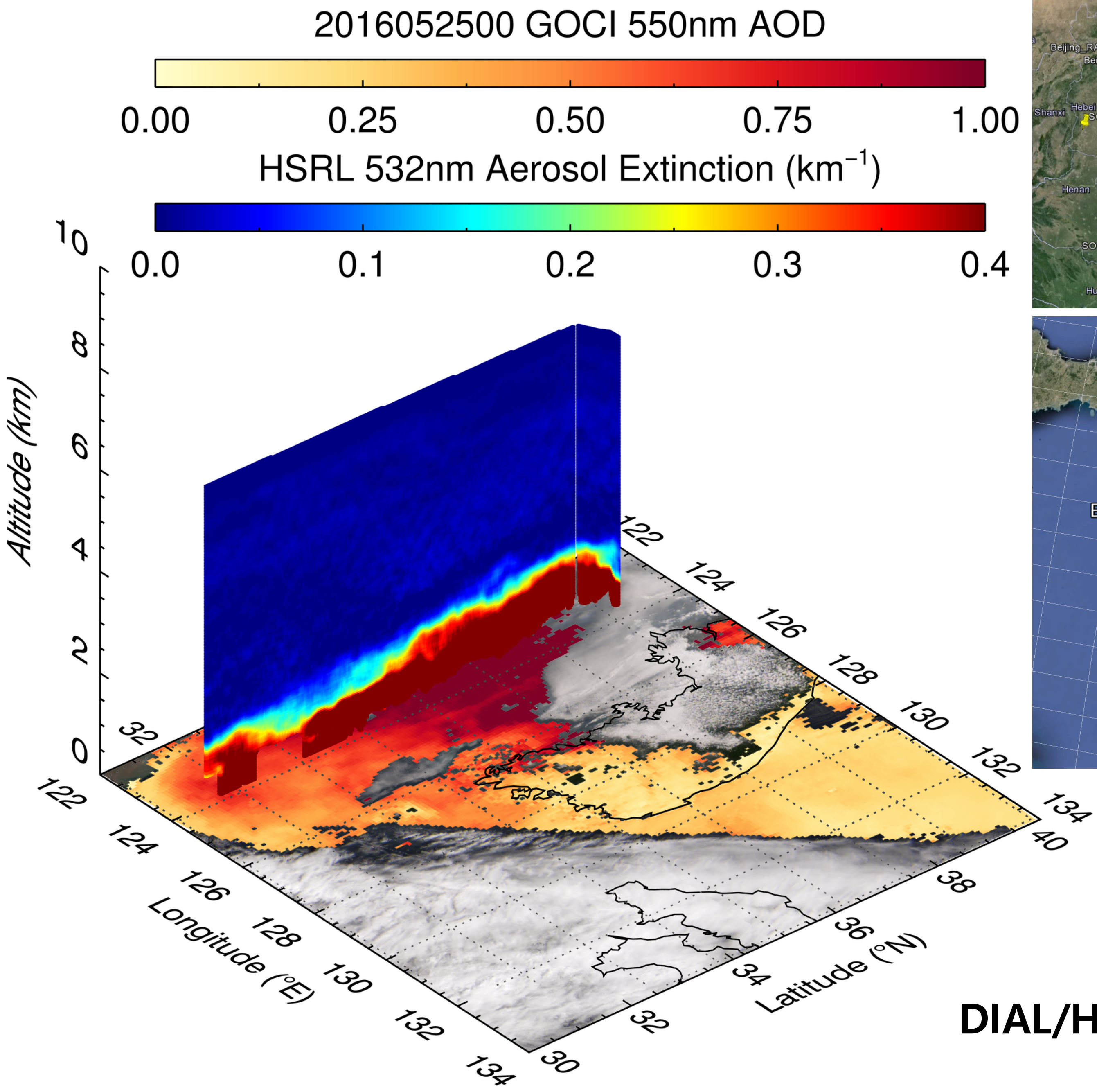
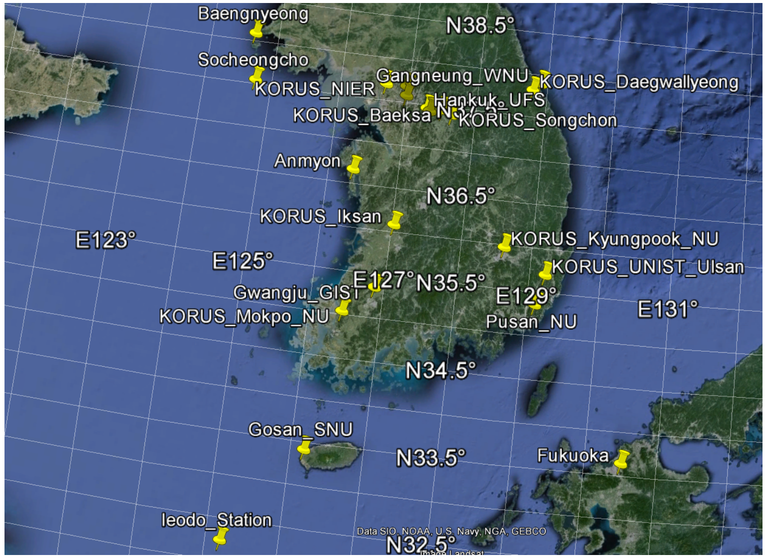
Outline

- Introduction
- GOCI
- AHI
- Synergy with multiple satellite dataset
  - GOCI + AHI
  - GEMS(OMI) + AHI(MODIS)
- PM estimation from satellite AOD
- Summary

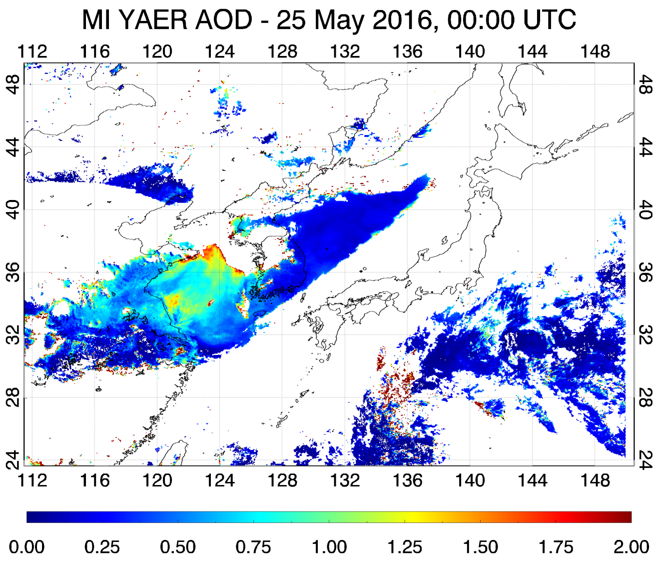
KORUS-AQ

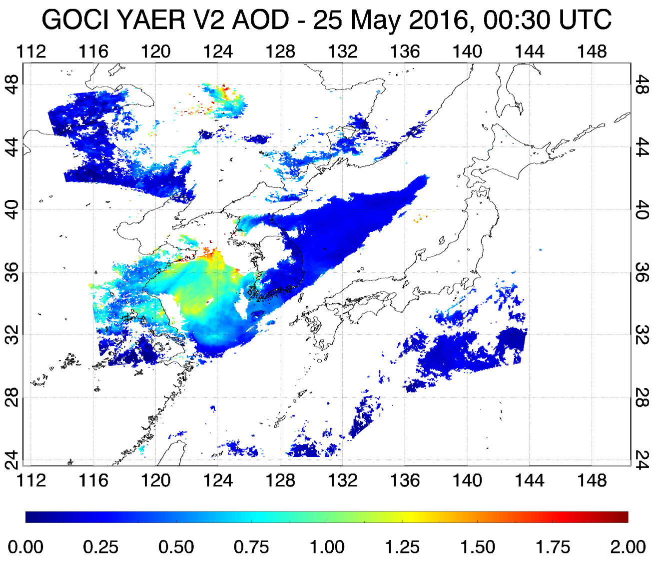


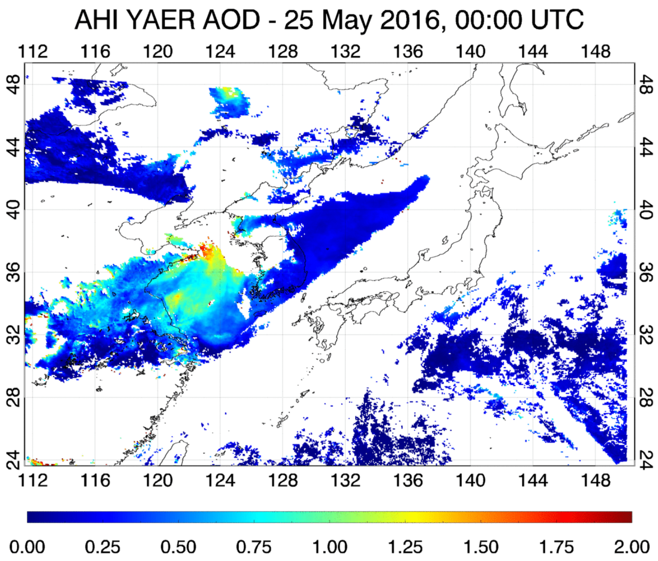


DIAL/HSRL John Hair, Jim Crawford (NASA LaRC),

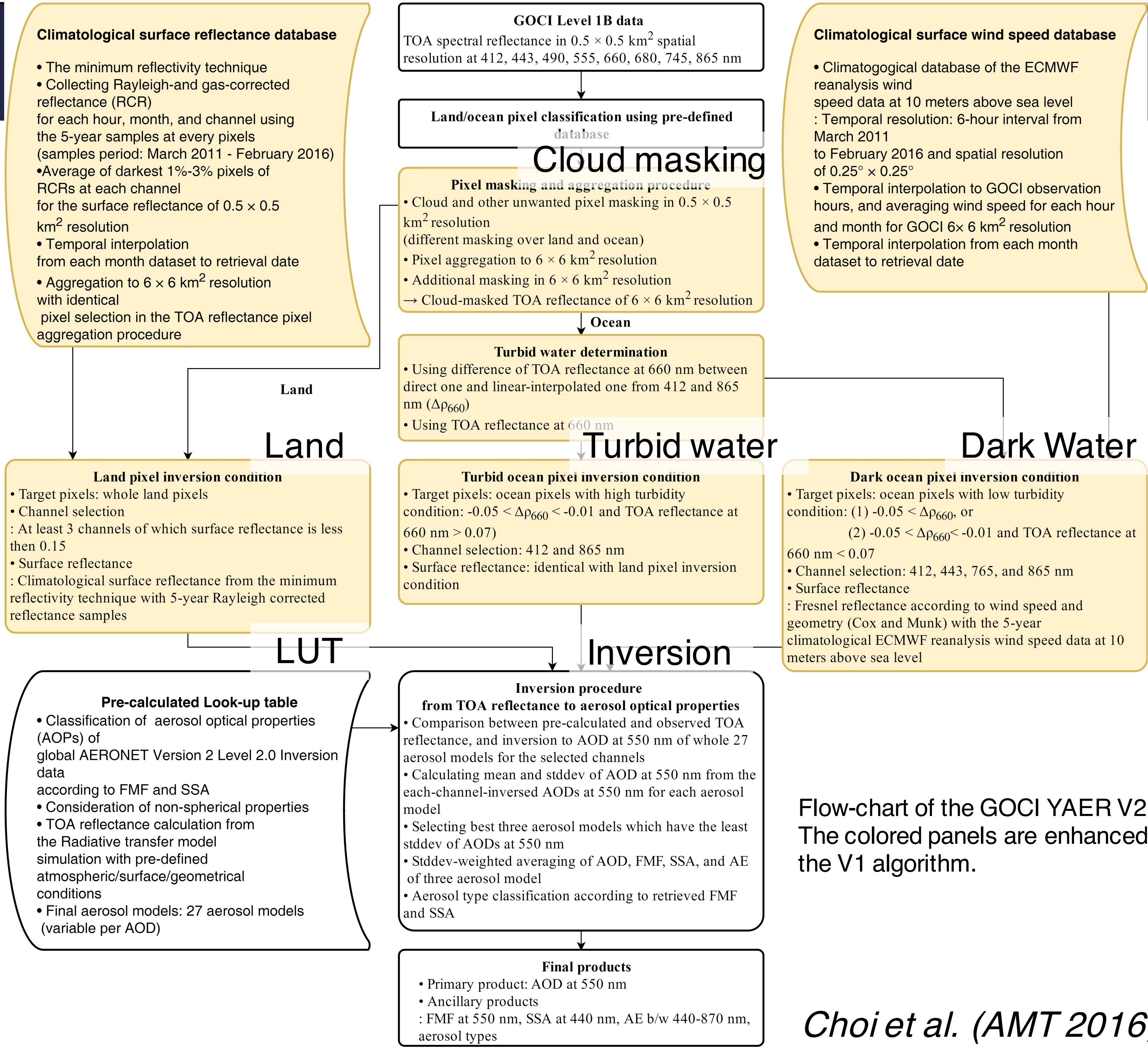
Geostationary observation of aerosol over East Asia







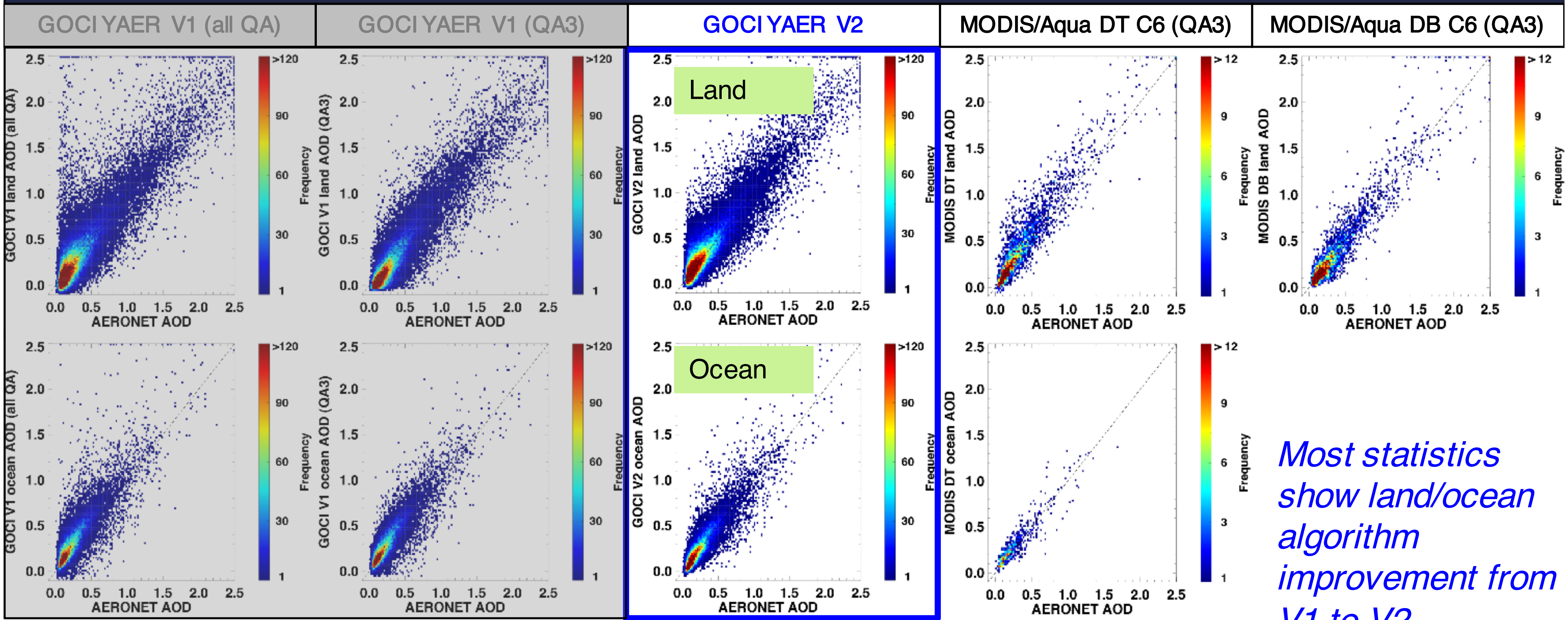
MI/COMS (NMSC/KMA, Korea)	GOCI/COMS (KOSC/KIOST, Korea)	AHI/Himawari-8 (JMA, Japan)
15-min interval for East Asia 3-hour interval for Full Disk (day and night)	1-hour interval for East Asia (total 8 times in daytime)	10-min interval for Full Disk (day and night)
1 bands in VIS (1 km) 4 bands in IR (4 km)	8 bands in VIS-NIR (0.5 km)	4 bands in VIS-NIR (0.5/1.0 km) 12 bands in IR (2 km)
Aerosol products (Yonsei) AOD (4km) *Mijin Kim et al. (2014, 2016)*	Aerosol products (Yonsei) AOD, FMF, AE (6 km) *Myungje Choi et al. (2016,2018)*	Aerosol products (Yonsei) AOD, FMF, AE (6 km) *Hyunkwang Lim et al. (2016; under review)*



Flow-chart of the GOCI YAER V2 algorithm. The colored panels are enhanced parts from the V1 algorithm.

Choi et al. (AMT 2016,2018)

Land/Ocean AOD (Total 27/17 AERONET sites, 2011.03-2016.02)

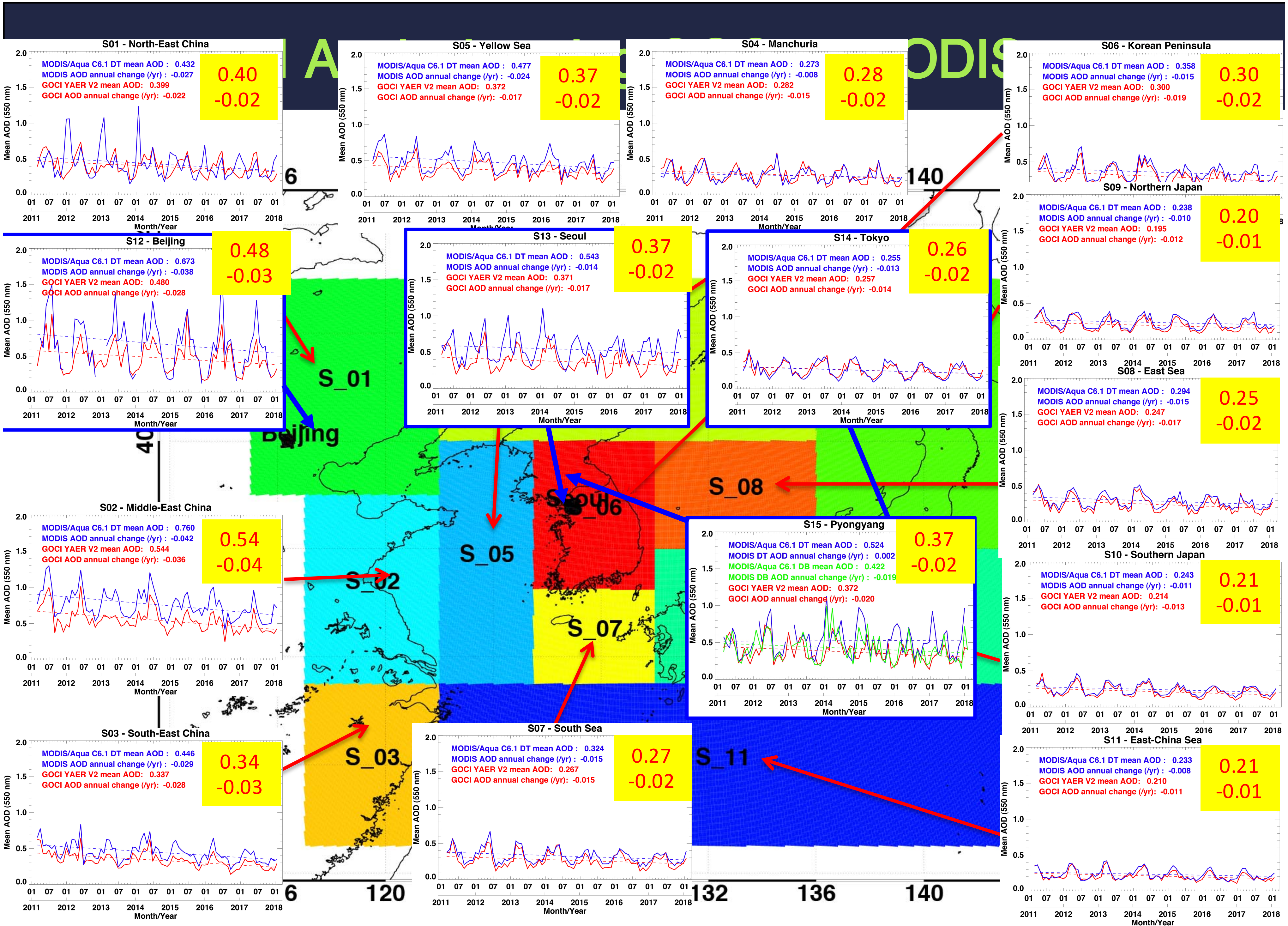


Most statistics show land/ocean algorithm improvement from V1 to V2

Land AOD	V1 AllQA	V1 QA3	V2	DT	DB
N	47850	38183	45818	3228	3463
R	0.86	0.92	0.91	0.92	0.93
Median Bias	-0.015	-0.066	0.019	0.043	0.007
Ratio within EE_{DT}	0.49	0.49	0.6	0.62	0.73
RMSE	0.24	0.18	0.16	0.18	0.16

Ocean AOD	V1 AllQA	V1 QA3	V2	DT
N	19945	18308	18588	680
R	0.83	0.88	0.89	0.92
Median Bias	0.056	0.043	0.008	0.033
Ratio within EE_{DT}	0.55	0.62	0.71	0.73
RMSE	0.17	0.13	0.11	0.09

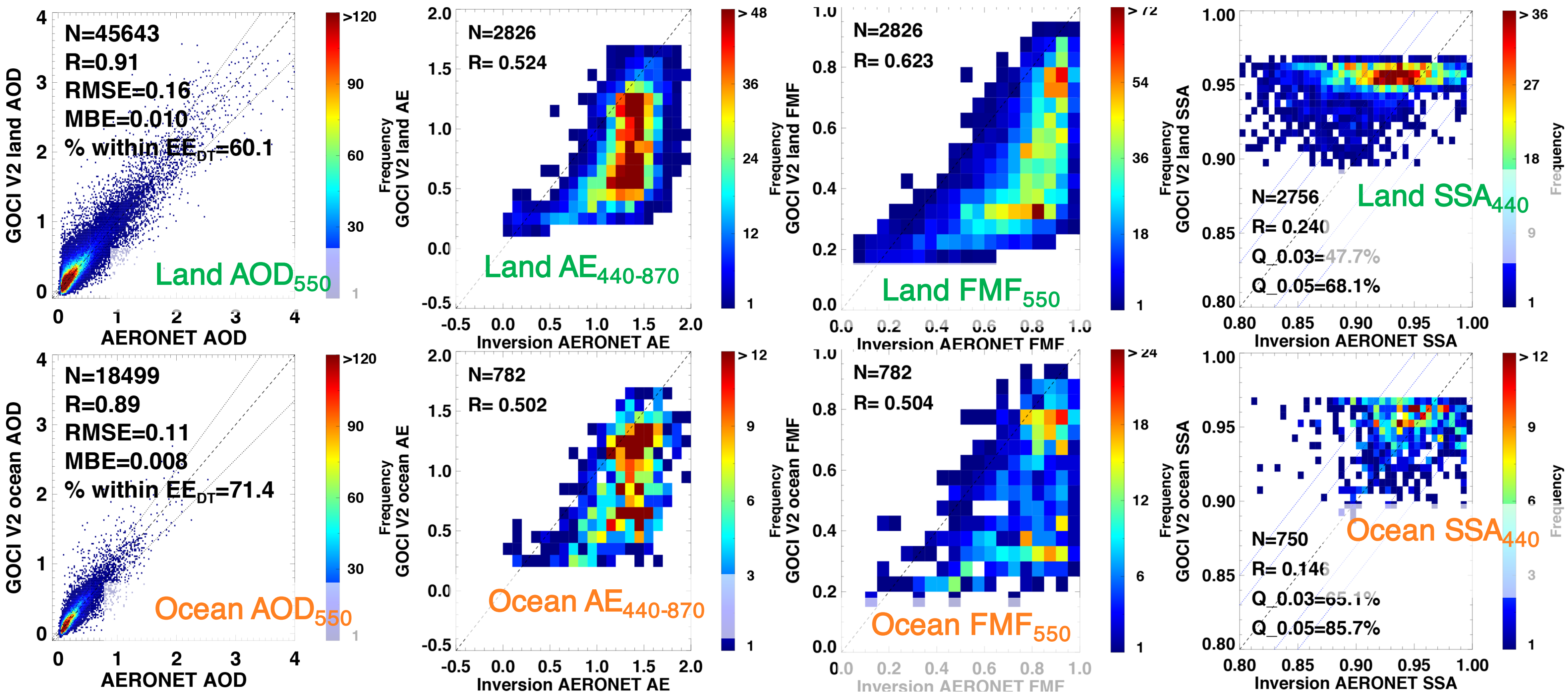
$EE_{DT} = \pm(0.05 + 0.15\ AOD_A)$



Kim et al. (2017) with update

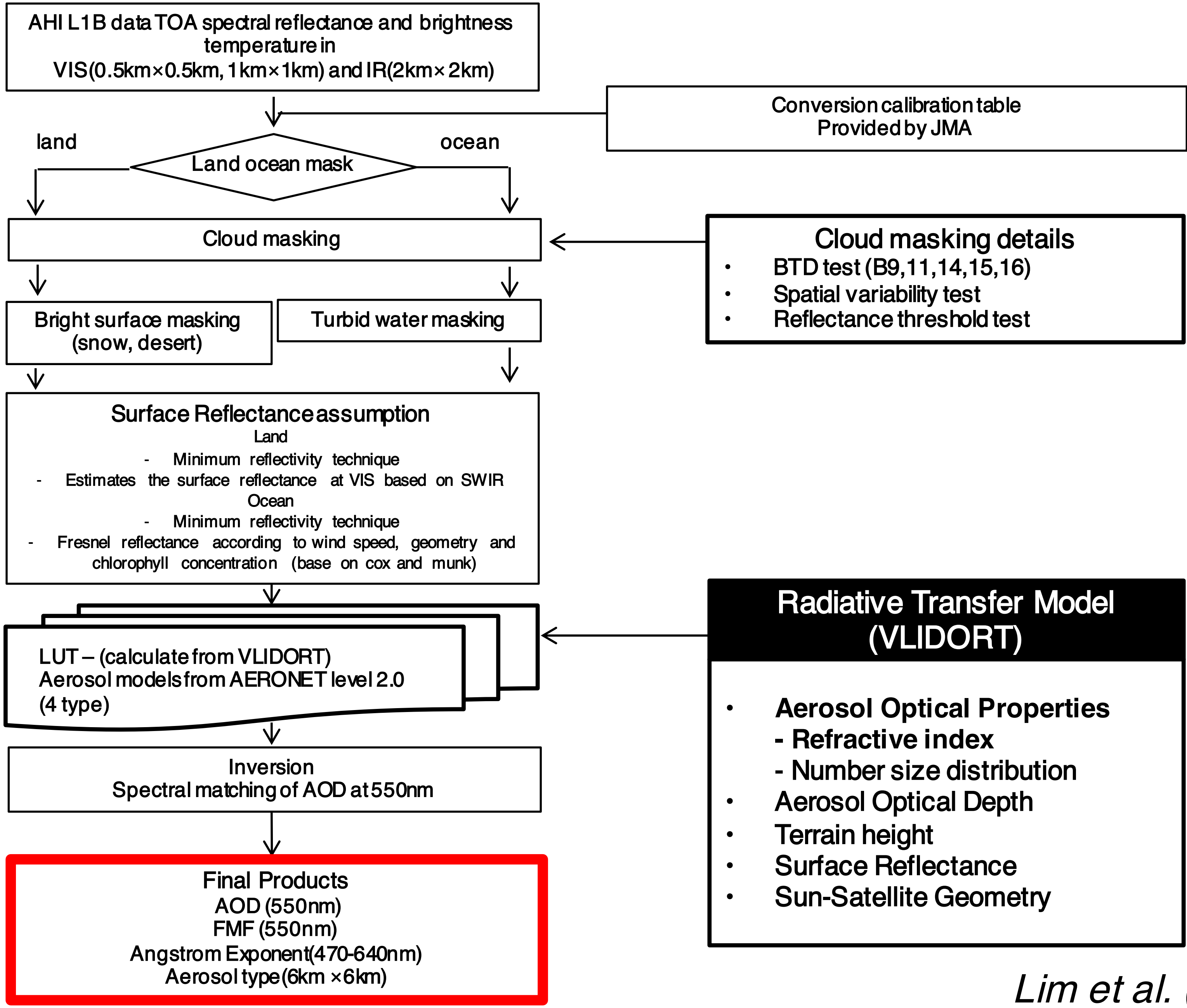
Validation of GOCI AOD, AE, FMF, and SSA (Mar 2011 – Feb 2016, 5-yr)

Collocation with 27 AERONET sites for land AOD, and 17 coastal sites for ocean AOD



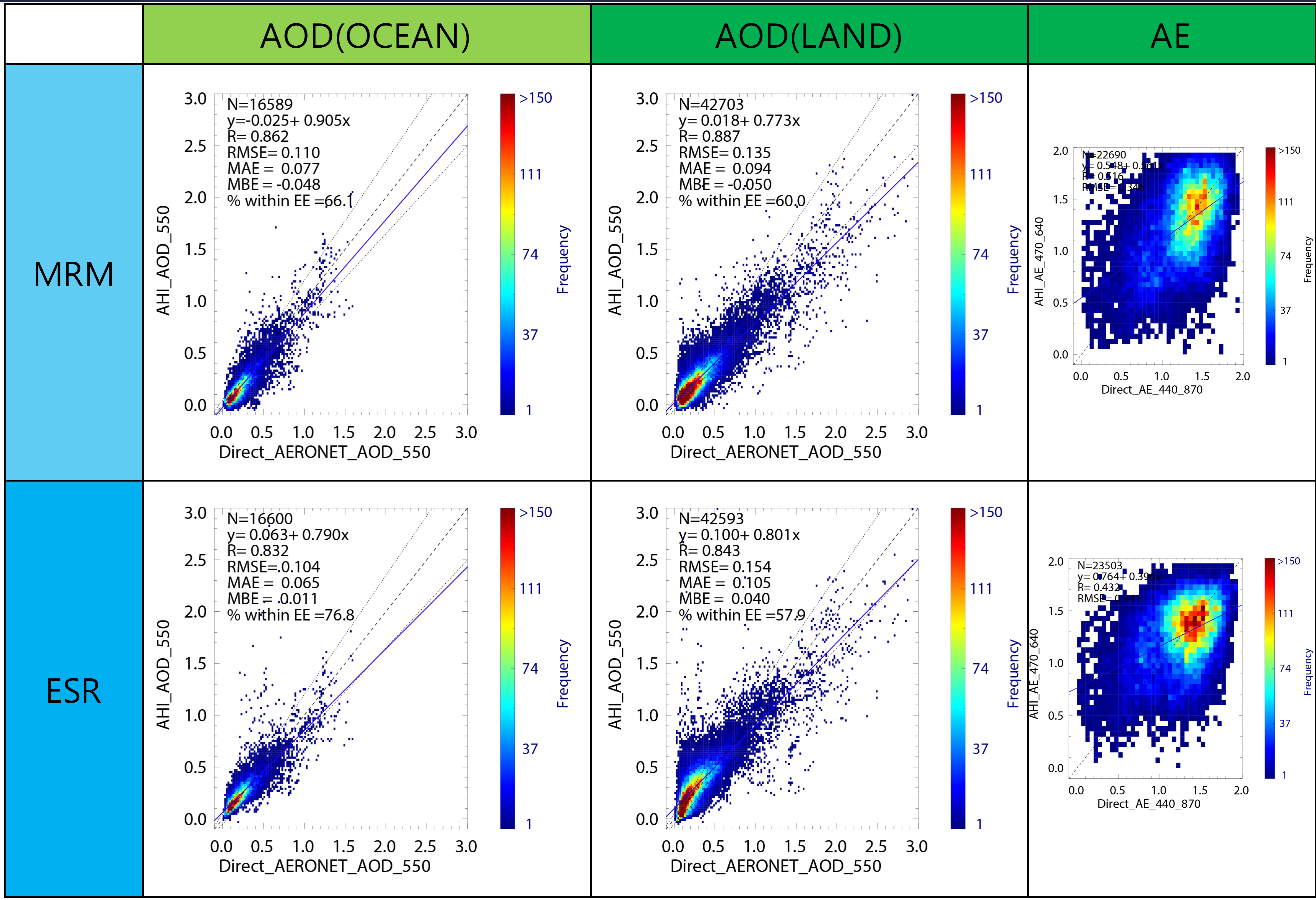
- $EE_{DT} = \pm (0.05 + 0.15 \times \text{AERONET AOD})$
- *AE, FMF, and SSA comparison: only for AERONET AOD > 0.3*
- Collocation criteria:
  (spatially) average satellite pixels **within 25 km** radius from AERONET sites
  (temporally) average AERONET data **within 30 min** from satellite measurement

Overview of AHI-YAER algorithm



Lim et al. (RS, 2018)

1-year validation of AHI in 2016



L2 Merged AOD products between MRM and ESR AOD

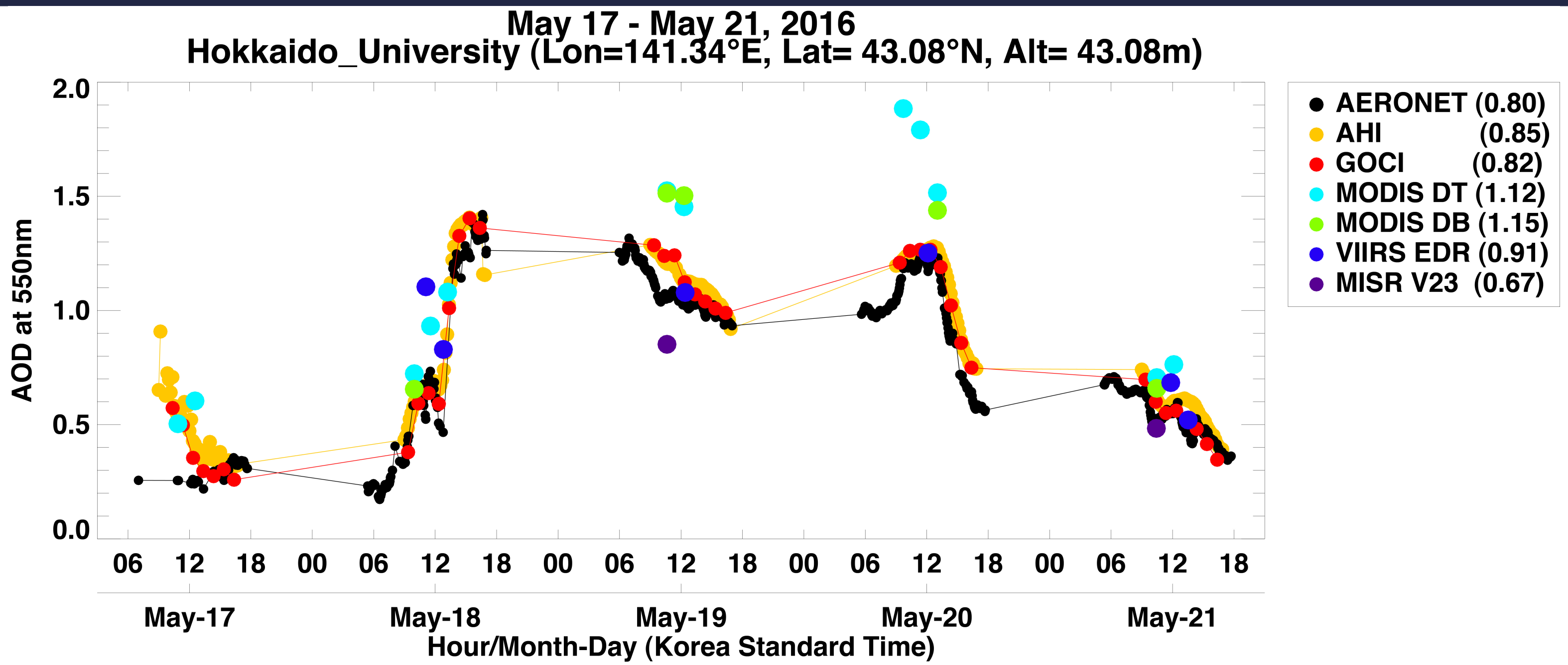
MRMver	N	R	RMSE	MBE	%EE
2	2826	0.779	0.09	-0.012	75.9
5	9064	0.893	0.117	-0.056	56.4
8	4419	0.834	0.138	-0.048	57.2
11	2466	0.796	0.087	0.016	75.5

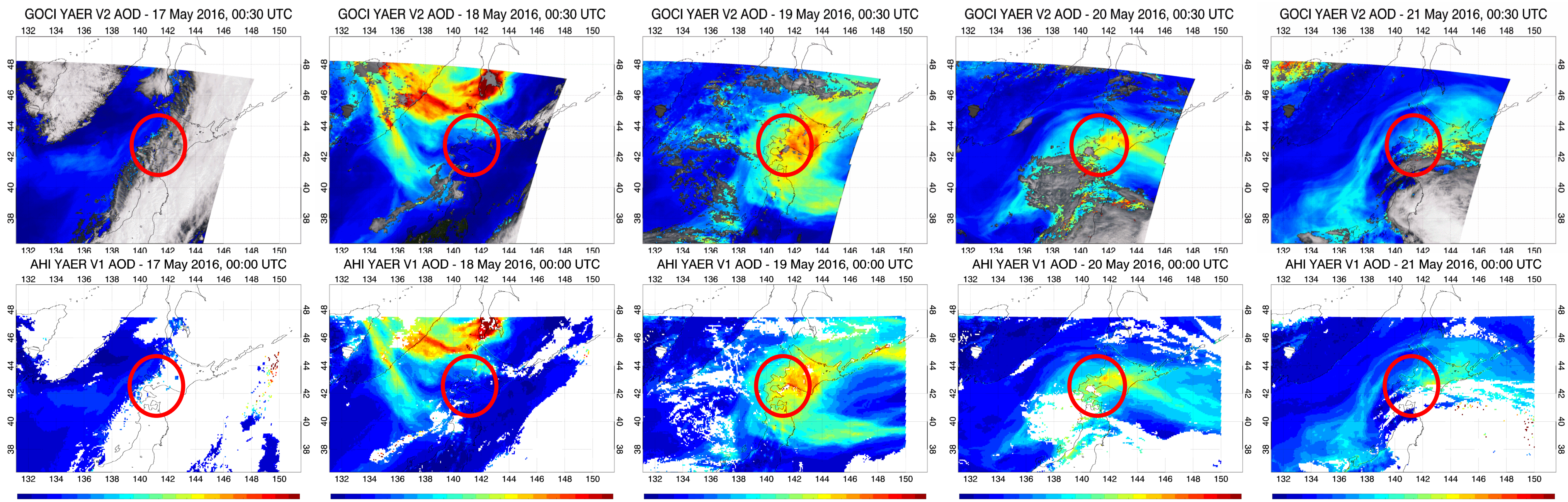
ESRver	N	R	RMSE	MBE	%EE
2	2691	0.655	0.121	-0.024	63.0
5	9080	0.892	0.103	-0.02	68.3
8	4463	0.815	0.137	0.013	63.1
11	2419	0.628	0.126	-0.062	47.3

Merged	N	R	RMSE	MBE	%EE
2	2826	**0.787**	**0.088**	-0.016	**82.2**
5	9080	**0.906**	**0.103**	-0.039	**68.3**
8	4419	**0.838**	**0.129**	-0.017	**63.7**
11	2466	0.78	0.089	-0.016	71.2

- The simple merge method takes an average if both ESRver AOD and MRMver AOD are present, and uses the retrieved value if it is retrieved only in one version.
- Overall, RMSE decreased and percent within EE increased. In other words, we could obtain better quality AOD by composing.
- However, the results of the ESR version were not good in November, and the merge AOD results were not improved.
- For future research, AHI YAER assumes that all aerosol models are spherical, but dust aerosol is non-spherical and should be considered.
- It is necessary to improve the surface reflectivity using the ESR method in autumn~winter, and it is also possible to merge at L1b status(merged surface reflectance) to establish accurate surface reflectance.

Diurnal variation for aerosol from satellite and ground-based measurements



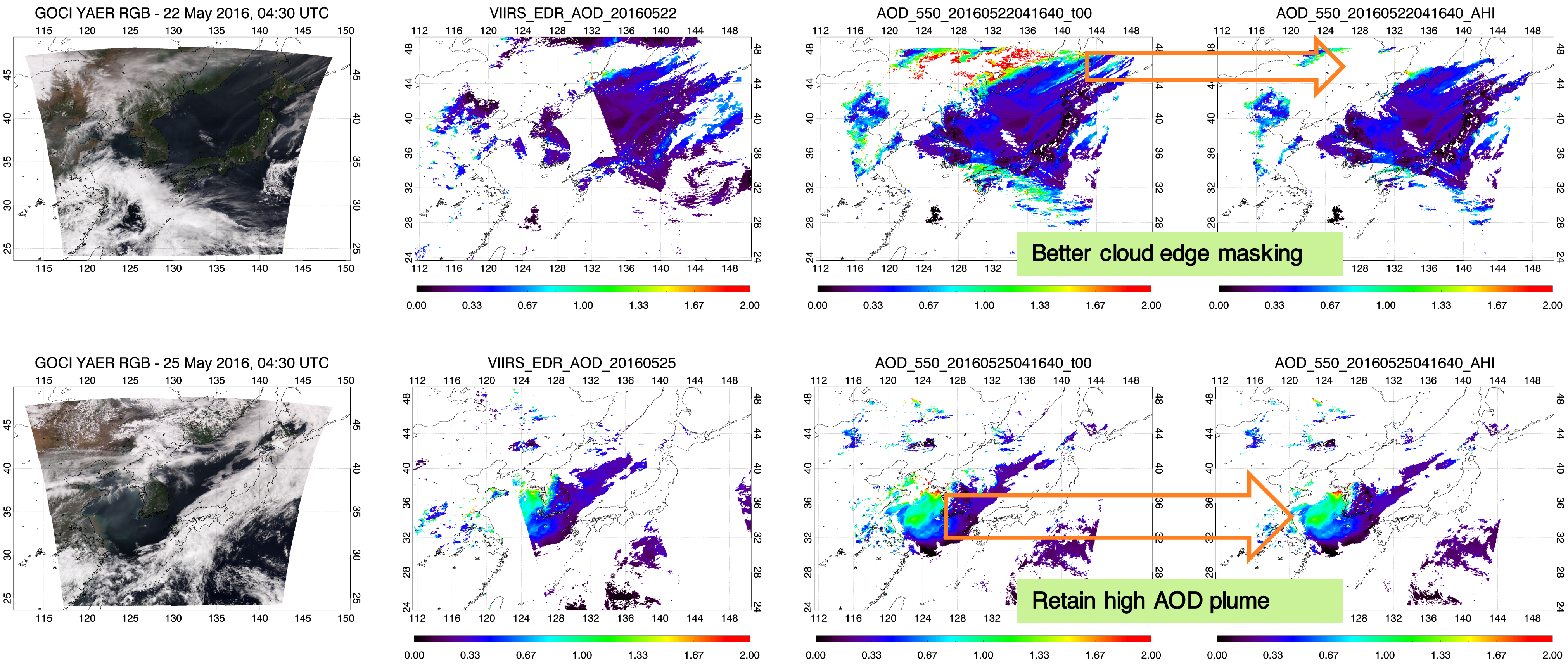


Synergistic use of GK2A, 2B

Satellite in Orbit	GEO-KOMPSAT-2A	GEO-KOMPSAT-2B	
Payload	AMI (~ABI)	GEMS(~TEMPO)	GOCI-2
Channels (㎛)	*16 channels (0.47~13.31)*	*1000 channels (0.3~0.5) Scanning UV-VIS Spectrometer*	*12 channels + 1 wideband (0.380~0.865) VIS, NIR*
Temporal resolution	within 10 min (FD)	1 hour (8 times/day) (30min imaging + 30min rest)	1 hour (10 times/day (Local) + 1 times (FD))
Spatial resolution	1km (<0.856㎛, VIS) 0.5km (=0.64㎛, VIS) 2km (>1.38㎛, IR)	Gas : 7(NS)x8(EW) km Aerosol : 3.5(NS)x8(EW) km	250m (@130°E) 1km (FD)
Spectral resolution	-	<0.6nm (3 samples) (spectral sampling < 0.2nm)	12 narrow bands (10 ~ 40 nm)
Field of regard (FOR)	**Full Disk**	5,000km(N/S) × 5,000km(E/W) N/S: 45°N ~ 5°S, E/W: 75°E ~ 145°E (E/W, Selectable)	2,500km(N/S) × 2,500km(E/W)
Baseline products	- Scene & Surface Analysis - Cloud & Precipitation - *Aerosol* & Radiation *: (AOD, Asian Dust detection, Particle Size)* - Atmospheric condition & Aviation	O_3 (Column, Profile), NO_2, SO_2, HCHO, *Aerosols (AOD, SSA, ALH)*, UVI, CHOCHO	- Water quality variable - Marine Environmental products - *Atmospheric Properties* *: AOD, dust detection, aerosol type..* - Land variable

Additional AHI IR cloud mask in GOCI AOD retrieval

RGB | VIIRS EDR (QA3) | GOCI YAER V2 | GOCI YAER V2 + AHI IR cloud masking

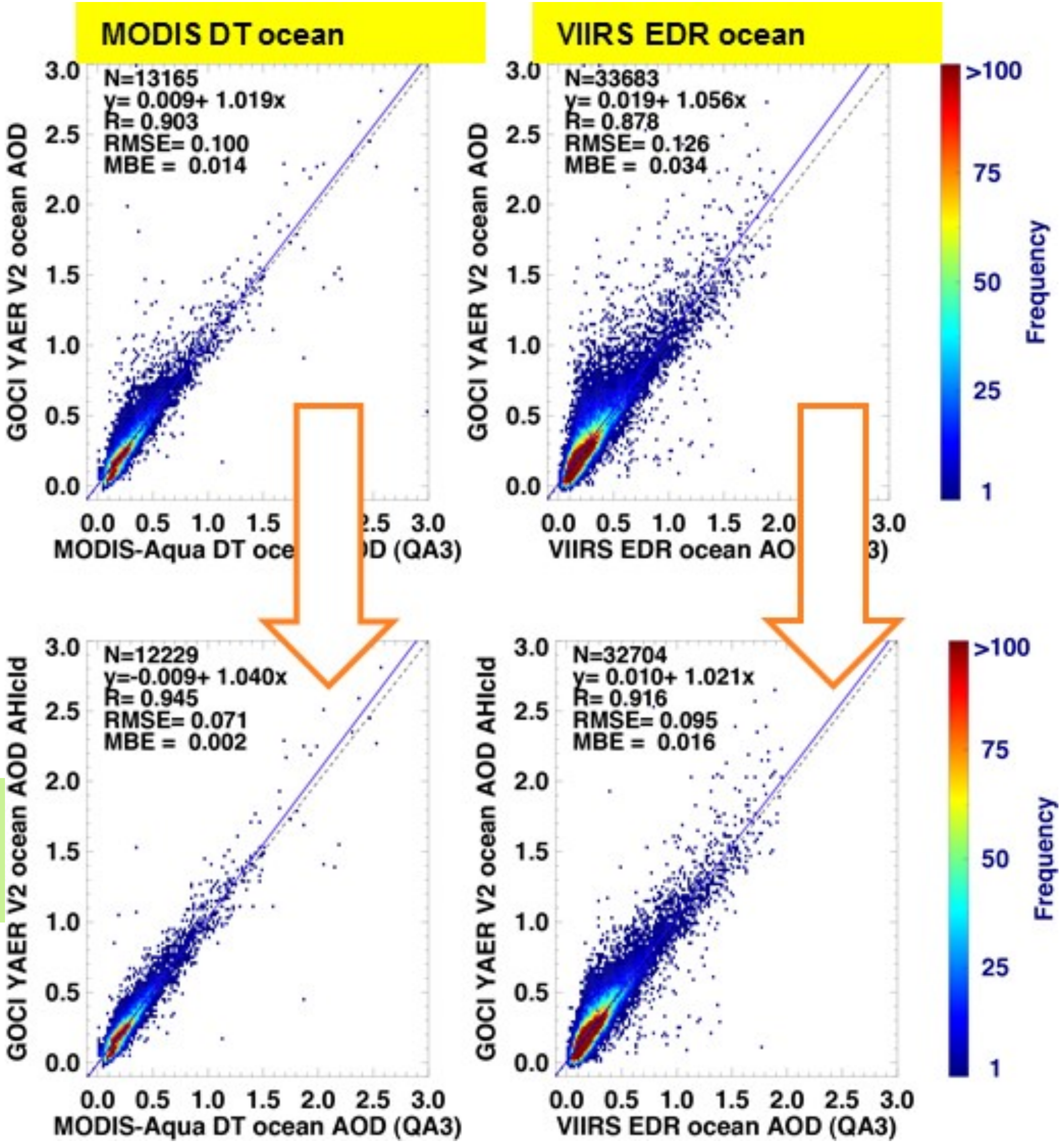


AHI IR cloud masking works successfully on GOCI AOD to filter out cirrus or shallow cloud contamination as retaining high AOD well.

Inter-comparison: MODIS/VIIRS vs GOCI (0.5 degree grid box) during the KORUS-AQ campaign

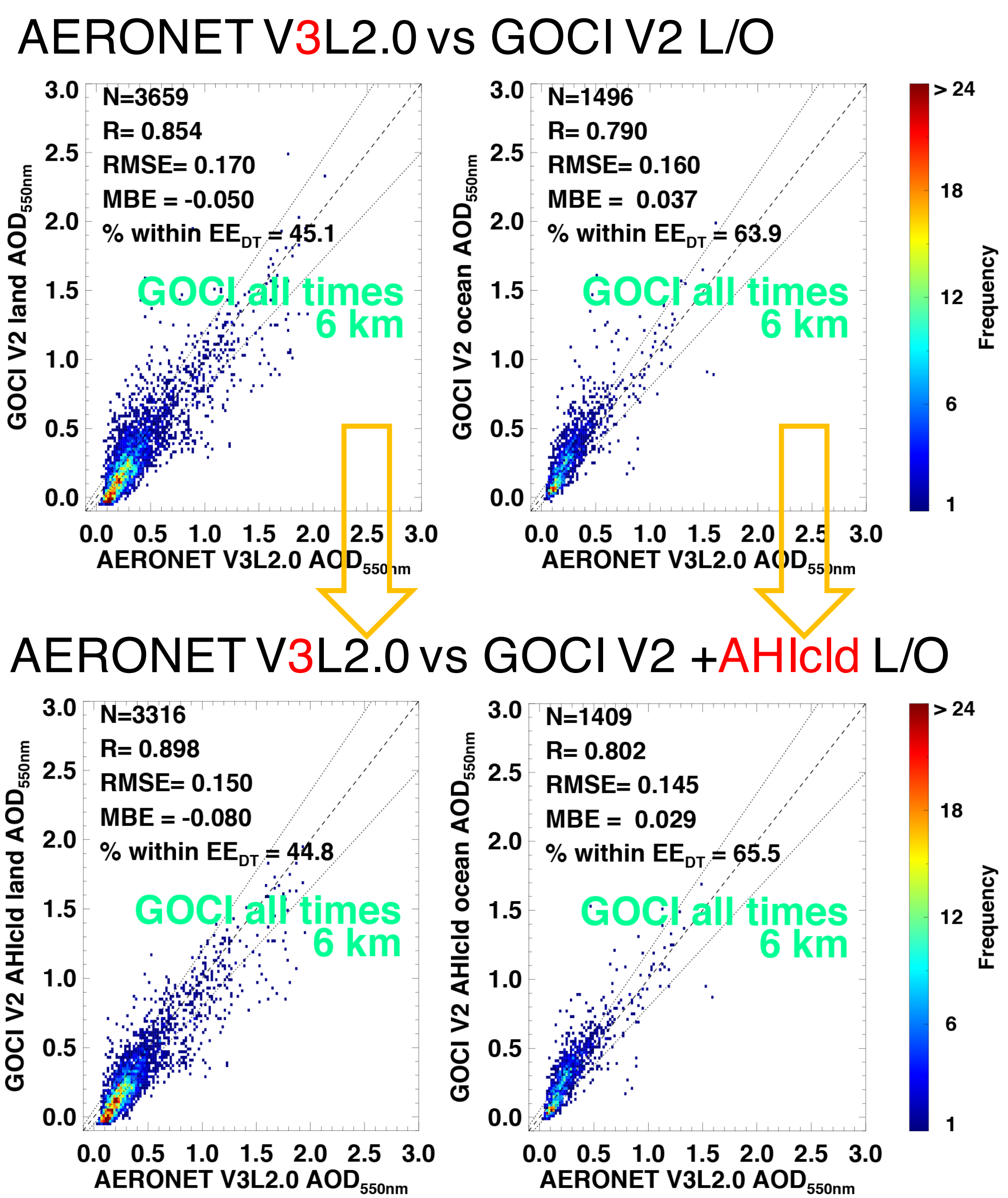
Ocean AOD
GOCI YAER V2

Ocean AOD
GOCI YAER V2
<u>+ AHI IR cloud masking</u>



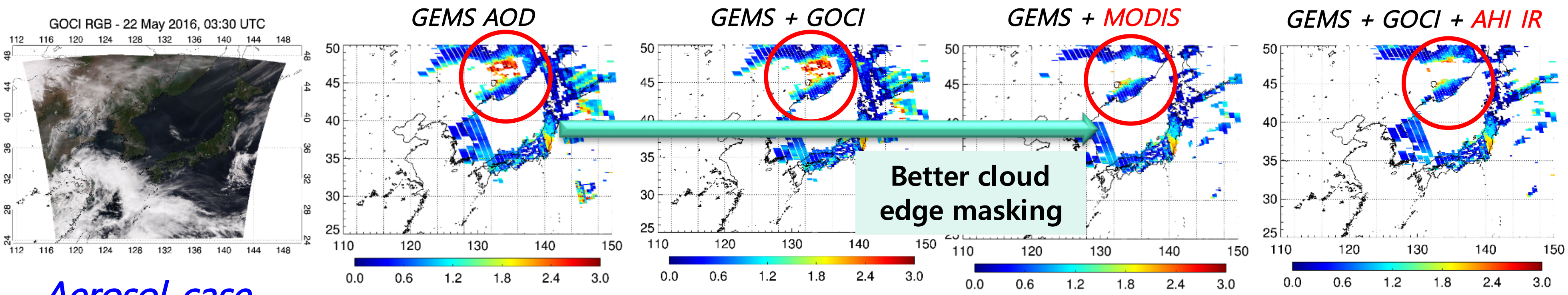
AHI IR cloud masking results in increased correlation coefficient b/w GOCI and MODIS/VIIRS over ocean (R: 0.90→0.95 with MODIS, 0.88→0.92 with VIIRS)

AERONET AOD vs GOCI AOD during KORUS-AQ

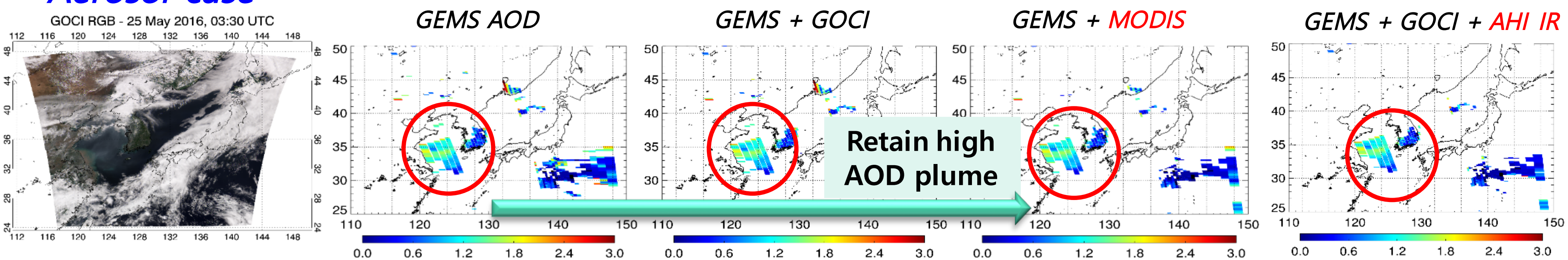


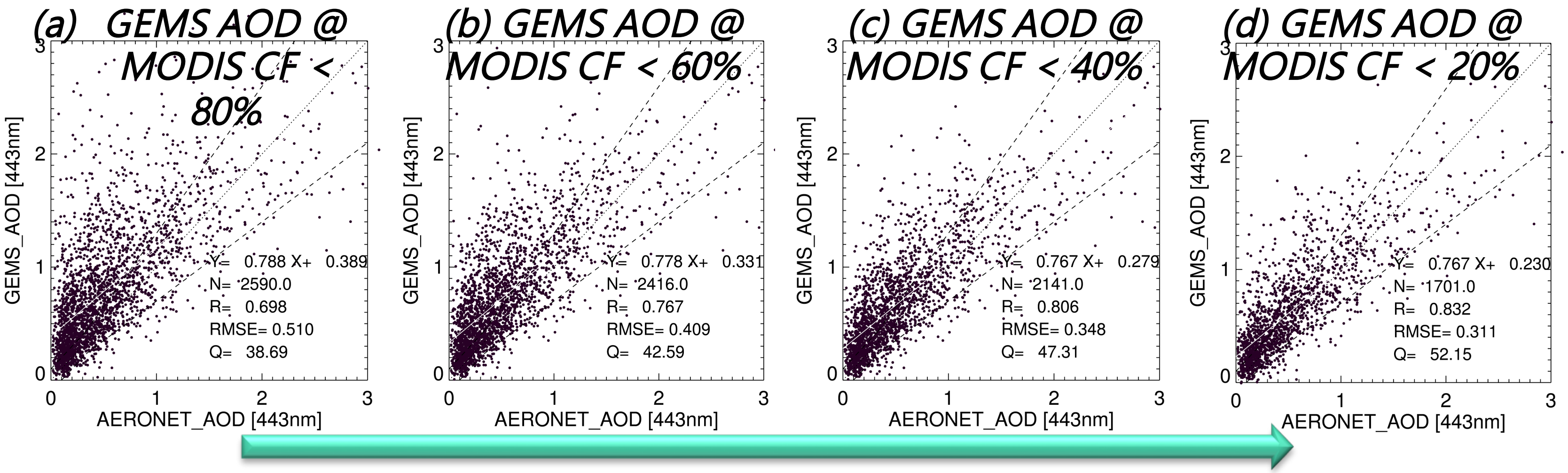
GEMS-AMI synergies : cloud masking

Cirrus case



Aerosol case



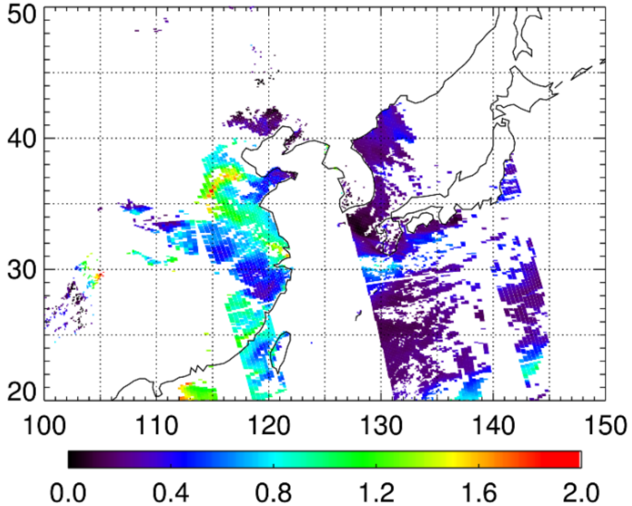


R=0.70 *R=0.77* *R=0.81* *R=0.83*

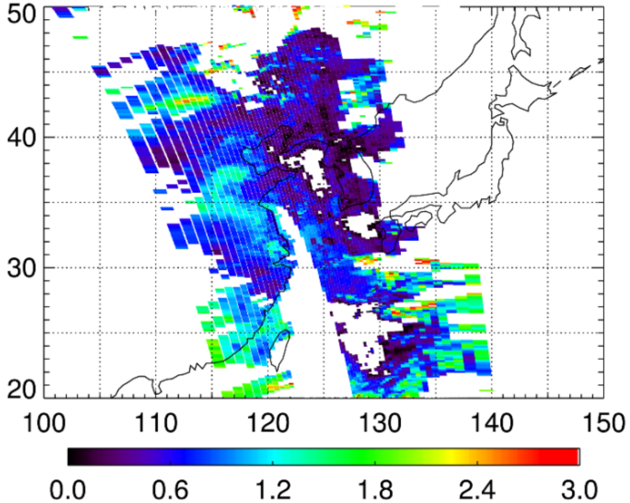
Case study of MLE method for OMI(GEMS) and MODIS(AMI)

Case of 30th Mar. 2016

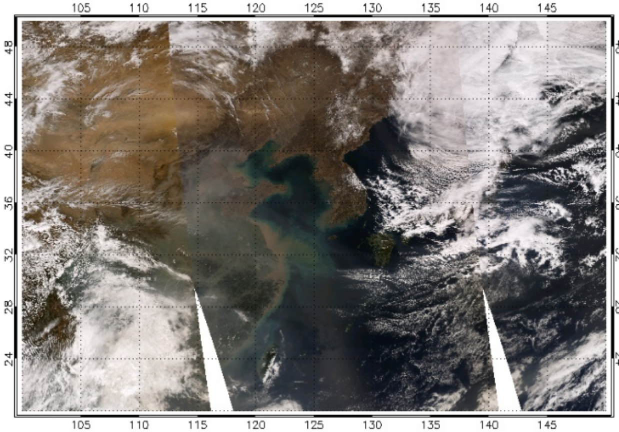
(a) MODIS DT C5.1 AOD 550



(b) GEMS AOD 443 nm



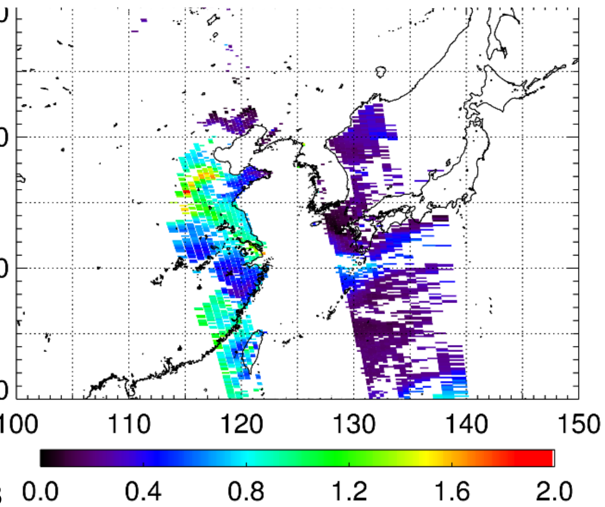
(c) MODIS RGB



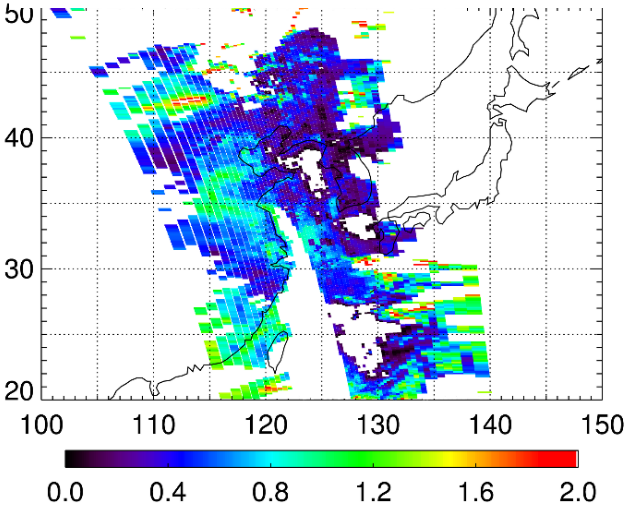
Convert to OMI resolution

Convert to 550nm AOD

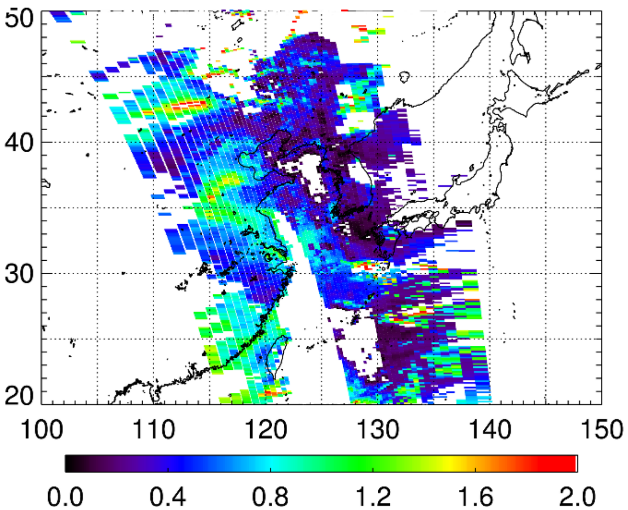
(d) MODIS DT C5.1 AOD 550



(e) GEMS AOD 550 nm

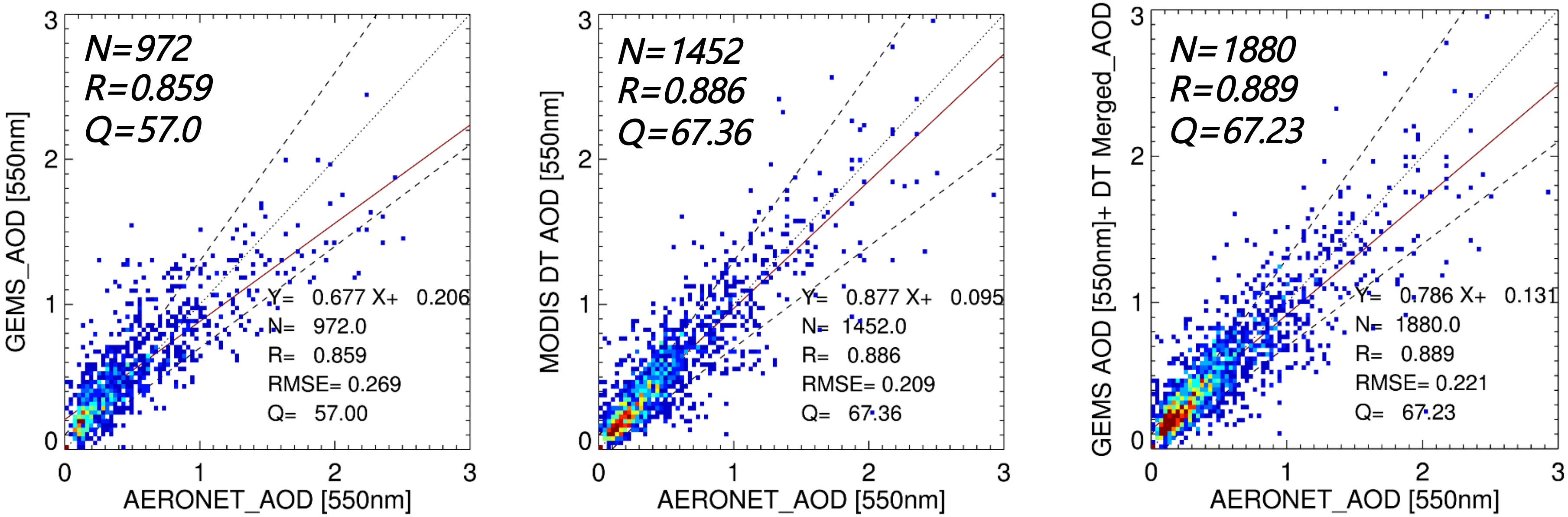


(f) Merged(GEMS+ MODIS) AOD 550 nm



AOD dataset of OMI (GEMS)& MODIS (AMI)

(a) GEMS AOD 550nm | (b) MODIS DT AOD 550nm | (c) GEMS + MODIS Merged AOD 550nm



- AERONET lv.2 Direct AOD
- Domain : 100°E-145°E, 20°N-50°N
- AERONET sites within 0.4°, ±30 minutes
- Period : 2005.01-2007.12

PM estimation from GOCI AOD using MLR models

No	Variable	M01	M02	M03	M04	M05	M06	M07	M08	M09	M10	M11	M12	M13	M14	M15	M16	M17
1	AOD	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
2	FMF			O		O		O	O		O	O	O	O	O	O	O	O
3	SSA				O	O			O			O						
4	NDVI						O	O	O	O	O	O	O	O	O	O	O	O
5	DAI						O	O	O	O	O	O	O	O	O	O	O	O
6	gAMF						O	O	O	O	O	O	O	O	O	O	O	O
7	SP		O	O	O	O	O	O	O	O	O	O	O	O				
8	WS		O	O	O	O	O	O	O	O	O	O	O	O				
9	BLH	O	O	O	O	O	O	O	O	O	O	O	O	O				
10	fRH	O	O	O	O	O	O	O	O	O	O	O	O	O				
11	ST		O	O	O	O	O	O	O	O	O	O	O	O				
	filtering									gFMF >0.4	gFMF >0.4	gFMF >0.4	gFMF >0.6	gFMF >0.8		gFMF >0.4	gFMF >0.6	gFMF >0.8
	R (PM2.5)	0.59	0.63	0.64	0.63	0.64	0.66	0.66	0.67	0.71	0.72	0.72	0.78	0.84	0.62	0.65	0.71	0.78
	R (PM10)	0.50	0.55	0.56	0.56	0.56	0.58	0.58	0.58	0.61	0.62	0.62	0.65	0.71	0.53	0.56	0.59	0.65

All reanalysis data
+ AOD, FMF

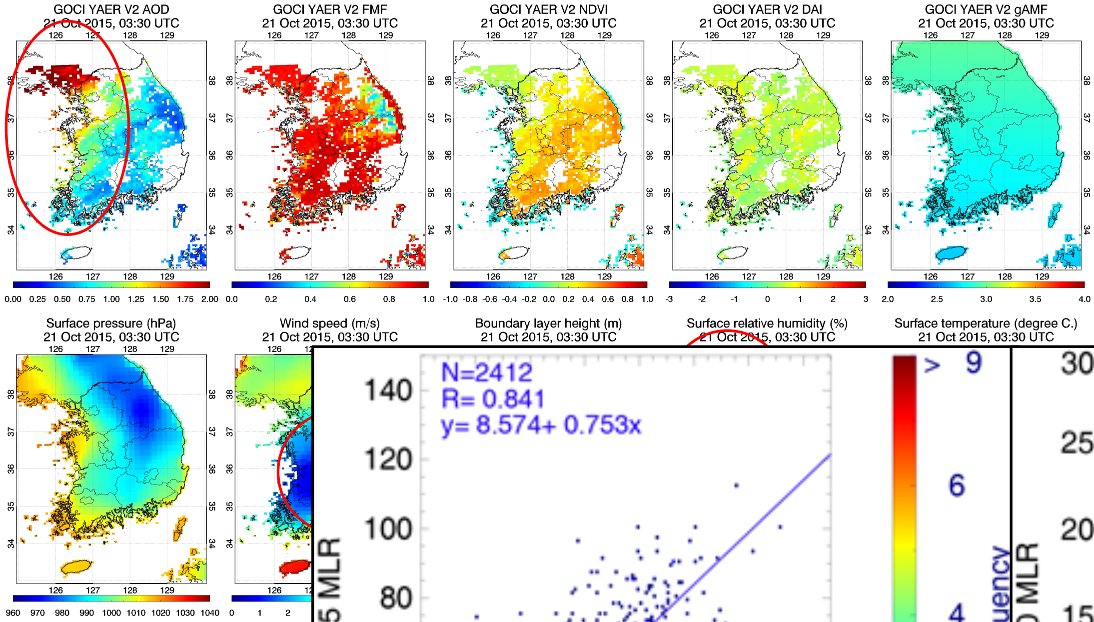
All reanalysis data
+ AOD, FMF
+ NDVI, DAI, AMF

All reanalysis data
+ AOD, FMF
+ NDVI, DAI, AMF
+ GOCI FMF filtering

Only GOCI data
+ GOCI FMF filtering

- As selecting pixels which FMF above 0.4, 0.6 and 0.8,
  → the number of compared is reduced to 34%, 19%, and 6% respectively. (M07→M10/M12/M13)
  → the *R* of PM2.5 increase from 0.66 to 0.72, 0.78, and 0.84, respectively.

PM prediction using M13: case of 21 Oct 2015, 0330UTC

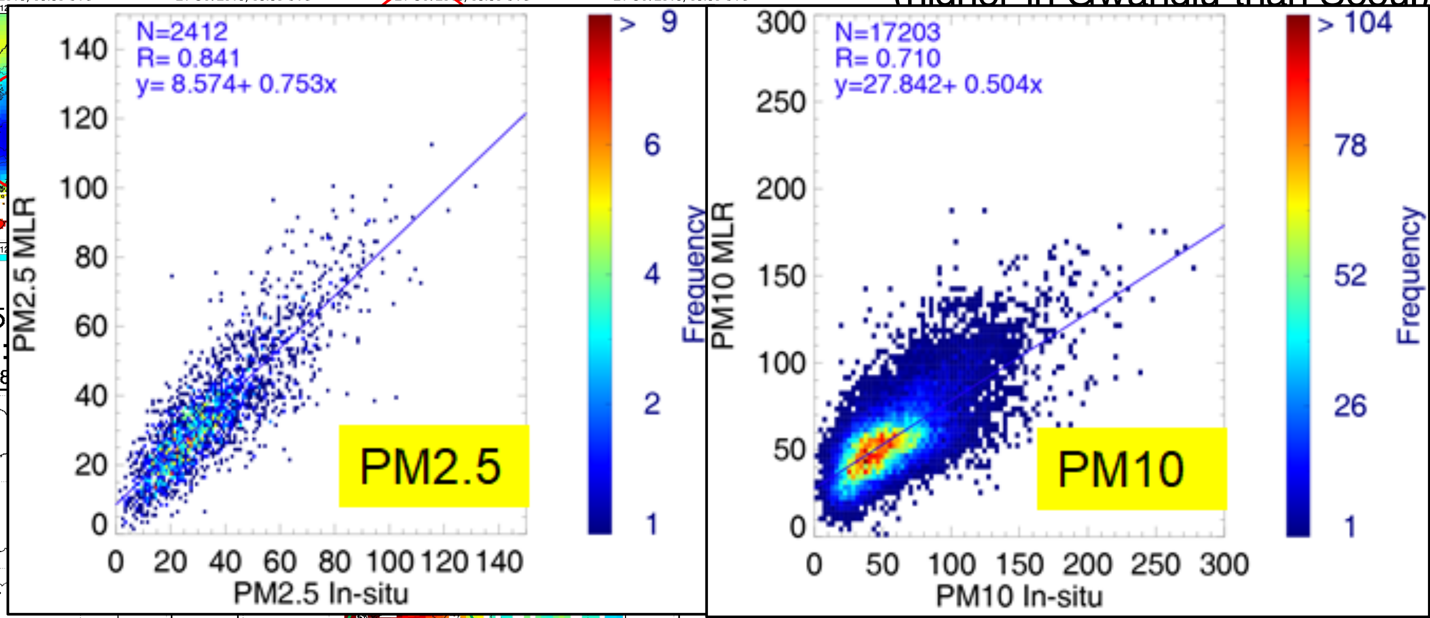


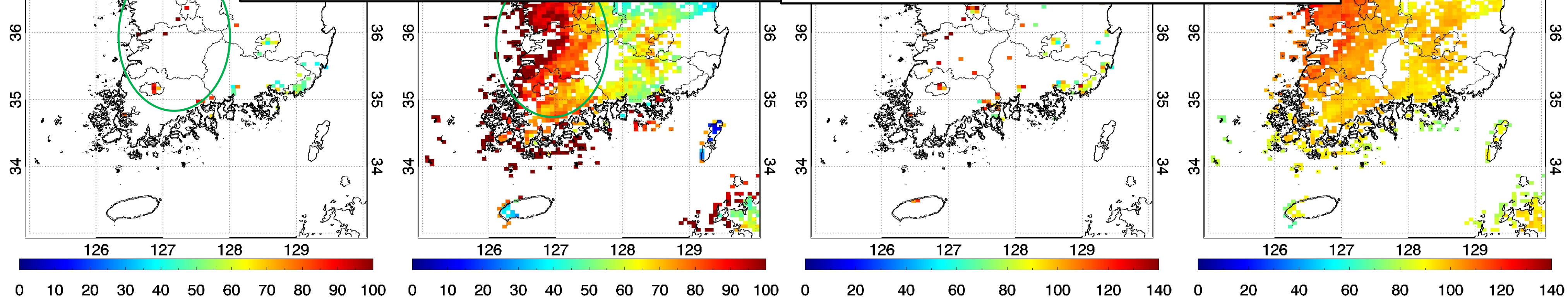
- High AOD at northwestern South Korea (SK)
- Low wind speed in southern SK
- High humidity in northwestern SK

- Measured PM is higher in Western SK (higher in Gwangju than Seoul)

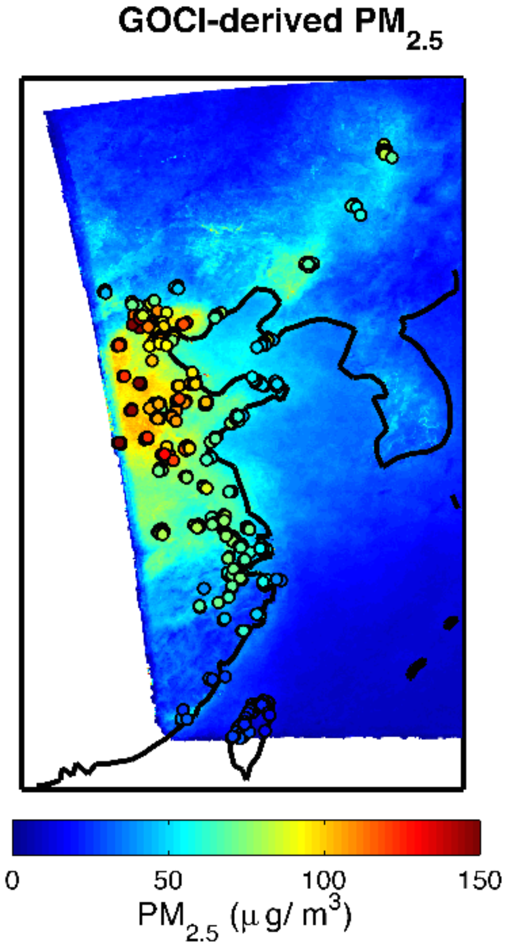
pattern with

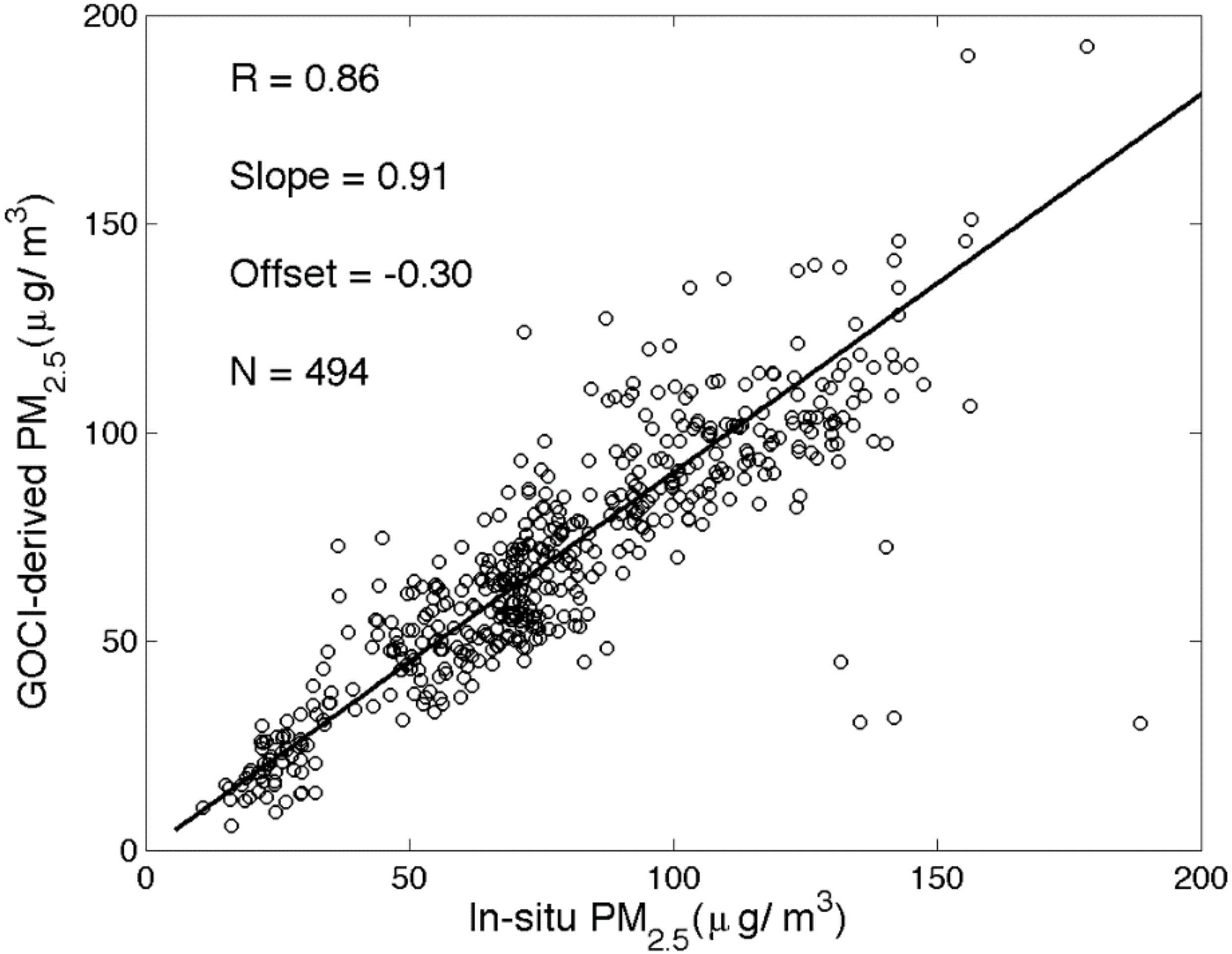
PM2.5 using





Estimation ground-level PM2.5 from GOCI AOD and GEOS-Chem (Dalhousie Univ.)





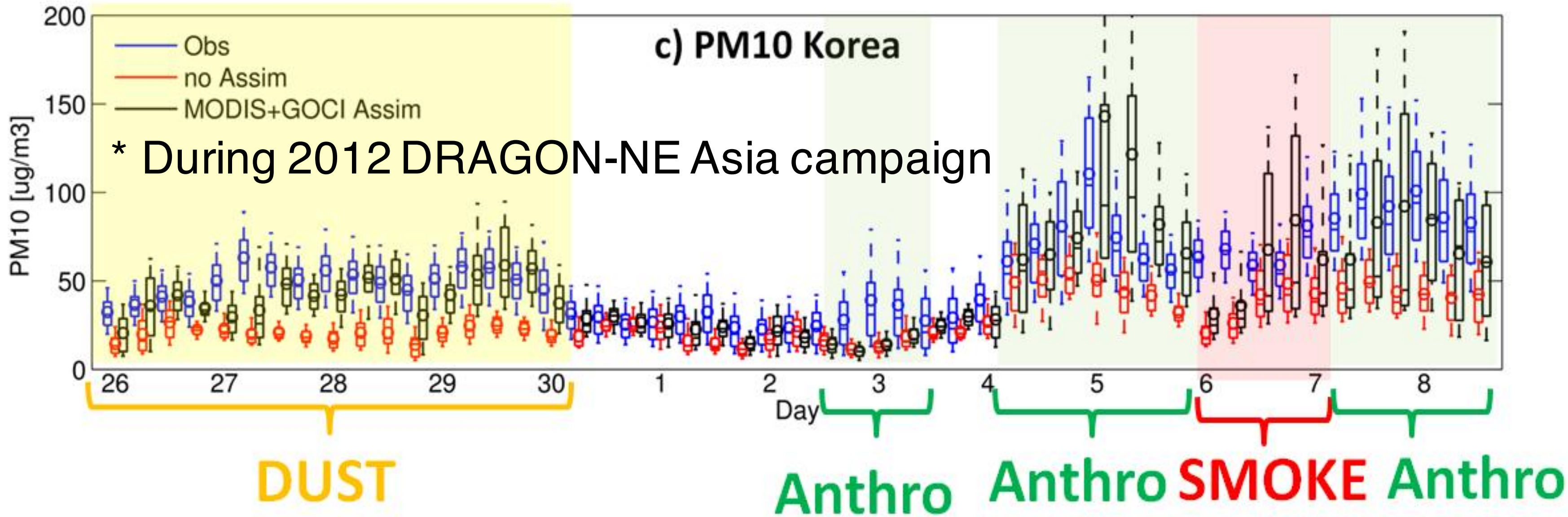
In Situ PM2.5 is better represented by GOCI-derived PM2.5 (slope = 0.91) than by GEOS-Chem (slope =0.53)

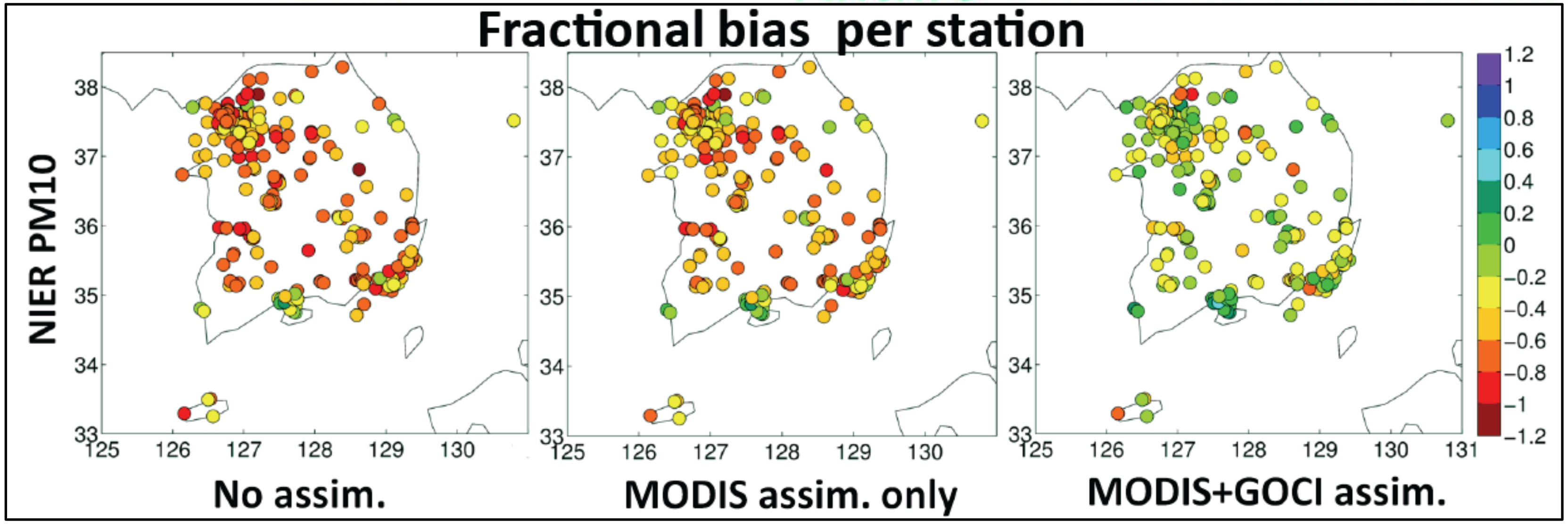
Xu et al., ACP, 2015

Data assimilation of GOCI & MODIS AOD with WRF-Chem Application to the PM_{10} (Univ. of Iowa & NCAR)

The GOCI can provide hourly AOD images, thus it can be assimilated multiple times with Chemical Transport Model within a day.

Saide et al. (GRL, 2014)

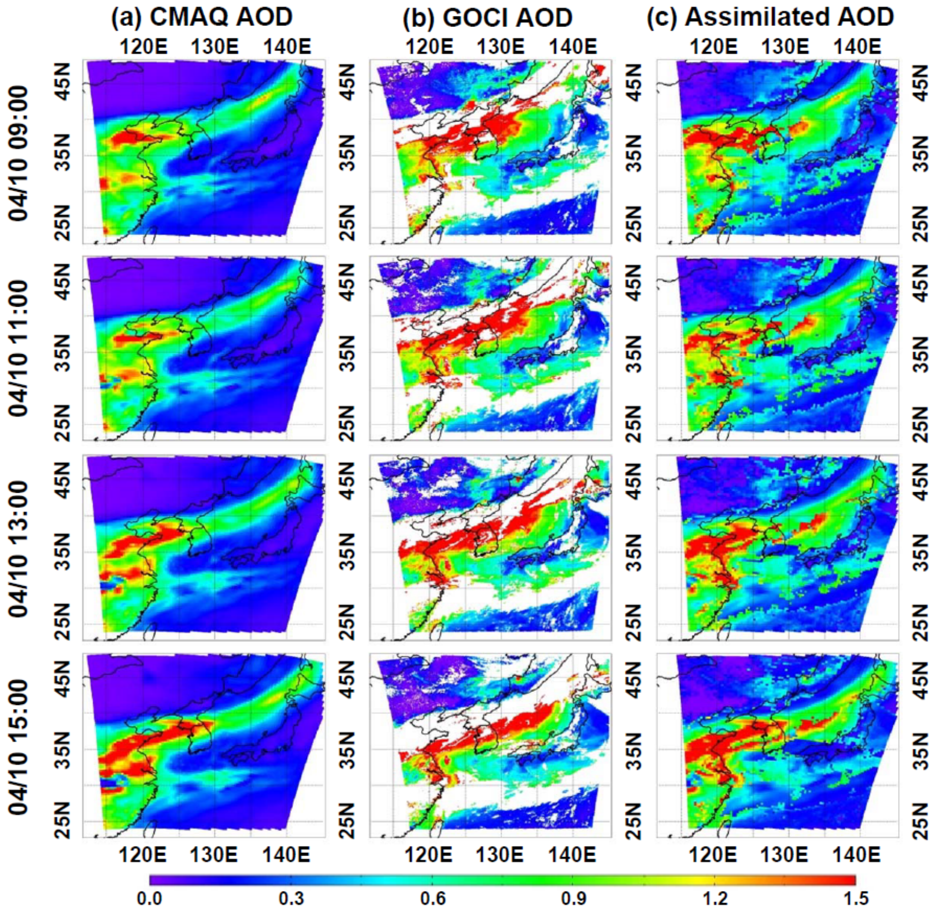




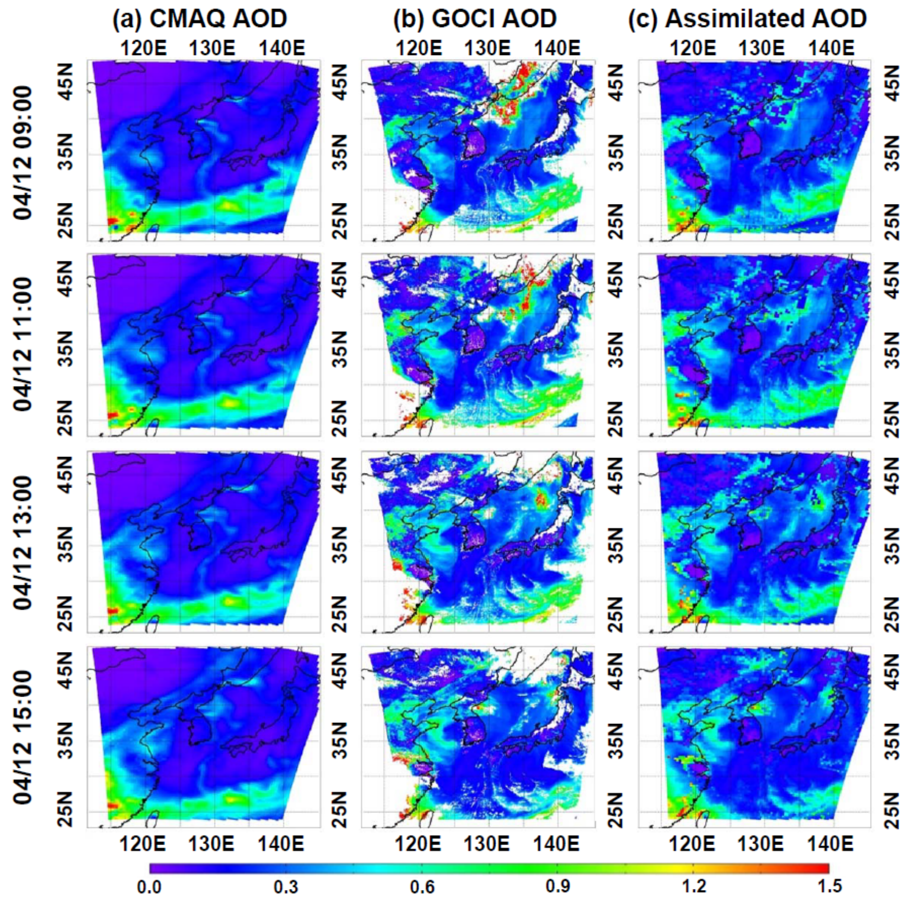
Data Assimilation of GOCI with CMAQ

◆ **CMAQ AOD vs. GOCI AOD vs. Assimilated AOD**

LRT case: 09, 11, 13, and 15 LST on 10 Apr. 2011



Non-LRT case: 09, 11, 13, and 15 LST on 12 Apr. 2011



Park et al. (ACP, 2014)

Data Assimilation of GOCI with CMAQ

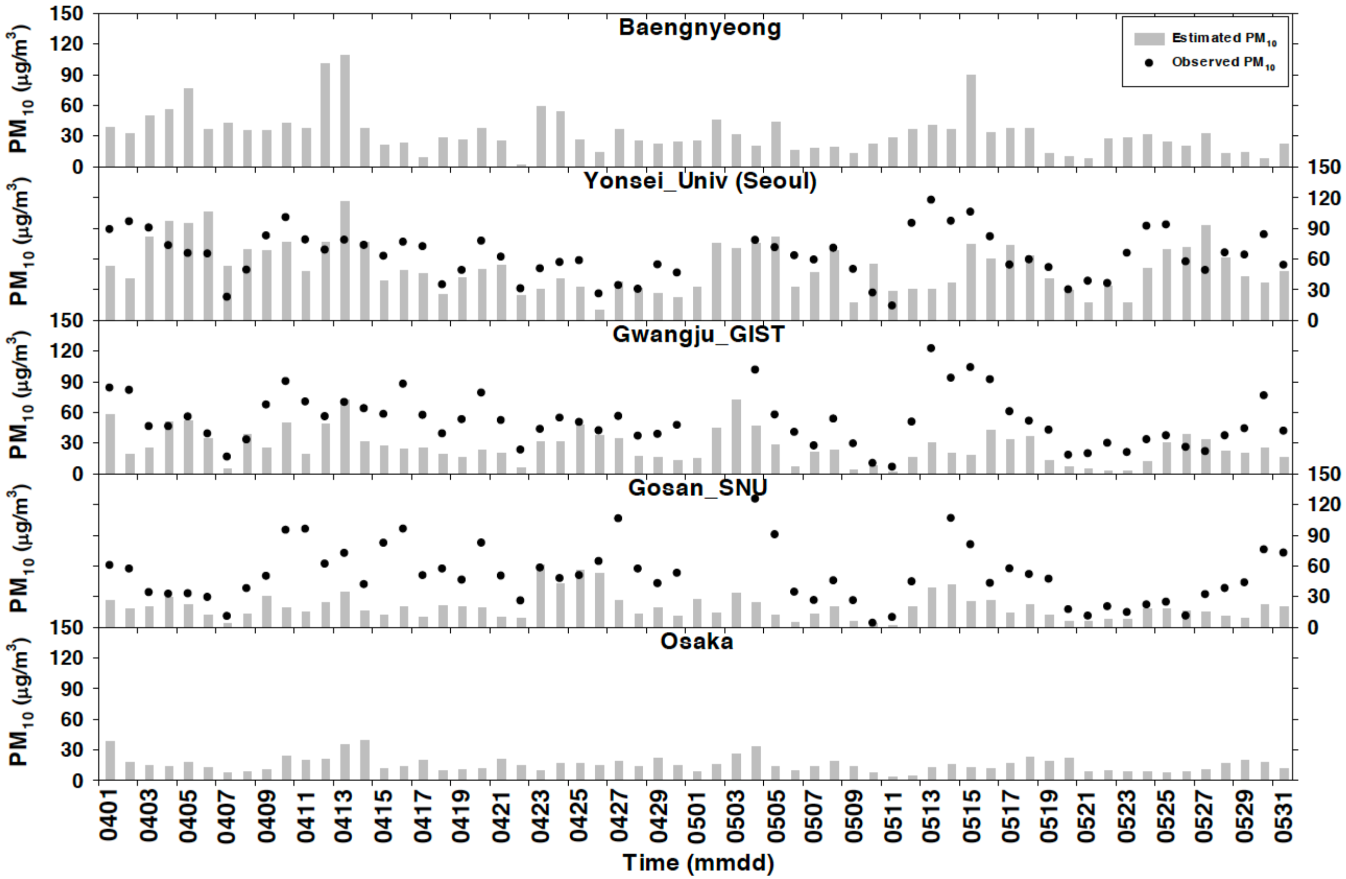


Fig. 8. Observed PM_{10} (black dots) vs. estimated PM_{10} (grey bars). Daily averaged estimated PM_{10} was converted from the assimilated AOD values at five AERONET sites. 24 h PM_{10} was measured at three AERONET sites (Yonsei_Univ (Seoul), Gwangju_GIST, and Gosan_SNU).

Summary

- GOCI Yonsei aerosol retrieval algorithm were developed and have been improved continuously through 2012 DRAGON-NE Asia and 2016 KORUS-AQ campaign. The qualities of retrieved V2 AOPs show reliable qualities against ground-based AERONET and other satellite products.
  → YAER algorithm is being improved for **GOCI-II with its higher spatial resolution of 250 m and additional channels in UV.**

- Hourly aerosol products from GOCI and 10 minutes AOPs from AHI YAER algorithm can provide diurnal variation information of aerosols. Therefore, these can provide observational dataset for data assimilation with several air-quality forecasting model over Asia.

- Consistent AOD dataset from OMI (GEMS) and MODIS (AMI) are retrieved. Preliminary results of merged AOD products showed similar accuracy to MODIS AOD products, with higher spatial coverage.

- PM estimation from satellite AOD has been demonstrated using multiple linear regression model and CTMs, both of which showed reasonable results. Further studies are undergoing to improve the accuracy.

Thank you for your attention!