Monitoring particulate pollution using GOCI COMS

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Collaborators

- **National Institute of Environmental Research**(NIER)
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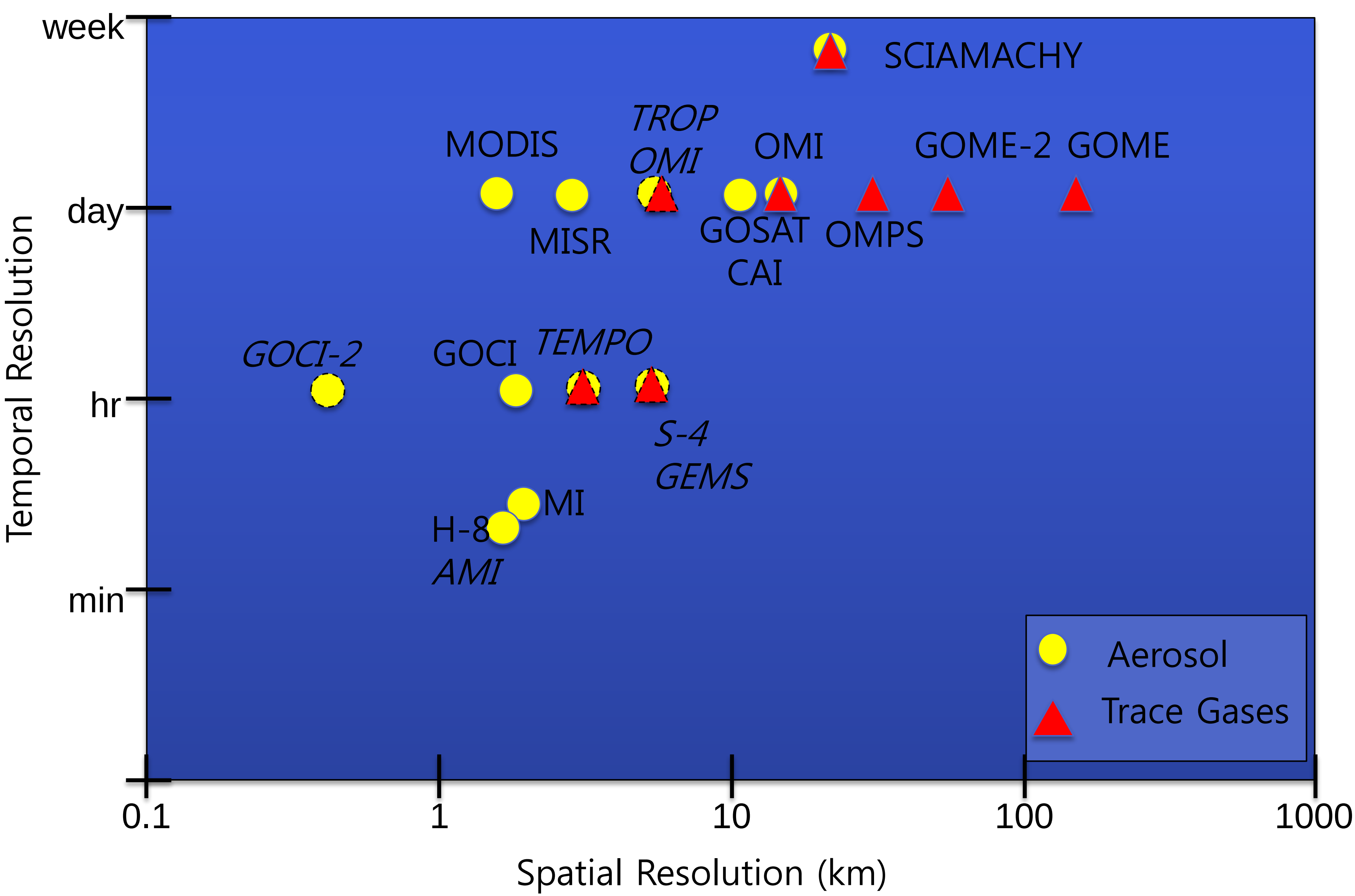
- **Sites in Korea**
  Baeksa Elementary School, Gangneung Wonju National University, GIST, Hanguk University of Foreign Studies, Iksan Fire Station, KMA (Anmyeon, Gosan Station), KNJ Engineering, Kyungpook National University, Pusan National University, Seoul National University, Songchon Elementary School, UNIST
- **Satellite Remote Sensing**
  Korea Meteorological Administration (MI), Korea Ocean Satellite Center(KOSC), JMA, NICT
- **NASA Goddard Space Flight Center**
  Brent Holben Tom Eck (AERONET), Jay R. Herman, Abuhassan Nader (Pandora)
  Scott J. Janz, Matthew G. Kowalewski (GeoTASO), Gordon Labow (MFRSR, UV-MFRSR)
- **NASA Langley Research Center**
  James Crawford, Jay Al-Saadi (GeoTASO, MOS), John Hair (DIAL/HSRL)
- **NASA Ames Research Center**
  Jens Redemann (4STAR)
- **Yonsei University**
  Ja-ho Koo, Mijin Kim, Myungje Choi, Woogyung Kim, Sujung Go, Hana Lee, Heesung Chong, Seoyoung Lee, Hyunkwang Lim

Development of Satellite RS Capability for AQ



KORUS-AQ

(1 May – 14 June 2016)

National Institute of Environmental Research (Ministry of Environment) · NASA

KORUS-AQ combined assets from the Korean and U.S. atmospheric science communities and their supporting organizations (NIER, NASA, Universities, etc.) to implement an integrated observing system for improving our understanding of Air Quality

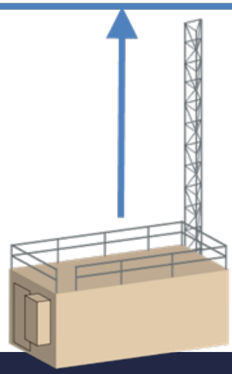
GOCI, MI, Himawari-8, MODIS, OMI, MOPITT.
.

- ✓ Broad spatial coverage for key atmospheric components (aerosols, ozone, precursors)

NASA DC-8
(HSRL, 4 STAR..)
LaRC King Air
(GEOTASO, MOS)
Hanseo King Air

Model evaluation and improvement, chemical process understanding, Satellite Cal/Val and observing strategies

Operational Air Quality Forecasts, Regional and Global models of atmospheric composition



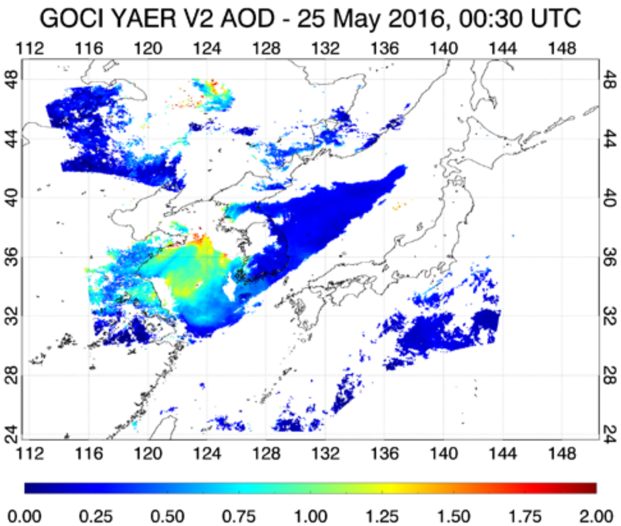
Air Quality Network, Research Sites, Research Vessels including in situ and remote sensing observations (Aeronet, Pandora, Lidar)

[Courtesy of James Crawford]

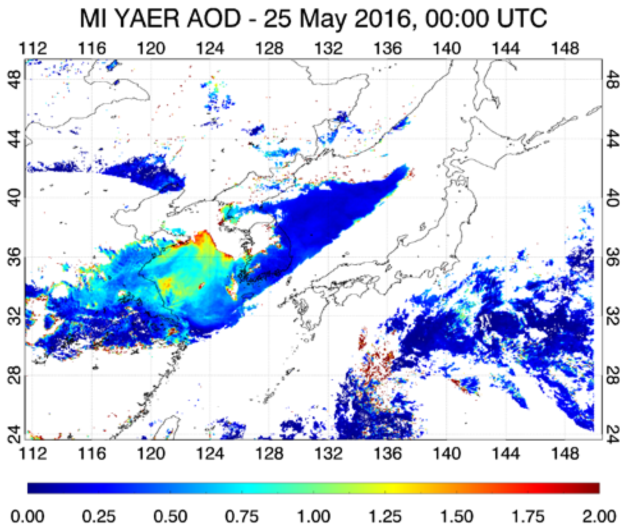
KORUS-OC

Geostationary satellites aerosol observation over East Asia

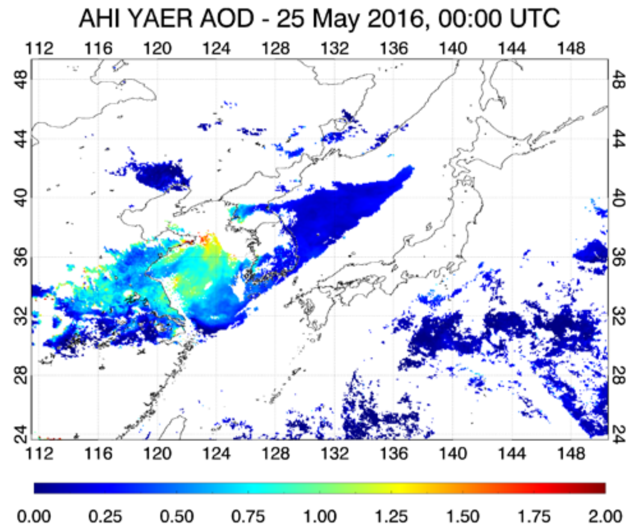
GOCI



MI



AHI

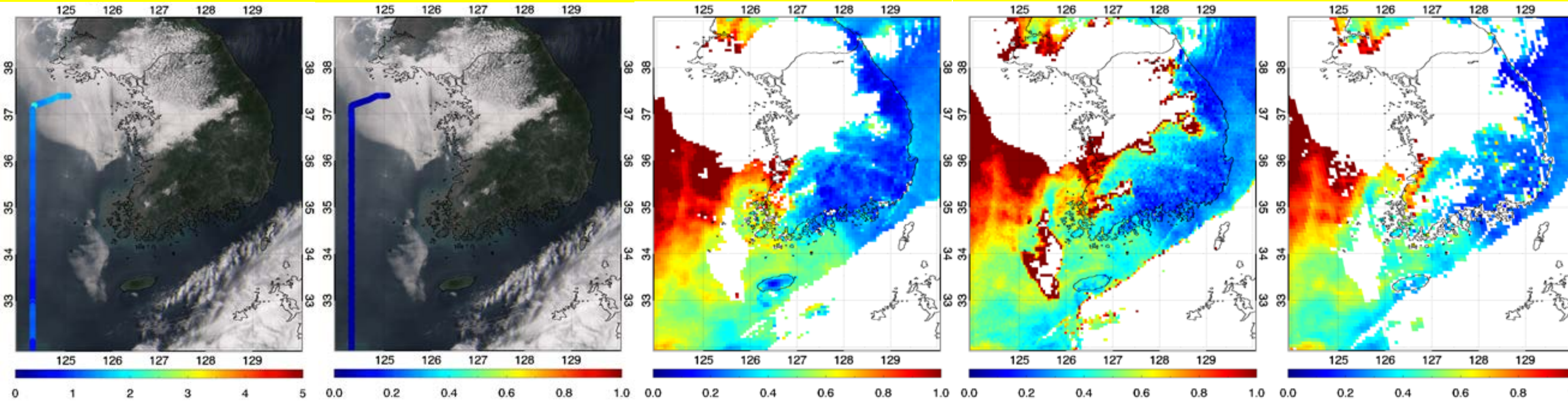


	GOCI/COMS (KOSC/KIOST, Korea)	MI/COMS (NMSC/KMA, Korea)	AHI/Himawari-8 (JMA, Japan)
Temporal Resolution	1-hour interval for East Asia (total 8 times in daytime)	15-min interval for Asia 3-hour interval for FD	10-min interval for Full Disk
Channels	8 bands in VIS-NIR (0.5 km)	1 bands in VIS (1 km) 4 bands in IR (4 km)	4 bands in VIS-NIR (0.5/1.0 km) 12 bands in IR (2 km)
Products	AOD, FMF, AE (6 km)	AOD (4km)	AOD, FMF, AE (6 km)
Reference	*M. Choi et al.(AMT 2016)*	*M. Kim et al. (RSE 2014; ACP 2016)*	*H. Lim et al. (KJRS 2016)*

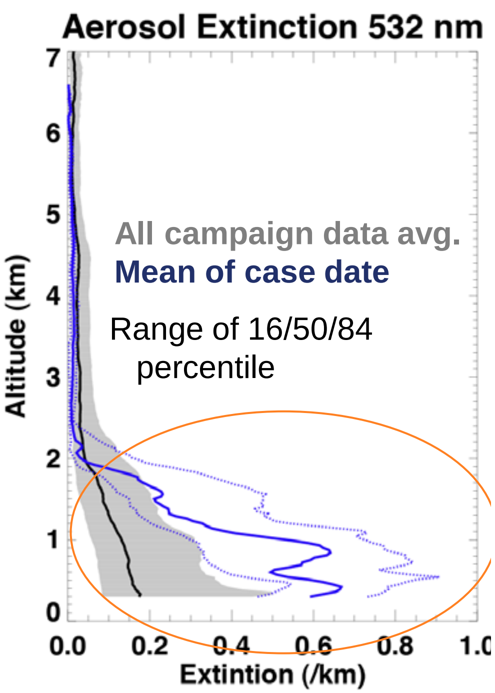
* Datasets readily available for past years for GOCI and MI. AHI dataset is under processing.

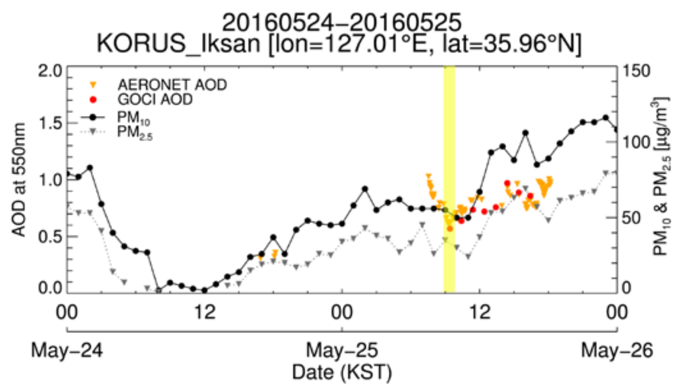
Case of 25 May 2016

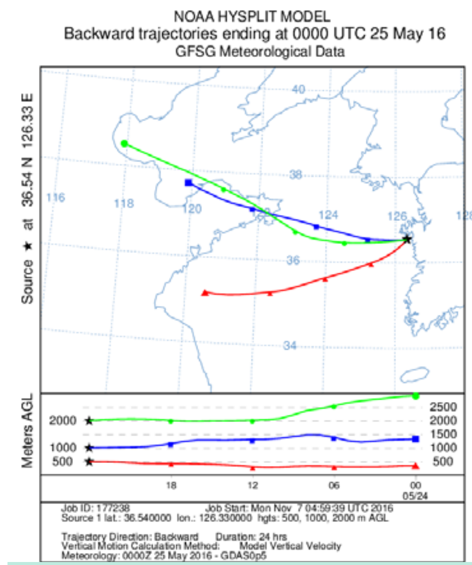
HSRL Height	4STAR AOD (Zenith)	GOCI AOD (1 hr)	MI AOD (15 min)	AHI AOD (10 min)



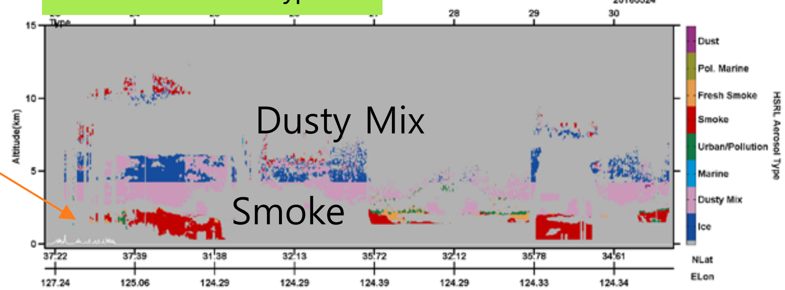
1~2 km (Median of aerosol extinction profile)







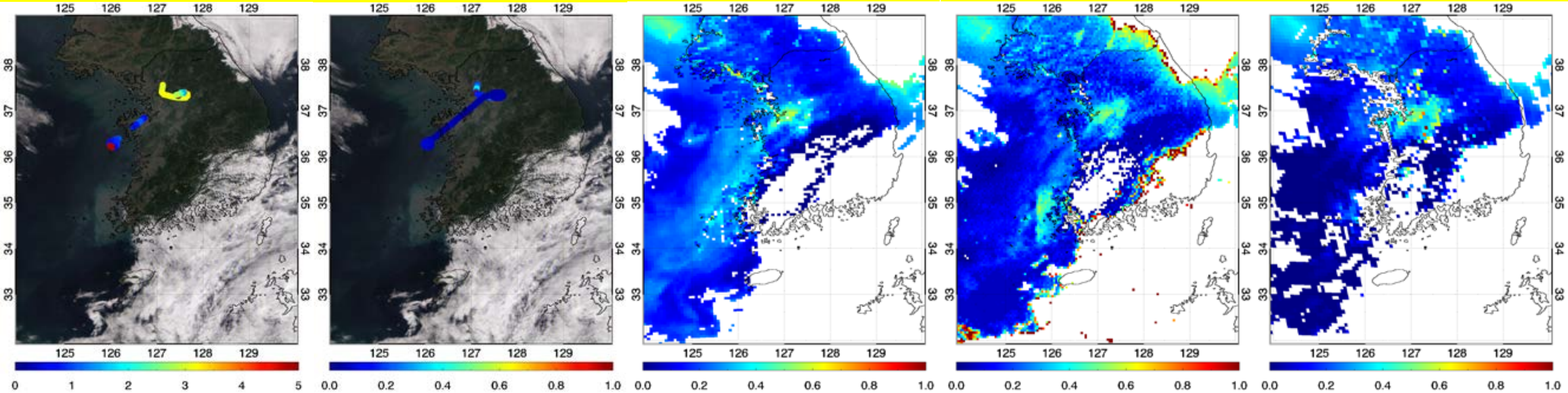
HSRL Aerosol type



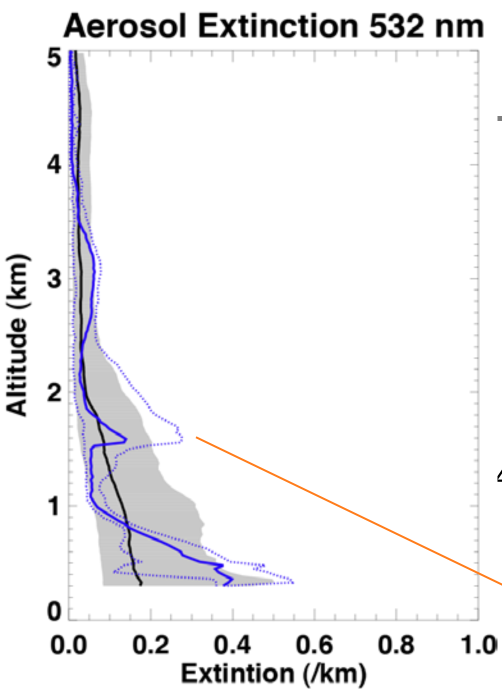
Anmyon (36.54N,126.33E)
NOAA HYSPLIT Backward trajectory modeling

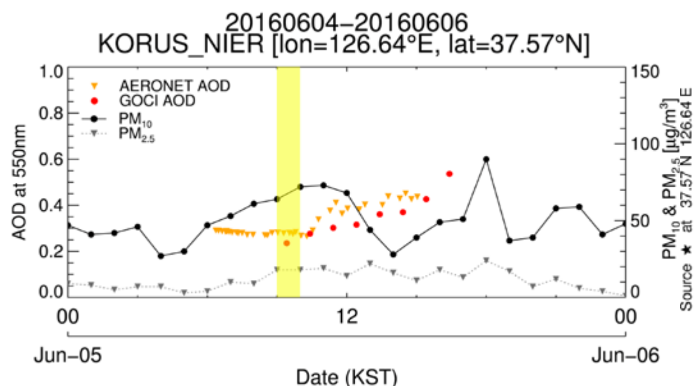
Case of 05 June 2016

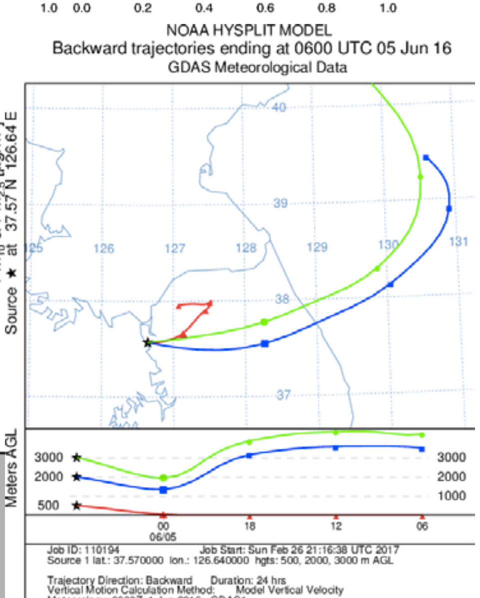
HSRL Height | 4STAR AOD (Zenith) | GOCI AOD (1 hr) | MI AOD (15 min) | AHI AOD (10 min)



1~3 km (Median of aerosol extinction profile)







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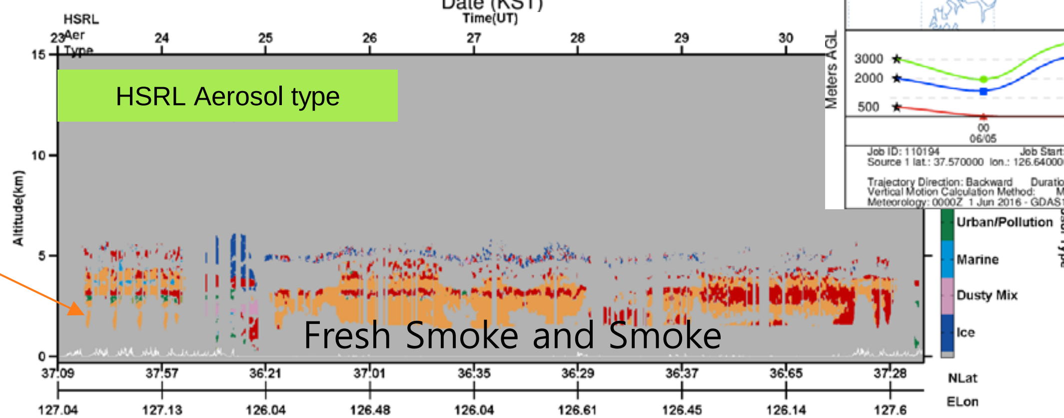
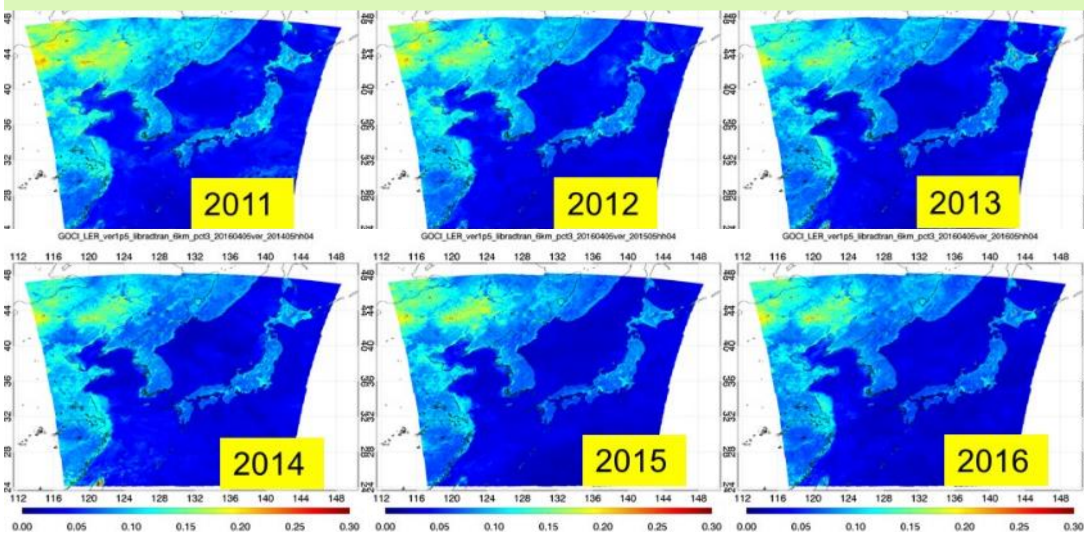


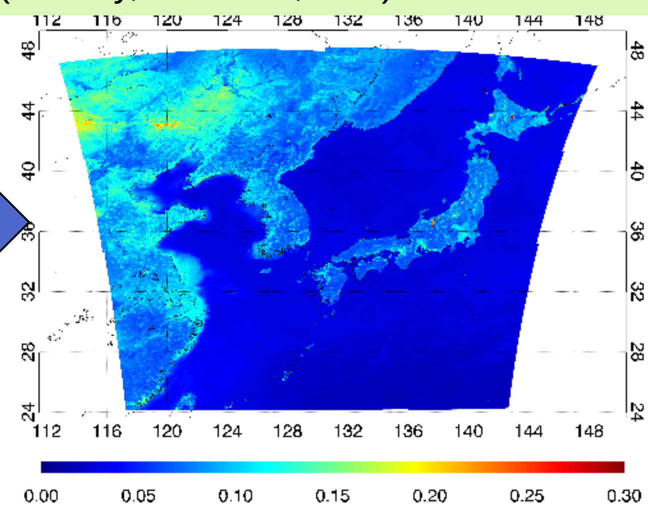
Land surface reflectance climatology using a minimum reflectivity technique with multi-year samples

Version 1 (Choi et al., AMT, 2016)	Version 2
Composite each year/month/hour samples within 6 km ×6 km → darkest 1-3% at 412 nm	Composite 5-year/month/hour samples within 500 m × 500 m as higher resolution (pros) → darkest 1-3% at each channel → possibility finding clear pixels increases (pros)
Less influence of degradation/calibration issue (pros)	Much influence of degradation/calibration issue Hard to reflect surface changes (cons)
Near-real-time retrieval impossible (cons)	Near-real-time retrieval possible (pros)

V1 Surface reflectance (15 May, 04:30utc, Ch3)

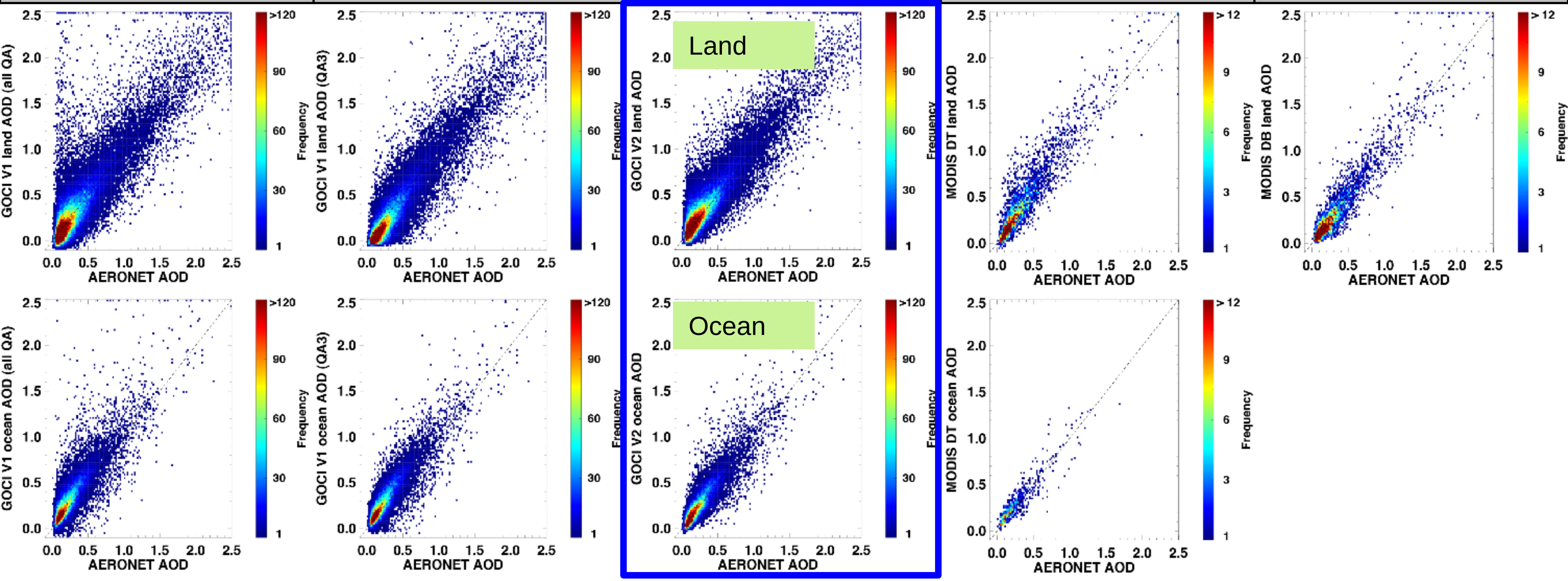


V2 Surface reflectance database (15 May, 04:30utc, Ch3)



Land/Ocean AOD (Total 27/17 AERONET sites, 5yr)

GOCI YAER V1 (all QA)	GOCI YAER V1 (QA3)	GOCI YAER V2	MODIS DT	MODIS DB



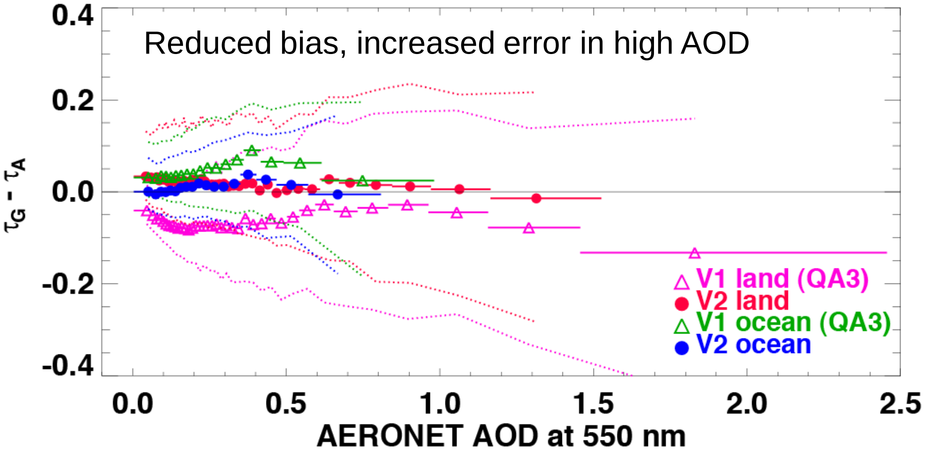
Land AOD	N	R	Median Bias	Ratio within EE_{DT}	RMSE
V1 AllQA	47850	0.86	-0.01509	0.49	0.24
V1 QA3	38183	0.92	-0.06581	0.49	0.18
V2	45818	0.91	0.01947	0.60	0.16
DT	3228	0.92	0.042744	0.62	0.18
DB	3463	0.93	0.007057	0.73	0.16

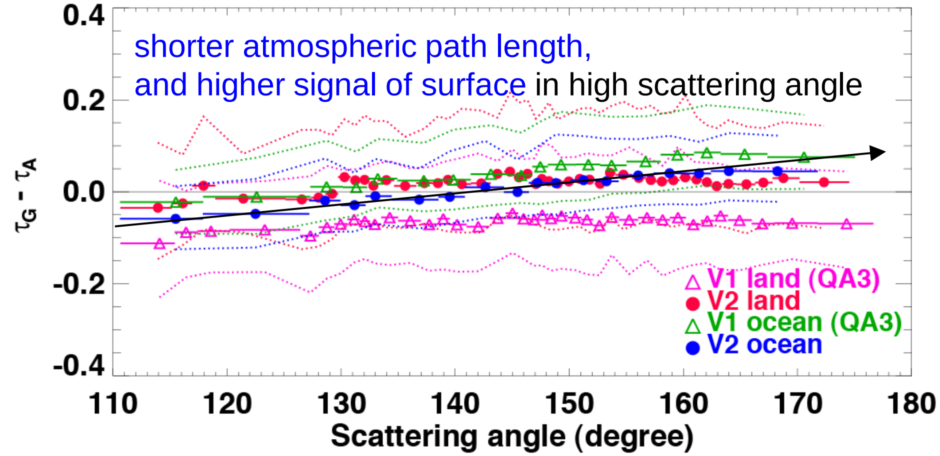
Ocean AOD	N	R	Median Bias	Ratio within EE_{DT}	RMSE
V1 AllQA	19945	0.83	0.056303	0.55	0.17
V1 QA3	18308	0.88	0.042779	0.62	0.13
V2	18588	0.89	0.008028	0.71	0.11
DT	680	0.92	0.033227	0.73	0.09

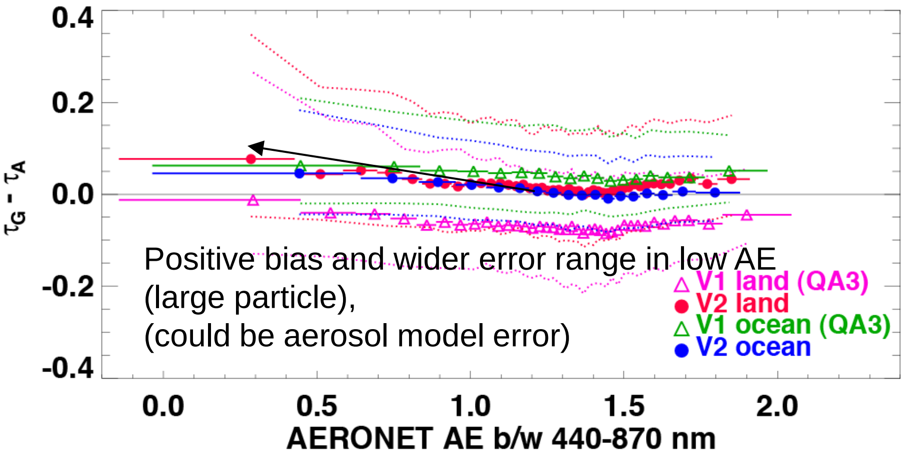
- Most statistics show land/ocean algorithm improvement from V1 to V2
- $EE_{DT} = \pm(0.05 + 0.15\ AOD_A)$

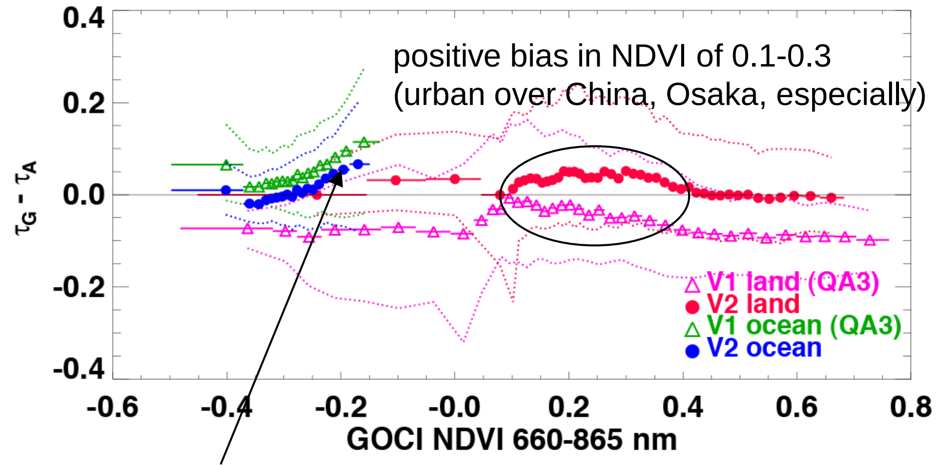
AOD error analysis from long-term validation

No. of each bin samples = 1000, Symbols: 50 percentile, Lines: 16-84 percentile



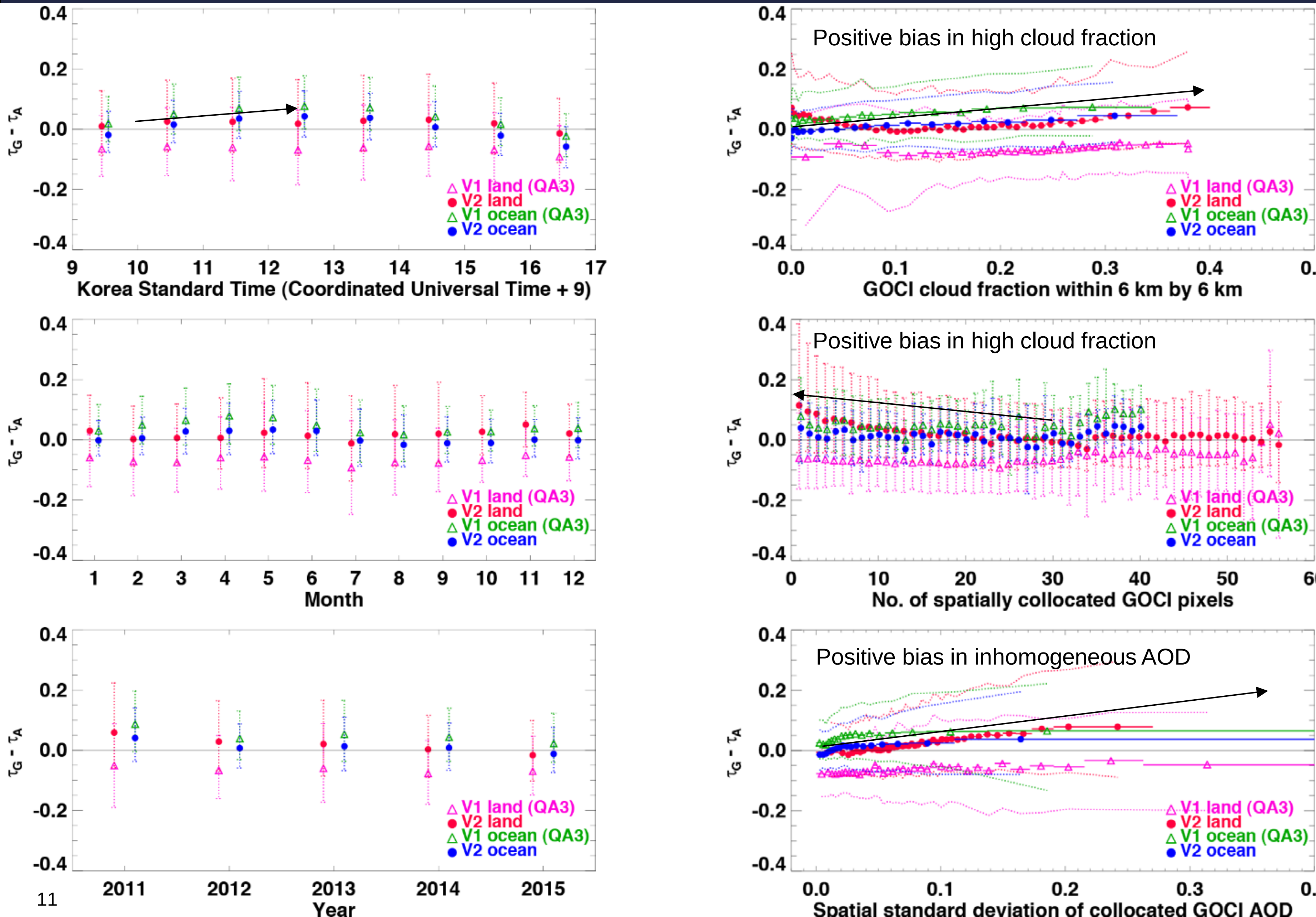




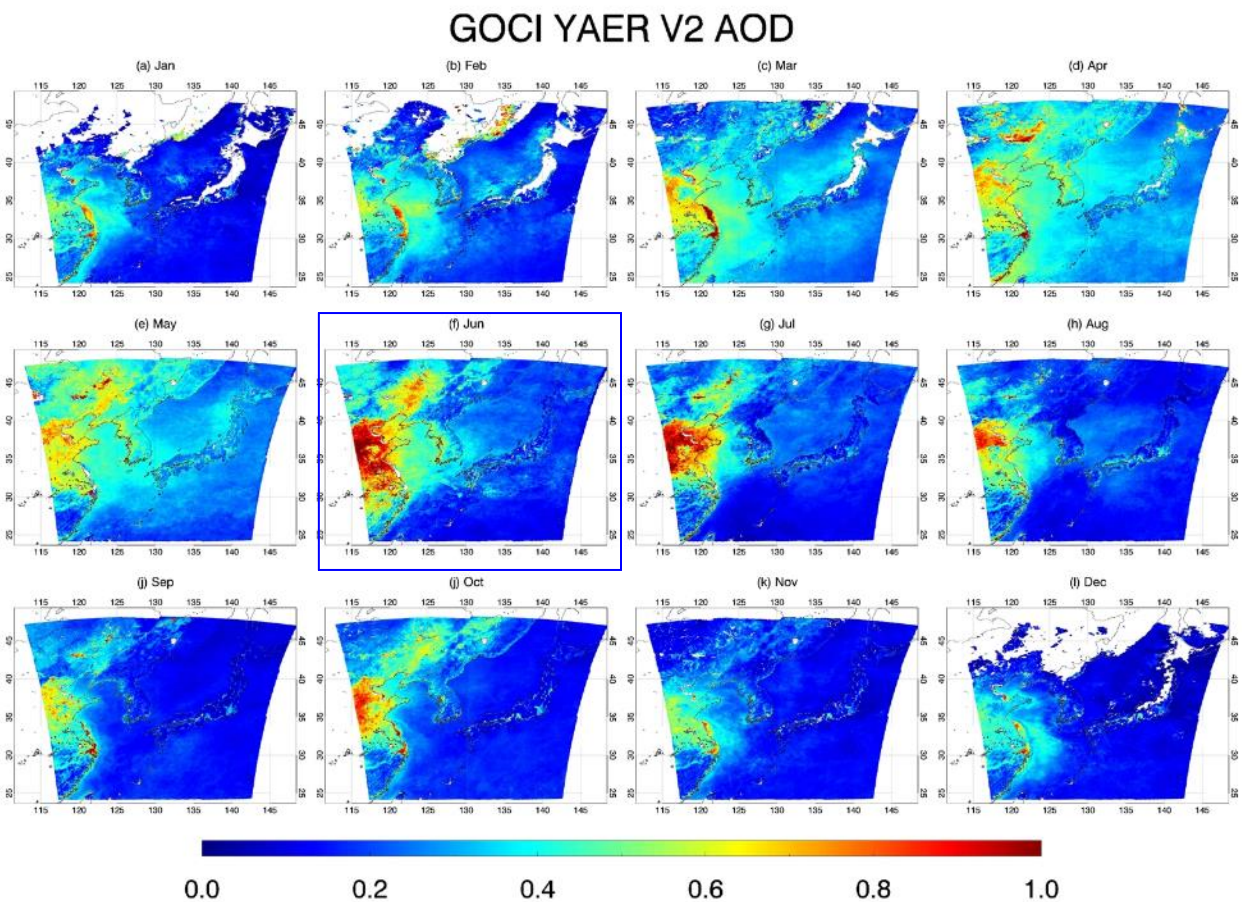


positive AOD bias in higher NDVI (open ocean)
due to not considering water-leaving radiance

AOD error analysis from long-term validation



Spatial distribution: GOCI monthly AOD



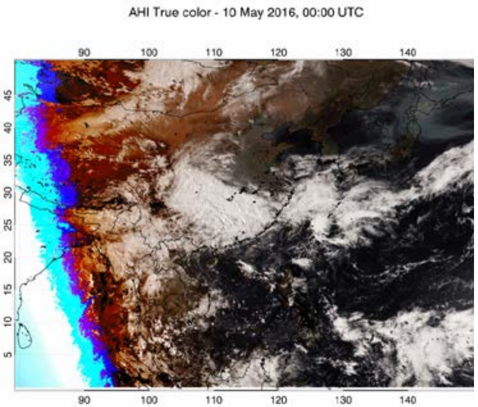
- North China Plane (including Beijing, Tianjin, and Hebei)
  - Expanded to Korea and Japan in March to May, highest in June-July-August
  - minimum mean AOD is above 0.4
- Korean Peninsula: increased in March and April, highest in June

→ Spatial distribution is well matched with MODIS results (Kim et al. 2007; Levy et al. 2013; Hsu et al. 2013) and VIIRS results (Liu et al. 2014)

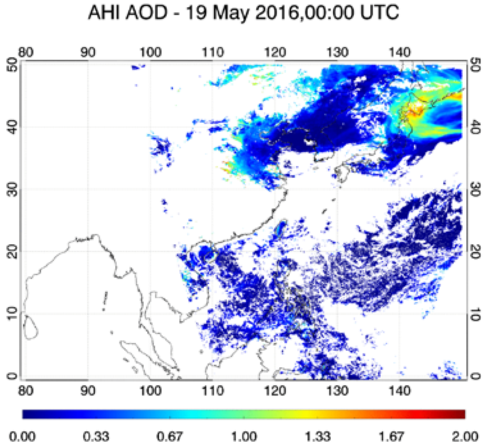
- High AOD over turbid water (a few samples)

AHI Aerosol Products

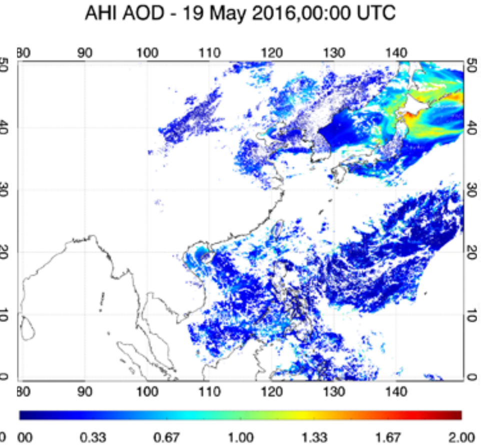
AHI RGB image



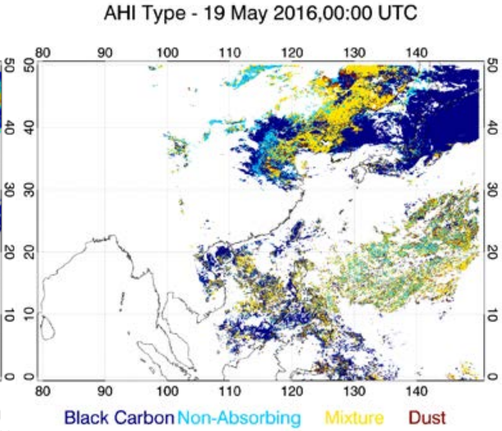
AHI YAER AOD

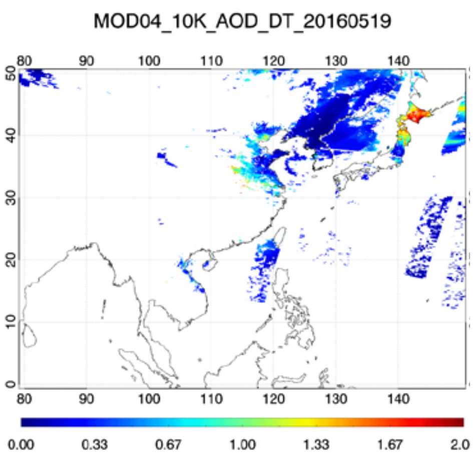


AHI JAXA AOD

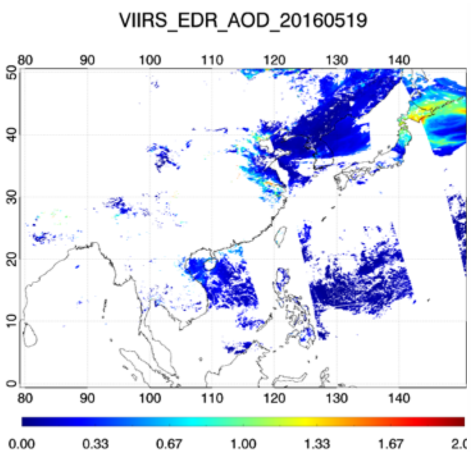


AHI YAER aerosol type

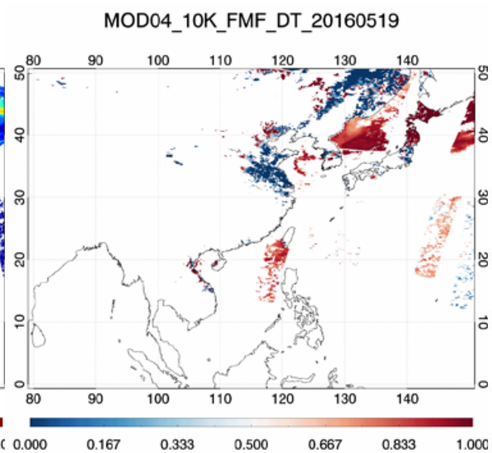




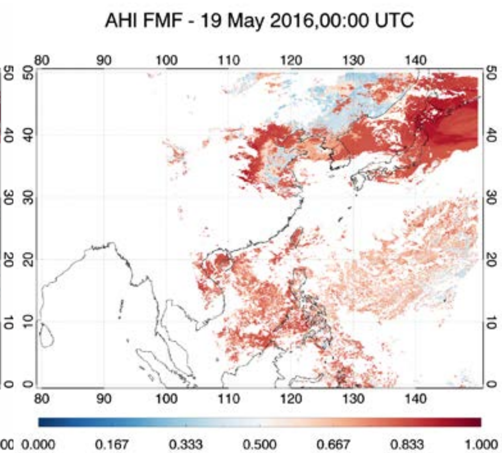
MODIS AOD (Terra,Aqua)



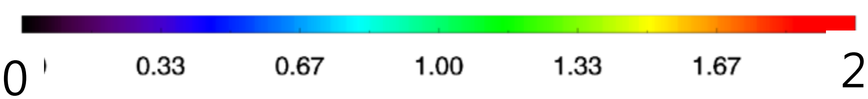
VIIRS AOD (suomi NPP)

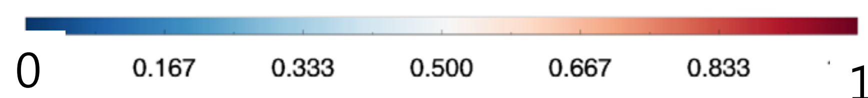


MODIS FMF (Terra,Aqua)



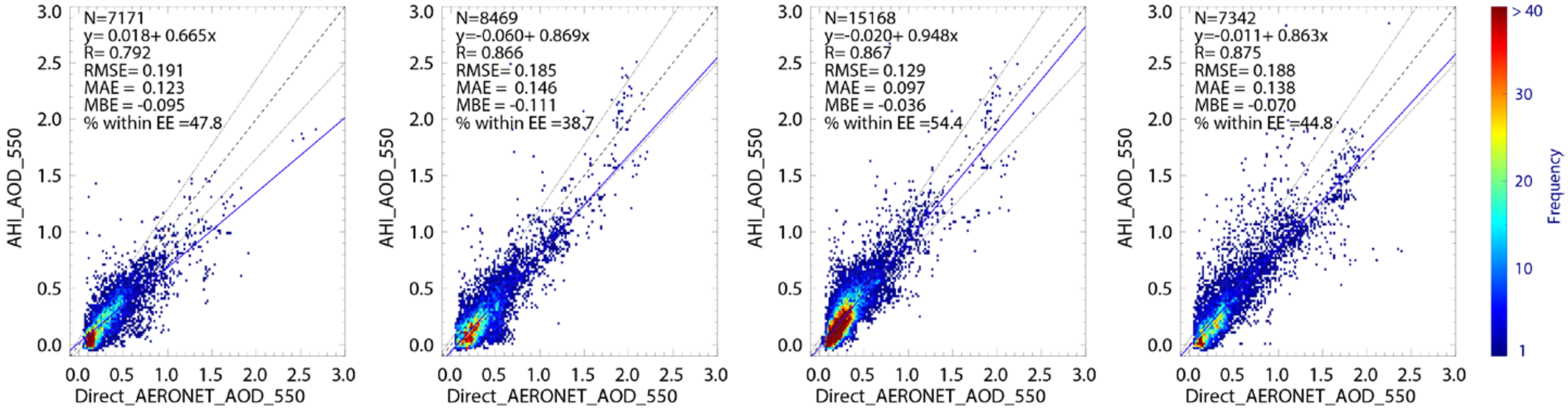
AHI YAER FMF



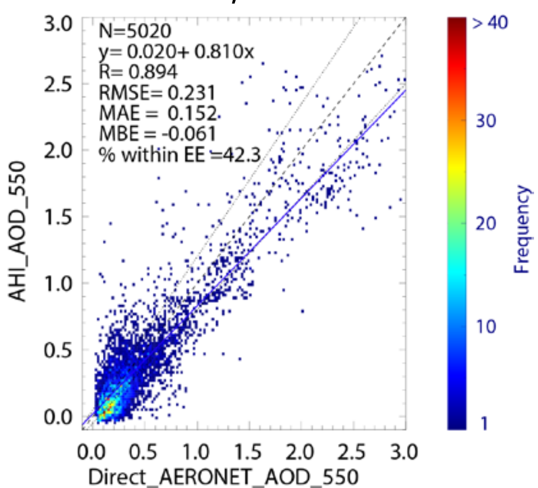


Monthly validation results – AHI YAER vs AERONET

Mar, 2016 Apr, 2016 May, 2016 Jun, 2016

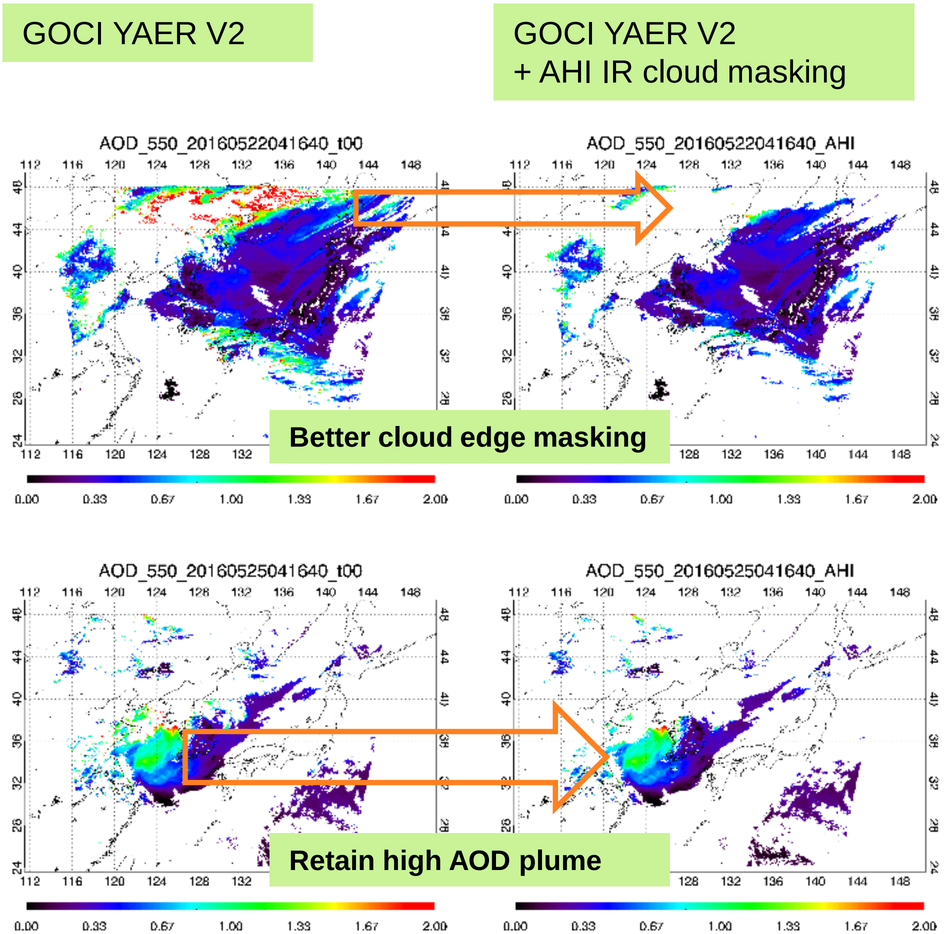


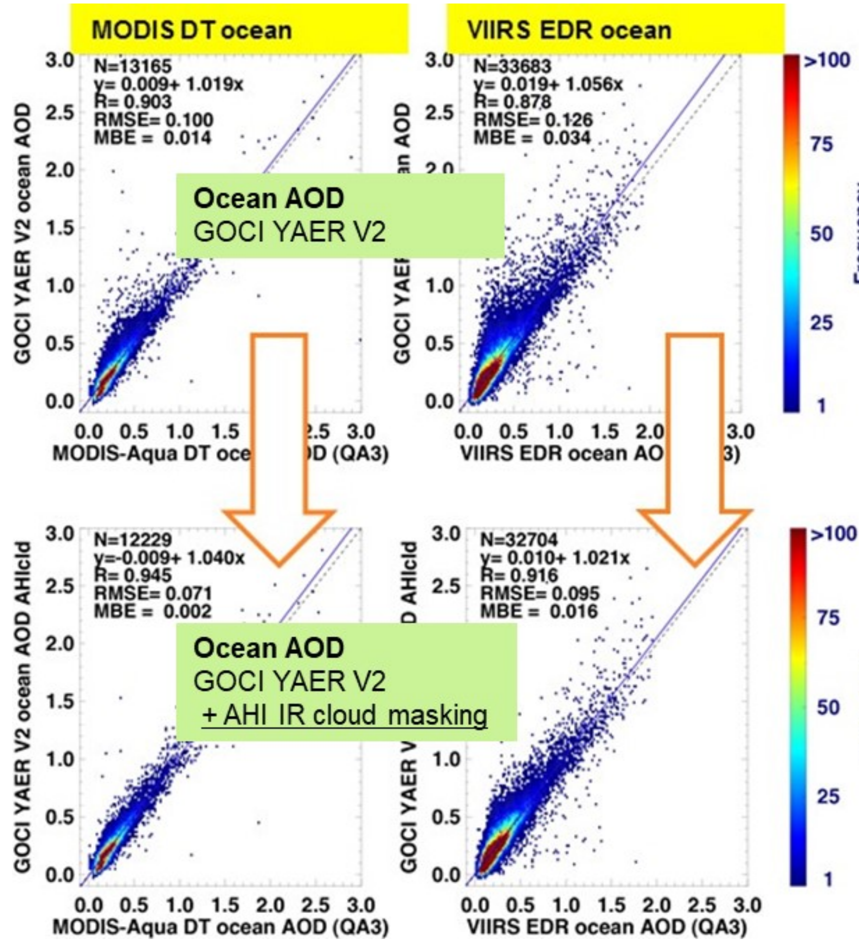
Jul, 2016



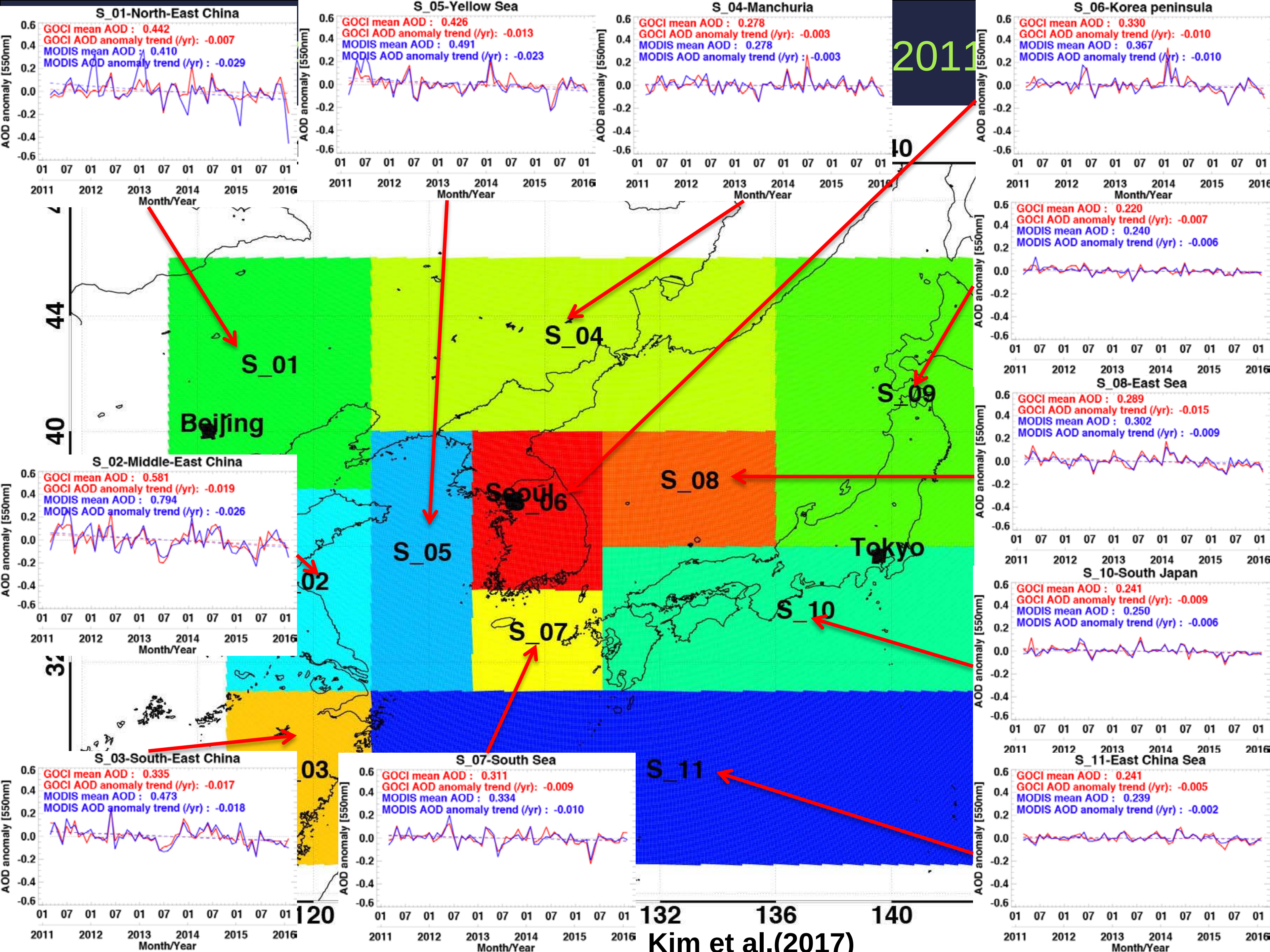
- Analysis period : 2016.03.01 – 2016.7.31
- Spatial colocation : average of AHI pixels within 25km at AERONET sites
  - (Mar: 29sites , Apr: 42sites, May: 44site, Jun:40 sites, Jul: 26sites)
- Temporal colocation : average of AERONET data within 5min at satellite measurement time
- Expected Error (EE) = 0.05 + 0.15*AERONET AOD (Levy et al., 2007)

AHI IR cloud masking in AHI YAER algorithm





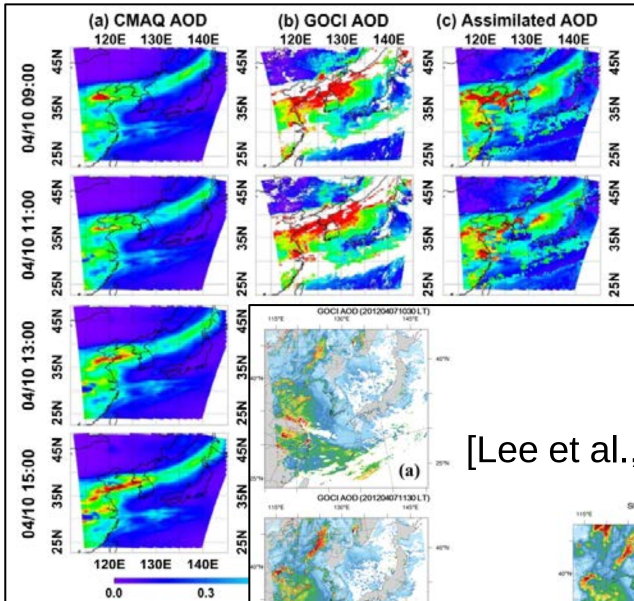
- AHI IR cloud masking works successfully on GOCI AOD to filter out cirrus or shallow cloud contamination as retaining high AOD well.
- AHI IR cloud masking results in increased correlation coefficient b/w GOCI and MODIS/VIIRS over ocean (*R*: 0.90→0.95 with MODIS, 0.88→0.92 with VIIRS)

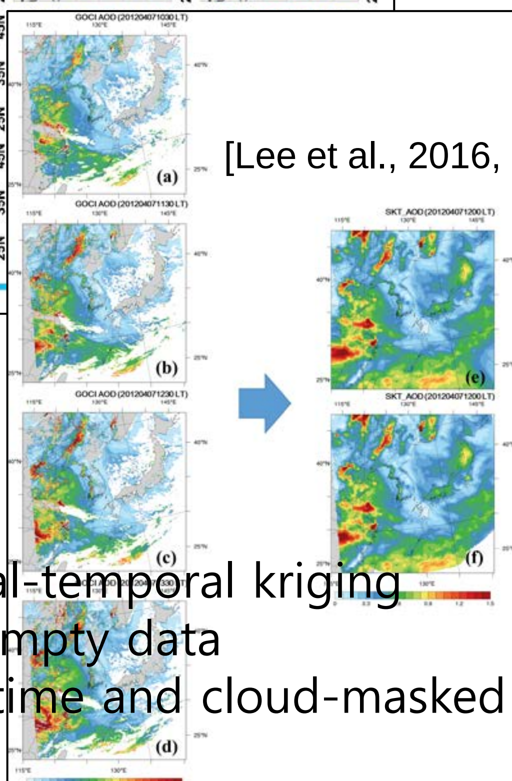


S_01-North-East China
GOCI mean AOD : 0.442
GOCI AOD anomaly trend (/yr): -0.007
MODIS mean AOD : 0.410
MODIS AOD anomaly trend (/yr) : -0.029
S_05-Yellow Sea
GOCI mean AOD : 0.426
GOCI AOD anomaly trend (/yr): -0.013
MODIS mean AOD : 0.491
MODIS AOD anomaly trend (/yr) : -0.023
S_04-Manchuria
GOCI mean AOD : 0.278
GOCI AOD anomaly trend (/yr): -0.003
MODIS mean AOD : 0.278
MODIS AOD anomaly trend (/yr) : -0.003
2011
S_06-Korea peninsula
GOCI mean AOD : 0.330
GOCI AOD anomaly trend (/yr): -0.010
MODIS mean AOD : 0.367
MODIS AOD anomaly trend (/yr) : -0.010
GOCI mean AOD : 0.220
GOCI AOD anomaly trend (/yr): -0.007
MODIS mean AOD : 0.240
MODIS AOD anomaly trend (/yr) : -0.006
S_08-East Sea
GOCI mean AOD : 0.289
GOCI AOD anomaly trend (/yr): -0.015
MODIS mean AOD : 0.302
MODIS AOD anomaly trend (/yr) : -0.009
S_10-South Japan
GOCI mean AOD : 0.241
GOCI AOD anomaly trend (/yr): -0.009
MODIS mean AOD : 0.250
MODIS AOD anomaly trend (/yr) : -0.006
S_11-East China Sea
GOCI mean AOD : 0.241
GOCI AOD anomaly trend (/yr): -0.005
MODIS mean AOD : 0.239
MODIS AOD anomaly trend (/yr) : -0.002
S_02-Middle-East China
GOCI mean AOD : 0.581
GOCI AOD anomaly trend (/yr): -0.019
MODIS mean AOD : 0.794
MODIS AOD anomaly trend (/yr) : -0.026
S_03-South-East China
GOCI mean AOD : 0.335
GOCI AOD anomaly trend (/yr): -0.017
MODIS mean AOD : 0.473
MODIS AOD anomaly trend (/yr) : -0.018
S_07-South Sea
GOCI mean AOD : 0.311
GOCI AOD anomaly trend (/yr): -0.009
MODIS mean AOD : 0.334
MODIS AOD anomaly trend (/yr) : -0.010
AOD anomaly [550nm]
Month/Year
S_01
S_04
S_05
S_06
S_07
S_08
S_09
S_10
S_11
Beijing
Seoul
Tokyo
Kim et al.(2017)

Application of GOCI YAER AOD to Air quality modeling studies

Data assimilation of GOCI AOD with **CMAQ**
Application to the PM_{10} (GIST)
[Park et al., 2014, ACP]



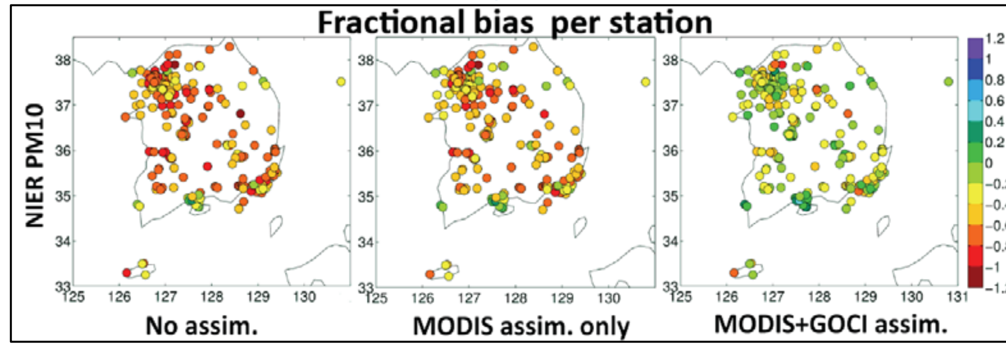


[Lee et al., 2016, GMD]

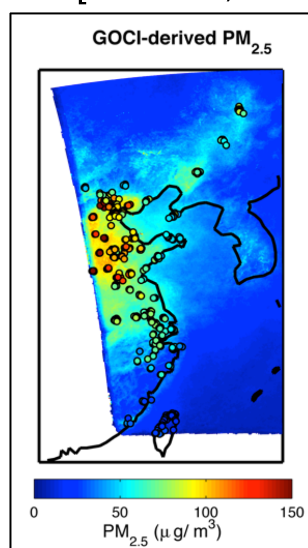
GIST: spatial-temporal kriging
to fill the empty data
for model time and cloud-masked area

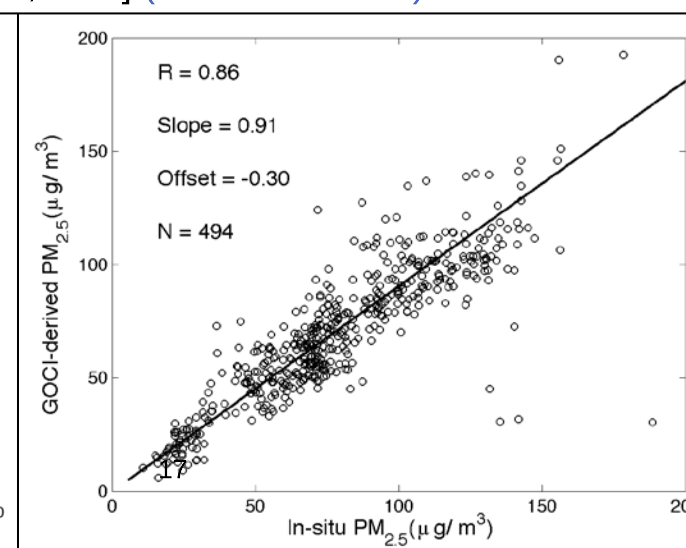
Data assimilation of GOCI & MODIS AOD with **WRF-chem**
Application to the PM_{10} (Univ. of Iowa and NCAR)
[Saide et al., 2014, GRL]

(also carried out during 2016 KORUS-AQ as NRT)



Estimation ground-level $PM_{2.5}$
from GOCI AOD and **GEOS-chem**
[Xu et al., 2015, ACP] (Dalhousie Univ.)





remote sensing

MDPI

Article

Retrieving X_{CO2} from GOSAT FTS over East Asia Using Simultaneous Aerosol Information from CAI

Woogyung Kim [1], Jhoon Kim [1,*], Yeonjin Jung [1], Hartmut Boesch [2], Hanlim Lee [3], Sanghee Lee [1], Tae-Young Goo [4], Ukkyo Jeong [1], Mijin Kim [1], Chun-Ho Cho [4] and Mi-Lim Ou [5]

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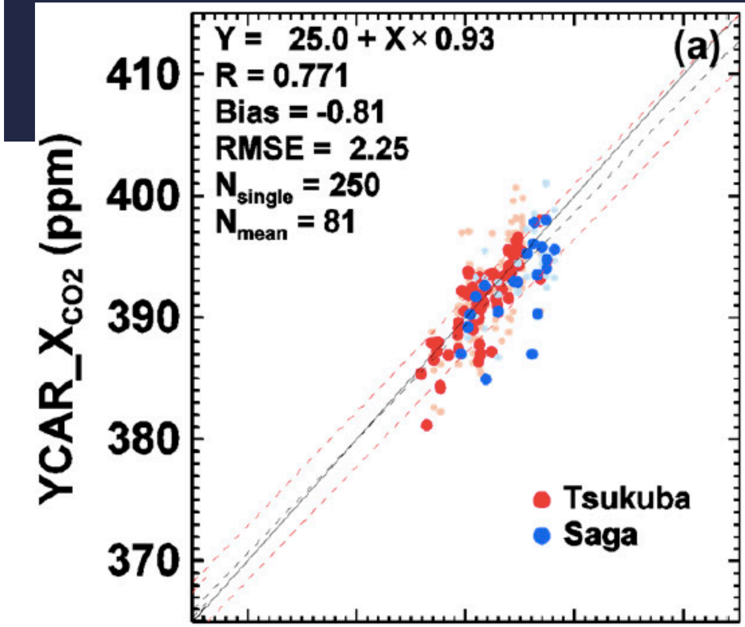

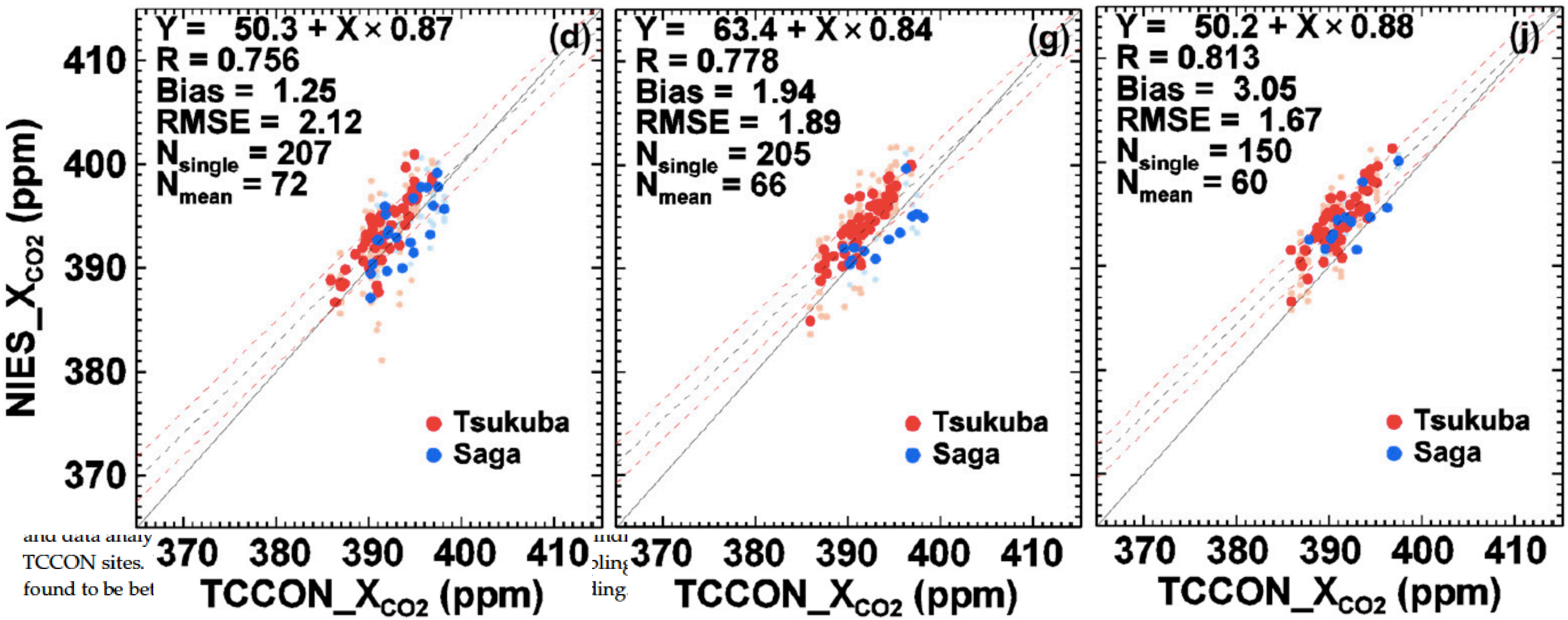

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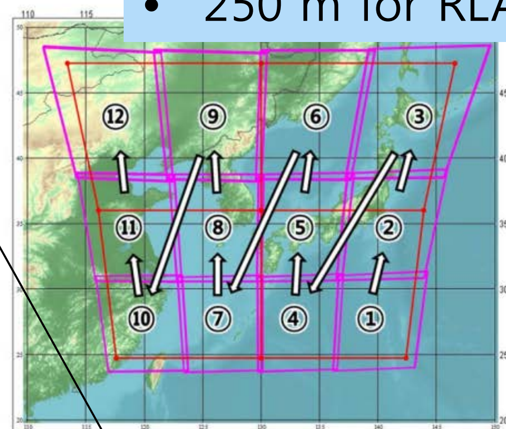
Keywords: CO_2; aerosols; GOSAT; East Asia; optimal estimation

GOCI-2

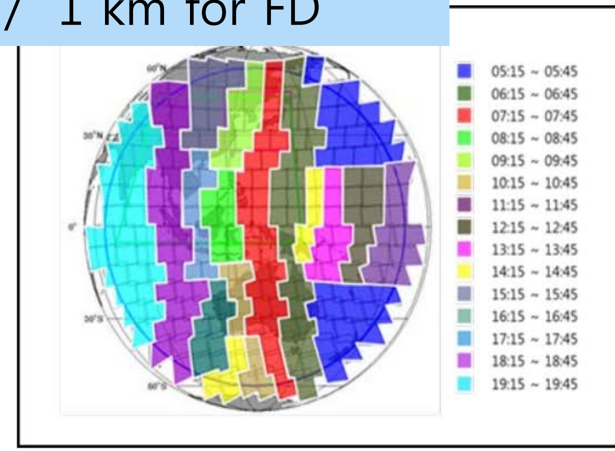
- Spectral bands

GOCI Band	GOCI-II Band	Band center	Bandwidth
-	1	380 nm	20 nm
1	2	412 nm	20 nm
2	3	443 nm	20 nm
3	4	490 nm	20 nm
-	5	510 nm	20 nm
4	6	555 nm	20 nm
-	7	620 nm	20 nm
5	8	660 nm	20 nm
6	9	680 nm	10 nm
-	10	709 nm	10 nm
7	11	745 nm	20 nm
8	12	865 nm	40 nm
-	13	643.5 nm	483 nm

- Reference Local Area (RLA), 10 images a day
- Full Disk (FD), once a day
- 250 m for RLA / 1 km for FD



GOCI-II Reference Local Area coverage by 12 slots



- Concept of GOCI-2 Aerosol algorithm

GOCI-2 L1B radiance (reflectance) in 250 m resolution
⇩
Land/Sea Separation
Inland water Masking
Cloud Masking
⇩
Surface reflectance retrieval
Land: Minimum reflectivity technique
Ocean: Ocean BRDF (wind speed)
⇩
Turbid water detection
Absorbing aerosol detection
(using short wavelength channels including 380 nm)
⇨

Aerosol Models
AERONET Inversion database
AOD/FMF/SSA classification
+)UV/Visible AI sensitivity
⇩
Pre-calculated Lookup-Table for each aerosol model and simulated status using RTM
⇩
Inversion from radiance to aerosol optical properties
Comparison b/w observed radiance and LUT
⇩
Final retrieved
Spectral AODs,
Particle size parameter (FMF/AE)
Absorbing parameter (AI, SSA)

Courtesy of Dr. Youngje Park (KOSC/KIOST)

Geostationary Constellation of UV-Vis spectrometer & Meteorological Payload

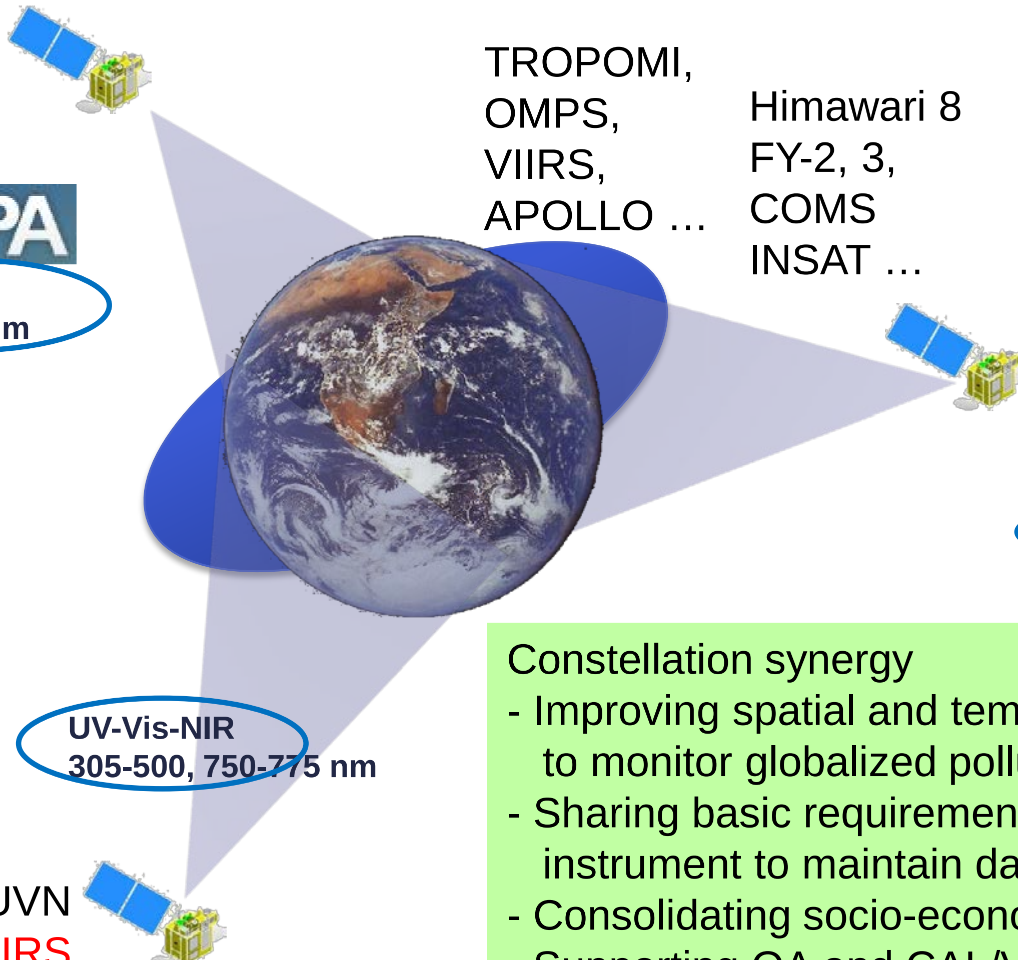
CEOS ACC(Committee on Earth Observaing Satellites Atm. Comp. Constella

TEMPO
+ GOES-R
(America)

UV-Vis
290-690 nm

TROPOMI,
OMPS,
VIIRS,
APOLLO …

Himawari 8
FY-2, 3,
COMS
INSAT …



GEMS + AMI + GOCI2
GEO KOMPSAT
(Asia)

UV-Vis 300-500 nm

UV-Vis-NIR
305-500, 750-775 nm

GMES S4 UVN
+ FCI + IRS
MTG (Europe)

Constellation synergy
- Improving spatial and temporal coverage to monitor globalized pollutants & SLCF
- Sharing basic requirements on data products and instrument to maintain data quality
- Consolidating socio-economic benefit analysis
- Supporting QA and CAL/VAL

Conclusion

- GOCI has provided long term dataset on aerosol properties in high spatial and temporal resolution, which has been validated with ground-based AERONET and SONET. Meteorological imager such as MI and AHI
- Satellite aerosol retrieval algorithm has been under continuous improvement through the evaluation and diagnosis of the AOPs, especially according to aerosol vertical distribution and types. It could provide the key of AOPs-PM relations over wider region.
- Data assimilation with GOCI aerosol datset improve the accuracy of air quality forecasting. Further application with GOCI AOD was demonstrated to estimate surface PM10 and PM2.5 with correlation coefficients up to 0.8, which then can be used for public health studies.
- GOCI-2 to be launched in 2019 is expected to provide much more information with its UV channels at 380 nm together with aerosol precursor measurements by GEMS and high temporal resolution observation by AMI.
- GOCI data is available in near real time(NRT) and the past, 6-yr dataset is readily available upon request. GOCI data are distributed through KIOST website.

Case of 09 June 2016