Development status of GEMS Aerosol Retrieval Algorithm: Sensitivity Test

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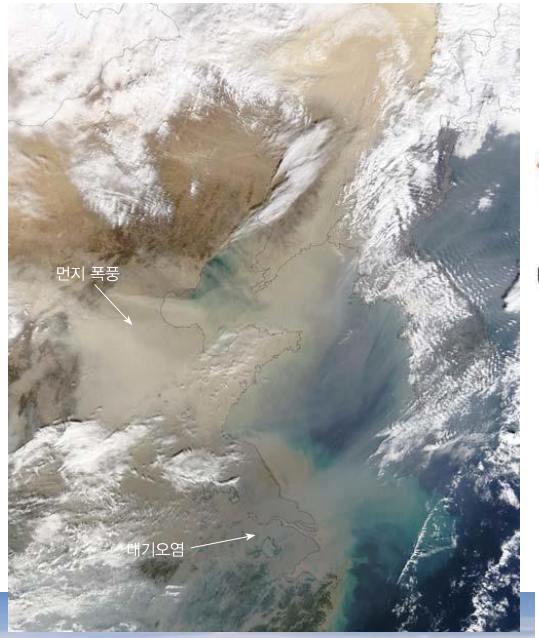
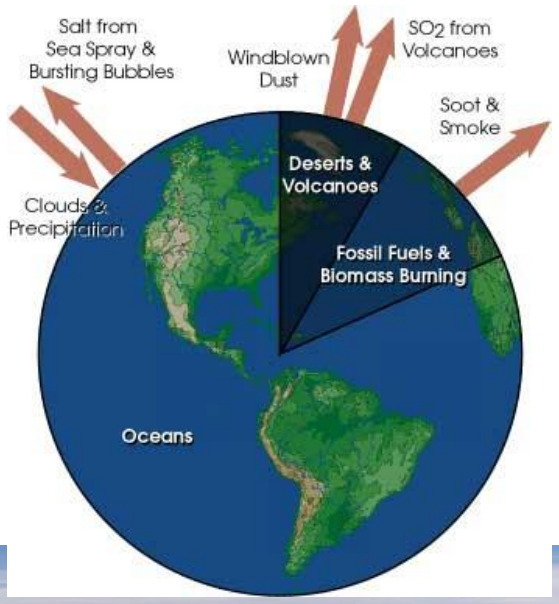
Introduction
- Aerosol-

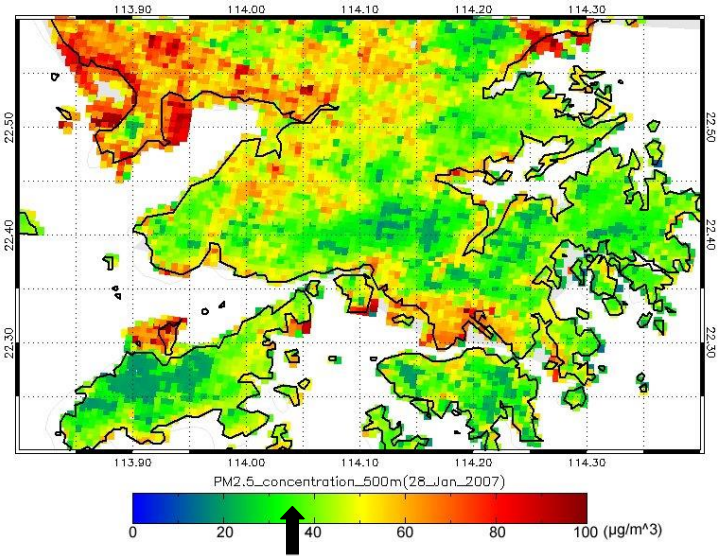
- ✓ Aerosol measurement has crucial role in the monitoring of climate changes.
- ✓ The accurate aerosol information is one of the key parameter to detect gas and ocean/land surface information.
- ✓ By using the correlation between AOD and PM concentration, the retrieved AOD from satellite measurement can provide the information of the surface air quality change over large area.

This image was made by compositing several days of TOMS data.
[courtesy, PK Bhartia, NASA]



(http://www.nasa.gov)





Retrieval of PM2.5 from MODIS AOD at Hong Kong (Wong et al., 2009)

Concept of Aerosol Retrieval

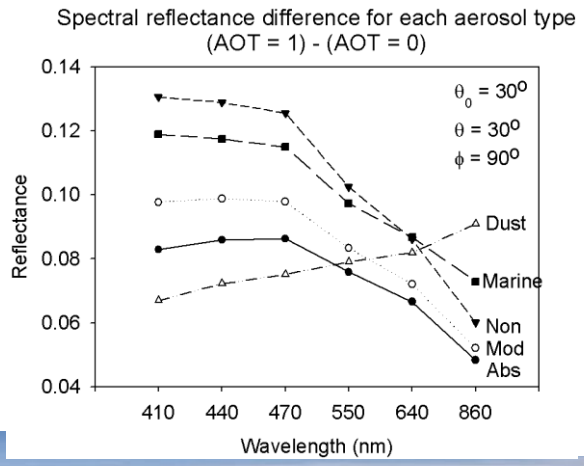
f(geometry, surface reflectance, aerosol optical properties)

AOP: refractive index, size distribution

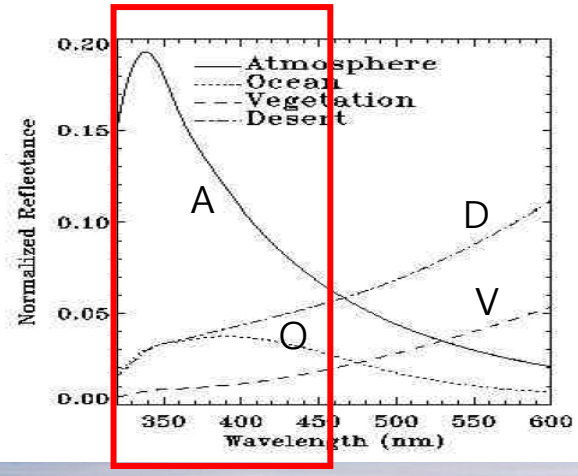
Forward modeling

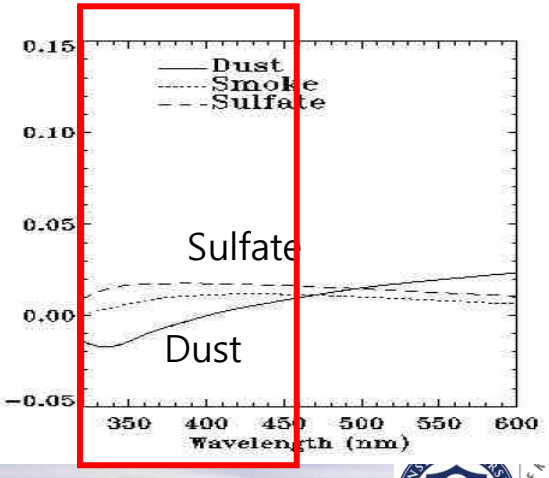
Inversion procedure

Calculated TOA reflectance ⟷ **Observed TOA reflectance**



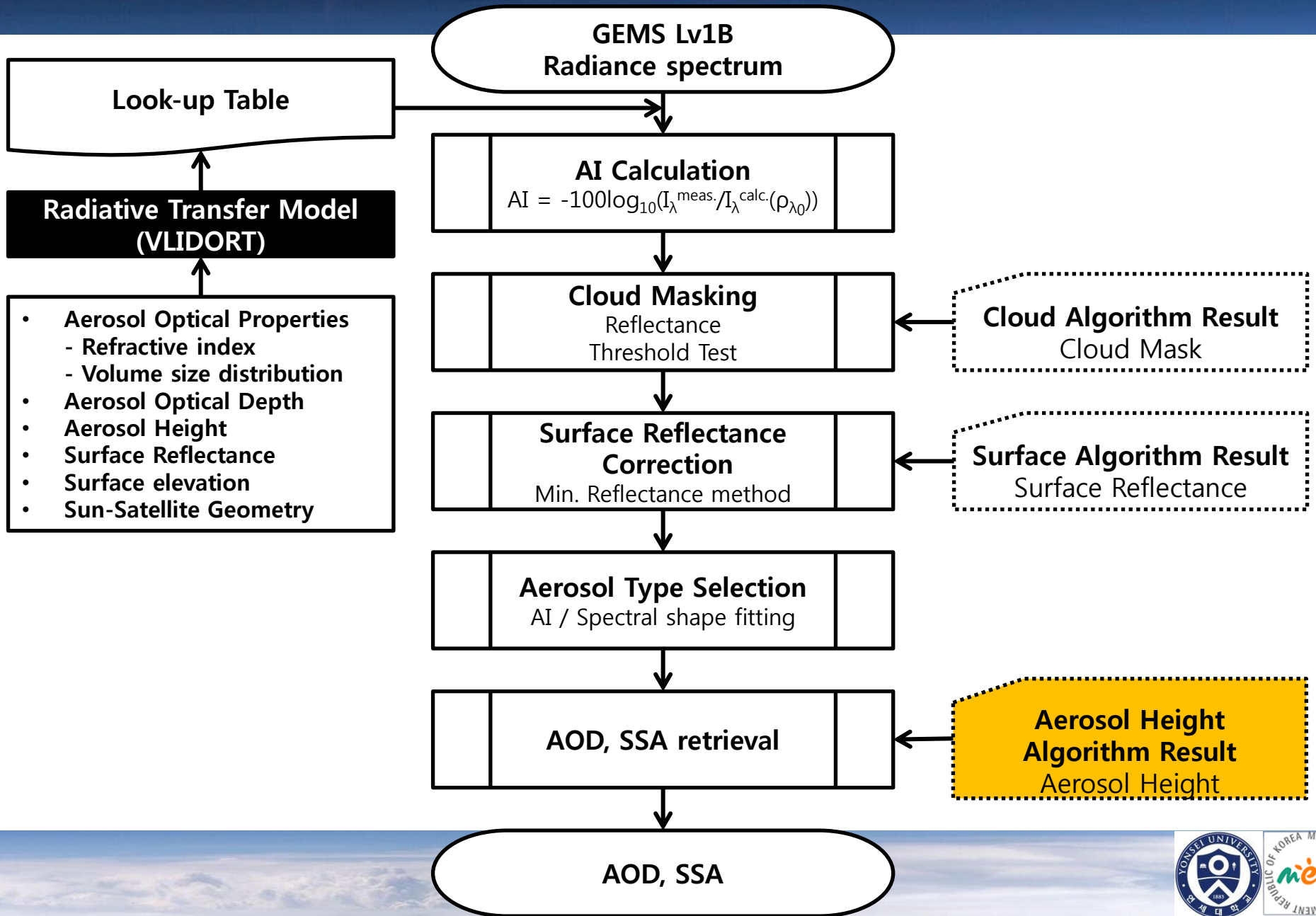
Lee et al. (2010)





[OMI ATBD version2, 2002]

Flowchart of Algorithm



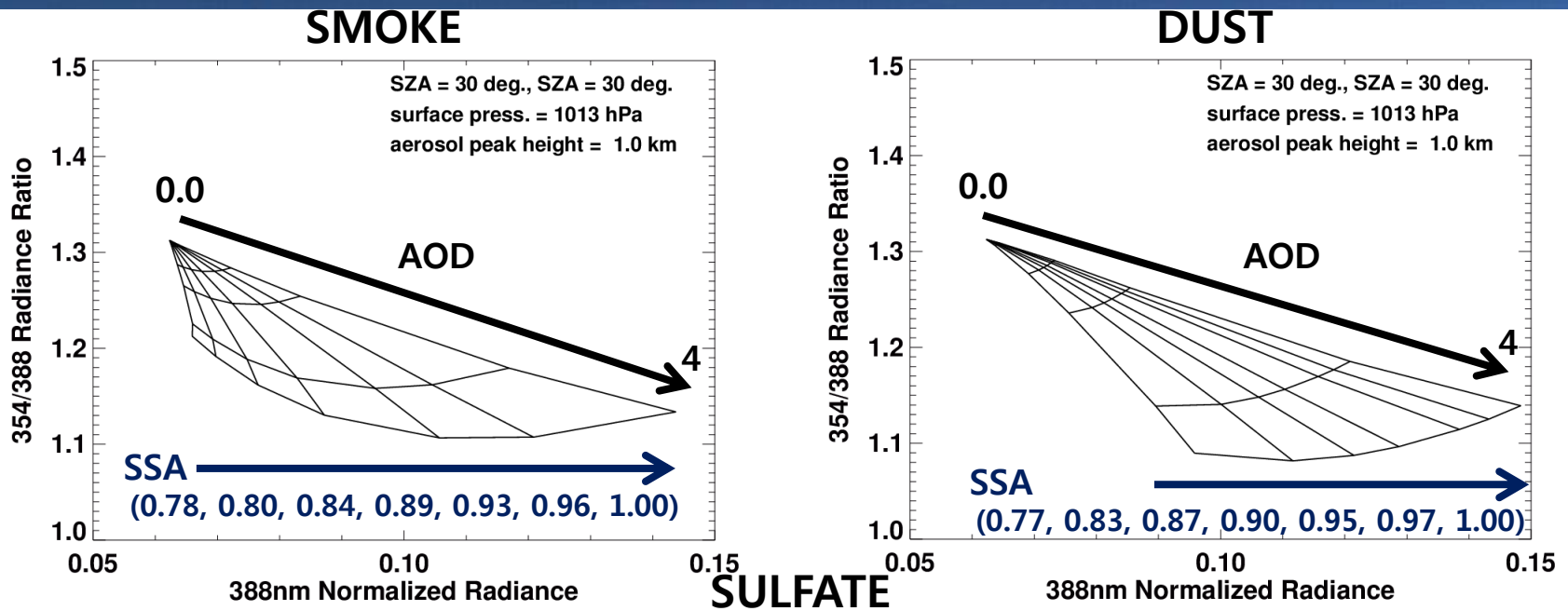
LUT calculation

Aerosol model (From O. Torres & Jethva et al., 2011)	r_m1	r_m2	σ_m1	σ_m2	Real	Imaginary
Smoke	0.080	0.705	1.492	2.075	1.5	0.0, 6e-3, 1.2e-2, 2.4e-2, 3.6e-2, 4.8e-2, 5.8e-2 (354 nm) 0.0, 5e-3, 1e-2, 2e-2, 3e-2, 4e-2, 4.8e-2 (388 nm)
Dust	0.052	0.670	1.697	1.806	1.55	0.0, 1.3e-3, 2.6e-3, 5.6e-3. 8.3e-3, 1.3e-2, 2.3e-2 (354 nm) 0.0, 0.9e-3, 1.8e-3, 4.0e-3, 6.0e-3, 9.2e-3, 1.7e-3 (388 nm) Wavelength dependence
Sulfate	0.088	0.509	1.499	2.160	1.40	.0.0, 2e-3, 4e-3,6e-3, 8e-3, 1e-2, 1.2e-2

Radiative Transfer Model : VLIDORT

Variable name	No. of entries	Entries
Wavelength	6	354, 388, 412, 443, 477 nm
SZA	8	0.1, 10, 20, 30, 40, 50, 60, 70
SAZA	8	0.1, 10, 20, 30, 40, 50, 60, 70
RAA	11	0.1, 30, 60, 90, 120, 150, 160, 165, 170, 175, 180
SUR	4	0.0, 0.05, 0.1, 0.2, 0.4
AOD	5	0.0, 0.1, 0.5, 1.0, 2.5, 4.0
Aerosol height	5	0.5, 1.5, 3, 6, 10 km
Surface pressure	3	1014hPa, 700hPa, 473 hPa

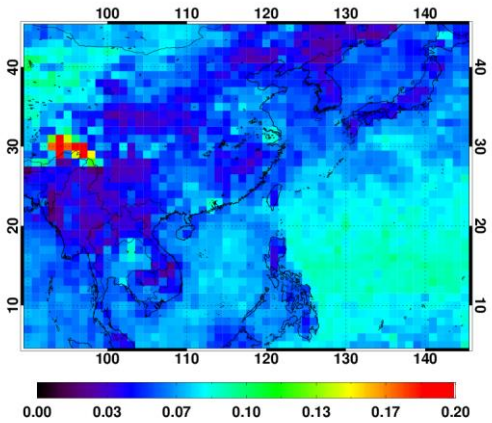
Examples of calculated LUTs



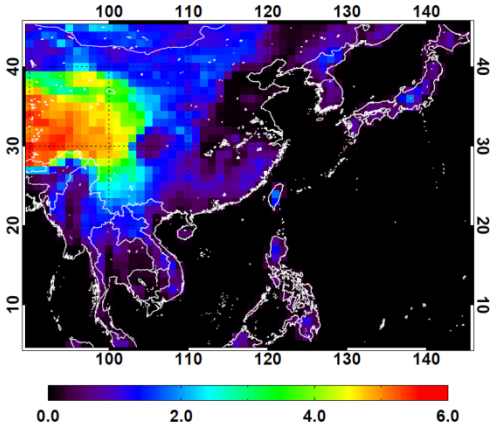
Algorithm Reference Test Input Condition

AOD = 0.7
Aerosol Peak Height = 1.5 km
SSA : 0.89/ 0.90/0.95
RTM : VLIDORT

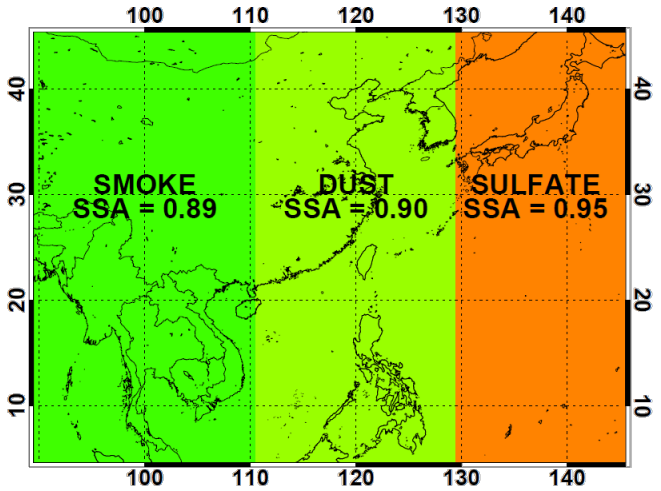
OMI Surface Reflectnace climatology
354nm,month =04



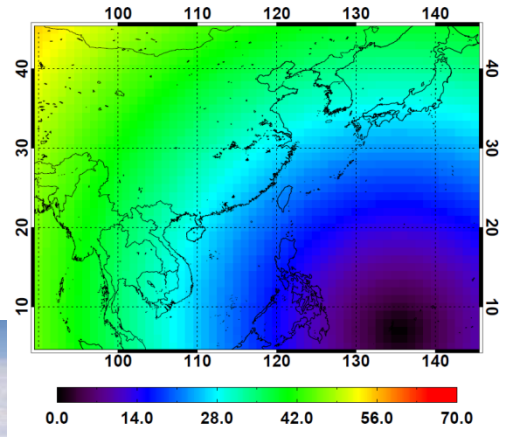
Input Surface Elevation



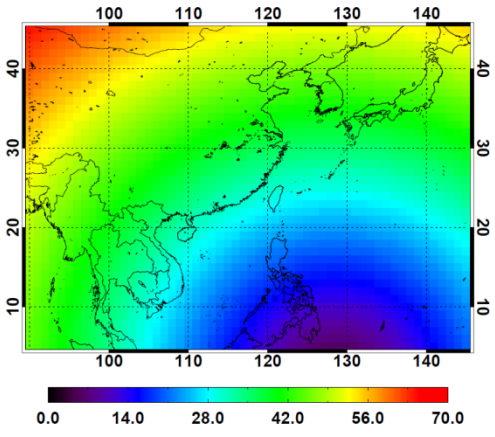
Input Aerosol Type



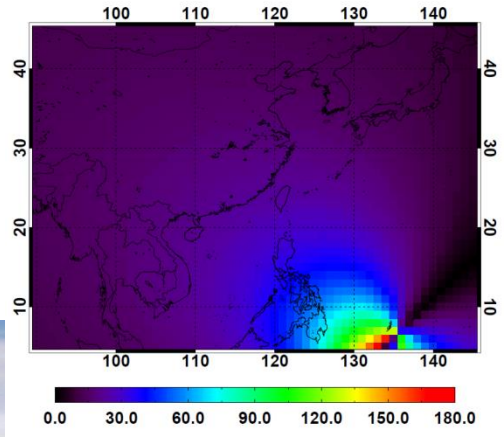
Input Solar Zenith Angle



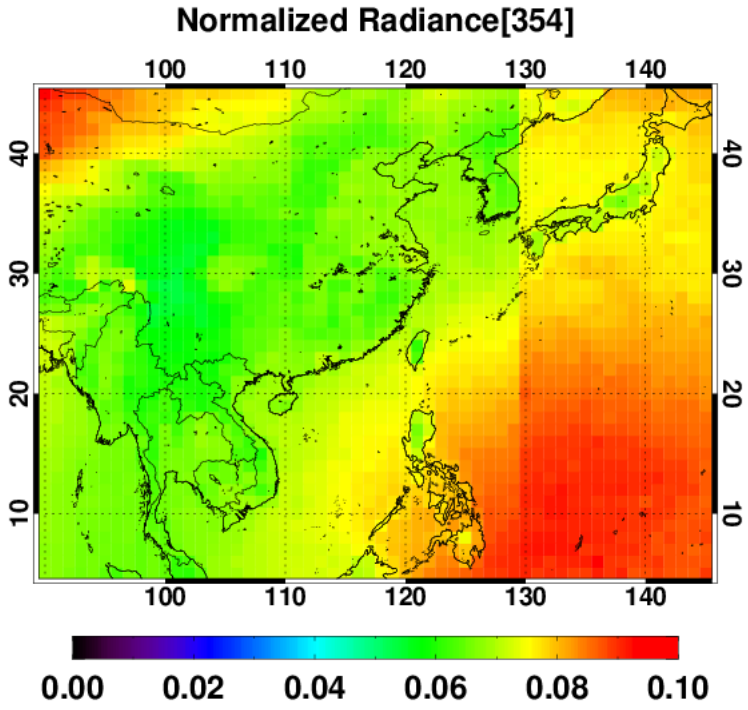
Input Viewing Zenith Angle

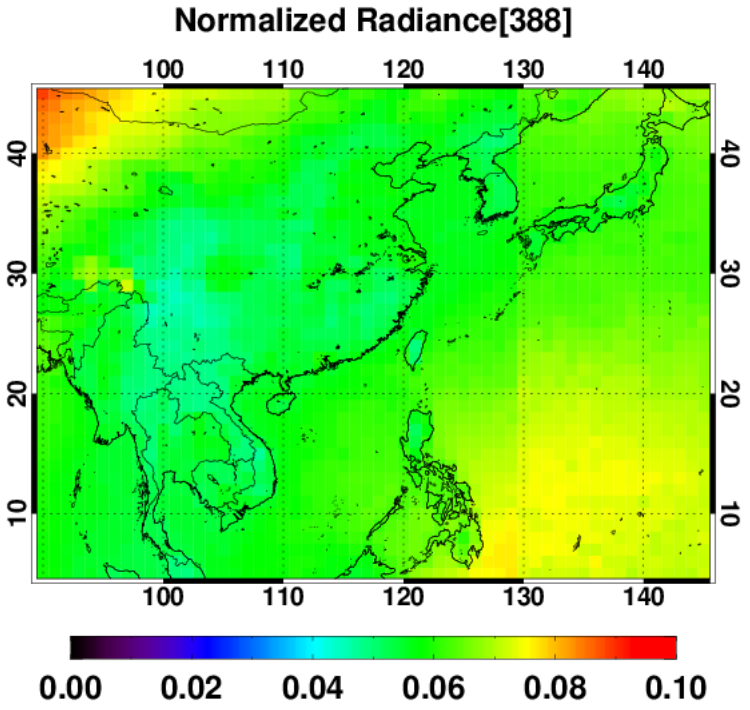


Input Relative Azimuth Angle

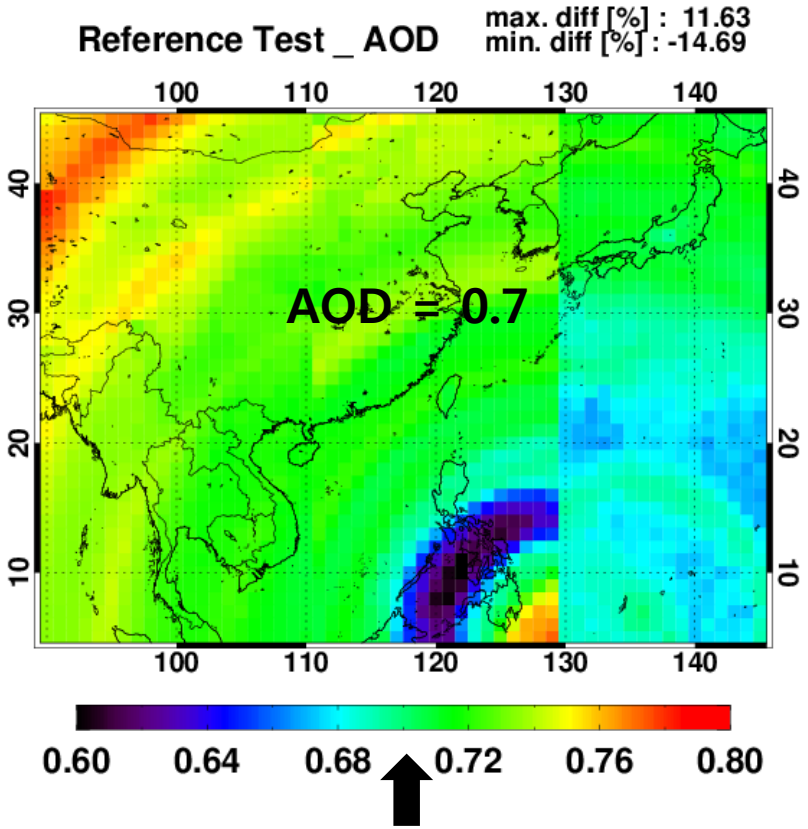


Algorithm Reference Test
Calculated Radiance [354 nm, 388 nm]





Algorithm Reference Test
Output : AOD, SSA

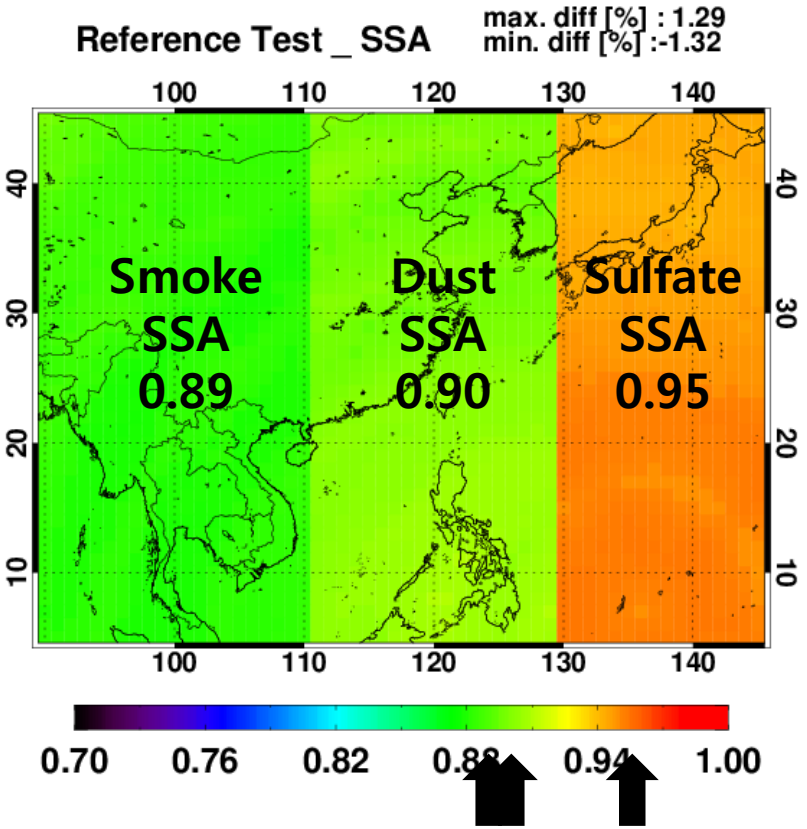


AOD Retrieval

***Error : -14.69% ~ 11.63%**

0.69 < AOD < 0.71 : 13.54 %

0.65 < AOD < 0.75 : 87.11 %



SSA Retrieval

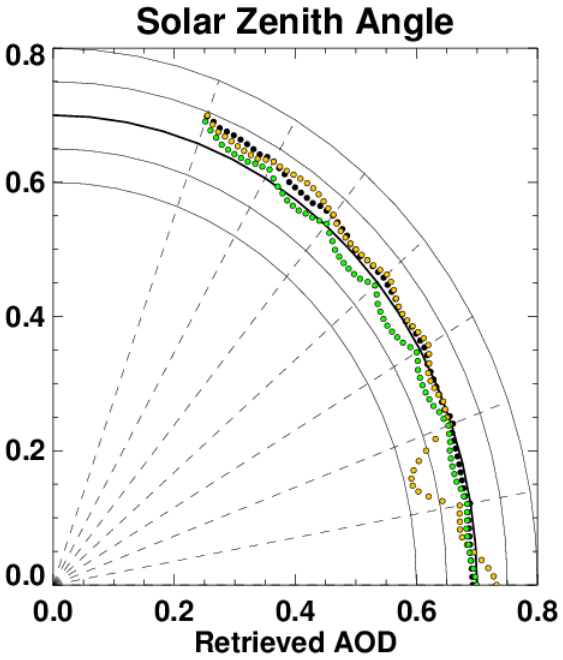
Error : -1.29% ~ 1.32%

***Error = (Calc.-Real.)/Real.*100 [%]**

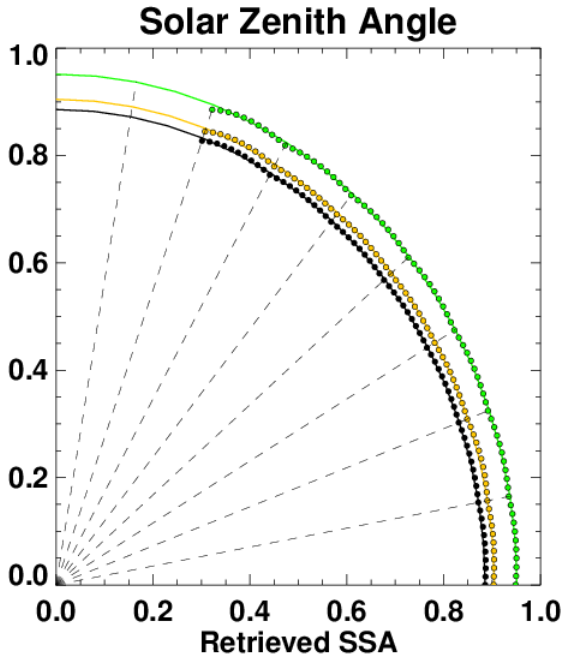
Angular Dependency of Retrieval Accuracy

SZA = 0 ° ~ 70 °, 1 °
VZA = 12.0 °
RAA = 33.0 °
Surface elevation = 0.0 km
Surface albedo [354 nm, 388 nm] = [0.068, 0.0665]
Reference AOD = 0.7
Reference SSA = 0.8856 (Smoke), 0.9046 (Dust), 0.9513 (Sulfate)

Retrieved AOD
From Reference test

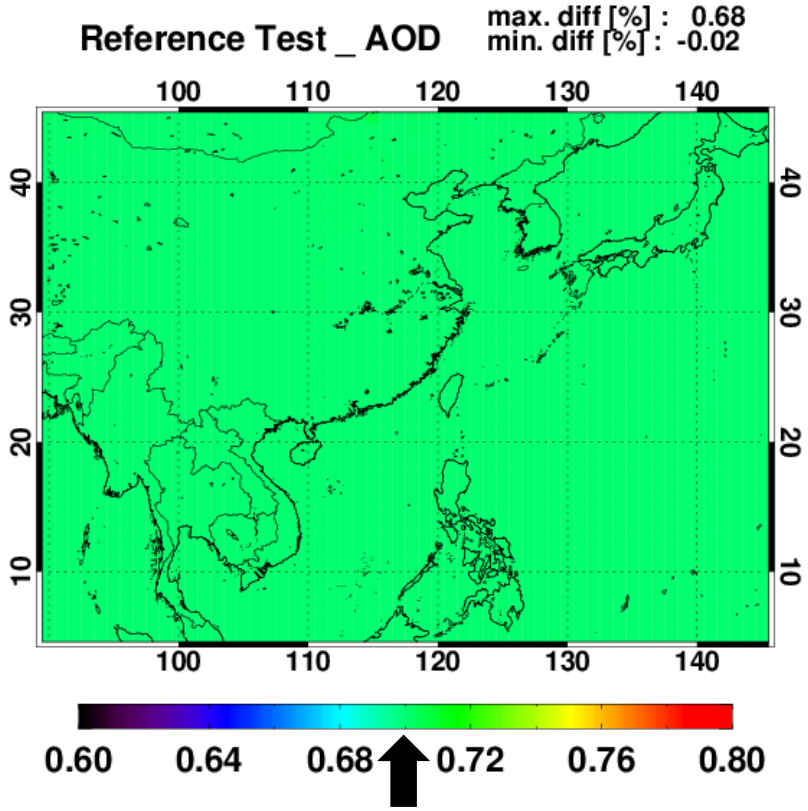


Retrieved SSA
From Reference test



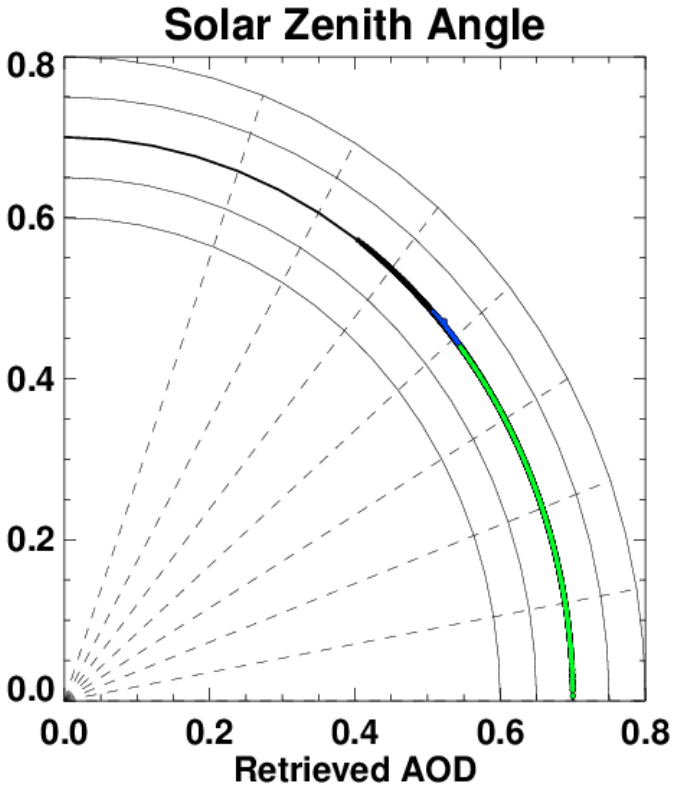
AOD retrieved from Online Calculation

P8. Jeong et al.



AOD Retrieval

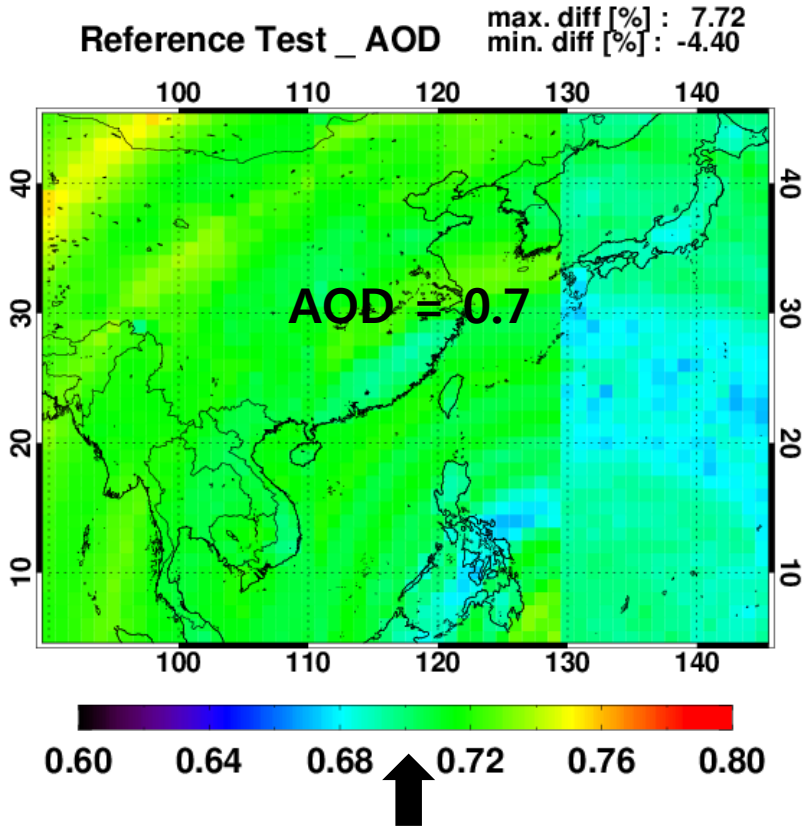
***Error : -0.02% ~ 0.68%**



LUT Calculation with Fine Angular Resolution

Variable name	No. of entries	Entries
Wavelength	6	354, 388, 412, 443, 477, 490 nm
SZA	10	0.01, 5, 10, 15, 20, 30, 40, 50, 60, 70
SAZA	10	0.01, 5, 10, 15, 20, 30, 40, 50, 60, 70
RAA	11	0.01, 15, 30, 45, 60, 80, 100, 120, 140, 160, 180
SUR	4	0.0, 0.05, 0.1, 0.2, 0.4
AOD	5	0.0, 0.1, 0.5, 1.0, 2.5, 4.0
Aerosol height	5	0.5, 1.5, 3, 6, 10 km
Surface elevation	3	0, 3, 6 km

Algorithm Reference Test Output: AOD, SSA
- new result : Fine angular resolution -

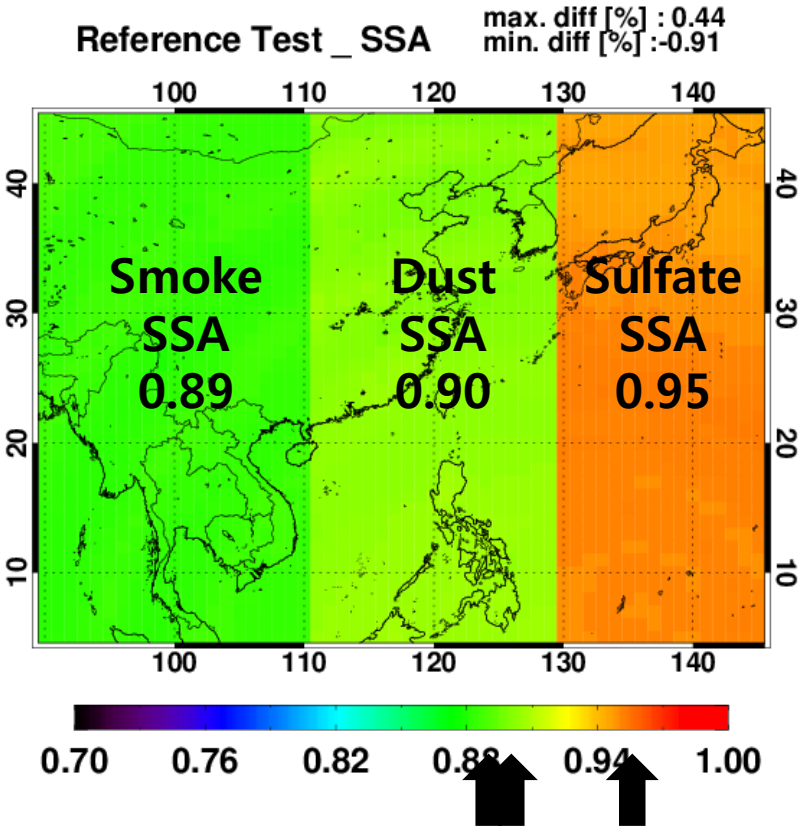


AOD Retrieval

***Error : -4.40% ~ 7.72%**

0.69 < AOD < 0.71 : 36.02 %

0.65 < AOD < 0.75 : 99.87 %



SSA Retrieval

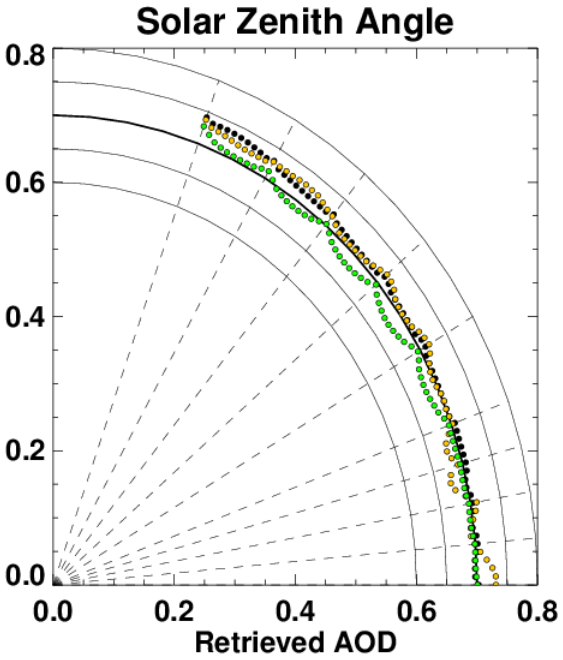
Error : -0.91% ~ 0.44%

***Error = (Calc.-Real.)/Real.*100 [%]**

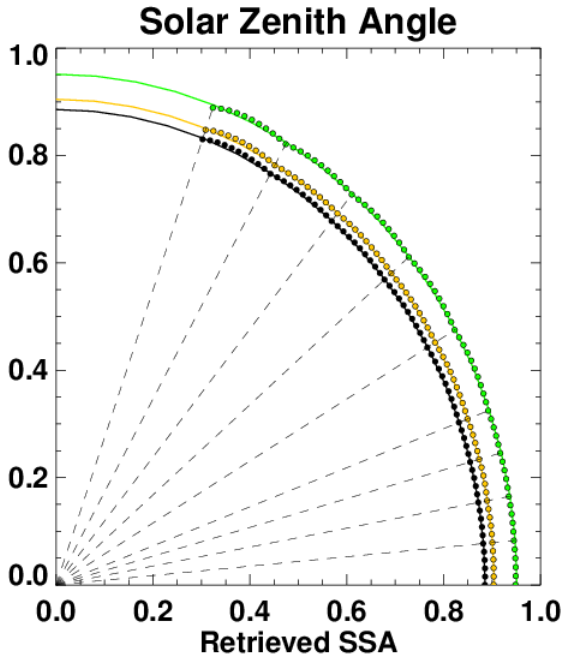
Angular Dependency of Retrieval Accuracy
with fine angular resolution

SZA = 0 ° ~ 70 °, 1 °
VZA = 12.0 °
RAA = 33.0 °
Surface elevation = 0.0 km
Surface albedo [354 nm, 388 nm] = [0.068, 0.0665]
Reference AOD = 0.7
Reference SSA = 0.8856 (Smoke), 0.9046 (Dust), 0.9513 (Sulfate)

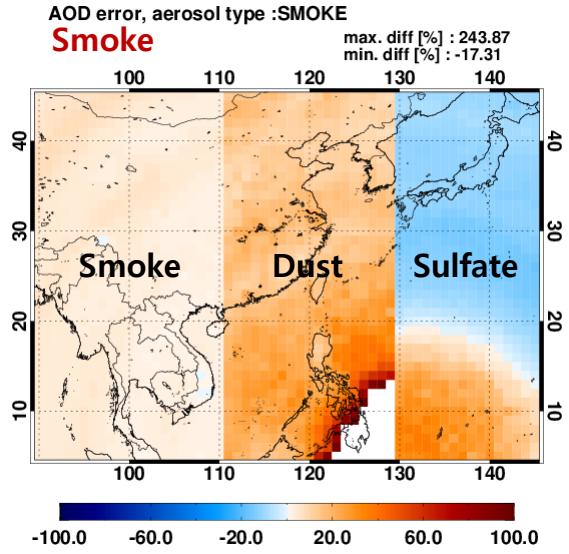
Retrieved AOD
With fine angle

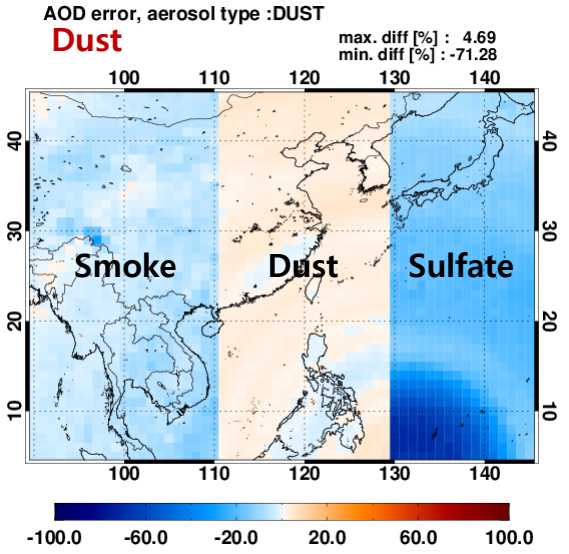


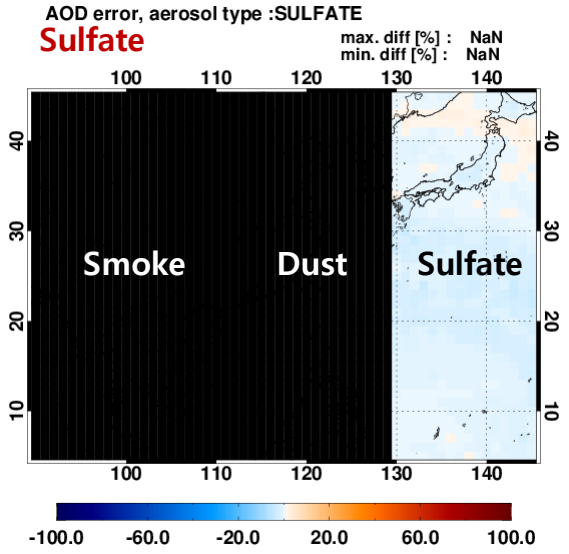
Retrieved SSA
With fine angle

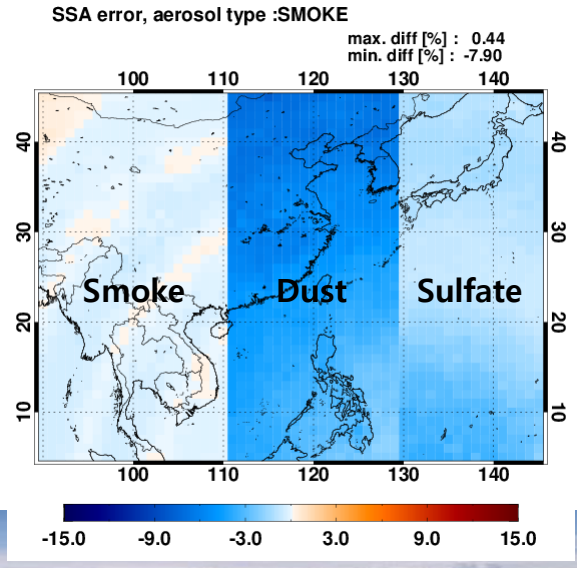


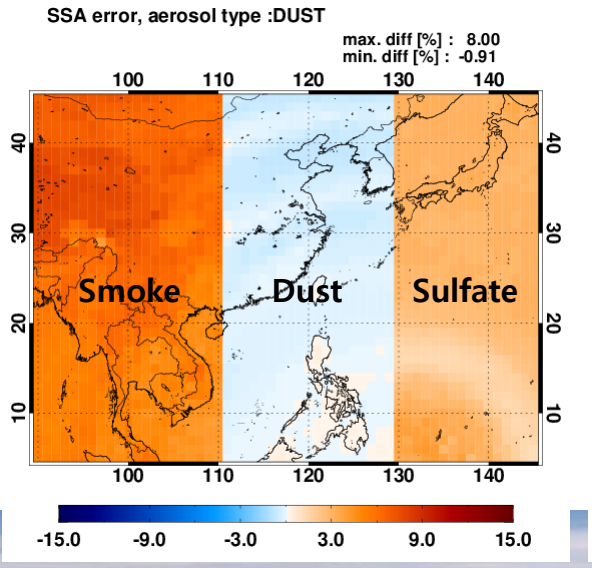
Aerosol Retrieval Sensitivity to Aerosol Type

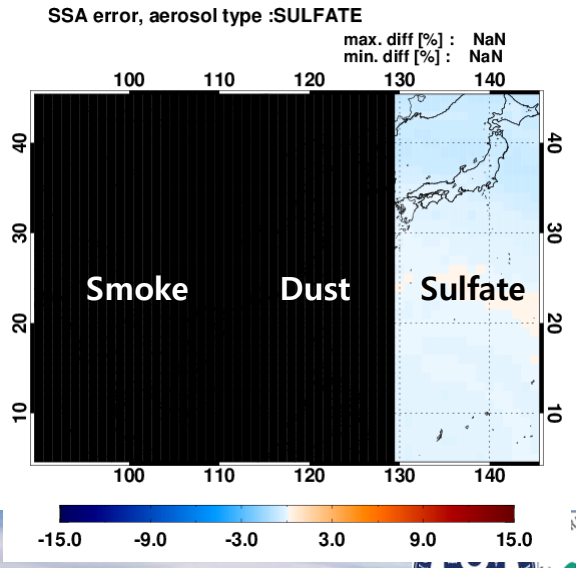






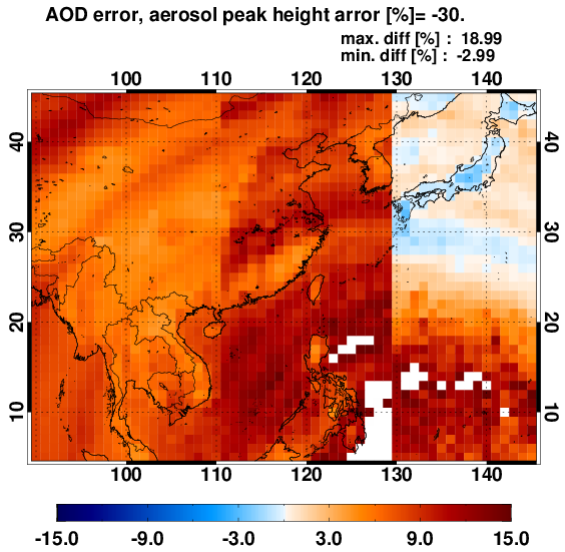


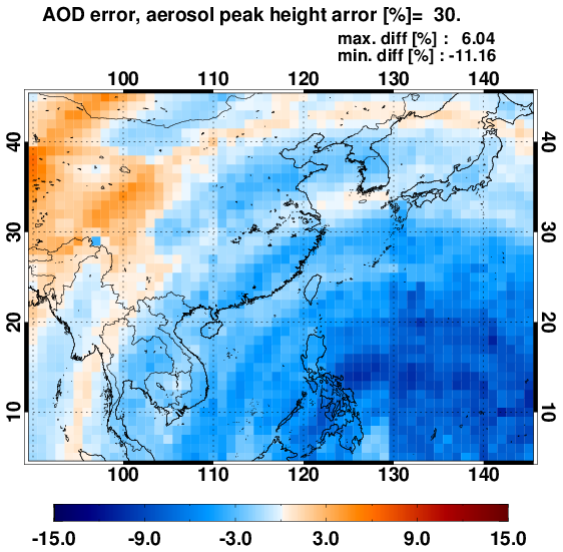




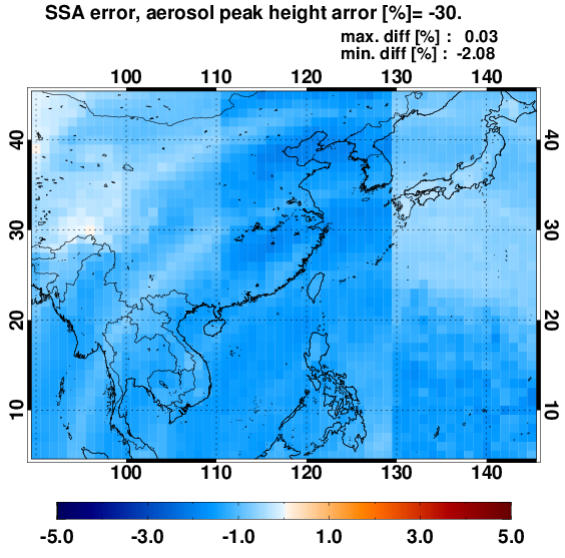
Aerosol Retrieval Sensitivity to Aerosol Height

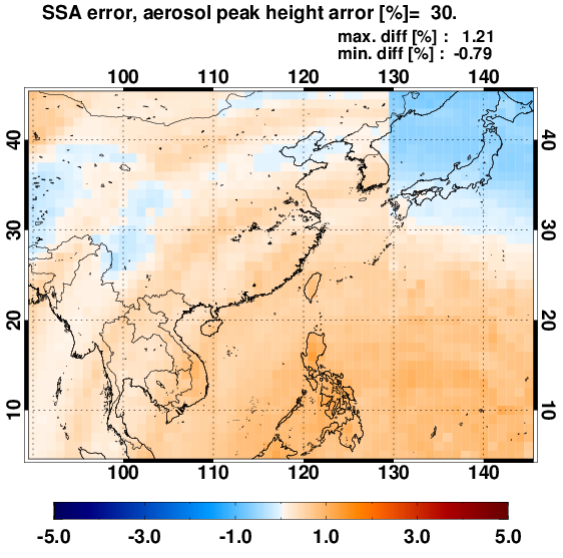
AOD
Retrieval Error
-11.16% ~ 18.99 %



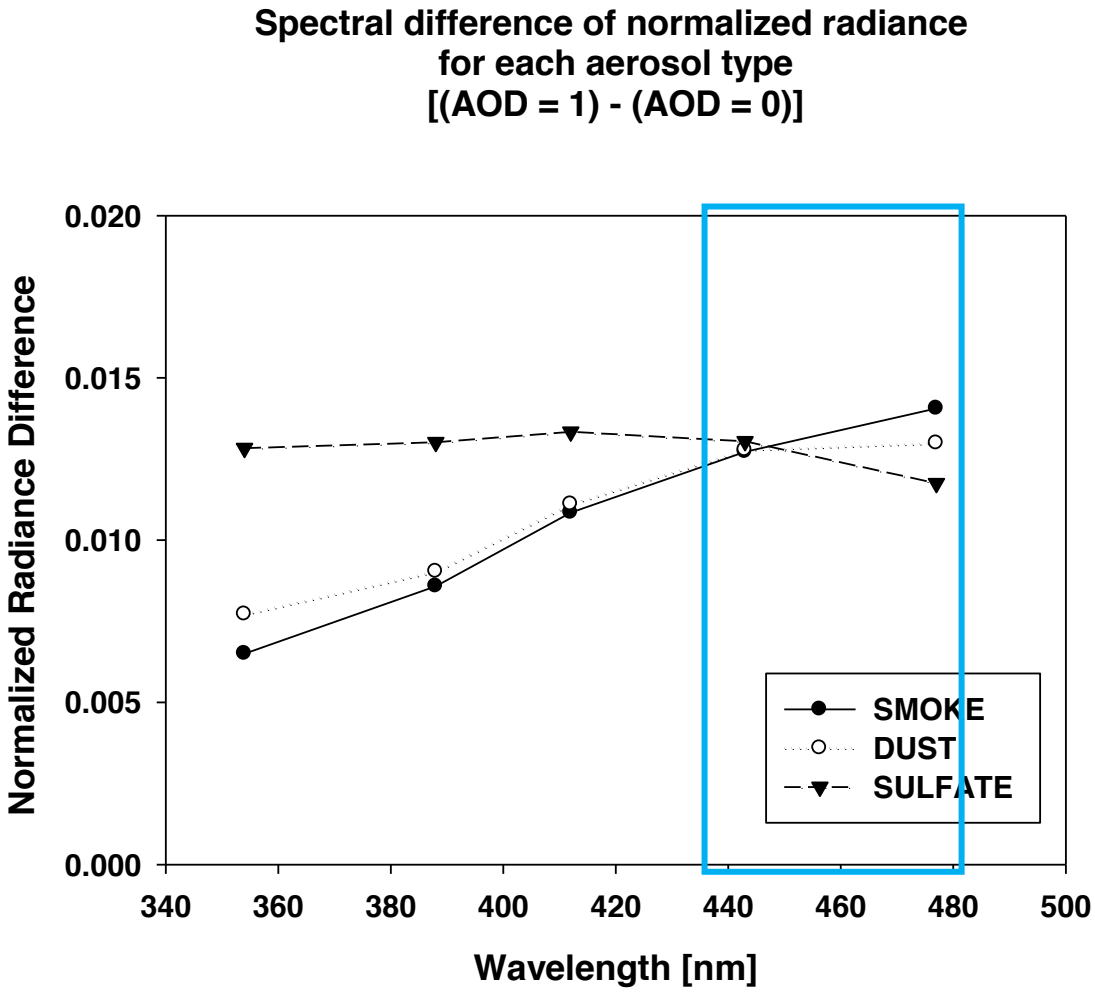


SSA
Retrieval Error
-2.08% ~ 1.21%





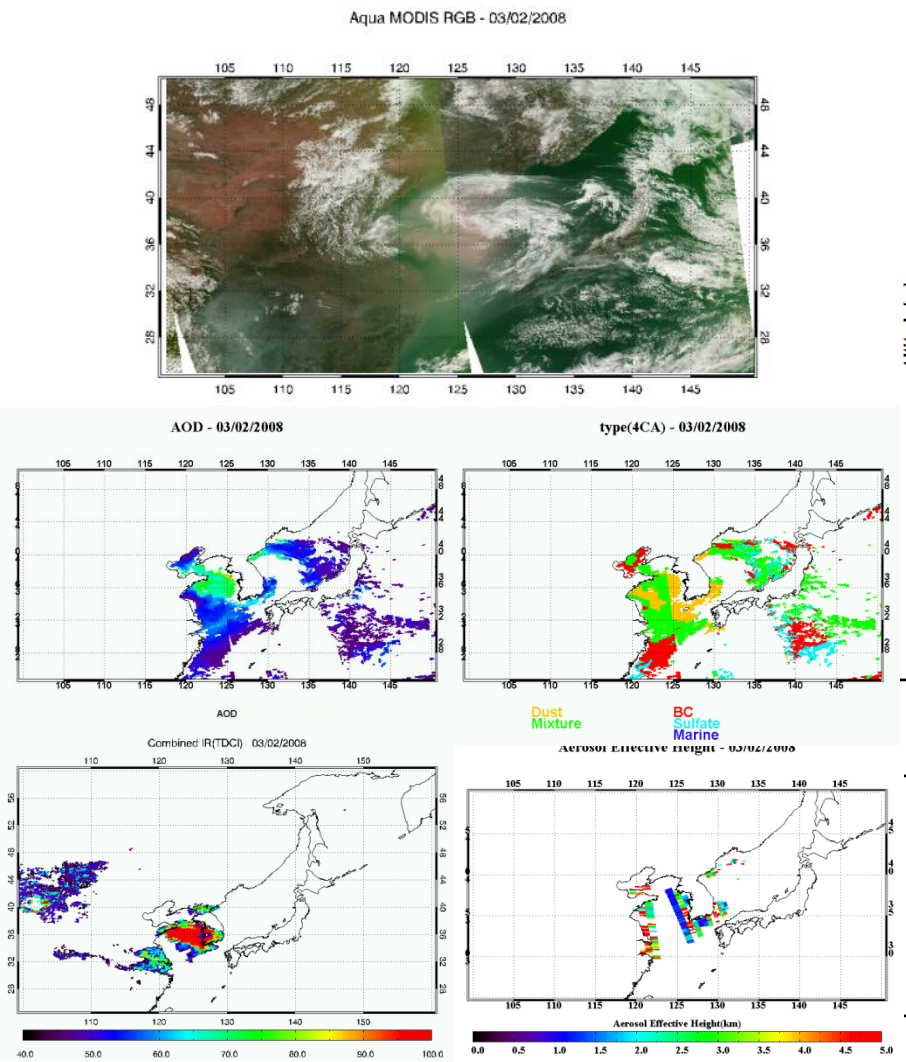
Feasibility Test for Aerosol Type Selection

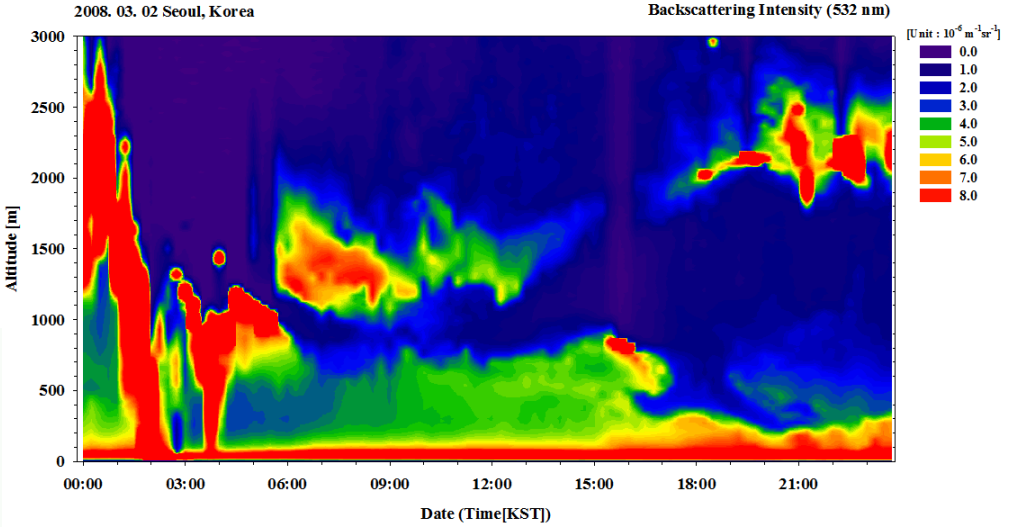


SMOKE SSA: 0.8856
DUST SSA: 0.9046
SULFATE SSA: 0.9513

Surface reflectance [388 nm] = 0.067

Retrieved Aerosol Height.
2008.03.02 – Elevated Dust (P9. Park et al.)





Region	East Asia	Near Seoul	Lidar (All day)	Lidar (Overpass)
Aerosol Height [km]	2.8±1.7	1.6±0.2	1.9±0.5	2.1±0.3
Number of data	359	8	94	8 (±1hr)

- Dust aerosol is elevated above PBL.

Summary of Error Analysis

P9. Park et al.

■ **Error source**

- **AOD : AOD ↑ → O_4 SCD ↓ (Shielding effect)**
- **SSA : SSA ↑ → Scattering ↑ → O_4 SCD ↑**
- **Albedo: High albedo → O_4 SCD ↑**

-Aerosol vertical distribution

Exponential vs Gaussian (MITR)

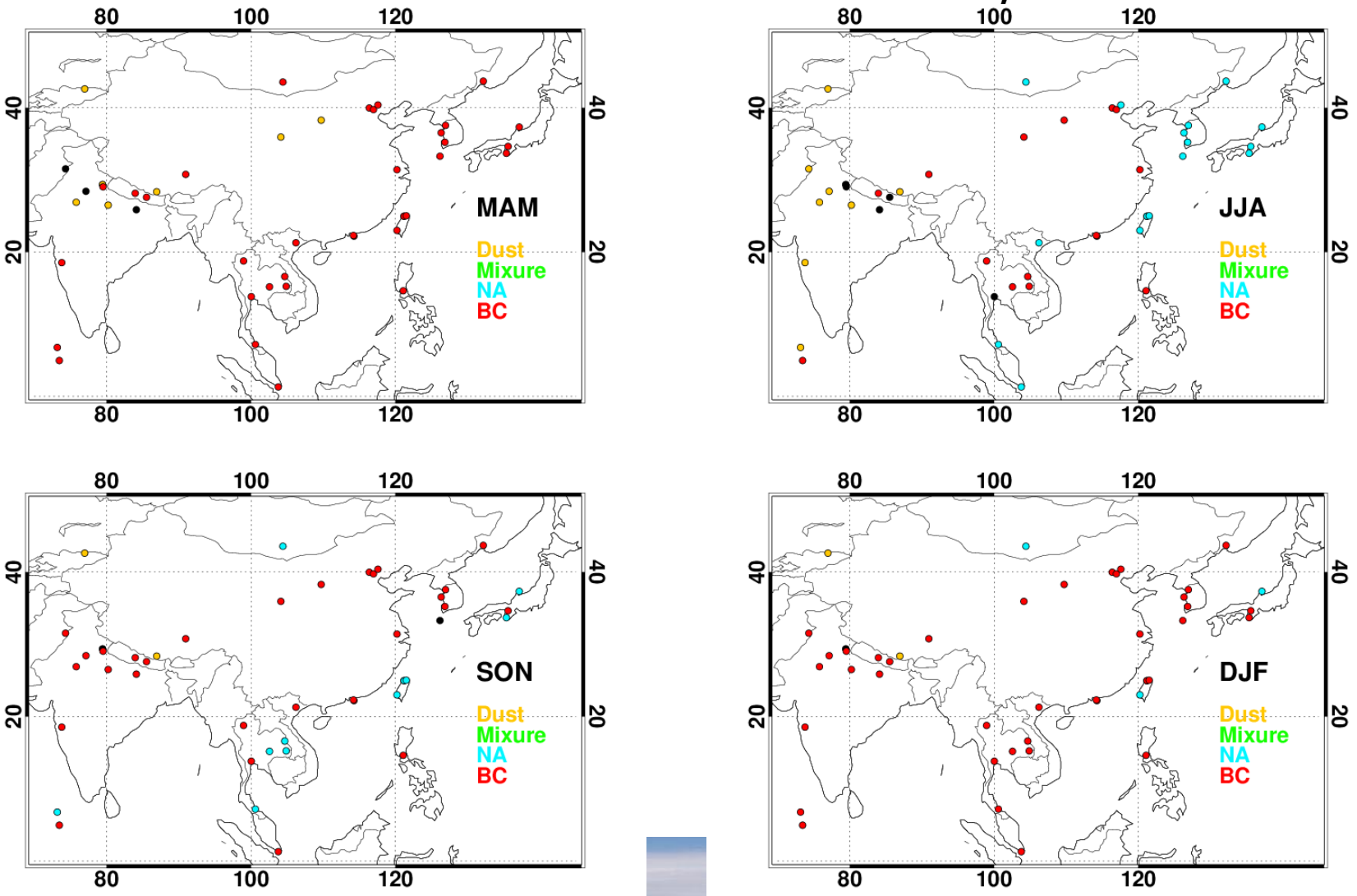
Exponential vs Box-shape (WASO,COPO)

Error source [unit : m]	MITR	WASO	COPO
AOD (ΔAOD = 0.2)	193±109	182±102	201±116
SSA (10% change)	1068±914	2373±1882*	488±436*
Surface Albedo (Δα = 0.01)	93±185	89±126	252±571
Aerosol vertical distribution	1843±4570	1884±2172	928±3332
Atmospheric Gases	Negligible	< 10	
O_4 cross section		~1.7% (O_4 SCD)	
Instrument (Shift : 0.02 nm)		< 10	
Total Error [unit : %]	28.2	56.6	22.9

*Aerosol Model : MITR (for dust), WASO (for non-absorbing), COPO (for absorbing) (Hess et al., 1998) – OPAC Aerosol Model

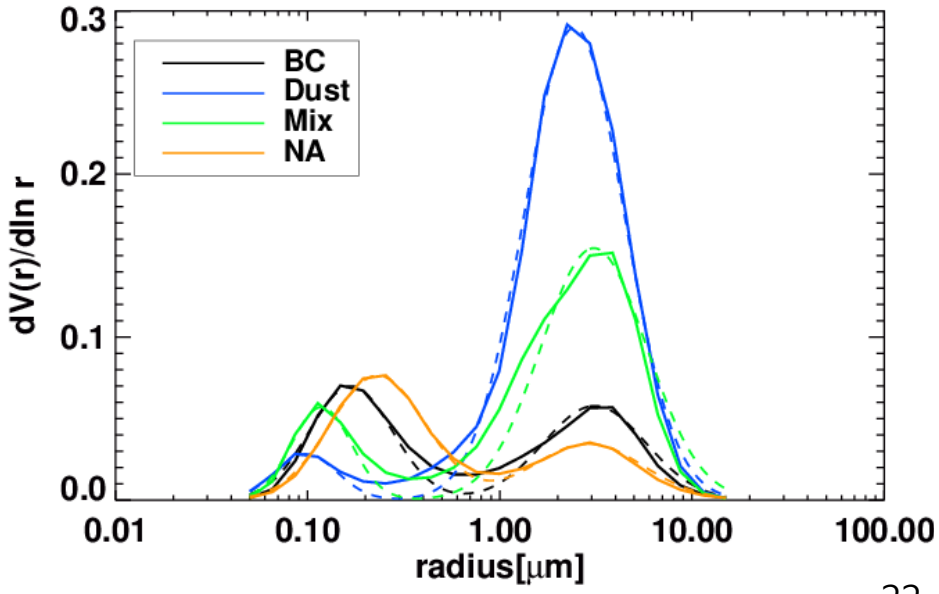
Aerosol Type over the Asia
Obtained from AERONET inversion data

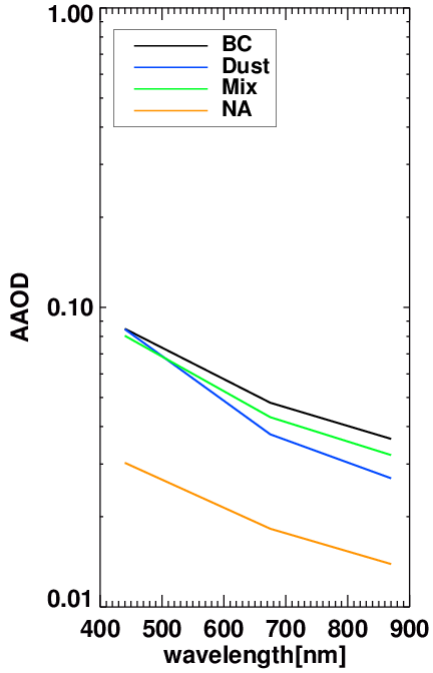
46 AERONET sites [70E – 145E, 0N – 50N]
Aerosol Classification Method : Lee et al., 2010

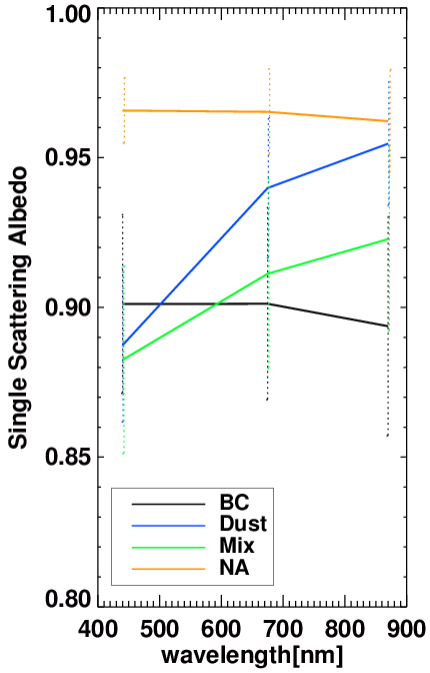


AOP over the Asia
Obtained from AERONET inversion data

	r_{m1}	r_{m2}	σ_{m1}	σ_{m2}	Real [440 nm]	Im. [440 nm]	SSA [440 nm]	Fine mode Contribution	AAE 440-675 nm
BC	0.0801	1.0049	1.6435	1.8485	1.45	0.01360	0.9011	0.99972	1.309
Dust	0.0648	0.8320	1.4507	1.8200	1.52	0.00515	0.8874	0.99778	1.858
Mix	0.0804	0.9212	1.4305	1.8847	1.47	0.00859	0.8825	0.99929	1.440
NA	0.0868	0.7414	1.7718	1.9761	1.41	0.00403	0.9657	0.99972	1.194







Summary and On-going issues

- GEMS aerosol retrieval algorithm is constructed based on the OMI UV algorithm.
- By using the calculated radiance from radiative transfer model, VLIDORT, the retrieval accuracy was estimated.
  - Coarse resolution of solar angle in the LUT causes the large error in AOD retrieval, in large scattering angle area. [Error : -14.69% ~ 11.63%]
  - The retrieval error is significantly reduced by calculating LUT with fine angular resolution.
- Underestimation of aerosol height related to overestimation and underestimation of AOD and SSA, respectively.
  - O4 algorithm also has large sensitive to accuracy of AOD.
  - Combining AOD algorithm and O4 algorithm is key issue in this study.
- Aerosol type selection is important to retrieve aerosol information, and this study planned to select aerosol type by using difference of spectral shape in visible range.
- Analyzed AOP over ASIA will be applied to AOD retrieval.

Thank You ☺

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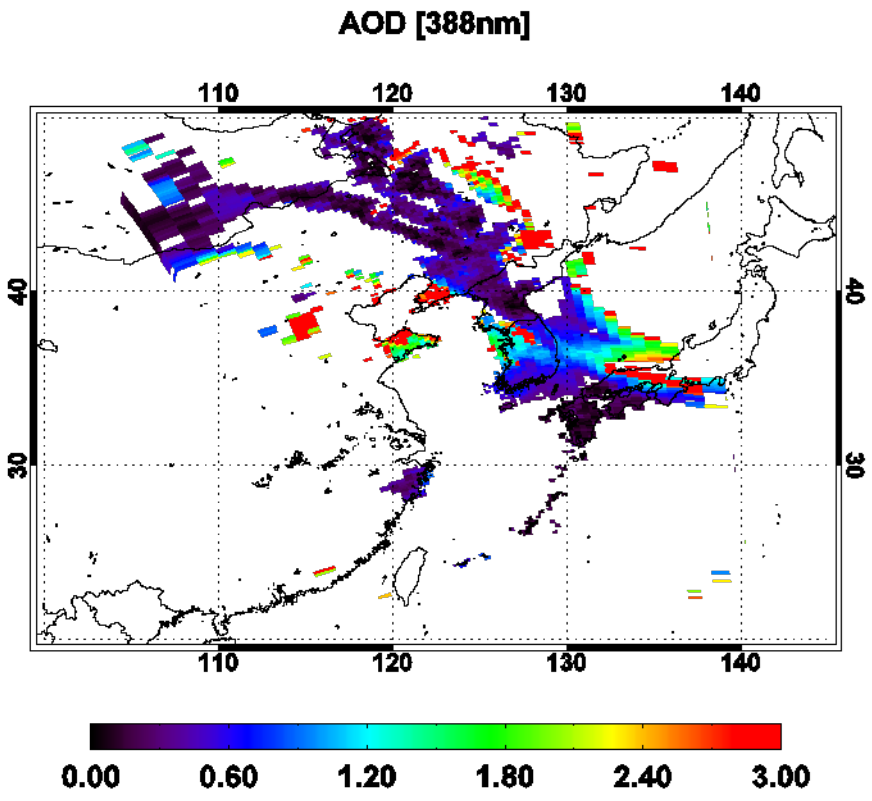
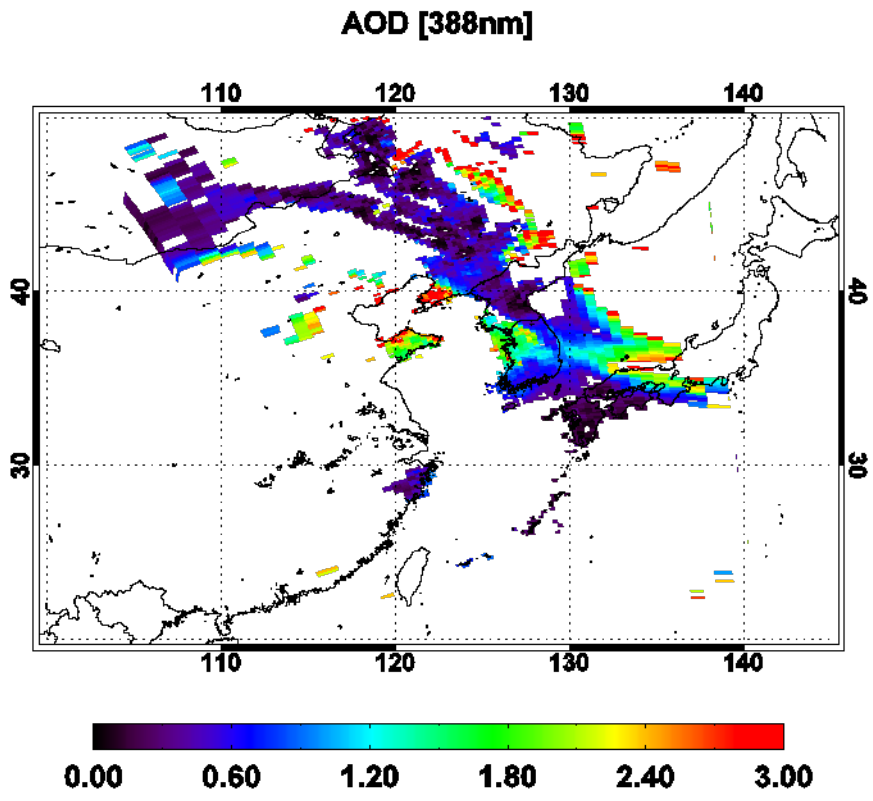
Algorithm Test with OMI products
AOD

Given condition : Normalized Radiance [354 nm, 388 nm], aerosol type, aerosol height, surface albedo, surface pressure

OMI Product



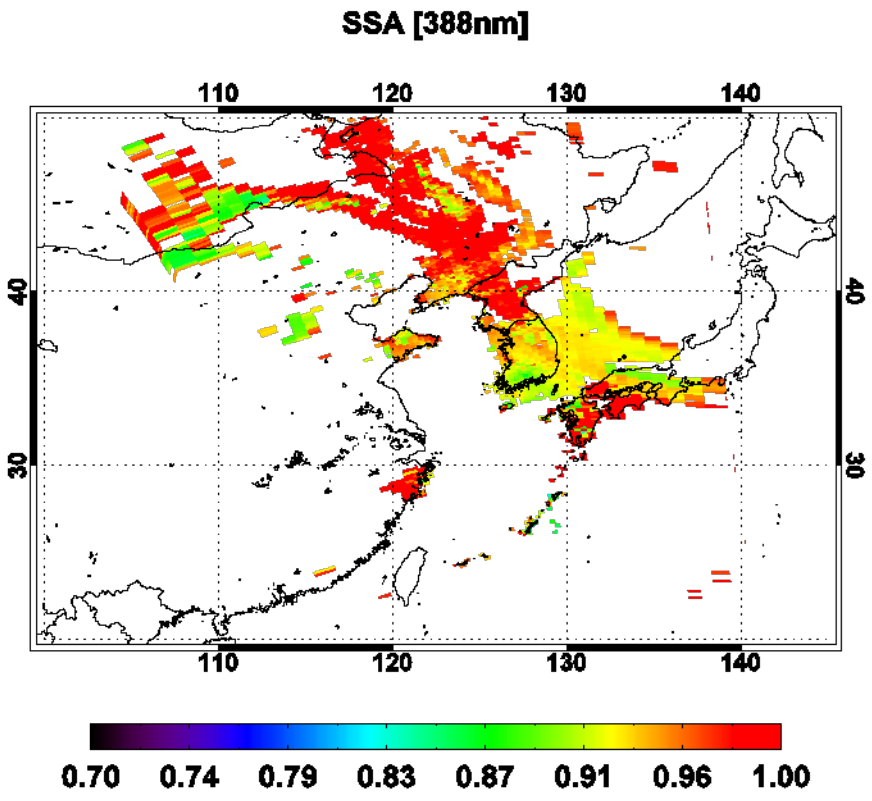
Retrieval Product



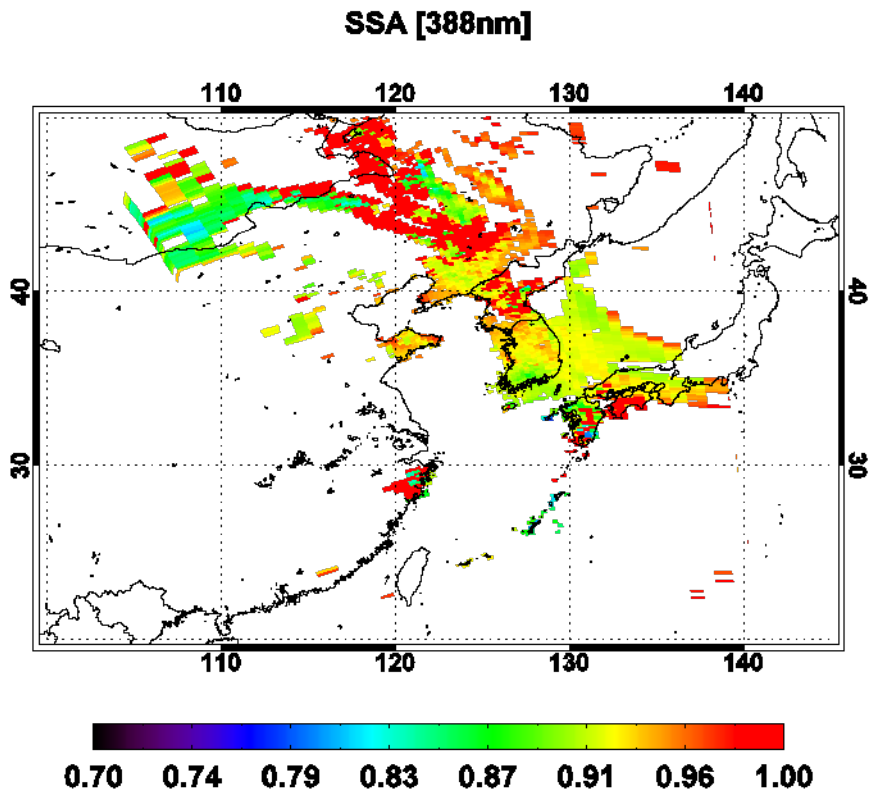
Algorithm Test with OMI products
SSA

Given condition : Normalized Radiance [354 nm, 388 nm], aerosol type, aerosol height, surface albedo, surface pressure

OMI Product

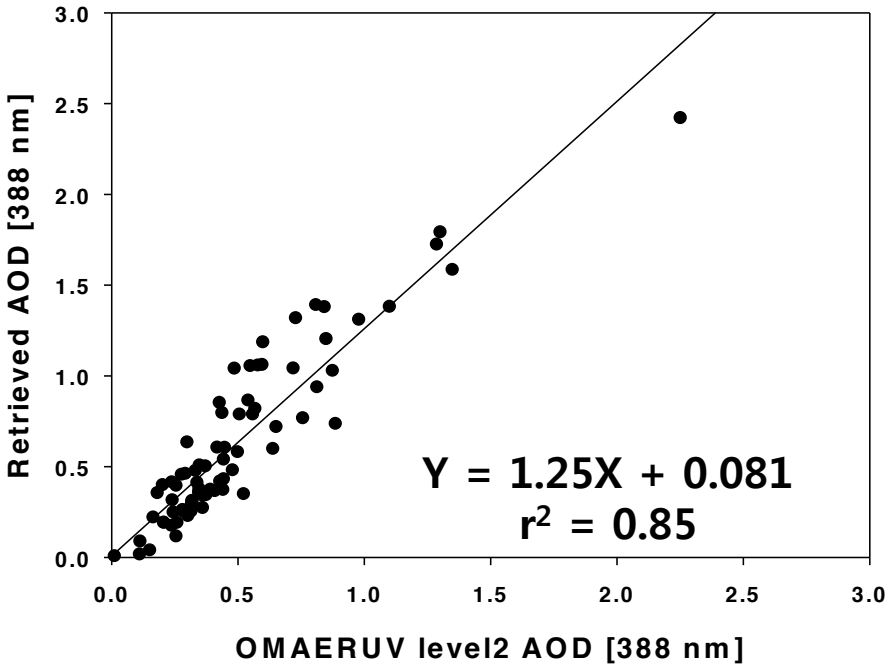


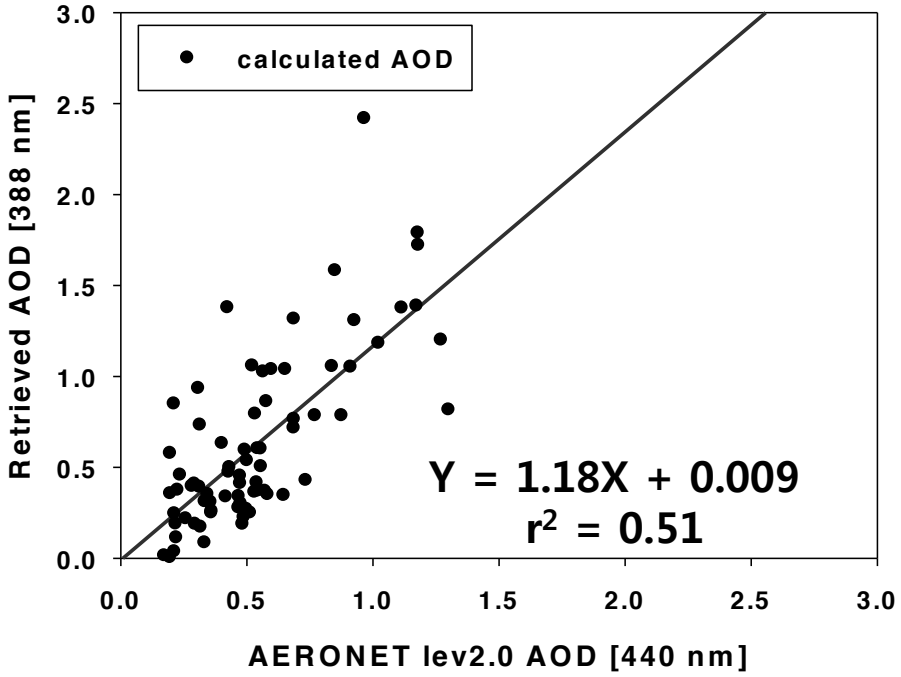
Retrieval Product



Algorithm Test with OMI products

Location : Yonsei University, Pusan_NU, Gwangju_GIST
Period : 2012. 03. 01 ~ 05. 31 (2012DRAGON Campaign)
Given condition : Normalized Radiance [354 nm, 388 nm], aerosol type, aerosol height, surface albedo, surface pressure





Aerosol Classification Method (Lee et al., 2010)