Algorithm development for aerosol retrieval and its validation based on combined use of polarization and radiance measurements

I. Sano, and CI team

CIs :

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Contents

Aerosol observation by SGLI

- Aerosol model
- Retrieval algorithms
  - 2ch polarization method (POLDER)
  - 2ch polarization & 1ch total radiance method (POLDER + CAI)
  - 2ch polarization & 2ch total radiance method (POLDER + CAI)

Application

- $PM_{2.5}$ retrieval

Aerosol model for RS

Aerosol characteristics are interpreted as

- microphysical properties :
  - shape, number-, volume-, surface area-distribution for size ....,
- optical properties:
  - cross sect. of scat., abs., phase fn, ref. idx., SSA, ...
- chemical properties :
  - aerosol species, mixing state, ...

Estimation of every parameters from space/ground is difficult.

⇨ Some assumptions are needed.

e.g., sphere & spheroid ---------- as ptl SHAPE

bi-modal lognormal distribution - as SIZE

several refractive indices ---------- as chem comp.

Size distribution

Bi-modal log-normal volume distribution

$$\frac{dV}{d\ln r} = (1 - F_{coarse}) \exp\left[-\frac{(\ln r - \ln r_{fine})^2}{2\sigma_{fine}^2} \right] + F_{coarse} \exp\left[-\frac{(\ln r - \ln r_{coarse})^2}{2\sigma_{coarse}^2} \right],$$

Fine mode aerosols :

$$r_{fine} = 0.135\ \mu m,\ \sigma_{fine} = 0.43$$

Coarse mode

$$r_{coarse} = 2.365\ \mu m,\ \sigma_{coarse} = 0.63$$

(Dubovik et al., JAS, 2002)

Adjustment parameter (F_{coarse})

Individual dust particle analysis by SEM – EDX

Target : Size (major & minor axis),

Elements

Samples : AERONET Osaka site

DRAGON-Asia 2012

PM_{10} inlet

April 24: polluted & dust

April 28: dust

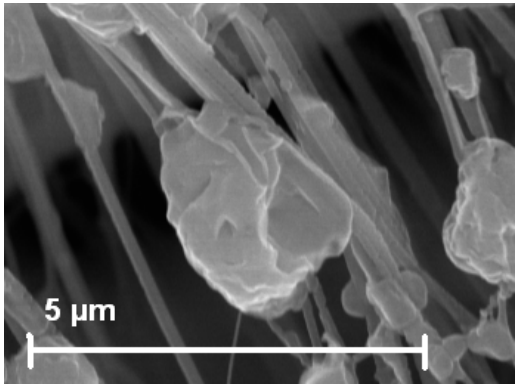
~1280 dust samples

Results :

Size dist : next page

Element : Si, Al

Aspect ratio: 1~2.5 (non spherical parameter)



Optical properties :
complex refractive index

For complex refractive index,

∗ each value should be set for each aerosol type

(e.g., sulfate, carbonaceous, oceanic, and dust),

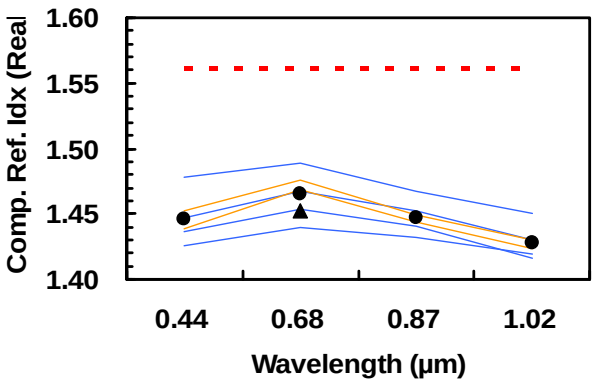
based on ground RS (AERONET) database,

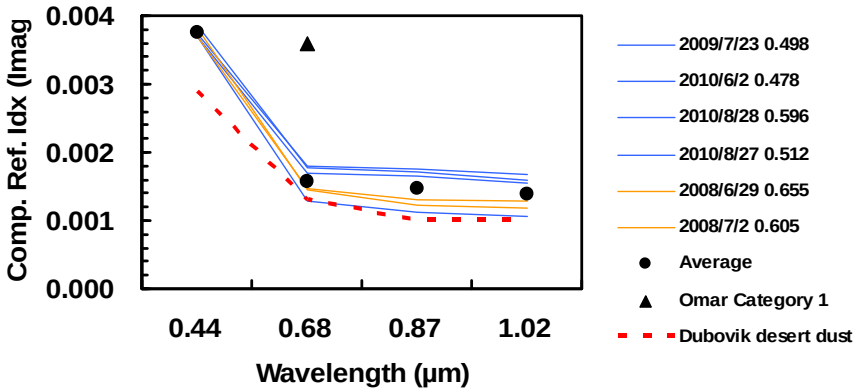
or theoretical rules.

Optical properties of aerosols :

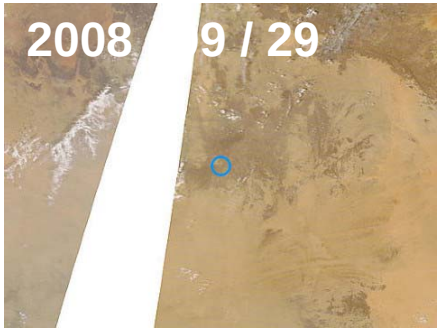
Saharan dust

over central (Tamanransset) and west coast (La_Laguna) of Africa

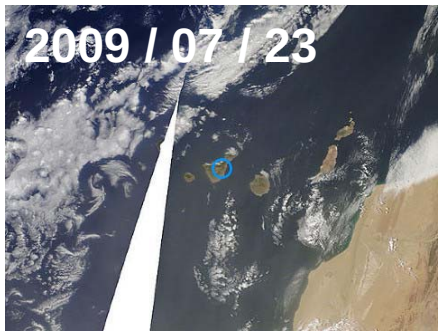


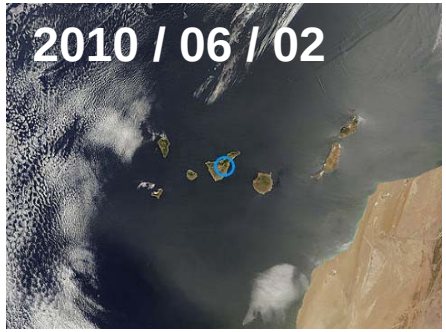


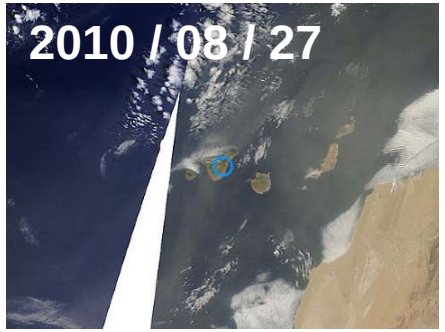
$\tau_{500} > 0.4$



0.44um	1.446-0.0037i
0.67um	1.465-0.0016i
0.87um	1.448-0.0015i
1.02um	1.428-0.0014i



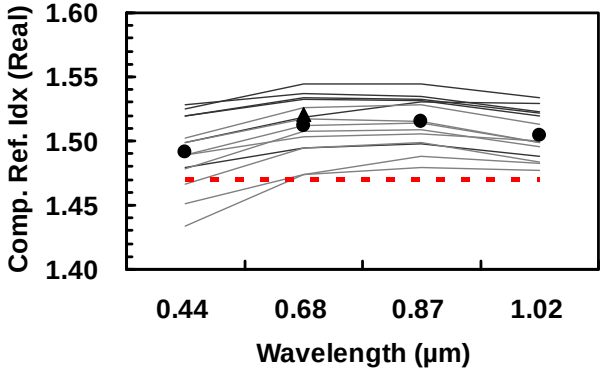


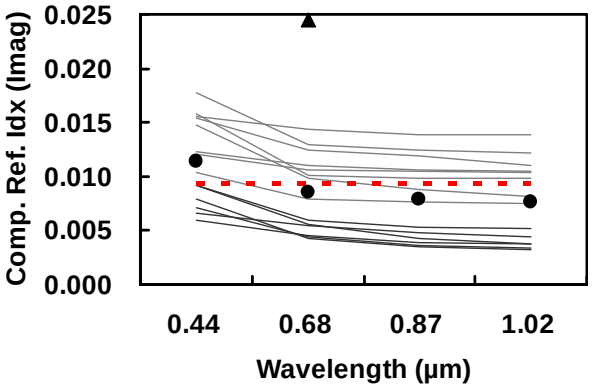


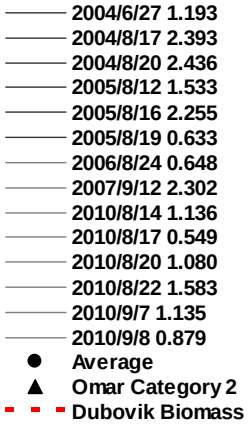
Optical properties of aerosols :

Biomass burning aerosols

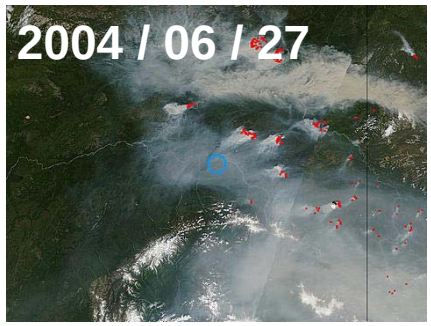
over Alaska (Bonanza), Amazon (JI_Parana_SE)

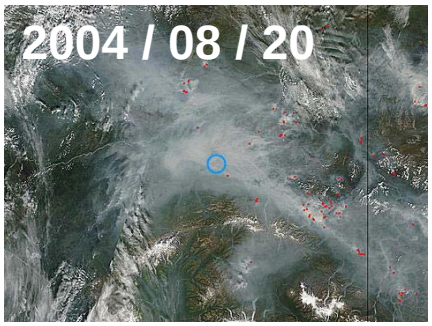


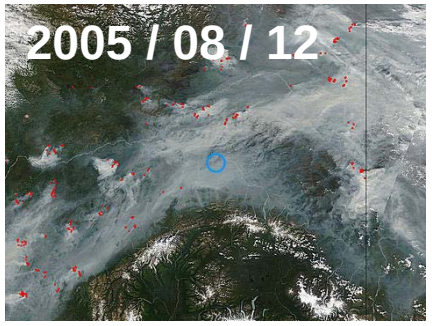




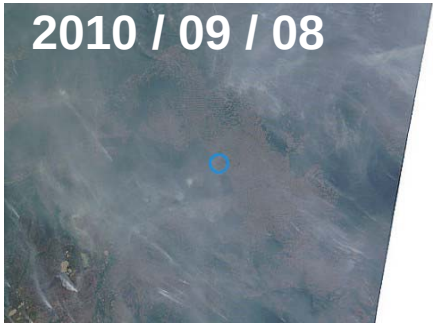
$\tau_{500} > 0.4$

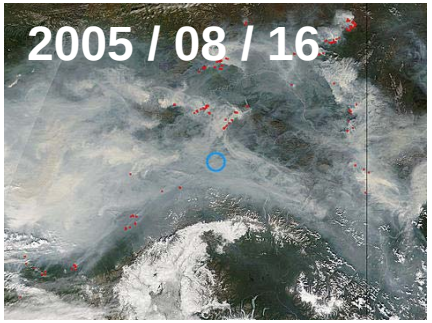






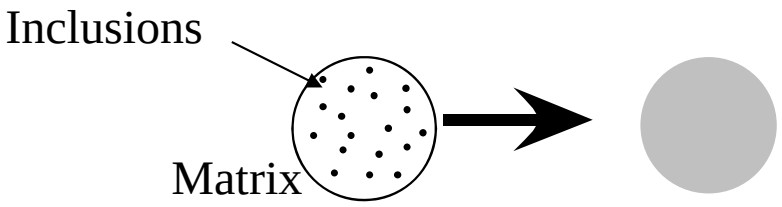
0.44um	1.491-0.0114i
0.67um	1.512-0.0085i
0.87um	1.515-0.0079i
1.02um	1.505-0.0077i





Optical properties :
internal mixture type (e.g., biomass burning aerosols)

Biomass burning aerosols should be expressed by heterogeneous particles as mixing of two kinds of species, interpreted by Maxwell-Garnett mixing rule.



f [%] : Volume fraction of inclusions against matrix

ex) matrix : $m=1.46 - 0.0002i$

inclusions: $m=1.61 - 0.022i$

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Standard aerosol products by SGLI

ARV : Aerosol products over ocean derived from VNIR measurements
AOT, Ang. Exp., Aerosol classification

ARU : Aerosol products over land by Near UV measurements
AOT, Absorbing information

ARP : Aerosol products over land by Polarization measurements
AOT, and Ang. Exp.

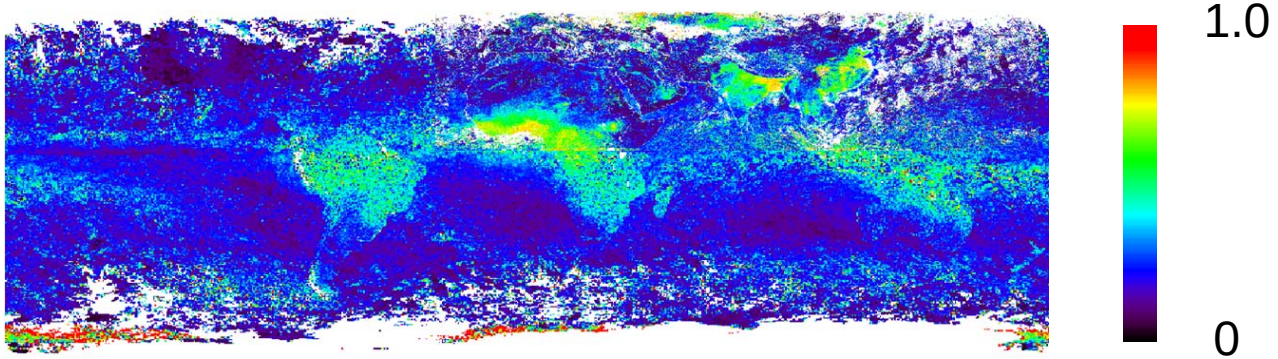
POLDER
2ch (red & NIR) polarization over land : AOT, and Ang. Exp.

2ch polarization algorithm for SGLI

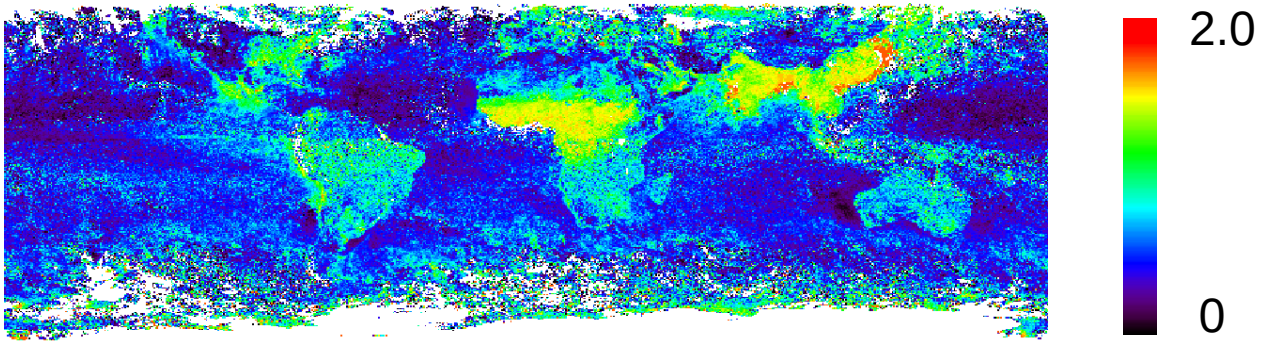
Courtesy of Dr. Hashiguchi (JAXA/EORC)

1 directional POLDER measurement
for SGLI simulation data

AOT @ 550 nm in Jan. 2009



Angstrom exponent in Jan. 2009

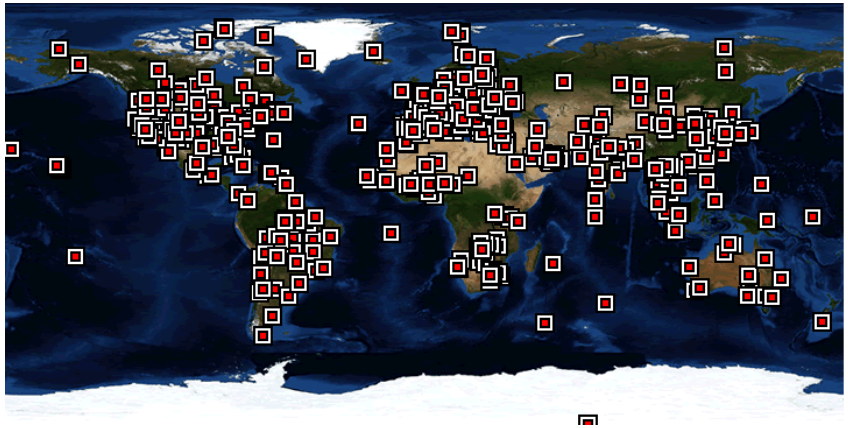


Comparison with AERONET

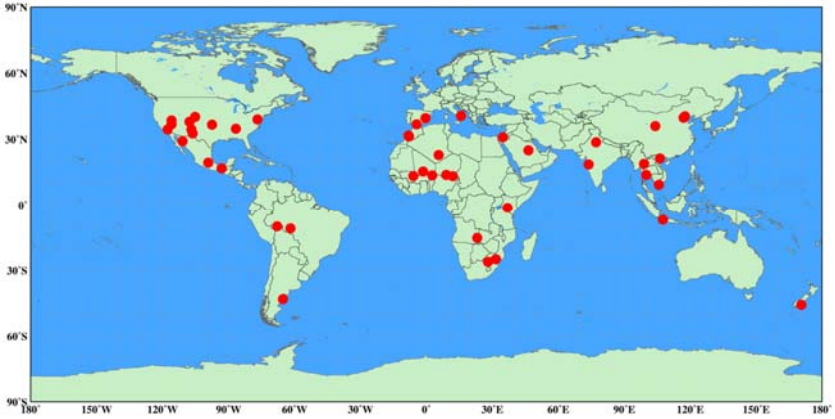
Courtesy of Dr. Hashiguchi (JAXA/EORC)

Dataset : AERONET　L 2 (cloud-screened and quality-assured)

1. The measurements are selected within the ±30 min satellite overpass.
2. The AOT of 0.443 and 0.870 μm as ground based measurements are selected for calculating Angstrom Exponent.
3. The AOT of 0.550 μm is estimated based on the Angstrom Exponent and the measurement of 0.670 μm.



AERONET sites in 2012

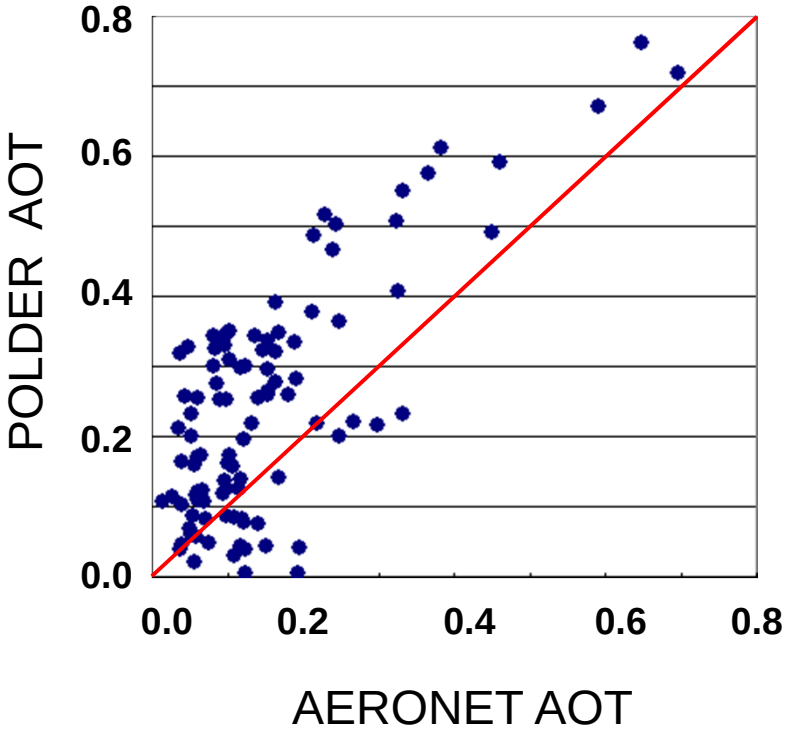


Match up AERONET sites

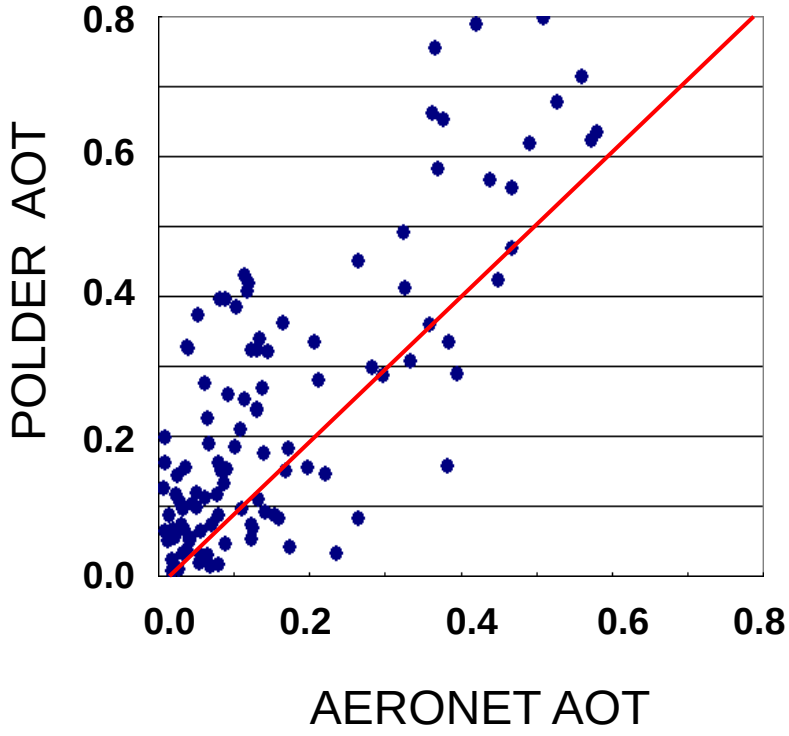
Comparison of retrieved AOT (0.55 µm)

Courtesy of Dr. Hashiguchi (JAXA/EORC)

ADEOS-2 / POLDER-2
April and May in 2003
(RMSE=0.14, Corr. C=0.76)



PARASOL / POLDER
January and July in 2009
(RMSE=0.15, Corr. C=0.76)



Retrieval algorithms

for aerosol parameters (τ_a, α, ω_0 , etc....)

POLDER

2ch (red & NIR) reflectance over ocean : AOT, and frac. of f/c mode

2ch (red & NIR) polarization over land : AOT, and frac. of f/c mode

CAI + PARASOL

1ch (NUV) nadir reflectance + 2ch (red & NIR) polarization

over land : AOT, frac. of f/c mode, & SSA

CAI + PARASOL

2ch (NUV, red) nadir reflectance + 2ch (red & NIR) polarization

over land : AOT, frac. of f/c mode, & complex ref idx

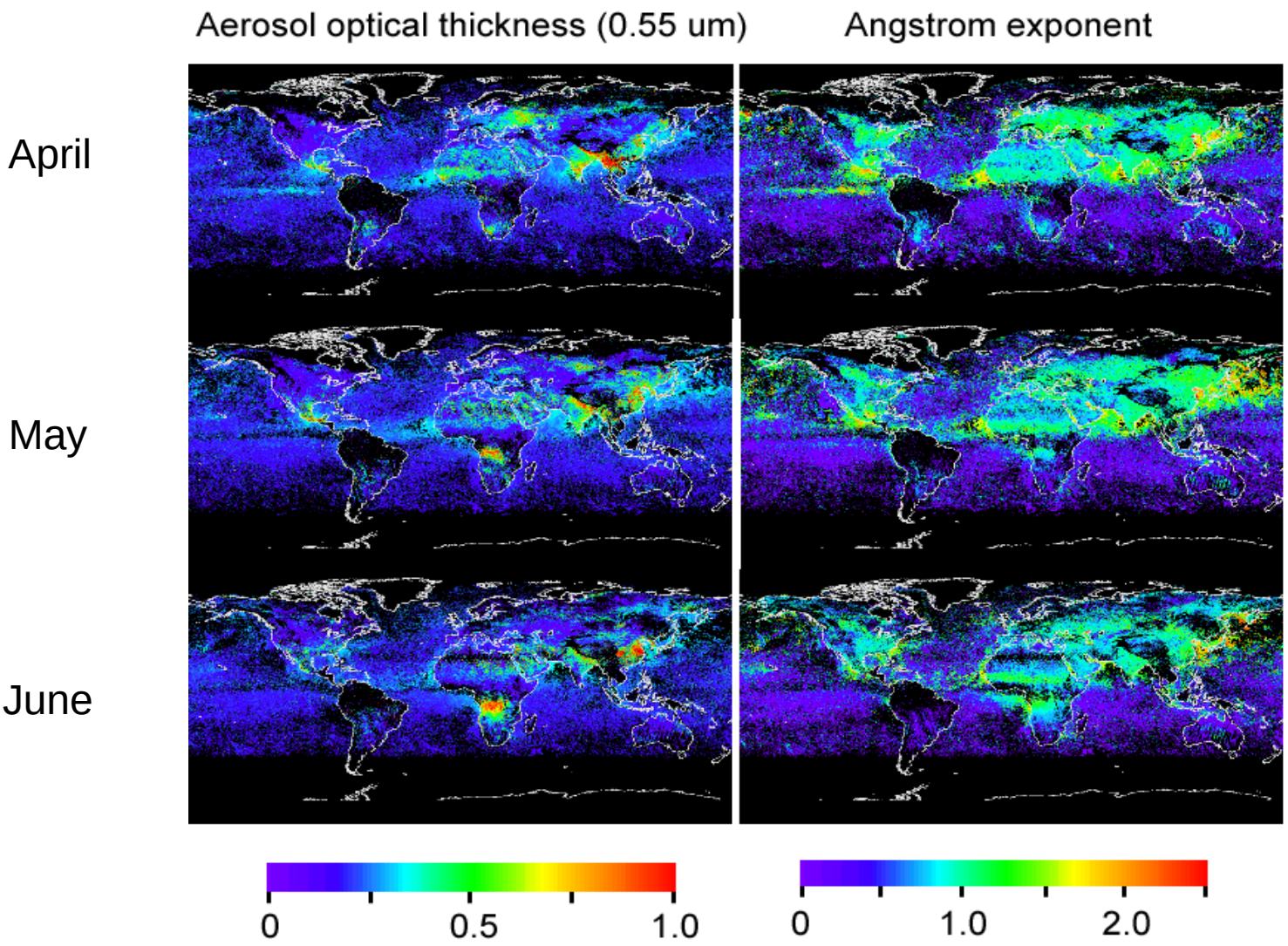
SGLI (future algorithm)

multi-channel, -temporal, -spatial radiance and polarization

over land : AOT, fraction of f/c mode, & averaged complex ref idx.

Retrieved results
AOT, fine and coarse mode fraction ->AE

April - June, 2009



Retrieval algorithms

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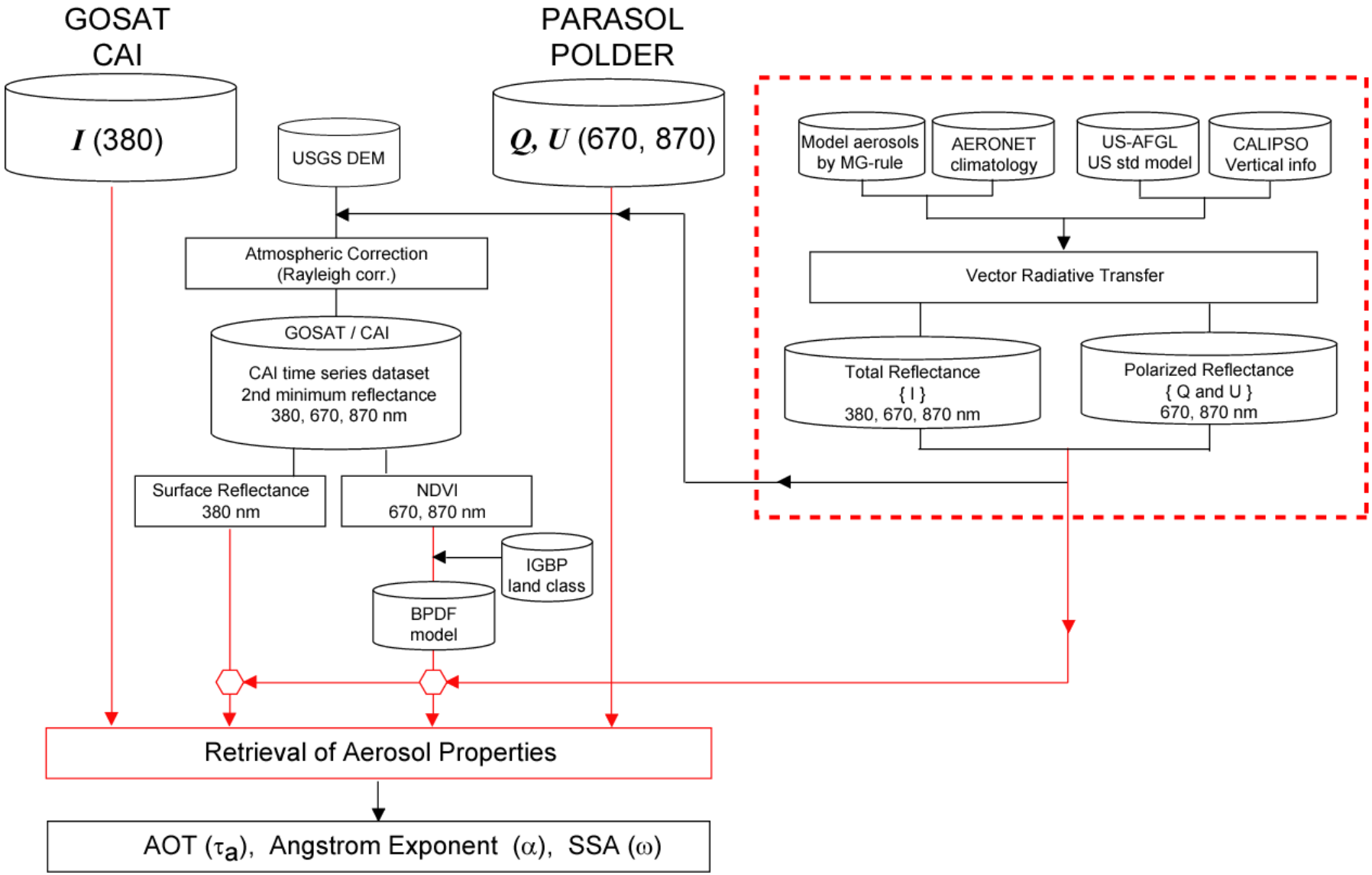
over land : AOT, frac. of f/c mode, & complex ref idx

SGLI (future algorithm)

multi-channel, -temporal, -spatial radiance and polarization

over land : AOT, fraction of f/c mode, & averaged complex ref idx.

Retrieval flow for biomass burning aerosols



Aerosol properties over Central Russia on August 5 and 8th, 2010

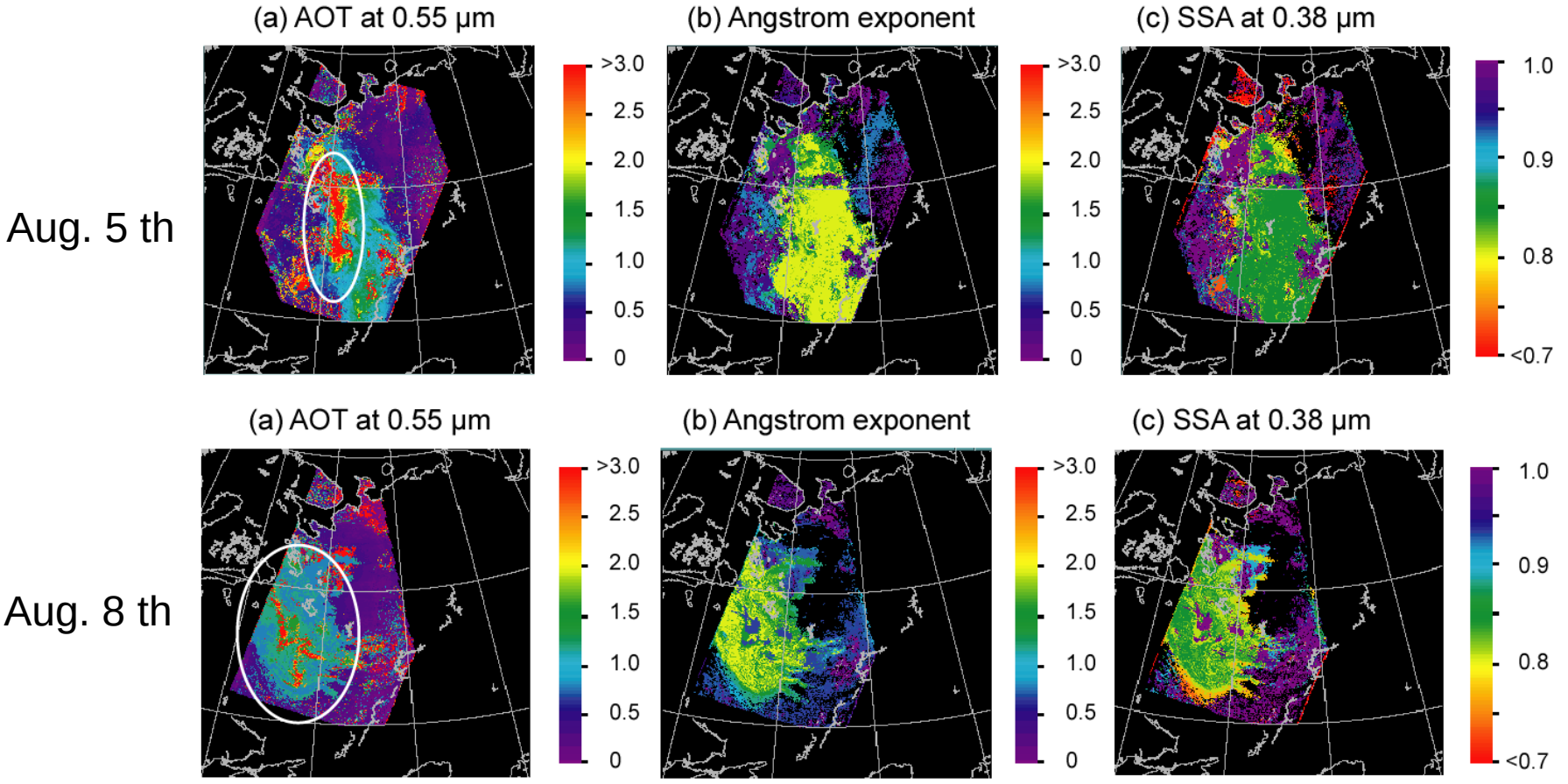
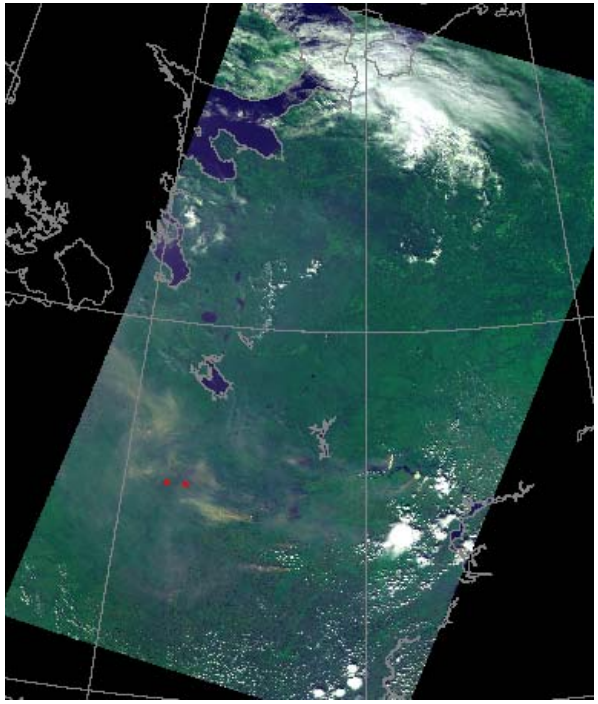
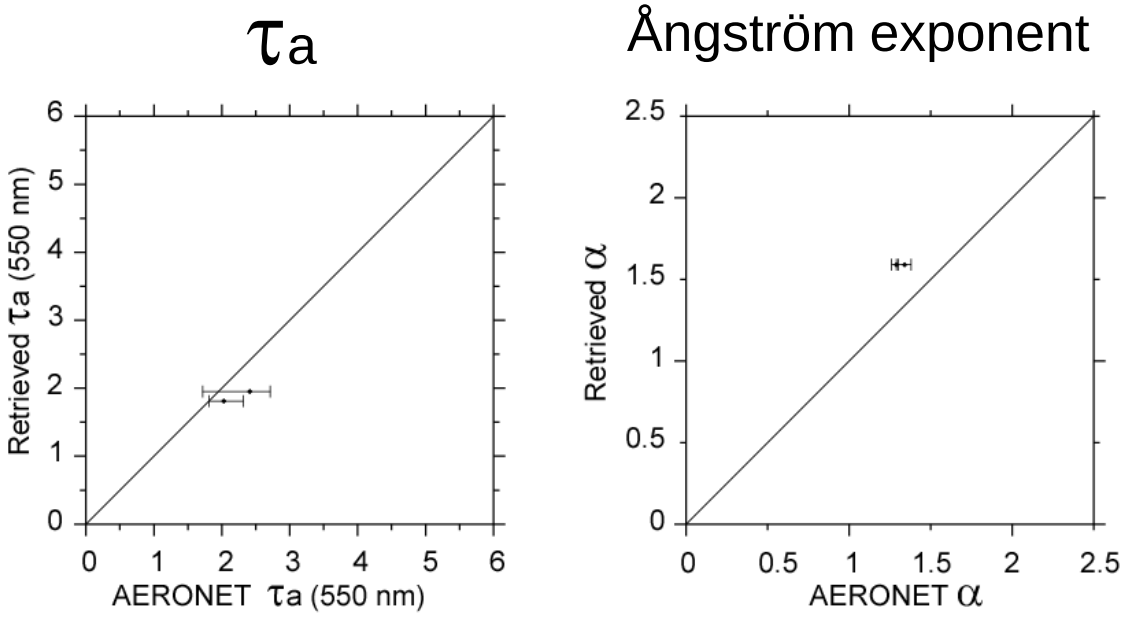


Figure Retrieved results of aerosol properties over Central Russia on August 5th (upper) and 8th (bottom), 2010. (a) AOT at 0.55 μm, (b) Angstrom exponent and (c) single scattering albedo at 0.38 μm.

Comparison of retrieved results

The AERONET AOT and Ångström data are selected during the ± 30 min against the satellite overpass.
Error bars : Min and max values of the measurements.





Scattergram of retrieved values τ_a, α against AERONET data.

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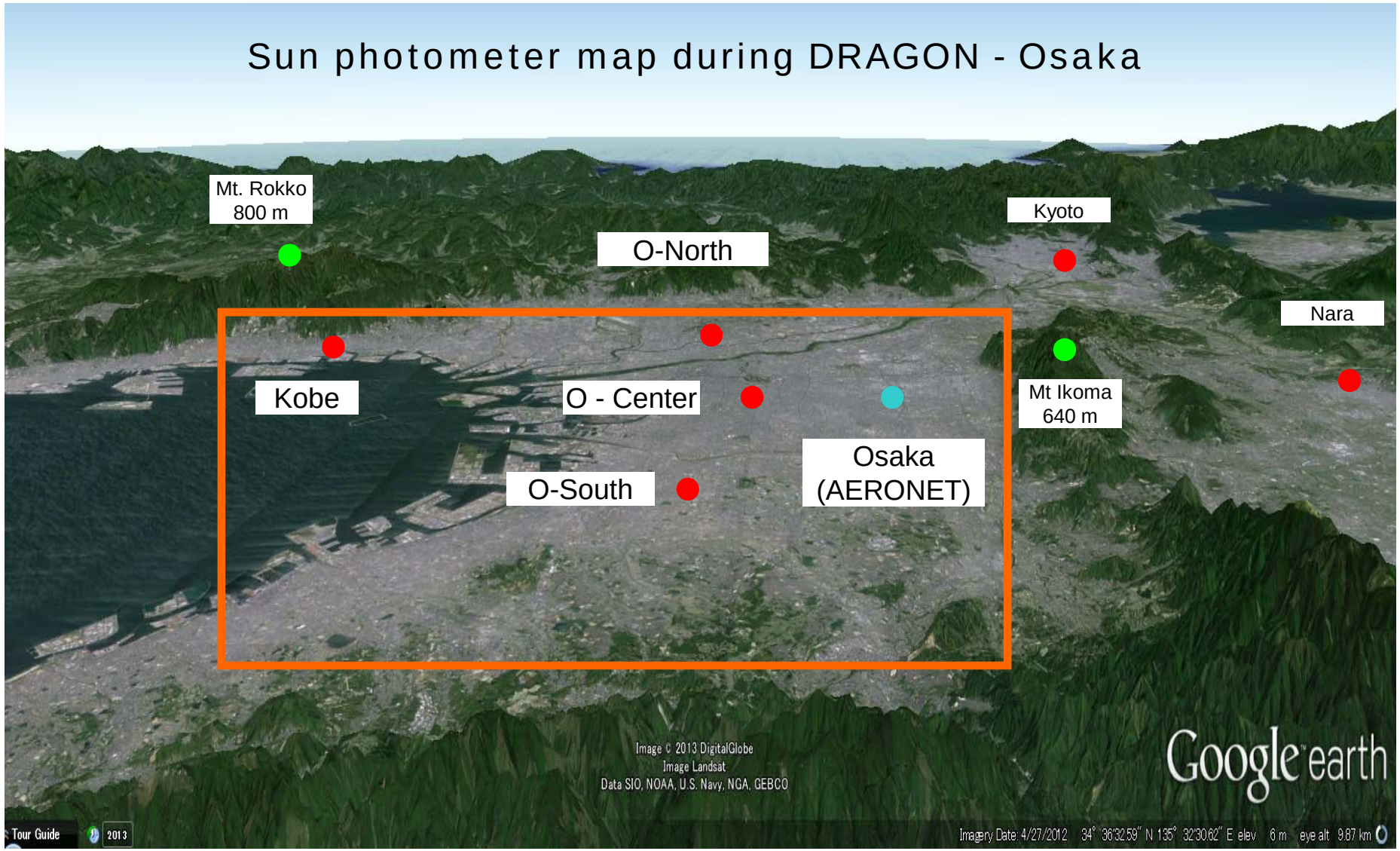
Application

- $PM_{2.5}$ retrieval

Target city : Osaka
Target period : March, April, and May (2012)



Estimation of surface reflectance and aerosol retrieval

AERONET Climatology

US-AFGL US std model

Vector R.T. calc

AERONET Osaka site τ_a, α

USGS DEM

Look up table

GOSAT / CAI time series TOA reflectance data 380, 670, 870 nm

Ref idx is fixed to m = 1.45 - 0.0001 i

Atmospheric Correction

Time series surface reflectance

Min ref. for 3 weeks from no clouds scene

Surface reflectance 380, 670, 870 nm

surface reflectance (380, 670, 870 nm)

USGS DEM

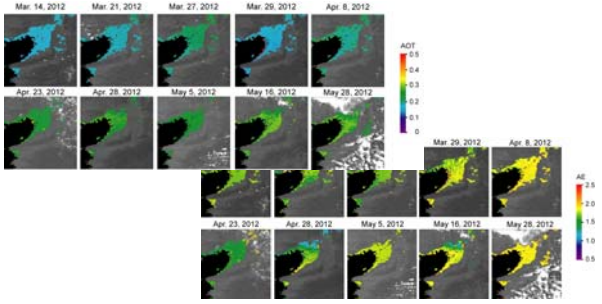
Look up table

GOSAT / CAI Level 1 (380, 670, 870 nm)

Aerosol Retrieval Col-AOT at 550, CMF, SSA

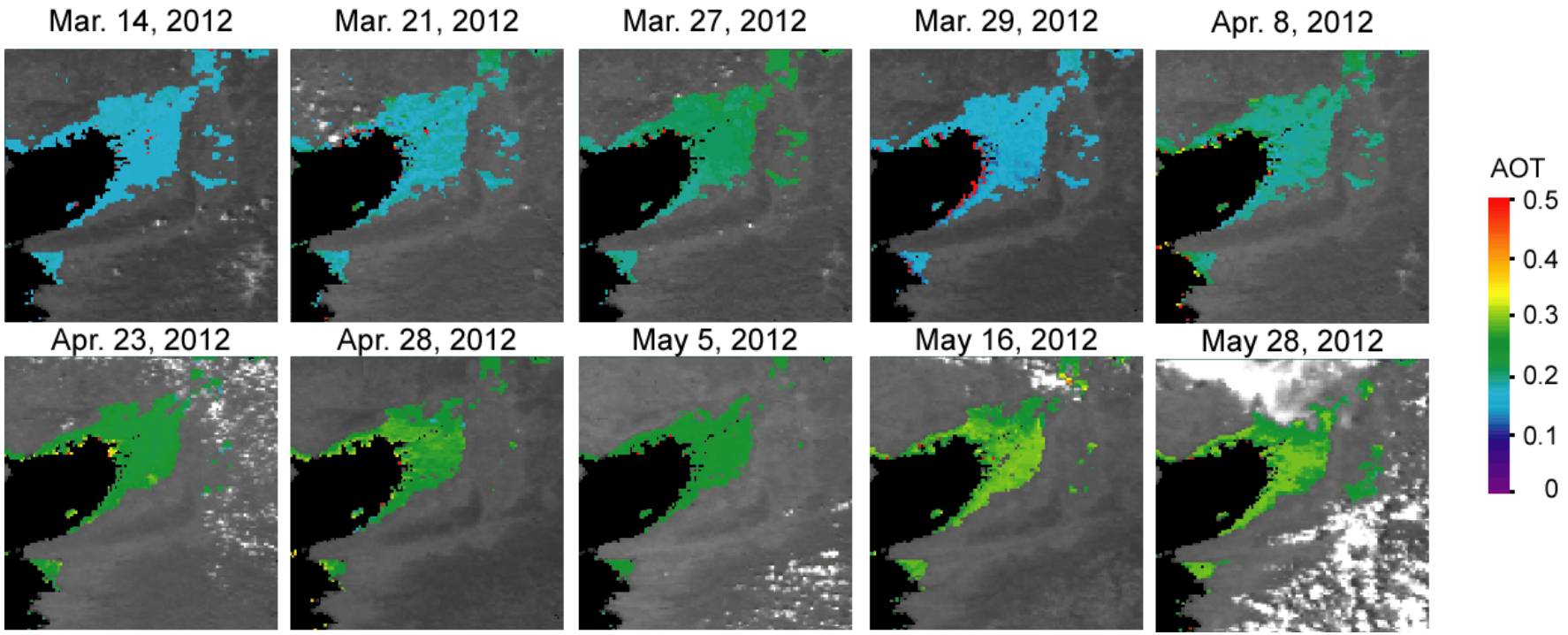
CMF : mixing ratio of coarse mode aerosol to fine and coarse mode

Col-AOT 380, 440, 670, 870 nm Ang. Exp, SSA



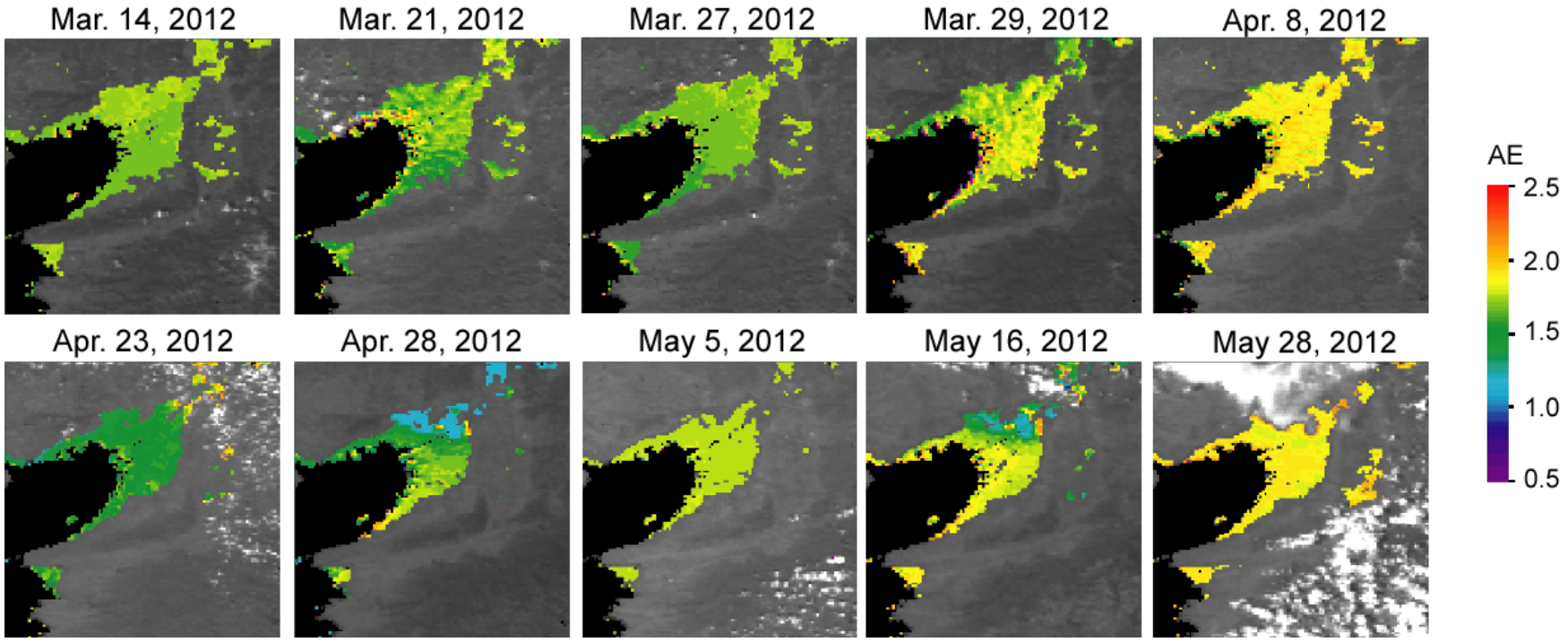
Aerosol properties over Osaka, Japan during DRAGON - Osaka

AOT (670 nm)

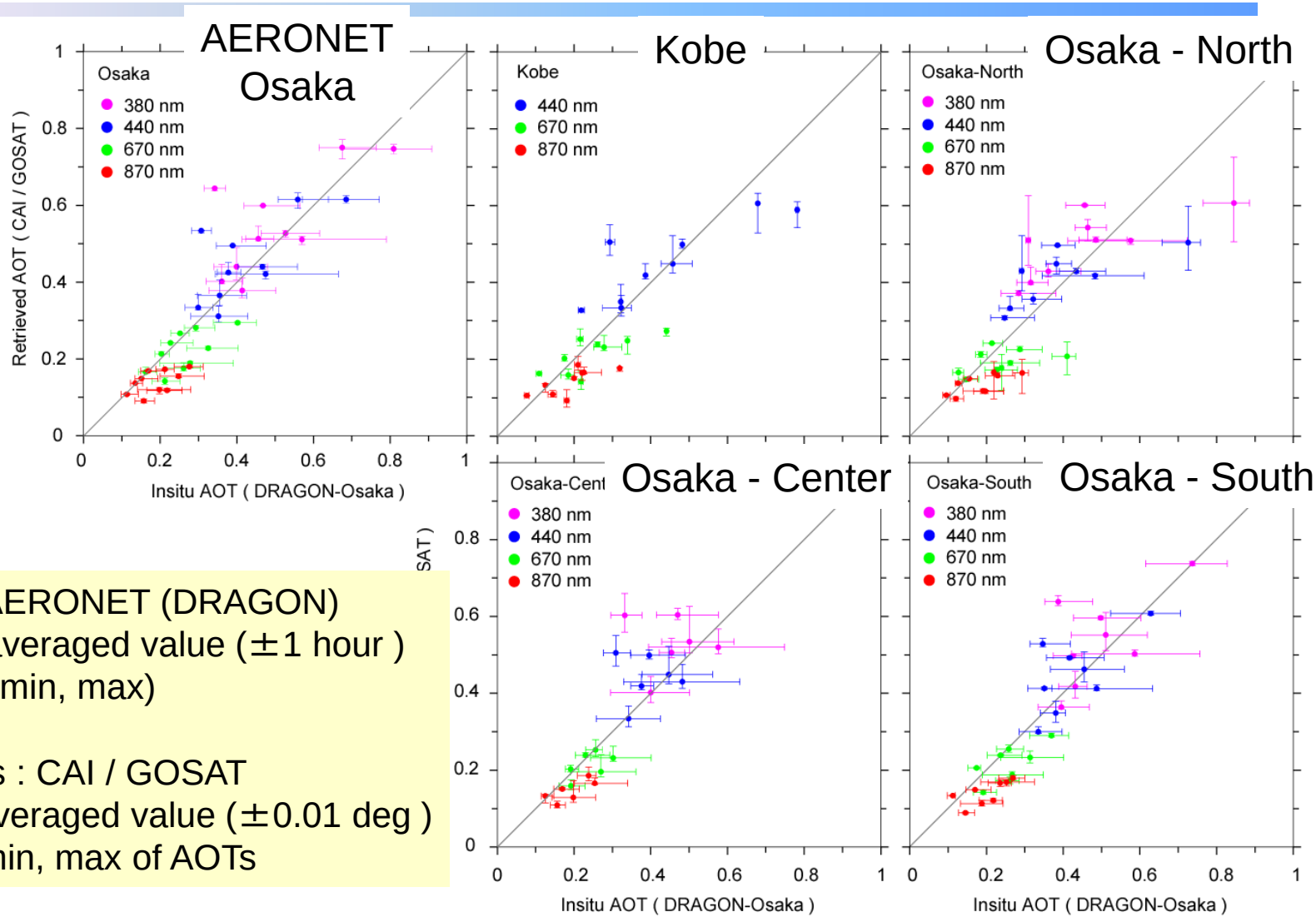


Aerosol properties over Osaka, Japan during DRAGON - Osaka

Angstrom exponent



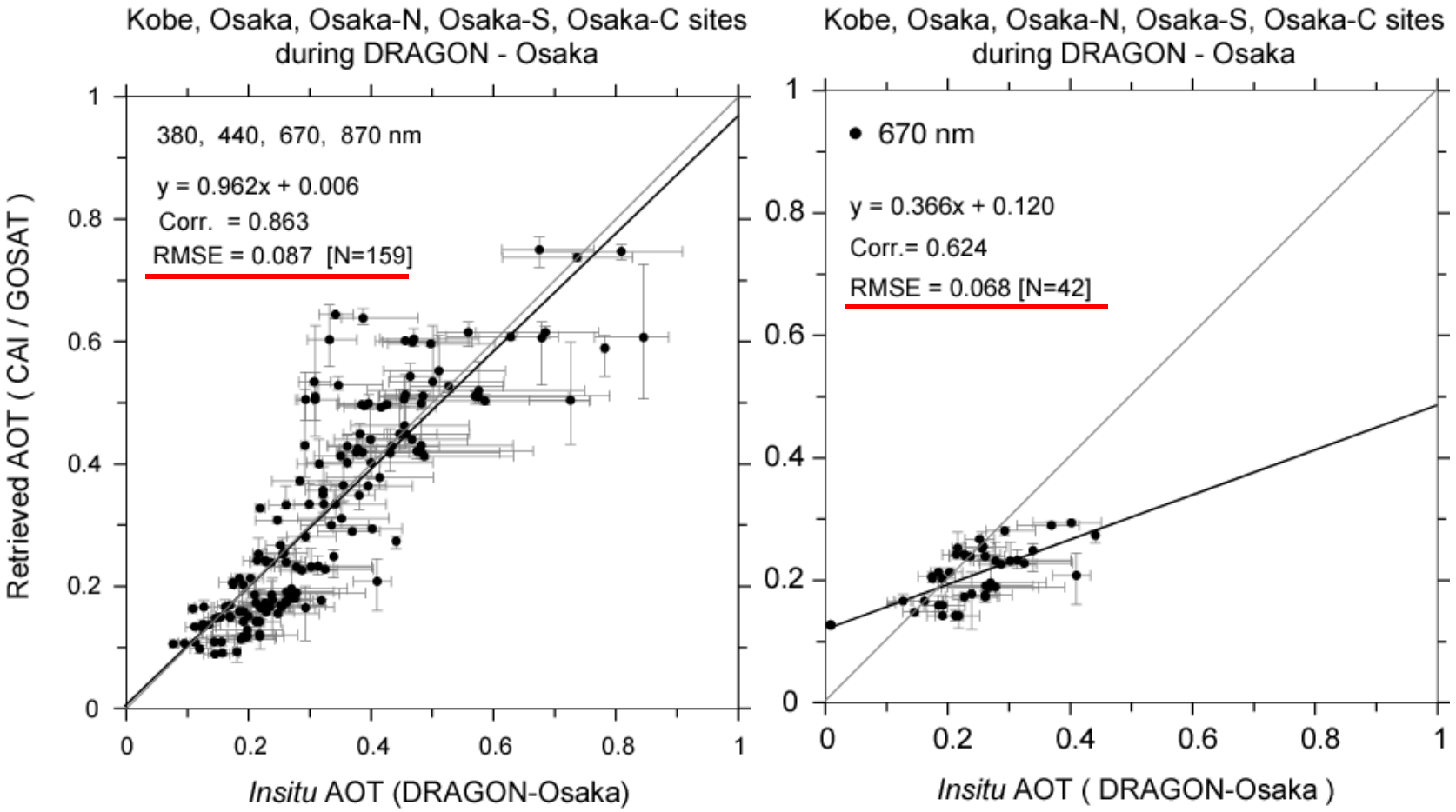
Comparison of retrieved AOTs with DRAGON-Osaka



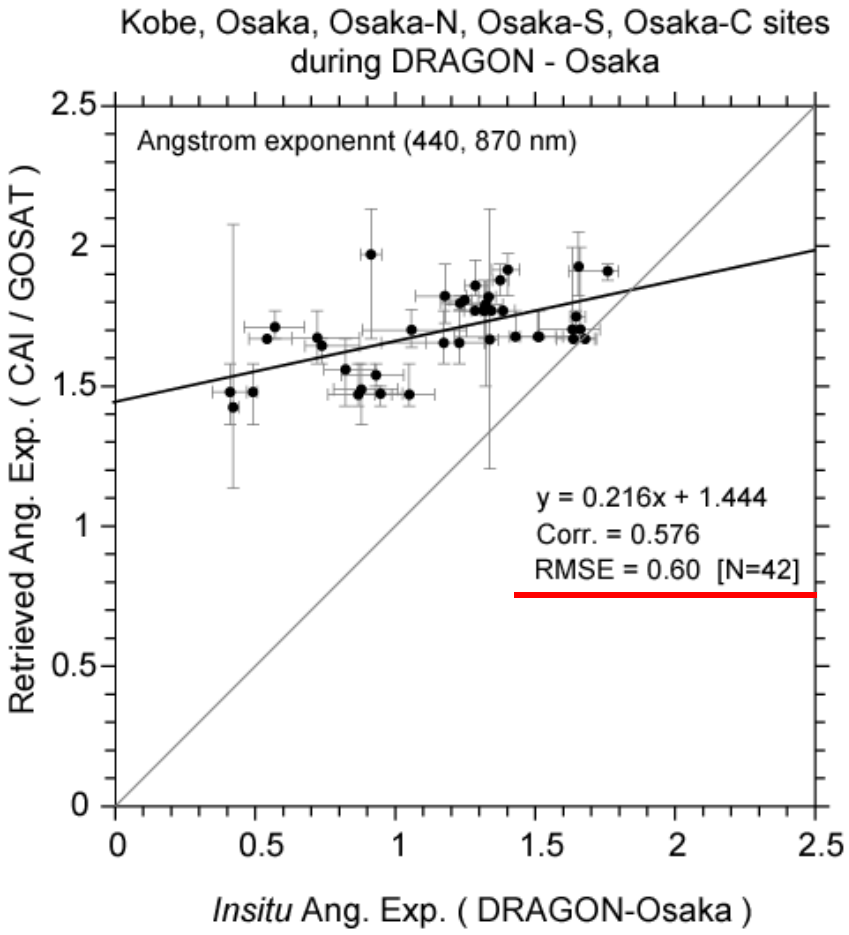
In situ AOTs : AERONET (DRAGON)
Dots : averaged value (±1 hour)
Error bars : (min, max)

Retrieved AOTs : CAI / GOSAT
Dots : averaged value (±0.01 deg)
Error bars: min, max of AOTs

Comparison of retrieved AOTs with DRAGON-Osaka

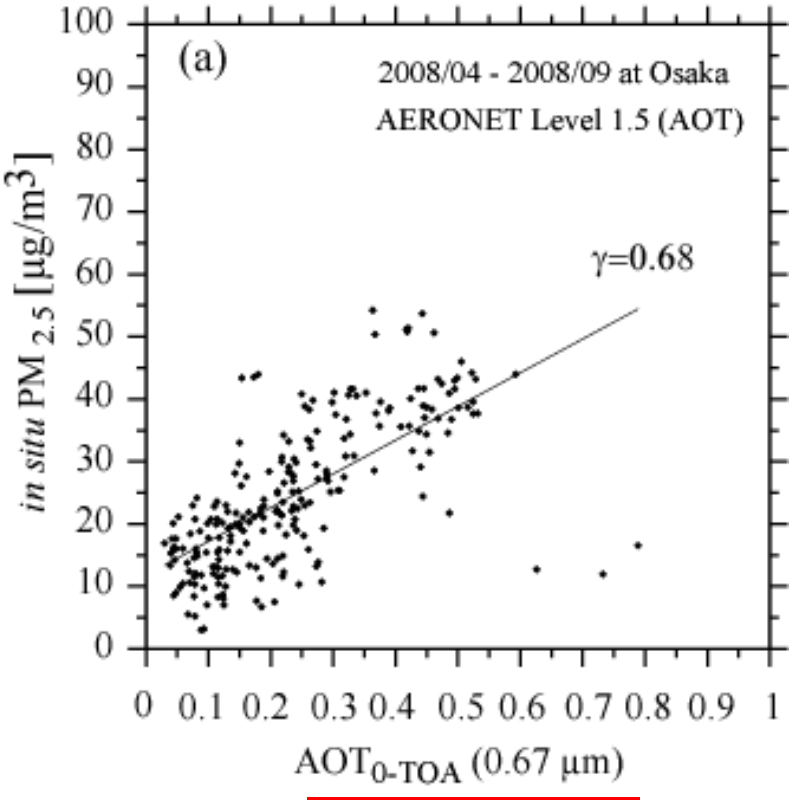


Comparison of retrieved AE with DRAGON-Osaka

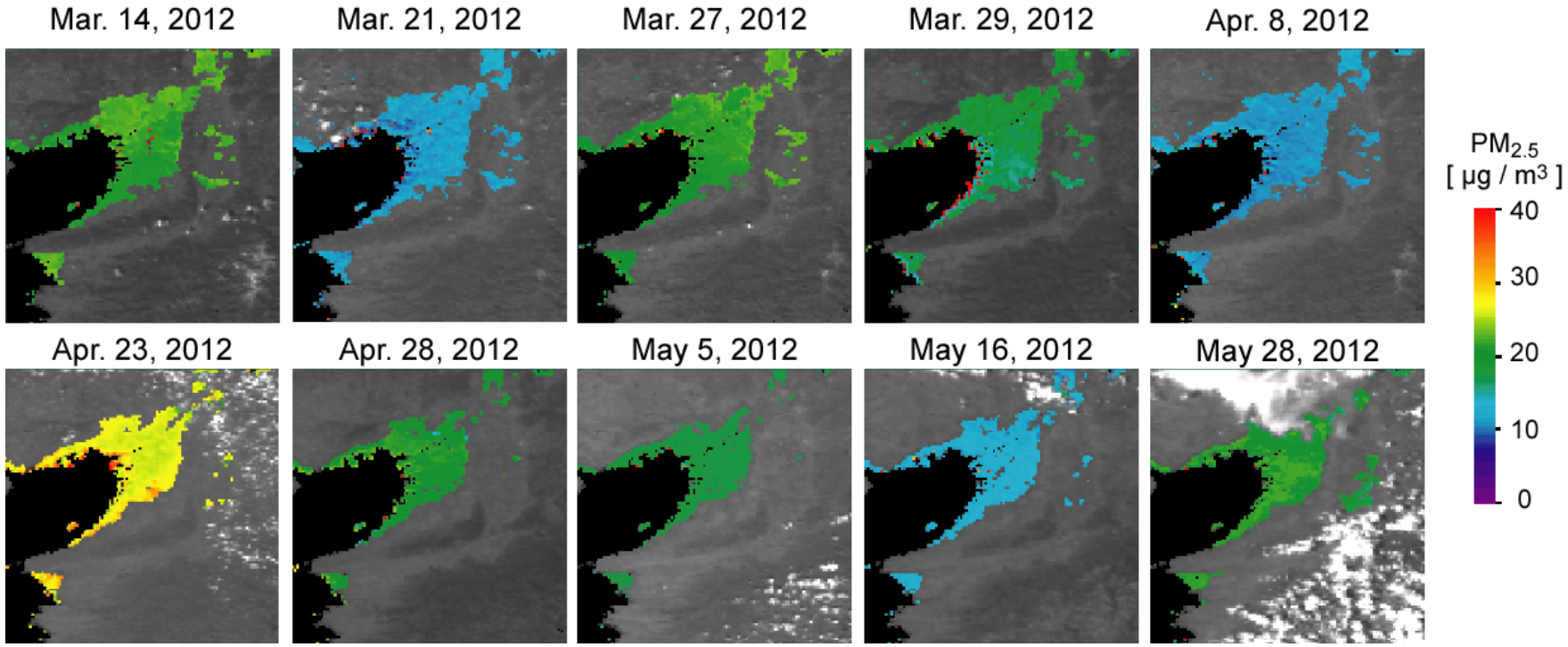


Relationship between $PM_{2.5}$ and columnar AOT (670 nm)

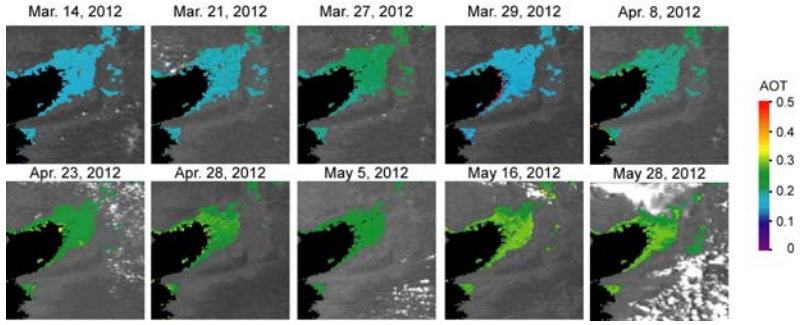
Columnar AOT



Satellite estimated $PM_{2.5}$ concentration during DRAGON - Osaka



AOT 670 nm

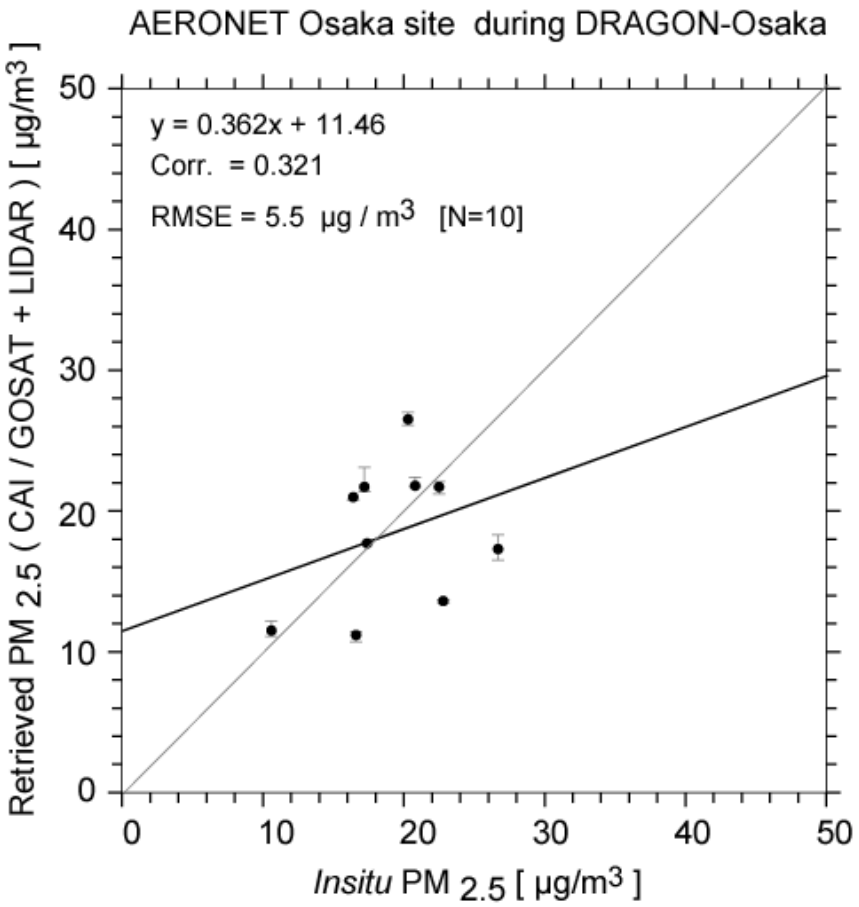


Comparison with *in situ* $PM_{2.5}$ data

$PM_{2.5}$ Instrument

SPM-712 (Kimoto Elec. Co., Japan)

- 1 hour meas.
- Beta ray gauge method
- Teflon tape role
- RH correction



Summary

Aerosol model

Comparison of AERONET results with dust particle analysis by shows good agreement.

Aerosol retrieval

New look up table (bi-modal size dist) provides AOT, CMF (coarse mode fraction) of bi-modal size dist.

Ver-0 code is also updated available for new LUT.

The 3ch-method is demonstrated with POLDER and CAI measurements to estimate AOT, CMF, SSA.

Application ($PM_{2.5}$)

$PM_{2.5}$ distribution is estimated from AOT 670 combined with LIDAR data over Osaka. The RMSE is ~5.5 μg/m^3.