Aerosol type classification using Depolarization Ratio derived by AERONET sun/sky radiometer data

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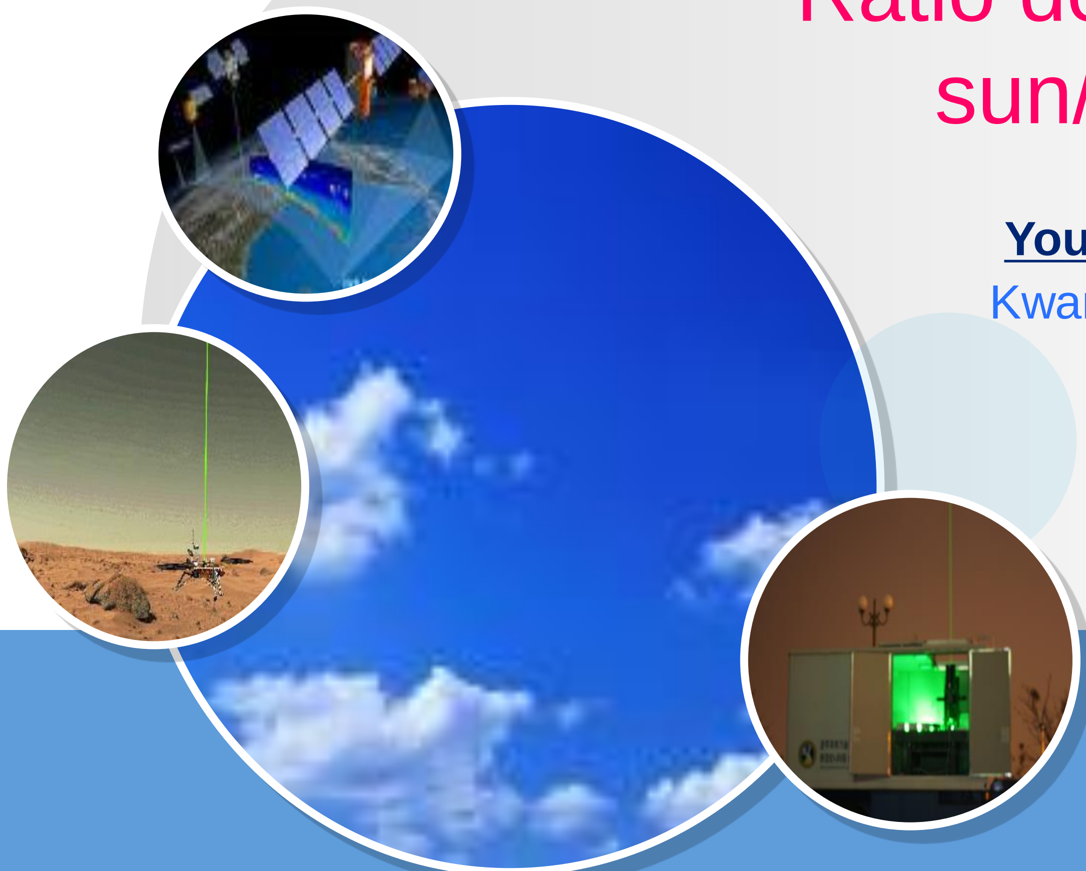

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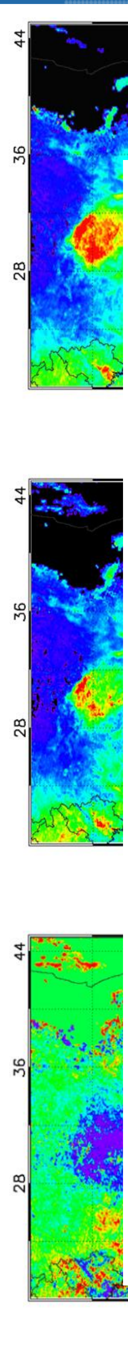
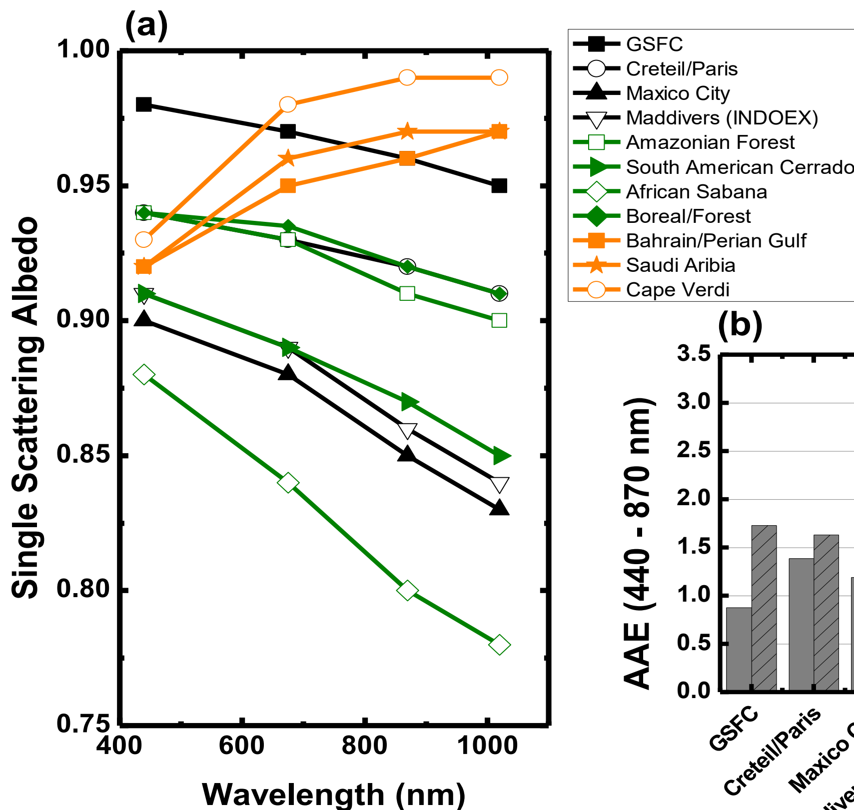
Gwangju Institute of Science & Technology

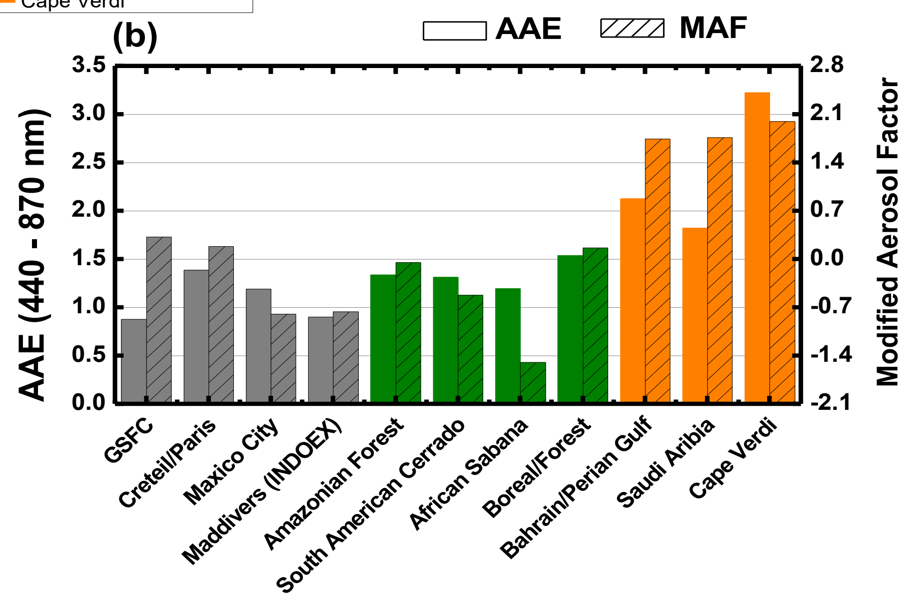
Contents

1. Introduction
2. Utilization of Depolarization ratio (DPR)
3. AERONET sunphotometer DPR
4. Aerosol Classification by DPR
5. Summary



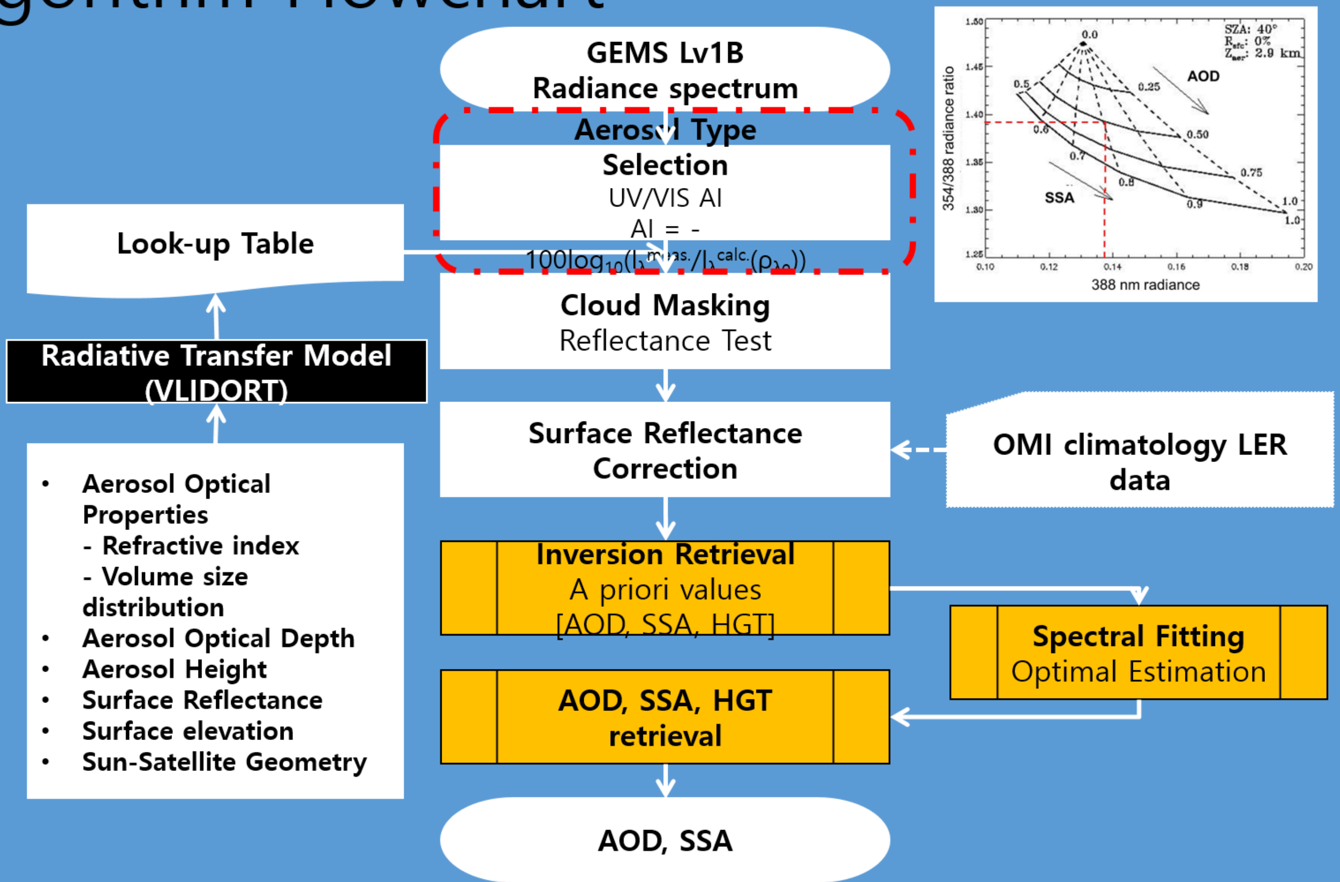


Different physical and optical properties between Dust and other particles



AOD & SSA retrieval from SATELLITE Data

Algorithm Flowchart



Aerosol type selection is very important

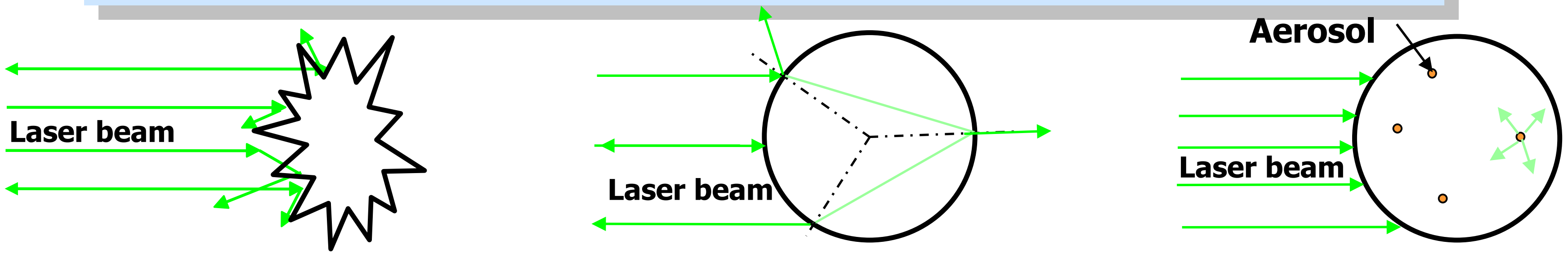
Depolarization Ratio

1. Depolarization ratio, definition : $\delta = I_{\perp} / (I_{//} + I_{\perp})$,

   Initial beam : $I_{//}$ (100 %)

2. The variation parameter of Aerosol Depolarization Ratio(DPR)

   : Shape, Size, Moist, etc



Type **1: Nonspherical particle**
Asian dust : 0.3 ~ 0.35
Saharan dust 0.31
Mixed dust : 0.08~0.2 (Externally)
Cirrus cloud : 0.4
Sea salt : 0.02

Type **2 : Ideal spherical particle**

DPR = 0

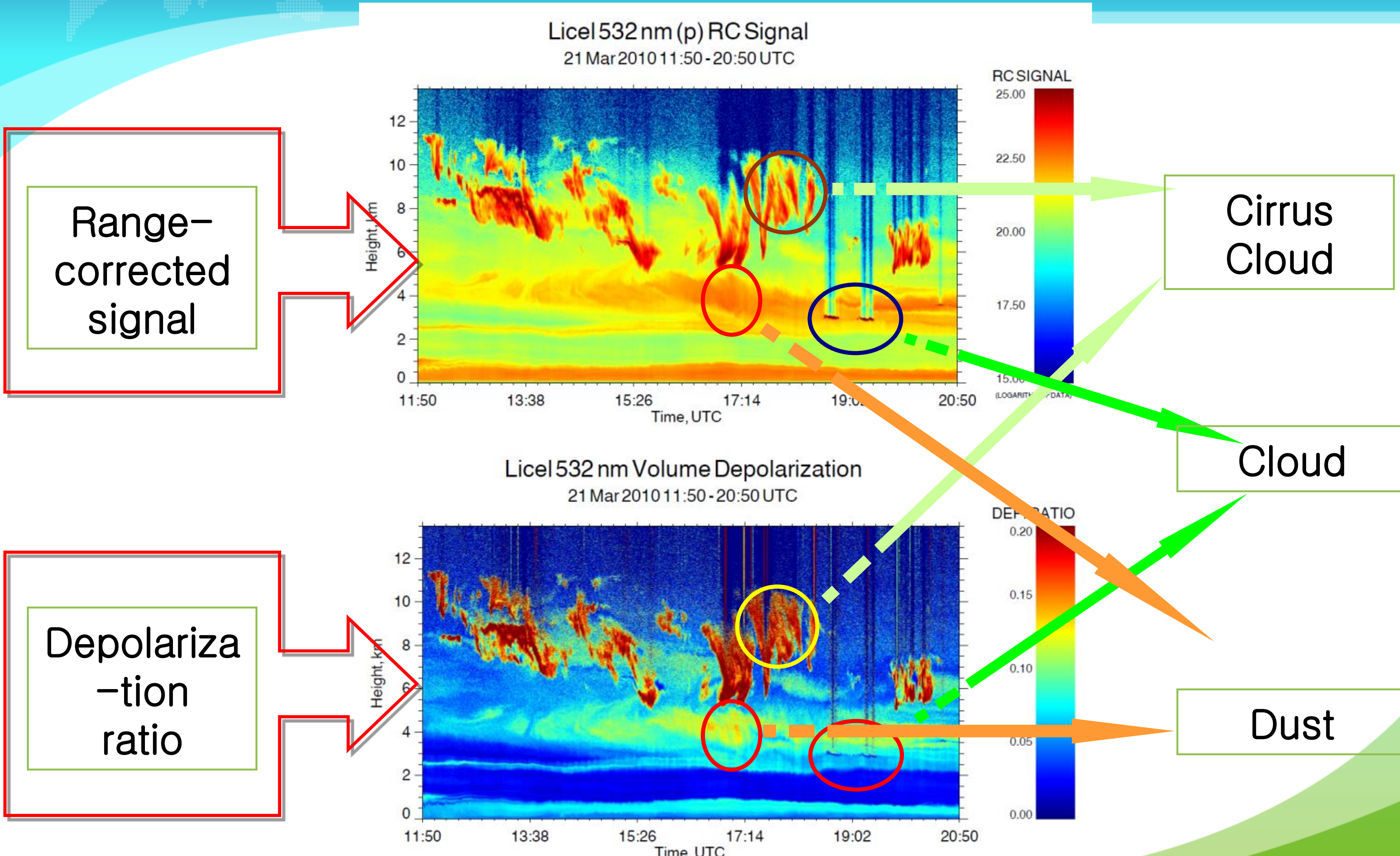
Sulphate : 0.04

Type 3: Internally mixed aerosol
Hygroscopic aerosol

- DPR depends on the internal structure

Aerosol Type Classification

Aerosol Type Classification by DPR



Value differences by mixing between dust and pollution

Optical properties of aerosol

Pure dust — Mixed dust — Pollutant

Depolarization ratio (DPR)

Non-spherical particle → Spherical particles

0.35 | 0.3 | 0.2 | 0.08 | 0.02

[Saharan dust :Feudenthaler et al., 2009]
[Asian dust : Iwasaka et al., 2003; Yi et al., 2014]

[Polluted dust : Shimizu et al., 2004;
Chen et al., 2009]

[Crystallized sulphate :
Sassen et al., 1989;
Cooper et al., 1974]

0.33 ← GIST measurements → 0.08

Lidar ratio (LR)

Low light absorption → High light absorption

30 | 50 | 60 | 80

[Saharan dust : De Tomasi et al., 2003][Saharan dust : Mueller et al., 2007]
[Asian dust : Murayama et al., 2004]

38 ← GIST measurements → 83

Ångström exponent (Å)

Larger particle → Smaller particle

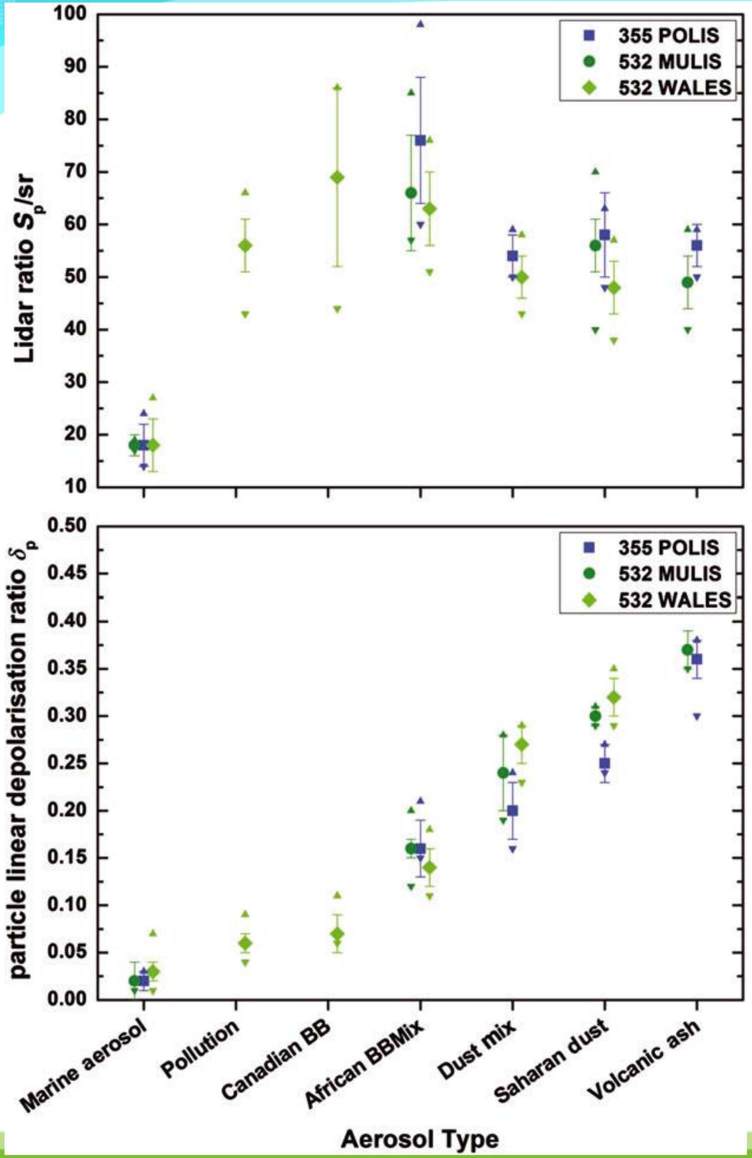
0 | 2

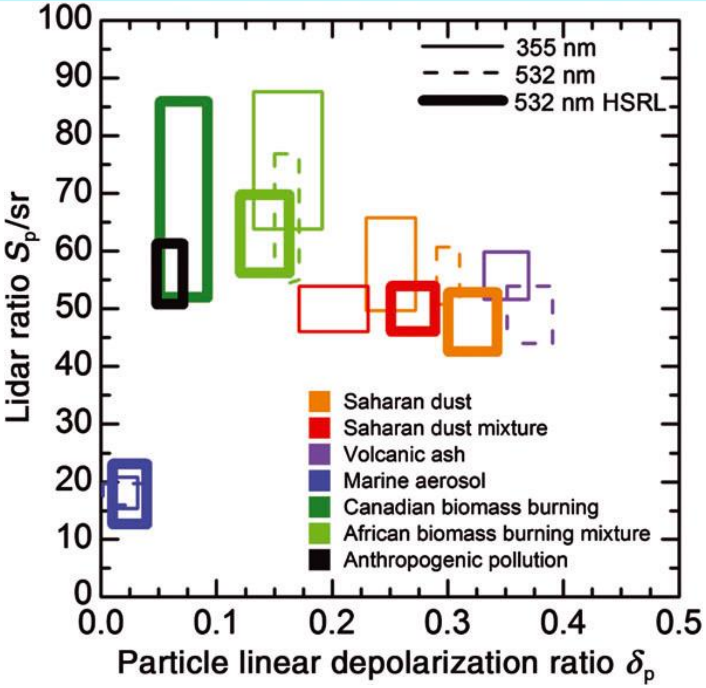
[Saharan dust : Eck et al., 1999
Asian dust : Sakai et al., 2002; Chen al., 2007]

[Fine mode, accumulation mode particle
: Eck et al., 1999]

0.38 ← GIST measurements → 1.71

AEROSOL Type Classification by DPR & LIDAR ratio





Five main Aerosol types

: Mineral dust, mineral dust mixtures, Marine aerosols, biomass burning mixtures and volcanic ash

[Groβ et al. (2015, Atmospheric Science Letters)]

Retrieval of Particle Depolarization Ratio

LIDAR

$$\delta(z) = \frac{S(z)}{P(z) + S(z)}$$

δ : Volume depolarization ratio
P : Initial laser beam
S : Depolarized laser beam

$$\delta_p(z) = \frac{\delta(z)R(z) - \delta_m(z)}{R(z) - 1}$$

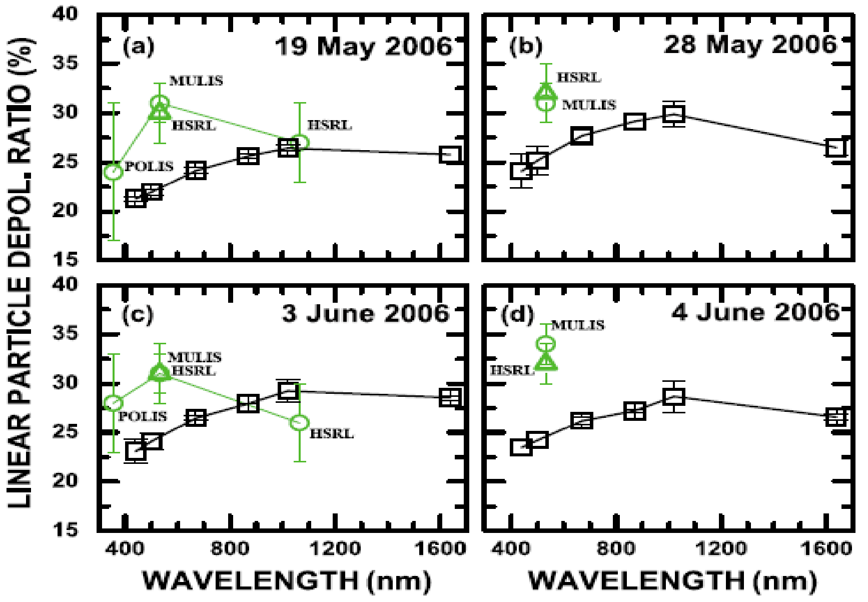
δ_P : Particle depolarization ratio
$R(z)$: Scattering ratio
δ_m : Depolarization ratio for air (0.014)

Sunphotometer

$$\delta_p(\lambda) = \frac{1 - F_{22}(\lambda,180°)/F_{11}(\lambda,180°)}{1 + F_{22}(\lambda,180°)/F_{11}(\lambda,180°)} \times 100(\%)$$

(Dubovik., 2006: JGR)

F11 and F22 (Müller scattering matrices) :
computed from the retrieved complex refractive indices and particle size distributions



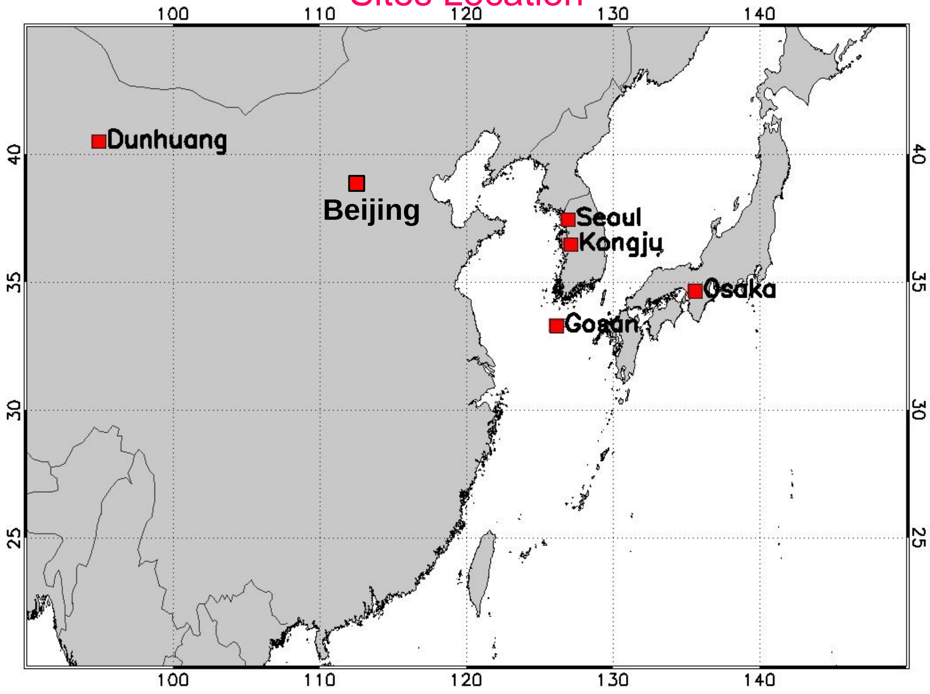
(Müller et al., 2012: JGR)

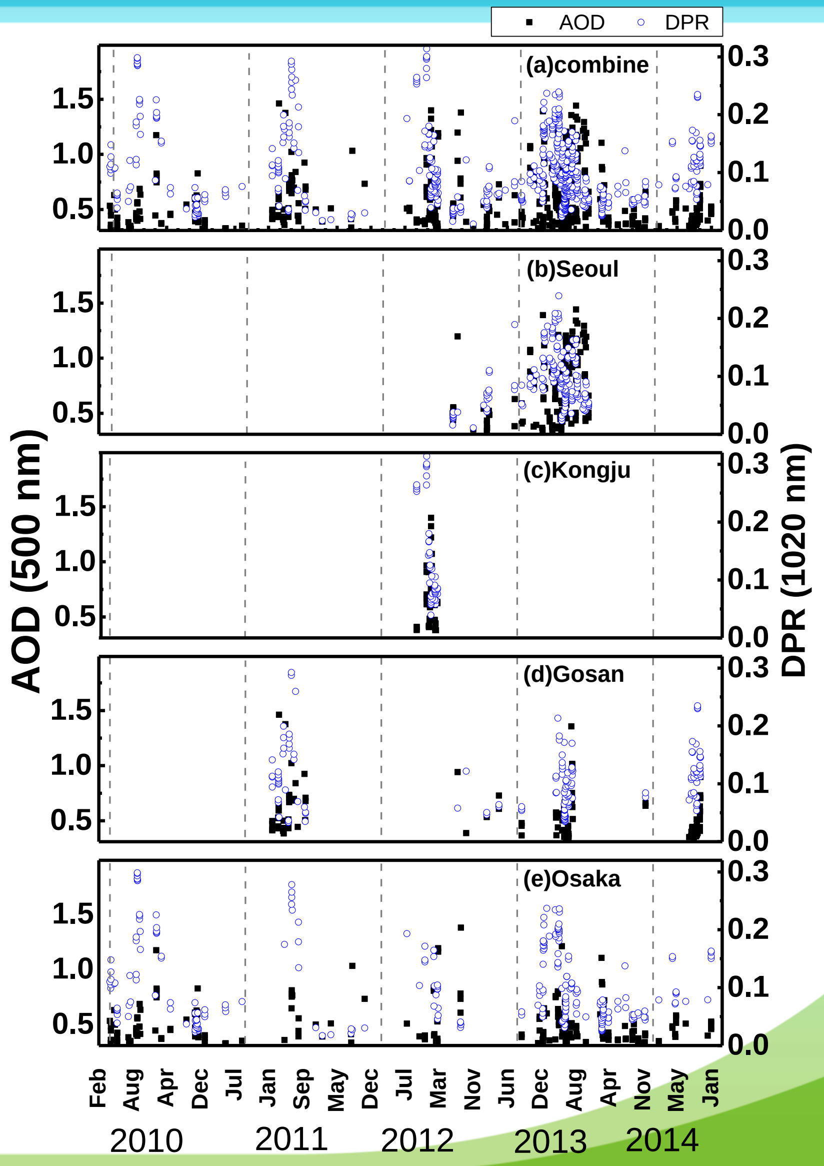
Depolarization comparison : Lidar & Sunphotometer

Analyzed Data: Observed at the same site and same time (2010 – 2014), Total 577 cases

- **Seoul (160 cases), Kongju (44 cases), Gosan (139 cases), Osaka (234 cases)**
- **Dunhuang (12 cases, only Sunphotometer data, Pure dust cases)**

Sites Location





Depolarization comparison : Lidar & Sunphotometer

LIDAR Depolarization Ratio (Vertical resolved data) ⟶ Column-integrated value

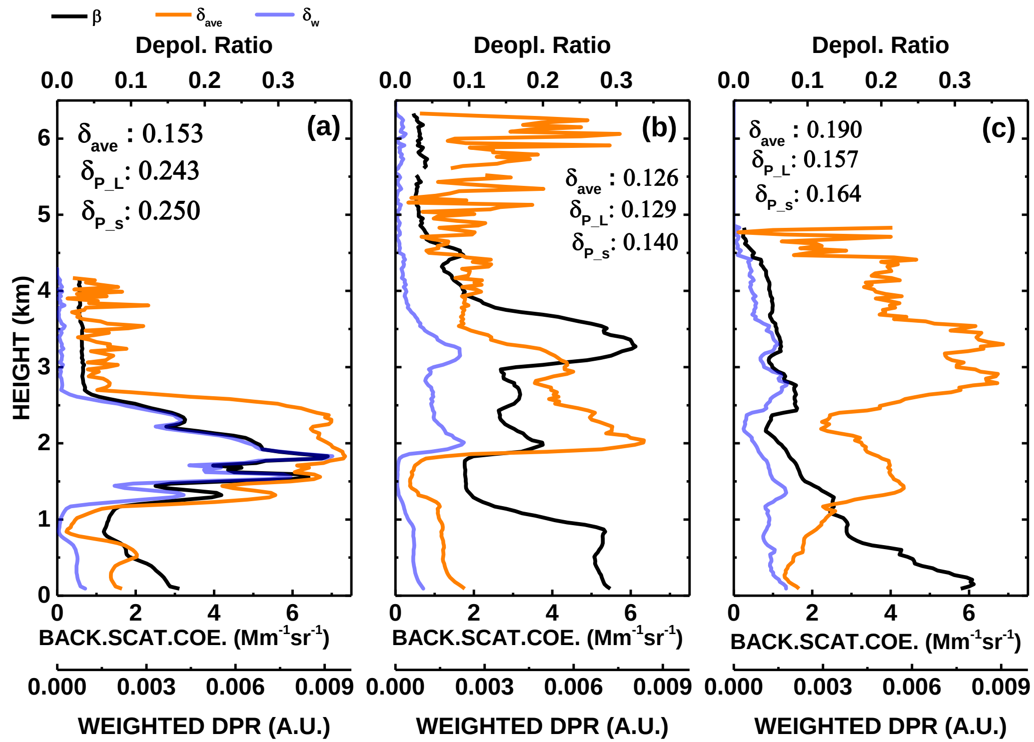
Column-integrated DPR (δ_{P_L})

$$\delta_{P\_L} = \int_0^z \delta_P(z)W(z)dz$$

$W(z)$: **Weight factor**

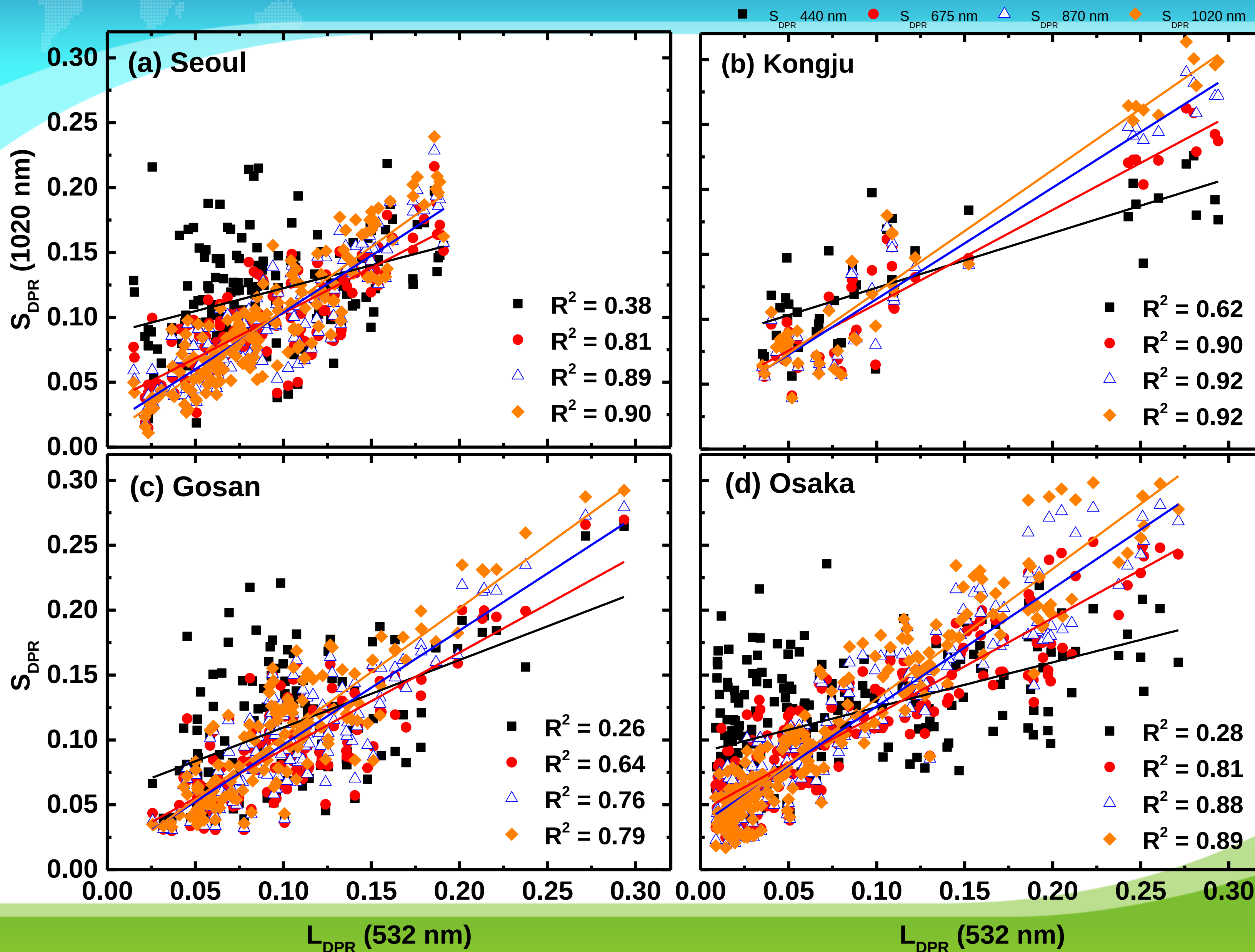
$$W(z) = \frac{\beta_a(z)}{\int_0^z \beta_a(z)dz}$$

β_a: **aerosol backscatter coefficient (LIDAR data)**



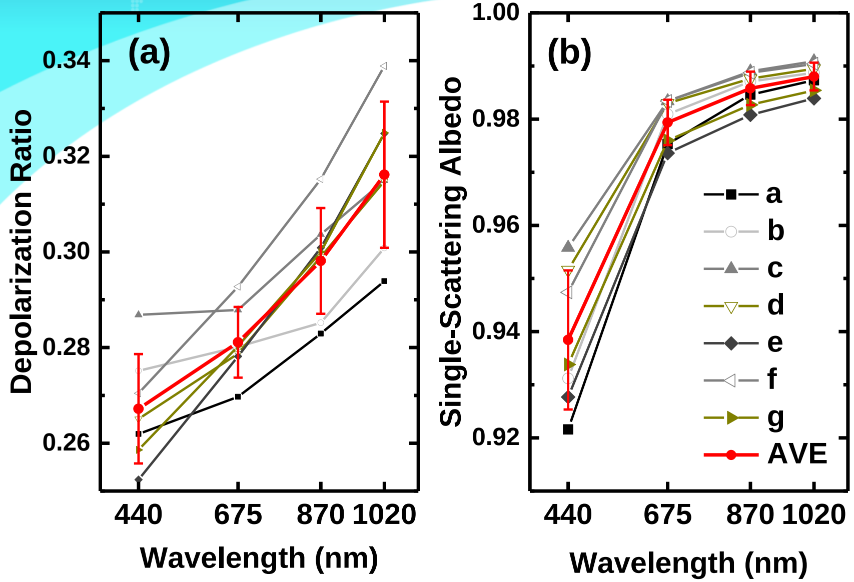
- Case I : High value of δ and high value of β
- Case II : Two aerosol layers, high value of only at above layer
- Case III : low value of β and high value of δ

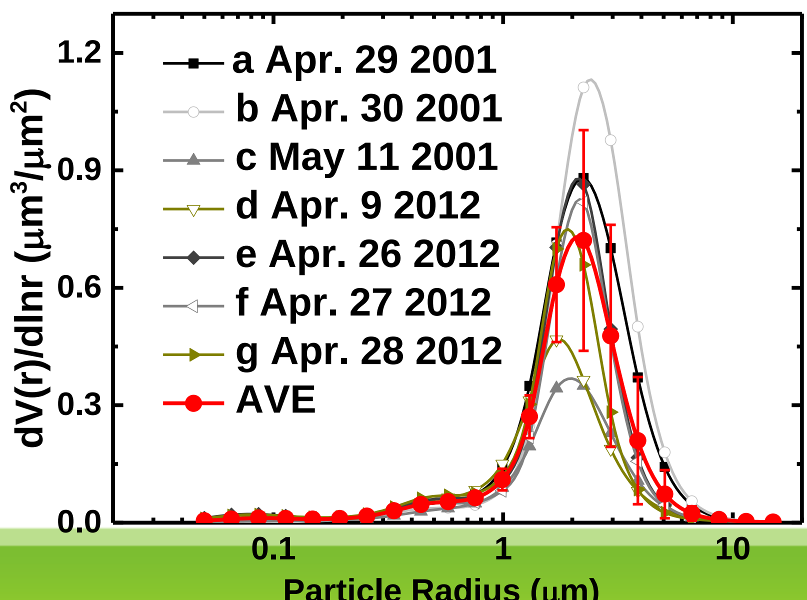
Depolarization comparison : Lidar & Sunphotometer



[Noh et al., 2017 (ACP)]

Dunhuang (Dust Source region) Data (2001, 2012)





- 7 cases of Pure dust particles are selected
- Ave. value of DPR at 1020 nm : 0.32 ± 0.02

$$R = \frac{(\delta_a - \delta_2)(1+\delta_1)}{(\delta_1 - \delta_2)(1+\delta_a)}$$

R : Dust ratio (0 ~ 1)
δ_1 : 0.32, assumed value for pure dust
δ_2 : 0.02, pure pollution
→ Empirical data by long-term lidar measurements

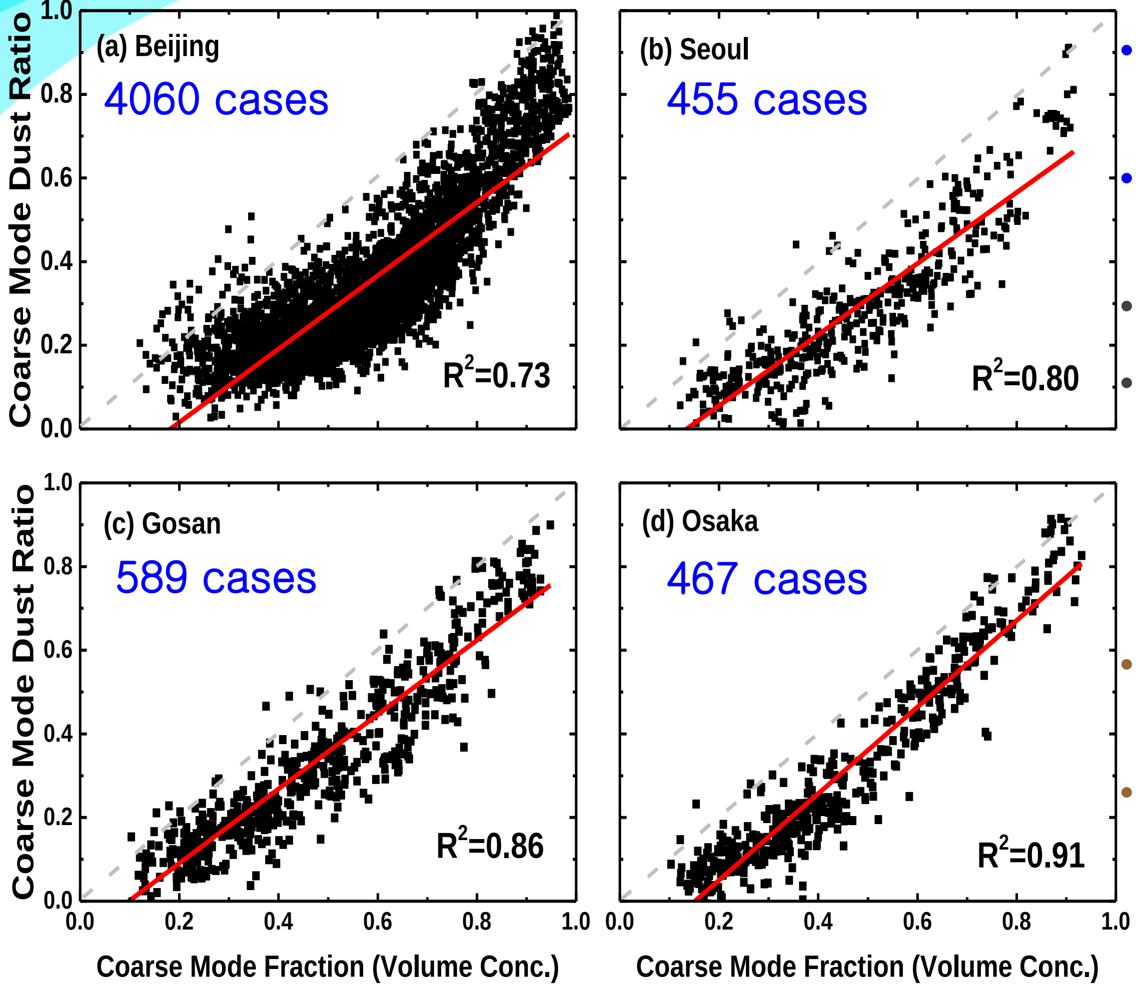
[Shimizu et al. (2004), Tesche et al. (2009), Noh et al. (2014)]

Dunhuang Average value

- Dust ratio : 0.98 ± 0.03
- Coarse-mode fraction by volume concentration : 0.95 ± 0.02

Comparison between Dust ratio and Coarse-mode fraction

Total 5561 cases

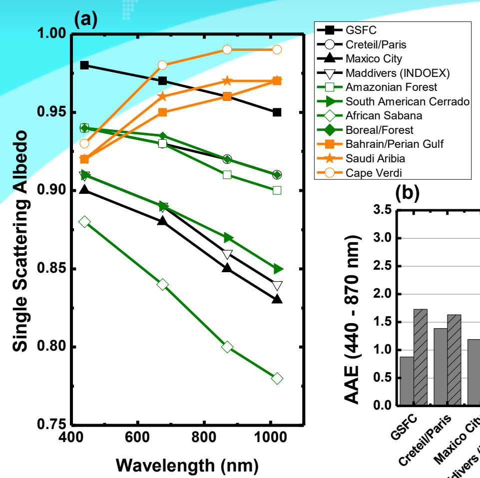


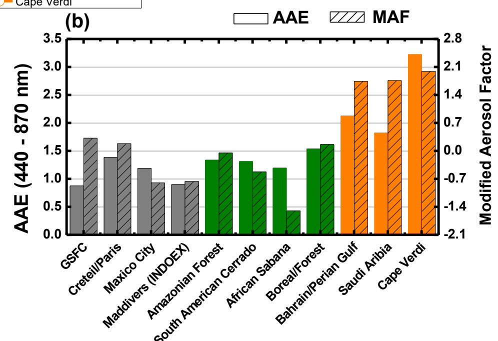
Year 2001 ~ 2016

- **Dust ratio (R_D) : the ratio of dust particle to pollution particles**
- **Coarse-mode fraction (CMF) : only related to particle size**
- **CMF is higher 10 – 20 % than R_D**
- **CMF and R_D show similar value at Dunhuang**

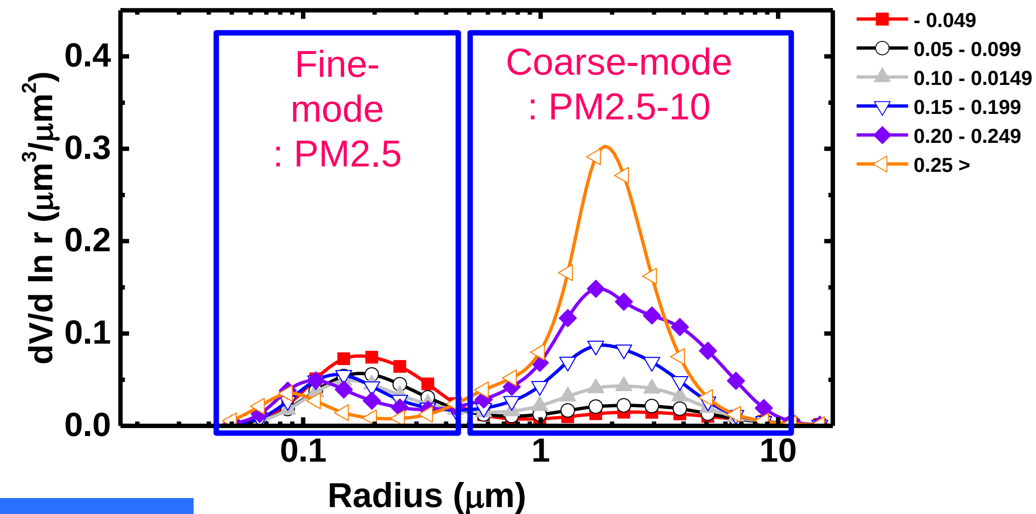
- **All coarse-mode particle is not dust particle**
- **Size parameter has high uncertainty to classify aerosol type**

Aerosol Separation as Asian dust, PM10, PM2.5

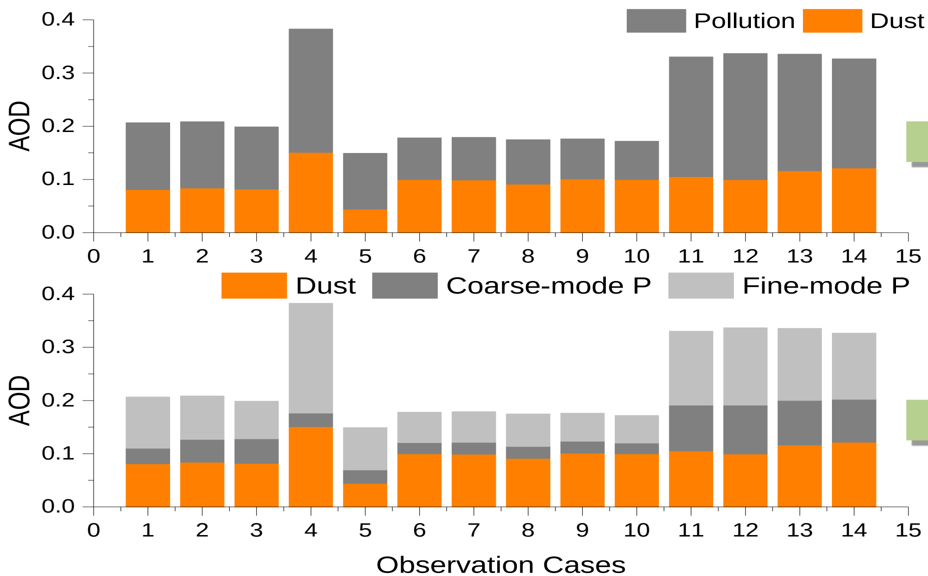




Different optical properties between Dust and Pollution



Separation of Aerosol Concentration

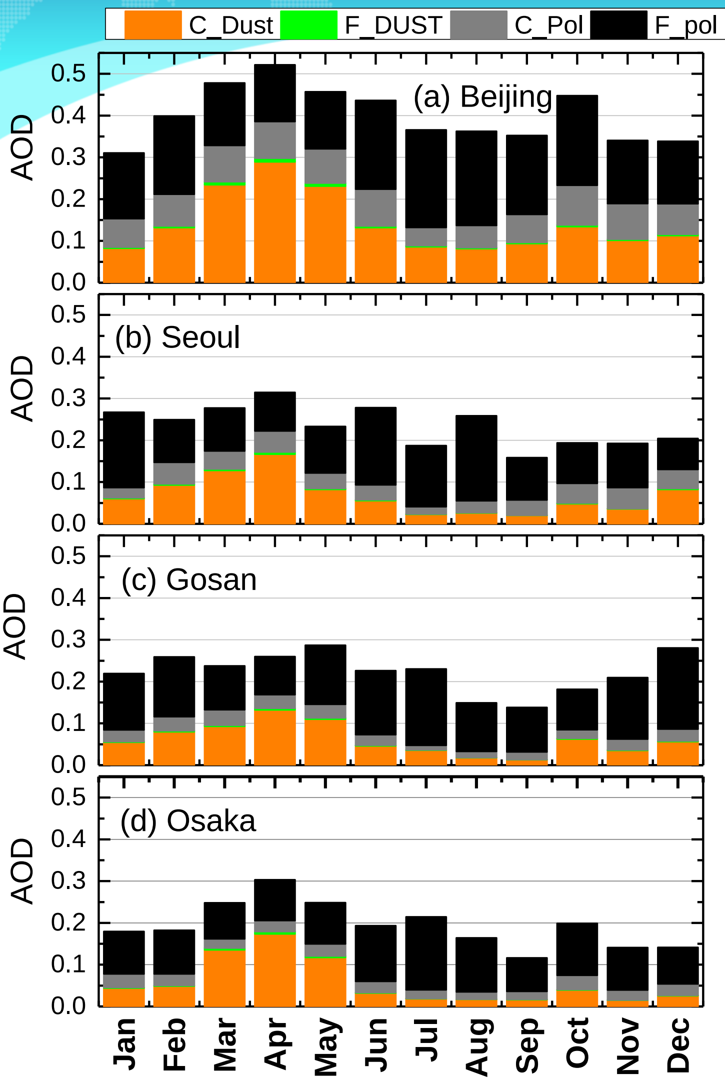


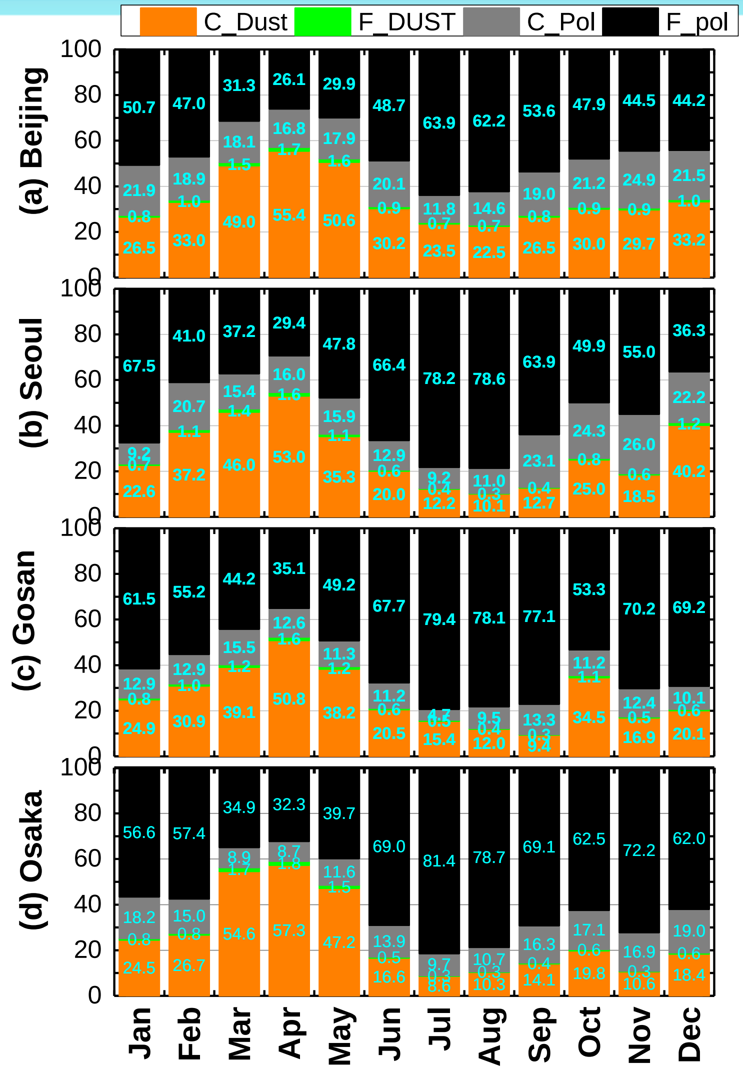
Dust and Pollution particle using only Dust ratio

Separation as Dust, PM10 and PM2.5 using Dust ratio & Size distribution

PM2.5 = Fine-mode pollution
PM2.5-10 = Dust+Coarse-mode Pollution

Seasonal variation of Dust and Coarse-mode pollution particle

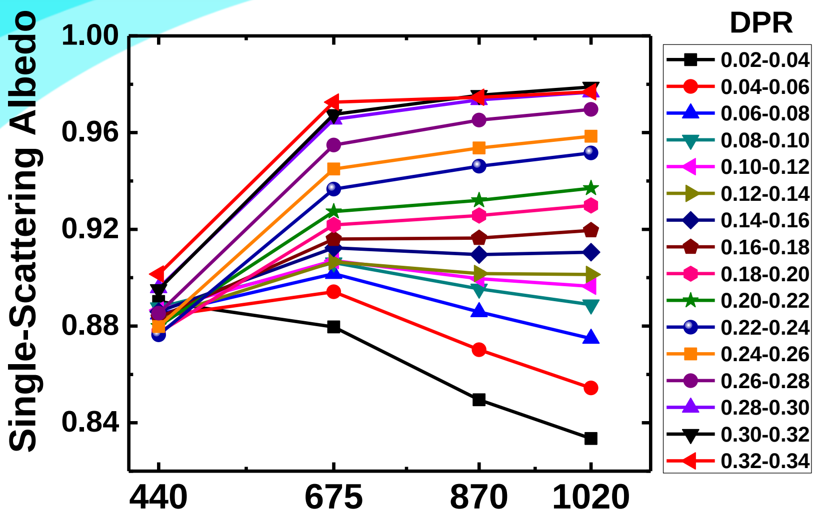




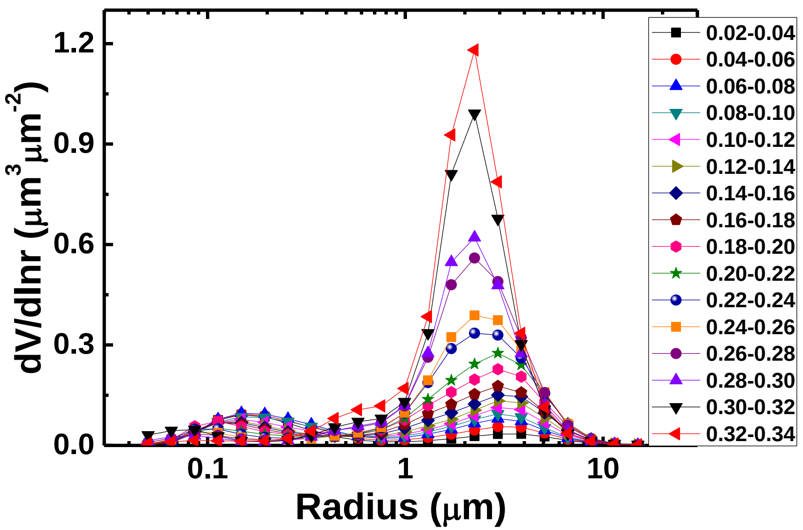
AOD : 1020 nm

Variation of Optical Parameter (Beijing)

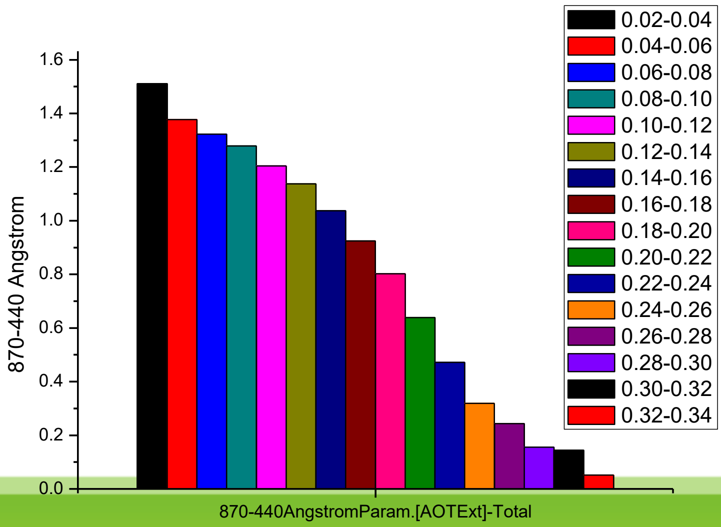
Single-Scattering Albedo



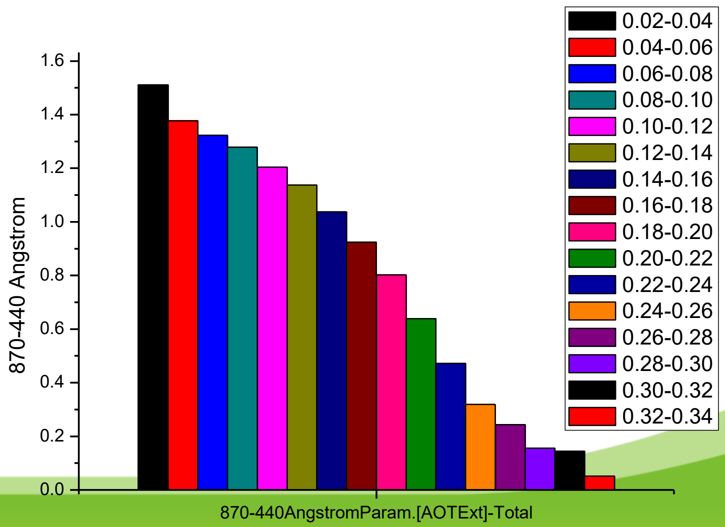
Size distribution



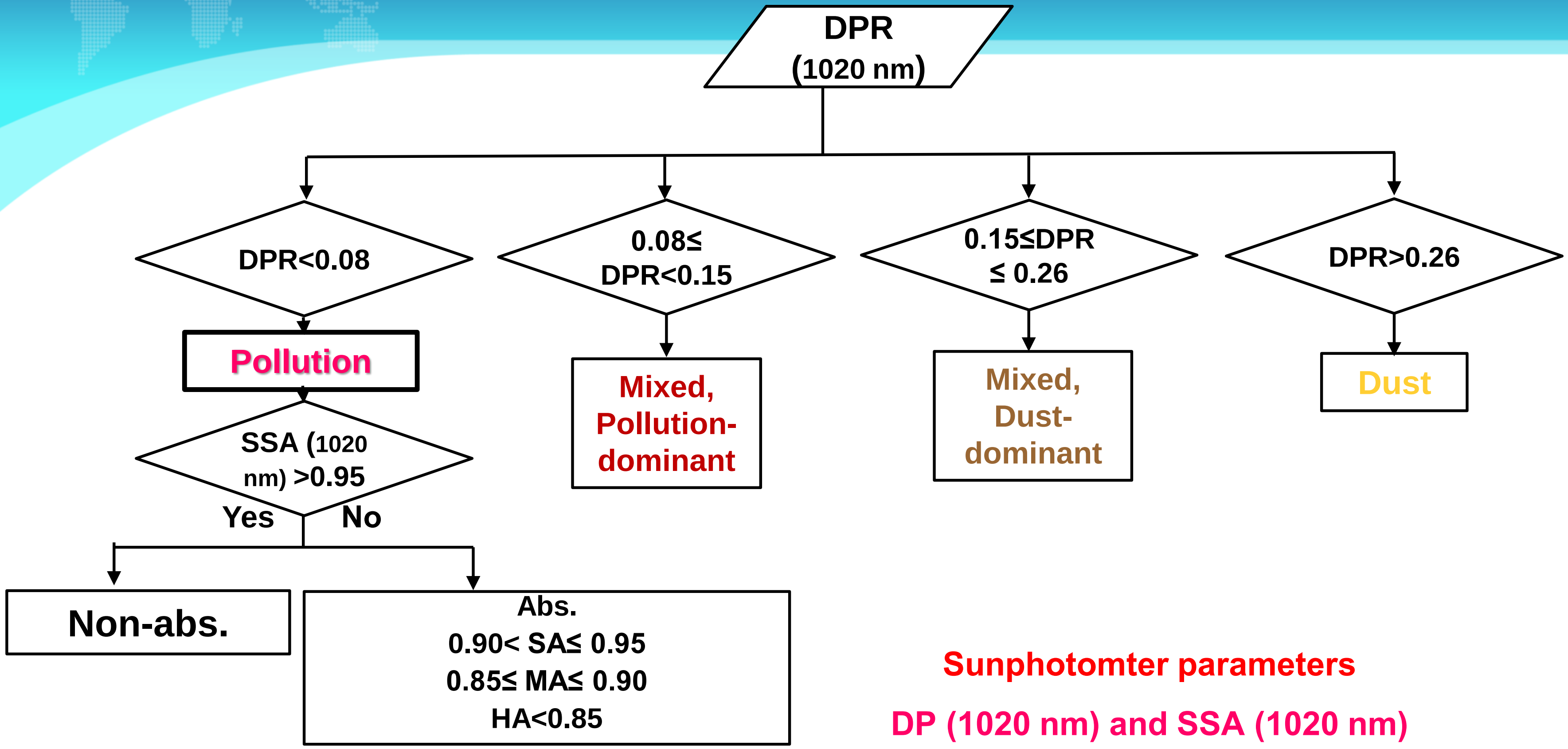
Fine-mode Fraction



Ångström Exponent (440-870 nm)



Flowchart of the aerosol classification algorithm

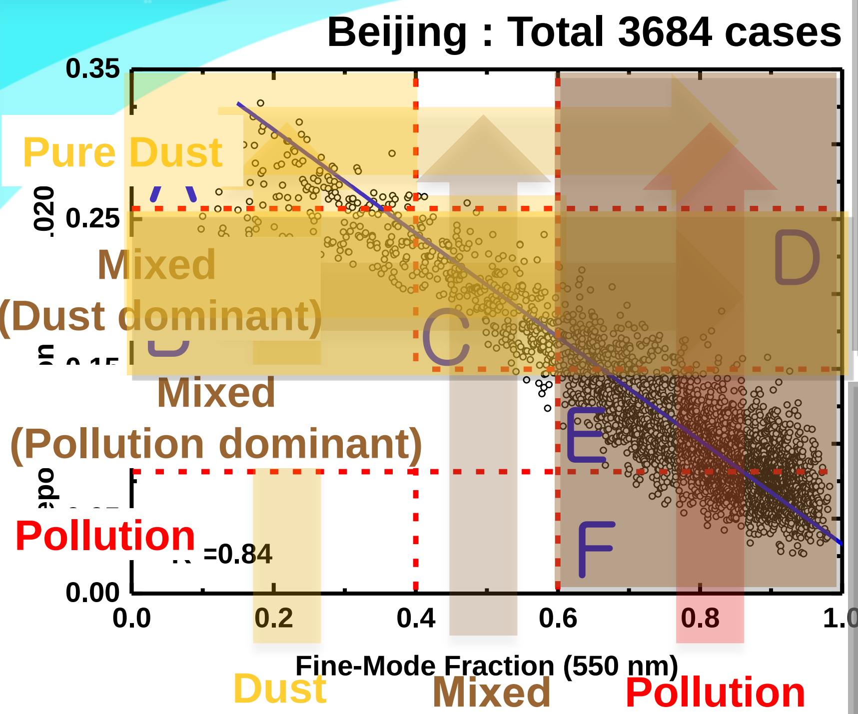


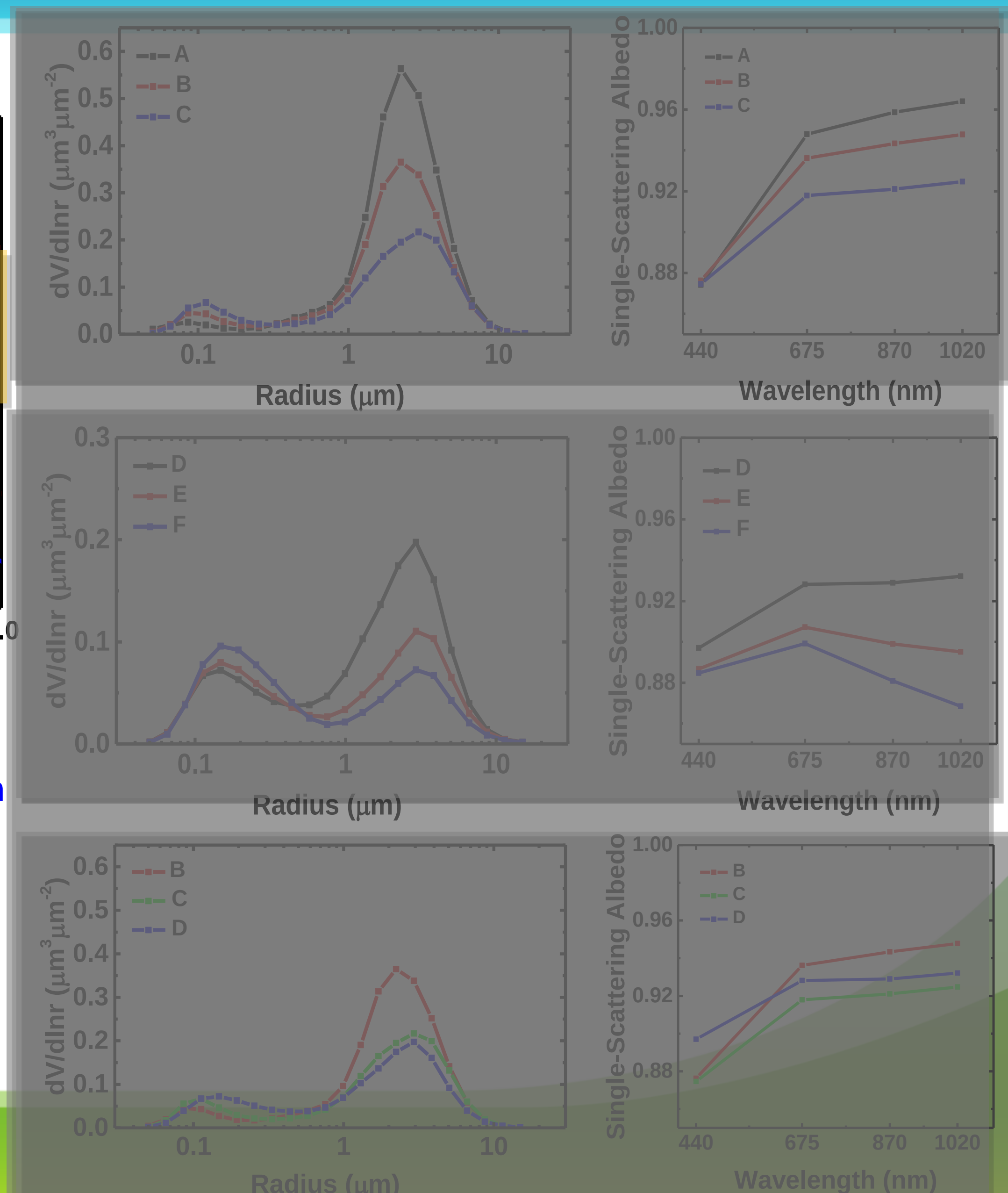
Sunphotomter parameters

DP (1020 nm) and SSA (1020 nm)

- **Dust aerosols (DPR to be greater than 0.26)**
- **Dust-dominant (0.15 ≤ DPR ≤ 0.26)**
- **Pollution-dominant (0.08 ≤ DPR <0.15)**
- **Pollution aerosols (DP to be less than 0.08)**
- **The HA, MA, SA, and NA represent highly-absorbing, moderately-absorbing, slightly-absorbing, and non-absorbing aerosols, respectively**

Comparison Between two Methods





Aerosol type classification by size information

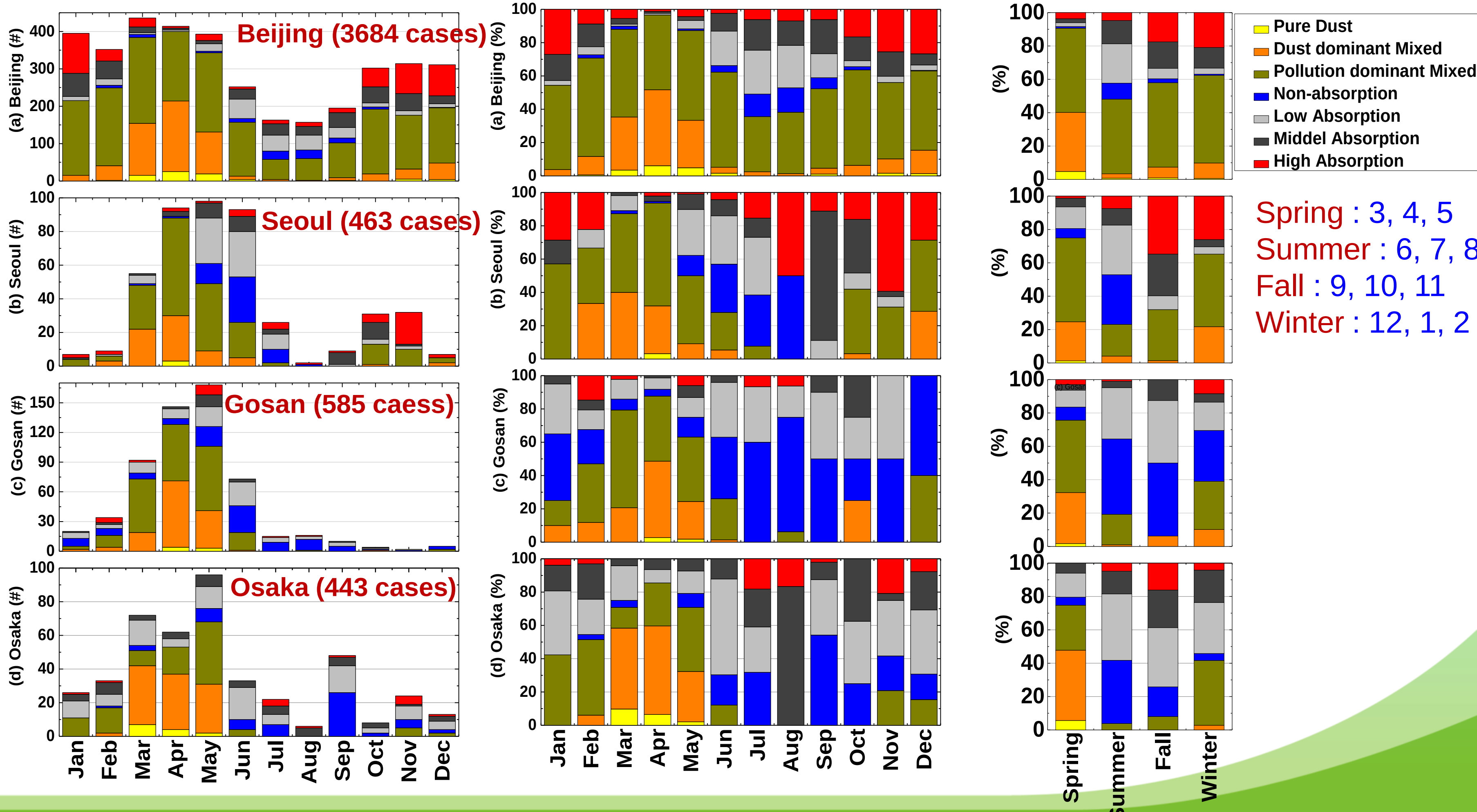
- Pollution (FMF > 0.6)
- Dust (FMF < 0.4)
- Mixture (between 0.4 and 0.6)

FMF at 550 nm
(Lee et al., 2010)

Aerosol Type Classification

(Dust, Mixed (Dust, Pollution), Pollution)

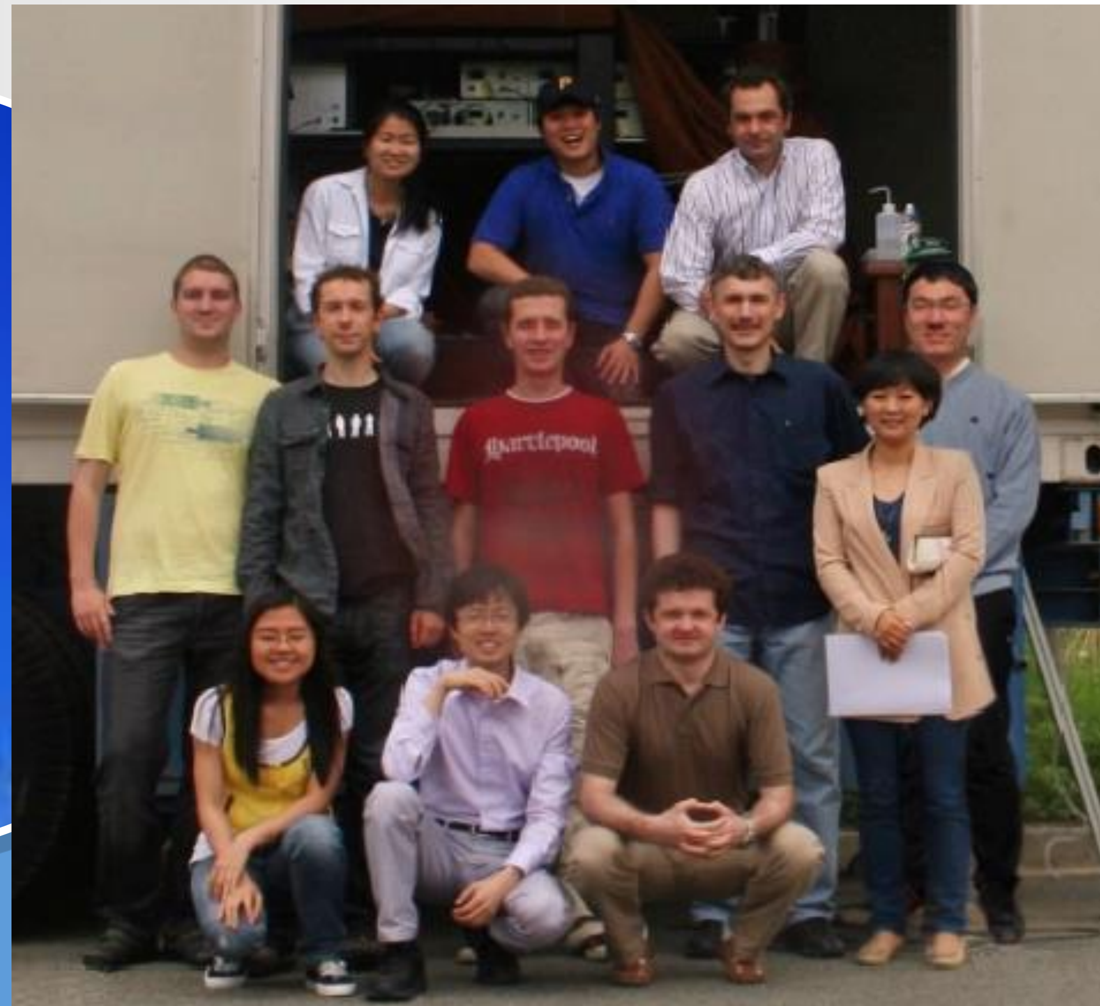
Numbers per Types | **% according to Types** | **Seasonal %**

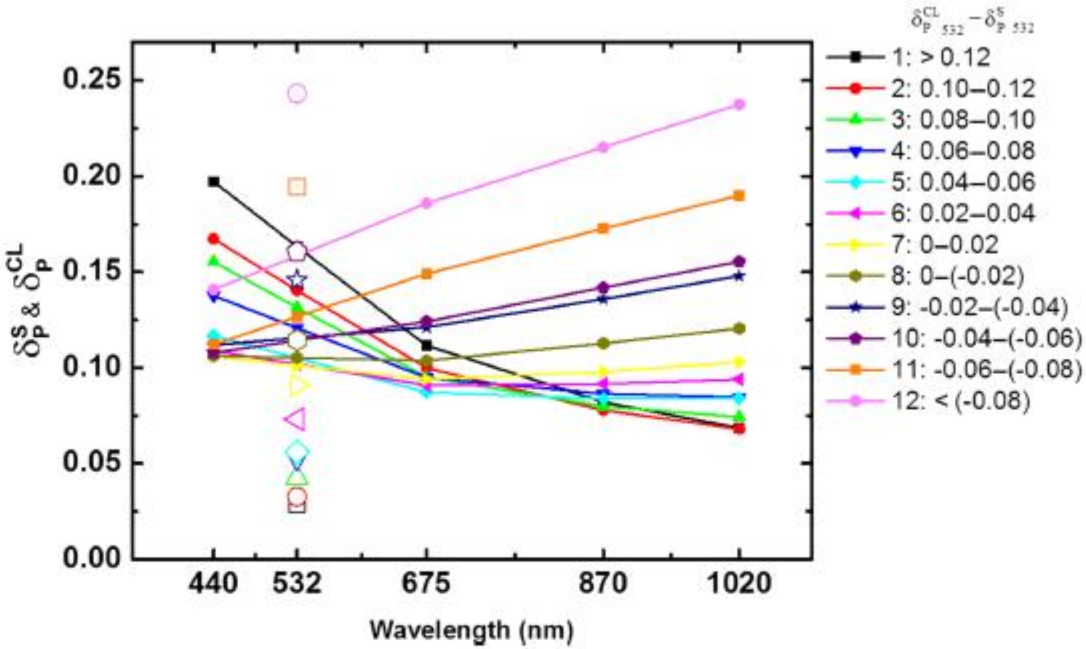


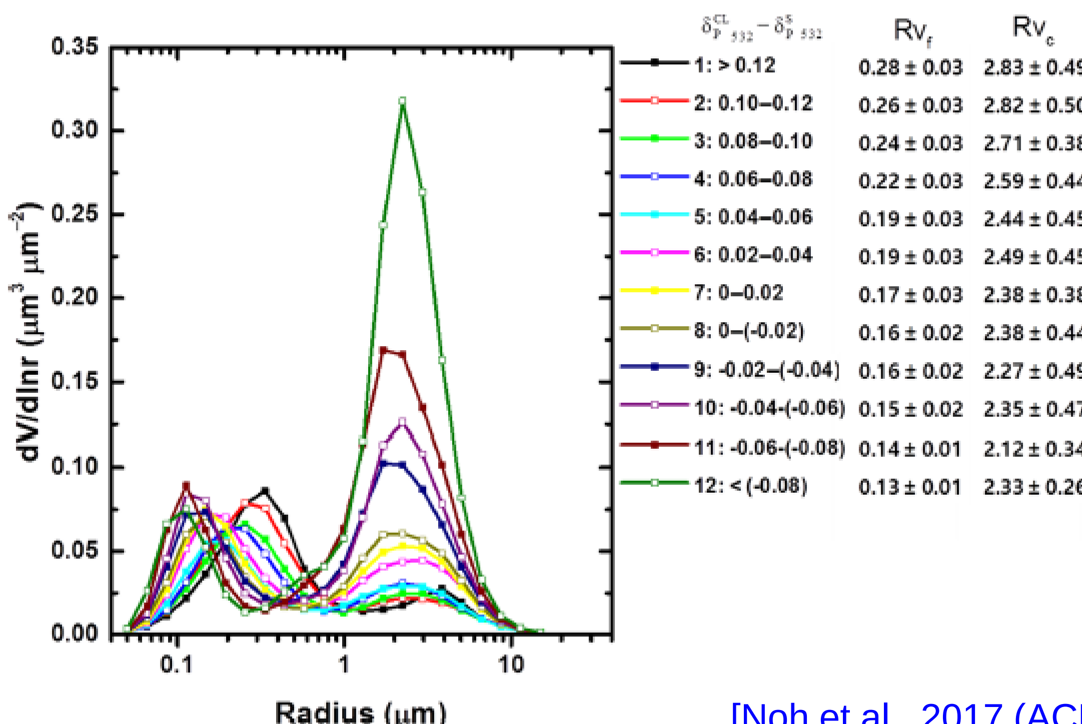
Summary

- We investigated the reliability of depolarization ratio derived by AERONET sunphotometer.
- The strong correlation between lidar and sunphometer depolarization were obtained as 0.90, 0.92, 0.79, and 0.89 at Seoul, Kongju, Gosan and Osaka, respectively.
- Sunphotometer depolarization ratio can provide comparably reliable information to identify the presence of Asian dust particles in the mixed aerosol plumes.
- Depolarization ratio is more effective to classify aerosol type than only using size information parameters.

Thank you for your listening







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