Dependence of Aerosol Light Scattering on the Chemical Composition and Size of Particles in Beijing Haze

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Backgroud: facts in severe haze pollution

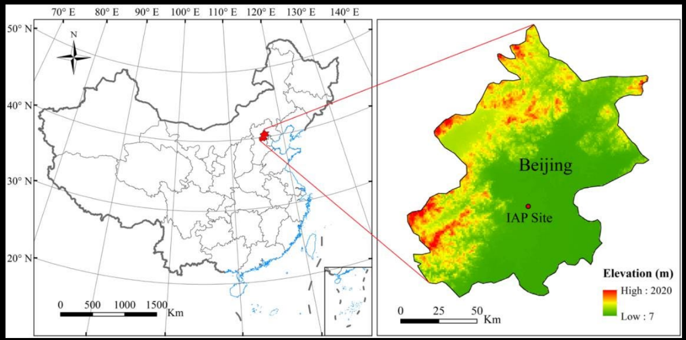
1. **Formation of secondary (inorganic and organic) species: Key Process leading to severe haze.**
2. **Optical properties (light scattering and absorption ability): Largely Enhanced by haze particles**

Purpose:

To quantify the dependence of aerosol scattering coefficients on aerosol size and composition in haze.

Method

Place: Institute of Atmospheric Physics (39°58′N, 116°22′E), Chinese Academy of Sciences



Realtime measurement items: (inlet-cutoff 2.5 μm)

Scattering coefficients of $PM_{2.5}$ (σ_{sp}) at 450, 525, 635 nm (Integrating nephelometer Aurora 3000, *calibrated per day*)

air dehydrated to RH < 40% σ_{sp_dry} (σ_{sp_dry} correction with Muller et al. (2011))

Scattering Ångström exponent (*SAE*)

$$SAE = \frac{\log(\sigma_{sp\_dry}(\lambda_2)) - \log(\sigma_{sp\_dry}(\lambda_1))}{\log(\lambda_2) - \log(\lambda_1)}$$

$[(\lambda_1, \lambda_2): (450, 635), (525, 635), (450, 525)]$

Method

Measurement items: (others)

- **$PM_{2.5}$ real time concentration (R&P Partisol® Model 2025)**
- **Size distribution: ~10–700 nm (DMA, model 3081)**
- **Daytime and nighttime $PM_{2.5}$ filter samples for ionic composition analysis (MiniVol PM sampler): February 19 - March 12, 2014**
- **Meteorological conditions: RH, T, P, WD, WS**

Composition analysis:

- **F^-, Cl^-, NO_3^-, SO_4^{2-}, NH_4^+, K^+, Na^+, Ca^{2+}, Mg^{2+} (Dionex ICS-90)**
- **Metals (ICP-mass Elan 6100)**
- **OC, EC (DRI-2001A)**

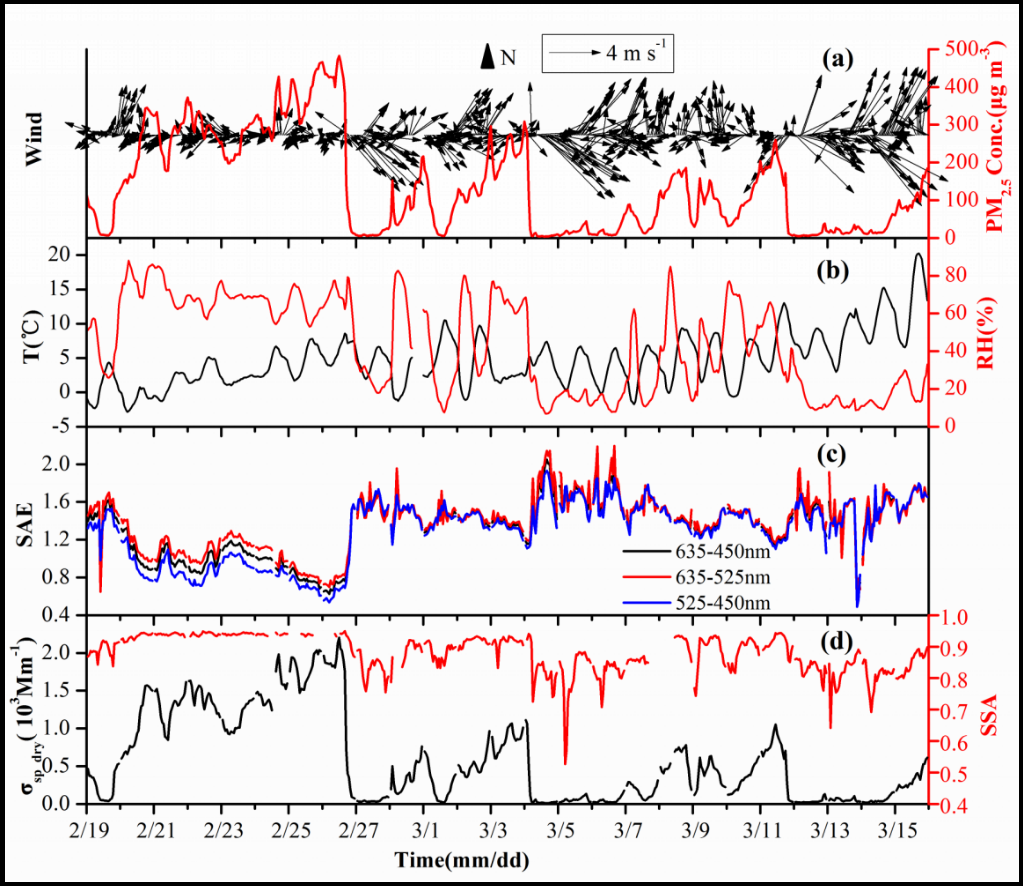
***Secondary inorganic aerosols (SIAs) = sum of SO_4^{2-}, NO_3^-, and NH_4^+**

***Organic matter (OM) = 1.4 × OC**

Aerosol water content (A.C.) : ISORROPIA II model with the ionic composition

Results

Overview of the filter collection period



σ_{sp_dry} at 525 nm :

530.3±573.5 Mm^{-1}

SSA: 0.88±0.06

$\sigma_{sp\_dry} \propto PM_{2.5}$ & RH

SAE: 1.3±0.3 (450-635nm)

var. ***opposite to*** σ_{sp_dry}

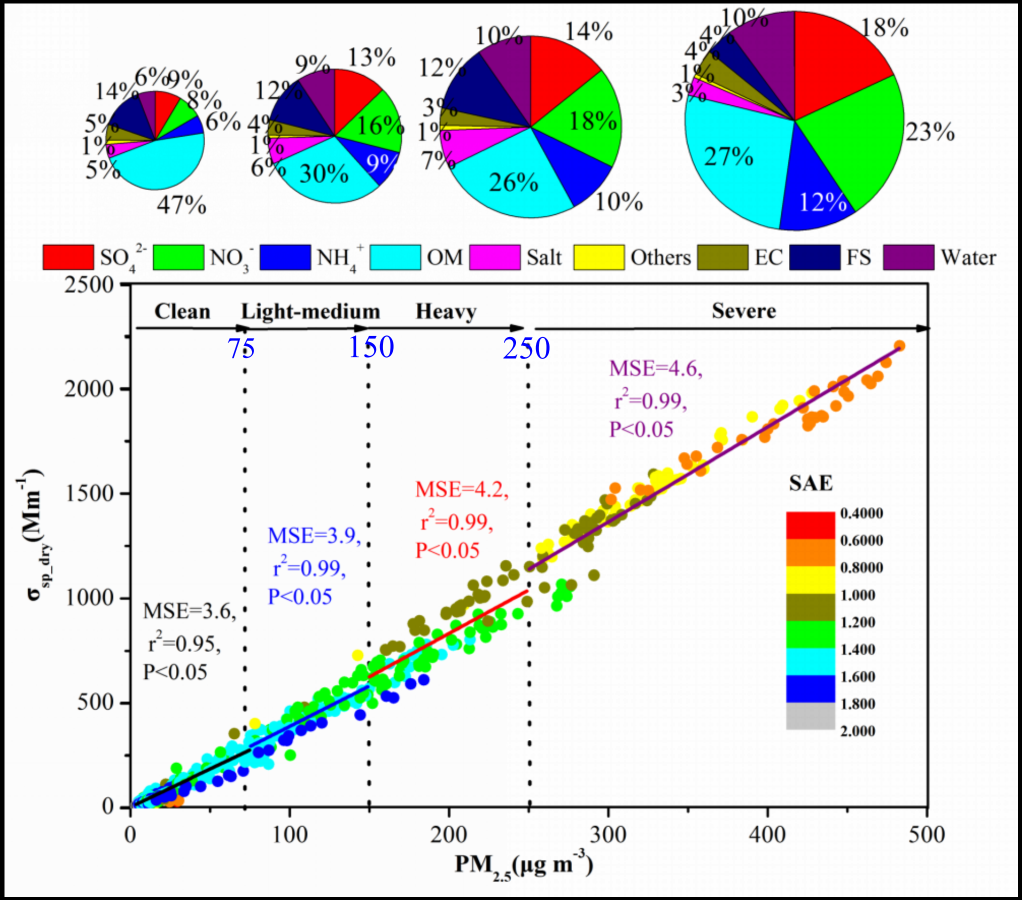
(high in clean and with small σ_{sp_dry} ;

small in polluted with large σ_{sp_dry})

(a) Wind, $PM_{2.5}$; (b) T, RH; (c) SAE of 635-450, 635-525, 525-450 nm;
(d) σ_{sp_dry}, Calculated single-scattering albedo (SSA).

Results

σ_{sp_dry} , SAE, MSE *vs* $PM_{2.5}$ mass and composition



σ_{sp_dry} increased dramatically with $PM_{2.5}$ but also was influenced by other factors (*different trends at the four $PM_{2.5}$ levels*).

SAE 1.4-2.0 → dominance of small particles (SIAs: 23-53%; OM: 47-26% in mass).

MSE (mass scattering efficiency):3.6 m^2 g^{-1}

σ_{sp_dry} at 525nm, colored by the SAE of 450-650 nm at four $PM_{2.5}$ levels.
pie graphs: relative chemical compositions of $PM_{2.5}$

Results σ_{sp_dry} , SAE, MSE *vs* $PM_{2.5}$ mass and composition

Pollution Level	σ_{sp_dry} (Mm^{-1})	SAE	MSE ($m^2\ g^{-1}$)	r_{SIAs} (%)	r_{OM} ($\mu g\ m^{-3}$)	$PM_{2.5}$ ($\mu g\ m^{-3}$)
Clean	- 270	1.4 - 2.0	3.6	23	47	<75
Light-Medium	270 - 560	1.2 - 1.8	3.9	38	30	75-150
Heavy	560 - 980	1.0 - 1.2	4.2	42	26	150-250
Severe	1000 - 2250	0.4 - 1.2	4.6	53	27	>250

σ_{sp_dry} light scattering coefficient; **SAE** Scattering Ångström exponent; **MSE** mass scattering efficiency; **r_{SIAs}** mass ratio of SIAs in $PM_{2.5}$; **r_{OM}** mass ratio of organic matter in $PM_{2.5}$

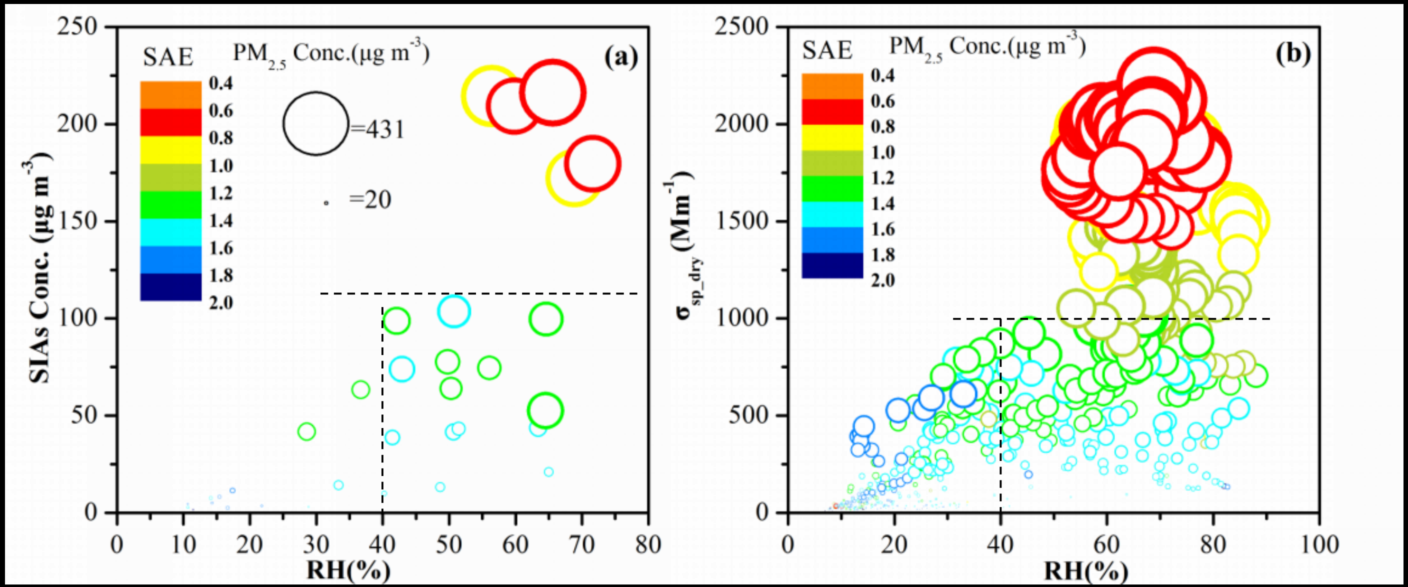
σ_{sp_dry}, MSE, r_{SIAs} increased with $PM_{2.5}$
SAE, r_{OM} decreased with $PM_{2.5}$

→ **Dependence of σ_{sp_dry} and MSE on particle size and composition**

Results σ_{sp_dry}, SIAs *vs* RH

RH: 10→70%

SIAs: 5→200μg m^{-3}; SAE: 2.0→0.4; PM2.5: 50→431 μg m^{-3}

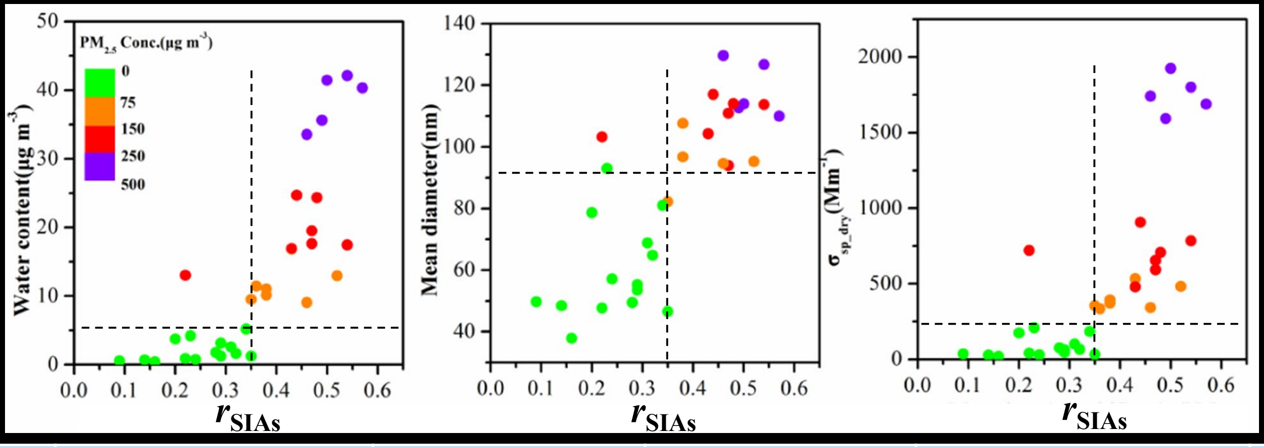


SIAs concentration and σ_{sp_dry} at 525nm wavelength versus RH, colored by the SAE of 450 nm and 650 nm. Size of circles represents $PM_{2.5}$ concentration.

σ_{sp_dry} increased largely with RH with large particles and high $PM_{2.5}$, and slowly with small particles and low $PM_{2.5}$.

σ_{sp_dry} : RH < 40%, low; RH>40%: rapid at SAE<1.0&high$PM_{2.5}$ and low at SAE>1.0&small $PM_{2.5}$

Results σ_{sp_dry} *vs* SIAs and Particle growth (PG)



Pollution Level	M_{SIAs}	W.C. (μg m^{-3})	M. D. (nm)	ΔWater/ΔM_{SIAs} (μg m^{-3})	$\Delta D_p/\Delta M_{SIAs}$ (nm)
Clean	0.1→0.35	0→10	40→80	~33	~67
>Light-Medium	0.35→0.6	10→40	80→140	~15	~40

Aerosol water content(WC), mean diameter(M.D.) of ~10–700 nm particles and σ_{sp_dry} *vs* SIAs/PM$_{2.5}$ (M_{SIAs})

Increase of W.C. and M.D. correlated closely with SIAs

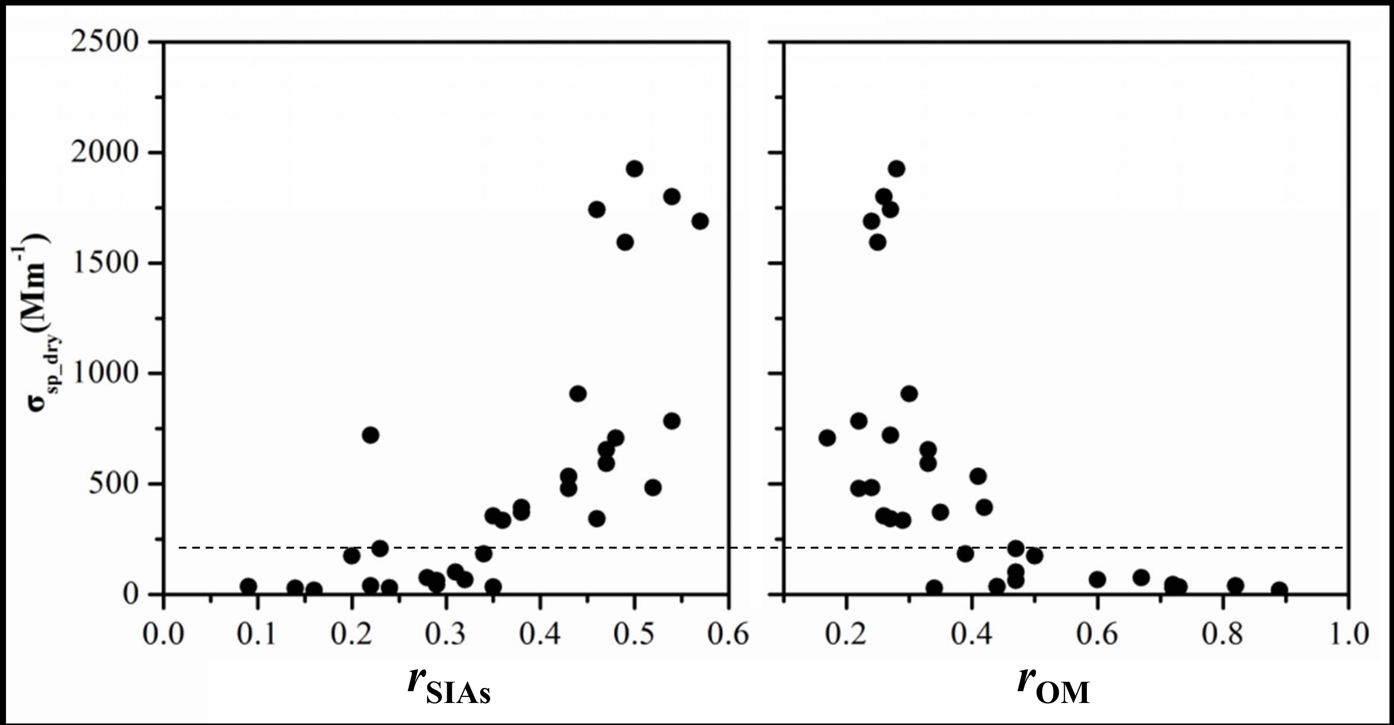
Changes of W.C. and M. D. much more sensitive to r_{SIAs} when r_{SIAs} > 0.35,

leading to the large σ_{sp_dry}: (critical value of r_{SIAs} 0.35)

Results

Positive correlation between σ_{sp_dry} and r_{SIAs}

Negative correlation between σ_{sp_dry} and r_{OM}

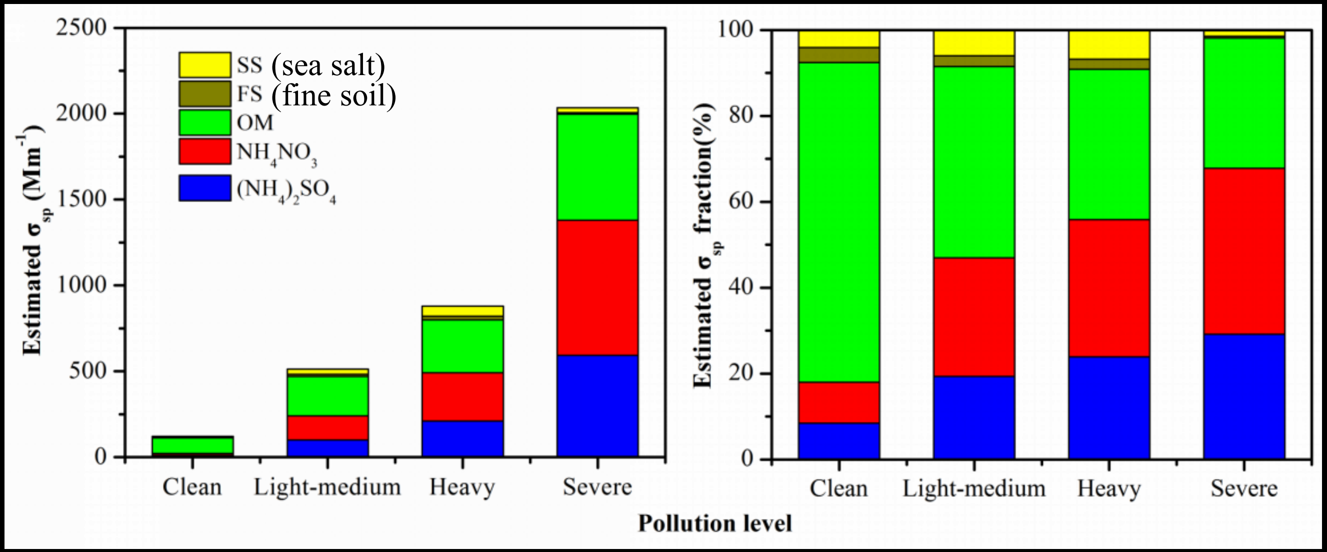


σ_{sp_dry} vs r_{SIAs} and r_{OM}

Enhancement of σ_{sp_dry} by SIAs much larger than by OM, *likely due to W.C.*

Results

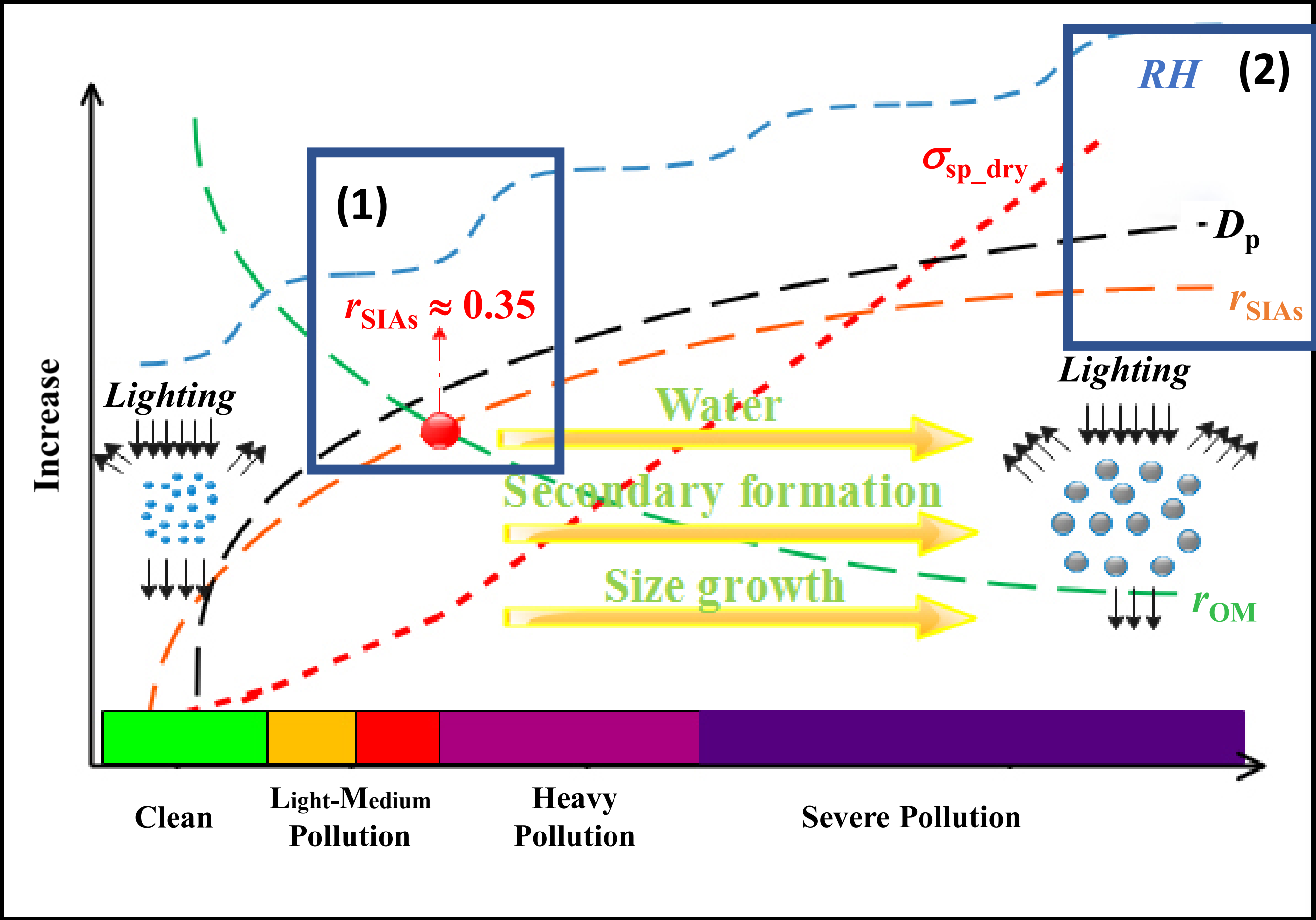
Respective contribution of chemical components (IMPROVE model estimation σ_{sp}: about 1.19σ_{sp_dry})



Estimated σ_{sp} and the contribution of major chemical components

SIAs contributed the largest fraction of σ_{sp}, supporting the fact that the formation of SIAs played a key role in the enhancement of the measured σ_{sp_dry}.

Summary



σ_{sp_dry} enhancement related to RH and aerosol composition and size in haze

Thanks for your attention.

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