Estimating contributions of black and brown carbon to solar absorption from skyradiometer measurements

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Topics in this talk

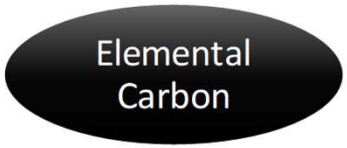
1. Estimating **Mass Absorption Cross-Section (MAC) of BC and BrC** from field measurements in East Asia

2. Determine the **contributions of BC and BrC to aerosol light absorption coefficient** from surface in-situ measurements

3. Determine the **contributions of BC and BrC to Absoprtion AOD (AAOD)** from skyradiometer measurements

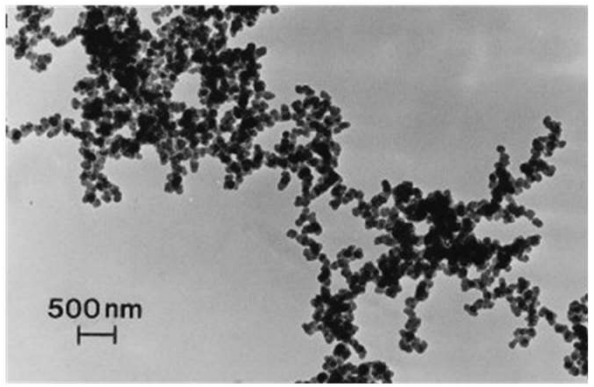
Black Carbon (BC) and Brown Carbon (BrC)

Black Carbon (BC)



Pure carbon rather than being chemically combined with hydrogen and/or oxygen

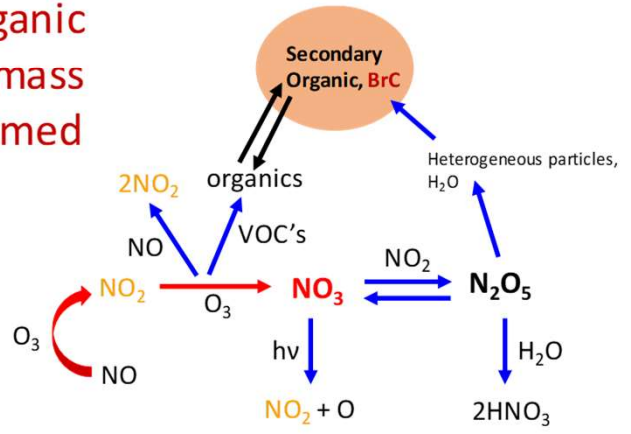
- BC is formed through the incomplete combustion of fossil fuels, biofuel, and biomass.



Brown Carbon (BrC)

Chemically combined with hydrogen and other elements (O, S, N, P, Cl, etc.)

- BrC is brown smoke released by the combustion of organic matter (mainly by biomass combustion, but also it formed under high-NO_x conditions.



Sources of BC in East Asia

$PM_{2.5}$ samples

November 1, 2021 (Gosan, Jeju, Korea)

Carbon Isotope Analysis

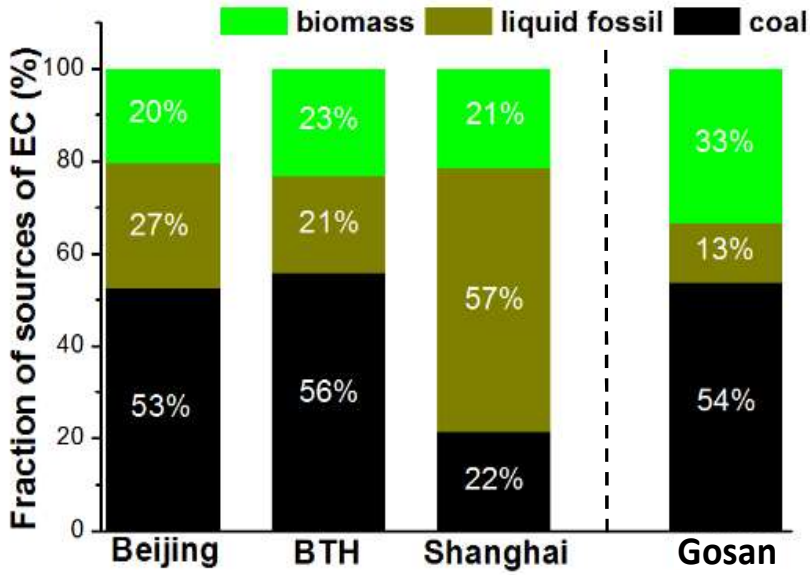
Radiocarbon [$^{14}C/^{12}C$ ($\Delta^{14}C$)]

and

Stable Carbon [$^{13}C/^{12}C$ ($\delta^{13}C$)]

	Biomass (C3 plants)	Liquid fossil	Coal
$\Delta^{14}C$ (‰)	112 ± 60	−1,000	−1,000
$\delta^{13}C$ (‰)	−26.7 ± 1.8	−25.5 ± 1.3	−23.38 ± 1.3

Black Carbon (BC) Sources

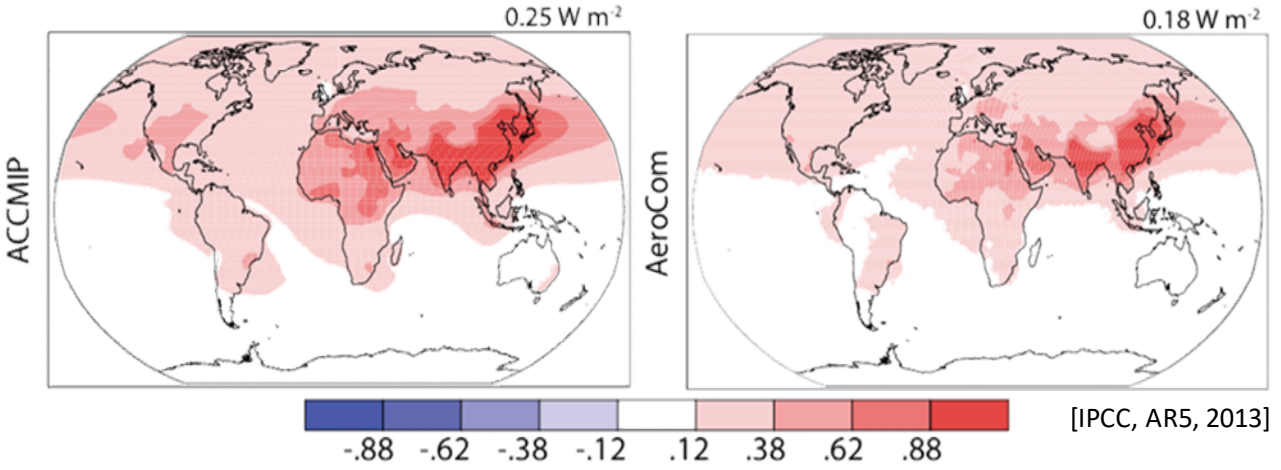


Direct Radiative Forcing of BC and BrC

Black Carbon (BC)

Elemental Carbon

Pure carbon rather than being chemically combined with hydrogen and/or oxygen



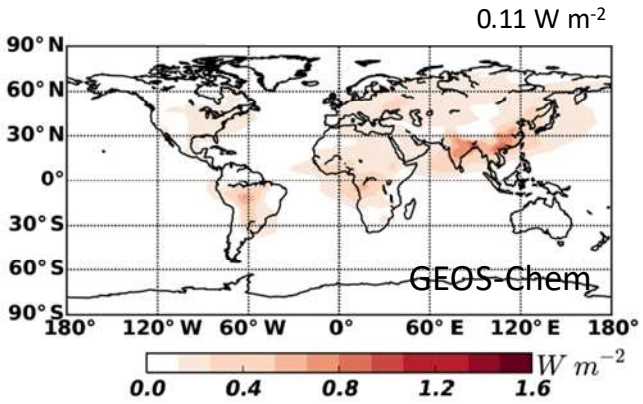
[IPCC, AR5, 2013]

Brown Carbon (BrC)

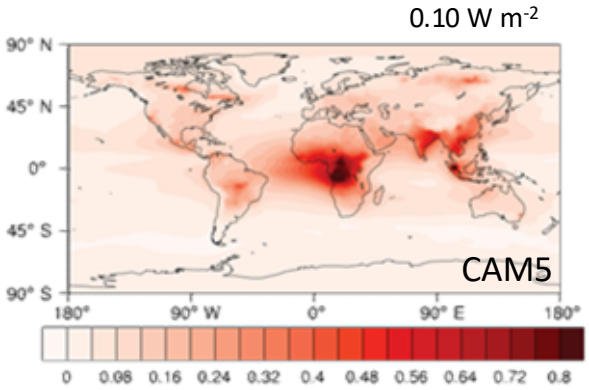
Organic Carbon

Brown Carbon

Chemically combined with hydrogen and other elements (O, S, N, P, Cl, etc.)

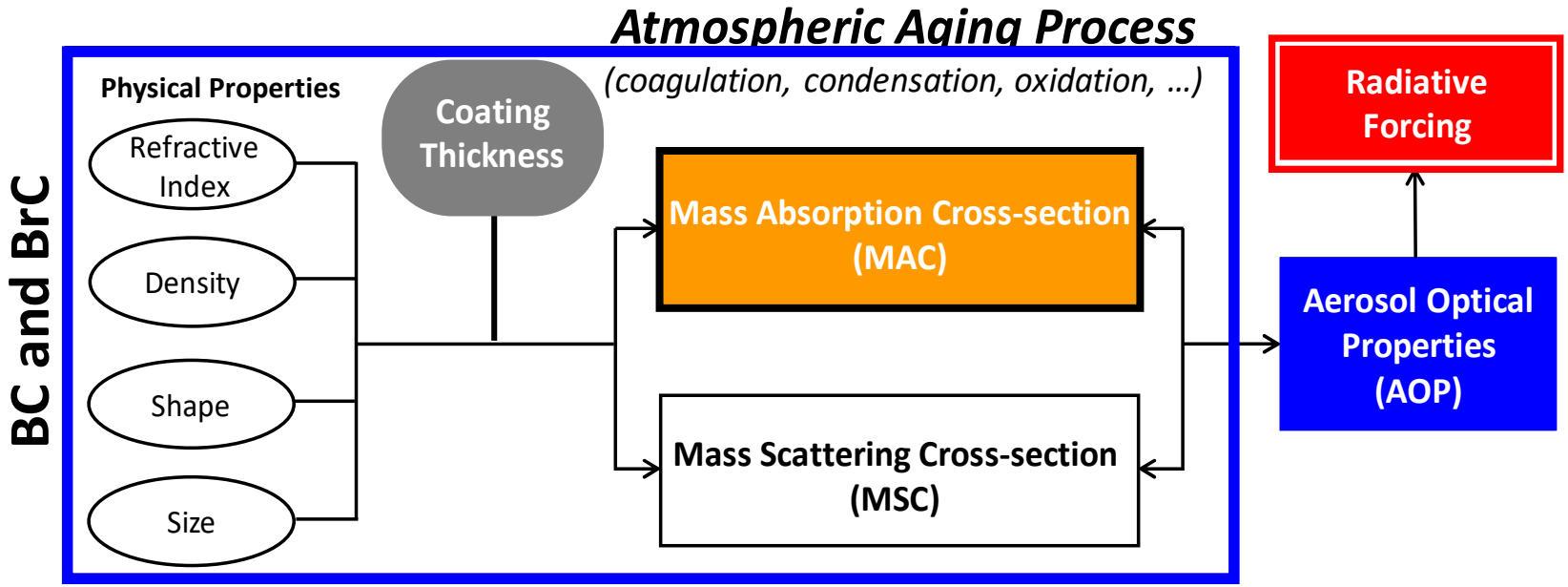


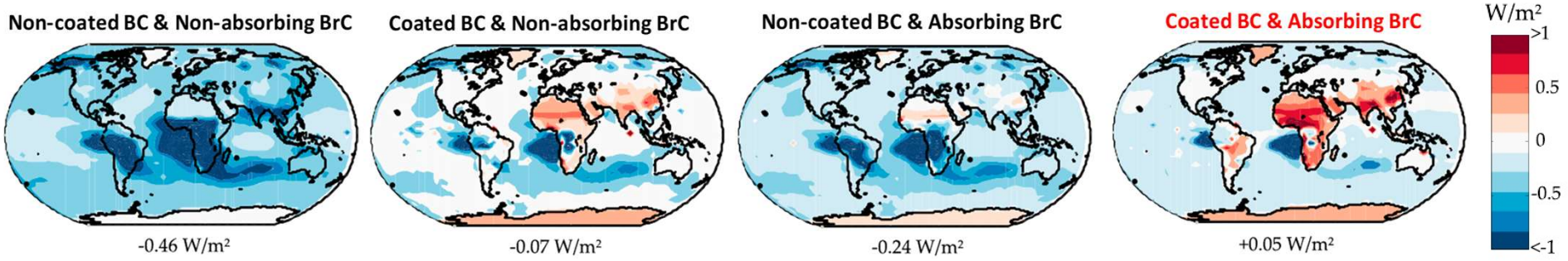
Jo et al. (2016)



Zhang et al. (2020)

Direct Radiative Forcing of BC and BrC



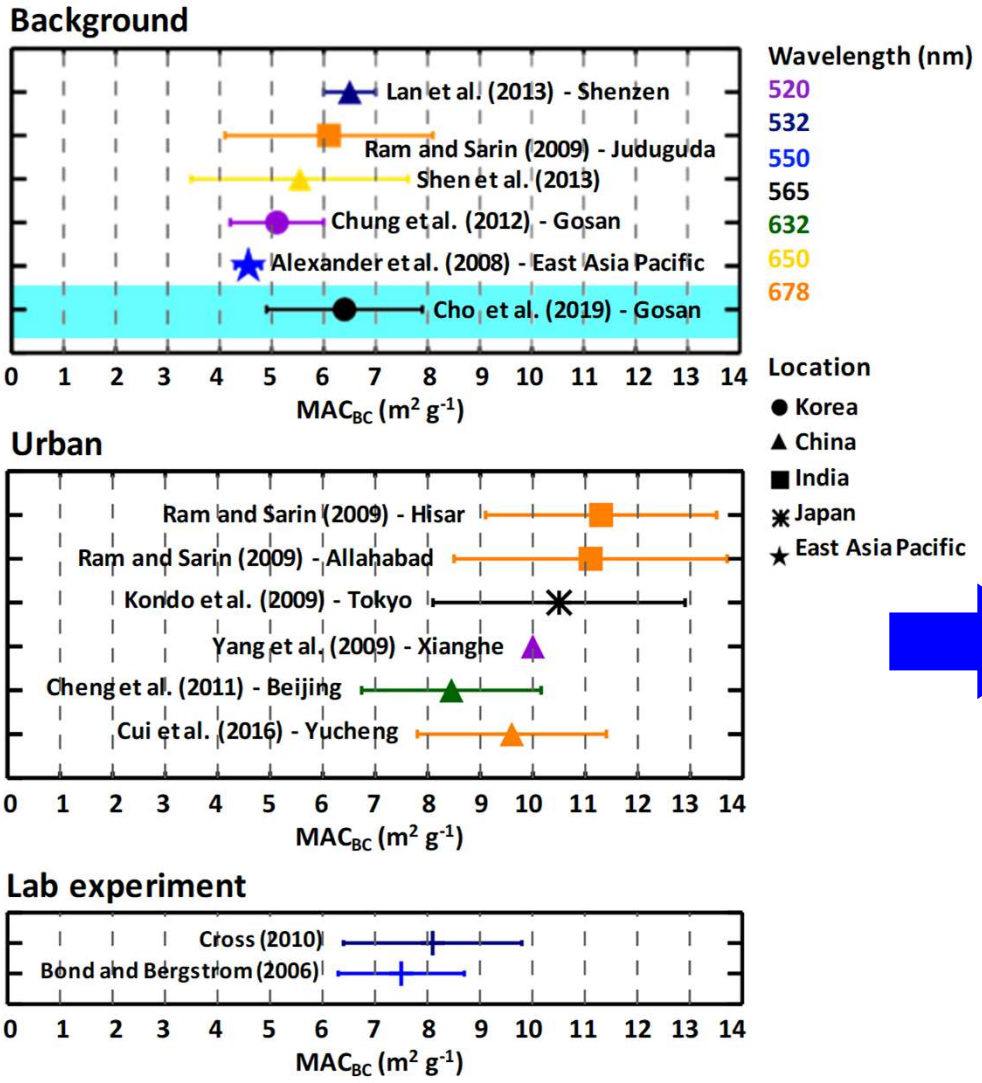


[Saleh et al., 2015]

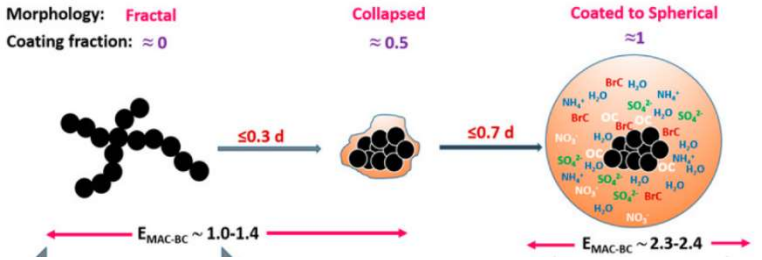
Absorption Coefficient [m^{-1}] = Mass [$g\ m^{-3}$] x Mass absorption cross-section [$m^2\ g^{-1}$]

- MAC of **7.5 ± 1.2 $m^2\ g^{-1}$ for fresh BC** [Bond and Bergstrom, 2006] is adapted to most global aerosol models.
- Some models have also used a broad range of MAC_{BC} ranging from 2.3 to 18 $m^2\ g^{-1}$ to account for the de-coating or coating-enhancement of ambient BC absorption.

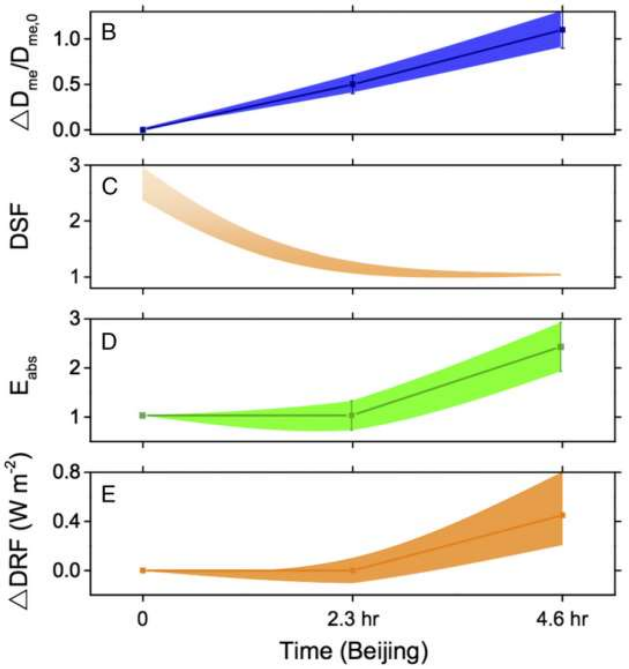
Mass Absorption Cross-Section [MAC] of BC



Coating-enhancement of BC absorption



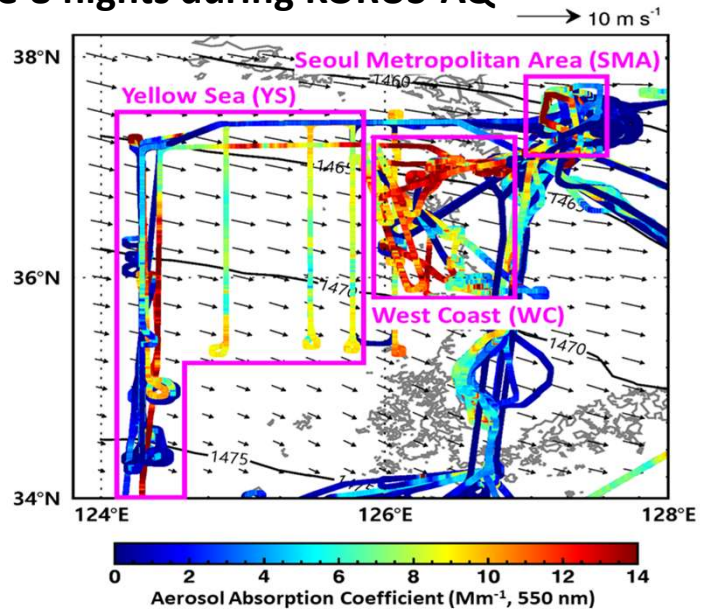
[Gustafsson and Ramanathan, PNAS, 2016]

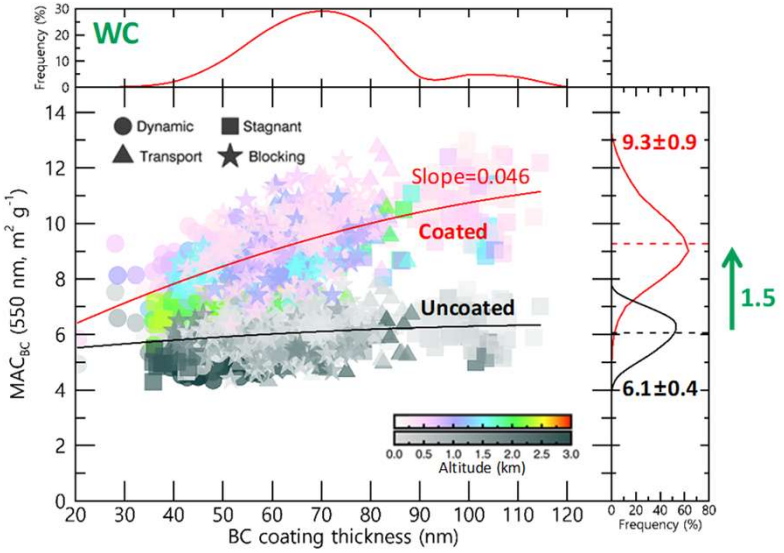


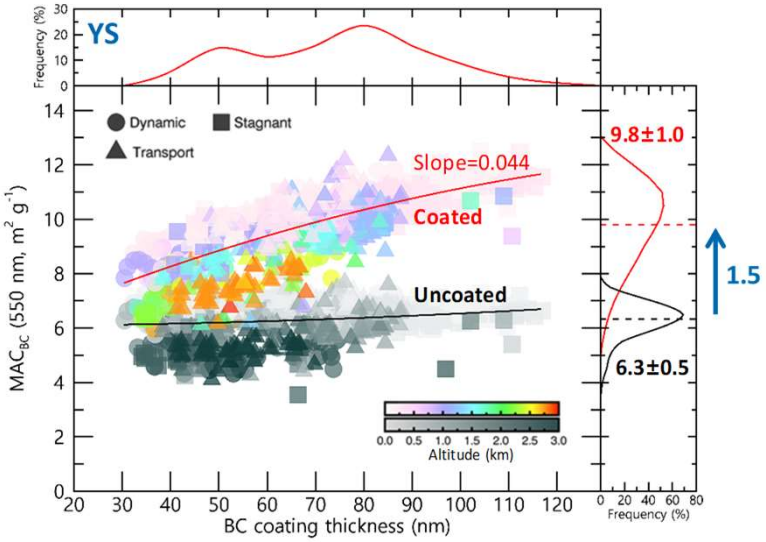
[Peng et al., PNAS, 2016]

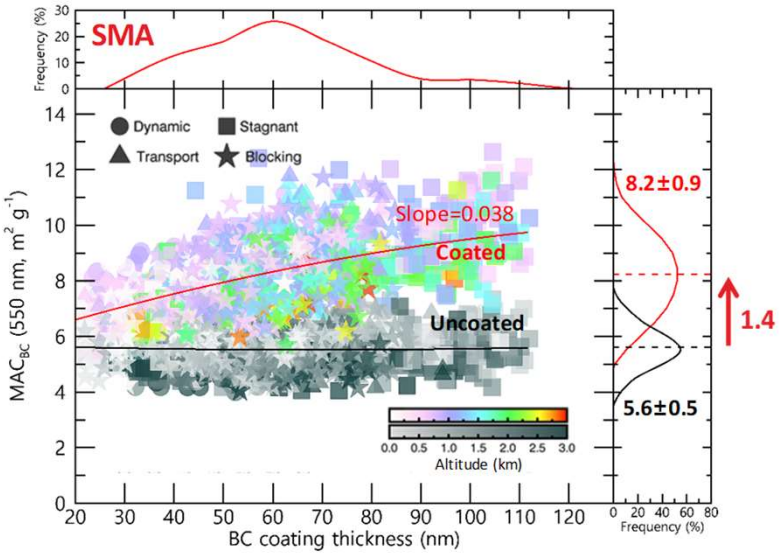
MAC_{BC} increases with coatings: Airborne SP-2

DC-8 flights during KORUS-AQ

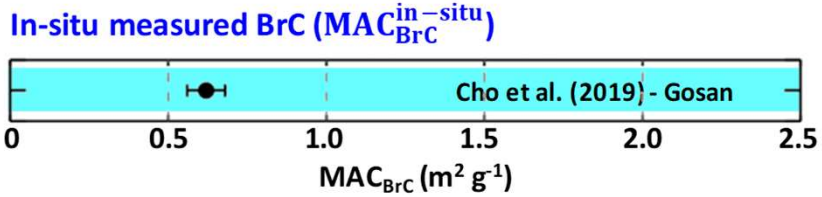


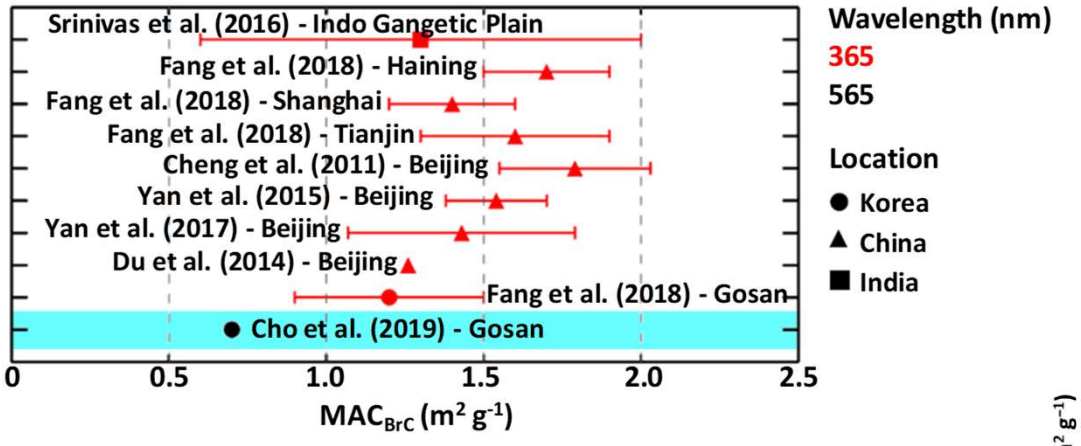


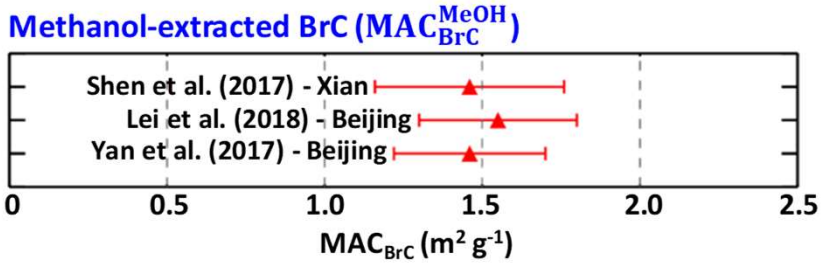


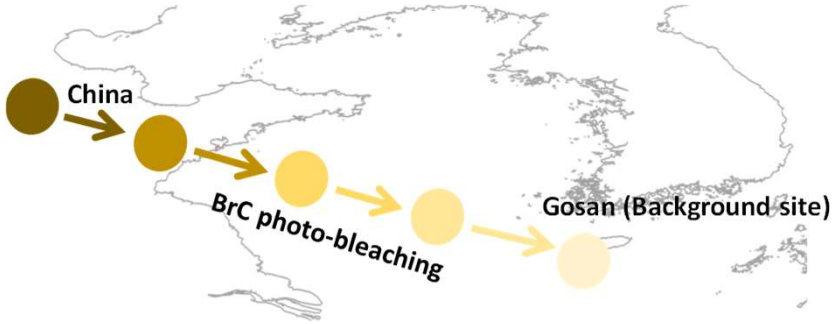


Mass Absorption Cross-Section [MAC] of BrC

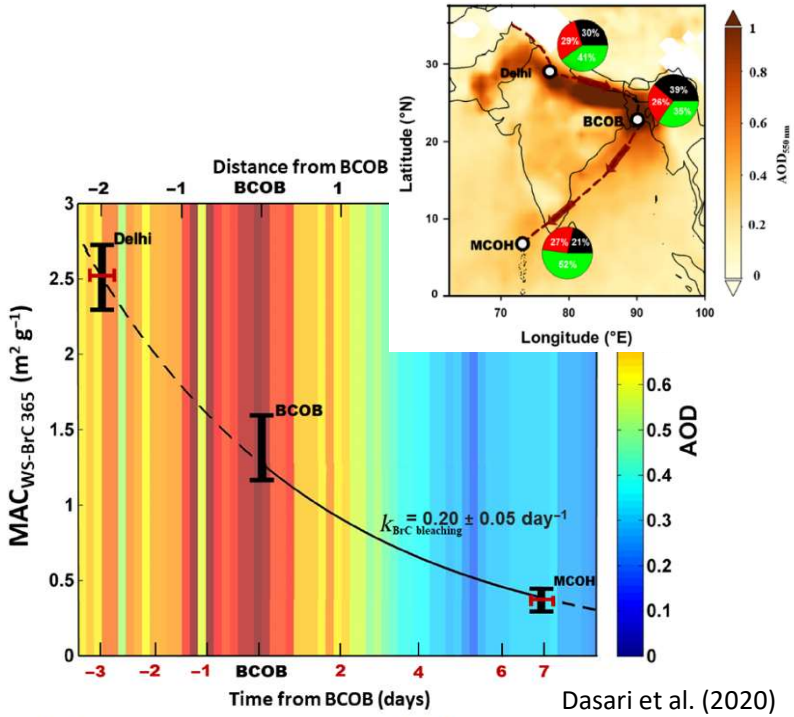








- BrC underwent **photo-bleaching process** during transportation, resulting in decreased MAC_{BrC} at Gosan.

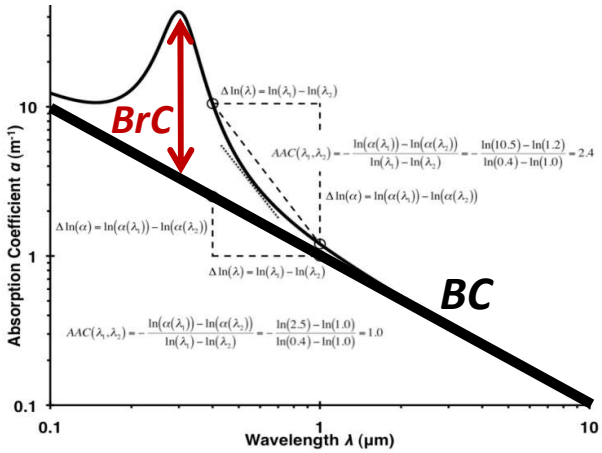


Dasari et al. (2020)

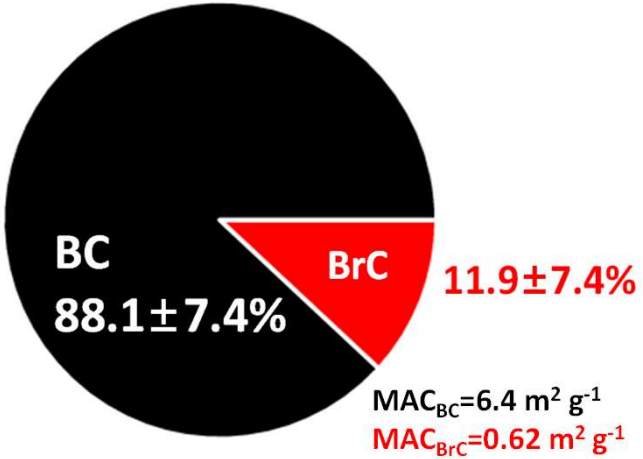
Fig. 5. Bounding the light absorption of WS-BrC in the South Asian outflow.

Contribution of BC and BrC to Light Absorption

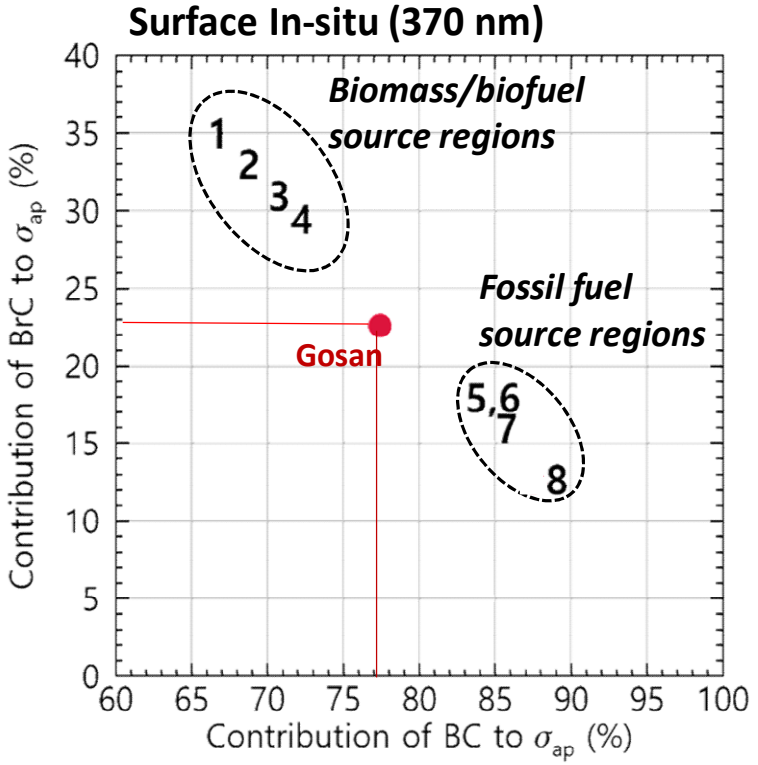
"Absorption Ångström Exponent (AÅE) method"



Aerosol absorption Coefficient (565nm)
(In-situ observations at Gosan, Jeju)



Surface In-situ (370 nm)

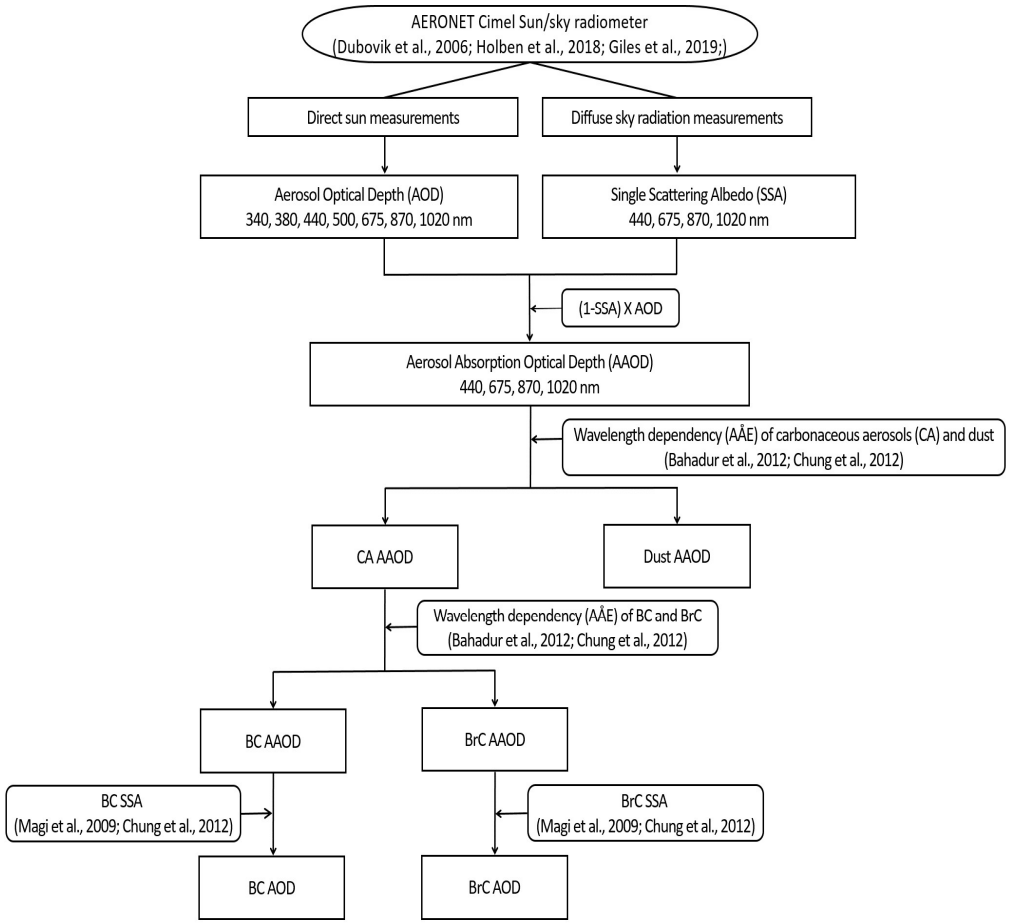


1. Kim et al. (2021)
   Kathmandu, Winter 2013 (370 nm)
2. Chen et al. (2019)
   Fresno, Winter 2014 (405 nm)
3. Liu et al. (2013)
   Atlanta, Fall 2012 (350 nm)
4. Shamjad et al. (2016)
   Kanpur, Winter 2014 (405 nm)
5. Wang et al. (2018)
   Xianlin, 2013–2016 (370 nm)
6. 6. Yan et al. (2015)
   Beijing, January 2013 (365 nm)
7. 7. Yang et al. (2009)
   Xianghe, March 2005 (400 nm)
8. 8. Yuan et al. (2016)
   Shenzhen, Winter 2014 (405 nm)

Partitioning CA between BC and BrC

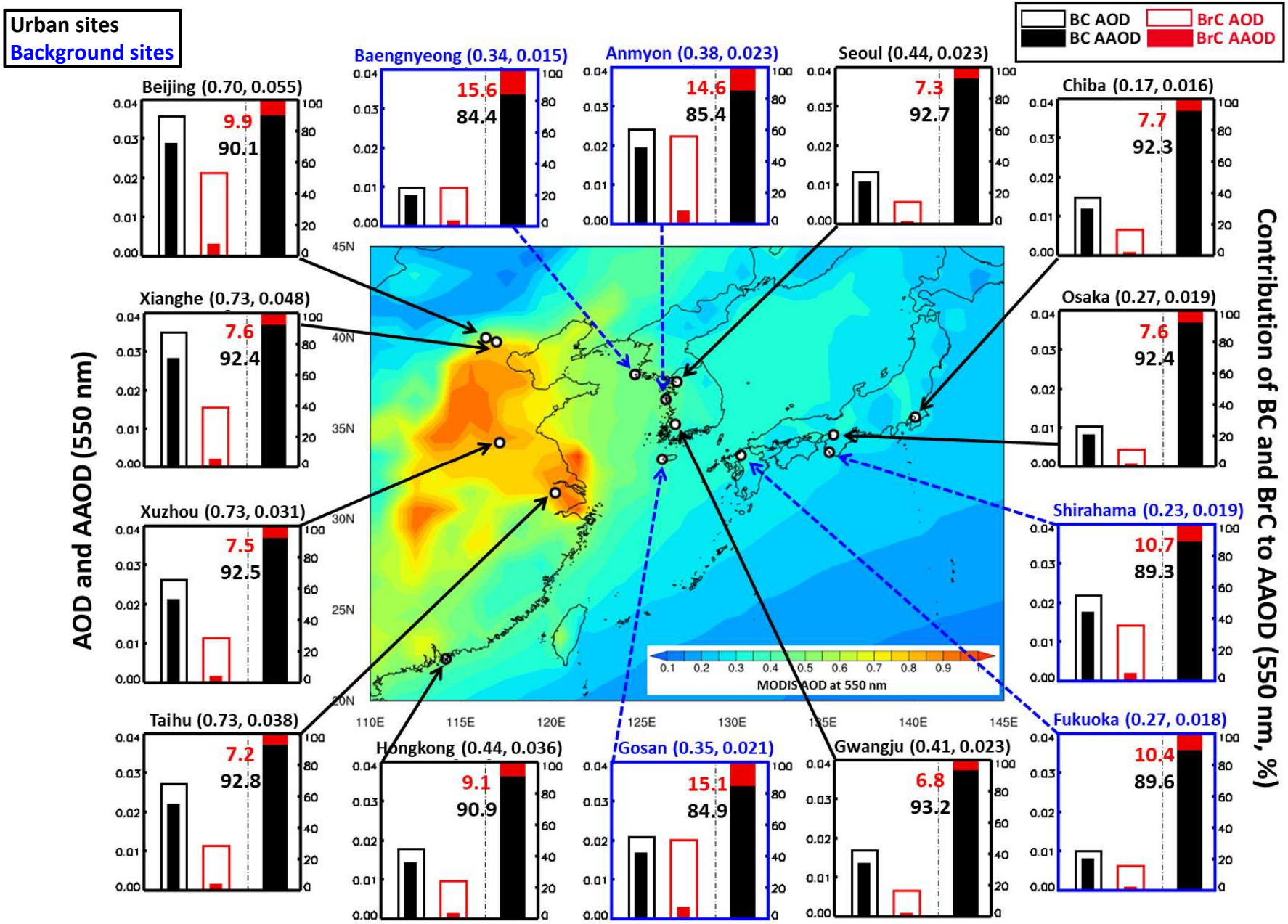
1) Removal of dust absorption was done using the wavelength dependence of absorption of dust particles, since aerosol optical depth (AOD) for dust is nearly wavelength independent, while aerosol absorption optical depth (AAOD) increases steeply at shorter wavelengths compared with carbonaceous aerosols (Russell et al., 2010; Bahadur et al., 2012; Chung et al., 2012b).

2) The AAOD, calculated as "AAOD=(1-SSA)×AOD", was **separated into BC ($AAOD_{BC}$) and BrC ($AAOD_{BrC}$)**, to account for their individual contribution, using their spectral dependence on absorption, normally represented by the absorption Ångström exponent (AÅE; the so-called "AÅE approach"; Bahadur et al., 2012; Chung et al., 2012b).

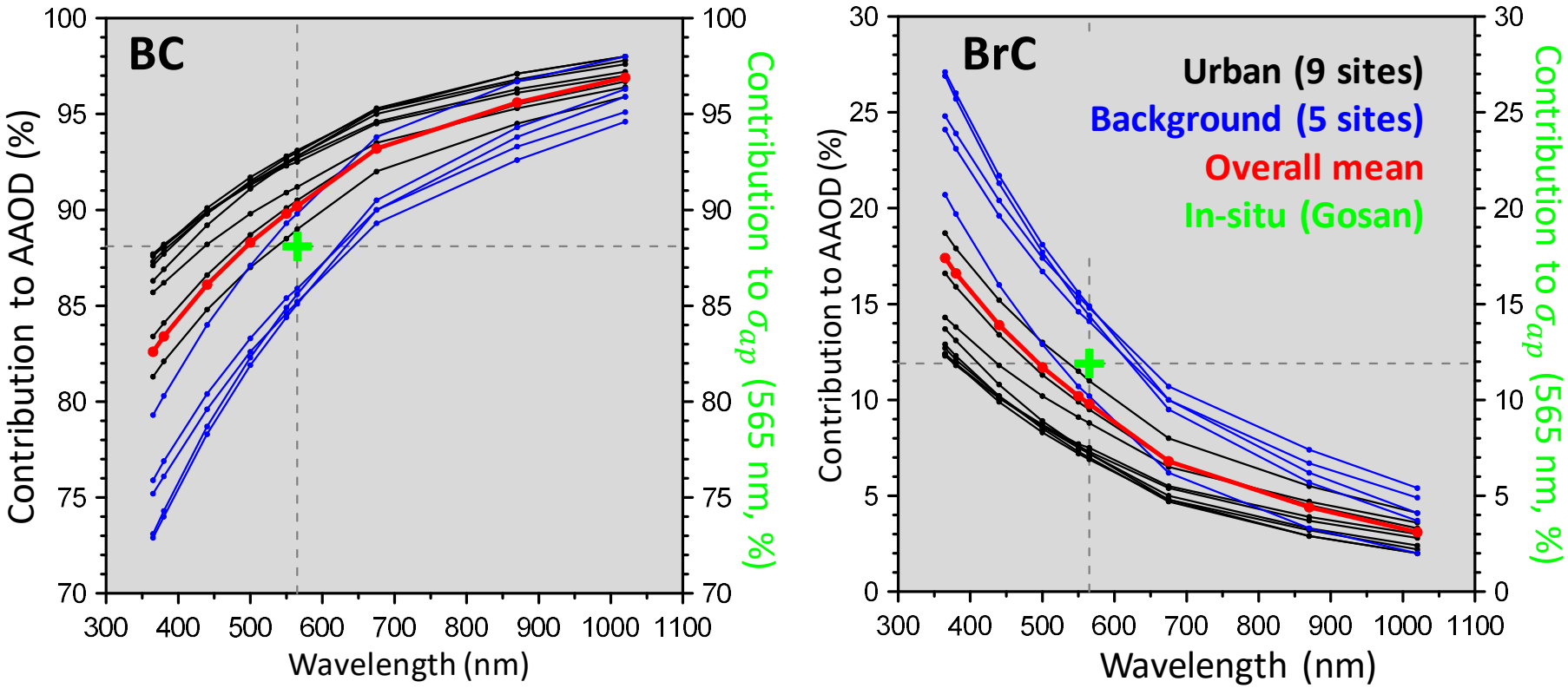


3) The AAOD for BC ($AAOD_{BC}$) and BrC ($AAOD_{BrC}$) were finally converted into **the AOD for BC (AOD_{BC}) and BrC (AOD_{BrC})**, respectively, by using the SSA for BC and BrC suggested by Magi et al. (2009) and Chung et al. (2012).

Contribution of BC and BrC to AAOD

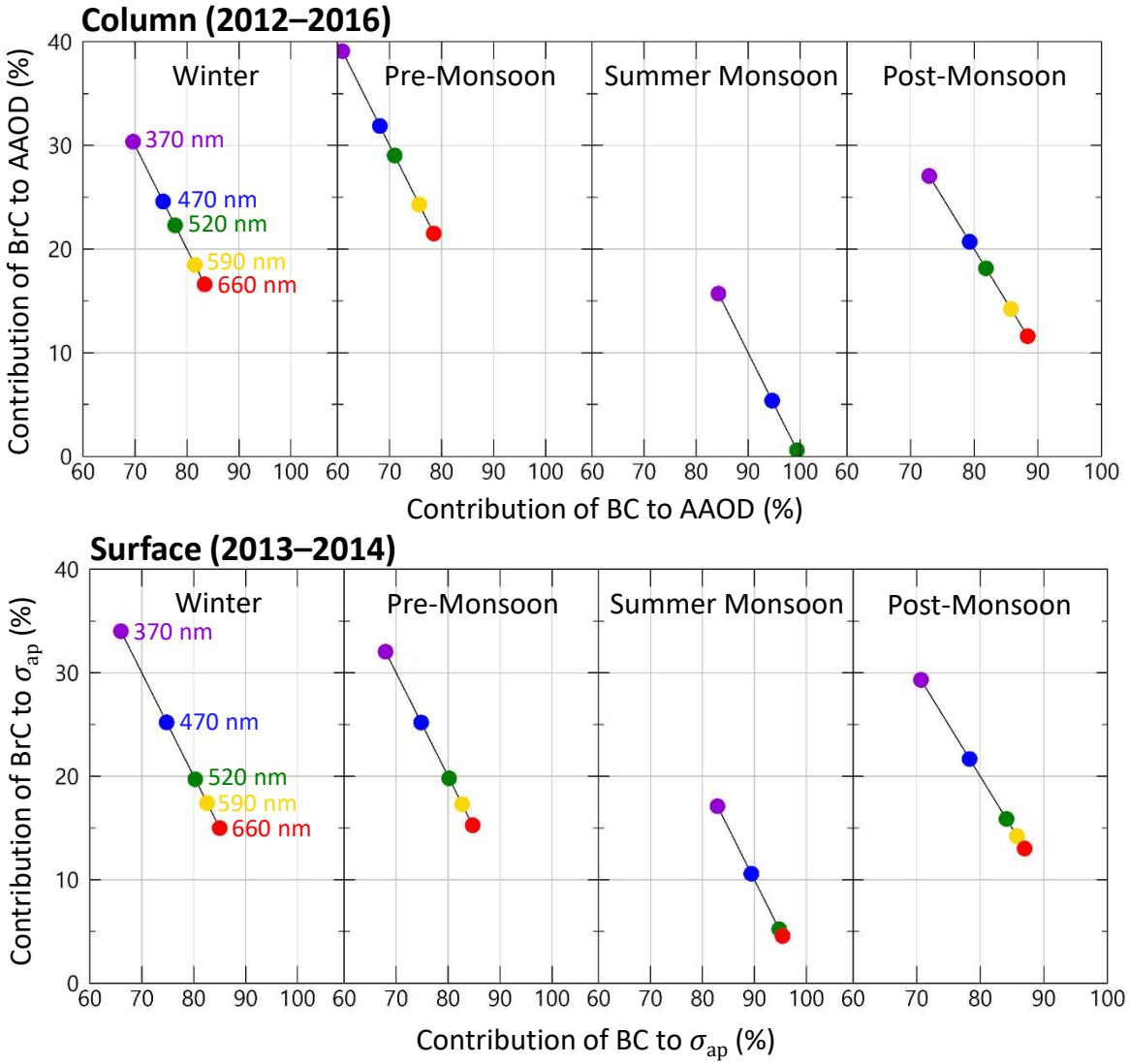


Contribution of BC and BrC to AAOD

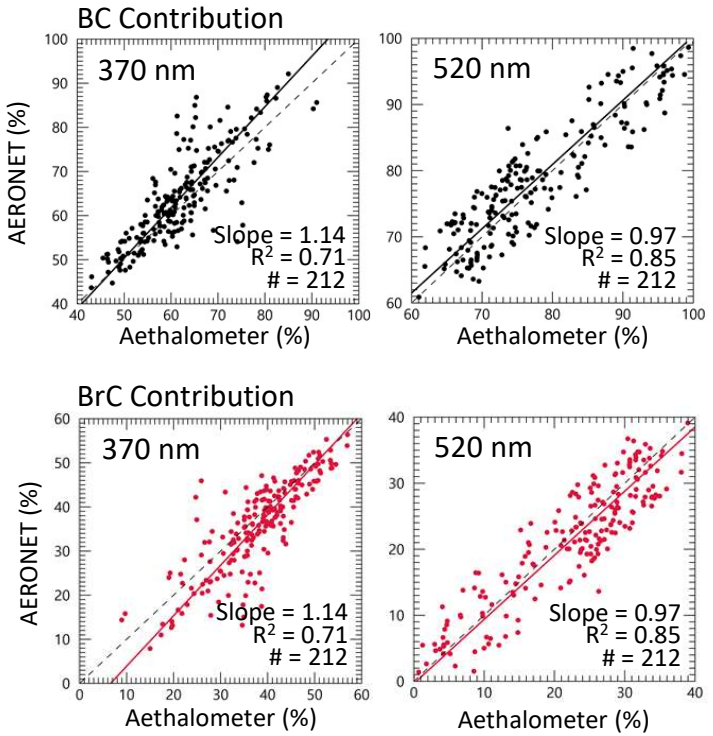


- The contribution of BC to AAOD was larger in polluted areas, whereas BrC contribution increased in background sites in East Asia.

Comparison of BC and BrC absorption in Kathmandu



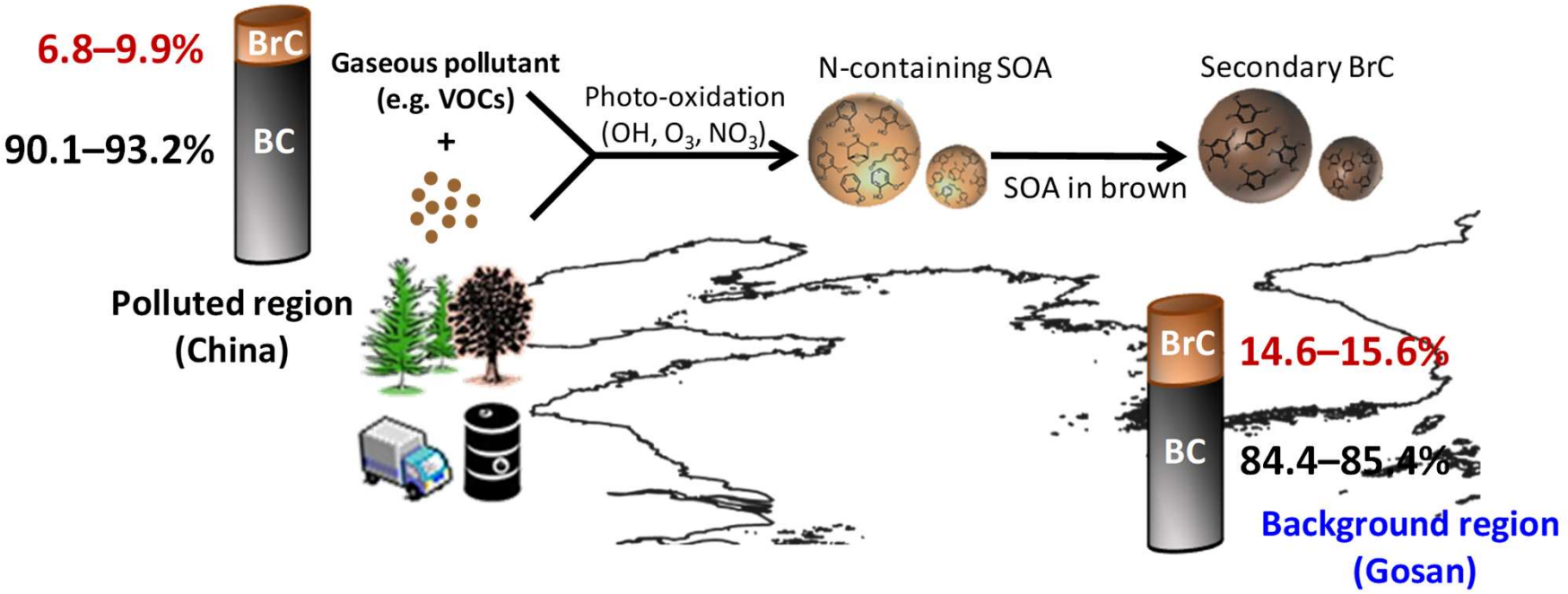
Simultaneous daytime observation data (February 2013–February 2014)



- The contributions of BC and BrC to light absorption at surface and in column were similar.

- In contrast to East Asia, BrC contribution was higher in the polluted site, whereas BC contribution was higher in the background site in South Asia.

Summary and Discussion



- BrC contribution to surface aerosol absorption coefficient (σ_{ap}) at 370 nm at Gosan was approximately 5% higher than that at 350–450 nm in polluted Chinese urban sites due to primary BrC transported from China and the formation of secondary BrC during long-range transport.
- In columnar atmosphere, the contribution of BC to AAOD was larger in polluted sites (mean: 92.1±3.5%; range: 90.1–93.2%), whereas BrC contribution increased in background sites (10.4–15.6%).

감사합니다

Thank you~!