Characteristics of Carbonaceous Aerosol in Guangzhou during the 2006 PRD Campaign: Optical Properties and Mixing State

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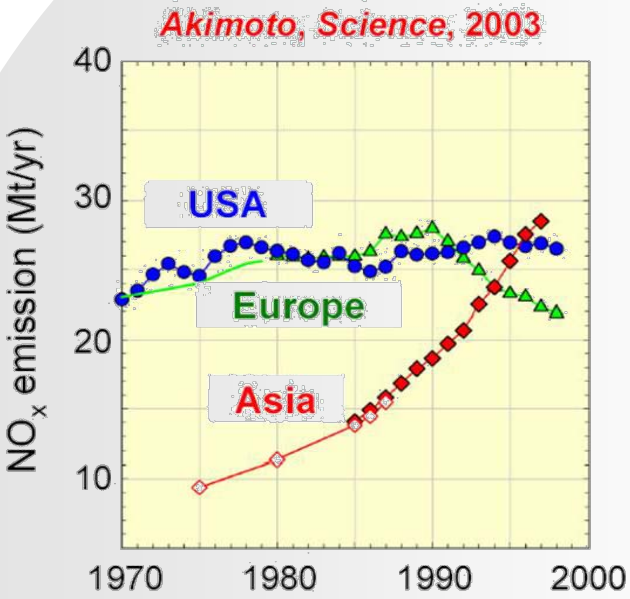
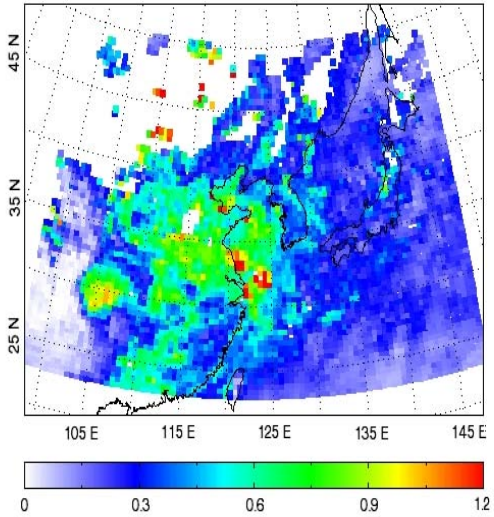
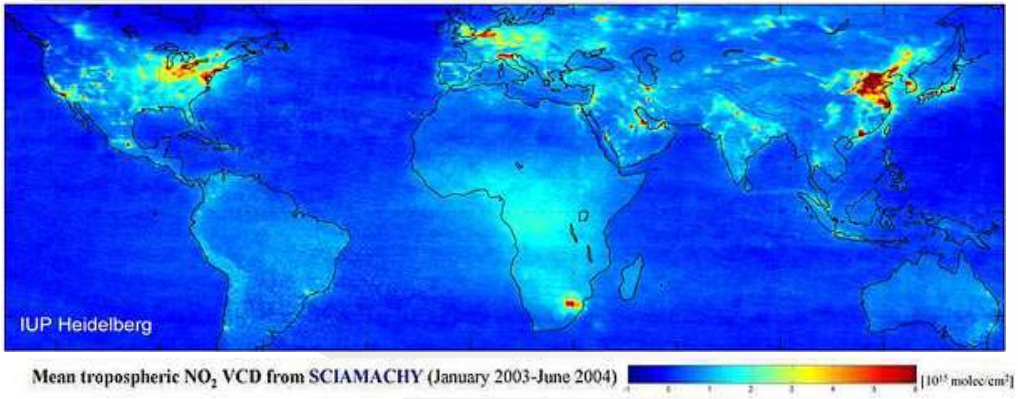
Increases of Emissions in Asia

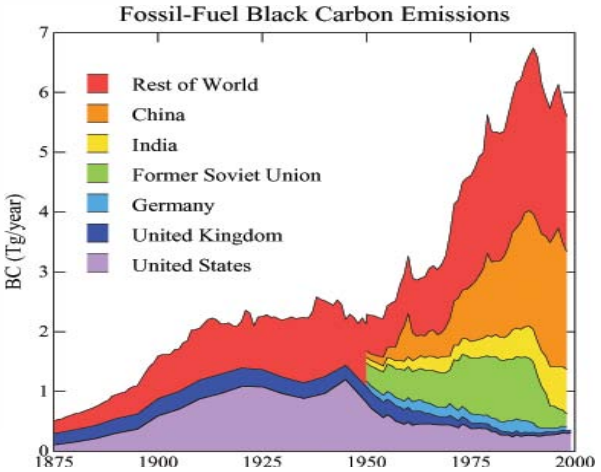


MODIS AOD (February 11 ~ 28, 2003)



Global NO_2 map (Jan. 2003~ June 2004)

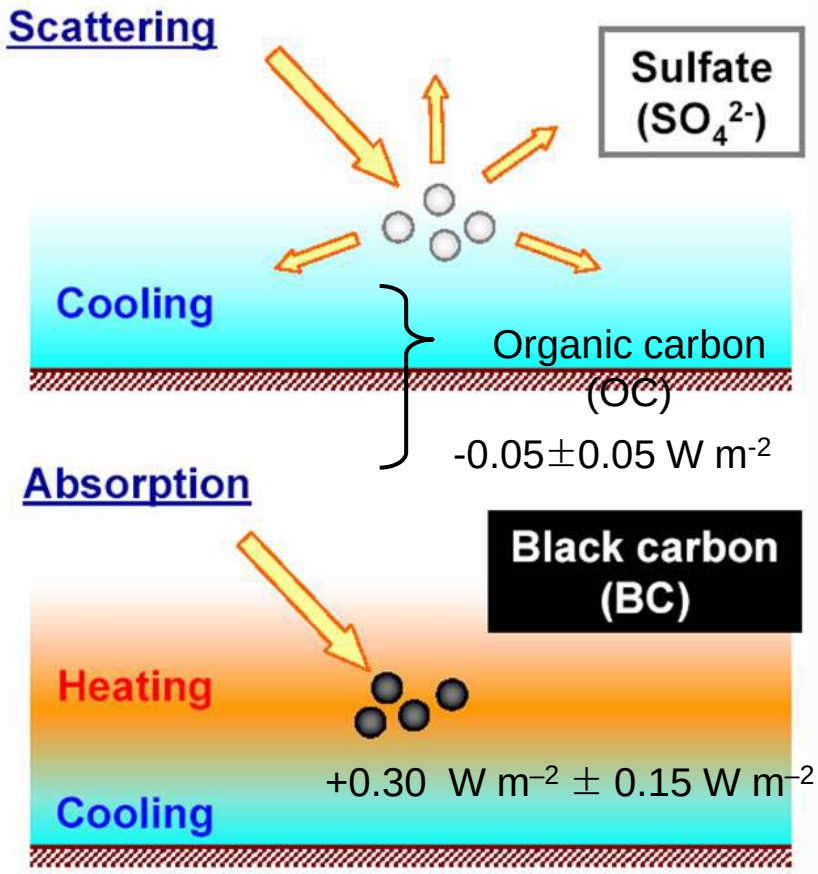




[Novakov et al., GRL, 2002]

Why carbonaceous aerosol is important?

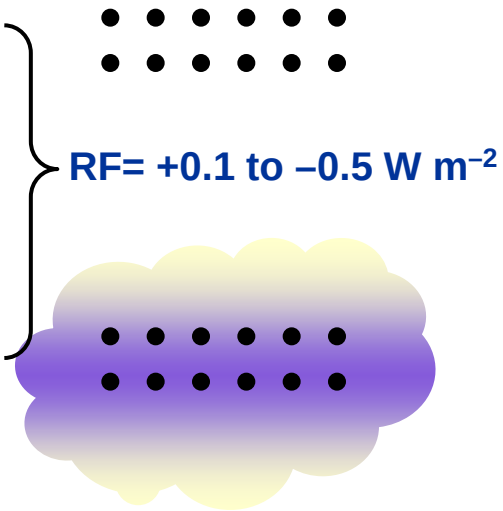
Direct effect



Semi-Direct Radiative Forcing

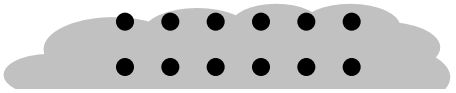
BC above Cloud layer
: increase cloud formation
➔ Cooling effect

BC within Cloud layer
: reduce cloud formation
➔ Warming effect



RF= +0.1 to –0.5 W m^{-2}

BC on Snow
: reduce albedo
➔ Warming effect

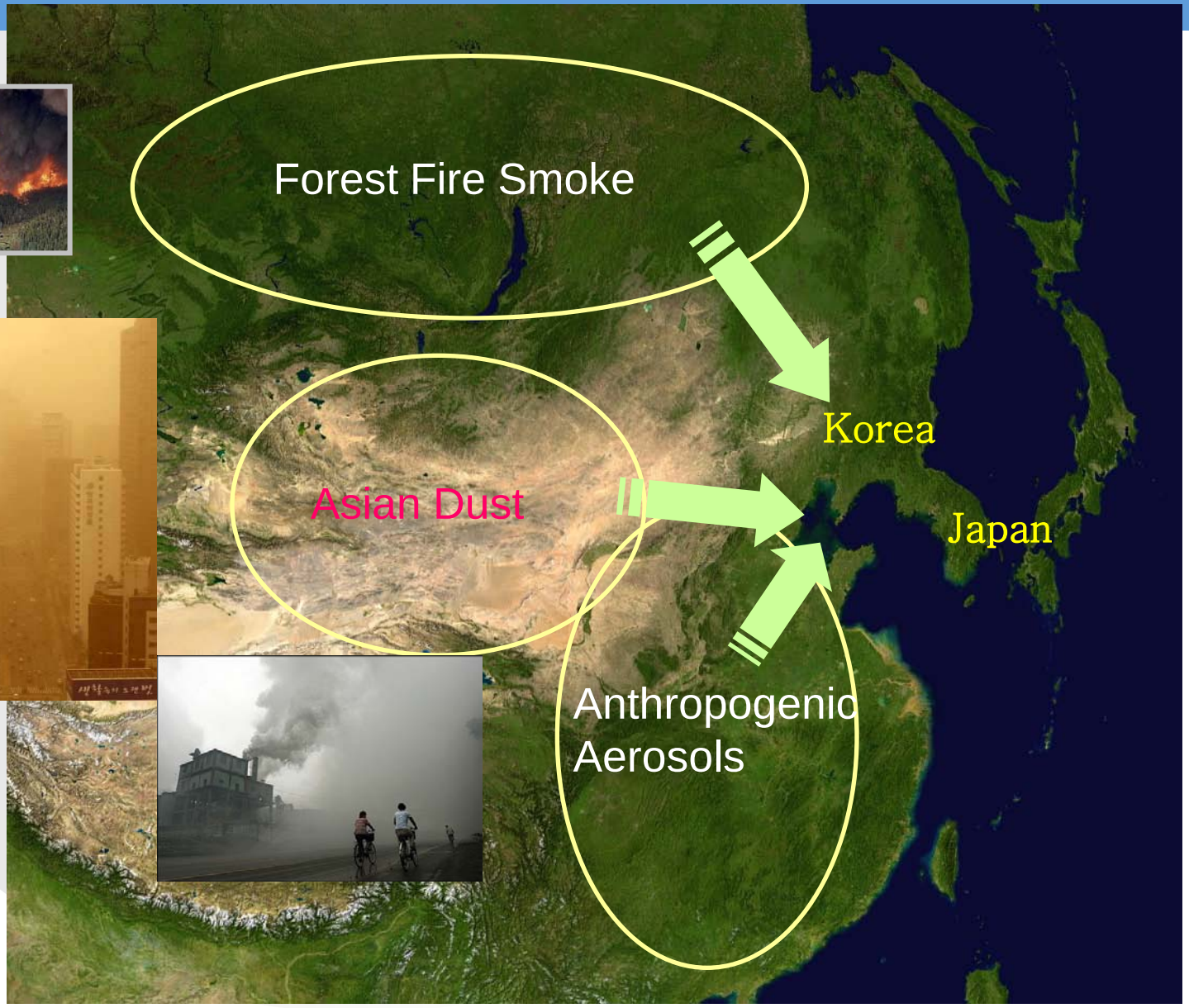


RF= +0.1W m^{-2} ±0.3 W m^{-2}

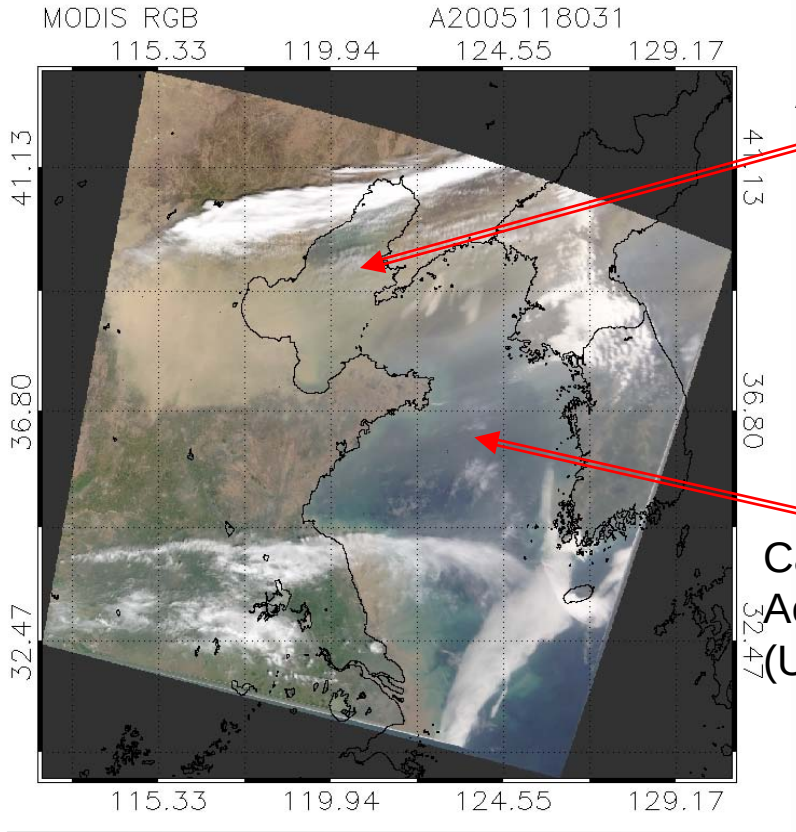
[IPCC, 2007]

Introduction

Long-range Transport of Aerosol in Asia



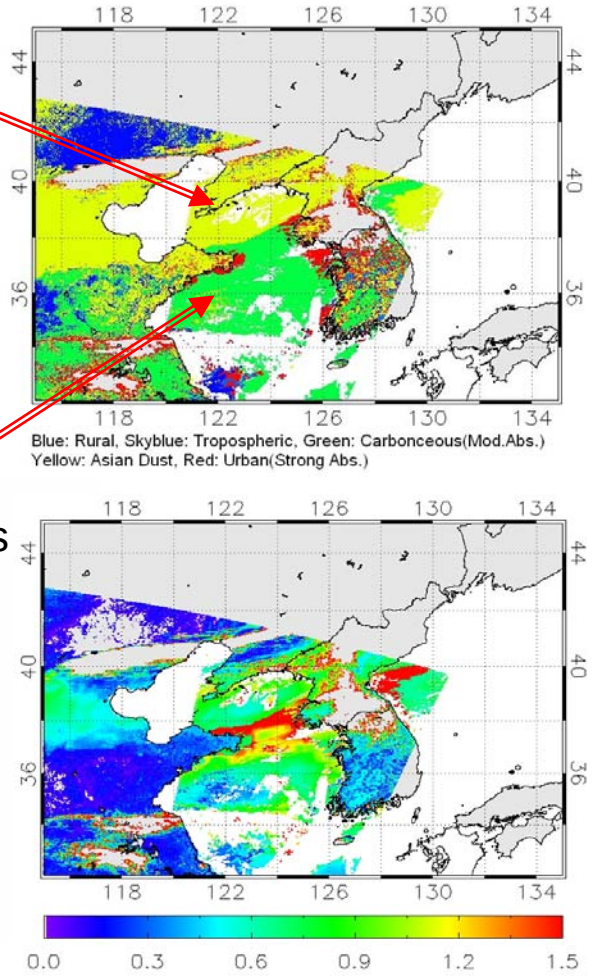
Long-range transport of aerosol in Asia



Asian Dust

Carbonaceous Aerosol (Urban)

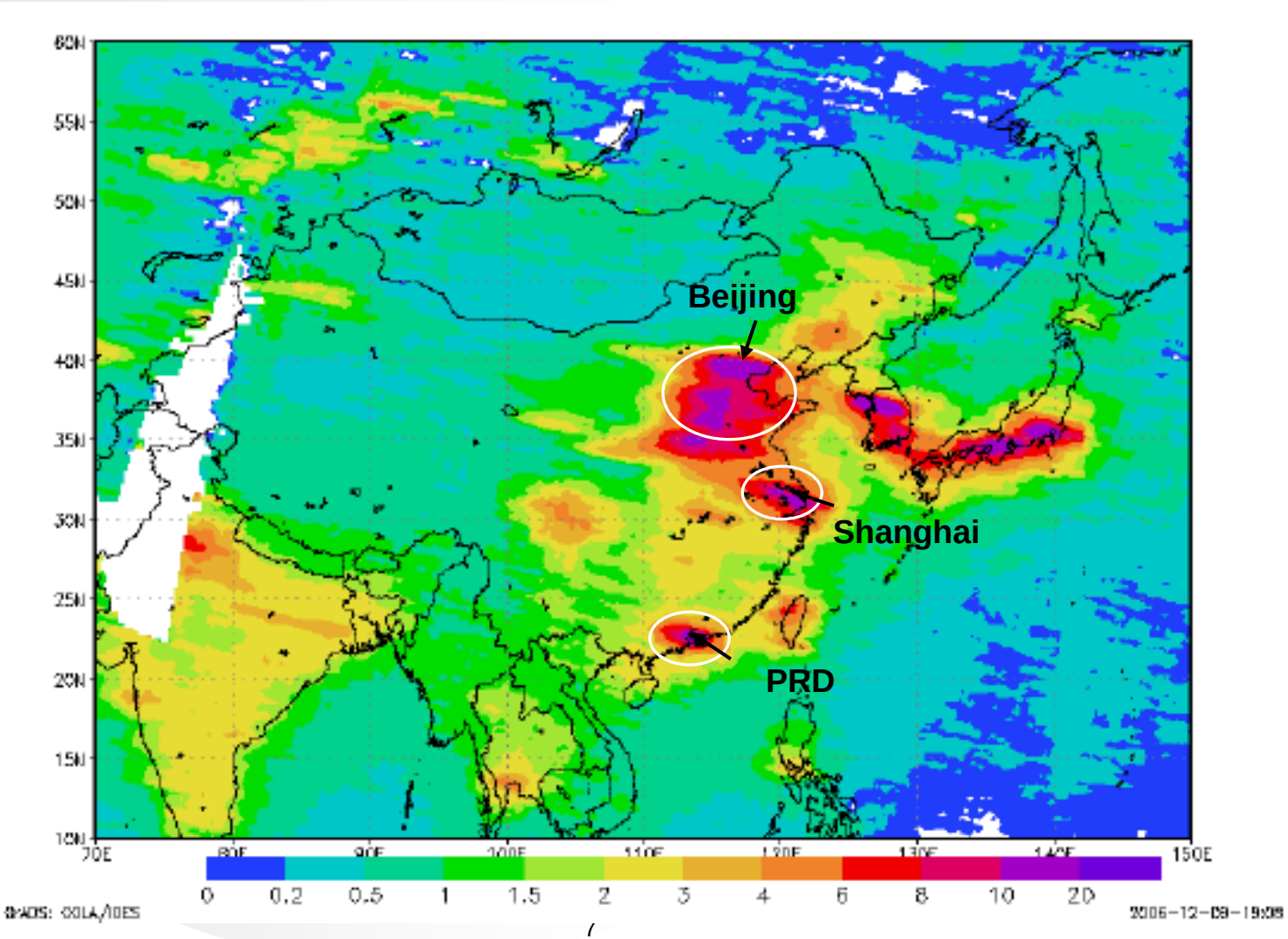
28~30 April 2005



[Jung et al., 2006]

Introduction

Average Vertical Column Density of NO2 Observed by GOME: 1997~2006



Program of Regional Integrated Experiment of Air Quality over Pearl River Delta (PRIDE-PRD) Campaign

►2004 PRIDE-PRD campaign
- Period: 4 October ~ 5 November 2004
- Sites: urban (Guangzhou), non-urban (Xinken)

►2006 PRIDE-PRD campaign
- Period: 2 ~ 31 July 2006
- Sites: urban (Guangzhou), downwind rural (Backgarden)

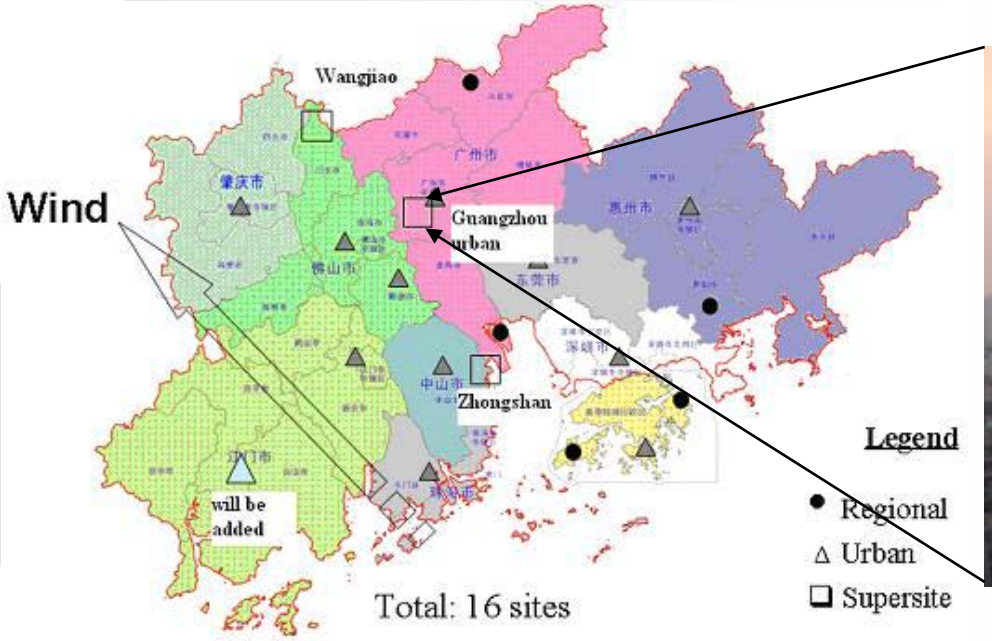
►2008 PRIDE-PRD campaign
- Period: mid October ~ mid November 2008
- Sites: upwind (Conghua), downwind (Jiangmen), urban (Guangzhou)

-Perticipants: Peking University, Chinese Universities and Institutes, RCEC (Taiwan), IFT, JRC, MPI (Germany), Univ of Tokyo & NIES (Japan), GIST (Korea), MIT (USA)

Objectives of PRIDE-PRD campaign

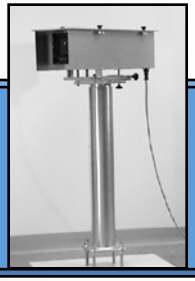
- Understand and quantify current complex air pollution problem in PRD.
- Understand chemical composition, size distribution, hygroscopic properties, and optical properties of aerosols.
- Quantify formation of oxidants and secondary aerosol by measurements and modeling
- Study on interaction of aerosols and gases through measurements of precursors of aerosols and oxidants (e.g., HNO3, NH3) as well as by modeling.
- Validation of modeling of transformation and transport for oxidants and aerosol
- Determine source-receptor relationship in PRD.
- Define the regional mitigation strategies and technical options to keep the air pollution load in PRD within sustainable limits in terms of ecological effects and human health effects.

GIST Measurement (PRD 2006)



GIST/ ADEMRC

Sunset OC/EC analyzer : thermal OC and EC, optical EC

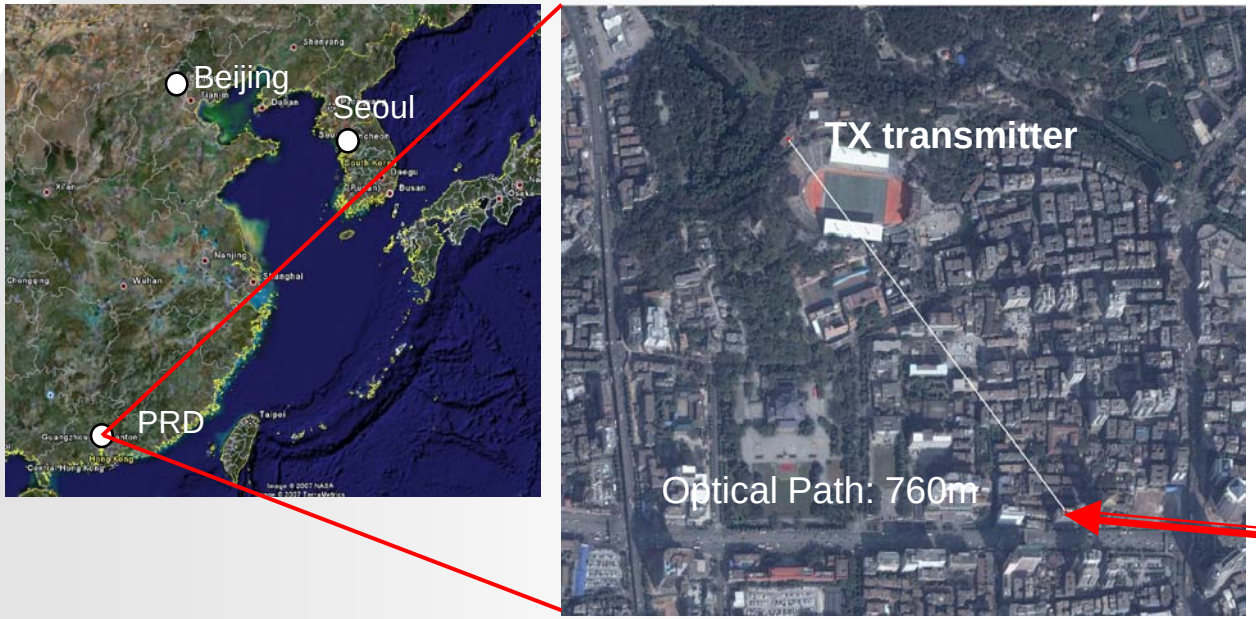


Transmissometer (TX) : bext

Aerosol spectrometer : PM mass, size distribution

MAX-DOAS : NO_2, SO_2, HCHO

Measurement site and parameters



-Site: Guangzhou, China
(23.13˚N, 113.26 ˚E)

- Period: 2 ~ 31 July 2006

PRD urban supersite
-TX receiver

Measurement parameters	Monitoring instrument	Diameter	Interval
Light absorption coefficient (b_{abs})	Aethalometer (AE16, Magee Scienctific, Berkeley, USA)	D_p < 2.5μm	5 minute
PM_{10}, $PM_{2.5}$, $PM_{1.0}$ mass concentration	Aerosol Spectrometer (265, Grimm Aerosol Technik, Ainring, Germany)	D_p < 10, 2.5, 1.0μm	30 minute
Organic carbon/ elemental carbon (OC/EC)	Semi-continuous OC/EC analyzer (RT3015, Sunset Laboratory, Oregon, USA)	D_p < 2.5μm	1 hour

Guangzhou

GIST Measurement Parameters (PRD 2006)

Measurement parameter	Instrument	Averaging time
SO_2, NO_2, aerosol	GIST MAX-DOAS	15 min
SO_2, NO_2, aerosol	GIST Imaging DOAS	20 min
Light extinction coefficient (b_{ext}) (Visibility)	Optec Transmissometer	1 min
Light scattering coefficient (b_{scat})	Ecotech Nephelometer (PKU)	5 min
Light absorption coefficient (b_{abs})	Magee Aethalometer (PKU)	5 min
$PM_{2.5}$ OC/EC mass concentration	Sunset semi-continuous carbon field instrument	1 hr

Objectives of GIST Measurement at Urban Site

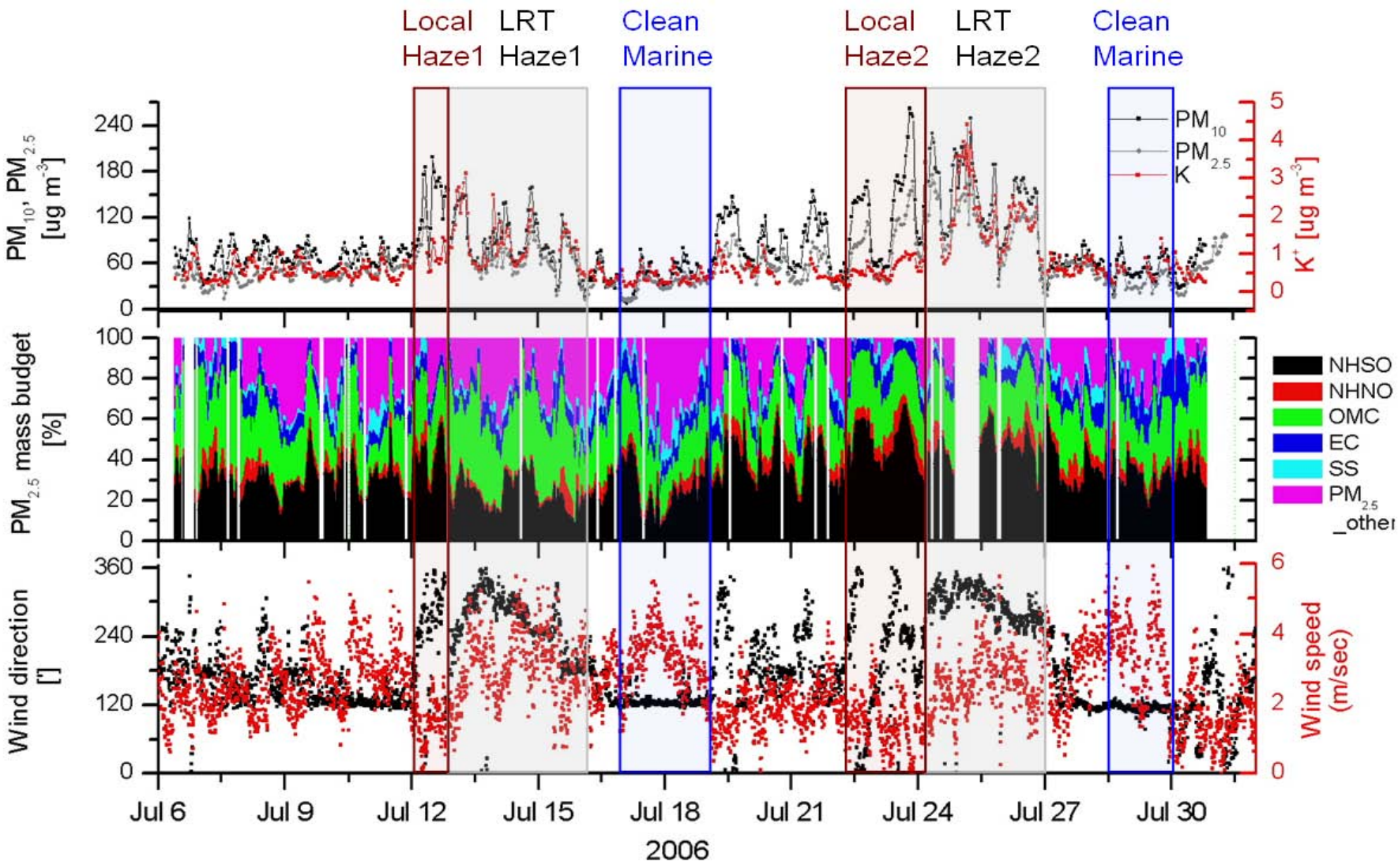
► The effect of aerosol chemistry and aerosol water on air quality, visibility impairment, and radiative forcing in Guangzhou

► Time-resolved measurement of carbonaceous aerosol in Guangzhou

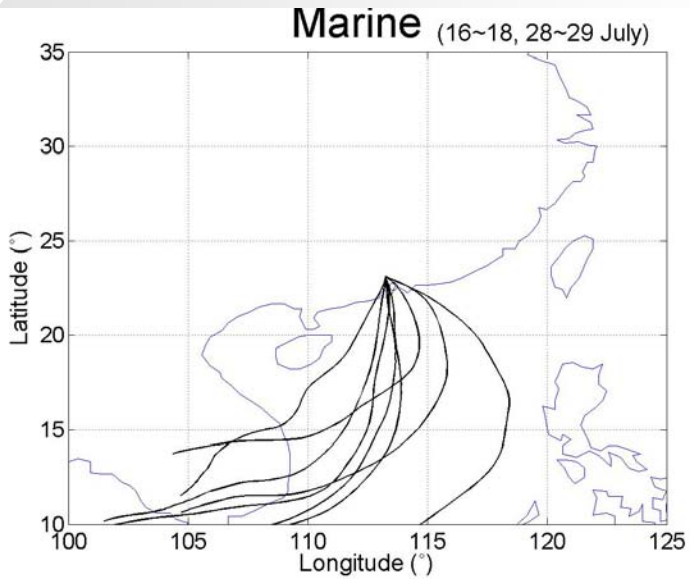
► MAX-DOAS measurement of gaseous and particulate pollutants

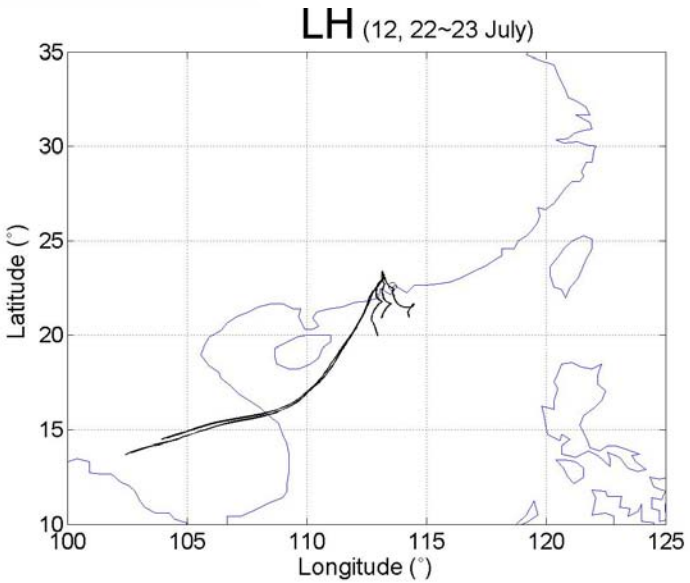
► Size distribution and f(RH) of urban aerosol

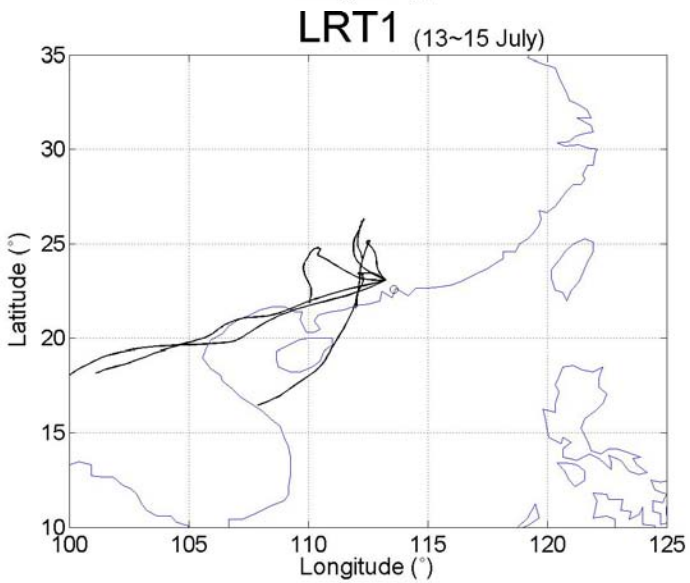
Classification of Atmospheric Conditions

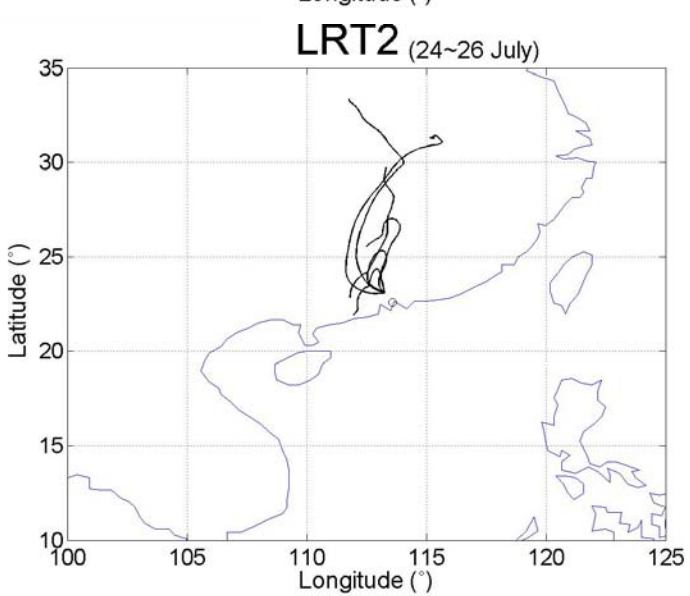


Three-day Air Mass Back-trajectories

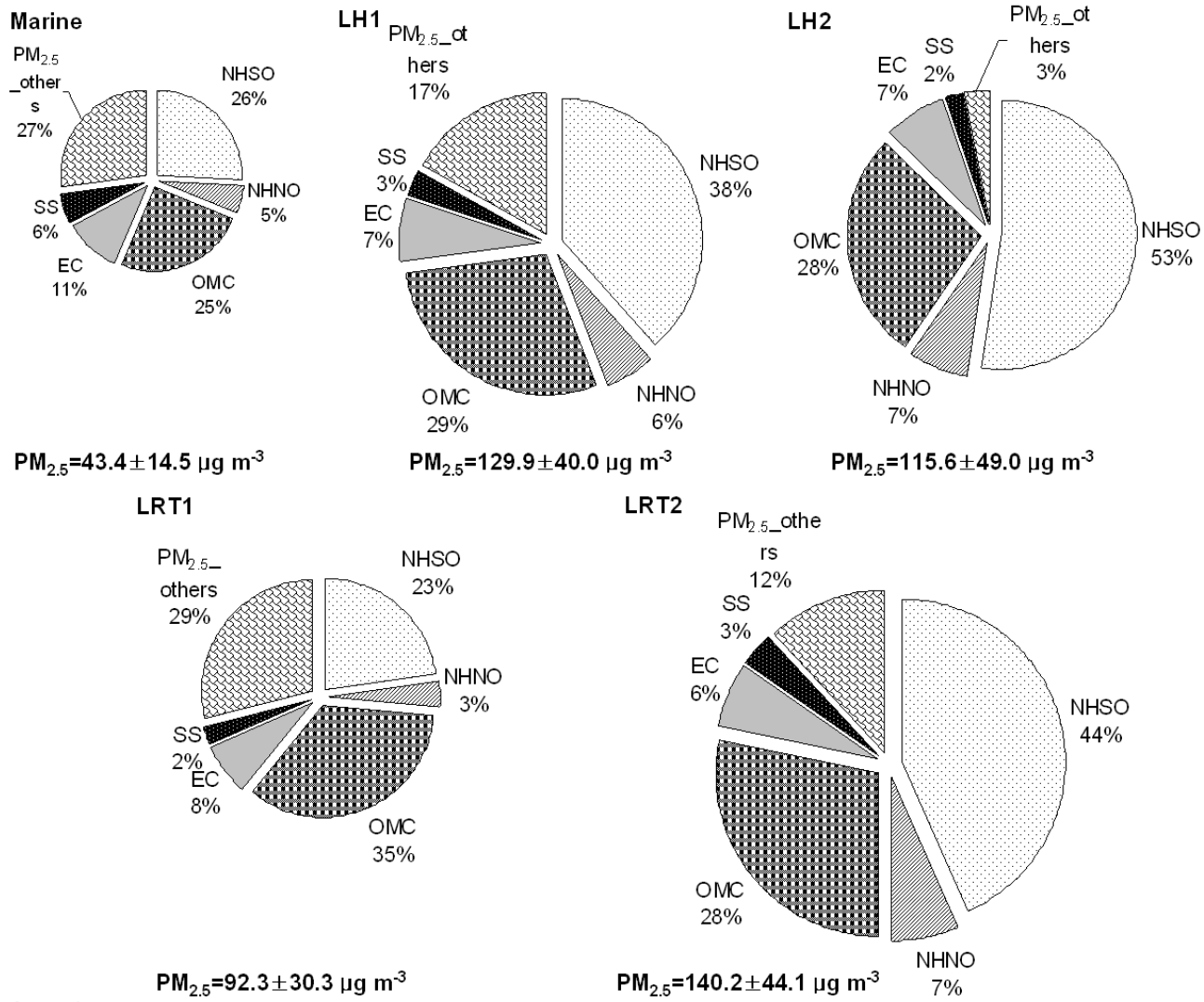








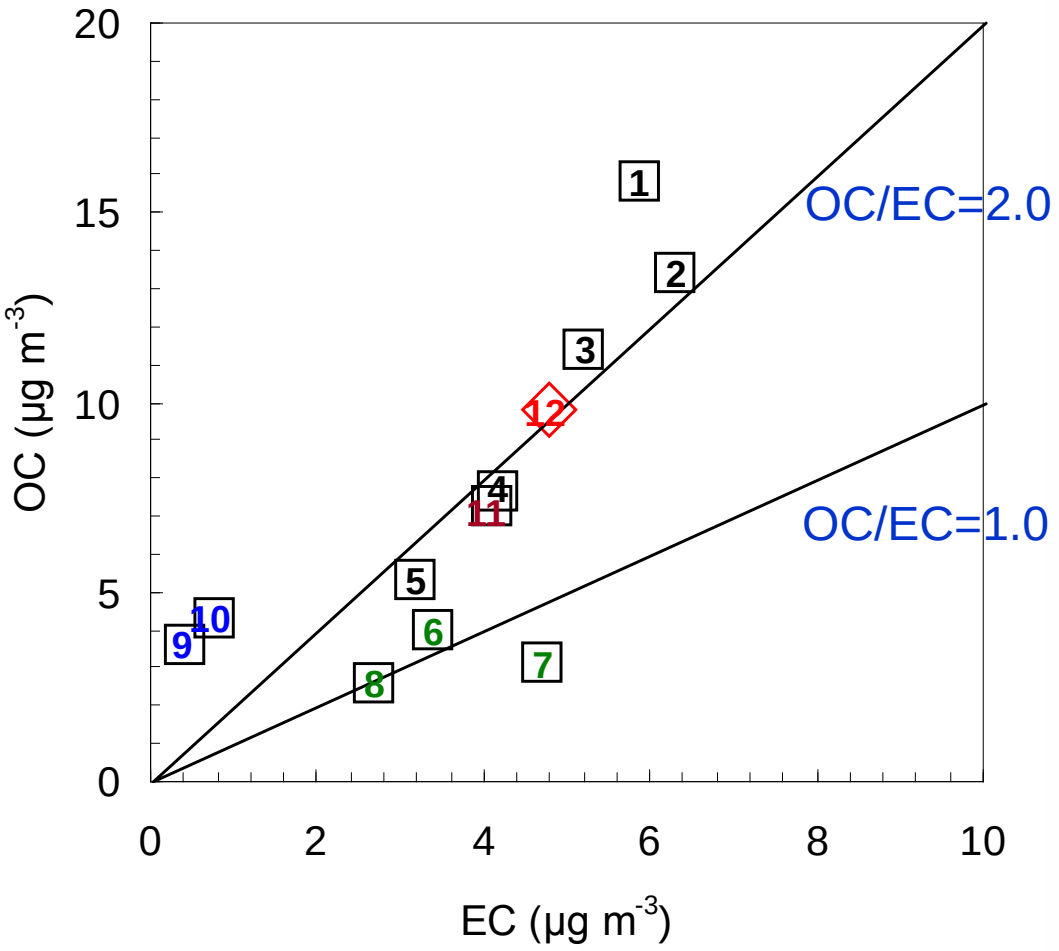
$PM_{2.5}$ Mass Budget



Summary of Aerosol Properties

	PM_{10}	$PM_{2.5}$	SO_4^{2-}	NO_3^-	OC	EC	BC	OC/EC	b_{scat}
	μg m^{-3}								Mm^{-1}
Marine	43.4 ± 14.5	34.0 ± 10.9	6.3 ± 2.8	2.5 ± 1.0	5.0 ± 2.8	3.6 ± 1.9	4.4 ±2.2	1.5 ± 0.7	74.1 ± 30.7
LH1	129.9 ±40.0	93.8 ± 27.3	26.4 ± 13.3	5.6 ± 2.8	15.9 ± 5.9	6.8 ± 2.5	9.0 ±3.7	2.4 ± 0.6	318.8 ± 110.4
LH2	115.6 ± 49.0	86.9 ± 37.2	33.9 ± 17.4	5.1 ± 3.0	14.4 ± 7.3	6.6 ± 2.9	9.0 ±4.3	2.1 ± 0.7	306.3 ± 165.7
LRT1	92.3 ± 30.3	68.2 ± 20.1	11.5 ± 6.0	3.2 ± 2.4	13.9 ± 5.3	5.4 ± 1.7	6.6 ±2.3	2.8 ± 1.2	220.5 ± 72.3
LRT2	140.2 ± 44.1	108.2 ± 32.2	31.5 ± 11.1	5.1 ± 4.1	16.9 ± 6.4	6.5 ± 2.5	9.5 ±4.3	2.8 ± 1.0	418.9 ± 155.0

Average $PM_{2.5}$ OC vs. EC in Different Areas in Asia



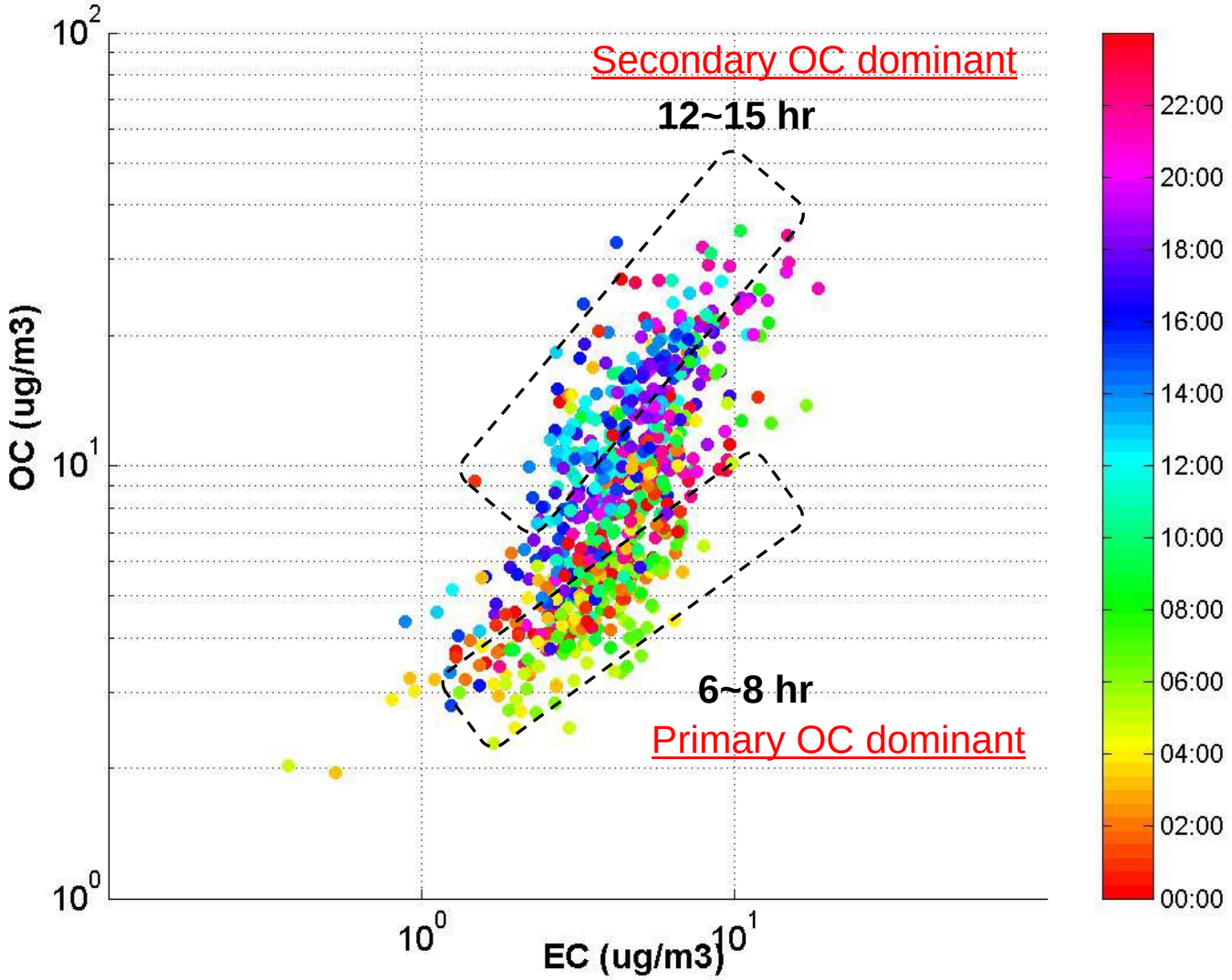
1 Guangzhou, China (Cao et al., 2004)
2 Beijing, China (He et al., 2001)
3 Shanghai, China (Ye et al., 2003)
4 Shenzhen, China (Cao et al., 2004)
5 Hong Kong, China (Cao et al., 2004)
6 Chongju, Korea (Lee and Kang, 2001)
7 Sapporo, Japan (Ohta et al., 1998)
8 Uji, Japan (Holler et al., 2002)
9 Kosan, Korea (Kim et al., 2003)
10 Kangwha, Korea (Kim et al. 2000)
11 Seoul, Korea (Kim et al., 2007)
12 Guangzhou, China (this study)

OC = 9.8 ± 6.1 μg m^{-3}

EC = 4.8 ± 2.3 μg m^{-3}

OC/EC = 2.1 ± 1.0

Correlation between OC and EC



Retrieval of Secondary OC

Minimum OC/EC ratio method (Turpin and Huntzicker, 1991; Castro et al., 1999):

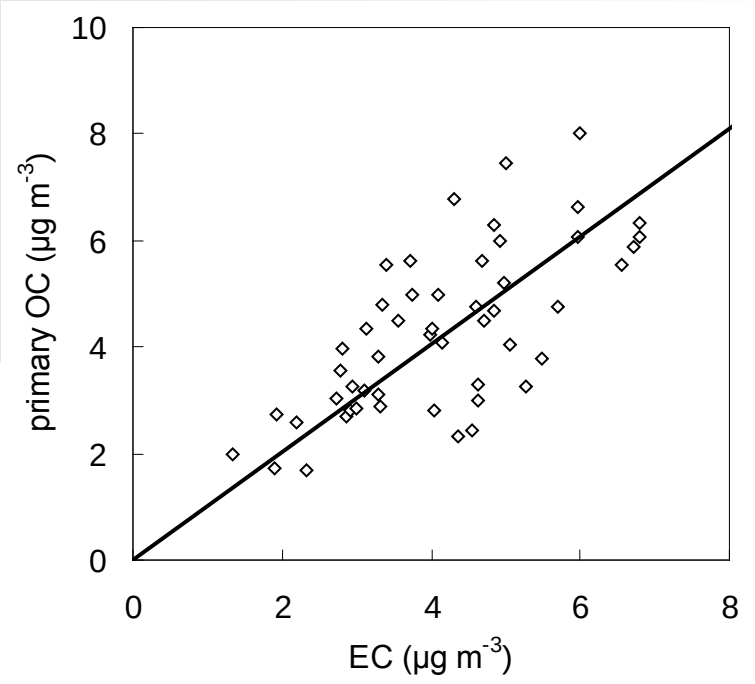
$$OC_{\text{sec}} = OC_{total} - EC \cdot (OC/EC)_{\min}$$

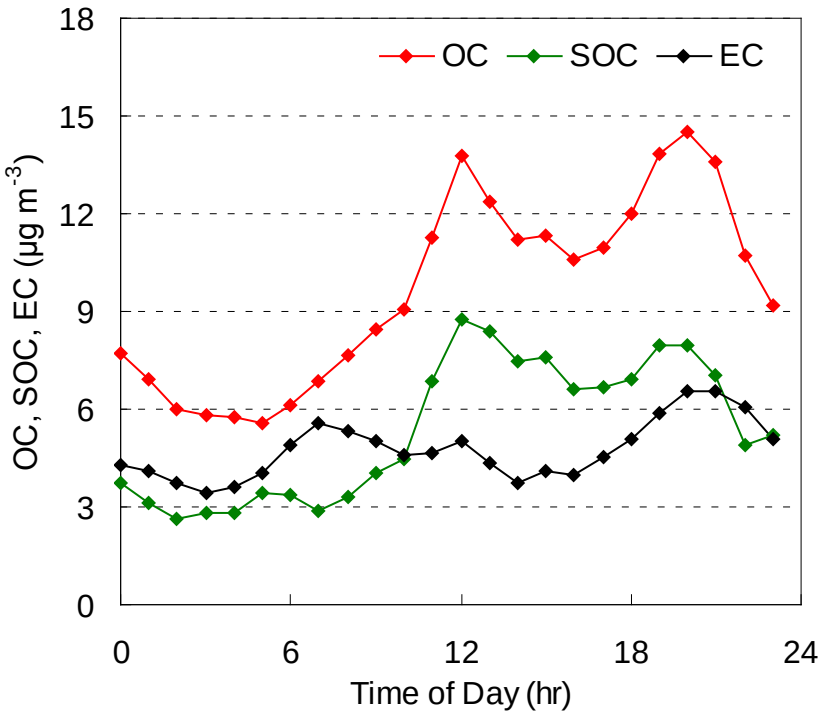
-Conditions:

Low photochemical processing period: 6~8 A.M.

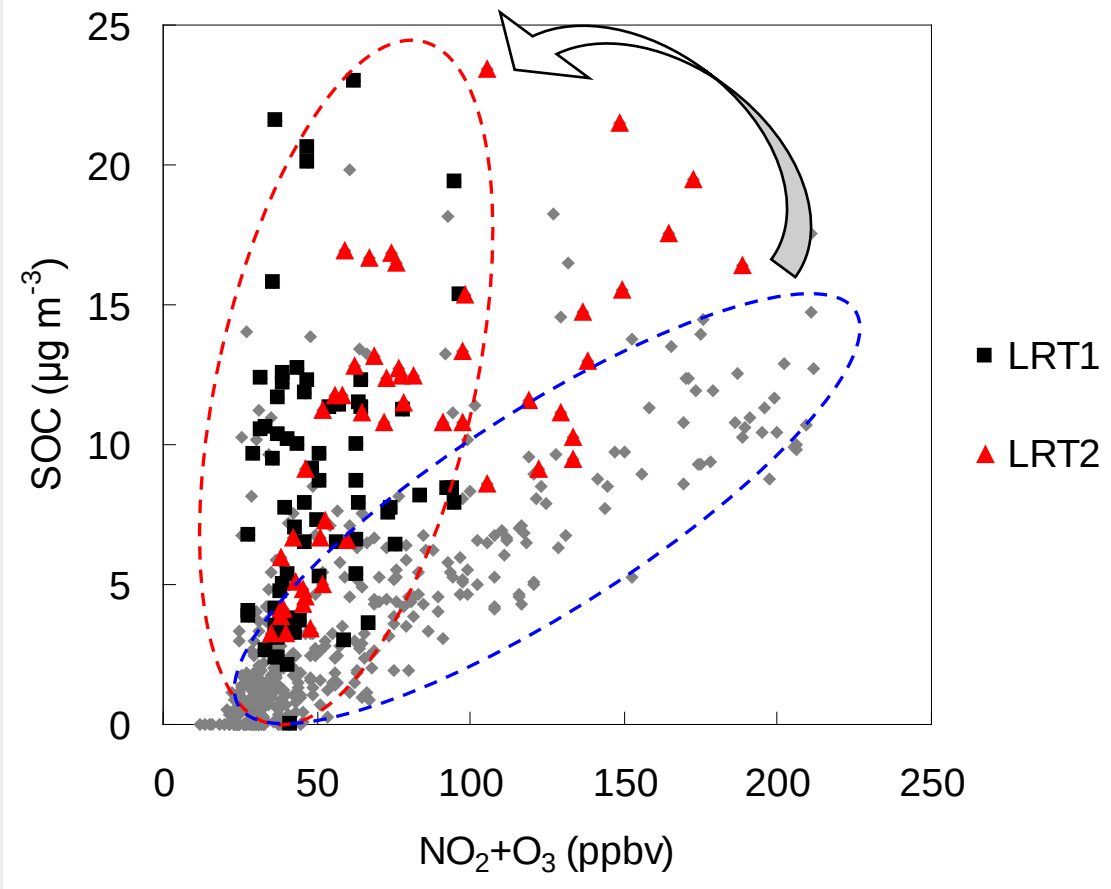
NO>40ppb, NO2+O3<40ppb

Avg. minimum OC/EC ratio = **1.06±0.28**



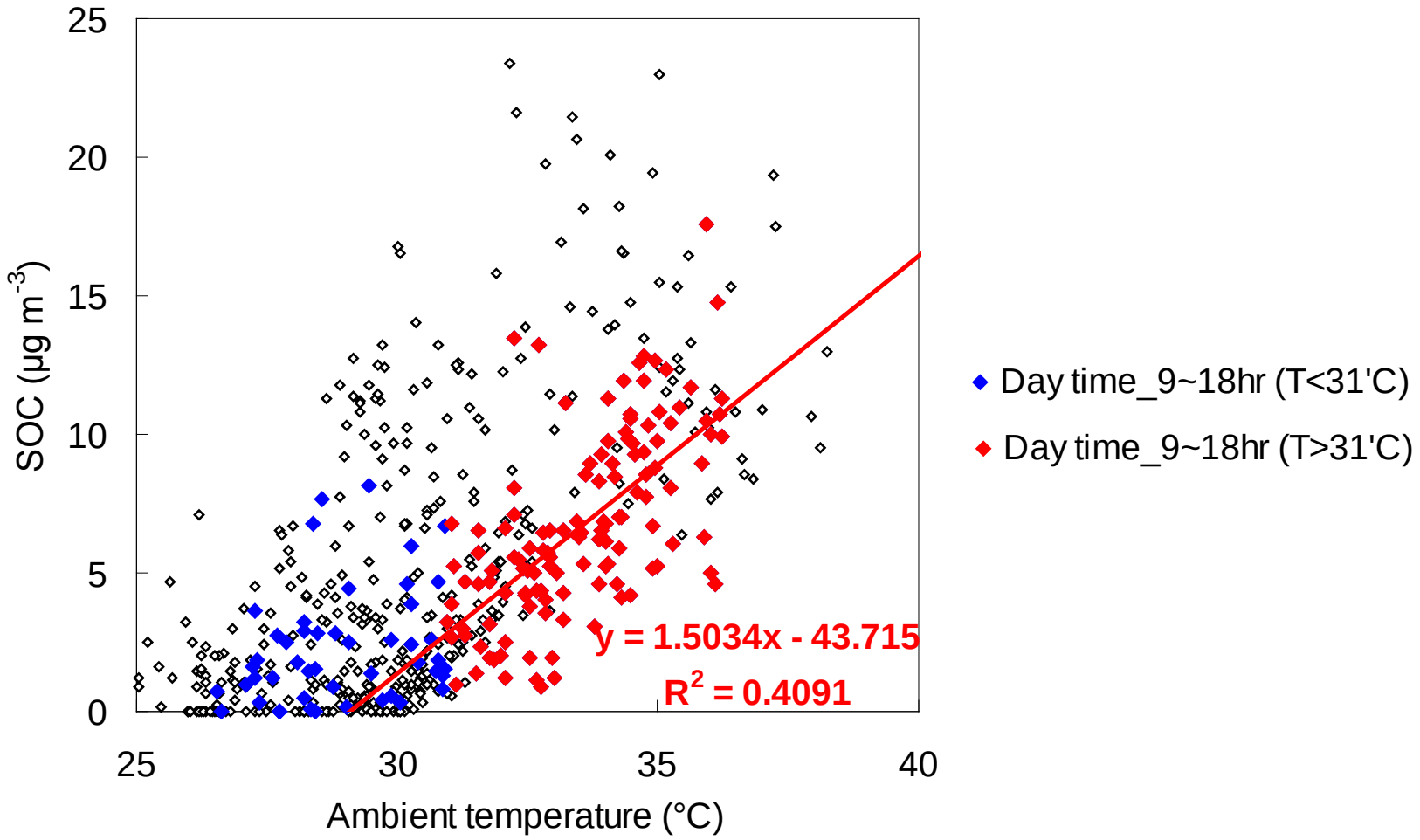


Secondary OC vs. Oxidant sum (NO_2+O_3)



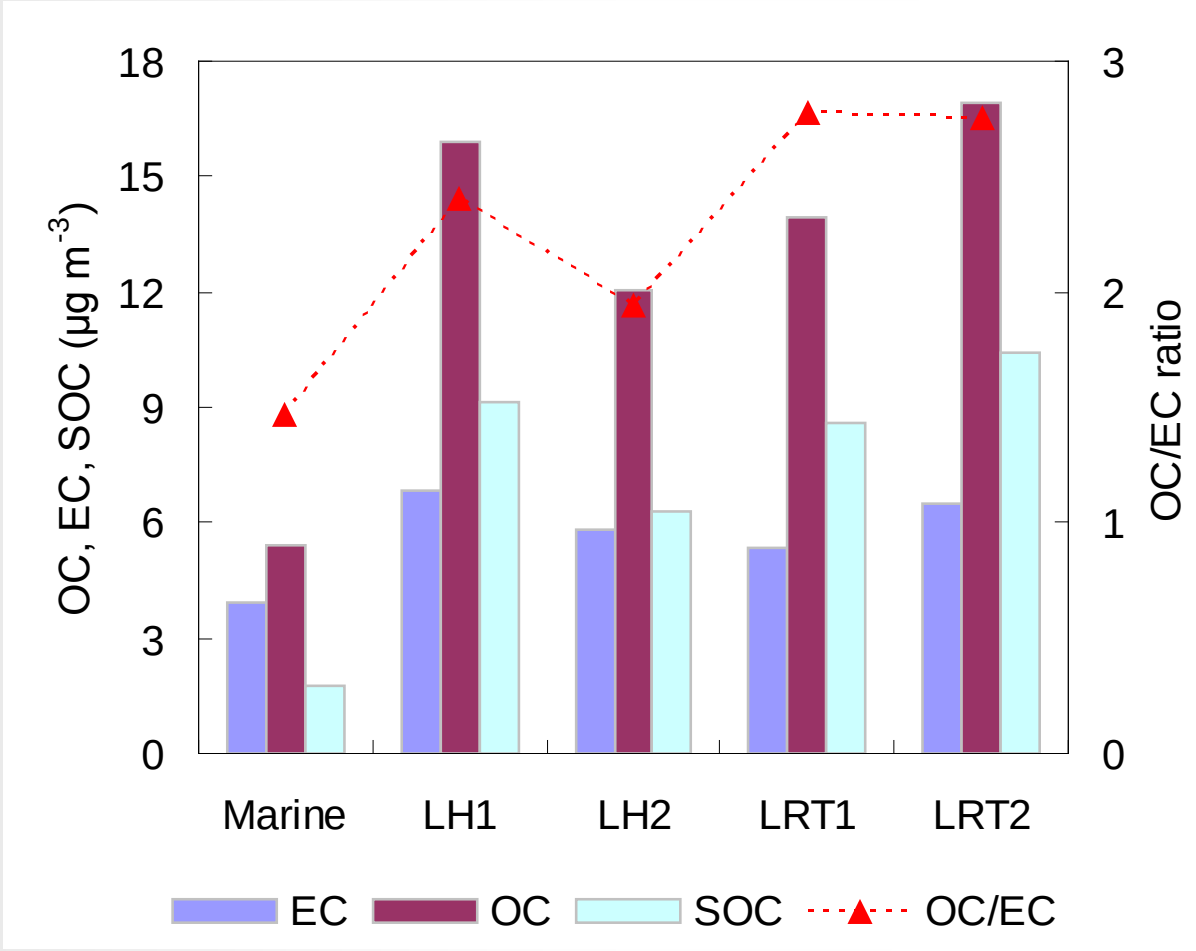
When SOC was compared with oxidant sum (NO_2+O_3), higher SOC was observed at the same value of oxidant sum during LRT period, which indicates the transport of secondary OC outside the measurement site.

SOC Formation vs. Ambient Temperature



The formation of secondary OC was highly correlated with ambient temperature as the formation rate of 1.5 µg C m^{-3}/C˚ under the condition of ambient temperature > 31˚C.

Carbonaceous Aerosol Characteristics



-Highest OC/EC ratio was observed during LRT period due to the transport of OC from biomass burning and the formation secondary OC during the transport.

Loading Effect on Aethalometer BC

"Shadowing" effect due to filter loading, R(ATN)

"Shadowing" effect due to filter loading ⇨ Decrease the b_{ATN} ⇨ R(ATN) <1

$$b_{aeth}(\lambda) = \frac{b_{ATN}(\lambda)}{C(\lambda) \cdot R(ATN)} \qquad R(ATN) = \left(\frac{1}{f} - 1\right) \cdot \frac{\ln ATN - \ln 10}{\ln 50 - \ln 10} + 1$$

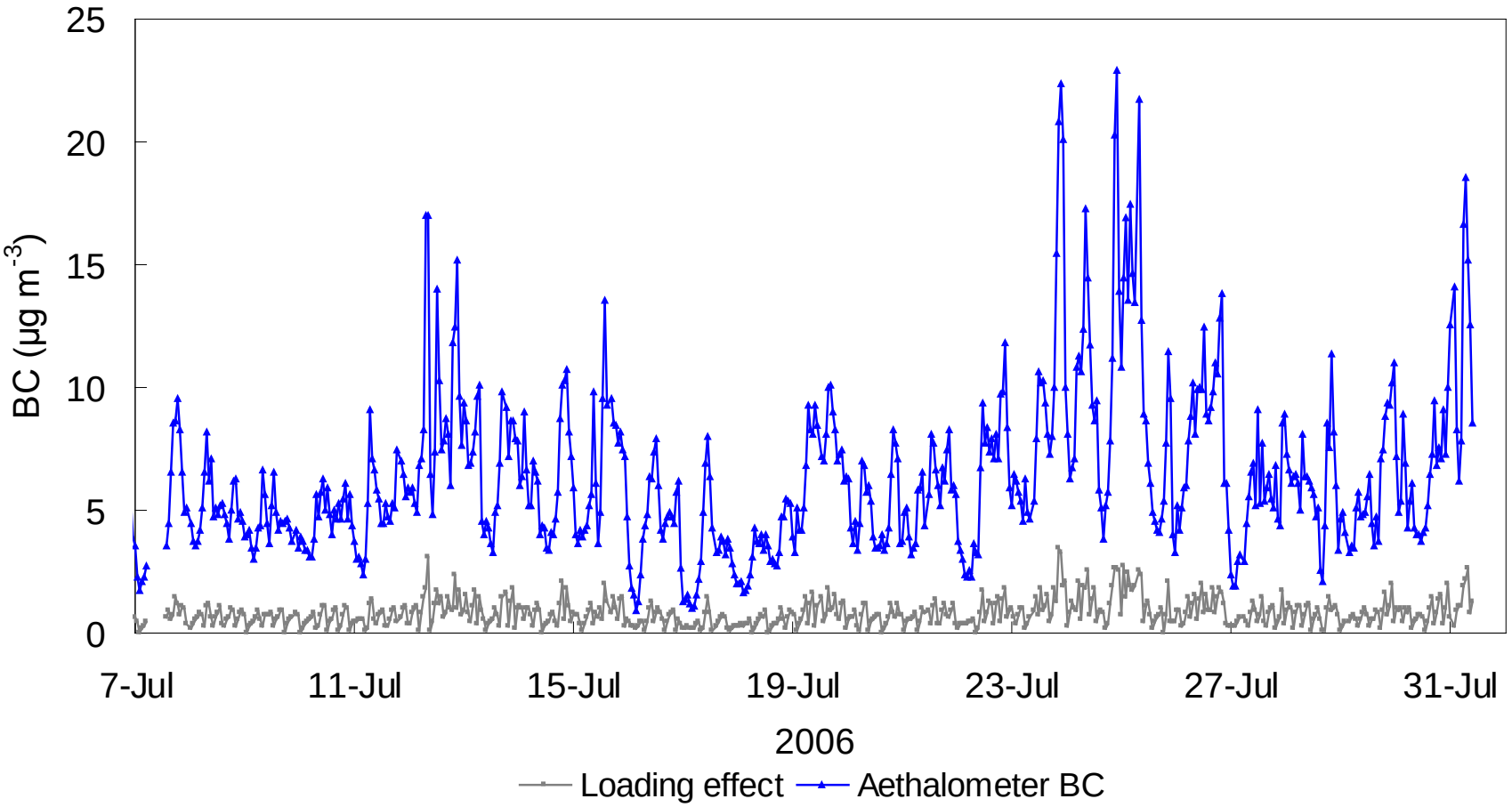
C(λ)>1 = multiple scattering correction factor within the filter.
Shadowing factor, f (when ω_0(532nm)<0.85)

$$f = a(1 - \omega_0) + 1$$

Here, a = 0.87±0.10 and 0.85±0.05 at λ=450 and 660nm, respectively. [Weingartner et al., 2003]

In this study,
f was determined to be **1.15** with $\omega_{0,PM2.5}$(550nm)=0.82.

Aethalometer BC after Loading Effect Correction



$$BC_{corrected} = Aethalometer\ \ BC + BC, loading\ \ effect$$

Average loading effect =12.3 ± 4.7 % of total BC.

Mixing State Effect on Aerosol Absorption

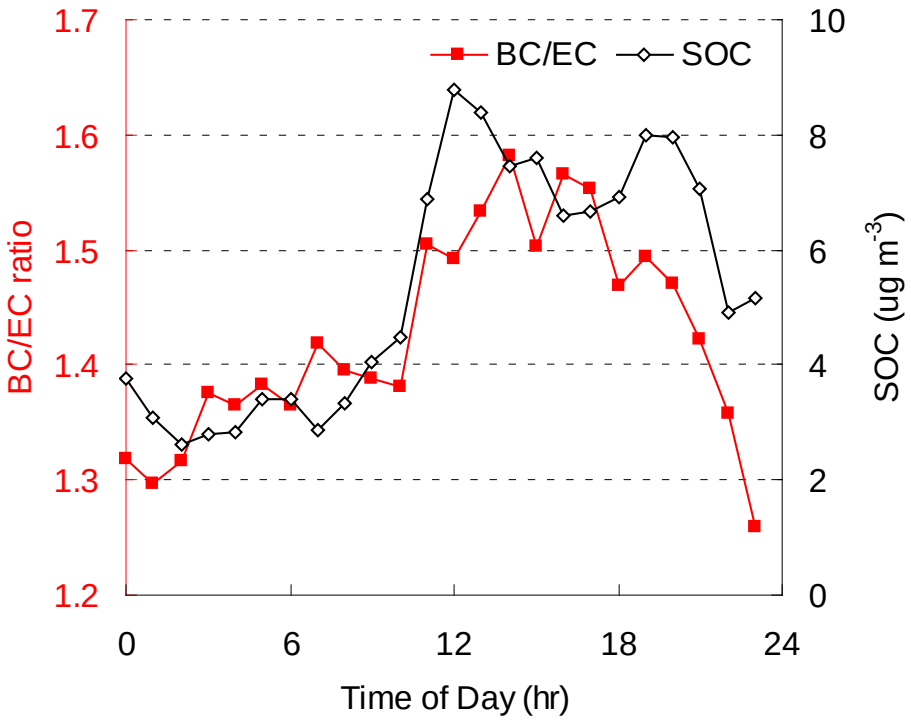
We Define: BC/EC minimum method

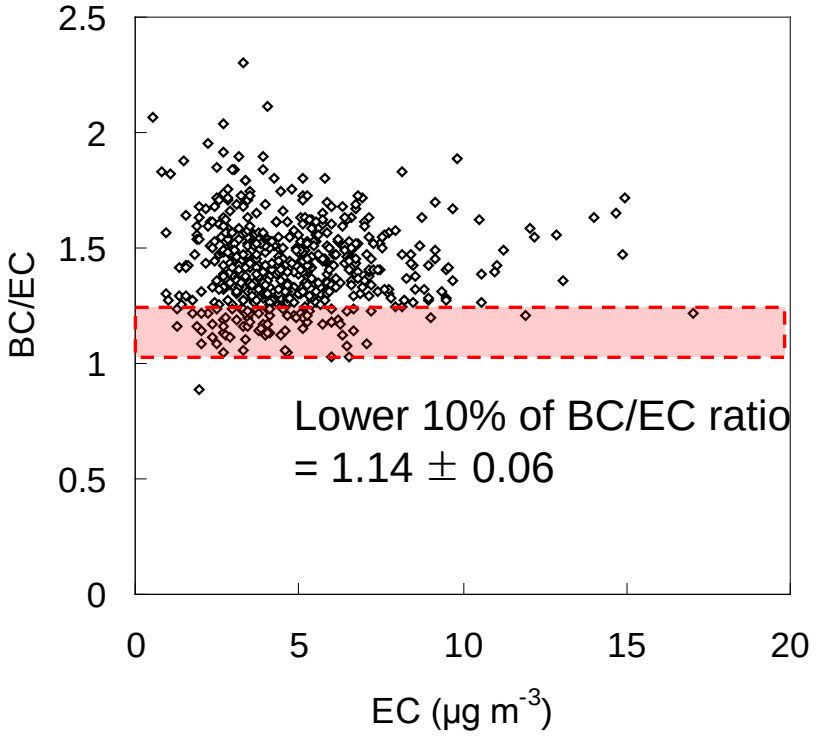
$$b_{abs,ext} = \sigma_{BC} \times BC / EC_{\min} \times EC$$

$$b_{abs,total} = \sigma_{BC} \times BC$$

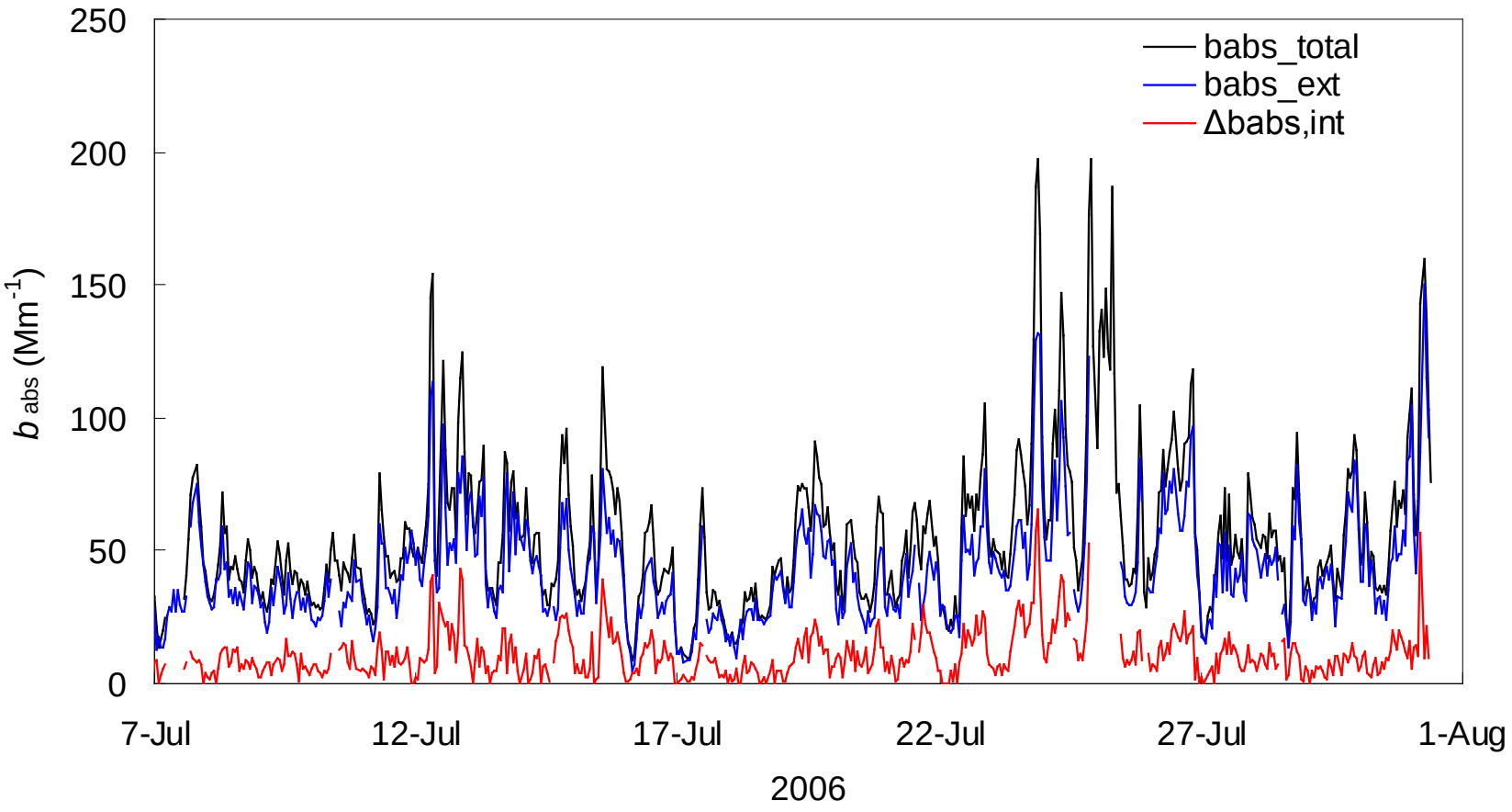
$$b_{abs,total} - b_{abs,ext} = \Delta b_{abs,\text{int}}$$

Where,
EC=Sunset EC (Thermally)
BC=Aethalometer BC (Optically)
σ_{BC}=Mass absorption efficiency, 7.7 m^2/g
by Andreae et al (2008)
BC/EC_{min}= average of lower 10 % of BC/EC ratio





Temporal variation of light absorption coefficient

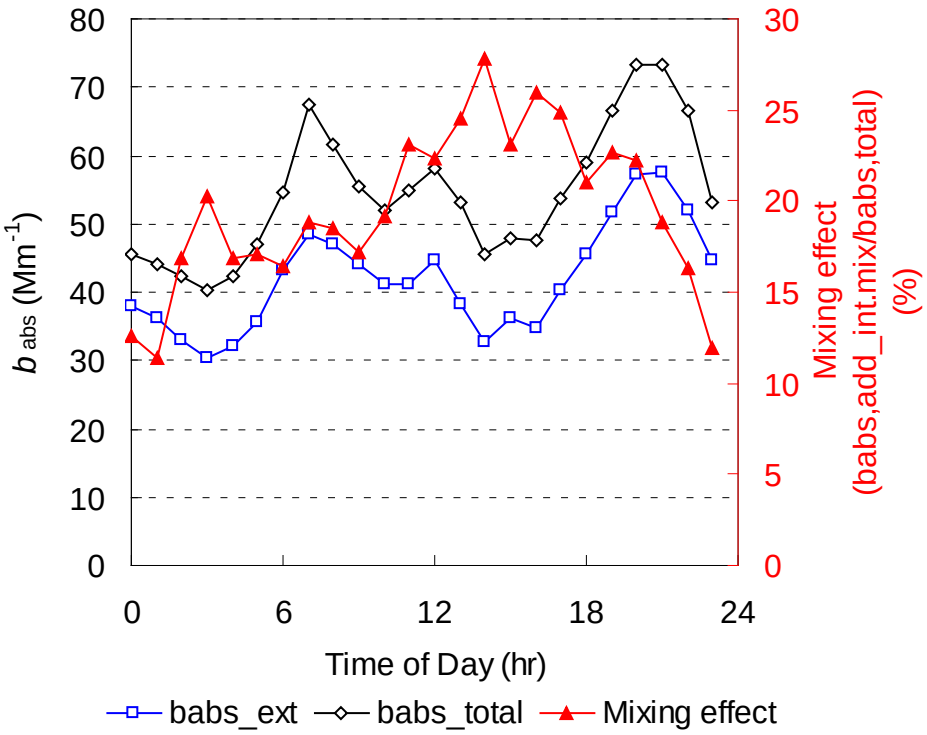


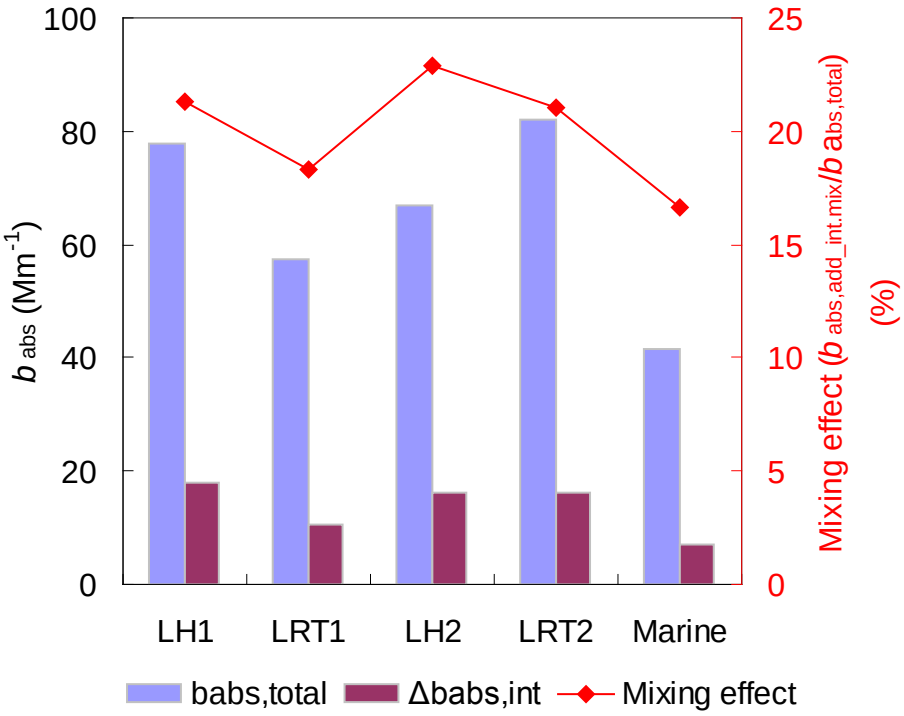
Total light absorption coefficient (b_{abs_total})=54.7±28.5 Mm^{-1}

Additional light absorption coefficient by the mixing state of EC ($\Delta b_{abs,int}$)=10.5±8.6 Mm^{-1}

19.4 % of total b_{abs} was due to additional absorption by internal mixing of EC.

Aerosol Absorption Coefficient





-Contribution of Δ $b_{abs,int}$ to b_{abs_total} shows minimum during night (11P.M.-2A.M.) and maximum in the afternoon (1P.M.-4P.M.).

-Generally high contribution of $\Delta b_{abs,int}$ to b_{abs_total} was observed during LH and LRT periods.

Aerosol absorption coefficient

	b_{abs_total}	$\Delta b_{abs,int}$	Mixing effect
	Mm^{-1}		%
Marine	41.4±19.5	6.9±4.9	16.6±9.1
LH1	77.9±32.4	18.0±12.5	21.3±10.0
LH2	67.0±39.4	16.1±14.0	22.9±8.8
LRT1	57.5±20.0	10.7±8.3	18.3±9.7
LRT2	81.9±37.9	16.0±9.8	21.1±7.2
All	54.7±28.5	10.5±8.6	19.4±9.1

-Generally high contribution of $\Delta b_{abs,int}$ to b_{abs_total} was observed during LH and LRT period.

Summary (1)

- Average OC/EC ratio were determined to be 1.5±0.6, 2.4±0.6, 1.9±0.8, 2.8±1.2, and 2.8±1.0 during clean marine (CM), LH1, LH2, LRT1, and LRT2 periods, respectively.

- Minimum OC/EC ratio was determined to be 1.06±0.28 under low photochemical processing condition (6~8 A.M.). Average fraction of secondary OC to total OC was determined to be 41.6±23.8% with a minimum of 26.8±16.8 % in the morning and a maximum of 64.4±8.7% at noon.

- It was found that the formation of secondary OC was highly correlated with ambient temperature as the formation rate of 1.5 μg C m^{-3}/C˚ under the condition of ambient temperature > 31˚C.

- Average shadowing effect was determined to 12.3±4.7% of total light attenuation, resulted in 12.3±4.7% underestimation of EC by aethalometer measurement.

Summary (2)

-**Diurnal variation of BC/EC ratio is very similar to that of secondary OC with low in the morning and high in the afternoon, which suggests the enhancement of light attenuation in the afternoon by the internal mixing of EC with secondary aerosols.**

-**Minimum BC/EC ratio method was used to determine the additional absorption due to internal mixing of EC. It is found that 19.4% of total b_{abs} was due to it.**

-**Generally high contribution of the additional absorption by the mixing state of EC to total b_{abs} was observed during LH and LRT periods.**

Thank you