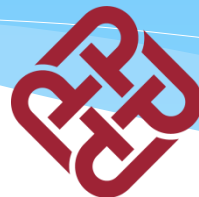




Characterization and source analysis on black carbon in the coastal area of southern China

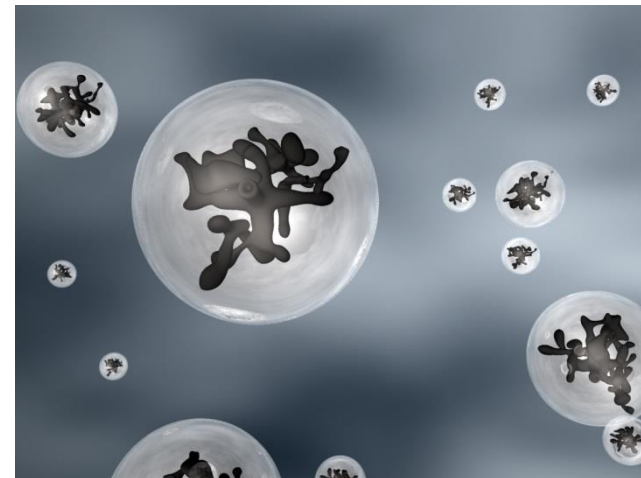
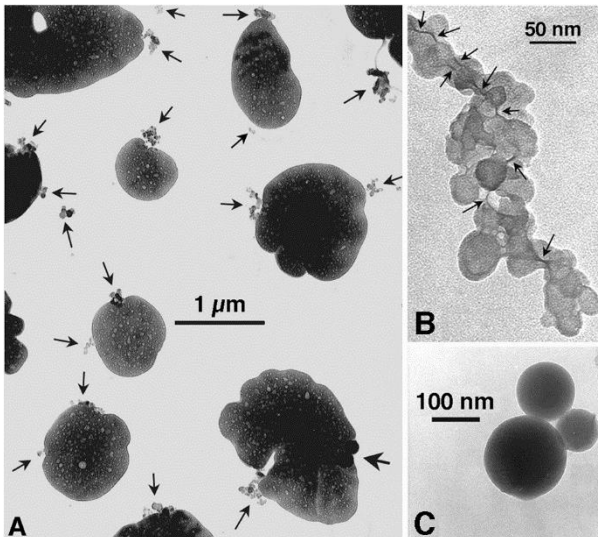
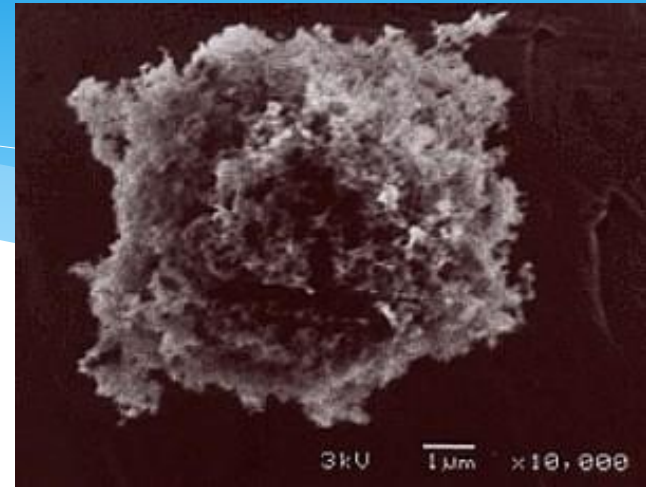
Lee Shun-cheng, Frank
Civil and Environment Engineering
The Hong Kong Polytechnic University



June 26-30, 2016
Beijing

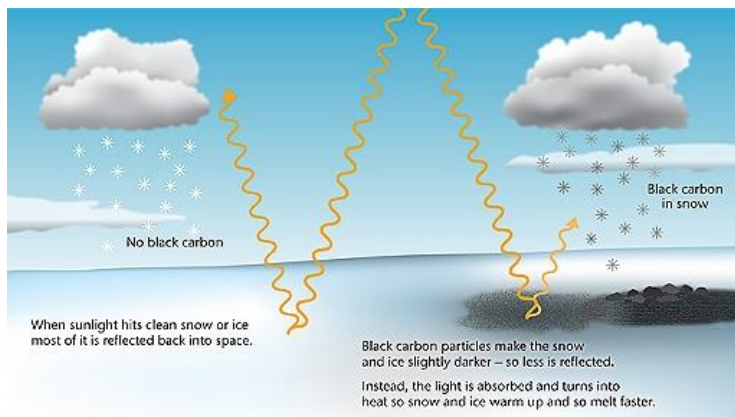
Black Carbon

- Product of *incomplete combustion of fossil fuel, biofuel and biomass*
- Commonly known as soot



Impact and effects of Black carbon

- ◆ Albedo Effect
- ◆ Global Warming
- ◆ Pollution/Visibility
- ◆ Human Health



Why we conduct this study...

30% of BC emission comes from China

✓ **Serious BC emission in China**

Hong Kong is located in the southern China

Obvious seasonal variation on particles in Hong Kong

✓ **BC emission in China may have large effect in Hong Kong**

So.....

It is **essential** to identify BC with **regional effect**.

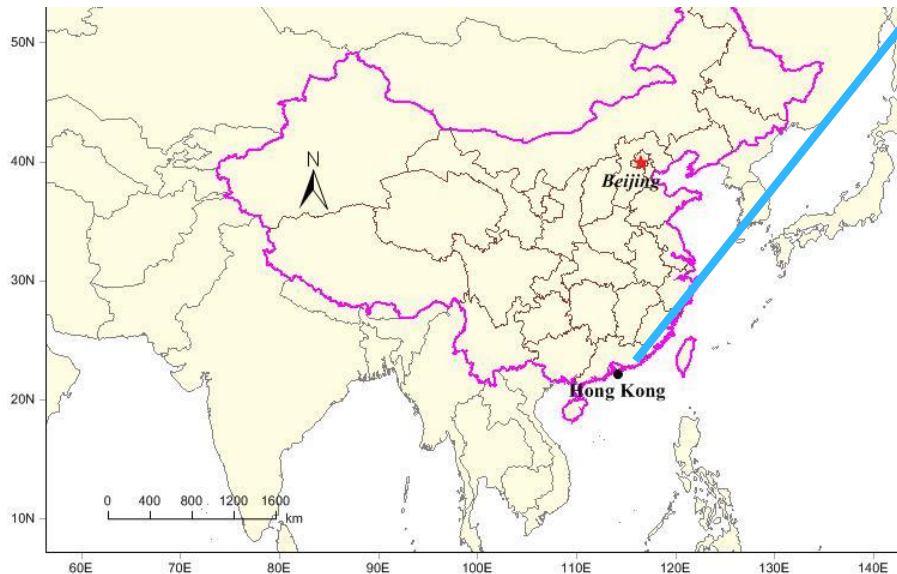
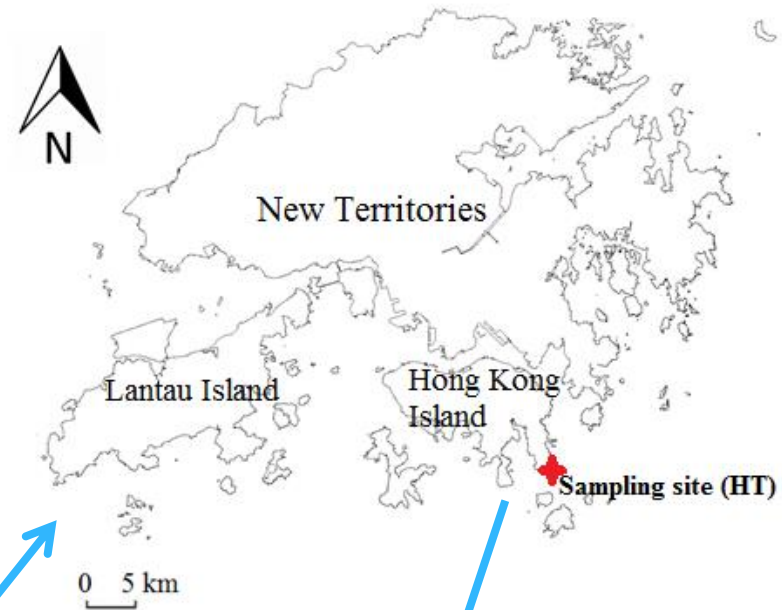
Hong Kong background site was chosen to investigate its regional effect

Objectives of the study

- ✓ Determine the BC **temporary variations** at Hong Kong background site (HT)
- ✓ Discuss the **influence of meteorological parameters** on BC
- ✓ Identify **variation of BC and other trace gas** under **different source areas**
- ✓ Discuss the **BC emission sources**

Sampling site

- **Site (rural area, background site)**
 - The Hok Tsui atmospheric research station (HT, $22.12^{\circ} N$, $114.15^{\circ} E$)
 - Located southeastern tip of Hong Kong Island
 - It faces the South China Sea (270° view of the sea).
 - 60 m above sea level and no major emission source (15 km far from urban site)

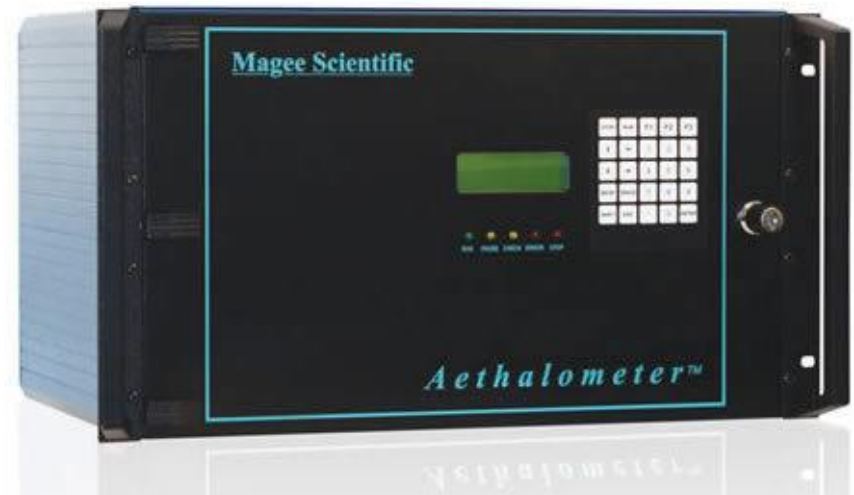


Black carbon (BC) measurement

- Instrument: Aethalometer Model AE-31
- 7 wavelengths: 370nm, 470nm, 520nm, 590nm, 660nm, **880 nm** and 950 nm
- Flow rate: 5 L/min
- Cut size: PM_{2.5} inlet

Sampling period:

October, 2011 to
September, 2013



Filters collection and analysis

- **PM_{2.5} particulate matters collection**
 - Instrument: High-volume sampler, Graseby-Andersen
 - Sampling period: October 2012 to September 2013
 - delta T (Δt): every 6 days
 - Flow rate: 1.13 m³/min
 - Cut size: PM_{2.5} inlet
- **Chemical analysis**
 - Gravimetric analysis
 - Carbonaceous analysis
 - Ions analysis

Visibility and Direct Radiative forcing (DRF) Calculation

* Particle light extinction calculation (IMPROVE):

$$B_{ext} = B_{sp} + B_{ap} \approx 2.2f_s(RH)[small\ AS] + 4.8f_L(RH)[large\ AS] + 2.4f_s(RH)[small\ AN] + 5.1f_L(RH)[large\ AN] + 2.8[small\ OM] + 6.1[large\ OM] + 1.7f_{ss}(RH)[sea\ salt] + 10[EC]$$

* Direct Radiative forcing (DRF) calculation:

$$DRF = \frac{S_o}{4} T_{atm}^2 (1 - N) [4\alpha\tau_{ap} - 2(1 - \alpha)^2\beta\tau_{sp}]$$

S_o is the solar irradiation (1370 W/m²),

T_{atm} is the transmittance of the atmosphere (0.79),

N is the cloud fraction (0.6),

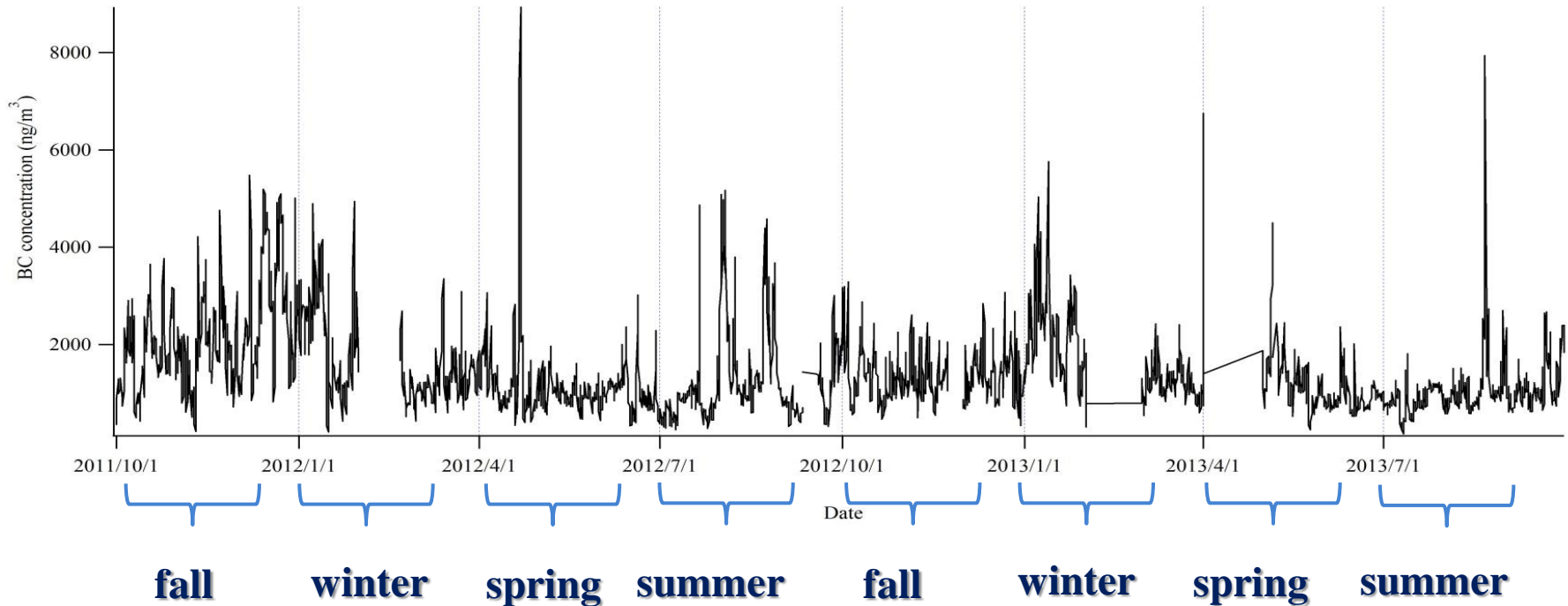
α is the surface albedo (rural area = 0.18),

β is the particle size dependent fraction of radiation scattered by aerosol (0.17).

τ_{ap} : absorption optical thickness $\tau_{ap} = B_{ap} \times H \times f_m$

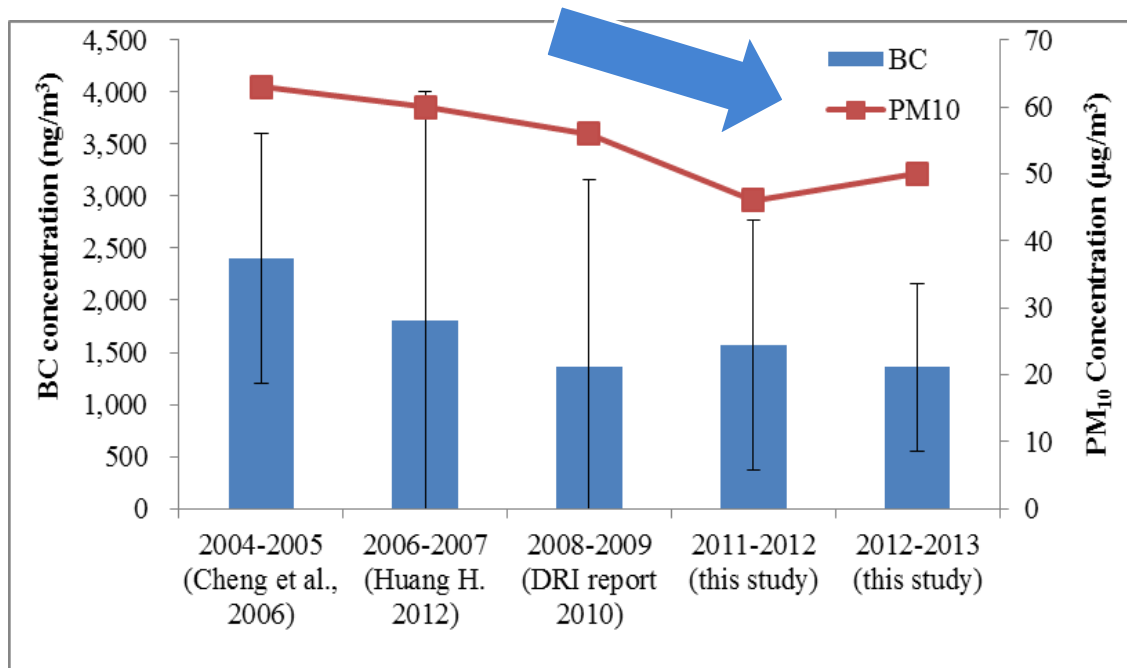
τ_{sp} : scattering optical thickness $\tau_{sp} = B_{sp} \times H$

BC temporary variations in HT



- BC concentration measurement started from October 2011 to September 2013, the annual mean is $1400 \pm 1100 \text{ ng/m}^3$
- Obvious seasonal variation was observed, fall and winter (October to March) and spring and summer (April to September), which are $1700 \pm 1000 \text{ ng/m}^3$ and $1200 \pm 1100 \text{ ng/m}^3$

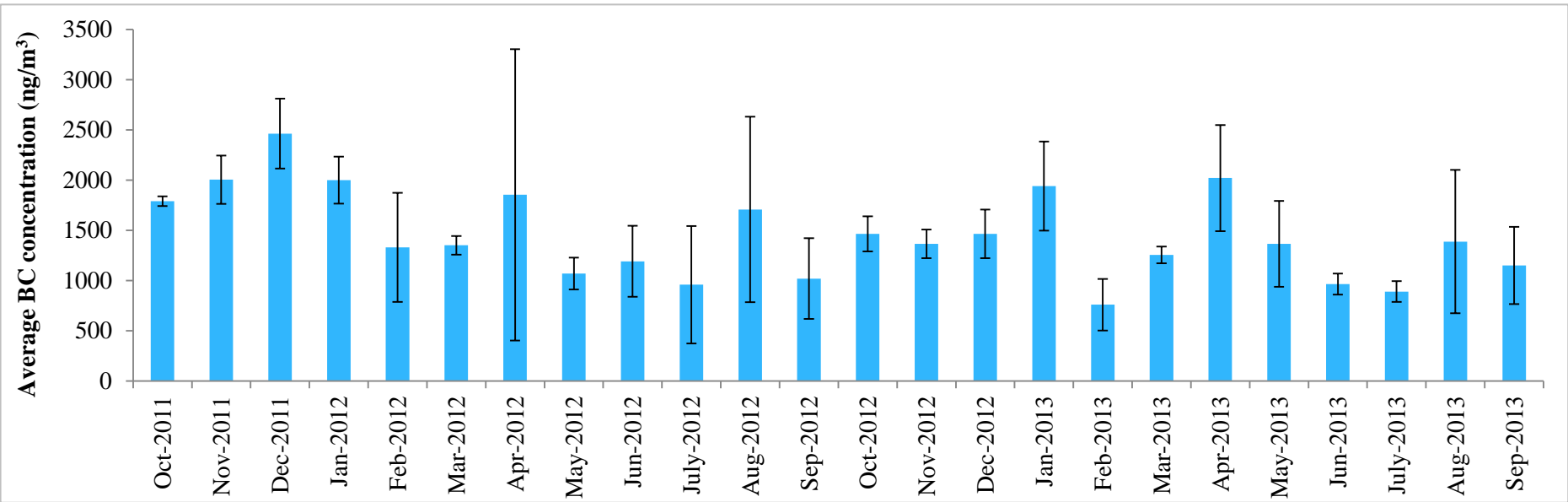
Yearly variations of BC in HT



YEAR	BC/PM ₁₀
2004-2005	8.0%
2006-2007	6.5%
2008-2009	5.4%
2012-2013	5.3%

✓ **BC concentration have 35% to 43% reduction in the past 10 years**

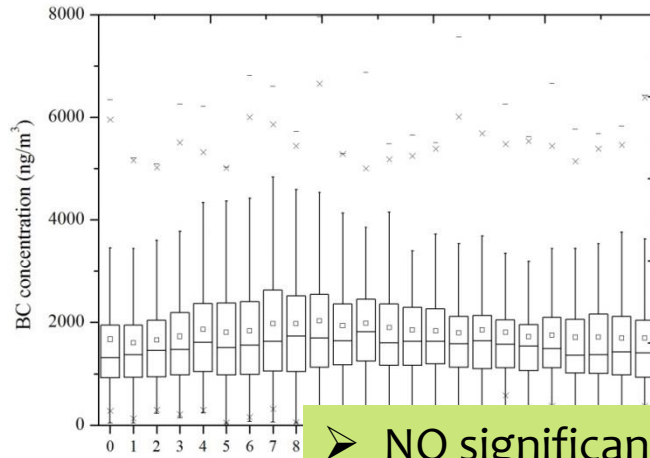
Monthly variations on BC concentration



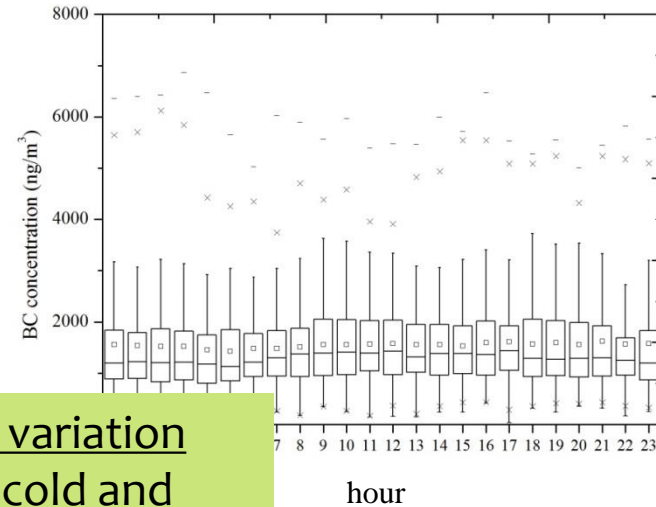
- The **Highest** BC value was in December-2011 (on average, **2463 ng/m³**); and the **lowest** BC value was in July-2012 (**958 ng/m³**)

Diurnal variation on BC

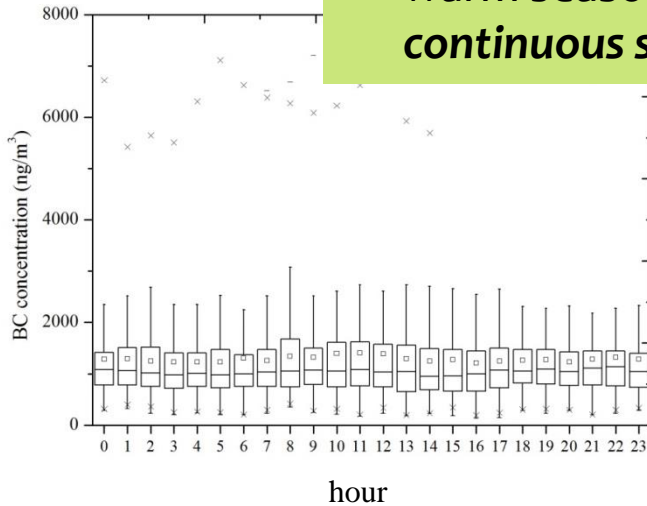
fall



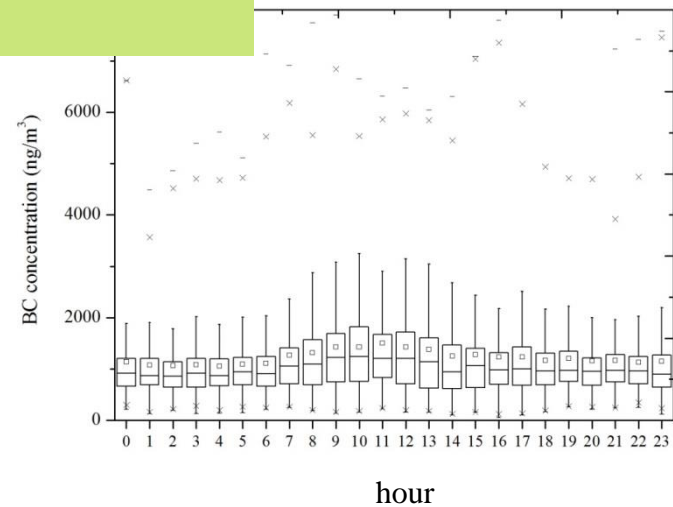
winter



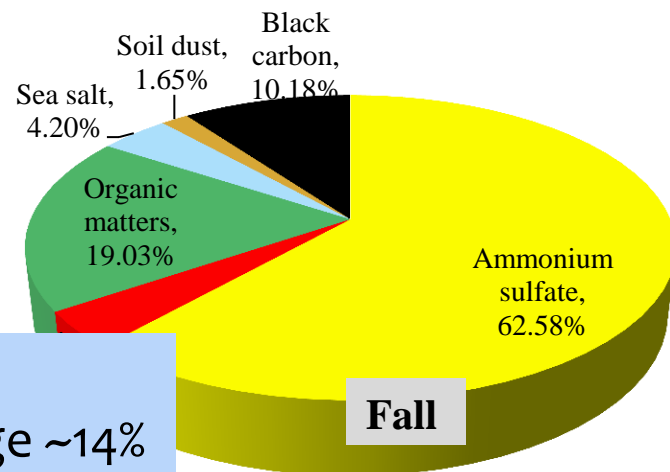
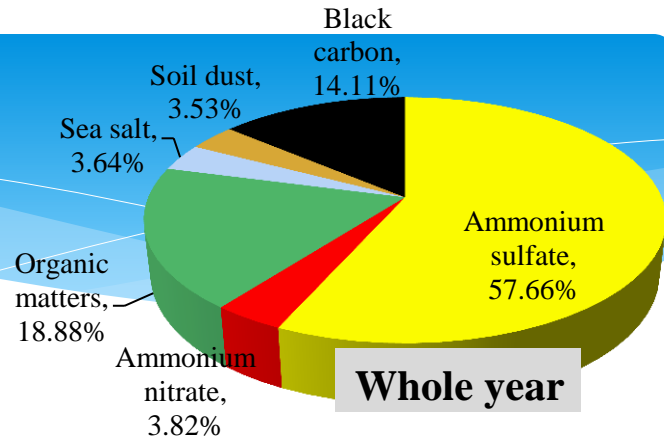
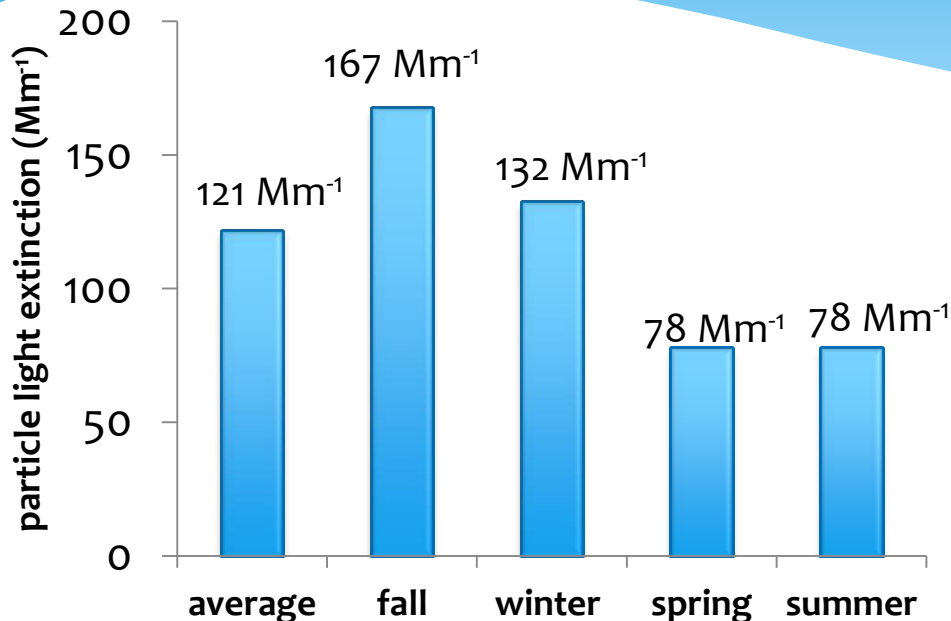
spring



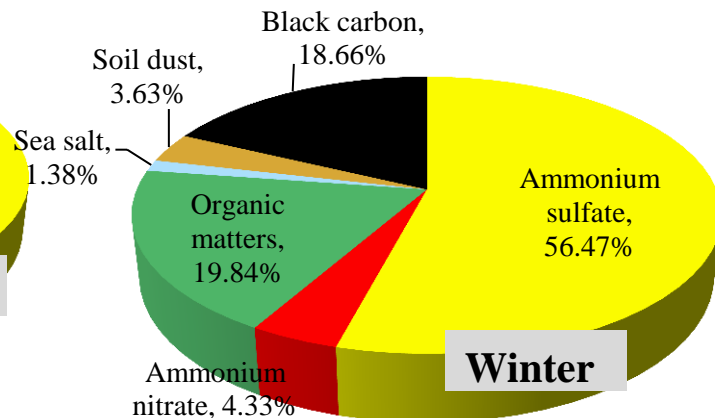
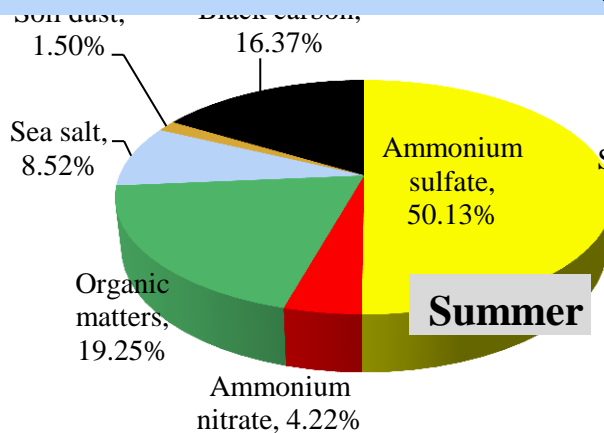
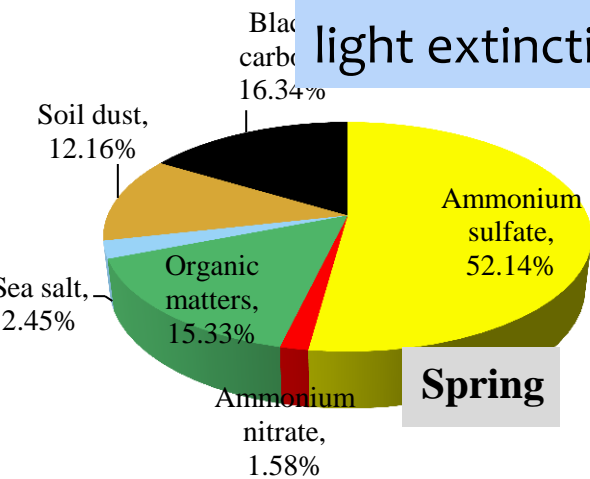
➤ NO significant diurnal variation
has been observed in cold and
warm season—*indicating no*
continuous source



Optical property on BC

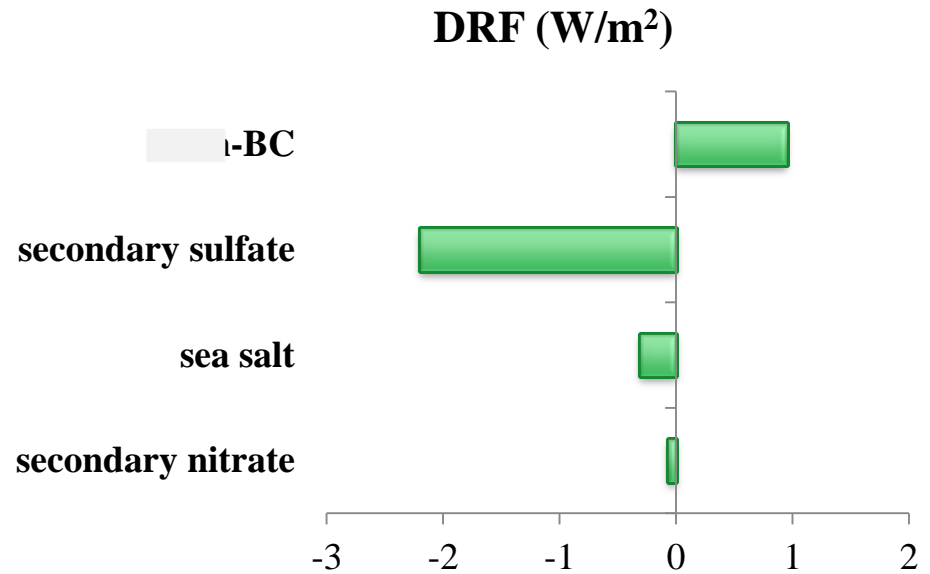
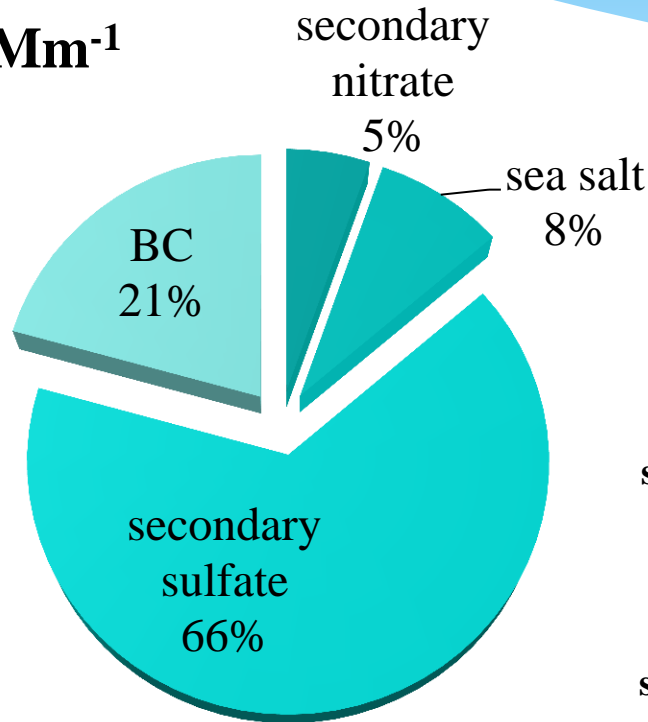


BC contribution to light extinction is 10% to 18%, with average ~14%



Visibility and Direct Radiative Forcing effect on BC

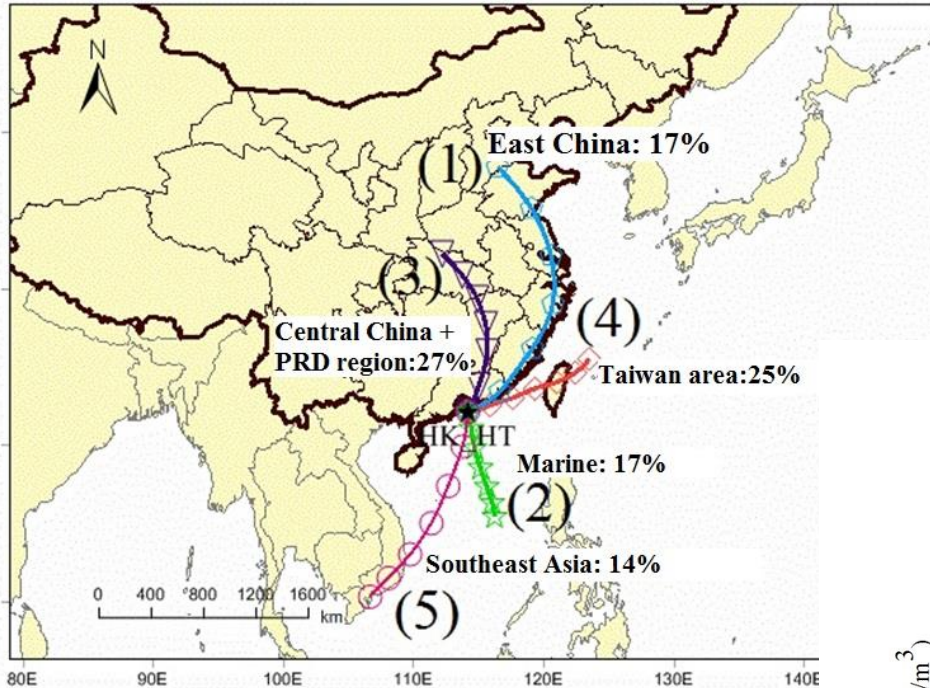
$$B_{\text{ext}} = 121 \text{ Mm}^{-1}$$



DRF Hong Kong (HT) > global BC emission > North America
0.95 W/m^2 > 0.2 W/m^2 > 0.09 W/m^2

BC value in varied source areas

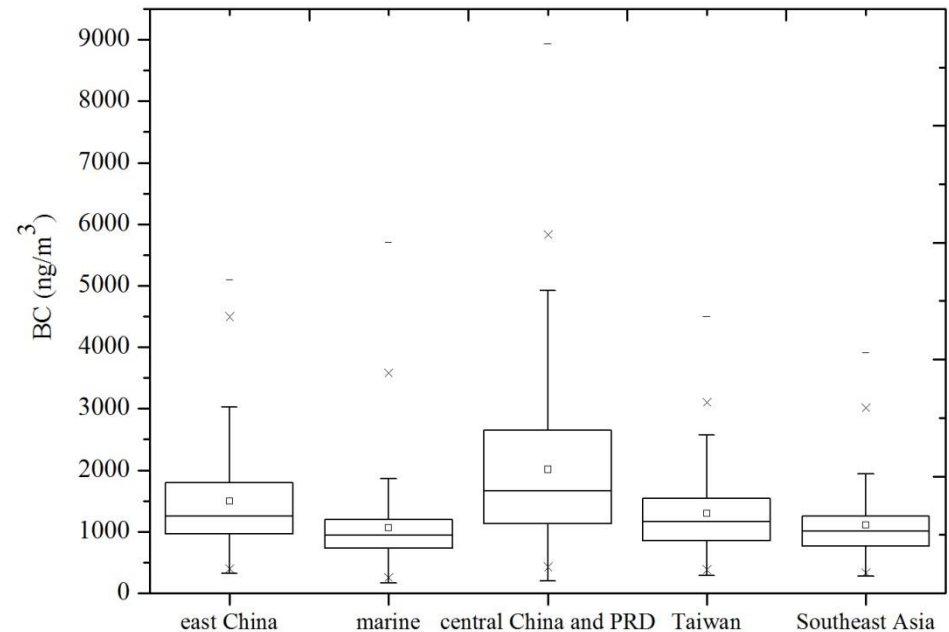
Air mass trajectory analysis package



Five source areas:

- ✓ East China
- ✓ Marine
- ✓ Central China +PRD region
- ✓ Taiwan
- ✓ Southeast Asia

Source area	Contribution	BC($\text{ng}\cdot\text{m}^{-3}$)
East China	17%	1549.5728
Marine	17%	1028.7489
Central China + PRD region	27%	2107.7826
Taiwan	25%	1315.5977
Southeast Asia	14%	1139.2627



BC and CO ratio in different emission sectors

	power plant	industry	residential	transportation
$(\text{BC}/\text{CO})_{\text{bottom-up}}$ (ng/m³/ppbv)^a				
East China	18.21	7.19	12.08	7.39
Central China+PRD	22.39	7.64	13.35	7.42

Sources contribution on BC

Source area	Contribution	$\Delta BC/\Delta CO$
East China	17%	4.8399
Marine	17%	9.5243
Central China + PRD region	27%	5.7562
Taiwan	25%	6.5002
Southeast Asia	14%	10.7396



Ship emission



Residential (biomass burning) emission

- Dominated BC sources **from industrial and transportation** in mainland China and Taiwan
- Comparative BC sources from **ship emission** and residential (biomass burning) in Southeast Asia

Conclusion

- * The 2-year BC mean value is $1400 \pm 1100 \text{ ng/m}^3$ with seasonal change (fall and winter : $1700 \pm 1000 \text{ ng/m}^3$ and spring and summer: $1200 \pm 1100 \text{ ng/m}^3$)
- * BC (~22%) was the **second largest factor** cause visibility degradation
- * The direct radiative forcing for BC factor are **much higher** than the other countries, indicating serious BC problem cause local climate change
- * Five **potential BC source areas**: East China, Marine, Central China +PRD region, Taiwan, Southeast Asia
- * The majority sources on BC is **industrial and transportation** from mainland China and Taiwan area



Acknowledge

- * The project was supported by Hong Kong Environmental Protection Department

Thanks

Q&A