Air Pollution in Hong Kong and PRD - the state of science

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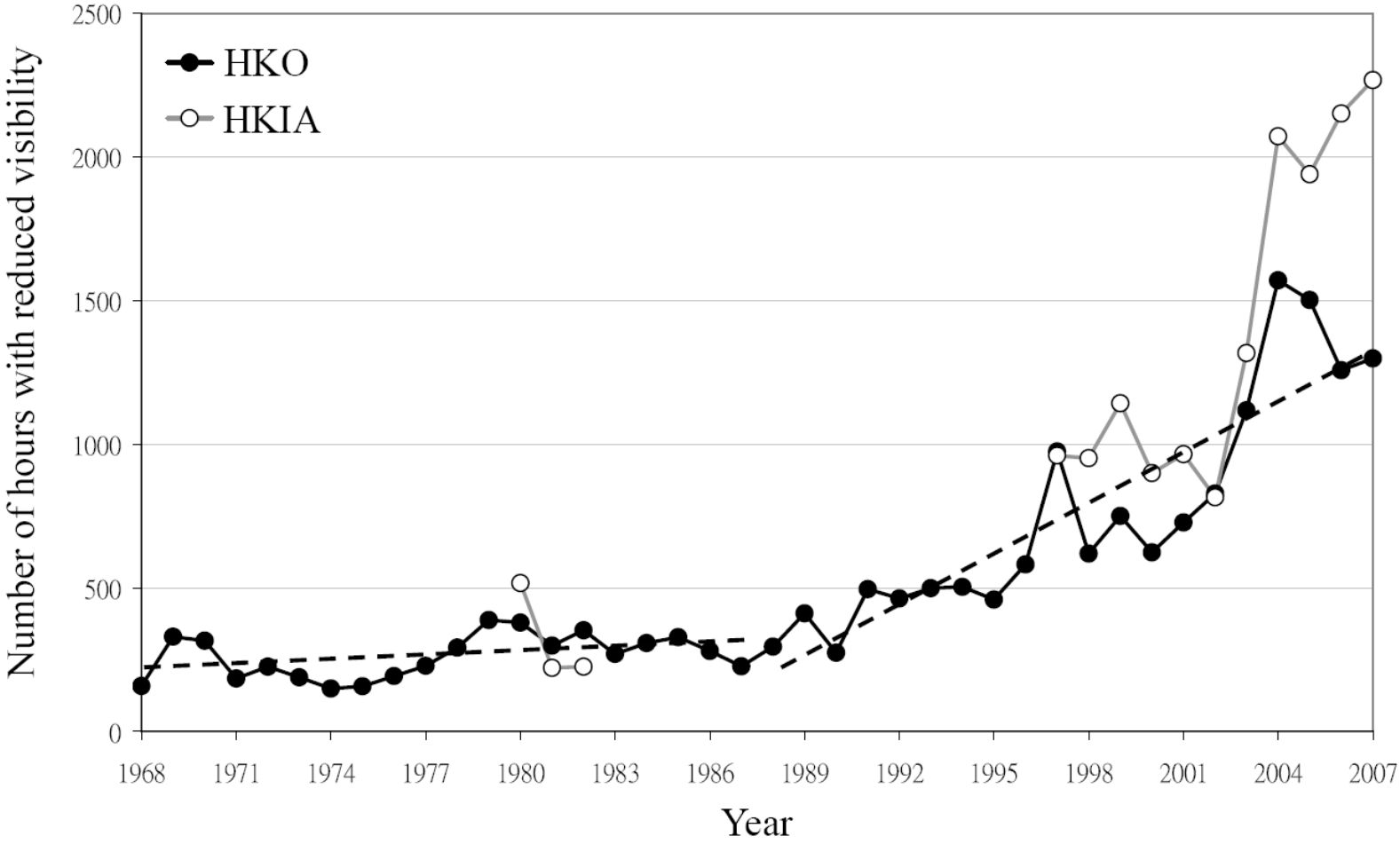
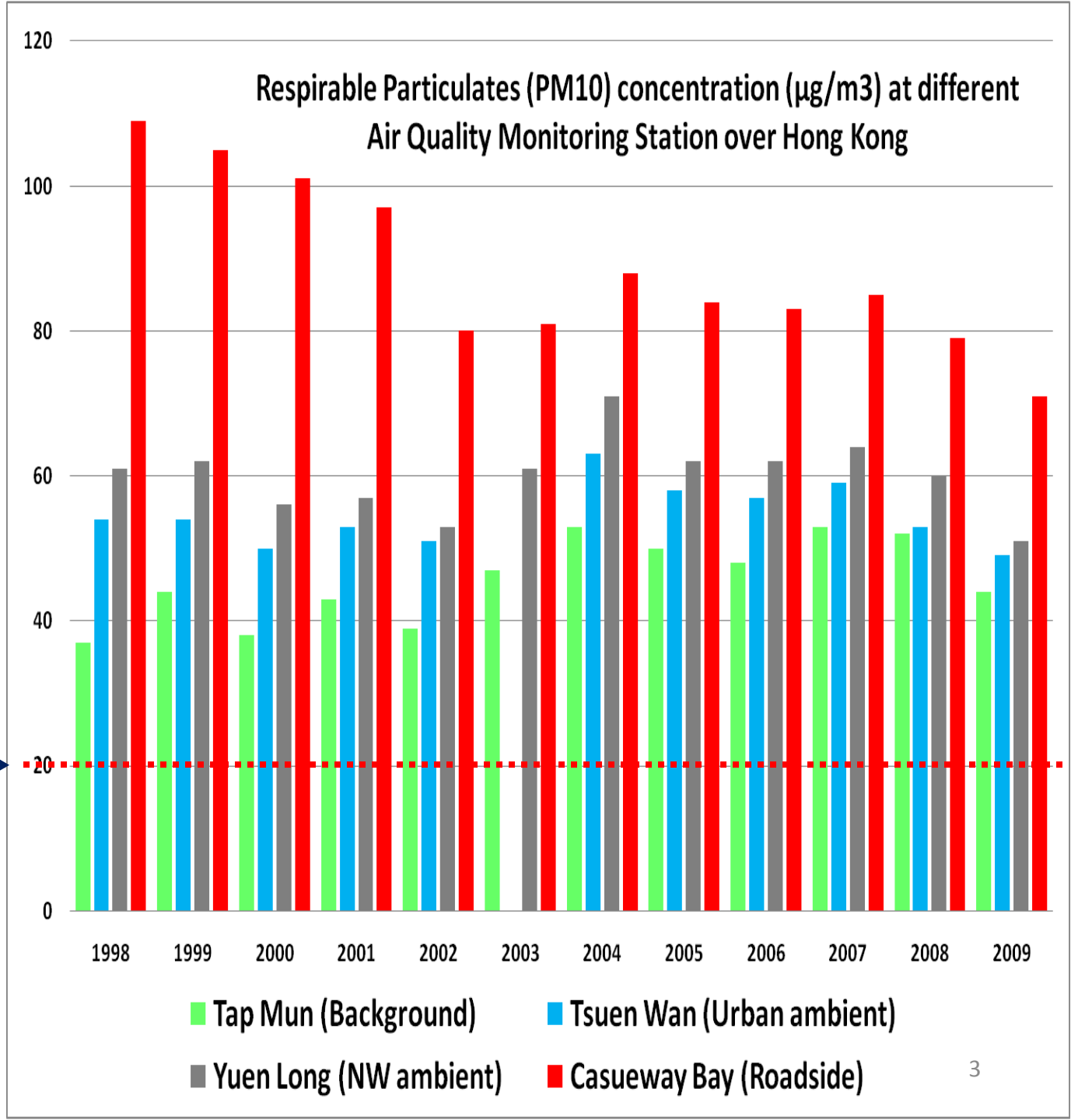


Time series of annual number of hours with reduced visibility observed at the Hong Kong Observatory Headquarters (HKO) and at Chek Lap Kok (now the Hong Kong International Airport (HKIA)) respectively. Reduced visibility refers to visibility below 8 km excluding cases of rain, mist, fog and high relative humidity (≧95%).

Source: HK Observatory
http://www.weather.gov.hk/publica/reprint/r838.pdf

We have a severe PM pollution problem.

WHO PM10 Air Quality Guideline (2006)

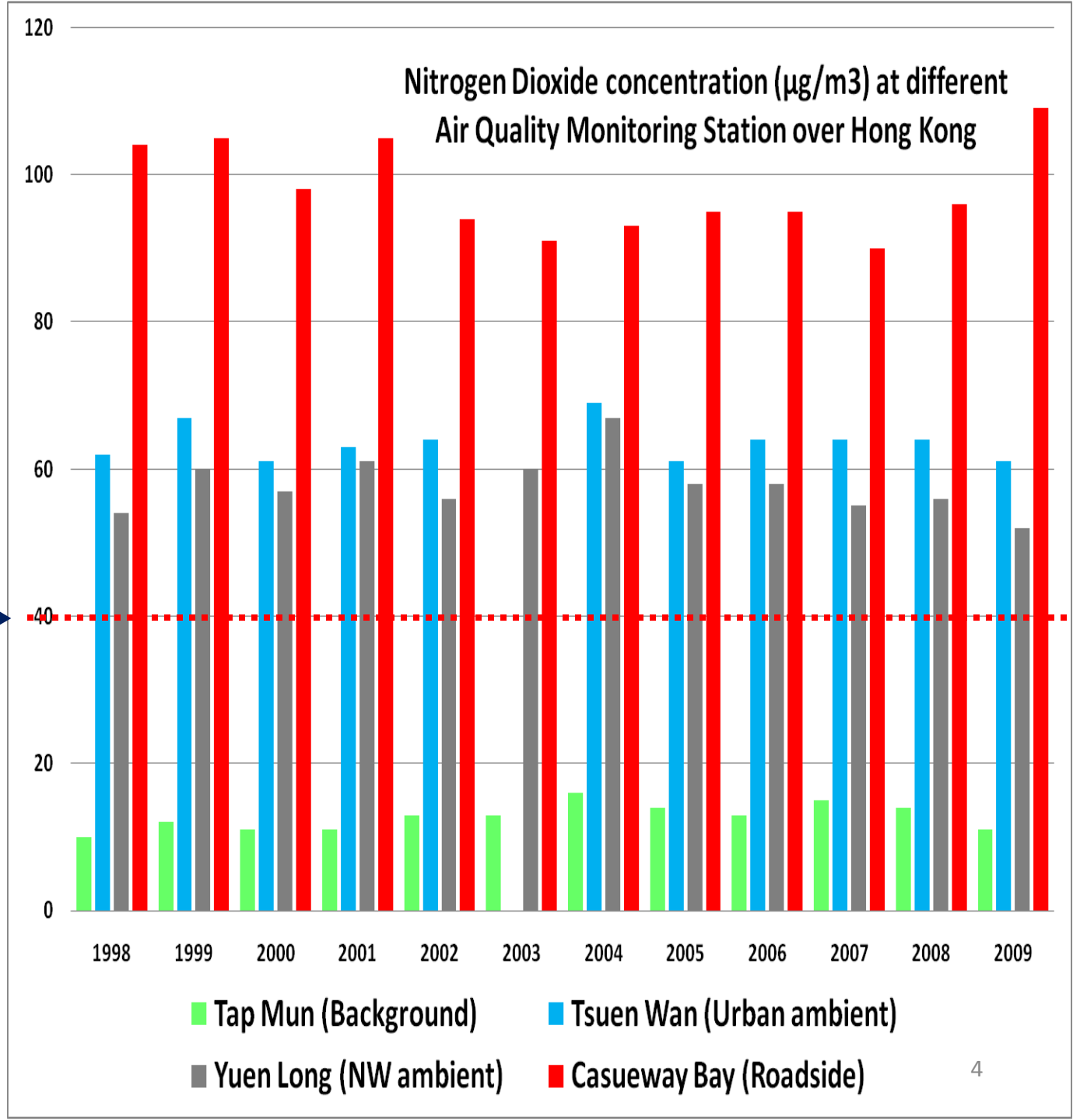


Source: EPD

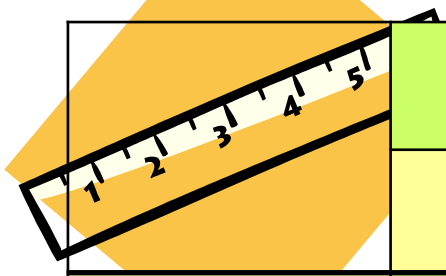
Source: EPD

WHO NO2 Air Quality Guideline (2006)

We also have a serious NO2 pollution problem.



Air Quality Objectives/Standards



	HKEPD AQO		WHO AQG	
	ug/m^3			
NO2	300 (1-hr mean)	150 (24-hr mean)	200 (1-hr mean)	40 (1-yr mean)
SO2	800 (1-hr mean)	350 (24-hr mean)	500 (10-min mean)	20 (24-hr mean)
CO	30,000 (1-hr mean)	10,000 (8-hr mean)	30,000 (1-hr mean)	10,000 (8-hr mean)
PM10	180 (24-hr mean)	55 (1-yr mean)	50 (24-hr mean)	20 (1-yr mean)
PM2.5	---		25 (24-hr mean)	10 (1-yr mean)
O3	240 (1-hr mean)		100 (8-hr mean)	

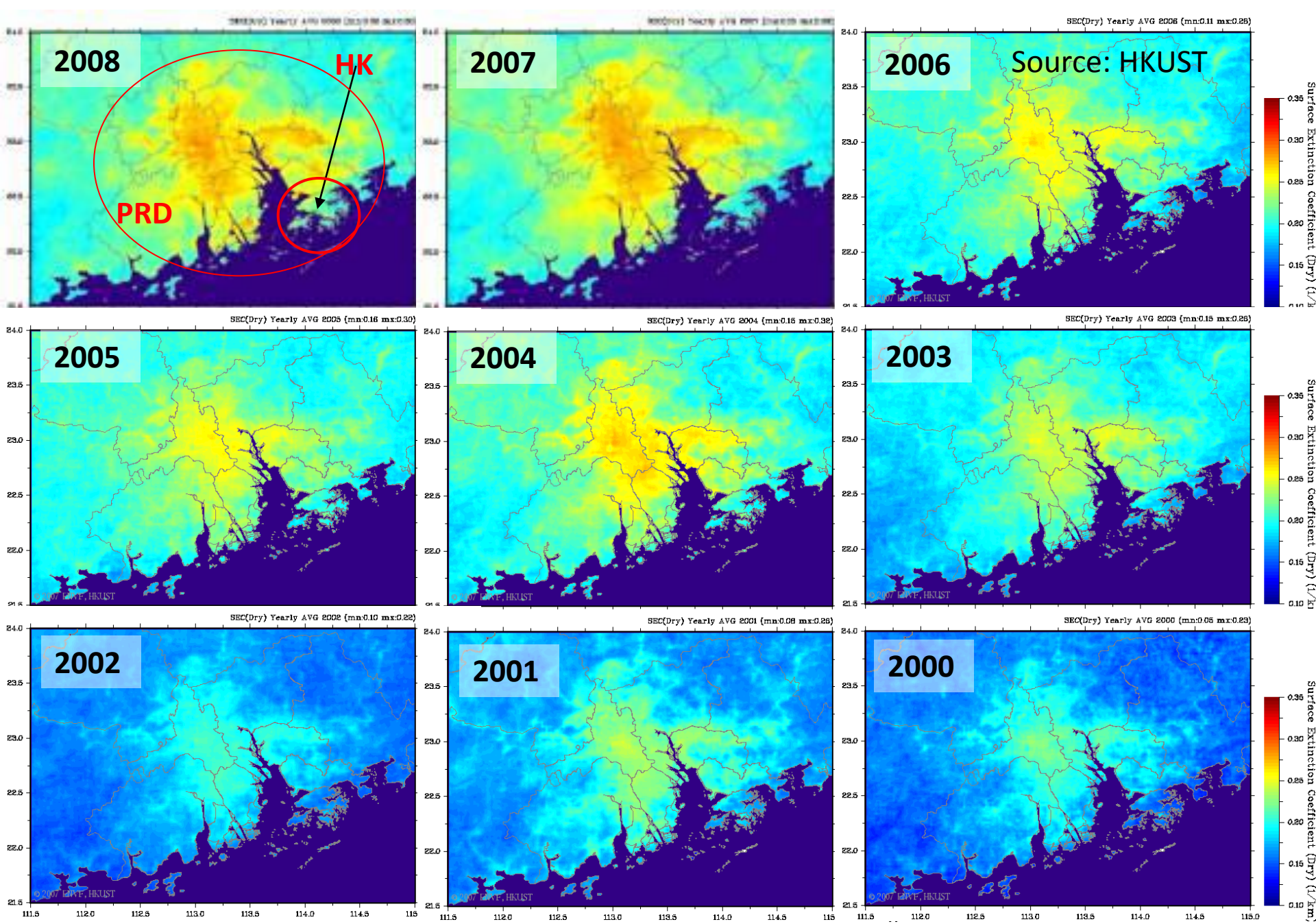
Health Costs of Air Pollution in Hong Kong

Five avoidable numbers to remember

200%	***Daily* Air pollutant concentrations** are now 200% higher than the World Health Organization Guidelines (2006) 24 hr Levels (Should not be exceeded more than 2 or 3 times annually)
6,800,000	**Family doctor** visits each year for respiratory problems.
64,000	**Hospital bed-days a year**, mostly for heart, lung and blood vessel diseases.
1,600	**Deaths** a year, mostly from heart attacks, stroke, pneumonia and other lung diseases.
20 billion	**Value of the direct benefits** of air quality improvement would be more than $20 billion a year.

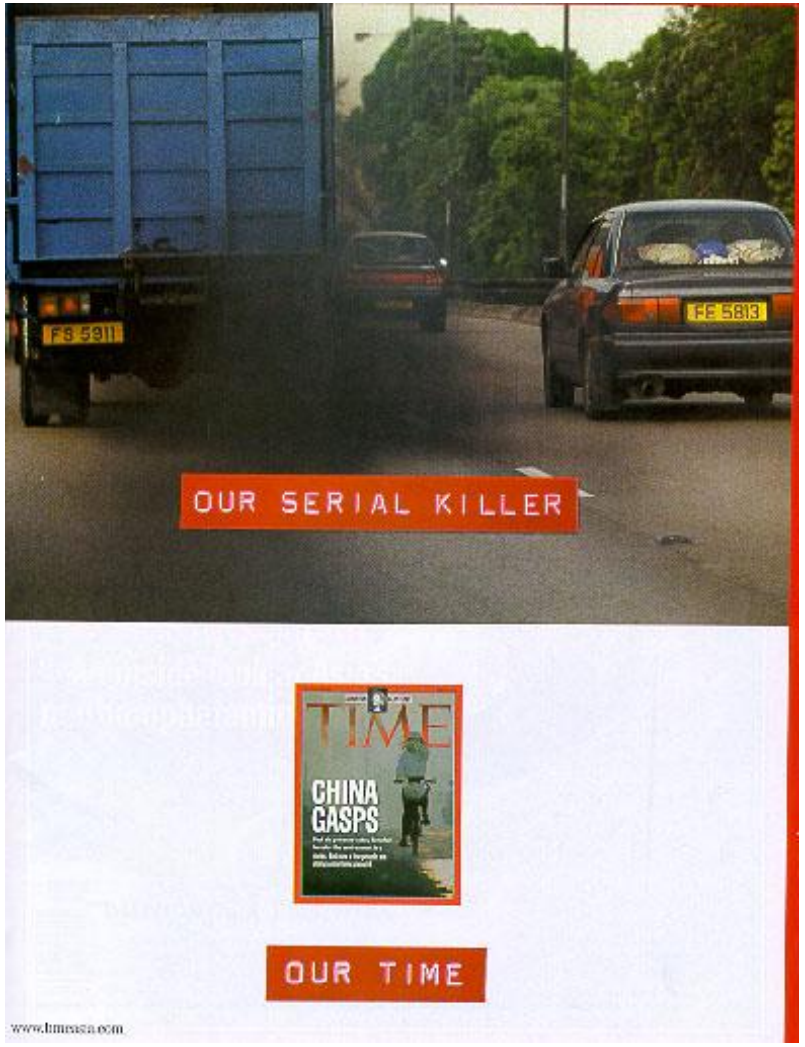
(HKU, CUHK, HKUST, Civic Exchange Report, 2006)

***The above does not include indirect costs (Tourism, Business, Talent and long-term competitiveness) which are several times larger!**

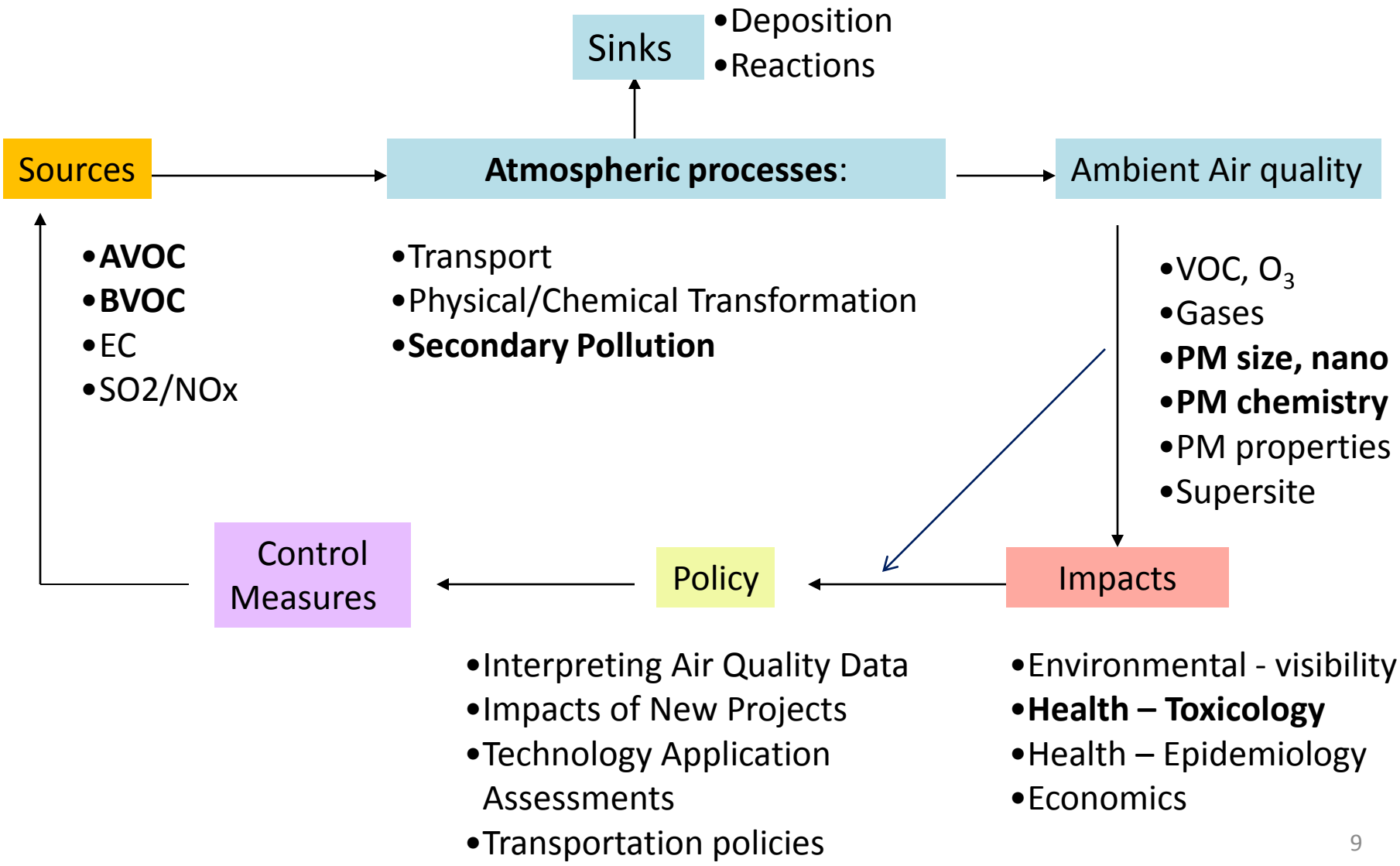


- **We have a clear and severe regional air quality problem getting worse!**

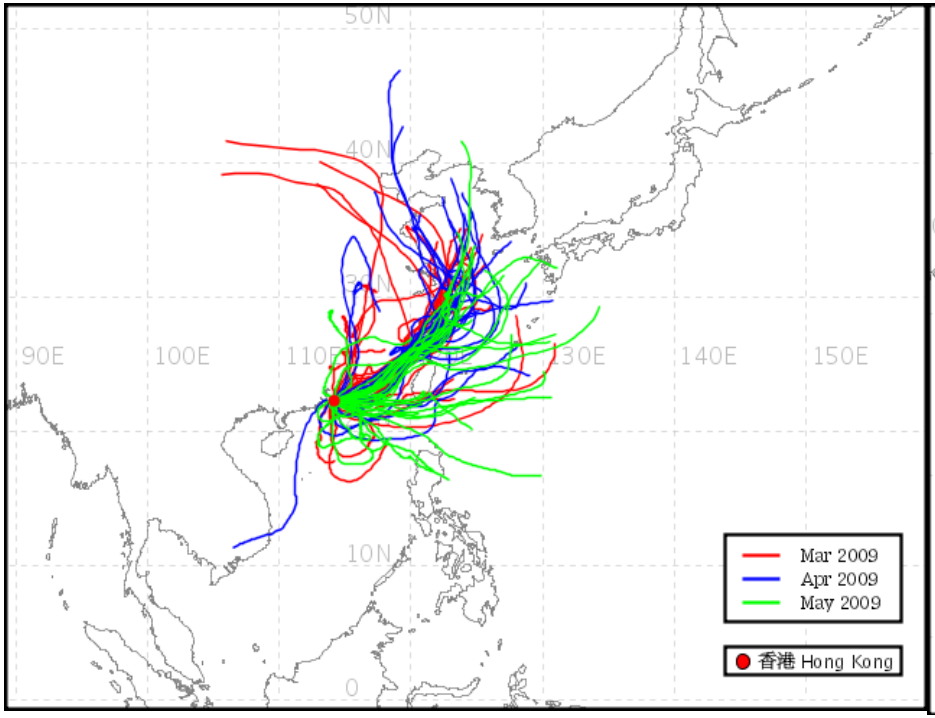
Air Pollution in HK



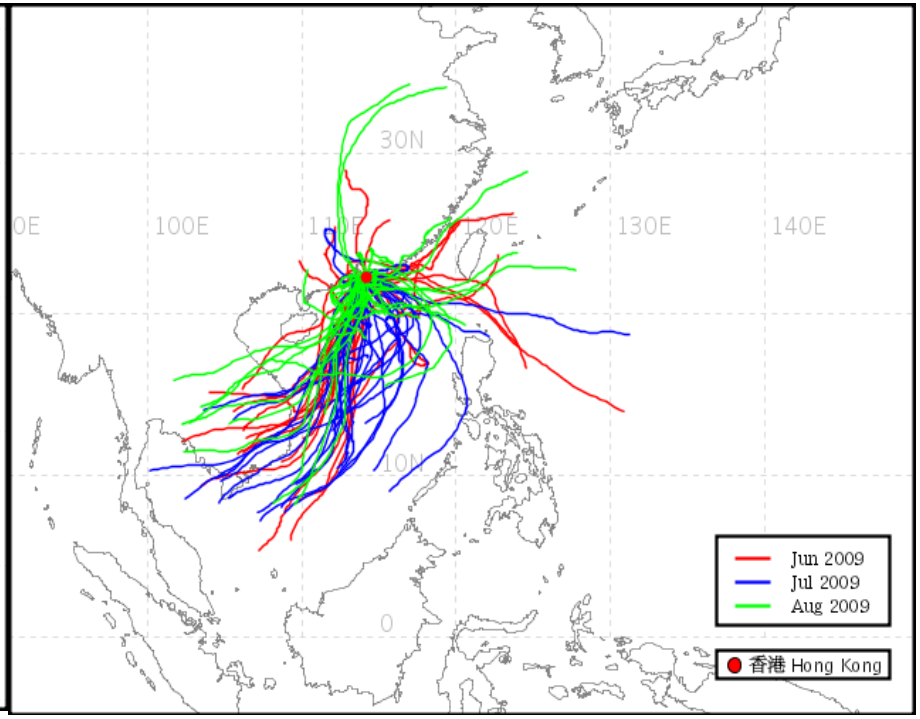
Air Quality Management



Seasonal backward trajectory of air mass reaching Hong Kong in 2009



Spring (March-May)

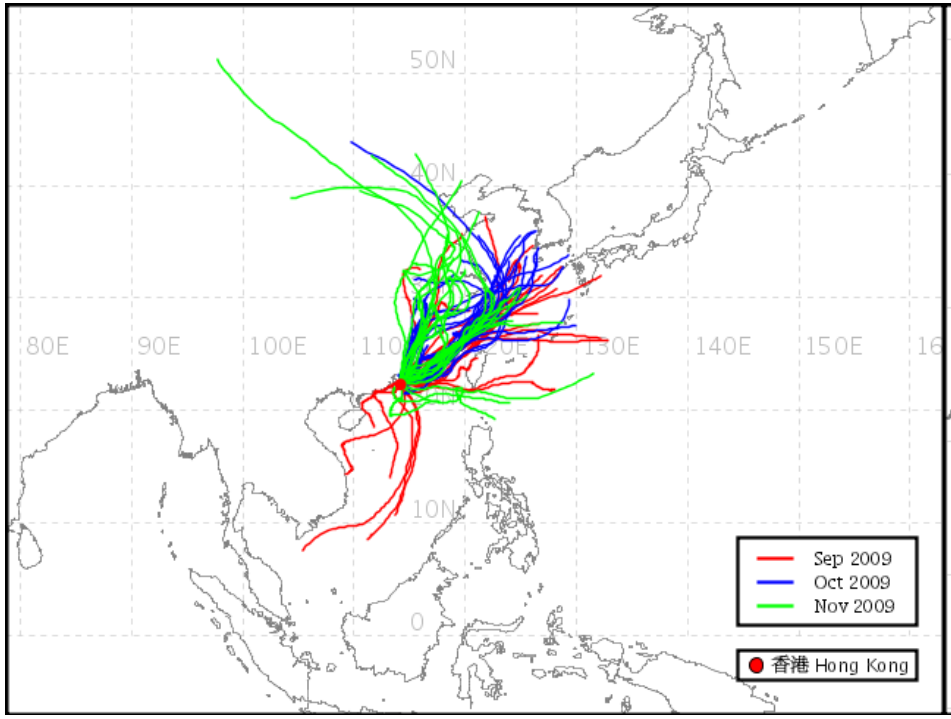


Summer (June-August)

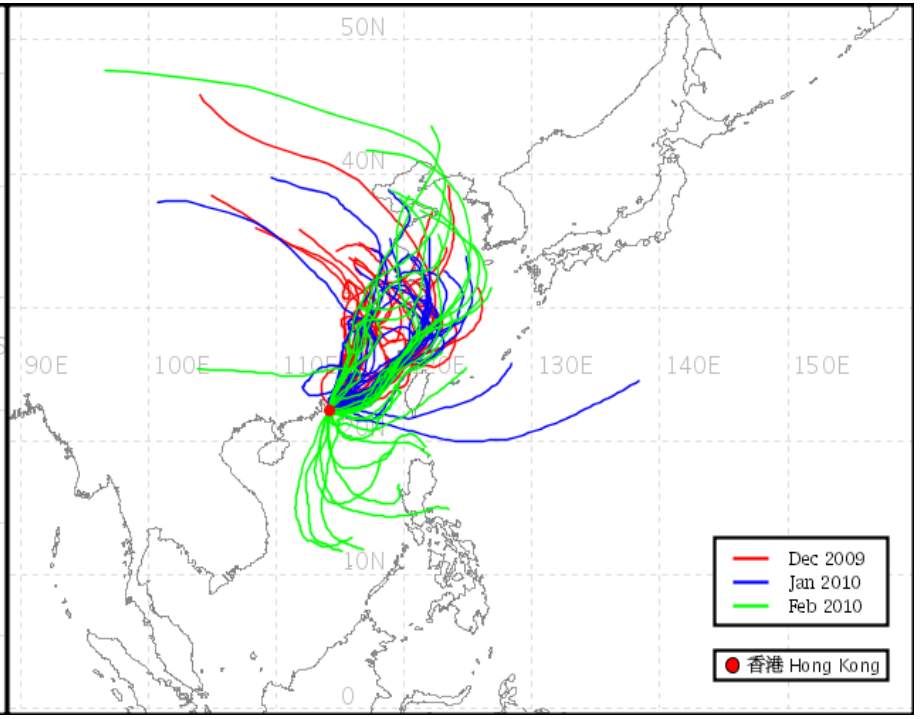
The above diagram shows all daily (past 72-hour) backward trajectories of air mass reaching Hong Kong at a height of 100 metres above ground level within the selected season.

Source: Hong Kong Observartory
http://www.weather.gov.hk/wxinfo/trajectory/trajectorySeasonal_e.shtml

Seasonal backward trajectory of air mass reaching Hong Kong in 2009



Autumn (September-November)



Winter (December-February (2010))

The above diagram shows all daily (past 72-hour) backward trajectories of air mass reaching Hong Kong at a height of 100 metres above ground level within the selected season.

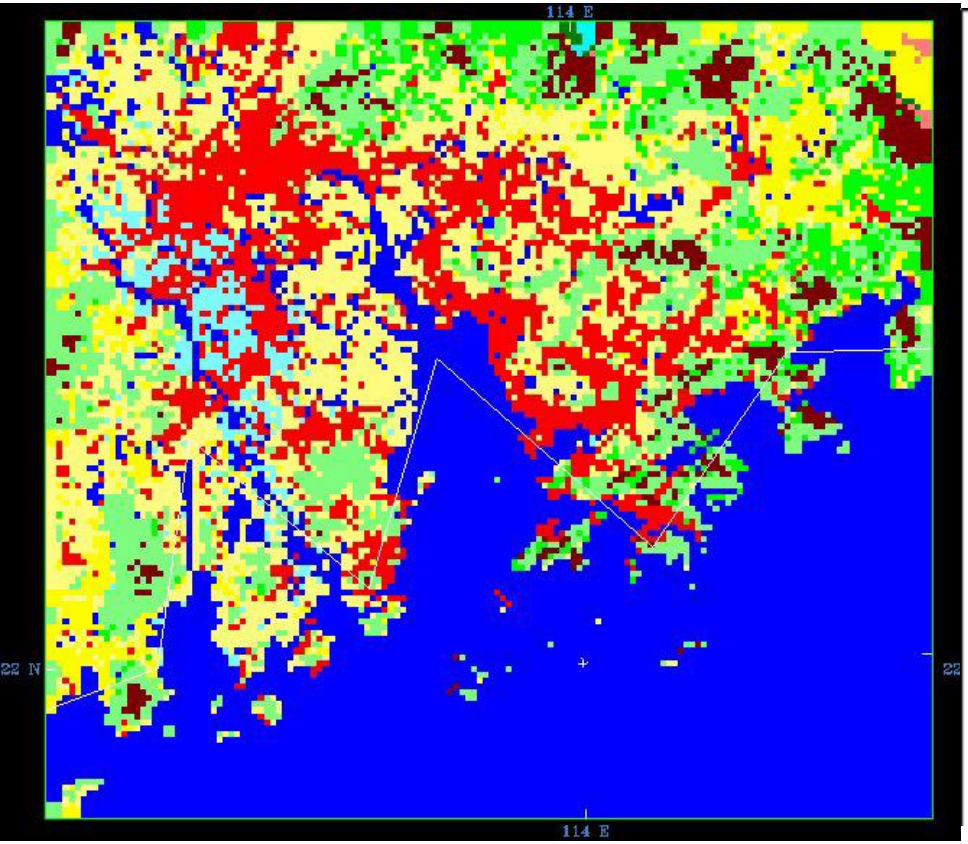
Source: Hong Kong Observartory
http://www.weather.gov.hk/wxinfo/trajectory/trajectorySeasonal_e.shtml

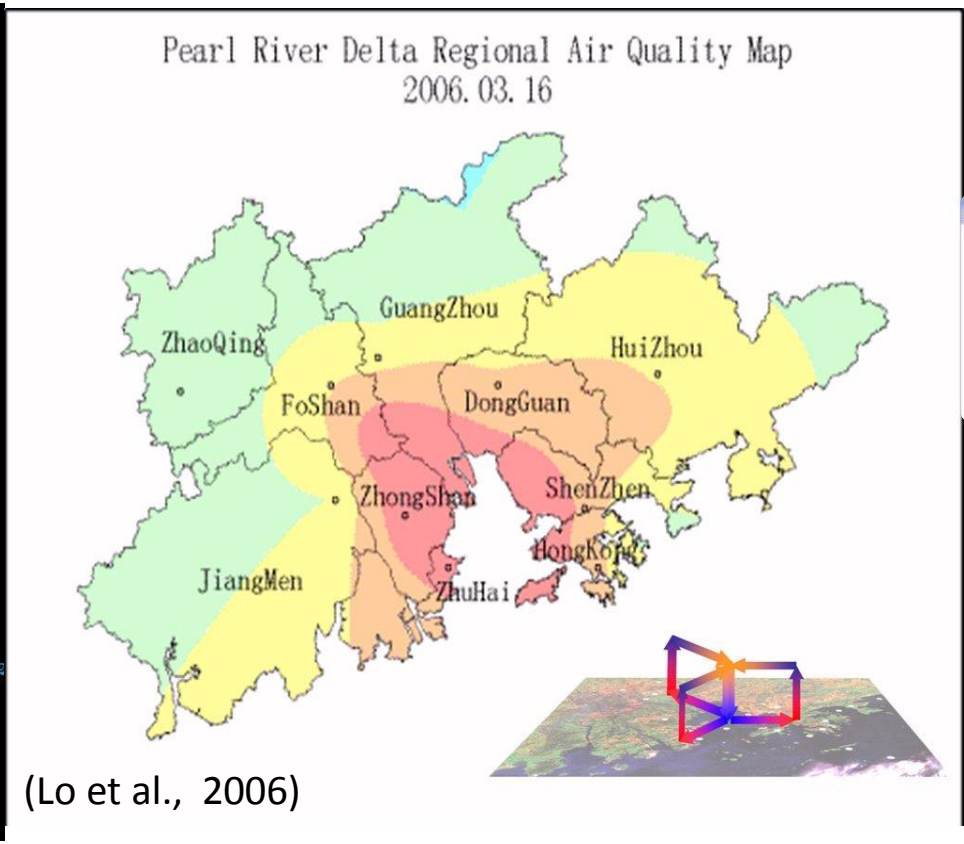
Classification of weather systems corresponding to the 83 high PM samples of Hong Kong in 2004–2005.

Weather type	Dominant regional surface wind direction	Period of occurrence	No. of high PM samples
HP	NW	October to May	8
	N		30
	NE		13
HPR	N or NE(1SE)	October to March	8
Typhoon	NW or N	June to October	17
LPT	NW (1SE)	Mostly August to September	7

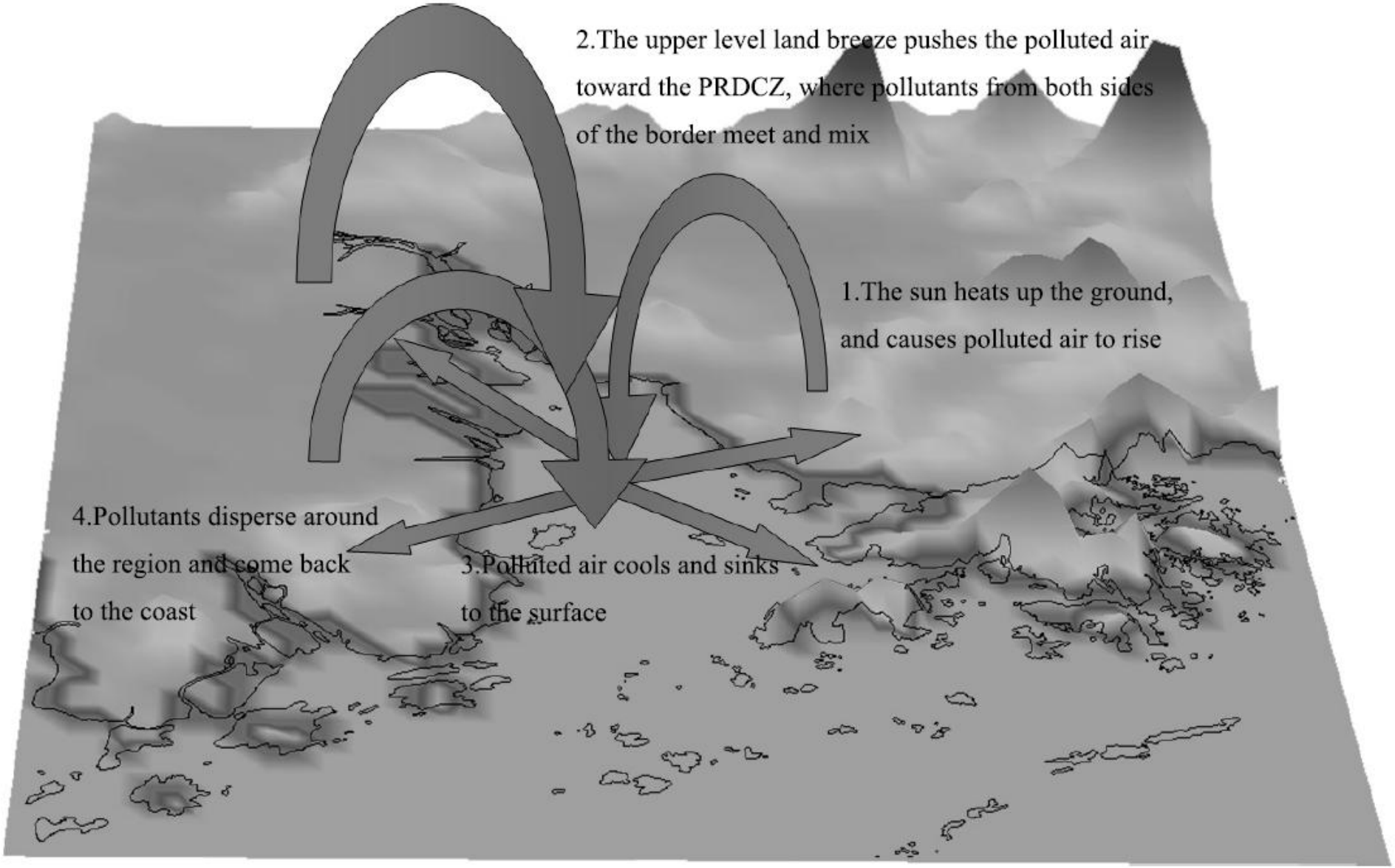
X.-F. Huang et al. / Atmospheric Environment 43 (2009) 1196–1203

Extensive urbanization and Land-use changes can modify local meteorology and alter pollution transport and trapping



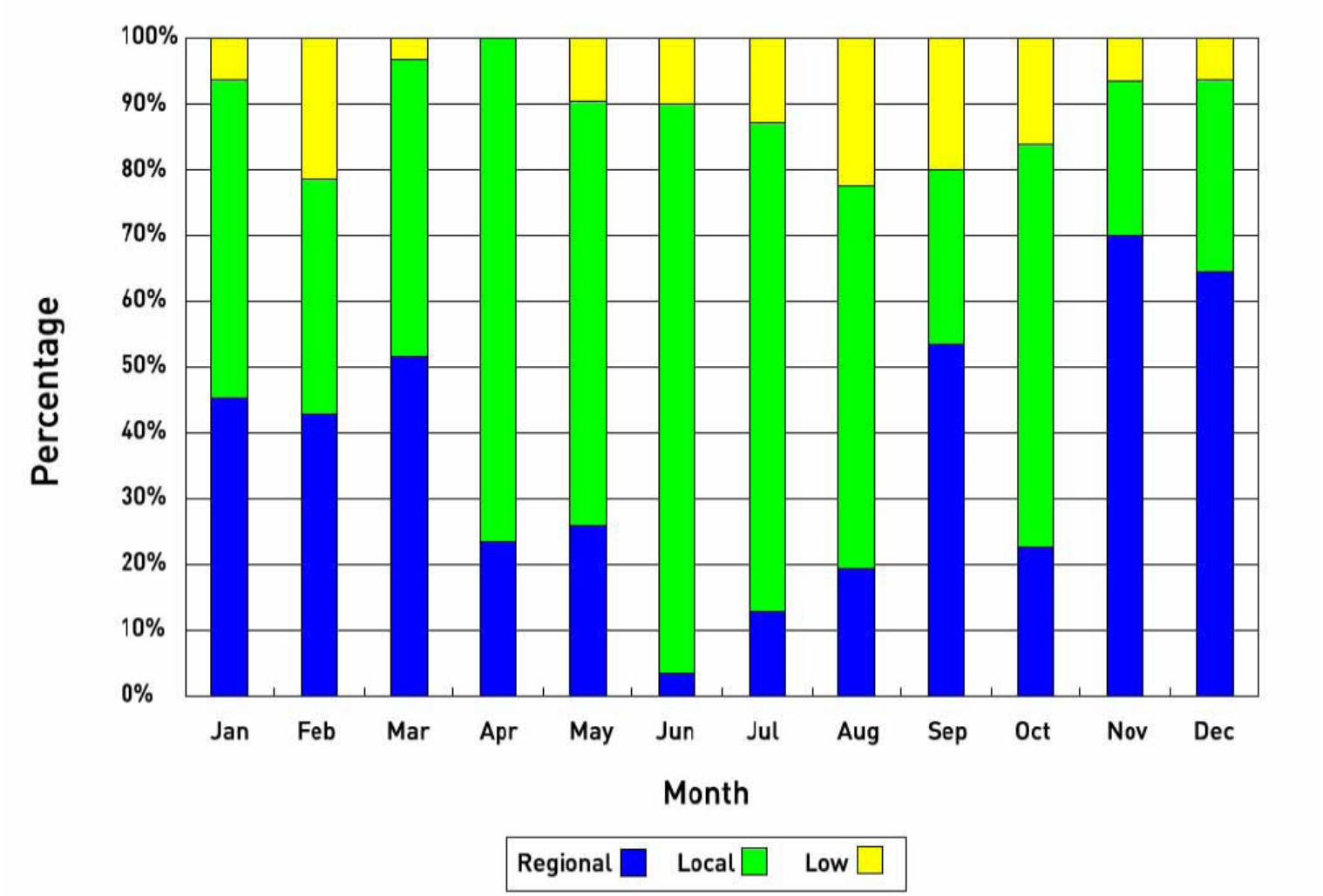


(Lo et al., 2006)



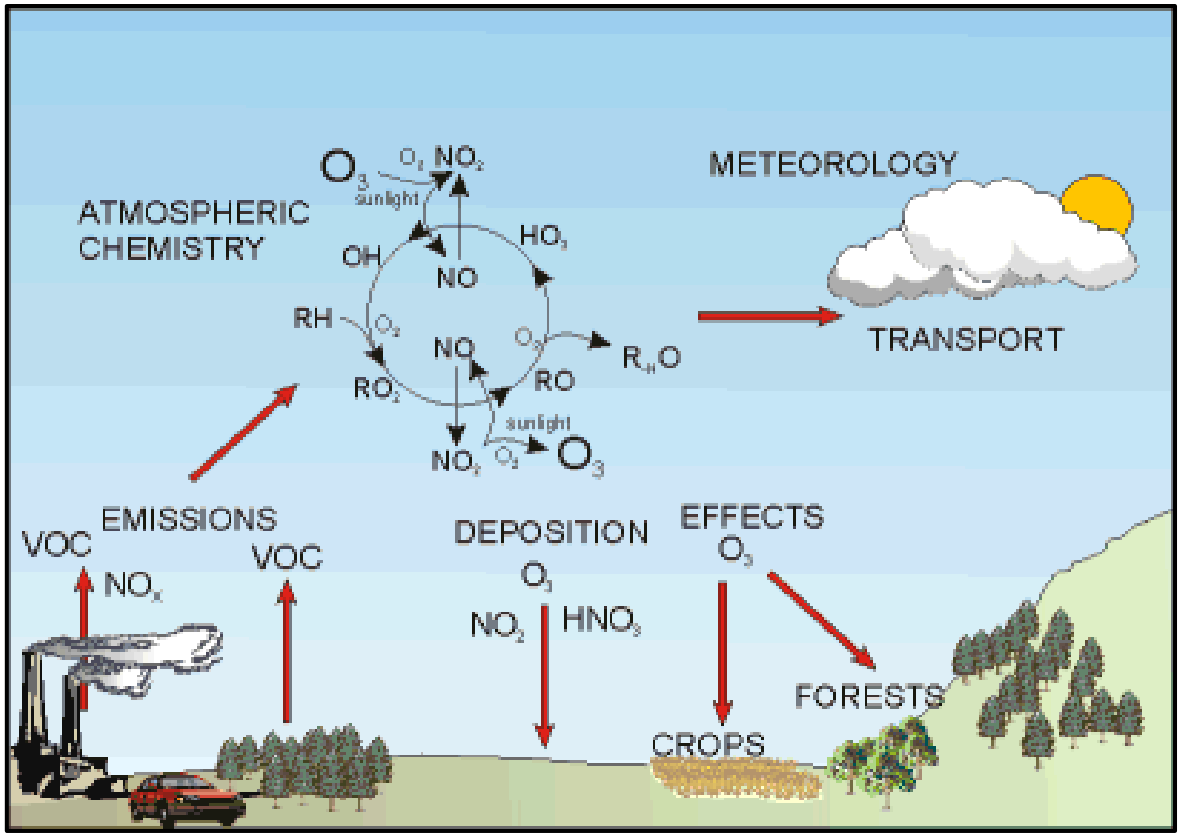
- Trapping of air pollutants mechanisms by coastal and urban land sea breeze circulations over the PRD regions

Local vs. Regional



Lau et al. Relative Significance of Local vs. Regional Sources: Hong Kong's Air Pollution, Civic Exchange, 2007

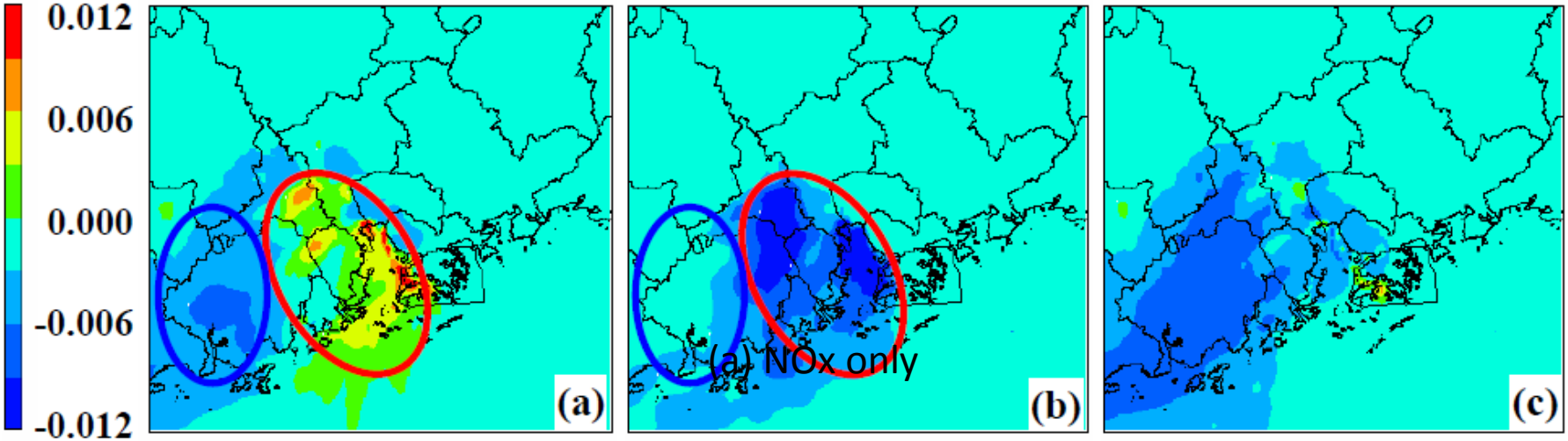
Ozone



- regional problem
- potent oxidant
- VOC/NOx/light
- AVOC & BVOC

From: http://www.globalchange.umich.edu/gctext/Inquiries/Inquiries_by_Unit/Unit_9.htm

Ozone formation – VOC limited



a: -25% NOx only **b: - 25% VOC only** **c: -25% both NOx and VOC**

- The MM5/SMOKE/CMAQ modeling
- sea-land circulation play an important role in region ozone formation & distribution

Wang et al Atmos. Chem. Phys., 10, 4423–4437, 2010

Fig. 14. Surface O3 change averaged over 12:00–17:00 LST on 16–22 October 2004 due to a 25% reduction in anthropogenic emissions of (a) NOx only, (b) VOCs only, and (c) both NOx and VOCs. The blue and red ellipses mark the regions with the O3 change characterized by NOx-limited chemistry and by VOC-limited chemistry, respectively.

The soup of volatile organic compounds (VOC)

	TM		C/W		TC		YL	
	Average	95% confidence interval	Average	95% confidence interval	Average	95% confidence interval	Average	95% confidence interval
Continuously measured trace gases								
O_3 (ppbv)	31.6	3.6	20.0	3.0	20.1	2.9	15.3	2.2
SO_2 (ppbv)	4.3	0.1	6.4	1.1	5.5	1.3	6.2	1.2
NO_2 (ppbv)	6.7	0.5	24.8	2.9	21.1	3.3	29.1	3.0
Canisters samples of CO and VOC (pptv, unless otherwise stated)								
CO (ppbv)	310	40	376	43	351	53	511	59
CH_4 (ppmv)	1.888	0.019	1.925	0.025	1.901	0.030	2.024	0.044
Ethane	1787	271	1829	263	1724	274	2116	300
Propane	861	142	1595	218	1196	266	2545	398
i-butane	341	57	899	98	502	102	1461	184
n-butane	592	96	1464	160	951	212	2625	356
i-pentane	369	51	519	62	450	91	1143	141
n-pentane	172	26	250	32	230	49	541	76
Ethene	859	143	1465	195	1297	259	2674	352
Propene	141	21	315	36	246	41	606	75
i-butene	114	22	173	26	140	28	344	35
1-butene	52	7	92	11	75	14	193	24
Isoprene	334	81	178	46	148	30	192	24
1,3-butadiene	19	3	48	6	38	7	106	13
Ethyne	1365	234	1950	279	1768	354	2872	460
Benzene	402	72	417	70	464	101	731	119
Toluene	1033	239	2765	421	2265	689	4340	871
o-xylene	57	15	222	39	163	50	306	61
m-xylene	95	26	445	87	311	108	590	130
p-xylene	62	18	258	46	178	54	340	70
Ethylbenzene	123	33	395	87	346	121	545	127

Guo et al. Atmospheric Environment 40 (2006) 2345–2359

VOC: Local contributions are large!

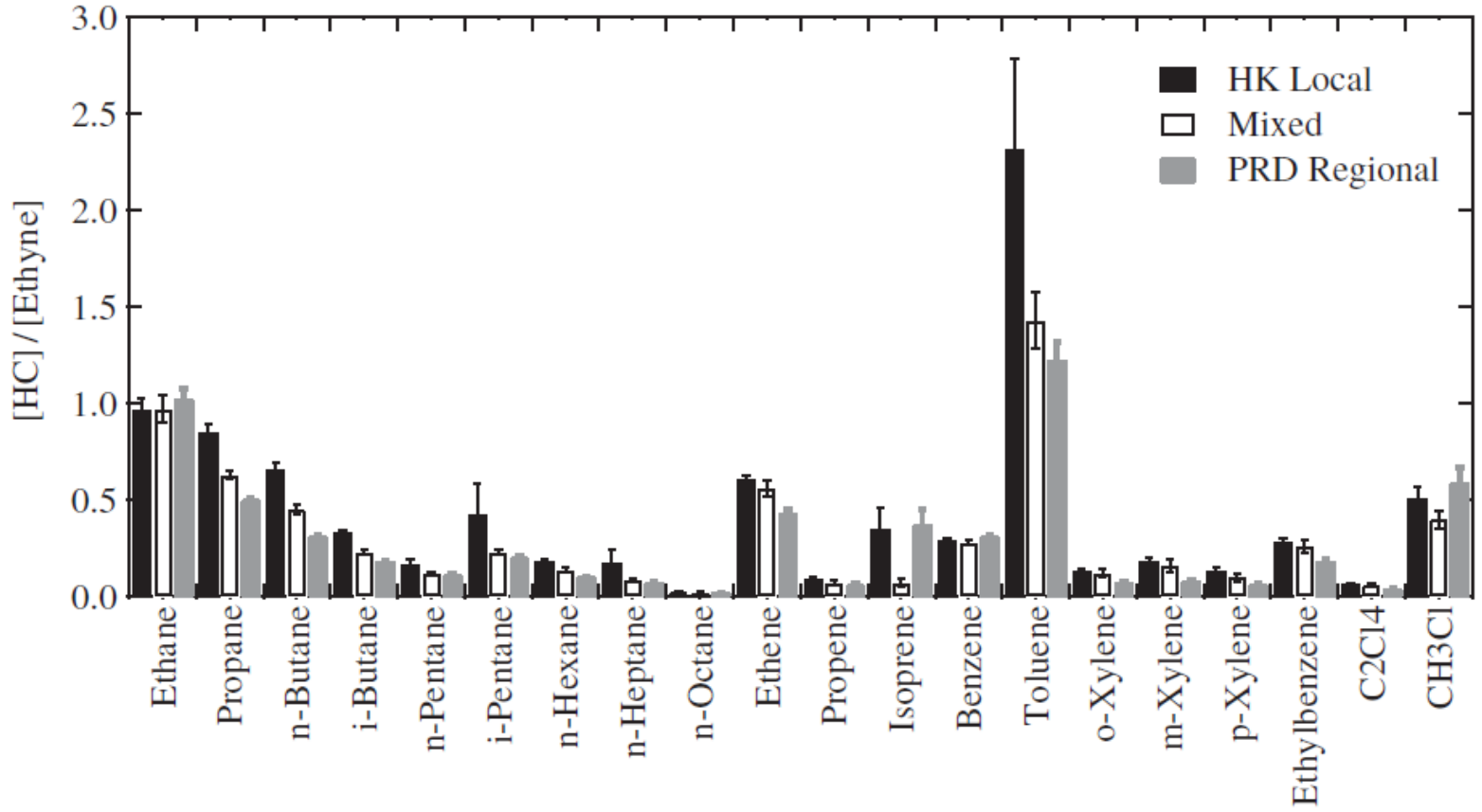
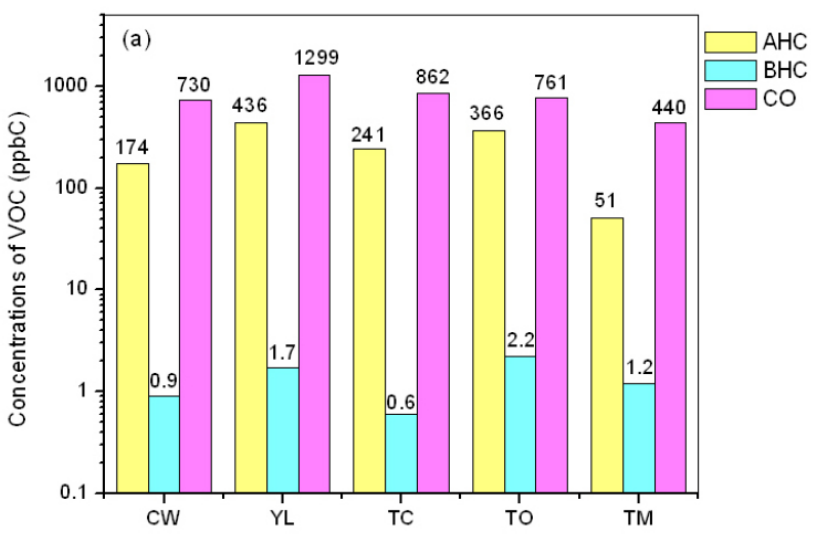
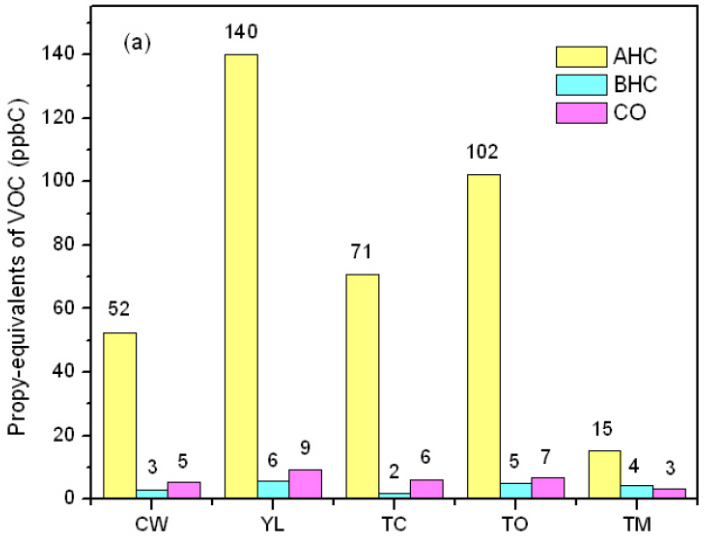
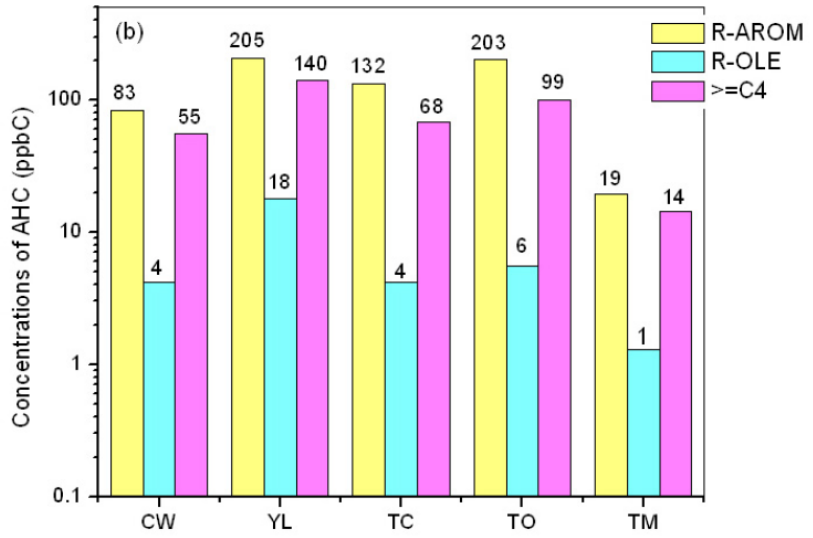


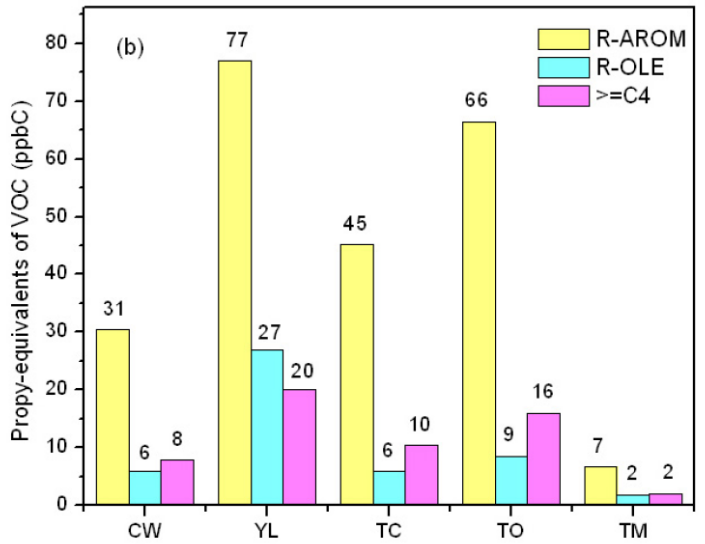
Fig. 3. Comparison of NMVOC distributions in HK (local) and the inner PRD (regional).

VOC concentrations and reactivity









Zhang et al. Atmos. Chem. Phys., 7, 557–573, 2007

Relative Incremental Reactivity (RIR)

AHC = Anthropogenic Hydrocarbon

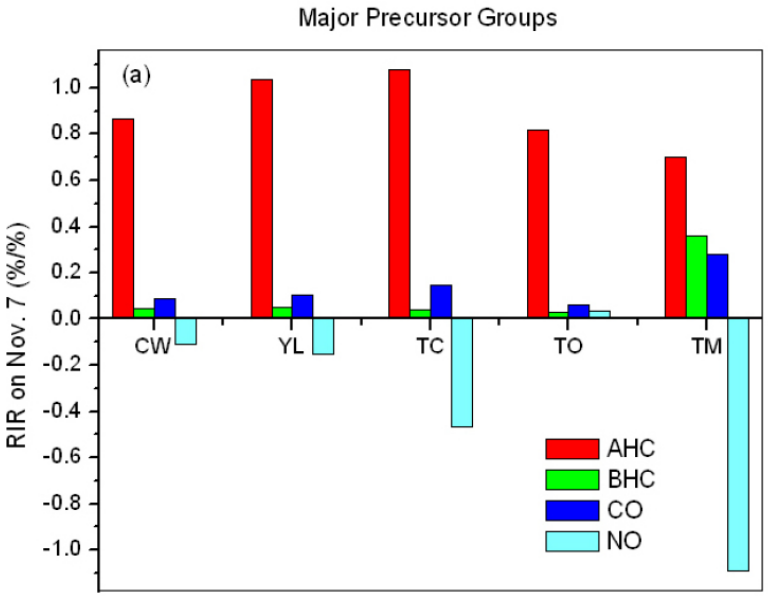
BHC = Biogenic Hydrocarbon

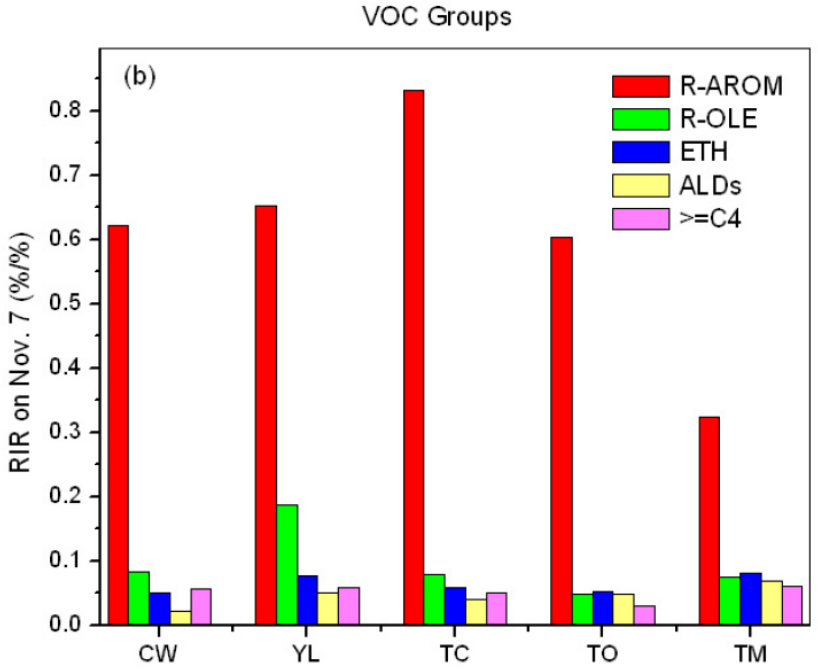
CO = Carbon Monoxide

NO = nitrogen oxide

R-AROM = Aromatic organic compounds

DOMINANT compounds in O3 formation





Zhang et al. Atmos. Chem. Phys., 7, 557–573, 2007

Toluene and Xylenes dominate VOC reactivity

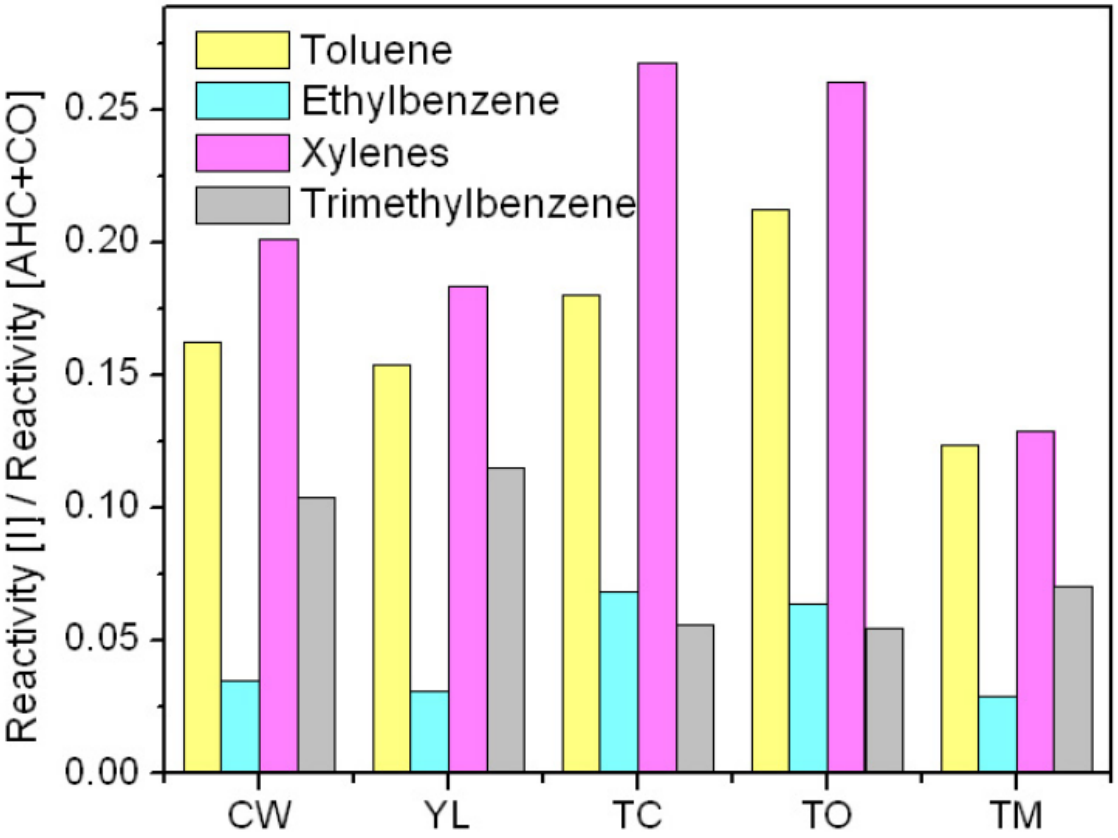


Fig. 8. Propy-equivalent reactivity fractions of different species to the total reactivity of anthropogenic VOCs and CO on 7 Novmeber 2002: Toluene, Ethylbenzene, Xylenes and Trimethylbenzene.

Vehicular contributions are large!

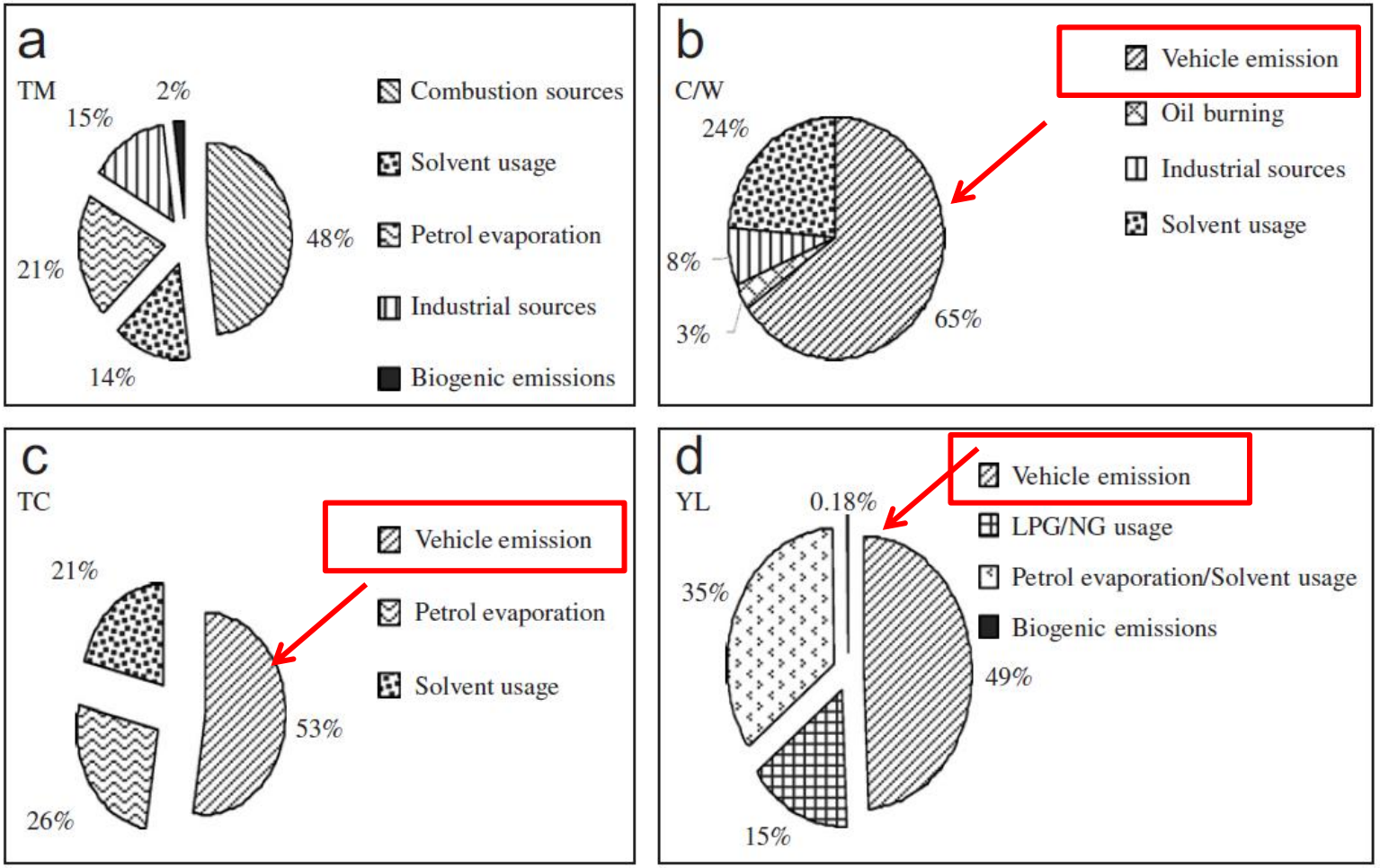


Fig. 6. Source contributions to the total NMVOCs at (a) TM, (b) C/W, (c) TC and (d) YL.

H. Guo et al. / Atmospheric Environment 41 (2007) 1456–1472

Role of BVOC in ozone formation

H.R. Cheng et al. / Atmospheric Environment 44 (2010) 4199–4208

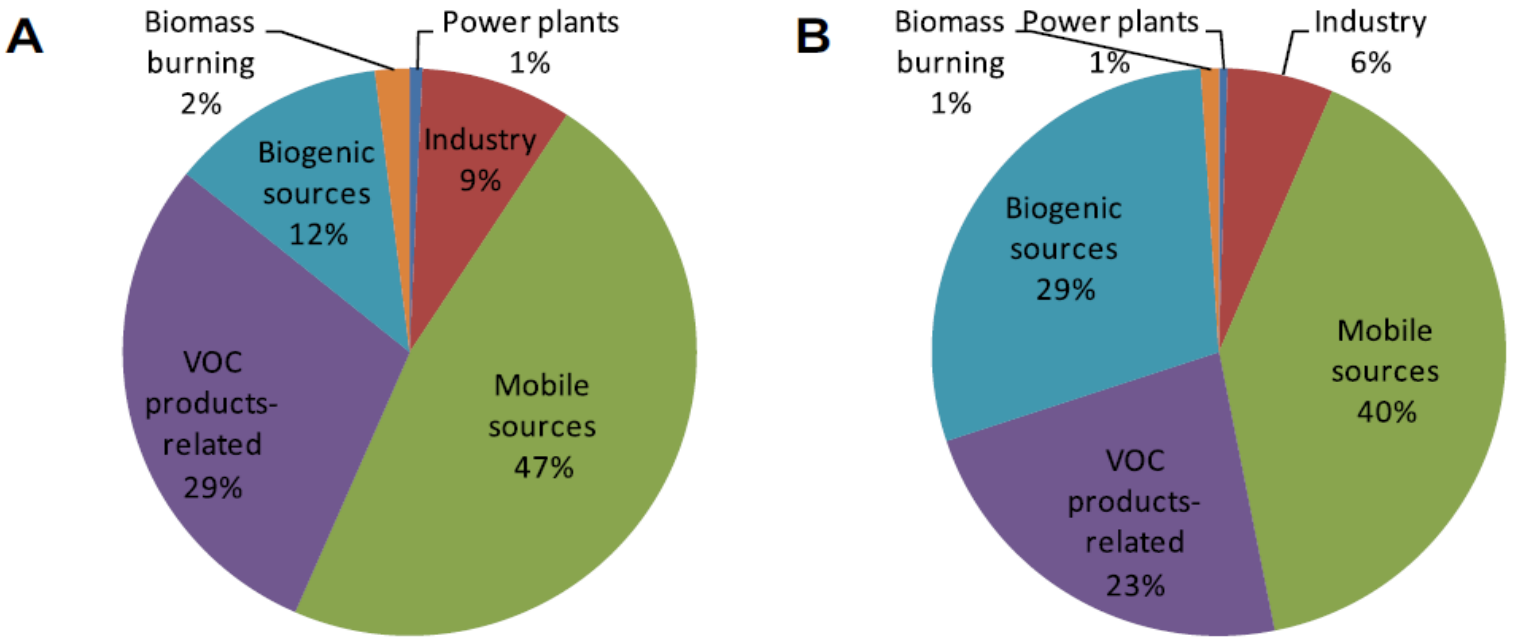
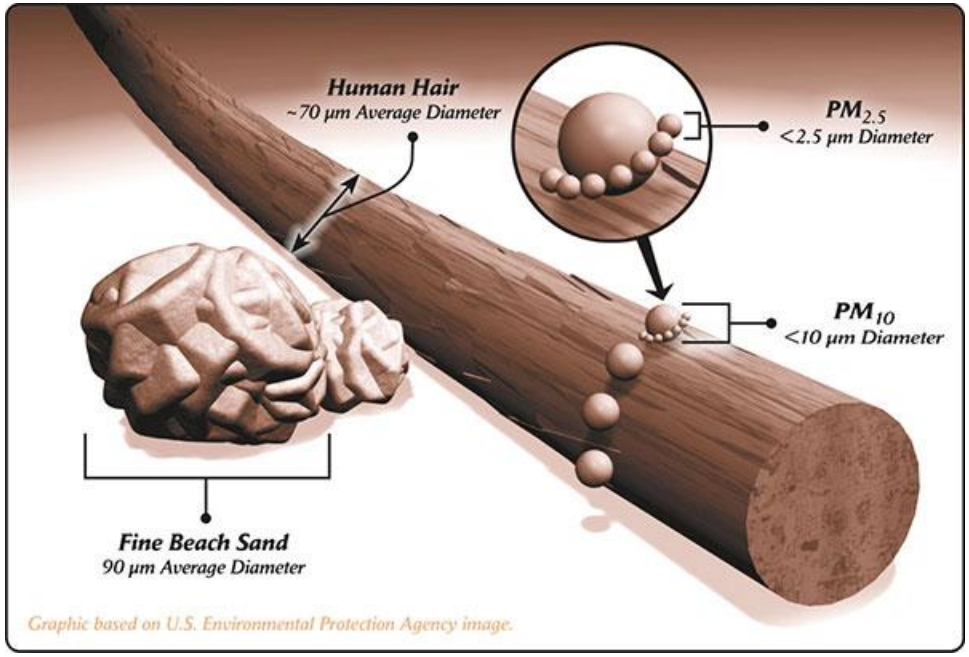


Fig. 8. Source contributions to anthropogenic VOC emissions (A) and source contributions to regional ozone formation (B).

A photochemical trajectory model (PTM), coupled with the Master Chemical Mechanism (MCM) describing the degradation of 139 volatile organic compounds (VOCs) in the troposphere, was developed and used for the first time to simulate the formation of photochemical pollutants atWangqingsha (WQS), Guangzhou during photochemical pollution episodes between 12 and 17 November, 2007.

Particulate Matter

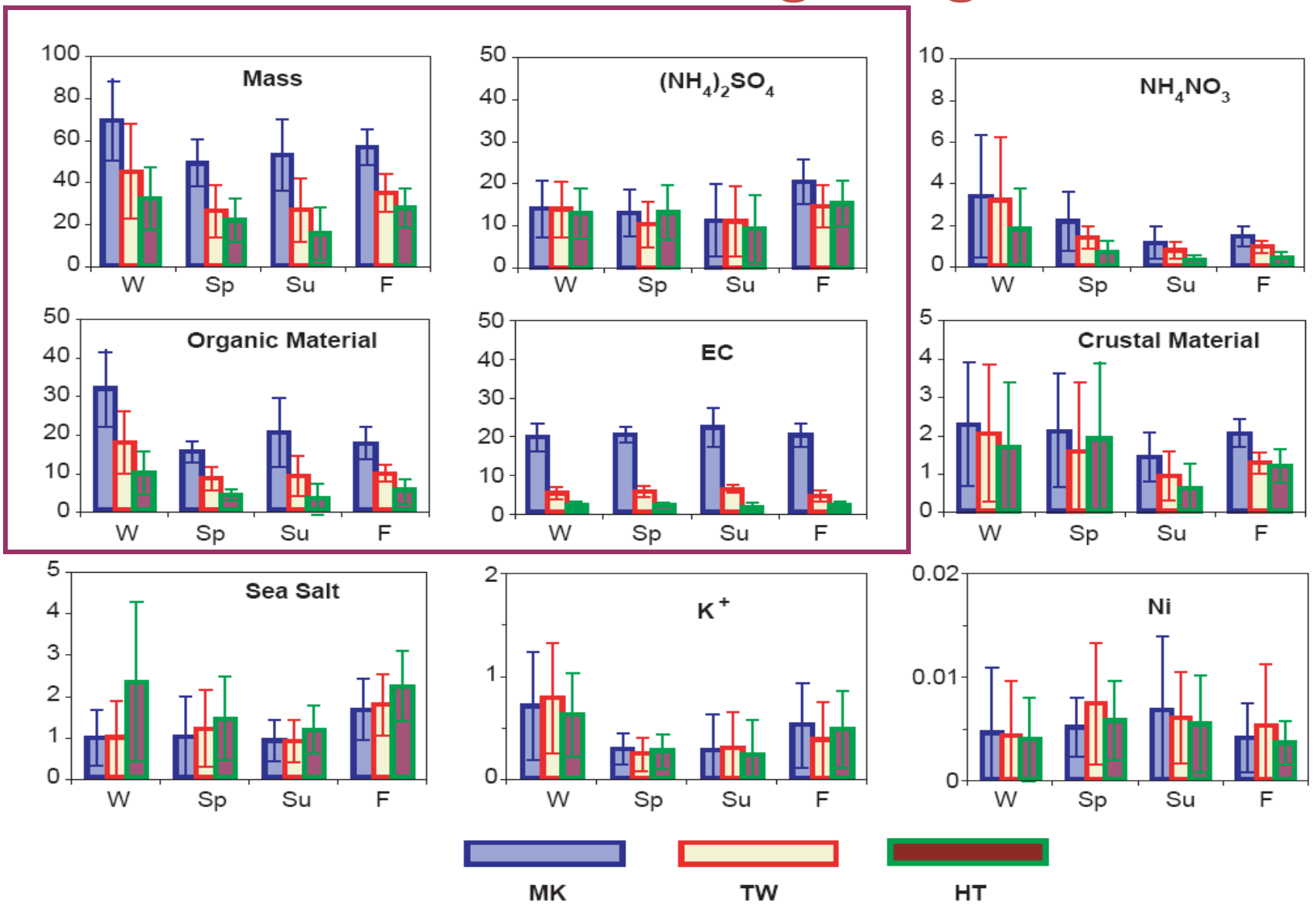


From http://www.sbcapcd.org/sbc/pollut.htm

Poschl , 2005

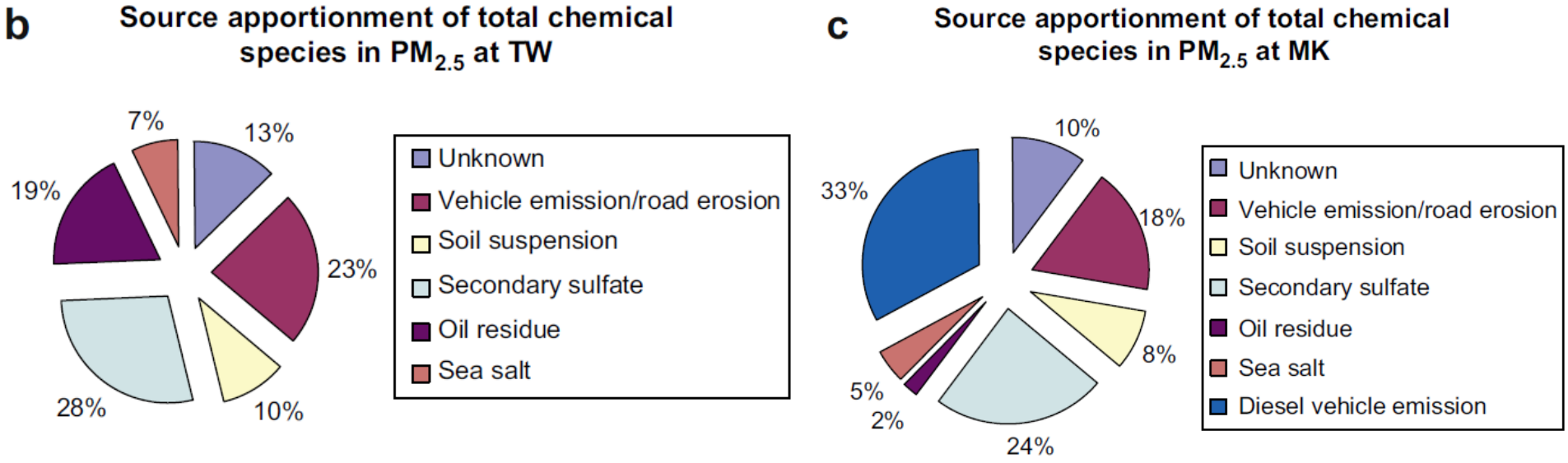
- Size: from molecule clusters (10^{-9} m) to fast-settling sand (10^{-4} m).
- Shape: as weird as you can imagine; depends strongly on composition and formation processes.

PM2.5 in Hong Kong



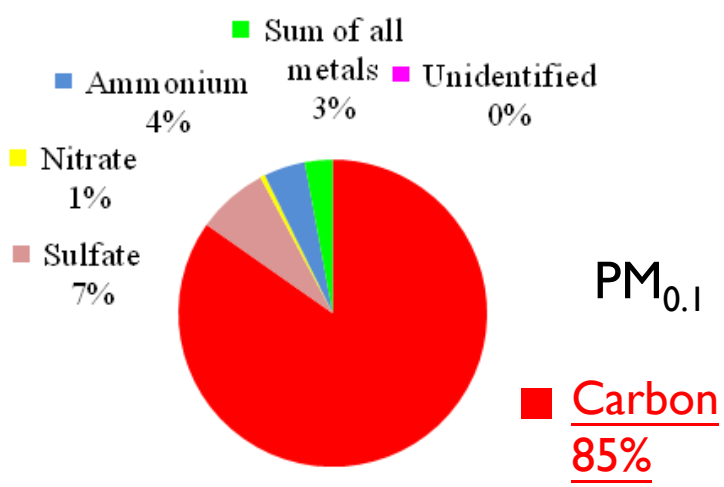
Louie et al. (2005), Atmospheric Environment 39, 1695.

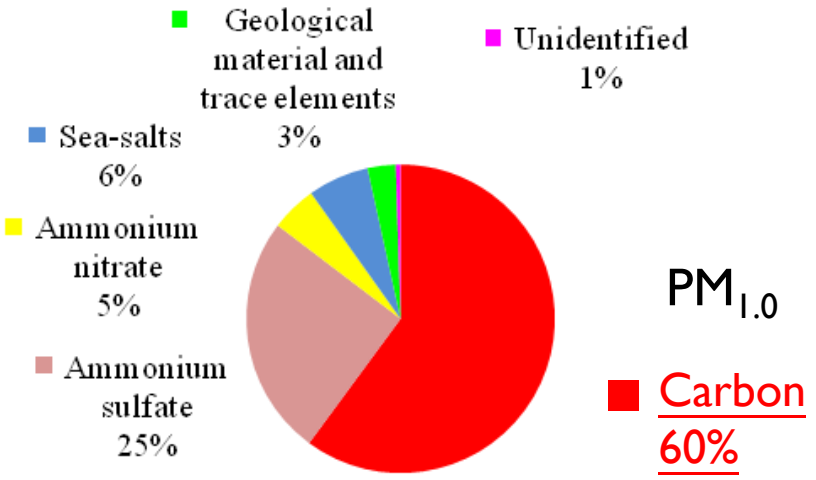
Source Apportionment of PM2.5

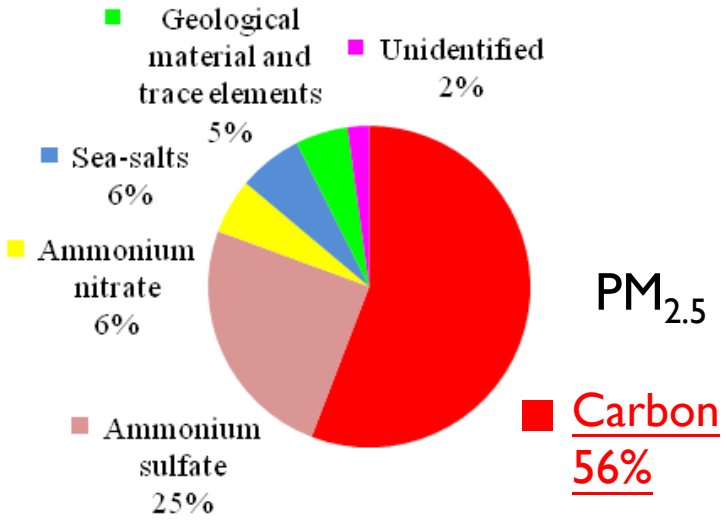


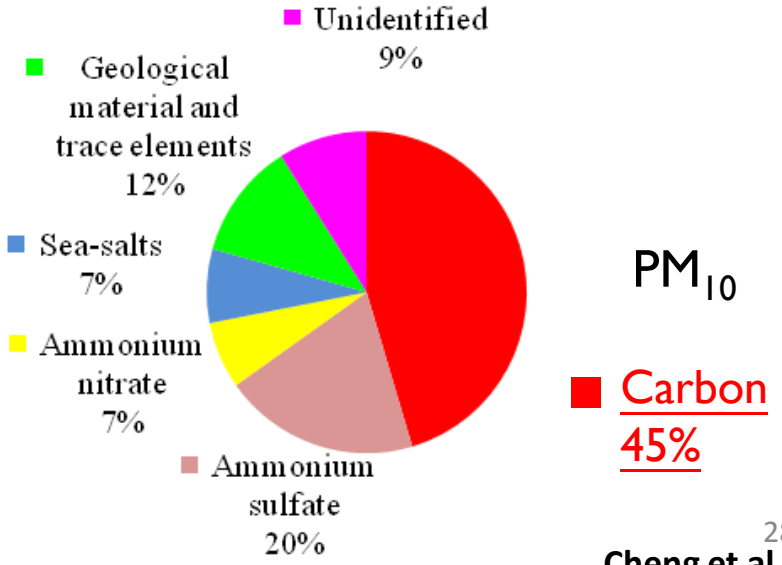
Guo et al. Atmospheric Environment 43 (2009) 1159–1169

Chemical composition of fine and coarse particles at a roadside site - Carbon Percent increase with Finer Particles





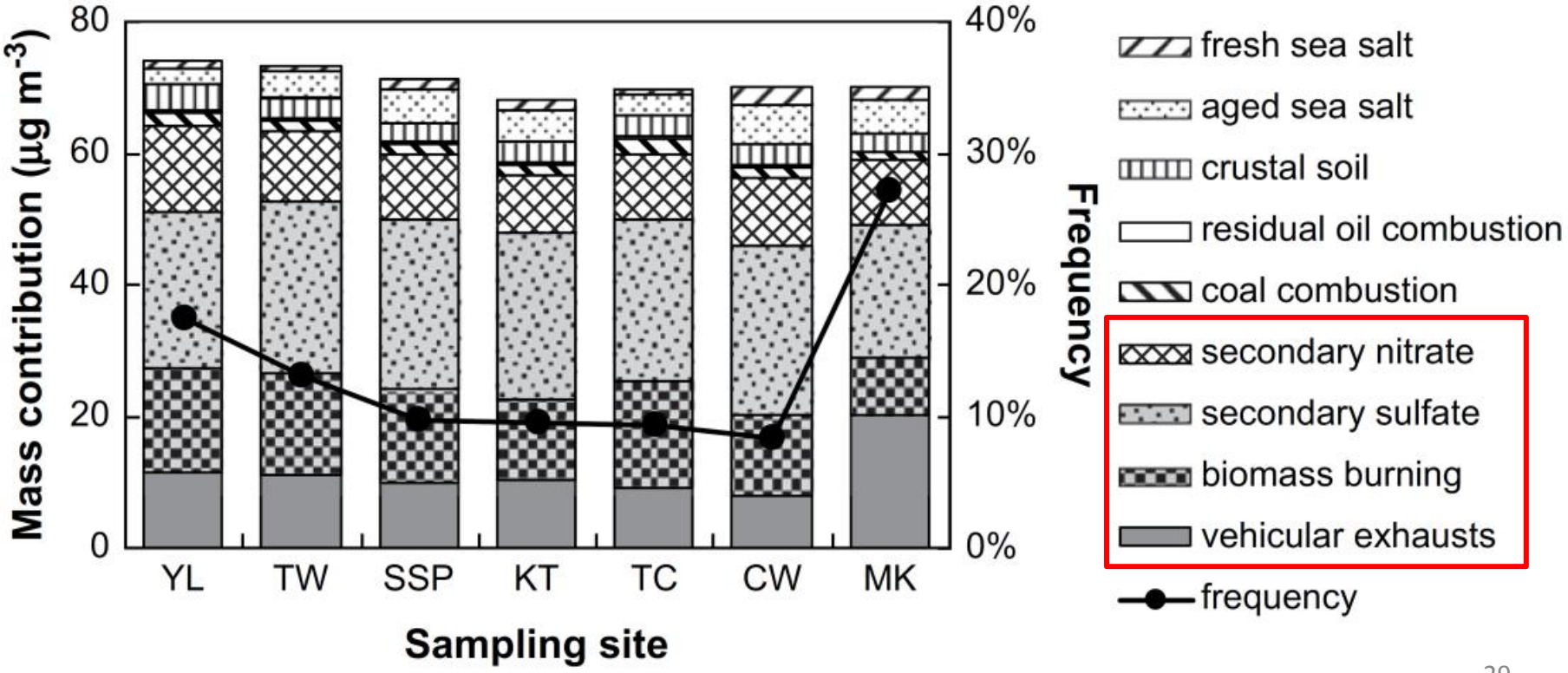




Cheng et al. (2006)

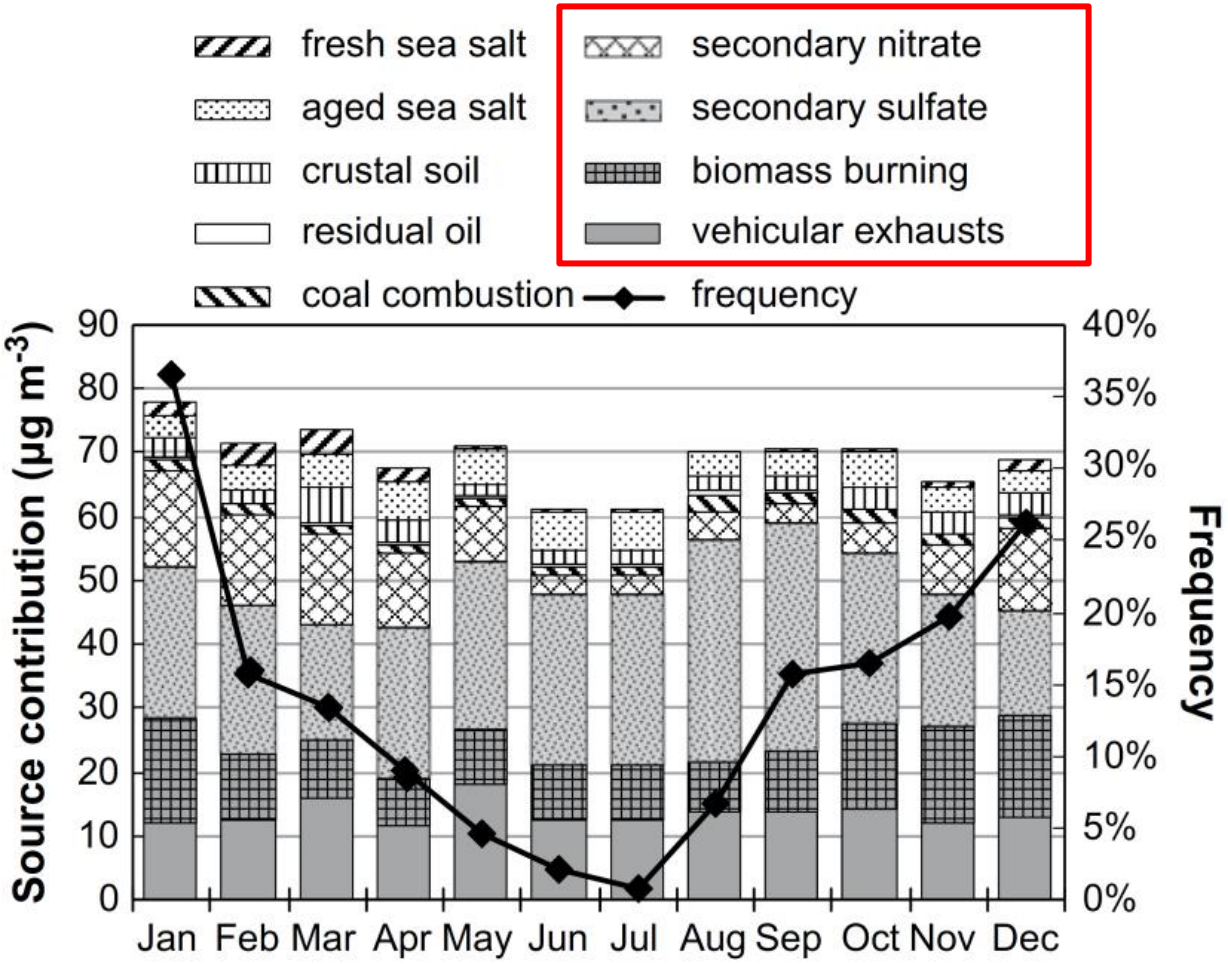
High particulate matter days in Hong Kong

- EPD samples in 1998-2005
- Days with PM10 levels exceeding 56 µg/m3, the average plus one standard deviation of the mass concentration of all samples, are defined as high PM days.



Huang et al. Atmospheric Environment 43 (2009) 1196–1203

High particulate matter days in Hong Kong



Huang et al. Atmospheric Environment 43 (2009) 1196–1203

Primary vs. Secondary PM

- Primary
  - Directly emitted from sources
  - Element Carbon (soot) and Organic Carbon (OC)
  - Seasalt aerosols
- Secondary
  - Not emitted but formed in the atmosphere
  - Sulfate, nitrate, ammonium
  - Secondary organic aerosols

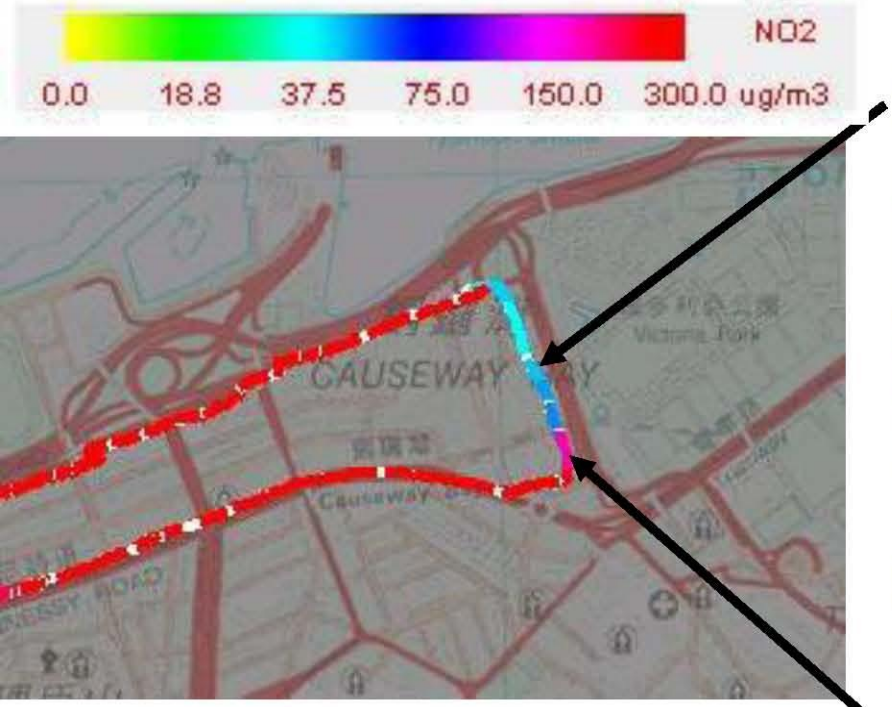
Local Hong Kong Sources

大氣監測走航平台 (MAP)
Mobile Air-monitoring Platform

33

Roadside Pollution:
Street Canyon & Ventilation Effects

- Traffic density is NOT the only factor controlling street level air quality



09:42-10:00, 23rd September 2009

Chan et al (2010)

Traffic vs. Pollution

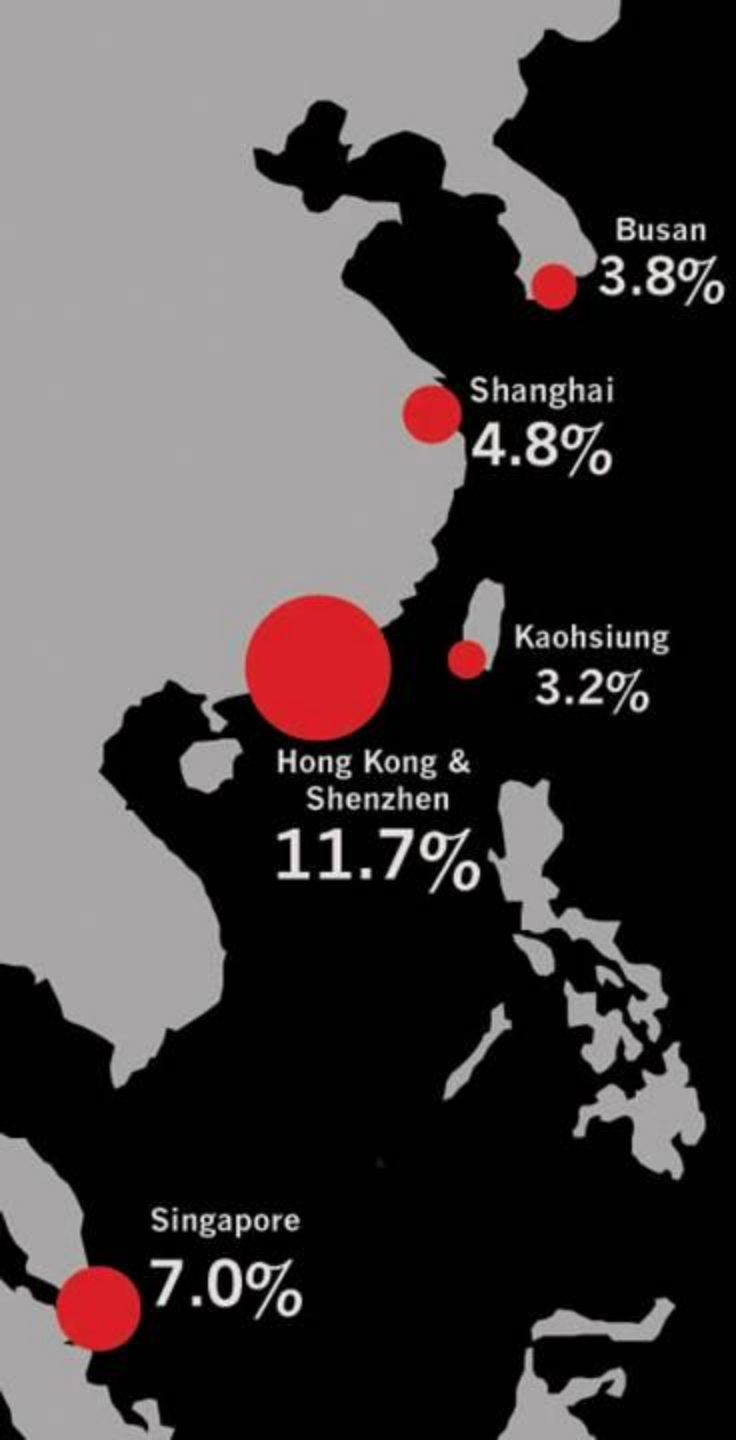
	Traffic density vehicles/day	NOx ug/m3	Fine particles #/cc
Island Eastern Corridor	91,000	540	37,000
Gloucester Road	74,000	600	24,000
Nathan Road	41,000	1,200	30,000
Ma Tau Wai Road	27,000	820	29,000
Hennessy Road	26,000	1,300	34,000
King's Road	24,000	860	34,000
King's Park	17,000	320	11,000
Ho Man Tin	17,000	320	15,000
Des Voeux Road	13,000	1,100	50,000
Canton Road	11,000	560	22,000
Stanley	6,400	220	12,000

Gloucester Road

Des Voeux Road C.

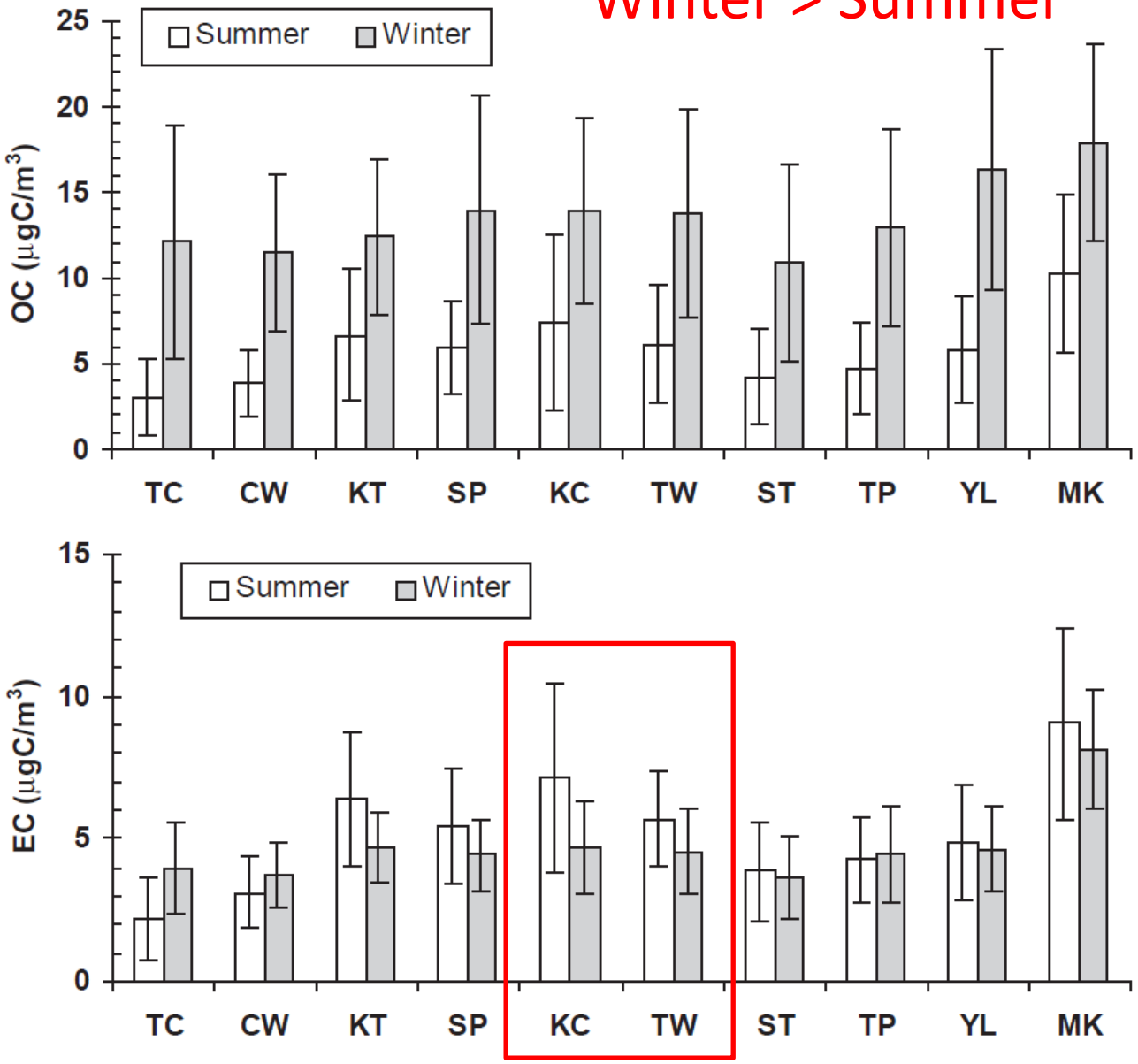
Canton Road


Image © 2009 GeoEye
©2009 Google
Imagery Date: Feb 5, 2009
22°17'48.17" N 114°10'08.28" E elev 80 ft
Eye alt 3089 ft



- Hong Kong and Shenzhen's port together handled 11.7% of the world's container throughput (Civic-Exchange 2007).
- As the port of Hong Kong and those in Shenzhen will continue to expand, clean-up is urgent
- Impact of local emissions (vehicle and shipping) was recently highlighted in RTHK program (鏗鏘集 - 屏息以待) on 1st August, 2010

Winter > Summer



J.Z. Yu et al. / Atmospheric Environment 38 (2004) 1511–1521

Secondary Particulate Pollution in HK/PRD

- Sulfate and Nitrate
- Secondary organic aerosols
  - Anthropogenic VOC
    - BTEX (benzene, toluene, ethylbenzene, and xylenes)
    - Gasoline
    - From vehicle, industry, power plant etc
  - Biogenic VOC
    - Isoprenoids: iosprene, monoterpenes, sesquiterpenes
    - Oxygenated BVOCs: hexenal
    - From plants & microorganisms
    - AVOC >BVOC in terms of concentrations (role of BVOC in ozone is small)

Contribution of Secondary OC in HK/PRD

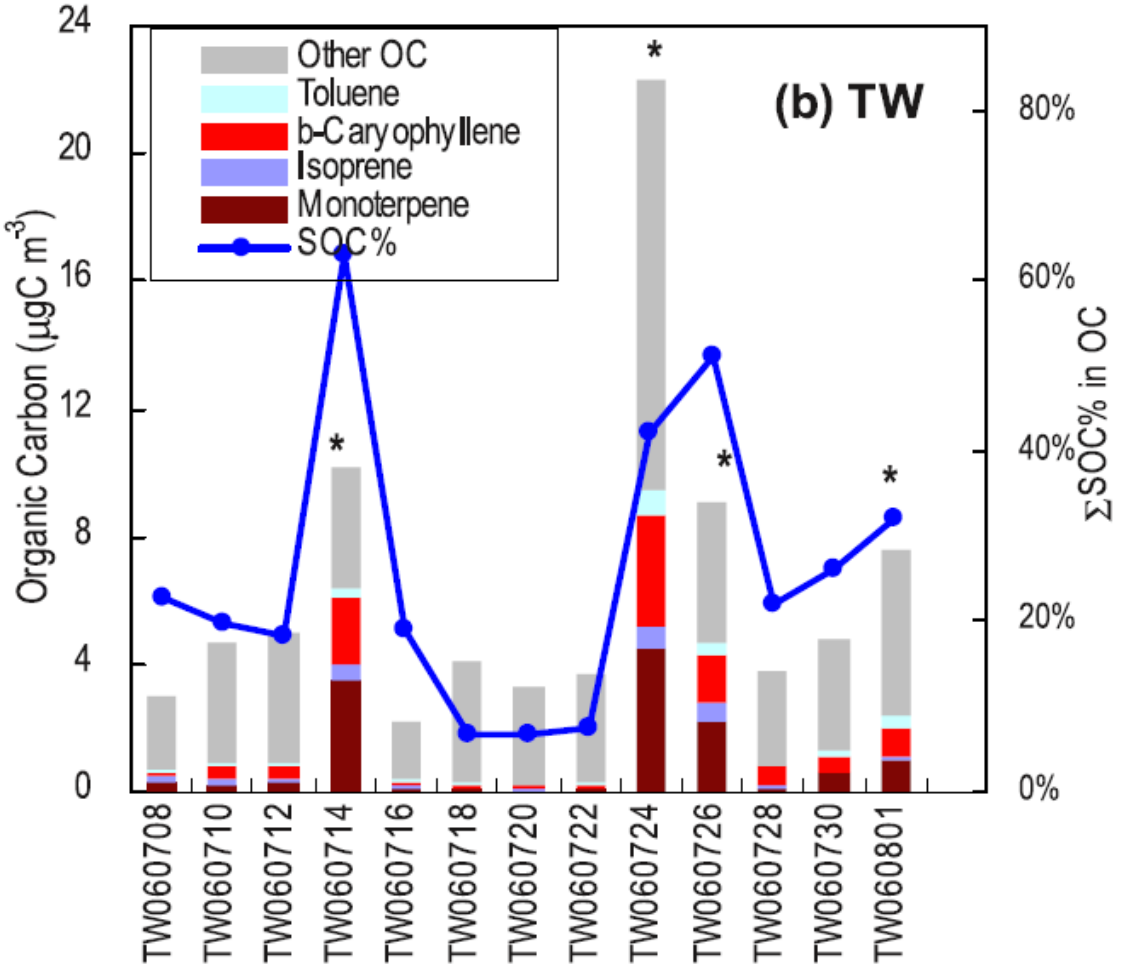
Tracer approach

1. WSOC – formed during photochemical aging, can be hydrophobic and hydrophilic in nature
   - Account for 60% of OC in Backyard Garden (rural) [Miyazaki et al., 2009, JGR]
2. EC/OC ratio – estimate SOC by the difference of OC and pri. OC
   - SOC account for 21-32% and 36-42% of OC in summer and winter, respectively, in GZ (urban) [Duan et al., 2007, AE]
3. SOA tracers of isoprene, monoterpene, toluene from lab expt.
   - Account for 21-49% of OC in HK (urban, suburban) [Hu et al., 2008, JGR]

Modeling approach

1. CMB – SOC account for 44- 72% of $PM_{2.5}$ OC in HK [Hu et al., 2010, JGR]
2. PMF – annual average SOC in HK estimated as 4.25µg C/m^3 [Yuan et al., 2006, ACP]

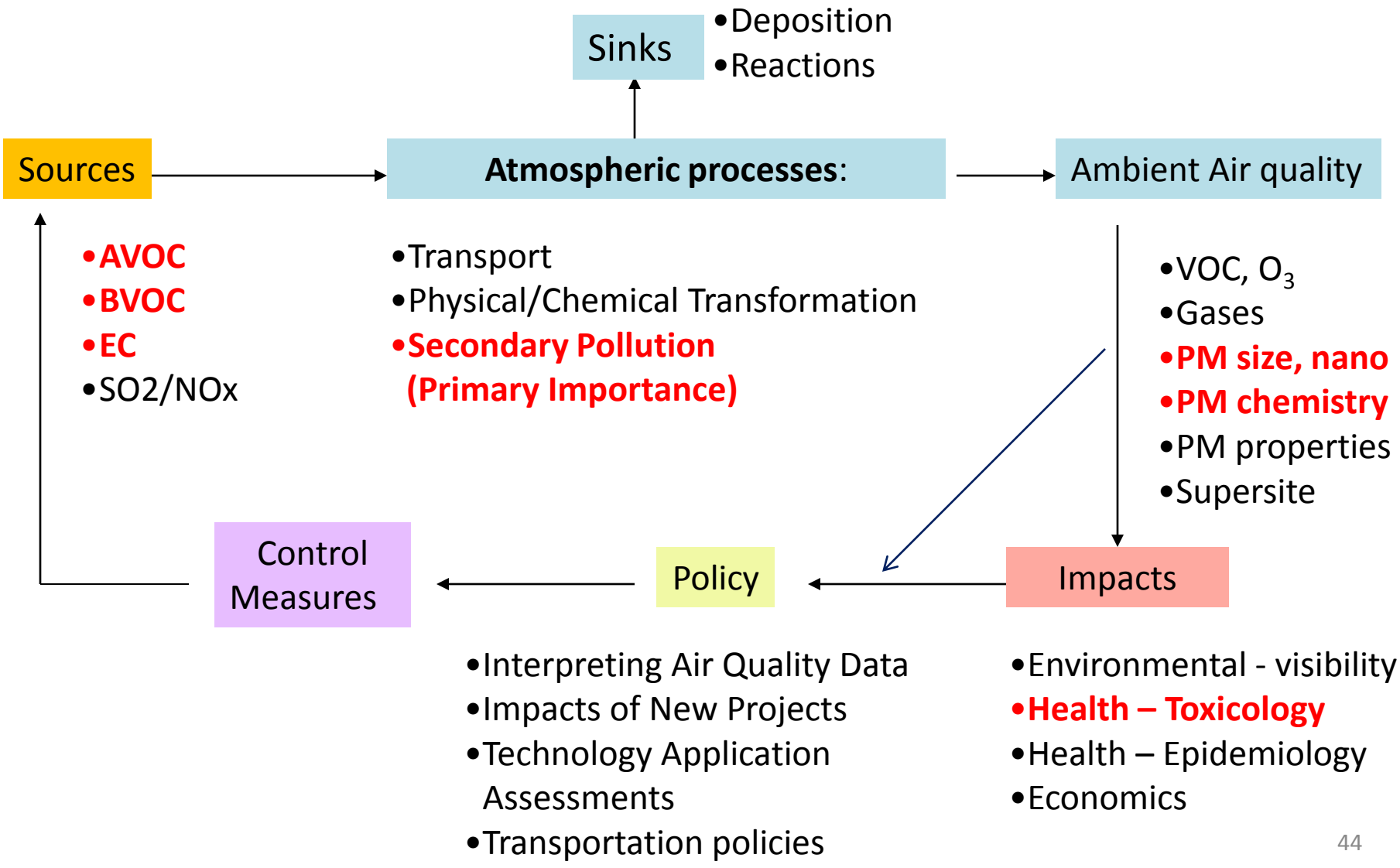
Secondary organic aerosols in HK -contributions of BVOC



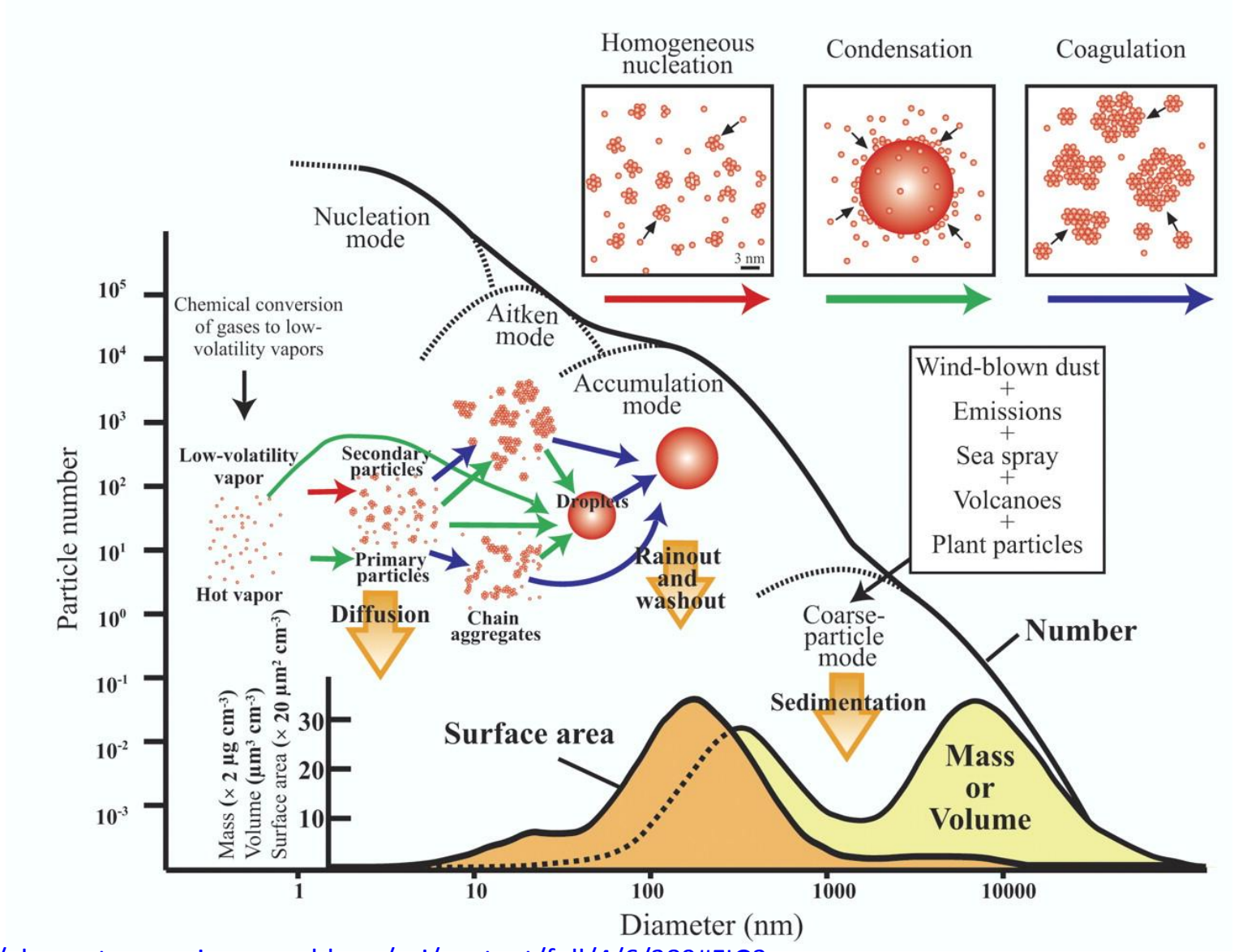
- tracer-based method to study contribution of isoprene, monoterpenes, β-caryophyllene, and toluene to SOA formation
- monoterpenes and β-caryophyllene are significant contributors to ambient PM2.5 in the summer

Hu et al. JGR, VOL. 113, D22206, doi:10.1029/2008JD010437, 2008

Air Quality Management



Complex world of PM



http://elements.geoscienceworld.org/cgi/content/full/4/6/389#FIG3

Buseck and Adachi, 2008

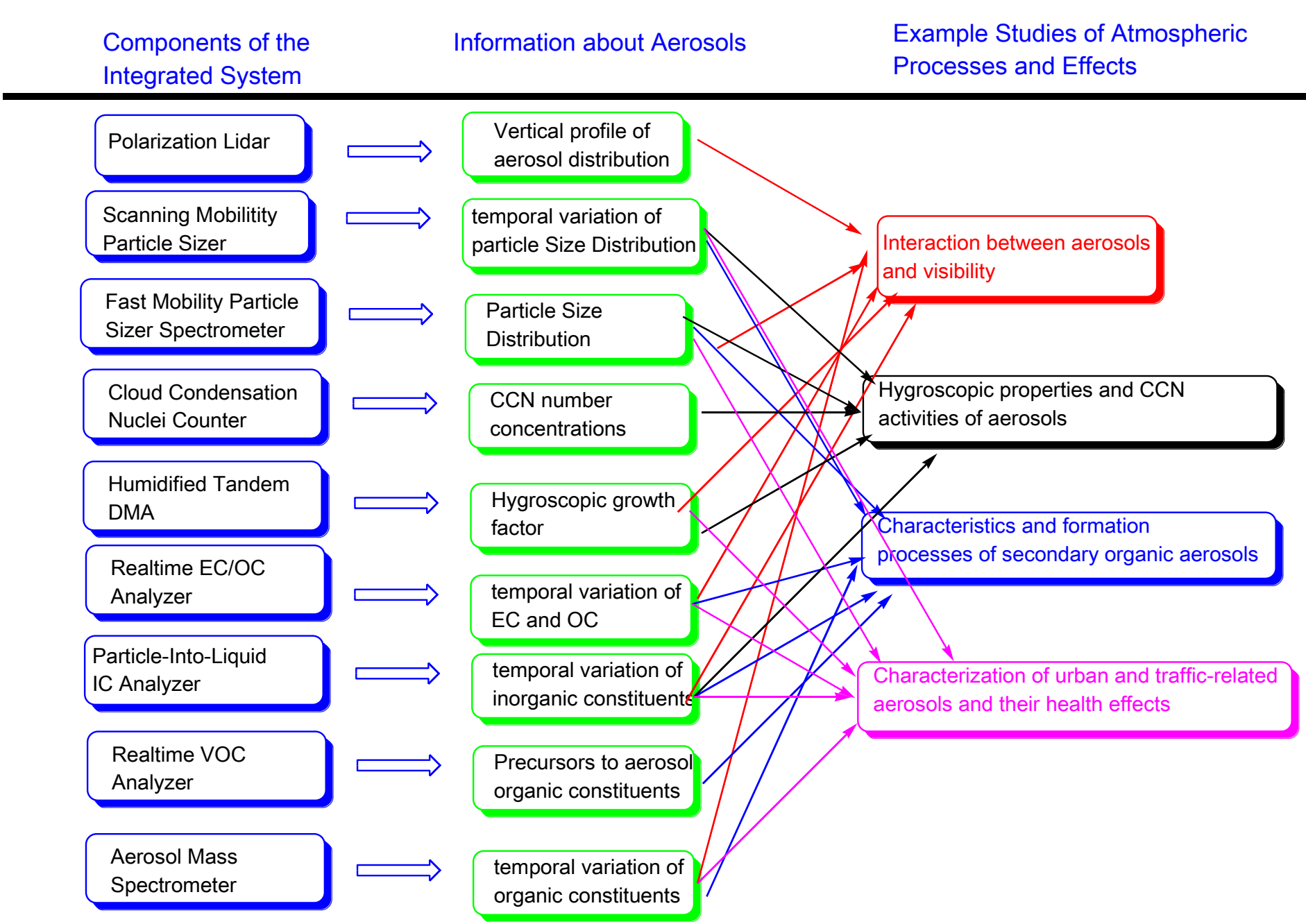
Air quality in Hong Kong: A supersite program for **real-time** characterization of Particulate Matter (PM)

Funding support from
The Environment and Conservation Fund

Partners:
Hong Kong Environmental Protection Department
Hong Kong Polytechnic University

UGC Supported SEG Equipment from HKUST

Module Name	Component
Physical Characterization System	Polarization Lidar
	Scanning Mobility Paticle Sizer System
	Fast Mobility Particle Sizer Spectrometer
	Cloud Condensation Nuclei counter
	Humidified tandem differential mobility analyzer (HTDMA)
Chemical Characterization System	Real-time EC/OC analyzer
	Real-time Particle-Into-Liquid Ion Chromatography
	Real-time VOC analyzer
	High resolution aerosol mass spectrometer


Components of the Integrated System
Information about Aerosols
Example Studies of Atmospheric Processes and Effects
Polarization Lidar
Scanning Mobilitity Particle Sizer
Fast Mobility Particle Sizer Spectrometer
Cloud Condensation Nuclei Counter
Humidified Tandem DMA
Realtime EC/OC Analyzer
Particle-Into-Liquid IC Analyzer
Realtime VOC Analyzer
Aerosol Mass Spectrometer
Vertical profile of aerosol distribution
temporal variation of particle Size Distribution
Particle Size Distribution
CCN number concentrations
Hygroscopic growth factor
temporal variation of EC and OC
temporal variation of inorganic constituents
Precursors to aerosol organic constituents
temporal variation of organic constituents
Interaction between aerosols and visibility
Hygroscopic properties and CCN activities of aerosols
Characteristics and formation processes of secondary organic aerosols
Characterization of urban and traffic-related aerosols and their health effects

A blue sky

Laboratory experiments

Modeling

Field measurements