Air quality modeling activities of 3C-Star in Pearl River Delta, China

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Outline

- Introduction to 3C-STAR
- PRD air quality Ensemble forecasting Model System
- CMAQ modeling in PRD-EMS
- Observational based approaches in PRD
- PRD-EMS activities in 2008

863 Major Project (2006-2010)
(Resource and Environmental Technology)

重点城市群大气复合污染综合防治技术与集成示范

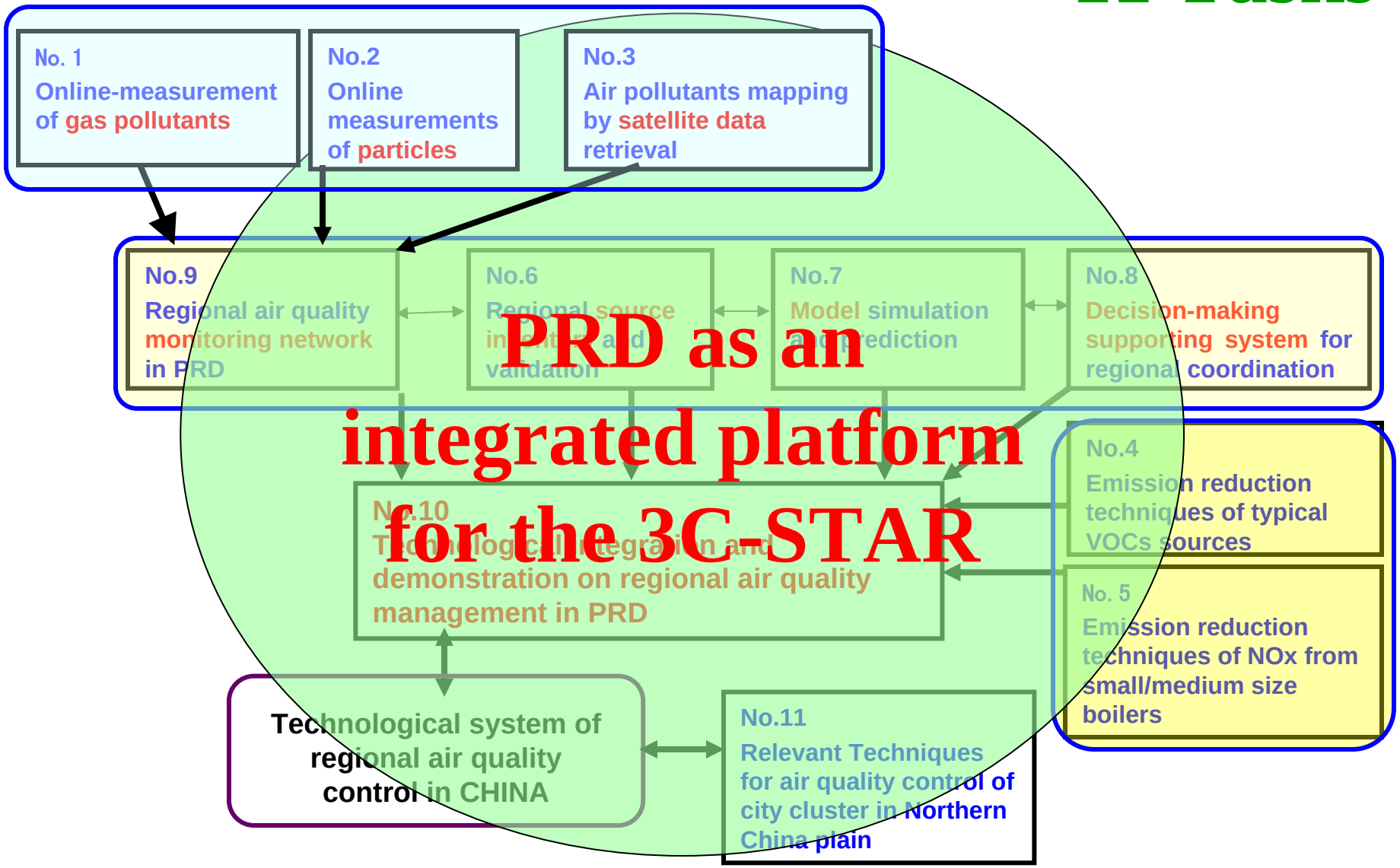
Synthesized Prevention Techniques for Air Pollution Complex and Integrated Demonstration in Key City-Cluster Region

3C-STAR

2006-2010

Framework of the 3C-STAR project:

11 Tasks



Ground based regional air quality monitoring and ensemble forecasting system

Feedbacks (setting standards and assess achievements)

Region

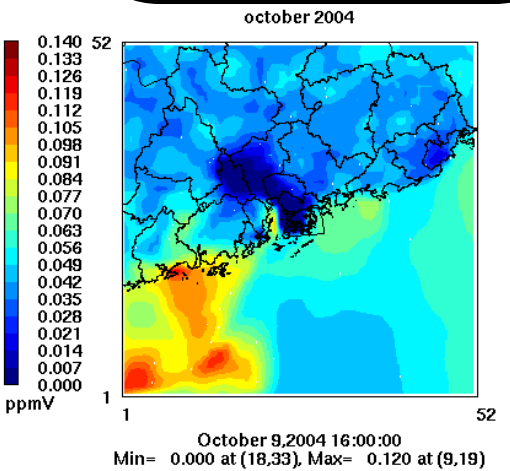
Super sites (1-2 st.)
+ monit. st. (many)

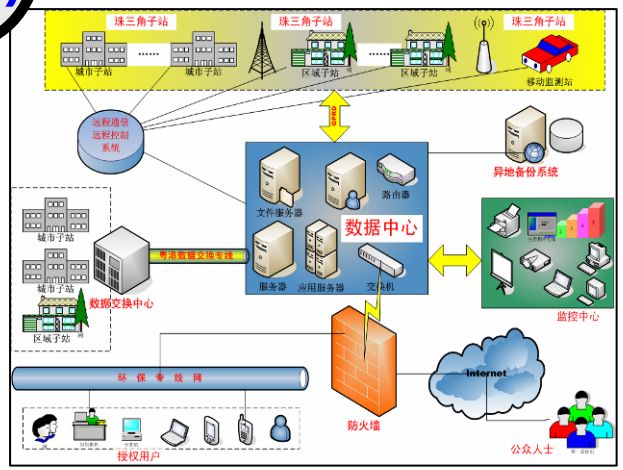
Prediction by PRD-EMS

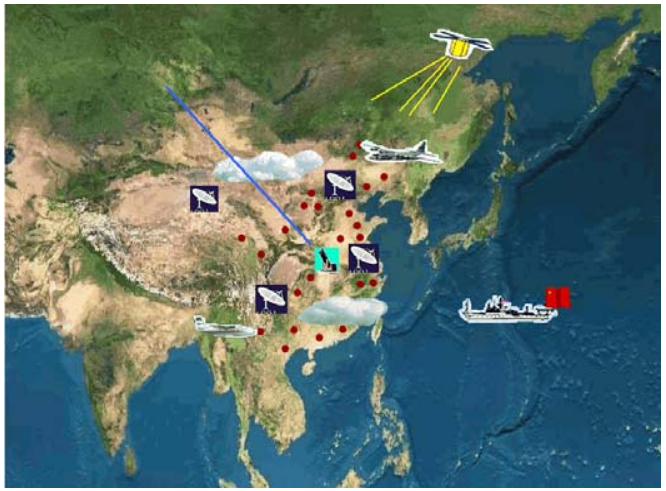
policy

Industry

Information on observations and model calculations







PRD air quality Ensemble forecasting Model System (PRD-EMS)

Goals: fully validated multi-scale and multi-pollutants regulated model

- Dynamic database
- 4-D Var data assimilation
- Karman Filter

Data assimilation

Diagnostic model for regional transport

- 3-D regional models CMAQ
- Chemical model
- Smart tagged source apportion

multi-scale regulated model

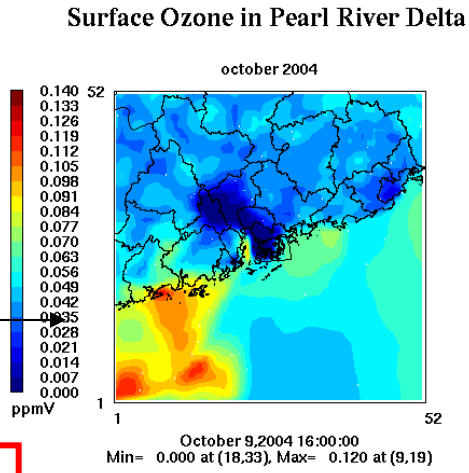
- OBM model
- Inverse modeling

- Supporting model
- Uncertainty analysis
- Manual for the forecasting

Ensemble forecasting

- Data platform for model intercomparison
- Validation of models
- Function testing of the models

Visualization



CMAQ modeling in PRD-EMS

Modeling Domain Configuration

13 vertical layers

extending 16km above ground,

the surface layer is about 18 m in height

Domain	Domain1	Domain2	Domani3
Cell size (km)	36	12	4
Cell number	184×124	52×52	93×87
Domain area (km^2)	6624 x 4464	624 x 624	372×348

Emission Data

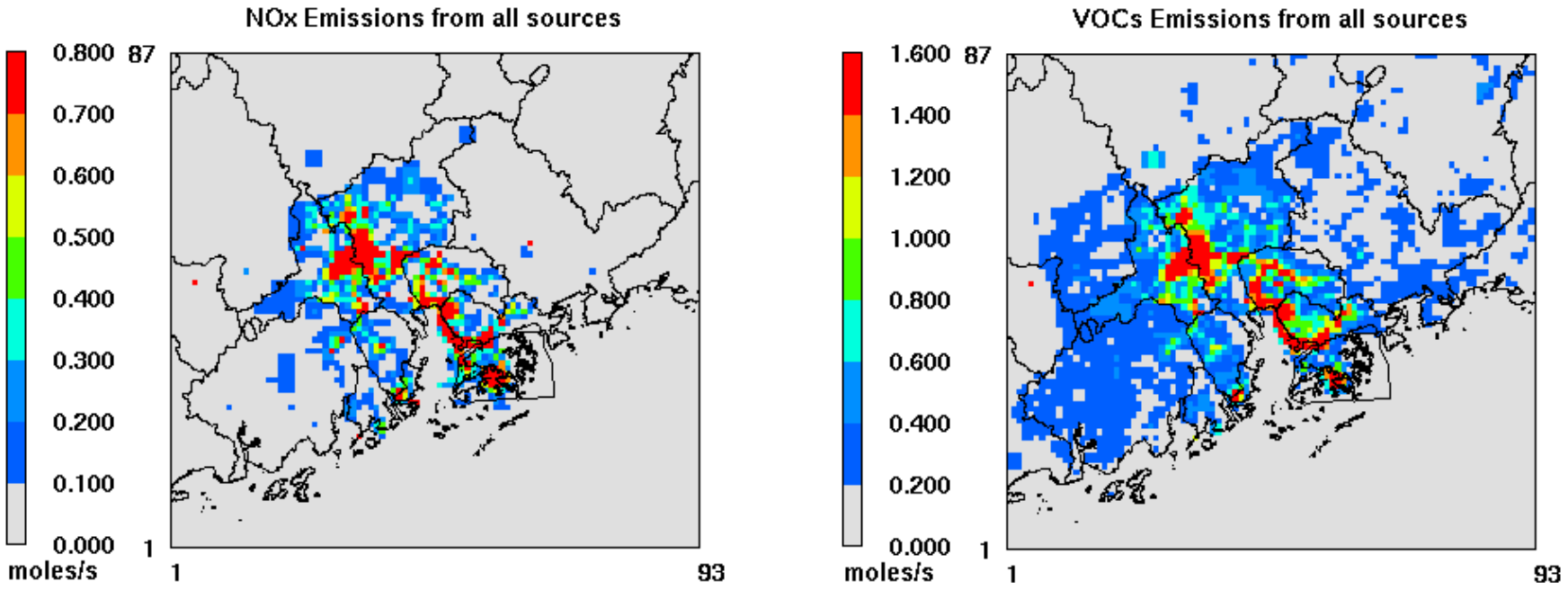
- **Domain 1st: emission data based on the TRACE-P emission inventory in 2000 (*Streets et al., 2003*)**
- **Domain 2nd & 3rd: prepared on the basis of the PRD emission inventory 2003 from Hong Kong EPD, and updated referring to *Song et al., 2006* and *Zhao et al., 2006***
- **Final dataset (based year 2005) in three nested domains will be available in 2009**

Streets, D.G. et al., 2003. An inventory of gaseous and primary aerosol emissions in Asia in the year 2000. Journal of Geophysical Research 108 (D21):8809

Song, X., et al., 2006. Development of Vehicular Emission Inventory in China, Chinese Journal of Environmental Science, 27: 6

Zhao, J., et al., 2006. Studies on the emission rates of plants' VOCs in China. China Environmental Science, 24: 6

NOx & VOCs Emissions in Domain 3rd

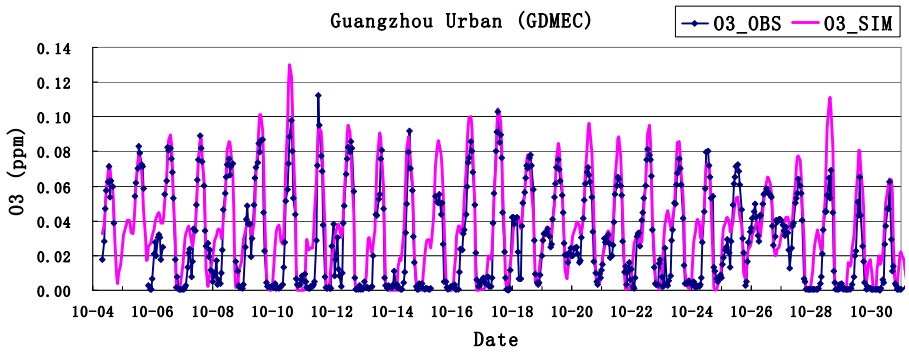


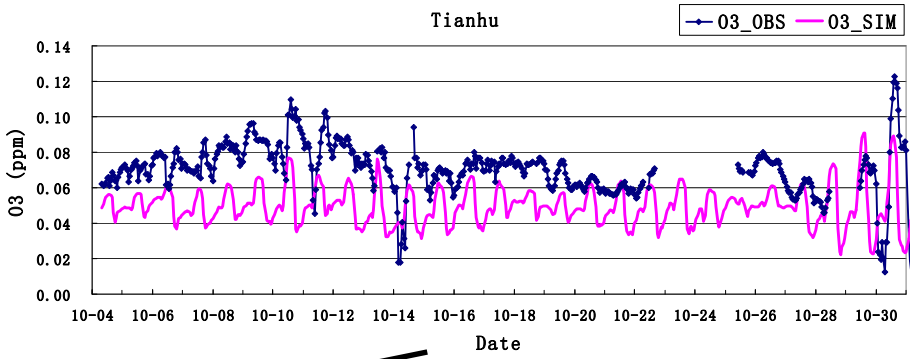
NOx (left) & VOCs (right) emissions in Domain 3rd at 12:00 (LST)

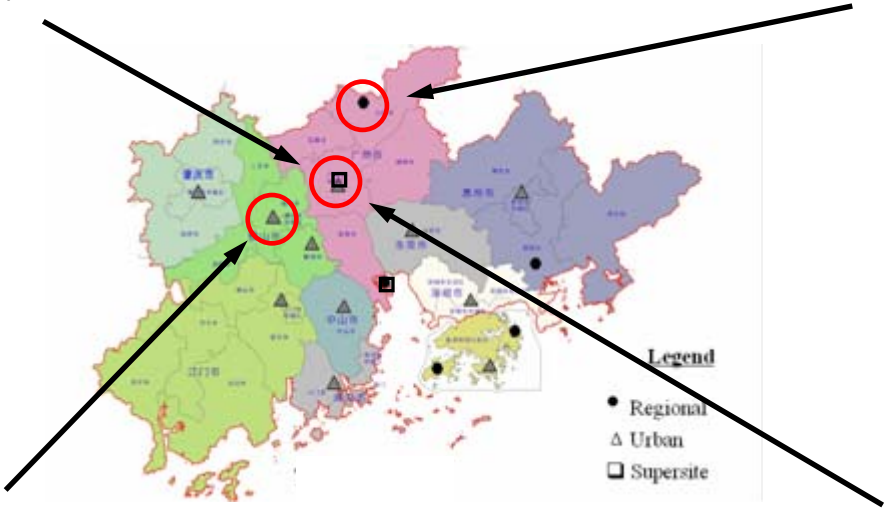
- **Spatial distribution: High NOx & VOCs emissions in Guangzhou, Foshan, Shenzhen and Hong Kong**
- **NOx: mobile source 45%, power plant point source 45%;**

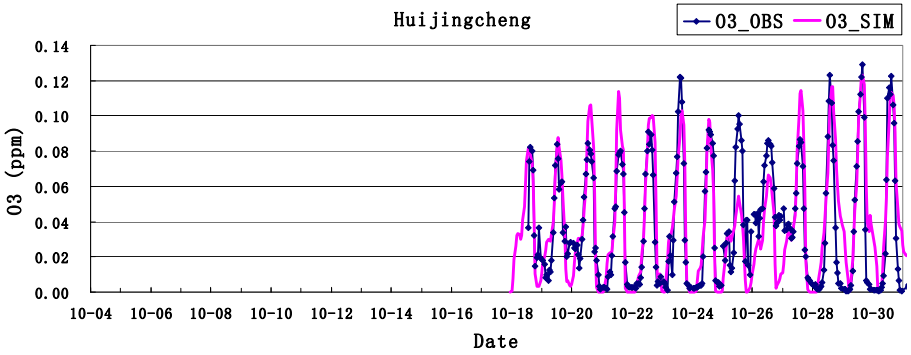
  VOCs: mobile source 43%, evaporation loss source 27%, biogenic source 14%
- **Mobile source is the most important to ozone precursor emissions**

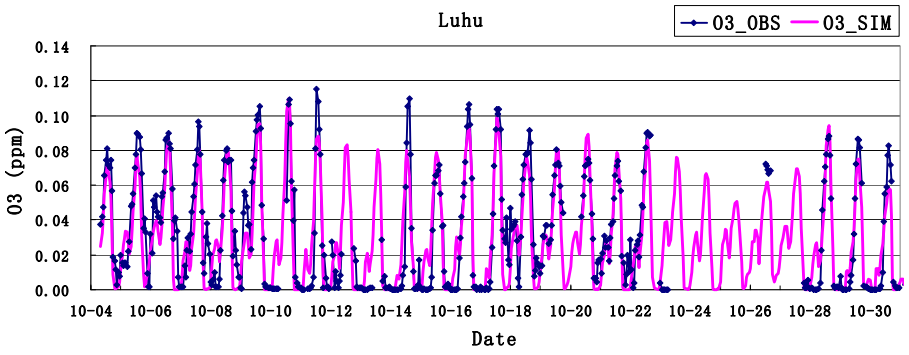
Comparison of modeled and observed O_3 concentrations



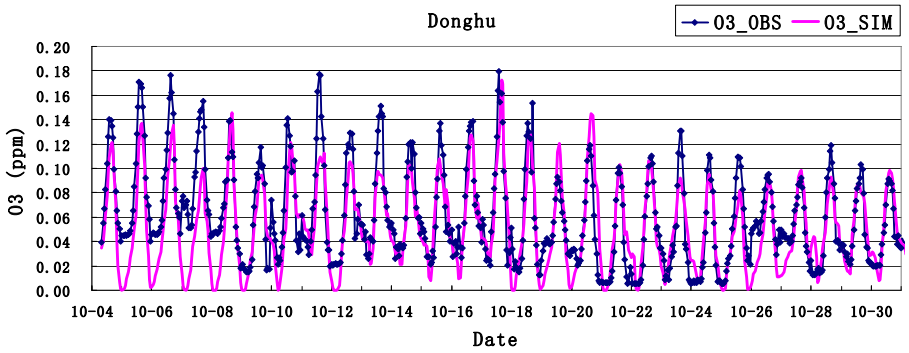


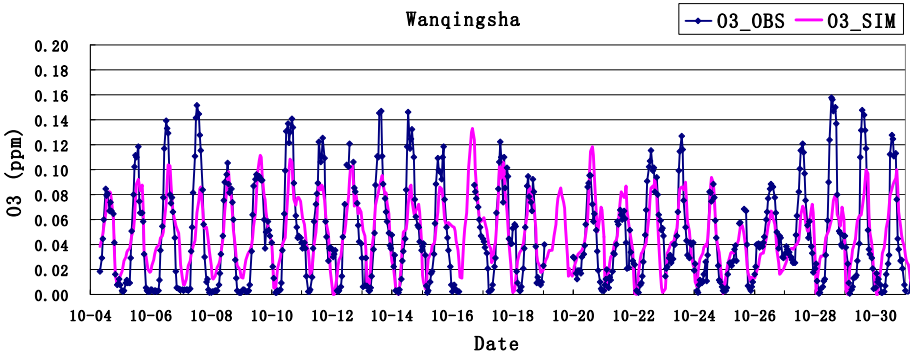


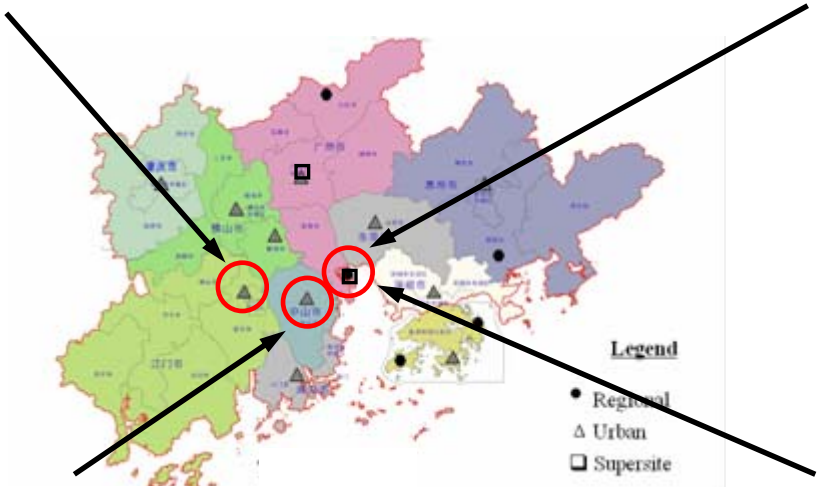


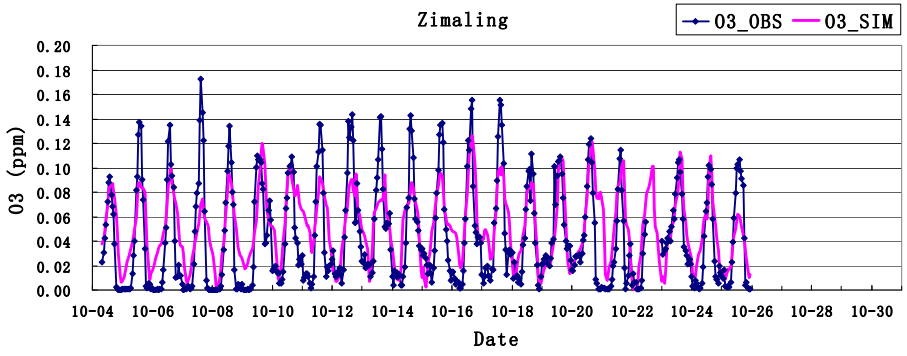


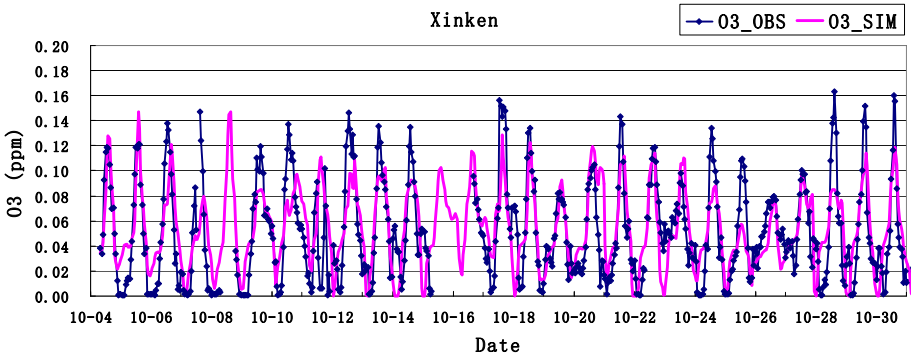
Comparison of modeled and observed O_3 concentrations



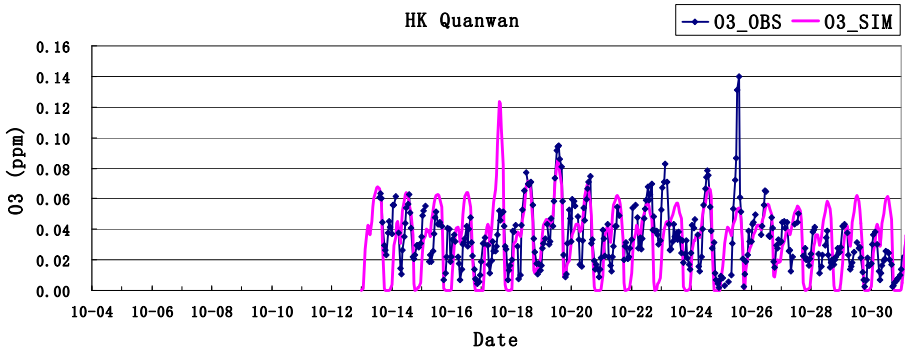


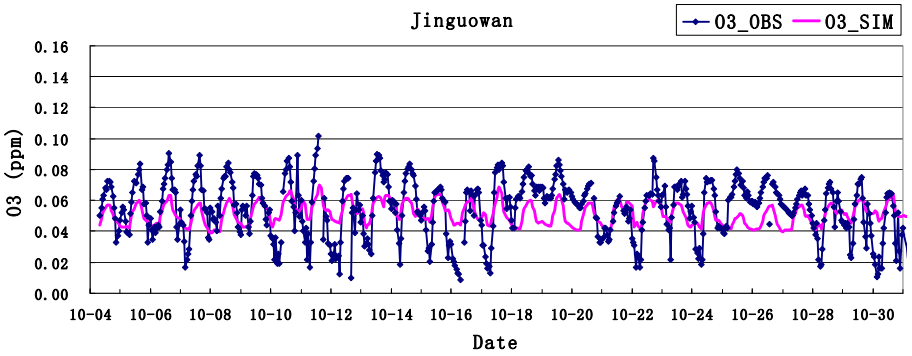


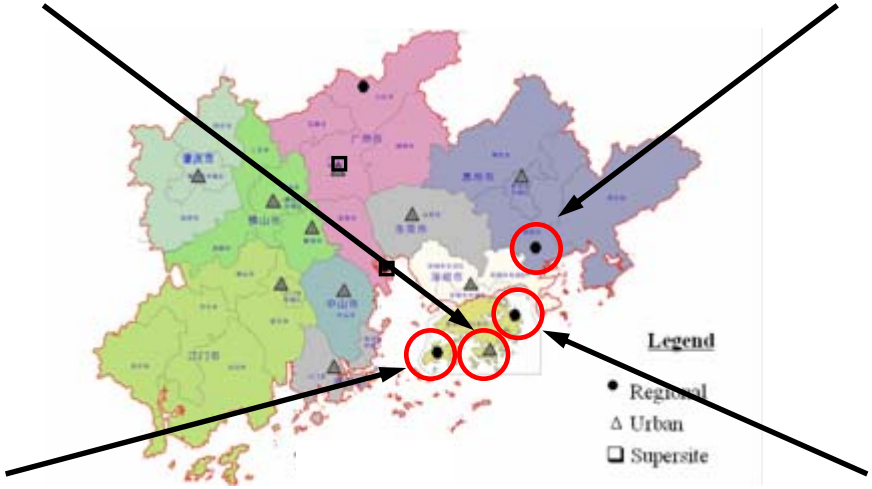


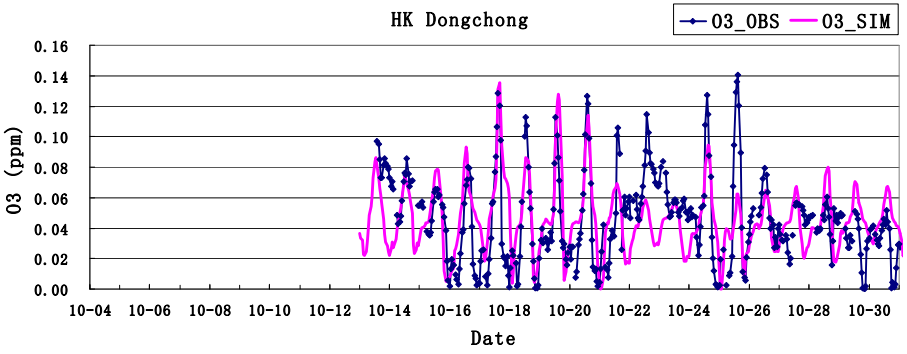


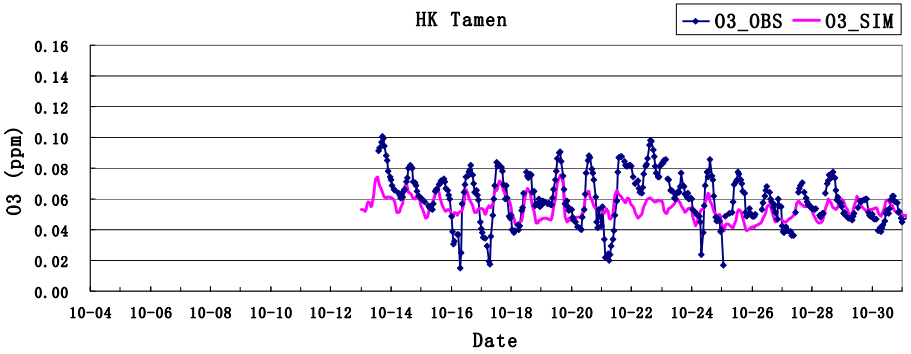
Comparison of modeled and observed O_3 concentrations



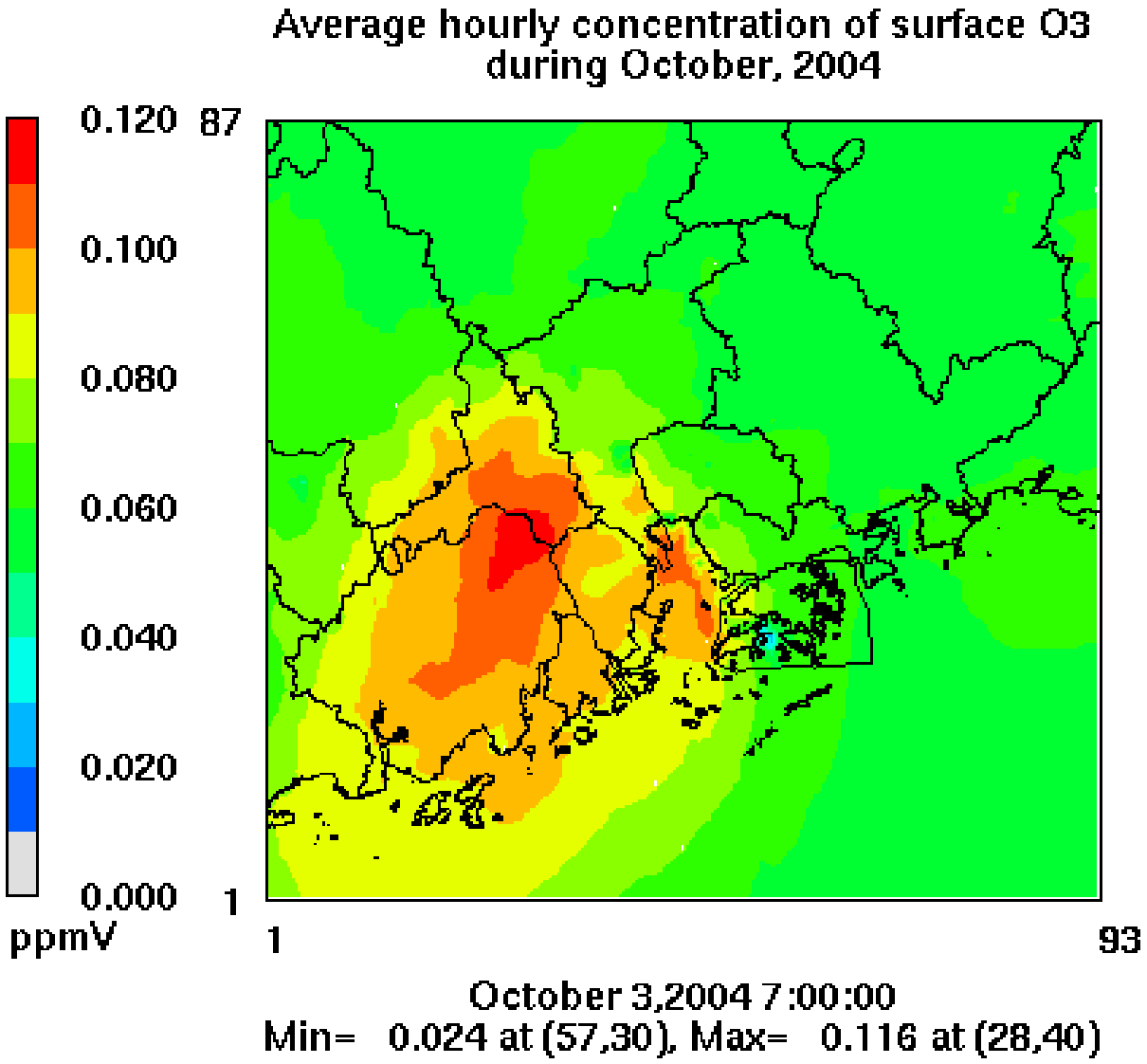








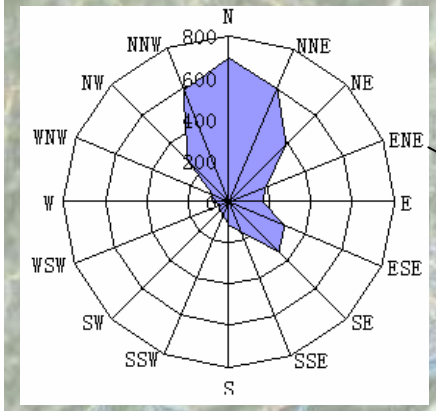
Model simulation of O_3 monthly mean at 15:00, October 2004

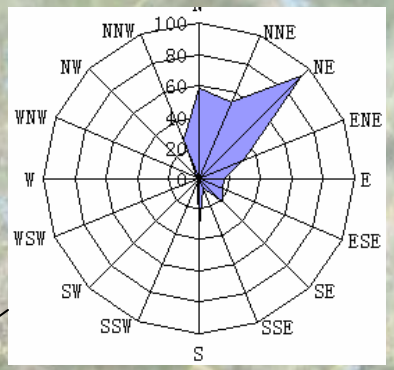


Two high O_3 areas:

- **Jiangmen & south Foshan (southwest PRD)**
- **Pearl River Estuary (PRE)**

Monthly 8hr average of O_3 in PRD, October, 2004





CH 74/82

HD 77/88

LH 67/88

86Z 73/88

PY 67/88

JGW 71/79

87/111

JM 100/127

ZML 87/119

YL 60/79

TW 48/63

TM 73/82

TC 73/101

CW 52/66

Qingyuan

Huizhou

Back Garden

Baiyun

Guangzhou

Zhaoqing

Fushan

Dongguan

Wanqingsha

Huangtian

Jiangmen

Zhongshan

Shenzhen

Zhuhai

Macau

Hong Kong

Victoria

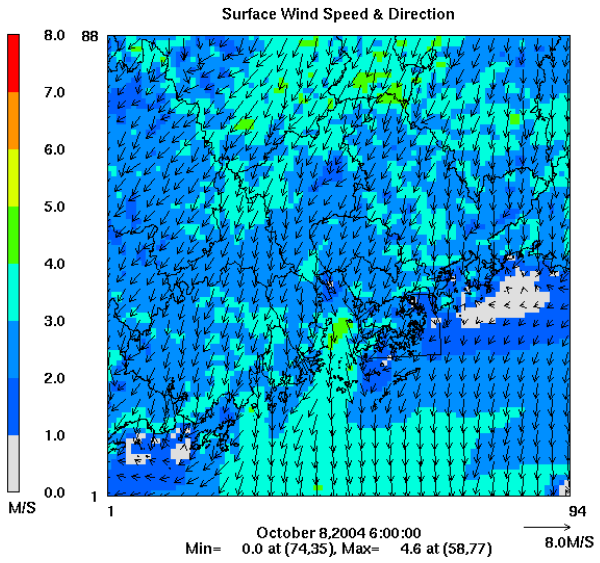
Cook Islands

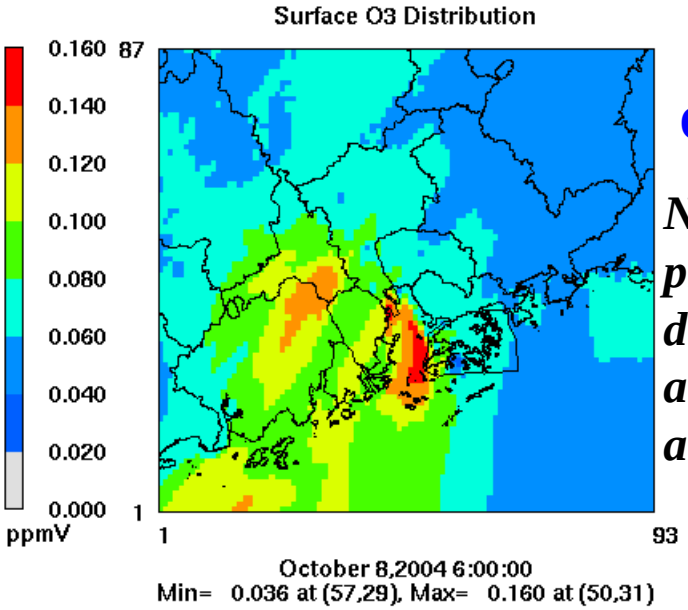
Image © 2006 TerraMetrics

Google

Pointer 22°58'49.17" N 113°24'29.23" E elev 40 ft Streaming 100% Eye alt 139.51 mi

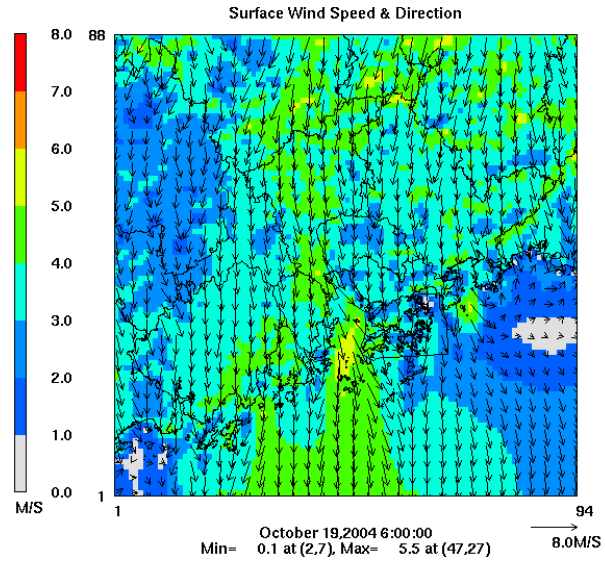
Surface O_3 Distribution *(right)* under Different Wind fields *(left)*

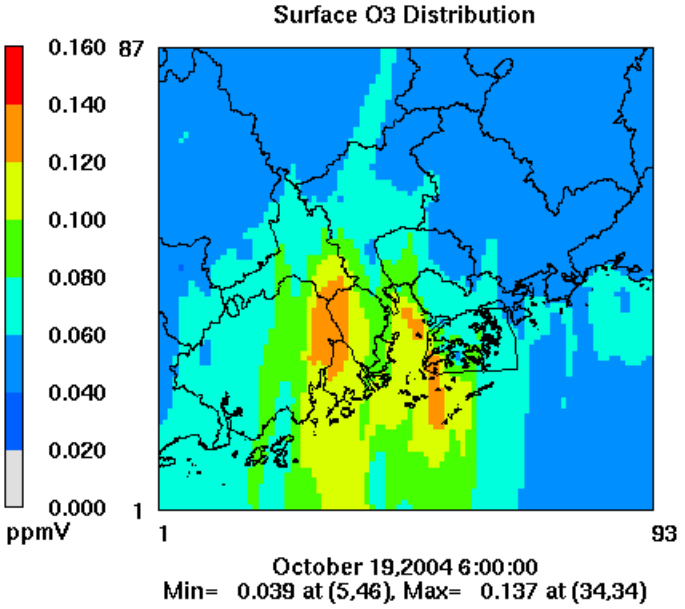




Oct. 8, 14:00 (LST)

Northeast wind prevailing, high O_3 distributed in southwest area of PRD (Jiangmen) and PRE

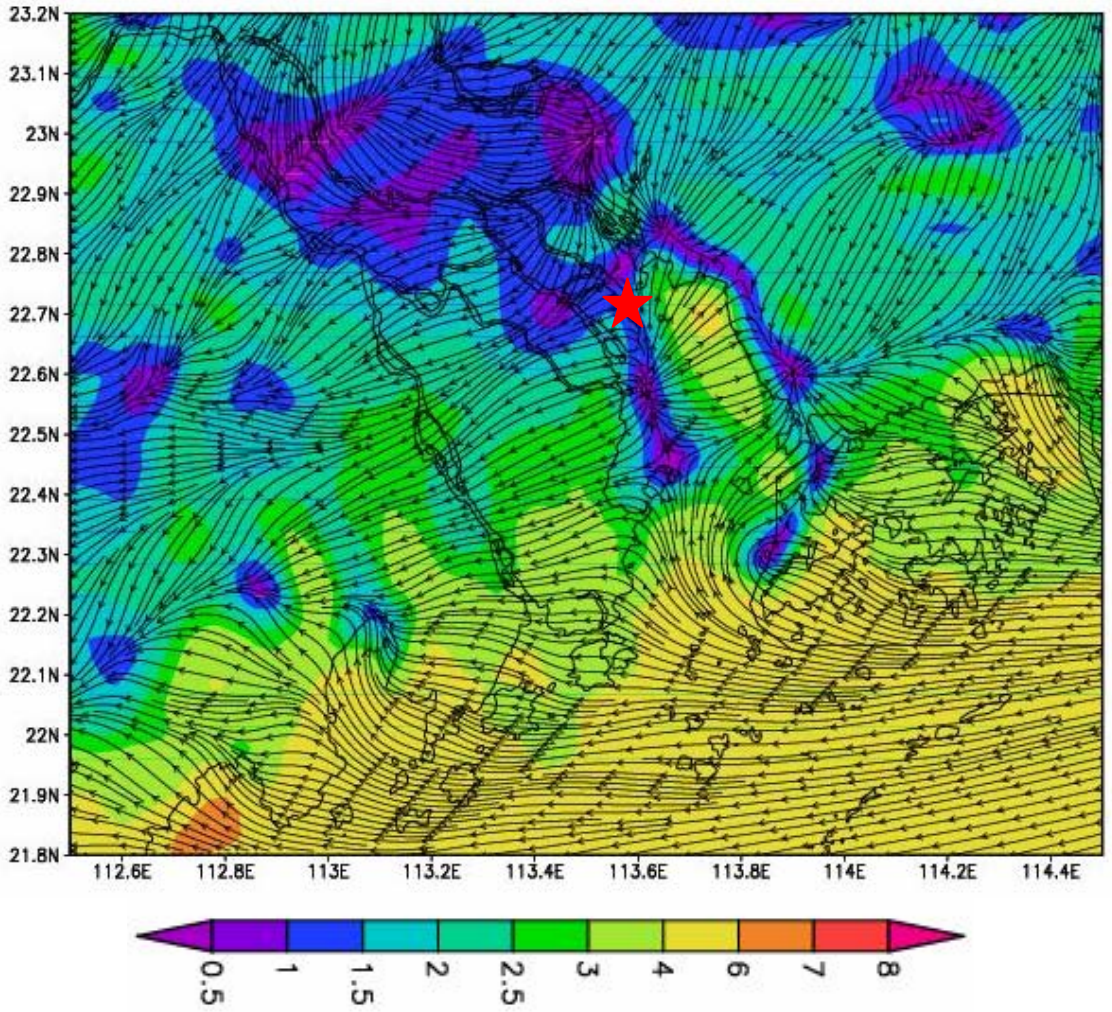




Oct. 19, 14:00 (LST)

Weak cold front invading PRD, north wind prevailing, high O_3 distributed in west Zhongshan, east Jiangmen and PRE

Land sea breezes over Pearl River Estuary (Horizontal u-v section)

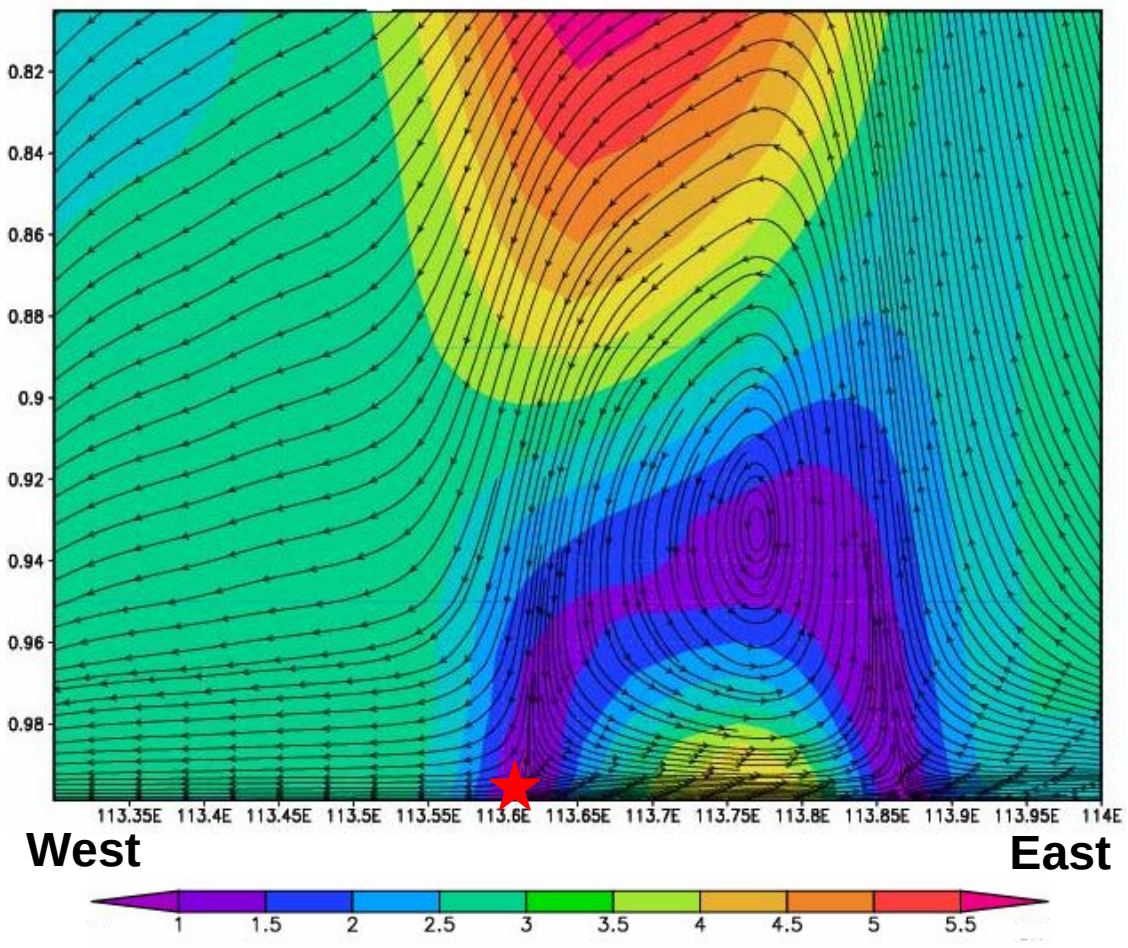


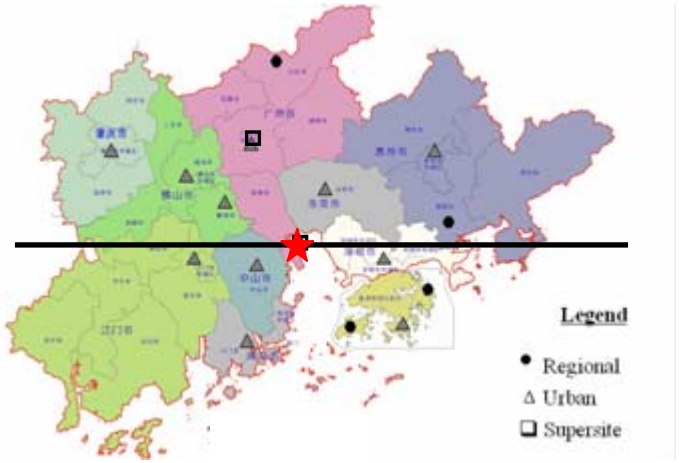
Surface wind stream at Oct. 17, 14:00

(colors show the wind speed, unit: m/s)

- **When no cold front invading PRD, land sea breezes were predominant over PRE.**
- **Land breezes prevailing from midnight to the next morning, while see breezes prevailing from afternoon to late night.**
- **A band-shaped area with low wind speed (<1.0 m/s) often formed along the shore of PRE in the afternoon, favoring pollutants accumulation**

Land sea breezes over Pearl River Estuary (Vertical u-w section crossing Xinken site)



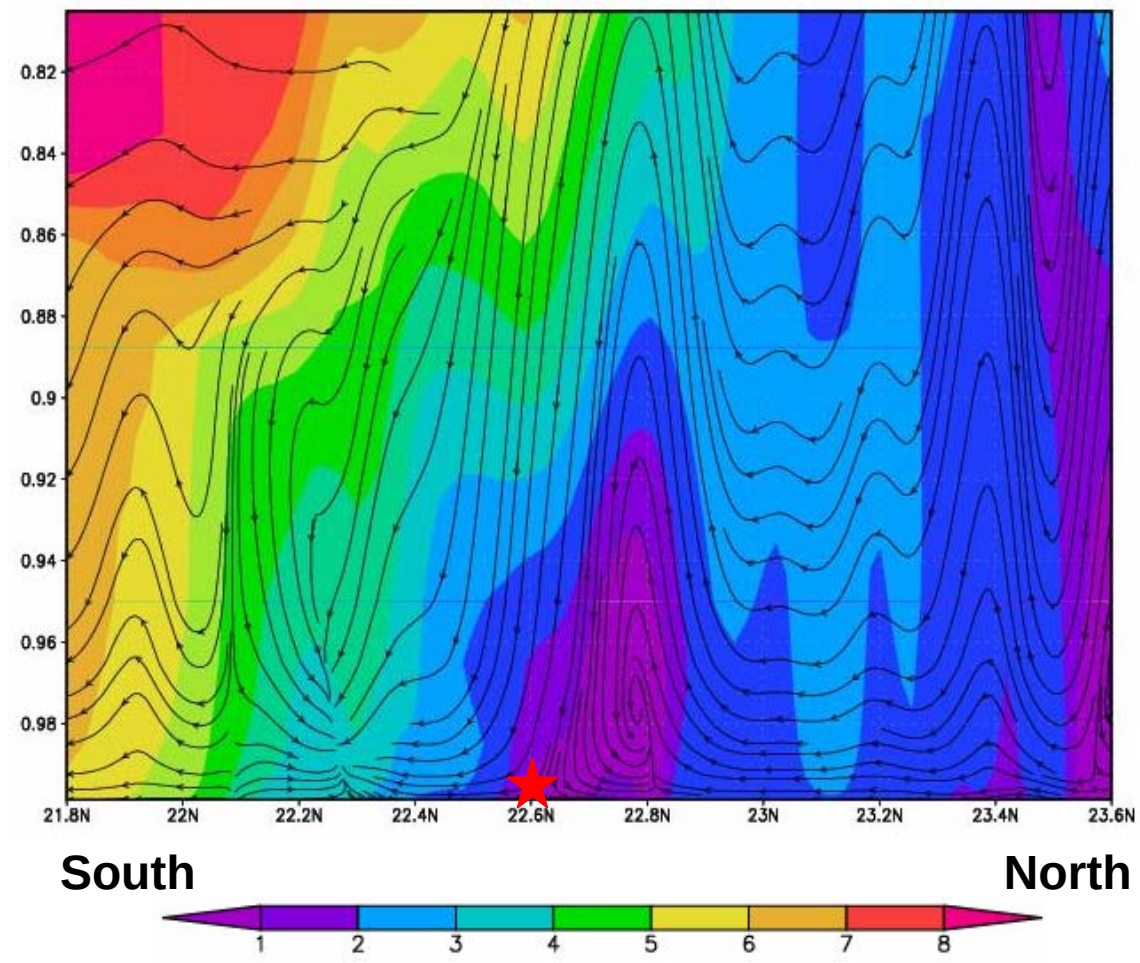


- **Strong air circulation existing over PRE along latitude direction**
- **At Xinken, downdraft in upper layers and divergence in lower layers, surface wind speed usually was very low**

Vertical wind stream at Oct. 17, 14:00

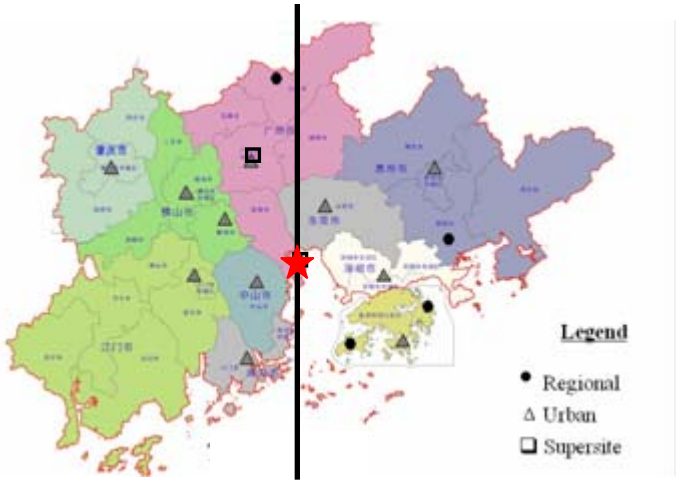
(colors show the wind speed, unit: m/s)

Land sea breezes over Pearl River Estuary (Vertical v-w section crossing Xinken site)



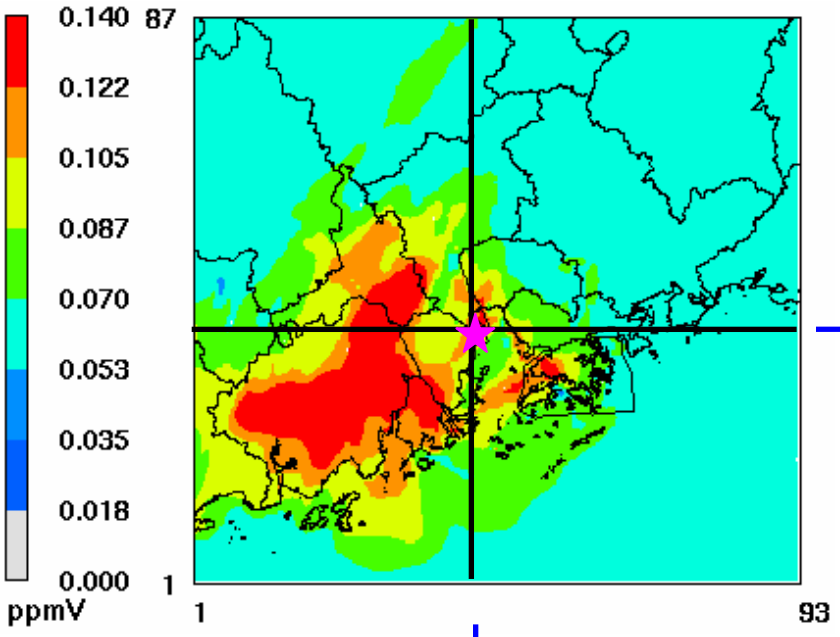
Vertical wind stream at Oct. 17, 14:00

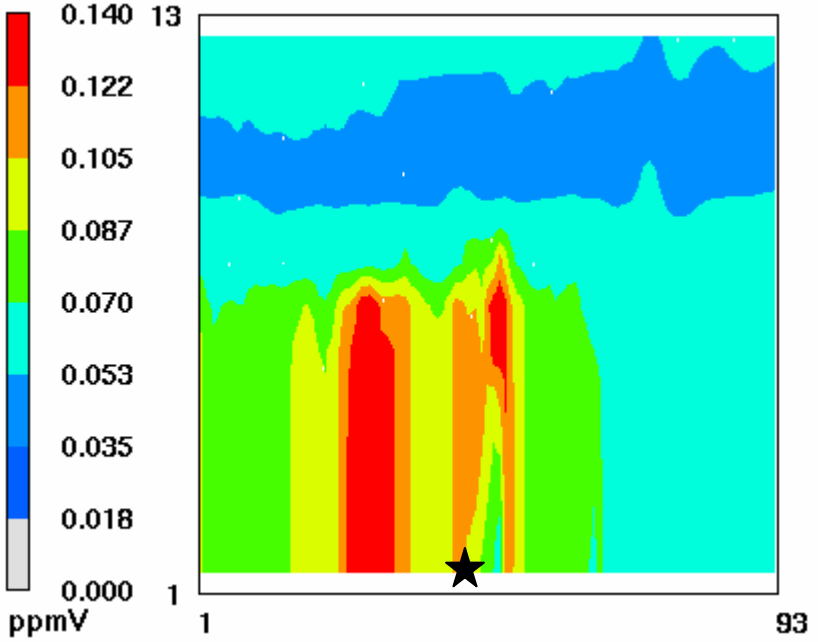
(colors show the wind speed, unit: m/s)

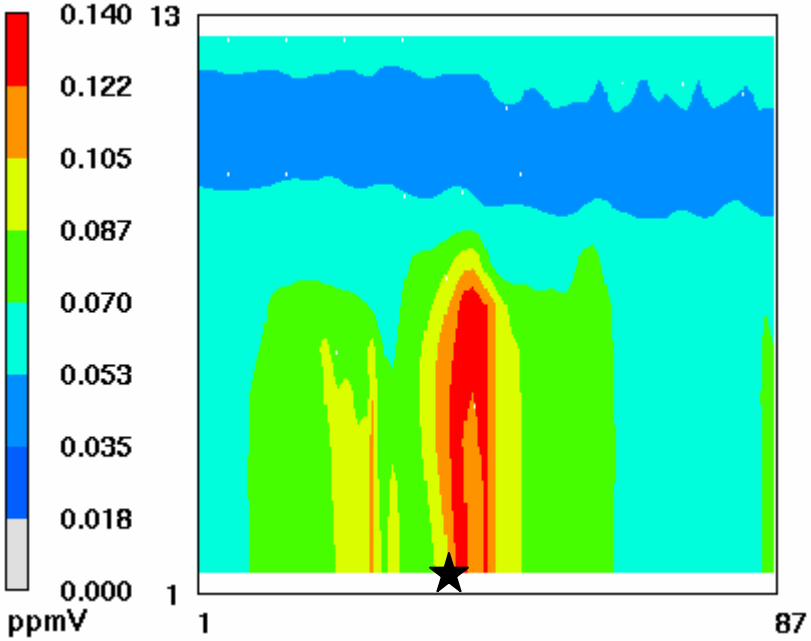


- **Local heat circulation also existing over PRE along longitude direction**
- **At Xinken, downdraft in upper layers and divergence in lower layers, similar to the situation in u-w cross section**

Modeled Ozone distribution over Pearl River Estuary







- **In horizontal direction, relatively high ozone distributed along the coastal areas of PRE, which were also the locations of the band-shaped areas with lower wind speed**
- **The distribution of vertical high ozone concentration had a similar shape with the vertical cross section of low wind speed area**

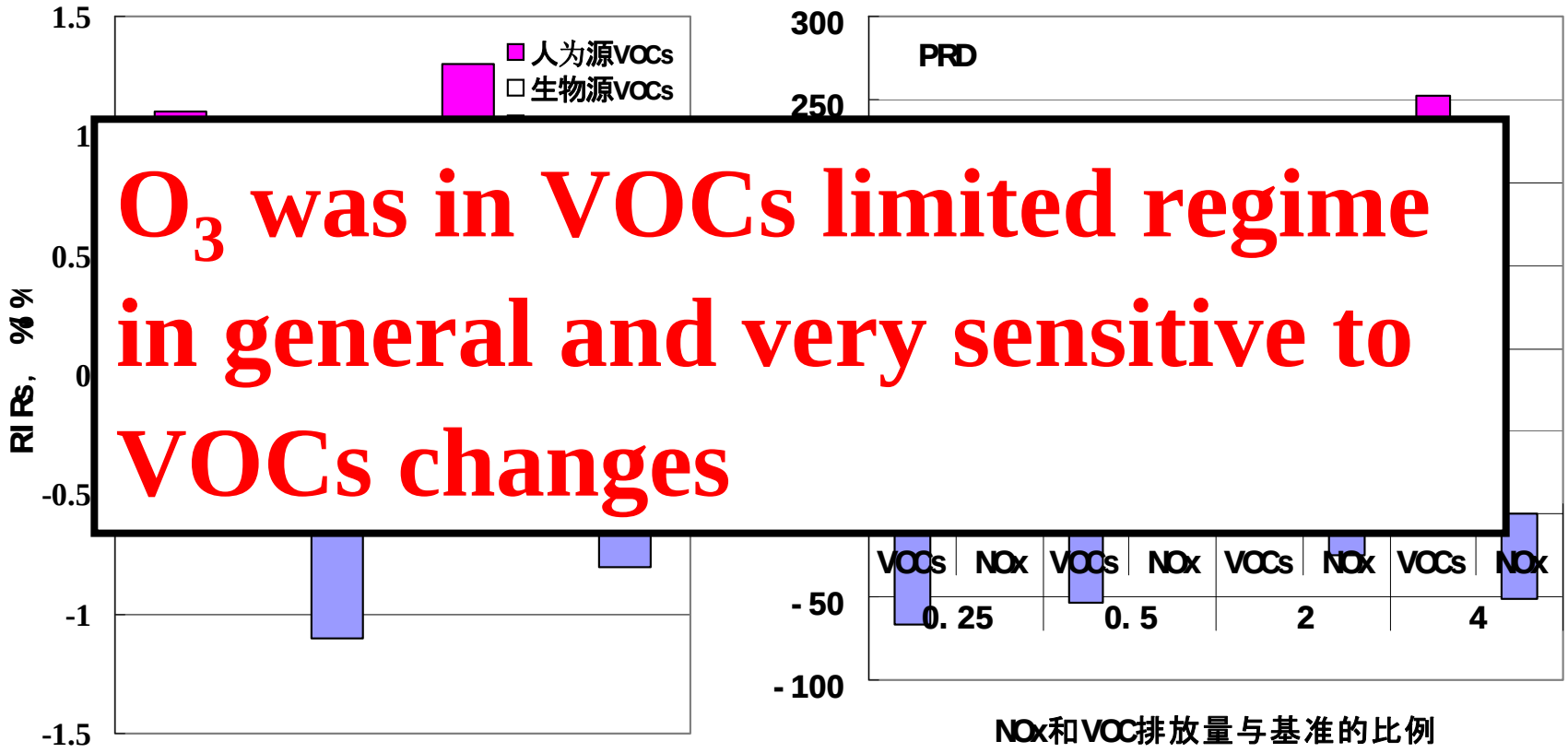
Observational based approaches in PRD

- **OBM model**
- **Inverse modeling**

- **Input:**
  - ✓ **high time resolution data (O_3, NO, HONO, HCHO, VOCs, meteorol.)**
- **Output:**
  - ✓ **O_3 production potential**
  - ✓ **Relative incremental reactivity, RIRs**

$$RIR^S(X) = \frac{\dfrac{P^S_{O3-NO}(X) - P^S_{O3-NO}(X-\Delta X)}{P^S_{O3-NO}(X)}}{\dfrac{\Delta S(X)}{S(X)}}$$

O_3 sensitivity to precursors (October, 2004)



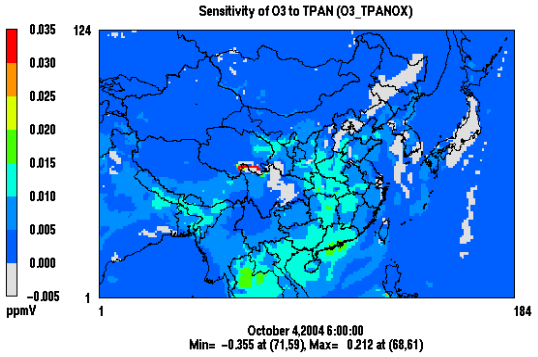
O_3 was in VOCs limited regime in general and very sensitive to VOCs changes

基于观测数据诊断O_3同VOC和NOx的非线性关系

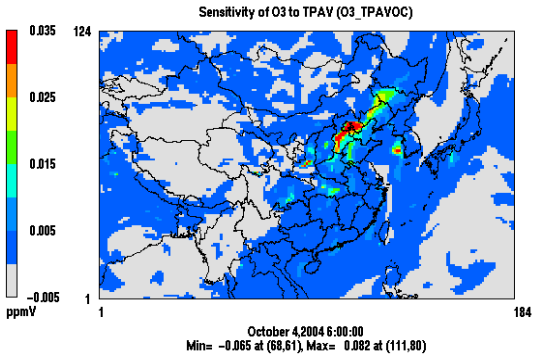
VOC和NOx排放对O_3最大小时浓度的影响（2D-空气质量模型）

Inverse Modeling Technique in CMAQ

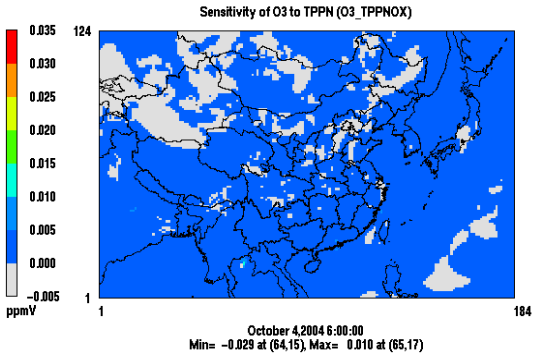
Sensitivity of surface O_3 to NOx & VOCs Source Emissions



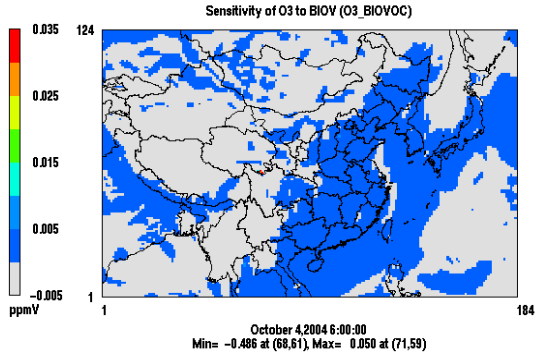
O_3_A_NOx



O_3_A_VOCs



O_3_P_NOx



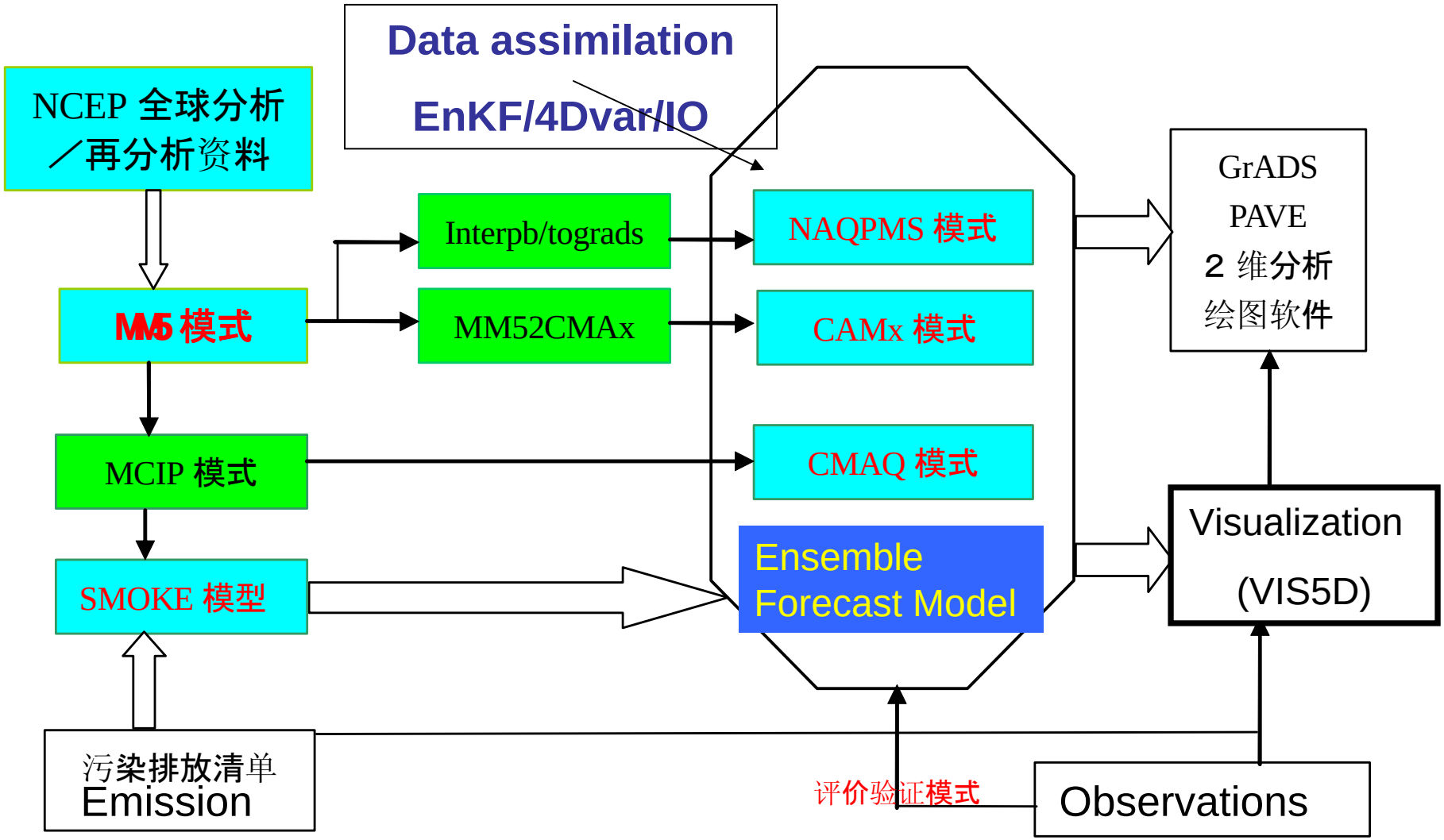
O_3_B_VOCs

Assimilation results of first iteration

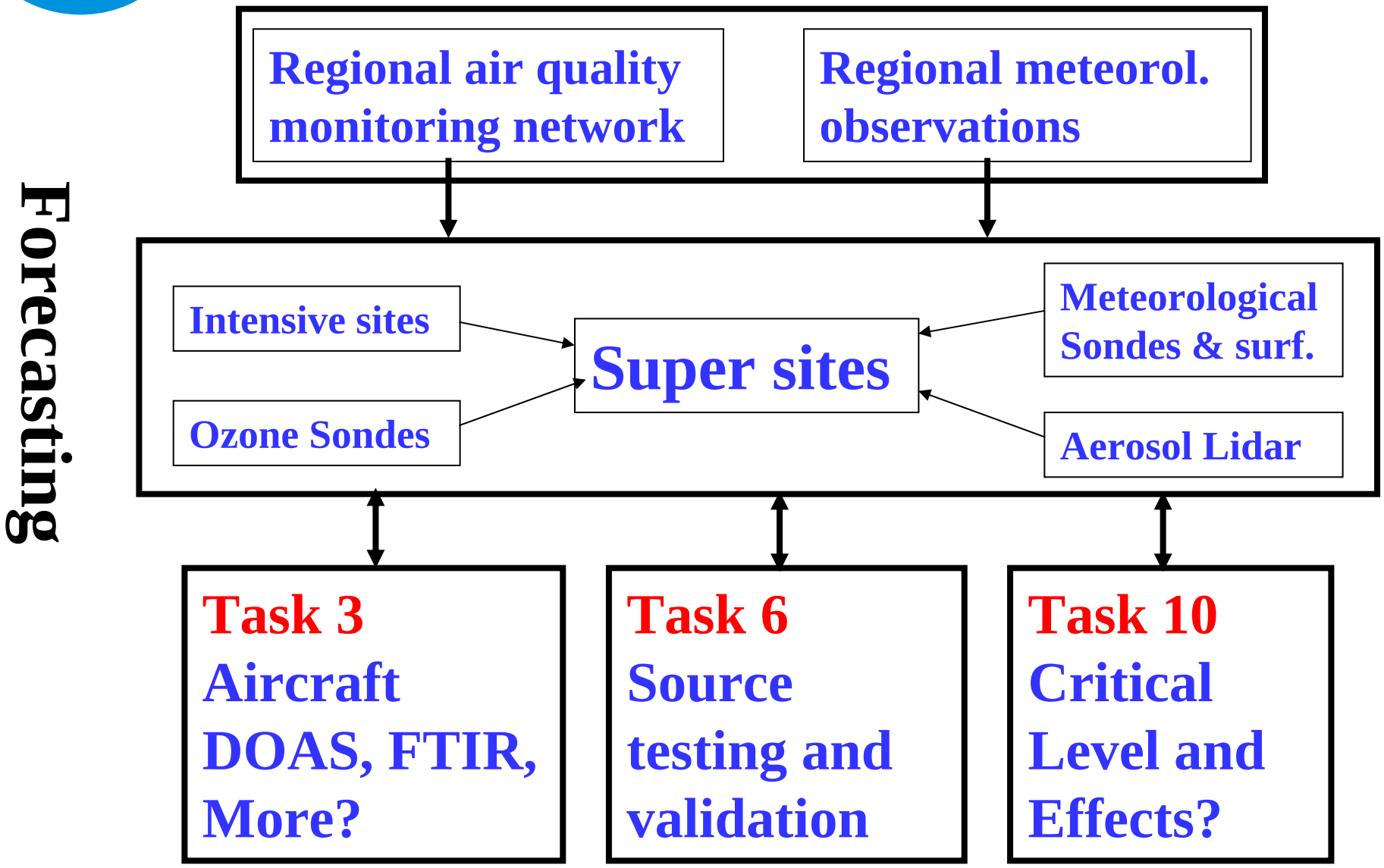
Fractional changes for each source：

A_NOx	0.85
P_NOx	-0.23
A_VOCs	0.28
B_VOCs	0.10

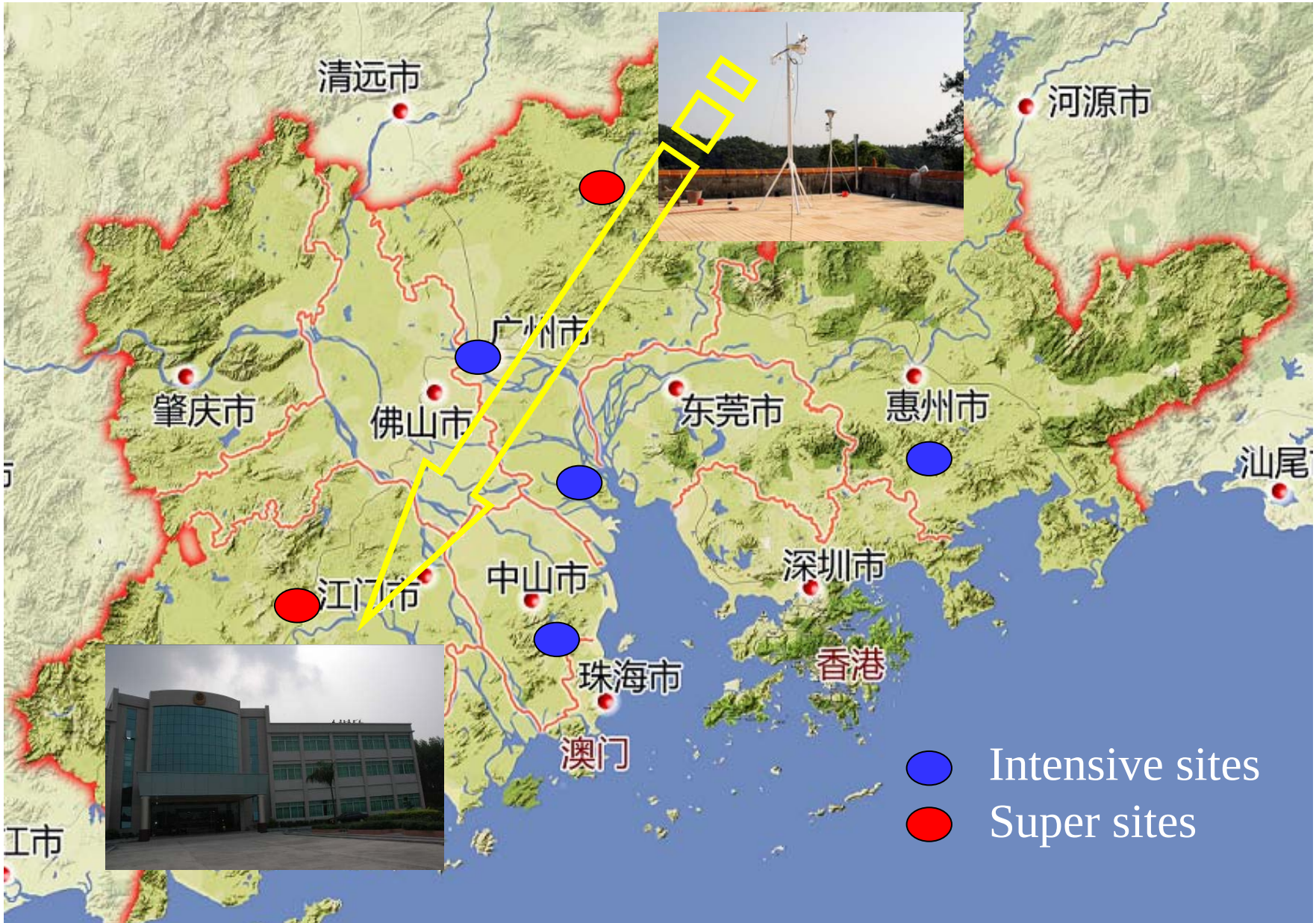
PRD-EMS Activities in 2008



Strategy of the 3C-Star2008 PRD Campaign



Intensive sites and super sites



Parameters observed at Super Sites

Meteorology：

- T, W, RH (Ground and vertical)
- J (O1D), J (NO_2) and other J-values, UV-A, UV-B

Gaseous chemistry

- NO, NO_2, NOy, O_3, SO_2, CO, CO_2 (TECO)
- HNO_3, HNO_2, HCl, NH_3 (GAC)
- PAN (GC in-situ)
- VOCs（GC-FID in-situ and Canisters)
- Oxy-Organics (HPLC, off-line)
- OH, HO_2, NO_3(LIF)
- HCHO (DOAS)
- HNO_2 (LP-DOAS, LOPAP)
- H_2O_2 (HPLC in-situ)

Closure measurement for O_3 production

Closure measurement for aerosol radiative forcing

Aerosol chemistry

- Mass loading of $PM_{2.5}$ (TEOM)
- Chemical speciation of $PM_{2.5}$ and size distribution (sampler)
- EC/OC (Sunset in-situ)
- EC (PSAP)
- Ions and WSOC, (GAC, PILS)
- Chemical composition of single particle (AMS)

Aerosol physical and optical properties

- Dry number distribution (DMPS/APS)
- Humidify number distribution (HDMPS)
- Ext. soot (VTDMA)
- CCN spectra (CCNC (DMT) + DMA(TSI))
- Light scattering and absorption (Nephelometer, MAAP, PAS)
- AOD (CEMEL)
- Aerosol vertical profile (LIDAR)

Milestones of 3C-Star2008 PRD Campaign

- **January: the 1st planning workshop (Guangzhou)**
- **May: Data protocol and MOU**
- **May or June: the 2nd planning workshop and field visit**
- **September: equipment arrival in Guangzhou harbor & airport**
- **Middle of September: equipment setup, calibration, testing and inter-comparison**
- **End of October: concludes the campaign**
- **Next January: the 1st data analysis workshop & the 3rd workshop on mega-city and regional air pollution**


谢谢！