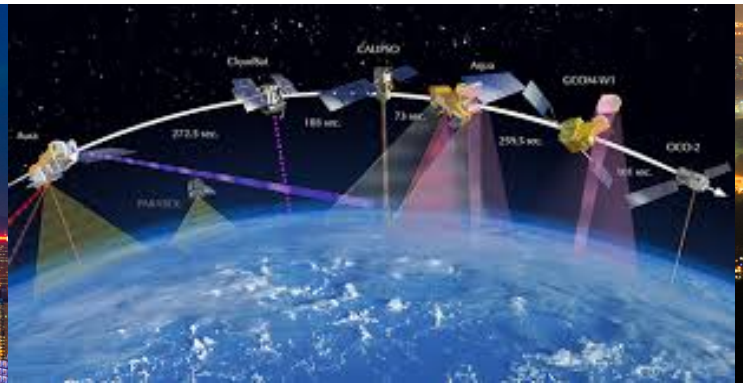


Urban CO_2 Monitoring and Inverse Modeling for Identifying Geographical Sources and Sinks of Carbon in Shenzhen, China

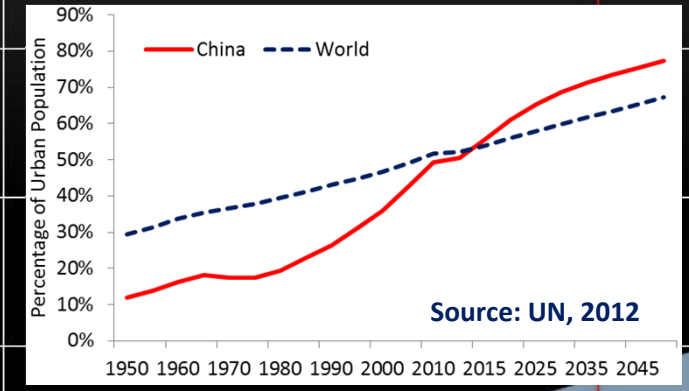
Jun Wang

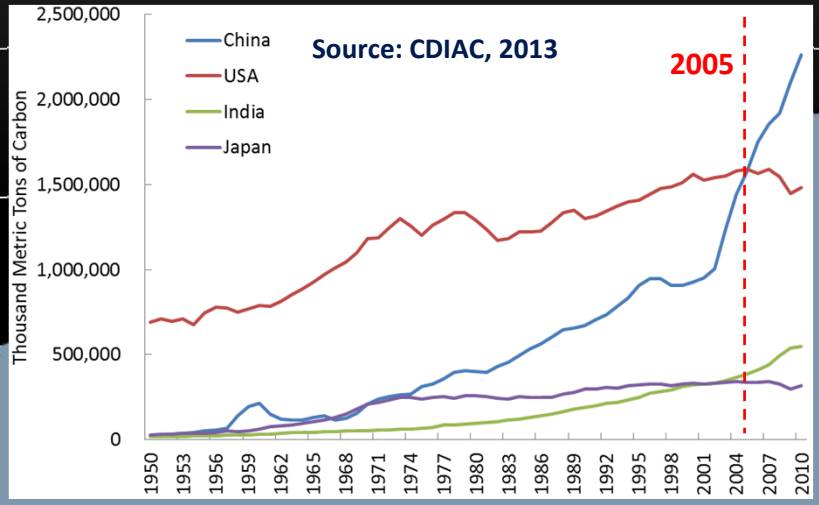
LSCE, Paris, France

October 13, 2014

China's population dynamics (1960-2012, in billion)

Data Source: world bank, 2014





1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0

Rural population

Pop in cities of < 1 million

Pop in cities of >= 1 million

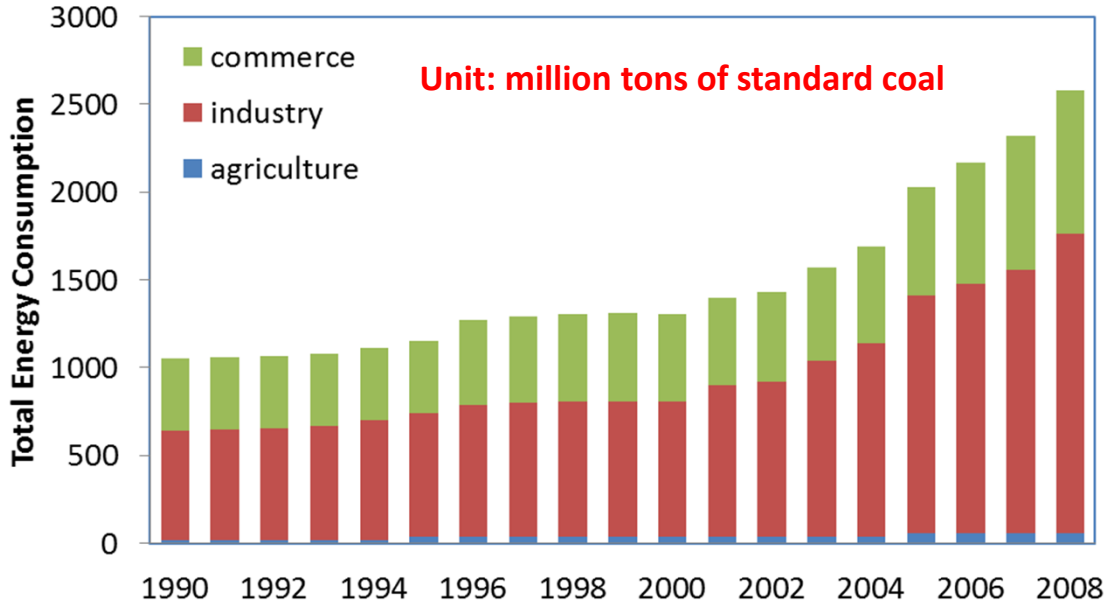
1960
16.2%

1978
18.6%

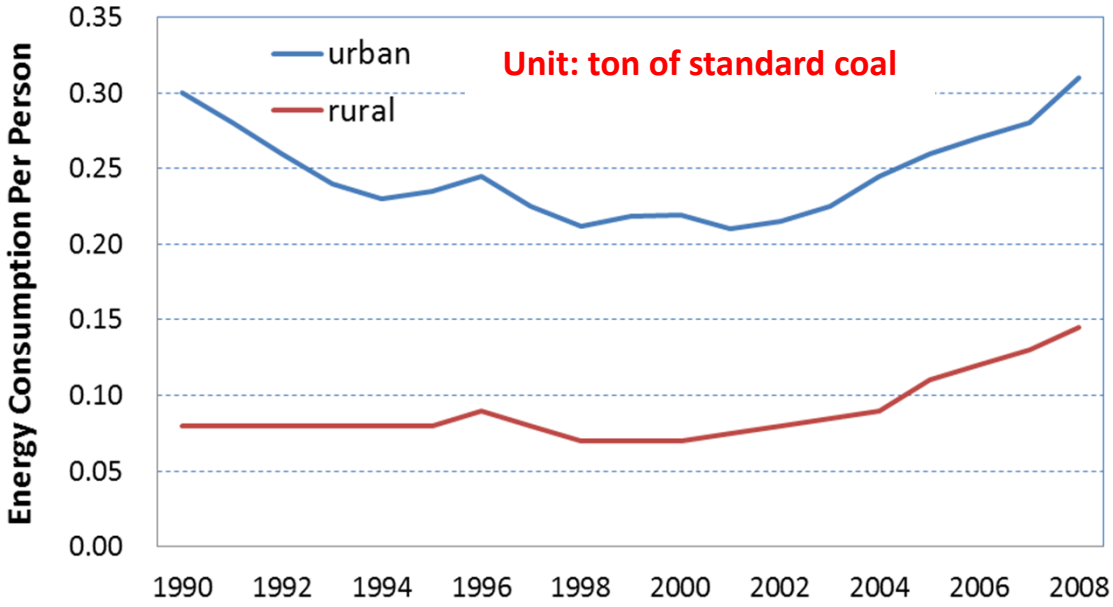
2011
50.5%

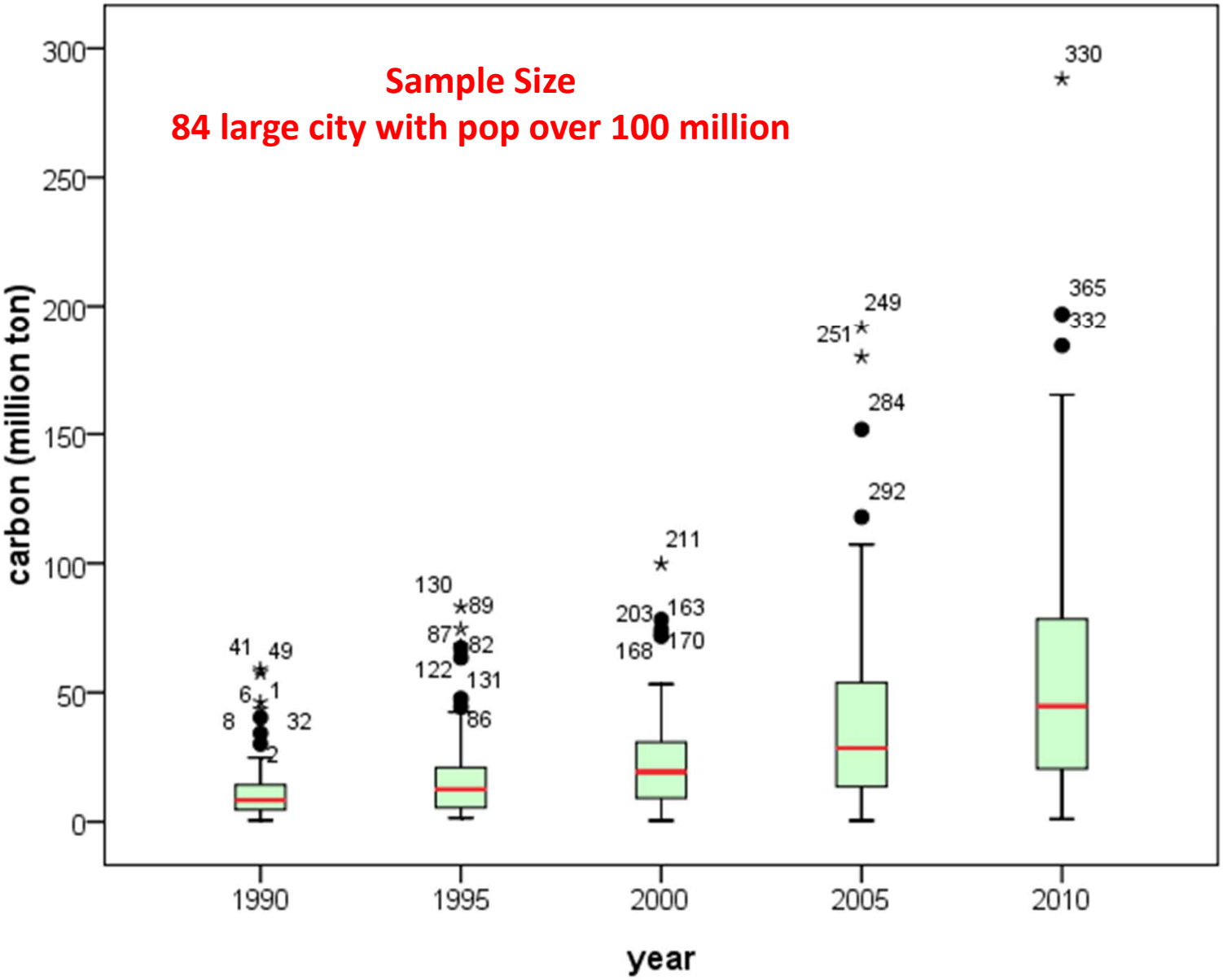
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010

Energy Consumption by Production

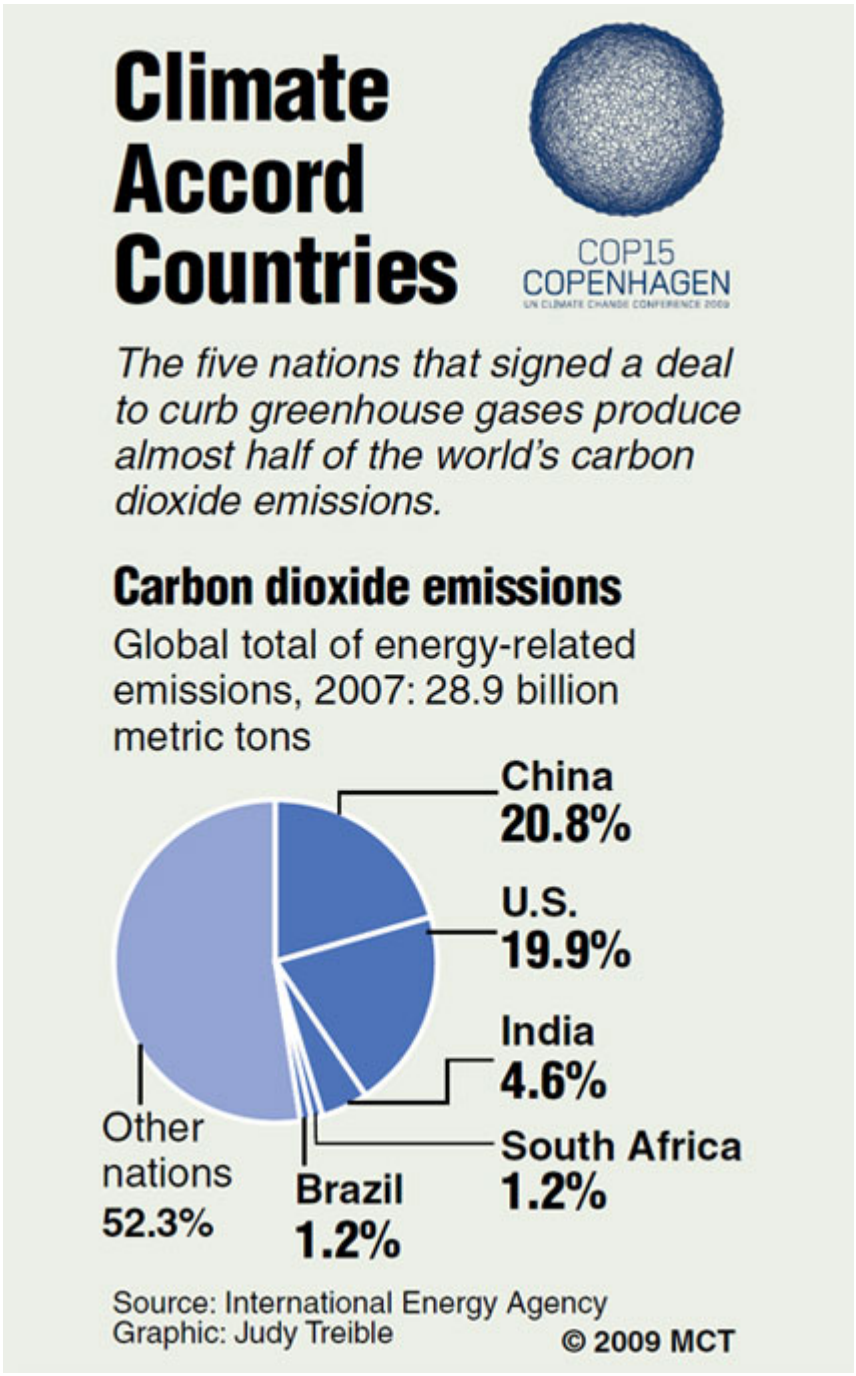


Energy Consumption by Daily Life





Urban carbon emissions were calculated using the method of IPCC 2006 and Sup. Data



By 2020, carbon emissions per unit GDP in China will drop 40%-45%, compared with the year 2005.

–UN Climate Conference, 2009

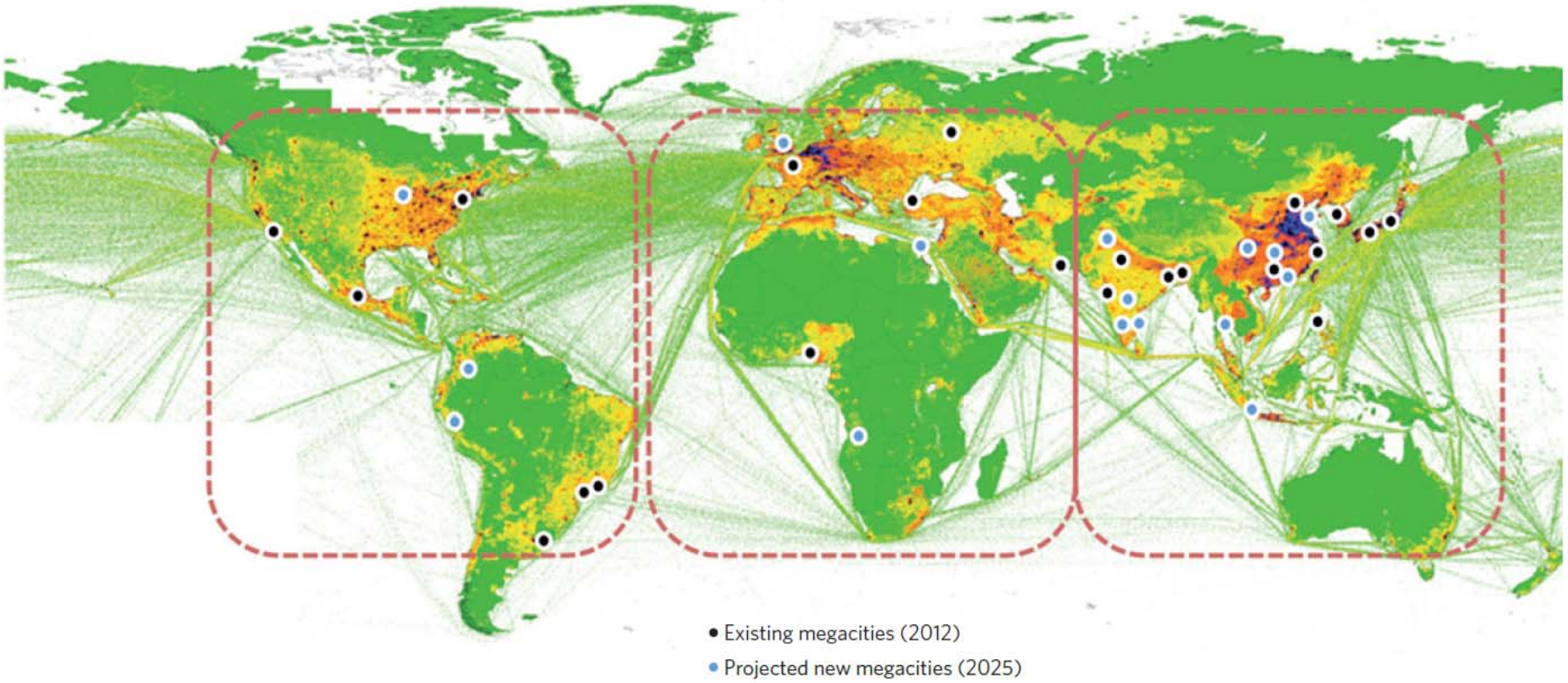
GOVERNMENT TARGETS

Main indicators and numerical targets in China's National New-type Urbanization Plan.

Indicator	2012	2020
Urbanization level		
Urbanization ratio (resident population) (%)	52.6	60
Public services		
Proportion of peasant worker's children accompanying parents receiving mandatory education (%)		≥99
Basic social-security coverage for urban and township resident population (%)*	66.9	≥90
Basic medical insurance coverage for urban and township resident population (%)	95	98
Infrastructure		
Public transportation share in total motorized travel in cities with more than 1 million people (%)	45†	60
Public water supply coverage in cities and towns (%)	81.7	90
Proportion of wastewater treated in cities (%)	87.3	95
Proportion of municipal waste decontaminated in cities (%)	84.8	95
Broadband Internet connection capacity of urban households (megabits per second)	4	≥50
Resource and environment		
Per capita urban land use (square metres)		≤100‡
Share of renewable energy consumption in cities and towns (%)	8.7	13
Share of 'green' buildings in new constructions in cities and towns (%)	2	50
Share of prefecture and above level cities that meet the national air-quality meeting standards (%)	40.9	60

Bai et al., 2014

Measuring the Carbon Emissions of Megacities



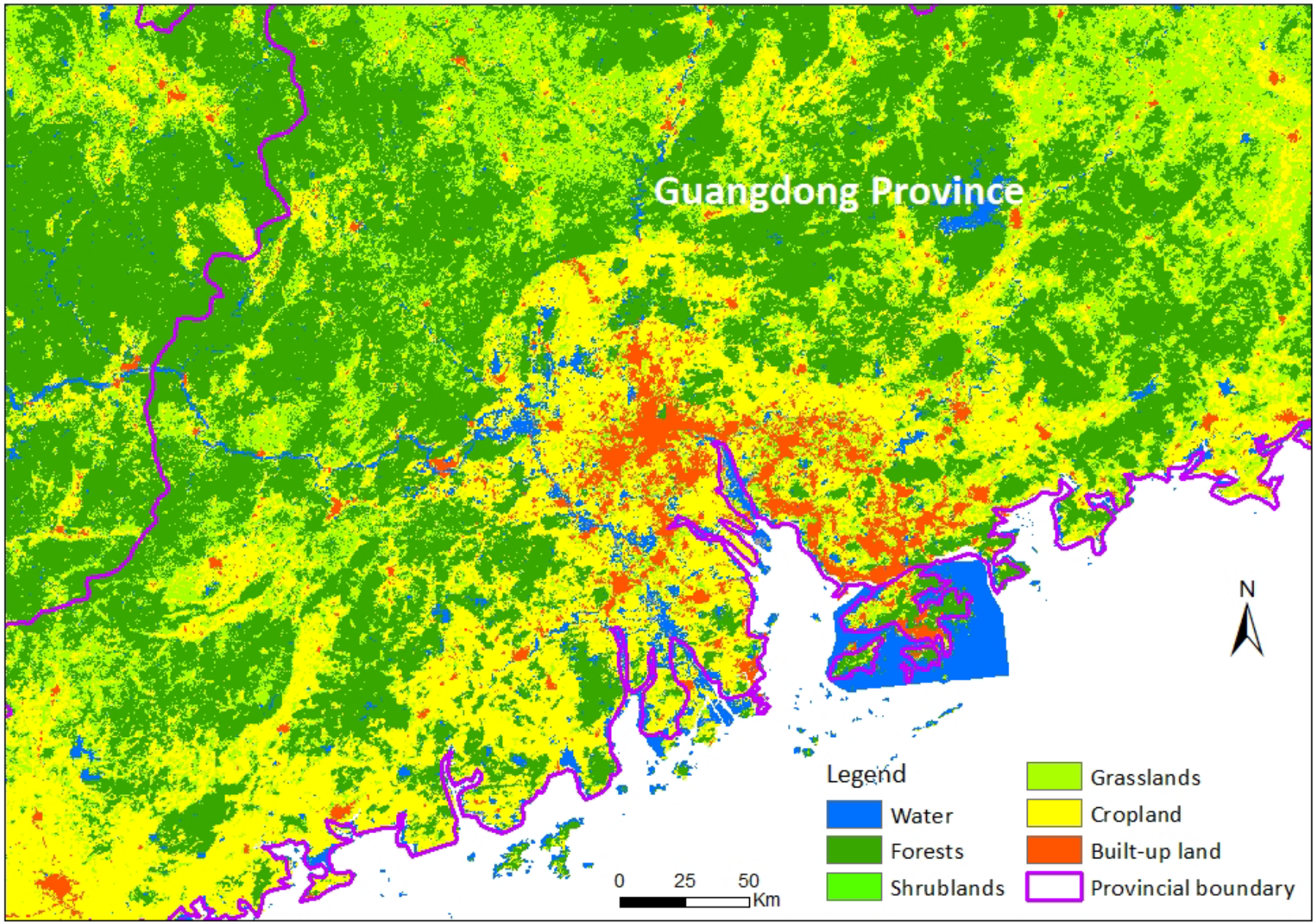
Duren and Miller, 2012

Urban Surface CO_2 Monitoring Stations in China

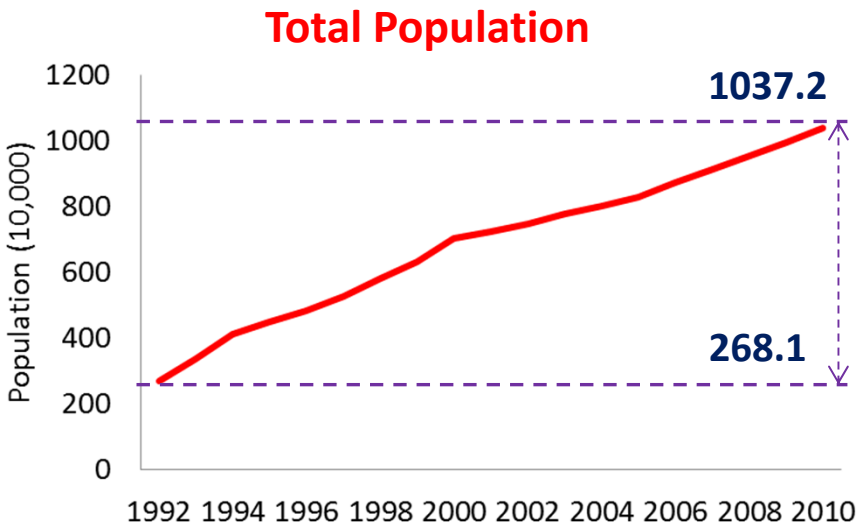
5 stations

5 stations

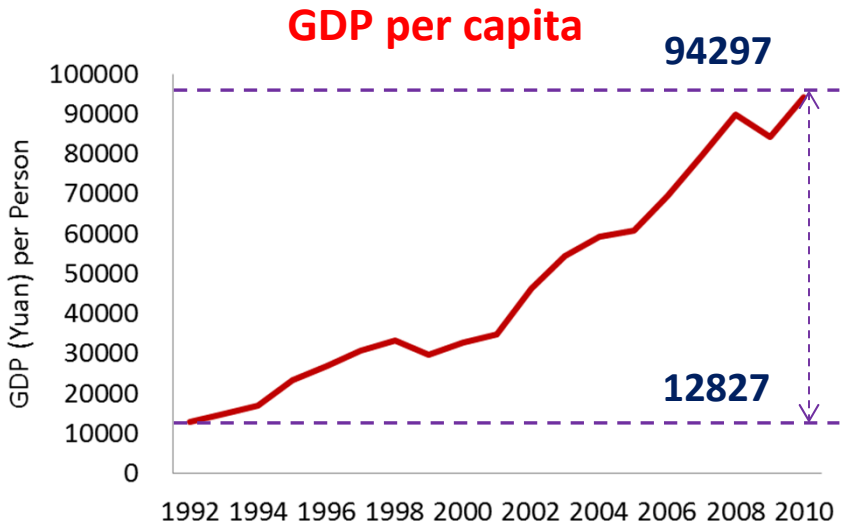
内蒙古
自治区
沈阳
辽宁
新疆维吾尔
自治区
北京
河北
天津
甘肃
宁夏回族
自治区
山西
陕西
山东
青海
中国
西安
河南
江苏
南京
上海
西藏自治区
成都
湖北
武汉
安徽
杭州
四川
重庆
浙江
尼泊尔
北方邦
勒克瑙
Lucknow
加德满都
不丹
贵州
湖南
江西
坎普尔
Kanpur
巴特那
Patna
比哈尔
梅加拉亚邦
那加兰
福建
曼尼普尔
加尔克
汉德邦
孟加拉国
云南
广西壮族
自治区
广州
广东
孟加拉邦
恰蒂斯
加尔邦
曼德勒
香港
特里普拉
缅甸
河内
Ha Noi
海防市
Hai Phòng
澳门
奥里萨邦
米佐拉姆
东沙群岛
老挝
永珍
海南
Shenzhen



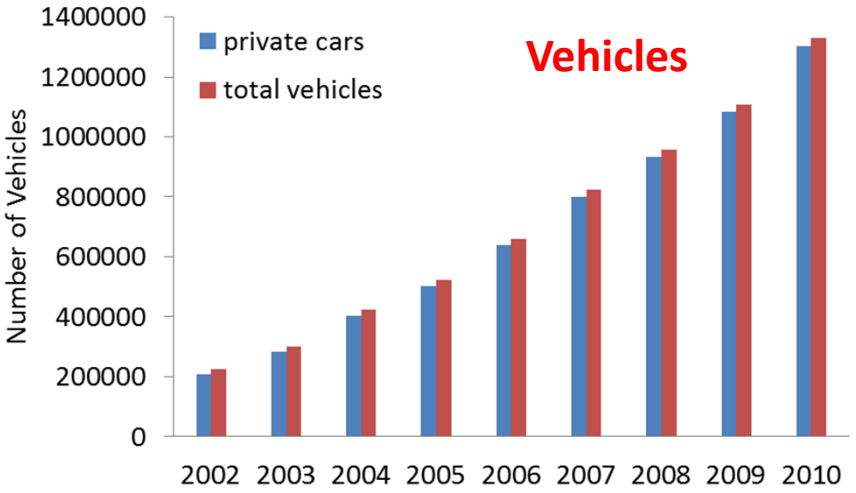
Data Source: MODIS Land Cover 2012 (MCD12Q1)



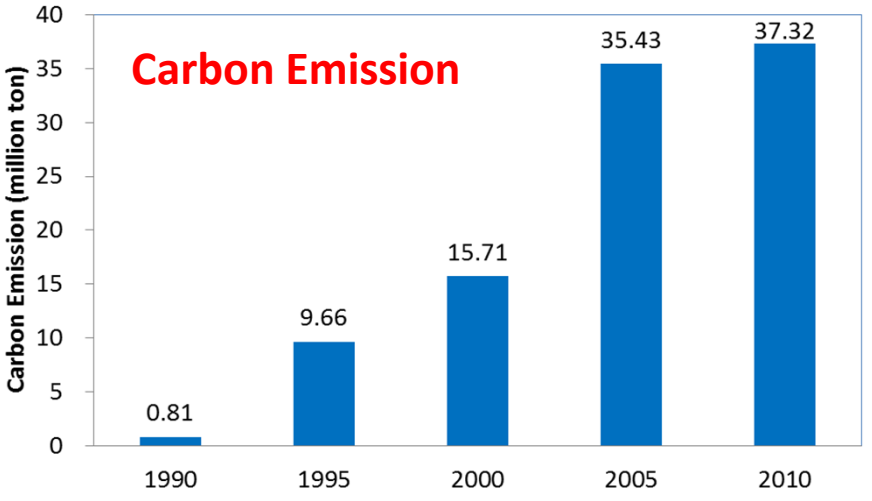
1992 -2010: pop increased about 7.7 million.



1992-2010: GDP per capita increased 7.4 times.



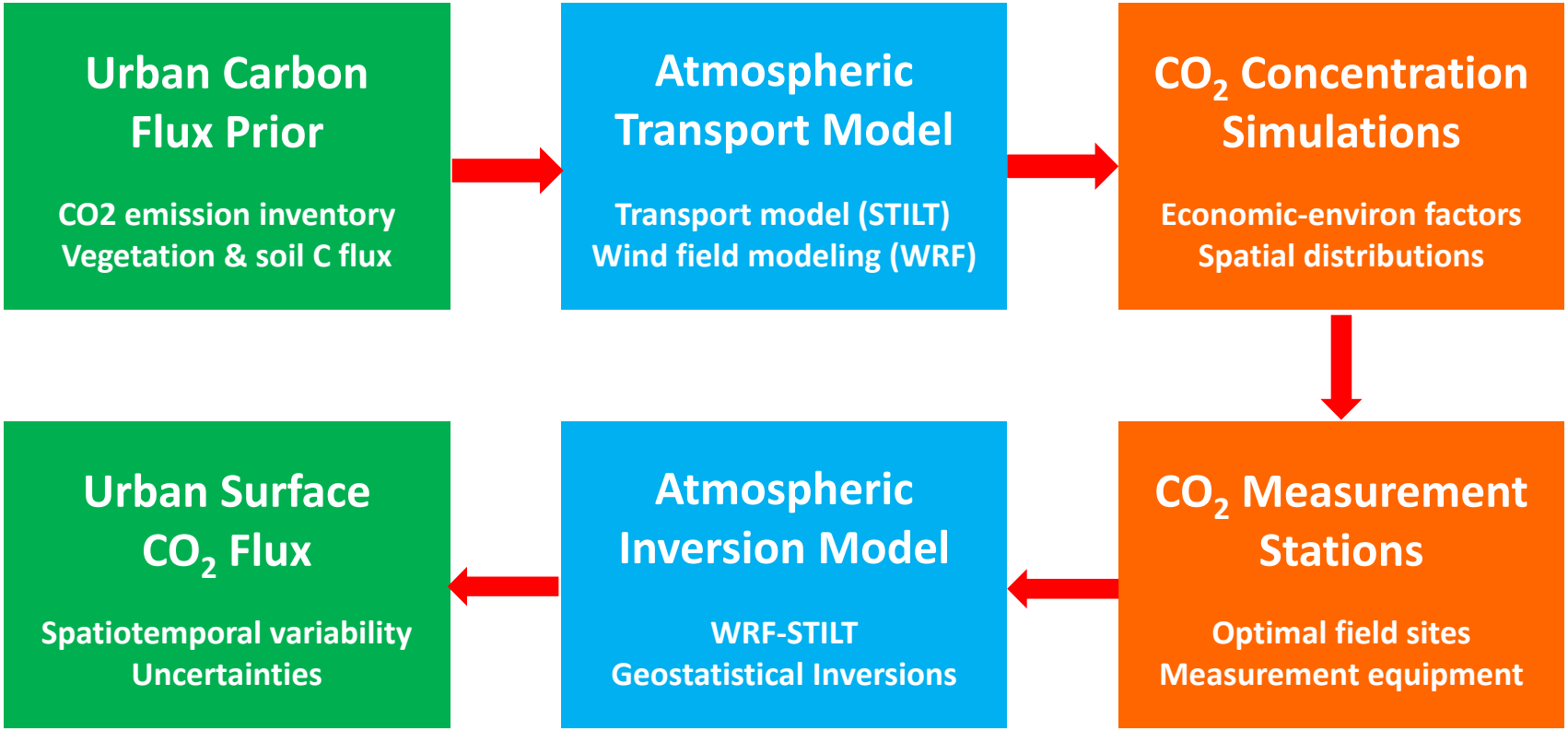
2002-2010, vehicle num increased 7 times.



2002-2010, carbon emission increased 46 times.

Urban CO_2 Monitoring & Atmospheric Inversions of Urban Surface CO_2 Fluxes

Simulating CO_2 concentrations over Shenzhen



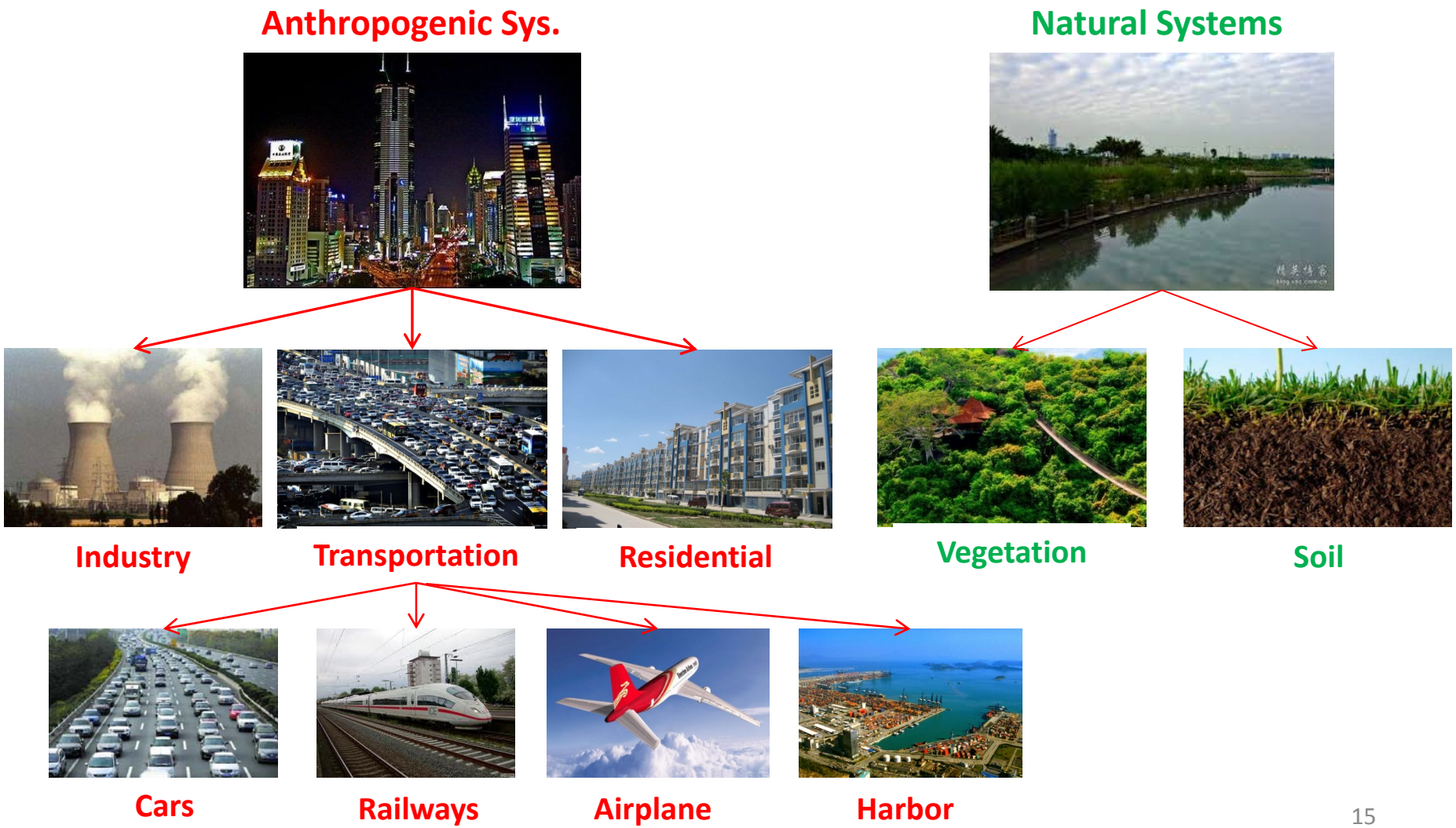
Estimating urban surface CO_2 fluxes over Shenzhen

Urban CO_2 Monitoring & Atmospheric Inversions of Urban Surface CO_2 Fluxes

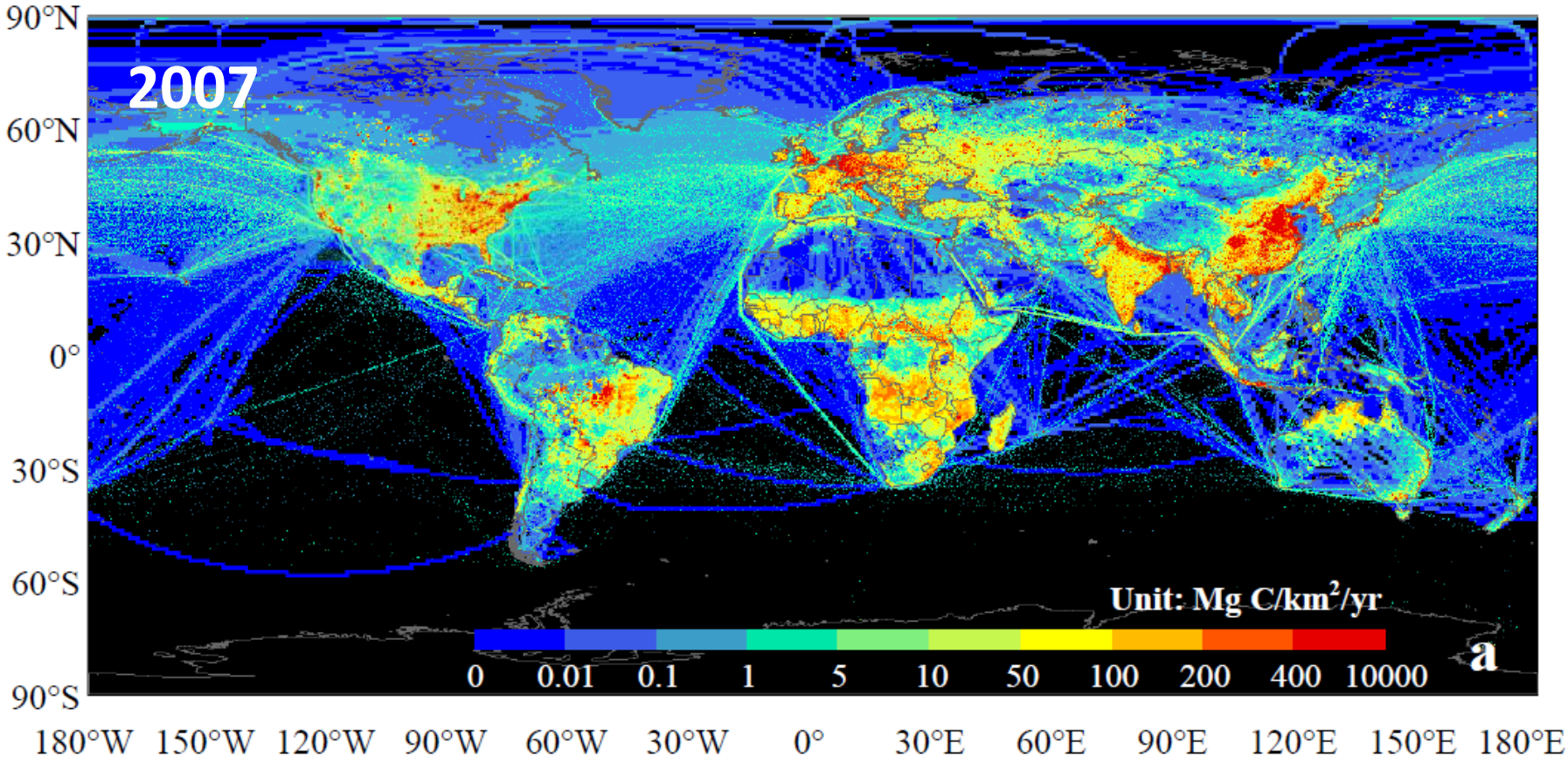
- Building CO_2 emission inventories for Shenzhen
- Building the long-term ground CO_2 measurement stations in Shenzhen (high accuracy)
- Building the CO_2 measurement sensor networks in Shenzhen (low accuracy)
- Fusing satellite CO_2 measurements and ground CO_2 measurements for atmospheric inversions

- Modifying and running atmospheric inverse models at urban scale for estimating surface CO_2 fluxes

Building CO_2 Emission Inventory of Shenzhen



PKU CO_2 Emission Inventory (2007)



Source: Wang et al., 2013

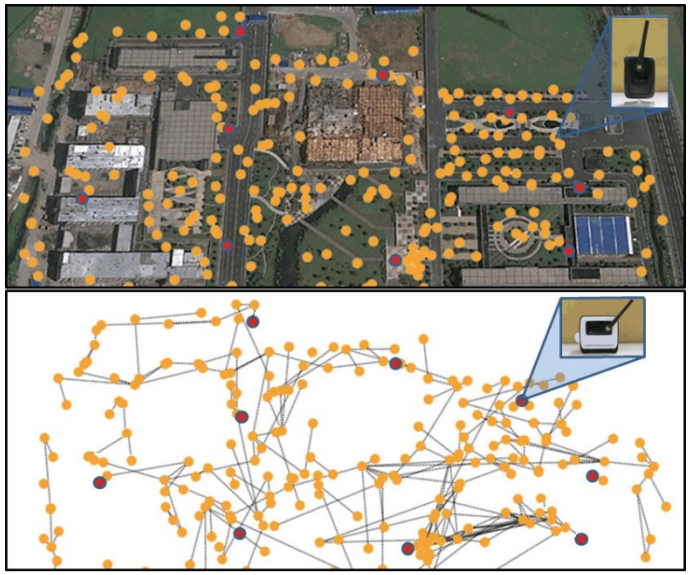
Accurate & Cheap Sensors for Urban CO_2 Monitoring

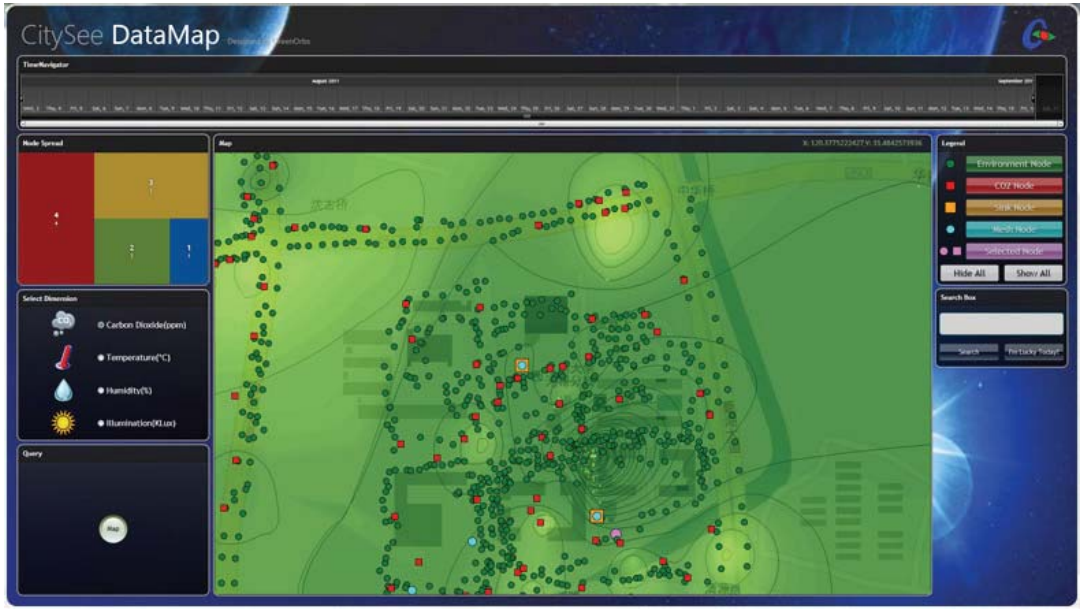
High accuracy CO_2 Measurements

CO_2 Monitoring Sensor Networks

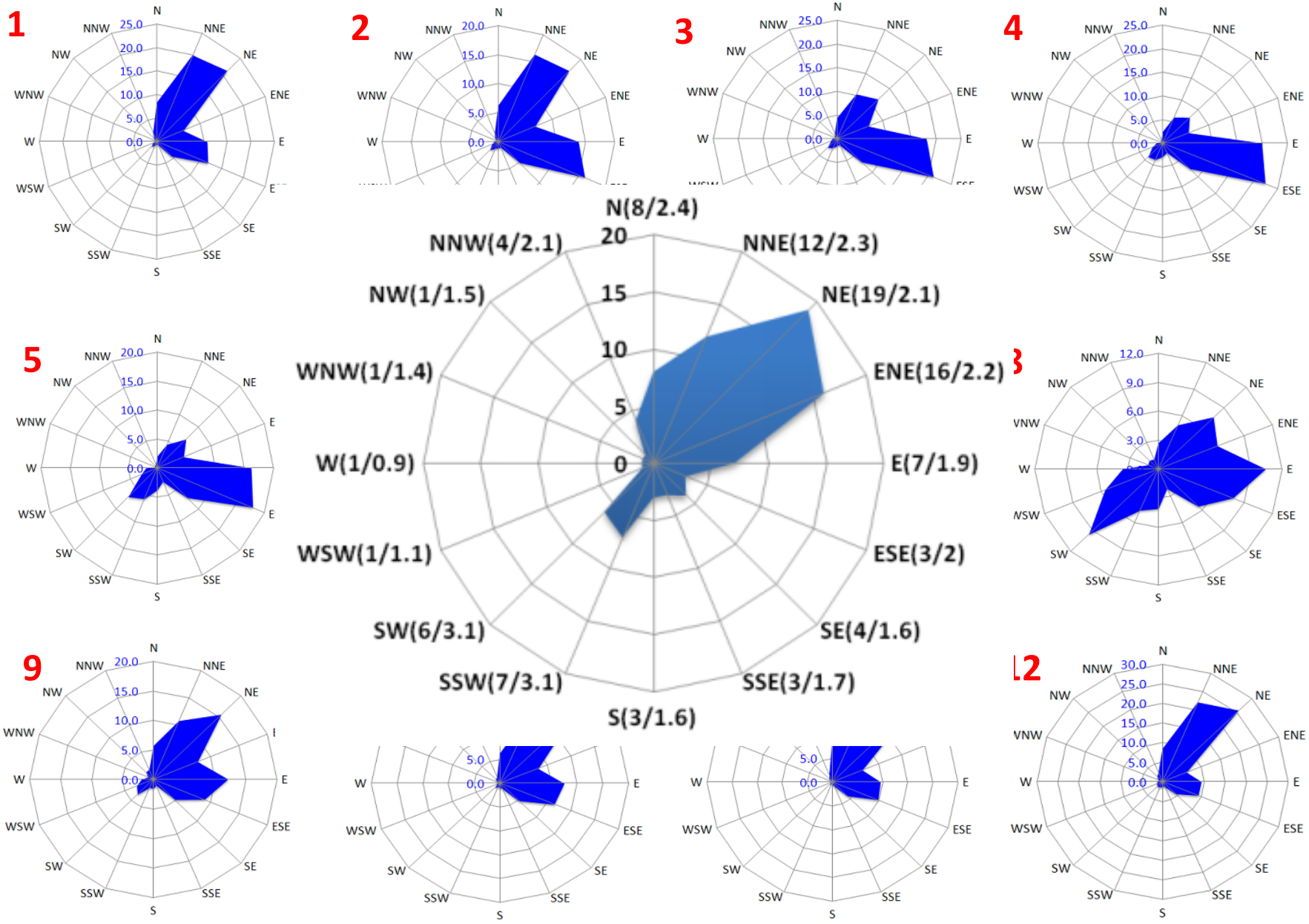
The cost of 1 accurate sensor is about the cost of 100 cheap sensors.

Urban CO_2 Sensor Networks, Wuxi, Jiangsu Province, China

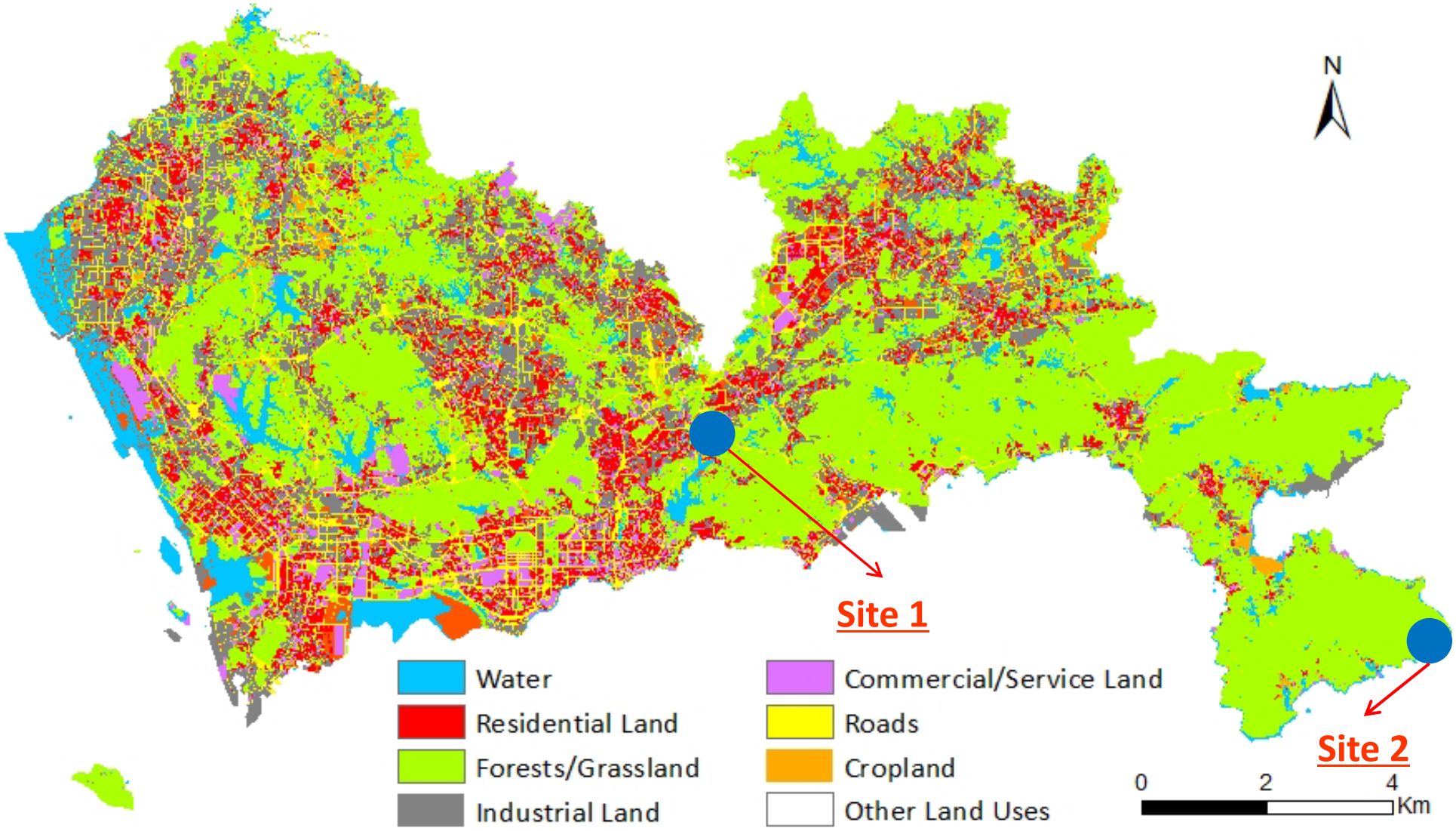




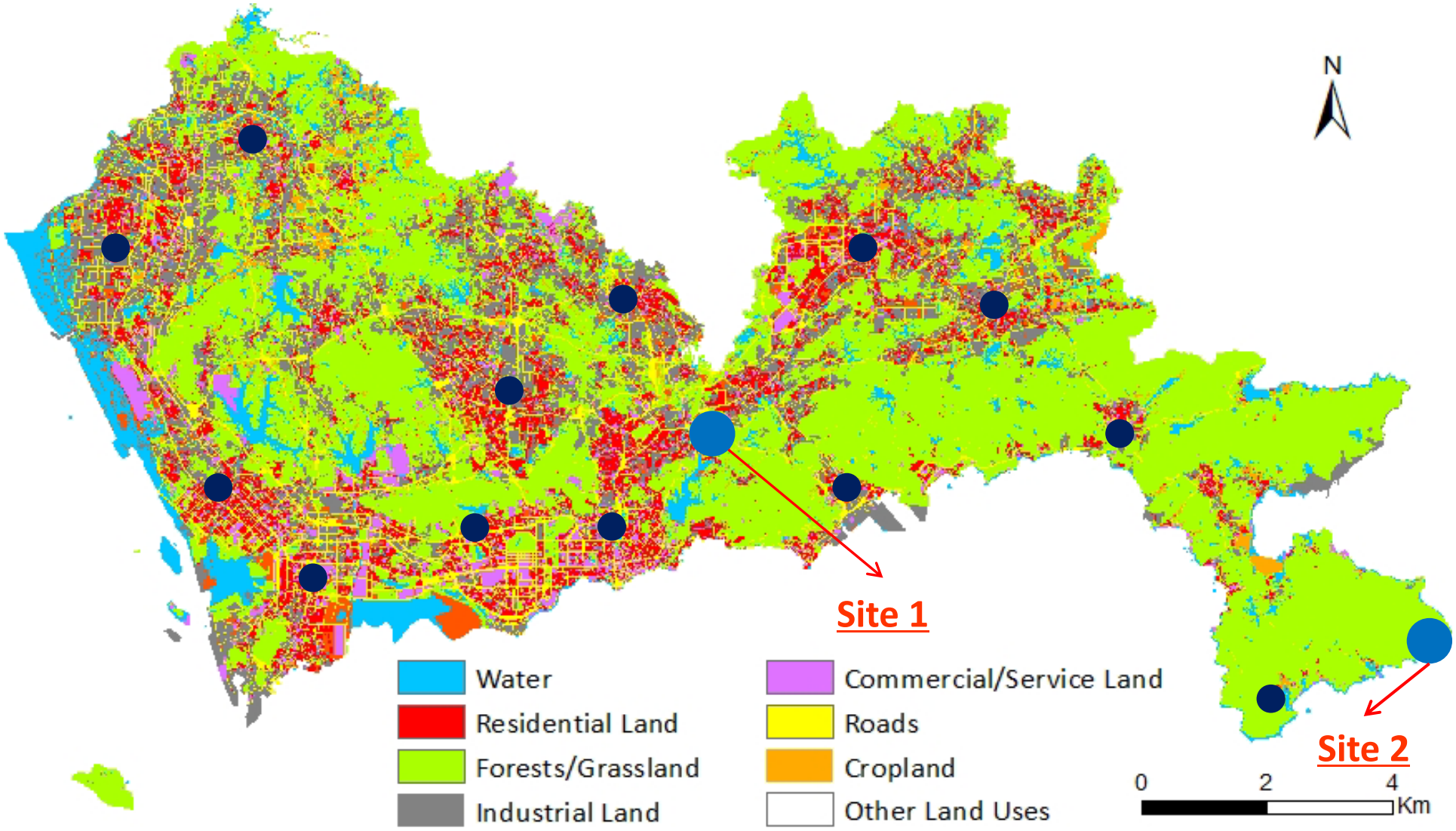
Mao et al., 2012
Proceedings of IEEE INFOCOM


1
2
3
4
5
N(8/2.4)
NNE(12/2.3)
NE(19/2.1)
ENE(16/2.2)
E(7/1.9)
ESE(3/2)
SE(4/1.6)
SSE(3/1.7)
S(3/1.6)
SSW(7/3.1)
SW(6/3.1)
WSW(1/1.1)
W(1/0.9)
WNW(1/1.4)
NW(1/1.5)
NNW(4/2.1)
3
9
12

Urban CO_2 Monitoring: Accurate Sensors



Urban CO_2 Monitoring: Accurate & Cheap Sensors



今天是：2014年10月5日

首页 | 机构介绍 | 在线办事 | 环境质量 | 监测动态 | 政策法规 | 环境标准 | 环保百科 | 网上投诉 | 联系我们 |

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环境空气质量

2014年10月04日

监测点位	AQI	级别	首要污染物
华侨城	61	二级	臭氧
南油	69	二级	臭氧
盐田	68	二级	臭氧
龙岗	70	二级	臭氧
西乡	69	二级	二氧化氮

预测04日夜间至05日之间我市空气质量指数AQI值为45~85，$PM_{2.5}$日均值为28微克/立方米左右.

办事指南

- 业务范围
- 委托监测程序
- 监测项目
- 服务收费标准

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深圳市首个国家环保公益性行业科研项目开题(图)

8月19日，深圳市首个国家环保公益性行业科研专项项目《餐饮业挥发性有机物和颗粒物排放特征及污染控制对策研究》开题会在市环境监测中心站实验基地大楼315会议室举行。

更多内容...

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- 华润五丰肉类食品（深圳）有限公司龙岗肉类联合加工厂项目竣... 2014-09-18
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- 《场地环境监测技术导则》（HJ 25.2-2014） 2014-05-15
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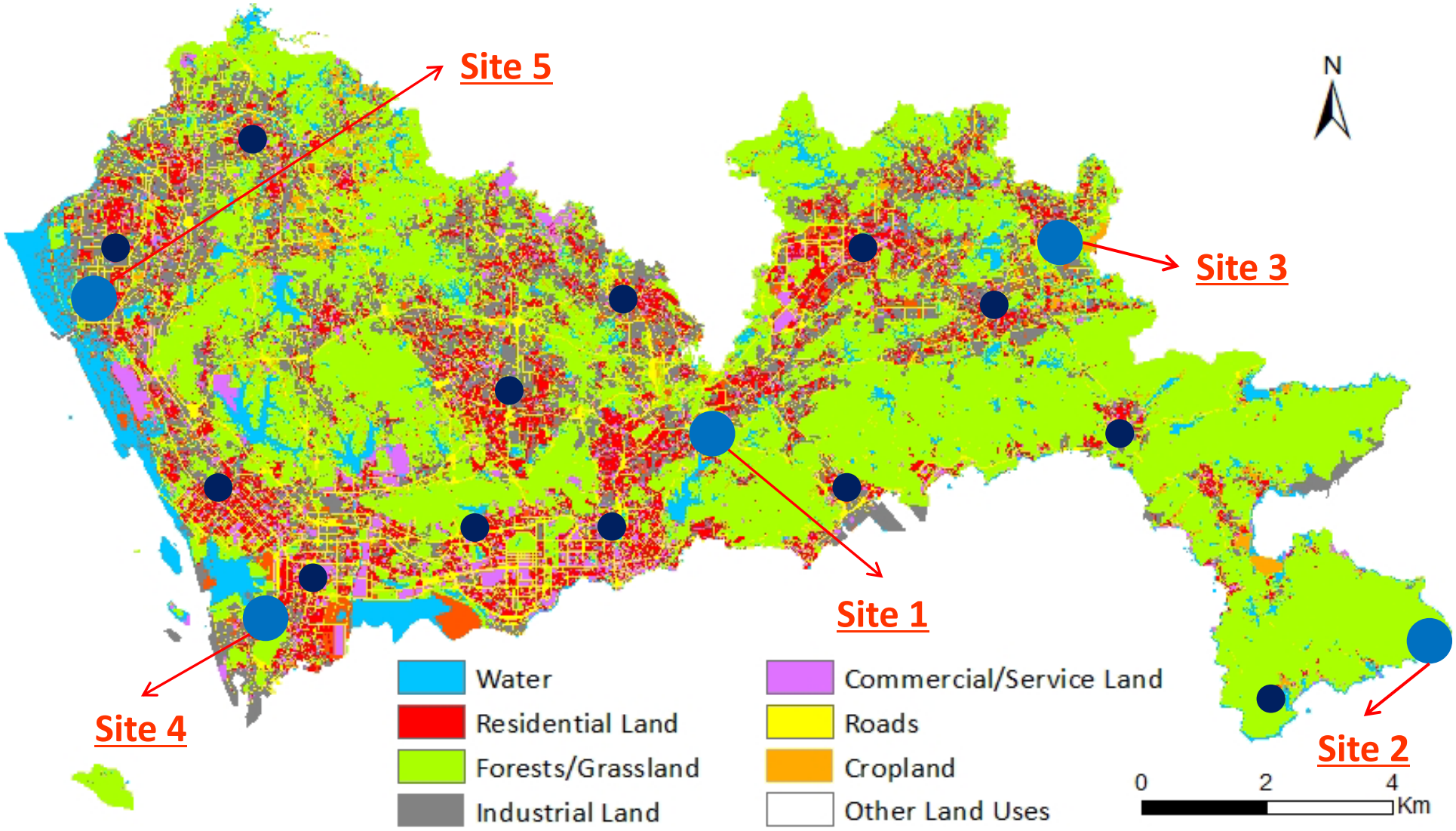
- 广东省排污许可证管理办法（政府规章） 2014-05-15

Urban CO_2 Monitoring: Accurate & Cheap Sensors



Bayesian Inference Applied to Inverse Modeling for Earth Surface CO_2 Flux Estimation

Likelihood of fluxes given atmospheric distribution

Prior information about fluxes

Posterior probability of surface flux distribution

$$p(\mathbf{s}|\mathbf{y}) = \frac{p(\mathbf{y}|\mathbf{s})p(\mathbf{s})}{\int p(\mathbf{y}|\mathbf{s})p(\mathbf{s})d\mathbf{s}}$$

$p(\mathbf{y})$ probability of measurements

$\mathbf{y}$: available observations ($n \times 1$)

$\mathbf{s}$: surface flux distribution ($m \times 1$)

Bayesian vs. Geostatistical Inverse Modeling

- **Classical Bayesian inverse modeling objective function**

$$L = \frac{1}{2}(\mathbf{y} - \mathbf{Hs})^T \mathbf{R}^{-1}(\mathbf{y} - \mathbf{Hs}) + \frac{1}{2}(\mathbf{s} - \mathbf{s}_p)^T \mathbf{Q}^{-1}(\mathbf{s} - \mathbf{s}_p)$$

  - $\mathbf{Q}$ and $\mathbf{R}$ are diagonal
  - $\mathbf{s}_p$ is prior flux estimate in each region

- **Geostatistical inverse modeling objective function**

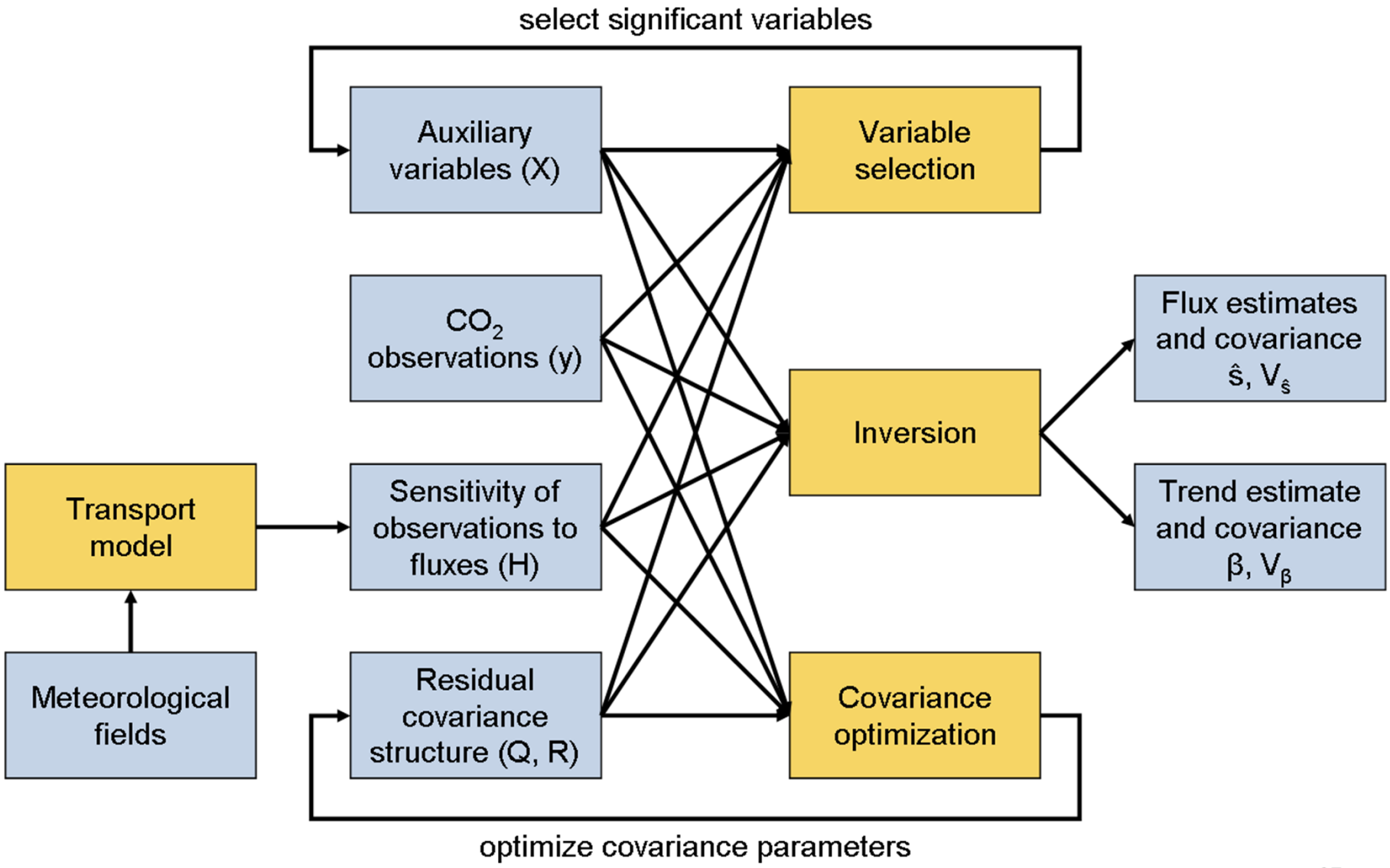
$$L = \frac{1}{2}(\mathbf{y} - \mathbf{Hs})^T \mathbf{R}^{-1}(\mathbf{y} - \mathbf{Hs}) + \frac{1}{2}(\mathbf{s} - \mathbf{X}\beta)^T \mathbf{Q}^{-1}(\mathbf{s} - \mathbf{X}\beta)$$

  - $\mathbf{R}$ is diagonal; $\mathbf{Q}$ is full covariance matrix
  - $\mathbf{X}$ and β define the model of the mean

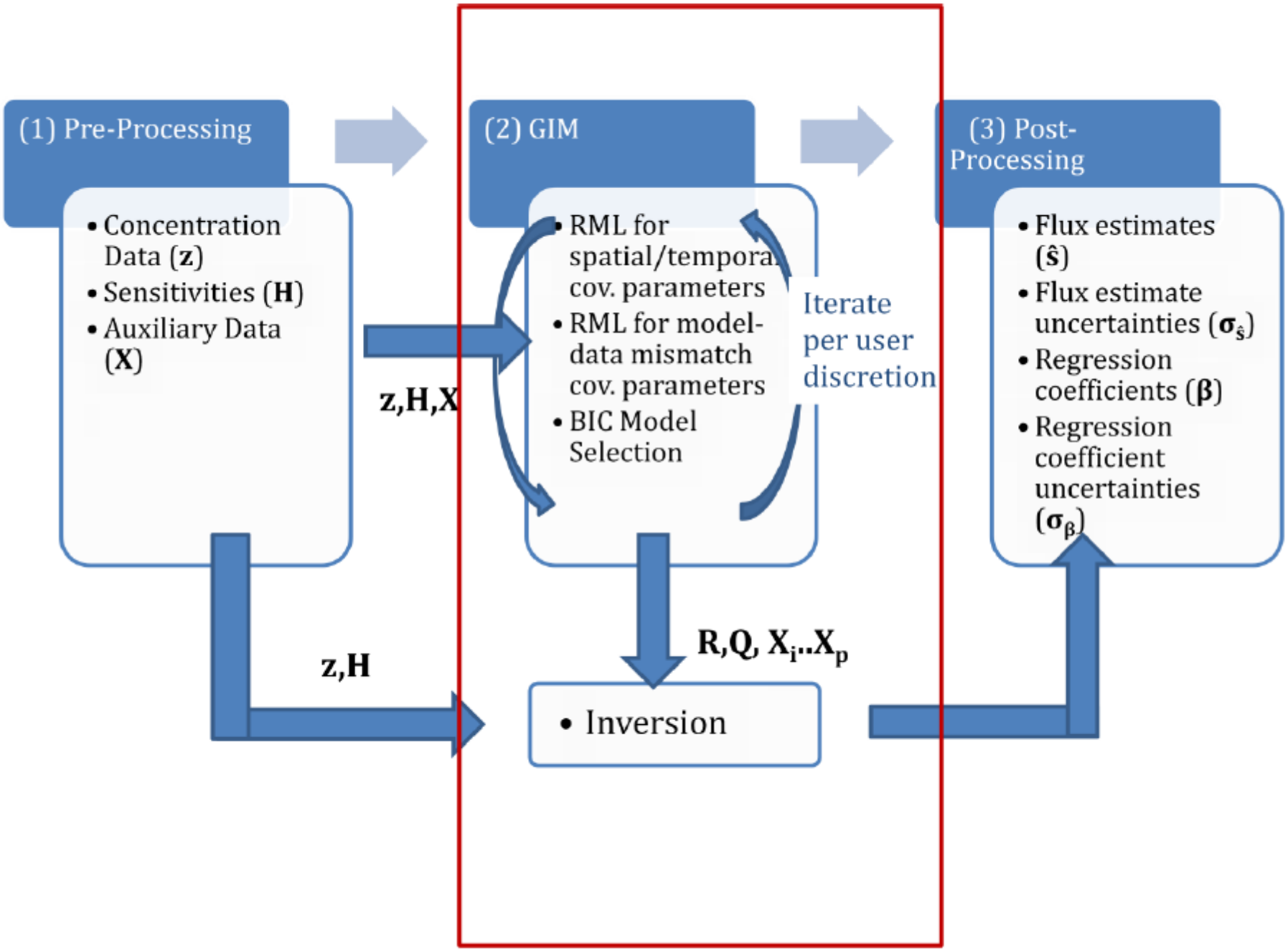
Geostatistical Approach to Inverse Modeling

- **Prior flux estimates are not required**
- **Key components**
  - Model of the mean
  - Prior covariance matrix
- **Prior based on spatial and/or temporal correlation**
  - Derived from available data
- **Covariance parameter optimization (RML)**
  - Model-data mismatch and prior covariance
- **Method yields physically reasonable estimates (and uncertainties) at any resolution**
- **Conditional realizations can be generated**

The Framework of Geostatistical Inverse Modeling

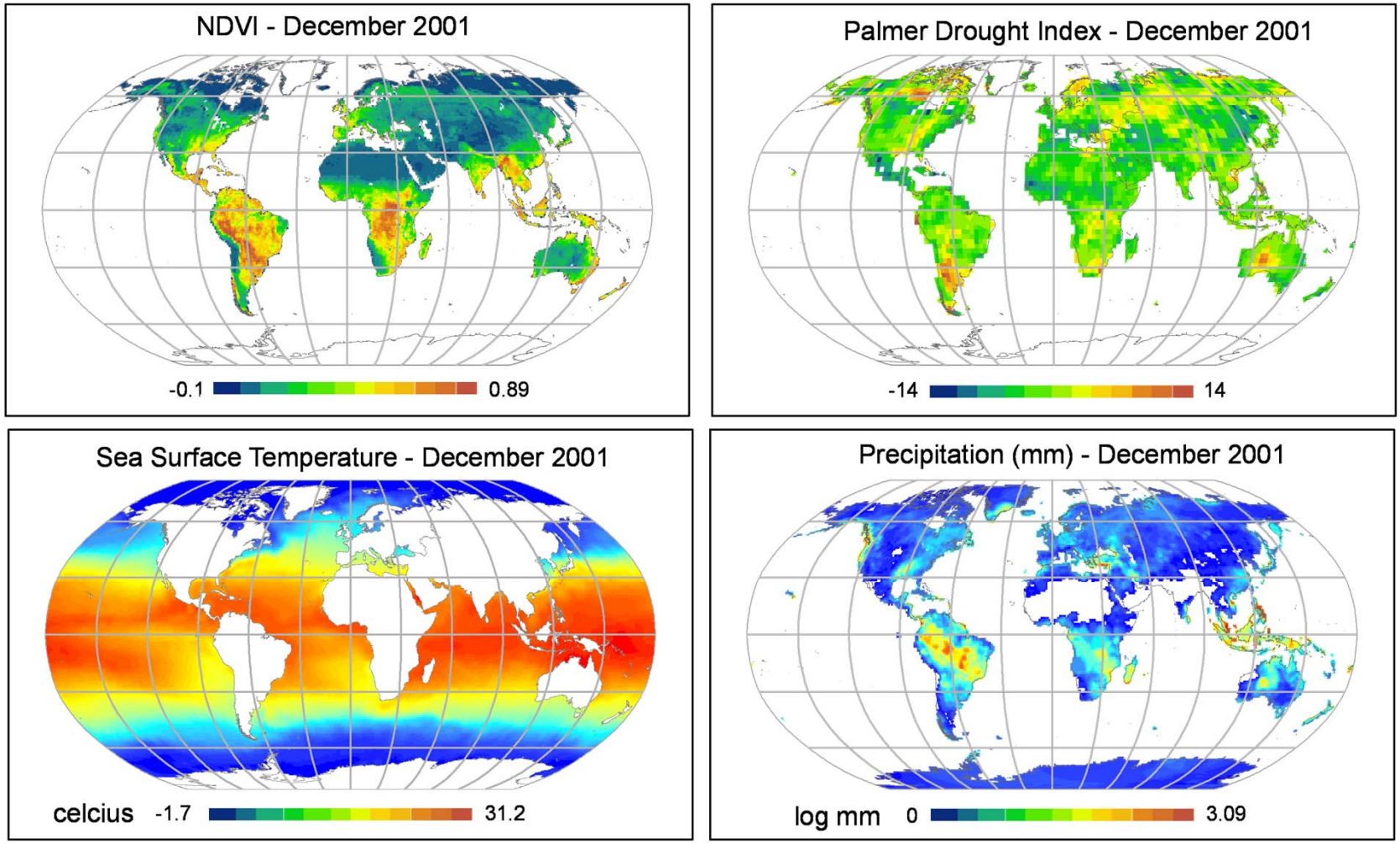


Source: Michalak et al. 2004



Source: Gourdji et al. 2010

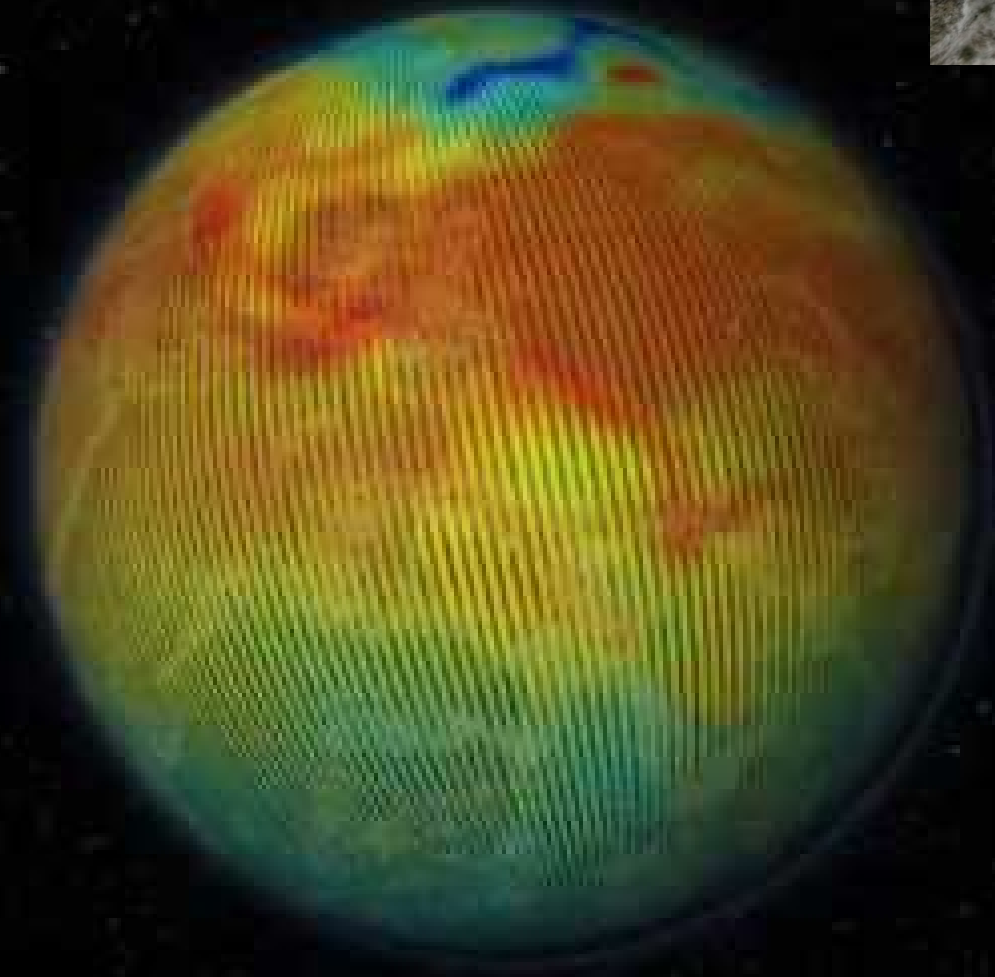
Auxiliary Information can be Included in GIM to improve inversion results.



Some others such as GDP density, pop density, LAI, FPAR ……

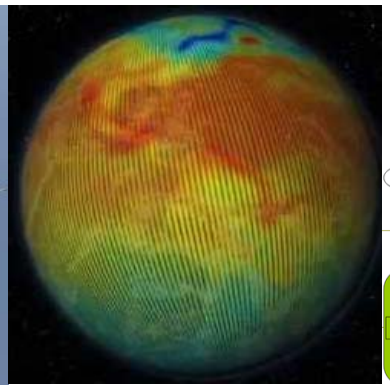
Source: Gourdji et al. 2008

OCO-2

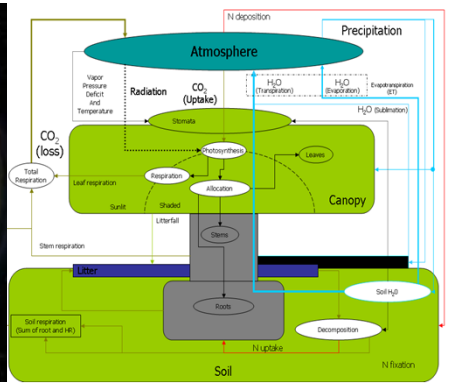


Urban socio-ecological systems of Shenzhen

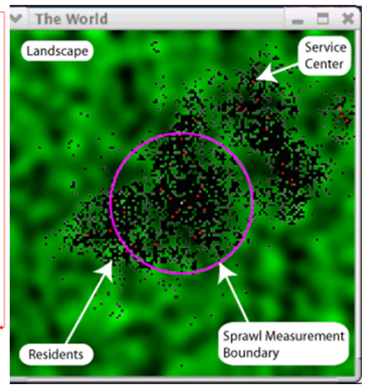
Urban CO_2 Monitoring Station



Remote Sensing Data of Column CO_2



Ecosystem Modeling of Carbon Cycle



Agent-based Modeling of Land Change

Looking forward to your suggestions and advice…