Modeling of Regional Air Pollution in North-East Asia

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Energy & Environment, CRAES

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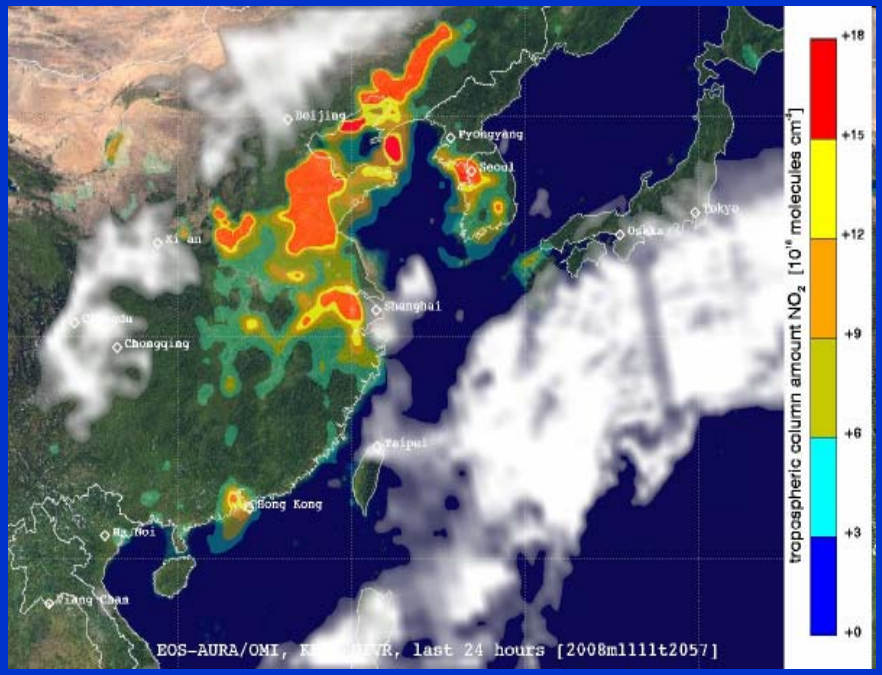
中国环境科学研究院
Chinese Research Academy Of Environmental Sciences

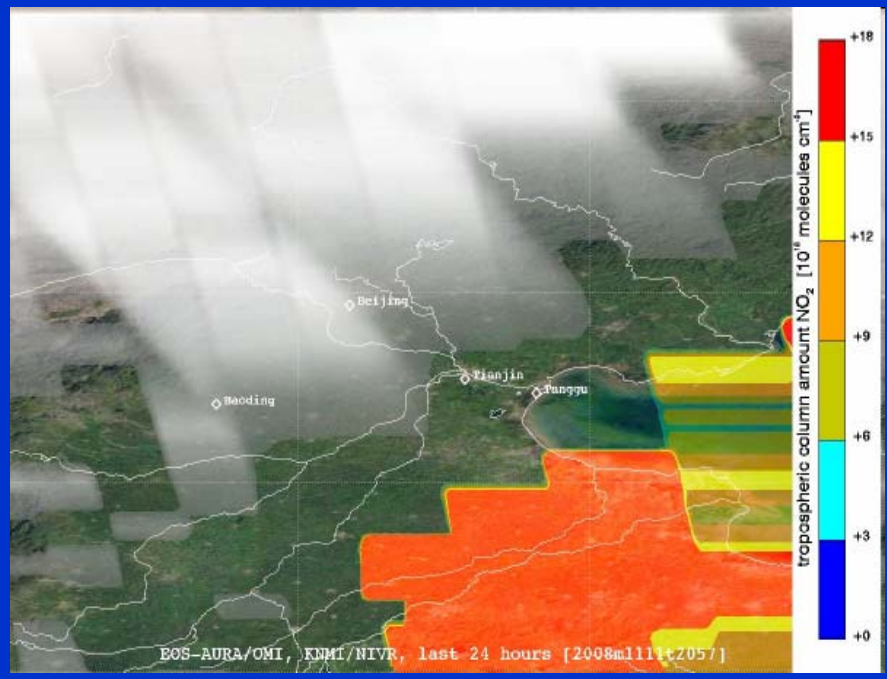
Regional Air Pollutions

Pictures of Great Wall taken on Nov. 30, 2008, 80km Northeast of Beijing

Most air quality monitoring sites are located in urban area and at ground level.

Regional Air Pollutions





Daily OMI tropospheric NO_2 over East Asia and Beijing Region, Nov.11,2008

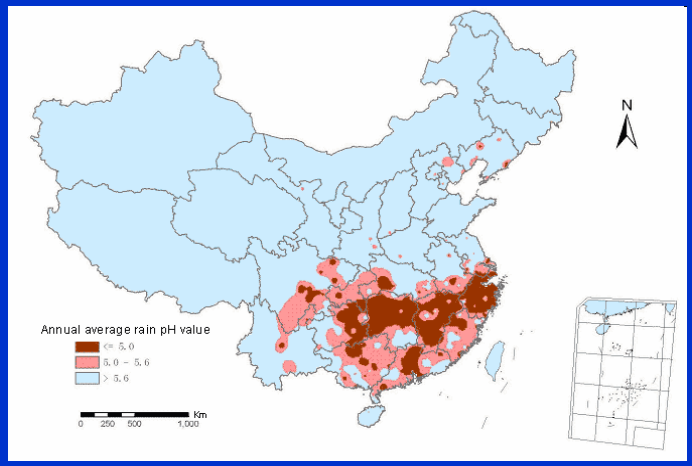
Air Pollution Problem in China

- Overall urban air quality was improved to some extent compared with the previous year.
- SO2 and PM are major problem. In 2004 NO2 concentrations are below Grade II for all cities. However, NO2 Concentrations are increasing.

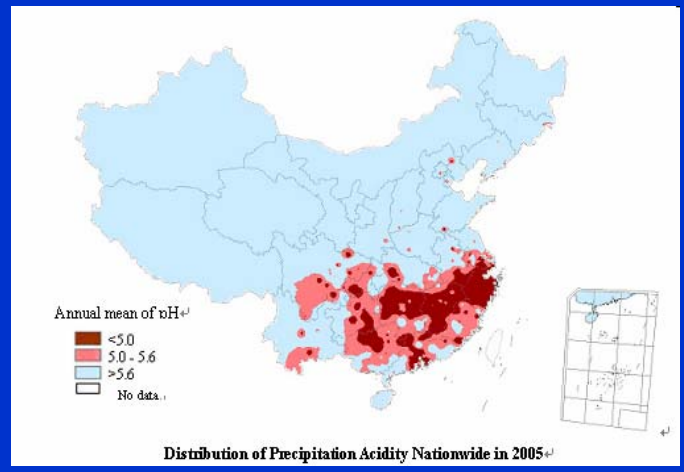
Grade of Air Quality	2004	2005	2006	2007
Grade II ，%	39.3	51.9	56.6	58.1
Grade III, %	40.2	37.5	34.9	36.1
Worse than Grade III, %	20.5	10.6	8.5	3.4

Grade I is nature reserves, scenic spots and other areas in need of special protection; Grade II function areas are residential areas; commercial, transportation and residential mixed areas, cultural areas and general industrial areas specified in urban planning as well as rural areas. Grade III areas are specific industrial zones.

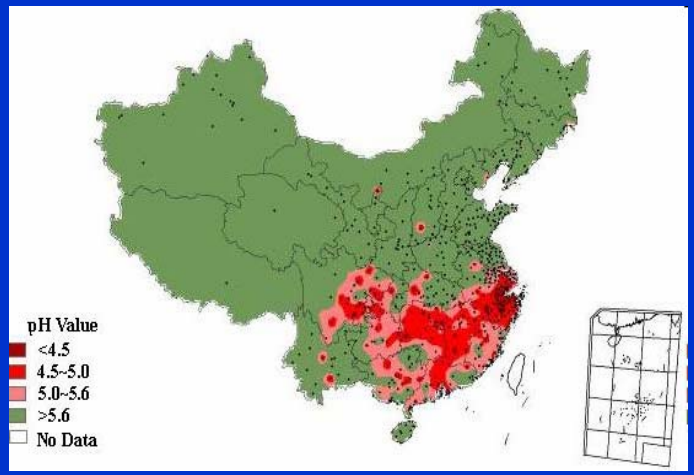
Nationwide Distribution of Acid Rain



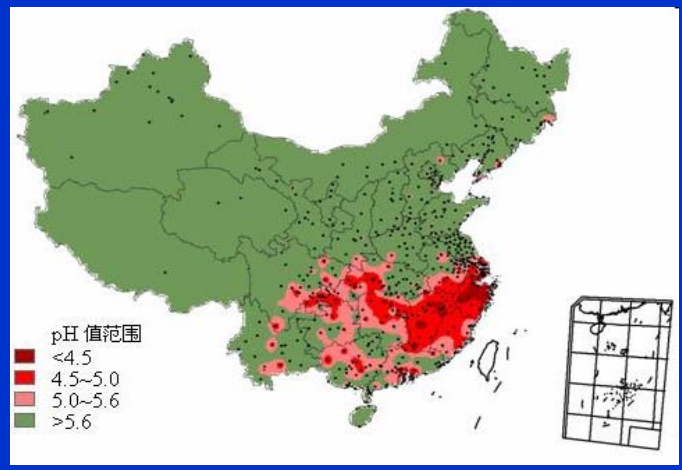
2004



2005



2006

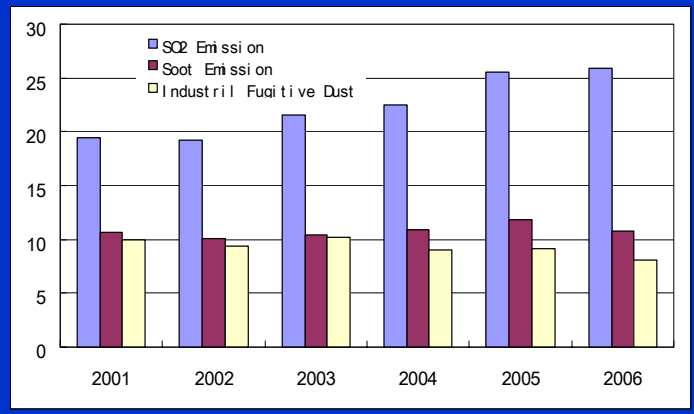


2007

Emission of Air Pollutants

- SO2 , Accoring 10th 5-year plan, SO2 emission of 2010 should be reduced 10% based on SO2 emission of 2005.

Item / Year	SO_2 Emissions			Soot Emissions			Emissions of Industrial Dust
	Total	Industrial	Domestic	Total	Industrial	Domestic	
2001	1947.8	1566.6	381.2	1069.8	851.9	217.9	990.6
2002	1926.6	1562.0	364.6	1012.7	804.2	208.5	941.0
2003	2158.7	1791.4	367.3	1048.7	846.2	202.5	1021.0
2004	2254.9	1891.4	363.5	1095.0	886.5	208.5	904.8
2005	2549.3	2168.4	380.9	1182.5	948.9	233.6	911.2
2006	2588.8			1078.4	854.8	223.6	807.5



Emission of NOx

- There is no NOx emission inventory available currently. Mobile emission model is under development in CRAES.
- By the end of July 2007, the total number of mobile vehicles of China is 152.8 million, 53.5 million are cars and trucks, 83.5 million are motorcycles. By the end of 2007, the total number of mobile vehicles of China is 159.8 million.
- By the end of Sep. 2008, the total number of mobile vehicles of China is 168.0 million, 5.17% increase from the end of 2007.
- According to one prediction: the number of passenger car in Being will increase from 1.73 million in 2008 to 2.21, 4.11, and 7.65 million in 2010, 2015 and 2020 respectively.

The National Tenth Five-Year Plan for Environmental Protection

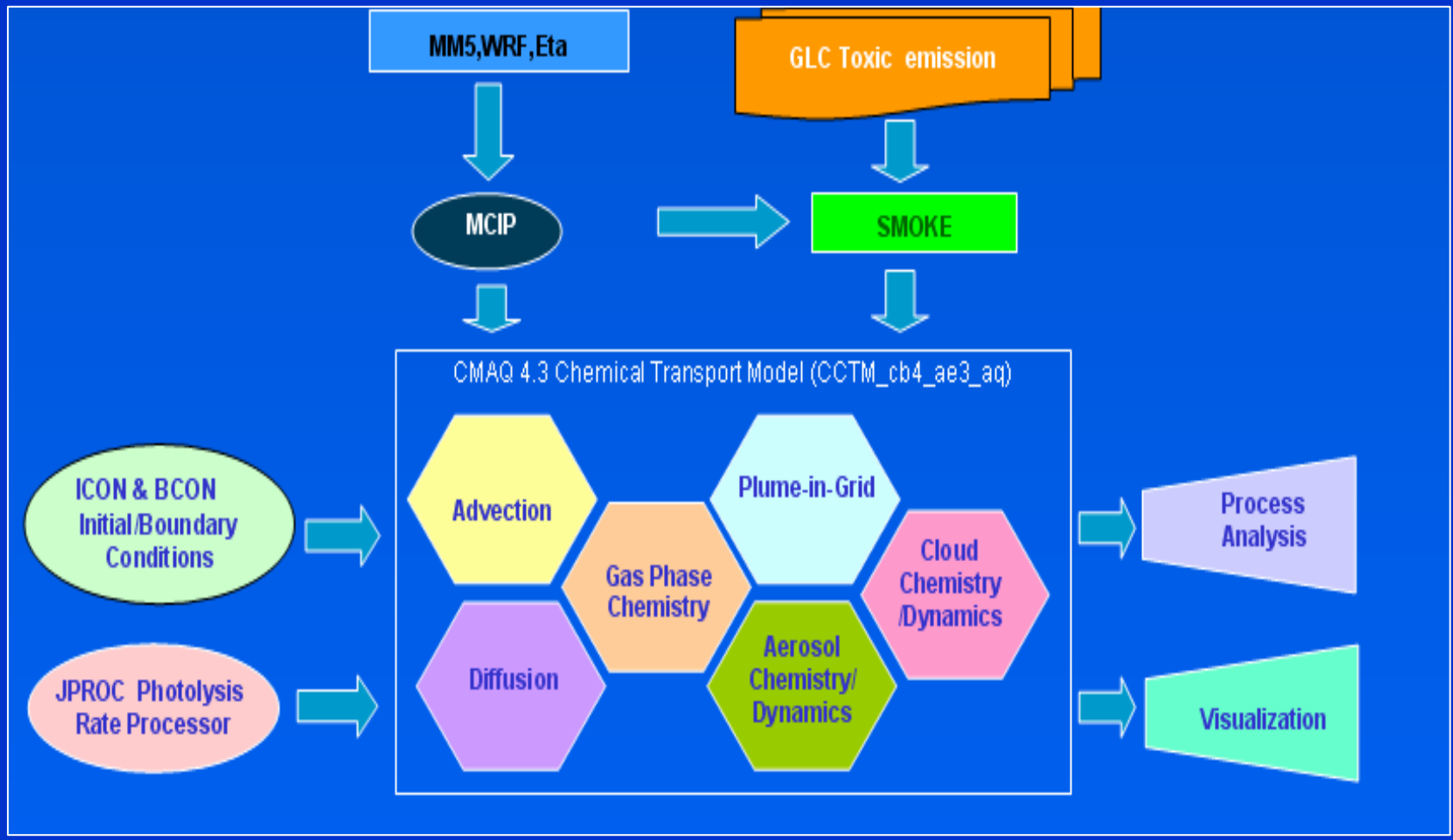
Indicators (10^6t/a)	2000	2005	Comparison of 2000 (+-%)
Amount of SO2 emission	19.95	17.96	-10.0
Industry:	16.13	14.50	-10.1
Domestic:	3.83	3.46	-9.5
Two-Controlling Zone	13.16	10.53	-20.0
Amount of soot emission	11.65	10.60	-9.0
Industry:	9.53	8.50	-10.8
Domestic:	2.11	2.10	-0.7
Amount of Industrial Dust emission	10.92	8.99	-17.7

The Eleventh Five-Year Plan for Environmental Protection

Indicator	2005	2010	**Comparison of 2005 (+-%)**
SO_2 (10^6 t/a)	25.49	22.95	-10%
Number of days in which urban air quality of key cities is superior to Grade II National Air Quality Standard exceeding 292 days (%)	69.4	75	5.6 percentage points

Model Description

CMAQ Modeling System



Vertical Layers: sigma-pressure coordinate, top is 100 hpa.

MM5: 32 sigma levels an 31 half sigma levels (layer)
Layer The 31σ-layers ,

1.0000,
0.9975,
0.9950,
0.9900,
0.9800,
0.9700,
0.9600,
0.9400,
0.9200,
0.9000,
0.8750,
0.8500,
0.8200,
0.7900,
0.7550,
0.7200,
0.6850,
0.6500,
0.6150,
0.5800,
0.5500,
0.5000,
0.4500,
0.4000,
0.3500,
0.3000,
0.2500,
0.2000,
0.1500,
0.1000,
0.0500,
0.0000

CMAQ:15 Levels (14 Layers)

1.0,
0.995,
0.99,
0.98,
0.96,
0.94,
0.91,
0.86,
0.80,
0.74,
0.65,
0.55,
0.4,
0.2,
0.0

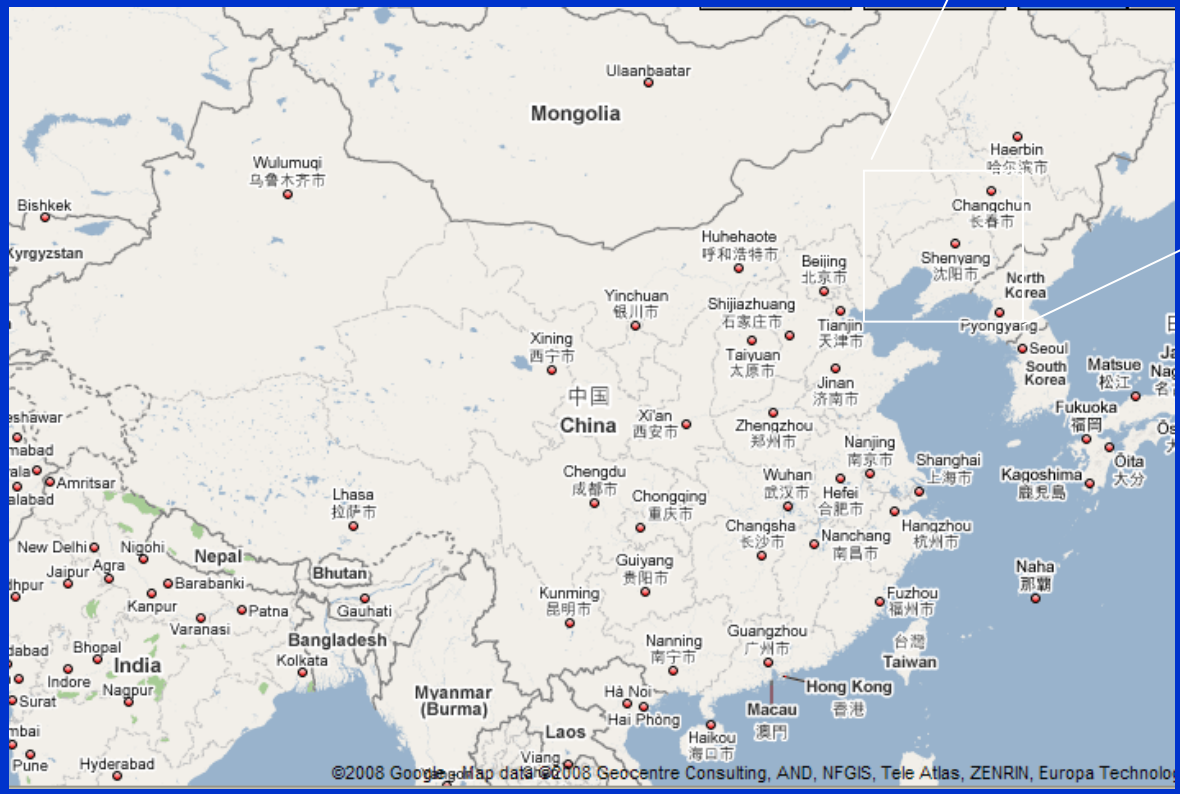
Modeling Application

- LTP project

  Critical Management Technology for Implementation Air Quality Standard in Typical Polluted Cities. Ministry of Environmental Protection

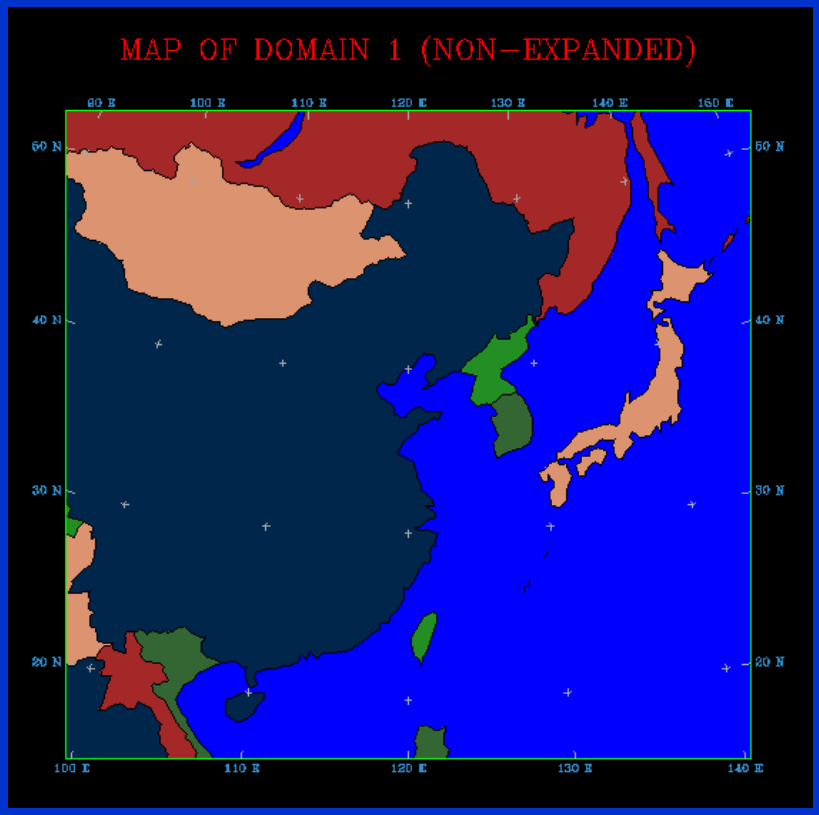
改善数值模拟精度的技术方法：

- 区域模式嵌套
- 空气污染预报：数据同化。
- 反向模式消除污染源的不确定性。

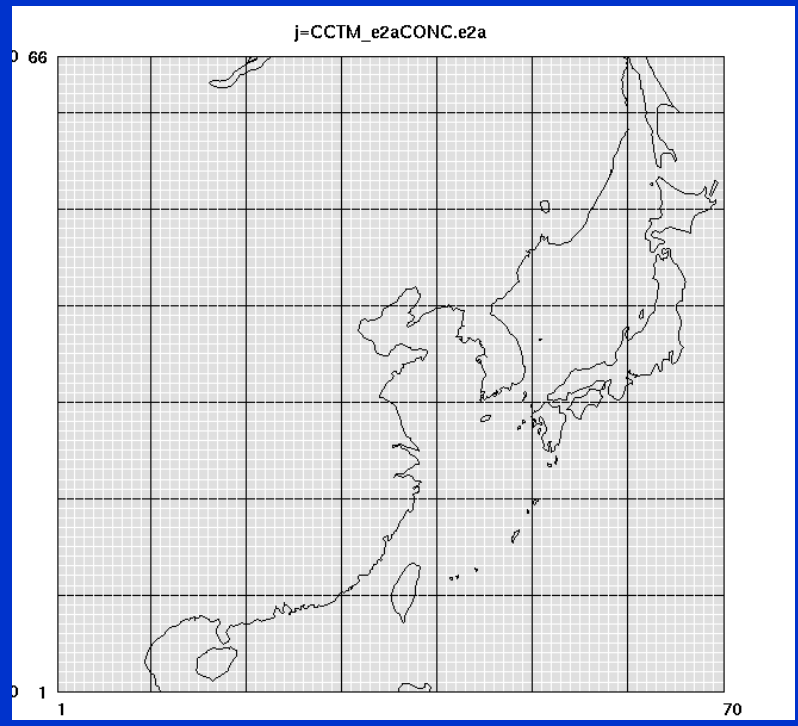


问题：
污染源不确定性很大；
缺乏区域/背景监测资料，作为模型验证和校正。

Domain of LTP Project



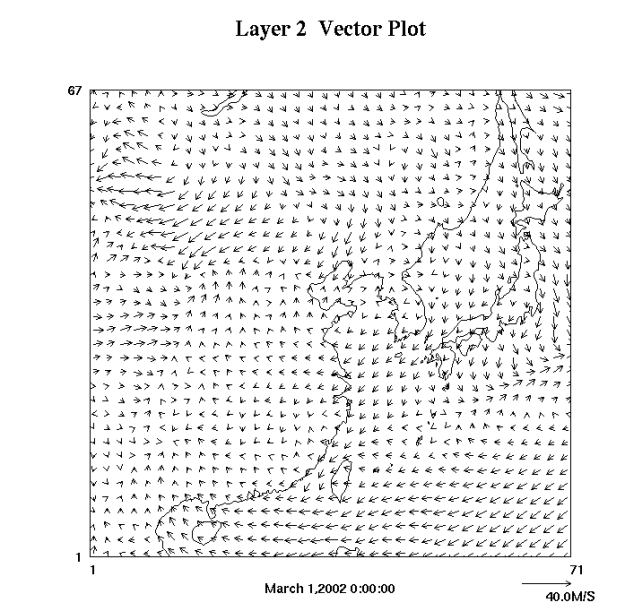
MM5 77x73, 60km

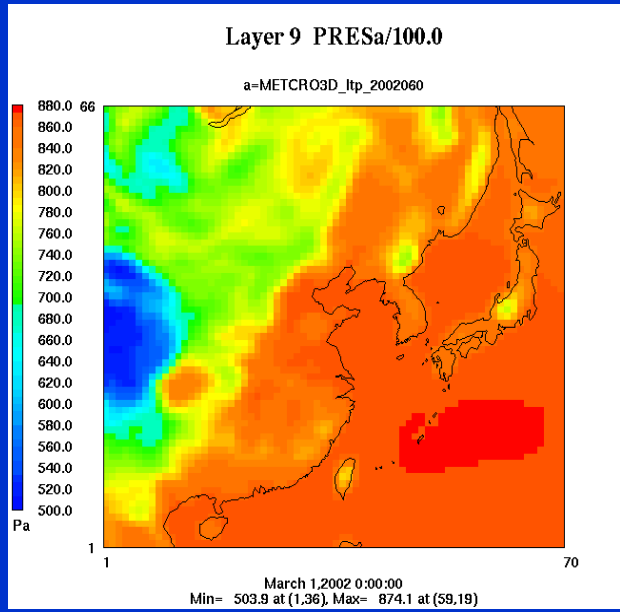


CMAQ 70x66, 60km

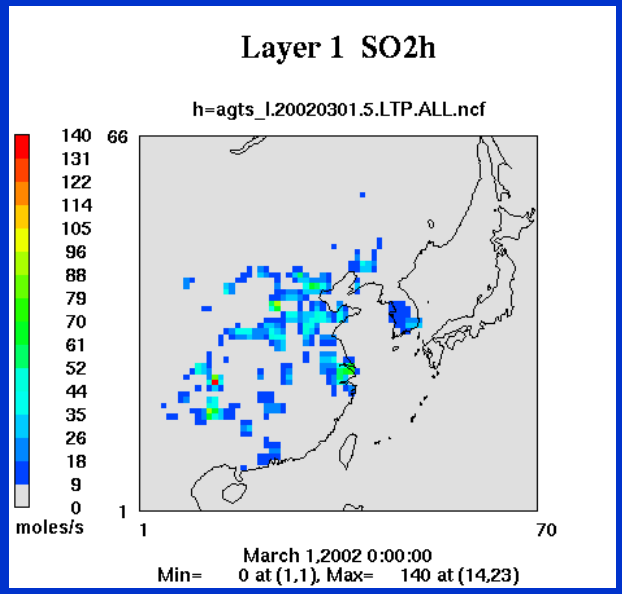
Lambert conformal center is at (120E ,36N), two standard parallels are 25N and 47N.

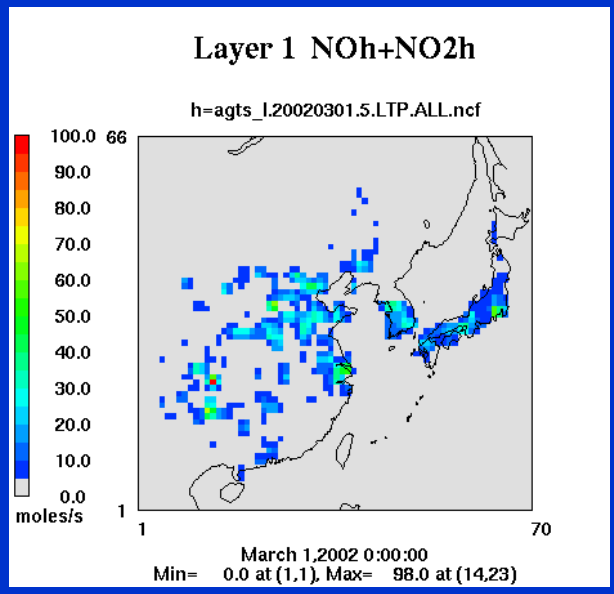
Meteorology

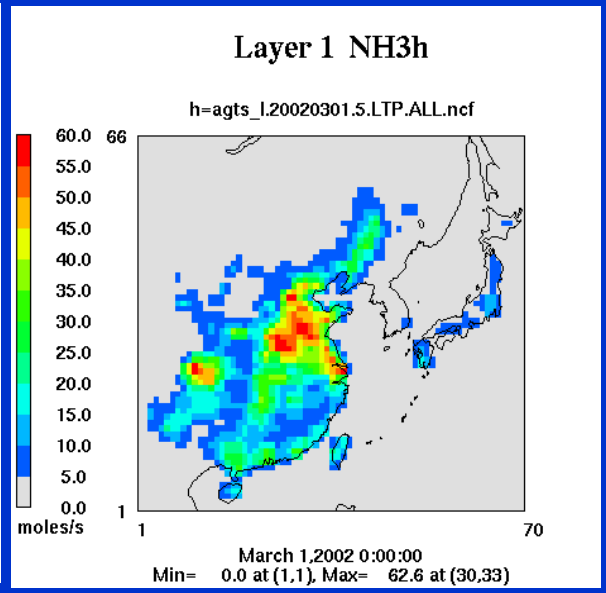




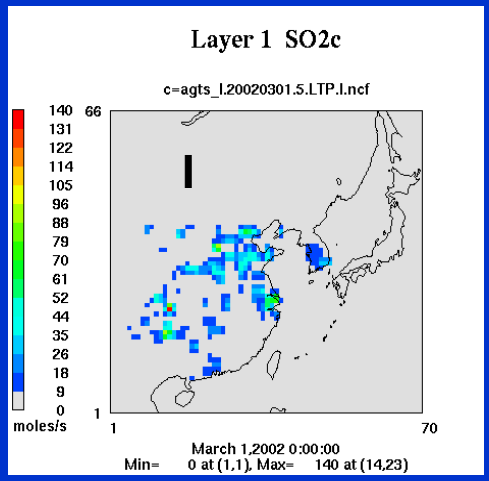
Gridded Emission

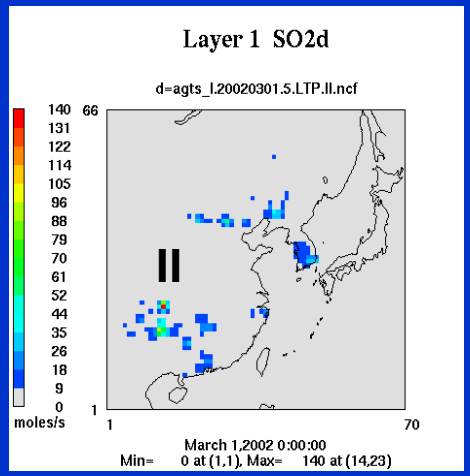


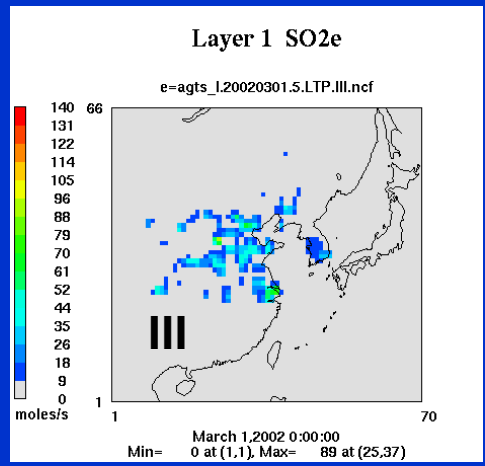


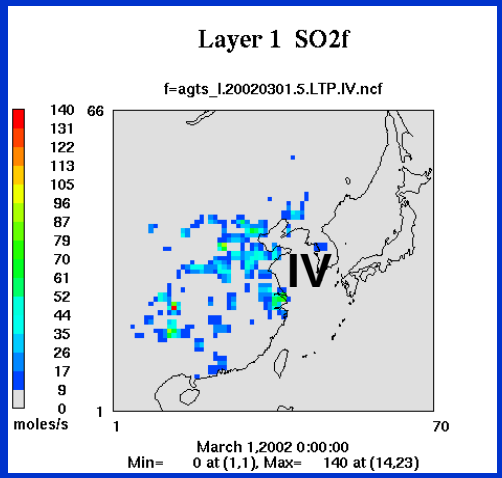


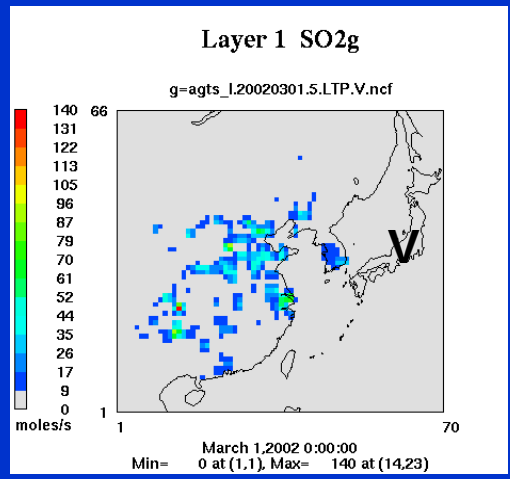
Modeling Scenarios-Source-Receptor Relationship

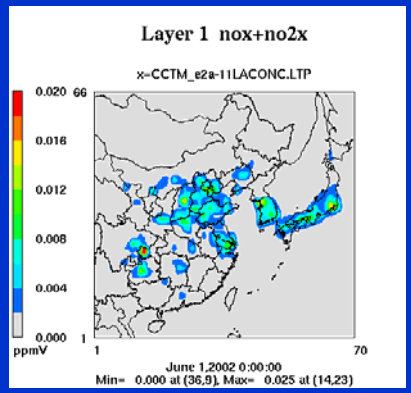


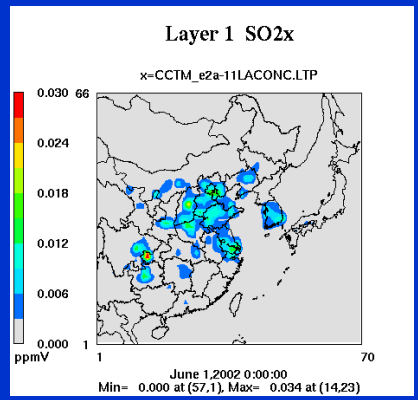


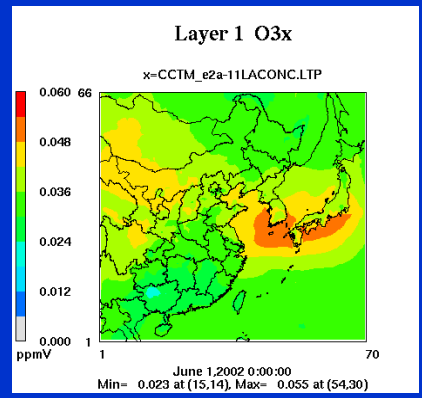




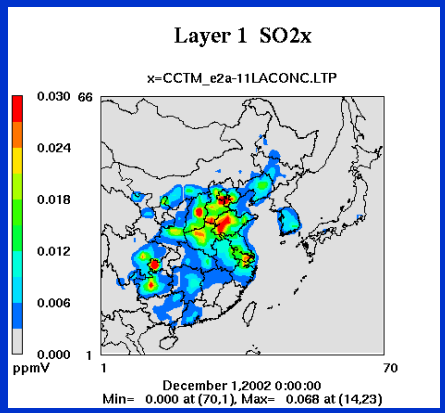


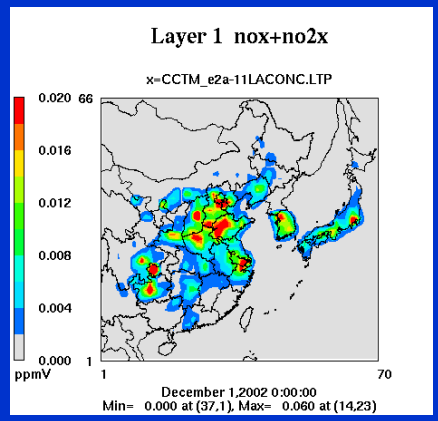


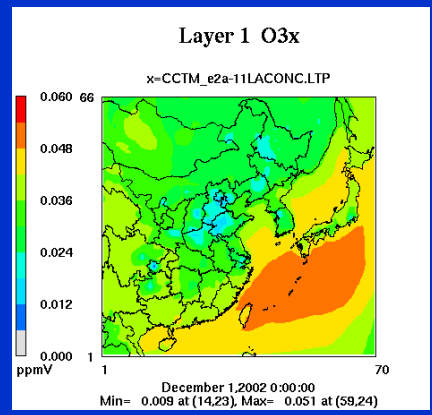




Monthly Averaged Gas phase Concentrations of July, 2002

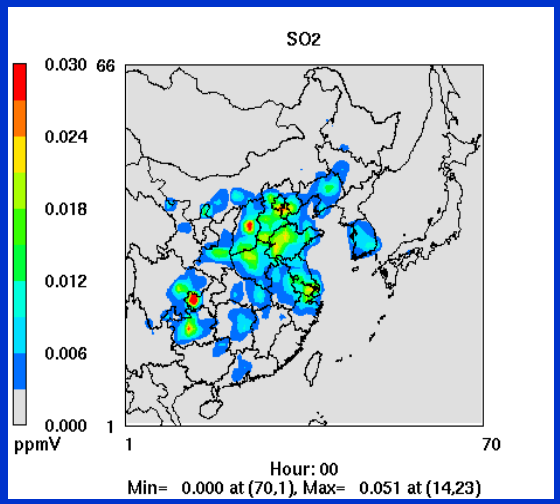


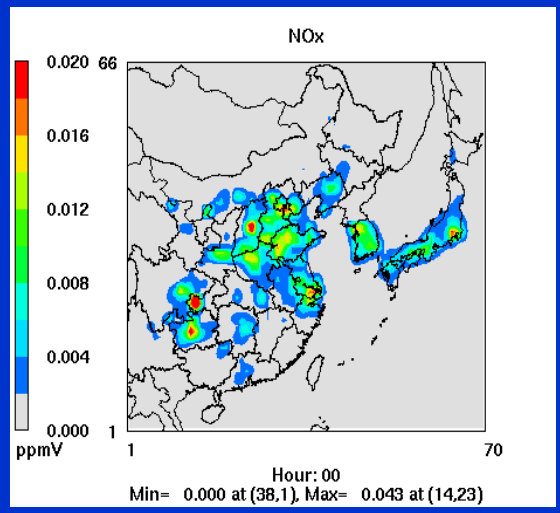


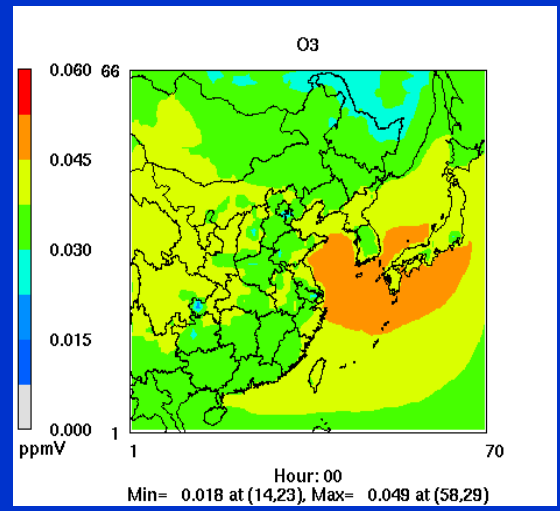


Monthly Averaged Gas phase Concentrations of Dec., 2002

Annual Averaged Gas phase Concentrations of 2002

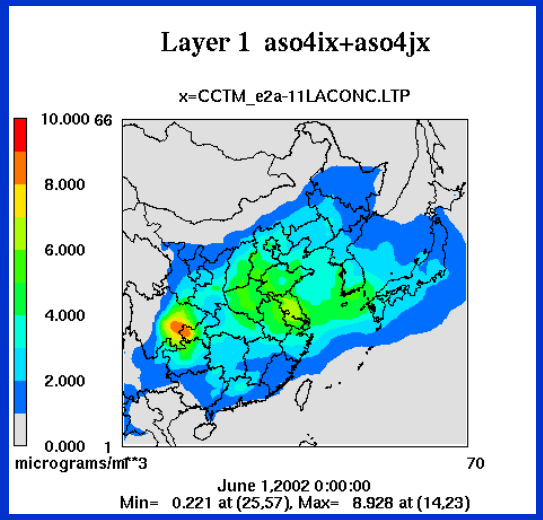


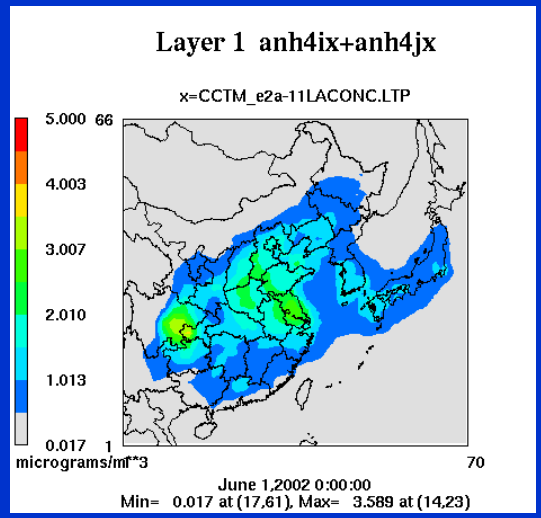


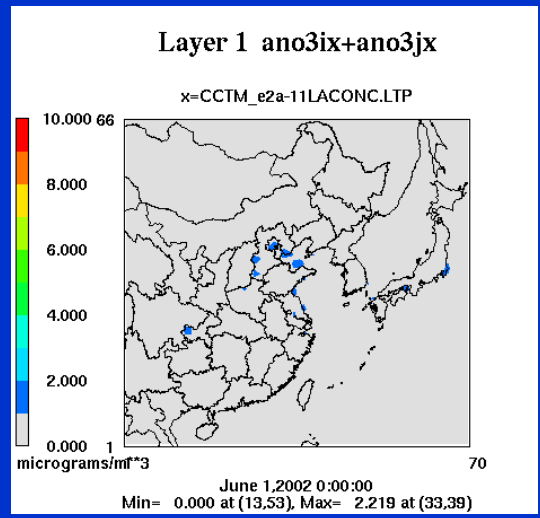


- Gaseous NOx and SO2 do not transport very far. However, high concentration of the secondary air pollutants, O3, found in remote areas.

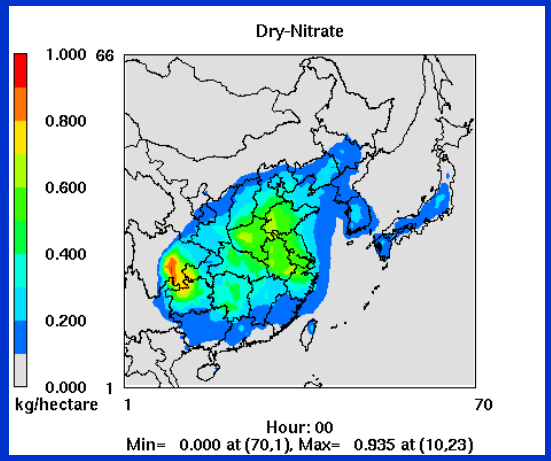
Monthly Averaged Concentrations of Aerosol of July, 2002

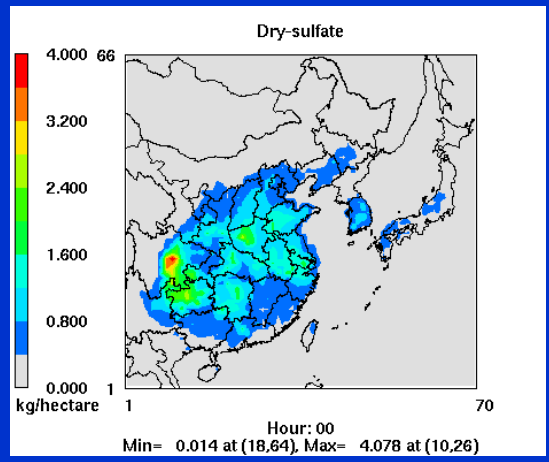




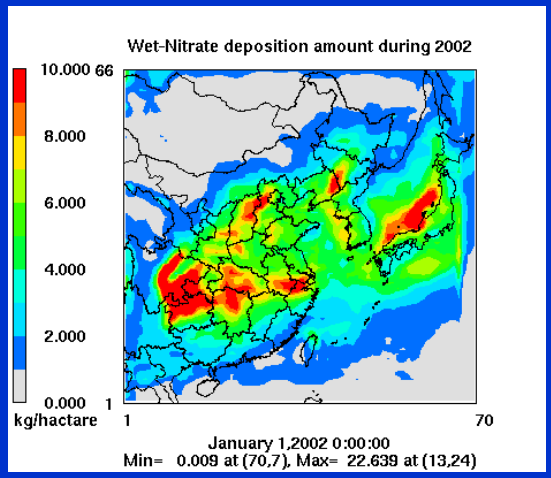


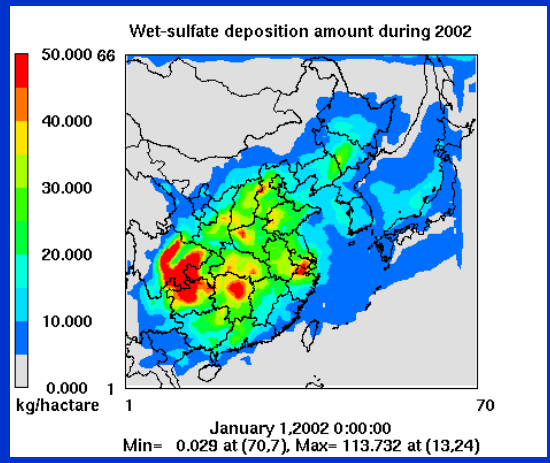
- Obvious lang-range transport of sulfate aerosol observed.





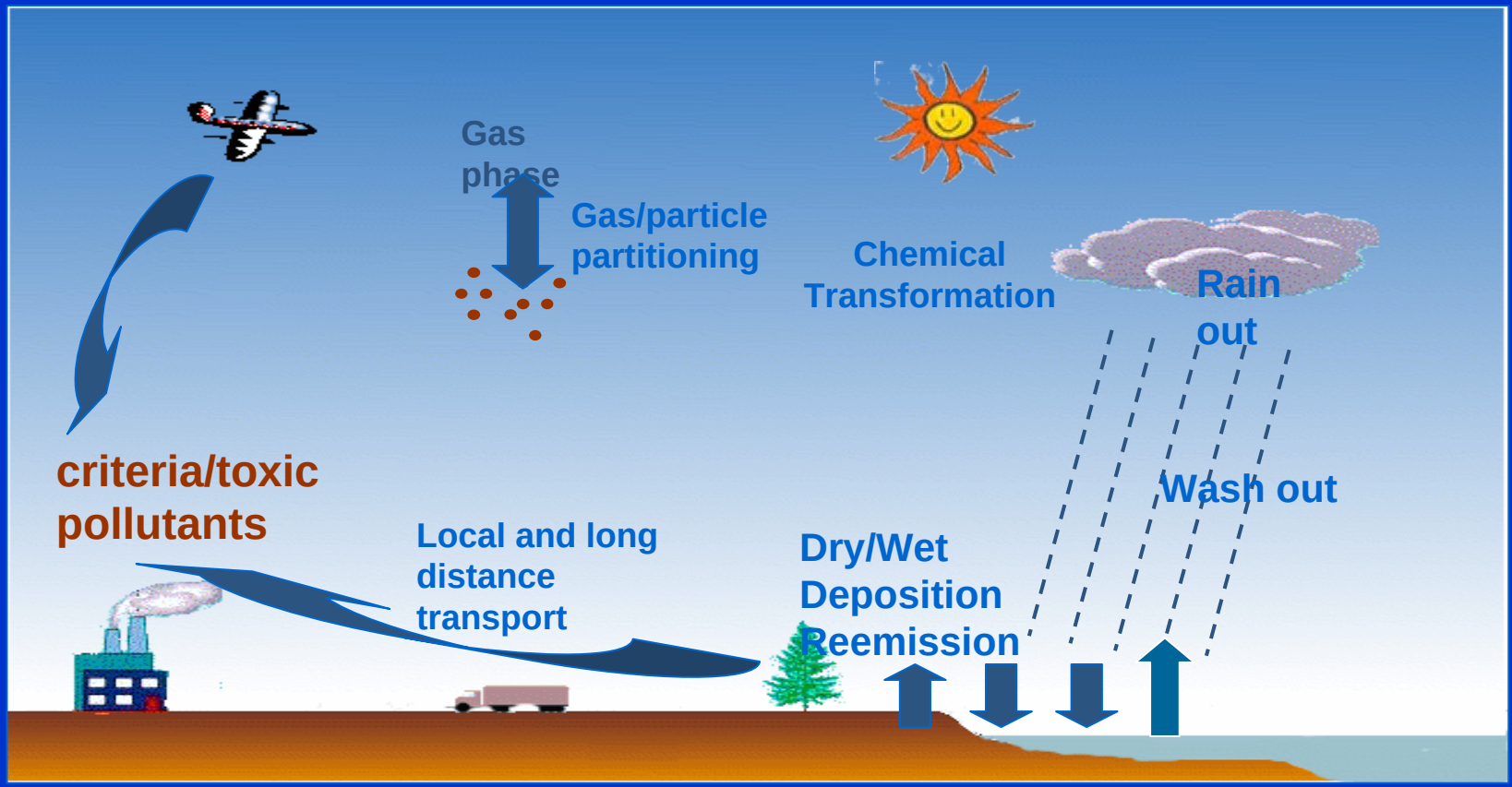
- Total dry deposition of sulfate and nitrate aerosols of 2002





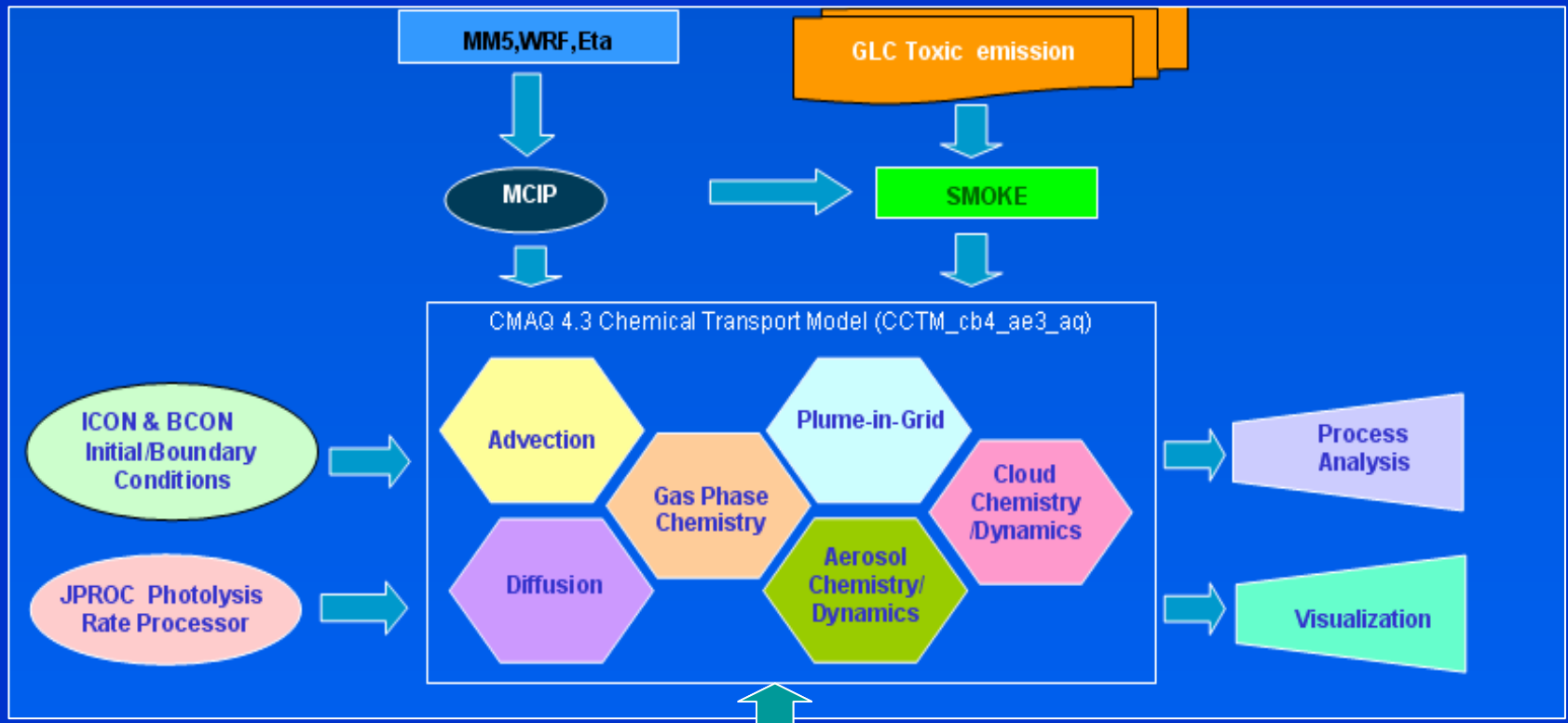
- Total wet deposition of sulfate and nitrate aerosols of 2002

Other Applications of Regional Air Quality Modeling



Fate of POPs in atmosphere
e.g. PCBs, PCDD/Fs, Hg

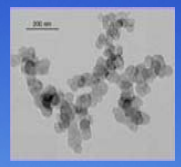
CMAQ Model Development for PCBs and PCDDFs



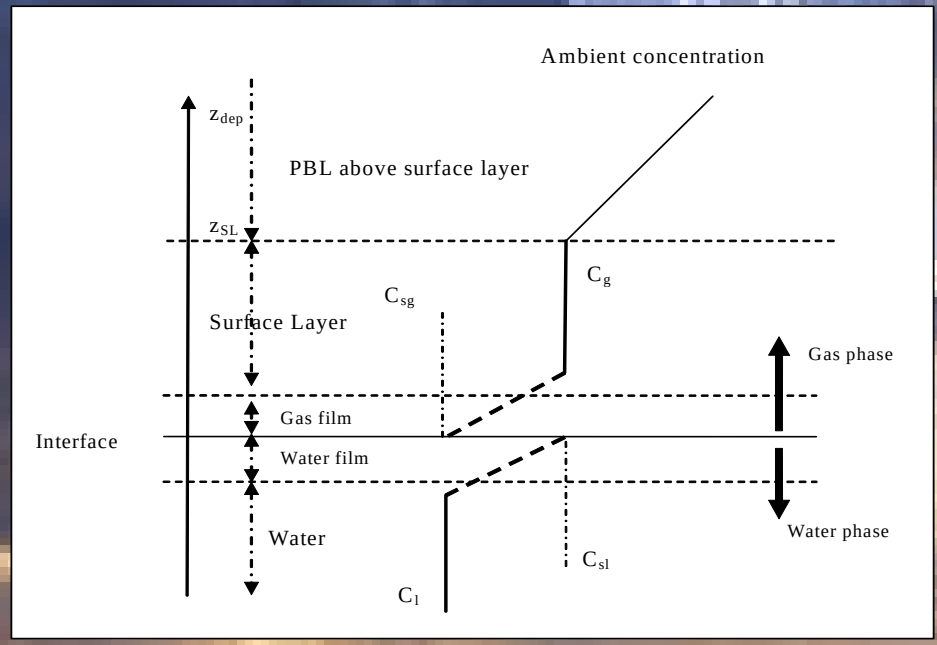
New Development for PCBs

- Gas/particle partitioning
- Chemistry
- Air/water surface exchange

Gas Phase
Toxic
Pollutants



Aerosol

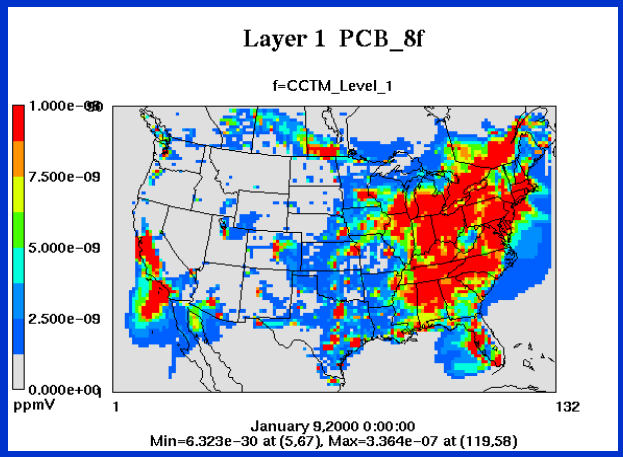


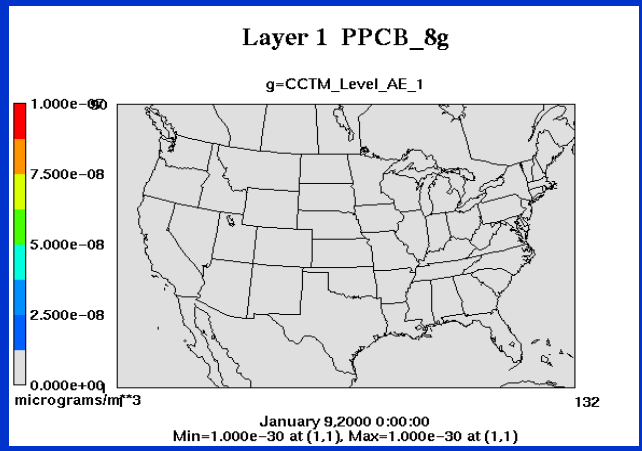
- Figure . Two-film exchange model of gas-water interface

For molecular transfer, the Fick's first law is used (Liss and Slater, 1974, Whiteman).

Air/aerosol, air/water/soil partitioning/exchange of semi-volatile POPs

PCB8 Model Results



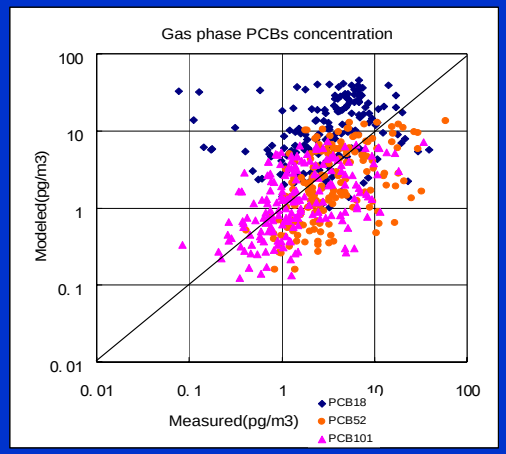


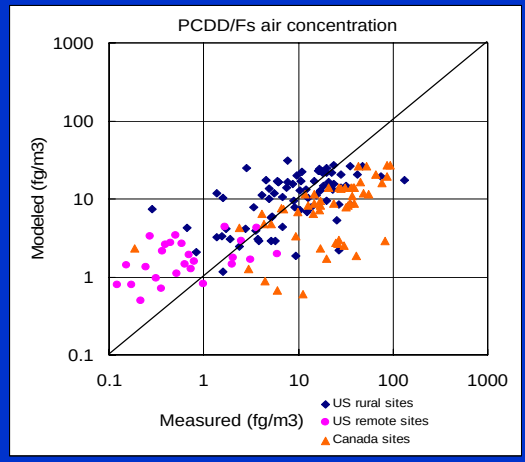
Gas phase

Particle phase

有毒空气污染物的模拟

- PCBs， PCDD/Fs等半挥发有毒有机空气污染物，主要的困难是缺乏可靠的气溶胶资料。





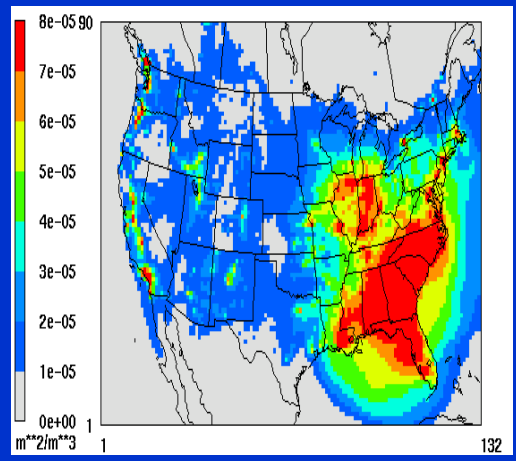
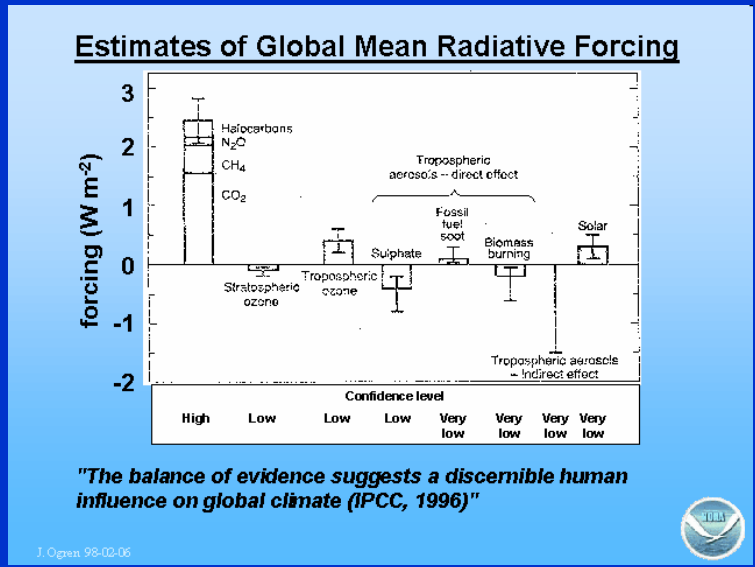


Figure 9. Comparison of modeling result with measurements. (a) gas-phase concentration of PCBs for Jan., 2000 to July 28, 2000; (b) air concentration of PCDD/Fs of January-February, April-May, August-September and November-December of 2000.

Figure 7 Modeled average aerosol surface area from the CMAQ model for April 30-May 2, 2000. Maximum is 1.501x10-4 m2/m3.

Modeling Application in Climate Change Study

- Green House Gas Sources and Sinks
- Climate Forcing of Aerosol : ABC。



Summary and Discussion

- Long-range transport of air pollutant found in North-east Asia.
- Air quality model showed ability for the assessments for current situation and prediction of future. Therefore modeling study is essential for control policy making.
- Model still need to be compared with measured data an more simulations are needed
- Cooperation among the science community and policy makers will be helpful.

Thank You