

Regional/Urban Air Quality Modeling in Beijing and Shanghai, China



Joshua S. Fu¹, Carey Jang², David Streets³, Zuopan Li¹, Kebin He⁴, Litao Wang⁴, Qiang Zhang⁴

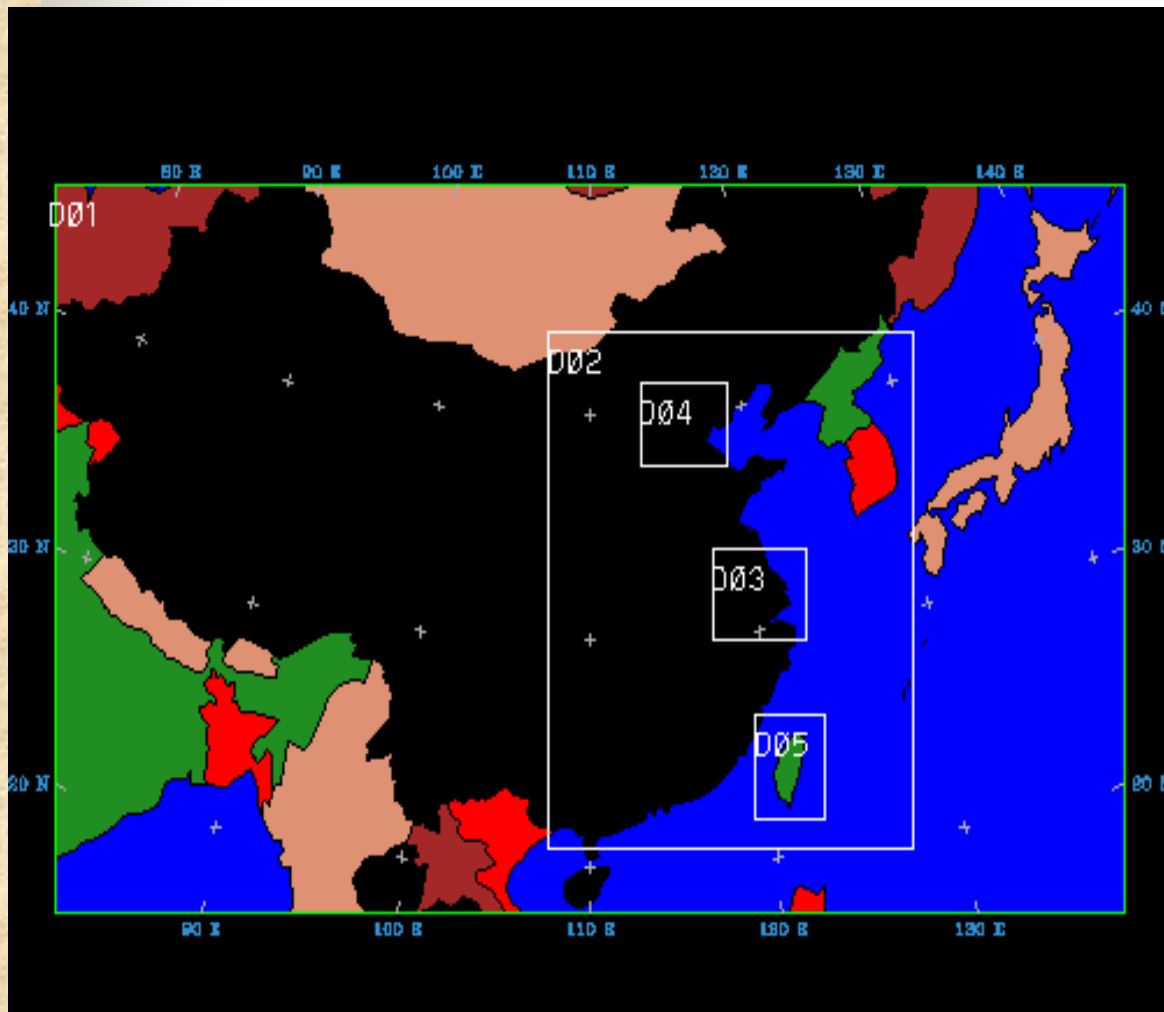
¹University of Tennessee, USA

²U.S. Environmental Protection Agency, USA

³Argonne National Laboratory, USA

⁴Tsinghua University, China

Models-3/CMAQ Study Domains



Domain :
Great China
Region

Grid Resolution :
36-/12-/4-km
(Nested Modeling)

Episode :
January, 2001
July, 2001

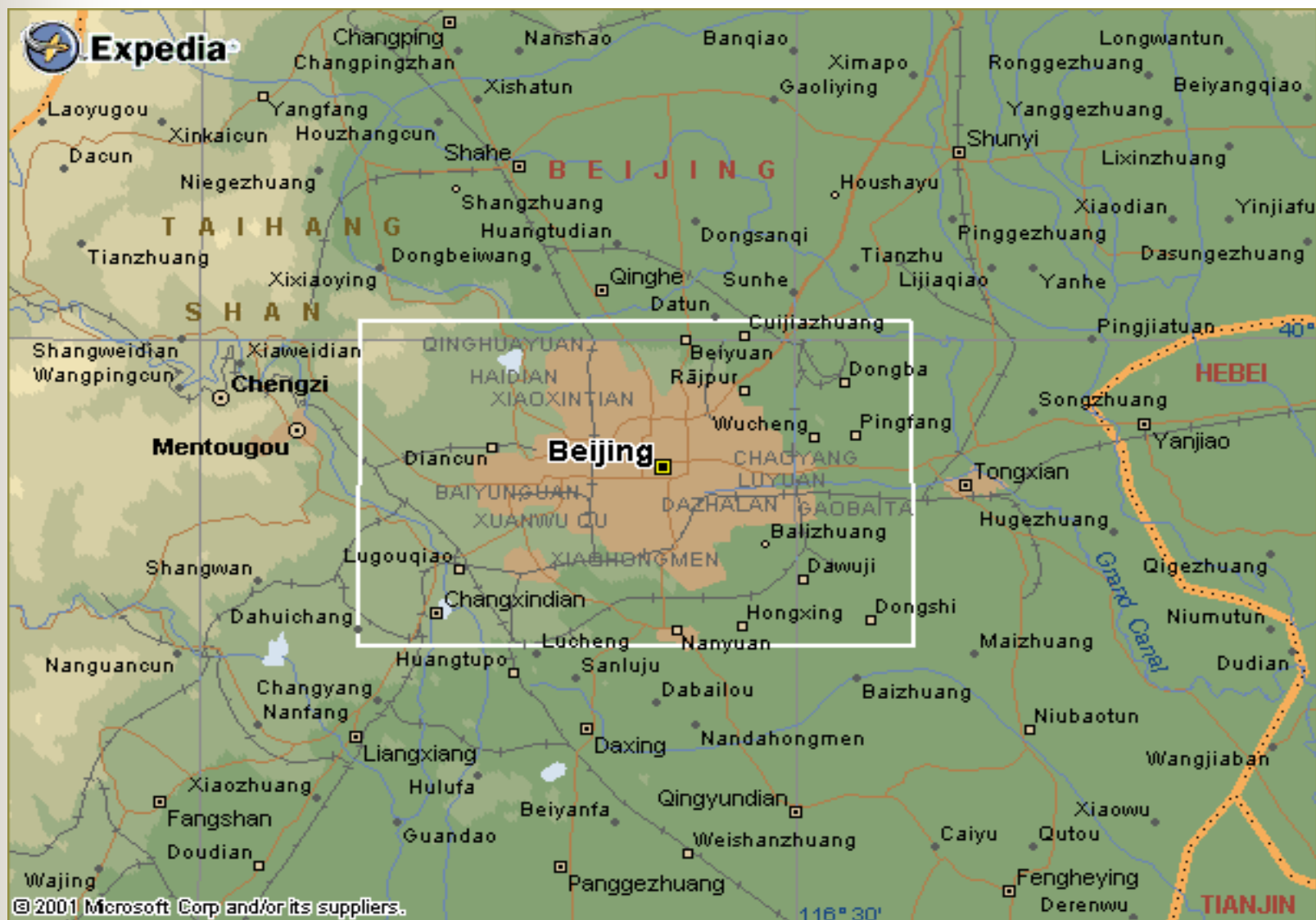
China National/Regional Modeling Configuration

- **Features : Models-3/CMAQ One-Atmosphere (multi-pollutants) Modeling**
 - 2001 January and July cases
 - Nationwide, East China/Beijing CMAQ Domains
- **Model Setup :**
 - NASA's TRACE-P emission inventories and Beijing local emissions and GEIA biogenic emission inventory
 - Emissions Processing: Spatial allocation (GIS/Gridding), Temporal, speciation needed for the M3/CMAQ simulations
 - 36-km (164x97), 12-km (175x211), and 4-km (160x142), (90x90), (97x133), 14 vertical layers
 - Meteorology : MM5 V3.6.2
 - CMAQ 4.4

Chemical Speciation

Trace-P		MW		CBIV(22)
No	Pollutant		Mapping from Trace-P to CB4	
1	Ethane	30.0	$2*[9] + 2.5*[16] + 1.5*[31]$	ALD2
2	Propane	44.0	[23]	CO
3	Butanes	58.0	[6]	ETH
4	Pentanes	72.0	[15]	FORM
5	Other Alkanes	86.0	[30]	ISOP
6	Ethene	28.0	[27]	NH3
7	Propene	40.0	$0.9*[21]$	NO
8	Terminal Alkenes	56.2	$0.1*[21]$	NO2
9	Internal Alkenes	56.2	$1.6*[1]+1.5*[2]+1.5*[10]+[24]+0.5*[32]$	NR
10	Acetylene	26.0	$[7]+[8] + 0.5*[32] + 0.5*[31]$	OLE
11	Benzene	78.0	$0.4*[1]+1.5*[2]+4*[3]+5*[4]+6*[5]+[7]+2*[8]+1.5*[10]+8.5*[32]+[11]+4*[17]+1.33*[19]+6*[31]$	PAR
12	Toluene	92.0	[25]	PEC
13	Xylenes	106.0	[29]-[28]	PMC
14	Other Aromatics	117.0	[28]-[25]-[26]-PNO3-PSO4	PMFINE
15	HCHO	30.0	[28]*x	PNO3
16	Other Aldehydes	88.0	[26]	POA
17	Ketones	126.0	[28]*x	PSO4
18	Halocarbons	150.0	[20]	SO2
19	Other	72.0	$0.02*[20]$	SULF
20	SO2	64.0	[31]	TERPB
21	NOx	46.0	$[12] + 0.5*[14]$	TOL
22	CO2	44.0	$[13] + 0.5*[14]$	XYL
23	CO	28.0		
24	CH4	16.0		
25	BC	12.0		
26	OC	12.0		
27	NH3	17.0		
28	PM2.5		Note: x will depend on sectors of SCC	
29	PM10			
30	ISOP (biogenic,GEIA)	5 carbons		
31	TERP (biogenic,GEIA)	10 carbons		
32	Other VOC (biogenic,GEIA)	10 carbons		

Beijing Map

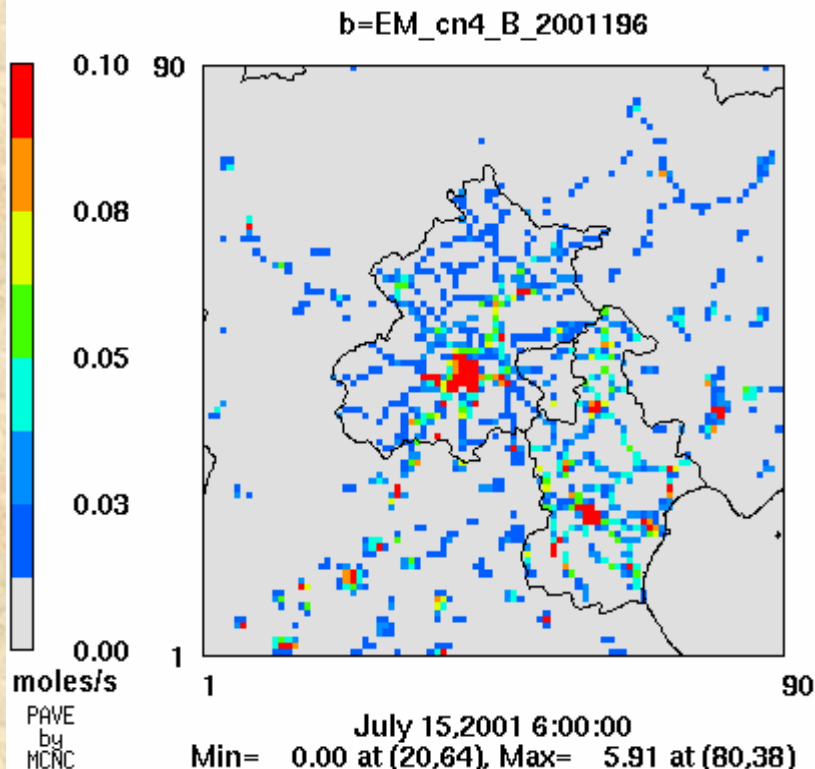


Shanghai Map

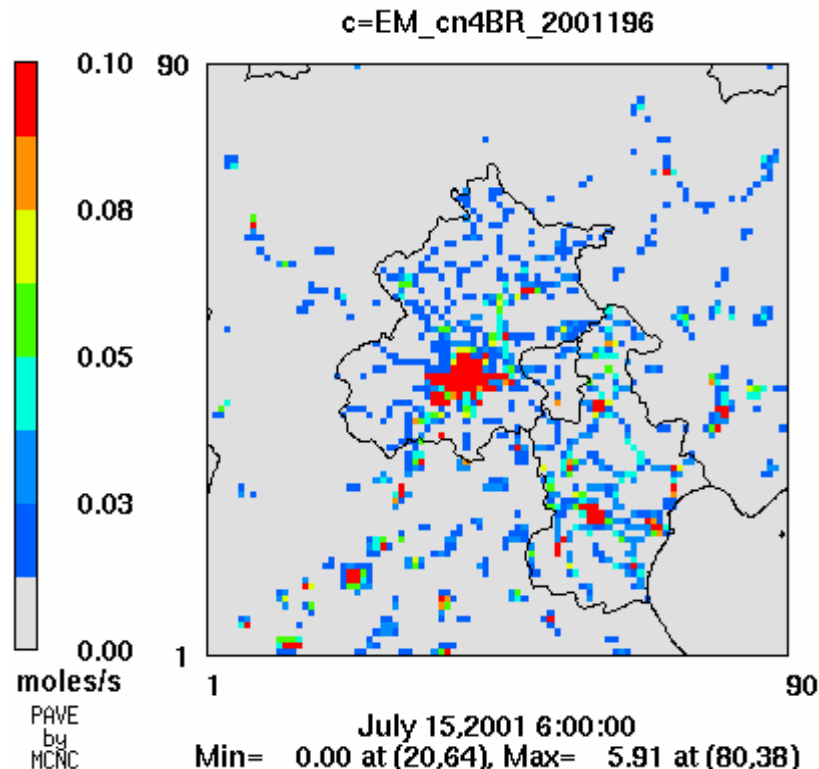


Beijing NO_x Emissions (4kmx4km)

TRACE-P EMISSION

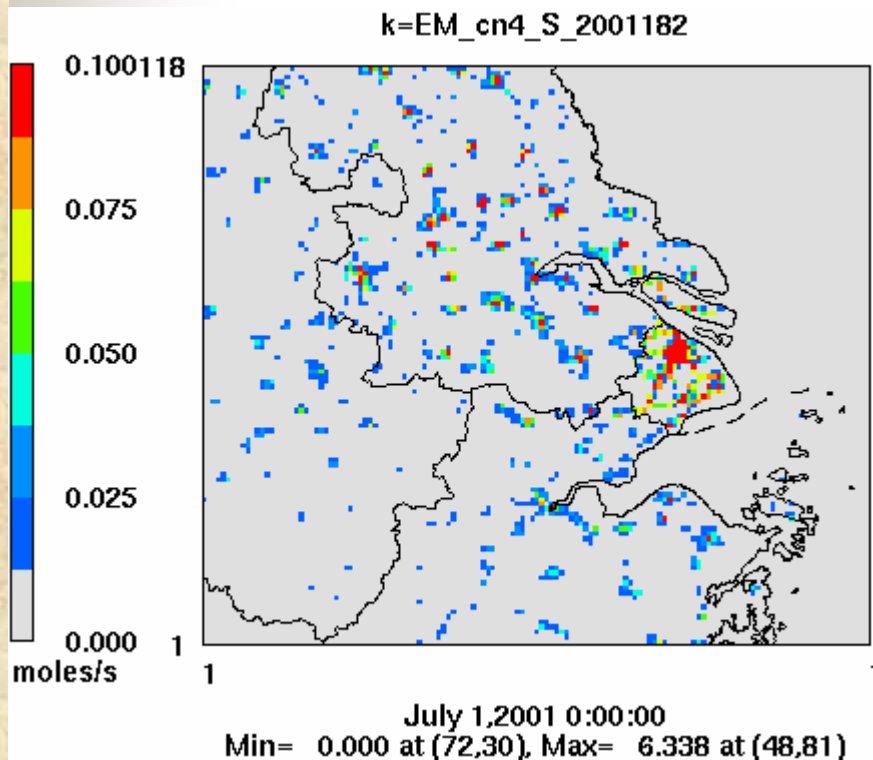


Beijing Replaced EMISSION

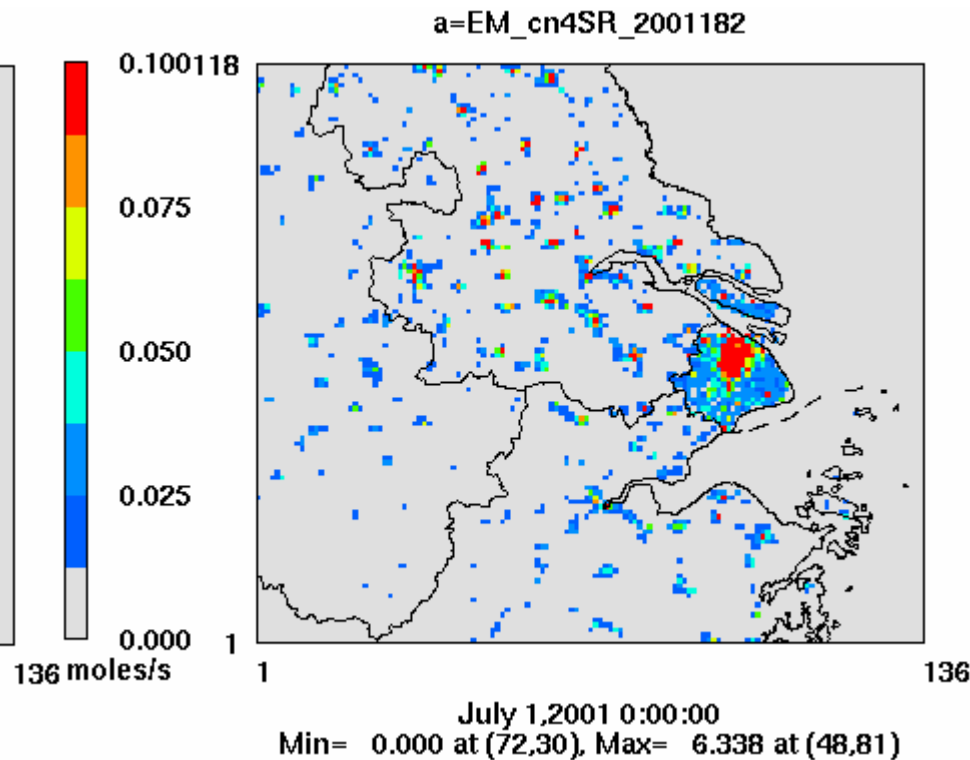


Shanghai NOx Emissions (4kmx4km)

TRACE-P EMISSION

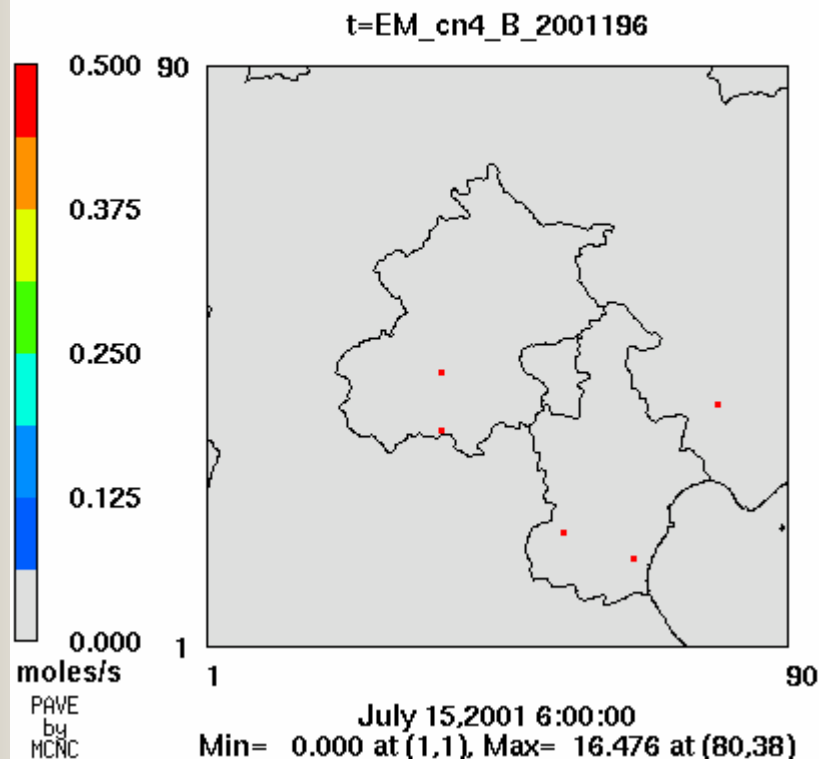


Shanghai Replaced EMISSION

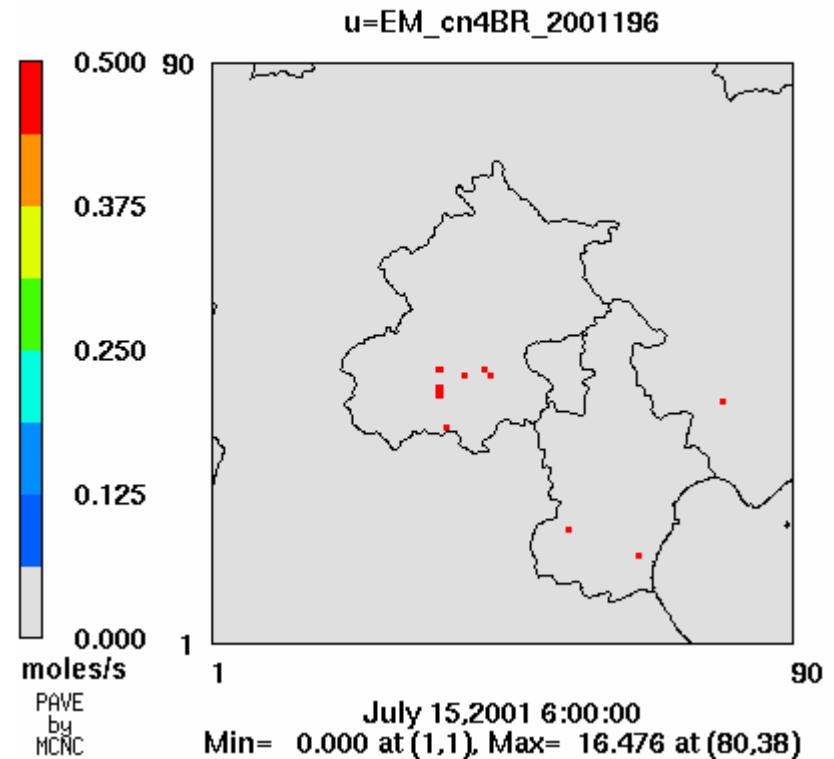


Power Plant Location between TRACE-P and Beijing Emissions

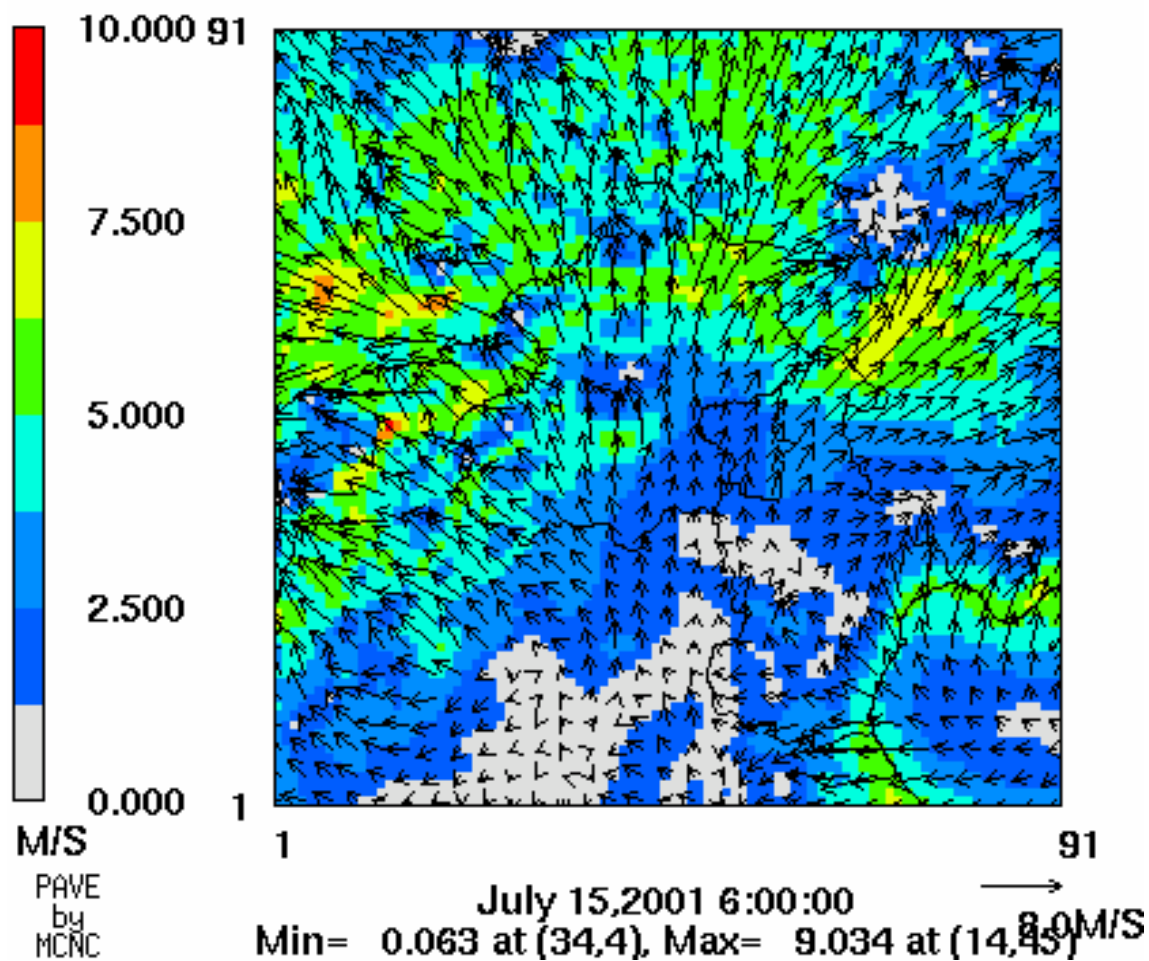
TRACE-P EMISSION



Beijing EMISSION



Wind Field



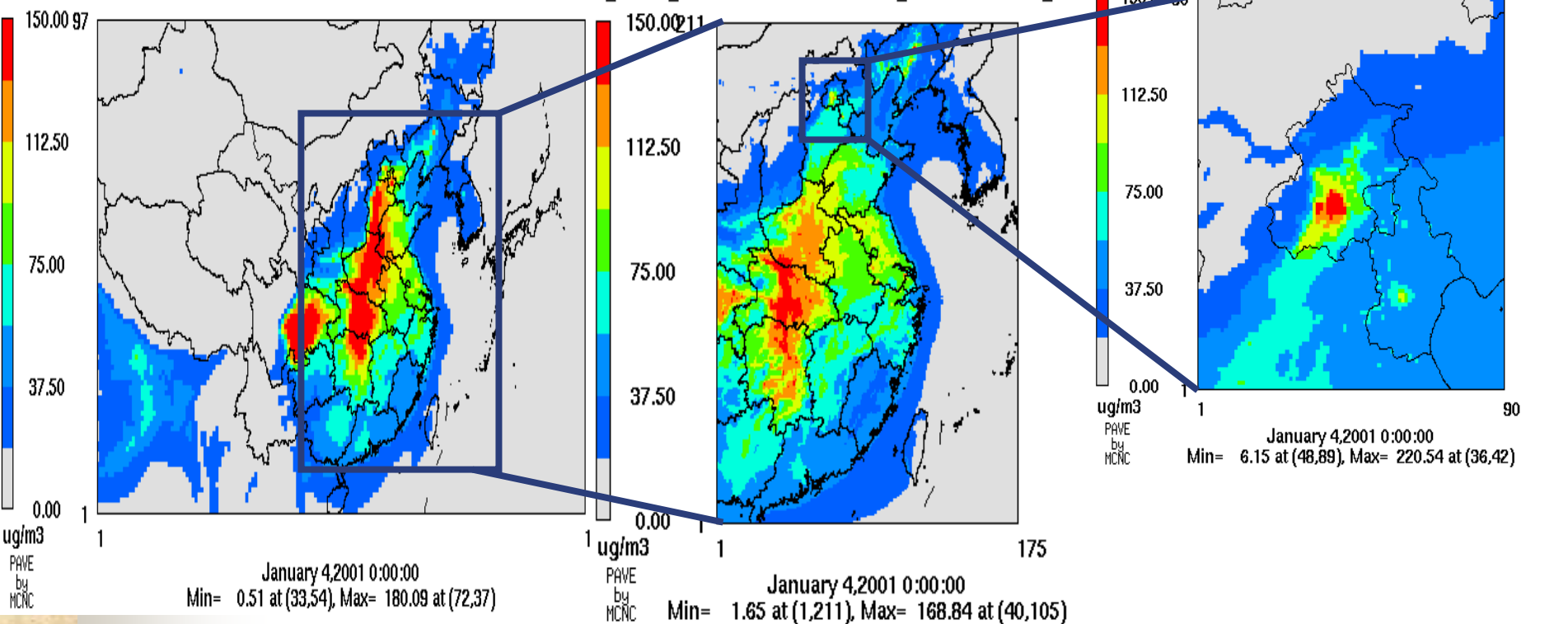
China National/Regional Modeling (Nesting): PM2.5 (Jan)

36-km

12-km

4-km

e=CCTM_P0616_L14.cn36.conc.EPISODIC_AVG.2001Jan04_00-2001Jan21_M_P0616_L14.cn12.conc.EPISODIC_AVG.2001Jan04_00-2
CTM_P0616_L14.cn4BR.conc.EPISODIC_AVG.2001Jan04_00-2001



Air Quality Modeling Assessment in Beijing (base case- July 2001)

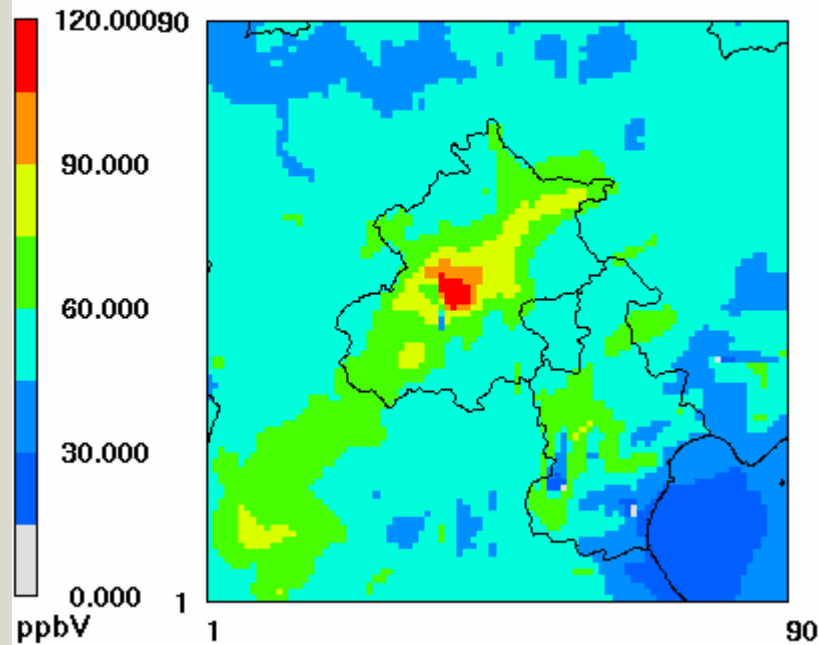
Ozone

TRACE-P EMs

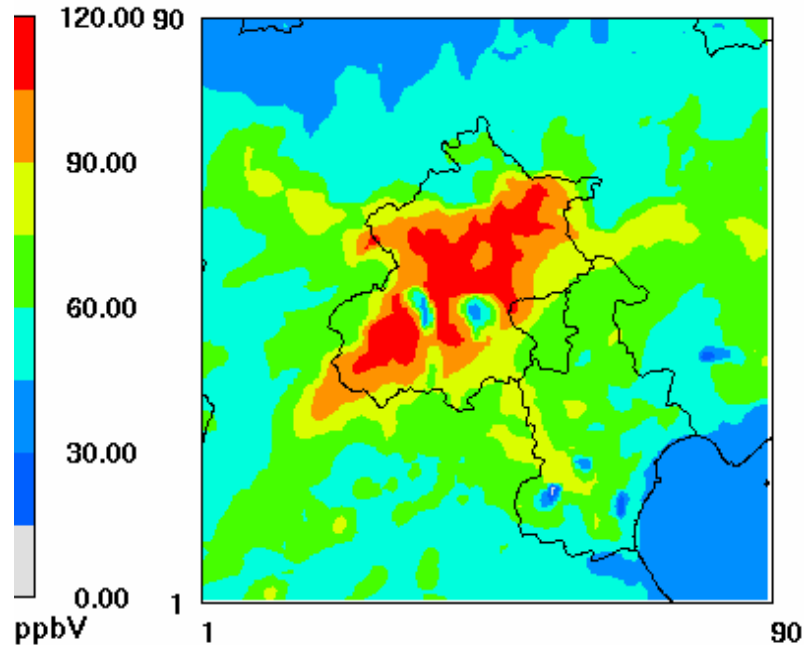
Beijing EMs

i=CCTM_P0616_L14.cn4_B.combine.conc.2001July04_00-2

j=CCTM_P0616_L14.cn4BR.cmbn.conc.2001Jun26_01-2001Aug



July 15,2001 6:00:00
Min= 8.055 at (67,14), Max= 127.577 at (39,47)

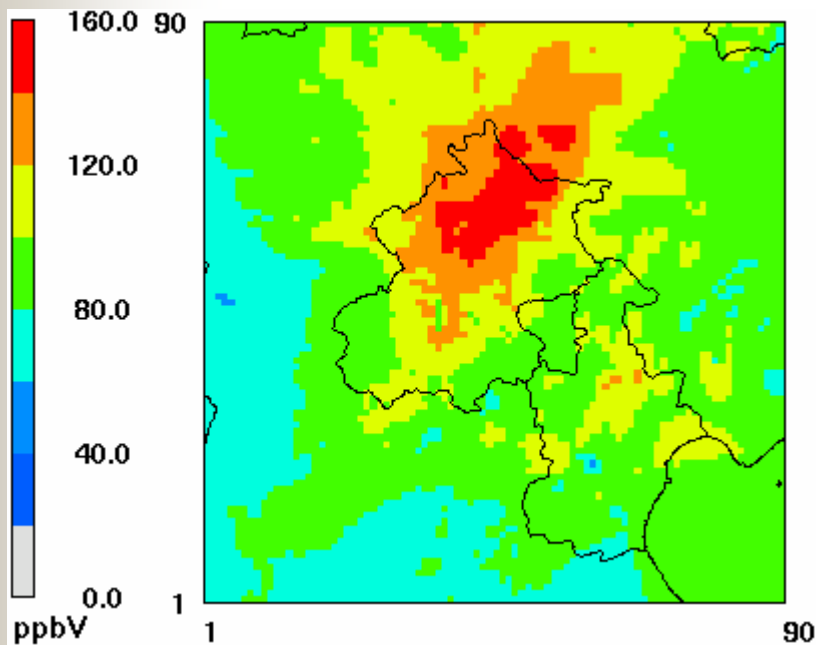


July 15,2001 6:00:00
Min= 8.38 at (56,18), Max= 126.79 at (39,46)

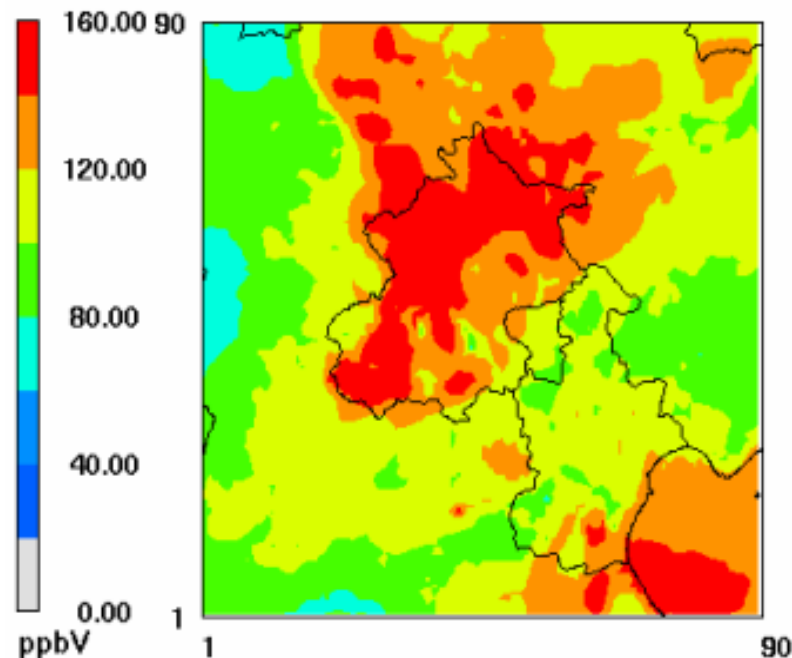
ppbV
PAVE
by
MCNC

Beijing Regional (4-km) Modeling: O₃

TRACE-P EMs

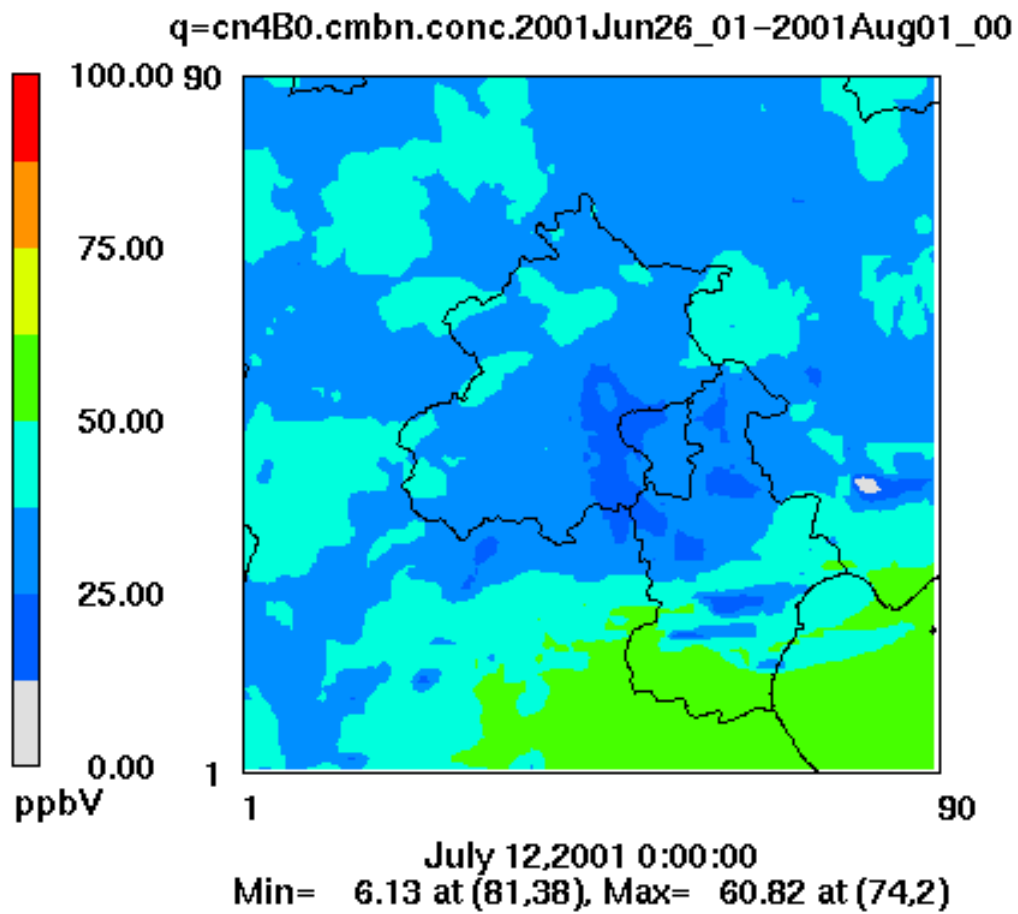


Beijing EMs



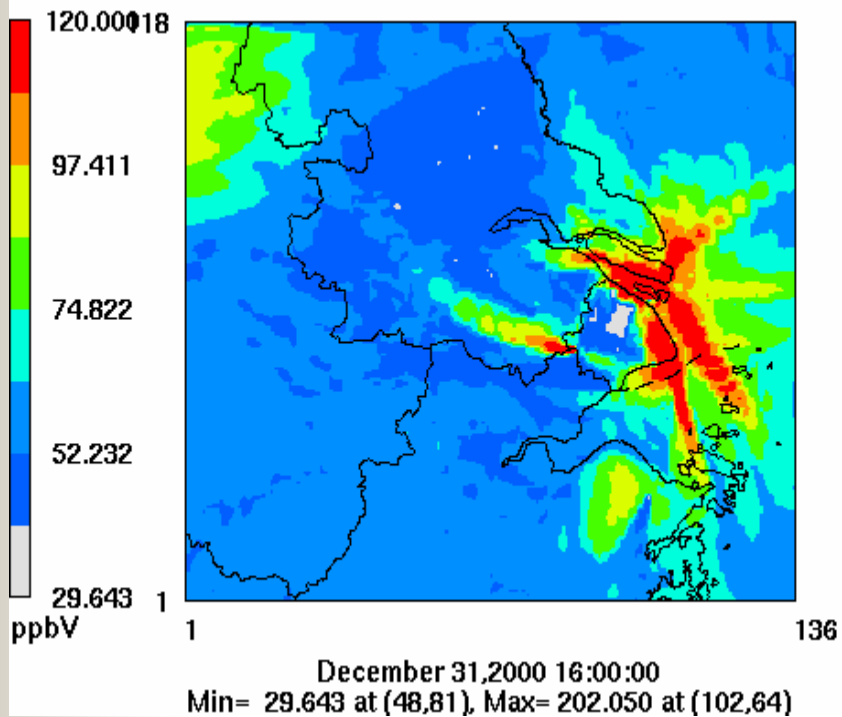
(July, 2001, monthly max.)

O3 Hourly Animation (Remove Beijing Emissions, 2001 July)

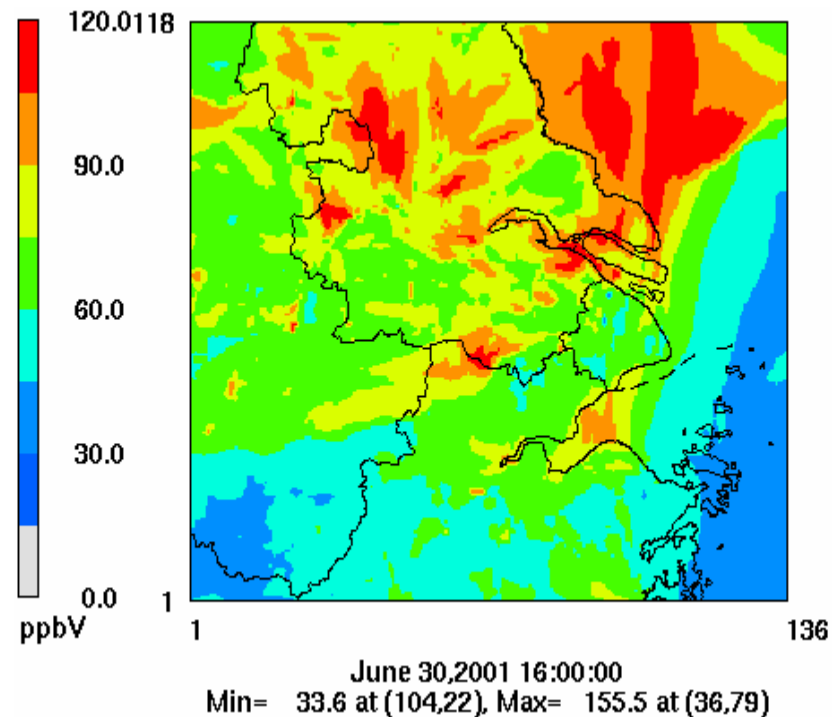


Shanghai Regional (4-km) Modeling: O₃

January



July



(monthly max.)

Monthly Max O3 (2001 July)

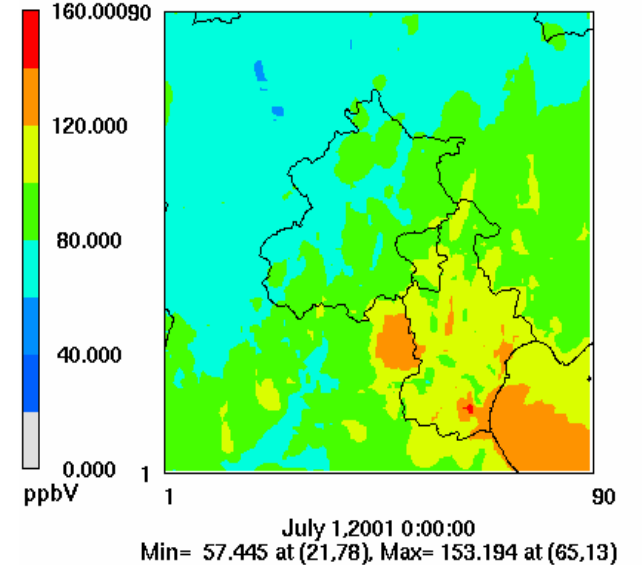
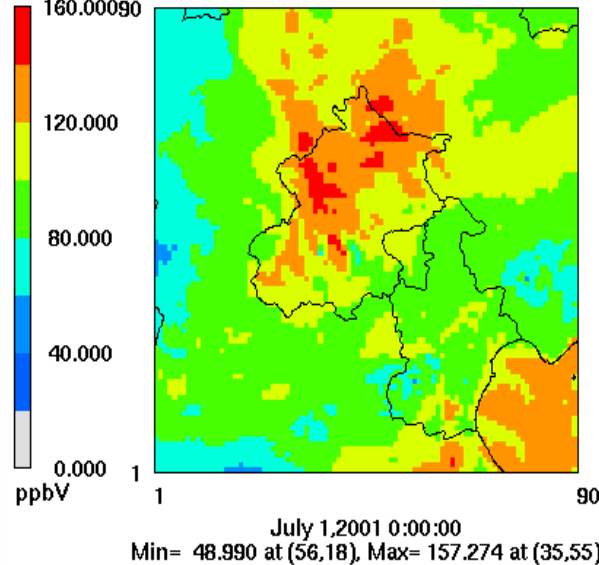
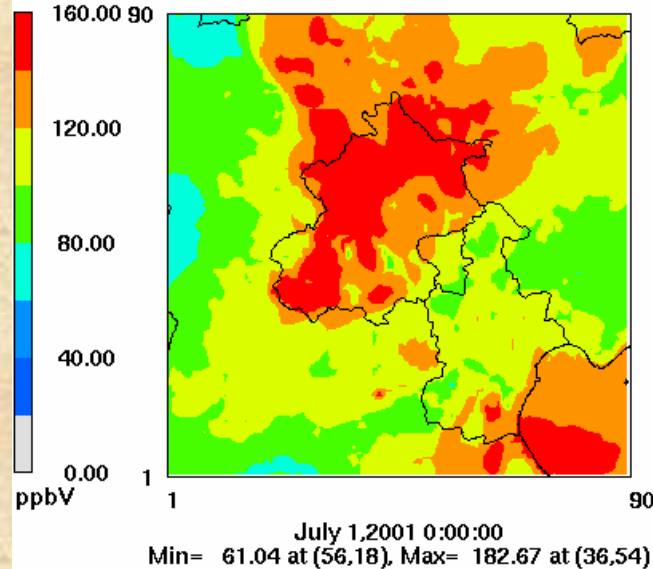
**Regional transport +
Local Emission**

Local Emissions

**Regional Transport
Contribution**

j=cn4BR.conc.EPISODIC_MAX.2001Jul01_00-2001Aug0616_L14_SBD.cn4BR.conc.EPISODIC_MAX.2001July01_00-2001Aug0616_L14_SBD

k=cn4B0.conc.EPISODIC_MAX.2001Jul01_00-2001Aug0616_L14_SBD

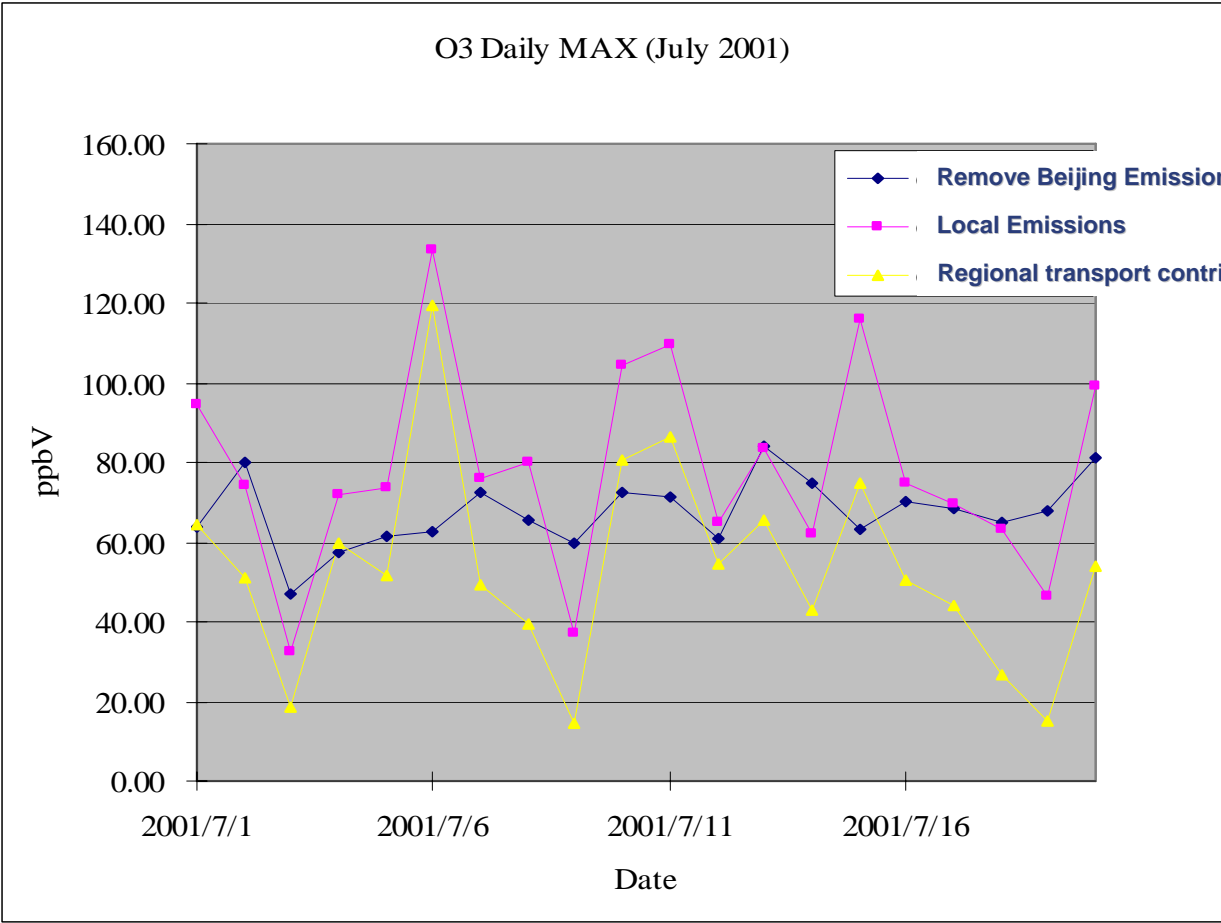


Modeling Nesting

Clean Air BC

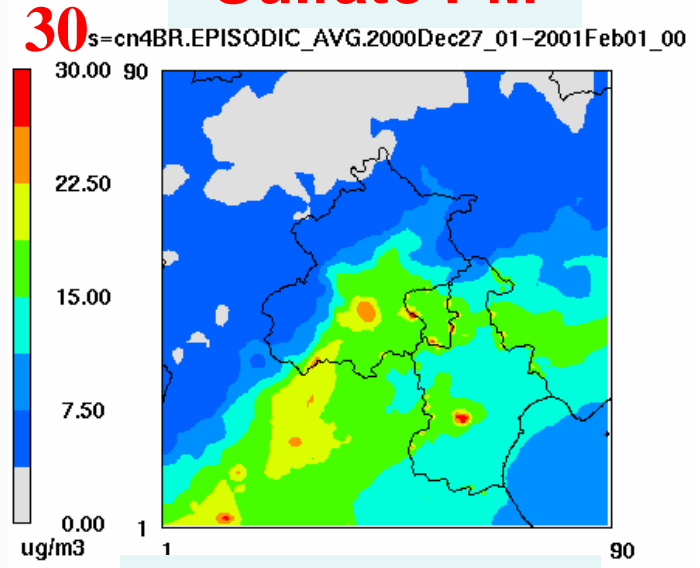
**Remove Beijing
Emissions**

O3 Daily Max (2001 July)

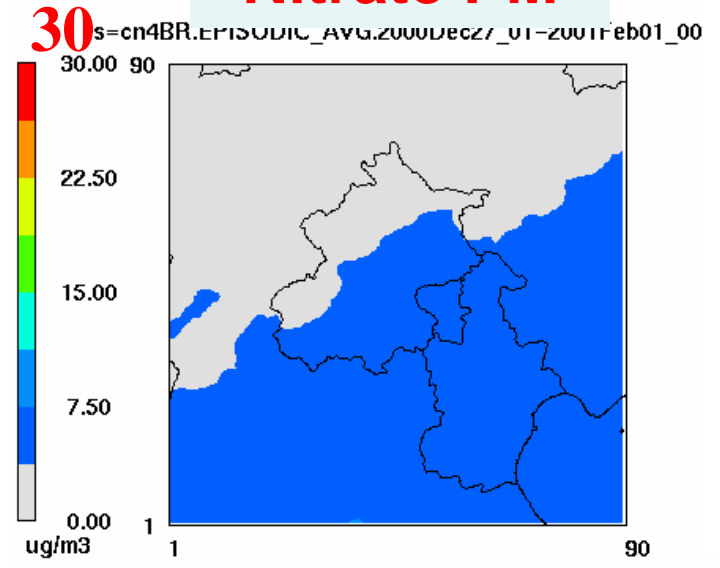


Beijing Regional Modeling: PM 2.5 Speciation (Jan)

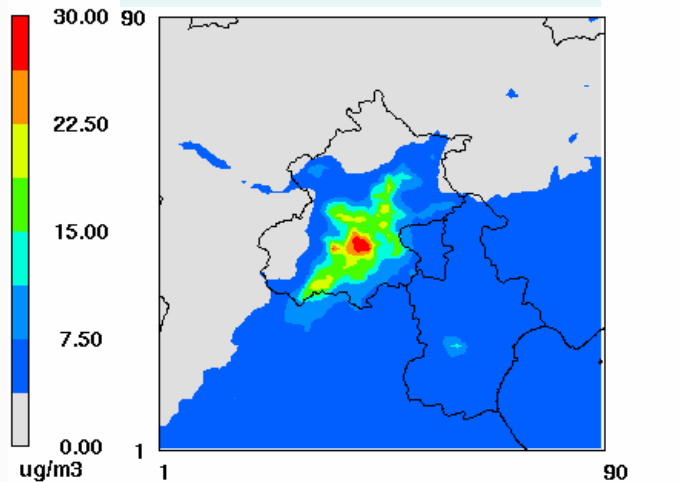
Sulfate PM



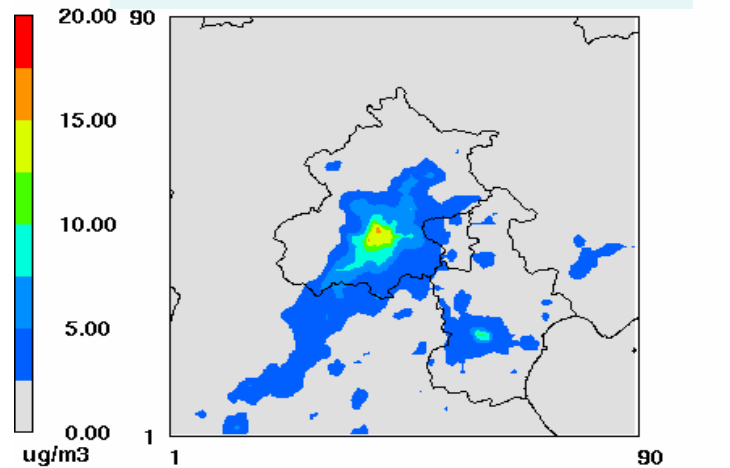
Nitrate PM



30_{s=c} Organic PM 2) b01_00



20_{s-} Elemental Carbon 00

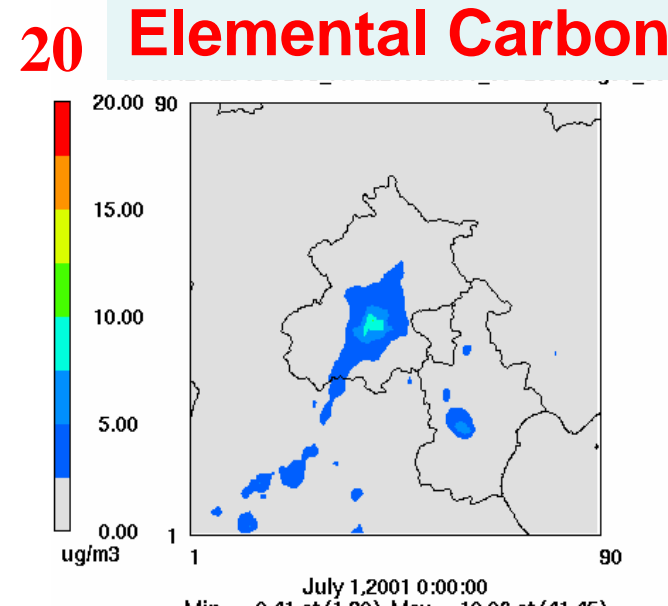
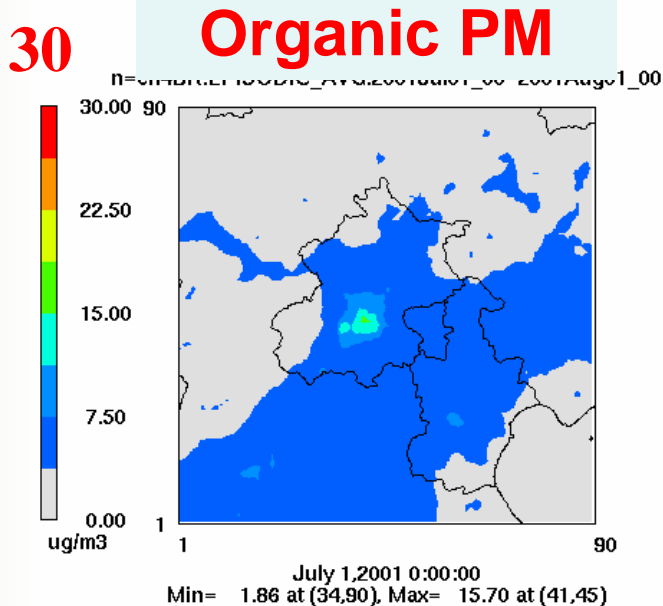
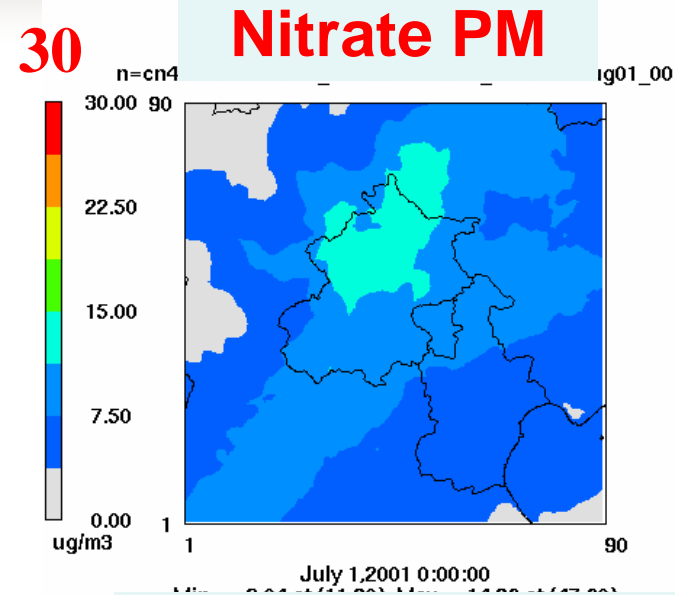
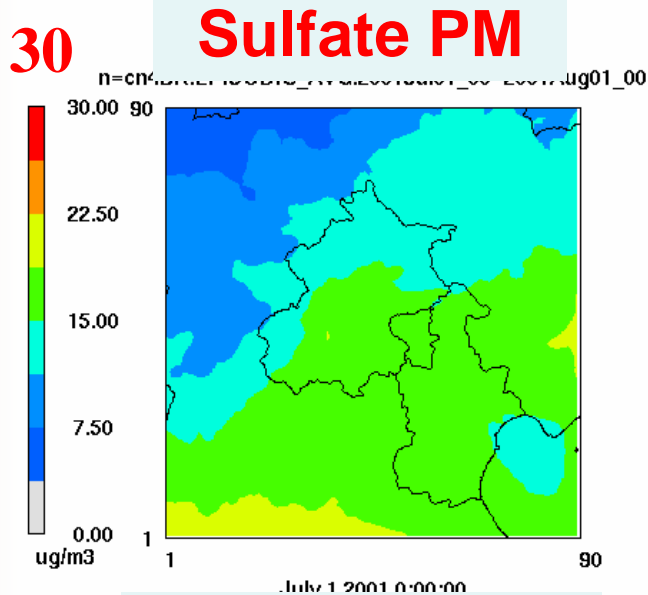


January 1,2001 0:00:00
Min= 0.63 at (37,89), Max= 29.39 at (43,42)

January 1,2001 0:00:00
Min= 0.21 at (37,89), Max= 15.84 at (41,44)



Beijing Regional Modeling: PM 2.5 Speciation (July)

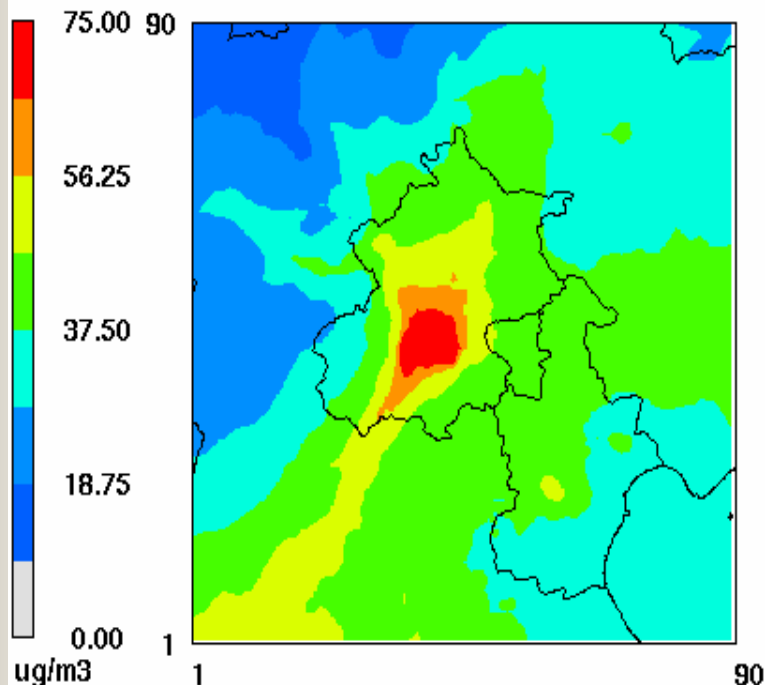


Beijing Regional (4-km) Modeling: PM 2.5

75 ug/m3

July

cn4BR.EPISODIC_AVG.2001Jul01_00-2001Aug01_00

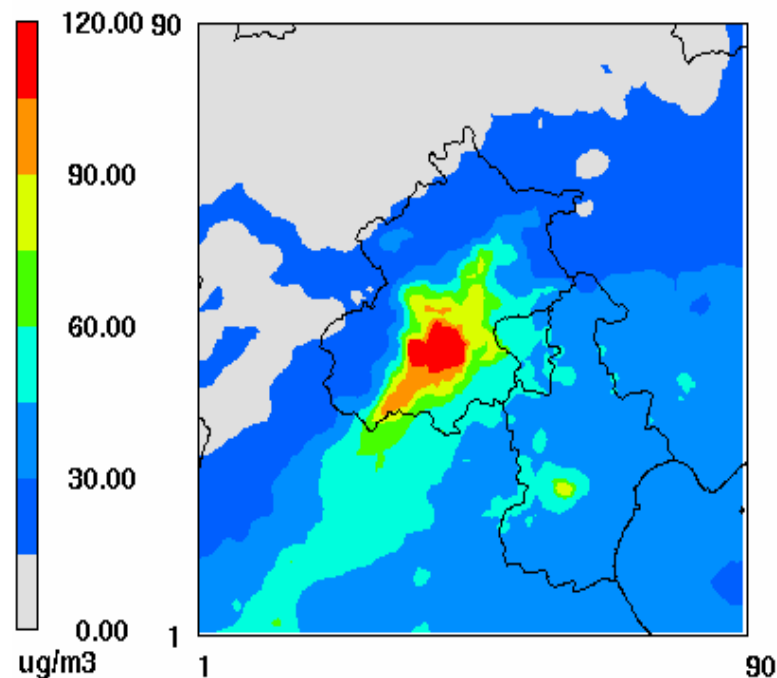


July 1,2001 0:00:00
Min= 13.97 at (1,90), Max= 115.59 at (36,42)

120 ug/m3

January

cn4BR.EPISODIC_AVG.2000Dec27_01-2001Feb01_00



January 1,2001 0:00:00
Min= 5.70 at (37,89), Max= 198.56 at (36,42)

(Jan./July, 2001, Monthly avg.)

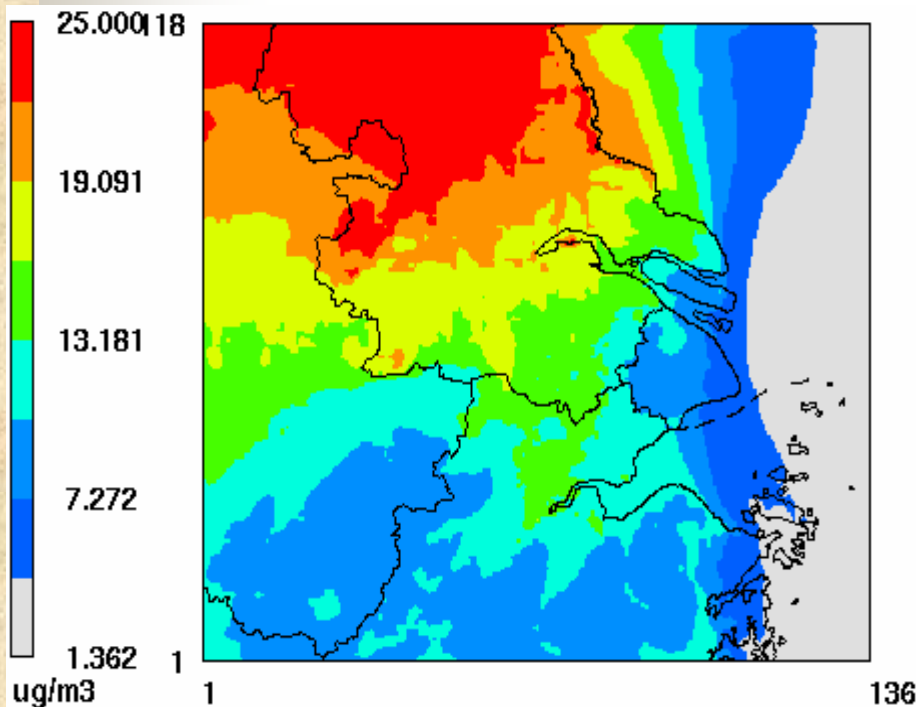
Shanghai Regional (4-km) Modeling: PM 2.5

10 ug/m³

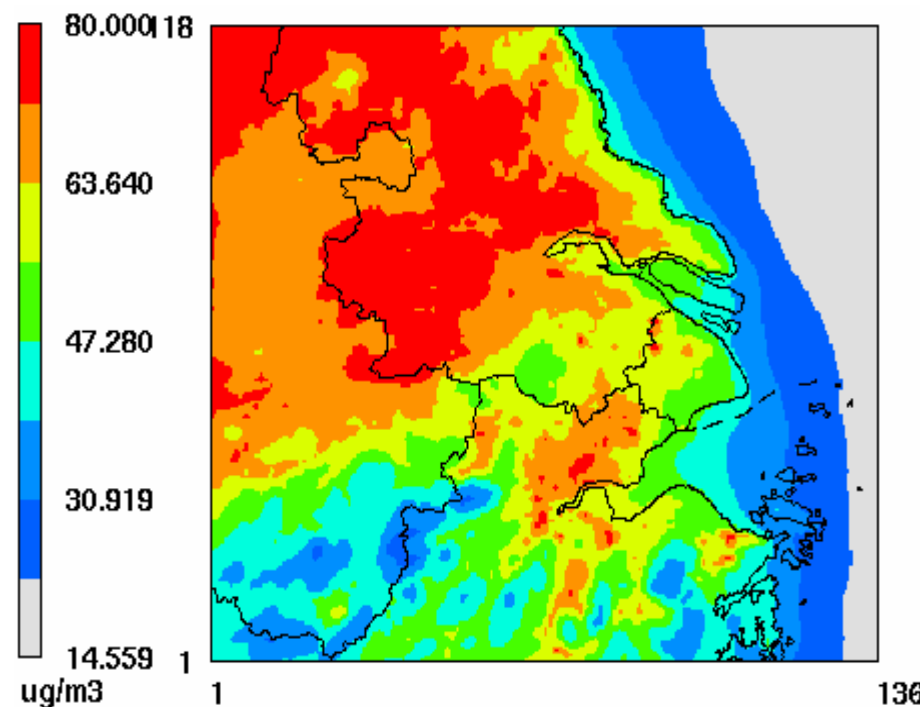
July

70 ug/m³

January



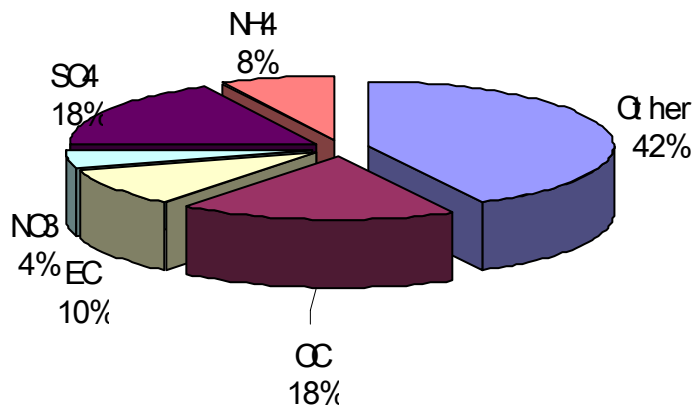
June 30, 2001 16:00:00
Min= 1.362 at (129,13), Max= 29.239 at (36,79)



December 31, 2000 16:00:00
Min= 14.559 at (134,113), Max= 105.146 at (35,76)

(Jan./July, 2001, Monthly avg.)

PM25 composition in Beijing (January 2001, cn4BR)
Episoc Avg = 104 ug/m3



**PM2.5 Composition
in Beijing (Jan.)**

M3/CMAQ (4-km)

January 2001

PM2.5: 104 (ug/m³)

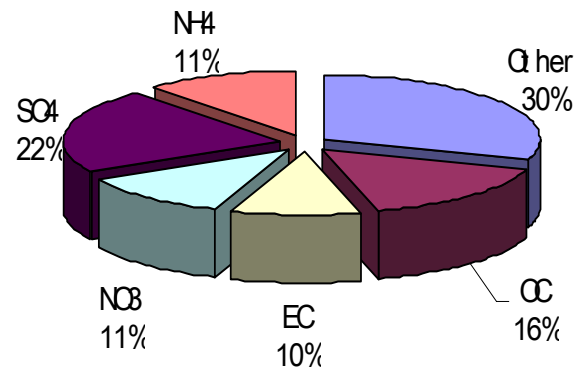
**PM2.5 Composition
in Beijing (July)**

M3/CMAQ (4-km)

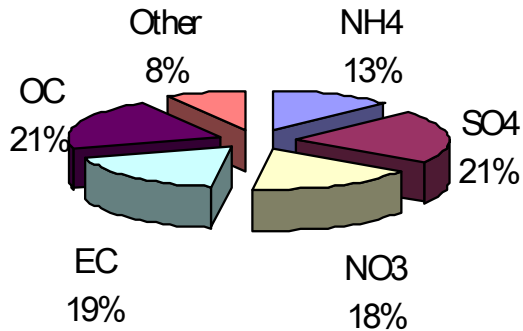
July 2001

PM2.5: 81 (ug/m³)

PM25 composition in Beijing (July 2001, cn4BR)
Episoc Avg = 81 ug/m3



PM2.5 composition in Shanghai (Jan 2001, cn4SR)
Episode Avg=64.1ug/m³



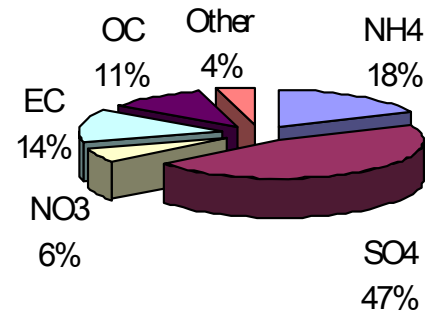
PM2.5 Composition in Shanghai (Jan.)

M3/CMAQ (4-km)
January 2001
PM2.5: **64** (ug/m³)

PM2.5 Composition in Shanghai (July)

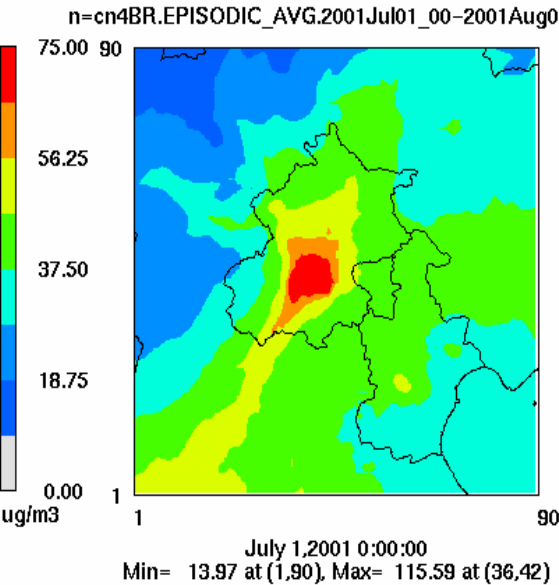
M3/CMAQ (4-km)
July 2001
PM2.5: **12** (ug/m³)

PM2.5 composition in Shanghai (July 2001, cn4SR)
Episode Avg=12.3ug/m³

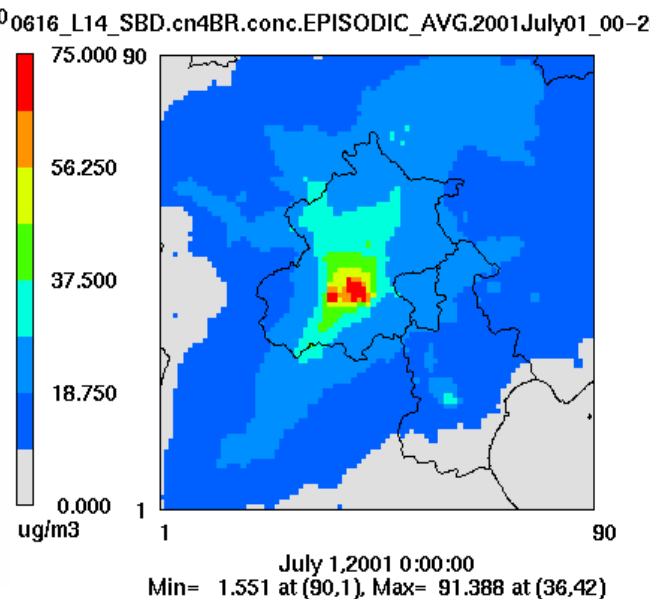


Monthly AVG PM2.5 (2001 July)

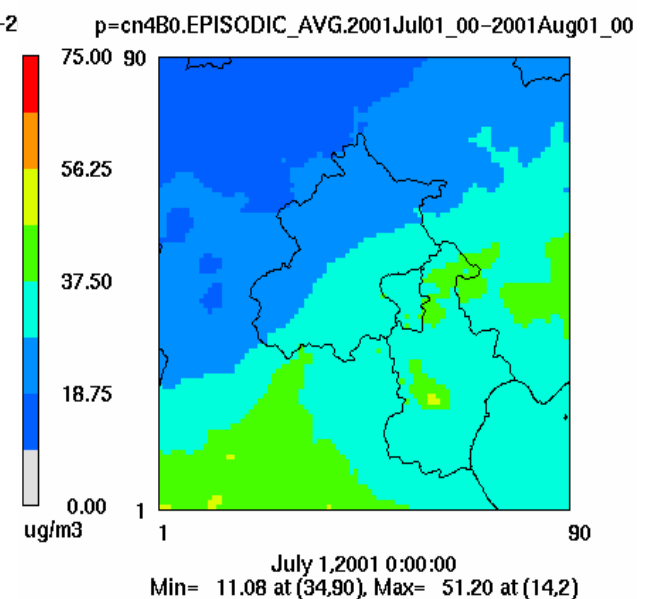
Regional transport + Local Emission



Local Emissions



Regional Transport Contribution



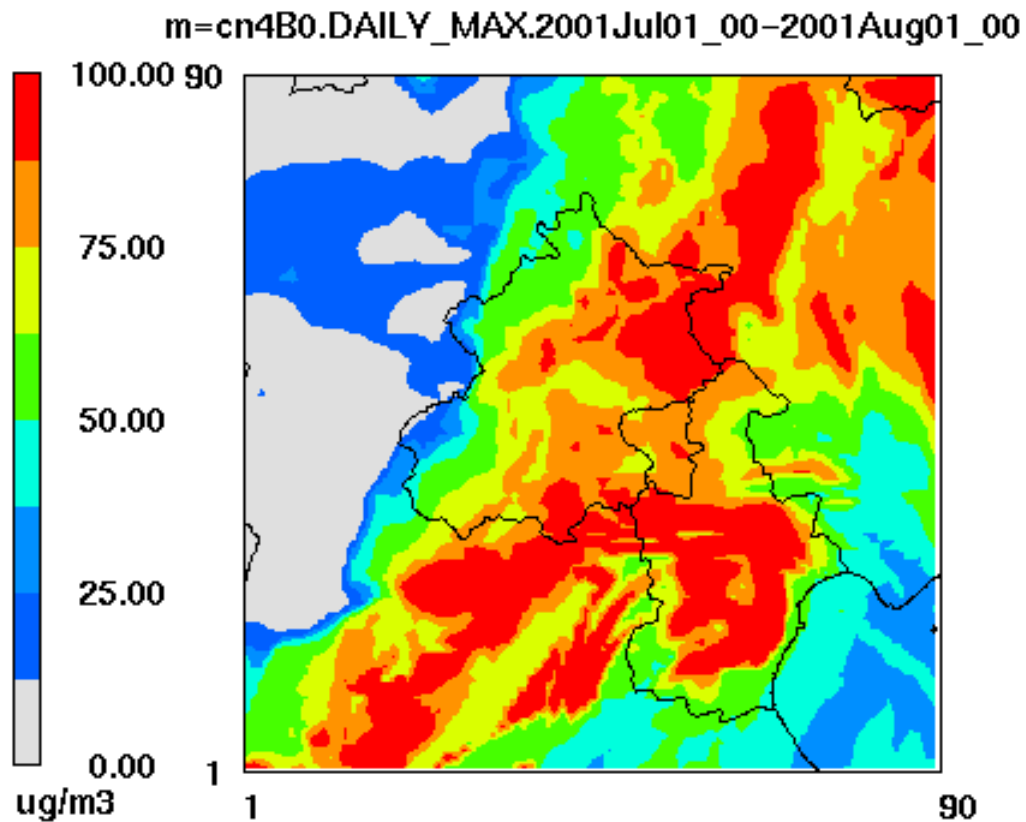
Modeling Nesting

Clean Air BC

Remove Beijing Emissions

PM 2.5 Daily MAX Animation

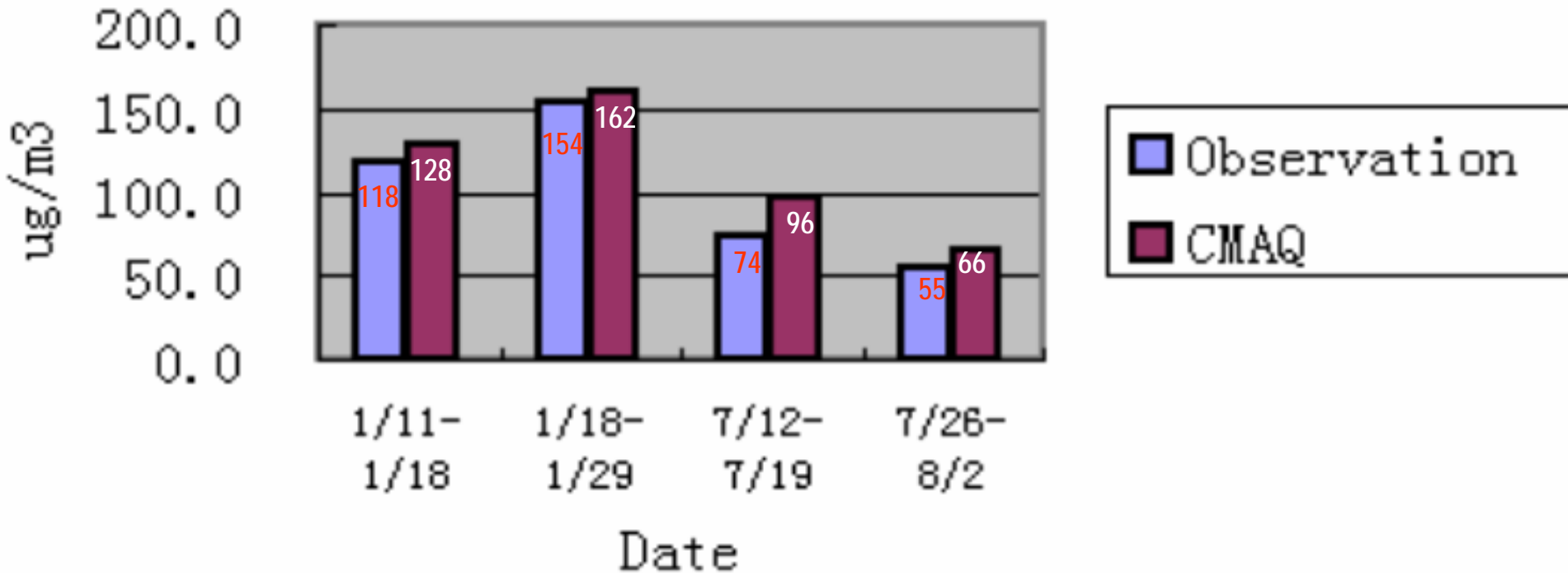
(Remove Beijing Emissions, 2001 July)



July 1,2001 0:00:00
Min= 2.30 at (15,38), Max= 193.52 at (37,9)

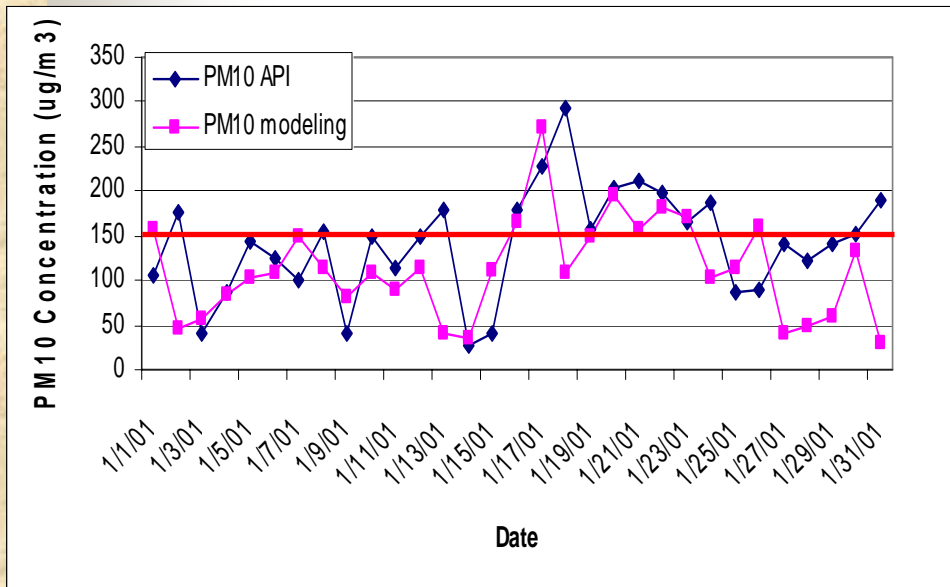
CMAQ vs. Obs. PM 2.5 Weekly Average

PM2.5 Weekly Average
Jan and July 2001

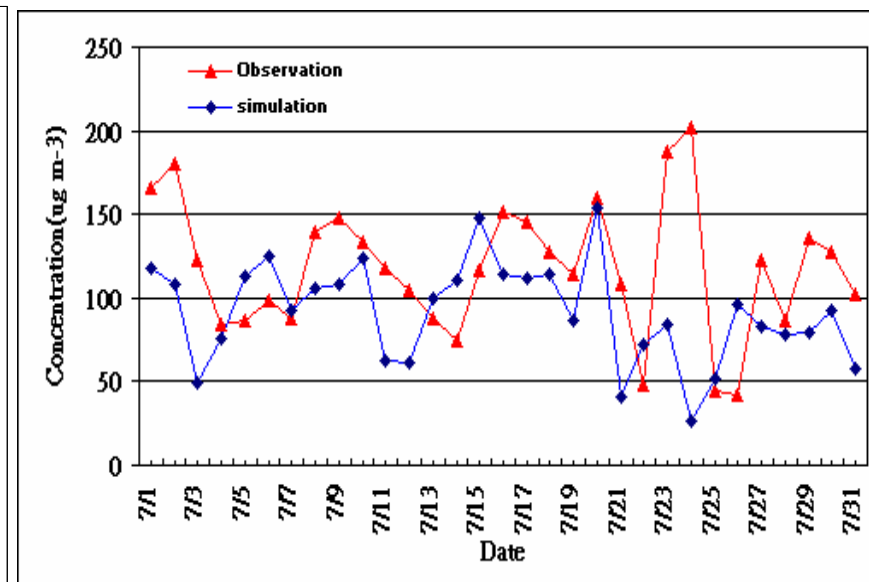


CMAQ vs. Obs. PM 10 Daily Average

January

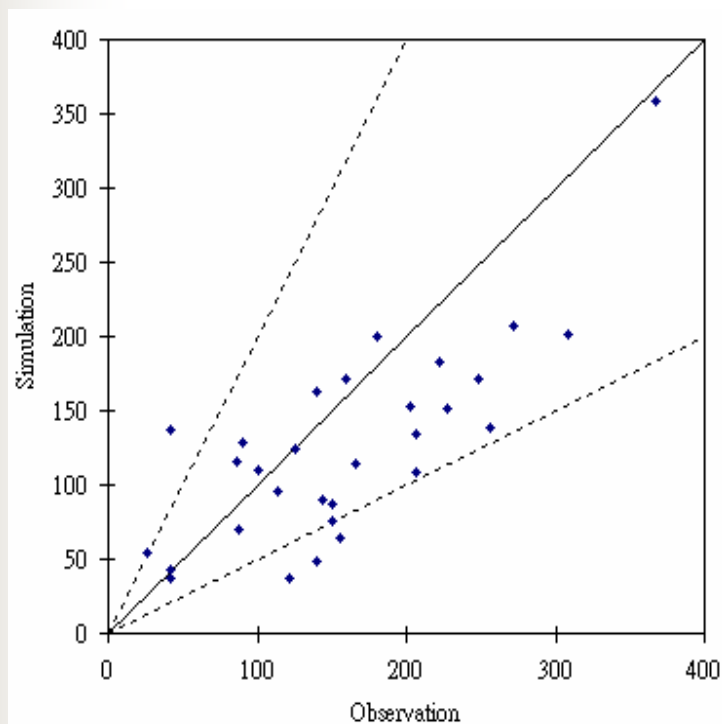


July

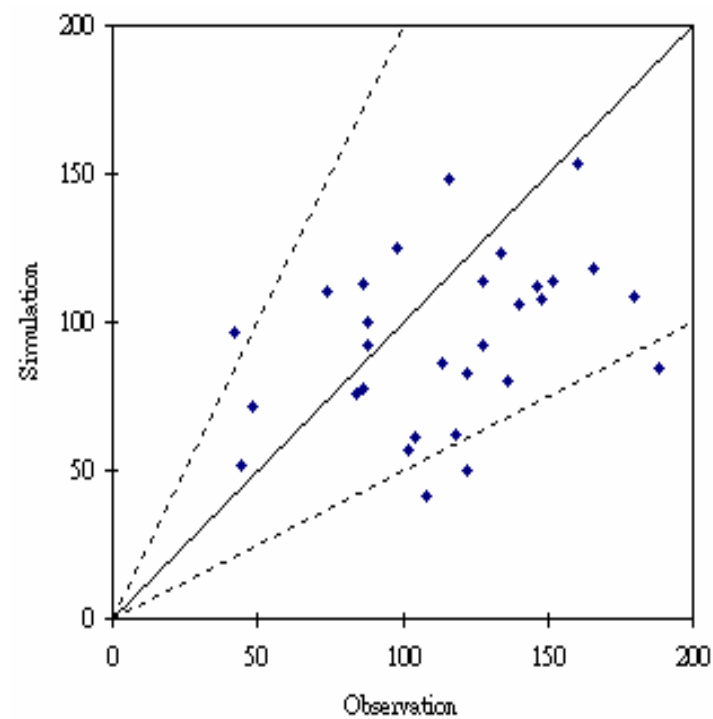


CMAQ vs. Obs. PM 10 Daily Average

January

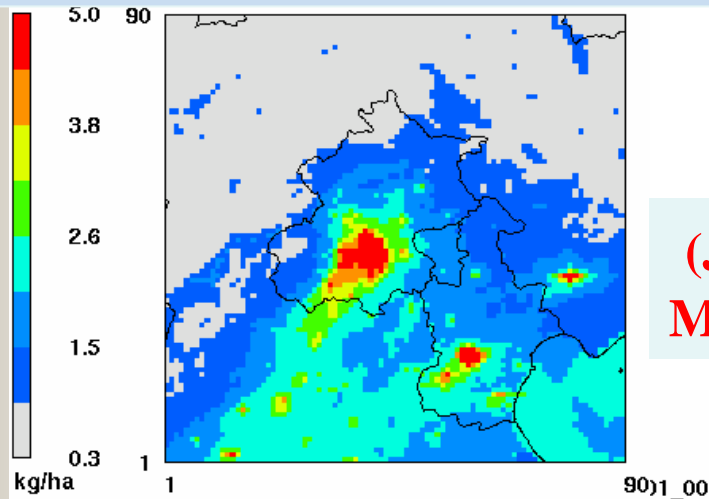


July

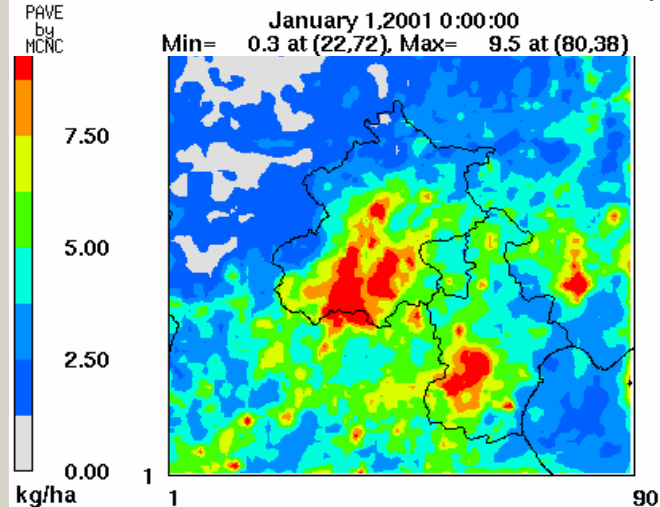


Beijing Urban Modeling: Deposition

Sulfur Deposition

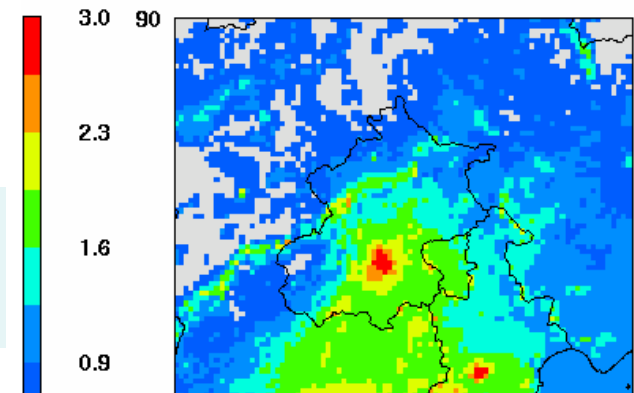


(Jan., 2001,
Monthly sum.)

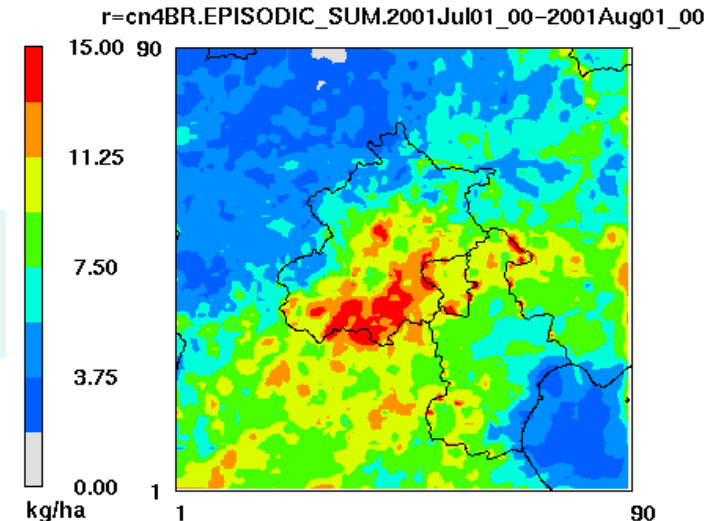


(July, 2001,
Monthly sum.)

Nitrogen Deposition



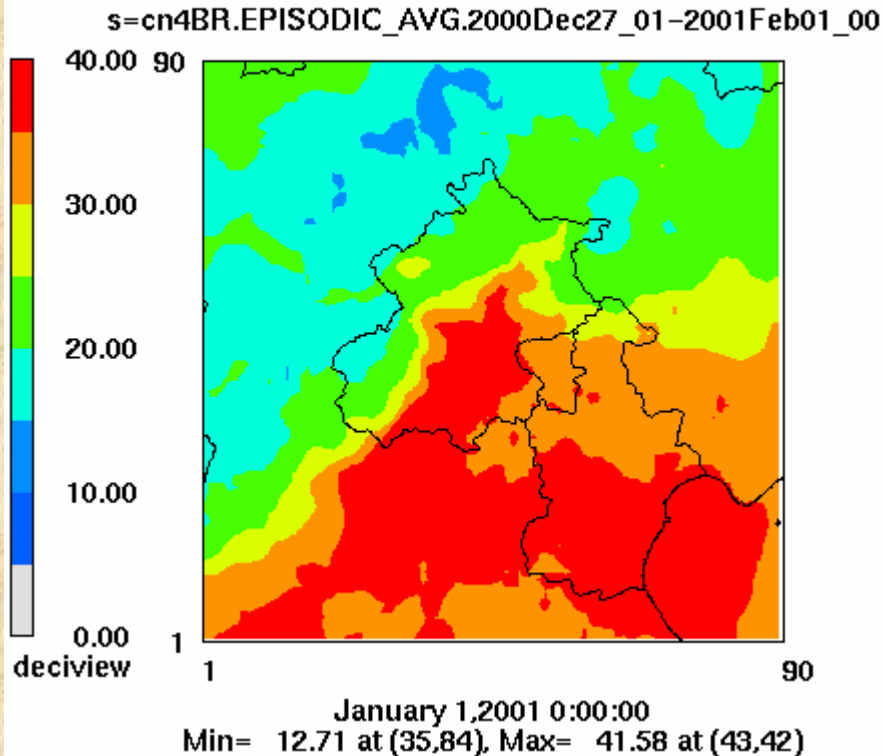
Layer 1 TDEP_TOT_Nr



July 1,2001 0:00:00
Min= 1.31 at (33,88), Max= 20.89 at (51,42)

Beijing Urban Modeling: **Visibility**

Layer 1 DCV_Recons



Visual Range Parameters:

Deciview (dv) :

$$dV = 10 \ln (b / 0.01),$$

b [km⁻¹] : extinction coeff.

Koschmieder Visual Range :

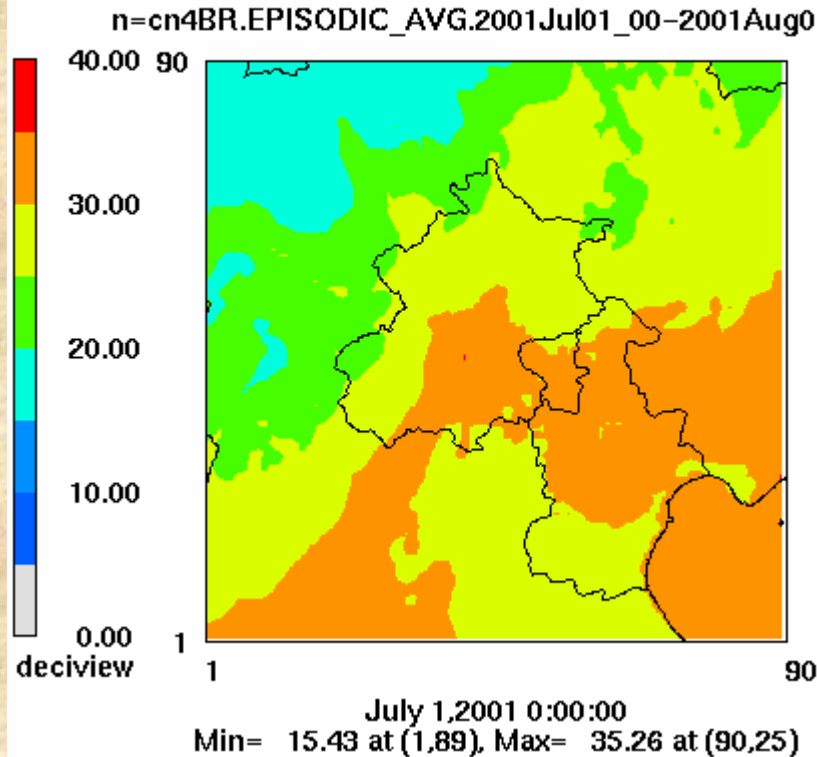
$$V_r = 3.91 / b \quad [\text{km}]$$

dV	V_r [km]	β [km⁻¹]
60	1.0	4.0
40	7.2	0.55
20	53	0.07
10	144	0.03
0	391	0.01

(January, 2001, Monthly avg.)

Beijing Urban Modeling: **Visibility**

Layer 1 DCV_Reconn



(July, 2001, Monthly avg.)

Visual Range Parameters:

Deciview (dv) :

$$dV = 10 \ln (b / 0.01),$$

b [km⁻¹] : extinction coeff.

Koschmieder Visual Range :

$$V_r = 3.91 / b \quad [\text{km}]$$

dV	V_r [km]	β [km⁻¹]
60	1.0	4.0
40	7.2	0.55
20	53	0.07
10	144	0.03
0	391	0.01

Summary

- The successful application using “One Atmosphere” CMAQ modeling system for Beijing regional air quality modeling
- **Emissions: Investigate Trace-P Asian emissions and apply Beijing and Shanghai local emissions, especially NO_x, SO₂ and VOC emissions, e.g., ALD₂, OLE, PAR.**
- The use of monitoring data is essential to against CMAQ modeling results (O₃, PM_{2.5}, PM₁₀) in Beijing and Shanghai
- CMAQ model performance is acceptable for PM₂₅ in Beijing but ozone concentrations are under predicted
- VOC found that it may be underestimated in China

Acknowledgment

- **USEPA funding support**
- **University of Tennessee Office of Research**
- **Argonne National Laboratory**
- **Tsinghua University**