China Map

Emissions Activity

Progress Report -- Update

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This report covers the ChinaMap activities related to Emissions which includes the efforts of David Streets at Argonne National Laboratory and Chip Levy at GFDL. This is an update to our report submitted prior to last November's ChinaMap Workshop held in Atlanta. The specific aspects of this report are: (1) the delivery of the newest versions of the NOx and SOx emission estimates for the years 1990, 1992/93, 1995 and 2000 on the ChinaMap grid; (2) delivery of CO and black carbon emissions for 1995 and 2000; and (3) Presentation of the soil dust emissions algorithm for use in on-line modeling analysis. Details are presented below.

1. NOx and SOx Emissions for 1990, 1992/93, 1995, 2000 and 2020.

The emission estimates for the targeted years have been completed for the ChinaMap study region. The China values are by fuel-use sector are presented in **Figure 1 and Figure 2**, and the gridded values are shown in **Figure 3 and Figure 4.** Complete details are presented in **Draft Final Report #1.**

2. CO Emissions for China in 1995 and 2020

A preliminary estimate of CO emissions for China in 1995 and 2020 has been completed. The emissions by sector are shown in **Figure 5**, and the gridded values are presented in **Figure 6**. Complete details are presented in **Draft Final Report #2.**

3. Black Carbon Emissions in China in 1995 and 2020

A preliminary estimate of CO emissions for China in 1995 and 2020 has been completed. The emissions by sector are shown in **Figure 7**, and the gridded values are presented in **Figure 8**. Complete details are presented in **Draft Final Report #3.**

The grid data can be downloaded here.

4. Wind blown Soil Emissions

Wind blown soil emissions can be modeled based on the work of Gillette and Passi, 1988.The basic algorithm is shown in **Figure 9**. In this model the mass flux of dust into the atmosphere occurs when the surface friction velocity exceeds the threshold surface friction velocity (which is a function of soil and surface properties). An example of how this model has been used in studies in China is shown in **Figures 10** **and Figures 11**, where the emissions are derived using ECMWF fields.

In order to calculate the dust emissions, it is necessary to estimate the threshold friction velocity (U_*^t) for the soil types of China. The soil types were simplified to 5 main soil categories. Then according to these main soil catogeries, an aerodynamic roughness height, z_0 was assigned, the U_*^t was then determined from **Figure 12**

In general, the values of aerodynamic roughness height, z_0, reflect the visual appearance of roughness. Extremely small z_0 correspond to flat and almost polished clay surfaces. The z_0 values of the five soil categories values range from 0.0001 to 0.1, and z_0 increases from those of fine sand and smooth crusted soils to gravelly sand soil and rough clay crusted soils. The values used as z_0=0.0001, 0.001, 0.0032, 0.01 and 0.2 cm for the five main soil categories. Figure 1 shows that when z_0=0.0001, disturbed hilly soils have a U_t^*=20cm/s; when z_0=0.001, loose sandy soils have a U_t^* =30cm/s; when z_0=0 .0032, disturbed gravel soils have a U_t^*=50cm/s; when z_0=0.01, crust soils have a U_t^*=100cm/s; when z_0=0.2, soils with vegetation have a U_t^*=250cm/s.

The base soil map used in the analysis is shown in **Figure 13**. These soils were then assigned a surface roughness and threshold velocities estimated. The map of threshold velocities is presented in **Figure 14**. The actual emissions depend upon the state of the surface as well. The presence of standing vegetation as well as recent precipitation will reduce the potential for wind blown emissions. The standing vegetation can be estimated by the use of satellite greenness data (Jing --ref or web site needed). Greenness map for the month of May is shown in **Figure 15**. Combining the greenness maps with the threshold velocity maps, provides a seasonal picture of potential source areas as in **Figure 16**. If the surface is dry then this information can be used on-line with a meteorological model to derive emission rates. To determine the dryness state of the soils one needs additional information such as time since the grid cell last received precipitation (or soil moisture).

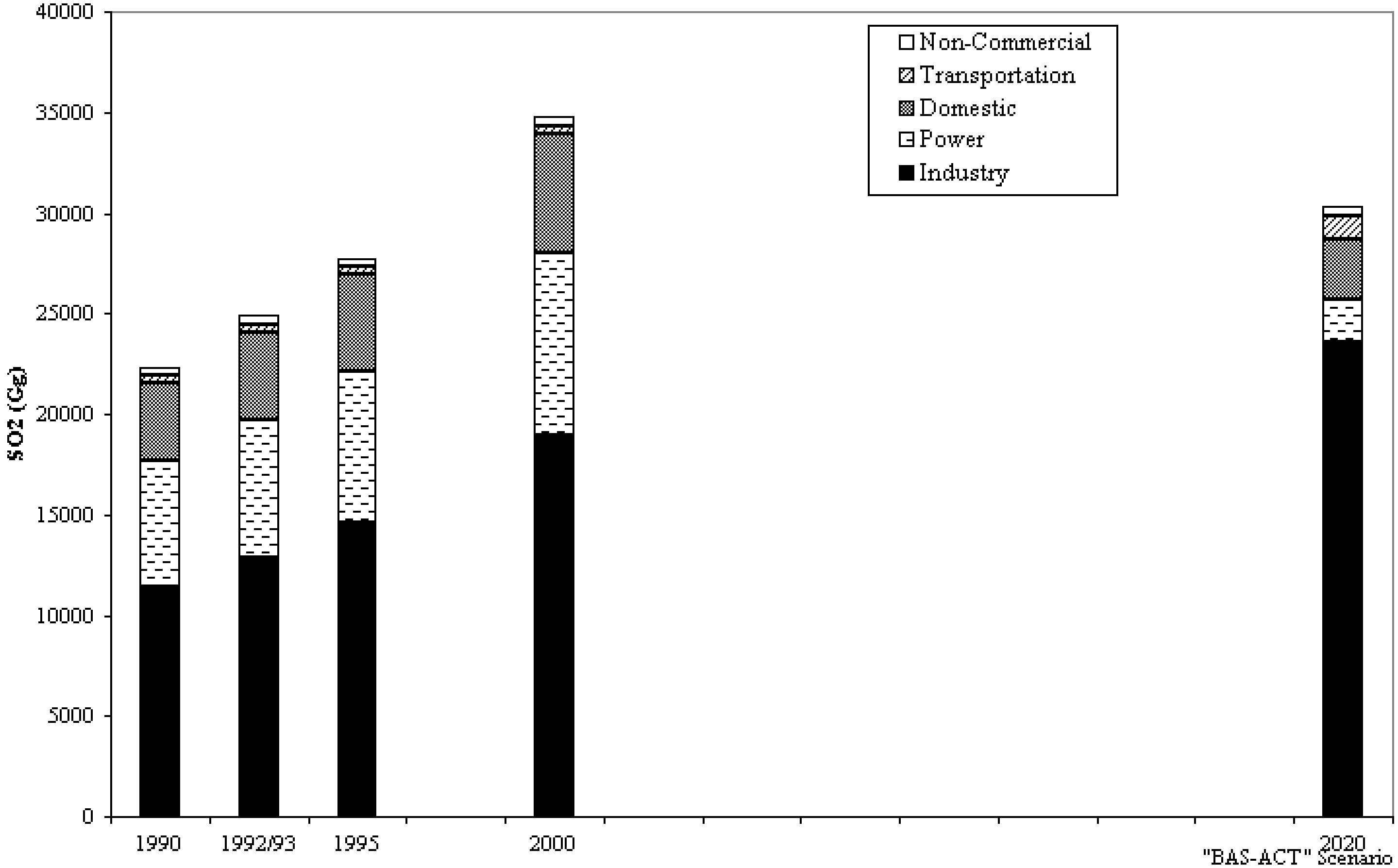
The gridded fields at 1° by 1° resolution are shown in **Figures17, 18, 19**. For some applications, it is useful to have chemical composition as well as mass flux. We have also prepared soil chemistry maps, for example, calcium **(Figure 20)**. The weight percent calcium can be used along with the dust emissions equation.

Reference:

1.Dale A. Gillette, John Adams, Danel Muhs and Rolf Kihl, *Threshold Friction Veolocities and Rupture Moduli for Crusted Desert Soils for the Input of Soil Particles into the Air*, Journal of Geographical Research, Vol. 87, No. C11, Page 90003-905, Oct. 20, 1982.

2.Beatrice Marticorena, Gilles Bergametti, Dale Gillette, Jayne Belnap, *Factors controlling threshold friction velocity in semiarid and arid areas of the United States*, Journal of Geographical Research, Vol. 102, No. D19, Page 23277-23287, Oct. 20, 1997.

Figure 1 – Chinese SO2 Emissions by Sector



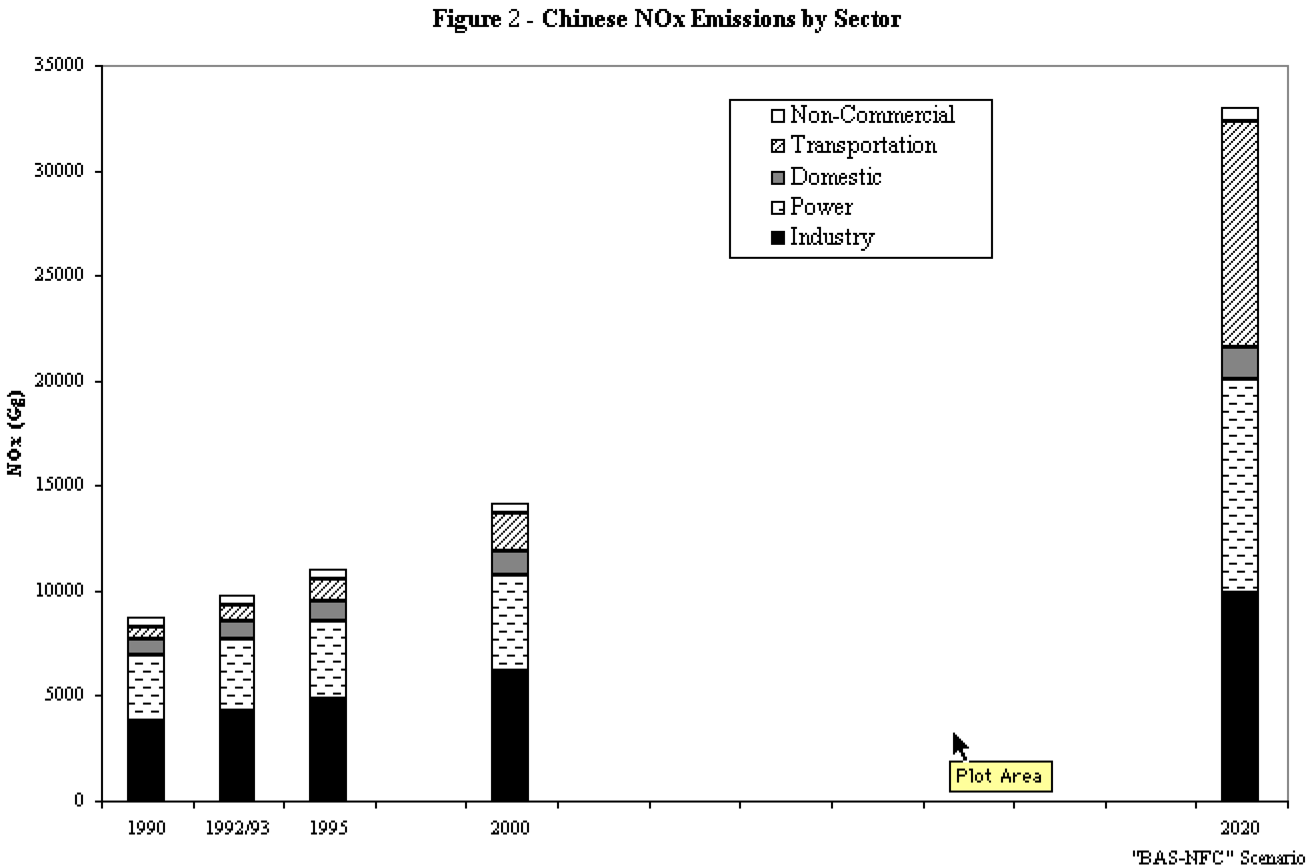
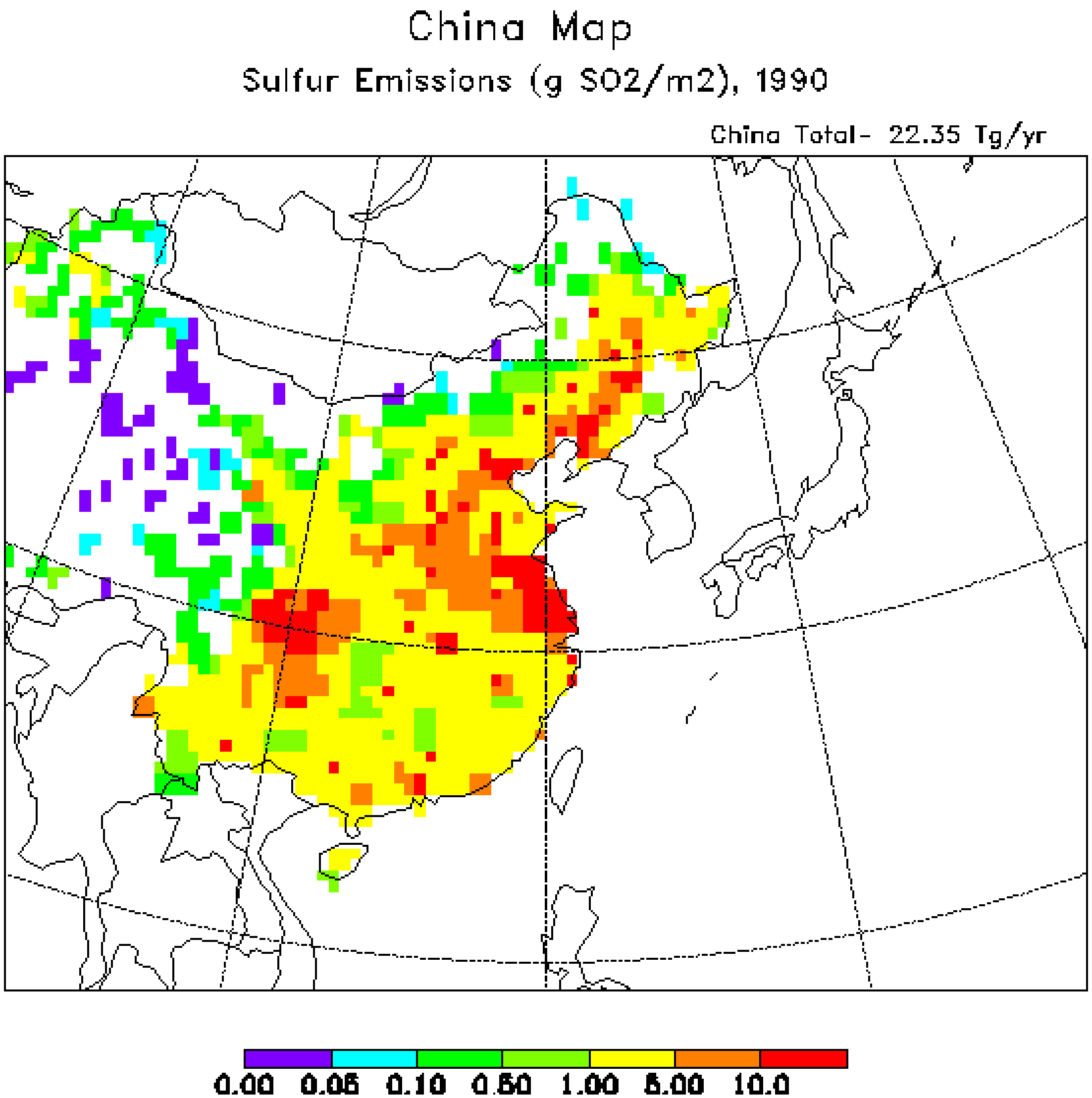
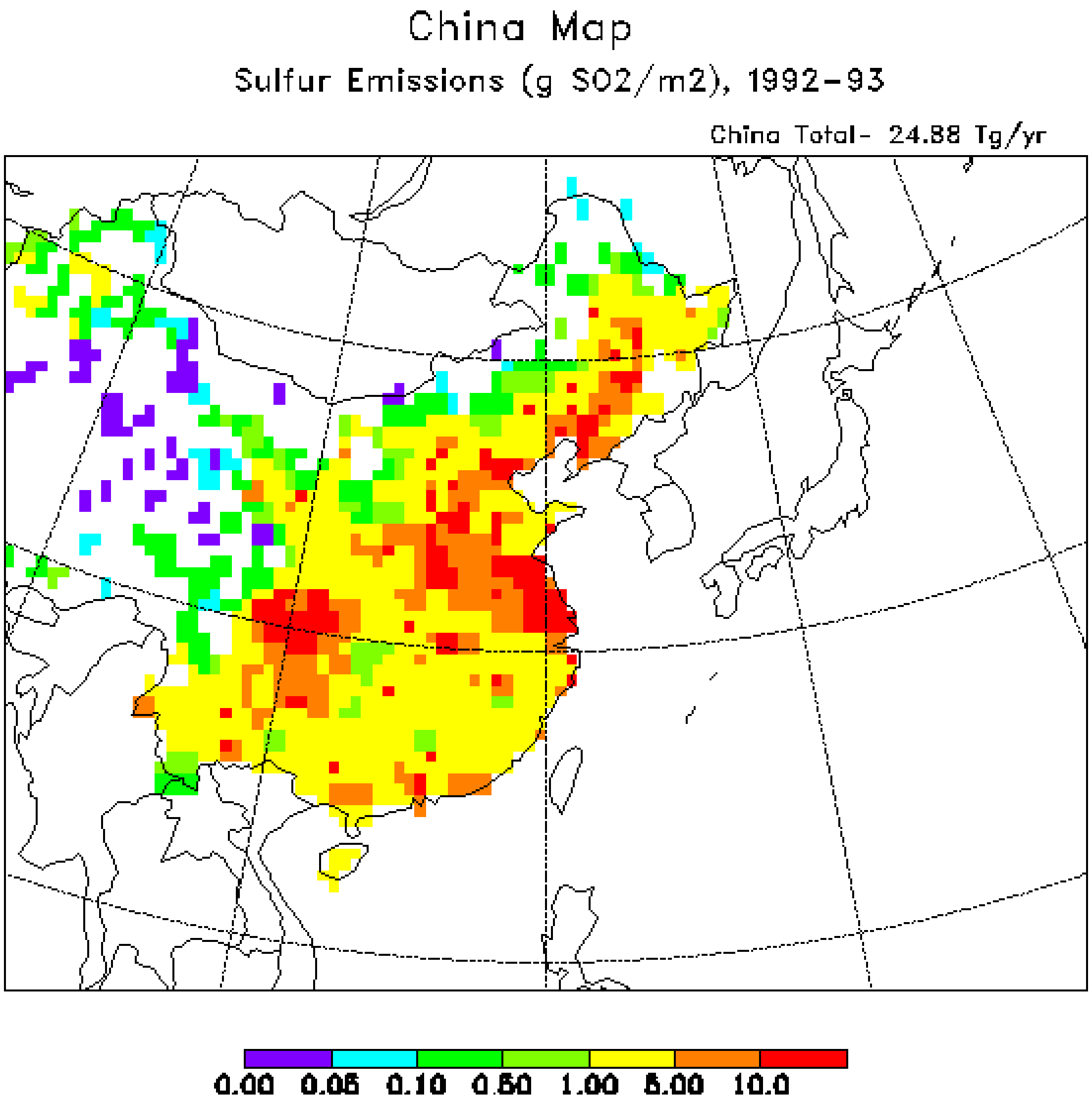
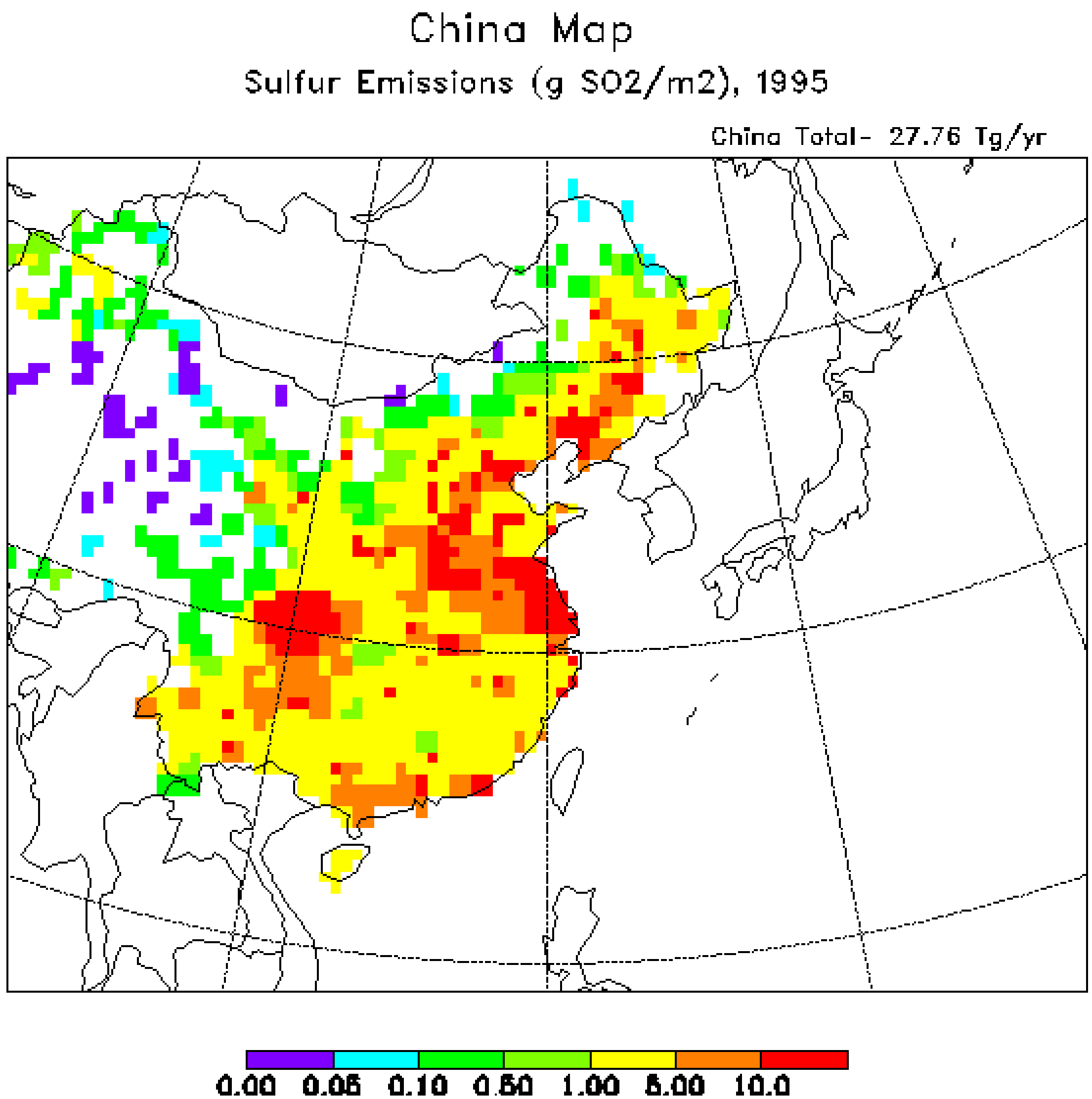


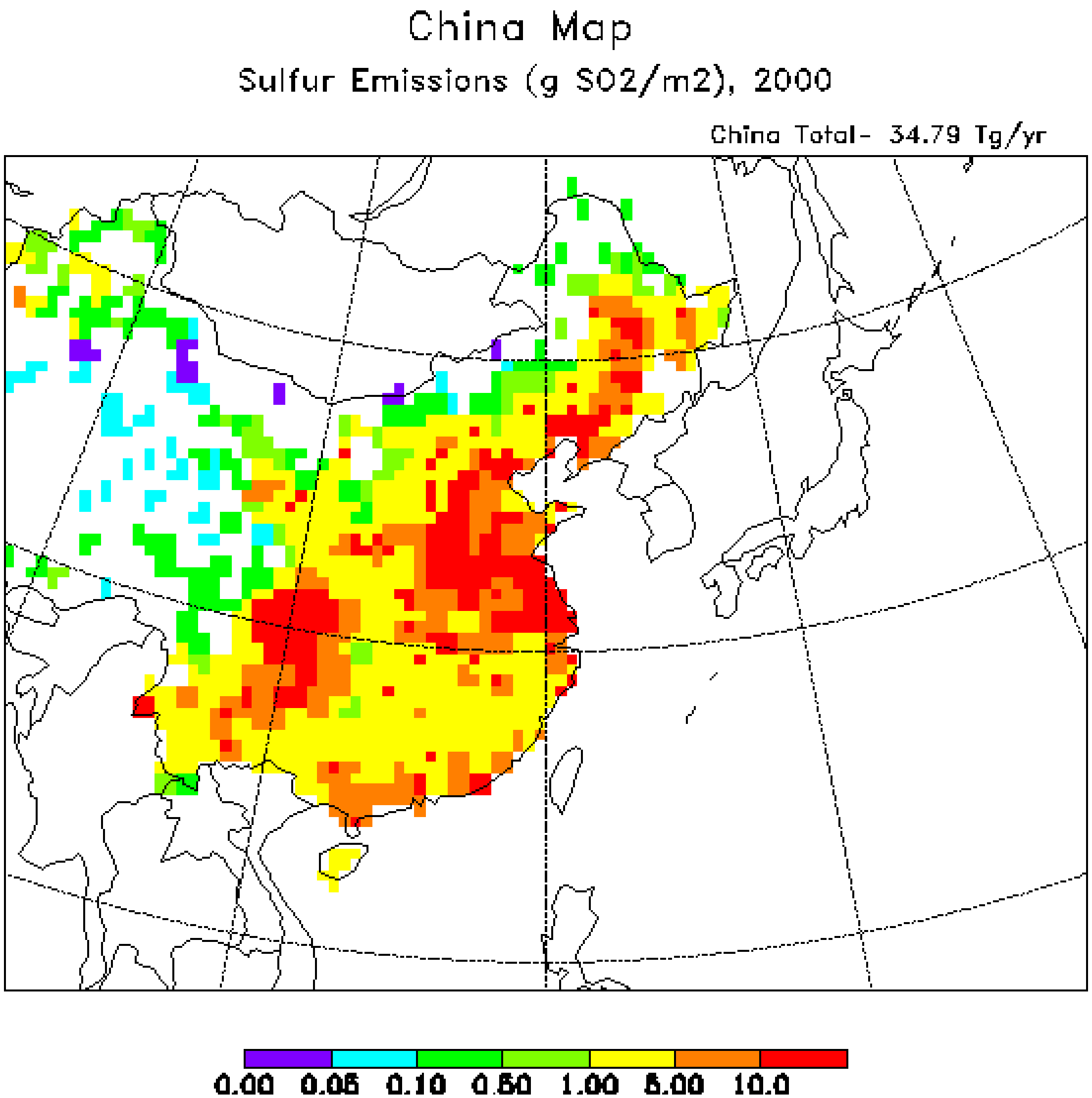
Figure 2 - Chinese NOx Emissions by Sector
NOx (Gg)
35000
30000
25000
20000
15000
10000
5000
0
Non-Commercial
Transportation
Domestic
Power
Industry
Plot Area
1990
1992/93
1995
2000
2020
"BAS-NFC" Scenario

Figure 3:


China Map
Sulfur Emissions (g SO2/m2), 1990
China Total- 22.35 Tg/yr
0.00
0.05
0.10
0.50
1.00
5.00
10.0


China Map
Sulfur Emissions (g SO2/m2), 1992-93
China Total- 24.88 Tg/yr
0.00 0.05 0.10 0.50 1.00 5.00 10.0


China Map
Sulfur Emissions (g SO2/m2), 1995
China Total- 27.76 Tg/yr
0.00
0.05
0.10
0.50
1.00
5.00
10.0


China Map
Sulfur Emissions (g SO2/m2), 2000
China Total- 34.79 Tg/yr
0.00 0.05 0.10 0.50 1.00 5.00 10.0

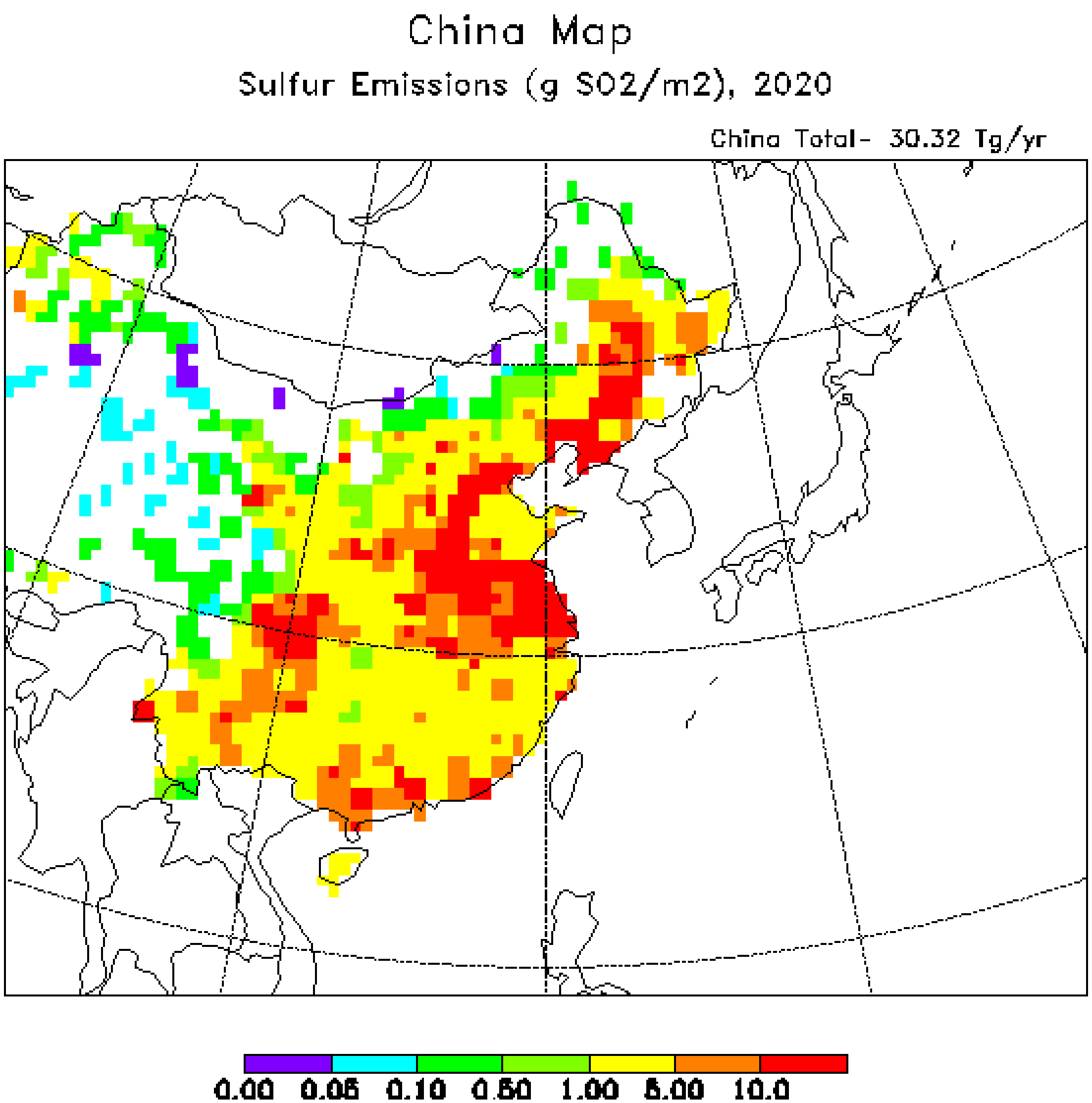
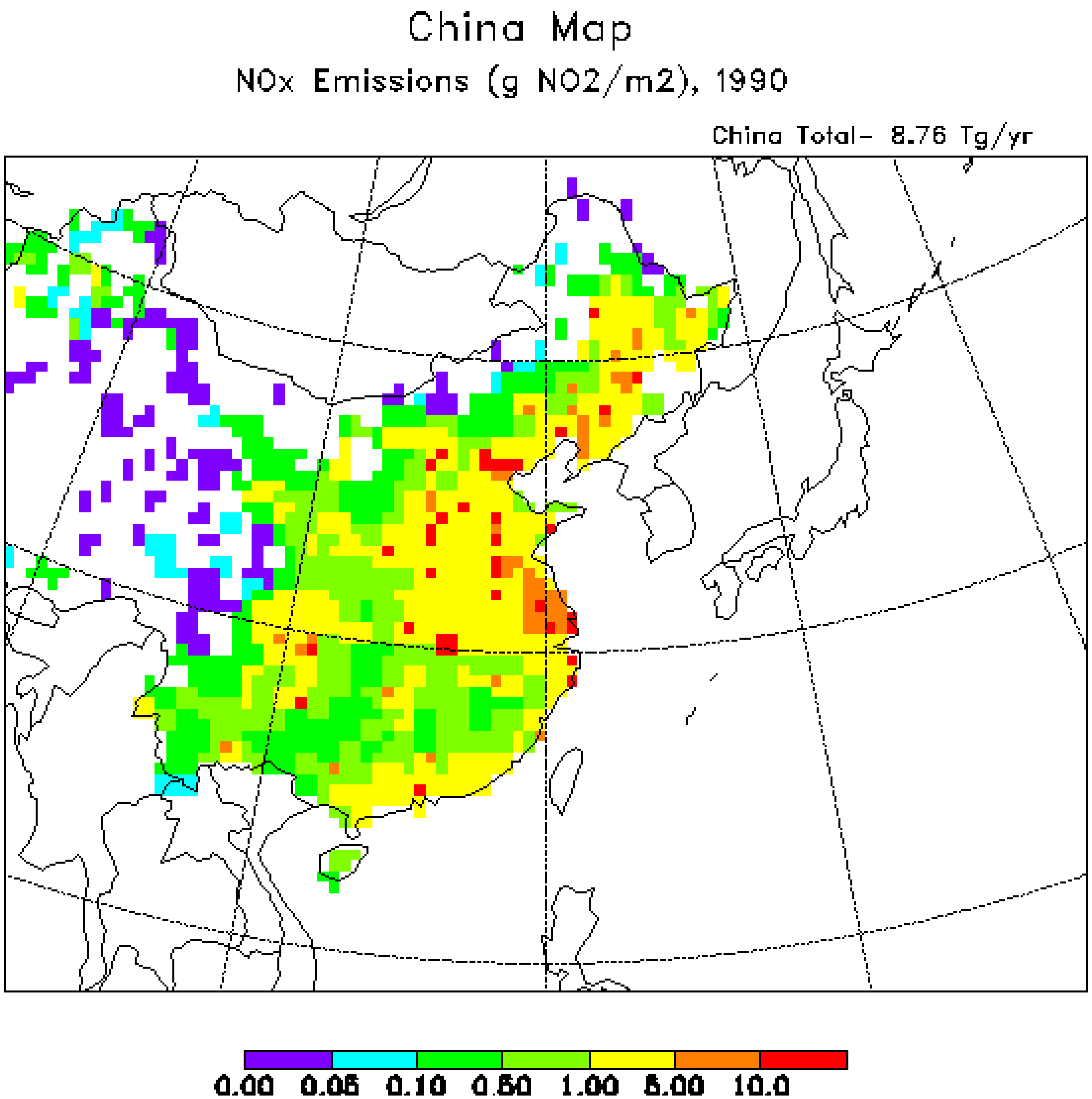
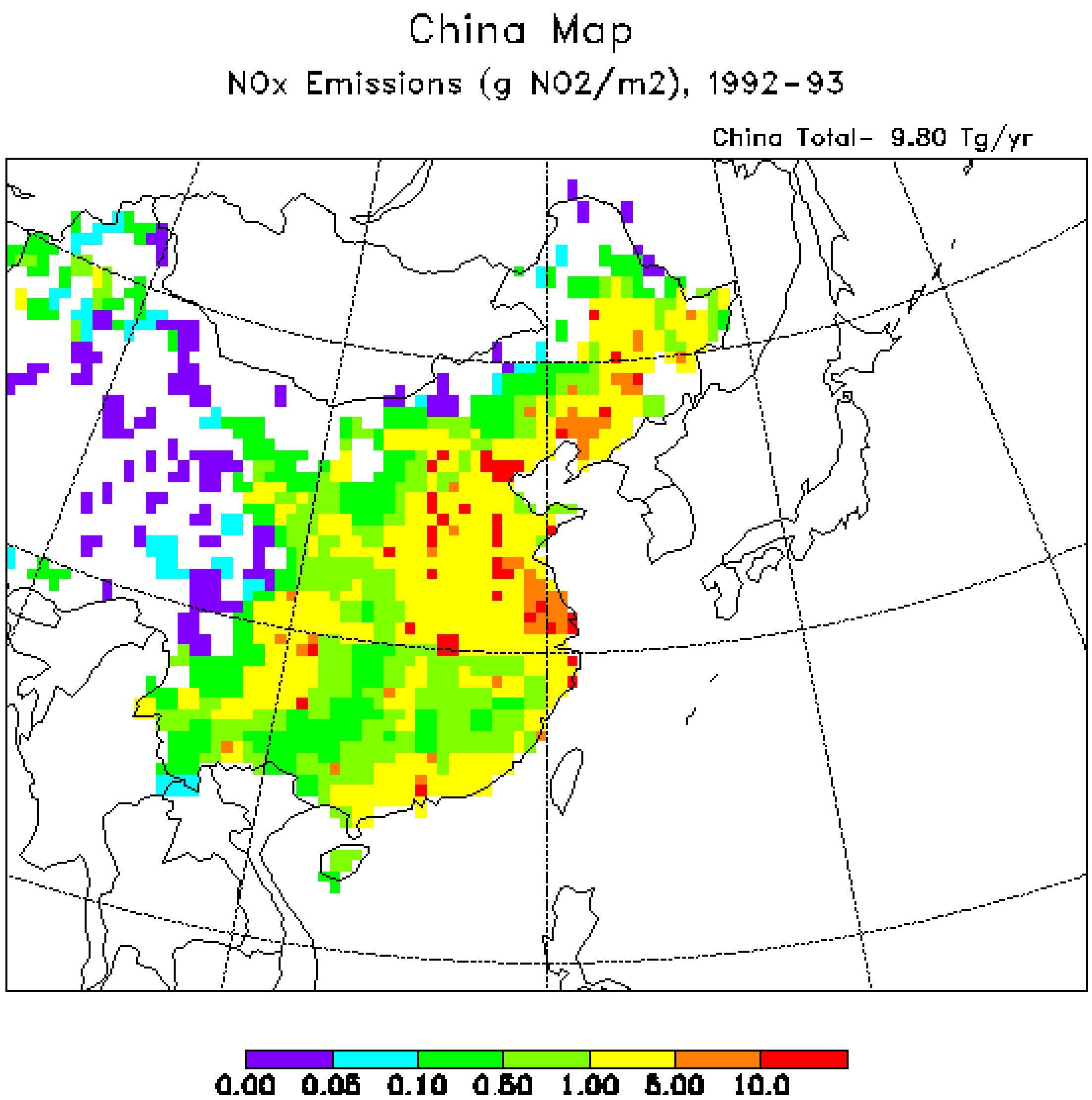
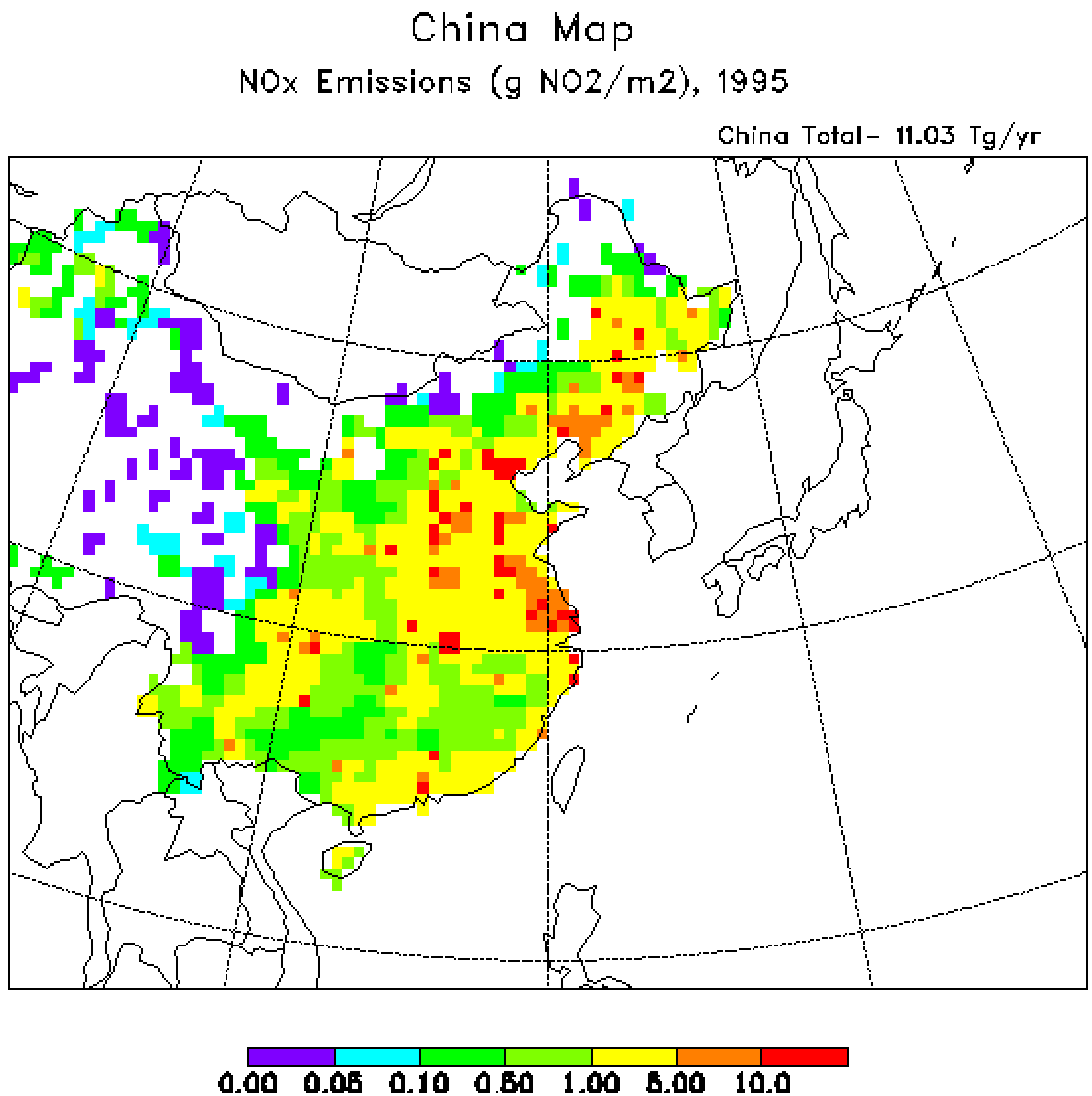


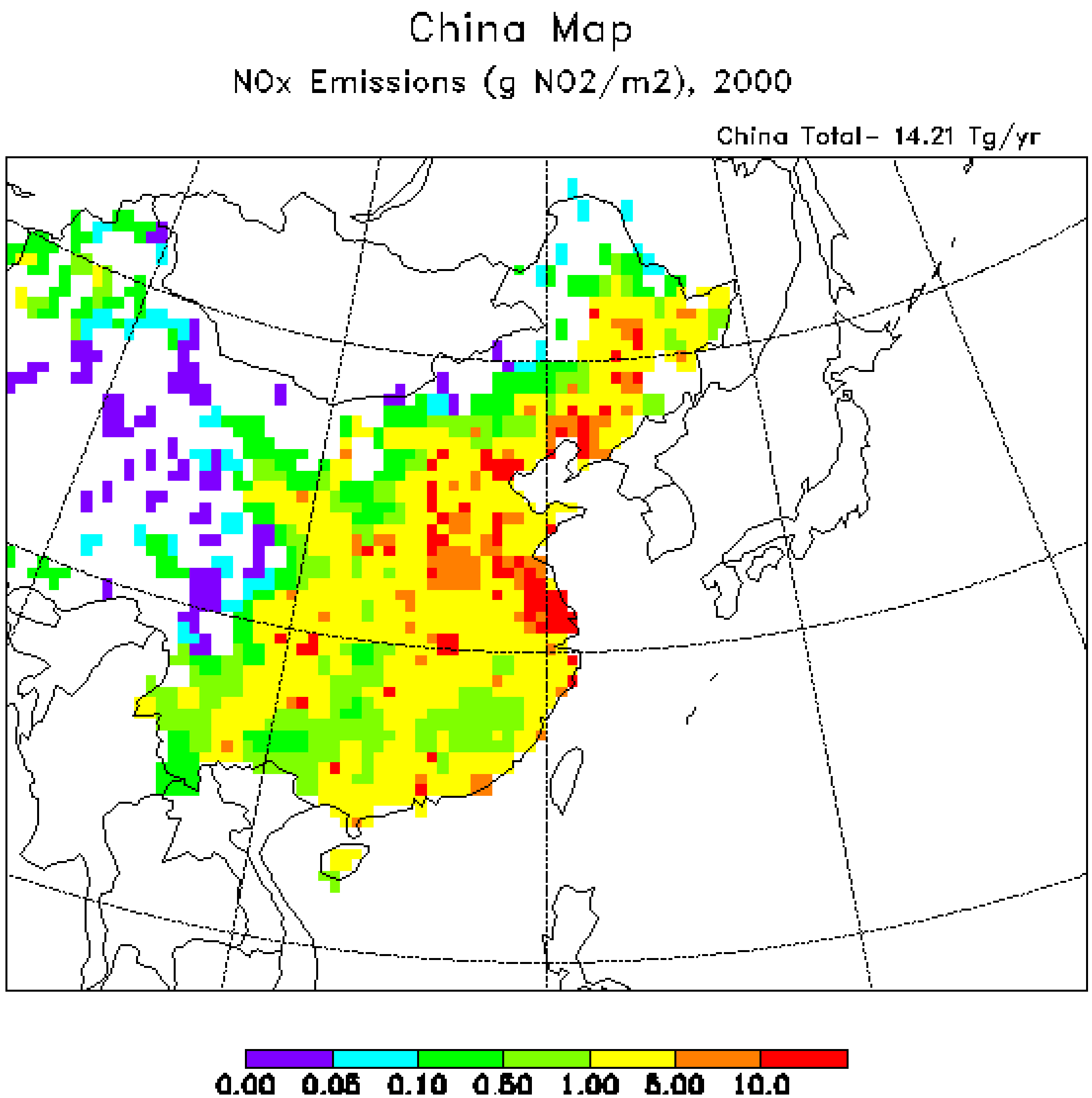
Figure 3: Estimated Sulfur Emissions, Units: g SO_2/m^2/yr

Figure 4:


China Map
NOx Emissions (g NO2/m2), 1990
China Total- 8.76 Tg/yr
0.00
0.05
0.10
0.50
1.00
5.00
10.0


China Map
NOx Emissions (g NO2/m2), 1992-93
China Total- 9.80 Tg/yr
0.00 0.05 0.10 0.50 1.00 5.00 10.0


China Map
NOx Emissions (g NO2/m2), 1995
China Total- 11.03 Tg/yr
0.00
0.05
0.10
0.50
1.00
5.00
10.0


China Map
NOx Emissions (g NO2/m2), 2000
China Total- 14.21 Tg/yr
0.00 0.05 0.10 0.50 1.00 5.00 10.0

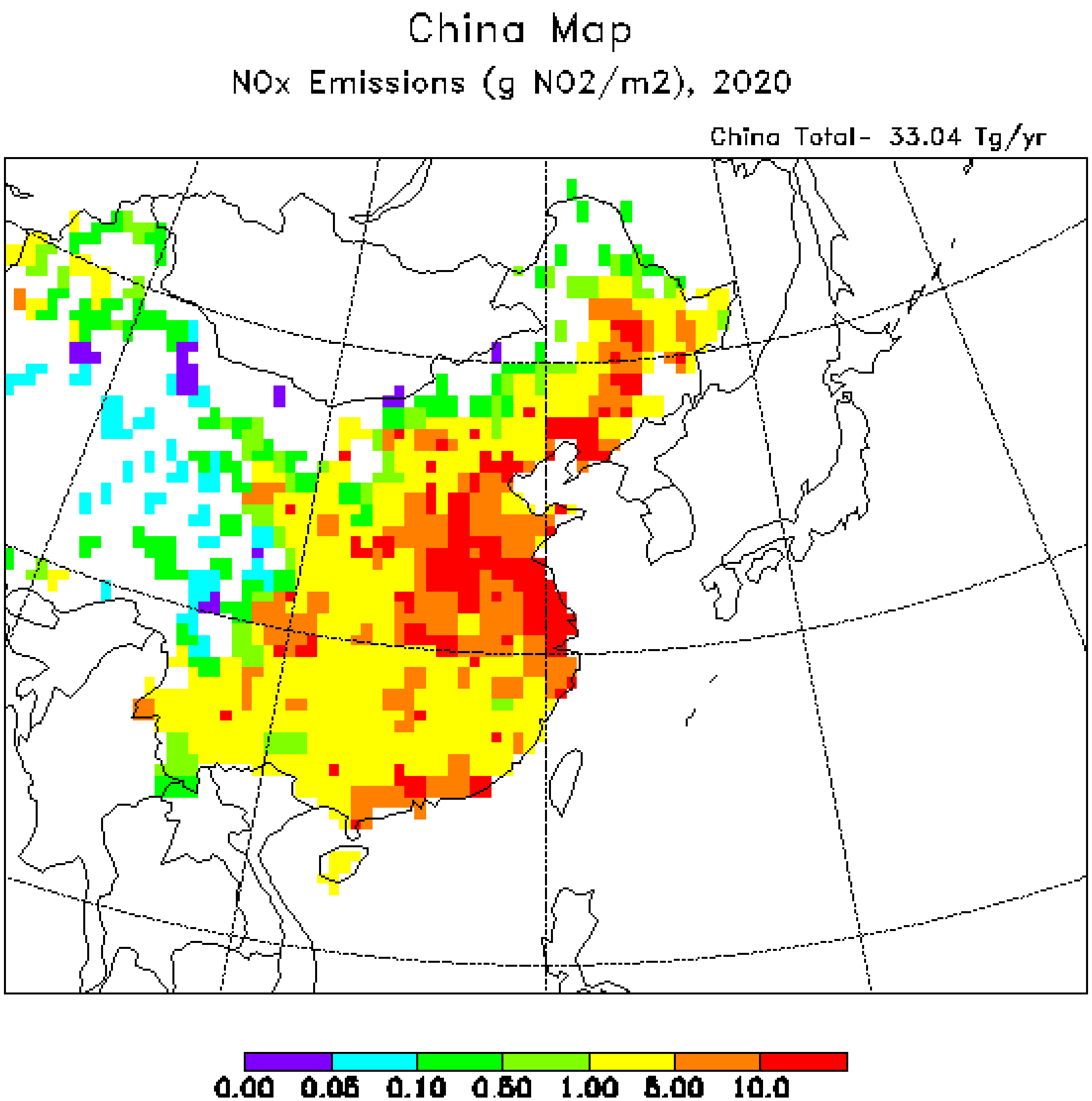


Figure 4: Estimated NOx Emissions, Units: g NO_x/m^2/yr

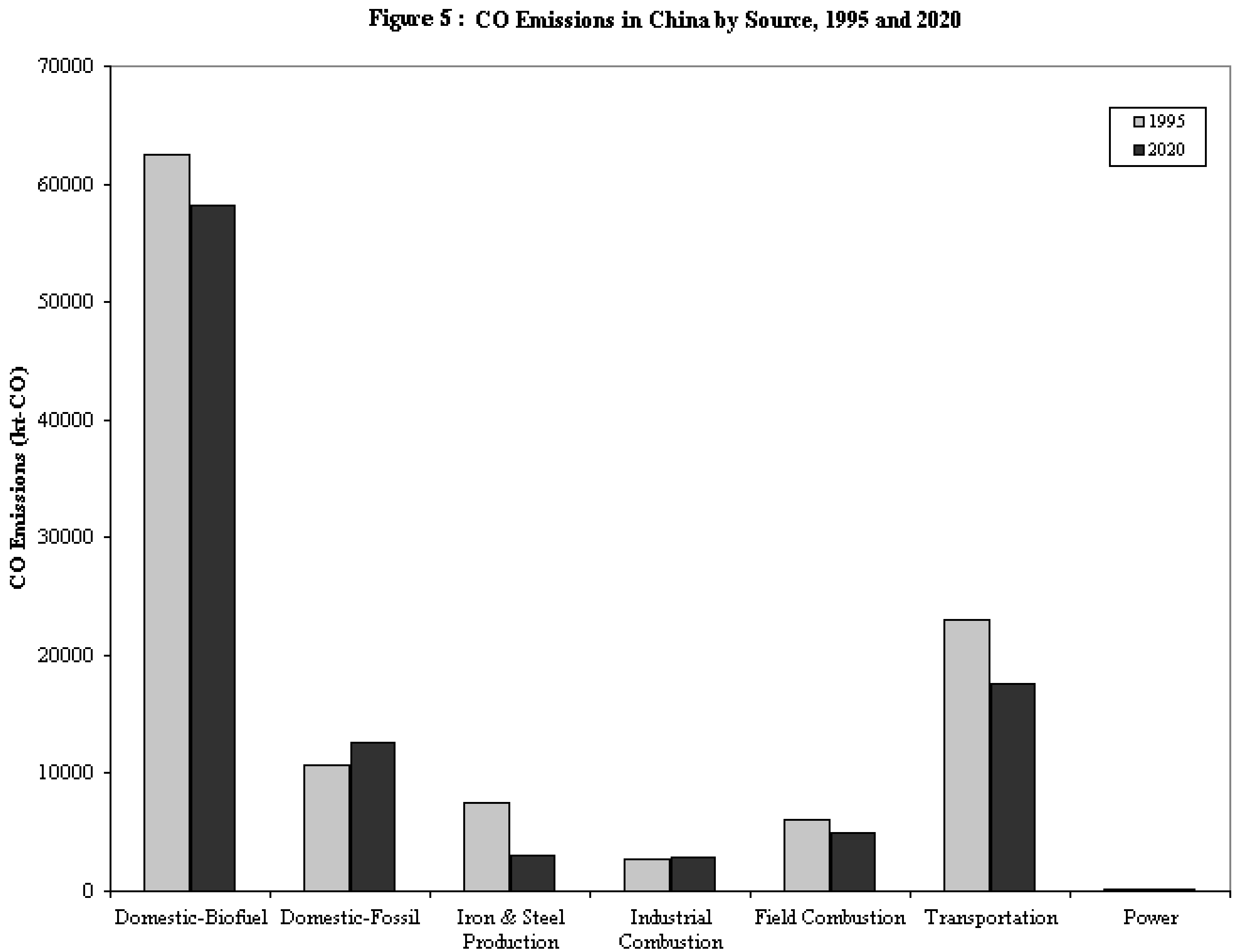
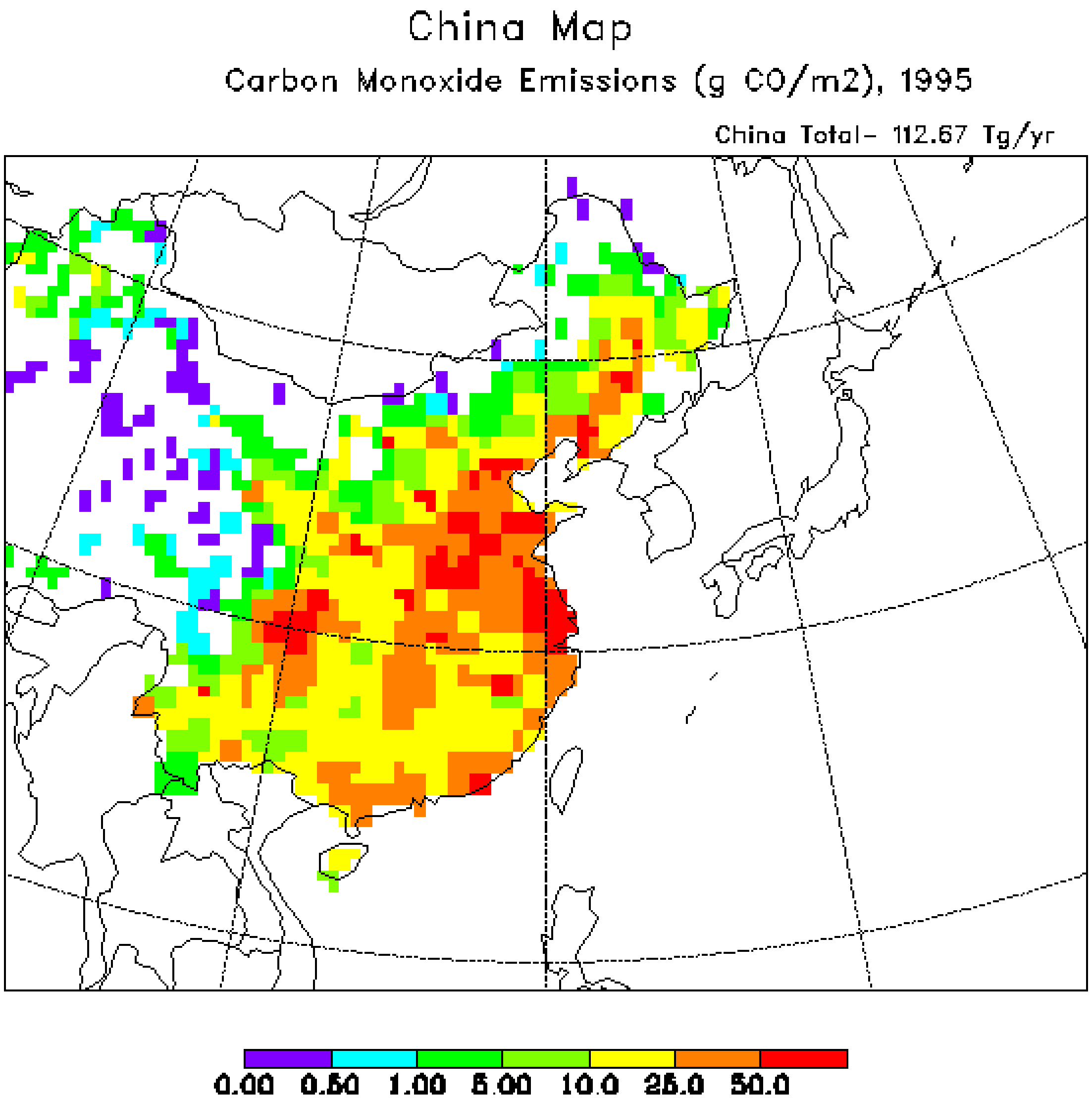


Figure 5 : CO Emissions in China by Source, 1995 and 2020
CO Emissions (kt-CO)
70000
60000
50000
40000
30000
20000
10000
0
1995
2020
Domestic-Biofuel
Domestic-Fossil
Iron & Steel Production
Industrial Combustion
Field Combustion
Transportation
Power

Figure 6:


China Map
Carbon Monoxide Emissions (g CO/m2), 1995
China Total- 112.67 Tg/yr
0.00 0.50 1.00 5.00 10.0 25.0 50.0

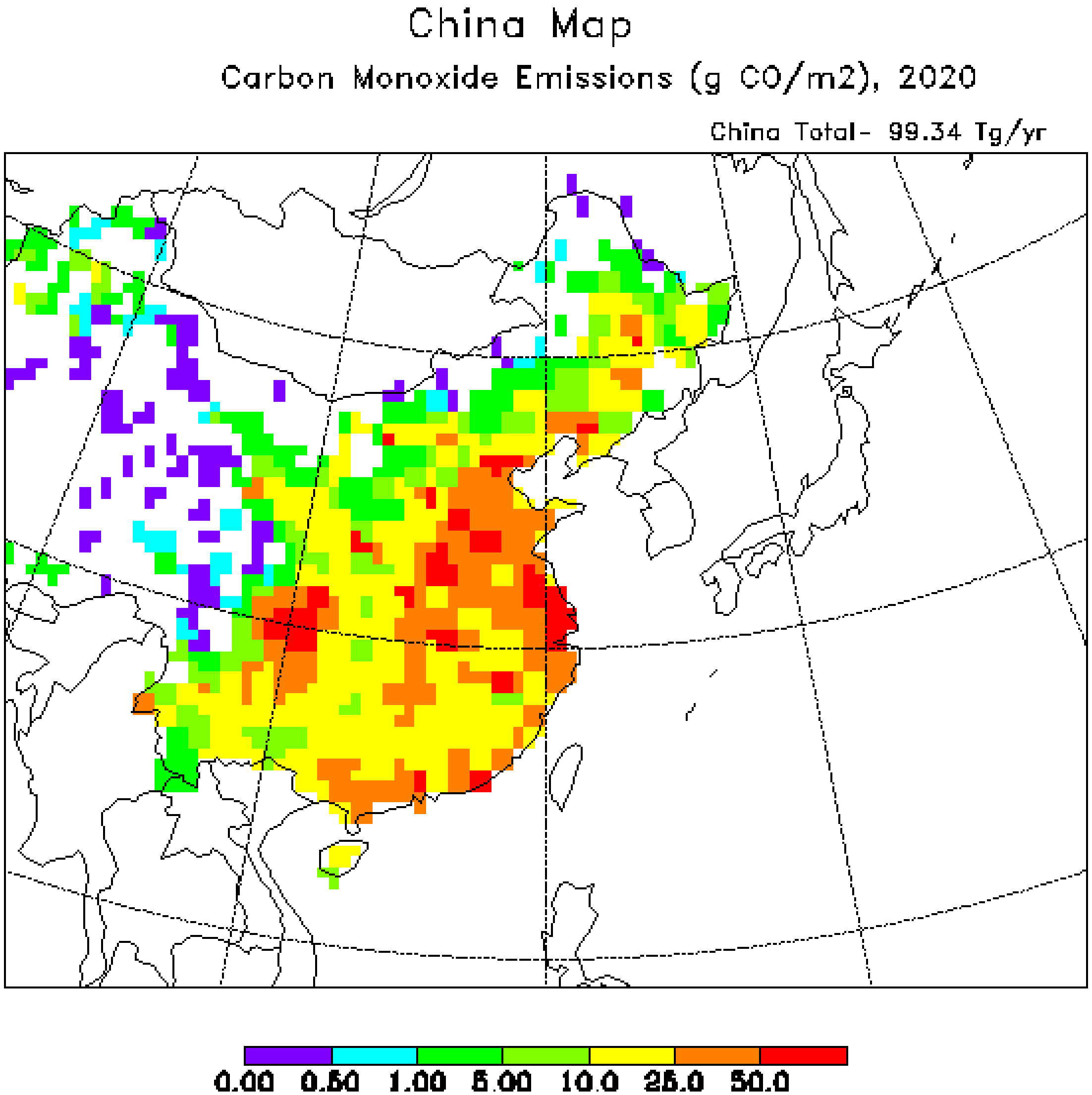


Figure 6: Estimated Carbon Monoxide Emissions, Units: g CO/m^2/yr

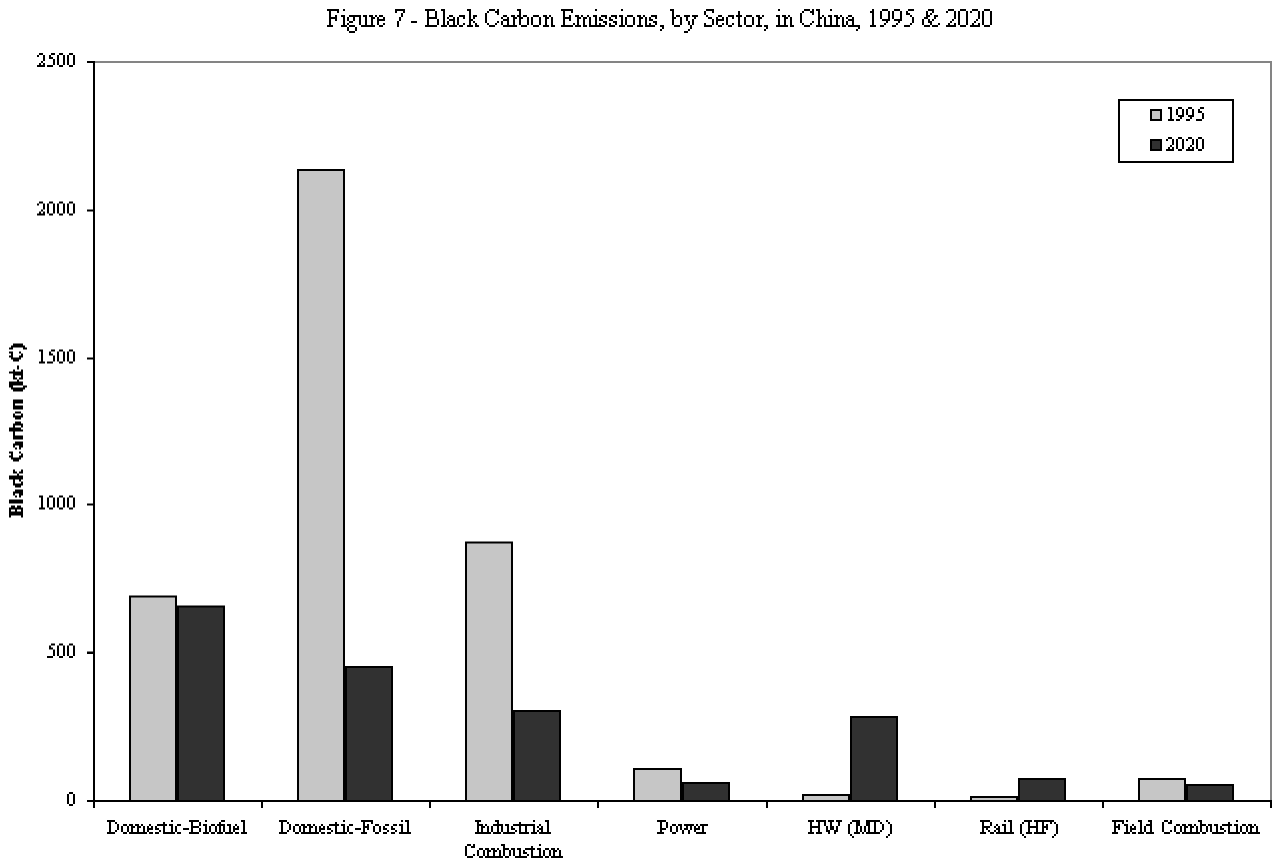
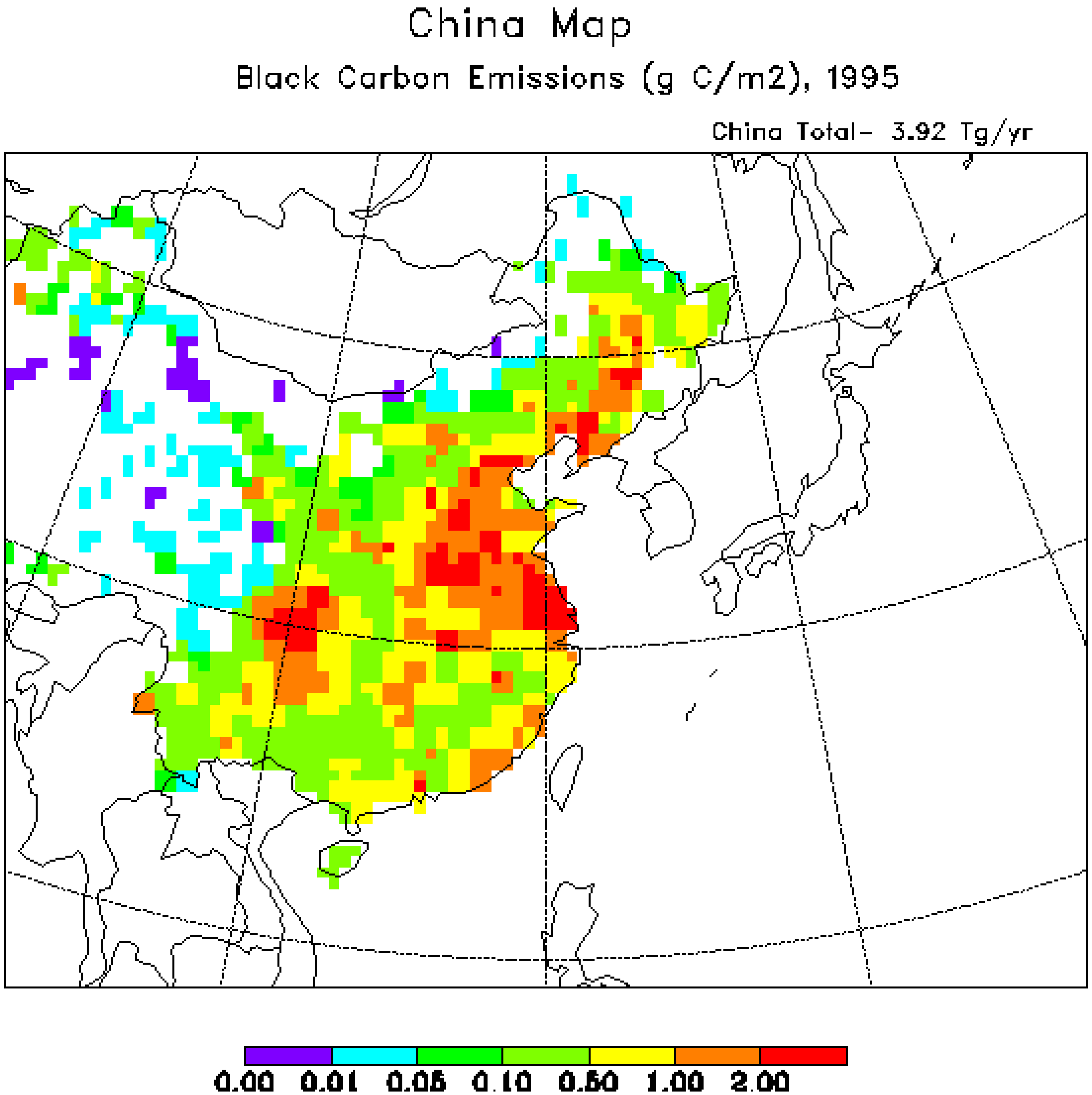


Figure 7 - Black Carbon Emissions, by Sector, in China, 1995 & 2020
Black Carbon (kt-C)
2500
2000
1500
1000
500
0
1995
2020
Domestic-Biofuel
Domestic-Fossil
Industrial Combustion
Power
HW (MD)
Rail (HF)
Field Combustion

Figure 8:


China Map
Black Carbon Emissions (g C/m2), 1995
China Total- 3.92 Tg/yr
0.00
0.01
0.05
0.10
0.50
1.00
2.00

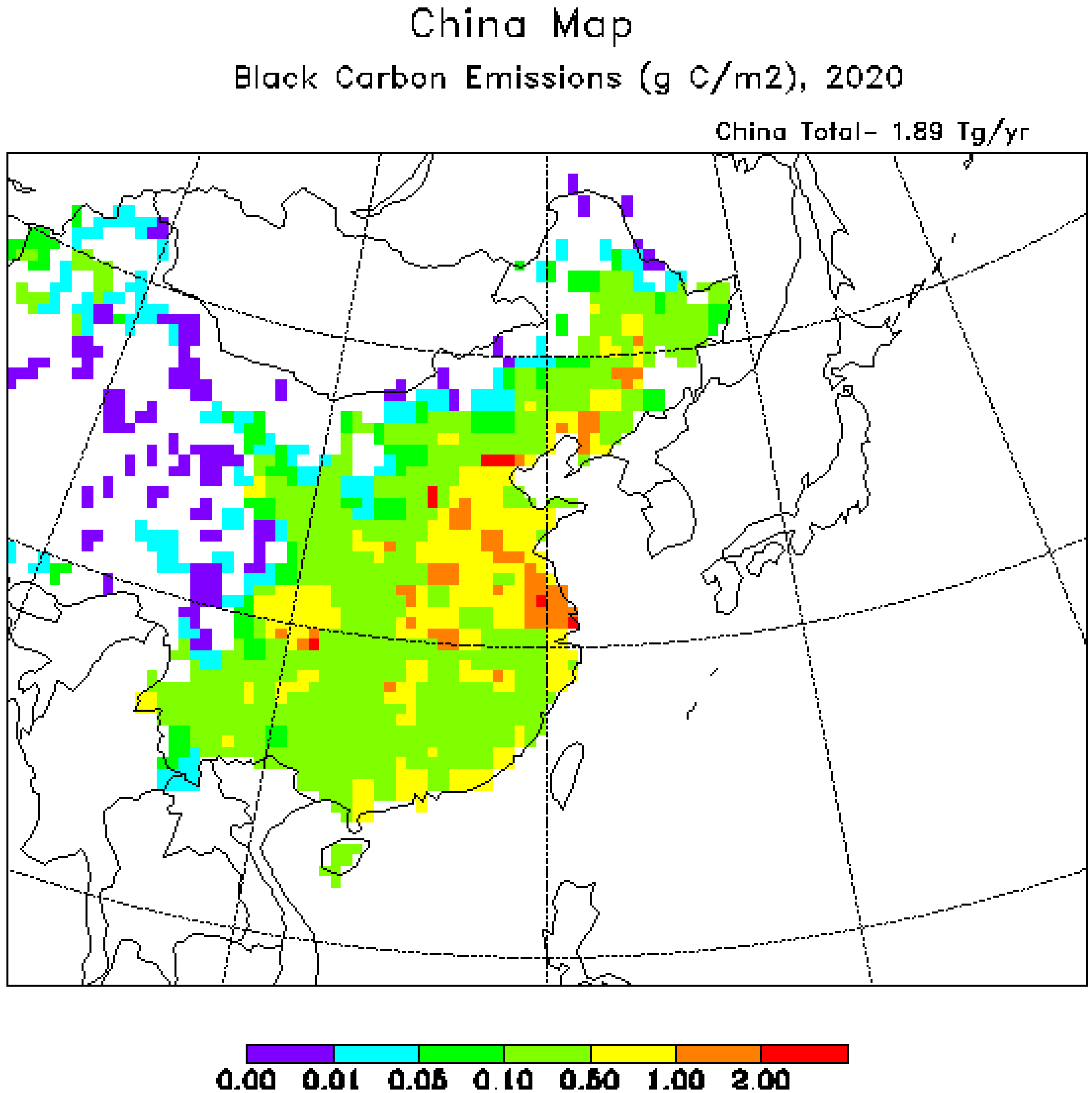


Figure 8: Estimated Black Carbon Emissions, Units: g C/m^2/yr

Dust Emission Model

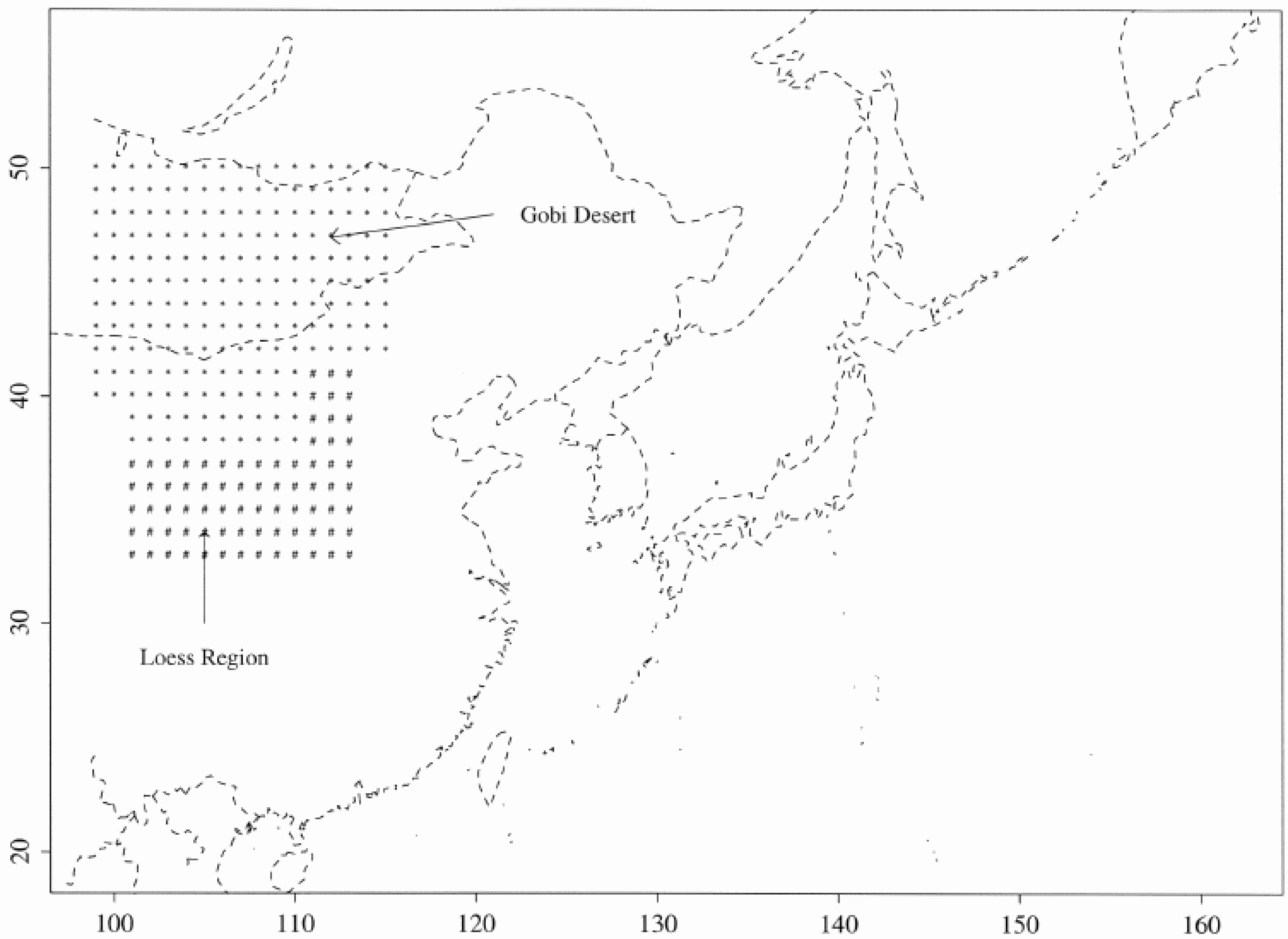
$$E = C\sum_{i=1}^{N} R_i g(L_i) A_i \Delta t \int_{U_{t_i}}^{\infty} G(U) p_i(U) dU$$ (Gillette & Passi, 1988)

$$G(U) = C_2 u_t^{*4}\left(1 - \frac{u_t^*}{u^*}\right)$$

$$E = CA\Delta t[C_2 u_t^{*4}\left(1 - \frac{u_t^*}{u^*}\right)]$$

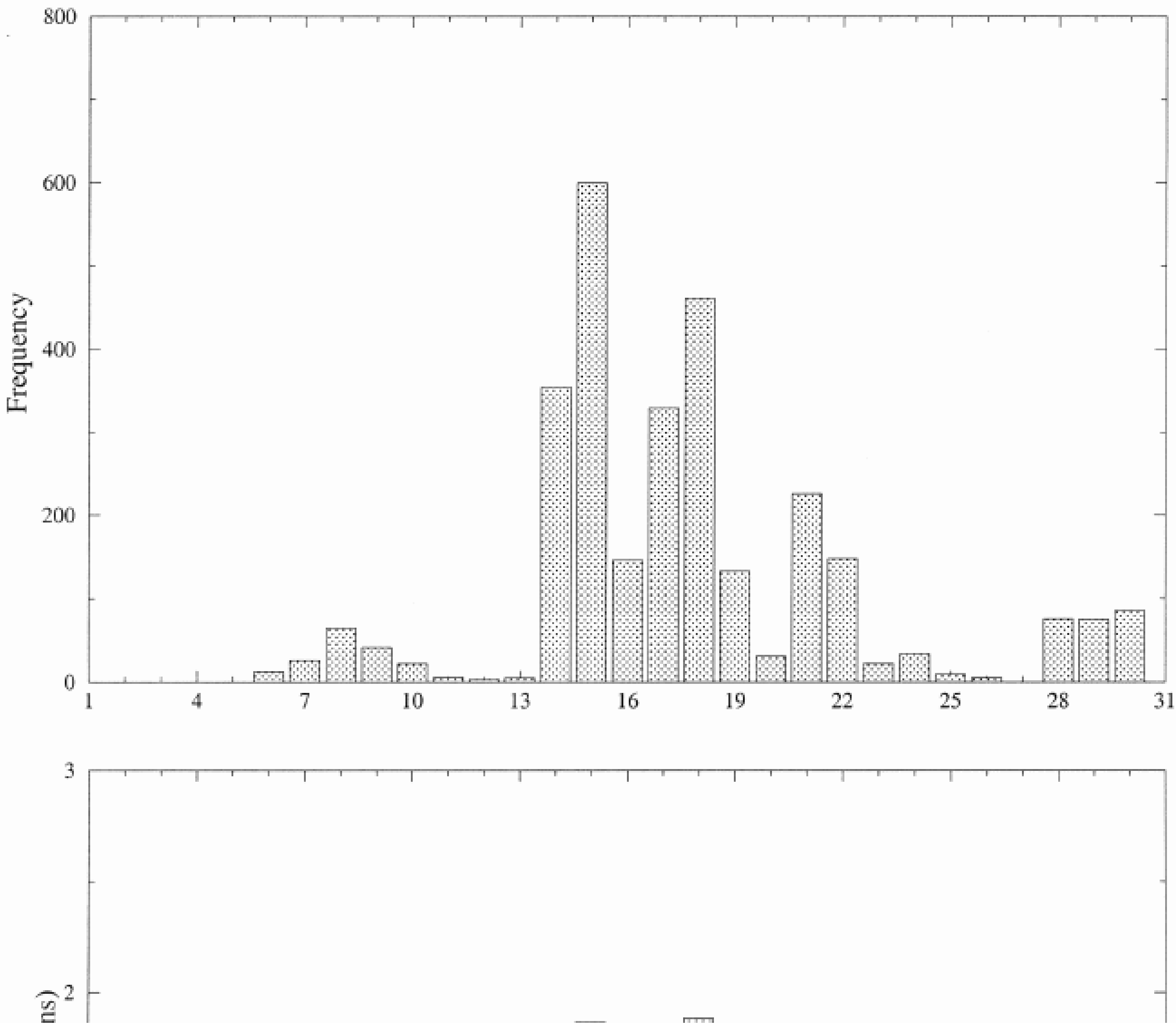
$$= C' A\Delta t[u_t^{*4}\left(1 - \frac{u_t^*}{u^*}\right)]$$

C′=constant
A=Area
Δt=time interval
u^*_t=threshold friction velocity
u*=friction velocity

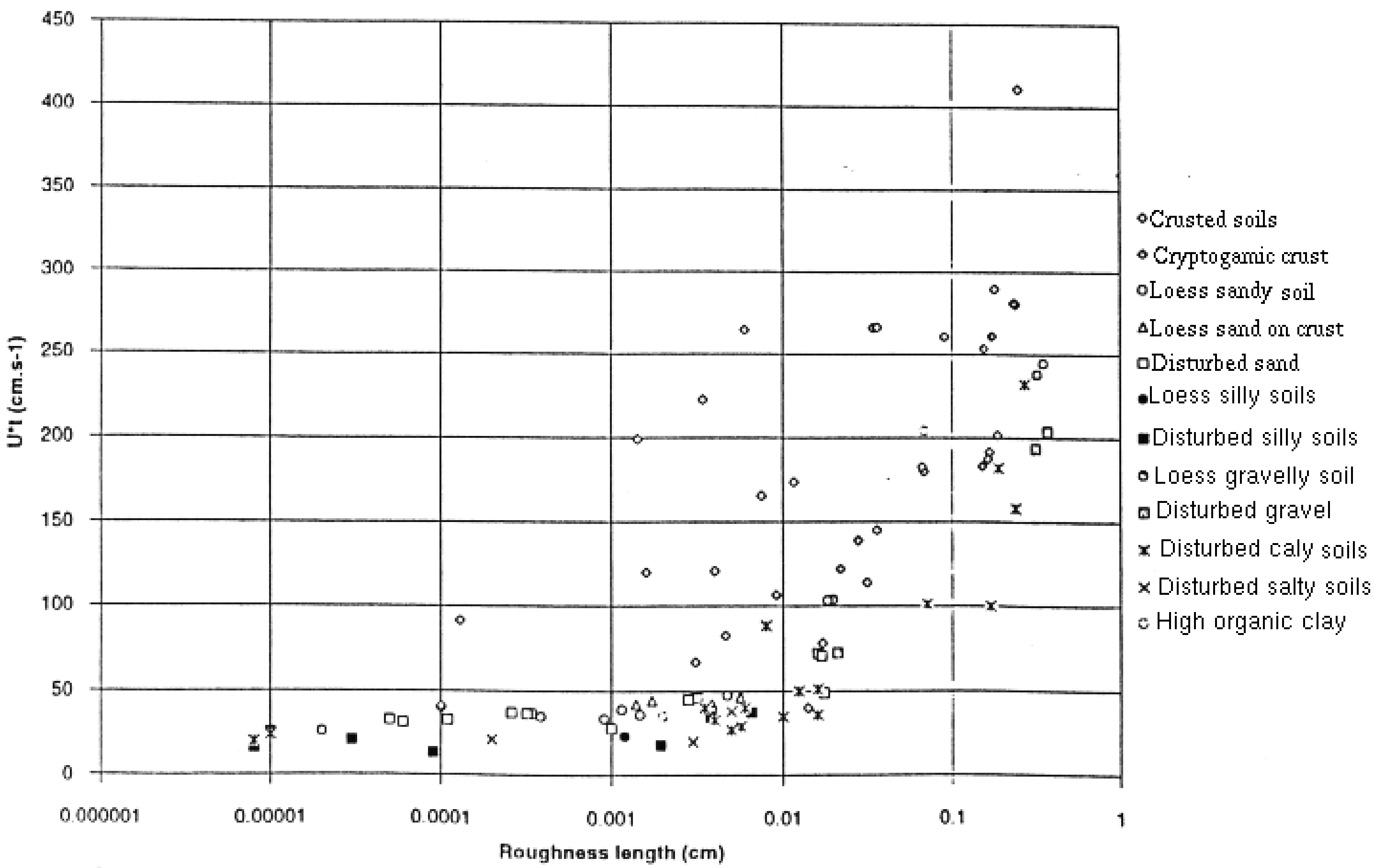


Domain for the east Asia. Shaded areas indicate arid and semi-arid regions.

Frequency of Occurence and Mass Emissions of Mineral Dust from China, May 1987.



Values of U_*^t versus z_o for the tests at the Jornada del muerto experimental range and for *Gillette et al. 's* [1982] data.



FAO Soil Map

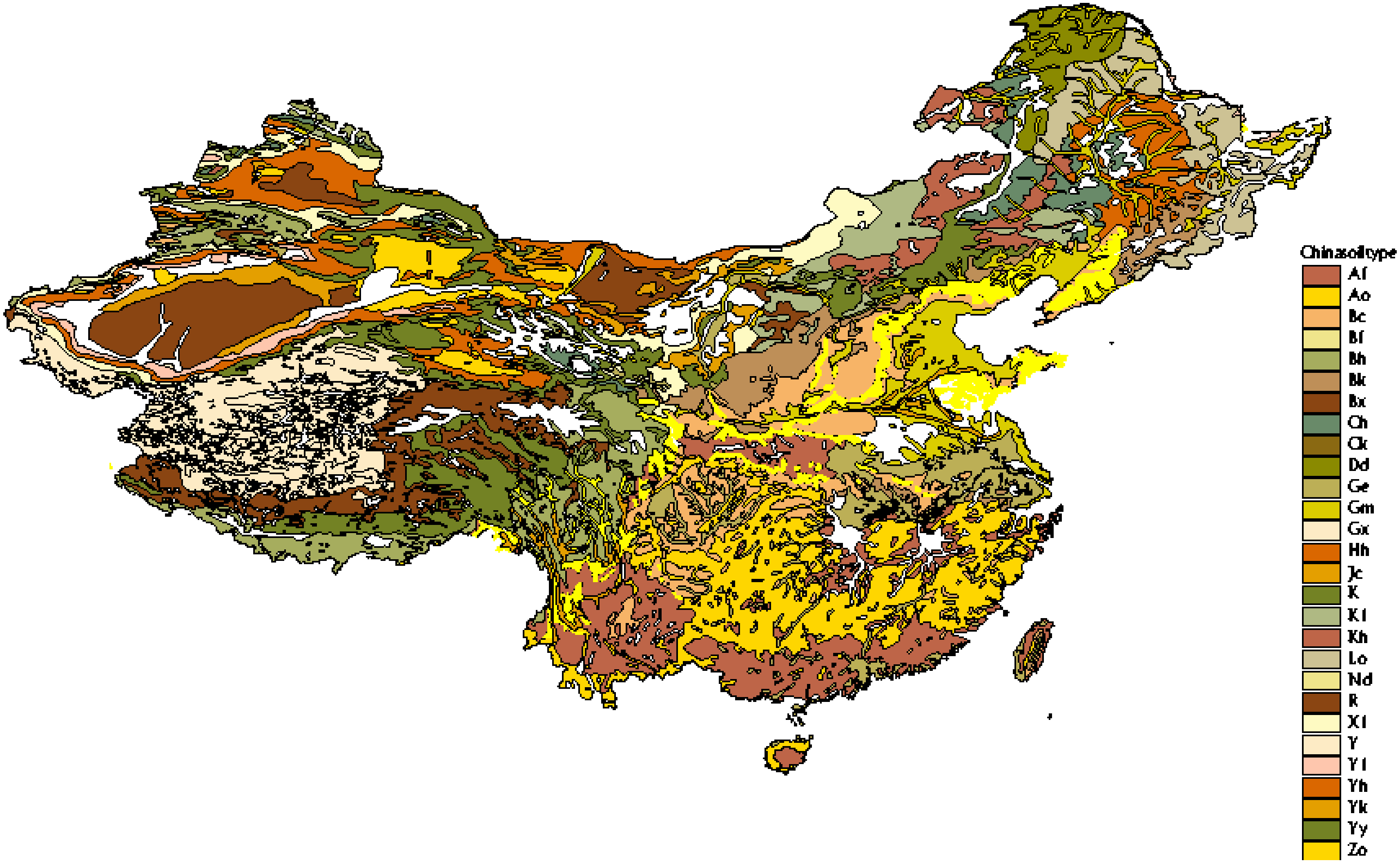

Chinasoiltype
Af
Ao
Bc
Bf
Bh
Bk
Bx
Ch
Ck
Dd
Ge
Gm
Gx
Hh
Jc
K
Kl
Kh
Lo
Nd
R
Xl
Y
Yl
Yh
Yk
Yy
Zo

Figure 13:

FAO Soil Map

Nomenclature: For the First Character

A: Acrisols, B: Cambisols, C:Chernozems, D: Podzoluvisols, G: Gyelsols, H: Phaezems, J: Fluvisols, K: Kastanozems, L: Luvisols, N: Nitosols, R: Regosols, X: Xerosols, Y: Yermosols, Z: Solonchaks

Threshold Friction Velocity

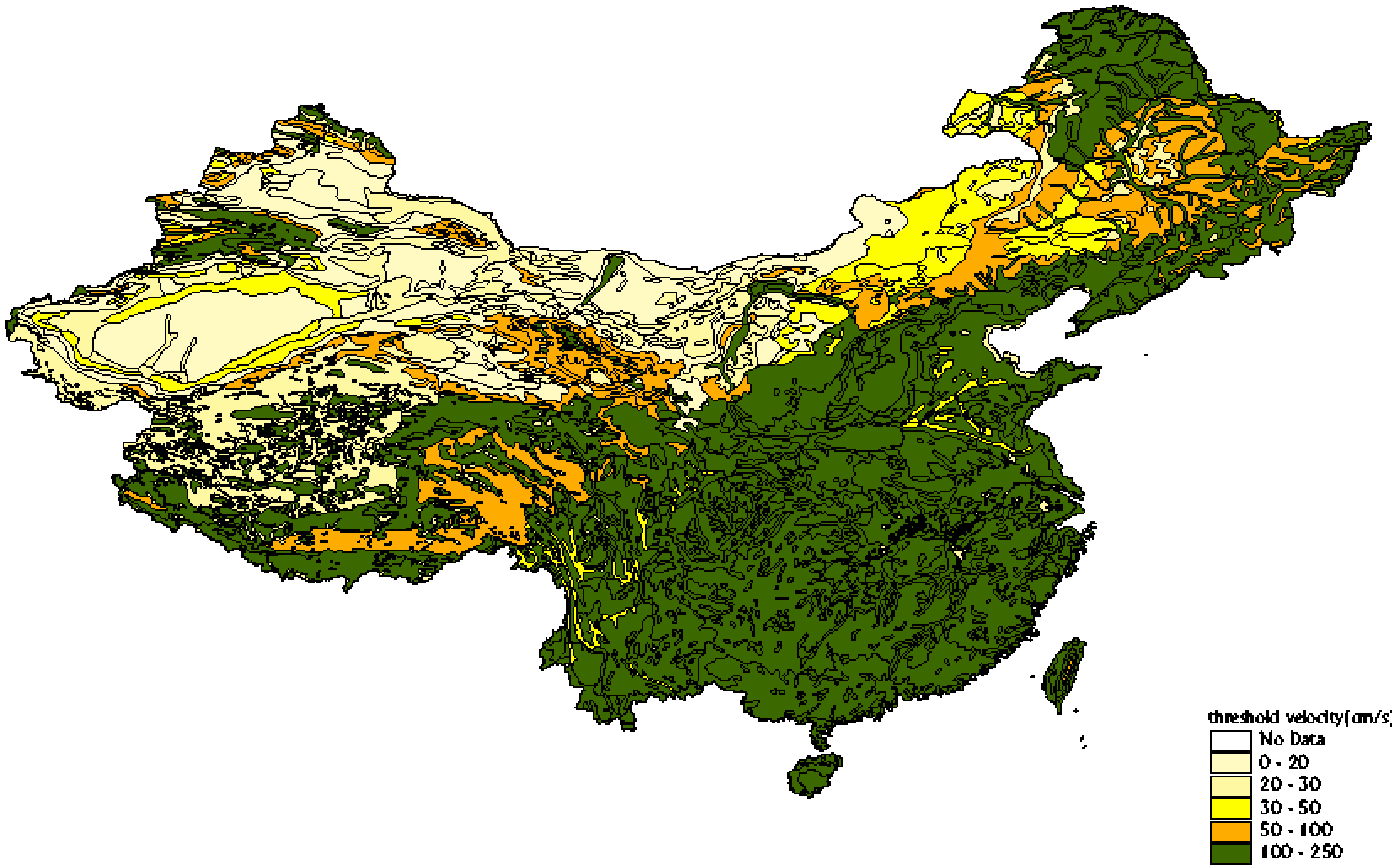


Figure 14:

Threshold Friction Velocity, U_t^* cm/sec

Greenness Map in May

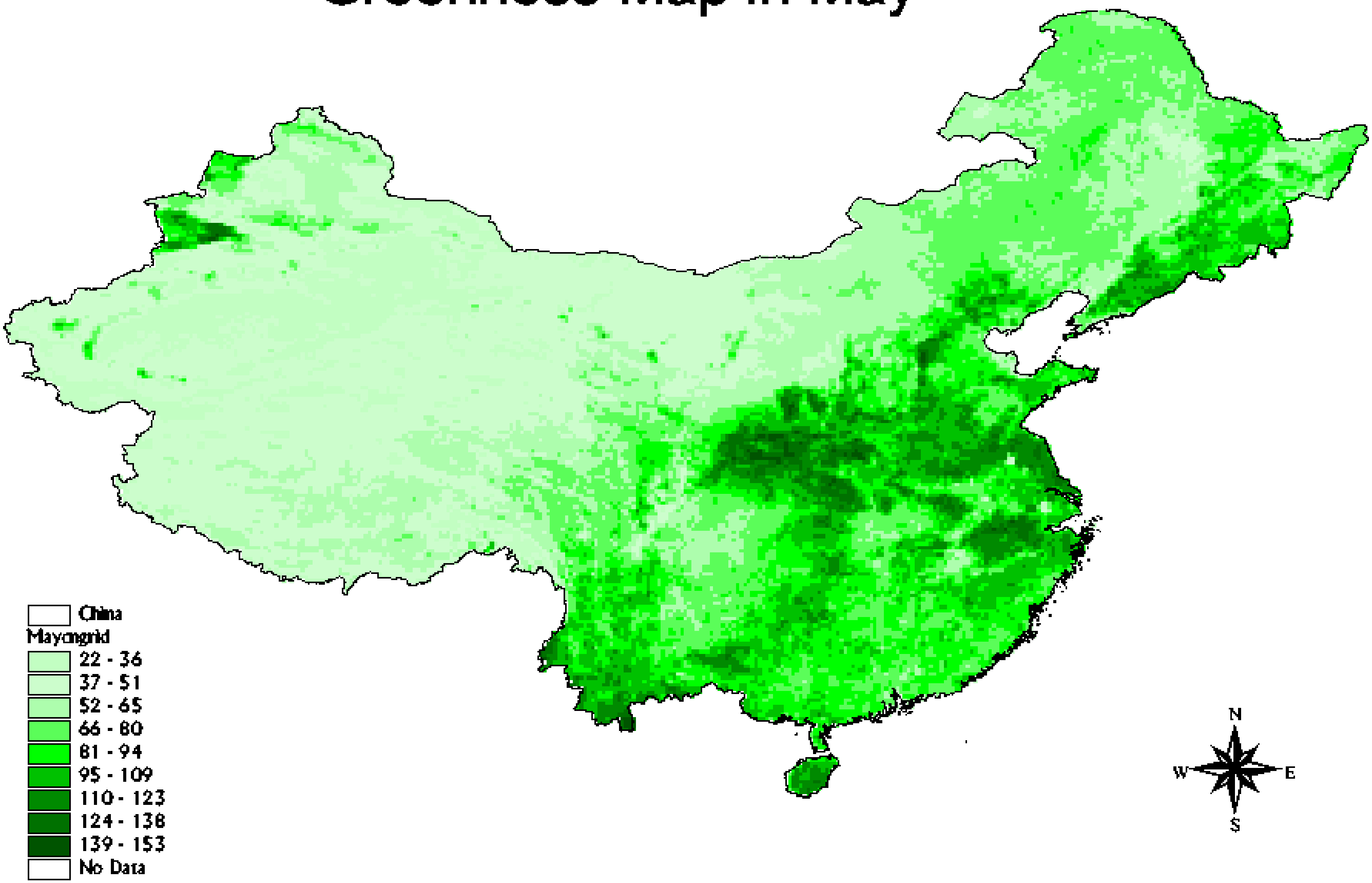


Figure 15:

Greenness Map for the month of May

Threshold Friction Velocity Overlayed with May Greenness Map

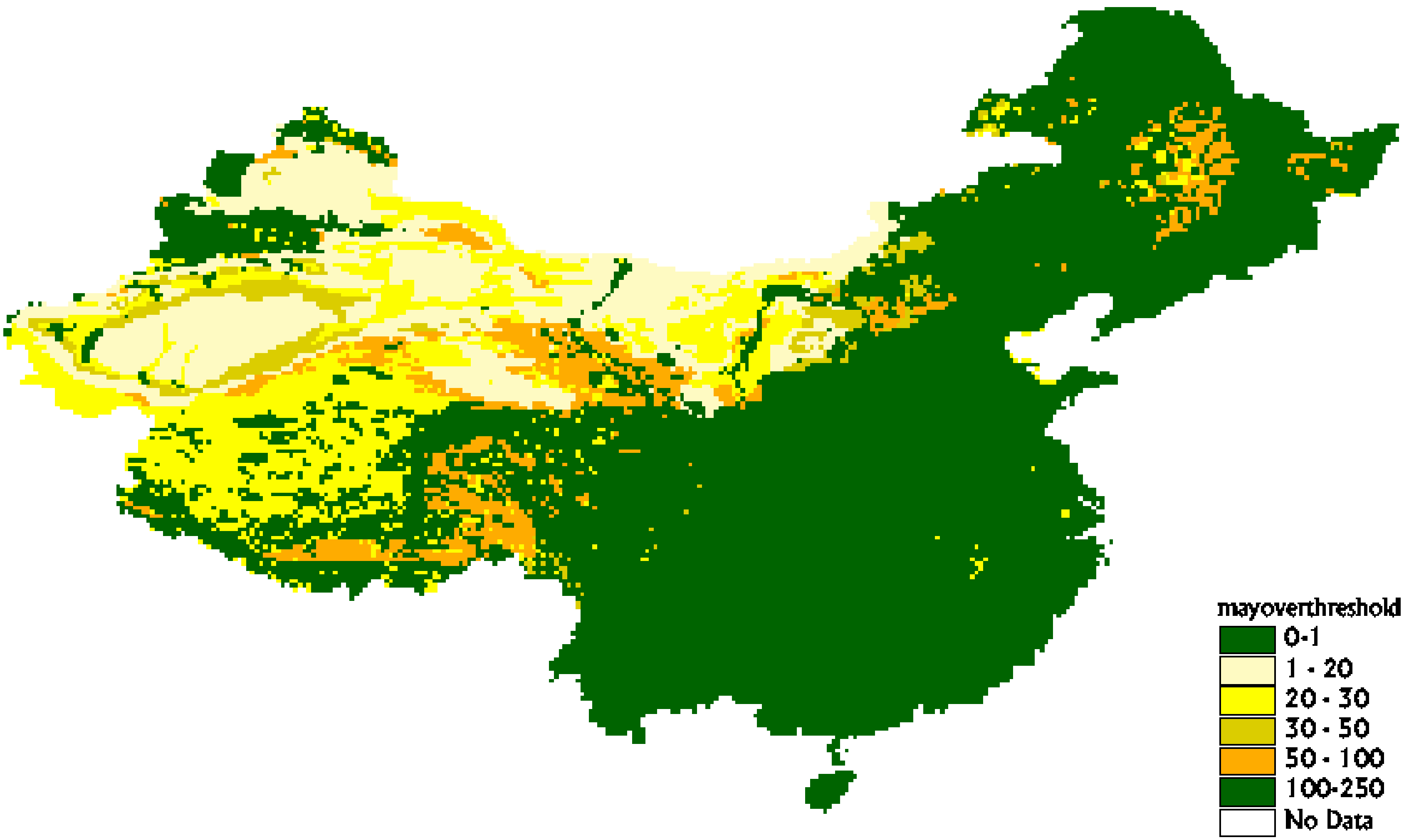


Figure 16:

Threshold Friction Velocity overlayed by the Greenness map for the month of May

Threshold Friction Velocity (1 X 1 Degree)

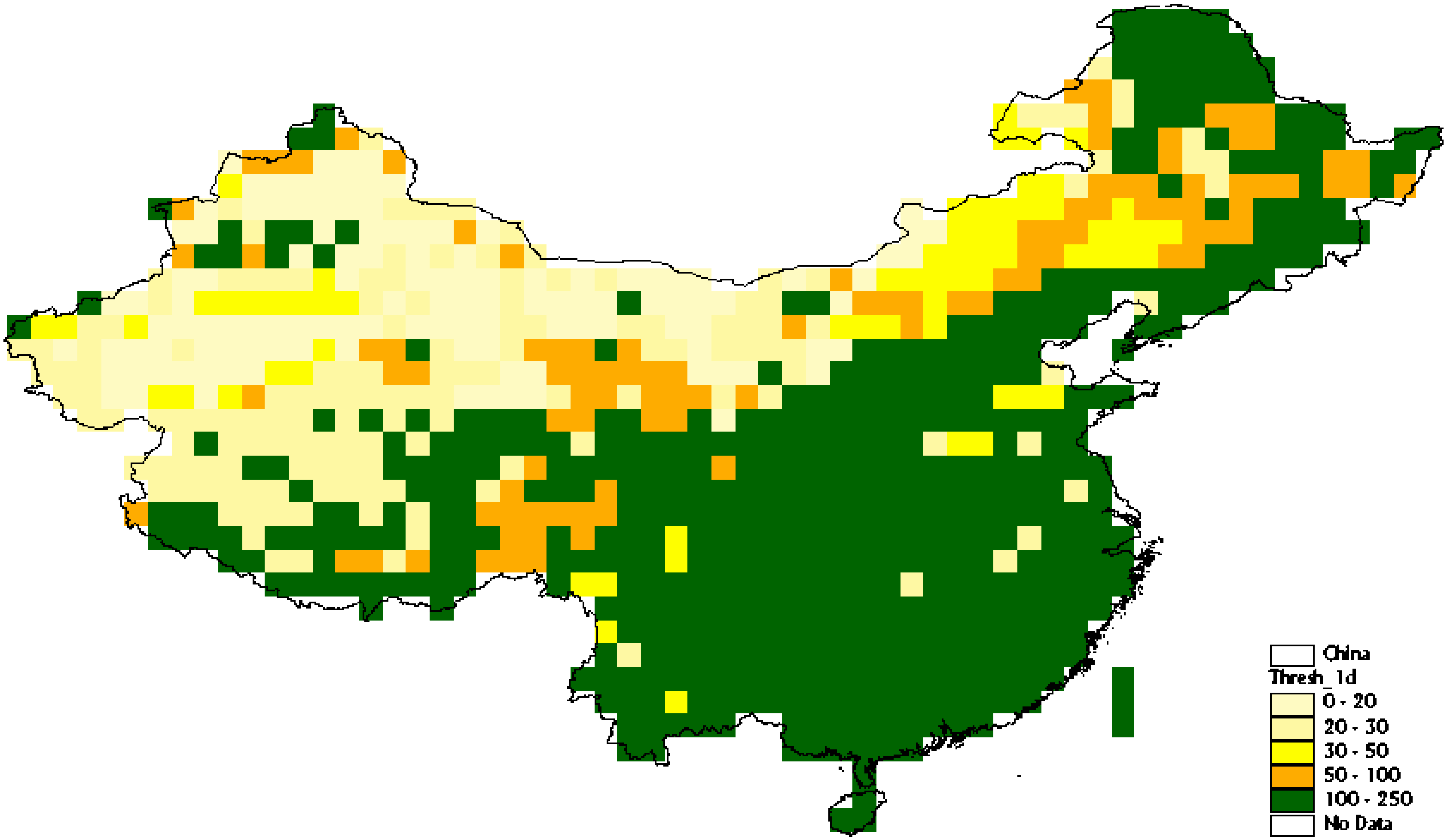


Figure 17:

Gridded Threshold Friction Velocity, cm/sec, 1° by 1° resolution

May Greenness Map (1 X 1 degree)

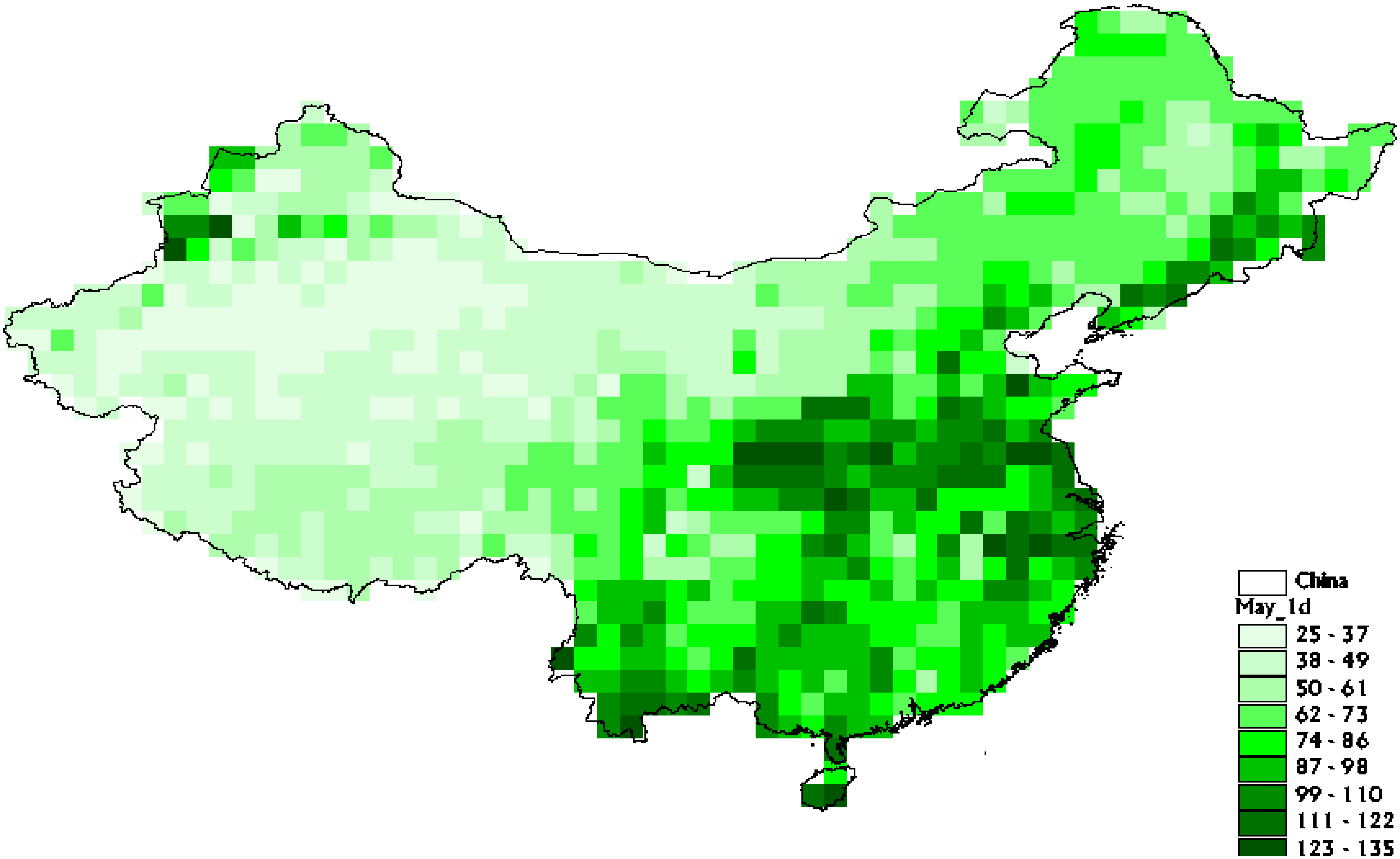


Figure 18:

Gridded Greenness map for the month of May, 1° by 1° resolution

Threshold Friction Velocity Overlayed with May Greenness Map

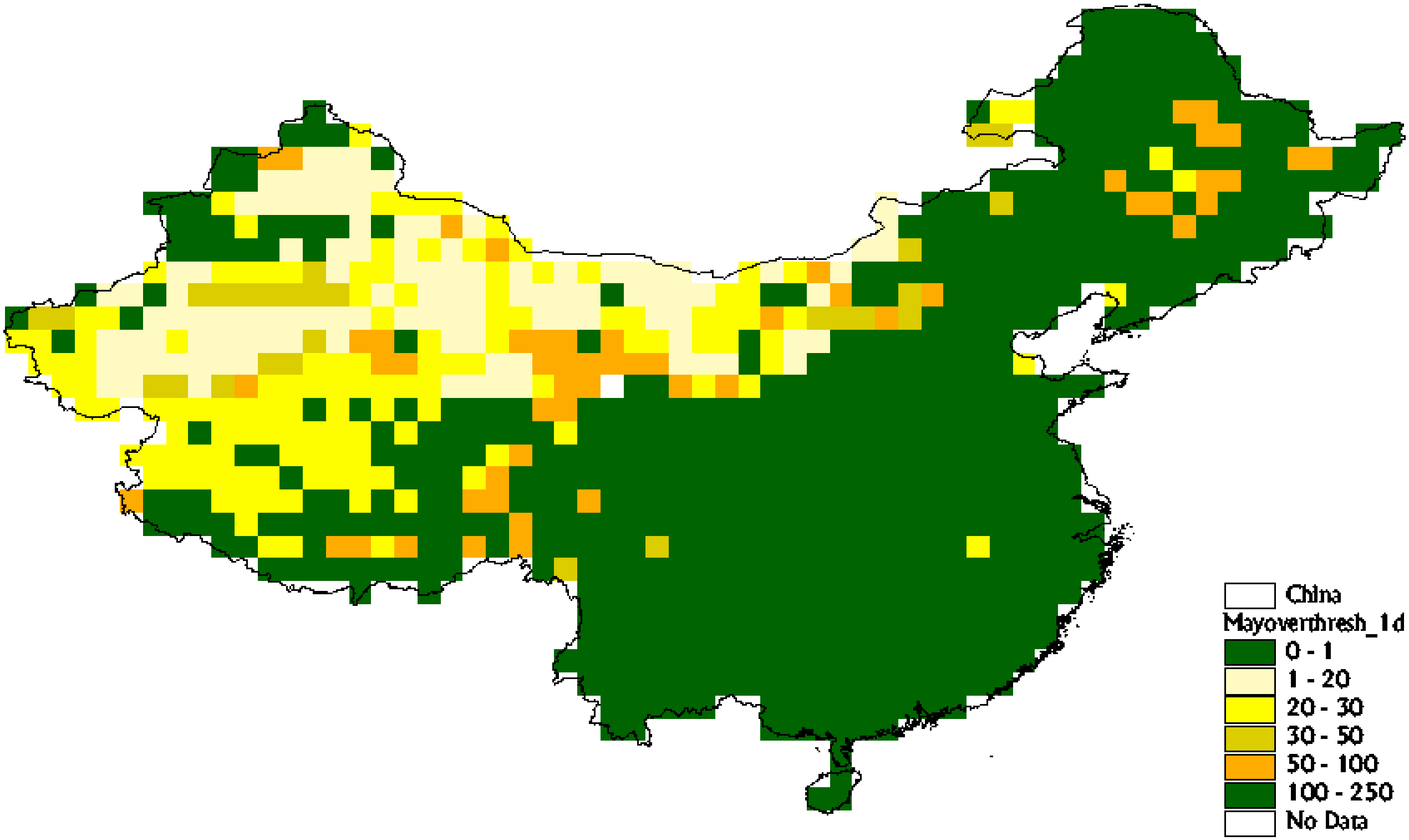


Figure 19:

Gridded Threshold Friction Velocity overlayed by Greenness map for the month of May, 1° by 1° resolution

Calcium (wt %)

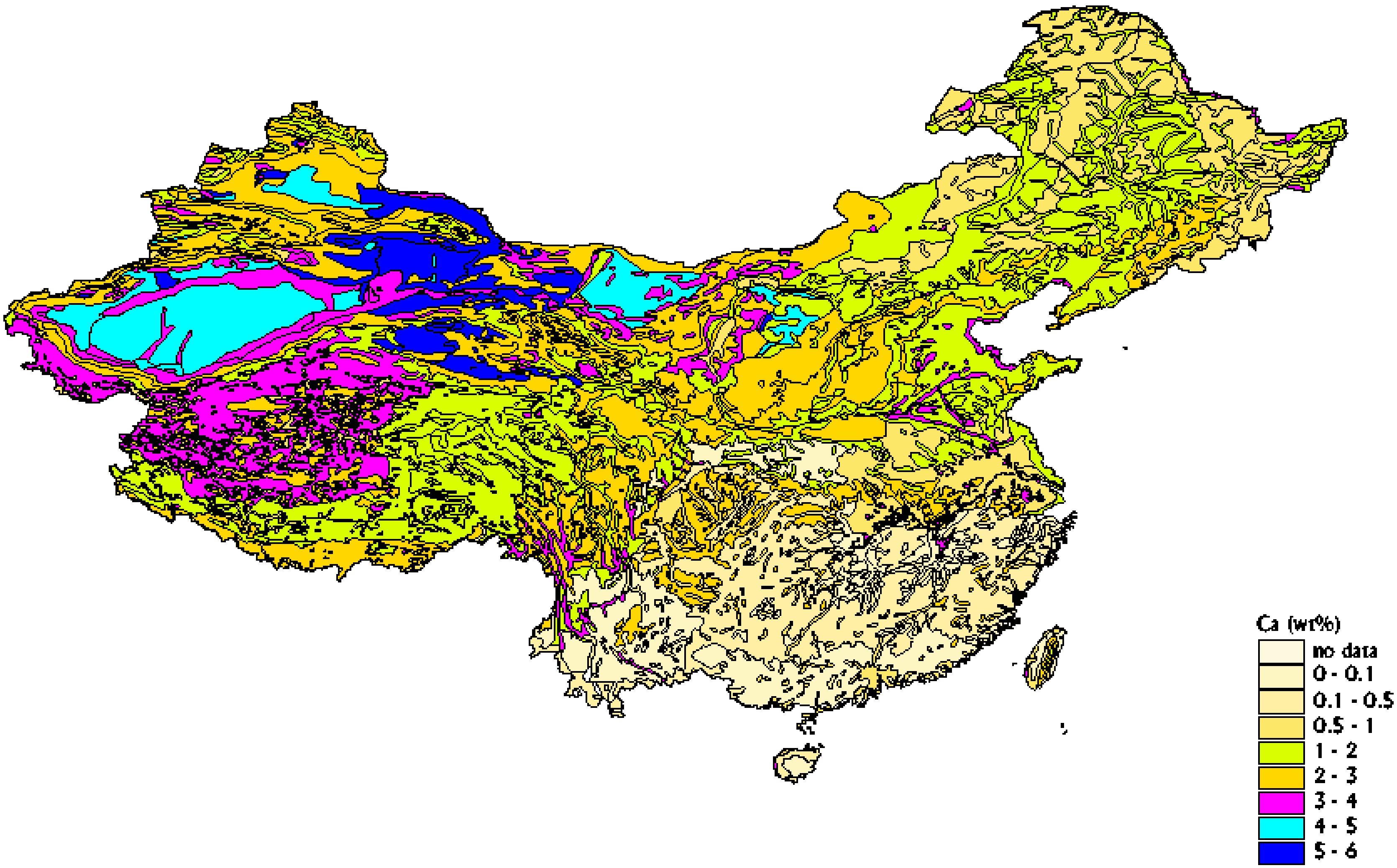


Figure 20:

Percantage of Calcium in Soil