APPENDIX A

Global Anthropogenic Sulfur Emissions for 1985 and 1990

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A.1. INTRODUCTION

For the last several decades the combustion of fossil fuels has been the major source of anthropogenic emissions of oxides of sulfur (SO_x) to the atmosphere (Cullis and Hirschler, 1980, Logan, 1983, Saeger, *et al.*, 1989, Várhelyi, 1985, Wagner, *et al.*, 1986). Coal combustion, especially in large electric and heat power plants, and combustion of residential fuel oil are responsible for most of the emissions.

The sulfur content of fuels, especially in coal, is a major factor affecting SO_x emissions. This content is extremely variable, ranging from less than 1% to about 9%. On average, from 5 to 15% of the sulfur in fuels used in electric and heat generating power plants is retained in bottom and fly ashes. Various types of flue gas desulfurization (FGD) control devices are used to remove SO_x from the exhaust gases, predominantly in power plants in the United States, Canada, Western Europe, Japan and Australia. Crude petroleum is also extremely variable in the sulfur content, ranging from 0.3 to 2%, depending on the location of the petroleum field. In the refining process, most of the sulfur in the crude oil may be recovered; what is not

recovered remains mainly in the residual oil fraction. The processing of sulfur-containing materials (e.g., roasting of ores, sintering plants, etc.), the production of sulfur compounds (e.g., sulfuric acid manufacturing), and the use of sulfur compounds to produce other industrial goods (e.g., cellulose production) generate large amounts of SO_x. Although most of this sulfur may be recovered, not all installations do so; the sulfur that is not recovered is released to the atmosphere.

A.2. GLOBAL ANTHROPOGENIC SULFUR EMISSIONS IN 1985

A global inventory of SO_x emissions from anthropogenic sources for circa 1985 was compiled by an international group under the umbrella of the Global Emissions Inventory Activity (Benkovitz and Graedel, 1992) of the International Global Atmospheric Chemistry Programme (Galbally, 1989). In order to make the inventory useful for modeling atmospheric transport, transformation and removal the emissions were allocated to a $1° \times 1°$ longitude/latitude grid. A gridded global "default" inventory was selected and more accurate gridded and updated regional and national inventories and surrogate information were evaluated and used if appropriate. The regional inventories used include the regional inventories for the United States and Canada to 60°N compiled by the National Acid Precipitation Assessment Program (NAPAP) (Saeger, *et al.*, 1989), EMEP and CORINAIR85 for Europe (Bouscaren, 1992, Sandnes and Styve, 1992), Kato and Akimoto (1992) and Tonooka (personal communication, 1993) for Asia, Carnovale (1992, Horseman and Carnovale, 1989) for Australia, and Loyd (personal communication, 1993) for South Africa. SO_x emissions for other regions of the globe were taken from a "default" inventory which was based on the work by Spiro *et al.* (1992) updated to 1985. Diagrams

of the relationship between the default inventories and the regional inventories used are presented in Figure 1. The work and results are described in Benkovitz *et al.* (1996); the resulting inventory has been designated Version 1A and is intended to serve as a basis for modeling and related activities by the international scientific community.

Global population density maps for 1985 were prepared on a 1° × 1° longitude/latitude grid by Logan (J. Logan, Harvard University, manuscript in preparation, 1995). Each grid cell is labeled with the country (or water area) occupying the major fraction of the area of the cell. The urban population of each country was assigned to specific locations using the longitude/latitude of large cities from Rand McNally (1987), scaling the city populations by the ratio of the urban population to the Rand urban population for each country. The remaining population was distributed over the habitable areas of each country, using a digital data base developed at the NASA Goddard Institute for Space Studies (Lerner, *et al.*, 1988) for the purpose of locating animals. These population density maps were used as surrogates to allocate the default inventory to the 1° × 1° grid and to aggregate the gridded emissions to the per country basis needed for this work. The regional inventories that were received in gridded format may have used additional surrogates to allocate the emissions to the 1° resolution grid; therefore, a small uncertainty is introduced in the per country emissions obtained from aggregating the final gridded inventory using the Logan country code identifiers. This uncertainty is smaller than the uncertainties associated with the emissions estimation.

Table A.2.1 presents the per country estimates of anthropogenic sulfur emissions in 1985 aggregated from the GEIA Version 1A inventory. Global

emissions total is 65.1 Tg S y^{-1}. Emissions are strongly localized in the highly populated and industrialized regions in Eastern North America, and across Europe from the United Kingdom over Central Europe to the Donbas region in Russia. Outside these areas are smaller regions or hot spots with quite large emissions, either in connection with densely populated areas with developed industries, or in connection with exploitation of fuels or mineral reserves. Figure 2 summarizes the latitudinal distribution of the emissions; the increase in emissions at latitude ~68°N is due to non-ferrous metal smelter operations in the Kola Peninsula.

A.3. GLOBAL ANTHROPOGENIC SULFUR EMISSIONS IN 1990

A.3.1 Methodology and Data Sources

A global inventory of anthropogenic sulfur emissions for 1990 is being developed as a collaborative effort between RIVM, Bilthoven, The Netherlands, IMW-TNO, Delft, The Netherlands and Brookhaven National Laboratory, Upton, NY, USA. The Dutch effort is part of the Emission Database for Global Atmospheric Research (EDGAR) project (Baars, *et al.*, 1991, Berdowski, 1992, Olivier, *et al.*, 1994). This section describes the methodologies and data sources used to compile an initial version of the inventory. Additional work is in progress to refine these estimates using more accurate regional inventories.

Anthropogenic sulfur sources were divided into four main source categories: fossil fuel combustion (including peat), biofuel combustion, industrial processes, and land use. Calculations were performed on a per country basis and aggregated to 13 major world regions/countries, as shown in Table A.3.1.1a. Fossil fuel and biofuel combustion calculations were done on a per sector basis, in which the following sectors were distinguished:

industry, commercial, residential, other sector, power generation, other fuel transformation sector (predominantly coke production and refineries), transportation (excluding marine bunkers), and international shipping. The definition of these sector largely follow the sectoral definitions used by the IEA and are summarized in Table A.3.1.1b. Industrial processes consist of metal production (copper, zinc, lead, iron, steel) and the production of sulfuric acid (H_2SO_4). Land use emissions relate to large scale biomass burning (deforestation and savannah burning) as well as local fires (agricultural waste burning).

To illustrate the general methodology and data sources used to develop the emissions estimates, a detailed description of the methodology used to estimate the emissions from the smelting of non-ferrous metals follows.

A.3.1.1. Smelting of Non-Ferrous Metals

Smelting of copper (Cu), lead (Pb), and zinc (Zn) are the main metallurgy industries contributing to sulfur emissions, with Cu the largest contributor. Some of the sulfur in the emissions from these industries is recovered; what is not recovered is released to the atmosphere. The following paragraphs describe how sulfur emissions from primary and secondary copper, lead and zinc smelters were estimated.

The production of copper, lead and zinc for each country was obtained from UN statistics (United Nations, 1992). Emission factors for these processes were computed assuming a simple stoichiometric relationship to give the release of sulfur dioxide (SO_2) in t(S)/t(metal) (Kato and Akimoto, 1992); AP-42 (U.S. Environmental Protection Agency, 1985) and the work of Spiro *et al.* (1992) were also used as sources for the emission factors. For each

country the gross emissions for each metal were calculated by the sum of the product of the UN production figures and the appropriate primary and secondary emission factor.

The Minerals Yearbook published by the US Bureau of Mines (U.S. Department of the Interior, 1992) presents information on the countries which recover sulfur from industrial activities. For the majority of countries listed the yearbook presents reported values for the sulfur recovered from primary metal production; for some countries the recovery values are estimated. For some countries the sulfur recovered was tabulated according to the industrial processes (metallurgy, oil and gas, etc) from which it was recovered; thus recovery from metallurgy was explicitly given. For other countries the values presented were for total sulfur recovered from all sources.

For countries where the sulfur recovered from metallurgy was included in the Minerals Yearbook (U.S. Department of the Interior, 1992) this recovery was allocated to copper, lead and zinc smelting proportional to the gross emissions from primary production of each metal. The countries where the sulfur recovery was not allocated to the various industrial processes included China, North Korea, New Zealand, Pakistan, Taiwan, Zimbabwe, Qatar, and Turkey. With the exception of China, North Korea, and Turkey, metal smelting is not included in a country's industrial processes. For Turkey, the Minerals Yearbook specifies the sulfur recovered from petroleum sources; the recovery labeled 'other sources' was assumed to be from metallurgy.

The sulfur recovery per unit of total oil refining and gas production in Asia and the Pacific regions was computed. In these regions, only Australia, Japan, and India have metal smelters; the regional average recovery rate

(ton/PJ) was calculated using the values for these three countries. The sulfur recovered from the oil and gas industries in China and North Korea was estimated using the average recovery rate and each country's refinery throughput figures. Subtracting this value from the total sulfur recovered yields the recovery from metallurgy.

For each country, the sulfur recovered from metal production is subtracted from the gross emissions for this category to obtain the net emissions.

For some countries the net sulfur emissions calculated were negative. For countries which had explicit data for sulfur recovery from metallurgy in the Minerals Yearbook (U.S. Department of the Interior, 1992), reasons for the negative values might be: a) an incomplete time series of estimated metal production values might result in an underestimation of the metal production and thus of gross emissions; b) the sulfur content of ores used in the individual countries may have been higher than the stoichiometric ratio on which the emission factors were calculated, thus underestimating gross emissions; c) the sulfur recovery from 'Metallurgy' might have been related to a group of activities larger than primary metal production (i.e., it may also include recovery from secondary production of these metals); and d) an error may have occurred in either metal production and/or sulfur recovery data. Negative emissions were obtained in India, Mexico, North Korea, the Netherlands, and the Philippines. Regional NET emission factors were computed based on the net emissions and production figures for all other countries; the appropriate regional factor was applied to estimate the net emissions directly in those countries where emissions estimates had resulted in negative values.

For countries which did not have explicit data for sulfur recovery from

metallurgy in the Minerals Yearbook (U.S. Department of the Interior, 1992) the negative values could be due to: a) derived estimates for sulfur recovery from oil and gas and/or for recovery from metallurgy that were very different from the values used; or b) same reasons presented in the preceding paragraph. For these countries, regional recovery rates per unit refining/production were calculated for sulfur recovery from oil refining and gas and then applied to the oil and gas production data to yield the oil and gas recovery. Subtracting this number from the total sulfur recovery yielded metallurgy component. For a subset of these countries the sulfur recovered from oil and gas exceeded the total sulfur recovered. For these countries, a regional sulfur recovery rate for metallurgy was computed first. If this estimate was smaller than the total sulfur recovery for the country, the difference was taken to be the sulfur recovered from oil and gas industries. If the estimate was larger than the total sulfur recovery, all the recovery was assumed to be from metallurgy and net emissions were adjusted accordingly.

Some of the sulfur recovered is used for the production of sulfuric acid (H_2SO_4); a small fraction of this sulfur is not converted into H_2SO_4 but is emitted into the atmosphere. Kato and Akimoto (1992) estimate that between 2 and 5% of the sulfur input is emitted to the atmosphere; this amount depends upon the efficiency of the conversion to SO_3. AP-42 (U.S. Environmental Protection Agency, 1985) presents a linear relationship to determine the emission factor of the SO_2 from sulfuric acid plants as a function of the above conversion. Kato and Akimoto (1992) quote 98% conversion efficiency for Japan, 97% for South Korea and 95.5% for the other Asian countries; these figures take into account the difference in the efficiency of plants and the fuel gas emission control. A similar high conversion efficiency of 98% can

also be assumed for most of the countries in western Europe, for the US and for Canada. The sulfuric acid production was obtained from the UN statistics (United Nations, 1992) and the emissions from sulfuric acid production were calculated. These values were added to the net emissions from metallurgy to give total sulfur emissions from this sector.

A.3.2 Emissions in the United States, Canada and Western European countries.

The methodologies used to develop these initial estimates do not account completely for the high levels of emissions control that are in effect in the industrialized areas of the world. Therefore, data from the following inventories should be considered more appropriate for the geographic areas covered: for the United States the U.S. Environmental Protection Agency (EPA) 1990 Interim Inventory (1993); for Canada the inventory compiled by the Pollution Data Analysis Division of Environment Canada (M. Deslauries, personal communication, 1995); for European countries the CORINAIR 90 inventory (G. McInnes, European Environment Agency, personal communication, 1995); and the inventory prepared for the Long Term Ozone Simulation Model (LOTOS) (Berdowski and Zandveld, 1995). The European inventories do not include the same countries; in the areas where they overlap the different estimates are currently being studied.

A.3.3. Initial Results

An overall summary of the 1990 global SO_2 emissions from anthropogenic activities by main source category and sector is presented in Table A.3.3.1a. Table A.3.3.1b presents emissions on a by-country basis. This table also includes emission estimates from the regional inventories described in Section

3.3.2. In estimating the emissions from European countries the EDGAR and LOTOS systems addressed the pre-1990 countries, (for example, Czechoslovakia), while the CORINAIR90 addressed the post-1990 countries (Czech Republic and Slovakia). Global total emissions are estimated at 75 TgS/year using the EDGAR values and at 71 TgS/year using estimates from regional inventories.

The following studies were developed using the EDGAR estimates because the sectoral resolutions needed were not always available from the regional inventories. The principal characteristics of SO_2 emissions from anthropogenic sources are presented in Table A.3.3.2, where emissions are reported for each main region and for each main source category. Fossil fuel combustion is the main contributing source category, at almost 80% of the anthropogenic global total, with more than half of these emissions originating in the USA, OECD Europe, the former USSR, and China regions. Industrial processes are the second largest contributing source category with 15% of global total, followed by land use at 5% and biofuels use at 1%. In the Latin America and Africa regions emissions from fossil fuel use account for less than 50% of the regional total due to the high contribution of land use and industrial emissions. Emissions from industrial processes are also important in the Oceania region; emissions from land use also have a relatively high contribution to regional emissions in the India region.

Table A.3.3.3 SO_2 presents emissions from the fossil fuel use source category by sector and region. The power generation sector is the largest contributor to emissions from this source category at 48% of the total followed by the industrial sector at 25%. This is the result of the high consumption of coal in these sectors, making coal combustion the highest contributor to emissions from fossil fuel use source category. The aggregate

statistics for the 'Commercial', 'Residential' and 'Other' sectors are often not well separated; this could result in the relatively low contribution from these three sectors to the emissions from the fossil fuel use source category.

About 70% of global emissions from the fossil fuel use source category originate in four regions: USA, OECD Europe, former USSR and China. The China region contributes about 30% of the global emissions from industrial use of fossil fuels and over 50% to the global emissions from residential use of fossil fuel. Due to the high consumption of coal and/or the high effective emission factors for coal combustion, the power generation sector contributes 60 to 70% of the total regional emissions for this source category in the Canada, USA, Eastern Europe, and Oceania regions. Coal consumption in the industrial and residential sectors in the China region is relatively high; these sectors contribute about 40% and 15% respectively of the regional emissions from the fossil fuel use source category. For the India and Japan regions the transportation sector has a relatively high contribution of about 15% to the regional emissions from the fossil fuel use source category, which is probably the result of high coal consumption in rail transport. The use of heavy fuel oils with high sulfur content as marine bunker fuels predominates over other fuels; combustion of these fuels accounts for about 5% of the global emissions from the fuel use source category. In the Middle East and East Asia regions marine bunkers contribute a relatively high 15% to the regional emissions from fossil fuel use, the result of a very high consumption of bunker fuel in the United Arab Emirates and Singapore.

Biofuel combustion is only a minor source compared to the other three main source categories. Table A.3.3.4 presents the distribution of emissions from this category by sector and by region. The total global energy output

from biofuels has been estimated at 49.5 EJ (Hall *et al.*, 1994); about 78% is assumed to be used in the residential sector where fuel wood is the dominant type. The remaining 22% is related to industrial consumption, mostly in the form of wastes. We can clearly distinguish two groups of regions in the industrial and residential sectors using biofuels, developed regions and less developed regions. Developed regions contribute at least 80% to regional biofuel emissions. About 50% of the global emissions from biofuels originates from industry in the OECD Europe and USA regions (each about 25%), while residential emissions in the India and China regions together contribute another quarter (17% and 10%, respectively). The 58% relative contribution of the industrial sector to emissions from biofuel use is much higher than the fraction of biofuel consumption in this sector; the high contribution is the result of the higher emission factors for non-woody biofuels. For example, black liquor used in the Canada, OECD Europe and Oceania regions has a very high emission factor of 1000 g/GJ as compared with 5 g/GJ for fuel wood.

Table A.3.3.5. presents emissions from the industrial processes source category by sector and region. More than 50% of emissions from this source category stem from primary and secondary copper production; the production of zinc contributes another 20% and the production of H_2SO_4 contributes another 15% to these emissions. Copper production in the Latin America, OECD Europe and the former USSR regions contribute about 30% of the emissions from the industrial processes source category. Production of H_2SO_4 accounts for approximately 50% of the regional emissions in the India region. Iron and steel, although regionally important as in the case of Japan, are minor sources of emissions from the industrial processes source category. Except for zinc production in the OECD Europe region, copper production in the USA

and China regions, and zinc and H_2SO_4 production in the former USSR region, which contribute about 5% each to the emissions from the industrial processes source category, the remaining emissions from this category are scattered over various sectors and regions.

Emissions from the land use sector, presented in Table A.3.3.6, stem from large scale biomass burning and agricultural waste burning with a global ratio of 2/3 and 1/3. Biomass burning occurs predominantly in the Africa and Latin America regions, where deforestation and savannah burning together contribute about 40% and 20%, respectively, to global emissions from the land use sector. Approximately 35% of emissions from agricultural waste burning originate in the India and China regions.

In general the distribution of global SO_2 emissions is largely dependent on the local economic structure and availability of resources, whether it is the use of coal, the production of metals, or regional agricultural practices. Although in a number of regions emission reduction technologies are being applied to some extent in the use of coal for power generation, in the iron and steel industry, and in copper production, these sectors contribute about 66.7% of global SO_2 emissions from anthropogenic sources.

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Table A.2.1 SO_2 Emissions from Anthropogenic Activities in 1985

Country	Emissions (metric tons S)	Country	Emissions (metric tons S)
AFGHANISTAN	4,240	EGYPT	279,500
ALBANIA	28,407	EL SALVADOR	7,214
ALGERIA	130,775	EQ GUINEA	40
ANGOLA	2,992	ETHIOPIA	6,928
ANTIGUA	211	FALKLAND	37
ARGENTINA	208,977	FAROE I.	590
AUSTRALIA	805,465	FIJI	500
AUSTRIA	116,250	FINLAND	261,845
BAHAMAS	14,705	FRANCE	625,466
BAHRAIN	71,000	FRGUIANA	472
BANGLADESH	26,696	FRPOLYNE	574
BARBADOS	3,376	GABON	3,619
BELGIUM	196,616	GAMBIA	95
BELIZE	125	GHANA	11,581
BENIN	561	GREECE	268,163
BERMUDA	744	GREENLAND	87
BHUTAN	236	GRENADA	5
BOLIVIA	8,304	GUADELPE	1,185
BOTSWANA	11,016	GUATEMALA	11,595
BRAZIL	1,187,697	GUINEA	3,341
BRUNEI	700	GUINEA-B	296
BULGARI	316,960	GUYANA	4,588
BURKINA	829	HAITI	1,529
BURMA	17,300	HONDURAS	3,801
BURUNDI	368	HONG KONG	72,000
CAFRREP	263	HUNGARY	670,067
CAMEROON	6,651	ICELAND	2,028
CANADA	1,799,512	INDIA	1,411,267
CAPE VERDE	152	INDONESI	217,950
CHAD	260	IRAN	572,680
CHILE	1,088,383	IRAQ	159,996
CHINA	9,037,328	IRELAND	61,046
COLOMBIA	65,798	ISRAEL	141,518
COMOROS	40	ITALY	1,038,335
CONGO	7,677	IVORY COAST	12,727
COOK ISLAND	2	JAMAICA	28,075
COSTA RICA	4,098	JAPAN	438,262
CUBA	119,066	JORDAN	21,222
CYPRUS	12,174	KAMPUCHEA	1,358
CZECHSLOVAKIA	1,017,013	KENYA	20,486
DENMARK	154,430	KIRIBATI	2
DJIBOUTI	5,786	KUWAIT	196,875
DOMINICA	22	LAOS	3,384
DOMREP	28,072	LEBANON	22,145
ECUADOR	41,510	LESOTHO	38
EGERMAN	2,210,679	LIBERIA	2,738

Table A.2.1 SO_2 Emissions from Anthropogenic Activities in 1985

Country	Emissions (metric tons S)	Country	Emissions (metric tons S)
LIBYA	71,804	SEYCHELLES	378
LIECHTENTEIN	3,162	SIERRA LEONE	3,400
LUXEMBURG	6,284	SINGAPORE	82,375
MADAGASCAR	3,415	SOLOMONI	26
MALAWI	1,664	SOMALIA	2,994
MALAYSIA	125,694	SOUTH AFRICA	930,659
MALDIVES	8	SOUTH KOREA	444,410
MALI	478	SPAIN	1,141,738
MALTA	7,270	SRI LANKA	11,805
MARTINIQUE	3,868	ST LUCIA	28
MAURITANIA	694	STCHRS-N	5
MAURITIUS	2,108	STVINC&G	4
MEXICO	1,314,600	SUDAN	8,476
MONGOLIA	41,296	SURINAM	3,631
MOROCCO	80,430	SWAZILAN	4,037
MOZAMBIQUE	3,860	SWEDEN	137,043
N. CALEDONIA	7,004	SWITZERLAND	16,338
NAMIBIA	51,650	SYRIA	226,163
NANTILLE	38,030	TAIWAN	340,083
NAURU	579	TANZANIA	7,592
NEPAL	4,830	THAILAND	252,103
NETHERLANDS	151,190	TOGO	800
NEW ZEALAND	55,819	TONGA	4
NICARAGUA	5,881	TRINIDAD & TOBAGO	20,295
NIGER	1,806	TUNISIA	50,866
NIGERIA	26,082	TURKEY	479,122
NORTH KOREA	263,564	TURKS&C.	0
NORWAY	51,279	TUVALU	0
OMAN	8,050	U.K.	1,878,465
PAKISTAN	180,116	U.S.A.	10,784,072
PALESTIN	11,315	UARABEMI	37,389
PANAMA	23,953	UGANDA	1,456
PAPUANG	5,110	URUGUAY	11,597
PARAGUAY	3,145	USSR/TOTAL	12,264,932
PERU	493,723	VANUATU	456
PHILIPPINES	247,952	VENEZUELA	459,956
POLAND	2,086,481	VIETNAM	21,900
PORTUGA	96,354	W.SAHARA	245
QATAR	7,365	W.SAMOA	42
REUNION	171	WGERMAN	1,114,631
ROMANIA	767,629	YEMEN/NORTH	1,447
RWANDA	972	YEMEN/SOUTH	33,365
SAN MARTIN	1,719	YUGOSLAVIA	759,165
SAOTOME&	3	ZAIRE	1,027,972
SAUDI ARABIA	499,174	ZAMBIA	147,914
SENEGAL	7,174	ZIMBABWE	99,462

Table A.2.1 SO_2 Emissions from Anthropogenic Activities in 1985

Country	Emissions (metric tons S)	Country	Emissions (metric tons S)

Total 65,056,490

Table A.3.1.1a. Definition of World Regions in EDGAR[1] Project.

EDGAR Region	Description/list of countries
A: CANADA	Canada
B: USA	USA
C: LATIN AMERICA	Central and South America
D: AFRICA	Africa
E: OECD EUROPE	European Union (15), Iceland, Norway, Switzerland, excluding Turkey (allocated in 'Middle East')
F: EASTERN EUROPE	Former Centrally Planned Europe: Albania, Bulgaria, former Czechoslovakia, Hungary, Poland, Romania, former Yugoslavia
G: CIS (FORMER USSR)	Former USSR
H: MIDDLE EAST	Afghanistan, Bahrain, Cyprus, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, Turkey, United Arab Emirates, Yemen (united)
I: INDIA REGION	Bangladesh, Bhutan, India, Maldives, Myanmar (former Burma), Nepal, Pakistan, Sri Lanka
J: CHINA REGION	China, Hong Kong, Kampuchea (former Cambodia), North Korea (Dem. People's Rep.), Laos, Macau, Mongolia, Vietnam
K: EAST ASIA	Brunei, Indonesia, South Korea (Rep. of), Malaysia, Papua New Guinea, Philippines, Thailand, East Timor
L: OCEANIA	Australia, New Zealand, minor Pacific islands
M: JAPAN	Japan

[1] Emission Database for Global Atmospheric Research (EDGAR) (Baars *et al.*, 1991; Berdowski, 1992; Oliver *et al.*, 1994).

Table A.3.1.1b. Definition of Sectors Used in EDGAR for Fuel and Biofuels Combustion Source Categories

EDGAR	IEA[1]	Remarks
Industry	Industry	Excluding the energy sector (e.g. power generation, refineries)
Commercial	Commercial	Commecial and public services
Residential	Residential	Household dwellings
Other	Other end-use sectors	IEA sub-sectors 'Agriculture' and 'Other-Non-Specified'
Transport	Transport	Road, rail, air, and water transport, excluding marine bunkers
International ships	Marine bunkers	
Power plants	Electricity	Public electricity, autoproducers of generation electricity, CHP plants
Other transf.	Other fuel	Refineries, coke ovens, blast furnaces, transformation gas works, district heating, etc.

[1] International Energy Agency.

Table A.3.3.1a. Summary of Anthropogenic SO_2 Emissions in 1990

Sector	Emissions (metric tons S)	Subtotals
Power generation	28,440,000	
Fossil fuel combustion		
Commercial	1,426,000	
Residential	3,334,000	
Others	1,843,000	
Other transformation (coke & refineries)	5,421,000	
Traffic		
International shipping	2,465,000	
All transport excl. international shipping	1,402,000	
Industry		
Combustion of fossil fuels	15,080,000	59,411,000
Production processes		
Copper smelters	6,689,000	
Lead smelters	388,300	
Zinc smelters	2,165,000	
Iron & steel industry	434,200	
Misc industial processes (H_2SO_4, etc.)	1,750,000	11,426,500
Biofuel combustion		
Industrial	476,800	
Residential	339,700	
Other	1,323	817,823
Deforestation & savannah burning	2,596,000	
Agricultural waste burning	1,263,000	3,859,000
Grand total	75,514,323	

Table A.3.3.1b. SO_2 Emissions from Anthropogenic Activities in 1990 (metric ton S)

Code	Country	EDGAR	LOTOS	Regional	Best Estimate
AFG	afghanistan	36,897			36,897
ALB	albania	36,523	55,900		55,900
DZA	algeria	93,430			93,430
ASM	american samoa	456			456
AGO	angola	147,610			147,610
AIA	anguilla	1			1
ATG	antigua and barbuda	1,073			1,073
ARG	argentina	173,568			173,568
ABW	aruba	4			4
AUS	australia	689,131			689,131
AUT	austria	112,836	86,219	46,500	46,500
BHS	bahamas	4,823			4,823
BHR	bahrain	19,134			19,134
BGD	bangladesh	52,454			52,454
BRB	barbados	3,215			3,215
BEL	belgium	1,116,896	181,281	153,500	153,500
BLZ	belize	2,513			2,513
BEN	benin	13,733			13,733
BMU	bermuda	2,138			2,138
BTN	bhutan	962			962
BOL	bolivia	52,455			52,455
BWA	botswana	77,881			77,881
BRA	brazil	1,135,448			1,135,448
VGB	british virgin islands	267			267
BRN	brunei	1,117			1,117
BGR	bulgaria	926,645	751,192	1,004,000	1,004,000
BFA	burkina faso	23,541			23,541
BDI	burundi	11,708			11,708
CMR	cameroon	38,948			38,948
CAN	canada	1,470,391		1,470,371	1,470,371
CPV	cape verde	271			271
CYM	cayman islands	803			803
CAF	central african republic	84,589			84,589
TCD	chad	49,295			49,295
CHL	chile	1,134,492			1,134,492
CHN	china	11,543,018			11,543,018

Table A.3.3.1b. SO_2 Emissions from Anthropogenic Activities in 1990 (metric ton S)

Code	Country	EDGAR	LOTOS	Regional	Best Estimate
COL	colombia	123,505			123,505
COM	comoros	527			527
COG	congo	15,267			15,267
COK	cook islands	1			1
CRI	costa rica	16,425			16,425
CIV	cote d'ivoire (ivory coast)	73,565			73,565
	croatia			90,000	90,000
CUB	cuba	157,859			157,859
CYP	cyprus	17,841			17,841
	czech republic			931,500	931,500
CSK	czechoslovakia	1,080,981	1,048,602		1,048,602
DNK	denmark	130,362	106,739	99,000	99,000
DJI	djibouti	3,512			3,512
DMA	dominica	272			272
DOM	dominican republic	21,744			21,744
ECU	ecuador	49,716			49,716
EGY	egypt	323,632			323,632
SLV	el salvador	10,955			10,955
GNQ	equatorial guinea	1,279			1,279
	estonia			137,500	137,500
ETH	ethiopia	89,427			89,427
FJI	fiji	2,555			2,555
FIN	finland	272,689	106,986	113,500	113,500
FRA	france	978,970	562,705	650,000	650,000
GUF	french guiana	2,812			2,812
PYF	french polynesia	2,047			2,047
GAB	gabon	11,164			11,164
GMB	gambia	907			907
DEU	german fed republic	930,459		456,000	456,000
DDR	german democratic repub	2,596,854	2,173,848	2,172,500	2,172,500
GHA	ghana	38,347			38,347
GIB	gibraltar	10,286			10,286
GRC	greece	409,316	290,672	320,500	320,500
GRD	grenada	539			539
GLP	guadeloupe	3,788			3,788
GUM	guam	4,759			4,759

Table A.3.3.1b. SO_2 Emissions from Anthropogenic Activities in 1990 (metric ton S)

Code	Country	EDGAR	LOTOS	Regional	Best Estimate
GTM	guatemala	17,456			17,456
GIN	guinea	19,229			19,229
GNB	guinea-bissau	3,044			3,044
GUY	guyana	6,596			6,596
HTI	haiti	3,588			3,588
HND	honduras	12,918			12,918
HKG	hong kong	121,093			121,093
HUN	hungary	328,406	318,173	452,500	452,500
ISL	iceland	2,029			2,029
IND	india	2,155,707			2,155,707
IDN	indonesia	338,508			338,508
IRN	iran, islamic republic of	574,951			574,951
IRQ	iraq	146,915			146,915
NTZ	iraq-saudi arabia n. zone	6,579			6,579
IRL	ireland	105,562	96,366	89,000	89,000
ISR	israel	143,153			143,153
ITA	italy	1,353,753	1,136,396	1,126,500	1,126,500
JAM	jamaica	170,603			170,603
JPN	japan	1,549,205			1,549,205
JOR	jordan	37,383			37,383
KHM	kampuchea (cambodia)	12,682			12,682
KEN	kenya	53,705			53,705
KIR	kiribati	4			4
PRK	korea, north	708,562			708,562
KOR	korea, south	1,158,910			1,158,910
KWT	kuwait	92,083			92,083
LAO	lao peoples dem repub	13,883			13,883
	latvia			57,500	57,500
LBN	lebanon	25,935			25,935
LSO	lesotho	350			350
LBR	liberia	20,316			20,316
LBY	libyan arab jamahiriya	76,563			76,563
	lithuania			111,000	111,000
LUX	luxembourg	14,178	11,262	7,000	7,000

Table A.3.3.1b. SO_2 Emissions from Anthropogenic Activities in 1990 (metric ton S)

Code	Country	EDGAR	LOTOS	Regional	Best Estimate
MAC	macau	3,681			3,681
MDG	madagascar	25,618			25,618
MWI	malawi	4,468			4,468
MYS	malaysia	161,620			161,620
MDV	maldives	242			242
MLI	mali	44,547			44,547
MLT	malta	10,651		3,000	3,000
MTQ	martinique	4,826			4,826
MRT	mauretania	29,203			29,203
MUS	mauritius	3,866			3,866
MEX	mexico	1,064,054			1,064,054
MNG	mongolia	28,307			28,307
MSR	montserrat	1			1
MAR	morocco	108,753			108,753
MOZ	mozambique	74,447			74,447
MMR	myanmar (former burma)	51,417			51,417
NAM	namibia	70,344			70,344
NRU	nauru	453			453
NPL	nepal	8,229			8,229
NLD	netherlands	101,440	101,440	100,500	101,440
ANT	netherlands antilles	69,800			69,800
NCL	new caledonia	4,989			4,989
NZL	new zealand	48,313			48,313
NIC	nicaragua	14,038			14,038
NER	niger	31,684			31,684
NGA	nigeria	153,125			153,125
NOR	norway	78,992	26,598	27,000	27,000
OMN	oman	17,271			17,271
PAK	pakistan	155,958			155,958
PAN	panama	35,074			35,074
PNG	papua new guinea	16,273			16,273
PRY	paraguay	20,451			20,451
PER	peru	285,810			285,810
PHL	philippines	300,004			300,004
POL	poland	1,940,145	1,389,848	1,636,500	1,636,500
PRT	portugal	173,470	133,428	141,500	141,500

Table A.3.3.1b. SO_2 Emissions from Anthropogenic Activities in 1990 (metric ton S)

Code	Country	EDGAR	LOTOS	Regional	Best Estimate
PRI	puerto rico	360			360
QAT	qatar	5,093			5,093
REU	reunion	3,653			3,653
ROM	romania	736,982	698,576	655,500	655,500
RWA	rwanda	9,475			9,475
STP	sao tome & principe	249			249
SAU	saudi arabia	403,441			403,441
SEN	senegal	30,245			30,245
SYC	seychelles	487			487
SLE	sierra leone	10,848			10,848
SGP	singapore	424,806			424,806
	slovakia			271,000	271,000
	slovenia			98,000	98,000
SLB	solomon islands	474			474
SOM	somalia	25,724			25,724
ZAF	south africa	977,303			977,303
ESP	spain	1,100,719	699,206	1,103,000	1,103,000
LKA	sri lanka	20,749			20,749
SHN	st helena	1			1
KNA	st kitts & nevis (st christop	270			270
LCA	st lucia	535			535
VCT	st vincent & the grenadine	275			275
SPM	st-pierre & miquelon	267			267
SDN	sudan	173,483			173,483
SUR	suriname	9,168			9,168
SWZ	swaziland	200			200
SWE	sweden	225,204	52,282	52,500	52,500
CHE	switzerland	38,987	33,019	22,000	22,000
SYR	syrian arab republic	92,860			92,860
TWN	taiwan	476,621			476,621
TZA	tanzania, united republic	107,246			107,246
THA	thailand	360,934			360,934
TMP	timor timur (east timor)	49			49

Table A.3.3.1b. SO_2 Emissions from Anthropogenic Activities in 1990 (metric ton S)

Code	Country	EDGAR	LOTOS	Regional	Best Estimate
TGO	togo	9,843			9,843
TON	tonga	232			232
TTO	trinidad and tobago	7,417			7,417
TUN	tunesia	101,386			101,386
TUR	turkey	761,005			761,005
TCA	turks & caicos islands	1			1
TUV	tuvalu	1			1
UGA	uganda	35,838			35,838
ARE	united arab emirates	214,362			214,362
GBR	united kingdom	2,178,525	1,862,154	1,893,500	1,893,500
USA	united states (usa)	12,465,230		10,969,496	10,969,496
URY	uruguay	19,298			19,298
SUN	ussr (former)	11,394,139	12,608,429		12,608,429
VUT	vanuatu	10			10
VEN	venezuela	193,035			193,035
VNM	vietnam	85,375			85,375
VIR	virgin islands (us)	88,758			88,758
WLF	wallis & futuna	1			1
ESH	western sahara	756			756
WSM	western samoa	463			463
YEM	yemen	26,499			26,499
YUG	yugoslavia (former)	540,142	468,754		468,754
ZAR	zaire	367,990			367,990
ZMB	zambia	560,604			560,604
ZWE	zimbabwe	75,498			75,498
	Totals	75,219,157			71,317,702*

* This value is not the sum of all values in the column because some of the old political divisions (such as Czechoslovakia) and the corresponding new countries (Czech Republic and Slovakia) are all listed.

EDGAR is the Emissions Database for Global Atmospheric Research project (Baars *et al.*, 1991; Berdowski, 1992; Olivier *et al.*, 1994).

LOTOS is the inventory compiled for the Long Term Ozone Simulation Model (Berdowski and Zandveld, 1995).

Table A.3.3.1b. SO_2 Emissions from Anthropogenic Activities in 1990 (metric ton S)

Values in the Best column:
For Canada, total from the inventory compiled by the Pollution Data Analysis Division of Environment Canada (M. Deslauries, Pollution Data Analysis Division, Environment Canada, personal communication, 1995).
For European countries, totals from the CORINAIR90 inventory (G. McInnes, European Environment Agency, personal communication, 1995).
For US, total from the US Environmental Protection Agency (EPA) 1990 Interim Inventory (1993).
For other countries, the EDGAR estimates.

Table A.3.3.2 SO_2 emissions from activities in 1990 (metric tons S)

Unit: Pg S/yr EDGAR Region	Fossil fuel	Biofuel	Industrial Processes	Land Use	Total
ED.A: CANADA	1.030	0.192	1.004	0.026	1.352
ED.B: USA	11.332	0.023	1.719	0.105	12.465
ED.C: LATIN AMERICA	2.300	0.017	0.756	0.884	4.920
ED.D: AFRICA	1.768	0.067	2.236	1.742	4.334
ED.E: OECD EUROPE	9.764	0.219	0.749	0.105	12.324
ED.F: EASTERN EUROPE	4.814	0.001	2.432	0.025	5.590
ED.G: CIS (FORMER USSR)	8.839	0.003	0.104	0.121	11.395
ED.H: MIDDLE EAST	2.409	0.014	0.111	0.095	2.621
ED.I: INDIA REGION	1.883	0.091	1.234	0.359	2.446
ED.J: CHINA REGION	11.415	0.140	0.523	0.205	12.994
ED.K: EAST ASIA	2.040	0.026	0.244	0.173	2.762
ED.L: OCEANIA	0.474	0.024	0.209	0.012	0.754
ED.M: JAPAN	1.334	0.000	11.426	0.006	1.549
TOTAL	59.403	0.818		3.859	75.505

Unit: Percentage of regional total EDGAR Region	Fossil fuel	Biofuel	Industrial Processes	Landuse	Total
ED.A: CANADA	76.2	14.2	7.7	1.9	100.0
ED.B: USA	90.9	0.2	8.1	0.8	100.0
ED.C: LATIN AMERICA	46.7	0.4	34.9	18.0	100.0
ED.D: AFRICA	40.8	1.6	17.4	40.2	100.0
ED.E: OECD EUROPE	79.2	1.8	18.1	0.8	100.0
ED.F: EASTERN EUROPE	86.1	0.0	13.4	0.5	100.0
ED.G: CIS (FORMER USSR)	77.6	0.0	21.3	1.1	100.0
ED.H: MIDDLE EAST	91.9	0.5	3.9	3.6	100.0
ED.I: INDIA REGION	77.0	3.7	4.6	14.7	100.0
ED.J: CHINA REGION	87.9	1.1	9.5	1.6	100.0
ED.K: EAST ASIA	73.8	1.0	18.9	6.3	100.0

Table A.3.3.2 SO_2 emissions from activities in 1990 (metric tons S)

ED.L: OCEANIA	62.9	3.2	32.4	1.6	100.0
ED.M: JAPAN	86.1	0.0	13.5	0.4	100.0
TOTAL	78.7	1.1	15.1	5.1	100.0

Unit: Percentage of source total EDGAR Region	Fossil fuel	Biofuel	Industrial Processes	Landuse	Total
ED.A: CANADA	1.7	23.4	0.9	0.7	1.8
ED.B: USA	19.1	2.8	8.8	2.7	16.5
ED.C: LATIN AMERICA	3.9	2.1	15.0	22.9	6.5
ED.D: AFRICA	3.0	8.2	6.6	45.1	5.7
ED.E: OECD EUROPE	16.4	26.8	19.6	2.7	16.3
ED.F: EASTERN EUROPE	8.1	0.2	6.6	0.7	7.4
ED.G: CIS (FORMER USSR)	14.9	0.3	21.3	3.1	15.1
ED.H: MIDDLE EAST	4.1	1.7	0.9	2.5	3.5
ED.I: INDIA REGION	3.2	11.2	1.0	9.3	3.2
ED.J: CHINA REGION	19.2	17.1	10.8	5.3	17.2
ED.K: EAST ASIA	3.4	3.2	4.6	4.5	3.7
ED.L: OCEANIA	0.8	2.9	2.1	0.3	1.0
ED.M: JAPAN	2.2	0.0	1.8	0.2	2.1
TOTAL	100.0	100.0	100.0	100.0	100.0

Unit: Percentage of global total EDGAR Region	Fossil fuel	Biofuel	Industrial Processes	Landuse	Total
ED.A: CANADA	1.4	0.3	0.1	0.0	1.8
ED.B: USA	15.0	0.0	1.3	0.1	16.5
ED.C: LATIN AMERICA	3.0	0.0	2.3	1.2	6.5
ED.D: AFRICA	2.3	0.1	1.0	2.3	5.7
ED.E: OECD EUROPE	12.9	0.3	3.0	0.1	16.3
ED.F: EASTERN EUROPE	6.4	0.0	1.0	0.0	7.4
ED.G: CIS (FORMER USSR)	11.7	0.0	3.2	0.2	15.1
ED.H: MIDDLE EAST	3.2	0.0	0.1	0.1	3.5

Table A.3.3.2 SO_2 emissions from activities in 1990 (metric tons S)

ED.I: INDIA REGION	2.5	0.1	0.1	0.5	3.2
ED.J: CHINA REGION	15.1	0.2	1.6	0.3	17.2
ED.K: EAST ASIA	2.7	0.0	0.7	0.2	3.7
ED.L: OCEANIA	0.6	0.0	0.3	0.0	1.0
ED.M: JAPAN	1.8	0.0	0.3	0.0	2.1
TOTAL	78.7	1.1	15.1	5.1	100.0

Table A.3.3.3. SO_2 Emissions from Fossil Fuel Use Source Category in 1990

Unit: Gg S/yr EDGAR Region	Industry	Comm	Resid	Other	Power Gen.	Other Transf.	Internat. Transp	Internat. Ships	Total
ED.A: CANADA	141	18	14	6	688	132	19	12	1,030
ED.B: USA	1,964	222	79	98	7,187	983	228	571	11,332
ED.C: LATIN AMERICA	668	13	21	133	756	526	49	133	2,300
ED.D: AFRICA	397	15	24	47	920	214	20	133	1,768
ED.E: OECD EUROPE	2,402	167	872	86	4,464	943	125	705	9,764
ED.F: EASTERN EUROPE	654	7	216	310	3,406	188	21	12	4,814
ED.G: CIS (FORMER USSR)	2,273	828	0	269	4,370	858	127	113	8,839
ED.H: MIDDLE EAST	423	0	122	286	710	520	26	323	2,409
ED.I: INDIA REGION	591	1	43	29	776	160	270	14	1,883
ED.J: CHINA REGION	4,629	136	1,742	488	3,622	434	296	68	11,415
ED.K: EAST ASIA	485	13	186	27	688	302	23	316	2,040
ED.L: OCEANIA	61	3	3	6	309	63	18	11	474
ED.M: JAPAN	388	4	12	59	540	98	180	54	1,334
TOTAL	15,076	1,426	3,334	1,843	28,436	5,421	1,402	2,465	59,403

Unit: Percentage of regional total EDGAR Region	Industry	Comm	Resid	Other	Power Gen.	Other Transf.	Internat. Transp	Internat. Ships	Total
ED.A: CANADA	13.7	1.7	1.4	0.6	66.8	12.8	1.9	1.2	100.0
ED.B: USA	17.3	2.0	0.7	0.9	63.4	8.7	2.0	5.0	100.0

Table A.3.3.3. SO_2 Emissions from Fossil Fuel Use Source Category in 1990

ED.C: LATIN AMERICA	29.1	0.6	0.9	5.8	32.9	22.9	2.2	5.8	100.0
ED.D: AFRICA	22.4	0.8	1.3	2.6	52.0	12.1	1.1	7.5	100.0
ED.E: OECD EUROPE	24.6	1.7	8.9	0.9	45.7	9.7	1.3	7.2	100.0
ED.F: EASTERN EUROPE	13.6	0.2	4.5	6.4	70.8	3.9	0.4	0.2	100.0
ED.G: CIS (FORMER USSR)	25.7	9.4	0.0	3.0	49.4	9.7	1.4	1.3	100.0
ED.H: MIDDLE EAST	17.5	0.0	5.1	11.9	29.5	21.6	1.1	13.4	100.0
ED.I: INDIA REGION	31.4	0.1	2.3	1.5	41.2	8.5	14.3	0.8	100.0
ED.J: CHINA REGION	40.5	1.2	15.3	4.3	31.7	3.8	2.6	0.6	100.0
ED.K: EAST ASIA	23.8	0.6	9.1	1.3	33.8	14.8	1.1	15.5	100.0
ED.L: OCEANIA	12.9	0.5	0.6	1.3	65.2	13.2	3.8	2.4	100.0
ED.M: JAPAN	29.1	0.3	0.9	4.4	40.5	7.3	13.5	4.0	100.0
TOTAL	25.4	2.4	5.6	3.1	47.9	9.1	2.4	4.2	100.0

Unit: Percentage of source total EDGAR Region	Industry	Comm	Resid	Other	Power Gen.	Other Transf.	Internat. Transp	Internat. Ships	Total
ED.A: CANADA	1.0	1.0	0.0	0.0	2.0	2.0	1.0	0.0	2.0
ED.B: USA	13.0	15.6	2.4	5.3	25.3	18.1	16.3	23.2	19.1
ED.C: LATIN AMERICA	4.4	0.9	0.6	7.2	2.7	9.7	3.5	5.4	3.9
ED.D: AFRICA	2.6	1.0	0.7	2.5	3.2	3.9	1.4	5.4	3.0
ED.E: OECD EUROPE	15.9	11.7	26.2	4.6	15.7	17.4	8.9	28.6	16.4

Table A.3.3.3. SO_2 Emissions from Fossil Fuel Use Source Category in 1990

ED.F: EASTERN EUROPE	4.3	0.5	6.5	16.8	12.0	3.5	1.5	0.5	8.1
ED.G: CIS (FORMER USSR)	15.1	58.1	0.0	14.6	15.4	15.8	9.1	4.6	14.9
ED.H: MIDDLE EAST	2.8	0.0	3.7	15.5	2.5	9.6	1.8	13.1	4.1
ED.I: INDIA REGION	3.9	0.1	1.3	1.6	2.7	2.9	19.2	0.6	3.2
ED.J: CHINA REGION	30.7	9.5	52.3	26.5	12.7	8.0	21.1	2.8	19.2
ED.K: EAST ASIA	3.2	0.9	5.6	1.5	2.4	5.6	1.7	12.8	3.4
ED.L: OCEANIA	0.4	0.2	0.1	0.3	1.1	1.2	1.3	0.5	0.8
ED.M: JAPAN	2.6	0.3	0.4	3.2	1.9	1.8	12.8	2.2	2.2
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Unit: Percentage of global total EDGAR Region	Industry	Comm	Resid	Other	Power Gen.	Other	Transp	Internat. Ships	Total
ED.A: CANADA	0.2	0.0	0.0	0.0	1.2	0.2	0.0	0.0	1.7
ED.B: USA	3.3	0.4	0.1	0.2	12.1	1.7	0.4	1.0	19.1
ED.C: LATIN AMERICA	1.1	0.0	0.0	0.2	1.3	0.9	0.1	0.2	3.9
ED.D: AFRICA	0.7	0.0	0.0	0.1	1.5	0.4	0.0	0.2	3.0
ED.E: OECD EUROPE	4.0	0.3	1.5	0.1	7.5	1.6	0.2	1.2	16.4
ED.F: EASTERN EUROPE	1.1	0.0	0.4	0.5	5.7	0.3	0.0	0.0	8.1
ED.G: CIS (FORMER USSR)	3.8	1.4	0.0	0.5	7.4	1.4	0.2	0.2	14.9
ED.H: MIDDLE EAST	0.7	0.0	0.2	0.5	1.2	0.9	0.0	0.5	4.1
ED.I: INDIA REGION	1.0	0.0	0.1	0.0	1.3	0.3	0.5	0.0	3.2

Table A.3.3.3. SO_2 Emissions from Fossil Fuel Use Source Category in 1990

ED.J: CHINA REGION	7.8	0.2	2.9	0.8	6.1	0.7	0.5	0.1	19.2
ED.K: EAST ASIA	0.8	0.0	0.3	0.0	1.2	0.5	0.0	0.5	3.4
ED.L: OCEANIA	0.1	0.0	0.0	0.0	0.5	0.1	0.0	0.0	0.8
ED.M: JAPAN	0.7	0.0	0.0	0.1	0.9	0.2	0.3	0.1	2.2
TOTAL	25.4	2.4	5.6	3.1	47.9	9.1	2.4	4.2	100.0

Table A.3.3.4. SO_2 Emissions from Biofuels Use Source Category in 1990

Unit: Gg S/yr EDGAR Region	Industrial	Residential	Total
ED.A: CANADA	191	0	192
ED.B: USA	19	4	23
ED.C: LATIN AMERICA	5	12	17
ED.D: AFRICA	3	64	67
ED.E: OECD EUROPE	218	1	219
ED.F: EASTERN EUROPE	1	0	1
ED.G: CIS (FORMER USSR)	2	0	3
ED.H: MIDDLE EAST	1	13	14
ED.I: INDIA REGION	9	83	91
ED.J: CHINA REGION	2	137	140
ED.K: EAST ASIA	4	23	26
ED.L: OCEANIA	22	2	24
ED.M: JAPAN	0	0	0
TOTAL	478	340	818

Unit: Percentage of regional total EDGAR Region	Industrial	Residential	Total
ED.A: CANADA	99.9	0.1	100.0
ED.B: USA	82.0	18.0	100.0
ED.C: LATIN AMERICA	28.7	71.3	100.0
ED.D: AFRICA	4.7	95.3	100.0
ED.E: OECD EUROPE	99.6	0.4	100.0
ED.F: EASTERN EUROPE	91.0	9.0	100.0
ED.G: CIS (FORMER USSR)	90.0	10.0	100.0
ED.H: MIDDLE EAST	5.5	94.5	100.0
ED.I: INDIA REGION	9.7	90.3	100.0
ED.J: CHINA REGION	1.8	98.2	100.0
ED.K: EAST ASIA	13.6	86.4	100.0

Table A.3.3.4. SO_2 Emissions from Biofuels Use Source Category in 1990

ED.L: OCEANIA	92.5	7.5	100.0
ED.M: JAPAN	87.4	12.6	100.0
TOTAL	58.5	41.5	100.0

Unit: Percentage of source total EDGAR Region	Industrial	Residential	Total
ED.A: CANADA	40.0	0.1	23.4
ED.B: USA	4.0	1.2	2.8
ED.C: LATIN AMERICA	1.0	3.6	2.1
ED.D: AFRICA	0.7	18.9	8.2
ED.E: OECD EUROPE	45.7	0.3	26.8
ED.F: EASTERN EUROPE	0.2	0.0	0.2
ED.G: CIS (FORMER USSR)	0.5	0.1	0.3
ED.H: MIDDLE EAST	0.2	3.8	1.7
ED.I: INDIA REGION	1.8	24.3	11.2
ED.J: CHINA REGION	0.5	40.4	17.1
ED.K: EAST ASIA	0.7	6.7	3.2
ED.L: OCEANIA	4.6	0.5	2.9
ED.M: JAPAN	0.0	0.0	0.0
TOTAL	100.0	100.0	100.0

Unit: Percentage of global total EDGAR Region	Industrial	Residential	Total
ED.A: CANADA	23.4	0.0	23.4
ED.B: USA	2.3	0.5	2.8
ED.C: LATIN AMERICA	0.6	1.5	2.1
ED.D: AFRICA	0.4	7.9	8.2
ED.E: OECD EUROPE	26.7	0.1	26.8
ED.F: EASTERN EUROPE	0.1	0.0	0.2
ED.G: CIS (FORMER USSR)	0.3	0.0	0.3

Table A.3.3.4. SO_2 Emissions from Biofuels Use Source Category in 1990

ED.H: MIDDLE EAST	0.1	1.6	1.7
ED.I: INDIA REGION	1.1	10.1	11.2
ED.J: CHINA REGION	0.3	16.8	17.1
ED.K: EAST ASIA	0.4	2.8	3.2
ED.L: OCEANIA	2.7	0.2	2.9
ED.M: JAPAN	0.0	0.0	0.0
TOTAL	58.5	41.5	100.0

Table A.3.3.5. SO_2 Emissions from the Industrial Processes Source Category in 1990

Unit: Gg S/yr EDGAR Region	Copper	Zinc	Lead	Iron & Steel	H_2SO_4	TOTAL
ED.A: CANADA	47	24	7	1	25	104
ED.B: USA	618	61	41	10	274	1,004
ED.C: LATIN AMERICA	1,327	125	35	19	213	1,719
ED.D: AFRICA	627	32	16	0	81	756
ED.E: OECD EUROPE	1,099	710	110	86	231	2,236
ED.F: EASTERN EUROPE	460	127	25	30	107	749
ED.G: CIS (FORMER USSR)	1,336	448	76	107	465	2,432
ED.H: MIDDLE EAST	86	0	2	3	13	103
ED.I: INDIA REGION	20	25	2	7	57	111
ED.J: CHINA REGION	550	362	46	71	204	1,234
ED.K: EAST ASIA	327	141	10	21	23	523
ED.L: OCEANIA	128	86	15	5	10	244
ED.M: JAPAN	65	23	2	72	47	209
TOTAL	6,689	2,165	388	434	1,750	11,426

Unit: Percentage of regional total EDGAR Region	Copper	Zinc	Lead	Iron & Steel	H_2SO_4	TOTAL
ED.A: CANADA	45.2	23.2	6.4	1.4	23.8	100.0
ED.B: USA	61.5	6.1	4.1	1.0	27.3	100.0
ED.C: LATIN AMERICA	77.2	7.3	2.1	1.1	12.4	100.0
ED.D: AFRICA	83.0	4.2	2.1	0.0	10.7	100.0
ED.E: OECD EUROPE	49.2	31.7	4.9	3.9	10.3	100.0
ED.F: EASTERN EUROPE	61.4	17.0	3.3	4.0	14.3	100.0
ED.G: CIS (FORMER USSR)	54.9	18.4	3.1	4.4	19.1	100.0
ED.H: MIDDLE EAST	82.7	0.0	1.5	3.3	12.6	100.0
ED.I: INDIA REGION	17.7	22.2	2.1	6.5	51.5	100.0

Table A.3.3.5. SO_2 Emissions from the Industrial Processes Source Category in 1990

ED.J: CHINA REGION	44.6	29.3	3.8	5.8	16.5	100.0
ED.K: EAST ASIA	62.6	27.0	1.9	4.0	4.4	100.0
ED.L: OCEANIA	52.3	35.3	6.3	1.9	4.1	100.0
ED.M: JAPAN	30.9	10.8	1.1	34.7	22.5	100.0
TOTAL	58.5	18.9	3.4	3.8	15.3	100.0

Unit: Percentage of source total EDGAR Region	Copper	Zinc	Lead	Iron & Steel	H_2SO_4	TOTAL
ED.A: CANADA	0.7	1.1	1.7	0.3	1.4	0.9
ED.B: USA	9.2	2.8	10.5	2.3	15.7	8.8
ED.C: LATIN AMERICA	19.8	5.8	9.1	4.3	12.2	15.0
ED.D: AFRICA	9.4	1.5	4.1	0.0	4.6	6.6
ED.E: OECD EUROPE	16.4	32.8	28.5	19.9	13.2	19.6
ED.F: EASTERN EUROPE	6.9	5.9	6.4	6.9	6.1	6.6
ED.G: CIS (FORMER USSR)	20.0	20.7	19.6	24.7	26.6	21.3
ED.H: MIDDLE EAST	1.3	0.0	0.4	0.8	0.7	0.9
ED.I: INDIA REGION	0.3	1.1	0.6	1.7	3.3	1.0
ED.J: CHINA REGION	8.2	16.7	11.9	16.4	11.7	10.8
ED.K: EAST ASIA	4.9	6.5	2.6	4.8	1.3	4.6
ED.L: OCEANIA	1.9	4.0	4.0	1.1	0.6	2.1
ED.M: JAPAN	1.0	1.0	0.6	16.7	2.7	1.8
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0

Unit: Percentage of global total EDGAR Region	Copper	Zinc	Lead	Iron & Steel	H_2SO_4	TOTAL
ED.A: CANADA	0.4	0.2	0.1	0.0	0.2	0.9
ED.B: USA	5.4	0.5	0.4	0.1	2.4	8.8
ED.C: LATIN AMERICA	11.6	1.1	0.3	0.2	1.9	15.0

Table A.3.3.5. SO_2 Emissions from the Industrial Processes Source Category in 1990

ED.D: AFRICA	5.5	0.3	0.1	0.0	0.7	6.6
ED.E: OECD EUROPE	9.6	6.2	1.0	0.8	2.0	19.6
ED.F: EASTERN EUROPE	4.0	1.1	0.2	0.3	0.9	6.6
ED.G: CIS (FORMER USSR)	11.7	3.9	0.7	0.9	4.1	21.3
ED.H: MIDDLE EAST	0.7	0.0	0.0	0.0	0.1	0.9
ED.I: INDIA REGION	0.2	0.2	0.0	0.1	0.5	1.0
ED.J: CHINA REGION	4.8	3.2	0.4	0.6	1.8	10.8
ED.K: EAST ASIA	2.9	1.2	0.1	0.2	0.2	4.6
ED.L: OCEANIA	1.1	0.8	0.1	0.0	0.1	2.1
ED.M: JAPAN	0.6	0.2	0.0	0.6	0.4	1.8
TOTAL	58.5	18.9	3.4	3.8	15.3	100.0

Table A.3.3.6. SO_2 Emissions from the Land Use Source Category in 1990

Unit: Gg S/yr EDGAR Region	Deforestation & savannah burning	Agricultural Waste	Total
ED.A: CANADA	0	26	26
ED.B: USA	0	105	105
ED.C: LATIN AMERICA	775	109	884
ED.D: AFRICA	1,624	118	1,742
ED.E: OECD EUROPE	0	105	105
ED.F: EASTERN EUROPE	0	25	25
ED.G: CIS (FORMER USSR)	0	121	121
ED.H: MIDDLE EAST	0	95	95
ED.I: INDIA REGION	59	300	359
ED.J: CHINA REGION	47	157	205
ED.K: EAST ASIA	90	83	173
ED.L: OCEANIA	0	12	12
ED.M: JAPAN	0	6	6
TOTAL	2,596	1,263	3,859

Unit: Percentage of regional total EDGAR Region	Deforestation & savannah burning	Agricultural Waste	Total
ED.A: CANADA	0.0	100.0	100.0
ED.B: USA	0.0	100.0	100.0
ED.C: LATIN AMERICA	87.7	12.3	100.0
ED.D: AFRICA	93.2	6.8	100.0
ED.E: OECD EUROPE	0.0	100.0	100.0
ED.F: EASTERN EUROPE	0.0	100.0	100.0
ED.G: CIS (FORMER USSR)	0.0	100.0	100.0

Table A.3.3.6. SO_2 Emissions from the Land Use Source Category in 1990

ED.H: MIDDLE EAST	0.1	99.9	100.0
ED.I: INDIA REGION	16.4	83.6	100.0
ED.J: CHINA REGION	23.2	76.8	100.0
ED.K: EAST ASIA	52.1	47.9	100.0
ED.L: OCEANIA	0.0	100.0	100.0
ED.M: JAPAN	0.0	100.0	100.0
TOTAL	67.3	32.7	100.0

Unit: Percentage of source total EDGAR Region	Deforestation & savannah burning	Agricultural Waste	Total
ED.A: CANADA	0.0	2.0	0.7
ED.B: USA	0.0	8.3	2.7
ED.C: LATIN AMERICA	29.9	8.6	22.9
ED.D: AFRICA	62.6	9.3	45.1
ED.E: OECD EUROPE	0.0	8.3	2.7
ED.F: EASTERN EUROPE	0.0	2.0	0.7
ED.G: CIS (FORMER USSR)	0.0	9.6	3.1
ED.H: MIDDLE EAST	0.0	7.5	2.5
ED.I: INDIA REGION	2.3	23.8	9.3
ED.J: CHINA REGION	1.8	12.5	5.3
ED.K: EAST ASIA	3.5	6.6	4.5
ED.L: OCEANIA	0.0	0.9	0.3
ED.M: JAPAN	0.0	0.5	0.2
TOTAL	100.0	100.0	100.0

Unit: Percentage of global total EDGAR Region	Deforestation & savannah burning	Agricultural Waste	Total

Table A.3.3.6. SO_2 Emissions from the Land Use Source Category in 1990

ED.A: CANADA	0.0	0.7	0.7
ED.B: USA	0.0	2.7	2.7
ED.C: LATIN AMERICA	20.1	2.8	22.9
ED.D: AFRICA	42.1	3.1	45.1
ED.E: OECD EUROPE	0.0	2.7	2.7
ED.F: EASTERN EUROPE	0.0	0.7	0.7
ED.G: CIS (FORMER USSR)	0.0	3.1	3.1
ED.H: MIDDLE EAST	0.0	2.5	2.5
ED.I: INDIA REGION	1.5	7.8	9.3
ED.J: CHINA REGION	1.2	4.1	5.3
ED.K: EAST ASIA	2.3	2.2	4.5
ED.L: OCEANIA	0.0	0.3	0.3
ED.M: JAPAN	0.0	0.2	0.2
TOTAL	67.3	32.7	100.0

1. Emission Database for Global Atmospheric Research (EDGAR) (Baars *et al.*, 1991; Berdowski, 1992; Olivier *et al.*, 1994).

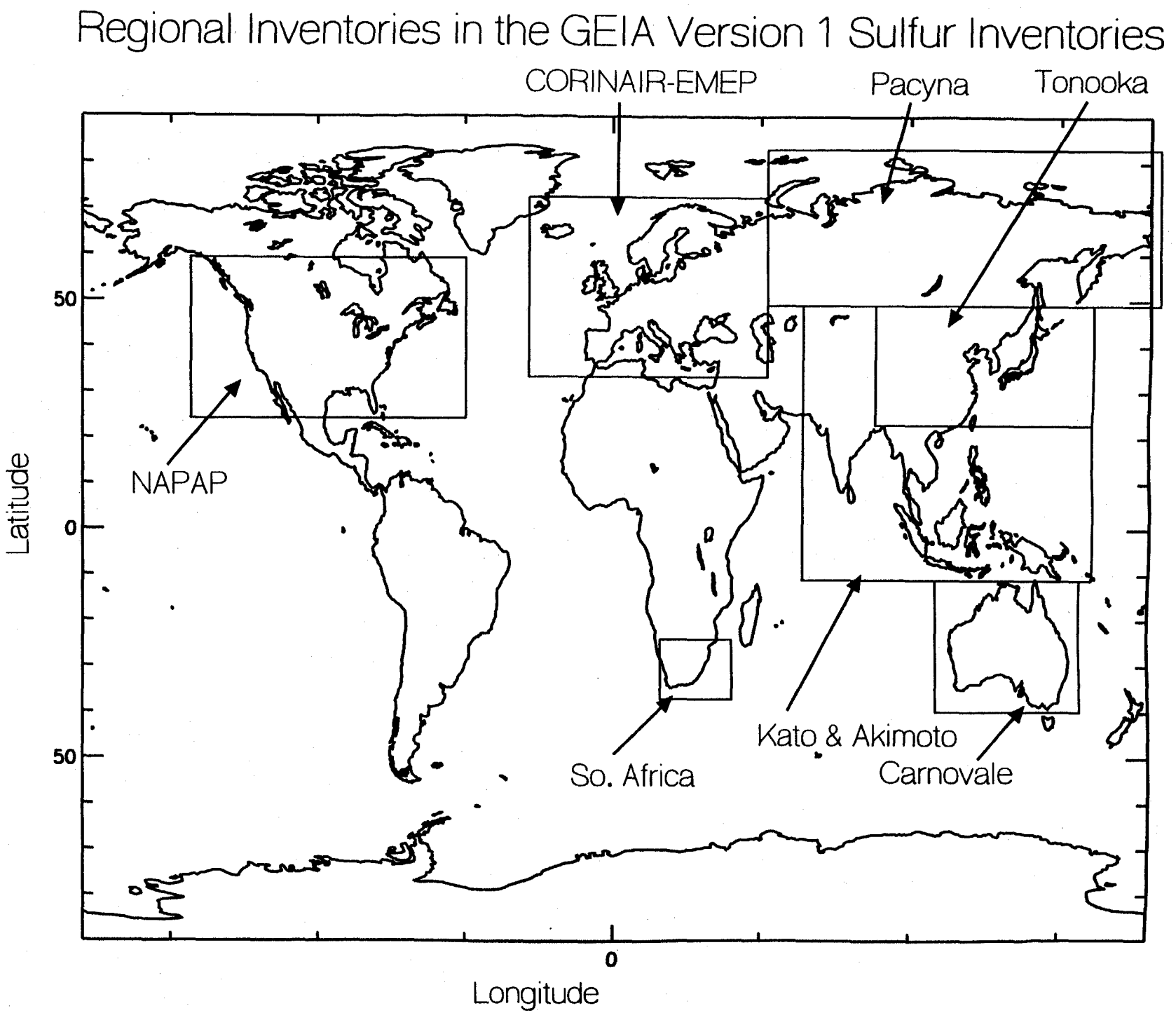
Regional Inventories in the GEIA Version 1 Sulfur Inventories
CORINAIR-EMEP
Pacyna
Tonooka
NAPAP
So. Africa
Kato & Akimoto
Carnovale
Latitude
50
0
50
0
Longitude

Figure 1

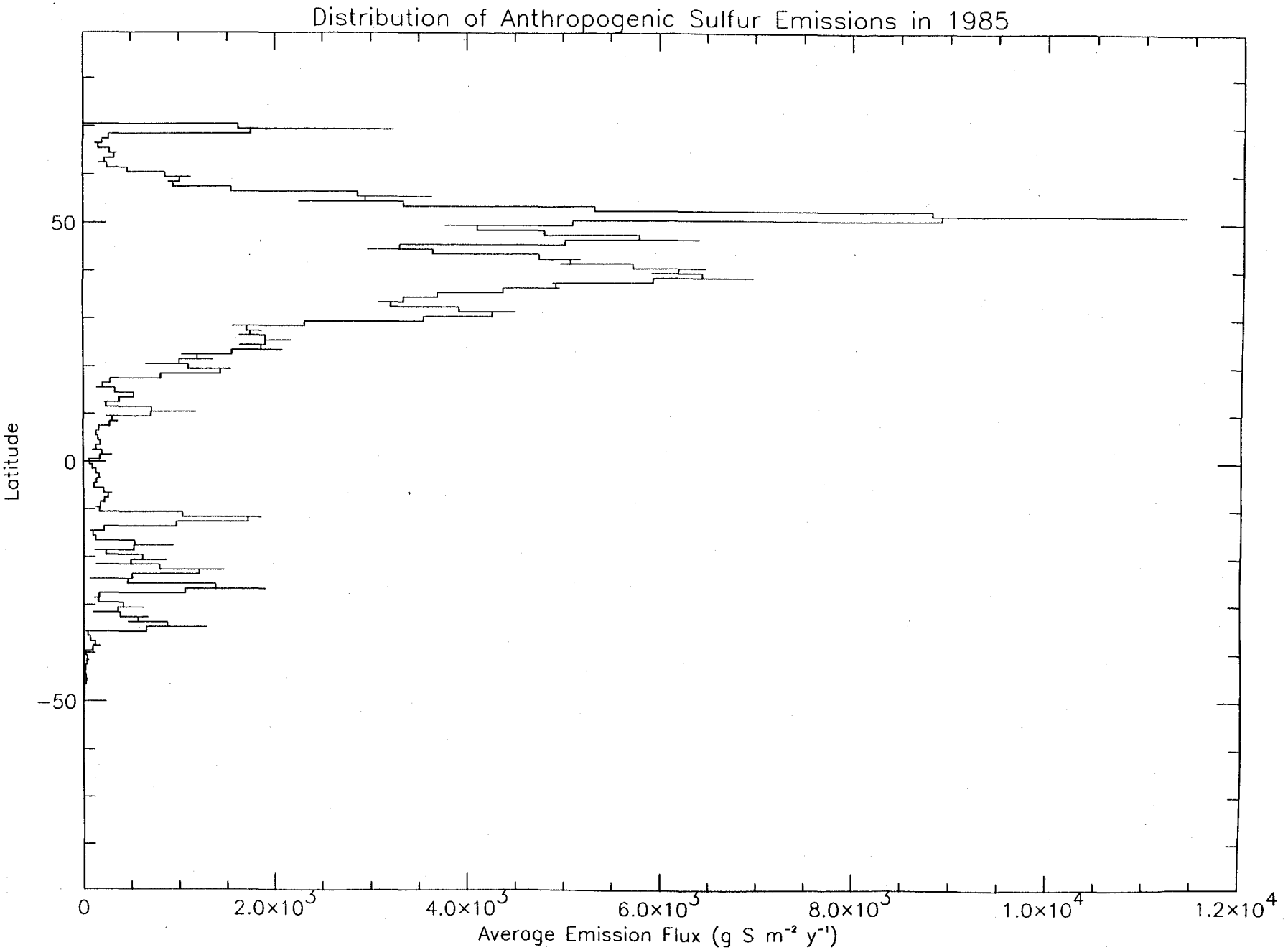
Distribution of Anthropogenic Sulfur Emissions in 1985
Latitude
50
0
-50
0
2.0×10^3
4.0×10^3
6.0×10^3
8.0×10^3
1.0×10^4
1.2×10^4
Average Emission Flux (g S m^-2 y^-1)

Figure 2