GEOS−Chem ANTHROPOGENIC SOURCES

Document for GEOS−Chem v8−02−03. *GEOS−Chem support, 10/16/09. Send questions, comments, suggestions, etc.. to geos−chem−support@as.harvard.edu*

GEOS−Chem Emissions are separated in four broad categories (anthropogenic, biofuel, biogenic, biomass). Sources relevant to aerosol chemistry are dealt with separately. Here is a brief overview "per module". For more information visit our wiki.

Anthro : by default 10 species from GEIA inventory (NOx, CO, PRPE, C3H8, ALK4, C2H6, ACET, MEK, ALD2, CH20). Several additional inventories and yearly anthropogenic scale factors for NOx, CO and SO2 are available for 1985−2005, They are both documented in more details hereafter. For BC/OC see Carbon Aerosol. For SOx and NH3 see Sulfate Aerosol.

Biofuel: Default inventory : NOx, CO, ALK4, ACET, MEK, ALD2, PRPE, C3H8, CH2O, C2H6 − Are regionally overwritten with EPA and/or STREETS 2006 if one of these inventories is used for anthropogenic emissions.

Biogenic: by default we emit : isoprene, monoterpenes, methyl butenol, acetone, and alkene. Can be overwritten by MEGAN : isoprene, monoterpenes, methyl butenol.

Biomass : 15 species from Duncan et al.: NOx, CO, ALK4, ACET, MEK, ALD2, PRPE, C3H8, CH2O, C2H6 and for aerosols chemistry SO2, NH3, BC, OC. All can be overwritten by monthly and 8−day GFED2 (1997−2007)

Carbon Aerosol : default sources (OC, BC) are read with their specific routines in the carbon module (Bond and Cooke inventories for anthropogenic, biofuel and biomass sources). Biomass sources of primary aerosol can be over written by those from Biomass module.

Sulfate Aerosol : default sources (ocean DMS, anth/biofuel/aircraft/volcano SO2, SO4, NH3) are read in the sulfate module. Anthro SO2 and/or NH3 and/or SO4 can be gathered from optional anthropogenic inventories.

The present document focuses on the anthropogenic emissions in GEOS−Chem. Tables 1 & 2 give the **DEFAULT** and **SUGGESTED** composite inventories available in GEOS−Chem. Table 3 and the notes that follow provide further details for each inventories. The emissions menu of an input file (input.geos) is commented.

	NOx / CO / VOC / SOx	NH3	BC/OC
Canada/USA	1985	1985	2000
WORLD	1985	1985	2000

Table 1: Base year (underlined: subject to yearly scaling) of the **DEFAULT** set of emissions in GEOS−Chem. See color legend of table 2.

	NOx	CO	VOC	SOx	NH3	BC/OC
Canada	2002, 2005	2002, 2005	1985	2002, 2005	2002, 2005	1996
USA	1999, 2002, 2004	1999, 2004	1999	1999	1999	
Mexico	1999	1999	1985	1999	1985	2000
Europe	1980−2005	1980−2005	1980−2000	1990−2005	1990−2005	
South East Asia	2004	2000	1985	2000	2000	
	2006	2006	2006	2006		
Rest of the World	2000	2000	1985	2000	1985	

Table 2: Base year of GEOS−Chem anthropogenic emissions per regions and per species, when optional **SUGGESTED** inventories are used. Color indicates inventory. Underlined base years are scaled into 1985−2005 to match simulated (i.e., met fields) year. Scale factors of CO are used for VOC.

CAC Canadian national estimate	**O**
EPA (corrected for CA mobile emissions; 2004 : with ICARTT based corrections, 2002: with VISTAS/ARP)	**O**
BRAVO strictly limited to Mexico	**O**
EMEP	**O**
Streets	**O**
EDGAR	**O**
GEIA	**S**
Bond	**S**
Cooke	**O**
ARCTAS pre-mission global ship SO2 based on EDGAR	**O**
IOCADS ship emissions	**O**

O : optional, set in input.geos
S : standard emissions, automatically on. Turned off when overwritten.

SHIP Emissions

	NOx as O3 + HNO3	CO	SO2	NH3	BC/OC
Europe	1990-2005(#)				2000
Rest of the World	2000	2000	2000		
Option 2	2002	2002	2002		

(#) EMEP Ship NOx for 1980-1989 is emitted as NOx, since it cannot be separated from the anthropogenic source.
Note: OPE from Ship-NOx is 10.

	INVENTORY	BASE YEAR	REGION	NOx	CO	PRPE	C3H8	ALK4	C2H6	ACET	MEK	ALD2	CH20	SO2	SO4	NH3	BC/OC	Variability (species)	for offline simul.
GLOBAL	GEIA	1985	global	X	X	X	X	X	X	X	X			X	X	X		season (NOx, SOx)	
	EDGAR	2000	global	X	X									X					
	BOND	2000	global														X	month	
REGIONAL	CAC	2002, 2005	CANADA	X	X									X		X			
	EMEP	1980-2005	EUROPE	X	X	X		X	X		X	X		X			X	Month (NOx)	
	EPA (ICARTT)	1999 (2004)	USA	X	X	X	X	X	X	X	X		X	X	X	X		Month, weekday/ weekend (all)	
	VISTAS	2002	USA	X															
	BRAVO	1999	MEXICO	X	X									X					
	STREETS	2000 (2004)	S.E. ASIA	X	X									X		X		Month (NOx, CO)	CH4, CO2
		2006		X	X	X	X	X	X	X	X	X	X	X					
	COOKE	1996	N. AMERICA														X	Month (all)	

Table 3: Inventories features. Yellow highlighting indicates default inventories turned on automatically, as seen in table 1.

Notes:

- Global **annual scaling factors** are available for NOx, CO, and SOx from 1985–2005. They are automatically applied to any inventory if needed to get as close as possible to simulated year conditions. This behavior can be overwritten. See **input.geos** description below. The scale factors are based on national inventories for Japan, USA, Canada, Europe and SE ASIA (REAS). For other locations, proportionality to CO2 is used (liquid CO2 for CO, total CO2 for NOx, and solid CO2 for SOx).
- A **diurnal variation** is applied to all NOx. It is derived from EDGAR hourly variations *sc(k,H)* for each sources *k*, spatially weighted by the sources. In other words: $ScaleFactor(H,I,J) = \frac{\sum sc(k,H)\, NOx(I,J,k)}{\sum NOx(I,J,k)}$
- EPA: **California** mobile sources were missing from NEI99 and have been estimated from EPA 2001 data.
- **"ICARTT"** is a correction to EPA NIE99 NOx and CO to match ICARTT observations. NOx from power sector is reduced by 30% during ozone season, and CO is reduced by 60% over the year. Base year is then 2004 for these two species. For more information please see references.
- The Visibility Improvement State and Tribal Association of the Southeast (**VISTAS**) is a compilation of recently available emissions inventories from

all the Regional Haze Planning Organizations in the United States.

- An additional monthly variability for VISTAS NOX is obtained from EPA Acid Rain Program (**ARP**) ozone season regulation factors.
- NOx **EMEP** monthly variability courtesy of the GENEMIS project coordinated by the Institute of Energy Economics and the Rational Use of Energy (IER) at the University of Stuttgart
- STREETS CO for 2000 inventory is corrected with 2001 inventory over China. See references. 2004 is used for NOx before 2006 to get monthly variations.
- STREETS 2006 does not separate biofuel emissions from anthropogenic ones. Be careful when interpreting totals.
- Scaling factors to simulate **2020** emissions in SE Asia are available but hardwired in Streets module.
- CAC and BRAVO must be both on or off. If there are on, EPA must be used too . Two **EPA masks** are available: one for BRAVO/CAC on, and another if they are off. Understand that other cases (BRAVO on, EPA off for example) would require different masks to avoid double counting.
- BRAVO has only mexican emissions, the american ones available in the original inventory have been disregarded.
- According to the original GEIA paper for NOx and SOx, it is not seasonal (Benkovitz et al., JGR, 101, 29,239, 1996). Later work was done to develop it in more detail, using the same regional inventories. See: http://www.geiacenter.org/ and go to GEIA v1. If you click on "documentation" under the seasonal NOx link (scroll down), you will see that the only seasonal parts of the inventory come from the regional inventories for North America, Europe, and Asia. See: http://www.ortech.ca/cgeic/poster.html

GEIA was built the way we overwrite regional inventories on EDGAR: it started with the regional ones, and used a default global inventory where nothing else was available.

input.geos

```
------------------------+-----
%%% EMISSIONS MENU %%%  :
Turn on emissions?      : T
Emiss timestep (min)    : 60
Include anthro emiss?   : T   ======> set to T to include anthropogenic emissions.
 => Scale to (1985-2005): -1  ======> -1 means automatic scaling and/or pick up best base year when
 => Use EMEP emissions? : T           several are available (recommended). You can force the “emission
 => Use BRAVO emissions?: T           year” here, but be aware that to use Streets 2006, you need to
 => Use EDGAR emissions?: T           set it to 2006 or above, even if scaling of other inventor will
 => Use STREETS emiss?  : T           not go further than 2005.
 => Use CAC emissions?  : T
Use EPA/NEI99 (anth+bf)?: T   ======> if you use EPA, both anth and biofuel products are used
    w/ ICARTT modif.?   : T   ======> will force using EPA and overwrite NOX and CO
    w/ VISTAS NOx emis? : F   ======> will force using EPA and overwrite NOX
Include biofuel emiss?  : T
Include biogenic emiss? : T
 => Use MEGAN inventory?: T
Include biomass emiss?  : T
 => Seasonal biomass?   : T
 => Scaled to TOMSAI?   : F
 => Use GFED2 biomass?  :---
```

Set any of those to overwrite default inventory

```
    => monthly GFED2?   : T
    => 8-day GFED2?     : F
    => 3-hr GFED2?      : F   ======> available for 4 months only
    => synoptic GFED2?  : F   ======> available for 4 months only
Individual NOx sources  :---
 => Use aircraft NOx?   : T
 => Use lightning NOx   : T
    => Scale glb flrate?: T
    => OTD reg redist?  : F
    => OTD loc redist?  : T
    => Use CTH param?   : T
    => Use MFLUX param? : F
    => Use PRECON param?: F
 => Use soil NOx        : T
Use SHIP emissions      :---
 => global EDGAR ?      : T   ======> NOx (O3 + HNO3), CO, SO2
 => global ICOADS?      : T   ======> NOx (O3 + HNO3), CO, SO2
 => EMEP over EUROPE ?  : T   ======> to overwrite O3, HNO3, CO, SO2 over Europe, and add NH3
 => ship SO2 Corbett ?  : F   ======> alternate global SO2
 => ship SO2 Arctas ?   : T   ======> alternate global SO2
Use COOKE BC/OC (N. Am.): T   ======> North American monthly BC/OC from Cooke et al. [1999]
Use AVHRR-derived LAI?  : F
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```

REFERENCE MATERIAL

- **GEIA**

Wang, Y. , D. J. Jacob, and J. A. Logan, Global simulation of tropospheric O3−NOx−hydrocarbon chemistry, 1. Model formulation, JGR, 103/D9, 10,713−10,726, 1998

- **EMEP 1980−1989 data**

Vestreng, V., and H. Klein (2002), Emission data reported to UNECE/EMEP: Quality insurance and trend analysis and presentation of Web−Dab, MSC−W Status Rep. 2002:, 101 pp., Norw. Meteorol. Inst., Oslo, Norway. This paper is on the EMEP web site:
http://www.emep.int/mscw/mscw_publications.html
http://www.emep.int/publ/reports/2002/mscw_note_1_2002.pdf

Auvray, M., and I. Bey, Long−Range Transport to Europe: Seasonal Variations and Implications for the European Ozone Budget, J. Geophys. Res., 110, D11303, doi: 10.1029/2004JD005503, 2005.

- **EMEP 1990−2005 data**

EMEP 2005 expert emissions, Vestreng et al., 2007.

- **VISTAS**

http://www.vistas−sesarm.org/
http://webcam.srs.fs.fed.us/emissions/

- **EDGAR**

EDGAR 3.2 FT2000 global inventory

- **CAC**

Source data : see http://www.ec.gc.ca/pdb/cac/cac_home_e.cfm

- **BRAVO**

Kuhns, H., M. Green, and Etyemezian, V, Big Bend Regional Aerosol and Visibility

Observational (BRAVO) Study Emissions Inventory, Desert Research Institute, 2003.

- **EPA with ICARTT modification**

Hudman et al., 2007, J. Geophys. Res., 112, D12S05, doi:10.1029/2006JD007912
Hudman et al., 2008, Geophys. Res. Lett., 35, L04801, doi:10.1029/2007GL032393

- **BOND / COOKE**

Bond, T.C. et al.: Historical emissions of black and organic carbon aerosol from energy-related combustion, 1850-2000, Global Biogeochem. Cycles, 21 GB2018, doi: 10.1029/2006GB002840, 2007.

Option to overwrite North American emissions with Cooke et al [1999].

- **STREETS 2001**

Streets, D.G, Q. Zhang, L. Wang, K. He, J. Hao, Y. Wu, Y. Tang, and G.C. Carmichael, "Revisiting China's CO emissions after the Transport and Chemical Evolution over the Pacific (TRACE-P) mission: Synthesis of inventories, atmospheric modeling, and observations", J. Geophys. Res, 111, D14306, doi:10.1029/2006JD007118, 2006.

- **Streets 2000 inventory**

Streets, D.G., T.C. Bond, G.R. Carmichael, S.D. Fernandes, Q. Fu, Z. Klimont, S.M. Nelson, N.Y. Tsai, M.Q. Wang, J-H. Woo, and K.F. Yarber, "An inventory of gaseous and primary aerosol emissions in Asia in the year 2000", J. Geophys. Res, 108, D21, doi:10.1029/2002JD003093, 2003.

- **Streets 2006 inventory**

INTEX-B, http://www.cgrer.uiowa.edu/EMISSION_DATA_new/index_16.html

Zhang, Q., Streets, D. G., Carmichael, G., He, K., Huo, H., Kannari, A., Klimont, Z., Park, I., Reddy, S., Chen, D., Duan, L., Lei, Y., Wang, L. and Yao, Z.: Asian emissions in 2006 for the NASA INTEX-B mission, manuscript submitted to Atmospheric Chemistry & Physics Discussions, 2009

- **ARCTAS pre-mission ship SO2**

The ship emission is based on the work by Eyring et al., JGR 2005, which estimates the total international ship emissions for 1985, 1990, 2001, and 2020 (projection). The ship emission for each individual year is interpreted based on the above years, and the spatial pattern (gridded) is mapped based on the EDGAR gridded ship emission for 2000 (total amount from EDGAR is scaled to Eyring-based number).

If you want to reference the work on publication or website, you may either mention "Diehl et al., manuscript in preparation, 2009" or refer to the AeroCom readme document for hindcast emissions for ship (prepared by Diehl): http://www-lscedods.cea.fr/aerocom/AEROCOM_HC/readme_ship/.

- **IOCADS ship emissions**

The International Comprehensive Ocean-Atmosphere Data Set (ICOADS) ship emissions. Base year is 2002.
Source: ICODS Emissions data for NOx, SOx, and CO were downloaded from http://coast.cms.udel.edu/GlobalShipEmissions/Inventories/

Reference: Wang, C., J. J. Corbett, and J. Firestone, Improving Spatial representation of Global Ship Emissions Inventories, Environ. Sci. Technol., 42 (1), 193-199, 2008.

- **SHIP NOx as O3 (OPE=10) + HNO3**

Chen, G., et al. (2005), An investigation of the chemistry of ship emission plumes during ITCT 2002, J. Geophys. Res., 110, D10S90, doi:10.1029/2004JD005236.

- **ANNUAL SCALE FACTORS**

a brief explanation in van Donkelaar et al., ACPD, 8, 4017-4057, 2008:

"We scale all regional and global inventories from their respective base year to 2003, the last year of available statistics, unless its base year is after 2003. Our approach follows *Bey et al.* (2001) and *Park et al.* (2004). Emissions are scaled according to estimates provided by individual countries, where available. These countries/regions include the United States, Canada, Japan and Europe. NO_x emissions of remaining countries are scaled proportional to changes in total CO_2 emissions. SO_x emissions are similarly scaled to solid fuel CO_2 emissions and CO emissions to liquid fuel CO_2 emissions. CO_2 emission data are obtained from the Carbon Dioxide Information Analysis Center (CDIAC)."

Note that the scale factor have been updated since that paper to go up to 2005, and are based on REAS data now for South East Asia:

Relative changes in the REAS inventory (Ohara et al., ACP, [2007], http://www.jamstec.go.jp/frsgc/research/d4/reas_h_a.html) over East Asia have been used.

This should be a good improvement as REAS emissions are gridded, rather than national scale emissions, giving us much better spatial detail. Also, these scalars are now based on actual NOx, SOx and CO emission estimates, not strictly an assumed proportionality between total, solid and liquid CO2 emissions.