The GEIA-ACCENT Web Portal on Emissions

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ABSTRACT

GEIA, the Global Emissions Inventory Activity, is an integrating project of the AIMES (Analysis, Integration and Modeling of the Earth System) project of the International Geosphere Biosphere (IGBP) program. Over the past four years, GEIA has established strong links with the ACCENT European network that coordinates the European activities on atmospheric composition change. This paper discusses the most recent activities of GEIA, the outcome of the workshops that were organized within GEIA, as well as the 2007 summer school, where the development of on-line e-working modules on emissions were outlined and discussed. We also present the GEIA-ACCENT web portal on emissions, which provides an easy access and detailed information on existing databases of emissions. Several inventories, either at the global or at the regional scale, are publicly available from the portal. We present a selection of comparisons of available inventories, and describe the first steps we have taken to organize an assessment of emissions inventories.

INTRODUCTION

The overall goal of the Global Emissions Inventory Activity (GEIA) is to quantify the anthropogenic emissions and natural exchanges of trace gases and aerosols that drive

Earth system changes. GEIA is a component of and contributes to large international programs, such as the AIMES project, which is itself part of the International Geosphere-Bisophere program (IGBP).

The International Geosphere-Biosphere Programme (IGBP) is a research programme that studies the phenomenon of Global Change. IGBP studies the interactions between biological, chemical and physical processes and interactions with human systems and collaborates with other programmes to develop and impart the understanding necessary to respond to global change. IGBP´s research goals are to (1) Analyze the interactive physical, chemical and biological processes that define Earth System dynamics, (2) Analyze the changes that are occurring in these dynamics and (3) Quantify the role of human activities on these changes. More details on the IGBP program, its projects and activities are available at www.igbp.kva.se.

The GEIA project (www.geiacenter.org) was created in 1990 to encourage the development of global emissions inventories of gases and aerosols emitted into the atmosphere from natural and anthropogenic sources. Until 2003, GEIA was one the projects of IGAC, the International Global Atmospheric Chemistry project of IGBP. The initial goals of GEIA within IGAC were to produce emissions inventories for the years 1985 and 1995 for all species of interest on a 1° x 1° global grid and a country-by-country basis.

The IGBP program was restructured in 2002-2003, and, in order to recognize the importance of the determination of surface emissions not only for atmospheric chemistry, but also for different issues in global changes in the Earth system, it was decided that GEIA would become part of the AIMES project. Over the past decades, it was increasingly recognized that global change must be studied in an integrated manner. The IGBP projects are dealing with different themes as shown in Figure 1: that is, the Atmosphere (IGAC project), ILEAPS (Land-atmosphere project), etc. The AIMES (aimes.ucar.edu) project focuses on the integration of the current knowledge of issues related to the Earth system. The overall challenge for AIMES is to achieve a deeper and more quantitative understanding of the role of human perturbations to global biogeochemical cycles and their role in altering the coupled climate system.

Figure 1: the IGBP projects.

THE GEIA PROJECT ORGANIZATION

Since 2004, GEIA has been chaired by Claire Granier (CNRS, France and CIRES/NOAA, USA) and Alex Guenther (NCAR, USA). The activities are organized by a steering committee that includes Paulette Middleton (USA), Hajime Akimoto (Japan), Ivar Isaksen (Norway), Cathy Liousse (France), Jean-Francois Lamarque (USA), Jos Olivier (Netherlands), Claire Reeves (UK), John VanAardenne (Italy), Vigdis Vestreng (Norway), Frank Dentener (Italy), Jean-Francois Muller (Blegium), Klaus Butterbach-Bahl (Germany), Laurens Ganzeveld (Netherlands), Zig Klimont (Austria).

The GEIA activities are currently supported by the European Commission, through its funding for the ACCENT European Network (Atmospheric Composition Change: A European Network; ACCENT, http://www.accent-network.org) and by U.S. NSF and NASA funding the GEIA Center. The overall ACCENT network is coordinated by S. Fuzzi (CNR, Italy) and the emissions component of ACCENT is coordinated by Claire Granier. The ACCENT network is funding the development of an emissions web portal, and is providing partial travel funds for participants to GEIA activities. Details on the ACCENT network can be found on the webpage. The are currently 44 European institutions participating in the network, and 131 associate partners from all countries of the world, including 10 US institutions.

THE GEIA CENTER

The hub of the global network of institutions and agencies developing these emissions inventories is the GEIA Data Management and Communication Center. The Center's activities are supported by the U.S. National Science Foundation (NSF) and National Aeronautics and Space Administration (NASA) and directed by Paulette Middleton of Panorama Pathways. The Center's role is to manage the website, to coordinate the distribution of emission inventory data, and to manage GEIA outreach activities.

GEIA Center has established an e-mail network, now totaling over 800 members, to easily inform the global community of conferences, other emissions related activities, and other relevant information. The Center also compiles short reviews of emissions information for key chemicals and source groups; updates on an ongoing basis web links to information directly related to GEIA; and retains the earlier GEIA inventories and their documentation. The GEIA center has provided support for the GEIA outreach activities and GEIA conferences as described below. Proceedings, presentations, planning documents, and other important information developed at these conferences, schools, workshops and other GEIA-related meetings are organized and provided on the GEIA web site.

GEIA CONFERENCES AND OUTREACH

Summer school on emissions and atmospheric composition
A summer school on "Surface emissions and prediction of atmospheric composition changes" has been organized for the benefit of early career scientists from different disciplines and nations to address current issues in surface emissions and modelling of the changes in the composition of the atmosphere. The school was held September 11-20, 2007 in Ile d'Oleron, France. The school gave attendees access to leading scientists in the field as well as the opportunity to form collaborations with scientists from other nations and disciplines. The tutorials, discussions and training focused on the following themes: (1) Emissions and deposition of gaseous compounds, (2) Emissions of aerosols, (3) Development of chemical schemes for studies of regional and global changes in the composition of the atmosphere, (4) Modeling of changes in the composition of the atmosphere, (5) Impact of changes in the atmospheric composition on vegetation and humans. In order to improve education and information in the fields related to Atmospheric Chemistry, the ACCENT European Network has started the development of internet-based tools for a better access to basic concepts and current research concerning both surface emissions and modeling of the atmospheric chemistry. Working groups were formed during the school to discuss the benefits of developing such web-based tools. These could be e-learning modules (i.e. on-line interactive tutorials), or e-working modules (i.e. interactive tools for data analysis, comparisons of data, and exchanges of research results). A combination of an e-learning module and an e-working module was determined to be the most valuable by the participants. A report summarizing the discussions is available at: http://www.accent-network.org/portal/publications/accent-series-reports (Granier et al., 2007).

GEIA 2006 conference
The GEIA 2006 conference was held in Paris on November 29 – December 1. It was attended by over 100 registered participants. The conference included posters and oral presentations organized into four main science themes: anthropogenic emissions, integrating spatial/temporal scales, terrestrial ecosystems and biomass burning, and aerosols. A concluding session provided an opportunity for participants to provide input on the development and direction of GEIA. A detailed description of the conference, as well as the presentations given at the conference and the recommendation for GEIA next steps, are available at www.geiacenter.org.

Workshop on emissions from combustion sources
The "Joint ACCENT/GEIA workshop on anthropogenic emissions for non-OECD countries in global inventories" took place in Vienna, Austria on February 8-10, 2006. It was organized by M. Amman (Institute for Applied Systems Analysis, Austria), J. Olivier (Environmental Assessment Agency, The Netherlands), and J. vanAardenne (Joint Research Center, Italy). The workshop focused on the following emission sectors: mobile (road and off-road) land-based sources, combustion in the power plant and industrial sectors, biofuel used in the residential sector and burning of agricultural waste. Different compounds were considered, greenhouse gases (CH_4 and N_2O), air pollutants (CO, NO_x, NMVOCs, NH_3, SO_2) and primary aerosols (BC, OC, $PM_{2.5}$ and PM_{10}). The

participants reviewed the information contained in existing global and regional emissions inventories, and discussed appropriate improvements for key sectors in different world regions.

THE GEIA EMISSIONS WEB PORTAL

The goal of the GEIA/ACCENT emissions data portal is to facilitate the access, the use, and the comparison of emission data from anthropogenic activities, biomass burning and natural sources. For this purpose, it provides surface emissions data (total and gridded data), for the main emission categories (total anthropogenic, total biomass burning, biogenic, and oceans). The compounds considered in the data portal are ozone precursors, greenhouse gases, organo-halogens, aerosols and their precursors, several heavy metals and Persistent Organic Pollutants (POPs).

The GEIA/ACCENT emissions web portal can be accessed through the GEIA web site, or through the following web site:
http://www.aero.jussieu.fr/projet/ACCENT/database.php

Global and regional inventories available through the emissions portal, are indicated in Table 1.

Global inventories:	**Regional inventories:**
• EDGAR FT2000	• ABBI (Asia)
• POET	• REAS (Asia)
• RETRO	
• CO2 emission inventory from Andres et al.	
• GFED v2	
• AMAP Mercury inventory	
• GEIA version1 inventories	

Table 1: List of emissions database included in the GEIA-ACCENT web portal.

The emissions portal provides emission data from many existing emission inventories which have been developed by different research groups or institutes. Information on the available emissions categories (anthropogenic, biomass burning or natural emissions) are provided for each inventory, together with information on the spatial resolution and the temporal period and resolution. The emission portal provides a link to the home web page of each inventory.

In addition, for each inventory, the data portal provides :
• Gridded emission files which can be downloaded in common ASCII and NetCDF formats (see below)
• Total annual emission data
• Emission maps for all species, and years/months considered

• Metadata and documentation on the inventory
• A visualisation tool for comparison

Emission data are provided by the owners of the data in their original format, which are very different from one another. To facilitate the use of the data, we have converted all the datasets into two common formats: a common ASCII format and NetCDF format. NetCDF is the most common format used within the modelling community, and also by all atmospheric scientists. Thus, providing these data in NetCDF ensures an easy use of the emission data for all modelers and scientists. When possible, the ASCII format is also made available, since it can be read more easily by non-scientists.

For each inventory, the data and information on the dataset are obtained by clicking on the name of the inventory. For users who are not sure about the dataset they are interested in, and want to know which species are available in each inventory, we also provide a table giving the list of species. The table obtained by the user is shown on Figure 2.

Data Portal - List of species

Specie	POET	RETRO	GEIA v.1	EDGAR 32FT2000	AMAP Mercury	ABBI
CO	•	•	•	•		•
NOx	•	•	•	•		
NO						•
NO2						•
CO2		•	•	•		•
CH4 (methane)		•	•	•		•
C2H6 (ethane)	•	•				•
C2H4 (ethene)	•	•				•
C3H8 (propane)	•	•				•
C3H6 (propene)	•	•				•
Butane and higher	•	•				•
Butene and higher	•					•
Toluene	•	•				•
CH3OH (methanol)	•	•				•
C2H5OH (ethanol)	•	•				•
C3H7OH (propanol)		•				•
CH2O (formaldehyde)	•	•				•
CH3CHO (acetaldehyde)	•	•				
CH3COCH3 (acetone)	•	•				•
CH3COCH2CH3 (Mek)	•					
C2H2 (ethyne)		•				
C6H6 (benzene)		•				
Xylene		•				•
Styrene						•
Phenol						•
Acetic acid						•
Formic acid						•
Isoprene (C4Hx)	•	•				•
Monoterpenes	•	•				
H2 (hydrogen)		•				
N2O		•	•	•		
N2						•
NH3 (Ammonia)		•	•			
Organic Carbon ('OC')		•	•			•
Black Carbon ('BC')		•	•			•
Total Carbon ('TC')		•				
SO2		•	•	•		•
Particulate Matter 2.5 ('PM2.5')		•				
Total Particulate Matter (TPM)		•				
CFC (cfc-11 & cfc-12)			•			
Lead (pb)			•			
Mercury (hg)			•		•	
Reactive chlorine			•			
Pesticides			•			
VOC			•	•		

Figure 2: List of species for which emissions inventories are provided

For each inventory, a standard template has been developed; it provides detailed information on the dataset. The metadata consist of the title of the dataset, an abstract, reference(s), contact details (names of authors, institutes, e-mail addresses), spatial and temporal information on dataset (coverage and resolution), methodology, data sources, as well as the unit and format of data. A web link to the inventory home web page and/or to more documentation is also provided when available. Figure 4 gives an example of the metadata for the RETRO inventory.

Short description of the inventories available through the GEIA-ACCENT portal

POET inventory
Global emissions of gases (ozone precursors) from anthropogenic, natural, and biomass burning sources have been estimated for the period 1990-2000. Anthropogenic emissions (containing 15 sectors) are based on national activity data (fuelwood combustion per year), emission factors (kg CO/ kg fuelwood combusted par activity), and grid maps (e.g. population maps) for spatial distribution of the emissions within a country. Biomass burning emissions are estimated with a climatology from Hao et al. (1994), and ATSR active fire maps are used for the spatial and temporal distribution of the emissions. Biogenic emissions are estimated with a vegetation canopy model.

RETRO inventory
Within the RETRO project, global gridded data sets for anthropogenic and vegetation fire emissions of several trace gases were generated, covering the period from 1960 to 2000 with a monthly temporal resolution. Anthropogenic emissions in the RETRO inventory are derived from the TNO database and the VERITAS inventory of international ship traffic emissions. Vegetation fire emissions were constructed from a large variety of sources with the objective to provide a reasonable estimate of emissions including their seasonal and interannual variability in the major burning regions of the world.

EDGAR FT2000
The EDGAR 3.2 Fast Track 2000 dataset (32FT2000) comprises global anthropogenic emissions for the year 2000 of the Kyoto Protocol greenhouse gases CO_2, CH_4, N_2O, and F-gases (HFCs, PFCs and SF_6) and of the air pollutants CO, NMVOC, NO_x and SO_2 (precursor gases for ozone and aerosols). The dataset is based on the EDGAR 3.2 estimates for 1995 and have been prepared by trend analyses at country level for each standard source category of EDGAR 3.2. The emissions data are presented as country/sector tables and as 1x1 degree grid files at the same level of detail as the EDGAR 3.2 emissions data that have been published on the internet. For gridded emissions of large-scale biomass burning four variants have been compiled: annual burned area estimates for either the 1997-2002 average - which are most consistent with the decadal smoothed EDGAR 3.2 emissions - or the actual 2000 area and either the EDGAR 3.2 emission factors or the factors compiled by Andreae and Merlet in 2001. These large-scale biomass burning datasets provide monthly emissions.

GFED v2 biomass burning inventory
Emissions from open fires have been estimated for the 1997-2005 period and will be updated annually. The methodology relies heavily on satellite data and includes all fires that can be detected from space. Smaller agricultural fires may not be detected, but all grassland, savanna, and forest fires (including deforestation fires) are included. Emissions were calculated as the product of burned area, fuel loads, combustion completeness, and emission factors. Satellite-derived burns drive the fire module of a biogeochemical model that calculates fuel loads for each month and grid cell. Combustion completeness was also calculated in the model based on fuel types and moisture conditions.

CO2 inventory Andres et al. (fossil fuel historical inventory)
One degree latitude by one degree longitude (1x1) data sets of carbon dioxide emissions from fossil fuel consumption and cement manufacture were produced for years 1751 to 2003. National estimates of carbon emissions were combined with 1x1 data sets of political units and human population density to create the new 1x1 carbon emissions data sets. The human population density data set has an effective resolution of the country/state level. This resolution translates to a 1x1 carbon emissions data set. The data show continual growth with time over most of the world, with increased growth rates in major urban areas. A slow southerly shift in the bulk of the emissions is also apparent as Asian countries increase their energy consumption to support their growing economies and populations.

AMAP Mercury inventory
National anthropogenic mercury emission estimates were compiled at NILU by J. Pacyna and E. Pacyna. The inventories presented are for the nominal years 1995 and 2000. For some countries, official emission estimates reported for other years (within 1-2 years of the target nominal year) have been used. In a very few cases where no new emissions estimates were available, 1995 emissions estimates for certain sectors in some countries were also used in 2000. The 1995 inventory is described in Pacyna & Pacyna (2002) and a paper describing the 2000 inventory is in preparation (Pacyna et al, 2005).

ABBI Asian Biomass Burning Inventory
An inventory of biomass burning emissions at 1°x1° over Asia has been derived for gases and particles for the Aerosol Characterization Experiment-Asia (ACE-Asia) and the Transport and Chemical Evolution Over the Pacific (Trace-P) campaign period (March to May 2001) in 2001, and also for the period from March to May 2000. The emissions are derived from SPOT-VEGETATION burnt area products, biomass density, burning efficiency data, and emission factors (per vegetation type)

REAS (Regional Emission inventory for Asia)
A new emission inventory was derived for Asia (Regional Emission inventory in ASia (REAS) Version 1.1) for the period 1980-2020. REAS is the first inventory to integrate historical, present, and future emissions in Asia on the basis of a consistent methodology. Emissions are presented for 2000, historical emissions for 1980-2003, predicted emissions for 2004-2009 on the basis of emissions for 2003 and 2010, and projected future emissions for 2010 and 2020: emissions include SO2, NOx, CO, NMVOC, black

carbon (BC), organic carbon (OC), CO2, NH3, and CH4 from anthropogenic sources (fuel combustion, industrial sources, and agriculture). Future emissions in 2010 and 2020 were projected by emission scenarios and from emissions in 2000. For China, three emission scenarios have been developed: REF (reference case), PSC (Policy Success Case), and PFC (Policy Failure Case).

A few examples

For each inventory, emission maps have been prepared for all species, years/months considered in the inventory: these are provided through the portal. Figure 5 shows an example of an emission map corresponding to the GFED inventory.
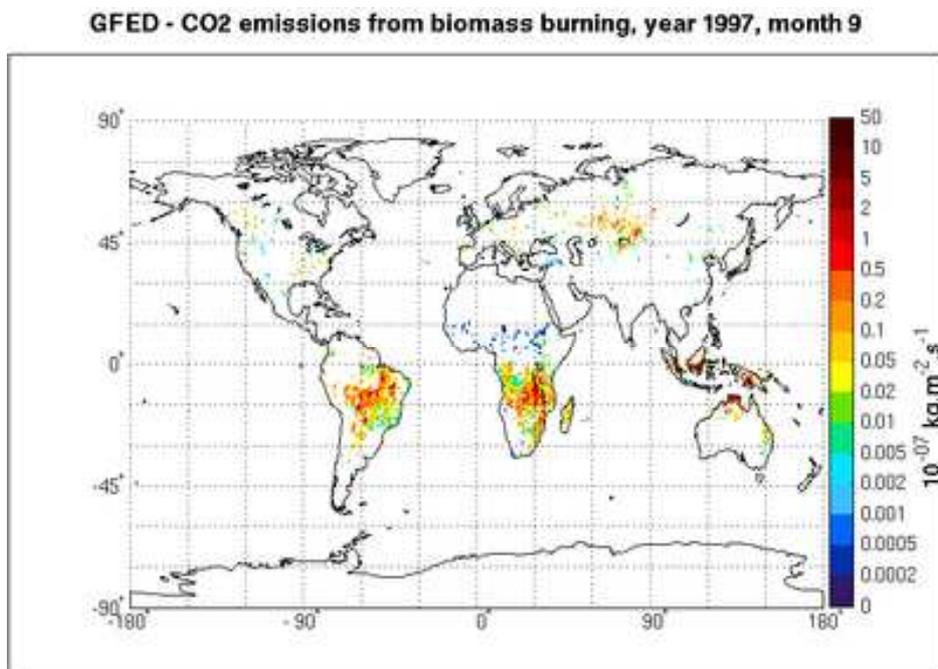

Figure 3: Example of a CO2 biomass burning emissions distribution in September 1997 from the GFED v2 inventory.

A tool has been developed in collaboration with the LSCE/IPSL French laboratory, for visualizing and comparing emission datasets. This tool is found on the portal under 'Data manipulation tools'. This tool allows users to plot 1 to 4 emission maps on one page, for any species, and any year/month considered in the inventories. Figure 6 provides an example of plots created using this tool.
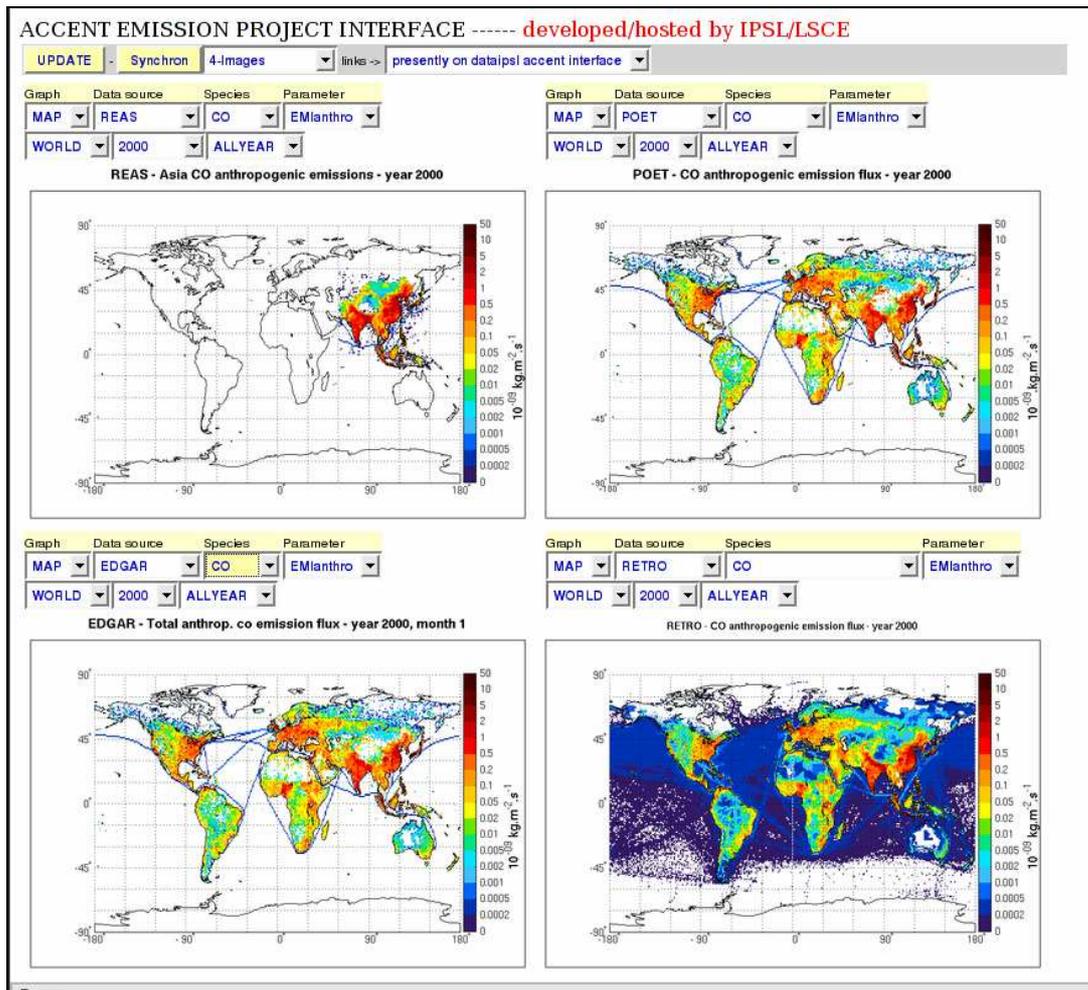
Figure 4: Example of a comparison between EDGAR FT2000, POET, RETRO and REAS inventories, for CO anthropogenic emissions for year 2000.

A link is provided on the portal (under 'Data manipulation tools') to all the tools developed within the RETRO project for manipulating data, in particular for NetCDF data. This package is very complete, and provides tools for (1) regridding emission data, (2) converting NetCDF files in text format, or (3) checking global totals of emissions.

CONCLUSIONS

Over the past few years, GEIA has organized several activities, including conferences and a summer school, as well as a coordination center, where issues concerning surface emissions at the global and regional scales have been discussed. An emission web portal was designed to provide access to a series of emission inventories under a common format. Tools are also available to assist comparisons of the different available inventories.

During the coming months, more inventories will be included in the emission portal, both for the global and regional scales. An international intercomparison of global inventories will be organized, and groups developing regional inventories are also expected to participate. Reviews of the knowledge of the emissions of the different species, or of the different emission sectors will be organized and included on the GEIA web site.

REFERENCES

Andres RJ, Marland G, Fung I, Matthews E (1996) "A one degree by one degree distribution of carbon dioxide emissions from fossil fuel consumption and cement manufacture, 1950-1990", *Global Biogeochem. Cycles,* 10:419-429.

Granier, C., J.F. Lamarque, A. Mieville, J.F. Muller, J. Olivier, J. Orlando, J. Peters, G. Petron, G. Tyndall, S. Wallens, "POET, a database of surface emissions of ozone precursors", available on internet at:
http://www.aero.jussieu.fr/projet/ACCENT/POET.php.

Michel, C., C. Liousse, J.-M. Grégoire, K. Tansey, G.R. Carmichael, and J.-H. Woo (2005), "Biomass burning emission inventory from burnt area data given by the SPOT-VEGETATION system in the frame of the TRACE-P and ACE-Asia campaigns", *J. Geophys. Res*, 110, D09304, doi:10.1029/2004JD005461.

Ohara, T. et al. (2007), "An Asian emission inventory of anthropogenic emission sources for the period 1980-2020". *Atmospheric Chemistry and Physics,* 7, 4419-4444',

Olivier J., J. Peters, C. Granier, G. Petron, J.F. Muller, and S. Wallens (2003), "Present and future surface emissions of atmospheric compounds", POET report #2, EU project EVK2-1999-00011, available on internet at:
http://www.aero.jussieu.fr/projet/ACCENT/POET.php , 2005.".

Olivier, J.G.J., Van Aardenne, J.A., Dentener, F., Ganzeveld, L. and J.A.H.W. Peters (2005). "Recent trends in global greenhouse gas emissions: regional trends and spatial distribution of key sources", in *Non-CO2 Greenhouse Gases (NCGG-4)*, A. van Amstel (coord.), page 325-330. Millpress, Rotterdam, ISBN 90 5966 043 9.

Pacyna, E.G., J. M. Pacyna, J. Fudala, E. Strzelecka-Jastrzab, S. Hlawiczka and D. Panasiuk (2006), "Mercury emissions to the atmosphere from anthropogenic sources in Europe in 2000 and their scenarios until 2020", *Science of the total Environment*, 370, 1, doi:10.1016/j.scitotenv. 2006.06.023.

Schultz, G. M., A. Heil, J. J. Hoelzemann, A. Spessa, K. Thonicke, J. Goldammer, A. Held, and J. M.C. Pereira, "Global Emissions from Vegetation Fires from 1960 to 2000" (2007), submitted to *Global Biogeochemical Cycles*.

van der Werf GR, Randerson JT, Giglio L, Collatz GJ, Kasibhatla PS, Arellano AF, Interannual variability in global biomass burning emissions from 1997 to 2004, *ACP*, 6: 3423-3441 AUG 21 2006

KEY WORDS
Emission Inventories
Biomass burning
Anthropogenic emissions
Chemical compounds
Aerosols
Global scale
Regional scale
Web portal
International projects