Emissions for GEMS (Biomass burning)

HALO
discussion paper

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1 Introduction

The paper gives an overview of activities related to global emissions, in particular from biomass burning, beyond the background of the requirements of the GEMS[1] integrated project. Within the GMES[2] initiative, GEMS will establish a global operational modelling and assimilation system for global greenhouse gases, reactive gases and aerosol as well as a system of regional air quality models. All these activities will need data on emissions. GEMS needs to deal with biomass burning because (i) biomass burning is a major source for greenhouse gases, reactive gases and aerosol, and (ii) biomass burning can be observed from space, which fits to the general objectives of the GMES initiative.

HALO[3]-SSA[4] deals with emissions for GEMS since emission fluxes into the atmosphere are mainly consequence of surfaces processes. Therefore, they are an example of the interaction between land, ocean and atmosphere. Although of particular importance, emissions are not a major research or operational activity in GEMS and in the other HALO partner projects MERSEA[5] and geoland[6], the former dealing with the ocean and the latter with land and vegetation. However, modelling and observation of fluxes between the earth surface and the atmosphere is vital for understanding, monitoring and predicting the state of the earth - system. The report intends to start a discussion on the emission issue within GEMS and among the HALO partners.

A summary of basic terms related to emissions is presented in chapter 2. Chapter 3 tries to summarise the activities on emissions in the GEMS project. A selection of global and European regional emission inventories is presented in chapter 4. The main part of the report is dedicated to biomass burning emissions. Chapter 5 briefly introduces the problem of inferring emission data from biomass burning, discusses different approaches to observe related data from space, and lists a selection of current fire counts and burnt area products. Finally, preliminary conclusions are provided on a united approach towards the harmonised emission approach in GEMS.

The paper has benefited from comments from Tony Hollingsworth (ECMWF), Michael Schultz (MPI-Hamburg), Stephen Plummer (ESA), Soumia.Serrar (ECMWF), Christian Pfrang (ECMWF) and Olivier Boucher (UK met office).

[1] **G**lobal and regional **E**arth-system **M**onitoring using **S**atellite and in-situ data is the atmosphere IP in GMES.
[2] **G**lobal **M**onitoring for **E**nvironment and **S**ecurity is a joint EC and ESA initiative
[3] Harmonised coordination of Atmosphere, Land and Ocean integrated projects of the GMES -backbone.
[4] Specific Support Action
[5] Marine Environment and Security for the European Area. MERSEA is the ocean IP in GMES.
[6] geoland is the land & vegetation IP in GMES.

2 Emissions - Basics

Emission data provide surface fluxes of gases and aerosols in the atmosphere due to man made activities (e.g. industry and traffic) and natural processes (e.g. dust, lightening, fires, volcanoes, biogenic VOC emissions etc.). However, the man made emissions are often emissions of the eco-system, which was subject to human activity such as agriculture and de-forestation. Processes that include both release and uptake of species such as the carbon cycles of the vegetation and the oceans are often not referred to as emissions but as sources and sinks.

Emissions inventories provide the emission quantities from anthropogenic sources, and sometimes also from natural sources. However, natural emissions (e.g. sea salt spray and wind blown dust) are often not given in total prescribed numbers but are modelled by means of parameterisation (**emission models**) from input data such as wind and surface conditions.

Emission data sets differ in many respects. The discrepancies are due to different total numbers, different selection of chemical species and breakdown of volatile organic compounds, different temporal and spatial resolution and variability, different selections of emitting processes, different injection heights and different, mostly not well documented, methodologies.

A typical way to obtain emission data, the so called **bottom-up approach**, is to combine species-specific **emission factors**[7], describing the emission efficiency of an activity or process, with a spatio-temporal **activity measure**[8] of a certain sector (e.g. road traffic) or natural process. Emission factors can partly be measured, but contain large uncertainties. Anthropogenic activity measures often have to be estimated from uncertain socio-economic data.

An alternative way for emission estimates is the **top-down approach,** which starts with observations of the concentration and infers the emissions by means of inverse modelling. This inversion problem is often not well defined (i.e. too few observations), which means that a first guess of the emission structure has to be assumed. The first guess is then altered in order to achieve a better fit of the model result with concentration observations. The top-down emission estimates do not directly reveal the cause of the emission.

Global (bottom-up) emission data sets typically have a resolution of 1x1° and a temporal resolution of one year or one month only. Global emission data are in general freely available to the research community. Regional emission inventories cover Europe with a resolution from 10 - 50 km and resolve emission variability on an hourly basis and, therefore, represent the diurnal cycle. The regional inventories attribute anthropogenic emissions to a complex breakdown of source groups in a standardised way. Regional inventories are mainly compiled for air pollution studies and need to be extended for research on global change issues since CO_2 and Methane are often not included. Because emissions are partly regulated by national and international law, emission data sets have a political dimension too.

[7] The emission factor could be NO emissions per km of one heavy duty vehicle or the CO emissions per km^2 of a certain wildfire type.
[8] The activity measure would be distribution of the heavy duty traffic or the wild fires.

3 Emission activities in GEMS, geoland and MERSEA

This section gives a short summary of tasks in GEMS, geoland and MERSEA, which are related to emissions. Emissions are a strong link between all the GEMS sub-projects. For example, emissions from man-made combustion and biomass burning will be needed in all GEMS subprojects. Therefore, it would be advisable to work towards a common emission data set or model for all global activities and a consistent data set for the regional activities on air pollution.

3.1 GEMS subproject on Greenhouse gases (GHG).

Appropriate CO_2 surface flux parameterisations will be developed varying from simple climatological means to more detailed physical parameterizations. The main surface fluxes arise from the following processes. Climatological data are obtained from the references given in brackets:

- Anthropogenic emissions from fossil fuel burning and cement manufacturing (estimates for the year 1995 by Brenkert, 1998, following Andres 1996 *et al.*)
- Net ecosystem production (NEP) of the terrestrial biosphere (Mean seasonal cycle from CASA model simulations, Randerson *et al.*, 1997)
- Ocean-atmosphere carbon exchange (Mean seasonal cycle of net fluxes for 1995, Takahashi *et al.*, 2002).

GHG uses inverse modelling methods to refine CO_2 sources and sinks (WP GHG_4). The observational data for this activity will be both in-situ and remotely sensed observation. Work package GHG_6 will later attribute the inferred sources and sinks to causes. The inverse modelling will also be applied to methane (WP_GHG_7).

3.2 GEMS subproject on Global reactive gases (GRG)

Within GRG, already existing emission data and products will mainly be used. The implementation of three global CTMs (MOZART, MOCAGE and TM3) at the ECMWF system (WP GRG_2) will include the provision of consistent anthropogenic and natural (mainly hydrocarbons from vegetation) emission data set (task GRG 2.9). A consistent data set is important for model inter-comparison.

A module providing emission of temperature-dependent biogenic hydrocarbons from vegetation and nitrogen oxides from lightning will also be added. Furthermore, a methodology to account for the daily, weekly and seasonally variations of anthropogenic emissions will be developed and implemented.

The Global Wild Fire Emission Model (GWEM, see chapter 5.1) developed at MPI-Hamburg (Hoelzemann *et al.*, 2004) will be implemented at the ECMWF computer system. Both the activities in GRG and AER may benefit from the data. GWEM needs data on fire activity and vegetation status.

3.3 GEMS subproject on global aerosol (AER)

One whole work package of AER lead by FMI is dedicated to the refinement of aerosol emission sources (WP_AER_2). The overall structure of the emissions data processing and their use is depicted in Figure 1. The WP tasks comprise the update of the anthropogenic aerosol and precursor emissions to the latest information available (task 1), the assimilation of information on the wild fires from satellites (task 2), the quantification of the wind-blown dust emission from desert areas (task 3), quantification of the wind-blown sea salt emission (task 4) and of the sources of stratospheric aerosols (task 5).

Task 2 on wild fire intends to develop and test an operational system for the provision of the emission amount and the injection height. The system relies on satellite fire count data and modelling of fire induced buoyancy and dispersion (BUOYANT).

3.4 GEMS subproject on Regional air quality (RAQ)

RAQ aims at compiling an anthropogenic emission data base for Europe with a 5 km resolution, which will be used by the participating regional CTMs. In addition, specific work on emissions factors for the Mediterranean vegetation will be carried out in Greece. Mediterranean vegetation is a strong source of biogenic volatile organic compounds. Within work package RAQ_2, the impact of the high resolution data set is investigated together with that of the boundary condition from GRG and AER as well as data assimilation.

3.5 HALO partner IPs geoland and MERSEA

Geolands Observatory Natural Carbon (ONC) will operationally provide carbon (CO_2) fluxes from land vegetation due to respiration and photosynthesis. The ONC carbon - land - vegetation model will be part of ECMWF forecast system, which also host the global GEMS system. Since the amount of burnt biomass depends on the vegetation status, the modelling of vegetation fire emissions could benefit from vegetation modelling in ONC. Geoland's Core Service Geophysical Parameters (CSP) provides a burnt area product for Africa and boreal Asia for the 2000-2003 period based on satellite data (Vegetation, ATSR, AATSR, Meris). Again, the data could be useful in the GEMS re-analysis exercise for atmospheric composition. MERSEA's activities in biogeochemical modelling, which have no operational commitment, may provide martime CO_2 fluxes.

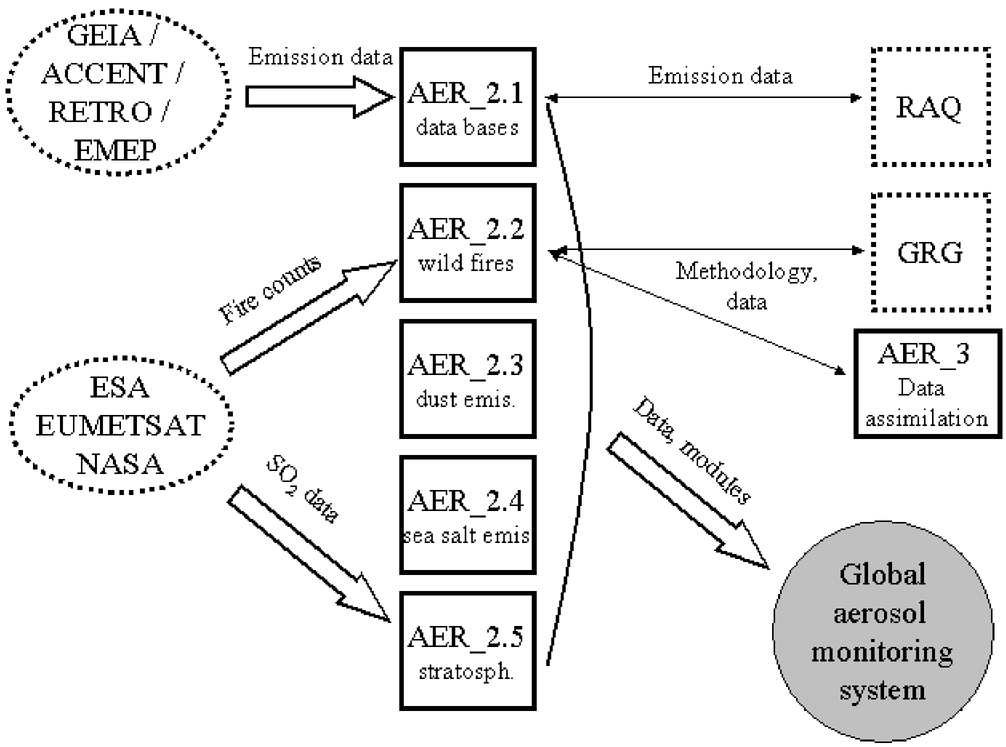

Figure 1 Graphical overview of GEMS WP AER_2 which deals with aerosol emissions.

4 Global and regional emission data inventories

The following global and European regional emissions inventories are available *inter alia* (see table below):

- Regional (Europe): EMEP, GENEMIS
- Global: GEIA, EDGAR, AEROCOM, POET, RETRO

GEIA (Global Emission Inventory Activity) is a consortium of about 100 partners worldwide in the framework of IGBP and IGAC. GEIA (Version 1) provides comprehensive global emissions on a 1x1° grid for the years 1985 and 1990. Apart from black carbon, biomass burning data is obtained from the inventory by Hao *et al.* (1994) . The data is aggregated in annual, seasonal or monthly averages. The recommended anthropogenic emissions are from the EDGAR data set.

EDGAR (version 3.2) is a global data set for anthropogenic emissions. It comprises data from 1990-1995, both on a 1x1 degree grid and as summary tables per region or country and source. For the direct greenhouse gases CO_2, CH4 and N2O also emissions estimates for 1970 and 1980 are available. Data for the gases CO, NOx, NMVOC and SO_2 will be limited to 1990 and 1995.

The **POET** (FP5) work package on emissions extended the EDGAR data base up to 1997 and 2000. The POET emissions are based on GEIA and EDGAR data and include new developments on biogenic VOC emissions.

The inventory of the **AEROCOM** project comprises global aerosol data (mass totals and simple size distribution) derived from various authors for anthropogenic and natural sources for the year 2000 and the year 1750. The data is provided in a 1 x 1° resolution; dust, sea salt and DMS are daily data, biomass burning are monthly values and the rest is annual data. The compilation of the data set was initiated within the AEROCOM project in order to compare different global CTMs on aerosols and radiative forcing while using the same emission data. Dust and sea salt emissions were determined by using use of ERA-40 wind fields.

Within the **RETRO** (FP5) project, an emission data set is being compiled for a period covering the past 40 years. The RETRO project will provide and investigate tropospheric composition data for the ERA-40 period. State of the art global CTM's and a variety of data sets from ground based, air and space borne measurements will be merged for this objective.

The **EMEP** inventory of anthropogenic emissions is based on data officially submitted by the parties to the CLRTAP (Convention on Long Range Transboundary Air Pollutants) via the UNECE secretariat. These official data are complemented by so called expert emissions inventories which try to fill the gaps in the reports and to decrease inconsistencies by applying a harmonised methodology. The expert EMEP emissions are widely used in regional CTM activities in Europe.

IER-Stuttgart has provided regional and local emission data sets for many applications. A European data set has been worked out as part of the GENEMIS project. IER usually provides high resolution data on demand and all temporal variability is already included in the data set.

TNO-MEP is an other organisation which provides European anthropogenic emission inventories. Data are supplied as yearly numbers and the temporal variability is modelled by means of time function describing the diurnal, weekly and annual cycle. These time function could perhaps be applied to achieve a better time resolution for global inventories.

C. Liousse *et al.* (1996) compiled a global and regional black carbon (BC) inventory. Main sources for BC are fossil fuel and biofuel consumption as well as biomass burning. Large differences between the data sets from different authors are present due to high uncertainties both in emission factors and activity information. In particular, global fire data products show large differences. BC is of special interest since it tends to warm the atmosphere due to absorption.

INVENTORY NAME (INSTITUTION) WEB LINK	SPATIAL COVER AND RESOLUTION	TEMPORAL COVER AND RESOLUTION	REMARKS
GEIA (IGAC) www.geiacenter.org	global, 1°x1° or per country	1985, 1990	natural and anthropogenic (EDGAR) emissions
EDGAR 3.2 (RIVM) arch.rivm.nl/env/int/coredata/edgar/	global, 1°x1°, or per country	1990-1995	only anthropogenic emissions
AEROCOM (MPI/LSCE) nansen.ipsl.jussieu.fr/AEROCOM/	global, 1°x1°	2000, 1750	natural, anthropogenic and "effective" secondary aerosol
POET (FP5) nadir.nilu.no/poet/index.htm	global, 1°x1°	1990-2000/	POET emission WP extended EDGAR and GEIA
RETRO (FP5) retro.enes.org	global, 0.5°x0.5°	global emissions for the ERA-40 period	RETRO is about modelling intra annual trends in tropospheric chemistry
EMEP (Met-No) www.emep.int/index.html	Europe, 50 km x 50 km	1990-2002, 1 hour	Anthropogenic emissions Based on official reporting of countries and experts assessment
GENEMIS (IER-Stuttgart) genemis.ier.uni-stuttgart.de/	Europe, Germany, 10 km	1 hour	Production on demands for selected episodes
TNO www.mep.tno.nl/emissions/	Europe, 25 km x 25 km	1 hour	

Table 1 List of selected global and regional emission inventory activities

5 Emissions from biomass burning

Biomass burning is a major source of CO_2, CO, aerosols, in particular black carbon (BC), NOx, Methane and further hydrocarbons. Biomass burning is a global phenomenon having a maximum in tropical regions. Biomass burning has both man-made and “natural” causes since it includes wild fires initiated by deforestation, lightning, agricultural waste burning, fuel-wood use, charcoal production and fires associated with forest and savanna clearing (Brasseur, G. P., Steffen, W. and Granier, C., 2004).

The effect of biomass burning on the net carbon cycle (CO_2) strongly interacts with vegetation cycle. It is therefore difficult to estimate the net effect on the atmospheric fluxes. Fires diminish both vegetation debris whose decomposition is a source of CO2 and green vegetation being a sink. Biomass burning is believed to only slightly alter the seasonal ecosystem production and to more strongly contribute to the inter-annual variability (up to 20%, Zeng *et al.* 2005). However, there are other studies that link fire activity and severity in boreal regions to climate change *(e.g. Amiro et al., 2001).*

Most of the world's burnt biomass matter is from the savannas, and because two-thirds of the Earth's savannas are located in Africa, that continent is now recognized as the "burn centre" of the planet. The vast majority of the world's burning is human-initiated, with lightning-induced natural fires accounting for only a small percentage of the total. (from: http://asd-www.larc.nasa.gov/biomass_burn/globe_impact.html) Figure 2 shows the contributions of fires in different ecosystems to total CO_2 emissions.

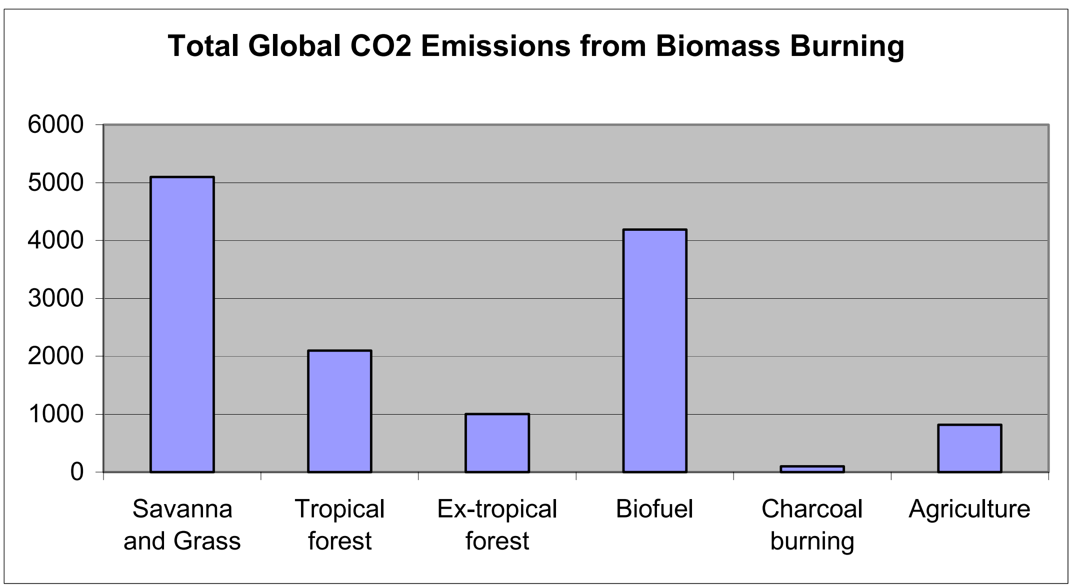

Figure 2 CO_2 released (Tg/year) by fires of different origin (Andreae and Merlet, 2001)

Fire emission factors and injection heights are highly variable and *inter alia* depend on the fire temperature and duration (flaming or smoldering), burnt biomass water content and meteorological conditions. Biomass burning occurs mainly in the dry season and differs from year to year. Very large inter-annual variability has been observed in particular in boreal regions.

To obtain biomass burning emission data for the CTM-modelling three major problems have to tackled (Liousse, C. *et al.,* 2004). All of them contribute to the large uncertainty of current biomass emission data:

1. Identifying location and duration of fire
2. Estimating amount and biome type of the burnt biomass (available fuel load)
3. Choosing the right specific species emission factors and injection height for the detected fire

Fires can be observed by satellite in a global scale. Satellite instruments can identify either fires or burnt areas in cloud free situations. Many satellite based fire count and burnt area products are available in various spatial and temporal resolution and coverage. The products vary because of different instruments, equatorial crossing times, detection algorithm and operational constraints on data provision. The next section reviews briefly the current activities and data set on fire proxies.

The available fuel load can be inferred from climatological vegetation maps, remote sensing of the vegetation status or from global vegetation modelling. Data assimilation of remotely sensed vegetation indices such as NDVI in vegetation models could account for the influence of the meteorological conditions on vegetation and consider satellite observed land cover change. However, estimates of available fuel load from NDVI or remotely sensed maps always need field data for validation (Barbosa *et al.*1999). The efforts of geolands ONC on vegetation modelling could therefore help to improve wild fire emission modelling within GEMS.

Determination of emission factors is based on concentration measurements in fire plumes and is complemented by laboratory experiments and fire modelling. The BIBEX- programme (http://diotima.mpch-mainz.mpg.de/bibex/) is part of GWAC and IGBP activities and started in the early 90ies. It coordinated several major field campaigns in different ecosystems of the world. The uncertainty in the emissions factor is also linked to the uncertainty in the information on the type of the burnt vegetation. Andreae and Merlet (2001) compiled a summary of emission factor data from the various field campaigns, which is typically used in emission modelling.

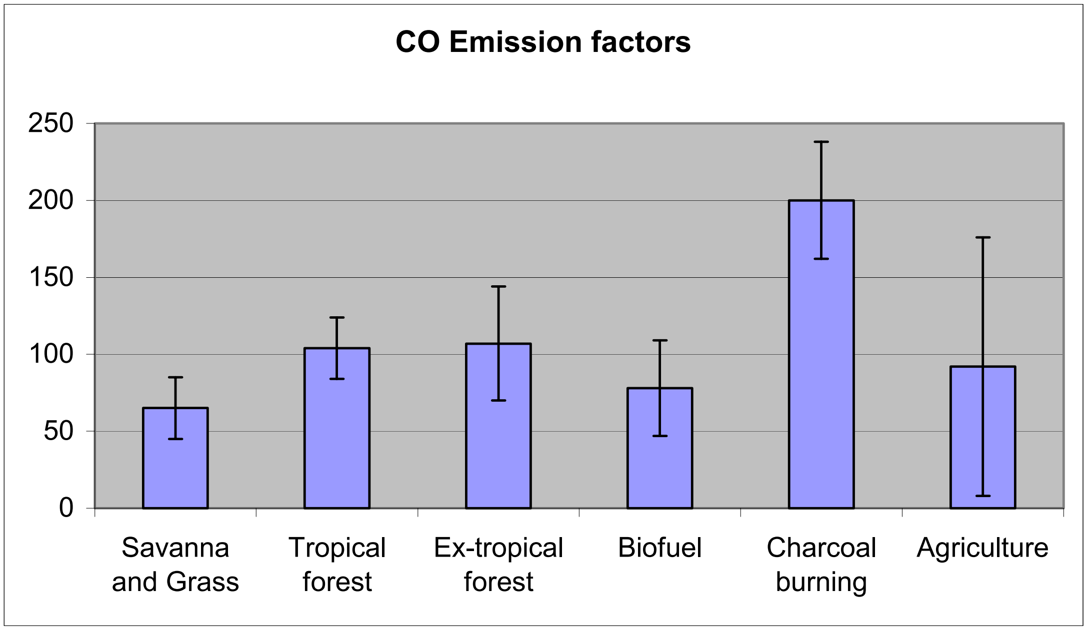

Figure 3 Emission factors for CO in gram species per kilogram dry matter burnt and associated errors. (Andreae and Merlet, 2001).

5.1 Emission inventories and models for biomass burning

Many CTMs are still based on climatological inventories such as Hao *et al.* 1990; Hao and Liu, 1994, or variants of these (e.g. the biomass inventory in EDGAR-3). These inventories do not reflect the inter-annual variability. The Hao and Lui data set is provided for Africa, tropical Asia and Central and South America in monthly values in a 5x5°resolution (http://eosweb.larc.nasa.gov/GUIDE/dataset_documents/bio_burn_5x5_hao_dataset.html).

A few CTMs adapted interim solutions by scaling the climatological inventories with fire satellite data in order to improve seasonality and to provide interannual variability. (Duncan *et al.*, 2003; Schultz, 2002; Generoso *et al.*, 2003)

MPI-Hamburg made considerable efforts in compiling data sets reflecting the inter-annual variability of biomass burning emissions and to evaluate the potential of satellite observations for this purpose. A **Global Wildfire Emissions Model** (GWEM) has been developed, which combines global satellite observations of ATSR and output from a dynamic vegetation model (LPJ-DGVM) in order to better quantify biomass burning emissions (Hoelzemann *et al.*, 2004). Emissions from peat fires in Indonesia have been assessed and work has begun to construct a time series of global peat fire emissions. GWEM will be installed at ECMWF within GEMS. A 20-year global burned area data set based on the 8-km AVHRR pathfinder data is currently under construction within the RETRO project.

The **Global Fire Emissions Database** (GFED) is a recent biomass burning inventory for the tropics and subtropics. It consists of 1° x 1° gridded monthly Carbon, CO_2, CO, and CH4 data for the time period 1997 - 2002. GFED is based on TRMM data, and fuel loads are modelled with the average FPAR, temperature and precipitation data. (http://www.gps.caltech.edu/~jimr/randerson.html and http://www.env.duke.edu/faculty/prasad/research/biomassburning/biomassburning.htm)

The atmospheric transport of fire emissions depends strongly on the injection height, which is a function of fire intensity and size. Large crown fires in boreal forests can cause injection at a height of more than 10 000 m, whereas emissions from smoldering are released in the PBL. Therefore, attention should be paid to the influence of fires on convective processes. Fire models such ATHAM (Trentmann *et al*., 2002) or BUOYANT (Kukkonen *et al*., 2000) are available to estimate the injection height. A simple relationship between fire intensity and injection height was established by Lavoué (PhD thesis, 2004).

5.2 Fire observation from space

Many activities on global, continental and regional scales deal with observing vegetation fires from space. The main motivation for the activities is land cover and forest assessment as well as risk management. Only a small number of programmes are concerned with the provision of emission data.

The Fire Team of the GOFC-GOLD (Global observation of forest cover and land dynamics) activity, being part of IGOS/GTOS (Global terrestrial observation system of the Integrated Global Observation System), provides a forum for research on fire observation from space. The GOFC-GOLD web-site http://www.fao.org/gtos/gofc-gold/f_fire.htm is a good starting point for exploring the different activities.

Fire observation data from space are provided as two different product types:

1. Active fire count or
2. Burnt area.

5.2.1 Active fire counts

Active fire counts has been the first and dominant approach for fire data. Pixels from imager instruments such as AVHRR or ATSR with temperatures above a threshold (> 312/308 K at night) are classified to be fires. Uncertainties of the fire count are due to loss of sub scale information, cloud cover, satellite coverage and false alarms due to hot non-burning surfaces. To avoid artifacts arising from solar reflection, ATSR fire detection is confined to night only, despite the fact that fire number are highest during the day. It is assumed that, in general, fire detection underestimates the extend of biomass fires due to sub scale loss and night detection (Arino *et al.,* 2001)

The instruments used have not been designed for fire detection and are often measuring closed to the upper detection limit. Since based on operational measurements, fire count data are often available in near real time. However, validated products are often averaged to at least monthly data.

Current activities involved with fire detection use the following instruments or satellites: AVHRR, GOES, MSG, DMSP, TRMM/VIRS, MODIS, ATSR, BIRD (DLR fire detection satellite) and ASTER.

Examples of fire count products:

ERS-2/ATSR-2 World Fire Atlas (ESA)

http://shark1.esrin.esa.it/ionia/FIRE/AF/ATSR/

- Based on ATSR - night time data in order to reduce false alarms
- 1995 to 2002: ATSR-2 night-time data (level 1B product).
- 2003 to Present: AATSR night-time data (level 1B product).

AVHRR World Fire Web (EU/JRC)

http://natural-hazards.jrc.it/fires/detection/wfw/help/overview.html

The fire map is a latitude-longitude raster, where each raster cell contains the number of fires detected within that cell over a period of time. The cell size is typically 0.5x0.5 ° and the time period is typically 1 day or 10 days.

GOES Automated Biomass Burning Algorithm -ABBA/WF-ABBA (University of Wisconsin, NOAA)

http://cimss.ssec.wisc.edu/goes/burn/detection.html

The GOES-8 ABBA fire product includes: fire location (lat./lon.), estimates of fire size and temperature, 3.9 and 10.7 micron observed brightness temperatures, background brightness temperatures, albedo statistics, ecosystem type, and a flag for non-processed fire pixels to indicate the reason for not processing.

The Wild fire -ABBA (WFABBA) imagery is generated blending data from the GOES 10 and 12 satellites and a land cover map derived from 1-km AVHRR.

Plans exist to provide a global products based on the geostationary satellite network.

MODIS Global Fire Rapid Response System (NASA)

http://modis-fire.umd.edu/products.asp

- 250 m product, daily update, North America emphasis
- 1 km global product composite 8 day fire product (MOD14A2)
- Several near real-time product on temperature anomalies

TRMM-VIRS fire counts

http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/hydrology/TRMM_VIRS_Fire.shtml

http://earthobservatory.nasa.gov/Observatory/Datasets/fires.trmm.html

- Tropical and Sub-tropical zones (+/- 40° from the equator) for 1998-2002, with possible extension to mid 2004
- Derived from Tropical Rainfall Measuring Mission (TRMM) Visible and Infrared Scanner (VIRS) measurements,
- Number of 4.4 km^2 pixels in each half-degree grid cell

5.2.2 Burnt area

The extent of burnt area is assumed to be a better proxy for the determination of fire emissions than fire counts because the burnt area last longer making the detection more likely, and because a better estimate of the burnt biomass amount is possible. However, knowledge about the burnt eco system is still required.

Detection of burnt areas is based on changes in the albedo or, more specifically, on changes of the TOA-NIR reflectance and surface temperatures. The transition from vegetation cover to burnt scar is characterised by a strong decrease in reflectance in NIR and increased day temperatures due to enhanced absorption. The NIR reflectance decrease is independent of the type of ecosystem, however the signal is less persistent in savannah regions than in temperate and boreal regions. The increase in day time temperature due to a lack of evapo-transpiration is in the range of 7-8 K.

Activities about burnt area determination uses the following instruments or satellites: AVHRR, MODIS, SeaWiFS, ATSR, AATSR, VEGETATION.

Examples of burnt **area products:**

GLOBSCAR (ESA)

http://shark1.esrin.esa.it/ionia/FIRE/BS/ATSR/

- global monthly data for 2000 in 1 km resolution
- ATSR based burnt area product for 2000 (500 km swath)
- GLOBACARBON will later also provide burnt vegetation data (2000-2003)

Global Burnt Area 2000 - GBA2000 (ECE/JRC)

http://www-gvm.jrc.it/fire/gba2000/index.htm

- global monthly data for 2000 in 1 km resolution
- Mapping, from SPOT-VEGETATION S1 (2000 km swath) imagery,
- used for Geoland CSP
- algorithms at regional scales by a network of partner

MODIS burnt area product

http://modis-fire.umd.edu/products.asp

- monthly gridded data in 500m resolution with the approximate day of burning

GLOBCARBON burnt area product (planned)

- global monthly maps of burnt areas for the period 1998-2007 in 10 km, 0.25° and 0.5° resolution
- based on the experience of both GLOBSCAR and GBA-2000.
- used sensors for burn scar detection: ATSR-2, AATSR, and VEGETATION
- MERIS is used to add confidence to the preliminary results.

geoland CSP burnt area product

http://geoland-csp.mediasfrance.org/Produits/Vegetation/BurntAreas/

- daily monthly maps for 2000-2003 for Africa and boreal Asia
- based on VEGETATION

5.2.3 Comparing fire and burnt area products

Remote sensing of fires and burnt areas is an active research area. The available products show large discrepancies, and require validation and calibration with either high-resolution imagers or ground-based observations. The differences between the products are not only systematic but depend on area and season.

Burnt area data is believed to be better input for emission estimates than fire count data since less assumption have to be made. In general, the total size of detected burnt areas largely exceeds that of fire pixels.

A validation study (Arino and Plummer, 2001) of the ATSR world fire product suggests a good geo-location of the hot spots but a global underestimation of the hot spot number, mainly due to night-time detection and re-visiting period.

Boschetti *et al.* (2004) recently conducted a comparison of two burnt area data sets (GBA-2000 and GLOBSCAR) and a fire count data set (ATSR world fire atlas). They conclude:" while there is generally a good spatial agreement, the disagreement in terms of areal estimates is major. […] Large differences in areal estimates are particularly evident when comparing either burnt area product with the active fire dataset, with a difference in the order of 10^2. More alarming are the large discrepancies in the areal estimates between the two burnt area products…. The temporal profiles of active fires and burnt areas also show significant differences, with a shift in the detection of the peaks of seasonal fire activity".

The provision of fire count data is more likely to be operational than that of burnt area data. Fire products are available in data sets longer than one year (for example ATSR, TOMS) whereas GBA-2000 and GLOBSCAR data are only available for 2000. To date (April, 2004), only the MODIS fire product seems to be available in near real time. Therefore, fire count data have been used to introduce temporal and partly spatial variability in existing inventories of biomass burning emissions (Schulz, 2002 and Generoso, 2003). However, based on the conclusions of Boschetti et al. (2004) and Hoelzemann (PhD thesis in preparation), it is clear that more work will be necessary to ensure the validity of such an approach.

6 Summary and Conclusion

The global and regional modelling activities in GEMS need emission data. A number of global and regional scale inventories of anthropogenic and natural emission sources are available, but the data have large uncertainties due to insufficient knowledge about emission factors and activity data. Nevertheless, for some key species inverse modelling studies suggest that the large-scale patterns and magnitudes of anthropogenic emissions are mostly, except for South Asia, captured with reasonable accuracy.

Global biomass burning emissions may become a focus in GEMS since (i) biomass burning is a major source for greenhouse gases, reactive gases and aerosol and (ii) biomass burning can be observed from space, which matches the general objectives of the GMES initiative. Emissions are an interface process between atmosphere, ocean and land and could, therefore, become an issue covered by the HALO specific support action.

Compiling biomass burning emission data requires knowledge about:

1. Location, area size and duration of fires
2. Amount and biome of burnt biomass (available fuel load)
3. Specific species emission factors and injection heights

Recent data sets on global biomass burning emissions make use of remotely sensed fire counts or burnt area data. Vegetation data to estimate the available fuel load can be obtained from climatological maps, satellite observation and vegetation modelling. Emissions factors are measured during field campaigns and in laboratory studies. The knowledge about all three problems is limited and of mostly unknown precision, which leads to a high uncertainty in the emission data set in particular on the global scale.

Fire count and burnt area retrieval is an active research area, but only a fraction is related to emission estimates. Many imager instruments have been applied to detect fire from space. State of the art fire count data (ATSR world fire atlas, ESA) and burnt area products (GBA-2000 from JRC and Globscar from ESA) seem to largely differ in area size and variability. Fire count data appear to underestimate the size of the fires but they are available from many instruments, for multiple years and in near real time mode (MODIS). They have been used to introduce temporal and spatial variability in inventory based emission data.

The assumption about the burnt vegetation type or, more general, the land cover properties has large impact on the emission estimate. Different underlying climatological vegetation maps (MODIS vs. IGBP) can cause emissions differences of 10-50% (Hoelzemann *et al*, 2004). Therefore, good data on vegetation and surface conditions are necessary for good emission estimates.

The content of this report leads to the following preliminary conclusions and recommendations concerning the use of emission in GEMS:

One of GEMSs major goals is the set-up of a global modelling and assimilation system within ECMWFs integrated forecast system. It seems to be advisable to harmonise the use of emissions during the development of the project. Major emission sources such as biomass burning and man-made emissions are relevant to all three global sub project (GHG, GRG and AER), and, moreover, the global emission data used for providing boundary conditions to the regional air pollution modelling should be consistent with the high resolution data.

Typical global emission data sets (e.g. EDGAR) are provided in a 1x1° horizontal and monthly temporal resolution. The smallest time scale the global GEMS-systems aim at is about one day. Improving the temporal variability of current emission data seems to become a necessity for GEMS.

As part of the GEMS-GRG subproject, the global wildfire emission model (GWEM) will be implemented at ECMWF. GWEM may provide data for GHG and AER. GWEM could benefit from surface modelling and data assimilation at ECMWF. ONCs (geoland) vegetation modelling and assimilation should be considered as a possible input for emission modelling. The CO_2 emission from biomass burning have to be related to the pronounced CO_2 cycle due vegetation. The importance of the relative impact seems to depend on the considered time scales.

Fire injection height or, more general, the impact of fires on convection should be taken into account within the GEMS system. Appropriate models are already developed, which should be implemented at ECMWF to directly use the meteorological data provided by IFS. However, research is still needed to link these models with fire observations.

A common problem will be the operational availability of near real time fire count or burnt area data for biomass burning emissions in GEMS pre - operational phase in 2007. Table 2 lists candidate data sets for the operational and reanalysis activities in GEMS. At present, the MODIS fire product seems to be only global operational near real time fire product. GEMS intends to use the MODIS-based product, which will almost certainly have an operational follow-on based on the VIIRS instrument on NPP and NPOESS.

The GOES based automated biomass burning algorithm (ABBA, University of Wisconsin, http://cimss.ssec.wisc.edu/goes/burn/detection.html) provides operational fire count products for America, which are also coupled to an operational transport model (RAMS) for South America (http://tucupi.cptec.inpe.br/meio_ambiente/). Plans exist at NOAA/NESDIS to provide a global fire product from the instruments of geostationary network from 2005.

GEMS should explore the availability and applicability of the geostationary fire product for operational biomass emission estimates. Advantages of the geostationary product could be a better temporal resolution and better operational provision.

The GLOBCARBON project will produce monthly global burnt area maps for the 1998-2007 period in 10 km resolution. The data could match the GEMS needs for fire information in re-analysis mode.

Inverse methods to infer correction to exiting emission data and the attribution of the causes will belong to the workload of the GEMS-GHG. It might be worthwhile to investigate whether changes found for CO_2 can be adapted to emissions relevant to GRG or AER. Moreover, the analysis of the concentration observation increments from the assimilation of satellite data could lead to an improved description of emission data.

DATA BASE (ORIGIN)	PERIOD AND AREA COVERED	VARIABLES PROVIDED	RESOLUTION	POSSIBLE USAGE
Globscar - ATSR (ESA)	global, 2000	burnt area	1 x1 km monthly	Reanalysis
GBA2000 - VEGET. (JRC)	global, 2000	burnt area	1 x 1 km monthly	Reanalysis
GLOBCARBON ATSR/AATSR/VEGET.	global, 1998-2007	burnt area	10 x 10 km monthly	Reanalysis
geoland CSP VEGET.	Africa, bor. Asia 2000-2003	burnt area	1 x 1 km daily	Reanalysis
Thermal anomaly MODIS (NESDIS)	global, NRT	fire count	1 x 1 km daily	Operations and reanalysis and
ABBA - GOES (NESDIS)	America NRT	fire count	1 x 1 km daily	Operations and Reanalysis
WF - ABBA Geost. Sat.	global RT (start in 2005?)	fire count	1 x 1 km daily	Operations and Reanalysis
FIMMA-AVHRR (NESDIS)	N-America NRT	fire count	1 x 1 km daily	Operations and Reanalysis
World fire web-AVHRR (JRC)	global 1996-2001	fire count	0.5x0.5° daily	Reanalysis
World fire atlas -ATSR (ESA)	global 1995-2004	fire count	1 x 1 km monthly	Reanalysis

Table 2 Candidate fire and burnt area data bases for GEMS reanalysis and operational mode

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