Recommendations for a Global Fire Assimilation System (GFAS) in GMES

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contributions from:
Outline

- Introduction
- Review of Available Data
- Recommendation: Global Fire Assimilation System (GFAS)
- Recent Developments in GEMS
- Summary
INTRODUCTION
Significance for Land Monitoring

- Wildfires are an important sink mechanism for the terrestrial carbon pools in the global carbon cycle.
  - wildfire emissions, typical global values: 1.5 – 4 Gt C / year
  - fossil fuel emissions of Europe + North America: 3 Gt C / year

- Wildfire behaviour characterises land cover types with repeated fire events.
  - typical fire repeat period
  - typical fire intensity
  - typical fire seasonality
  - ...

- Wildfires can change the land cover type irreversibly
  - tropical deforestation
  - ...

Atmosphere: Biomass Burning (BB) Emissions ...

AIR QUALITY:
- ... can dominate local and regional air quality with poisonous smoke
- ... can elevate background of atmospheric pollutant after long range transport [Stohl et al. 2001, Forster et al. 2001, Andreae et al. 2001]

POLLUTION CONTROL:
- ... significantly contributes to global budgets of several gases
  - Kyoto, CLRTAP, ...

WEATHER: (absorbing aerosols)
- ... influences the radiative energy budget [Konzelmann et al., JGR 1996]
- ... provides cloud condensation nuclei [Andreae et al., Science 2004]
- Heat release accelerates deep convection. [Damoah et al., ACP 2006]

REMOTE SENSING:
- ... affects essential a priori information for remote sensing (AOD, profiles)

CHALLENGE:
- ... are highly variable on all time scales from hours to decades
Biomass Burning in GMES

- **GMES** is an initiative by EU and ESA. It aims at designing and establishing a European capacity for the provision and use of operational services for Global Monitoring of Environment and Security.

- The integrated project (IP) **GEMS** develops the atmosphere monitoring system for GMES.

- The integrated project (IP) **GEOLAND** develops the land monitoring system for GMES.

- **Biomass Burning (BB)** is a major interface between both the atmosphere and land monitoring systems.
Global Earth-system Monitoring using Space and in-situ data – GEMS

- Creation of an **operational system** for greenhouse, reactive gases, and aerosols in the troposphere and in the stratosphere on the regional and on the global scale by 2009.

- Production of near-real-time and retrospective **analyses** of global monitoring, and medium and short range **forecasts** of atmospheric chemistry and dynamics.

- **Information** relevant to the Kyoto and Montreal protocols, to the UN Convention on Long-Range Trans-boundary Air Pollution.

- **Regional Air Quality Forecasts for Europe.**
Organisation of the GEMS Project

GEMS is organised in 6 projects
Scientific recommendations

Land-Atmosphere: Biomass estimates

Land Carbon component of GEOLAND

Objectives

• Improve the current carbon accounting systems (i.e. National forest inventories with a sampling time of about 10 years)

• Address all temporal scales (hour to decade)

• Global/continental maps on a regular grid:
  ➢ account for all vegetation types (not only forests)
  ➢ use all the available data (EO/in situ)

• Assess the uncertainties
Scientific recommendations
Land-Atmosphere: Biomass estimates

Modelling: „greening“ of operational weather forecast models

ORCHIDEE  ISBA-A-gs  C-TESSEL

SURFEX
Météo-France

CY30R1
ECMWF

http://www-lsceorchidee.cea.fr/

Operational modelling platforms

Demo NRT processing chain
LSCE

http://www-lsceorchidee.cea.fr/
Motivation for this Presentation

- Monitoring and forecasting of the atmospheric composition requires input of
  - fire emission of various atmospheric trace constituents
    - aerosols, CO, CO2, NOx, HCHO, …
  - fire emission injection heights

- Monitoring of terrestrial carbon fluxes requires input of
  - pyro-changes of terrestrial carbon stocks

- Fire Monitoring is required
  - globally
  - near-real time
  - retrospectively
# GEMS/GEOLAND BB PRODUCT REQUIREMENTS

<table>
<thead>
<tr>
<th>PRODUCTS</th>
<th>GEMS</th>
<th>GEOLAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>amounts of trace gases (CO2, CH4, CO, O3, NO2, SO2,...) and aerosols emitted</td>
<td></td>
<td>amount of biomass burnt</td>
</tr>
<tr>
<td>date, time, and location of fire</td>
<td></td>
<td>type of vegetation burnt</td>
</tr>
<tr>
<td>injection height profiles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COVERAGE</td>
<td>spatial:</td>
<td>global, consistent</td>
</tr>
<tr>
<td></td>
<td>temporal: &gt; 8 years</td>
<td>&gt; 10 years, consistently</td>
</tr>
<tr>
<td>RESOLUTION</td>
<td>spatial:</td>
<td>≈ 25 km</td>
</tr>
<tr>
<td></td>
<td>temporal: 1-6 hours</td>
<td>1 day</td>
</tr>
<tr>
<td>AVAILABILITY</td>
<td>near-real time</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>retrospectively</td>
</tr>
</tbody>
</table>

[Kaiser et al. 2006]
REVIEW OF AVAILABLE DATA
# Observation System: Current Fire Products

<table>
<thead>
<tr>
<th>NAME</th>
<th>REFERENCE</th>
<th>SENSOR(S)</th>
<th>COVERAGE</th>
<th>RESOLUTION</th>
<th>AVAILABILITY</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Active Fire Products (no quantitative information)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MODIS active fire</td>
<td><a href="http://modis-fire.umd.edu/products.asp">http://modis-fire.umd.edu/products.asp</a></td>
<td>Aqua/Terra-MODIS</td>
<td>global</td>
<td>1 km</td>
<td>1 day</td>
<td>NRT</td>
</tr>
<tr>
<td>World Fire Atlas (WFA-algo1)</td>
<td><a href="http://dup.esrin.esa.int/tonia/wfa">http://dup.esrin.esa.int/tonia/wfa</a></td>
<td>ERS2-ATSR2, Envisat-AATS</td>
<td>global</td>
<td>1 km</td>
<td>1 day</td>
<td>NRT</td>
</tr>
<tr>
<td>Active Fire Monitoring (FIR)</td>
<td><a href="http://www.eumetsat.int/idcplg?IdcService=SS_GET_PAGE&amp;nodeld=522">http://www.eumetsat.int/idcplg?IdcService=SS_GET_PAGE&amp;nodeld=522</a></td>
<td>Meteosat-SEVIRI</td>
<td>Africa &amp; Europe</td>
<td>3 km</td>
<td>15 min</td>
<td>NRT</td>
</tr>
<tr>
<td>IGBP-GFP</td>
<td><a href="http://www-temp.jrc.it/">http://www-temp.jrc.it/</a></td>
<td>NOAA-AVHRR</td>
<td>global</td>
<td>1 km</td>
<td>1 day</td>
<td>retrospectively finished</td>
</tr>
</tbody>
</table>

| **Active Fire Products with quantitative information** |                                                                         |                     |              |            |              |                 |
| MODIS FRP                   | http://modis-fire.umd.edu/products.asp Justice et al. [2002]             | MODIS                | global       | 2001-present | 1 km         | 1 day           | NRT             | operational     |
| SEVIRI FRP                  | http://www.eumetsat.int/idcplg?IdcService=SS_GET_PAGE&nodeld=522        | Meteosat-SEVIRI     | Africa & Europe | 3 km       | 15 min       | NRT             | under development |
| global FRP from GEOs        | M. Wooster, private comm.                                                | several GEO satellites | global | 4 km       | 30 min       | NRT             | in planning     |

| **Burnt Area Products**     |                                                                         |                     |              |            |              |                 |
| MODIS Fire Affected Area    | http://modis-fire.umd.edu/products.asp#8                                 | Aqua/Terra-MODIS    | global       | 2001-present | 500 m        | 1 day           | retrospectively under development |
| Global Daily Burnt Area (GDBAv1) | GDBA partnership: Leicester Univ.(UK), Louvain-La-Neuve Univ.(B), Tropical Res. Inst.(P), JRC(EC) | SPOT-VGT            | global       | 2000-2005  | 1 km         | 1 day           | retrospectively under development |
| Burnt Area for GEOLAND (BAG) | http://www-gvm.jrc.it/temf/Restricted access (GEOLAND)                  | SPOT-VGT            | Africa & Eurasia | 1988-2003 | 10 days | retrospectively under development |
| VGT4Africa                  | http://www-gvm.jrc.it/tem/                                              | SPOT-VGT            | global       | 2006-present | 1 km | 1 day | NRT | under development |
| GLOBCARBON                  | http://dup.esrin.esa.int/projects/summaryr43.asp                       | ERS2-ATSR2, Envisat-AATS, Envisat-MERIS, SPOT-VGT | global | 1998-2007 | 8 km | 1 month | retrospectively under development |

[Kaiser et al. 2006]
Issues with Available Products

- No single EO product satisfies all technical GMES requirements.

- It is non-trivial to assess the quality of existing EO products:
  - complementary (GEO – LEO, hot spots – burnt areas) [e.g. C. Michel et al., JGR 2005]
  - consistency [Boschetti et al. 2004]
  - spatial resolution
Relevant Pros and Cons

- geostationary observation
  - operational real time availability
  - good temporal resolution
  - quantitative products: WF_ABBA, SEVIRI-FRE
  - no global coverage
  - no burnt area inventories and long time series

- fire radiative power products
  - eliminate sources of uncertainty in emission modelling
  - not well established, i.e. validated
  - no burnt area estimation
**OBSERVATIONS:** Calculating Emission Amounts

- **traditional:**
  
  \[ M(\ldots) = \text{Area} \times \text{Biomass} \times \text{Burning efficiency} \times \text{Emission factor} \]

  "pixels" burnt per vegetation type

  Area burnt per vegetation type: ha

  Fuel: T. ha\(^{-1}\) ????

  Globe: \(\sim 400\) millions hectares burnt in 2000

  Med. Basin: \(\sim 500000\) hectares

  Dry tropical grass savanna: \(\sim 2\) tons/hectare

  Moist tropical savanna: \(\sim 10\) tons/hectare

  Boreal forest: \(\sim 20\) tons/hectare

  Moist tropical forest: \(\sim 40\) tons/hectare

  Woodland & forests:

  - \(\sim 1600\) g CO\(_2\) / kg biomass
  - Grasslands:
    - \(\sim 1700\) g CO\(_2\) / kg biomass

  \(\sim 25\%\) forest \(\rightarrow\) \(\sim 80\%\) savanna

**Fire Radiative Power (FRP):**

- \(M(X) = \text{FRP} \times \text{time} \times \text{scaling factor} \times \text{emission factor}(X)\)
Current NRT Fire Emission Monitoring Systems

- NRL/NAAPS aerosol model in the FLAMBE project
  - Additionally assimilates the MODIS active fire product
  - Delivers global aerosol emissions

- RAMS model at INPE/CPTEC
  - Assimilation of WF_ABBA product from GEOS satellites
  - Delivers CO and aerosol emissions over the Americas

Adapted from E. Prins
Conclusions on Available Systems

- Two existing monitoring systems for aerosols / carbon monoxide
  - prove the feasibility of atmospheric composition monitoring based on fire EO data and a meteorological model
  - highlight the importance of quantitative geostationary fire products
RECOMMENDATION:
Global Fire Assimilation System
(GFAS)
Benefits of Near-real-Time fire information for GEMS & GEOLAND

- GEMS largely neglects the variability of fire emissions.
- Biosphere carbon monitoring in GEOLAND-2 suffers from inaccuracy of the existing fire products.
- A future service, GFAS, could use complementary satellite fire observations, plus a fire model, to provide:
  - Emissions
  - Profiles of emission injection heights
  - Pyro-change in biomass
  - burnt area
- GEMS would benefit through more realistic and timely fire emission information.
- GEOLAND would benefit through estimates of change in carbon stocks.
- GFAS would benefit from fuel estimates provided by GEOLAND-2 as experience develops.
HALO-GFAS serves GEMS and GEOLAND.

- **GEMS**
  - fire emissions
  - injection heights

- **GFAS**
  - fire observations

- **GEOLAND**
  - available fuel load
  - land cover type
  - pyro-changes in carbon stocks
Additional GFAS Benefits

- single, consistent, operational fire processing for all GMES systems
  - global and regional
- GEOLAND will benefit from improved land cover characterisation and land cover change detection, i.e. burnt areas.
- Numerical Weather Prediction will benefit from fire heat release product for driving the convection.
- A multi-parameter inversion of the observed fire plumes will yield
  - improved fire emission fluxes (GEMS)
  - information on the fire properties
  - improvement of the fire model to be used by, e.g., climate models

- Collaboration of space agencies, satellite retrieval experts, biosphere & atmosphere modellers, and other users
RECENT DEVELOPMENTS IN GEMS
Preliminary Approach for Global Reanalyses

- use fire emission inventory GFEDv2 [van der Werf et al., ACP 2006]
  - CO2
  - aerosols

- thus combining
  - MODIS hot spot observations
  - biomass from CASA vegetation model driven by EO
  - modelling of atmospheric CO2 and aerosols

- shortcomings
  - not near-real time
  - time resolution of 8 days
CO2 Fire Emission on 20 Aug 2003 12UTC
[g/m²/month / 24] (GFEDv3-8d)
CO2 Model Field with Fires @ 500hPa [ppm]
Excess CO2 due to Fires I [ppm]
Excess CO2 due to Fires II [ppm]

Cross section of co2 20030820 00 step 12 Expver esvu
No fire emissions

With fire emissions

very preliminary!
Regional PM2.5 Emission by Fire Modelled in NRT from MODIS FRP (M. Sofiev, FMI)
Model evaluation: Tropospheric NO$_2$ column

Satellite: SCIAMACHY

Model: MOZART with ECMWF meteorology

Model agrees reasonably well with satellites.

But fire emission in Siberia not observed!?
SUMMARY
SUMMARY

- GEOLAND and GEMS need global Biomass Burning modelling in near-real time and consistent multi-year time series.
- No single suitable EO product or monitoring service is available.

- We propose to develop a Global Fire Assimilation System (GFAS) to serve the GMES requirements. It should combine:
  - fire EO products
  - meteorological conditions
  - land cover: ecosystem, biomass incl. all carbon stocks
  - numerical model of fire activity

- A global fire radiative energy product from geostationary satellite observations would provide an important and unique input to such a GFAS.

- The recommended GFAS is widely supported in the European science community.
- GFAS needs funding and a host.
MORE INFORMATION

- www.ecmwf.int/research/EU_projects/HALO
- www.ecmwf.int/research/EU_projects/GEMS
- www.gmes-geoland.info
- j.kaiser@ecmwf.int

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