# Scientific Recommendations Land-Atmosphere: Wildfires / Biomass Burning

**J.W. Kaiser**

contributions from:

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# Outline

- Introduction
- GEMS / GEOLAND Requirements
- Available Data
- Recommendation
- Summary

# INTRODUCTION

# What is Biomass Burning (BB)?

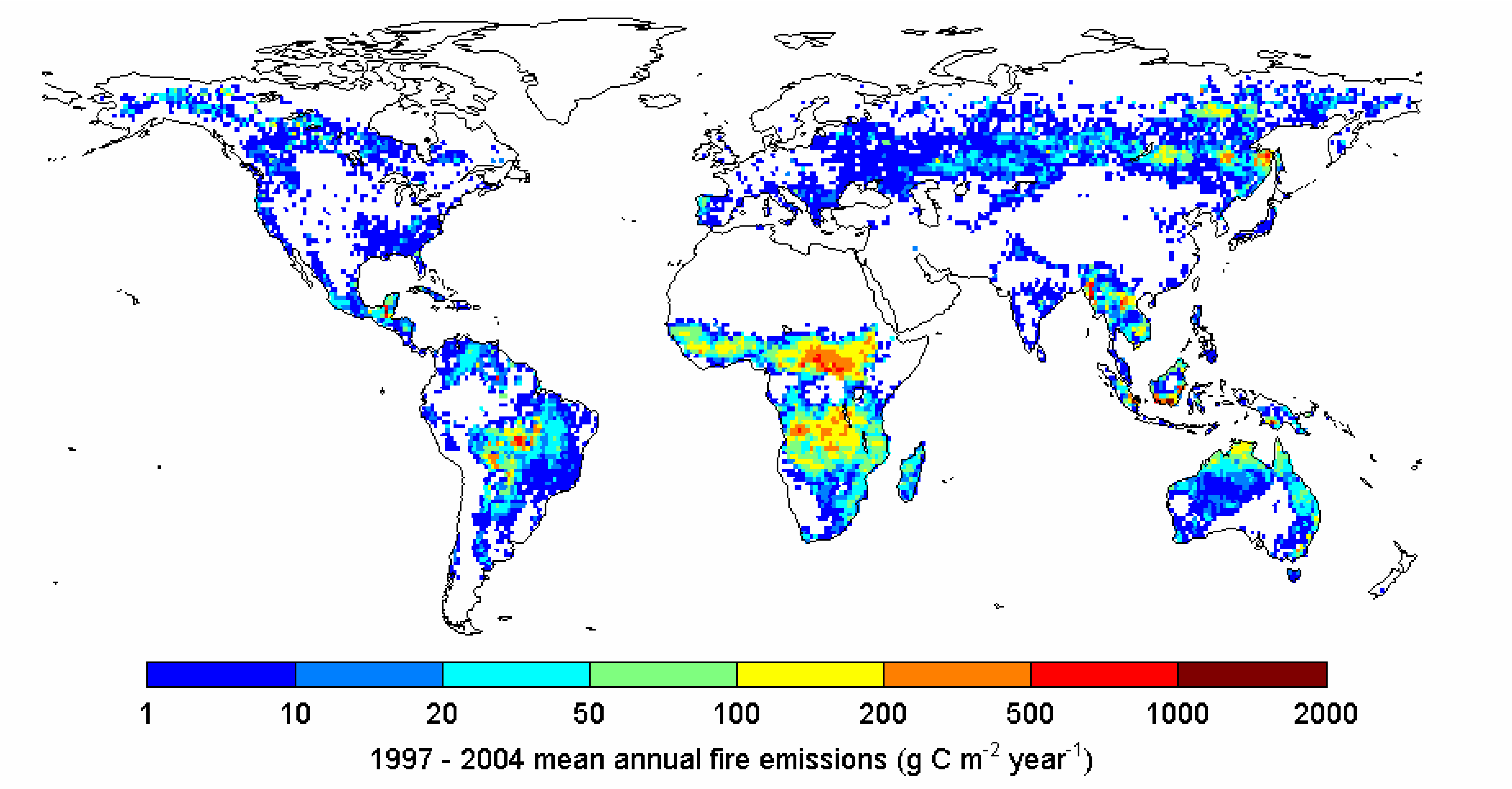
- biomass:
  - green vegetation, wood, litter, soil organic matter, peat
- ignition:
  - lightning or human activity

- visible from space by thermal radiation or burnt area
  - gas flares etc. excluded from observations

- function:
  - natural cycle of ecosystem
  - deforestation
  - agriculture
  - accident
  - …

- a.k.a. “vegetation fires”, “wildfires”

# Annual Fire Emissions, averaged over 1997–2004




[Van der Werf et al., ACPD 2006]

# 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 reversibly**
  - **tropical deforestation**
  - **…**

# Atmosphere: Biomass Burning (BB) Emissions …

**<u>AIR QUALITY:</u>**

- **… 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]

**<u>POLLUTION CONTROL:</u>**

- **… significantly contributes to global budgets of several gases**
  - **Kyoto, CLRTAP, …**

**<u>WEATHER:</u> (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]

**<u>REMOTE SENSING:</u>**

- **… affects essential a priori information for remote sensing (AOD, profiles)**

**<u>CHALLENGE:</u>**

- **… are highly variable on all time scales from hours to decades**

# GMES REQUIREMENTS

# GEMS/GEOLAND BB PRODUCT REQUIREMENTS

<table>
<tr><th></th><th>GEMS</th><th>GEOLAND</th></tr>
<tr><td rowspan="5">PRODUCTS</td><td>amounts of trace gases (CO2, CH4, CO, O3, NO2, SO2,…) and aerosols emitted</td><td></td></tr>
<tr><td></td><td>amount of biomass burnt</td></tr>
<tr><td></td><td>type of vegetation burnt</td></tr>
<tr><td>date, time, and location of fire</td><td>date and location of fire</td></tr>
<tr><td>injection height profiles</td><td></td></tr>
<tr><td rowspan="2">COVERAGE</td><td colspan="2">spatial: global, consistent</td></tr>
<tr><td>temporal: > 8 years</td><td>> 10 years, consistently</td></tr>
<tr><td rowspan="2">RESOLUTION</td><td colspan="2">spatial: ≈ 25 km (1 km for GEOLAND-2)</td></tr>
<tr><td>temporal: 1-6 hours</td><td>1 day</td></tr>
<tr><td rowspan="2">AVAILABILITY</td><td>near-real time</td><td></td></tr>
<tr><td colspan="2">retrospectively</td></tr>
</table>

[Kaiser et al. 2006]

# AVAILABLE DATA

# OBSERVATIONS

Two types of fire products accessible from Earth obs. systems

ACTIVE FIRE product

BURNT AREA product

- Active fire
- Hot spot
- Fire pixel
- Fire count

Fire front

- thermal emission, MIR
- only during fire

- Burnt area
- Burnt pixel
- Burnt scar

Area burnt

- spectrally flat
- BRDF flat
- dark
- only after fire

# Observation System: Current Fire Products

| NAME | REFERENCE | SENSOR(S) | COVERAGE | | RESOLUTION | | AVAILABILITY | STATUS |
|---|---|---|---|---|---|---|---|---|
| | | | spatial | temporal | spatial | temporal | | |
| **Active Fire Products (no quantitative information)** | | | | | | | | |
| MODIS active fire | http://modis-fire.umd.edu/products.asp Justice et al. [2002] | Aqua/Terra-MODIS | global | 2001 – present | 1 km | 1 day | NRT | operational |
| World Fire Atlas (WFA-algo1) | http://dup.esrin.esa.int/ionia/wfa | ERS2-ATSR2, Envisat-AATSR | global | 1995 - present | 1 km | 1 day | NRT | operational |
| Active Fire Monitoring (FIR) | http://www.eumetsat.int/idcplg?IdcService =SS_GET_PAGE&nodeId=522 | Meteosat-SEVIRI | Africa & Europe | | 3 km | 15 min | NRT | operational |
| IGBP-GFP | http://www-tem.jrc.it/ Dwyer et al. [2000] | NOAA-AVHRR | global | 1992-1993 | 1 km | 1 day | retrospectively | finished |
| TRMM | http://earthobservatory.nasa.gov/ Observatory/Datasets/fires.trmm.html Giglio et al. [2000] | TRMM-VIRS | 40°N - 40°S | 1988-2002 | 2 km / 0.5° (sensor/ product) | 1 month | retrospectively | finished |
| **Active Fire Products with quantitative information** | | | | | | | | |
| WF_ABBA, Dozier method | http://cimss.ssec.wisc.edu/goes/burn/ detection.html Prins et al. [2001, 2004] | GOES-E/W | N/S-America | 1995- present | 4 km | 30 min | NRT | operational |
| WF_ABBA, Dozier method | Prins et al. [2001, 2004] | several GEO satellites | global | | 4 km | 30 min | NRT | in planning |
| 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&nodeId=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** | | | | | | | | |
| GBA1982-1999 | http://www-tem.jrc.it/ Carmona-Moreno et al.[2005] | NOAA-AVHRR | global | 1982-1999 | 8 km | 1 week | retrospectively | finished |
| GBA2000 | http://www-tem.jrc.it/fire/gba2000 Tansey et al.[2004a, 2004b] | SPOT-VGT | global | Nov1999- Dec2000 | 1 km | 1 month | retrospectively | finished |
| GLOBSCAR | http://dup.esrin.esa.int/ionia/projects/ summaryp24.asp Simon *et al.* [2004] | ERS2-ATSR2 | global | 2000 | 1 km | 1 month | retrospectively | existing |
| MODIS Fire Affected Area | http://modis-fire.umd.edu/products.asp#8 | Aquaa/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/tem/ Restricted access (GEOLAND) | SPOT-VGT | Africa & Eurasia | 1998-2003 | 1 km | 10 days | retrospectively | under development |
| VGT4Africa | http://www-gvm.jrc.it/tem/ | SPOT-VGT | global | 2005- present | 1 km | 1 day | NRT | under development |
| GLOBCARBON | http://dup.esrin.esa.it/projects/ summaryp43.asp | ERS2-ATSR2, Envisat-AATSR, Envisat-MERIS, SPOT-VGT | global | 1998-2007 | 8 km | 1 month | retrospectively | under development |



[Kaiser et al. 2006]

# OBSERVATIONS: Calculating Emission Amounts

- **traditional:**

"pixels" burnt per vegetation type

Area burnt per vegetation type: ha

Fuel: T. $ha^{-1}$ ????

M (...) = Area . Biomass . Burning efficiency . Emission factor

Globe: ~ 400 millions hectares burnt in 2000
Med. Basin: ~ 500000 hectares

Dry tropical grass savanna: ~ 2 tons/hectare
Moist tropical savanna: ~ 10 tons/hectare
Boreal forest: ~ 20 tons/hectare
Moist tropical forest: ~ 40 tons/hectare

~ 25% forest --→ ~ 80% savanna

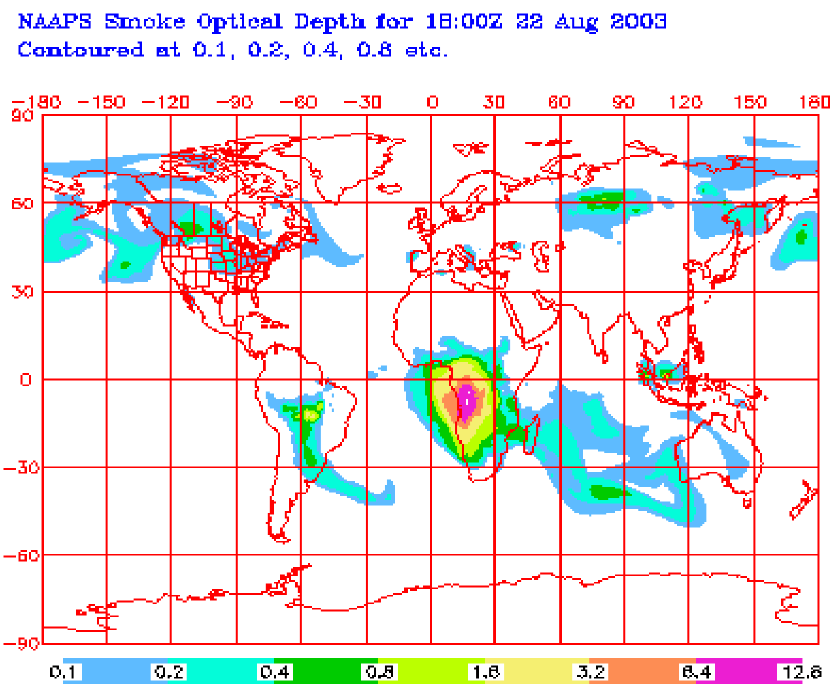
Woodland & forests
~ 1600 g $CO_2$ / kg biomass
Grasslands
~ 1700 g $CO_2$ / kg biomass

- **Fire Radiative Power (FRP):**
  - **M(X) = FRP * time * scaling factor * emission factor(X)**

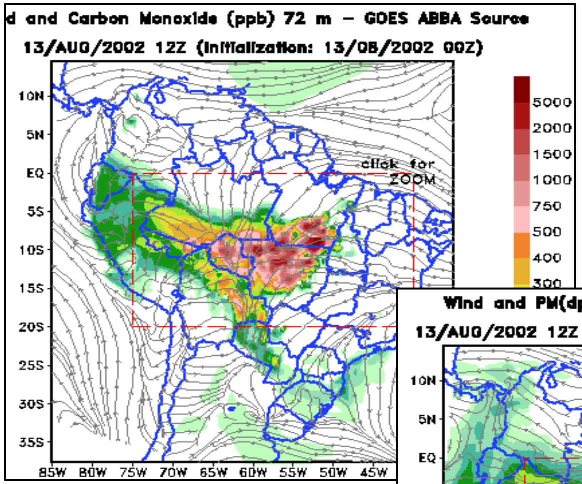
# Current NRT Fire Emission Monitoring Systems

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

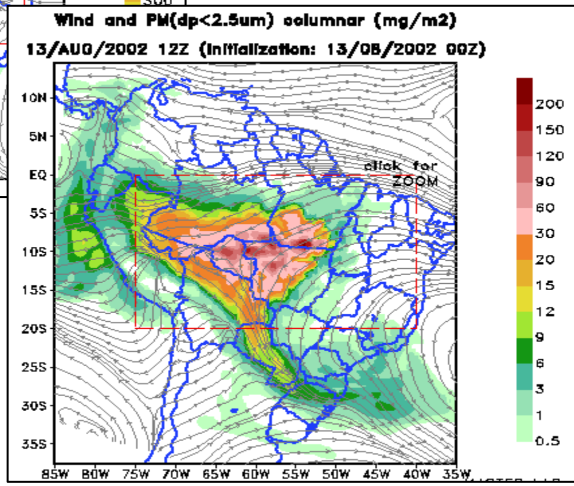
- **RAMS model at INPE/CPTEC**
  - Assimilation of WF_ABBA product from GEOS satellites
  - Delivers CO and aerosol emissions over the Americas




NAAPS Smoke Optical Depth
22 August 2003 at 18:00 UTC




RAMS
CO Product




RAMS
PM2.5 Product

Adapted from E. Prins

# Global Fire Activities in GEMS @ ECMWF

- **CO2 and aerosol fire emission from inventory GFEDv2**

  [van der Werf et al., ACP 2006]

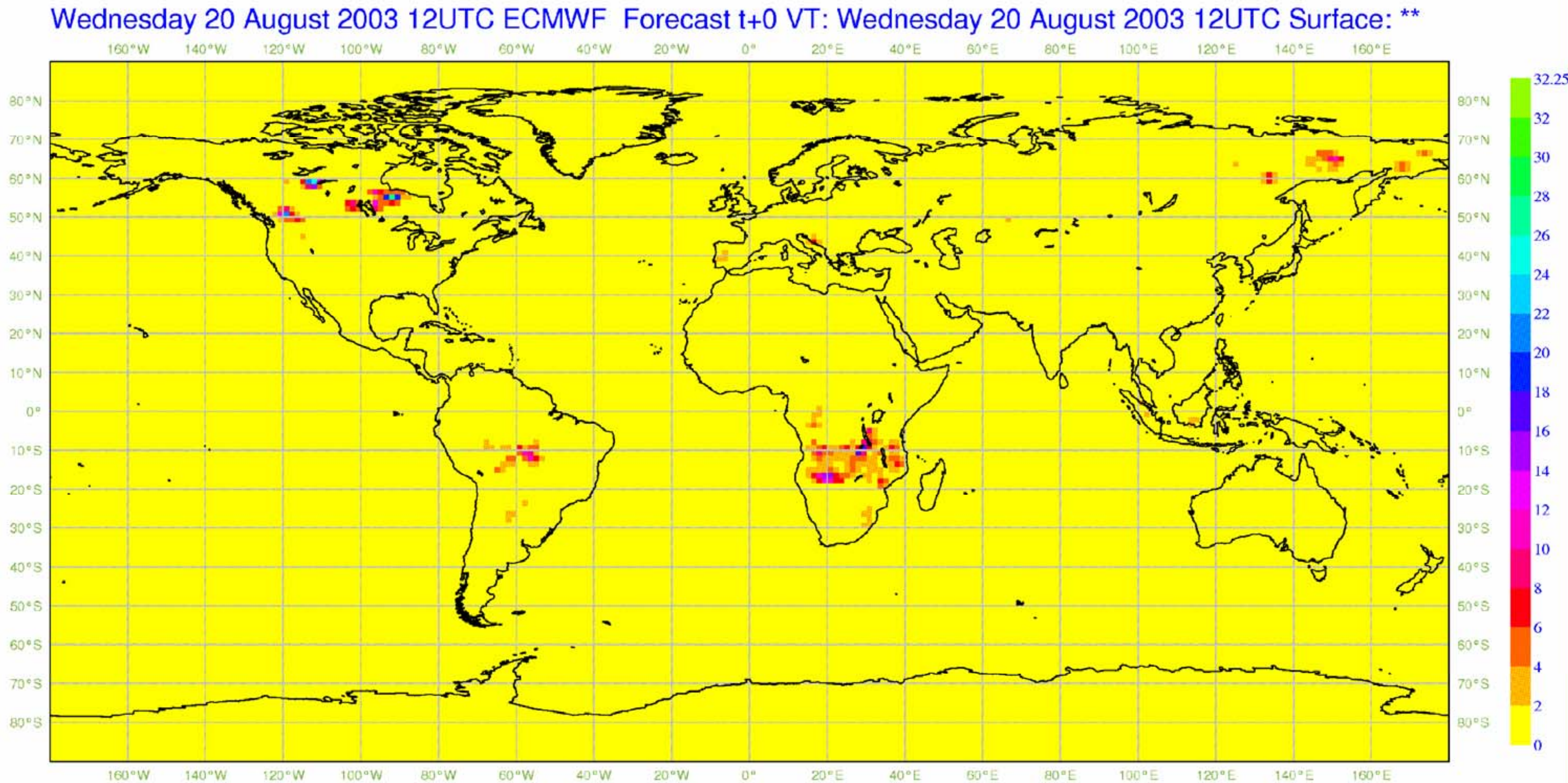
  - **hot spot fire observations from satellite-borne MODIS**
  - **available fuel load from CASA vegetation model**

  - **no near-real time availability**
  - **time resolution: 8 days**

  - **Can be used as dummy for future fire monitoring system in reanalyses.**

- **"global" GEO FRP**
  - **participation in 2 new projects as user**

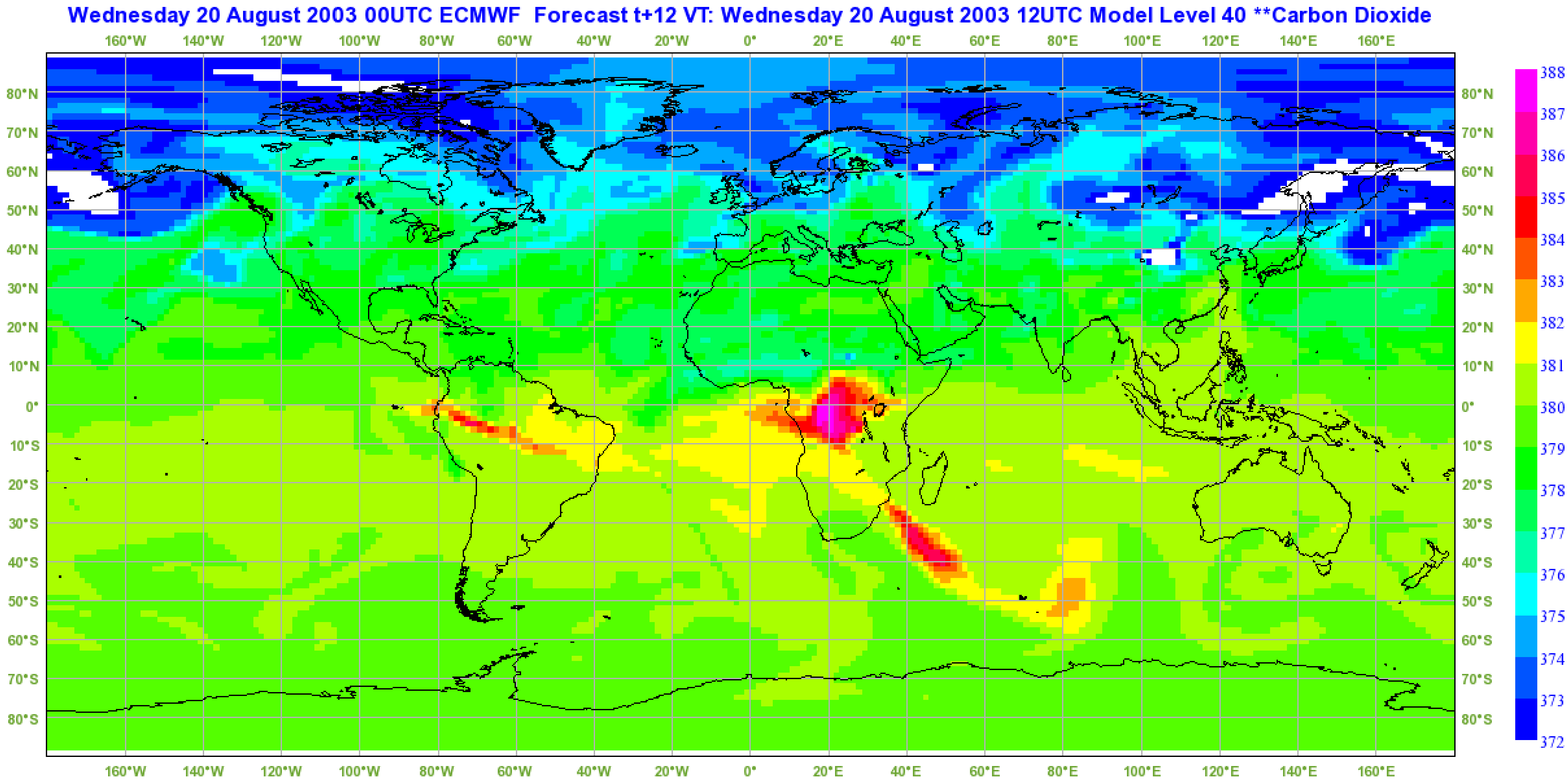
# Fire CO2 Emission on 20 Aug 2003 [g / m2 / day]
# (GFEDv2_8day, re-gridded to T159)



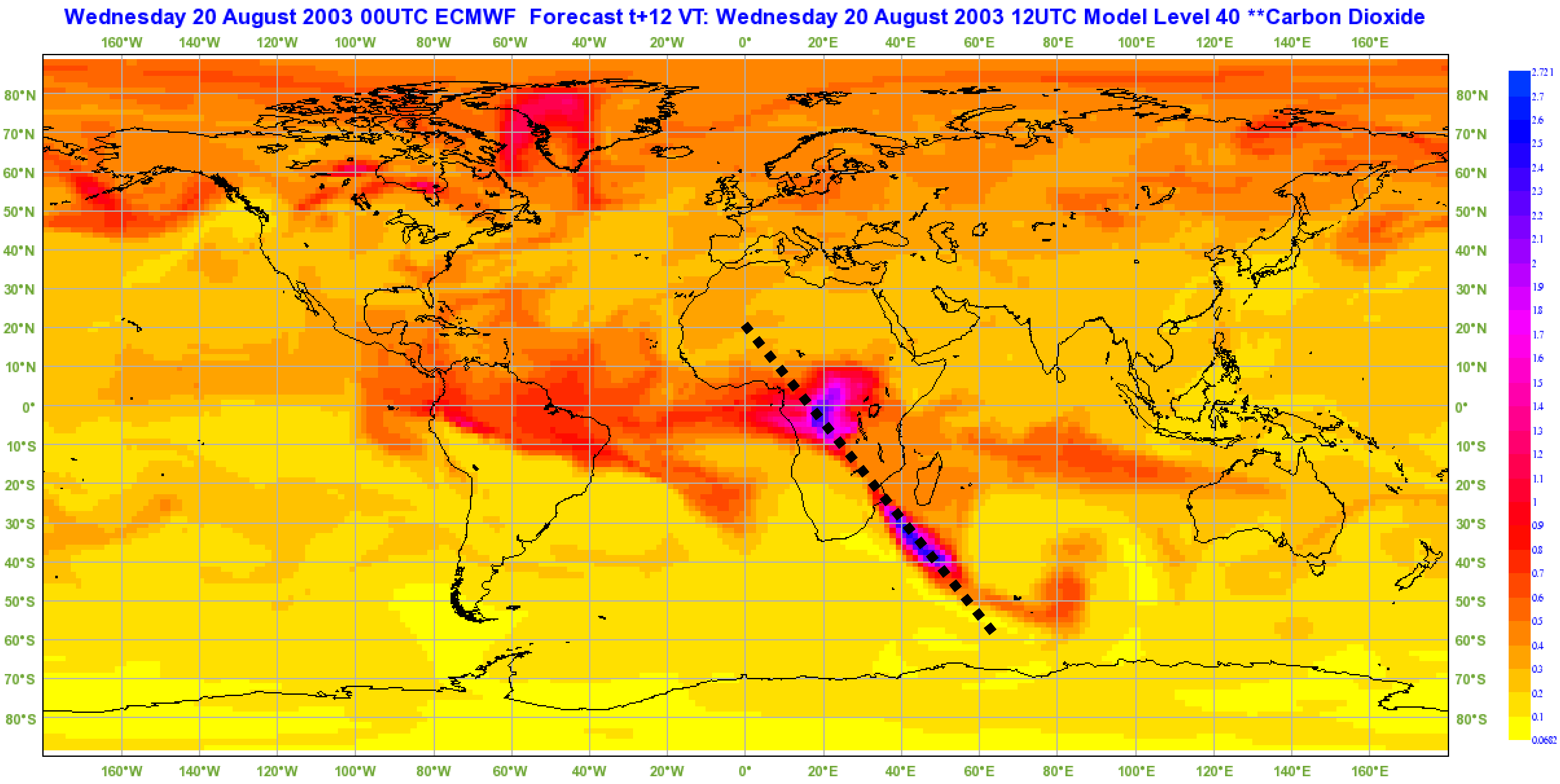



ECMWF

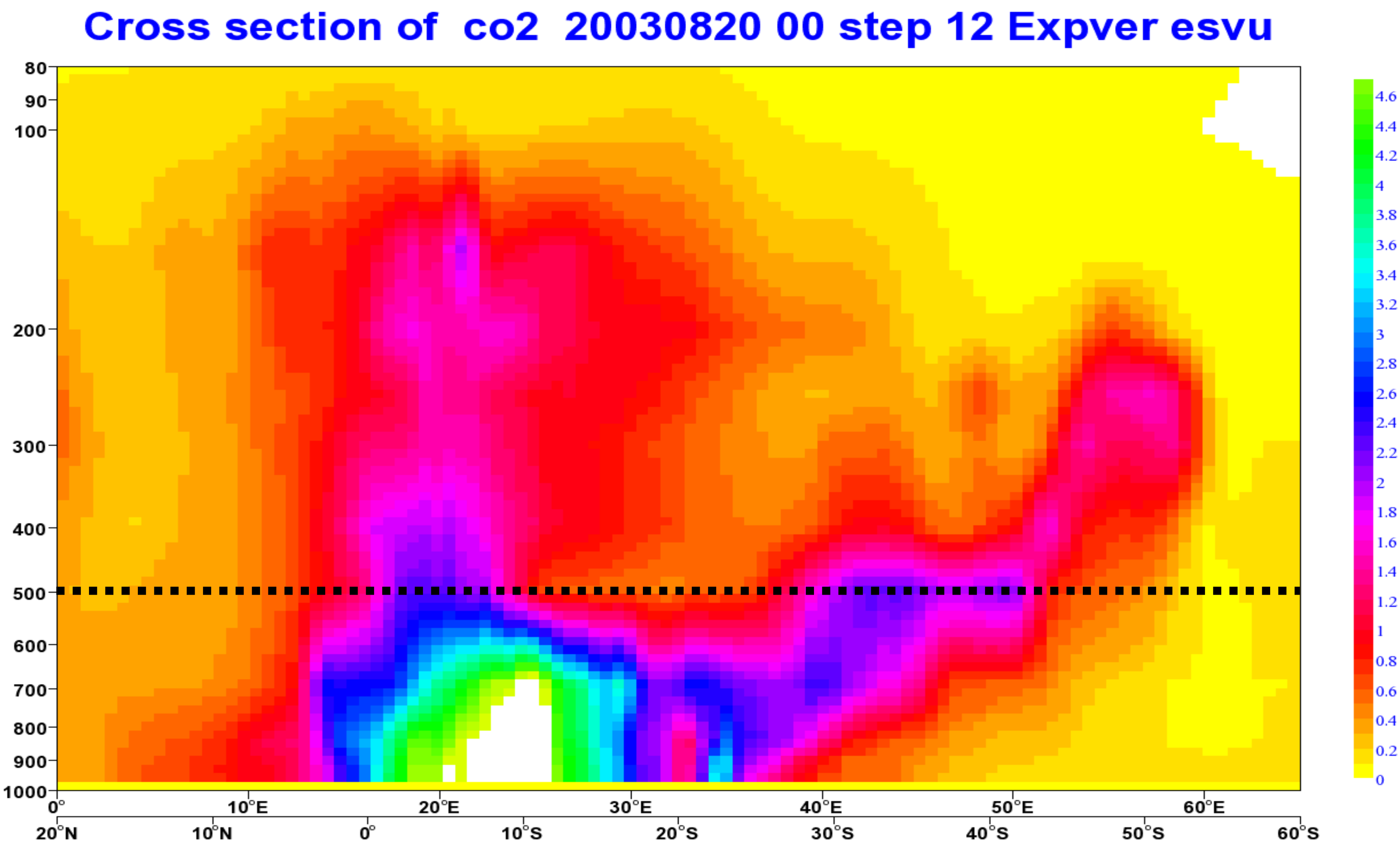
# CO2 Model Field with Fires @ 500hPa [ppm]

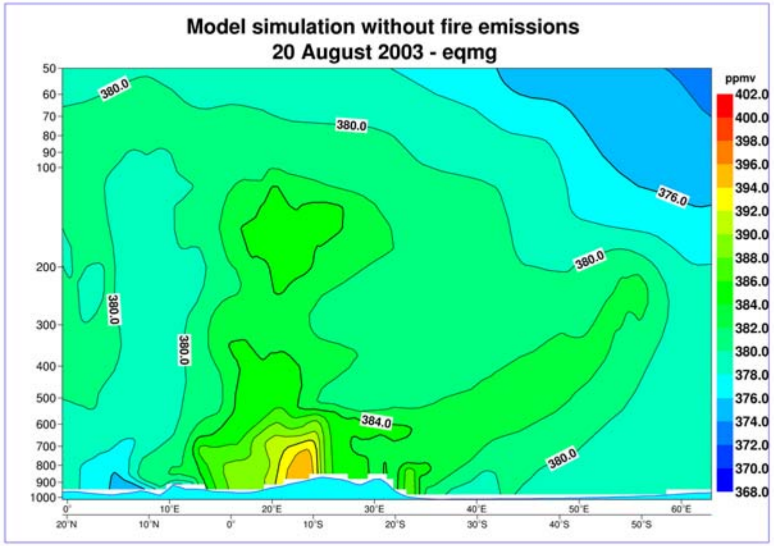


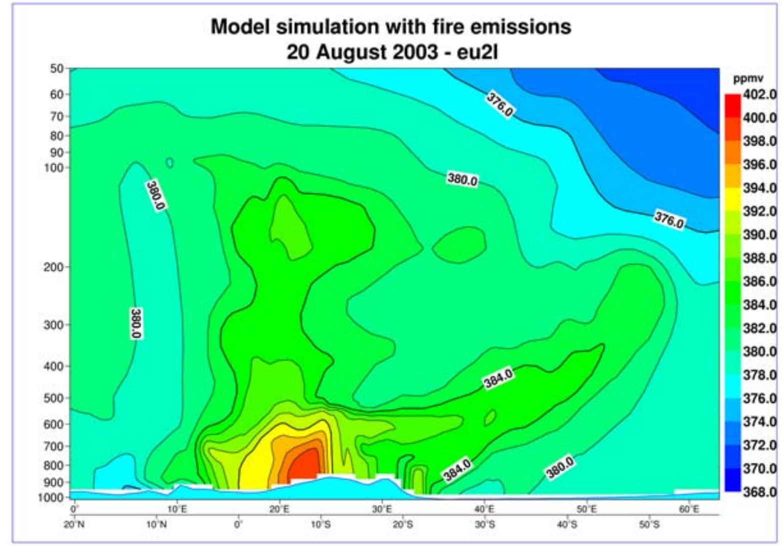
# Excess CO2 due to Fires I [ppm]



# Excess CO2 due to Fires II [ppm]





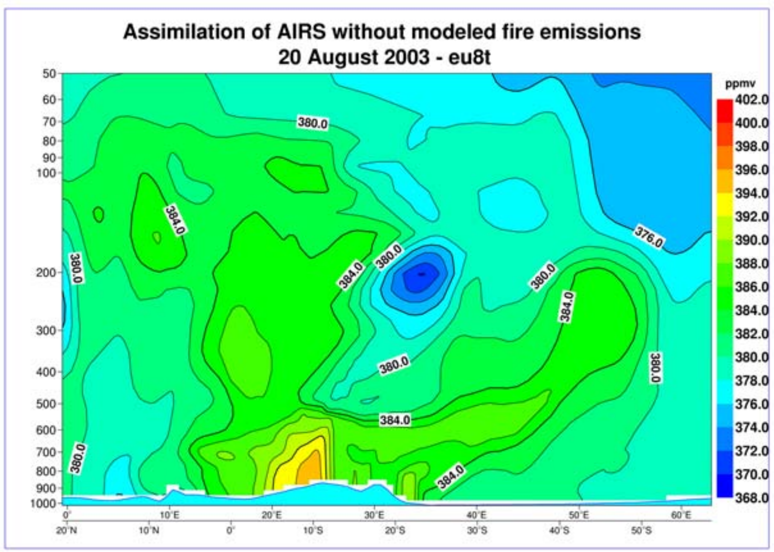




No

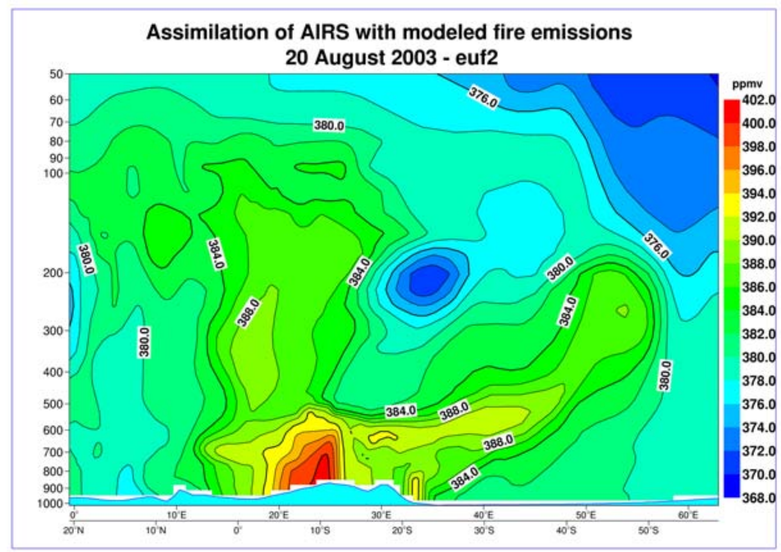
AIRS

No fire emissions

With fire emissions




AIRS



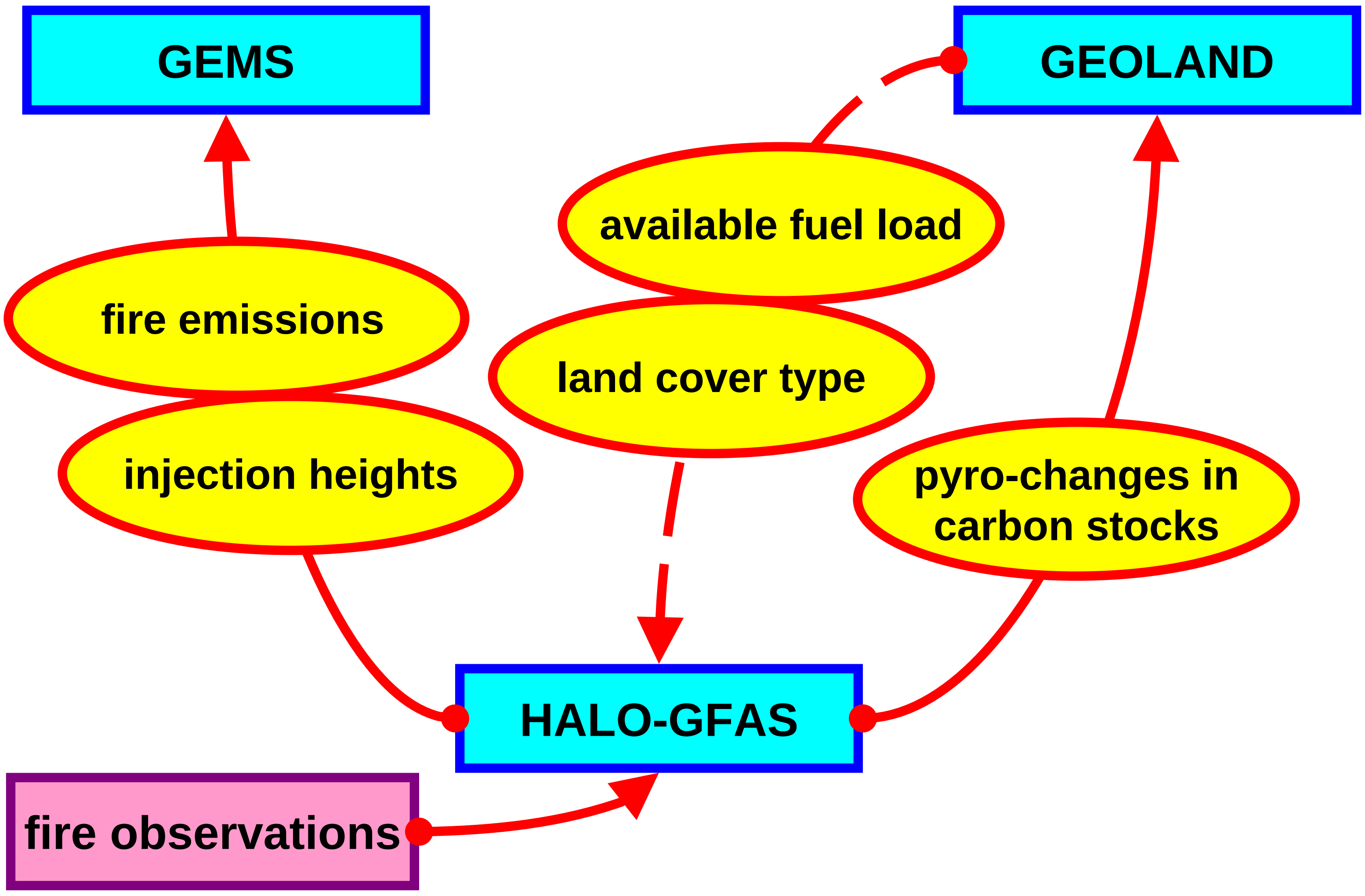

(satellite data assimilation by R. Engelen, ECMWF)

# RECOMMENDATION:
# Global Fire Assimilation System
# (HALO-GFAS)

# Benefits of Near-real-Time fire information for GEMS & GEOLAND

- **GEMS would benefit from near-real time fire information, but currently uses climatological fire information.**
- **Biosphere carbon monitoring in GEOLAND-2 would benefit from an accurate burnt biomass product, but the existing products have limited accuracy.**
- **A future service, HALO-GFAS, could use complementary satellite fire observations, plus a fire model, to provide**
  - **Emissions**
  - **Profiles of emission injection heights**
  - **Pyro-change in biomass**
- **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.

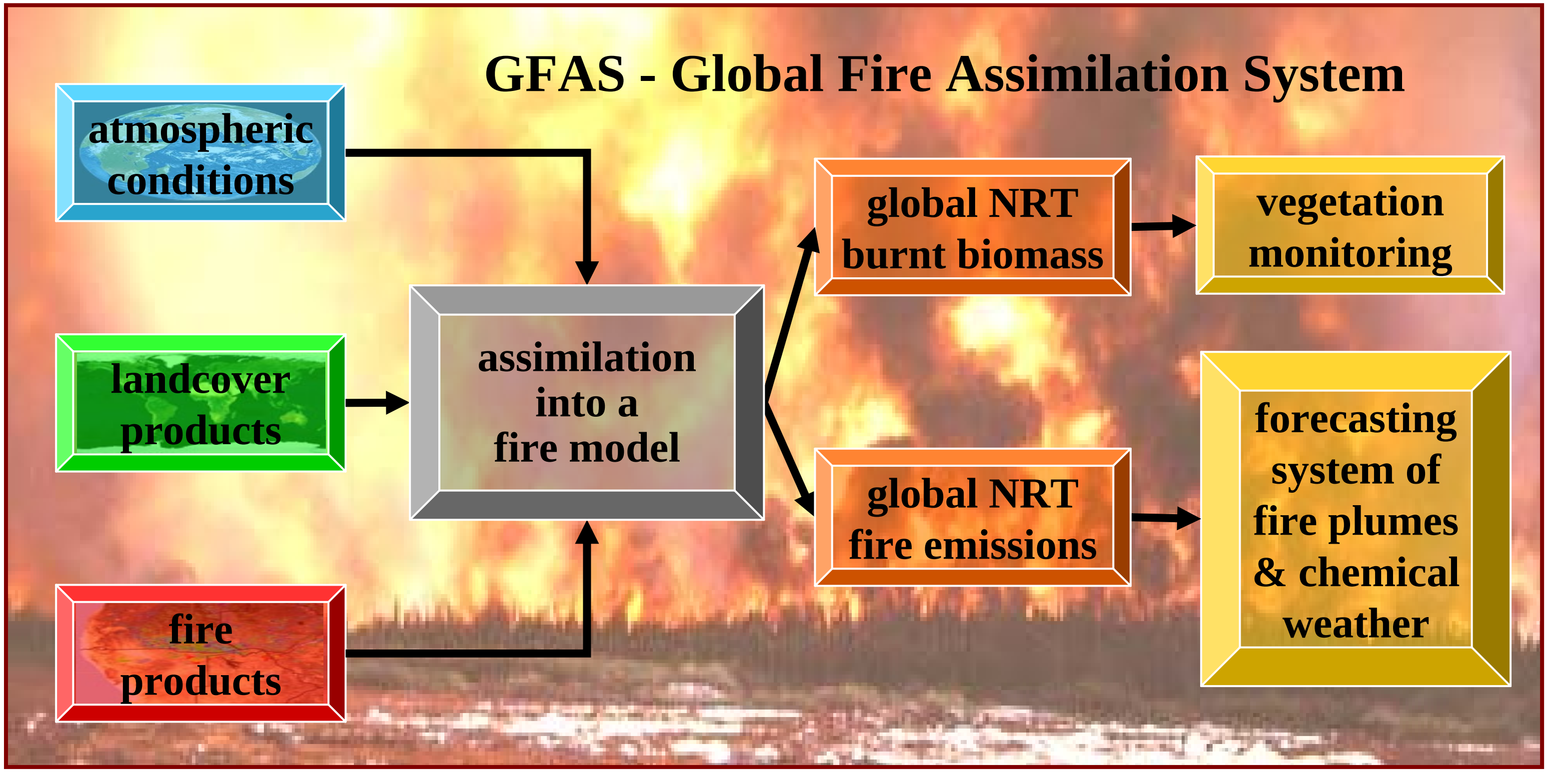





ECMWF

# Global Fire Assimilation System (HALO-GFAS)

- **A GFAS is needed to provide the required fire input for the GMES land and atmosphere monitoring systems.**




- **Assimilation of the best available satellite products into a numerical model of the global fire activity including information on atmospheric conditions and land cover**

# Additional HALO-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.**
- **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**
    - HALO-GFAS
    - climate models

- **Collaboration of space agencies, satellite retrieval experts, biosphere & atmosphere modellers, and other users**
- **“Expression of Interest” formulated (March 2006)**
  - **supported by 30+ scientist from 30+ institutions in Europe**

- **Funding needed!**

# SUMMARY

- **GEOLAND-2, GEMS/GAS, will 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 recommend to develop a Global Fire Assimilation System (HALO-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**
- **The recommended HALO-GFAS is widely supported in the European science community.**
- **HALO-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

# ACKNOWLEDGMENTS

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# SCIENCE DISCUSSION

# Issues in implementing/developing MERSEA, GEOLAND, GEMS in the period 2008-2013

- **<u>OCEAN</u>**
  - **Current Ocean-Atmosphere set-up looks OK for 2008-2013**
  - **Ocean-Land issues look difficult**
    - little can be done before 2013

- **<u>LAND-ATMOSPHERE</u>**

  **The main issue is how to quantify better the land-atmosphere interactions**
  - **biomass exchange of $H_2O$, $CO_2$, $CH_4$ (GEOLAND-2)**
  - **Burnt biomass & emissions (GFAS)**

- **GEOLAND-2**
  - **Will assimilate satellite data on LAI, fAPAR..,**
    - either online in the IFS, or offline from the IFS
  - **Will improve C- TESSEL through extensive validation**
  - **Will generate improved estimates of soil organic matter and forest biomass through modelling**
  - **Could generate surface flux estimates offline from IFS, from several SVATS including ORCHIDEE**
  - **GFAS will use biomass estimates and satellite data to provide**
    - improved estimates of burnt biomass

- **GEMS/GAS can use GEOLAND-2 products in several ways**
  - **Use C-TESSEL inline in IFS, and assimilate LAI data**
  - **Use offline GEOLAND-2 fluxes as additional information sources in an ensemble of synthesis inversions**
  - **The best utilisation can only be determined by experimentation**

- **GFAS needs funding and a host.**