Fire Emissions in GEMS

Johannes Kaiser

Martin Schultz, Mikhail Sofiev, Johannes Flemming, Soumia Serrar, Olivier Boucher, Tony Hollingsworth

Guide van der Werf, Elaine Prins

Overview of Presentation

- Introduction to Fire Emissions
  - Why? What? Today.
- WF_ABBA Satellite Products
- GFED
- Global Fire Assimilation System Proposal

Introduction

WHY? Fire Emissions …

- … may dominate regional air quality in “severe air pollution” events
- … may elevate background after long range transport [Stohl et al. 2001]
- … significantly contributes to emission budgets of several gases (Kyoto, CLRTAP, …)

- … may influence weather by heat production and absorbing smoke.
- … provide essential a priori information for remote sensing

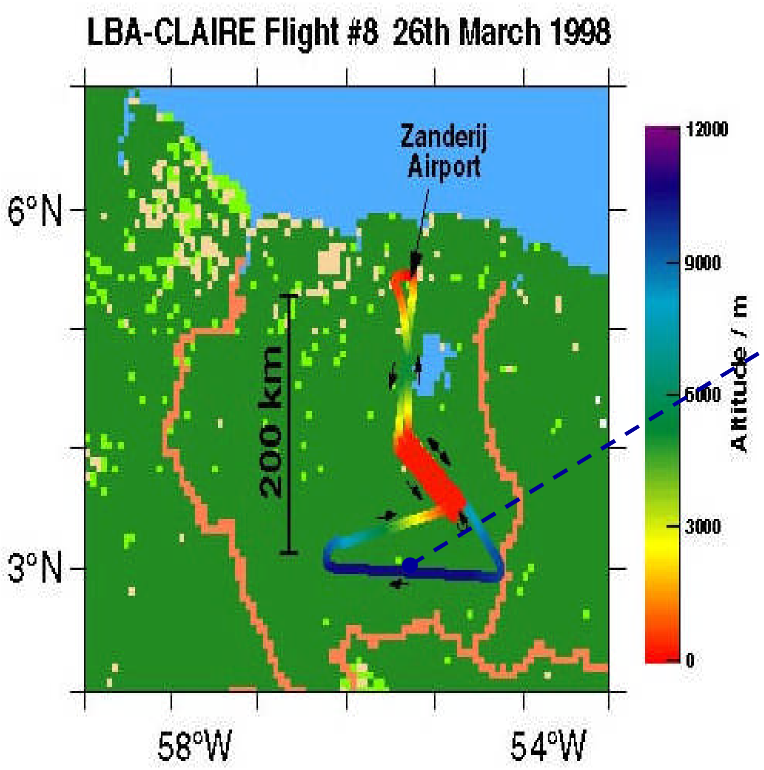
- … are variable on all time scales from hours to decades

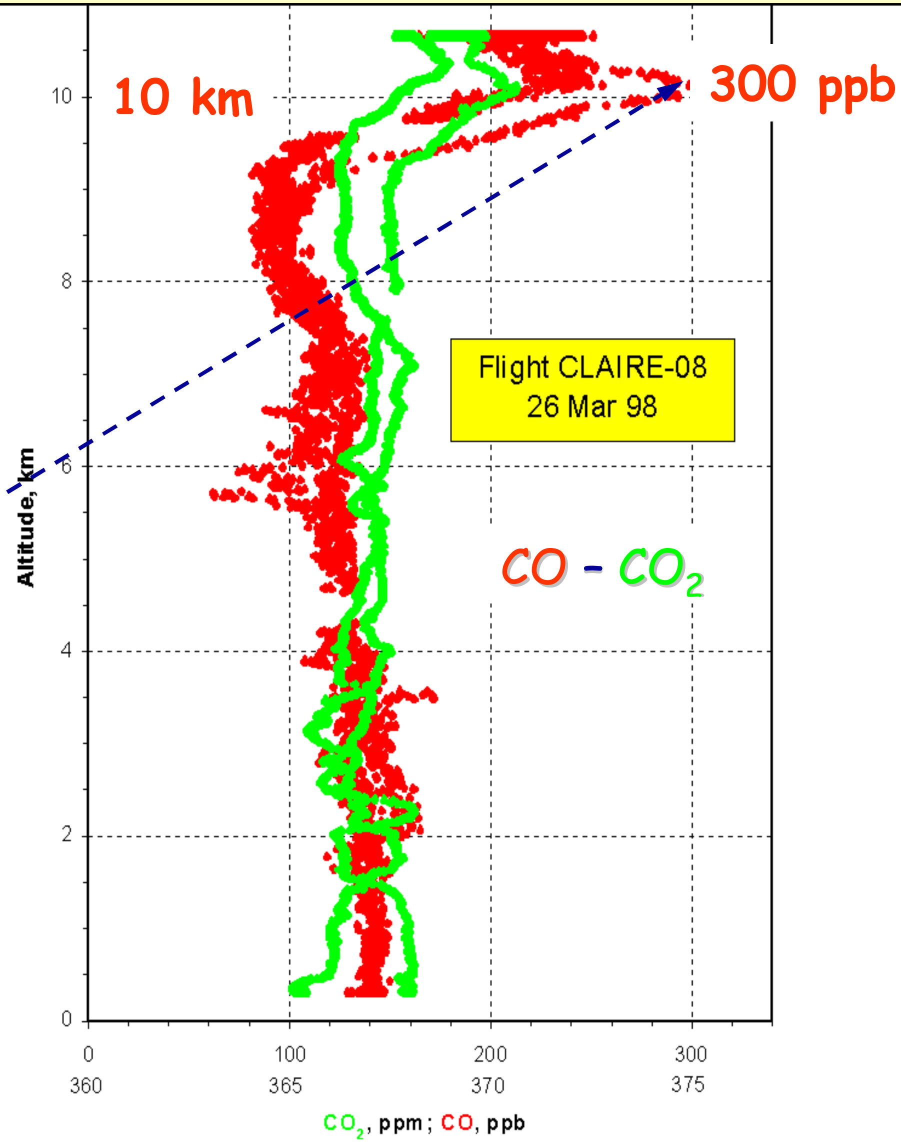
near London-Luton, 2005-12-11 <news.bbc.co.uk>

NOAA, 2005-12-11

Short-term Variability: CO, CO2

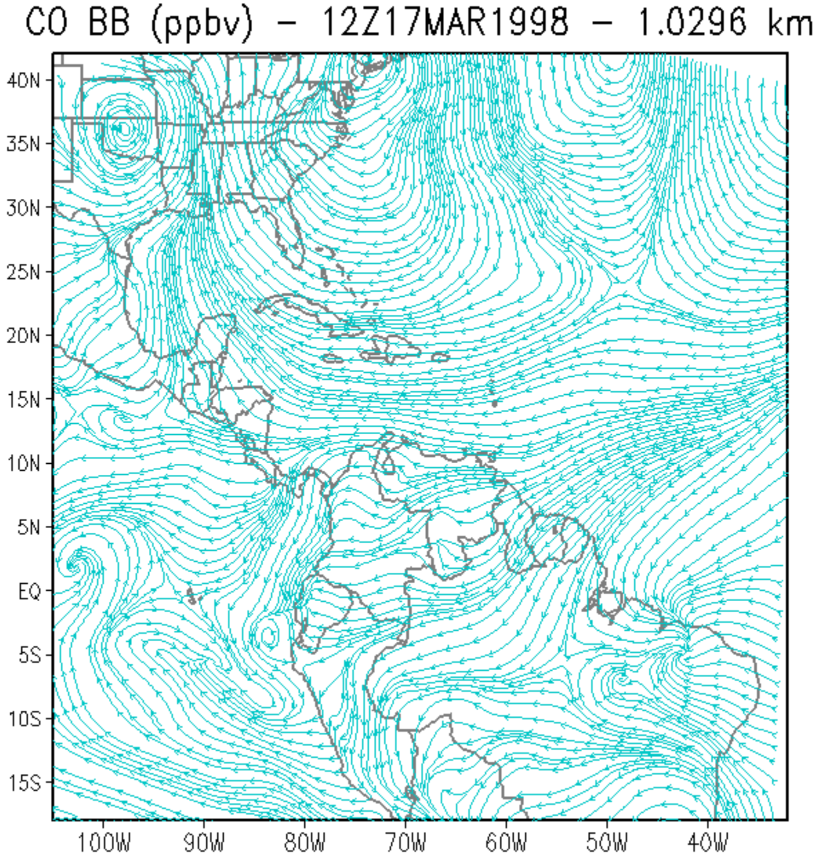
CLAIRE 1998 – vôo sobre o Suriname e Guianc

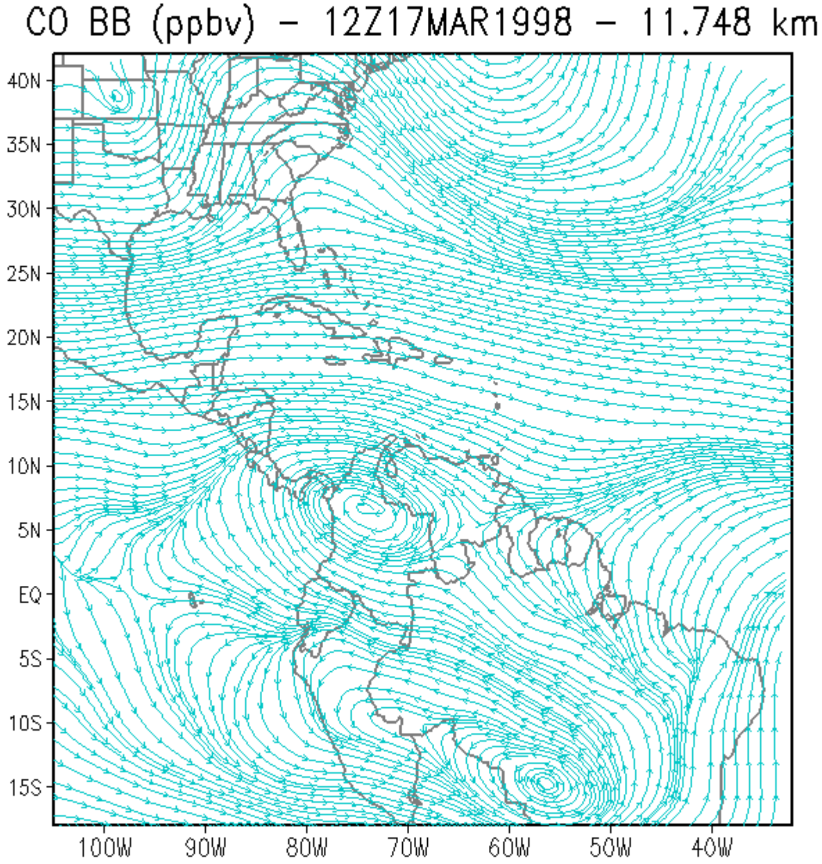




(courtesy M. Andreae, MPI Mainz)
[Andreae et al. 2001]

CLAIRE 1998 – Roraima Fires
Simulation using CATT-BRAMS Eulerian Transport Model
1000 m ---------------------- 11700 m





(produced by INPE/CPTEC, courtesy of M. Andreae, MPI Mainz) [Freitas et al. 2005]

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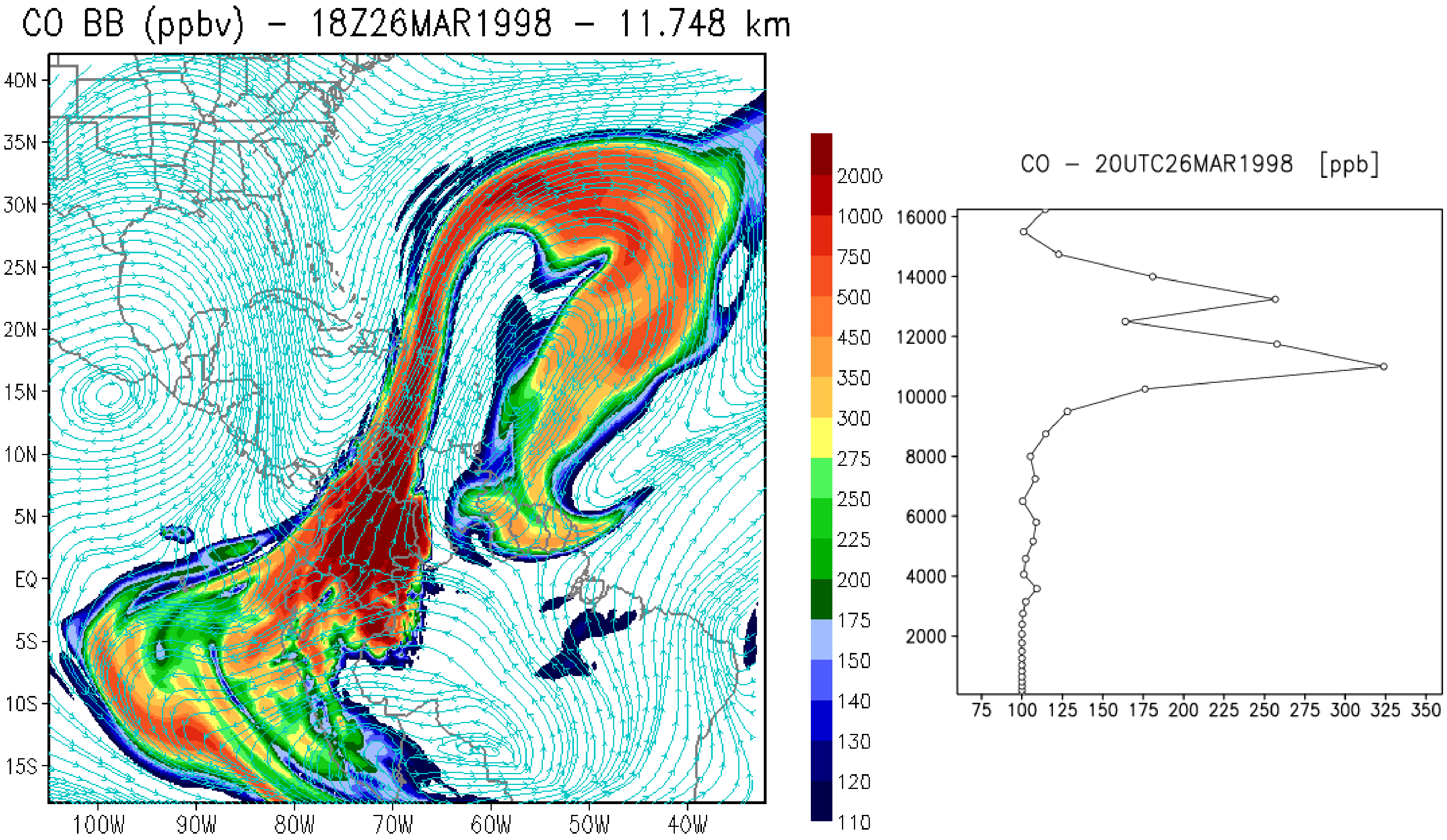

(produced by INPE/CPTEC, courtesy of M. Andreae, MPI Mainz) [Freitas et al. 2005]

Some Conclusions from Existing Fire Pollution Models

- No global operational system for all GEMS components exists.
- INPE/CPTEC monitor and forecast severe events of aerosol and CO pollution by fires on continental.
- NRL Monterey (FLAMBE) monitor and forecast severe events of aerosol pollution by fires globally.
    - It is possible.
    - Fire EO input is essential.

WHAT? GEMS Required Fire Products

- Products
    - amount emitted: aerosol, trace gases
    - location, time
    - injection height profile
- Availability
    - global
    - near-real time and retrospectively
    - time resolution of several hours to one day

Schedule of GEMS Work at Central Site

Year 1 May 2005+12 mo	• Build and validate 3 separate assimilation systems for Greenhouse gases, Reactive gases, Aerosol. • Acquire data; build web-site
Year 2 May 2006+12 mo	• Produce 3 different reanalyses for GHG, GRG, Aerosol • Make reanalyses available for validation by all partners • Provide feedback to data providers
Year 2-2.5 May 2007 + 6 mo	• Merge the 3 assimilation systems into a unified system; • Upgrade the models and algorithms based on experience
Year 2.5-3.5 Nov 2007+ 12 mo	• Produce unified reanalyses for GHG, GRG, Aerosol • Build operational system, & interfaces to partners
Year 3.5 - 4 Nov 2008+ 6 mo	• Final pre-operational trials • Documentation & Scientific papers

Schedule of GEMS Wildfire Requirements

Year 2 May 2006+12 mo	• Produce 3 different reanalyses for GHG, GRG, Aerosol • global emissions for 2003 of correct order of magnitude • "Deliverable 1"
Year 2.5-3.5 Nov 2007+ 12 mo	• Produce unified reanalyses for trace gases and aerosol • high-resolution (temporal & spatial) global fire products for 2000–2007 • "Deliverable 2"
Year 3.5 - 4 Nov 2008+ 6 mo	• Final pre-operational trials • high-resolution (t&s) global fire products in NRT • "Deliverable 3"

13.30 Claire Granier, Christiane Textor, GEMS Welcome
Johannes Kaiser, HALO Introduction to fire emissions

Today

13.40 Peter Rayner, GEMS	GHG requirements
13.45 Olivier Boucher, GEMS	AER requirements
13.50 Martin Schultz, GEMS	GRG requirements
13.55 V.-H. Peuch, GEMS	RAQ requirements
14.00 Kevin Tansey, Uni Leicester	Burnt area & hot spot satellite products
14.10 Martin Wooster, King's C	Fire radiative energy satellite products
14.20 Johannes Kaiser, HALO	WF_ABBA satellite products
14.30 Martin Schultz, GEMS	Comparison of satellite products
14.40 Alain Chedin	Tropical fires, tropospheric CO2 concentration, NOAA-10
14.50 Mikhail Sofiev, GEMS	Emissions heights
15.00 Johannes Kaiser, HALO	GFED
15.10 Claire Granier	ACCENT, EVERGREEN
Martin Schulz	RETRO
Christiane Textor	AEROCOM

15.20 Break

15.40 Decision on GEMS Deliverable 1: Inventory for reanalysis simulations of 2003:
- Which inventory? GFEDv2
- Are the needs of the different themes covered?
- Which improvements are needed?

16.10 Johannes Kaiser HALO Proposal

16.20 Discussions
- GEMS Deliverable 2: Extended reanalysis simulations 2000-2007, implementation of fire emission model (GFAS), use of existing fire emission data set
- GEMS Deliverable 3: Operational System

19.00 Dinner meeting at Nepalese Restaurant

WF_ABBA

Overview of the GOES Wildfire ABBA, Applications, and Future Plans

GOFC/GOLD Global Geostationary Fire Monitoring Applications Workshop
EUMETSAT, Darmstadt, Germany   23 March 2004

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Advanced Satellite Products Team (ASPT)

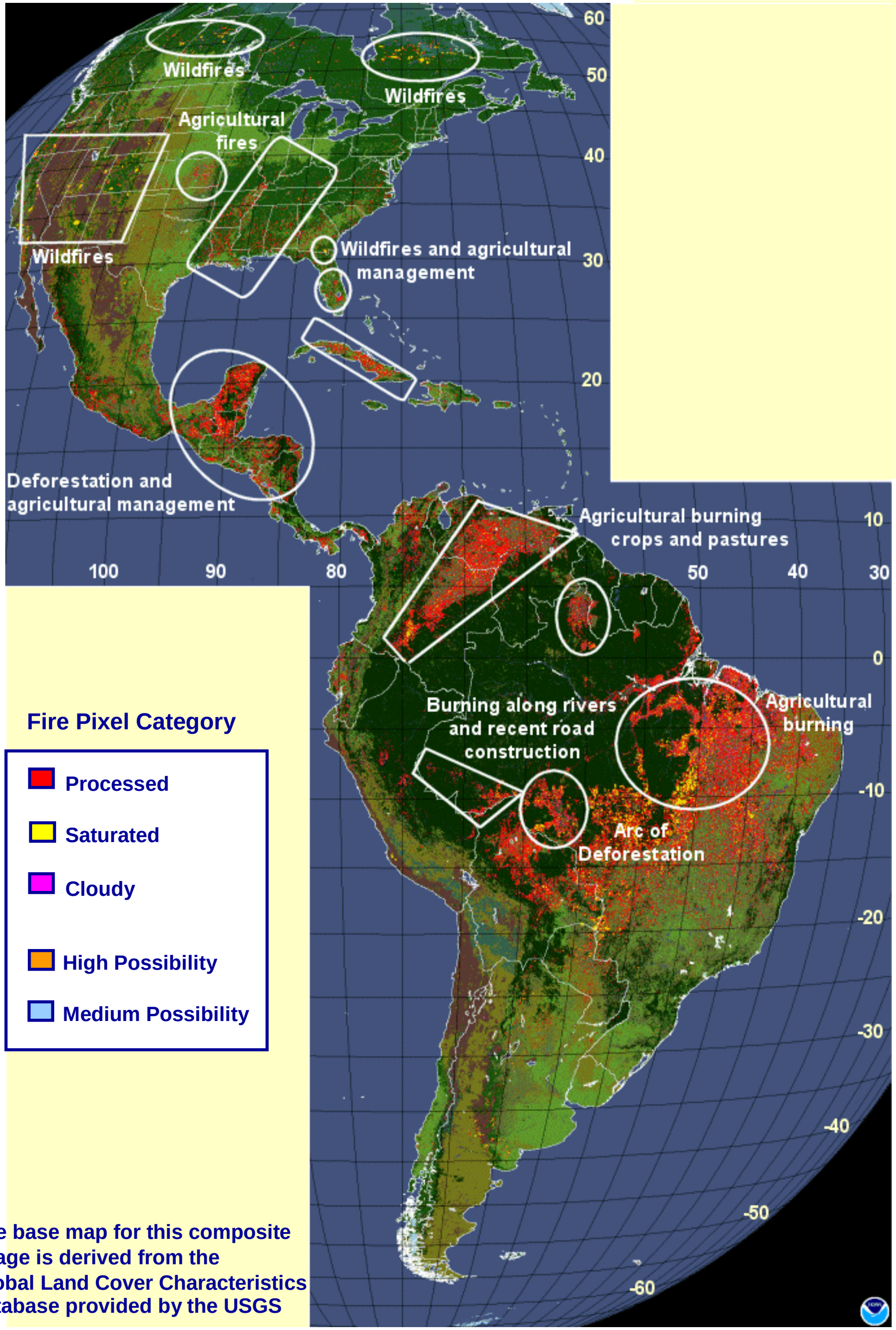
National Aeronautics and Space Administration

UW-Madison Cooperative Institute for Meteorological Satellite Studies (CIMSS)

GOES-8 Wildfire ABBA Summary Composite of Filtered Half-Hourly Fire Observations for the Western Hemisphere

Time Period:

September 1, 2001 to August 31, 2002



The base map for this composite image is derived from the Global Land Cover Characteristics database provided by the USGS

The composite shows the much higher incidence of burning in Central and South America, primarily associated with deforestation and agricultural management.

Fire Pixel Distribution

North America (30-70°N): 12%
Central America (10-30°N): 11%
South America (70°S-10°N): 77%

The GOES Wildfire Automated Biomass Burning Algorithm (WF_ABBA)

Automatically locates and characterizes sub-pixel fires in GOES imagery

- The WF_ABBA uses GOES visible, 3.9 µm and 10.7 µm data and ancillary data to identify and characterize sub-pixel fires.

- Contextual techniques are used to locate hot pixels that are statistically different from the background and assign fire pixel categories:
  (processed; saturated; cloudy; and high, medium and low probability fire pixels)

- Numerical techniques are used to determine instantaneous estimates of sub-pixel fire size and average temperature for the processed fire pixel category based on the Dozier technique.

Ancillary data used to augment the GOES data in finding and characterizing fires

- These data help to screen for false alarms and correct for water vapor attenuation, surface emissivity, solar reflectivity, and semi-transparent clouds.

- The AVHRR-derived Global Land Cover Characteristics (GLCC) data base is used to assign surface emissivity values and helps screen for false alarms.

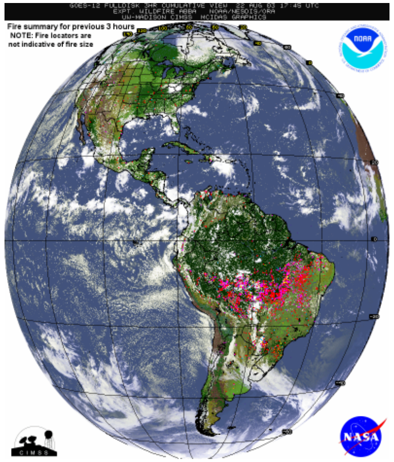
- The Aviation Model total column precipitable water is utilized to correct for water vapor attenuation.

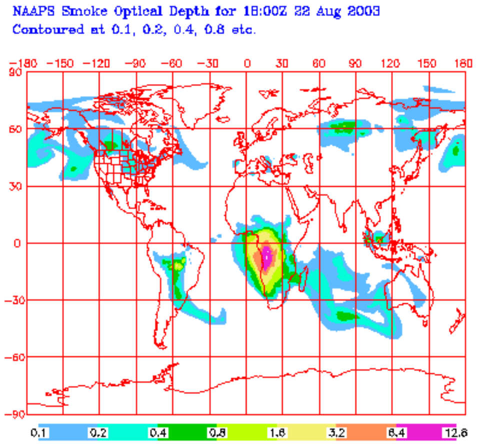
WF_ABBA fire product consists of:

- ASCII text files, McIDAS MD and AREA files
- Alpha-blended composite imagery (http://cimss.ssec.wisc.edu/goes/burn/wfabba.html)

Applications of the GOES Wildfire ABBA in Modeling Programs

Real-time Assimilation into the Naval Research Laboratory Navy Aerosol Analysis and Prediction System (NAAPS)

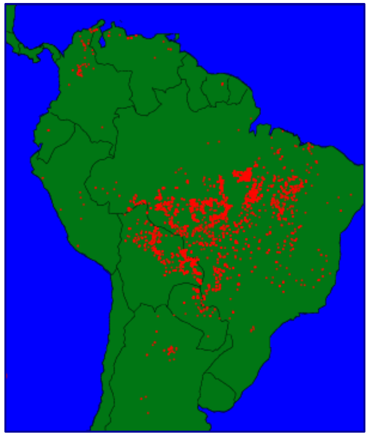




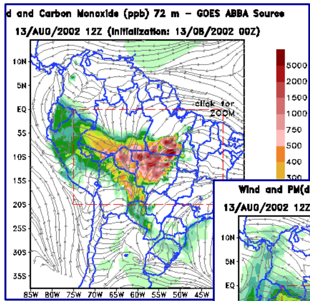
GOES WF_ABBA Fire Product
22 August 2003 at 17:45 UTC

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

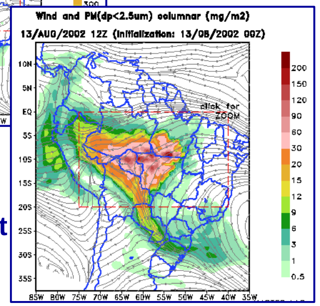
Real-time Assimilation at the University of Sao Paulo and CPTEC/INPE into the RAMS model



GOES-8 WF_ABBA Fire Product
Point Sources for 13 August 2002



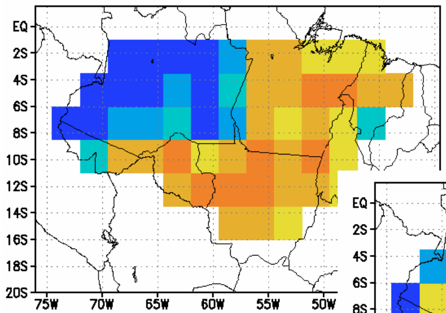
RAMS
CO Product



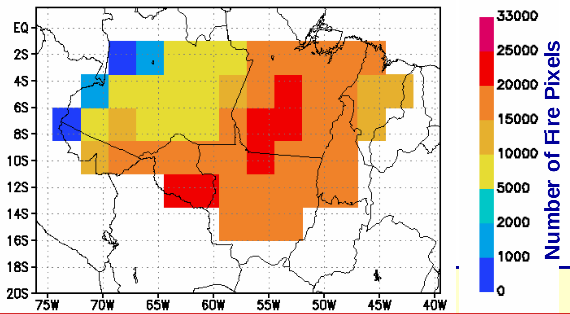
RAMS
PM2.5 Product

GOES-8 ABBA Fire and MACADA Cloud Products Used in Study to Model and Predict Future Fire Activity at UNH

Collaboration with Univ. of New Hampshire Inst. for Study of Earth, Oceans, and Space



Intermediate Deforestation Scenario
Predicted increase in future regional fire activity: 22%



Complete Deforestation Scenario
Predicted increase in future regional fire activity: 123%

Other Modeling Efforts and Collaborations

- **Climate Modeling at NASA/GSFC**: Assimilation into the GOCART model
- **Real-time Air Quality Modeling at NASA/Langley**: Real-time assimilation into the RAQMS model as part of IDEA (Infusing satellite Data into Environmental Applications)
- **Fire Emissions and Regional Air Quality Modeling at NCAR**: Assimilation into the U.S. EPA Community Multiscale Air Quality model in support of the 2002 SMOCC campaign in Brazil

Collaborations result in submission/publication of 3-peer reviewed publications in FY03

Overview

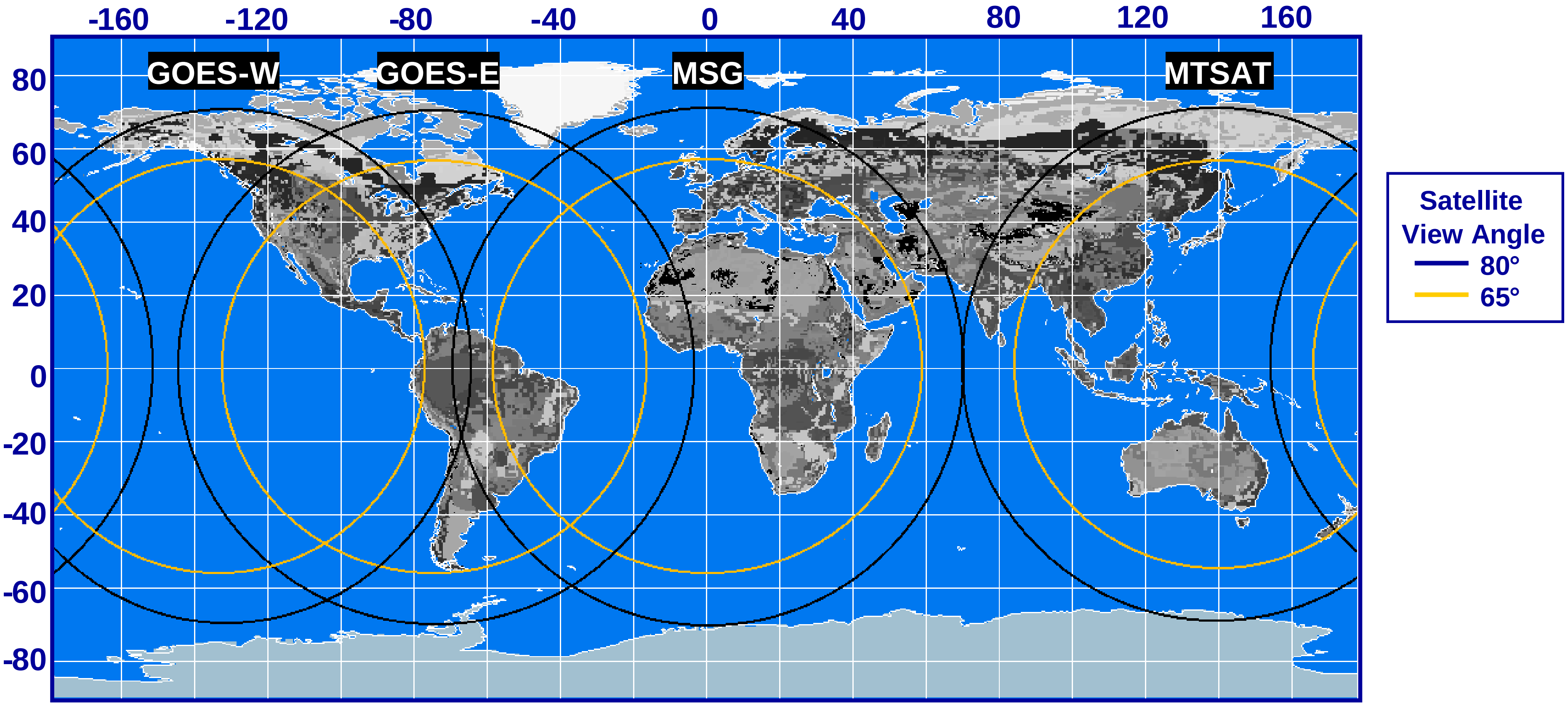
- The GOES WF_ABBA processing system has been providing half-hourly fire products for the Western Hemisphere since September 2000. Made operational in NESDIS OSDPD/SSD in August 2002.

- In the Western Hemisphere GOES WF_ABBA fire products are providing new insights into diurnal, spatial, seasonal and interannual biomass burning activity.

- User community includes: hazards, global change, land-use land-cover change, aerosol/pollutant monitoring and modeling, carbon cycle studies, socio-economic and health, educational institutions, policy makers, and the general web community

- Future plans
  - Implement a Rapid Scan WF_ABBA for hazards applications, with products available within 5 minutes
  - Adapt GOES WF_ABBA to GOES-9
  - Adapt GOES WF_ABBA to MSG
  - Adapt GOES WF_ABBA to MTSAT-1R
  - Transfer global WF_ABBA to NESDIS Operations
  - Participate in multi-sensor validation and intercomparison studies
  - Get ready for the next generation geostationary platform (ABI)

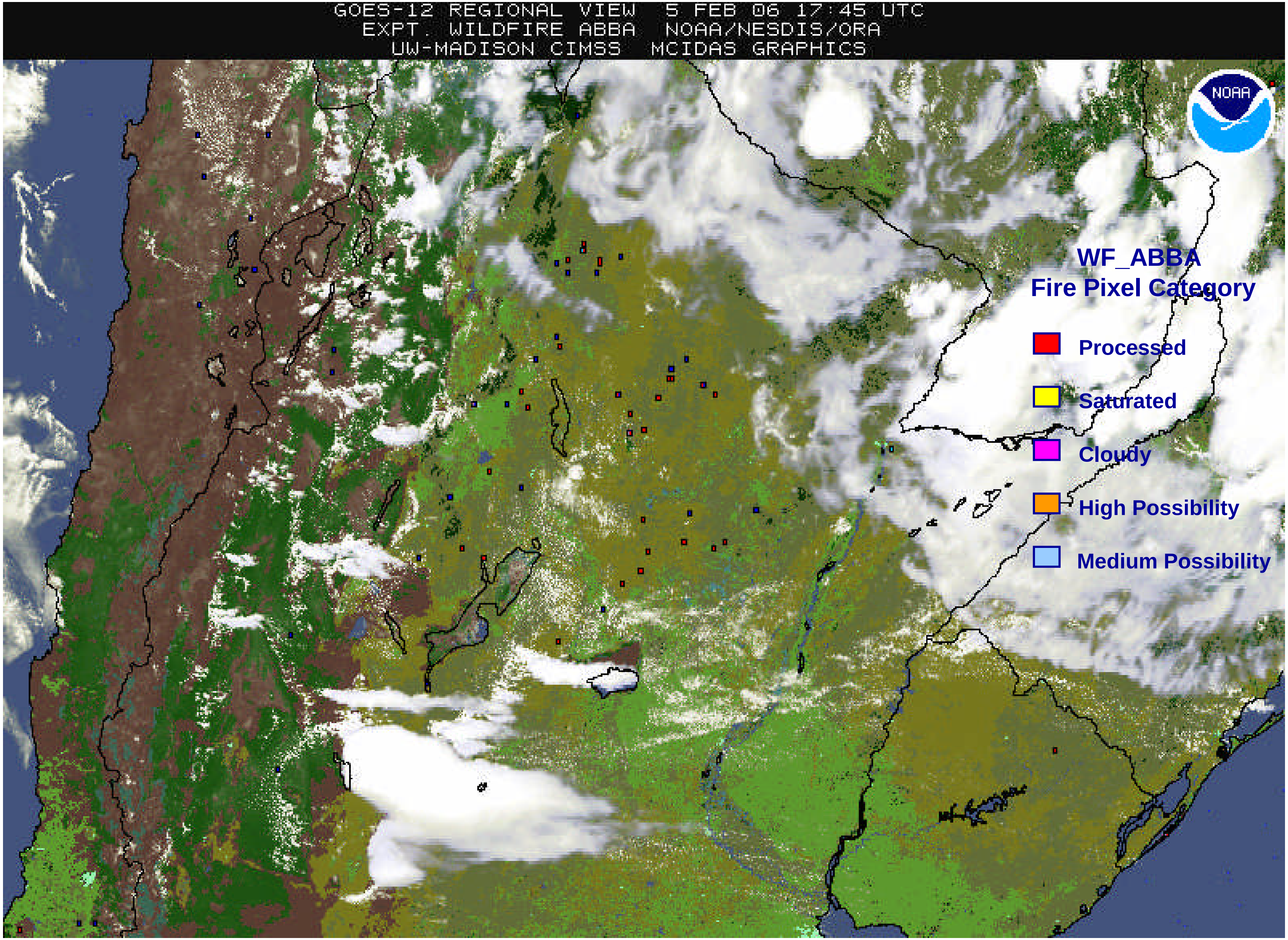
International Global Geostationary Active Fire Monitoring: Geographical Coverage



Satellite	Spectral Bands	Resolution IGFOV (km)	SSR (km)	Full Disk Coverage	4 μm Saturation Temperature (K)	Minimum Fire Size at Equator (at 750 K)
GOES-E	1 visible 4 IR	1.0 4.0 (8)	0.57 2.3	3 hours	335 K	0.15
GOES-W	1 visible 4 IR	1.0 4.0 (8)	0.57 2.3	3 hours	322	0.15
MSG SEVIRI (2002)	3 visible 1 near-IR 8 IR	1.6 (4.8) 4.8 4.8	1.0 (3.0) 3.0 3.0	15 minutes	> 335	0.22
MTSAT-1R JAMI (2003)	1 visible 4 IR	0.5 2.0		18 minutes	~320	0.03

WF_ABBA

- PROs:
  - half-hourly product
    - captures diurnal cycle
    - exploits short gaps in cloud cover
  - established, operational product
  - sub-pixel burning area and average fire temperature
- CONs:
  - not global (yet)
  - limited accuracy


GOES-12 REGIONAL VIEW 5 FEB 06 17:45 UTC
EXPT. WILDFIRE ABBA NOAA/NESDIS/ORA
UW-MADISON CIMSS MCIDAS GRAPHICS
NOAA
WF_ABBA
Fire Pixel Category
Processed
Saturated
Cloudy
High Possibility
Medium Possibility

G F E D

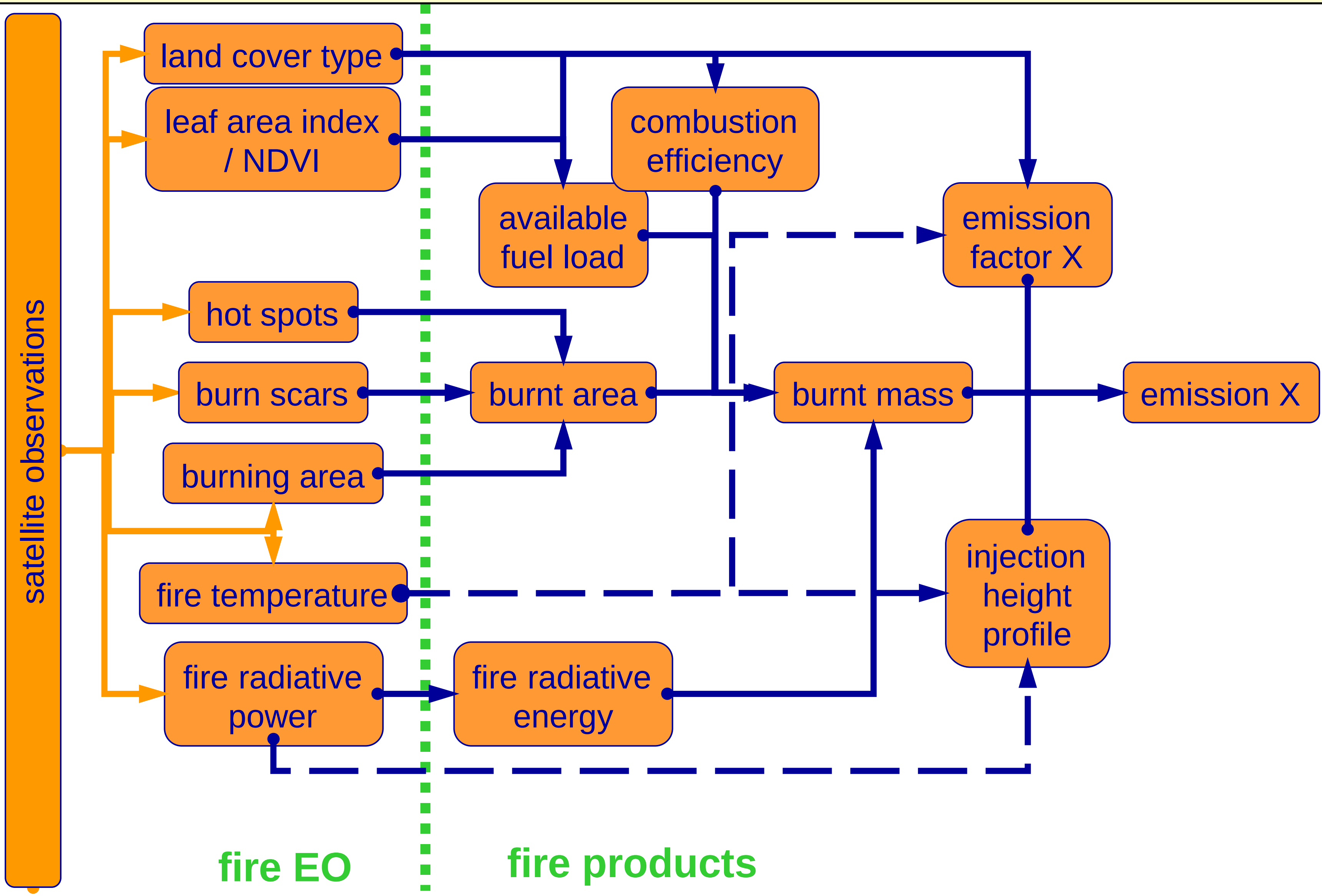
Species in GFED v2

Species	Year										
	1997	1998	1999	2000	2001	2002	2003	2004	Mean	SD	SD / Mean
C	2991	3183	2284	2038	2224	2386	2251	2320	2460	403	0.16
DM	6646	7074	5077	4529	4942	5303	5002	5156	5466	896	0.16
CO2	10760	11454	8291	7423	8108	8640	8143	8406	8903	1416	0.16
CO	557	591	392	337	365	418	397	405	433	91	0.21
CH4	30.4	29.8	18.8	15.1	16.6	20.1	18.5	20.1	21.2	5.8	0.27
NMHC	38.7	38.2	24.9	20.5	22.6	26.4	24.4	26.4	27.7	6.9	0.25
H2	16.1	14.8	9.4	7.3	8.2	9.9	8.9	10.3	10.6	3.1	0.30
NOx	14.1	16.2	11.5	10.4	11.2	12.1	11.7	11.4	12.3	1.9	0.15
N2O	1.37	1.52	1.07	0.96	1.04	1.13	1.08	1.08	1.16	0.19	0.16
PM2.5	48.2	54.4	34.0	29.0	30.9	37.2	36.4	34.8	38.1	8.7	0.23
TPM	58.4	70.9	46.6	41.9	44.3	50.8	50.5	46.1	51.2	9.4	0.18
TC	33.2	37.2	23.8	20.6	22.0	25.9	25.2	24.3	26.5	5.7	0.22
OC	29.1	34.5	21.4	18.5	19.5	23.6	23.5	21.5	23.9	5.3	0.22
BC	3.64	3.78	2.62	2.27	2.49	2.75	2.58	2.70	2.85	0.55	0.19

- all derived from burnt biomass
- extendable using additional emission factors
- monthly product

Strategy Proposal

Products from Fire EO



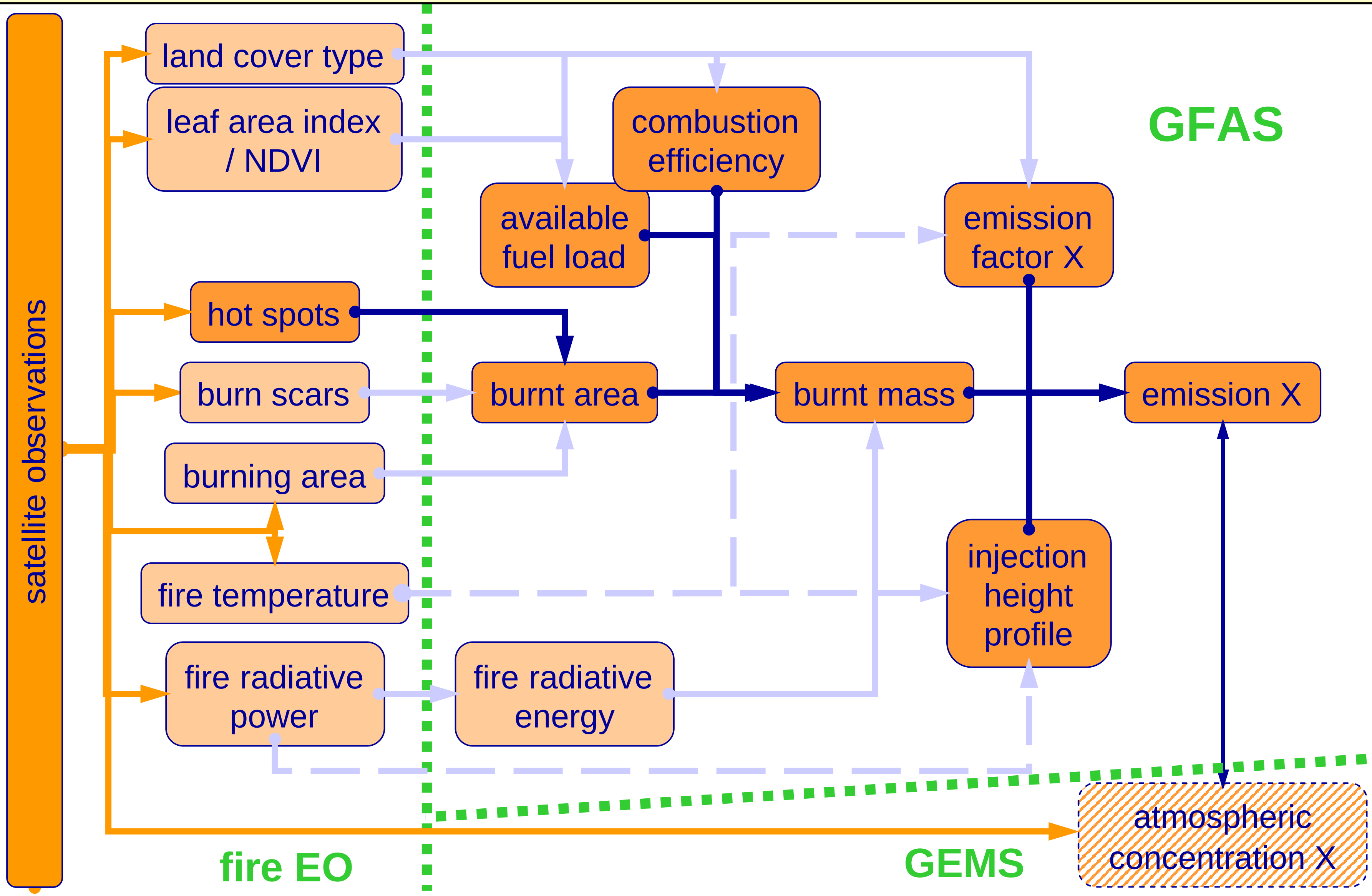
Some Conclusions on EO Fire Products

- No current product satisfies all GEMS requirements.
- Many existing products are inconsistent. (Boschetti et al. 2004)
- Fire observation and modelling requires a regionalised approach, distinguishing in particular between mid-latitude and boreal fires and using different EO fire products.
- very active area of research: Several new operational products are anticipated.
  - Burnt Area from MODIS (D. Roy)
  - Fire Radiative Power from SEVIRI (M. Wooster)
  - WF_ABBA from global GEO system (E. Prins)
  - …
- We want to use several EO fire products!

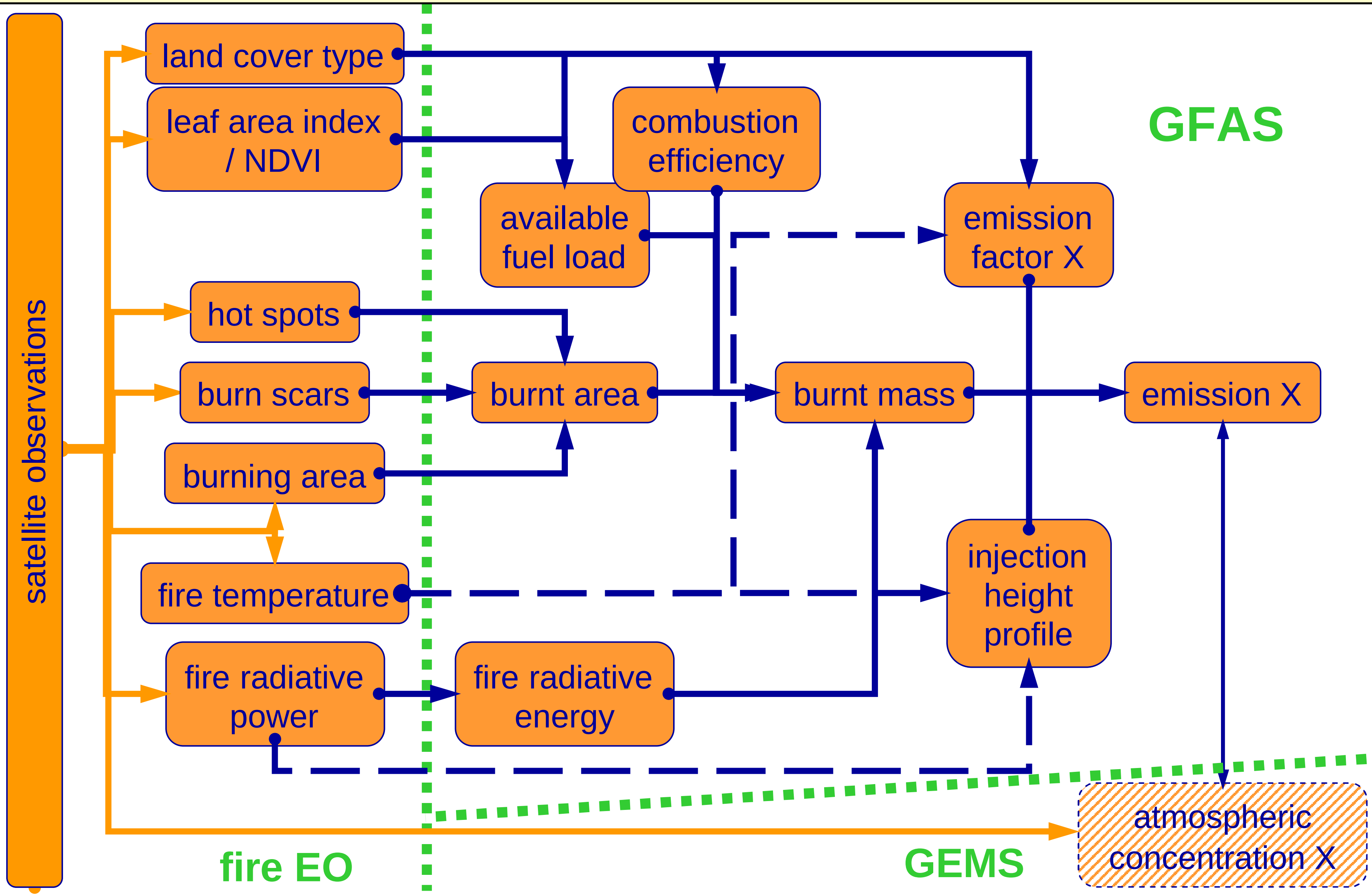
GEMS Baseline Approach (AER)

- **GWEM for amount, MPI-MET [Hoelzemann et al. 2004]**
- **BUOYANT for injection height, FMI [Nikmo et al. 1999]**

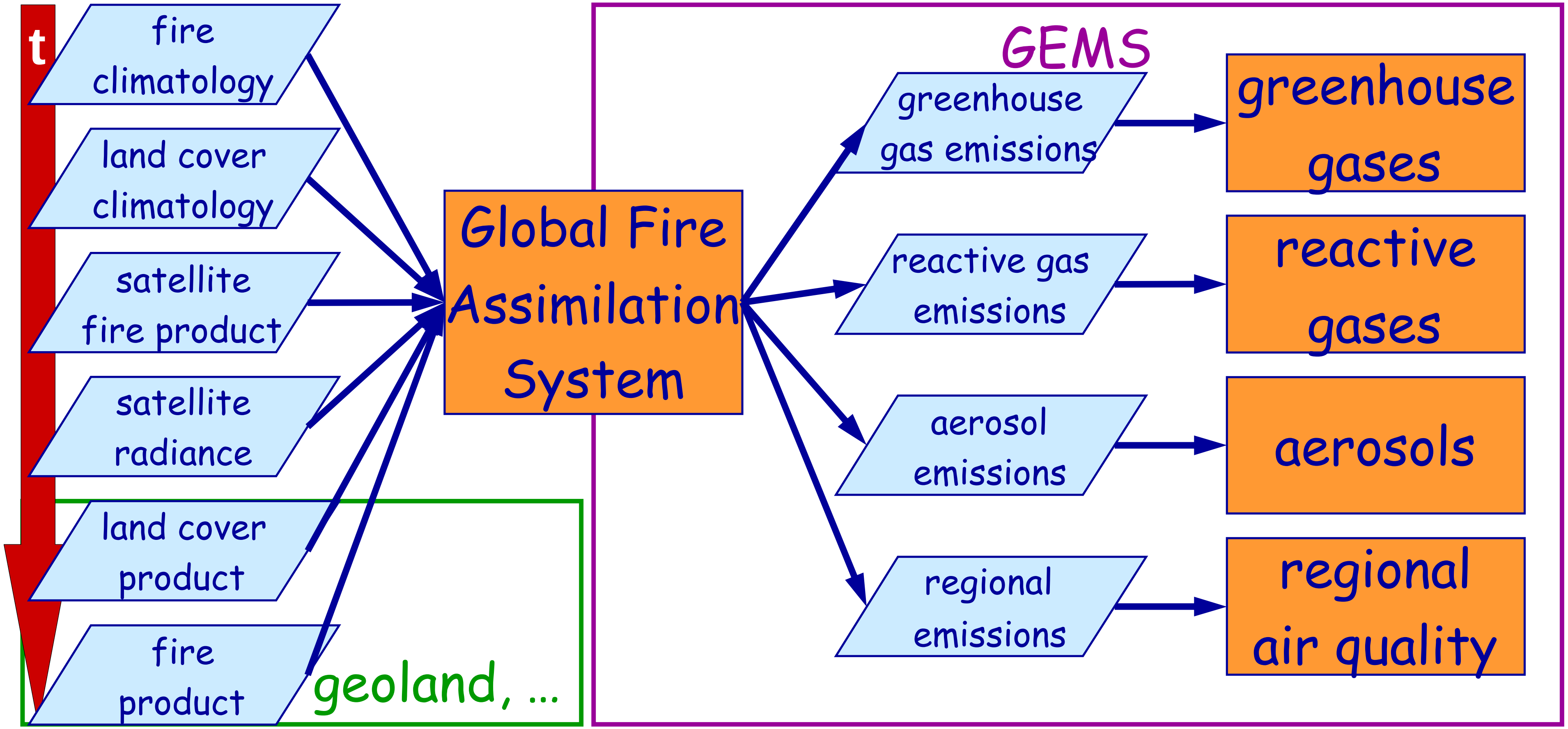
Proposed: Global Fire Assimilation System GFAS



Proposed: Global Fire Assimilation System GFAS



Proposed: Single Software Interface



- GFAS input:
  - Emission inventories
  - Climatologies (ecosystems, available fuel load, fire statistics)
  - Fire EO (hot spots, burn scars, FRP, radiances,…)
  - Meteorology

- GFAS output:
  - 4-d fields of emissions by fire for all GEMS species

- Let all of GEMS benefit from GFAS developments without technical overhead.

- MODIS hot spots can be used in the early stages as the product is global and operationally established.

- GEO satellites, supplemented by a polar orbiter, should ultimately be used to achieve optimal coverage, spatially and temporally. (FRP and/or WF_ABBA products)

- Use of Fire Radiative Power (FRP) eliminates major error sources in the processing chain.

- GEMS should invite people from NRL and INPE/CPTEC.

Proposed Treatment of Wildfire in GEMS

Year 2 May 2006+12 mo	• Produce 3 different reanalyses for GHG, GRG, Aerosol • global emissions for 2003 of correct order of magnitude • climatology: GFED2, RETRO, AEROCOMM-B
Year 2.5-3.5 Nov 2007+ 12 mo	• Produce unified reanalyses for GHG, GRG, Aerosol • high-resolution (t&s) global fire products for 2000–2007 • burnt area, hot spots from MODIS, GLOBCARBON…
Year 3.5 - 4 Nov 2008+ 6 mo	• Final pre-operational trials • high-resolution (t&s) global fire products in NRT • hot spots and/or FRP from MODIS, …
Year 5 - 2009 -	• operational phase • high-resolution global (t&s) fire products in NRT • hot spots and/or FRP from MODIS, … • FRP and/or WF_ABBA from GEO satellites

Partial Funding

No Funding

Summary

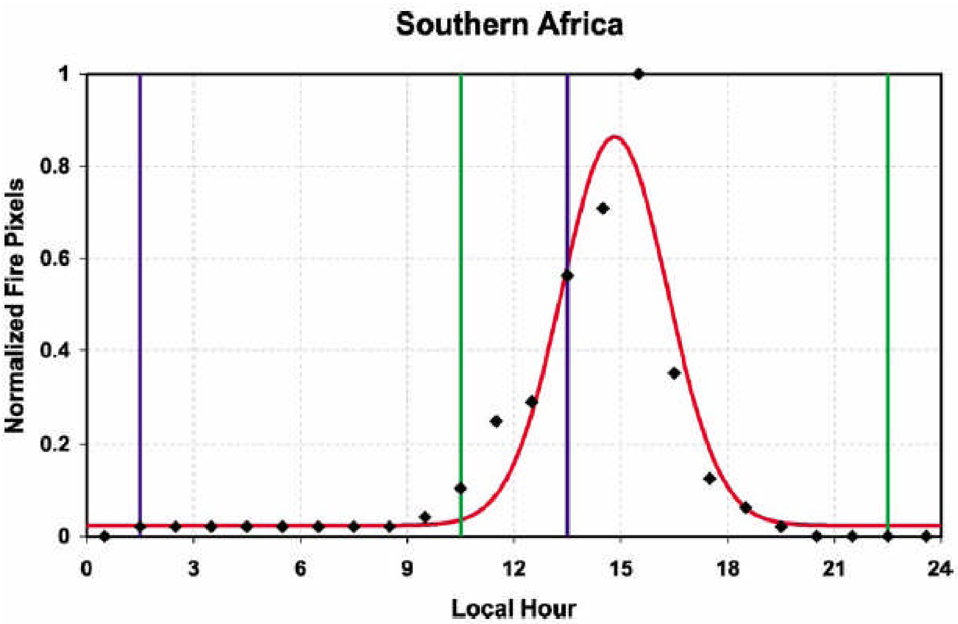
- The emission by wildfires is ultimately needed globally in near-real time as well as with a time lag.
- No suitable wildfire emission product is available.
- Various fire EO products complement each other.
- Several promising developments are visible.

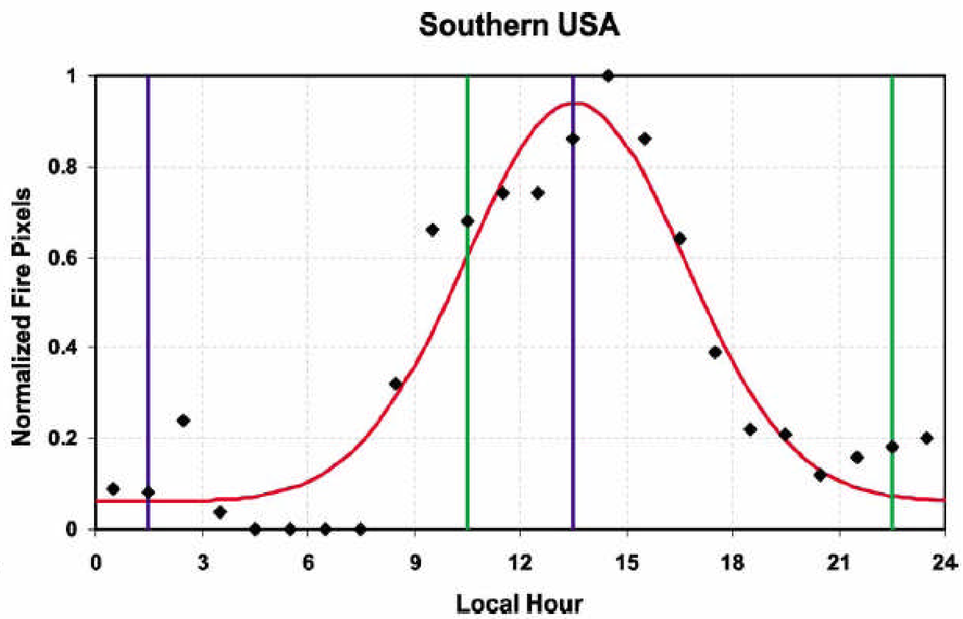
- We propose a phased development strategy for wildfire emission modelling for GEMS:

  Global Fire Assimilation System (GFAS) serving the GEMS subprojects, ultimately in near-real time.
- (Feedback through inverse modelling is ultimately expected.)

- We need to collaborate with the fire EO and land monitoring communities.
- We need additional funding.

Diurnal Variability





(Justice et al. 2002)

More Info

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