Satellite Meteorology: Past, Present, and Future

A Symposium in Celebration of the CIMSS Silver Anniversary

July 11-13, 2005

CIMSS Biomass Burning Monitoring Program

Cast of Players

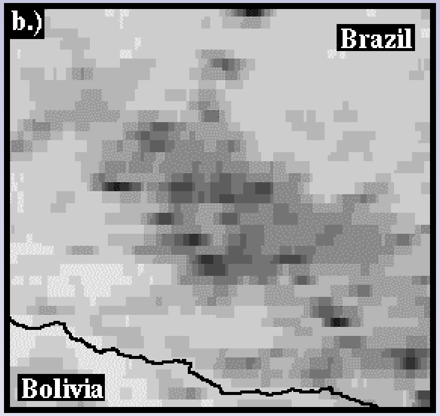
Paul Menzel   Elaine Prins   Elen Cutrim

Tracy DeLiberty   Joleen Feltz   Christopher Schmidt

Jason Brunner   Jay Hoffman   Bob Rabin

SSEC McIDAS Staff ♦ NOAA/NESDIS ♦ MODIS Team ♦ GOES Retrieval Team

The Early Days Characterized by "Optimism" for Geostationary Satellite Remote Sensing of Fires



August 1988, GOES-7 3.9 micron data

"About the only thing we can't see is the guy lighting the match."

W. Paul Menzel

From "Scientists turn satellite's eye to Amazon", Terri Devitt, Wisconsin Week, July 25, 1990

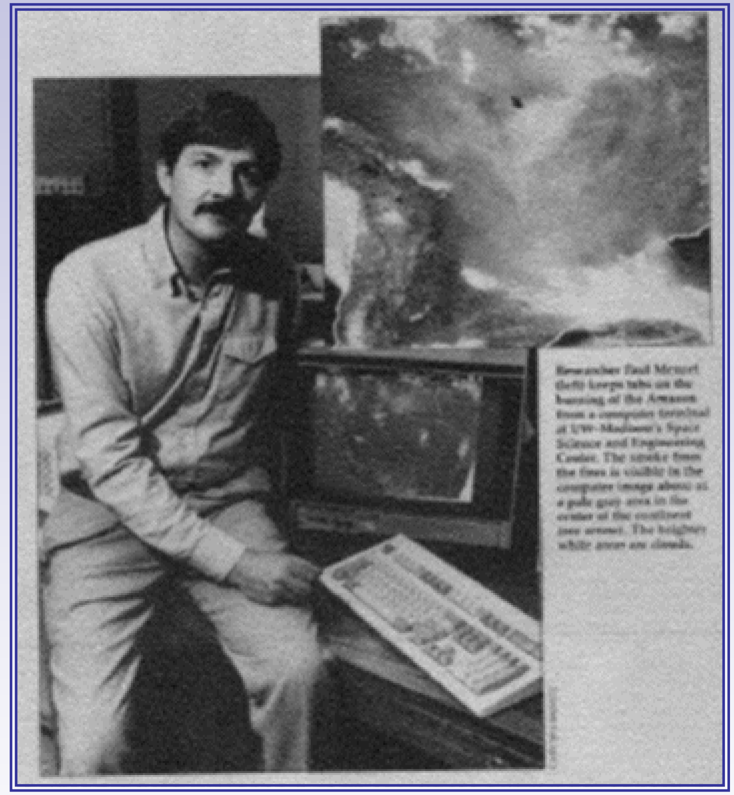
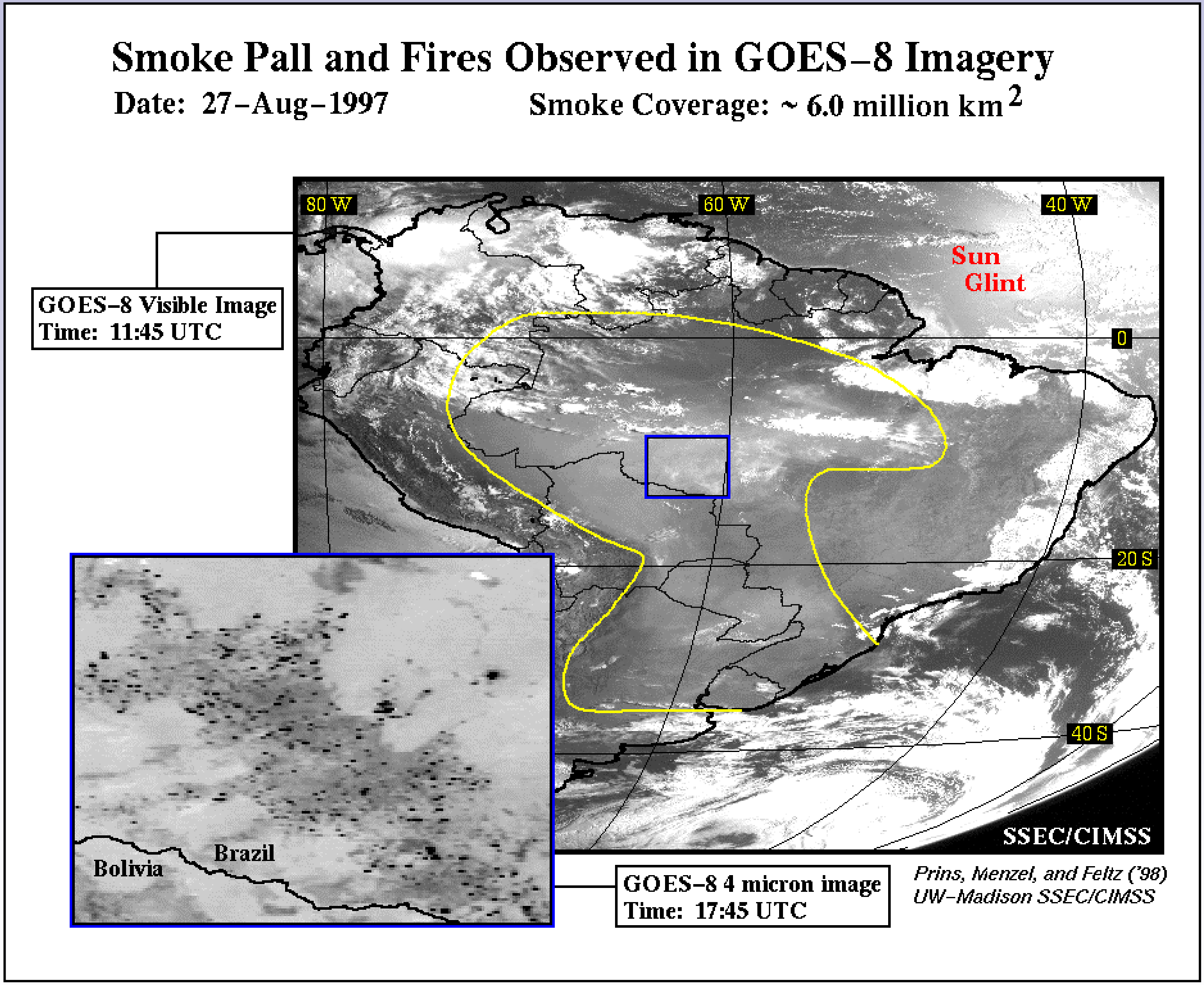
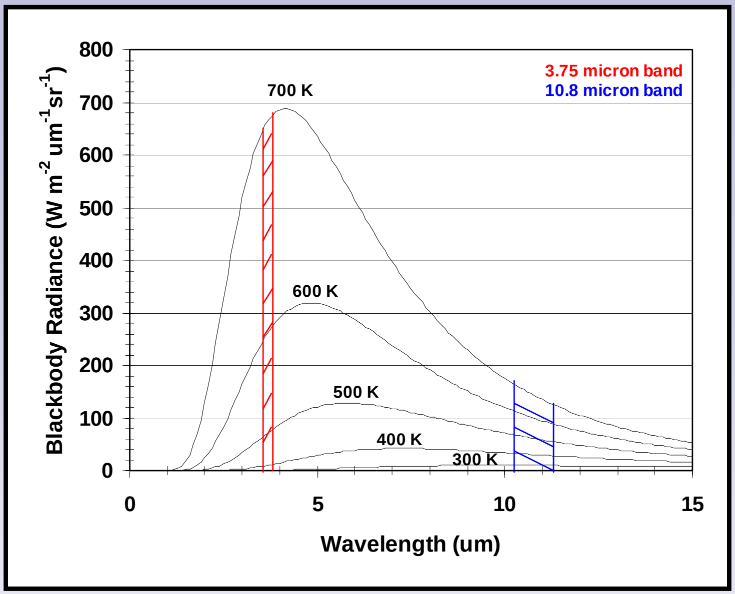
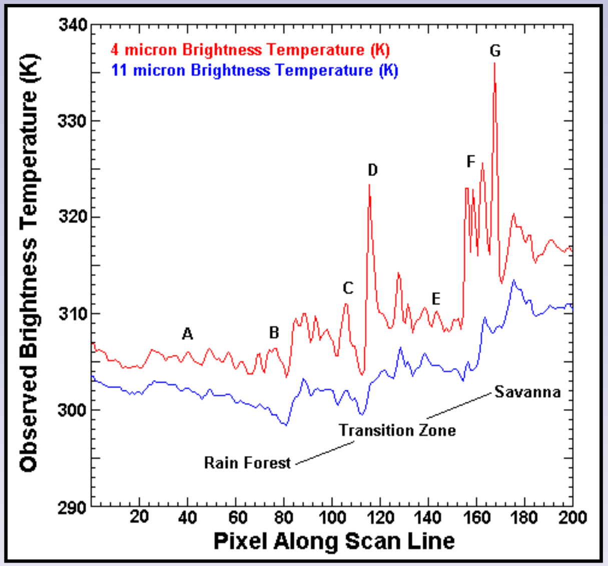


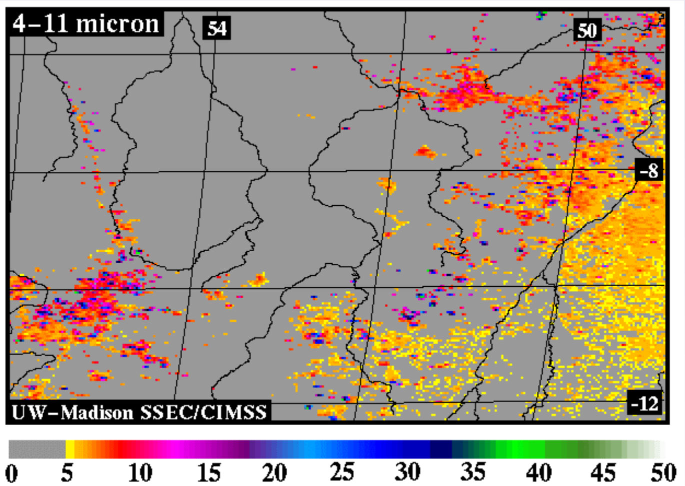
Photo by: Cary Shlimovitz


Smoke Pall and Fires Observed in GOES–8 Imagery
Date: 27–Aug–1997
Smoke Coverage: ~ 6.0 million km2
GOES–8 Visible Image
Time: 11:45 UTC
80 W
60 W
40 W
Sun Glint
0
20 S
40 S
SSEC/CIMSS
Bolivia
Brazil
GOES–8 4 micron image
Time: 17:45 UTC
Prins, Menzel, and Feltz ('98)
UW–Madison SSEC/CIMSS

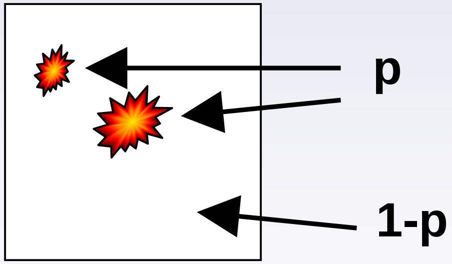
The Basics of GOES Infrared Fire Detection





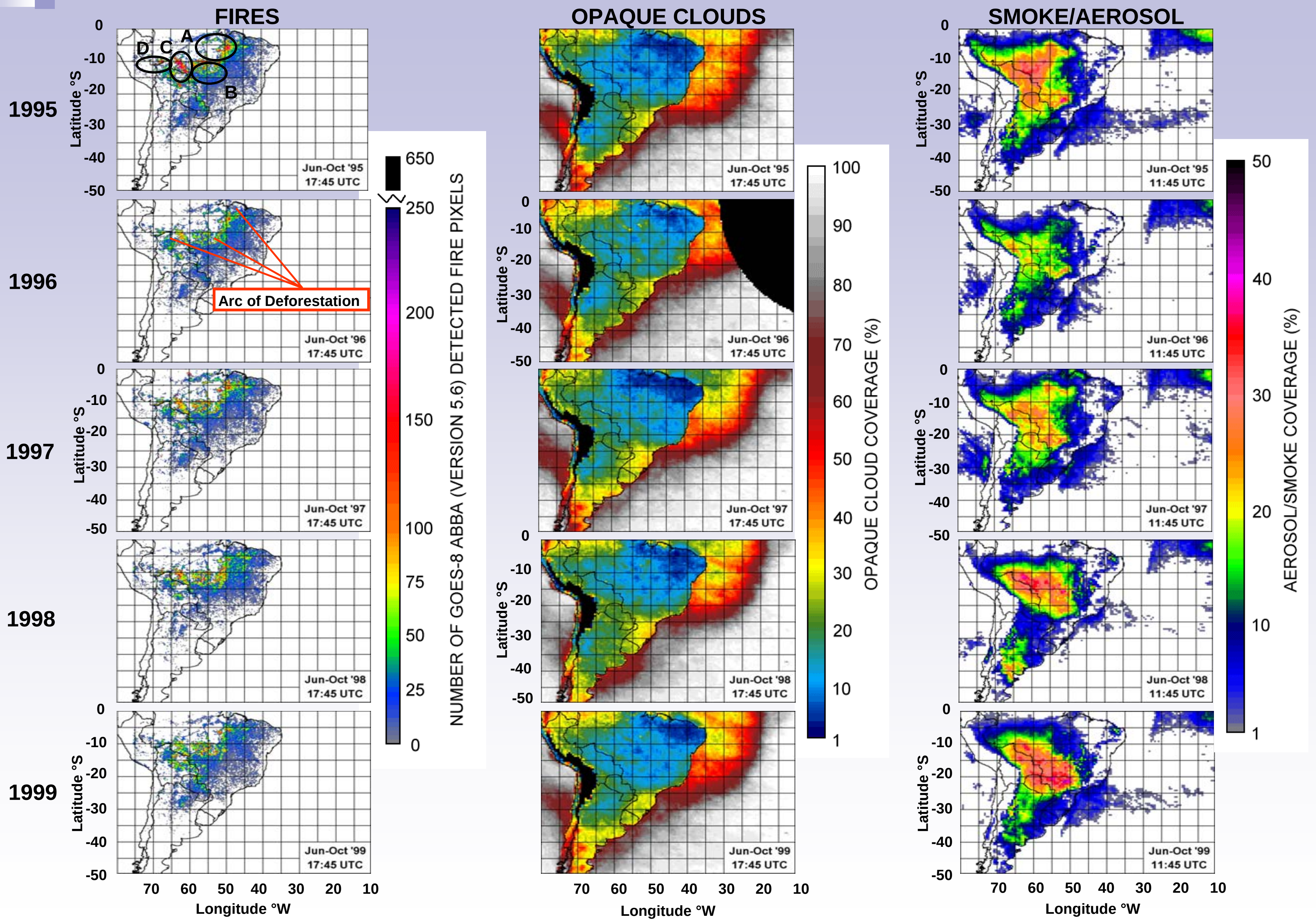


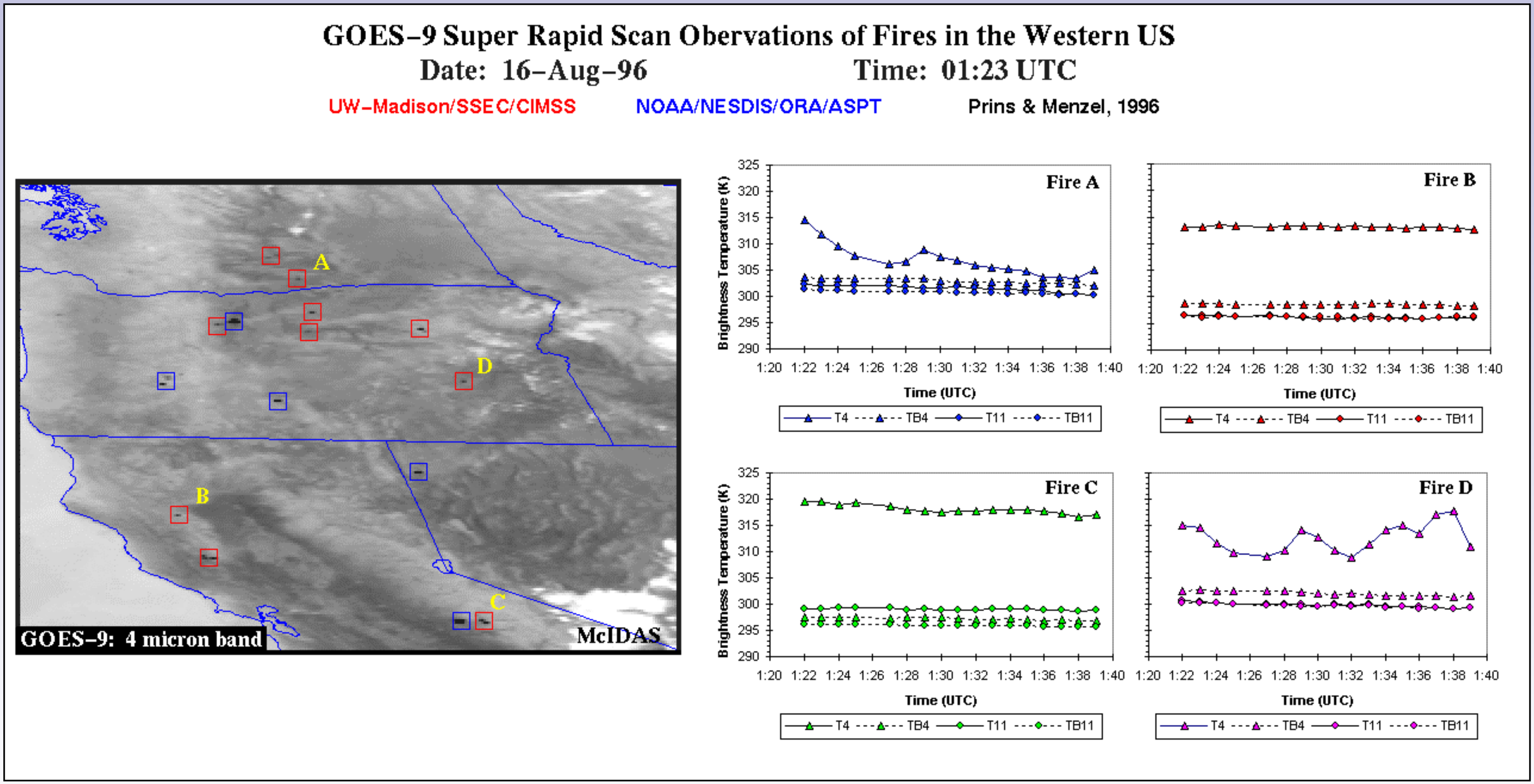
4 – 11 micron Brightness Temperature Difference (K)



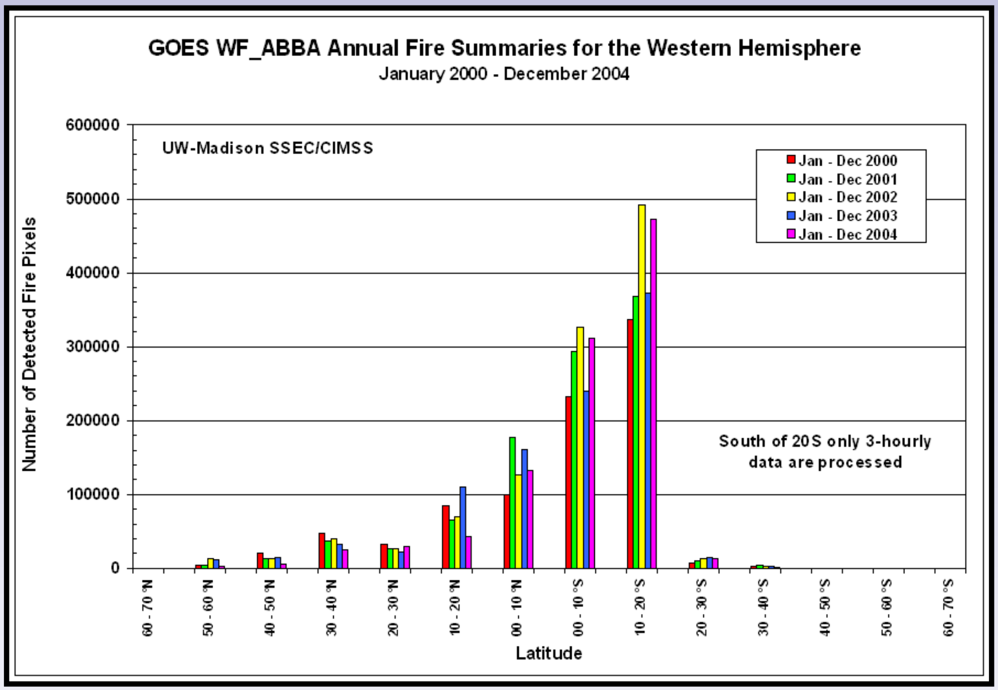
$$L_4(T_4) = p\,L_4(T_f) + (1-p)\,L_4(T_b) + (1-\varepsilon_4)\,\tau_{4s}\,L_{4\ solar}$$

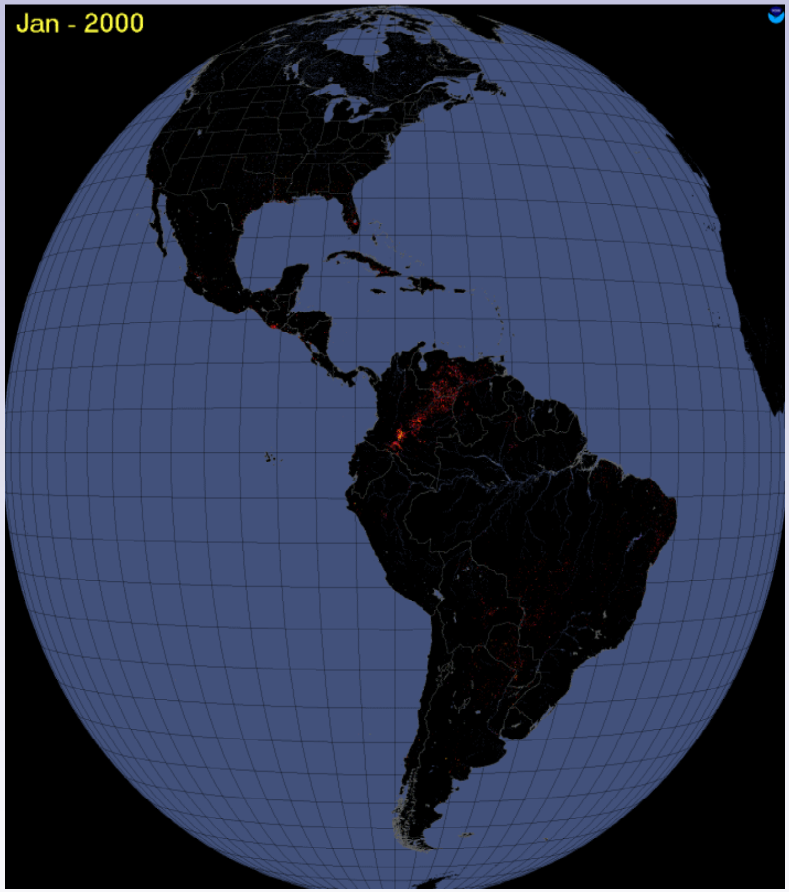
$$L_{11}(T_{11}) = p\,L_{11}(T_f) + (1-p)\,L_{11}(T_b)$$


FIRES
OPAQUE CLOUDS
SMOKE/AEROSOL
1995
1996
1997
1998
1999
A
B
C
D
Arc of Deforestation
Latitude °S
Longitude °W
Jun-Oct '95
17:45 UTC
Jun-Oct '96
17:45 UTC
Jun-Oct '97
17:45 UTC
Jun-Oct '98
17:45 UTC
Jun-Oct '99
17:45 UTC
Jun-Oct '95
11:45 UTC
Jun-Oct '96
11:45 UTC
Jun-Oct '97
11:45 UTC
Jun-Oct '98
11:45 UTC
Jun-Oct '99
11:45 UTC
NUMBER OF GOES-8 ABBA (VERSION 5.6) DETECTED FIRE PIXELS
650
250
200
150
100
75
50
25
0
OPAQUE CLOUD COVERAGE (%)
100
90
80
70
60
50
40
30
20
10
1
AEROSOL/SMOKE COVERAGE (%)
50
40
30
20
10
1
0
-10
-20
-30
-40
-50
70
60
50
40
30
20
10


GOES–9 Super Rapid Scan Obervations of Fires in the Western US
Date: 16–Aug–96
Time: 01:23 UTC
UW–Madison/SSEC/CIMSS
NOAA/NESDIS/ORA/ASPT
Prins & Menzel, 1996
A
B
C
D
GOES–9: 4 micron band
McIDAS
Fire A
Fire B
Fire C
Fire D
Brightness Temperature (K)
Time (UTC)
T4
TB4
T11
TB11

Five Years of Half-Hourly GOES WF_ABBA Fire Products for the Western Hemisphere



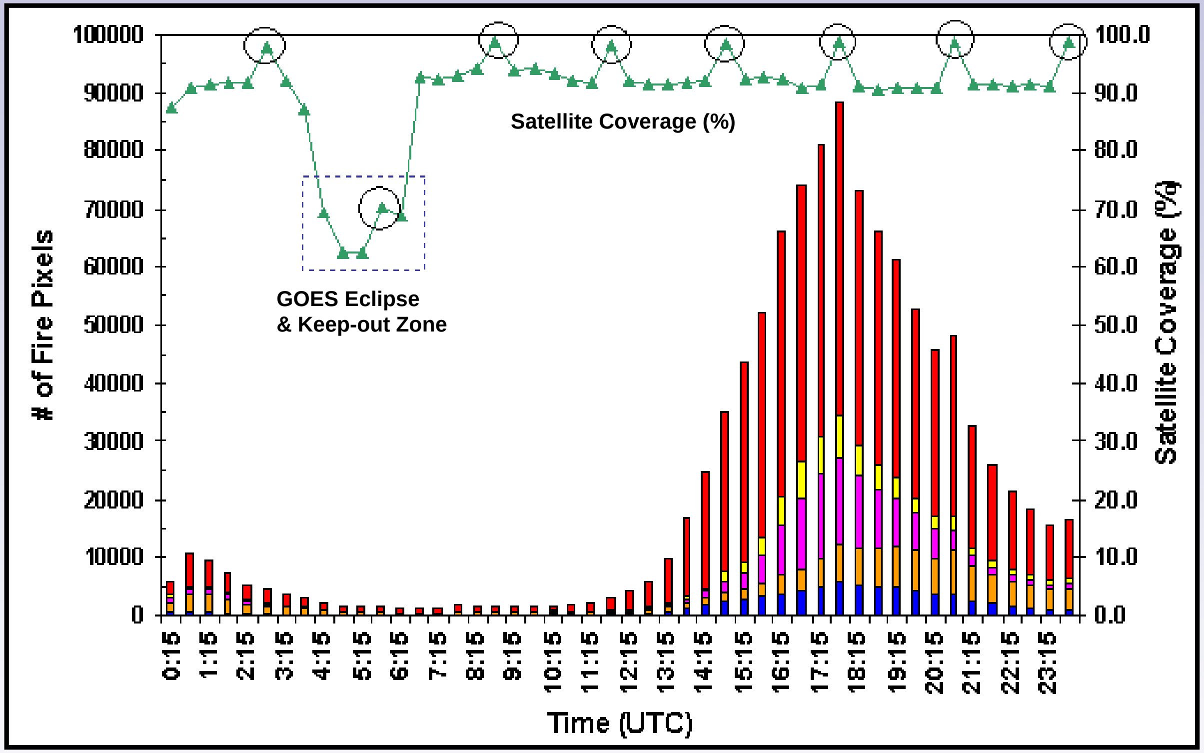


Animation of GOES-East WF_ABBA Fire Detects
January 2000 – December 2004

The half-hourly GOES WF_ABBA fire data base for the Western Hemisphere extends over 5 years providing a unique look at patterns in burning in North, Central, and South America.

Although the general distribution of fires is similar from year to year, there is considerable variability associated with climatic and anthropogenic forcing.

Diurnal Distribution of GOES-8 WF_ABBA Fire Pixel Product for the Western Hemisphere



Dates: 1 September 2001 – 31 August 31 2002

GOES WF_ABBA becomes operational at NOAA NESDIS OSDPD in 2002 as part of the Hazard Mapping System.

Applications of Meteorological Satellite Fire Products

Hazards Detection and Monitoring

Each year millions of acres of forest and grassland are consumed by wildfire resulting in loss of life and property with significant economic costs and environmental implications.

- Although the capabilities of current geostationary satellites are limited, they can provide valuable regional and global fire products in near real-time, and are critical for fire detection and monitoring in remote locations and developing countries.

Global Change and Air Quality Monitoring

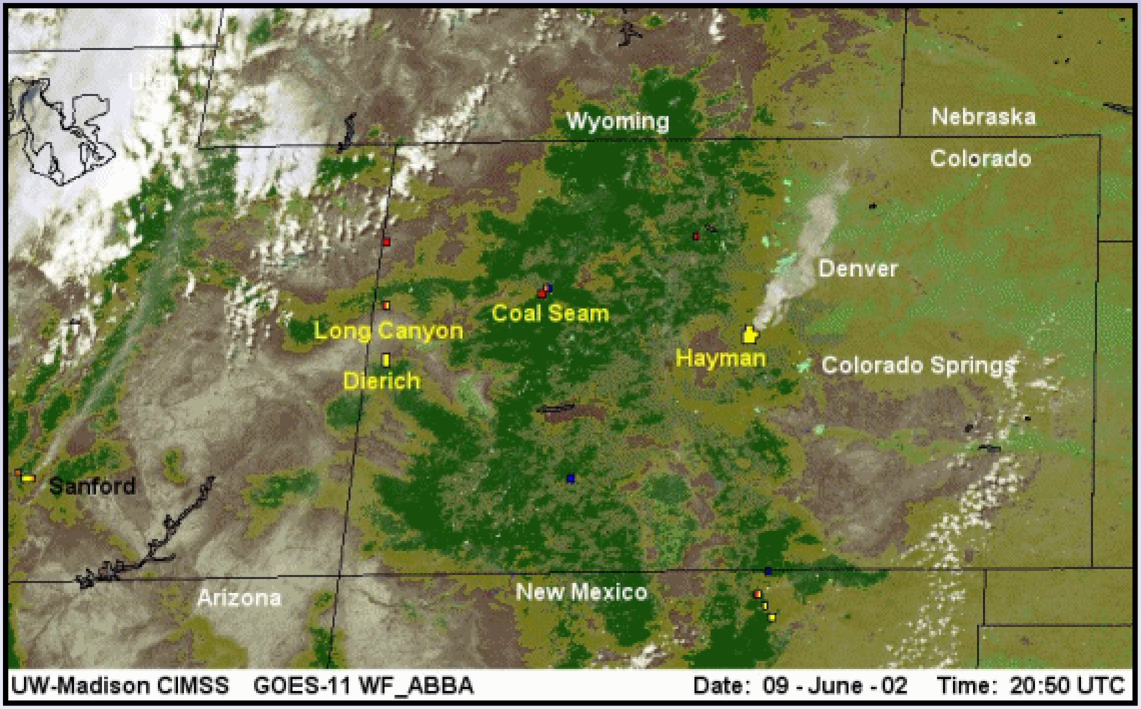
Biomass burning is a distinct biogeochemical process that plays an important role in terrestrial ecosystem processes and global climate change

- Land use and land cover change monitoring (socio-economic factors):
  Fire is used in the process of deforestation and agricultural management. Approximately 85% of all fires occur in the equatorial and subtropical regions and are not adequately documented.

- Estimates of atmospheric emissions for global and regional assessments:
  Biomass burning is a major source of trace gases and an abundant source of aerosols
  NO, CO_2 (40%), CO (32%), O_3(38%), NO_X, N_2O, NH_3, SO_X, CH_4(10%), NMHC (>20%) , POC (39%)

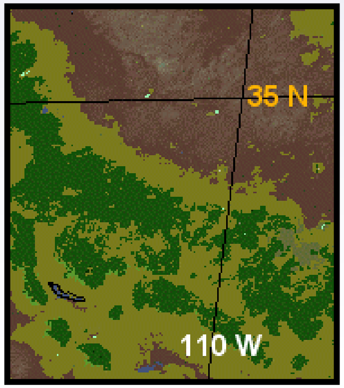
- Within the Framework Convention on Climate Change (FCCC) countries will need to report on greenhouse gas emissions including those from biomass burning.

Fire Detection Using Rapid Scan Imagery

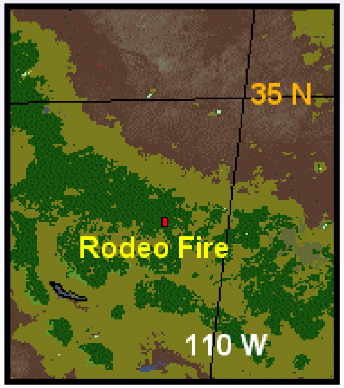


Using rapid scan GOES-11 data, the WF_ABBA was able to identify several wildfires in imagery near/at the initial reported start times during the 2002 fire season in the Western U.S.

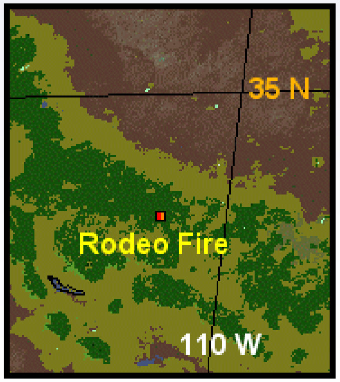
Rodeo/Chediski Complex in Arizona



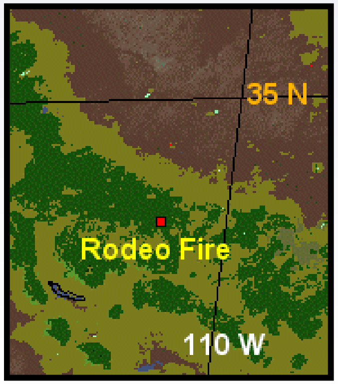
2303 UTC



2307 UTC



2315 UTC



2320 UTC

Rodeo/Chediski Complex: Largest Wildfire in Arizona's Recorded History

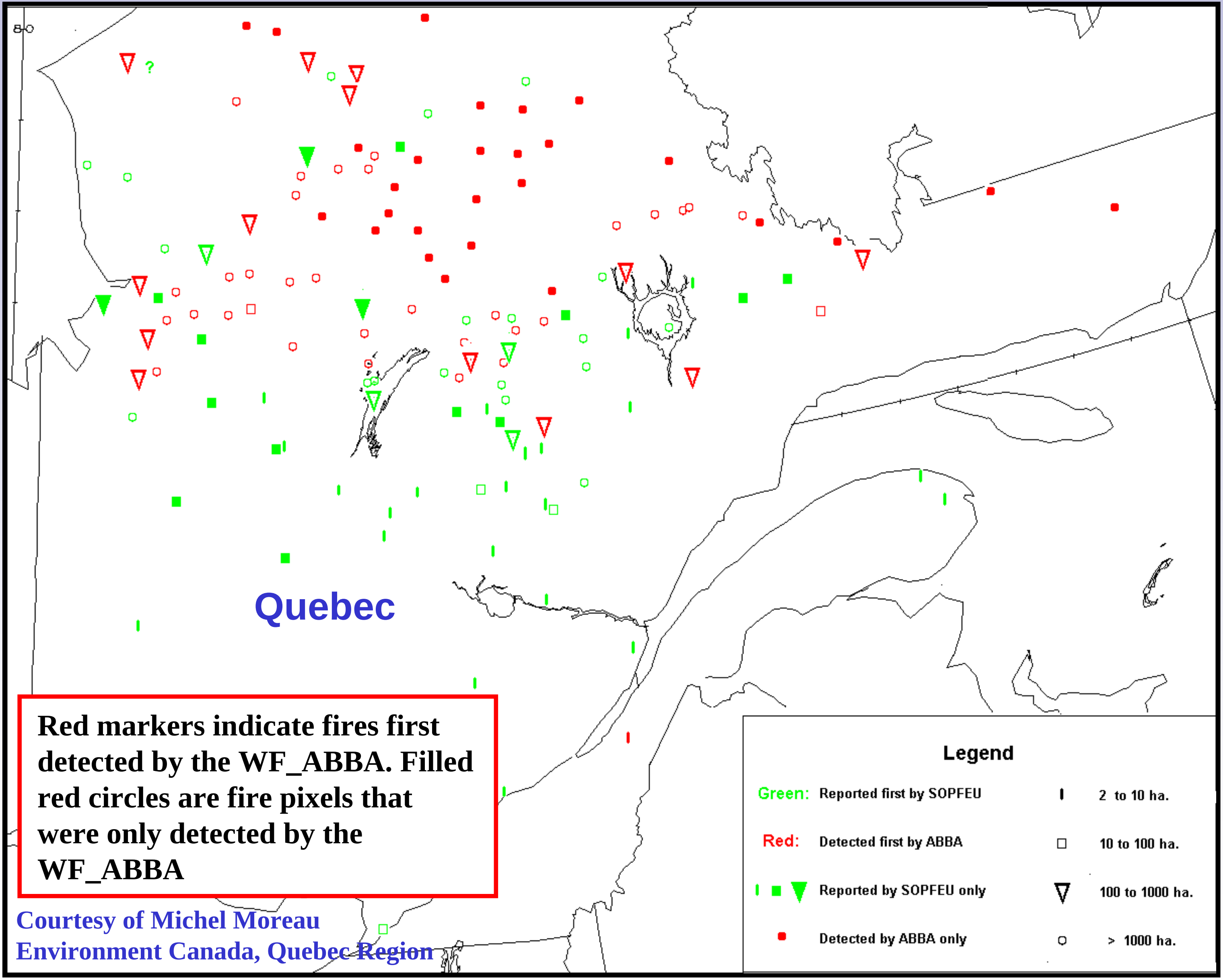
Size: > 480,000 acres
Cost: > $170 million

Start Date of Rodeo Fire:
18 June 2002

Official report time by suspected arsonist: *23:11 UTC*

Initial detect in post-processed GOES-11 image: *23:07 UTC*

2002 Fire Validation Study in Quebec Canada

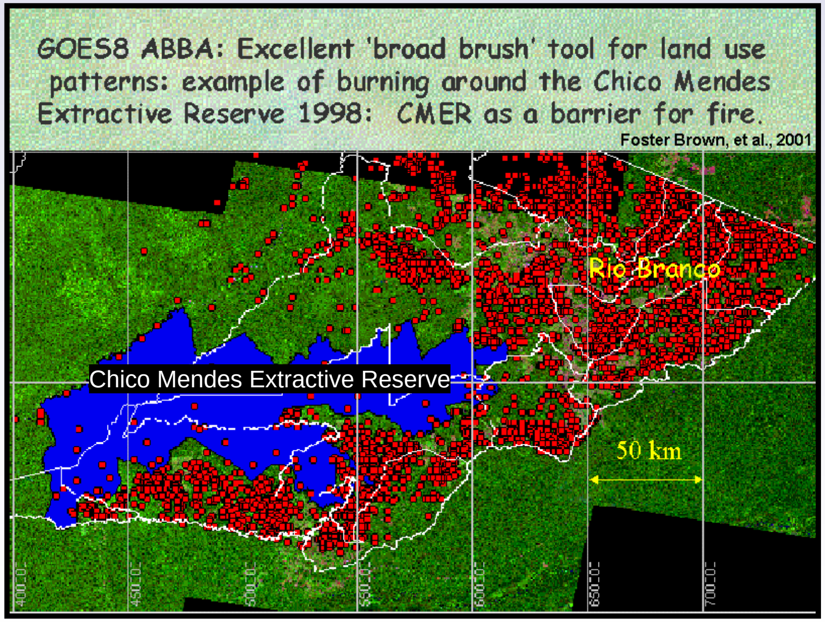


Red markers indicate fires first detected by the WF_ABBA. Filled red circles are fire pixels that were only detected by the WF_ABBA

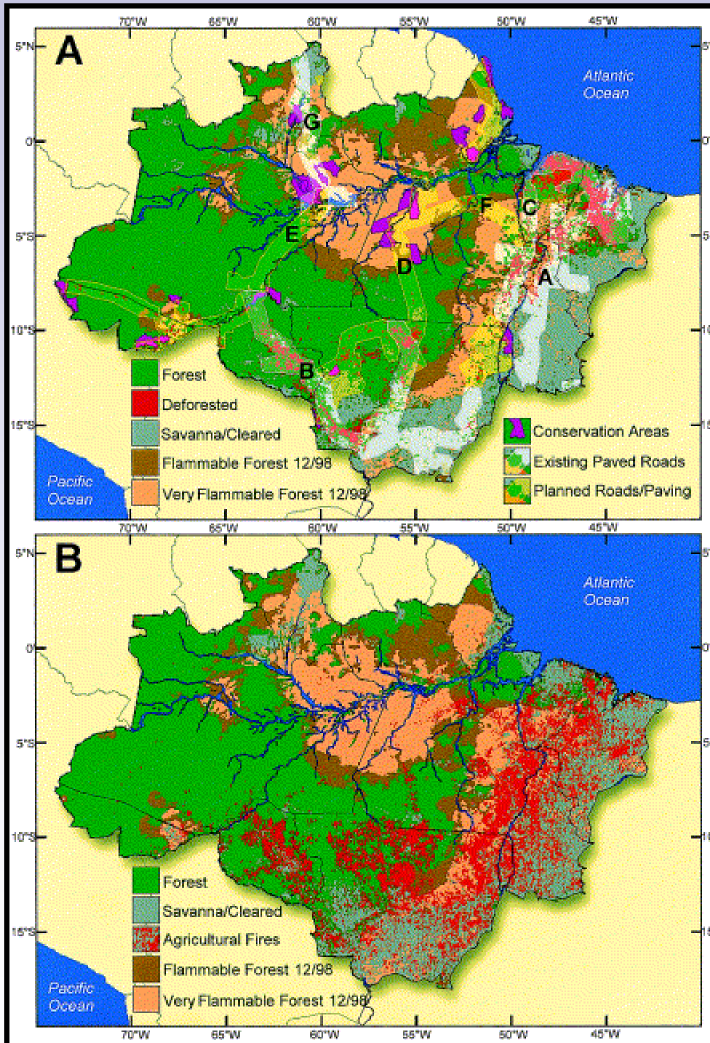
Courtesy of Michel Moreau
Environment Canada, Quebec Region

GOES South American ABBA Fire Products Used in Land Use/Land Cover Change and Fire Dynamics Research

Universities, research institutes, and government planning agencies are using the GOES ABBA fire product as an indicator of land-use and land-cover change and carbon dynamics. GOES fire products also are being used to study the impact of road paving in South America on fire regime feedbacks and the future of the Amazon forests.



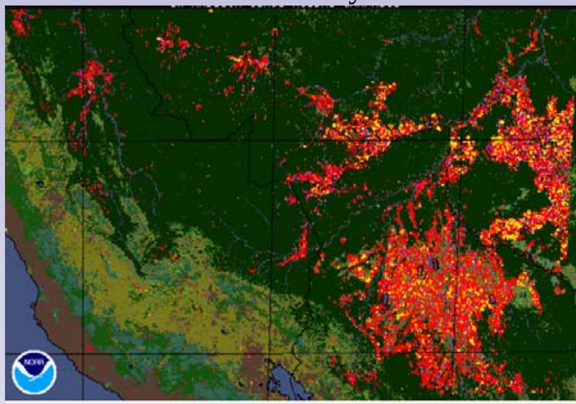
Foster Brown, et al., 2001



Nepstad, et al., 2001: Road paving, fire regime feedbacks, and the future of Amazon forests, Forest Ecology and Management, 154, 395-407.

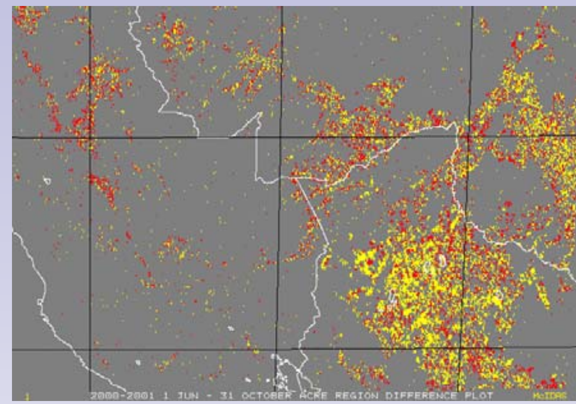
GOES WF_ABBA Observations of Fire Activity in the Tri-Frontier from 2000 – 2004

2000 Fire Season Summary



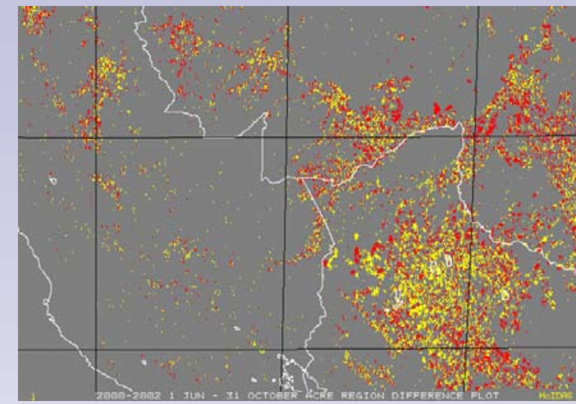
1 June – 31 October 2000

2000 – 2001 Difference Plot



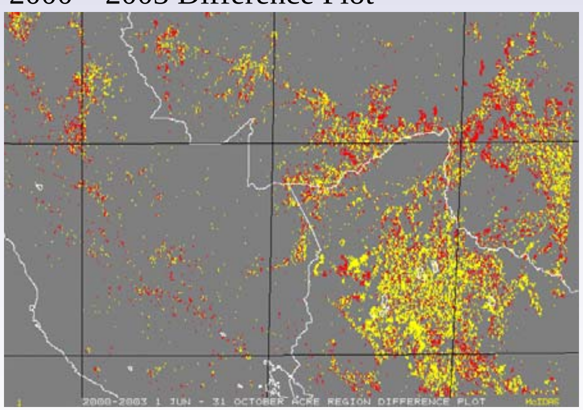
Fires unique to 2000 (yellow)
Fires unique to 2001 (red)

2000 – 2002 Difference Plot



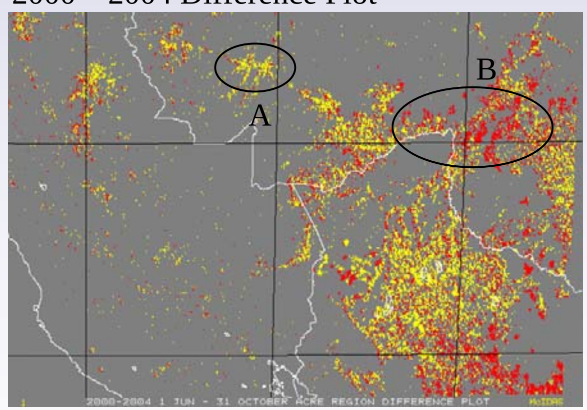
Fires unique to 2000 (yellow)
Fires unique to 2002 (red)

2000 – 2003 Difference Plot



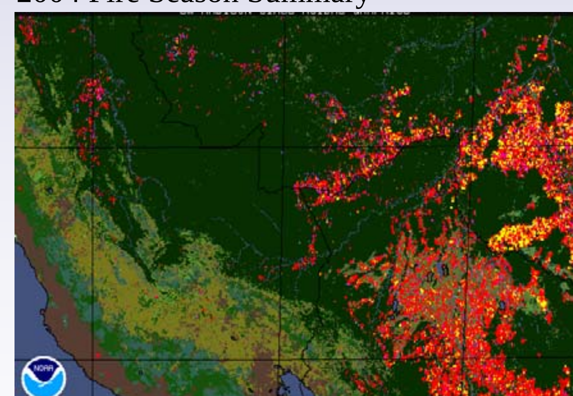
Fires unique to 2000 (yellow)
Fires unique to 2003 (red)

2000 – 2004 Difference Plot



Fires unique to 2000 (yellow)
Fires unique to 2004 (red)

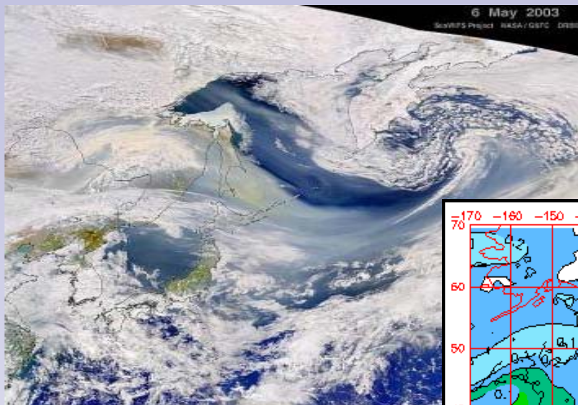
2004 Fire Season Summary



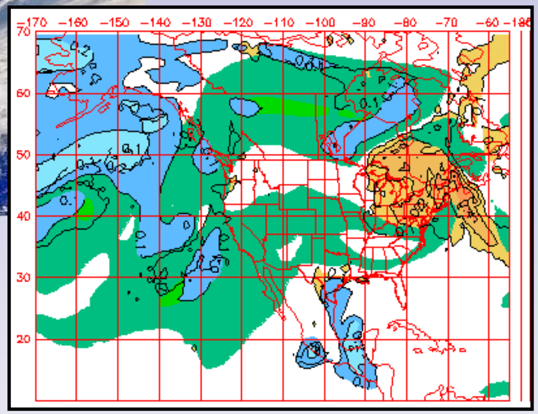
1 June – 31 October 2004

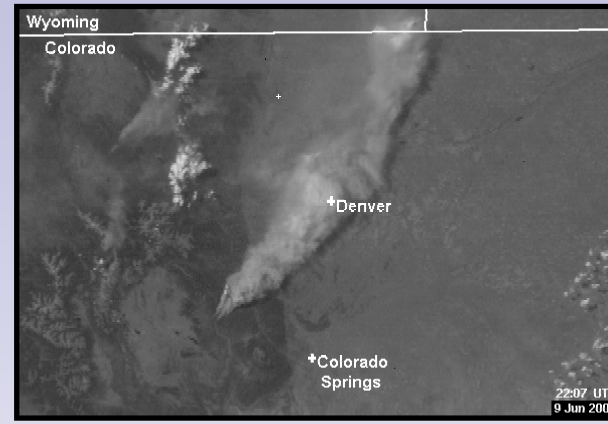
The difference plots show fire pixels unique to each year and can show regions of expansion of fire activity in the tri-frontier. At location A (along a new road in Acre, Brazil) there does not seem to be significant expansion of fire into new areas during the time period from 2000 to 2004, while at location B there appears to be more fire activity.

Where are Biomass Burning Aerosols Coming From and Where are They Going?



Smoke Transport Across Pacific from Siberia
6 May 2003



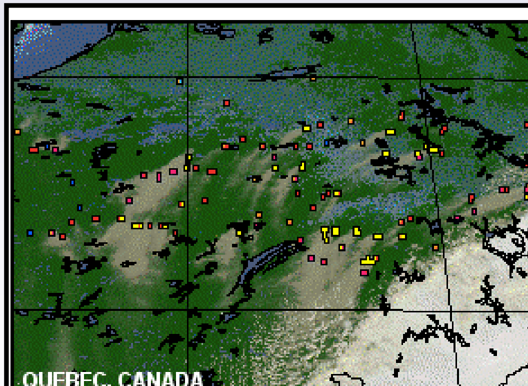


GOES-11 Rapid Scan Visible Imagery (1 km)
22:07, 9 June 2002 – 00:50, 10 June 2002
Courtesy of CSU - CIRA

Before

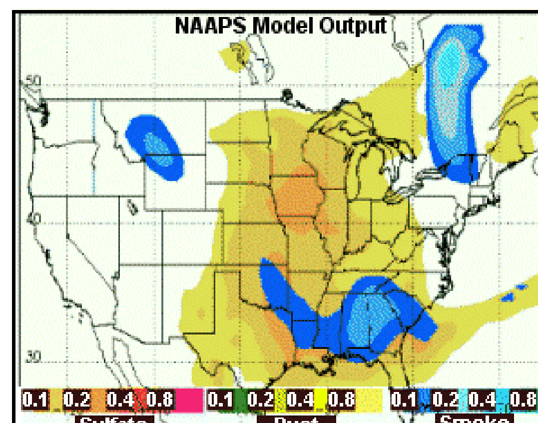
After

Smoke Transport Across Gulf of Mexico
9 May 2003



Wildfire ABBA Fire Product
Date: 6-Jul-2002
Time: 17:45 UTC

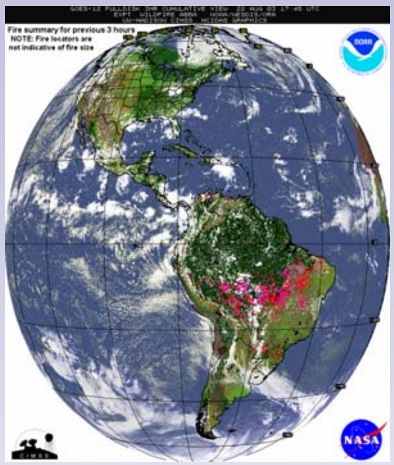
NOAA/NESDIS/ORA ASPT UW-Madison CIMSS



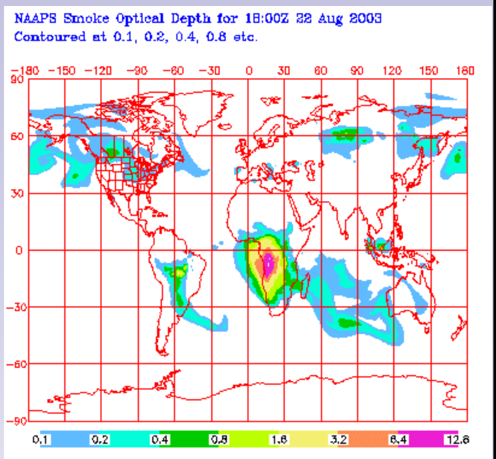
Date: 7-Jul-2002 Time: 1200 UTC
Navy Aerosol Analysis and Prediction System (NAAPS)
Courtesy of Doug Westphal, NRL, Monterey, CA

Applications of the GOES Wildfire ABBA in Modeling Programs

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

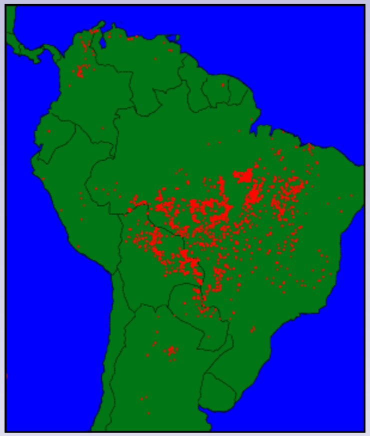


GOES WF_ABBA Fire Product
22 August 2003 at 17:45 UTC

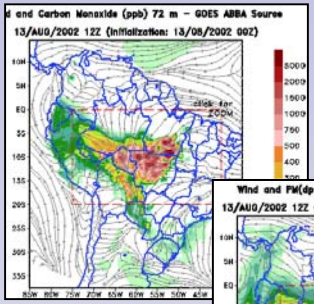


NAAPS Smoke Optical Depth
22 August 2003 at 18:00 UTC

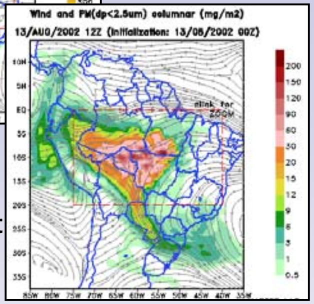
Real-time Assimilation at the University of Sao Paulo and CPTEC/INPE into the RAMS model



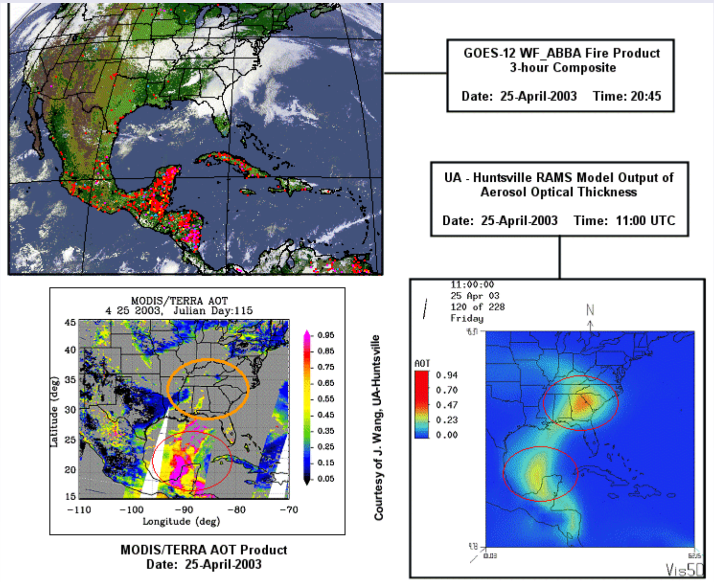
GOES-8 WF_ABBA Fire Product
Point Sources for 13 August 2002



RAMS
CO Product



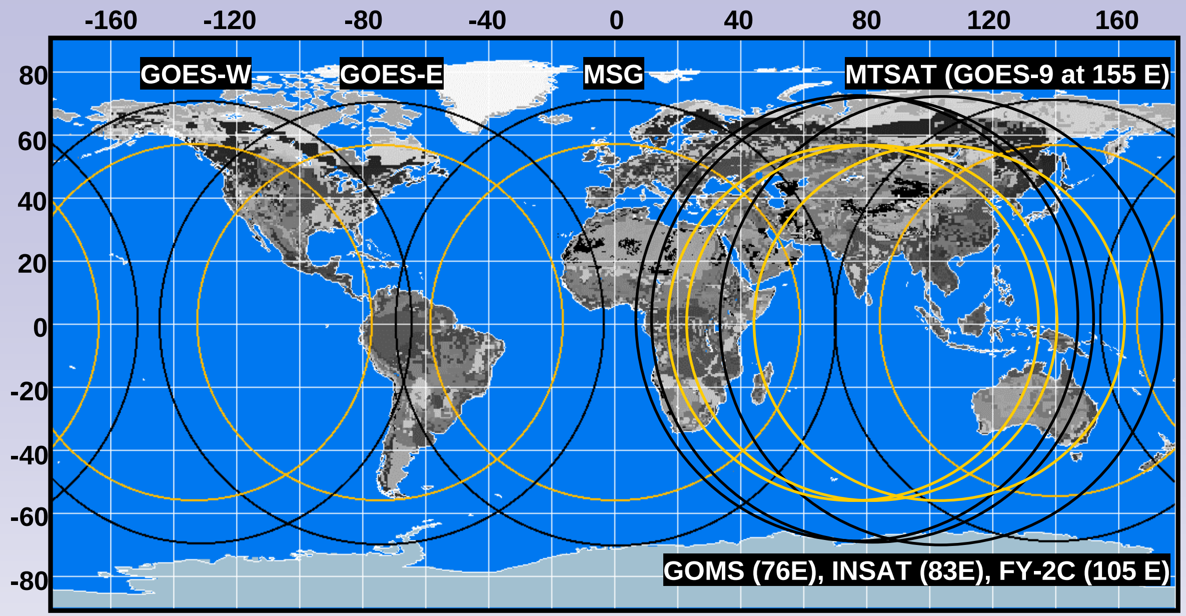
RAMS
PM2.5 Product



Other Modeling Efforts and Collaborations

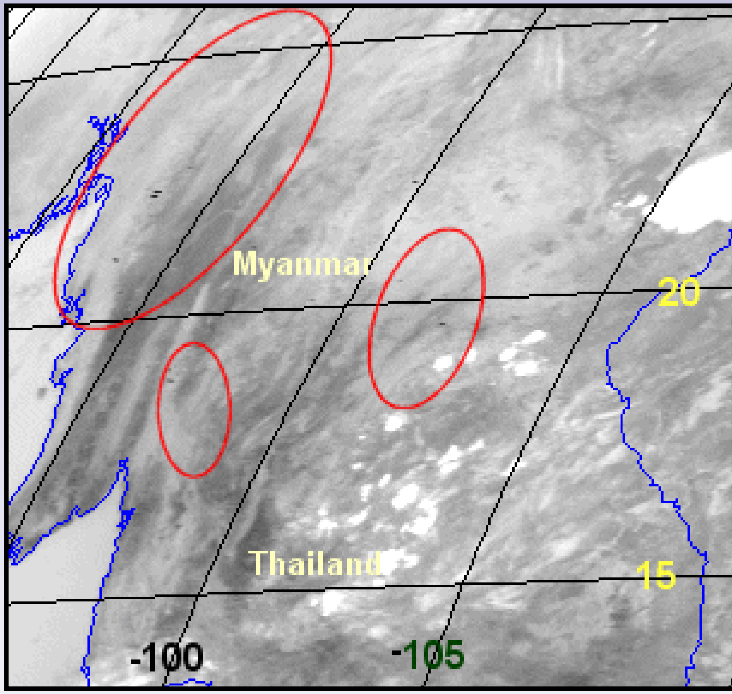
- **Climate Modeling at NASA/GSFC:** Assimilation into the GOCART model
- **Real-time Air Quality Modeling at NASA/Langley:** Real-time assimilation into the RAQMS model as part of IDEA (Infusing satellite Data into Environmental Applications)
- **Fire Emissions and Regional Air Quality Modeling at NCAR:**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

Global Geostationary Active Fire Monitoring Capabilities



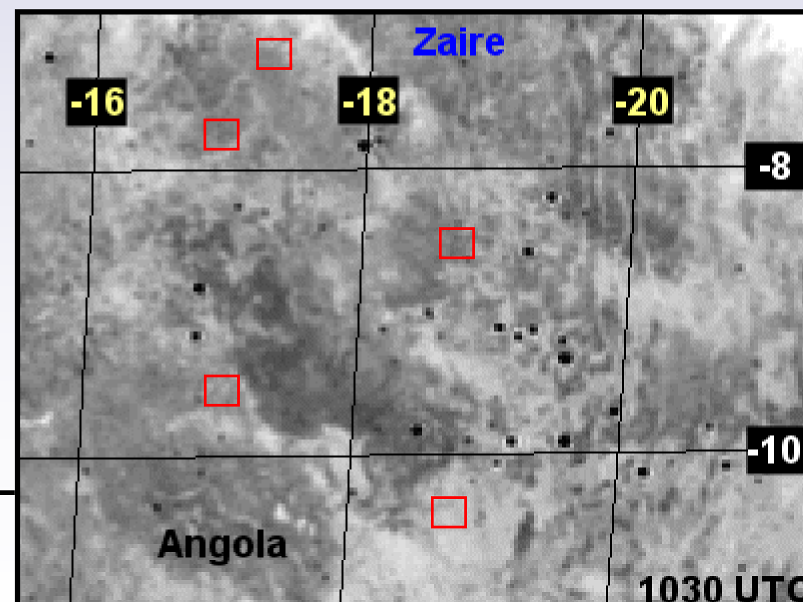
Satellite	Active Fire Spectral Bands	Resolution IGFOV (km)	SSR (km)	Full Disk Coverage	3.9 µm Saturation Temperature (K)	Minimum Fire Size at Equator (at 750 K) (hectares)
GOES-12 Imager	1 visible 3.9 and 10.7 µm	1.0 4.0 (8.0)	0.57 2.3	3 hours	~335 K	0.15
GOES-9 & GOES-10 Imager	1 visible 3.9 and 10.7 µm	1.0 4.0 (8.0)	0.57 2.3	1 hour (G-9) 3 hours (G-10)	~324 K (G-9) ~322 K (G-10)	0.15
MSG SEVIRI	1 HRV 2 visible 1.6, 3.9 and 10.8 µm	1.6 4.8 4.8	1.0 3.0 3.0	15 minutes	~335 K	0.22
FY-2C SVISSR (Fall 2004)	1 visible, 3.75 and 10.8 µm	1.25 5.0		30 minutes	~330 K (?)	
MTSAT-1R JAMI (2005)	1 visible 3.7 and 10.8 µm	0.5 2.0		1 hour	~320 K	0.03
INSAT- 3D (2006)	1 vis, 1.6 µm 3.9 and 10.7 µm	1.0 4.0	0.57 ? 2.3 ?	30 minutes		
GOMS Electro N2 MSU-G (2006)	3 visible 1.6, 3.75 and 10.7 µm	1.0 km 4.0 km		30 minutes		

Fire Monitoring in Southeast Asia (GOES-9) and Africa (MSG)



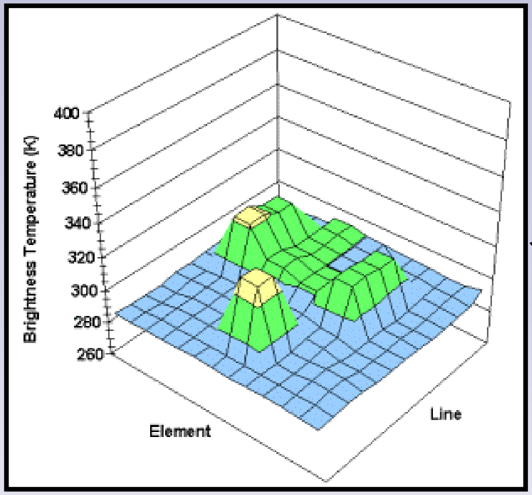
Satellite view angle: 70º

Animation of GOES-9 3.9 micron imagery
Date: 19- Mar-2004
Times: 0325 - 0725 UTC

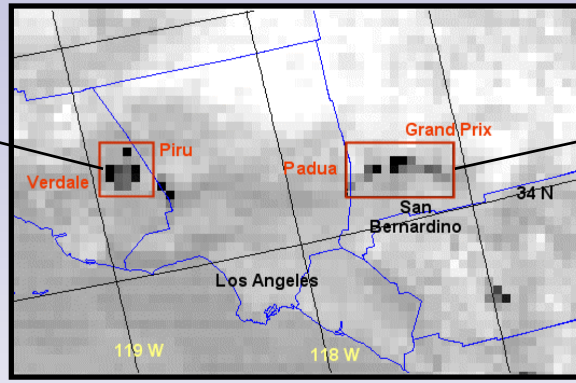


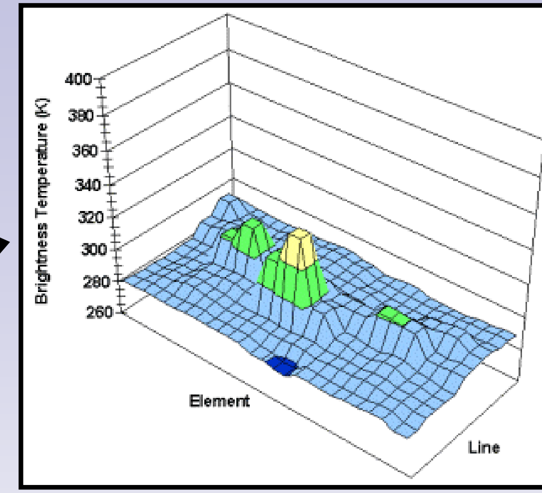
Animation of MSG 3.9 micron imagery
Date: 30- Jul-2004
Times: 1030 - 1215 UTC

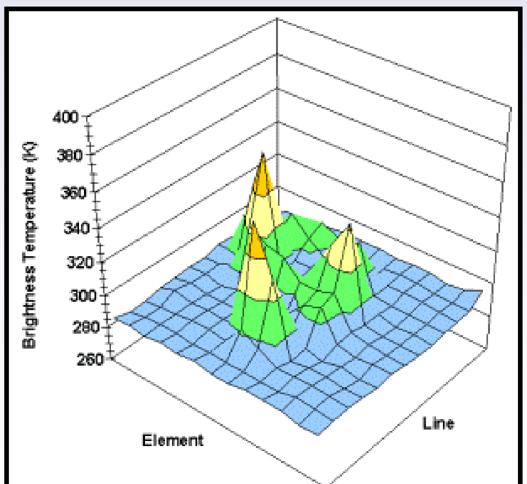
GOES-R and GOES-I/M Simulations of Southern California Fires



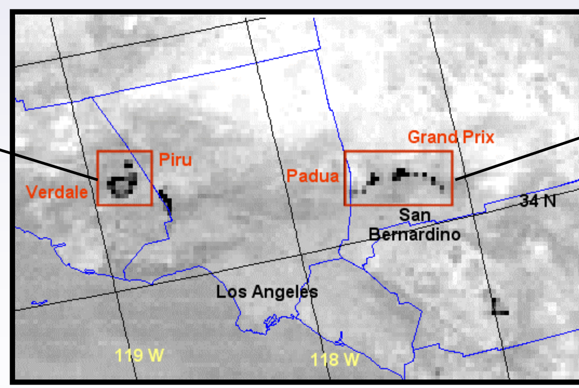
GOES-12 Simulated 3.9 micron Data
Padua/Grand Prix Fires
Date: 27-Oct-03 Time: 09:50 UTC

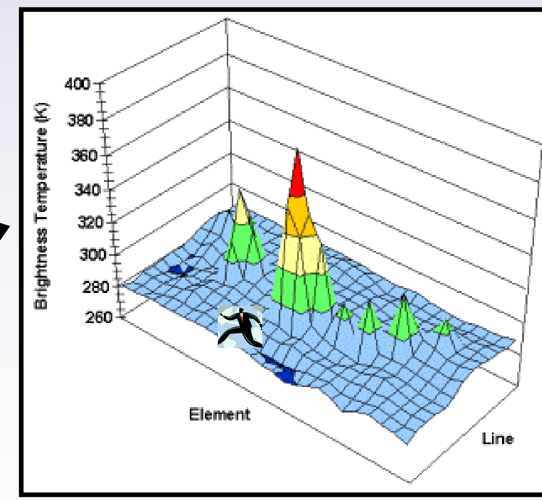






GOES-R Simulated 3.9 micron Data
Padua/Grand Prix Fires
Date: 27-Oct-03 Time: 09:50 UTC





Brightness Temperature (K)

260-280 | 280-300 | 300-320 | 320-340 | 340-360 | 360-380 | 380-400

Ongoing Activities and Future Plans

- Implement a Rapid Scan WF_ABBA for hazards applications, with products available within 5 minutes
- Develop and implement a consistent global geostationary fire monitoring network in association with IGOS GOFC/GOLD (GOES-E/-W/-9, MSG, FY-2C, MTSAT-1R, INSAT-3D, GOMS Electro N2)
- Participate in multi-sensor validation and intercomparison studies
- Regional to global aerosol/trace gas model data assimilation
- Fused fire products (MODIS, GOES → NPOESS VIIRS, ABI/HES)
- Continue trend analysis in Western Hemisphere and around the globe for applications in land-use/land-cover change, climate change, and socio-economic studies.
  (Reprocess the GOES-8 data base back to 1995.)
- Get ready for the next generation geostationary platform (ABI & HES). Improved fire identification and characterization, emissions

Global geostationary fire monitoring and model assimilation of fused geo/polar fire products will result in greatly improved assessments of global burning and effects on the environment.

Science Advance

Resources

- **Approved**
- Deficiency

Development/Implementation of GOES-R fire algorithm and other future geostationary fire monitoring capabilities around the globe

Enhanced fire monitoring in the Western Hemisphere and throughout the world.

Fusion of current and future polar/geo fire products

Maximize use of multiple data sources. Take advantage of strengths of each system to create improved fused fire products.

Operational global geostationary fire monitoring system

Transfer of global geo fire monitoring system to NESDIS OSDPD; ongoing support would ensure routine long-term stable global fire record for numerous applications.

Global geostationary fire monitoring system

Adapt the GOES WF_ABBA for application with MSG, GOES-9 and MTSAT-1R. Significant development effort due to differences in the instruments and respective fire monitoring capabilities.

Rapid Scan WF_ABBA

Develop and implement a rapid scan WF_ABBA for early detection and high temporal wildfire monitoring in North America with minimal false alarms (<5%). Incorporate into NESDIS OSDPD Hazards Mapping System (FY05).

Western Hemisphere Wildfire ABBA (WF_ABBA)

Implementation of half-hourly WF_ABBA throughout Western Hemisphere: Applications in hazards, global change, visibility/air quality monitoring (NASA-IDEA) . Near real time assimilation in aerosol/trace gas transport models (NRL-NAAPS, INPE/CPTEC RAMS). Validation efforts: Canada, U.S. and Brazil. Transfer to NESDIS OSDPD (2003).

South American ABBA

Implementation of first automated contextual geostationary diurnal fire detection system in South America. Applications in trend analysis, land-use/land-cover change, emissions monitoring, and carbon cycle studies.

1995 2001 2002 2003 2004 2005 2007 2008 2009 2010