

September 14, 2001

Dr. Jeffrey Reid
Atmospheric Propagation Branch Code D858
SPAWAR System Center San Diego
53560 Hull St.
San Diego, CA 92152-5001

Re: Contract No. N66001-00-C-0039

Dear Dr. Reid,

Attached is a copy of the annual report for contract No. N66001-00-C-0039. The following summary outlines the collaborative work performed by the Cooperative Institute for Meteorological Satellite Studies (CIMSS) and the NOAA/NESDIS/ORA Advanced Satellite Products Team (ASPT) in providing diurnal remote sensing of fires using geostationary satellites and the Wildfire Automated Biomass Burning Algorithm (WF_ABBA). The report includes an overview of activities performed during the past quarter as well as annual data processing statistics and preliminary fire statistics for the Western Hemisphere. If you need any additional information please contact me at (608) 263-6607 or by email at elaine.prins@ssec.wisc.edu

Best Regards,


Elaine Mae Prins

cc: John Roberts, UW-Madison SSEC Executive Administrative Director
Chris Schmidt, UW-Madison CIMSS

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Commanding Officer
Space and Naval Warfare Systems Center
Code D027
San Diego, CA 92152-5001



To: Dr. Jeffrey Reid

From: Ms. Elaine Prins (NOAA/NESDIS/ORA), Mr. Chris Schmidt (UW-Madison CIMSS)

Date: September 14, 2001

Regarding: Annual report for contract N66001-00-C-0039

The following annual report provides a summary of the work performed during the fourth quarter of contract **N66001-00-C-0039** and an overview of annual processing and preliminary fire statistics for the Western Hemisphere. We also present a tentative outline of future activities. Our efforts focused on:

- a.) real-time half-hourly implementation and dissemination of the GOES-8/-10 Wildfire Automated Biomass Burning Algorithm (WF_ABBA) product throughout the Western Hemisphere;
- b.) compilation of summary statistics for data access and product generation;
- c.) generation of annual composites of GOES-8/-10 WF_ABBA fire products for the Western Hemisphere;
- d.) preliminary analysis of annual GOES-8/-10 fire statistics;
- e.) case study analyses published on the web.

Summary:

Implementation and Internet Distribution of the GOES-8/-10 Wildfire ABBA Products

For the past 3 months UW-Madison Cooperative Institute for Meteorological Satellite Studies (CIMSS) has continued to apply the GOES Wildfire ABBA (WF_ABBA) to half-hourly GOES-8 and GOES-10 data throughout the Western Hemisphere, providing GOES-8 fire products for North and South America and GOES-10 fire products for the western half of North America and Hawaii. The fire products include ASCII text files and alpha-blended composite fire imagery. The ASCII text files contain information about the detected fires including location; observed 4 and 11 micron brightness temperatures; estimates of sub-pixel fire temperature and size; ecosystem classification; and fire flags. The alpha-blended composites consist of clouds taken from the GOES imagery, an ecosystem base-map that was derived from Advanced Very High Resolution Radiometer (AVHRR) data made available by the USGS at <http://edcdaac.usgs.gov/glcc/glcc.html>, and fire locations which are highlighted in the composite imagery. The GOES WF_ABBA fire products were typically made available via the Internet within 90 minutes of receipt of the GOES imagery. The GOES WF_ABBA ASCII text files were made available to our collaborators via anonymous FTP. The GOES WF_ABBA fire composite images were made available on the world wide web at <http://cimss.ssec.wisc.edu/goes/burn/wfabba.html>. The web site provides animations of half-hourly GOES-8/-10 composite fire products for the past 24 hours. This includes GOES-8 overview animations for North and South America and GOES-10 overviews for North America and 35 "zoomable" regional sectors.

In response to a request from the principal investigator, CIMSS also began providing 3-hourly summary WF_ABBA fire composites for the Western Hemisphere for display on the Fire Locating and Mapping of Burning Emissions (FLAMBE) web site.

Summary Data Acquisition and Processing Statistics

As part of this contract UW – Madison CIMSS is required to provide GOES WF_ABBA Western Hemisphere fire results every 3 hours. During the past quarter the WF_ABBA successfully processed approximately 99.5% of the available GOES-8 data for North America and 98.5% for South America. For GOES-10 the WF_ABBA had a success rate of 98.9% for the same period. The WF_ABBA achieved slightly lower results for the half-hourly fire processing primarily due to difficulties in obtaining necessary meteorological model output data from Washinton D.C. The breakdown was 97% for both the GOES-8 North and South America sectors and 95.4% for the GOES-10 North American sector. Tables 1-3 (contained in MS Excel file: fireproc_yr1_qtr4.xls) list the results of the WF_ABBA for May 29, 2001 through September 1, 2001. A percentage is provided reflecting the percentage of the image used in the WF_ABBA processing. The number will not be 100% all the time for a number of reasons, including missing lines due to bad data reception at the ground station and solar intrusions. The three-hourly full-disk scan is used as the basis for the statistics, so most scans that are not full-disk scans will appear to be slightly incomplete. The day-to-day trend indicates what the expected fraction should be for any given time period. A zero indicates that the data were not processed for that particular time period (satellite data or numerical model data may have been missing). “NA” means that the satellite data were unavailable due to the GOES eclipse and “keep-out” schedule (the GOES imager is turned off to avoid viewing the sun).

A summary of data processing success rate for the first year of this contract is presented in Table 4. The success rate for 3-hourly processing of available data was greater than 98% for all sectors. The success rate for half-hourly processing was similar.

Table 4. Annual summary of GOES-8/-10 WF_ABBA processing statistics

Sector	3-hourly	Half-hourly
GOES-8 North America	99.0 %	98.0 %
GOES-8 South America	98.7 %	97.8 %
GOES-10 North America	98.2 %	97.4 %

Annual Composites of GOES-8/-10 Wildfire ABBA Fire Products for the Western Hemisphere

Annual cumulative fire composites were created from all available half-hourly GOES-8/-10 WFABBA fire pixels identified in the Western Hemisphere from September 1, 2000 through August 31, 2001. The results are shown in Figures 1, 2, and 3. Figures 1 and 2 show the GOES-8 WF_ABBA annual composite for North and South America, respectively. Figure 3 displays the GOES-10 results for North America. Low possibility fire pixels are not included in the composites. The composites do not include an offset to account for multiple detects of the same

fire along a scan line due to oversampling of the GOES Imager in the East/West direction; the ASCII WF_ABBA fire product output files made available via ftp include this correction. In all three composites, a satellite image noise identification and removal algorithm was used to reduce the number of false alarms associated with linear series of noisy pixels in the 4 micron imagery. This algorithm cannot identify isolated noise, which is still evident in the imagery in all fire categories. Suspect clusters of fire pixels are evident in all 3 summary composites. These summary composites provide valuable information on the distribution of fires throughout the Western Hemisphere, identify problem regions, and offer insight into possible modifications to improve the WF-ABBA and minimize false alarms.

The GOES-8 annual fire composite for North and Central America (Figure 1) shows a number of regions with enhanced fire activity. In Canada clusters of fire pixels are evident in Saskatchewan and Manitoba (location a) associated with burning in both cropland and forested regions. Fires are also evident in North Dakota. In the western U.S. (location b) fire pixels are distributed throughout Idaho, Washington and Oregon. This composite does not include the conflagrations that burned in this region in August of 2000, although many fires continued burning into September and are represented in this summary. Clusters of fire pixels are observed in the Great Plains states of Kansas and Oklahoma (location c). The majority of this fire activity occurred in the spring of 2001. Many of the fire pixels located in the Mississippi Delta region (location d) were also evident in the semi-annual composite which was included in the semi-annual report and covered the time period from September 1, 2000 through February 28, 2001. These fires are primarily associated with agricultural practices in the fall and spring. Many of the fires in the southeastern U.S. (location e) were also identified in the semi-annual composite and are located in both cropland and forested areas. The large cluster of fires in southern Florida is somewhat suspect (location f), but smoke plumes were observed in this region on a number of occasions. Fire activity in Cuba (location g) was evident in the semi-annual composite, but the number and extent of fire pixels is much greater in the annual composite and may be associated with increased burning prior to spring planting. The greatest concentration of fire pixels occurs in the Yucatan Peninsula, Guatemala, Belize, Honduras, El Salvador, Nicaragua, and Costa Rica (location j) associated with agricultural activities and deforestation in the late winter and spring. There is also considerable fire activity along the western coast of Mexico (locations h and i). Many of the fire pixels identified along the Gulf of California (location h) are false alarms associated with solar contamination and elevated surface temperatures during the hot summer months.

The GOES-8 annual fire composite for South America (Figure 2) appears similar to the semi-annual composite and reflects the extensive use of fire in deforestation and agricultural management practices in the Southern Hemisphere. Most of burning in Brazil, Bolivia, Paraguay, and Northern Argentina occurs in the months of August through October. In northern Brazil, Venezuela, Colombia, and Guyana, peak fire activity occurs in the austral spring/summer. Much of this activity was documented in the semi-annual composite. The fires in the northwestern portion of South America in the countries of Venezuela and Colombia (location a) are predominantly located in cattle ranching regions, although other crops are grown here as well. Some of this fire activity is also located in forested regions. Numerous fire pixels were also detected in the Guiana Highlands region of Venezuela, Guyana, and Northern Brazil (location b). Thousands of fire pixels were located along the arc of deforestation in Brazil

(locations c, d, e, and f). The burning pattern is similar to what has been documented by the South American GOES-8 ABBA (Prins et al., 1998, 2000). The majority of these fires are associated with agricultural applications and deforestation activities. The composite shows distinct burning patterns along rivers and in areas with recent road construction (linear features) as observed at locations c, e, and f. The fires observed at location f represent a new region of expanding deforestation in western Amazonia associated with a new road being constructed over the Andes to link Brazil with Peruvian ports on the Pacific Coast. Fire pixels in the eastern Brazilian states of Maranhao, Tocantins, Goias, Piaui, Bahia, and Minas Gerais (location h) primarily reflect burning in previously deforested regions and grasslands. This is also true for the fire activity identified in Mato Grosso (location d). Burning in central Bolivia (location g) is primarily associated with ongoing agricultural management and grassland fires. The cluster of saturated fire pixels in south-central Argentina (location i) represents extensive fires that burned throughout December and January along the grassland/desert boundary. They produced large smoke palls that extended to the Atlantic Ocean. These fires were also observed in NOAA AVHRR imagery and were documented on the NOAA Operational Significant Events Imagery web site.

Figure 3 is the GOES-10 annual summary for the western portion of North America and Hawaii. The low saturation temperature in the 3.9 micron band on GOES-10 results in numerous false alarms and hinders the ability to separate hot or highly reflective non-fire surface features from actual fire activity. This is especially evident along the Gulf of California (location d). It may be necessary to limit GOES-10 fire processing to certain periods of the day to avoid solar contamination in the 3.9 micron band and to avoid ecosystem types that become hot enough to saturate the instrument. Locations a and b show fire activity in Canada, Idaho, Washington and Oregon. Much of this was also recorded in the GOES-8 product. Fire activity in Kansas and Oklahoma (location c) and the western coast of Mexico (location e) was also identified in the GOES-8 annual composite. The GOES-10 WF_ABBA also documented numerous agricultural fires in Hawaii (location f) and hot spots associated with volcanic activity.

Preliminary Analysis of Annual GOES-8/-10 Fire Statistics

In order to obtain a more quantitative summary of the distribution of fire activity throughout the Western Hemisphere, the number of fire pixels in each fire category was determined from the annual GOES-8 WF-ABBA composites for North, Central and South America. Although some fire pixels (4 km resolution at the sub-satellite point) reported multiple fire occurrences throughout the year, only one occurrence was reported for each. In some cases navigation error may result in multiple reports of the same fire in adjacent pixels. Furthermore, oversampling by the GOES Imager in the East/West direction may result in multiple detects of the same fire along a scan line. Tables 5, 6, and 7 provide summaries for North, Central, and South America, respectively. The North America summary includes all fires contained in the region from 30 to 70°N. Central America and Mexico represents the region from 10 to 30°N and South America includes fire activity in the region from 10°N to 70°S. The totals for all fire pixel categories show that over 1 million fire pixels were identified during the past year. 60% of all fire pixels detected in the Western Hemisphere were located in South America, while 27% were identified in North America, and 13% in Mexico and Central America. These percentages provide a summary overview of all burning in the Western Hemisphere, but do not represent a

Table 5. GOES-8 WFABBA Fire Pixel Summary for North America*

Fire Pixel Category	Number of Fire Pixels	Percent of Regional Total	Percent of Western Hemisphere Total
Processed	31590	11.8	3.2
Saturated	4709	1.8	.5
Cloudy	14815	5.5	1.5
High Possibility	48824	18.2	4.9
Medium Possibility	11822	4.4	1.2
Low Possibility	156928	58.4	15.7
Total:	268688		27%

Table 6. GOES-8 WFABBA Fire Pixel Summary for Central America and Mexico*

Fire Pixel Category	Number of Fire Pixels	Percent of Regional Total	Percent of Western Hemisphere Total
Processed	57950	43.6	5.8
Saturated	5025	3.8	.5
Cloudy	6625	5.0	.7
High Possibility	12156	9.1	1.2
Medium Possibility	3552	2.7	.4
Low Possibility	47629	35.8	4.8
Total:	132937		13%

Table 7. GOES-8 WFABBA Fire Pixel Summary for South America*

Fire Pixel Category	Number of Fire Pixels	Percent of Regional Total	Percent of Western Hemisphere Total
Processed	256912	42.9	25.7
Saturated	52979	8.8	5.3
Cloudy	33602	5.6	3.4
High Possibility	60333	10.1	6.0
Medium Possibility	18657	3.1	1.9
Low Possibility	176485	29.5	17.6
Total:	598968		60%

* Note: These values include false alarms and do not include an offset to account for multiple detects along a scan line due to oversampling of the GOES in the East/West direction.

complete picture. When considering only the processed, saturated, cloudy, and high possibility fires, the total number of detected fire pixels is approximately 600,000 and the percentage of fire pixels detected in North America is 17%, Mexico and Central America is 14%, and South America is 69%. Nearly 60% of the fire pixels detected in North America are in the low

possibility category; only 13.6% are in the processed and saturated categories representing only 36,000 fire pixels. In Central America/Mexico and South America approximately half of the detected fire pixels are in the processed and saturated categories representing approximately 63,000 and 310,000 fire pixels, respectively. Only 30-35% of the fire pixels in this region are in the low possibility category. The largest number of saturated pixels are located in South America reflecting the high temperature intense fires in this region and the proximity to the sub-satellite point.

Figure 4 shows the latitudinal distribution of GOES-8 WF_ABBA detected fire pixels in the Western Hemisphere for each fire category. It also clearly shows that the possible fires, especially the low possibility fires, mask the true signature of fire activity in North America and should be screened with some additional filtering techniques. A post-processing filtering algorithm is currently being designed to better eliminate false alarms. This preliminary analysis of annual GOES-8 WF-ABBA statistics provides valuable insight into the biases and problematic regions for fire detection and will be used in modifying the WF_ABBA and designing the post-processing filtering algorithm.

Case Study Analyses

During the first year of this contract UW-Madison CIMSS published 9 case studies on the web (<http://cimss.ssec.wisc.edu/goes/burn/interesting.html>) highlighting current examples of GOES in real-time fire detection and aerosol/pollutant transport monitoring in various ecosystems in North and South America. A few examples are listed below.

GOES WF_ABBA fire observations were compared with Terra satellite Measurements Of Pollution In The Troposphere (MOPITT) carbon monoxide (CO) distributions provided by the MOPITT science team for two case studies in the Western Hemisphere. Figure 5 shows a comparison of GOES fire products and Terra MOPITT CO products in the western U.S. GOES Wildfire ABBA observations of the Idaho and Montana wildfires (August 22-27, 2000) were compared to a composite MOPITT CO image for the same time period (http://cimss.ssec.wisc.edu/goes/misc/000822_2/000822_2.html). During the entire week smoke plumes observed in the GOES visible imagery and 700 and 500 mb streamline analyses document the transport of emissions to the region of enhanced CO.

A case study of the Viejas fire in San Diego was published on-line and was discussed in a sidebar titled "GOES Burns Bright" which appeared in the July issue of the Geospatial Solutions magazine. The sidebar described the history and current applications of the GOES Wildfire ABBA and focused on the successful identification of the San Diego Viejas fire (January 3, 2001) by the GOES-10 Wildfire ABBA within minutes of ignition. The sidebar was included as part of an extended article titled "Blazing Ahead: Mobile GIS for Emergency Management" discussing the use of Geographic Information Systems (GIS) to combat the Viejas fire.

A case study of GOES WF_ABBA observations of the rapid intensification of the Thirty Mile Fire on July 11, 2001 in the state of Washington that resulted in the deaths of 4 firefighters, was featured in "The Why Files." The "Why Files" is an on-line publication (<http://whyfiles.org/>)

that focuses on the science behind the news and is a resource for teachers and students and covers issues of science, health, environment and technology. This publication uses current events as a springboard to explore science in a way that students can relate to.

Future Plans

We will continue to process fires on a half-hourly basis for the study region and expect the success rates to remain high. In an effort to further reduce the amount of false fires associated with satellite noise and current algorithm limitations, the preliminary annual fire statistics presented in this report will be used to modify the Wildfire ABBA and finalize a post-processing algorithm. This post-processing algorithm will be implemented in real time and will also be applied to all GOES-8/GOES-10 WF_ABBA fire products produced since August 2000. Once this is completed, additional summary statistics will be generated from GOES WF_ABBA output to characterize the spatial and temporal distribution of fires in various biomes. CIMSS will collaborate with SPAWAR, NRL, and the University of Alabama at Huntsville on assimilation of satellite fire products into the NAAPS and subsequent analyses.

The launch of the European Meteosat Second Generation (MSG) satellite has been delayed until some time in 2002. Diurnal geostationary satellite monitoring of fire activity in Europe and Africa will not be possible in the immediate future. Once the MSG is launched and post-launch check-out is completed, CIMSS will adapt the WF_ABBA for application with MSG data.

Wildfire ABBA User

Internet Community

National Weather Service-Florida: Fire weather forecasting

National Weather Service-Storm Prediction Center, Oklahoma: Fire weather forecasting

Smithsonian/National Zoo Amazonia Science Gallery

NESDIS Satellite Services Division: National Hazards Information Strategy user community

Publications and Conferences

Prins, E., J. Schmetz, L. Flynn, D. Hillger, J. Feltz, 2001: Overview of current and future diurnal active fire monitoring using a suite of international geostationary satellites, In *Global and Regional Wildfire Monitoring: Current Status and Future Plans*, SPB Academic Publishing, The Hague, Netherlands, pp. 145-170.

Prins, E., J. Feltz, C. Schmidt, K. Goodstein, 2001: Plans for a global geostationary fire monitoring network, Presented at the CEOS Global Observation of Forest Cover Regional Fire Workshop, NASDA, Tokyo, Japan, February 20-21, 2001.

Prins, E. and C. Schmidt, 2001: GOES burns bright, *Geospatial Solutions*, July 2001, pp. 35.

Prins, E., J. Feltz, and C. Schmidt, 2001: An overview of active fire detection and monitoring using meteorological satellites, Submitted to Proceedings of the 11th Conference on Satellite Meteorology and Oceanography, Madison, WI, October 15-18, 2001, pp TBD.

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the Space and Naval Warfare Systems Center, San Diego, CA.

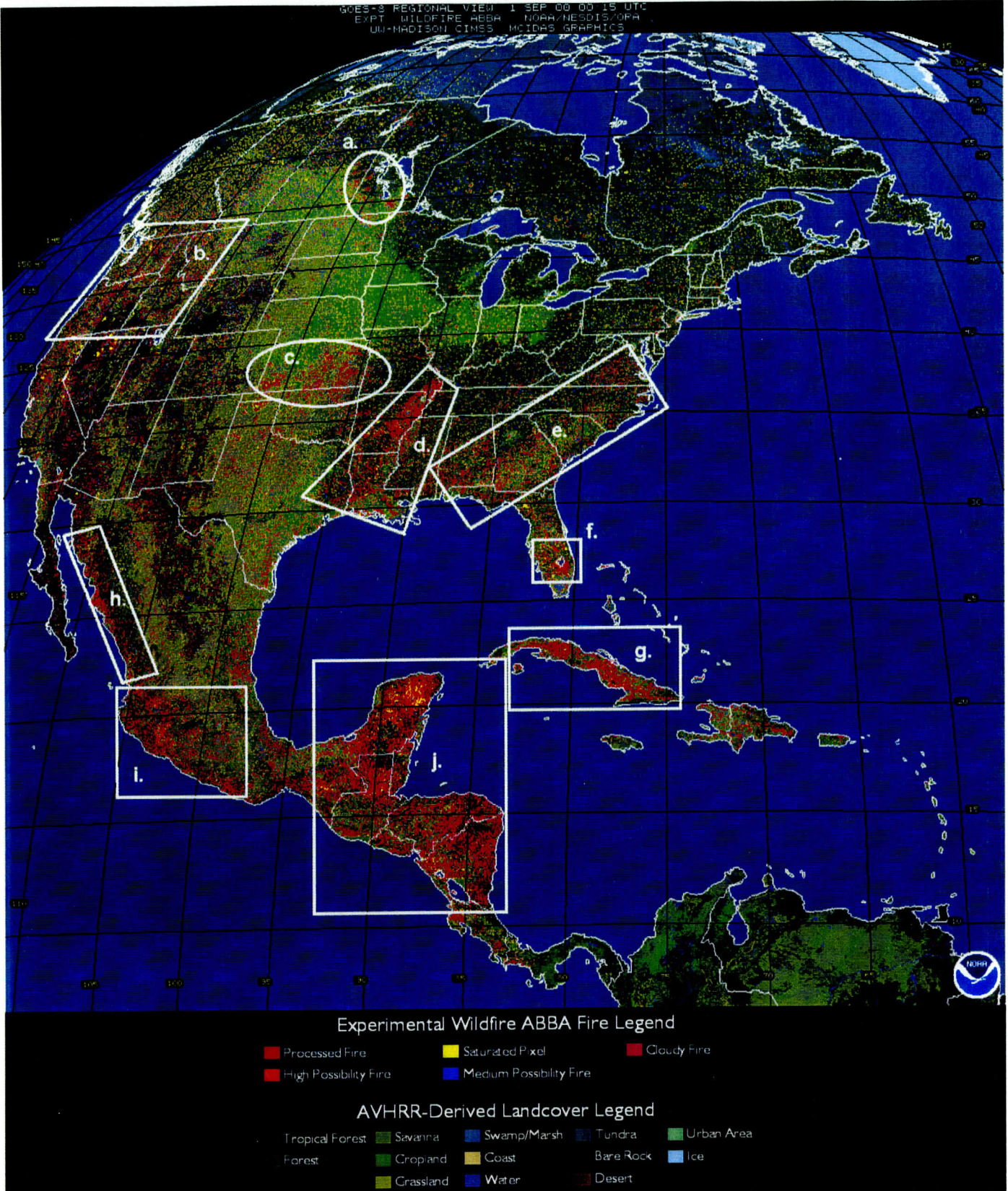


Figure 1. GOES-8 WF_ABBA fire pixel composite for North and Central America for the time period September 1, 2000 through August 31, 2001. All processed half-hourly data, including false fires due to isolated noise, are represented in this image.

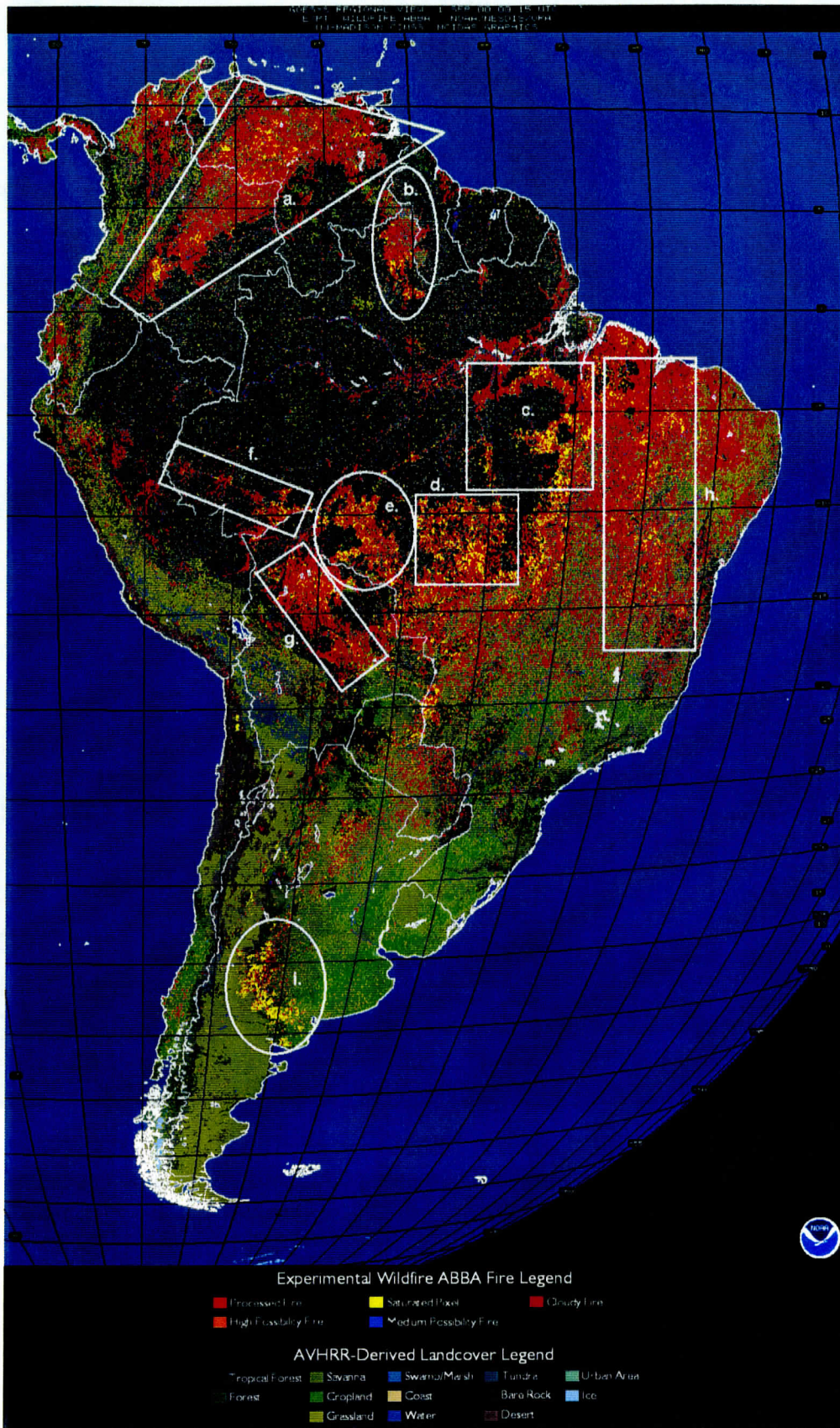


Figure 2. GOES-8 WF_ABBA fire pixel composite for South America for the time period September 1, 2000 through August 31, 2001. All processed half-hourly data, including false fires due to isolated noise, are represented in this image.

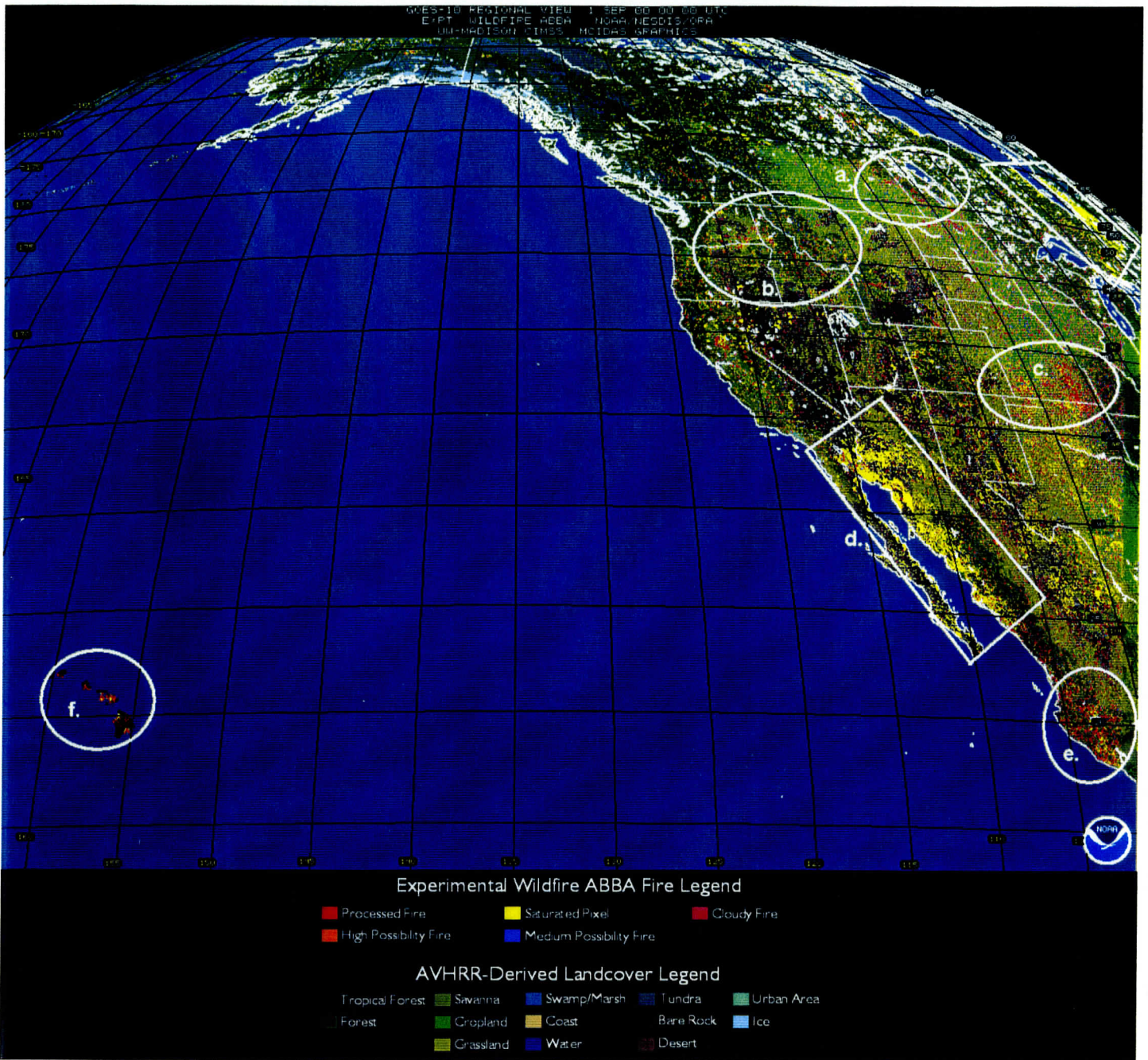


Figure 3. GOES-10 WF_ABBA fire pixel composite for the Western U.S. and Canada for the time period September 1, 2000 through August 31, 2001. All processed half-hourly data, including false fires due to isolated noise, are represented in this image.

**Preliminary Overview of the Geographical Distribution of
GOES-8 WFABBA Detected Fire Pixels for the Western Hemisphere
September 1, 2000 - August 31, 2001**

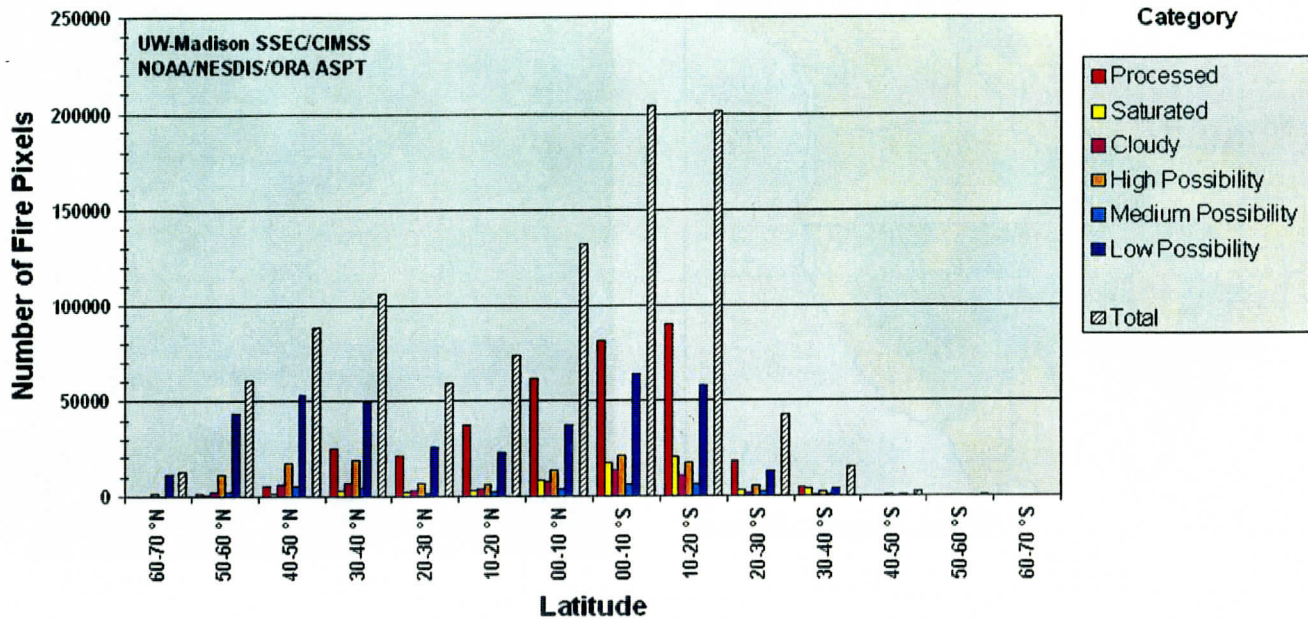
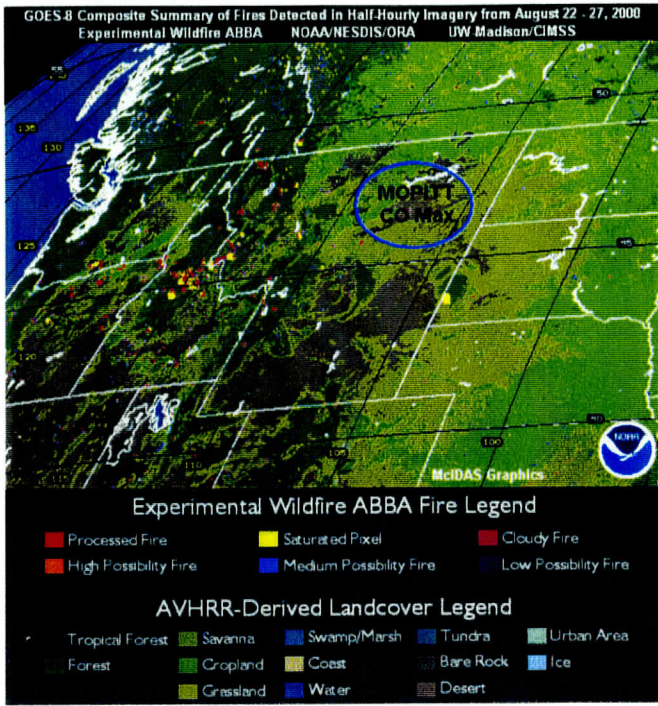


Figure 4. Latitudinal distribution of GOES-8 WF_ABBA detected fire pixels in the Western Hemisphere for each fire category. The greatest number of fire pixels are located from 10°N to 20°S. In this region most of the fire pixels are processed fire pixels. North of 20°N, most of the detected fire pixels are in the low possibility category.



MOPITT Carbon Monoxide Total Column Retrieval
 Average for Aug 22-27, 2000

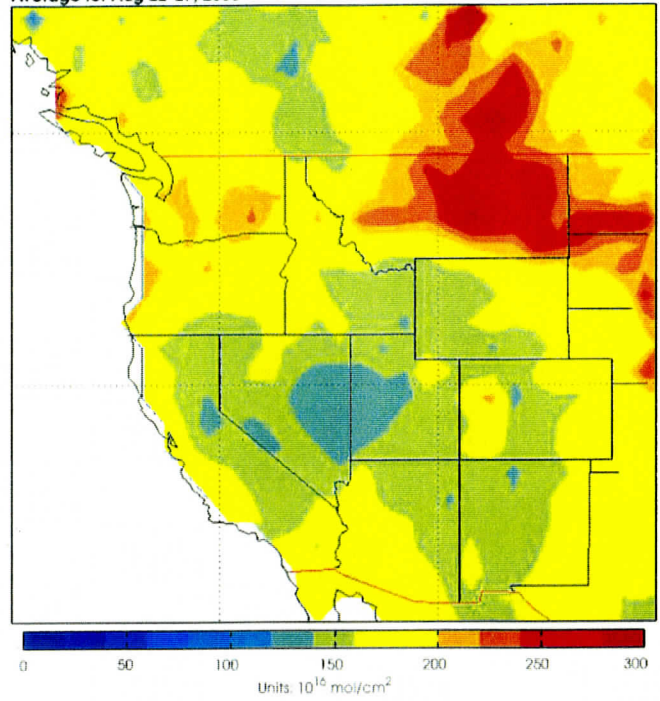
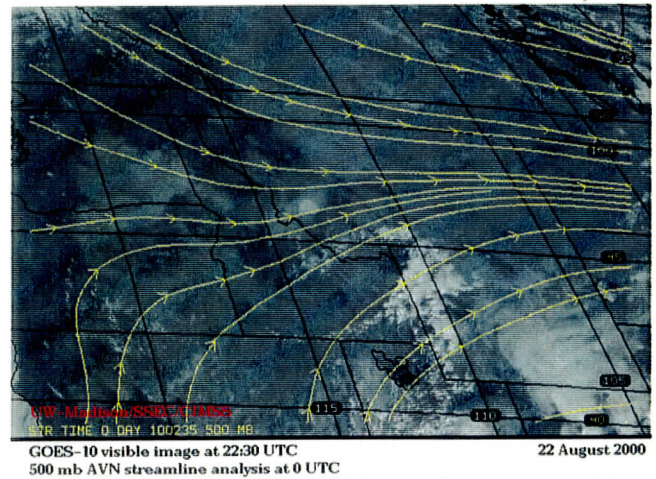


Figure 5. GOES Wildfire ABBA observations of the Idaho and Montana wildfires (August 22-27, 2000) were compared to a composite MOPITT CO image for the same time period. During the entire week smoke plumes observed in the GOES visible imagery and 700 and 500 mb streamline analyses document the transport of emissions to the region of enhanced CO.

The MOPITT carbon monoxide composite is provided courtesy of the MOPITT team: John Gille (NCAR), James Drummond (University of Toronto), and David Edwards (NCAR).



GOES-8 North America

Time (UTC)

Table with 48 columns (Day of Year 01 to 366) and 100 rows (01 to 100). The table contains a grid of data points, likely representing satellite observations or time-series data for North America.

Table 1

