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RECENT VALIDATION STUDIES OF THE GOES WILDFIRE AUTOMATED BIOMASS BURNING ALGORITHM (WF_ABBA) IN NORTH AND SOUTH AMERICA

Joleen M. Feltz*
Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin, Madison, Wisconsin

Michel Moreau
Environment Canada/Meteorological Services/Quebec Region, Quebec, Canada

Elaine M. Prins
NOAA/NESDIS/ORA Advanced Satellite Products Team, Madison, Wisconsin

Kirsten McClaid-Cook
State University of New York, Albany, New York

Irving F. Brown
Woods Hole Research Center-WHRC, Federal University of Acre-UFAC, Federal University Fluminense-UFF

1. INTRODUCTION

One of the goals of the Global Observation of Forest Cover (GOFC) initiative within the Committee on Earth Observation Systems (CEOS) is to make better use of satellite data in monitoring the conditions of the global forests. Operational satellite products provide long-term stable records that offer a historical record useful in land-use/land-cover change research as well as global change research. Several automated algorithms now provide satellite derived active fire products in near real time for hazards applications and climate change research. Active fires are input into aerosol models to aid air quality predictions and are helpful in early detection of fires in remote regions. These products remain underutilized due in part to the lack of information regarding product validity.

In this paper results are presented from several validation case studies for the Geostationary Operational Environmental Satellite (GOES) Wildfire Automated Biomass Burning Algorithm (WF_ABBA) fire product in North and South America. In North America the WF_ABBA has successfully identified and monitored wildfires throughout the U.S. and Canada. During the 2002 fire season in North America the GOES WF_ABBA detected many conflagrations in the Western U.S. Validation studies in Quebec, Canada have shown that the GOES WF_ABBA was the first to detect a number of fires in remote regions at northerly latitudes with satellite viewing angles in excess of 60°. Some fires were as small as 2 to 3 hectares in size. In the state of Acre, Brazil ground truth studies performed during the 2002 fire season provided new insights regarding the capability of the GOES WF_ABBA for monitoring fires associated with deforestation and agricultural management.

2. THE WILDFIRE AUTOMATED BIOMASS BURNING ALGORITHM PRODUCT

The Wildfire Automated Biomass Burning Algorithm (WF_ABBA) is a modified version of the Automated Biomass Burning Algorithm (ABBA) that has been used to monitor fire activity in South America since 1995. The WF_ABBA was developed as a cooperative effort between NOAA/NESDIS/ORA and UW-Madison CIMSS. The WF_ABBA has operational continental coverage of the Americas and runs throughout the year on a half-hourly basis. This is a tremendous improvement over the diurnal monitoring capabilities of the ABBA, which provided fire observations for South America on a three-hourly basis from June-October. The WF_ABBA is a contextual treshholding algorithm which uses the visible (when available), 3.9 µm and the 10.7 µm bands to statistically locate and characterize hot spot pixels related to fires in the GOES imagery. The algorithm is based on the Matson and Dozier technique (1981) used for the Advanced Very High Resolution Radiometer (AVHRR), which takes advantage of the 3.9 µm sensitivity to high temperature sub-pixel anomalies.

Once initial hot spots are located, the data must be screened for false alarms and the values are corrected for water vapor attenuation, surface emissivity, solar reflectivity and semi-transparent clouds. Fire pixels are then subjected to a temporal filter to further eliminate false alarms. The filtered WF_ABBA results only retain fire pixels that have been observed at least one other time in the last 12

* *Corresponding author address:* Joleen M. Feltz, University of Wisconsin-Madison, Cooperative Institute for Meteorological Satellite Studies, 1225 W. Dayton, Madison, WI 53706; email: joleen.feltz@ssec.wisc.edu.

hours. This temporal filtering can eliminate valid fire pixels, so the WF_ABBA results obtained prior to the time filtering are also provided every half-hour. Prins and Menzel (1992, 1994) and Prins et al. (1998 a; b, 2001; 2003) provide more information regarding the algorithm and determination of subpixel fire characteristics.

3. CASE STUDY VALIDATION OF THE WF_ABBA IN NORTH AND SOUTH AMERICA

Diurnal remote monitoring of fires for different applications, over a full year, makes designing a common algorithm that spans North, Central and South America challenging. The algorithm must be robust enough to enable fire identification and monitoring under different satellite viewing conditions and variable solar contributions in a variety of topographical regions and biomes. One strength of the WF_ABBA in South America is that much of the observing area is close to the sub-satellite point. This means fire size along with latitude and longitude are easier to determine. As the view angle increases, smaller fires are more difficult to identify and the determination of latitude and longitude is less accurate. In addition to view angle considerations, diurnal heating and variable ecosystem types result in subtle differences between fire and non-fire pixels, which complicates the process of distinguishing between fire pixels and background. Topographic features present unique challenges. In some areas sun glint off rivers and lakes must be screened, and depending on the viewing angle, it can be difficult to observe small fires in mountainous regions. In South America, subpixel cumulus in the west can skew the statistical calculation of the background and make fire detection more difficult. Early detection is critical for fire containment of the many lightning induced wildfires in Canada. In many cases, early stage detection of a lightning induced fire must be done through non-opaque clouds or in a break in the cloud coverage. Since regional challenges are present when monitoring fires throughout the Western Hemisphere, it is essential to validate the algorithm in many regions.

Three validation case studies are presented for the 2002 fire season representing fire monitoring in very different regions in North America and the Amazon Basin. Multi-year drought conditions made most of North America very dry in 2002 and provided ample opportunity to test the capabilities of the GOES-8 WF_ABBA in the Western U.S. and Canada. The WF_ABBA documented the diurnal characteristics of many fires in the Western United States during the 2002 fire season and was the first to identify some of the lightening induced fires in Quebec, Canada. In addition a team of scientists in Brazil provided ground truth verification for fires in the state of Acre.

3.1 *Quebec, Canada*

The Societe de protection des forets contre le feu (SOPFEU) reported 111 fires that burned more than 10 hectares from June 18 through July 20, 2002 for the Quebec region. The unfiltered analysis of the WF_ABBA detected 91 of the 111 reported fires. Over the entire period, the WF_ABBA unfiltered analysis recorded close to 11000 hot spot detections. Of these detects, 78% are confirmed fires, and 20% are false detects. The remainder of the data is listed as possible because both the statistics and imagery are characteristic of a fire pixel, but confirmation is difficult. The filtered statistics improve the overall ratio of confirmed to false detections; however, many positive fire detections are eliminated. After filtering, the WF_ABBA reported slightly more than 8000 hot pixels. The filtering reduced the number of false detections to 3% and increased the positive detections to 96% of the total observed pixels.

Figure 1 summarizes the fire season as observed by WF_ABBA in Quebec, Canada from 20 June through 31 August 2002. Fires reported by SOPFEU are plotted in overlay as black squares. It is apparent in figure 1 that many of the false detects are identified as lower probability fire pixels. Figure 1 also shows the GOES-8 WF_ABBA detects most fires reported by SOPFEU and possibly reported many more fires never reported by the fire agency while burning. In one case, the WF_ABBA detected a fire (fire 501) 17 days in advance of the first fire agency report. This fire eventually burned more than 55000 hectares. It must be noted that fire 501 is in a remote region of northern Quebec where there is no need for systematic daily detection by SOPFEU. Automated algorithms can be very useful in these circumstances for initial detection of fires in remote regions where it is impractical and unnecessary to allocate human resources for routine monitoring

Table 1 lists the number of fires observed for each fire flag and the final analysis of positive fire identification, possible and false detects for the filtered fire analysis. The unfiltered file totals are listed in parenthesis. In the filtered case, when the WF_ABBA flagged a pixel as a fire pixel, a saturated pixel, cloud covered, or a high possibility fire pixel, at least 97% of the detects are accurate. The largest error is in the medium to low possibility fire flags. Similar results are obtained with the unfiltered dataset. Positive fire detects are greater than 95% for the processed, saturated and cloud-covered pixels. The unfiltered data high possibility results are still reasonable with 80% of the detects being positive fire detects. For the unfiltered data, the largest error is in the two lowest categories of fire flags. Table 1 also shows that the filtering process removes many valid fire detects; 628 valid fires are observed in the unfiltered data which were removed during the filtering process.

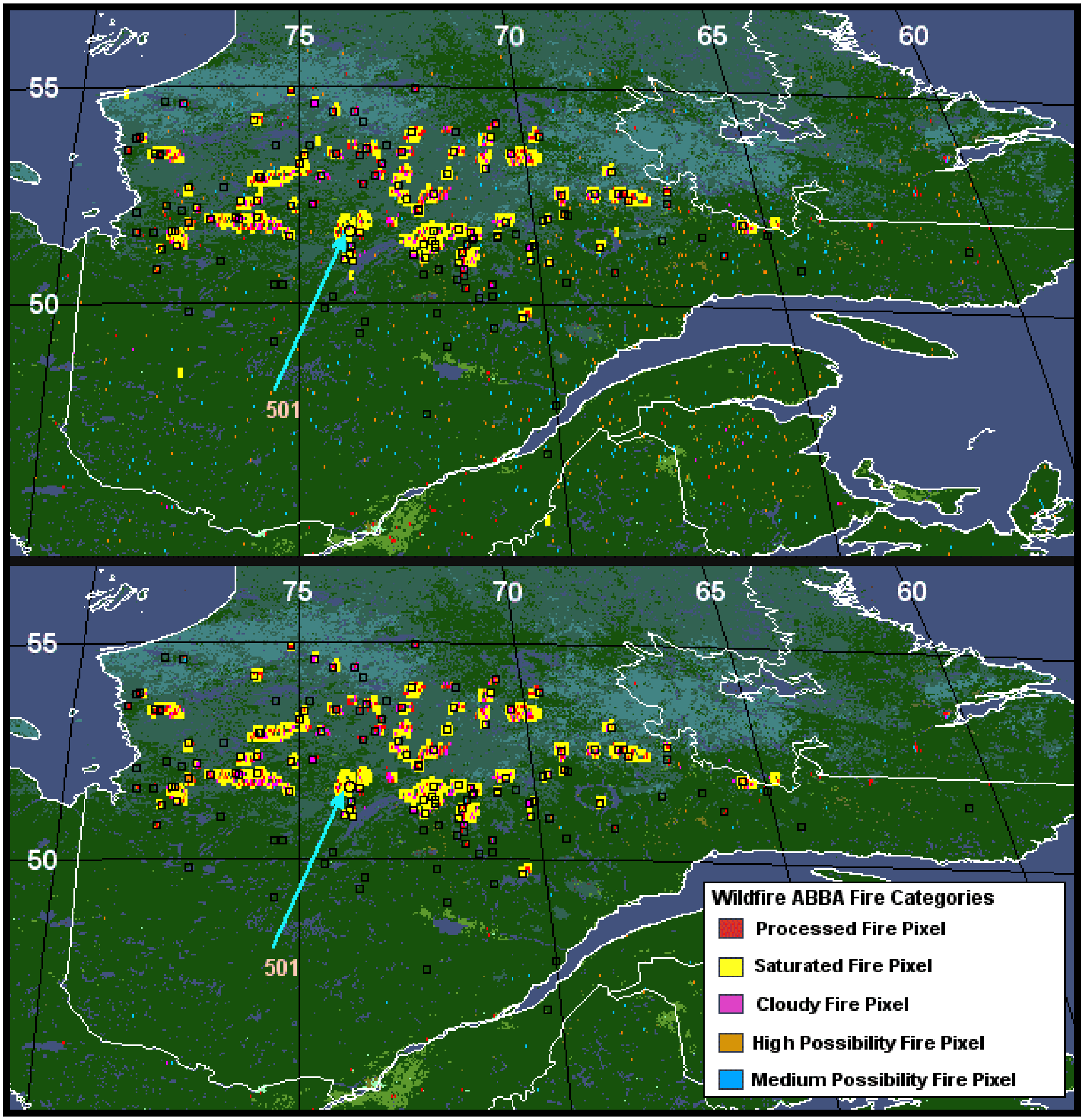

Figure 1. GOES-8 Wildfire ABBA composite of all half-hourly detected fire pixels for the time period of 20 June through 31 August 2002. Both the unfiltered (top) and filtered (bottom) analyses are shown. SOPFEU identified fires are indicated by black squares. Fire 501 was detected 17 days in advance by the WF_ABBA. **NOTE:** Fire 501 is in an area where there is no organized fire detection insured by SOPFEU.

	POSITIVE FIRE DETECITONS	POSSIBLE FIRE DETECTIONS	FALSE DETECTIONS
Processed Fire Pixels	2775 (3030)	20 (20)	52 (133)
Saturated Fire Pixels	1979 (2001)	0 (0)	0 (6)
Cloudy Fire Pixels	1978 (2120)	2 (3)	3 (11)
High Probability Fire Pixels	598 (689)	1 (1)	5 (170)
Medium Probability Fire Pixels	61 (88)	9 (12)	18 (197)
Low Probability Fire Pixels	448 (539)	75 (113)	168 (1660)

Table 1. Number of filtered (unfiltered) WF_ABBA detected fire pixels listed by fire flag and manually analyzed to determine if the fire detection was a positive or false fire detection. In some cases, absolute determination of positive or false detection was difficult. These cases are listed as "possible fire detections."

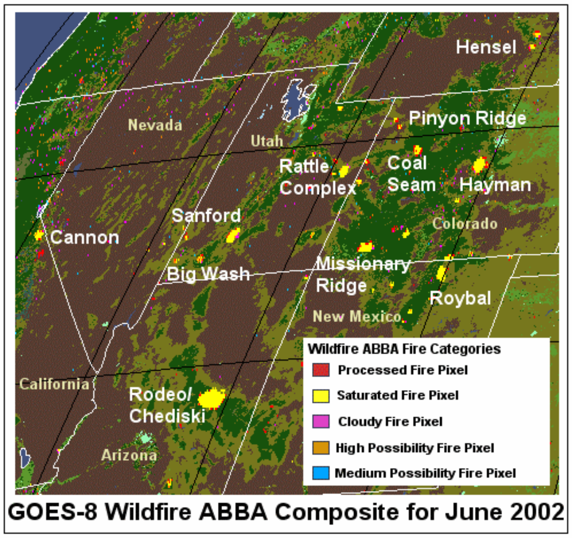

Figure 2. GOES-8 WF_ABBA Observations in the Western United States in June 2002.

3.2 *Western United States*

Multi-year drought conditions made the summer of 2002 one of the most active fire seasons on record in the Western United States. While the National Interagency Coordination Center 2002 fire statistics and summary lists the number of fires in the United States to be around 73,467, less than the 5 and 10 year average, the area burned was officially 6,937,584 acres, much larger than the 10 year average (National Interagency Fire Center statistics for the 2002 fire season (http://www.nifc.gov/fireinfo/2002/index.html).

The WF_ABBA was effective in documenting the large wildfires in the western United States during the summer of 2002 in spite of the fact that fire detection there can be problematic. The western United States is at a satellite view angle between 50-70 degrees, thus smaller fires are more difficult to distinguish. At these view angles, mountainous topography also acts to hide the fire signal. Complicating this problem, diurnal heating of the barren desert and rocky landscape of the west creates large regions that radiate close to the 3.9 micron saturation temperature of the satellite. This diminishes the ability of the algorithm to distinguish between the background and a fire.

Most large fires during June occurred in Arizona (Rodeo/Chediski Complex), Colorado (Hayman, Coal Seam and Missionary Ridge), and New Mexico (Roybal Complex). Many of these fires were observed with the WF_ABBA near the reported start times. The Rodeo/Chediski fire complex formed when the Rodeo fire merged with the Chediski fire on June 23, 2002. Both fires started earlier in the month with the Rodeo fire starting on June 18th while the Chediski fire was first reported on June 20th, 2002. The fire complex burned more than 467,000 acres before it was contained (Wilmes et al. 2002). The Hayman fire was the largest in Colorado's history at 137,760 acres and cost millions to contain (http://www.fs.fed.us/r2/psicc/hayres/index.htm). Starting on June 9th, the Missionary Ridge fire cost $40,600,000 to contain and burned 70,485 acres (http://www.fs.fed.us/r2/sanjuan/bulletin_board/MR.htm). The Coal Seam fire began on June 8th and was 90% contained by June 23rd; it had consumed more than 12,000 acres. North of Pecos, New Mexico, the Roybal Complex was a combination of the Roybal and Trampas fires, which burned over 5,000 acres (http://www.fs.fed.us/r3/news/nfp/2002/020621_RoybalFireUpdate_NM.html).

Figure 2 shows the GOES-8 WF_ABBA half-hourly composite during June of 2002. There are few false alarms and the composite clearly identifies the major fires. Most of the fires burning that month saturated the GOES-8 sensor indicating the intensity of these wildfires. These fires had strong diurnal signatures and some produced both large smoke palls as well as pyro-cumulus. The GOES Gallery at CIMSS provides excellent examples of the wildfires in Colorado and Arizona at the following URL (http://cimss.ssec.wisc.edu/goes/misc/020609/020609.html).

3.3 The State of Acre, South America

Biomass burning is heavily utilized throughout Brazil as one of the primary tools used to clear the land for development, farming, and pasture maintenance. Fire is also used for pest control and to restore nutrients to the soil. Land-use/land-cover change research activities are focused on cataloguing current trends in biomass burning as well as predicting future activity and implications for climate change. In order to do this, accurate consistent fire data is needed on a basin-wide level. To date, many fire activity records are based on in-situ and remote level observation during field campaigns, extrapolation from burn scars, and government records. Satellite technology could provide a practical, objective and cost efficient means of determining trends, if the strengths of the dataset can be parameterized.

The region of Acre, Brazil is the new frontier in Western Brazil where land-use and land-cover change has accelerated in recent years along a new road being built across the Andes from Brazil to Peru. Fire is used in deforestation and agricultural management. The burning patterns in Acre are clearly present in a composite image of GOES-8 WF_ABBA detected fires from 1 June through 31 October 2002 (Figure 3). The linear features represent burning along roadways. More intense burning is also evident along the border between Brazil and Bolivia.

In an effort to determine the capability of satellites to detect fire activity in this area, a validation effort was conducted near the city of Rio Branco in Acre, Brazil during the months of August through October 2002. Data was collected from 88 fires in the region. A recent study found that 58 of the 88 fires were identified by the GOES-8 unfiltered WF_ABBA detection scheme within +/- 6 hours for active fires and +/- 24 hours for fire scars. In addition, the missing fire detections could be partially explained by cloud coverage (McClaid-Cook et al. 2003). The filtered files were also used in this study. In the case of the filtered data, a window of +/- one day was used for both the active fires and the burn scars. Typically, the filtering process in South America has less of an impact than in North America. The result was that 76 of the 88 fires were matched with a WF_ABBA filtered fire pixel observation. This highlights the importance of the diurnal monitoring in South America.

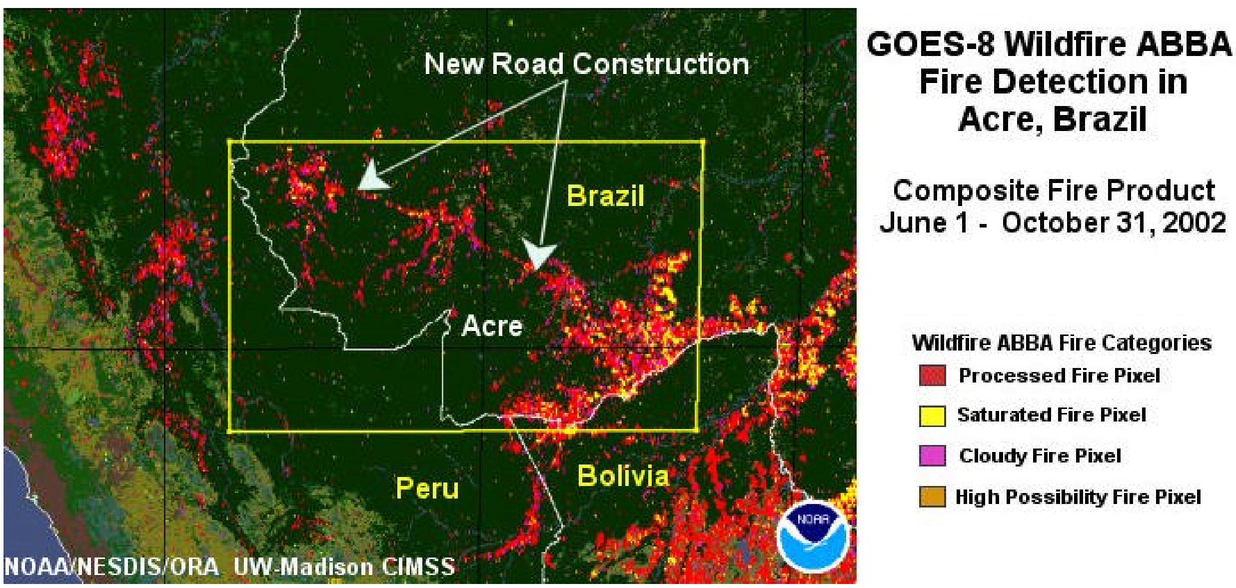

Figure 3. GOES-8 Wildfire ABBA fire detection in Southwestern Brazil from 1 June to 31 October 2002.

4. CONCLUSIONS

Biomass burning has a tremendous impact on the environment. Large lightning induced fires in Canada or human induced fires such as the Rodeo/Chediski and the Hayman cost millions to contain while destroying vast expanses of forest. In many countries, biomass burning is used as a tool for conversion of forest to pasture and agricultural land as well as a means to controls pests and fertilize the soil. Fires also contribute trace gases and aerosols to the atmosphere (Crutzen et al, 1985; Andreae et al., 1988; Crutzen and Andreae, 1990; Levine, 1991). Satellite fire detection is a cost-effective way to quantify fire events for input into climate, pollution and land use/land-cover change models. It can also be a useful tool for early detection of fires in remote regions.

The international scientific community has realized the importance of geostationary satellite data in a global fire monitoring network. These three case studies show that is it possible to apply a consistent algorithm for monitoring fires throughout the world. The algorithm must be dynamic to adjust for varying conditions due to cloud coverage, diurnal heating, satellite view angle and ecosystem type. These issues also must be considered when interpreting the data.

In the next few years, a suite of satellites will allow for global geostationary detection of fires (Prins et al. 2001). Continuing efforts to validate the satellite data with field verifications will help the user community to better utilize these datasets.

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