P7.5 GOES WILDFIRE ABBA APPLICATIONS IN THE WESTERN HEMISPHERE

Christopher C. Schmidt*
Cooperative Institute for Meteorological Satellite Studies (CIMSS), University of Wisconsin, Madison, WI

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

1. INTRODUCTION

Recent fire seasons have garnered the attention of the public, media, and politicians for the spectacular forest fires in the Western United States. While the human and financial costs and locations of these fires have been documented, massive fires such as the Hayman in Colorado or Rodeo/Chediski in Arizona represent a small fraction of the total biomass burning that occurs globally on a daily basis. In the near future geostationary satellites such as the Geostationary Operational Environmental Satellites (GOES) and Meteosat Second Generation (MSG) will allow for geostationary fire monitoring of much of the globe, providing fire detection and classification at high temporal resolutions with a lower latency than seen with polar-orbiting platforms. The Wildfire Automated Biomass Burning Algorithm (WF_ABBA, http://cimss.ssec.wisc.edu/goes/burn/wfabba.html) detects and classifies fires using data from properly equipped satellites. Currently, GOES fire data can be available within 20 minutes of receipt of satellite data. Improvements to the processing system and faster hardware continue to reduce this product latency.

The hazards, international environmental monitoring, and scientific research communities have varying requirements with regards to satellite fire detection, but do share common ground in that they all desire as few false alarms as possible, accurate fire classification and duration estimates, and accurate geolocation. Additionally, the hazards community has set goals regarding wildland remote sensing fire detection and response. In regions where a rapid initial attack is crucial, remote sensing fire reports must be accessible within 5 minutes with a subsequent confirmation in 5 minutes and a revisit time of 15 minutes thereafter.- Current generation GOES and MSG are capable of meeting the temporal sampling requirement of 15 minutes but initial detection and confirmation requirements can only be met with a sampling resolution greater than 5 minutes. Despite this, the hazards community indicates that the use of current geostationary and polar orbiting fire detection platforms remains important (Dull and Lee, 2001).

In August of 2000 the GOES WF_ABBA began detecting and classifying fires using GOES-8/-10 data on a half-hourly basis for the Western Hemisphere. Since then GOES-11/-12 data have also been processed, and plans are to add processing for GOES-9 and MSG to provide coverage over the Western Pacific, Europe, and Africa. The WF_ABBA data set allows an illustration of the utility of timely geostationary fire products for applications from climate monitoring to hazards. In several cases the GOES WF_ABBA has detected fires before they were reported, even in the United States where the population density and efforts of the Forest Service usually allows for rapid location of active fires. Improvements are being made to the WF_ABBA processing system to reduce processing time and latency to their respective minima.

* *Corresponding author address:* Christopher C. Schmidt, University of Wisconsin-Madison, Cooperative Institute for Meteorological Satellite Studies, 1225 W.Dayton St., Madison, WI 53706; email: chris.schmidt@ssec.wisc.edu

2. OVERVIEW OF THE WF_ABBA ALGORITHM AND OUTPUT PRODUCTS

The WF_ABBA is a modified version of the Automated Biomass Burning Algorithm (ABBA) which monitored fire activity in South America from 1995 to 2002. The WF_ABBA was developed as a collaborative effort between the National Oceanic and Atmospheric Administration (NOAA)/National Environmental satellite, Data, and Information Service (NESDIS)/Office of Research and Applications (ORA) and UW-Madison Cooperative Institute for Meteorological Satellite Studies (CIMSS) personnel. The WF_ABBA is a dynamic multispectral thresholding contextual algorithm that uses the visible (when available), 3.9 µm, and 10.7 µm infrared bands to locate and characterize hot-spot pixels. The algorithm is based on the sensitivity of the 3.9 µm band to high temperature subpixel anomalies and the relative insensitivity of the 10.7 µm band to the same. The current WF_ABBA technique is derived from that of Matson and Dozier (1981) who applied a similar concept to NOAA's Advanced Very High Resolution Radiometer (AVHRR).

The WF_ABBA classifies fires into six categories. Processed fires have the highest confidence level and have associated instantaneous sub-pixel fire size and temperature estimates. Saturated pixels indicate that the 3.9 µm sensor detected the maximum possible temperature that it was capable of. Saturated fire pixels indicate extremely intense fires but at times they can be false alarms due to solar reflection and surface heating. The core WF_ABBA includes a number of checks to minimize these occurrences by taking into consideration satellite view angle, diurnal solar contributions, and surface characteristics. Cloudy fires do not have size and temperature estimates due to intervening cloud. High, medium, and low possibility fires are considered relatively likely as their labels indicate. Low possibility fires are the most likely to be false alarms, though they also may indicate the early phases of a fire or a fire of limited extent.

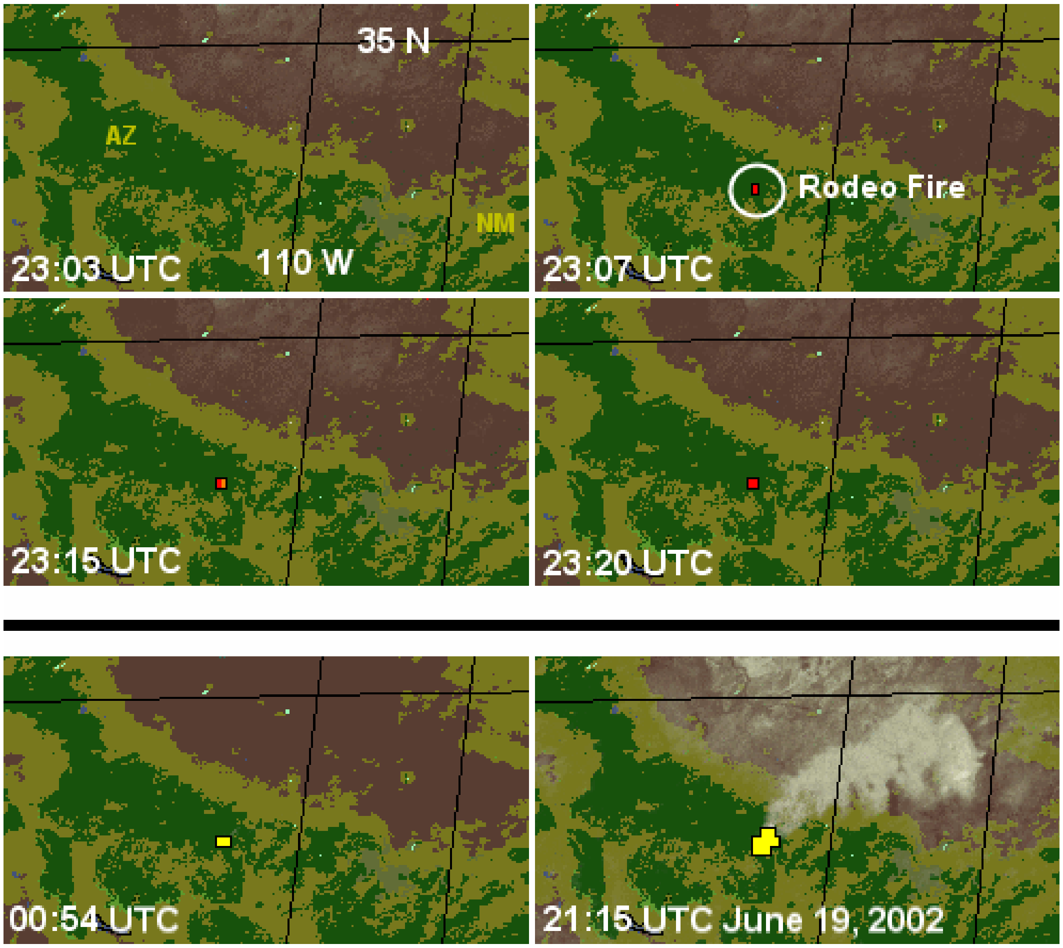

Figure 1: Sequence of GOES-11 Rapid Scan Operation (RSO) images showing the rapid growth and intensification of the Rodeo fire on June 18-19, 2002. The arsonist who set the fire reported it at 23:11 UTC. Green indicates forested areas, green-gold is grasslands and scrub, and brown represents mountains and deserts. The light green dots are urban areas. Red indicates a processed fire, orange represents a high possibility fire, and yellow indicates a saturated pixel. The 00:54 UTC image illustrates the fire size and intensity by the time the standard WF_ABBA processing running at the time would have detected it (the current implementation of the WF_ABBA would have reported the fire by 23:27 UTC). By 21:15 UTC on June 19, 2002 a huge smoke plume extended into New Mexico and exhibited signs of glaciation in its eastern-most segment.

A temporal filter within the WF_ABBA provides further screening of false alarms due to reflection off of clouds and extreme solar zenith angles at sunrise and sunset, as well as satellite noise. The temporal filter utilizes WF_ABBA output from the previous twelve hours and rejects fires that do not appear at least twice within that time period. Fires are collocated within 0.1° for the purposes of the temporal sampling. Both filtered and unfiltered WF_ABBA fire products are made available to the user community as temporal filtering will eliminate short-lived agricultural fires and also delay the identification of a fire start time.

WF_ABBA output comes in various forms. Text files containing basic information on each fire are available and have been integrated into Geographical Information Systems (GIS) as layers and aerosol transport models as emission sources (Freitas et al, 2003; Reid et al., 2001; Reid et al. 2003). Imagery is also generated by CIMSS for the web. This imagery utilizes the Modified Alpha-Blending (MAB) technique to combine visual and infrared satellite data with the Advanced Very High Resolution Radiometer (AVHRR) Global Land Cover Characteristics (GLCC) as a background and the fire data to create an image that illustrates clouds, the ecosystem types, and the fires and their classifications (Schmidt, 2002). Fig. 1 contains an example of MAB imagery that was produced using GOES-11 Rapid Scan Operation (RSO) data acquired during the GOES-11 check-out.

More information on the algorithm and the determination of sub-pixel fire characteristics can be found in Prins and Menzel (1992, 1994), Prins et al. (1998; 2001a; b; 2003), and Schmidt and Prins (2002).

3. TEMPORAL RESOLUTION AND TIMELINESS

The greatest advantage of geostationary fire detection over polar orbiter-based fire detection is the temporal sampling frequency. Instruments such as the

Figure 2: GOES-10 WF_ABBA image of the Viejas fire (3 January 2001) at the time it was first detected, 12:30 UTC. The fire start time was reported to be 12:24 UTC.

Moderate Resolution Imaging Spectroradiometer (MODIS) have a higher resolution than GOES (1 km for MODIS versus 4 km for GOES), but only achieve one overpass per day per instrument at mid-latitudes. Short-lived fires or fires that start after the MODIS overpass are completely missed and do not appear within its data set. Under the normal imaging schedule, GOES scans North and Central America once every 15 minutes, and the full disk once every three hours.

The GOES-11 Rapid Scan Operation (RSO) imagery shown in Fig. 1 illustrates the need for processing higher temporal GOES data when available. The current 30 minute resolution of the GOES WF_ABBA operational fire product is too coarse to resolve the best possible estimates of the start times of some fires. Fire detection must be at a high temporal resolution to provide emergency management services with as much lead-time on new fires as possible. Processing all available GOES data is a step towards that goal.

The latency between the receipt of satellite data and the availability of the fire products is a problem for all current platforms. Recent work has made it possible for the WF_ABBA to produce fire data in ASCII file form within less than five minutes of the start of processing. Generating web imagery takes an additional five minutes. The current implementation of the WF_ABBA requires a delay between the time when the satellite data is expected to be available and the start of processing, which raises the typical time from nominal image time to the availability of ASCII data to approximately 20 minutes. Further advances in CPU processing power and changes to the algorithm that downloads satellite data promise to shorten these times further. Latency is extremely important because fire detection is a real-time process and minutes count. Fig. 1 illustrates the Rodeo-Chediski fire complex in its early stages. The WF_ABBA detected a fire at 23:07 UTC on 19 June 2002, while the fire was first reported by the suspected arsonist at 23:11 UTC. Had that person not reported it, at least several more minutes might have passed before it was seen by local observers. The fire complex burned over 480,000 acres, cost $43 million to fight, and resulted in $28 million in damages and over $100 million in insurance claims. Given the rapid intensification of the Rodeo fire, minutes counted. GOES RSO WF_ABBA imagery with a low latency could provide crucial extra minutes of lead time for fire fighting teams in similar situations.

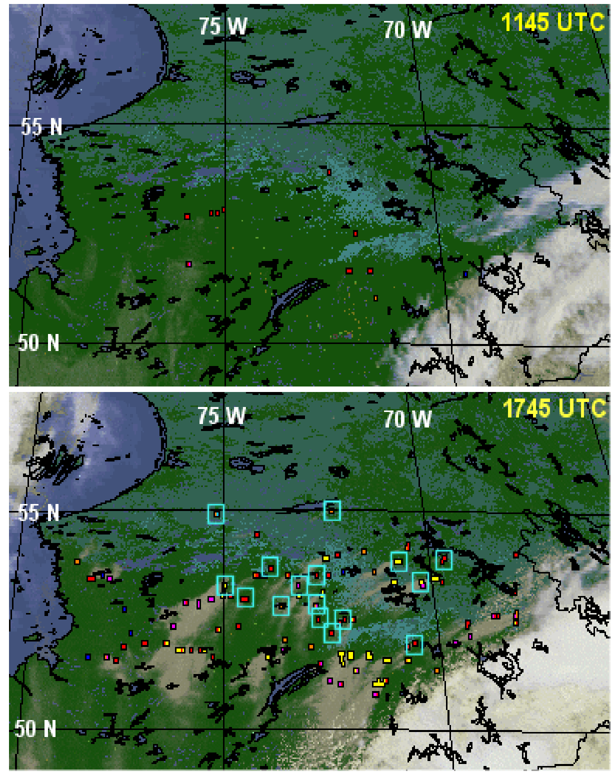

Figure 3: WF_ABBA images over northern Quebec for 11:45 UTC and 17:45 UTC on 6 July 2002. A number of fires flared up during the six hour period between sunrise and mid-day. Fires outlined in cyan boxes were detected by the WF_ABBA before their recorded start times. See Feltz et al. (2003) for more information regarding the validation efforts for this event.

There are other cases of the WF_ABBA also detecting fires slightly before or near their documented start times. The Viejas fire near San Diego had a reported start time of 12:24 UTC on 3 January 2001. The GOES-10 WF_ABBA first detected the fire at 12:30 UTC during routine scanning (Fig. 2). Earlier detection would have been likely if the satellite had been under a RSO, since by 12:30 UTC the 3.9 µm band was already saturated at the location of the fire. The Viejas fire went on to burn over a dozen homes around the Cleveland National Forest and do at least $2 million in damage.

Feltz et al. (2003) document cases in Canada where the GOES WF_ABBA detected several fires in the boreal forests before their recorded detection times. Fig. 3 illustrates fires that the WF_ABBA detected before their start times as recorded by Canada's Société de protection des forêts contre le feu (SOPFEU). There is no fire protection for the northern region of Quebec, and as such SOPFEU does not perform systematic daily detection over that region. The WF_ABBA fills in the gaps in the fire record that would otherwise be available and assists in the prediction of smoke events over the United States through aerosol models, such as the Navy Aerosol Analysis and Prediction System (NAAPS), which is a component of the Fire Locating and Modeling of Burning Emissions (FLAMBÉ, http://www.nrlmry.navy.mil/flambe/) system (Reid, 2001).

4. CONCLUSION

In recent years wildfires in the western US have highlighted the need for rapid identification of fires, and geostationary satellites play an important role in meeting that goal. As the WF_ABBA moves to being an operational tool used by the hazards, environmental monitoring, and scientific communities, the timeliness and latency are being reduced to their absolute minima and geographic coverage is being increased by the inclusion of GOES-9 and MSG. While some technical issues remain, the largest hurdles between the current state of affairs and the goal consist primarily of resources for the necessary hardware and labor. Once these challenges are met the WF_ABBA will produce the best possible fire detection data set in terms of temporal sampling and timeliness. Further improvements require new satellite platforms with faster scan times, such as the proposed Advanced Baseline Imager intended for the next generation of GOES satellites, which will allow for scans of the continental US every 5 minutes and the entire hemisphere every 15 minutes.

5. REFERENCES

Dull, C. W., and B. S. Lee, 2001: Satellite earth observation information requirements of the wildland fire management community. In Global and Regional Wildfire Monitoring: Current Status and Future Plans (F. J. Ahern, J. G. Goldammer, C. O. justice, Eds.), SPB Academic Publishing, The Hague, Netherlands, pp.19-33.

Feltz, J. M., M. Moreau, E. M. Prins, K. McClaid-Cook, I. F. Brown, 2003: Recent validation studies of the GOES Wildfire Automated Biomass Burning Algorithm (WF_ABBA) in North and South America, presented at the 2nd International Wildland Fire Ecology and Fire Management Congress, Orlando, FL, November 15-18, 2003.

Freitas, S. R., K. M. Longo, M. A. F. Silva Dias, P. L. Silva Dias, F. S. Recuero, R. Chatfield, E. Prins, P. Artaxo, F. S. Recuero, 2003: Monitoring the transport of biomass burning emissions in South America, submitted to *Environmental Fluid Dynamics*.

Matson, M., and J. Dozier, 1981: Identification of subresolution high temperature sources using a thermal IR sensor. *Phot. Engr. and Rem. Sens.* 47, 1311-1318.

Prins, E. M., and W. P. Menzel, 1992: Geostationary satellite detection of biomass burning in South America. *Int. J. of Remote Sensing*, 13, 2783-2799.

Prins, E. M., and W. P. Menzel, 1994: Trends in South American biomass burning detected with the GOES VAS from 1983-1991. *J. Geophys. Res.* 99(D8), 16,719-16,735.

Prins, E. M., J. M. Feltz, W. P. Menzel, and D. E. Ward, 1998: An overview of GOES-8 diurnal fire and smoke results for SCAR-B and the 1995 fire season in South America. *Jour. Of Geo. Res.* 103(D24), 31,821-31,836.

Prins, E., J. Schmetz, L. Flynn, D. Hillger, J. Feltz, 2001a: Overview of current and future dirunal active fire monitoring using a suite of international geostationary satellites. In Global and Regional Wildfire Monitoring: Current Status and Future Plans (F. J. Ahern, J. G. Goldammer, C. O. Justice, Eds.), SPB Academic Publishing, The Hague, Netherlands, pp. 145-170.

Prins, E., J. Feltz, and C. C. Schmidt, 2001b: An overview of active fire detection and monitoring using meteorological satellites. Proceedings of the 11th Conference on Satellite Meteorology and Oceanography, Madison, WI, October 15-18, 2001, pp. 1-8.

Prins, E. M., C. C. Schmidt, J. M. Feltz, J. S. Reid, D. L. Wesphal, and K. Richardson, 2003: A two-year analysis of fire activity in the Western Hemisphere as observed with the GOES Wildfire Automated Biomass Burning Algorithm. Preprints, 12th Conf. on Satellite Meteorology and Oceanography, Long Beach, CA, Amer. Meteor. Soc., CD-ROM, P2.28.

Reid, Jeffrey R., E. M. Prins, D. L. Westphal, C. C. Schmidt, K. Richardson, S. Christopher, T. F. Eck, E. A. Reid, and J. Hoffman, 2003: Real-time modeling of South American smoke particle emissions and transport using a coupled remote sensing/box-model approach, submitted to *Geophysical Research Letters*.

Reid, J. S., E. M. Prins, D. L. Westphal, S. Christopher, C. Schmidt, K. A. Richardson, M. Theisen, E. A. Reid, and T. Eck, Flambe: The Fire Locating and Modeling of Burning Emissions Project, Presented at the Fall meeting of the American Geophysical Union, San Francisco CA, Dec 10-14, 2001.

Schmidt, C. C. and E. Prins, 2002: The GOES Wildfire Automated Biomass Burning Algorithm Processing System, presented at the AGU Spring Meeting, Washington, D.C., May 28-31, 2002.