FIRE DETECTION FREQUENCY PERFORMANCE BASED ON GEOSTATIONARY AND POLAR-ORBITING SATELLITES BLENDING FOR FIREFIGHTING DISPATCH

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ABSTRACT

Active fire time series from the VIIRS and MODIS sensors bring 8 possibilities of fire detection when integrated in a 24 hours timeframe. GOES-16 satellite has a geostationary orbit and produces one image every 10 minutes. In order to reduce the window without fire detection between polar orbit satellites passes, Censipam has integrated an automatic status into the active fire event product that considers the integration of GOES-16 satellite. The goal of this paper is to present the integration methodology and, as a result, show the performance of blended temporal resolution from geostationary and polar-orbiting satellites and its impact in fire detection. The result showed that 14% of fire events from June to September 2022 intersected with GOES data. For medium, large and very large events, it reached about 100%. The average increase in detection was about 100% higher for each event area class, when compared to the smaller one.

Key words — fire detection, temporal resolution, near real time, fire dispatch, Amazon forest.

1. INTRODUCTION

Censipam is a Brazilian agency specialized in geospatial and earth observation products with the goal of monitoring the Brazilian Amazon Forest (e.g., deforestation, fire, and hydrology). Every year, Censipam receives innumerous requests to identify most important active fires to be handled by firefighters. To improve this response, Censipam created a webgis application called "Fire Panel" in 2021.

This system provided a near real-time fire tracking through a vector layer of fire events integrating active fire data from MODIS and VIIRS sensors. A fire event is defined as the grouping detections of intersecting active fire points buffer [1]. This tool was designed to provide a robust and responsive GIS system able to track the fire diversity that occurs in Brazil.

Due to high environmental impacts besides risk to death, firefighters work under pressure and all information matter to fire combat [2]. Earth observation systems such as the Fire Panel should allow the transformation of near real time remote sensing data into informed decision making about firefighters dispatch during fire occurrences, in addition to monitoring events until extinction.

Several earth observation systems have delivered geospatial products about thermal anomalies that can locate active fire across the territory. Most of them are based on polar orbit satellites that bring up to two fire detection possibilities per day [3]. From an operational context, the detection temporal resolution needs to be greater than that. Hence, temporal resolution can be improved by integrating different sensors for the same fire event.

Polar orbit satellites, like the ones with MODIS and VIIRS sensors on board, are good for models of thermal anomalies that give rise to active fire products [4]. However, for integrating different sensors, the spatial resolution is constantly suggested as a concern [2]. These sensors combined bring eight possibilities of fire detections per day. However, this frequency still brings concern because the interval between satellite passes is irregular and leaves great part of the day without data. In addition, Censipam fire event has 2-6 hours of latency between satellite data retrieval and update on the webgis application.

To fill these gaps, the integration of fire event with data from geostationary earth observation systems can be explored. This kind of orbit makes the temporal resolution higher because by travelling in high altitude elevation and at the exact same rate as Earth. GOES-R series constellation detect fires at an unprecedented spatiotemporal resolution of nominal 2 km at nadir every 5–15 min [5].

In a preliminary assessment of GOES-16 ABI, fire detection probability was found to be related to fire size and temporal period, but the omission and commission errors decrease as fire size grows [6]. Here there is a great possibility to inform an Incident Command System especially at its highest levels, because these kind of fire events are generally medium to very large. Considering the same characteristics of the polar-orbiting sensors approach, GOES-R series spectral resolution is able to detect small fire events [5], but has a very coarse resolution (2 km) for this study, thus becoming impossible to integrate with vector perimeter from VIIRS/MODIS fire event model.

A hybrid solution is proposed here by Censipam considering just polar orbit satellites to model the vector perimeter of fire event and using geostationary data to improve the update frequency of fire events active status. The goal of this paper is to show the performance of blended temporal resolution from geostationary and polar-orbiting satellites, and its impact in fire detection. With a backtest in Censipam fire event database, this research aims at understanding how the fire size behavior influenced the update frequencies of fire events.

2. MATERIAL AND METHODS

The time series data used here is part of Fire Panel database, a system designed by Censipam with multiple Brazilian firefighters [8]. Its use has been presented and validated by de Faria et al. [1]. The Fire Panel only shows currently active fire events, since its purpose is centered on dispatching firefighters. Nevertheless, this work used the complete database – including extinct events – to conduct a backtest and find the increase in fire event active status detection using GOES-16 satellite in addition to VIIRS/MODIS data. The complete database is available at the Brazilian National Spatial Data Infrastructure geoservices catalog [8]. This catalog contains all Fire Panel vectors and raster layers, built from PostgreSQL techniques.

As cited before, Censipam fire event perimeter is derived from MODIS and VIIRS active fire FIRMS [9], which generates a delay of 2-6 hours between satellite detection and update on Fire Panel webgis. To fill the time gap, Censipam has received GOES-16 database from INPE via FTP link, with 5 minutes of latency between detection and information availability at Fire Panel. Once GOES-16 data is received, Fire Panel processing flow checks for GOES-16 active fire points intersecting Censipam fire events. If confirmed, the time of last detection for each event intersected is updated to GOES-16 time without changing the event vector perimeter.

The spatial preservation is an assumption that profits from the blended temporal resolution and still manages to be conservative with spatial representation. As a consequence, this method presents fire size dependencies, which is in accordance to previous studies [7]. Events of larger size have a higher probability of intersecting GOES-16 active fire points. The analysis conducted in this study shows how size affects the frequency performance of GOES-16.

For this backtest we applied mainly two layers from our database: layer (A) that stores data from each fire event VIIRS/MODIS detection, and layer (B) that stores data from GOES-16 active fire points. We have applied the following criteria to consider events in the analysis:

- Fire event area ≥ 1 km^2 (same criteria used to show events in Fire Panel webgis);
- Spatial scope: Brazilian Amazon minus spurious areas (i.e. areas that typically generate active fire points that do not correspond to fires in rural areas: urban areas, village areas, industrial areas, sandbanks, etc.);
- Timeframe: events with beginning date from June 2022 and extinction date up to September 2022.

A SQL query was performed in our database to select Fire events according to the criteria defined. To evaluate size dependencies, these fire events were classified according to their area applying Jenks Natural Breaks method [10] using a SQL query. The variables used to assess frequency performance were generated using a combination of SQL and R scripts [11]. They are defined as follows:

- *detection* - one or multiple active fire points observed in the same satellite pass for a given event;
- d_{GOES} - number of GOES-16 detections observed for a given fire event;
- d_{FIRMS} - number of VIIRS/MODIS detections observed for a given fire event;
- Δd - fire event increase in detection considering GOES-16:

$$\Delta d = \frac{d_{GOES}}{d_{FIRMS}}$$

More information about Censipam fire event theory and vector perimeter model, severity dispatch indicator, and spurious area mask can be found in the Fire Panel Frequently Asked Questions (FAQ) [12].

3. RESULTS AND DISCUSSION

More than 57,000 fire events were registered by Fire Panel along the 120 days corresponding to the period here investigated and were selected to assess the frequency performance. Table 1 shows the distribution of fire events by area class. We can see that more than 95% have up to 8.6 km^2 and just seven performed like very large fire events.

Table 1 results are in line with the overall picture of Fire Panel: the massive majority of events are small. This factor influences all results when we do not analyse them divided by categories. For instance, when looking at all events analysed, 14% were intersected by at least one GOES-16 active fire point. But looking by area class, we can see that only small events are little updated by GOES-16 (Table 2).

On the contrary, from small-medium to larger events, the result is inverted and most events intersect GOES-16 active fire, reaching almost 100% for medium, large and very large events. It is important to consider here that the sample for these classes is small, thus a generalization of the outcome would require an analysis of a larger period.

Area class	Area range (km^2)	Number of fire events	%
small	1-8.6	54,435	95.18%
small-medium	8.7-42.7	2,454	4.29%
medium	42.8-136.3	242	0.42%
large	136.4-571.6	51	0.09%
very large	571.7-878.4	7	0.01%

Table 1. Natural jenks and area range for 57,189 fire events for five area classes.

Table 2 shows how much the active status update of a fire event can be increased by considering the GOES-16 intersection rule. For small-medium to very large events, the average status update more than doubles in frequency performance. The average increase in detection was about 100% higher for each area class, when compared to the previous one. Data variance also increased according to average increase, which indicates that frequency performances vary more from case to case for bigger events.

Area class	% of fire events intersecting GOES-16	Avg d_{GOES}	Avg d_{FIRMS}	Avg Δd	Δd variance
small	9.8%	1	4	9%	19%
small-medium	88.6%	32	25	130%	269%
medium	99.6%	165	72	233%	363%
large	100%	580	144	353%	423%
very large	100%	899	184	460%	509%

Table 2. GOES-16 frequency performance for each area class.

Although the overall average increase in detection stayed below 100%, the histogram in Figure 1 shows that this growth can reach five times and higher for some fire events. The histogram has intention to show the frequency of the increase in detection when is considered the blended temporal resolution. The boxplot show the same frequencies but highlight the outliers in the blended detections. Note that, there are many outliers which can be increase to 18 times.

The highest increase in detection for the sample analyzed was of 1,875%. This was the case of a small-medium event that happened in August 2022 at Amazonas state near Mapinguari National Park: it lasted almost less than 24 hours, had 75 GOES-16 detections and only 4 VIIRS/MODIS detections.

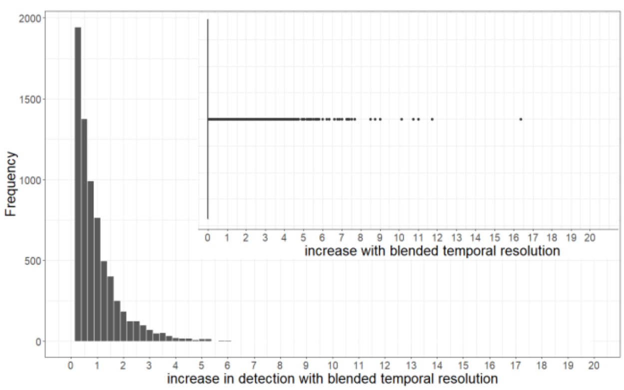

Figure 1. Histogram and Boxplot of increase in fire events detections when GOES-16 is considered. The boxplot are masking quartis range box because of the outliers variability.

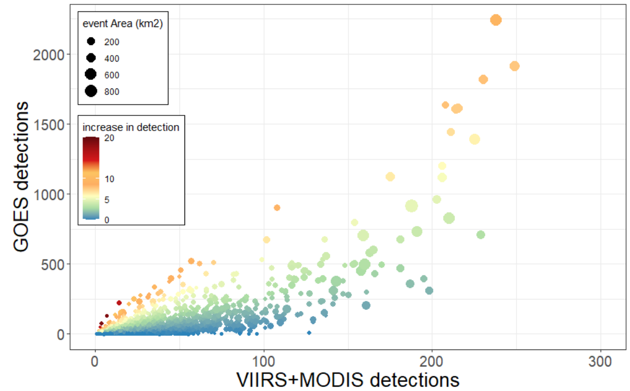

Figure 2. Scatter plot showing the relationship between VIIRS/MODIS and GOES-16 detections.

In general, outliers presented an increase higher than 1200% (see the boxplot in Figure 1) and were small or small-medium events lasting less than a day or up to 2 days. One exception worth mentioning was a small-medium event (34 km^2) at Mato Grosso state with 4 days of persistency that registered 223 GOES-16 detections compared to 14 VIIRS/MODIS (increase of 1,593%). Hence, the blended temporal resolution improved the average status update of the event from about 7 h to 25 min.

This conclusion is corroborated by Figure 2 that shows the positive relationship between VIIRS/MODIS and GOES-16 detections. We added a color label representing the increase in detection (Δd) and dots size according to event area. The highest increases in frequency performance are for events with smaller area and fewer VIIRS/MODIS detections. Most events are concentrated in the low left corner of the scatter plot, indicating they are small events, probably of small persistency, that present few or none GOES-16 detections along with few VIIRS/MODIS detections.

In short, GOES-16 detection outliers are in the upper right corner in green-yellow-orange (A) – representing in general larger events that have many detections for both satellites – and increase outliers are in the low left corner in red (B) – representing smaller events with high detection increase. The same outliers can be observed in Figure 3: group A is located at the center and group B is concentrated at the left upper side.

Using QGIS for visual inspection, we noted that these high frequency performance fire events seem to be related to deforestation, considering geolocation (Rondônia, Mato Grosso, Amazonas, Pará and Acre states) and the intersection with deforestation vector perimeter of DETER system [13].

Figure 3 scatter plot also shows how the increase distribution shown in Figure 1 is better correlated to the relationship between event duration and GOES-16 performance. In general, as the persistency increases, GOES-16 performance decreases, even for larger events. Large events appear roughly from 10 days persistency on and they all present GOES-16 detection.

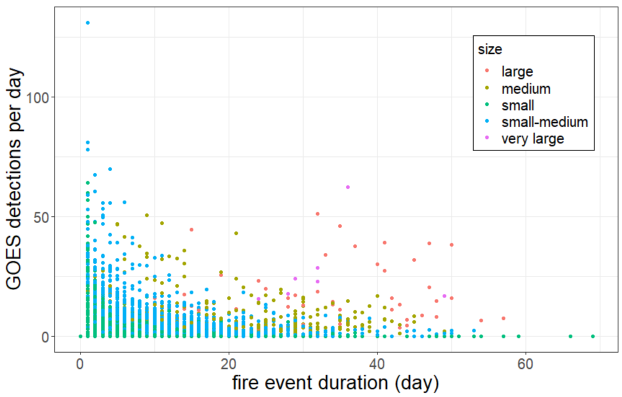

Figure 3. Scatter plot showing the relationship between fire event duration and GOES-16 detections per day for each area class.

Furthermore, we can see the outlier events that profited from GOES-16 performance presenting an update frequency of about 10-30 min, which is the highest achievable frequency. Nevertheless, the blended fire detection average performance was able to offer a 5 h frequency update for small-medium events, 2 h for medium and 1 h for large and very large.

4. CONCLUSIONS

This paper has proposed to understand how the blended temporal resolution (geostationary plus polar satellites) improves the fire detection frequency in the Brazilian Amazon. Size analysis enabled the comprehension of fire diversity and it showed that small fire events are majority. Their detection frequency can surpass 50 times a day (30-30 min), for extreme cases, when blending polar and geostationary satellites. Nevertheless, for this area class, only 9% of fire events were intersected by GOES-16 active fire points.

These results are in line with Li et al. [5] conclusion that GOES-16 ABI fire detection probability is related to fire size and temporal period if consider the blended temporal resolution on fire events was less significant for small events. Though, as shown in the tables and figures, even small events can be updated on an hourly basis.

For medium to large events, the results were better and with higher data variance. The average increase in detection was about 100% higher for each area class, when compared to the smaller one. Fire detection average performance was able to offer a 5 h frequency update for small-medium events, 2 h for medium and 1 h for large and very large.

Now Fire Panel is able to offer a fire event with spatial resolution update at 2-6 hours and up to 30 min for temporal resolution using blended geostationary plus polar orbit satellites. All these events can be viewed everyday on Fire Panel webgis.

GOES-16 capabilities can be further exploited to obtain more gains from its temporal resolution. Another Censipam product under development aims at showing possible new events that arise in between MODIS/VIIRS passes. This would be a great improvement, especially for detections that occur between 3-11 pm, when the time lapse of fire detections for polar orbit satellites is higher.

5. REFERENCES

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