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A three-year Analysis of the Biomass Burning Season in Southeast Mexico by Using a Contextual Fire Detection Algorithm

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Abstract

A three-year analysis of the biomass burning season in southeast Mexico and northern Guatemala, by far the region with most burning in Central America, is presented in this study. We use a contextual algorithm implemented in our group three years ago. The algorithm is based in Justice (1996) originally developed to be used with AVHRR data, but we readapted it to work with GOES data.

Even though some spatial resolution is lost when we use GOES data in comparison with AVHRR, a large increment on time resolution is gained. This permits to detect on-time and continuously monitor fires in a given area, which is quite useful for environmental and civil protection government institutions.

The algorithm (called here ADFA) has been monitoring fires in the study area since 2003 during the biomass burning season (approximately from March to May). The results indicate that this year biomass burning season was the most active of the three years. On the other hand, the main of sources of burning also varied from year to year. In 2003 the main burning sources were located in north-western Guatemala, and the peak was found in April; while for 2004, the main burning sources were located in middle Chiapas (Mexico) during April that year; finally, 2005 was somewhat similar to 2003, but the main sources in Guatemala moved a little bit to the south compared to that year.

1. Introduction

The atmospheric environment, as it is known, is being modified by diverse anthropogenic sources such as fossil fuel and biomass burning, among others (Charlson/Heintzenberg 1995). Biomass burning itself is an important source of gases and particles emitted to the atmosphere. The gases produced by biomass burning include: (1) greenhouse gases: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), that lead to global warming; (2) chemically active gases: nitric oxide (NO), carbon monoxide (CO), methane, and hydrocarbons (nonmethane), that lead to the photochemical production of ozone (O_3) in the troposphere; and (3) methyl chloride (CH_3Cl) and methyl bromide (CH3Br), which lead to the chemical destruction of ozone in the stratosphere (Levine 1996).

One of the major challenges of the scientific community that studies biomass burning is to accurately evaluate the space and temporal distribution of the burning for a given period of time (Levine 1996). Since more than two decades, different algorithms have been developed to detect biomass burning with different remote sensors (Justice 1993). To date, the main sensor used for biomass burning detection has been the Advanced Very High Resolution Radiometer (AVHRR), on board of NOAA polar-orbit satellites. Other sources that are used for detection of biomass burning include the Defence Meteorological Satellite Program - Optical Linescan (DMSP-OLS), the Along Track Scanning Radiometer (ATSR), and the Geostationary Operational Environmental Satellite (GOES) (Fuller 2000). Recently, another hi-res sensor has been raised for fire detection, the Moderate Resolution Imaging Spectroradiometer (MODIS).

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The present work describes the adaptation of a contextual algorithm to detect fires with GOES-East images. The work is based on the algorithm of Justice (1996) originally created for AVHRR. The algorithm, which we named ADFA (for Algorithm of Fire Detection in Active-duty, in spanish), has been used to give pursuit and to analyze the biomass burning seasons from 2003 to date in the south-eastern region of Mexico and northern Central America. This zone has been proved to be the most active biomass burning region in Central America (Galindo 2003). The results are presented here.

2. Methodology

Giglio and collaborators (1999) describe the most updated version of the algorithm developed by Justice (1996), base of the present work. The images used here were freely obtained from NASA-GSFC via FTP. The format of the collected GOES-East images is known as mode-A counts (8-bits data). For this work, we use the data from the channels 2 and 4 from the *Imager* instrument, which corresponds to 3.9 µm and 10.7 µm, respectively.

The steps to determine fires on the Earth surface are the following ones:

i) The count values from the pixels (8-bits) are converted to brightness temperatures (in Kelvin) for both channels by using the following relations:

From 0 to 176 (pixel value = vp),	T(K) = (660-vp)/2,	vp = 660-2T(K)
From 177 to 255,	T(K) = 418-vp	vp = 418-T(K)

ii) The criteria for a pixel to be considered as a fire candidate is the following:

a) T(3.9 µm) ≥ 316 K, this number is a minimum widely used, and it was proposed by Kaufman (1990) for tropical biomes. If this minimum criterion is not satisfied, the pixel is classified as a non-fire pixel.

b) T(10.7 µm) ≥ 280 K, threshold determined through empirical analysis of time series of multiannual data (Justice 1996), it is applied to assure that the pixel is substantially free of clouds and bodies of water.

iii) If the pixel has been determined as a fire candidate, an attempt is made to use the neighbouring pixels to estimate the brightness temperature of the potential fire pixel in the absence of fire. To be a valid background pixel, these neighbouring pixels, a) should not be a fire candidate pixel themselves {T(3.9 µm) < 316 K}, b) nor to be clouds {T(10.7 µm) ≥ 280 K}. This latter test is intended to prevent background fire pixels from biasing the background brightness temperature estimates. The window starts as a 3x3 pixel area and is gradually expanded into a 7x7 pixel grid as necessary until at least 25% of the background pixels within it are valid and the number of valid background pixels is at least three. If an insufficient number of background pixels are obtained the algorithm cannot make a determination and the pixel is classified as unknown. On the other hand, if a sufficient number of valid background pixels is found, the following statistics are computed for those pixels: the mean brightness temperature for channels 4 pixels (T_{4B}), the mean of the brightness temperature difference between channels 2 and 4 (T_{24B}), and the standard deviation of the brightness temperature difference between channels 2 and 4 (σ_{24B}). In addition, for the potential fire pixel, we calculate the difference of the brightness temperature between channels 2 and 4 (T_{24}), and the brightness temperature for channel 4 (T_4).

iv) Let ΔT represents the larger of 2 σ_{24B} and 5K. If $T_{24} > T_{24B} + \Delta T$ and $T_4 \geq T_{4B}$, the potential fire pixel is classified as a fire, otherwise it is classified as a non-fire. The T_4 test is intended to reduce false detections caused by undetected clouds.

v) the pixels determined as fires were geolocated by using the Fortran program 'readgnav.f', provided by GSFC-NASA and then plotted over a map.

For more information on the algorithm please follow Montero-Martinez/Polanco-Martinez (2004) (in spanish), the whole algorithm has been programmed in IDL.

3. Results

As mentioned above, the region studied here is by far the most active biomass burning region in all Central America. The following information will show some of the significant points of the biomass burning season in south-eastern Mexico and northern Central America according to the results provided by ADFA.

3.1 Total number of fires

One of the main issues in this project was to know how many fires per image ADFA detected for the study zone. Figure 1 shows three time series which describe the behaviour of the biomass burning season in the study zone (delimited in Figure 2) for 2003, 2004, and 2005. Each 'x' symbol means the number of fires detected by ADFA per GOES image (the average time per GOES image is between 15 and 30 min.), which means all these fires were simultaneous. The small gap with lack of data during the first week of April 2003 had to be with the replacement of GOES-8 by GOES-12.

By comparing the three years we certainly see marked differences for the total burning activity in the zone. For instance in 2003, NASA already reported an intensive fire activity in the zone[2]. This year also was notable because it registered some days with very intense burning such as those around March 18, April 19, and May 8 (cases with peaks well above 200 fires per image). On the other hand, 2004 registered a much lower fire activity, especially during March, in addition the burning season finished quite a bit earlier with respect to the other two years. It is also shown that there was not any case with more than 200 fires per image. Finally, 2005 was again another year with an intense fire activity consistently reported by different media of mass communication in the region. The burning season increased fast during March up to the peak which according to our results was around the last week of April, and then the burning rapidly started to decrease due to the first signs of the beginning of the rainy season in the zone.

3.2 Locations with high fire activity (frequency)

Another interesting point is to show the pixel locations which registered the highest fire activity (in frequency) during the analyzed period (2003-2005). First, Figure 2 shows the area delimited for this study. On the other hand, it shows the pixels which registered a fire in at least 10 or more images for the month of April, the month which registered most of the burning for the three years analyzed. The above was done to try to show the places where the burning was more frequent. In the figure the 'green' colour denotes the pixels which registered fires with a frequency from 10 to 29, the 'yellow' one the same as above but from 30 to 49, and the 'red' one from 50 or more.

As we can see there are some differences from year to year with respect to the locations of the burning. In 2003, the region with most of the burning in April was the northwest of Guatemala (also noted by NASA with MODIS see webpage at the footnote). It is worth to say that inside this region is a zone very rich in biodiversity, the Lacandon jungle. Also some of the burning in this period was registered in the middle north of the Yucatan peninsula and some in the coast of Chiapas. In 2004, it is again evident, from the plot, the decrease in the fire activity. We observe that for this period almost no burning was carried on for north-western Guatemala. The main burning sites now were located in the centre and south part of Chiapas. Finally, 2005 was somewhat similar to 2003 in relation to the burning sources. Again, the northwest of Guatemala and the coast of Chiapas are among the main burning sources. However, now the highest activity in Guatemala (which we can delimit following the red points) is located a little bit to the south compared to 2003, maybe there was not any more enough wood to burn far north after the events in 2003. Also, there were some locations in the north of the Yucatan peninsula and in the state of Campeche (Mexico) located to the northwest of Guatemala.

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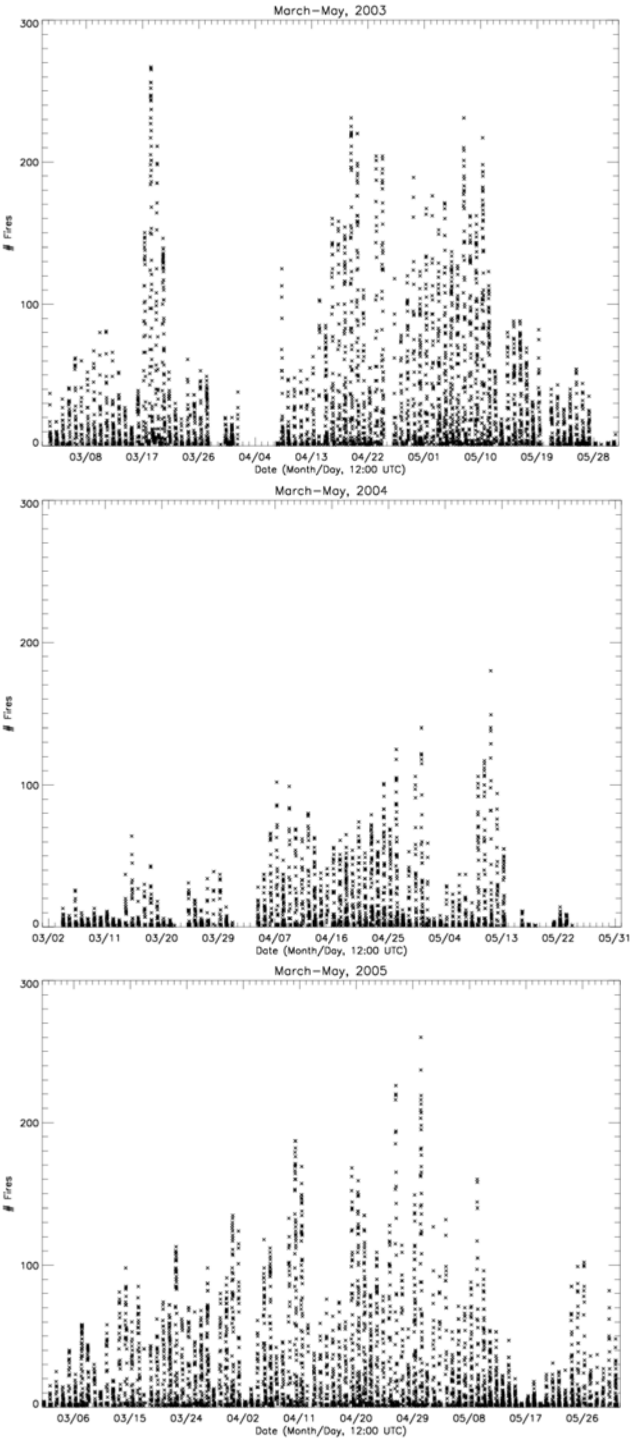
[2] http://ciencia.nasa.gov/headlines/y2003/16may_biocorridors.htm



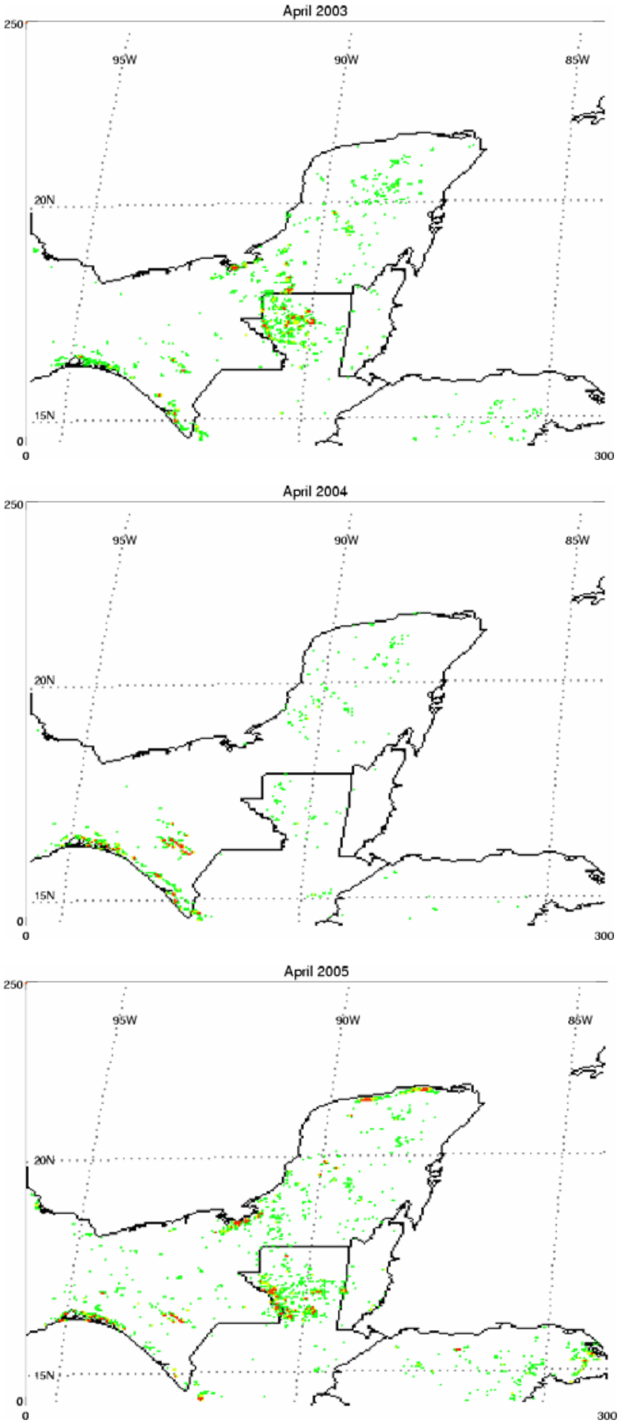


Fig. 1: Time series with the total number of fires per image (small crosses) for the study region during the biomass burning seasons from 2003 to 2005.

Fig. 2: Pixel points where a fire was located in 10 or more images during the April months. The 'green' colour denotes the pixels which registered fires with a frequency from 10 to 29, the 'yellow' one the same as above but from 30 to 49, and the 'red' one from 50 or more.

3. Summary

Some of the total numbers obtained with ADFA can be summarized in Table 1.

	2003		2004		2005	
March	TNFI =	28369	TNFI =	3236	TNFI =	29214
	Np_10 =	853	Np_10 =	88	Np_10 =	814
	Np_50 =	56	Np_50 =	4	Np_50 =	45
April	TNFI =	40999	TNFI =	23027	TNFI =	54670
	Np_10 =	1079	Np_10 =	499	Np_10 =	1406
	Np_50 =	66	Np_50 =	53	Np_50 =	145
May	TNFI =	28369	TNFI =	7890	TNFI =	19419
	Np_10 =	853	Np_10 =	218	Np_10 =	371
	Np_50 =	56	Np_50 =	8	Np_50 =	23

Table 1. Summary of the fire activity detected by ADFA for the period and region of study. TNFI represents the total number of fires per image found during that time; Np_10 represents the number of pixels with a frequency of fires ≥ 10 (that is the sum of green+yellow+red points, Figure 2); and Np_50 is for a fire frequency ≥ 50 (red points). The above results indicate that the year with more fire activity registered by ADFA was 2005, closely followed by 2003, and 2004 was comparatively low. Even for the peak month (April) 2005 registered more fire activity in all categories analyzed in Table 1. Finally, it is worth to say that even though this algorithm has not received any field validation, we are planning to do that in the next future. There is no doubt that this kind of tool could be quite useful to complement the estimations given for higher spatial resolution sensors (AVHRR, MODIS), particularly on the temporal resolution of the events.

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