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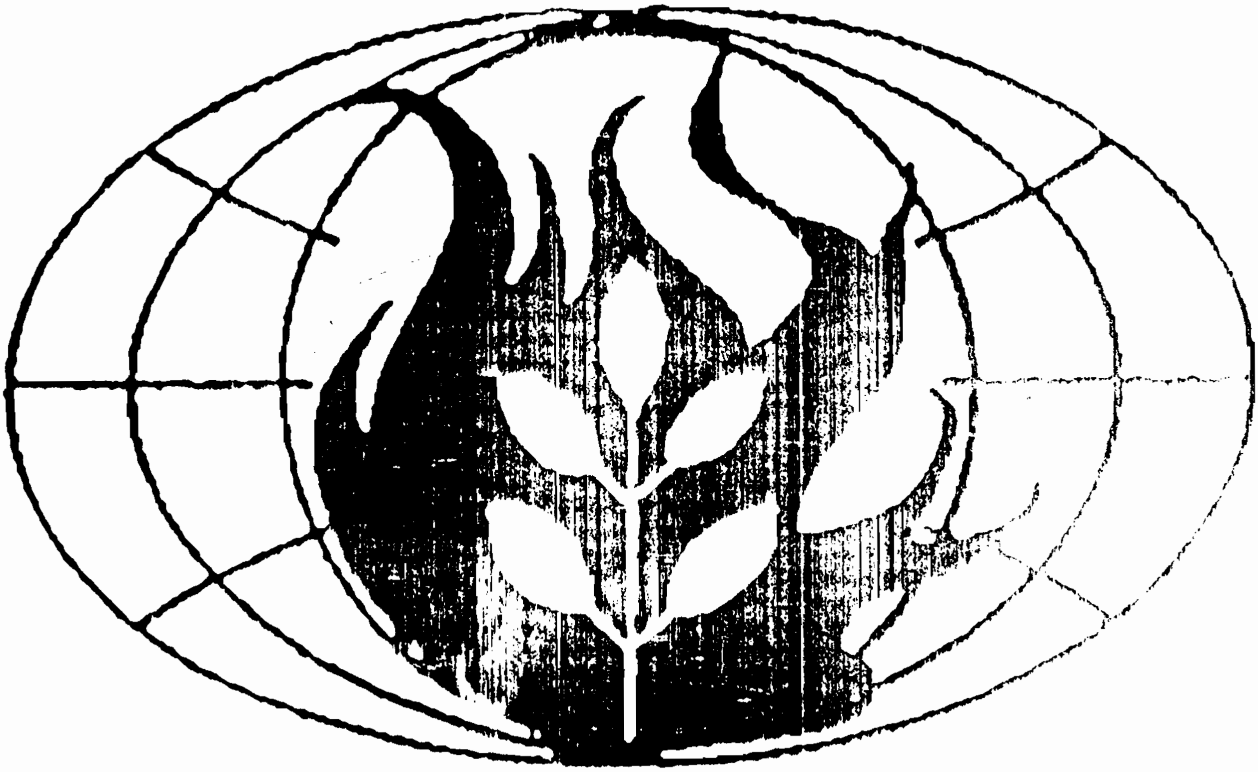

INTERNATIONAL FOREST FIRE NEWS

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BRAZIL

Operational Satellite Monitoring of Fires in Brazil

Fire detection and control are complex tasks in Brazil. The country has old and popular established traditions of burning the vegetation whenever possible, weak environmental concerns, and little or nor capability of fire detection in most of its territory (8 million km^2). Among its main uses, fire is normally employed to renew pastures all over the country, to clear felled trees and shrubs in areas of new deforestation, and in sugar cane plantations prior to manual harvesting. A pronounced dry season of about four months in the southern and central regions during the austral winter create very favorable conditions for the wide spread use and propagation of fires. Natural fires (e.g. lightning fires) represent a negligible fraction of fire events.

Since 1987 an operational system of fire detection based on orbital remote sensing has been used in Brazil. This report summarizes the technique used and the products available, pointing to its main advantages, limitations and future needs. Readers interested in more details should be directed to the references listed at the end of the text.

The satellites used for fire detection and monitoring are the NOAA-series meteorological satellites of polar orbit (~98°, 840 km altitude). There are always two of these satellites in operation, resulting in at least four overpasses per day for any tropical regions of the globe. At present, four NOAA satellites can be used (NOAA 9-12) and an additional one (NOAA-13) is expected to be in use by July 1993. The early afternoon images (at 2 p.m. local solar time) are particularly used for fire monitoring because most fires lit around noon are still active during the satellite pass. Each image covers a ground strip of about 2,500 km oriented in the SSE-NNW direction for day-time ascending passes, or NNE-SSW in night-time descending passes. The length of the strip is about 4,000 km, centered in the latitude of the receiving station. Such wide-area coverage in a short time interval (14 minutes) available a few times per day is the main advantage of these satellites in fire detection. No cost or restrictions exist to receive these AVHRR images/HRPT mode. Accredited commercial complete receiving stations have been sold for less than US$100,000; ones of 1/10 of this price are currently offered!

The detection of fires relies on the picture elements (pixels) of the image above a certain threshold in the thermal channel 3 (3.9 μm) of the 4-channel AVHRR sensor aboard the NOAA satellites. This channel, with nominal saturation at 43°C, was designed for ocean and temperature measurements. Nevertheless, it is the most sensitive one to targets with temperatures of vegetation fires. Its signal, therefore, can be used only to detect fires but not to estimate their temperature or size. Hot targets like cities of dense construction or exposed soils under a hot sun are seen by channel 3 with much lower temperatures than active fires and are not erroneously mistaken with them. Any fire front with ca. 50 m or more will be detected by channel 3, and will be indicated by at least one pixel. Since the size of a pixel is at least 1.1 x 1.1 km, area estimates of fire fronts for field operations planning is impossible. The precision of fire detection is one pixel, which at nadir is $\pm$ 500 m; at the edges of the image, because of pixel geometric distortion, it may reach $\pm$ 3,000 m. A major constraint is caused by sun glint in water bodies and in very reflective hot exposed soils in particular cases of sun-target-satellite geometry. In Brazil this problem was greatly reduced by using always the most west pass of the satellites for the region of interest. When this pass occurs the sun is at a lower angle for that region and the soil temperature has decreased in relation to the previous pass which was ca.25 degrees eastward, highly reducing the chances of sun glint.

Two types of products are made and operationally distributed in Brazil by the National Space Institute (Instituto Nacional de Pesquisas Espaciais - INPE), which receives the NOAA images and processes them on real time. The first one is directed to those with operational needs of fire detection and fighting, like organizations in charge of protected areas or commercial forests, and environmental agencies. A special image processing software coupled with a geographical information system identifies all "fire pixels" in the images received, determines their geographical coordinates, selects those in each individual area of interest, and prepares and sends a telex message to specific users. Within about 30 minutes of the satellite pass individual users have at their telex machines a list of geographical coordinates of the fires detected in their own regions. Telex transmissions are preferred to avoid noise problems found in regular fax/phone lines. Until 1992 only the afternoon satellite passes were used on a regular basis, with night and early morning passes processed only on special request; in 1993 an early morning image should also be included in the monitoring.

This fire monitoring system is operational on a daily basis in Brazil for six months, from 1 June until 30 November. The size of the areas monitored varies according to the users needs, ranging from small ones with just a few km^2 to those of large states of many thousands of km^2. Users usually relay the locations of the fires received by telex to fire brigades in the field by radio. Fire fighting brigades which checked hundreds of the fires detected by this satellite system reported that ca.98% of them were correctly identified; the remaining 2% were never reached because of logistical problems. In relation to other sources of information on fires, like calls from the public, park guards, aircraft pilots, the satellite detection accounted for ca.96% of all fires detected. For statistical and control purposes, the system also generates a monthly statement for each area monitored, indicating the total number of fires detected each day.

A second operational product of the system gives an estimate of fire distribution and density for the country with cumulative weekly and monthly data obtained from the daily image processing. Fire pixels are counted in

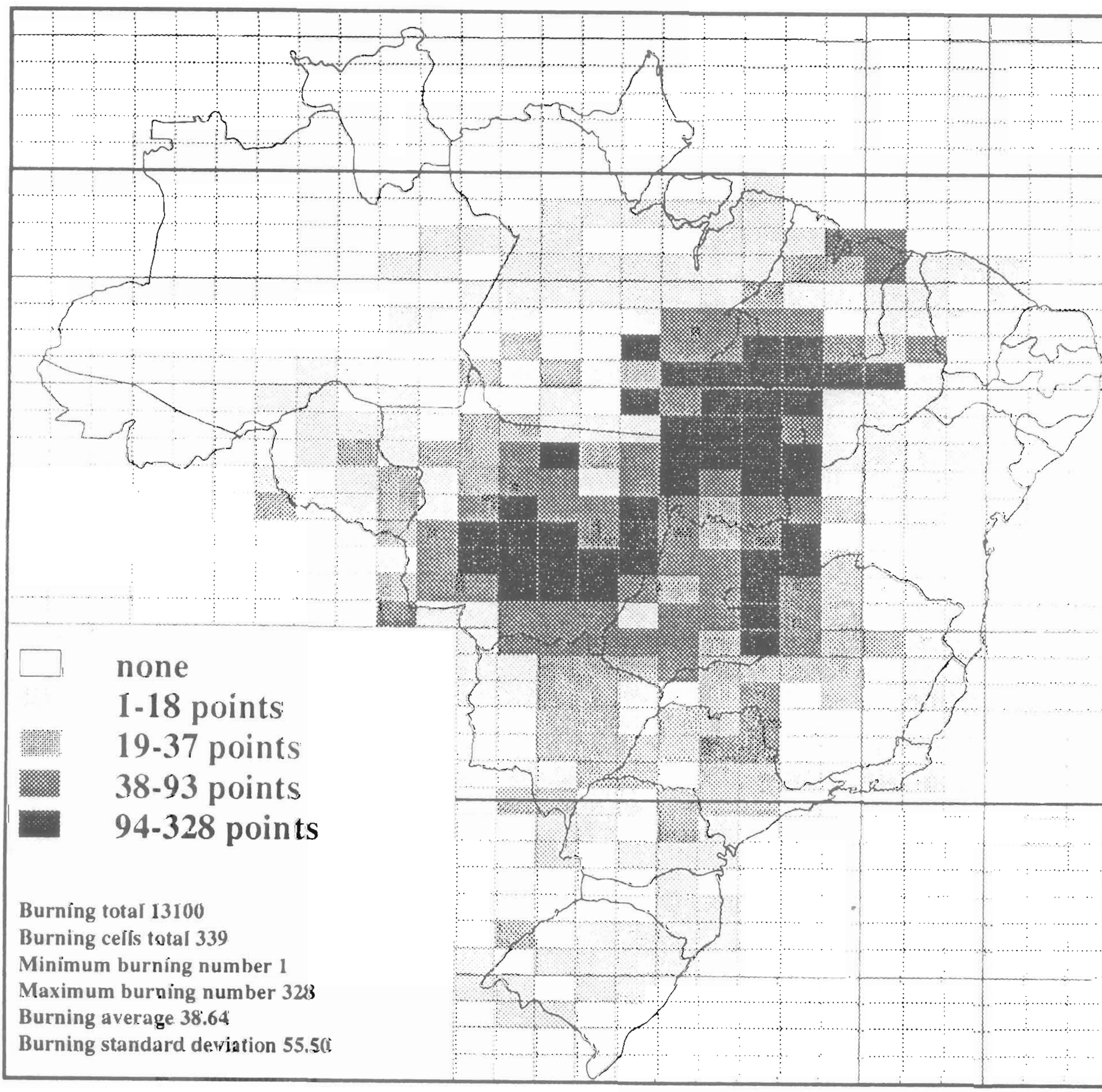

Fig.1. Fire activities in Brazil during July 1992 as recorded by NOAA satellite data. Source: National Institute for Space Research INPE, Sao Paulo, Brazil.

grid cells of 0.5° of latitude by 0.5° of longitude and sent every week to users by E-mail. Three matrixes of data are produced and sent: the first contains the number of fire pixels detected in each grid cell during the week; the second contains the number of times each cell was imaged by the satellite; and the third has the average number of fire pixels in each grid cell. The E-mail file containing the three matrix has ca.70 Kbytes. Users of these weekly products include newspapers that publish maps of fire density in the country or in specific states, and different scientific groups interested in studies on vegetation, atmospheric chemistry and climate modelling.

The two figures show an example of maps made from such matrixes for the months of July and August 1992. The month of August, which includes the peak of the fire activity, had over 100,000 fires, while July, still at the beginning of the fire season, had only 15,000 fires detected by satellite. The highest density of fires is found along the current south limit of the Amazon forest. This is a region subject to intense deforestation through fire. The vegetation is cut at the end of the wet season or start of the dry season, and then left to dry for one or two months. Fire is used to burn the dead organic matter and will be used in the same place for many years until all organic matter from the original forest is consumed.

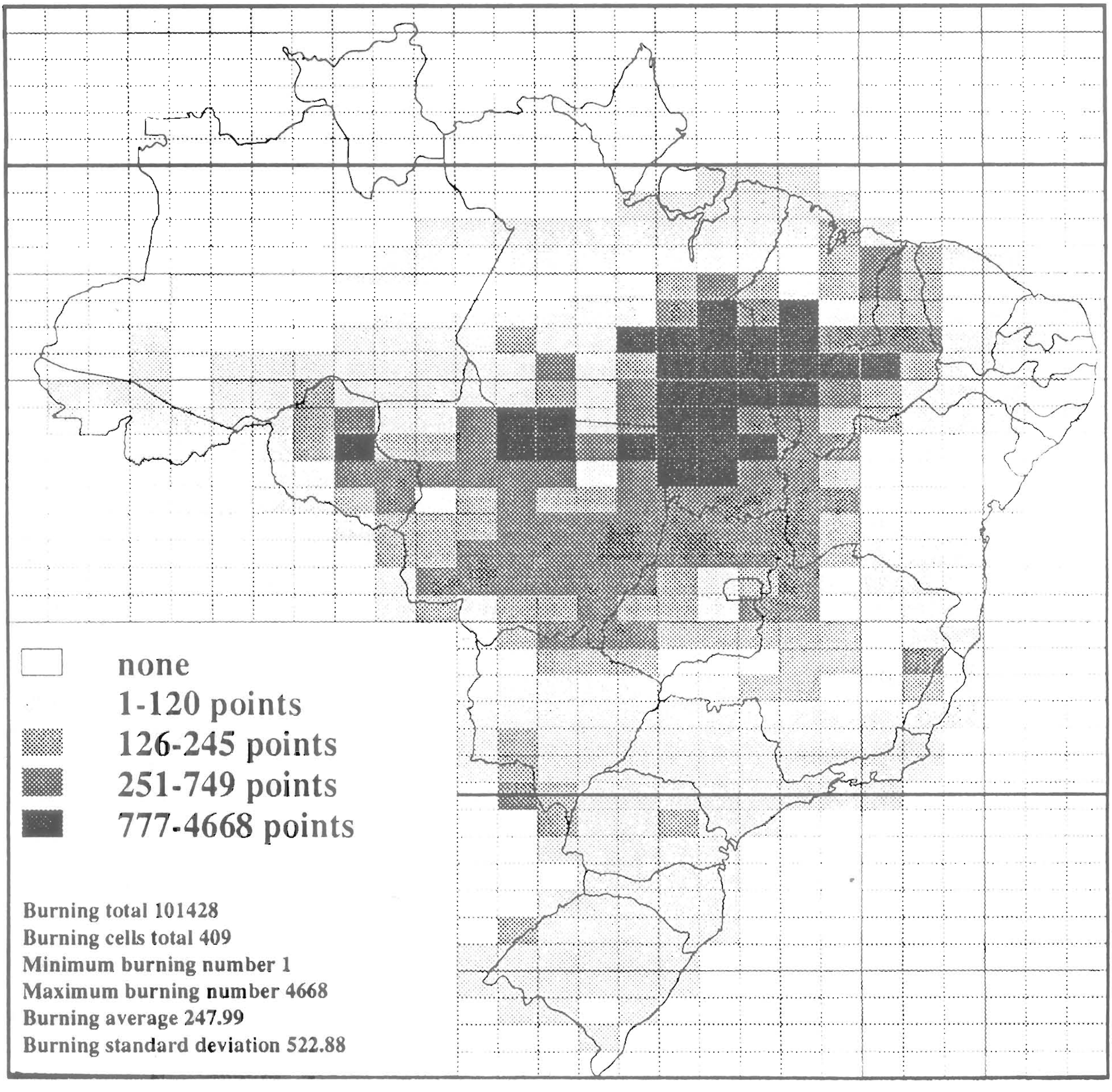

Fig.2. Fire activities in Brazil during August 1992 as recorded by NOAA satellite data. Source: National Institute for Space Research INPE, Sao Paulo, Brazil.

Although restricted by the Brazilian government, deforestation and the associated burnings are extremely difficult to control in such extensive and inhospitable regions. The control has been made in recent years largely based in the satellite detection technique described above: helicopters stationed in the region have been directed to the geographical coordinates of the fire pixels in AVHRR's channel 3 images. This enabled the Environmental Institute of Brazil to enforce existing legislation on fires and deforestation with millions of dollars in fines imposed on law offenders. In fact, AVHRR images in 1987 were responsible for showing the scientific community and the public in general that biomass burning in Amazonia was taking place at unprecedented rates and out of control.

Without discussing extensive existing field and validation work or theoretical considerations, the following pros and cons of the AVHRR detection of fires are listed:

Main advantages

- methodology of detection regular and uniform
- use of satellite data not restricted, costs are less than other images
- four images daily anywhere in the globe, at least
- coverage ranging from few to millions of km^2
- precise location of fires for fire control purposes
- fast acquisition and distribution of information on fire locations
- simple detection principle, field proven
- products of simple output
- answers individual needs of different users
- fast, simple and diversified delivery of products
- low product cost for users

Main limitations

- no detection of fires not active during the satellite time overpass
- no detection of fire fronts smaller than ca.50 m
- obscuring clouds (but not smoke) in the fire-satellite line-of-sight
- no detection of fires not reaching the canopy
- solar reflection in a few cases
- very coarse estimate of area in fire
- misses advance of fires between consecutive images

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