ALONG TRACK SCANNING RADIOMETER WORLD FIRE ATLAS

Validation of the 1997-98 Active Fire Product

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1 PREFACE

The 1997 Kyoto Convention revealed to the general public that, industrial and agricultural emissions of carbon dioxide, methane and other Greenhouse gases threaten to change the climate rapidly. The Baveno Manifesto reflected the importance to Europe of Global Environment Monitoring by space as a component of the Kyoto Convention implementation. Remote sensing data from the ERS-2 ATSR-2 (Along Track Scanning Radiometer) allows monitoring of agricultural fire and wildfire distribution at a global scale and in near real time.

The ATSR Fire Atlas is the first multi-year Global Fire Atlas ever developed and it will extend from 1995 (launch of ERS-2) to the present. In addition the continuity of data capture, required for long term monitoring, will be ensured by the AATSR instrument onboard ENVISAT up to 2005.

Each year of ATSR Fire Atlas requires the processing of 80000 images. All Hot Spots (including gas flares) with a temperature higher than 312 K at night are precisely localised (better that 1km).

2 ATSR WORLD FIRE ATLAS PROJECT DESCRIPTION

2.1 Introduction

A long-term and frequently updated fire atlas is needed for land use, forestry, atmospheric chemistry, global climate and fire management applications. The fire product has been identified by IGBP as an important input for global change analysis.

The ATSR World Fire Atlas Project aims at developing a continuous fire distribution global atlas, from the launch of ERS-2 in 1995 to the present. Continuity of the measurements will be ensured with the AATSR instrument on board ENVISAT, to be launched in 2001. All night passes of the ATSR-2 instrument will be processed over land surfaces.

When referring to this product please acknowledge:

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ATSR World Fire Atlas Project,
with support from the IGBP-DIS Office.
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2.2 ATSR-2 data

The Along Track Scanning Radiometer (ATSR) flying on-board ERS-2 has four visible and infrared channels centred at 0.55, 0.67, 0.87 and 1.6 micrometers and three thermal infrared channels centred at 3.7, 11.0 and 12.0 micrometers. It has been designed to produce a dual view (forward view at 55 degrees of the nadir) of the same surface at 1 kilometre resolution. The swath of 512 kilometres allows a revisiting period of 3 days at the equator. The satellite cycle is 35 days.

To develop this atlas, the following ATSR Level 1B product was used:

ATSR-2 Level 1B GBT (Gridded Brightness Temperature):

- Infrared and thermal channels (1.6, 3.7, 11.0 and 12.0 micrometers);
- Nadir view only;
- Night time only;
- Land Surface only.

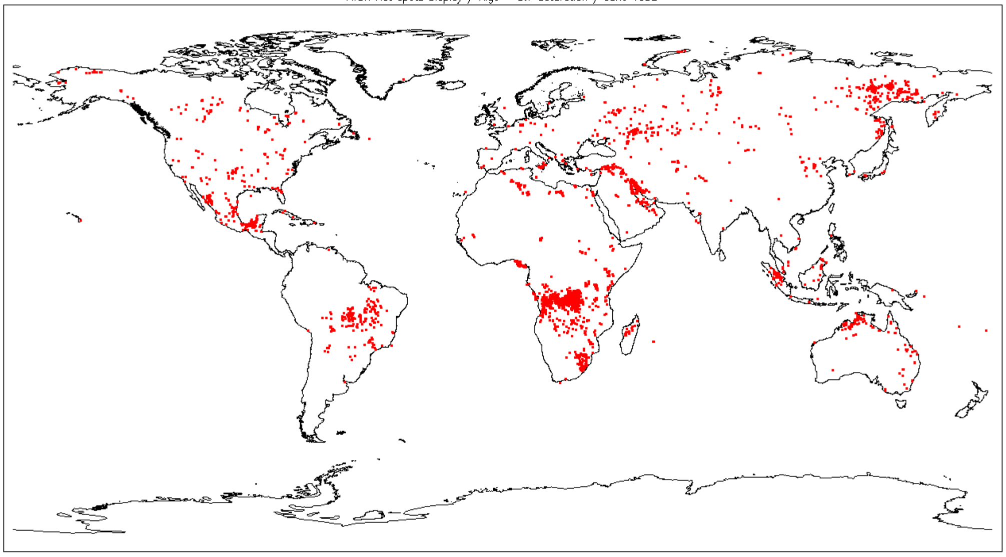
The accurate calibration of ATSR-2 Level 1B is achieved by the use of low noise infrared detectors, cooled to near-optimum temperature by a Stirling cycle mechanical cooler and by the continuous on-board radiometric calibration of the infrared channel against 2 blackbody targets. The stability of ERS-2 orbit along with the accurate orbit prediction algorithm ensure a precise geo-location.

2.3 ATSR Active Fire Product Format Description

Latitude and longitude of the pixels identified as fire pixels (resolution better than 1 km) are provided in monthly global ASCII files. These are complemented by monthly global maps (GIF format, cylindrical equidistant projection) showing the location of the hot spots.

- Example Monthly Map

ATSR Hot spots Display / Algo = 3.7 saturation / June 1998



- Monthly Fire Location File ASCII file (1 line per hot spot detected)
  Line format = `[Date Time Latitude Longitude NDVI Station EOL]`
  With:

Field Name	Format	Description
Date	YYMMDD	Year Month Day
Time	HHMMSS.MMM	Hour Minute Second . Milliseconds
Latitude	S999.999	(S: Sign)
Longitude	S999.999	(S: Sign)
NDVI	-.--	Not used
Station	ESR	ESRIN
EOL	\r\n	Carriage Return Line Feed

(Record length = 46)

2.4 ATSR Active Fire Algorithm Description

The ATSR night time data used contains 4 channels: 1.6, 3.7, 11.0, 12.0 micrometers. 2 straightforward algorithms were tested in this project, using only the 3.7 micrometer channel:

Algorithm 1:

Brightness Temperature at 3.7 micrometers ($BT_{3.7}$) > 312 Kelvin (Instrument saturation)

Algorithm 2:

$BT_{3.7}$ > 308 Kelvin

The detected fires can be considered as highly likely, however some fires can be missed. The user of the fire product needs to take into account the algorithm simplicity. Note limitations due to cloud presence, atmospheric effects, bi-directionality of emissivity, fire temperature and extension and timing/duration are not taken into account in the processing.

Nevertheless the advantages of the ATSR Active Fire Algorithm are the following:

- Night Time detection means that reflection of incoming solar radiance does not affect the algorithm.
- Only quasi nadir viewing pixels are analysed: fewer pixel size and bi-directional problems are expected.
- Lack of drift of the ERS orbit allows year to year comparison.
- High radiometric sensitivity allows selection of small and discrete fires.

2.5 Processing Facility

Hardware list:
- 2 DEC/VMS workstations: ATSR-2 Level 1B GBT production;
- 1 SUN/Solaris workstations: Fire processing, GBT catalogue management;
- 1 SUN/Solaris workstations: GBT archive management;
- 1 DLT library (48 DLTs): GBT archive.

Processing capabilities:
The ATSR Fire Processing Chain is able to process up to 7000 frames per week. 1 year of data is about 80000 frames (processed in 12 weeks).

Fire Processing Chain design:
The Fire Processing Chain has been designed to process fire products from both raw data and Level 1B products. Re-processing from Level 1B data allows the testing of new algorithms on the data already archived (more than 2 years) without restarting the processing from the raw data.

2.6 Processing Problems

2.6.1 Day time products

During the processing, all the daytime frames were removed. From February to August 1997 some data beyond 60 degrees Latitude North are missing in the data set. The impact on boreal forest fire detection potential is not negligible.

2.6.2 Archive

Due to initial hardware problems some fire products for 1997 were lost from the archive. These products were missing in from the data provided for the validation. However, the re-processing has since been accomplished and the data are available.

2.7 Validated regions and Validation Data

To validate the outputs of the two algorithms a large number of scientists were contacted and asked to compare burn records with the Hotspot data. The areas listed in Table 1 provided responses.

Validated region	**Date**	**Validation Data**
Turkey	Unknown	Fire Reports
Province of Catania – Sicilia	August 99	Groud truth information - (Fire Brigades)
	Year 98 (June September)	Landsat TM Burned Area Maps
	Year 99 (June September)	Landsat TM Burned Area Maps
Northwest Spain	March- April 1997	Fire reports from the Area De Incendios Forestales in the Direccionn General de Conservacion de la Naturaleza. IRS-1C WiFSimage (May 1, 97)
Spain	1997	Spanish Forest Service Information
Portugal	June-September 98	Landsat TM Burned Area Maps
Siberia, Mongolia, North China	April-October 97	NOAA AVHRR Hotspot data
Indonesia – Kalimantan (South Borneo)	1997	Landsat TM images (1998) with visual delineation of burnt scars, field data
Indonesia – Kalimantan (South Borneo)	August-November 97	NOAA AVHRR Hotspot data, Landsat TM Burned Area Map
South East Asia	Year 97	Visual interpretation of Hotspots
Northern Territory and Western Australia	1997	Operational AVHRR Fire and Scar products
Canada - Ontario and Quebec	May-August 97	NRCAN Large Fire DataBase (LFDB)
Canada	April-October 97	AVHRR Hotspot Data Canadian Forest Service (CFS) Burned Area Statistics
Alaska	Summer 97	Locations of fire boundaries
South America (Amazon and Orinoco Basins)	Unknown	Visual interpretation of Hotspots

3 Validation Reports

EUROPE

ATSR World Fire Validation: Turkey

Ertugrul Bilgili

Mediterranean and Aegean Region

After cross-checking with ATSR data, we found 10 fires correctly detected by the satellite. These fires lasted at least two days, so there was at least a night pass for detection. In this regard results seem satisfactory.

South–eastern Anatolia

To the east of Mediterranean region (35.000 longitude and greater) many points were detected. Unfortunately, we had no real fire record from that part of the country. The reason is that few fires, mostly small, occur there. And the area is used mostly for agricultural purposes. Summertime temperature normally reaches 40 ºC.

Central Anatolia

There are some points in the central part of the country. In Turkey, we virtually have no forest in Central Anatolia. Agricultural fields cover a high percentage of the area.

Concerning the causes of these unexplained points, I can only say the following:

i) There is a cultural exercise of burning of plant residues in agricultural fields. Farmers usually set fires in their fields after harvesting in summer, usually in the evening. This may explain most of the points detected especially in Central and Southeastern Anatolia. There is a strong ban on residue or any kind of burning in fire sensitive forested areas in the fire season.

ii) The other reason may be the high temperatures reached on surface (This may have some effect on the points detected especially in South-eastern Anatolia). If the differences between Algorithm 1 and 2 are based on temperature differences, these may have something to do with it.

ATSR Hot Spot validation – Catania (Italy) Fire seasons 1997-1999

Massimo Cristaldi

Two different test zones in the south of Italy (Catania, Sicily and Taranto, Puglia) were scanned for Hot spots for the years 1997-1999. The present work concerns the area of Catania. The Hot spots acquired for 1999 were checked against ground truth information available form the local Fire Brigades and Corpo Forestale dello Stato. For the years 1997 and 1998 a comparison between Hot Spot and TM Burned Area Maps was performed.

The zone of Catania can be considered a typical example of Mediterranean environment with the northern part characterised by the presence of Mt. Etna (3325 mt.) and of a large number of Coniferous and Broad-leaved forests, and a mainly flat part – south of Mt. Etna. The southernmost zone is characterised by hills and some rare mixed forest.

For the 'fire season' 1998 (June-September) two different sets of Hot spots produced by the ATSR World Fire Atlas were analysed:

- Algorithm 1: 3.7 micrometers > 312 Kelvins (Saturation)
- Algorithm 2: 3.7 micrometers > 308 Kelvins

In the area of interest the two algorithm produced the following results:

	Description	Number
Algorithm 1	Hot spot 1998 Total (June-September)	32
	Hot spot 1998 due to Etna activity	26
	Hot spot 1998 Fires	**6**
	Intersections with TM Burned Area[a]	**3**
Algorithm 2	Hot spot 1998 Total (June-September)	56
	Hot spot 1998 due to Etna activity	40
	Hot spot 1998 Fires	**16**
	Intersections with TM Burned Area	**7**

[a] *The intersection was performed buffering the Hot Spot with a circumference of r=0.5km*

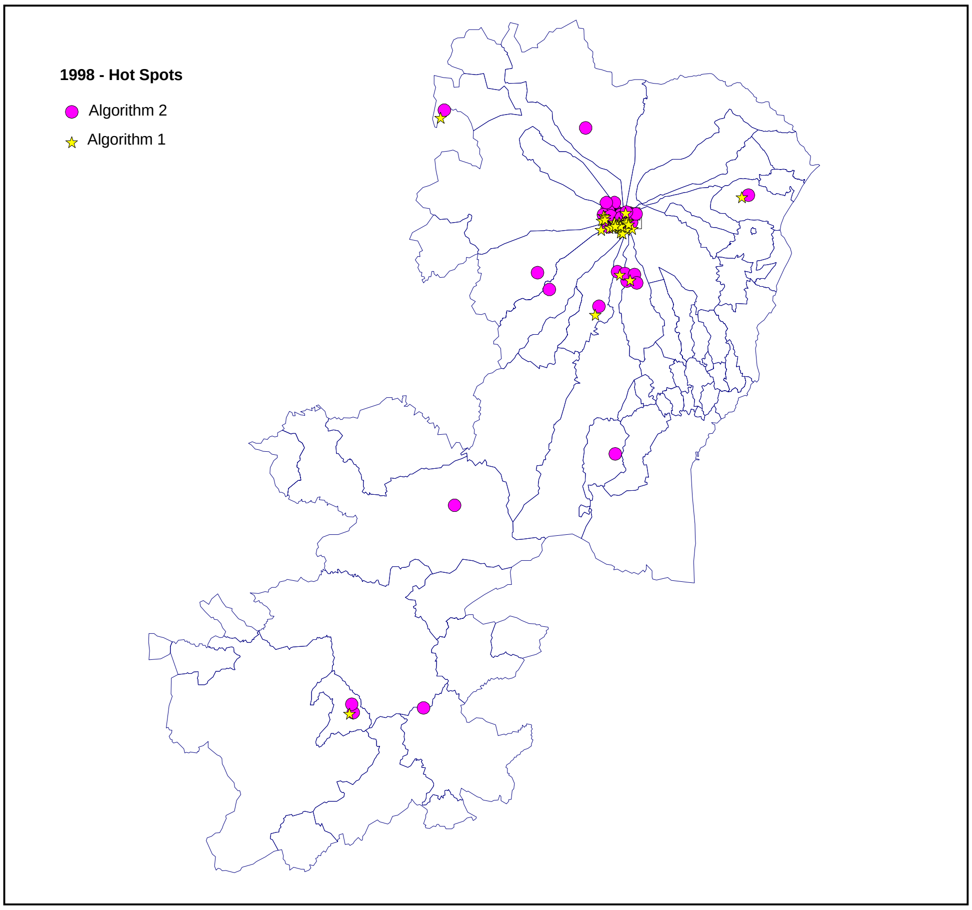


Fig. 1 – Hot Spots for 1998 with Algorithm 1 and 2

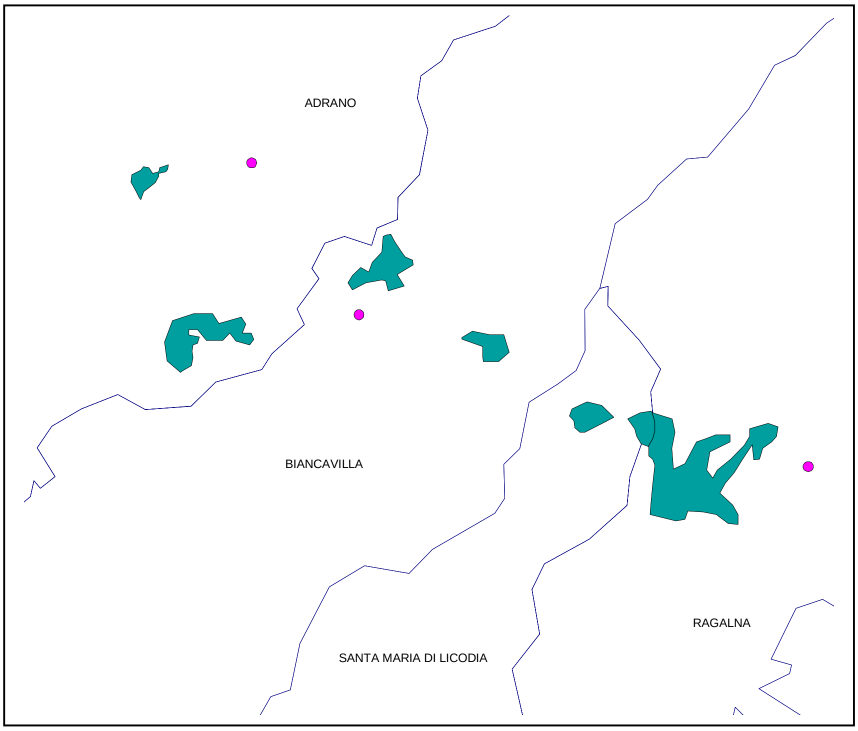


Fig. 2 – Example of Hot Spots and TM Burned Areas

The second algorithm gave the best results for the area of interest and was used in the analysis of the series for 1998 and 1997.

Tables 2 and 3 give the 'Success' in Hot Spot fire recognition. Fire Brigade and Corpo Forestale logs were scanned for the municipal areas with the Hot Spot detections.

Tab. 2: 1998 (June-September) – Success Table for Hot Spots

	Fires – Fire Brigades			Satellite Data		Fires Corpo Forestale	Hectares Burned (B) or Not (NB)			Success	
Municipality	*Trees*	*Sclerophyllous*	*Wood*	*HS*	*HS TM*	*CF*	*B CF*	*NB CF*	*B TM*	*Fire*	*#*
ADRANO	**3**	**10**	**0**	**1**	**1**	**2**	**40**	**20**	**14**	**30/6**	**1**
BIANCAVILLA	**2**	**7**	**3**	**1**	**1**	**1**	**2**	**1**	**27**	**3/7**	**1**
GRAMMICHELE	**1**	**2**	**0**	**2**	**2**	**4**	**55**	**0**	**41**	**3/7**	**1**
MASCALI	**5**	**0**	**0**	**1**	**1**	**7**	**1**	**1**	**5**	**3/7**	**1**
RAGALNA	**1**	**8**	**0**	**1**	**1**	**2**	**100**	**30**	**112**	**3/7**	**1**
RANDAZZO	**5**	**4**	**1**	**1**	**1**	**7**	**149**	**225**	**167**	**30/6**	**1**
VIZZINI	**3**	**0**	**1**	**1**	**1**	**5**	**4**	**196**	**67**	**1/7**	**1**
Totals	**20**	**31**	**5**	**8**	**8**	**28**	**351**	**473**	**433**		**7**

Total number of fires reported by CF: **91**
Total Burned Area for CF: **2435** Hectares
Total Burned Area for TM: **3121** Hectares

Legend

HS	*Hot Spot*
TM	*Landsat TM Burned Area*
CF	*Corpo Forestale*
B	*Burned Area*
NB	*Not-Burned Area*
Fire	*Date of match*

All the large fires were successfully detected by ATSR and there is a good relation between the burned areas reported in the logs and the TM burned areas.

For 1997 the same analysis was performed and the results are summarised in Tab.3.

Tab. 3: 1997 – Success Table for Hot Spots

	Fires – Fire Brigades			Satellite Data		Fires Corpo	Hectares Burned (B) or Not (NB)			Success	
Municipality	*Trees*	*Sclerophyllous*	*Wood*	*HS*	*HS TM*	*CF*	*B CF*	*NB CF*	*B*	*Fire*	*#*
GRAMMICHELE	**0**	**5**	**1**	**1**	**1**	**6**	**15**	**10**	**12**	**14 / 7**	**1**
MINEO	**1**	**0**	**0**	**1**	**1**	**1**	**15**	**10**	**12**	**14 / 7**	**1**
Totals	**1**	**5**	**1**	**2**	**2**	**7**	**30**	**20**	**24**		**2**

Total number of fires reported by CF: **84**
Total Burned Area for CF: **913** Hectares
Total Burned Area for TM: **1160** Hectares

The results for 1997 are in line with the results of 1998. In 1997 the total area burned was around 1/3 of the area burned in 1998. The success of the hotspots is therefore restricted to two cases against the 7 of 1998.

For the year 1999 the data sets considered are a bit different. The hotspots were derived from the Algorithm 1, there were no TM Burned Area Maps for comparison so the data are referred only to the Fire Brigade logs for the month of August. As shown in Fig. 4 the results are quite good with 5 cases of possible success in fire recognition. It is foreseen that the processing of the same data with Algorithm 2, the comparison with TM Burned Area Maps and with the logs for the Corpo Forestale dello Stato will give a better indication of the validity of ATSR in the detection of possible fires.

Conclusion

For the area of Catania the hotspots derived from Algorithm 2 have to be considered a valuable source of information for large fires or those of long duration.

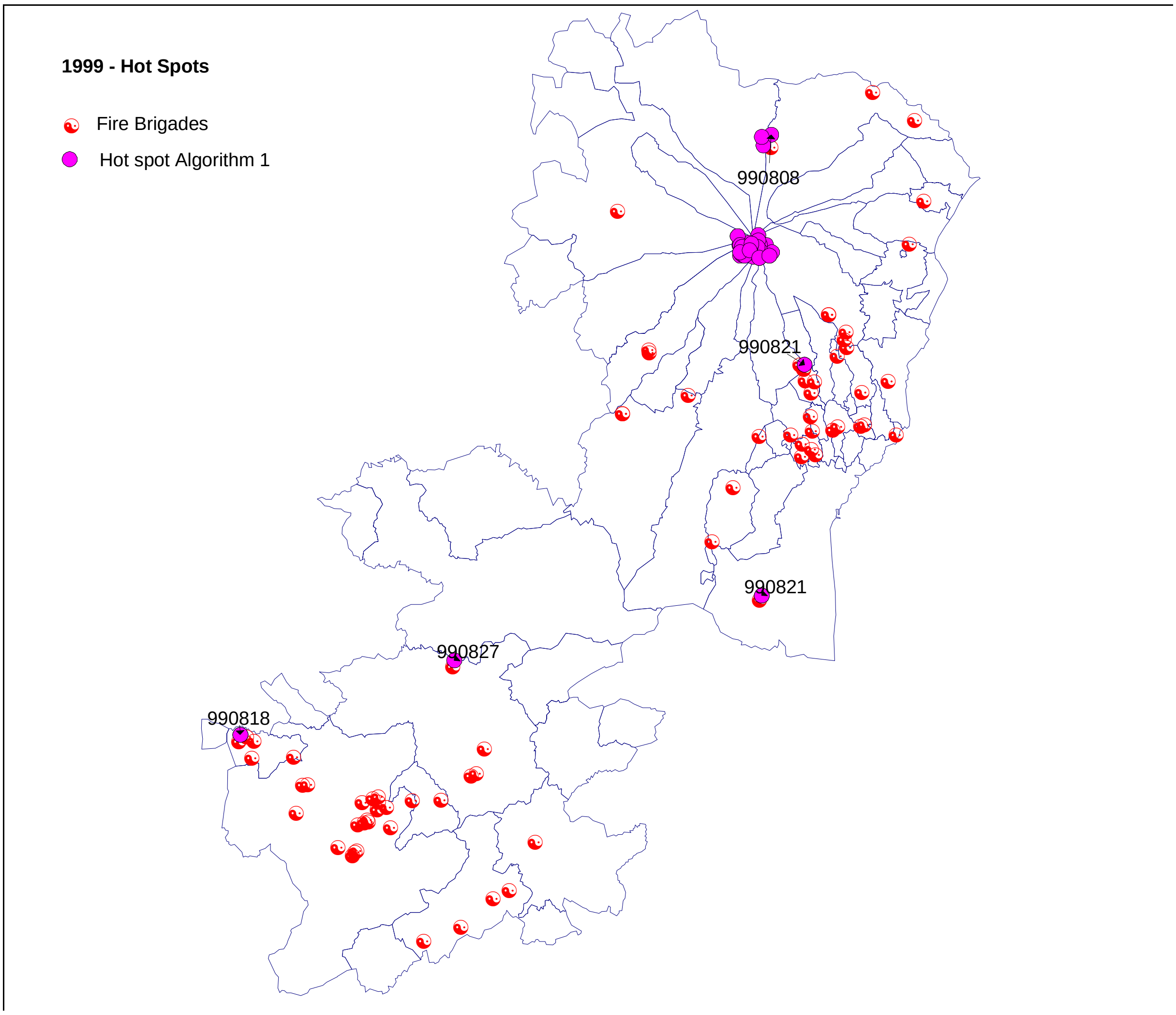


Fig 3 – Hot Spots and Fire Brigade logs – August 1999

Forest fires detected by the ATSR sensor over Northwest Spain during 1997

Antonio Vázquez de la Cueva, Federico González Alonso,
José Luis Casanova Roque & Abel Calle Montes

Introduction

The main objective of this report was to contrast the "hotspots" detected by the ATSR sensor against the forest fire data available in digital format at the Spanish Forest Fire Service. Additionally we present some data about the relationships between the ATSR data and a WiFS image showing the area burned by some of the detected fires.

The analysis was centred on Northwest Spain from –10° W and 5° E longitude and 36° S and 44° N latitude. The records selected were for 12 days during March and April 1997. These corresponded to days in which the ATSR detected a large number of "hotspots" and also the days with an active large fire (fires with >=250 ha burned). This accounted for 219 "hotspots". The detected fires (hot spots) are listed by day in Table 1.

Material and Methods

Forest fire data: "Fire Reports"
Forest fire data were obtained from the Area de Incendios Forestales in the Direccion General de Conservación de la Naturaleza (DGCONA). The only spatial information available in the fire reports was the administrative unit (council) in which fire started. We do not know the spatial coordinates of the area burned. The administrative division of Spain (in more than 8,000 units) was therefore the spatial reference for forest fire occurrence used in this report.

Criteria for the selection of active fires at satellite overpass
The selection of the administrative units with active forest fires at the time of ATSR overpass was performed according to the time registered in the detected "hotspots". For each of the 12 selected days (see later) an average time was computed for the "hotspots" detected over Spain. Based on these "average times" (for each day) we have applied two selection criteria:

- Criteria A: active fires at the time of satellite overpass. The selected fires were those that started at least one hour before and were extinguished at least one hour after the satellite pass.

- Criteria B: fires extinguished during the evening previous to ATSR passing. For this criterion we have selected only fires >= 50 ha (according to fire reports).

Qualitative checking procedure
Given the doubts about ATSR coverage for each day, we performed qualitative checking between fire activity and ATSR data over different areas each of the days. That is, in each of the 12 days we have sampled only a rectangle delimited by the detected hotspots. The analysis, summarised in Table 1, was carried out counting the administrative units with fires under the criteria A or B and counting the administrative units with at least one hot spot within its limits. Examples of two of the 12 days are in Figures 1 and 2.

WiFS data

We have used an IRS-1C WiFS image from May 1, 1997 in order to analyse the area burned. This image is very close to the dates of forest fire occurrence and the areas affected by the fires appear quite clear. Nevertheless, the high number of fires registered during the previous months make the assignment of burned patches to specific days very complicated. In this report we present two examples (Figures 4 and 5) overlaying the "hotspots" detected by ATSR on the WiFS image.

Results

Forest fire data by provinces and months during 1997

During 1997 the number of forest fires registered over Spain was 22,319 with a burned area close to 100,000 ha. The 7 provinces analysed (A Coruña, Lugo, Ourense, Pontevedra, Oviedo, León and Zamora) accounted for 17,289 fires and nearly 80,000 ha burned during 1997. Additionally, March and April were the months with the highest fire incidence in this area. In the 7 provinces analysed these two months accounted for 9,955 fires and near 65,000 ha burned. The 12 ATSR selected days belong to these two months (Table 1).

ATSR "hot spots" and administrative units with selected forest fires.

Based on the qualitative checking procedure, the agreement percentage between administrative units selected by criteria A or B and those with a "hotspot" within its boundary was dependent on the area burned in those administrative units (Table 1 and Figure 1).

For the administrative units with a burned area of less than 10 hectares the mean agreement percentage, for the 12 satellite overpasses, was 22%. For administrative units with an area burned between 10 and 50 ha this percentage increased to a 36%; for the administrative units with an area burned between 50 and 250 ha the mean agreement was 60% and increased to 76% for those administrative units with >=250 ha burned (although these burned surfaces could be due to one or more fires) (Table 1 and Figure 1).

Checking of large fires

Out of the 36 fires >250 ha registered in Spain during 1997, 25 were selected according to the established criteria (active fires or recently extinguished). Five of these fires were theoretically active in more than one satellite pass (Table 2). Additionally, in 6 cases there was doubt about the satellite coverage, reducing the dataset to 24 cases. In 11 of these 24 cases there was at least one "hot spot" in the administrative unit in which fire started. These data would mean an agreement close to 46%. Also in 3 cases there was more than one large fire active in the same administrative unit (assigned to the one in which the fire started). These cases were considered as only one agreement. It is important to note that in nearly half of these 11 cases there was more than one "hotspot" and up to a maximum of 6 contiguous "hot spots".

Discussion

Constraints due to the geographical extent of ATSR scenes

The selection of overpass days was based on the number of detected "hotspots" over Spain. The maximum number of "hot spots" was 60 for April 5, 1997. As we have explained previously the qualitative checking was limited to the rectangle delimited by the most extreme detected "hot spots". With this sub-sampling we limited the number of available "hot spots" or documented forest fires but we obtained a greater reliability. Nevertheless, we must remember that we have checked at an administrative unit level and in some cases there could be more than one active fire in the same administrative unit at the same time.

Constraints due to the cloud cover

Another major constraint was the cloud cover at the satellite pass given that clouds limit the “hotspot” detection. A quantitative analysis at a regional scale should take into consideration the cloud coverage.

Constraints due to the geolocalization of “hot spots”

The visual analysis performed with the WiFS image and the ATSR “hot spot” is a very useful tool to check for problems in the geolocalization of ATSR “hot spot” (Figure 2). The Figure 2 shows a more frequent situation: some of the “hotspots” were located over areas burned (and with active fires at the satellite pass).

Until now we have not performed and analysis based on individual forest fires given the large number of them registered in a short time period and the difficulties to assign a burned patch to a specific day or fire.

Constraints due to the available forest fires data

There are two main problems in relation to the forest fire data:

1. The two criteria used in this report (active fires or recently extinguished) do not make necessarily ensure that at the overpass of the ATSR there was a source of heat with the necessary extension or with enough intensity to be detected by the sensor.
2. In the spatial location of fires we have information about the administrative unit in which fire started but it could spread over contiguous administrative units. This is especially important in the case of large fires.

General validation

It is difficult to make a general validation of the agreement between the several data sources used in this report. Our first strategy has been the selection of theoretical active fires per administrative unit at the satellite overpass. The results show an increasing agreement for administrative units with larger area burned. This could be explained by the greater chance that in these administrative units, even with officially active fires, a large area burning at the satellite pass could be found. But it is important to note also the contrary situation: “hotspots” were detected in administrative units without active fires, at least according to the official data.

In relation to the large fire analysis, typically lasting several days, it would be necessary to use more detailed forest fire data. The problem of fires spreading out of the original administrative unit could be important in this kind of analysis. In general our results show an agreement under 50% although in some cases it is possible to track the fire spread given the high number of hot spots detected.

Finally the other checking procedure (using another image as the WiFS in our case) could be the more accurate but the difficulties in individualising the burned patches, the image resolution (180 m), and the doubts in the geolocalization of “hotspots”, prevent presentation of more detailed results in this report.

Table 1. Qualitative validation of the number of administrative units with active forest fires, number of administrative units with "hotspots" detected by ATSR and agreement percentage between both sources. Administrative units were classified according to the selection criteria: Crit. A means active fires (at least theoretically) and Crit. B fires recently extinguished. Additionally, administrative units selected by the criteria A were classified as a function of the area burned by the active fires for each of the analysed satellite passing.

3.1.1.1.1.1	**Number of administrative units with active or recently extinguised forest fires (1)**						**Number of adminstrative units with "hot spots" detected by ATSR (2)**							**Agreement percentages (1/2)**				
	Crit. A				Crit. B		Crit. A				Crit. B	Non active		Crit. A				Crit. B
	0.1-10	10-50	50-250	> 250			0.1-10	10-50	50-250	> 250				0.1-10	10-50	50-250	> 250	
1-March	2	7	5	1	3		0	1	1	1	1	5		0%	14%	20%	100%	33%
4-March	3	7	2	0	5		1	2	2	0	1	2		33%	29%	100%		20%
7-March	7	5	1	2	0		2	2	1	1	0	4		29%	40%	100%	50%	
10-March	2	3	5	0	1		0	2	4	0	0	1		0%	67%	80%		0%
17-March	6	2	6	1	1		2	1	2	0	0	5		33%	50%	33%	0%	0%
20-March	9	5	3	1	2		3	1	0	1	0	7		33%	20%	0%	100%	0%
23-March	14	5	6	3	3		3	1	4	3	1	5		21%	20%	67%	100%	33%
26-March	5	0	1	0	0		2	0	1	0	0	2		40%		100%		
30-March	1	6	4	0	0		0	1	2	0	0	0		0%	17%	50%		
2-April	7	8	2	1	1		1	4	1	1	0	1		14%	50%	50%	100%	0%
5-April	23	12	5	5	3		8	7	3	3	0	9		35%	58%	60%	60%	0%
21-April	0	0	0	1	0		0	0	0	1	0	0					100%	
Total	**79**	**60**	**40**	**15**	**19**		**22**	**22**	**21**	**11**	**3**	**41**						
Means														**22%**	**36%**	**60%**	**76%**	**11%**

Table 2. Detailed analysis of large forest fires (> 250 ha) theoretically actives at the satellite passing. The first three columns are the passing code, the date and the selection criteria for each of the analysed fires. The next columns indicate if there was satellite coverage over the administrative units (based on the visual appraisal), if there were hotspots over the affected administrative unit and the number of detected "hotspots". The last four columns show the province, the starting and extinguished date of the fire and the final area reported to be burned.

Satellite passing and selection criteria			**Forest fire detection**			**Forest fire data**			
Passing Code	*Date*	*Selection Criteria*	*Satelite coverage*	*"Hot spots" detected*	*Number of "hot spots"*	*Province*	*Starting date*	*Extinguished date*	*Final area burned (ha)*
6	1-March	A	YES	YES [a]	1 [a]	León	28/2/97	4/3/97	309.0
7	4-March	B	YES	NO	-				
6	1-March	A	YES	YES [a]	1 [a]	León	28/2/97	5/3/97	492.0
7	4-March	A	YES	NO	-	Oviedo	2/3/97	5/3/97	900.0
7	4-March	A	YES	NO		Oviedo	4/3/97	9/3/97	310.0
10	7-March	A	YES	NO					
10	7-March	A	YES	YES [b]	1 [b]	Oviedo	6/3/97	9/3/97	580.0
10	7-March	B	YES	YES [b]	1 [b]	Oviedo	7/3/97	7/3/97	250.0
10	7-March	A	YES	NO	-	León	7/3/97	9/3/97	313.0
10	7-March	A	YES	YES [1]	-	León	7/3/97	11/3/97	400.0
11	10-March	A	Doubt	NO	-	Oviedo	9/3/97	12/3/97	425.0
17	20-March	A	YES	YES	1	Oviedo	18/3/97	25/3/97	300.0
18	23-March	A	YES	YES	1				
18	23-March	B	Doubt	NO	-	León	21/3/97	23/3/97	415.0
18	23-March	A	YES	YES	4	León	22/3/97	25/3/97	443.0
19	26-March	A	Doubt	NO	-	Zamora	26/3/97	27/3/97	610.0
20	27-March	B	Doubt	NO	-				
22	30-March	A	Doubt	NO	-	León	28/3/97	2/4/97	395.0
23	2-apr	B	YES	YES [c]	4 [c]				
22	30-March	A	Doubt	NO	-	Lugo	29/3/97	1/4/97	875.0
22	30-March	A	YES	NO	-	Zamora	30/3/97	31/3/97	250.0
23	2-apr	A	YES	YES [c]	4 [c]	León	1/4/97	5/4/97	270.5
24	5-apr	A	YES	YES	1	León	3/4/97	7/4/97	610.0
24	5-apr	A	YES	NO	-	Oviedo	4/4/97	7/4/97	403.0
24	5-apr	A	YES	NO	-	Oviedo	4/4/97	7/4/97	796.0
24	5-apr	B	YES	NO	-	León	4/4/97	5/4/97	262.0
24	5-apr	A	YES	YES	4	Oviedo	5/4/97	9/4/97	349.0
24	5-apr	B	YES	YES	6	Avila	5/4/97	5/4/97	326.0
24	5-apr	A	YES	YES	2	Zamora	5/4/97	7/4/97	332.0
32	21-apr	A	YES	YES	2 (4)	Oviedo	18/4/97	22/4/97	400.0

Notes: (1) "Hotspots" near the starting administrative unit

(a) Impossible to discriminate between more than one active forest fire in the same administrative unit

(b) Idem

(c) Idem

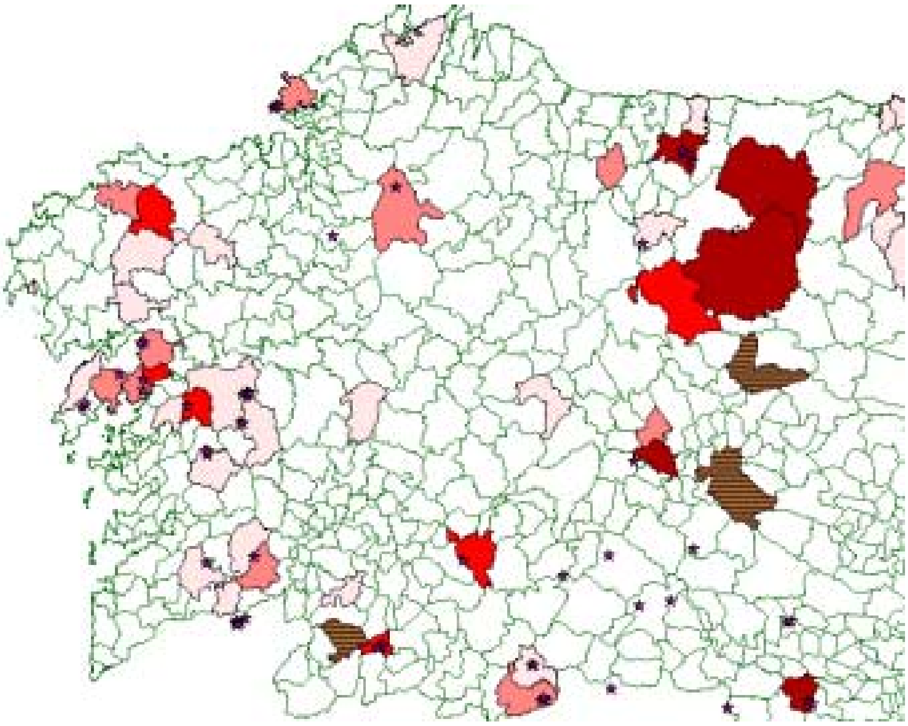


Figure 1. Area burned per administrative unit by the active fires (Criteria A) or recently extinguished (Criteria B) during April 5, 1997. Stars indicate ATSR “hotspots”. The four levels of red represent the area burned by the active fires (Criteria A) at the satellite pass: <10 ha (light pink); 10-50 ha; 50-250 and >250 ha (dark red). Brown units are those of the Criteria B (only for fires >50ha).

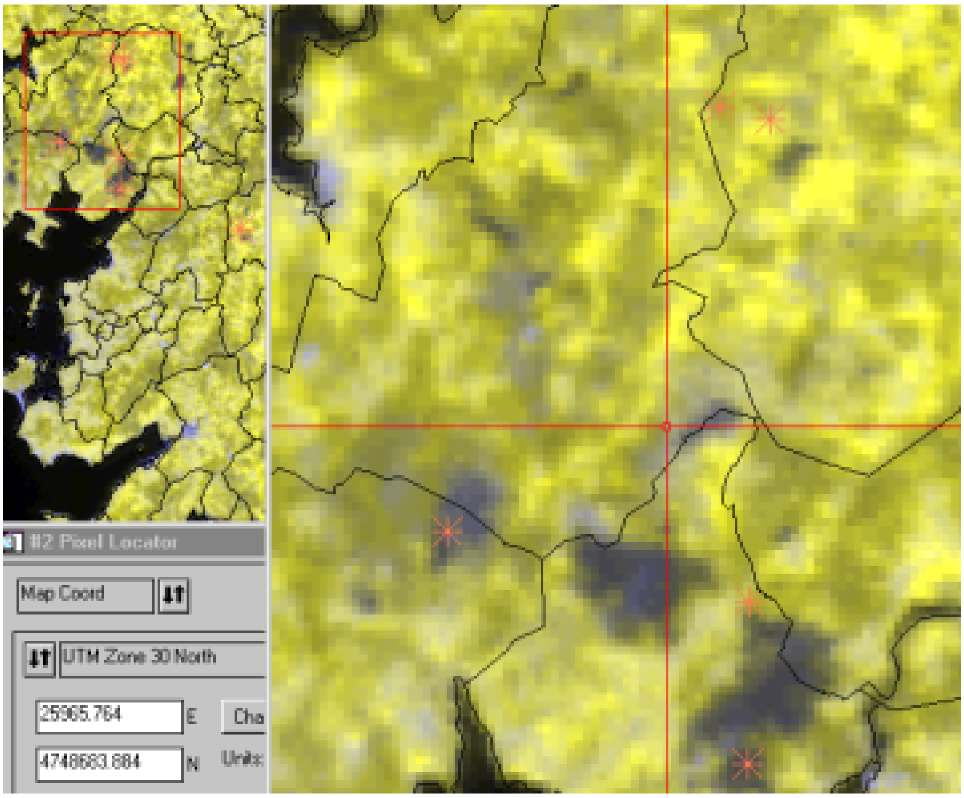


Figure 2. Example of “Hotspots” from April 5 (coral stars) overlaid over a WiFS image from May 1, 1997 In this example there is a close agreement of both data sources. Dark Grey areas are likely to be burned.

Validation of the ATSR Fire Atlas in Spain, 1997 Data

Pilar Martín and Emilio Chuvieco

Validation data

Data used for validation has been collected in situ by the forest fire fighting personnel and compiled by the Spanish Forest Service where an accurate database of forest fires is available. This database is organised in Dbase files where each record represents one fire. All fires, even those that affected a total area smaller than 0.1 hectares are registered. However, fire statistics do not include an accurate mapping of burned area, but only the 10 x 10 km UTM grid cell where the fire was detected. We have used those grid cells as a spatial reference for comparison with fires detected by the ATSR instrument.

According to the information on the detection sensitivity of the ATSR provided by Dr. Arino, we decided to use as validation data all fires occurring in Spain that affected a total area equal or larger than 0.1 ha. The 10 x 10 Km grid cells of all those detected fires have been represented in monthly maps and compared with the spatial location of fires discriminated by ATSR with algorithms 1 and 2 (see figures 1-3 below).

Assessment

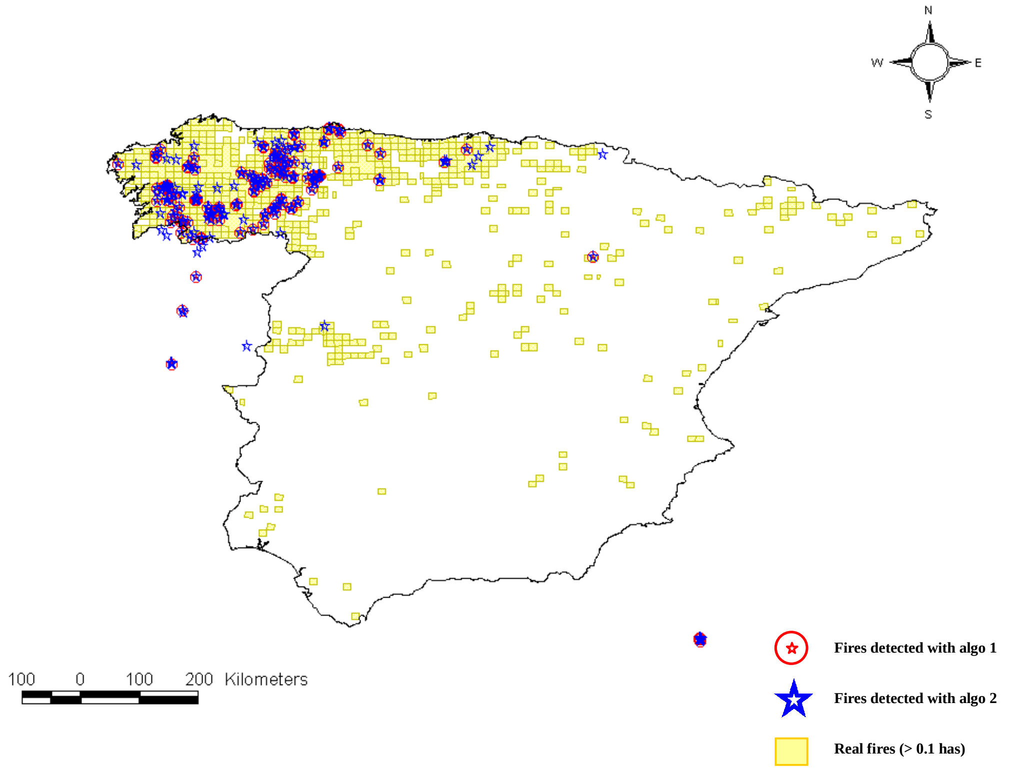
The first noticeable thing when analysing the maps is that a large number of fires have been missed by the system. Algorithm 2 seems to work a little bit better than algorithm 1 (less omission errors) but both methods tend to underestimate fire occurrence. These results can be a consequence of the minimum fire size used as a reference for comparison with ATSR. In Spain each year there are a large number of small fires that obviously the system is not able to detect. A more detailed study would allow us to check the size of those fires that were detected by the ATSR in order to better understand the real detection sensitivity of the system. However, it is interesting to notice that the system allow us to follow the general tendency of fire occurrence in Spain during 1997. During this atypical year, most of the fires occurred in spring (March and April), and not in summer (June to September) as usual. As can be observed in the maps, most of the fires detected by the ATSR also occurred in spring (March and April).

Some systematic commission errors can be observed in the north coast where all monthly maps include one or several fires, even in those months where no real fires where reported (see September maps, see figure 3 below). The same systematic error can be observed in the north coast of Africa.

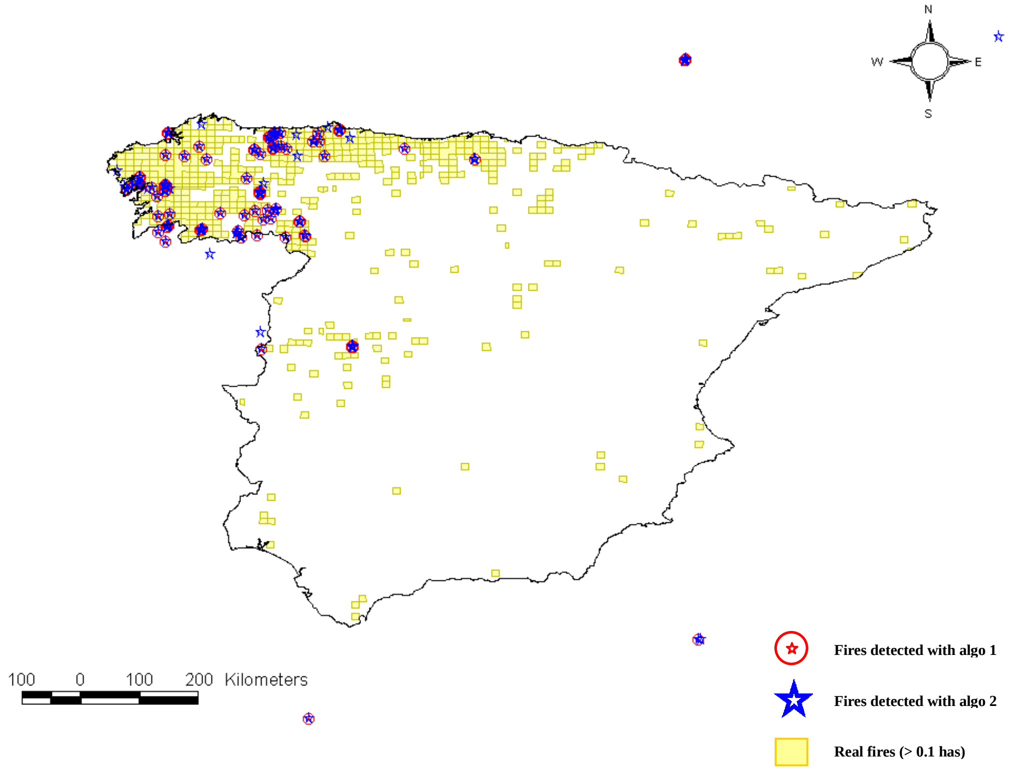
Further quantitative assessment would require establishment of specific thresholds of fire size to check the performance level of algorithms applied to ATSR data to different fire sizes and months. This assessment would allow to obtain cross-tabulation tables of omission and commission errors, but it would involve considerable additional analysis, since the current data are not suitable for this purpose.

Regarding the ATSR data we received for validation, we have realised that in some cases the monthly files include several fires located in the same geographic coordinates. It is not logical that several fires considered as separate events could occur in the same location during the same month. This problem should be checked in order to reduce commission errors.

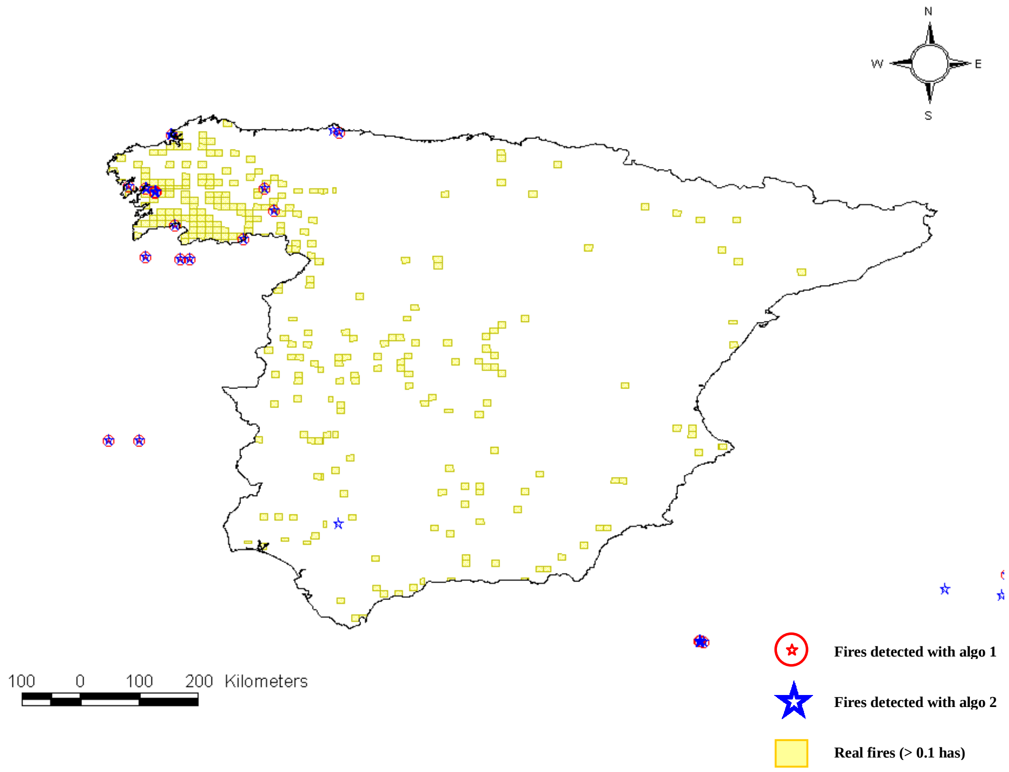
March 1997



April 1997



September 1997



Assessment of the ATSR-2 night time active fire product (Portugal, 1998)

José M.C. Pereira and Ana C.L. Sá

The ATSR-2 night time active fire data were compared with a map of burn scars derived from Landsat 5 TM imagery. This map is produced at a scale of 1:100 000, and contains the perimeters of all fires >= 5ha. The assessment was done by overlaying the ATSR-2 active fires detected with both algorithms, over a Landsat TM 743 RGB color composite, which also had the fire perimeters represented in vector format.

Some clear conclusions can be drawn:

1. The ATSR-2 night time active fires product severely underestimates fire activity over Portugal, during the period June-September 1998.
2. Conversely, omission errors are insignificant. The great majority of active fires detected can be clearly associated with a burn scar mapped with the TM. When this is not the case, the active fires are located in areas where fire is plausible, i.e. forests and shrublands. No active fires were found over agricultural regions, bare soils, rock outcrops, water bodies, or urban areas.
3. Some large fires were detected multiple times, i.e. there are several active fires for a single burn scar. But some of the largest fires of 1998 were never detected, including the largest fire of the year, which burned an area of over 6900ha, and lasted for a period of 4 days (from the morning of August 5 to the morning of August 9).
4. The regional distibution of fire activity is relatively well characterized, in geographic terms, with the already mentioned problem of severe underestimation. But the omission error appears to be relatively constant over the entire country, unrelated to climatic, topographic and land cover patterns.
5. The geographical positioning of the active fires appears to be very accurate. There was no need to co-register the two datsets, in spite of the scale difference between TM and ATSR.

We queried the Direcção Geral das Florestas (the Portuguese Forest Service) field records database for all fires in activity between 21:30 and 23:30, June-September, and derived the following quantitative comparison with the night time ATSR-2 active fires:

Month	DGF database	312ºK	308ºK
June	161	2	30
July	699	26	37
August	1875	216	314
September	386	17	30

These results quantify the level of underestimation of fire activity. They also indicate that the less restrictive threshold performs somewhat better, which is in agreement with the conclusions from our visual inspection of the active fires plotted over the colour composite.

Considering that the active fires detected by ATSR-2 at night appear to provide a reasonably good representation of the geographical pattern of fire activity, they may be adequate for integration in a burnt area mapping procedure, along the lines of the HANDS algorithm recently developed at the Canadian Centre for Remote Sensing.

ASIA

ATSR Fire Atlas Validation 1997 - Siberia, Mongolia, North China

Nickolay P. Minko

A validation of the fire atlas was performed for the analysis region with the boundaries of 73-151 degrees E and 46-68 degrees N from 4 April to 20 October 1997. The spatial and temporal limits were determined from the presence of hot spots identified in AVHRR/NOAA images. For the entire period of observation, within the above boundaries, 6001 and 8593 pixels, respectively, were identified by ATSR algorithms 1 and 2. According to the AVHRR/NOAA data, 21298 pixels were detected.

The ATSR data validation was carried out by searching for fires identified in ATSR images with similar NOAA data. The search was conducted from co-ordinates and the time. The time search was performed within the radius of three days, and the co-ordinate-based search was effected within the radius of 1.2 arcminutes. During the whole period of observation, 632 and 842 coincident points were identified for the 1st and 2^{nd} algorithms, respectively.

The basis for the second version of the analysis was the fact that large forest fires occupy several pixels and are seen during several days; therefore, we decided to compare not simply the co-ordinates of hot spots but combine them into fire areas and then compare the fires themselves. The preliminary data processing of the ATSR and AVHRR data involves identifying such fragments with a subsequent comparison of their co-ordinates. As a result of such processing, it was possible to identify 2009 fires (419 of them coincided with the AVHRR data) from the ATSR1 data, and 2678 fires (555 of them coincided with the AVHRR data) from the ATSR2 data.

Note that forest fires in the region with the above-mentioned boundaries were not recorded in 1997 on a regular basis until July. We have complete data on fires detected from AVHRR data for the territory of the Irkutsk region with the boundaries of 98-116 degrees E and 52-61 dgrees N. For this region, we have also a report of the Irkutsk aviation forest protection base, containing comprehensive information about all fires which occurred on the Irkutsk region's territory in 1997. We have therefore repeated the comparison of the ATSR and AVHRR data for the Irkutsk region's territory both with each other and with the aviation forest protection data. The analysis period covered the time interval from 3 April to 17 October. The number of AVHRR points is 5475, and the number of ATSR points is 790 for the 1st algorithm and 1189 for the 2nd algorithm.

The number of ATSR pixels that coincided with the fire coordinates, according to the report of the aviation forest protection, is:

1st algorithm of ATSR	58
2nd algorithm of ATSR	99
AVHRR method	135

The number of ATSR pixels that coincided with the AVHRR data is:

1st algorithm of ATSR	78
2nd algorithm of ATSR	123

By consideration of hotspot accumulations as fires 790 hot spots for algorithm 1 and 1189 for algorithm 2 transform to 306 and 410 fires, respectively. Of these 141 and 186 fires, coincide with the data AVHRR respectively, while 114 and 157 fires coincided with the data of the aviation forest protection. For the AVHRR data, 416 of the 1338 fires coincided with the aviation protection data.

In our opinion, the low percentage of coincidence of the ATSR data with the AVHRR data is caused by the high value of threshold *BT3.7*. For the 21298 hot spots that were identified from the AVHRR data in 1997 the distribution of BT3 reveals that 45% of the hot spots have a brightness temperature below 308K and cannot be recorded with the ATSR algorithm.

Monitoring of 1997/1998 Fires and Burnt Scars in Central Kalimantan, Indonesia

Dr. H.-D.V. Böhm and F. Siegert

Central Kalimantan covers an area of 153,564 km² which is 28% of the total area of Kalimantan. The southern part of the province consists of lowlands and wetlands (mostly peatland), constituting a total of 36,716 km² or 24% of the total extent of the province. This area comprises 812 km² of coastal plains, 12392 km² of alluvial plains (including floodplains), 1,027 km² of tidal swamps, and 22,485 km² of peat swamps. The middle and northern belts of the land vary from low-altitude uplands to rolling hills with a height of up to 2,500 m (the Schwaner and Muller Mountains at the northern boundary).

Indonesia has a large amount of tropical peat (between 17 and 27 Million ha), located mainly on the three islands Sumatra, Kalimantan and Irian Jaya. Peat age varies from several hundred years up to 15,000 years. In the last few decades the size of the peat area has been shrinking continually due to conversion into land use. Peatland ecosystems are not only amongst earth's most important ecosystems, but are also well known for their extreme fragility. Their huge carbon content is well known.

The "Mega-Rice-Project" was initiated in 1995 by Presidential Decree No. 82. (Development of One Million Hectares of Peatland for Food Crop Production in the Province of Central Kalimantan, Peat reclamation) between the Rivers Sebangau in the west, River Kahayan, River Kapuas and River Barito in the east and the Java Sea in the South (figs.1. and 2). In 1997, Central Kalimantan was one of three main regions in Indonesia where forests and peatlands were on fire. The "Mega-Rice-Project" was a major location of "hot spots" because burning for land clearance had been started at the onset of the dry season. It is now estimated that up to **one billion tons of carbon** were released during the fires of July-October 1997. This equals the entire European output of one year. Burning and oxidisation of peat are largely responsible for these huge releases.

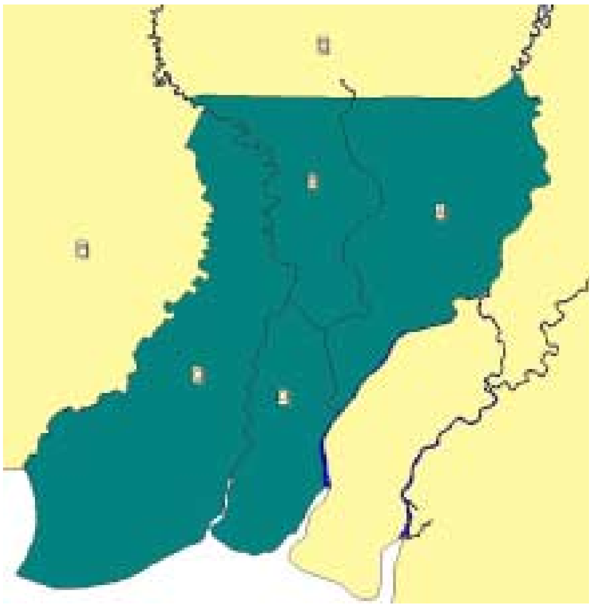


Fig. 1: Island of Borneo with the Indonesian Province of Kalimantan highlighted.
Fig. 2: Mega Rice Project with Blocks A, B, C, D and E and pristine Peatland P.

We have used LANDSAT TM images and ATSR data to investigate the ecological impact for this large scale development project.

2. Methods

Results obtained from remotely sensed vegetation as well as peat and land use mapping have been linked to extensive field surveys, ecological studies and laboratory analyses within the frame of the EU-project, *Natural Resource Functions, Biodiversity and Sustainable Management of Tropical Peatlands*. Natural, secondary, developed and degraded peat swamp forest (PSF) has been investigated. Species have been documented, compared and evaluated while peatland area, peat thickness, geochemistry, hydrology and hydrochemistry, forest sub-types and structure, tree biomass and nutrient dynamics are being determined for the purpose of understanding the ecological processes and natural resource functions of tropical peatland and the impact of development thereon.

The purpose of the aerial survey and ground truth campaigns was to verify the classified signatures of the satellite images in peatland areas of Central Kalimantan and to monitor the rapid changing of the landscapes. The aerial survey flight was carried out on 7 August 1999 over the pristine PSF between rivers Sebangau and Katingan and the Mega Rice Project over Block B and C. Heavy illegal logging could be monitored at the edge of rivers Sebangau and Katingan. The PSF exhibits many burn scars mainly in Blocks B and C.

3. Results and Findings

In 1997, Central Kalimantan was one of three main regions in Indonesia where forests and peatlands were on fire.

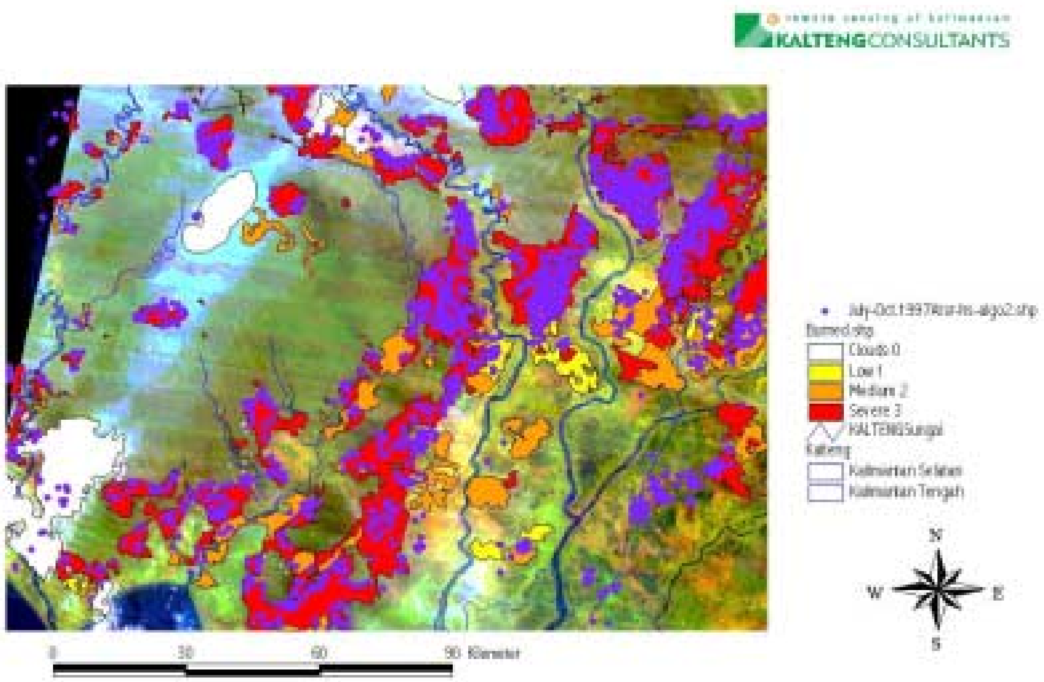


Fig. 3: ATSR-Hot Spots in blue acquired in 1997 superimposed on a LANDSAT image (RGB=543) from 29 March 1998 with visually delineated burnt scars in red. Clouds are white.

The "Mega-Rice-Project" was one major location of "hot spots" because burning for land clearance for the project started at the onset of the dry season. Most of the fires were man made, see Figure 3.

4. Conclusion

Satellite images from 1998 compared to those from 1997 and 1996 show rapid conversion of Peat Swamp Forest areas. This change was caused by the huge fires of 1997 and 1998 combined with the MRP activities. Frequent fires give forests no time to recover and the tropical climate causes quick overgrowth by ferns and alang-alang. Most of the Kalteng fires in 1997/1998 were man-made. Fire was used for cheap land clearing in the framework of the MRP. Huge amounts of stored carbon were released into the atmosphere. A very good agreement was observed between ATSR Hotspots and Landsat TM burned areas (figure 3).

Comparison of ATSR and NOAA AVHRR hotspot data acquired during an exceptional fire event in Kalimantan (Indonesia)

F. Siegert, A. Hoffmann & S. Kuntz

Introduction

In 1997/98 Indonesia experienced one of the worst fire disasters ever observed on earth. Fires started by men and driven by the exceptional El-Niño event evolved into uncontrolled wildfires which destroyed large areas of lowland dipterocarp forest, peat swamp forest, heath forest and grassland. The European ERS-2 satellite is of particular interest for fire monitoring and burned scar mapping since it has complementary instruments like the optical ATSR and the microwave SAR sensors onboard. The low spatial resolution ATSR-2 instrument allows the detection of active fires during night acquisition using its thermal infrared channel centered at 3.7 µm. The ERS-2 SAR sensor provides a much higher spatial resolution of 25 m and is able to deliver images also when haze and clouds cover the area. The NOAA-AVHRR sensor detects the presence of active fires at a similar wavelength and resolution as ATSR (channel 3, 3.8 µm, ~1.1 km^2), but both day and night. The objective of this study was to compare the capabilities of the ERS-2 ATSR and NOAA-AVHRR instruments for fire detection by comparison with known burned area information from Landsat TM.

Material and Methods

The ATSR data were provided in the framework of the ATSR Fire Atlas Validation study by ESRIN/ESA for the period April 1997 and September 1998 . ESRIN processed the ATSR images with two different algorithms, i.e. a threshold of 312 Kelvin (algorithm 1) or a threshold of 308 Kelvin (algorithm 2). Along with AVHRR hotspots acquired these data were imported into an ARCVIEW GIS to compare the spatio-temporal pattern of hotspots detected by both optical systems and the burned scars mapped by Landsat TM (or alternatively ERS SAR). In this case a Landsat TM image acquired after the fire event (118-62, 29.3.1998) was used for the comparison.

Results

Between August and November 1997 both the NOAA AVHRR and ATSR system acquired images regularly. Therefore we used this period for our investigation. **Figure 1A** shows the island of Borneo and all hotspots detected by the ATSR (purple) and AVHRR (yellow) instruments in that period. **Figure 1B** shows hotspots detected by the two instruments on the same dates in 1997.

Most hotspots are concentrated in the southern province of Central Kalimantan. During the fire season of 1997/98 the processing window of the NOAA-AVHRR images used ends at the western edge of Borneo and also did not cover the northern Malaysian province of Sabah. Furthermore there were technical difficulties with the sea mask, which normally prevents false alarm detection over the sea. Therefore a small strip along the whole coast of Borneo was excluded from the fire detection.

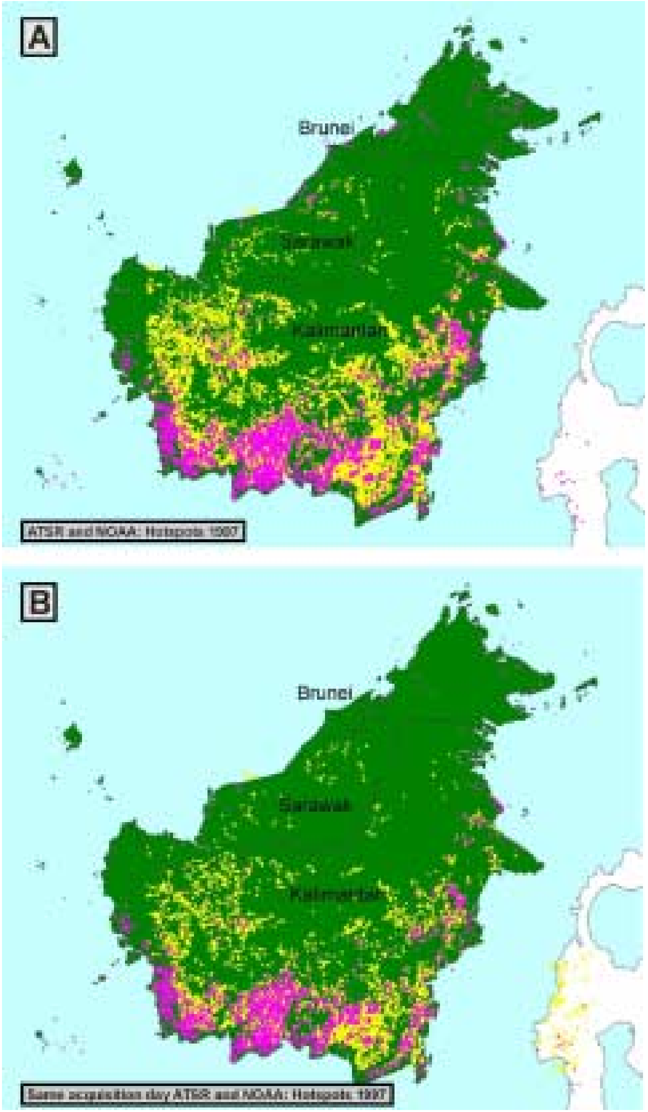


Figure 1: A. ATSR and NOAA hotspots in Borneo 1997. B ATSR and NOAA hotspots acquired at same dates in 1997.

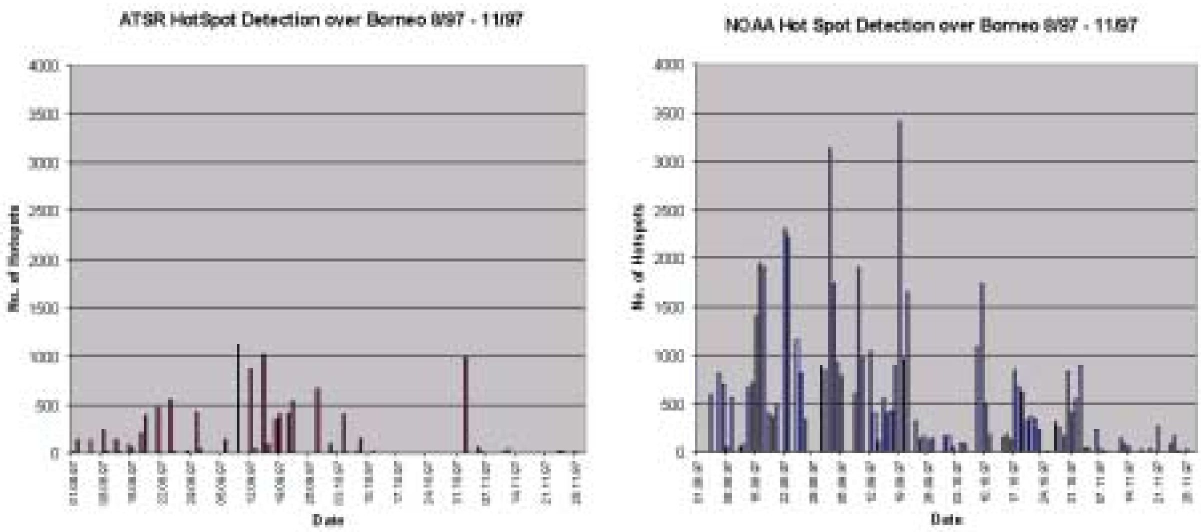


Figure 2. Comparison of ATSR and NOAA derived hotspots

Fewer hotspots were found by both systems in the central mountainous region of Borneo and the Malaysian Provinces Sarawak and Sabah. Many more hotspots were detected using the NOAA 14 satellite night and day time overpasses. Fires detected by ATSR can be considered as highly likely, however some fires can be missed because of high threshold temperatures. Making the algorithm more resilient to misinterpretation results in greater omission of fires. Furthermore NOAA AVHRR 14 images can be received two times a day while ERS ATSR images are available only every three days over this geographic area. Between August and November 1997 97 NOAA AVHRR images were acquired over the test site and only 50 ATSR images. **Figure 2** shows a quantitative comparison of all acquired hotspots by both systems. On average 2-3 times more hotspots were acquired using AVHRR night and day time images than the ATSR night-time images only.

In order to further evaluate the spatial accuracy of the hotspots we processed (channel combination 5,4,3) a Landsat TM image acquired 5 months after the fires of March 1998. To measure the extent of the burned area we performed a visual interpretation of all burned scars at a scale of 1:100,000 by visually delineating red colored surfaces and assigning three different damage classes. The total burned area was calculated to be 568,000 hectares.

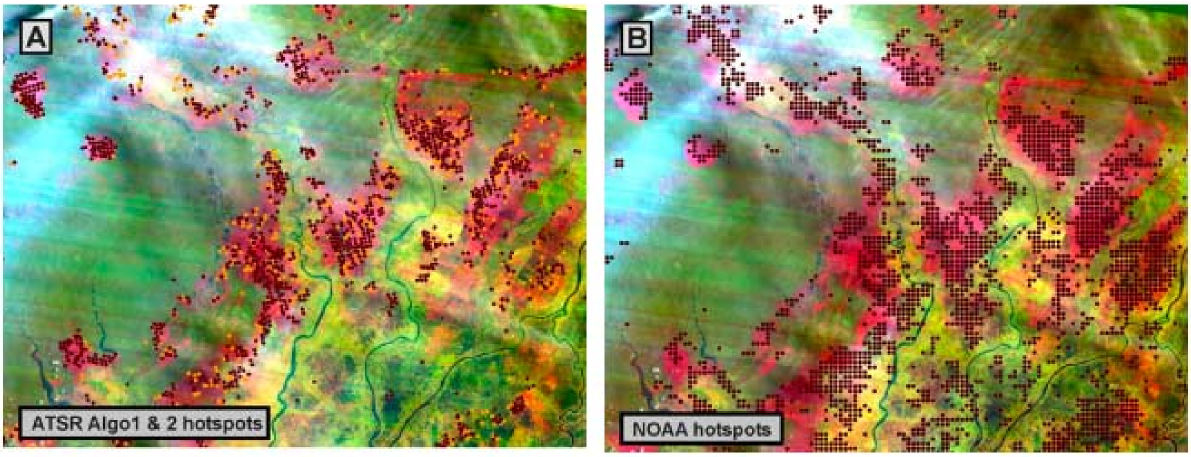


Figure 3. Comparison of ATSR and NOAA derived hotspots overlaid on a Landsat TM image.

Initially hotspots from the ATSR (**Figure 3A**) and the AVHRR system (**Figure 3B**) were overlaid on the Landsat TM image. **Figure 3A** shows that the spatial accuracy of ATSR hotspots (algorithm 1+2) is generally very good, although the size of the burned area is severely underestimated. Since there was only a slight difference between the two algorithms we restricted a further quantitative evaluation to algorithm 2. **Figure 3B** shows all NOAA AVHRR hotspots at the same acquisition dates as ATSR. The NOAA system achieves a similar spatial accuracy to the ATSR system, however, many more hotspots were selected. If day and night time acquisitions were discriminated a very good agreement between ATSR and AVHRR night time hotspots was found (not shown).

Conclusion

In 1997 and 1998 uncontrolled fires devastated huge tracts of tropical rainforests in Kalimantan on the island of Borneo in Indonesia. Here we report on results of a comparative study of ERS-2 ATSR hotspot and NOAA-AVHRR hotspot data used to analyse the extent of this disaster. A burned scar map derived from a Landsat TM image acquired after the fires and extensive ground data were used to assess the accuracy of both systems in fire detection and burned scar mapping. With both it was possible to detect most burned scars. Complete mapping was probably impeded by thick haze which covered the area during active burning. Significantly more hotspots were detected by the NOAA AVHRR 14 system, which covers the area of Indonesia 2 times a day and acquires images at day and night. ATSR derived hotspots showed a slightly higher spatial accuracy than NOAA. By calculating the burned area from the hotspot data and its comparison to the Landsat TM derived burned scar map it was found that ATSR strongly underestimates the fire affected area using the presently applied algorithms, while NOAA AVHRR with day and night acquisitions slightly overestimates the burned area.

ATSR Night fires, South East Asia - 1997

Jurgen Stibig

Jan	**Fire season continental SE Asia, small 'dry' season insular SE Asia** more fires expected in cont. SE Asia, however many of them are day fires due to shifting cultivation
Feb	**Fire season continental SE Asia, small 'dry' season insular SE Asia** fires due to shifting cultivation, in deciduous forests, on harvested rice fields
Mar	**High Fire season continental SE Asia, No Fire Season insular** fires due to shifting cultivation, in deciduous forests, more fires on harvested rice fields (e.g. Thailand) some fires on insular SE Asia mainly in plantation/agricultural areas on Sumatra, Borneo & Sarawak
April	**High Fire season continental SE Asia, No Fire Season insular** More fires expected
May	**End fire season continental SE Asia, No Fire Season insular** Some fires on insular SE Asia mainly in plantation/agricultural areas on Sumatra, Borneo & Sarawak
June	Some fires on insular SE Asia mainly in plantation/agricultural areas on Sumatra, Borneo & Sarawak
Jul	**Start Fire season insular SE Asia** fires on insular SE Asia mainly in plantation areas on Sumatra and agricultural areas on Borneo
Aug	**Fire season insular SE Asia** fires on insular SE Asia mainly in plantation areas on Sumatra and agricultural areas on Borneo, but including forest areas fires on PNG in deciduous shrub-forest area
Sep	**Fire season insular SE Asia** As above, further extension of fires to forested areas on all 3 islands, also to E-Kalimantan. Further extension on PNG, mainly into deciduous forest and shrubland, but also evergreen forest affected. Non-forest parts in the mountains.
Oct	**Fire season insular SE Asia** Situation as above
Nov	**End fire season insular SE Asia** Continuation of fires
Dec	**Start Fire season continental SE Asia, Limited fires insular SE Asia** Remaining fires in agriculture and plantation parts of insular SE Asia. First fires on Myanmar.

- cannot verify & interpret single fires
- difficult to say from here whether alg1 or alg 2 better, sometime alg2 appears to be too high
- however depends also on scale and display size of fires
- displays 'normal' seasonal cycle, overlaid by the intensive fires on Kalimantan/ Sumatra

AUSTRALIA

Validation of suitable ERS-2 ATSR night-time 3.7 μm threshold brightness temperatures using AVHRR fire scar maps from Australia

Sindre Langaas, Jackie Marsden, Natalie Raisbeck and Mike Steber

Introduction

This paper reports on the findings from Western Australia and the Northern Territory, Australia, an area with considerable fire activity. The analysis uses fire scar maps derived from AVHRR data. by the Satellite Remote Sensing Services, Department of Land Administration, Perth, Western Australia (WA).

Material and method

ATSR data
The ATSR hot spot detection data was provided as global, monthly data sets with the locations of detected fires given as latitude - longitude co-ordinates in ASCII format for the two candidate threshold temperatures. These files were converted via IDRISI into ArcView shape format for display and analysis.

AVHRR fire scar data
DOLA is currently operationally mapping fire scars for WA and the Northern Territory (NT) under the framework of the FireWatch project (Craig et al. 1995, McMillan et al. 1997). This activity started in 1994 when DOLA began operational mapping of fire scars in the Kimberley region of Western Australia (WA). Previously this was done only when requested by the Bush Fire Service of WA. The mapping was expanded to cover the entire state of WA and from 1996 onwards the Northern Territory (NT) was included. Now the entire Australian continent is being covered. From a global perspective, the operational and applied dimensions of this AVHRR based fire scar mapping enterprise are rather unique and therefore of great interest outside Australia.

The data processing approaches used involve an in-house change analysis and visual interpretation technique involving channels 2, 3 and 5 from the afternoon overpass of NOAA-AVHRR. The selected channels of the current data are combined with similar channel data from within the previous 9 days cycle using a differencing technique, and displayed for visual discrimination of fire scars and subsequent on-screen digitising to map the fire scars.

Screen colour	Difference image
Red	DN ch. 2 (current) - DN ch. 2 (previous)
Green	DN ch. 3 (current) - DN ch. 3 (previous)
Blue	DN ch. 5 (previous) - DN ch. 5 (current)

The fire scars, or more correctly fire-affected areas, are observed as dark regions against the surrounding background. Individual bands are also viewed to check for the presence of clouds and cloud shadow. DOLA also automatically detects fire hotspots, and those from the periods covered by the change (difference) image are used as an indicator of where fire scars may exist.

It should be noted that AVHRR fire scar mapping implicitly does not suppose that the areas burnt are completely burnt. It is known that considerable areas may be left unburned, particularly during the early dry season. The 'average' fraction unburned for any particular time period or region is not known.

In 1997 the AVHRR fire scar mapping did not start until April for WA and the NT, and for the NT the last month was November. However, the very small areas normally burnt during the remaining period of the year (the wet season) for the area concerned are not believed to be of any major importance in the analysis.

A thematic quality assessment of the AVHRR fire scar maps have recently been conducted for the Kimberley region, WA, using airborne transect data acquired at three different points in time in 1997 and 1998 (Langaas et al. 1999). The overall accuracy values were found to be in the range of 70 - 90%.

Methods
In this validation exercise we chose to use two very simple validation techniques:

- Visual analysis of a combined map depicting all the hot spot locations for both threshold temperatures and the mapped AVHRR fire scars
- Number of ATSR fire pixels within and outside fire scar polygons for both regions, NT and WA.

Results and discussion

The results are presented in the two figures below, the first being the combined map and the second being a graphical representation of the percentages of ATSR fire pixels outside and inside the AVHRR fire scars.

The main considerations in the validation using the present reference data will be the risk of errors of omission and commission. In particular, the risk that non-fire but still hot areas are detected using the cooler temperature threshold needs particular attention. Both figures quite clearly show that there is no major risk for many non-fire areas being included in the 308K case. Thus the risk of errors of commission is fairly limited. In particular, Figure 2 shows that the percentages of fire pixels found inside and outside the fire scars are virtually identical for the two threshold temperatures.

There are notable differences in the percentages of ATSR fire pixels that are found within the fire scars between NT and WA, being around 70% and 30%, respectively. An explanation to this may be the more numerous small agricultural and low biomass fires in WA compared to NT where most biomass burning is represented by extensive bushfires. The use of the most conservative threshold temperature, saturation at 312K, results in many errors of omission. This clearly suggests that based upon the present validation data and case area that a ATSR 3.7 μm brightness temperature of 308K is the most appropriate to use for the ATSR Fire Atlas Project.

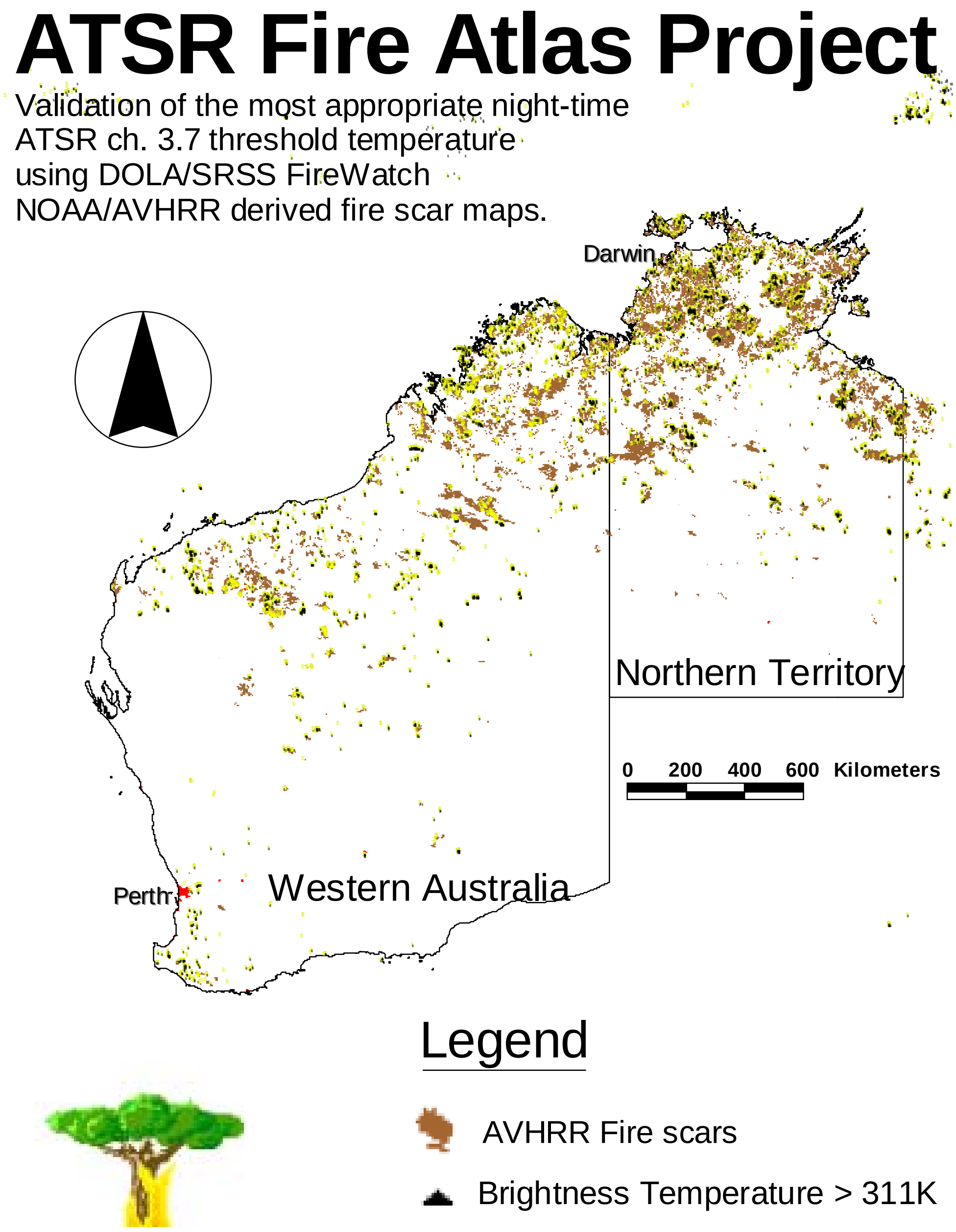


Figure 1. Map showing the distribution of ATSR fire pixels and AVHRR fire scars, WA and NT 1997.

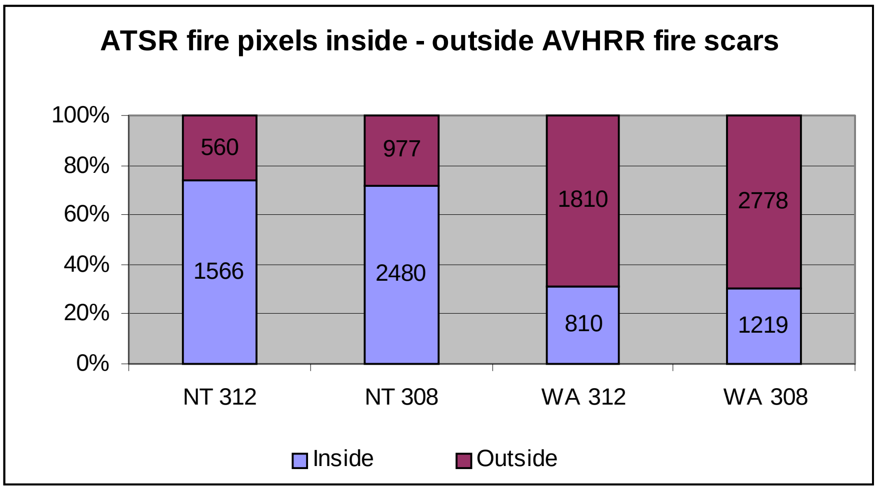


Figure 2. The percentage of ATSR fire pixels inside and outside the DOLA AVHRR fire scars, for NT and WA, and 312 and 308K, respectively. Actual numbers are shown in the bars.

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NORTH AMERICA

Validation of the ATSR World Fire Atlas using the NRCAN Large Fire Database: Ontario and Quebec 1997

Brian Stocks

Ontario

Fires detected via satellite using Algorithm 2 (308K)

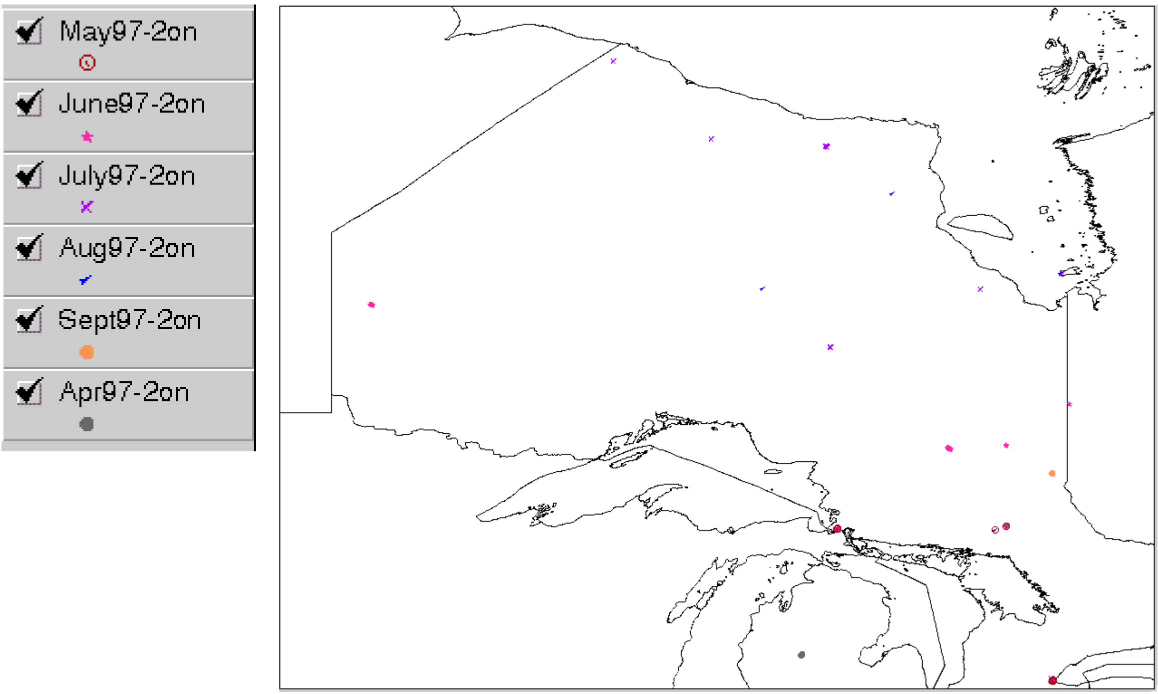


Figure 1: Every potential fire that was detected using Algorithm 2 in Ontario.

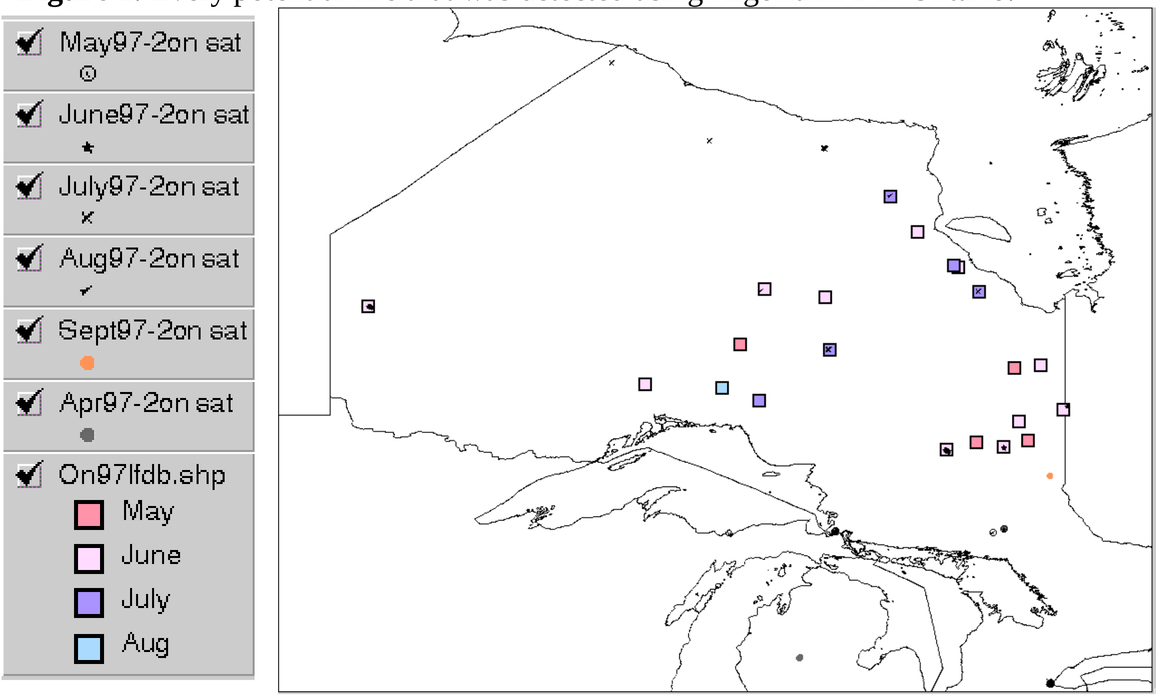


Figure 2: Match between LFDB and fires detected by Algorithm 2. To notice a satellite fire "hit" one of the designators must be within one of the coloured boxes.

There are 8 boxes in this diagram that have a point from the satellite data within them. This means that the satellite only detected 8 of the 21 fires that were over 100 ha

Fires in LFDB that were detected in Ontario

Table 1 provides details of the fires which were detected in Ontario (bold) and those which were not

Longitude	Latitude	Area Burned (ha)	Start Month	Start Day
-94.3630	**51.303**	**1873**	**6**	**3**
-85.9067	**51.6755**	**675**	**6**	**9**
-84.5338	**50.3911**	**380**	**7**	**18**
-83.2311	**53.6394**	**2250**	**7**	**22**
-82.0309	**48.2691**	**3266**	**6**	**10**
-81.3539	**51.6190**	**8500**	**7**	**25**
-80.8179	**48.3185**	**9538**	**6**	**7**
-79.5477	**49.1057**	**569**	**6**	**10**
-88.4612	49.6408	200	6	11
-86.8271	49.5779	100	8	25
-86.4290	50.4940	136	5	30
-86.0233	49.3086	142	7	31
-84.6233	51.4920	480	6	30
-82.6646	52.8890	650	6	2
-81.8849	52.1826	480	7	21
-81.7815	52.1294	130	6	18
-81.4122	48.4196	204	5	29
-80.5953	50.0046	*4155*	5	31
-80.4956	48.8528	*2514*	6	5
-80.3034	48.4605	120	5	29
-80.0361	50.0553	213	6	7

Ontario Satellite Discussion

It would appear that on every month major industrial cities, such as Sault Ste Marie (Steel Plant), Sudbury (Mine and Refinery), and Hamilton are detected as fires. The satellite also missed some relatively large fires of about 4100 and 2500 ha (italics), even though the process detected 3 other fires that were under 1000 ha. The only difference between algorithm 1 and algorithm 2 in this instance was algorithm 1 had one less false positive.

Quebec

Fires detected via satellite using Algorithm 2 (308K)

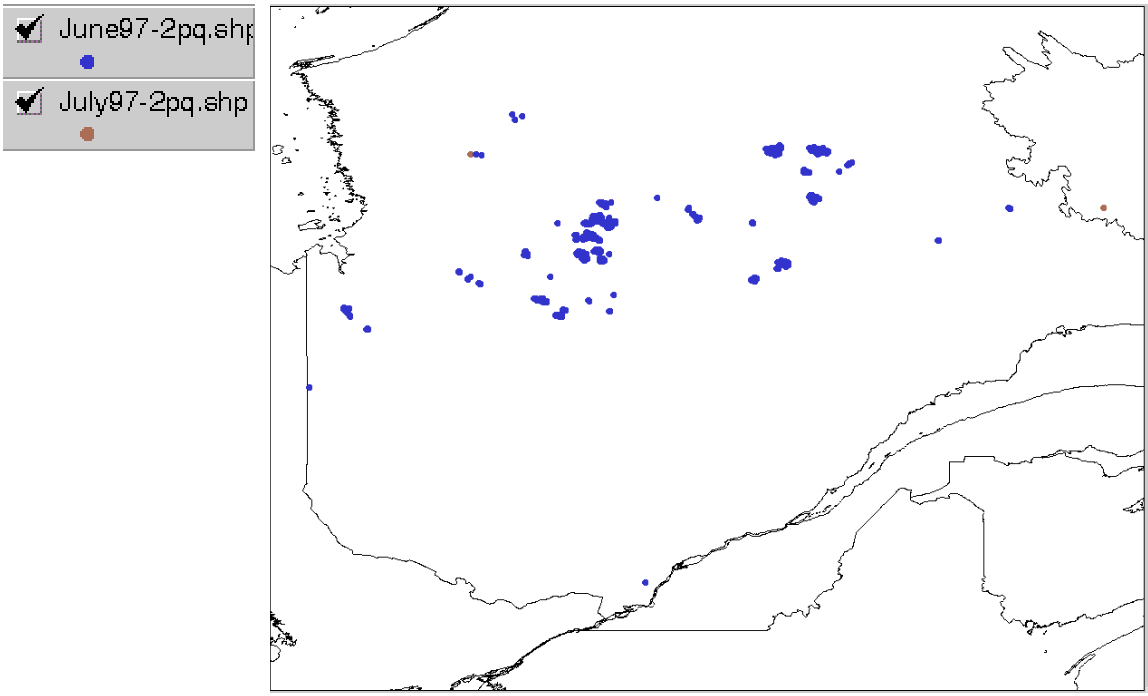


Figure 3: Potential fires detected by Algorithm 2 in Quebec

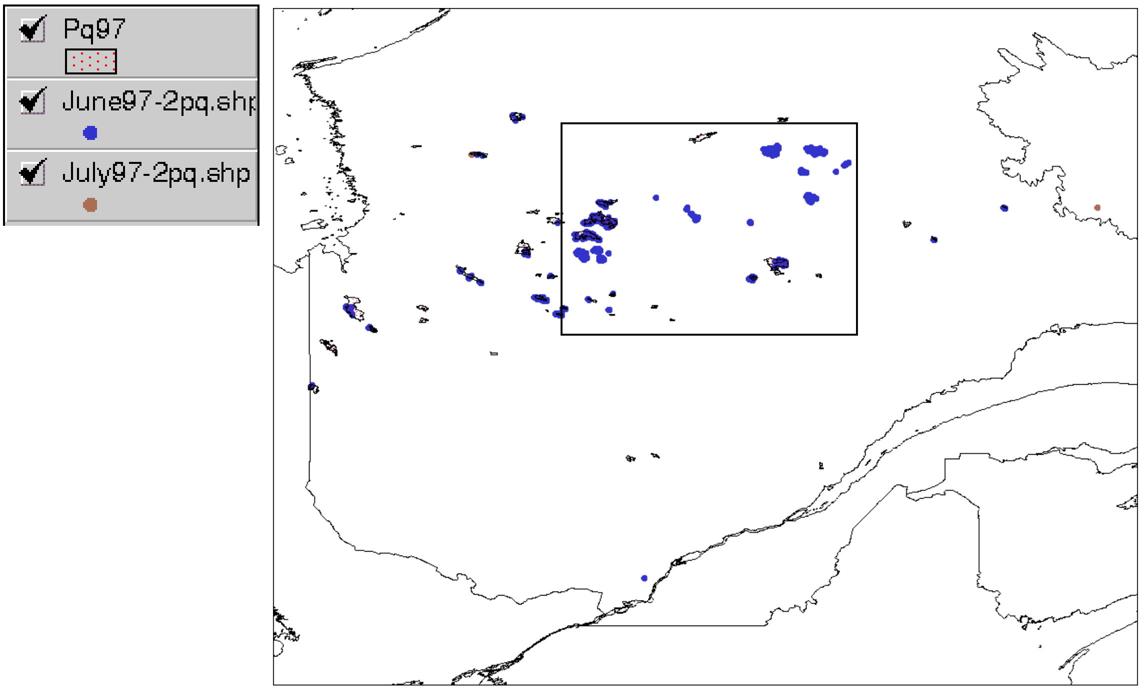


Figure 4: Match between LFDB fire polygons and Algorithm 2 fires.

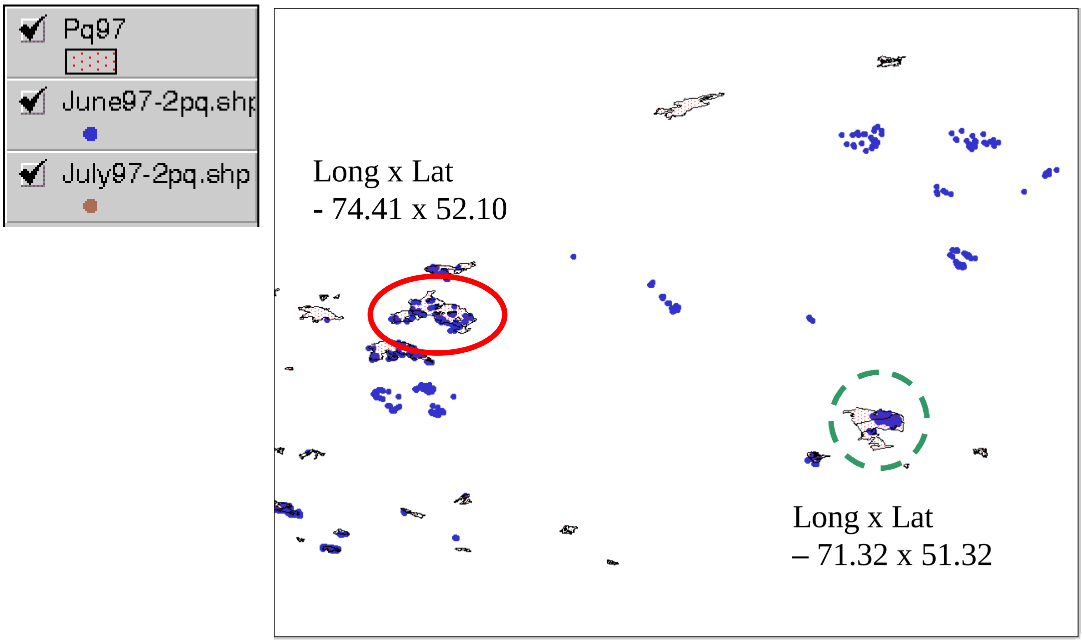


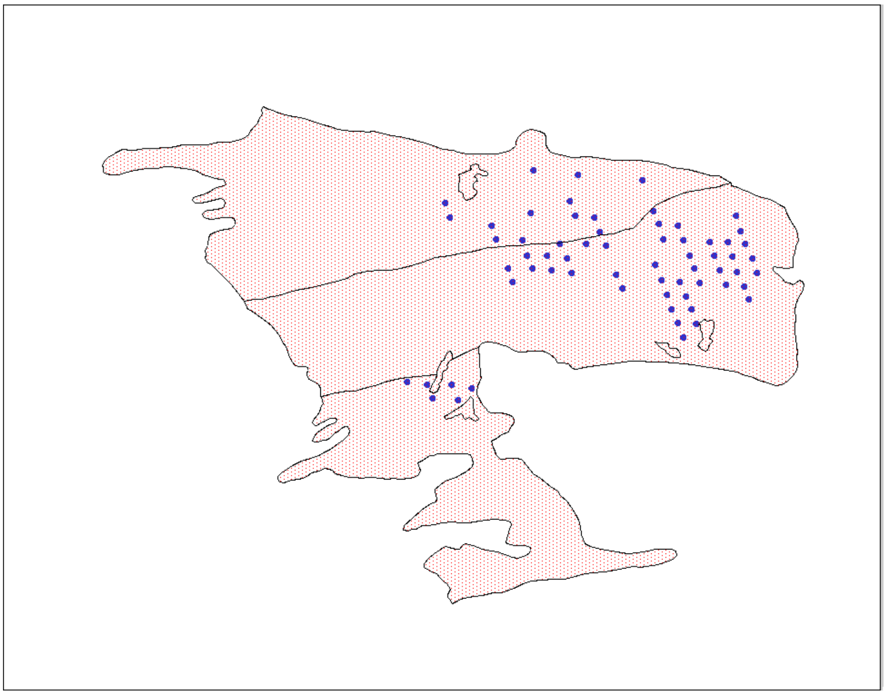
Figure 5: Enlargement of part of figure 4 delineated by box

Red Oval

There are a total of 66 hits from the satellite data. 19 of them are from June 13th. 47 of them are from June 10th. In the Large Fire Database this circle contains two fires. One is from June 7th and is 38873 ha. The other is also from June 7th but is only 6789 ha.

This image clearly shows that the satellite is picking up fire outlines that are similar in size and shape to ones in the LFDB. It also shows outlines of fires that are not in the LFDB.

Fire within the Green Dashed Oval



There are a total of 64 hits from the satellite data. All of them occur on the 10th of June. The Large fire database records this as 3 separate fires. The topmost fire is 18841 ha and has a start date of June 7th. The middle fire is 16217 ha and has a start date of June 7th. The bottom fire is 9073 ha and has a start date of June 10th.

Validation of the 1997 World ATSR Fire Atlas: Canadian Boreal Forest

Robert H. Fraser and Zhanqing Li

Below we present the results of a validation exercise performed for the 1997 ATSR World Fire Atlas. Specifically, we assessed the performance of ATSR fire detection over Canadian boreal forest by comparing ATSR hotspots with AVHRR hotspots and Canada-wide burned area statistics. Detailed ground data for individual fires were not available for inclusion in the analysis.

ATSR Fire Detection Algorithm

The ESA/ESRIN fire algorithm detects hotspots using ATSR night-time imagery that has been calibrated and geo-referenced. Active fires are detected using two algorithms, each of which uses a single threshold in the mid-infrared channel: $BT_{3.7} > 312$ K or $BT_{3.7} > 308$ K. In this analysis, we assessed ATSR hotspots detected using the second, more sensitive algorithm.

Methods

The analysis was restricted to the months April-October, 1997, which spans the entire forest fire season in Canada. Monthly latitude/longitude fire location files were downloaded from the ESRIN/IONIA server. Since the files were obtained July 30th, we used the most recently compiled versions. The monthly files were concatenated and reformatted for import as a point coverage into ARC/INFO. The fire points were re-projected to Lambert Conformal Conic projection (to be compatible with existing satellite fire products) then resampled to a 1 km resolution grid. The comparison was thus based on a composite mask of all ATSR hotspots detected during the April-October study period.

The ATSR fire mask was compared to an AVHRR hotspot mask and Canadian Forest Service (CFS) national burned area statistics. AVHRR hotspots were detected using a fire detection algorithm developed at the CCRS specifically for boreal forest (Li et al., 1999a). The AVHRR algorithm was applied to only land classified as forested, while the ATSR algorithm was applied to all land cover types.

Results

Several investigations have demonstrated that satellite hotspot detection does not reliably estimate burned area due to limited satellite revisit and cloud cover. Nevertheless, a comparison of hotspot area to official burned area statistics is useful because it provides a first estimate of the number of fires missed by satellite detection. In 1997, the CFS reported that 624,646 ha of forest were burned in Canada by wildfires. Hotspots from the AVHRR algorithm sum to 425,700 ha in 1997, which represents 68% of the official burned area. Hotspots from the ATSR night-time algorithm sum to 95,700 ha, or 15% of CFS burned area. It thus appears that ATSR has a significantly lower fire detection rate compared to AVHRR.

Figure 1 below shows the distribution of ATSR hotspots across Canada, while figure 2 shows the same for AVHRR hotspots. These figures indicate that the country-wide distribution of hotspots from the algorithms is generally similar. The ATSR algorithm, however, completely misses a large number of fires detected using AVHRR. ATSR indicates some fire activity in south-central Canada that is not identified by AVHRR. These may correspond to grassland fires in the prairies, which are not considered by the AVHRR algorithm.

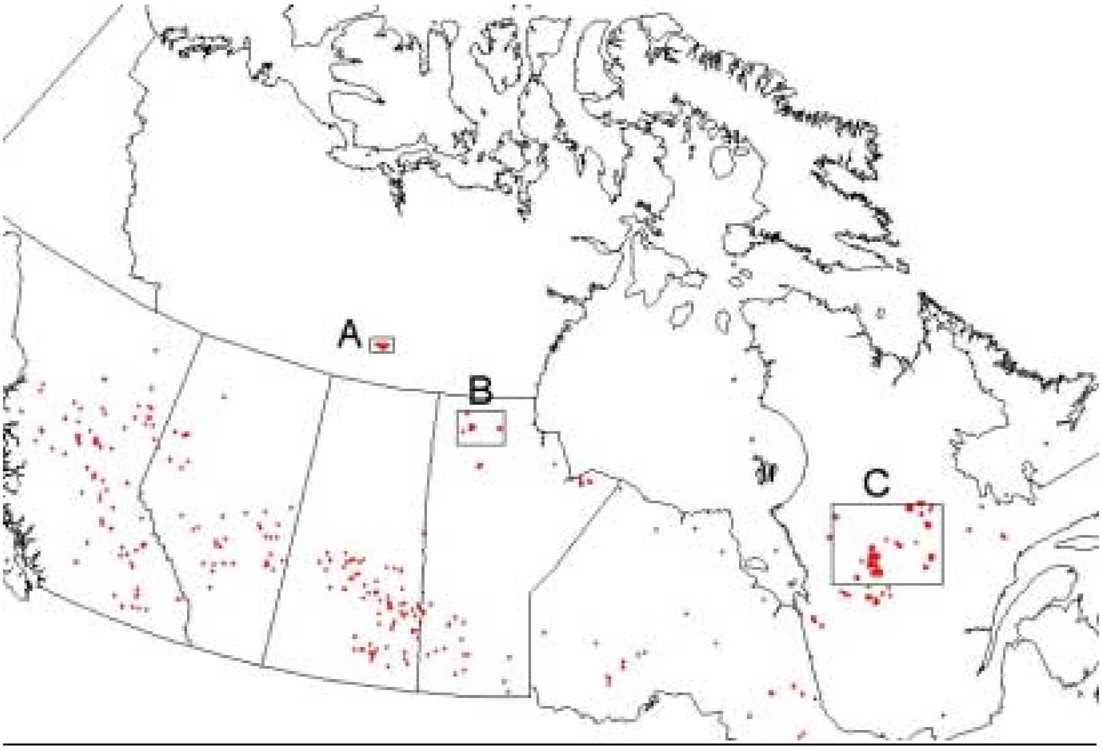


Figure 1. ATSR hotspots detected over Canada between April-October, 1997

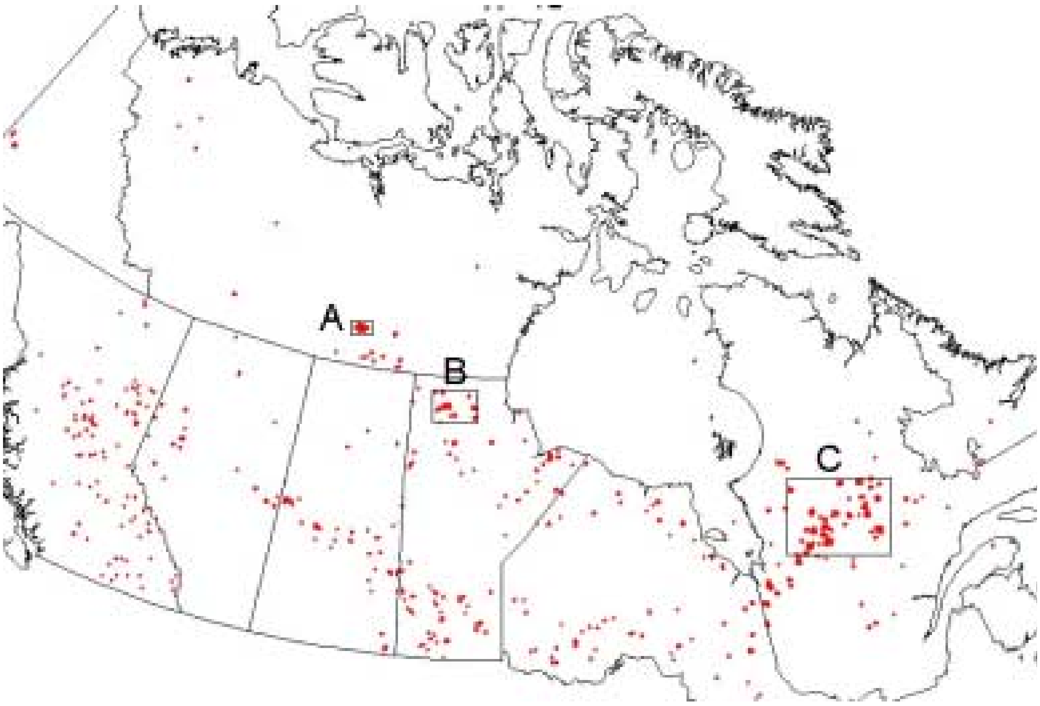


Figure 2. AVHRR forest fire hotspots detected over Canada between April-October, 1997

Figures 3, 4, and 5 show satellite hotspots detected within especially active fire regions marked as A, B, and C, respectively in Figures 1 and 2. These close-up views illustrate that ATSR misses many large (> 1000 ha) boreal forest fires that were detected with AVHRR. Based on earlier validation work performed for the AVHRR algorithm (Li et al., 1999b), most of the large AVHRR fires shown are quite reliable.

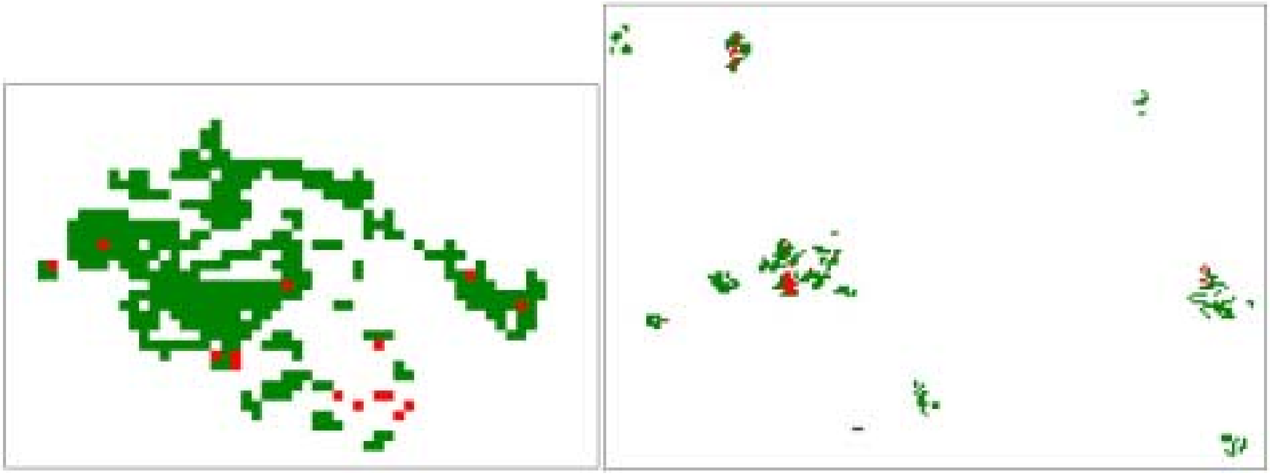


Figure 3 and 4. ATSR hotspots (red) superimposed over AVHRR hotspots (green) for large burn in Northwest Territories (see region A on Figure 1) and in Manitoba (see region B)

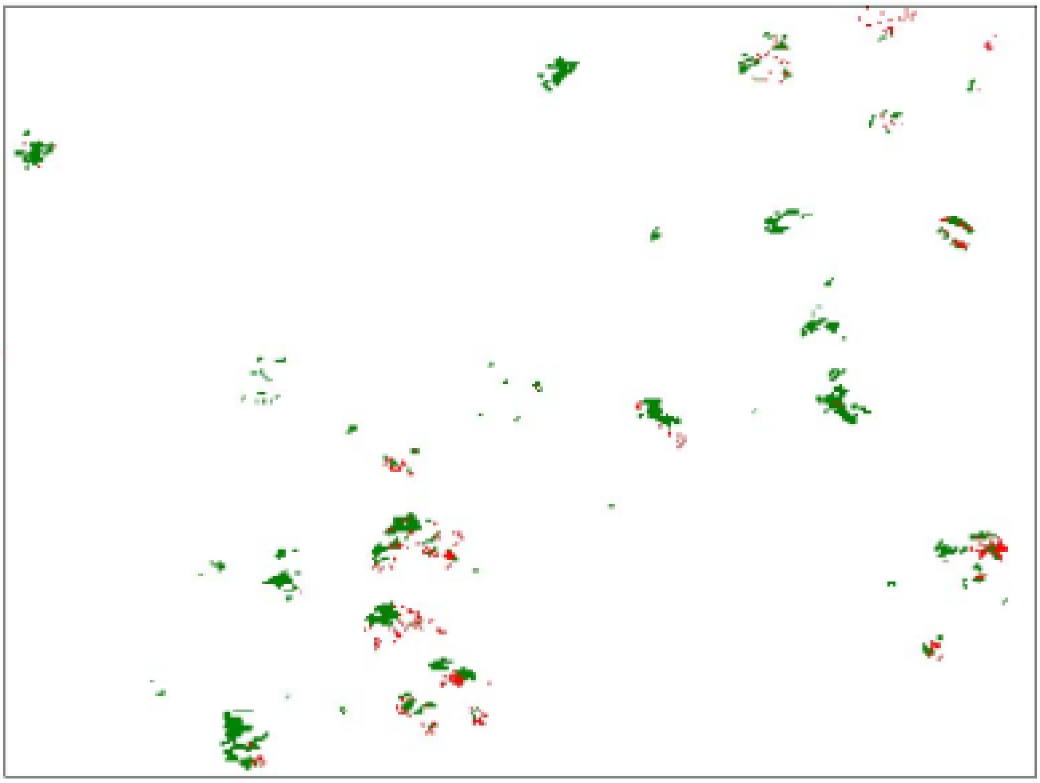


Figure 5. ATSR hotspots (red) superimposed over AVHRR hotspots (green) for active fire region in Quebec (see region C on Figure1)

ATSR fire detection data for summer 1997 over Alaska

Eric Kasischke

We analysed the ATSR fire detection data for the summer of 1997 over Alaska. During 1997, a total of 775,000 ha burned in the state, with most of the total area burned (~80%) occurring in just three large events. We analysed the outputs from the two algorithms. Algorithm 1 resulted in a total of 13 detections, while Algorithm 2 resulted in 22 detections. By comparing the locations of the ATSR detections to locations of the fire boundaries contained within a GIS, we determined that 4 of the Algorithm 1 detections corresponded to actual fires, while 8 of the Algorithm 2 detections corresponded to actual fires. Note that none of the large fire events (that took place over a several week or month-long time period) was detected by the ATSR algorithms.

The conclusions from our analysis are as follows:

1. The good news: the false alarms corresponded to three geographic areas: Prudhoe Bay, Kodiak Island, and one location in the Aleutian Islands. Through logic, these locations can be easily eliminated as potential fire locations.

2. The bad news: as we had anticipated, neither of the active fire detection algorithms operated well for the fires found in Alaskan boreal forests. It has been our experience in the past that the thermal signatures generated from fires in this region do not result in dependable signatures for detection of overall fire activity.

There are those who want to use global fire data products produced from analysis of thermal IR signatures for analysis of patterns of global fire activity. Because such algorithms do not adequately detect fires in the boreal region (as clearly shown by the results from our analysis of the ATSR data), we do not believe that conclusions drawn from such global studies have any validity whatsoever.

SOUTH AMERICA

ATSR Night time fire data for South America, Algorithm 1

Hugh Eva

Overview

The ATSR night time fires over South America have been examined mainly in the context of the humid forest ecosystem. Only the countries around the Amazon and Orinoco basins have been examined. No analysis has been carried out on Argentina, Paraguay, Chile and Uruguay.

Main Observation

The night time fires, as detected by ATSR, seem to highlight those fires used in new land clearance. The majority of the fires seen during the day, from other imagery, detect the agricultural fires which burn in the savannah ecosystems. These tend to be put out at night. In contrast, fires in the forest-savannah frontier may be left to burn at night, as they threaten “only” the degraded forest areas. While it is obvious that the ATSR underestimates fires, for this region, it provides an important data set for observing new incursions into the forest domain.

This leads to three conclusions:

1. *This data set may be useful to highlight areas of agricultural expansion into the forest in the Amazon basin.*
2. *The data set cannot be used to assess fire activity in the savannah/agricultural regions.*
3. *No data on emissions can be extracted from the night-time fires*

Regional analyses

Brazil
The main set of fires detected are in the “arc of deforestation” frontier, Para, Mato Grosso, Rondonia and Acre.

In Para many fires are detected in the logging area around Paragominas. The main trans-amazonian highways (BR 163 and BR 230) show extensive fire activity. The Carajás mine and the Ourilándia frontier region show up. The major expansion around Alta Floresta is highlighted by many fires. Of note is that these night-time fires tend to be away from the central concentrations of the frontier towns. This may indicate that they are uncontrolled fires, taking place in predominantly forested, or degraded forest areas. Along the Manaus-S.Loius-Boa Vista road fires are also seen, these can also be associated with expansion.

An apparent error is the detection of fires in the Balbina dam – there are a large number of fires detected here. As the dam is only partially filled with water it is not certain that these are false detections. A similar “error” occurs in the Blomstein reserve in Surinam.

Bolivia
There is a huge concentration of fires around S.Cruz de la Sierra. This region has undergone a rapid agricultural expansion in the last decade. It is not clear if these fires are agricultural fires or clearance fires. Very few fires are seen in the rest of the country. Even the Llanos de Mojos savannah has a low frequency of fires.

Peru and Ecuador
Virtually no fires are seen in these two countries – one fire is found in the expansion area around Napo (Ecuador) and several around Pulcallpa.

Venezuela / Colombia
Once again the fire activity in the savannah area (Llanos) is very low. Fires are seen at the fringes of Florencia (Col.) a frontier town. A significant number of fires are found on the western (Colombian) reaches of the Sierra de Perija.

The Guyanas
As expected, there are only a few fires detected and these are along the coastal regions. Fires are also detected in the Rupununi and Trombetas savannahs – again in lower numbers than expected.

4 CONCLUSIONS

4.1 Problems with the product

4.1.1 Data set composition

The frame and cloud coverage was not provided to the validation team. In most cases it was not possible to determine the reason for omission errors, but the following three issues are likely to have an effect:

- Cloud coverage;
- Satellite coverage;
- Threshold value.

The first of these was not tested as cloud coverage was not supplied to the validation team, therefore conclusions are restricted to the latter two issues.

4.1.2 Algorithm limitations highlighted by the validation

4.1.2.1 Omission errors

The main limitation of both algorithms is the underestimation of the hot spot number. With the second algorithm the number of omission errors is slightly reduced but it remains significant if we compare our data set with other remote sensing derived data set (AVHRR) or with ground–based data sets. These omission errors are partly due to:

- The night time acquisition of the ATSR-2: - while the night-time detection is more reliable it gives incomplete information. The major fire activity period occurs in the afternoon from burning as part of the agricultural cycle and most of the agricultural fires do not last beyond sunset.
- The narrow swath of the ATSR-2 (512 km), which allows a revisit time of 3 days at the equator (compared to the 1 day revisiting period for AVHRR). Many fires that last less than one day are not detected because they are not covered by the ATSR;
- The threshold level and the resolution of the instrument limits the detection of fires of small size. However, the specific size limitation is related to the intensity of the fire;
- The threshold level is not well suited to the detection of even some large fires at high latitudes. Specific adaptations may be required for boreal forests in the same manner as AVHRR.

Thus the algorithms should be used with caution for the detection of:

- agricultural fires;
- savannah fires;
- small fires;
- boreal forest fires.

4.1.2.2 Commission errors

Some commission errors occur with both algorithms, specifically:

- cities;
- gas flares.

These commission errors are easily identifiable and can be removed with simple post-processing based on latitude / longitude and statistics on energy generation.

While commission errors due to environmental effects were not reported with algorithm #1, some warm surfaces (desert areas) are registered as hot spots with algorithm #2. These commission errors can be removed using 11.0 and 1.6 micrometer channels (see 4.3).

4.1.2.3 Geo-location errors

A few geo-location errors were reported (Spain), however, the majority of validation reports indicate strong correspondance between burned surfaces and detected fires.

4.1.2.4 Multiple detection

Some hot spots are detected twice, due to overlap of ATSR frames. This will require post-processing to separate repeat 'hits' from real new hotspots.

4.2 Validation methodology

In the above validation a large number of teams were contacted but there was considerable variation in the quality of the validation returns with the majority of returns focusing on qualitative comparison with fire records, mapped fire scars or comparable AVHRR hot spot detections. Therefore validation requests for future products such as GLOBSCAR will follow a more closely defined methodology as identified in Appendix III.

4.3 Quality of the product

The main qualities of the product are:

- the low level of commission errors;
- the good spatial distribution of the hot spots;
- the accurate geo-location of the hot spots.

Despite the limitations of the detection indicated above, the availability of the product for a long period of time (1995 - present) along with the good spatial distribution of the detection allows the use of this product for large-scale analysis or as a complement to AVHRR fire detection.

4.4 Further Improvement

4.4.1 Internal testing with 1998 data

Internal testing with 1998 data produced a large number of false alarms as a function of warm surfaces over a region in Mexico. However, the commission errors due to warm surfaces introduced by algorithm #2 were removed using tests based on 11.0 and 1.6 micrometer channels. The principal additional problem identified from the results of the validation on 1997-98 data was the limited fire detection capability in boreal forest.

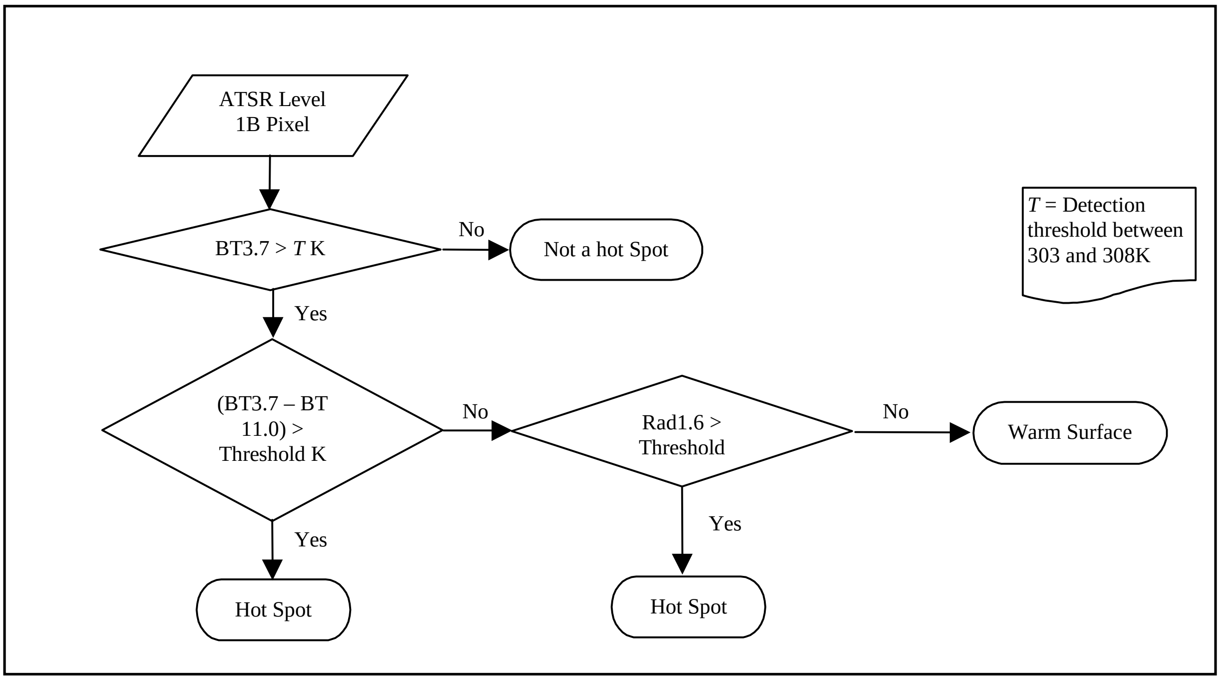
Two improvements are suggested to address these issues:

- algorithm #2 should be improved to discard false alarms due to warm surfaces, using 11.0 micrometer and 1.6 micrometer channels.
- the detection threshold should be decreased to be useful for boreal forest fires (for AVHRR it is set to 303 K for night-time data).

Note, however, because the product is global, reducing the threshold to account for boreal forest fires will increase false detection elsewhere and therefore the additional tests for warm surfaces become of paramount importance.

4.4.2 Proposed ESA revised algorithm

Test 1: Detection test (Algorithm #2.x – as #2 but with a lower threshold)
Test 2: Hot background detection. Keep only pixels with relatively cold background (Difference between BT3.7 and BT11 is greater than threshold, currently 10 K)
Test 3: Very hot fire detection. Test 2 removes pixels with a hot background but also pixels containing very hot (intense) fires. For these fires, the radiance in the 1.6 channel is greater than 0%. Note, however, that the level of this threshold has still to be determined. Further, this test is very sensitive to solar reflected radiation and therefore should NOT be applied to any data where value in the 1.6 channel contains visible reflectance information.



APPENDICES

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Appendix II. Acronyms

ATSR	Along Track Scanning Radiometer
AVHRR	Advanced Very High Resolution Radiometer
CCRS	Canadian Centre for Remote Sensing
CEOS	Committee for Earth Observation Satellites
CSE	Centre de Suivi Ecologique, Senegal
CSIRO	Commonwealth Scientific and Industrial Research Organisation, Australia
DMSP	Defense Meteorological Satellite Program (USA)
EOC	Earth Observation Centre, CSIRO, Australia
EOS	Earth Observing System (NASA, USA)
ERS	European Research Satellite
FWG	Fire Working Group
GAC	Global Area Coverage
GFP	Global Fire Product
GOES	Geostationary Operational Environmental Satellite
GOFC	Global Observation of Forest Cover
GVM	Global Vegetation Monitoring Unit, JRC
HRPT	High Resolution Picture Transmission
IFFMS	Integrated Forest Fire Monitoring System
IGBP	International Geosphere-Biosphere Programme
IGBP-DIS	International Geosphere-Biosphere Programme - Data and Information System
IGOS	International Global Observation Strategy (CEOS)
JRC	Joint Research Centre of the European Commission, Ispra, Italy
LANDSAT	Land Remote-Sensing Satellite (USA)
MODIS	Moderate Imaging Spectroradiometer
MSG	Meteosat Second Generation (European)
MTSAT	Multi-functional Transport Satellite (Japanese)
MTV	Monitoring of Tropical Vegetation, JRC
NASA	National Aeronautics and Space Administration (USA)
NOAA	National Oceanic and Atmospheric Administration (USA)
REIMP	Regional Environmental Information Management Project
SAI	Space Applications Institute, JRC
START	Global Change System for Analysis, Research and Training (IGBP/IHDP/WCRP)
TFIS	Tropical Forest Information System
TREES	Tropical Ecosystem Environment observation by Satellite (MTV, JRC)
VTGEO	Vietnam Centre for Remote Sensing and Geomatics, Hanoi, Vietnam
WFW	World Fire Web

Appendix III. GLOBSCAR Product Validation Guidelines

(Details abstracted from M.Simon, 2001, GLOBSCAR product validation guidelines, ESA ESRIN Working Paper).

1. Validation Considerations

The validation exercise will address all attributes that are characteristics of the final product:

Several criteria have been identified against which to test the performance of the product. These are listed in 1.1. Requirements on the type of validation data required and on its quality assessment are listed in 1.2 and 1.3 respectively.

Several key elements for the validation have been identified. They are listed in 1.4.

The overall validation exercise will be performed in two main steps:

Individual validation on each of the validation data-sets.
Statistical analysis and interpretation of the results.
These two processes are described in detail in Sections 3 and 4.

1.1. Sampling requirements and validation criteria

The product developed is a global product. Extensive validation over a large validation data set is therefore necessary to assess, with good confidence, the quality of the final product.
Sampling of the overall zone under study must satisfy the following conditions:

- The biomes most affected and/or contributing most to emissions must be well represented. In particular, **boreal** forests, **tropical** savannas/forests and **temperate** Mediterranean forests must be represented in the validation data set.
- Different fire sizes and fire types (if validation information is available) must be represented.
- Various types of land cover (forest, agriculture, semi-natural habitats..) must be present.
- Data for different periods of the year and different meteorological conditions within the same region are needed.
- An extensive distribution of sites (latitude/longitude) should be covered.

This sets up a series of criteria, some of which are mandatory and others optional. The latter are not because of reduced interest but because of the practical difficulties in addressing them in a systematic way (lack of information).

<u>Mandatory criteria:</u>

- type of vegetation affected,
- fire size,
- location,
- period of the year

<u>Optional criteria:</u>

- land cover types
- period of the burning season,
- meteorological conditions
- fire type

1.2. Type of validation data

The data requested can be field data (fire service reports/measurements), airborne data, high spatial resolution satellite imagery. To be of interest, the data need to be properly dated and geo-located. Spatial resolution of the data must be indicated.

1.3. Validation data quality

A degree of confidence in the validation data will be specified in terms of:

1. source of data
2. accuracy of measurements / sensor accuracy
3. quality control strategy (quantify representativeness of samples)

This will result in a rating of the validation data to be used when drawing the conclusions of the validation exercise.

1.4. Key elements of the validation

Several aspects of the product must be evaluated during the validation exercise, through identified measurables in order to perform a comprehensive validation of the final products. These are grouped by category and listed below. For each of these issues, the dependency on all identified criteria will be shown in the overall statistical analysis of results (described in Section 4).

- Measures of the instrument performance
- Measures of performance for each algorithm:
- Algorithm performance comparison
- Monthly incremental aspect assessment:
- Additional quality assessment

2. Validation Data

2.1. Validation data access

2.2. Validation data format

2.3. Validation data available

3. Validation Process

This section describes the validation process applied to each individual validation data-set in order to evaluate all possible measurables against all available criteria.

Whenever possible, this process will be applied to all types of end-products.

When the measurable evaluation is image-based, the analysis will be first qualitative and then quantitative.

Measurables associated with the key elements of the validation (see 1.4) are presented in detail in Appendix I, together with suggestions for possible methods of evaluation for these measurables.

The standard chosen for process description is the Unified Modelling Language (UML). It is the industry-standard language for specifying, visualising, constructing, and documenting the artefacts of software systems.

Each validation data-set is first examined, information on the format, resolution, location, date, vegetation type, fire size, cloud coverage etc... retrieved [*Describe Data*] and a quality control of the data is performed [*Rate Data*].

The corresponding data is then extracted and formatted if needed (*Find Corresponding BSM product* and *Adjust Format)*.

Depending on the type of validation data, measurables and criteria are identified (*Identify Appropriate Measures* and *Identify Criteria*), and evaluation is performed (*Calculate Measurables* and *Evaluate Measurable n Against Criteria*).

All results are then collected (*Collect Results*).

Finally, an individual validation report is produced describing the input data used and the results obtained (*Produce Individual Report*) for each measurable. Whenever available, qualitative information will be given in addition to the quantitative figures

The format of the individual validation report will be chosen to facilitate the statistical analysis on the overall set of results.

4. Analysis and interpretation of results

After all individual validation data-sets have been processed, a general statistical analysis of the results is performed and possible interpretations of errors are proposed. Then a summary of product performance and limitations is given, followed by proposals for algorithm improvement.

4.1. Reliability of the results

The validation report will indicate what coverage has been achieved for each category of the criteria retained (listed in 1.1), and the level of testing of each measurable (some can be evaluated over all data-sets available, others can only be evaluated occasionally in the validation exercise). This information will be converted into the level of confidence that can be associated with the validation results.

In an ideal world, one chooses the level of sampling necessary to achieve a level of confidence by risk assessment of the results. We are in the opposite situation here: the level of sampling is fixed (data made available to the project) and will result in a level of confidence over the conclusions of the validation exercise.

It is also useful to indicate what percentage of the overall products has been used for the validation, as it will show the level of testing achieved for the final products. This can be done during the validation process (It can be area or number related).

4.2. Statistical analysis

The conclusions of the qualitative analysis will be given first.

The quantitative analysis will provide information on the various individual key points against all criteria, as well as on the overall performance of the algorithms in specific conditions (e.g. particular location or vegetation type).

On reading of the document, one should be able to find out, for example, what the strong and weak points of the product are for a specific vegetation type or what the behaviour of one aspect of the product is in varying conditions.

Results obtained will be related to the level of coverage reached for each category. A level of confidence will thus be introduced on the results.

Quality control techniques will be chosen to quantify the level of confidence on the results obtained.

4.3. Global validation process

The validation exercise will be as follows:

- After processing of all individual validation data-sets [*Run IVP i*], results are grouped [*Collect Results*] and criteria of interest for the statistical analysis are selected [*Identify Statistical criteria*]
- A statistical analysis is then performed over the overall results [*Produce Statistical Study*] according to guidelines indicated in X.

Then as a second level of investigation, a more in-depth validation step will be carried out [*Perform Complementary Validation*] on intermediate products (e.g. individual GBT_validation products or monthly absolute products) in the following situations:

- insufficient testing of one algorithm-specific key-point (see 1.4)
- problem identified which requires additional in-depth information (e.g. individual probability values etc..)

Following this complementary investigation, suggestions for improvement are given [*Propose Solution*].
All results are finally combined [*Draw Conclusions*] and lead to an updated version of the Global Validation Report.

5. Summary

The present document forms the framework to be followed when elaborating the GLOBSCAR Product Validation Plan. The following sections will be present in the final validation report of the GLOBSCAR Burn Scar Map products:

- Preface/Background
- Presentation of the GLOBSCAR project
- Validation points covered
- Measurables of the validation
- Validation data used
- Level of confidence on the results obtained
- Instrument-related performance and limitations
- Statistical analysis of algorithm-related performance and interpretation of errors
- Summary of product performance and limitations
- Suggestions for further improvement

Appendix IV. IGBP-DIS Working Papers

WP # 1: A Special meeting on AVHRR Data Preprocessing and Compositing Methods
(P. Teillet, Canada Centre for Remote Sensing, Canada - June 1992)

WP # 2: Requirements for Terrestrial Biospheric Data for IGBP Core Projects
(S.I. Rasool, IGBP-DIS, France - June 1992)

WP # 3: The Global 1km AVHRR Data Set: Further Recommendations
(J. Townshend, University of Maryland, USA - June 1992)

WP # 4: IGBP-DIS Strategy for Implementation
(P.Williamson, IGBP Secretariat, Sweden / S.I. Rasool, IGBP-DIS, France - June 1992)

WP # 5: The 5th CEOS Cal/Val Working Group Meeting
(Philippe Teillet, Canada Centre for Remote Sensing, Canada - July 1992)

WP # 6: Simple User Manual for the Global Change Master Directory
(Anne O'Donnel, NOAA, USA / Ludovic Andres, IGBP-DIS, France - November 1992)

WP # 7: IGBP-DIS / GCTE Global Soils Database Workshop
(John Ingram, GCTE Focus 3 Associate Office, UK - June 1993)

WP # 8: Monitoring and Modelling of Terrestrial Net and Gross Primary Production
(S.D. Prince and C.O. Justice, University of Maryland, USA / B.Moore III, University of New Hampshire, USA - January 1994)

WP # 9: IGBP-DIS Satellite Fire Detection Algorithm Workshop Technical Report
(Chris Justice, NASA/GSFC, USA / Pete Dowty, Univ. of Virginia, USA - April 1994)

WP # 10: A Global Database of Soil Properties: Proposal for Implementation
(R.J. Scholes, CSIR, South Africa / D. Skole, University of New Hampshire, USA / J.S. Ingram, GCTE Focus 3 Associate Office, UK - January 1995)

WP # 11: A First Step Towards a Reference ΔPCO_2 Map for the North Atlantic Ocean
(N. Lefèvre, LODYC, France / IGBP-DIS, France - April 1995)

WP # 12: Global Primary Production Data Initiative Project Description
(S.D. Prince, University of Maryland, USA / R.J. Olson, Oak Ridge National Laboratory, USA / G. Dedieu, CESBIO, France / G. Esser, Institute of Plant Ecology, Germany / W. Cramer, PIK, Germany - April 1995)

WP # 13: The IGBP-DIS Global 1km Land Cover Data Set « DISCOVER » Proposal and Implementation Plans
(A.S. Belward, Joint Research Centre, Space Applications Institute, Italy - October 1996)

WP # 14: The IGBP-DIS Fire Algorithm Workshop 2, Report of the meeting
(Chris Justice, NASA/GSFC, USA, Jean-Paul Malingreau, JRC, Space Applications Institute, Italy, December 1996)

WP # 15: Pedotransfer Functions for Thermal Soil Properties
(Lode Hubrechts, Jan Feyen, Katholieke Universiteit Leuven, Belgium, December 1996)

WP # 16: GPPDI (Global Primary Production Data Initiative) Workshop
« From Sparse Field Observations to a Consistent Global Dataset on Net Primary Production », Report of the Meeting
(R.J. Olson, J.M.O. Scurlock, Oak Ridge National Laboratory, USA; W. Cramer, Potsdam Institute for Climate Impact Research, Germany; S.D. Prince, University of Maryland, USA, and W.J. Parton, Colorado State University, USA; April 1997)

WP # 17: Definition and Implementation of a Global Fire Product derived from AVHRR data - 3rd IGBP-DIS Fire Working Group Meeting Report
(J.P. Malingreau, JRC, Space Applications Institute, Italy and C.O. Justice, NASA/GSFC, USA; with contributions from E. Dwyer, JRC, Space Applications Institute, Italy; H. Eva, Université Catholique de Louvain, Belgium;, J. Kendall, NASA/GSFC, USA; M. Michou, IGBP-DIS Office, France; J. Pereira, Department of Forestry/ISA, Portugal and S. Pinnock, JRC, Space Applications Institute, Italy; August 1997)

WP # 18: IGBP Data and Information Management – Recommendations for Strategy and Implementation - First IGBP-DIS Focus 2 Expert Workshop Report
(Gunter Schreier, DLR- DFD, Germany; Gérard Szejwach, Martine Michou and Géraldine Verrière, IGBP-DIS Office, France, September 1998)

WP # 19: IGBP-DIS Wetland Data Initiative – A first step towards identifying a global delineation of wetlands,
(S. Darras, M. Michou and C. Sarrat, IGBP-DIS Office, France; February 1999)

WP # 20 IGBP Related Activities in the Siberian Transect
(Michael A. Korets, V.N. Sukachev Institute of Forest, Siberian Branch, Russian Academy of Science, Krasnoyarsk, RUSSIA ; February 1999)

WP # 21 Report of the 4th IGBP-DIS Fire Working Group Meeting
(M. Michou, IGBP-DIS Office, France ;
with contributions from S. Bartalev and G. Korovin, International Forest Institute, Russia; E. Dwyer and H. Eva, JRC Ispra, Italy; J. Feltz and E. Prins, University of Wisconsin-Madison, USA; L. Giglio, NASA/GSFC, USA; C.O. Justice, University of Virginia, USA; C. Liousse, LSCE, France; M. Michou; S. Pinnock, JRC Ispra, Italy; K. Rasmussen, University of Copenhagen, Denmark; D. Roy, NASA/GSFC, USA and B. Stocks, Canadian Forest Service, Canada; May 1999)

WP # 22 Comparison of Pedotransfer Functions To Compute Water Holding Capacity Using the van Genuchten Model In Inorganic Soils – Report to IGBP-DIS Soil Data Tasks
(B. Imam and S. Sorooshian, University of Arizona, USA; T. Mayr, SSLRC, Cranfield University, UK; M. Schaap, United States Salinity Laboratory, USA; H.

Wosten, Winand Staring Centre, The Netherlands and R.J. Scholes, CSIR, South Africa; May 1999)

WP #23 The Along Track Scanning Radiometer World Fire Atlas – Detection of Night-Time Fire Activity: Validation Report (eds. O. Arino, ESA-ESRIN and S. Plummer, IGBP-DIS;
with contributions from E. Bilgili, Faculty of Forestry, Trabzon, Turkey, H.- D.V. Boëhm, Kalteng Consultants, Höhenkirchen, Germany, A. Calle Montes, Lab.de Teledeteccion, Fac. de Fisicas, Univ.de Valladolid, Spain, J.L. Casanova Roque, Lab.de Teledeteccion, Fac. de Fisicas, Univ.de Valladolid, Spain, E. Chuvieco, University de Alcala, Alcala de Henares, Spain, M. Cristaldi, Mestor Snc, Catania, Italy, H. Eva, Joint Research Centre, Trees Project, Ispra, Italy, Robert H. Fraser, Canada Centre for Remote Sensing, Ottawa, Canada, F. Gonzalez Alonso, Lab.de Teledeteccion, CIFOR/INIA, Madrid, Spain, A. Hoffmann, Zoologisches Institut des LMU, Munchen, Germany, E. Kasischke, Environmental Research Inst. of Michigan, Ann Arbor, USA, S. Kuntz, Zoologisches Institut des LMU, Munchen, Germany, S. Langaas, UNEP/GRID, Norway and Royal Inst. of Technology, Sweden, J. Marsden, Satellite Remote Sensing Services, W.Australia, P. Martin, University de Alcala, Alcala de Henares, Spain, M.Michou, IGBP-DIS, N. P. Minko, Institute of solar-terrestrial physics SD RAS, Irkutsk, Russia, J.M.C. Pereira, Instituto Superior de Agronomia, Lisboa, Portugal, N. Raisbeck, Satellite Remote Sensing Services, W.Australia, J-M. Rosaz, ESA-ESRIN, A.C.L. Sa, Instituto Superior de Agronomia, Lisboa, Portugal, F. Siegert, Zoologisches Institut des LMU, Munchen, Germany, M. Simon, ESA-ESRIN, M. Steber, Satellite Remote Sensing Services, W.Australia, J. Stibig, Joint Research Centre, Trees Project, Ispra, Italy, B. Stocks, Canadian Forest Service, Sault Sainte Marie, Canada, A.Vasquez de la Cueva, Lab.de Teledeteccion, CIFOR/INIA, Madrid, Spain, Zhanqing Li, Canada Centre for Remote Sensing, Ottawa, Canada, May 2001).