The EUMETSAT Satellite Application Facility on Land Surface Analysis (LSA SAF)

Validation Report

Fire Detection and Monitoring (FD&M)

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Issue / Revision	Date	Description:
Version I/2010	08/03/2010	Version to be presented to ORR
Version II/2011	23/05/2011	Changes following the ORR meeting of April 2010: (1) The validation report was updated with the aim of demonstrating that the accuracy requirements are fulfilled; (2) Results related to the comparison with the FRP pixel (LSA-31) are now included.

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1. Introduction

Geostationary meteorological satellite systems provide much higher frequency of observation of the land surface than sun-synchronous systems but, until recently, their spatial and spectral resolutions were sub-optimal for vegetation fire monitoring. Nevertheless, several authors demonstrated the capability of earlier geostationary satellites to detect active fires (e.g. Prins & Menzel, 1994; Prins & Schmetz, 2000) as well as to estimate burned areas (Boschetti et al., 2003).

New possibilities were opened up with the launch in 2002, by the European Space Agency (ESA) in cooperation with the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), of Meteosat-8, the first satellite of the Meteosat Second Generation (MSG). Temporal, spatial and spectral characteristics of the MSG series were substantially improved (Schmetz et al., 2002), rendering its satellites very adequate for Earth surface observation, and namely for fire monitoring (Cihlar et al., 1999; Pereira & Govaerts, 2001). The potential of MSG was promptly explored, namely by expanding the scope of previous fire applications of geostationary systems with the goal of quantifying fire intensity and biomass consumption (Roberts et al., 2005; Roberts & Wooster, 2008).

Developed within the framework of the LSA SAF, FiDAlgo is a contextual algorithm for detecting active fires, every 15-min using information provided by MSG at the maximum temporal resolution (LSA SAF, 2010b).

This document reports on the set of results that were obtained from a comprehensive validation exercise of the Fire Detection and Monitoring (FD&M) product. The validation exercise was performed over the North Africa window (NAfr) covering the complete 15-minute cycle of February 2nd, 2011.

The validation exercise was organized in the two following main parts:

i) a consistency analysis between the FD&M and the Fire Radiative Power (FRP) products (LSA SAF, 2010a), both based on information from Meteosat-8;

ii) a systematic comparison of the FD&M and FRP products against independent data, namely those from the MODIS Fire Team (Justice et al., 2002).

2. The FD&M product

The FD&M product is based on the above-mentioned FiDAlgo algorithm which takes advantage of the temporal resolution of SEVIRI (one image every 15 min), and relies on information from SEVIRI channels (namely 0.6, 0.8, 3.9, 10.8 and 12.0 µm) together with information on illumination angles. The method is based on heritage from contextual algorithms designed for polar, sun-synchronous instruments, namely NOAA/AVHRR and MODIS/TERRA-AQUA (Amraoui et al, 2010).

A potential fire pixel is compared with the neighbouring ones and the decision is made based on relative thresholds as derived from the pixels in the neighbourhood. As shown schematically in Fig. 1, the method consists of the following four main steps; 1) Pre-processing, 2) Selection of potential fire pixels, 3) Detection of contaminated pixels and 4) Confirmation of active fire pixels. Details about the procedure may be found in LSA SAF (2010b) and in Amraoui et al. (2010).

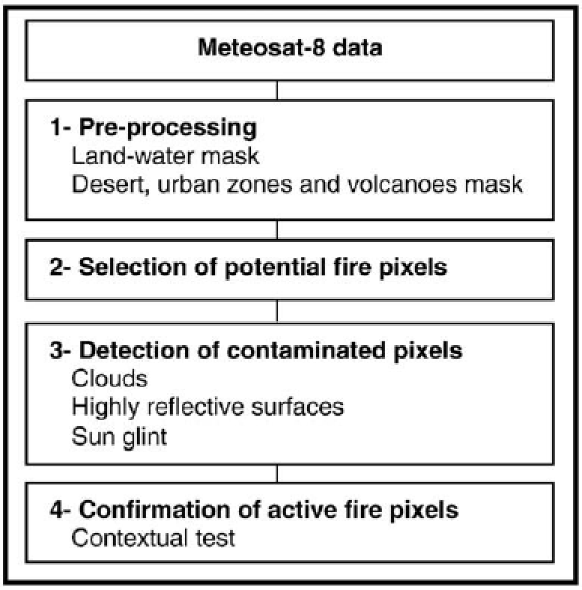


Figure 1 Schematic overview of the processing stages of FiDAlgo.

The procedure allows identifying both *active fires* (i.e. occurrences in a given pixel of a given image) and *fire pixels* (i.e. pixels where at least one active fire was detected, throughout the study period). Identified fire pixels are further classified into the following three categories;

1. *Single occurrence fires*, defined as active fires that are isolated events in space and time, i.e. having occurred only once in the entire period and with no active fires identified in the neighbouring pixels, neither in the same image nor in the previous and the following ones;
2. *Fires over sparse vegetation* (sparse herbaceous or sparse shrub cover), defined as active fires not included in the previous category and occurring over pixels classified as belonging to GLC2000 class 14;
3. *Vegetation fires*, which include all active fires that do not belong to the previous categories.

3. Rationale

In the case of detection and monitoring of active vegetation fires, any validation procedure involves checking at least the following two key aspects of the developed detection algorithm; i) whether it is sensitive, minimizing *omission errors* (i.e. missed hits), and ii) whether it is selective, minimizing *commission errors* (or false alarms).

For this purpose, an analysis of consistency between the FD&M and the FRP products, over the NAfr window, is first performed by checking the outputs of both products along the daily cycle of February, 2nd 2011. Both the FD&M and the FRP products are based on information from SEVIRI on-board Meteosat-8 and it may be noted that this sensor provides a very high temporal resolution (*i.e.* images with a 15-minute repeat cycle). However the spatial resolution is rather low, corresponding to 3×3 km^2 at the sub-satellite point (SSP) and decreasing with increasing distance from SSP. A systematic comparison of both the FD&M and FRP products is then performed on a contemporaneous basis against independent data, namely the global daily active fire product developed by the MODIS Fire Team (Justice et al., 2002).

The MODIS active fire data consist of hot spots as detected by the MODIS radiometer on-board the polar-orbiting Terra and Aqua platforms. The MODIS fire detection algorithm is based on a contextual algorithm developed by Giglio et al. (2003). Information is obtained from thermal channels at coarse spatial resolution (*i.e.* with a pixel size of the order of 1×1 km^2) and with a low temporal resolution consisting of four observations per day (Justice et al., 2002) and corresponding to the maximum temporal resolution of the above mentioned radiometer. The MODIS active fire data is part of the MODIS Fire Products that include an identification of the occurrence of thermal anomalies, as well as estimates of the total emitted power from the fire as well as of the burned area. It may be noted that results of the systematic comparison of the FD&M/FRP products versus MODIS are expected to be of low quality since when comparing data from geostationary sensors, such as SEVIRI, with those from polar-orbit sensors, such as MODIS, the different spatial and the temporal resolutions of the two instruments have to be accounted for. Moreover, when the comparison involves data from polar sensors with finer spatial resolution, the procedure is especially complex due to errors caused by data misregistration (Calle et al., 2008).

4. Validation Results

4.1. Consistency analysis: FD&M vs. FRP

As shown in Table 1, during the complete daily cycle of February, 2nd 2011 (96 slots), a grand total of 34 218 active fire pixels was detected by both FRP and FD&M products, 25 182 (74%) of them by FRP 5 919 (17%) by FD&M and 3 117 (9%) by both products. Large discrepancies between the two products are conspicuous and reasons for that will be now investigated.

Table 2 provides an overview of the reasons why the FiDAlgo algorithm did not consider as active fires the above mentioned 25 182 pixels, which were detected by FPR and not by FD&M. It may be observed that the large majority of pixels (~90%) were not considered as active fires by FD&M because the specified thresholds for TB039 or for the difference (TB039-TB108) were not attained. This is understandable since the criteria adopted by the FRP algorithm are much less strict than those used in FiDAlgo (Govaerts *et al.*, 2009; LSA SAF 2010b). The remaining 10% of pixels were not considered as active fires by FiDalgo either because the number of neighbouring pixels was deemed as insufficient to adequately characterise the background (~6%) or because the pixels were previously masked as desert, water, volcano or urban.

Table 1 Fire pixels over the NAfr window as detected by the FRP and FD&M products during the daily cycle of February 2nd, 2011.

	FRP Only	Both FRP and FD&M	FD&M Only	Total
Number of fire pixels	25 182	3 117	5 919	34 218
Fraction of fire pixels (%)	74	9	17	100

Table 2 As in Table 1 but respecting to the reasons why active fires detected by the FRP product were not considered as such by FD&M.

	FD&M Code (*)							
	1	2	3	4	5	**6**	7	Total
Number of fire pixels	70	1 535	0	11	42	**22 748**	776	25 182
Fraction of fire pixels (%)	0.3	6.1	0.0	0.0	0.2	**90.3**	3.1	100.0

(*) FD&M Code description:

1	The potential active fire did not pass the contextual test (active fire undetermined).
2	Insufficient number of clear neighbouring pixels to assess the spectral characteristics of the background.
3	Pixel contaminated by clouds.
4	Pixel contaminated by sunglint.
5	Pixel contamimated by high reflectivity.
6	Pixel value of TB039 or of the difference (TB039-TB108) did not reach the prescribed thresholds.
7	Pixel masked as desert, water, volcano or artificial zone (e.g. urban)

Table 3 presents a summary of the reasons why the FRP algorithm did not consider as active fires the above mentioned 5 919 pixels. More than 80% of the pixels were considered as being affected by clouds or as being located close to a cloud edge, the large majority due to the latter reason. This result may be explained by the fact that the FRP algorithm makes use of a modified SAF Nowcasting cloud (Govaerts *et al.*, 2009) whereas cloud identification by FiDAlgo relies on simpler threshold tests (LSA SAF 2010b). More than half of the remaining pixels (~12%) were not identified by the FRP algorithm as potential active fires and the others were rejected due to reasons mainly associated with the background.

Table 3 As in Table 1 but respecting to the reasons why active fires detected by the FD&M product were not considered as such by FRP.

	FRP Code (*)						
	1	2	3	4	5	6	Total
Number of fire pixels	142	120	**4870**	29	62	696	5 919
Fraction of fire pixels (%)	2.4	2.0	**82.3**	0.5	1.0	11.8	100.0

(*) FRP Code description:

1 The signal of the potential fire pixel was not sufficiently above that of the background (FRP Quality Flag 7).

2 It was not possible to define the background temperature (FRP Quality Flag 6).

3 The pixel is classed as cloud contaminated (FRP Quality Flag 3) or the pixel is close to a cloud edge (FRP Quality Flag 8).

4 The pixel is classed as being affected by sun glint (FRP Quality Flag 4) or The SUNGRATIO test failed (FRP Quality Flag 5).

5 Considered as a potential fire but not processed.

A random selection was then made of 50 pixel locations where active fires were detected by the FD&M product but not by FRP. Results are shown in Table 4 by decreasing order of *duration* (here defined as the number of slots where active fires were detected in a given pixel location). The more strict character of the criteria used for cloud contamination in the case of the FRP algorithm, when compared to the one used in the case of FD&M, is well apparent in the cases of longer duration, where active fires identified by both algorithms (FRP=1) alternate with active fires rejected by FRP because of cloud contamination (FRP=3 or FRP=8)

Table 4 Location in the NAfr window (Line and column), date (month and day) and time (hour and minute), geographical position (latitude and longitude), spectral signature (TB039-TB108), land surface cover (from GLC2000) and FRP flag (see codes below) for a set of 50 randomly selected pixels where active fires were detected by FD&M and not detected by FRP.

Codes of field FRP (see Table 7 of LSA SAF (2010a) for more details).

1. Agreement between FRP and FD&M products
2. Unprocessed pixel
3. The pixel is classed as cloud contaminated
4. The pixel is classed as being affected by sun glint.
5. The SUNGRATIO test failed.
6. It was not possible to define the background temperature.
7. The signal of the potential fire pixel was not sufficiently above that of the background.
8. No fire detection took place because the pixel is close to a cloud edge.
9. Not identified as a potential active fire

Table 4 (continued)

LINE	COL.	MON	DAY	HR	MIN	LAT	LONG	TB039	DIF-TB	SZA	REF006	REF008	TB108	TB120	GLC	FRP
Duration: 22 slots																
937	1457	2	2	9	15	6.12	23.83	324.63	23.18	29.72	0.09	0.12	301.45	297.75	3	1
937	1457	2	2	9	30	6.12	23.83	318.71	16.06	27.52	0.09	0.12	302.65	299.17	3	1
937	1457	2	2	9	45	6.12	23.83	325.78	22.54	25.67	0.09	0.13	303.24	299.42	3	1
937	1457	2	2	10	0	6.12	23.83	318.86	15.26	24.25	0.09	0.12	303.60	299.55	3	1
937	1457	2	2	10	15	6.12	23.83	330.66	26.12	23.33	0.09	0.13	304.54	300.31	3	1
937	1457	2	2	10	30	6.12	23.83	321.79	17.25	22.99	0.10	0.13	304.54	300.44	3	1
937	1457	2	2	10	45	6.12	23.83	323.80	16.82	23.24	0.09	0.12	306.98	303.57	3	1
937	1457	2	2	11	0	6.12	23.83	320.16	12.49	24.06	0.09	0.12	307.67	304.44	3	1
937	1457	2	2	11	15	6.12	23.83	329.43	22.22	25.40	0.10	0.13	307.21	303.45	3	1
937	1457	2	2	11	30	6.12	23.83	327.41	21.82	27.19	0.10	0.13	305.59	302.08	3	1
937	1457	2	2	11	45	6.12	23.83	330.73	24.67	29.34	0.11	0.13	306.06	302.33	3	8
937	1457	2	2	12	0	6.12	23.83	322.54	15.33	31.77	0.10	0.13	307.21	303.95	3	1
937	1457	2	2	12	15	6.12	23.83	320.31	13.33	34.43	0.10	0.13	306.98	304.07	3	1
937	1457	2	2	12	30	6.12	23.83	319.82	12.38	37.27	0.10	0.13	307.44	304.32	3	1
937	1457	2	2	12	45	6.12	23.83	324.41	17.09	40.25	0.10	0.13	307.32	304.44	3	1
937	1457	2	2	13	30	6.12	23.83	318.71	17.74	49.79	0.12	0.14	300.97	298.01	3	8
937	1457	2	2	14	15	6.12	23.83	323.66	24.40	59.86	0.13	0.13	299.26	296.06	3	8
937	1457	2	2	14	30	6.12	23.83	320.75	22.72	63.30	0.14	0.14	298.03	295.54	3	8
937	1457	2	2	20	30	6.12	23.83	309.41	17.10	148.50	0.00	0.00	292.31	291.67	3	1
937	1457	2	2	20	45	6.12	23.83	306.11	14.19	151.93	0.00	0.00	291.92	291.40	3	1
937	1457	2	2	21	0	6.12	23.83	308.86	16.94	155.29	0.00	0.00	291.92	291.13	3	1
937	1457	2	2	22	15	6.12	23.83	305.11	14.77	168.67	0.00	0.00	290.34	289.49	3	1

Table 4 (continued)

LINE	COL.	MON	DAY	HR	MIN	LAT	LONG	TB039	DIF-TB	SZA	REF006	REF008	TB108	TB120	GLC	FRP
Duration: 14 slots																
1002	1635	2	2	9	45	4.35	29.49	318.19	14.95	22.02	0.09	0.12	303.24	299.55	13	8
1002	1635	2	2	10	0	4.35	29.49	318.96	14.54	21.33	0.09	0.12	304.42	300.82	13	1
1002	1635	2	2	10	15	4.35	29.49	320.51	16.56	21.28	0.10	0.12	303.95	300.19	13	1
1002	1635	2	2	10	30	4.35	29.49	325.90	22.07	21.86	0.10	0.12	303.83	300.19	13	8
1002	1635	2	2	11	0	4.35	29.49	317.77	15.60	24.70	0.12	0.13	302.17	298.78	13	6
1002	1635	2	2	11	15	4.35	29.49	315.93	16.30	26.79	0.15	0.17	299.63	295.93	13	9
1002	1635	2	2	11	30	4.35	29.49	316.37	13.25	29.20	0.13	0.15	303.12	299.42	13	8
1002	1635	2	2	11	45	4.35	29.49	317.40	14.87	31.85	0.13	0.15	302.53	298.91	13	8
1002	1635	2	2	12	15	4.35	29.49	317.82	13.51	37.70	0.12	0.15	304.31	300.69	13	8
1002	1635	2	2	12	45	4.35	29.49	319.57	16.80	44.01	0.13	0.16	302.77	298.66	13	1
1002	1635	2	2	13	30	4.35	29.49	315.02	11.90	54.01	0.12	0.15	303.12	299.93	13	1
1002	1635	2	2	19	15	4.35	29.49	309.69	24.25	135.64	0.00	0.00	285.44	281.98	13	8
1002	1635	2	2	21	15	4.35	29.49	307.66	23.90	161.90	0.00	0.00	283.76	281.68	13	8
1002	1635	2	2	21	30	4.35	29.49	309.55	22.31	164.38	0.00	0.00	287.24	285.44	13	1
Duration: 11 slots																
867	1390	2	2	9	15	8.06	21.87	315.98	13.81	32.42	0.08	0.13	302.17	299.68	3	8
867	1390	2	2	9	30	8.06	21.87	315.02	11.42	30.19	0.08	0.13	303.60	300.82	3	8
867	1390	2	2	9	45	8.06	21.87	319.01	14.70	28.26	0.08	0.13	304.31	302.08	3	1
867	1390	2	2	10	0	8.06	21.87	331.74	26.26	26.71	0.08	0.13	305.48	303.08	3	1
867	1390	2	2	10	15	8.06	21.87	328.24	22.76	25.61	0.09	0.13	305.48	303.08	3	1
867	1390	2	2	10	30	8.06	21.87	320.80	15.21	25.02	0.09	0.14	305.59	303.45	3	8
867	1390	2	2	10	45	8.06	21.87	318.14	12.32	24.97	0.09	0.14	305.82	303.57	3	8
867	1390	2	2	11	0	8.06	21.87	324.24	18.07	25.47	0.09	0.14	306.17	303.82	3	8
867	1390	2	2	11	15	8.06	21.87	324.24	19.23	26.48	0.10	0.14	305.01	302.58	3	8
867	1390	2	2	11	45	8.06	21.87	315.82	11.99	29.81	0.10	0.15	303.83	301.33	3	3
867	1390	2	2	12	30	8.06	21.87	316.04	12.80	37.09	0.11	0.15	303.24	300.82	3	8

Table 4 (continued)

LINE	COL.	MON	DAY	HR	MIN	LAT	LONG	TB039	DIF-TB	SZA	REF006	REF008	TB108	TB120	GLC	FRP
Duration: 11 slots (cont.)																
914	1614	2	2	9	0	6.82	28.95	321.37	19.92	29.44	0.12	0.15	301.45	296.98	3	8
914	1614	2	2	9	30	6.82	28.95	318.29	11.77	25.74	0.11	0.15	306.52	303.57	3	1
914	1614	2	2	9	45	6.82	28.95	321.46	12.88	24.53	0.10	0.14	308.58	305.30	3	1
914	1614	2	2	12	45	6.82	28.95	328.90	19.19	44.89	0.11	0.16	309.71	306.64	3	1
914	1614	2	2	13	15	6.82	28.95	326.44	18.54	51.33	0.12	0.16	307.90	304.81	3	1
914	1614	2	2	13	30	6.82	28.95	328.74	22.57	54.65	0.11	0.14	306.17	303.33	3	1
914	1614	2	2	13	45	6.82	28.95	318.40	13.63	58.01	0.12	0.15	304.77	302.08	3	1
914	1614	2	2	14	0	6.82	28.95	316.26	11.49	61.41	0.12	0.16	304.77	301.95	3	1
914	1614	2	2	14	30	6.82	28.95	316.32	13.20	68.30	0.13	0.16	303.12	300.95	3	1
914	1614	2	2	14	45	6.82	28.95	313.32	11.03	71.78	0.13	0.15	302.29	300.06	3	1
914	1614	2	2	15	15	6.82	28.95	314.51	14.15	78.80	0.15	0.16	300.36	298.27	3	1
Duration: 10 slots																
1027	1599	2	2	11	45	3.65	28.26	318.50	15.85	30.46	0.15	0.17	302.65	298.27	9	8
1027	1599	2	2	12	0	3.65	28.26	321.08	16.19	33.29	0.11	0.15	304.89	300.31	9	8
1027	1599	2	2	12	15	3.65	28.26	316.10	13.81	36.28	0.14	0.18	302.29	297.62	9	8
1027	1599	2	2	12	45	3.65	28.26	316.65	17.39	42.58	0.18	0.22	299.26	294.88	9	9
1027	1599	2	2	13	0	3.65	28.26	317.08	14.07	45.86	0.11	0.14	303.01	298.40	9	8
1027	1599	2	2	13	15	3.65	28.26	319.97	22.56	49.19	0.22	0.25	297.41	293.15	9	9
1027	1599	2	2	14	0	3.65	28.26	323.80	26.02	59.47	0.12	0.14	297.78	293.42	9	1
1027	1599	2	2	14	15	3.65	28.26	331.06	34.40	62.94	0.16	0.18	296.66	292.62	9	1
1027	1599	2	2	14	30	3.65	28.26	333.60	36.94	66.45	0.13	0.14	296.66	292.08	9	1
1027	1599	2	2	14	45	3.65	28.26	315.71	21.46	69.97	0.17	0.19	294.25	290.59	9	8

Table 4 (continued)

Duration: 9 slots

LINE	COL.	MON	DAY	HR	MIN	LAT	LONG	TB039	DIF-TB	SZA	REF006	REF008	TB108	TB120	GLC	FRP
864	1758	2	2	9	30	8.30	34.13	318.50	11.52	25.65	0.10	0.11	306.98	300.82	12	1
864	1758	2	2	10	0	8.30	34.13	321.37	13.82	25.30	0.10	0.12	307.55	301.20	12	1
864	1758	2	2	10	15	8.30	34.13	317.61	10.06	25.93	0.10	0.12	307.55	301.33	12	9
864	1758	2	2	10	45	8.30	34.13	319.06	11.16	28.63	0.11	0.13	307.90	301.58	12	1
864	1758	2	2	11	15	8.30	34.13	321.98	14.20	32.82	0.13	0.14	307.78	301.58	12	6
864	1758	2	2	11	30	8.30	34.13	323.08	16.56	35.32	0.14	0.15	306.52	300.44	12	8
864	1758	2	2	11	45	8.30	34.13	316.92	15.11	38.01	0.24	0.24	301.81	295.80	12	8
864	1758	2	2	12	15	8.30	34.13	315.59	12.70	43.84	0.21	0.20	302.89	296.59	12	9
864	1758	2	2	13	15	8.30	34.13	318.40	17.79	56.61	0.19	0.19	300.61	295.80	12	8

Duration: 8 slots

LINE	COL.	MON	DAY	HR	MIN	LAT	LONG	TB039	DIF-TB	SZA	REF006	REF008	TB108	TB120	GLC	FRP
826	1650	2	2	8	45	9.33	30.41	316.86	24.42	32.76	0.11	0.13	292.44	288.39	15	3
826	1650	2	2	9	0	9.33	30.41	318.96	26.52	30.68	0.11	0.13	292.44	288.66	15	3
826	1650	2	2	9	15	9.33	30.41	319.12	26.03	28.93	0.12	0.13	293.09	289.63	15	3
826	1650	2	2	9	30	9.33	30.41	316.86	23.51	27.56	0.13	0.14	293.35	290.04	15	3
826	1650	2	2	9	45	9.33	30.41	316.86	22.74	26.64	0.13	0.14	294.12	290.72	15	3
826	1650	2	2	10	0	9.33	30.41	315.02	20.51	26.23	0.13	0.14	294.51	290.72	15	3
826	1650	2	2	10	30	9.33	30.41	315.76	19.73	26.94	0.14	0.14	296.03	292.62	15	3
826	1650	2	2	11	15	9.33	30.41	315.14	15.39	31.46	0.12	0.13	299.75	296.46	15	3
941	1755	2	2	9	15	6.11	33.80	318.96	10.61	24.68	0.06	0.06	308.35	300.95	16	8
941	1755	2	2	9	30	6.11	33.80	320.46	10.86	23.58	0.06	0.06	309.60	302.08	16	8
941	1755	2	2	9	45	6.11	33.80	321.51	10.90	23.04	0.07	0.06	310.61	303.08	16	8
941	1755	2	2	10	0	6.11	33.80	322.67	11.51	23.08	0.07	0.07	311.16	303.70	16	8
941	1755	2	2	10	15	6.11	33.80	323.93	11.99	23.71	0.07	0.07	311.94	303.95	16	3
941	1755	2	2	10	30	6.11	33.80	324.19	12.03	24.89	0.08	0.08	312.16	304.07	16	3
941	1755	2	2	10	45	6.11	33.80	325.14	11.99	26.53	0.08	0.08	313.15	304.93	16	8
941	1755	2	2	11	0	6.11	33.80	324.11	12.61	28.56	0.10	0.10	311.50	303.20	16	8

Table 4 (continued)

LINE	COL.	MON	DAY	HR	MIN	LAT	LONG	TB039	DIF-TB	SZA	REF006	REF008	TB108	TB120	GLC	FRP
Duration: 8 slots (cont.)																
966	1702	2	2	9	45	5.38	31.85	318.60	10.36	22.53	0.09	0.12	308.24	301.33	12	8
966	1702	2	2	10	15	5.38	31.85	320.84	10.23	22.59	0.10	0.13	310.61	303.57	12	8
966	1702	2	2	10	30	5.38	31.85	319.67	10.52	23.51	0.11	0.14	309.15	302.45	12	8
966	1702	2	2	10	45	5.38	31.85	318.71	10.59	24.96	0.12	0.16	308.12	300.95	12	8
966	1702	2	2	11	15	5.38	31.85	320.21	10.39	29.08	0.13	0.16	309.82	302.70	12	8
966	1702	2	2	11	30	5.38	31.85	319.77	10.51	31.59	0.14	0.17	309.26	302.58	12	8
966	1702	2	2	11	45	5.38	31.85	318.55	11.00	34.32	0.18	0.22	307.55	301.07	12	8
966	1702	2	2	12	0	5.38	31.85	317.88	10.67	37.21	0.19	0.23	307.21	300.95	12	8
Duration: 7 slots																
766	1919	2	2	8	0	11.27	40.95	315.82	10.81	34.71	0.21	0.23	305.01	298.78	13	9
766	1919	2	2	8	15	11.27	40.95	316.81	10.99	32.68	0.21	0.23	305.82	299.30	13	9
766	1919	2	2	8	30	11.27	40.95	317.98	11.81	30.96	0.22	0.23	306.17	299.68	13	9
766	1919	2	2	8	45	11.27	40.95	318.55	12.03	29.61	0.22	0.24	306.52	299.55	13	8
766	1919	2	2	9	0	11.27	40.95	319.12	12.37	28.68	0.22	0.24	306.75	299.55	13	8
766	1919	2	2	9	15	11.27	40.95	318.86	12.57	28.21	0.23	0.24	306.29	299.42	13	3
766	1919	2	2	9	30	11.27	40.95	318.50	12.68	28.22	0.24	0.25	305.82	299.17	13	3
Duration: 6 slots																
844	1644	2	2	8	15	8.81	30.15	333.87	38.85	37.52	0.13	0.16	295.02	291.81	12	8
844	1644	2	2	8	30	8.81	30.15	334.37	39.86	34.91	0.13	0.16	294.51	290.45	12	3
844	1644	2	2	8	45	8.81	30.15	324.32	29.69	32.51	0.13	0.16	294.63	290.31	12	3
844	1644	2	2	9	0	8.81	30.15	316.48	22.36	30.38	0.13	0.16	294.12	289.63	12	3
844	1644	2	2	10	15	8.81	30.15	319.92	23.51	25.78	0.12	0.15	296.41	292.08	12	3
844	1644	2	2	10	45	8.81	30.15	315.87	16.85	27.46	0.12	0.15	299.02	294.35	12	3

Table 4 (continued)

LINE	COL.	MON	DAY	HR	MIN	LAT	LONG	TB039	DIF-TB	SZA	REF006	REF008	TB108	TB120	GLC	FRP
Duration: 6 slots (cont.)																
1002	1815	2	2	9	15	4.40	35.88	319.87	10.05	22.39	0.17	0.19	309.82	303.20	14	8
1002	1815	2	2	9	30	4.40	35.88	320.60	10.11	21.53	0.18	0.19	310.49	303.82	14	8
1002	1815	2	2	9	45	4.40	35.88	320.65	10.49	21.28	0.18	0.19	310.16	303.45	14	8
1002	1815	2	2	10	0	4.40	35.88	321.08	10.70	21.67	0.18	0.19	310.38	303.33	14	8
1002	1815	2	2	10	15	4.40	35.88	321.42	10.48	22.67	0.19	0.20	310.94	303.95	14	8
1002	1815	2	2	10	30	4.40	35.88	321.65	10.04	24.21	0.19	0.21	311.61	304.93	14	8
885	1749	2	2	10	45	7.70	33.73	320.94	13.73	27.91	0.09	0.12	307.21	301.20	3	8
885	1749	2	2	11	0	7.70	33.73	318.50	13.61	29.85	0.13	0.16	304.89	299.04	3	8
885	1749	2	2	11	30	7.70	33.73	317.45	11.63	34.60	0.12	0.15	305.82	299.93	3	8
885	1749	2	2	14	45	7.70	33.73	317.98	20.07	76.57	0.19	0.20	297.91	294.35	3	8
885	1749	2	2	15	0	7.70	33.73	316.48	18.95	80.08	0.20	0.20	297.53	294.75	3	1
885	1749	2	2	15	30	7.70	33.73	307.88	11.85	87.14	0.23	0.22	296.03	293.29	3	1
Duration: 4 slots																
874	1688	2	2	8	15	7.98	31.59	326.19	32.20	35.93	0.12	0.19	293.99	289.08	18	3
874	1688	2	2	8	45	7.98	31.59	333.67	35.64	31.00	0.12	0.17	298.03	293.15	18	8
874	1688	2	2	10	0	7.98	31.59	321.61	16.37	24.85	0.11	0.17	305.24	300.06	18	6
874	1688	2	2	10	15	7.98	31.59	320.36	14.54	25.13	0.11	0.17	305.82	300.44	18	6
Duration: 3 slots																
944	1518	2	2	12	45	5.94	25.75	317.82	14.34	41.72	0.11	0.18	303.48	300.31	3	8
944	1518	2	2	13	0	5.94	25.75	329.99	27.58	44.87	0.11	0.17	302.41	298.91	3	8
944	1518	2	2	13	15	5.94	25.75	320.46	20.46	48.10	0.11	0.15	300.00	296.85	3	3
1105	2017	2	2	9	45	1.52	43.99	318.40	11.88	20.21	0.13	0.16	306.52	299.42	13	3
1105	2017	2	2	10	0	1.52	43.99	317.88	11.71	21.99	0.14	0.17	306.17	299.42	13	3
1105	2017	2	2	10	30	1.52	43.99	316.70	12.28	26.77	0.16	0.19	304.42	298.14	13	3

Table 4 (continued)

LINE	COL.	MON	DAY	HR	MIN	LAT	LONG	TB039	DIF-TB	SZA	REF006	REF008	TB108	TB120	GLC	FRP
Duration: 3 slots (cont.)																
903	1638	2	2	12	45	7.14	29.78	319.47	12.72	45.76	0.12	0.15	306.75	302.95	12	8
903	1638	2	2	13	15	7.14	29.78	320.60	16.06	52.22	0.13	0.16	304.54	300.44	12	1
903	1638	2	2	13	30	7.14	29.78	323.84	19.53	55.54	0.13	0.16	304.31	300.69	12	1
917	1687	2	2	10	15	6.76	31.44	317.72	10.97	23.89	0.17	0.19	306.75	299.68	15	8
917	1687	2	2	10	30	6.76	31.44	318.71	10.59	24.71	0.17	0.19	308.12	301.58	15	9
917	1687	2	2	10	45	6.76	31.44	318.55	11.23	26.04	0.18	0.20	307.32	300.95	15	8
907	588	2	2	12	0	6.84	-0.82	316.86	10.11	23.81	0.10	0.15	306.75	300.95	12	7
907	588	2	2	12	15	6.84	-0.82	316.86	10.46	23.72	0.10	0.15	306.40	300.69	12	7
907	588	2	2	12	30	6.84	-0.82	317.13	10.04	24.21	0.10	0.15	307.09	301.45	12	7
945	1759	2	2	9	15	6.00	33.93	319.92	11.23	24.53	0.09	0.10	308.69	300.95	16	8
945	1759	2	2	9	30	6.00	33.93	320.11	11.42	23.45	0.11	0.12	308.69	300.95	16	3
945	1759	2	2	9	45	6.00	33.93	320.21	11.40	22.92	0.12	0.12	308.81	301.33	16	9
884	616	2	2	12	15	7.47	-0.05	318.09	13.08	24.41	0.12	0.15	305.01	300.06	3	8
884	616	2	2	12	30	7.47	-0.05	316.59	13.11	24.99	0.12	0.16	303.48	298.40	3	8
884	616	2	2	12	45	7.47	-0.05	316.65	15.08	26.10	0.11	0.14	301.57	296.19	3	8
977	1713	2	2	9	45	5.08	32.22	317.45	13.26	22.18	0.19	0.20	304.19	297.24	12	9
977	1713	2	2	11	45	5.08	32.22	322.95	11.34	34.40	0.13	0.15	311.61	304.56	12	9
977	1713	2	2	12	0	5.08	32.22	319.12	13.53	37.32	0.22	0.24	305.59	298.78	12	9
Duration: 2 slots																
991	1530	2	2	10	15	4.64	26.06	319.27	11.03	21.59	0.08	0.13	308.24	303.33	9	1
991	1530	2	2	10	30	4.64	26.06	319.32	15.49	21.59	0.10	0.15	303.83	297.75	9	6
989	1739	2	2	10	30	4.75	33.12	325.44	21.25	23.36	0.17	0.21	304.19	298.78	12	8
989	1739	2	2	10	45	4.75	33.12	315.87	14.30	24.99	0.21	0.24	301.57	296.33	12	8
1032	1709	2	2	11	0	3.53	31.99	316.10	12.38	25.37	0.15	0.18	303.72	297.75	3	8
1032	1709	2	2	11	15	3.53	31.99	315.54	11.71	27.73	0.16	0.20	303.83	298.14	3	8
816	1197	2	2	13	15	9.42	16.19	318.29	12.12	42.19	0.15	0.20	306.17	302.33	18	8
816	1197	2	2	13	45	9.42	16.19	324.93	16.24	48.22	0.15	0.19	308.69	305.05	18	1

Table 4 (continued)

LINE	COL.	MON	DAY	HR	MIN	LAT	LONG	TB039	DIF-TB	SZA	REF006	REF008	TB108	TB120	GLC	FRP
Duration: 2 slots (cont.)																
861	612	2	2	11	45	8.10	-0.16	316.26	10.09	25.53	0.11	0.16	306.17	301.07	12	8
861	612	2	2	12	0	8.10	-0.16	317.24	10.03	25.01	0.11	0.16	307.21	301.95	12	8
811	1372	2	2	13	0	9.62	21.44	320.80	19.59	43.49	0.13	0.18	301.21	297.37	12	3
811	1372	2	2	13	15	9.62	21.44	315.14	15.02	46.49	0.13	0.18	300.12	296.59	12	8
853	562	2	2	14	0	8.32	-1.53	316.26	10.55	36.61	0.12	0.15	305.71	300.95	3	8
853	562	2	2	14	15	8.32	-1.53	317.88	13.46	39.39	0.13	0.15	304.42	299.93	3	1
772	290	2	2	12	45	10.60	-9.08	316.26	14.81	27.45	0.12	0.18	301.45	296.72	12	8
772	290	2	2	13	0	10.60	-9.08	315.25	13.56	27.78	0.13	0.18	301.69	297.24	12	8
1090	1695	2	2	10	45	1.90	31.44	317.72	11.20	21.64	0.10	0.13	306.52	299.68	16	2
1090	1695	2	2	11	45	1.90	31.44	316.97	11.03	31.73	0.12	0.15	305.94	299.55	16	2
869	609	2	2	12	15	7.88	-0.25	318.60	12.66	24.80	0.12	0.15	305.94	299.93	12	7
869	609	2	2	12	30	7.88	-0.25	318.03	11.97	25.35	0.11	0.15	306.06	300.31	12	7
1032	1709	2	2	11	0	3.53	31.99	316.10	12.38	25.37	0.15	0.18	303.72	297.75	3	8
1032	1709	2	2	11	15	3.53	31.99	315.54	11.71	27.73	0.16	0.20	303.83	298.14	3	8
816	1665	2	2	11	45	9.62	30.97	319.12	12.03	36.69	0.13	0.16	307.09	302.45	18	8
816	1665	2	2	12	0	9.62	30.97	324.06	15.59	39.35	0.13	0.16	308.47	304.44	18	1
Duration: 1 slot																
760	526	2	2	10	30	10.91	-2.53	316.15	11.49	38.19	0.13	0.18	304.66	300.31	12	8
966	1630	2	2	10	0	5.36	29.38	320.60	18.67	22.35	0.15	0.18	301.93	297.50	3	8
914	1712	2	2	9	45	6.86	32.32	316.48	10.42	23.92	0.11	0.12	306.06	299.04	12	9
965	1697	2	2	11	15	5.41	31.68	317.08	10.79	28.99	0.19	0.24	306.29	299.68	12	9
990	1061	2	2	16	45	4.59	12.13	308.23	14.88	83.42	0.14	0.16	293.35	291.00	1	8
826	1650	2	2	11	45	9.33	30.41	315.93	17.53	36.10	0.13	0.14	298.40	295.01	15	3
882	1629	2	2	10	15	7.73	29.53	320.06	11.14	24.66	0.11	0.13	308.92	302.95	18	6
866	1739	2	2	12	30	8.24	33.43	316.54	13.53	46.30	0.16	0.22	303.01	298.01	12	8
875	1248	2	2	9	0	7.79	17.60	320.60	23.19	37.81	0.11	0.15	297.41	293.02	3	3
935	1752	2	2	11	15	6.28	33.70	316.75	12.21	30.97	0.18	0.21	304.54	297.88	12	9

Table 4 (continued)

LINE	COL.	MON	DAY	HR	MIN	LAT	LONG	TB039	DIF-TB	SZA	REF006	REF008	TB108	TB120	GLC	FRP
Duration: 1 slots (cont.)																
903	1780	2	2	9	15	7.20	34.82	316.54	11.77	25.36	0.10	0.11	304.77	298.91	16	8
908	1711	2	2	9	45	7.03	32.30	318.71	10.02	24.09	0.10	0.12	308.69	302.33	12	6
904	1772	2	2	9	0	7.17	34.52	318.96	10.38	26.86	0.08	0.10	308.58	301.70	3	9
889	612	2	2	13	0	7.33	-0.16	320.02	16.30	27.49	0.12	0.14	303.72	298.53	3	8
997	1714	2	2	12	15	4.51	32.22	315.76	10.40	40.05	0.18	0.23	305.36	299.55	3	9
993	1291	2	2	10	30	4.53	18.73	318.45	17.60	22.06	0.08	0.14	300.85	296.85	9	8
667	121	2	2	14	0	13.60	-14.07	316.37	11.48	33.64	0.14	0.18	304.89	301.33	18	8

Results shown in Figures 2 and 3 allow assessing the impact on the characteristics of the daily cycle of fire activity of the discrepancies between the FD&M and the FRP products. It may be noted that the NAfr window was subdivided into an eastern region (east of 15º E) and a western region (west of 15ºE) and the daily cycles of active fires (namely the number of fire pixels per time slot and this number normalized by the total daily amount) were computed on a local solar time basis. It may be observed that the FD&M product has a much pronounced daily cycle than the FRP product and that differences between the two products are more pronounced when the values are normalized. Since the FRP algorithm is less restrictive than FiDAlgo in what respects to the thresholds of radiative temperature, differences between the two products seem to point out the plausible fact that large fires have a more pronounced daily cycle as opposed to weak fires that are less dependent on temperature and humidity conditions along the day and therefore tend to have a more uniform distribution. This aspect deserves further investigation.

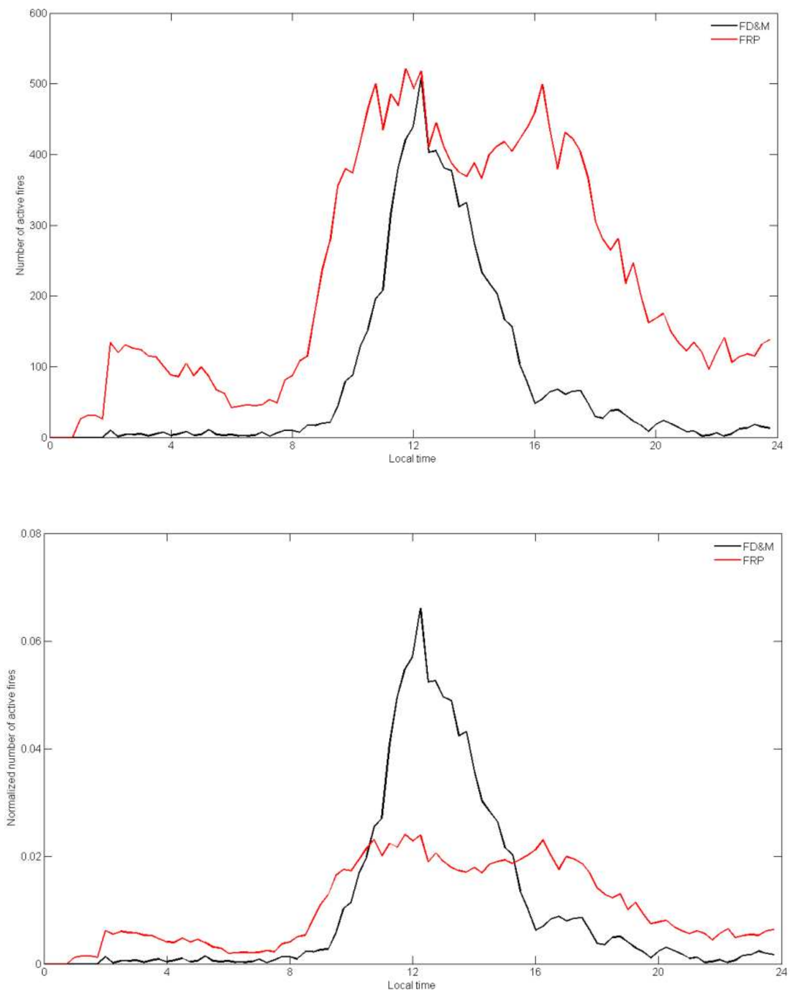


Figure 2 Daily cycles of fire activity (top panel) and of normalized fire activity (bottom panel) as a function of local solar time and as derived from FD&M (black curve) and from FRP (red curve) products over the eastern region (east of 15º E) of the NAfr window on February 2nd, 2011.

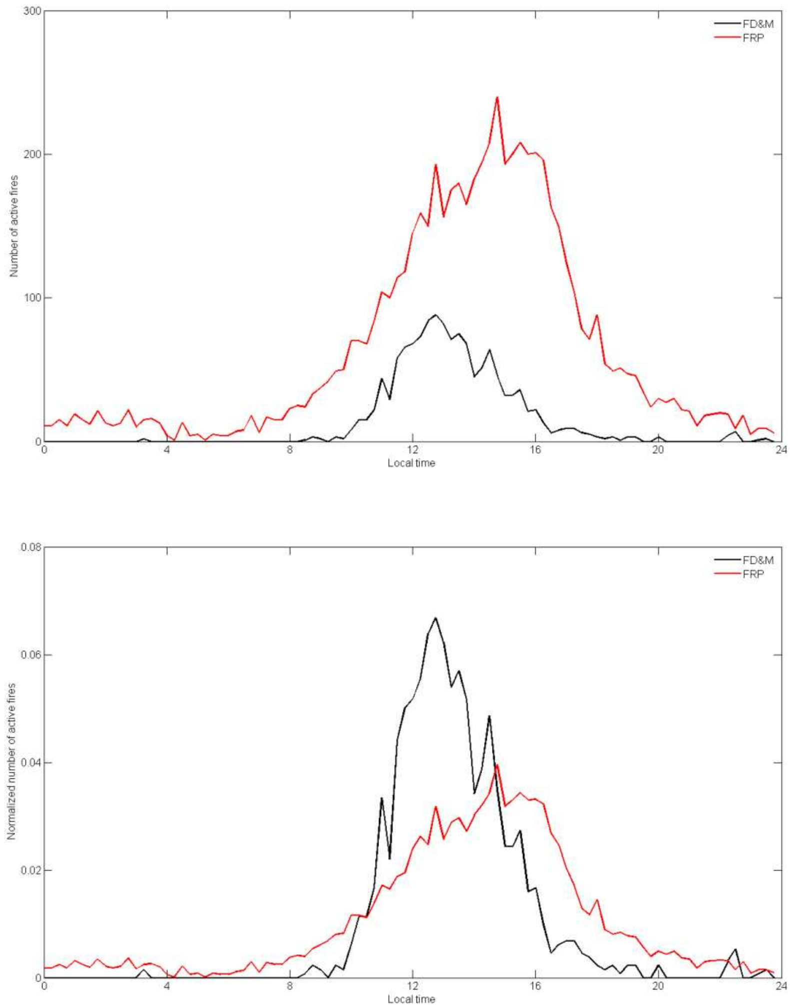


Figure 3 As in Figure 2 but over the western region (west of 15º E) of the NAfr window.

4.2. Systematic comparison: FD&M and FRP vs. MODIS

As shown in Table 5, six MODIS files of active fires were chosen covering the daily cycle of February 2nd, 2011. For each MODIS image the closest subsequent MSG slot was selected and an area of study was defined as limited by the two latitude circles corresponding to the 5th and 95th percentiles of latitudes of the MODIS sample of active fires and by the two meridians corresponding to the 5th and 95th percentiles of longitudes of that MODIS sample. Figures 4 to 9 show the results of the comparison of active fires as identified by MODIS at the six chosen time slots against those identified by the FD&M and the FRP products. As expected, given the larger spatial resolution of MODIS, the number of active fires identified by the latter instrument is about one order of magnitude larger than those identified by either FD&M or FRP. On the other hand the number of FRP hits (i.e. the number of MSG pixels containing an active fire identified by FRP and at least an active fire identified by MODIS) is systematically larger than the corresponding FD&M hits. As shown in Table 6, this feature translates into a larger value of probability of detection (POD ~ 8%) for the FRP product than for FD&M (POD ~ 5%). As already pointed out, this is also to be expected due to the fact that FD&M is based on FiDAlgo, an algorithm that is based on more restrictive criteria than the ones adopted by FRP. However, as shown by the higher value of the false alarm ratio in the case of FRP (FAR ~ 61%) than the one for FD&M (Far ~ 54%), the number of FRP false alarms (i.e. the number of pixels containing only an active fire identified by FRP) is also larger than the corresponding FD&M false alarms.

Table 5 Fire pixels, as detected by MODIS and FD&M/FRP over selected regions over the NAfr window, at six time slots of February 2nd, 2011.

		FD&M			FRP		
		FD&M & MODIS	FD&M only	MODIS only	FRP & MODIS	FRP only	MODIS only
MODIS	01:00	0	0	9	1	5	8
	08:50	40	60	780	57	119	763
	10:30	2	3	210	8	14	204
	11:50	79	72	1161	107	133	1133
	13:30	20	32	552	33	55	539
	21:15	0	0	44	22	35	22

Table 6 As in Table 5 but for the combined six time slots, together with derived values of probability of detection (POD) and of false alarm ratio (FAR).

	FD&M / FRP Only [A]	FD&M / FRP and MODIS [B]	MODIS Only [C]	POD (%) $100 \times \frac{[B]}{[B]+[C]}$	FAR (%) $100 \times \frac{[A]}{[A]+[B]}$
FD&M	167	141	2 756	4.8 %	54.2 %
FRP	361	228	2 669	7.9 %	61.3 %

For both the FD&M and the FRP products, the number of false alarms was greater than the number of corresponding hits, leading to values of FAR greater than 50%. In order to check whether this problem might be related to problems of geolocation of MSG pixels (which are known to exist), the procedure was repeated using MSG blocks of 3×3 pixels. Results are shown in Tables 7 and 8 and it may be noted that FD&M and FRP false alarms are now consistently lower than the respective hit, leading to higher values of POD (from 4.8 to 5.6% in the case of FD&M, and from 7.9 to 11.6% in the case of FRP), as well to lower values of FAR (from 54.2 to 34.6% in the case of FD&M and from 61.3% to 3.9%). The improvements are therefore more noticeable in the case of the FRP product.

Table 7 As in Table 5 but when computed in a 3×3 MSG pixel grid.

		FD&M			FRP		
		FD&M & MODIS	FD&M only	MODIS only	FRP & MODIS	FRP only	MODIS only
MODIS	01:00	0	0	9	1	2	8
	08:50	32	25	572	68	41	536
	10:30	3	2	187	10	8	180
	11:50	65	29	860	115	49	810
	13:30	23	9	415	44	22	394
	21:15	0	0	34	18	9	15

Table 8 As in Table 6 but when computed in a 3×3 MSG pixel grid.

	FD&M / FRP Only [A]	FD&M / FRP and MODIS [B]	MODIS Only [C]	POD (%) $100 \times \frac{[B]}{[B]+[C]}$	FAR (%) $100 \times \frac{[A]}{[A]+[B]}$
FD&M	65	123	2 077	5.6 %	34.6 %
FRP	131	256	1 943	11.6 %	33.9 %

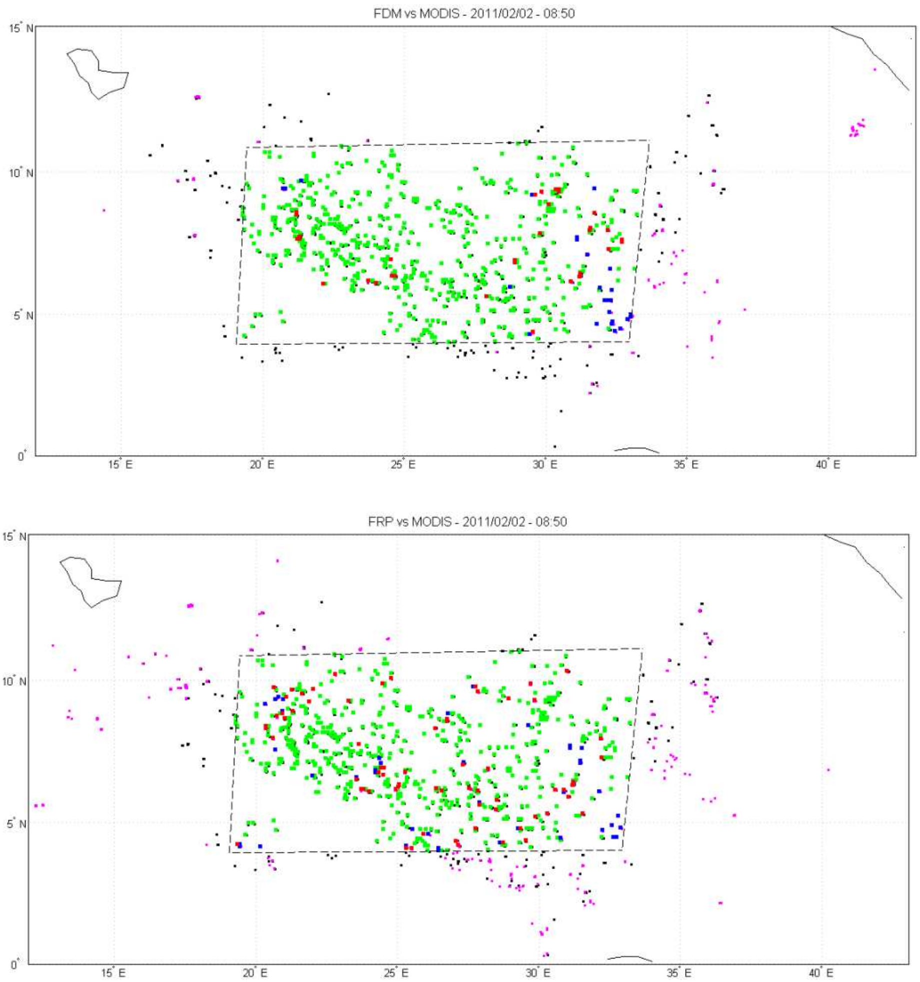
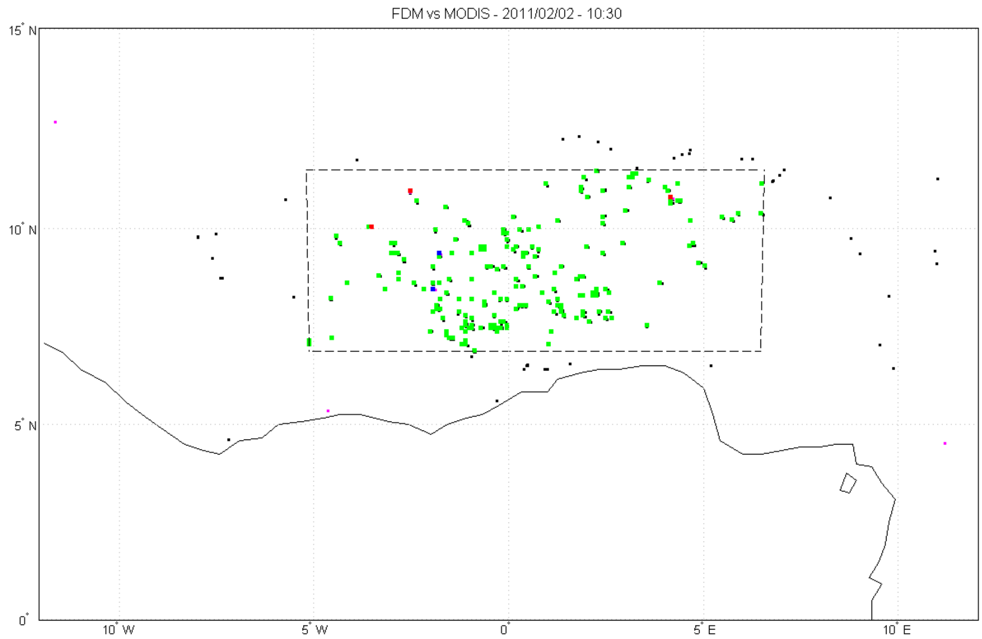


Figure 4 Comparison of active fires as identified by MODIS at 08:50 of February 2nd, 2011 versus those identified by FD&M (top panel) and by FRP (bottom panel) products. The colour code is as follows: A) Inside the selected region, identified by the dashed rectangular frame - RED pixels <> active fires identified by both MODIS and FD&M/FRP, GREEN pixels <> active fires identified by MODIS only, BLUE pixels <> active fires identified by FD&M/FRP only. B) Outside the selected region: BLACK pixels <> active fires identified by MODIS, MAGENTA pixels <> active fires identified by FD&M/FRP



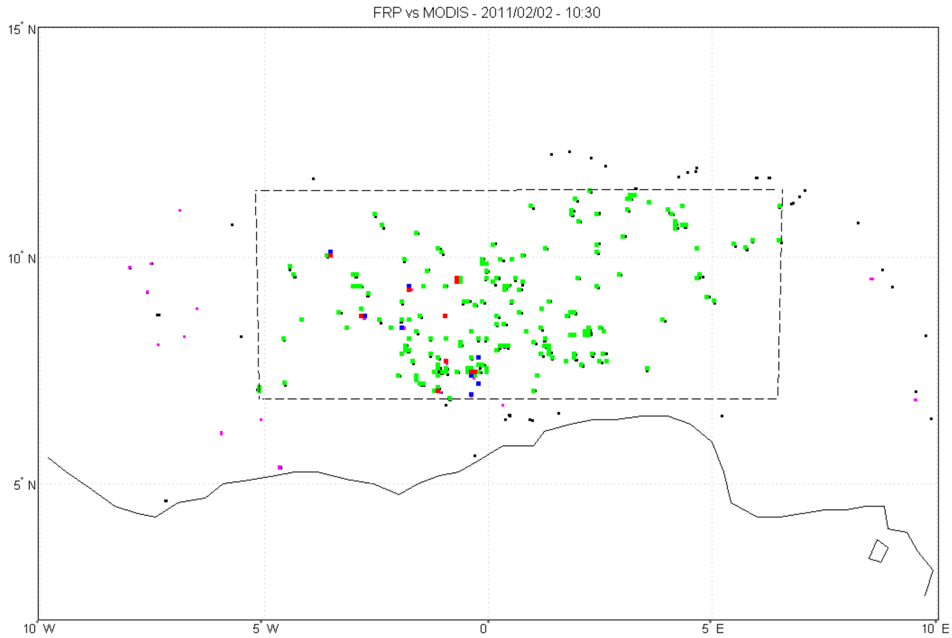


Figure 5 As in Figure 4 but at 10:30.

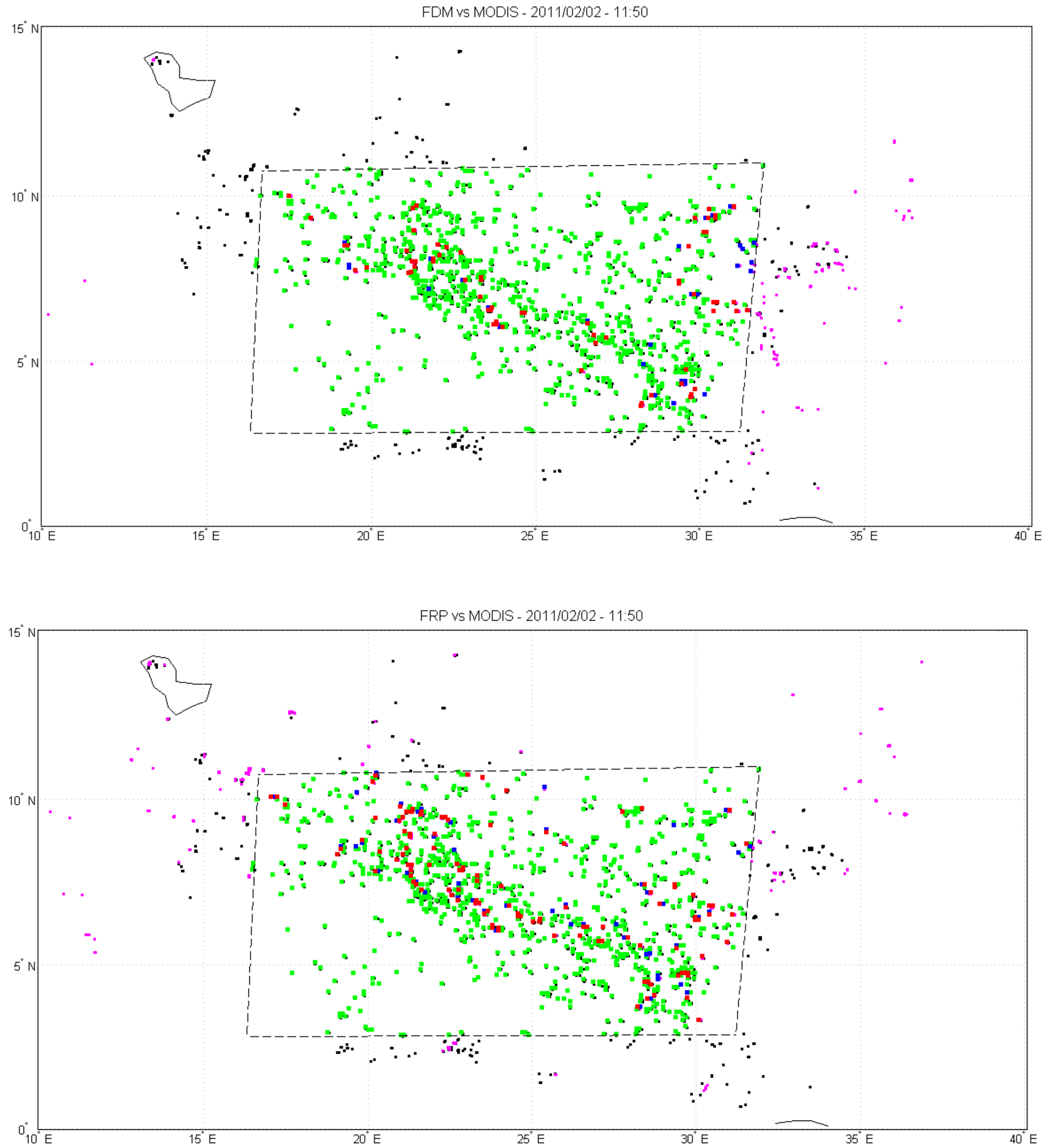


Figure 6 As in Figure 4 but at 11:50.

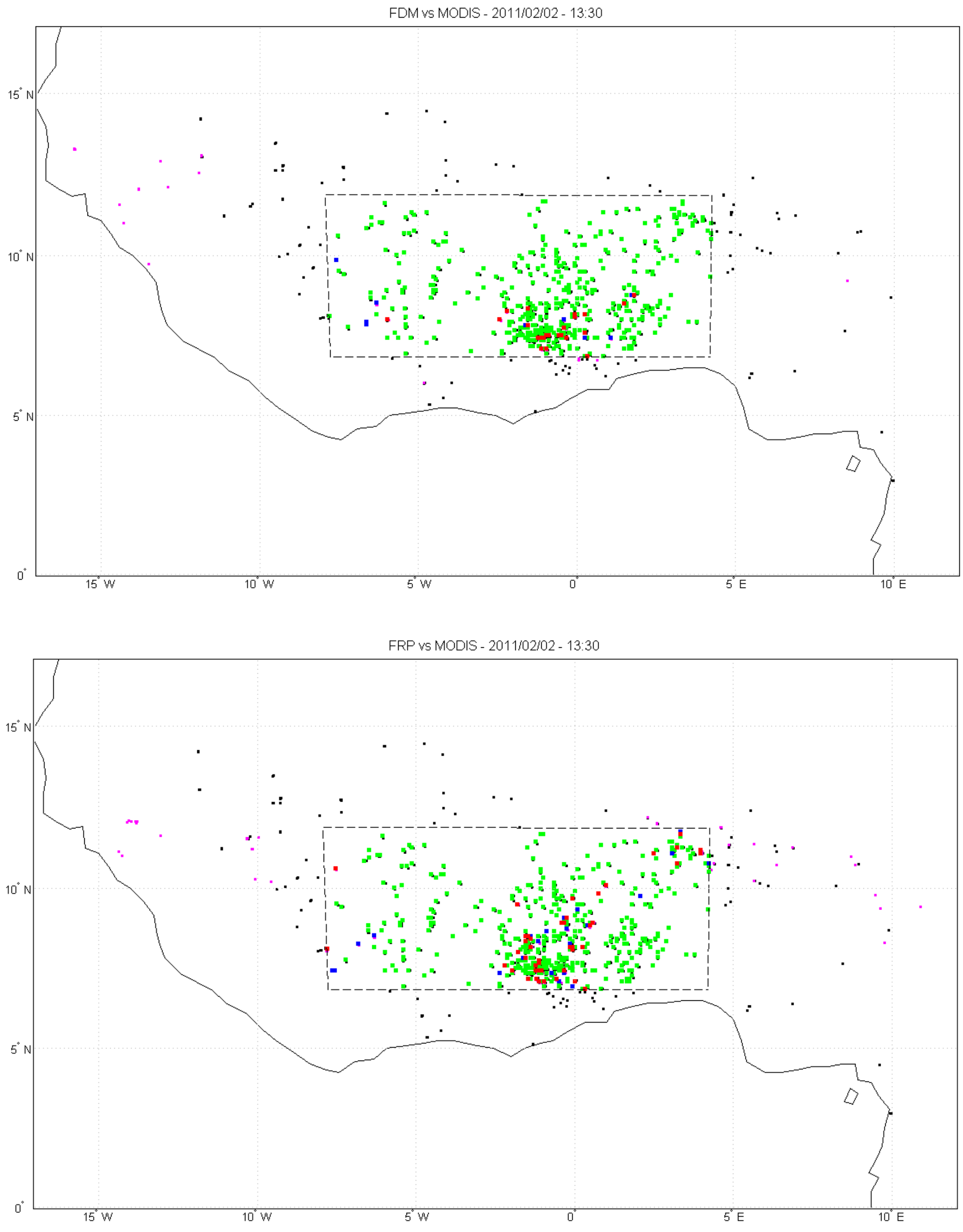
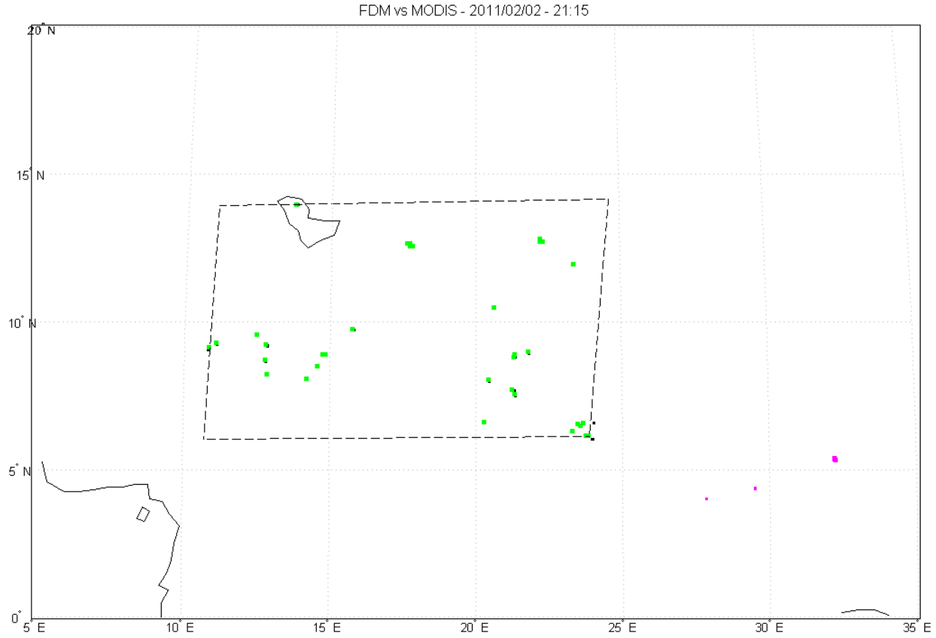


Figure 7 As in Figure 4 but at 13:30.



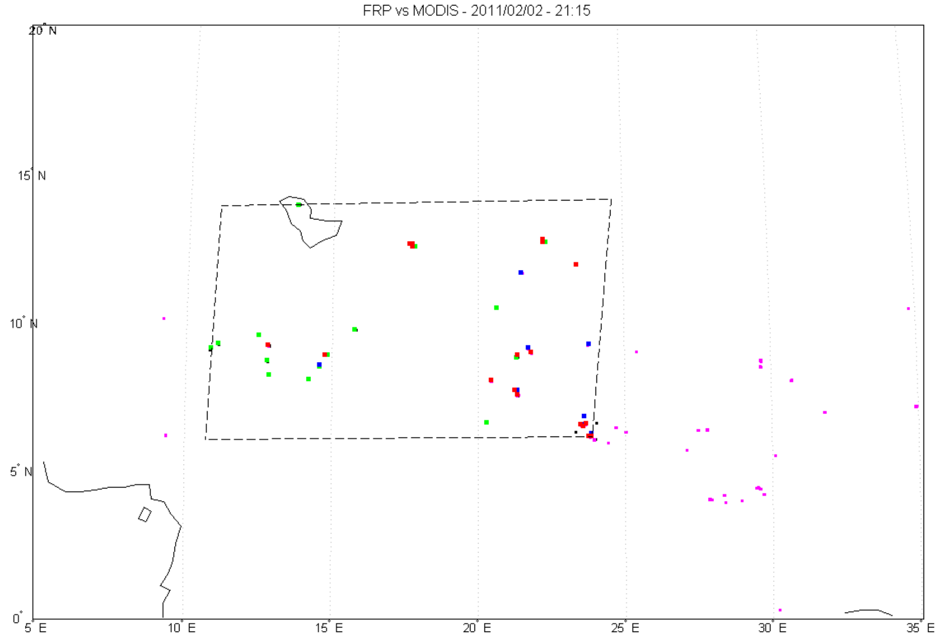


Figure 8 As in Figure 4 but at 21:15.

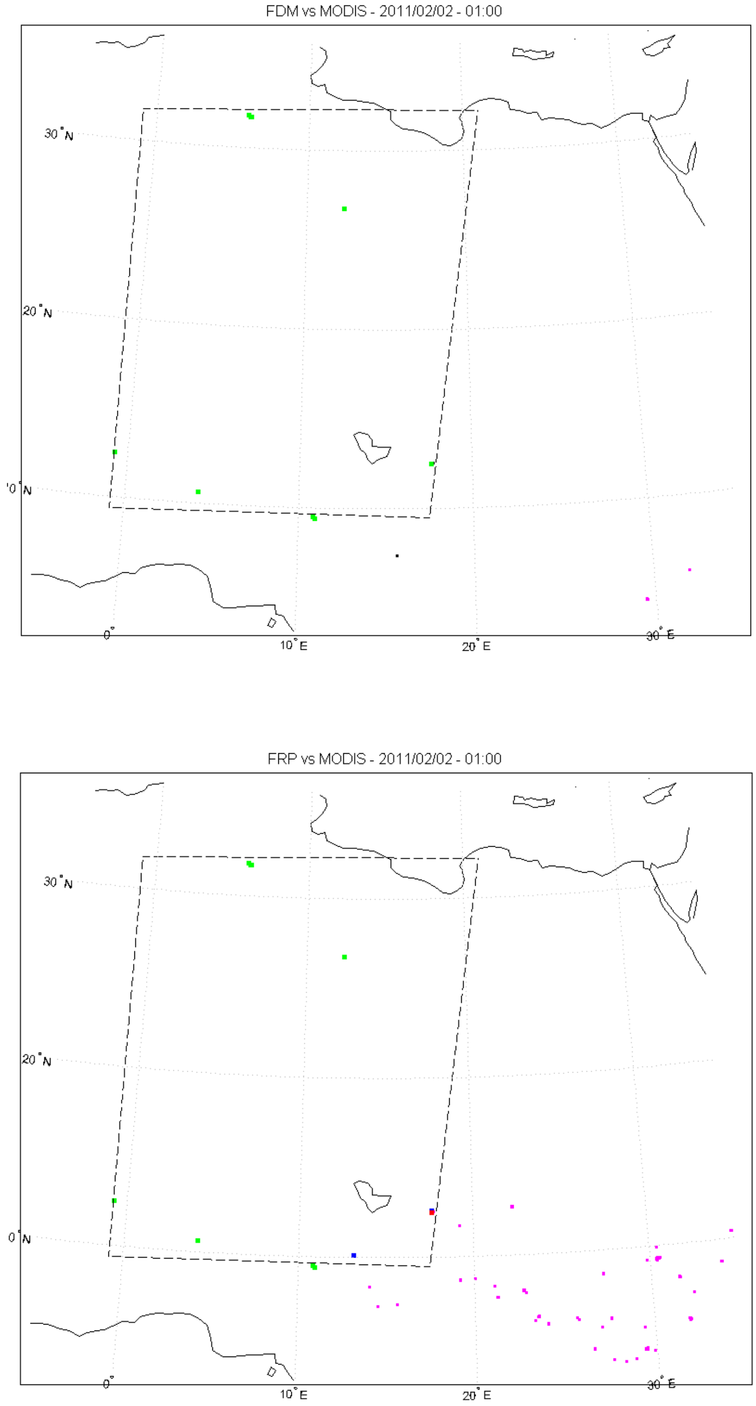


Figure 9 As in Figure 4 but at 01:00.

5. Conclusions

5.1. Product validation summary

The FD&M product was evaluated in what respects to:

- its sensitivity, i.e. to its capacity of mitigating omission errors (or missed hits);
- its selectivity, i.e. to its capacity of mitigating commission errors (or false alarms).

An analysis of *consistency* was first undertaken between the FD&M and the FRP products which are both derived from information derived from SEVIRI on-board Meteosat-8. The analysis was performed over the NAfr window and covered the whole daily cycle (i.e. 96 SEVIRI frames) of February, 2nd 2011. Large discrepancies were found between the two products, with 74% of the total active fires being detected by FRP, 17% by FD&M and the remaining 9% by both instruments. It was also found that the large majority of pixels (~90%) solely detected by FRP did not attain the specified thresholds specified by FD&M in what respects to the values of TB039 and of the difference TB039-TB108. On the other hand, more than 80% of the active fires solely detected by FD&M were discarded by FD&M because of being located in pixels contaminated by clouds. An analysis of the daily cycles of pixels with active fires only identified by FD&M has put into evidence that a significant amount of pixels identified only by FD&M alternate in time with pixels identified by both products. The analysis of the daily cycle of active fires over two regions of the NAfr window has further shown that the FD&M product has a much pronounced daily cycle than the FRP product and that differences between the two products are more pronounced when the values are normalized.

A systematic comparison was then undertaken of the FD&M and FRP products against the product by the MODIS Fire Team. Six MODIS files of active fires were compared against the FD&M and FRP products as derived from the respecting closest subsequent MSG slot. The number of active fires identified by MODIS has shown to be about one order of magnitude larger than the ones identified by FD&M or FRP products. As indicated by the values of POD, respectively about 8% for FRP and about 5% for FD&M, the number of FRP hits was systematically larger than the number of FD&M hits. On the other hand, the number of FRP false alarms has shown to be larger than the number of FD&M false alarms, which translated into a value of about 61% of FAR in the case of FRP and of about 54% in the case of FD&M. With the aim of mitigating the effects associated to errors in geolocation of MSG pixels, the comparison was repeated using blocks of 3×3 MSG pixels. An increase in POD was observed from about 5 to about 6% in the case of FD&M and from about 8 to about 12% in the case of FRP. A decrease in FAR was also observed, from about 54% to about 35% in the case of FD&M and from about 61% to about 34% in the case of FRP.

Results obtained from the analysis of consistency between the FD&M and the FRP products reflect the current different nature of the two products. The FD&M was designed to detect intense active fires whereas FRP relies on less strict criteria in the definition of thresholds for TB039 and for the difference TB039-TB108. On the other hand, FRP relies on more strict criteria than FD&M in what respects to the definition of cloud contaminated pixels. When compared against active fires detected by MODIS, both the FD&M and the FRP products have a rather small number of hits and a rather large number of false alarms. Results improve when the comparison is performed on blocks of 3×3 MSG pixels, an indication of possible problems of geolocation of MSG pixels.

From an overall perspective, it seems that the FD&M product may benefit from less strict thresholds of TB039 and of the difference TB039-TB108 whereas FRP may use less stringent criteria to exclude cloud contaminated pixels. More important than this, the current estimation of thresholds (which, for both products, is based on statistical information of the surrounding pixels) will benefit from the use of multi-temporal observations of fire pixels together with a temporal model (e.g. a Kalman filter). This aspect is planned to be investigated during CDOP-2 (LSA SAF, 2011).

5.2. Accuracy requirements

Accuracy requirements are based on the three following accuracy values:

- *Threshold accuracy* that is defined as the accuracy limit which is required in order that the product fulfils its purpose;
- *Target accuracy* that is defined as the average product accuracy under the present operating conditions together with the instrument characteristics of SEVIRI.
- *Optimal accuracy* that is defined as the accuracy that can be reached under optimum conditions (e.g. sub-satellite point, cloud-free scene, homogeneous background).

The accuracy requirements for the FD&M product are shown in Table 9 and it is worth noting that fulfilment of the target accuracy means that the product is valuable for most of the users. The results obtained provide evidence that the SEVIRI FRP product fulfils the accuracy requirements and will prove to be a useful product. In this respect, it may be noted that the computation of risk in the Fire Risk Map (FRM) product is currently based in information provided from FD&M and that such information has proven to be accurate enough for that purpose.

Table 9 Accuracy requirements for the FD&M product

Threshold Accuracy	Target Accuracy(*)	Optimal Accuracy(*)
A successful detection of a significant fraction of active fires such that the spatial and temporal distribution is adequately reproduced.	POD=5% FAR=33%	POD=10% FAR=33%

(*) Computed against MODIS on a 3×3 MSG pixel grid

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