PARALLEL USE OF SEVIRI LSA SAF FRP AND MPEF FIR PRODUCTS FOR FIRE DETECTION AND MONITORING

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Abstract

The paper is focused on operational application of LSA SAF FRP product as additional data to the MPEF FIR product for fire detection over South-eastern Europe. Detections by NASA TAP MODIS product are used as a reference for assessing the efficiency of the two algorithms using MSG SEVIRI measurements as input data. The performance of the MPEF FIR and LSA SAF FRP products over Bulgaria in July/August 2012 (an year of moderate fire activity) and August 2013 (an year of very low fire activity) is studied considering 40 forest fires (reported by State Forest Agency of Bulgaria). The actual differences or mismatches are studied in order to analyse the following products' capabilities.

- First detection by a product including early warnings (before fire detection by ground observations as reported in the National Fire Data Base of Bulgaria).
- Which of the two algorithms using MSG SEVIRI measurements as input data was able to better detect the signals from the fires during the whole duration of the event (as reported in the National Fire Data Base).
- Cases of small fires not detected by one of the SEVIRI fire products and detected by the other one.

INTRODUCTION

The aim of this study is to evaluate the efficiency of the fire detection algorithms based on data from Meteosat Second Generation (MSG) satellites. Products from two kinds of satellite systems and algorithms are available via the EUMETSAT's primary dissemination mechanism EUMETCast:

- Two products based on MSG SEVIRI instrument:
  - FIR product of Meteosat Products Extraction Facilities (MPEF) of EUMETSAT for thermal anomalies detection by MSG data.
  - Fire Radiative Power (FRP) product of Land Surface Analysis (LSA) Satellite Application Facilities (SAF) Programme of EUMETSAT.
- Thermal Anomalies Product (TAP) at the land surface of National Aeronautics and Space Administration (NASA) based on MODIS instrument on Aqua/Terra satellites.

The MPEF FIR product has been operationally used since 2007 at NIMH of Bulgaria and, in parallel, the performance of its three versions has been evaluated (Stoyanova, et al., 2008; Stoyanova and Georgiev, 2010).

In this paper the LSA SAF FRP product, available from 2008 in its five versions up to 2009 (LSA SAF, 2010) is used as an additional tool for fire detection (Wooster et al., 2003; Govaerts et al., 2010). The FRP product Version I/2010 has been used in the environment of NIMH of Bulgaria since 2012.

Attention is given to some limitations of using satellite fire products regarding the dissemination file formats as well as specific synoptic situations, which are favourable for development of both fires and cloudiness aiming to avoid misunderstanding when assessing the performance of fire detection algorithms.

FIRE DETECTION ALGORITHMS AND DATA SET

The so-called Fire Thermal Anomaly (FTA) algorithm (Giglio et al., 2003) is used for generation of the MODIS TAP as well as the LSA SAF FRP products. The first stage of the FTA algorithm work is the detection of all "fire pixels" within the image that are believed to contain actively burning fires. For Fire Detection the algorithm works mainly on statistics derived from the 3.9 μm and 10.8 μm brightness temperatures, and their differences. On a first pass a series of absolute thresholds are used with these data to detect "potential" fire pixels, which are then further assessed as "true" or "false" fire detections based on a series of further "contextual" tests whose thresholds are adjusted based on statistics derived from the immediately neighbouring non-fire "background" pixels. A cloud mask is used in order to eliminate specular reflections and cloud edges that can present a similar signature to fires under certain daytime conditions (Giglio et al., 2003). The FRP product is operationally generated by data from MSG2 Full scanning, sub-satellite point location 0.0 longitude, repeat cycle every 15 min, resolution 3 km at the sub-satellite point and 5-6 km over South Eastern (SE) Europe.

The MPEF FIR SEVIRI product is operationally generated by EUMETSAT in two modes:

- MSG2 Full scanning, sub-satellite point location 0.0 longitude, repeat cycle every 15 min, resolution ~ 3 km at the sub-satellite point and 5-6 km over SE Europe.
- MSG2 Rapid scanning, sub-satellite point location 9.5°E longitude, repeat cycle every 5 min, resolution ~ 3 km at the sub-satellite point and ~5 km over SE Europe.

The MPEF fire detection algorithm is based on a simple threshold test technique, using SEVIRI channels 4 (3.9 μm) and 9 (10.8 μm), considering a set of parameters: Brightness temperature IR3.9; Standard Deviation IR3.9); Standard Deviation IR10.8); Standard Deviation difference (StdDev3.9–StdDev10.8); Brightness temperature difference (IR3.9-IR10.8). The algorithm is applied for all land surface pixels, excluding desert/bare soil surface pixels and coastal pixels. The algorithm does not need any cloud masking as an input. Instead of cloud mask, it uses SEVIRI channel 1 (0.6 μm) to eliminate (low) clouds with a high reflectance. The algorithm does not perform "contextual" tests.

The study is performed on the base of 31 forest fires in the summer of 2012 and 9 fires in August 2013 reported in the National Data Base, which is maintained by the State Forest Agency (SFA) of Bulgaria. The National Fire Data Base consists of information about various fire characteristics: The village, in which region a fire is located, fire evolution, ignition cause, affected area (total, under/at the forest canopy, herbs & grass), fire rescue operations, etc. Detections by MODIS TAP product are used as a reference for assessing the efficiency of the two SEVIRI algorithms.

The performance of the MPEF FIR and LSA SAF FRP products is studied regarding the following products' capabilities.

- First detection by a product, including early warnings (before fire detection by ground observations as reported in the National Fire Data Base).
- Which of the two algorithms using SEVIRI measurements as input data was able to better detect the signals from the fires during the whole duration of the event (as reported in the National Fire Data Base).
- Cases of small fires not detected by one of the SEVIRI algorithms and detected by the other one.

Data from Thermal Anomalies Product based on measurements of MODIS instrument on polar orbiting satellites with repeat cycle four ooverpasses daily and resolution 1 km at the sub-satellite point, including ~ 1 km over SEE are used as a reference.

DIFFERENCES AND MISMATCHES BETWEEN THE LSA SAF FRP AND MPEF FIR: CASE STUDY EXAMPLES OF FOREST FIRES IN 2012-2013

Tables 1 and 2 show results for a set of forest fires registered at the SFA Data Base. The fire cases are chosen to cover various fire characteristics (regarding size of area affected, duration and diurnal evolution, type of fuel burned). A comparison of the fire detection efficiency of the two MSG SEVIRI products are presented in Table 1.

Table 1. Actual differences between the performance of SEVIRI LSA SAF FRP and MPEF FIR products

Product/Instrument	Detection firstly by this product		Better monitoring fire evolution by this product	Number of nights with detections of the fire with this product	Miss to detect by this product	
	Total number of first fire detections	Early Warning, before ground observations			Total fires failed to detect	Partially cloudy cases
July-August 2012: moderate fire activity over Bulgaria						
Total number of cases	31	31	31	31	31	
LSA SAF FRP / SEVIRI	16	6	9	3	9	2 (of 9)
MPEF FIR / SEVIRI	9	2	9	3	16	5 (of 16)
August 2013: very low fire activity over Bulgaria						
Total number of cases	9	9	9	9	9	
LSA SAF FRP / SEVIRI	2	0	2	1	4	0 of 4
MPEF FIR / SEVIRI	6	0	2	1	0	0

In the year of moderate fire activity 2012, the results show that LSA SAF FRP is more efficient than MPEF FIR in detection of small fires as well as more efficient in providing early warnings. In the year of very low fire activity 2013, the results are opposite: FIR is more efficient than FRP in detection of small fires as well as more efficient in providing early warnings. FRP or FIR are efficient at a different extend (depending on specific conditions) in detecting signals during the whole duration of the fire events for the two years studied.

Table 2 shows the performance of MODIS TAP algorithm regarding the fire detections by SEVIRI LSA SAF FRP and MPEF FIR products.

Table 2. Performance of MODIS TAP product for July-August 2012.

Performance of MODIS TAP	Number	Total number of cases
Fires failed to detect by MODIS TAP algorithm	12	31 (all studied)
MODIS faled to detect, while FRP and/or FIR detected	10	
MODIS TAP detections when FRP and FIR failed to detect fire	4	6 (no detected by both FPR and FIR)
MODIS TAP detections prior to FRP and/or FIR fire detection	2	15 detected by both FPR and FIR)

For 2012, an year of moderate fire activity, among the fires detected by any of the three satellite products, the omissions by MODIS TAP are twice more than the omissions by the three MSG SEVIRI products considered all together. These are usually MODIS TAP omissions of small forest fires, because the high frequency observations by geostationary satellites (especially for the MSG Rapid Scan service) is critical for a remote sensing product to efficiently catch such a fire in a short period of its development. MODIS TAP managed to detect 2 fires (13 %) earlier than both SEVIRI products when the fire ignition time is very close before an Aqua/Terra satellites overpass allowing availability of relevant MODIS data. Large forest fires are usually detected by all products, and each of the products can show various abilities to follow the evolution of high energy and long lasting fire events.

Table 3. Burned area (ha) characteristics of the fires in Fig. 1.

Figure	Date	Location	Total	Forest	Under canopy	At Canopy	Grass, herbs
1a	26/08/2012	42.267 N 27.067 E	8000.0	954.7	844.7	110.0	85.6
1b	22-30/08/2013	41.91 N, 26.4 E	366.4	366.4	318.5	47.9	124.9

Figure 1 shows the detections by the different products during the development of two large fire cases detected by ground observations on 26/08/2012 at 1100 UTC in the area of village Valtchanovo (42.267 N, 27.067 E) and Studena (41.91 N, 26.4 E) with two fire development stages: 22/08/2013 1050UTC - 26/08/2013; 26/08/2013 1645 UTC - 30/08/2013, along with the fire energy release at each detected pixel measured by the FRP product. The burned area characteristics are presented in Table. 3.

(a) (b)

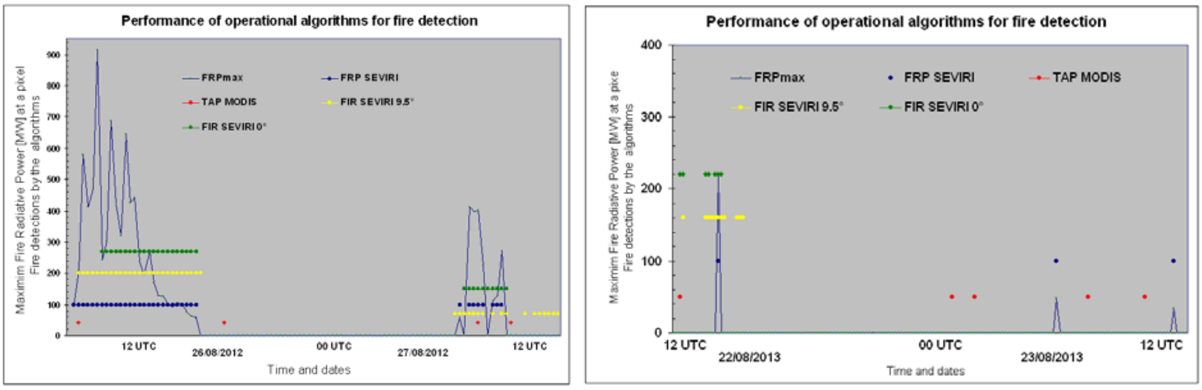

Fig. 1. Fire detections by different fire products: MSG 0º MPEF FIR (green dot symbols), MSG 9.5º MPEF RSS FIR (yellow dot symbols), LSA SAF FRP (blue dot symbols) and TAP MODIS (red dot symbols) for the two fires described in Table 3.

For the first fire in Fig. 1a, there are successful fire detections by all products at the beginning of fire development and high energy release (up to 900 MW) as measured by FRP product. For SE Europe, the Rapid Scan FIR product from 9.5° E, because of its higher spatial resolution at the region, provides more efficient fire monitoring than FRP, which is based on Full Scanning from 0°.

During the first stage of the second fire (Fig. 1b), starting with burning, which produces high Fire Radiative Energy (up to 220 MW), there are fire detections by all products at the beginning of fire development. However, TAP and FRP (derived through FTA algorithm using MODIS and SEVIRI data accordingly) show better fire monitoring than the MPEF FIR product at the later stage of fire development of low radiative energy (lower that 60 MW) release.

LIMITATIONS

Cloudiness in Fire Weather situations: Failure detection by Satellite Products

A significant fire remote sensing constrain is the presence of cloudiness in fire weather situations. The algorithms could not detect existing fires due to elimination of cloudy pixels or assuming some detections in partially cloudy pixels as "false" fire detections based on "contextual" tests. False alarms are also possible in cases of sun glint reflection from undetected small clouds. Specific synoptic situations, which are favourable for development of both fires and cloudiness have been identified to help avoid misunderstanding when assessing the performance of fire detection algorithms. This section presents several instances of differences/mismatches between SEVIRI FIR, SEVIRI FRP and MODIS TAP products in detection of actual fires reported in the National Data Base of SFA of Bulgaria in such synoptic conditions.

Shallow convection during the summer produces partial cloudiness in the MSG satellite view (Fig. 2d). In some cases of partial cloudiness the SEVIRI fire products may be able to detect a fire in single slots due to its higher frequency of MSG observations, while TAP MODIS does not detect the fire because of cloudy conditions at the moment of satellite overpassing the fire location. Fig. 2 shows such an example of actual fire on 4 August 2012, at 42.66N 25.95E detected in single pixels by FRP and FIR RSS and no detected by TAP MODIS.

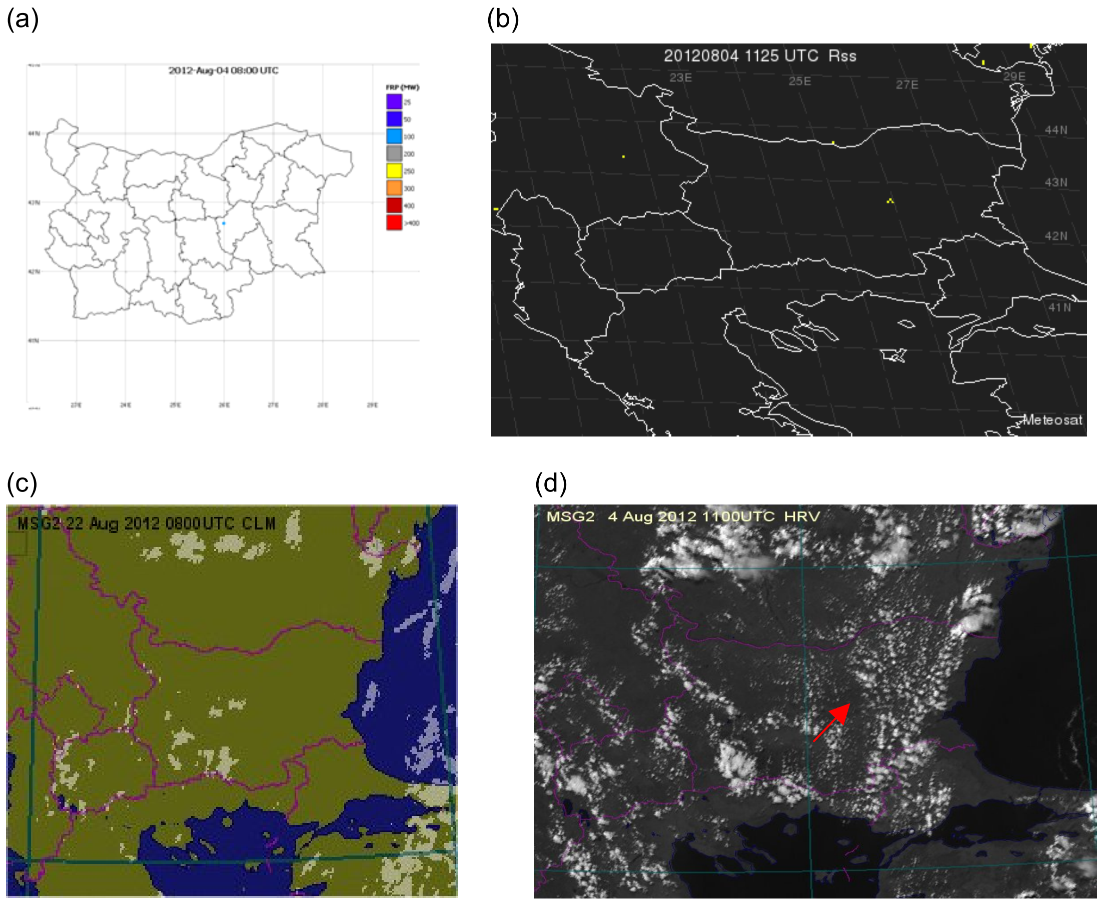

Fig 2. A situation of shallow convection on 4 August 2012 in which TAP MODIS failed to detect a fire detected by (a) LSA SAF FRP at 0800 UTC and (b) MPEF FIR RSS at 1125 UTC. (c) MPEF Cloud Mask product at 0800 UTC, (d) MSG HRV channel image at 1100 UTC.

In other partially cloudy cases (Fig. 3b), fires are detected by MODIS because of higher spatial resolution while the SEVIRI algorithms classify the corresponding pixel as cloudy and do not detect the fire. Such an example of a fire on 19 August 2012 at location 42.3N 27.23E is presented in Fig. 3. There is only detection by TAP MODIS and no detections by FRP and FIR products based on MSG SEVIRI data.

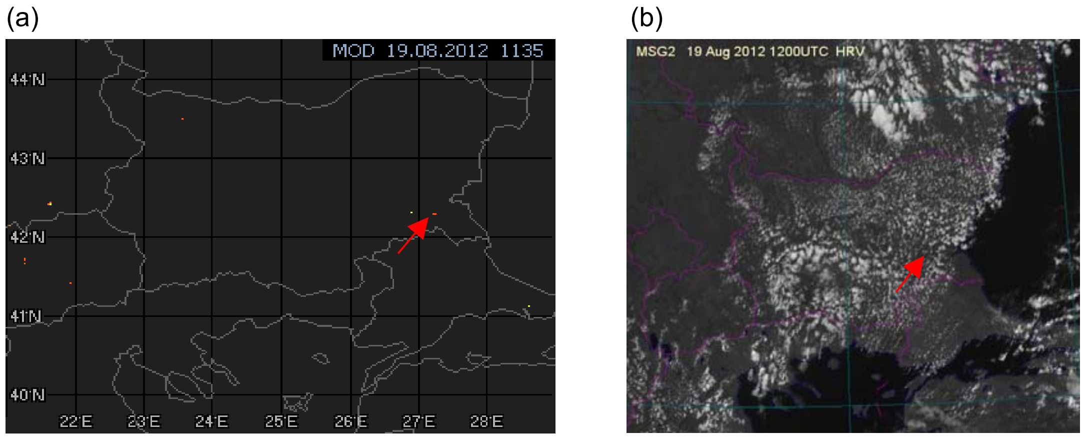

Fig 3. A situation of shallow convection on 22 August 2012 in which MPEF FIR and LSA SAF FRP failed to detect a fire detected by (a) TAP MODIS at 1135 UTC. (b) MSG HRV channel image at 1200 UTC.

In other cases, partially cloudiness can be produced my deep convection (Fig. 4b) and a fires can be detected by MODIS because of higher spatial resolution while the SEVIRI algorithms classify the corresponding pixel as cloudy and do not detect the fire. As an example, the fire case on 22 August 2012 at location 42.3N 23.767E is presented on Fig. 4. In this case of deep convection TAP MODIS product was able to detect the fire at a cloud free area near the convective development, while FRP and FIR algorithms did not detect the fire in this cloudy scene.

(a) (b)

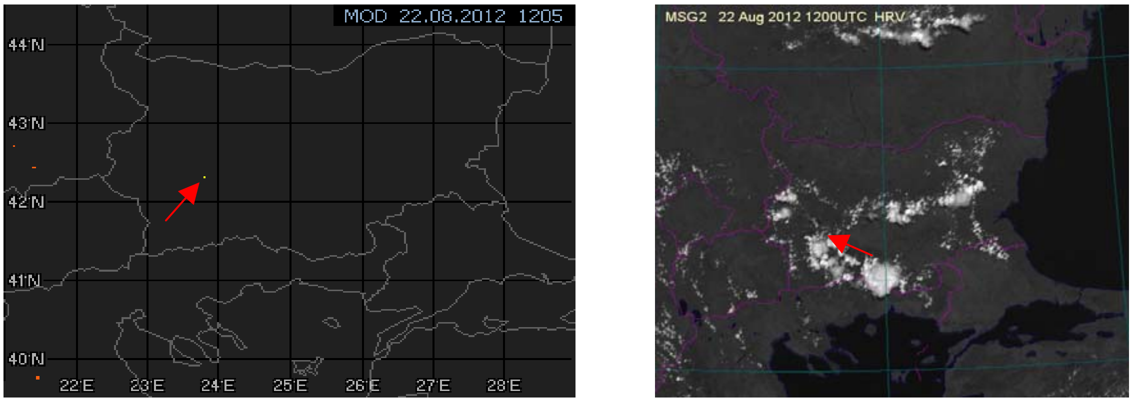

Fig 4. A situation of deep convection on 22 August 2012 in which MPEF FIR and LSA SAF FRP failed to detect a fire detected by (a) TAP MODIS at 1205 UTC. (b) MSG HRV channel image at 1200 UTC.

Invalid EUMETCast files of MPEF FIR in CAP format: Mismatches between the MPEF FIR files in GRIB2 and CAP format

In 2011, EUMETSAT changed the file format for dissemination of fire pixel coordinates from ASCII (American Standard Code for Information Interchange) to CAP (Common Alert Protocol). After this change, some MPER FIR files, disseminated in CAP format do not consist fire pixels, which are present in the corresponding GRIB2 files, received via EUMETCast . Many of these invalid CAP-format files from the Full Scan service have been received on EUMETCast DATA CHENNEL-3. The invalid CAP format files can cause fire misdetection in the first stage of fire development. Fig. 5 shows the MSG 0º MPEF FIR fire pixels indicated in the GRIB2 file (green dot symbols) and in the CAP format file (magenta triangular symbols).

(a) (b)

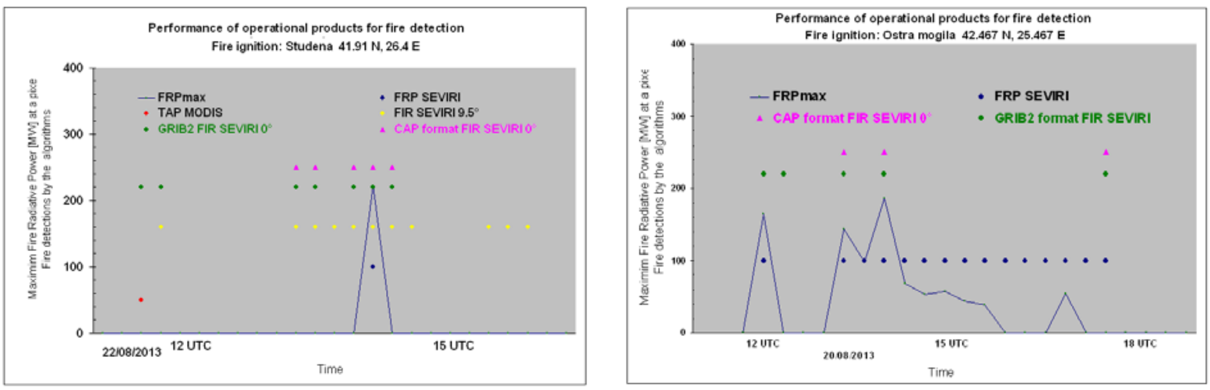

Fig. 5. MSG 0º MPEF FIR fire pixels indicated in the GRIB2 file (green dot symbols) and in the corresponding CAP format file (magenta triangular symbols) along with the detections by other fire products (LSA SAF FRP in blue dot symbols, MSG 9.5º MPEF RSS FIR in yellow dot symbols and TAP MODIS in red dot symbols). (a) Fire on 22 August 2013 at location Studena, 41.91 N, 26.4 E; b) Fire on 20 August 2013 at location Ostra Mogila, 42.467 N, 26.467 E.

In an invalid CAP-format file, all fire-pixels latitudes are negative. There are no any fire locations in the Northern hemisphere (positive longitude) that is not the case for the corresponding GRIB2 file. The problem is reported to EUMETSAT and entered in the incoming register of User Service Helpdesk as “300023176 Meteosat 0° Service” enquiry from 23 August 2013. According to our experience, there are no any examples for such invalid CAP format files from the Rapid Scan service disseminated on EUMETCast DATA CHENNEL-6. A few invalid CAP format files for MPEF product from Full Scan Service in the end of August 2013 are listed below.

L-000-MSG3__-MPEF________-FIRC_____-000001___-201308201245-__
L-000-MSG3__-MPEF________-FIRC_____-000001___-201308211045-__
L-000-MSG3__-MPEF________-FIRC_____-000001___-201308211100-__
L-000-MSG3__-MPEF________-FIRC_____-000001___-201308221115-__
L-000-MSG3__-MPEF________-FIRC_____-000001___-201308221130-__
L-000-MSG3__-MPEF________-FIRC_____-000001___-201308261000-__
L-000-MSG3__-MPEF________-FIRC_____-000001___-201308261330-__

The invalid CAP is a problem concerning the operational application of MPEF FIR data because fire warnings for the National Authorities should be normally provided based on the FIR data in CAP format. It was announced that the fix for this issue, regarding the data in CAP format, is introduced operationally by EUMETSAT on the 14th November 2013.

CONCLUSIONS

Fire detection is subject to several remote sensing constrains because satellite data is available only at discrete intervals, as well as due to the sensor and satellite orbit geometry and cloud contamination. The results of this study for a year of moderate fire activity and a year of very low fire activity show that the different satellite fire products do not exhibit any systematic fire detection characteristics (advantages and/or shortcomings).

For small fires (FRP < 100 MW per pixel, as derived by MSG data), SEVIRI fire products may fail to detect fires detected by MODIS product, and LSA SAF FRP may provide more efficient early warnings and fire monitoring than MPEF FIR.

For Large fires (reaching FRP > 200 MW per pixel, as derived by MSG data), SEVIRI FRP and FIR (both based on Full Scan from 0° and Rapid Scan from 9.5° E measurements) can be equally efficient for fire detection. For the South Eastern Europe, the FIR product from Rapid Scan at 9.5° E sub-satellite point provides a better view for fire monitoring than FRP, which is based on Full Scanning from 0° because of the higher spatial resolution over the region. Since the FIR and FRP algorithms are different, the performance of these two products (both using MSG SEVIRI measurements as input data) is case dependent.

In synoptic situations which are favourable for development of both fires and cloudiness, SEVIRI fire products may be able to detect a fire in single slots due to their higher frequency of observations, while MODIS TAP does not detect the fire because of cloudy conditions at the moment of satellite overpassing the fire location. In other partially cloudy cases fires may be detected by MODIS TAP because of higher spatial resolution while the algorithms using SEVIRI data classify the corresponding pixel as cloudy and do not detect the fire.

Invalid CAP format files currently disseminated for some slots via EUMETCast can cause problems in operational application of MPEF FIR data

Therefore, for an efficient fire detection, it calls for using various available sources of information in order to avoid as mush as possible the remote sensing constrains due to the sensor and satellite orbit geometry and cloud contamination.

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