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Case Report

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Validation of the Prototype System for Wildfire Hotspot Detection and Monitoring of the African Sub-Sahara Region: A Case Study of the Horn of Africa Region

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Abstract

The Italian Space Agency (ASI) recently installed a prototype system for hotspot detection and monitoring (FIRE) at its Broglio Space Centre (ASI/BSC) facility in Malindi (Kenya). FIRE has been developed at ASI Space Geodesy Centre (Matera, Italy) to monitor hotspots in the Mediterranean Regions and successively adapted to monitor hotspots in Sub-Saharan Africa.

The FIRE system implements a processing chain that routinely receives Meteosat Second Generation (MSG) data through the EUMECAST Channel and extracts and transforms the SEVIRI data into geocoded reflectance, radiance and brightness temperature images. The Temperature images at 3.9 μm and 10.8 μm are used to detect the local thermal anomalies (hotspot). The time delay between the MSG data acquisition and the hotspot detection by the FIRE system is about 30 min.

All the detected hotspots are archived in a POSTGRES database with POSTGIS extensions. The database archives the hotspot geographical coordinates, temperature and radiance. All the hotspots can be displayed as a layer on a simple geographical map with a graphical user interface built on OPENLAYERS library. The hotspot can also be visualized on Google Earth System in order to obtain more geographical or thematic information about the site and the area affected by the local thermal anomaly.

All the hotspots detected on the Sub-Saharan Africa region from May 2011 to date are archived in a database. The validation of the ASI/BSC hotspot products is in progress and the hotspots database is used for research activities at ASI/BSC. In this framework the analysis of the hotspots data for countries in the Horn of Africa region, namely Kenya, Tanzania, Uganda and Somalia has been done for the period from May to December 2011. Moreover the comparison between the ASI/BSC hotspots and others hotspots products (FIRMS, AFIS) has been performed.

Keywords

Prototype; Hotspot; Sub-Sahara; Validation

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Introduction

The Italian Space Agency (ASI) started remote sensing activities at BSC on April 2011, by installing some preliminary facilities for data acquisition and processing to be used to support educational and promotional activities in the field of remote sensing applications in Kenya and in sub-Saharan regions.

These preliminary facilities include a system that routinely receives Meteosat Second Generation data (EUMETCAST Channel) and others EUMETSAT products like LST (Land Surface Temperature), SST (Sea Surface Temperature) and FIR (hotspot products) [1].

Meteosat Second Generation (MSG-2) provides weather monitoring data through its primary instrument, the Spinning Enhanced Visible and InfraRed Imager (SEVIRI) which has the capacity to observe the Earth in 12 spectral channels (Table 1).

Since May 2011 a prototype hotspot detection system (ASI/BSC FIRE) using MSG-2/SEVIRI data acquired on sub-Saharan Africa regions has been installed and is operating at ASI-BSC in Malindi (Kenya). The FIRE prototype has been developed at ASI Space Geodesy Centre (Matera, Italy) for hotspots detection in the Mediterranean Regions and successively adapted to monitor the hotspots in Sub-Saharan Africa.

Similar satellite based products have been derived over Africa from NASA/MODIS [2] data. Hotspot products (FIR) from MSG/SEVIRI data are also routinely provided by EUMETSAT, and distributed via EUMETCAST channel [1] and downloaded at ASI/BSC. In the South Africa the Advanced Fire Information System (AFIS) provides near real time satellite-based fire information to users across the globe [3].

This paper briefly describes the ASI/BSC- FIRE system and the main results obtained in the preliminary validation activity performed at ASI/BSC in the first period of the system operations, since May 2011.

Hotspot Detection System

The ASI/BSC FIRE system implements a processing chain that routinely receives MSG data through the EUMECAST Channel, extracts and transforms SEVIRI sensor data into geocoded Reflectance, Radiance and Brightness Temperature images (Figure 1).

The hotspot area is a fire detection product indicating the probable presence of fire within a MSG/SEVIRI pixel. The algorithm is based on the fact that the SEVIRI channel IR3.9 is very sensitive to hotspots which are caused by fires. Even for fires occupying a small fraction of the observed area, the overall pixel Brightness Temperature ($T_{3.9}$μm) in IR 3.9 μm channel increases respect to the neighbouring fire free pixels and respect to the IR10.8 μm channel ($T_{10.8}$μm). This behaviour is due to the very high MIR blackbody radiance at fires temperatures.

The MSG/SEVIRI Radiance data (8.7 μm) is used to generate a background image for Cloud detection Analysis. The background image pixel value is obtained as the maximum value in 10 days:

Background Image (tn) = Max [Radiance (tn),……., Radiance (n-8), Radiance (n-9)] (1)

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Table 1: MSG-2 SEVIRI bands.

Band	Centre (µm)	99% Energy Band (µm)	Res.(Km)	Band	Centre (µm)	99% Energy Band (µm)	Res.(Km)
HRV	0.75	About 0.4-1.1	1	IR 10.8	10.8	9.80-11.80	3
VIS 0.6	0.64	0.56-0.71	3	IR 12.0	12	11.00-13.00	3
VIS 0.8	0.81	0.74-0.88	3	WV 6.2	6.25	5.35-7.15	3
IR 1.6	1.64	1.50-1.78	3	WV 7.3	7.35	6.85-7.85	3
IR 3.9	3.92	3.48-4.36	3	IR 9.7	9.66	9.38-9.94	3
IR 8.7	8.70	8.30-9.10	3	IR 13.4	13.4	12.40-14.40	3

Every 15 minutes, the Radiance Image (8.7 µm) is compared to the Background image to extract the Cloud Mask through an algorithm that meets established thresholds in the difference of radiance pixels values. The hotspot analysis is performed for all the no-cloud pixels on land image by locally applying the following empirical formula:

$$\Delta T = \left(T_{3.9\mu m} - T_{10.8\mu m}\right) > \phi \text{AND} T_{3.9\mu m} \geq \left(m_{3.9\mu m} + N\sigma_{3.9\mu m}\right)$$

Where N, Φ are constant, empirically determined.

$m_{3.9\mu m}$ = Mean (T3.9$_{\mu m}$) and $\sigma_{3.9\mu m}$ = σ $T_{3.9\mu m}$ in 5x5 neighbouring pixels kernel

All the hotspots detected are archived in a POSTGRES database with POSTGIS extensions. The database archives the hotspot geographical coordinates, temperature and radiance. The system can be remotely accessed by internet and the user can visualize in Near Real Time all the hotspots detected on the last MSG image acquired at BSC and/or the hotspot detected more than twice in the last three hours (Figure 2).

This selection is useful because there are many false alarms in the single image hotspot detection, while because of the fire extension and duration, the hotspot corresponding to true fires are usually observed many consecutive times by the FIRE system. By using this selection, the false alarm for example as a result of solar reflections, corresponding to a single hotspot can be filtered. Users can also access the overall database and select all the hotspots having a given number of hits in a user selected time range and region of interest.

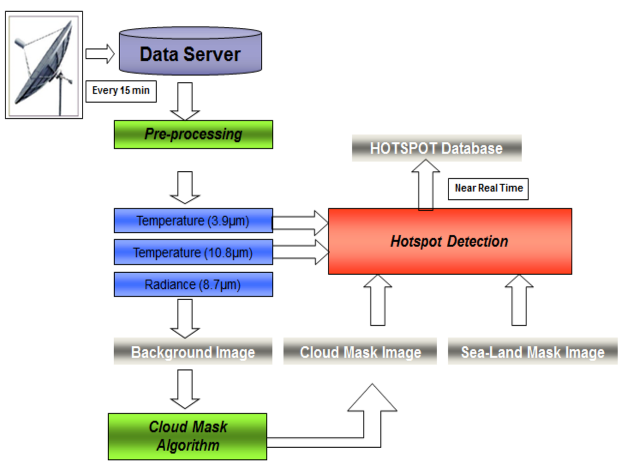

Figure 1: MSG-2 SEVIRI data acquisition and FIRE system processing chain.

All the hotspots can be displayed as a layer on a simple geographical map with a graphical user interface built on OPENLAYERS library. Cloud layers can also be displayed to support evaluation of weather conditions.

Data Analysis and Results

Africa has diverse climatic and weather patterns with unique geographical and land utilization tendencies that affect the occurrences of fires. Figure 3 below shows the accumulative overall number of hotspots detected on Africa sub-Sahara region by the BSC/FIRE system in the period May-December 2011.

By visual analysis it was found that up to the month of September, a lot of hotspot activities were mainly concentrated in the western, central and middle region of sub-Sahara Africa covering Angola, Zambia, Botswana, Namibia and the DRC. Less spots are found in Zimbabwe, Mozambique, Tanzania and S. Africa, and even less in eastern Africa countries. Other western Africa countries with lesser spots include Nigeria, Chad, Central Africa republic and Cameron. For November and December, spots were more concentrated in the Northern parts of the sub-Sahara mainly Chad, Central Africa republic, Cameron, Nigeria, and Sudan; and virtually no spots in the mid-western - central region of Africa. In the period of November-December 2011, there was a drastic upsurge change in the rainfall pattern around mid and central Africa, which may have contributed to the non-occurrence of hotspots in that region. This is attributed mostly by the annual migration of the Inter-Tropical Convergence Zone (ITCZ) pattern, and its associated rainfall.

During the first months of operation of May and July 2011, a more detailed hotspot analysis was done (over the Kenyan territory)

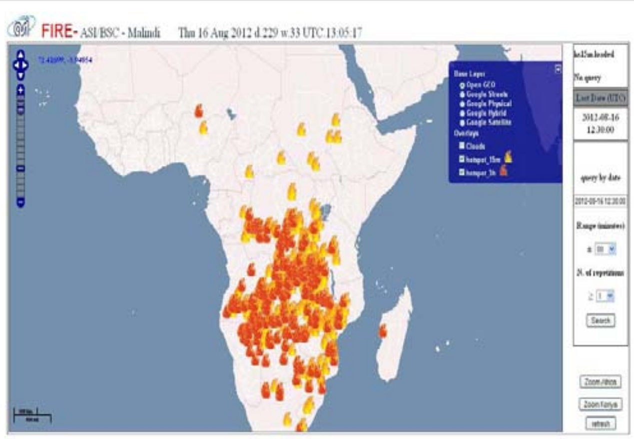

Figure 2: FIRE user interface.

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by monitoring the detected hotspots every 15 minutes and having at least 2 hits in the 3 hours. Figures 4 and 5 below show the results of this analysis.

For the months of September and December 2011 which exhibited more hotspot activities, only the 3-hour endurance was monitored with number of hits of three and above. This time duration gives a high confidence in accenting the presence of a fire (Figures 6 and 7).

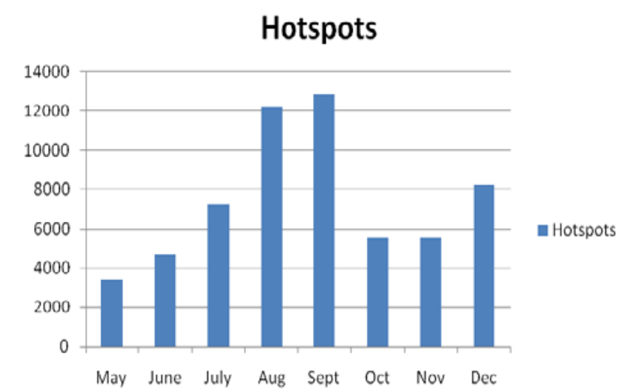

Figure 3: ASI/BSC FIRE hotspot on Africa sub-Sahara region (May-Dec. 2011).

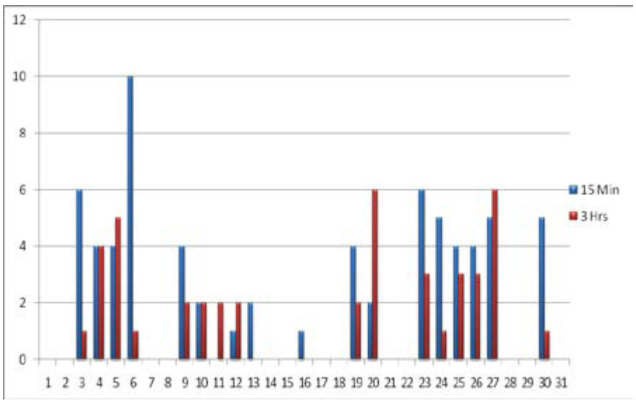

Figure 4: Hotspots May 2011.

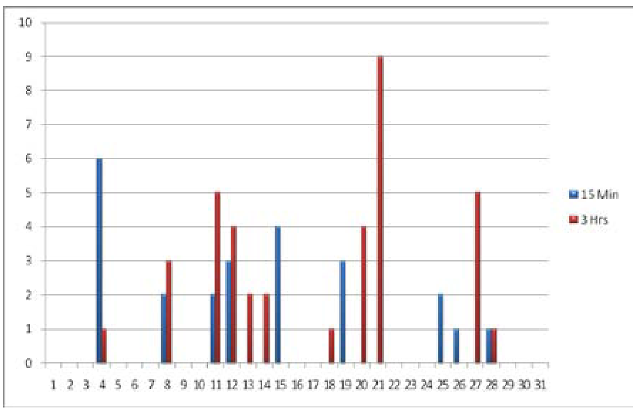

Figure 5: Hotspots July 2011.

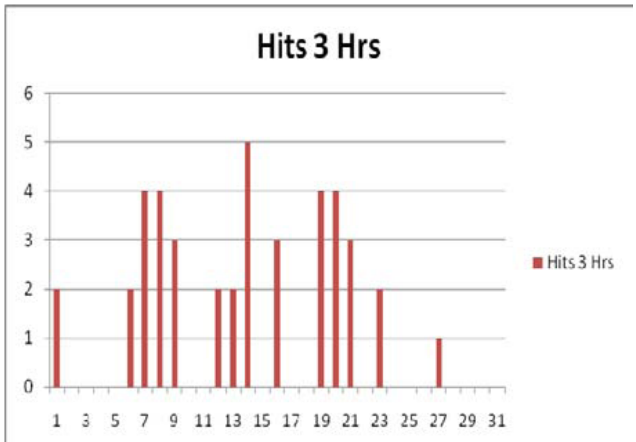

Figure 6: Hotspots September 2011.

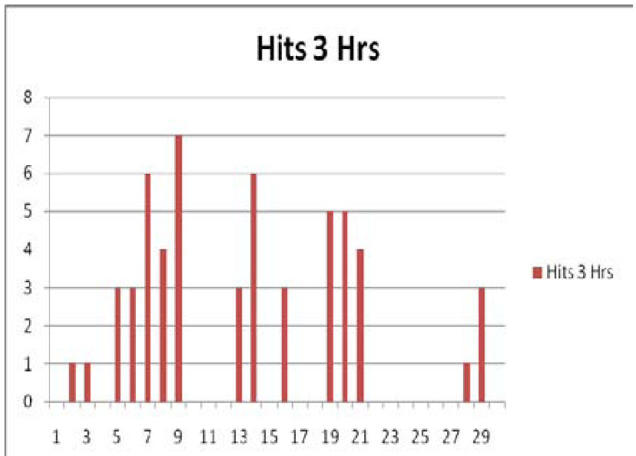

Figure 7: Hotspots December 2011.

Validation

As a first approach for the system and product validation for the sub Saharan Africa region, a system based on MODIS imagery for fire detection (Fire Information for Resource Management System - FIRMS) developed by NASA has been used [2]. NASA MODIS/FIRMS hotspot detected on the Kenya territory having 100% confidence are assumed reliable enough to qualify such areas as fires or hotspots and has been compared with ASI/BSC FIRE hotspot products. This validation has been performed by comparing through inspection of coordinates of hotspots detected by the two systems, which also form part of ongoing research activities at ASI BSC in Malindi (Kenya); the results of comparison (Figure 8) on the Kenya territory indicate that both systems fairly agree in hotspot locations. The number of the hotspots detected by the two sensors is different because of the different temporal resolution: while MSG images are acquired every 15min, MODIS provides only two acquisitions per day, determining a different overall number of hotspots and poor coincidences of events.

The analysis was also extended to cover part of the sub Saharan African region, namely Somalia, Tanzania, and Uganda including Kenya. Based on the same method, the aim was to investigate the performance of the system in those regions having diverse grassland

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and forest and other vegetation indicators. These countries also have different rainfall patterns.

Figures 9 to 11 below show the number of hotspots coincidence from the ASI/BSC and NASA MODIS/FIRMS systems. Where there is no data recorded implies that the BSC system was not functioning or both systems did not detect any hotspot.

The volcanic regions of the Congo and Eritrea, when active, may also serve as most probable hotspots to be used for validation. These particular areas have been registered as hotspots mainly during the night. It may be suggested that the systems better perform during the night.

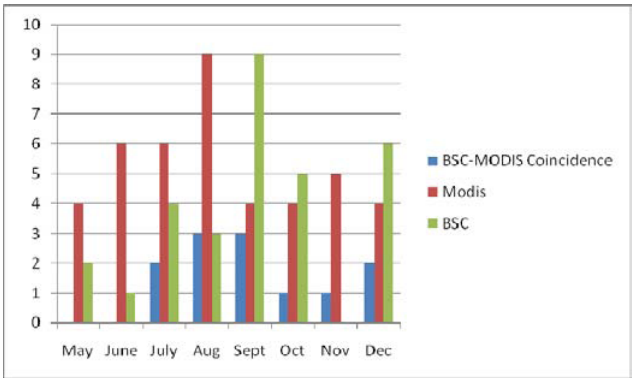

Figure 8: BSC FIRE and MODIS hotspots coincidence on Kenya (May-December 2011).

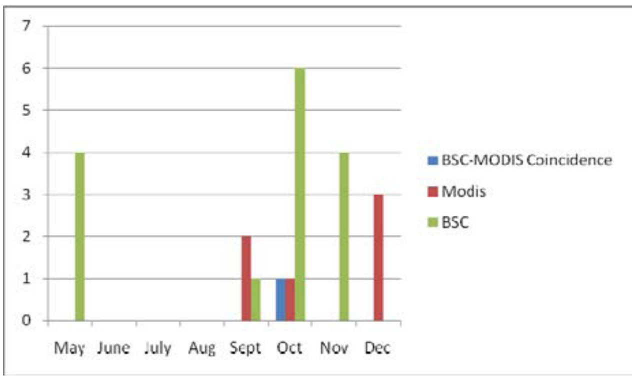

Figure 9: Somalia.

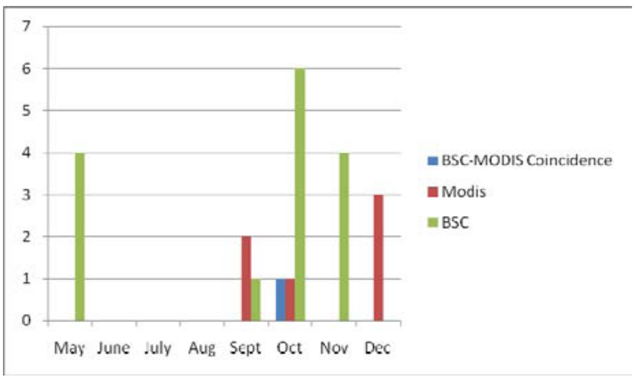

Figure 10: Uganda.

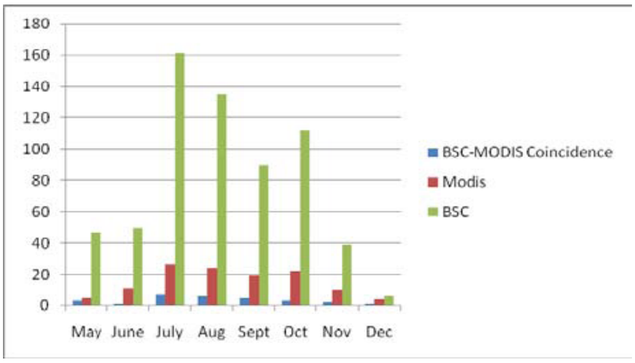

Figure 11: Tanzania.

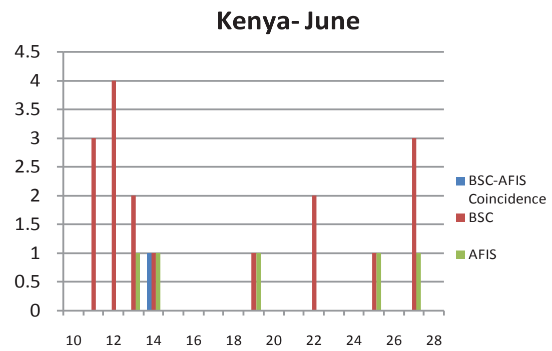

Figure 12: BSC FIRE and AFIS hotspots coincidence.

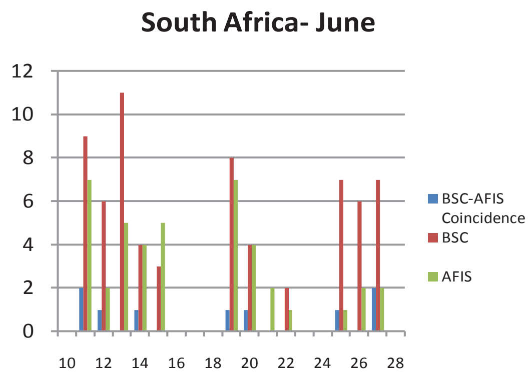

Figure 13: BSC FIRE and AFIS hotspots coincidence.

The validation of the ASI/BSC FIRE system is still in progress. During the last wildfires season (June-August 2012) the hotspot product provided ASI/BSC FIRE has been compared with the similar AFIS/CSIR hotspot data operationally used in South Africa and available on the website. The analysis was limited to Kenya and South Africa territory.

The results of the hotspot coincidence analysis in the period June-August 2012 are reported in the following Figures 12 to 15.

Conclusions

The FIRE ASI/BSC prototype system is able to confirm the

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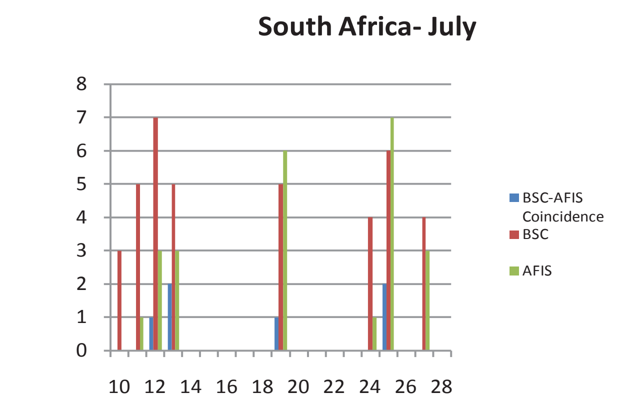

Figure 14: BSC FIRE and AFIS hotspots coincidence.

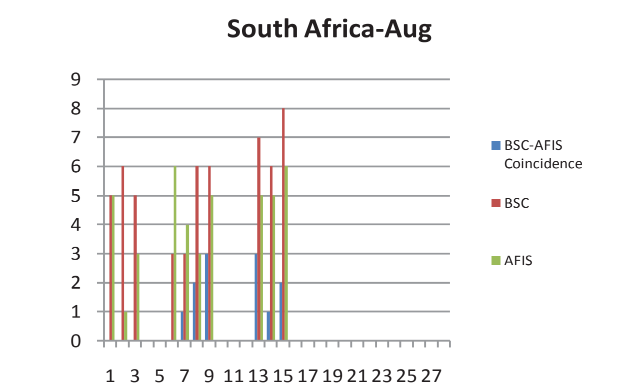

Figure 15: BSC FIRE and AFIS hotspots coincidence.

hotspot detection and monitoring in near real time in relatively high and sustainable temperatures like the volcanic areas. However, due to the low spatial resolution of the SEVIRI optical sensor of about 3 km, many forest or bush fires in Africa which in most cases are small, go undetected.

In the absence of ground truth fires information it may not be certain if hotspots, even having a high number of hits, constitute a fire or not. Therefore at the moment the system can be only used as a research tool. Ground-truth data should be undertaken to physically validate the ASI/BSC FIRE system sensitivity, to determine the spatial resolution extent or magnitude of the fire that can be detected by the system.

The ASI/BSC system when completely validated could compliment other similar systems available to the sub Saharan Africa region based on MODIS (FIRMS/NASA) and MSG/SEVIRI (AFIS/CSIR) data.

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