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DLR new functionalities for the European Forest Fire Information System

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Abstract

The European Forest Fire Information System (EFFIS) provides timely and reliable information on wildland fires in Europe since 1998. EFFIS supports agencies in charge of the protection of forests within the European Union. The services comprise the daily analysis and publication of weather based fire danger information, as well as the timely delivery of active fire locations and recently occurred burnt areas. As part of Copernicus Emergency Management Service, EFFIS contributes directly to the disaster management in Europe and helps monitoring indicators of the Sustainable Development Goals.

The Earth Observation Centre from the German Aerospace Centre (DLR) has been entrusted with modernizing the EFFIS service and with improving the near real time products delivery by shortening timeliness.

The new main functionalities comprise analysis, derivation and delivery of burnt areas from Sentinel-3 OLCI and MODIS data. In this regard, a methodology has been developed, as well as implemented and tested, to efficiently derive reliable and accurate burnt area perimeters from different optical earth observation satellite sensors.

The functionalities are integrated and validated in an operational environment. Results of these functionalities will benefit the fire situation monitoring in Europe through faster, more reliable and accurate detections and bring considerable progress towards achieving the SDGs.

Keywords: forest fire, burnt area, EOC, DLR, SDG

Acronyms/Abbreviations

Earth Observation Center (EOC)
European Forest Fire Information Service (EFFIS)
Fire Information for Resource Management System (FIRMS)
Joint Research Center (JRC)
Moderate Resolution Imaging Spectroradiometer (MODIS)
Normalized Difference Vegetation Index (NDVI)
Ocean and Land Colour Instrument (OLCI)
Sea and Land Surface Temperature Radiometer (SLSTR)
Visible Infrared Imaging Radiometer Suite (VIIRS)

1. Introduction

Forests are synonyms of life, says Pierre Rahbi, a French environmentalist [1]. The most well-known functions of forests are to offer protection, food and water to both vegetable and animal worlds. They also capture carbon, helping to reduce the global warming effects. The United Nations have acknowledged within the Sustainable Development Goals (SDGs) the primary role played by forests on biodiversity [2]. Consequently, wild fires represent a serious threat to human lives and properties, as well as landscape functionality and ecosystem diversity.

Global monitoring is a key step to understand and later prevent and manage such disasters and can be split in two different types of detections: hotspots (also known as active fires) and burnt areas. In this paper, we focus on satellite based technology which offers the best compromise between temporal and spatial resolution. Typical satellite-based products for burnt area monitoring are delivered on a monthly basis (e.g. MCD64A1 product from the MODIS Collection 6 [3]).

We present here new functionalities which improve timeliness, reliability and accuracy on the wild fires monitoring compared to existing systems like the European Forest Fire Information System (EFFIS).

2. Background

2.1 Aqua and Terra [4]

In 1999 and 2002 NASA launched respectively the Terra (EOS AM-1) and Aqua (EOS PM-1) satellites. Those satellites carry the Moderate Resolution Imaging Spectroradiometer (MODIS) which delivers data from 36 spectral bands ranging in wavelength from 0.4 µm to 14.4 µm and at varying spatial resolutions (2 bands at 250 m, 5 bands at 500 m and 29 bands at 1 km).

Together, they provide information such as cloud cover, radiation budget or high temperature events.

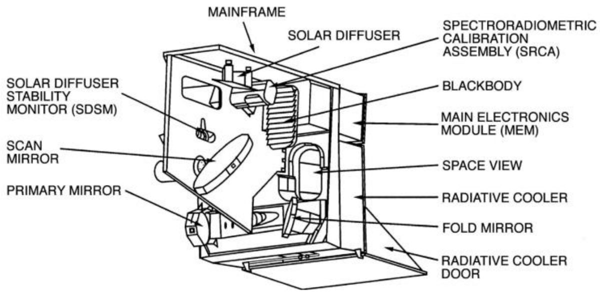

Fig. 1: MODIS instrument

2.2 EFFIS [5], [6]

EFFIS is the European Forest Fire Information System developed by the Joint Research Center (JRC). The main target is to deliver up-to-date and reliable wildfire information to the European Commission and to other actors of forest protection in the European and Mediterranean areas. Though, other entities like newspapers use this information source to inform their readers.

EFFIS publishes among others active fires and burnt areas through a viewer or via data request forms. EFFIS active fires are published within 2 to 3 hours after the satellite fly-over. EFFIS burnt areas base on MODIS and VIIRS data as well as on Sentinel-2 data. Timeliness ranges from 12 hours (MODIS/VIRRS) up to several days (Sentinel-2).

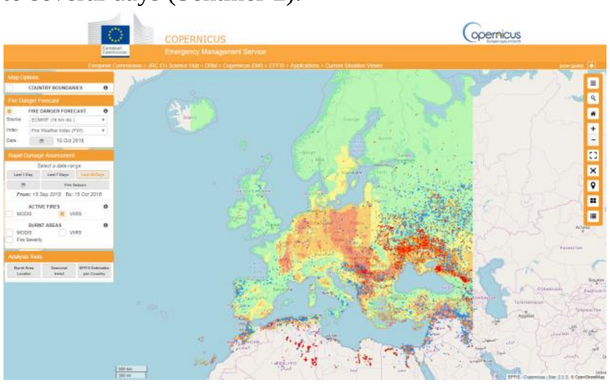

Fig. 2: EFFIS active fire and burnt area viewer [6]

EFFIS is part of the Emergency Management System from the European Union's Earth observation programme Copernicus and contributes to the Global Wildfire Information System from the Group on Earth Observations (GEO).

2.3 DLR

Since 2001, the Earth Observation Center of the DLR is receiving direct broadcast MODIS data from Aqua and Terra with its two stations located in Oberpfaffenhofen and Neustrelitz. The EOC acquires about 8 gigabytes daily and process to the level 1b using NASA algorithms. Results are e.g. daily cloud mask, hotspots, and daily composites. MODIS products related to hotspot detection are available for more than 14 years. The latest processing chain integrated by DLR for this purpose was the MO14 Collection 5.1 (status: end of 2016).

Fig. 3: MODIS receiving antenna in Oberpfaffenhofen [7]

In 2016, JRC called for a tender to modernize its EFFIS system. In fact, due to increasing instrument resolution, e.g. with Sentinel satellites, JRC searched for improvements both on spatial and temporal resolution of their system, as well as on detection of burnt areas in near-real time (NRT). Acknowledging the evolution of instruments and algorithms for fire monitoring, DLR has been developing new functionalities (burnt area detection), using Sentinel data in addition to MODIS, and improving previous capabilities (e.g. with hotspot detection) [8].

2.4 Area of interest

While historically, devastating fires have occurred mainly in North- and South America, Northern Russia, Australia and Africa, they also pose an ever increasing problem in Europe [9]. For Mediterranean ecosystem, they represent the most important natural disturbance factor. The total burnt area in Southern European states amounts to more than 900.000 ha annually [10].

Consequently, this document focuses on the European area. This area offers a wide range of landscape and ecosystem diversity. In addition, selecting this region allows a comparison with already existing systems.

3. Monitoring burnt areas throughout Europe in near-real time (NRT)

The presented system was designed for monitoring burnt areas throughout Europe in near-real time. It allows the derivation of timely and accurate burnt area perimeters. It makes use of several satellites featuring high temporal resolution, namely the Aqua and Terra satellites operated by NASA, as well as Sentinel-3A and Sentinel-3B operated by ESA. These satellites carry medium-resolution optical sensors sensitive in the wavelengths relevant for vegetation monitoring. Aqua and Terra carry the MODIS instrument, with a spatial resolution of 250 m for the red and the near-infrared band. The Sentinel-3 satellites both carry two optical sensors (OLCI and SLSTR), of which the first one is utilized because of the superior spatial resolution (300 m, opposed to 500 m for SLSTR).

The satellite data from Aqua and Terra is automatically received in Oberpfaffenhofen, while Sentinel-3 data is acquired from the EUMETSAT CODA platform in near-real time. Both data sources are subsequently processed to a Level 1B product. The system relies on several well-known optical vegetation indices in combination with a pre/post approach, targeted at detecting rapid, fire-induced decreases in vegetation fitness. Indices used include the Normalized Difference Vegetation Index (NDVI), both in its differential as well as single scene form of application, as well as the Burnt Area Index (BAI). Its strength is the complete avoidance of manually defined thresholds, making it suitable for a variety of sensors and geographical regions of interest. In most operational systems, data is classified using parameters which have been derived beforehand, either statistically or empirically. This allows for a precise calibration of a model based on the input data.

For the presented system however, the input data in heterogeneous (being supplied by different sources). Also, the geographical region of application covers a variety of differing biomes and ecozones throughout Europe. This makes the classification of burnt areas, being themselves highly manifold phenomenon regarding size, shape and severity, very error-prone when using fixed thresholds.

Therefore, an approach has been designed, implemented and tested, to define required thresholds dynamically from context information. The approach makes use of the Active Contour Level Set methodology, which utilizes an energy function in combination a dynamically growing curve to approximate the actual perimeter until an optimal outcome is achieved. [11]

It uses internal generated as well as NASA FIRMS near-real time active fires as auxiliary data, and performs a rectangular region growing to get the extend of each accumulation of active fires. For this region, the Active Contour is calculated, using the active fires as starting locations for the curve. By using the region growing step first, the dynamically generated thresholds are optimized for the current region of interest, rather than for the whole scene. This implies that the algorithm is capable of detecting burn areas even if the actual burn severity of a specific fire event was very low.

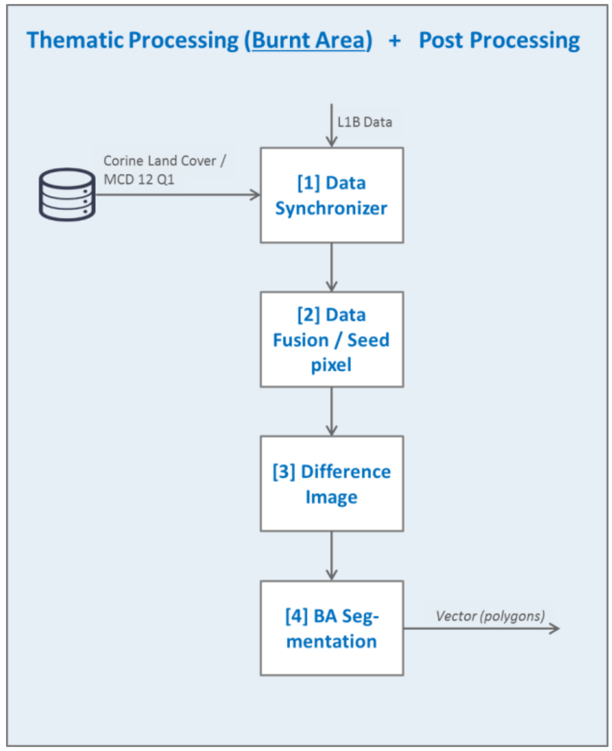

Fig. 4: DLR NRT burnt area processing

4. Implementing NASA's MOD14 Collection 6

In 2018, we integrated the latest MOD14 algorithms available to the public: the MOD14 Collection 6.0, into the DLR MODIS reception, processing and delivery chain.

Main improvements from the previous collection are: better refinement of the internal cloud mask to prevent false identification of heavy smoke, fixing commission errors caused by small clearings within forests or by cloud and water adjacent to fires, using dynamic thresholds for improving omission errors with small fires, and improving fire detection on and along water. [12], [13]

The advantage of a "local" approach for processing is the much higher timeliness compared to the approach with the NASA Fire Information for Resource Management System (FIRMS) server. In fact, while data is available 1 to 3 hours after fly-over on the FIRMS server due to data retrieval only through selected ground stations, L1b products are generated from the raw data retrieved with the direct broadcast signal within 10 minutes after ingestion (usually corresponding to the end of the satellite acquisition). And active fires are generated from L1b products in 2 minutes. Thus, DLR active fire data for the defined area of interest is available between 4 and 12 times faster than NASA FIRMS data [14].

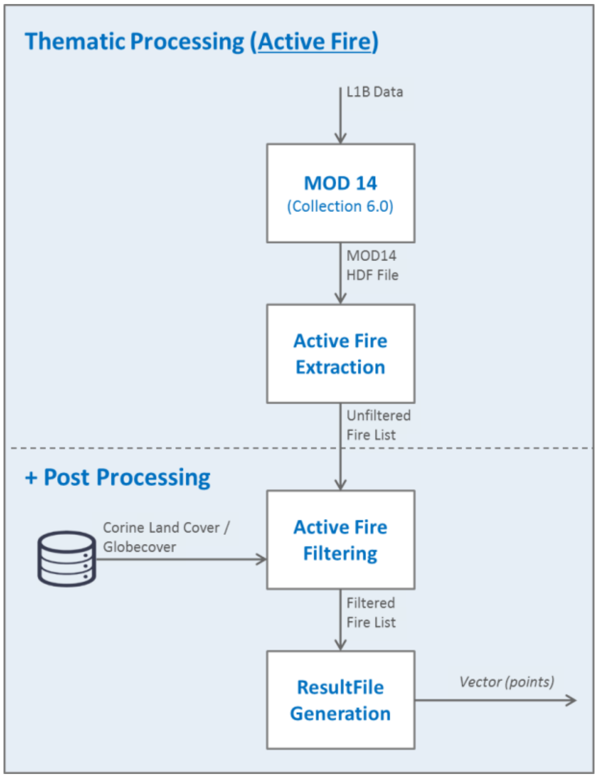

Fig. 5: DLR NRT active fire processing

5. Results

5.1 Burnt areas

The result of the DLR NRT burnt area processing system is vectorized, with polygons located in close vicinity being regarded as belonging to a common fire event and therefore being accumulated as a single multipolygon. Several metadata attributes are added to the result (such as affected area in hectares). For every resulting polygon, a database of recent detections is queried to check for intersections. By that, the system allows for assigning a unique ID to overlapping areas and so empowers a tracking of burnt area growth over time.

Results for a testing period in August 2017 are in congruence with the official NASA MCD64 product, which is generated over a two-month time span.

Another comparison has been made with EFFIS burnt area products on European fires during the period of June 2019. Below are some examples of this comparison. On the pictures, the blue line delimits the DLR NRT burnt areas based on MODIS data, and the red line delimits EFFIS burnt areas based on Sentinel-2 data.

Fig. 6: Burnt area comparison for Tarragona (Spain) – period: between 27.06.2019 and 01.07.2019

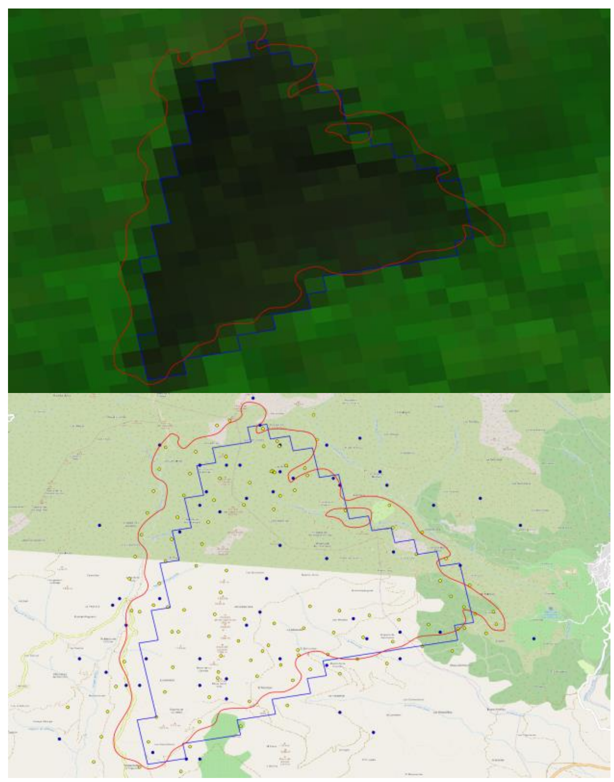

Fig. 7: Burnt area comparison for Avila (Spain) – period: between 29.06.2019 and 02.07.2019

5.3 Active fires

Following the integration of the Collection 6 processing chain, the results of the DLR updated system were validated by comparing them to the NASA FIRMS hotspots. The resulting consistency between NASA FIRMS active fires and DLR active fires is in average above 98%.

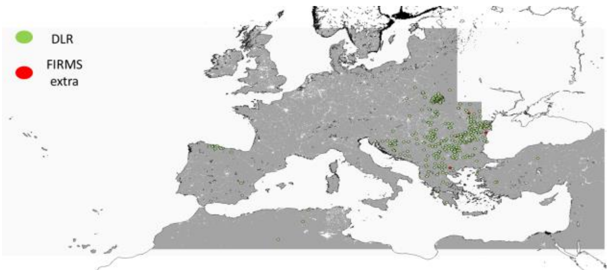

Fig. 8: Typical active fire comparison result over Europe – period: 04.03.2019.

On the picture above, 433 active fires were detected by FIRMS, while DLR missed 9 FIRMS active fires. These small differences can be explained by the facts that:

- NASA uses internally the newer Collection 6.1 while only the Collection 6.0 is available to the DLR;
- On-board recorder data does not contain gaps due to e.g. Deep Space Network or data dumps [4].

6. Advancing SDGs

The United Nations (UN) recognizes that forests play a major role in biodiversity and in the balance of the ecosystems (SDG 15: Life on land). Forests are in reality housing many other functions such as providing food, water, medicines, construction materials and income from its products, or capturing carbon [15].

Fig. 9: Familiar forest goods and services support SDGs [16]

In 2000, the Earth's forest areas represented 4.1 billion hectares. In 2015 it was about 4 billion hectares. If the rate of forest loss has drastically decreased since the beginning of the twenty-first century, trends are still showing regular losses of forest areas. These losses endanger the human well-being and action shall be taken to slow down this trend. Consequently, within the sustainable development goal 15, the UN identified the following targets and indicators [2]:

Target 15.1

By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements

Indicator 15.1.1: Forest area as a proportion of total land area

Indicator 15.1.2: Proportion of important sites for terrestrial and freshwater biodiversity that are covered by protected areas, by ecosystem type

Target 15.2

By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally

Indicator 15.2.1: Progress towards sustainable forest management

The DLR wildfire monitoring functionalities, by assessing active fires and burnt areas in near-real time, bring considerable progress towards monitoring of the indicators 15.1.1 and 15.1.2 from SDG15. Evolution can be observed on a daily basis. Analyses of this data foster in first instance the situation monitoring and understanding of forest fires. In a further instance, it can be easily imagined that, due to the reduced product delivery time, this data shall serve active wildfire management or combatting, actions suggested for the Global Forest Goal 1 (GOF 1+) of the United Nations Strategic Plan for Forests 2017-2030 [18]. These actions will result in decreasing negative consequences of deforestation such as death, health impacts and socio-economic impacts.

6. Conclusions and outlook

The new functionalities and improvements developed and integrated by DLR for monitoring forest fires assess the active fire and burnt area situations with an unprecedented timeliness and accuracy compared to existing systems. Within 12 minutes after the satellite passed over the area of interest, a list of active fires is available and reaches 98% accuracy compared to FIRMS data. Within few hours (in average 2 to 4) after the satellite fly-over, the detected burnt areas are already available on the DLR system, while other typical systems deliver this data within days. And the surface of commission errors remains below 5% for burnt areas.

Nevertheless, efforts are now under way to drastically increase processing speed by caching intermediate results, so that recurring steps are only computed once. Thereby, the analysis of a MODIS overpass covering the main part of Europe now only takes about 20 to 30 minutes on a single CPU setup.

Furthermore, a methodology is implemented which makes use of additionally available post datasets, given that the system is not run in near-real time mode. In that case, a mosaic is generated from post scenes equivalent to the pre scenes handling as described in chapter 3. By that, dynamically occurring sources of false detections, like cloud shadows, can be reliably excluded from the input data. The analysis is subsequently done comparing the pre and post NDVI mosaics.

To further enhance the geometric accuracy of the output, a subsequent processing step is currently under development: The locations of results achieved with the medium resolution data can be used to download higher resolution Sentinel-2 data for the regions of interest, which can be processed using the same methodology. Through this approach, high quality results can be achieved in reasonable processing time.

Such data from already existing space assets represent a tremendous potential for monitoring globally the evolution of forests and wildfires. This information is vital for everyone and particularly for the decision-makers due to the potential impacts of forest losses on health, hunger, poverty, energy, infrastructure and life [14]. Considering its high timeliness, the data produced by the DLR system could also serve to manage appropriate emergency responses in Europe, which will actively help our forests and advance the sustainable development goals, particularly the SDG15.

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