DOMAINE : Sciences et Technologies (ST)

Forest Fires Remote Sensing with Spinning Enhanced Visible and Infrared Imager Data

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ملخص:

يوفر جهاز الاستشعار SEVIRI (Spinning Enhanced Visible and Infrared Imager) للقمر الصناعي MSG صورة كل 15 دقيقة، وبالتالي تطوير خوارزمية التي يمكن أن تستغل السلوك الزمني من الملاحظات لنصف القرص الأرضي المتمركز في إفريقيا رغم الحجم الكبير للعنصر الأساسي للصورة( ) pixel، يعد أمرا حاسما لهذه التطبيقات القريبة من الزمن الحقيقي.

هذا المنشور يعطي لمحة عامة عن جهاز MSG SEVIRI ، للمراقبة العامة لكشف النار النشطة ، ووصف الخوارزمية و تطبيقاتها العملية و اختباراتها. الخوارزمية F2RSA (Forest Fires Remote Sensing Algorithm أو خوارزمية للكشف عن الحرائق) التي طورت في هذا العمل , تكشف عن معظم الحرائق المتأججة القائمة بحد أدنى على الإنذارات الخاطئة . الخوارزمية F2RSA تتغير وفق فترات اليوم نهارا أو ليلا. وتستند الخوارزمية نفسها إلى طريقة بسيطة في تحديد مستوى المجالات ووصف بعض النتائج ومناقشتها.

الكلمات المفتاحية: صور القمر الصناعي, MSG ,SEVIRI ,النار, خوارزمية F2RSA .

Résumé:

Le capteur SEVIRI (Spinning Enhanced Visible and Infrared Imager) à bord du satellite MSG fournit une image toutes les 15 minutes, ainsi le développement d'un algorithme qui peut exploiter le comportement temporel des observations de demi-disque terrestre centré sur l'Afrique, malgré leur grande taille de Pixel, est cruciale pour ces applications proches en temps réel.

Cet article donne une vue d'ensemble de l'instrument des MSG SEVIRI, l'approche générale pour la détection du feu actif, et la

description de l'algorithme ainsi que l'application pratique des essais et de l'algorithme. L'algorithme F2RSA (Forest Fires Remote Sensing Algorithm ou Algorithme de Détection des Feux des forêts) développé dans ce travail peut détecter la plupart des feux actifs existants avec un minimum de fausses alarmes. L'algorithme d'F2RSA distingue les périodes du jour diurnes et nocturnes. L'algorithme lui-même est basé sur un algorithme simple de seuillage. Quelques résultats sont décrits et discutés.

Mots clés: Images satellite, SEVIRI, MSG, Feux, algorithme F2RSA.

Abstract:

The SEVIRI (Spinning Enhanced Visible and Infrared Imager) sensor on the MSG satellite provides an image every 15 minutes, so the development of an algorithm that can exploit the temporal behavior of the observations of terrestrial half-disc centered on Africa, in spite of their large pixel size, is crucial for these near-real-time applications.

This paper gives an overview of the MSG SEVIRI instrument, the general approach for the active fire monitoring, and the description of the algorithm together with the practical application of the tests and the algorithm. The F2RSA algorithm (Active Fire Monitoring Algorithm) developed in this work is able to detect most of the existing active fires with a minimum of false alarms. The F2RSA algorithm distinguishes between Diurnal and Nocturnal periods of day. The algorithm itself is based on a simple threshold algorithm. A few results are described and discussed.

KEYWORDS: *Satellite images, SEVIRI, MSG, Fires, F2RSA algorithm.*

INTRODUCTION

Forest and vegetation fires have typical temperatures in the range of 500 °K to 1000 °K [2]. According to Wien's Displacement Law, the peak emission of radiance for blackbody surfaces of such temperatures is at around 4 μm (MSG channel Ch4) [3]. For an ambient temperature of 290 °K, the peak of radiance emission is located at approximately 11 μm (MSG channel Ch9). Active fire detection algorithms from remote sensing use this behaviour to detect 'hot spot' fires. MSG fire monitoring algorithms are typically using the combination of measured brightness temperatures in channels Ch4 and Ch9, their differences and their standard deviation over a 3x3 pixel array. Anyway, the main signal for active fires is an increase of the observed brightness temperature in channel Ch4, compared to the ambient temperature of the neighbouring pixels. The sensitivity of the channel Ch4 to "hot spots" is so high that it shows small sub-pixel fires, which do not have any significant impact upon the Ch9 temperature. However, the measurements in channel Ch4 can be attenuated or misled by CO2 and water vapour absorption, solar reflectance during day, and sub-pixel clouds over hot surfaces [4].

The developed algorithm is named F2RSA (Active Fire Monitoring Algorithm) tries to filter out the active fires by a combination of threshold tests using channels Ch4 and Ch9. The algorithm and its limitations are described in this work.

2. MATERIALS

The F2RSA algorithm uses data acquired from MSG 1 (METEOSAT 8) and MSG-3 (METEOSAT 10) geostationary satellites; it uses channels Ch4 and Ch9 for the fire detection and channel Ch7 for the identification of bare soil.

From the cloud mask (derived by the SCE algorithm) the clear land surface pixels are extracted. A description of the SCE algorithm is given by Lutz in references [5] and [6].

3. METHODS AND ALGORITHMS

Our methodology in this research is primarily to collect maximum MSG images data, to trust the continuous observation of the Earth's full disk with a multi-spectral imager. The repeat cycle of 15 minutes for full-disk imaging provides multi-spectral observations of rapidly changing phenomena such as fires. Data as collected from MSG satellites are not physically exploitable, they must to be calibrated. After that, Active Fire Monitoring Algorithm (F2RSA) is applied to land surfaces to depict fire pixels.

3.1. Forest fires monitoring algorithm

The basic principles of the Active Fire Monitoring Algorithm (F2RSA) are similar to those already in use for other instruments like GOES [7], AVHRR [8], and Modis [9].

Active Fire Monitoring Algorithm (F2RSA) is only applied to cloud-free land surfaces, which means that off-shore oil burning fires or fires on small islands (e.g. active volcanoes which also fall under the "hot spot" category) are be monitored by the algorithm. Bare soil land surfaces are also excluded from the processing. Pixels are considered as bare soil, if the surface types are desert or open shrub land, where this classification is taken from a climatologically background information for the MSG field of view. In addition, the brightness temperature difference between channels Ch9 and Ch7 (T9-T7) is used to check for bare soil: Because of the fact that the emissivity of the Ch7 is much smaller for bare soil surfaces than the emissivity of the Ch9, the difference of the two channels is high in

these cases. For the remaining valid pixels, the F2RSA algorithm uses the following four criteria to check for fire pixels:

1-Brightness temperature of channel Ch4 (T4),
2- Standard deviation of channel Ch4 (SDiv4),
3-Brightness temperature difference of channel Ch4 and Ch9 (T4-T9),
4- Standard deviation of channel Ch9 (SDiv9).

The brightness temperature of channel Ch4 (T4) picks up hot spots caused by the fire. The other MSG channels are less sensitive to hot spots. In this test, simple fixed temperature thresholds are used, which are different for day and night (see Table 1). The standard deviation of channel Ch4 (SDiv4) over 3 by 3 pixels around a central hot spot is used to identify the real hot spot versus the natural (heated) background temperature of the surface.

As channel Ch9 is much less sensitive to hot spots, the brightness temperature T9 will not be as high as the brightness temperature T4. This means that the brightness temperature difference of channels Ch4 and Ch9 is also higher than for non-fire pixels. The reduced sub-pixel fire sensitivity of Ch9 is furthermore used to correct for misclassified fire pixels. Pixels that have passed the first three of the above tests can also be missed clouds, highly variable surface types or highly variable terrain elevation. The correction is done by using the standard deviation of channel Ch9, which will be relatively low in fire regions because the fire pixels have similar brightness temperatures as the surrounding non-fire areas. The standard deviation is calculated on a 3x3 pixel array around each MSG pixel. Water and cloud pixels are excluded from the calculation of the standard deviation. The standard deviation tests are abandoned if less than 3 pixels can be used for the calculation.

3.2. Description of the threshold tests

The algorithm distinguishes between Diurnal and Nocturnal periods of day. The algorithm itself is based on a simple threshold algorithm. From the cloud mask the clear land surface pixels are extracted. In addition the algorithm excludes all pixels, which are defined as desert/bare soil, and all pixels for which the Ch9-Ch7 difference is larger than a threshold (= 4 °K), from further processing. Figure 1 shows the conditions for each pixel to be classified as a diurnal fire pixel and as a nocturnal fire pixel respectively. The current thresholds are listed in Table 1. “Diurnal period” is defined with a local solar zenith angle lower than 70º and “nocturnal period” with a solar zenith angle of higher than 90º. For solar zenith angles between 70º and 90º the thresholds are linearly interpolated.

Figure 2 presents a summary flowchart of the different steps used to extract fires pixels by using F2RSA algorithm.

4. RESULTS AND DISCUSSION

The efficiency of each step of the F2RSA algorithm was computed from some scenes (12 scans) of 6000 km X 11100 km from north of Europe to south of Africa during 2006 fire season. For this training dataset fires were identified by visual inspection after applying all steps, associated with thresholds of Table 1.

	Threshold		Forest Fire	
Test	Day	Night	Day	Night
T4	Threshold 1	Threshold 5	314 °K	288 °K
SDev Ch4	Threshold 2	Threshold 6	3 °K	3 °K
SDev Ch9	Threshold 3	Threshold 7	2 °K	3 °K
T4- T9	Threshold 4	Threshold 8	8°K	6 °K

Table 1*. Thresholds for the four fire tests separated for day/night periods*

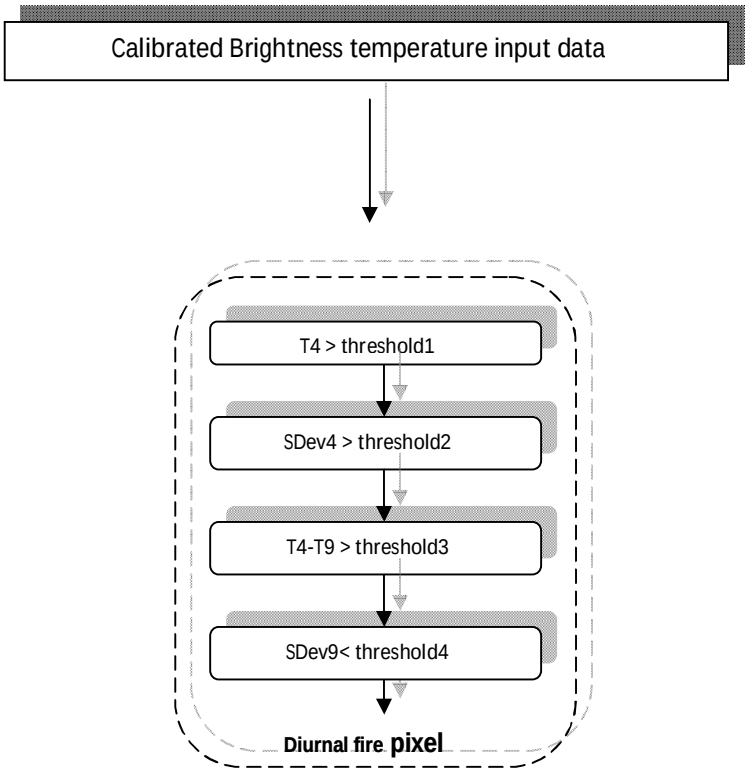

Figure 1. *F2RSA algorithm: Pixel to be classified as a diurnal pixel.*

As samples, for diurnal period, the algorithm is applied to Meteosat-10 (MSG-3) data of 25 August 2015 at 12h30min UTC (Figure 3).

For the scan, during this day, 153 fire pixels were detected by using the F2RSA algorithm.

Figure 3 shows a part of Channel Ch 4 (IR3.9) as acquired. Overlay mask is processed after saving the raw image. After calibration of each channel and applying the F2RSA algorithm. In this figure, 11 hot spots of the fires are clearly visible in the channel CH4 measurements (red dots centred in yellow squares mean hot surfaces).

Fire pixels are located in north west of Algeria , Spain, Morocco, and, south of France.

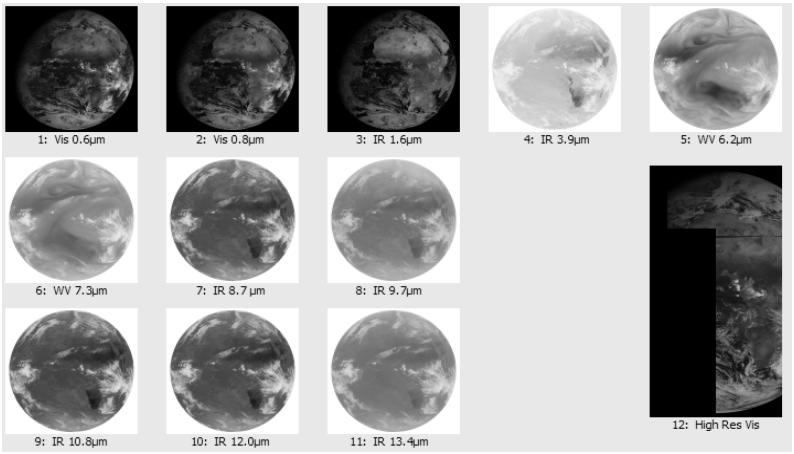

Figure 2. *A full scan as acquired on August 25th 2014 at 12h30 min UTC from SEVIRI MSG-3.*

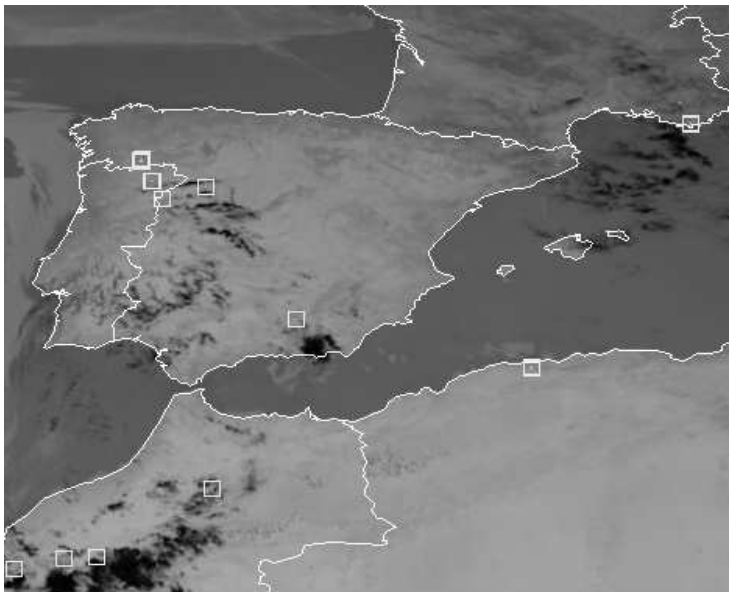

Figure 3. *Apart of Channel (CH 4) IR3.9 brightness temperature acquired on 25th August 2014 at 12h30 min UTC. Dark means low temperatures, bright means high temperatures due to the solar reflection in channel IR3.9, low clouds appear warmer than the clear Atlantic Ocean and Mediterranean Sea. Pixels in red dot on the yellow squares present the forest fire regions depicted by applying F2RSA algorithm.*

5. CONCLUSION

The F2RSA algorithm (Active Fire Monitoring Algorithm) developed in this work is able to detect most of the existing active fires with a minimum of false alarms. Application of the F2RSA algorithm is non limited by time of day or by regions of the Earth surface (i.e. land surfaces), but this algorithm is only applied to cloud-free land surfaces, which means that off-shore oil burning fires or fires on small islands (e.g. active volcanoes which also fall under the "hot spot" category) are be monitored by the algorithm. Bare soil land

surfaces are also excluded from the processing. The validation of the algorithm is still on-going and may lead to some further improvements of the algorithm. These will be reflected in the future works. In particular some of the remaining problems listed below need to be solved, which is: 1-Undetected clouds, sub-pixel clouds, fire under thin Cirrus,2-Mixed water (river/lake/coast) and land scenes,3-Inhomogeneous land surfaces,4-Unknown land surface emissivities, in particular in channel CH4,5-Dusk and dawn periods with rapidly changing CH4 values.

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