A produção do conhecimento nas Ciências Exatas e da Terra 2

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APRESENTAÇÃO

A obra “A produção do conhecimento nas Ciências Exatas e da Terra” aborda uma série de livros de publicação da Atena Editora, em seu II volume, apresenta, em seus 21 capítulos, discussões de diversas abordagens acerca do ensino e educação.

As Ciências Exatas e da Terra englobam, atualmente, alguns dos campos mais promissores em termos de pesquisas atuais. Estas ciências estudam as diversas relações existentes da Astronomia/Física; Biodiversidade; Ciências Biológicas; Ciência da Computação; Engenharias; Geociências; Matemática/ Probabilidade e Estatística e Química.

O conhecimento das mais diversas áreas possibilita o desenvolvimento das habilidades capazes de induzir mudanças de atitudes, resultando na construção de uma nova visão das relações do ser humano com o seu meio, e, portanto, gerando uma crescente demanda por profissionais atuantes nessas áreas.

A ideia moderna das Ciências Exatas e da Terra refere-se a um processo de avanço tecnológico, formulada no sentido positivo e natural, temporalmente progressivo e acumulativo, segue certas regras, etapas específicas e contínuas, de suposto caráter universal. Como se tem visto, a ideia não é só o termo descritivo de um processo e sim um artefato mensurador e normalizador de pesquisas.

Neste sentido, este volume é dedicado aos trabalhos relacionados a ensino e aprendizagem. A importância dos estudos dessa vertente, é notada no cerne da produção do conhecimento, tendo em vista o volume de artigos publicados. Nota-se também uma preocupação dos profissionais de áreas afins em contribuir para o desenvolvimento e disseminação do conhecimento.

Os organizadores da Atena Editora, agradecem especialmente os autores dos diversos capítulos apresentados, parabenizam a dedicação e esforço de cada um, os quais viabilizaram a construção dessa obra no viés da temática apresentada.

Por fim, desejamos que esta obra, fruto do esforço de muitos, seja seminal para todos que vierem a utilizá-la.

Ingrid Aparecida Gomes

SUMÁRIO

CAPÍTULO 20

REMOTE SENSING TOOLS FOR FIRE MONITORING: THE CASE OF WILDFIRE IN CHILE IN 2017

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ABSTRACT: Wildfires are a major concern throughout the world, causing catastrophes and environmental losses. At the beginning of 2017 Chile was affected by large-scale wildfires that lasted for several days. The objective of this work was to compare MODIS, Landsat 8/OLI, and Sentinel 2 images from a region between Concepcion and Valparaiso in Chile during the wildfires cases in 2017. The MODIS sensors on-board TERRA and AQUA satellites, have a daily temporal resolution that is indispensable for detection and monitoring wildfires. Landsat 8/OLI has a better spatial resolution but 16-days temporal resolution. Sentinel 2 presents an even better spatial resolution and 5-days temporal resolution if considered both satellites of the series. Besides the presentation of the images of the daily event monitoring, some results obtained by fire detection algorithms for specific satellites/sensors are also presented. The satellite images associated to the detection algorithms allow the identification and spatial distribution of wildfires in a near real time, thus enabling the management and continuous monitoring of territorial extensions grids.

KEYWORDS: Satellite fire detection; algorithm detection; MODIS; Landsat 8; Sentinel 2

1 I INTRODUCTION

Wildfire prevention, detection, monitoring and suppression are key economic and public safety concerns in many parts of the world. Mitigating the economic impact of wildfires and avoiding advance on inhabited areas, depends on successful monitoring and suppression. Successful suppression is greatly facilitated by early detection allowing for suppression activities to begin while the fire is still small and manageable [1,2].

One way to verify the spatial distribution of heat sources is to use remote sensing, which allows the monitoring of large territorial extensions with the use of different images from different satellites and sensors, such as GOES satellites; NOAA satellites; TERRA and AQUA satellites and MODIS sensors; VIIRS sensor on-board S-NPP satellite; as well as medium-resolution images captures by Landsat satellite family, Sentinel 2, among others [3,4,5,6,7].

Satellite imagery is an important tool for fire management and strategic fire intelligence that can cover large swaths of territory and detect medium to large fires based on automated or semi-automated algorithms [2]. With the advent of new technologies aimed at the development of satellite sensors with better spatial, spectral, radiometric and temporal resolutions, it is possible to estimate heat sources for near real-time monitoring.

Many studies indicate the efficiency of using remote sensing for fire mapping and monitoring. Examples of that are observed in different regions such as Marantaceae forests in the north of the Republic of Congo [8], in the detection of high and low intensity fires in Alaska [9] and quantification of post-fire recovery of temperate and boreal vegetation in North America [10].

According to [11], the use of Landsat-class data to detect thermal anomalies has been successfully demonstrated in previous studies. For example, [12] and [13] applied near infrared (NIR) and short-wave infrared (SWIR) Landsat-5 Thematic Mapper data to analyse volcanic activity. Others expanded on thermal anomalies applications to include long-wave infrared data from Landsat-5 Thematic Mapper (TM) and Landsat-7 Enhanced Thematic Mapper Plus (ETM+) [14, 15]. A more generic application of NIR and SWIR Landsat-class data to detect actively burning fires was also demonstrated [16, 17]. However, because of limited data availability and access restrictions previous studies using those active fire data were mainly focused on regional validation analyses of active fire products derived from the 1-km Moderate Resolution Imaging Spectroradiometer (MODIS) and the 4-km Geostationary Operational Environmental Satellite (GOES) imager [18, 19,17].

The MODIS active fire products fall within the suite of terrestrial products and provide information about actively burning fires, including their location and timing, instantaneous radiative power, and smoldering ratio, presented at a selection of spatial and temporal scales [20, 21].

However, in addition to the visual analysis, for the continuous monitoring of the occurrence and distribution of heat sources, it is necessary to implement algorithms for fire identification that can be developed and implemented for different regions and using different sensors [22,23,24,25.26].

Wildfires have been recurrent all over the world. Many of the large forest fires have raised great international media attention due to large areas burned, residential areas affected, mobilized and relocated residents, or even caused human losses. In particular, we can mention the fires that occurred in Chile (2017), Portugal (2017), Greece (2018) and Los Angeles, USA (either in 2017 and 2018).

In this context the objective of this work was to present and use some of the methodologies already historically consolidated as well as new approaches using new sensors for the detection of heat sources. In particular, the case of the occurrence of large forest fires occurring in Chile between the cities of Concepcion and Valparaiso in the year 2017 is used to present the daily imagery event monitoring, the different spatial resolution of satellite images and results of some active fire algorithms.

2 I MATERIALS AND METHODS

2.1 The event

Fires' event in Chile in beginning of 2017 was a series of forest fires across multiple areas, especially in the central and southern Chile - between the regions of Coquimbo and Los Lagos, with highest intensity in the regions of O'Higgins, Maule and Biobío. Also there were some fires in the region of Magalhães and Chilean Antartica (southern part of the country). A total of 587,000 hectares were burned between January and February, 2017 in central-southern Chile.

On January 20, the Chilean government declared emergency state in response to the wildfires. But on January 27 and 28, a wildfire killed at least 11 people, including five firefighters and displacing thousands of people. It was described as the worst in Chile's modern history.

The study area focused this work is presented in Figure 1.

Figure 1. Study Area.

2.2 Remote Sensing Data and Detection Algorithms

At higher temperatures typical of smoldering fires or open flame the peak of the response shifts to mid-wave infrared (MWIR, 3–5 μm) or shorter wavelengths (SWIR). Thus, there is a wide range of sensors for detecting infrared radiation.

Most imaging techniques intended to detect the heat signature of fire are based on MWIR and thermal infrared (TIR) sensors. While smoke can be a cue for detection it can also obscure the visibility of the flame. TIR imaging has an advantage because even thick smoke is transparent at these wavelengths allowing imaging of hotspots through smoke. This can be a useful property in monitoring active fires and searching for spot fires. Another advantage of TIR imaging over shorter wavelength infrared (IR) is that the dynamic range of the scene in the presence of fire is limited in the TIR, making it easier to imaging both the fire and background without saturating the sensor [2].

MODIS sensors are onboard the polar orbit AQUA and TERRA satellites. They revisit approximately the same area daily (twice a day if considering both satellites), but with a spatial resolution of 250m to 1km. On the other hand, Landsat 8 satellite also has polar orbit, with 30-100 meters of spatial resolution but with a 16-days revisit period. Sentinel 2 refers to a group of satellites, including Sentinel 2a and Sentinel 2b. They have a polar orbit too, with 10-60 meters of spatial resolution and 5-days revisit period, if considering both Sentinel 2a and Sentinel 2b. All of these satellites and sensors onboard have NIR and SWIR, but just MODIS and Landsat 8 have TIR bands.

MODIS' algorithm uses brightness temperatures derived from the MODIS 4-11 μm channels, denoted by T4 and T11, respectively. The MODIS instrument also has two 4 μm channels, numbered 21 and 22, which are used in the detection algorithm. Channel 21 saturates at nearly 500 K and channel 22 saturates at 331 K. Since the low-saturation channel (22) is less noisy and has a smaller quantization error, T4 is derived from this channel whenever possible. However, when channel 22 saturates or has missing data, it is replaced with the high saturation channel to derive T4.

T11 is computed from the 11 μm channel (channel 31), which saturates at approximately 400 K for the TERRA and 340 K for the AQUA. The 12-μm channel (channel 32) is used for cloud masking and brightness temperatures for this channel are denoted by T12 [3].

The 250 m resolution red (0.65 μm) and near-infrared (0.86 μm) channels are used to reject false alarms and mask clouds. The 500 m 2.1 μm band is used to reject water-induced false alarms. A summary of all MODIS bands used in the algorithm can be found in [3] and [25].

The purpose of the detection algorithm is to identify pixels in which one or more fires are actively burning at the time of the satellite overpass; such pixels are commonly referred to as “fire pixels”. In particular, the algorithm looks for a significant increase in radiance at 4 μm in both an absolute sense as well as relative to the observed 11 μm radiance. This characteristic active fire signature is the result of the enormous difference in 4 and 11 μm blackbody radiation emitted at combustion temperatures as described by the Planck function [3].

The MODIS' active fire / hotspots detection is provided freely and in near real time by FIRMS (Fire Information for Resource Management System). FIRMS is part of NASA's Land, Atmosphere Near real-time Capability for Earth Observing System (LANCE-EOS).

On the other hand, [11] have presented a new active fire algorithm using Landsat-8/OLI day and nighttime input data. The methodology expands on previous algorithms proposed for ASTER and Landsat-7/ETM+, incorporating additional visible and near-infrared channel data and a multi-temporal analysis scheme. Detailed analyses of the input OLI data indicated frequent saturation of fire-affected pixels on the fire-sensitive SWIR channel 7 (2.11 μm - 2.29 μm), and to a lesser extent of the channel 6 data (1.57 μm - 1.65 μm).

The Landsat-8 active fire detection algorithm is divided into day and nighttime modules. Both detection modules are driven by the fire sensitive SWIR channel 7 data, exploiting the emissive component of fires in the 2.2 μm spectral window. During the daytime orbits the emissive fire component is mixed with the background, which is dominated by the reflected solar component. In order to separate those, [11] algorithm uses the NIR channel 5 data that are mostly unresponsive to fire-affected pixels, though highly correlated to the SWIR channel data over fire-free surfaces [16]. During night orbits the reflected solar component is absent from the scene, making the SWIR band particularly responsive to the emitted radiance from active fires in an otherwise dull background.

In both day and nighttime data, the radiometric signature of active fires produces a SWIR radiance or reflectance anomaly when compared to the background, thereby mimicking the concept of thermal anomaly detection using mid-to-thermal infrared channels [11].

For this work, we present the results of the algorithm for MODIS and Landsat-8 data. The MODIS' active fire detection is provided by FIRMS. For Landsat-8's active fire detection, we have implemented the code as specified in [11].

3 I RESULTS

Figure 2 presents the MODIS images for all the fires events in Chile (01/14/17 – 01/30/17). First, it is possible to see the evolution of fires and burned scars in the images. Comparing the 01/14 image (Figure 2a) with the 01/30 image (Figure 2q), the size and location of the burned scars can be identified.

Also, the images show the dates when fires occur in broader areas. For example, in the 01/25 and 01/26 images (Figure 2l-m) fires were more intense generating bigger scars and a lot of smoke.

It is also possible to see the clouds and smokes dynamics for each day. In this band composite (R7G2B1), clouds are shown in white shade while smokes are in a light blue shade. Then, it is possible to see the days when more smoke were generated (01/20 – 01/27). Also, in the image 01/28 (Figure 2o) it is possible to see that smoke produced in the previous days did not dissipate, being stucked due the mountain chain (Andes Mountains Range).

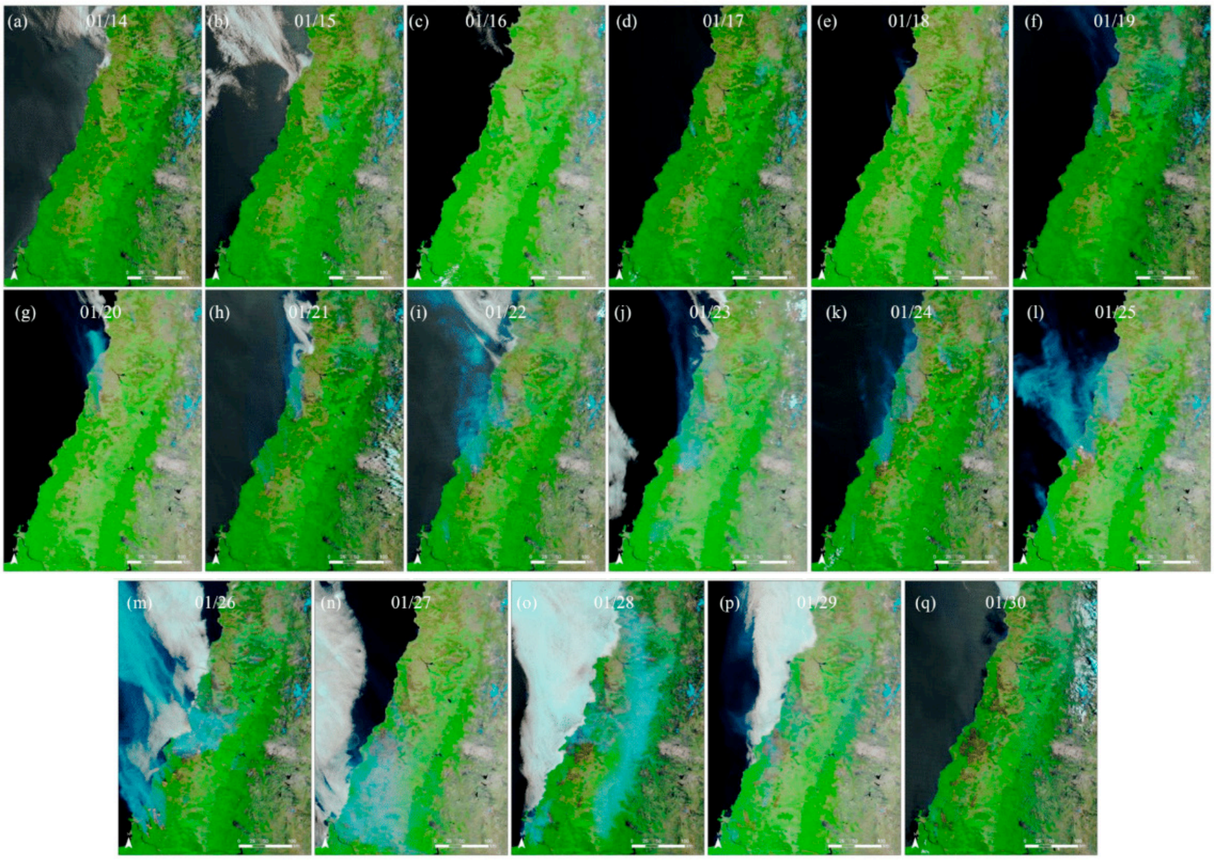

Figure 2. The wildfire daily evolution. MODIS 721 images from 01/14/17 to 01/30/17.

4 I DISCUSSION

Figure 2 brings a good example of daily monitoring of wildfire dynamics through MODIS images. Then, to show other possibilities of fire monitoring, Figure 3 and 4 presents the comparison of these MODIS images to better spatial resolution images (Landsat 8 and Sentinel 2, respectively). Pairs of images from the same day and event are presented in these comparisons. Unfortunately, it is not possible to have a daily imagery from Landsat 8 and Sentinel 2, but there is a great difference between the images considering fire identification, burned scar, and land cover situation.

Figure 3 brings the comparison between the MODIS and Landsat 8 images, 250 and 30 meters of spatial resolution, respectively. In fact, MODIS has just 2 channels with spatial resolution of 250 meters, the channel 7 , originally with 500 meters of spatial resolution had to be resample to be able to make this image composition. Thus, for the each pair of images presented in Figure 3, we can highlight the distinctness in the wildfire front delimitation, the burn scars left and the land cover with potential to be burned.

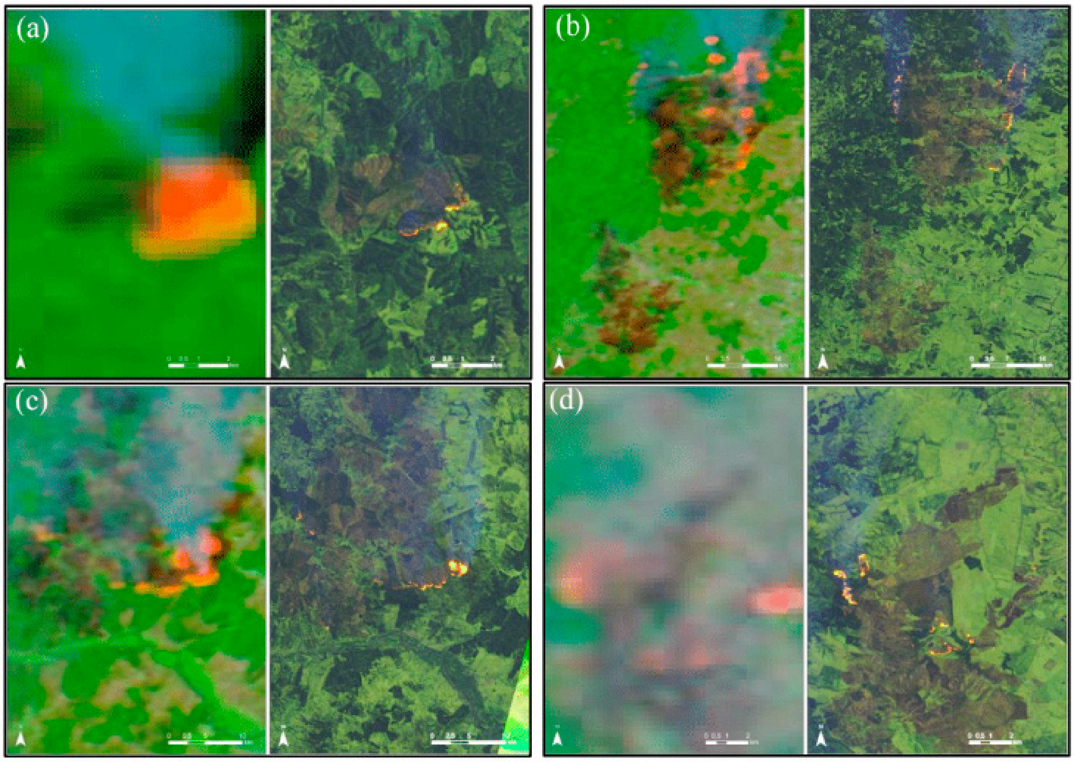

Figure 3. Comparing the spatial resolution for the fire detection.
MODIS (250m) versus Landsat 8 (30m).

The same analysis is done by comparing MODIS and Sentinel 2, 250 and 20 meters of spatial resolution, respectively as presented in Figure 4. The pairs of images represent the same day and fire event. The fire front, the burned scars as weel as the land cover can be identified. It is also possible to measure the distance between the wildfire event and the city boundary.

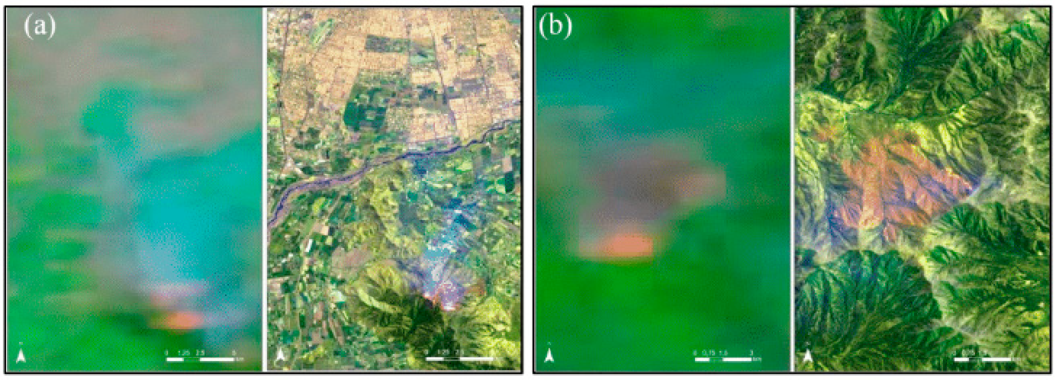

Figure 4. Comparing the spatial resolution for the fire detection.
MODIS (250m) versus Sentinel 2 (20m).

Figure 5 brings the results from the fire/thermal anomalies detection algorithms for the MODIS and Landsat 8 images. Then, by using these algorithms it is possible to automatic quantify the size, extension, and severity from the fire event. Also, by using these algorithms it is possible to automatic highlight where the active fire is happening, without the need of a visual analysis over each satellite image.

Also, another advantage of the use of detection algorithms associated with remote sensing, is the possibility of autonomous and continuous monitoring of large territorial extensions in different regions of the world, sometimes in real-time (or near real-time).

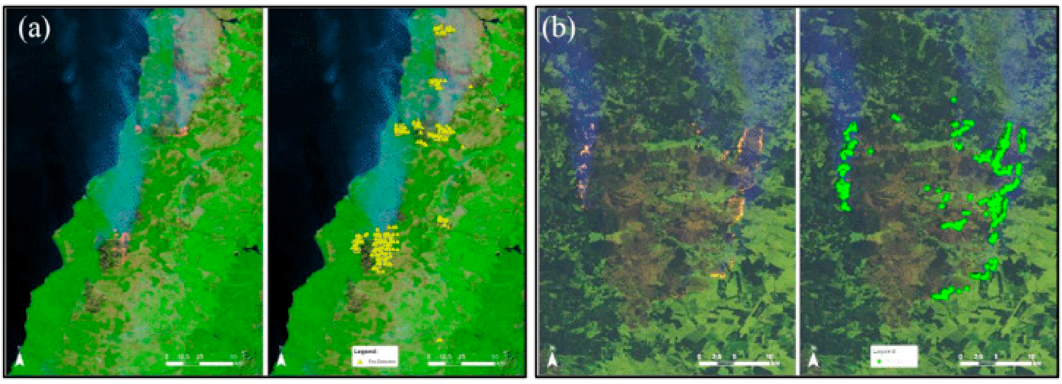

Figure 5. Results from Fire Detection Algorithms.

5 I CONCLUSIONS

This work has shown the use of Remote Sensing technology for fire detection and monitoring. The fire events in Chile in 2017 where used as a study case.

By using Remote Sensing images for fire detection and monitoring, it is possible to map where, and even when, the wild fire is happening. Also, its size, extension, and severity. Due to the temporal resolution of MODIS images, it is possible to establish a daily monitoring. Also, due the Landsat 8 and Sentinel 2 spatial resolution, it is possible to have a better interpretation of the land use and land cover, what is burning, where and how are the burned scars left, detect the fire front, how close are the fires from cities, and other situations.

Likewise, by using fire/thermal anomalies detection algorithms, it is possible to determine with great efficiency its location and to estimate its movement and direction and to correlate with wind intensity. Thus, depending on the magnitude of the event, any information generated and obtained in advance or even during the phenomenon, can be helpful in the decision making process and establish the best alternative for firefighting.

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SOBRE A ORGANIZADORA

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