12th EARSeL Forest Fires SIG Workshop

Remote sensing of forest fire:
Data, science and
operational applications

3-5 October 2019
Rome , Italy

Book of Abstracts

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EARSEL

REMOTE SENSING OF FOREST FIRE DATA, SCIENCE AND OPERATIONAL APPLICATIONS

3-5 OCTOBER 2019 - ROME, ITALY

ORGANIZED BY

EUROPEAN ASSOCIATION OF REMOTE SENSING LABORATORIES

BOOK OF ACBSTRACTS

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Speaking on behalf of the organising welcome all of you to this international assembly.

The organisation of this event started almost two years ago when Prof. Gitas invited me to organise the next workshop of the EARSeL Special Interest Group on Forest Fires. After a great deal of effort by all members of the organizing committee and the kind contribution by distinguished experts an intensive program, with a large number of excellent lectures and papers has been developed.

The aim of the 12th international workshop is to focus on recent developments related to 'Remote Sensing of Forest Fires' related to:

- the availability of new sensors,
- the free access to large archives of data and satellite imagery, and
- recent developments in computer technology and data processing techniques

that have opened new perspectives in both fire science and applications.

This idea clearly links with international programmes of a similar scope, such as the COPERNICUS and the Global Observation of Forest Cover/Land Dynamics (GOFC-GOLD) who, together with the Joint Research Center of the European Union and NASA support this event.

Dear guests, allow me to express my sincere appreciation and acknowledgement to all members of the organizing committee and the sponsors (national and international) who made this conference a reality. Once more, on behalf of the local organizing committee I wish you an enjoyable and interesting stay in Rome. Thank you very much.

The 12th EARSeL Forest Fires SIG Workshop, titled "Remote sensing of fire: Data, science and operational applications" is organized by CNR, ESA, Aristotle University of Thessaloniki, and chaired by Rosa Lasaponara and Ioannis Gitas.

The workshop brings together experts in remote sensing, forest managers, researchers, local governments and global organizations to address the key strategic issues of fire data science, modelling, management, and monitoring. Among the invited speakers, it is worth noted, Emilio Chuvieco, Professor of Geography and director of the Environmental Ethics chair at the University of Alcalá (ES), Antonello Provenzale, Director of the Institute of Geosciences and Earth Resources, CNR (IT) and Jesus S. Miguel, Senior researcher at the European Commission Joint Research Centre.

The thematic sessions include oral presentations and posters focused on the following

- Dynamic modelling of fire occurrence, fuel and fuel moisture models
- Application of image processing techniques and machine learning to support fire management
- Integration of satellite, airborne, and field sensor for wildfire management
- Fire detection and monitoring on multiple scales
- Fire behavior and fire impacts
- Burned area, severity estimation and ecological impacts,
- Fuel consumption and fuel load estimation
- Laboratory and field studies of fire and post-fire residues
- Fire emissions estimation and air quality monitoring
- wildfire impacts and post-fire treatments.
- Exploitation of Big Earth Data and satellite time-series for fire disturbance monitoring
- Studies on the impact of climate change on forest fires occurrence and severity;
- Contribution of Sentinel missions on forest fire research;
- Improved methods of modelling post-fire vegetation trends;

As accompanying event of the workshop, the **IV ESA EARSEL CNR SCHOOL** is held at the ESA headquarter in Frascati to spread the application of active and passive remote sensing techniques for fire research. The training course will take place from 30 September to 1 October. It will focus on the use of active and passive Earth Observation (EO) Technologies for fire monitoring.

We wish all the participants good luck

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Logistic details

CNR headquarter, Conference room, "Sala Marconi"
Location
Piazzale Aldo Moro,7, Roma

INVITED SPEAKERS

JESUS SAN MIGUEL-AYANZ

Although the term wildfires hints on a potential natural cause of the fire, far from human nature, our data show that most of the fires occurring worldwide have a human cause. Over 400 million ha are burnt every year and the number and effect of wildfires is still on the raise, despite the human efforts of fighting their effects by increasing firefighting fleets and means. Climate change is already influencing fire regimes and has recently led to a series of unprecedented wildfires in many regions of the world.

Leader on the development of the European Forest Fire Information System (EFFIS) and the Global Wildfire Information System (GWIS), Jesus San Miguel-Ayanz, is a Senior researcher at the European Commission Joint Research Centre. Until 2017, he led the development of other EU information systems such as the Forest Information System for Europe (FISE) and the European Forest Data Center (EFDAC), supporting EU Regulations on forest information and monitoring. He has a background on forestry research and remote sensing, including aspects of forest dynamics, inventory and disturbances, specifically on forest fires, and a wide experience in data handling and in the development of information systems.

Education: PhD (1993) and MSc (1989) on Remote Sensing and GIS by University of California-Berkeley, Forest Engineering Degree (87) by Polytechnic Univ. of Madrid.
Professional experience: (95-97) Associate Professor of Forest Inventory, Forest Mensuration and Remote Sensing. (94-95) Assistant Professor same topics, University of Cordoba, Spain. Research: Fulbright scholar at the Univ. California-Berkeley (1989); research fellow at the University of California-Berkeley (89-93), the European Space and Technology Centre (ESTEC) of the European Space Agency (93-94), and the Joint Research Centre (94-96).

List of publications available at: https://www.researchgate.net/profile/J_San-Miguel-Ayanz

EMILIO CHUVIECO

Professor of Geography and director of the Environmental Ethics chair at the University of Alcalá, SPAIN.

The lecture will cover the recent developments in the use of RS data for burned are mapping, including both the generation and validation of the products, as well as their use for climate and atmospheric models. Special emphasis will be given to global products, produced from new sensors, including coarse (MODIS, OLCI, SLSTR) a medium spatial resolution (OLI, MSI, SAR).

Professor of Geography and director of the Environmental Ethics chair at the University of Alcalá, Spain, where he coordinates the Master program in Geographic Information Technologies, and leads the "Environmental Remote Sensing Research Group". Visiting professor at the U.C. Berkeley and Santa Barbara, the Canadian Remote Sensing Center and the University of Maryland. He has given short post-graduate courses en 23 countries. Advisor of 36 Ph.D. dissertations. Principal investigator of 31 research projects and 23 contracts. Author of 29 books and 363 scientific papers and book chapters, 159 of which are indexed in Scopus. Former president of the Spanish Remote Sensing Society and the Geographic Information Technologies group of the Association of Spanish Geographers. Corresponding member of the Spanish Academy of Sciences since 2004. He is the science leader of the Fire Disturbance project within the European Space Agency's Climate Change Initiative Program since 2010. Co-editor in Chief of Remote Sensing of Environment. His main professional activity has been focused on the environmental analysis of Satellite Earth observation, with particular emphasys on forest fire applications. In addition, he is interested in Faith-Science relations and environmental ethics, and particularly on the impact of large religious traditions in environmental conservation. He founded and currently leads a publishing company (http://www.digitalreasons.es/), oriented towards publishing essays on social, cultural and scientific controversial issues (all books in Spanish). Metrics: h-index: 49 by Scopus, 64 by Google scholar (as for 04.06.2019)

ANTONELLO PROVENZALE

In this talk we review the state and trends of wildfires in the Mediterranean area, focusing on the summer burned area. Using an empirical, data-driven model built on the available data from EFFIS and national inventories, we discuss possible future scenarios and show how the model can be used to improve seasonal wildfire forecast. Finally, we discuss the comparison between fire-related remote sensing products and the ground data provided by EFFIS.

Director of the Institute of Geosciences and Earth Resources, CNR. Research on impacts of climate change on ecosystems and the environment, geosphere-biosphere interactions, planetary climates. Invited professor at Universitè Pierre et Marie Curie in Paris; Ecole Normale Superieure in Paris; University of Colorado, USA; Ben Gurion University, Israel. Faculty member of the Program on Geophysical Fluid Dynamics at WHOI, MA, USA. Recipient of the Golden Badge Award of the European Geophysical Society (EGS). Coordinator of the EU H2020 Project "ECOPOTENTIAL: Improving Future Ecosystem Benefits Through Earth Observations" and of the Italian project PON IR “LifeWatchPlus”. Author of more than 160 publications in ISI journals.

VINCENT G. AMBROSIA

Vince Ambrosia is a Senior Research Scientist / Adjunct Faculty Member at California State University – Monterey Bay, and the NASA Applied Science Associate Program Manager for Wildfire at NASA HQ, responsible for management of a portfolio of projects related to Earth Observations in support of wildland fire management. He currently supports the Group on Earth Observations (GEO) Global Wildfire Information System (GWIS) initiative as the NASA Wildland fire community representative, and since 2003, co-chairs the NASA / USFS Tactical Fire Remote Sensing Advisory Committee (TFRSAC). He has received numerous awards, including the 2009 NASA Outstanding Public Service Medal for supporting emergency wildfire observations with UAS / sensors; the 2009 Federal Laboratory Consortium for Technology Transfer, Interagency Partnership Award for improving national wildfire observations; and the 1999 ASPRS Best Remote Sensing Paper Award in Photogrammetric Engineering & Remote Sensing (PE&RS) for his article entitled: “"An Integration of Remote Sensing, GIS, and Information Distribution for Wildfire Detection and Management". In 2019, he also received the journal Remote Sensing award for best peer reviewed article in the journal’s 10-year history, entitled: “Considerations for the Use of Unmanned Aircraft Systems in Remote Sensing and Scientific Research”.

He has authored or co-authored over 140 papers, journal articles, and book chapters. He holds a BS in Geography from Carroll University (Waukesha, WI) and the MS from the University of Tennessee- Knoxville (1980), and has been at NASA-Ames in various positions since 1980.

IV ESA EARSEL CNR SCHOOL

On the occasion of the conference **12th EARSeL Forest Fires SIG Workshop** a training will be held on the application of active and passive remote sensing techniques for fire research. The training course will take place from 30 September to 1 October. It will focus on the use of active and passive Earth Observation (EO) Technologies for fire monitoring.

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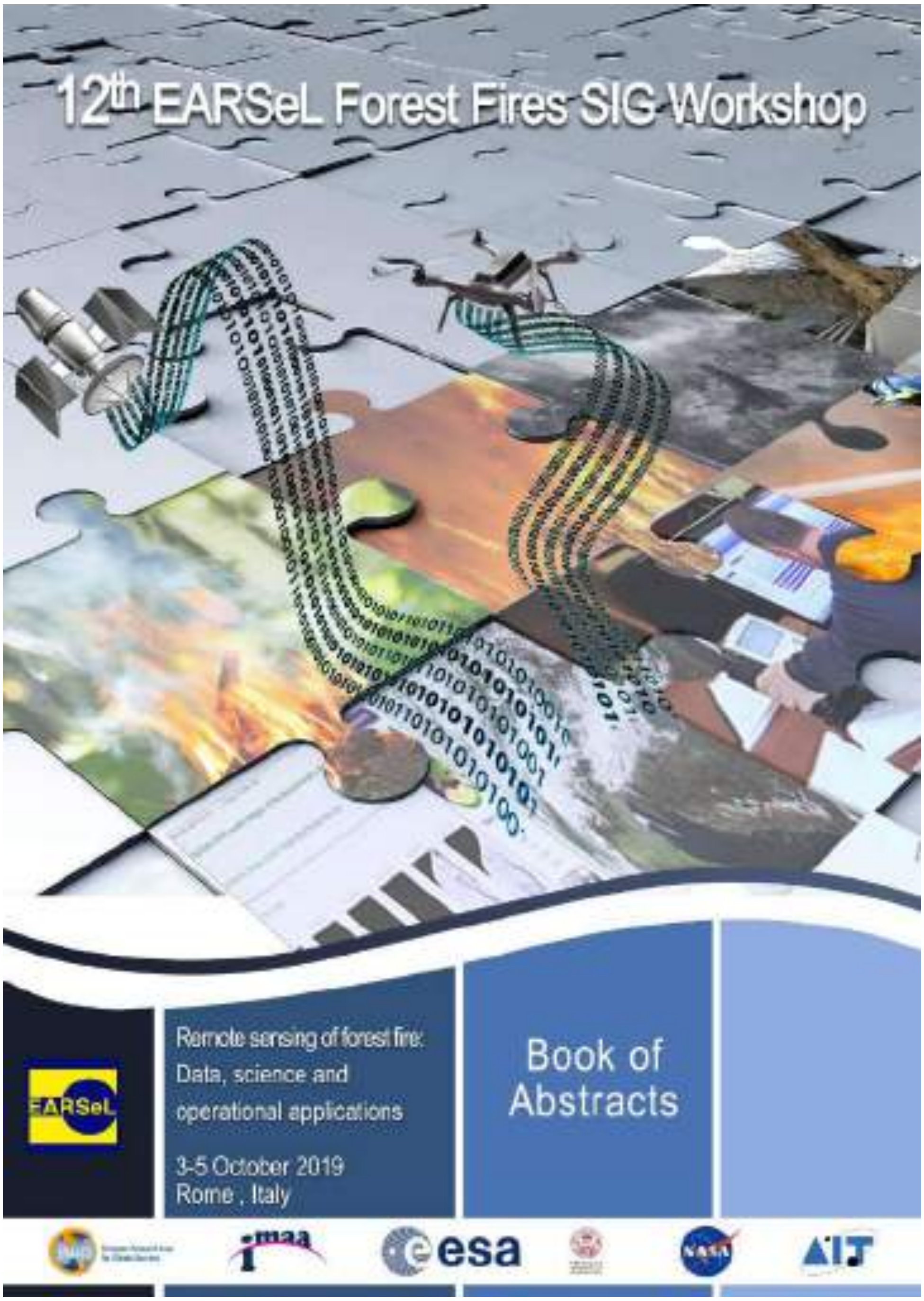
Session: Exploring fire-related forest dynamics

Poster Session



EARSEL

REMOTE SENSING OF FOREST FIRE DATA, SCIENCE AND OPERATIONAL APPLICATIONS

SESSION: FIRE DETECTION AND MONITORING ON MULTIPLE SCALES

Testing Operational use of Sentinel 2 for fire danger assessment and management in Italy

EARSeL 2019
Digital I Earth I Observation
Abstract
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Keywords: Sentinel 2 mapping, Fire detection, danger rating, prevention & preparedness

Abstract

Italy is a high fire-risk region, where fires cause important damages and economic losses every-year. On recent decades, the annual burned area and annual number of fires have generally decreased. The increased efforts in fire suppression have probably played an important role in driving the general downward trends described for most of the Mediterranean area. Indeed, in recent decades fire management strategies have improved thanks to new technologies and experience while climate drivers would have probably led to an opposite trend.

Since 2000, Liguria Region, first, and then the Italian Civil Protection Department, carried out independent research programs that led to the development of RISICO (in Italian RISchio Incendi e COordinamento, fire risk and coordination) system, a fire danger rating system adapted to the vegetation coverage of the Mediterranean. RISICO integrates meteorological observations and forecasts provided by Limited Area Models (LAM) with vegetation cover and topography as additional input to the system. This allows to discriminate the behaviour of fire among different fuels types considering the effect of slope and wind on fire behaviour, including important aspect related with the process of fire spread beyond the weather.

This system is currently used in Italy at national level by the Italian Civil Protection Department (Dipartimento della Protezione Civile, http://www.protezionecivile.gov.it) to assess the wildland fire danger over the whole national territory. The main use of the information provided by the RISICO system is to support the decision makers, at national level, on the management of national water bombers fleet. At regional level, RISICO is currently used by several regions in order to issue a daily fire danger bulletin and support decisions in prevention and preparedness activities. The limitation of the system was mainly represented by an overestimation of the fire danger in the period of transition between the main fire seasons. In fact, the system originally considered the herbaceous vegetation with a constant amount of dead fuel, representing in this way the worst-case scenario. To overcome this limit, satellite data have been used to produce different high-resolution vegetation indices with a maximum revisit time of 5 days over the Italian territory. This is possible using the Copernicus constellation of Sentinel 2 (A- B) satellites. Thus, a service for the automatic mosaic of Sentinel-2 (Level2A) images at national scale has been fulfilled in order to validate the capacity of the sensors to capture the changes in vegetation textures and to improve RISICO model capabilities. Another value added of the implemented algorithm is the ability to localize and estimate the spatial extension of potentially burned areas with a daily update. Those products would allow to assess a more suitable and targeted fire management strategies at local and national level. The validation of results obtained during the 2019 summer period will be performed taking also into account warnings from different sources (available satellites and in-situ observation).

Support Wildfire management in Mediterranean Territories using multi-source satellite images

EARSeL 2019
Digital I Earth I Observation
Abstract
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Keywords: Wildfires, Vulnerability, Hazard, Modis

Abstract

Wildfires are an uncontrolled phenomenon occurring in all man-forest systems around the globe. Catastrophic wildfires, however, not only represent a threat to the natural ecosystems and to soil preservation, but may also cause significant socio-economic damage and loss of human lives. In the last decade (JRC, 2017), an average of about 50'000 hectares of Italian soil burned each year as a result of 5500 wildfires, and this number remained practically unchanged despite all the prevention efforts.

The objective of the S2IGI (Sistema Satellitare Integrato Gestione Incendi) project is to assist the management and prevention of forest fires and to support the firefighting activities through the use of advanced technologies and the exploitation of satellite data. The operational firefighting activities cover the three phases in the pre-event, intra-event and the post-event, and consist respectively in the allocation of the resources on the territory on the basis of the daily and seasonal risk, on the localization and monitoring of the active fires with real-time prediction of the propagation, and finally the estimation of the geological and economic damages. In order to provide support during all three phases, the products of the S2IGI research project are also divided into the three research macro-areas of forecast, detection and damage assessment. With regard to the forecast area of research, the development of products for wildfire vulnerability and daily fire hazard assessment was recently completed for the Italian region of Sardinia. In this framework, improvements were done to the already available vulnerability and Daily Fire Hazard Indices (also developed by the researchers of La Sapienza in the context of the PREFER and SIGRI projects) by modelling the effects of road density in the first case and wind speed and direction in the second case.

The Vulnerability Index calculation is carried out following a stepwise approach that involves three main components: exposure, sensitivity and coping capacity. Composite indices for each of the components were created using GIS data of population density, fuel types, protected areas location, roads infrastructure and surveillance activities, taking into account the effect of the third dimension wherever necessary. The additive-type model was selected for the aggregation of components by allocating weights in the order of importance, mainly to differentiate the effects of individual elements and to streamline the interpretation of the outputs. Specifically, coping capacity was improved by including road density along with other institutional variables such as firefighters and surveillance areas.

The Daily Fire Hazard Index (DFHI) provides a daily fire risk assessment through the estimation of the actual state of the vegetation by exploiting meteorological forecast data provided by the Italian Aeronautica Militare and medium resolution satellite data in the form of MODIS (MODerate resolution Imaging Spectrometer) imagery. The state of the vegetation at a certain instant in time is estimated on one hand exploiting satellite data by computing the Live Vegetation fraction (using measured NDVI and EWT comparing it to their historical records) and on the other hand using the FAO Penman-Monteith method for the calculation of the reference Evapotranspiration (ET0) in order to assess the moisture content of the vegetation. In its latest iteration, the index improves on its predecessors by accounting for the effect of the local topography on the solar illumination conditions, and for the effect of wind speed on the actual temperature of the vegetation.

Both products, represented in (Figure 1), are currently undergoing validation processes while the necessary data becomes available, and the results will be presented and discussed during the workshop.

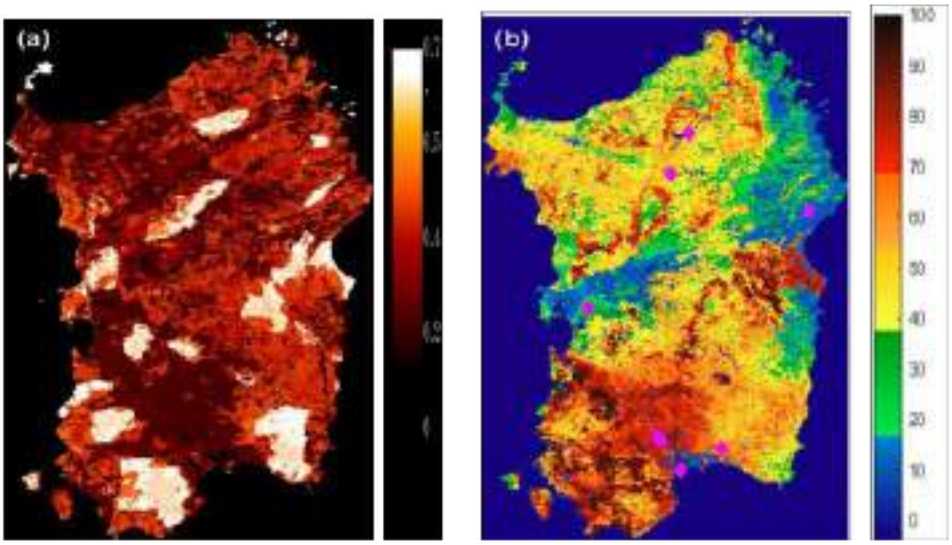

Figure 1.(a) Wildfire Vulnerability map and (b) Daily Fire Hazard Index map

Use of GIS for the dynamic generation of forest fire risk maps based on a probabilistic model and Forest Fire Weather Index

EARSeL 2019
Digital I Earth I Observation
Abstract
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Keywords: logistic regression, weather, gis, fire forest, fwi

Abstract

For millions of years, fire has played a major role in the composition, structure and functioning of ecosystems. Fires, often with disastrous social, environmental and economic consequences, regularly attack forests. Fire is a threat not only to human lives and property, but also to vital ecosystem services, such as soil conservation, the preservation of biological resources and the regulatory capacity of the ecosystem Climate.

Forest fires are a threat to many forests and their biodiversity. They affect each year important surfaces in the Algerian forest massifs. Despite the alarm signal fired by forest guards to deter nature's terrorists from acting, the attacks continue to reduce the forest's surface.

In this context, the fight against forest fires has become a national obligation, so it is the objective of this work, which is the development of a methodology that can lead to a dynamic map of fire risk. In this work, we will develop Under a GIS a dynamic map of fire risk for the department of Medea. The method used combines the structural factor that is reflected in the fire history and the dynamic factor that introduces the weather conditions that play a key role in the occurrence of forest fires. The structural index was calculated using a statistical method (logistic regression) exploiting the fire history data from the period 2009 to 2013 brought back from forest conservation in the department of Medea. On the other hand, a calculation tool developed under Python using meteorological data generated the dynamic index. These two indexes are combined into a single index to obtain a final map. All of these tools are integrated into a GIS application to produce a dynamic map that changes in both space and time.

Exploring ECOSTRESS data for wildfires in Mediterranean ecosystems

EARSeL 2019
Digital I Earth I Observation
Abstract
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keywords: ecostress, fire temperature, burned areas.

Abstract

Mediterranean countries have always been affected by wildfires. However, global warming and more frequent hot summers increase the intensity, extension and impact of wildfires and may induce a shift in fire season. Earth Observing (EO) programs such as MODIS, VIRSS, and Sentinel 3 provide valuable information for wildfire detection due to daily overpass and thermal spectral bands, while Sentinel 2 (10-20m/px) and Landsat 8 (30m/px) data can provide more detailed information on small size wildfires and their impact on the ecosystem.

In 2018 the ECOsystem Spaceborne Thermal Radiometer Experiment (ECOSTRESS) was deployed on the International Space Station (ISS) in order to provide temperature and evapotraspiration maps of vegetation to be used to detect vegetation water stress at its early stage and provide useful information for decision makers. The instrument has 70 m spatial resolution with 5 thermal spectral bands in the 8-12.5 µm range and an additional band at 1.6 um for geolocation and cloud detection. To minimize the electronic noise the focal plane is cooled by two commercial Thales cryocoolers. Two on board black bodies: one controlled between 16C to 24C and one controlled to 46C are used for calibration.

The present study, carried out within the Early Adopter Program, aims to explore how ECOSTRESS data can provide, besides its primary mission, information on active fire that can complement fire characteristics derived by other programs such as Copernicus and Landsat.

We examined La Drova wildfire, in Spain that ignited on 6 August 2018 and lasted 4 days. The fire was the result of 11separated fires and went rapidly out of control. 800 fire-fighters and soldiers and 30 helicopters and small aircraft were needed for the suppression while 2500 people were evacuated

ECOSTRESS imagery was acquired on 8 August 2018 while the fire was still active. Sentinel 2 and Landsat 8 images acquired during the fire were cloudy. A pre- and post-fire cloud-free Sentinel 2 pair was used for NDVI and burn severity, and these were used for comparison with the ECOSTRESS image. Figure 1 (a) shows the ECOSTRESS image over La Drova fire processed by using band rationing tecnique. We adopted this tecnique to highlight clouds and active fire. Note that the burned area was clearly delineated as the fire is still active; unburned regions within the burn scar were identified with good agreement with vegetated (unburned) areas retrieved using high resolution NDVI (10m/px) derived from Sentinel 2 imagery acquired on 24 August 2018.

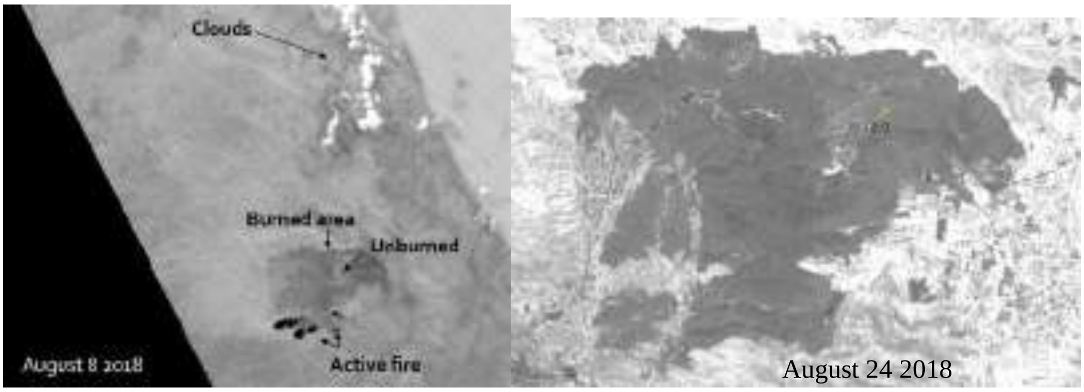

Figure 2. (a) ECOSTRESS band 5 and band 1 ratio and (b) NDVI at 10m resolution obtained from Sentinel 2 imagery acquired 16 days after the fire.

EARSeL 2019
Digital I Earth I Observation
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Current improvements at INPE´s Fire System for Brazil and Latin America

Alberto Setzer[1], Fabiano Morelli[1], Willian D.M. Rosa[1],

[1] INPE- National Space Institute of Brazil/Wildfire Program, Brazil

Keywords: Wildfires, monitoring systems, satellites, fire risk, intelligent systems.

Abstract

Wildland fires relate to fields of interest such as the suppression, management and prevention of fire use, and to impacts on human health, vegetation, wildlife, properties and transportation; on a regional and global scale the resulting gases and aerosols emitted interfere in atmospheric chemistry and with the Earth´s radiation balance. The involvement of scientific, administrative and technical communities regarding vegetation fires, as well as of the public in general, increased significantly since the mid-1980s; at that time satellite images and airborne experiments showed how emissions from deforestation fires in the Amazon affected millions of km2 and the CO2 produced could interfere in the Planet´s climate balance.

In this context of assorted interests and with the current availability of near real-time data from a dozen sensors/satellites and unlimited instantaneous capability of processing, modeling and distribution of information, a "Fire System" becomes a highly complex task.

This paper briefly describes the evolution of INPE´s Fire System for Brazil and Latin America since the late 1980s when only the early NOAA-series satellites were used to detect fires and the information was relayed with Telex machines, to the current configuration (www.inpe.br/queimadas) based on ten different satellites and operational web application tools.

Specific systems now monitor Active Fires, estimate Burned Area at 01 km and 30 m, calculate and predict Weather Fire Risk, map and spatially analyze Air Pollution, maintain a wildfire National Coordination website, supply users with a Regional Fire System identical to INPE´s, support Brazil´s national power grid lines Terrain Maintenance etc. The system´s web portal also distributes individually tailored instantaneous alerts and bulletins updated daily with data summaries, time- series, maps etc produced by the Fire System. About 3,000 users are registered and the web visitors to the portal since the new 2018 version amounts to some 410,000. Two main articles per day appear in the digital media and hundreds of technical and scientific publications have used the system´s data. Validation experiments made with drones to verify and calibrate algorithms of fire detection and burned area mapping are conducted regularly and in different ecosystems. Examples of the many fire-related products and activities are included in the text.

The paper also discusses applications under development to answer requests from the users that are now feasible using new remote sensing products and information technology developments. Among them, automatic location and even fining of unauthorized use of fire in croplands and areas

of protected vegetation, integrated with CAR (the national geo-referenced database of rural properties in Brazil).

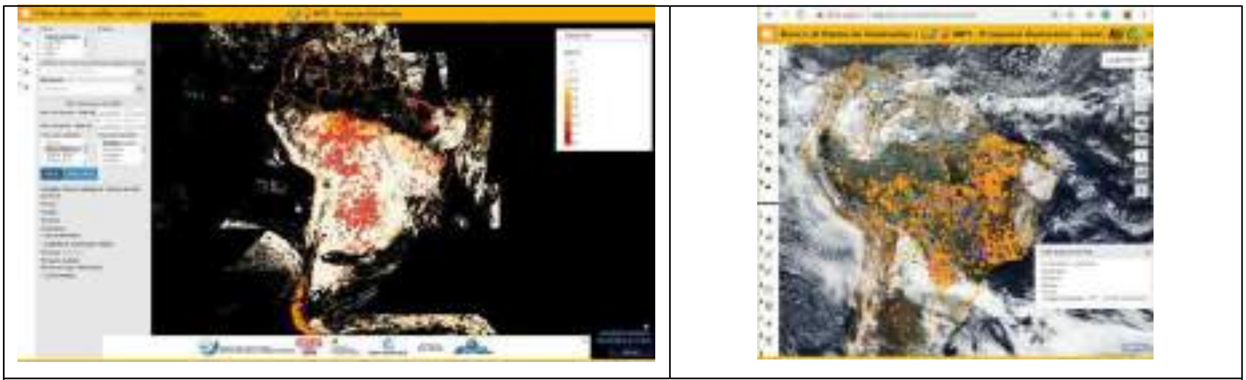

Figure 1. (a) Example of a new INPE Fire System product combining MODIS Atmospheric Optical Density estimates and fire detections form MODIS and VIIRS images for 2018Sept05; data retrieval since 2001. (b) Example of fire pixels detected by 10 different satellites for June 29-30, 2019 over the VIIRS background image

Projection of forest fire danger due to climate change in Greece

EARSeL 2019
Digital I Earth I Observation
Abstract
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Keywords: EARSeL 2019, abstract, RCP, climate change, fire danger

Abstract

The Mediterranean basin has been identified as one of the two most responsive regions to climate change globally. The IPCC Fifth Assessment Report considers the Region as "highly vulnerable to climate change", also mentioning that it "will suffer multiple stresses and systemic failures due to climate changes". Forest fires are an integral part of the ecology of the Mediterranean Basin, including Greece, where temperature, wind conditions, the amount of fuel load and moisture historically favour their occurrence during the summer period, however, forest fires are expected to become more intense and catastrophic in the future due to climate change.

The Fire Weather Index (FWI) system, part of the Canadian Forest Fire Danger Rating System (CFFDRS), which has been recognized worldwide as one of the most reliable indicators of meteorological fire danger, is also broadly used for the mapping and study of fire danger due to climate change.

Estimation and mapping a number of FWI system components, for Greece, on a daily basis for the fire seasons (1st May- 15th October) of a historic and a future time period, was the basis for studying the effects of climate change to the fire danger. More particularly, Fire Weather Index, Drought Code, Initial Spread Index and Fire Severity Rating were calculated, using high resolution climatic for a historical time period (2006-2015) and a near future time period (2036-2045) data- sets for two RCP scenarios (RCP 4.5 and RCP 8.5) , which are built on assumptions of socioeconomic and land-use changes projections. The climate model data, were obtained from EURO-CORDEX climate model and consist of atmospheric variables, such as temperature, relative humidity, wind speed and wind direction at 12:00 hr as well as and total 24hr precipitation at 12.5 km spatial resolution. The final datasets of the above mentioned variables used for the study, were processed at with 5 km spatial resolution for the domain of interest, after applying re-gridding based on the nearest neighbour interpolating process.

Depending on the FWI system parameter, mean and maximum values, as well as total number of days of high and extreme values for the historic and future periods, were calculated for each spatial unit (cell), of the area of interest. Corresponding raster map layers were created for further spatial analyses and evaluation of the results. The elaboration of the resulting datasets was done with GIS spatial analysis tools, which have been applied on the series of the daily raster maps of the indices, in order to provide a number of output maps for the whole country.

The obtained results depict various levels of changes in fire danger, in the near future, depending on the examined index. The current study on the expected distribution of Forest Fire Danger in Greece, due to climate change, both at a spatial and temporal level, can be a significant support to the decision makers for the effective planning of forest fires prevention and management strategy.

The current work is carried out in the framework of SERV_FORFIRE project funded through H2020 ERA4CS ERA-NET and the European Commission (Grant Agreement No 690462).

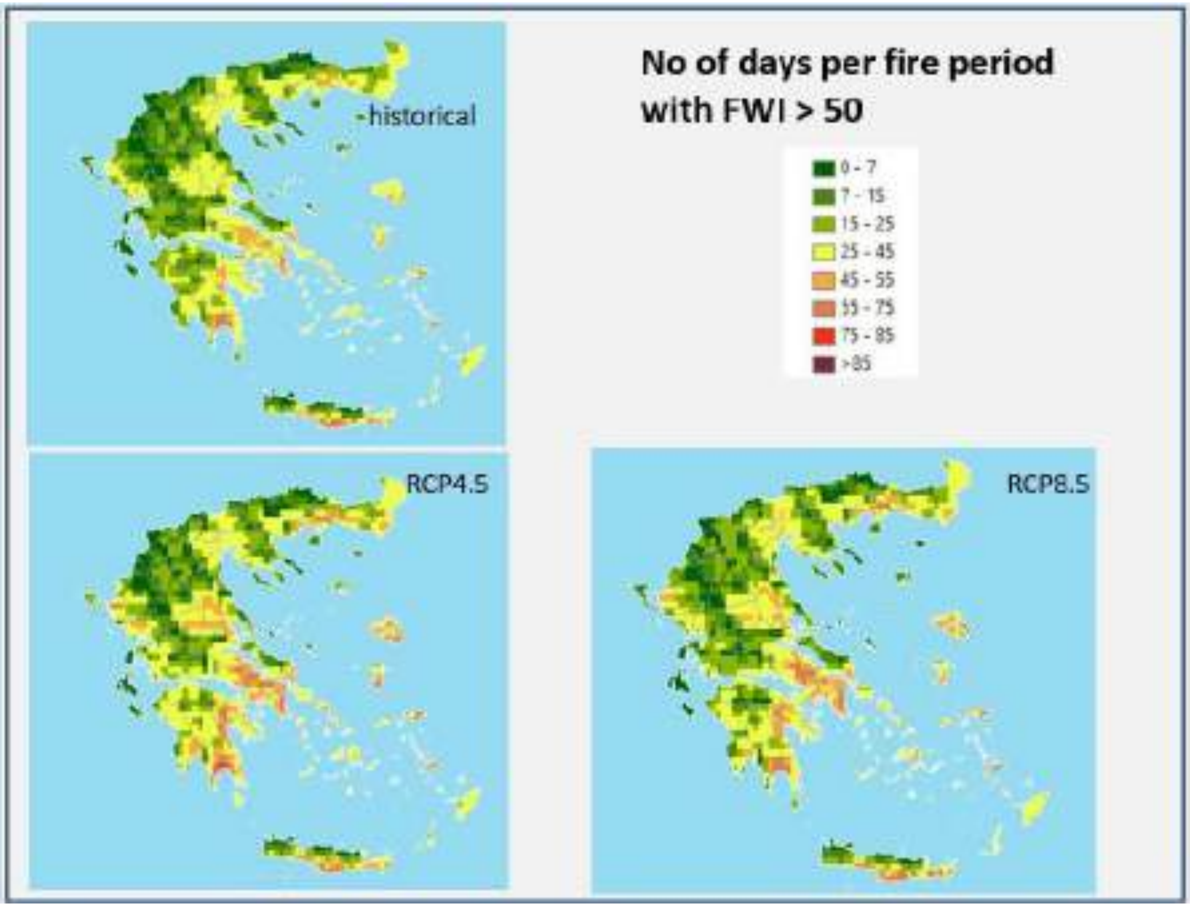

Figure 1. Maps of the historic (2006-2015) and near future (2036-2045) depicting number of days per yearly fire period season

Attribution of the role of global warming in recent forest fires in Europe

EARSeL 2019
Digital I Earth I Observation
Abstract
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Keywords: EARSeL 2019, fire weather risk, climate change, attribution, Europe

Abstract

Over recent years we have witnessed multiple large wild fires in Europe, such as the wild fires in Sweden in 2018 and in Portugal in 2017. Wild fires are an integral part of Europe's ecosystem and help control e.g. insect and disease damage. The impact of the recent large wild fires however is enormous, with numerous casualties and vastly disturbed ecosystems. An important driver in all these wild fires were the persistent warm and dry periods. With ongoing climate change, these conditions are expected to increase. An often raised question therefore is whether these recent wild fires are caused by climate change. Here, we will try to answer this question by analysing the recent wild fires in an event attribution framework. We quantify the fire weather risk through the widely used Canadian Fire weather index (FWI). We use multiple reanalysis datasets to assess the return times of recent wild fires and identify possible trends in fire weather risk. Further, we use 3 (large ensemble) climate model simulations (EC-Earth, CESM1-LENS and W@H) to assess the risk of such events in different climate states. tool to be considered for review.

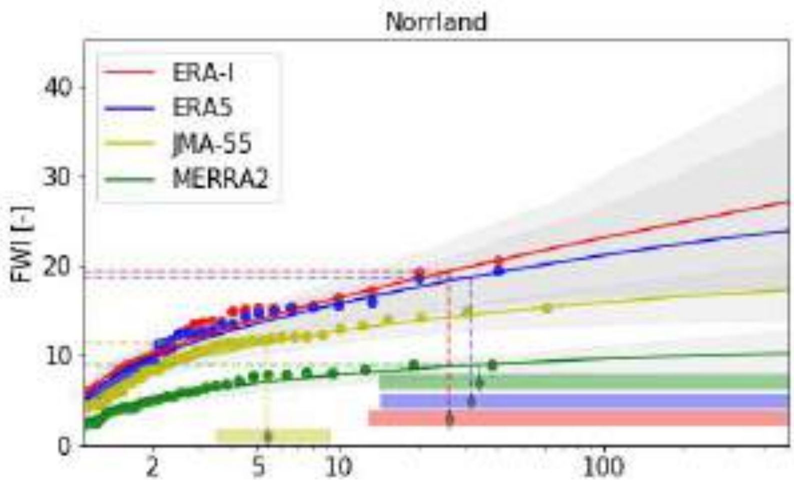

Figure 3. Return times of July–August maximum FWI values for north Sweden for all four reanalysis datasets. The dots represent the actual FWI maximum values and the lines the GEV model fit with a 5 to 95% uncertainty band in gray. The dashed horizontal lines represent the 2018 event, whilst the vertical line represents the associated return time with the horizontal bars giving the 5% to 95% uncertainty estimate (estimated with a non-parametric bootstrap).

EARSeL 2019
Digital I Earth I Observation
Abstract
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Towards a comprehensive characterisation of flammability and fire danger in Australia

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Keywords: fire danger, remote sensing, flammability

Abstract

The Australian Flammability Monitoring System provides the first Australia-wide product of flammability (FI) from satellite estimates of live Fuel Moisture Content (FMC). The FI gives a picture of the likelihood of fire to ignite given an ignition source and moisture conditions as it was adjusted using a continuous logistic probability model between fire occurrence and FMC. However, the FI does not provide information on fire danger as a fire will only propagate across the landscape if there is enough fuel connectivity and the weather conditions are favourable for fire to spread. Additionally, the FI, while consider the FMC conditions of cured grass does not consider the dynamic on dead FMC underneath a forest canopy. This work aims to quantitatively integrate these additional factors (i.e. fuel load, high air temperatures, low relative humidity and high wind speeds) in a probabilistic flammability and fire danger prediction framework. To achieve that, the Geoscience Australia Sentinel Hotspots from 2001 onwards database was used as the fire occurrence database. A brightness temperature threshold was applied to include only hotter and larger fires. Spatial soil moisture estimates (a proxy of dead FMC), satellite derived Life FMC and fuel load, as well as temperature, relative humidity and wind speed derived from atmospheric reanalysis data were used as explanatory variables to predict fire occurrence. Fire occurrence was then translated into fire danger using the frequency of MacArthur's Fire Danger Rating System classes for fire weather districts. This resulted in probability thresholds achieving similar danger category frequency as the current system. Preliminary results show a reasonable sharpness in the predictions, and reliability in a forecast skill sense. The proposed approach provides a more observation-based and comprehensive assessment of flammability and fire danger than current national approaches that only consider on meteorological variable

Land and Forest Fire Prevention Strategy during 2018 Fire Season in Sumatera, Indonesia

EARSeL 2019
Digital I Earth I Observation
Abstract
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Keywords: forest fire, peat, integrated patrol

Abstract

Land and forest fires are a recurrent phenomenon in Indonesia and represent a problem for the country as they result in devastating environmental effects, significant impacts on economic and livelihood assets, and significant expenditures for fire suppression efforts. Indonesia fires were burnt between June and October 2015 resulting in massive losses and damages of an estimated $16.1B USD, estimated to be equivalent to 1.9 percent of the country's GDP. Peat fires in Sumatera are largely anthropogenic caused. Those human-caused fires are amplified during prolonged droughts related to El Niño events and accelerated by peat land as potential fuel mainly at eastern part of Sumatera.

To reduce the fire risk, we developed an integrated patrol system which involved Manggala Agni fire brigades, army, police and local communities. The purpose of the integrated patrol was to synergize the parties involved to conduct preventive action at the site level. During 2018 fire season in Sumatera, we established 160 village stations in 4 fire prone province: 30 in North Sumatera, 65 in Riau, 15 in Jambi and 50 in South Sumatera which cover altogether 556 fire prone villages. This activity also showed the real presence of officers in the field, and sociological approach towards changing people behavior related to fire as tool for land planting preparation while the patrol member should also mastery the working area.

This strategy significantly reduced fire hotspot (Terra/Aqua MODIS) up to 90% comparing to the fire episode in 2015. In line with the decreasing of fire hotspot in Sumatera, Landsat imagery analysis showed that the burned area decreased also significantly from 1.048.635 ha to 76.366 ha. However, this strategy should be experienced the real dry season to prove the strategy effectiveness as year of 2018 categorized as wet-dry season.

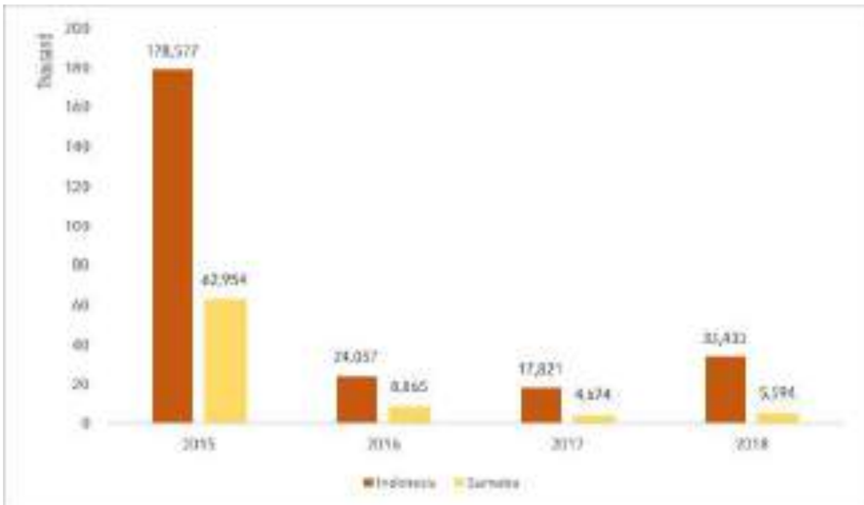

Figure 4. Fire hotspot in Indonesia and Sumatera 2015-2018

EARSeL 2019
Digital I Earth I Observation
Abstract
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Sub-seasonal predictability of forest fire danger in Finland

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Keywords: forest fire risk, sub-seasonal forecasting, boreal forest, six-week climate outlooks, operational service prototype

Abstract

Forest fires are one of the largest natural disturbances in the boreal forests. Due to the active fire suppression activities and legislation the average size of forest fires has decreased to 0.5 ha recently, although there still occurs approximately 1000 forest fire annually. In Finland, the Finnish Meteorological Institute (FMI) operationally monitors conditions favourable for forest fire potential and issues short-range forest fire warnings during the fire season both to the authorities and public. The forest fire danger is assessed using the Finnish Forest Fire Index (FFI) developed for boreal forest environment. The 10-days forest fire risk forecasts issued operationally to the rescue services are used by the authorities in planning the fire survey flights which contribute to the early detection of the ignited fires. Predicting forest fire weather conditions a few weeks and even months in advance would allow rescue services and other authorities to prepare and take sufficient provision of resources for potential forest fires danger earlier in advance. However, sub-seasonal to seasonal predictions of forest fire risk are still rare and have not been studied at FMI yet. In this study, we examine the sub-seasonal predictability of forest fire weather conditions in Finland and present the newly developed six-week forest fire risk outlook prototype tested with the Finnish end-users during the fire season 2019. The sub-seasonal fire risk forecasts are developed and tested within the framework of the ERA4CS SERV_FORFIRE project.

To estimate the predictability of sub-seasonal fire risk forecast in forest fire danger assessment in Finland, a statistical model has been developed which has as a starting point the Finnish Forest Fire Index. FFI is determined by estimating the volumetric moisture of a 60 mm thick surface layer. Gridded observational data of air temperature, precipitation rate, relative humidity and computed volumetric soil moisture of the 60 mm thick soil surface layer for the time period 2003-2016 were used in the development of the statistical model. For evaluation purposes, 6-week forest fire risk outlooks were produced for the whole country using ensemble extended range re-forecast data sets from the European Centre for Medium-Range Weather Forecasts (ECMWF) ENS system for the time period 2010-2018. Both re-forecasts and forecasts are run twice a week in the ENS system and are available up to 46 days ahead. The performance of the developed statistical model and the skill of the fire danger prediction was examined using standard verification methodology. According to the first evaluation results of the re-forecast runs the sub-seasonal model slightly underestimate the probability of the fire risk conditions, the skill of the forecast being higher for the first weeks.

The developed six week forest fire risk outlooks are produced for the whole Finland using real forecast data and iterated with the fire managers and authorities during summer 2019. The forecast product describes the weekly probability of forest fire risk weather conditions during the forecast week. The forest fire risk outlooks are produced and disseminated to the users through an operational forecast delivery system. Following the demonstration phase of the six week climate outlooks the first feedback from the users and evaluation of the product performance will be presented for discussion.

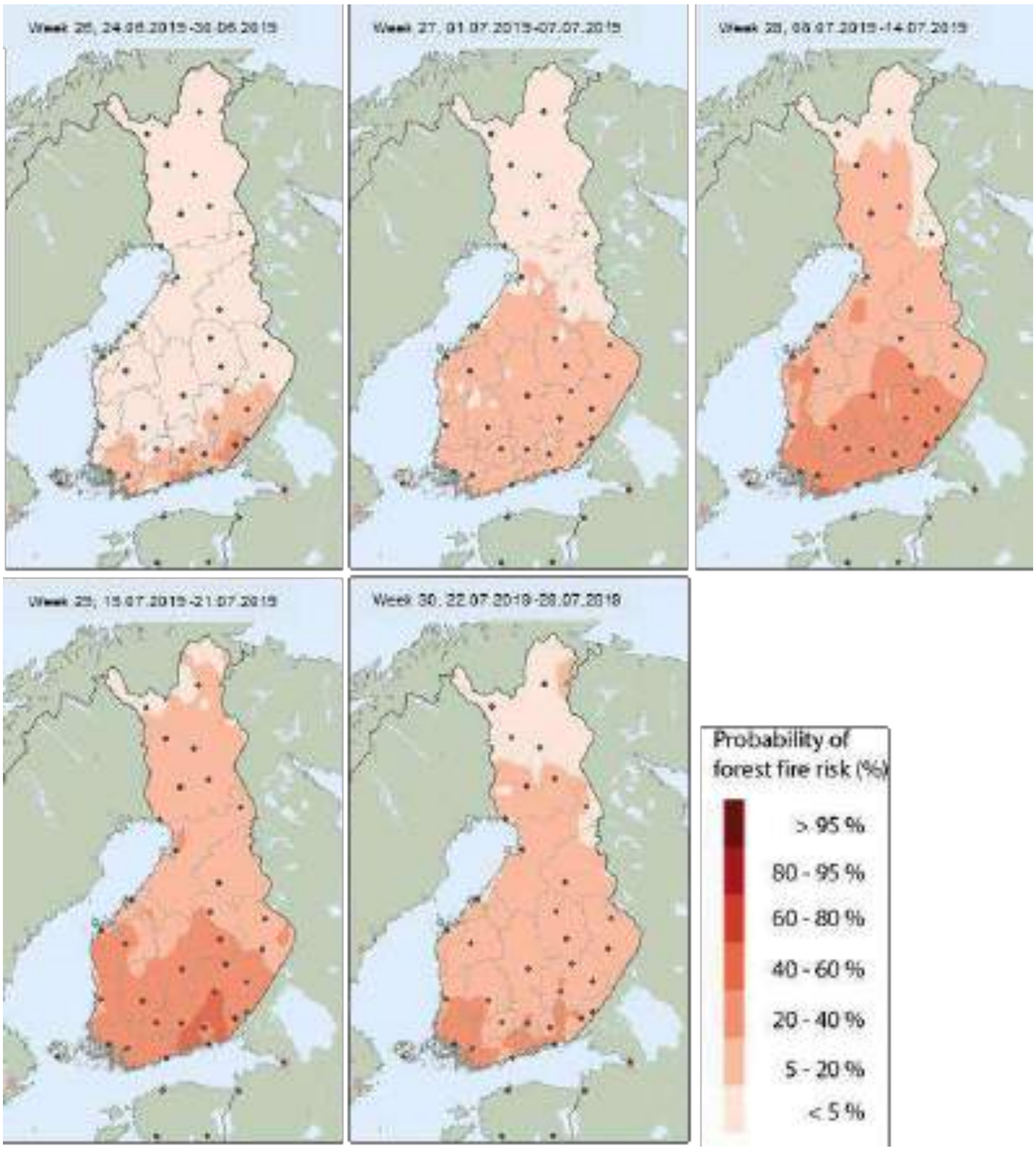

Figure 1. The 6-week forest fire risk climate outlook issued to the end-users for testing on June 18, 2019.

H SAF project: satellite derived products for the monitoring of precipitation, soil moisture and snow cover

EARSeL 2019
Digital I Earth I Observation
Abstract
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Abstract

The EUMETSAT Satellite Application Facility on Support to Operational Hydrology and Water Management (H SAF) started in 2005 and aims to provide remote sensing estimates of relevant hydrological parameters: instantaneous rain rate and cumulated rainfall, soil moisture at surface and in the root zone, snow cover and water equivalent. The project involves experts from 12 national meteorological and hydrological European Institutes of Austria, Belgium, Bulgaria, Finland, France, Germany, Hungary, Italy, Poland, Romania, Slovakia and Turkey, and from the European Centre for Medium-range Weather Forecast (ECMWF).

The H SAF main objectives are two: 1) to provide new satellite-derived products (precipitation, snow parameters and soil moisture) from existing and future satellites with sufficient time and space resolution to satisfy the needs of operational hydrology, and 2) to perform independent validation in order to assess the usefulness of the new products for fighting against floods, landslides, avalanches, and evaluating water resources.

The operational goal of H SAF highlights the need to provide products with a reliable measure of their accuracy in order to make aware the potential users of the advantages and drawbacks of the use of the H SAF products in their operational activities. To this aim, a large effort is devoted within H SAF to the estimation of the error structure for the different satellite products. This type of activity, always related to the development of any remote sensing retrieval technique, is often called "validation", indicating that the satellite product is compared to a reference field, obtained by different sensors, not directly involved in the product build-up, and a measure of the discrepancy is assumed as error of the product. Within H SAF, three Validation Groups have been established: one for precipitation, one for soil moisture and one for snow products.

A patch-based multisensor approach for fuel types mapping in a Mediterranean landscape

EARSeL 2019
Digital I Earth I Observation
Abstract
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Keywords: sentinel-2, time series, cnn, deep learning, tensorflow, texture

Abstract

In Europe most of the wildfire activity is located in Mediterranean areas, where natural vegetation and forests present a diversity of species and high spatiotemporal heterogeneity of patterns. Mapping the characteristics of this vegetation is one of the most relevant components to fuel types assessment.

This study aims to evaluate the potential of a deep learning approach to combine a time series of multispectral images and a very high resolution image, and to classify them for fuel types mapping. Our hypothesis is that spatial, spectral and temporal information are needed altogether to identify vegetation species and their distribution. This patch-based approach is then compared to a classical pixel-based supervised classification using Random Forest, the same time series and additional textural information from the VHSR image.

The study area covers about 100 000 ha (36 by 28 km) n a fire prone area in the southern Mediterranean coast of France. The landscape is dominated by Mediterranean shrubs, holm oaks, deciduous oaks, various pine species and grassland. Cultivated land is mainly dedicated to vineyards.

Our reference is a fuel types map of the area surveyed by expert from the French National Forest Office. The fuel types are identified by their vegetation types and an index relative to combustibility. The nomenclature is more detailed than usual land cover map and it is adjusted to fuel types characterisation. It defines 15 classes: 5 classes dedicated to shrubland with various density or fuel load;
5 forest classes with various species and structures; the remaining 5 classes describe grassland, agriculture and urban areas. About 900 homogeneous polygons covering 2% of the total area were systematically sampled. Randomly selected 50% of those plots were dedicated to train the classifications, the remaining 50% to validation.

Two sensors were taken into consideration. To assess spatial information, a SPOT-6 Panchromatic image at 1.5 m resolution acquired in July 2018 was processed. Spectral and temporal information is based on an annual time series of Sentinel-2 images, with 10 bands (in the visible, red edge, near infrared and short-wave infrared domains) resampled at 10 m resolution. The 12 of Sentinel-2 images were processed to level 3 monthly synthesis of cloud-free surface reflectance, from April 2018 to March 2019, by THEIA-Land data center (www.theia-land.fr).

Processing was performed with the open source Orfeo toolbox developed by the French National Space Agency (www.orfeo-toolbox.org) and the deep learning module OTBTF based on the Tensorflow library.

The patch-based approach was developed using a simple convolutional neural network (CNN). The point was to extract image patches and classify the centre of each patch. Training inputs were 3D samples: 3 pixels x 3 pixels x 10 bands x 12 dates for Sentinel-2 images, 20 pixels x 20 pixels x 1 band x 1 date for SPOT-6 image, and a label from the training dataset. The CNN is composed of 7 convolutional

layers to create new features maps with a high level of abstraction. These features were stacked then classified with Random Forest

Patch-based and pixel-based approaches were compared, although they did not consider the same input object. To balance this lack of spatial information in the pixel-based approach, we computed 8 Haralick textural features on the SPOT-6 very resolution image using a 7 by 7 pixel

s windows (energy, entropy, correlation, inverse difference moment, inertia, cluster shade, cluster prominence, Haralick correlation). The texture layers were resampled at the Sentinel-2 resolution, 10 m. A supervised classification, with Random Forest, was performed using the time series of 12 Sentinel-2 images and the resampled texture layers as input features.

The capability of time series of Sentinel-2 images to map fuel types with a good accuracy seems demonstrated. Fuel types maps showed Kappa coefficients of agreement equal 0.8, and they are similar for both approaches. Some confusions remained between shrublands with different densities and between cropland, abandoned cropland and low shrubland. However, the two maps are quite different when visually compared. The patch-based approach tends to generalize while local heterogeneity is maintained with the pixel-based approach. Their complementarity needs yet to be evaluated.

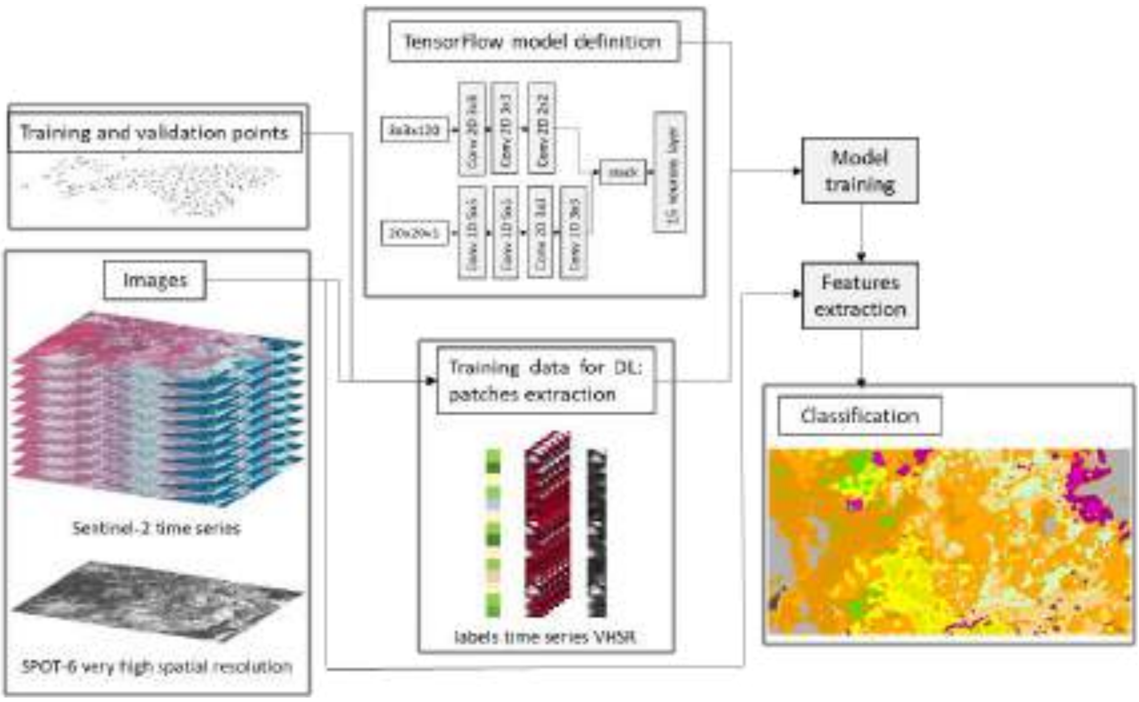
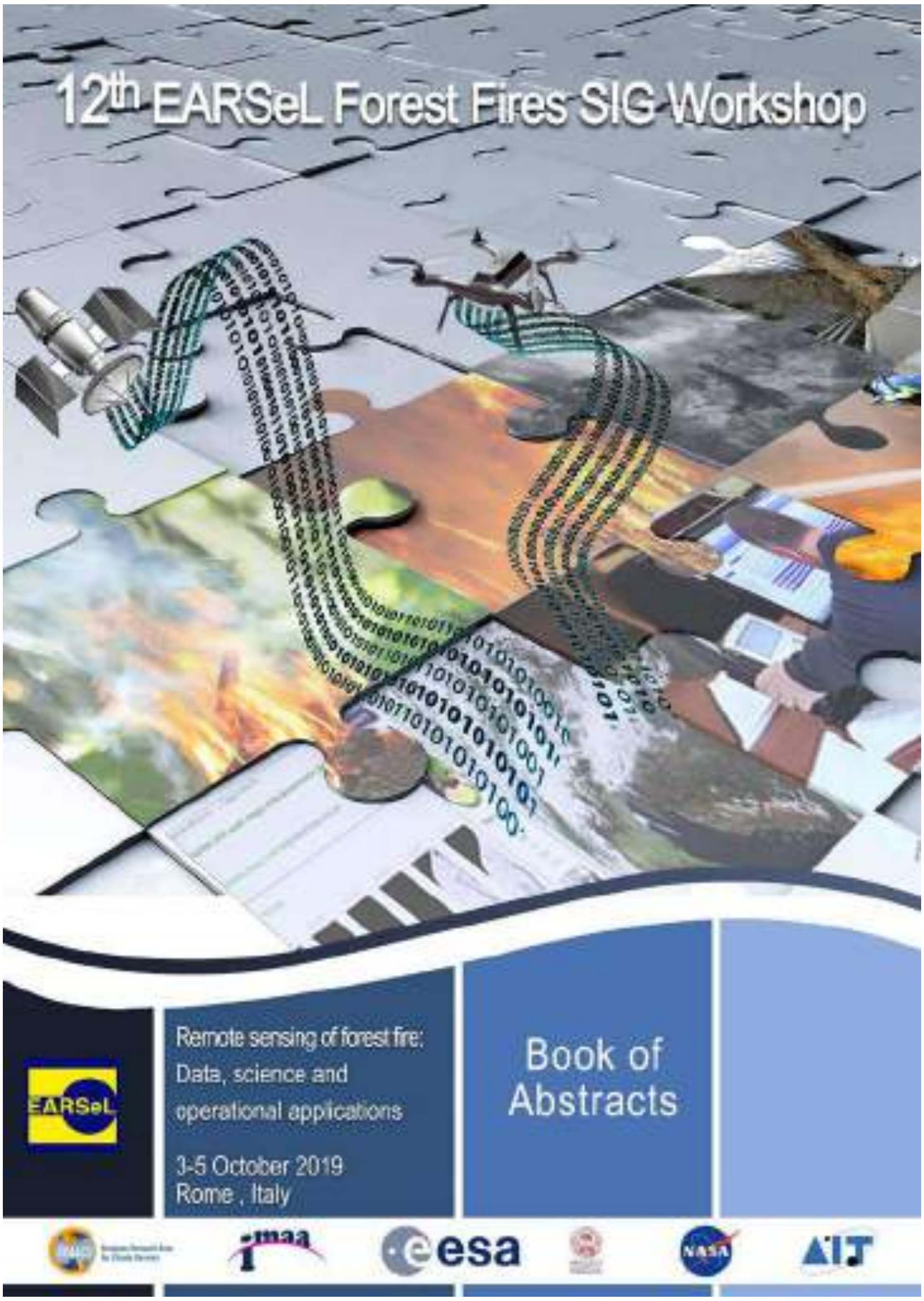


Figure 1. Workflow for deep learning classificati



EARSEL

REMOTE SENSING OF FOREST FIRE DATA, SCIENCE
AND OPERATIONAL APPLICATIONS

SESSION: FIRE DETECTION AND MONITORING ON MULTIPLE SCALES

NASA FIRMS: Near Real-Time Global Fire Monitoring using Data from MODIS and VIIRS

EARSeL 2019
Digital I Earth I Observation
Abstract
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Keywords: NASA, LANCE, FIRMS, VIIRS, MODIS, active fire/hotspots, near real-time

Abstract

NASA's Fire Information for Resource Management System (FIRMS) provides near-real time active fire / hotspot products from MODIS and VIIRS to users in over 160 countries. The goal of FIRMS is to meet the needs of natural resource and protected area managers that face considerable challenges in obtaining timely satellite-derived information on fires burning within and around their management area. FIRMS has been reliably providing active fire / hotspot data in easy to use formats since its inception in 2006. Fire information is provided through a web map interface, email alerts, a web mapping service, and a range of downloadable files (SHP, CSV, KML and JSON). FIRMS data are used directly by end users and by brokers who take the data and add value to it before re-distributing it.

FIRMS was initially developed by the University of Maryland in 2006; it was funded by the United Nations FAO and NASA's Applied sciences program under a NASA ROSES call. In 2012 FIRMS became integrated in to NASA's Land Atmosphere Near realtime Capability for EOS (LANCE); a virtual system that leverages NASAs existing science processing capabilities to deliver NRT data from ten instruments within 3 hours of satellite overpass.

This presentation will describe the FIRMS system, provide an overview of the system, briefly describe some of the known applications and describe plans to further integrate the data in to NASA's Global Imagery Browse Services (GIBS) public mapping services and Worldview website

Figure 1. FIRMS Fire Map interface showing fires/hotspots in red, overlaid on VIIRS corrected reflectance imagery from 16th July 2019

Airborne high resolution remote sensing for near real time forest fire detection and surveillance

EARSeL 2019
Digital I Earth I Observation
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Keywords: fire detection, surveillance, post-fire monitoring, image processing, flexible sensor platform

Abstract

Nowadays, dramatic increases in forest fires can be observed worldwide, even in countries in northern and central Europe where large forest fires have hardly occurred in the past (e.g. Sweden 2014 and 2018). In order to improve the protection of human lives and resources it is mandatory to support large scale forest firefighting strategies and management solutions with innovative technical developments. The EU has initiated international co-operations and initiatives to provide interoperable systems and information in order to support prevention and firefighting efforts to protect human lives and resources and to reduce the negative environmental impact of these fires to a minimum. For this reason, the Joint Research Centre works closely with European countries and other relevant EC services to monitor forest fires through the European Forest Fire Information System.

An important complement to the existing EU-wide initiatives is the development of an optimized technical solution for various phases of a forest fire management concept leading into an immediate support of fire brigades and other involved organizations. In this context, a major national initiative is the KIRAS project "3F-MS" which focused on an optimized assistance in time critical tasks during a forest fire situation. The key issues to support time critical tasks comprise firstly the realization of a demand driven data acquisition procedure, secondly a near real-time processing and analyses environment as well as an end user oriented data and resource management application (see Figure 1). To guarantee an efficient deployment and management of firefighting teams, prerequisites are to deliver a common operational picture (COP) and to enable a powerful scenario-related management solution very quickly. The 3F-MS approach ensures that resources, such as mobile firefighting and rescue teams, vehicles/equipment on the ground as well as planes and helicopters, can be deployed efficiently based on a solid and reliable data base. In frame of the research projects "AIRWATCH" and "3F-MS" (see https://www.kiras.at/en/financed-proposals/) the airborne based solution ARGUS (Airborne Ground Unit Support) was developed. The carrier platform of ARGUS is a plane of the type "Pilatus Porter PC6" of the Austrian army, where the benefits in disaster relief were demonstrated in principle. However, limitations and weaknesses in terms of system flexibility, sensor stability, resolution and fast large-area coverage and rapid system readiness have been identified. These shortcomings are essential objectives of the new research project "ARGUS-Flex" which focuses on the transfer of ARGUS into a compact sensor box as well as the development of new sensor fusion methods for optical and thermal sensor data considering an available high resolution. This meets the requirement of users to have the system also available on different carrier platforms, such as helicopters, ultra-light planes and UAS. Also the sensor box will be upgraded by providing a very high resolution optical camera with 150 MP as well as a fixed optimized and stabilized 4 TIR-camera system. This aims at extending its field of application by simultaneously making the system more reliable. From the algorithmic point view, ARGUS-Flex focuses on innovative techniques to raise thermal resolution facilitating high resolution optical images as well as enhanced relative accuracy. The new thermal camera concept also provides a better focus to forest- fire related thermal situations and so better results from analysis and information extraction process can be achieved. Furthermore, innovative methods for data processing and data analysis are being developed, such as automated, simultaneous

calibration, multi-sensor data fusion, data optimization or data analysis, and information extraction based on machine learning methods.

The ARGUS-Flex system is intended to meet the requirements of rapid, location-independent and continuous 24/7 deployment, as required especially in large scale natural disasters such as floodings or forest fires. Next to sensor data with an enhanced resolution, it still provides fast and near-real-time data and information availability. The new, compact hardware design and integration level ensures to be more compatible to different carrier platforms as well as higher stability and reliability. Also it aims at proving an optimal service for the users by an improved data quality as well as new processing methods for the derivation and provision of targeted, scenario-specific information. Beyond the national framework, the project initiated an international cooperation with partners from China, Germany, Denmark, Israel and Spain to open up perspectives for using the system on an international level as well as providing an internationally relevant service for disaster relief actions.

Figure 3. General concept of data acquisition, real-time data communication, data processing and information distribution to support time critical decision processes in forest fire situations figure

The ESA Sentinel 3 Fire Detection Prototype Algorithm and Product

EARSeL 2019
Digital I Earth I Observation
Abstract
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Keywords:

Abstract

The ATSR World Fire Atlas detected nightime active fires from 1995 to 2012, (Arino et al., 2010) using data from ERS-2 ATSR-2 and ENVISAT AATSR instruments.
Global and temporal statistical representation of fire distribution has been used by scientists worldwide.The algorithm developed by Woodster, 2012 has been adapted to the operational context of the sentinel ground segment and DIAS and applied to the fire channels of the SLST on board of both S3A and S3B using both the night and day times satellite overpasse
This paper describes the algorithm and the first 6 months' trial over a European window.
The active fire distribution during the 2019 summer at night and day time will be analysed in detail.

Development of a Harmonized Multi-Sensor Global Active Fire Data Set: Current Status and Multi-Product Validation Results

EARSeL 2019
Digital I Earth I Observation
Abstract
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Keywords: Fire; Biomass Burning; GOES ABI; MSG SEVIRI; Landsat

Abstract

The recent launches of the new generation of geostationary weather satellites provides an opportunity for the establishment of a robust global network of geostationary fire products that can greatly complement existing polar orbiting satellite fire data sets. The suite of fire-capable geostationary sensors now available include the Advanced Baseline Imager (ABI), on board the National Oceanic and Atmospheric Agency (NOAA) GOES-16 and GOES-17 satellites, the Advanced Himawari Imager (AHI), on board the Japan Meteorological Agency's (JMA) Himawari-8 and Himawari-9 satellites, and the Spinning Enhanced Visible and Infra-Red Imager (SEVIRI), on board the European Space Agency's (ESA) Meteosat Second Generation (MSG) satellite series. Under an effort sponsored by the National Aeronautics and Space Administration's Applied Sciences Program, we are in the process of developing a harmonized, global geostationary-sensor fire data set to complement existing polar orbiting satellite fire monitoring data, to be integrated into the Global Wildfire Information System (GWIS), with special attention to product validation and data harmonization. Here we discuss the current status of the project, with an emphasis on the results of a comprehensive assessment of fire- product omission and commission errors built upon established validation protocols using near- coincident higher resolution Landsat reference imagery.

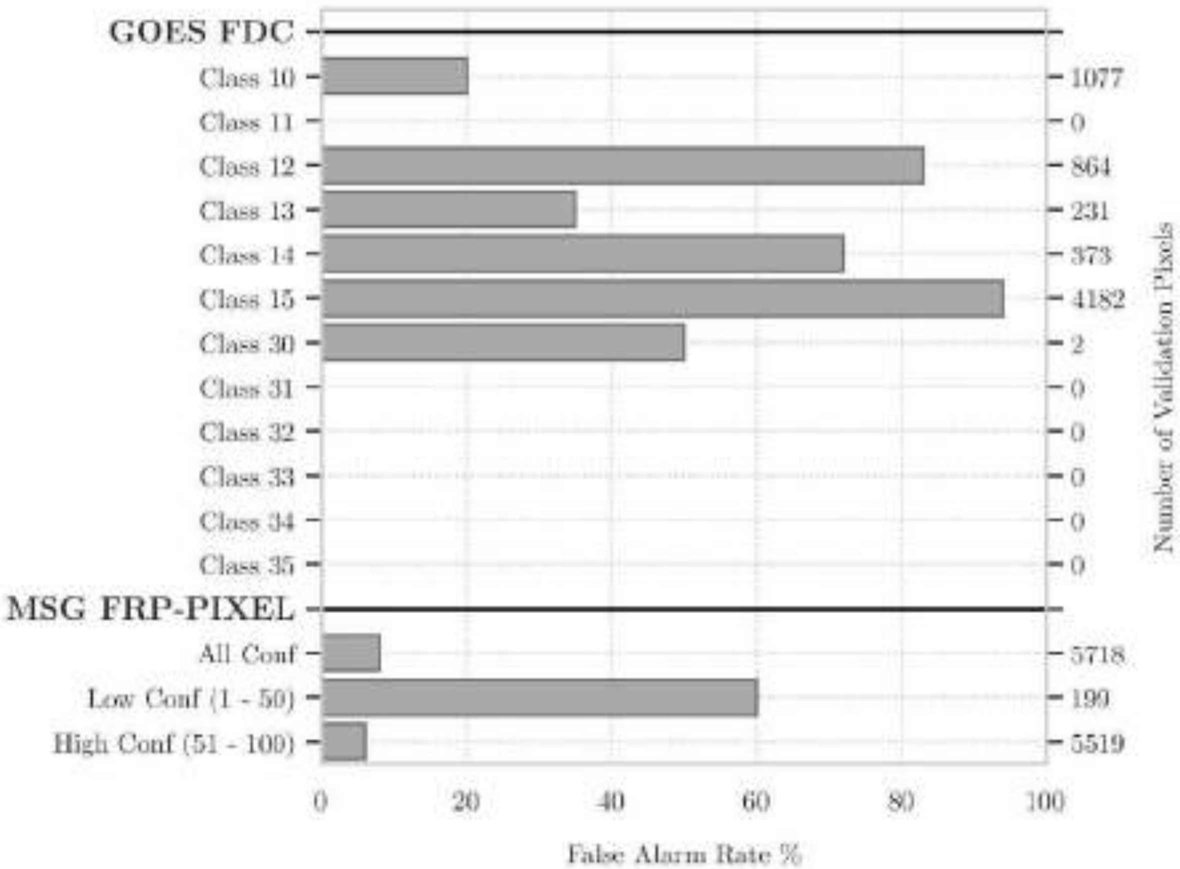

Figure 1. GOES-16 Fire Detection and Characterization (FDC) algorithm and MSG SEVIRI FRP- PIXEL commission error. FDC classes: 10 or 30 = processed fire pixel (highest confidence); 11 or 31 = saturated fire pixel; 12 or 32 = cloud contaminated fire pixel; 13 or 33 = high probability fire pixel; 14 or 34 = medium probability fire pixel; and 15 or 35 = low probability fire pixel.

Earth Observation Big Data and Deep Learning for Near Real-Time Wildfire Monitoring

EARSeL 2019
Digital I Earth I Observation
Abstract
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Keywords:

Abstract

In recent years, the world witnessed many devastating wildfires that resulted in devastating human and environmental impacts across the globe. Hotter summers and drought across northern Europe and North America have resulted in increased wildfire activity in cooler and wetter regions such as Sweden, even north of the Arctic Circle. Emergency response and rapid response for mitigation call for effective methods for near real-time wildfire monitoring. Capable of penetrating clouds and smoke, and imaging day and night, synthetic aperture radar (SAR), together with optical data, can play a critical role in wildfire monitoring. Owing to the rapid development of the satellite technology, we are moving forward to the new era of Earth Observation (EO). National and International space agencies as well as innovative companies have initiated various EO programs that are able to acquire massive amounts of satellite imagery with higher spatial resolution and impressive temporal coverage. With the recent launches of the European Space Agency (ESA)'s Sentinel-1 and Sentinel-2 satellites, SAR and optical data with global coverage and operational reliability become freely available. These open EO big data represent a great opportunity to develop innovative methodologies for near real-time wildfire monitoring. The main challenge is the lack of robust and automated methods to extract relevant information from the massive amount of EO data.

The objective of this research is to investigate and demonstrate the potential of Earth Observation big data and deep learning for near real-time wildfire progression monitoring through smoke, cloud and night. A deep learning framework based on a convolutional neural network (CNN) is developed to detect burnt areas continuously using every new image acquired by Senitnel-1 SAR and Sentinel-2/Landsat optical sensors during the wildfires (Figure 1). To ensure its global applicability, the method is being tested in several wildfire sites around the world including the 2019 Chuckegg Creek wildfire in northern Alberta, Canada, the 2017

Elephant Hill Fire in British Columbia, Canada, the 2018 Camp Fire, California, USA, and the 2019 Siberian Wildfires. The results show that Sentinel-1 SAR backscatter and Sentinel-2/Landsat shortwave infrared (SWIR) can detect wildfires and capture their temporal progression as demonstrated in Figure 2. The results also show that. compared to the traditional log ratio operator, CNN-based deep learning framework can better distinguish burnt areas with higher accuracy. These findings demonstrate that Earth Observation big data with deep learning can play a significant role for near real-time wildfire monitoring when the data becomes available at daily and hourly intervals with the launches of SAR and SWIR CubeSat constellations.

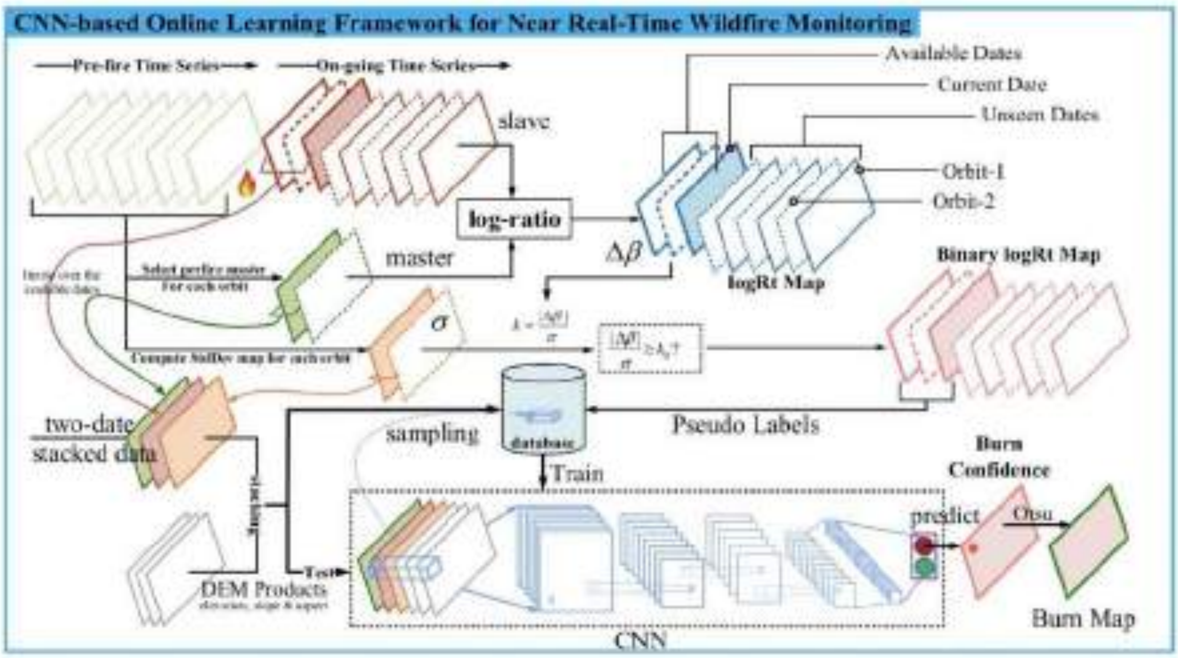

Figure 1. Wildfire Monitoring with EO Big Data and CNN-based Deep Learning Framework

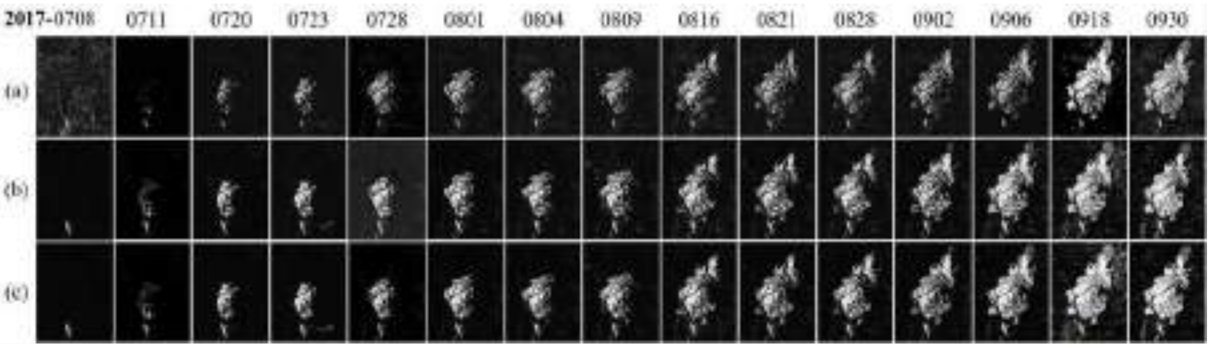

Figure 2. Elephant Hill Wildfire Progression Maps using Sentinel-1 SAR Data
(a) VV band (b) VH band (c) VV-VH bands

On the estimation of fire susceptibility, fire expantion and post-fire damage based on the integration of satellite, meteorological data and forecasts: the experience of firesat project

EARSeL 2019
Digital I Earth I Observation
Abstract
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Keywords: Fire Management, Fire Risk estimation, Satellite Images, Sentinel, Protezione Civile, Basilicata Region,

Abstract

The purpose of this paper is to illustrate the results derived from the scientific collaboration established in 2008 between the Office of Civil Protection of the Department of Infrastructure of the Basilicata Region and the Institute of Meth-odologies for Environmental Analysis of the National Research Council (CNR-IMAA) aiming at the implementation and experimentation of a model for fire and post fire risk prediction and monitoring.

The central assumption underlying the testing of new approaches adopted is (i) the definition of an integrated methodology for the characterization of fire haz-ard capable of combining different techniques and (ii) the activation of profitable synergies between the various actors involved in the management and active firefighting processes. The integration of diverse fire hazard factors (among them the assessment of the presence, typology and status of fuels and their fire suscep-tibility) does provide very significant indications encompassing all the planning phase of forest fire monitoring: forecasting, prevention, active fight, damage as-sessment and post-fire damage and recovery.

The methodologies adopted for the diverse phases of fire risk, damage estima-tion and post fire risk assessment, evolved from the development and testing of prototype models and algorithms (developed in the laboratories of CNR-IMAA) to the pre-operational and operational applications. The models for fire, post fire risk and damage estimation were initially only based on the use of MODIS satel-lite data (2008-2010), later integrated with TM (for fuel mapping and damage estimation 2011-2013), further with meteorological data and forecast available for free (Meteo Model NOAA-GFS, 2014-2016), later improved with the highest spatial resolution meteo forecast from Cosmo 5 (5 km 2017) and Cosmo 2 (2 km 2018-2019 made available by the National Civil Protection up) up to the use of Sentinel 1 and 2 along with manned and unmanned multispectral and thermal aerial surveys.

The use of the most advanced data and forecast (from remote sensing, meteo forecast etc) does allow us to obtain several advanced products that are firstly tested and progressively incorporated in the operational or pre-operational mod-els connected to static and dynamic parameters related to fire risk assessment, estimation of fire expansion (based on Firesite software tools), assessment of fire damage using Sentinel 1-2 and aerial data from manned and un-manned surveys. As a result, the system (developed by the ARGON research group of CNR-IMAA and adopted by the Civil Protection of the Basilicata region) is based on the as-sumption that from one year to another the operational application is coupled with new research activities and experimentation in order to continuously im-prove the system through the assimilation of advanced data, information and products as soon as they are available and tested.

Implementation of Airborne MidWave Infrared Imagery for Mapping Wildfires

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Abstract
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Keywords: wildfires, midwave infrared, geocorrection, fire radiative power, wildfire monitoring

Abstract

Wildfire monitoring is becoming a key concern and focus for governments around the globe. Following the predictions of an increase in annual wildfires worldwide, there have been international efforts to deploy sensors on airborne and space platforms (e.g. Sentinel-3 SLSTR) to map wildfires and understand their behaviour. Infrared remote sensing data is able to capture naturally-occurring and controlled-fires to better comprehend wildland fire behaviour, build fuel consumption models and learn how they impact their surrounding environments. Every step, from sensor calibration, mission planning to data processing, is critical to map wildland fire, detect spatial patterns and implement monitoring systems. For satellite fire products, given the dynamic nature of a fire, mission planning, data acquisitions and further coordination with satellite imagery can be a challenge, especially in remote areas. Once airborne remote sensing data is successfully acquired over wildfires areas, the amount of fuel being consumed can be addressed in order to develop the information necessary to carry out wildfire management. For instance, it is possible to estimate fuel consumption through calculated fire indices such as Fire Radiative Power (FRP), which is related to the measure of radiant energy output from the source of the fire along with the smoke generated. These estimations can be further compared and integrated with satellite imagery (e.g. Sentinel-3 SLSTR) to establish a wildfire management system at local and national scales.

In order to validate satellite products, the National Research Council of Canada (NRC) Flight Research Laboratory, in collaboration with the National Resources Canada, carried out an airborne campaign to collect thermal imaging of wildland fires near Pickle Lake, Northern Ontario in August 2017 (Figure 1). For this campaign, multiple Being Observed Burn (BOB) fires were acquired using an on-board MidWave Infrared (MWIR) broadband FLIR SC8300 sensor equipped with a flame filter (3.74 μm) at four different integration times (i.e. 1.4 ms, 0.3 ms, 0.04 ms, and 0.002 ms). Here we show multiple aspects required for successful data collection, including proper sensor calibration, mission planning and data processing methodologies. The first step focused on the calibration of the FLIR sensor with the flame filter against a blackbody port to determine the appropriate integration times for the superframing process. From these measurements, the FLIR's counts units (ranging from 0 to 16,383 proportional to the incident energy) were transformed into temperature and radiance values using the electromagnetic radiation principal of Plank's Law of emitted radiation. The next step involved mission planning and the actual deployment campaign over a naturally-occurring wildfire. The flights were flown in a "racetrack" pattern, to collect imagery that would overlap at the edge of each path, and allow for the development of orthorectified images. Taking into account the dynamic nature of a fire, the flight lines were planned according to the extent of the reported fire. During the campaign, six flight deployments at different time in the day were carried out between August 2nd and 3rd, 2017, of which two were cancelled due to technical issues and weather conditions. In total, 63 flight lines were acquired during daytime (10:00 EST – 17:00 EST, +5 UTC) and night time (22:20 EST, +5 UTC) over the main study area.

Considerable efforts were put into developing an in-house geocorrection methodology of the acquired FLIR imagery. The aircraft's raw GPS is processed using a nearby GPS base station for differential GPS data, and combined with the raw IMU data in a Kalman filter. This combined GPS/IMU solution, at 100 Hz, was associated with the GPS-time tagged FLIR imagery, where each pixel was given an approximate GPS location. Unfortunately, there were two separate points of hardware failure during the data acquisition: the sensor never received GPS timing information and the aircraft's IMU failed to record at the correct frequency. An alternative geolocation method was then developed to circumvent these two

major issues. The FLIR frames were aligned with a backup GPS-tagged camera and assigned geolocations, before being combined into full orthoimages through an image-registration process that did not require IMU information. The orthoimages were then further georeferenced using a developed grid system to improve the geolocation error. This second step was necessary to allow for an effective comparison with mid-resolution satellite sensors (≤ 30-300 m). For example, in the high altitude (2915 m MSL) flight collected during daytime on August 3, 2017, the image's average RMSE was reduced from 234 m to 11m following this georeferencing step. Based on the geocorrected imagery we showcase calculated FRP, taking into account a variety of conditions (changing winds, humidity, day vs. night, etc.) and how weather-based fire indices can be used to provide a corrected FRP (Figure 1). Further, the variances of the FRP are investigated as a function of spatial size where single pixel calculations and standard deviations are compared against image and mosaicked image data sets. The scalability of the FRP as a function of size is fundamental to show how this method may be applicable to orbital platforms with MWIR bands such as the Sentinel 3.

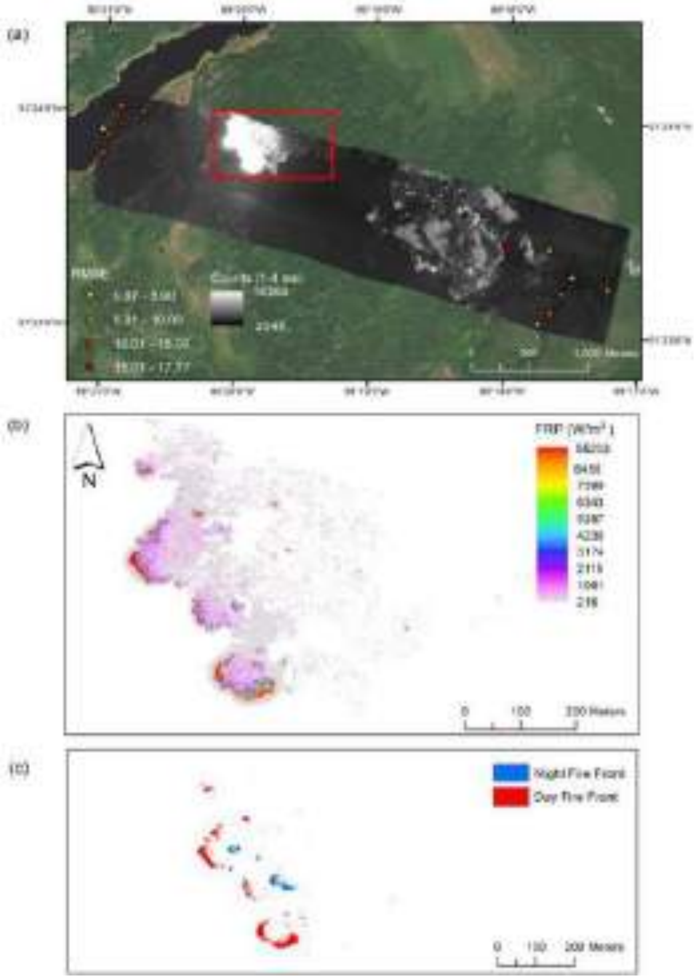

Figure 1. (a)Example of geocorrected FLIR imagery in counts (1.4 ms integration time) and RMSE error of 13 points following the georeferencing process. FLIR imagery and RMSE errors displayed on ESRI baseline map. (b) Example of Fire Radiative Power (FRP) captured with the FLIR sensor during a daytime flight on August 3, 2017, at 10:54 EST near Pickle Lake, Ontario. (c) Fire front movement between night flight (August 2, 22:20 EST) and day flight (August 3, 10:54 EST).

WildFireSat: Operationalizing of Wildfire Remote Sensing Science

EARSeL 2019
Digital I Earth I Observation
Abstract
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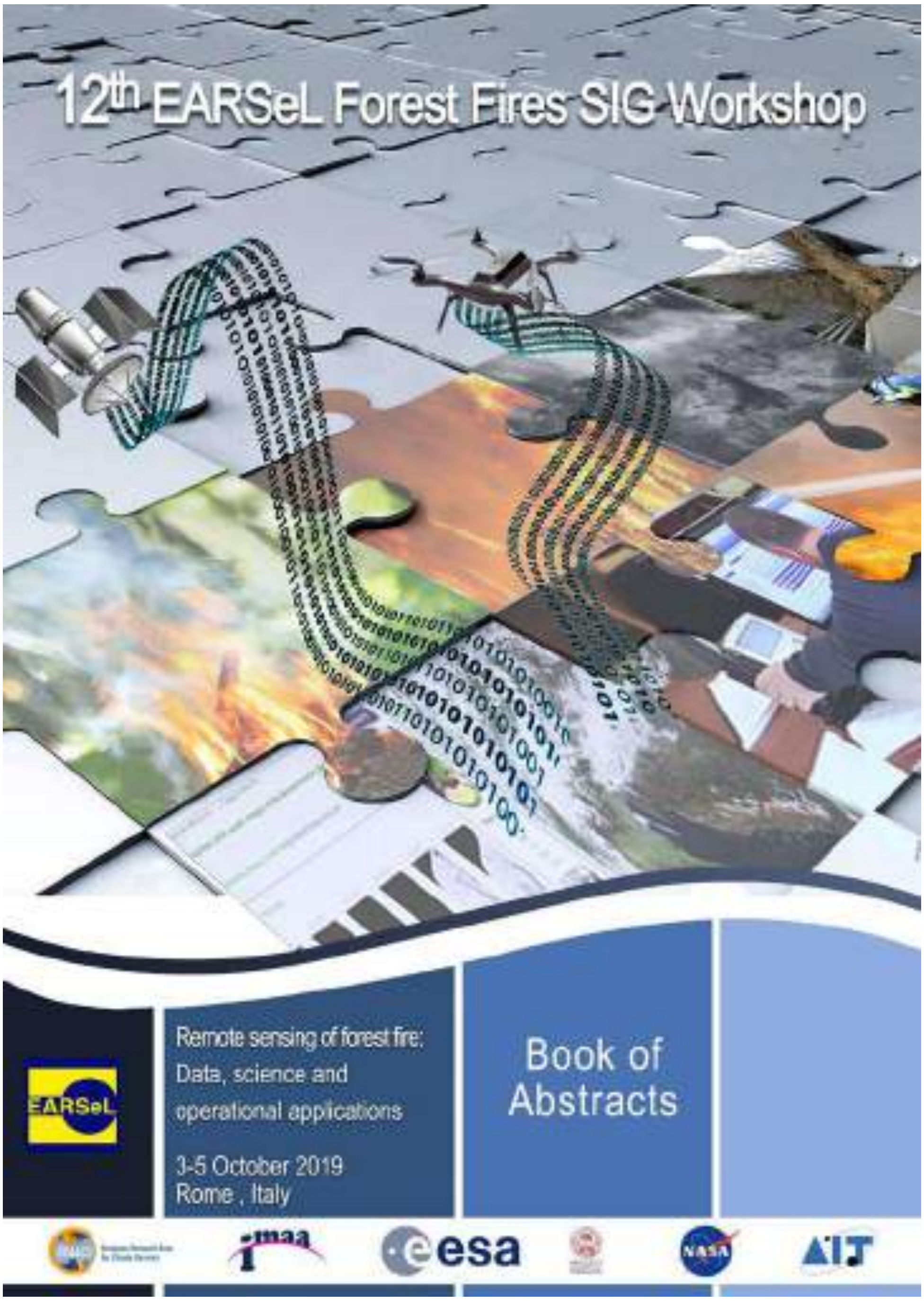
Keywords: wildfire, fire monitoring, mapping, thermal infrared, wildfire management, carbon emission reporting, air quality forecasting, smoke forecasting, data service

Abstract

Early in 2019 the government of Canada provided pan-departmental support for the initiation of the WildFireSat satellite mission, to be launched in or around 2024. The Canadian Forest Service leads the initiative to adapt fire monitoring science to deliver the world's first truly operational dedicated wildfire monitoring satellite mission. WildFireSat is designed to address critical gaps in satellite fire monitoring for Canada's unique geography, and to primarily address the needs of wildfire management. This presentation provides a summary of the system design, alignment with existing systems, tier 1 and 2 data products, and the concept of operations (CONOPS) which will deliver comprehensive situational awareness to Canadian fire managers and decisions-makers in near-real-time, and support smoke forecast services. The intention of the presentation is to initiate discussions with respect to broadening the mission scope to include the international community.



EARSEL

REMOTE SENSING OF FOREST FIRE DATA, SCIENCE AND OPERATIONAL APPLICATIONS

SESSION: FIRE EMISSIONS ESTIMATION AND AIR QUALITY MONITORING

EARSeL 2019
Digital I Earth I Observation
Abstract
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Application of mobile ground-based remote sensing systems to study plume dynamics of large wildfires

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Keywords: doppler lidar, radar, dual-polarization, plume dynamics, wildfire behaviour, fire weather

Abstract

Meteorological observations of plume dynamics during large wildfires are required to not only better understand the dynamics of fire behaviour, but also to help evaluate the next coupled fire-atmosphere modelling systems. This requirement is exacerbated by the lack of observations due to the complexity of the fire environment in which observations are generally difficult to obtain. In order to better understand mechanisms responsible for extreme fire behaviour associated with large wildfire plumes and obtain data for model evaluation, a number of new field campaigns have been conducted on large active wildfires (e.g., Clements et al. 2018; McCarthy et al. 2018). As part of these field efforts, new remote sensing systems have been deployed and tested in the fire environment to measure and quantify the atmospheric conditions around large wildfires and subsequently shed light on plume dynamics such as kinematic structures within the plumes. These systems include scanning Doppler lidars and radars that have high temporal and spatial resolutions and can be easily mounted on. Additionally, radars with dual-polarization capability can provide information on the microphysics of the particles that are associated with the reflectivity of the returned energy.

A rapid-response deployment strategy is needed to enable adequate placement of observational assets. This approach allows for a number of scanning strategies to be leveraged to better sample both the plume and the surrounding atmospheric environment. For example, with a lidar positioned upwind of the plume and fire front, vertical wind profiles can be obtained periodically while also scanning vertically through the plume using a continuous Range-Height Indicator (RHI) scan pattern. The RHI scan can provide both plume height evolution and boundary-layer height. Additionally, stacked PPI (Plan-Position Indicator) scans can be used to obtain a volume scan of the plume while also quantifying fire-induced circulations within and around the plume and spreading fire front.

Figure 1 shows an example of the plume observations made during the devastating Camp Fire in California on 8 November 2018. The mobile profiling system is a truck equipped with a scanning Doppler lidar and surface and upper-air observation instruments and was positioned along a road near the south flank of the fire (Fig. 1a). As the fire approached the observation location, both vertical wind profiles were measured (Fig. 1b) as well as vertical stare scans that provided backscatter intensity observations that indicated smoke plume height (Fig. 1c). As the fire front came within 100 m of the observation location, the mobile system was able to move to a new observation location.

his presentation will discuss the advantages of rapid-response mobile observations that have led to new insights of plume dynamics from various field studies and will describe future needs and tools for planned experiments going forward.

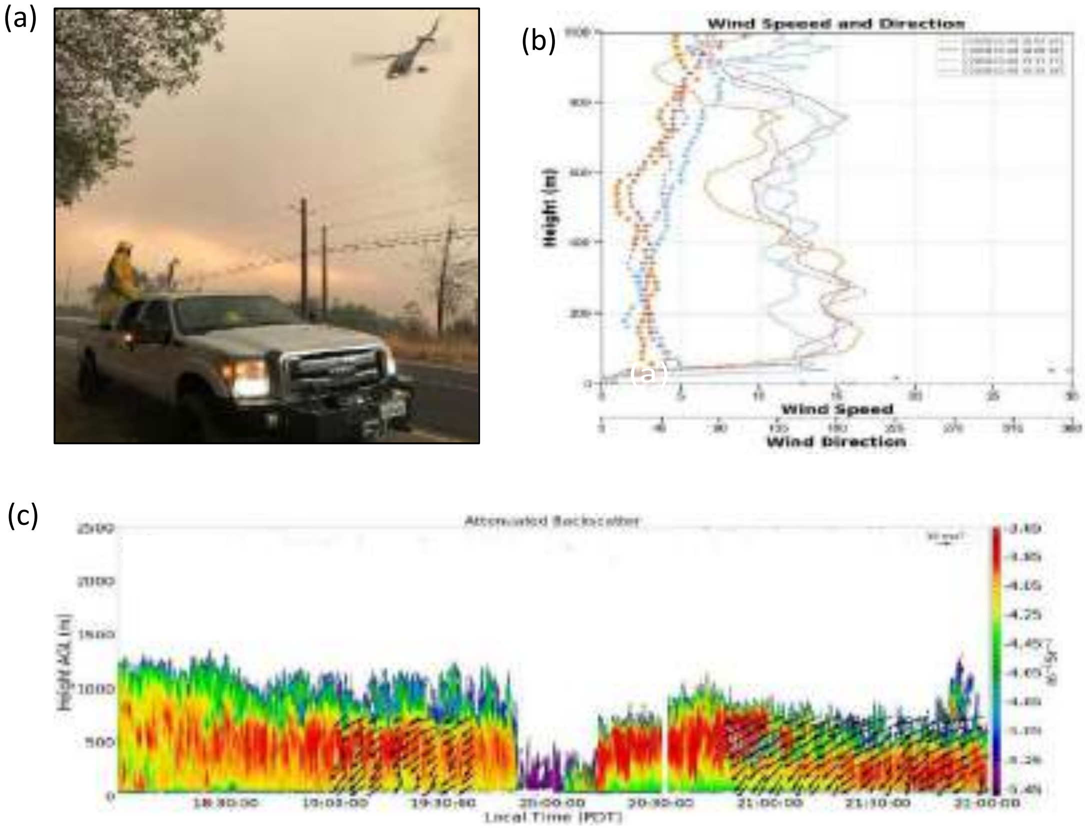

Figure 1. (a) photograph of deployment site during Camp Fire, California (8 Nov. 2018), (b) vertical wind profiles obtained from Doppler lidar during Camp Fire, (c) lidar backscatter and wind profiles during deployment perio

A weather-based prediction method to forecast regional emissions from wildfires in African grasslands

EARSeL 2019
Digital I Earth I Observation
Abstract
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Keywords: EARSeL 2019, wildfires, grass fires, emissions, forecasting

Abstract

Our objective is to be able to forecast particulate matter emissions from wildfires worldwide in order to improve the global- and regional-scale air quality forecasting. As the first step, we present a prediction method to forecast emissions from areas with numerous fires that typically emerge within daytime. We have therefore chosen the neighbourhood of south-central Africa as our test area because it is rich with such fires during the dry seasons. The method presented is built on a phenomenological basis based on the weather data and the remotely-sensed fire occasions and cloud cover data by the SEVIRI geostationary instrument.

The input of the model is the weather forecast and output is an estimation of fire radiative power, which is directly proportional to the particulate matter emission rate. In the prediction procedure, the test region is split into areas sized 1.44 degrees squared. Each area possesses its own unique areal characteristics. The forecasted fire radiative powers arise from the combination of weather forecasts, climatic factors and wildfire history according to which the model for each area is parameterized. The key element of the method is a function that predicts temporal fire radiative power. The function is composed of three components: weather function and annual and diurnal bell-like fire radiative power curves built from the logistic growth and decay. The annual fire radiative power curve defines not only the period of fire season but also takes care of the difficulties that arise from the lack of detailed knowledge about the non-weather reasons for the occurrence of fires. It works as a reference curve and sets somewhat reasonable estimates for the shapes of the diurnal fire radiative power curves, which are further modulated by the weather component that employs an appropriate fire index or something analogous to it.

The current version of the method shows promise in predicting emissions from grass fires in highly fire concentrated areas in Africa, but it is still yet to be seen how it will work, for example, in the case of forest fires in much less fire concentrated areas. To demonstrate the predictive power of the method, we present some results of the predicted diurnal fire radiative power profiles emitted by the test areas on different days and years. The blue curve in Figure 1 shows an example of a weather-based prediction of our method on one day.

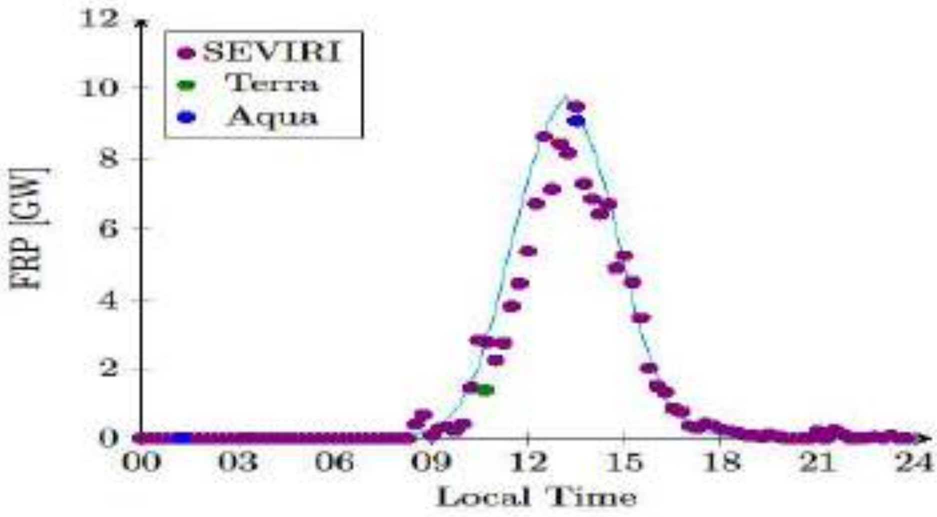

Figure 5. Diurnal fire radiative power of Angolan grass fires observed by SEVIRI, Terra, and Aqua instruments on the 8th of June 2010. The blue curve is a weather-based prediction of our method. The horizontal axis is in the 24 hour clock format. The figure represents fire radiative power (FRP) form an area sized 1.44 x 1.44 degrees squared with the center point at 18.00 degrees of longitude and -9.36 degrees of latitude in Angola, Africa.

Developing Earth observation based products on fire intensity and fire emissions to support operational fire management in savanna areas

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Digital I Earth I Observation
Abstract
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Keywords: Fire behaviour and fire impacts, Fire emissions estimation, Fuel consumption and fuel load estimation, Contribution of Sentinel missions on forest fire research

Abstract

Vegetation and peat fires contribute substantially to global emissions of greenhouse gases (GHG). According to latest estimates, net fire emissions (i.e. the part of fire GHG not balanced by regrowth) amount to 6% of global fossil fuel GHG emission. Improving the management of fires in frequently burning ecosystems can help reduce GHG emissions and thus contribute to mitigation of climate change. In order to implement, monitor and document success in fire management, timely and accurate data on fire extent and impact, as well as weather and burning conditions is needed. Monitoring and analysis of fires over large and often remote areas is only feasible with the help of Earth Observation (EO) satellites. Over the last decades, availability of free EO data has increased enormously, as has the availability of computing power, network speed and web based geospatial visualization and analysis technologies. Since collected raw data is being frequently updated and often requires extensive processing for the extraction of information, there is a demand for a solution to simultaneously handle data pre-processing, analysis, and dissemination of results to be able to provide quick, reliable and user-friendly statistical information to assist decision-makers in different levels of management. Key features of the firemaps.net platform presented here are: near real time monitoring of fire activity and carbon fluxes, weekly updated burned areas, daily analysis and forecast of relevant weather parameters, long time series of fire emissions to calculate baselines, fire risk and vulnerability maps and tools to monitor success of fire management planning and implementation. The coupling of remote sensing data with weather information and fire spread models enables forecasting and detailed hindsight analysis of the behaviour of wildfires. Here the rate of spread and fire intensity are key parameters to understand effects of fires on affected areas and to support management planning. To develop a new information product to analyse fire intensity, we assessed fire spread and fire radiative energy release rate (fire radiative power) over savanna fires using infrared sensors with different spatial, spectral and temporal resolutions, focusing on sensors providing a spatial resolution higher than 500 m. The sensors used offer either high spatial resolution (Sentinel 2, Landsat 8) for fire detection with low temporal resolution, moderate spatial resolution and fire radiative power retrievals with moderate temporal resolution over selected sites (FireBird satellites), or moderate spatial resolution, high temporal resolution, but no fire radiative power retrievals (S-NPP VIIRS I-band active fire product), or moderate to low spatial resolution and fire radiative power retrievals at high temporal resolution (MODIS). We extracted fire fronts from Landsat and Sentinel 2 (using the Shortwave Infrared bands) and used the available fire products for S-NPP VIIRS, MODIS and Meteosat. From these results we derive metrics on fire behaviour (fuel consumption, fire rate of spread, fire intensity) in our study areas. We relate our results to outputs of fire behaviour models and to published values.

Field experiments in a study area in West Africa provide insight into the performance of the fire behaviour model used in predicting fire spread and fire intensity driven by forecasted weather data in relation to field measurements of these properties using infrared radiometers mounted over the fires.

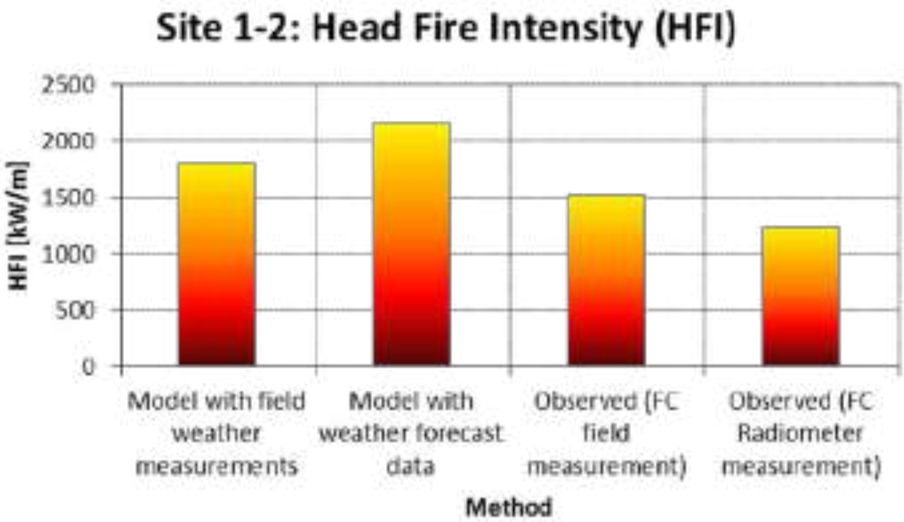

Figure 1. Comparison of modelled Head Fire Intensity using either field measurements or weather forecast data with HFI observed in the field for one site using destructive sampling and radiometer (i.e. FRP) derived fuel Consumption

EARSeL 2019
Digital I Earth I Observation
Abstract
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Comparing burned area and combustion efficiency for estimating GHG and particulate emissions from Italian fires

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Keywords: fire emissions, burned area, combustion efficiency, Copernicus products, Italy

Abstract

One of the main primary effects of fires is the production of a remarkable amount of greenhouse gases and solid particulate matter due to biomass combustion. It can contribute significantly to the atmospheric budgets at local, regional, and even global scale: it is estimated that the combustion of biomass contributes 38% to the emission of CO_2 into the atmosphere, against 62% caused by the combustion of fossil fuels. Further, it could approach levels of anthropogenic carbon emissions, especially in years of extreme fire activity (e.g. 2003, 2017).

According to the equation proposed by Seiler and Crutzen (1980), fire emission estimation uses information on the amount of burned biomass, the emission factors associated with each specific chemical species, the burned area, and the combustion efficiency. Still, simulating emission from forest fires is affected by several errors and uncertainties, due to the different assessment approaches to characterize the various parameters involved. Regional assessment relied on fire-activity reports from forest services, with assumptions regarding the type of vegetation burned, the characteristics of burning, and the burned area. Improvements and new advances in remote sensing, experimental measurements of emission factors, fuel consumption models, fuel load evaluation, and spatial and temporal distribution of burning are a valuable help for accurately predicting and quantifying the source and the composition of fire emissions. For example, in the last decade, satellite inventories of fire activity and characteristics (e.g. Very High Resolution Radiometer, Visible and Infrared Scanner, Moderate resolution Imaging Spectroradiometer, etc.) have grown based on active fire detection, burn-scars mapping, rapid damage assessment.

With the aim to contribute to a better estimation of biomass burning emission, in this work we compared fire emission estimations using two different types of burned area products and combustion efficiency approaches in the framework of the recently developed system for modelling fire emissions in Italy (Bacciu et al., 2012).

This methodology combines a fire emission model (FOFEM - First Order Fire Effect Model, Reinhardt et al., 1997) with spatial and non-spatial inputs related to fire, vegetation, and weather conditions. The perimeters and burned area of selected large fires occurred in 2017 and 2018 in Italy were obtained by the former Corpo Forestale dello Stato (actually Carabinieri C.U.F.A.A.) and by the Copernicus Emergency Management Service (EMS). The vegetation types were derived from CORINE LAND COVER (2012). For each vegetation type, fuel loading was assigned using a combination of field observations and literature

data (e.g., Mitsopoulos and Dimitrakopoulos 2007; Ascoli et al., 2019). Fuel moisture conditions, influencing the combustion efficiency, were derived from the daily Canadian Fine Fuels Moisture Code (FFMC), calculated from MARS interpolated weather data (25km x 25km). The daily FFMC was then associated to the two types of fire data with the aim to group fires in function of their relative ease of ignition and flammability of fine fuel (burning conditions, from low to extreme). The EMS data allowed to further define fire severity through the assessed fire damage grade.

The results showed differences in the total emissions ranging from a minimum of 3% to a maximum of 19% according to the fire product and the approach to estimate the combustion efficiency. Furthermore, the differences in the approaches used in the evaluation of fire severity affected the fire emission estimations more than the differences in terms of area burned. Overall, the results pointed out the crucial role of appropriate fuel, fire, and weather data and maps to attain reasonable simulations of fuel consumption and smoke emissions.

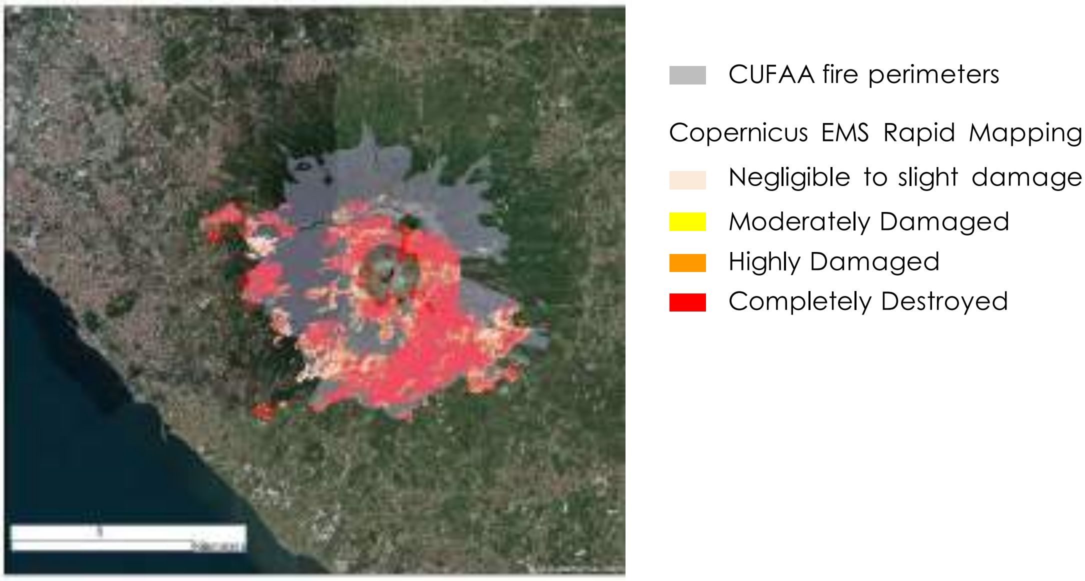
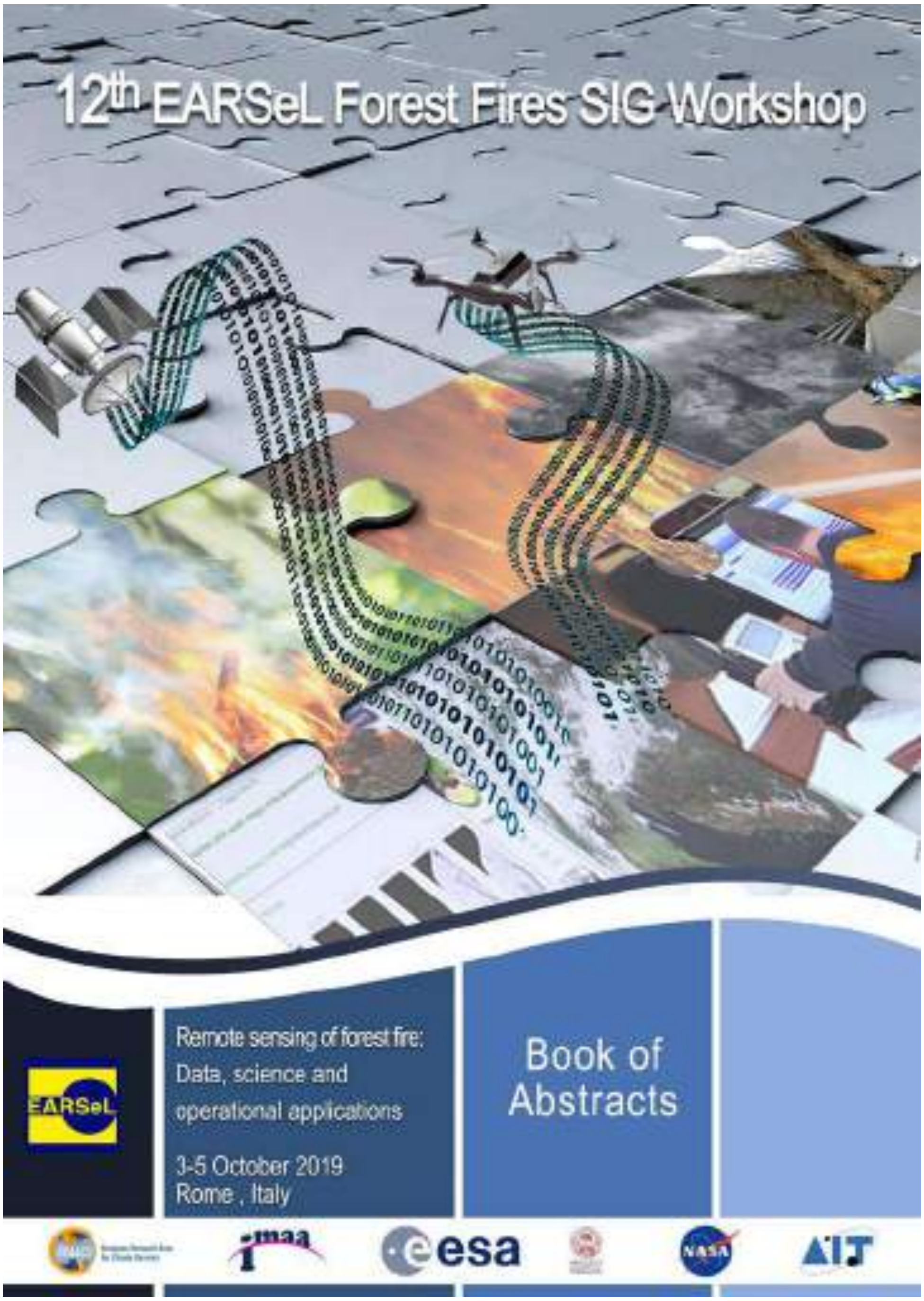


Figure 1. Vesuvio fire, 2017-07-19. In grey, the fire burned area as collected by the Carabinieri C.U.F.A.A.; in shades of orange to red, the four classes of damage grade from the Copernicus EMS Rapid Mapping



EARSEL

REMOTE SENSING OF FOREST FIRE DATA, SCIENCE
AND OPERATIONAL APPLICATIONS

SESSION: REMOTE SENSING OF BURNED AREAS AND FIRE SEVERITY: DATA, SCIENCE AND APPLICATIONS

Fully automated burned area mapping using Sentinel-2 imagery and following the multiple spectral–spatial classification approach

EARSeL 2019
Digital I Earth I Observation
Abstract
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Keywords: Automated burned area mapping, multiple spectral–spatial classification (MSSC), minimum spanning forest (MSF), support vector machine (SVM)

Abstract

Accurate burned area mapping of wildfires is essential for post-fire management, necessary for quantifying the environmental impact of the wildfire, for compiling statistics, and for designing effective short- to mid-term impact mitigation measures. The Sentinel-2 satellites are providing an unparalleled wealth of high-resolution remotely sensed information with a short revisit cycle and a rich set of spectral bands, which is ideal for mapping burned areas both accurately and timely. However, the high detail and volume of the information provided actually encumbers the automation of the mapping process, at least for the level of automation required to map wildfires systematically on a national level.

This paper presents a fully automated burned area mapping methodology tailored for Sentinel-2 data, although it could also be adapted to support Landsat 8 OLI data as well. The only information required by the user is the approximate bounding area encompassing the burn scar and the date the fire was extinguished, which make it easy to employ it for countrywide and timely operational use. To do so, two cloud-free Sentinel-2 images are considered, a pre-fire and a post-fire one. The classification methodology is based on the so-called multiple spectral–spatial classification (MSSC) scheme using the minimum spanning forest (MSF) marker-based region growing algorithm (MSSC-MSF). Initially, a pixel- based two-class (burned vs. unburned) classification is performed by means of the support vector machine (SVM) classifier. The training set is formulated by automatically labelling some of the image's pixels through a set of empirical rules, which combine information extracted from both the pre-fire and the post-fire images (differences or ratios of spectral indices suitable for burned area discrimination). Subsequently, the four 10 m bands of the post-fire Sentinel-2 image are split into objects using three different image segmentation algorithm, namely, the watershed, the fuzzy C-means (FCM) clustering and the mean shift segmentation algorithms. A spectral–spatial classification is derived for each segmentation, by performing a majority voting among the individual SVM pixel classifications within each object (i.e., all pixels of the object are assigned to the class exhibiting the maximum number of SVM pixel classifications within the object's boundaries). These three spectral–spatial classifications are used to derive a new set of markers: if all three classifications agree the pixel is assigned to the common class (marker), otherwise it is left unclassified. The latter are classified by means of a minimum spanning forest (MSF) grown from the markers which is a graph-theoretic region-growing algorithm ultimately obtaining the final classification map. The similarity measure used as the edge weight of the MSF considers the spectral band values of the post-fire image, as well as differences and ratios of burn- sensitive spectral indices derived from the pre-fire and post-fire images. The MSSC-MSF practically exploits the complementary information provided by the three individual spectral–spatial classifications, in order to derive a map of higher accuracy.

The proposed method's accuracy was assessed considering six wildfire events in Greece in 2016 and 2018, selected to cover representative cases of the Greek ecosystems and to present varying challenges in burned area mapping (e.g., semi-arid areas with low vegetation, forested areas near in-between

agricultural areas, populated areas with high vegetation cover, etc.). Well-known measures derived from the confusion matrix were calculated considering manually delineated reference perimeters. The classification accuracy of the proposed MSSC-MSF approach ranged between 93% and 97%, the F-measure between 92% and 97%, whereas the Matthews correlation coefficient (MCC) between 86% and 93%. A visual comparison also highlighted that the proposed approach produced fewer misclassification than the individual spectral–spatial classifications, as well as the initial pixel-based SVM one.

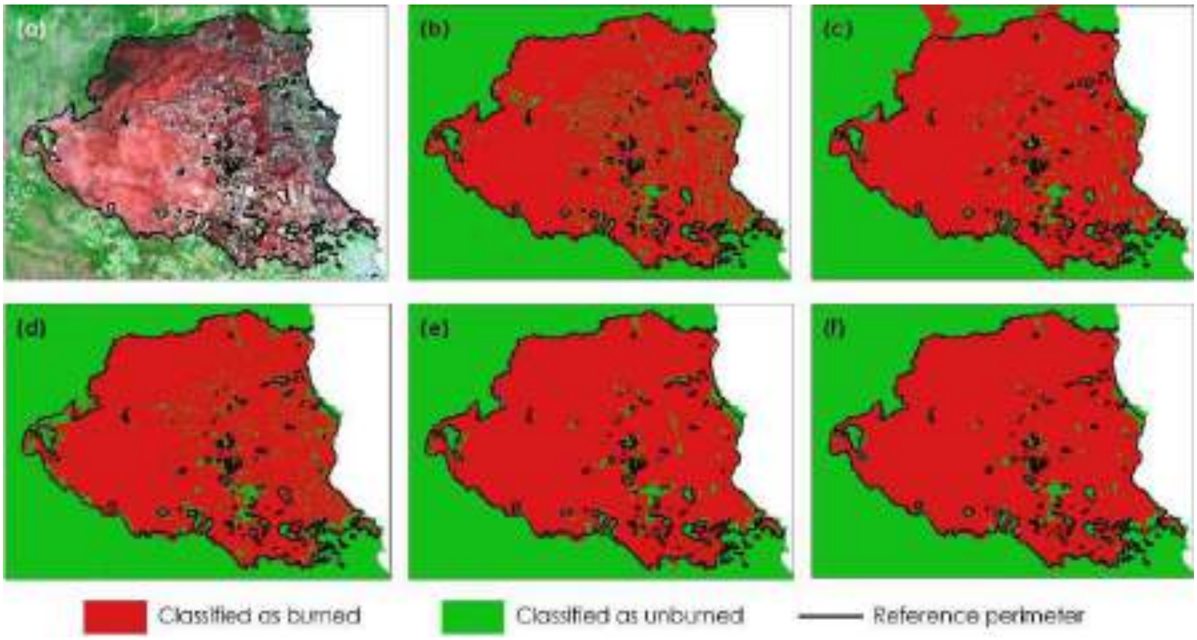

Figure 1. Example from the devastating wildfire event of Kallitechnoupoli (Mati), Attica, Greece in July 2018: (a) false-colour composite of the Sentinel-2 post-fire image (using B12, B08, and B04 in lieu of the view's red, green, and blue channels, respectively) and the classifications obtained by the (b) pixel-based SVM, (c) watershed majority voting, (d) FCM majority voting, (e) mean shift majority voting and (f) proposed MSSC-MSF.

EARSeL 2019
Digital I Earth I Observation
Abstract
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Rheticus® Wildfires: actionable geoinformation on burnt areas for post- fire assessment.

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Keywords: wildfire detection, fire severity, rheticus, info-as-a-service

Abstract

Rheticus® Wildfires is an operational high-performing geoinformation service, available under subscription, for burnt area detection, fire severity classification, vegetation regrowth monitoring as well as detection of possible illegal building activities within burnt areas.

Wildfires represent a major threat to environmental resources, with hundreds of thousands of hectares of burnt areas and invaluable loss of woods and biodiversity every year, in Italy as well as all over the world. Hot summer conditions increases the frequency, extent, and severity of fires through increased temperatures and drought. Climate change threatens to increase the risk of wildfires, allowing fires to start more easily and burn hotter. Although climate change is not the only factor that influences patterns in wildfires. They can also come from negligent or malicious people who set fires by accident or on purpose.

In order to properly manage post-fire recovery activities, holding a database of burnt scars and keeping it up-to-date are crucial tasks. Those activities require great effort in terms of costs and time. Moreover, it is difficult to perform accurate field surveys over inaccessible areas. As a result, stakeholders such as National and Regional Park Services quite often face the lack of actionable information for post-fire management and recovery planning. Satellite data together with Artificial Intelligence (AI) algorithms and high computational capabilities can help addressing those difficulties.

Over the past few years, the ESA's Copernicus Program gave birth to a new era of Big Data in the field of Earth Observation (EO) through the launch of the new family of satellites called Sentinels, made available as free and open data. Thus, relevant satellite data are now freely available with high temporal and spatial resolutions. Benefits of using satellite EO are significant especially for post-fire assessments, as EO by satellite enables automatic and continual monitoring, regardless of the extent and morphology of the area of interest.

The increasing volume and varieties of remote sensing data has generated new great challenges in handling datasets that require a new paradigm in order to extract relevant knowledge and actionable information for effective and efficient EO activities. In the light of the new era of Big Data, it is not feasible to let operators carrying out the collection, management, processing and analysis of such a huge amount of data through out-dated approaches. Thus, it is necessary to provide EO community with automatic high-performing processes. AI contains several methodologies, algorithms and strategies that can "instruct" machines to execute some operations autonomously. One of the most important characteristic of AI methodologies is the ability to extract useful information from data that means, highlighting only the relevant data. In the above mention steady-evolving scenario, information cannot be provided through traditional maps, but need to be released in smart and more dynamic ways through geo-analytics and Business Intelligence interfaces. Moreover, the adoption of cloud-based computing environments permits faster prototyping and easier implementation of solutions than ever before.

From the point of view of service providers, the Sentinels provide an unprecedented opportunity for developing continuous operational Earth monitoring services. Following this new philosophy, Planetek Italia designed and developed a cloud-based platform for automatic and continuous processing of satellite data, called Rheticus®, from the name of Nicolaus Copernicus' solely pupil. The platform consumes satellite data such as Sentinels' imagery, weather data and other open data sources to provide several continuous Earth monitoring services available under subscription, ranging from the detection and monitoring of geo-hazards and infrastructure instability, to marine water quality monitoring, from supporting aquaculture activities, to wildfire detection as well as land cover monitoring.

Among Rheticus® services, Wildfires is a geo-information service for a posteriori wildfire detection, based on different spectral responses of healthy vegetation in comparison with recently burnt areas in various bands of the spectrum through the use of the Normalised Burnt Ratio index. Every time a new Sentinel-2 data is available over the end user's area of interest, the platform automatically downloads the image and processes the latter downloaded image together with the former one in order to detect new burnt scars possibly occurred over the area of interest. Then, on the cloud-based platform a dedicated database is updated with new events occurred. The platform provides end-user with key information retrieved from Sentinel-2 optical data together with other open data sources through extensively tested models and AI algorithms, to better classify burnt areas and reduced misclassified pixels. Those insightful and purpose-built contents from many different perspectives are made available through a web-based application with thematic maps, geo-analytics and pre-set reports. Thanks to Sentinel-2 data, the service ensures higher quality information than those provided by the European Forest Fires Information System (EFFIS), which exploits MODIS and VIIRS data.

The Copernicus Sentinels will ensure continuity to the service. The integration of Sentinel-3 data will be explored for further improvements of the processing chain.

Figure 1. Rheticus® Wildfires User Interface

A rule-based semi-automatic method to map burned areas using Landsat and Sentinel-2 images – revisited and improved

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Abstract

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Keywords: EARSeL 2019, abstract, formatting guidelines

Abstract

This study presents an improvement of an old rule-based semi-automatic method to map burned areas by using multi-temporal Landsat images. The rule-based approach consists of a set of rules developed based on spectral properties of burned areas as compared to the pre-fire unburned vegetation and to the spectral signatures of other land cover types found in post-fire satellite scene. Actually, the spectral properties based on which the rules have been developed are presented in two graphs, one that corresponds to spectral signatures plots and the second that corresponds to the histogram data plots. The spectral patterns based on which the rule-based approach has been developed are not always the same. For example, depending on the type of the fire-affected vegetation (e.g. dry vegetation instead of green) the spectral pattern of the SWIR channel that correspond to channel 7 in Landsat 4-7 and 8 is not valid. Instead, there is a similar spectral behaviour but in the SWIR channel that correspond to channel 5 in Landsat 4-7, or channel 6 in Landsat 8. Additionally, the threshold value of 0.10-0.25 of the second rule seems not to be sufficient to cover all variability since there are cases that this value should be higher. Two characteristic examples of the insufficiencies found on the old-rules are concerned in the current analysis, one that presents limitations concerning the rule 5 (Serifos) and one that represents limitations concerning the rule 2 (Portugal).

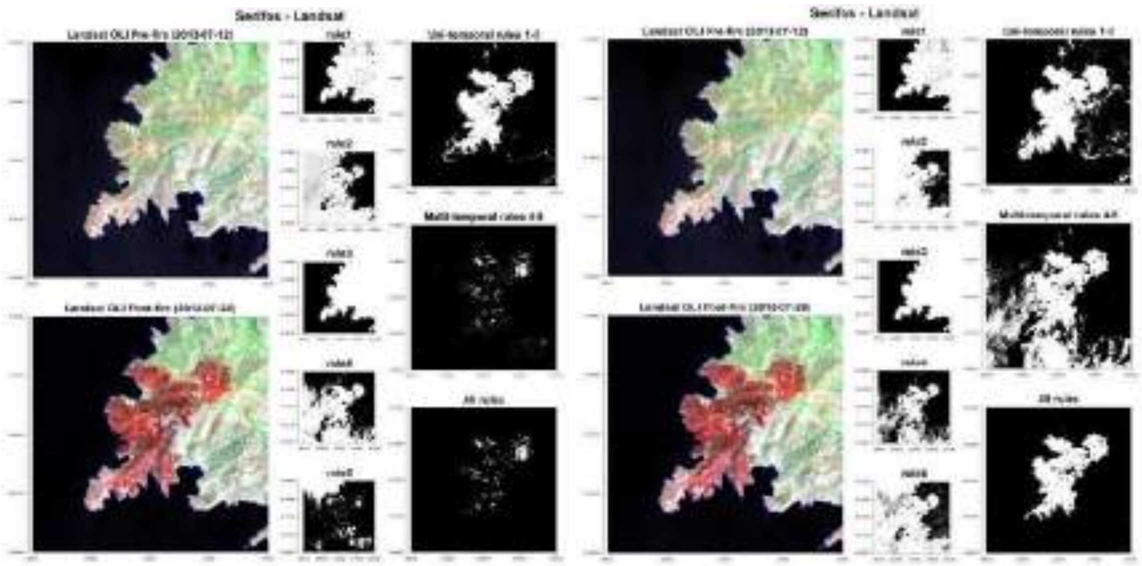

Figure 1. (a) old set of rules and (b) new set of rules

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Extending time series of burned area estimations: from Terra-MODIS 250 m to Sentinel 3-OLCI 300 m

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Keywords: Sentinel 3, burned area, OLCI, algorithm, fire

Abstract

The information related to the temporal and spatial distribution of burned area (BA) is an essential input to understand the effect of its derived emissions in the atmosphere, and its impacts on vegetation dynamics. At the same time, vegetation and climate have a considerable effect on fire. They set the environmental conditions that guide the fire regimes of a certain location. Some services such as civil protection services or environmental and forest protection services have started using BA products due to their increasing accuracy and operational delivery. Taking these needs into account, the Fire_cci project, which is part of ESA's Climate Change Initiative Programme, started in 2011 with the aim of providing climate modellers with long term time series of global BA data. Now, eight years later, an algorithm developed within the project, known as FireCCI51, has been considered by the Copernicus Climate Change Service (C3S) mature enough to be integrated into an operational system. This operational system is based on the Sentinel 3 OLCI sensor and the aim of the service is to ensure that consistent ECV products are systematically delivered to the users in the following years.

FireCCI51 was initially developed for the Terra's Moderate Resolution Imaging Spectroradiometer's (MODIS) highest resolution bands (250 m). It is a hybrid algorithm that detects BA based on active fires and data in the near-infrared (NIR) spectral region. It uses a two-phase approach. In the first step, the commission error is reduced by selecting pixels with a high probability of being burned (seeds). In a second phase, a contextual growing is applied from these seeds to fully detect the burned patches, reducing omission errors.

The NIR band is usually one of the satellite's highest spatial resolution bands, which reduces the smallest BA patch that can be detected. Other commonly used bands for burned area detection, such as the short wave infrared (SWIR), have a coarser spatial resolution. As the NIR band is commonly found in most of the coarse resolution satellites, FireCCI51 is highly adaptable to other sensors. The main objective of every adaptation is to ensure consistency between the old and the new product. Hence, the most similar European sensor was chosen to provide the operational BA product: The Ocean and Land Colour Instrument (OLCI) aboard Sentinel 3. This sensor provides a near daily global coverage at 300 m when both Sentinel 3A (launched on February 2016) and Sentinel 3B (launched on April 2018) are available, similarly to Terra's MODIS. It has 21 bands in the Visible-NIR region, including the 865 nm band, which matches the one provided by MODIS.

Active fire information is provided by the MODIS MCD14ML product. The pre-processing of the OLCI Level 1b product is carried out by Brockmann Consult, which provides atmospherically-corrected surface directional reflectance images in 10°x10° tiles. These tiles are the processing unit of the algorithm. Thirteen of these tiles, encompassing different fire regimes and biomes, are used to guide and calibrate

theadaptation from MODIS to OLCI. The calibration year is 2018, the last year provided by the FireCCI51 product, and also by reference perimeters of different forest fire services worldwide, used also for calibration purposes. This first operational product will cover the period 2017 – 2019, which ensures an overlap of two years between the FireCCI51 and the C3S BA products. It will be released on two global formats: the pixel product at 300 m resolution and the aggregated grid product at 0.25°.

The intercomparison of both products at different resolutions performed in the calibration sites shows a very high correlation (r2 = 0.894 at 5 km, r2 = 0.936 at 10 km and r2 = 0.969 at 25 km). This intercomparison will be extended to the global scale once the product is available (August 2019). Additionally, a stage 3 validation will be performed for each year (2017 – 2019) based on 100 Landsat Thiessen Scene Areas (TSA) per year that are selected following a stratified random sampling approach. The reference perimeters are obtained using a semi-automatic algorithm and then verified and adjusted by visual interpretation.

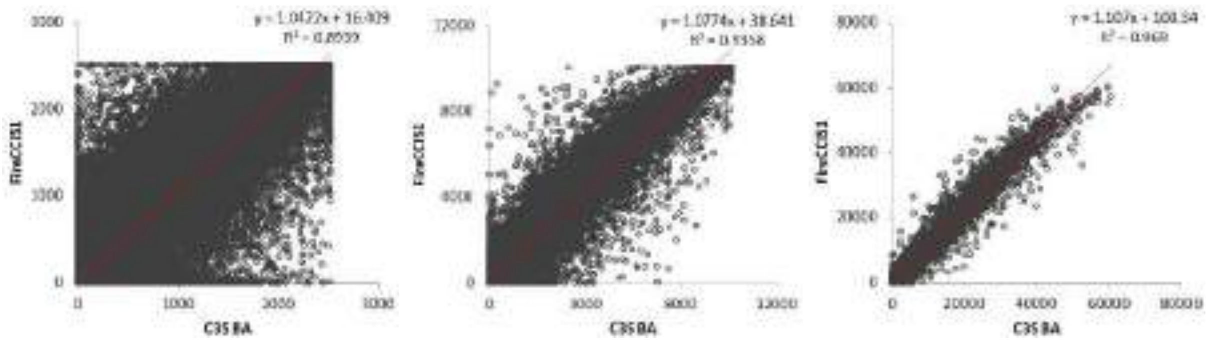

Figure 1. Scatter plot of the BA in hectares of 5 x 5 km (left), 10 x 10 km (centre), and 25 x 25 km cells (right) labelled as burned by the Sentinel 3 OLCI C3S BA at 300 m and Terra-MODIS FireCCI51 at 250 m in the 13 study sites in 2018

Temporal decorrelation analysis of C- band backscatter coefficient in burned areas

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Abstract
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Keywords: C-band, Burned area, temporal decorrelation, Sentinel-1, backscatter coefficient

Abstract

Fire is considered by the Global Climate Observing System (GCOS) an Essential Climatic Variable (ECV) due its key role in the climatic balance. Since 2010 fire disturbances are included in the ESA's Climate Change Initiative (CCI) programme, where the aim has been to produce long-term and consistent time series burned area (BA) maps. The increasingly use of the Synthetic Aperture Radar (SAR) in the BA mapping is due to its cloud cover independence and detailed spatial resolution, which complement the current BA global products, mainly based on optical data at coarser resolutions (≥250 m). Most SAR based BA detection approaches use pre- and post-fire differences of the backscatter coefficient, since fire use to produce variations of the backscattering process over vegetated areas. However, the use of temporal pairs (i.e. pre- and post-fire) to carry out such purpose is not enough since variations in the backscatter coefficient due to fire effects may be observed only some time after the fire (up to several months). Such effect is known as temporal decorrelation, and the aim of this work is to analyse it over C-band backscatter coefficient by land cover classes in the Mediterranean ecosystem.

Temporal series of col-polarized (vertical-horizontal VH) C-band backscatter coefficient acquired by the sensors on board of Sentinel-1 A and B satellites were used. Sentinel-2 images were used to derive spectral indices used to extract information of some environmental variables that may affect C-band backscattering process. In addition, the Surface Soil Moisture (SSM) information was extracted from an operational product available on the Copernicus Land Monitoring Service. Data from the Shuttle Radar Topography Mission (SRTM) at 30 m was employed to derive the topographic information. Lastly, the land cover information was obtained from the Corine Land Cover (CLC) 2018 at 100 m of spatial resolution. The study site selected was an area located in Portugal largely affected by fires in 2017 (Figure 1).

In order to separate which burned pixels were affected by the temporal decorrelation from the rest, we developed a potential detection framework where the temporal (pre- and post-fire) and contextual (burned and unburned) backscatter coefficient variations were taking into account to know the time when the BA detection was possible. When pre- to post-fire backscatter variations were small and did not allow the detection, but sometime after the post-fire time such variation was sufficiently high to carry out the detection, the existence of temporal decorrelation was confirmed. Several variables, such as fire severity, water content, vegetation chlorophyll content and topography, which may affect the backscattering process of C-band, were evaluated to determine their relationship with the temporal decorrelation. Random forests were employed to predict the importance of such variables over the temporal decorrelation process. The preliminary results shown that a third of the study area burned pixels were affected by the temporal decorrelation process. Over most of the decorrelated pixels, the burned area detection was able to be carried out during the first month after post-fire time. Fire severity and water availability (soil

moisture and vegetation water content) seemed the main factors which conditioned the detection ability immediately after a fire event. Water availability both in soil and vegetation seemed the main factor which allowed the burned vegetation detection time after post-fire date, generating thus the temporal decorrelation process

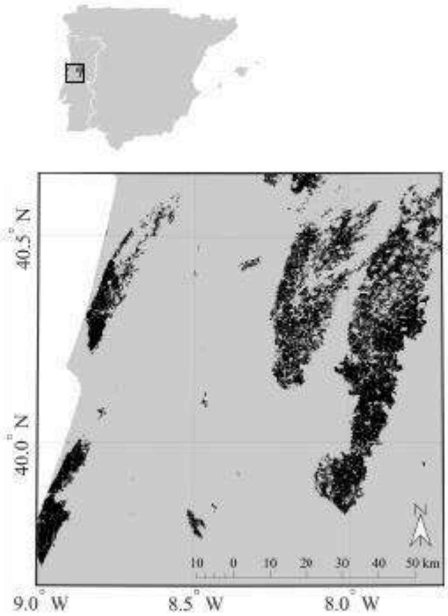

Figure 1. Location of the study area, being showed in black the burned and respectively in grey the unburned areas.

Evaluating the capability of LiDAR data measure post-fire effects using a radiative transfer modelling approach

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Abstract
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Keywords: Post-fire effects; LiDAR; full waveform; CBI; fire severity

Abstract

Providing accurate information on fire effects is critical to understand post-fire ecological processes and design appropriate land management strategies. The heterogeneity of fire effects, both in space and time, lends itself to study using remote sensing techniques. Fire/burn severity is commonly estimated using spectral indices, particularly NBR and its derivatives, from multispectral moderate resolution sensors. These indices are commonly evaluated against field measures of the Composite Burn Index (CBI), which provides a semi-quantitative measurement of severity by considering the changes caused by fire in five strata: substrate; herbs, low shrubs and trees < 1m; tall shrubs and trees up to 5 m; understory trees; and dominant trees. Changes are scored from 0 (no change) to 3 (highest severity). More recently, LiDAR data has been tested to measure fire effects. Previous studies using LiDAR data have been based on the use of structural metrics derived from the height distribution of returns. The rationale behind this approach lies on the changes in vegetation structure produced by fires. By taking into account only structural changes they failed to provide a more complete characterization of fire severity as they did not consider tree mortality or change in leaf colour (scorched leaves) or soil (charred soil). Nevertheless, LiDAR data have been proved able to discriminate snags (dead standing trees) from living trees.

This study evaluates the full potential of LiDAR data to measure fire severity using a 3D radiative transfer modelling (RTM) approach. Ten plots, characteristics of coniferous and mixed Mediterranean vegetation were recreated based on field measurements, representing the pre-fire scenario. Subsequently, LVIS full-waveform LiDAR data were simulated for each plot using the FLIGHT 3D radiative transfer model. For the post-fire scenarios, we considered change in substrate colour as well as changes in vegetation colour and cover. We reduced the five strata evaluated in the CBI into three strata by grouping low and tall shrubs layers as well as dominated and dominant tree layers together. Six different cases (changes caused by fires) were considered for each CBI stratum and effect (change in colour or cover), and combined, resulting in 7776 scenarios. In order to avoid unrealistic situations for Mediterranean environments, the original scenarios were filtered reducing the output to 1348 burn scenarios. The FLIGHT model was modified in order to be able to model the different effects of fire on each stratum. For each of these scenarios, the FLIGHT model was run to simulate post-fire full waveforms. Leaf reflectance values used in

the FLIGHT model were measured in the field both for green and scorched leaves with different levels of burn degree. Transmittance values were estimated using leaf level RTM prospect and liberty models. Ash and charcoal values were obtained from the literature.

Once the full-waveforms were generated, different metrics commonly used to estimate vegetation structure from full-waveform data were derived including: relative height of energy percentiles 10th to 90th; height to median ratio –HTRT; mean canopy height –MCH-; quadratic mean canopy height – QMCH-; coefficient of variation of the relative canopy height profile. In addition, we proposed a new metric called area of the waveform (AW). In order to estimate the damage caused by fires we computed the absolute relative change for each of the metrics. The sensitivity of each metric to the different simulated burn severity scenarios was measured using Spearman´s rank correlation coefficient. The relative change of the area of the waveform showed the strongest correlation to CBI (=0.9 ± 0.02) followed by QMCH (=0.5 ± 0.3). All other variables showed moderate to low correlation values of around 0.3.

In this study the potential of LiDAR data to measure fire effects beyond structural changes has been demonstrated using an RTM approach. Our simulations considered not only changes in leaf cover but also changes in leaf and soil colour. A new metric has been proposed which capture the effect of fire on the different strata considered for the evaluation of fire using the commonly used CBI method

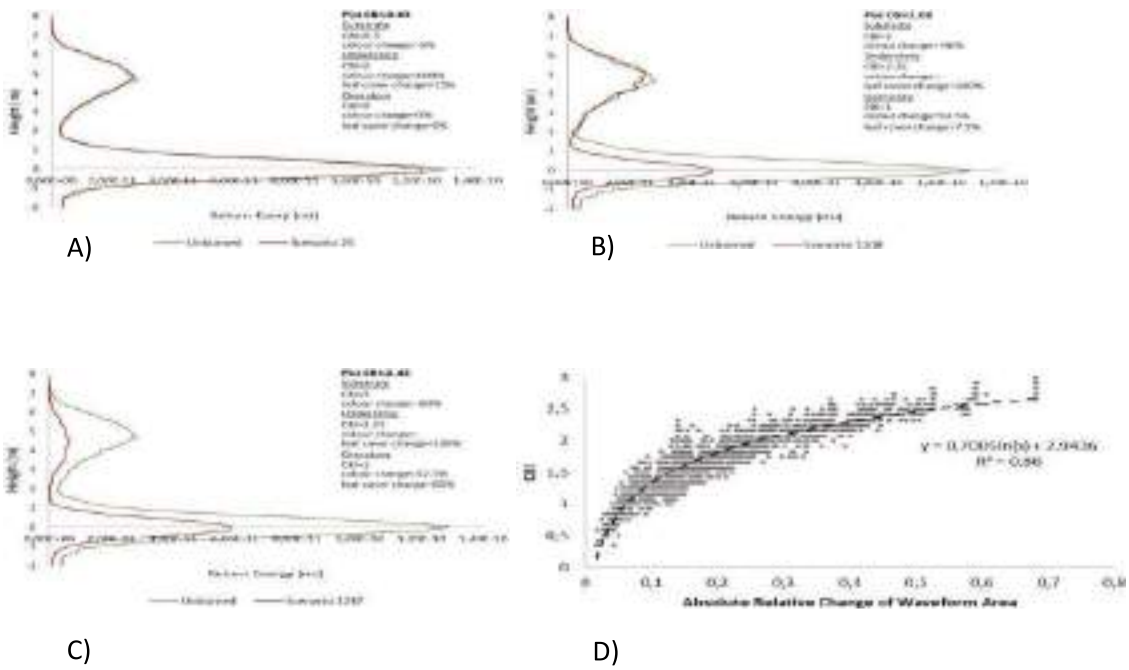
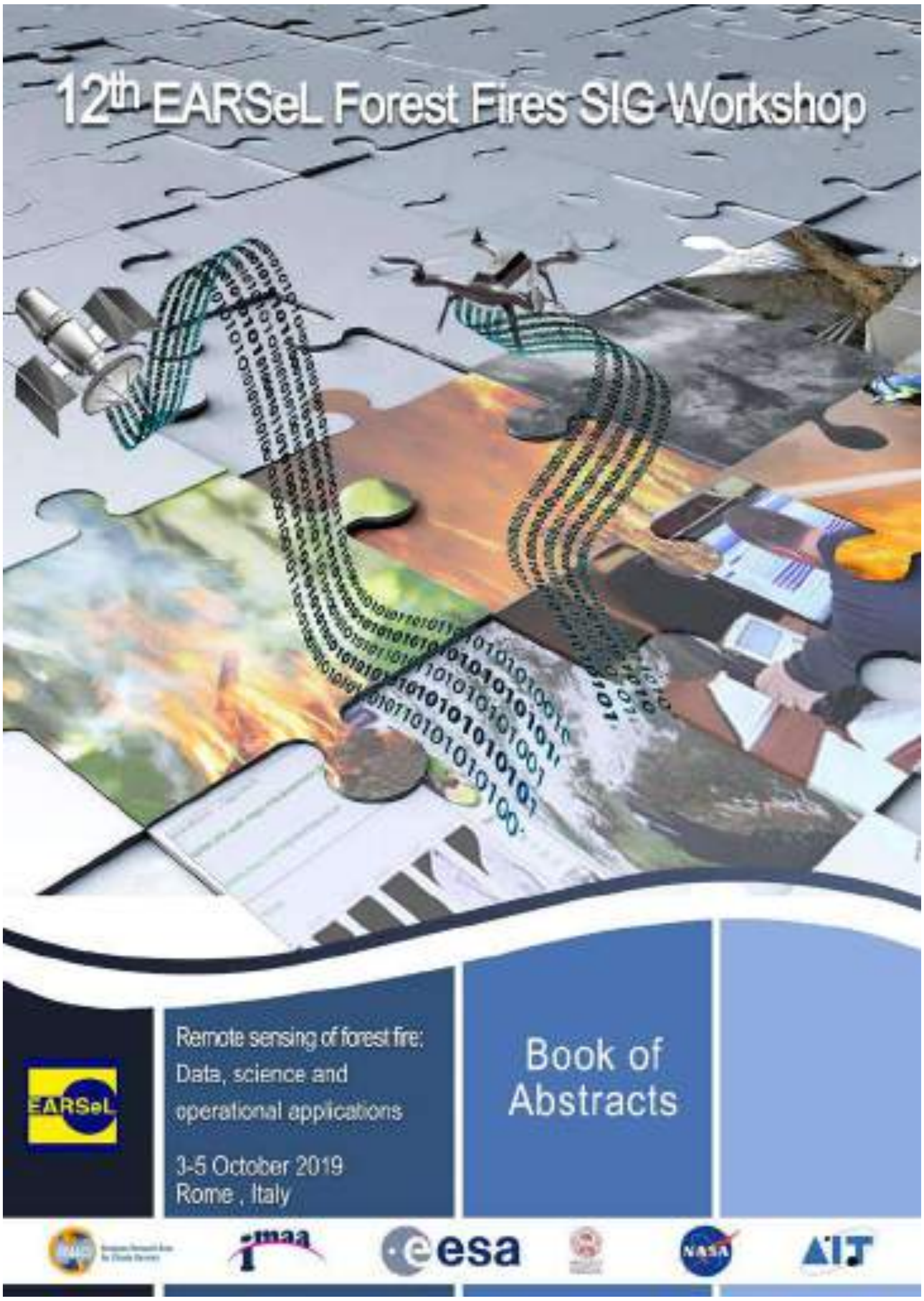


Figure 1. A) Simulated unburned and burned full waveform for a plot CBI=0.83; B) Simulated unburned and burned full waveform for a plot CBI=2.08; C) Simulated unburned and burned full waveform for a plot CBI=2.42; D) relationship between the absolute relative change of the waveform area and the composite burn index (CBI



EARSEL

REMOTE SENSING OF FOREST FIRE DATA, SCIENCE AND OPERATIONAL APPLICATIONS

SESSION: FIRE REMOTE SENSING OF BURNED AREAS AND FIRE SEVERITY: DATA, SCIENCE AND APPLICATIONS

Operational application of remote-sensing for assessing prescribed burn severity, bushfire fuel structure and fuel moisture content in the forests of the australian capital territory

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Abstract
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Keywords: Fuel mapping, fire severity, fuel moisture content, Landsat, MODIS, Sentinel 2, LiDAR, Normalised Burn Ratio, radiative transfer model, random forests, water quality, shortwave radiation

Abstract:

The Parks and Conservation Service of the Australian Capital Territory has embarked on a research utilisation program aimed at operationalising remotely-sensed products for bushfire management. The program commenced in 2015 with a trial of the United States Forest Service (USFS) FIREMON system and has expanded to include fire severity-derived post-fire water quality risk assessment, LiDAR-derived fuel structure mapping, sub-canopy microclimate modelling for dead fuel moisture prediction and satellite-derived live fuel moisture prediction. The work has been greatly facilitated by operator/researcher partnerships established under the auspices of the Australian Government-funded Bushfire and Natural Hazards Cooperative Research Centre (BNHCRC). The ongoing partnerships have created a fertile environment for research utilisation and technology transfer.

ACT Parks trialled the USFS FIREMON fire severity mapping system adapted for Australian conditions. The project used the Geoscience Australia Landsat 8 Nadir-corrected Bidirectional reflectance distribution function Adjusted Reflectance (NBAR) product which is designed for change detection. Fire severity is estimated using the differential Normalised Burn Ratio (dNBR) but the Composite Burn Index used for ground-truthing was replaced with a method analogous to the Overall Fuel Hazard (OFH). The OFH reflects Australian fuel structure and is in regular use by Australian bushfire practitioners. Vegetation structural heterogeneity caused considerable variation in the signal received by the satellite especially at intermediate fire severities. Accuracy in the order of 80 percent was achieved by limiting the classification to three classes: unburnt, low severity and high severity. The output of the program has been used to: 1) assess post-fire hydrological risk due to wildfires and prescribed burns; 2) to determine changes in fuel distribution, and 3) to improve prescribed burn planning by determining the relative flammability between different aspects in mountainous terrain. Despite the well-documented limitations of the method, the program produces valuable information and it has become an expectation that prescribed burn severity maps are produced. Future work will investigate: 1) the use of Sentinel 2 data; and 2) compare dNBR with other methods such as the vegetation structure perpendicular index, radiative transfer models and random forests.

Another technology being trialled for fire severity and fuel mapping in the ACT is LiDAR. A LiDAR dataset covering the whole of the ACT was flown in 2015-16. The density of returns was 8ppm over the urban area and 4ppm over the remainder of the territory. The data were processed for bushfire fuel products by BNHCRC research partners funded by the Terrestrial Ecology Research Network AusCover Landscape Observatory project. A qualitative assessment of the accuracy of the LiDAR-derived fuel

maps found that the patterns in fuel cover compare well to the severity levels shown by dNBR. Key uses of the LiDAR fuel maps are for: 1) prescribed burn planning; and 2) wildfire suppression (Figure 1). A barrier to uptake of LiDAR by fire agencies is the relatively high cost of acquisition. The trials demonstrate that useful information can been obtained up to four years after acquisition.

Another use for LiDAR that is being trialled is the application of sub-canopy microclimate models for prediction of landscape flammability patterns. The input of shortwave radiation to the forest floor is a major driver of dead fuel moisture. Models which downscale shortwave radiation and temperature from regional weather observations require landscape attribute data (leaf area index, tree height, slope and aspect all derived from LiDAR) combined with gridded climate data. High resolution maps (25m) of monthly average shortwave radiation at the forest floor may assist by defining the likely area conducive to prescribed burning within a mountainous forest burn unit. In conjunction with these maps, ACT Parks will also trial a fuel moisture truthing or calibration method using 10-hour fuel sticks.

A formal research project of the BNHCRC that ACT Parks is the Australian Flammability Monitoring System (AFMS). The AFMS derives near real-time estimates of live fuel moisture and forecasts of flammability for the whole of Australia from 500m resolution MODIS data. The products are made available to users via a website (http://anuwald.science/afms/). A key use of AFMS is as an input to the new Australian National Fire Danger Rating System. It also has very good potential for improving implementation of prescribed burns, though experience suggests that 500m resolution is too coarse. Future plans are to develop a 20m resolution version of AFMS based on Sentinel 2. If this proposal proceeds, ACT Parks will evaluate the product for prescribed burn planning in conjunction with the new sub-canopy micro-climate model. Our expectation is that the two products will be complementary.

Remote-sensing products are transforming bushfire management practice in Australia. But at present, the products are often being used to derive analogues of metrics that were originally developed for human-scale collection, sometimes with great difficulty. We suggest that the next step is to develop new fire behaviour models that use metrics easily derived by remote-sensing.

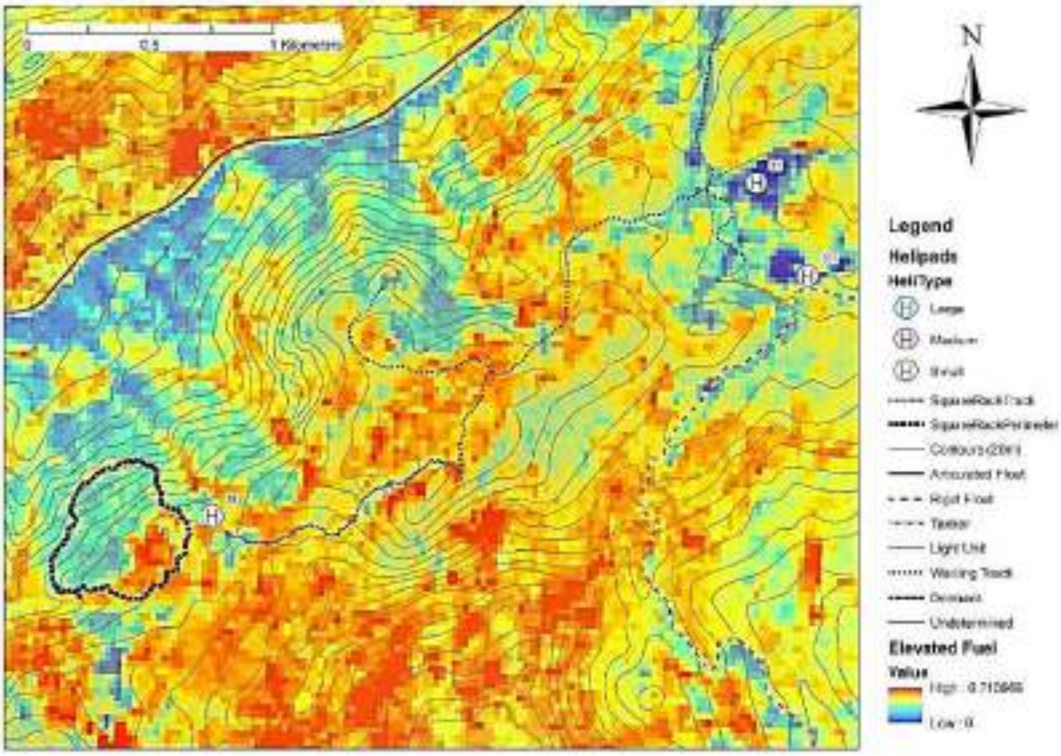

Figure 1. A LiDAR-derived elevated fuel (0.5m – 2.0m) map showing the distribution of fuel following a prescribed burn together with the perimeter of a wildfire that was ignited six years after the burn. The pattern of fuel suggested by the LiDAR was confirmed by firefighters on the ground and the information was used to plan the suppression effort. Fuel map also have value for planning construction of foot tracks, such as the one constructed to fight this fire, by allowing firefighters to avoid areas with heavy fuels

Correlating Sentinel-1 C-Band SAR and Sentinel-2 Multispectral Time Series for Burn Severity Estimation

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Digital I Earth I Observation
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Keywords: Burn Severity, Sentinel-1, Sentinel-2, Synthetic Aperture Radars (SAR), Multispectral Data

Abstract

Wildfires affect wide areas and their effects on the local ecosystem can be estimated with time series remote sensing data, including both multispectral (MS) and radar data. As a common measurement of fire effects to vegetation and soils, burn severity can be defined as the effect of a change event on an ecological community or a measure of the degree to which a site has been altered. The literature has demonstrated that the MS burn index is highly correlated to the near infrared (NIR) and short-wave infrared (SWIR) bands. However, cloud-cover and smoke may greatly reduce the frequency of effective sensing to vegetation situation. Compared to MS sensors, Synthetic Aperture Radars (SAR) occupy several advantages such as the sensitivity to the changes of vegetation structure and independence of cloud cover or solar elevation. In this study, our objective is to investigate the relationship between MS and SAR-based burn severity estimations, where time series profile of vegetation is used to model the variance range of stable historical time series before wildfire events happen. The preliminary investigation shows that MS and SAR-based burn severity estimations share high consistency in the high burn severity regions and lower consistency in the lightly burnt areas, and SAR and MS data has the potentials to serve as two complementary sources for estimating burn severity from two perspectives: scattering mechanism and living chlorophyll.

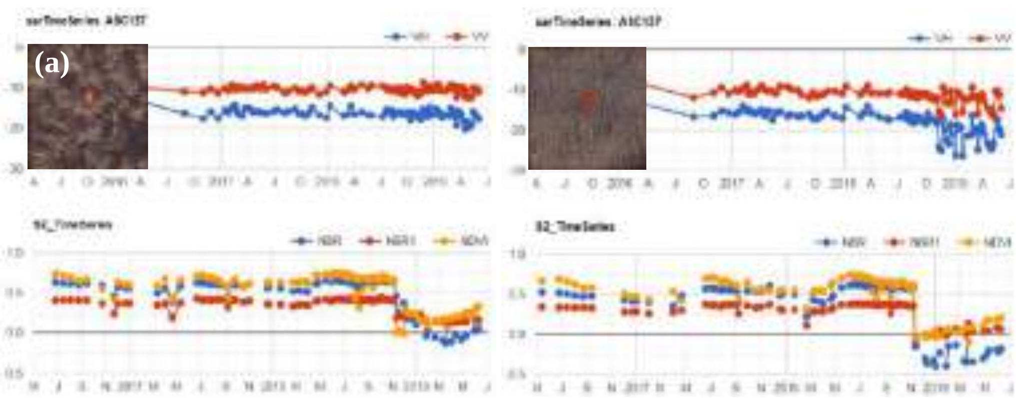

Figure 1. Temporal behaviour patterns of low and high burn severity regions: (a) SAR and MS time series of low burn severity region. (b) SAR and MS time series of high burn severity region. The comparison shows that MS time series is sensitive to both low and high severity forest areas, and high severity area show larger drop than low severity one, while SAR time series is less sensitive to low burn severity area and show high variance to high severity area. Preliminary observation indicates that SAR and MS-based SAR severity estimations show higher consistency in the high burn severity areas, and both SAR and MS data has the potentials to server as two complementary roles for improving the accuracy of burn severity estimation from two different perspectives by multi-source sensors.

Uni-temporal approach for fire severity mapping using multispectral simulated databases and Random Forests

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Digital I Earth I Observation
Abstract
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Keywords: Fire severity, Machine learning, Mediterranean ecosystem

Abstract

After a fire event, severity is one of the main variables demanded by forest management agencies because it influences the post-fire response. In a context where fire regimes are being modified and the destructive capacity of fires is expected to increase, a reliable fire severity assessment is vital to evaluate the impact of fire on ecosystems. Fire severity classification is usually undertaken through the identification of discrete categories in spectral indices, being the differenced Normalized Burn Ratio (dNBR) the most widely used. However, several shortcomings have been identified such as the lack of biophysical meaning of these intervals without specific field calibration or their inadequate prediction of second order effects in terms of vegetal regeneration and erosion. The quantification of the fractional abundance of post-fire ground cover types through spectral unmixing techniques overcomes many of these limitations but, on the contrary, its complexity is much higher because requires advanced data processing, a careful selection of endmembers and a highly supervised method to classify sub-pixel results in severity levels. Our study assesses the performance of ecosystem-specific simulated spectral databases for improving the accuracy of wildfire severity mapping through the development of empirical models with Random Forests (RF). In July 2015, we collected 455 field spectral samples of the dominant ground cover classes (green vegetation (GV), non-photosynthetic vegetation (NPV), soil and char) from different locations in the are burned by the Sierra de Luna fire (Aragón, Spain). Measurements in the 0.4-2.5 µm spectral range were obtained under natural illumination conditions with an ASD spectrometer. For the vegetation class, main species representative of the ecosystem were registered. This spectral library was resampled to Landsat 8-OLI and Sentinel-2A using the EnMAP end-to- end Simulation Tool (EeteS) accounting for sensor-specific band characteristics and signal-to-noise ratios. From the simulated spectral databases optimal endmembers (five per category) were selected using the Count-based Index (CoBI), the Endmember Average RMSE (EAR) and the Minimum Average Spectral Angle (MASA) techniques.

Four severity categories were modelled, based on levels of canopy consumption: unburned (UB), where only GV and soil endmembers are present; partial canopy unburned (PCU), where GV is still present but NPV and char appear from the partial consumption of the crowns; canopy scorched (CS), where GV disappears and canopy foliage is scorched; and canopy consumed (CC), where NPV disappears and the surface is covered by char. For these four classes, five iterations of 1000 mixed spectra were performed from the endmembers previously selected, randomly assigned to each iteration, and a shadow endmember. The 1000 mixed spectra were generated with fractional covers randomly assigned but fulfilling the constraints of each category. RF was applied in a twofold analysis: as a classification method of the four severity categories modelled and as a regression method for the quantification of the individual ground cover abundances. Classification and regression models developed from the simulated databases were applied to satellite images registered in the short post- fire environment for OLI and

S2A sensors. A contemporary Pleiades image (pan-sharpened VIS-NIR image of 0.5m spatial resolution) was used for validation. The RF classification for OLI data obtained an OOB estimate of error rate of 5.66% and a test set error rate of 14.55%, with the highest confusion for the CS class and a great importance of the NIR (band 5) and SWIR (band 7) regions. For S2A data the OOB estimate of error rate was 2.33% and the test error rate was 8.57%, with the highest error in the PCU class and a great importance of the SWIR (band 12), NIR (band 7) and red-edge regions (bands 6 and 7). Classification maps produced from the simulated datasets are quite comparable to the maps that would be produced from a direct RF classification of OLI and S2A satellite images (OOB estimate of error rate of 10.91% and 13.57%), indicating that using this indirect approach guarantees a correct classification of fire severity without the need of site-specific training. Regarding RF regression models, the accuracy levels obtained highlight the great capacity to estimate GV (R2 of 0.90 and 0.83 for OLI and S2A), soil (R2 of 0.89 and 0.77 for OLI and S2A) and char (R2 of 0.79 and 0.87 for OLI and S2A) and the moderate estimation levels for NPV (R2 of 0.46 and 0.45 for OLI and S2A). This RF regression outperformed the results obtained from Multiple Endmember Spectral Mixture Analysis (MESMA) applied to the same dataset for all ground covers, especially for NPV (R2 < 0.25). Our study shows that the development of ecosystem-specific simulated spectral databases could provide a robust method for mapping fire severity, with the only need of a single post-fire image. Furthermore, the automated implementation of this routine allows the rapid adaptation to other ecosystems and, in this way, its operational application in the context of forest management.

a)

		Predicted class			
		UB	PCU	CS	CC
Observed class	UB	83	17	0	0
	PCU	4	93	3	0
	CS	0	30	67	3
	CC	0	0	5	95

b)

		Predicted class			
		UB	PCU	CS	CC
Observed class	UB	95	5	0	0
	PCU	8	86	6	0
	CS	0	8	89	3
	CC	0	0	6	94

Figure 6. (a) confusion matrix of the RF classification for the L8-OLI test set (values in percentage) and (b) confusion matrix of the RF classification for the S2A test set (values in percentage)

Remote sensing of forest fires: operational applications in the matter of repression of the phenomenon

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Abstract
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Keywords: Fire, Earth observation, inverse propagation fire algorithms, fire injection point

Abstract (STYLE: Heading Abstract)

Forest fires in Portugal have become a serious environmental problem in recent years. According to the Annual Report 2017 Repression of forest fires, passes trough virtual reality, indeed the new functions of environmental Simulator located in Carabinieri Forestry School of Castel Volturno (CE), make possible refine and improve operator's training in crime investigation on forest fires.

Simulation platform uses forest ecosystems sceneries attacked by fire in an interactive virtual reality environment, according to the teaching methods used in the so-called "Serious Games".

The system creates an "immersive" simulation environment : a space of about 200 square meters where is simulated the execution of the judicial police technical activities developed by the Carabinieri Command for Forest Protection through its specialized unit called NIAB (Forest Fire Information Unit).

This initiative will allow an improvement in the generation and management of post-forest fire sceneries, by means of a greater effectiveness of the training courses, through a deeper involvement of the learner and a greater ability to evaluate the results by the instructors.

The system will automatically position the Physical Evidence generated by the forest fire, using for this purpose the M.E.G. algorithm, Geometric Evidence Method, developed by the Department of Agriculture of the Federico II University of Naples in collaboration with the NIAB of the Carabinieri Command for Forest Protection .

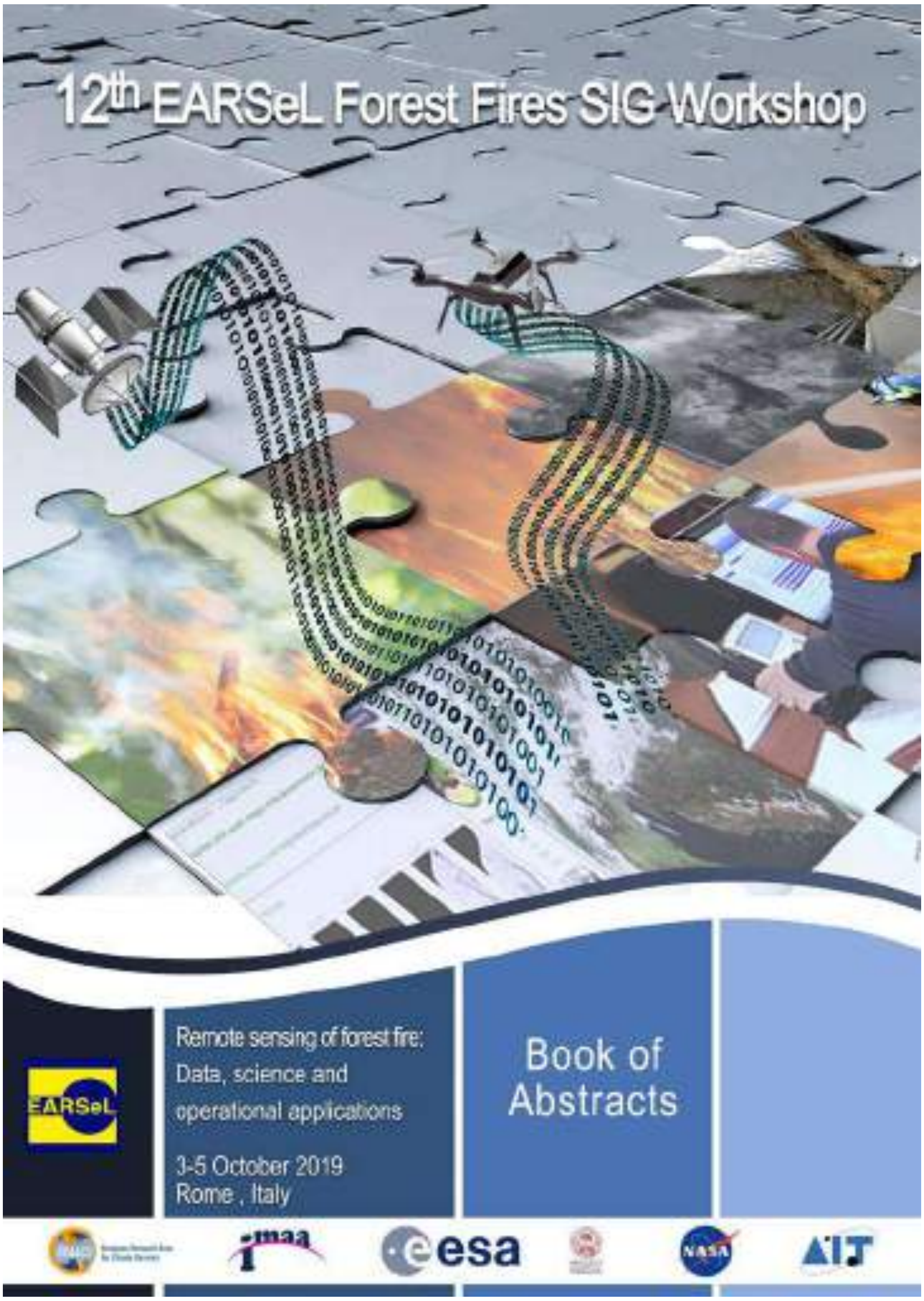
In detail, the virtual reconstruction of the forest fire will apply the correlation rules of the MEG algorithm between wind, land orography, forest vegetation models.

This action will guarantee the Carabinieri Corp a reduction in training and specialization times of the CUFA military personnel, who will be able to take advantage in the real time virtual reconstruction of the environmental crime scene generated by the simulator.

The implementations to be carried out will allow the director operator to quickly generate the NIAB training scenery, simply by providing the following information:

- Indication of the point of ignition of the flames;
- Start time and duration of the fire;
- Weather conditions during the event (temperature, rain, wind);
- Actions of AIB operators generated during shutdown activities.

The placement of the simulator at the Carabinieri Forestry School of Castel Volturno strengthens the presence of the Corps in a territory in strong demand for legality and social requalification. The Castel Volturno environmental simulator is the only training center, in the world, dedicated to the training of specialized personnel in the methodologies of technical retrieval on the forest stands crossed by fire, aimed at identifying the point of ignition of the flames, in order to allow investigators to determine the causes of the forest fire.



EARSEL

REMOTE SENSING OF FOREST FIRE DATA, SCIENCE
AND OPERATIONAL APPLICATIONS

SESSION: EXPLORING FIRE-RELATED FOREST DYNAMICS

Exploring fire-related forest dynamics in the Aosta Valley (Italy) through multivariate analysis and linear trends of Landsat time series

EARSeL 2019
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KEYWORDS: LANDSAT VEGETATION INDICES, SPECTRAL TREND, FOREST DISTURBANCE DETECTION, POST-FIRE FOREST RECOVERY

Abstract

Large crown fires in the Aosta Valley region mostly occur in south-facing slopes where xeric conditions favour the presence of highly flammable conifer stands dominated by Scots pine (Pinus sylvestris). Because of the availability of large fuel amounts and prolonged drought periods, during recent years fires also occurred in North-facing slopes, which are usually less prone to wildfires. Stand-replacing wildfires affected about 20% of the total burned forests between 1989 and 2017 and the natural regeneration of Scots pine has been often observed to be limited due to ecological and anthropogenic factors. Landsat TM, ETM+ and OLI images from 1985 to 2018 with less than 80% cloud cover were collected to assemble a one-year interval time series. The geometric median compositing algorithm was employed to generate a synthetic image at the pixel-level for each vegetative season, spanning from June to September. Forest dynamics due to fire occurrence and recovery were explored through different spectral vegetation indices. A novel index named Robust Distance to Forest (RDF) was developed to detect both abrupt changes caused by fire and gradual spectral changes due to post-fire forest recovery. RDF is equal to the Mahalanobis distance of a pixel from the spectral response of undisturbed forest cover and it's computed by performing a robust estimation of the multivariate location and scatter with respect to the Tasseled Cap Wetness (TCW) and the Tasseled Cap Angle (TCA) band transformations. A reference forest cover map was created for each year of the time series by locating stable forest pixels from the Copernicus Tree Cover Density map produced in 2015 at 20m spatial resolution resampled to match the 30m Landsat grid. The interval of tree cover percentages selected as reference ranged from the most represented tree cover density in the studied region to its maximum value. Multiple change-points corresponding to linear trend changes in the spectral indices time series were detected using a novel bottom-up approach in which a wavelet basis is adaptively constructed by merging neighbouring segments of the data. This method doesn't require a priori knowledge of the time series parameters making it fully automated. The RDF linear trends were compared to those obtained using the widely employed Normalized Burn Ratio (NBR). Results showed that RDF is effective in detecting abrupt spectral changes at different disturbance magnitudes providing a similar sensitivity compared to that of NBR. Moreover, RDF highlighted an enhanced sensitivity toward post-fire forest recovery dynamics, exhibiting slower recovery rates compared to that shown by NBR trends. This determines that RDF generally takes longer to recover its pre-fire values compared to NBR, as displayed in figure 1. Moreover, RDF trends often exhibited differences between early and advanced stages of forest recovery, suggesting a different sensitivity toward the development of herbaceous and shrubby cover, compared both to tree canopy closure and to biomass increments. Being RDF dependent on the spectral characteristics of the forest cover, its values should be more informative about the abundance of forest cover itself compared to that of normalized spectral vegetation indices such as NBR. Future work is expected to provide a rigorous and wide scale-based assessment of the index capabilities to track post-fire forest recovery and will be likely

based on the integration of field data and remote-sensing data such as recent high-resolution tree cover maps and LiDAR measurements of forest structure.

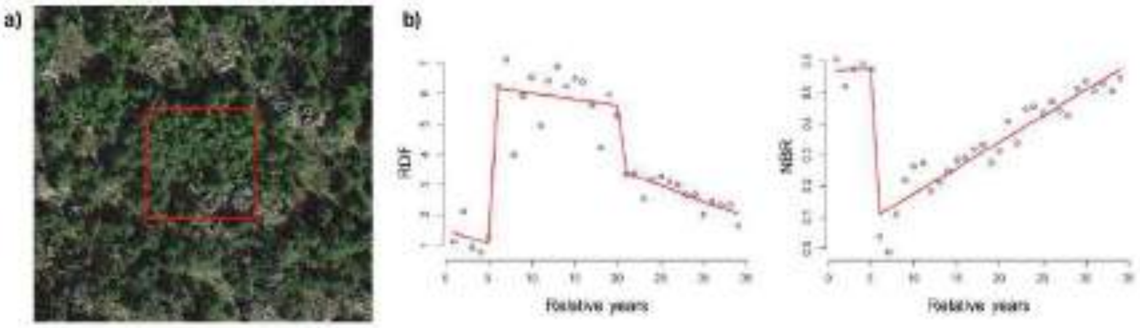

Figure 7. (a) Young forest regenerating after a stand-replacing wildfire occurred in 22/3/1990 in the municipality of Chatillon (Aosta Valley) within a Landsat pixel (red contours) superimposed on a Google Satellite image acquired on 3/9/2017. (b) Time series of RDF and NBR indices (grey points) relative to the selected Landsat pixel with segmented linear trends (red lines). Linear trend changes indicate both fire occurrence during the 5th year of the time series (1990) and the subsequent stages of forest recovery.

Evaluation of satellite time series spectral and temporal segmentation methods for fire disturbance detection and mapping

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Keywords: forest fires, burned area mapping, satellite imagery, time series analysis, cloud computing

Abstract

Continuous monitoring of terrestrial ecosystems is of primary importance for assessing current conditions of vegetation dynamics, for detecting disturbances and for predicting future changes. Forest fires are considered one of the most severe ecological disturbances, and as such detailed and timely spatial information is required for analyzing the spatial and temporal patterns of fire occurrence and for studying fire behaviour due to climatic variations. Satellite remote sensing has been widely utilized in fire- related applications during the past decades with many studies focusing on the exploitation of multi- temporal datasets for burned area monitoring. Initially, coarse resolution imagery from sensors such as MODIS and AVHRR were extensively used due to their high temporal resolution. However, in the recent years there is an increase in methods relying on analysis of higher spatial resolution optical imagery, mainly from Landsat and Sentinel-2 sensors, due to their free access policies. Taking advantage of dense series of imagery is considered essential for extracting accurate spatio-temporal profiles of vegetation and therefore for assessing reliably both short and long-term effects of forest fires. Advanced techniques for analyzing time-series trends have been developed, while emerging cloud-oriented tools and technologies for managing geospatial datasets are becoming available to the scientific community.

In this study, we investigate the efficiency of two algorithms, which are widely utilized in detection of seasonal and trend changes of ecosystems, for mapping burned areas in a Mediterranean ecosystem with the use of long-term series of Landsat images. An important objective of this study was to assess the overall effort from the user's perspective considering that one of the algorithms was implemented through the cloud-based Earth Engine computing platform and the other was locally applied. The study area was the island of Thasos in northern Greece, an island that has been severely damaged by forest fires during the last 30 years, almost in its entirety. The analysis was conducted for the years 1986 to
2005 and Landsat 5 Thematic Mapper (TM) images were used to derive NDVI (Normalized Difference
Vegetation index) values.

The first method was based on the BFAST (Breaks For Additive Seasonal and Trend) algorithm which integrates statistical models and logistic regression for decomposing time series and detecting significant breaks and trends. The Level-2 surface reflectance Landsat 5 TM images that were acquired, were additionally pre-processed with the use of specific libraries included in the BFAST software package, to remove cloud and shadow pixels. Then, the BFAST algorithm was applied locally to monthly Landsat NDVI series after performing necessary parameterizations and adaptations to the original code. This resulted in producing spatial maps of time and magnitude of changes due to fires. The second method that was tested is the LandTrendr (Landsat-based

Detection of Trends in Disturbance and Recovery) algorithm through the cloud-based Google Earth Engine (GEE) platform. This algorithm is designed to be applied in dense Landsat time series and perform spatial and temporal segmentation at annual rate. Within the GEE platform, all available Landsat 5 TM images were pre-processed and NDVI images were derived for each year using the Euclidean spectral distance median, after performing additional user-defined parameterizations. The results included spatial maps of time, magnitude and rate of recovery for detected fire disturbances. Both applications were assessed for their accuracy in fire detection and burned area mapping, as well as for the overall effort required by the user, including computation times and level of expertise.

Results and Recommendations from the Wildfire Remote Sensing Workshop at the EO Summit 2017 in Montreal

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Abstract
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Keywords: remote sensing, Earth Observation, wildfire management, carbon emission reporting, smoke and air quality forecasting

Abstract

A three-day wildfire remote sensing workshop as part of the Earth Observation Summit 2017 in Montreal, brought together a wide breadth of representation in the field of applications and research in remote sensing for wildfire management.

The workshop had eight topical presentation sessions, two keynote speakers and two panel discussions. The panel discussion topics were, "Bridging Research & Reality" and "Air, Ground and Space Helping Each Other Out".

Through the active participation from more than 50 attendants from Canada, The United States, South Africa, The United Kingdom, France and Belgium, the workshop identified thirty needs, challenges and lessons learned. Thirteen key recommendations were made.

The goal of this presentation is to share the findings of the three-day wildfire remote sensing workshop that took place in Montreal in 2017, with the audience of the current workshop, to spark further conversations on these shared topics.

WildFireSat – Unlocking the Potential for a Global WildFire Monitoring Constellation

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Digital I Earth I Observation
Abstract
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Keywords: remote sensing, Earth Observation, thermal infrared, wildfire management, carbon emission reporting, smoke and air quality forecasting

Abstract

To increase its capability to monitor wildland fires, the Government of Canada has initiated the first step of the development of a satellite system dedicated to wildfire monitoring. This system, called WildFireSat, will provide data for the whole of Canada on a daily basis, more specifically in the afternoon when fire activity is at its peak. Data users such as the Canadian Forest Service (CFS) for wildfire management purposes, and Environment and Climate Change Canada (ECCC) for carbon emission reporting and smoke and air quality forecasting purposes, will have access to the data within 30 min of data acquisition.

Apart from its direct benefits, WildFireSat is meant to serve as a steppingstone towards the achievement of a longer-term goal: the realization of a future, potentially commercial, satellite constellation that would provide global, continuous, near real-time wildfire monitoring services.

WildFireSat could help prepare the user community in Canada and possibly abroad, and thus create the user base that would be needed to make a strong business case for a global operational wildfire monitoring satellite constellation. Other nations are invited to join the WildFireSat initiative and to help pave the way towards a global initiative.

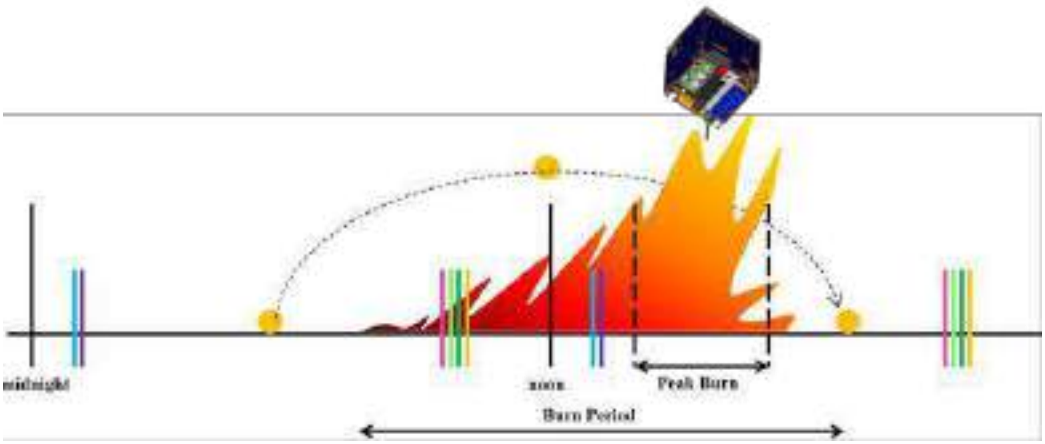

Figure 1. (a) Distribution of polar-orbiting satellite overpasses within the diurnal fire cycle. Coloured bars approximate the overpass times of MODIS Terra (dark green) and Aqua (blue), VIIRS Suomi-NPP (purple), SLSTR Sentinel 3-a,b (light green), Sentinel-2 (orange) and Landsat-8 (pink). WildFireSat aims to fill a crucial gap in peak burn fire monitoring, and to be used in conjunction with existing systems.

Semi-automatic fuel break monitoring with Sentinel-2 imager

EARSeL 2019
Digital I Earth I Observation
Abstract
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Keywords: change detection, monthly compositing, time series analysis, Google Earth Engine, QGIS, random forests, neural network

Abstract

A fuel break (FB) is a strip of land that has been strategically modified, in which vegetation density is reduced to break up the continuity of fuel. It acts as a barrier to slow or stop the progress of wildfire, thus improving fire control opportunities. The Portuguese National Forest Fire Protection Plan defined a primary FB system estimated to include 130,000 hectares when completed. This network consists of linear clearings (with a minimum width of 125 m) along ridges and strategic topographical breaks designed to provide more effective firefighting locations. To fulfil this goal, FBs must be maintained over time. Monitoring such a large, countrywide network can only be efficiently achieved by new satellite missions, which provide unprecedented capabilities for monitoring fuel treatments and biomass accumulation in the FBs.

This work aims to develop a semi-automatic monitoring system of the Portuguese primary FB network based on Sentinel-2 imagery, due to its unique time-frequency (5 days) and spatial resolution (10 m), particularly important for the case of narrow linear structures, such as FBs.

Image pre-processing includes cloud and shadow masking (Sen2Cor algorithm) and pixel geolocation correction (Single-step Discrete Fourier Transform algorithm). The geolocation errors may occur at the subpixel level and with 1.5 pixels of maximum offset. Due to the narrow dimensions of the FBs and the spatial resolution of the images, this means that 10% of the data used may not be from the FB.

A selection of the most adequate bands was performed, based on variance analysis and spectral separability. Several vegetation indices were also tested, including the Normalized Difference Vegetation Index (NDVI), the Normalized Difference Index, the Enhanced Vegetation Index, the Excess of Red Index and the Modified Excess of Green Index (MExG). Band B03 (Green) and MExG showed the lowest correlation. Band B11 (SWIR1) also proved to be reasonably independent from band B03. MExG and NDVI revealed to give different signals during and after the interventions.

Three alternative methodological approaches have been evaluated for five test areas of the Portuguese primary FB network with different vegetation types and primary productivity, whose locations follow a north-south gradient. All approaches rely on change detection techniques that will allow mapping fast disturbances in the FBs (e.g. mechanical fuels treatments and prescribed fires) and slower processes, such as biomass accumulation in the treated areas.

In the first method (M1), the pre-processed images are used to extract monthly maximum NDVI composites. The difference of the pre- and post-disturbance composites allow identifying abrupt drops of the vegetation indices values within a month (Figure 1.a). A pixel-based Random Forest classifier is then trained using the difference images and their relative post disturbance composite. The information of treated and undisturbed areas inside and outside the FB, selected over the whole country and for different periods of the year, is used to construct an exhaustive and representative training dataset. This

classification shows promising results (Figure 1.b), allowing to identify monthly interventions for a whole year.

The second method (M2) exploits the information of the full time series from all available images in each FB pixel. The characteristic signal of an intervention is a sudden drop followed by a slow recovery of vegetation indices values (Figure 1.c). Neighbour pixels from a buffer of 100m around the FB line are used as a reference of NDVI behaviour. The variation that is not explained by phenological patterns is interpreted as a human or wildfire disturbance, depending on its spectral behaviour.

The third method (M3) detects the interventions in the entirety of the FB, divided into segments and using an Artificial Neural Network. First, homogenous segments within the FB are extracted. Then, for each segment, the mean value of the bands and the indices are computed. To use a regular time-step, a period of one month is defined for the detection, where the median value for each period is calculated. The previous month values for each segment are also used, with the goal of training the classifier for changes in the normal behaviour of the vegetation, which are caused by an intervention (Figure 1.c, d and f).

The processing chain is automatized in two platforms. M3 runs with the Python interface of QGIS, and promptly indicates if a ground observation is needed. However, if the FB segments are not correctly defined the quality of the detection may degrade. M1 and M2 are run in Google Earth Engine and do not need a manual definition of the segments. Plus, M2 does not need any training area.

The final goal is to develop an efficient monitoring system by comparison and possible aggregation of those three methods. The semi-automatic nature of the procedure will allow its application to the whole country and to other Mediterranean countries where FB monitoring is needed, such as Spain, Greece and the South of France.

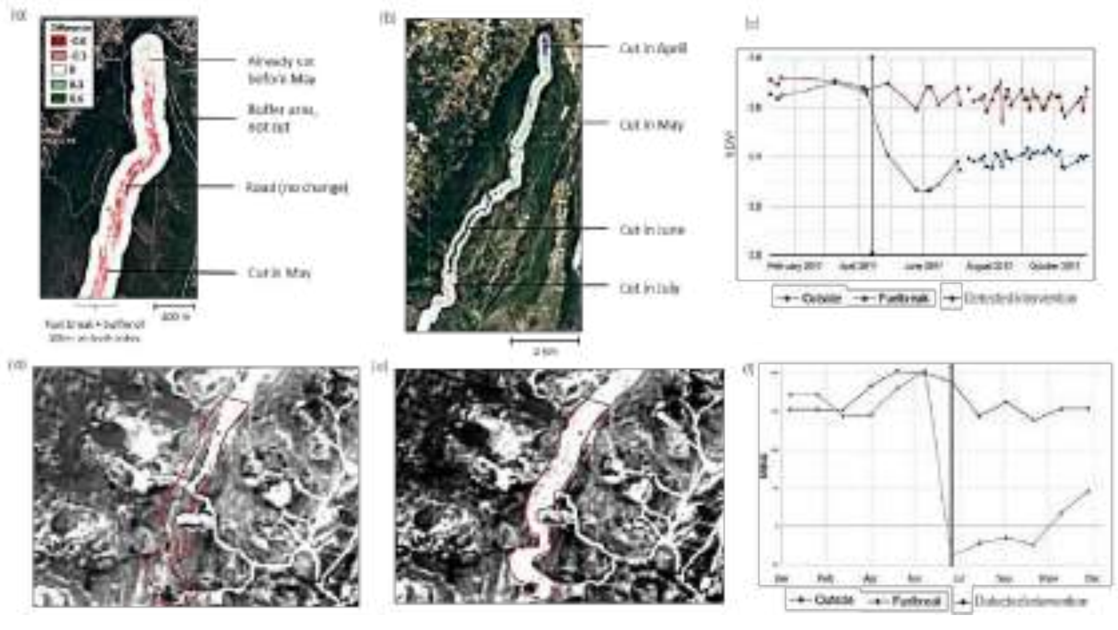

Figure 1. Examples of application of the three methods. M1: (a) Monthly maximum NDVI composites difference (June - May); (b) Disturbances detected for 4 months with a Random Forest pixel-based classification. M2: (c) Comparison of intervention (FB) and phenological (Outside) NDVI signals in a full time series. M3: (d) FB segment before intervention (Green Band, June); (e) after intervention (July); (f) Temporal Evolution of the Modify Excess of Green in 2017 with detected month of intervention.

Assessment of fire-induced mortality of Russian forests based on multi-year time series of MODIS data

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Digital I Earth I Observation
Abstract
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Keywords: Russian forests, fire, burnt area, burn severity, forest mortality, remote sensing, MODIS, data time series

Abstract

Wildfires annually affect millions of hectares of forests and other terrestrial ecosystems in Russia. A burnt area and trees mortality are key parameters to characterise wildfires and critical inputs for both fire management and post-fire impact assessment, including economic and environmental consequences.

The IKI has developed based on multi-annual time series of 250 m MODIS data number of thematic products, which conjointly provide opportunity to quantify impact of wildfires on forests over the entire country. This set of MODIS derived thematic products includes in particular annually updated maps of burnt area and forest burn severity along with land cover types. These products allow deriving in particular a multi-annual country-wide statistics on characteristics of fires and burnt area considering different land cover types. The burnt severity data provide fire impact estimates in terms of trees mortality in respect to various forest types. The time series data provide new information about changes of fire regimes in the forest ecosystems of Russia considering geographical pattern of fires, their frequency and size, as well as burnt area and fire-induced forest die-back for the period of years 2006-2018.

A multi-annual average of burnt area in Russian forests has been estimated based on MODIS data at 5.46×106 ha. Further refinement of forest burnt area estimate has been achieved through combination of MODIS data and samples of Landsat-ETM+/QLI-TIRS images. In particular for fires of year 2013 the Landsat-ETM+/QLI-TIRS based burnt area mapping results have been combined with MODIS derived wall-to-wall burnt area map, which led to about 40% increase of total forest burnt area in the country. Tacking this incremental rate into account we estimated the annual average of burnt area in the Russian forests at about 7.64×106 ha. This annual average forest burnt area value is significantly higher than earlier published estimates and up-to-date we are considering it as a most complete and reliable assessment at the entire country level.

Based on our assessment the total fire-induced forests loss area in the period of years 2006-2018 is about 33x106 ha, while its inter-annual variations is ranged between 0.57x106 ha and 6.67x106 ha with maximum in year 2012 (figure 1). The annual percent of fire-induced forest loss varies in range from 27.6% until 67.4% with multi-year mean at 49.9%.

Our analysis has shown also that spring fires provide maximum contribution into total forest burnt area, while summer fires are most destructible with forests mortality peak in July. The multi-year averaged seasonal pattern of fire-induced forest mortality rate is clearly demonstrates lower destructivity of spring and autumn fires in comparison to summer ones.

Fire-caused forest mortality is significantly depends on tree species. It has been shown that about 50% of burned area and 62% of forest fire scars accounted for larch ecosystems. Coniferous forests and especially dominated by dark needleleaf tree species are demonstrated significantly lower level of fire resistance in comparison to deciduous broadleaf forests.

These results support forest science and can be used to develop a fire protection strategy in Russian forests.

The study was supported by the Russian Science Foundation (project no. RSF-19-77-30015).

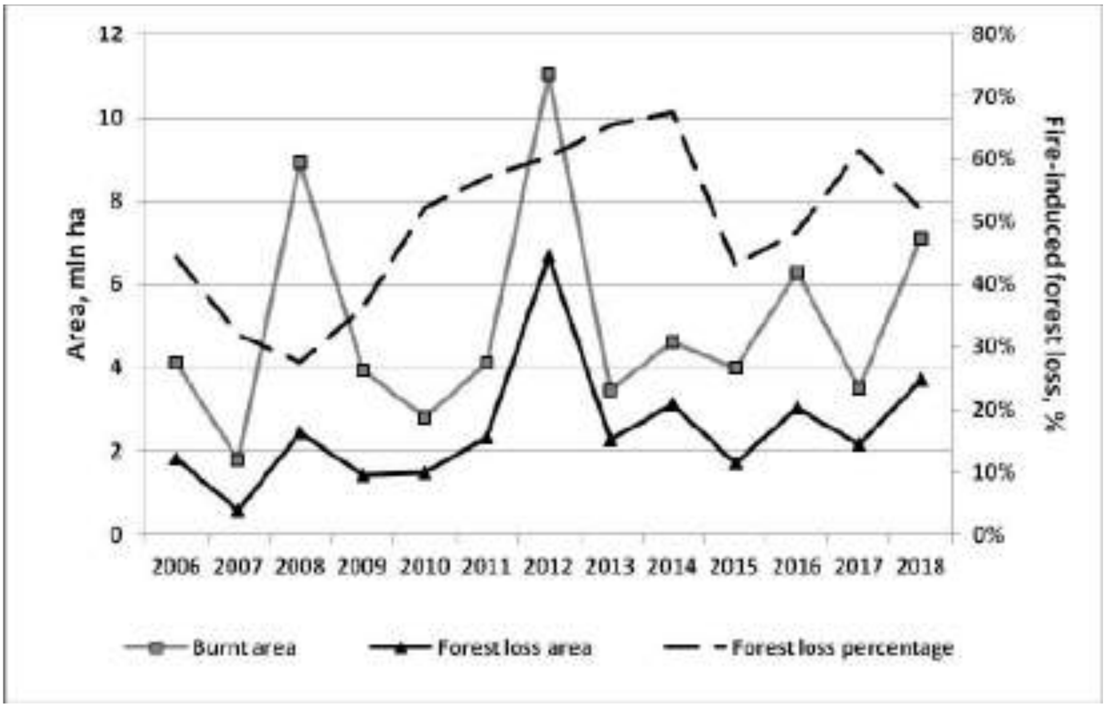
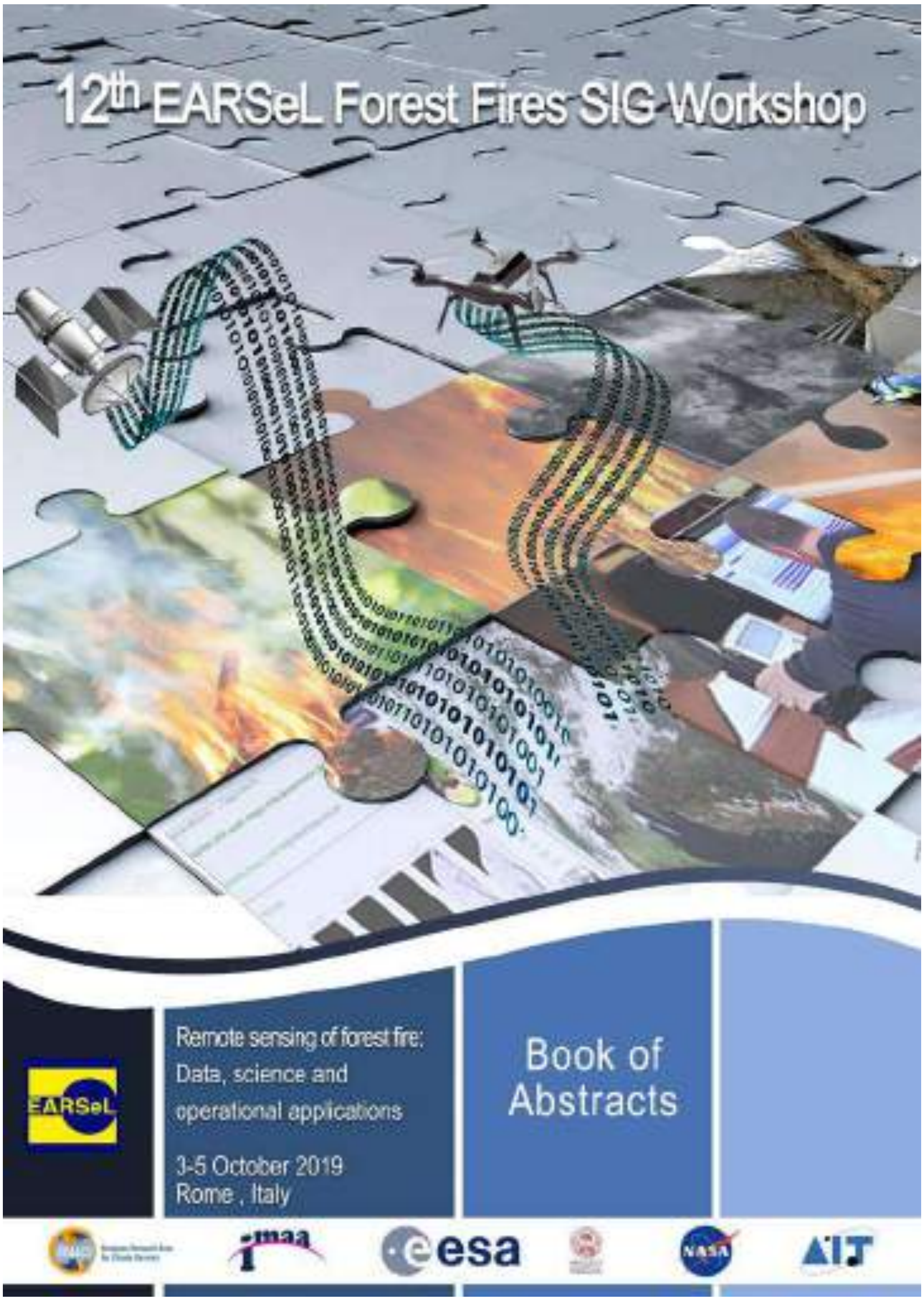


Figure 8. Inter-annual area variations of forest burnt and fire-induced forest loss in Russia



EARSEL

REMOTE SENSING OF FOREST FIRE DATA, SCIENCE AND OPERATIONAL APPLICATIONS

POSTER SESSION

Forest fire susceptibility modelling using boosted regression tree data mining technique

EARSeL 2019
Digital I Earth I Observation
Abstract
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Keywords: Spatial modelling, data mining technique, GIS, Iran

Abstract

This study aims to consider forest fire susceptibility in an important province of southern Iran using boosted regression tree (BRT) data mining techniques. At first, forest fire inventory map (FFIM) prepared using satellite images including Landsat 8 and MODIS, national reports, and also field surveys. In total, 358 locations identified as fire areas and then divided into two data-sets including training (705) and validation (30%). For forest fire spatial modelling, ten effective factors selected. These factors are elevation, slope, topographical wetness index, aspect, distance from urban areas, annual mean temperature, land use, distance from road, annual mean rainfall, and distance from river. The BRT data mining technique used for forest fire spatial modelling in R statistical package version of 3.5.1. The results showed that 53.00, 20.37, 11.27, and 15.36% of studied area classified as low, moderate, high, and very high susceptibility (Figure 1). By the way, accuracy results indicated that the built forest fire map has an AUC value of 88.2% indicating very good class of the ROC curve (Figure 2). Also, in the current study tried to assess variables importance using the LVQ (Learning Vector Quantization) machine learning algorithm. The LVQ results reveal that land use, annual mean rainfall, and slope angle were the most useful divers on forest fire in the Fars Province. So, the final forest fire map can be used for land use planning and management of forest resources in this province.

Fig.1

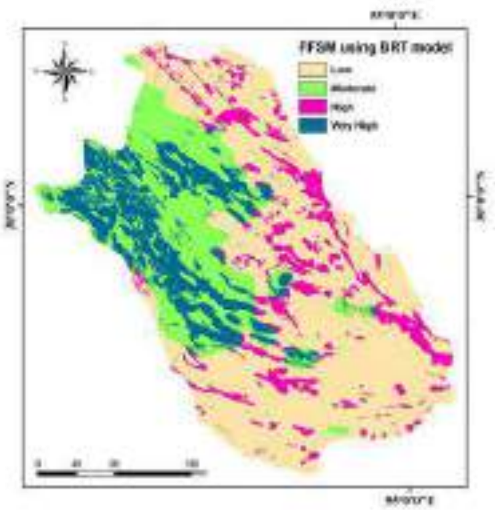

Fig.2

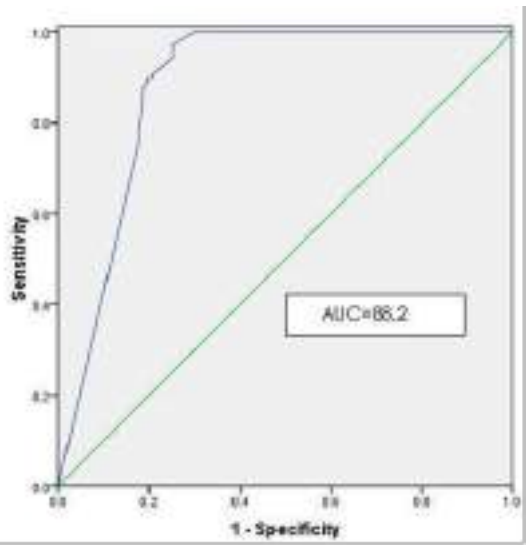

Figure 1. Forest fire susceptibility map created by the BRT data mining technique

Figure 2. The AUC value of the BRT data mining model

The use of Random Forest classifier for the mapping of burnt areas based on satellite sentinel 1 and sentinel 2 data

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Keywords: Sentinel 2, Sentinel 1, fire severity, classification, Random Forest

Abstract

Forest fires in Portugal have become a serious environmental problem in recent years. According to the Annual Report 2017 drawn up by EFFIS (European Forest Fire Information System), the number of fires that occurred was around 21002 for a burned area of about 540630 ha; in 2018 the burned areas decreased, but 37436 hectares have been affected however. In this paper, the study area is located in southern Portugal, particularly in the Algarve region. The event took place in August 2018, it damaged the town of Monchique and burned down about 27,000 ha. The satellite data used for this case study are the optical images and SAR images (respectively Sentinel 2 and Sentinel 1 of the ESA Copernicus program), which have different resolutions, to better understand how the two sensors return different information based on the processing of the data. The identification and mapping of the surfaces affected by fire is based on the recognition of the spectral response of the burnt vegetation, that is different from the response of the unburnt surface. In this case we used vegetation spectral indexes such as NDVI (Normalized Difference Vegetation Index), the NIR-SWIR index to estimate the water content of vegetation, as the fire causes a strong decrease in the content of humidity of plants and soil, so as to obtain the subdivision of it in the different classes of risk.

We also use other indexes such as NBR (Normalized Burn Ratio), concerning the NIR reflection pattern with an increase in infrared reflection, the BAI (Burned Area Index) which has a higher sensitivity to distringuish the burned areas from everything different such as bare soils, areas not very vegetated or areas with various ground covering; this let us underline the signal of the burned areas, allowing us a satisfactory and accurate classification. A comparison was made between the limits values of the normalized combustion ratio (dNBR) and the normalized differential vegetation index (dNDVI) (from pre- and post-fire images).

This study wants to demonstrate that the spectral indexes return information about the valutation of the risks, fire and burn severity, characterizing the entity of the damage,but they are not adequate for greater discrimination of the burnt areas and of the damaged they went through. However, dNBR can present problems in areas with low pre-fire vegetation cover, where the absolute change between pre-fire and post-fire NBR is not significant, so we applied an additional RBR index (Relativized Burn Ratio), in which the relativized version of the gravity of the fire is advantageous for our classification.

On the latter, new Machine Learning techniques were being applied, with a particular attention to the Random Forest, a special classifier formed by a set of simple classifiers represented as independent and identically distributed random element. This procedure allows us to obtain better classification accuracy. It is important to carefully choose the attributes to be provided to the Random Forest as they must be as significant as possible. Our features are determined by the results of the mapping of the burned area from which, thanks to the RBR (Relativized Burn Ratio), we obtained the different levels of fire severity; these levels are catalogued by the United States Geological Survey (USGS), which proposed a classification table to interpret the severity of burns.

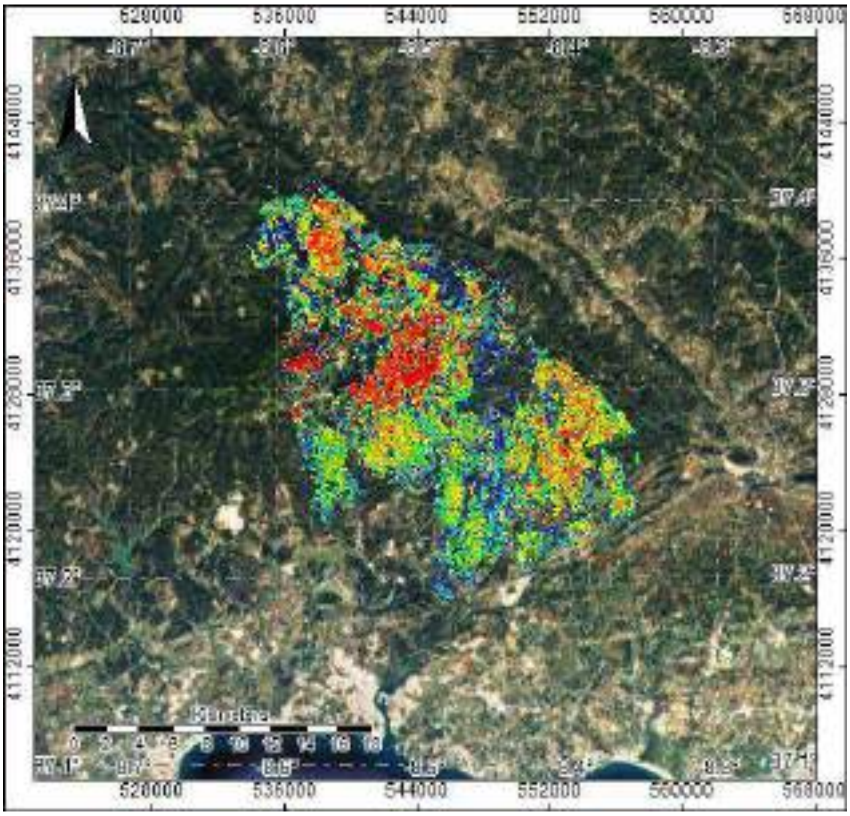

Figure 1. Relativized Burn Ratio (RBR) index: different levels of fire severity

New methods for burnt severity extraction from satellite data: The Self-Organizing Map

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Keywords: Self-Organizing Map, burnt severity, Remote Sensing

Abstract

Satellite data capturing fires contains multidimensional and heterogeneous informations. In literature it is still difficult to treat with this type of data and obtain a well-defined extraction. This is still more difficult for burnt severity classes automatic extraction. Classically there are many indices that can be derived. Recently in other application fields, new works and methods were proposed for the visualization [1], dimensionality reduction and classification of satellite data. Between these, Self- Organizing Map (SOM) [2] is an unsupervised type neural network, belonging to Geovisual-analytics.

In this work the SOM was used in combination with spectral indices classically used in literature: NDVI, NBR and BAIS. This allowed to extract burnt severity classes in an automatic way and without the need to fix threshold.

The method was tested on different study cases, that are located in different parts of the world: 1) Portugal, 2) Italy and Argentina, 3)

On the impacts that fire on soil and hydrogeological risk: the case study of Basilicata Region

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Keywords: Fire, satellite, soil degradation, post fire damage, landslides

Abstract

Fire represents one of the main disturbances to Mediterranean ecosystems, bringing profound transformations at different temporal and spatial scales including, vegetation cover, landscape, ecosystems, soils, etc. Moreover, climate change is expected to bring increased forest fire risk by altering the water cycle at seasonal time scale, by increasing the occurrence of prolonged droughts and heat waves in the Mediterranean basin, as well as in Alpine ecosystems and boreal forests, with severe environmental and economic consequences. Managers need to be aware of the impacts that fire can have on soil systems, and how these impacts can lead to undesired changes in site productivity, sustainability, biological diversity, and watershed hydrologic response. For this reason providing reliable and qualified information on the impact of fire on vegetation and soil and related changes is crucial to maximize post fire risk prevention and related potential damage.

In this paper, we present outputs from research activities we conducted in the framework of the FIRESAT project (funded by the Office of Civil Protection of the Department of Infrastructure of the Basilicata Region) in the context of burn severity mapping addressed to the estimation of post fire damage mainly for the (i) assessment of the impact of fire on soil and hydrological risk and (ii) to support the definition of mitigation strategy.

At local scale, managers need to be aware of the impacts that fire can have on soil systems, and how these impacts can lead to undesired changes in site productivity, sustainability, biological diversity, and watershed hydrologic response. For this reason, the availability of reliable and timely information on fire affected areas and burn severity (and expected changes) is crucial to mitigate post fire damage and optimize strategies related to post fire damage management.

The full exploitation of data provided by the diverse satellite sensors (MODIS, TM, ASTER; Sentinel 1 and 2), ancillary information and data base, with specific reference to the landslides catalogues, are integrated with all the available information (in digital and non-digital format) within a GIS environment for the elaboration, integration and publication(via a webgis. Statistical analysis on the co-occurrence of fires and landslides enable us to assess the impact of fire events on the landslide susceptibility and to provide useful information for improving landslides risk estimation and mitigation strategies. As an example, Figure 1 and 2 show the co-occurrence of fires and landslides as assessed for the 2011 and 2012 in the Basilicata Region.

Figure 1. Co-occurence of fires and landslides (orange dots in the figure) as assessed for the 2011 events in the Basilicata Region

Figure 2 Co-occurence of fires and landslides (red dots in the figure) as assessed for the 2012 events in the Basilicata Region

Satellite based burnt areas and burn severity mapping: preliminary results in the framework of SERV-FORFIRE project

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Keywords: Burnt areas , burn severity, Sentinel 1, Sentinel 2, SERV FOR FIRE projects

Abstract

The recent Copernicus (Sentinel) missions and information access services (Copernicus -DIAS) provide advanced data and systematic updated information suitably to develop innovative applications and to obtain timely information for risk management and resource monitoring, with particular reference to forest fires. Fires represent a serious environmental, economic and social problem that in recent years, also due to climate changes, tends to increase, causing more and more damage (at various time and space scales) not only to vegetation, but also to soil (accentuating the processes of erosion, desertification and increasing the hydrogeological fragility of the slopes), atmosphere (they are one of the causes of greenhouse gas emissions) and ecosystem functionalities.

In this paper, we present and discuss the preliminary tools we devised for the automatic recognition of burnt areas and burn severity developed in the framework of the EU-funded SERV-FORFIRE project (https://servforfire-era4cs.eu/) funded by EU in the framework of ERA4CS (http://www.jpi-climate.eu/nl/25223459-SERV_FORFIRE.html).

Remote sensing of burned areas has been traditionally based on optical data and actually, up to now, significant efforts have been addressed from the major national and international space agencies to space, so that several open products are currently made available by NASA (see for example http://modis-fire.umd.edu/index.php), ESA (see for example http://www.esa.int/About_Us/ESRIN/World_fire_maps_now_available_online_in_near-real_time), EFFIS in the framework of the Copernicus initiatives.

Traditionally satellite based investigations on fire have been mainly based on the use of NOAA/AVHRR, MODIS/TERRA and AQUA, ATRS, AATRS, MERIS, SPOT/VEGETATION, TM, ASTER, due to their technical characteristics (i.e. spectral, spatial, and temporal resolution). Moreover, microwave active and passive data have been also used. In the framework of SERV_FORFIRE project both optical and SAR have been used for mapping burnt areas and burn severity. The data processing is mainly based on the use of multitemporal satellite based indices obtained from both sentinel 1 and sentinel 2. The Sentinel based indices are further processed using Local Indices for Statistical Analysis (LISA) and unsupervised (ISODATA) classification to automatically categorize and map burnt areas and burn severity without using fixed threshold values.

One of the most important expected advantages of our approach compared to the traditional ones is that both burned areas and the different levels of burn severity can be identified automatically and without using fixed threshold values. This is a particular critical issues, because as suggested by many authors such fixed threshold values are generally not suitable for fragmented landscapes and inadequate for vegetation types and geographic regions different from those for which they were devised.

Our findings pointed out that the use of Sentinel 1 and 2 data did allow us to develop standardized burn-severity maps for evaluating fire effects and addressing post fire management activities and post-fire restoration strategies according to the magnitude of the damage and the condition of the affected site.

Integrated services and approaches for assessing effects of climate change and extreme events for fire and post fire risk prevention

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Keywords: fire and post fire risk seasonal forecast, mitigation strategy, forecasting simulations, emissions, burned areas

Abstract

SERV_FORFIRE has the aim of creating an international collaborative community, to share the best methodologies related to the fire and post fire risk prevention. Experts in remote sensing of soil and vegetation, risk management and mitigation, and climate change are joined under this project to provide information to stakeholders and users to better understand and manage fires. The core activities are the seasonal fire occurrence model development, the Post fire risk assessment and the implementation of the joint activities among partners. Monitoring and mitigation strategies are shared at European and local scales also investigating pilot areas selected in Europe as well as in Argentina and China

SERV_FORFIRE Joint Activities is taken place in Pilot Areas which have been selected in South and North European geographical regions:

- Finland
- EASTERN ATTIKA (Greece)
- Basilicata (Italy)
- Tuscany (Italy)
- Czech Republic

During the two years of activities, these main highlights have been achieved:

- seasonal and sub-seasonal forecasts of fire and post-fire risks such as landslides and erosion, for improving mitigation strategy;

- an operational service for decision making by water authorities, researchers and general stakeholders such as the developed drought-monitoring and forecasting system;

- Forecasts of particulate matter emissions from wildfires worldwide, useful in global-scale air quality forecasting simulations.

Acknowledgements

The activities were carried out within the project SERV_FORFIRE that is part of ERA4CS, an ERA-NET initiated by JPI Climate, and funded by FORMAS (SE), DLR (DE), BMWFW (AT), IFD (DK), MINECO (ES), ANR (FR) with co-funding by the European Union (Grant 690462). The investigations have been performed jointly with Protezione Civile of the Basilicata Region. Special thanks to Guido Loperte for providing logistic support and fire data.

Analysis, interpretation and discussion on mismatch of Fire severity mapping from UAV, Sentinel -2 and EFFIS: case studies in the Basilicata Region

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Abstract
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Keywords: Fire severity, Sentinel-2, EFFIS, MODIS, UAV

Abstract:

The purpose of this study is to compare the fire severity between EFFIS (Modis) and Sentinel-2 through the use of UAV (Unmanned Aerial Vehicle) for the validation of data. The study case is on a wildfire of 15th July 2019 near the urban centre of Pisticci (Matera, Basilicata, Italy).

EFFIS (European Forest Fire Information System) has been part of the EU Copernicus programme since 2015, as part of the Emergency Management Service (EMS), and involves all European and extra-EU countries. The identification of the areas burned during the fire season is verified through the Rapid Damage Assessment (RDA) system that uses the daily images of Modis sensors, with a spatial resolution of 250m.

Furthermore, the mapping of burnt areas with Modis images does not show any distinction between forest fires, environmental fires and prescribed fires. This non-differentiation causes some inconvenience to the user who has to work on the case to be investigated. Fire severity is estimated using the Difference Normalized Burnt Ratio (dNBR) as described by Key and Benson but dNBR is not enough to estimate the damage. EFFIS provides important information about the event, such as (i) geographical location, (ii) the beginning and the end of events, (iii) the extent of damage, (iv) the quantity of hectares burned. The lack of discrimination of the event type and the spatial resolution of Modis data makes this information sometimes not accurate. EFFIS (Modis) data report the event as a hotspot with an average fire severity level, which mainly involved agricultural areas (33.7%) and "other natural areas" (66.3%).

The use of Sentinels 2, with a spatial resolution of 10m, allows to better identify burnt area, through the use of spectral indices such as NDVI, NBR and OSAVI, making the comparison of pre- and post-fire indices. Analysis of Sentinel-2 images returned values of low vegetative coverage ($0.1 < NDVI < 0.3$), with an abundance of bare soil and shaded areas ($-0.6 < OSAVI < 0.1$) and a moderate-low fire severity ($0.27 < dNBR < 0.35$).

Flight operations were carried out on 1st August 2019 using a Parrot Disco Ag Pro fixed-wing UAV equipped with a Parrot Sequoia multispectral camera. Parrot Sequoia camera has five sensors: (i) four 1.2 megapixel sensors that allow to acquire images in Green (550nm), Red (660nm), Red-Edge (735nm), and Near Infrared (790nm); (ii) one 16 megapixel RGB sensor. The survey was conducted in a flat area, chosen within the burnt area as sample, in order to facilitate the take-off / landing operations of the drone. The flight covered 0,092km2 / 9,2ha. The UAV flew at a constant height of 60 m above ground level, acquiring 932 multispectral images with 75% frontal and lateral overlap. The data processing was carried out using Pix4D mapper Pro software (version 4.4.12), useful for the creation of georeferenced (i) orthophotomosaics, (ii) point cloud, (iii) DEM and (iv) reflectance maps. The multispectral outputs have a GSD (Ground Sampling Distance) of 6.91cm/pixel and were used for the processing of several indices and images within SAGA (System for Automated Geoscientific Analysis) software.

A High Resolution False-Colour Infrared image were created (R: Nir, G: Red, B: Green), in order to observe the real situation of the area; while the multispectral bands have been combined to obtain indices (NDVI, NDRE, OSAVI) useful to discriminate between live green vegetation, bare soil and burnt area. The high resolution image shows that the fire has involved a small area of Mediterranean vegetation and stubble, leaving unburned forest, olive trees and cultivated fields. Pixels with a negative value or close to zero occupy 19.8% of the image(1,76ha) and most of them are produced by shadow (south, west and north-west); bare soil is 52,28% (4,97ha), and low vegetation/grass and forest are 27,92%.

The data collected by the drone, even if with a different resolution, are close to those acquired by the Sentinel images. In both cases the effects of Fire Severity seem much less critical than those described by EFFIS and the bare soil/rock is the major component of the area. The usefulness of EFFIS is well documented on large events, where the classification of the Fire Severity is accurate, but loses its effectiveness on small events (≃70ha), failing to calculate an accurate Fire Severity due to the resolution of the Modis sensor. For this reason, in the case of small events or hotspots, an accurate classification of the burnt area still requires the use of higher resolution tools, such as Sentinel-2 or UAV.

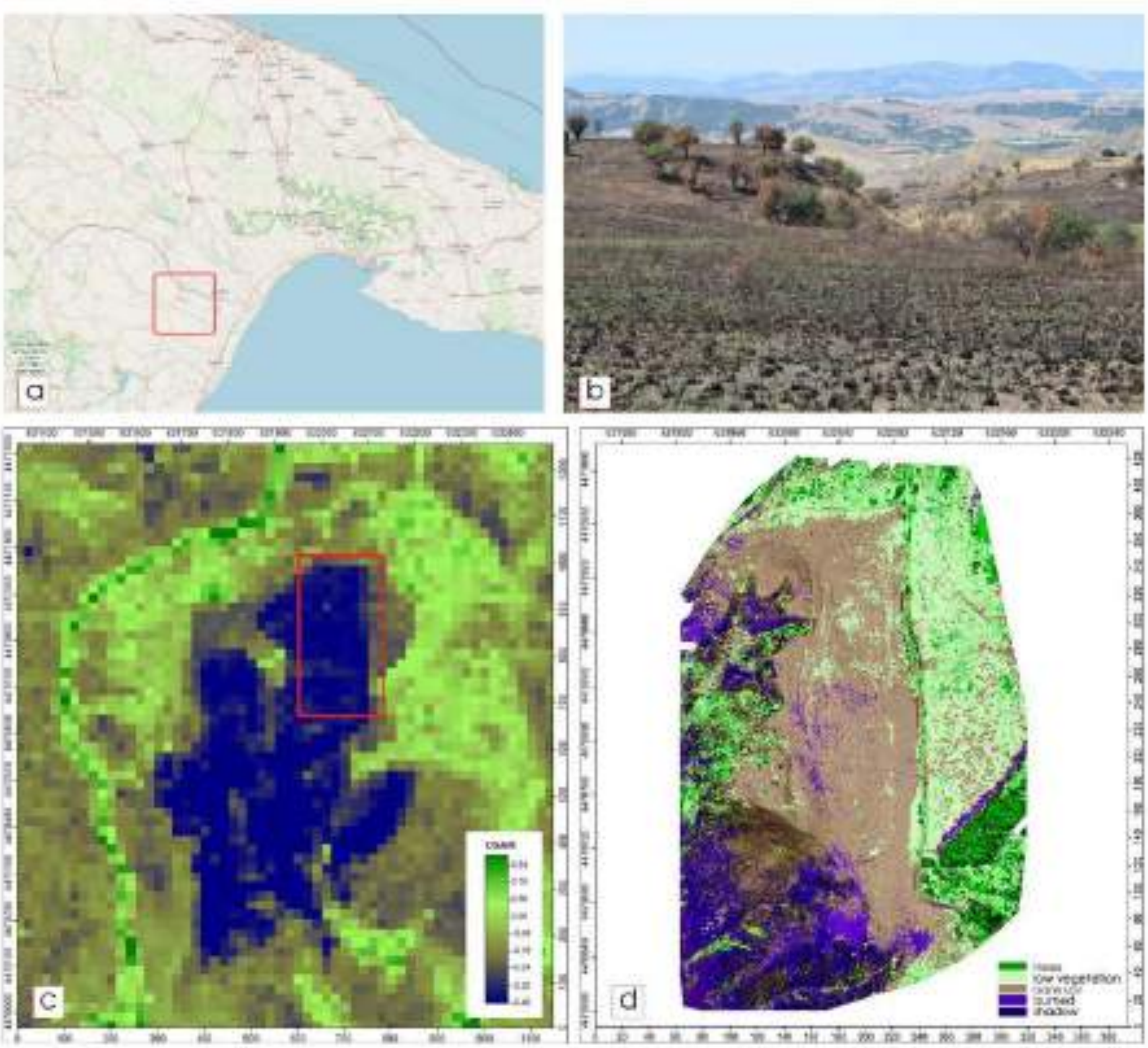

Figure 9. **a.** Pisticci (Matera, Basilicata, Italy); **b.** View of burnt area (1st August 2019); **c.** Sentinel-2 OSAVI index; **d.** UAV OSAVI index.

Fire emission Estimation using Landsat TM: the case study studies of 2011 Fires occurred in the Ionian coast (southern Italy)

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Abstract
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Keywords: FIRESAT, LandsatTM, fire emission

Abstract:

Fires are considered as one of the most important causes of degradation being that they induce significant alterations not only on the vegetation cover but also on fauna, soil, atmosphere thus producing high direct and indirect damages including economic ones. At a global scale, yearly 50 million hectares of forest are burnt producing a significant impact on global atmospheric pollution, being that biomass burning contributes to the global budgets of greenhouse gases, like carbon dioxide, etc. Actually, wildfires contribute to carbon emissions and human-induced climate change, a process that is likely to cause progressive aridness of parts of Europe with increased risk for wild fire and subsequent secondary disasters such as erosion, floods and landslides. At a global scale forest fires produce a remarkable amount of greenhouse gases and solid particulate matter.

Current and future challenges of wildfire contrast and governance, oriented to a comprehensive approach to limit fire incidence, can be addressed creating a system focused on social and ecological resilience and based on reliable and update information on fire occurrence and characteristics, including the assessment of fire damage with specific reference to the missions from forest fires which depend on (1) the duration and intensity of the fire, (2) the total area burnt by the fire, and (3) the type and amount of the burnt vegetation generally referred to as fuel load. In our study case, we used the fuel load mapping developed for the Basilicata region in the framework of FIRESAT project based on Landsat TM data and assessed the burnet areas using Landsat TM data acquired before and after the fire event. The assessment of the emission is based on the formula:

E x = F(A, B, C, E)

Where: - Ex emission of compound x –

A burnt area (m2) – estimated from landsat

B fuel load (g dry matter m-2) – estimated from Landsat (in terms of Fuel load as developed for the Basilicata in the framework of FIRESAT project)

C burning efficiency – estimation from, landsat (in terms of fire severity)

E emission factor (g g-1 dry matter burnt) for which we used CO, CH4, VOC, NOx, N2O and SOx taken from the current state of the art as available in Miranda et al. (2005).

Acknowledgment

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Archaeology on fire. Remote sensing base approach for the damage analysis: the case of Ventarron in Peru

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Keywords: Fire, archaeological heritage, satellite, drone

Abstract:

Recently wildfires and burned areas have increased dramatically throughout the world affecting even more frequently urban-rural interface areas and more often cultural heritage. Fire risk assessment at a local scale should will include and support management of cultural heritage sites threatened by wildfires. Recent improvements in earth observation techniques offer data which can enable new applications specifically for the documentation, assessment and monitoring cultural heritage. In particular, the availability since 2000 of satellite Very High Resolution data along with the unmanned survey can suitably support quantitative evaluations of fire risk and fire impact on cultural heritage.

Historical buildings and monuments are usually characterized by materials with low resistance to fire, whereas the archaeological sites are almost mainly made up of stone and/or brick masonry structures, but often archaeological sites are (i) located in extra-urban contexts adjacent to vegetated areas, wooded or cultivated, which due to their potential vulnerability to ignite may constitute a risk factor for any adjacent archaeological areas, (ii) 'protected' by structures made using construction materials with low resistance to fire.

The fire event occurred in 2007 close to Olympia (Greece) represents an emblematic case of an interface fire that, not only affected vegetation, but also caused damage to the adjacent urban areas, including the archaeological site.

This paper deals with an emblematic case of interface fire occurred in Lambayeque region, in Northern Peru, on November -2017, which devastated Huaca-Ventarron, including a mural painting believed to be the oldest discovered in the Americas. Huaca Ventarrón, built from 4600 to 3500 before the present, is considered the cradle of prehispanic civilization in Northern Peru, due to its sophisticated architecture and first use of mural art in America.

Ground documentation, drone flights (figure 1e) and satellite acquisitions (figure 1abcd) showed that the fire was caused by the burning of weeds of a sugar company in the contour of the fields, adjacent to the archaeological monument. The fire began as part of the regular work of burning fields. It was also found that the burning of weeds was not controlled and spread for more than 200 meters in favor of the wind. The fire in its uncontrolled route reached the roofs of the warehouses located on the west side of the archaeological site. Immediately afterwards, the fire spread rapidly and became uncontrollable due to the flammable nature of the material used on the roof covering the archaeological structures (Figure 1f-g).

The Peruvian Ministry of Culture announced an official investigation to determine who was responsible for the fire. To this end, remote and proximal sensing tools, from satellite data to images acquired from drones, could help to identify responsibilities, destructive dynamics of the event, possible errors in the management of agricultural fields. With such regard, the multitemporal data set (figure 1 a-d) available from Google Earth evidenced that before 2016 March (figure 1a-b), the area where the fire started, was not cultivated and characterized by sparse herbaceous cover, with a (conscious or unaware?) function of firebreak. From March 2016 up the fire event the plot of land adjacent the

archaeological site was covered by cultivations (figure 1c), eliminating the fire cut function that probably would have made the fire less destructive.

Figure 1 - (a-d) Satellite multitemporal data set; (e) aerial image taken from drone (courtesy by Ignacio Alva); (f) roof of the monument on fire (courtesy by Ignacio Alva); (g) Damage caused by the fire (courtesy by Ignacio Alva)