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Operational Wildfire Monitoring and Disaster Management Support Using State-of-the-art EO and Information Technologies

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***Abstract*—The National Observatory of Athens (NOA) has been established in Greece as a research institute offering, among others, operational services for disaster management of forest wildfires. In this paper the main activities of NOA related to fire monitoring and the Burn Scar Mapping damage assessment services are presented. The current capacities in delivering fire-related products and services are greatly enhanced by the integration of state-of-the-art Information Technologies, which provide the potential of refining the thematic accuracy of our products, allows the connection to other distributed databases for the generation of new and innovative added-value products, and suggest the establishment of an operational system that can be extended to include other applications related to natural disaster management.**

Keywords- emergency response;emergency support; fire monitoring; burn scar mapping ; semantics; database technologies

I. INTRODUCTION

Fires have been one of the main driving forces in the evolution of plants and ecosystems, determining the current structure and composition of the landscapes [1, 2]. However, significant alterations [3] in the fire regime have occurred in the recent decades, primarily as a result of socioeconomic changes, increasing dramatically the catastrophic impacts of wildfires as it is reflected in the increase during the 20th century of both, number of fires and the annual area burnt. Therefore, the establishment of a permanent robust fire monitoring system is of paramount importance to implement an effective environmental management policy.

Such an integrated system has been developed in the Institute of Astronomy, Astrophysics, Space Applications and Remote Sensing of the National Observatory of Athens (IAASARS/NOA). Volumes of Earth Observation images of different spectral and spatial resolutions are being processed on a systematic basis to derive thematic products that cover a wide spectrum of applications during and after wildfire crisis, from fire detection and fire-front propagation monitoring, to damage assessment in the inflicted areas. The processed satellite imagery is combined with auxiliary geo-information layers and meteorological data to generate and validate added-value fire-related products. The service portfolio has become available to institutional End Users with a mandate to act on natural disasters in the framework of the operational Global Monitoring for Environment and Security (GMES) projects SAFER[1] (Services and Applications For Emergency Response) and LinkER (Supporting the implementation of operational GMES services in Emergency Response) addressing fire emergency response and emergency support needs for the entire European Union. Towards the goal of delivering integrated services for fire monitoring and management, IAASARS/NOA employs observational capacities which include the operation of MSG/SEVIRI and NOAA/AVHRR receiving stations, NOA's in-situ monitoring networks for capturing meteorological parameters to generate weather forecasts, and datasets originating from the European Space Agency and third party satellite operators.

The qualified operational activity of IAASARS/NOA in the domain of wildfires management is highly enhanced by the integration of innovative Information Technologies that have become available in the framework of the TELEIOS (EC/ICT) project[2]. Through this activity a fully automatic processing chain has been developed reliant on, a) the effective storing and management of the large amount of EO and GIS data, b) the post-processing refinement of the fire products using semantics, and c) the timely creation of fire extent and damage

[1] http://www.emergencyresponse.eu/
[2] http://www.earthobservatory.eu/

thematic maps. These technologies are built on top of a robust and modular computational environment, to facilitate several wildfire applications to run efficiently, such as real-time fire detection, fire-front propagation monitoring, rapid burnt area mapping, after crisis detailed burnt scar mapping, and time series analysis of burnt areas. The approach adopted allows IAASARS/NOA to routinely serve requests from the end-user community, such as Civil Protection and Forestry Services, irrespective of the location and size of the area of interest, the observation time period, or the size of data volume involved, granting the opportunity to combine innovative IT solutions with remote sensing techniques and algorithms for wildfire monitoring and management.

II. FIRE MONITORING

A. *Fire monitoring service architecture*

NOA has been developing a real-time fire hotspot detection service for effectively monitoring a fire-front. The technique is based on the use of acquisitions originating from the SEVIRI (Spinning Enhanced Visible and Infrared Imager) sensor, on top of MSG-1 (Meteosat Second Generation satellite) and MSG-2 satellite platforms. Since 2007, NOA operates an MSG/SEVIRI acquisition station, and has been systematically archiving raw satellite images on a 5 and 15 minutes basis, the respective temporal resolutions of MSG-1 and MSG-2. The fire monitoring service architecture is depicted in Fig. 1.

The distinct processes, from acquiring raw satellite imagery to final product generation are outlined:

- The ground-based receiving antenna collects all spectral bands from MSG-1 and MSG-2.
- The raw datasets are decoded and temporarily stored in the METEOSAT Ground Station.
- The application SEVIRI Monitor manages the data stream in real-time by offering the following functionalities: a) Extract and store the raw file metadata in an SQLite database, b) Filter the raw data files and dispatch them to a dedicated disk array for permanent storage, c) Remotely trigger the processing chain [4] to derive hotspots, and d) dispatch these hotspot products to the disk array and additionally store them to a PostGIS database.

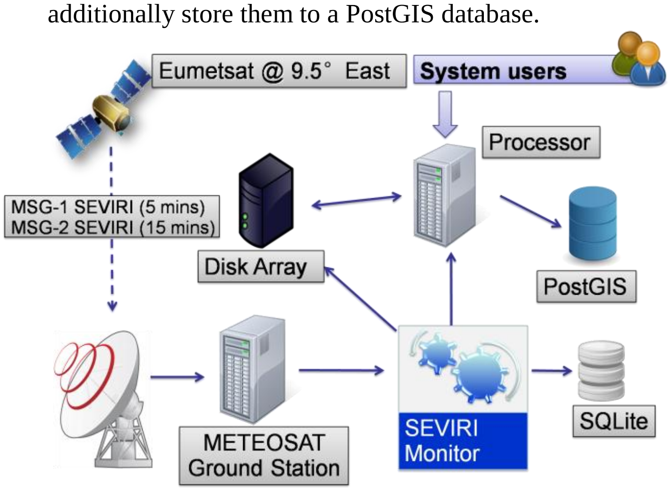

Figure 1. Fire monitoring service architecture of NOA

- Dissemination to the end user community (civil protection agencies, regional authorities) through a web application.

B. *Typical fire monitoring products*

Final products are both in raster and vector format cropped to the area of interest – Greece in this scenario, georeferenced to the Hellenic geodetic reference system (HRGS 87) and classified to fire and potential-fire pixels according to EUMETSAT's recommendation [4]. Characteristic examples of such products are presented in Fig. 2.

III. BURN SCAR MAPPING

A. *Methodology*

Since 2007, NOA has been generating products for accurate burnt area mapping at prefecture, regional and country level all over Greece, on an operational basis with remote sensing techniques. Using Very High Resolution (e.g. Formosat, IKONOS, WorldView-2) and High Resolution (Landsat 5 TM and SPOT) satellite imagery, a robust processing chain has been developed to produce damage assessment thematic maps [5, 6], named BSM_NOA technique.

The applied BSM_NOA method was developed and deployed in the framework of the GMES European programme, and aims at contributing to a standardised and homogeneous mapping of burnt areas in the EU member states.

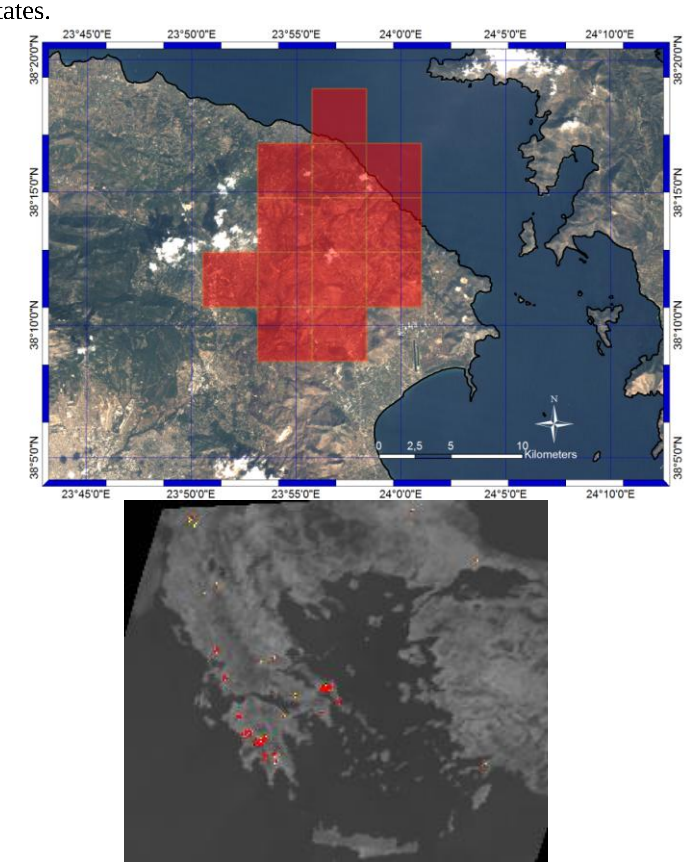

Figure 2. (top) Vector hotspot layer depicting fires that occurred in 2009 at northeastern Attica, and (bottom) raster overview of the 2007 Peloponnesus forest wildfires. Red pixels correspond to 'fires', whereas yelow to 'potential fires'.

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The technique allowed to accurately and rapidly assessing damages in areas extending up to 225,814.8 ha in less than 2 months, for the entire Greek territory during the time period 2007-2011. Assessing burnt areas in Greek mountainous regions is a difficult task due to landscape complexity, highly accentuated morphology and the heterogeneity and mixture of land cover. Previous attempts for burnt area mapping using conventional surveying methods allowed only partial and rough assessments of burnt areas.

B. Mapping products and analysis

The service provided burn scar maps at high spatial resolution (20-30 m pixel size, spatial accuracy of ~40m, minimum detected fire size of 1 ha) and very high spatial resolution (2-8 m pixel size, spatial accuracy of 4-10m, detected fire size of 0.5 ha), as well as damage assessments at prefecture level in respect to the existing Corine Land Cover (CLC 2000) database. Damage assessment products for selected sever forest wildfires are shown in Fig. 3.

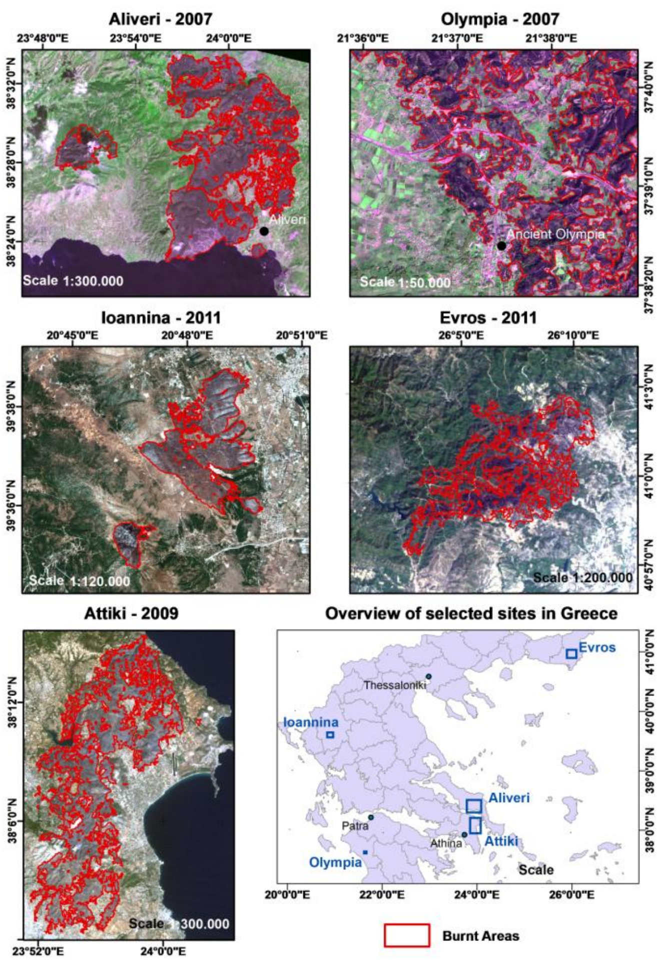

Figure 3. Damage assessment for selected fire events in the period 2007-2011.

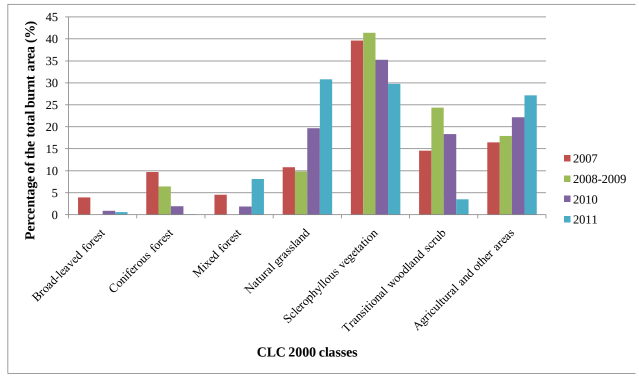

Figure 4. Analysis on the land cover types burnt for the period 2007-2011

A classification of the burnt areas based on the CORINE Land Cover maps was performed for each service year, in order to assess the vulnerability of different classes to wildfires and estimate the degree of land cover change in the Greek territory. In Fig. 4 this analysis is presented, highlighting the detrimental effect of the wildfires on the natural ecosystem of Greece in the last five years.

IV. INFORMATION TECHNOLOGIES

NOA as a service provider, aims at delivering reliable and comprehensive information for fire related emergency situations to constitutional end-users. Provision of such services on a systematic basis calls however for an integrated approach, where qualified processing chains are supported by a robust infrastructure. This infrastructure consists of a system encompassing state-of-the-art Information Technologies (IT), reliant on i) the effective storing, processing and management of the large amount of EO and GIS data, with a robust and user-friendly system that will allow the integration and customization of the available capacities, ii) post-processing refinement of the fire products using semantic rules, in order to increase the thematic accuracy of the delivered fire-products, and iii) creation of thematic maps and added-value services, via the combination of diverse information sources.

These are expected to be achieved in the TELEIOS ICT project, for upscaling the existing service capacities of NOA. TELEIOS main innovation is the development of a Virtual Observatory infrastructure that goes beyond the current state-of-the-art in EO portals and Image Information Mining systems. This will be achieved by combining advanced image mining, database, geospatial and semantic web technologies. The envisaged service architecture is depicted in Fig. 5. The main IT advancements anticipated are:

- The data vault, responsible for the ingestion policy, enabling the efficient access to large archives of image data and metadata in a fully transparent way, without worrying for their format, size and location.
- The backend of the system consisting of MonetDB[3] and Strabon[4] for:

[3] www.monetdb.org

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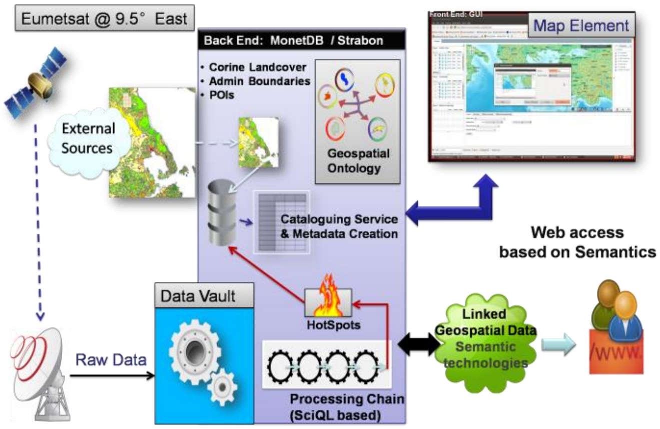

Figure 5. Envisaged service architecture in the framerork of TELEIOS

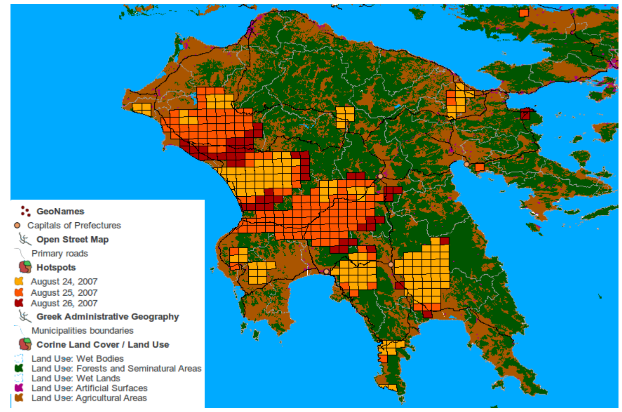

Figure 6. Thematic map produced by combining locally stored fire products with geospatial layers found in distributed databases.

- the implementation of processing chains using the SciQL query language [8] for image processing operations.
- the evaluation of semantic queries for improving the accuracy of the products and generating thematic maps, based on stSPARQL [7].
- a geospatial ontology which links the generated hotspot products with stationary GIS data (Corine Land Cover, Coastline, Greek Administrative Geography), and with linked geospatial data available on the web (LinkedGeoData, GeoNames), expressed in OWL.

- The front-end interface, for controlling the back-end functionality with user-friendly tools, and disseminating the products to the end-user community.

A. *Semantics*

The system relies on the model stRDF, an extension of the W3C standard RDF that allows the representation of geospatial data that change over time. stRDF is accompanied by stSPARQL for querying and updating stRDF data, based on OGC standards [7]. These technologies are implemented on top of the Strabon system and are used for:

- Product refinement using semantics - Use spatio-temporal reasoning for a) identifying and eliminating hotspots occurring in non-consistent underlying land use (e.g. urban or agricultural areas), b) attributing a variable confidence level to each hotspot according to its spatio-temporal persistence, and c) deleting false alarms in the detection of burnt areas.
- Generation of thematic maps using Linked Data, by posing stSPARQL queries which connect distributed datasets with NOA's fire products, as more and more organizations expose their data as Linked Data. An example of such a product is presented in Fig. 6.
- Posing complex semantic queries. An indicative query would be to "Find an image taken by a MSG satellite on August 25, 2007 which covers the area of Peloponnese and contains hotspots corresponding to forest fires located within 2 km from a major archaeological site".

B. *Database technologies*

SciQL [8] is a new SQL-based query language for scientific applications with arrays as first-class citizens, implemented on top of the state-of-the-art MonetDB database. SciQL uses multi-dimensional arrays to represent EO data of various processing levels. This allows us to store EO data (e.g. satellite images) in the database, and query and manipulate their content transparently within the high-level declarative database query language. This has three important advantages. First, it allows us to express low level image processing (e.g., cropping, resampling, geo-referencing, etc.) as well as image content analysis (e.g. feature extraction, pixel classification) in a user-friendly high-level declarative language that provides efficient array manipulation primitives. Second, it opens up these algorithms to be optimized by the DBMS's query optimizer. Third, using the seamless integration and symbiosis of relational tables and multi-dimensional arrays, query processing and knowledge discovery can exploit both image metadata (tables) and image data (arrays) at the same time.

V. CONCLUSION

This paper highlights the operational capacities of the National Observatory of Athens, in delivering high quality thematic products to the end-user community, for fire monitoring and damage assessment after forest wildfires. The current capacities established in the framework of SAFER project are enhanced through the TELEIOS project with the use of semantic and database technologies, by refining the thematic accuracy of the generated products, connecting them to other distributed geospatial databases, and allowing of easy integration of new processing modules using the purpose-built MonetDB.

[4] http://www.strabon.di.uoa.gr/

ACKNOWLEDGMENT

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