

## Letter

### A MODIS assessment of the summer 2007 extent burned in Greece

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Devastating fires affected Greece in the summer 2007, with the loss of more than 60 human lives, the destruction of more than 100 villages and hundreds of square kilometres of forest burned. This Letter presents a map of the extent burned and the approximate day of burning in Greece mapped by the MODIS burned area product for 22 June to 30 August 2007 and the burned areas mapped independently by the European Forest Fires Information Service (EFFIS). The characteristics of the two datasets, and an evaluation of the areas burned comparing the MODIS and EFFIS data for the same temporal interval are described.

#### 1. Introduction

There is a perceived increasing incidence, extent, and severity of uncontrolled burning globally that has led to calls for international environmental policy concerning fire (FAO 2007) and increasing debate on the relationship between fire and climate change (Westerling *et al.* 2006). In Europe, forest fires in July 2007 were considered the worst for any July on record (EU 2007), with media attention subsequently focused on the devastating fires across Greece in August 2007 which resulted in significant loss of life and property damage.

It is well established that environmental satellite sensor data may be used to map the extent of burned areas, although the methodologies, accuracy and subsequent use of such products are subject to several constraints (Robinson 1991, Giglio *et al.* 2003, Roy *et al.* 2005, Boschetti *et al.* 2006, Trigg and Roy 2007). NASA Moderate Resolution Imaging Spectroradiometer (MODIS) data have been used to systematically generate a suite of MODIS land products (Justice *et al.* 2002) including a 1 km active fire product (Giglio *et al.* 2003) and recently a burned area product that maps the approximate day and extent of burning at 500 m resolution (Roy *et al.* 2005, Roy *et al.*, 2008). Burned areas are characterized by deposits of charcoal and ash, removal of vegetation, and alteration of the vegetation structure (Roy *et al.* 1999). The MODIS algorithm to map burned areas takes advantage of these

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spectral, temporal, and structural changes to detect the approximate date of burning by locating the occurrence of rapid changes in daily reflectance time-series. It improves on previous detection methods due to the use of a bi-directional reflectance model to account for angular variations found in the satellite sensor data and uses a statistical measure to detect change probability from a previously observed state (Roy *et al.* 2005). The most recent Collection 5 version of the MODIS burned area product is publicly available, with a Product User Guide, news and other supporting information, graphics and animations (University of Maryland 2008). The Collection 5 product is being revised through a process of quality assessment and validation, and algorithm refinements are underway to improve its performance. In this Letter, results for a slightly modified version of the Collection 5 algorithm are shown.

The European Forest Fires Information Service (EFFIS) is a meteorological and satellite based mapping system developed by the European Commission's in-house scientific arm, the Joint Research Centre (JRC). Its purpose is to provide Member States with daily fire danger warnings and subsequent damage assessments during the European fire season from May to October. The EFFIS Rapid Damage Assessment system provides a weekly assessment of the burned area perimeters mapped by visual interpretation, with a minimum mapping unit of 50 ha, of the MODIS 250 m red and near-infrared bands, the 500 m short-wave infrared bands, and the MODIS 1 km active fire product (Giglio *et al.* 2003) and using ancillary media news reports of forest fires (Barbosa *et al.* 2006). Burned areas occurring in agricultural land as defined by the CORINE2000 land cover map are masked out.

This Letter presents an estimate of the extent of the burning in Greece in the summer of 2007, and highlights the potential of MODIS data for mapping burned areas at regional to local scale.

## 2. Description of the burned area map

Figure 1 illustrates mainland Greece, and the major Greek islands not including Crete. MODIS true colour 500 m land surface reflectance data are shown generated from 500 m MODIS nadir bi-directional modelled red ( $0.645 \mu\text{m}$ ), green ( $0.555 \mu\text{m}$ ) and blue ( $0.469 \mu\text{m}$ ) reflectance. Neighbouring countries, Albania, the Former Yugoslavian Republic of Macedonia, Bulgaria, and Turkey, are shown with a semi-transparent white overlay. The extent burned for 22 June to 30 August 2007 mapped by the MODIS burned area product and independently by EFFIS are shown superimposed. The MODIS-detected 500 m burned pixels are colour coded with a rainbow scale to display the approximate day of burning: blue corresponds to the beginning of the period (22 June) and red to the end of the period (30 August). The white vectors show the boundaries of the EFFIS mapped burned areas.

Extensive burning is evident across much of southwest Greece, in the Peloponnese, and also close to Athens, in central mainland Greece, and in Albania near the Greek border. The first large fires occurred in late June, notably with the destruction of the Parnitha forest close to Athens, followed by relatively few fires in July, and then extensive fires in the Peloponnese peninsula in the last 2 weeks of August.

## 3. Summary statistics of extent burned and product evaluation

The MODIS burned area product (MCD45) mapped 292657 ha as burned from 22 June to 30 August 2007 across the whole of Greece (including the islands), and the



Figure 1. Map of the extent burned and approximate day of burning in Greece mapped by the MODIS burned area product for 22 June to 30 August 2007 with white vectors superimposed showing the burned areas mapped independently by the European Forest Fires Information Service (EFFIS). See text for further details.

EFFIS reported 272163 ha burned for the same period and area (table 1). Of these 242 900 ha were identified as burned by both products, corresponding to approximately 2% of Greece. Differences between the two products occur primarily

Table 1. Total area burned estimated by the MODIS burned area product (MCD45) and by the EFFIS system, reported in hectares. The areas are reported to the nearest hectare, although this is a false level of precision as a MODIS 500 m pixel is 25 ha. The two products are largely in agreement: the areas mapped as burned by both products (their intersection) correspond to 82.7% of the total area mapped by MCD45 and to 88.7% of the total area mapped by EFFIS.

Total area mapped as burned by MCD45	Total area mapped as burned by EFFIS	Total common area mapped as burned by both MCD45 and EFFIS	Total area mapped as burned by MCD45 but not by EFFIS	Total area mapped as burned by EFFIS but not by MCD45
292 657	272 163	242 900	49 758	29 263

along the borders of EFFIS mapped polygons, in agricultural regions which are not considered by EFFIS, and for small burned areas that were mapped by EFFIS but not by MCD45.

This assessment illustrates how the two burned area products, both derived independently from MODIS data, provide comparable estimates of the burnt area extent with good spatial agreement. Future comparison with official figures from the national Greek administration will allow for a further independent assessment of the figures presented in this study.

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