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→ 4th ADVANCED TRAINING COURSE IN LAND REMOTE SENSING

EO based fire disaster management services

Real time fire detection and monitoring
Burnt area rapid mapping
Situation awareness mapping
Damage assessment

Dr Haris KONTOES
Research Director

NATIONAL OBSERVATORY OF ATHENS

INSTITUTE OF ASTRONOMY & ASTROPHYSICS, SPACE APPLICATIONS AND REMOTE SENSING

IAASARS

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Introduction to Emergency Response in GMES

GMES provides Institutional Users and stakeholders with environmental information through services dedicated to a systematic monitoring and forecasting of the state of the Earth's subsystems. Six thematic areas are developed: marine, land, atmosphere, emergency response, security and climate change

In Emergency Response field, several pre-operational and operational activities have been undertaken aiming to implement and deliver qualified and standardised Services, reinforcing the European capacity to respond to natural disasters

- Priority 1: Generate, validate and deliver an information service focusing on rapid mapping during the response phase
- Priority 2: Enrich this service with a wider set of thematic products

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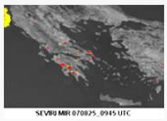
Introduction to Emergency Response in GMES

Early warning

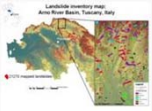


Reference maps
Infrastructures, Populated areas, Land use, toponyms etc. Historical assets
Area covered > 5Mio km²

Deliver to headquarters, decision-makers and in-field operatives, Europe and worldwide

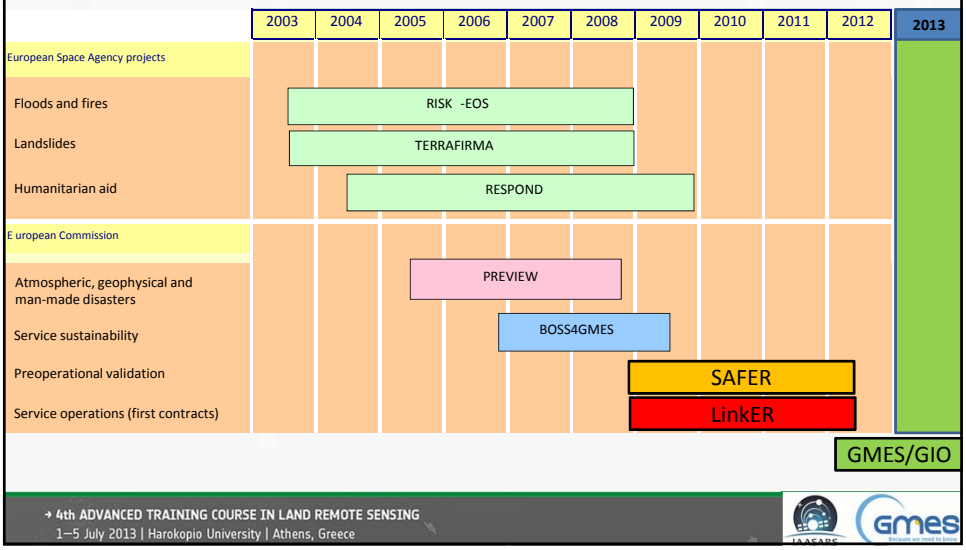
Situation assessment maps , Rapid Mapping assessment, Situation maps and threatened assets
> 35-60 activations/year

Thematic Products
Flood risk and Plain/Flash, flood early warning, Fire risk and monitoring at medium resolution, Fire mapping & damage assessment, Earthquakes, landslides



Four main types of ERS products

GMES ERS road map, heritage and schedule



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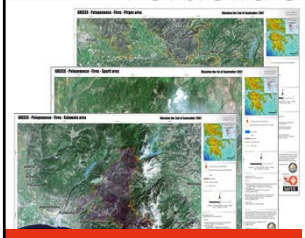
Portfolio of Fire Services delivered in GMES



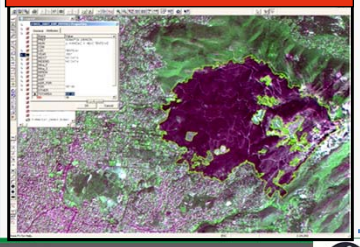
Rapid Fire Mapping

Regional Real Time Fire Monitoring

During fire Crisis On line Emergency Response Services

BSM High Resolution (30m pixel-1ha)

BSM Very High Resolution (2-8m pixel-0.5 ha)



After fire Crisis Off line Emergency Support and Recovery Services

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Regional Real Time Fire Monitoring Service based on EUMETSAT MSG SEVIRI Data

Active Fire Mapping – Algorithm Theoretical Basis

Stefan-Boltzmann Law:

The amount of energy than an object radiates can be expressed as follows:

$$M = \varepsilon s T^4$$

M = total radiant exitance from the surface of a material (watts m^{-2})
s = Stefan-Boltzmann constant, (5.6697×10^{-8} W m^{-2} K^{-4})
T = absolute temperature (K) of the emitting material
ε = **emissivity**

• The total energy emitted from an object varies as T^4 and therefore increases **rapidly** with temperature.

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Regional Real Time Fire Monitoring Service based on EUMETSAT MSG SEVIRI Data

Active Fire Mapping – Algorithm Theoretical Basis

Wien's Displacement law:

The **dominant wavelength** at which a blackbody radiation curve reaches a maximum, is related to temperature by **Wein's Law**:

$$\lambda_{max} = \frac{A}{T}$$

λ_{max} = wavelength of maximum spectral radiant exitance, mm
A = constant, equal to 2898 µm, K
T = Temperature, K

Examples:

- (i) Earth ambient temperature ~ 300 K (27 °C)

$\lambda_{max} = C_W / 300\ (x10^6)$ µm = 10 µm (TIR)

- (ii) Vegetation fire temperature ~ 850 K (577 °C)

$\lambda_{max} = C_W / 1000\ (x10^6)$ µm = 3.5 µm (MIR)

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Regional Real Time Fire Monitoring Service based on EUMETSAT MSG SEVIRI Data

Active Fire Mapping – Algorithm Theoretical Basis

The best suited MSG SEVIRI Channels for active fire detection of forest and vegetation fuels and discrimination from ambient temperatures are:

Channel	Central Wavelength (µm)	Spectral Band (µm)
IR 3.9	3.92	3.48 - 4.36
IR 10.8	10.8	9.80 - 11.80

Classification approach #1: The EUMETSAT Fire mapping algorithm (FIR) is based on fixed thresholding approach, applied on the spectral bands **IR 3.9** and **IR10.8.** The FIR algorithm uses the following criteria to check for **potential fire and fire pixels**:

1. Brightness temperature of channel IR3.9 > **threshold 1**
2. Brightness temperature difference of channels IR3.9 and IR10.8 > **threshold 2**
3. Difference of the standard deviations of channel IR3.9 and IR10.8 > **threshold 3**
4. Standard deviation of channel IR3.9 > **threshold 4**
5. Standard deviation of channel IR10.8 < **threshold 5**

(all standard deviations are computed over a 3x3 pixel group)

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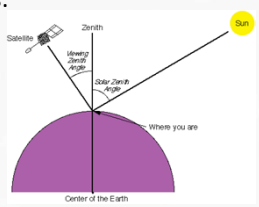
Regional Real Time Fire Monitoring Service based on EUMETSAT MSG SEVIRI Data

Active Fire Mapping – Algorithm's enhancement by NOA

- **Classification approach #2: The thresholds are dynamically calculated** for each new image and for every pixel of the raw imagery as follows:

Step 1: Calculation of latitude and longitude for each pixel using bilinear interpolation.
Step 2: Estimation of Solar Zenith Angle per image, per pixel.
Step 3: Definition of new thresholds depending on this angle, with a linear interpolation.



- **Classification approach #3: Classification refinement**

Step 4: Refine first classification output and calculate fire occurrence probability in a 500 m x 500 m wide cell, enhancing thus the resolution of the initial observation by accounting for **a)** Wind direction, **b)** Fuel type's proneness to fire, **c)** Altitudinal zone, slope and aspect of affected surface, **d)** thematic consistency (eliminate false alarms e.g. in sea, on top of inconsistent LC types, keep only the land part of the polygon), **e)** account for time persistence of the fire observations

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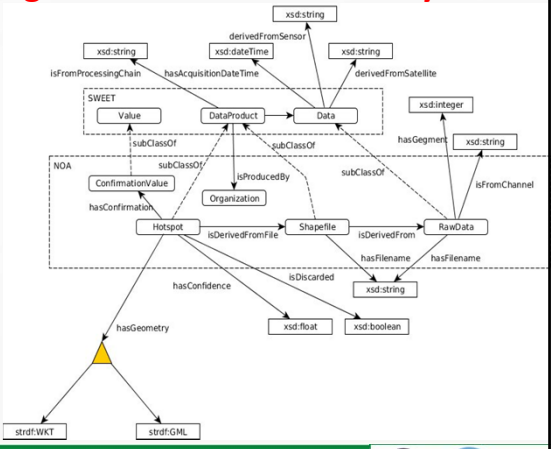
Regional Real Time Fire Monitoring Service based on EUMETSAT MSG SEVIRI Data

Active Fire Mapping – Algorithm's enhancement by NOA

Ontology, concepts, entities, and properties used in the classification refinement process

- Hotspot data
- Corine Land Cover
- Greek coastline
- Greek Administrative geography
- LinkedGeoData
- GeoNames



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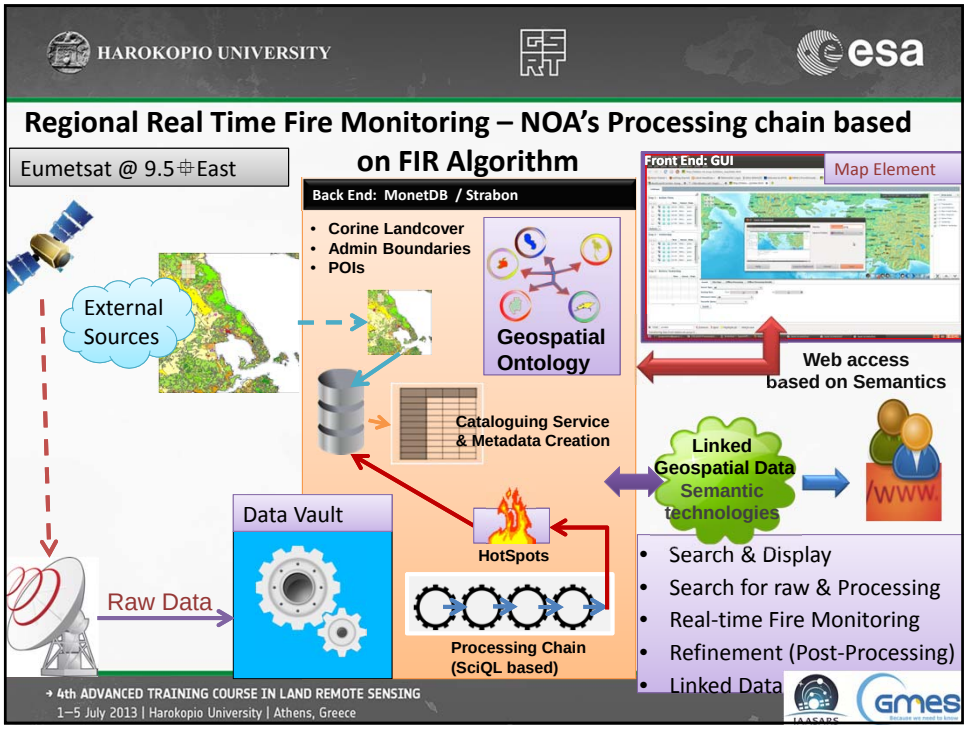
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Regional Real Time Fire Monitoring – NOA's Processing chain based on FIR Algorithm
Eumetsat @ 9.5°East
Back End: MonetDB / Strabon
Corine Landcover
Admin Boundaries
POIs
Front End: GUI
Map Element
External Sources
Geospatial Ontology
Web access based on Semantics
Cataloguing Service & Metadata Creation
Linked Geospatial Data
Semantic technologies
Data Vault
HotSpots
Raw Data
Processing Chain (SciQL based)
Search & Display
Search for raw & Processing
Real-time Fire Monitoring
Refinement (Post-Processing)
Linked Data
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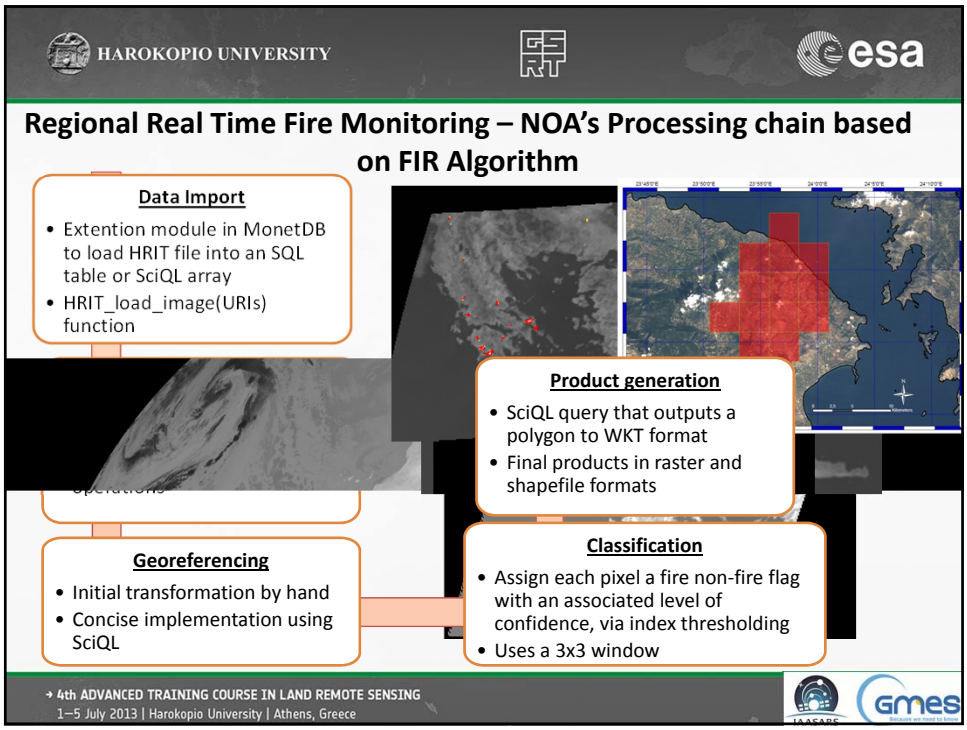
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Regional Real Time Fire Monitoring – NOA's Processing chain based on FIR Algorithm
Data Import
Extention module in MonetDB to load HRIT file into an SQL table or SciQL array
HRIT_load_image(URIs) function
Product generation
SciQL query that outputs a polygon to WKT format
Final products in raster and shapefile formats
Georeferencing
Initial transformation by hand
Concise implementation using SciQL
Classification
Assign each pixel a fire non-fire flag with an associated level of confidence, via index thresholding
Uses a 3x3 window
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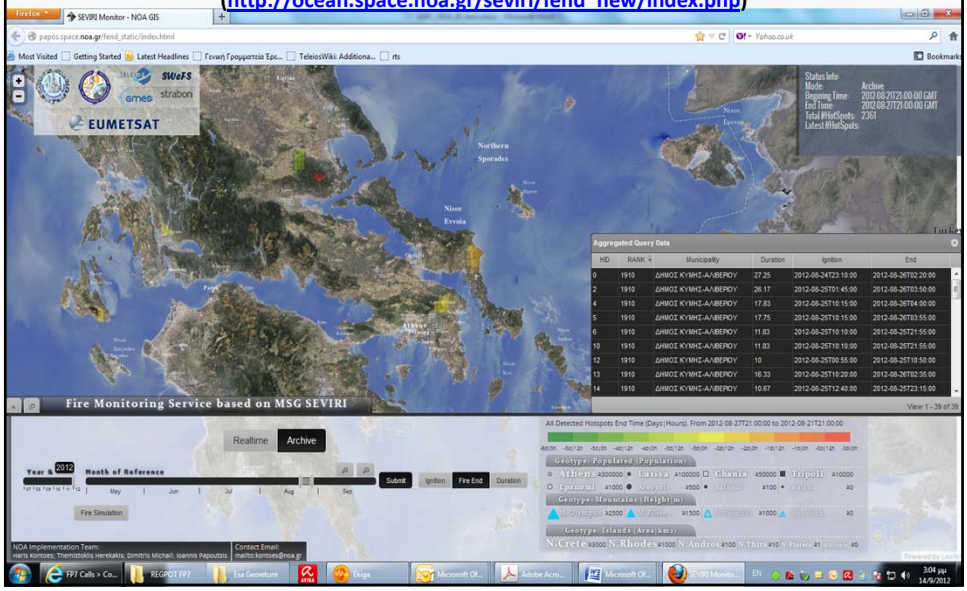
On-line Fire Services dissemination through NOA's dedicated web interface

(http://ocean.space.noa.gr/seviri/fend_new/index.php)



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Regional Real Time Fire Monitoring Service using NOA's MSG SEVIRI Station - Raw mode

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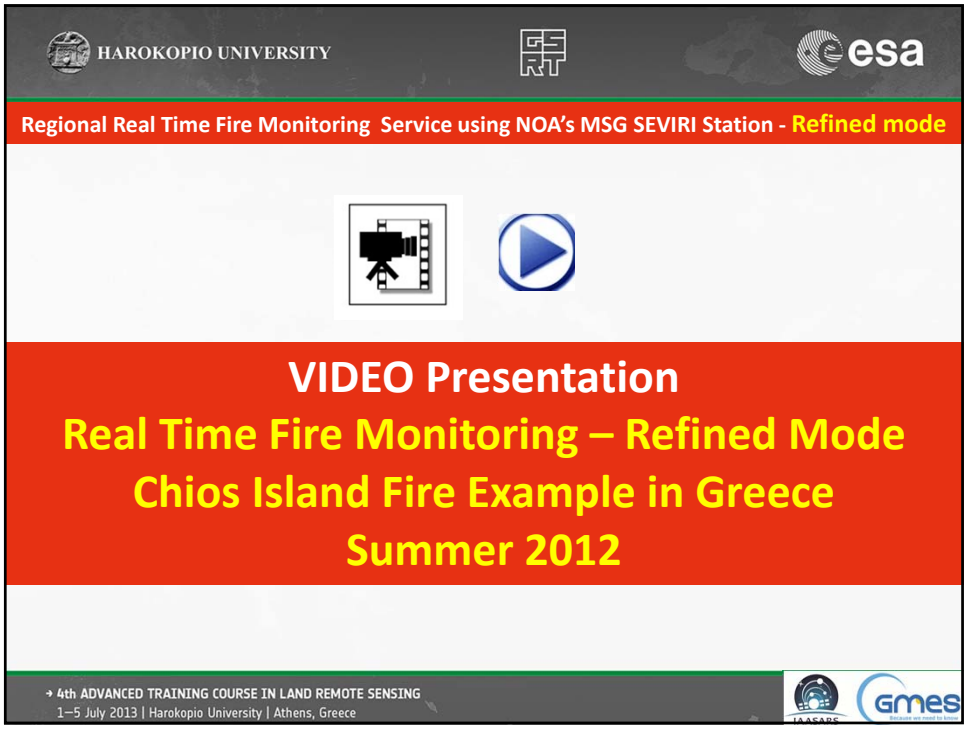
EMERGENCY SITUATION

SEVIRI MIR 070823_1030 UTC

POTENTIAL FIRE

CONFIRMED FIRE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Regional Real Time Fire Monitoring Service using NOA's MSG SEVIRI Station - Refined mode
VIDEO Presentation
Real Time Fire Monitoring – Refined Mode
Chios Island Fire Example in Greece
Summer 2012
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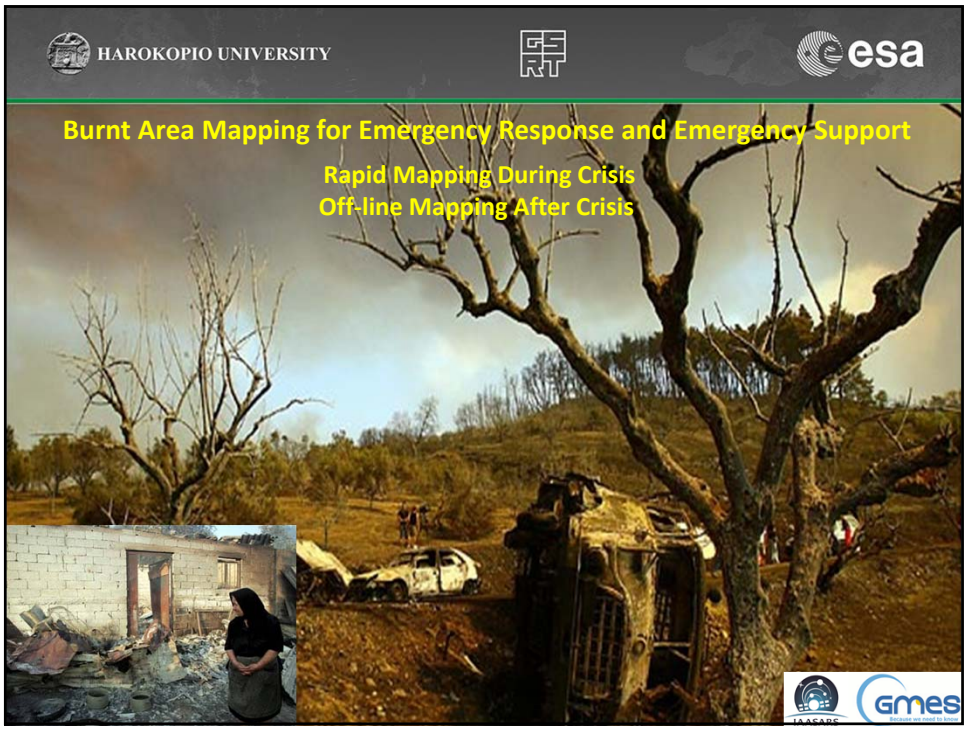
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Burnt Area Mapping for Emergency Response and Emergency Support
Rapid Mapping During Crisis
Off-line Mapping After Crisis
GMES

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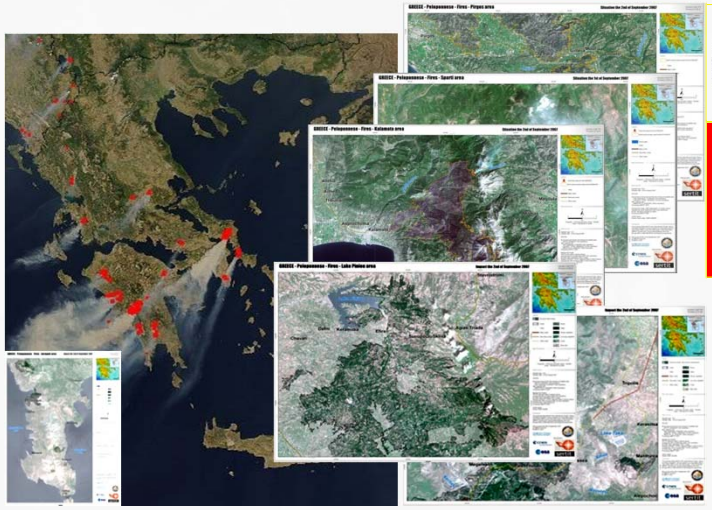
Rapid Fire Mapping Activation in Greece – Peloponnesus 2007



INTERNATIONAL CHARTER OF MAJOR DISASTERS IS ACTIVATED

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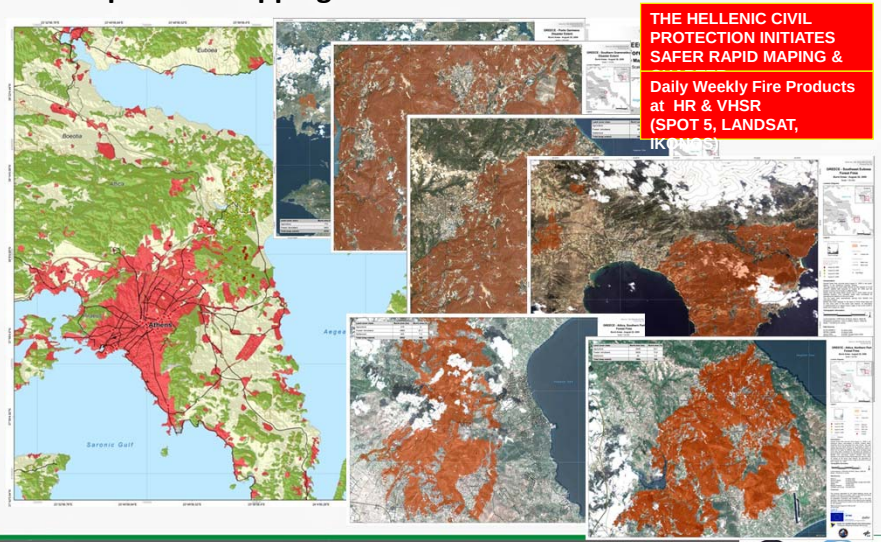
Rapid Fire Mapping Activation in Greece – Athens 2009



THE HELLENIC CIVIL PROTECTION INITIATES SAFER RAPID MAPING &

Daily Weekly Fire Products at HR & VHSR (SPOT 5, LANDSAT, IKONOS)

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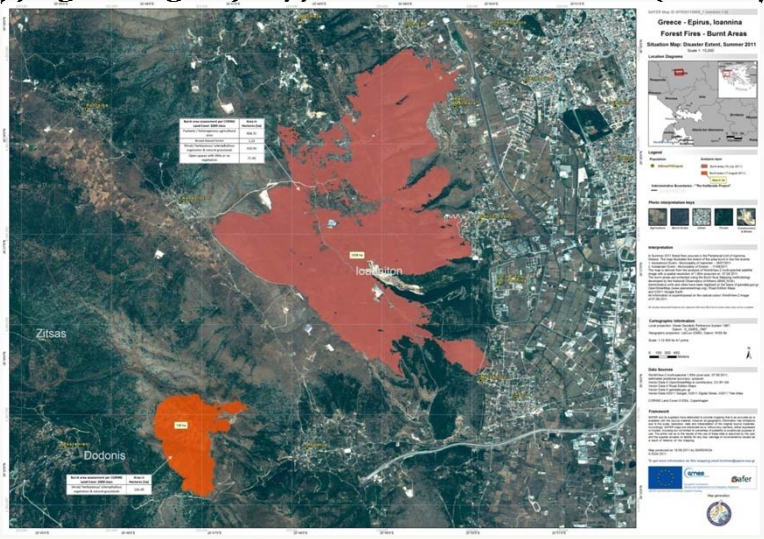
Fire Mapping - Emergency Support Activation – Ioannina (Greece) 2011



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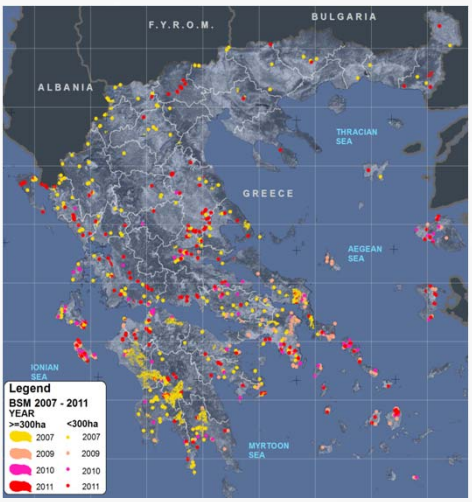
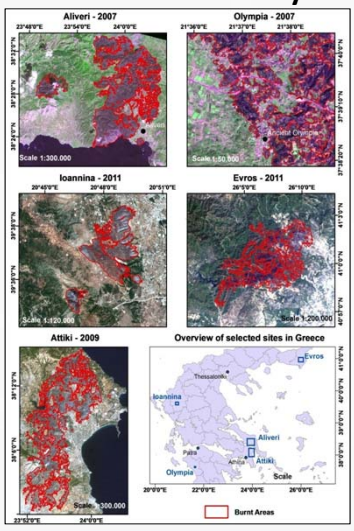
Seasonal Burn Scar Mapping & Damage Assessments – Recovery Phase





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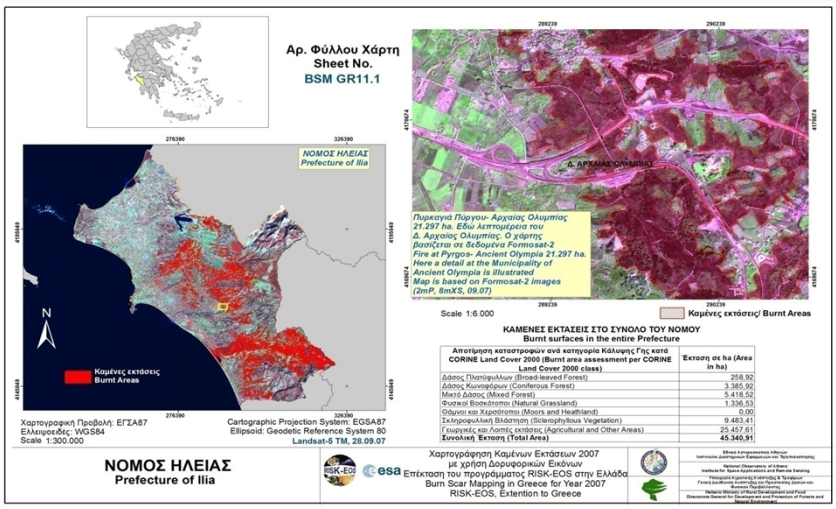
Seasonal Burn Scar Mapping & Damage Assessments at HR & VHSR



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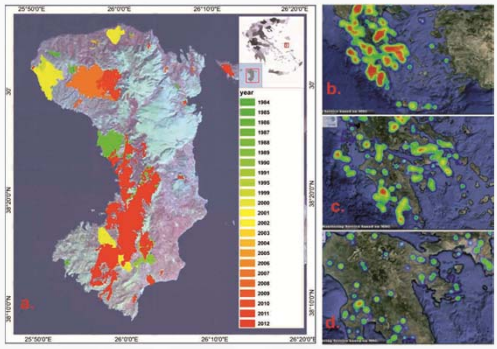
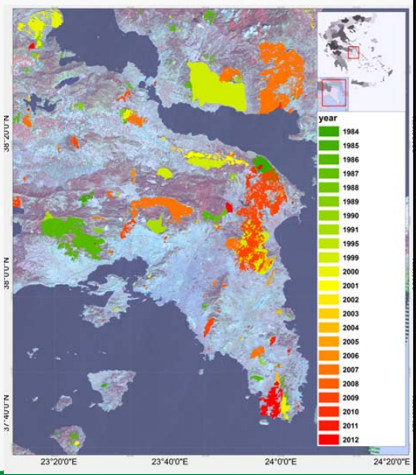
Diachronic Burn Scar Mapping & Damage Assessments at HR

On-line dissemination through NOA's dedicated web interface (http://ocean.space.noa.gr/diachronic_bsm/index.php)





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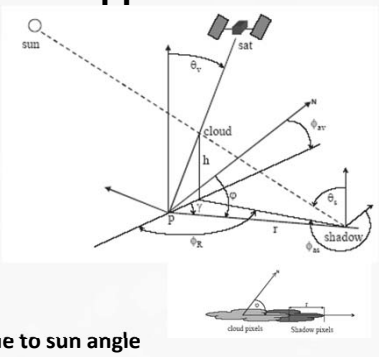
Burnt Scar Mapping – Algorithmic Approach #1.a



BSM_NOA Pre- Processing using Landsat TM data
Example will follow in Practical session

Cloud - water - shadow mask creation

(1) Separate clouds from vegetation by thresholding bands TM 1 or TM2
(2) Isolate water bodies and shadows by thresholding bands TM 4 and TM5
(3) Measure the cloud-to-ground image displacement due to sun angle
(4) Select all cloud pixels which comply with the threshold value
(5) Buffers the cloud pixels and project these areas using the calculated cloud-to-shadow vector
(6) Combine steps 2 and 5, find the union of the two outputs and apply, if necessary editing to the initial cloud and cloud shadow classification to remove any remaining miss-classifications

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Burnt Scar Mapping – Algorithmic Approach #1.b

BSM_NOA Processing using Landsat TM data
Example will follow in Practical session

Band transformations (multi-temporal NBR, ALBEDO, NDVI, CHANGE VECTOR)

NORMALISED BURN RATIO INDEX (NBR)

- TM bands 4 and 7 exhibit the greatest reflectance change in response to fire
- TM7 increases↑ with fire and TM4 decreases↓
- Those trends are accentuated in the normalized ratio calculated as:

NBR = (R4-R7) / (R4+R7)

Rationale

A. Natural vegetation and forested zones are characterized by:
1. Fuel accumulation for longer periods due to the abandonment of the land
2. Pine and shrub ecosystems which when burnt are characterized by a significant reduction in green healthy vegetation

Therefore,

NBR SUCCESSFULLY DIFFERENTIATES BURNT FROM UNBURNED AREAS OVER LARGE AREAS

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Burnt Scar Mapping – Algorithmic Approach # 1.c

BSM_NOA Pre-Processing using Landsat TM data
Example will follow in Practical session

Band transformations (multi-temporal NBR, ALBEDO, NDVI)

Rationale

B. In the usual case of high landscape diversity in the Mediterranean countries, the main characteristics of land are:

1. Large variety in vegetation vigour and forest density especially as we move from north to south
2. Too much fragmented forest land with the mixing of forests with agricultural lands, parcels of permanent crops and open abandoned pasture areas with less significant vegetation cover

BECAUSE OF THIS NBR ONLY CANNOT SUCCESSFULLY DIFFERENTIATE BURNT AREAS FROM OPEN FIELDS OR AGRICULTURAL PARCELS LOCATED INSIDE THE FORESTED LAND

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Burnt Scar Mapping – Algorithmic Approach # 1.c

BSM_NOA Pre-Processing using Landsat TM data
Example will follow in Practical session

Band transformations (multi-temporal NBR, ALBEDO, NDVI)

TWO MORE INDEXES ARE USED AS CRITERIA TO REFINE THE NBR OUTPUT:

1. **THE EMPIRICAL APPROXIMATION OF THE SURFACE ALBEDO**

$$ALBEDO = (NIR_{TM5}+R_{TM4})/2$$

2. **THE SPECTRAL MULTITEMPORAL VARIATION OF VEGETATION VIGOUR IN PRE- & AFTER-FIRE IMAGES DENOTED BY THE VARIATION OF $NDVI_{DIFF}$ INDEX**

$$NDVI_{DIFF} = NDVI_{PRE} - NDVI_{AFTER}$$

$$NDVI = (NIR_{TM5} - R_{TM4}) / (NIR_{TM5} + R_{TM4})$$

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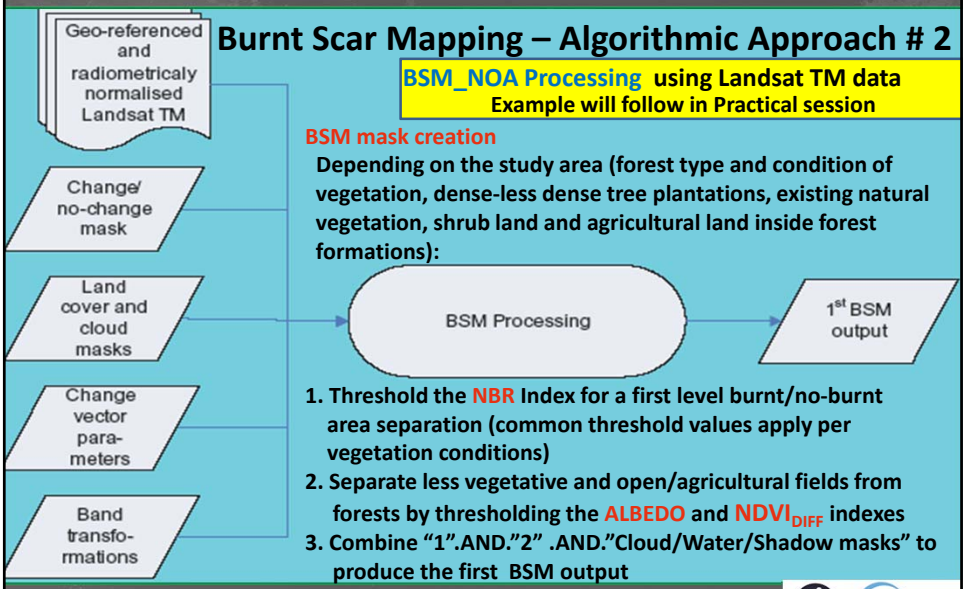
Burnt Scar Mapping – Algorithmic Approach # 2

BSM_NOA Processing using Landsat TM data
Example will follow in Practical session



BSM mask creation

Depending on the study area (forest type and condition of vegetation, dense-less dense tree plantations, existing natural vegetation, shrub land and agricultural land inside forest formations):

1. **Threshold the NBR Index for a first level burnt/no-burnt area separation (common threshold values apply per vegetation conditions)**
2. **Separate less vegetative and open/agricultural fields from forests by thresholding the ALBEDO and $NDVI_{DIFF}$ indexes**
3. **Combine "1".AND."2" .AND."Cloud/Water/Shadow masks" to produce the first BSM output**

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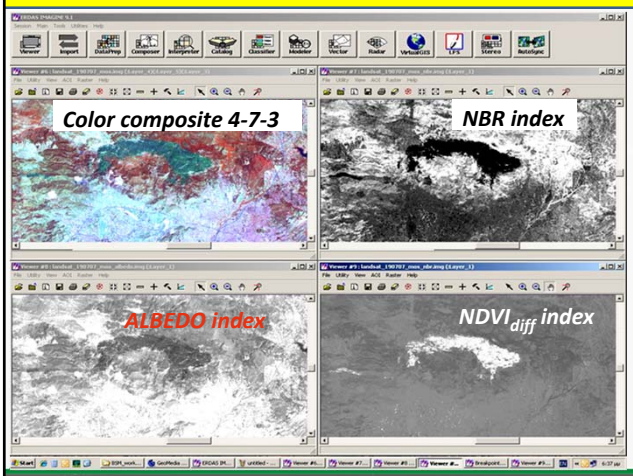
Burnt Scar Mapping – Algorithmic Approach # 2

BSM_NOA Processing using Landsat TM data
Example will follow in Practical session



Contribution of NBR, ALBEDO, and $NDVI_{diff}$ to BSM mask creation

The example of the Parnitha 2007 fire to the northern of the city of Athens

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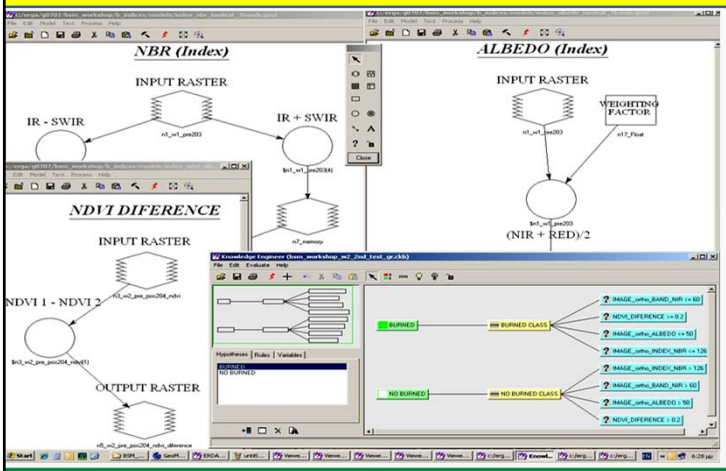
Burnt Scar Mapping – Algorithmic Approach # 2

BSM_NOA Processing using Landsat TM data

Example will follow in Practical session



ERDAS modeler

and

ERDAS knowledge based

(Expert classifier)

interface of

BSM_NOA

Processing Chain

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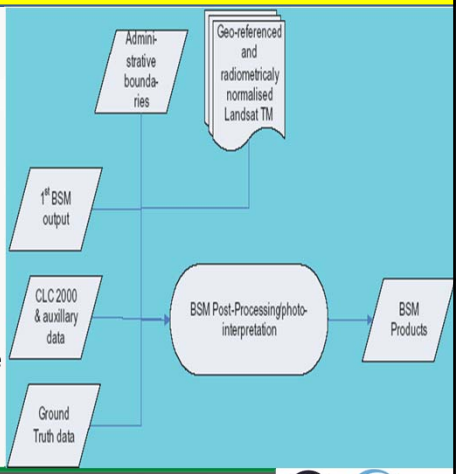
Burnt Scar Mapping – Algorithmic Approach # 3

BSM_NOA Post- Processing using Landsat TM data

Example will follow in Practical session

BSM FINAL PRODUCTS creation

1. Filter out pixel noise by using a 3x3 pixel wide kernel
2. Filter out small objects of less than 1ha in size, by clumping pixels and eliminating objects
3. Apply a series of expert knowledge and geospatial reasoning queries in GIS, releasing BSM masks from noise, and generate refined classifications of Burnt Areas
4. Apply raster-to-vector conversion and create Burn Scar Area boundaries
5. Smooth/simplify boundaries and eliminate the "pixel effect" from the generated boundaries
6. Create Burn Scar polygons: close/clean boundary shapes & insert attributes



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Burnt Scar Mapping – Algorithmic Approach # 3

BSM_NOA Post- Processing using Landsat TM data

Example will follow in Practical session

BSM FINAL PRODUCTS creation

1. Filter out pixel noise by using a 3x3 pixel wide kernel
2. Filter out small objects of less than 1ha in size, by clumping pixels and eliminating objects
3. Apply a series of expert knowledge and geospatial reasoning queries in GIS, releasing BSM masks from noise, and generate refined classifications of Burnt Areas
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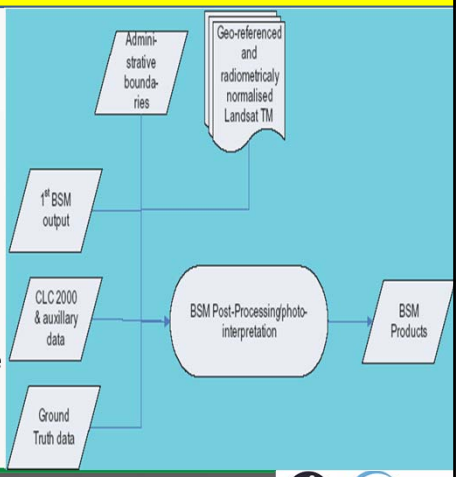

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Burnt Scar Mapping – Algorithm Validation

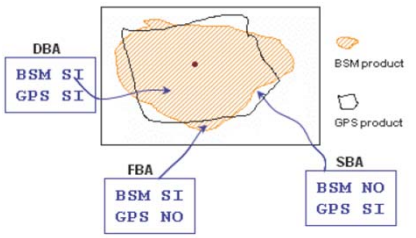
Validation Scheme

$$\text{Detection efficiency rate} = \frac{DBA}{DBA+SBA}$$

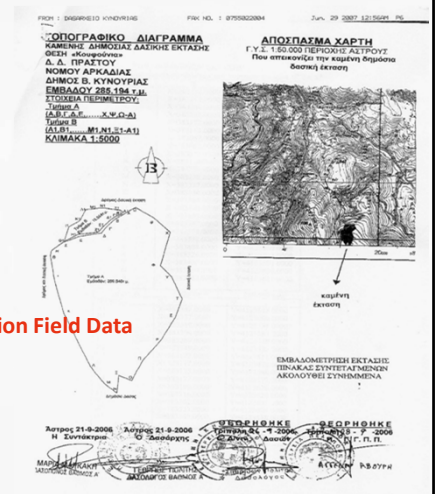
$$\text{Commission error (False Alarm rate)} = \frac{FBA}{DBA+FBA}$$

$$\text{Omission error} = \frac{SBA}{DBA+SBA}$$

- DBA: Detected burnt areas
- FBA: False burnt areas
- SBA: Skipped burnt areas



Validation Field Data



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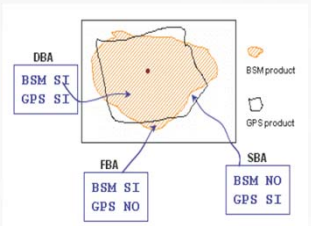
Burnt Scar Mapping – Algorithm Validation Results

$$\text{Detection efficiency rate} = \frac{DBA}{DBA+SBA}$$

$$\text{Commission error (False Alarm rate)} = \frac{FBA}{DBA+FBA}$$

$$\text{Omission error} = \frac{SBA}{DBA+SBA}$$

- DBA: Detected burnt areas
- FBA: False burnt areas
- SBA: Skipped burnt areas



Area statistics (ha)		Accuracy statistics (percentage)	
Detected Burned Areas(DBA):	*6125.83*	*Detection Efficiency Rate:*	*85%*
Skiped Burned Areas(SBA):	*1051.85*	*Omission Error:*	*3%*
False Burned Areas(FBA):	*216.84*	*Commission Error:*	*15%*

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Users benefited from NOA's Fire Emergency Response and Emergency Support Services

DELIVERY of Fire Services to Core End Users at National, Regional, and European Level

Examples

1. **HELLENIC MINISTRY OF ENVIRONMENT AND CLIMATE CHANGE/ Directorate General of Forest and Natural Resources Development and Protection**
2. **GENERAL SECREATARIAT OF CIVIL PROTECTION**
3. **FOREST RESEARCH INSTITUTE - NATIONAL AGRICULTURAL RESEARCH FOUNDATION**
4. **HELLENIC CENTER of GREEK BIOTOPES AND WETLANDS**
5. **HELLENIC MAPPING CADATSRAL ORGANISATION**
6. **KTIMATOLOGIO SA**
7. **The Directorate for Forests of the Region of Peloponnesus**
8. **The Forestry Service of Corinth Prefecture (Peloponnesus)**
9. **The Forestry Service of Lakonia Prefecture (Peloponnesus)**
10. **The Forestry Service of Ioannina Prefecture (Epirus)**
11. **The Forestry Service of Chalkidiki Prefecture**

Users' Collected Feedback

A. The Services are useful for:

a) Fire fighting planning and fire fighting resources coordination
b) Early warning for fire occurrence and monitoring.
c) Reliable situation awareness picture creation
d) Post-fire planning and natural land/soil recovery management.
e) Generate timely, accurate and standardized damage assessments throughout the entire country/Europe to support rehabilitation measures in the affected local economies.
f) Monitor and control the enforcement of the law for maintaining the original land uses.
g) Support the reforestation activities in respect to the national legislation.
h) Update the biotope maps according to the needs of NATURA 2000.
i) Support planning and prioritisation actions in the implementation of the National Cadastral Project
j) Deliver products with the same standards (accuracy and cost) throughout the entire country/Europe
k) Consist the only alternative to the field surveys which in general are:
Non exhaustive and, much diversified in terms of mapping accuracy and mapping scale (depending on time and budget restrictions and the mapping method-GPS, ortho-photos).

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VIDEO Presentation
Emergency Response & Emergency Support GMES services delivered during the fire disaster crisis in the region of Peloponnesus – Year 2007

→ 4th ADVANCED TRAINING COURSE IN LAND REMOTE SENSING
1–5 July 2013 | Harokopio University | Athens, Greece