Executive Summary

Study for Monitoring of Fires in the Mediterranean Area by Geostationary and Polar Satellites

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Earth Observation Department

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1. INTRODUCTION

1.1 SCOPE OF THE DOCUMENT

This documents represents the executive summary of FiresMed, an ESA founded project devoted to the analysis of a system for monitoring of fires in the Mediterranean Area based mainly on existing Geostationary and Polar Satellites.

1.2 ACRONYMS

AIB	Anti Forest-Fire Service (*Servizio Antincendio Boschivo*)
AVHRR	Advanced Very High Resolution Radiometer
CFS	*Corpo Forestale dello Stato*
COA	*Centro Operativo Aeromobili*
COAU	Italian Unified Air Operating Centre
COL	*Centro Operativo Locale*
COP	*Centro Operativo Provinciale*
COR	*Centro Operativo Regionale*
FIRES	Forest fIRes imaging Experimental System
GIS	Geographical Information System
GOES	Goe-stationary Orbiting Environmental Satellite
HRUS	High Rate User Station
MODIS	MODerate resolution Imaging Spectro-radiometer
MSG	Meteosat Second Generation
NASA	National Administration for Space and Aeronautics
NIR	Near Infrared Region
RTM	Radiative Transfer Model
SEVIRI	Spinning Enhanced Visible and Infrared Imager
SOC	*Sala Operativa Centrale*
SOUP	*Sala Operativa Unificata Permanente*
TIR	Thermal Infrared Region
TOA	Top Of Atmosphere
VVFF	Italian Firemen Corp (*Corpo dei Vigili del Fuoco*)

1.3 APPLICABLE DOCUMENTS

[A1] FIRES-MED "**Study for Monitoring of Fires in the Mediterranean Area with Geo-stationary and Polar Satellites**", *Technical, Management, Administrative & Financial Proposal to ESA, OTC02.015-2.0, 23 April 2002*

1.4 REFERENCE DOCUMENT

[R1] E. Cisbani et al., "**Early fire detection system based on multi-temporal images of geostationary and polar satellites**", *IGARSS 2002, Toronto, July 2002*

[R2] Telespazio S.p.A., "**Fire Observability from Existing or Planned Satellites**", FiresMed Project, *ESRIN/Contract No. 14496/00/I-IW, CCN No. 01, May 2002, Telespazio reference 190.191.40-SPA-TN-001, January 2003*

[R3] Telespazio S.p.A., "**Annex to Fire Observability from Existing or Planned Satellites**", *FiresMed Project, ESRIN/Contract No. 14496/00/I-IW, CCN No. 01, May 2002, Telespazio reference 190.191.40-SPA-TNX-001, January 2003*

[R4] Telespazio S.p.A. "**Service Characterization**", *FiresMed Project, ESRIN/Contract No. 14496/00/I-IW, CCN No. 01, May 2002, Telespazio reference 190.191.40-SPA-TN-002, November 2002*

[R5] Telespazio S.p.A. "**Service Implementation**", *FiresMed Project, ESRIN/Contract No. 14496/00/I-IW, CCN No. 01, May 2002, Telespazio reference 190.191.40-SPA-TN-003, January 2003*

[R6] Z. Wan, "**MODIS Land-Surface Temperature ATBD**", MODIS ATBD-MOD-11, April 1999, available on-line at *modis-land.gsfc.nasa.gov/pdfs/atbd_mod11.pdf*

[R7] J. Dozier, "**A method for satellite identification of surface temperature fields of subpixel resolution**", *Remote Sensing of Environment, 11 (1981) 221-229*

[R8] A. Berk et al., "**MODTRAN4 User's Manual**" *AIR Force Research Laboratory, Space Vehicles Directorate, Hanscom AFB, MA, June 1999*; A. Berk et al., "**MODTRAN4 radiative transfer model for Atmospheric Correction**" *proceedings of the AVIRIS Airborne Geoscience Workshop, 1999*

2. OVERVIEW

Since the early seventies, satellite based fire monitoring techniques are developed and implemented as stand-alone processor or experimental services. However, an effective, competitive and fully operational fire monitoring system does not actually exist due to the limitation of the current sensor satellites.

Basically, and noteworthy in the highly populated Mediterranean area, a successful fire alarm and monitoring service requires, at least:

- prompt response, that is strongly linked to a frequent acquisition of the monitored area, that at present is guaranteed by geo-stationary sensors only.
- Good spatial localization and excellent resolution, offered by several polar sensors.
- High efficiency and low false alarm rate, related to the hardware capabilities and the detection mechanism.

Unfortunately, the wide swath polar sensors with thermal bands, such as MODIS and AVHRR, which combine suitable radiometric and spatial characteristics, cannot assure proper monitoring of the same area; in fact, an optimal orbit distribution of all these sensors offers a minimum revisit time of 2 hours, which is not enough for a prompt alarm.

On the other hand, the geo-stationary sensors, which may acquire large earth area every 15 minutes (or even less), have a limited spatial resolution, which generally compromises the detection of a fire at an early stage.

In the last couple of years, an innovative, physics based, approach for early fire automated detection using remote sensing data [R1] has been proposed and prototyped by Telespazio within the NASA founded programme FIRES. The new method, combines the promptness of the geo-stationary sensors and the multi-spectral capability of the polar satellites: polar images are exploited to estimate the slowly varying parameters (e.g. the ground emissivity). Automated multi-temporal analysis of geo-stationary radiance data in the TIR is performed to detect possible hot spots; in order to improve the limited spatial resolution, the analysis is carried out with sub-pixel accuracy.

The feasibility of such early fire alarm system has been tested on simulated and real data of the GOES/IMAGER and TERRA/MODIS geo-synchronous and polar sensors

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respectively: the results demonstrated the validity of the approach in spite of the limitations of the IMAGER sensor.

At the end of November 2002, the first set of images from MSG/SEVIRI has been acquired; actually, SEVIRI offers unique and superior characteristics among the existing meteorological geo-stationary sensors: effective multi-spectral capabilities with 12 radiometrically performing bands, 3×3 km^2 nadir pixel size for the NIR and TIR bands, down to 5 minutes of revisit time. For the first time, these characteristics may give the chance to exploit remote sensors for an effective and operative fire service in the European hemisphere.

The FIRES study and the imminent start of the routine operation of SEVIRI has triggered the present FiresMed project founded by ESA, whose activities focused on:

- the critical review of the FIRES multi-temporal sub-pixel technique with emphasis on the positive impacts of the use of the superior MSG/SEVIRI geo-synchronous sensor in the Mediterranean Area;

- the evaluation of the additional support of other polar sensors and/or external (to remote sensing) data;

- the study of an optimal, improved fusion of the different data (polar and geo-stationary) involved;

- the review of the existing fire management structure in Italy and the identification of the potential users;

- the characterization and implementation of a possible operative fire monitoring service, based primarily on remote sensing data.

The results of the work is detailed in the released documentation [R2], [R3], [R4] and [R5]; the present document summarizes the main issues and conclusions.

It is worth noting that the FiresMed has primarily focused on the fire monitoring questions related to the early detection of fires.

3. FIRE OBSERVABILITY

Physics based fire detection systems involve quite a few quantities with a rather large spectrum of temporal peculiarities: e.g. the very changing fire extension, the slowly varying ground emissivity, or the quasi-periodic excursion of the background temperature. These temporal differences permit the retrieval at various times exploiting diverse detectors.

3.1 EARLY FIRE DETECTION, THEORETICAL BACKGROUND

Four main actors have been identified in the fire detection physics from remote sensing: sun, earth surface, atmosphere and the satellite sensor at TOA. These actors are described within a simplified, and reasonable radiative transfer model (RTM) of the atmospheric windows in the near infrared and thermal region of the electromagnetic spectrum. Traditional approximations (black-body radiation law, Lambertian ground surface, no atmospheric diffusion, one atmospheric layer) have been adopted to derive a radiative transfer equation which related the measured radiance (in a given electromagnetic band) to the surface thermal emissivity, the up and down welling atmospheric contribution and the solar, ground reflected, irradiance, graphically represented in Figure 3-1.
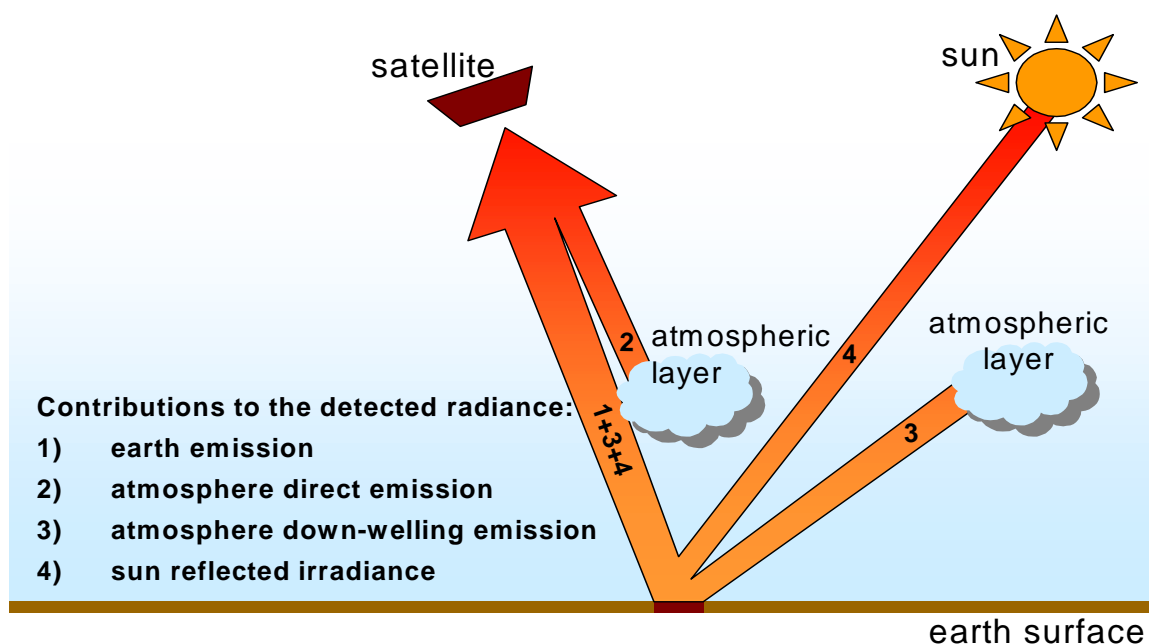

Figure 3-1: Schematic view of the processes concurring to the satellite detected radiance.

On one side, the radiative equation has been used to build a system which groups the day/night radiances from at least 4 different thermal bands for the measurement of the slowly varying (weekly period) ground emissivity (a method similar to [R6]). Due to the peculiarities of the bands - two doublets are required – the system may be applied once per day using the day and night MODIS passes. Eventually the emissivity map is obtained combining the most recent (within 10 days) day/night emissivity retrievals.

On the other side, from the RTM expression, following [R7], a multi-temporal, sub-pixel equation has been derived. The final equation is the base of the fire detection algorithm, which describes the radiation energy, in a given wavelength band λ, of a partially burning pixel:

$$\Delta R_\lambda \equiv R_\lambda(t + \Delta t) - R_\lambda(t) = \varepsilon_\lambda \cdot \tau_\lambda \cdot [B_\lambda(T_T) - B_\lambda(T_E)] \cdot \Delta f \qquad (1)$$

where ΔR_λ is the radiance difference between two successive measurements at time t and $t + \Delta t$, ε_λ and τ_λ are the ground emissivity and the atmospheric transmittance, $B_\lambda(\ )$ is the black-body Planck expression, T_T and T_E are the fire and background temperatures, and finally Δf is the variation of the burning pixel fraction, within the given pixel. Both solar and atmospheric radiances changes have been neglected.

The background temperature, the potential fire temperature and fire size variation are the unknown of a system of at least 3 equations derived from the above formula and applied to the available atmospheric windows of the geo-synchronous sensor (GOES in America and the advanced SEVIRI in Europe).

The ground emissivity is pre-estimated by the polar sensor as mentioned above. The atmospheric transmissivity is parameterized by the water vapor content, a moderately varying quantity on clean sky areas, that can be retrieved from bands of the geo-stationary sensor every half hour or so.

Finally, a bunch of physical criteria (thresholds) are applied to the retrieved quantities:

- radiance difference above some factor of the intrinsic noise level,
- fire-background temperature difference higher than a given temperature (around 200K)
- background temperature within feasible values.

Those events (pixels) that fulfil all the above physical conditions are assumed to contains a burning area.

The whole system has been tested on the TERRA/MODIS and GOES/IMAGER real data and results have been rather positive.

3.2 MSG/SEVIRI Performances

The fire detection technique has been adapted and implemented on the MSG/SEVIRI in order to investigate the improvement due to the advanced capabilities of this sensor. SEVIRI data of partially burning areas have been generated by the ModTran, radiative transfer simulation code [R8] coupled to a linearly growing fire model and taking into account the background temperature and atmospheric water vapor content variations during a typical sunny day. The synthesized data have been analyzed in term of:

- detection efficiency, the number of events detected as fires respect to the total number of events

- false alarm rate, the number of events mis-identified as fires respect to the total non-fire events;

- retrieval accuracy of the fire temperature and the burning pixel fraction variation;

- saturation effects which limits the fire recognition in presence of large fires.

These key quantities do depend on several other factors and parameters; the most significant of them have been identified as:

- combustion temperature between 500 K and 1000 K, taking into account that the flame temperature is generally much above 800 K;

- band combinations always including the most sensible channel at 3.9 µm (assuming the background temperature is known, at least 2 bands are required for the sub-pixel detection, while SEVIRI has up to 5 exploitable bands in the NIR and TIR);

- burning area extension, that is the pixel fraction;

- fire detection thresholds: channel noise and fire-background temperature difference;

- errors on input quantities: emissivity, transmissivity, radiances and possibly background temperature.

The first impressing result, which is represented by the plot of Figure 3-2, is the enhancement up to 100% of the detection efficiency due to the use of SEVIRI respect to GOES. The same figure gives also indication of the optimal band combination 1.6 - 3.9 - 8.7 µm; however other band groups offer excellent performance.
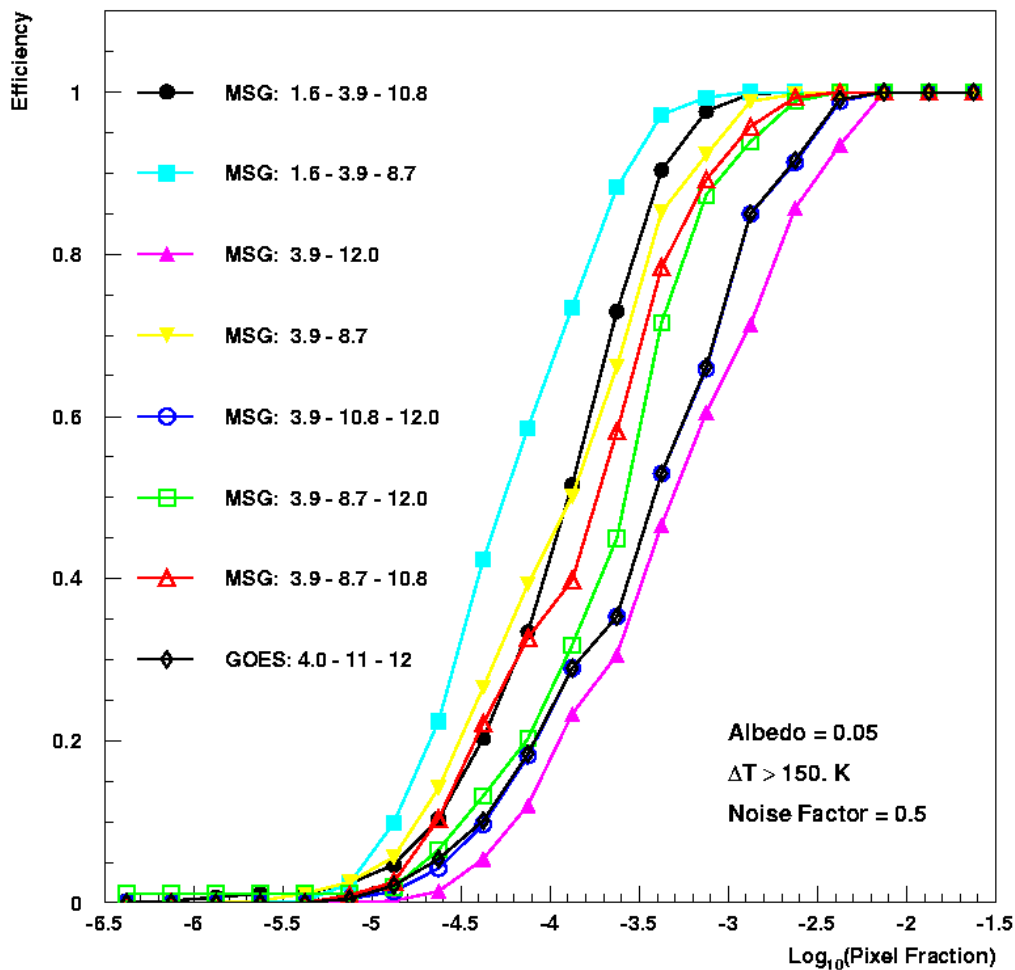
Figure 3-2: Fire detection efficiency as a function of the pixel fraction variation of the burning area and different combinations of SEVIRI bands; also included is the GOES curve as reference.

Efficiency of up to 60% could be expected for fires on a pixel fraction of 10^{-4}, that corresponds to a linear size of 50 m (for a full pixel size of 5x5 km^2); more extensive analysis lower such efficiency to the pessimistic value of 10% in case of data effected by 5% of error, that should represent an upper limit. In addition, the errors on the input parameters affect the detection in different ways: uncertainty on background temperature slightly influences the efficiency, while the technique is quite sensible to the radiance uncertainties and moderately to the emissivity and transmissivity errors.

False alarm rate analysis has confirmed the importance of the solar irradiance especially on high albedo surfaces (see Figure 3-4).

In terms of low false alarm (at different conditions) the best performing SEVIRI band arrangement is the group 1.6 – 3.9 – 10.8 μm, that combined to the efficiency results can probably be elected as preferred choice.

It is worth noting that the false alarm rates obtained from the simulated data look higher than the result of the FIRES real data analysis. This discrepancy can be explained by a weak correlation between the simulated data and the radiative model used for the fire detection. Such correlation should also influence the efficiency analysis, but at a level that does not exceed few percent (as it is for the false alarms).
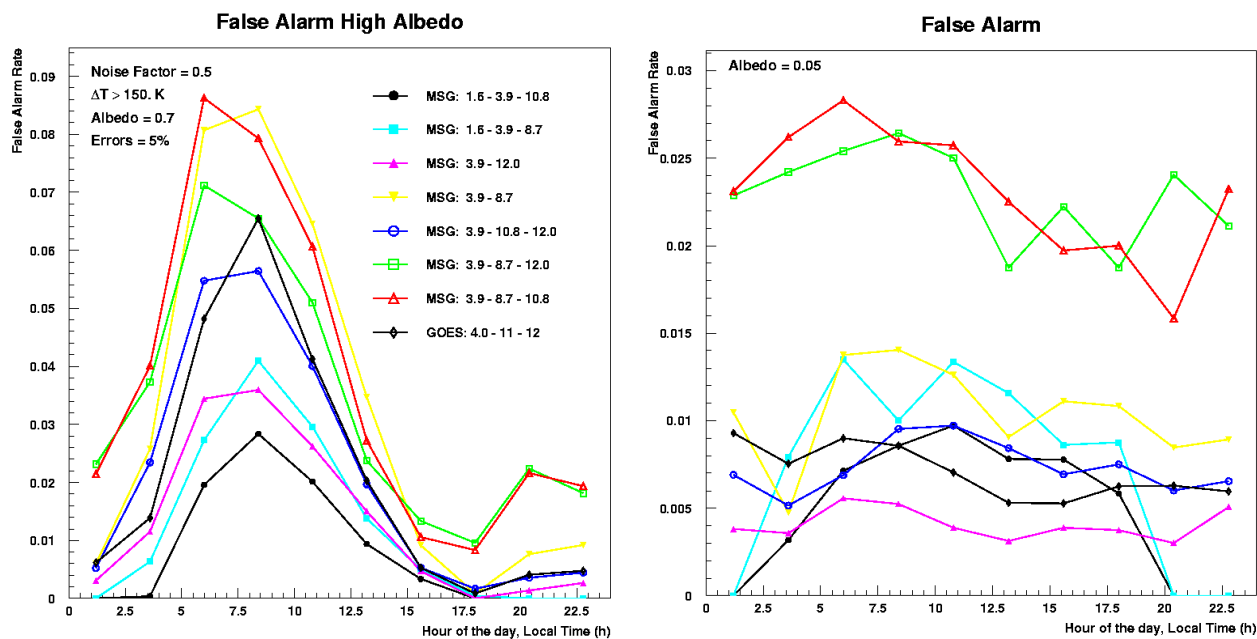

Figure 3-3: False alarm rate as a function of the hour of the day and for the same SEVIRI band combinations presented in Figure 3-2; high albedo surface (70%) left, low albedo surface (5%) right. The bump in the left plot is related to the sun presence.

The accuracies on the estimated quantities, fire temperature and pixel fraction variations are generally acceptable for the detected fires; as shown in Figure 3-4 the pixel fraction is generally slightly overestimated, especially when errors are assigned to the input quantities. The same results have been experienced with the GOES real data within the FIRES work. The fire temperature accuracy is at the acceptable level of 10%.
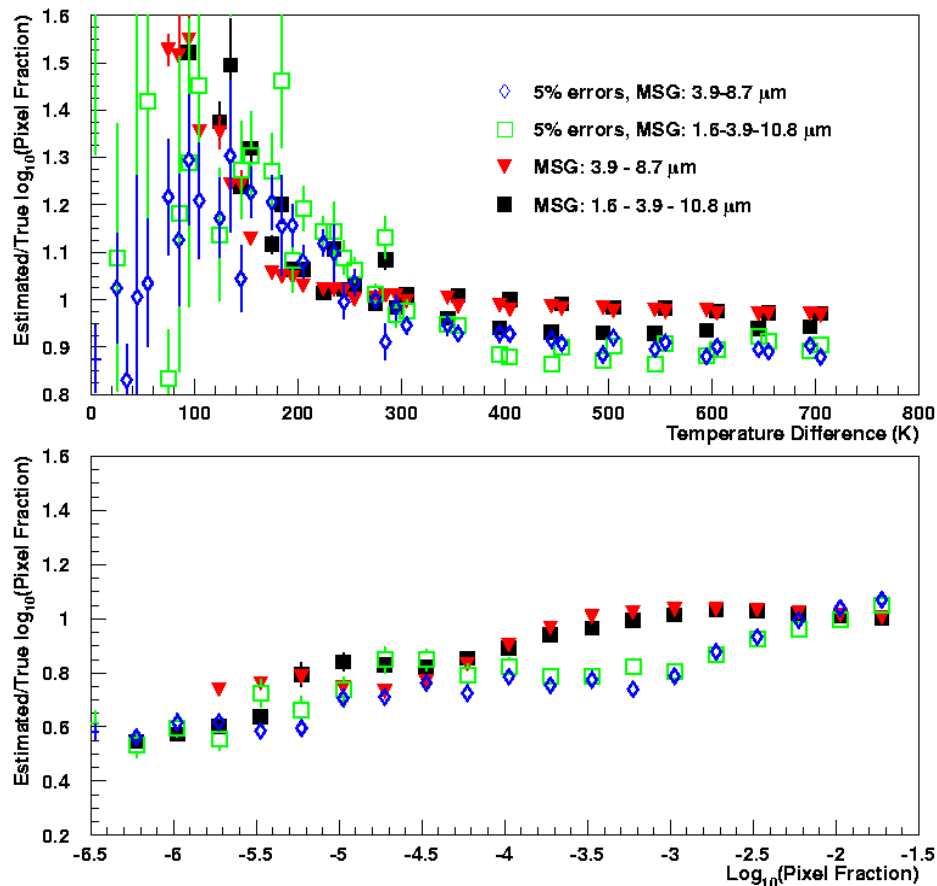
Figure 3-4: Burning pixel fraction variation estimation accuracy as a function of the fire-background temperature difference and the simulated pixel fraction, for two significant SEVIRI band combinations, with and without errors on the input parameters.

One of the main limitation in the fire detection is represented by the saturation radiance (between 335 and 340 K in SEVIRI) of the most sensible channel around 4 µm. However, the exploitation of the channel at 1.6 µm, should significantly mitigate the saturation effects; Figure 3-5 shows the net improvement on the maximum detectable pixel size for both bands 1.6 and 3.9 µm; the size refer to the nadir pixel (3×3 km^2).

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Fire Monitoring: Saturation in IR 1.6 and 3.9 μm

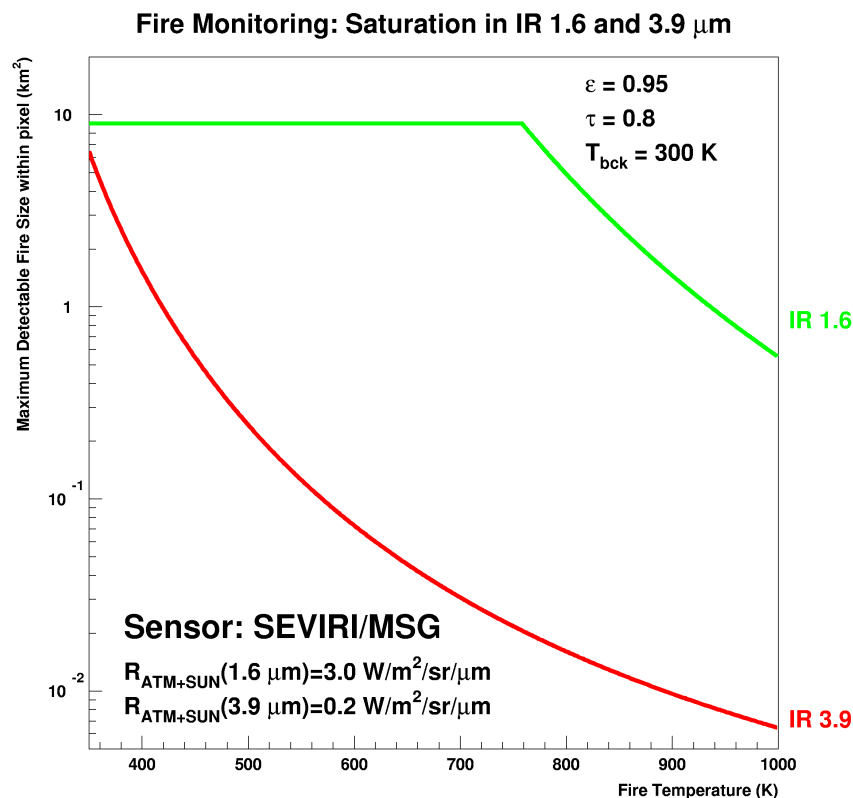
Figure 3-5: Saturation effects for the two SEVIRI channels at 1.6 and 3.9 µm.

Further improvements in the fire detection can be obtained at least following to directions:

- refine the basic multi-temporal, sub-pixel equation including additional contributions such as the solar term.

- exploit the visible bands of SEVIRI together with the infrared ones for both smoke detection (to be correlated to the above fire detection) and high reflectivity masking.

3.3 POLAR AND ADDITIONAL SUPPORTS

The existing polar satellites with suitable field of view and thermal bands have been reviewed with the aim of identify new support to the geo-synchronous sensor and possible alternatives to the MODIS sensor for the ground emissivity map estimation.

As mentioned, the day/night emissivity retrieval requires at least 4 independent bands, coupled in two doublets; unfortunately only MODIS seems to offer such a configuration; however, the MODIS sensors in orbit has recently doubled with the successfully launched of the AQUA satellite.

An emissivity validated product is provided, on regular basis, by the ASTER sensor (on board of the TERRA satellite), but for a limited number of bands which do not correspond to all the 5 SEVIRI exploitable channels.

High resolution visible images (to 30 m) are excellent candidates for supporting the tuning and validation of the fire detection processor.

Information on static, well known hot spots, sea and lakes, un-burning regions and perennial ice can be used to mask unnecessary pixels. Moreover, the constant hot spots may be used to calibrate the processor, while well geolocated and identifiable coastlines represent potential landmarks for image coregistration.

Possibly, precise ground based weather information (specifically background temperature and atmospheric humidity) may help the improvement of the retrieval accuracy. The proposed tuning procedure assumes an additive systematic error of the remote sensing measurements which is compensated by the ground data, via a polynomial interpolation.

3.4 COREGISTRATION AND DATA FUSION

The fire detection technique described in the previous sections requires precisely coregistered images: polar to polar, polar to geo-stationary and geo-stationary to geo-stationary. In fact, the multi-temporal sub-pixel equation for fire detection is very sensitive to pixel alignment between successive frames. Moreover, the needed coregistration of the 'polar' emissivity maps and the geo-synchronous radiances improve the geolocation accuracy of the latter (expected to varies from 0.6 to 3 km, depending on the type of data).

The proposed coregistration approach, which shall guarantee real-time performance and sub-pixel accuracy, bases on the maximization of the correlation between small sub-images of a master and a slave. Both images are pre-coregistered using the ancillary data, which allows the course location of the sub-images around the position of selected landmarks. In order to assure a sub-pixel registration, the maximization is dove by a preliminary polynomial regression of the discrete correlation function around its discrete local maximum. The maximizers represent the shifts to be added to the slave image to maximize the sub-images correlation; such shifts are used to compute the optimal coefficients of a projective (for geo-geo alignment) or pseudo-local (for polar-polar and polar-geo) transformation. Once the coefficients are computed, they are used for the final warping of the slave image, with a bilinear or cubic interpolation.

This general coregistration procedure shall be applied to the three kind of image couple, at different times and with different frequency, as described by the flow-diagram of Figure 3-6.
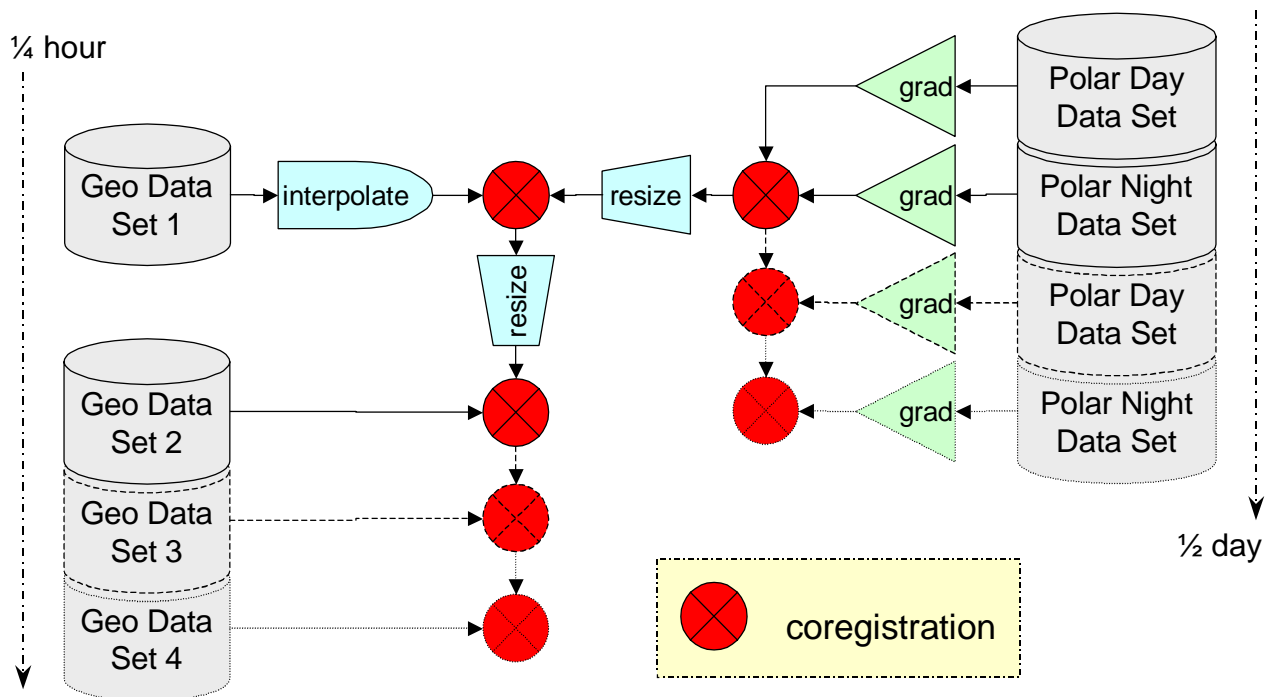

Figure 3-6: Coregistration scheme, for the three type of image couples: polar-polar (less frequent), polar-geo (via emissivity map) and geo-geo (most frequent).

The additional information associated to the higher spatial resolution and the better radiometric performance of the polar sensors can be transferred to the geo-stationary images, improving fire detection, by an optimal data fusion of the emissivity map and the geo-stationary radiances.

However, the enhancement of the generic data fusion method bases mainly on the assumption that the input images refer to the same - unchanged - scene, while the fire detection technique, by definition, is looking at radiometric changes; moreover the fusion process tends to modify the radiometric information content of each pixel.

An alternative to the generic data fusion is represented by the modification of the basic multi-temporal sub-pixel equation: in the easiest implementation, the extra resolution of the emissivity map is downgraded by average to the resolution of the geo-stationary sensor. However, the emissivity spatial resolution may be (partially) preserved introducing few burning pixel fraction Δf_i for each emissivity sub-pixel, so that the basic equation (1) becomes:

$$\Delta R_\lambda = \tau_\lambda \cdot \left[B_\lambda (T_T) - B_\lambda (T_E) \right] \cdot \sum_{i=1}^{N} \left(\varepsilon_{\lambda,i} \cdot \Delta f_i \right) \tag{2}$$

The number of emissivity sub-pixels cannot exceed the number of independent equations that can be built from the spectral bands subtracted of the number of additional unknowns, such as fire and background temperatures. The few emissivity sub-pixels are obtained by a suitable arrangement of the original emissivity sub-pixels within the geo-stationary larger pixel, such as to minimize the deviation of the resampled emissivity values respect to the original ones.

Preliminary analysis of this extended technique using the 5 bands of SEVIRI shows an average detection efficiency compared to the above mentioned results. However, there is tendency (5% of the event) to assign the correct fraction value to the proper sub-pixel, enhancing the sub-location of the fire. Such tendency may be further improved releasing the simplifying assumption of a wavelength independent emissivity.

4. FOREST FIRE SERVICE

The ultimate aim of the early fire detection and monitoring system analysed in the previous sections is its integration in a operational, remote sensing based, fire management service, able to guarantee:

- effectiveness: good detection efficiency and low level of false alarms,

- completeness: the early fire alarms shall be supported by additional useful information for the fighting activities, and basic tools such as GIS enriched digital map navigation;

- simplicity: easy of use service;

- integrability: the service shall be integrated in the already existing chain;

- integrity: the automated service cannot be influenced by unauthorized people (a significant fraction of fires are caused by deliberate actions).

4.1 MANAGEMENT STRUCTURE

The European countries present peculiar aspects and diversification at the regional level. The Italian scenario in forest fire fighting management is coordinated by the National Civil Protection Service founded in 1992 and successively (2001) reorganized in Department. The chief of the Civil Protection Department operates in charge of the Prime Minister's office. The Department consists of several components (as shown in Figure 4-1) and, among others, has responsibility for the coordination of activities concerning the forest fire risk.

According to recent laws (2000-2002) the management of the fire risk is demanded to the Regional Authorities through operative unified centres (SOUP) which tightly collaborate with the Civil Protection and the National Forestry Corp (CFS). The CFS, under the control of the Ministry of Agriculture and Forests, is the most important operative structure in fire risk (prevention, fighting and post-operations) through the Anti Forest-Fire Service (AIB), which is organized by one coordinating national centre (SOC), one airplane operative centre (COA) and 15 operative regional centres (COR). These centres are expected to be

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connected by rather fast internet connections, although phone and fax are largely used to communicate between them.
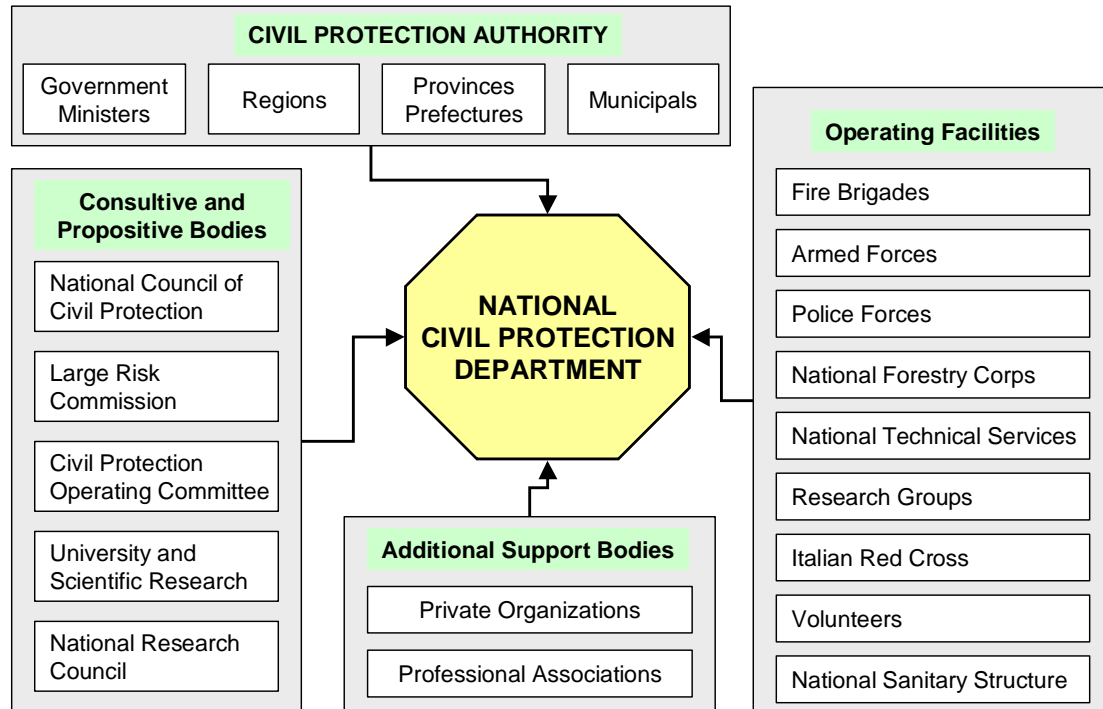

Figure 4-1: Components of the Italian Civil Protection Service.

The Forest Corp experts oversee emergency management operations at the COR and collaborate with the competent regional bodies, the Firemen Corp (VVFF - for inhabited area). With the recent normative (2000) the SOUP, under setting up, shall manage all the emergencies at regional level. Well organized regions have sub-centre at Provincial (COP) and/or at Municipal (COL) levels, which make use of highly skilled anti-forest fire prompt intervention human units.

The fire alarm network is mainly composed of seasonal lookout posts or patrols (which are connected by radios to the operative centre), private citizens, and in specific cases of video camera and ground sensor based detection systems; airborne detection is rarely used. Private citizens fire alarm are generally forwarded to the local Carabinieri stations, the VVFF or directly to the AIB. A scheme of the management chain is represented in Figure 4-2. As soon as the COR is alerted by a fire alarm, it coordinates the fire-fighting units and, in case of large fires, requires the intervention of the Unified Air Operating Centre COAU which coordinates the COA and other airplane forces.
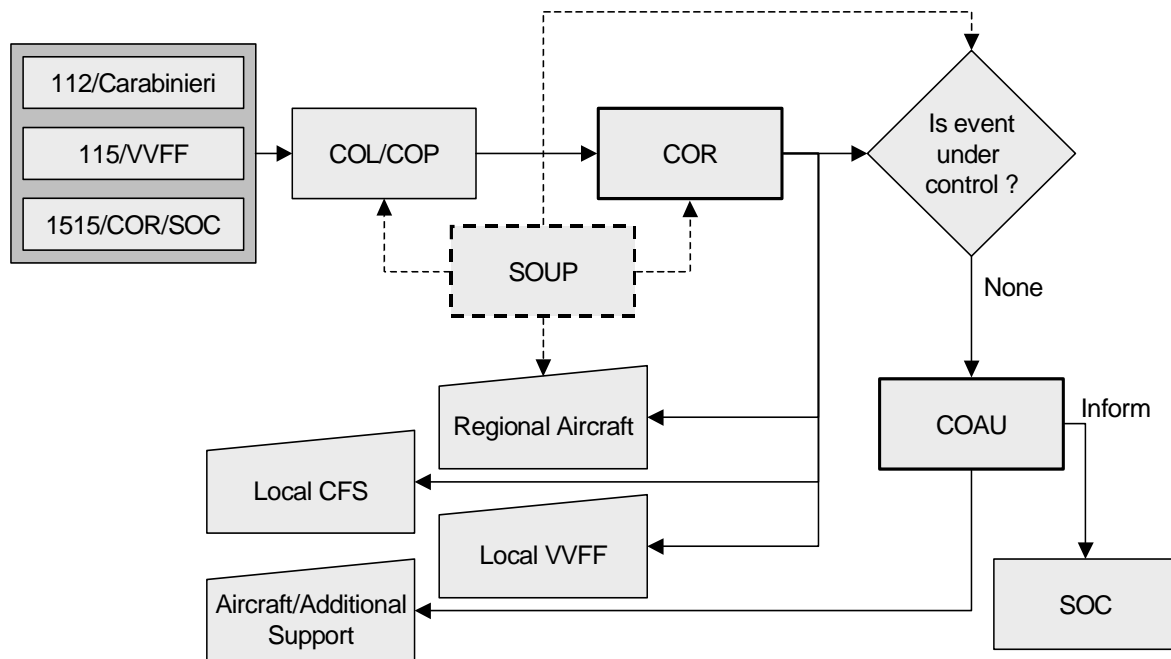
Figure 4-2: Italian forest fire event management chain; the SOUP are still under setting up in most of the Italian Regions.

In general, in the European countries, the traditional human based fire detection methods are widely used; terrestrial automatic detection devices (such as video cameras in the visible and infrared) is limited to areas with frequent fires or high naturalistic values.

Use of digital topographic maps or more advanced GIS is still very inadequate; in fact, the use of hardcopy maps appears to be preferred by a large number of operators engaged in the fire management.

Forest fire command chains differ substantially between countries due to historical, administrative and political reasons; the Italian scenario represent a complex example. Civil Defence agencies and Forest fire management authorities at regional levels are the main potential users of a fire service; in fact the Civil Defence has a central role in forest fire management, although, the initial phase of a forest fire alarm is commonly faced by Forest Service authorities, which may have local financial autonomy even thou are centrally coordinated.

Other potential users are the companies operating in the electricity transport and distribution, gas distribution, railways and motorways network maintenance. In fact most of these companies are alerted by the fire management authorities when the fire threatens their infrastructures. This alert is often given with very short notice while a more timely information would be appreciated.

4.2 FIRE SERVICE CHARACTERISTICS

A successful fire service should proficiently integrate both satellite-based and ground-based systems and provides not only an early, trustable and exhaustive fire alarm but also a preventive fire risk forecast on a periodic basis and a continuous monitoring during the fire event emergency. Main sources of information are: the thermal infrared and visible remote sensing images at various resolution, ground meteorological stations, GIS database, field campaigns and fire reports (for the validation of the service). Several basic data shall be handled and processed in the context of the service, as presented in Figure 4-3.
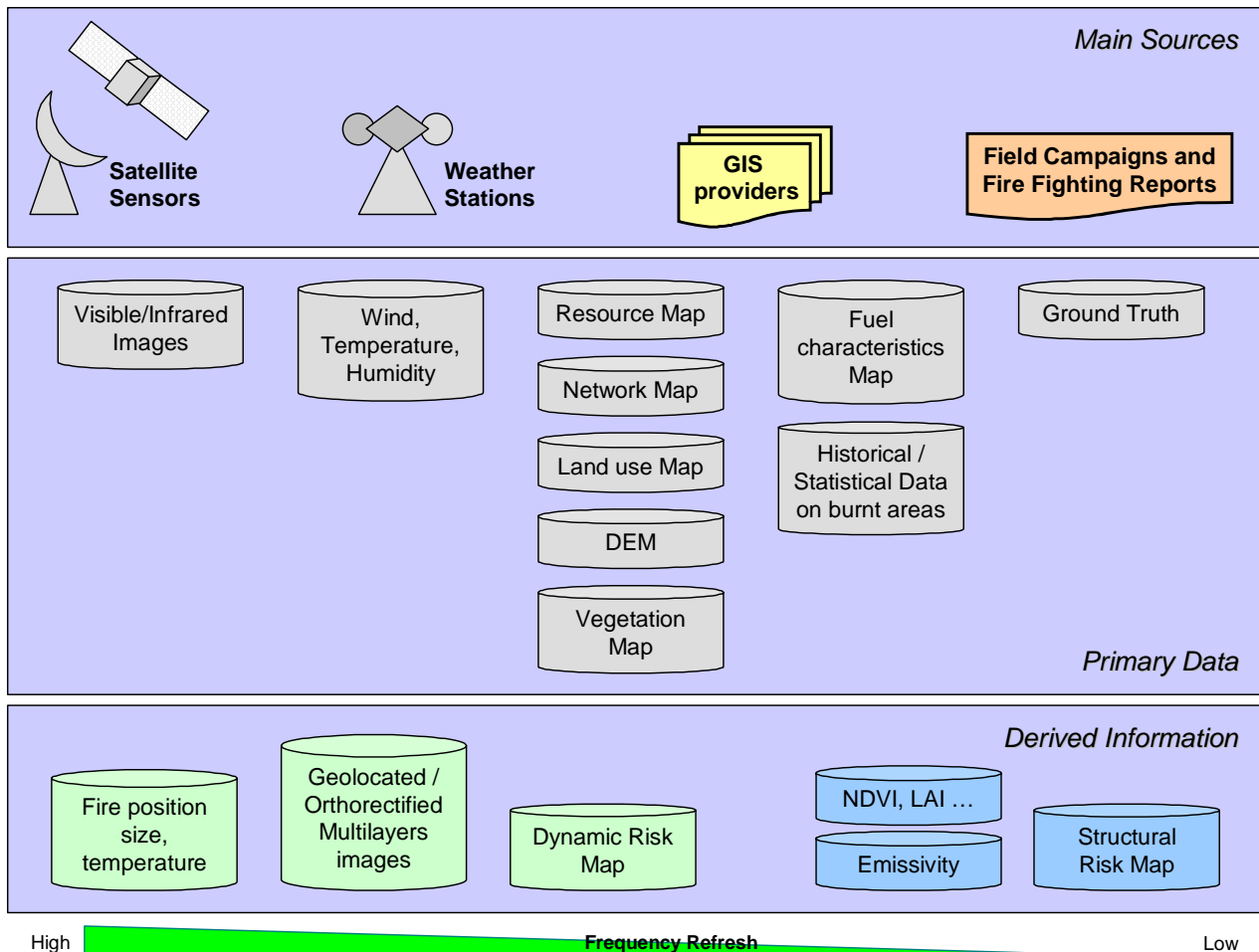

Figure 4-3: Potential information and data used by the fire service.

All these data are expected to give support to the 4 phases of the fire risk management:

- prevention via fire forecast risk maps, either structural and dynamic.
- Early alarm delivery; exploiting the fire detection processor, a concise but detailed alarm message shall be sent to the operative centres.

- Fighting action support as fire monitoring, where the detected fires are monitored (by the fire detection processor) and in the meanwhile, additional data are collected (e.g. from high resolution sensors); eventually fire simulation software should generate synthetic fire behaviour predictions.

- Fire assessment, for the evaluation of the damages due to the fires.

The present work has mainly examined the early alarm and fire monitoring – which base on the fire detection processor discussed above. After the detection of a fire, the service should collects, process and organize all the available information to produce a prompt fire alarm bulletin to be sent via fax/phone/SMS or e-mail. The bulletin should contains the following basic information:

- event code number,

- detection date and time,

- x and y coordinate (e.g. latitude/longitude and topographic coordinate)

- region number and place name

- vegetation type (no more than 10 classes)

- distance from houses or villages in km

- presence of power/gas lines or critical infrastructure

- overall priority (1 to 5) extracted from the fire risk assessment

- possibly, weather conditions of the area

- address of the web page containing further, more detailed information

- if applicable a map of the area

The successive bulletin, produced in the monitoring phase, should possibly provide information on the most probable fire progression, as indicated by a fire behaviour simulator processing the most up-dated information on the fire location, meteorological conditions, topographic aspects. The produced information are published on the web, as shown in Figure 4-4. The web page shall include an easy to use GIS based service and could also present operative/administrative information from the management centre.
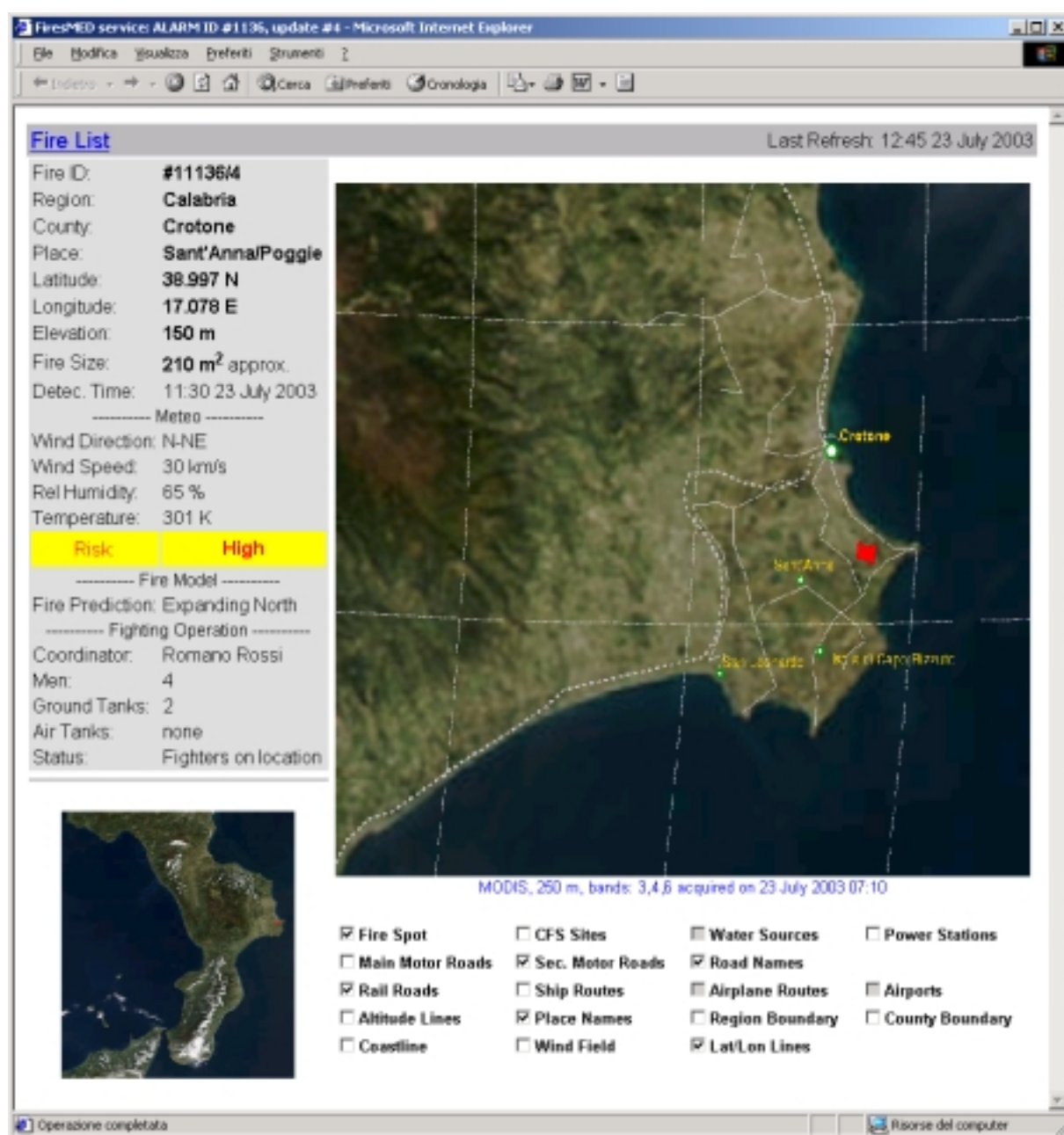
Figure 4-4: Prototype of the fire service web page; all information produced by the fire service after the fire alarm and during the monitoring should be posted here.

Actually, the fire service, in all its phases is supported by a GIS with several layers, such as: land use, vegetation characteristics, fuel characteristics, digital elevation maps, network maps, fire risk structural indices and data on historical fire occurrences. The GIS layers are provided either by external suppliers and/or generated within the service.

4.3 FIRE SERVICE IMPLEMENTATION

The overall structure which comes out from the service characterization analysis, consists of several modular components (graphically represented in Figure 4-5):

- the fire service centre which essentially provides the alarm processing and the monitoring service.

- MSG HRUS receiver station: provides the SEVIRI real-time data

- High resolution Near Real Time distribution network: either MODIS data, which can be acquired directly by a MODIS receiving station, and higher resolved images (such as Landsat and Spot) of the area involved by the fire as a support to the fighting activity.

- Auxiliary data provider: almost static data that do require a very low refresh rate (GIS layers, static fire risk map ...)

- National Meteorological Centre, in charge of providing weather forecast information and meteorological data such as pressure, humidity, temperature and wind.

- Fire Prevention and Management Centres: they represent the end users identified above, such as the Italian Regional Operative Centres (COR). Minimally, the centre shall have: communication line to receive the fire alarm (phone line, fax or GSM/UMTS terminal) and an internet connection in order to access the fire monitoring web page.
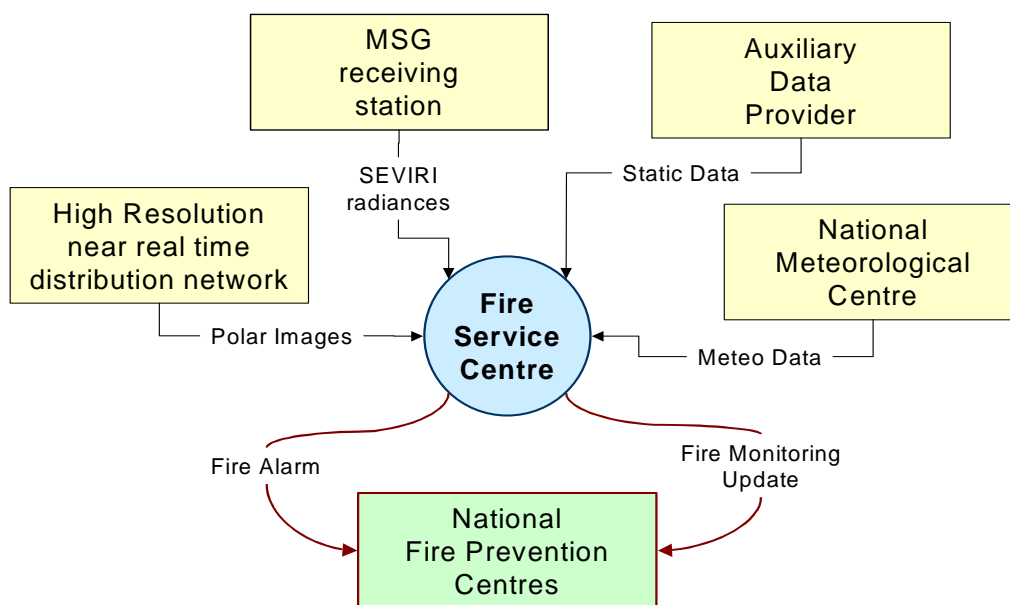

Figure 4-5: Fire Service Context Diagram

The fire service centre is the core component in the whole fire service system; it is physically located near the MSG (MODIS) receiving station and can be decomposed in the following sub-components (refer to Figure 4-6):

- satellite data acquisition, which acquires the MSG and possibly the MODIS images from the receiving stations.

- Fire alarm processor, in charge of the main processing activity outlined in the previous sections. It is implemented as a modular cluster; it shall generate the fire detection information which are transferred to the fire monitoring and fire service processors for further processing and delivering respectively.

- Fire monitoring processor; it processes each detected fire information exploiting a fire behaviour simulator and auxiliary data. It products additional information such as GIS enriched images and fire prediction, helpful to the fire-fighter operations

- Auxiliary data ingestion and archiving; data not coming from the satellite receiving station are handled by this sub-component which also provide the cataloguing and storing support. The total amount of archived data has been estimated on the order of 200 Gbyte.

- Fire service processor has the main task of monitor and coordinate all other sub-components and finalized the fire alarm and monitoring service, receiving data from the fire alarm processor, the fire monitoring processor and providing the distribution and storage of the produced data.

- Web/GIS server shall publish in a human readable and effective way the alarm and monitoring information. It is under the control of the fire service processor and shall interactively provide the GIS layer available in the archive. The operator at the fire management centre should interact with the web service either browsing the data or inserting the minimal information on the status of the fire fighting operations.

All these components can be implemented in a incremental/modular way, by means of 5 successive phases (the first 3 of them followed by the corresponding calibration and validation activity) as summarized in Table 4-1.
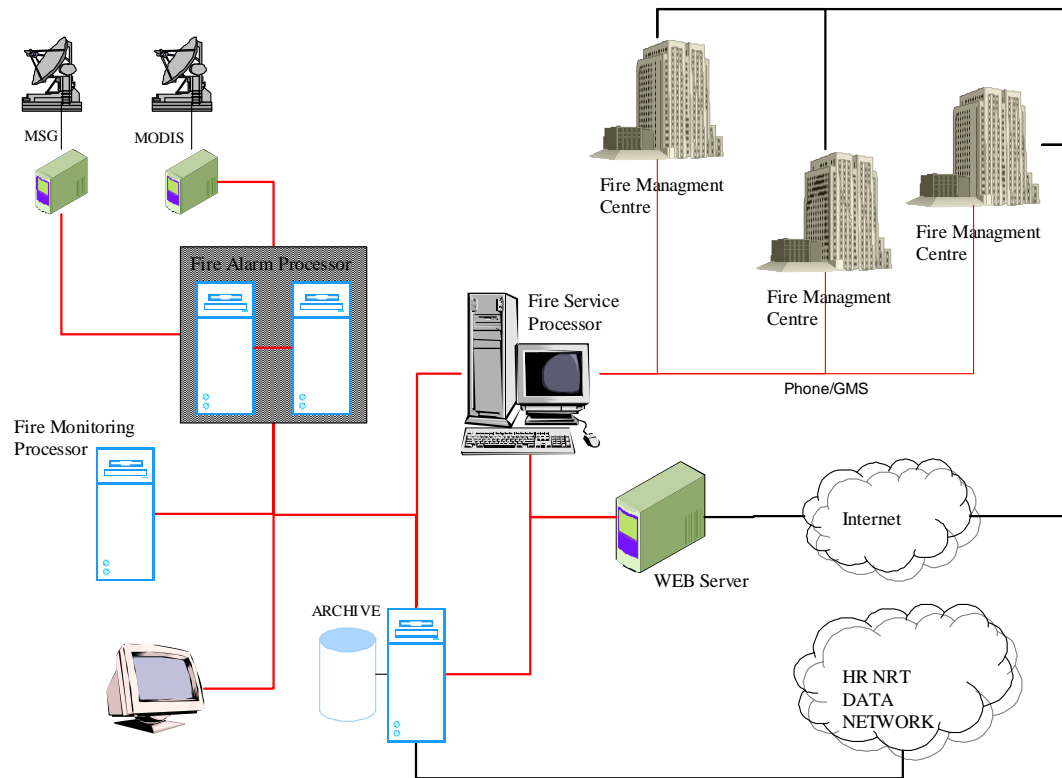
Figure 4-6: Fire Service Centre Components

Significant effort is required for the procurement and maintenance of the needed hardware (in particular the MSG HRUS Receiver Station) and the procurement (or generation within the service) of the auxiliary data such as the land use, vegetation characterization, fire risk, topographic maps and ground based meteorological information.

Finally, the fire management people should be involved in the development for the optimal definition of the user requirement and in the validation phase. Since the beginning, a minimal prototype, with web capability should be implemented in order to provide the basic system of the promotional activity.

Phase	Activity	Requirements	Objective
0	Development of the fire alarm processor Development of the GIS prototype and web server Development of a prototype fire service	Off line SEVIRI and MODIS data, Small PC cluster COTS software	FIRE ALARM PROCESSOR ASSESSMENT
0c	Verification of the effectiveness of the fire alarm processor	Official fire reports High resolution images (possibly field campaign)	
1	Integration of the on-line data Integration with the existing fire management centre system	MSG HRUS station Connection to one or more fire management centre	INTEGRATION WITH FIRE MANAGEMENT CENTRE
1c	Previously established calibration and validation procedure Assimilation of the fire fighting people feedback	Official fire reports, High resolution images Field campaign	
2	Finalize the fire monitoring and supervisor processors Implement on-line MODIS data and near real-time high resolution connection, Routine auxiliary data	MODIS receiving station High resolution near real time acquisition system Auxiliary data acquisition system	FINALIZATION OF THE SERVICE
2c	Final assessment of the quality of the service by the end-users	Extensive field campaign	
3	Routine operation		
4	maintenance, extension and customisation of the service to new fire management centres	Possibly addition and/or upgrade of hardware equipment and software	MAINTENANCE, UPGRADE

Table 4-1: The fire service implementation activities, requirements and main objectives.

5. CONCLUSIONS

The FiresMed study proposes a possible exploitation of existing geo-stationary and polar sensors for the implementation of an operative fire monitoring service, which can be easily integrated in the present fire management command chain. The service is expected to provide a considerable support to the existing ground and man based systems of fire alarm detection and monitoring. For a successful application, the proposed system will combine, in a modular way, several source of information: satellite data, ground based meteorological data, GIS layers.

The core of the service is represented by an early fire detection processor which exploits the high acquisition frequency of the meteorological MSG/SEVIRI and the multi-spectral capabilities of the polar sensor MODIS. A prototype of the processor has been implemented on real off-line GOES and MODIS data for the NASA sponsored FIRES programme. The considerable enhancement of the superior SEVIRI has been proven on simulated data.

As soon as SEVIRI images will be routinely available, the fundamental fire detection processor can be tested on real data and a preliminary service could be implemented in a short period of time.