Earth Observation – A Fundamental Input for Crisis Information Systems

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Abstract

Space-borne and airborne earth observation (EO) is a highly valuable source of spatio-temporal information promoting the ability for a rapid up-to-date assessment and (near-) real-time monitoring of natural or and man-made hazards and disasters. Such information has become indispensable in present-day disaster management activities. Thereby, EO based technologies have a role to play in each of the four phases of the disaster management cycle (i.e. mitigation, preparedness, response and recovery) with applications grouped into three main stages:

- Pre-disaster (preparedness and mitigation): EO-based information extraction for assessing potential spatial distributions and severities of hazards as well as the vulnerability of a focus region for disaster risk evaluation and subsequent mitigation and preparedness activities.
- Event crisis (response): Assessment and monitoring of regional extent and severities of the characteristics and impacts of a disaster to assist rapid crisis management.
- Post-disaster (recovery): EO based information extraction to assist recovery activities.

Within the PHAROS system a wide range of data products are used, which are varying in temporal, spatial and spectral resolution and coverage. The used sensor platforms comprise space-borne satellites and airborne systems, i.e. aircrafts as well as unmanned aerial systems (UAS).

Monitoring the Earth with Satellite based Hotspot Detection Services

One of the main concerns of the EO part in the PHAROS system is to provide fire hot spots as an input for the Simulation Service. For this purpose two hot spot services are used, the MODIS hot spot service [1] and the MSG Seviri hot spot service [1]. Both satellite data are received at the two DLR (Deutsches Zentrum für Luft- und Raumfahrt, German Aerospace Center) ground stations. One is located in Oberpfaffenhofen (Bavaria) in southern Germany and the other one in Neustrelitz (Mecklenburg-West Pomerania) in Northern Germany.

The MODIS Hot Spot Service

The MODIS (Moderate-resolution Imaging Spectroradiometer) instrument is on board the Terra (EOS AM-1) and Aqua (EOS PM) satellite platforms as part of the NASA international Earth Observing System (EOS). Each MODIS sensor provides daily image coverage of almost the entire surface of the Earth in the mid to high latitudes, producing observations in 36 spectral bands at moderate spatial resolutions (250, 500, and 1000 m). Daily, the thermal information is collected with a spatial resolution of 1000 m, twice by each sensor, providing up to four thermal observations daily. The MODIS images used for fire detection are acquired from two direct broadcast receiving stations from DLR located in Oberpfaffenhofen (Figure 0-1) and Neustrelitz (Figure 0-2) in Germany [2].

Figure 0-1: MODIS antenna on the roof of DFD's building in Oberpfaffenhofen

Figure 0-2: MODIS antenna on the roof of DFD's building in Neustrelitz

Subsequent to the data reception the MODIS data are processed in near real time (NRT). After the MODIS pre-processing is finished, the fire hot spots (thermal anomalies) are derived automatically from the MODIS data. For this detection of high temperature events (HTE) the MOD14 algorithm is used. The algorithm is based on the shift of the radiances/reflectance to shorter wavelengths (middle infrared) with an increasing surface temperature. MOD14 is well documented and tested in operational services and guarantees comparability and reproducibility as well as a standardized international acknowledged product [1].

The pre-processing of the MODIS data and also the derivation of the MOD14 hot spots is based on an OGC (Open Geospatial Consortium) compliant Web Processing Service (WPS). Also the interface for the MODIS products is OGC compliant:

- the MODIS hotspots are delivered as Web Feature Service (WFS)
- the MODIS scenes are provided for portrayal purposes as Web Mapping Service (WMS)

This assures the seamless integration of the MODIS processing results in the PHAROS system and furthermore in already existing applications of the potential end users.

The MSG SEVIRI Hot Spot Service

The MODIS hot spots are complemented by the MSG Seviri hot spot service. The SEVIRI Sensor (Spinning Enhanced Visible and Infrared Imager) is installed on top of MSG-1 and MSG-2 (Meteosat Second Generation satellite) platforms. These satellites are geostationary and cover Europe and northern Africa. For the normal mode a dataset is received every 15 minutes. The SEVIRI Sensor provides data in 12 different wavelengths within the visible to infra-red spectrum and with a pixel size of 1 km for the high resolution visible channels, and up to 3 km for the infrared channels. Accordingly to MODIS, the active fire detection uses the shift of the peak emission and the increased sensitivity to temperature changes to detect high temperature events within a pixel [1]. The MSG data are received already preprocessed as part of the EUMETCAST payload.

Analog to the MODIS ones, the MSG SEVIRI hot spots are provided as OGC conformable web services.

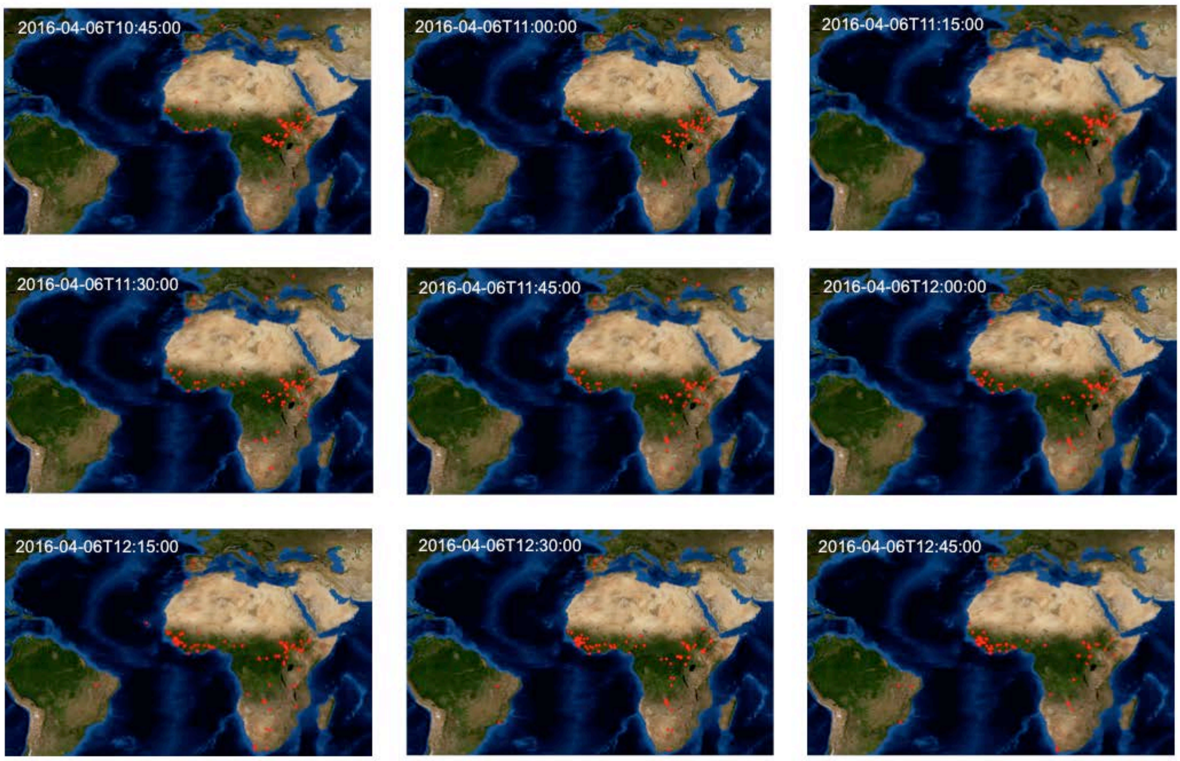


Figure 0-3: Example for MSG SEVIRI Hot Spots for an arbitrary day and a time period of 2 hours.

Getting a Real Immediate Response with the Usage of Airborne Earth Observation

The usefulness and added value of the provision of near-real-time (NRT) images for monitoring purposes is clearly proven. Especially for the response phase after a disaster event the rapid availability of EO-data has been often emphasized by end users during the project lifetime. NRT imagery can provide a timely and more accurate overview of the situation, allowing primary users to know the status of the available infrastructure (for instance, accessible roads or escape routes) as well as of their own resources (estimated location of vehicles and involved first responders). On the other hand, it has been pointed out by end users that the sensors and systems to be used in an operational scenario shall be mounted in the aerial resources (helicopters, aircrafts) owned by the corresponding authorities in charge of the situation.

For the image acquisition during the prescribed pilot demonstration, a helicopter (BO 115) has been provided and coordinated by DLR, which is certified to carry the used optical and thermal sensor systems.

The Optical 4k Sensor

The 4k system is a proprietary real-time optical sensor system of the German Aerospace Center (DLR) originally developed for a wide variety of applications, e.g. for automatic traffic data extraction and for rapid mapping applications (comp.[4], [5]) developed in the frame of the VABENE++ DLR internal project [6].

The sensor system is designed weight-optimized, small, and relatively low-cost, but equipped with a full real-time image processing chain including a high-capacity data downlink to the ground station. Figure 0-4 below shows the sensor system mounted on a DLR helicopter and the components of the 4k system with three non-metric off-the-shelf cameras, a microwave datalink system including two antennas, three processing units and a high-end GNSS/IMU system.

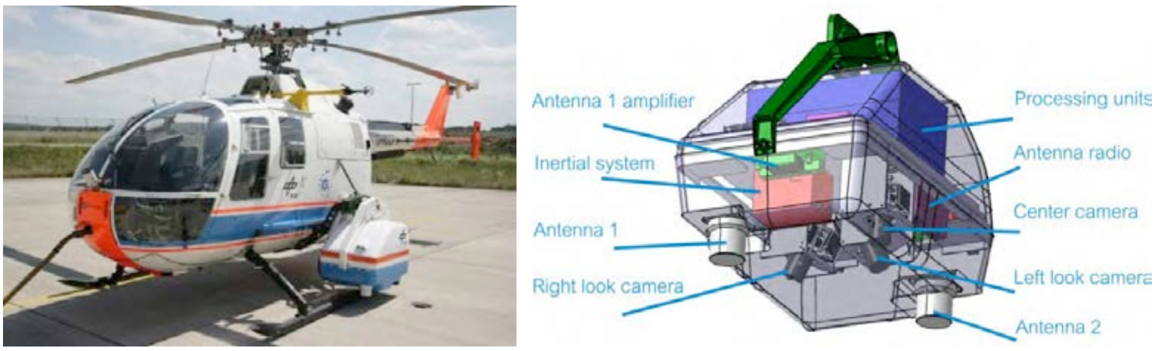


Figure 0-4: 4k system mounted on the helicopter BO-105 (left) and system components (right)

The system is connected to the 28V/35A power supply of the helicopter and to the GNSS antenna on top of the cabin. The system can be commanded from inside the helicopter via LAN or from the ground station via data link.

Three optical non-metric cameras are integrated in the sensor with different looking directions. The latest camera generation from Canon EOS, two 1D-X and one 1D-C, are installed on the platform. Each of them is capable of acquiring 17.9 MPix images with a frame rate of up to 14Hz. Additionally, the Canon EOS 1D-C is capable of acquiring 4k movies (Ultra-HD) with a resolution of 4096 x 2160 pixels at 25 fps and is installed in nadir direction.

For the data provision of 4k aerial imagery during the PHAROS pilot demonstration campaign a technical setup was applied, which consists of the helicopter based 4k camera and on-board processor on the one hand, and the ground station on the other hand. Images of the side looking cameras equipped with 50mm focal length were acquired with a frame rate of 0.5-1.0fps. The standard flight height during the demonstration was 1000m above ground level, which leads to a coverage of 1400m in across and 400m in flight direction. The ground sample distance was 13cm. During the orthorectification process, which was performed aboard, the images were projected on a surface model and then resampled to 10cm. After this preprocessing, the images with accompanying auxiliary files were sent to the ground station via a bidirectional microwave datalink (SRS) using 40MHz bandwidth in the C band.

The ground station contains several components (e.g. receiving antenna, several rack mounted workstations and a screen, if required), which are connected in a private network. The single image files, which are assigned to one overpass, were optimized and processed to a virtual mosaic, which obtains a distinct time stamp. Finally the virtual mosaics were exposed as portrayal web services.

The visualisation of the aerial imagery was realised with a webmapping client, which was displayed on a distinct monitor screen in addition to the actual PHAROS system monitors. The chosen webmapping solution was based on ESRI's ArcGIS for Javascript API [7]. The following figure provides a screenshot of the client with a virtual 4k-image mosaic and additional reference layer.

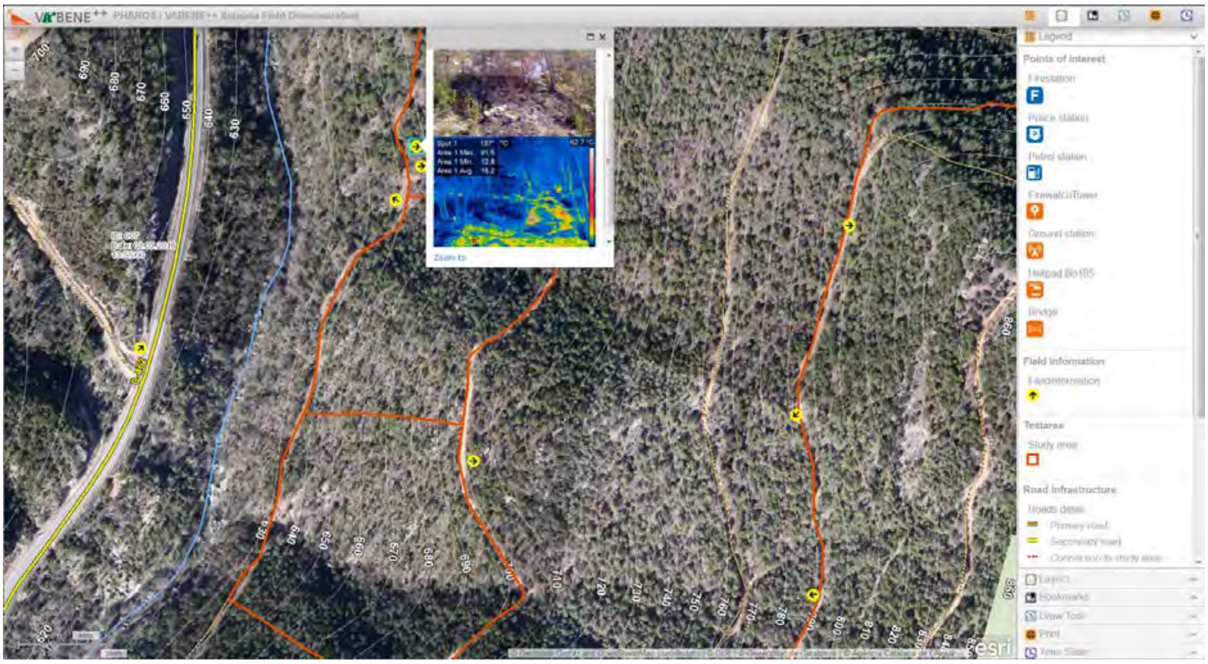


Figure 0-5: PHAROS / VABENE++ Aerial Imagery viewer

During the demonstration flights on March 02, 2016 and March 03, 2016 in total 523 images with file sizes between 15 MB and 250 MB (which adds up to 26.5 GB in total) were acquired and 30 virtual mosaics were processed. The time for data acquisition, downlink, processing, ingestion and service provision averages on 3:35 minutes per virtual mosaic / time step. The shortest response time between the start of the image acquisition and the data provision through the web service in the local network added up to 2 minutes. The following table provides an overview of the characteristics of the provided image mosaics.

Table 0-1: VABENE++ image mosaic specification

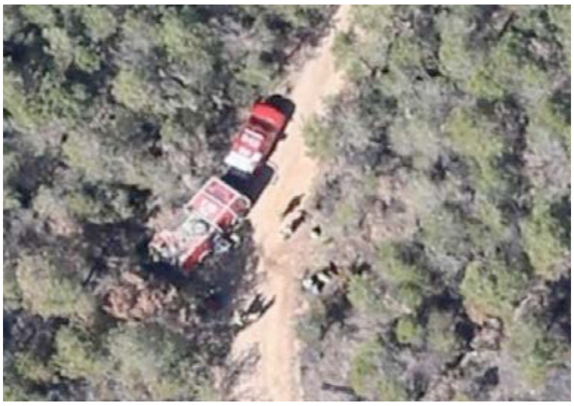
File format	GeoTIFF
Number of bands	3, RGB
Radiometric resolution	8 bit
Spatial resolution	0.1m

Temporal resolution	2 – 5 minutes, depending on flight conditions
Spatial reference system	UTM31, WGS1984
Number of columns / rows	7000 – 14000, depending on flight direction and conditions
Spatial accuracy	< 2m, depending on relief conditions

It is obvious that data with such a high spatial resolution provides very valuable information for the immediate response to small scale natural or technical disasters, especially in dynamic and fast changing scenarios. During the prescribed burning operation in the PHAROS demonstration campaign in Solsona, it could be demonstrated that not only the smoke plumes, but also the active fire front could partly be mapped, even under the very difficult conditions of a surface or ground fire. Additionally a detailed resource management could be supported.

Fire front, 2016-03-02, 10:46 UTC

Fire front, 2016-03-02, 10:54 UTC



Fire brigade, 2016-03-03, 13:40 UTC

Fire brigade, 2016-03-03, 11:00 UTC

Figure 0-6: Sample imagery of the fire front and fire brigade, acquired by the 4k-camera

While the timely and fully automatic analysis of data would be uttermost preferable, it is not yet feasible for every use case. Nevertheless, it could be demonstrated that in combination with mapping services, which are available at the national level in Germany with e.g. the

Center for Satellite based Crisis Information (ZKI) [9] or at European level with the Copernicus Emergency Management Service, a broader and quite timely - albeit of course not a near real time - analysis can be performed. During the Solsona campaign, the data exchange with the ZKI mapping unit was realised via FTP transfer. Transfer, analysis and product delivery could be carried out within 18 – 24 hours after image acquisition. Example map products you can find at Figure 0-7 and Figure 0-8.

The field information map in Figure 0-7 gives a detailed overview on the study site of the PHAROS pilot demonstration on March 02, 2016, the first day of the exercise. The map includes geolocated on-site optical and thermal photos. Thereby, the yellow points depict the location and the arrows the viewing direction of the photos. 4k aerial imagery (spatial resolution: 0.1m) acquired on March 02, 2016, 11:06 UTC is used as backdrop for the main map. A WorldView-2 image (0.5m spatial resolution) acquired on March 02, 2016, 11:17 UTC is used as backdrop for the zoom box on the lower left.

The monitoring map in Figure 0-10 shows the development of the fire hot spot and its corresponding smoke plume during the PHAROS forest fire exercise event on March 03, 2016 from 10:20 to 11:05 UTC by means of a 4k aerial imagery time series.

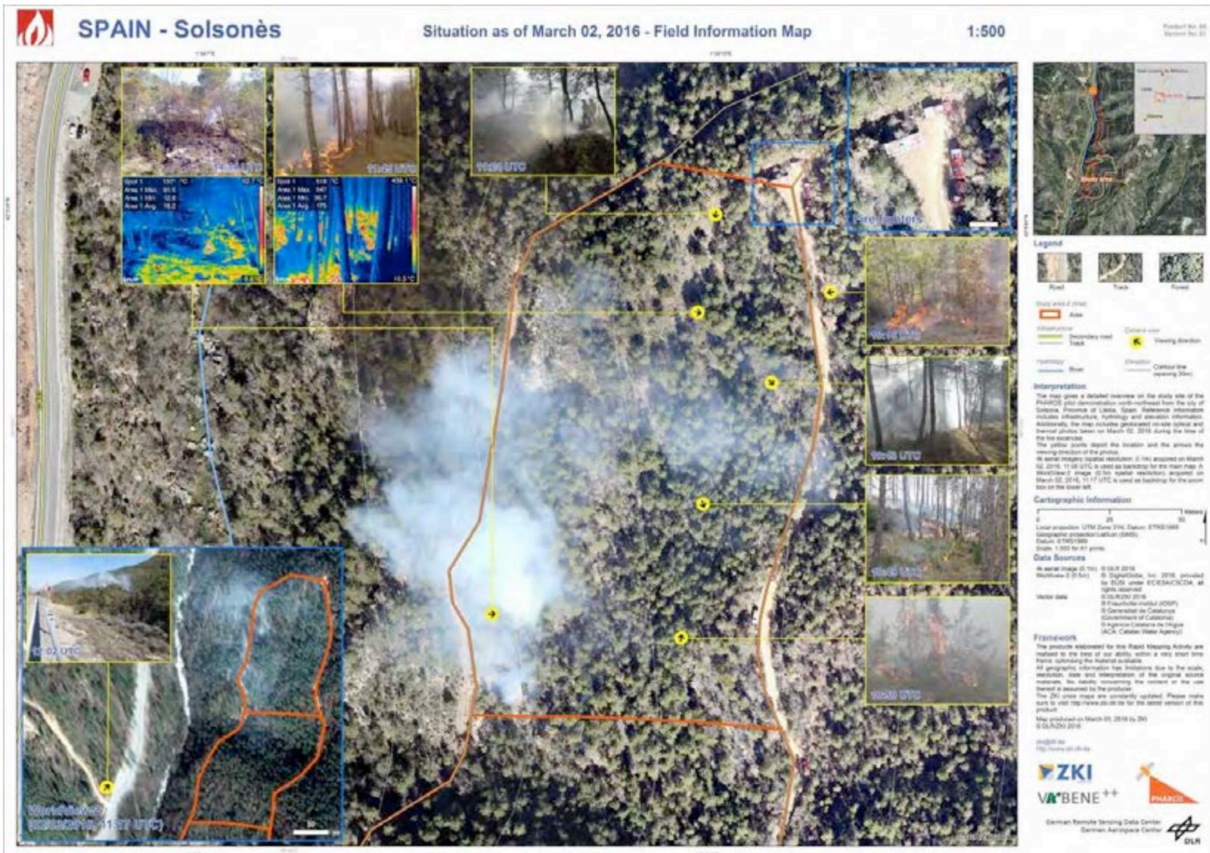


Figure 0-7: ZKI field information map, situation as of March 02, 2016

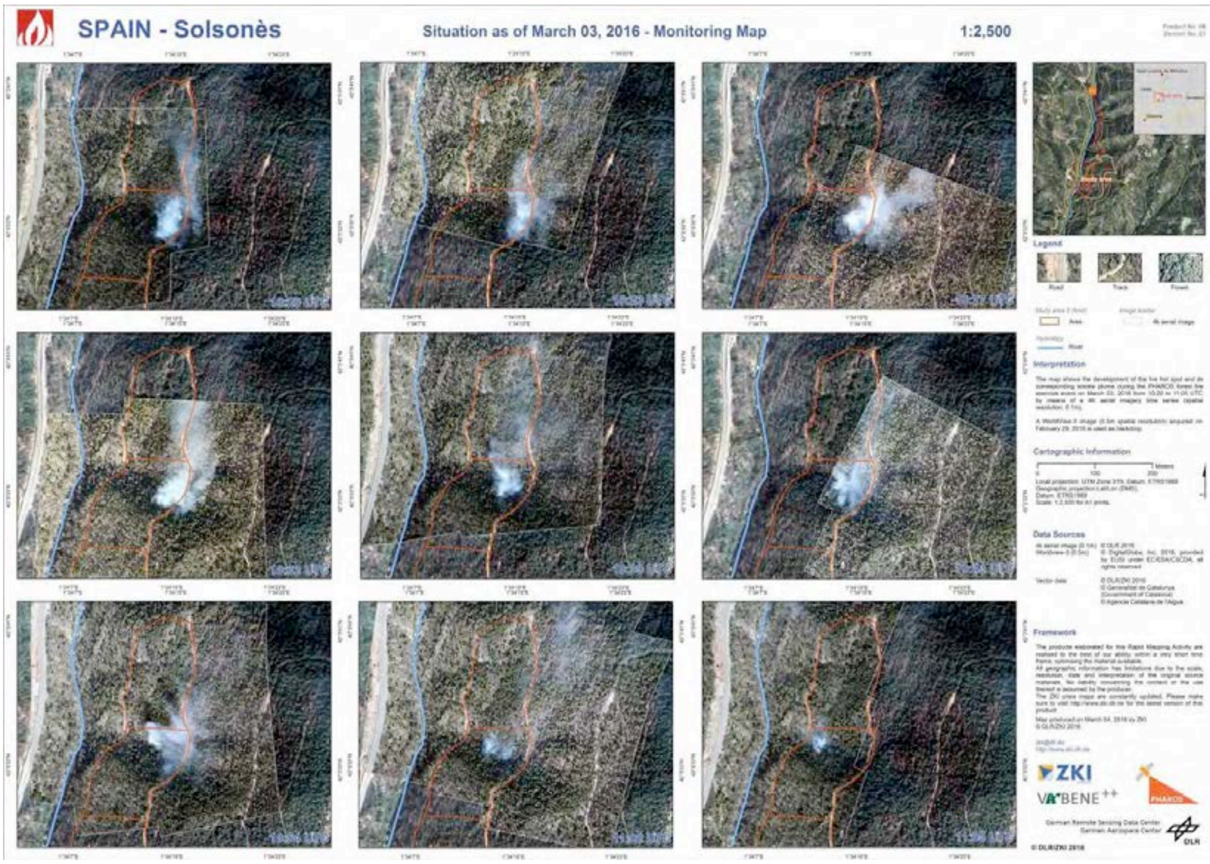


Figure 0-8: ZKI monitoring map, situation as of March 03, 2016

The Thermal AirSIG Sensor

Besides NRT information the view through smoke and tree canopy with infrared sensors is a crucial point for fire fighters. For the pilot demonstration in Solsona the AIR-Sig sensor from Fraunhofer IOSB was used. This sensor is often used for field investigations in the field of applied research tasks, especially for radiometry and image exploitation. It is often combined with aerial observation (compare Figure 0-9), because the target objects are not accessible via ground-based measurements [8]. This is also the case for the usage of the AIR-Sig in the PHAROS project.

Figure 0-9: AIR-Sig system mounted on the helicopter BO-105 (left) and AIR-Sig sensor (right)

The technical data of the AIR-Sig sensor [8] are:

Dual-Band IR Measurement System

- IRCAM Dual-Band FPA640 LM Aero "Clementine"
- IR Spectral Bands/FPA: midwave: CMT 3.5 – 5.1 mm longwave: QWIP, 7.5 – 9.2 mm
- Resolution 640 x 512 pixel, 50Hz, 14bit
- Field-of-View 8.8° x 7.0° (iFoV 0.2 mrad x 0.2 mrad)

With this infrared data the temporal-spatial progression of the fire front can be identified (compare Figure 0-10), which is of high value for the fire brigades and also for the scientists working in fire propagation.

Data Processing and Analysis of the thermal data includes the following steps:

- Pre-processing of the raw data (homogenization, non-uniformity compensation (NUC), bad pixel correction
- Radiometric calculation of the equivalent radiance and temperature distribution
- Higher Level Data processing (flight sequences based on estimated object temperatures (= effective temperatures) or apparent temperatures (= brightness temperatures) and single geocoded images)

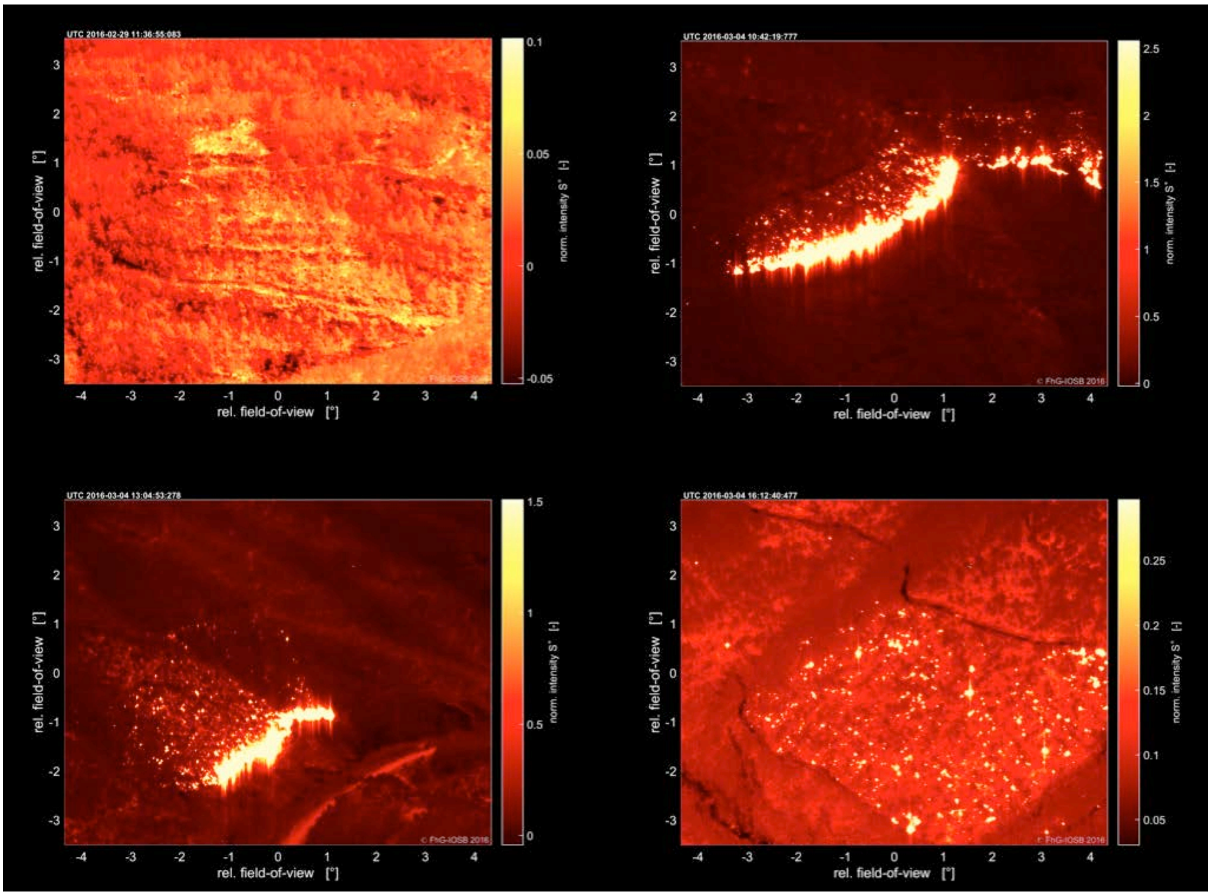


Figure 0-10: AIR-Sig Images showing the pre-fire situation (upper left), the fire front starting at ca. 10:30 (upper right), the fire front approaching the lower end of the fire exercise at 13:30 (lower left) and finally the situation 3 hours after the fire exercise was stopped (lower right).

Satellite based Earth Observation

Satellite-based Earth Observation (EO) can be applied to a variety of emergency responses for predicting, monitoring and/or managing natural or man-made disasters. It has been proven to be a valuable source of information for disaster management on local, regional and global scale, because of the following advantages [10]:

1. synoptic (i.e. large area) coverage,
2. frequent and repetitive data collection of the Earth's surface,
3. diverse spectral, spatial and potentially three dimensional information, and
4. relatively low cost for per unit coverage.

With regard to forest fires – the PHAROS implementation and test hazard – satellite based EO data features high potential to provide important information for the support of disaster management activities within all 4 phases of the disaster management cycle (Table 0-2). With regard to the PHAROS pilot demonstration a comprehensive set of satellite based Earth Observation (EO) pre- as well as post-event data has been tasked from the Copernicus data ware house via the Copernicus Space Component Data Access (CSCDA) system [11].

Table 0-2: Relevance of satellite data acquired for PHAROS within the different phases of the disaster management cycle with regard to the forest fire hazard

Sensor category: Spectral characteristics/ Resolution/	Satellites	Contribution to disaster management: Forest fire			
		Mitigation	**Preparedness**	**Response**	**Recovery**
Optical Multispectral / VHR1, VHR2, HR1, HR2	WorldView-2/3; Pléiades; RapidEye; Spot-5/6/7	Assessment of vegetation state, LULC, built environment and infrastructure, elevetation information (requires stereo imagery); planning of mitigation, e.g. the creation of wildfire defensible zones	Detailed and up-to-date reference and exposure information e.g. building footprints and (critical) infrastructure (requires VHR); LULC; monitoring of vegetation state; investigation of potentially affected areas; e.g. for evacuation planning	Localisation, quantification and monitoring of burnt area, smoke plumes, affected built environment, infrastructure and LULC	Monitoring and planning of recovery / reconstruction, e.g. recovery of LULC and reconstruction of infrastructure or resettlement
SAR/ VHR1, HR1	TerraSAR-X, Radarsat-2	Elevation information for mitigation planning e.g. extraction of digital terrain features	Reference and exposure information: LULC (requires polarimetric SAR data); elevation information (DEMs), e.g for slope information; localisation of waterbodies	Localisation, quantification and monitoring of burnt area	

The pre-event data ordered before the PHAROS pilot demonstration in standard acquisition mode [12] is listed in Table 0-3. In more detail

Table *0-4* shows the pre- and post-event acquisitions ordered in rush acquisition mode. Rush mode new acquisitions satellite imagery is delivered between 2 and 5 hours from sensing [12].

The data sets comprise optical as well as synthetic aperture radar (SAR) satellite imagery and cover the resolution classes Very High Resolution (VHR)1 (resolution <= 1m), VHR2 (1m <

resolution <= 4m), High Resolution (HR)1(4m < resolution <= 10m) and HR2 (10m < resolution <=30m) [12].

Table 0-3: Data sets acquired from Copernicus DWH in standard acquisition mode (via CSCDA Standard Data Request)

Acquisition date [dd/mm/yyyy]	Satellite / Sensor or beam	Data type	Archive / New acquisition
11/03/2012	RapidEye / Multispectral	Optical HR1	Archive
25/06/2012	RapidEye / Multispectral	Optical HR1	Archive
03/01/2012	RapidEye / Multispectral	Optical HR1	Archive
18/12/2012	Spot-5 / Multispectral	Optical HR1	Archive
06/05/2013	RapidEye / Multispectral	Optical HR1	Archive
31/07/2013	RapidEye / Multispectral	Optical HR1	Archive
16/09/2013	RapidEye / Multispectral	Optical HR1	Archive
05/05/2014	RapidEye / Multispectral	Optical HR1	Archive
23/07/2014	RapidEye / Multispectral	Optical HR1	Archive
11/09/2014	RapidEye / Multispectral	Optical HR1	Archive
07/12/2014	Spot-5 / Multispectral	Optical HR1	Archive
10/03/2015	RapidEye / Multispectral	Optical HR1	Archive
09/05/2015	RapidEye / Multispectral	Optical HR1	Archive
30/06/2015	RapidEye / Multispectral	Optical HR1	Archive
20/09/2015	RapidEye / Multispectral	Optical HR1	Archive
12/01/2016	RapidEye / Multispectral	Optical HR1	New acquisition
16/02/2016	RapidEye / Multispectral	Optical HR1	New acquisition
10/09/2014	Deimos-1 / Multispectral	Optical HR2	Archive
26/03/2015	Deimos-1 / Multispectral	Optical HR2	Archive
29/12/2015	WorldView-2 / Bundle	Optical VHR1	New acquisition
05/02/2016	WorldView-2 / Bundle	Optical VHR1	New acquisition
20/02/2016	Pléiades / Multispectral	Optical VHR1	New acquisition
09/05/2015	Spot-7 / Bundle	Optical VHR2	Archive

Acquisition date [dd/mm/yyyy]	Satellite / Sensor or beam	Data type	Archive / New acquisition
22/05/2015	Pléiades / Multispectral	Optical VHR2	Archive
17/09/2015	Pléiades / Multispectral	Optical VHR2	Archive
14/02/2016	TerraSAR-X / High Resolution Spotlight	SAR VHR1	New acquisition
16/02/2016	TerraSAR-X / High Resolution Spotlight	SAR VHR1	New acquisition
25/02/2016	TerraSAR-X / High Resolution Spotlight	SAR VHR1	New acquisition
27/02/2016	TerraSAR-X / High Resolution Spotlight	SAR VHR1	New acquisition
07/03/2016	TerraSAR-X / High Resolution Spotlight	SAR VHR1	New acquisition
09/03/2016	TerraSAR-X / High Resolution Spotlight	SAR VHR1	New acquisition
18/03/2016	TerraSAR-X / High Resolution Spotlight	SAR VHR1	New acquisition
20/03/2016	TerraSAR-X / High Resolution Spotlight	SAR VHR1	New acquisition
05/02/2016	Radartsat-2 / Fine Quad-Pol	SAR HR1	New acquisition
06/02/2016	Radartsat-2 / Fine Quad-Pol	SAR HR1	New acquisition
29/02/2016	Radartsat-2 / Fine Quad-Pol	SAR HR1	New acquisition
01/03/2016	Radartsat-2 / Fine Quad-Pol	SAR HR1	New acquisition
24/03/2016	Radartsat-2 / Fine Quad-Pol	SAR HR1	New acquisition
25/03/2016	Radartsat-2 / Fine Quad-Pol	SAR HR1	New acquisition

Table 0-4: Data sets acquired from Copernicus DWH in rush acquisition mode (via CSCDA Service Project Emergency Request Form)

Acquisition time [dd/mm/yyyy hh:mm (UTC)]	Satellite / Sensor or beam	Data type	Archive / New acquisition
01/03/2016 11:40	RapidEye / Multispectral	Optical HR1	New acquisition
02/03/2016 11:15	RapidEye / Multispectral	Optical HR1	New acquisition

Acquisition time [dd/mm/yyyy hh:mm (UTC)]	Satellite / Sensor or beam	Data type	Archive / New acquisition
03/03/2016 11:18	RapidEye / Multispectral	Optical HR1	New acquisition
04/03/2016 11:21	RapidEye / Multispectral	Optical HR1	New acquisition
05/03/2016 11:24	RapidEye / Multispectral	Optical HR1	New acquisition
01/03/2016 10:40	SPOT-6 / Bundle	Optical VHR2	New acquisition
02/03/2016 10:32	SPOT-7 / Bundle	Optical VHR2	New acquisition
03/03/2016 10:25	SPOT-6 / Bundle	Optical VHR2	New acquisition
04/03/2016 10:17	SPOT-7 / Bundle	Optical VHR2	New acquisition
05/03/2016 10:10	SPOT-6 / Bundle	Optical VHR2	New acquisition
29/02/2016 11:19	WorldView-3 / Bundle	Optical VHR1	New acquisition
01/03/2016 10:16	WorldView-2 / Bundle	Optical VHR1	New acquisition
02/03/2016 11:17	WorldView-2 / Bundle	Optical VHR1	New acquisition
03/03/2016 10:42	WorldView-2 / Bundle	Optical VHR1	New acquisition
05/03/2016 11:06	WorldView-2 / Bundle	Optical VHR1	New acquisition
06/03/2016 10:45	WorldView-2 / Bundle	Optical VHR1	New acquisition
07/03/2016 10:45	WorldView-3 / Bundle	Optical VHR1	New acquisition
07/03/2016 17:47	RADARSAT-2 / Fine Quad Pol	SAR HR1	New acquisition
10/03/2016 17:59	RADARSAT-2 / Fine Quad Pol	SAR HR1	New acquisition
01/03/2016 06:12	TerraSAR-X / Staring Spotlight	SAR VHR1	New acquisition
02/03/2016 05:55	TerraSAR-X / Staring Spotlight	SAR VHR1	New acquisition
03/03/2016 17:51	TerraSAR-X / Staring Spotlight	SAR VHR1	New acquisition
04/03/2016 06:54	TerraSAR-X/ Staring Spotlight	SAR VHR1	New acquisition
05/03/2016 06:37	TerraSAR-X/ Staring Spotlight	SAR VHR1	New acquisition

The acquired satellite EO data was integrated into the PHAROS system providing very valuable thematic information on the PHAROS pilot demonstration study site in Solsonès, Catalonia. Furthermore, due the Copernicus DWH rush mode delivery times acquired data sets could be successfully integrated into the rapid mapping activities of the ZKI within relatively short time frames (Section 0). Pre-event data served for the collection of up-to-date reference data useful for pre-/post-event analyses as well as for the planning of the PHAROS pilot demonstration campaign.

The imagery sensed during the course of the exercise enabled a monitoring of fire hotspot locations and corresponding smoke plumes with a temporal resolution of 1 day. In addition VHR1 post-event imagery enabled the semi-automatic derivation of potentially fire affected areas.

DLR's Center for Satellite based crisis information (ZKI)

The Center for Satellite based Crisis Information (ZKI) of the German Aerospace Center (DLR) provides services for the rapid geospatial support of actors involved in the management of natural disasters, man-made emergency situations and humanitarian crises [9]. This includes the production of thematic information products derived by the use of satellite- and aerial remote sensing data analysis methods as well as the integration of ancillary data from further sources (e.g. population census information). Such products (e.g. thematic information layers) represent valuable input for (multi-) hazard management systems such as the PHAROS system. Within the PHAROS pilot demonstration several thematic information layers and maps were produced on the basis of the EO data sensed by the previously mentioned airborne (Section 0) and spaceborne (Section 0) EO sensors. Examples of ZKI mapping products and analyses are presented below (Figure 0-7 and Figure 0-8 and Figure 0-11 to Figure 0-15).

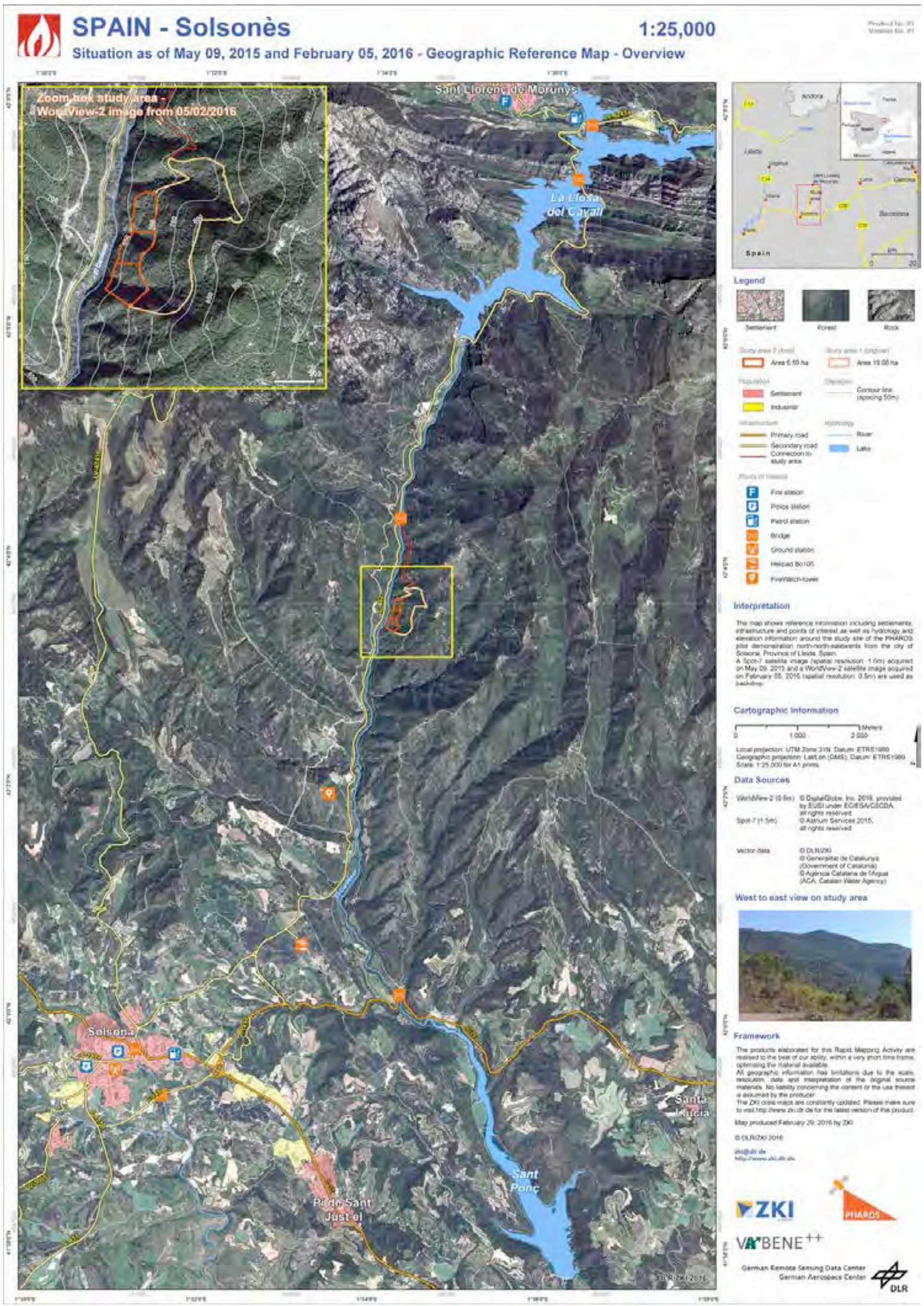


Figure 0-11: Geographic reference map of the region around the study site

Figure 0-11 shows a geographic reference map of the region around the study site of the PHAROS pilot demonstration in Solsonès, Catalonia. Within the map optical satellite imagery from the satellites SPOT-7 (VHR2; main map) and WorldView-2 (VHR1; zoom box) are used as backdrop and provide up-to-date large area information on the spatial distribution of settlements, infrastructure and hydrology.

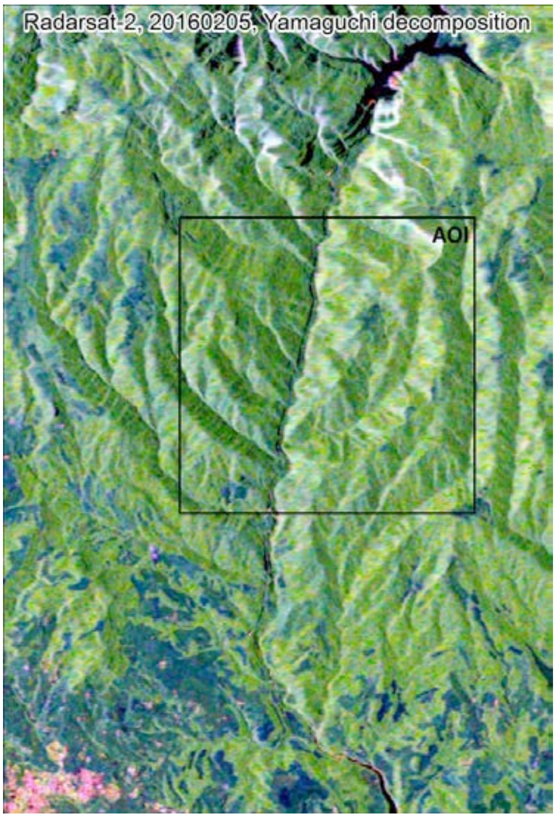


Figure 0-12: Radarsat-2 polarimetry based Yamaguchi decomposition for the region around pilot demonstration study site

Polarimetric SAR (PolSAR) data such as Radarsat-2 quadpol imagery can be additionally deployed in order to extract reference information (e.g. land cover). Figure 0-12 shows the result of a polarimetric decomposition for a Radarsat-2 scene of the pilot demonstration area. Herein the red coloured areas are indicating urban areas. Green colours indicate dense and high vegetation such as tree crowns. Dark green and blue colours indicate areas covered predominantly by low and sparse vegetation. Very dark areas indicate open water bodies.

The acquisition of satellite imagery within the demonstration week in rush acquisition mode enabled the capturing of the state of fire hot spots at acquisition time due to their corresponding smoke plumes. Figure 0-13 shows the state of fire hotspots/smoke plumes for each day of the pilot demonstration at about 10:30 UTC.

Post-disaster multispectral optical imagery serves for the extraction of areas potentially affected by the fire. **Error! Reference source not found.** shows a corresponding map highlighting potentially fire affected areas (depicted in red) which were extracted by means of semi-automatic image analysis.

Figure 0-13: Satellite imagery based monitoring map for the days of the pilot demonstration

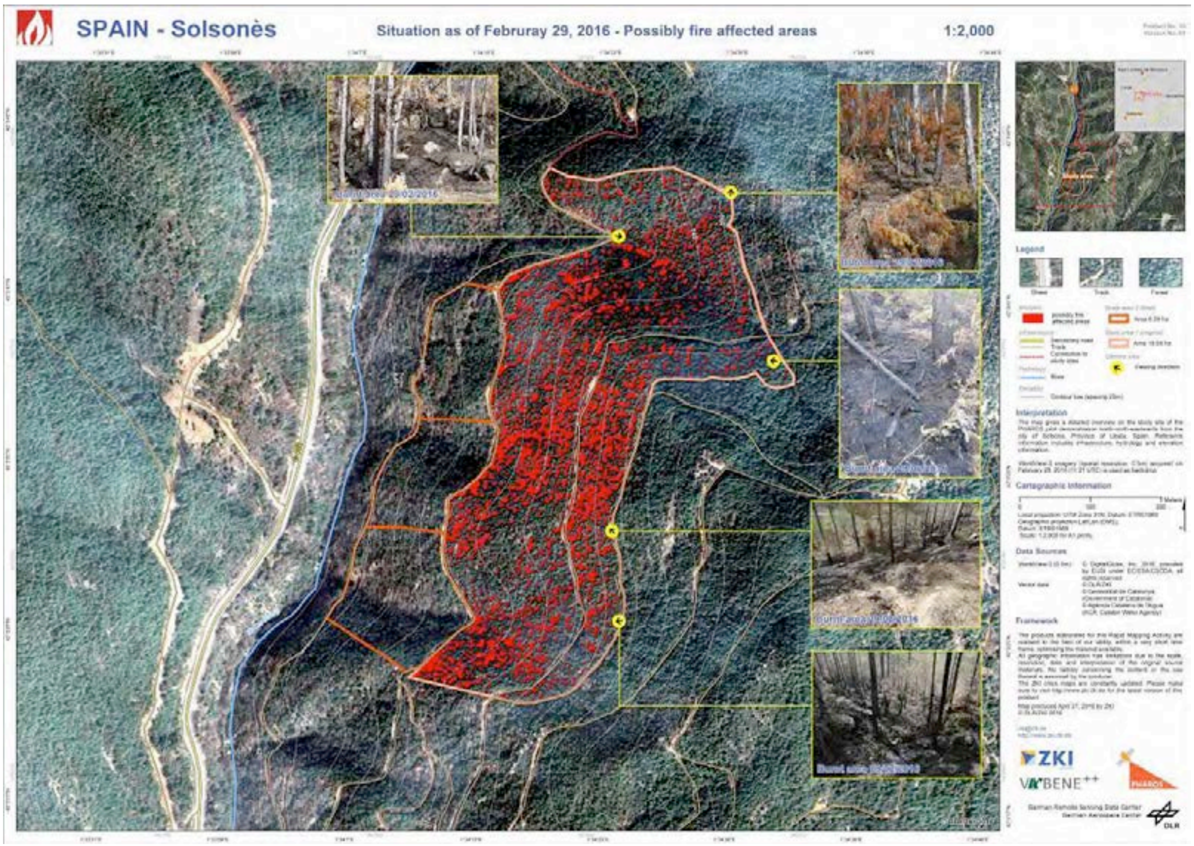


Figure 0-14: Map of possibly fire affected areas

The map in Figure 0-15 shows the surface temperature development within the study area during the PHAROS forest fire exercise event on March 04, 2016 by means of AIR-Sig imagery thermal imagery (Section 0) from 09:42 UTC, 12:06 UTC and 15:12 UTC. Additional information is given by geolocated on-site optical and thermal photos. A Pléiades image acquired on February 20, 2016 with 0.5m spatial resolution is used as backdrop.

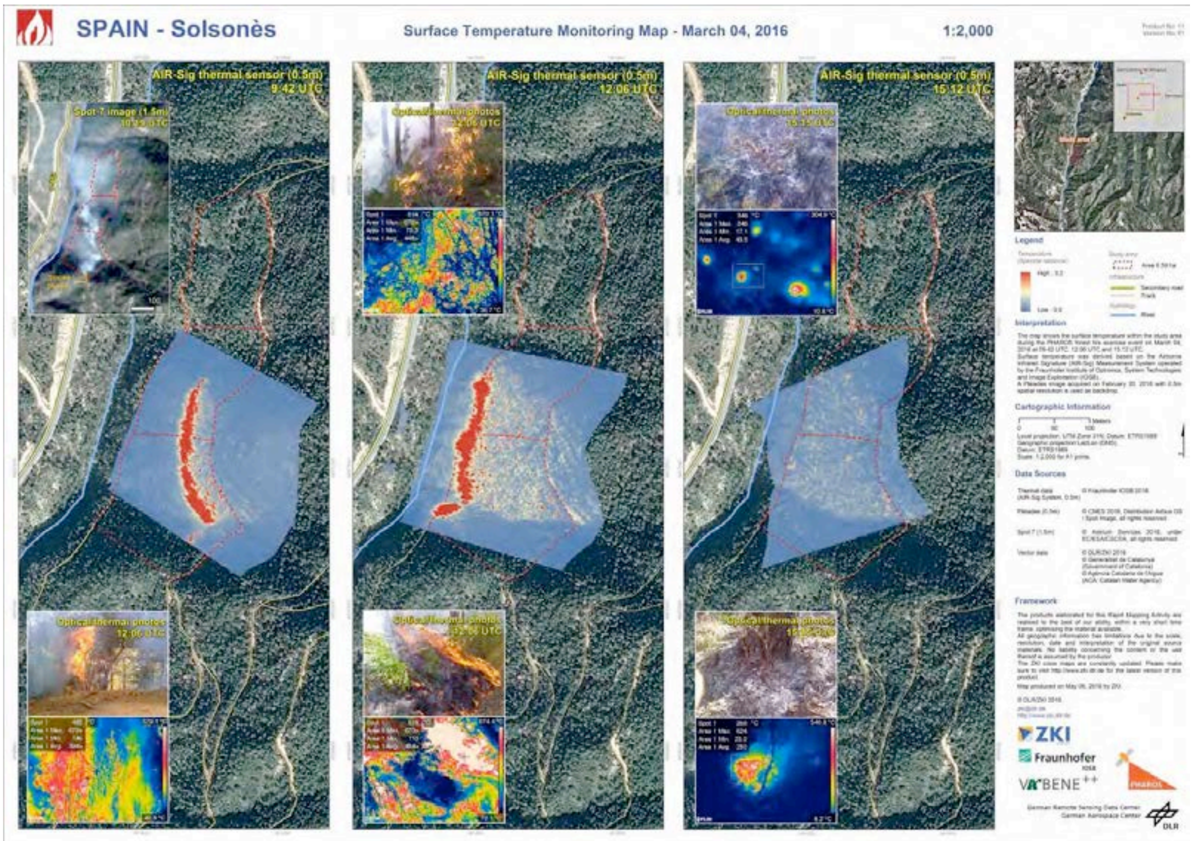


Figure 0-15: Surface Temperature monitoring map, situation as of March 04, 2016.

The map products provided by DLR-ZKI can be accessed and downloaded via https://www.zki.dlr.de/article/2773.

Conclusion and Outlook

In the context of the PHAROS Wildfire System Earth Observation was proven as a valuable part during the whole crisis cycle. For fire detection it is a cheap and effective alternative to in-situ sensors, which is most useful for areas with a small population density. To get near real time information from the on-going fire front airborne sensors are without alternative. To get more insight through smoke and tree canopy infrared information turned out to be of a great value to the relief units. In addition to all this information additional high and very high resolution satellites can be tasked within a few hours. Finally all this earth observation data is used to create crisis maps by the ZKI unit of the German Aerospace Center. These maps comprise valuable information, which is especially tailored to the needs of the fire brigades.

The PHAROS system contains already nearly all interfaces for the integration of Earth Observation data. Especially the future usage of services of the European Union, like the Copernicus Emergency Mapping Service (EMS), the Copernicus Space Component Data Access (CSCDA) and also

Sentinel 3 for hot spot detection are taken into account. In this respect the already pre-operational PHAROS system can be seen as the first step to a future Multi Hazard Crisis System.

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