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Purpose of the Document

This document summarizes the work performed during the RASOR project in the WP7 “Historical Disaster Extent and Damage Overlay” which objectives are, first to build an historical disaster events geo-database over the RASOR test sites, and then to prepare impact and risk scenarios with the exploitation of the land cover-stakes database to be built in the WP4. A focus is given on the historical disasters cases analysis.

Executive Summary

To assist in risk identification, end users require comprehensive information on past disasters (historical events) and on land cover-stakes of the landscape under investigation. Moreover, analysis of historical events can also be useful to test, adjust and validate the proposed modelling. EO archive can bring part of these two types of information.

Over the different test sites, selected in order to demonstrate representative products of the RASOR platform, after having set up the list of historical disasters events (WP7.1) associated to the list of potential relevant EO data (WP7.2), and selected the a priori most convenient dataset (WP7.3), the WP7.4 activity was focused on the procurement and thematic processing of these historical images in order, to build the historical event database. The present document synthesizes the work done over the test sites and present the Rapid actions carried over Jakarta in February 2016.

A first step of the RASOR project consisted in the constitution of the historical case DB, a step that has been strongly limited by the unavailability of the Data Ware House which should have given access to the EO data since the beginning of the RASOR project. Alternative solutions for the procurement of EO data have been set up which allowed the integration in the RASOR platform of flood events layers having affected the Haiti pilot site. Finally, in April 2015, access to DWH was open, and first ordering of convenient EO data was possible. Therefore, the project was confronted to delay and problems in accessing identified EO data set. A first order was well received but did not reach the CCM's, so it was re ordered in fall 2015. In addition, despite numerous and intense email exchange with Copernicus EO support, exchanges began, in phase advance, with data providers in Singapore, US and Italy, it was not possible to reach an interesting set of Ikonos imagery over one test site, i.e. Cilacap, related to a tsunami event.

A major step of Rasor project corresponds to the integration of Sentinel data for catastrophic event characterization, data coming both from Sentinel 1, over Italian and Indonesian tests cases as well as Sentinel 2, over Italian test site. For future dramatic events, such data would address the lack of data availability, thanks to the systematic acquisition scheme, and the ramp up of the constellation in 2016 with the launch of Sentinel1B and later the launch of Sentinel 2B. For the future exploitation of the Rasor Platform, it can be expected that this access/availability to Sentinel1 and Sentinel2 data will improve very much the situation.

A second major step corresponds to the initialization of Rapid capabilities linked to the February 2016 Indonesian flood events. On the one hand, the analysis of available EO data shown the lack of data acquired during events over Indonesian test cases on the other hand, the exchanges with the Indonesian End Users, principally the National Disaster Management Authority – Badan Nasional Penanggulangan Bencana (BNPB), highlighted their demands in term of monitoring events affecting Jakarta town. After a training session, Rasor team got access to the Copernicus Emergency Satellite Tasking (REACT) service coordinating the rush ordering and delivery of new and archived imagery. Then, in less than 4 weeks, in February 2016, 3 actions of monitoring have been carried out exploiting both VHR2 SAR and optical imagery. From a technical point of view, these three consecutive actions were very successful in term of time for accessing programing, receiving acquired data in a rush mode, highlighting also the potential of optical data even over unfavorable areas in term of cloud coverage etc .. In term of thematic, i.e. flood mapping, the success is less obvious. This is due to the targeted area, dense urban areas, in regards to the available EO satellite resource: RASOR is limited to VHR2 data. It was not possible to detect any portion of flooded water from the requested VHR2 SAR data, and for the optical VHR2, the SPOT6-7 data, flooded areas were well observed, but the 1.5 meter of the merged product is not enough to provide any valuable information in a very dense urban area where the distance between houses is in the same range of the image resolution. If VHR1 optical imagery would have been accessible to the project, this limitation would have been overcome, but the monitoring would have been possible over less extended areas, requiring then a stronger exchange with End Users in the definition of the targeted area.

A very successful point it is that, thanks to these actions, Rasor team got the opportunity to demonstrate its rush capacity and to carry on a real rapid action, and this is very positive in term of gained experience as well as for the recognition of its competencies for future developments.

Abbreviations

Abbreviation	Meaning
RASOR	Rapid Analysis and Spatialisation of Risk
SC	Steering Committee
AB	Advisory Board

RASOR context

The Rapid Analysis and Spatialisation and Of Risk (RASOR) project will develop a platform to perform multi-hazard risk analysis to support the full cycle of disaster management, including targeted support to critical infrastructure monitoring and climate change impact assessment, exploiting internally produced and available services. RASOR adapts the newly developed 12m resolution Tandem-X Digital Elevation Model (DEM) to risk management applications, using it as a base layer to interrogate data sets and develop specific disaster scenarios.

RASOR overlays archived and near-real time very-high resolution optical and radar satellite data, combined with in situ data for both global and local applications. A scenario-driven query system allows users to project situations into the future and model multi-hazard risk both before and during an event.

Managers can determine the extent of flooding in a given area and determine, for example, the risk pending on Critical Infrastructure Systems in terms of their residual functionality as a basis for a systemic vulnerability analysis. Public authorities can determine the impact of coastal subsidence on flood defenses over several years given various sea surge scenarios and based on actual, accurate subsidence information. RASOR allows managers to use real scenarios when determining new mitigation or prevention measures, and integrate new, real-time data into their operational system when organizing response activities.

The RASOR Consortium will offer three tracks of services based on adding value through customized exploitation of the RASOR tool for risk management and insurance markets: a global risk assessment service, and SME-led national and local services through innovative partnering arrangements in each national marketplace. These tracks are validated in five different geographic locations (Haiti, Indonesia, Italy, Netherlands and Greece) with end users and practitioners, as well as with international organizations representing three different markets (World Bank for developing country and global analysis markets; UNOSAT for UN Agencies; Munich Re and RMS for insurance markets; and the European Commission's agencies interested in risk management issues). End users have been involved in conceiving the RASOR tool, and will shape its ultimate outcome through the in-depth development of requirements, a User Workshop and a dedicated Service Validation activity and Service Level Agreements (SLA) that demonstrate the viability of a commercial RASOR service to be offered at the conclusion of the project.

WP7 "Historical Disaster Extent and Damage Overlay" context

To assist in risk identification, End users require comprehensive information on the past disasters (historical events). EO archive can bring part of this information. The aim of the WP7 is to mine satellite images archives over the five pilot areas of RASOR in order to accumulate data over a ten year or longer reference period, these EO data corresponding to the major past events having occurred in the pilot areas. From these, geo spatial information on the maximum damage extent, duration, frequency, etc, will be produced. The focus of this analysis will be on floods, but will include other hazards when relevant (e.g. earthquake and floods associated with cyclones in Haiti; tsunami and floods in Indonesia). This activity will allow building a database of EO

derived information for hazard characterization over the different test sites, with these thematic layers being uploaded on the RASOR platform.

Indonesian case of study

Based on the End Users requirements, 3 test sites were defined within Java Island, Jakarta town, Bandung depression and Cilacap coast (Fig.1)



Figure 1 : Location of the test sites in Java, Indonesia

INDONESIA									
	Event	Continent	Country	location	date	Duration	Fatalities	Injured	Displaced
11	Floods	Asia	INDONESIA	Jakarta	1996				
12	Floods	Asia	INDONESIA	Jakarta	01/02/2002	1	50		
13	Landslide	Asia	INDONESIA	Java - sulawesi	29/01/2002	5	147		
14	Volcano eruption	Asia	INDONESIA	Java	26/04/2006	1			
15	Earthquake	Asia	INDONESIA	Yogyakarta	26/05/2006	1	6000	36000	
16	Landslide	Asia	INDONESIA	Cijeruk	04/01/2006	1	200		
17	Earthquake	Asia	INDONESIA	Java	17/07/2006	1	730	9299	54256
18	Landslide	Asia	INDONESIA	Bandung	21/02/2005	1	140		
19	Tsunami	Asia	INDONESIA	Java	17/07/2006	1	147		
110	Floods	Asia	INDONESIA	Jakarta	31/01/2007	1	80		
111	Earthquake	Asia	INDONESIA	West Java - Bandung - Jakarta	02/09/2009	1	74	34	
112	Floods	Asia	INDONESIA	Java - Bandung - Cilacap	23/02/2010	9	35	9	
113	Volcano eruption	Asia	INDONESIA	Mount MERAPI	03/11/2010	1			
114	Floods	Asia	INDONESIA	Legon Kulon, Pamanukan	18/01/2011	2			
115	Tropical Cyclone Iggy	Asia	INDONESIA	Java	25/01/2012	1	17	60	
116	floods	Asia	INDONESIA	Jakarta	01/01/2013	1	47		20000
117	floods	Asia	INDONESIA	Jakarta	30/01/2014	1	11		31000

Table I: List of major disasters affecting the Java test sites

Bandung case study

With over 2.5 million inhabitants in 2014, Bandung is the third Javanese city after Jakarta and Surabaya (Fig.1). Located in a flood plain (between 600 and 750 meters above sea level), surrounded by volcanic mountains, Bandung has developed on alluvial and fluvial sediments of the River Citarum and on volcanic deposits. The vast

alluvial plain of Bandung contains a dense network of irrigation canals and drainage. Located at low latitudes (between 6 ° and 7 ° 57 S), it enjoys a tropical climate with high inter-annual variability.

Flooding of Citarum and its tributaries are relatively common during the rainy season between the months November to April. These rains are characterized by a high intensity that can exceed 100 mm / hour (Bouheng, 2013). During the last thirty years, six major flooding have severely impacted the district of Bandung in March 1986, February 2005, April 2005, April 2007, February 2010 and December 2014 (Fig. 1). The flood of March 1986 affected 27,310 homes. The February 2005 event have engulfed the area for 7 days 20 km² requiring the evacuation of 50,000 residents (Shimamura, 2009; Bormudoi & Hazarikaa, 2011). Tectonic (i.e. subsidence) and climatic phenomena amplify the floods (Hasanuddin.Z et al., 2015).

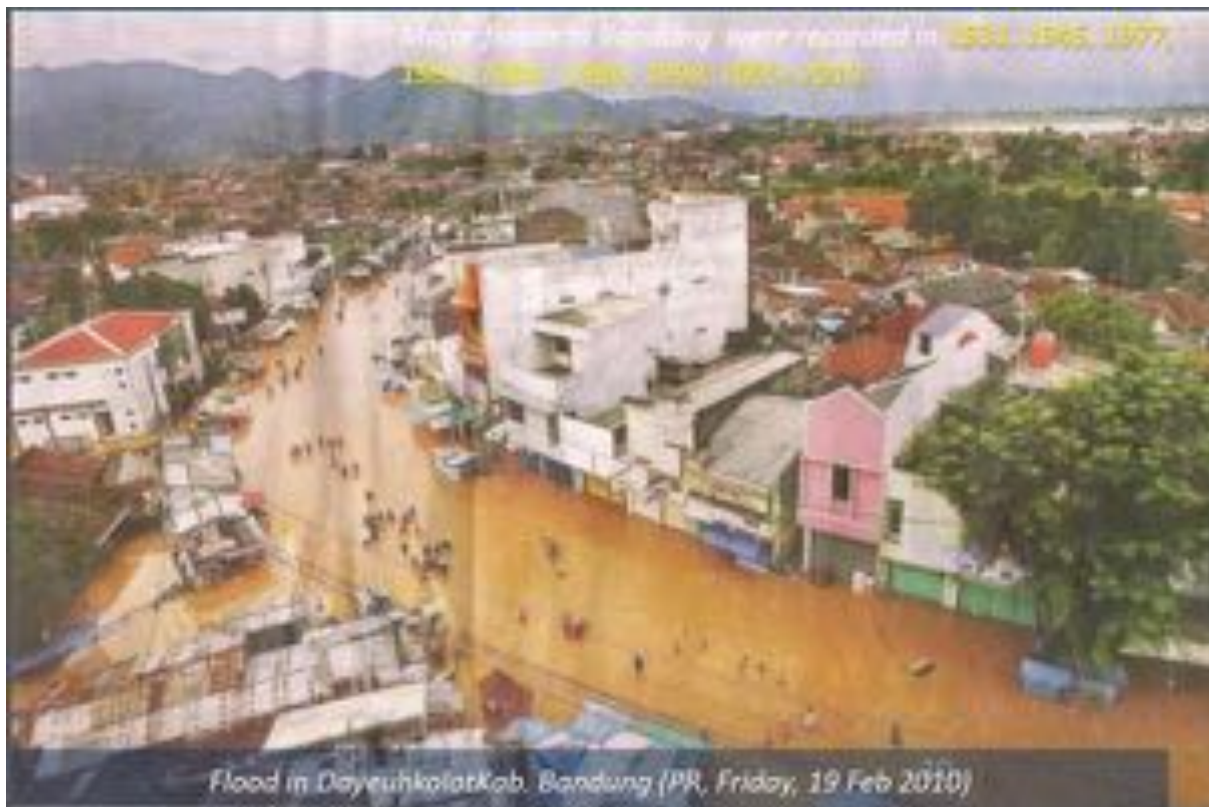


Figure 2: Flood in Bandung, February 2010

In a first time, reports and scientific papers on flood analysis over Citarum watershed have been collected. These documents are presenting also a large diversity in terms of approach and apparent data quality, making them rarely exploitable for a GIS/platform approach (Fig. 3)

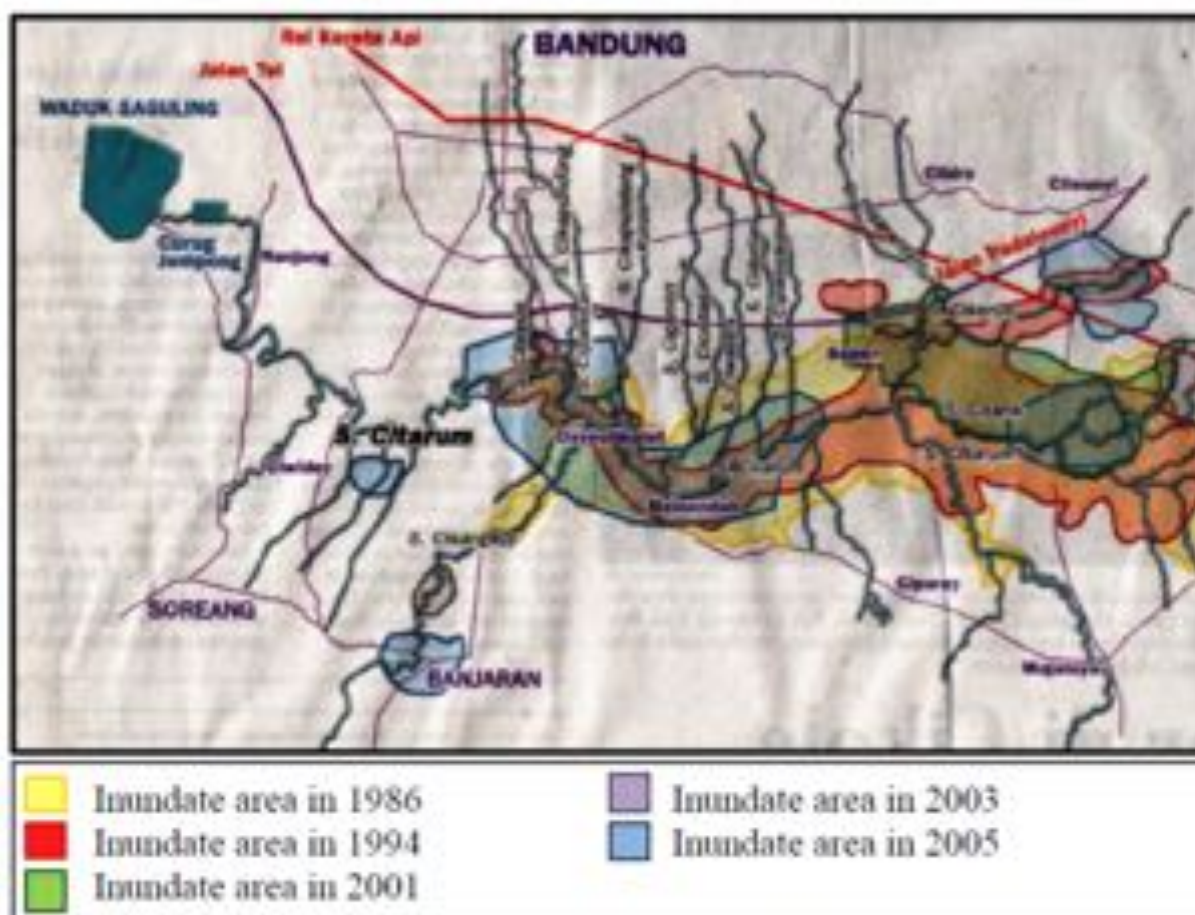


Figure 3: Example of a Bandung Flood historical map, (Nuraeni, & Arai, 2010)

Search of relevant EO data

An analysis of relevant Earth Observation images have been done exploiting various EO data providers, and looking for ancient and recent archives.

Date or period of flood event	source	Availability of EO data potentially relevant
2005 – Feb 22		None
2007 – Feb 20-22		None
2008 – Nov 6-8		None
2009 – Dec 20-25	http://www.thejakartapost.com/news/2009/12/26/3000-houses-south-bandung-hit-flash-flood.html	None
2010 February (18-19-	Jakarta Post news papers	SPOT4 25 - 02 & 02-03 (out of

21) to March (27-30)		sensitive areas), SPOT5 26-02
2010 – Dec 2	http://reliefweb.int/report/indonesia/indonesia-floods-bandung-district-pmi-establish-command-post	None
2011- April 16		None
2012 – Feb	http://reliefweb.int/sites/reliefweb.int/files/resources/Indonesia%20Humanitarian%20Bulletin%2C%20February%202012_0.pdf	None (data only out of AOI or cloudy)
2013 – Jan 20	http://reliefweb.int/disaster/fl-2013-000006-idn	None (data only out of AOI or cloudy 31-01-2013)
2014 – Nov 20	http://en.tempo.co/read/news/2014/11/20/055623225/Bandung-Stricken-by-Floods-as-Citarum-River-Banks-Bursts	CSK
2014 - Dec 20-25	http://www.thejakartapost.com/news/2014/12/24/bandung-declares-emergency-floods-spread.html	None
2015 – Feb 3 & 24		CSK, S1

Exploitation of relevant EO data set

Based on the available information, a set of images have been ordered to DWH or accessed directly from open source archives (i.e. Landsat TM or Sentinel 1 Hub); their exploitation was not fruitful at all.

Example of the February March 2010 event.

Press releases, Jakarta Post, announced on the 6 of February 2010, that the Citarum river has inundated at least 6000 houses, and again 7 000 homes on the 23 of march 2010 knowing that on the 23 of February a landslides have affected the Bandung district already ravaged Bandung District.

Within the various accessible databases, a set of SPOT4 and SPOT5 images have been identified in a first step. However, a deeper analysis has showed that part of them was not covering the sensitive area, i.e. the Dayeuhkolot and Baleendah suburbs, being acquired over the Eastern part of the Bandung depression (Fig. 4).



Figure 4: SPOT 4 scene acquired on the 25 February 2015 over the Eastern part of the Bay of Bengal, i.e. out of the sensitive areas

The SPOT5 imagery acquired on the 26 of February 2010 was apparently the adequate resource for these event recognition and mapping (Fig. 5).



Figure 5: SPOT 5 image acquired over Bandung on the 26 of February 2010. Bright colors corresponds to clouds but also to signal saturated over water bodies (wind and sun glint effect?), green colors correspond to agricultural areas whereas deeper green to forest, and brown pink to the city of Bandung.

Therefore the analysis of this relatively cloud free image was not successful. As already indicated floods event affected mostly the Southern part of the Bandung agglomeration, i.e. the Dayeuhkolot and Baleendah suburbs (Fig. 6). On the SPOT 5 image acquired on the 26 of February these areas do not present any radiometric or textural information suggesting the presence of inundation water within the urban areas as well as within the agricultural parcels. The large water body area (with a dual spectral answer bright and dark) -which can be observed corresponds in fact to classically inundated fields.

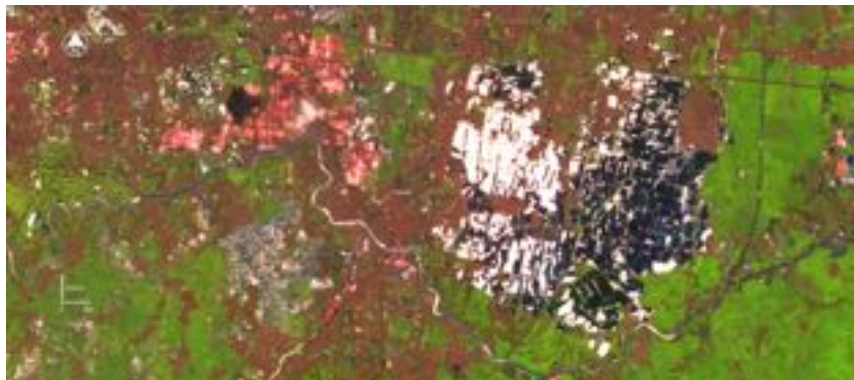


Figure 6: Citarum reaches, south of Bandung, observed by SPOT5 on the 26 of February 2010: The green areas correspond to agricultural fields, the pink to industrial building (mostly located in Dayeuhkolot) and the brown ones to individual housing. Large bright and dark patches correspond to inundated paddy field (mostly in the Ballendah and Bojongsoang suburbs)

In order to confirm the importance of inundated paddy field a search over Landsat 8 and Sentinel 1 data have been carried out. Available Landsat 8 imagery cover periods of potential floods events as acquired in December 2013, December 2014, January 2015, as well as after the rainy season in May 2015.

The analysis of all these multi-years Landsat 8 images, as well the 2015 Sentinel 1 images (Fig. 7-9) points out that during the rainy season, major part of the paddy fields are under water, as indicated by large dark areas on the Eastern part of the Bandung depression (Solokan Jeruk and Rancaekek). And in spring, with the growth of vegetation these are becoming dryer and are covered by paddy fields.

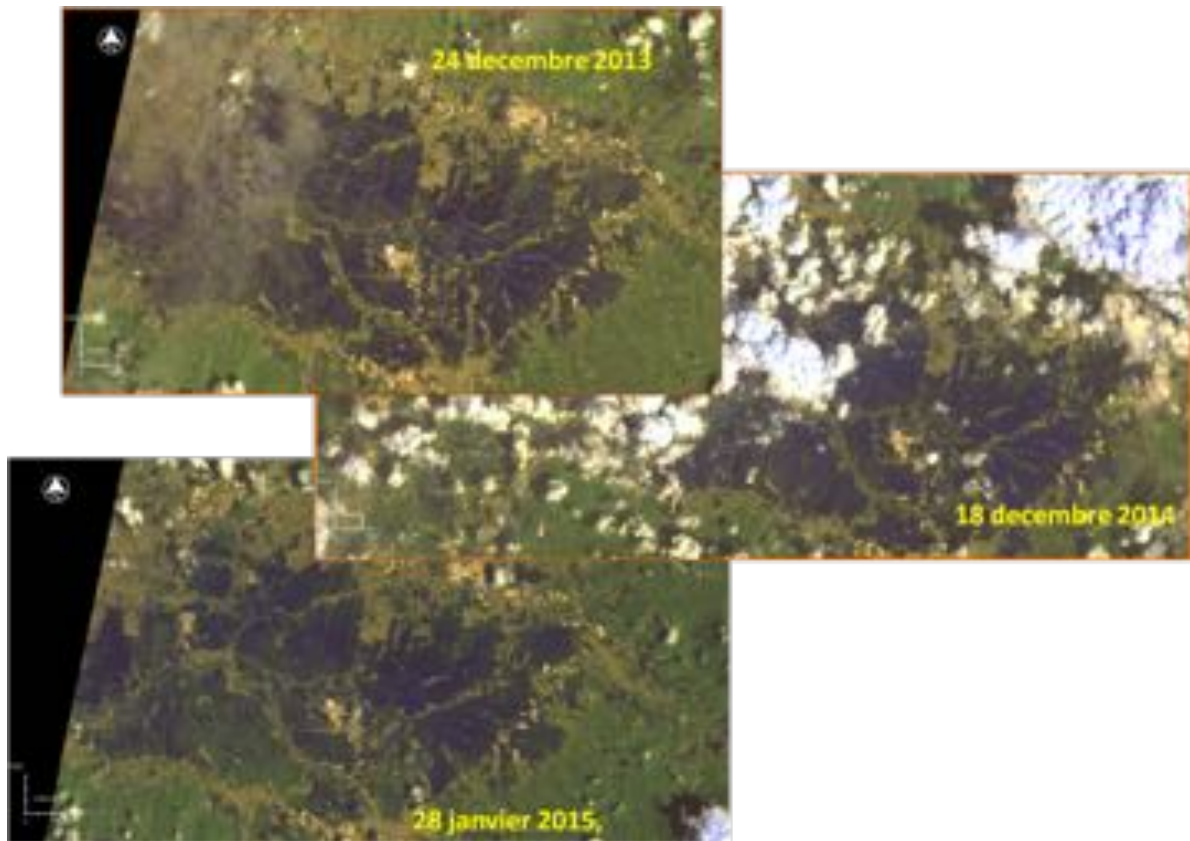


Figure 7: Landsat 8 images acquired during the rainy season over Bandung area. The dark areas correspond to inundated paddy fields

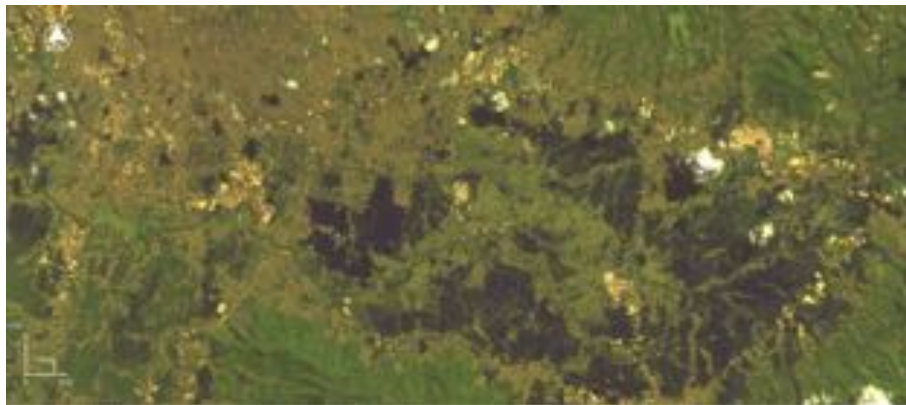


Figure 8: Landsat 8 image acquired on the 27 of May 2015 illustrating the rice growth in the paddy fields and by the way the redraw of the water bodies.

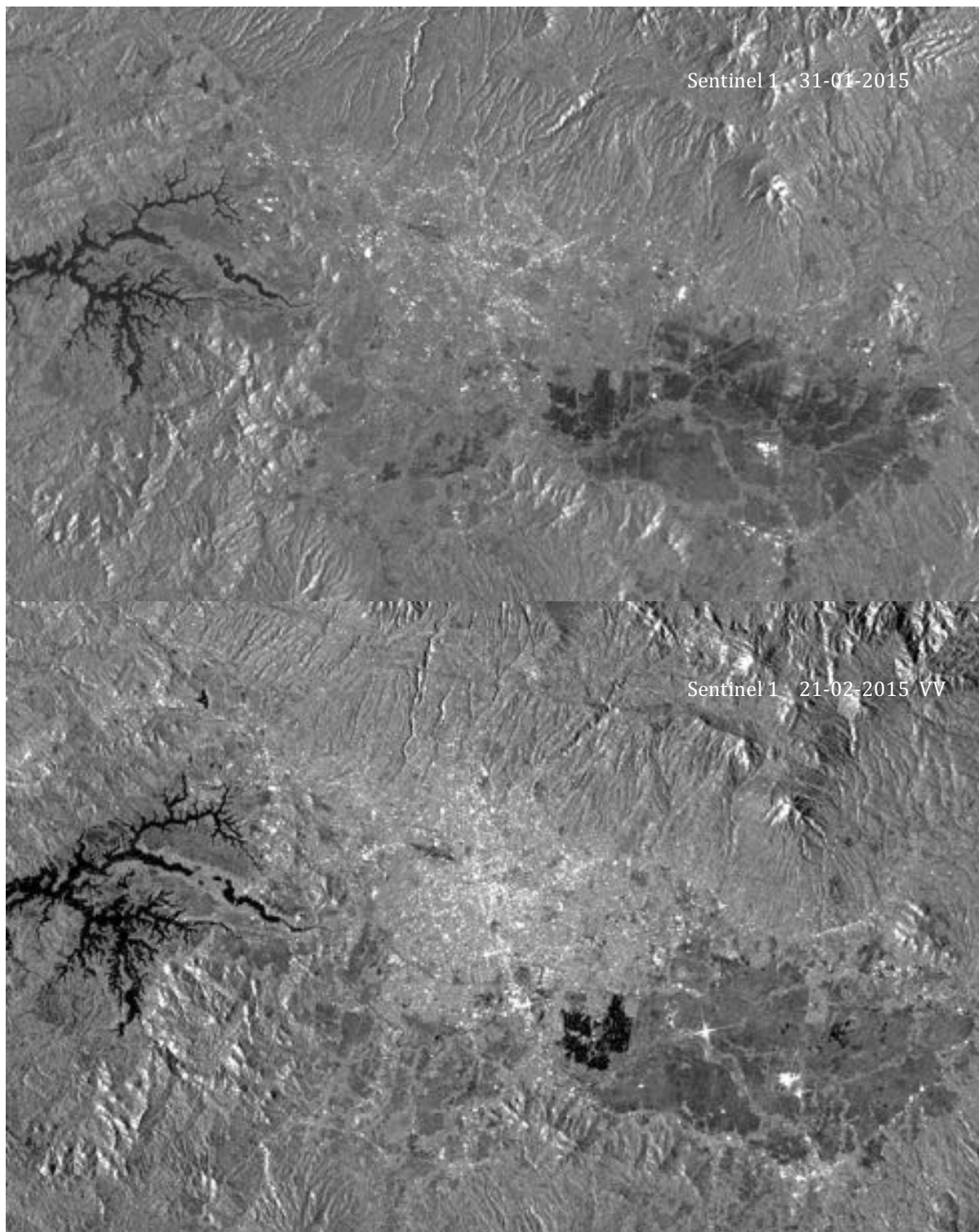


Figure 9: Sentinel data acquired at the end of the raining season. Large dark patch correspond to inundated paddy fields occupying the eastern half of the Bandung depression zone

The concluding remarks concerning exploitation of EO archive for historical flood vent mappings in Bandung are the following:

- A list of historical event have been set up

- A corresponding list of potential data of interest have been set up
- Analysis of accessed data shows that none of the previously identified data are relevant for flood mapping in the urban areas of Bandung
- The available EO data allow the monitoring of water presence within the paddy fields, a seasonal behaviour that has to not be confused with the motion of floods.
- For flood mapping, specific acquisition of VHR optical data has to be ordered, knowing that the success of getting a relatively exploitable data due to the cloud coverage is not guaranteed. Over such urban environment, VHR SAR data would be useless because confronted to signal saturation due to double bounced signal on urban fabrics elements.
- For the Rasor Bandung case study, alternative ways of accessing information have to be set up.

Additional search for relevant information on flood extents over Bandung

As the exploitation of EO data was not fruitful to characterize flood events over Bandung area, a search within open access sources have been carried out as well as exploiting direct regional contacts.

Hopefully this search was more fruitful than the EO ones. It gave the opportunities to reach interesting approaches on historical flood events. Most of these studies were associating the Rasor partnership's Deltares and its local partners. The two most interesting reports were:

- "Upper Citarum Basin Flood Management Strategy" a study funded by the Asian Development Bank, ADB, (Deltares 2012) in which a nice set of maps of historical events was presented (Fig. 9). The analysis of this documents confirms the importance of the 2010 event, and also that the proposed area of interest focused on residential and industrial southern part of the Bandung agglomeration (Dayeuhkolot and Baleendah suburbs) is one of the most commonly affected area by floods. This area being indicated on the documents as inundated in 2010, 2009, 2007, 2005 and 1990 (Fig. 10).
- Upper Citarum Basin Flood Management Project. (2010). Institutional Strengthening For Integrated Water Resources Management in the 6 CIS River Basin Territory (Deltares et al., 2010) with an historical flood map (1986-2007) (Fig. 11). Compared to the previous document, this map has in common the 2005 and 2007 events, with similar spatial definition. It also presents complementary information such as an older dramatic event, ie 1986 flood affecting the eastern part of the Bandung depression.

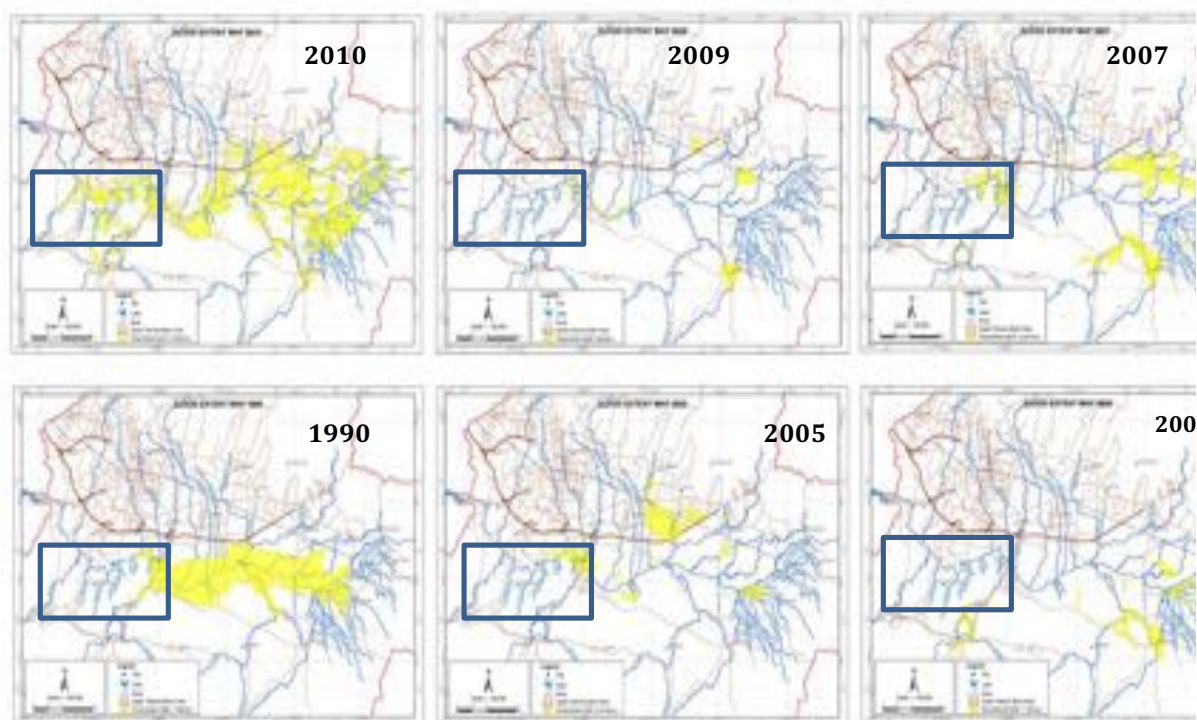


Figure 10: Historical flood events over the Citarum watershed. inundated areas are indicated in yellow whereas the blue cartouche corresponds to the Dayeuhkolot and Baleendah suburbs (Upper Citarum Basin Flood Management Strategy" (2012)



Figure 11: Historical floods map (Upper Citarum Basin Flood Management Project. (2010).

Despite our efforts it was not possible to reach original material from which are based these studies. The quality of accessible documents, coarse scale, none real geometry etc. ..., did not allowed their exploitation within the Rasor platform.

A second set of documents was also reached; this set corresponds to studies on flood forecasting, with outputs of models (Nuraeni & Arai 2010; Hamdami & Kaertiwa, 2014). These were digitalized and then integrated within the Rasor Platform (Fig. 12 & 13)



Figure 12: Flood extent/depth forecast for a 2 years return period flood event with water depths ranging from 23.65-47.30 cm; 47.31-70.94 and 70.95-94.60 cm with corresponding blue colors from the lighter one to the darker ones (70.95-94.60).

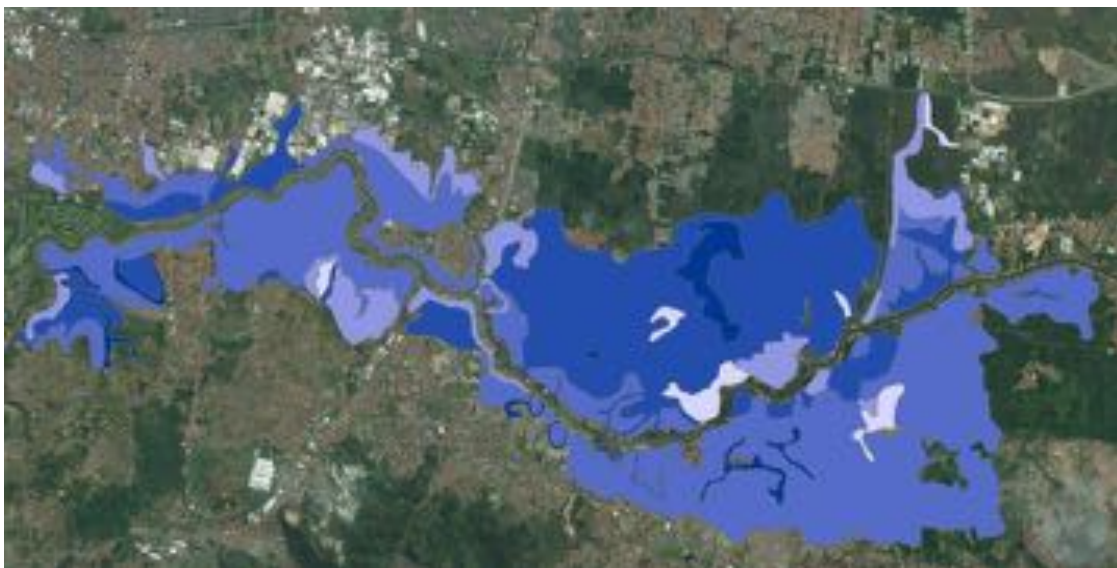


Figure 13: Flood extent/depth forecast for a 25 years return period flood event with water depths ranging from 0-44.65cm, 44.66-89.29cm; 89.30-133.94cm; 113.95-178cm and more than 178.60 cm

Cilacap case of study

The town of Cilacap, on the southern coast of the island of Java is one of the rare sea ports that exists on the southern coast of Java. The city's harbor is protected by Nusakambangan, an island best known as the site of several high-security correctional facilities although there are also hopes that the island can be developed as a tourist hub. Nusakambangan sheltered Cilacap from the worst of the December 2004 tsunami. Nevertheless, the disaster took 147 lives, devastated beaches, damaged 435 fishing boats and inflicted material losses amounting to about \$9 million. In July 2006, another tsunami hit the South coast of Java. The 17 July 2006 magnitude Mw 7.8 earthquake off the south coast of western Java, Indonesia, generated a tsunami that affected over 300 km of coastline and killed more than 600 people (Fig. 14). Measured tsunami heights and run-up distributions were uniform at 5 to 7 m along 200 km of coast; however there was a pronounced peak on the south coast of Nusa Kambangan, where the tsunami impact carved a sharp trim line in a forest at elevations up to 21 m and 1 km inland. On the Nusa Kambangan area, West of Ciclap, local flow depth exceeded 8 m along the elevated coastal plain between the beach and the hill slope; Cilacap town being less affected as protected by Nusa Kambangan peninsula. A little far to the west, the Pangandaran touristic city was also affected by the 5m waves (Lavigne et al., 2007; Fritz et al. 2007),

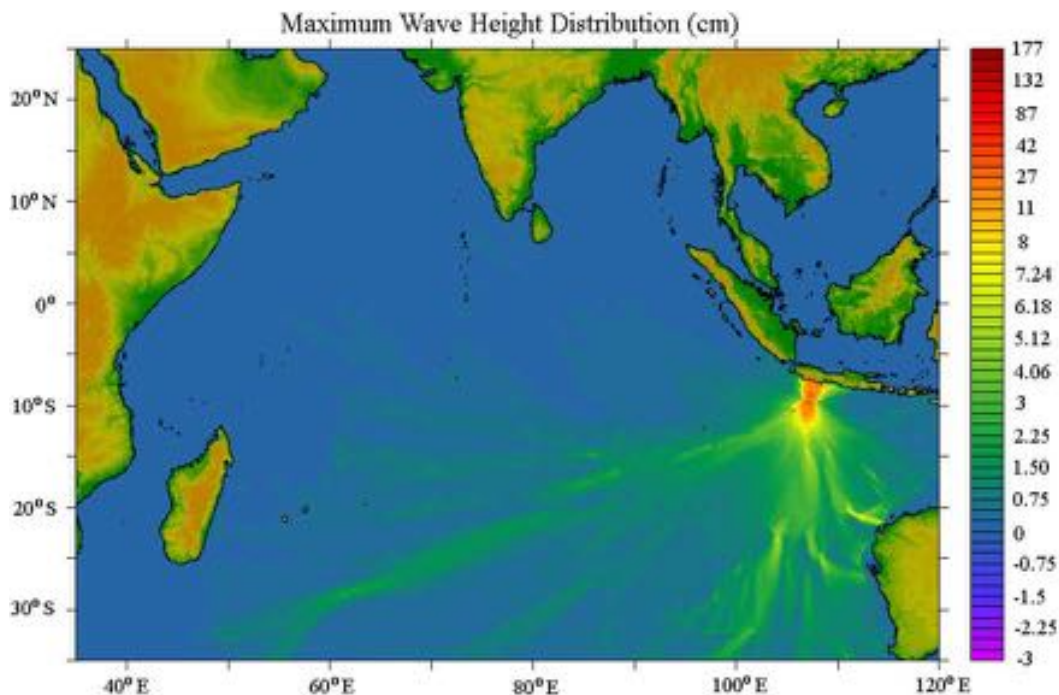


Figure 14: Maximum estimated July 2006 tsunami heights across the entire Indian Ocean (Fritz et al., 2007)

Search of relevant EO data

Search of relevant data covering the July 2006 tsunami was carried out at earlier stage of Rasor project. In addition contact with the Copernicus EO support was engaged before the DWH access was allowed to Rasor team, and this because, key data, SPOT5 and Ikonos imagery, have been identified but located in Singapore Crips data centre.

The SPOT data set consisted in:

- Pre event data acquired on the 22 January 2006 and 13 February 2006 (Fig. 15)
- Post crisis imagery acquired the 22 July 2006, 13 August 2006 and 23 August 2006 (Fig. 16)

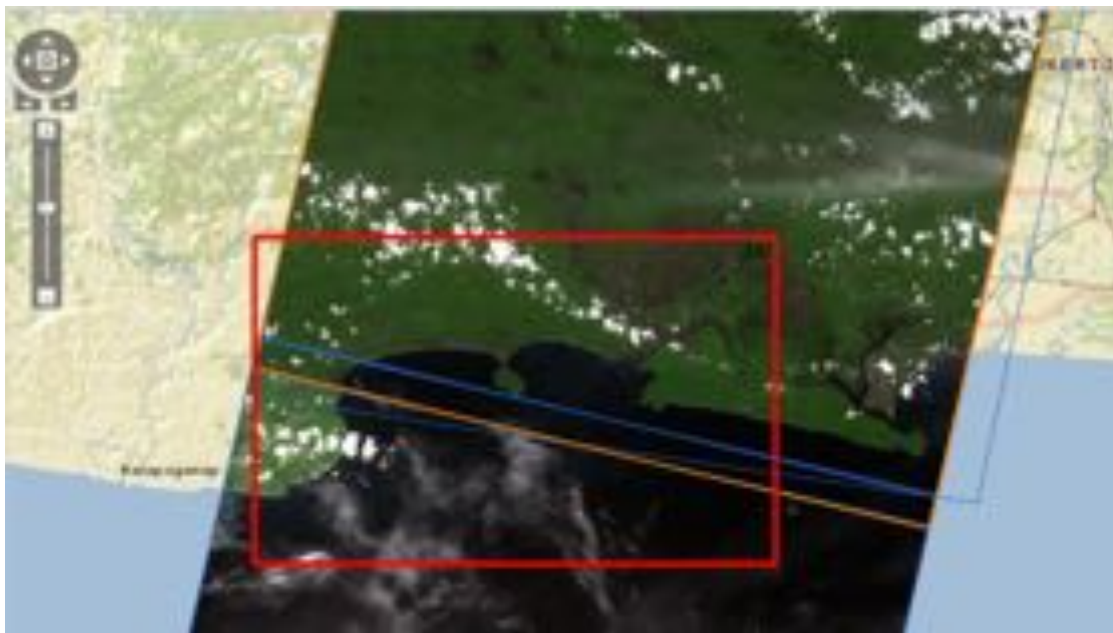


Figure 15: Pre event SPOT track covering the Cilacap Pangadaran area, image of the 22 of January 2006. Notice that two images North-South have to be ordered to cover the AOI

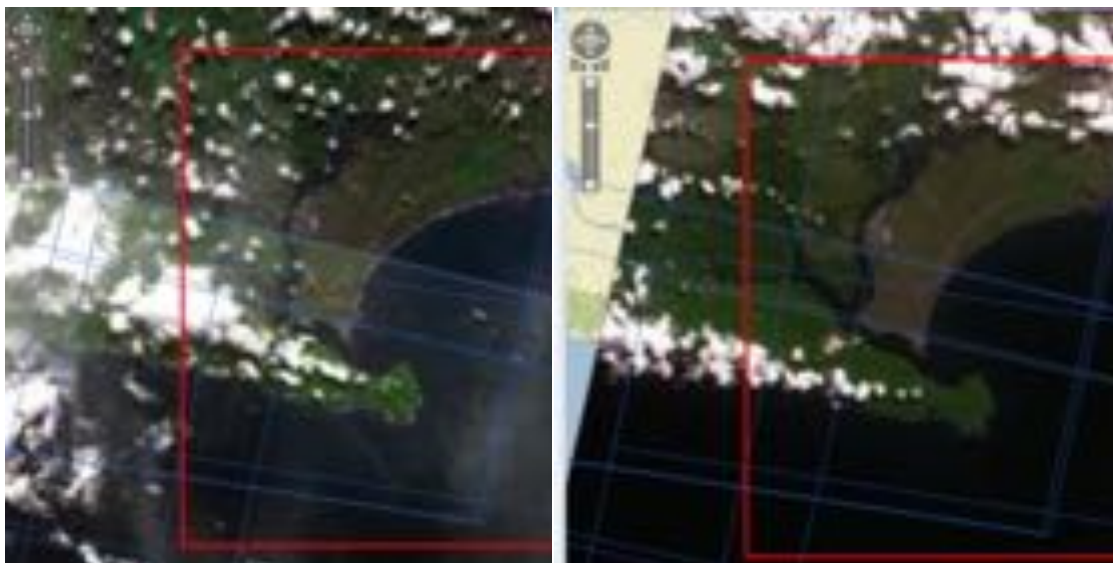


Figure 16: Post disaster SPOT data acquired on the 13 of August (left image) and 23 of August 2006 (right)

In April 2015, the Copernicus EO Support took informal contact with ADS, which took the decision to repatriate the SPOT archive from Singapore to Europe processing centre. Then a set of reference and crisis SPOT 4 and SPOT5 imagery was selected and ordered to DWH. Two problems occurred:

- SPOT1- 4 BW 10 m was NOT part of the Copernicus offer, SPOT-4 is offered at 20 m under HR2, and this would limit the possibility of exploiting SPOT4 imagery by not allowing the merging of Pan and XS channels, and not merging the spectral information with the panchromatic (BW) to reach the best spatial resolution possible.
- The orders were well created in June 2015 but did not reach the CCM's, and a re-order of the data was done in August 2015 with data done available in mid-September 2015.

Finally these pre and post disaster SPOT images have been received at the end of summer 2015. These were:

- Pre event data: 2006-02-13, 2006-01-22, 2006-01-22
- Post event data: 2006-07-22, 2006-08-13, 2006-08-17; 2006-08-23

In addition, concerning the identified Ikonos imagery, from April to November 2015, lot of exchanges were carried on with the Crips data centre, the Copernicus EO Support, and independent data provider i.e. eGeos, in order to understand the way to reach this Ikonos data set (Fig. 17). Despite these numerous exchanges, and efforts to either side, it was not possible at this date to access this relevant data set either exploiting the DWH way or the EO data provider networks.



Figure 17: Comparison of pre and post crisis Ikonos imagery over the Nusa Kambangan showing an important redraw of the coast line and the affected/destroyed forest (© Crips 2006)

Exploited EO data set

For the pre and post events SPOT images, the panchromatic and multispectral channels were merged in order to get the most relevant products associating the spectral information and the spatial description.

The analysis of the images' pair has been carried out by a team of three experts in damage mapping. Therefore no damage has been identified on the post crisis SPOT imagery, neither on the flat coastal areas, in the city part bordering the seashore nor in the harbor (Fig. 18-19). Few remarks can be done:

- The level of damages in Cilacap area is lower than on the Pangadaram bay, due to the protector role of the Nusa Kambangan area
- The resolution of SPOT5, ie a theoretical 2.5m on the merged product but in the practical more near 3 to 3.5m, is not relevant to identify damages induced by the tsunami.
- The most relevant information obtained during this analysis it is than on the Pre event image, acquired during the raining 2005-2006 season , shallows areas are inundated when these areas are presented in summer an healthy vegetation



Figure 18: Pre (up) and post (down) disaster SPOT imagery over Cilacap coast respectively on the 13 of February and 13 of August 2006. Notice that on the pre event, as acquired during the wet season lot of depression areas are inundated and are covered in the August image by an healthy vegetation appearing in red



Figure 19: Pre and post disaster SPOT merged PAN-XS imagery over Cilacap petroleum complex , data acquired respectively on the 13 of February and 13 of August 2006

Jakarta case of study

As noticed in the previous D74 report, there is no satellite data available over floods events in Indonesia. In order to be able to insure historical analysis, a search of exogenous information has also been performed and is still going on. This information, not derived from EO data, could correspond to historical event documents or to a flood simulation, as indicated in the User Requirements document (D 2.4).

For example, in the case of Jakarta floods, some valuable items and information have been identified and can be made available by the Deltares partners (Fig. 20 – 22). Once provided, these flood information have to be uploaded on the RASOR Platform.

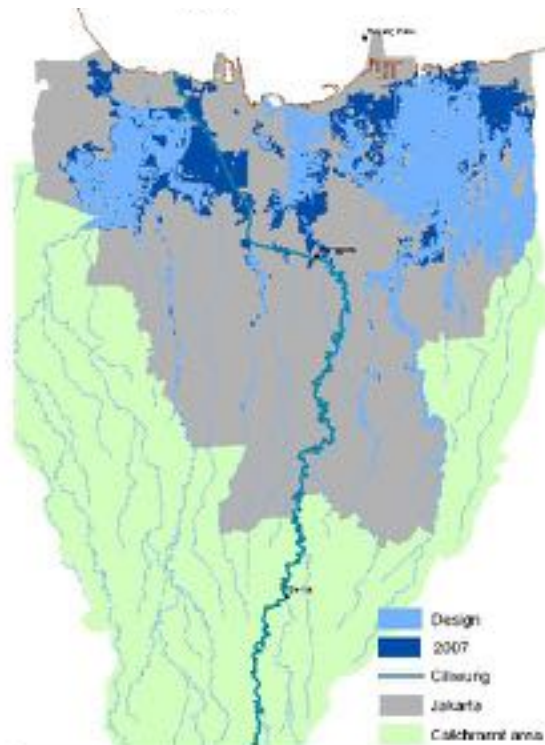


Figure 20: The 2007 flood event map, from Jakarta Flood Hazard Mapping Framework Brinkman, JanJaap (Deltares) and Hartman, Marco (HKV consultants)

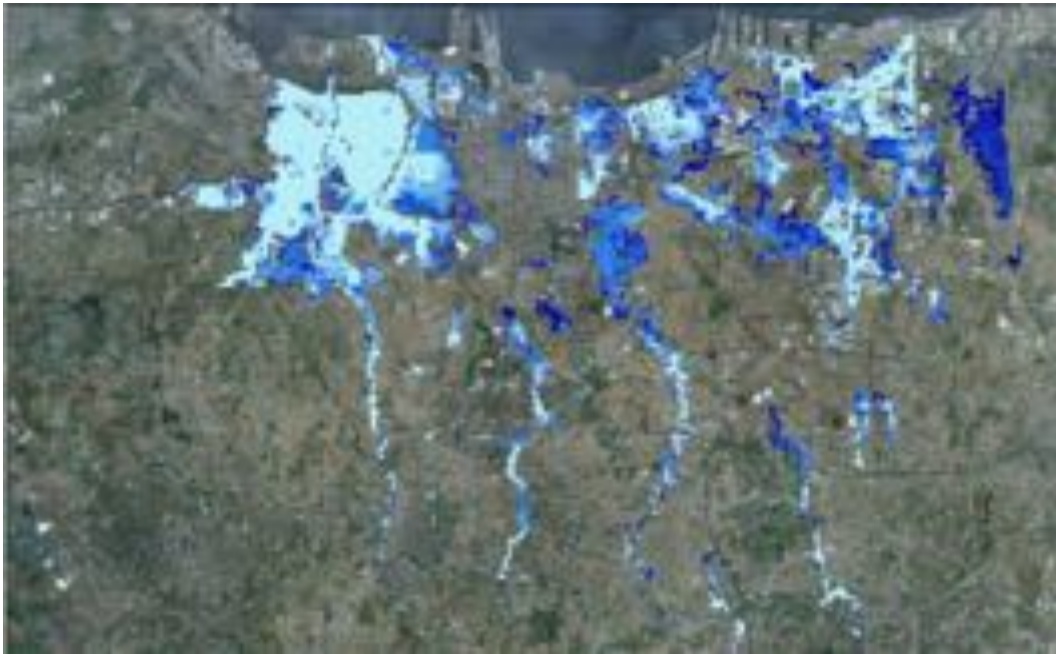


Figure 21: Jakarta flood hazard for several recurrence periods from the FMIS project 2012 (Deltares, 2015)



Figure 22: Jakarta Floods of January 2013, (from Deltares, HKV, PusAir, RHDHV, April 2013)

Haiti Case of Study

For Haiti there are two major test sites, Gonaïves in the North West part of the country and the capital Port au Prince (Fig. 23).



Figure 23: Map of Haiti presenting the Gonaïves city location, as well as the Artibonite department and the Nord Ouest département with the Cap à Foux, and the town of Port au Prince, capital of the country

Regarding the 16 major events having affected dramatically the country the last 20 years (Table II), Gonaïves and Port au Prince are the two mostly affected areas. Gonaïves was hit in 2004 and 2008 by two major floods in total 2379 casualties, whereas Port au Prince was devastated by the January 2010 earthquake and two years later partially affected by the Sandy cyclone. An interesting case would have been the May 2004 flood event, but it has affected mostly the Dominican Republic and so was not retained

HAITI									
ID	Event	Continent	Country	location	date	Duration	Fatalities	Injured	Displac
H1	Hurricane	Caribes	HAITI	Sud-Est	12/11/1994	2	2000		
H2	Hurricane	Caribes	HAITI	Sud-Est Nord Ouest	23/09/1998	1	147		
H3	Flood	Caribes	HAITI	Jimani	26/05/2004	1	1232		
H4	Hurricane	Caribes	HAITI	South	10/09/2004	1			
H5	Hurricane	Caribes	HAITI	Gonaives	19/09/2004	2	1870	2620	846
H6	Hurricane	Caribes	HAITI	Wilma	15/10/2005	9	12		
H7	Hurricane	Caribes	HAITI	ernesto	27/08/2006	7	14		
H8	Flood	Caribes	HAITI	Grand Anse	22/11/2006	2			
H9	Flood	Caribes	HAITI	Grand Anse, S-E, W, N, N-W, N-E	17/03/2007	1			
H10	Flood	Caribes	HAITI	N, N-E et S	08/05/2007	2			
H11	Hurricane	Caribes	HAITI	Gonaives region	30/08/2008	1	529		
H12	Earthquake	Caribes	HAITI	Port-au-Prince	12/01/2010	1	100 000 to 160 000		
H13	Floods	Caribes	HAITI	Port-au-Prince	01/06/2011	9	34	6	
H14	Floods	Caribes	HAITI	Grand Anse	08/04/2012	18	9		
H15	Hurricane	Caribes	HAITI	Port-au-Prince, Gonaives	26/08/2012	1	24	130	13600
H16	Hurricane	Caribes	HAITI	Grand Goave	24/10/2012	1	51	120	

Table II : List of major disasters affecting Haiti test site

Gonaives study case

Gonaives is a commune in northern Haiti, and the capital of the Artibonite Department. It has a population of about 300,000 people (2011 census). In September 2004, hurricane Jeanne caused major flooding and mudslides in the city. Four years later, in September 2008, the city was again devastated by successive storms, Hurricane Gustav, Hanna, and Ike which killed more than 3000 people, mostly in flooded sections of Gonaives, where the destruction was described as "catastrophic". At least 48,000 people from the Gonaives area were forced into shelters. These are two severe events affected the West coast of Haiti, following the Hurricane Georges, 23 September 1998, or preceding the Isaac and Sandy Hurricane that hit Haiti in August and October 2012.

Search of relevant EO data

In regards to the terrific drama of the Jeanne and Hanna Hurricanes, the Charter Space and Major Disaster were triggered by the French Civil Protection involving the acquisitions of numerous EO data. The others devastating events did not lead to such triggering, and thus, the search of EO data covering these event is more hazardous. For the first dramatic event of the selected event covering the last 20 years, the Gordon hurricane, which induced more than 2000 casualties, in November 1994, no image have been acquired. Considering the Georges Hurricane which hit Haiti in September 1998, a first search over all the North Western part of Haiti has well confirmed acquisition of SPOT imagery. Therefore when we focussed on Gonaives vicinity, it appears that firstly the identified image is restricted to the North West peninsula, Cap à Foux and Cap Nicolas, and secondly is acquired just before the hurricane (Fig. 24). For the previous event, the Gordon hurricane, in November 1994,

By the way, there were no available imagery to observe/describe these first dramatic events of the recent period.

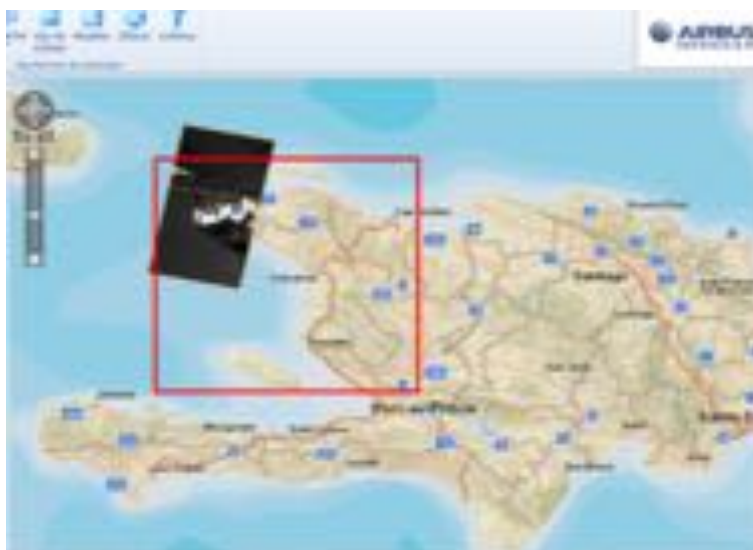


Figure 24: Search of EO data acquired during or after the Georges Hurricane in September 1998

A similar search was performed concerning the 2012 events. For the Isaac hurricane, there is a large Pleiades coverage over the Artibonite and Centre departments. Unfortunately, the Pleiades strips begins just South of Gonaïves city (Fig. 25). For the Sandy event, acquisition was focussed over Port au Prince's area. So there is no possibility to map potentially damaged zones in Gonaïves after these two events.

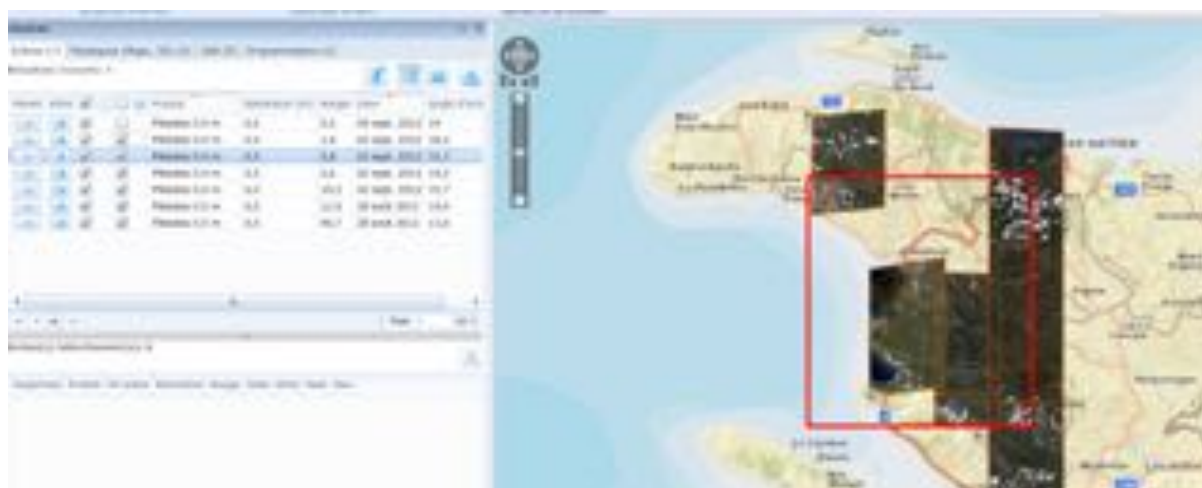


Figure 25: Search of EO data acquired during or after the Isaac Hurricane in August 2012 over Gonaïves

Exploited EO data set

SPOT 4 multispectral data were exploited to extract the September 2004 and September 2008 flood extents over Gonaïves (Fig. 26).

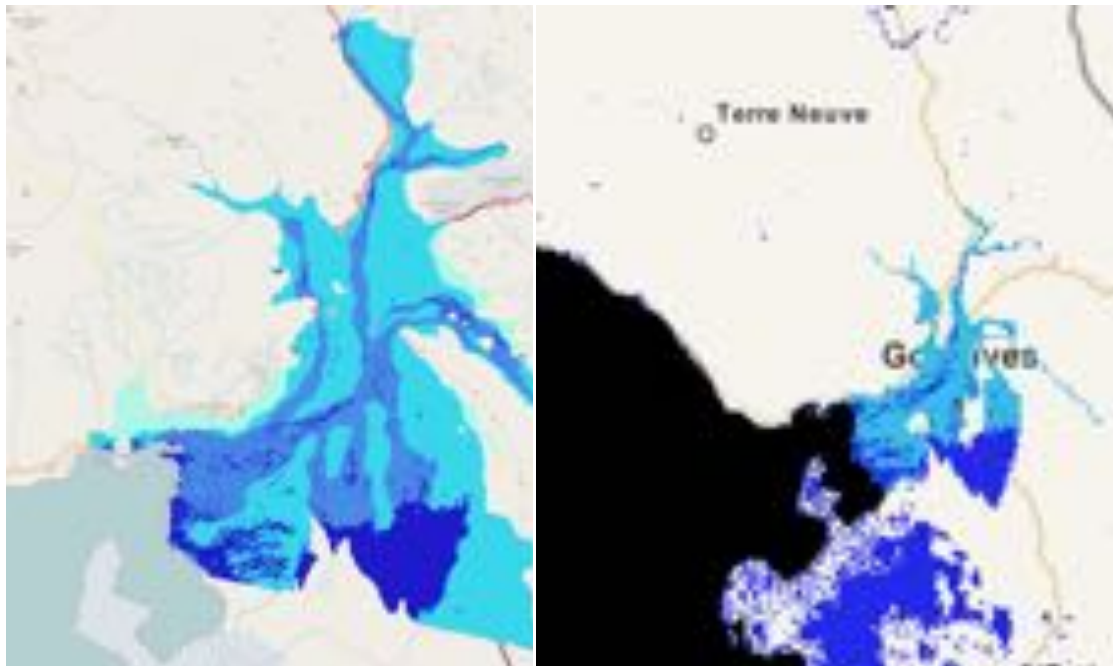


Figure 26: 2004 and 2008 Floods events' extent over Gonaïves derived from SPOT4 imagery. Cyan : flood traces, and dark blue: observed flooding water

Port au Prince study area

Port-au-Prince is the capital and largest city of the Caribbean country of Haiti. The city's population was estimated at 1,897,859 in 2015. And the metropolitan area, defined as including the communes of Port-au-Prince, Delmas, Cite Soleil, Tabarre, Carrefour, and Pétionville has an estimated population of 3,296,386. Port-au-Prince was catastrophically affected by a 7 Mw earthquake on 12 January 2010, with large numbers of structures damaged or destroyed. An estimated three million people were affected by the quake. Death toll estimates range from 100,000 to about 160,000 whereas Haitian government figures from 220,000 to 316,000 that have been widely characterized as deliberately inflated by the Haitian government. The government of Haiti estimated that 250,000 residences and 30,000 commercial buildings had collapsed or were severely damaged. Haiti capital is also under the threat of hurricanes. Hurricane Sandy was the deadliest and most destructive hurricane of the 2012 Atlantic hurricane season. At least 233 people were killed along the path of the storm in eight countries. Sandy's outer bands brought flooding to Haiti, killing at least 51, causing food shortages, and leaving about 200,000 homeless

Exploited EO data

For the 2010 earthquake damage (Fig. 27), analysis was carried out based on various source of EO data, one major sources was a GeoEye post event image acquired on the 13 of January 2010.

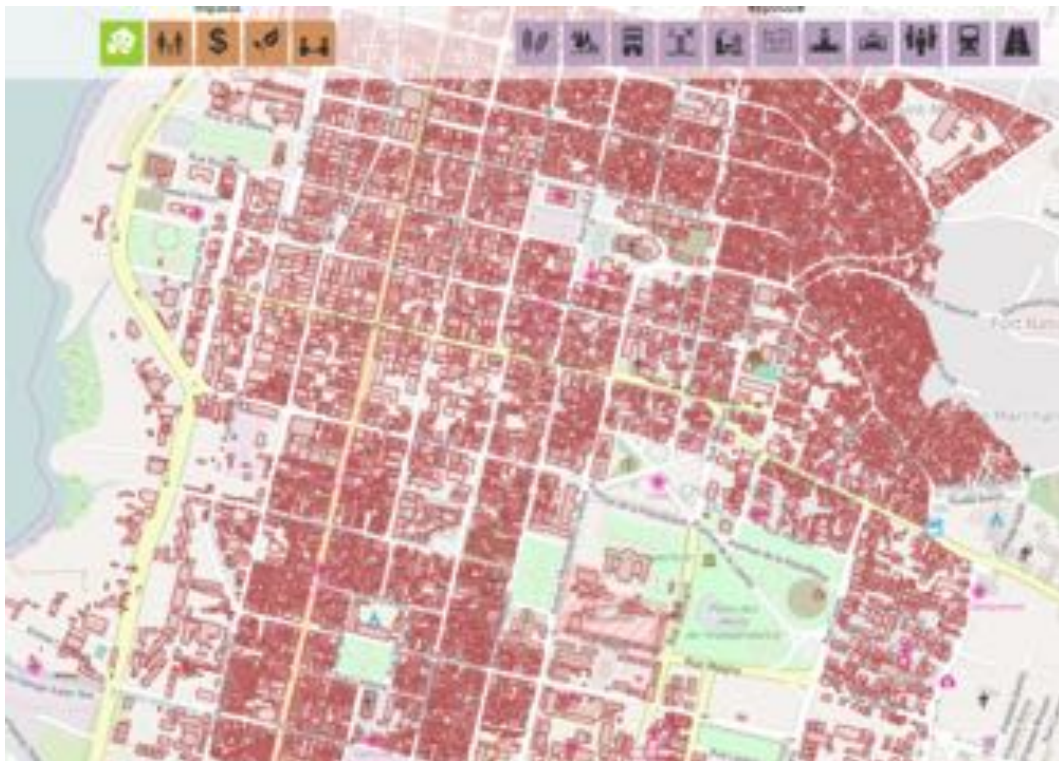


Figure 27: Urban center of Port au Prince derived from VHR satellite imagery and to each building is associated a level of damage

In the case of the Sandy Hurricane, it was Pleiades VHR data that have been acquired. The exploitation of these data allowed to precise the flood extent and the modification of the Rivière Grise course (Fig. 28); this Sandy flood extent was uploaded on the RASOR platform / geonode.

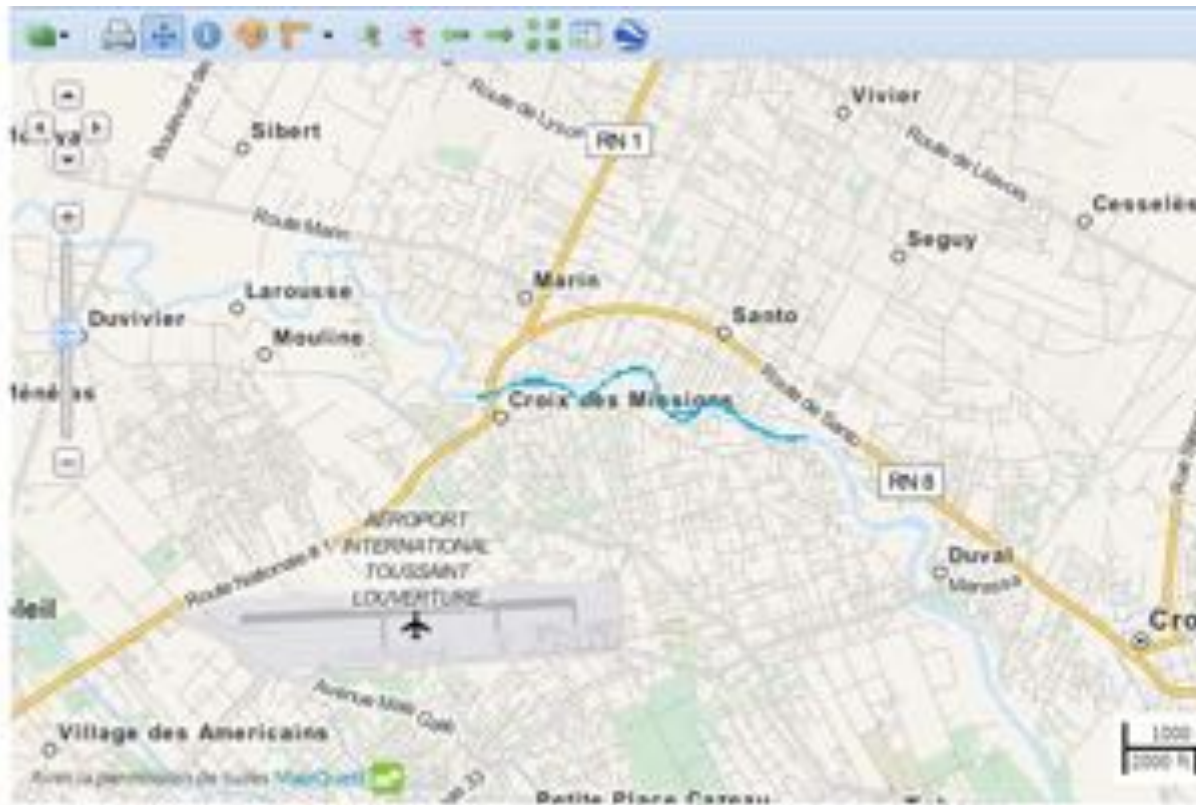


Figure 28: 2012 Sandy impact over Riviere Grise shores based on Pleiades HR data exploitation as viewed on GeoNode

Plaine of Po case of study

The Po is a river, that flows more than 650 km, begins in the Alps, flows eastward through a delta projecting into the Adriatic Sea near Venice. The slope of the valley decreases from 0.35% in the west to 0.14% in the east, a low gradient. The river flows through many important Italian cities, including Turin (Torino), Piacenza and Ferrara. It is connected to Milan through a net of channels. Near the end of its course, it creates a wide delta (with hundreds of small channels and five main ones. The river is subject to heavy flooding such as November 1951 (Fig. 29), November 1994, October 2000, and April 2009 and at a lesser level December 2010 and November 2014 (Fig. 29. Tabl III)

Italie - PO river plain									
	Event	Continent	Country	location	date	Duration	Fatalities	Injured	Displac
P1	Earthquake	EUROPE	ITALY	Piemonte	18/06/2000				
P2	Flood	EUROPE	ITALY	Valenza	01/10/2000	1			
P3	Flood	EUROPE	ITALY	Pontelagoscuro	02/10/2000				
P4	Flood	EUROPE	ITALY	San Benedetto Po - Portio	14/10/2000				300
P5	Flood	EUROPE	ITALY	Emilia Romagna	22/11/2002	12	2		
P6	Flood	EUROPE	ITALY	Reggio Emilia	26/11/2002				30
P7	Coastal submersion	EUROPE	ITALY	CESENATICO	27/06/2005	1			
P8	FLOOD	EUROPE	ITALY	Cremona	01/06/2008	1			
P9	Flood	EUROPE	ITALY	Pontelagoscuro	01/04/2009	1			
P10	Flood	EUROPE	ITALY	Campogalliano - Bomporto	25/12/2009				400
P11	Flood	EUROPE	ITALY	Bovolenta - Montagnana	01/11/2010				
P12	Flood	EUROPE	ITALY	Pontelagoscuro	01/12/2010				
P13	Flood	EUROPE	ITALY	Bovolenta - Historic Centr	17/03/2011				
P14	Earthquake	EUROPE	ITALY	Emilia Romagna	20/05/2012	1	7		7000
P15	Flood	EUROPE	ITALY	Bastiglia and Bomporto	19/01/2014	1			
P16	Flood	EUROPE	ITALY	Modena	21/01/2014	5			
P17	Flood	Europe	ITALY		15/11/2014	5	3		

Table III: List of disasters affecting the Italian test site

In November 2014, floods and landslides occurred across northern Italy. Damage has been estimated at almost \$150 million so far. Five people have died in the floods and landslides so far this month. This came after the flood disasters in northern Italy, in particular Genoa, - the month before, which left 3 people dead. The worst affected areas consisted in Liguria, Lombardy and Piedmont regions. Parts of Milan have also been affected, and many schools have been closed as a result of the severe weather. The Seveso and Lambro rivers burst their banks and levels of the Po River were increasingly high. It was reported that levels of the Po River in Piacenza, i.e. 50 km up stream of Suzzara, stood at 6.8 metres, 20cm below flood stage.



Figure 29: Papers on the Cornell Daily Sun announcing 36000 homeless during the Great 1951 flood

Accessing relevant EO data

The plain du Po case of study was interesting for few reasons. One of them it is that Sentinel data, both the SAR element, Sentinel1, and also the optical ones, Sentinel2, covered the area.

A search of relevant Sentinel1 data was done for the flood event of November 2014 (Fig. 30). An image was acquired in an IWS mode on the 17 of November 2014 (Fig. 30)

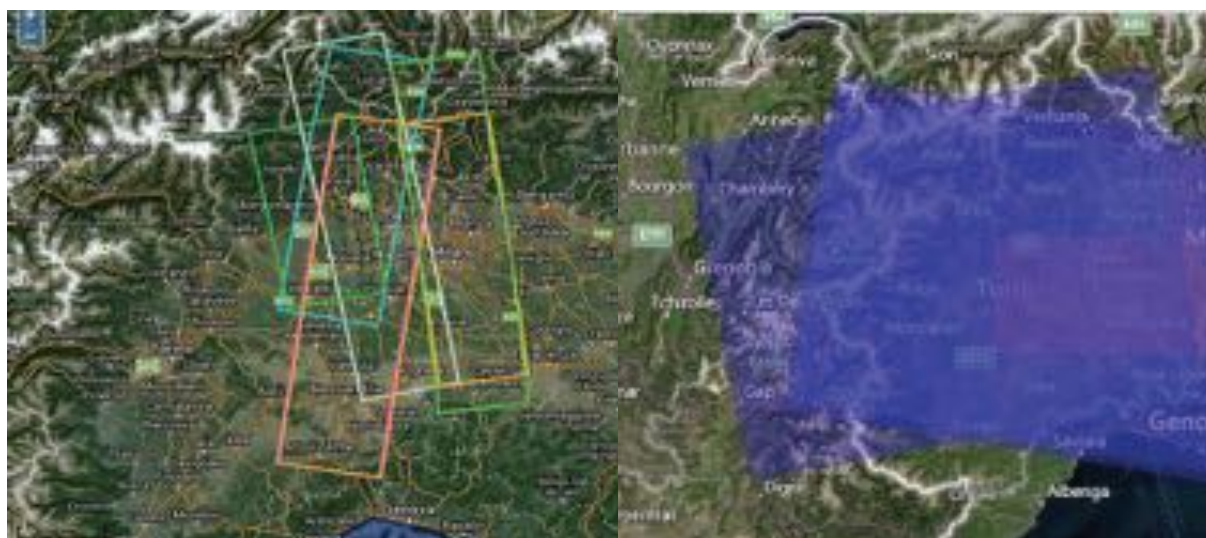


Figure 30: Spatial coverage of CSK and Sentinel1 acquisitions over the 2014 Po River Flood from 15th to 20th of November 2014 (Boni et al., 2015)

The case of the monitoring of the Po River flood and its tributaries in November 2014 is an example of synergistic use of the observations from different sensors. The careful use of the specific space/time resolution and the different revisit time of each sensor have allowed an optimal integration of the observations. Of course, Sentinel 1 is a new impressive EO resource, thanks to its considerable width of the swath (250 km) and this at High resolution, with 10m pixel spacing, i.e. 20m of averaged spatial resolution (Fig 31). And this taking into account that Sentinel1 has a much better radiometric quality than the previous ESA SAR, i.e. ENVISAT APP or IMP modes in term of radiometry and WSM in term of swath (Yésou et al., 2014). Thanks to the large swath and high resolution characteristics of Sentinel1, its allowed to map the event all over the Intermediate and low River Po sectors, from Suzzara to the Adriatic Sea.



Figure 31: Sentinel1 imagery acquired on the 17 of November 2014 capturing the overflow of the Po river with VV, VH and VV/VH respectively in RGB (Upper part) and a zoom over the Po River, (Bottom part), focused on Ruzzara - San Benedetto area ,the zoom area is indicated by an orange rectangle on the top figure

At the opposite, the CSK data were acquired mostly on the upper stream part of the River. In regards to Sentinel swath, CSK data have a more limited spatial coverage, i.e.

40km swath for a strip map mode, but a higher image resolution (5m). In addition, thanks to the constellation of 4 satellites, the revisit frequency of CSK can be very high, with satellite passing at 6 am, 12, and 6 pm, giving the possibility of a quasi-daily monitoring of an event.

With the launch of Sentinel1B, in spring 2016, the revisit frequency will increase, improving the monitoring capabilities over an event. In addition, it has to be said that Sentinel2 is offering a strip map mode, with a resolution of 5m, identical to CSK, but with a swath of 80km; i.e. twice more than CSK or TerraSAR X, which would be a very powerful tool for flood mapping and monitoring (Yésou et al., 2013). Therefore, this mode is very rarely operating, in all likelihood in order to not disturb the systematic acquisition scheme in IWS mode over terrestrial areas. One example of exploitation of this Sentinel Strip Map mode is case of the flood event in May 2014, affecting the Bosnia – Herzegovina borders, a flood event mapped during the EMS 087 Bosnia Herzegovina activation (ESA, 2014).

In addition, a search for relevant Sentinel2 imagery was performed. By luck one of the first available Sentinel2 image was covering the Plain of Po (Fig. 32). The interest of reaching such data was that on a real case it was possible to access the Sentinel2 data and exploit them for water bodies' extraction (Fig. 33). More precisely, accessing these data allowed to:

- Integrate Sentinel2 data which has a specific file structure (4 to 12 granules of 12 bands, 3 spatial resolution etc ..)
- Test water extraction procedures, combining the 10 and 20 meters channels

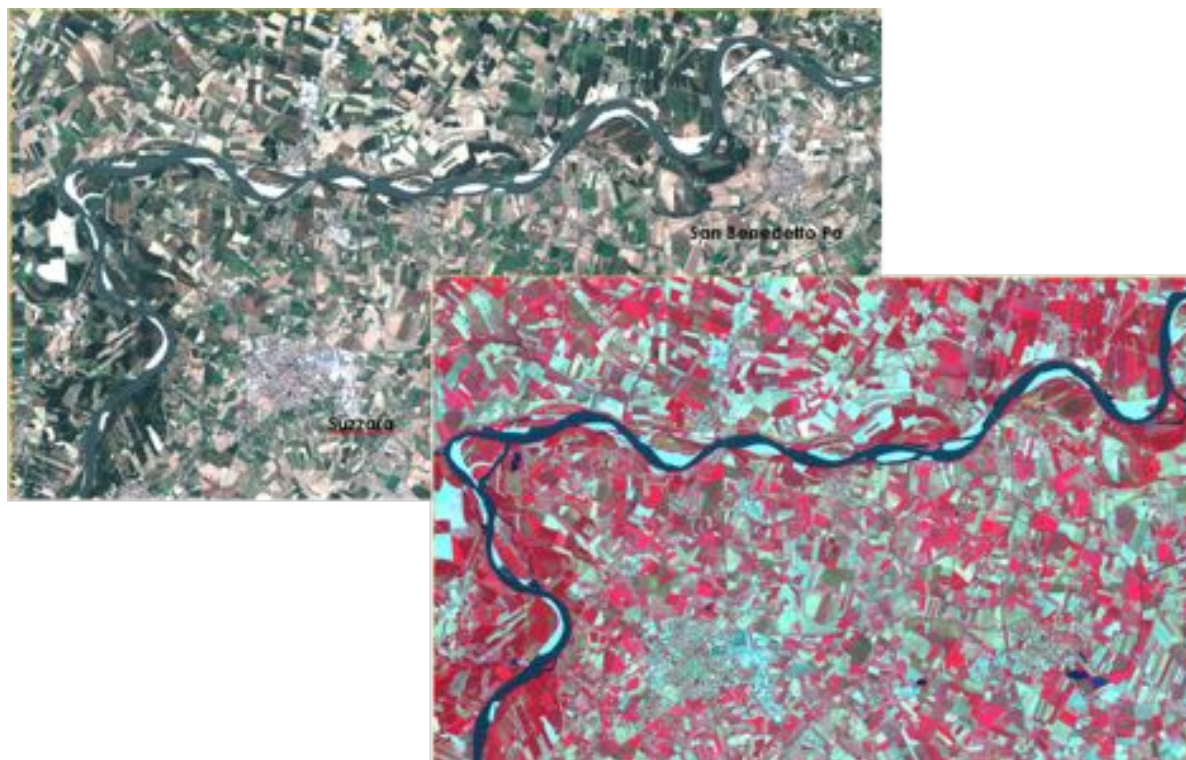


Figure 32: Sentinel2 colour composites, top: true natural colour composite, bottom: false NIRRG color composite, over Suzzara- San Benedetto area affected by the November 2014 flood

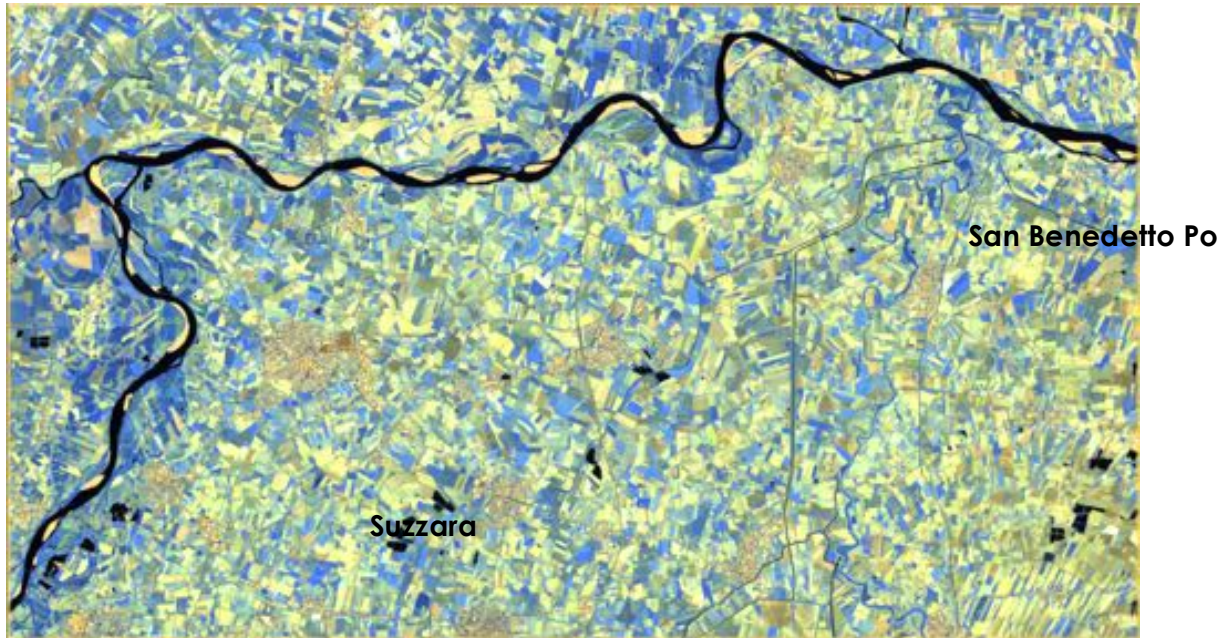


Figure 33 : Exploitation of SWIR channels, part of electromagnetic spectrum well adapted for water bodies mapping. Along the river bed, blue patches are relative to wet areas.

Exploited relevant EO data over Plain of Po

The Sentinel 1 and Sentinel 2 images, representing respectively crisis and reference image, where exploited thanks to the ESA Sentinel ToolBox, SNAP and SBT-S1. From the Sentinel 1 data (Fig. 34) the water extent relative to the flood event have been extracted. The Sentinel2 data allowed to generate the reference water mask (Fig. 35). Thanks to the high spatial resolution, of the 10 meter, the derived reference water bodies and network is precise and detailed. The Riviera St Mincio and the Canal Bianco, as well as the triangle connecting the canal to the Po River are very well observed. Sentinel derived products were uploaded on the razor platform.

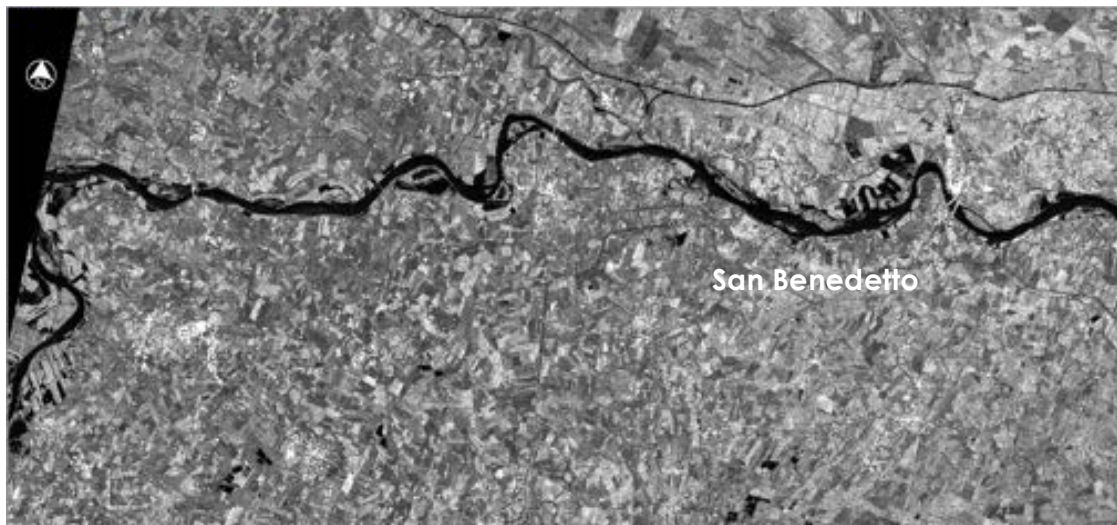


Figure 34: Sentinel 1 imagery, VV channel, acquired on the 17-11-2014 over the Suzara- San Benedetto



Figure 35 : Demonstration product presenting the synergy of Sentinel1 and Sentinel2 for flood mapping, light blue, flooding water derived from Sentinel1; darker blue , reference water from Sentinel2

The CSK SAR data, acquired from the 15th to 20th of November, 2014 were exploited by CIMA to generate a water surface file corresponding to inundated areas (Fig. 36).



Figure 36 : Exploitation of CSK data over the November 2014 flood event (© Cima, 2014)

Rapid mapping service through Rasor

Context

Initially RASOR platform, dedicated to rapid risk analysis, was disconnected with ongoing events. However, in regards to the requests of end users, it appeared that the capability to access rapidly to imagery in order to answer End Users requested about a short term scheduled or on going event was necessary, and this independently from others rapid mapping mechanisms (Charter, EMS Copernicus, Sentinel Asia, etc.). Indeed, lot of events that are dramatic or involving important economic losses are not at all covered by satellite image acquisitions, or adequate satellite image acquisitions.

An access to rapid ordering capacity was required and been accepted by the Commission. An on line preparation of the team was done by the REACT, the Copernicus Emergency Satellite Tasking (REACT) service operated by ESA to coordinate the rush ordering and delivery of new and archived imagery. After this training, Rasor team got access to the tools allowing to request in rush data acquisition, as the same level as the Copernicus Services.

Organization of Rapid activities within Rasor

Based on Charter experience, as service provider and PM (Project manager) of activation, as well as On-Duty-Operator (ODO) and Production Service (PS) of EMS Copernicus, Emergency Management Service, a chain of decision was defined within Rasor partnership and was concerning the following aspects:

- Who takes the decision of triggering the rapid acquisition ?
- Who realizes the data ordering (SPERF) and follow the acquisitions during the action ?
- Who analyses the data and generated added value products?
- Who diffuses the information?

It has been defined that the Rasor project's Prime, i.e. CIMA will take the decision of triggering, in regards to the project responsibility and then that SERTIT-UNISTRA, due to its long experience in rapid mapping within Charter Space and Major Disaster, as well as in SAFER and EMS Copernicus, will insure the data ordering, processing and analysis. The dissemination was also defined as being in charge of the CIMA; RASOR partnership being informed on the ongoing event.

In February 2016, this service was activated three times under the request of the National Disaster Management Authority – Badan Nasional Penanggulangan Bencana (BNPB):

- o On the 4 of February, at 16h 20
- o On the 12 of February, at 16h03
- o On the 26 of February, at 9h58

For each of these activations, it was decided, in regards to the weather forecast and to the weakness of the information concerning the ongoing coming event, that a monitoring mode over three days would be the best or more adequate approach.

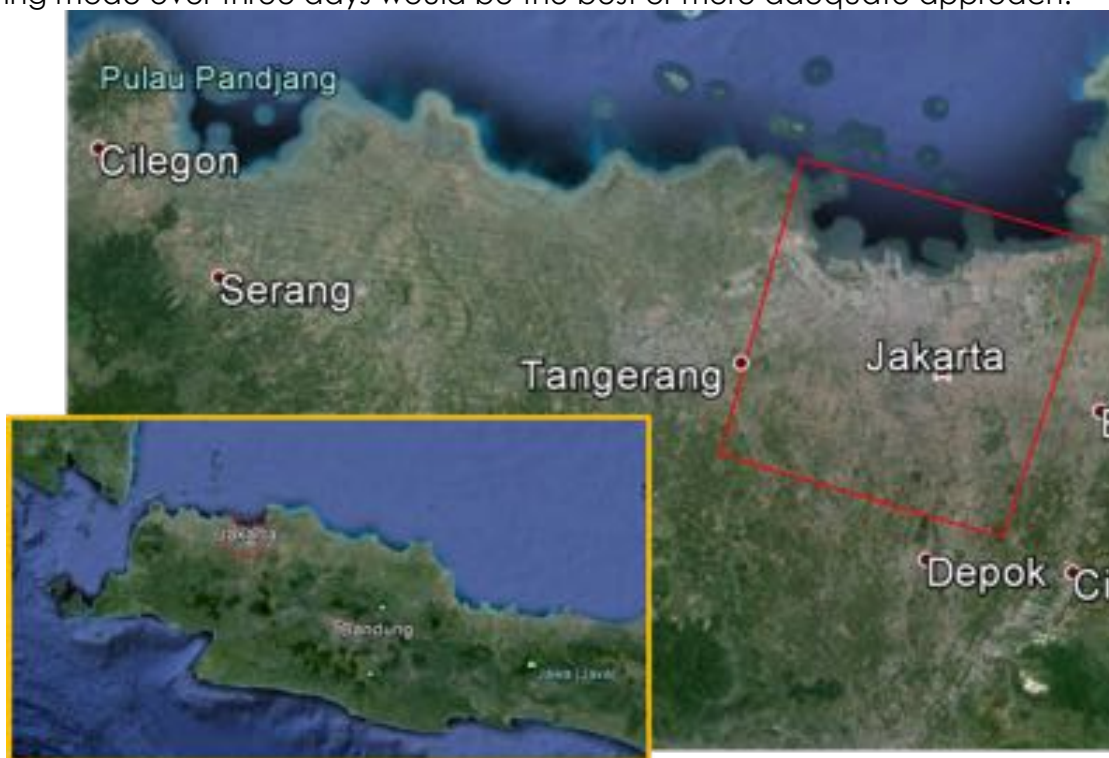


Figure 37: Area of interest targeted during the rapid actions

In addition, as the target area (Fig. 37) consisted mostly to the Jakarta urban area (Fig.43), both optical and SAR images have been required despite the fact that the possibility of accessing optical images can be much reduced due to weather cloudy conditions.

In regards to the size of the Area of Interest and to the urban coverage characteristic, it was all Jakarta zone, i.e. 30 by 30 Km, it was VHR2 data that have been requested, each time: 3 SAR images (RDS-2 or TerraSAR-CSK Stripe map like) and 3 optical images (SPOT6-7 like). It can be noticed that VHR1 images, with a better spatial resolution, cannot be requested in a rush mode by RASOR; this strongly limits the observation and mapping capacity of flooded zones, especially with optical data in dense urban areas.

In addition to the REACT data, a check of Sentinel availability through the ESA scientific Hub have been done.

Analysis of Jakarta rapid action

As already indicated, for each activations, both SAR and optical VHR2 images have been requested though the REACT, these were corresponding to RASO_0001_001/002 requests, and then to RASO_0001_003/004, and RASO_0001_005/006 (Tabl. IV).

RASO_0001 - Flooding in Jakarta									
Art_Subart ID	AOI Name	Art/View	Art. Reference Date & time	Dataset ID	Resolution Type	Satellite	Sensor/Team	Start Sensing of Product	Status
RASO_0001_001	raso_jakarta_flood_01_2016.kml	New Acquisition	04/02/2016 16:42	ADG_004b	VHR2	SPOT-6/7	Bundle	06/02/2016 01:25	Rejected
RASO_0001_001	raso_jakarta_flood_02_2016.kml	New Acquisition	04/02/2016 16:42	ADG_004b	VHR2	SPOT-6/7	Bundle	07/02/2016 01:06	Rejected
RASO_0001_001	raso_jakarta_flood_03_2016.kml	New Acquisition	04/02/2016 16:42	ADG_004b	VHR2	SPOT-6/7	Bundle	06/02/2016 02:58	Delivered
RASO_0001_002	raso_jakarta_flood_03_2016.kml	New Acquisition	04/02/2016 16:42	ADG_004b	VHR2	SARASAT-2	Wide Ultra Fine (UFR)	06/02/2016 13:04	Delivered
RASO_0001_002	raso_jakarta_flood_03_2016.kml	New Acquisition	04/02/2016 16:42	ADG_004b	VHR2	TerraSAR-X	Stripmap	07/02/2016 23:30	Rejected
RASO_0001_003	raso_jakarta_02_2016_003_001	New Acquisition	11/02/2016 16:29	ADG_004b	VHR2	SPOT-6/7	Bundle	11/02/2016 03:03	Rejected
RASO_0001_003	raso_jakarta_02_2016_003_001	New Acquisition	11/02/2016 16:29	ADG_004b	VHR2	SPOT-6/7	Bundle	14/02/2016 03:03	Delivered
RASO_0001_003	raso_jakarta_02_2016_003_001	New Acquisition	11/02/2016 16:29	ADG_004b	VHR2	SPOT-6/7	Bundle	15/02/2016 03:53	Delivered
RASO_0001_004	raso_jakarta_02_2016_004_SAR	New Acquisition	11/02/2016 16:29	ADG_004b	VHR2	COSMO-SkyMed	Stripmap HRR	11/02/2016 22:32	Delivered
RASO_0001_004	raso_jakarta_02_2016_004_SAR	New Acquisition	11/02/2016 16:29	ADG_004b	VHR2	COSMO-SkyMed	Stripmap HRR	14/02/2016 10:24	Delivered
RASO_0001_004	raso_jakarta_02_2016_004_SAR	New Acquisition	11/02/2016 16:29	ADG_004b	VHR2	COSMO-SkyMed	Stripmap HRR	15/02/2016 10:24	Delivered
RASO_0001_005	raso_jakarta_flood_03_2016.kml	New Acquisition	14/02/2016 10:11	ADG_004b	VHR2	SPOT-6/7	Bundle	21/02/2016 03:03	Delivered
RASO_0001_005	raso_jakarta_flood_03_2016.kml	New Acquisition	15/02/2016 10:11	ADG_004b	VHR2	SPOT-6/7	Bundle	26/02/2016 03:57	Delivered
RASO_0001_005	raso_jakarta_flood_03_2016.kml	New Acquisition	15/02/2016 10:11	ADG_004b	VHR2	SPOT-6/7	Bundle	27/02/2016 03:46	Delivered
RASO_0001_006	raso_jakarta_flood_03_2016.kml	New Acquisition	15/02/2016 10:11	ADG_004b	VHR2	TerraSAR-X	Stripmap	27/02/2016 13:06	Delivered
RASO_0001_006	raso_jakarta_flood_03_2016.kml	New Acquisition	15/02/2016 10:11	ADG_004b	VHR2	SARASAT-2	Wide Ultra Fine (UFR)	16/02/2016 13:14	Delivered
RASO_0001_006	raso_jakarta_flood_03_2016.kml	New Acquisition	15/02/2016 10:11	ADG_004b	VHR2	TerraSAR-X	Stripmap	16/02/2016 17:30	Rejected

Table IV: Synthesis of the data request and reception during the Jakarta rapid actions

First action over Jakarta: 4th of February 2016

A first Sar data, ie Radarsat2 Wide ultrafine mode, was acquired on the 6 of February (Fig. 38). The exploitation of these data over dense urban area were and is very difficult. No water surfaces are observable on the image. The optical data were all cloudy and by the way rejected. Therefore, this first rapid action gave the opportunity to test the different elements of the chain, from the decision taking, data ordering, data provision in a rush mode, to the information dissemination.



Figure 38: Radarsat2 image acquired on the 06 February 2016 over Jakarta

Second action over Jakarta: 12 February 2016

Same approach was followed, ie the request for a monitoring over 3 days, based on VHR2 SAR and Optical data. A set of 3 CSK data Strip map mode data, have been

acquired. In addition a search of complementary available Sentinel imagery have been done. A Sentinel1 image acquired on the 16 of February have been downloaded and processed for analysis (Fig. 39-41).

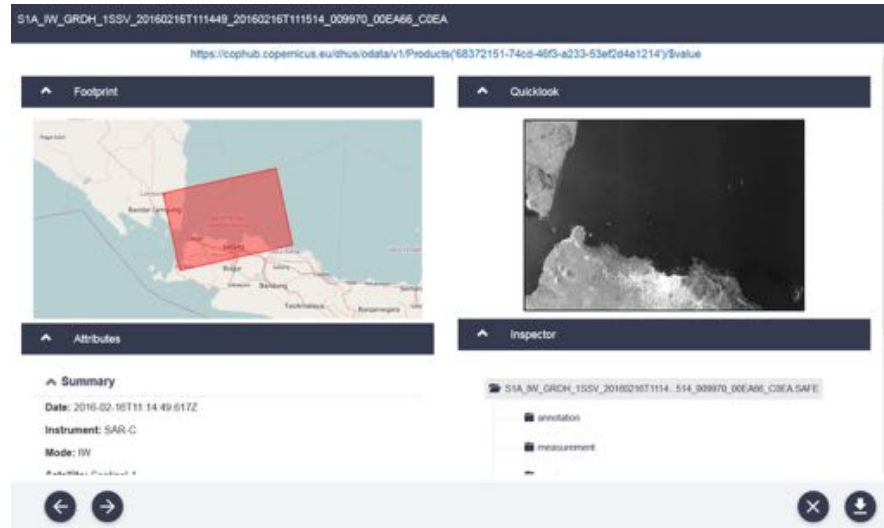


Figure 39: Search of Sentinel during Mid February 2016 flood event of Jakarta area.

The Sentinel1A data presented over the city of Jakarta an important signal saturation effect due to high corner effects of the buildings (Fig. 40-41). Over the agricultural and wetlands areas of the Eastern part of the city, water can be well observed, as black areas, whereas, these did not presented a greater extension than usual.



Figure 40: Zoom over the city of Jakarta, ie covering 40km in EW from a Sentinel1A image acquired on the 16 of February 2016,



Figure 41: Zoom over Jakarta city, Tanjung Priok district, highlighting the signal saturation

Thanks to relatively clement weather conditions it was also possible to acquired two SPOT6-7 images with a relative low cloud coverage on two consecutive days , the 14 and 15 of February 2016 (Fig. 42).

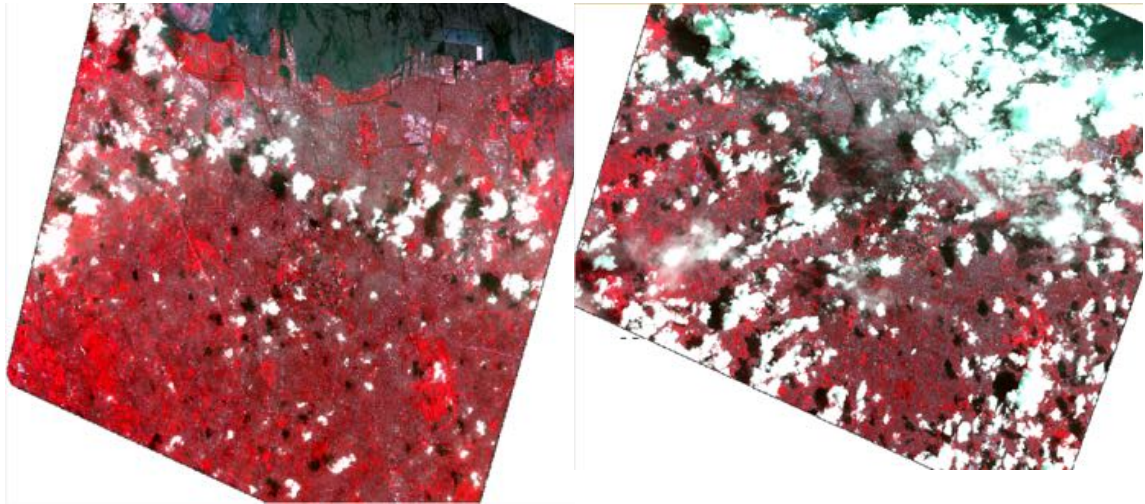


Figure 42: SPOT 6 Image acquired on the 14 of February 2016 (left); SPOT 7 image acquired on the 15 of February 2016 (Right) Each image is covering a 60*60 km² area

Local press indicated that “Pekayon subdistrict, Cibubur Market and Cipinang Melayu sundistrict in East Jakarta were still inundated by 50 centimeters of water. A number of river walls collapsed when they were hit by flood waters, causing flooding in a number of residential areas in Ciracas, East Jakarta” (Jakarta Post, 2016). Based on these information, an analysis of the SPOT data have been carried out, subdistrict by subdistrict (Fig. 43-44).

Over these urban areas, the water presence was well observable, therefore mostly within open areas, ie parks, low vegetated agricultural parcels, rather than on the dense urban part. In these urban dense areas, the VHR2 resolution of the data was too limited to see water around buidings or in the street network.

On the North East part of the town of Jakarta, Koja_Cilincing sub districts, flooded and water saturated agricultural parcels were observable (Fig. 45). From the 14 of February to the 15 of February, there was apparently an increase of the water level.



Figure 43: Zoom over the Pekayon sub district presenting saturated areas, well visible within parks and grassland parcels (Blue circle) as well as clouds shadows (Green circle)



Figure 44: Zoom over the Pekayon sub district presenting saturated areas, well visible within parks and grassland parcels (Blue circle) as well as clouds shadows (Green circle)

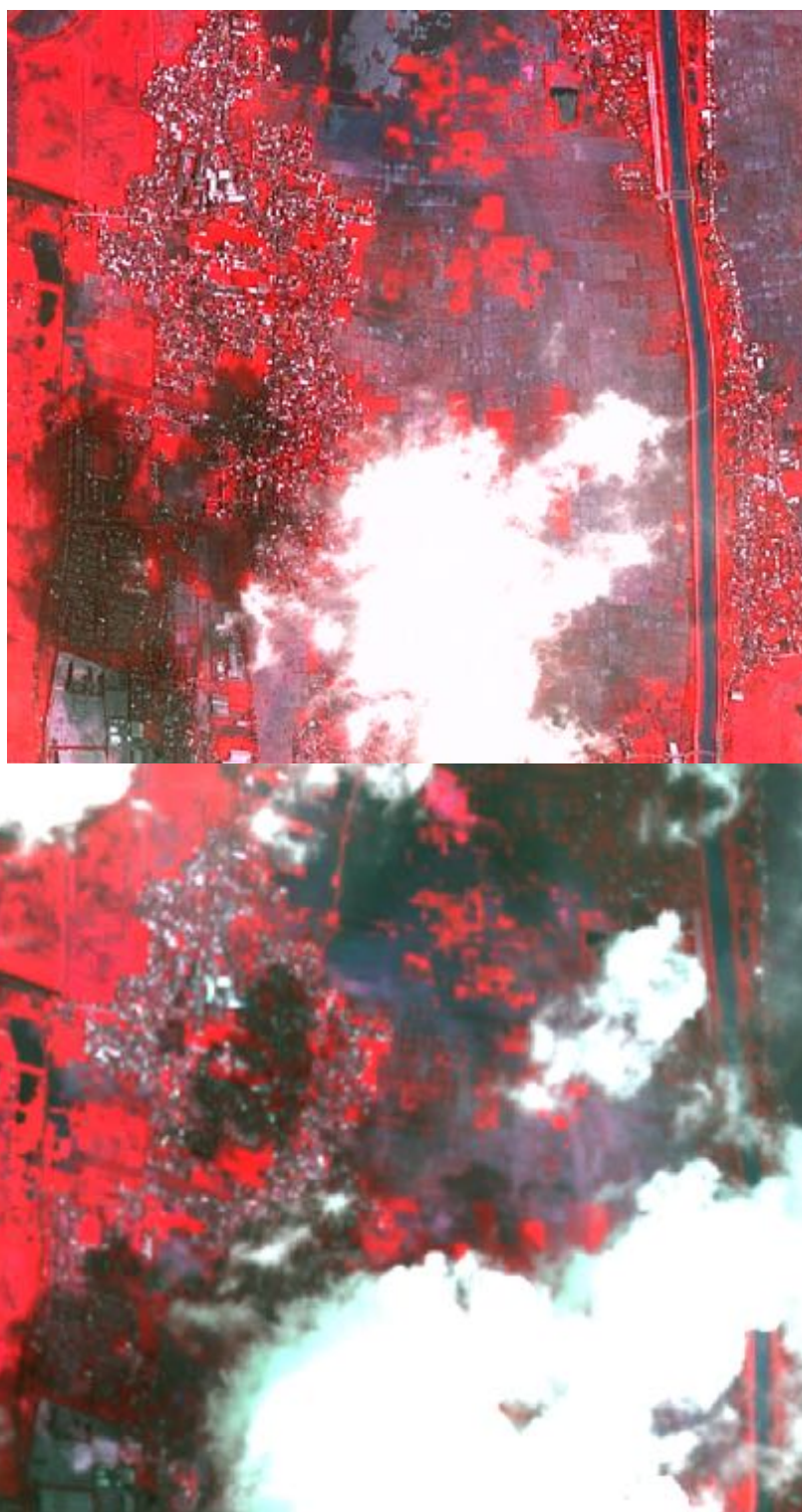


Figure 45: water surfaces and water saturated agricultural area as observed on the SPOT6 acquired on the 2016/0/14 (top) and on the SPOT7, acquired on the 2016/02/15 (bottom) in the Kojá_Cilincing sub districts

Third action over Jakarta: 22 February 2016

For the third rapid action over Jakarta, the same approach was followed, ie the request for a monitoring over 3 days, based on VHR2 SAR and Optical data. The optical set was not exploitable as fully cloudy (Fig. 46) . A set of 2 TerraSAR Strip map mode data, have been acquired in ascending and descending mode completed by a Radarsat2 image (Fig. 47).

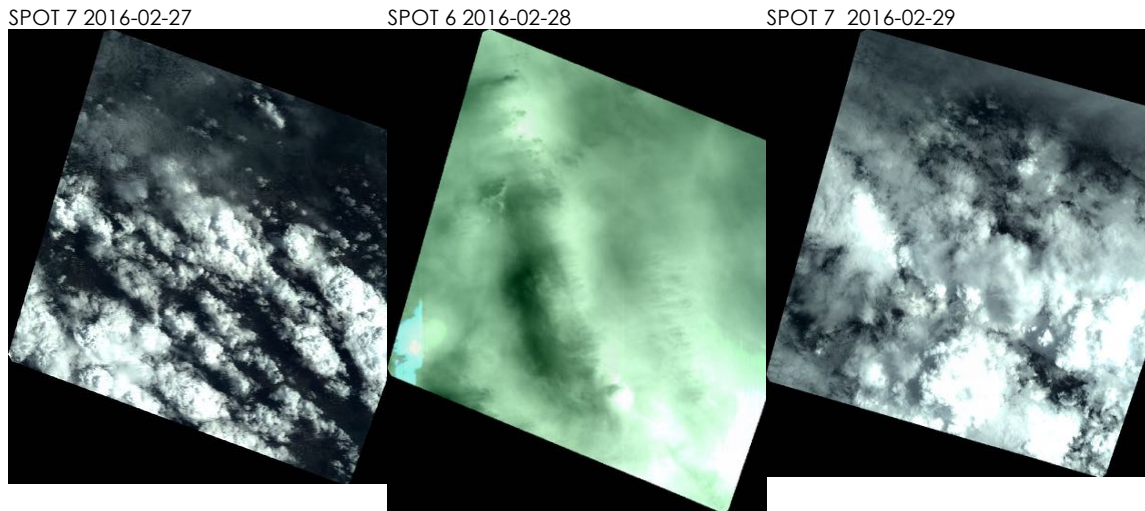


Figure 46: SPOT6 -7 images acquired between the 27 and 29 of February 2016

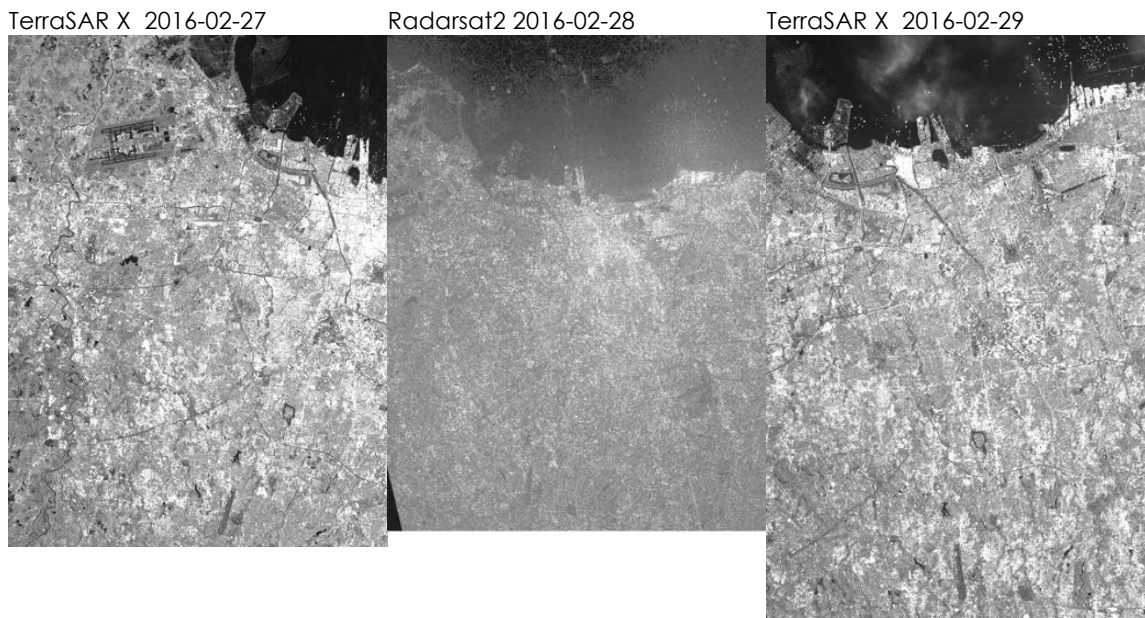


Figure 47: VHR2 Sar data acquired between the 27 and 29 of February 2016 over Jakarta

Local press announced that “KFT housing complex in Cengkareng Barat, which is privately managed, was amongst the areas that observed the worst flooding,

with up to 70 centimeters of water." About 250 residents left their homes, taking shelter in nearby mosques and setting up a communal kitchen". And also that the "Grogol River, which passes through several neighborhoods in Pondok Labu and Lebak Bulus, South Jakarta, burst its banks and caused severe flooding. Although the water had receded by noon, dozens of houses were left inundated and some residents were evacuated to nearby mosques while others chose to stay on the second floor of their homes" (Jakarta post, 2016b-c). These information were exploited to focus the analysis of the SAR data (Fig.48-50).

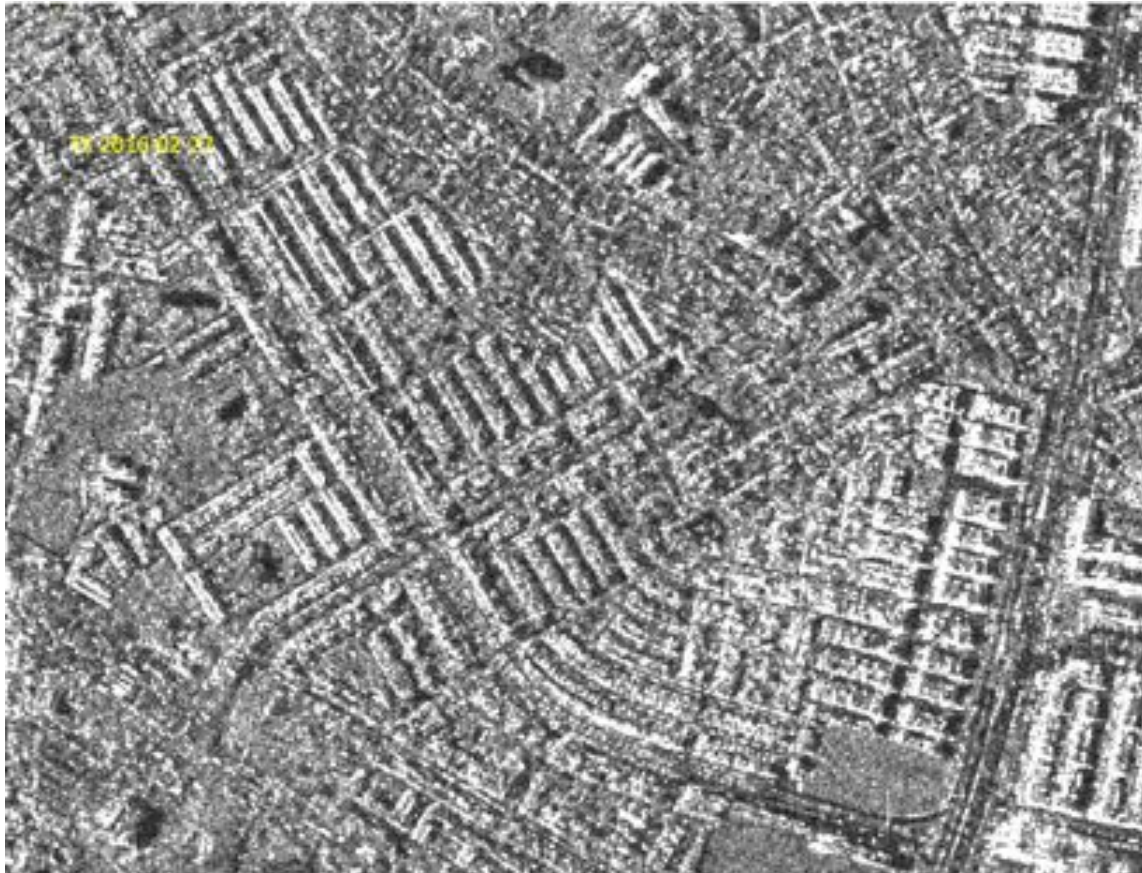


Figure 48: West Cengkaren barat as observed by TerraSAR on the 27 of February 2016.

However the analysis of the Sar image was not successful. Water was not observable on the SAR images which are dominated by a saturated signal. Over West Cengkaren suburb, the only water patches that have been observed are corresponding to ponds (Fig. 48). Over the Lebak Bulus sub-district, South Jakarta, on this dense urban area, where housing are very close one to the other (Fig. 49), the Sar signal was mainly dominated by buildings' scattering mechanism, and so the image was near to be fully saturated, no water bodies can be objectively observed (Fig. 50).



Figure 49: Example of very close buildings in Lebak Bulus sub-district (BNPB, 2016)

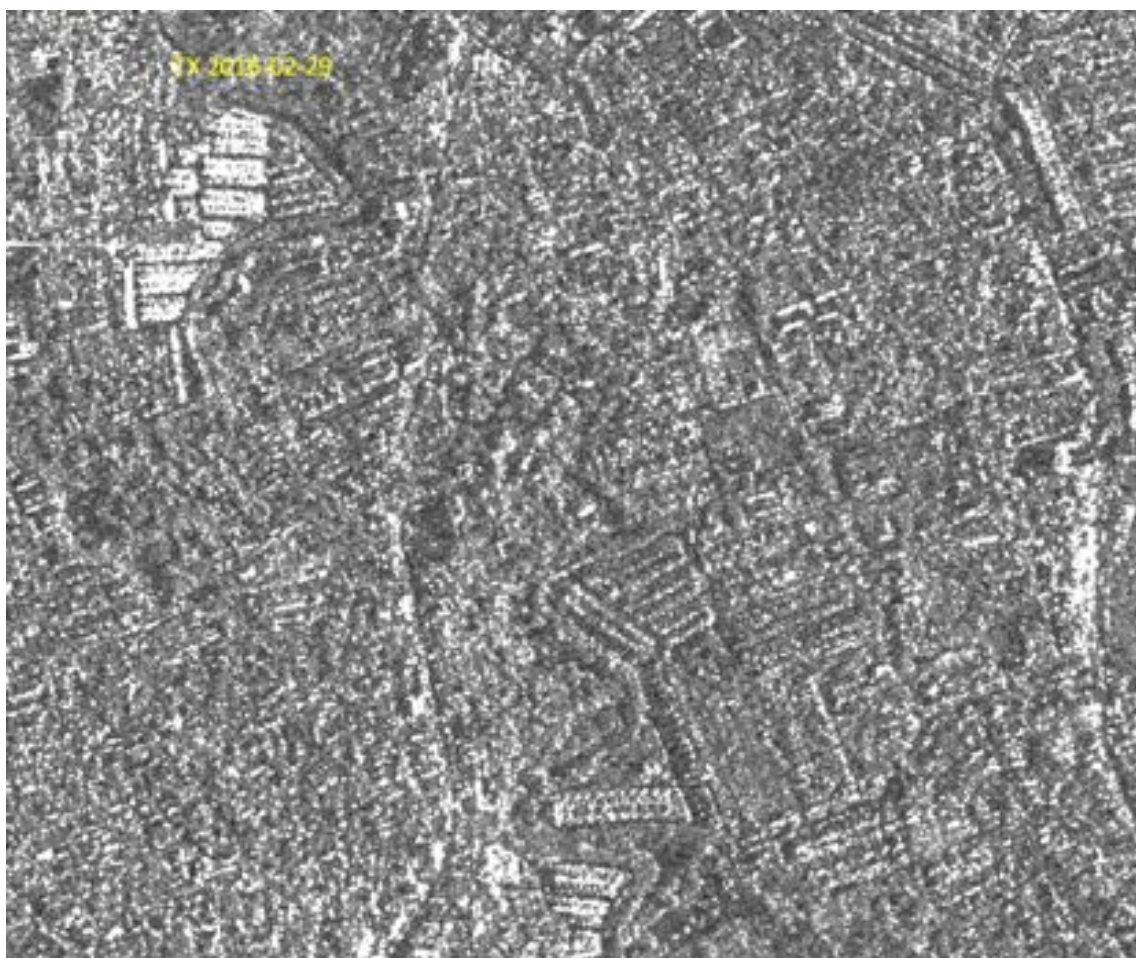


Figure 50: Lebak Bulus sub district, South Jakarta, as observed by TerraSAR on the 29 -02-2016.

Synthesis, concluding remarks on Rasor rapid action

Rasor team got the opportunity to carry rapid actions, and this is very positive in term of gained experience as well as for the recognition of its competencies for future developments.

From a technical point of view, these three actions, very relatively dense in term of timing, were very successful.

- The data request on line SPERF was done rapidly after the End Users request of triggering satellite mobilisation
- The exchange with REACT was very fluent, professionnall and friendly, frienly is a word that can be see as strange in a such context. Therefore, when exchange and discussion are done during the evening or night, courtesy/civility is one of the basement of professionnall and efficient exchange
- In term of timing, for satelite acquisition trigering, data avalibility notification, as well as data transfert , these were equivalent of those observed for a EMS activation.
- All data have been dowloaded and processed and analysed at SERTIT in time.
- The defined strategy of acquiring both optical and SAR data was confirmed as during the second triggering two SPOT6-7 images very acquired withn a very limited level of cloud coverage
- The information dissemination towards the End Users was done in time

In term of thematic, i.e. flood mapping, the success is less obvious. This is due to the targeted area, in regards to the available EO resource. Of course, these action give the same results as EMS activations over urban area when exploiting SAR even if it was VHR2 data. Due to the interaction of the signal within the buildings shape, SAR images were very saturated and it was not possible to detect any portion of flooded water. For the SPOT6-7 data, the 1.5 meter of the merged product is too low in order to provide any valuable information in a very dense urban area where the distance between houses is in the same range of the spatial resolution.

To obtain better results few ways of improvement can be proposed:

- In case of consecutive actions, try to acquire all SAR data with the same sensor, same orbit type (ie ascending or descending), same mode (and if possible quite same incidence angles) in order to allow an easier search of changes in landscape that could have been linked with flood extent.
- Continue research's work on flood detection in urban area based on SAR and optical data, i In another framework,
- For optical data, move from VHR2 acqusition to VHR1 (VHR1 access was not allowed for rush acqusiton to Rasor). For this, it is necessary to have a better exchange with end users in order to reduce the area of interest, as it is between 6 to 8 VHR images that are necessary to cover Jakarta town in all...
- In term of demonstration, it might be more successful if the area targeted would correspond to an area with mixed landscape, dense urban, towards more open space.

EO data aspects: learn lessons and perspectives

Concerning EO data availability and access, globally speaking, the coverage of historical events is relatively weak and disappointing in term of really relevant information. In regards of the apparent weakness of convenient EO data exploited over the Rasor test cases, few reasons can be advanced:

- A lack of EO data acquisitions As up to now, most of the EO HR mission were on an "on demand" principle, or when acquired, with a too weak revisiting frequency (ie 16 days of Landsat). In most of case data are available when a rapid mapping action have been carried in framework such as the International Charter Space and major Disaster, such as the former EU SAFER project and following Copernicus programs (GIO, EMS).
- When available, some limitations are also due to spatial resolution, as example, the case of SPOT5 for recognition of low level of damage after a tsunami for example.
- Distinctions have to also to be made between, recurrent events, such as inundation more or less dramatic within large flood plains taking place over weeks and sometime months, and fast/rapid flood events. In the first case, EO data archive can be relatively rich whereas in the second case, if no rapid action has been triggered, most of the time the event is not covered by EO data or neither by convenient EO data.

During the project, a new request was made by the project leader concerning the Malawi country and flood events, in order to demonstrate RASOR capacities. First tests were done and then it was decided to wait for future developments within a Rasor Phase II. We propose to present as example case of Zambezi River in Mozambique and its tributaries the Shire river in Malawi, to illustrate these cases of long flood period.

The Zambezi river case

The Zambezi River is the fourth-longest river in Africa, the longest east flowing river in Africa and the largest flowing into the Indian Ocean from Africa (Fig.51). The area of its basin is 1,390,000 square kilometers slightly less than half that of the Nile. The 2,574-kilometre-long river rises in Zambia and flows through eastern Angola, along the eastern border of Namibia and the northern border of Botswana, then along the border between Zambia and Zimbabwe to Mozambique, where it crosses that country to empty into the Indian Ocean. Our area of interest corresponds to the Lower Zambezi part.



Figure 51: Location of the area of interest within the Zambezi River Basin (Source Natural Earth, UNEP)

The lower Zambezi's 650 km from Cahora Bassa to the Indian Ocean is navigable, although the river is shallow in many places during the dry season. This shallowness arises as the river enters a broad valley and spreads out over a large area. Only at one point, the Lupata Gorge, 320 km from its mouth, is the river confined between high hills. Here it is scarcely 200 m wide. Elsewhere it is from 5 to 8 km wide, flowing gently in many streams. The river bed is sandy, and the banks are low and reed-fringed. At places, however, and especially in the rainy season, the streams unite into one broad fast-flowing river. About 160 km from the sea the Zambezi receives the drainage of Lake Malawi through the Shire River. On approaching the Indian Ocean, the river splits up into a delta. Each of the four primary distributaries, Kongone, Luabo and Timbwe, is obstructed by a sand bar. A more northerly branch, called the Chinde mouth, has a minimum depth at low water of 2 m at the entrance and 4 m further in, and is the branch used for navigation. 100 km further north is a river called the Quelimane, after the town at its mouth. This stream, which is silting up, receives the overflow of the Zambezi in the rainy season.

Zambezi, Shire and Delta areas suffer regularly of flood, with some dramatic events, such as in 2007, 2010, 2012 and December 2014-January 2015 for the latest event, information on rapid mapping actions can be found at the following Http addresses:

2015 : http://www.tiger.esa.int/tiger_news_page61.php

2012 : <http://sertit.u-strasbg.fr/RMS/action.php?id=971397431>

2010 : <http://sertit.u-strasbg.fr/RMS/action.php?id=974458501>

2007 <http://sertit.u-strasbg.fr/RMS/action.php?id=59448257>

http://sertit.u-strasbg.fr/SITE_RMS/2007/1_mozambique_2007/mozambique_2007.html

<http://www.zki.dlr.de/map/463>

http://www.disasterscharter.org/web/charter/activation_details?p_r_p_1415474252_assetId=ACT-145

Accessing relevant EO data over Zambezi

This part of Africa is relatively well covered by EO data, mainly because of ongoing project as TIGER. So the ESA mission archive and ESA TPM ones are relatively rich.

As example a search of EO data, more precisely for ENVISAT ASR WSM data (Fig. 52) which can be very convenient in term of revisit and spatial resolution versus spatial coverage for such event, have been done over The Zambezi and Shire confluence, for the period January to March over 10 years from 2003 to 2012. Depending of the year, 2 to 9 ASR WSM images are available.



Figure 52: Search and ordering of ASAR Envisat data over Malawi flood prone area exploiting EOLISA facilities

In addition, a search for ESA TPM has been done with a focus on Deimos data (Fig. 53), optical imagery with 22 m of spatial resolution.

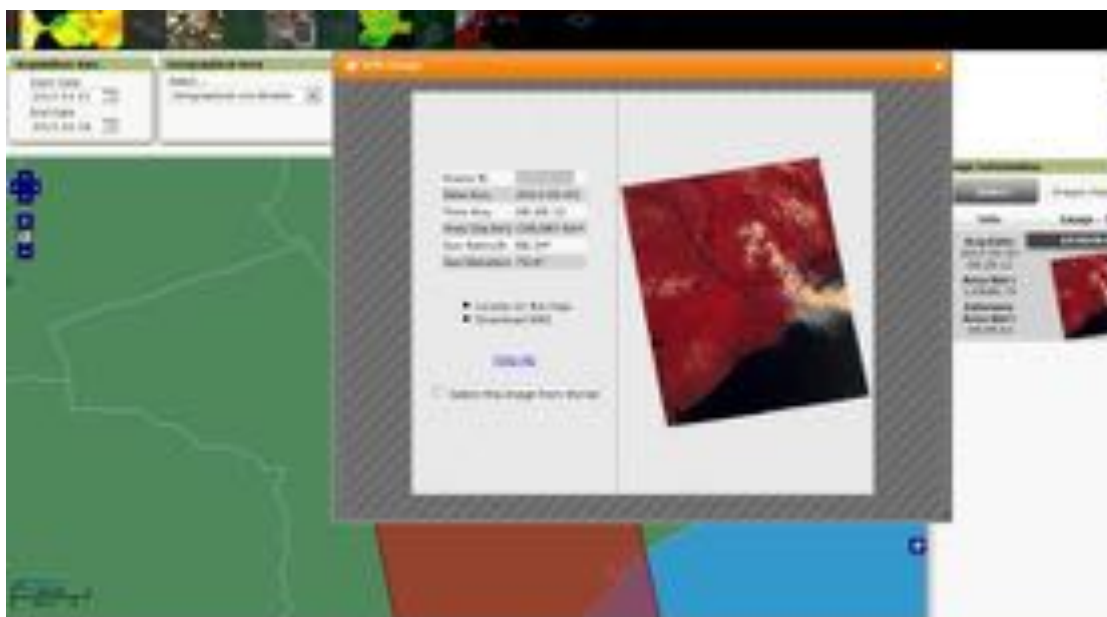


Figure 53: Search of Deimos imagery over Zambezi and Shire rivers for the 2003-2013 flood seasons

For the Sentinel 1 data set, as the system is already in a ramp up phase, the first priority was to secure the data, i.e.: identify, select and download appropriate imagery (Fig. 54).



Figure 54: Evolution of the acquisition of Sentinel1 for the period 18 of March to 4 of April and the following period 4 to 27 of April 2015 illustrating the ramp up effect in term of quantity of acquired data

Processing relevant EO dataset over Zambeze and Shire rivers

Once the EO data set was available, the different processing tasks have corresponded to the preprocessing of the data (radiometric/ geometric corrections, mosaicking ...), the thematic information extraction and its preparation for the uploading of the geo-information on the RASOR platform. These processing steps are illustrated hereafter with the example of the Malawi flood of end of January 2015 (Fig. 55-56) which flood extent has been integrated in the RASOR platform.

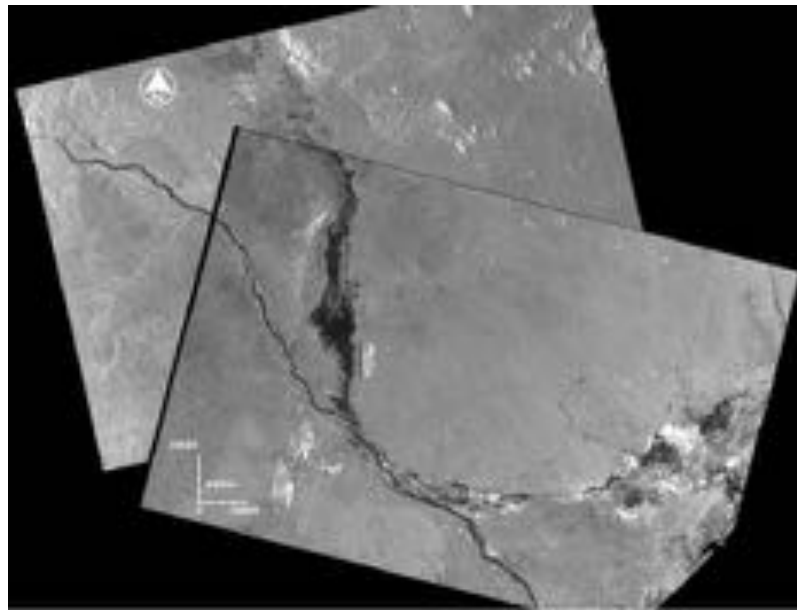


Figure 55: Processing of Sentinel1 images acquired on the 4 and 22 of January 2015

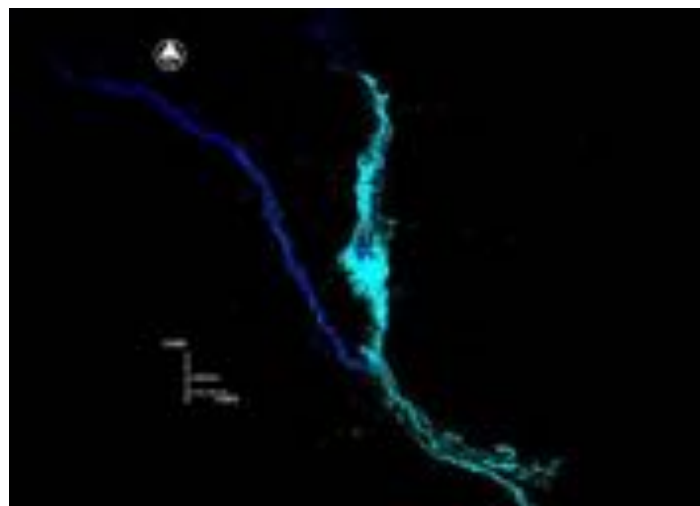


Figure 56: Diachronic analysis of the January 2015 flood event affecting the Shire watershed, Southern Malawi. In blue water extent extracted from a Sentinel 1 image acquired on the 04-01-2015, and in cyan water from Sentinel 1 image acquired on the 22-01-2015.

Conclusions/Implications for RASOR

Over the different test sites, selected in order to demonstrate representative products of the RASOR platform, after having set up the list of historical disasters events (WP7.1) associated to the list of potential relevant EO data (WP7.2), and selected the a priori most convenient dataset (WP7.3), procurement and thematic processing of these historical images in order, to build the historical event database (WP7.4). The present document synthesizes the work done over the test sites and present the Rapid actions carried over Jakarta in February 2016.

During the first months of the RASOR project the constitution of the historical case DB has been strongly limited by the unavailability of the Data Ware House which should have given access to the EO data since the beginning of the RASOR project. Alternative solutions for the procurement of EO data have been set up which allowed the integration in the RASOR platform of flood events layers having affected the Haiti pilot site. In April 2015, access to DWH was open, and first ordering of convenient EO data was made possible. Therefore, the project was confronted to delay and problems in accessing identified EO data set. In addition, concerning key data, i.e. Ikonos set of images over the Cilacap area expected to illustrate tsunami damages, despite numerous and intense email exchange with Copernicus EO support, exchange began, in advance, with data providers in Singapore, US and Italy, it was not possible to reach these data.

Even if it was already known that for a certain amount of sites or events, such as over Rotterdam flood, and also over Santorini events, there were no availability of EO data, globally speaking, the coverage of historical events is relatively weak in term of really relevant information. Few reasons can be advanced:

- A lack of EO data acquisitions As up to now, most of the EO HR missions were on an "on demand" principle, and with a too weak revisiting frequency (ie Landsat). In most of case data are available when a rapid mapping action have been carried out in frameworks such as the International Charter Space and major Disaster, or such as the former EU Safer project and following Copernicus programs (GIO, EMS).
- When available, there are some limitations in the exploitation of the imagery, this can be related to the resolution. As example, the case of SPOT5 over Cilacap; the resolution, 2.5m, was too low to insure the recognition of low level of damage after the July 2007 tsunami.
- Distinctions have also to be made between, recurrent events, such as inundation more or less dramatic within large flood plains taking place over weeks and sometime months, for example case of Zambezi River in Mozambique and its tributaries the Shire River in Malawi, and fast/rapid flood events. In the first case, EO data archive can be relatively rich when in the second case, if any rapid action has been triggered, most of the time the event is not covered by EO data or not by convenient EO data.

- For the future exploitation of the Rasor Platform, it can expect that access/availability to Sentinel1 and Sentinel2 data will improve very much the situation.

By the way, a major step of the Rasor project corresponds to the integration of Sentinel data for catastrophic event characterization, data coming both from Sentinel 1, over Italian and Indonesian tests cases as well as Sentinel 2, once over Italian test site. For future dramatic events, such data would address the lack of data availability, thanks to the systematic acquisition scheme, and the ramp up of the constellation in 2016 with the launch of Sentinel1B and later the launch of Sentinel 2B. For the future exploitation of the Rasor Platform, it can be expected that this access/availability to Sentinel1 and Sentinel2 data will improve very much the situation. And first months of acquisition with the two system seems to confirm this.

A very successful point it is that, thanks to these actions carried during the February 2016 flood event over Jakarta, Rasor team got the opportunity to carry on rapid actions, and this is very positive in term of gained experience as well as for the recognition of its competencies for future developments. Therefore access to relevant very high resolution data (VHR1) would be a key point for the Rasor development and this both for SAR and optical data.

Historical Events in RASOR

The RASOR platform has a dedicated functionality of the Monitor table for exploring the Historical events. In particular the user is presented a timeline showing all available historical events in that geographic area the timeline dynamically updates as one moves on to the world map. The user can select the icon relative to one of the historical events and all layers related to the historical event will be filtered from the RASOR Catalog. The interface displays an abstract related to the Historic event that summarizes the main characteristics of the historical event.

The historical events are stored into an historical event table that summarizes:

- the Event ID (a GLIDE Number or a GLIDE-Like Number if a GLIDE number does not exist for that event);
- The starting-, end- and reference-date of the event;
- An abstract
- A reference case study area

Tagging the layers with the EventID will automatic relate these layers to the event in object.

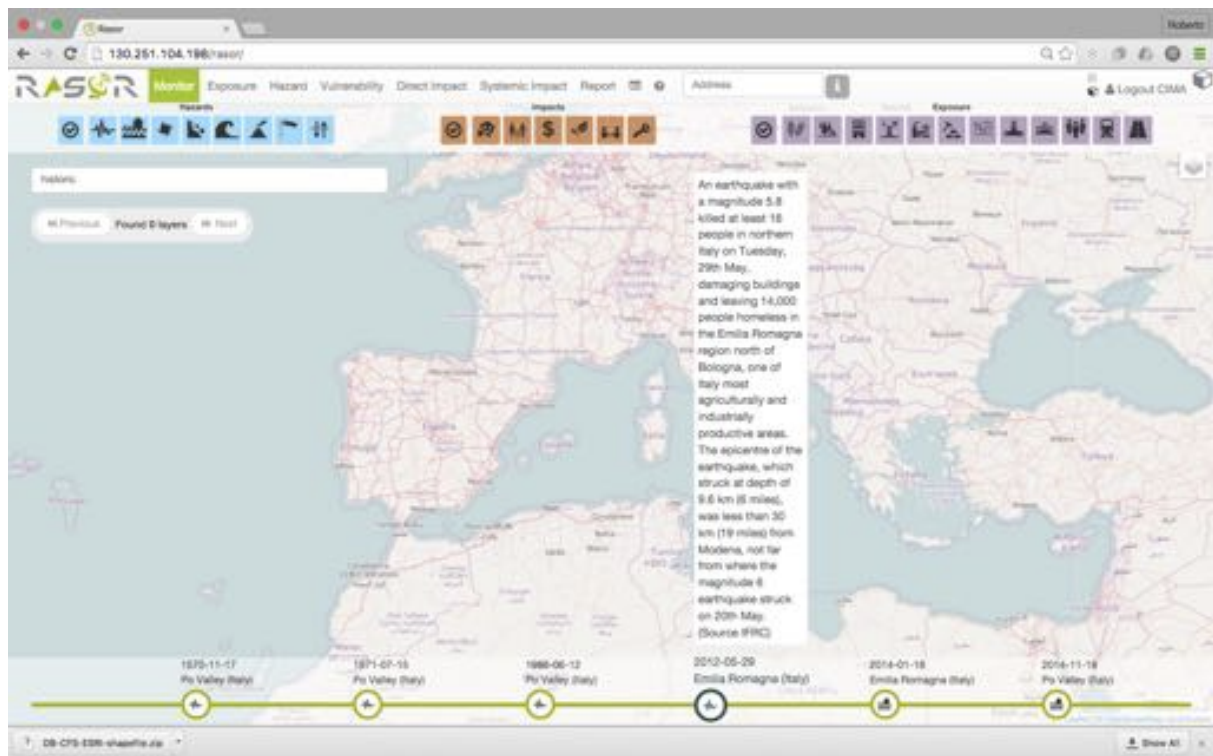
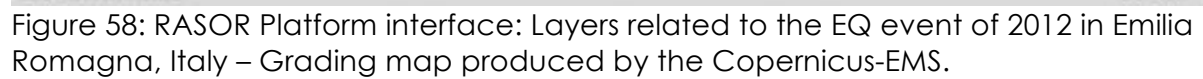


Figure 57: RASOR Platform interface: Historical events timeline.



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Jakarta Post, 2016c : <http://www.thejakartapost.com/news/2016/02/29/hundreds-evacuate-one-toddler-dies-after-heavy-rain-jakarta.html#sthash.MnnNeiGk.dpuf>

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