Rapid Mapping and Early Warning Systems

IWG-SEM White paper

The proposition:

EWS POTENTIAL IN REDUCING THE TIME LAG BETWEEN A CATASTROPHIC EVENT AND SATELLITE DATA ACQUISITION

Version 1.0 – as of April **2018**

International Working Group on Satellite-Based Emergency Mapping

Contents

Foreword

Satellite-based Rapid or Emergency Mapping (SEM, or Rapid Mapping) is defined as the creation of maps, geo-information products and spatial analyses to provide situational awareness for emergency management and immediate crisis information for response. This is by means of extraction of reference (pre-event) and crisis (post-event) geographic information/data from satellite or aerial imagery. SEM derives mapping products that are useful in decision-making and can be potentially also be used as input to other phases of the disaster cycle as well, such as the early recovery and the prevention phases.

Rapid Mapping especially focusses on the situation during and immediately after an event. As already stated in the IWG-SEM Guidelines, the rapid mapping workflow can be broken down into four crisis phases: 1) the decision to trigger or activate a mapping event in response to or in anticipation of a disaster; 2) the remote sensing data acquisition process (satellite or aerial); 3) the downlinking and data acquisition procedures; and 4) the production of crisis geo-information. The decision to activate can take some time but this part is outside the control of many parties engaged in Rapid Mapping. However, activation decisions and procedures are being streamlined and strengthened amongst decision makers as the availability of these services becomes more widely appreciated. Data acquisition can be the most time-consuming phase. Since 2000 for the International Charter "Space and Major Disasters" and since 2012 for Copernicus Emergency Management Service this has often been the case, often consuming 70-90% percent of the time to deliver geo-information products.

Attempts have been made to reduce the time related to data acquisition. Principally this has involved the stream-lining of the satellite data programming structure and the reduction of the time interval between data ordering and satellite programming. Increasingly satellites can be programmed to acquire with only a few hours lead time before data acquisition. Images can be ordered much closer to an activation time and, notwithstanding weather-conditions, are generally delivered faster (also exploiting new cutting-edge laser technology such as the European Data Relay System). Another method, described here, is to use pre-emptive image acquisitions based on alert /early warning mechanisms and working with data providers to direct the image order in time and geographic area accordingly. The pre-programming of data acquisitions over an area that will probably be affected by an event can gain precious time, but entails risk that an event will not occur (in that foreseen specific area) or be less severe. In Europe and elsewhere, the establishment of pre-emptive triggering procedures using early warning systems such as the Copernicus European Flood Awareness System (EFAS) or Pacific Disaster Center's DisasterAWARE™ is being explored.

This white paper specifically treats the case of integrating the exploitation of early warning and alert systems into rapid mapping and can be seen as a complementary document to the IWG-SEM Guidelines. The Guidelines (periodically updated) give an overview of what Satellite-based Emergency Mapping is and define best practices within the domain. This white paper work is a first version and will be updated as practices in the field evolve.

1. Main issue: Timeliness of data acquisitions in Rapid Mapping

The data acquisition phase, which is the period from satellite tasking until data acquisition, is often the most time-consuming when a rapid mapping production service is triggered. During a disaster, this time lag reduces the utility of the work. Since 2000 (International Charter "Space and Major Disasters") and since 2012 (Copernicus Emergency Management Service Rapid Mapping) this has been the case, often consuming 70-90% of the time to deliver geo-information products. Below, an example taken from the early days of rapid mapping within the Charter (Figure 1) and a very recent example taken from Copernicus EMS Rapid Mapping (Figure 2) are provided. At the beginning of the Charter (2000-2005), the acquisition phase, took on average 3 days (Figure 1). At present, on average 1-2 days are generally required, (as highlighted in Voigt el al, 2016 (1) for satellite acquisitions: the number of satellites has risen dramatically and both programming and delivery mechanisms have much improved. The time taken by this phase has reduced but could still improve. The message in this White Paper is that EWS integration into Emergency Mapping workflows should help in this task.

As an aside, an interesting but important issue is highlighted in Figure 1: the time taken by the mobilisation phase. This phase is defined as the time between an event happening and an activation being triggered by an AU. At the beginning of the Charter (2000-2005), the mobilisation phase took on average 3 days. Please note that in the more recent Copernicus EMS this phase is not measured. As response units have integrated the triggering of rapid mapping resources into their workflows, it is likely that this time lag has dropped significantly, but no current statistics exist. This lag is plainly critical to increasing overall effectiveness. It is suggested in this White Paper that triggering pre-emptive satellite acquisitions through EWS should reduce this time lag. Of course, potential users need to be made aware of the pre-emptive acquisitions to best benefit from a speedy service.

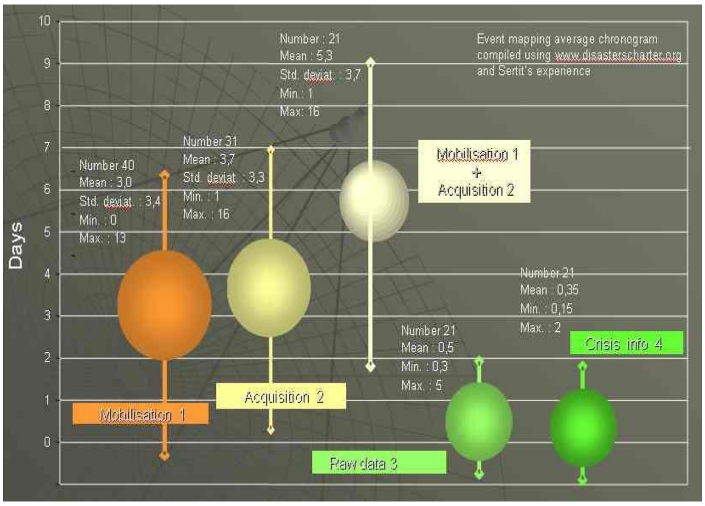

Figure 1: Average event mapping chronogram for the 2000-2005 period concerning Charter activations and SERTIT's experience (2)

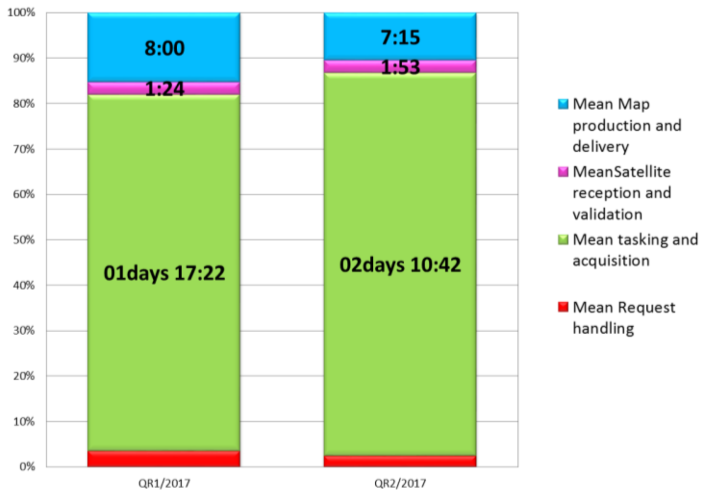

Figure2 : Average times per rapid mapping phase (version 1 delivery) for the first 2 quarters of 2017 within the Copernicus EMS RM context (Source Copernicus Emergency Management Service © European Union 2017, compiled by e-GEOS)

While the data acquisition situation is improving, it is improving in an unequal way, this is detailed below. The probability of obtaining an acquisition, whether useful or not, has increased as:

- There are many more satellites,
- Many of these satellites are more agile, capable of taking images at variable angles,

- There are an increasing number of (virtual) satellite constellations that can be efficiently programmed together to cover large areas and acquire daily coverage over much of the globe,
- The coverage by fixed viewing satellites has also greatly increased,
- Access to these images once acquired is improving as a number of satellite imagery distributors are delivering much faster through automatic delivery chains. Also, internet network capacities are greatly increasing.

Radar and especially optical satellite image coverage and data availability are greatly increasing, but access to these data in an emergency is still being held back in many cases by:

- Long lead time for satellite programming due to cut-off times, although this has improved for VHR (very high resolution) data with up to a daily coverage at 0.5 m resolution[1],
- The necessity for morning daylight acquisitions (except some cases[2]),, which often implies a wait until the next day,
- Downlink and pre-processing time before delivery,
- Latency of the public Sentinel SAR data,
- Weather conditions,
- Availability of 24/7/365 services.

Although radar can be acquired day and night and during cloudy weather, even such SAR image acquisitions are not always easy and rapid to obtain. This is due to:

- Relatively few operational 24/7 radar satellite systems exist,
- Even fewer responsive radar constellations that guarantee a wide and frequent coverage, (COSMO-SkyMed),
- The time between down-link and delivery can be long due to complex image processing (TerraSAR-X),
- The radar system that delivers imagery the fastest (RADARSAT-2) unfortunately isn't part of a constellation and hence coverage can be limited both geo-spatially and temporally,
- Weather conditions, notably wind, can adversely affect the utility of acquired SAR radar data,

Furthermore, an impediment to radar data usage lies in the fact that it can't be exploited for all types of emergencies and that non-remote sensing specialists will find it hard to use. Hence, specialists need to process the data and extract the geo-information before it is delivered to most users.

Overall, the more-delayed the interval between identified need and data delivery, the less pertinent the satellite image acquisitions are, which impacts in turn the usability of the crisis geo-information that is delivered to the users. Of course, improvements can be made by increasing the number and agility of satellites, reducing the imagery order-to-acquisition time interval, downlink time, and speeding up the imagery delivery to map-makers from the ground stations. Otherwise, part of the solution could be the use of Early Warning Systems (EWS) to pre-emptively trigger image acquisitions. The objective in this case is to automatically schedule acquisitions for the next peak of an event from predictive modelling and sensing.

[1] Combined Pléiades and Digital Globe resources
[2] http://www.euspaceimaging.com/category-news/item/worldview-1-successfully-changes-orbit

2. Proposed improvement: Integrate Early Warning Systems into the data acquisition process

The main proposition here is that *early warning system information can help to reduce the time lag between an event and data acquisition*. Thus, anytime night or day, the EWS predicts an event, perhaps detects the actual occurrence of the event, and then automatically schedules image acquisition for mapping purposes. This can be described further, as follows:

First, awareness of an event happening or about to happen is the key starting point. Hence, access to disaster tracking systems and emergency alerts is fundamental: not just for the general emergency response community but also, in particular, for SEM components. Platforms such as "GDACS" and "Tropical Storm Risk" exist but there is no multi-scale, multi-thematic 'dashboard' available. This is understandable as it is a complex issue and the relevant technologies are diverse (Figure 4). SEM users will need to be contacted to ascertain how they predict or detect actual events. The picture will differ greatly depending on, amongst others, a user's type of entity, their thematic scope, and the scale and geography of the areas being dealt with. This subject will be further developed in future versions of the paper and in the IWG-SEM Guidelines.

The remote sensing-based and modelling-based predictions and/or detections of dangerous phenomena are essential in obtaining the earliest warning possible. It is also proposed that the smooth integration of social network technologies could be an asset. Social networks can rapidly provide an indication of the location of impacts and the type of impacts that have occurred. Semi-automatic detection, data mining and quality/reliability selection procedures could alert the Emergency and SEM communities to need for emergency mapping and more precisely where to map. In the early hours after a major event this could be vital in speeding up the SEM process. This whole domain is accelerating with SEM users already delving into the field and R&D projects exploring ideas. There is already the prospect of exploiting operational tools within SEM environments. Social media has also already been used to map damage within a SEM context (Copernicus EMS – H2020 Em2C project) and could enable mappers to produce useful information while waiting for satellite imagery.

The rapid sharing of SEM metadata is also needed in order to speed up service to users. The fact that certain mechanisms trigger for an on-coming or existing event can be an early warning that an event has potential or actual impact. Sharing in the early phases of an event can reduce redundancy, increase collaboration and speed up the delivery of crisis geo-information to users. This can be attained through groups such as the Global Flood Partnership (3).

Importantly, the active collaboration among emergency response groups can help share work over the most important AOI's; again speeding up and improving geo-information delivery. This is a principal goal of the IWG-SEM and is increasingly happening, between Copernicus EMS and the International Charter activation. Furthermore, satellite imagery is being shared through a collaborative protocol. IWG-SEM members have played roles in this.

3. Discussion on EWS integration potential per disaster type and information exchange

EWS integration into SEM is clearly feasible for hydro-meteorological events that can be forecast up to a few days ahead and more precisely 24 hours before affecting an area. This is highly relevant for rapid emergency mapping as a large proportion of the events that it is used for are related to floods or to damage related to storms (flooding, wind-affected buildings, landslides, forest windfall…) (Fig. 3 & 4).

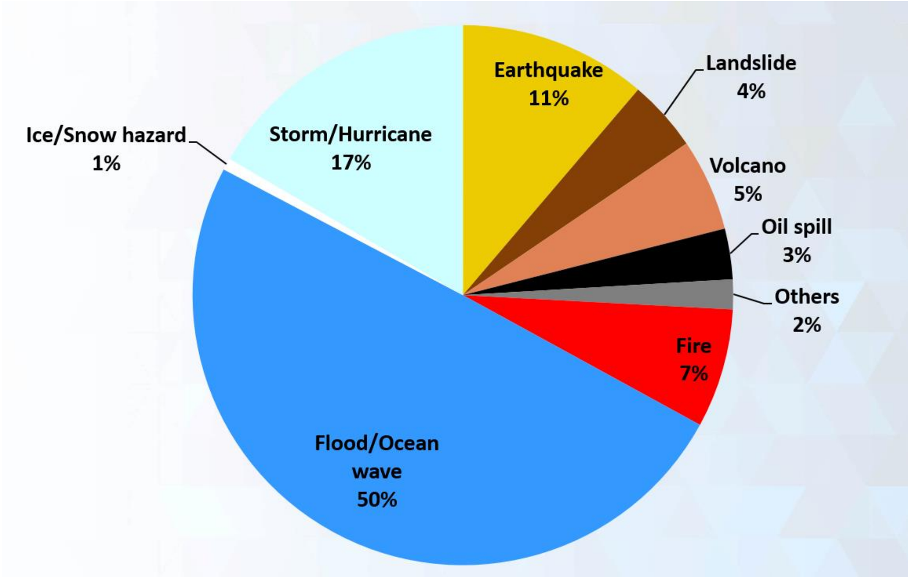

Figure 3 : Type of disaster event covered by the International Charter Space and Major Disasters from 2000 to 2017 (Source CNES Charter)

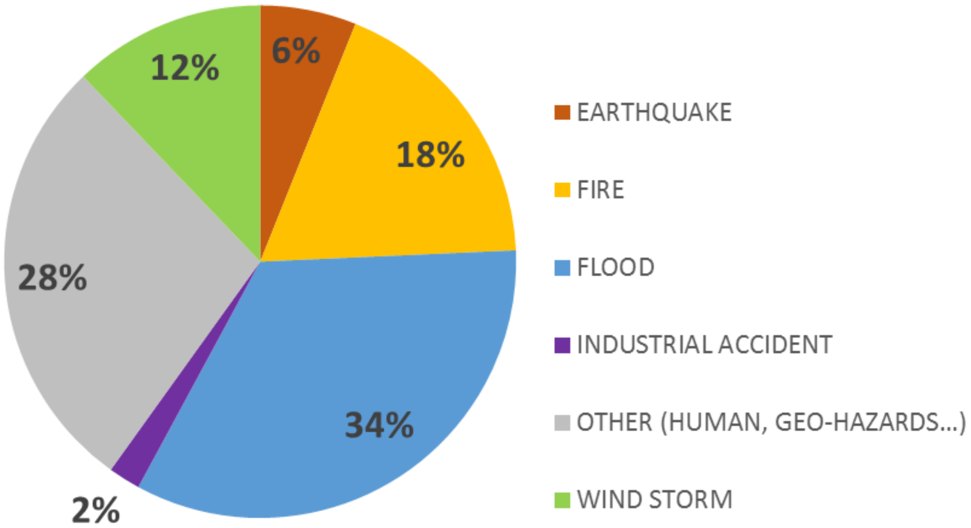

Figure 4: Type of disaster event covered by Copernicus EMS Rapid Mapping concerning close to 262 activations (Source Copernicus Emergency Management Service (@ European Union, 2012-2017), "other" includes e.g. humanitarian crisis, landslides, volcanic eruptions, industrial accidents)

Of the other major disasters, fire events generally occur during good weather and hence especially VHR acquisitions can be programmed and acquired up and until the early morning of the day of acquisition. This does not mean that EWS systems cannot be used to help trigger rapid mapping activations. Hot spot and low-resolution fire extent mapping such as available in the Copernicus European Forest Fire Information System (EFFIS) could be used as indicators in triggering rapid mapping.

On the other hand geo-seismic events (earthquakes, landslides) do not give a forewarning and hence classic EWS are not applicable. For these or any other event type the system could be accelerated if value adding entities or any other 24/7 emergency entity could trigger satellite data acquisitions without waiting for a request if an event of a certain large magnitude occurs. Furthermore, social media early warning could greatly help in the early focussing of SEM resources by indicating the location, type, severity of damage with the SEM community in combination with knowledge concerning where the vulnerable populations and assets are. Thus, automated geophysical earthquake detection systems have long existed, but the challenge is to immediately understand what areas should be acquired by satellite imaging systems due to likely damage, and to link such knowledge directly to targeting by the satellites.

The information that is sent by alerting agencies to the user community is already in the process of being formalised to enable the sharing of this information and incorporation into many applications. One of the major initiatives is the Common Alerting Protocol (CAP), which is an XML-based data format for exchanging public warnings and emergencies between alerting technologies. The CAP is incorporated then into the Emergency Data Exchange Language (EDXL) Distribution Element (DE), a more flexible container of XML format. The OGC Geographic Marker Language is also incorporated into the EDXL standard. EDXL was developed as a royalty-free standard by the OASIS (Organization for the Advancement of Structured Information Standards) International Open Standards Consortium. Hence, if communication between EWS and rapid mapping occurs it is good to respect this standard. It is increasingly accepted and implemented internationally and was developed for Disaster Management software. EDXL-DE belongs to a suit of other standardised emergency messages targeted at other purposes such as Resource Messaging (RM), Hospital Availability Exchange (HAVE) and Situation Reporting (SitRep), and Tracking of Emergency Patients (TEP).

4. Implementation of the link between EWS and Rapid Mapping

The implementation or the hard wiring of the link between EWS outputs and triggering rapid mapping is not a simple issue as it involves a combination of the elements below:

- Administrative and financial issues and, hence, who takes the decision to trigger, based on what, and who pays for any costs,
- Technical issues such as what are the event-related criteria to use in order to trigger the image acquisition process. This in itself involves testing and validating EWS output stipulating what kind of information is needed and what are the thresholds,
- As noted, EWS might need to be adapted as most of them only provide hazard information. However, to identify the relevant areas for pre-tasking with a high impact (population, infrastructure, land use) risk forecasts incorporating such information are required. Risk forecasts are already provided by EFAS and DisasterAWARE for certain event types. This can be used as a preliminary impact estimate map. Information of potential damages caused by wildfires is also available in the EFFIS. However, the triggering of rapid mapping for wildfires is not always driven by this information.
- Also needed is a linkage specifying different types of data to be ordered based on the event type,
- Geographical issues could be incorporated, such as deciding what the priority areas are,
- How should false alerts dealt with (most systems will produce such on occasion),
- Can flexibility be incorporated: in the case where an event’s location is somewhat different than that forecast?

For a system to be effective, it appears necessary that a command chain is set-up with a clear workflow to follow. Since the availability of EWS, SEM has used this resource when and where available for hydro-meteorological events but rarely in a hard-wired mode. In the past this connection has also been attempted in a Charter context but it did not flourish due to a lack of risk acceptance, i.e. some alerts do not lead to events. At present, EWS are beginning to be formally integrated into rapid mapping, for example within the Copernicus EMS context. Integration examples will be given in chapters below but for now a selection of the EWS commonly used in rapid mapping will be briefly mentioned.

5. EWS's presently used in rapid mapping

In this section a selection of Early Warning Systems or systems that can be used for disaster event warning are presented. These are and can be used by the rapid mapping community as awareness tools concerning potential disasters and potential triggering of mapping activations. These sites sometimes do not push out alerts but needs to be followed. A number of different kinds of systems exist covering different topics:

- Multiple alert and potential disaster systems, notably Global Disaster Alert and Coordination System (GDACS-Worldwide). GDACS is backed by the United Nations, the European Commission and disaster managers worldwide to improve alerts, information exchange and coordination in the first phase after major sudden-onset disasters. While Meteoalarm is a system developed for EUMETNET, the Network of European Meteorological Services. Its website integrates all important severe weather information originating from the official National Public Weather Services across a large number of European countries and is strongly supported by the WMO (World Meteorological Organization).
- The US-based and USGS-supported Pacific Disaster Center (PDC) has developed the DisasterAWARE disaster monitoring, early warning and decision support platform (Fig. 5). Instances of DisasterAWARE are operated by PDC, for example EMOPS (emops.pdc.org), and used by thousands of disaster management professionals. Others versions have been customized for use by regional organizations (e.g., DMRS for AHA Centre) and national organizations (e.g., InAWARE for Indonesia's BNPB). DisasterAWARE uses authoritative national and international sources to automate hazard detection and alerting for earthquakes, tsunamis, tropical storms, high winds, high surf, tornados, volcanos, and wildfires and leverages a network of analysts and partner organizations to manually trigger alerts for floods, droughts, landslides, biomedical and other hazards. It provides alerts via email, SMS and the Telegram app as well as via CAP. Additionally, an API is provided to allow third-parties to more directly integrate PDC hazard feeds and post situational awareness products to the application.

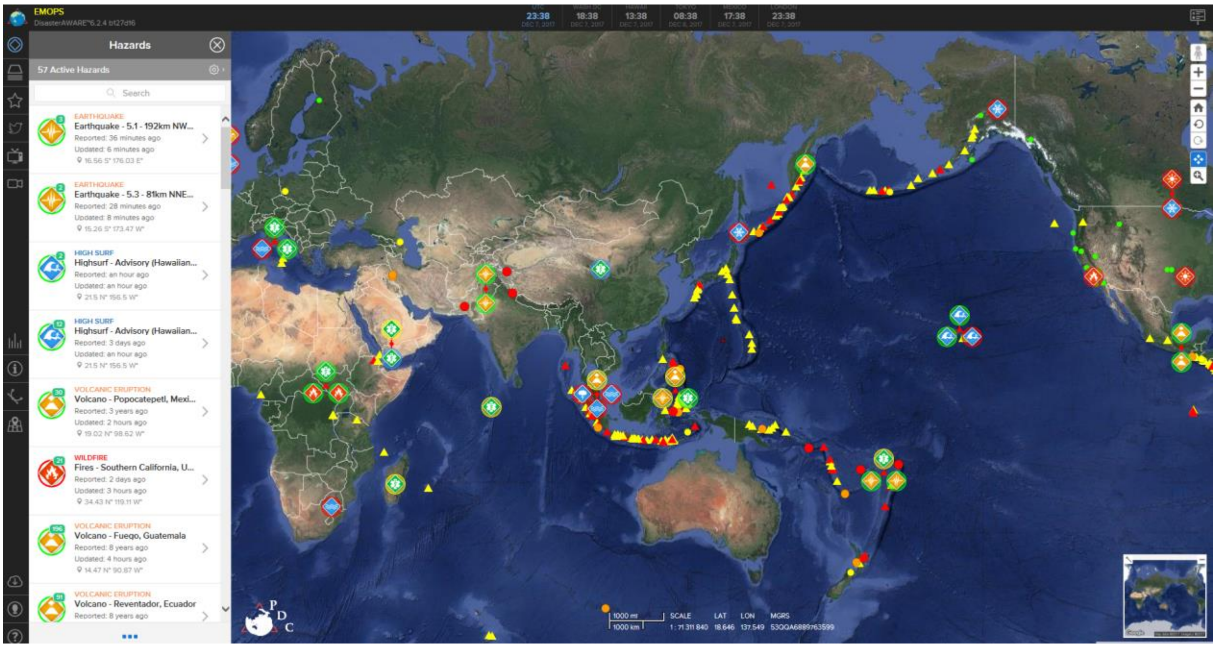

Figure 5: DisasterAWARE disaster monitoring, early warning and decision support platform (Source PDC)

- Storm monitoring with the World Meteorological Organization Tropical Cyclone Programme and the Tropical Storm Risk consortium, which are examples of a dedicated system, are important resources for predicting and mapping tropical storm activity worldwide. Copernicus EMS regularly uses Tropical Storm Risks to track storms and be aware of landfall predictions.
- Fire danger, fire hot spot and low resolution burnt area mapping systems such as the European Forest Fire Information System (EFFIS). Fire Danger Forecast: The fire danger forecast module of EFFIS generates daily maps of fire danger level using numerical weather predictions that are received on a daily basis. This service is used by the rapid mapping community as a danger awareness system and not directly as an activation trigger because extreme danger does not necessarily mean fires will happen. Active fires are detected using their thermal anomaly fire detection provided by the NASA FIRMS (Fire Information for Resource Management System) which provides near real-time active fire geo-locations derived from both the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Visible Infrared Imaging Radiometer Suite (VIIRS). Above a certain threshold, the potential fire is confirmed as an active fire or "hot spot". The results are filtered. The Rapid Damage Assessment (RDA) module of EFFIS maps burnt areas during the fire season. These burnt areas are derived from daily MODIS images at 250 m spatial resolution with the burnt area being delivered a few hours after the acquisition. Additionally, the burnt areas are produced by interpolation of the filtered active fire points in VIIRS, being ready shortly after the imaging of the area by the satellite. The rapid mapping community and users can use this kind of information to access whether major dangerous fires (above 30 ha in size) are developing or not.

At present, it is the flood related EWS that are most integrated into the rapid mapping workflow but US and EU organisations are working hard on expanding the integration to other disaster event types. Flood monitoring, prediction and warning systems are extremely important resources in the context of rapid mapping service flood mapping and monitoring. Initially at least given the need for a wide overall view of events that might occur or are occurring, the most valuable sites are those that cover continental type surfaces. Globally, the Global Flood Awareness System (GloFAS), jointly developed by the European Commission and the European Centre for Medium-Range Weather Forecasts (ECMWF), couples state-of-the art weather forecasts with a hydrological model and with its continental scale set-up it provides downstream countries with information on upstream river conditions as well as continental and global overviews. GloFAS produces daily flood forecasts in a pre-operational manner since June 2011. Otherwise, systems that push out alerts giving a level of certainty of an event happening and a degree of severity are extremely value. These alerts can be integrated into a rapid mapping pre-alert image acquisition phase to gain time in the event triggering and image acquisition phases. In Europe a test protocol has been set-up within the Copernicus EMS Rapid Mapping service to try to speed up and hence reduce the time to the first satellite image acquisitions. In the next paragraphs the European Flood Awareness System (EFAS) and, then, the Copernicus pre-alert protocol will be described.

6. A hard-wired EWS-Rapid Mapping success story: Copernicus EMS EFAS-Rapid Mapping

EFAS, the European Flood Awareness System, was set-up to provide coherent flood information on a pan-European scale to all the major European Institutional and member state agencies involved in dealing with floods. EFAS was developed by the Joint Research Centre, the Commission's in-house science service, in close collaboration with national hydrological and meteorological services, European Civil Protection and other research institutes. EFAS provides maps of flood probabilities up to 10 days in advance as well as detailed forecasts at stations where the national services are providing real time data. It provides its unique overview to the European Commission's DG ECHO Emergency Response Coordination Centre (ERCC). Since September 2012 EFAS is part of Copernicus Emergency Management Service (EMS) and it contributes to the timely activation of the Copernicus EMS Rapid Mapping for improved flood extent mapping and monitoring. In fact, what has really enabled EFAS to be linked to the pre-tasking of SEM is the fact that EFAS has developed a risk forecast rather than a hazard forecast service. This EFAS risk forecast of the potentially highest impacted areas enables Copernicus EMS to define AOI. This is a unique feature in EFAS as almost all flood EWS do only predict hazard (4). An early example of EFAS predicting flood probability impact maps in given in figure below concerning the Central European floods of May/June 2010. A more recent operational success story will be given later covering the May/June 2016 flood in France.

Figure 6 .Overview of EFAS flood probability maps several days before the devastating Central European floods of May/June 2010.

Presently, EFAS alerts of a certain level can trigger the Copernicus EMS Rapid Mapping pre-tasking of satellites to cover the most likely affected areas. This represents the first concrete procedure in

Copernicus linking an EWS alert to action within rapid mapping. The procedure was published in Wania et al., 2017 (5) and is continuously updated according to experience from real cases.

The pre-tasking is ordered under Rapid Mapping, the 24/7/365 on-demand service of CEMS Disaster impact mapping in collaboration with the Rapid Emergency Activation for Copernicus Tasking (ESA/REACT) service.

The procedure has been defined based on the experience of EFAS alerting for flood in Europe but aims at being applicable to other disaster events and early warning systems. It is limited to the initial steps up and until the submission of an image tasking request. Once an image is planned the potential mapping user is informed of the acquisition status of an image over the area(s) of interest. The procedure does not automatically imply value added mapping. According to the current Copernicus EMS Mapping set-up, an Authorised User must submit an official service activation request to continue towards the mapping phases.

Besides serving to anticipate satellite tasking the procedure set up inside Copernicus EMS also aims at raising awareness on the user side about the available systems both early warning and rapid mapping. It is assumed that users who are more aware also contribute to improving the efficiency of both systems (timelier user reactions). This was already mentioned as part of the mobilisation phase.

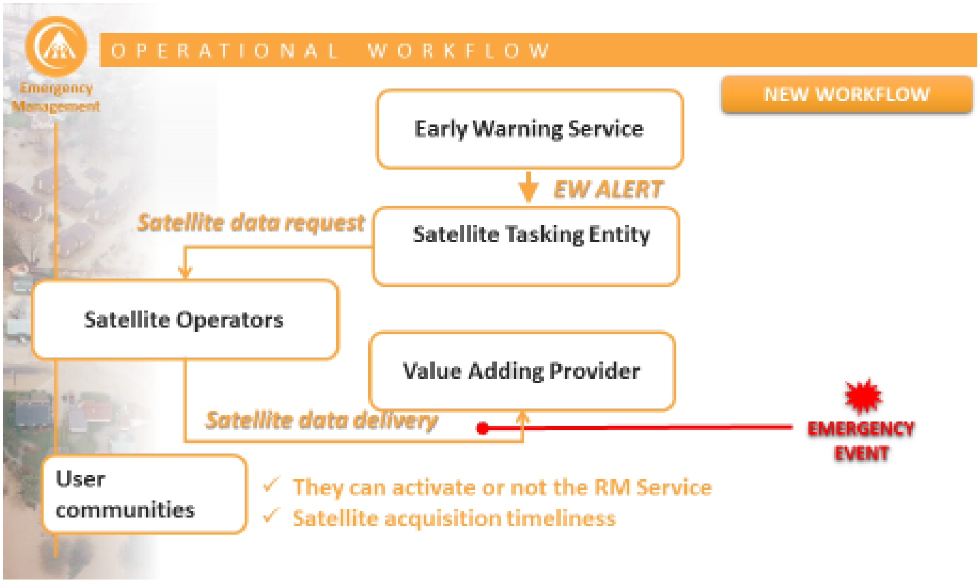

Figure 7: The Copernicus EMS workflow integrating the Early Warning Systems

The criteria for a pre-tasking request are as follows:

- A severe impact should be forecast by the Early Warning System (EWS),
- The request should be made not more than 24 hours before the expected event.

Beforehand, confidence levels concerning the given EWS are considered and also Areas of Interest (AOI) are established. The approximate forecast time of the expected first peak is taken into account when requesting imagery acquisitions.
A number of Pre-Tasking success stories have occurred with the Floods in the Loiret of May - June 2016 being an example. On the 30/05/2016 EFAS sent an early warning message concerning the high risk of flooding from Tuesday 31 May onward for the Seine and Loire river basins. The EFAS alert mechanism

is illustrated below (Figure 7) highlighting, briefly, the forecast for a river section in Auxerre, France, on the 30 May 2016 indicating a forecast for a 20-year return period flood over the coming days. The triangles in the map indicate for what river sections authorities have been notified. The alert message received by the SEM service is shown in figure 8, whereas in figure 9 a comparison is illustrated between the EFAS warning areas in a transparent orange-brown, the initial pre-tasking Areas Of Interest in blue and the chosen SEM user-defined AOIs in purple. The illustration of the EU Level 3 regions (NUTS3) mentioned in the alert helps focus preparation activities for satellite tasking.

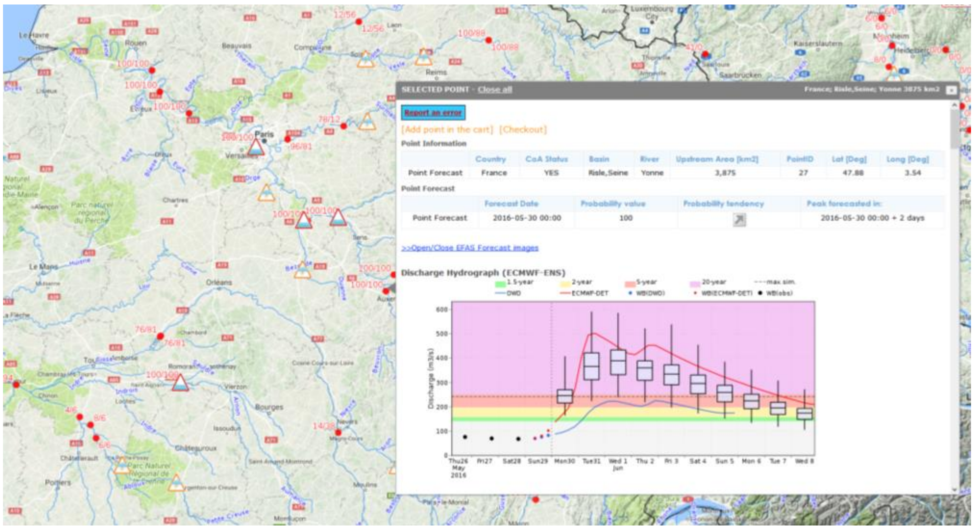

Figure 8: EFAS forecast for 30 May 2016. The triangles denote river sections for which EFAS Flood or Flash Flood notifications have been sent to the relevant authorities. The hydrograph shows the forecast for the Yonne River close to Auxerre. The purple colour denotes return periods greater than 20 years. The red/blue line denotes the deterministic forecasts from ECMWF and the German Weather service respectively. The Box-Whisker plots represent the probability distribution of the ECMWF ensemble forecast.

<u>EFAS early warning for potential rapid mapping activation for France</u>

Situation description: Heavy rains are affecting central and northern parts especially during Monday 30 May until Wednesday 1 June. EFAS predicts a high risk of flooding from Tuesday 31 May onward for the Seine and Loire river basins.
Affected country: France
Affected river basin(s): Seine, Loire
Affected region(s): Indre-et-Loire, Seine-et-Marne, Essonne, Loir-et-Cher, Loiret
Predicted start of the event: Tuesday 31 May
Major affected cities: Montrichard, Romorantin-Lanthenay, Salbris (Region: Loir-et-Cher; severe flooding/peak expected 31 May); Amilly, Chalette-sur-Loing, Montargis (Region: Loiret; severe flooding/peak expected 31 May); Moret-sur-Loing, Nemours (Region: Seine-et-Marne; severe flooding/peak expected 31 May); Crosne (Region: Seine-et-Marne; severe flooding/peak expected 1 June); Coulommiers (Region: Seine-et-Marne; severe flooding/peak expected 2 June); Tours (Region: Indre-et-Loire; severe flooding/peak expected 3 June),
Next situation update: 31 May 2016

Figure 9: EFAS alert text message received by the SEM EMS rapid mapping service (Source: Copernicus Emergency Management Service (© 2016 European Union)).

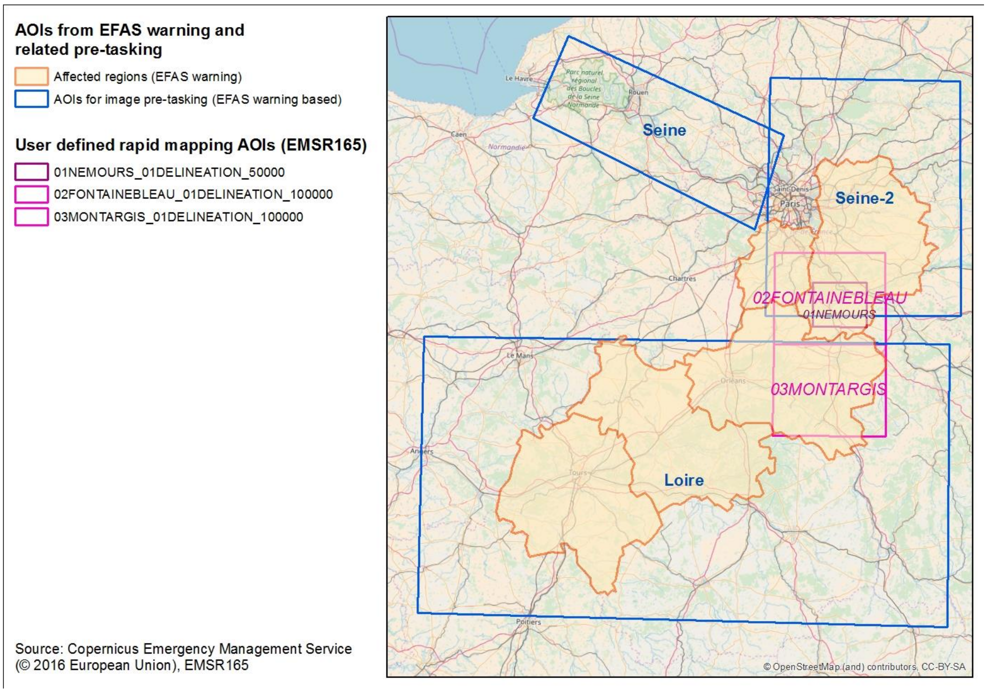

Figure 10: Illustration of the administrative regions (NUTS3) for which the EFAS warning was issued, the initial pre-tasking Areas Of Interest and the AOIs requested by the SEM user for the rapid map production.

The message led to the pre-emptive programming of satellite data and eventually, in this case, to the production of Rapid Mapping value added products. Imagery was ordered via the EWS procedure. In the meantime, on the afternoon of the 01 of June 2016 an activation was triggered. A standard image acquisition procedure request was made within 30 minutes of the activation for an image acquisition in the morning of the following day (earliest possible in the standard set-up).The pre-emptive data acquired thanks to the EWS was received less than 2 hours after the official activation. The cartographic products derived from the pre-emptive procedure were already delivered before the standard imagery order was received. This represents a clear gain of close to 14 hours with products being delivered less than 6 hours after the activation (Fig. 10). This could have been even better depending on satellite configurations and a speedier delivery of Sentinel-1 data which just happened to acquire on the 31/05, perhaps a little early, whose delivery was slow at that time. Also, the fact the EWS alert was sent, the value adding service provider was already focused on the event and hence was ready to deliver the value adding products in under 3 hours after image reception or, more importantly, 5 hours after the user triggered the event (Fig. 11).

Figure 11: Time-line of the Loiret activation (EMSR165) success story (Source: Copernicus Emergency Management Service (© 2016 European Union)).

Conclusion

Since its beginning Satellite-based Emergency Mapping or Rapid Mapping has used tools to help it forecast eventual activations and predict the most likely affected areas. Various weather and storm forecasting services at national, continental and worldwide levels have been employed for prediction purposes. Over the years these Warning or Early Warning Systems have multiplied and have become more accessible covering further event-types such as fires and other meteorological factors such as potential wind damage that can be mapped by SEM value adders.

Some systems show pertinent information related to possible damaging, disrupting events but do not necessarily push out alerts, most do. In this category, potential flood prediction alerts and storm impact systems are the most advanced and integrated into rapid mapping activation workflows. The table below illustrates the present EWS integration into SEM triggering protocols. A 'Yes' in the 'SEM Integration' column means that there is an existing hard-wired protocol that leads from an EWS alert to at least pre-emptive satellite imagery acquisitions. The list is most likely not exhaustive and will hopefully be enhanced as knowledge of other EWS being used in SEM increases and other EWS come on-line.

Table 1: EWS integration into SEM triggering protocols.

EWS type entity	Alerts (Y/N)	Impact severity prediction on populations, assets	SEM Integration (Y/N)
Flood (EFAS)	Y	Y	Y
Fire (EFFIS)	Y	Y	On-going
Tropical Storm Risk	Y		
GDACS	Y	Y	On-going
DisasterAWARE for tsunami, tropical cyclone, wildfires, etc.	Y		
…			

As already discussed, no doubt work is needed concerning the type of information contained within the EWS alerts in order to incorporate emergency service standards from other fields. This would help in sharing these alerts amongst a wider community.

At present, there is perhaps one true hardwired example where an EWS alert can lead to pre-emptive image acquisitions within a SEM system. This is through the Copernicus EMS - EFAS protocol which is aimed at speeding up the availability of imagery to cover an event. The application of this protocol is still at an early stage but its use is increasing and feedback will be vital for fine-tuning. Initial feedback is provided in table 2. In the near future, other systems may be integrated such as Copernicus EMS EFFIS or a system like Tropical Storm Risk, but protocols need to be set-up and criteria need to be found.

A major issue here is also where to image and with what data. Also, fine-tuning is needed depending on the event scenario (geography, place, size, type). The lessons learnt from the EMSR165 activation success story concerning the use of EWS over the Loiret and its impact on rapid mapping is illustrated below.

Also, a culture of risk needs to develop, in parallel with EWS–SEM integration, where it is accepted that images will sometimes be acquired on occasions where an event's impact does not meet predictions or the areas initially thought of as most exposed were not affected.

Finally, this is an important domain that is developing that should improve SEM timeliness, enhancing its pertinence, and further increase SEM acceptance and usage.

Table 2: Lessons learnt from EWS use in rapid mapping

Advantages	Aspects to work on
The use of Early Warning can greatly reduce the time between activation request and the first post-event acquisition	**It is not always possible to obtain forecasts on impact severity and hence focus on areas of interest**
Risk acceptance has developed as it is now accepted that a certain number of pre-emptive images might image non optimal areas or non-pertinent events	**Even if AOI's are large, a focus is needed in the acquisition process on priority area to obtain VHR-HR resolutions for optimal mapping**

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