Contribution of Pleiades HR imagery for disaster damage mapping: initial feedback over Asia, Africa, Europe or the Caribbean

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Abstract. Involved in disaster management support for more than 10 years, SERTIT’s Rapid Mapping Service is specialized in the rapid delivery of crisis information derived from Earth Observation satellite imagery, in particular within the framework of the International Charter “Space and Major Disasters” or European and National emergency programs. This service, available 24/7/365, provides in a rush mode to organizations in charge of crisis management, rescue operations and humanitarian aid up-to-date geo-information showing the extent and the impact of a catastrophic event and its evolution. SERTIT’s Rapid Mapping Service has been activated more than 120 times since its creation and has provided rapid mapping products related to different types of events all over the world, including floods, fires, earthquakes, hurricanes, storms, tsunami or volcanic eruptions... The recent launch of the new Pleiades HR constellation providing very high resolution optical products not only increases the number of Earth Observation satellites and acquisition possibilities but also gives further opportunities for disaster damage mapping. Since these launches, many times, CNES, Astrium GEO-Information Services and SERTIT combined their efforts to support disaster management actors, anticipating satellite acquisitions and analyzing crisis Pleiades HR images. Pleiades HR system confirmed its potential for disaster mapping and crisis management through various cases, such as Sandy cyclone over Haiti, Bopha typhoon over the Philippines, Krymsk urban floods in Russian Federation... The first feedbacks are more than positive, demonstrating that Pleiades HR products are fully adapted to emergency response. Its very high spatial resolution allowing precision mapping, essential in critical areas such as urban landscapes or sensitive infrastructures, daily revisit possibility and fast data delivery are significant assets for Earth Observation applications, especially for risk management.

Keywords. Pleiades, VHR, International Charter, disaster mapping, emergency response.

1. The rapid mapping context

In the case of a major event (flood, earthquake, tsunami, forest fire, storm...), authorities and organizations in charge of disaster management, such as civil protection or humanitarian aid, have immediate information needs for dimensioning and deploying rescue means in the field [1]. Faced with a major emergency, rescue and relief organizations that get quickly reliable information are better equipped to save lives and limit damages.

Rapid mapping can be a response element providing in a rush mode useful geo-information and maps derived from Earth Observation (EO) images acquired before and just after (or during) the catastrophic event such as the ones provided by the International Charter ‘Space and Major Disasters’. Updated cartographic maps of areas that are difficult to access help also to identify zones where aid is still needed [2].

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SERTIT is specialized in disaster damage assessment by remote sensing for more than 15 years and has provided crisis information related to different and numerous types of events all over the world. Among them the tsunami in Banda Aceh (Indonesia), the earthquake in Haiti (figure 1) and the tsunami in Japan respectively in 2004, 2010 and 2011 as well as the 2006 and 2010 Eastern European Floods and the 2012 Niger flood, represented a huge work effort 24/7 in order to provide the first crisis analysis to decision makers and rescue teams on the field. SERTIT’s rapid mapping service certified ISO 9001 is capable of mobilizing expert teams 24 hours a day, 365 days a year, and this to produce and publish within 6 hours after reception of the first satellite data of crisis geo-information for civil protection agencies.

Figure 1. First damage assessment map, derived from VHR satellite data, over Port-au-Prince worldwide disseminated and used 48h after the 2010 earthquake.

The International Charter ‘Space and Major Disasters’ has been operating since 2000 and promotes worldwide cooperation among space agencies, enabling EO data to be made available in rush mode in case of disaster. The range of satellite imagery available is very complete with optical and radar data, from very low resolution to infra-metric pixel size. The recent launch of the Pleiades HR constellation gives new opportunities, the system being particularly adapted to meet the requirements of disaster damage mapping [3].

2. Pleiades constellation benefits

The Pleiades constellation is composed of two very high resolution optical satellites designed for civil and military users. The dual system was designed under a cooperation program ORFEO between France and Italy, Pleiades being the optic component and Cosmo-Skymed the radar one [3].

Pleiades-1A, launched on the 17th of December 2011, and Pleiades-1B, launched on the 1st of December 2012, are two nearly identical satellites offering a spatial resolution nadir of 0.7 m (pan-chromatic channel) and four spectral bands (blue, green, red and near-infrared) with a 2.8 m resolution. This very high resolution in Pleiades imagery brings impressive spatial details, approaching aerial imagery. Infra-metric resolution data offer a more precise detection of landscape features, smaller elements than those visible on lower resolution can be identified. In the context of a disaster mapping, the pixel size is small enough to assess damages at a building scale. The benefit is huge for rapid mapping, in particular in urban areas: the limit of a flooding can be identified with high precision, the resolution permitting water detection even in narrow streets, the level of damage in
case of earthquake distinguishing slightly affected buildings, partially and completely destroyed buildings…

A very high resolution is often to the detriment of the images swath but the coverage of Pleiades HR products is fairly large with a field of view of 20 km and an impressive acquisition capacity, in a single pass, of 100x100 km² mosaic of images (Fig. 2). This good compromise resolution/swath enables a detailed disaster mapping over a large area.

![Figure 2](image1.png)

**Figure 2.** The Great Barrier Reef (100 km wide) was collected on 1st of April 2012 in a single pass of the satellite Pleiades-1A (© Astrium 2012)

Thanks to the huge agility of the satellites maximized in order to meet the urgent needs of the defense or the civil securities, the system is very reactive and able to satisfy many users requests simultaneously (tasking conflicts minimized). A single pass is enough to acquire images over numerous targets on a large area (up to 1000x1000 km²) [4 & 5] as illustrated in Fig 3, covering different areas of interest such as different cities affected by an earthquake. The flexibility of the sensors permits also to acquire image in any direction and so the tasking is optimized to monitor linear elements such as a coastline affected by a tsunami or a flooded river.

![Figure 3](image2.png)

**Figure 3.** Satellite capabilities to image on a 1000x1000 km² area, during a single fly-by, with about 20 targets in one pass (© CNES 2006)

Moreover, Pleiades dual system offer worldwide coverage and a daily accessibility to any point of the globe enabled by the use of both satellites simultaneously, which is a critical need for disaster damage mapping. An area can also be acquired in the same pass by stereoscopic pairs or tri stereoscopic triplets, even with low base over height ratio. The Digital Elevation Model (DEM) generated from Pleiades HR data is very accurate, statistics of the RMS error being in altimetry around 1m for
the mean and around 0.65m for the standard deviation [6]. This kind of promising data can be very helpful in field understanding and hopefully in disaster delimitation and damages mapping. Optimizing satellites tasking, image acquisition and production reactivity prove that the dual Pleiades HR constellation is fully adapted to emergency response, confirming by the first operational exploitation cases presented hereafter.

3. Results of Pleiades HR exploitation in crisis context

Unfortunately, since the launch of Pleiades HR constellation, some disasters have already affected people, infrastructure and environment. Nevertheless the opportunity was giving to exploit in “avant-première” the first Pleiades-1A crisis images in disaster context (floods in Russian Federation, July 2012, earthquake in Iran, August 2012, and floods in Niger, August 2012 and cyclone in Haiti, December 2012 before integration in the International Charter.

Figure 4. Crisis water detection and damaged buildings identification after Haruna cyclone in Madagascar, from 26/02/2013 Pleiades-1A image

Later, the operational use of both satellites within the International Charter contributed then to map efficiently damages of the Bopha typhoon in Philippines, December 2012, the Cyclone Evan in Wallis Island (French Polynesia), December 2012, the Cyclone Haruna in Madagascar (as illustrated in Fig.4) , February 2013 and the recent floods in France in May 2013, taking advantage of both satellites. Only three representative cases are presented in this paper: the Krymsk flood event, the super-storm Sandy in Haiti and the Bopha Typhoon in Philippines.

3.1. Floods in Russian Federation, July 2012

Pleiades-1A was activated only a few months after its launch to acquire images over Krymsk in Russian Federation in July 2012, just after torrential rains killing more than 150 people. Pleiades-1A was not even yet in the International Charter ‘Space and Major Disasters’ but the French spatial agency CNES and Astrium Services jointly decided to exceptionally task the satellite.
SERTIT processed the data, from the orthorectification to the extraction of disaster information, and published a disaster damage map 3h35 after the reception of the Pleiades HR image. The flood water bodies and the mud residual are detected with high precision even within the city (Fig.5), which makes easier the delimitation of urban area potentially affected. Broken bridges and emergency camps, crucial information for rescue organization, are also visible thanks to the Pleiades resolution data and highlighted in the map derived [7].

**Figure 5.** Comparison of mud detection (orange) with SPOT 5 and Pleiades HR in Krymsk area (10km wide)

### 3.2. Super-storm Sandy in Haiti, October 2012

Before reaching USA, the hurricane Sandy hit Haiti with intense downpours and violent winds causing flooding and landslides, mostly along the River Grise that runs through Port-au-Prince. According to civil protection, it left 51 dead and a number missing in its wake. A number of dwellings, infrastructure and fields were destroyed.

Despite poor weather conditions, an image of the capital could be acquired by Pleiades-1A just after the disaster in order to bring help on crisis management to Haiti’s authorities and to the NGOs present on site. The comparison with a recent archived Pleiades HR image acquired last summer enabled to precisely map the riverbank changes, and more particularly to delineate the areas swept away by the river. A comprehensive inventory of the sunken buildings, over 150, was then realized (Fig. 6) and delivered rapidly to users.

Beyond this impact inventory following hurricane Sandy, the mapping of riverbank displacements using Pleiades aims to feed into risk memory concerning this ever-present hazard in Haiti. This feedback will be particularly useful to Haiti’s authorities in charge of the risk management and the land use planning, to refine the delineation of the urban areas liable to flooding.
3.3. **Bopha Typhoon in Philippines, December 2012**

The Bopha Typhoon which devastated Midanao Island, southern Philippines, on Wednesday the 5th of December 2012, may be one of the most violent typhoons to have hit the country. The authorities have announced 700 dead, 900 missing and 450,000 homeless in its aftermath. The damage could reach 75 million euros due to the destruction of 70 to 80% of plantations.

Some Pleiades HR images were acquired in the International Charter framework in order to map damages on urban areas and forest. Processed and analyzed by SERTIT in rush mode, the maps reveal the strength of the wind and the rain that devastated the island (Fig. 7): destroyed buildings, roofless and flooded dwellings, washed-out shanty-town, tree windfall with trunks on ground, landslide…

![Figure 6. Damage inventory using Pleiades-1A data along the Grise River, Port-au-Prince, Haiti](image)

![Figure 7. Comparison before/after Bopha Typhoon with 10/12/2012 Pleiades crisis data](image)
An inventory of damaged and undamaged building was produced few hours after data reception. Others precious information for rescue teams in the field were also detected in Pleiades HR images like road blocked due to trees fall and landslides. The situation was particularly very catastrophic in the Baganga Bay, most buildings being unroofed. The spatial details and the radiometric quality of Pleiades images are very useful for this kind of building-scale analysis.

4. Conclusions

The Pleiades sensors did not waste time to be operational contributing efficiently to damage mapping during or just after various and numerous disasters. The very high spatial resolution combined with its acquisition capacity allows detailed mapping over large areas. The first feedback are more than positive: Pleiades HR data are already delivering precious information to authorities and organizations of disaster management through various cases, such as Sandy Cyclone in Haiti, Bo-pha typhoon over the Philippines, Krymsk urban floods in Russian federation, etc. In all cases, Pleiades dual system proved its ability in emergency response delivering quickly detailed images adapted to disaster damage mapping with high precision. The building-scale analysis permitted by the infra-metric pixel size is a step forward in rapid mapping, giving simultaneously the means to dimension the overall damages and also a detailed review of affected building, communication infrastructure or individual tree in order to guide relief teams in the field.

Disaster damage mapping is greatly improved and more efficient by the contribution of Pleiades dual constellation, offering a performing acquisition system in term of revisit and coverage as well as very high resolution imagery fully adapted to emergency response.

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References

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