USING EARTH OBSERVATION TO SUPPORT FIRST AID RESPONSE IN CRISIS SITUATIONS– LESSONS LEARNED FROM THE EARTHQUAKE IN TÜRKIYE/SYRIA (2023)

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ABSTRACT:

In the early morning hours on Tuesday, February 6, 2023, the southern part of Türkiye was struck by two large and several smaller earthquakes, causing destruction and casualties over a remarkably large area. In such cases, quick response and well-informed coordination is a key factor to successful first aid responses since damage and the number of people buried or in need often remain unclear in the hours after the disaster. The German Aerospace Center (DLR) responded to the earthquake by rapidly providing a number of information products, all above very high-resolution imagery in an easy-to-use web-based application. Next to satellite and drone imagery, damage information and pre-disaster imagery were provided to the users. Drone imagery was acquired in person for Kirikhan, a city in the south of the disaster area. Access to the viewer was granted to authorized users from public authorities, humanitarian aid organisations, and research institutes. Furthermore, DLR generated information products in the fields of settlement pattern, AI based damage assessment and tectonic movements. These data, as scientifically significant as they are, were not part of the web viewer. Within this paper, the reasons will be assessed as well as the general workflow of the activation. The paper will also discuss what steps need to be taken to ensure research outcomes being integrated into information products for users in future and how to prepare for the next disaster to still ensure a quick response but with an enriched product suite.

1. INTRODUCTION

With its location on the Anatolian block and being influenced by the movement of the Arabian, Eurasian, Indian, and African tectonic plates, Türkiye is considered one of the seismically most active regions in the world (Schmitt et al., 2023; Tan et al., 2008). Although Türkiye experiences on average almost 16,000 earthquakes per year (with ~1 of a magnitude 5-6), disaster preparedness is still insufficient, resulting in potentially high damages and fatalities (Uzun and Oglakci, 2019; Turkish Earthquake Data Center System).

The earthquake, that struck Türkiye on February 6, 2023 with a magnitude of 7.8 is considered the strongest within 80 years and was followed 9 hours later by an earthquake with the magnitude of 7.5 (Dal Zilio and Ampuero, 2023; Schmitt et al., 2023). Both epicentres were located in southern-central Türkiye, close to the border to Syria. More than 50,000 people lost their live due to the disaster and more than 2.4 million people were displaced (Reliefweb, 2023b). International relief was early requested and provided. However, due to the large area and consequently the high number of people affected, no situation overview was available right after the earthquakes. This impeded efficient rescue as well as relief activities as coordination of the different humanitarian, state and search and rescue (SaR) organisations proved difficult. On the same day as the disaster hit Türkiye, the German Aerospace Center (DLR) started its activities in providing satellite data and additional information to authorized users. The executing DLR entity in this context was the Center for Satellite-Based Crisis Information (ZKI) of the German Remote Sensing Data Center, which has, next to a long-term experience in crisis mapping, also a large user network of humanitarian organisations, official authorities and research institutions. Due to a close link to European Space Imaging and their quick provision of very high resolution (VHR) satellite data, ZKI started publishing the first satellite imagery on February 7, 2023, right after the first acquisitions were possible. Within the following eight days, DLR provided almost 2500 km² of satellite data covering 18 cities. The VHR satellite data was combined with auxiliary data, like the epicentre of the earthquakes, their radius, damage grading product from Copernicus Emergency Mapping Service (EMS), Open Street Map (OSM) data and pre-disaster imagery for comparison reasons. In addition to the satellite data, two researchers from the DLR Institute of Optical Sensor Systems arrived in the area on February 7, 2023, together with a team from International Search and Rescue (I.S.A.R.) to acquire drone imagery.

Satellite data and auxiliary geodata were mainly provided via a web service, that allowed the viewing of the data as well as simple features, like measuring or swipe. Only few static maps were generated since all the information could be accessed in the viewer. Moreover, the publication of the data was restricted due to the high resolution of the satellite data and the sensitive region between Türkiye and Syria. Access to the viewer was available on the day after the disaster and distributed to a wide user network with every organization with legitimate interest being granted access. Daily updates to integrate the latest VHR imagery as well as damage grading products and to improve the web service, were carried out until February 15, 2023. From this point onwards, the Turkish government had published an aerial imagery atlas and information on damages could be sufficiently found at open source emergency mapping providers. Access to

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the web viewer with all acquired satellite imagery remains possible until today.

2. AD-HOC CRISIS RESPONSE

2.1 Study area

The area is located in southern-central Türkiye between the Mediterranean Sea in the west and the Syrian border in the south. The epicentre of the first earthquake was roughly located in the Gaziantep region, close to the Syrian border in southern Türkiye. The second earthquake struck further north, close to Kahranmanmaras (USGS, 2023). More than 6,212 aftershocks were recorded after the initial quake on February 6, 2023 (Gunasekera et al., 2023).

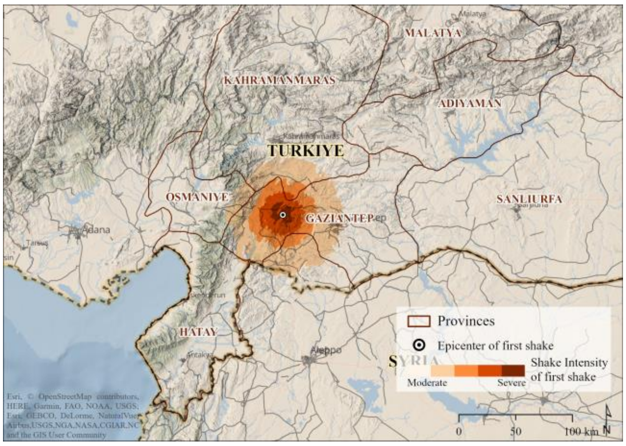

Figure 1: Study area in southern Türkiye with the epicenter and shake intensity of the first earthquake being displayed as well as the province borders. Epicenter and Shake intensity: ©USGS

The most affected provinces were Hatay, Kahramanmaraş, Gaziantep, Malatya, and next to almost 51,000 fatalities, more than 100,000 people were injured and more than 2.4 million people displaced (Reliefweb, 2023b). Characteristic to this area is also its political sensitivity as it is a hotspot of border crossing from Syria to Türkiye due to the Syrian Civil War (Tumen, 2023).

2.2 ZKI activation procedure

The Center for Satellite Based Crisis Information (ZKI) is an entity within DLR's German Remote Sensing Data Center and offers rapid mapping products in the case of natural or man-made disasters, throughout the whole disaster cycle, mainly derived from satellite and/or geodata.

ZKI is ISO certified with its standardized procedures (Lechner and Gähler, 2017) and forms a link between research at DLR and the user (Figure 2). Established in 2004, the main goal of ZKI is to generate and provide up-to-date situational awareness information before, during or after a disaster situation or in case of major events. This includes in particular the transfer of scientific results into information products and applications. ZKI is also involved in several research projects and innovation developments, always aiming at using the outcomes of the research to being better prepared for the next disaster support (Lechner and Gähler 2017). Main users of ZKI are in the national and international fields of political decision making, relief organisations, situation centers, and research institutions. Examples of ZKI's activities, research projects and disaster support can be found under www.zki.dlr.de (German Aerospace Center, 2023a).

2.3 Satellite data acquisition

The provision of very detailed information, preferably on house level was the first priority during the activation. In case of an earthquake, earlier studies found the use of VHR data the most valuable, since detailed damages on buildings and infrastructure can be derived (Gähler, 2016; Joyce et al., 2009). For this reason, we acquired VHR satellite data with a spatial resolution of 50 cm or higher from European Space Imaging (EUSI) that allowed for visual damage detection as well as the testing of the artificial intelligence approach. With their partnership to Maxar and one of their ground stations localized at DLR, EUSI provides access to VHR satellite data, like the WorldView Series in near-real time (European Space Imaging, 2023; Reliefweb, 2023a).

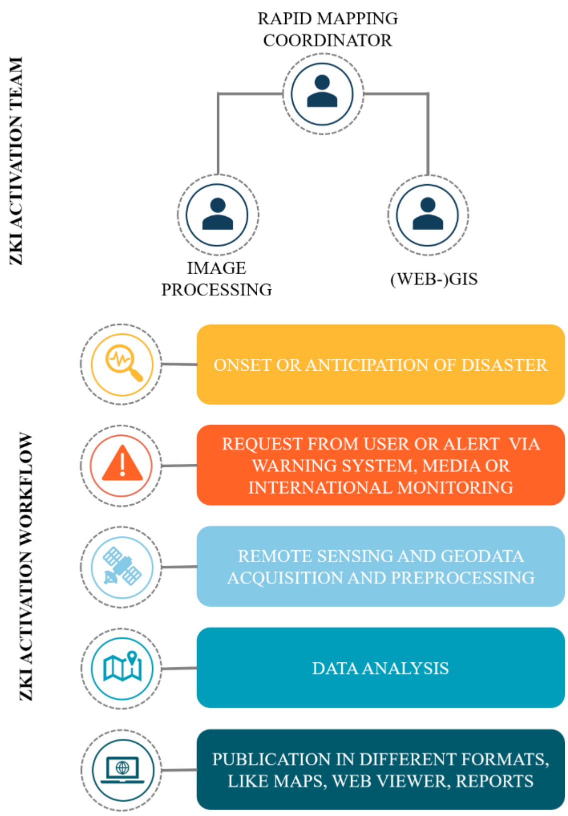

Figure 2: ZKI crisis response procedure, including the different roles on duty (above) and the workflow of a standard activation.

During this activation and in general, the time from data acquisition to delivery is often less than 12 hours due to the close proximity between EUSI and DLR. The data was provided via FTP, which allowed for large amounts of data being transferred in short time. As soon as the imagery was available on DLR's infrastructure, it was published, usually on the same day within a few hours. While on the first day of the disaster, tasking of the satellite was ordered by DLR and Copernicus EMS, the coming days after the disaster, tasking was left to other organisations or companies in the context of first aid, with DLR still receiving the acquired data. Reason is that priority was given to those actually needing the imagery for their first aid response or for coordination of relief action. However, all acquired imagery over the study area was integrated into the viewer on the same day or the day after.

2.4 UAV Data acquisition and transfer

Since 2016, the DLR Institute of Optical Sensor Systems and the non-profit aid organization I.S.A.R. Germany have been cooperating in the field of drone-based situational awareness. The goal of this partnership is to develop and evaluate the application of a novel real-time mapping system for crisis management. To achieve this, DLR employees were trained by the aid organization in basic activities of search and rescue of people in disaster situations and participated in regular exercises.On the morning of February 6, 2023, I.S.A.R Germany was activated via UN-INSARAG (https://www.insarag.org) to provide SaR support in the earthquake affected region of southern Turkey. Given the established cooperation, the DLR drone team was also requested to provide on-site support with up-to-date situation information. As a result, two DLR employees including the entire drone equipment set off for the disaster region together with the other response units on the same day. Overall, a team of 42 members of I.S.A.R Germany was sent to the city of Kirikhan in the Hatay region to be the first international SaR team to provide emergency support. They were to be followed by a Jordanian and the German Rapid Response Unit Salvage Abroad (SEEBA) team of the German Federal Agency for Technical Relief (THW).

During the operation, a total of four drone flights were conducted over Kirikhan. The resulting situational picture covered the most severely affected areas over a total area of 8.5 km² with a ground resolution GSD of about 2 cm. The high resolution enabled a detailed assessment of the extent of destruction and efficient planning of forces and resources (Figure 3). The flight system used is an electrically powered, vertical take-off fixed-wing drone (eVTOL) from the German manufacturer Quantum-Systems ("Vector"). It can continuously stay in the air for about 2 hours and has a broadband data link for payload data transmission. The payload is the high-performance camera system "MACS-nano" developed by the DLR-OS (www.macs.dlr.de).

Figure 3: Screenshot of the MACS camera imagery showing the level of detail with 2 cm GSD (above). Comparable setting of building damage and vehicles on World View-2 imagery with 50 cm GSD (below). In both cases, a red box is drawn around a car to highlight the difference in resolution.

This camera system is specifically tailored to take on mapping tasks with fast-flying drones and is capable of capturing high-resolution images, pre-processing them directly on board (Hein and Berger, 2018), and transmitting intermediate products to the ground via the broadband radio link.

In the ground segment, the image stream is continuously processed into an interactive real-time aerial map that is used for an initial on-site situation assessment. In addition, the camera system data stream can be transmitted to a web server, which makes the generated fast ortho-mosaic map available to a variety of users and systems via a web map service (WMS). In particular, the integration of the real-time aerial maps into various operational command and control systems via the WMS service has already proven successful in the past. This allowed the immediate integration of the latest situation picture into the official INSARAG Coordination Management System (ICMS) of the UN and thus made it available to all accredited partners in the disaster relief environment as well. For the visualization and use of the data, both self-developed software and the open source system QGIS were used.

2.5 Other DLR products

Besides the immediate provision of VHR and drone imagery as well as damage grading products, further research at DLR was assessed for its suitability to support relief activities in the earthquake situation. For this purpose, the results from research on AI based damage detection, population information and geological changes were evaluated regarding their suitability to enrich the web viewer as an additional information layer.

AI-based image analysis
Recent developments in computer vision and the rapid evolution of graphics processors have led to faster algorithms that open up new possibilities for disaster relief and humanitarian aid. Earlier studies showed that by combining remote sensing data with deep learning techniques, it becomes feasible to automate image analysis for large-scale impact assessments, specifically for the extraction of relevant features such as roads, buildings and building damage (Yuan et al., 2021). The extracted information can support rescue teams to understand the full extent of a disaster more quickly and to plan rescue missions to be more efficient.

Figure 4: GeoEye-1 data of Islahiye with automated road detection (blue) and automated building damage assessment (green: no damage, orange: damaged, red: destroyed). Satellite Imagery © Maxar Technologies Provided by European Space Imaging

In order to extract the road network from an image, a Dense-U-Net-121 (Henry et al., 2021) trained on the large-scale DeepGlobe18 road dataset is used (Demir et al., 2018). This dataset contains over 6000 images from Southeast Asia with manually annotated roads at pixel level. If a pre- and post-disaster image is available, both road detections can be compared and an up-to-date map showing the intact parts of the road network can be generated. Buildings and building damage were assessed following a two-step approach, first identifying existing buildings from pre-disaster imagery and then classifying damage based on the predicted building masks and the corresponding pre-disaster and post-disaster satellite image pairs. The applied model is based on the solution proposed by the winning team (Durnov, 2019) of the xView2 challenge (Defense Innovation Unit, 2019). For the training of the network, the xBD dataset was used (Gupta et al., 2019). In contrast to the original dataset, the two classes "minor damage" and "major damage" were merged into a class "damage" ending up with the three categories "no damage", "damage", "destroyed". Some example results for the road detection and building damage assessment in Türkiye are shown in Figure 4. The results were locally quite precise, however, on a large scale the different viewing angles, weather and light conditions did not allow for a continuous derivation of damages. The results were thus not integrated in the viewer, because only fragments of information were available.

World Settlement Footprint (WSF)
Urbanization and more specifically the distribution of population is a crucial information layer during disasters. It enables international relief organizations to know hot spots of people affected and whether residential or e.g. industrial areas are affected. DLR offers a global layer, in which settlement pattern, their temporal and spatial development, building height and the population density is derived (Marconcini et al., 2021; Scientific Data Curation Team, 2020).While settlement pattern and development are available in 30 m resolution and annually since 1985, the 3D height product offers information at 90 m resolution (due to the additionally needed radar information) (Esch et al., 2022). Population density is not yet published but available for internal purposes on demand. For this purpose, national population statistics are intersected with the distribution and height of residential buildings at 30 m resolution. This information was also available for the Türkiye earthquake. However, since the key information of the web viewer consisted of VHR satellite imagery in 50 and 2 cm resolutions, respectively, the comparably low resolution of the WSF led to the decision not to add it to the viewer. The reason was to avoid confusion due to the scale discrepancy for users that are not well experienced in the use of satellite data.

Tectonic movement
The severity of earthquakes can also be visualized by observing the Earth's surface movement. Researchers of DLR used Synthetic Aperture Radar data from Sentinel-1 to derive the movement of the tectonic plates in the disaster area. By comparing pre- and post-disaster imagery (January 29 and February 10, 2023), they revealed the fractures in the surface for a length of 250 km along the converging area of the Anatolian and Arabian plate with the land surface being displaced by up to 6 metres (German Aerospace Center, 2023b; Brcic et al., 2017). The information was visualized and published by DLR but not integrated into the web viewer. Although it is scientifically of high value, the user does not gain any additional value for first aid responses. The scale of the product is very large which might rather confuse potential users when overlaid with VHR data.

2.6 Web application

In order to make the data and analyses available to a defined group of users as quickly as possible, the web application at ZKI was created using Esri technology. Esri Web Viewer supports customization and extensibility allowing the appearance and functionality to be tailored to meet specific requirements. Web Viewers prove to be highly advantageous in distributing data and information, whereby the data can be explored interactively in a web-based environment (Esri, 2023). The viewer's accessibility allows emergency management teams or government agencies to access the collected earthquake data, such as damaged buildings

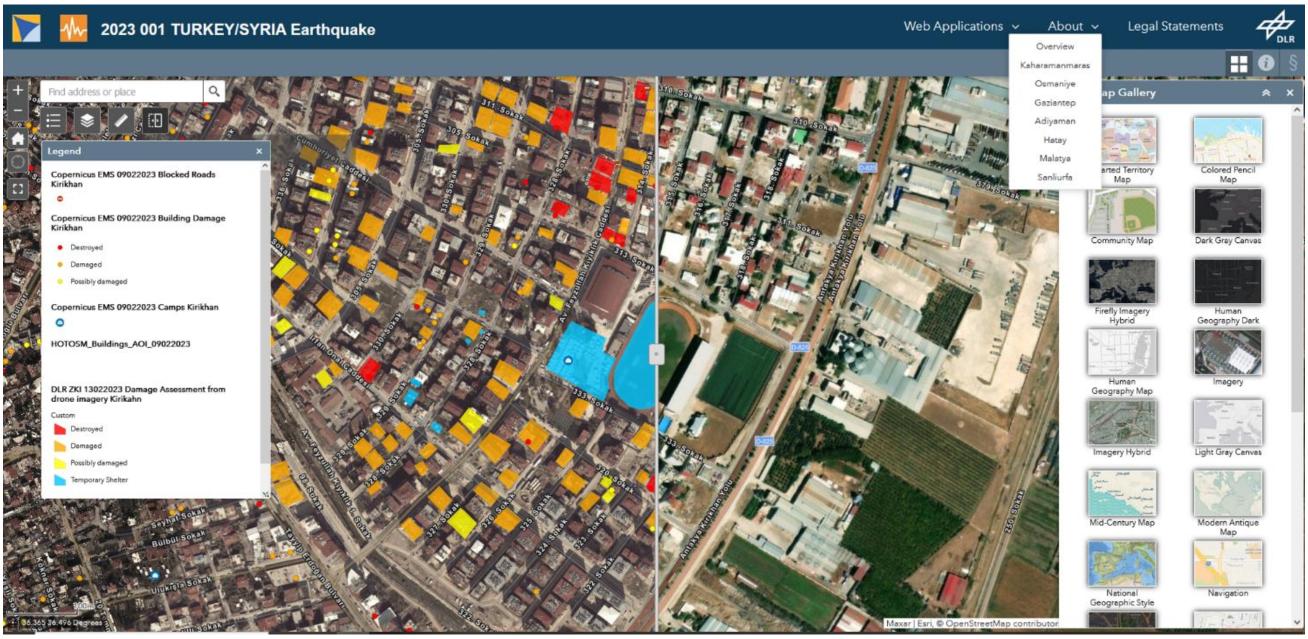

Figure 5: Screenshot of the web viewer as it was available to authorized users. The viewer included simple operations, like swiping between a pre- and post-disaster satellite image, the visualization of the CEMS damage grading product or of different base maps. Satellite Imagery © Maxar Technologies Provided by European Space Imaging

or post disaster satellite imagery and related information from any device without the need for specialized software installations. Web applications can be retrieved on mobile devices, providing flexibility and mobility for Public Protection Disaster Relief (PPDR) forces in the field. Responders can access maps, and important spatial information on the move, allowing for quick decision making and adaptation to changing circumstances. Its user-friendly interface enables easy exploration of the datasets, affected areas, and infrastructure vulnerabilities. The dissemination of integrated critical information to various stakeholders thereby can help to coordinate emergency response and support regions specifically affected.

The main focus of the DLR web application created in the context of the earthquake is the fusion of various existing information streams from different providers in order to establish a central platform for the visualization and coordination of the relief efforts and to provide an easy access to any kind of geoinformation. In the DLR web viewer, different data was integrated. Damaged buildings, blocked roads and camps were received from Copernicus EMS (European Union, 2023), additional buildings from Humanitarian Open Street Map Team (HOTOSM) (UN OCHA, 2023) (Figure 5).

Satellite data from EUSI at various points in time after the earthquake, as well as the UAV based orthophotos and DLR-ZKI damage assessments were additionally integrated. These data sets can be turned on and off as needed. Likewise, different background maps, such as satellite, OSM or human geographic information can be activated, in order to overlay further required information. The web-based display allows interactive exploration of the affected areas through the integration of various analysis tools: Bookmarks allow zooming in on different areas of interest and exploring data specifically tailored to them. Layer Swipe enables before and after comparisons of the region dynamically, making changes more visible. Likewise, distances and areas can be determined using the measuring instruments and thus allowing for better determination of the dimensions of destroyed areas. Access to the viewer was shared with all organisations that had a legitimate interest in the data, i.e. that were using it for humanitarian purposes. The reason for a password protection is on one hand the location of the earthquake, which was close to the active conflict area between Türkiye and Syria and on the other hand that especially the drone data reveals such a high level of detail that mis-use of the information cannot be excluded. Access was in most cases granted and only refused if no direct link to a humanitarian, coordination or research task existed. Within the organisations, access credentials were allowed to be freely shared.

2.7 Map generation

Overall, four static maps were generated and published. For each of the maps, an expert based damage assessment was conducted based on the pre- and post-disaster VHR image. The selection of areas for mapping was based on the degree and location of damages, i.e. affected residential areas were preferably mapped. The gradation of damages roughly follows the Copernicus EMS damage classes, indicating in red destroyed buildings (with the structure being totally damaged), damaged buildings in orange (structure of the building still visible, but with visible changes or debris), yellow for potentially damages (no changes visible from above, but debris) and blue for relief actions.

Maps were created for the cities of Kahranmanmaras, Antiochia, Düzce and Kirikhan, with the map for Kirikhan being based on the drone data. Although the resolution of the satellite imagery reveals a good level of detail, the different acquisition angles made a clear identification of damages difficult in some of the areas. This is why the transition between the gradation of "damaged" and "potentially damaged" is not always clear. Still, the maps provide information about certain degrees of damage for the observed areas and also indicate, where damage is potentially most substantial. Furthermore, a key demand of users is getting to know existing relief actions to which they can potentially direct affected population or those in need. Relief actions are usually visible in VHR imagery in the form of tents or mobile shelters and they are mostly set up in former free spaces, like stadiums or village squares.

Figure 6: Map example for the city of Kirikhan including the expert-based damage classification (yellow: potentially damaged, orange: damaged, red: destroyed, blue: relief action).

3. DISCUSSION AND LESSONS LEARNED

In the event of a crisis, in addition to the timing, the adaptation of information products to user needs is of critical importance. To continuously ensure that the products prove beneficial for the users, their feedback should be collected after each activation to improve and further develop the crisis products (Lechner and Gähler, 2017). However, the demands of the users might differ so significantly, that they cannot all be covered by one application. In these cases, different products might be derived, or, given the short time frame, a reasonable compromise must be found.

Many actors are involved in crisis response, making it often overwhelming for users to keep an overview of all available data and to merge it into useful information. This high fragmentation of information is well known within the community and has already been stated in other large-scale events (Voigt et al., 2011). However, with organisations, like Copernicus EMS, providing their data as free to use WMS services, the individual crisis information does not remain isolated anymore but can quickly be integrated to automatically updated results. Yet, this does not solve the problem of an overwhelming amount of information available to users, which makes it even more important to keep the disaster data as understandable and easy-to-use as possible.

3.1 Satellite Data acquisition

VHR satellite data was quickly and reliably available starting from day one after the disaster. Transfer of the data worked mostly fine via FTP with communication mainly carried out via e-mail. Due to the long-term partnership between DLR and EUSI, this process has proven functional throughout the years. However, to save time and resources in further processing and evaluation, standardised data ordering, e.g. via an API, would be convenient. This also applies to the delivery of the data, which could be automatized via an automatic interface. In the case of new image acquisitions for automated evaluations in the event of a disaster, there is often no possibility to wait for ideal acquisition parameters and an attempt is made to provide information as quickly as possible, even if this is associated with qualitative limitations. This makes fast and automated crisis mapping a notable challenge.

3.2 UAV Data acquisition and transfer

Capturing drone imagery in the crisis area allowed for a completely new level of detail in damage assessment. While this data is especially valuable in SaR activities and for information products, like the web viewer, it requires specially trained personnel on site. This can be achieved either by providing special training to emergency personnel or, as in this case, by deploying DLR personnel to the affected area. The transfer of data proved difficult in the Türkiye case. No mobile internet connection was available due to the heavily destroyed infrastructure. The satellite communication system was also not approved at the beginning and was only activated in the course of the third day of the mission. Nevertheless, the data could be distributed directly after landing to the operational staff of I.S.A.R Germany and THW on site and used for mission preparation.

3.3 Other DLR products

In general, the enrichment of satellite data with additional information, like damage gradation, infrastructure or population information is crucial for non-expert users (Gähler, 2016). The aim for future activations is therefore to keep certain datasets ready or knowing where to acquire them from in case of a disaster. This includes building footprints, amenities, like hospitals, or population numbers on different administrative units. This information can be used as standalone in the viewer but also be intersected with products like the WSF or the road network to retrieve additional information layers.

AI-based image analysis
The success of a fast and automated satellite image evaluation depends on various acquisition parameters and general conditions. For example, in order to capture streets and buildings completely and accurately, the sensor's viewing angle plays a major role. Images would be ideally acquired from the nadir perspective, but the further the angle deviates, the greater the tilt and shadowing that impair the evaluation, especially in urban areas with high-rise buildings. Shadow effects at low sun elevations can further affect the evaluation. In addition to the general sensor properties, the viewing angle also affects the geometric resolution of the data. The higher the resolution of the data, the more detailed the infrastructures and buildings can be mapped and the more reliable the analysis results become. One factor that unfortunately cannot be influenced during new surveys in the context of crisis mapping is the weather. On the one hand, fog and clouds influence the data and make an evaluation difficult or even impossible. On the other hand, the earthquake in Türkiye took place in winter, which led to fresh snowfall. This is not only an added catastrophe for the affected people in the earthquake areas but also a major challenge for the AI algorithms, which have so far mostly been trained on snow-free data. In order to recognise possible changes and reliably classify damage as such, comparable images of a reference time before the disaster are absolutely necessary and must be coregistered in a professional way. The more similar the data are with regard to the recording parameters, the more reliably changes can be recognised and assigned. As can be seen in Figure 7, the evaluations were complicated by various factors, such as fresh snow and varying acquisition angles with corresponding shadowing effects.

Figure 7: WorldView-2 pre- (left) and post-disaster (right) images of Elbistan (top) and Duezici (bottom). Background imagery: Satellite Imagery © Maxar Technologies Provided by European Space Imaging

Additionally, structural measures between the pre- and post-disaster images affect the comparison and the detection of real damages caused by the disaster. Based on these data, automated evaluations are only possible to a very limited extent.

World Settlement Footprint
The use of the WSF was hampered due to the difference in spatial resolutions. This is a general challenge since global products, like the WSF will most likely not be available in VHR resolution in the near future. However, additional information layers could have helped to link the rather coarse scale WSF with the VHR information. One example is the intersection of WSF information with vector building outlines. If a reliable layer of building footprints would have been available (e.g. by OSM), intersection between the WSF population density and building footprints would have led to population estimation on house level and thus to a good impression for first aid responders about where people are located. Yet, the OSM community is very active, and especially in cases of disasters, with support from HOTOSM (www.hotosm.org), chances of complete datasets rather increase in the future.

3.4 Web application

The setup of the web application was accomplished within one day but required expert knowledge and IT configurations. The process could be smoothed by automatizing the workflow for publishing geodata in the viewer. This includes the definition of standard coordinate systems, the definition of standard data transfer procedures or having a database of geodata that is usually integrated in case of a disaster. Having geodata ready to use is not a straightforward procedure. While in some areas of the world, OSM data for example provides a quite complete set of geoinformation (e.g. roads, buildings and amenities), this might not be necessarily true for other parts of the world e.g. African countries. In such cases, national or partner databases need to be acquired. The quality of such information is often country specific and for certain areas in the world, information, like the location of hospitals is not completely available.

Since different users might have different requirements to a web viewer, this could also be considered in the future. While some users are experienced in operating with geodata, others prefer a very simple, viewing-only solution. This difference could be met by providing a more interactive version of the application, that also allows for the uploading of own data or simple analyses tools and another slim version, that ensures that only significant information is displayed and that guarantees an intuitive handling of the viewer.

4. CONCLUSION

The translation of research outcomes into actually useful tools for first aid responders, humanitarian organizations and governmental authorities is a continuous challenge. In general, the connection of ongoing research and its integration in a crisis context needs to be well orchestrated and conferred with the users. Given the amount of information that is available to actors in a disaster, an easy-to-use and easily accessible solution is crucial and not all available research results should be added only for the sake of completeness. However, the assessment and translation of existing research into user-friendly products should be evaluated after every disaster in preparation for the next activation. We could show that especially the very timely and detailed information proves valuable in such a large-scale event. We also show what other results were available and why they were not added to the final product. However, the goal is always to overcome the challenges that impeded the current research being added to the crisis products and to being able to provide an improved information layer for the next disaster.

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