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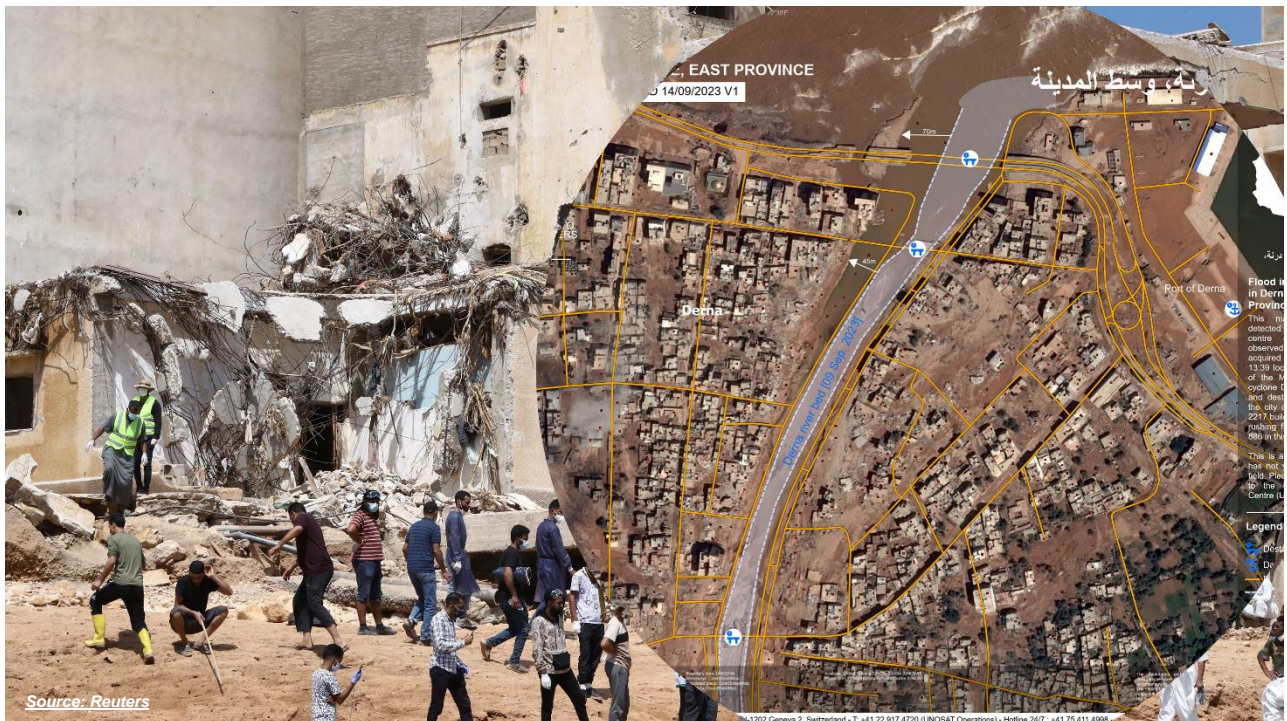


UNOSAT
United Nations
Satellite Centre

10 September 2023 Mediterranean Sea Storm Daniel in Libya, Preliminary Satellite-Based Comprehensive Damage Assessment Report

East Province
Libya

11 October 2023



Prepared by
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I. Overview

On the night of the 10th of September 2023, after its journey through the Mediterranean Sea, the storm Daniel brought heavy rains that triggered floods in Benghazi, Almarj, Al Jabal Al Akhdar and Derna Governorates, in northeastern Libya. The increase of water levels in the region caused the collapse of two dams located upstream Derna River and the consequences was tremendous. The dam breach released a massive amount of water and a huge flood wave wiped out entire neighbourhoods in the city of Derna. Hundreds of people were reported missing by the Libyan Red Crescent Society.

According to the Libyan National Meteorological Centre, the storm reached its peak with winds going up to 70-80 km/h. This led to the falling of electricity towers and tress causing communications interruption. Between 150 – 240 mm were reported and caused flash floods in several cities. Al-Bayda have recorded the highest daily rainfall rate: 414.1 mm in the night of the 10 to 11 September 2023.



Figure 1: Pre- and post-image from Derna City. To the left, ESRI Basemap from before the event, to the right a Pleiades image from 13 September 2023.

II. Comprehensive Satellite-Detected Building Damage Assessment

The United Nations Satellite Centre (UNOSAT) emergency mapping service was triggered on behalf of the United Nations Office for the Coordination of Humanitarian Affairs (UNOCHA) / Joint Environment Unit for the areas affected by the Storm Daniel. Following this request, UNOSAT has activated the International Charter Space and Major Disasters. UNOSAT was nominated as Project Manager (PM) for this Charter Call 966 – Floods in Libya. Argans provided a PM Deputy and several other satellite mapping groups were nominated as Value-Adders (VA): Copernicus EMS, Mohammed Bin Rashid Space Centre, British Geological Survey, K-water Research Institute, EMERCOM of Russia. To communicate and coordinate between multiple actors involved in the activation, an event was set up on the platform GDACS – Satellite Mapping and Coordination System (SMCS). This was published and shared with the Value-Adders and the end-users and allows the end-users to have an overview and an update of the status of each area of interest additionally to a link to the satellite derived products made available.

UNOSAT released a live web map on the 12 September 2023 showing all the areas of interest that would be analysed by all the Value-Adders from this Charter Call. UNOSAT implemented various baseline data including administrative boundary, populated place, and the location of 6 dams in the 4 affected governorates: Derna, Al Jabal Al Akhdar, Almarj and Benghazi. UNOSAT continuously updated the live web map with the ongoing analysis carried out by UNOSAT and Copernicus EMS, allowing their availability and the visibility for the end-users.

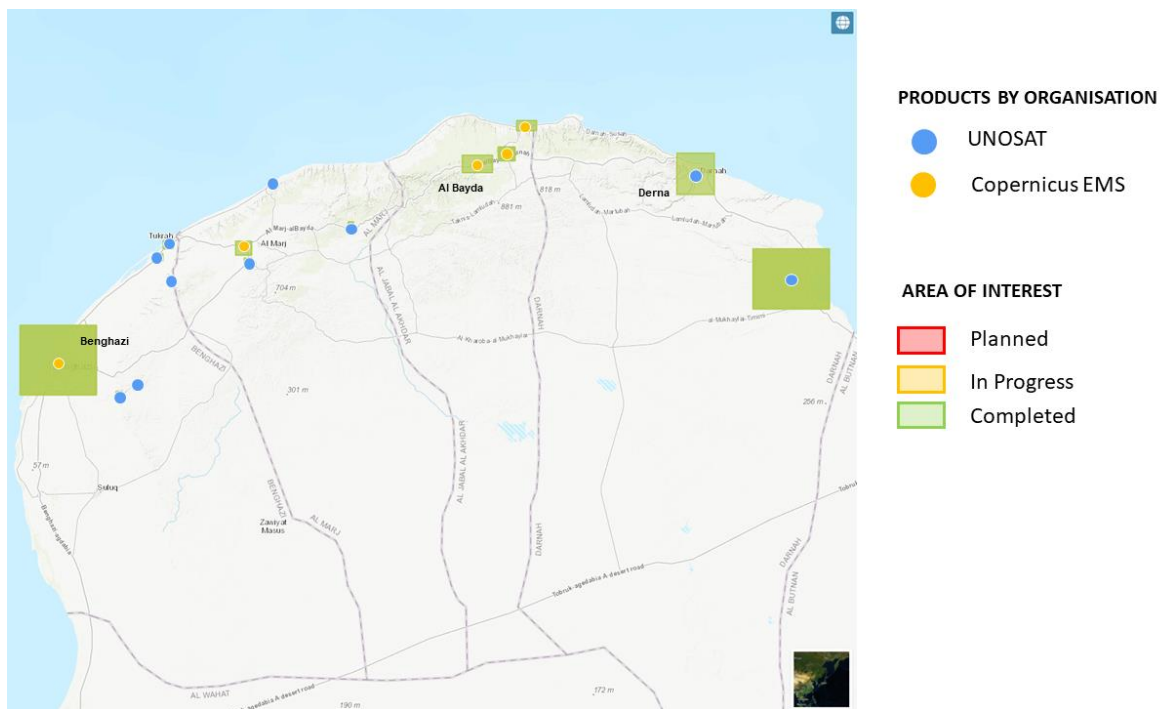


Figure 2 - Snapshot of the GDACS-SMCS for the activation related to the Floods in Libya. Gives an overview of the extent and the analysis status of each area of interest

II.1 Satellite-derived analysis

The International Charter Space and Major Disasters provided a vast amount of pre- and post-event satellite imagery used to perform an overview of the distribution of damaged infrastructures and the

extent of floods after the heavy rain of the 10 September 2023. Additionally, to the live web map, UNOSAT released 2 maps showing the flood extent and the affected infrastructure in the city of Derna, 1 similar map over Al Tamimi town, 3 satellite-derived reservoir assessment over 6 dams in the northeastern part of Libya and 3 power supply assessment using Night-time Light Imagery in collaboration with Wuhan University.



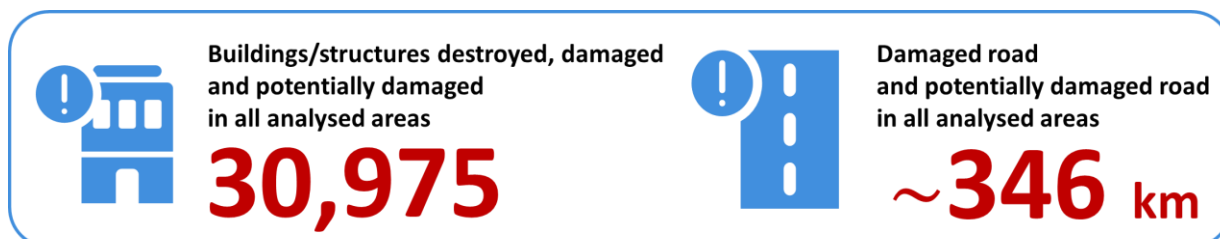
Figure 3 - This map depicts the analysis extents in Derna, Al Jabal al Akhdar, Almarj and Benghazi Governorates, East Province, Libya examined by UNOSAT and Copernicus EMS to determine infrastructure damage caused by the storm Daniel that hit Libya on the night of the 20th of September 2023.

Area of interest	Pre event satellite data	Post event satellite data
Area 1, Derna	1. GeoEye 1, 07 Mar. 2022	1. Pléiades, 13 Sep. 2023
Area 2, Al Jabal Al Akhdar	2. WorldView 2, 22 Jan. 2023	2. WorldView 2, 13 Sep. 2023
	3. ESRI Basemap	3. Pléiades, 13 Sep. 2023
	4. ESRI Basemap	4. GeoEye 1, 13 Sep. 2023
Area 3, Almarj	5. ESRI Basemap	5. Pléiades, 13 Sep. 2023
Area 4, Benghazi	6. ESRI Basemap	6. Planet, 17 Sep. 2023
	7. ESRI Basemap	7. Pléiades, 13 Sep. 2023

Table 1 – Overview of satellite imagery used for the damage assessment covering all analysed areas and their respective acquisition dates.

II.2 Analysis summary

This comprehensive satellite-derived building damage analysis identifies a total of 30,975 buildings/structures with visible damages constraints within Derna, Al Jabal Al Akhdar, Almarj and Benghazi Governorates. Benghazi and Al Jabal Al Akhdar recorded the highest number of affected structures with respectively 13,951 and 12,818.



Governorate / Area of interest	Analysed area (km ²)	Building damage assessment			Road damage assessment		
		Damaged/Destroyed Buildings	Potentially Damaged Buildings	Total of Damaged/Destroyed and Pot. Damaged Buildings	Damage/Destroyed road (m)	Potentially Damaged road (m)	Total of Damaged/Potentially damaged road (m)
Derna		4,088	19	4,107	23,352	51,455	74,807
Derna	57	3,976	3	3,979	23,352	51,455	74,807
Al Tamimi	147	112	16	128	-	-	-
Al Jabal Al Akhdar		3,880	8,938	12,818	59,557	124,524	184,081
Al Bayda	81	259	8,919	9,178	42,437	40,819	83,256
Shahat	27	19	19	38	43	337	379
Susah	23	3,602	-	3,602	17,078	83,368	100,446
Almarj		33	66	99	3,716	2,285	6,002
Al Marj	44	33	66	99	3,716	2,285	6,002
Benghazi		3,045	10,906	13,951	1,858	79,273	81,131
Benghazi	213	3,045	10,902	13,947	1,858	79,273	81,131
Al Mabni	99	-	4	4	-	-	-

Table 2 – Overview of building/structure damage assessment in East Province. The table gives an overview of the analysed area of each affected populated place; the destroyed and damaged/potentially damaged buildings and the damaged road in 4 governorates: Derna, Al Jabal Al Akhdar, Almarj and Benghazi.

II.3 Building/Structure damage assessment in Derna Governorate

As shown in Figure 3, the overall analysis extent for Derna Governorate is made of 2 distinctive areas of interest covering Derna and Al Tamimi settlements. Table 2 shows that amongst the 30,975 structures that were identified as potentially damaged, damaged, or destroyed in the 4 governorates, 4,107 of them were located within Derna governorate, with 128 of those structures in Al Tamimi settlement.

UNOSAT Rapid Mapping team conducted the damage assessment to buildings and structures in Derna and Al Tamimi settlements by using a photo-interpretation approach using very-high resolution satellite imagery from before and after the storm Daniel reached the northeastern part of Libya. Both pre- and post-event satellite imagery were acquired through the Space Charter mechanism.

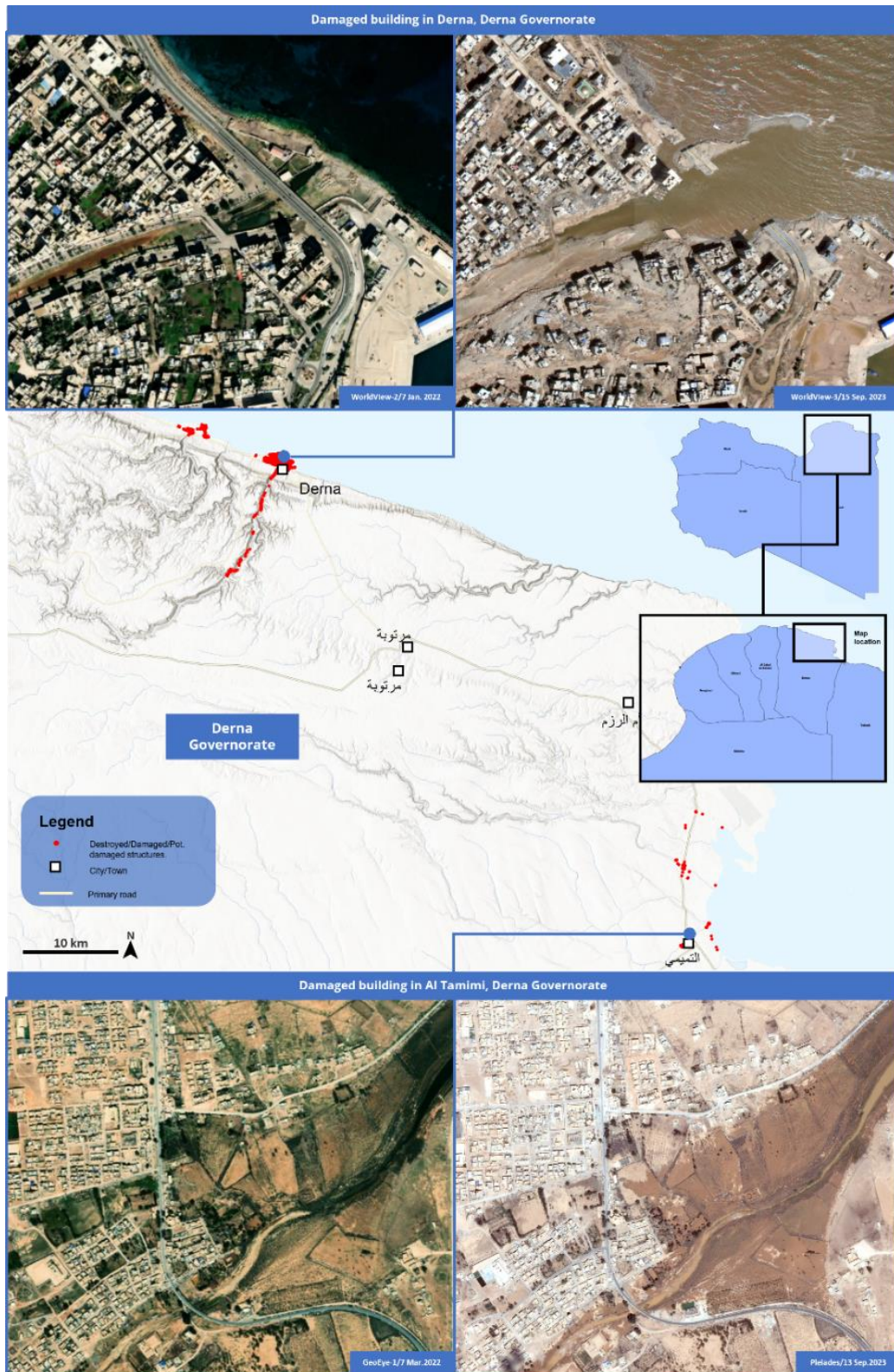


Figure 4 - This map depicts the extent of damaged buildings in Derna and Al Tamimi, Derna Governorate. Additional inset images from Pleiades and WorldView-3 satellite acquired on the 13 and 15 September 2023 highlight and visualise the extent of damage to the buildings within Derna and Al Tamimi settlements.

WorldView-2 image copyright: © DigitalGlobe, Inc. (2023)
 Source: USGS / HDDS and the International Charter Space and Major Disasters

Pleiades image copyright: © CNES (2023), distribution by Airbus DS
 Source: Airbus DS and the International Charter Space and Major Disasters

III. Additional Analysis

III.1 post-event night-time light monitoring using satellite images.

In the aftermath of the storm Daniel, UNOSAT, in collaboration with Wuhan University, conducted an analysis over the affected areas to estimate the loss of electricity in some of the major cities and villages using night-time light images acquired with optical sensors. On 27 September 2023, UNOSAT published two preliminary night-time light loss assessment report showing a significant power outage in Derna and Al Bayda. Derna has recovered to 80% its usual and normal level by 24 September 2023 whereas Al Bayda has recovered to 90% of its normal level as of 24 September 2023.

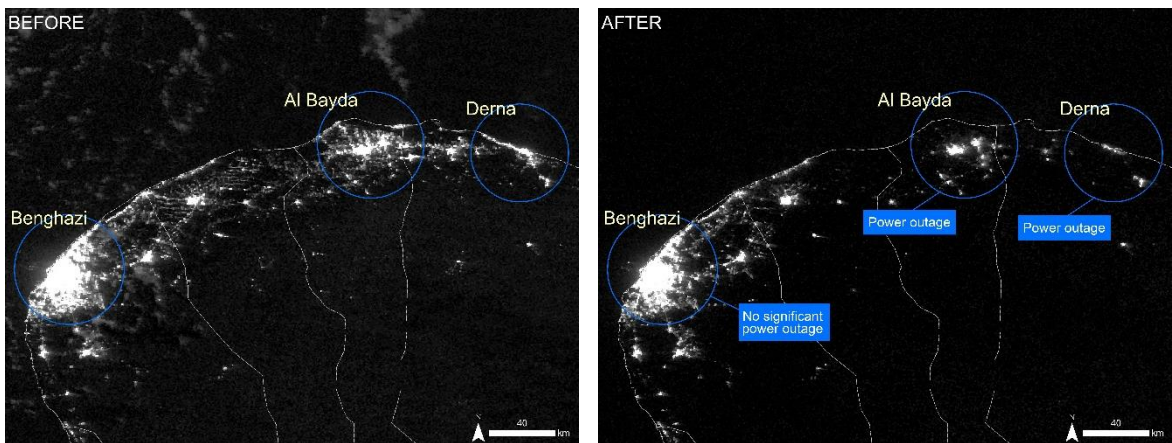


Figure 6 - These images illustrate data retrieved from optical satellite images in Derna, Al Jabal Al Akhdar, Almarj and Benghazi Governorates. The pre- and post- image was acquired with VIIRS VNP46A2 on the 08 Sep. 2023 and VIIRS VNP46A2 on the 12 Sep. 2023.

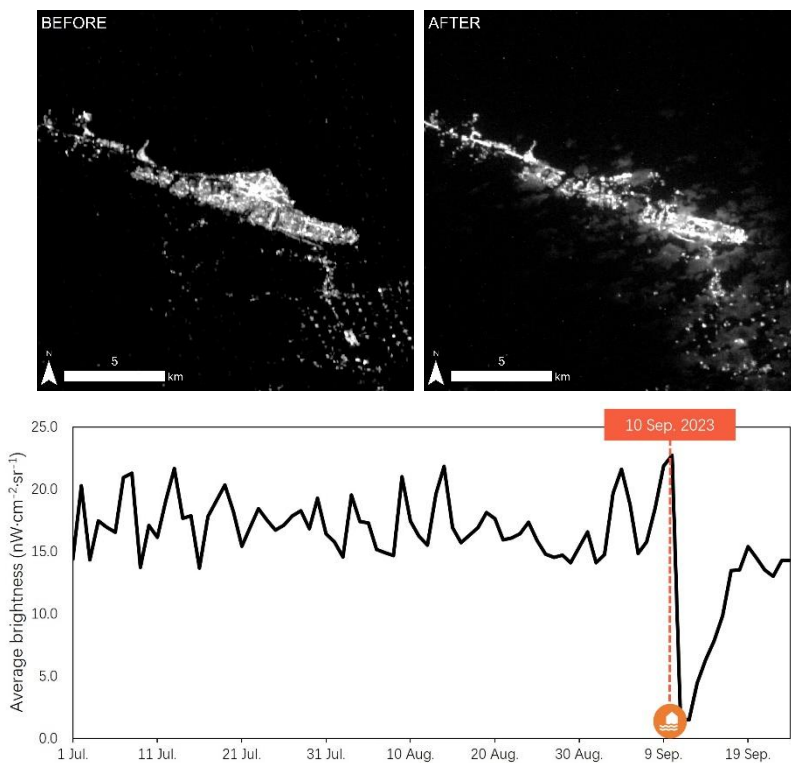


Figure 5 - These images illustrate data retrieved from very-high resolution satellite images over Derna, Derna Governorate. The pre- and post- image was acquired with SDGSAT-1 on the 04 Apr. 2022. and Yangwang-1 on the 19 Sep. 2023. The graph represents the power supply trend calculated using VIIRS VNP46A2 from 01 Jul. to 24 Sep. 2023.

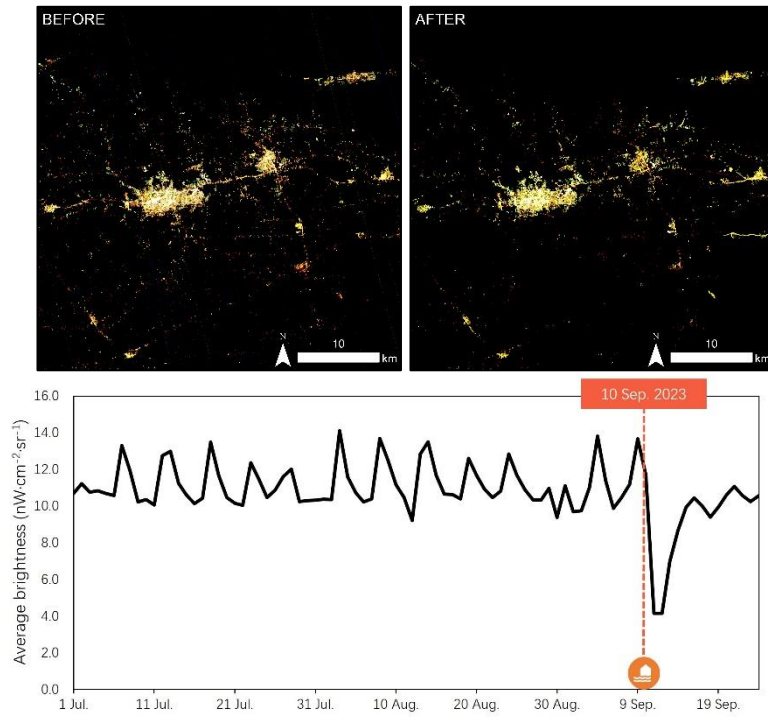


Figure 7 - These images illustrate data retrieved from very-high resolution satellite images over Al Bayda, Al Jabal Al Akhdar Governorate. The pre- and post- image was acquired with SDGSAT-1 on the 20 Apr. 2022. and SDGSAT-1 on the 17 Sep. 2023. The graph represents the power supply trend calculated using VIIRS VNP46A2 from 01 Jul. to 24 Sep. 2023.

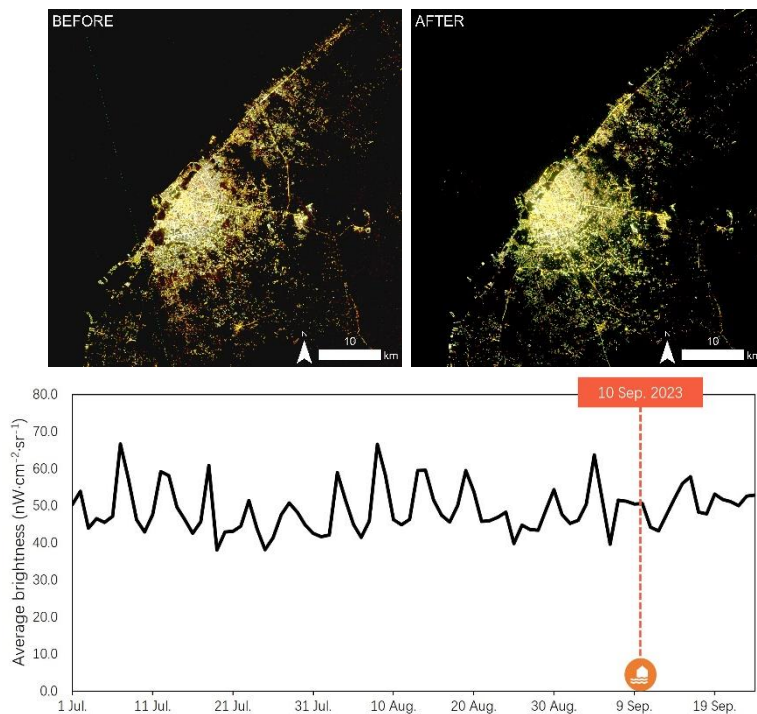


Figure 8 - These images illustrate data retrieved from very-high resolution satellite images over Benghazi, Benghazi Governorate. The pre- and post- image was acquired with SDGSAT-1 on the 16 May 2022. and SDGSAT-1 on the 22 Sep. 2023. The graph represents the power supply trend calculated using VIIRS VNP46A2 from 01 Jul. to 24 Sep. 2023.

SDGSAT-1 image copyright: International Research Center of Big Data for Sustainable Development Goals (CBAS)
 Source: International Research Center of Big Data for Sustainable Development Goals (CBAS)
 Yangwang-1 Space Telescope night-time data Copyright: Origin Space Co., Ltd., China
 Source: Origin Space Co., Ltd., China
 VIIRS VNP46A image Copyright: NASA
 Source: NASA

III.2 Satellite-derived reservoir assessment

UNOSAT performed a satellite-derived reservoir assessment over 6 dams in Benghazi, Almarj and Derna Governorates. Using very-high resolution optical satellite imagery, UNOSAT concluded that the 2 dam walls along the Derna River appears to be destroyed. The other 4 dams appears to be filled at the date of the imagery acquisition.

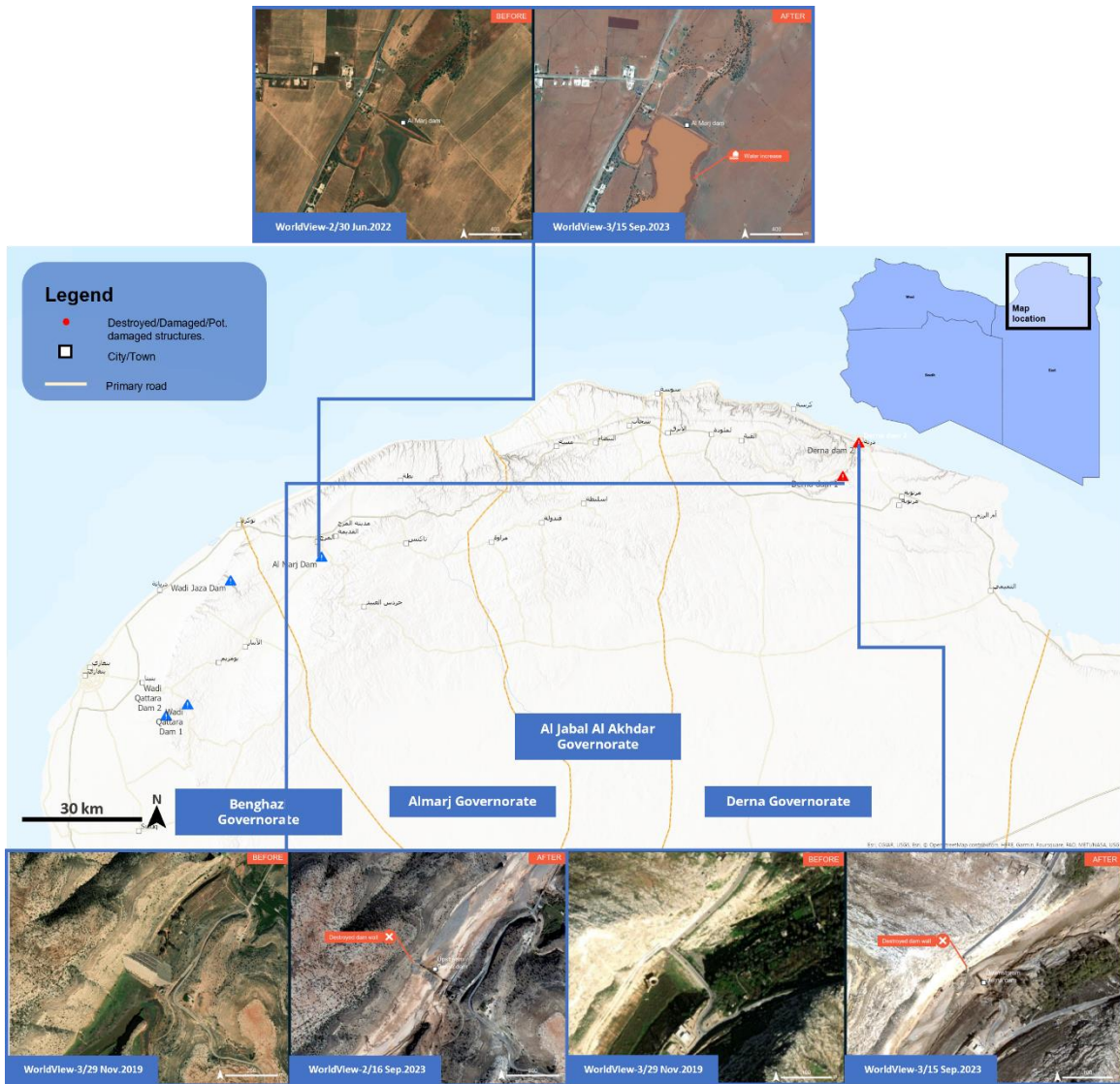


Figure 9 – This map depicts the extent of 6 dams in the affected governorates. Additional inset images highlight the status of 3 dams. The 2 dams in Derna governorates appears to be destroyed whereas the other 4 dams in Almarj and Benghazi governorates appears to be filled.

IV. UNOSAT LIVE Web map

A dedicated “[UNOSAT Damage Assessment Live Map](#)” was published by the United Nations Satellite Centre (UNOSAT) to provide the humanitarian actors with a comprehensive overview of the satellite derived damage assessments conducted by the United Nations Satellite Centre and other Copernicus EMS. With access to this web map, users have the possibility to view and download damage analyses (such as building damage points in GIS format) covering all areas of interest defined for satellite damage analyses in Libya.

Furthermore, through this live web map it is possible to access field pictures taken with the UN-ASIGN application, which provides important details on the ground situation and in particular about the intensity of damage to buildings and infrastructures.

The added value of this web map tool was to provide all humanitarian actors with up-to-date and publicly available building damage datasets from different mapping organisations supporting response operations in Libya through satellite imagery analysis.



Figure 10 - A snapshot of the UNOSAT web map interface displaying structures identified as damaged (red and orange) and potentially damaged (yellow), and showing the status of dams following the storm Daniel in Libya.

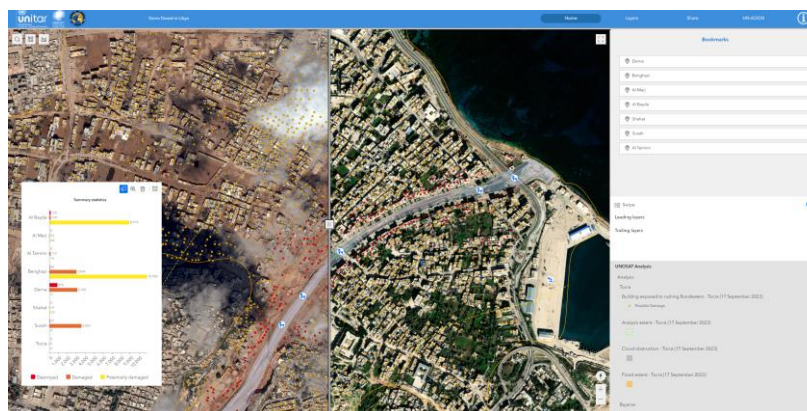


Figure 11 - showcases the UNOSAT web map interface, featuring a swipe mode that enables users to compare pre-event and post-event images by following the provided bookmarks to each critical area.

V. Ground photos

The United Nations Satellite Centre (UNOSAT) used ground photos from the media and residents to visualize the damage on the ground caused by the storm Daniel in northeastern part of Libya the 8th of September 2023.



Figure 12 – Topleft: Search teams look for people into wrecked buildings in Derna. Credit photo: Yousef Murad / AP Photo. Top right: Damage caused by the flash flood in Derna, Libya on September 11, 2023. Credit photo: The Atlantic AFP /Getty. Bottom left: Aerial view of Derna after the flash floods on September 11, 2023. Credit photo: Ayman Al-sahili / Reuters. Bottom right: Survivors of the flash floods in Libya searching people stuck in the wreckage. Credit photo: Yousef Murad / AP Photo.

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The analysis has not been verified in the field yet; please send your comments and feedback to unosat@unitar.org.