

## **Copernicus EMS Activation: EMSR558 Volcano eruption in Tonga**

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**Abstract.** Copernicus Rapid Mapping (RM) is one of the two on-demand Mapping components of the Copernicus Emergency Management Service (CEMS) [1]. It is a 7/24/365 service funded by the European Commission to the local, regional, national, and global emergency and disaster management stakeholders to provide time-critical geospatial information helping coordinate humanitarian assistance during disaster management cycle activities. As one of the six other partner institutions involved in the RM Service Consortium and as a Production Site, ITHACA S.r.l. is in charge of geospatial data analysis and thematic map provision to the End-Users.

On the 15 January 2022 at 17:14 local time (04:14:45 UTC, 15 January) [2], the Hunga Tonga-Hunga Ha'apai submarine volcano (20.536°S 175.382°W) located in the Kingdom of Tonga in the proximity of Fiji, South Pacific Ocean violently erupted, generating a massive surge of an ash plume that reached the mesosphere with an altitude of about 58 km [3] and resulting in one of the most remarkable natural phenomena of the 21<sup>st</sup> century. As a result of the eruption, tsunami waves of about 1.2 m hit the Tongan capital Nuku Alofa on the Tongatapu island [4], located 69 km in the South-East of the Hunga Tonga-Hunga Ha'apai. Tsunami warnings have also been issued for several countries, from Japan to Australia, Chile to Samoa, Fiji, and Vanuatu [5,6].

The CEMS-RM was activated 10 hours after the eruption, on the 15 January 2022 at 16:45 UTC [7], by the Emergency Response Coordination Centre of the Directorate-General for European Civil Protection and Humanitarian Aid Operations (DG-ECHO ERCC) to perform the damage grade assessment built upon the comparison and pre and post-event optical satellite imageries.

In the efforts to support local and international disaster management bodies, two Areas of Interest (AoI) were defined as Nuku Alofa (AoI 01), the capital of Tonga; and Lifuka (AoI 02), located in the northern part of an archipelago including Uiha, Uoleva, Lifuka, Foa, and Ha'ano with a total surface of 505 km<sup>2</sup>.



In collaboration with the International Disaster Charter, the European Union and ESA under Copernicus Programme have provided very high-resolution satellite imageries to optimize image acquisition, processing, and data analysis time. A total of five Pleiades1A/B very high-resolution images (with a geometric resolution of 50 cm) acquired in the aftermath of the volcanic eruption (16/01/2022 - 20/01/2022) were used to delineate the ash deposit extent and to assess the damage grading of the buildings, facilities, and road network referring to the RM Service Consortium standard approach. Based on this approach, the structures are classified with destroyed, damaged, possibly damaged, and no visible damage grading. Destroyed corresponds to more than 50% of the collapse of a structure. In contrast, damaged illustrates a partial collapse of the roof or serious failures of walls with the presence of damage proxies around the buildings. Possibly damage leaves room for uncertain interpretation due to the image quality with the presence of possible damage proxies such as small traces of debris around the building [8]. The analyses were performed through the Computer Assisted Photo-Interpretation (CAPI) at an analysis scale of 1:10000. Thus, expert teams composed of 3 to 4 GIS professionals working on rotational 24-hour shifts, examined the pre-event and post-event images, respectively (Fig. 1), and recognized objects logically and rationally, depicting homologous zones by color gradient, shape, size, pattern, and textural similarities. The production time respected the RM standards for the grading assessments up to 12 hours following the delivery of the satellite imagery.

To accentuate the most affected areas in both the AoIs, 18 detail maps were produced in addition to 2 Grading Overview products delivered in vector and ready-to-print formats. The first product was delivered less than 48 hours following the initial activation request.



Fig. 1. A sample of comparison of pre and post event images analyzed during the EMSR558 production in Tonga.



The analyses revealed an ash deposit concerning the entire ground surface on the AoIs, 27406 ha and 4006 ha, for Nuku Alofa and Lifuka, respectively. The total number of people affected by the event was estimated 77794 in the AoI01 (corresponding to 98% of the residents) using the Global Human Settlements (GHS) population density dataset. The damage grading analyses indicated that 131 buildings were assessed as destroyed, 87 as damaged, and 1719 as possibly damaged. The road network was also subjected to extensive damage, with 5.8 km classified as destroyed, 25 km damaged, and 31.7 km as possibly damaged. The damage concentration in the AoI01 is represented in the Fig. 2 below.



**Fig. 2.** A more straightforward representation of the damage concentration in AoI01 in Nuku Alofa. On the right, the red portion of the pie chart corresponds to the destroyed structures, whereas the orange represents damaged and the yellow is for the possibly damaged ones. The numbers illustrated in the center of the charts correspond to the Total Affected with the sum of destroyed, damaged, and possibly damaged structures.



Fig. 3. Comparison of the damage concentration in the NW coast of the Tongatapu island (open-water side of the NW coast vs. inner side)



The damage assessment allowed the analysts also to hypothesize the direction of the tsunami waves hitting the Tongatapu island. Tsunami waves were inferred to initially hit the island's Northwest coast facing the open water considering the local high damage concentration (Fig. 3). However, the inner side of the NW coast seemed to have significantly reduced damage as the buildings remained almost intact.

Regarding the AoI02, it was estimated that 4482 people (corresponding to 87% of the residents) were affected by the disaster. The grading assessments classified 4 buildings as damaged and 485 as possibly damaged. The damage concentration in the AoI02 is illustrated in the <u>Fig. 4</u> below. In this case, 0.1 km of roads were detected as damaged and 2.5 km as possibly damaged. In addition, both the airports present on the island were revealed to be entirely covered by ash deposits; therefore, they were presumed not to be in a fully operational state.



**Fig. 4.** A more straightforward representation of the damage concentration in AoI02 in Lifuka. On the right, the orange portion of the pie chart corresponds to the damaged structures, whereas the yellow represents the possibly damaged ones. The numbers illustrated in the center of the charts correspond to the Total Affected with the sum of damaged and possibly damaged structures.

In comparing the damage concentration in both the AoIs, AoI01 Nuku Alofa was the most affected - which has been an expected inference given the distance of the islands from the Hunga Tonga-Hunga Ha'apai Volcano (69 km for AoI01 Nuku Alofa and 137 km for AoI02 Lifuka, respectively).

In terms of financial correspondence, the World Bank estimated US\$90.4M in damage caused by the volcanic eruption, tsunami, and ashfall. In addition, residential buildings were estimated to have US\$43.7M of damage by the tsunami waves, and the infrastructures (including roads, water, and power supply network) were subjected to estimated damage of US\$20.9M. Moreover, clean-up costs were estimated to be around



US\$5M. Lastly, the damage to the agricultural sector with the crop loss and the damage to the shallow reef fisheries were estimated at US\$20.9M [9].

On the CEMS – RM perspective of the conclusions of this event, two weeks after the closure of the activation, the DG ECHO ERCC provided entirely positive feedback about the analyses putting forth the fact that the quality of the production has met their expectations. Furthermore, despite the highly well-established CEMS-RM workflow with a relatively rigid structure, the EMSR558 has shown that it can adapt to a somewhat flexible setup based on peculiar non-standard requests.

Keywords. Copernicus, rapid mapping, volcanic eruption, tsunami, Hunga-Tonga

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