INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION
(of UNESCO)

Hunga Tonga – Hunga Ha`apai
Volcanic Tsunami Hazard Response

PTWS Interim Procedures Implementation Plan

Version 1.0, February 10, 2022

Due to the potential for another HTHH, immediate implementation of this Plan was begun following the proposal presentation to Member States, their feedback, and agreed upon 'Actions Forward' concluded from the PTWS Post-Event Brief I: 15 January 2022: Hunga Tonga – Hunga Ha`apai Volcanic Eruption and Tsunami held on 20 January 2022. Further Member State feedback was provided during PTWS Post-Event Brief II on 3 February 2022 and PTWS Post-Event Brief III on 10 February 2022.

This document presents the ICG/PTWS Interim Procedures Implementation Plan for the Hunga Tonga – Hunga Ha`apai Volcanic Tsunami Hazard Response for urgent consideration and adoption by the ICG/PTWS Steering Committee.

INTRODUCTION

This Implementation Plan describes interim standard operating procedures (SOP) that will be carried out by the Pacific Tsunami Warning Center (PTWC) as a Pacific Tsunami Warning and Mitigation System (PTWS) Tsunami Service Provider (TSP) to address the possibility of future tsunamis originating from additional volcanic eruptions or associated processes at the Hunga Tonga - Hunga Ha'apai Volcano (HTHH) that erupted explosively on January 15, 2022, and created a Pacific-wide tsunami.

The SOP is designed to provide timely advice to PTWS Member States in order to alert them to any future potential threat from this volcano and to help guide their response with information about expected tsunami amplitudes and arrival times. This interim plan has been constructed by the PTWC and a special task team within the ICG Working Group 2.

The procedures contained in this plan describe a best-endeavours response by PTWC to any further tsunamigenic activity in the HTHH region. Because of the large uncertainties involved in forecasting volcanic tsunamis, the SOP allows for expert interpretation of data, including consideration of data sources other than seismic or water observations (e.g. other data to suggest a volcanic eruption has occurred).

1. BACKGROUND

The January 15, 2022, Hunga Tonga – Hunga Ha'apai explosive eruption came from an existing largely submerged volcanic edifice represented at the surface by a couple of small islands. The volcano has a summit caldera with a floor that is ~150 m below sea level. The activity on 15 January, is part of a broader eruption episode that started in 2009 and continued in 2014/2015. The latest eruptive phase that led to the January 15 tsunami started on Dec 20, 2021. On January 14, an explosive eruption excavating the central scoria cone and may have involved collapse. It did not generate a damaging tsunami, but did generate small tsunami waves. A day later at around 1910 UTC an active submerged vent violently exploded resulting in the generation of tsunami waves.

The eruption plume ascended very quickly and punctured the stratosphere ~30 km above sea level and produced a massive acoustic pressure wave that travelled in the atmosphere around the globe at least 3 times. The role of this acoustic wave in tsunami generation is still being researched, but its occurrence provided both a significant tsunami natural warning and increased challenges for tsunami forecasting. Processes associated with the volcanic eruption generated a series of tsunami waves that impacted local, regional and distant coastlines (Figure 1). These waves generated land threat (>1m amplitude) at local, regional and distant coastlines. Immediate PTWS response was challenging because of the volcanic source of the tsunami. Volcano tsunamis are difficult to forecast because large uncertainties exist in our ability to rapidly characterise both the complex eruption process and the mechanism by which this process generates tsunamis.
A unique features of this event include the very high plume, a relatively small erupted volume (~0.5 km3 of magma), smaller than expected from a very short duration eruption. Enhanced explosivity likely related to a near perfect mix between magma and water (too much of either dampens explosivity) so this suggests a vent covered by 10's but not 100's m of sea water. This vent geometry has probably led to a detonation near sea surface-atmosphere boundary to generate the shockwave(s) and increase tsunami amplitudes.

With limited near real-time monitoring, it is very difficult to assess what activity may follow. After large eruptions, recovery of the magma system will likely lead to small events that begin to rebuild the vent area. A new cone/island may form in the coming months. Flank stability maybe compromised, and partial edifice collapse in the short-term is possible. It is less likely is a much larger event will follow because of ‘un-roofing’ of the overlying rock during this eruption. However, the potential for further tsunamigenic events at HTHH is significant and is the primary motivation for this interim SOP.

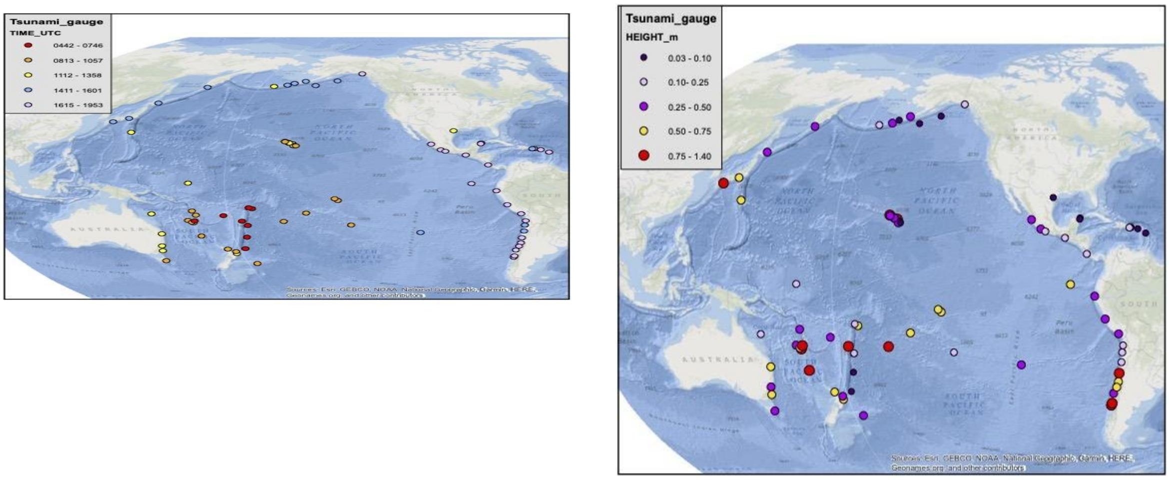

Figure 1: Left, time of arrival of maximum tsunami amplitude recorded on coastal tide gauges and DARTs. Right, maximum tsunami amplitude reported by PTWC on 15 January.

2. INTERIM STANDARD OPERATING PROCEDURES (SOP)

Background

The PTWC response to the 15 January tsunami presented some extraordinary challenges, as its operational procedures, forecasting tools, and message generation and dissemination are all predicated on earthquake sources. Its initial pre-forecast threat is based only on the preliminary earthquake parameters. Its later forecast threat is underpinned by an estimation of the earthquake fault parameters – the strike, dip, and rake of the fault and the total seismic moment. These parameters are used to estimate seafloor displacement that becomes the initial condition for the hydrodynamic tsunami forecast model.

Tsunami generation in the HTHH eruption was driven by entirely different processes that still are not fully understood but likely involve several mechanisms including forcing by atmospheric gravity waves. Consequently, there currently is not a method to dynamically model them in real time for a forecast, nor is there a method to even quickly detect or characterize the volcanic source.

Interim SOP

Because of this, we will use first available information that a tsunami has been generated to underpin PTWC Threat Messages. Specifically, PTWC

- Will use observed tsunami amplitudes as the basis of a forecast. These include amplitudes from the tide gauge at Nuku`alofa and the deep ocean NZG DART gauge. Tsunamis generated at HTHH will arrive at those gauges within approximately 30 minutes. Observations on these stations will likely constitute the first evidence of a tsunami threat.

- Create the forecast by scaling observed maximum amplitudes observed across the Pacific from the January 15 event with observed amplitudes for any future event, starting with the observed amplitudes at Nuku`alofa and the NZG DART. Forecast values are only for specific gauge locations and do not represent a wider forecast for that coast.

NTWCs will need to apply their knowledge of what happened along all their coasts with the January 15 event and also scale it accordingly.

These interim Threat Messages for HTHH are not meant to provide same level of detail and/or certainty as normal forecasting products delivered during earthquake generated tsunami responses. It is expected that this interim SOP will evolve as appropriate based on advancing science as well as recommendations from WG2.

This will be a best endeavors approach to creating Threat Messages. Some judgement of the PTWC duty staff will be applied to limit or extend the region around the volcano designated to have a threat and to raise or lower forecast amplitudes based upon the evolving observations as the tsunami propagates across the Pacific.

Message Content

Messages will contain:

1. the estimated time tsunami waves were generated by the volcano along with the HTHH coordinates,
2. the names of the countries or territories with a possible tsunami threat (threat region),
3. the aforementioned tsunami amplitude forecast and estimated arrival times at gauge locations in the threat region,
4. estimated tsunami arrival times at the normal warning points in the threat region, and
5. observed tsunami amplitudes on coastal and DART gauges.

Message Dissemination

Messages will be disseminated to all the normal designated PTWS recipients via the standard methods used by PTWC for earthquake-generated tsunamis. These include:

- WMO Global Telecommunications System (WEPA40 PHEB header)
- Aeronautical Fixed Communications Network (AFTN)
- Email
- Fax
- Website. PTWC messages will also appear on the tsunami.gov website but with reference to a magnitude 1.0 earthquake at the site of HTHH. It will require much more work to modify the website to reflect a volcano source