New TSP Product – Tsunamis generated by non-seismic and complex sources

Dr Robert Greenwood
robert.greenwood@bom.gov.au

ICG Indian Ocean Tsunami Warning & Mitigation System SOP Workshops July 2023:
Standard Operating Procedures (SOPs) for
National Tsunami Warning Centres (NTWCs) and
Disaster Management Organisations (DMOs)

Introduction

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1. Atypical event types
2. Threat assessment technique
3. Source Identification
4. Update IOTWMS Service Definition
5. TSP Product Examples
6. Case Study: Hunga Tonga-Hunga Ha'apai Volcano Jan 2022 Eruption

Volcanic Eruption

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Celestial Impact

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Landslide

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Unknown

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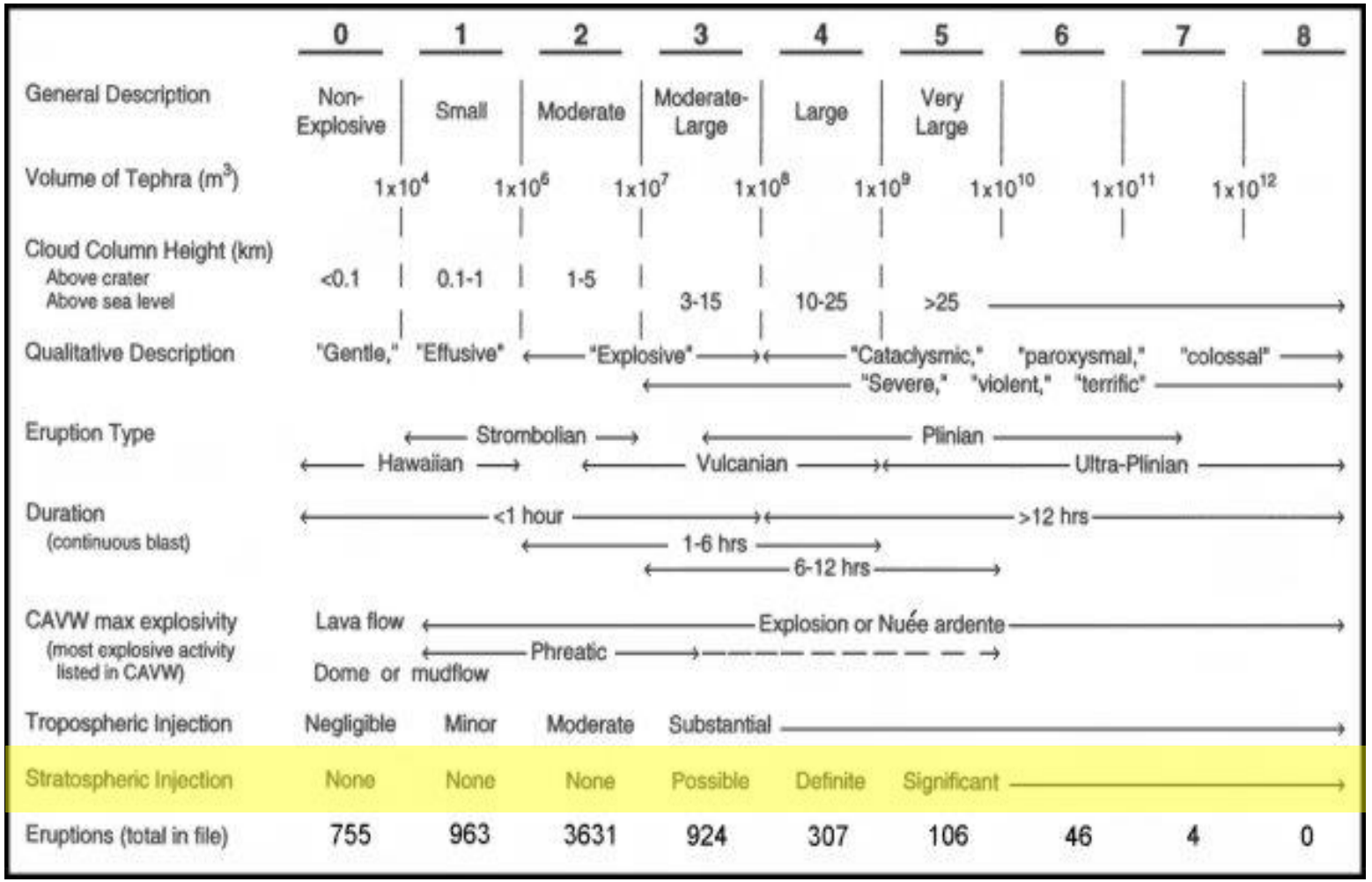
JATWC Threat Assessment technique

Severity	Action
Level 1	The threat area is defined to be within the 1 hour travel time isochrone
Level 3	The threat area is defined to be within the 3 hour travel time isochrone
Level 6	The expanding threat area is defined by the elapsed time since event + 6 hour travel time isochrone

Volcanic Eruption



	0	1	2	3	4	5	6	7	8
General Description	Non-Explosive	Small	Moderate	Moderate-Large	Large	Very Large			
Volume of Tephra (m^3)		$1x10^4$	$1x10^6$	$1x10^7$	$1x10^8$	$1x10^9$	$1x10^{10}$	$1x10^{11}$	$1x10^{12}$
Cloud Column Height (km) Above crater Above sea level	<0.1	0.1-1	1-5	3-15	10-25	>25			
Qualitative Description	"Gentle,"	"Effusive"	"Explosive"	"Explosive"	"Cataclysmic,"	"Cataclysmic,"	"paroxysmal,"	"colossal"	
					"Severe,"	"violent,"	"terrific"		
Eruption Type	Hawaiian	Strombolian	Strombolian	Vulcanian	Plinian	Plinian	Plinian	Ultra-Plinian	
Duration (continuous blast)	<1 hour	<1 hour	<1 hour	1-6 hrs	>12 hrs	>12 hrs	>12 hrs	>12 hrs	
				6-12 hrs					
CAVW max explosivity (most explosive activity listed in CAVW)	Lava flow	Phreatic	Phreatic	Explosion or Nuée ardente	Explosion or Nuée ardente	Explosion or Nuée ardente	Explosion or Nuée ardente	Explosion or Nuée ardente	
	Dome or mudflow								
Tropospheric Injection	Negligible	Minor	Moderate	Substantial	Substantial	Substantial	Substantial	Substantial	
Stratospheric Injection	None	None	None	Possible	Definite	Significant	Significant	Significant	
Eruptions (total in file)	755	963	3631	924	307	106	46	4	0

Volcanic Eruption

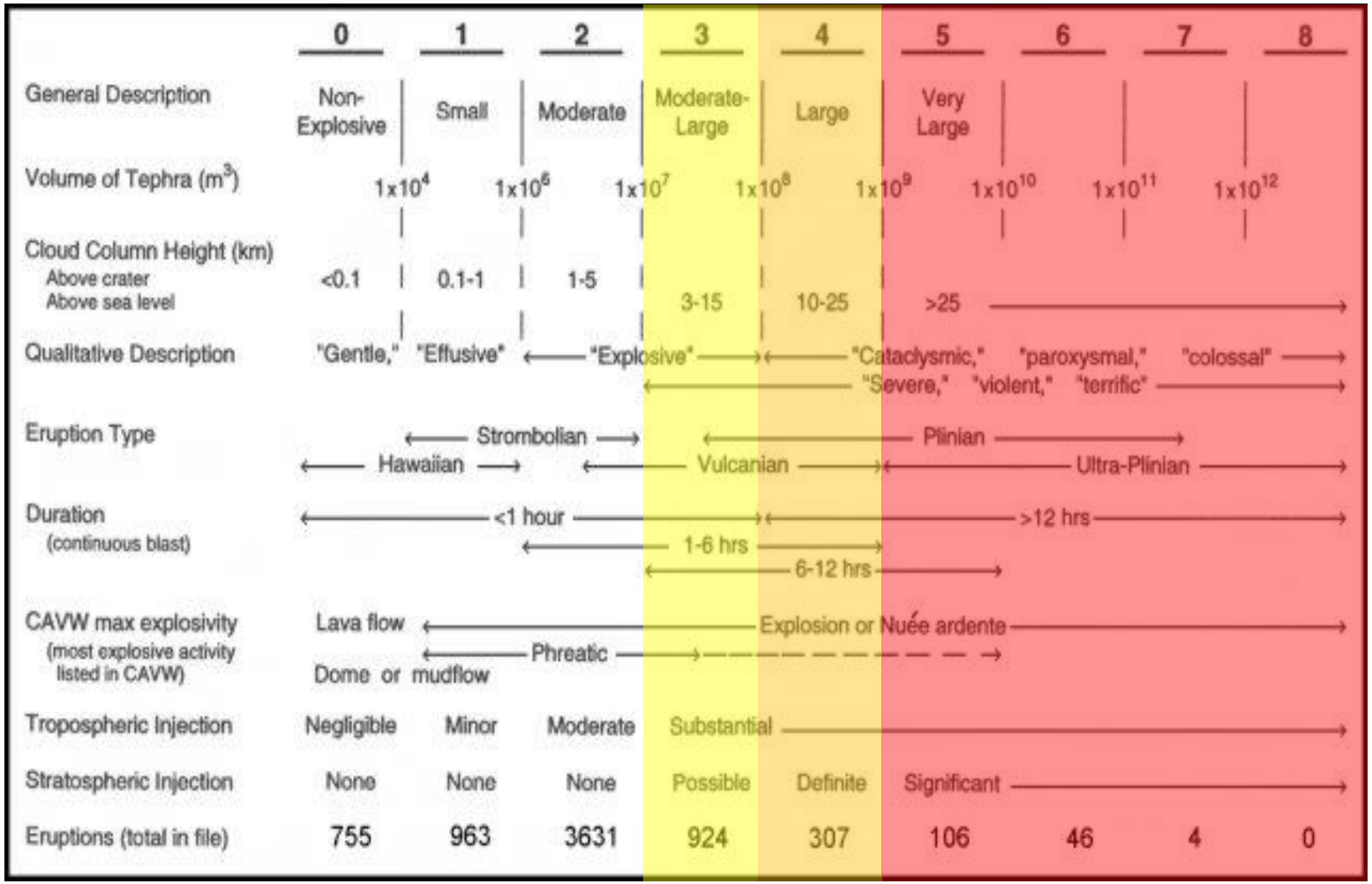
(1) Issue no products and monitor for any potential tsunami: This action should be taken if there is little to no stratospheric injection and there is no evidence a tsunami has been generated.

(2) Create the event with a Severity of 1 hour: This action should be taken if there is little to no stratospheric injection and there is evidence that a small tsunami has been generated and the impacts are consistent with a low-level Marine Threat.

(3) Create the event with a Severity of 3 hours: This action should be taken if there is obvious stratospheric injection consistent with a VEI of 4 and/or there are reliable observations or reports that indicate a tsunami has been generated and the impacts are consistent with a high-level Marine Threat or low-level Land Threat.

(4) Create the event with a Severity of 6 hours: This action should be taken if there is significant stratospheric injection consistent with a VEI of 5+ and/or there are reliable observations or reports that indicate a catastrophic tsunami has been generated.

Volcanic Eruption



Celestial Impact

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Approximate impactor radius	Approximate equivalent earthquake magnitude
10m	M6.5
20m	M7.0
30m	M7.5
60m	M8.0
110m	M8.5
200m	M9.0

Celestial Impact

(1) Create the event with a Severity of 3 hours: This action should be taken if the celestial body is known to have a radius of between 10 and 60m and/or there are reliable observations or reports that indicate a tsunami has been generated.

(2) Create the event with a Severity of 6 hours: This action should be taken if the celestial body is known to have a radius of greater than 60m or the radius in unknown, and/or there are reliable observations or reports that indicate a catastrophic tsunami has been generated.

Landslide

(1) Create the event with a Severity of 1 hour: This action should be taken if there are reliable observations or reports that indicate a small tsunami has been generated.

(2) Create the event with a Severity of 3 hours: This action should be taken if there are reliable observations or reports that indicate a tsunami has been generated and the impacts are consistent with a low-level Marine Threat.

(3) Create the event with a Severity of 6 hours: This action should be taken if there are reliable observations or reports that indicate a catastrophic tsunami has been generated and the impacts are consistent with a high-level Marine Threat or low-level Land Threat.

Unknown

(1) Create the event with a Severity of 1 hour: This action should be taken if there are reliable observations or reports that indicate a tsunami has been generated and the impacts are consistent with a low-level Marine Threat

(2) Create the event with a Severity of 3 hours: This action should be taken if there are reliable observations or reports that indicate a tsunami has been generated and the impacts are consistent with a high-level Marine Threat or low-level Land Threat.

(3) Create the event with a Severity of 6 hours: This action should be taken if there are reliable observations or reports that indicate a catastrophic tsunami has been generated.

Unknown

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Update IOTWMS Service Definition to V5.0

11. Service Level 2 products may also be issued for non-seismic and complex source events if a regional or ocean wide scale tsunami has been generated or there is reason to believe one may have been generated. This is an area for future development and is not a current requirement. Due to the nature of non-seismic and complex source events and the limitations of current operational setups there it is high likelihood that many of them will not be detected in a timely manner. If a TSP chooses to respond to a non-seismic and complex source event, they should modify the standard templates as per Annexure-5.

TSP Bulletin Types

TSP Bulletin Type 1: Earthquake Bulletin

- Not Issued for atypical events

TSP Bulletin Type 2: No Threat Bulletin

- Issued as soon as possible

TSP Bulletin Type 2: Potential Tsunami Threat Bulletin

- Issued as soon as possible
- Only applicable to Volcanic Eruption and Celestial Impact events

TSP Bulletin Type 3: Confirmed Tsunami Threat Bulletin

- Issued as soon as possible
- Could be the first bulletin issued for any atypical event

TSP Bulletin Type 4: Final Tsunami Bulletin

- No Change to criteria compared to earthquake event

TSP Australia Bulletin Examples: Notification Message

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TSUNAMI BULLETIN NOTIFICATION MESSAGE NUMBER 1 IOTWMS TSUNAMI SERVICE PROVIDER AUSTRALIA [JATWC] ISSUED AT 1046 UTC THURSDAY 13 FEBRUARY 2020

-
TO: INDIAN OCEAN NATIONAL TSUNAMI WARNING CENTRES [NTWCs]
FROM: IOTWMS-TSP AUSTRALIA

NOTIFICATION:
IOTWMS-TSP AUSTRALIA HAS JUST ISSUED TSUNAMI BULLETIN NUMBER 1 FOR THE INDIAN OCEAN, BASED ON THE FOLLOWING ~~EARTHQUAKE~~ EVENT:

~~MAGNITUDE: 6.9 MWP~~
~~DEPTH: 145KM~~
TYPE: LANDSLIDE
DATE: 13 FEB 2020
ORIGIN TIME: 1033 UTC
LATITUDE: 45.65N
LONGITUDE: 148.99E
LOCATION: KURIL ISLANDS

TO VIEW THE BULLETIN GO TO THE IOTWMS-TSP AUSTRALIA WEBSITE AT:

http://reg.bom.gov.au/tsunami/rtsp/index.shtml

NOTE: THIS IS A RESTRICTED-ACCESS WEBSITE CONTAINING TECHNICAL DATA FOR NATIONAL TSUNAMI WARNING CENTRES ONLY. IT IS NOT FOR GENERAL PUBLIC ACCESS.

GENERAL PUBLIC INFORMATION FOR THIS EVENT IS AVAILABLE FROM:

JOINT AUSTRALIAN TSUNAMI WARNING CENTRE [JATWC] BUREAU OF METEOROLOGY MELBOURNE, AUSTRALIA http://www.bom.gov.au/tsunami

END OF NOTIFICATION MESSAGE

-

TSUNAMI BULLETIN NOTIFICATION MESSAGE NUMBER 1 IOTWMS TSUNAMI SERVICE PROVIDER AUSTRALIA [JATWC] ISSUED AT 1046 UTC THURSDAY 13 FEBRUARY 2020

TO: INDIAN OCEAN NATIONAL TSUNAMI WARNING CENTRES [NTWCs]
FROM: IOTWMS-TSP AUSTRALIA

NOTIFICATION:
IOTWMS-TSP AUSTRALIA HAS JUST ISSUED TSUNAMI BULLETIN NUMBER 1 FOR THE INDIAN OCEAN, BASED ON THE FOLLOWING EVENT:

TYPE: LANDSLIDE
DATE: 13 FEB 2020
ORIGIN TIME: 1033 UTC
LATITUDE: 45.65N
LONGITUDE: 148.99E
LOCATION: KURIL ISLANDS

TO VIEW THE BULLETIN GO TO THE IOTWMS-TSP AUSTRALIA WEBSITE AT:

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END OF NOTIFICATION MESSAGE

TSP Australia Bulletin Examples: Type 2 No Threat Bulletin

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TSUNAMI BULLETIN NUMBER 1 (TYPE-II THREAT ASSESSMENT BULLETIN)
IOTWMS TSUNAMI SERVICE PROVIDER AUSTRALIA (JATWC)
ISSUED AT 1214 UTC Friday 02 August 2019

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... NO TSUNAMI THREAT IN THE INDIAN OCEAN ...

This bulletin applies to areas within and bordering the Indian Ocean. It is
issued in support of the UNESCO/IOC Indian Ocean Tsunami Warning and Mitigation
System (IOTWMS).

1. EARTHQUAKE TSUNAMI SOURCE INFORMATION
IOTWMS-TSP AUSTRALIA has detected an earthquake a landslide with the following details:

Magnitude: 7.1 Mwp
Depth: 69km
Date: 02 Aug 2019
Origin Time: 1203 UTC
Latitude: 7.47S
Longitude: 104.58E
Location: Southwest of Sumatra, Indonesia

2. EVALUATION
Based on pre-run model scenarios a tsunami travel time threat assessment, there is NO THREAT to countries in the Indian Ocean.

3. ADVICE
This bulletin is being issued as advice. Only national/state/local authorities and disaster management officers have the authority to make decisions regarding the official threat and warning status in their coastal areas and any action to be taken in response.

4. UPDATES
No further bulletins will be issued by IOTWMS-TSP AUSTRALIA for this event
unless other information becomes available.

Other IOTWMS-TSPs may issue additional information at:
IOTWMS-TSP INDIA:
http://www.incois.gov.in/Incois/tsunami/eqevents.jsp
IOTWMS-TSP INDONESIA: http://rtsp.bmkg.go.id

5. CONTACT INFORMATION
IOTWMS-TSP AUSTRALIA
Joint Australian Tsunami Warning Centre (JATWC)
Bureau of Meteorology
GPO BOX 1289 Melbourne, Victoria, Australia, 3001
http://reg.bom.gov.au/tsunami/rtsp

END OF BULLETIN

TSP Australia Bulletin Examples: Type 2 Potential Threat Bulletin

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TSUNAMI BULLETIN NUMBER 1 (TYPE-II THREAT ASSESSMENT BULLETIN)
IOTWMS TSUNAMI SERVICE PROVIDER AUSTRALIA (JATWC)
ISSUED AT 1509 UTC Sunday 19 August 2018

... POTENTIAL TSUNAMI THREAT IN THE INDIAN OCEAN ...

This bulletin applies to areas within and bordering the Indian Ocean. It is
issued in support of the UNESCO/IOC Indian Ocean Tsunami Warning and Mitigation
System (IOTWMS).

1. EARTHQUAKE TSUNAMI SOURCE INFORMATION
IOTWMS-TSP AUSTRALIA has detected an earthquake a volcanic eruption at Mt Rumble with the following details:

Magnitude: 7.0 Mwp
Depth: 12km
Date: 19 Aug 2018
Origin Time: 1456 UTC
Latitude: 8.47S
Longitude: 116.69E
Location: Sumbawa Region, Indonesia

2. EVALUATION
Earthquakes of this size are capable of generating tsunamis. However, so far there is no confirmation about the triggering of a tsunami.

An investigation is under way to determine if a tsunami has been triggered. This TSP will monitor sea level gauges and report if any tsunami wave activity has occurred.

Based on pre-run model scenarios a tsunami travel time threat assessment, the zones listed below are POTENTIALLY UNDER THREAT.

3. TSUNAMI THREAT FOR THE INDIAN OCEAN
For this event all locations within 3 hours are considered under Threat.

The list below shows the forecast arrival time of the first wave estimated to exceed 0.5m amplitude at the beach in each zone, and The amplitude of the maximum beach wave predicted for the zone. Zones where the estimated wave amplitudes are less than 0.5m at the Beach are not shown.

The list is grouped by country (alphabetic order) and ordered according to the earliest estimated times of arrival at the beach.

Please be aware that actual wave arrival times may differ from those below, and the initial wave may not be the largest. A tsunami is a series of waves and the time between successive waves can be five minutes to one hour.

The threat is deemed to have passed two hours after the forecast time for last exceedance of the 0.5m threat threshold for a zone.
Dangerous conditions should be expected to continue for a minimum of 5 hours after the predicted arrival time. As local conditions can cause a wide variation in tsunami wave action, CANCELLATION of national warnings and ALL CLEAR determination must be made by national/state/local authorities.

INDONESIA

NTB SUMBAWA B	1512Z 19Aug2018	0.51m
NTB LOMBOK-TIMUR S	1527Z 19Aug2018	0.51m
NTB LOMBOK-TENGAH	1542Z 19Aug2018	0.51m
NTB SUMBAWA S	1545Z 19Aug2018	0.51m
NTB LOMBOK-BARAT S	1546Z 19Aug2018	0.51m
BALI KLUNGKUNG P.NUSAPENIDA	1549Z 19Aug2018	0.51m
BALI DENPASAR PANTAI-SANUR	1555Z 19Aug2018	0.51m
BALI BADUNG PANTAI-KUTA	1555Z 19Aug2018	0.51m

4. ADVICE
This bulletin is being issued as advice. Only national/state/local authorities and disaster management officers have the authority to make decisions regarding the official threat and warning status in their coastal areas and any action to be taken in response.

5. UPDATES
Additional bulletins will be issued by IOTWMS-TSP AUSTRALIA for this event
as more information becomes available.

Other IOTWMS-TSPs may issue additional information at:
TSP INDIA: http://www.incois.gov.in/Incois/tsunami/eqevents.jsp
TSP INDONESIA: http://rtsp.bmkg.go.id

6. CONTACT INFORMATION
IOTWMS-TSP AUSTRALIA
Joint Australian Tsunami Warning Centre (JATWC)
Bureau of Meteorology
GPO BOX 1289 Melbourne, Victoria, Australia, 3001
http://reg.bom.gov.au/tsunami/rtsp

END OF BULLETIN

TSP Australia Bulletin Examples: Type 3 Confirmed Threat Bulletin

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TSUNAMI BULLETIN NUMBER 2 (TYPE-III CONFIRMED THREAT BULLETIN)
IOTWMS TSUNAMI SERVICE PROVIDER AUSTRALIA (JATWC)
ISSUED AT 1345 UTC Sunday 05 August 2018

... CONFIRMED TSUNAMI THREAT IN THE INDIAN OCEAN...

This bulletin applies to areas within and bordering the Indian Ocean. It is
issued in support of the UNESCO/IOC Indian Ocean Tsunami Warning and Mitigation
System (IOTWMS).

1. EARTHQUAKE TSUNAMI SOURCE INFORMATION
IOTWMS-TSP AUSTRALIA has detected an earthquake a volcanic eruption at Mt Rumble with the following details:

Magnitude: 7.0 Mwp
Depth: 25km
Date: 05 Aug 2018
Origin Time: 1146 UTC
Latitude: 8.56S
Longitude: 116.49E
Location: Sumbawa Region, Indonesia

2. EVALUATION
Sea level observations have confirmed that a TSUNAMI WAS GENERATED.
Maximum wave amplitudes observed so far:

Benoa	INDONESIA	8.83S 115.33E	0.01m	05 Aug 12:45 UTC
Lembar	INDONESIA	8.70S 116.07E	0.13m	05 Aug 13:08 UTC

Based on pre-run model scenarios a tsunami travel time threat assessment, the zones listed below are POTENTIALLY UNDER THREAT.

3. TSUNAMI THREAT FOR THE INDIAN OCEAN
For this event all locations within 3 hours are considered under Threat.

The list below shows the forecast arrival time of the first wave estimated to exceed 0.5m amplitude at the beach in each zone, and the amplitude of the maximum beach wave predicted for the zone.
Zones where the estimated wave amplitudes are less than 0.5m at the beach are not shown.

The list is grouped by country (alphabetic order) and ordered according to the earliest estimated times of arrival at the beach.

Please be aware that actual wave arrival times may differ from those below, and the initial wave may not be the largest. A tsunami is a series of waves and the time between successive waves can be five minutes to one hour.

The threat is deemed to have passed two hours after the forecast time for last exceedance of the 0.5m threat threshold for a zone.
Dangerous conditions should be expected to continue for a minimum of 5 hours after the predicted arrival time. As local conditions can cause a wide variation in tsunami wave action, CANCELLATION of national warnings and ALL CLEAR determination must be made by national/state/local authorities.

INDONESIA

NTB SUMBAWA B	1202Z 05Aug2018	0.51m
NTB LOMBOK-TIMUR S	1217Z 05Aug2018	0.51m
NTB LOMBOK-TENGAH	1232Z 05Aug2018	0.51m
NTB SUMBAWA S	1235Z 05Aug2018	0.51m
NTB LOMBOK-BARAT S	1236Z 05Aug2018	0.51m
BALI KLUNGKUNG P.NUSAPENIDA	1239Z 05Aug2018	0.51m
BALI DENPASAR PANTAI-SANUR	1245Z 05Aug2018	0.51m
BALI BADUNG PANTAI-KUTA	1245Z 05Aug2018	0.51m

4. ADVICE
This bulletin is being issued as advice. Only national/state/local authorities and disaster management officers have the authority to make decisions regarding the official threat and warning status in their coastal areas and any action to be taken in response.

5. UPDATES
Additional bulletins will be issued by IOTWMS-TSP AUSTRALIA for this event
as more information becomes available.

Other IOTWMS-TSPs may issue additional information at:
TSP INDIA: http://www.incois.gov.in/Incois/tsunami/eqevents.jsp
TSP INDONESIA: http://rtsp.bmkg.go.id

6. CONTACT INFORMATION
IOTWMS-TSP AUSTRALIA
Joint Australian Tsunami Warning Centre (JATWC)
Bureau of Meteorology
GPO BOX 1289 Melbourne, Victoria, Australia, 3001
http://reg.bom.gov.au/tsunami/rtsp

END OF BULLETIN

TSP Australia Bulletin Examples: Type 4 Final Bulletin

TSUNAMI BULLETIN NUMBER 5 (TYPE-IV FINAL BULLETIN)
IOTWMS TSUNAMI SERVICE PROVIDER AUSTRALIA (JATWC)
ISSUED AT 1448 UTC Sunday 05 August 2018

... FINAL TSUNAMI BULLETIN FOR THE INDIAN OCEAN ...

1. EARTHQUAKE TSUNAMI SOURCE INFORMATION
IOTWMS-TSP AUSTRALIA has detected an earthquake with the following details:

Magnitude: 7.0 Mwp
Depth: 25km
Date: 05 Aug 2018
Origin Time: 1146 UTC
Latitude: 8.56S
Longitude: 116.49E
Location: Sumbawa Region, Indonesia

2. EVALUATION
Data from sea-level gauges confirmed that a tsunami was generated.

The expected period of significant tsunami waves is now over for all threatened
Indian Ocean countries, based on IOTWMS-TSP AUSTRALIA modelling.

Because local conditions can cause a wide variation in tsunami wave action,
CANCELLATION of national warnings and ALL CLEAR determination must be made by
national/state/local authorities. Please be aware that dangerous currents can
continue for several hours after the main tsunami waves have passed.

3. TSUNAMI WAVE OBSERVATIONS
Listed below are maximum wave amplitudes recorded at the specified locations.
Note that wave amplitude is measured relative to normal sea level; it is NOT
the crest-to-trough wave height.

Benoa	INDONESIA	8.83S 115.33E	0.01m	05 Aug 12:45 UTC
Lembar	INDONESIA	8.70S 116.07E	0.13m	05 Aug 13:08 UTC

4. ADVICE
This bulletin is being issued as advice. Only national/state/local authorities
and disaster management officers have the authority to make decisions regarding
the official threat and warning status in their coastal areas and any action to
be taken in response.

5. UPDATES
No further bulletins will be issued by IOTWMS-TSP AUSTRALIA for this event unless
additional information becomes available.

Other IOTWMS-TSPs may issue additional information at:
TSP INDIA: http://www.incois.gov.in/Incois/tsunami/eqevents.jsp
TSP INDONESIA: http://rtsp.bmkg.go.id

6. CONTACT INFORMATION
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Bureau of Meteorology
GPO BOX 1289 Melbourne, Victoria, Australia, 3001
http://reg.bom.gov.au/tsunami/rtsp

END OF BULLETIN

TSP Threat Table Example

EARTHQUAKE: Sumbawa Region, Indonesia 11:46 UTC 05 August 2018 Mag 7.0

INFORMATION FOR BULLETIN 5.Final Bulletin 1448UTC 05 Aug 2018

Exchange Bulletins | Threat Map | Threat Table | Deep Water Wave Amplitude Map | Travel Times Map | NTWC Status Reporting Form | Other Data

SELECT COUNTRY:

- AUSTRALIA
- BANGLADESH
- COMOROS
- DJIBOUTI
- FRANCE
- INDIA
- INDONESIA
- IRAN
- KENYA
- MADAGASCAR
- MALAYSIA
- MALDIVES
- MAURITIUS
- MOZAMBIQUE
- MYANMAR
- OMAN
- PAKISTAN
- SEYCHELLES
- SINGAPORE
- SOMALIA
- SOUTH AFRICA
- SRI LANKA
- TANZANIA
- THAILAND
- TIMOR-LESTE
- UNITED ARAB EMIRATES
- UNITED KINGDOM
- YEMEN

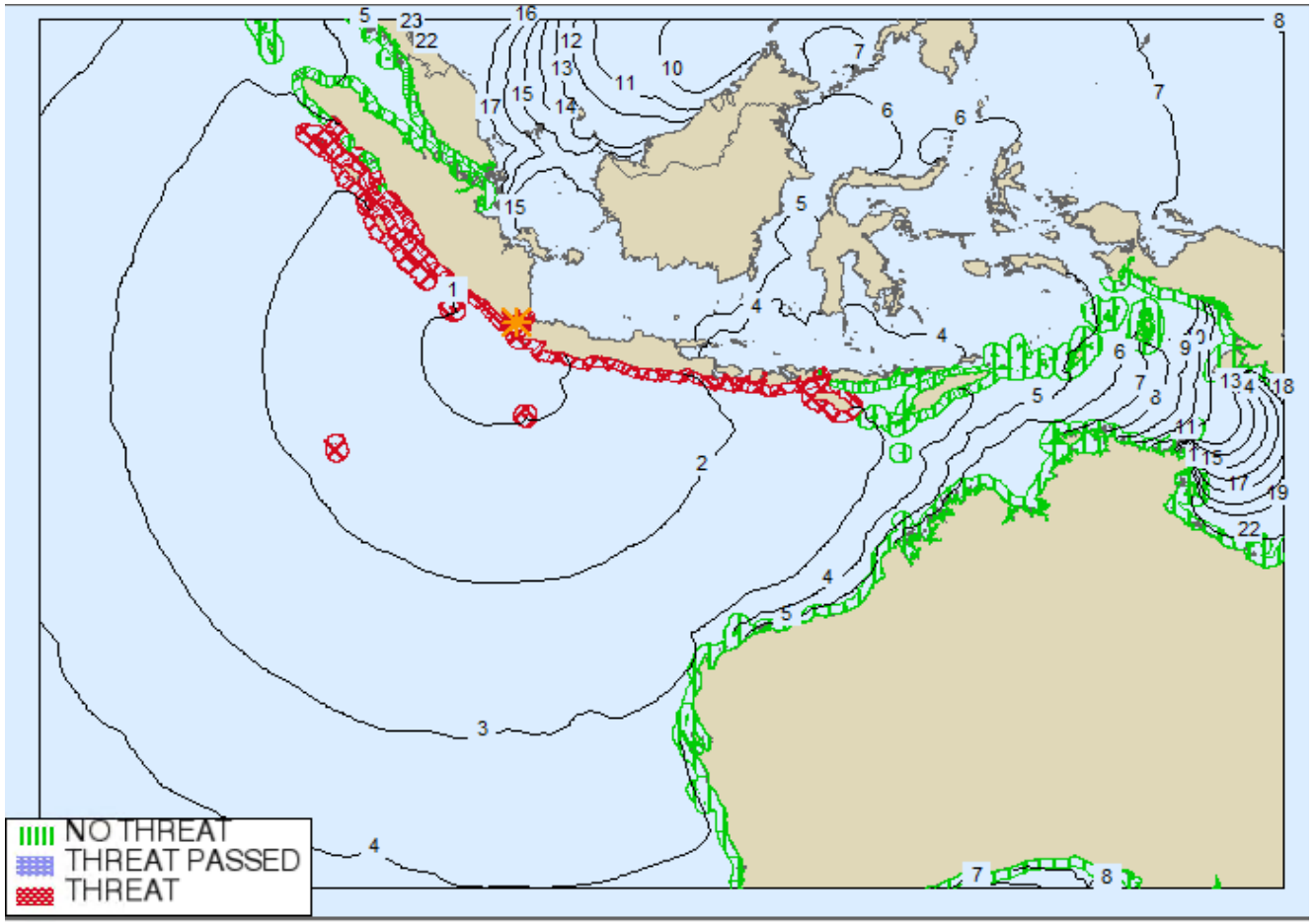
(Red = Threat, Blue = Threat Passed, Green = No Threat)

ZONE PREDICTIONS FOR INDONESIA:

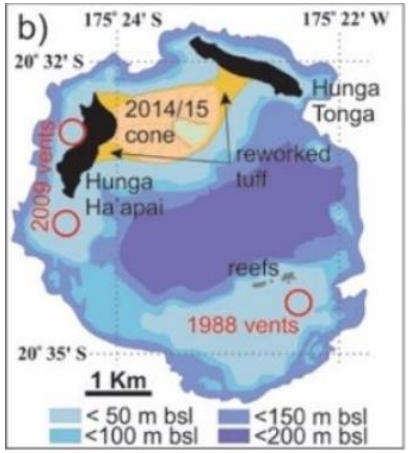
COUNTRY ZONE	MAX BEACH (m)	MAX DEEP (m)	DEPTH AT MAX DEEP (m)	T1 (UTC) First Wave	T2 (UTC) First Above Threat Level	T3 (UTC) Max Wave	T4 (UTC) Last Above Threat Level	THREAT CATEGORY
NTB LOMBOK-TIMUR S	0.51	0.24	-20	05 Aug 1217Z	05 Aug 1217Z	05 Aug 1217Z	05 Aug 1517Z	Threat
NTB SUMBAWA S	0.51	0.24	-20	05 Aug 1235Z	05 Aug 1235Z	05 Aug 1235Z	05 Aug 1535Z	Threat
NTB LOMBOK-TENGAH	0.51	0.24	-20	05 Aug 1232Z	05 Aug 1232Z	05 Aug 1232Z	05 Aug 1532Z	Threat
NTB LOMBOK-BARAT S	0.51	0.24	-20	05 Aug 1236Z	05 Aug 1236Z	05 Aug 1236Z	05 Aug 1536Z	Threat
NTB SUMBAWA B	0.51	0.24	-20	05 Aug 1202Z	05 Aug 1202Z	05 Aug 1202Z	05 Aug 1502Z	Threat
BALI DENPASAR PANTAI-SANUR	0.51	0.24	-20	05 Aug 1245Z	05 Aug 1245Z	05 Aug 1245Z	05 Aug 1545Z	Threat
BALI KLUNGKUNG P.NUSAPENIDA	0.51	0.24	-20	05 Aug 1239Z	05 Aug 1239Z	05 Aug 1239Z	05 Aug 1539Z	Threat
BALI BADUNG PANTAI-KUTA	0.51	0.24	-20	05 Aug 1245Z	05 Aug 1245Z	05 Aug 1245Z	05 Aug 1545Z	Threat
NTT TIMOR-TENGAH-SELATAN								No Threat
NTT ALOR S								No Threat

Example of TSP Australia assessment for a non-seismic event

Assign threat area to all zones within 3 hours tsunami travel time.



Hunga Tonga-Hunga Ha'apai Volcano



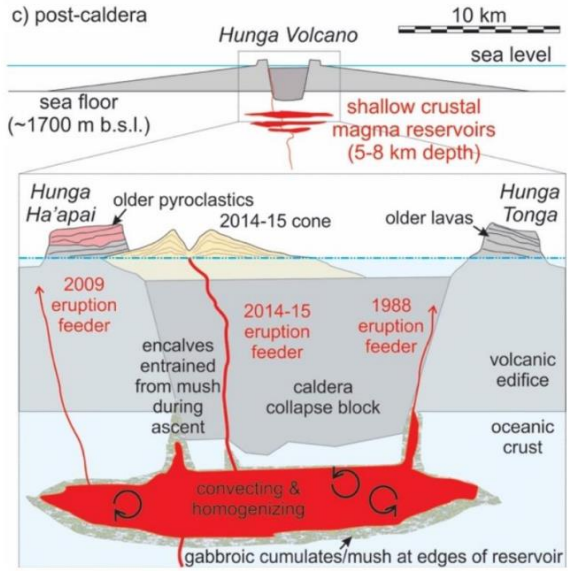
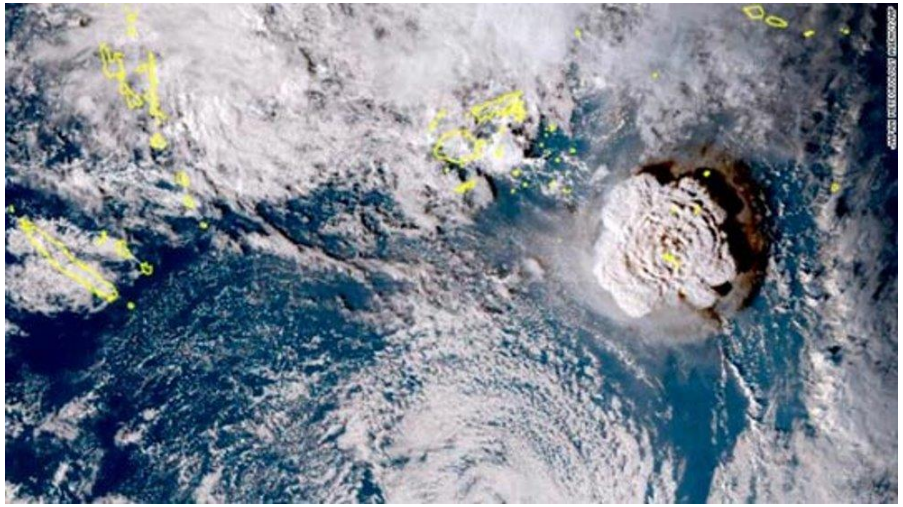
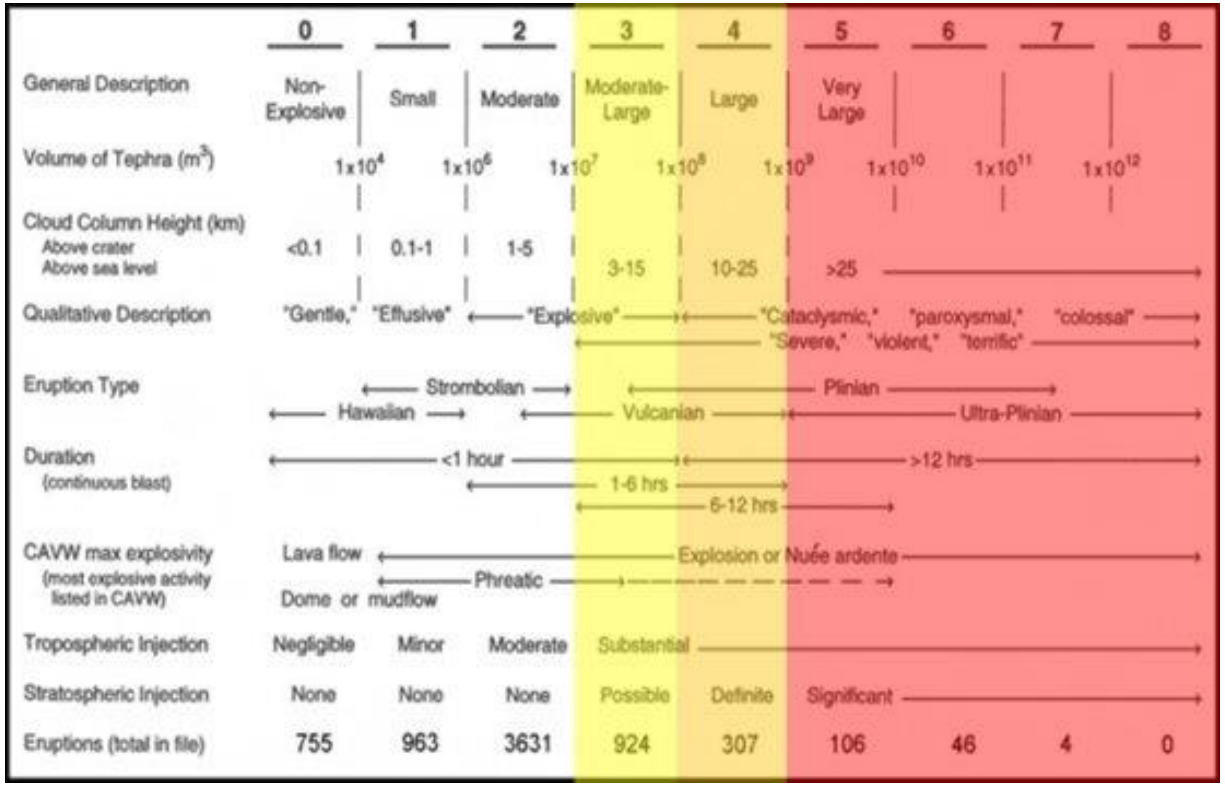


Image of volcanic eruption, the day before – January 14, 2022.



Satellite image of the volcanic eruption – January 15, 2022.

JATWC SOPs for Volcanic Events



Severity	Action
Level 1	The threat area is defined to be within the 1 hour travel time isochrone
Level 3	The threat area is defined to be within the 3 hour travel time isochrone
Level 6	The expanding threat area is defined by the elapsed time since event + 6 hour travel time isochrone

(1) *Issue no products and monitor for any potential tsunami*: This action should be taken if there is little to no stratospheric injection and there is no evidence a tsunami has been generated.

(2) *Create the event with a Severity of 1 hour*: This action should be taken if there is little to no stratospheric injection and there is evidence that a small tsunami has been generated and the impacts are consistent with a low-level Marine Threat.

(3) *Create the event with a Severity of 3 hours*: This action should be taken if there is obvious stratospheric injection consistent with a VEI of 4 and/or there are reliable observations or reports that indicate a tsunami has been generated and the impacts are consistent with a high-level Marine Threat or low-level Land Threat.

(4) *Create the event with a Severity of 6 hours*: This action should be taken if there is significant stratospheric injection consistent with a VEI of 5+ and/or there are reliable observations or reports that indicate a catastrophic tsunami has been generated.

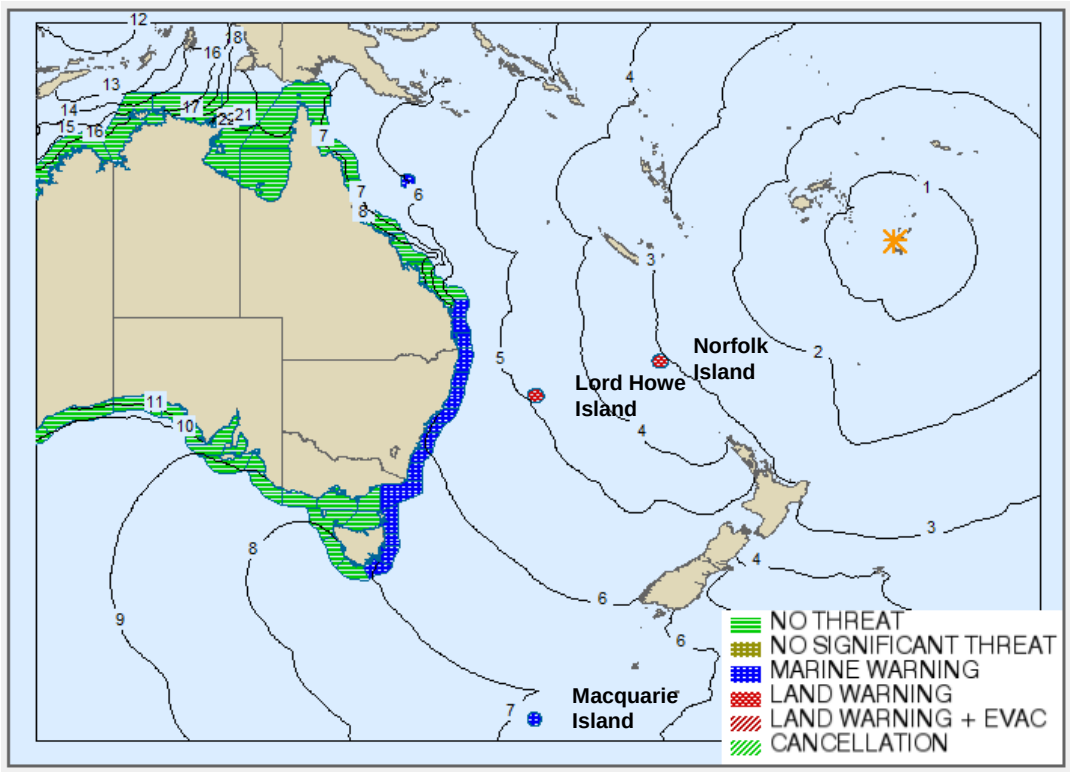
JATWC WARNING TIMELINE

Time (AEDT)	Elapsed Time (hh:mm)	Key Event: 15 January 2022
15:10	00:00	Explosive volcanic eruption of the Hunga Tonga-Hunga Ha'apai volcano (Tonga)
15:30	00:20	Observations confirm a tsunami was generated at 3:30 PM AEDT at Nuku Alofa.
16:58	01:48	No Threat Bulletin issued with additional text to advise that a tsunami had been generated and that the JATWC would continue to monitor observations. Initial assessment based on 3 hours travel time.
19:36	04:26	Marine Warning for Norfolk Island issued after 50 cm wave observed at the tide gauge.
20:00	04:50	Marine Warning issued for Lord Howe Island based on tide gauge measurements increasing at Norfolk Island.
20:37	05:27	Significant observations in NSW and QLD: (40cm at Twofold Bay at 8:10 PM AEDT; 25 cm at Gold Coast at 7:40 PM AEDT) prompts the issuing of Marine Warnings.
20:58	05:48	Norfolk Island Warning upgraded to Land Threat after wave observations exceed 1.0 m at the tide gauge.
21:00	05:50	Marine Warnings extended to Victoria, Tasmania and Macquarie Island using a 7 hours travel time threat assessment.
21:18	06:08	Lord Howe Island Warning upgraded to Land Threat with evacuation order issued at 10:12 PM AEDT.
10:09 +1	18:59	Land warnings for Norfolk Island and Lord Howe Island downgraded to marine.
10:30 to 11:50 +1	19:20 to 20:40	QLD, Macquarie Island, Victoria and Tasmanian marine warnings cancelled.
19:56 to 21:59 +1	28:46 to 30:49	Lord Howe Island, Norfolk Island and NSW warnings cancelled.

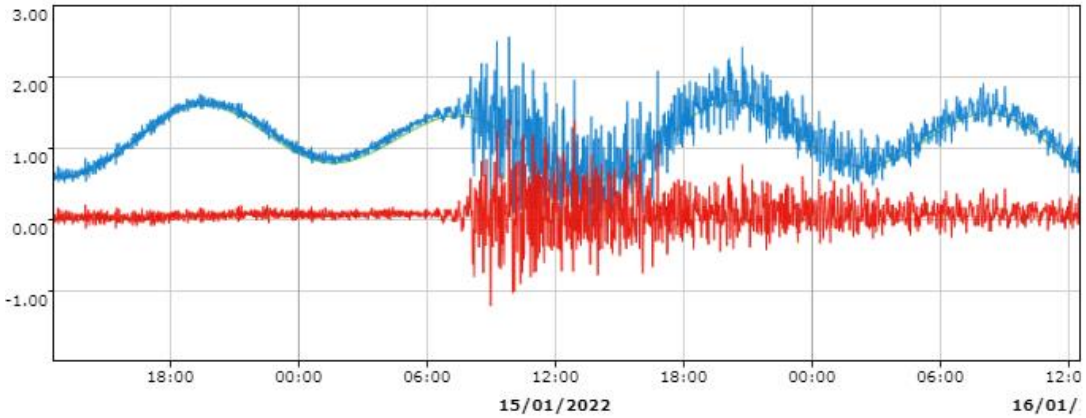
Key Challenges

- Initial detection of the volcanic eruption / tsunami and scale of eruption.
- Lack of event-specific tsunami modelling.
- Lack of a unified sea-level observing tool.

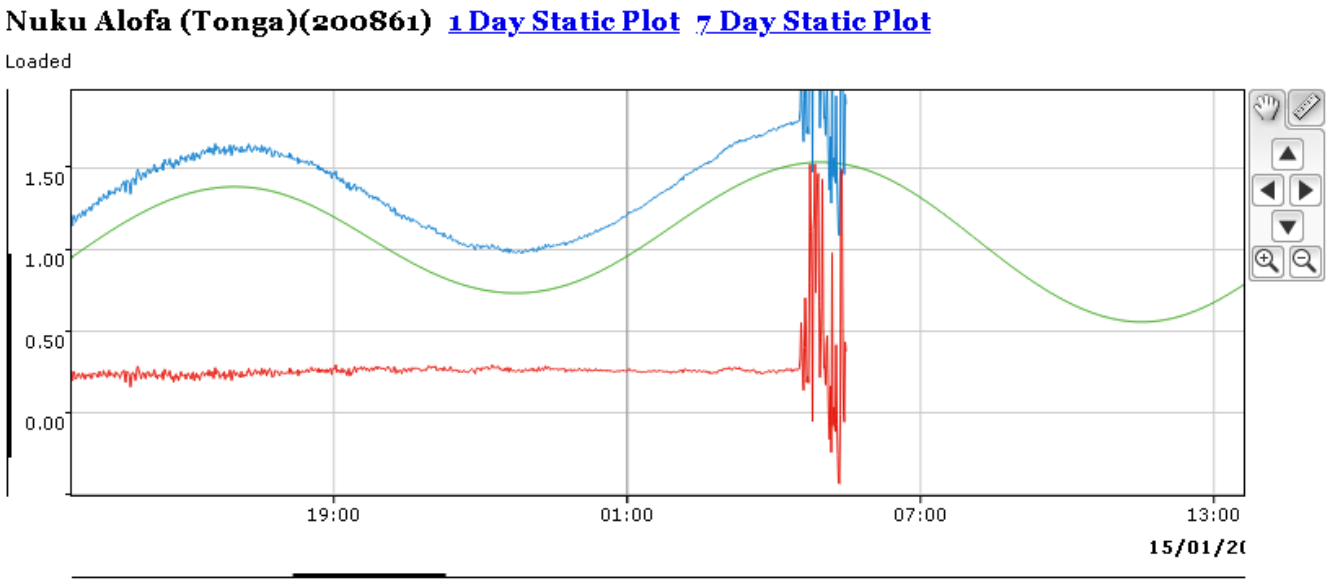
JATWC Tsunami Threat Assessment – Within 7 Hours Travel Time



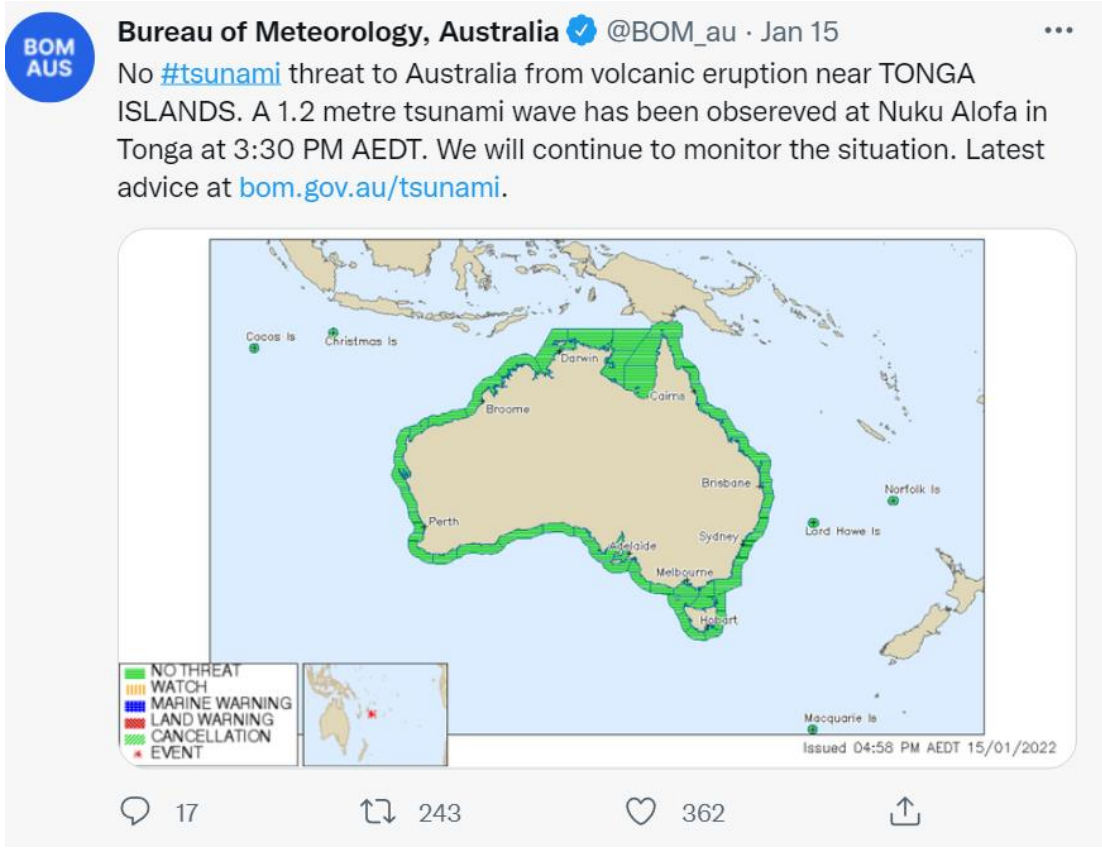
Norfolk Island – 1.27



Hunga Tonga-Hunga Ha'apai Volcano – Initial Assessment

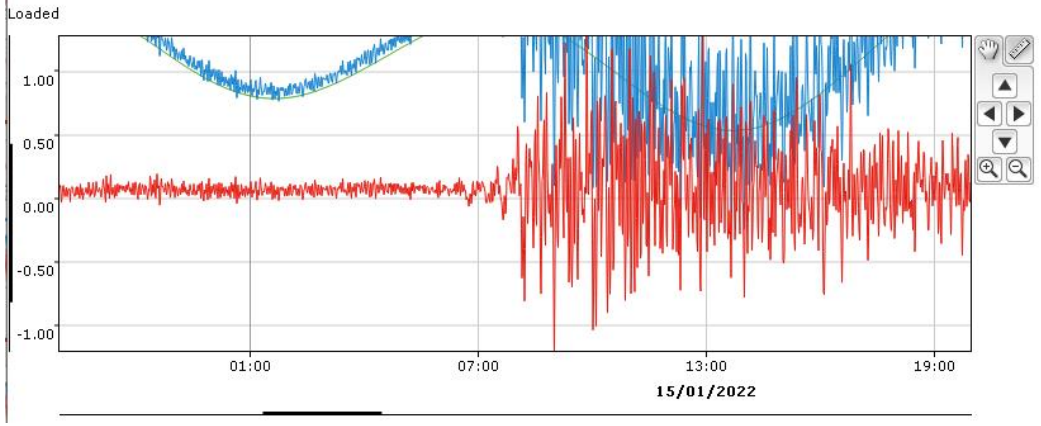


- Identified a 1.25 m Tsunami at Nuku Alofa
- Told by Darwin VAAC that there was stratospheric injection
- Opted for severity level 3 but continued to monitor observations

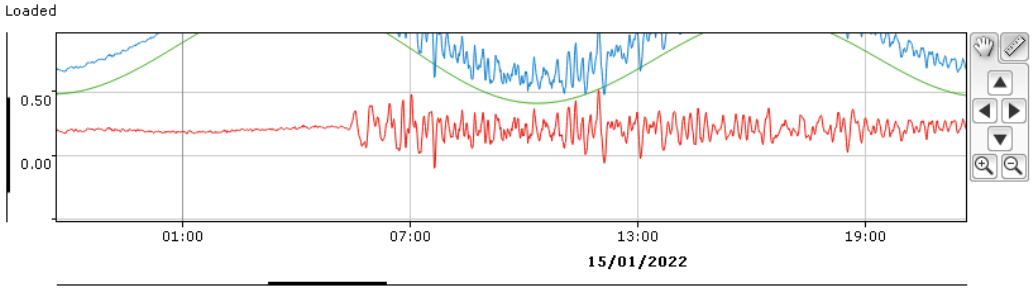


Hunga Tonga-Hunga Ha'apai Volcano – Early Observations

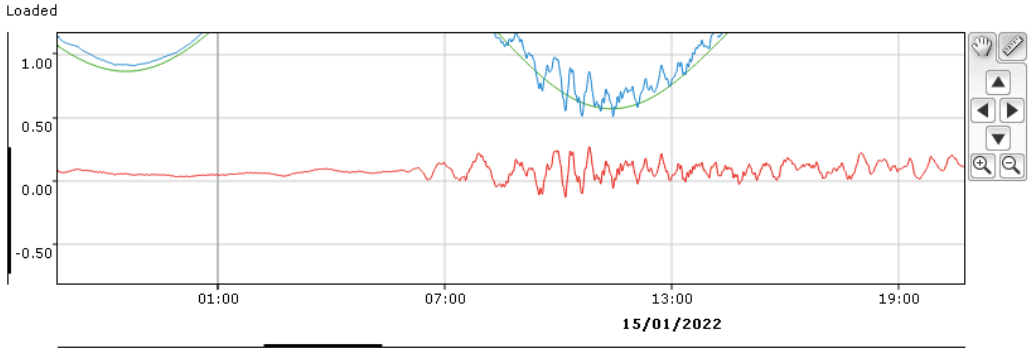
Norfolk Is (Australia)(200883) 1 Day Static Plot 7 Day Static Plot



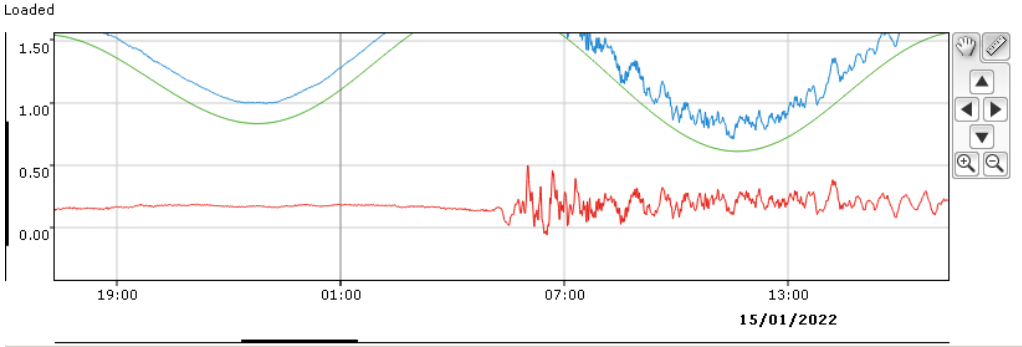
Apia (Samoa)(200814) 1 Day Static Plot 7 Day Static Plot



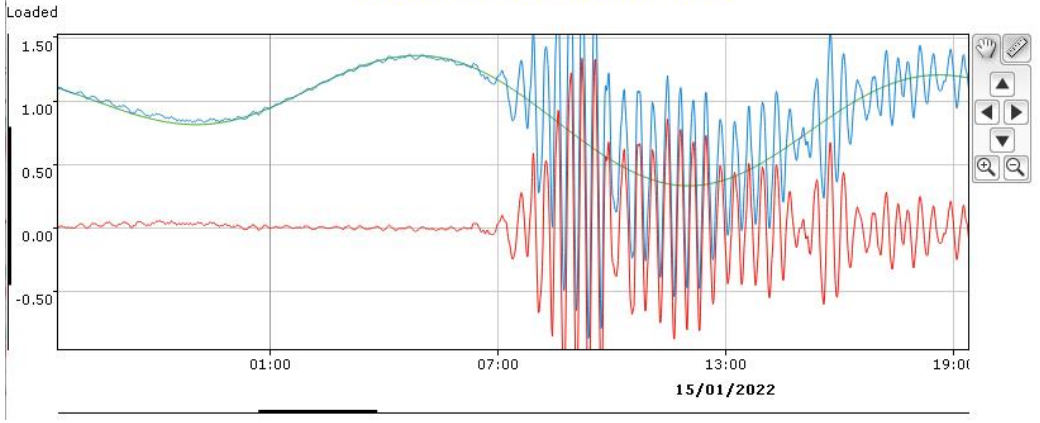
Lautoka (Fiji)(200856) 1 Day Static Plot 7 Day Static Plot



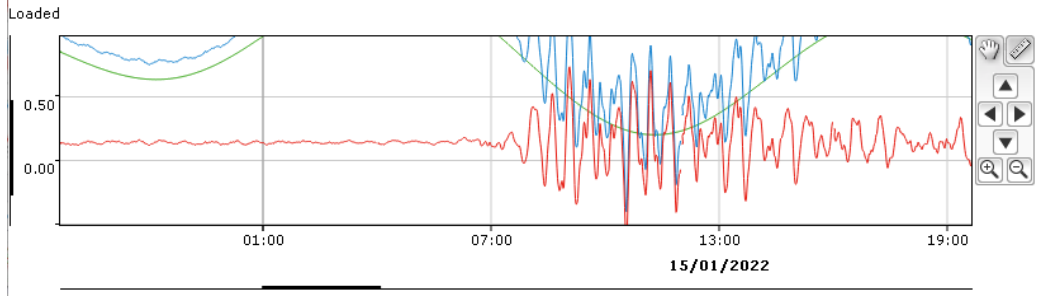
Suva (Fiji)(200863) 1 Day Static Plot 7 Day Static Plot



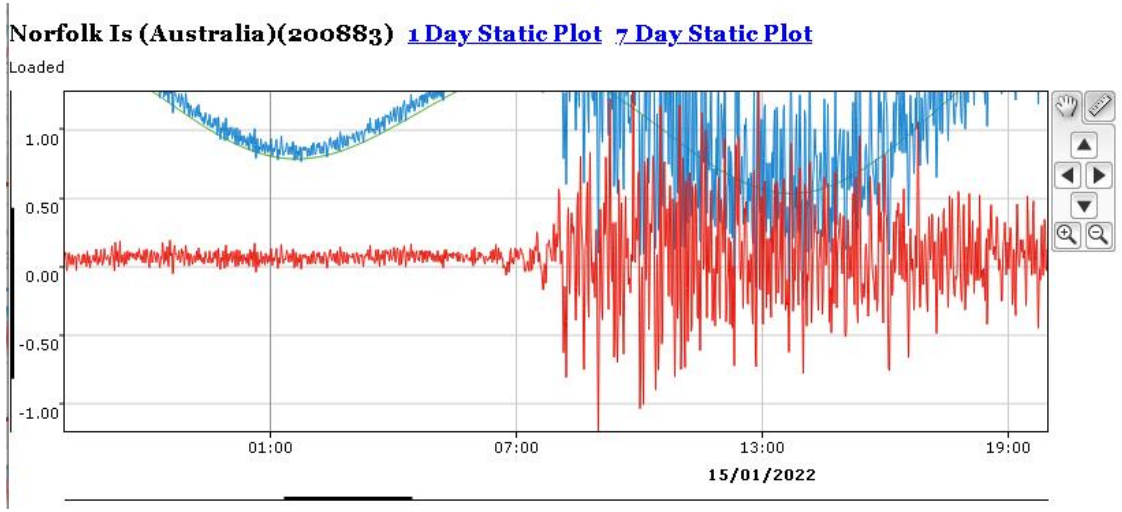
Port Vila (Vanuatu)(200857) 1 Day Static Plot 7 Day Static Plot



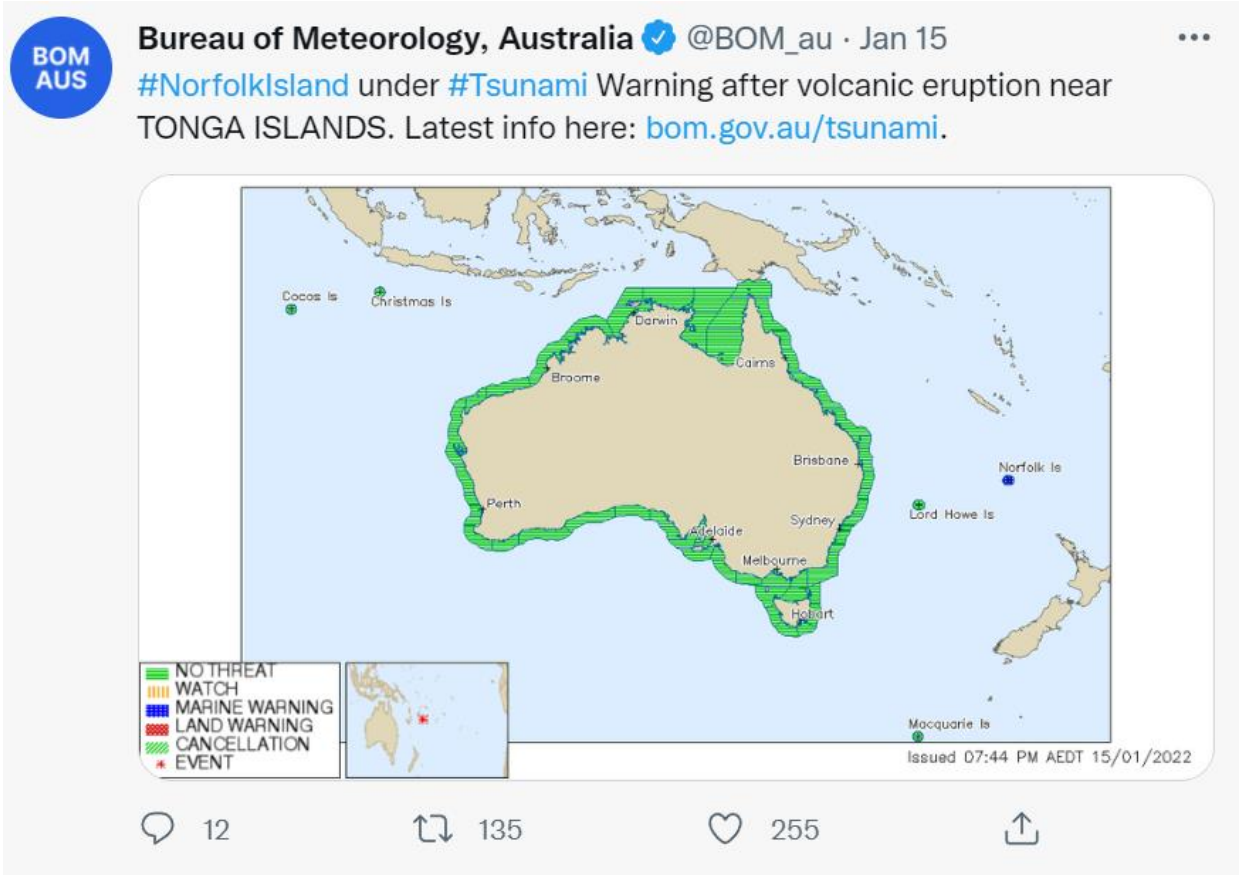
Luganville (Vanuatu)(200871) 1 Day Static Plot 7 Day Static Plot



Hunga Tonga-Hunga Ha'apai Volcano – Norfolk Island Warning

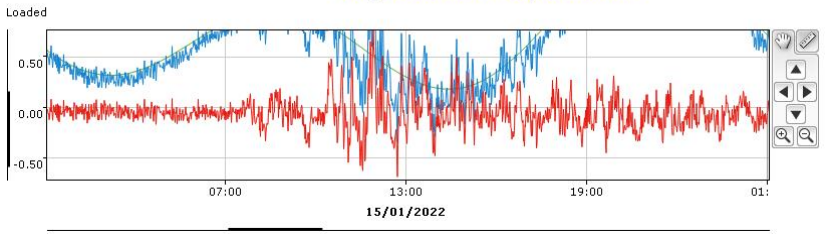


- Observed a 50cm tsunami at Norfolk Island
- Almost 3 hours after the No threat we issued a Marine Warning for Norfolk Island

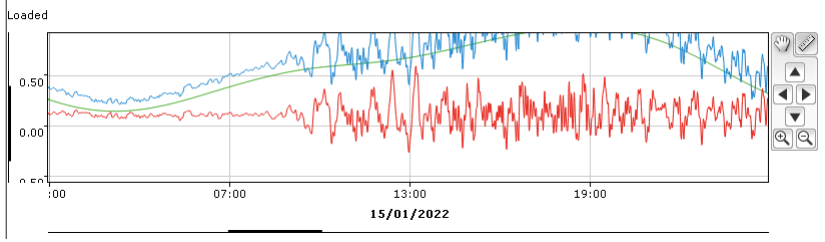


Hunga Tonga-Hunga Ha'apai Volcano – Updated Warnings

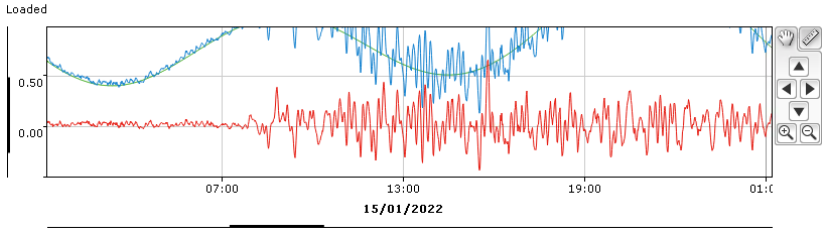
Gold Coast (QLD,Australia)(40987) 1 Day Static Plot 7 Day Static Plot



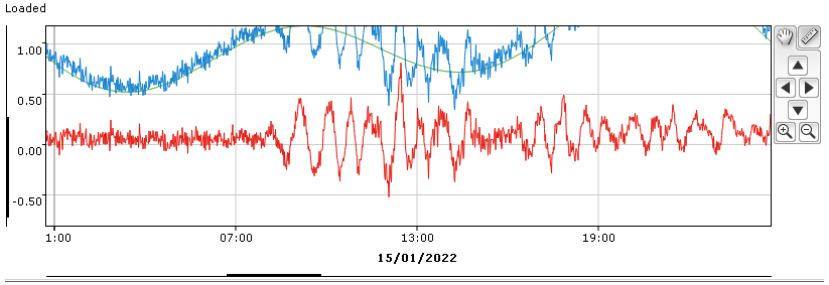
Southport (TAS,Australia)(94243) 1 Day Static Plot 7 Day Static Plot



Port Kembla (NSW,Australia)(68253) 1 Day Static Plot 7 Day Static Plot



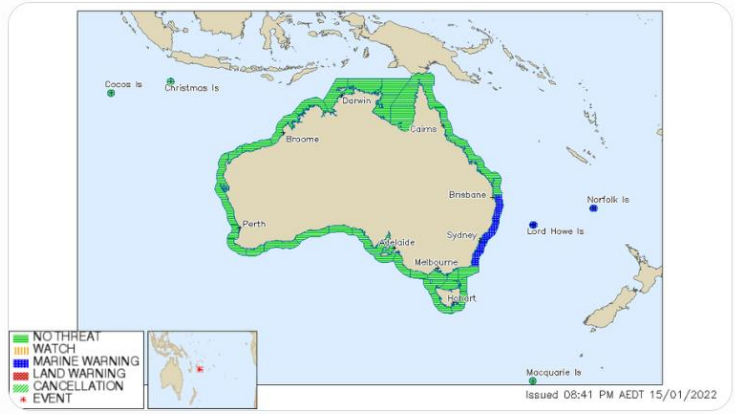
Twofold Bay (NSW,Australia)(69129) 1 Day Static Plot 7 Day Static Plot



- Rapid escalation of the situation resulted in Marine Threat issued for the SE coast of Australia and Land threat upgrade for Norfolk Island
- Based off tsunami tide gauge observations and travel time method
- Recognised a pattern of low observations that increase at closer locations
- Tsunami observed earlier than expected at Australian locations.

Bureau of Meteorology, Australia @BOM_au · Jan 15

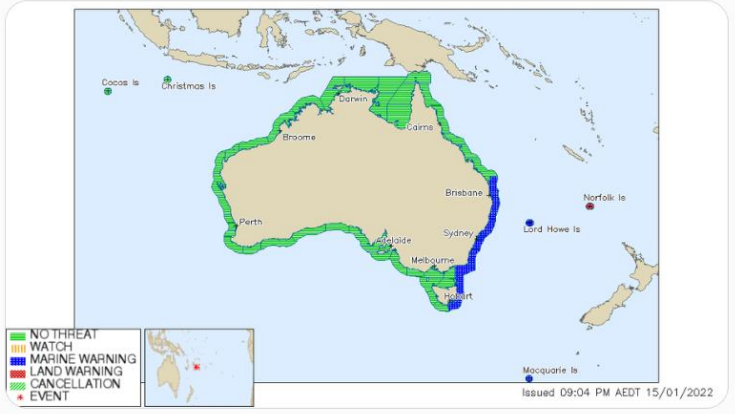
#NSW, #QLD, #LordHoweIsland, #NorfolkIsland under #Tsunami Warning after volcanic eruption near TONGA ISLANDS. Latest info here: bom.gov.au/tsunami.



23 564 648

Bureau of Meteorology, Australia @BOM_au · Jan 15

#NSW, #QLD, #TAS, #VIC, #LordHoweIsland, #MacquarieIsland, #NorfolkIsland under #Tsunami Warning after volcanic eruption near TONGA ISLANDS. Latest info here: bom.gov.au/tsunami.



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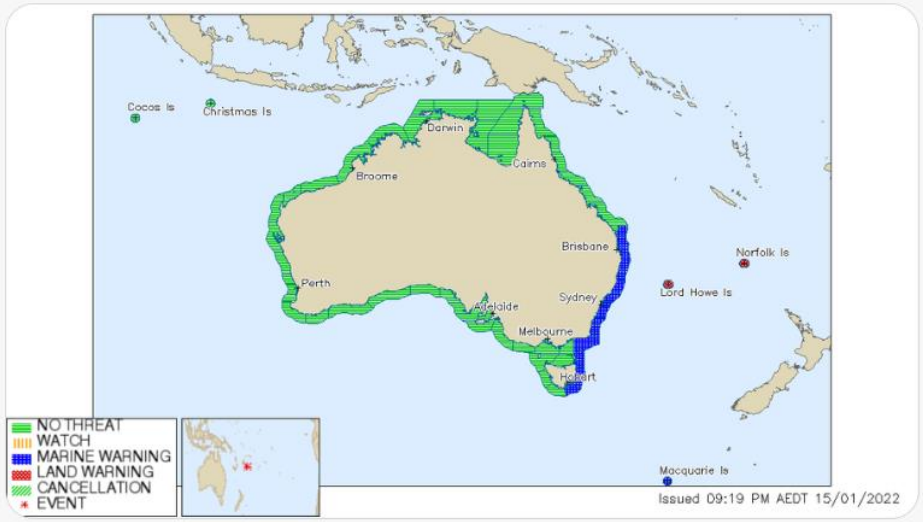
Hunga Tonga-Hunga Ha'apai Volcano – Evacuation Order for Lord Howe Island

- Land Threat based on Norfolk Island Observations and Bureau Observer reports at Lord Howe Island
- Evacuation Order lasted for ~ 13 hours
- Impacts at Lord Howe Island extended past the immediate foreshore but did not impact any structures

Bureau of Meteorology, Australia @BOM_au · Jan 15

Marine Threat to #NSW, #QLD, #TAS, #VIC, #MacquarieIsland. Land threat to #LordHoweIsland, #NorfolkIsland. #Tsunami Warning after volcanic eruption near TONGA ISLANDS. Latest info here: bom.gov.au/tsunami.



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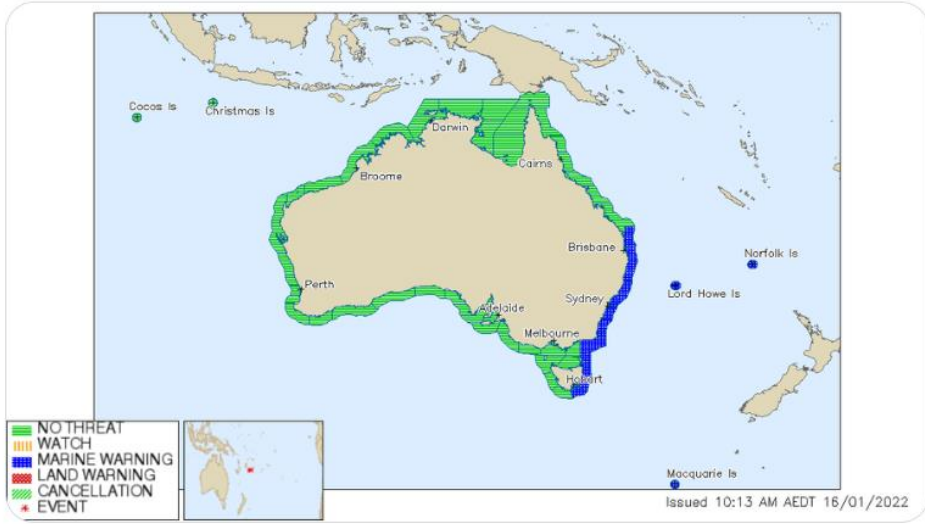
Bureau of Meteorology, Australia @BOM_au · Jan 16

#LordHoweIsland, #NorfolkIsland #Tsunami Warnings downgraded to Marine Threat. #NSW, #QLD, #TAS, #VIC, #MacquarieIsland #Tsunami Warnings unchanged at Marine Threat after volcanic eruption near the TONGA ISLANDS. Latest info here: bom.gov.au/tsunami.



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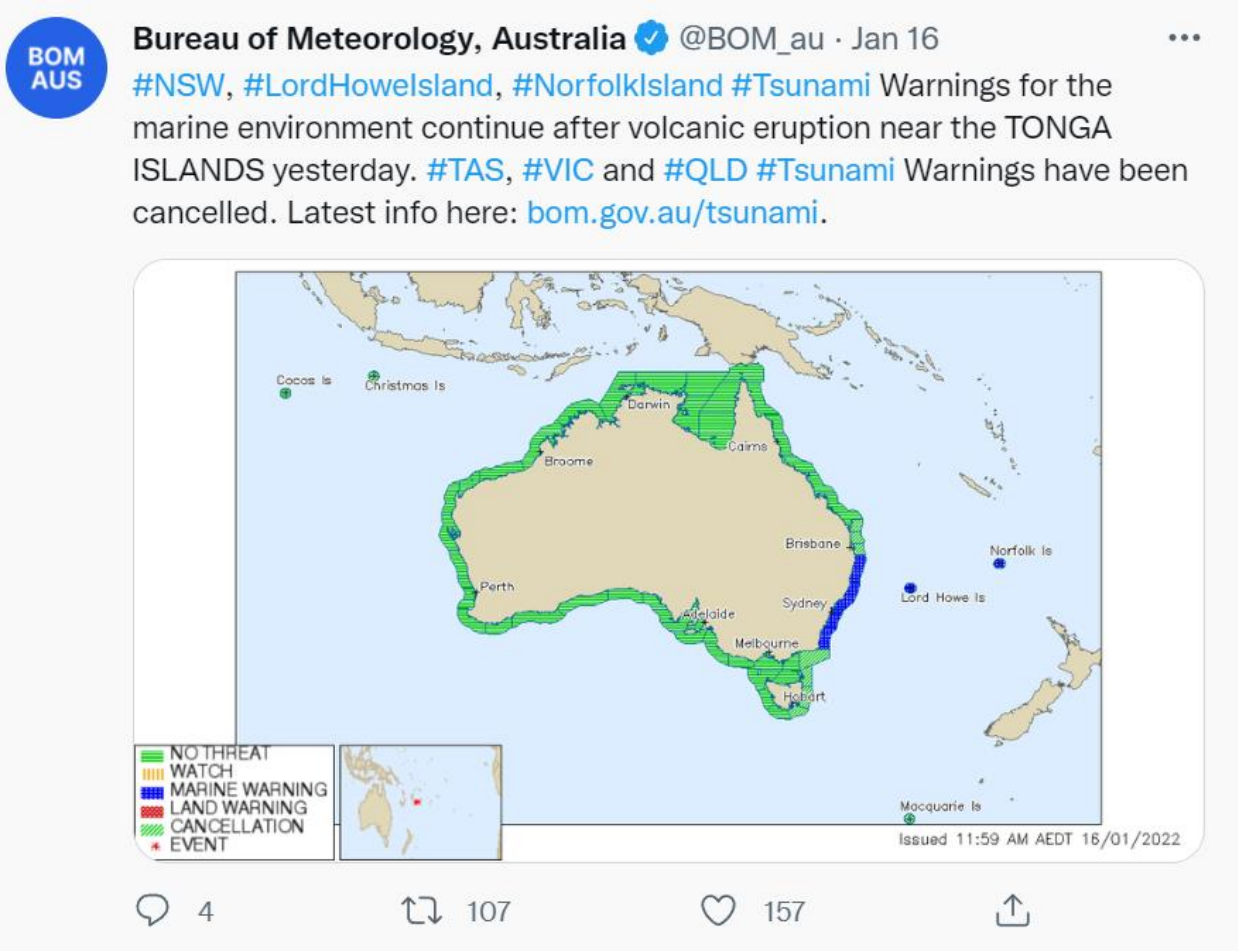
Hunga Tonga-Hunga Ha'apai Volcano – Cancelations



- Cancelled in consultation with emergency services.
- QLD, Macquarie Island, Victoria and Tasmanian marine warnings were cancelled ~19-20 hours after the eruption
- Lord Howe Island, Norfolk Island and NSW warnings were cancelled ~28-30 hours after the eruption.
- Tide gauge observations are useful but sparse
- In the case of NSW – observations at tide gauges had met the cancellation criteria but reports from NSW SES and Lifesaving NSW extended the warning period

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Intergovernmental
Oceanographic
Commission

THANK YOU

Dr Robert Greenwood
robert.greenwood@bom.gov.au