JMA's tsunami operation for tsunami genarated by volcanoes

Understanding and lessons learned from the tsunami generated by the Hunga Tonga-Hunga Ha'apai volcano eruption on 15 January 2022 for development of Tsunami Warning and Mitigation System for tsunamis generated by volcanoes and other non-seismic sources

Session 3: Lessons and learned on tsunami warning and mitigation

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8th Joint ICG/PTWS– IUGG/JTC Technical Workshop
in association with the ICG/PTWS sessions
11 September 2023
Nuku'alofa, Kingdom of Tonga

Outline

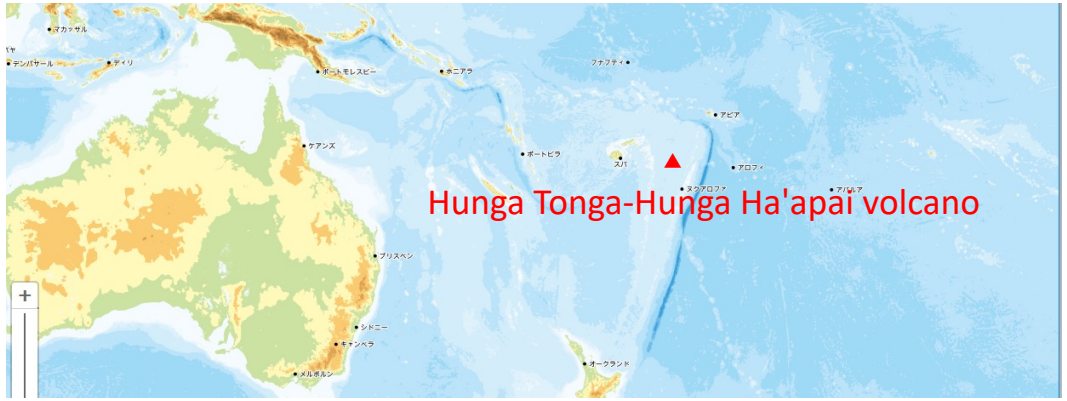
1. JMA's Response for the Sea Level Changes Triggered by the Tongan Eruption
2. Expert Advisory Panel on Tsunami Prediction
3. Expert Advisory Panel on Disaster Mitigation

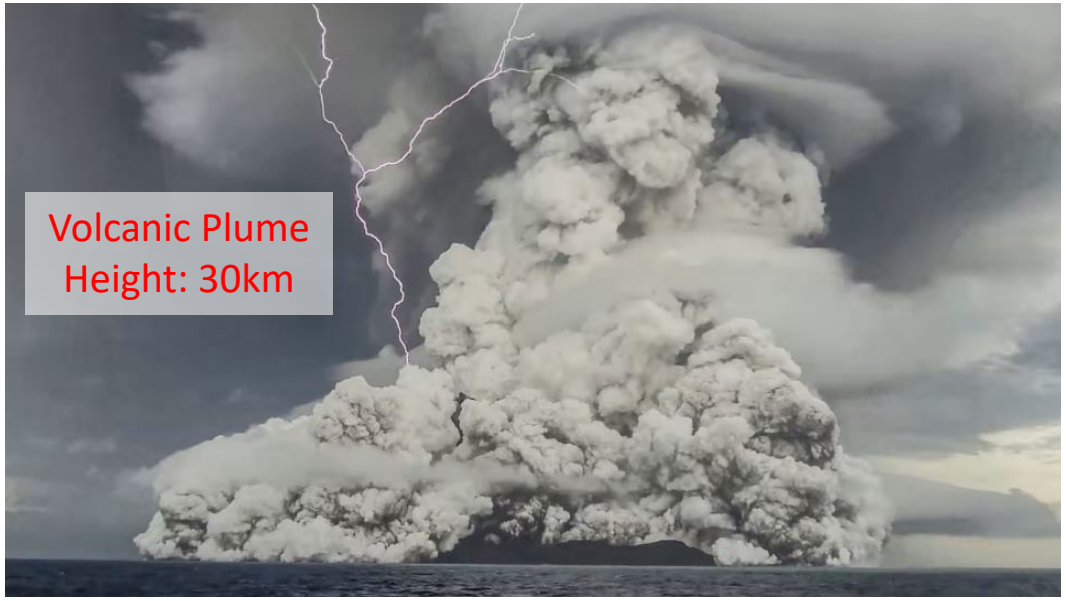
JMA's Response
for the Sea Level Changes Triggered by the Tongan Eruption

Eruption of Hunga Tonga-Hunga Ha'apai Volcano

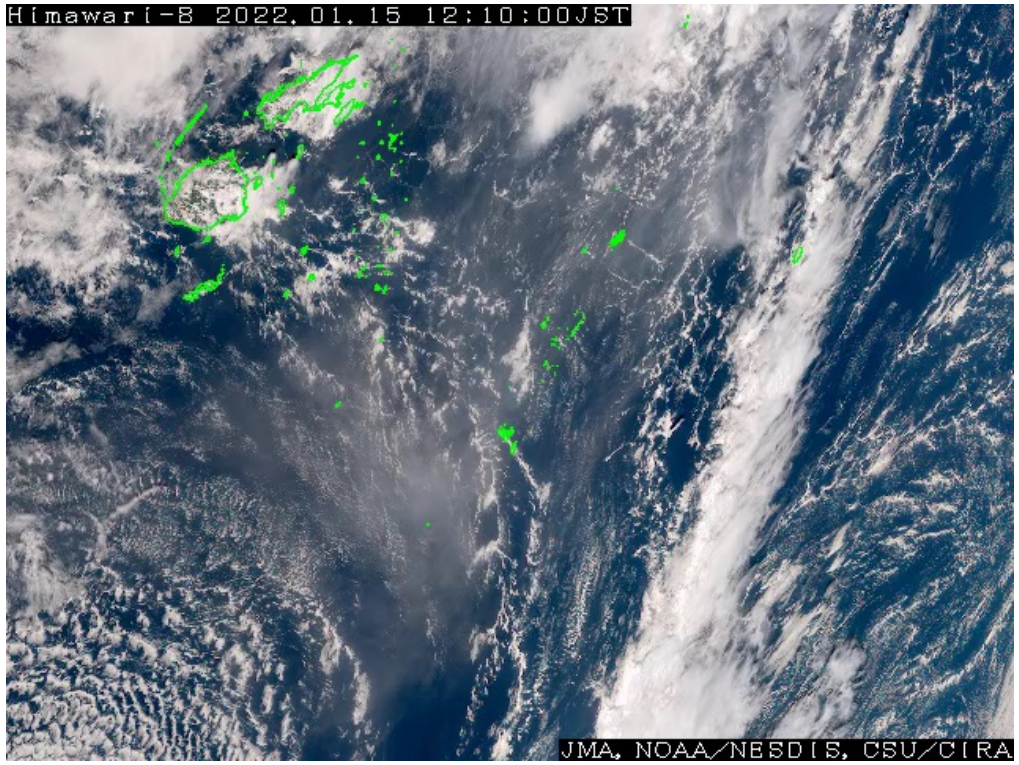
15 January 2022
Around 13:00(JST)

The Hunga Tonga-Hunga Ha'apai volcano erupted.





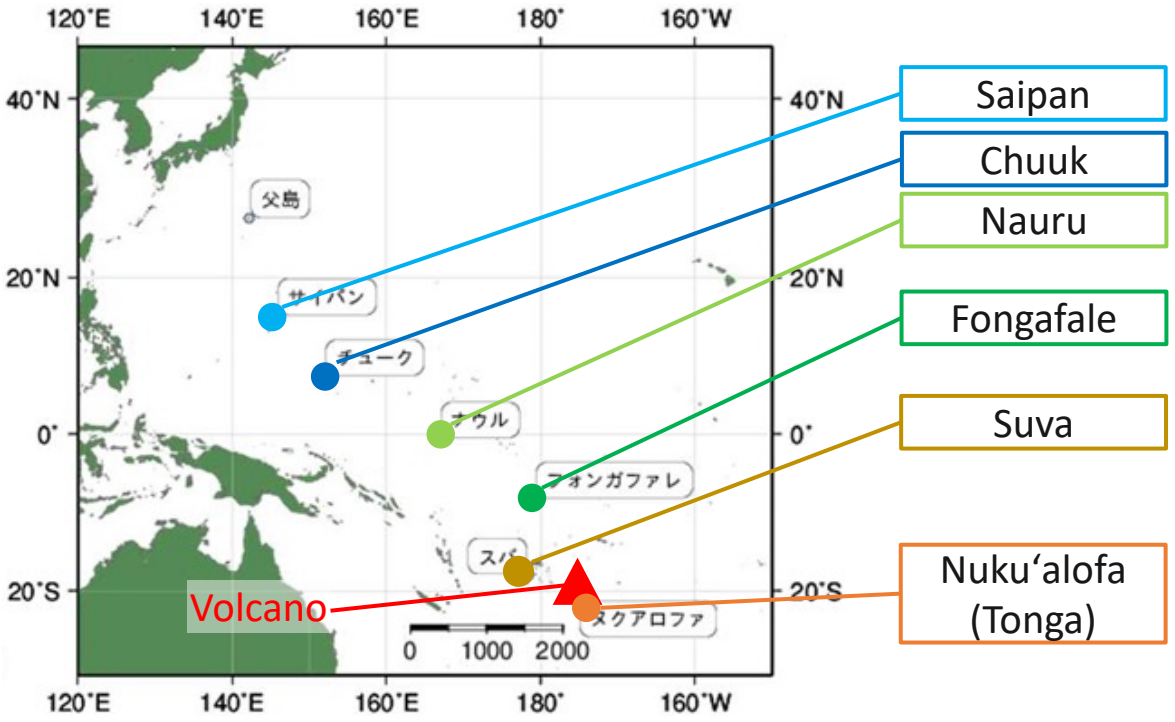
(Source: Asia.Nikkei.com)



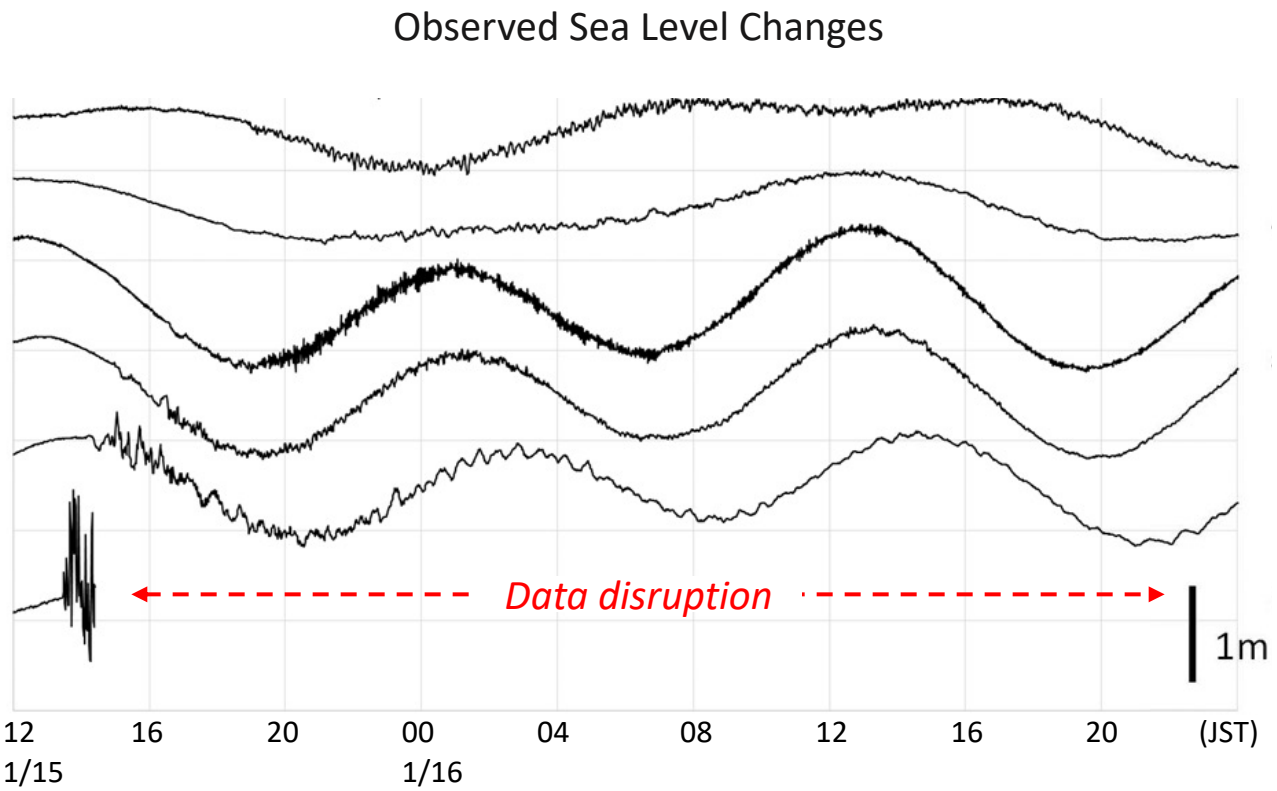
Himawari Satellite image

Observed Sea Level Changes

- ✓ Sea level changes of up to around 1.0 meter were observed in Tonga and its neighboring countries.
- ✓ Slight sea level changes were observed at the tsunami monitoring stations between Tonga and Japan.



Saipan
Chuuk
Nauru
Fongafale
Suva
Nuku‘alofa (Tonga)



Government of Japan
Japan Meteorological Agency

Tsunami Forecast

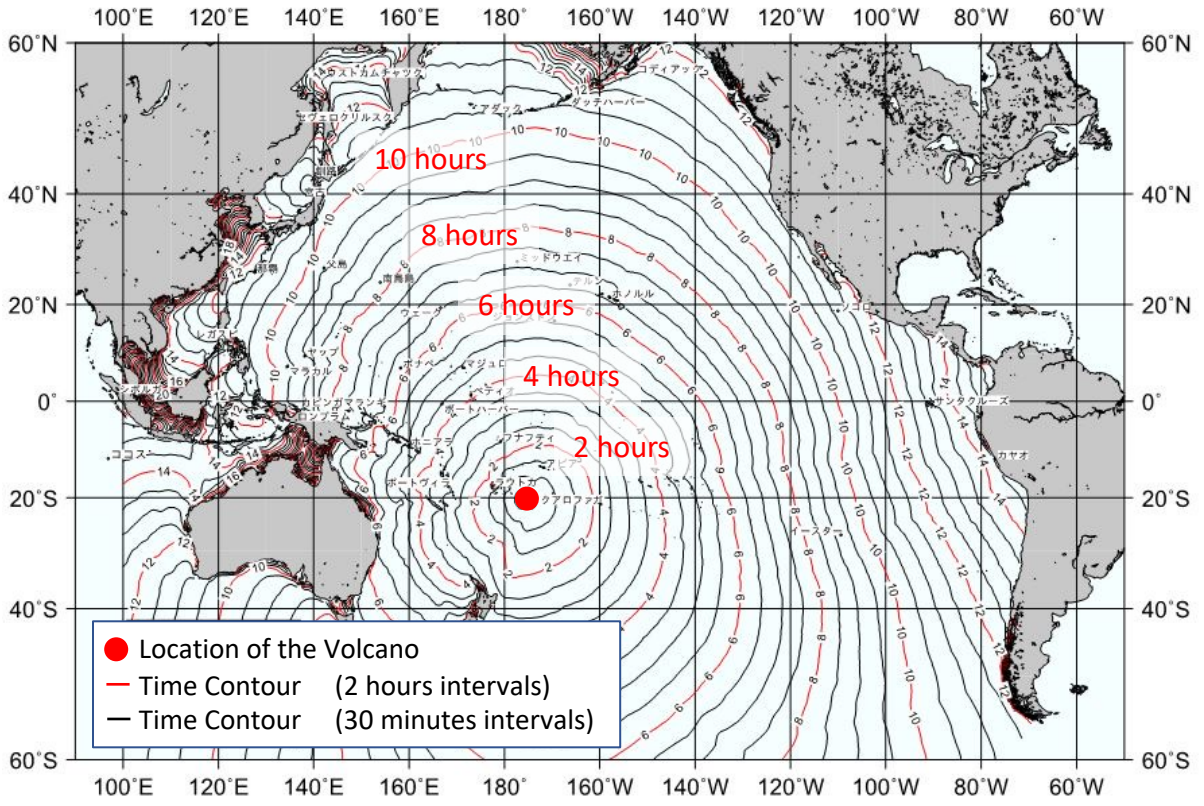
15 January 2022
19:03

Tsunami Forecast:

- Slight sea level changes (< 0.2 meter) with no damages are expected in Japan.
- No particular action is required.

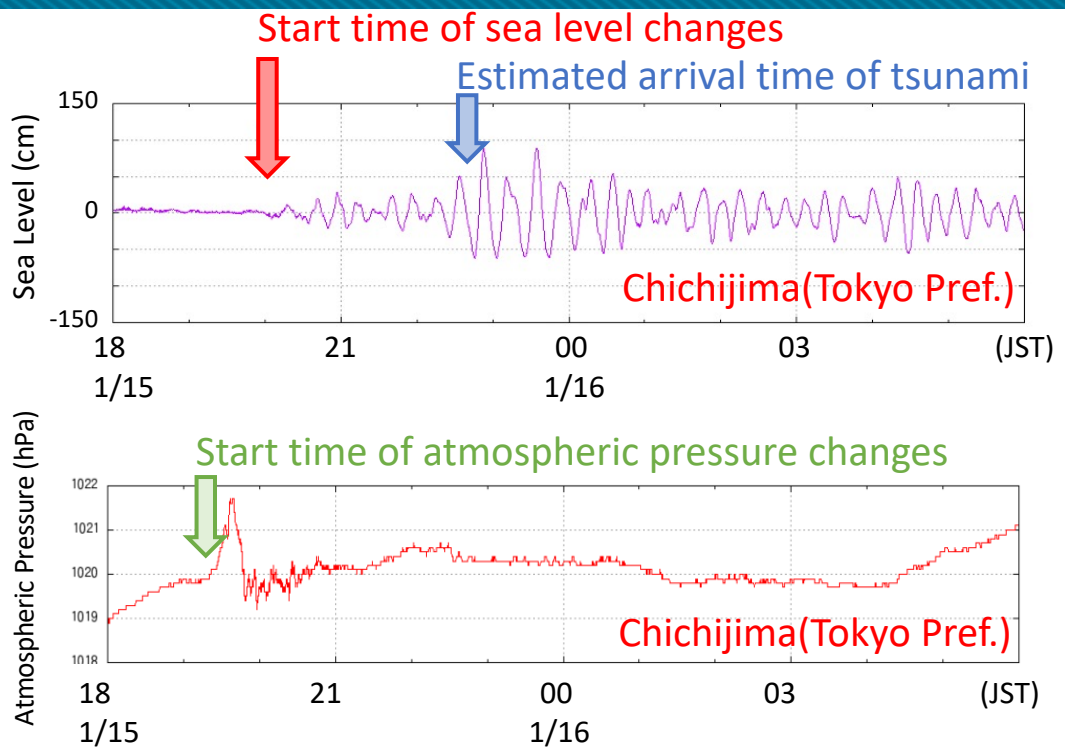
Category	Estimated tsunami heights	Action to be taken
Major Tsunami Warning	< 3.0m	Evacuate immediately to a safer place such as high ground or an evacuation building. Do not leave safe ground until the warning is lifted.
Tsunami Warning	1.0m - 3.0m	Evacuate immediately to a safer place such as high ground or an evacuation building. Tsunami waves are expected to hit repeatedly. Do not leave safe ground until the warning is lifted.
Tsunami Advisory	0.2 m - 1.0m	Get out of the water and leave coastal regions immediately. Due to the risk of ongoing strong currents, do not enter the sea or approach coastal regions until the advisory is lifted.
Tsunami Forecast	0.2 m <	No particular action is required.

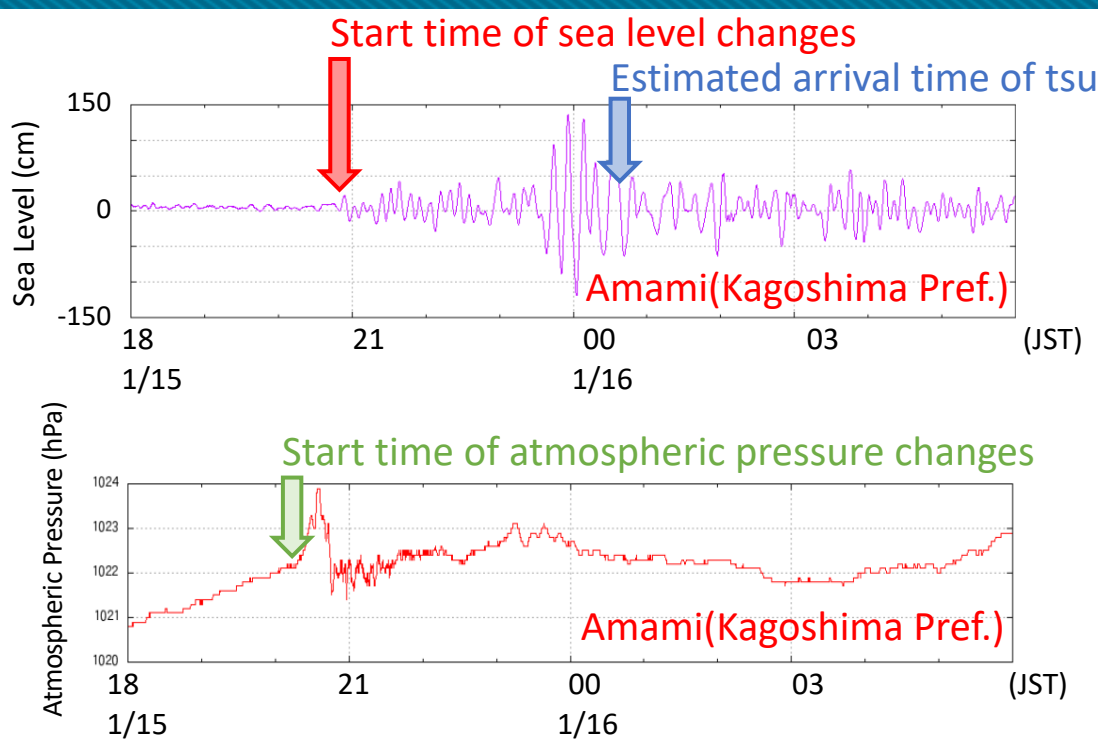
Simulation of Tsunami Propagation

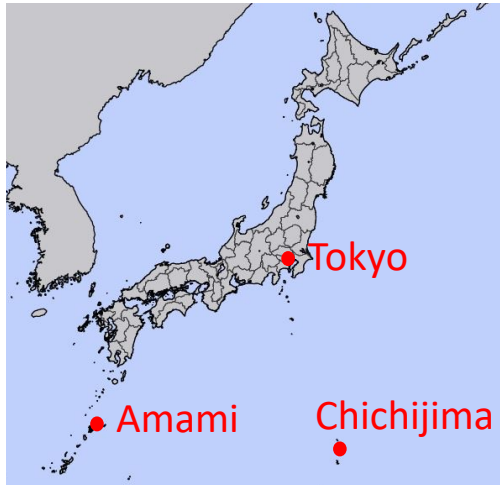


Government of Japan
Japan Meteorological Agency

Observed Sea Level Changes in Japan







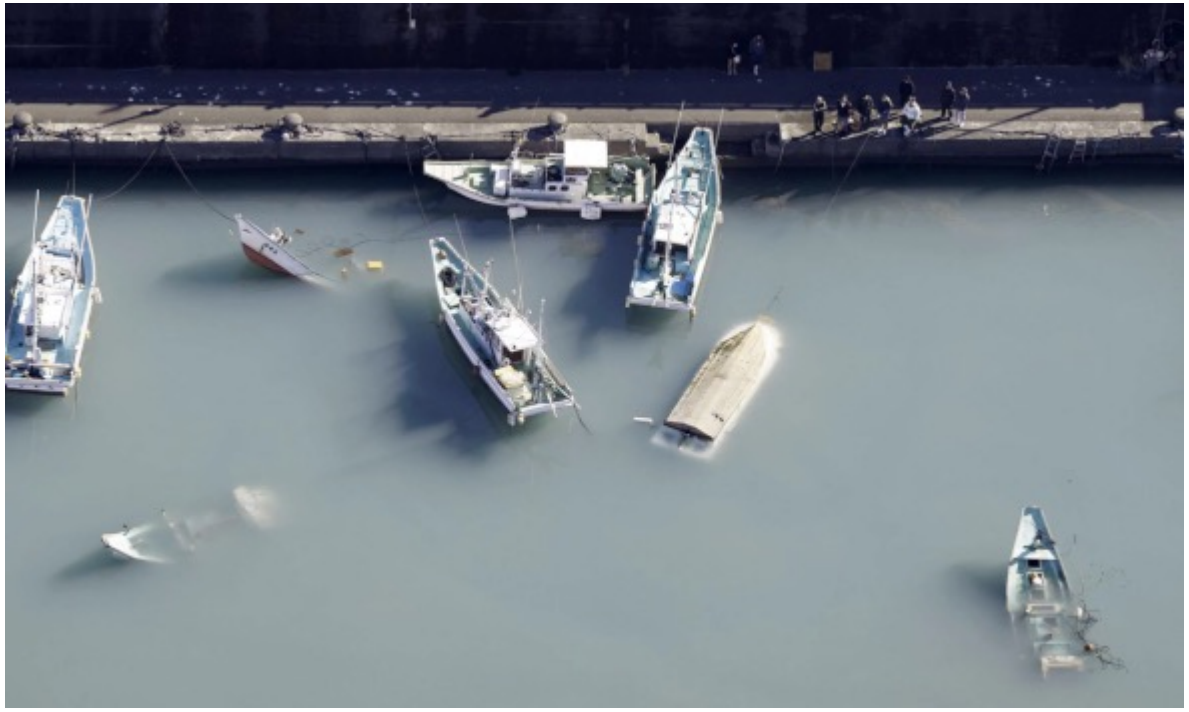
16 January 2022

00:15(JST) Tsunami warnings for Amami Islands and Tokara Islands
Tsunami advisories for the Pacific Coast of Japan

02:54 Tsunami warning for Iwate Prefecture

Impact/Damage in Japan

- ✓ In the coastal area where Tsunami Warnings were available:
  - Evacuation instructions* for 229,000 people
    **People are required to evacuate without exception.*
  - Suspension of train services and road closures
- ✓ Capsizing/sinking of small vessels and damages to fish farming facilities



Capsized fishing vessels at a port in Muroto, Kochi Prefecture (Source: Japan Times)

Damage to farming facilities in Toba, Mie Prefecture (Source: Yomiuri online)

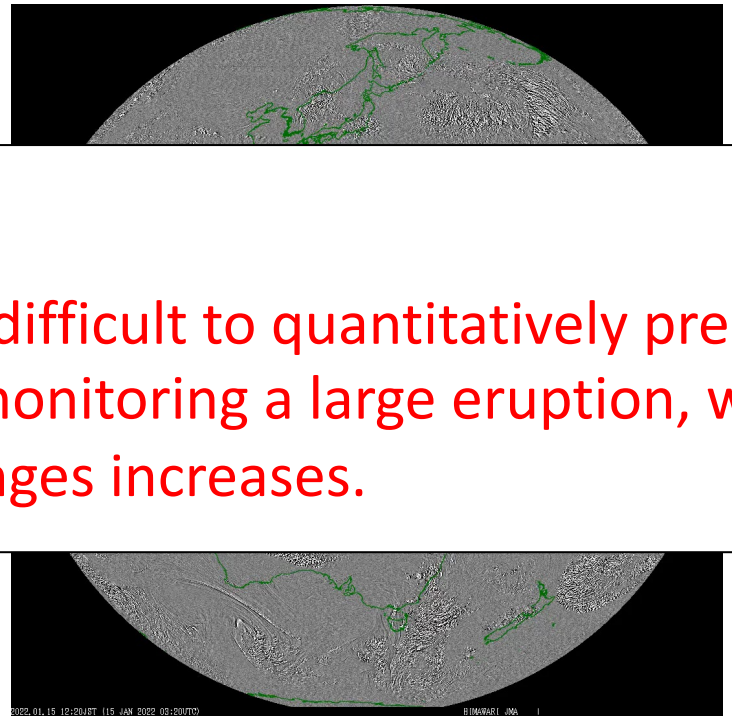
Expert Advisory Panel on Tsunami Prediction

Committee member : Scientist

Expert Advisory Panel on Tsunami Prediction

✓ The panel pointed out the following:

- The Tongan eruption generated massive atmospheric pressure waves that propagated around the globe.
- When the propagation speed of sea waves is comparable to that of atmospheric pressure waves, they can be strongly amplified.
- The observed sea level changes were amplified by the atmospheric pressure waves due to the eruption. But it is unclear how much the atmospheric pressure waves contributed to the sea level changes.



Visualized Image of Propagation of Changes in Brightness Temperature

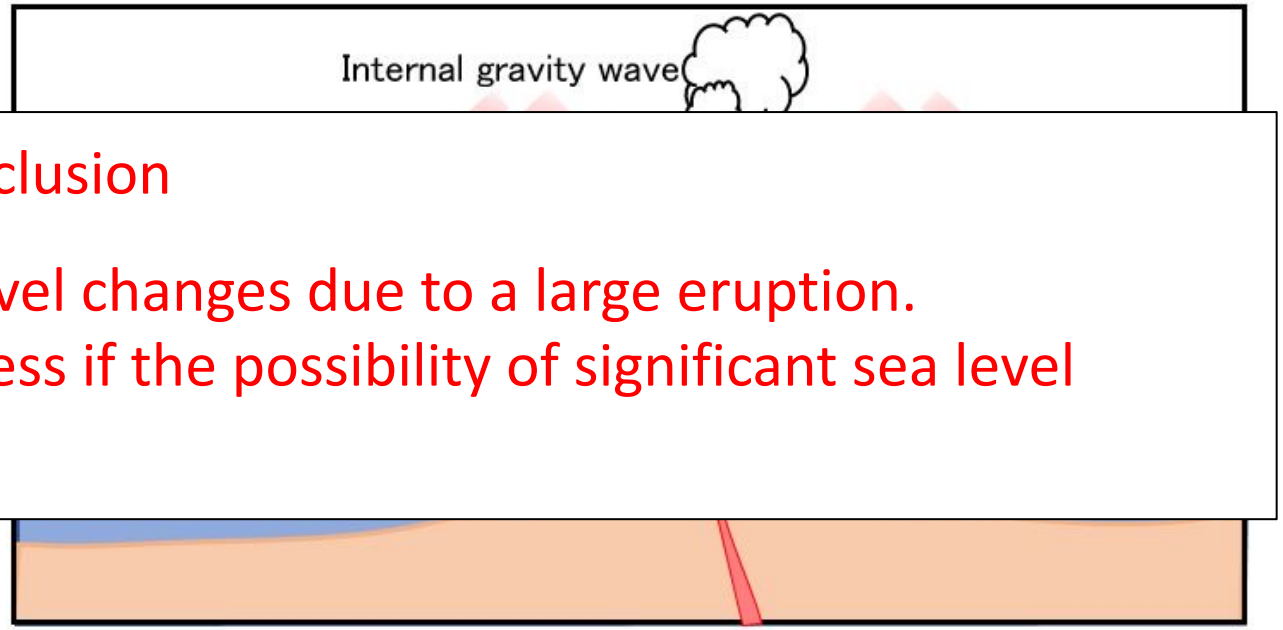


Image of how the sea level changes are amplified by atmospheric pressure waves

Conclusion

✓ It is difficult to quantitatively predict sea level changes due to a large eruption.

✓ By monitoring a large eruption, we can assess if the possibility of significant sea level changes increases.

Expert Advisory Panel on Tsunami Prediction
(on the previous page)

Expert Advisory Panel on Disaster Mitigation

Committee member : Scientist
Autonomous body (prefecture, city)
Press
Related ministries and agencies

Expert Advisory Panel on Disaster Mitigation

Task 1. From a point of view of disaster mitigation, what should JMA call these kinds of sea level changes triggered by an eruption?

- ✓ This kind of tsunami-like sea level change is called a “meteo-tsunami” or “meteorological tsunami” in academic community, but it’s not common.
- ✓ JMA should use terms in its information that people can easily understand.

JMA should call sea level changes triggered by an eruption “tsunamis” in its information so that people can easily understand it.

Expert Advisory Panel on Disaster Mitigation

Task 2. What kind of information should JMA use to call for vigilance against sea level changes triggered by a large eruption?

- ✓ In order to encourage the public to take action such as evacuation, JMA should issue warnings/advisories.
- ✓ It's not appropriate to create a new category of warnings/advisories for these kinds of very rare events.
- ✓ The responses for tsunamis can be applied similarly to responses for sea level changes triggered by volcanic eruptions.

JMA calls for vigilance against sea level changes due to a large eruption by using the mechanisms of tsunami warnings and tsunami advisories.

Expert Advisory Panel on Disaster Mitigation

Task 3. How should JMA inform the public of potential sea level changes before they arrive in Japan? And what is the right timing to issue information?

- JMA should inform the public of the following;
  - Possibility of sea level changes as soon as it detects a large eruption.
  - Arrival time of sea level changes estimated by simulation of Lamb wave propagation.
  - Sea level changes and barometric changes observed abroad.
- JMA should explain carefully the expected flow of information announcements before the sea level changes arrive in Japan.
- When sea level changes are observed in Japan, JMA should issue tsunami warnings/advisories based on their heights.

Available Data to Monitor Future Events

Sea Level Data

- Around 400 tsunami monitoring stations in Japan send real-time data to JMA.
- Under the framework of World Meteorological Organization(WMO) and UNESCO Inter-governmental Oceanographic Commission(IOC), real-time sea level data is exchanged globally.

Volcanic Ash Advisories(VAAs)

- Information on eruptions and volcanic ash clouds that may endanger aviation
- The International Civil Aviation Organization(ICAO) has created 9 Volcanic Ash Advisory Centers (VAACs) that monitor volcanos around the globe and issue a VAA immediately after an eruption.

Satellite Images of Brightness Temperature

- The JMA's satellite, Himawari is an effective tool to monitor changes in brightness temperature due to atmospheric pressure waves.
- It should be noted that analyzing satellite images takes a few hours after an eruption and that there are some rooms to improve estimation of volcanic plume height with high accuracy.

Atmospheric Pressure Data

- 155 meteorological observatories send real-time data in under 10 minutes intervals to JMA.
- Although atmospheric pressure data is exchanged globally under the framework of the WMO, the observation intervals are longer than periods of atmospheric pressure waves.

Operations for volcanic tsunamis

Case of a tsunami or barometric pressure caused by a large-scale volcanic eruption far from Japan is observed.

Large eruption occurred

a large-scale eruption with an eruption altitude of about 15,000 m or more was observed.

Information #1
・Large-scale eruption
・the estimated arrival time of a tsunami based on velocity of Lamb wave, etc.

Confirm clear change at brightness temperature on satellite image

Observe tsunami at overseas observation sites

Information #2
・Observation of tsunami overseas
・Clear barometric pressure wave analysis with satellite images

(Issuing information as things progress)

(as things progress)

Press Release
Explain the phenomena that are occurring, similar cases, scenarios for timing of information and precautions

Observe the tsunami at domestic site

Tsunami warning/advisory
(for observed area)

Observe the tsunami in various domestic sites

Tsunami warnings /advisories
(for each observed areas)

Thank you

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(Reference)

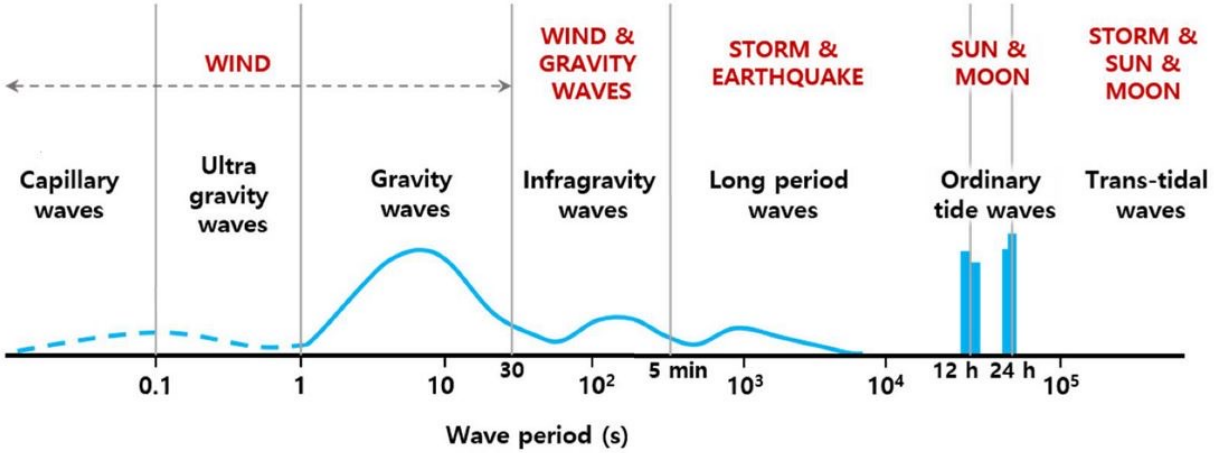
Past Eruptions with Sea Level Changes

Case	VEI	Eruption Pattern	Location	Atmospheric pressure change (distance from the volcano)	Sea level Change	
					Vicinity to the volcano	Over 1000km away
1883 Krakatau, Indonesia	6	Ultra Plinian	Undersea	85hPa Jakarta, Indonesia (150km) 45hPa Tokyo, Japan(6000km)	41m Merak, Indonesia 2.58m Batavia, Indonesia	0.18m San Francisco 0.14m Honolulu Slight changes Japan
1956 Bezymianny, Russia	5	Sector collapse	Inland	23.5hPa (45km) 7.5hPa (120km) 1hPa (1100km)	1.4m damming due to landslide 0.1m river mouth(100km)	0.3m* Kahului, Hawaii 0.2m* Avila Beach, California 0.1m* Chuuk, Micronesia * Low reliability
1980 St.Helens, USA	5	Sector collapse	Inland	0.1hPa Tokyo, Japan (7000km)	260m in a lake	—
2022 Hunga Tonga-Hunga Ha'apai	5~6?	Plinian ?	Undersea	2hPa Chichijima, Japan (7000km)	0.82m Nuku'alofa(Tonga) * Data disruption	1.3m Amami, Japan (8000km)

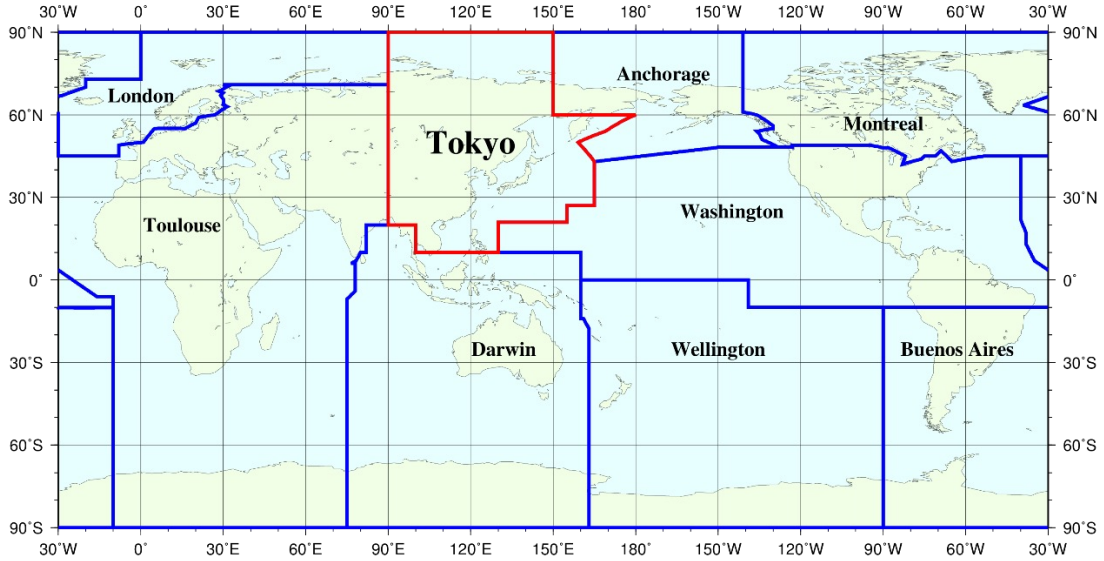
VEI	1	2	3	4	5	6	7	8
Scale	Non explosive	Small	Moderate		Large		Very large	
Erupted tephra volume	0.00001 km^3	0.001 km^3	0.01 km^3	0. 1 km^3	1 km^3	10 km^3	100 km^3	1,000 km^3

(Reference)

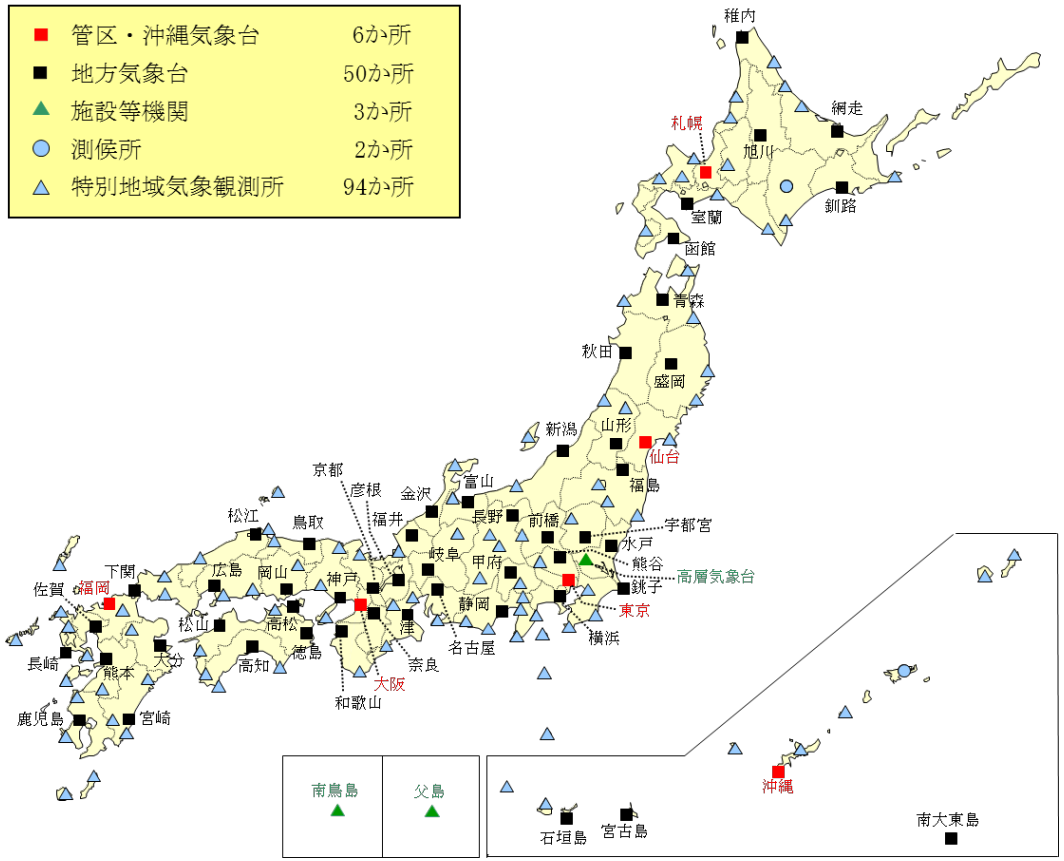
Classification of the spectrum of ocean waves according to wave period



Area of Responsibility of each VAAC

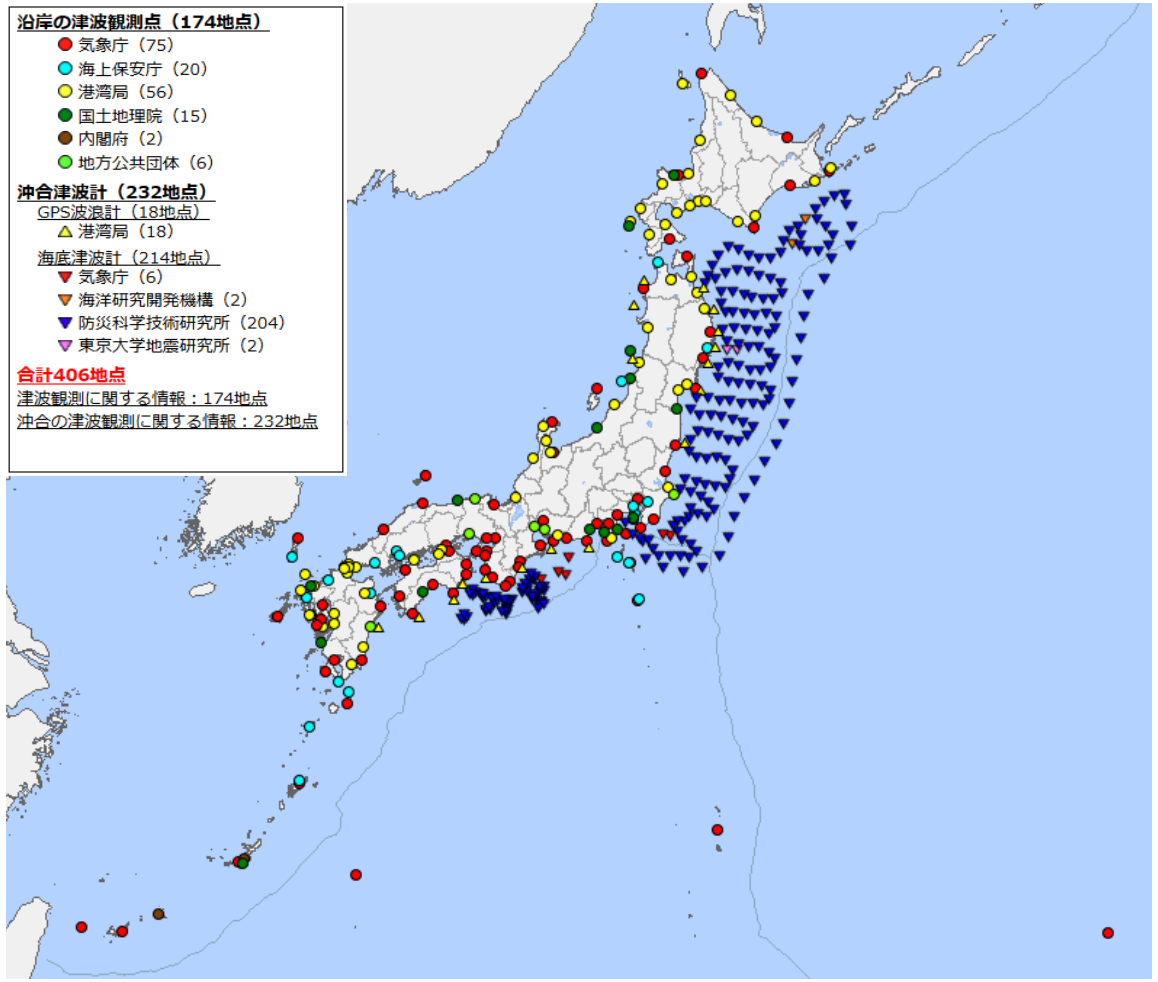


Atmospheric pressure stations in Japan

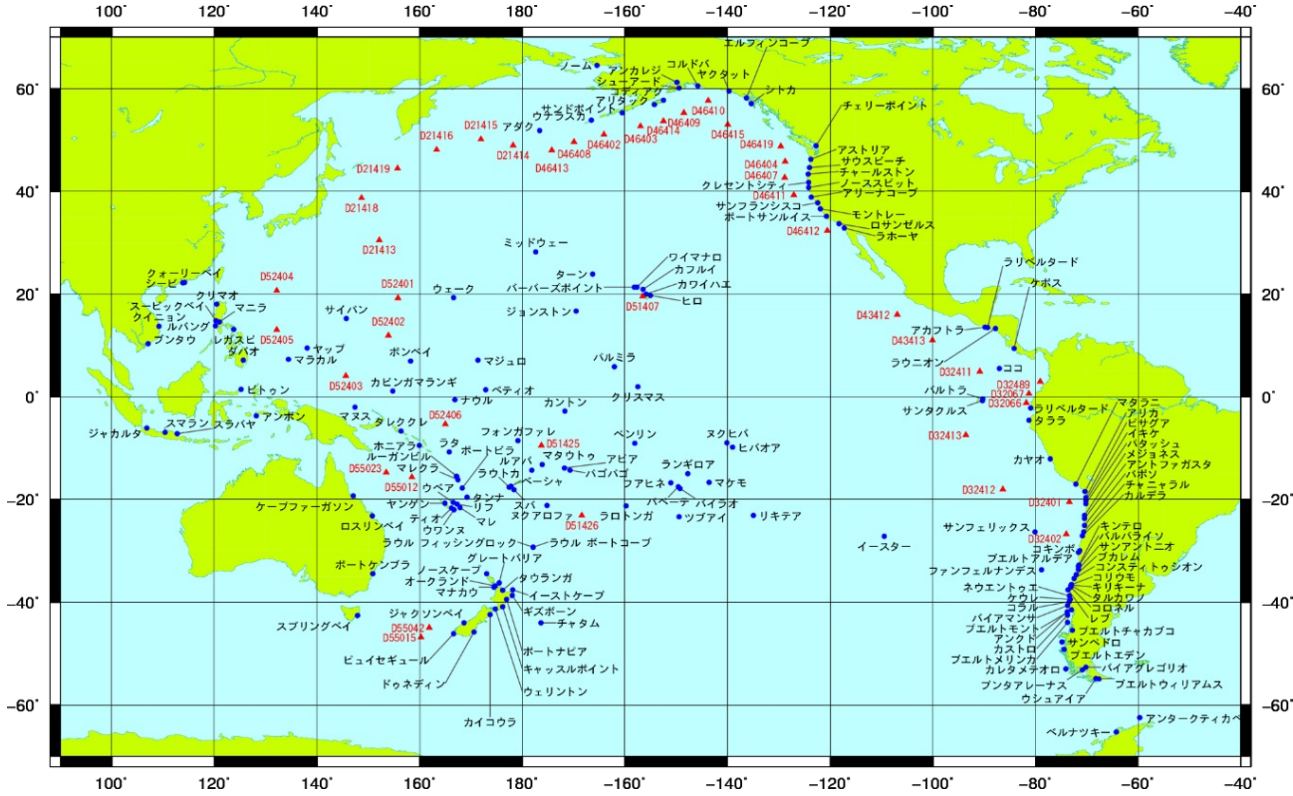


(Reference)

Tsunami monitoring stations in Japan



Tsunami monitoring stations around the globe



(Reference)

Annual number of volcanic ash plumes by altitude reported by VAAC from August 2011 to July 2023

Plume height (obs)	2011 (May～)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023 （～Jul）	Sum
≧50,000 ft	3	0	1	5	2	0	2	5	11	4	3	5	2	43
≧45,000 ft	7	2	3	8	3	1	2	10	11	7	4	6	2	66
≧40,000 ft	10	6	6	10	6	2	11	12	15	8	16	8	6	116
≧35,000 ft	17	13	10	16	13	9	19	17	21	11	25	12	11	194
≧30,000 ft	20	19	14	21	19	16	31	25	27	14	27	21	24	278

(Reference)

Cases of issuing tsunami warnings, advisories and/or information
against sea level changes due to a major eruption following the HTHP event

Date	Volcano（Country）	Plume height above sea level (based on VAAC information)	Issued warnings, advisories and/or information
2022/03/08	Manam（Independent State of Papua New Guinea）	50,000 ft	Information (No tsunami impact on Japan)
2022/05/28	Bezymianny（Russian Federation）	50,000 ft	Information (No tsunami impact on Japan)
2022/12/04	Semeru（Republic of Indonesia）	50,000 ft	Information (No tsunami impact on Japan)
2023/04/10	Sheveluch（Russian Federation）	52,000 ft	Information (No tsunami impact on Japan)