Assessing volcanic ash hazard: Where are we and where are we going?

Paul A. Jarvis

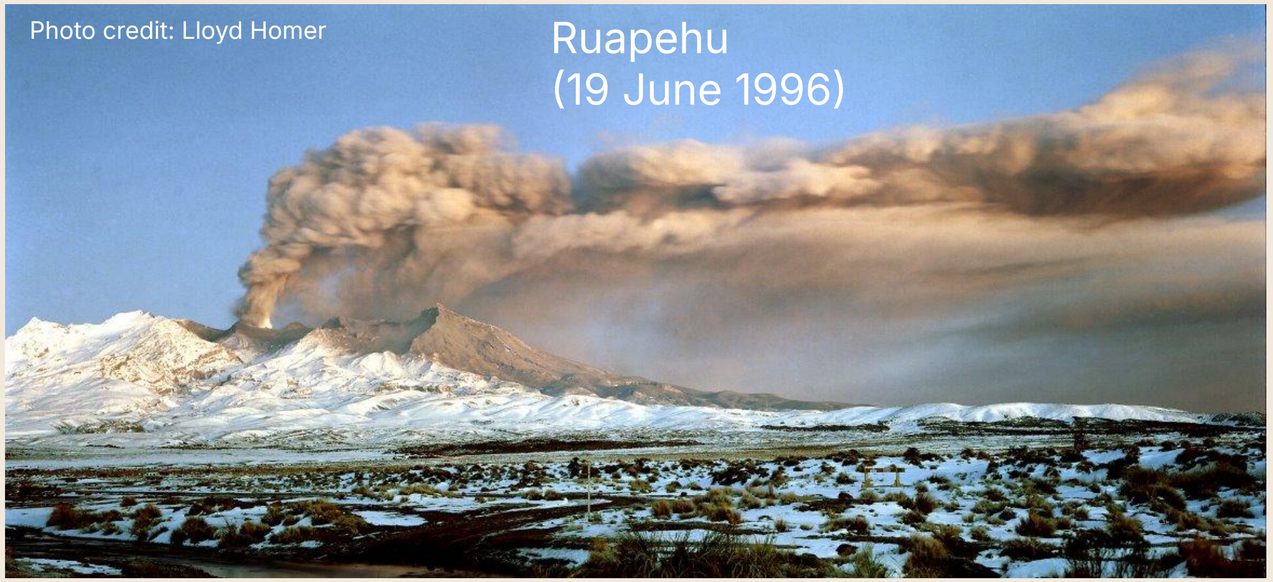
p.jarvis@gns.cri.nz

GNS SCIENCE TE PŪ AO

21/02/2025

Summary

1. Volcanoes in Aotearoa New Zealand
2. The role of GNS Science and GeoNet
3. Assessing volcanic ash hazard – The now
4. Assessing volcanic ash hazard – The future



Volcanoes in Aotearoa New Zealand

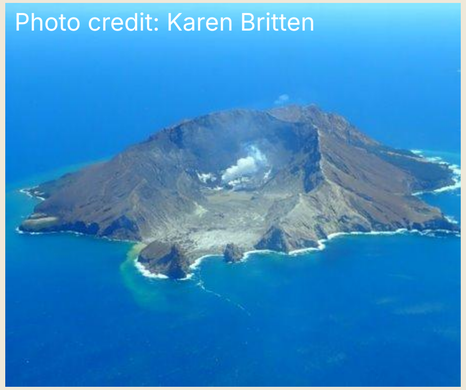


Photo credit: Karen Britten

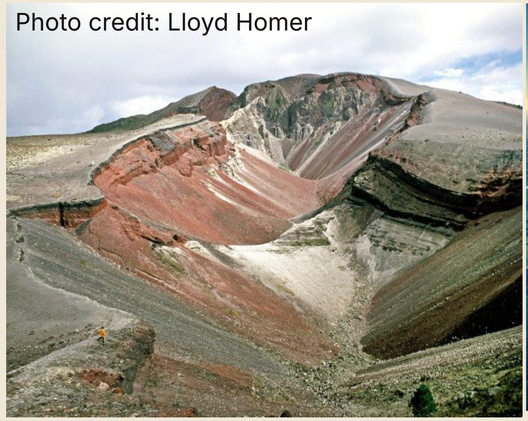


Photo credit: Lloyd Homer


Credit: Dougal Townsend


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Photo credit: Brad Scott

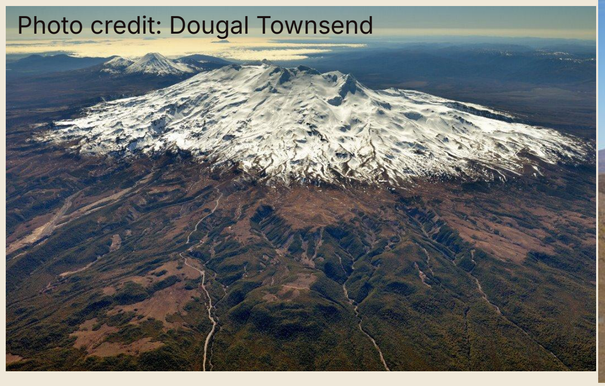
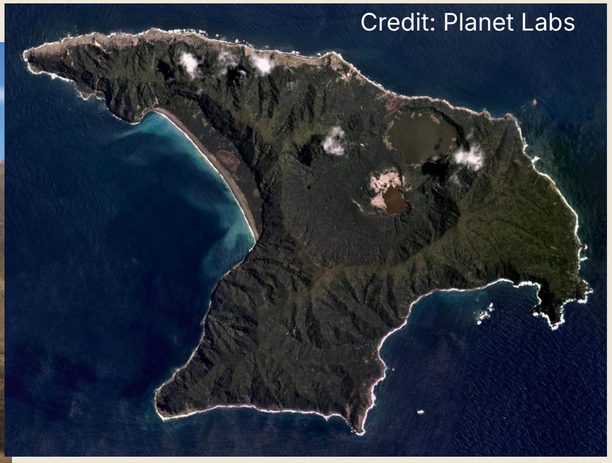


Photo credit: Dougal Townsend


Photo credit: Agnes Mazot


Credit: Planet Labs

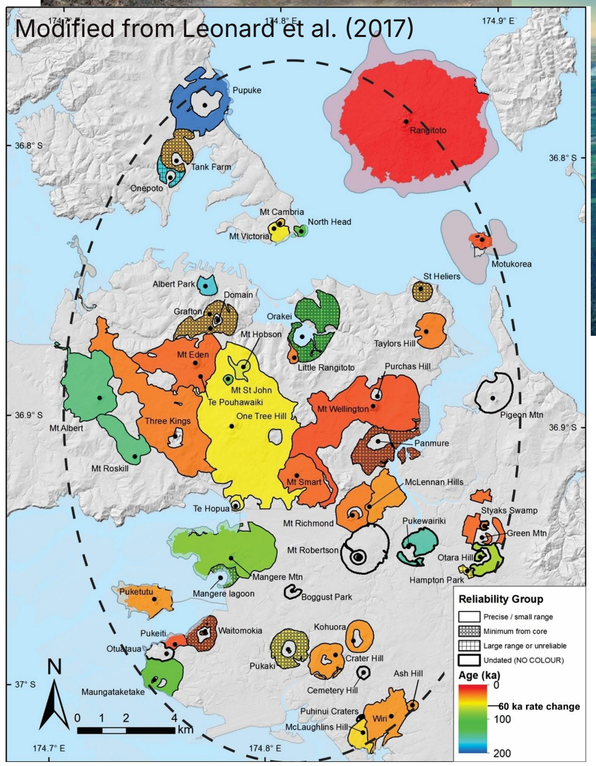
Volcanism in Aotearoa New Zealand

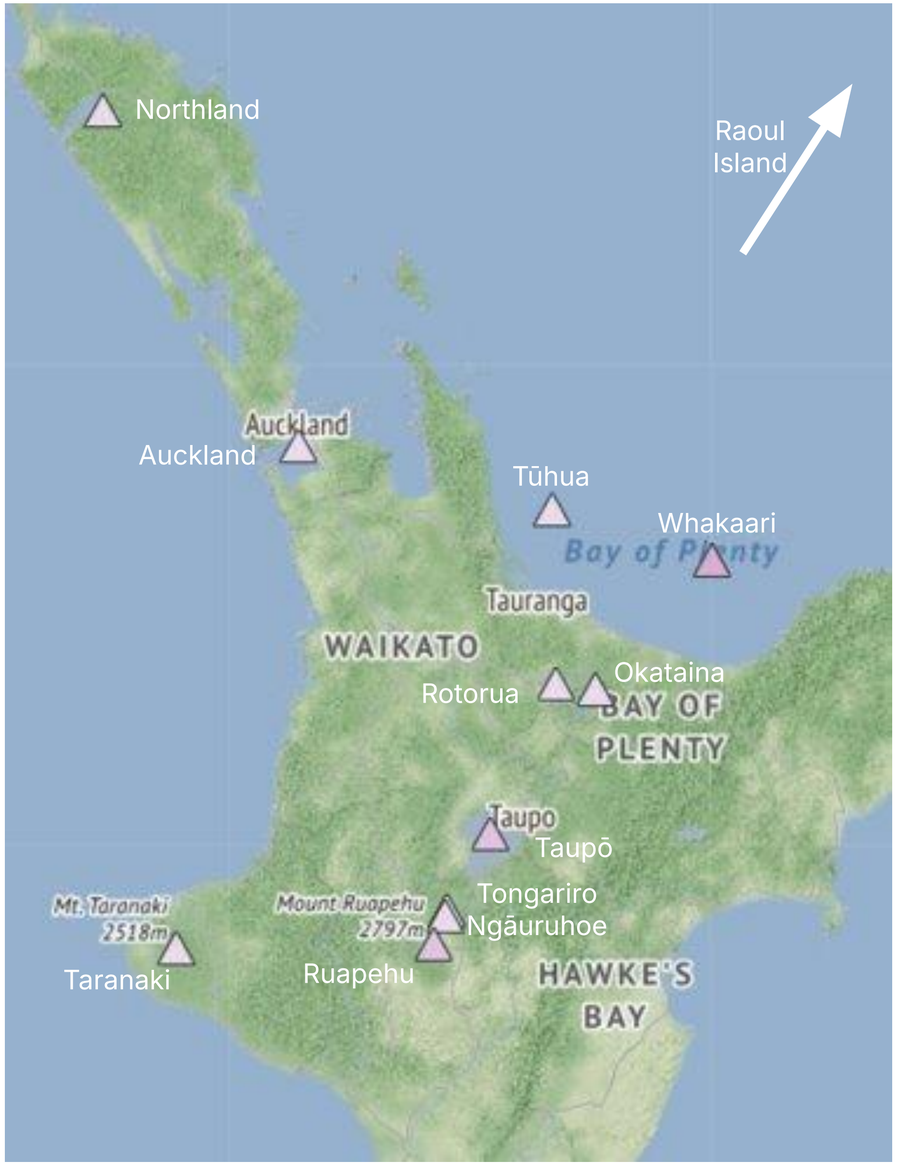
GNS Science monitor and set alert levels for 12 volcanoes in NZ

Cone volcanoes:
- Whakaari White Island
- Ruapehu
- Tongariro
- Ngauruhoe
- Taranaki

Calderas:
- Taupō
- Okataina
- Rotorua
- Tūhua Mayor Island
- Raoul Island

Volcanic fields:
- Auckland
- Northland





The role of GNS Science and GeoNet

What do GNS do?

GNS Science monitor NZ's geohazards through the GeoNet programme:

- **Volcano**
- Earthquake
- Tsunami
- Landslide

We **monitor volcanoes** using:

- Seismometers
- GPS stations
- Cameras
- Gas/fluid sampling geochemistry
- Satellite observations (in collaboration with MetService)

Volcano Monitoring Group (VMG) responsible for day-to-day monitoring operations

To facilitate response to changes in volcanic activity:

- 24/7 National Geohazards Monitoring Centre (NGMC)
- On-call Volcano Duty Officer (VDO)
- Volcano Science Advisor (VSA)

Based on monitoring, **issue scientific advice** to government, emergency management, key partners and public

Volcano advice products

We provide updates on NZ volcanic activity through the following products:

- Volcanic Alert Levels (VALs)
- Aviation Colour Codes (ACCs)

- Volcano Activity Bulletins (VABs)
- Volcano Observatory Notice to Aviation (VONA)

- Ashfall forecasts

No more volcanic ash observed in ongoing steam and gas plumes at Whakaari. Volcanic Alert Level remains at 2 and Aviation Colour Code lowered to Yellow.

Published: Mon Feb 10 2025 12:30 PM

Volcanic Activity Bulletin

VOLCANIC ACTIVITY BULLETIN **WI - 2025/03**

Mon Feb 10 2025 12:30 PM; Whakaari/White Island Volcano

Volcanic Alert Level remains at 2

Aviation Colour Code is lowered to **Yellow**

VOLCANO OBSERVATORY NOTICE FOR AVIATION (VONA)

Item No	Element	Content
1	**Message title**	**VOLCANO OBSERVATORY NOTICE FOR AVIATION**
2	**Issued**:	20250210/2300Z
3	**Volcano:**	White Island 241040
4	**Current Aviation Color Code**:	Yellow
5	**Previous Aviation Color Code**:	Orange
6	**Source**:	GNS Science, New Zealand
7	**Notice Number**:	NZ VONA 2025/02
8	**Volcano Location**:	37 31S 177 11E
9	**Area**:	Whakaari White Island – off the north coast of the North Island of New Zealand.
10	**Summit Elevation**:	1053FT
11	**Volcanic Activity Summary**:	No ash emission visible from webcam and satellite imagery.
12	**Volcanic Cloud Height**:	2000 ft
13	**Other Volcanic Cloud information:**	Weak steam and gas plume.
14	**Remarks**:	Volcanic monitoring capability is degraded.
15	**Contacts**:	Duty Volcanologist, +6473748211ph.
16	**Next Notice**:	Will be issued when conditions at the volcano warrant changing the aviation color code or when a significant volcanic event occurs within the current color code.

New Zealand Volcanic Alert Level System

	Volcanic Alert Level	Volcanic Activity	Most Likely Hazards
Eruption	5	Major volcanic eruption	Eruption hazards on and beyond volcano*
	4	Moderate volcanic eruption	Eruption hazards on and near volcano*
	3	Minor volcanic eruption	Eruption hazards near vent*
Unrest	2	Moderate to heightened volcanic unrest	Volcanic unrest hazards, potential for eruption hazards
	1	Minor volcanic unrest	Volcanic unrest hazards
	0	No volcanic unrest	Volcanic environment hazards

An eruption may occur at any level, and levels may not move in sequence as activity can change rapidly.

Eruption hazards depend on the volcano and eruption style, and may include explosions, ballistics (flying rocks), pyroclastic density currents (fast moving hot ash clouds), lava flows, lava domes, landslides, ash, volcanic gases, lightning, lahars (mudflows), tsunami, and/or earthquakes.

Volcanic unrest hazards occur on and near the volcano, and may include steam eruptions, volcanic gases, earthquakes, landslides, uplift, subsidence, changes to hot springs, and/or lahars (mudflows).

Volcanic environment hazards may include hydrothermal activity, earthquakes, landslides, volcanic gases, and/or lahars (mudflows).

***Ash, lava flow, and lahar (mudflow) hazards may impact areas distant from the volcano.**

This system applies to all of New Zealand's volcanoes. The Volcanic Alert Level is set by GNS Science, based on the level of volcanic activity. For more information, see geonet.org.nz/volcano for alert levels and current volcanic activity, gns.cri.nz/volcano for volcanic hazards, and getthru.govt.nz for what to do before, during and after volcanic activity. Version 3.0, 2014.

ICAO Colour Code	Status of activity of volcano
GREEN	Volcano is in normal, non-eruptive state. *or, after a change from a higher level*: Volcanic activity considered to have ceased, and volcano reverted to its normal, non-eruptive state.
YELLOW	Volcano is experiencing signs of elevated unrest above known background levels. *or, after a change from higher alert level* : Volcanic activity has decreased significantly but continues to be closely monitored for possible renewed increase.
ORANGE	Volcano is exhibiting heightened unrest with increased likelihood of eruption. *or*, Volcanic eruption is underway with no or minor ash emission. *[specify ash-plume height if possible].*
RED	Eruption is forecasted to be imminent with significant emission of ash into the atmosphere likely. *or*, Eruption is underway with significant emission of ash into the atmosphere. *[specify ash-plume height if possible].*

Volcanic Alert Levels (VALs)

Currently:

Whakaari/White Island	2
Ruapehu	1

All other volcanoes at 0
Taupō, Ngauruhoe have previously been at 1 since current system established in 2014

VAL is set by:

- A weekly vote among the VMG
- VDO after discussion with VSA, if no time for a vote
- VDO alone in case of immediate risk to life safety

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Find all current VALs at geonet.org.nz/volcano or on the GeoNet app!

For Android:

For Apple:

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Currently:

Whakaari/White Island	**Yellow**

All other volcanoes at green

Defined by the International Civil Aviation Organisation (ICAO)

For aviation information only

Volcano Activity Bulletins (VABs)

NZ's official source of volcano status information
Issued:

- If VAL or ACC changes
- To provide a general update
  - Summarise volcano status and recent events
  - Increasing, decreasing or steady state activity
- Can contain forecasts, e.g., ash forecasts

Can be found at https://www.geonet.org.nz/volcano/vab or the GeoNet app*!

*can get notifications

No more volcanic ash observed in ongoing steam and gas plumes at Whakaari. Volcanic Alert Level remains at 2 and Aviation Colour Code lowered to Yellow.

Published: Mon Feb 10 2025 12:30 PM

Volcanic Activity Bulletin

VOLCANIC ACTIVITY BULLETIN **WI - 2025/03**
Mon Feb 10 2025 12:30 PM; Whakaari/White Island Volcano
Volcanic Alert Level remains at 2
Aviation Colour Code is lowered to **Yellow**

Whakaari / White Island continues to passively emit weak-to-moderate steam and gas plumes. No volcanic ash has been observed in the plume recently. The Volcanic Alert Level remains at 2 and the Aviation Colour Code is lowered to Yellow.

Activity at Whakaari / White Island is dominated by weak-to-moderate steam and gas plumes, as seen on our webcams at Whakatāne and Te Kaha, as well as on satellite imagery. Unlike what we've observed since late December when ash was regularly present in the steam and gas plumes, volcanic ash has not been observed during the past week.

Sometimes larger plumes are seen from the Bay of Plenty coast above and downwind of Whakaari, when weather conditions are clear and/or wind strength is lighter. Similarly, activity can change at short notice and produce stronger steam and gas plumes which are seen from the coast.

Volcano Observatory Notice to Aviation (VONA)

Format and guidance set out by ICAO

International template for disseminating critical, operationally relevant information about volcanic activity

Should be issued when:

- Change of ACC
- Within an ACC when an ash producing event or significant change in behaviour occurs
- *For episodes of re-suspended ash that could pose a hazard to aviation*

Intended for aviation users

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Volcanic ash hazard assessment: The now

Volcanic ash: What is it and where does it come from?

What is ash?

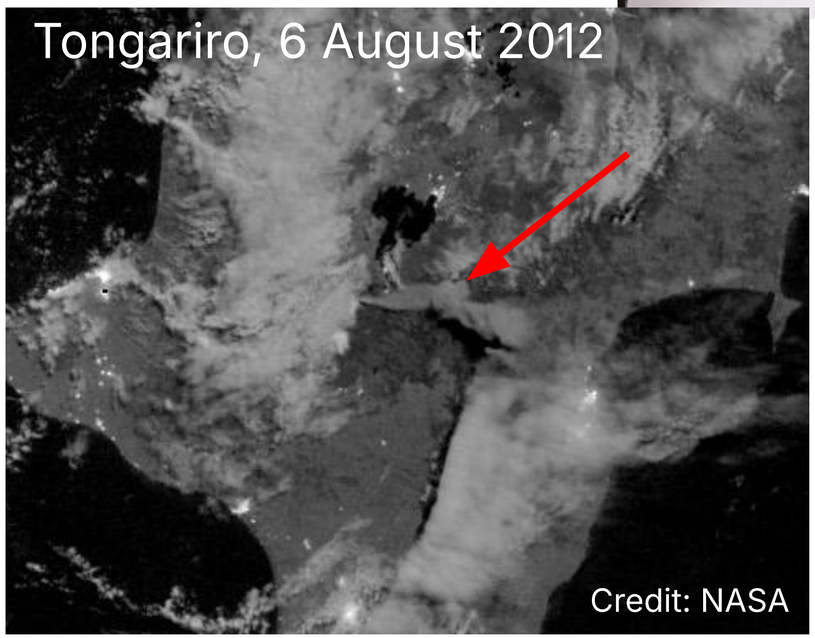
- Fragments (< 2 mm) of rock from the explosion
- Can be highly abrasive (hard, sharp, angular)
- Can be electrically conductive and corrosive due to surface coatings of chemicals

Where does it go?

- Lifted upward by the volcanic plume
- Disperses with the wind


Credit: Grant Wilson

Credit: Lloyd Homer



Credit: NASA

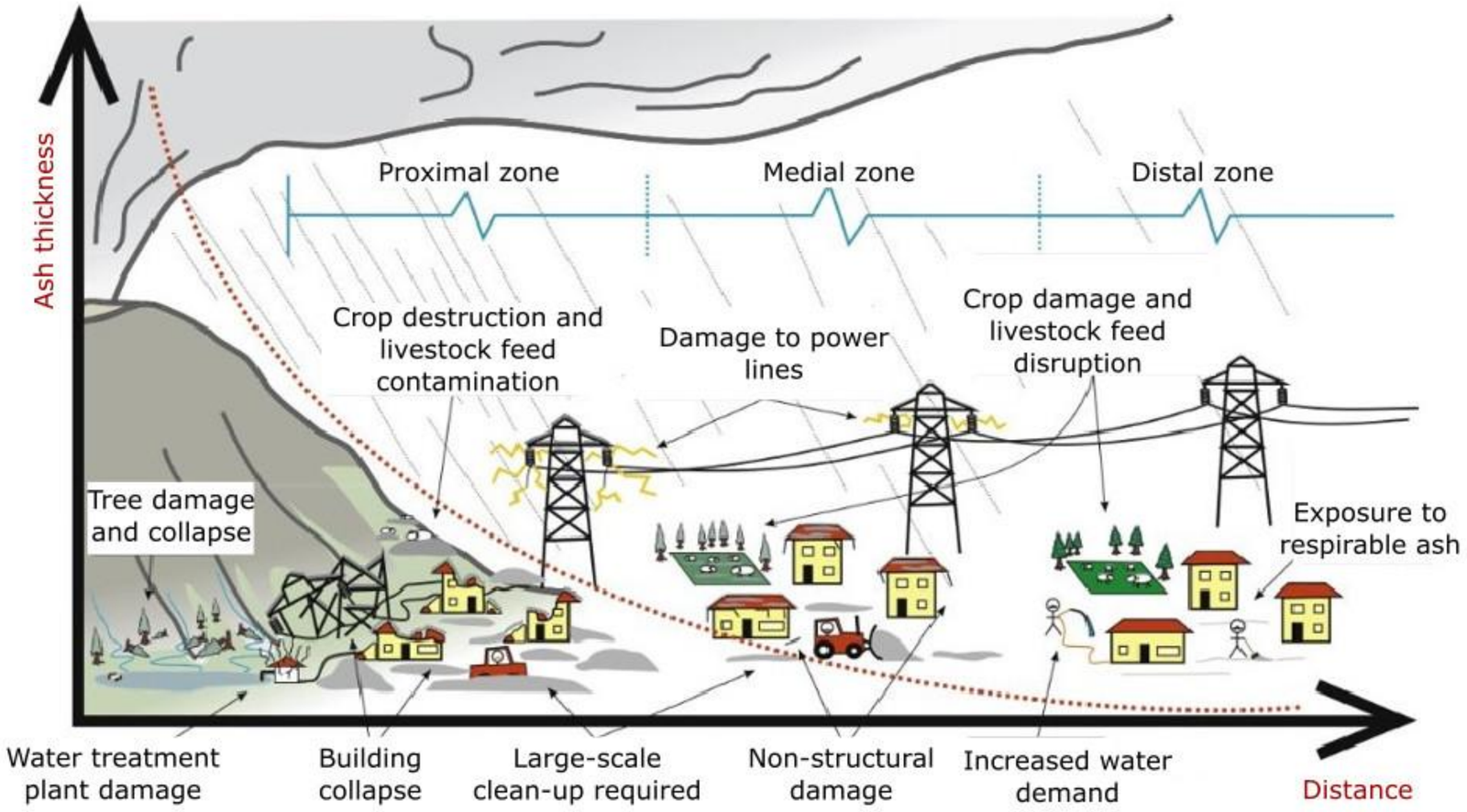
Need for ash forecasts during eruptions

Volcanic ash is impactful on the ground and in the air

Type and scale of impact depends on amount of ash

Forecasts can inform mitigation and decision making by:

- Emergency managers (NEMA, local CDEM)
- Infrastructure managers
  - Waka Kotahi
  - **Airports**
  - ***Buildings***
  - Water supply / wastewater
  - ***Generators***
- To be effective, forecasts need to be:
  - Rapid
  - Reliable (accurate + known uncertainty)
  - Dynamic

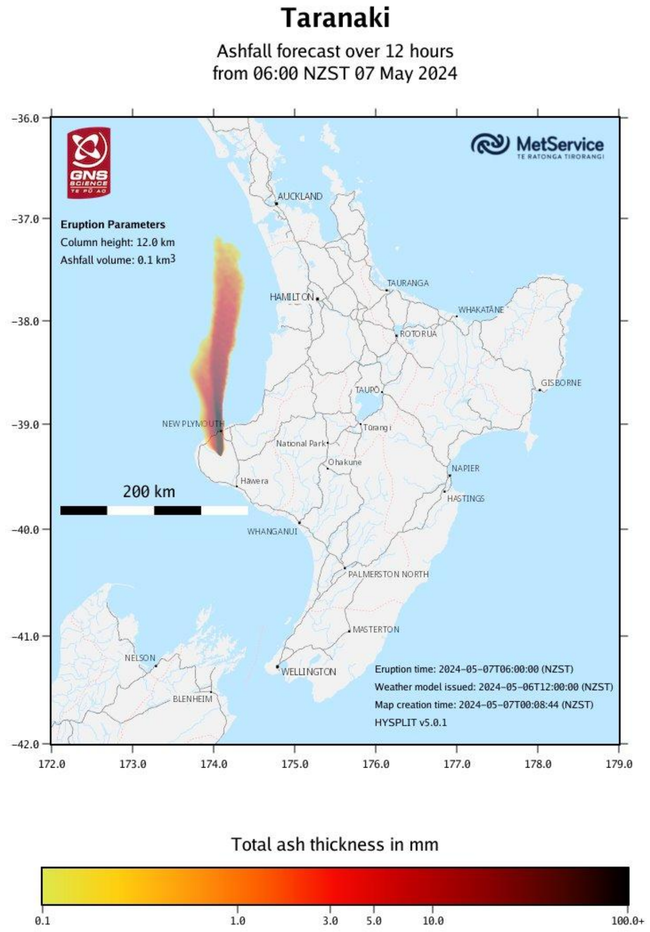


Jenkins et al. (2015)

Current ash forecasting in New Zealand

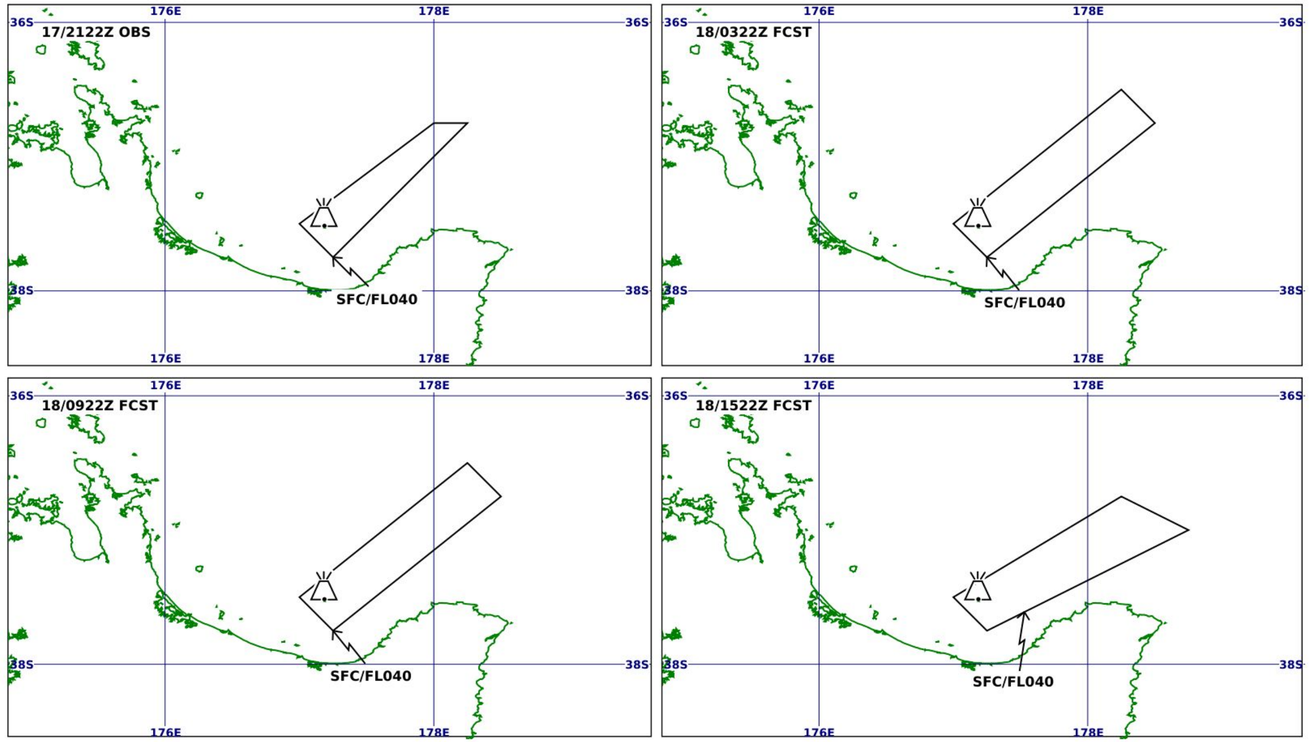
GNS (through GeoNet):

- Responsible for **ashfall** forecasts
  - Amount of ash accumulation on ground



MetService (Wellington Volcanic Ash Advisory Centre):

- Responsible for **ash dispersion** forecasts
  - Concentration of ash in the atmosphere



VOLCANIC ASH ADVISORY

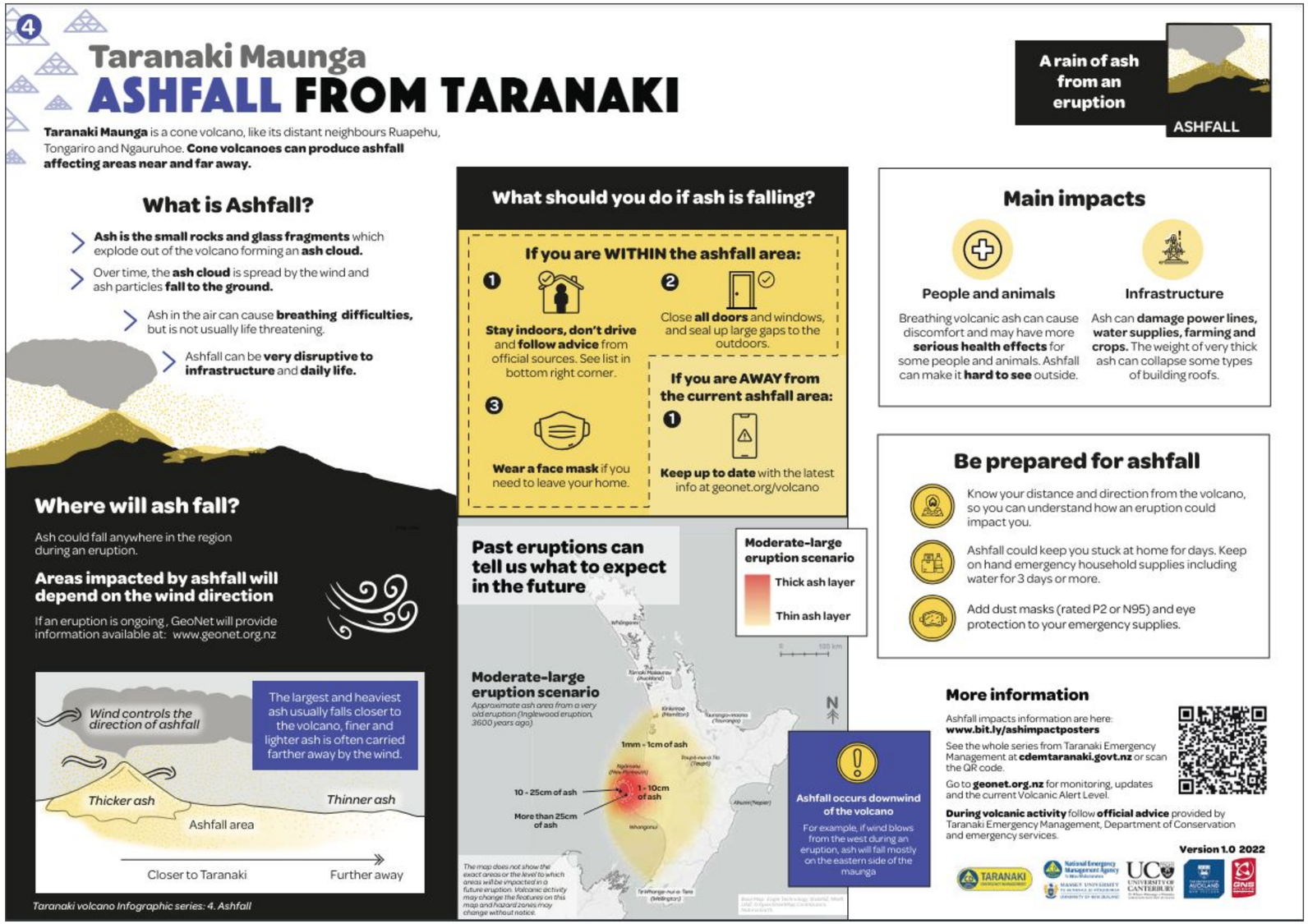
DTG:	20240917/2122Z	ADVISORY NR:	2024/171
VAAC:	WELLINGTON	INFO SOURCE:	H9 SATELLITE IMAGERY, WEBCAMS
VOLCANO:	WHAKAARI/WHITE ISLAND 241040	AVIATION COLOUR CODE:	ORANGE
PSN:	S3731 E17711	ERUPTION DETAILS:	ERUPTION AT 20240917/2000Z CONTINUOUS LOW LEVEL ERUPTION
AREA:	NEW ZEALAND	RMK:	CONTINUOUS LOW LEVEL ERUPTION. ASH PLUME VISIBLE IN H9 SATELLITE IMAGERY.
SUMMIT ELEV:	294M	NXT ADVISORY:	NO LATER THAN 20240918/0322Z=

Background ashfall hazard maps

Useful for planning and readiness activities

Scenario-based:
- Representative examples, e.g., small, moderate, large
- Often based on historic events
- Indicative example

Infographic posters on TEMO website: https://taranakiem.govt.nz/hazards/volcanic-activity



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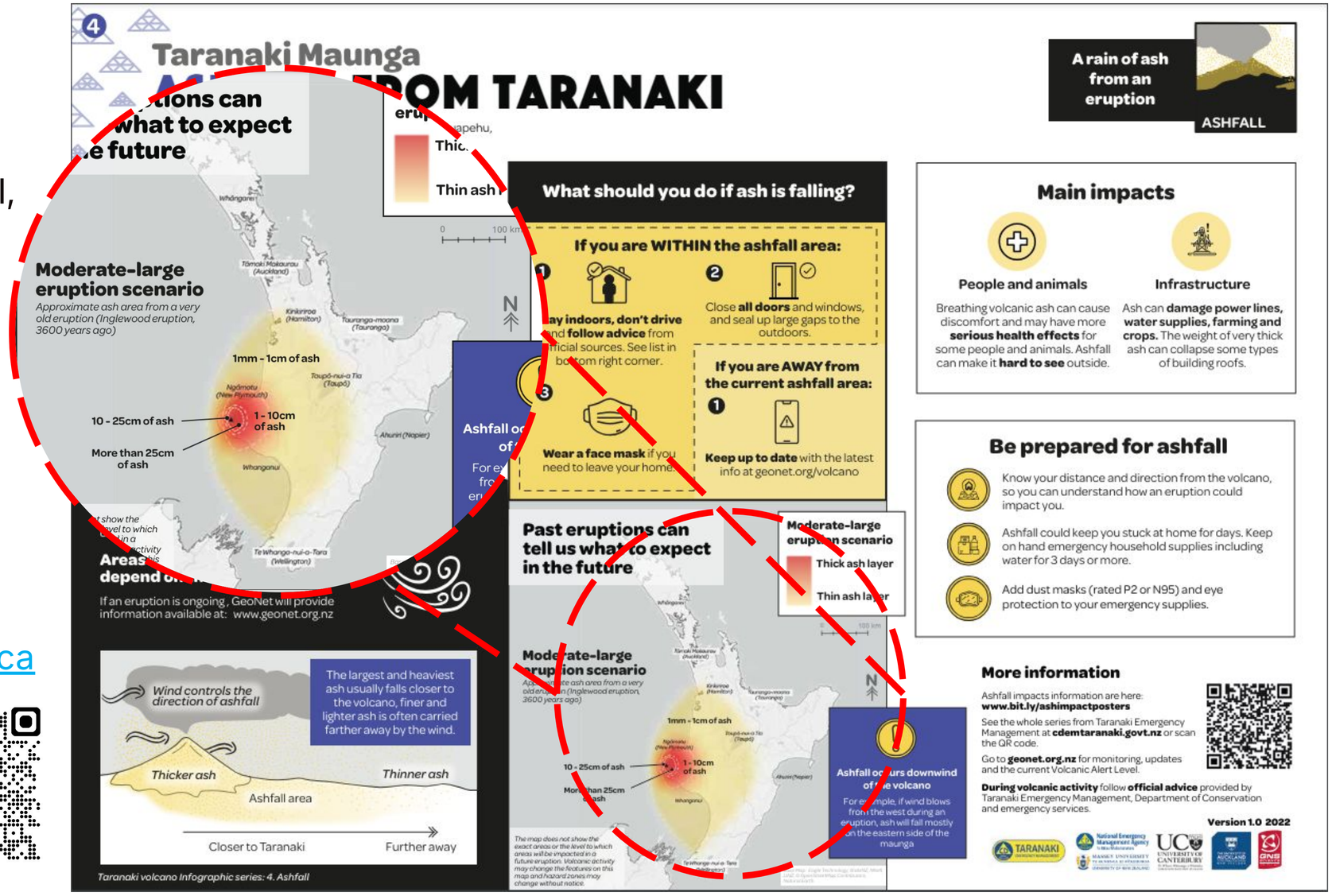
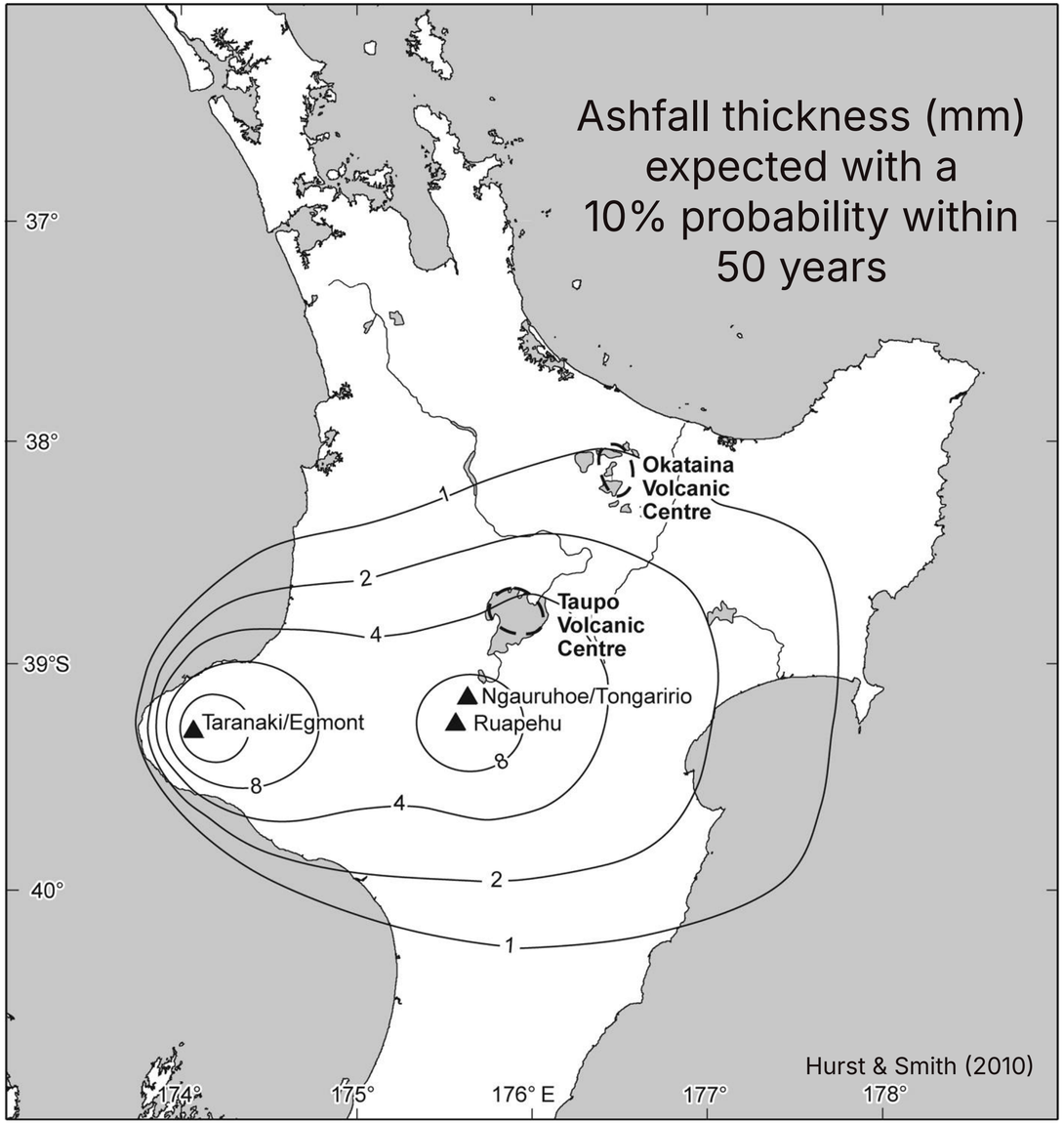


Background ashfall hazard maps

Useful for planning and readiness activities

Scenario-based:
- Representative examples, e.g., small, moderate, large
- Often based on historic events
- Indicative example

Probability-based:
- Simulate ashfall from many events
- Based on:
  - Historic eruption frequency
  - Historic eruption properties
  - Wind field distribution
- Can include multiple volcanoes



Response ashfall hazard maps

Issued if eruption has happened or considered imminent/likely

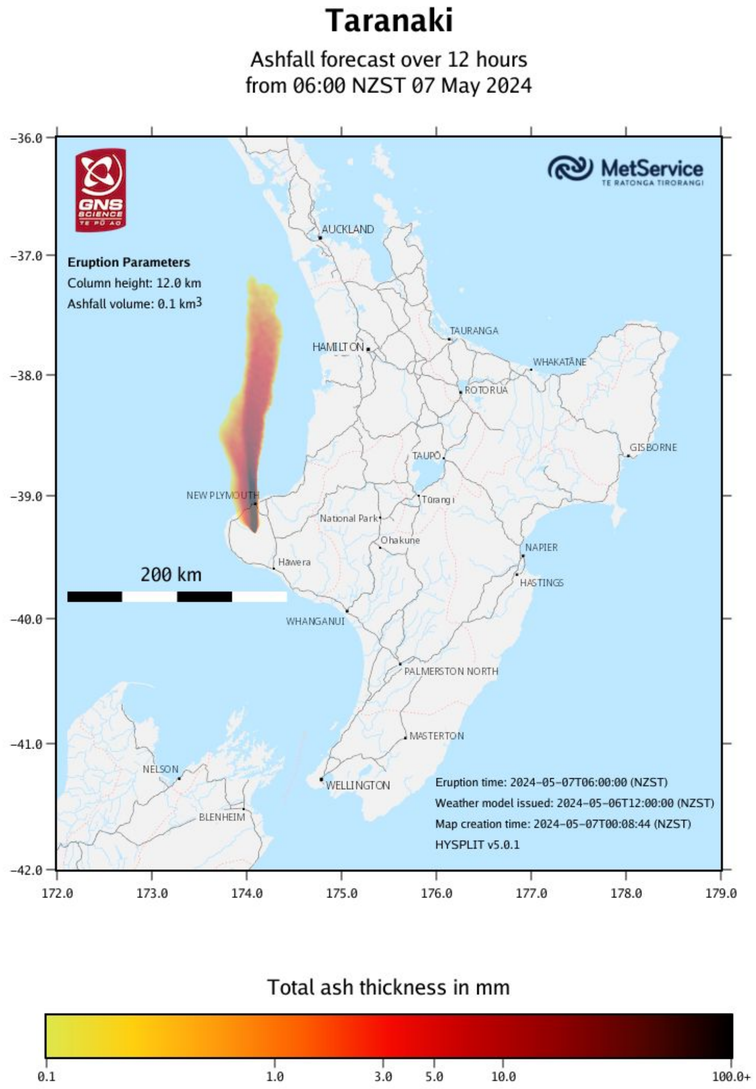
Simulation of a specific event, ideally representative of actual eruption

- Can be revised and updated if and when more information about eruption becomes available

Uses up-to-date weather forecast

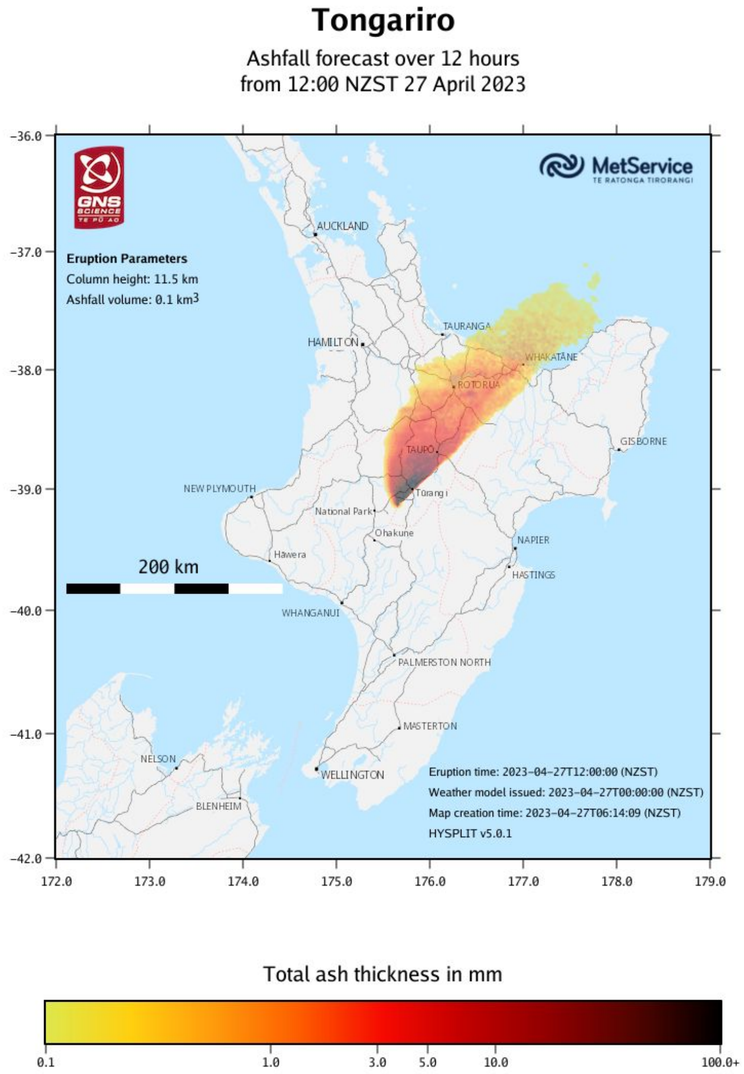
Sources of uncertainty:

- Knowledge of eruption properties (model inputs): plume height, eruption volume, start time, duration, ash size distribution
- Weather forecast



Response ashfall forecasting at GNS

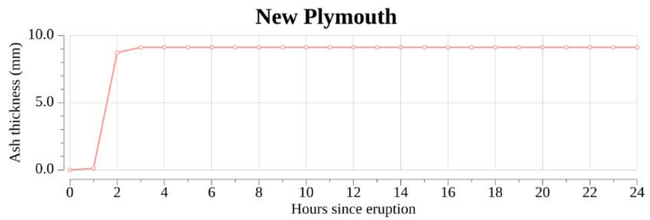
- Model: HYSPLIT – *Hybrid Single Particle Lagrangian Integrated Trajectory*:
  - Created and maintained by NOAA (National Oceanic and Atmosphere Administration), USA
  - Used widely to model trajectories and dispersion of:
    - Radioactive material
    - Wildfire smoke
    - Atmospheric pollutants
    - Volcanic ash
- Partnership with MetService

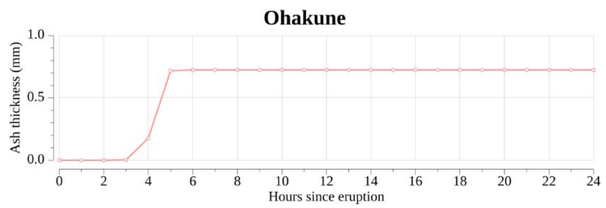


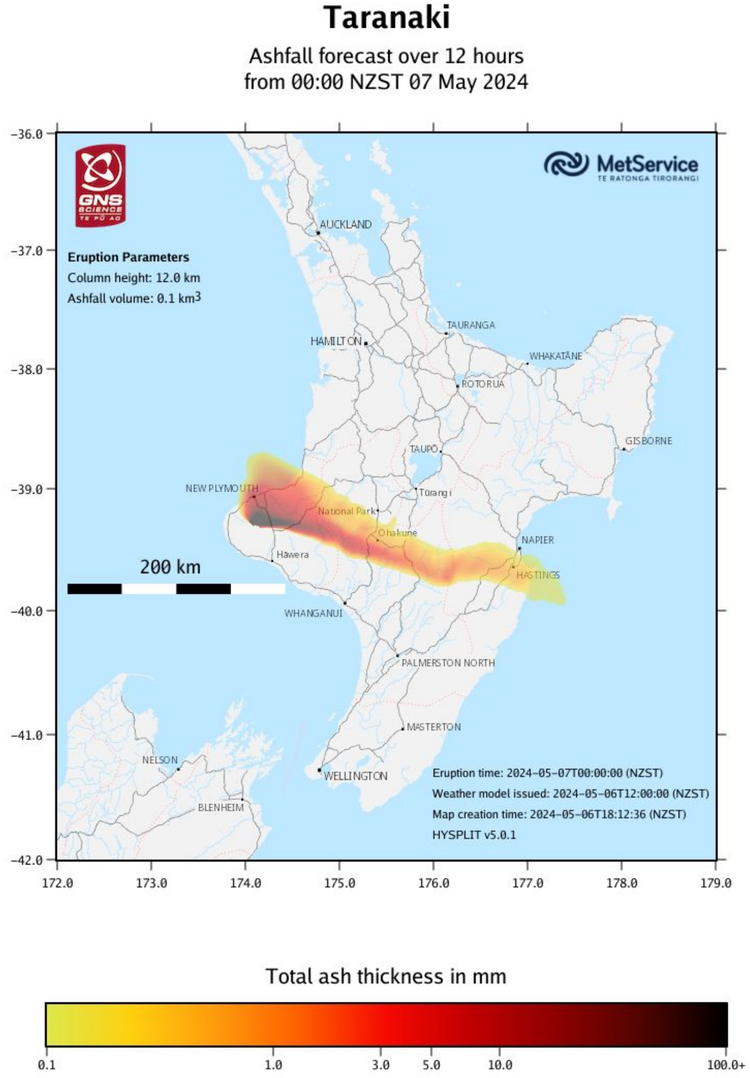
Response ashfall forecasting at GNS

- Model runs performed by MetService
- 6 scenarios for each volcano simulated every six hours:
  - Small, medium, large (volume)
  - Low and high plume height
- Forecasts thickness and timing
- Generates visual outputs from forecasts and displays them on dashboard for Volcano Duty Officers

Taranaki scenarios 1-hour duration eruption		Eruption volume /km^3		
		0.001 (Small)	0.01 (Medium)	0.1 (Large)
Plume height above sea level /km	6 (Low)			
	12 (High)			X







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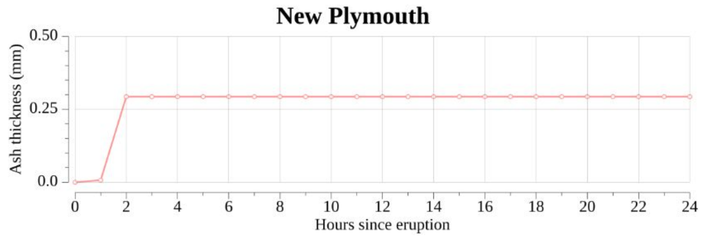
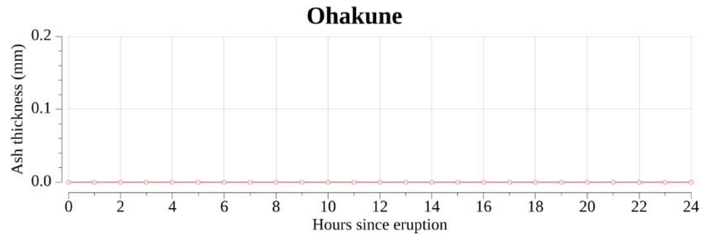
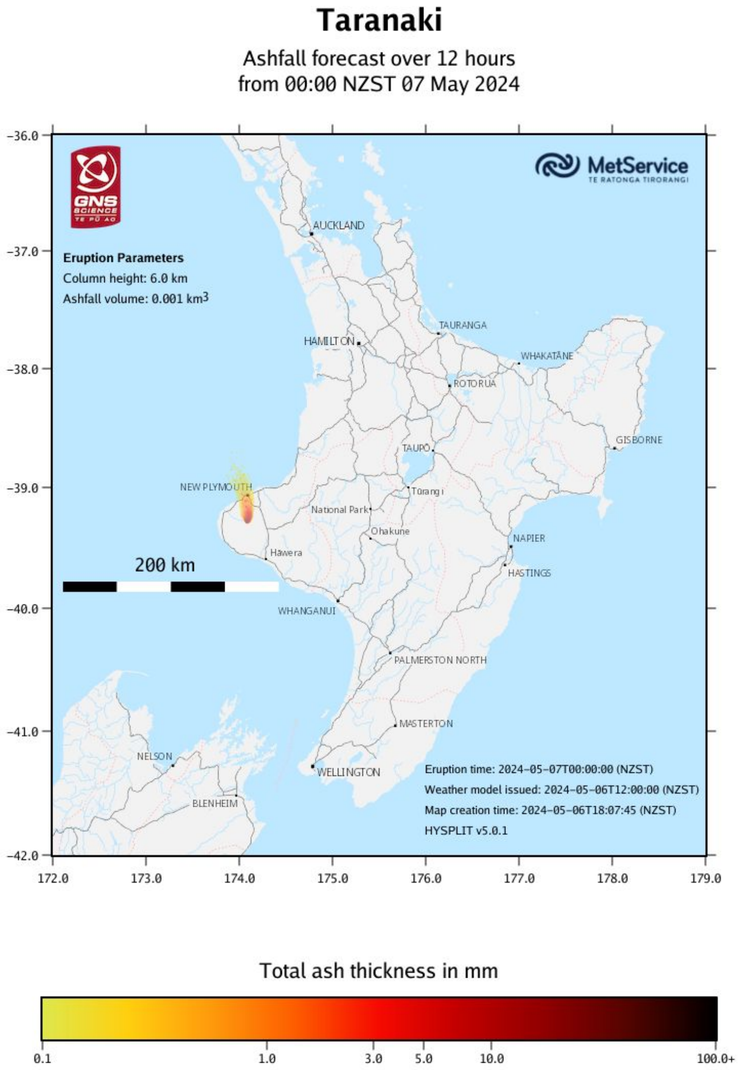






In the event of an eruption …

Initial response:

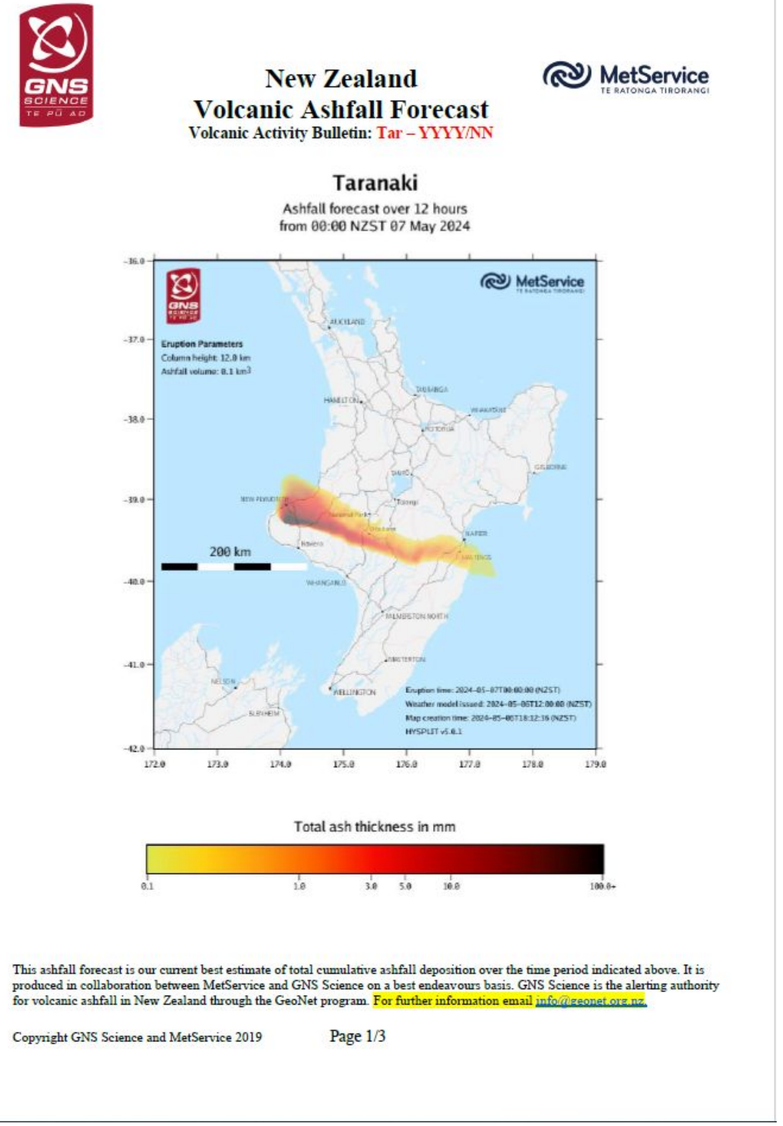
- VDO confirms an eruption has occurred
- Issues Volcano Activity Bulletin (VAB) notifying of eruption

Subsequently:

- VDO goes to Ashfall dashboard and selects the scenario most akin to the eruption
- Manual quality control.
  - Model has rare issues in certain weather conditions
- Graphics selected and inserted into ashfall forecast template
- Forecast disseminated as a Volcanic Activity Bulletin (VAB)

Page 1:

- Map of expected ashfall thickness
- Details of model and scenario used



New Zealand
Volcanic Ashfall Forecast
Volcanic Activity Bulletin: Tar – YYYY/NN

MetService
TE RATONGA TIRORANGI

Taranaki
Ashfall forecast over 12 hours
from 00:00 NZST 07 May 2024

This ashfall forecast is our current best estimate of total cumulative ashfall deposition over the time period indicated above. It is produced in collaboration between MetService and GNS Science on a best endeavours basis. GNS Science is the alerting authority for volcanic ashfall in New Zealand through the GeoNet program. For further information email info@geonet.org.nz.

 Page 1/3

In the event of an eruption …

Initial response:

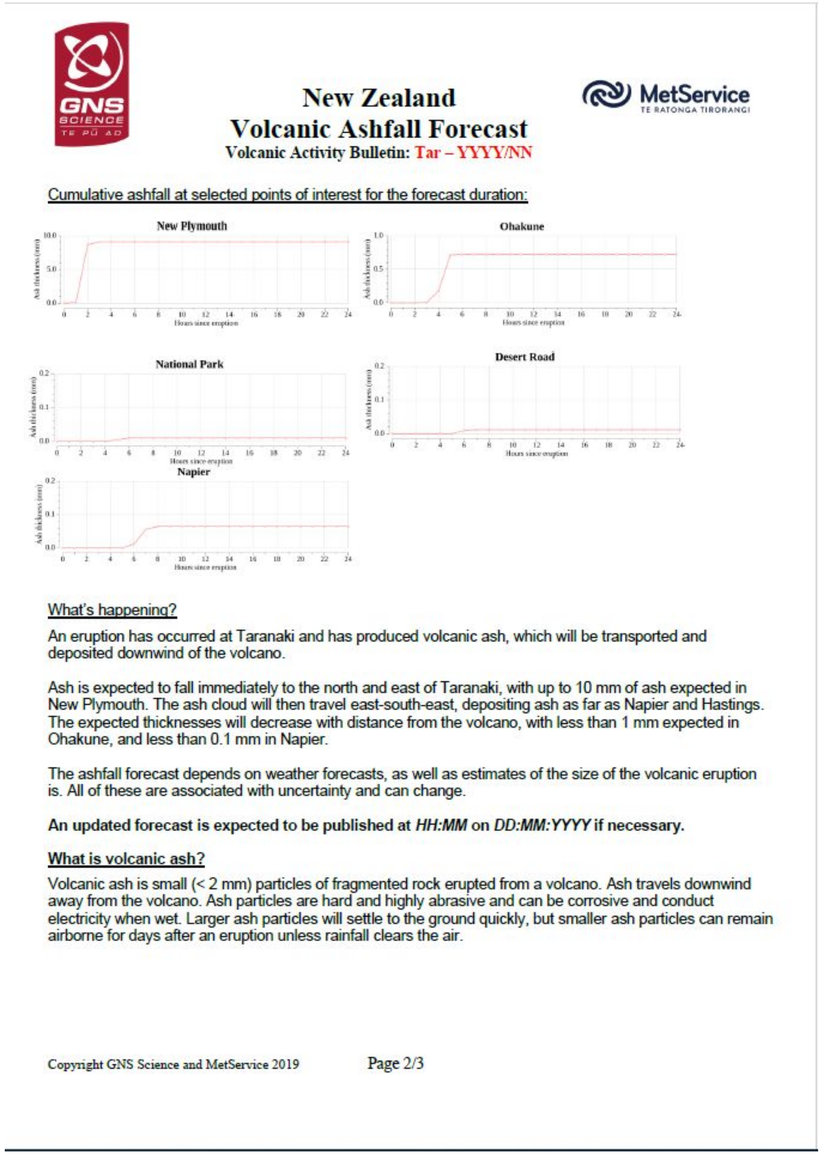
- VDO confirms an eruption has occurred
- Issues Volcano Activity Bulletin (VAB) notifying of eruption

Subsequently:

- VDO goes to Ashfall dashboard and selects the scenario most akin to the eruption
- Manual quality control.
  - Model has rare issues in certain weather conditions
- Graphics selected and inserted into ashfall forecast template
- Forecast disseminated as a Volcanic Activity Bulletin (VAB)

Page 2:

- Plots showing timing of ashfall
- Qualitative summary
- General information on ash hazard



New Zealand
Volcanic Ashfall Forecast
Volcanic Activity Bulletin: Tar – YYYY/NN

MetService TE RATONGA TIRORANGI

Cumulative ashfall at selected points of interest for the forecast duration:

New Plymouth

Ohakune

National Park

Desert Road

Napier

What's happening?

An eruption has occurred at Taranaki and has produced volcanic ash, which will be transported and deposited downwind of the volcano.

Ash is expected to fall immediately to the north and east of Taranaki, with up to 10 mm of ash expected in New Plymouth. The ash cloud will then travel east-south-east, depositing ash as far as Napier and Hastings. The expected thicknesses will decrease with distance from the volcano, with less than 1 mm expected in Ohakune, and less than 0.1 mm in Napier.

The ashfall forecast depends on weather forecasts, as well as estimates of the size of the volcanic eruption is. All of these are associated with uncertainty and can change.

An updated forecast is expected to be published at *HH:MM* on *DD:MM:YYYY* if necessary.

What is volcanic ash?

Volcanic ash is small (< 2 mm) particles of fragmented rock erupted from a volcano. Ash travels downwind away from the volcano. Ash particles are hard and highly abrasive and can be corrosive and conduct electricity when wet. Larger ash particles will settle to the ground quickly, but smaller ash particles can remain airborne for days after an eruption unless rainfall clears the air.

 Page 2/3

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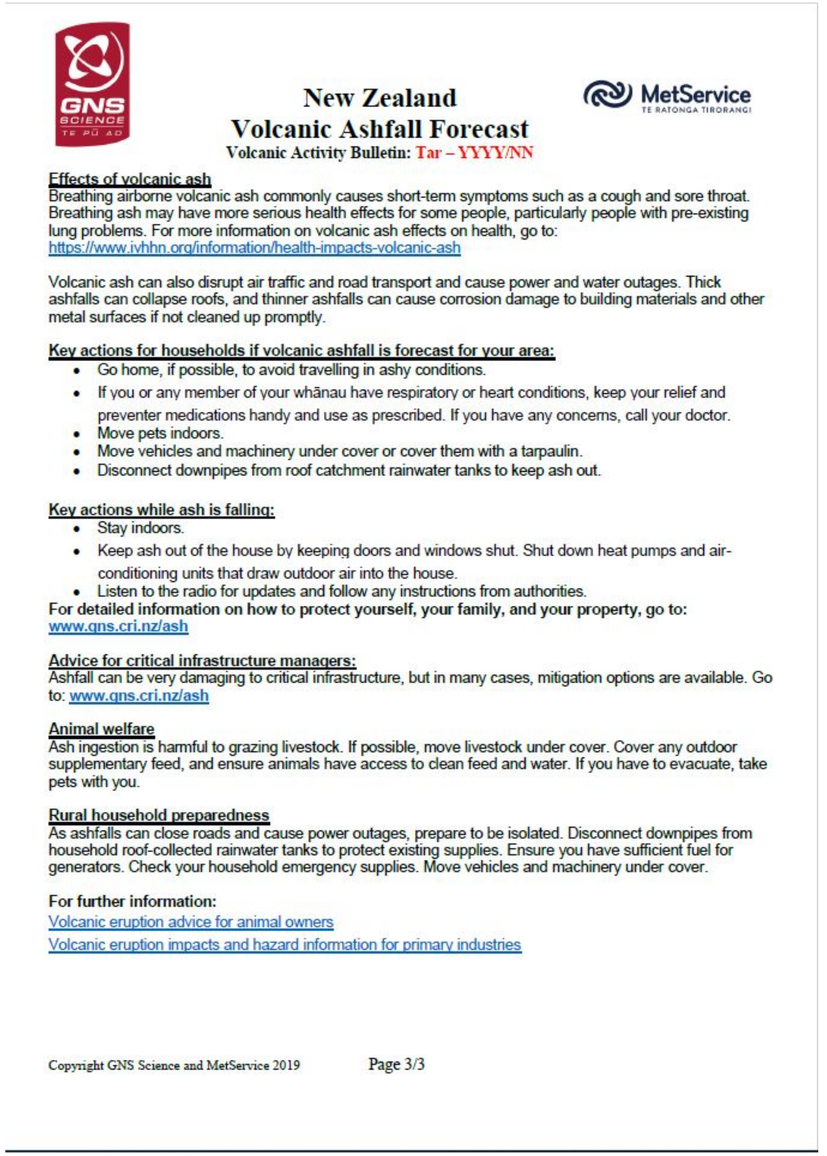
Page 3:

- General summary of ashfall impacts
- General actions and advice
- **Links to further information**



New Zealand
Volcanic Ashfall Forecast
Volcanic Activity Bulletin: Tar – YYYY/NN

MetService
TE RATONGA TIRORANGI

Effects of volcanic ash
Breathing airborne volcanic ash commonly causes short-term symptoms such as a cough and sore throat. Breathing ash may have more serious health effects for some people, particularly people with pre-existing lung problems. For more information on volcanic ash effects on health, go to:
https://www.ivhhn.org/information/health-impacts-volcanic-ash

Volcanic ash can also disrupt air traffic and road transport and cause power and water outages. Thick ashfalls can collapse roofs, and thinner ashfalls can cause corrosion damage to building materials and other metal surfaces if not cleaned up promptly.

Key actions for households if volcanic ashfall is forecast for your area:
- Go home, if possible, to avoid travelling in ashy conditions.
- If you or any member of your whānau have respiratory or heart conditions, keep your relief and preventer medications handy and use as prescribed. If you have any concerns, call your doctor.
- Move pets indoors.
- Move vehicles and machinery under cover or cover them with a tarpaulin.
- Disconnect downpipes from roof catchment rainwater tanks to keep ash out.

Key actions while ash is falling:
- Stay indoors.
- Keep ash out of the house by keeping doors and windows shut. Shut down heat pumps and air-conditioning units that draw outdoor air into the house.
- Listen to the radio for updates and follow any instructions from authorities.

For detailed information on how to protect yourself, your family, and your property, go to:
www.gns.cri.nz/ash

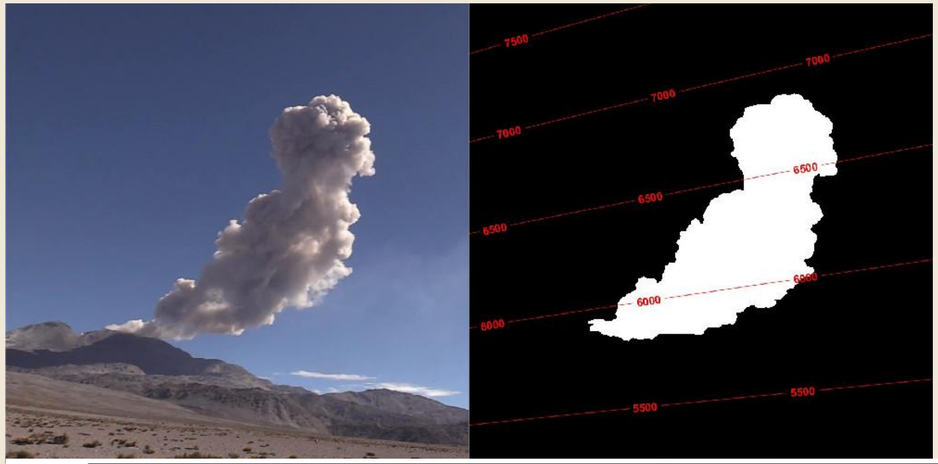
Advice for critical infrastructure managers:
Ashfall can be very damaging to critical infrastructure, but in many cases, mitigation options are available. Go to: www.gns.cri.nz/ash

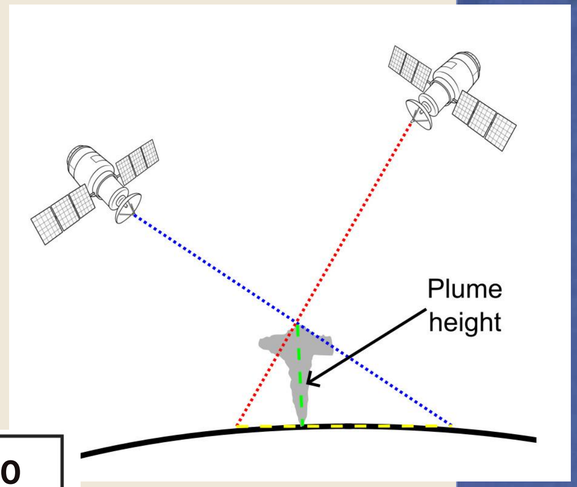
Animal welfare
Ash ingestion is harmful to grazing livestock. If possible, move livestock under cover. Cover any outdoor supplementary feed, and ensure animals have access to clean feed and water. If you have to evacuate, take pets with you.

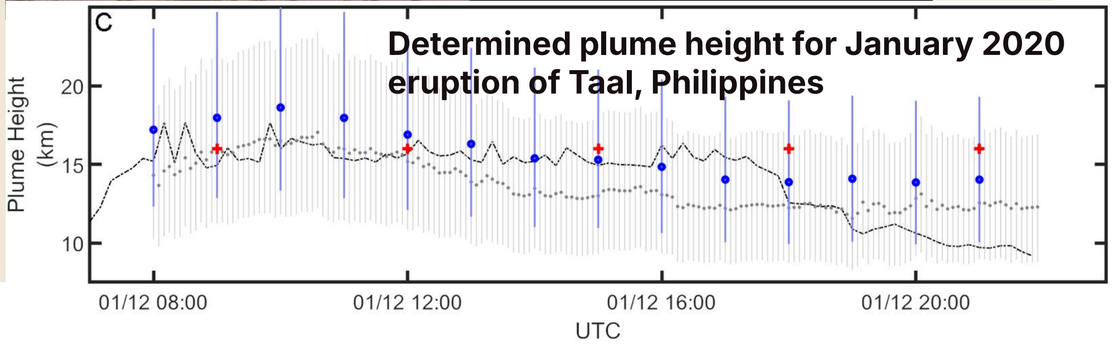
Rural household preparedness
As ashfalls can close roads and cause power outages, prepare to be isolated. Disconnect downpipes from household roof-collected rainwater tanks to protect existing supplies. Ensure you have sufficient fuel for generators. Check your household emergency supplies. Move vehicles and machinery under cover.

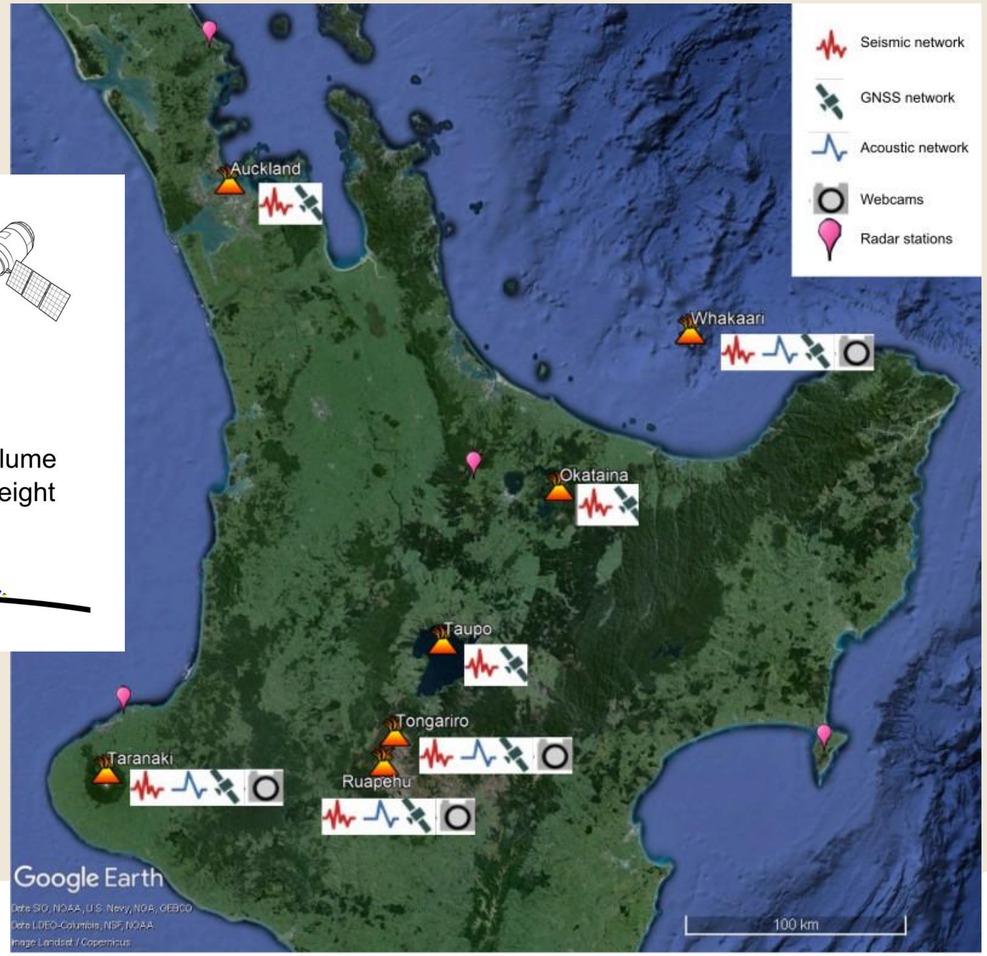
For further information:
Volcanic eruption advice for animal owners
Volcanic eruption impacts and hazard information for primary industries

Volcanic ash hazard assessment: The future









Current challenges in ashfall forecasting

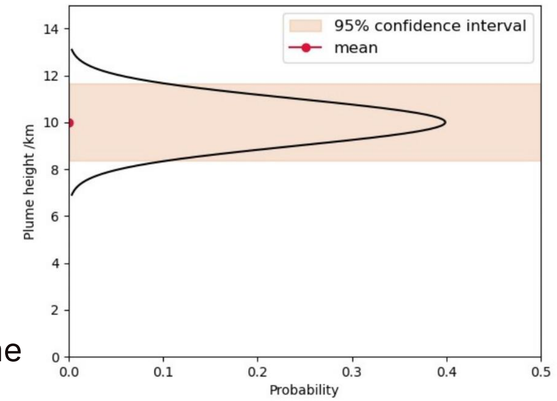
Forecast refinement in eruption response:

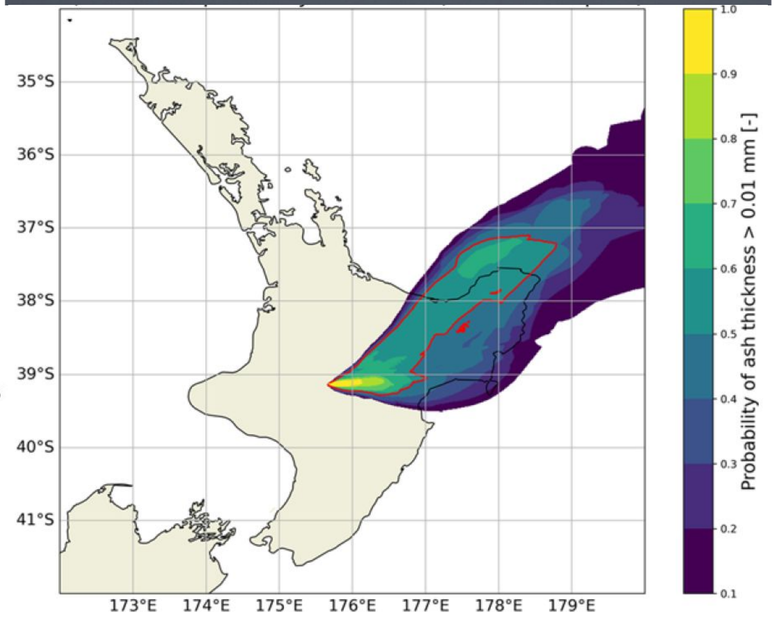
- Generated forecasts are pre-defined scenarios designed to be issued in immediate response (within 1-2 hours)
- Ideally, forecasts should be updated as data on eruption source parameters comes in:
  - **Plume height**
  - **Eruption volume**
  - **Eruption duration**
  - **Eruption start time**

Current arrangement has no automated provision for creating bespoke forecasts for individual eruptions:

Current models are deterministic:

- Do not account for uncertainty in model input parameters
- Could be resolved with probabilistic forecasts:
  - Determine probability distributions of input parameters
  - Sample input parameters and run large number of simulations
  - Can determine probabilistic measures of ash thickness / arrival time





Credit: Trancoso et al. (2022)

Better characterisation of forecast source

input parameters can address both these

Next-generation ash forecasts

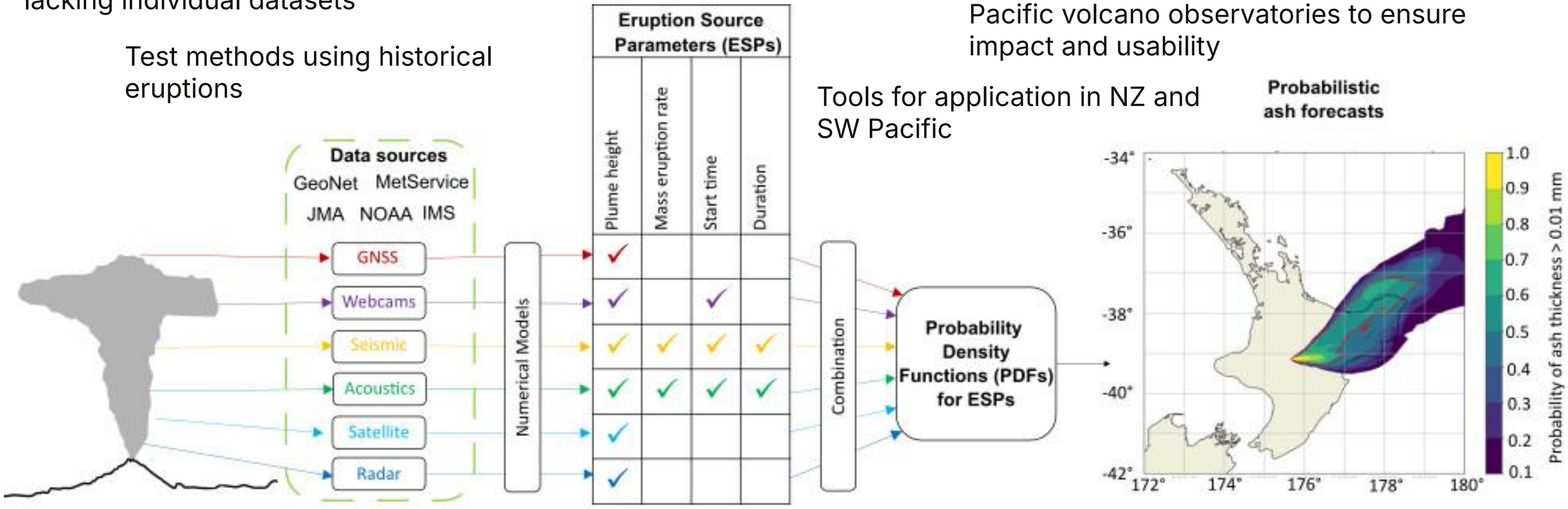
2024-2027: $1M MBIE-funded Smart Idea
Develop a suite of tools to use multiparametric data to estimate eruption source parameters (ESPs)
Combine different estimates to assess uncertainties on ESPs
Use ESP estimates and uncertainties to produce probabilistic ash forecasts

Multiple methods mitigates against lacking individual datasets

Test methods using historical eruptions

Engagement with partners across CDEM, VAAC, infrastructure managers, iwi, SW Pacific volcano observatories to ensure impact and usability

Tools for application in NZ and SW Pacific

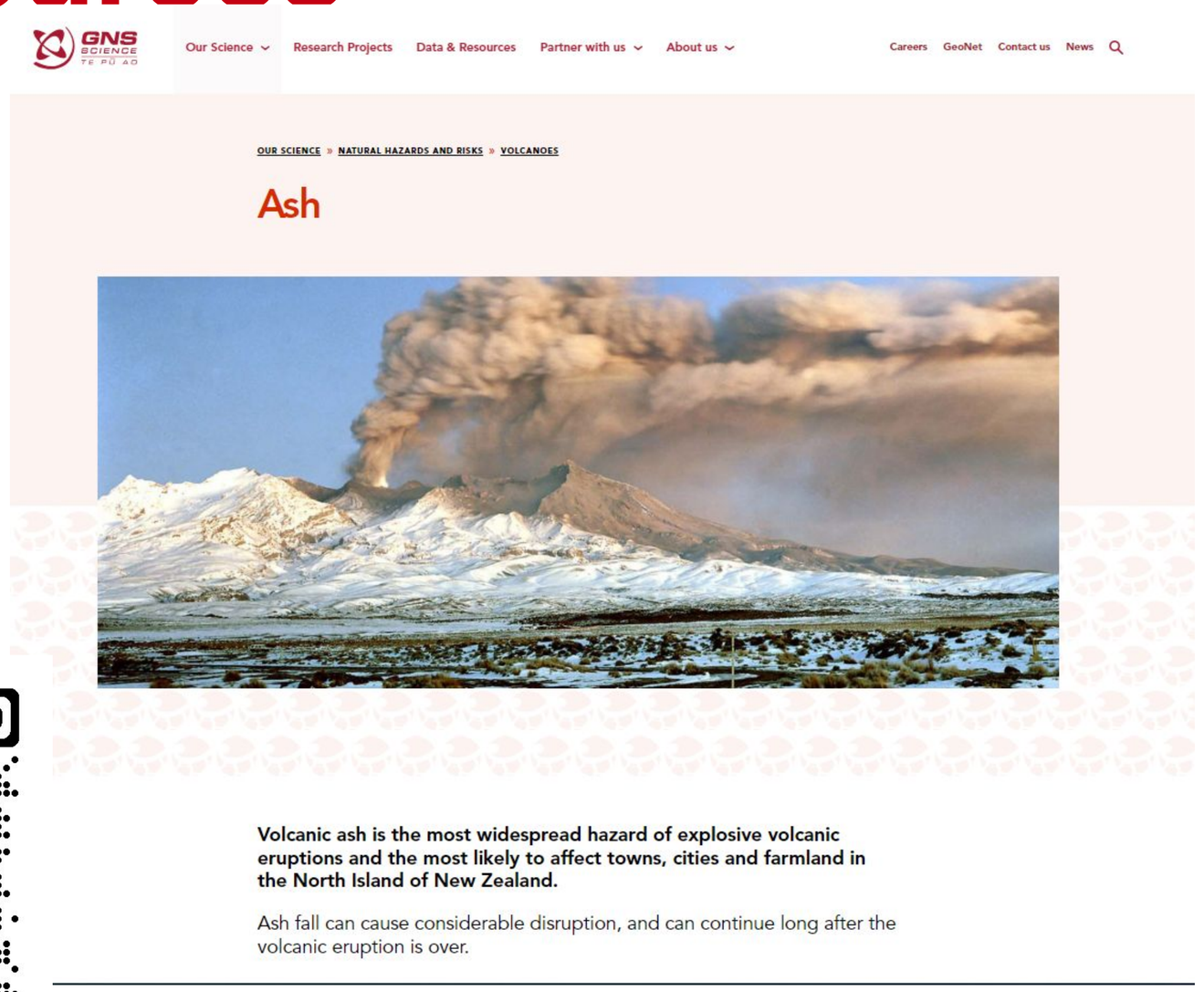


Wrapping up

Volcanic ash resources

GNS website:

- Ashfall hazards and impacts
- Links to posters:
  - Wastewater managers
  - Water supply managers
  - Roading managers
  - **Airport operators**
  - Power transmission and distribution system operators
  - Power plant operators
  - ***Facilities managers: Buildings***
  - ***Facilities managers: Gensets and HVAC***
  - ***Facilities managers: Computers and electronics***
  - ***Urban Clean-up Operations***



Summary

Volcano advice products

GNS (GeoNet) produce a range of products on volcano hazard information:

- Volcanic Alert Levels (VALs)
- Aviation Colour Codes (ACCs)
- Volcano Activity Bulletins (VABs)
- Volcano Advisory Notice to Aviation (VONA)

Products can be accessed through GeoNet website or app.

GeoNet Website

GeoNet App

For Android:

For Apple:

Ashfall hazard and impacts

- All of NZ's active volcanoes can produce ash
- Ashfall can cause a wide variety of social, economic and environmental impacts

GNS volcanic ash resources

Ashfall forecasts in response

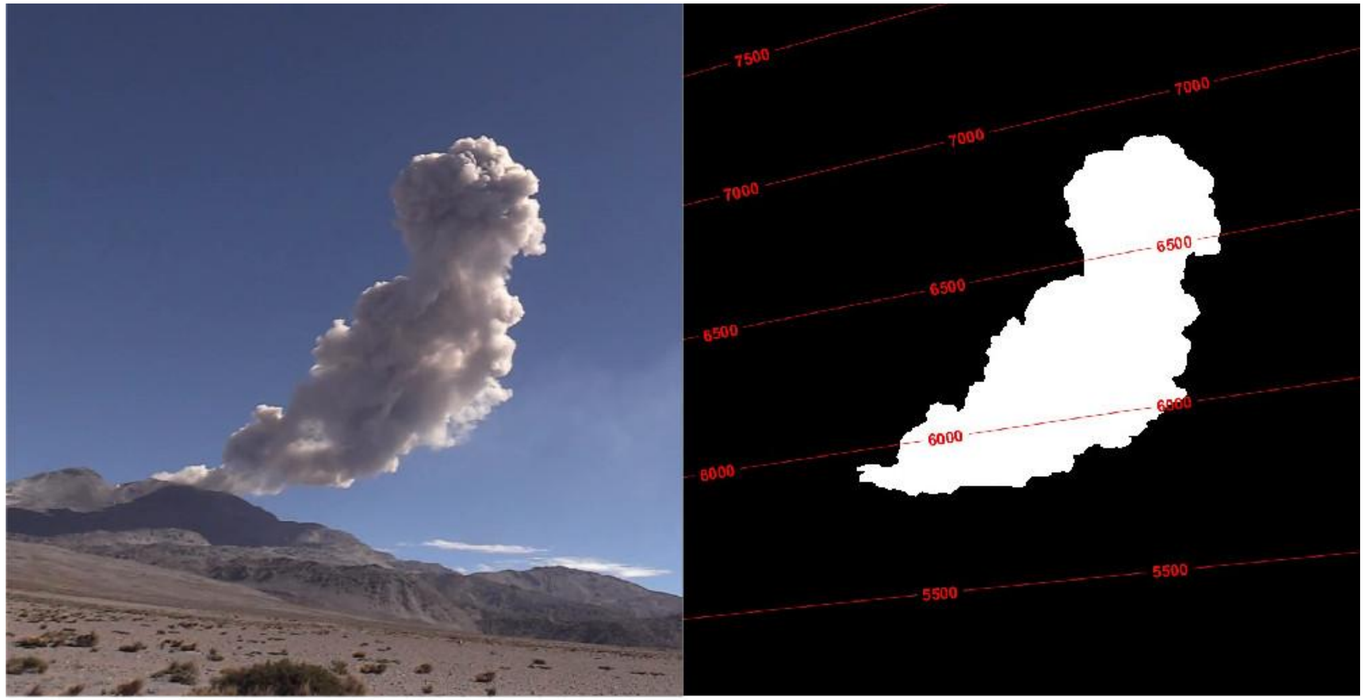
- Issued as a VAB
- Includes:
  - Map and timings for populated areas
  - Text-based summary
  - General advice on ash hazard, impacts and actions

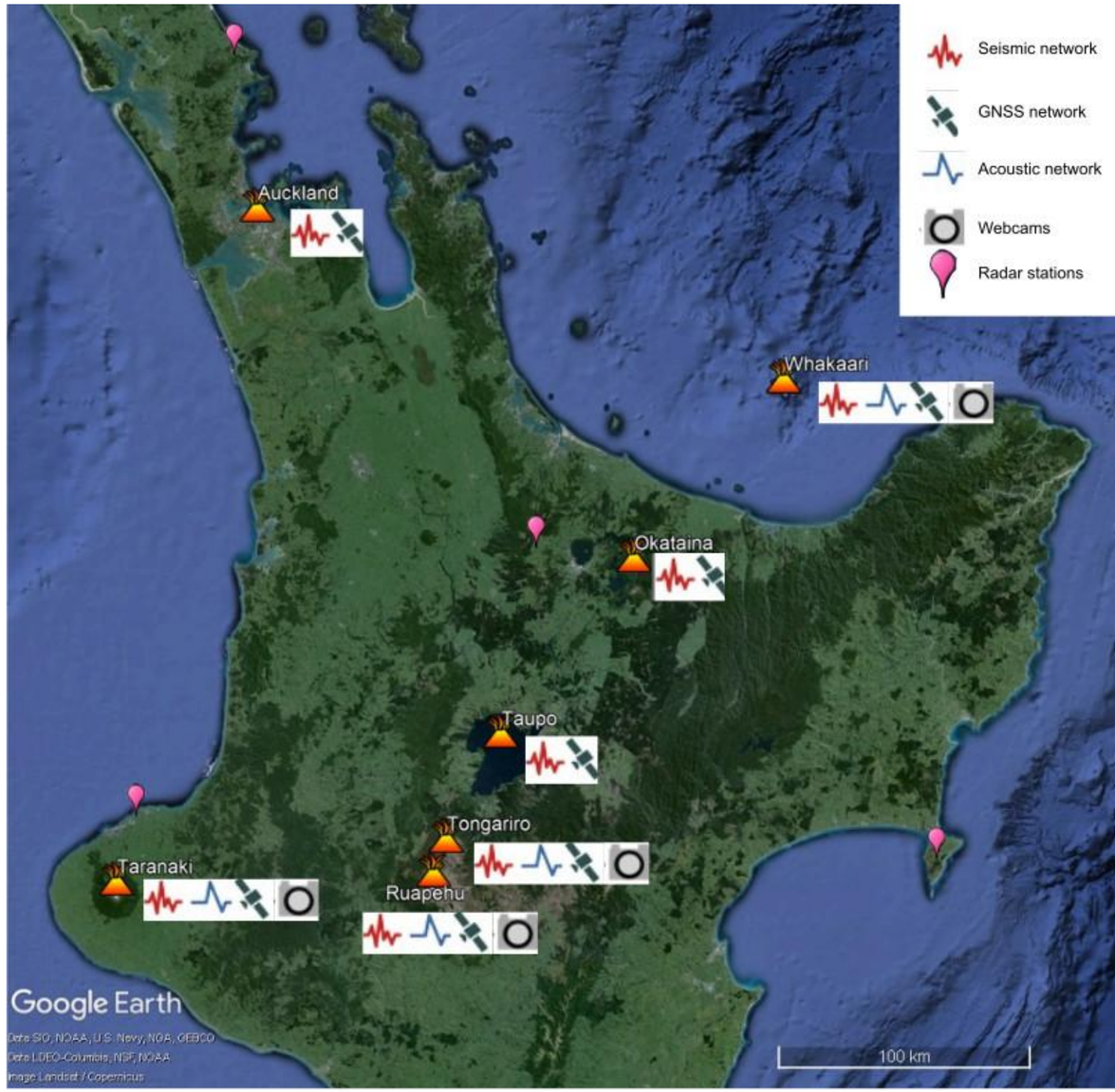
New MBIE-funded Smart Idea aiming to create tools for dynamic, reliable and timely forecasts by 2027 (ambitious)

Extra slides

Webcams

Plume height detection:
- Potentially automated
- Geometric calibration depending on camera properties and wind direction



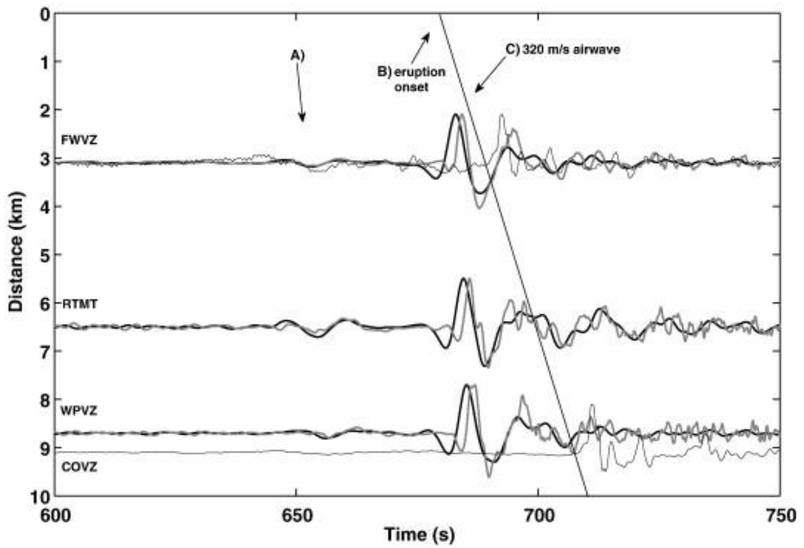


Seismo-acoustic

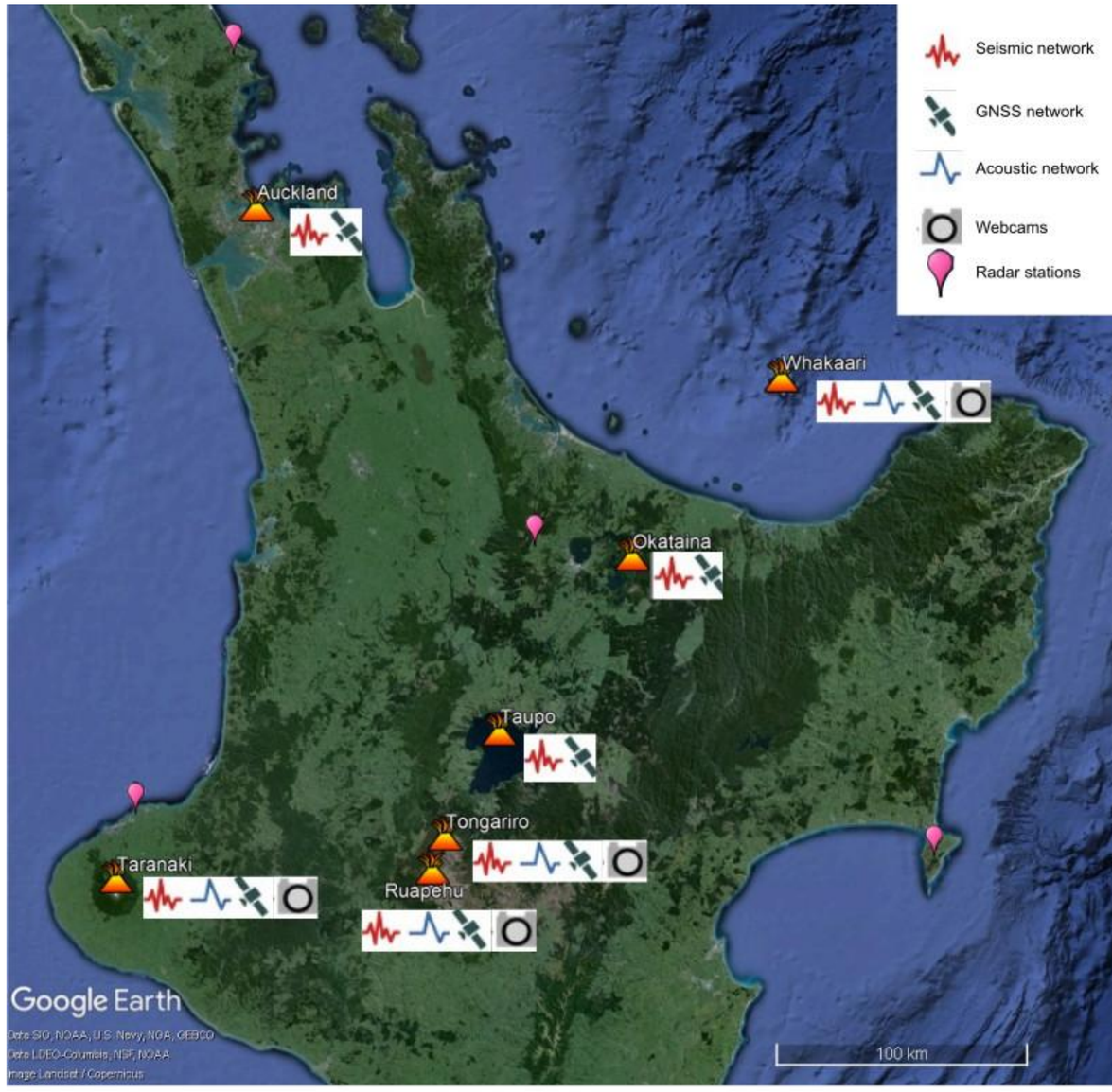
Waveforms provide info on:

- Eruption start time
- Eruption duration

Models can link signal amplitude to MER / plume height



Credit: Jolly et al. (2010)



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Waveforms provide info on:
- Eruption start time
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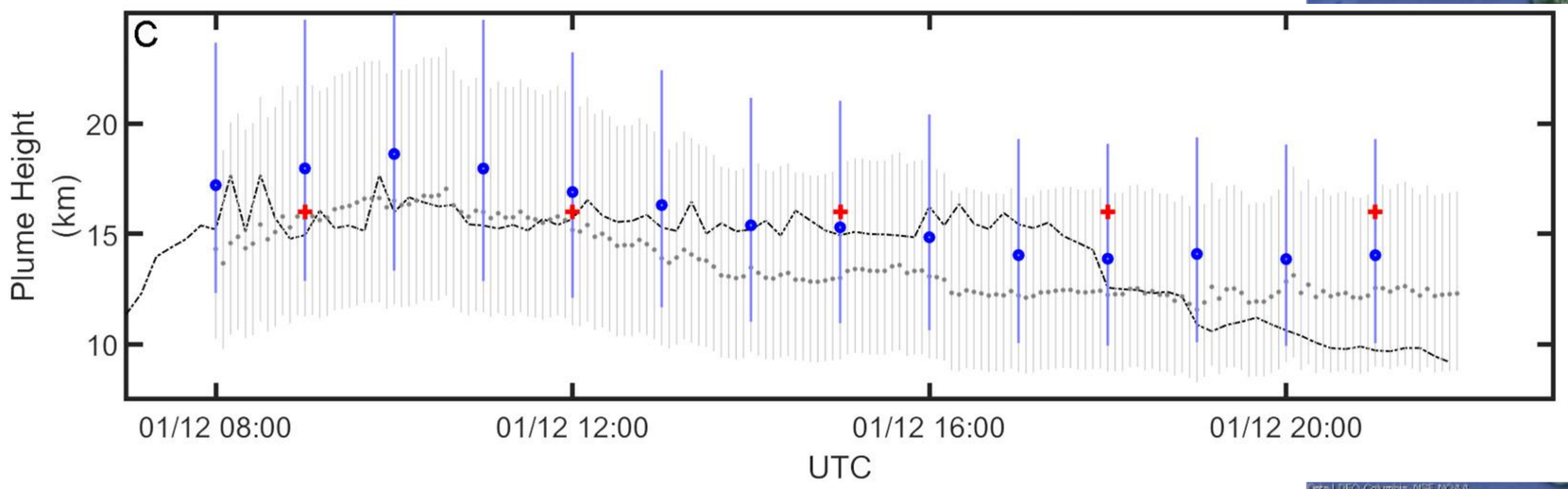
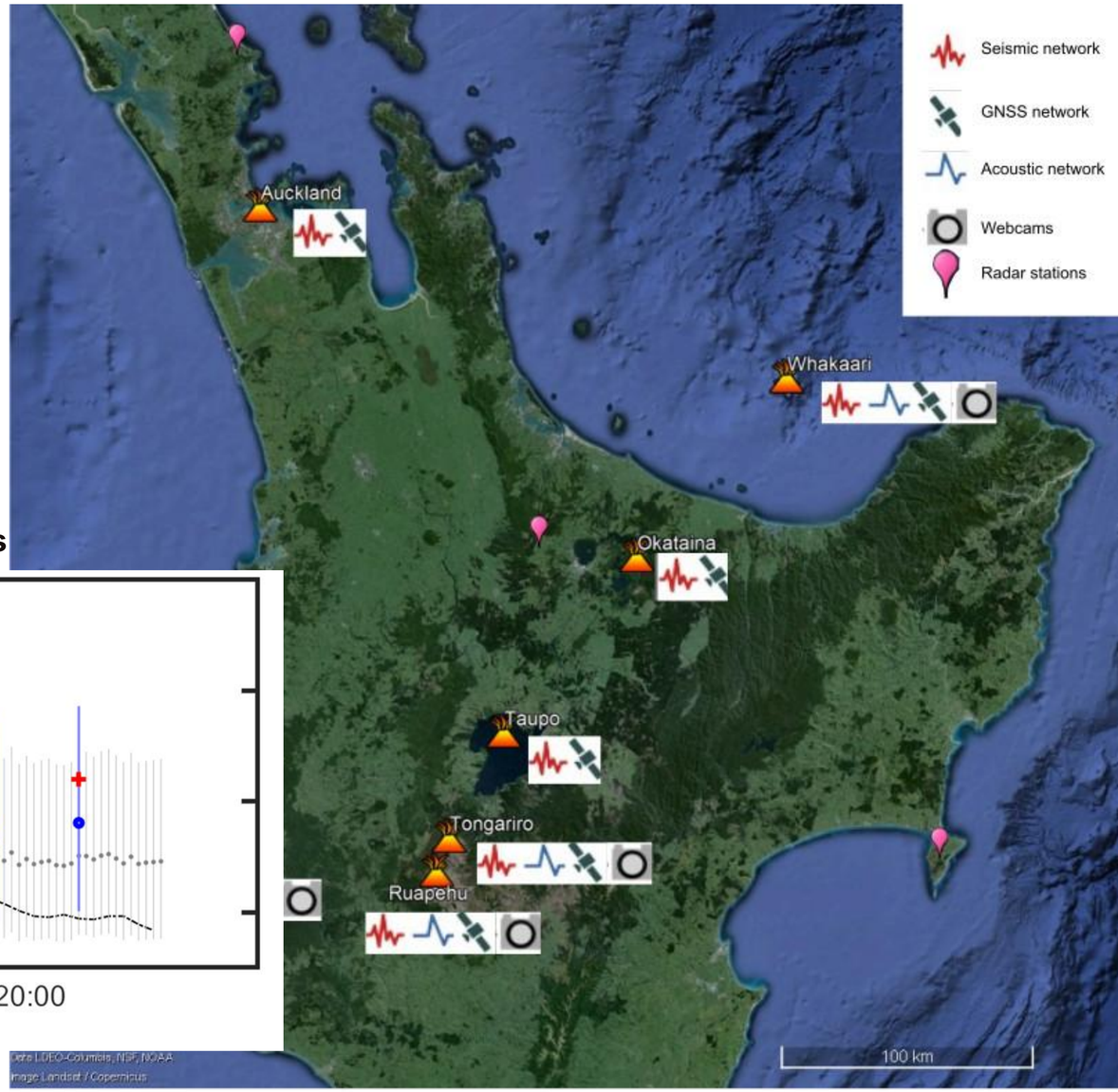
Comprehensive Nuclear Test Ban Treaty Organisation (CTBTO) International Monitoring System (IMS) acoustic stations can be used for regional monitoring

Determined plume height for January 2020 eruption of Taal, Philippines





GNSS

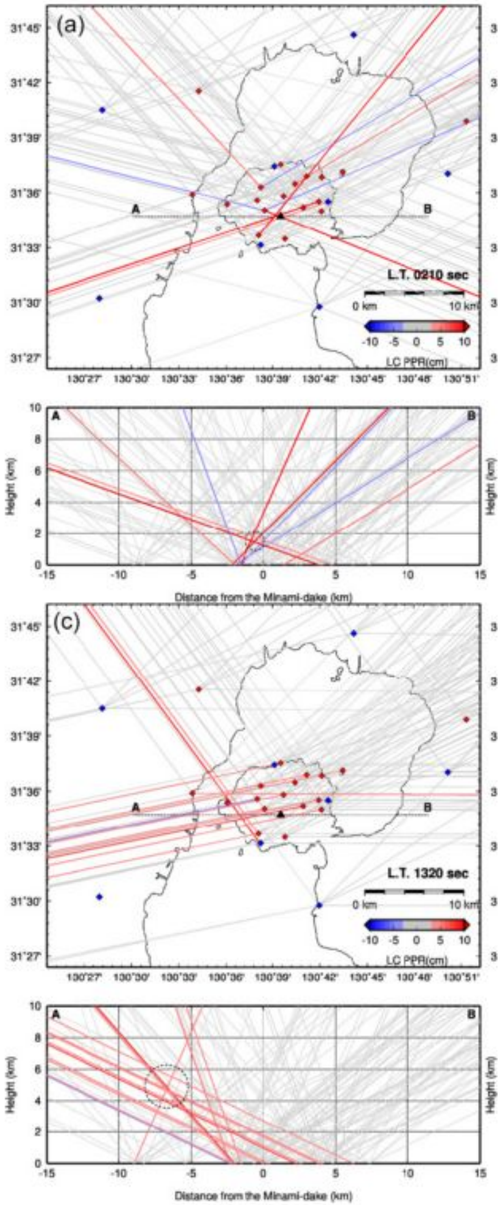
Signals from satellites to receivers can intersect plume, leading to anomalous data

Can use anomaly (signal strength, phase difference, multiple stations) to locate position of ash in the atmosphere

Can provide information on **plume height**

Most experimental of our methods, but we know we have data for:

- 2019 Whakaari
- 2012 Te Maari



Credit: Iguchi (2018)

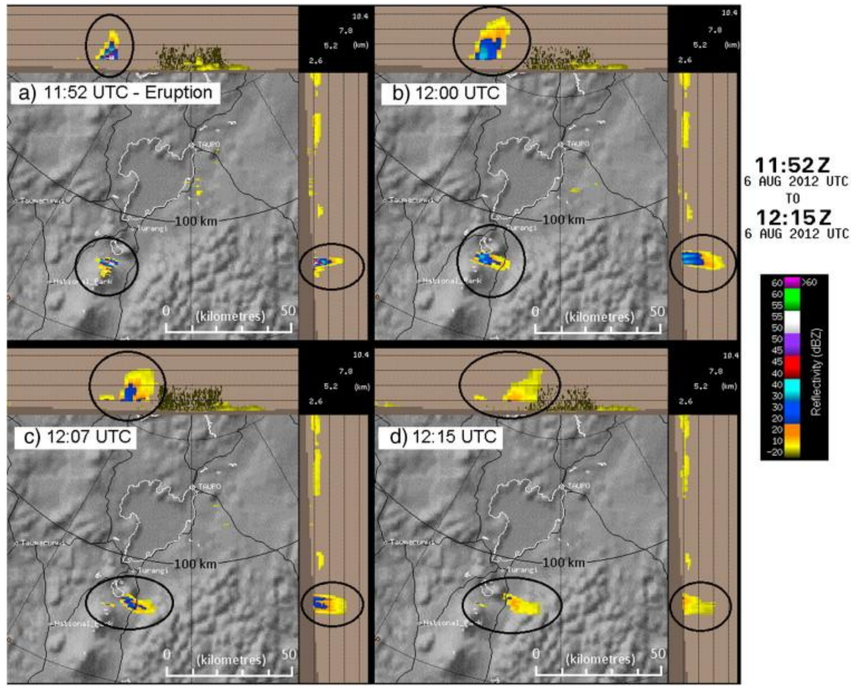
Radar

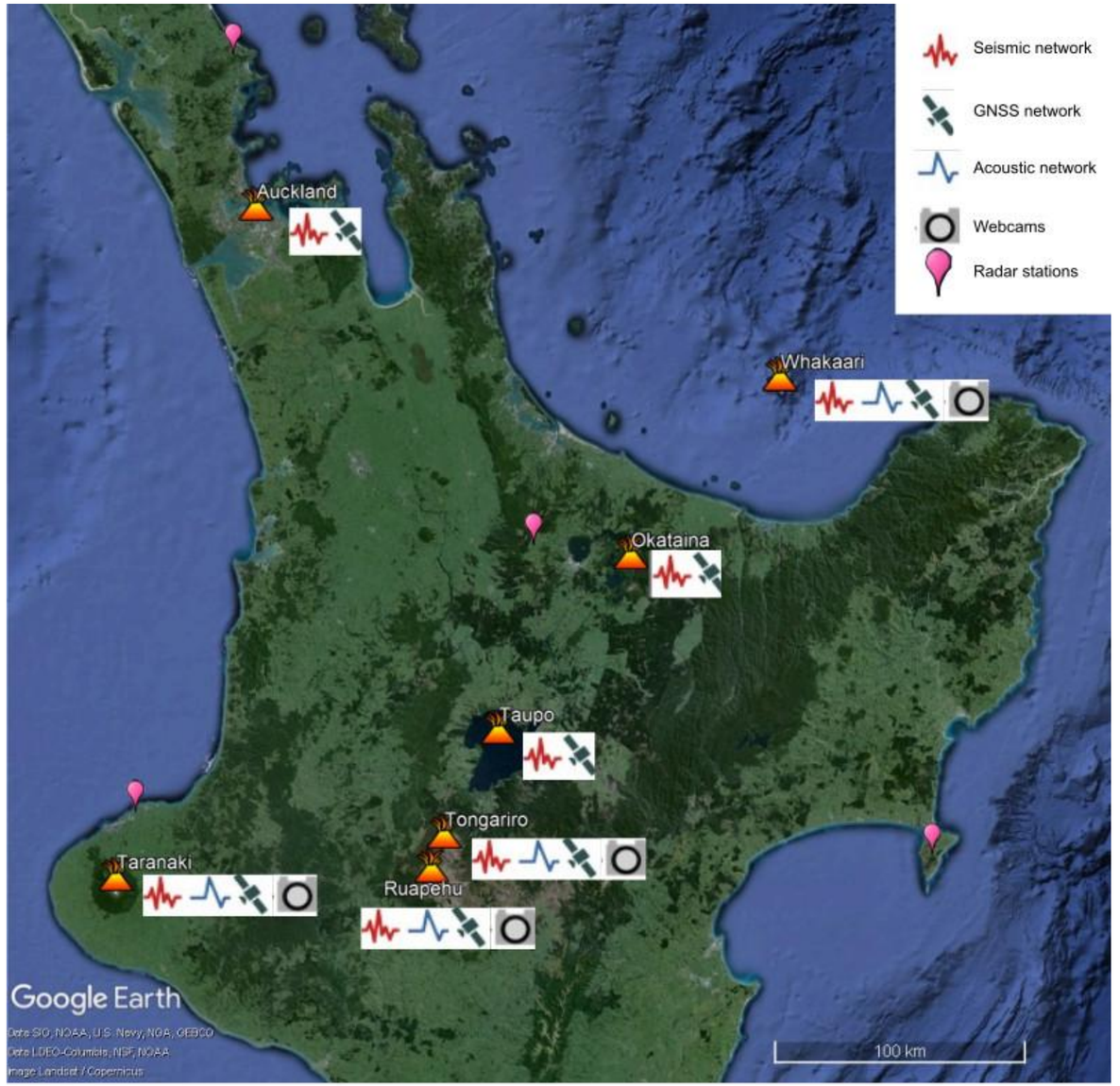
MetService have 4 radar which can image atmosphere above NZ's volcanoes

Data for:

- Whakaari 2024
- Whakaari 2019
- Whakaari 2016 (?)
- Te Maari 2012

Can determine plume height





Credit: Iguchi (2018)

Satellite

Operational tools for plume height detection from satellites exist:

- VOLCAT
- HOTVOLC

Depending on brightness temperature of plume pixels

Various uncertainties

Develop geometric-based methods for operational use

Will require sufficiently large eruptions

Could be applied across SW Pacific