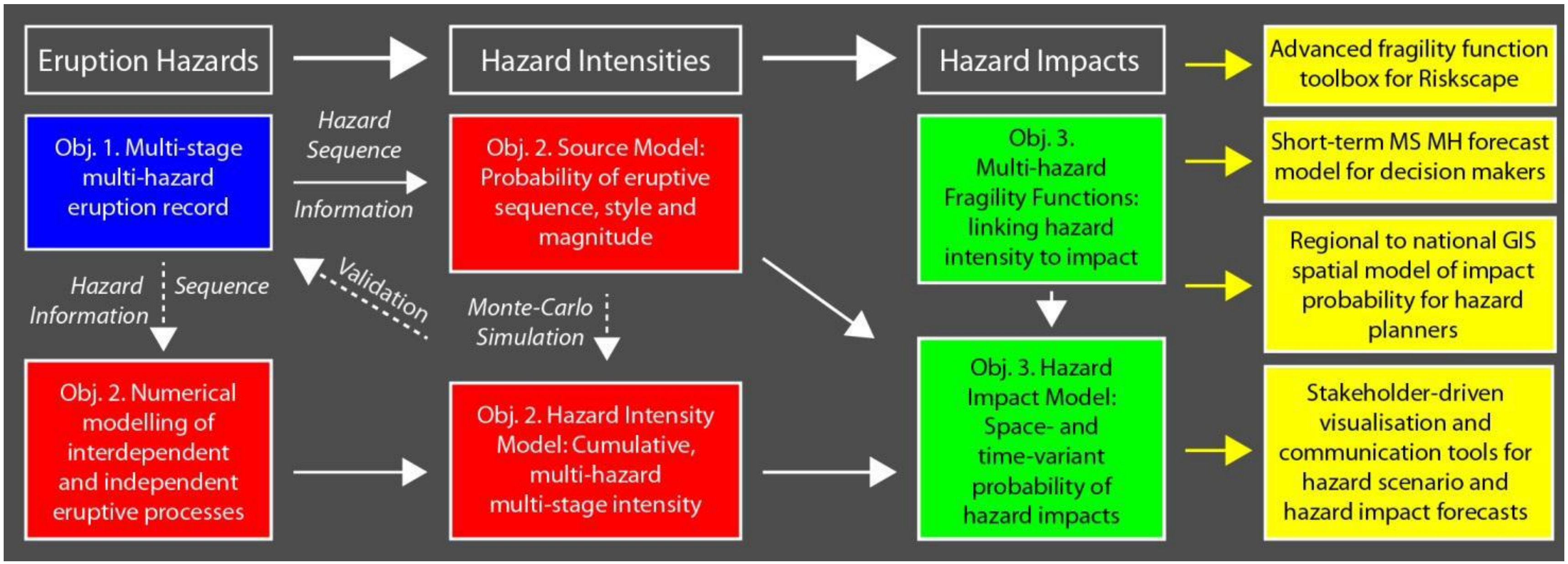
“Quantifying exposure to specific and multiple volcanic hazards”

NZHRP 2015-2019

"End to end" delivery of research to inform solutions

Volcanic Hazards *Modelling Hazard & Risk* *The Community and Risk*



Gert Lube, Karoly Nemeth, Jon Procter, Shane Cronin, Phil Shane, Ben Kennedy, Colin Wilson

Mark Bebbington, Gert Lube, Jon Procter, Tom Wilson, Ben Kennedy, Stuart Mead

Tom Wilson, Jon Procter, Mary Anne Thompson, Carol Stewart, Iwi Researchers (Ngati Rangi, Taranaki)

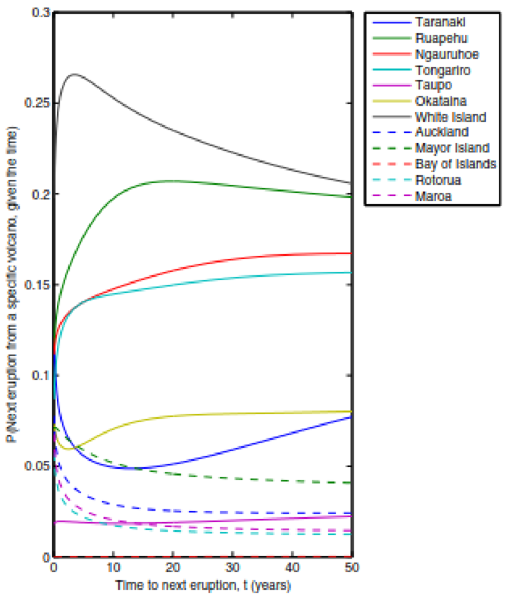
NZVSAP, CPVAG, TVASG, TRC, MWRC, Iwi, Industry

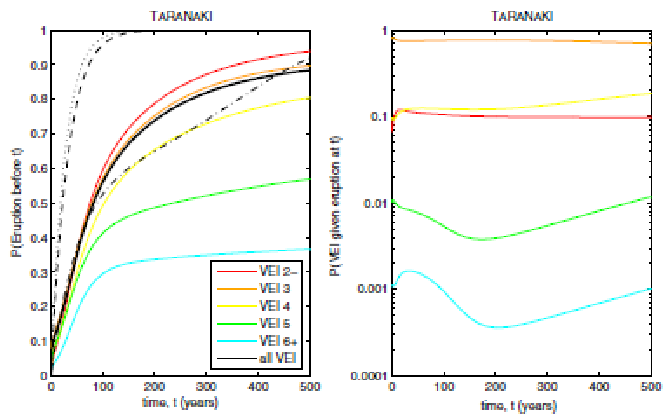
NATURAL HAZARDS RESEARCH PLATFORM
MASSEY UNIVERSITY TE KUNENGA KI PŪREHUROA UNIVERSITY OF NEW ZEALAND
THE UNIVERSITY OF AUCKLAND NEW ZEALAND Te Whare Wānanga o Tāmaki Makaurau
UC UNIVERSITY OF CANTERBURY Te Whare Wānanga o Waitaha
VICTORIA UNIVERSITY OF WELLINGTON
GNS SCIENCE TE PŪ AO

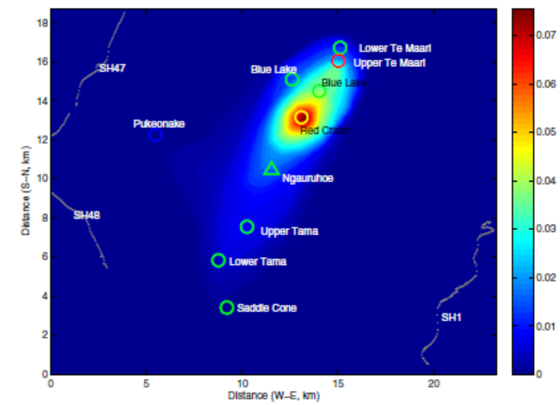
First steps to a national volcanic hazard model

What is the likely time, size and location (for VF) of the next eruption from NZ volcanoes?
No consistent models or data - Expert Elicitation

Time	Size	Location







These provide baseline (mixing) probabilities of when, where and how large and eruption will be.

Volcanic hazard = P(impact | style, intensity) × P(style, intensity | eruption phase) × P(eruption phase | eruption, size) × P(eruption, size)

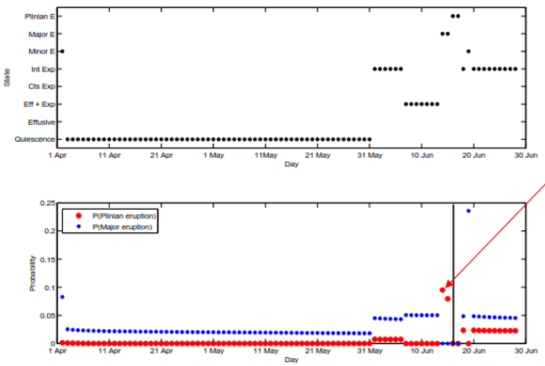
Intra-eruption modelling – phase durations and transitions

Eruptions are complex

Date | Date range
Distance | Eruption style
Eruption consequence

Ash eruptions were recorded at Sheveluch on August 15, October 27, November 1, and November 24. On December 27, a possible gas-and-ash plume was reported. Intermittent gas-and-ash explosions continued into 2002. A short-lived explosive eruption was observed at 1135 on 29 August sending an ash-rich plume to an estimated altitude of 10 km. The ash cloud drifted SE, and was recorded by geostationary weather-satellite imagery moving E across the Bering Sea. Following strong tremor on May 7, 2002, a new lava dome was first seen on May 12 between the 1980 dome and the NW crater wall. A major explosion on May 22 destroyed the new dome and the west part of the old dome and produced a 20-km-high eruption column. Dome growth, gas-and-ash emissions, and occasional pyroclastic flows were recorded through 2005. Dome growth and occasional thermal anomalies were reported in 2006, although no ash eruptions were reported until December 4. Dome growth, intermittent ash eruptions, and occasional pyroclastic flows continued into 2008. On March 31, 2007, a mudflow covered an approximately 900-m-long section of road, in an area ~ 20 km from Sheveluch. A large explosive eruption on October 28, 2010 produced an ash plume to 12 km altitude and pyroclastic flows that travelled 15 km; half of the lava dome was destroyed. Dome growth and intermittent explosive activity continued into 2011.

Example: Pinatubo 1991



Spike in P(Plinian) 2 days before Plinian stage

Cost-benefit for evacuation exceeded by P = 0.094?

(Vesuvius / VEI3 threshold is c. 0.09)

Code into states, durations

State	Description	Notes
1	Effusive	**Effusive** subdivided as .1 = extrusion/dome, .2 = effusive/flow, .3 = fountains
2	Effusive and explosive	**Explosions** subdivided as .1 = phreatic, .2 = phreatomagmatic, .3 = magmatic
3	Continuously explosive	e.g. Strombolian
4	Intermittently explosive	Includes Vulcanian, but also multiple irregular, undated individual eruptions
5	Minor explosive eruption	~ < 10 km column height. **Eruptions** are discrete events of 0-4 days duration
6	Major explosive eruption	~ 10-20 km column height. Many VEI 3, most VEI 4 eruptions will have at least 1.
7	Plinian explosive eruption	~ > 20 km column height. Most VEI 5, all VEI 6+ eruptions will have at least 1.
8	Deformation	No eruptive activity
9	Quiescence	More than 1 day between states 1-8
0	Eruption Start	Nominal
10	Eruption End	Nominal

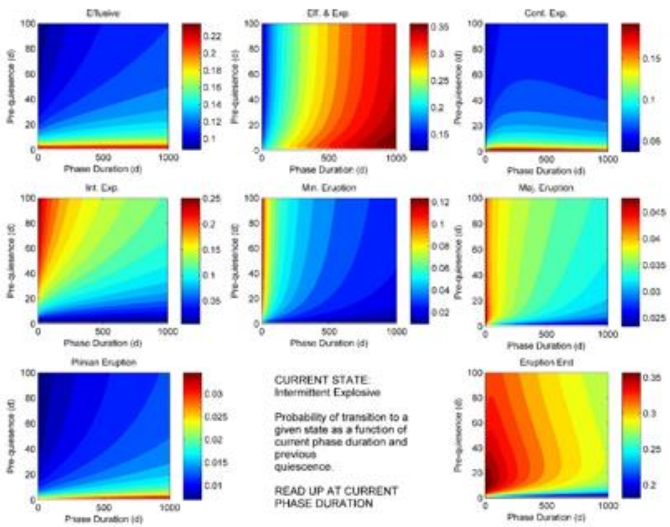
GVP phase data
698 multiphase eruptions (2785 phases) from 187 volcanoes

Sheveluch (1999) looks like:

Major eruption · Minor eruption · Dome growth + int. exp.

State	9	5	5	5	5	5	4	1.1	6	1.1	5	2.1	1.1	2.1	6	2.1	10
Duration	0	1	1	1	1	1	~800	10	1	88	1	~1150	~180	~600	1	65	0
Quiesence	START	72	4	22	2	0	~100	0	0	0	0	~380	~90	~850	12	(90)	END

Series of minor eruptions (dates known) · Intermittent exp. · Dome growth (effusive only) · Major eruption



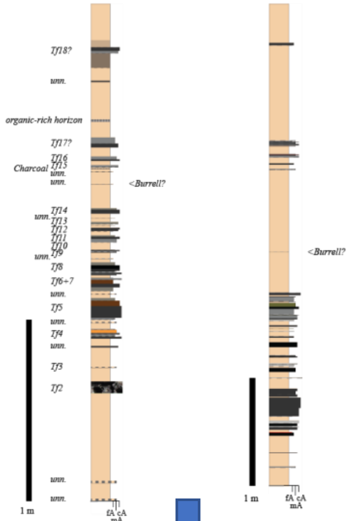
Probability model

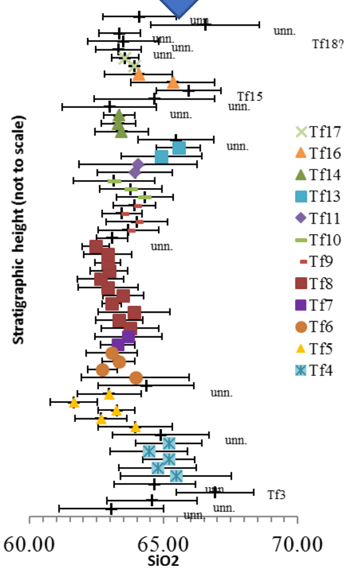
Next Steps (RNC2):

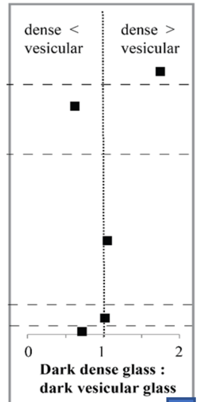
- Geological data to tailor to NZ volcanoes
- Value of analogue volcanoes
- State & time dependent hazards

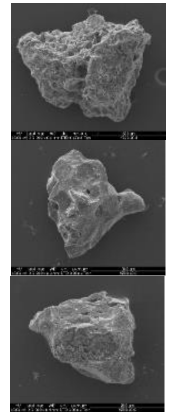
Developed multi-stage eruption records and databases

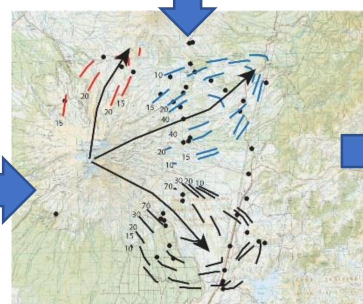
How 'good' are statistical models?

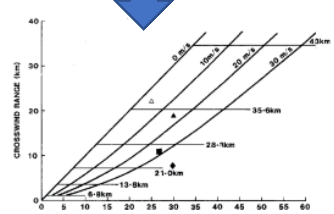




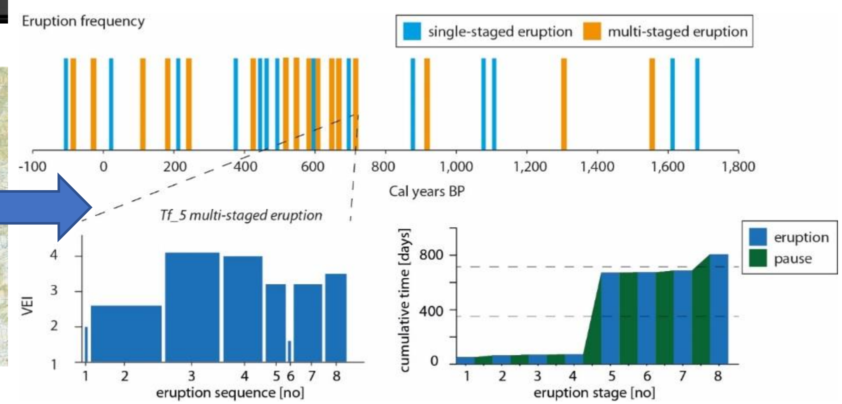








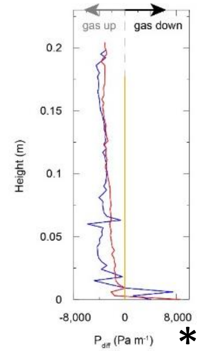
- c. 55 % of Ruapehu eruptions are multi-staged
- Eruption magnitudes, eruption style, eruption number and order through event dispersal mapping, geochemical signature and componentry
- New mapping methods allow estimating temporal evolution of multi-staged eruption sequences



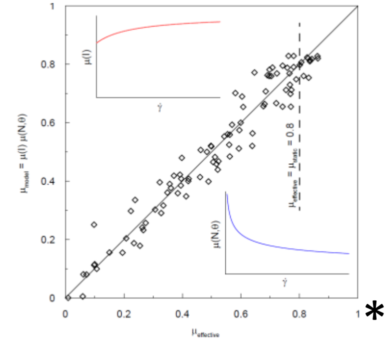
...as good as the base field data!

Advancing Volcanic Hazard Models (example PDCs)

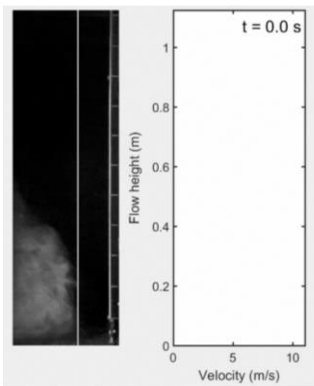
Understanding Flow Processes

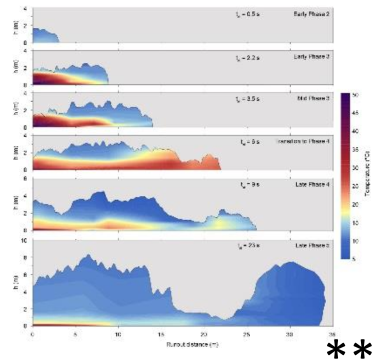


- Air-lubrication to reduce apparent friction in PDCs
- New rheology for high-energy gas-particle mass flows

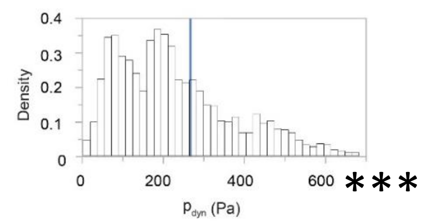


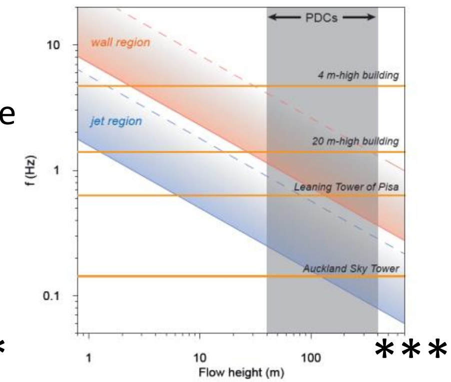
Understanding Hazard impact





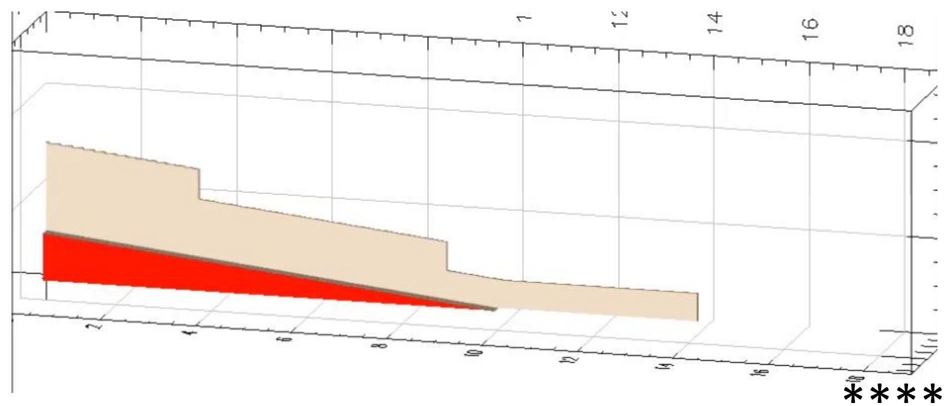
- Thermal impacts through large- eddy pulsing
- PDCs cause building resonance





Advancing hazard models

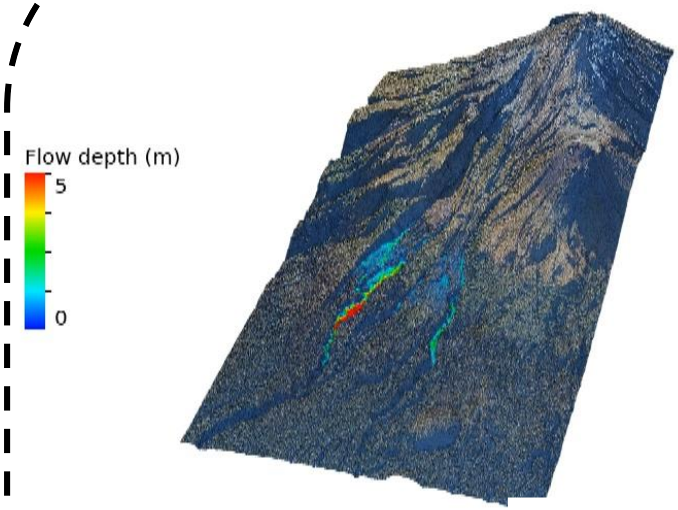
- First international benchmark for PDC model inter-comparison and validation
- 11 modelling schools from 7 countries
- NZ's PELE data forms benchmark for inter-comparison
- Model down-stripping approach (3D→2D1D→0D) identifies gaps in understanding & optima in cost/accuracy



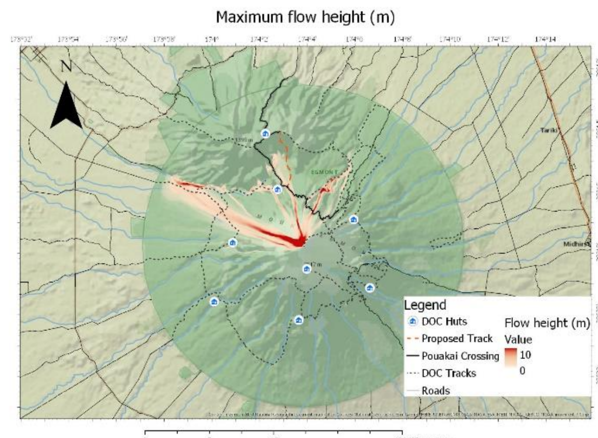
Quantifying volcano multi-hazard impact

Should I build my hut/track/infrastructure here?

Single hazard assessment



1. Simulations of volcanic processes
   (e.g. pyroclastic flow)

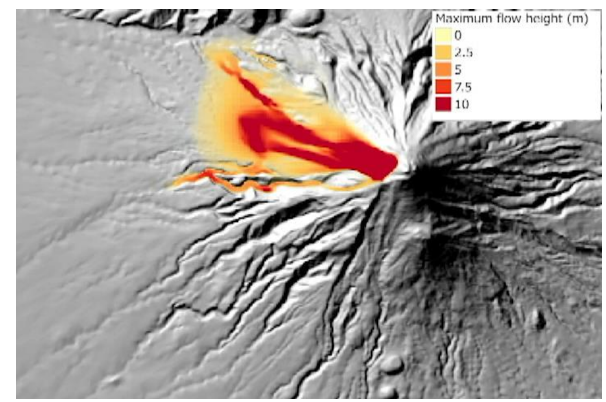


2. Map impact
   (e.g. maximum depth)

BUT:

Multi-hazard assessment needs to estimate P(impact | style, intensity) across 1000's of inputs for each hazard.

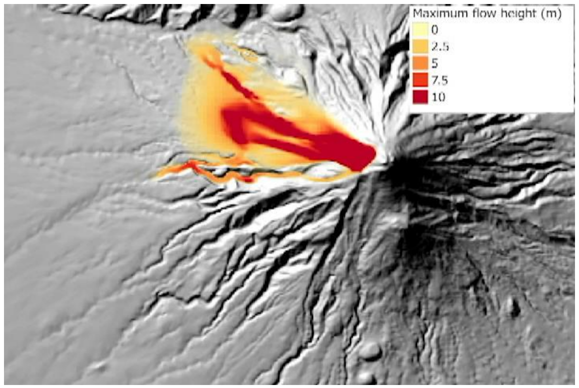
Array of impacts



e.g. 250 (of 1,000) block-and-ash flows at Taranaki

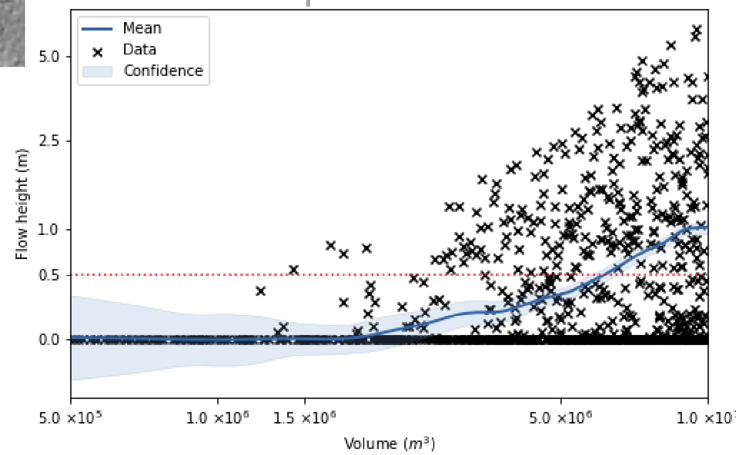
Location-centred quantification of multi-hazards

For each *location* and hazard:



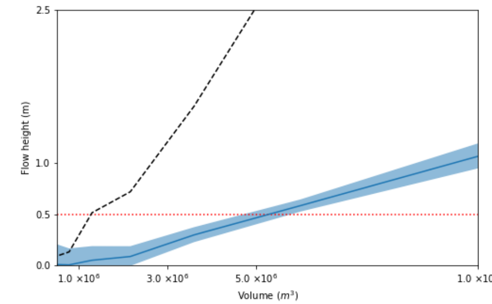
1. Array of impacts

Gaussian process emulation



2. Learn the function f that maps the input space $\mathcal{X}$ to the impact space $\mathcal{Y}$.

Impact model



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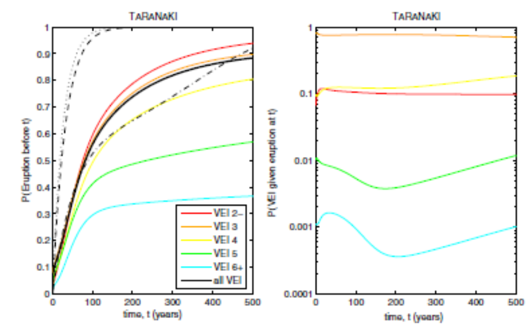
Source model



$= P_{x,y}(\text{impact}|\ldots,\ldots,\ldots)$

Pouakai crossing: Probabilistic volcanic multi-hazard

Pouakai Crossing volcanic hazard assessment

Report prepared for Department of Conservation by Volcanic Risk Solutions, Massey University, New Zealand

Authors:

Associate Professor Jonathan Procter, Professor Mark Bebbington, Dr. Stuart Mead

VOLCANIC RISK SOLUTIONS

1

Quantitative hazard assessments delivered through integration of statistical models, benchmarked simulators and modelling techniques.

Event	Estimated probability	Comments
One or more eruption of Mt. Taranaki in the next 50 years.	0.35 – 0.38	Expert elicitation suggests the most likely next eruption size is VEI 3.
Ashfall affecting Pouakai Hut requiring moderate repair to replacement.	0.2 following an eruption	Assuming moderate damage begins at ~100 mm of ashfall.
Ashfall affecting Holly Hut requiring moderate repair to replacement.	0.4 following an eruption	Assuming moderate damage begins at ~100 mm of ashfall.
Debris avalanche at Mt. Taranaki	0.00018 per year 0.03 – 0.3 following a VEI4 or larger eruption.	
Debris avalanche affecting Pouakai Crossing.	> 0.045 if a debris avalanche is triggered.	
Block-and-ash flow affecting Pouakai Crossing	Less than 0.73 following an eruption.	Based on the likelihood of generating a sufficient dome-growth episode.
Primary lahar affecting Pouakai Crossing	Similar to block-and-ash flow probability if climatic conditions are present	Requires a snow/ice water source.

“Āhea riri ai ngā maunga puia? When will our volcanoes become angry?”

RNC 2019-2024

“We will generate the fundamental and applied hazard, and risk science to support resilience in response to future activity of New Zealand’s most active cone volcanoes. This includes developing reliable forecasts of volcanic eruptions, their multiple dynamic hazards and their complex impacts on our businesses, infrastructure and society.”