Hunga Volcano:
Post Peaukula Survey Results

Jose Borrero[1,2]

Shane Cronin[3] Folauhola Helina Latu'ila[4] Pupunu Tukuafu[4] Nikolasi Heni[4] Ana Maea Tupou[4] Taaniela Kula[4] Ofa Fa'anunu[5] Laura Kong[6]

[1]eCoast Marine Consulting and Research

[2]University of Southern California Tsunami Research Centre

[3]University of Auckland

[4]Tonga Geological Services

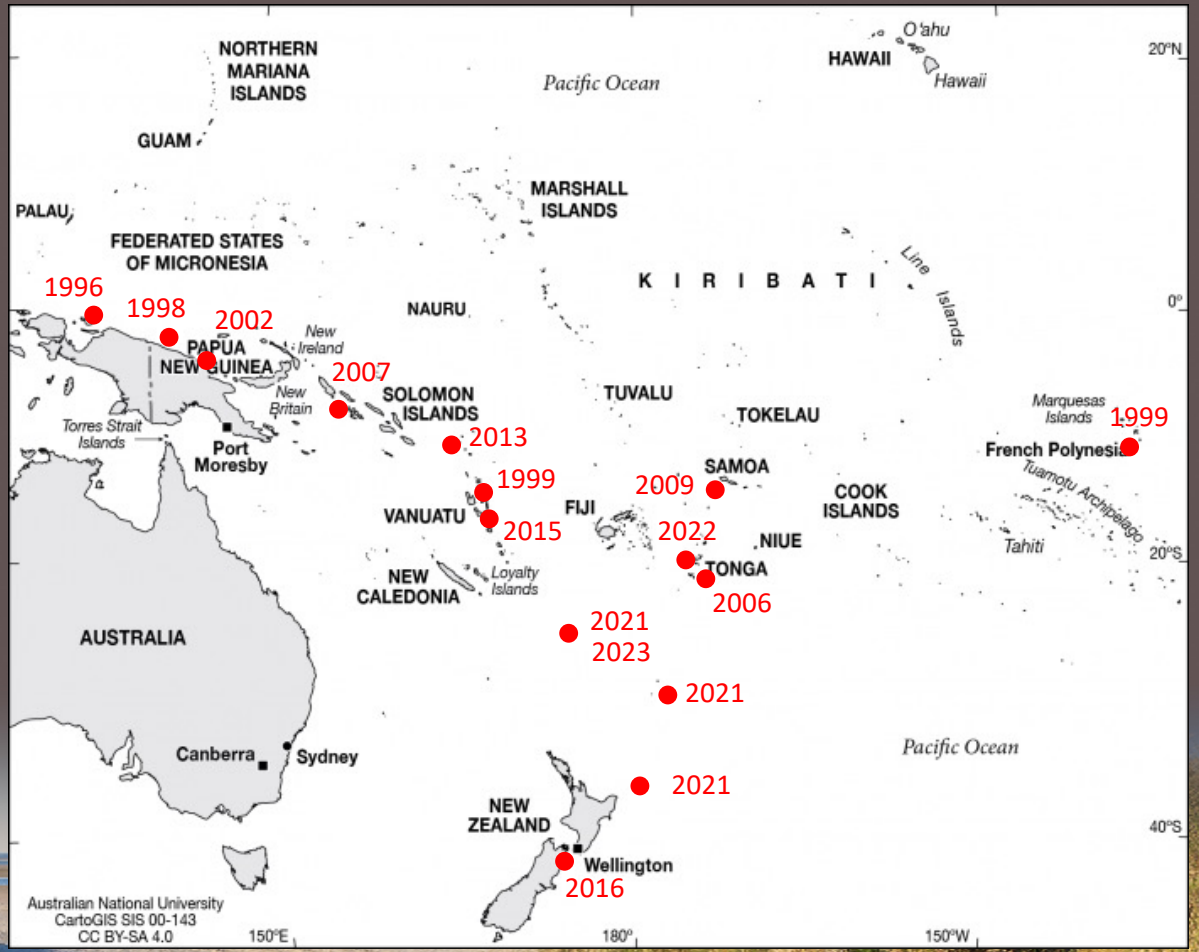
[5]Tonga Meteorological Service

[6]UNESCO/IOC International Tsunami Information Centre


15 Jan 2022
TONGA GEOLOGICAL SERVICES
MLNR TONGA
“Me’a fakaofo ia ‘a ‘etau hao mai; Tau tuku kololia ki he ‘Otua ‘i Langi.” Himi 614, SUTT, Veesi 4.
(“It is a miracle that we are safe; lets give glory to the God in Heaven.”)

Some recent history…

- Biak, Irian Jaya 1996
- PNG, Aitape 1998
- Marquesas, Fatu Hiva 1999
- Vanuatu, Ambrym 1999
- Vanuatu, Port Vila, 2002
- PNG, Wewak 2002
- Tonga, Tongatapu 2006
- Solomon Islands, Ghizo 2007
- Samoa-Tonga, 2009
- Solomon Island, Lata 2013
- Vanuatu, Paama 2015
- New Zealand, Kaikoura 2016
- New Zealand, Kermadec 2021
- Tonga, Hunga 2022



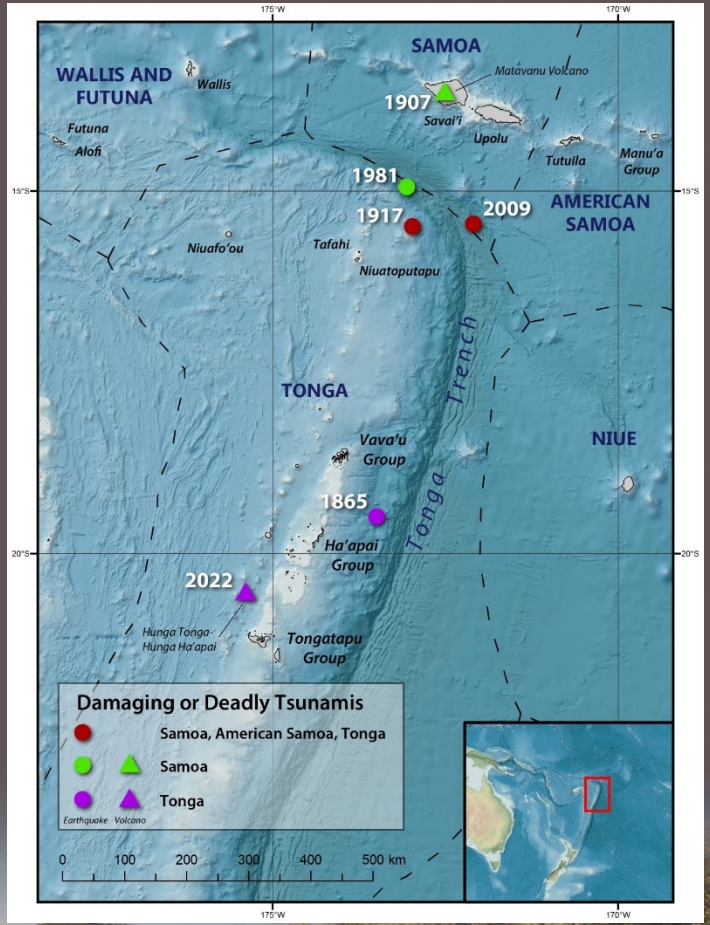
Some Tonga Tsunami History…

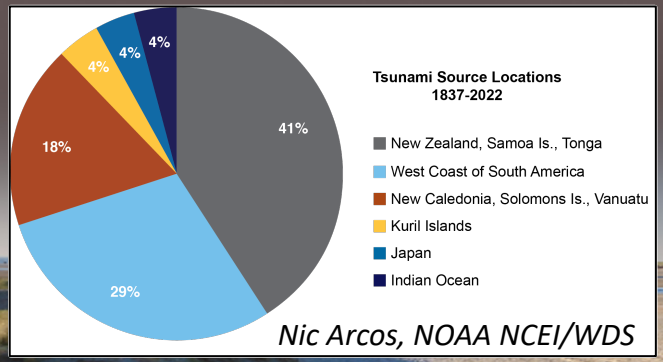
- NGDC Database has 32 tsunami events (including 14 & 15 January)
- 27 earthquake source, 4 volcano and 1 ‘unknown’ (March 8, 1889)

Some notable events:

- May 2006 (M 8.0) Close to Tongatapu, ~0.2 m on tide gauge. Event used for model calibration/validation
- Sept 2009 (M 8.0+) Samoa-Tonga event – major damage in Samoa, deaths in northern Tonga (Niuatoputapu)
- Jan 14/15 2022 (Hunga Volcano) This event…

Nic Arcos, NOAA NCEI/WDS





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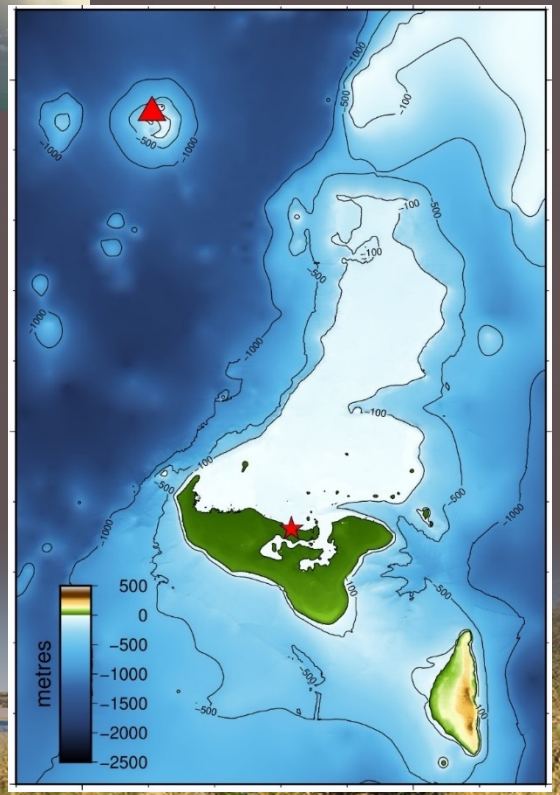
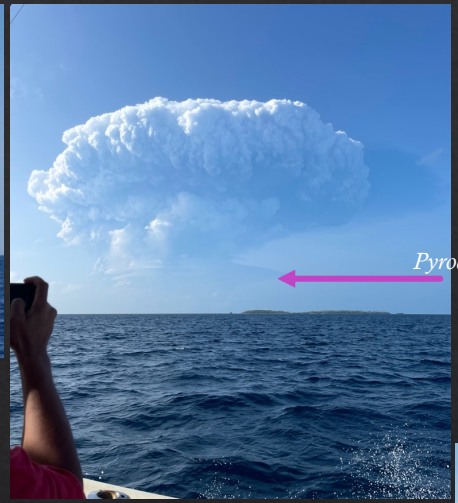
January 2022 Hunga Volcano Tsunami

- Weeks of Activity beginning in December 2021
- Significant activity on January 14th, swirling currents observed
- Main eruption late afternoon (~3pm Jan 15th)



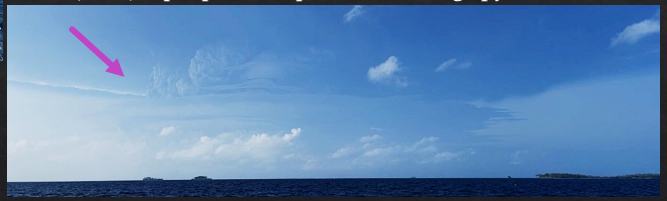
The 15th January 2022 Hunga eruption – eyewitness views

1711 (0411 UTC) first eruption "normal"



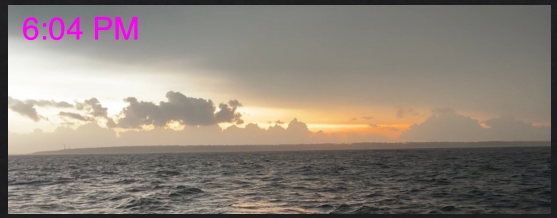
1718 (0418) Sudden upsurge in energy

1725 (0425) rapid plume expansion and huge pyroclastic



1732 (0432) Sonic booms

1733 (0433) Tsunami approaching north Tongatapu (west hit already with first wave)



1800 (0500) Ashfall begins on Tongatapu

Hunga 15th January Eruption timeline

Work with U. Auckland, Otago, USGS, GNS Science

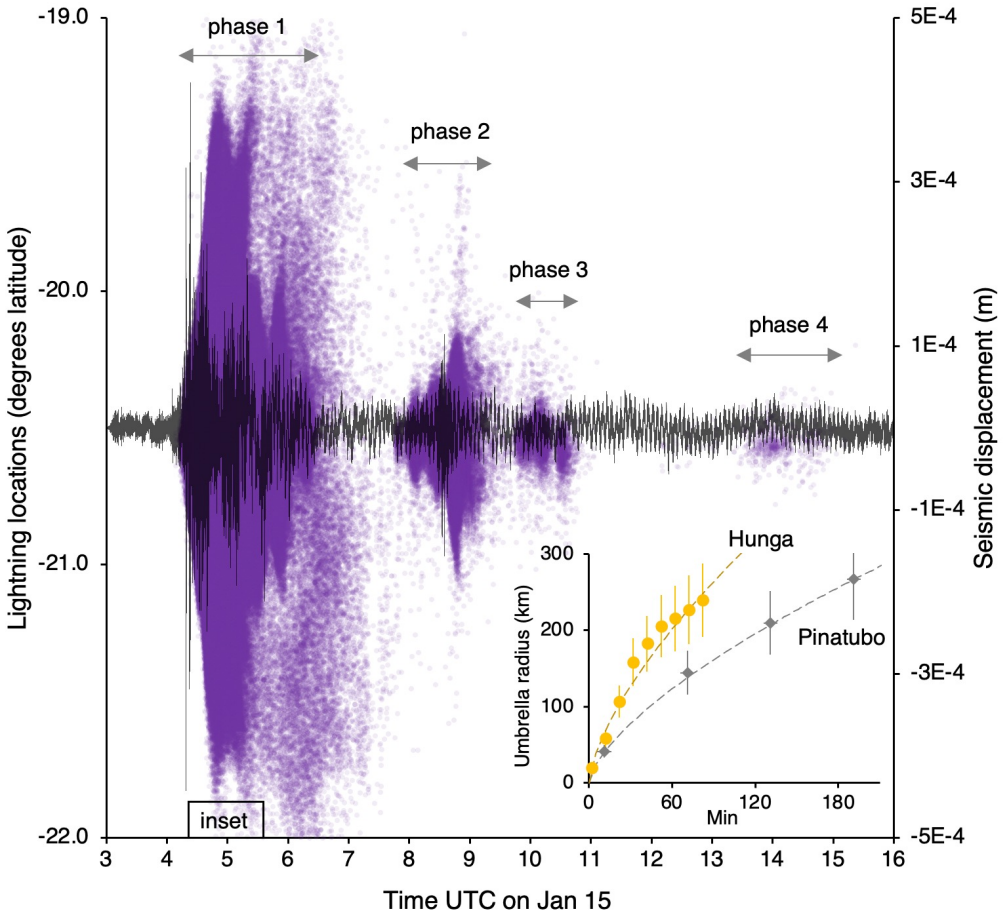
Four phases, declining in energy

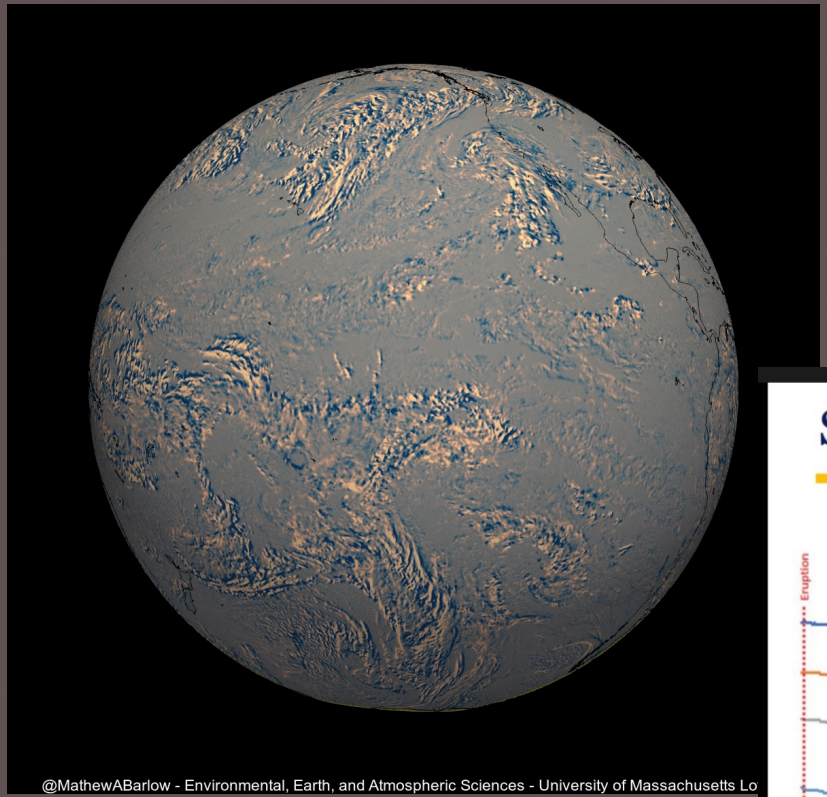
Initial eruptions were small and “normal”

Sudden changes at 5:15 and 5:25 pm driven by arrival of new rising magma and cracking of caldera top, allowing violent mixing of sea water and magma

Rise and spread of eruption was up to two-times faster than the next biggest eruption on record (Pinatubo, Philippines, 1991).

Most lightning detected for any natural event ever in the world!





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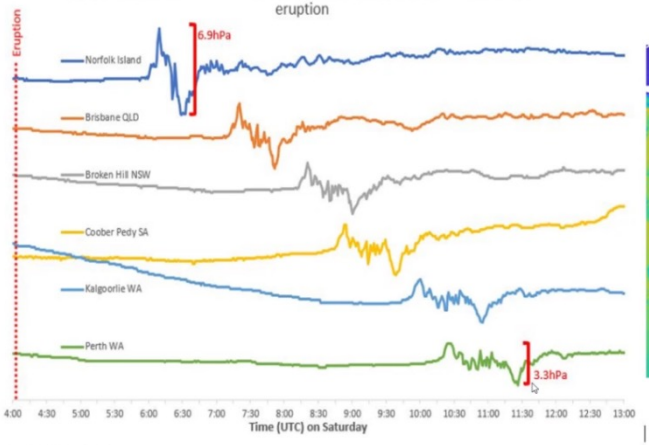
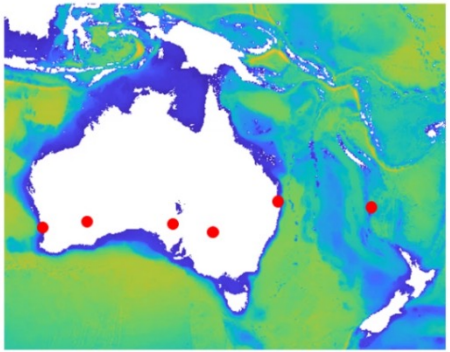
Speed of pressure jump

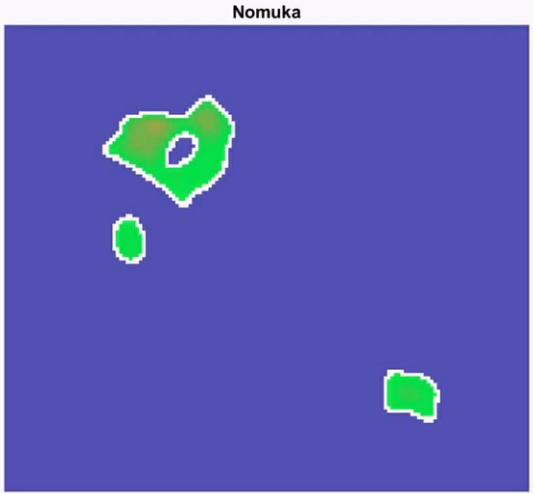
THE UNIVERSITY OF WESTERN AUSTRALIA

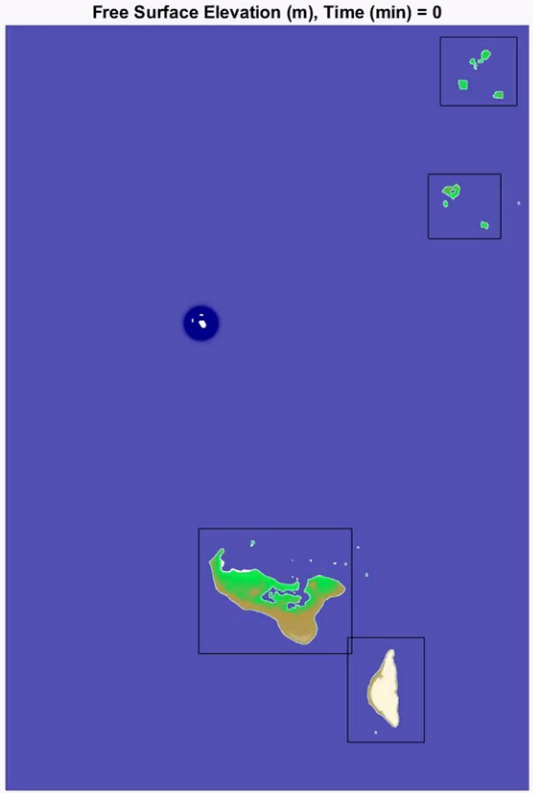
MSLP change across Australia from the Hunga Tonga-Hunga Ha'apai volcanic eruption

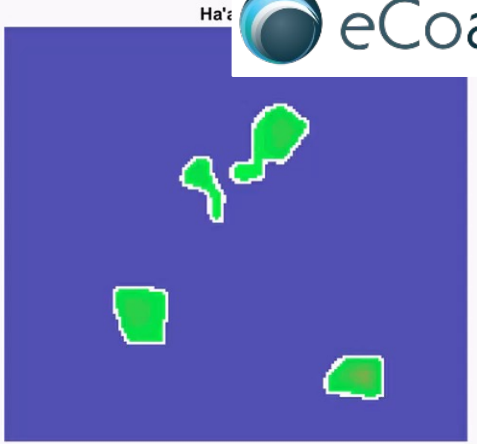


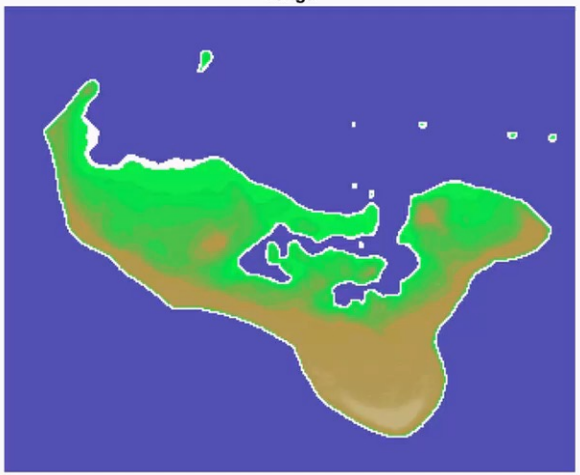


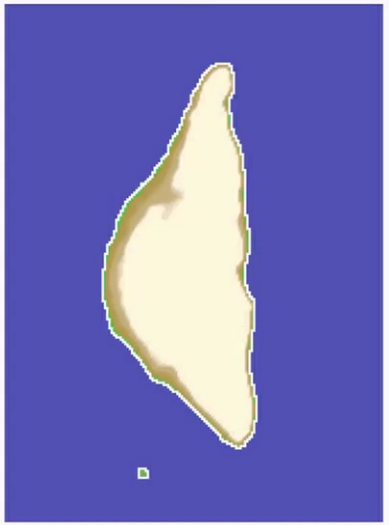
Chari P. (UWA)

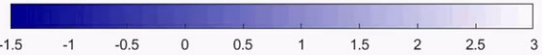












Patrick Lynett
University of Southern California

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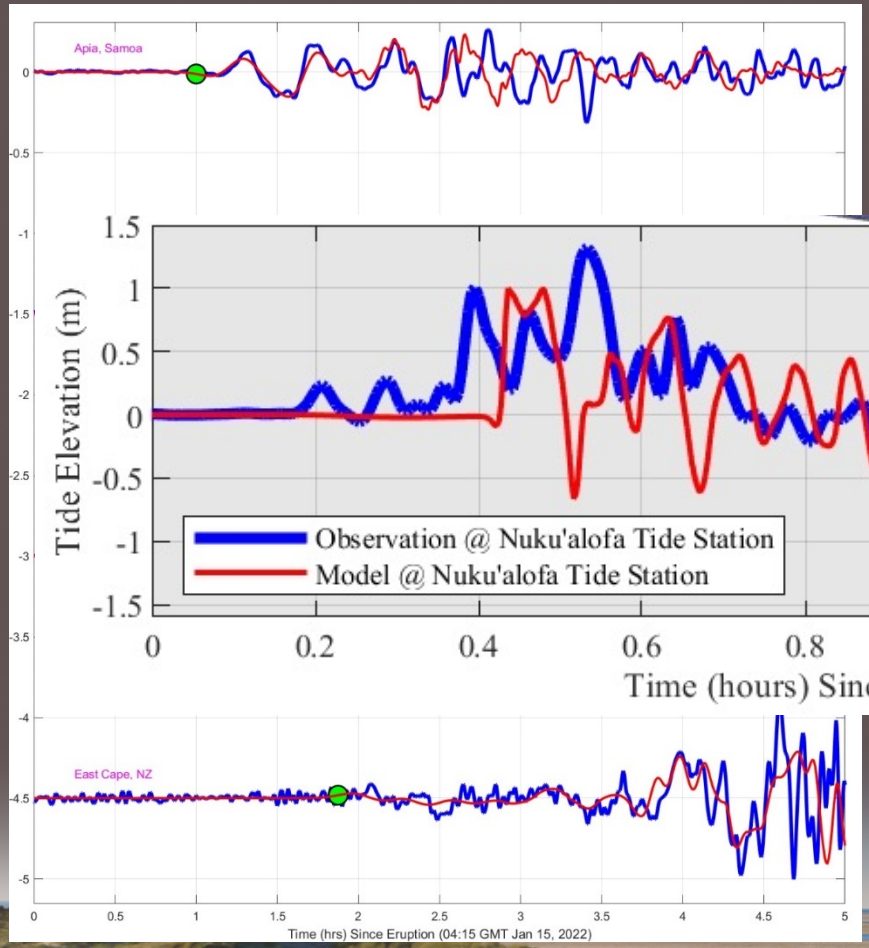
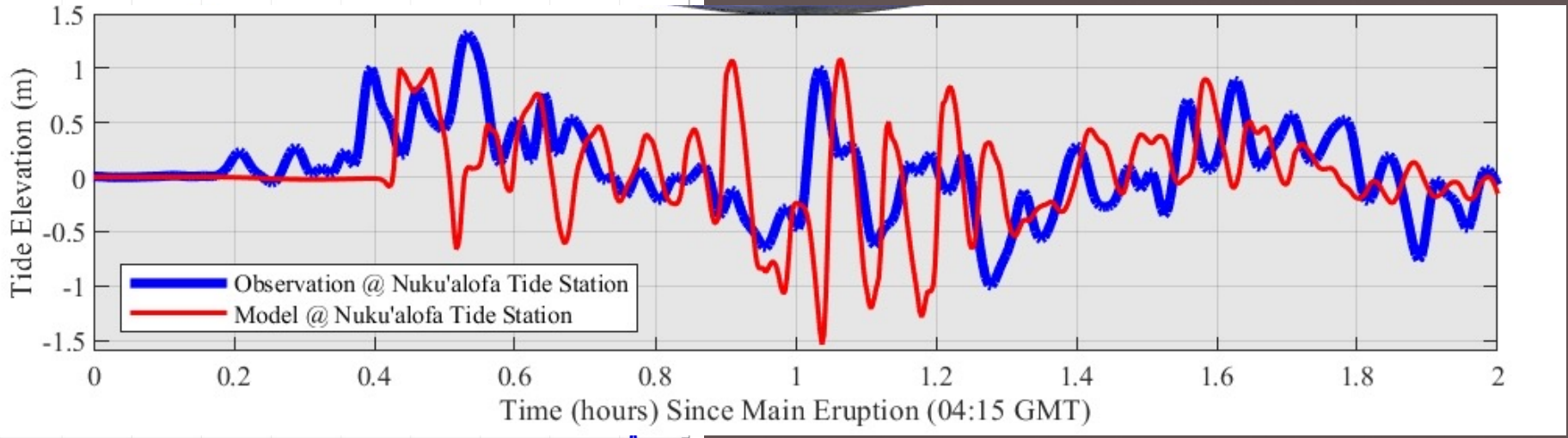
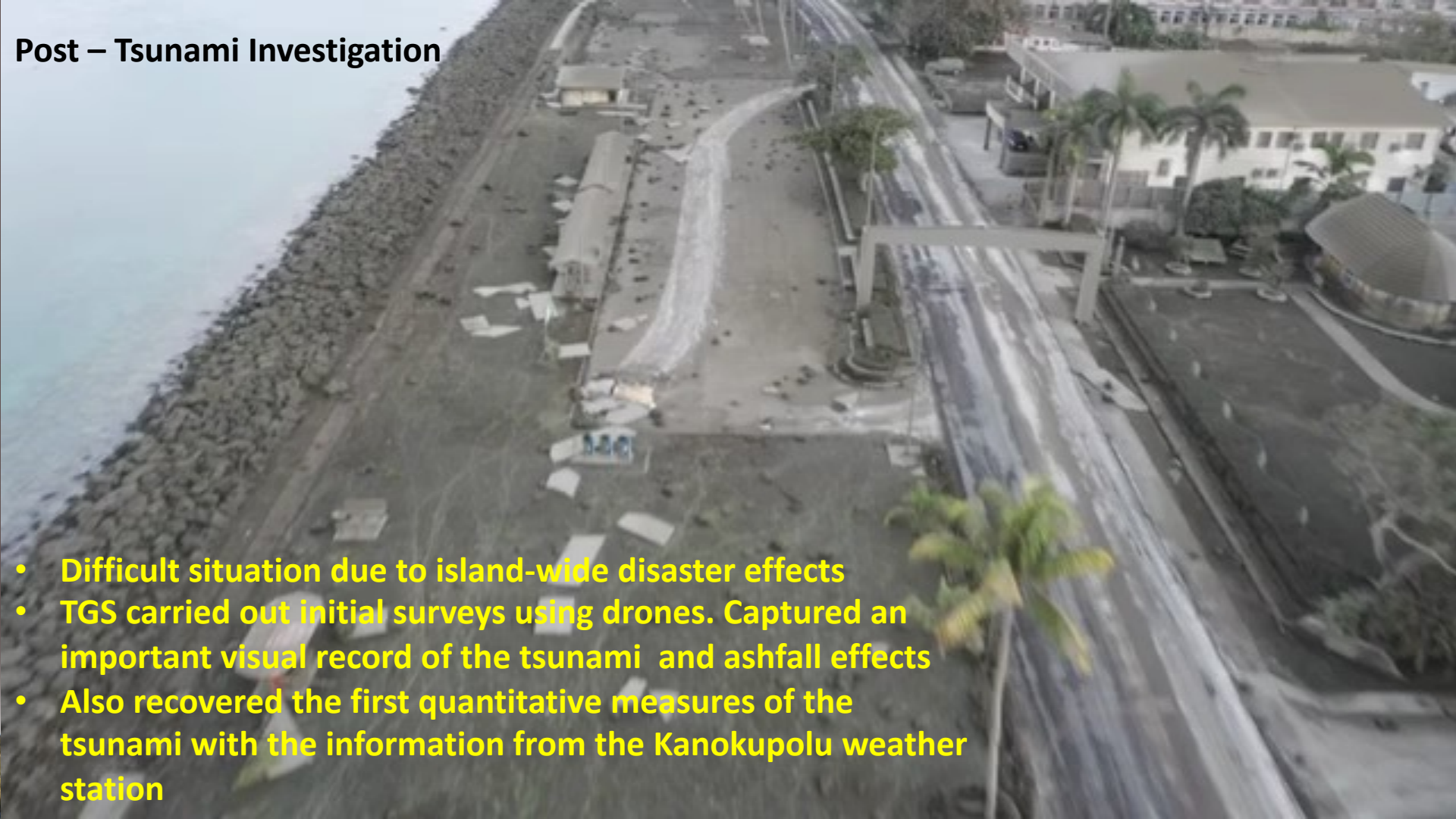
University of Southern California



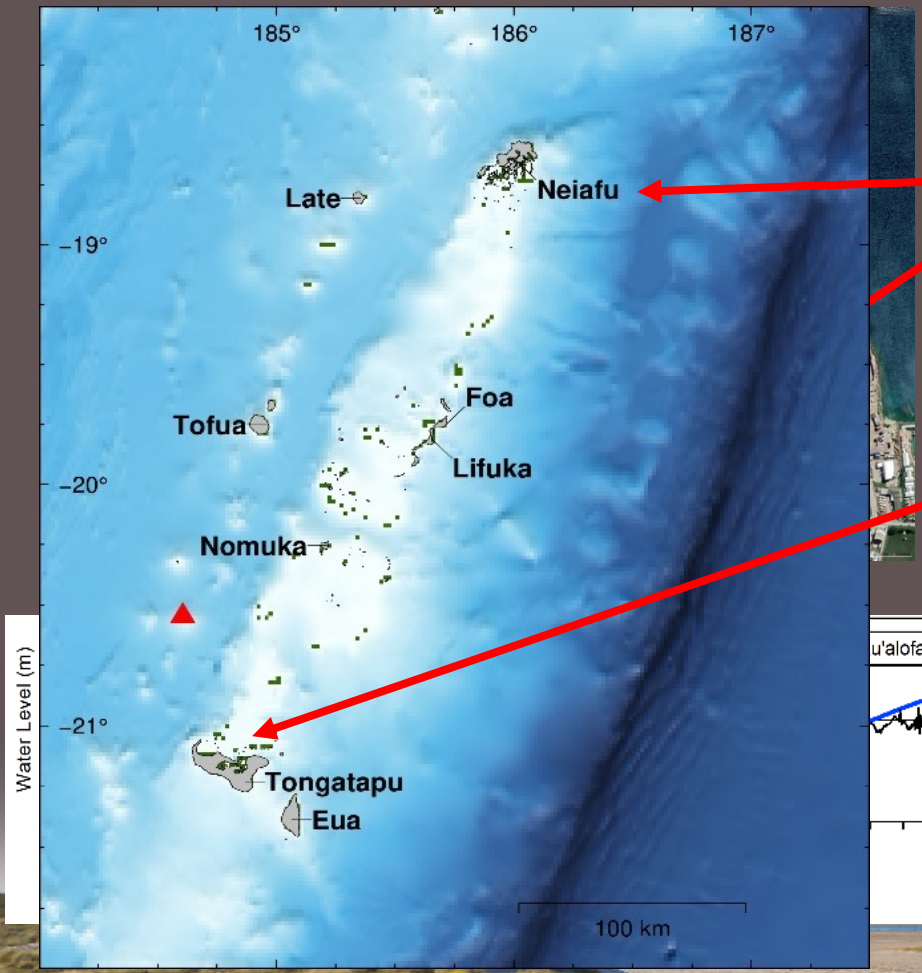


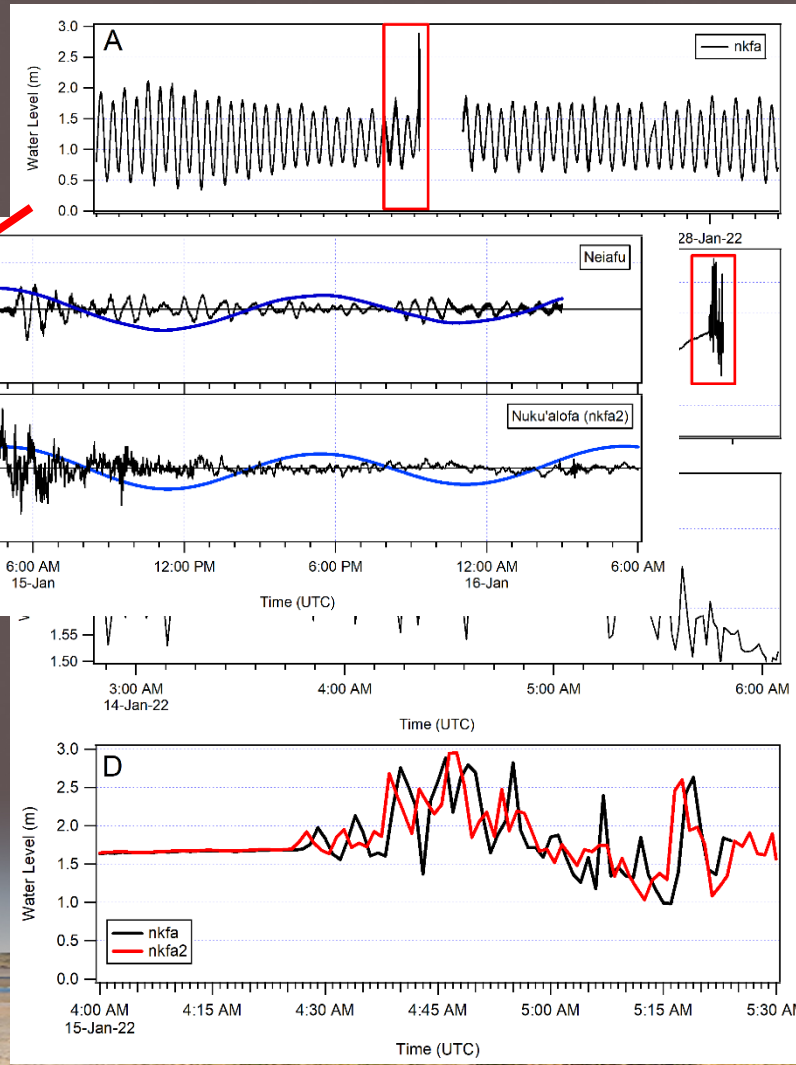
Post – Tsunami Investigation

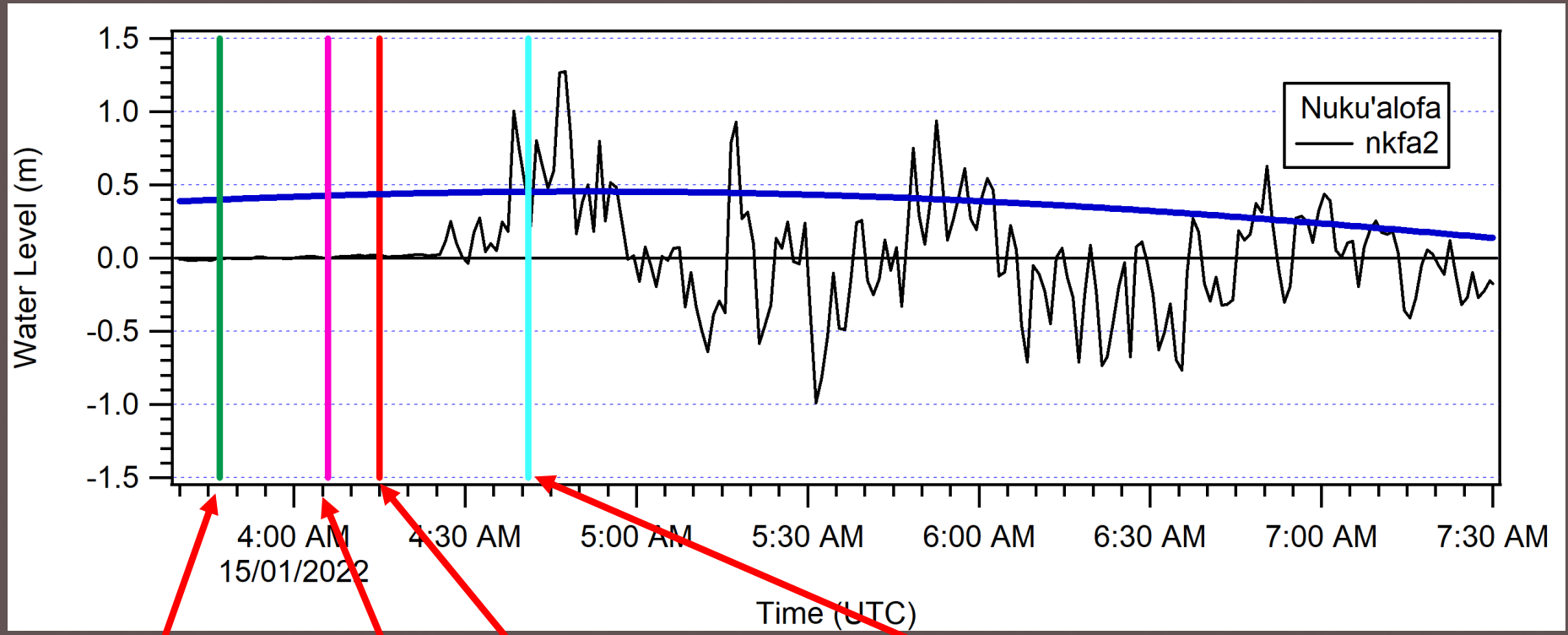


- Difficult situation due to island-wide disaster effects
- TGS carried out initial surveys using drones. Captured an important visual record of the tsunami and ashfall effects
- Also recovered the first quantitative measures of the tsunami with the information from the Kanokupolu weather station

Tide Gauge Summary







(0347) the start of the surface eruption

(0406) eruption plume visible on satellite imagery

(0415) large explosion at Hunga

Computed peaukula arrival time from the volcano to Vuna Wharf – based on a 0415 source.

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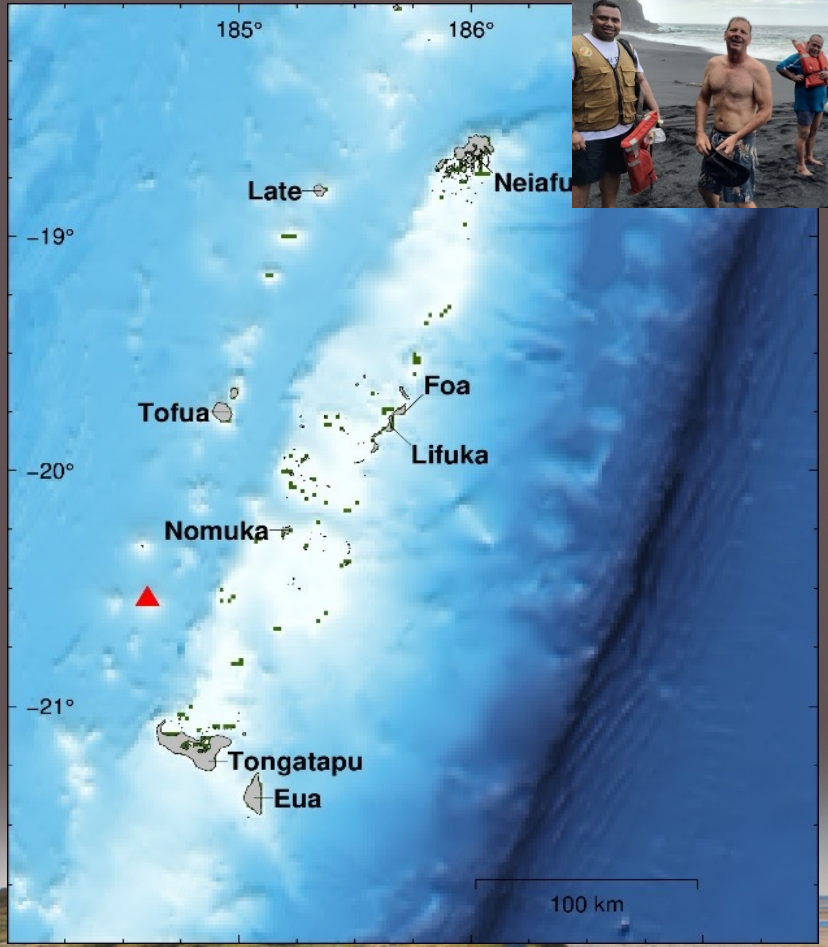
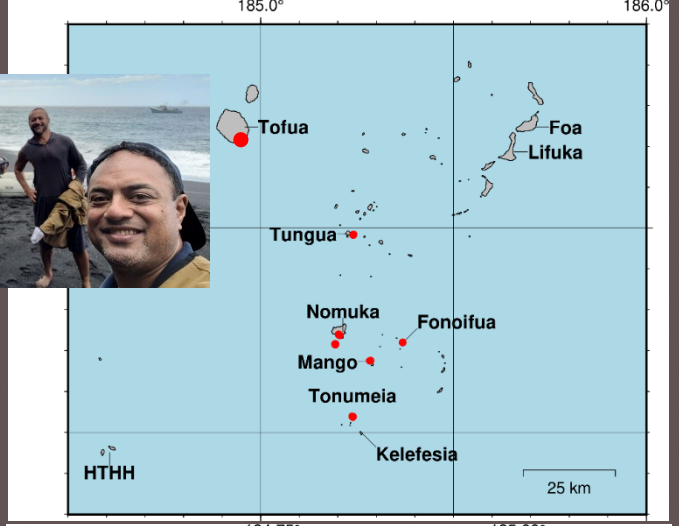
The Survey… Shane Cronin and the TGS





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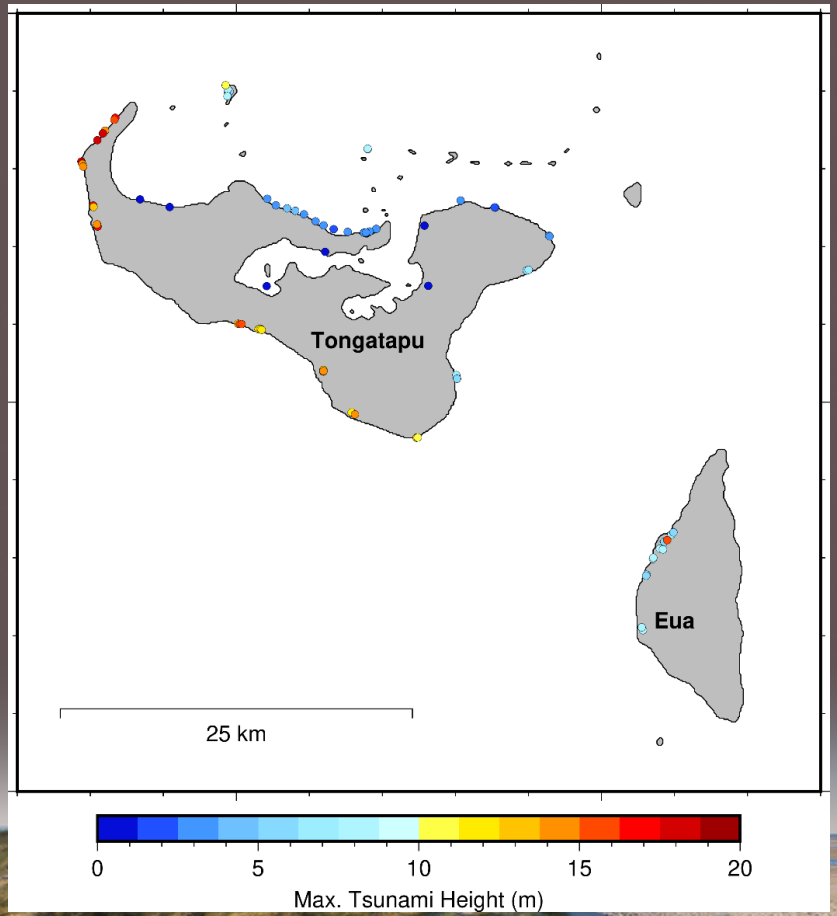
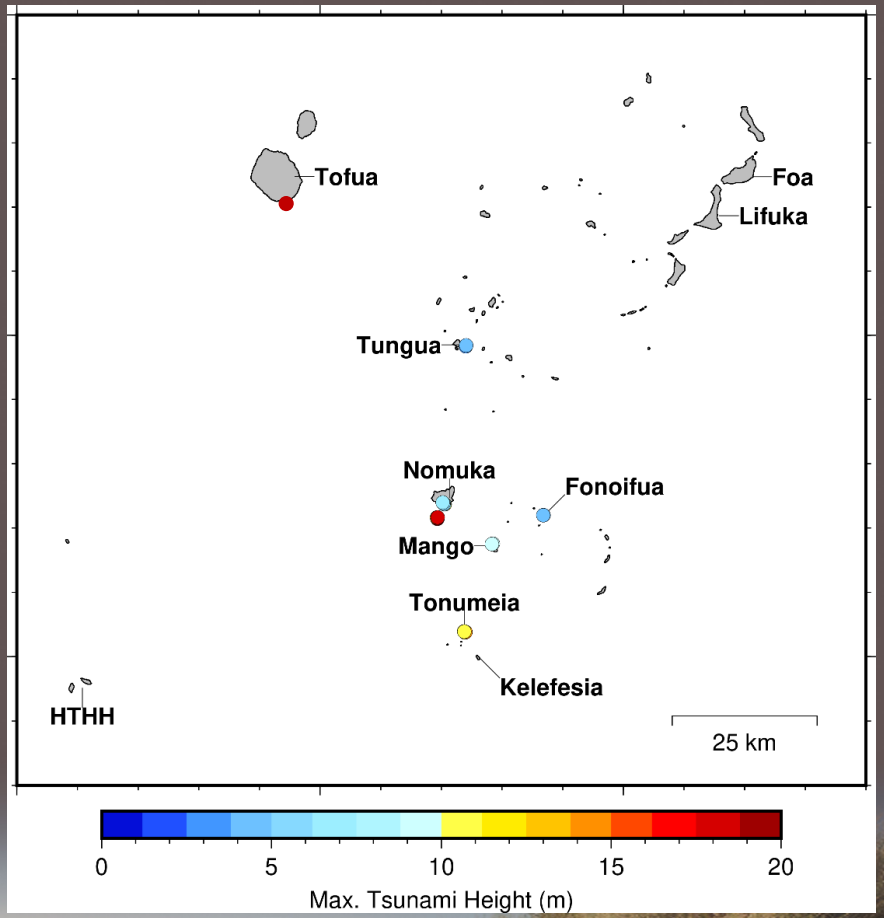

Tongatapu
Eua
25 km
0
5
10
15
20
Max. Tsunami Height (m)


Tofua
Foa
Lifuka
Tungua
Nomuka
Fonoifua
Mango
Tonumeia
Kelefesia
HTHH
25 km
0
5
10
15
20
Max. Tsunami Height (m)

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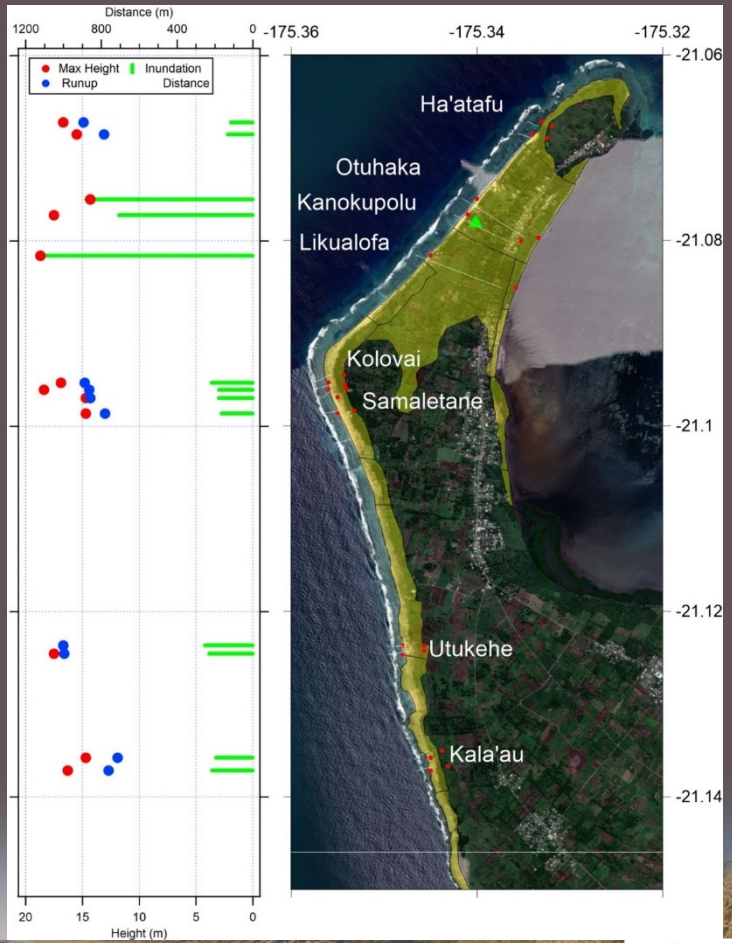
Distance (m)
1200
800
400
0
Max Height
Runup
Inundation
Distance
20
15
10
5
0
Height (m)
-175.36
-175.34
-175.32
-21.06
-21.08
-21.1
-21.12
-21.14
Ha'atafu
Otuhaka
Kanokupolu
Likualofa
Kolovai
Samaletane
Utukehe
Kala'au

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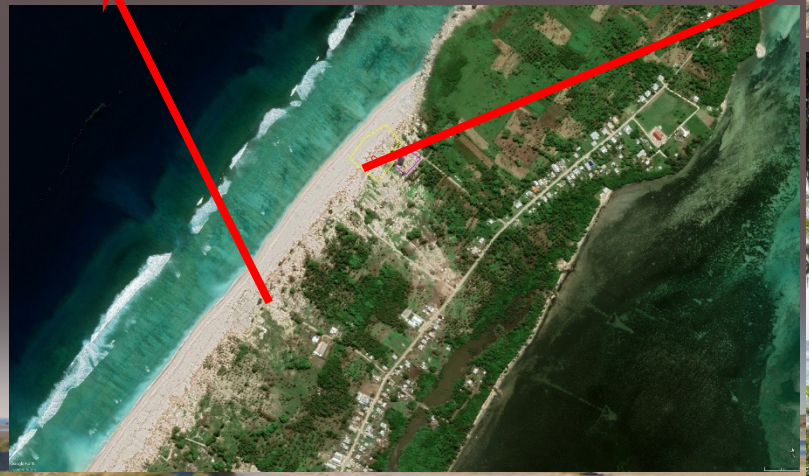
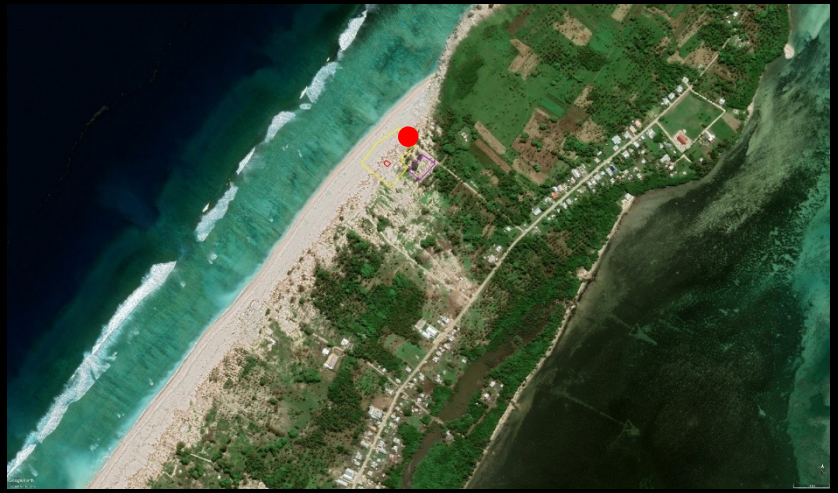
Shane Egan, Blue Banana Resort



Rachael Moore (Aus. High. Comm. in Tonga)



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5:17pm 15Jan22 from
MV Ngahau Koula, Ha'apai

5:18pm 15Jan22 from
MV Moonshine, Tongatapu

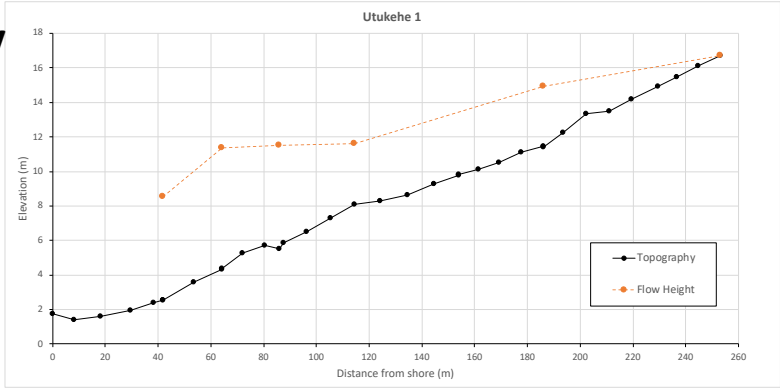
5:50pm 15Jan22 from
MV Ngahau Koula, Ha'apai

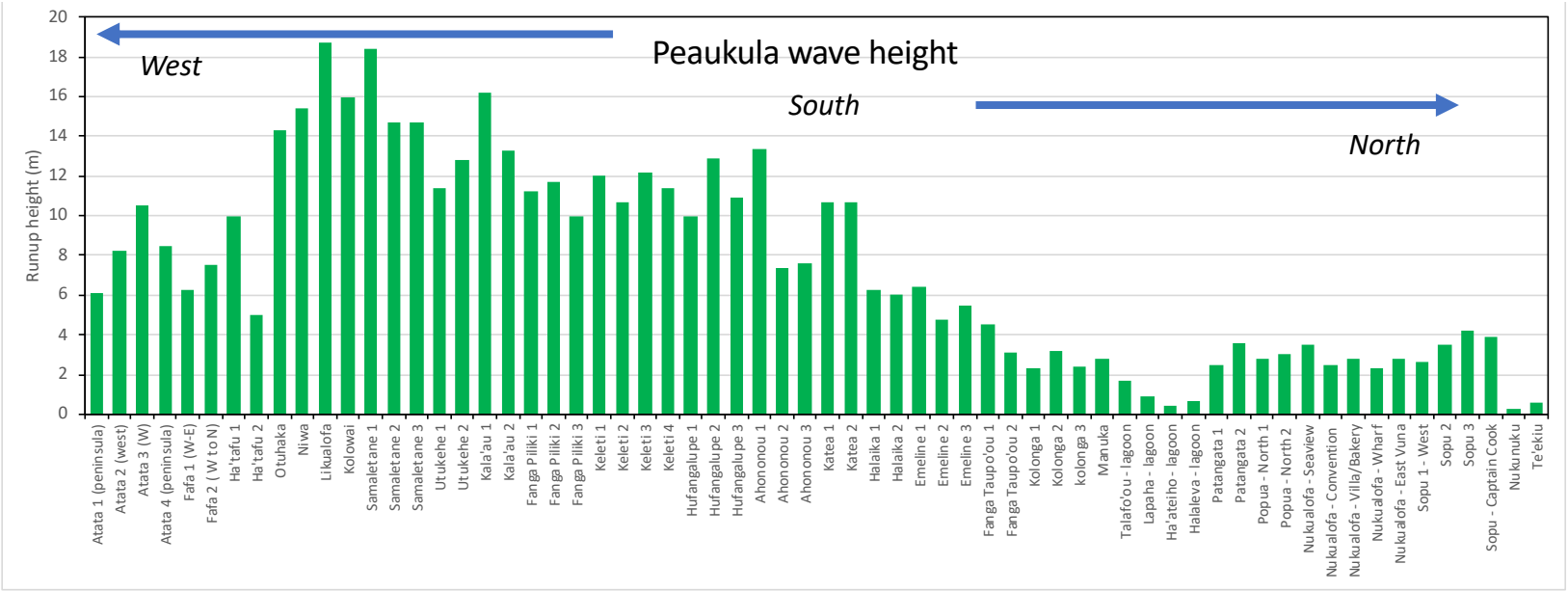

TONGA GEOLOGICAL SERVICES
MLNR TONGA
5:28pm 15Jan22 from
MV Ngahau Koula, Ha'apai


Google Earth

Peaukula run-up study

Detailed mapping and analysis of peaukula wave damage and deposits, Tongatapu, Ha'apai





Moana's Escape…

- Alerted to waves by guests
- Water came to border of property
- Alerted guests, prompted evacuations
- Saw Ms. Moore's car leaving
- Started running to look for 'tsunami rock' – heard large boom
- Couldn't find rock, found mango trees
- Climbed trees
- Got phone call from brother on the way in a car.
- Came down from trees
- Went to road, climbed to roof with others, looking east, saw waves wrapping in to the bay.
- Pumice started raining down
- Brother arrived, they jumped in car and sped off
- THEN the surge crossed the peninsula…

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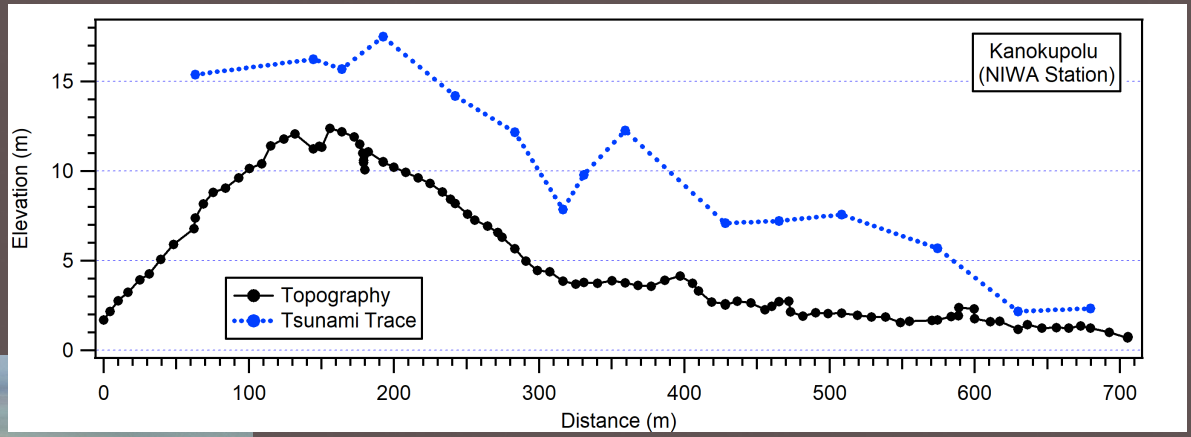
Kanokupolu

Weather station recorded data until 0500 UTC (6 pm local).

Antennae is sensitive to movement
Rain gauge did not record any moisture



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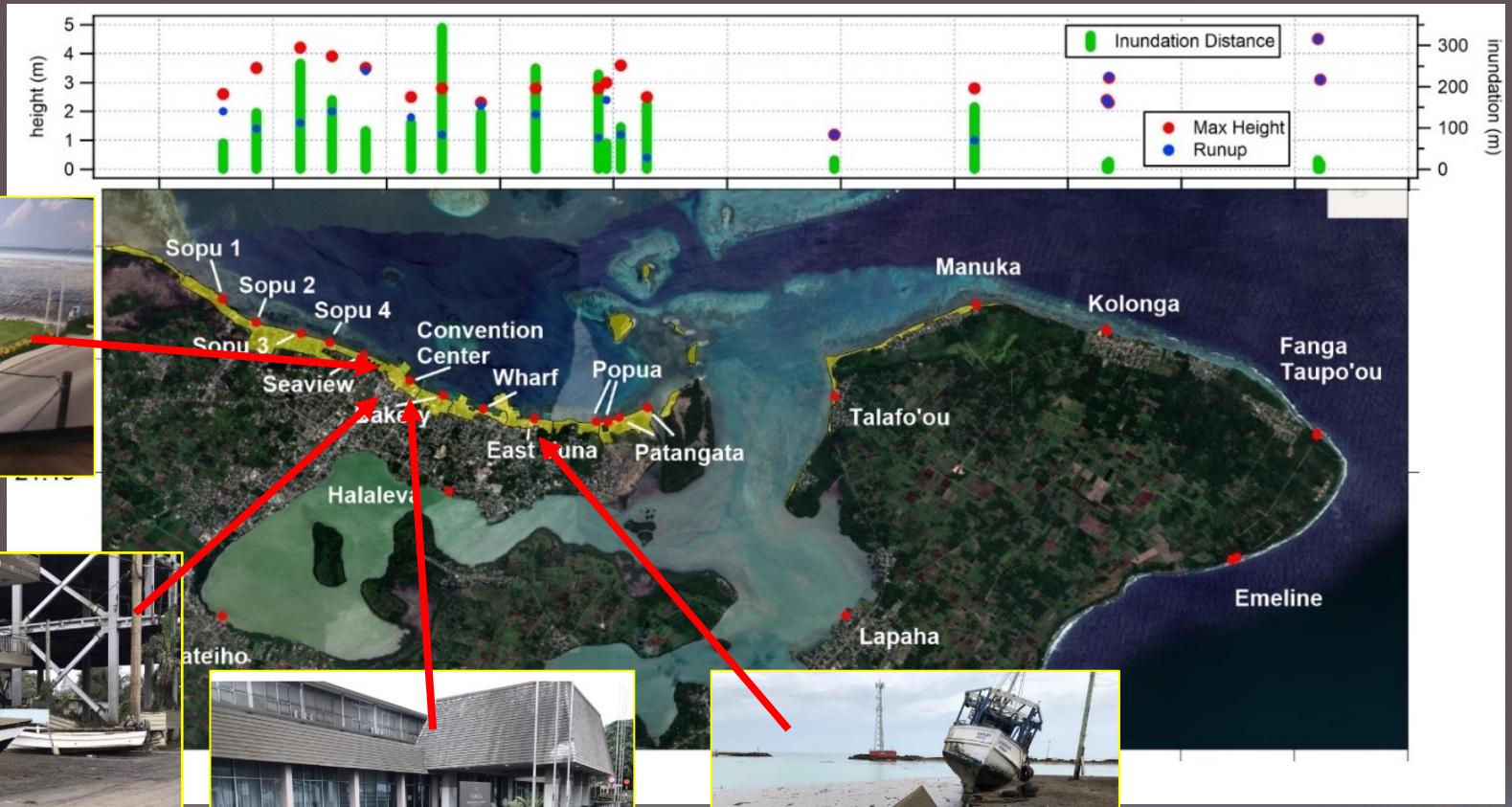
Nuku'alofa



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Atata

- Mr. Lisala Folau – washed off the island, ‘lost’ for 30 hours

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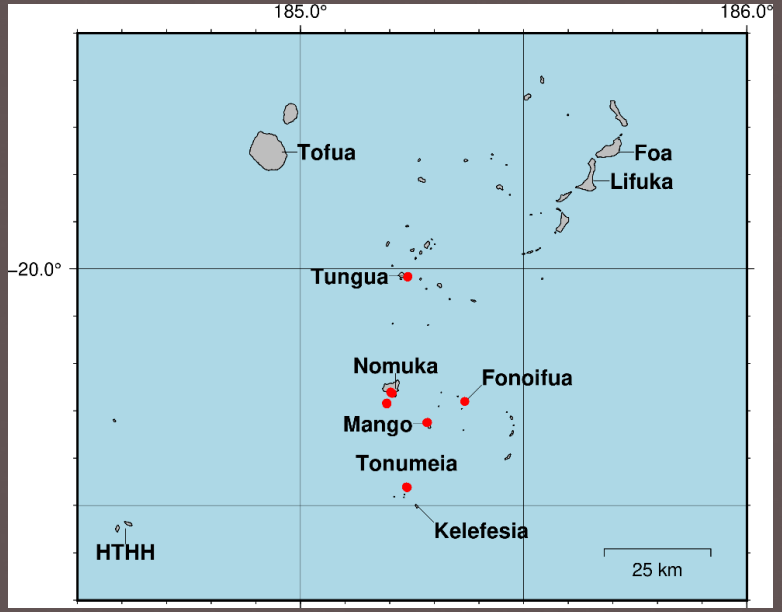
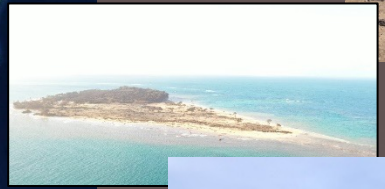
Ha’apai Islands



Nomuka & Nomuka Iki

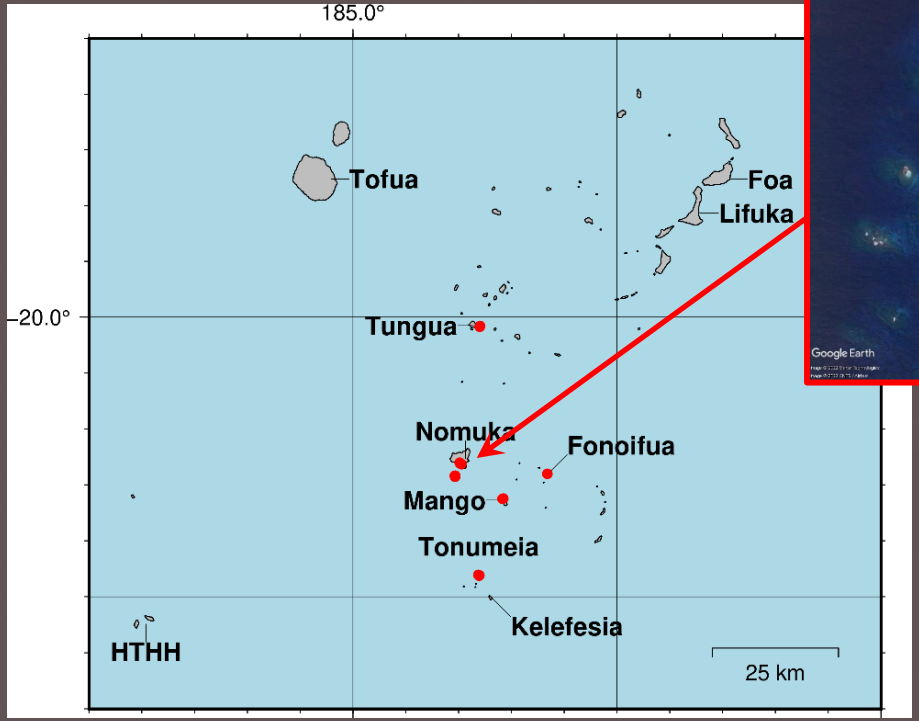


Kelefesia

Mango

eCoast

Nomuka & Nomuka Iki



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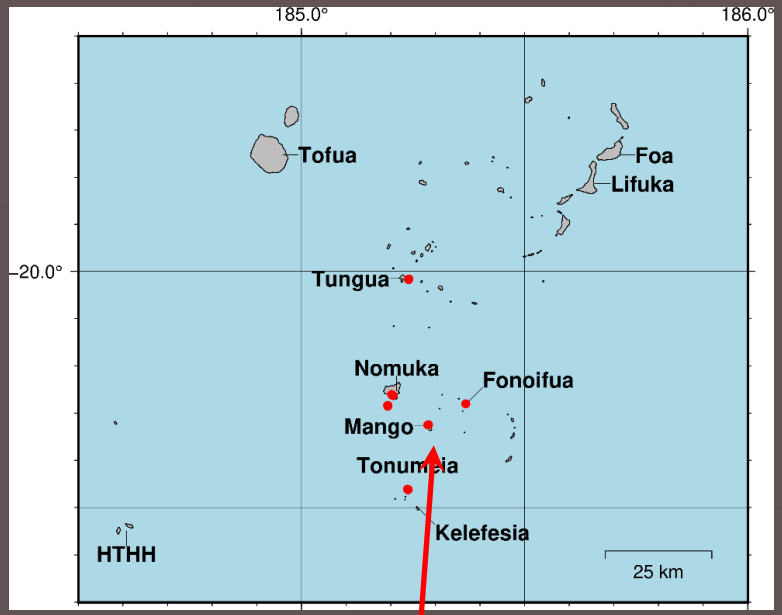

Mango

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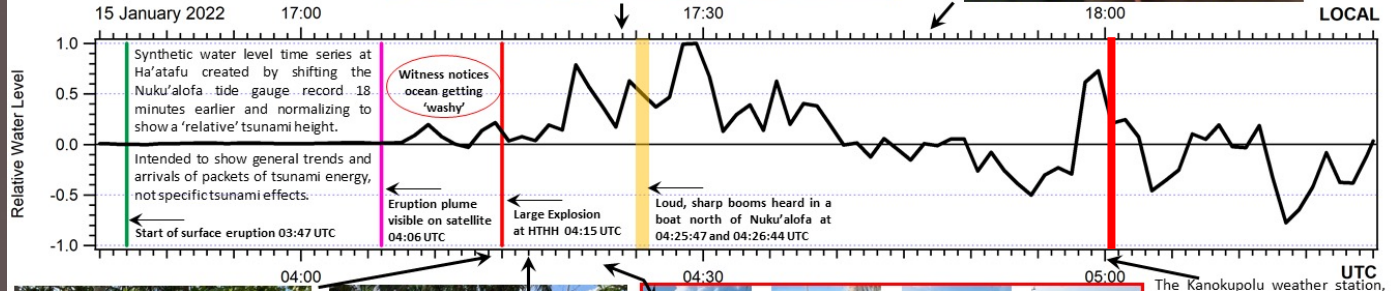

Photos from a guest at the Ha'atafu Beach Resort of the first small surges. The 16:41 photo is prior to the onset of tsunami activity. The 17:14 photos show a surge (red arrows) propagating towards shore and hitting the beach. The 17:17 photo shows another surge. These surges prompted the guest to return to her room and start packing to leave and likely prompted the men in the sequence at right to evacuate the beach.

Video 1 (red), shows men evacuating the beach after the first surges. They filmed as a wave hits, then continue filming from a car as a larger surge comes ashore. Video 2 (green) shot form further inland shows the back of the car (circled in red) and the departing car of the Ha'atafu beach resort guest who took the photos shown to the left

The Kanokupolu weather station, situated at an elevation of ~+13 m ASL, transmitted data until 18:00 (05:00 UTC). This corresponds to the arrival of the second large surge.

A boom can be heard at the end of the second video, likely corresponding to the booms recorded from the boat.

Possible timeline ?

- Presents a problem for modelling…
- Wide range of proposed source producing results with a 'good fit' to measured data, but modellers are being selective on which data they are comparing results.

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Hunga 15th January Eruption timeline

Surtseyan eruptions from 20 Dec 2022, similar vigor to 2009 or 2014/15 in similar location to 2015 activity

~8 day pause

14th Jan 2022, eruption and collapse of 2015 cone in north of caldera

15th Jan 2022, three phases, declining in energy

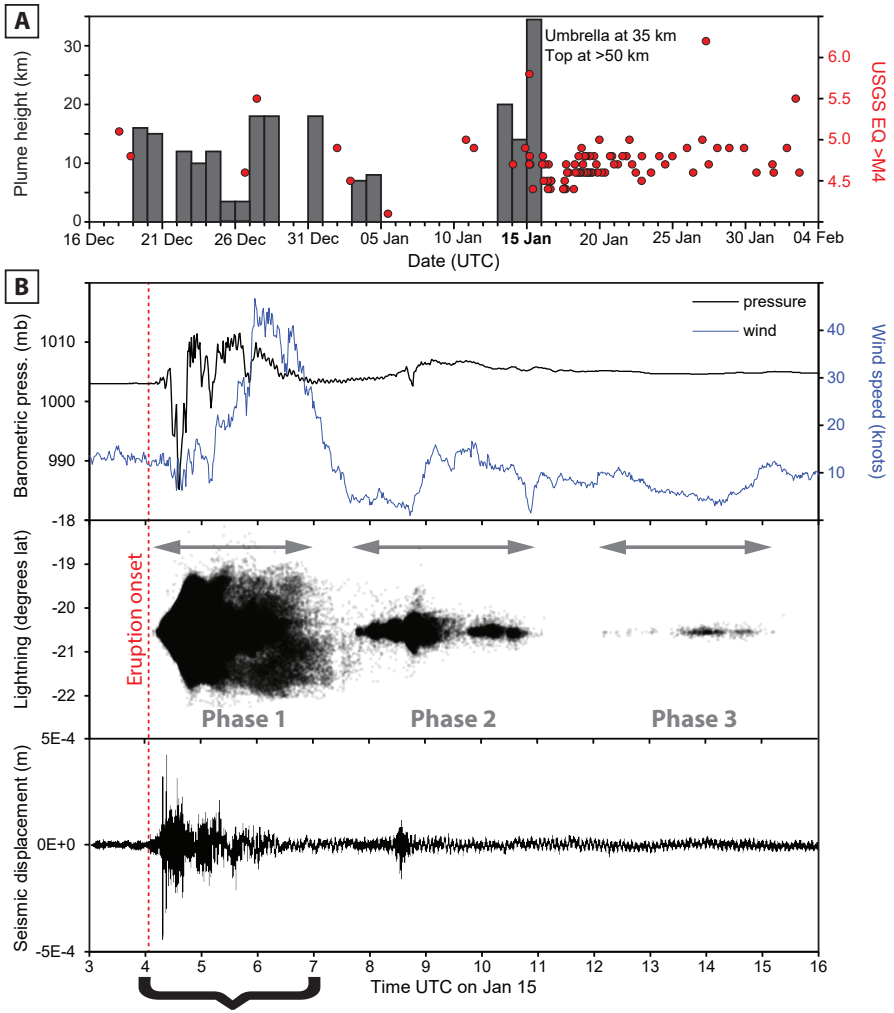
Onset 03:47 UTC, sudden increase in energy at ~04:15 and 04:25

Sonic booms (5-7) felt widely across Tonga (04:25-05:00)

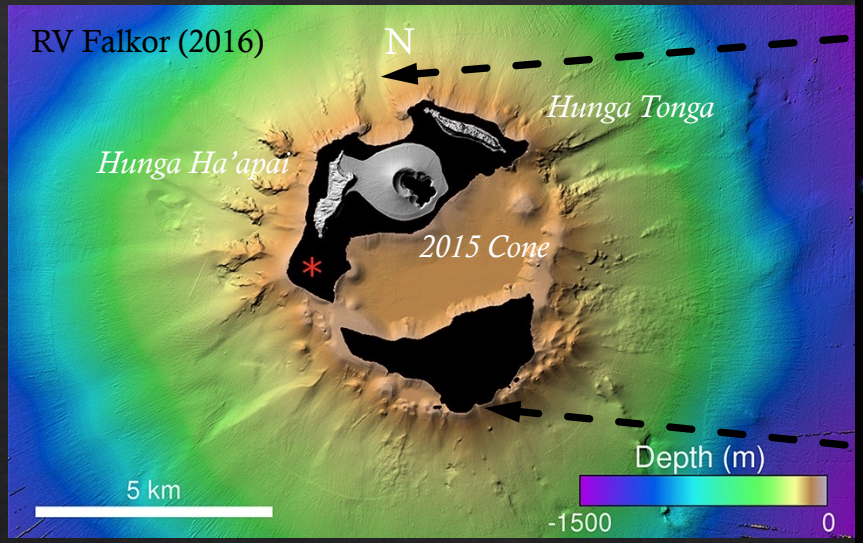
Unusual waves/currents reported from ~02:30 onward, Tsunami arrived 04:15 in west Tongatapu, with two small waves preceding the >18 m inundation shortly after 05:00

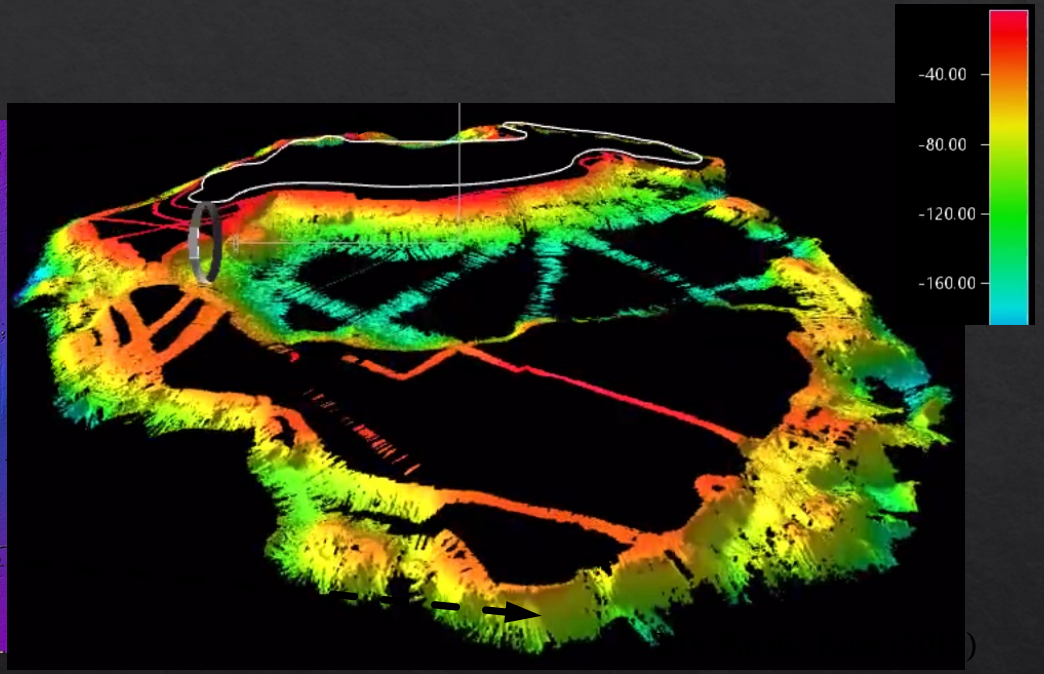
Ashfall from 04:45 until ~11:00 and smaller tsunami from ~09:00

Shallow earthquake swarm in the days following the eruption



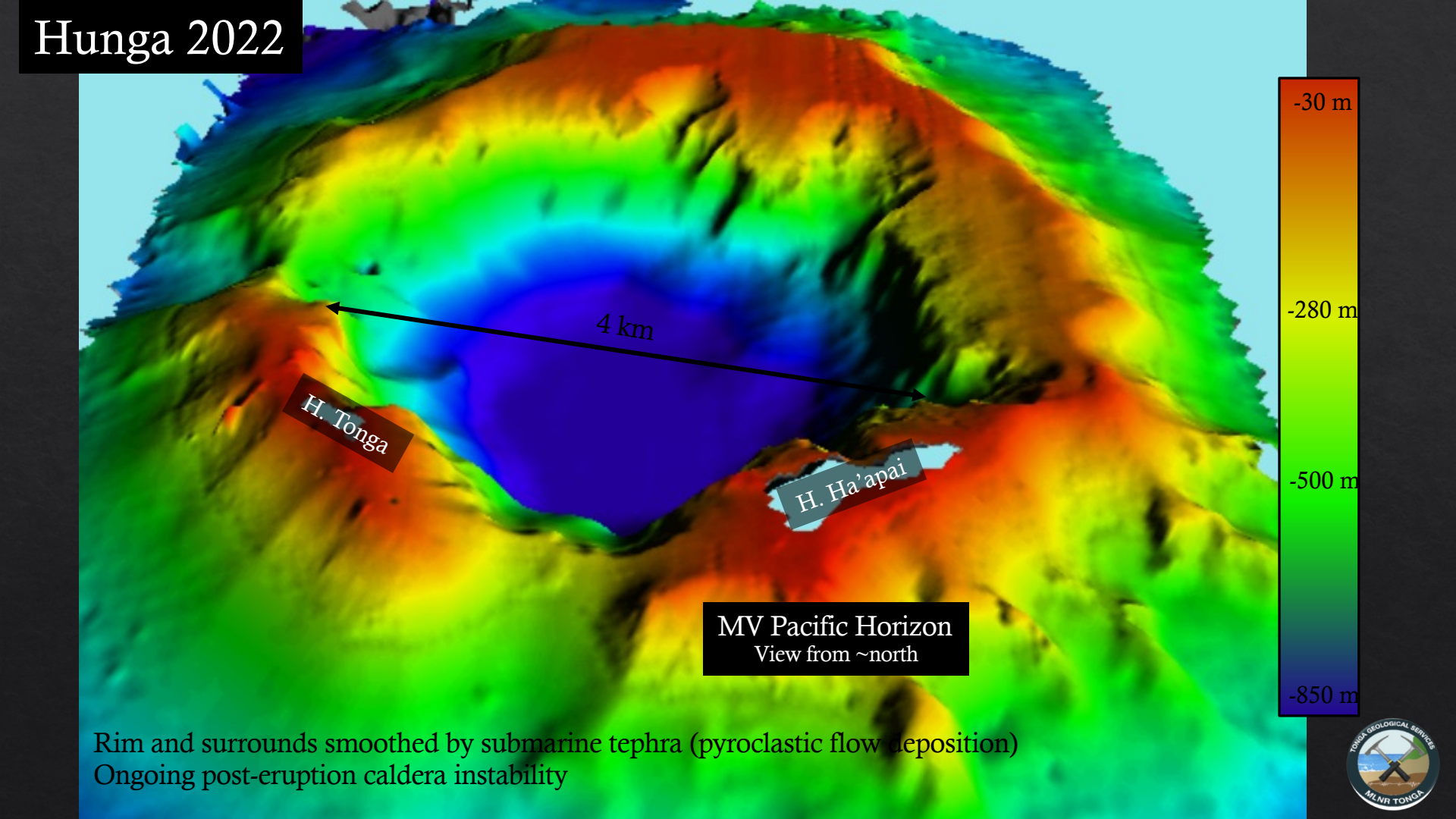
Hunga Caldera pre-eruption



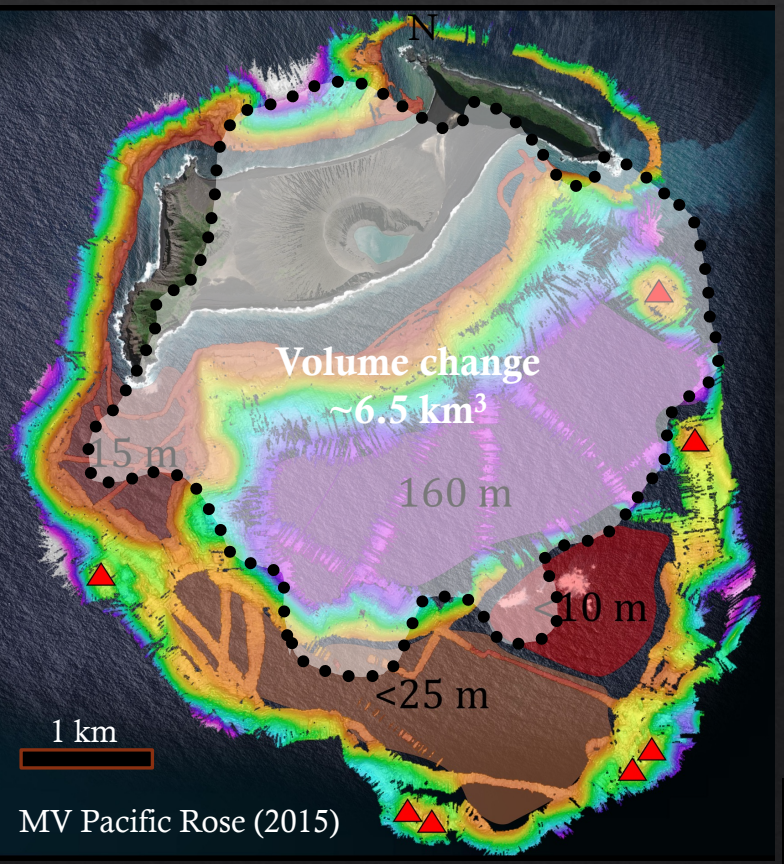


- Shallow caldera, island-platform to north, shallow reefs in south
- Deepest central caldera basin was 150 m, with a volume of ~1.2 km^3
- Many small cones around the caldera rim
- Two major channels radiating from caldera to North and East
- Uplifted coral platforms noted along Hunga Tonga inner shore in 2015 – recent uplift

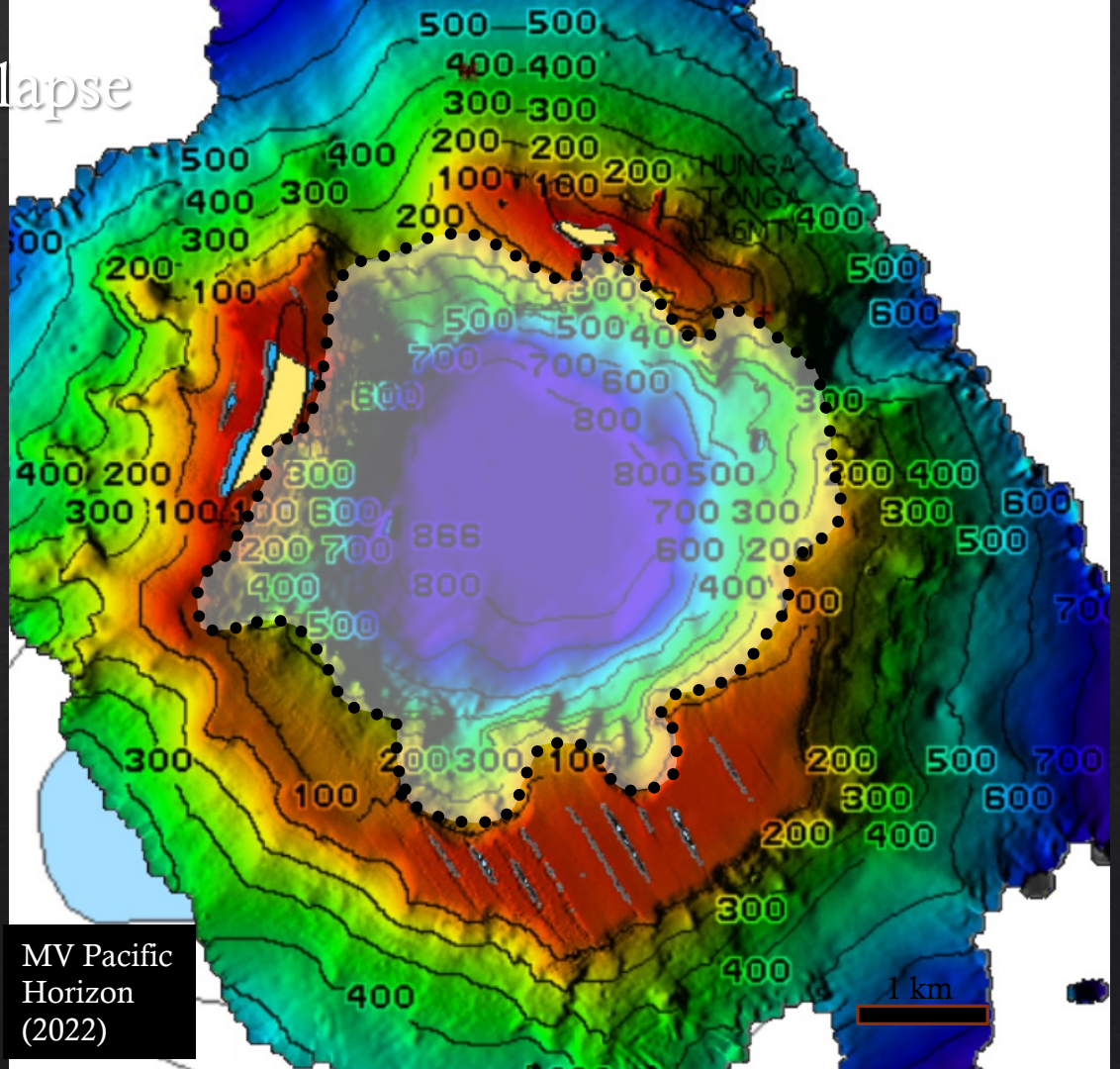
See Stern et al. presentation, this session


Hunga 2022
4 km
H. Tonga
H. Ha'apai
-30 m
-280 m
-500 m
-850 m
MV Pacific Horizon
View from ~north
Rim and surrounds smoothed by submarine tephra (pyroclastic flow deposition)
Ongoing post-eruption caldera instability

Massive inward caldera collapse

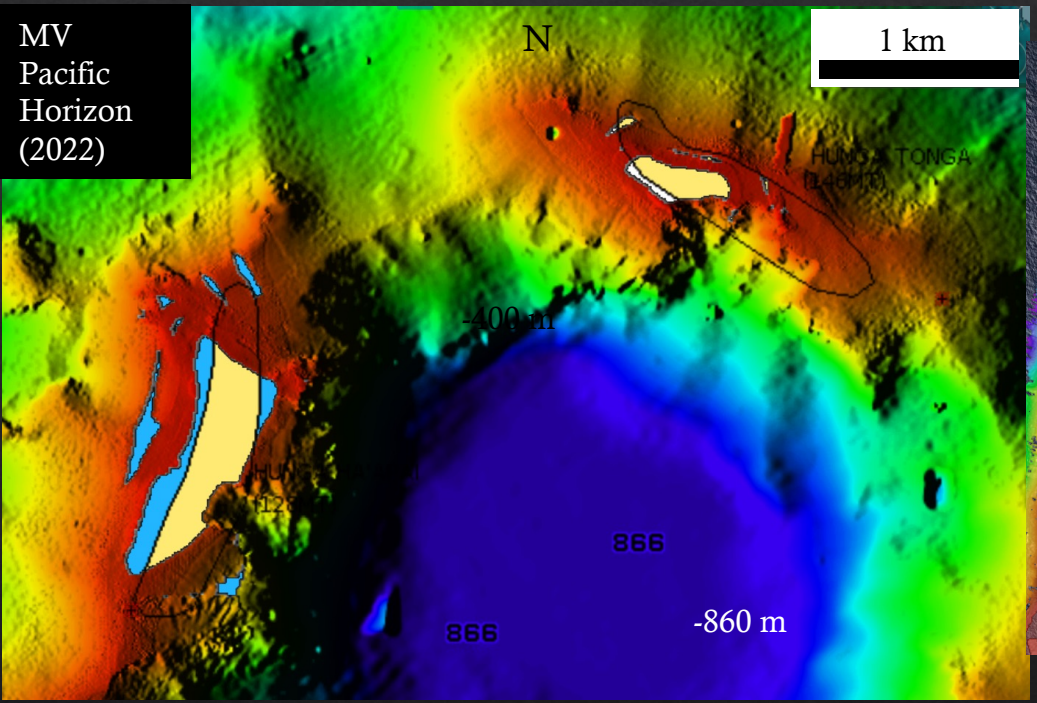


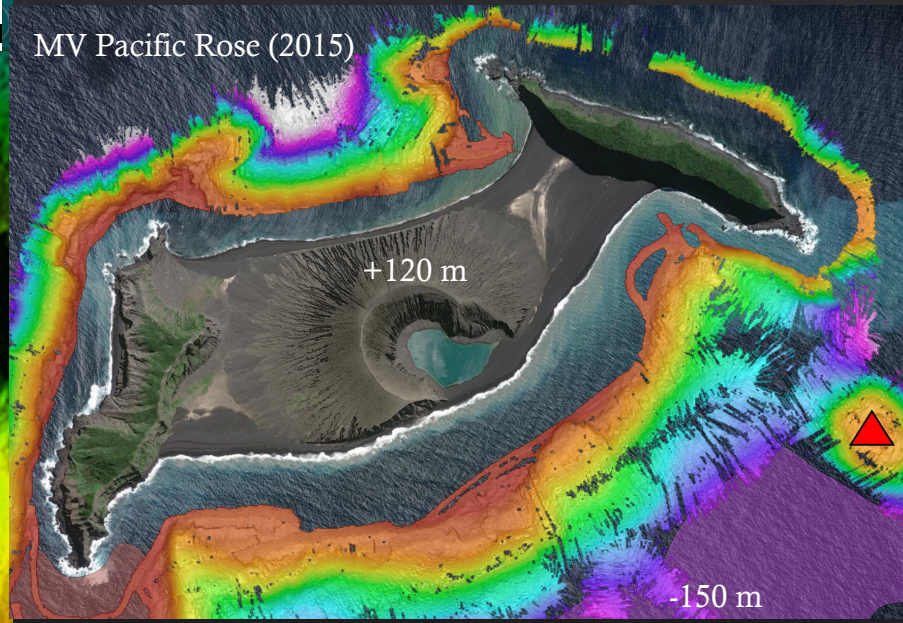
MV Pacific Rose (2015)



MV Pacific Horizon (2022)

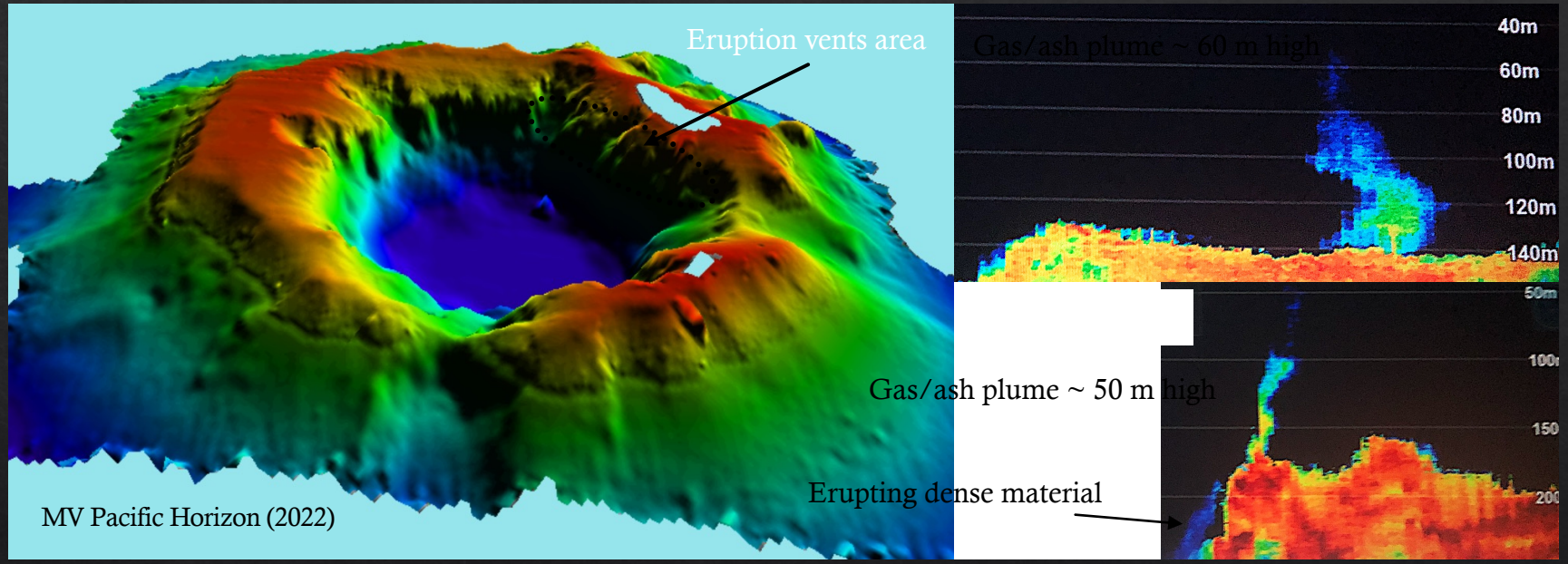
Hunga – The 2014-15 Island and platform below it collapsed into caldera





Did Caldera instability begin on the 14th January?

Post-15th January volcanism continues at a low level



Many small vents emitting gas and solid material (lava? + ash) at a continuous low level – especially in NW caldera wall

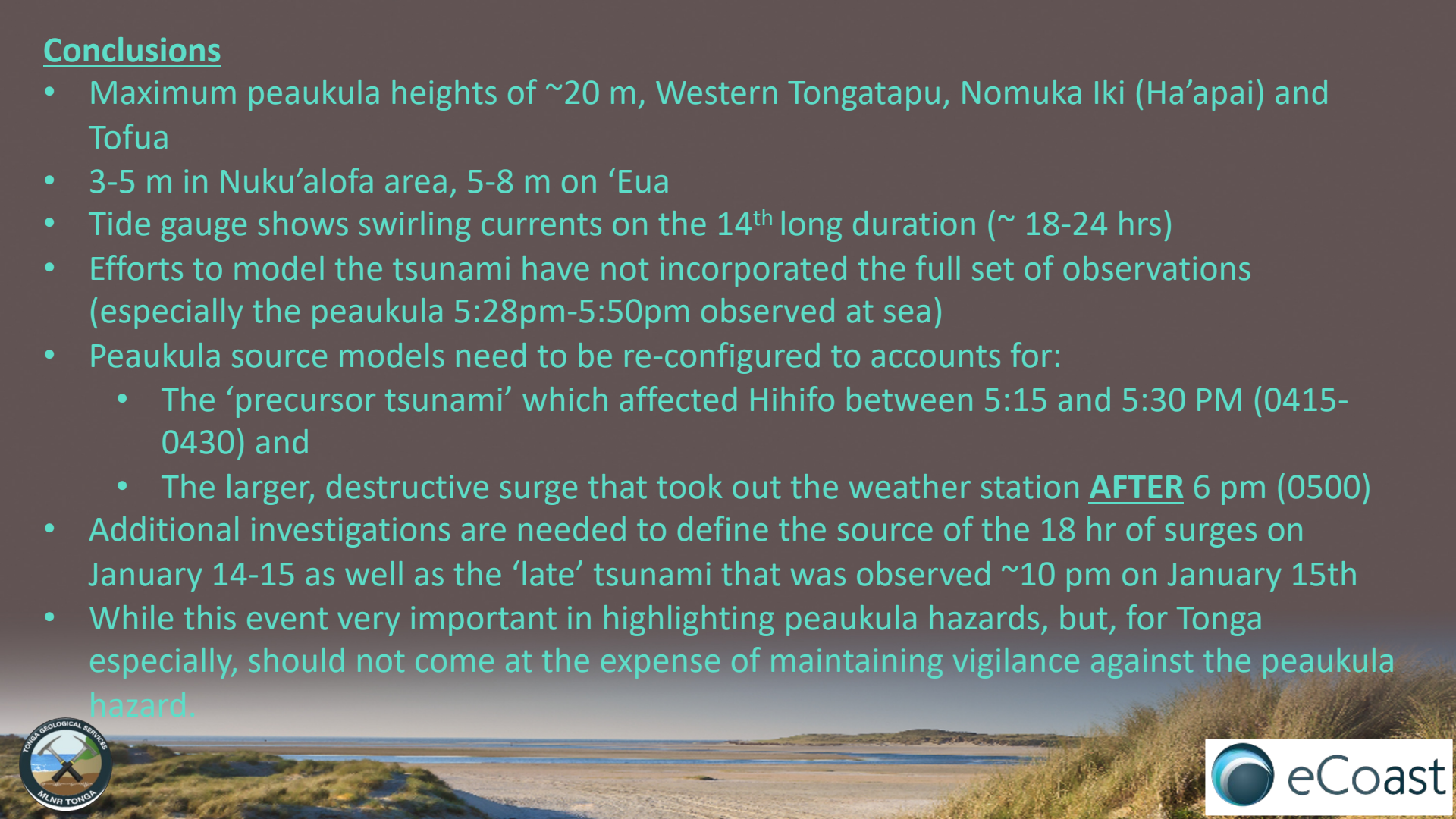
Ccreate ash/pumice plumes and rafts, with energetic phases causing local surface eruption hazards

Why so few casualties?

- Peaukula occurred in daytime
- Peaukula and warning/advisory of the 14th
- Precursor waves on 15th
- Lack of tourists
- Peaukula education activities since 1998 (PNG), 2004 (Indian Ocean), 2009 (Samoa), WTAD 2021 etc…
- Daily Prayers.

Conclusions

- Maximum peaukula heights of ~20 m, Western Tongatapu, Nomuka Iki (Ha'apai) and Tofua
- 3-5 m in Nuku'alofa area, 5-8 m on 'Eua
- Tide gauge shows swirling currents on the 14th long duration (~ 18-24 hrs)
- Efforts to model the tsunami have not incorporated the full set of observations (especially the peaukula 5:28pm-5:50pm observed at sea)
- Peaukula source models need to be re-configured to accounts for:
  - The 'precursor tsunami' which affected Hihifo between 5:15 and 5:30 PM (0415-0430) and
  - The larger, destructive surge that took out the weather station **AFTER** 6 pm (0500)
- Additional investigations are needed to define the source of the 18 hr of surges on January 14-15 as well as the 'late' tsunami that was observed ~10 pm on January 15th
- While this event very important in highlighting peaukula hazards, but, for Tonga especially, should not come at the expense of maintaining vigilance against the peaukula hazard.



Peaukula recommendations:

The Hunga event was a maximum-likely event, but deposits show other similar large volcanic-related events in the last hundreds of years.

- Consider additional coastal protection and re-location of low-lying coastal villages or dwellings, including areas surrounding Nuku'alofa as well as vulnerable sites in Ha'apai.

- Consider soft and hard coastal defences in key population areas, as well as the immediate planting of trees as a first line of defence on the western coasts of Tongatapu and Eua, and Ha'apai.

Trees produce a "log-dam" barrier that reduces peaukula energy

Acknowledgements:

People of Tonga who suffered and have persevered.

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Tonga Geological Services
Tonga Meteorological Services


THANK YOU!
MALO AUPITO!
Questions ???
Discussion
eCoast