

Historical Tsunami Effects near the Tonga Trench (1837-2023)

Introduction

American Samoa, Samoa and Tonga are vulnerable to both local and regional tsunamis, and distant tsunamis generated around the Pacific. NOAA's National Centers for Environmental Information (NCEI) and co-located World Data Service (WDS) for Geophysics, and the International Tsunami Information Center (ITIC), a UNESCO/IOC-NOAA partnership, have collaborated to produce a poster showing historical tsunami effects in countries near the Tonga Trench. NCEI provides long-term archive, data management, and access to global tsunami data. The Global Historical Tsunami Database includes information on the tsunami source, maximum wave heights, and effects such as deaths and damage. The ITIC has worked in collaboration with the NCEI/WDS to collect post-tsunami event information since its inception in 1965.

American Samoa, Samoa and Tonga are located in the tectonic region that is dominated by the Tonga Trench, one of the most seismically active areas in the world. In this region, the Pacific Plate subducts west beneath the Australian Plate at a rate of 6-9 cm/year. The trench strikes south-north, and bends west in the north into the Lau Basin, a tectonically-complex back-arc basin on the eastern margin of the Australian Plate. Earthquakes occur along the subducting slab, within the Pacific plate on both sides of the trench, and within and on the boundaries of the Lau Basin microplates, and focal depths extend to more than 600 km. While most historical damage has been caused by earthquake-generated tsunamis, ground motions are occasionally strong enough to cause damage to infrastructure.

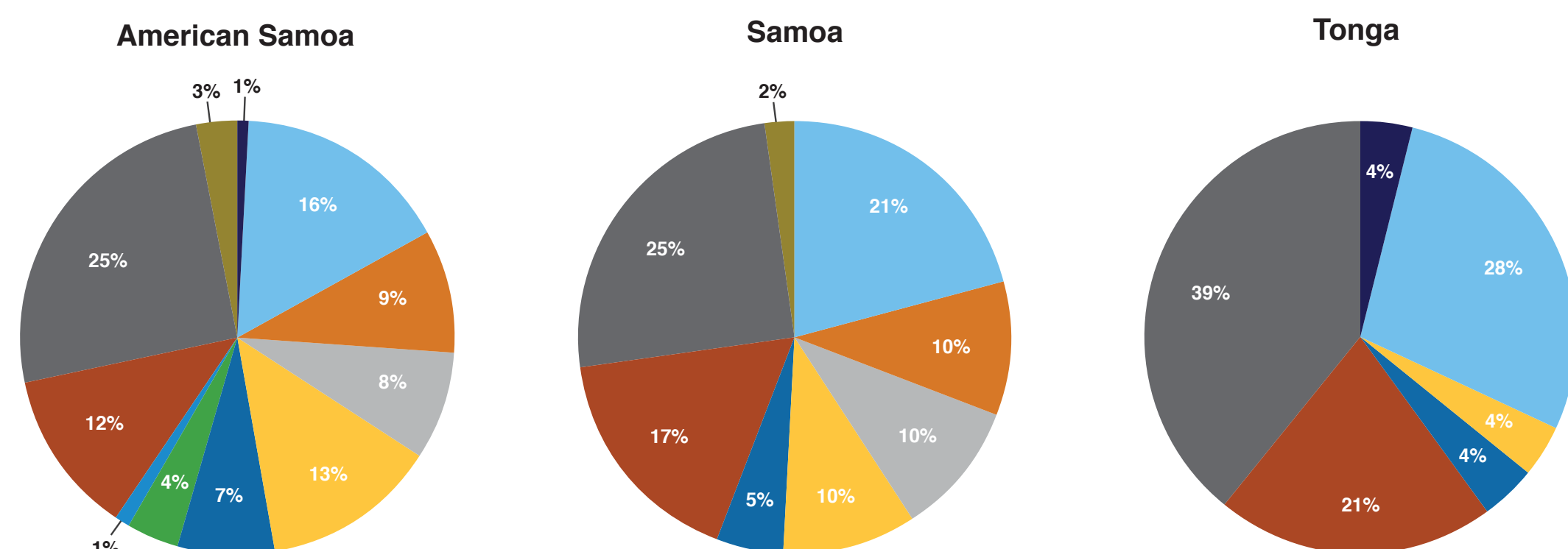
Tsunamis in American Samoa, Samoa & Tonga

Examination of the NCEI/WDS Global Historical Tsunami Database reveals that the earliest confirmed historical account of a tsunami impacting any of the three island groups occurred on November 07, 1837. A wave generated by an earthquake off the Southern Chilean coast was observed in Apia (Samoa), Pago Pago (American Samoa) and the Vava'u Group (Tonga). This was the first recorded event of a tsunami among the islands, although tsunamis undoubtedly reached the islands prior to this. The earliest habitation among the islands appears to be in Samoa dating to about 800 B.C. However, the Samoan and Tongan languages did not have a written form until the early 19th century. Consequently, the written record is limited. The Apia tide gauge records date back as far as 1917 and the first Pago Pago tide gauge was established in 1948. Tonga's first tide gauge was installed in Nuku'alofa in 1990.

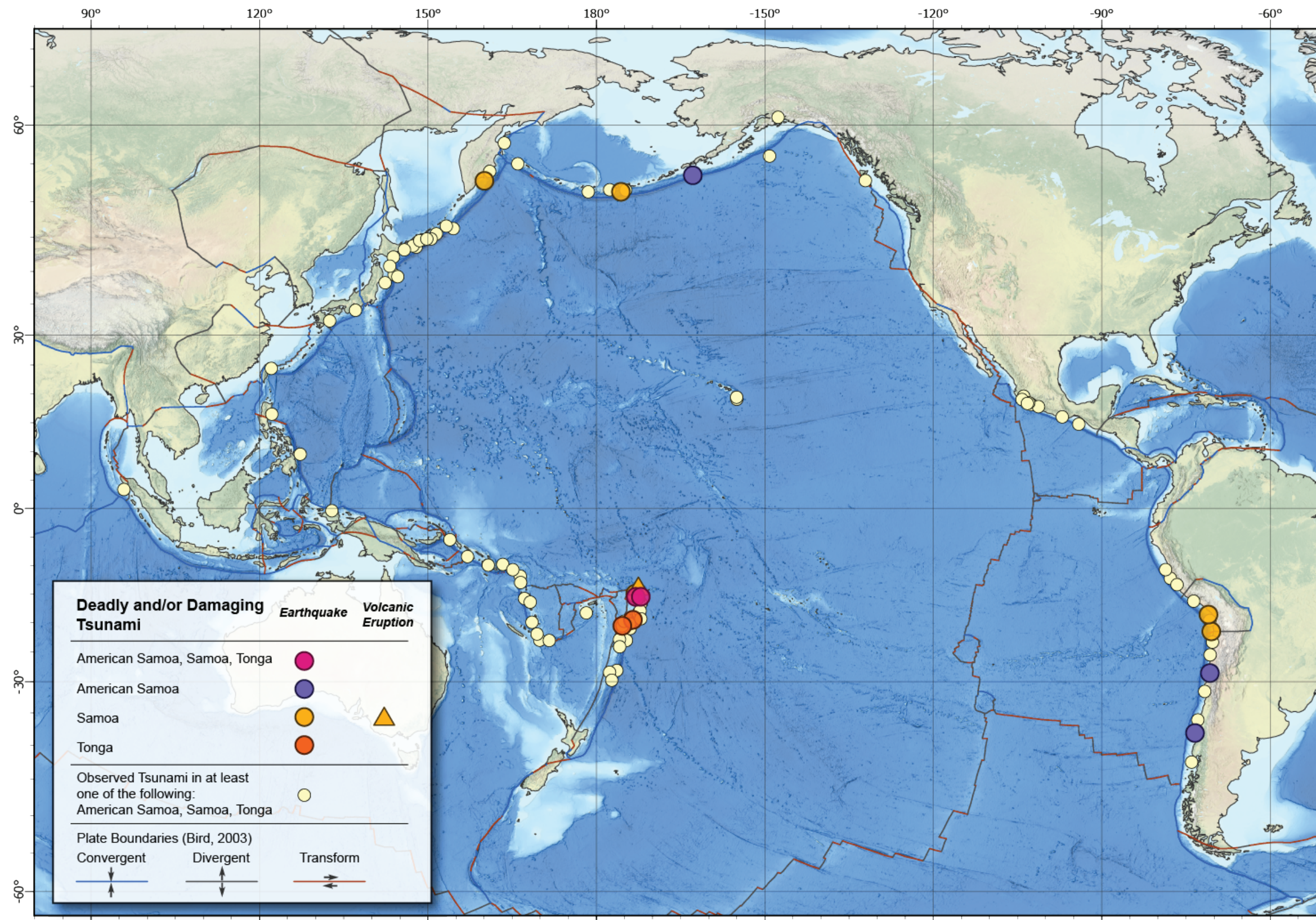
Only two historical tsunami events (1917 and 2009) have caused documented damage in American Samoa, Samoa and Tonga in a single tsunami event. Records of damage and deaths in the region are scarce, but recent events in 2009 and 2022 were well documented by national governments and International Tsunami Survey Teams. The September 29, 2009 event consisted of at least two separate earthquakes at the Tonga Trench, one an outer rise normal fault and the other a subduction zone thrust fault, that occurred within 2-3 minutes of each other. The resulting tsunami was the deadliest in history for American Samoa, Samoa, and Tonga, and the most damaging for American Samoa and Samoa. On January 15, 2022, the eruption of the Hunga Tonga - Hunga Ha'apai (HTHH) volcano generated a significant local tsunami that was in the most damaging tsunami in history for Tonga. This eruption generated a massive atmospheric pressure wave and a series of small tsunamis observed around the world.

Distribution of Tsunami Sources

The majority of tsunamis observed in American Samoa, Samoa and Tonga are distant tsunamis (source > 1000km). Distant tsunamis (NCEI event validity ≥ 3) make up 83% of tsunamis observed in American Samoa, 81% in Samoa, and 61% in Tonga. Local and regional tsunamis (source < 1000 km) account for 17% of tsunamis in American Samoa, 19% in Samoa, and 39% in Tonga.



Confirmed Tsunami Source Locations affecting American Samoa, Samoa and Tonga



Historical Tsunamis Causing Damage and/or Deaths in American Samoa, Samoa and Tonga

Date	Location	EQ Mag ¹	Tide Gauge ² (m)			Eyewitness & Field Survey ³ (m)			Damage (in Million ⁴) in			Deaths in			
			Am. Samoa	Samoa	Tonga	Am. Samoa	Samoa	Tonga	Am. Samoa	Samoa	Tonga	Am. Samoa	Samoa	Tonga	
1865	Tonga Islands	8.0								Y					
1868	Northern Chile	8.5				4.5				Y	Y			2	
1877	Northern Chile	8.3				0.9	3.6			Y					
1907	Matavau Volcano							3.6		Y					
1917	Samoa Islands	8.3		0.4		2.4	12.2	4.2		Y	Y	Y		2	
1922	Northern Chile	8.7				0.9				Y					
1946	Unimak Island	8.6		0.3		0.8	1.2			Y					
1952	Kamchatka	9.0	0.9	0.9			1.4			Y					
1957	Andeanof Islands	8.6	0.2	0.2		1.5				Y					
1960	Southern Chile	9.5	0.8			2.4	4.9		0.5						
1981	Samoa Islands	7.7	0.1	0.1			1.0			Y				Y	
2009	Samoa Islands	8.1	2.7	0.8	0.2	17.6	14.5	22.4	172	205	13	34	149	9	
2022	Hunga Tonga-Hunga Ha'apai Volcano		0.6	0.2	0.8			22				90.4		4	

¹ Earthquake magnitudes (Ms or Mw) are instrumental (from USGS) or estimated based on intensity before 1900 (from NCEI).

² Half of the maximum height (minus the normal tide) of a tsunami wave recorded at the coast by a tide gauge. Also called the amplitude.

³ The height of the tsunami at the point of maximum inundation above the state of the tide at the time. The measured value may be from eyewitness or field survey.

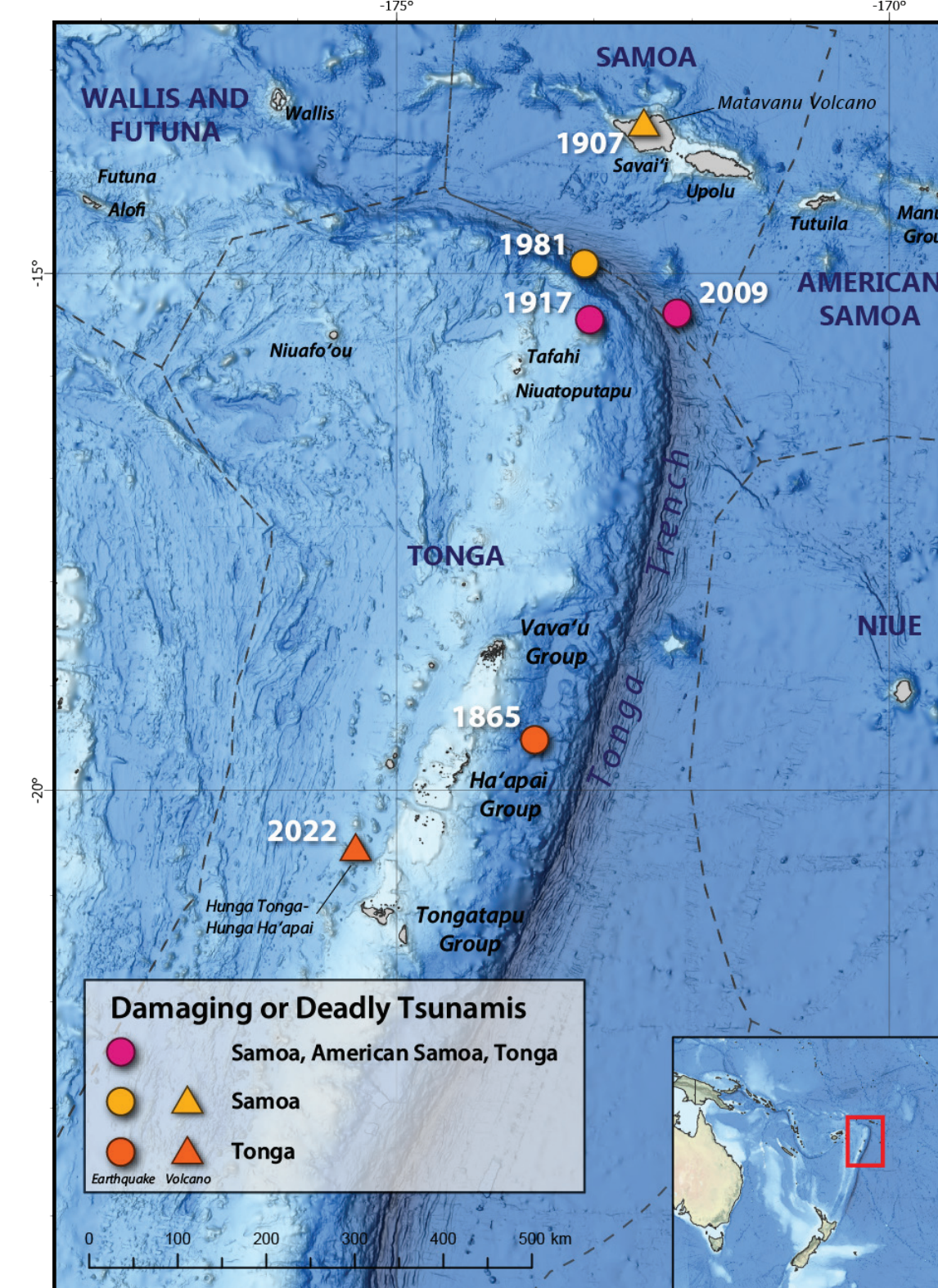
⁴ Adjusted for inflation to 2022 dollars.

Historical Tsunami Observations near the Tonga Trench

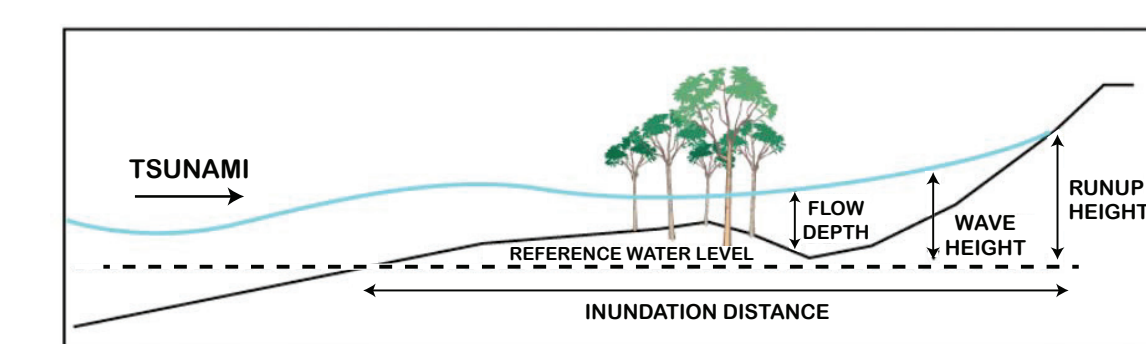
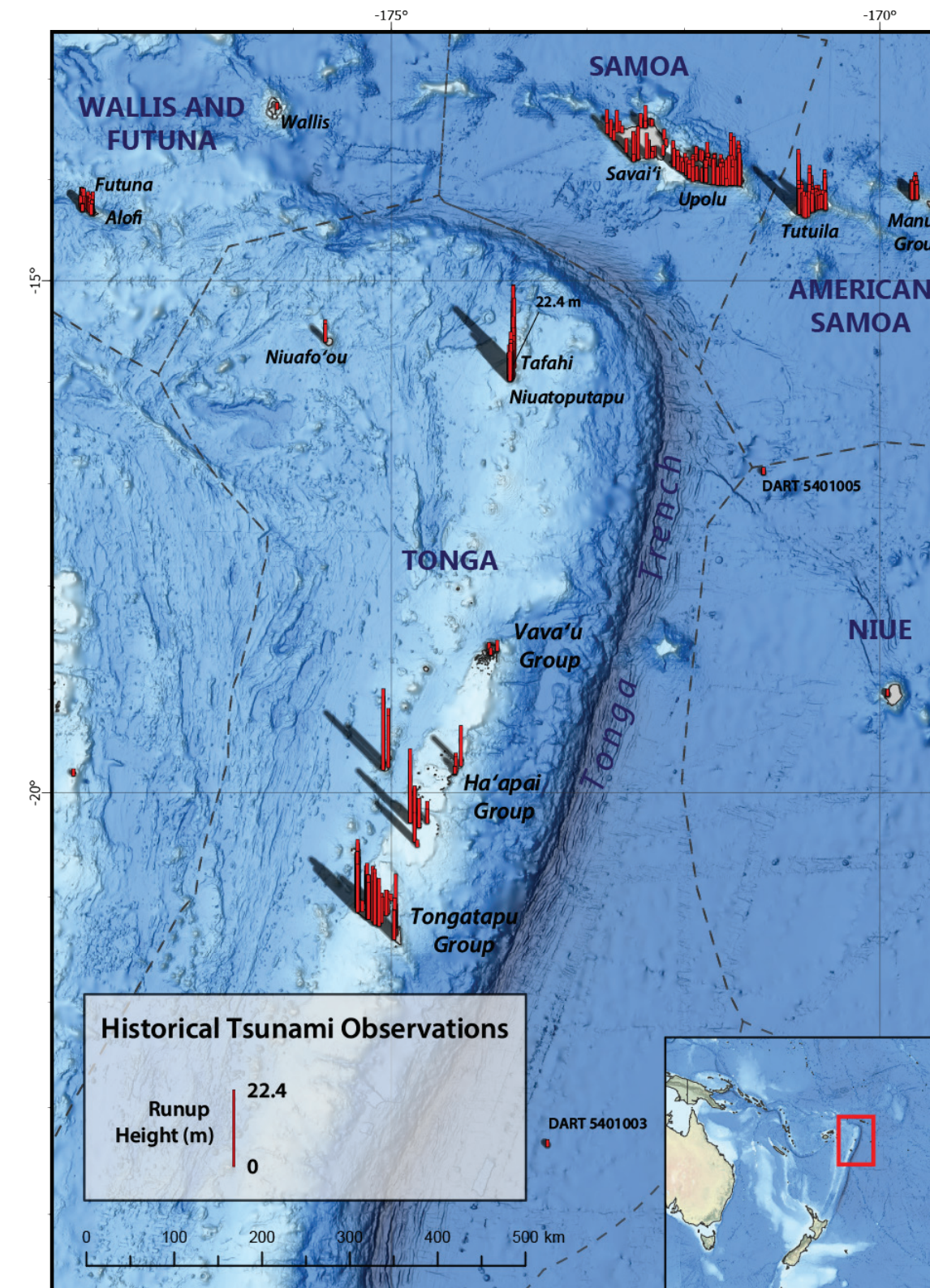
Location	Prior to 2000				Post-2000			
	Tide Gauge (year)	Eyewitness & Field Survey (year)	Total Number of Runups	Total Number of Events	Tide Gauge (year)	Eyewitness & Field Survey (year)	Total Number of Runups	Total Number of Events
American Samoa	0.9 (1952)	2.4 (1917 & 1960)	56	51	2.7 (2009)	17.6 (2009)	234	24
Samoa	0.9 (1952)	12.2 (1917)	60	35	0.8 (2009)	14.5 (2009)	184	17
All of Tonga	0.1 (1995)	4.2 (1917)	10	8	0.8 (2022)	22.4 (2009)	196	20
Tonga north of 17°S	-	2.7 (1917)	1	1	< 0.1 (2022)	22.4 (2009)	71	2
Tonga south of 17°S	0.1 (1995)	4.2 (1917)	9	7	0.8 (2022)	22 (2022)	125	18



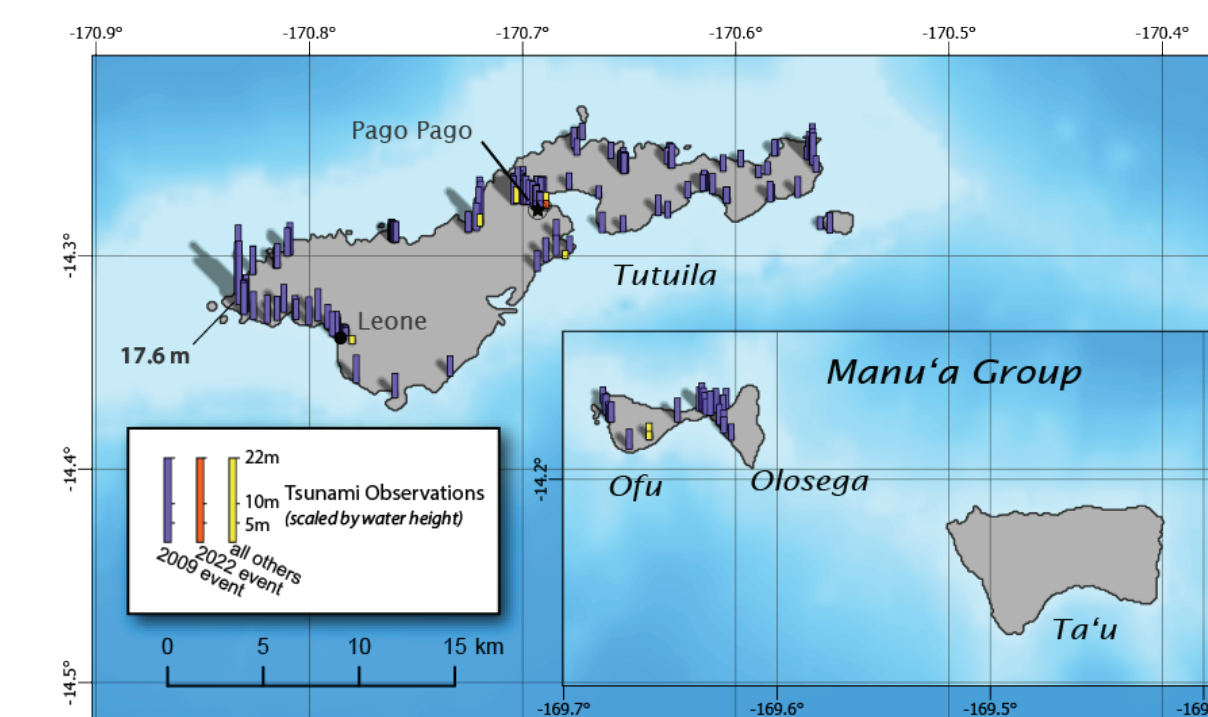
Local & Regional Tsunami Source Locations causing Damage and/or Deaths in American Samoa, Samoa and Tonga



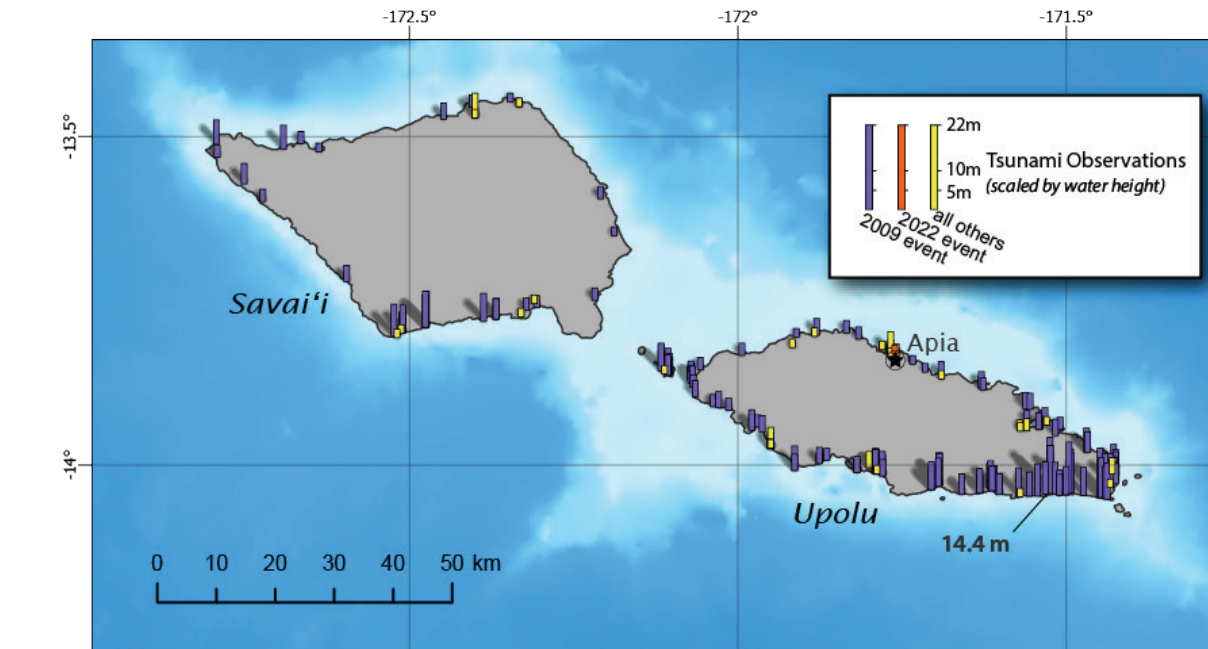
Historical tsunami observations near the Tonga Trench



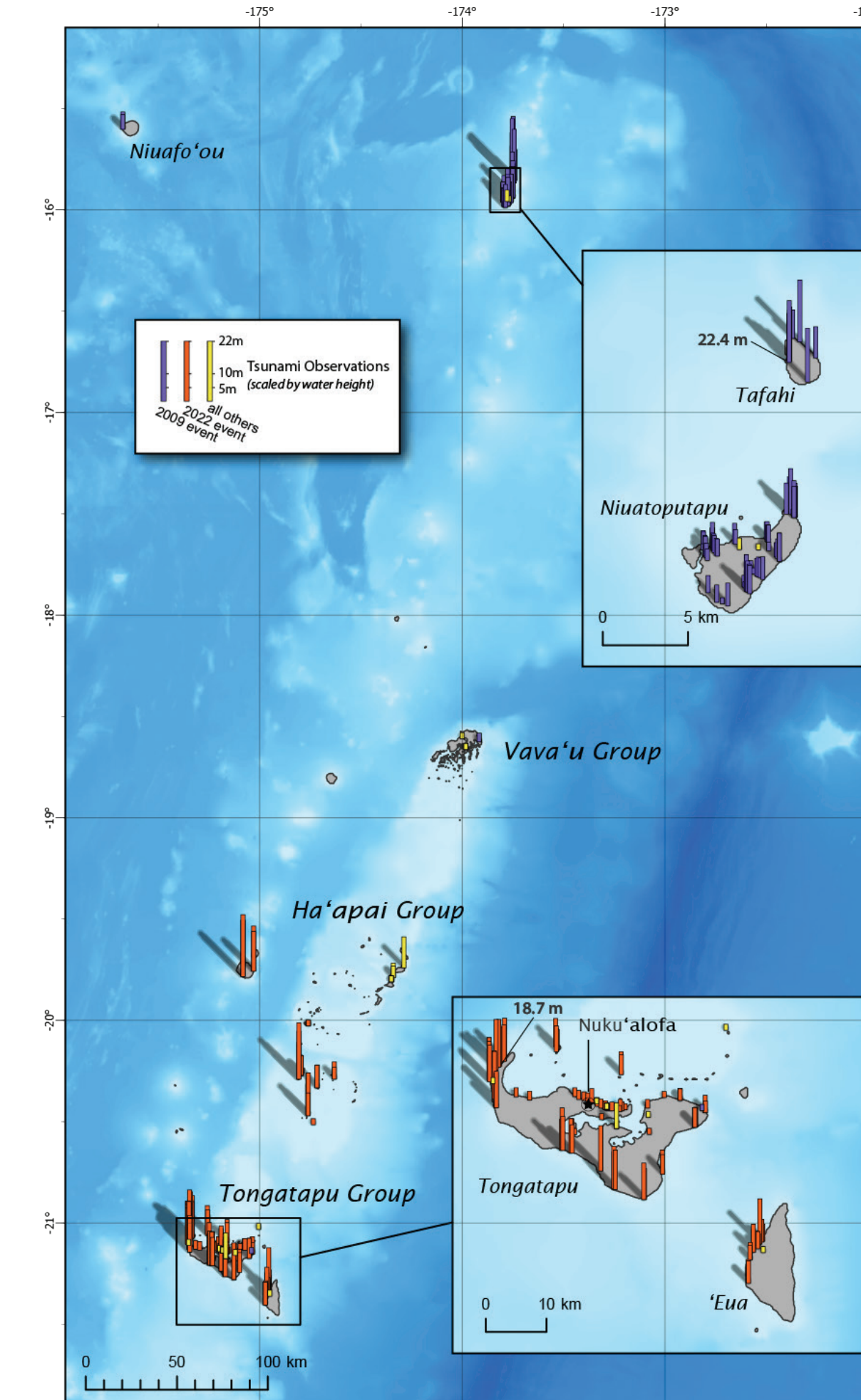
American Samoa



Samoa



Tonga



Tsunami hydrodynamic data terminology (after ITST Post-Tsunami Survey Field Guide, 2nd ed, IOC MG 37, UNESCO, 2014).

29 September 2009 tsunami.

Left: Tsunami flooding Pago Pago Harbor, American Samoa, lifted boats onto submerged structures and into tops of coconut trees. Credit: R. Madsen, aboard sailboat *Barbarella*
 Middle: Many coastal villages along the south and east coasts of Upolu, Samoa were destroyed - only foundations of homes remained. Credit: ITST Samoa Social Science team

Right: Tsunami-damaged Hihifo, the main town in Niuaotupapu, Tonga. Overall, the highest runups (> 22 m) were measured on the island's eastern coast. Credit: Tonga Met. Svc.



15 January 2022 tsunami. All seven resorts along the northwestern tip of Tongatapu, including the Vakaloa Beach Resort (left), were destroyed by the tsunami generated by the HTHH volcanic eruption. Credit: Tonga Geol. Svc.