Regional Tsunami Catalog Completeness of a Global Database

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ABSTRACT

A comprehensive tsunami catalog for a region would include both small and large tsunamis during a given time period. However, instruments that record small tsunamis (e.g. coastal tide gauges and deep ocean bottom pressure recorders) are relatively recent technological developments. In regions such as the Southwest Pacific and the Caribbean Sea, both written and instrumental records are sparse in the early 20th century and significantly scarcer further back in time. NOAA's National Centers for Environmental Information (NCEI) and collocated World Data Service for Geophysics (WDS) provides long-term archive, data management, and access to national and global tsunami data. The Global Historical Tsunami Database includes information on the tsunami source, maximum wave heights, and effects such as deaths and damage. Examination of the NCEI/WDS Global Historical Tsunami Database can help reveal the level of completeness of historical records of tsunamis in different regions. This study takes the preliminary steps to statistically determine the quality of a regional historical tsunami catalog based on the function of time, location and observed runup height in the global database. The goal is to better understand the occurrence of all known earthquake-generated tsunamis to help characterize future tsunami hazards.

TSUNAMI RECORD ASSESSMENT

The goal of this study is to understand the completeness of the regional tsunami record, for the Caribbean and Southwest Pacific. The initial step is to begin to determine the completeness of the earthquake records and possible correlations to tsunamis generated by these earthquakes. Although earthquakes are not the only mechanisms that have generated historical tsunamis, they are the most common with over 80% of global tsunamis generated by earthquakes (NCEI, 2020).

We analyze Mw 6.5+ earthquakes in this study because 1) it is close to or is the threshold for tsunami warning system messaging in the regions, 2) it is an approximate lower end for measurable tsunami generation. In the Caribbean, the Member States of the Tsunami and other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (CARIBE-EWS) only receive a "Tsunami Threat" message for shallow earthquakes (<100 km depth) with magnitude (Mw) greater than 7.1. Although the U.S. territories of Puerto Rico and Virgin Islands would receive at least an Advisory message for magnitude (Mw) greater than 6.5. In the Pacific, the Pacific Tsunami Warning System (PTWS) Member States have similar initial messaging thresholds, though, the U.S. Territory of American Samoa would receive at least an Advisory message for magnitude (Mw) greater than 6.7.

In both regions, earthquakes with magnitudes lower than Mw 6.5 have generated tsunamis. For instance, the 2004 and 2005 French Guadeloupe, 1993 Wallis & Futuna, 1953 Fiji, 1950 Venezuela tsunamis are associated with earthquake magnitudes lower than Mw 6.5. For the warning criteria reasons listed above, as well as the fact that Mw 6.5+ earthquakes would be damaging or at least felt even in the sparsely populated areas in the Caribbean and Southwest Pacific, this study is only considering Mw 6.5+. Depth is not taken into consideration given the even larger degree of uncertainty as you go further back in time. The authors considered the ISC-GEM, USGS and NOAA catalogs when identifying offshore or nearshore earthquakes.

TSUNAMAGENIC EARTHQUAKES

After identifying Mw 6.5+ earthquakes for the study regions, tsunamigenic earthquakes were flagged (*Figure 1 and 2*). The NOAA NCEI/WDS database was utilized and tsunamis of low and high validities were considered.

20TH CENTURY SEISMIC INSTRUMENTATION

Two regions are considered for this initial study, the Caribbean and Southwest Pacific (*Figure 3*). These areas are considered due to the relatively small amount of tsunami data relative to other regions (e.g., Northwest Pacific, Southeast Pacific). The compact area of interest in the Southwest Pacific is three times smaller than the Caribbean. However, this more compact area was chosen due to the high seismicity and higher concentration of population compared to neighboring parts of the region as well as the establishment of early seismic stations.

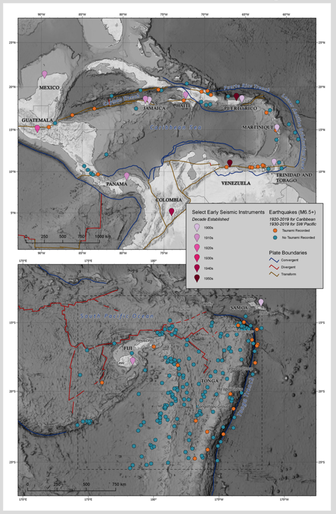

Figure 3. Earthquakes in the Caribbean (top), from 1920--2019, and the Southwest Pacific (bottom), from 1930-2019. The dashed box represents study area in the Southwest Pacific.

TEMPORAL EARTHQUAKE DISTRIBUTION AND TSUNAMI OBSERVATIONS

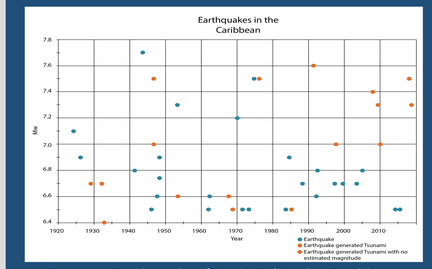

Figure 1. Earthquakes (Mw 6.5+) in the Caribbean, 1920-2019

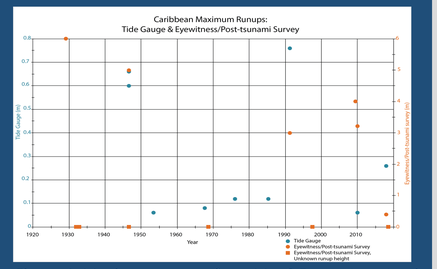

Figure 4. Maximum runups from Mw 6.5+ earthquakes in the Caribbean, 1920-2019

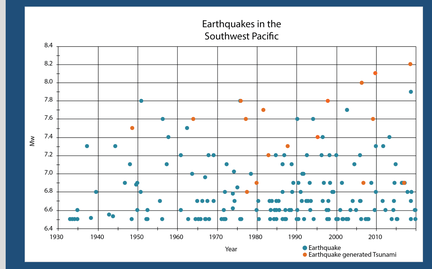

Figure 2. Earthquakes (Mw 6.5+) in the Southwest Pacific, 1930-2019

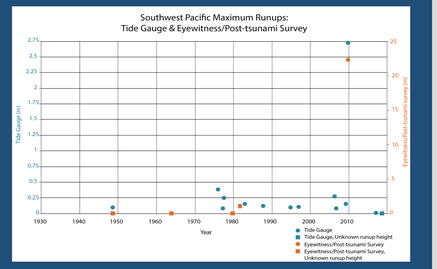

Figure 5. Maximum runups from Mw 6.5+ earthquakes in the Southwest, 1930-2019

TSUNAMI AND EARTHQUAKE OBSERVATIONS FROM THE CARIBBEAN AND SOUTHWEST PACIFIC

	Caribbean		Southwest Pacific Islands	
Years	Earthquakes M6.5+	Tsunamigenic Earthquakes M6.5+	Earthquakes M6.5+	Tsunamigenic Earthquakes M6.5+
1920-29	3	1	–	–
1930-39	2	2	8	0
1940-49	8	2	10	1
1950-59	2	1	10	0
1960-69	5	2	20	1
1970-79	4	1	22	4
1980-89	4	1	31	3
1990-99	6	2	33	2
2000-09	4	2	30	4
2010-19	5	3	24	2
Total	43	16	188	17

Table 1. Recorded Earthquakes and Associated Tsunamis

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CARIBBEAN

The Caribbean had more than five seismic stations functioning by 1920. Although the functionality and reliability may have been inconsistent, the larger number of stations and geographic distribution makes it acceptable to consider Mw 6.5+ earthquakes since 1920.

SOUTHWEST PACIFIC

The first seismograph installed in the region was near Apia, Samoa, in 1902. In Suva, Fiji, a station was established in 1913 but was largely for research purposes. According to Everingham (1983) it was not until the 1930s that earthquakes magnitude greater than 6.0 in the Fiji region became routinely recorded. For this reason, the authors are only looking at Mw 6.5+ earthquakes since 1930.

CARIBBEAN

We binned Mw 6.5+ earthquakes by decade. In the Caribbean, when looking at a Mw 6.5+ earthquakes since 1920 there are no unusual increases over time despite increased and improved instrumentation (*Table 1*). The greatest number (8) occurred from 1940-49, this is the only decade to have experienced a "spike". Similarly, the number of tsunamis observed in the region stayed remarkably consistent throughout the decades despite the increased and improved sea level instrumentation. In the most recent decade (2010-19) all the events were observed by eyewitnesses, as such, they were not only instrumental tsunamis (i.e., only detected by tide gauges). Four tsunamis (1953, 1967, 1976, 1985) in the Caribbean were only observed on tide gauges. Despite the lack of tsunami records on tide gauges between 1920 and 1945, based on a decadal approach, the number of observed tsunamis is not significantly lower than more recent years (*Figure 4*). A total of five Mw 6.5+ earthquakes between 1920-1945 do not have an associated tsunami record, it is certainly possible these earthquakes produced small tsunamis that could have been recorded on instruments had they been set up.

SOUTHWEST PACIFIC

Due to the tectonic setting, the study area in the Southwest Pacific has significantly more Mw 6.5+ earthquakes per decade relative to the Caribbean (*Table 1*). Additionally, increased and sustained number of Mw 6.5+ earthquakes occurred in the 1960s and, again, in the 1980s. This might be in part due to increased seismological observations from Fiji in the 1950's and 1960's by the Lamont Geological Observatory. From 1979 to 1984 new networks were established and/or strengthened by U.S. and Japanese supported projects in the Fiji region (Kruger-Knuepfer, et al. 1986). A total of 12 tsunamis (of the 17 total) in the region were only recorded on tide gauges, the earliest in 1948 (*Figure 5*).

Despite the larger number of Mw 6.5+ earthquakes in the Southwest Pacific, the number of tsunamis generated is comparable to the Caribbean. This may be due to 1) including depth (over 50% of the earthquakes were greater than 100 km), 2) limited permanent sea level instruments, 3) other factors including the behavior of local faults. An important observation is that between 1930 and 1969 only two tsunamis were recorded in this region despite nearly 50 Mw 6.5+ earthquakes. This brings doubt on the completeness of the tsunami record in this time period.

As expected in both regions, the rate of tsunamigenic earthquakes correlates with larger magnitude earthquakes. From the catalogs used in this study, Mw 8.2 is the largest magnitude event in the Southwest Pacific and Mw 7.7 is the largest in the Caribbean (*Figures 1 and 2*).

TSUNAMI RECORDS MOSTLY COMPLETE SINCE 1920S AND 1930S

CARIBBEAN

In the Caribbean, both the earthquake and tsunami catalogs should be considered very strong, if not complete since 1920, given the consistency throughout the decades.

SOUTHWEST PACIFIC

The record of earthquakes increases starting in the 1960s, though, there is strong ability to record Mw 6.5+ as far back as the 1930s. As a result, the associated tsunami record should be considered strong, if not complete, as far back as 1970. However, the level of confidence in completeness of the tsunami record between 1930 and 1969 is lower. The Apia tide gauge records date back as far as 1917 and the first Pago Pago tide gauge was established in 1948, a closer examination of the paper tide gauge records might uncover small tsunamis prior to 1969.

This study is an initial step, as such significantly further work is required to fully understand the completeness of the earthquake and tsunami records. Further work would include assessing the coverage and capability of tide gauges as well as the earthquake mechanisms and depth.

NOAA National Centers for Environmental Information
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