National SCIENCE Challenges

RESILIENCE TO NATURE'S CHALLENGES

Kia manawaroa – Ngā Ākina o Te Ao Tūroa

Multi-Hazard Metadata

MRm team – internal report

Resilience to Nature's Challenges 2

Multi-Hazard Metadata: An overview of data availability for the investigation of triggering, amplification, and damping during hazard cascades

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EXECUTIVE SUMMARY

Multi-hazard data is required for the statistical analyses of hazard occurrence, magnitudes, frequencies, and subsequent inference as to potential hazard cascades and interactions. As part of the Resilience to Nature's Challenges 2 – Multi-Hazard Risk Model, this work details the current state of open multi-hazard data alongside links to directly access each dataset.

This is a short report that serves as deliverable 1.1.1: "Metadata set: Suitable data from New Zealand and overseas assembled for investigation of triggering, amplification, and damping during hazard cascades". Hazard and multi-hazard metadata at global, country, and regional levels are presented in a series of tables. Applicability of these data to the MRm case-study is also discussed. A table of published works under the banner of multi-hazard research (current as of July 2021) is also provided as an appendix and serves as a broader overview of data that exist but are not directly obtainable.

Abbreviations

ANSS	Advanced National Seismic System (USGS)
AVI	Aree Vulnerate Italiane, Areas affected by Landslides or Floods in Italy
BFW	Austrian Research Centre for Forests
COORD	Co-ordinates
CSV	Comma-Separated Variable
DFO	Dartmouth Flood Observatory
EM-DAT	Emergency Events Database
ESWD	Europe Severe Weather Database
FLASH	Flooded Locations And Simulated Hydrographs project
GFM	Global Flood Monitor
GLADIS	Global Archive of Dome Instabilities
GLC	Global Landslide Catalogue
GVP	Global Volcanism Program
ICNZ	Insurance Council of New Zealand
IDMC	Internal Displacement Monitoring Centre
IRIS	Incorporated Research Institutions for Seismology
JMA	Japan Meteorological Agency
JTWC	Joint Typhoon Weather Centre
M_L	Local Magnitude (earthquake)
M_S	Surface Magnitude (earthquake)
M_W	Moment Magnitude (earthquake)
MMI	Modified Mercalli Intensity
MRm	Multi-hazard Risk Model
NatCat	Natural Catastrophes (Munich Re)
NCEI	National Centres for Environmental Information
NEIC	National Earthquake Information Centre
NOAA	National Oceanic and Atmospheric Administration
PDE	Preliminary Determination of Epicentres
PHIVOLCS	Philippine Institute of Volcanology and Seismology
RNC	Resilience to Nature's Challenges Kia manawaroa – Ngā Ākina o Te Ao Tūroa
SCEC	Southern California Earthquake Catalogue
SSN	Servico Sismologico Nacional (Mexico)
UNISDR	United Nations Office for Disaster Risk Reduction
URL	Uniform Resource Locator (web address)
USGS	United States Geological Survey
WLK	Forest technical Service of the Austrian Torrent and Avalanche Control
WOVO	World Organization of Volcano Observatories

Figures & Tables

1. Introduction

Multi-hazard data are required for the statistical analyses of hazard occurrence, magnitudes, frequencies, and subsequent inference as to potential hazard cascades and interactions. As part of the Resilience to Nature's Challenges 2 – Multi-Hazard Risk Model, this work details the current state of open multi-hazard data alongside links to directly access each dataset.

Hazard related terminology is inconsistent; thus, the following terms are formally defined here to avoid ambiguity:

- A **hazard** is an event that *may have* negative impacts on society (UNISDR, 2009). Examples: ash fall, flood.
- A **disaster** is an event that *has* caused an adverse impact on the human population or activities. Examples: tsunami causing fatalities, flood destroying homes.
- A **multi-hazard** is the occurrence of multiple (>1) hazards partially or completely overlapping in space-time that may or may not be causally related. Examples: ash fall during a storm, a landslide into a lake generating a tsunami.
- A **hazard-producing event** is a (usually physical) process during which hazards are generated. Examples: earthquake causing surface deformation and shaking, volcanic eruption causing ash fall and lava flows.
- **Datum** is a single piece of information, **data** are multiple datum, a **database** is a structured set of data, and **metadata** are data that describe other data.

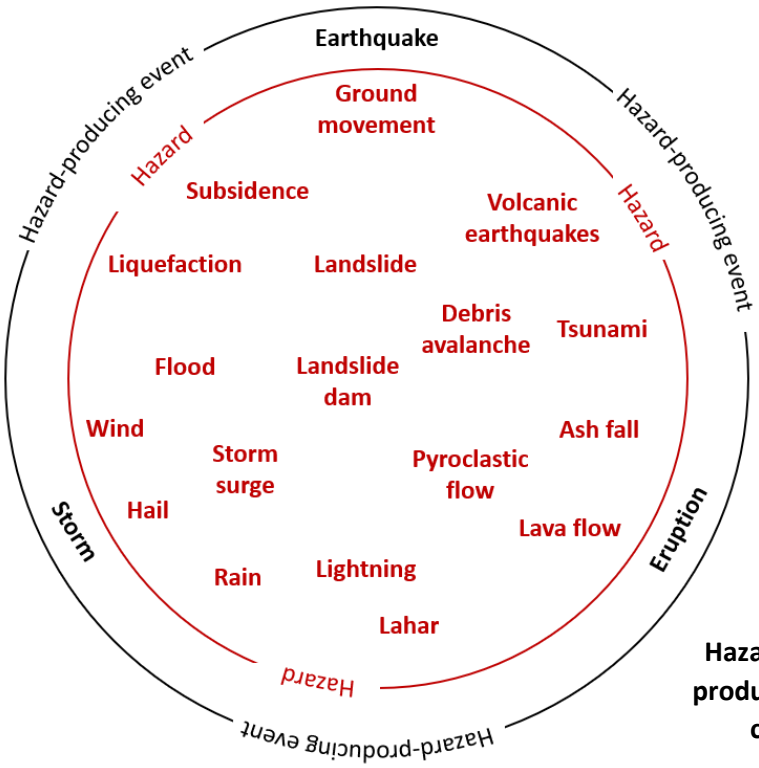

Figure 1

Hazards and hazard-producing events data classification

There are many natural hazards with several different classification systems (Kappes et al. 2012; Gill and Malamud 2014; Guha-Sapir et al. 2016). For this work, the hazards and hazard-producing events are centred around those immediately related to the RNC-MRm Case-Study (Davies et al. 2020a; 2020b) and are shown in Figure 1.

2. Databases

Hazard databases contain the most directly applicable data required for this project, however they do not hold sufficient data for statistical work within the RNC-MRm remit. Hazard databases tend to be for a single hazard type (e.g., floods), similarly, hazard-producing databases tend to be for a single hazard-producing event type (e.g., volcanic eruptions). In addition to these two types (as defined in figure 1) are disaster databases. Databases of hazards and/or hazard-producing events that have caused an adverse impact. Unlike hazard and hazard-producing databases, disaster databases tend to span multiple hazard types and multi-hazard events. Thus, for this metadata set, three types of database are included:

(1) Hazard
(2) Hazard-producing
(3) Hazard-related disaster

As the entry threshold for these different databases vary, this distinction must be retained for any future analyses as the data within each are not necessarily directly comparable. Whether a database is classified as a hazard or hazard-related disaster dataset is primarily defined via the entry threshold criteria. For example, the Austrian Torrential Event Catalogue lists debris flows that have caused damage (Heiser et al., 2019), thus is designated as a hazard-related disaster dataset as it does not include all torrential events, solely the ones that caused damage. Conversely, although the Manawatu Large Landslides dataset (Forrest Williams, pers. comm.) is only a subset of the landslides occurring in the Manawatu, the entry criterion is based on landslide size, not impact, thus is classified as a hazard database.

To be included within this metadata set, data must be openly available and readily accessible for download. Data must include at minimum a temporal and spatial stamp (ideally via date and coordinate), cover more than a single event (e.g., earthquake-specific landslide databases are not included unless they reside within the Bay of Plenty (case study region)), identification of at least one hazard or hazard-producing type included in figure 1, and ideally some measure of hazard magnitude (whether ordinal or numerical).

The following subsections comprise of tables detailing the purpose, entry threshold, spatial and temporal coverage and resolution, hazard types, number of records, magnitude data, trigger/origin data, data sources, access method, and URL for global, country, and region-level data for each of the following: hazard (2.1), hazard-producing (2.2), and hazard-related disaster (2.3).

2.1 Hazard datasets

Table 1a: Global Hazard Databases – Flood and Landslide			
	FloodArchive [a]	**GLC**	**GFM: Global Flood Monitor**
Purpose	Humanitarian use, assess changes in global surface water, scientific research	Identification of global rainfall-triggered landslides	To assist rapid-response efforts
Entry threshold	Large floods (magnitude unspecified)	Rainfall triggered landslide [b]	Detection by person (twitter based)
Spatial coverage	Global	Global	Global
Spatial resolution	COORDS: 100 %	COORDS: 100 %	COORDS: 100 % - check
Temporal coverage	1985 – 2020	2007 – 2017	2014 - present
Temporal resolution	Days: 100 %	Days: 100 %	Days: 100 %
Hazard types	Flood	Landslide	Floods
Number of records	5,000	11,000	~ 50,000
Number of NZ records	39	106	250
Magnitude data	100 % (Area measurement)	~ 100 % (ordinal) (70 % shp files)	No
Trigger / origin data	99.7 %	84 %	No
Data sources	Government agencies, news outlets, remote sensing	News outlets, disaster databases, scientific reports	Filtered twitter data
Links to data origin	No	77 %	No
Access	Excel file	Excel file	Csv download
URL	Floodobservatory.colorado.edu	Catalog.data.gov/dataset/global-landslide-catalog-export	Globalfloodmonitor.org

[a] Also called the DFO: Dartmouth Flood Observatory

[b] Triggering entries include non-rainfall events

Table 1b: Global hazard databases – Earthquake & Tsunami		
	NOAA: NEIC PDE	**NOAA: NCEI**
Purpose	Earthquake hazard assessment and mitigation efforts	Global historical tsunami database for source events and runups (tsunami effects)
Entry threshold	≥ 10 deaths, > 1 mil. USD damage, ≥ Mag 7.5, ≥ MMI X, or tsunami	No minimum measurement
Spatial coverage	Global	Global
Spatial resolution	COORDS: 100 % (from 1900 on)	COORDS: 98 %
Temporal coverage	2150 BC – 2020 (1900 – 2020)	2000 BC – 2020 (1960 – 2020)
Temporal resolution	Days: 99.7 % Months: 99.7 % Years: 100 % (from 1900 on)	Days: 99 % Months: 99.6 % Years: 100 %
Hazard types	Shaking, ground deformation, tsunami	Tsunami
Number of records	6,200 (3700)	28,000 runup from 2700 source (21,000 runup from 700 source)
Number of NZ records	67 (51)	578
Magnitude data	92 % Magnitude, 40 % MMI (35 % both)	85 % water height, 33 % horizontal inundation (32 % both)
Trigger / origin data	100 % (‘earthquake’)	97 % distance from source
Data sources	‘significant earthquake catalogue’ publication, measurements	Scientific reports, regional catalogues, gauge and sensor data, event reports
Links to data origin	No	No
Access	Excel or kml file	Excel file
URL	Ngdc.noaa.gov/hazel/view/hazards/earthquake/search	Ngdc.noaa.gov/hazard/tsu_db.shtml

Table 2a: Country-specific hazard databases: Hong Kong				
	HK Notable Landslides	**Daily total rainfall**	**Lau et al. (2010) Tsunamis**	**JTWC* Typhoons**
Purpose	Slope safety	Climatological information	Scientific research	Warnings and hazard mapping
Entry threshold	Notable (no further definition)	> 0.5 mm rain	Reported	> 119 km/hr wind speed
Spatial coverage	Hong Kong	Hong Kong	South China Sea	Western North Pacific Ocean
Spatial resolution	COORDS (approx.): 100 %	COORDS: 100 % (22 stations)	Region: 93 %	
Temporal coverage	1977 – 2018	1997 – 2018	1076 – 2006	1945 – 2018
Temporal resolution	Days: 100 %	Days: ~ 100 %	Days: 86 % Months: 98 % Years: 100 %	Days: 100 % (6 hrly reporting)
Hazard types	Landslides, Debris flows, rockfalls	Rainfall	Tsunami runup	Wind
Number of records	57	~ 175,000	58	~ 40,000 (~2,000 typhoons)
Magnitude data	100 % (source volume)	~ 100 % (rainfall in 0.5 mm increments)	60 % (water height)	100 % (max. sustained wind speed)
Trigger / origin data	~ 100 % (56)	N/A	91 % (approx. earthquake location)	N/A
Data sources	HK government	HK observatory	Historical accounts	Measurements
Links to data origin	No	Yes	Yes	No
Access	Freely available but no direct download (copy + paste)	Freely available but no direct download (copy + paste)	Table in paper	Freely available. Single text file for each typhoon, downloaded as yearly zip files
URL / Ref	Hkss.cedd.gov.hk	Hko.gov.hk	Nhss.copernicus.org	Metoc.navy.mil/jtwc

[a] Joint Typhoon Weather Centre

Table 2b: Country-specific hazard databases: USA				
	Jones et al. (2019) – USGS	**NOAA – NCEI [a]**	**NOAA - most intense US Tropical Cyclones [b]**	**FLASH**
Purpose	Landslide inventory for hazards	Climate data archive	To meet requests for information	US flash flooding database
Entry threshold	Existence in smaller inventory	Measured at station	Category 3,4, or 5 on Saffir/Simpson Scale	Identified in one of 3 data sources
Spatial coverage	USA	USA (lower resolution coverage globally)	USA	Contiguous USA (split into 18 HUC basins)
Spatial resolution	COORDS: 100 % (polygons OR points)	COORDS: 100 % (~ 2,000 stations)	Track coordinates	COORDS: 100 %
Temporal coverage	1960 – 2013 data, sporadic at best (1900 – 2019 stated)	1970 – 2014	1851 – 2017	1976 - 2016
Temporal resolution	24 % time stamped (pt data)	Days: 100 % (up to 15 min resolution)	Years: 100 % (6 hrly track data for individual storms [a])	Days: 100 %
Hazard types	Landslides, debris flows, debris slides, rockfall, fill failure	Rainfall	Wind, rainfall, flooding	Flash flood
Number of records	246,000 poly 64,000 pt	Hard to estimate (v. large number)	~ 100 tropical cyclones	18,000 [c] (highly variable by basin)
Magnitude data	100 % (shape area, length)	100 % (rainfall total / time)	100 % (minimum pressure at landfall)	100 % (peak discharge)
Trigger / origin data	No	N/A	N/A	No
Data sources	USGS, researchers, regional inventories	NOAA / NCEI and local / regional weather stations	NOAA	USGS stream measurements, NOAA storm database reports, public survey responses
Links to data origin	Yes	Yes	No	Yes
Access	ArcGIS layers	Individual stations via separate links.	Individual track data is available but must be searched for via storm designation.	Shp, kml, csv (all zip files)
URL / Ref	Sciencebase.gov	Ncei.noaa.gov	Nhc.noaa.gov	FLASH

[a] Mirrored data at Climate Data Online: https://www.ncdc.noaa.gov/cdo-web/

[b] Data for all hurricanes is also available: https://www.coast.noaa.gov/hurricanes/, however, you have to pull the data one (specified) hurricane at a time.

[c] Multiple records per flash flood as each gauge overflow has an individual row entry.

Table 2c: Country-specific hazard databases: NZ			
	GeoNet felt reports	**Geonet Tsunamis**	**GNS Landslide database**
Purpose	Shaking information	Tsunami historical events inventory	Inventory of NZ landslide data
Entry threshold	Recorded felt reports	Unknown	Observed
Spatial coverage	New Zealand	New Zealand	New Zealand
Spatial resolution	COORDS: 100 % (distance and direction to nearest locality) [a]	COORDS: 100 % (for source), qualitative info for runups	COORDS: 100 %
Temporal coverage	1772 – present [b]	1855 – 2016	1900 – 2015
Temporal resolution	Days: 100 % [b]	Days: 100 %	Days: 18 % (rest have no timestamp)
Hazard types	Shaking	Tsunami (runup)	Landslides (multiple types)
Number of records	645,000 [b]	10	19,000
Magnitude data	100 % (NZ MMI)	100 % (source and runup)	7 % Ordinal (small, moderate, large)
Trigger / origin data	100 % (Earthquake ID)	100 % (Quake, volcano, landslide info.)	14 %
Data sources	No (privacy issue)	Historical accounts, tidal gauge, seismic network	Photo interpretation, field work, news outlets
Links to data origin	No	No	All say “Landslide GIS”
Access	API queries, GeoJSON files	Word docs generated from individual webpages	Excel file
URL / Ref	Api.geonet.org.nz	Geonet.org.nz	Data.gns.cri.nz

[a] Assumption that the closest locality would show largest shaking?

[b] Assumed to match Geonet QuakeSearch database – see Table 5a

Table 2d: Country-specific hazard databases: Europe, Italy			
	AVI Landslides Catalog [a]	**AVI Flood Catalog**	**ESWD (Europe Severe Weather Database)**
Purpose	Inventory for hazard analyses	Inventory for hazard analyses	Collect and provide information on severe convective storms in Europe
Entry threshold	Identification	Identification	Event-specific criteria
Spatial coverage	Italy	Italy	Europe
Spatial resolution	Commune (town / descriptive road location)	Commune (town / road description) [b]	COORDS: ~ 100 % (point-data encouraged)
Temporal coverage	1009 – 2001	1030 - 2001	Pre-1900 - present
Temporal resolution	Days: ~ 75 % (very approx.)	Days: ~ 95 % (very approx.)	Days: ~ 100 %
Hazard types	Landslides	Floods	Avalanche, whirlwind, hail, ice, lightning, heavy rain / snow, tornado, severe wind gust
Number of records	22,346 records (1:1 records: landslides)	8403 floods (? Records)	247,000 [5,000 before 1900]
Magnitude data	Sparse	Sparse (e.g., river level)	Highly variable (depends on source)
Trigger / origin data	Yes (% unknown)	"Main: meteorological event" [c]	Only for avalanche (manmade / natural)
Data sources	Published work, existing databases, news outlets	Published work, existing databases, news outlets	News / media outlets, individual's reports, meteorological services
Links to data origin	No	No	Yes
Access	Each record details on separate webpage. (labour intensive)	Each record details on separate webpage. (labour intensive)	Max. 25 records without log-in. Free to obtain log-in but requires signing user agreement / emailing / project info etc.
URL / Ref	Db.gndci.cnr.it Guzzetti et al. (1994)	Db.gndci.cnr.it Guzzetti et al. (1994)	Essl.org/cms

[a] Giano / Janus project data can be found at the same URL however is significantly smaller than AVI

[b] Individual records for each location affected (e.g., for one flood event may have 10 records)

[c] Some records also include indirect effects (e.g., landslides)

Table 2e: Country-specific hazard databases: Philippines, Australia			
	PAGASA – Tropical Cyclones*	**PHIVOLCS – destructive earthquakes**	**Australian Landslide Database**
Purpose	Recent tropical cyclone summary data	Destructive earthquakes in the Philippines	Natural disaster management
Entry threshold	Identified as tropical storm, tropical depression, or typhoon	Caused destruction	Identified
Spatial coverage	Philippines	Philippines	Australia
Spatial resolution	Map of track	COORDS: 100 %	COORDS: 100 %
Temporal coverage	2018 – 2019	1968 – 2019	~ 1850 – 2017
Temporal resolution	Days and duration: 100 %	Days: 100 %	Days: 65 % Months: 75 % Years: 90 %
Hazard types	Tropical storm related	Liquefaction, tension cracks, landslides, shaking (structural damage)	Landslide, cave-in, erosion, submarine slide, mine-related
Number of records	10	18	1,974
Magnitude data	Yes (total accumulated rainfall).	Yes	~ 5 % (e.g., displacement distance)
Trigger / origin data	N/A	N/A	25 % Triggering factors [Contributing factors: 11 % human, 19 % natural]
Data sources	PAGASA monitoring	PhiVOLC + assoc network	Published work, news outlets, pers. comms.
Links to data origin	No	Some	47 %
Access	Pdf download for each TC	Pdf download for each	Excel download
URL / Ref	Bagong.pagasa.dost.gov.ph	Phivolcs.dost.gov.ph	Data.gov.au

* Map based data with a wider temporal span is also available at: https://mcgillgis.maps.arcgis.com/apps/MapJournal/index.html?appid=586f9150ae87491a8c7f1b86db7952a9

Table 2f: Country-specific hazard databases: Indonesia, Colombia		
	Geoportal Kebencanaan Indonesia – BNPB	**Inventory of mass movements, INGEOMINAS**
Purpose	Natural hazard database	Zoning of susceptibility and threat
Entry threshold	Identification	Identification
Spatial coverage	Indonesia	Colombia
Spatial resolution	100 % province (and location description)	1:25,000
Temporal coverage	2008 - present	?
Temporal resolution	Days: 100 %	? Geomorphological inventory supposedly includes temporal information but not directly apparent to download
Hazard types	Gempabumi (quake), Letusan Gunang Api (Volcanic Eruption), Banjir (flood), Tanah Longsor (landslide), Putting Beliung (tornado), Gelomb bang pasang (tidal wave), kekeringan (drought), kebakaran hutan dan lahan (fire)	Landslide, fall, flow, creep (glide, drop, flow, crawling, overturning, gravitational deformation, lateral propagation)
Number of records	29,000	6,800
Magnitude data	Sometimes in description	No (maybe via shp file?)
Trigger / origin data	No	No
Data sources	Unknown (google translate issues)	Red cross, civil defence, news outlets
Links to data origin	No	No
Access	Excel download (data in Indonesian)	Shp, kml, excel, geodb download
URL / Ref	Gis.bnpb.go.id	Datos.sgc.gov.co

Table 3a: Region-specific hazard databases: Omokoroa Peninsula (NZ), Manawatu (NZ), Teziutlan (Mexico)			
	Kluger et al. (2020)	**Manawatu large landslides [b]**	**Teziutlan, Puebla, Mexico**
Purpose	Scientific research to determine rainfall threshold for landslides	Scientific research	Scientific research into spatial distribution of landslides
Entry threshold	Identified after 2017 cyclone season	Slow-moving deep-seated (large) landslides	Identification
Spatial coverage	Omokoroa Peninsula (Tauranga Harbour, NZ)	Manawatu, NZ	Teziutlan municipality (163 km^2)
Spatial resolution	COORDS: 100 %	COORDS: 100 % (polygons)	1:25,000
Temporal coverage	April 2017	Unspecified	1942 – 2015 [c]
Temporal resolution	No timestamps [a]	Ordinal (young, medium, old)	61 slides: 1955, 292 slides: 1999, 32: pre 1942, rest: no temporal resolution
Hazard types	Landslides	Landslides (mainly rock slides)	Landslide (silt flowslide, debris flowslide, silt planar slide, slides/fall, silt rotational, soil silt, rock fall, rock avalanche)
Number of records	26 (main)	1,200	662
Magnitude data	100 % (Volume, length, width)	100 % (area)	100 % (area)
Trigger / origin data	100 %	No	Yes: “Seasonal”, “1955”, “1999”, “relict” (before 1942).
Data sources	Field work	Forrest Williams’ observations	Aerial/satellite images, field surveys
Links to data origin	Map of area	N/A	No
Access	Excel files (landslides + rain events)	Direct request	Tif download
URL / Ref	Link.springer.com	Massey.ac.nz	Murillo-Garcia et al. (2017)

[a] Landslides directly attributed to Cyclone Debbie (April 5th, 2017), or Cyclone Cook (April 13th, 2017)
[b] Evolving dataset from Forrest Williams, PhD Student at Massey
[c] 32 slides are pre-1942 (5 %)

Table 3b: Region-specific hazard databases: Asturius (Spain), Colorado (US)			
	BAPA database	**Colorado Flood Database**	**Porta (Massey PhD) data**
Purpose	Scientific research	Flood information	Scientific research
Entry threshold	Identified	Identified	Identified
Spatial coverage	Asturius (NW Spain)	Colorado, US	Emilia-Romagna, Italy
Spatial resolution	COORDS: 100 %	COORDS: 100 %	COORDS: 100 % (quakes) Municipality: 100 % (rainfall, landslides)
Temporal coverage	1980 – 2015	1867 – 2015	1981 – 2018
Temporal resolution	Days: 36 %	Days: 100 % (est. based on subset)	Days: 100 % (rainfall, quakes) "Day at best": landslides
Hazard types	Landslide, rockfall, slide, flow, subsidence/collapse, crack	Floods	Rainfall, quakes, landslides
Number of records	2,063	6,886	Rain ~ 2 billion Landslides: 7,743 Quakes: > 8,000 (M>3)
Magnitude data	?	Discharge rates	100 %
Trigger / origin data	71 % (incl. natural / anthropogenic factors)	No	No
Data sources	News outlets, citizen reports, institutions	USGS surveys, discharge measurements, USGS peak-streamflow database, peer-reviewed work	INGV (quakes), ARPAE (rainfall), ISPRA, 2019 [b] (landslides)
Links to data origin	No	Yes	No (maybe via paper / Mark)
Access	Via email request: bapa@geol.uniovi.es [a]	Map based interface – not all datapoints are floods (looking for peak-discharge events etc)	Github download
URL / Ref	Geol000.geol.uniovi.es	Usgs.gov, cr.usgs.gov	https://github.com/gfrigerioporta/eqrfls

[a] We have not previously utilized this service so do not know how well this account is monitored.
[b] https://www.isprambiente.gov.it/it/evidenza/progetti/iffi-project-inventory-of-landslide-phenomena-in-italy

2.2 Hazard-producing datasets

Table 4a: Global hazard-producing databases: IRIS, GVP		
	IRIS [a]	**GVP**
Purpose	Acquisition, management, and distribution of seismic data	Document and disseminate information on global volcanic activity
Entry threshold	Detection on monitored network	Known or inferred Holocene eruption from 1422 volcanoes
Spatial coverage	Global (choose MIXED data)	Global
Spatial resolution	COORDS: 100 %	COORDS: 100 %
Temporal coverage	1970 – 2020	Holocene: 10,000 BC – present (1900 – 2020)
Temporal resolution	Days: 100 %	Days: 46 % (86 %) Months: 53 % (93 %) Years: ~ 100 %
Hazard types	Earthquake related	Eruption related
Number of records	~ 6,000,000	11,200 (3800 since 1900)
Number of NZ records	~ 110,000	350 (195)
Magnitude data	100 %	74 % VEI (98 % 1900 on) 31 % duration (70 %)
Trigger / origin data	N/A	N/A
Data sources	USGS, ISC, most other seismic monitoring networks	Volcanoes of the world publications, volcano observatories, USGS
Links to data origin	No.	Yes via website (not directly from download)
Access	Excel or NetCDF file download	Excel file download
URL	Ds.iris.edu	Volcano.si.edu

[a] ICS Bulletin data (http://www.isc.ac.uk/iscbulletin/) is mirrored at IRIS from 1970 onwards

Table 4b: Global hazard-producing databases: GLADIS, WOVOdat		
	GLADIS	**WOVOdat**
Purpose	Global Archive of Dome Instabilities (GLADIS)[a]	Volcanic unrest database for understanding pre-eruptive processes for eruption forecasts
Entry threshold	Known source, known year, and identified as a 'significant event in dome growth chronology'	Volcano with monitoring data
Spatial coverage	Global (but only 35 volcanoes)	Global but 385 volcano specific locations
Spatial resolution	Volcano COORDS from GVP: 100 %	COORDS: 100 %
Temporal coverage	No cut-off but under- recording before 1950	Volcano specific (min. 1600, max. 2017)
Temporal resolution	Days/Months/Years: 98% 6 are X ka, 1 is between 1755 and 1885 (Taranaki)	Days: 100 %
Hazard types	Dome collapse related (rock avalanche, BAFs etc)	Eruption or unrest related
Number of records	294 events from 42 volcanoes	730 datasets
Number of NZ records	3 (Taranaki, Tarawera x 2)	~ 25
Magnitude data	42.7 % Volume (dome) 64 % Volume (deposit) 20.4 % duration (mins)	N/A (direct data links)
Trigger / origin data	45 % (7 options)[c]	N/A
Data sources	GVP or Published literature (all provided)	Volcano observatories
Links to data origin	Yes	Yes via website
Access	Excel snap-shot at vhub (requires free log-in)[b]	No direct download
URL	https://vhub.org/resources/4149	Wovodat.org

[a] see https://link.springer.com/article/10.1007/s00445-019-1276-y for database details

[b] Can email author for full dataset: eeceh@leeds.ac.uk

[c] Options - 1: Gravitational, 2: Rain, 3: Pressurisation, 4: Switch in extrusion direction, [no number 5], 6: Earthquake(s), 7: Topography, 8: Other (including weathering).

Table 5a: Country-specific hazard-producing databases: US, NZ, Italy			
	ANSS ComCat	**Geonet QuakeSearch**	**CPTI15_v2.0: Parametric Catalog of Italian Earthquakes**
Purpose	Inventory for seismicity related parameters	Inventory for NZ seismicity	Catalogue and provision of homogeneous earthquake data
Entry threshold	Detection on a monitoring network	Detection on NZ monitoring network	≥ Mag 4.0, or ≥ MMI 5
Spatial coverage	Conterminous US (48 states)	NZ and close surrounding sea	Italy
Spatial resolution	COORDS: 100 %	COORDS: 100 % [a]	COORDS: 63 %
Temporal coverage	1600 – present	1460 – present [b]	1000 – 2017
Temporal resolution	Days: 100 % (older ones entered from historical accounts)	Days: 100 % since 1854 Month: 100 % since 1854 Years: 100 % since 1460 [c]	Days: 97 % Months: 99 % Years: 100 %
Hazard types	Earthquake – related	Earthquake – related	Earthquake – related
Number of records	Hard to estimate (18,000, M>3, 2000-2019)	~ 658,467 (2021-06-07 1800 UTC)	4,760
Magnitude data	100 % (Magnitude units vary)	~ 100 % Mag (66 % ML; 32 % M)	97 % (Mw)
Trigger / origin data	100 % x,y,z for earthquake source location	N/A (see spatial resolution)	N/A
Data sources	USGS measurements, other (global) seismic networks	Seismic networks, historical records for pre-1930s' events, paleo for earliest events	INGV, ISC, Italian seismic centre, "various authors from different institutions"
Links to data origin	No	No	No
Access	Downloads limited to 20,000 events	URL below will download everything as a csv file (currently about 130Mb)	Excel file
URL	Earthquake.usgs.gov	Quakesearch.geonet.org.nz; http://wfs.geonet.org.nz/geonet/ows?service=WFS&version=1.0.0&request=GetFeature&typeName=geonet:quake_search_v1&outputFormat=csv	Emidius.mi.ingv.it

[a] Spatial resolution provides hypocentre location with shallow depth poorly determined. In 2020, approx. 77% of events with depth ≤ 40 km, M ≥ 3.5 were recorded as 5, 12, or 33km. For M ≥ 4 this is approx. 75%.

[b] The magnitude threshold of recorded events increases going back into the historical past. Reasonably "complete" for M ≥ 4 (NZ landmass) since about 1965.

[c] Temporal resolution: 100 % hour since 1939; 100 % minute since 1942 (minus one event in 2014); 100 % seconds since 1964 (minus 100 events).

Table 5b: Country-specific hazard-producing databases: Mexico, Colombia, Philippines			
	SSN Earthquake Catalog	**Seismic history of Colombia**	**PHIVOLCS – Eruption history**
Purpose	Inventory of Mexican earthquakes	Large magnitude events catalogue	Volcanic eruption history inventory
Entry threshold	Detection on monitoring network	M > 5	Eruption detected
Spatial coverage	Mexico	Colombia	Philippines
Spatial resolution	COORDS: 100 %	COORDS: 100 %	COORDS: 100 % (indirectly – linked to volcano vent)
Temporal coverage	1900 – present	1644 – 2016	1454 – present
Temporal resolution	Days: 100 %	Days: 100 %	Days: 70 %
Hazard types	Earthquake-related	Earthquake – related	Volcano – related
Number of records	213,458	81	219
Magnitude data	100 %	100 % (MW, ML, or MS)	No (~ 80 % eruption type)
Trigger / origin data	N/A	N/A	N/A
Data sources	Seismic network detection	Colombian Geological Survey, ISC, National Seismological Network of Colombia	unknown
Links to data origin	No	No	No
Access	Csv download (no record limit)	Excel, pdf download	Copy + past 20 records at a time
URL	Ssn.unam.mx	Sish.sgc.gov.co	Vmepd.phivolcs.dost.gov.ph

Table 5c: Country-specific hazard-producing databases: Japan	
	JMA (Japan Meteorological Agency) – Earthquakes
Purpose	Inventory for Japan seismicity
Entry threshold	Since 1997-10-01, detection by the JMA network [a]
Spatial coverage	120E-150E, 20N-50N, 0.0km-700.0km
Spatial resolution	See notes within URL section
Temporal coverage	1926-01-01 - 2019-12-31 as at 2021-06-24 [b]
Temporal resolution	Recent events to fractions of a second
Hazard types	Earthquakes
Number of records	JMA (M>=3, prior to 1997-10-01) >100k events, JMA1 (M>=2, prior to 1997-10-01) >2.5m events
Magnitude data	See https://www.data.jma.go.jp/svd/eqev/data/bulletin/catalog/notes_e.html
Trigger / origin data	See Spatial Resolution
Data sources	Data originate from the Japan Meteorological Agency (JMA)
Links to data origin	-
Access	Data access is somewhat complicated. One can access all data mentioned below on the JMA website, though for the best data, this is rather tortuous (GUI based, month by month). Access to ERI (University of Tokyo) ftp site not yet managed (see Appendix A for shell script).
URL	https://www.jma.go.jp/jma/en/Activities/earthquake.html [c]

[a] Prior to that two versions are available: JMA where M >= 3, and a "unified" version (JMA1) with M >= 2; see http://evrrss.eri.u-tokyo.ac.jp/db/index.html; see [b] for details

[b] The web based catalogue seems to be split into two holdings, until 1997-09-30 held by ERI, University of Tokyo; and since then by JMA (see URLs). The most recent, ~18 months, are not yet included. Periodically added: https://www.data.jma.go.jp/svd/eqev/data/bulletin/update_e.html. Prior to 1923, the records were paper based, held at JMA. These got destroyed in the fire following the Great Kanto Earthquake (1923-09-01).

[c] URLs: http://evrrss.eri.u-tokyo.ac.jp/db/jma/index.html
JMA Catalogue from University of Tokyo
Data Source: ftp://ftp.eri.u-tokyo.ac.jp/pub/data/jma/mirror/JMA_HYP/
Contains data: 1926/01/01 to 1997/09/30 (JST)
Have not managed to connect to this site.

https://www.data.jma.go.jp/svd/eqev/data/bulletin/eqdoc_e.html
Overall summary of various data formats, most relevant listed below.
In each replace YYYYMM with month and year, where 199710 <= YYYYMM <= 201912
wget https://www.data.jma.go.jp/svd/eqev/data/bulletin/catalog/table2/hYYYYMMt.zip
Contains hYYYYMM.txt, ASCII format, human readable
wget https://www.data.jma.go.jp/svd/eqev/data/bulletin/catalog/table3/dYYYYMMt.zip
Contains dYYYYMMa.txt, dYYYYMMb.txt, dYYYYMMc.txt; concatenate for complete dataset
ASCII format, human readable, includes station response to each event
https://www.data.jma.go.jp/svd/eqev/data/bulletin/data/hypo/hYYYYMM.zip
Contains hYYYYMM, ASCII format, computer readable file
Unfortunately wget does *not* work here, need to use GUI, month by month:
http://www.data.jma.go.jp/svd/eqev/data/bulletin/index_e.html

Data are recorded to most dp's in hYYYYMM (hYYYYMM.zip), same in "dYYYYa|b|c.txt" (dYYYYMMt.zip) except depth rounded to 0dp in "dYYYYa|b|c.txt" compared to 2dp in hYYYYMM, latitude & longitude also rounded in hYYYY.txt (hYYYYMMt.zip).
Unfortunately, hYYYYMM.zip is tedious to download (see above), both dYYYYMMt.zip & hYYYYMMt.zip easily done as a shell script, though "human readable" content needs cleaning (easily done with grep). If depth is OK rounded to integers, "dYYYYa|b|c.txt" quickest & best option.

Table 6: Region-specific hazard-producing databases	
	Southern California Earthquake Catalogue (SCEC)
Purpose	Inventory for Southern California (SC) seismicity
Entry threshold	Detection on SCEC monitoring network and within "spatial coverage" region below
Spatial coverage	Lat: 32 to 37 (dec deg) Long: -122 to -114
Spatial resolution	Long-lat: 3 dp Depth: 1 dp [a]
Temporal coverage	1932 – present. Lower mag threshold ~ 1980
Temporal resolution	No obvious date/time components missing
Hazard types	Earthquake-related
Number of records	777,867 (2021-05-23 07:00 UTC)
Magnitude data	100 % (2 dp) Various types
Trigger / origin data	See spatial resolution
Data sources	Seismic network
Links to data origin	No
Access	Download entire catalogue using wget on URL below. Tar.gz file of ~ 17.5 Mb (one file per year)
URL	URL: wget --retry-connrefused --tries=0 --waitretry=10 --no-verbose http://service.scedc.caltech.edu/ftp/catalogs/SCEC_DC/SCEDC_catalogs.tar.gz

[a] Depth: disproportionately high number at 6.0, and to a lesser extent at 7.0, 10.0, and 15.0. An additional field "Q" gives the quality of spatial resolution see: http://service.scedc.caltech.edu/ftp/catalogs/SCEC_DC/README

2.3 Hazard-related disaster datasets

Table 7a: Global hazard-related disaster databases			
	EM-DAT [a]	**DesInventar**	**NatCat** [b]
Purpose	Disaster loss data for vulnerability assessments and global aid distribution	Local disaster information for national disaster inventories	Insurance industry
Entry threshold	≥ 10 fatalities, ≥ 100 affected, state of emergency, or international assistance	> 1 fatality, > 1 US dollar of economic loss	Any financial or human loss
Spatial coverage	Global	Africa, Asia, S. America	Global
Spatial resolution	COORD: 10 % Region: 90 % Country: 100 %	COORD: 0 % Region: 90 % Country: 90 %	?
Temporal coverage	1900 – present	1970 – 2013	1980 – 2013
Temporal resolution	Days: 85 % Months: 85 % Years: 100 %	Days: 70 % Months: 70 % Years: 70 %	Annual data summaries (no individual event records)
Hazard types	Natural, Technological	Natural, Technological	Natural
Number of records	> 25,000 (> 15,000 natural)	375,000 [c] (324,000 natural)	28,000
Number of NZ records	Total: 84 Natural: 73	None	?
Magnitude data	20 %	9 %	?
Trigger / origin data	15 %	62 %	?
Data sources	Aid and government agencies, news outlets	Government agencies, news outlets	Aid agencies, news outlets, insurance companies, weather services
Links to data origin	No	83 %	?
Access	Excel file download	Excel file download	No data freely available
URL	public.emdat.be	desinventar.net	natcatservice.html

[a] Data includes GLIDE entries (https://glidenumber.net/)

[b] Also at NATHAN (https://www.munichre.com/en/solutions/for-industry-clients/risk-suite.html)

[c] Each affected locality is a separate entity, not a separate hazard or event

Table 7b: Global hazard-related disaster databases		
	Volcano Fatalities Database (Brown et al. 2017)	**IDMC**
Purpose	Academic	Monitoring people forced to evacuate homes but remain within country
Entry threshold	≥ 1 fatality	> 1 displacement
Spatial coverage	Global	Global
Spatial resolution	Volcano: 100 % (Coords from GVP)	Country: 100 %
Temporal coverage	1500 (?) – 2017	2008 – 2019
Temporal resolution	Years: 27 %	Days: 100 % Months: 100 % Years: 100 %
Hazard types	Volcano - related	Natural, Conflict
Number of records	635	8,400 natural
Number of NZ records	21	38
Magnitude data	VEI (98 % of eruption-related), 11 % N/A	No
Trigger / origin data	Possibly in some descriptions where eruption not assumed as trigger	No
Data sources	Published work, EM-DAT, GVP, Munich Re	Aid and government agencies, news outlets, situational monitoring
Links to data origin	References for each entry	No
Access	Excel file download (ESM1)	Excel file download
URL	https://appliedvolc.biomedcentral.com/articles/10.1186/s13617-017-0067-4#Sec41	Internal-displacement.org

Table 8a: Country-specific hazard-related disaster databases – Austria, Switzerland		
	Austrian Torrential Event Catalog	**Switzerland Natural Hazard fatalities [d]**
Purpose	Hazard mapping	Scientific research
Entry threshold	Caused damage	Fatality associated with a natural hazard [e]
Spatial coverage	Austria	Switzerland
Spatial resolution	COORDS: ~ 100 %	"Switzerland"
Temporal coverage	1340 – 2017 (~ complete from 1945)	1946 – 2015
Temporal resolution	Sub-years: 30 % Years: 100 % (incl. uncertainty range)	Yearly: 100 %
Hazard types	Debris flow [a]	Floods, Landslide, rockfall, lightning, windstorm, avalanche (rock / ice), earthquake-related, lacustrine tsunamis
Number of records	1,400	635
Magnitude data	No. (not in open dataset, likely in original)	100 % (number of fatalities)
Trigger / origin data	No.	100 %
Data sources	Archives, BFW [b], WLK-Austria [c]	Swiss flood and landslide database [f], Swiss destructive avalanche database [g], news outlets
Links to data origin	Yes	No
Access	Excel file	Excel file
URL / Ref	Heiser et al. (2019)	Badoux et al. (2016)

[a] Full catalogue also includes floods but I've only found freely available data on the debris flows
[b] BFW: Austrian Research Centre for Forests
[c] WLK-Austria: Forest technical Service of the Austrian Torrent and Avalanche Control
[d] A related database exists: StorMe but requires a (not-freely available) log-in.
[e] In which "victims did not expose themselves to an important danger on purpose" (Badoux et al., 2016)
[f] Not freely available (all publications based on this is by the same three people): https://www.wsl.ch/en/natural-hazards/understanding-and-forecasting-floods/flood-and-landslide-damage-database.html#tabelement1-tab4
[g] Paid service: https://www.slf.ch/en/services-and-products/data-and-monitoring/extracts-from-the-destructive-avalanche-database.html

Table 8b: Country-specific hazard-related disaster databases – New Zealand		
	NZ historic weather events catalogue	**ICNZ events**
Purpose	Catalogue of major weather events	Records of the monetary cost of natural disasters
Entry threshold	Significant damage or casualties	"Severe weather event or natural disaster"
Spatial coverage	New Zealand	New Zealand
Spatial resolution	Town / locality: 100 %	Event: 100 % [a]
Temporal coverage	1800 – present	1968 – present
Temporal resolution	Days: ~ 100 % (and duration)	Days: 100 % (including duration)
Hazard types	Flooding, fog, hail, heavy rain, high wind/gust, landslide, lightning, maritime/coastal, multi-hazard, snow/ice, tornado	Flood, storms/tornado/ cyclone related, snow/hail, fire, earthquake-related, power outage, coastal erosion
Number of records	851	195
Magnitude data	Sparse / qualitative	100 % (Monetary cost)
Trigger / origin data	100 % ("Weather"?)	~100 % (can be inferred for most)
Data sources	News outlets, published work, existing databases	No
Links to data origin	No	No
Access	Xml database	Excel file
URL / Ref	Hwe.niwa.co.nz	Icnz/org.nz

[a] However, event includes either hazard (e.g., Cyclone Fehi) or region hit by hazard (e.g, Napier flooding)

2.4 Case-study-related datasets

2.4.1 Database overview

Case-study specific hazards were presented in Figure 1, given the above datasets, those hazards identified to have readily available data are shown below (Tables 9 – 11). It is apparent that to cover all case-study hazards, disaster and hazard-producing datasets are required, but these come with significant data bias. Additionally, not all databases are created equal, none can be considered complete, but regional ones appear to be more complete than country / global databases (compare relative numbers of events for example).

Another significant issue for some of the hazards is the definition of a hazard and differing terminologies. For example, when is rainfall a hazard? Over a minimum total accumulated amount? When rainfall rate exceeds a specific threshold? When it has rained for x consecutive days? Landslide terminology is complex. Here these are collapsed into two categories: Landslide and Debris Avalanche/Rockfall to reflect the terminology in most of the databases. It may not matter too much during this metadata collection but will likely become an issue as the driving / triggering mechanisms and consequent hazard footprints vary with landslide 'type'.

Table 9: Hazard databases overview

Hazard	Global	Country	Region
Ground Movement	**LARGE EVENTS ONLY** (NOAA: NEIC PDE)	NZ; Philippines	
Subsidence			Asturius (SP)
Liquefaction		Philippines	
Landslide	GLC (rain-fall trigger)	Hong Kong; USA; NZ; Italy; Philippines; AUS; Indonesia; Colombia	Tauranga (NZ); Manawatu (NZ); Teziutlan (MX); Asturius (SP); Emilia-Romagna (IT)
Volcanic Earthquake			
Debris Avalanche / Rockfall		Hong Kong; USA; NZ; Colombia	Teziutlan (MX); Asturius (SP)
Landslide Dam			
Tsunami	NOAA: NCEI	Hong Kong; NZ	
Flood	FloodArchive; GLM	USA; Italy; Indonesia	Colorado (USA)
Wind		Hong Kong; USA; Europe; Philippines	
Rain		Hong Kong; USA; Europe; Philippines	Emilia-Romagna (IT)
Hail		Europe	
Storm Surge		Indonesia	
Lightning		Europe	
Lahar			
Lava Flow			
Ash Fall			
Pyroclastic Flow			

Table 10: Database overview by hazard trigger			
Hazard - producing	**Global**	**Country**	**Region**
Earthquake	IRIS; IDMC (disaster)	Indonesia; Japan; USA; NZ; Italy; Mexico; Colombia	Emilia-Romagna (IT); S. California (USA)
Volcanic Activity	GVP; WOVOdat; IDMC (disaster)	Indonesia; Philippines	
Dome Collapse	GLADIS		
Storm	IDMC (disaster)	USA; Europe; Philippines	

Table 11: Disaster database overview by hazard		
Hazard	**Global**	**Country**
Ground Movement	EM-DAT; DesInventar	Switzerland; NZ
Subsidence	EM-DAT; DesInventar	Switzerland; NZ
Liquefaction	EM-DAT; DesInventar	Switzerland; NZ
Landslide	EM-DAT; DesInventar; IDMC	Switzerland; NZ
Volcanic Earthquake	EM-DAT; DesInventar; VolcFatalities*	
Debris Avalanche / Rockfall	EM-DAT; DesInventar; IDMC; VolcFatalities*	Austria; Switzerland
Landslide Dam / Dam break	EM-DAT	
Tsunami	EM-DAT; DesInventar; VolcFatalities*	Switzerland
Flood	EM-DAT; DesInventar; IDMC	Switzerland; NZ
Wind	EM-DAT; DesInventar	Switzerland; NZ
Rain	EM-DAT; DesInventar	NZ
Hail	EM-DAT; DesInventar	NZ
Storm Surge	EM-DAT; DesInventar	NZ
Lightning	EM-DAT; DesInventar; VolcFatalities*	Switzerland; NZ
Lahar	DesInventar; VolcFatalities*	
Lava Flow	EM-DAT; DesInventar; VolcFatalities*	
Ash Fall	EM-DAT; DesInventar; VolcFatalities*	
Pyroclastic Flow	EM-DAT; DesInventar; VolcFatalities*	

*Brown et al. (2017) ESM1

References

ANSS ComCat: https://earthquake.usgs.gov/data/comcat/

Australian Landslide database: https://data.gov.au/dataset/ds-ga-c1f01610-e359-330f-e044-00144fdd4fa6/distribution/dist-ga-c1f01610-e359-330f-e044-00144fdd4fa6-0/details?q=landslide

AVI Flood catalog: http://wwwdb.gndci.cnr.it/php2/avi/catalogo_p_regione.php?lingua=it

AVI Landslides catalog: http://wwwdb.gndci.cnr.it/php2/avi/catalogo_f_regione.php?lingua=it

Badoux, A., Andres, N., Techel, F., & Hegg, C. (2016). Natural hazard fatalities in Switzerland from 1946 to 2015. *Natural Hazards and Earth System Sciences*, *16*(12), 2747-2768.

BAPA: http://geol00.geol.uniovi.es/BAPA/

BNPB Geoportal Kebencanaan Indonesia: https://gis.bnpb.go.id/

Brown, S. K., Jenkins, S. F., Sparks, R. S. J., Odbert, H., & Auker, M. R. (2017). Volcanic fatalities database: analysis of volcanic threat with distance and victim classification. *Journal of Applied Volcanology*, *6*(1), 1-20.

Colorado Flood Database: https://www.usgs.gov/centers/co-water/science/flood-database-colorado?qt-science_center_objects=0#qt-science_center_objects

CPT15_v2.0: https://emidius.mi.ingv.it/CPTI15-DBMI15_v2.0/download_CPTI15.htm

Davies, T., Mead, S., Bebbington, M., Dunant, A., Grimson, D., Harmsworth, G., Harte, D., Harvey, E., Paulik, R., McDonald, G., Smith, N., & Whitehead, M. (2020a). Multi-Hazard Risk Model, Flooding Case Study: Selection of River System and Potential Hazard Cascades. Technical Report 2020/1. MEResearch, Takapuna.

Davies, T., Mead, S., Bebbington, M., Dunant, A., Whitehead, M., Harte, D., Crawford-Flett, K., & Hicks, M. (2020b). Multi-Hazard Risk Model, Flooding Case Study: Initial quantification of critical triggers and cascades for occurrence of major flooding. Technical Report 2020/11. MEResearch, Takapuna.

DesInventar: https://www.desinventar.net/what_is.html

EM-DAT: https://public.emdat.be/

Europe Severe Weather Database: https://www.essl.org/cms/european-severe-weather-database/

FloodArchive: https://floodobservatory.colorado.edu/

GeoNet Felt reports: https://api.geonet.org.nz/#intensity

GeoNet Quake search: https://quakesearch.geonet.org.nz/

GeoNet Tsunamis: https://www.geonet.org.nz/tsunami/story

Gill, J. C., & Malamud, B. D. (2014). Reviewing and visualizing the interactions of natural hazards. *Reviews of Geophysics*, *52*(4), 680-722.

Global Flood Monitor: https://www.globalfloodmonitor.org/about

Global Landslide Catalog: https://catalog.data.gov/dataset/global-landslide-catalog-export

GNS Landslide database: http://data.gns.cri.nz/landslides/index.html

Guha-Sapir, D., Below, R., & Hoyois, P. (2016). EM-DAT: the CRED/OFDA international disaster database.

Guzzetti, F., Cardinali, M., & Reichenbach, P. (1994) The AVI Project: A bibliographical and archive inventory of landslides and floods in Italy. *Environmental management*, *18*(4), 623-633.

Global Volcanism Program: https://volcano.si.edu/

Heiser, M., Hübl, J., & Scheidl, C. (2019). Completeness analyses of the Austrian torrential event catalog. *Landslides*, *16*(11), 2115-2126.

Hong Kong Climate database: https://www.hko.gov.hk/en/cis/climat.htm

Hong Kong Notable Landslides: https://hkss.cedd.gov.hk/hkss/eng/land_investigation_04.aspx

ICNZ: https://www.icnz.org.nz/natural-disasters/cost-of-natural-disasters/

IDMC: https://www.internal-displacement.org/database/displacement-data

INGEOMINAS: https://datos.sgc.gov.co/datasets/312c8792ddb24954a9d2711bd89d1afe_0

IRIS: https://www.iris.edu/ieb

Joint Typhoon Weather Centre: https://www.metoc.navy.mil/jtwc/jtwc.html?western-pacific

Jones, E.S., Mirus, B.B, Schmitt, R.G., … & Stanley, T.A., (2019) Summary Metadata – Landslide Inventories across the United States: U.S. Geological Survey data release

Kappes, M. S., Keiler, M., von Elverfeldt, K., & Glade, T. (2012). Challenges of analyzing multi-hazard risk: a review. *Natural hazards*, *64*(2), 1925-1958.

Kluger, M. O., Jorat, M. E., Moon, V. G., … & Lowe, D. J. (2020). Rainfall threshold for initiating effective stress decrease and failure in weathered tephra slopes. *Landslides*, *17*(2), 267-281.

Lau, A. Y. A., Switzer, A. D., Dominey-Howes, D., Aitchison, J. C., & Zong, Y. (2010). Written records of historical tsunamis in the northeastern South China Sea–challenges associated with developing a new integrated database. *Natural Hazards and Earth System Sciences*, *10*(9), 1793-1806.

Murillo-García, F. G., & Alcántara-Ayala, I. (2017). Landslide inventory, teziutlán municipality, puebla, méxico (1942–2015). *Journal of maps*, *13*(2), 767-776.

NatCat: https://www.munichre.com/en/solutions/for-industry-clients/natcatservice.html

NIWA historic weather: https://hwe.niwa.co.nz/

NOAA Cyclones: https://www.nhc.noaa.gov/pdf/nws-nhc-6.pdf

NOAA FLASH: https://inside.nssl.noaa.gov/flash/database/database-2016v1/

NOAA:NCEI Climate: https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.ncdc:C00505

NOAA:NCEI Tsunami: https://www.ngdc.noaa.gov/hazard/tsu_db.shtml

NOAA:NEIC PDE: https://www.ngdc.noaa.gov/hazel/view/hazards/earthquake/search

PAGASA: http://bagong.pagasa.dost.gov.ph/tropical-cyclone/tropical-cyclone-summary

PHIVOLCS Earthquakes: https://www.phivolcs.dost.gov.ph/index.php/earthquake/destructive-earthquake-of-the-philippines

PHIVOLCS Eruptions: https://vmepd.phivolcs.dost.gov.ph/volcan/erupt-history

SGC: http://sish.sgc.gov.co/visor/

SNN Earthquake catalog: http://www2.ssn.unam.mx:8080/catalogo/

UNISDR (2009) United Nations International Strategy for Disaster Reduction. *Terminology*. Geneva: UNISDR

WOVOdat: https://www.wovodat.org/

Appendix A – shell code for JMA download (Author: D.Harte)

```
#!/bin/sh

yr="2004"
suffix="a b c"

url="https://www.data.jma.go.jp/svd/eqev/data/bulletin/catalog/table3/"

#   "1" means download, "0" do not
download="1"

#  place data files into subdirectory "Data"
cd Data



#---------------------------

allmths="01 02 03 04 05 06 07 08 09 10 11 12"

echo -n > ${yr}.txt

for mth in $allmths; do

   #---------------------------
   #   Download Data from JMA

   if [ "$download" = "1" ]; then
      fname="${url}d${yr}${mth}t.zip"
      echo "$fname"
      wget "$fname"
   fi

   #---------------------------
   #   Reformat Data
```

```
unzip d${yr}${mth}t.zip

echo -n > d${yr}${mth}t.txt
for sf in $suffix; do
   cat "d$yr$mth$sf.txt" >> d${yr}${mth}t.txt
   rm "d$yr$mth$sf.txt"
done

#   replace preceding zero with blank
bmth=`echo "$mth" | sed -r "s/^0/ /g"`

grep -A 1 "${yr}Y ${bmth}M" d${yr}${mth}t.txt > tmp.txt

#   remove separator line
grep -v "\-\-" tmp.txt > d${yr}${mth}t.txt

#   join pairs of lines (are 2 lines/event)
sed -z -e "s/\n             LAT=/ LAT=/g" \
   -i d${yr}${mth}t.txt

sed -E -i d${yr}${mth}t.txt              \
   -e "s/[A-Za-z0-9 ]{14}${yr}Y/${yr}Y/g" \
   -e "s/LAT=//g"                       \
   -e "s/LONG=//g"                       \
   -e "s/DEPTH=//g"                      \
   -e "s/\) MAXI=[A-Za-z0-9]/\)/g"       \
   -e "s/MAG1=-/-/g"                     \
   -e "s/MAG1=/ /g"                      \
   -e "s/MB=/ /g"                       \
   -e "s/MW=/ /g"                        \
   -e "s/R=//g"

#---------------------------
```

```
    #   Concatenate into One File

    cat "d${yr}${mth}t.txt" >> "${yr}.txt"
    rm "d${yr}${mth}t.txt" tmp.txt

done

cd ..
R CMD BATCH --no-save read.R
```