CATDAT

Integrated Historical Global Catastrophe Database

Damaging Volcanoes Database 2010 – The Year in Review

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Author's Note

I hope that you enjoy the first edition of the CATDAT Annual Review of Damaging Volcanoes. I have been collecting volcanic eruption, earthquake, flood and other natural disaster loss data for quite a few years, with a more concerted effort in the past 2 to 3 years to build up the databases further. This report on 2010 only shows a small percentage of the data collected.

The purpose of this report is to present the damaging volcanoes of the year 2010 around the world that were entered into the CATDAT Damaging Volcanoes Database in terms of their socio-economic effects. This 2010 report will also seek to introduce the CATDAT Damaging Volcanoes Database for those people who have not read or heard about it.

First of all a big thanks to my fiancée, Maren, for supporting me through the sporadic late nights (when volcanic eruptions have occurred), as well as with SMS updates, translations, constant volcano discussions and intellectual conversations. I would also like to thank my parents, Anne and Trevor, and also my sister, Katherine, for the numerous reports and papers I have sent them and they have checked and for the numerous updates as to potential natural disaster data.

A big thank you goes to the **General Sir John Monash Foundation** (supported by the Australian Government) who have been funding my PhD research at Karlsruhe at KIT/CEDIM and had allowed me to choose these from all worldwide institutions.

I would like to thank the **University of Adelaide, Australia**, Université Joseph Fourier, University of Pavia and **Karlsruhe Institute of Technology** for the background to undertake my study and to always promote learning outside the course environment.

Thank you also to the **Center of Disaster Management and Risk Reduction Technology (CEDIM)** for supporting me in my research in the natural disaster field. In addition, I would like to thank Friedemann Wenzel, Bijan Khazai, Armand Vervaeck, Kevin McCue, Ellen Gottschämmer and Tina Kunz-Plapp for their interest, support and motivating me to publish my work.

I have also been aided by a number of interested individuals for components of the database but with the amount of data around on historical damaging volcanoes, I am always interested in new reports, studies, questions, comments, improvements and collaboration.

I would also like to urge people's involvement with some great worldwide volcano and natural disaster risk related initiatives out there – just to mention a few; **earthquake-report.com**, **SOS Earthquakes**, Volcanoes at the Smithsonian Institute, Volcanism Blog, USGS and of course, **CATDAT.**

Many thanks,

James Daniell.

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1 Introduction

2010 will be etched in many people's memories as the "year of the earthquake" – however, in terms of economic losses, it should be called the "year of the volcano" too.

The number of affected people this year through the Eyjafjalla disruptions to air travel was one of the highest on record (exceptions of Laki 1783, Tambora 1815) and it was definitely the largest number of people affected by a VEI (Volcanic Explosivity Index) 4.

The Icelandic volcano (over USD5 billion economic loss distributed across the globe) caused about the same losses as that of the Sojaerdo mud volcano (if mud volcanoes are to be included) and thus are the highest since 1900.

In addition, the Merapi volcanic eruption in October and November 2010, caused just under USD1 billion in damages. The total losses for the year come in somewhere between $3.12 billion US and $6.81 billion US.

In the following discussions, the 2010 damaging volcanoes will be first listed and then compared with some of the historic losses.

2010 Damaging Volcanoes in Numbers	
Number of Eruptive Volcanoes worldwide:	64+
Number of Effect-bearing Volcanic Incidents:	36+ (at least 6 fatal)
Country with the most CATDAT Damaging Volcanic Incidents:	Russian Federation (5)
Total Countries Affected:	16+
Total Fatalities:	Between 362 and 400
Total Injuries:	±500
Total Homeless:	±11550
Total Evacuated:	±386697
Total Economic Losses:	$3.12 billion - $6.81 billion US (Median = $6.21 billion US)
Total Insured Losses:	±$103 million US

Please note that for the purposes of this report due to different meanings of billion and million worldwide:
1 billion = 1,000,000,000 or 10^9 1 million = 1,000,000 or 10^6

2 What is CATDAT?

CATDAT originated as a series of databases that have been collected by the author from many sources over the years (2003 onwards). It includes global data on floods, volcanoes and earthquakes (and associated effects). This report will focus on the damaging volcanoes in 2010, and a comparison as provided by the Damaging Volcanoes Database part of CATDAT. These databases have been presented at numerous conferences and in the form of papers and reports.

As of December 2010 in CATDAT Damaging Volcanoes Database v2.77, over 2000 sources of information have been utilised to present data from over 1650 damaging volcanic incidents and eruptions historically, with approximately 950 volcanic eruptions and incidents since 1900 examined and validated before insertion into the CATDAT Damaging Volcanoes database.

2.1 The development of the Damaging Volcanoes Database

The first step was a list of socio-economic details for various volcanoes that the author had collected online (OCHA ReliefWeb archives, NGOs, insurance companies), from news reports (global and historical), from volcano-related books (Earthshock, Encyclopaedias etc.), from papers (BSSA 1911-2005, Bulletin Volcanologique) and not to mention least the work of R. Blong (1984) and also Siebert and Simkin (1994 etc.) over a number of years collating statistics of volcano losses, due to the author's interest in natural disaster effects.

It was then realised that a detailed review and comparison was needed with other existing global databases. A review of existing global volcano socio-economic effect databases was undertaken to see the completeness of these volcano databases, as well as to source all the known lists of volcano data worldwide. During this process, a report by Tschoegl et al. (2006) was very useful detailing information about existing Natural Disaster databases globally. This process was also used for volcanoes. It contains information on 6 international databases (EM-DAT, MunichRe NatCat, SwissRe Sigma, ADRC: GLIDE, University of Richmond: Disaster Database Project and BASICS) and a number of regional, national and sub-national databases. In addition, a comparison of 3 of these – EM-DAT, MunichRe, Sigma – revealed that there were major gaps in these databases (Guha-Sapir et al. 2002).

Also reviewed were many other global volcano catalogues that have been created around the world, including the Tanguy et al. catalogue (1998), the Witham volcano database (2005), Blong (1984), NGDC/NOAA (2008 searchable version), Simkin and Siebert (1994 etc.), EM-DAT and MRNATHAN. However, it was found that some of these volcano databases lacked consistency and omitted or had erroneous volcano details. There were even many mythical volcanoes and untrue assumptions.

Thus, it was decided to expand the global CATDAT damaging volcanoes database to validate, remove discrepancies and expand greatly upon the existing global databases; and to better understand the trends in vulnerability, exposure and possible future impacts of such historical volcanoes.

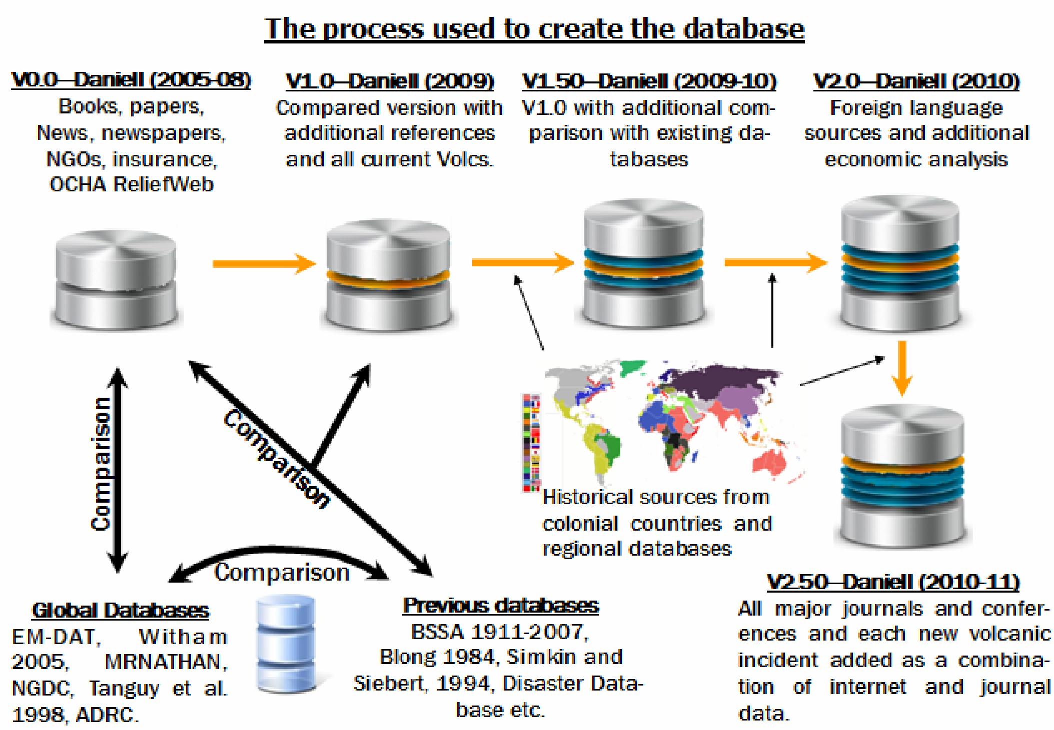

Figure 1 - The process used to create the CATDAT Damaging Volcanoes Database

2 examples in EM-DAT which show the need for such a new database, (as also commented by other authors) shows a repeated volcanic eruption in 1930 and 1931 of Merapi, one causing 1300 deaths, the other causing 1369 deaths. In fact, this is simply double-counting, and only one death toll of 1300 deaths actually occurred. These type of problems with EM-DAT for social losses (including 9 double-counting errors etc.) are detailed up to 2004, in Witham (2005). The second, is the value of USD211 million as the event year loss due to the Pinatubo eruption. This, like many of the other economic estimates in EM-DAT is a gross underestimation of the approx. USD711.4 million that actually occurred. These inconsistencies are detailed in Daniell and Gottschämmer (2011) along with comparison with other databases.

This expert validation procedure has been undertaken for each volcano and hence a range of social and economic losses is gained. It was also seen that regional and country based databases and reports need to be used, as only using English-speaking references reduces the volume and accuracy of the volcanic record collection. Searches were made in both the language of colonisation as well as the official current languages of the respective countries. In this way, many old records were sourced. This is further defined in Daniell and Gottschämmer (2011).

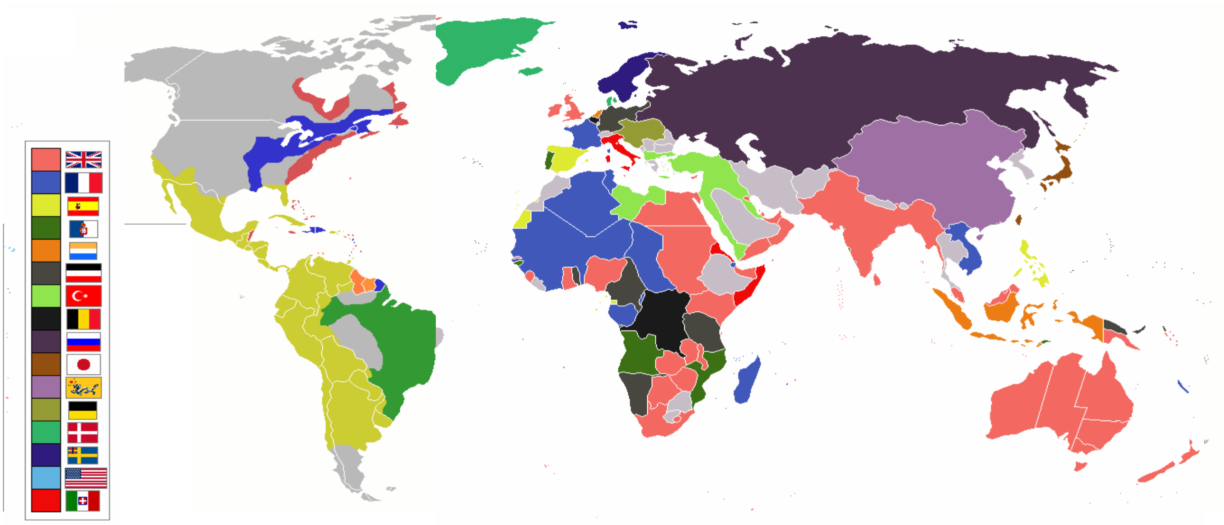

Figure 2 – The colonisation of countries used to determine languages required for searching for historic volcanic eruptions records (adapted from Wikipedia Commons 2010)

2.2 What is contained in the database?

Each validated volcano includes the following parameters filled in to the best available detail:-

- Start Date (Day, Month, Year), End Date (Day, Month, Year).
- Volcanological Information (Volcano Location ; Name ; Latitude; Longitude; Elevation (m)); Type of Volcano (Strato, Submarine, Shield, Caldera, Pyroclastic Shield, Mud etc.) ; Volcanic Explosivity Index (0-8).
- ISO3166-2 Country code, including Kosovo; ISO Country Name; Region Location.
- Additional Agents (Lava Flows, Volcanic Unrest or hazard via precursors, Pyroclastic density currents including direct blasts, Tephra including ballistics and explosions – suffocation or tephra loading, Mudflows – primary lahars, Secondary lahars/flooding which are non-eruptive, Jökulhlaups, Seismicity associated with volcanic activity, leading to building collapse, Tsunami waves from volcanogenic source, Gas/acid rain, Epidemic, Indirect, Famine Indirect, Lightning, other related sources.
- Tsunamigenic or Associated Earthquakes.
- Human Development Index of country; HDI Classification; Economic Classification; Social Classification; Urbanity Index; Population at time of event; Nominal GDP at time of event – split into developed or developing countries.
- CATDAT Preferred (Best Estimate) Deaths; Secondary Effect Deaths (As shown above in additional agents); CATDAT Upper and Lower Bound Death Estimates; Global Literature Source Upper and Lower Bound Death Estimates; Severe Injuries; Slight Injuries; CATDAT Upper and Lower Bound Injury Estimates; Global Source Upper and Lower (U/L) Bound Injury Estimates; Homeless (and U/L Bound); Affected (and U/L Bound), Total Affected; Missing.
- Buildings destroyed; Buildings damaged; Buildings damaged – L4, L3, L2, L1; Infrastructure Damaged; Critical and Large Loss Facilities; Lifelines damaged.
- Secondary additional agents that occurred, % of the social losses that were caused by each secondary effect; % of economic losses that were caused by each secondary effect.
- Disease and additional long-term problems.
- Full word description of various sources contributing to the data, including associated references.
- Country-based CPI at time of disaster; Country-based Wage Index at time of disaster; Country-based GDP Index; USA CPI for comparison; Hybrid Natural Disaster Economic Conversion Index.

- CATDAT Preferred (Best Estimate) Total Economic Loss; CATDAT U/L Bound of Economic Loss; Global Source U/L Bound of Economic Loss; Additional Economic Loss estimates from varying sources; CATDAT Economic Loss 2010 HNDECI-Adjusted; CATDAT Economic Loss 2010-country based CPI adjusted.
- Insured Loss; Insured Loss In 2010 dollars; Insured estimate source; Estimated Insurance Takeout (or approx. takeout) at time of event.
- Indirect and Intangible economic losses.
- Estimated life cost given social values, working wages etc. at the time.
- Total Economic Loss as a percentage of country's GDP; Social losses trended by population.
- CATDAT Volcanoes ranked via the Munich NatCat Service methodology, EM-DAT cutoff, SwissRe methodology.
- CATDAT Volcanoes ranked for the CATDAT Economic Disaster Ranking and CATDAT Social Disaster Ranking based on relative values and not absolute values. This will be explained further below.
- Link to ReliefWeb archive where available.
- Aid contribution; Aid delivered; Aid Source.
- Split country impacts (social and economic) where volcano has affected more than 1 country.
- Various ratios between components for trends analysis.
- Normalisation strategies for current conditions. (Daniell et al. 2010b)
- Links to EQLIPSE, the author's global building inventory (part of his PhD).

This is contained in a Microsoft Excel framework with external links to other resources. It is also in SQL format.

2.3 Entry criteria

A damaging volcano is entered into the CATDAT database by the following criteria:-

- Any volcano causing collapse of structural components.
- Any volcanic incident causing death, injury, homelessness or evacuation to a decent level.
- Any volcano causing damage or flow-on effects exceeding $10,000 international dollars, Hybrid Natural Disaster Economic Conversion Index adjusted to 2010.
- Any volcano causing disruption to a reasonable economic or social impact as deemed appropriate, including major air travel.
- A requirement of validation of the volcanic incident existence via 2 or more systems and/or direct information recorded by stations and at least 1 of the 4 definitions above.
- Validation via external sources if Corruption Index < 2.7, subject to Polity ranking.
- If part of an eruptive sequence, only 1 entry will occur.

3 Damaging Volcanic Incidents from 2010 in the CATDAT Damaging Volcanoes Database

3.1 Where have the damaging volcanoes occurred?

There have been at least 34 damaging volcanic incidents in 2010 (under the new criteria set this year). These have occurred in the following countries, as shown in the diagram below. There have been 5 volcanic incidents in the Russian Federation that are classified under the new CATDAT criteria and 4 damaging volcanic incidents in Indonesia and Ecuador.

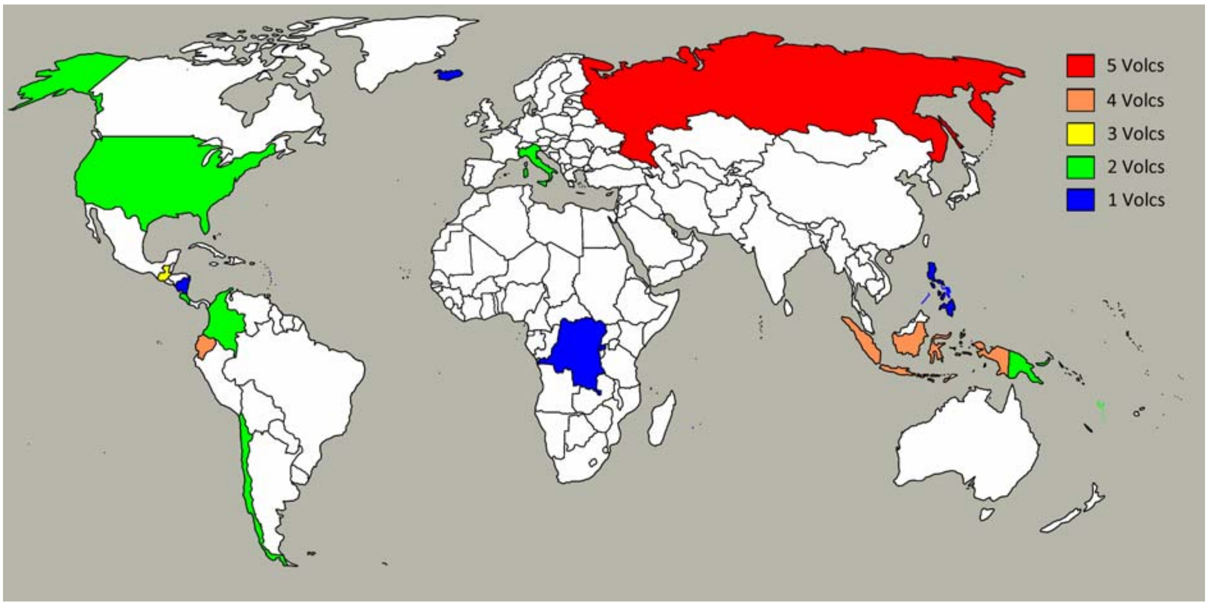

Figure 3 – The number of damaging volcanoes in various countries during 2010

3.2 Casualty-bearing 2010 volcanoes

There have been at least 6 fatal volcanic incidents in 2010. The most fatalities from a volcanic incident in 2010 was that of Merapi in Indonesia which claimed somewhere between 353 and 386 deaths from the series of eruptions in October and November. The proportion of these deaths were due to burns as a result of debris avalanches and hot air clouds. Approximately 17000 people complained of repiratory problems.

In addition, mudslides (lahars) as a result of eruptions on Karangetang in Indonesia, caused 4 deaths. The first Holocene eruption of the volcano named Sinabung, caused 2 deaths, one heart attack, and one respiratory death. Pacaya in Guatemala also caused 2 deaths and 3 missing children through the eruption and associated mudslide effects through Hurricane Agatha. Eyjafjalla had 2 indirect deaths, with 2 tourists being killed via exposure while driving back from the eruptions.

Bulusan volcano had one death associated due respiratory problems with a 28 year old man. There are also reports of possible deaths in DPR Congo.

Table 1 – List of casualty-bearing volcanic incidents in 2010

Volcano Name	Cnt. ISO	Date	Best Estimate of Fatalities	Range of Fatalities	Injuries (Heavy or Slight)	Pref. Source
Merapi	IDN	26.10.2010	386	(353-386)	(H=427, Out=17000+)	Indonesian Govt.
Pacaya	GTM	27.05.2010	5	(1-5)	65 (Out= diff. Hurricane)	GT News

Karangetang	IDN	06.08.2010	4	(4-4)	5	Indonesian News
Sinabung	IDN	30.08.2010	2	(1-2)	31 (Out=2807+)	ReliefWeb
Eyjafjallajökull	ISL	14.04.2010	2	? indirect		News
Bulusan	PHL	10.11.2010	1	(1-1)	9	ReliefWeb
Nyamuragira	ZAR	04.01.2010	?		Increase in eye diseases, diahorrea etc.	ReliefWeb, News
Turrialba	CRI	06.01.2010	0	(0-0)	2 hospitalised	ReliefWeb
Tungurahua	ECU	28.05.2010	0	(0-0)	1	ReliefWeb
Total		**No. EQ**	**400+**	**(362-400)**	**At least 500**	

3.3 2010 volcanoes with homeless, evacuated and affected people

The volcano with the most homeless people in 2010 was caused by Merapi with at least 11,000. In terms of evacuated people this was also the most with around 350,000 evacuated to shelters for about a month or so before the alert level was reduced. UN OCHA provides good accounts of this series of volcanic eruptions.

In terms of affected people however, the air travel disruptions over Europe due to ash from Eyjafjalla, the greatest for 2010 was over 7,000,000.

Sinabung volcano in Indonesia reactivated after a long pause without any activity. This forced people living near the volcano into camps for about a month. A full report is available from IFRC operation no. MDRID005 Situation Report No. 3, detailing the exact activities. At the peak 28756 people were in evacuation centers, with about 20000 remaining evacuated for 3 weeks, tailing off after the 18 September 2010.

Mt. Bromo or the Tengger Caldera, has caused many problems since 23 November 2010, with eruptions causing major losses in the tourism trade, but also affecting around 68000 local residents with breathing problems and light ash falls. 50 homeless have been recorded as a result of ash covered houses subject to tephra roof collapse.

Mt. Nyamuragira in the DPR Congo, near the city of Goma, has caused problems with increases in diahorrea and eye disease seen as a result of the eruptions in early January 2010, with suspected ash in the water open spring and rainwater supplies the culprit. People around the volcano also reported the death of domestic animals and damage to crops. Around 52,096 people are suspected to have been affected, including: 7,901 from Mugunga, 13,000 from Rusayo and 31,195 from Sake & Kingi localities.

Mt. Bulusan in Philippines also caused many problems with 14,161 people affected due to crop damage, breathing problems etc.

Table 2 – List of homeless, evacuated and affected-bearing volcanic eruption incidents in 2010

Volcano Name	Cnt. ISO	Date (2010)	Homeless Range	Evacuated Range	Affected Range	Pref. Source
Merapi - series	IDN	26.10	11500 (11000-15000)	350000 (137140-400000)	350000 (350000-500000)	ReliefWeb, News
Tungurahua	ECU	03.12	2464 (Govt.)	2500	2500	ReliefWeb
Bromo	IDN	23.11	50 (ash covered houses)	1000	68000 (68000-200000)	ReliefWeb
Sinabung	IDN	30.08		28756	34000 (15060-34000)	News, WHO
Bulusan	PHL	10.11		1671	14161	PHL Govt.
Pacaya 1	GTM	27.05		1700	1700	GTM Govt.

Manam	PHL	01.01		1000	1000	PHL News
Galeras 1	COL	03.01		900	8000	COL Govt
Eyjafjalla	ISL	14.04		845 (500-1000)	7000000 (5000000-7500000)	News
Galeras 2	COL	25.08		813	8000	COL Govt
Tungurahua	ECU	28.05		500	2500 (1800-2500)	ECU News
Pacaya 2	GTM	09.07		150	150	GTM News
Karangetang	IDN	06.08		65	65	IDN News
Turrialba	CRI	06.01		37	37 (37-60)	CRI Govt.
Sarigan	USA	29.05		16	16	Marianas News
Nyamuragira	ZAR	04.01			52096	Aid Govt.
Kliuchevskoi	RUS	23.10			5000	KVERT
Yasur	VUT	31.05			3567	VU Aid
Chaiten	CHL	01.01-31.05			Red alert in place (full evacuation)	ONEMI

3.4 2010 volcanoes which affected air travel

Eyjafjalla caused an even bigger disruption to air travel than that of the September 11 bombings. Over 105000 flights were cancelled with around 5,000,000 to 7,000,000 people affected, in many different countries around the world.

The Merapi volcanic eruption sequence also caused the closure of the Yogyakarta airport for 2 weeks. In addition, some flights were cancelled, but most transferred to Semarang airport. Soufriere Hills, Tungurahua and Pacaya also caused major discruptions to air travel.

Table 3 – List of Air travel disruptions from volcanic incidents in 2010

Volcano Name	Cnt. ISO	Date (2010)	Affected Flights/Airports	Affected Passengers	Length	Pref. Source
Eyjafjalla	ISL	14.04	105000	5000000-7500000	Multi-country – Main - 14.04-21.04, Total - 21.03-24.05	Worldwide
Merapi - series	IDN	26.10	Yogyakarta (Adisucipto International)		3 weeks (30.10-20.11) – also minor at Jakarta, Bandung etc.	ID News, ReliefWeb
Sinabung	IDN	30.08	Medan Airport		30.08	Indonesian News
Santiaguito	PHL	27.04	Airspace closed for 20km			GT News
Pacaya 1	GTM	27.05	La Aurora International Airport		20 hours	ReliefWeb, GT News
Soufriere Hills	MSR	01.02	Flights between Dominica, Guadeloupe, Antigua, Barbuda, Barbados, Martinique, St Kitts and Nevis and St Maarten.		11-13 February	Caribbean News Sources
Tungurahua	ECU	28.05	Guayaquil Airport		>1 day	EC News
Pacaya 2	GTM	09.07	La Aurora		minor	GT News
Etna	ITA	13.01	Catania airport		Overnight closure	ITA News
Bromo	IDN	23.11	Juanda Airport, local airports, Abdurahman Saleh Airport		29 Nov-4 Dec (initial)	ID News
Yasur	VUT	31.05	New Caledonia domestic airlines cancelled flights to Mare and Lifou.		minor	VU News, NZ News
Bezymianny	RUS	01.06	Flight diversions		RED Alert	KVERT
Gorely	RUS	12.06	Regional Air traffic		RED Alert	KVERT
Kliuchevskoi	RUS	23.10-29.10	Flight diversions		RED Alert	KVERT
Shiveluch	RUS	28.10	Flight diversions		RED Alert	KVERT

3.5 Economic Losses from volcanoes in 2010

Economic losses from volcanoes in 2010 have been between $3.12 billion and $8.10 billion US, with the proportion of these coming from the Eyjafjalla eruption and Merapi eruption. The median value has been **$6.20 billion US.**

These two volcanic eruptions had significant economic losses of over $1 billion USD. Total loss refers to indirect and direct loss combined. For the Eyjafjalla volcanic eruption, as of May 24, 2010, global aviation sector losses were between USD2.6-2.8 billion, global loss in visitor spending at destinations between USD1.6-1.75 billion and productivity losses from stranded workers between USD490 and 550 million as part of an Oxford Economics Study. This increased slightly up to the end of the air travel disruptions. This therefore had a global GDP impact of around USD5.05 billion.

Table 4 – List of economic losses for volcanoes in 2010 with over $5 million USD or other notable losses

Volcano	Country	Date UTC	Total Loss Range (USD)	Pref. Source
Eyjafjalla	Iceland	14.04.2010	$5050m ($1990m-$5050m) Total	Oxford, Ext.
Merapi	Indonesia	26.10.2010	$890m ($791m-$1479m) Total	Govt., Ext.
Tunguruhua	Ecuador	28.05.2010	$160.22m	EC Sources
Pacaya	Guatemala	27.05.2010	$68.385m (7.5% of total losses via Agatha)	Est.
Bromo	Indonesia	23.11.2010	$5.55m (in place)	ID News
Stromboli	Italy	30.06.2010	$5m	IT News
Sinabung	Indonesia	30.08.2010	$3.295m	ID News
Karangetang	Indonesia	06.08.2010	$0.682m	ID News
Bulusan	Philippines	10.11.2010	$0.282m	Govt., Aid Resp.

Merapi in Indonesia caused a major amount of damage in the form of forest industry (destruction of trees), and also crop losses, infrastructure and housing. Estimates range from IDR7.1 trillion (USD791 million) to IDR13.3 trillion (USD1479 million).

In terms of the Pacaya volcanic eruption in Guatemala, this was followed by Hurricane Agatha, causing mudslides and other effects across proportions of Guatemala.

PhP12.264 million (USD0.282 million) in total damages to crops in the Irosin and Juban areas. Banana, fruit trees and vegetables were on 80 hectares destroyed. 24ha of these have no chance of recovery. This value does not account for lost wages, changes in tourism trends etc. Approximately PhP2 million was spent on combined food and health for the evacuated people.

3.6 Insured Losses from volcanoes in 2010

The table below shows the insured loss ranges for each damaging volcano with insurance loss in 2010.

Table 5 – List of insured losses in volcanoes in 2010 over $1m

Volcano	Country	Date	Insured Loss Range	Pref. Source
Eyjafjalla	Iceland	14.04.2010	>USD 2.3 million + USD95.3 million	Est., ISK Ins.
Merapi	Indonesia	26.10.2010	Minor < USD5 million	Est.

The losses from the Eyjafjalla eruption were mainly not covered by insurance in terms of the losses to airlines as there were generally no clauses for insurance cover if there was no damage to the aircraft for business interruption. In terms of direct insured losses to buildings as a result of Eyjafjalla were around ISK255 million (or USD2.3 million) with around ISK200 million for metal roof cladding, ISK14 million for walls, ISK13 million for window pane damage, ISK10 million for floor finishing and ISK18 million for contents.

Apart from that, I can find no estimates of travel insurance losses etc. The only quote is from the Association of British Insurers stating that insured losses were expected to top GBP62 million (USD95.3 million), mainly due to minor delay payouts etc.

4 How does 2010 compare to the past 110 years of losses?

4.1 Damaging Volcanoes – 1900 to 2010

It must be noted that the criteria was changed as of 2010, thus a trend of damaging volcanoes will be included next year with reanalysis of the historic volcanic eruptions recorded, that did not classify under CATDAT criteria previously, but now under the new criteria, do.

The author has developed the first complete Human Development Index for all 244 nations through time from 1900 to 2010 (Daniell, 2010c) as part of his work in his PhD. This meant the creation of life expectancy, GDP (PPP) per capita, literacy rate and enrolment rate tables for each country through time, in order to create this index. It also required the knowledge of wars, history of countries, and country border changes. Thus, with CATDAT, for the first time, a standardised look at natural disaster losses as a function of country status can be gleaned. It can be seen that a proportion of the earth is still developing, and that a large proportion of high seismic risk countries have an HDI which is still less than 0.8, as of 2010 (in the old HDI scale). Please note, that as of November 2010, a new method of calculating HDI has been formulated which will be incorporated into the 2011 version of the report when the author has formulated the indices for 1900-2010 (UNDP, 2010).

As can be observed in Figure 4 below, the number of fatal volcanoes is not outstanding.

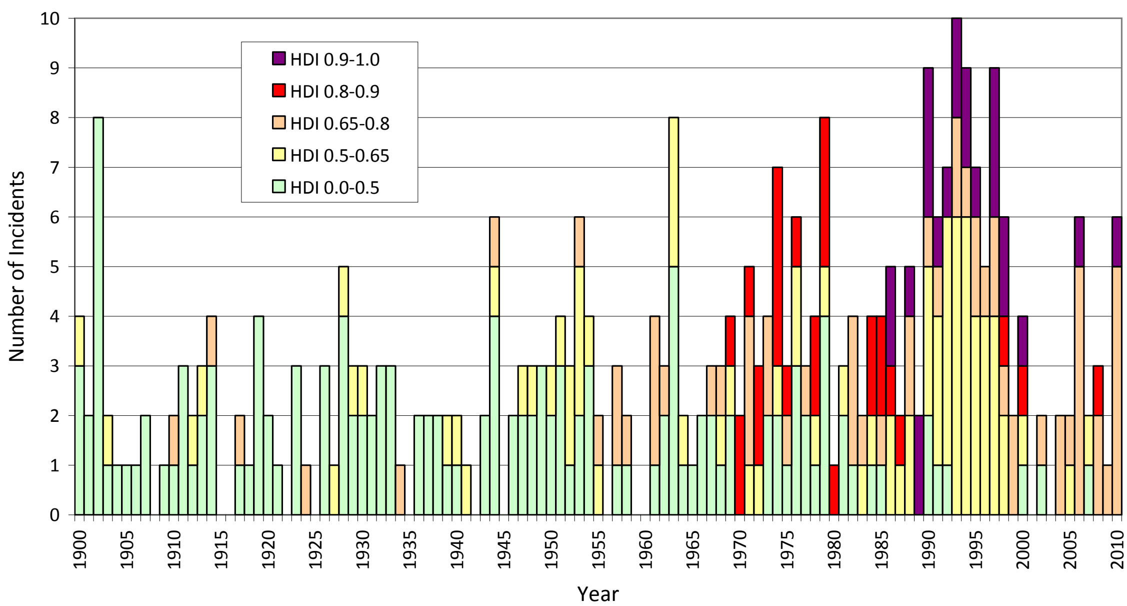

Figure 4 – Fatal Volcanoes in the CATDAT damaging volcanoes database from 1900-2010.

4.2 Social Losses from Volcanoes – 1900 to 2010

The number of deaths in all countries since 1900 has been found to be 97388 people (82501-107257 people). There have been approximately 28000 major injuries recorded; yet the trended value of injured (accounting for where injury data is unavailable) is towards 45000 (indicating about 0.5

injuries per death from volcanoes). There have been over 322 fatal volcanic incidents since 1900, and a great number more have caused homelessness or affected the lives of the populations that inhabit these volcanoes and also elsewhere.

The top 10 fatal volcanoes since 1900 will now be presented in order to lessen some of the discrepancies shown in other major databases like EM-DAT, MRNATHAN, NGDC etc. For more information, see Daniell and Gottschämmer, 2011. Common errors are around the 1902 sequence of volcanoes and the doubling up of the Merapi 1930 volcanic eruption.

Table 6 – The top 10 highest ranked volcano losses since 1900 in terms of median fatalities– CATDAT Volcanoes v2.77, Daniell, 2005-2011.

Rank	Volcano	Main Country	Date	Median Fatalities	CATDAT Lower/Upper
1	Pelee	Martinique	08.05.1902	29000	28000-33000
2	Nevado del Ruiz	Colombia	13.11.1985	24442	23080-24442
3	Santa Maria	Guatemala	24.10.1902	11000	6000-13000
4	Kelut	Indonesia	19.05.1919	5115	5110-5160
5	Lamington	Papua New Guinea	15.01.1951	2942	2942-3000
6	El Chichon	Mexico	28.03.1982	2000	1879-3500
7	Oku Volc. Field	Cameroon	21.08.1986	1746	1700-1746
8	Soufriere St. Vincent	St. Vincent & the Grenadines	07.05.1902	1680	1565-1680
9	San Cristobal	Nicaragua	30.10.1998	1560	1560-1680
=10	Merapi	Indonesia	25.11.1930	1369	1300-1400
=10	Taal	Philippines	27.01.1911	1335	1335-1335

*subject to further confirmation from a non-government source due to Corruption Perceptions Index value.

The full extent of the Laki 1783, Iceland event, and also the Tambora 1815, Indonesia event has been presented in Daniell and Gottschämmer (2011), however, excluding the induced global effects of these volcanoes, since 1700, the value of **290538 deaths** has been recorded. When compared to the global population, it can be observed that the fatality rate as a % of population is decreasing, considering the greatly increased population. Many trends referring to death counts etc. are shown in Daniell and Gottschämmer (2011). The exact number of deaths can never be exactly quantified post-disaster, due to quick burials, quick decomposition, indistinguishable deaths, inaccurate counting and other reasons; however, with careful analysis of all sources detailing effects relating to a volcano, an educated judgement can be made as to a range of fatalities. The CATDAT upper and lower bounds show the most feasible range. This has been similarly undertaken for estimates of injured, homeless, affected, building damage, economic losses and other socio-economic consequences of volcanoes for each volcano through time. The global upper and lower bound refer to the upper and lower bounds found in literature (deleting obvious errors). This is not the range condoned by CATDAT.

It can be seen in the following Figure 5 that there is a very low value of deaths from 1900 onwards in developed countries when compared to developing countries. This is in part due to the increasing development of countries through the time period. In Figure 5, the annualised global fatalities are presented. The average deaths per year are approximately **885**. Trends as to affected, aid, homelessness and injuries are also included in the CATDAT Damaging Volcanoes database. It can be observed that there are virtually no deaths for volcanoes occurring in countries with HDI over 0.8.

This is due to two reasons:- 1) as these countries develop, more attention is paid to disaster management and volcanic monitoring, and 2) there are comparatively less fatal volcanic eruptions that have occurred since 1900 in these nations (as seen in Figure 4) due to development status of countries.

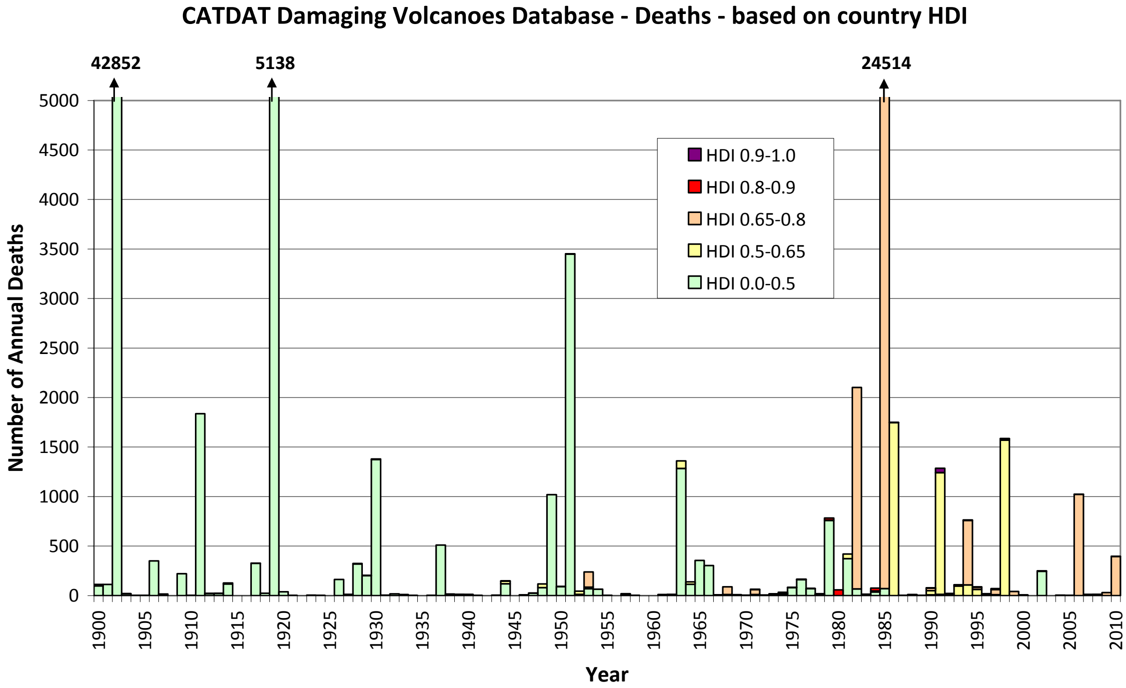

Figure 5 – CATDAT v2.77 Damaging Volcanoes – Best estimate of yearly deaths based on HDI from various volcanic events from 1900-2010 (Daniell and Gottschämmer, 2011)

Seen below in Figure 6 are the volcanic incident deaths as defined by subsequent causes of death from various volcanic related products.

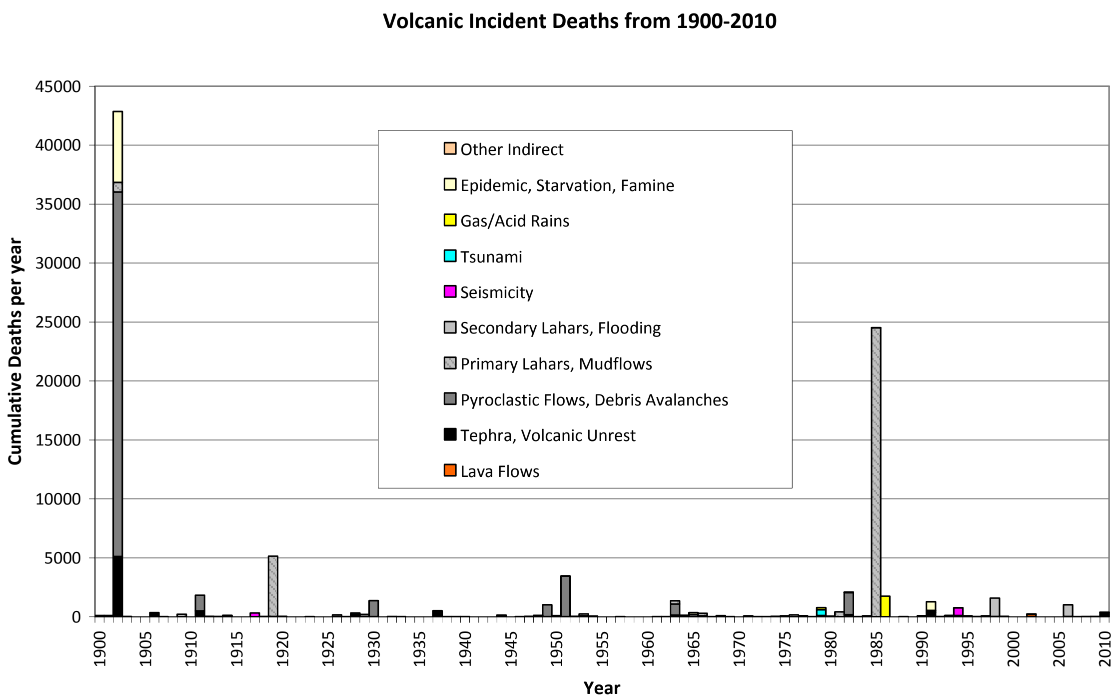

Figure 6 – CATDAT v2.77 Damaging Volcanoes – Best estimate of yearly deaths from various volcanic causes for events from 1900-2010 (Daniell and Gottschämmer, 2011)

4.3 Effect Losses from Volcanoes – 1900 to 2010

The secondary effects of 330 fatal volcanic incidents since 1900 were separated into loss types and are shown below in Figure 7.

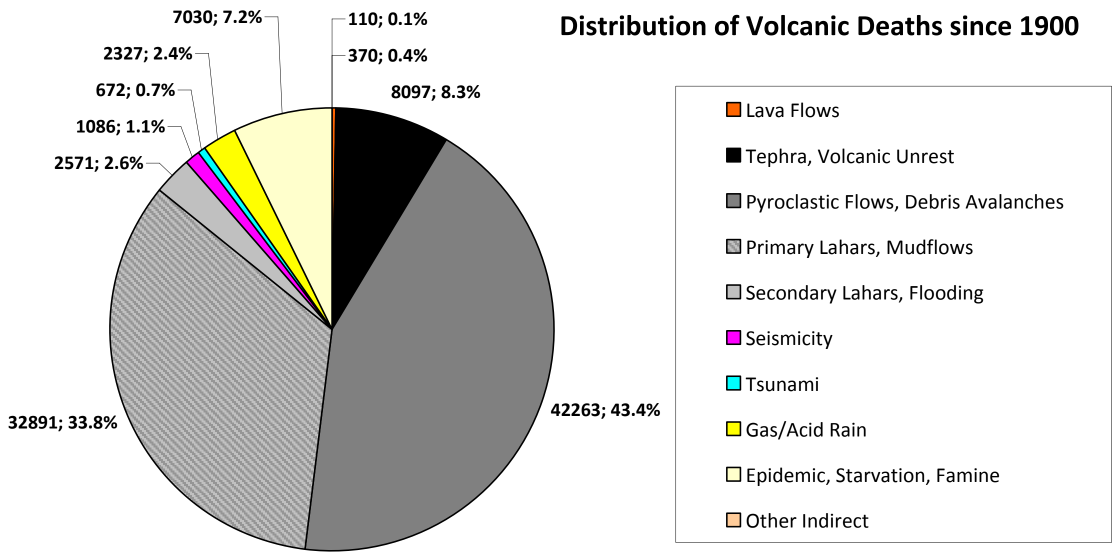

Figure 7 – Distribution of Volcanic Deaths since 1900 (Daniell and Gottschämmer, 2011)

4.4 Economic Losses from Volcanoes – 1900 to 2010

4.4.1 Total Economic Losses

As mentioned previously, a significantly increased database of economic losses from volcanoes has been created during this process. Much collection of building damage details and other infrastructure losses has occurred for the CATDAT entered volcanoes. In order to analyse and rank volcanoes due to economic criteria, an extensive global database of exchange rate, CPI and GDP (nominal and real) information was created in order to be able to adjust and compare foreign volcanic eruption loss estimates (Daniell, 2010f). This has also been used for volcanoes. Global databases of wage rate and other parameters such as purchasing power parity (PPP) were also created as part of the study from sources such as Maddison (2003), World Bank GEM (Global Economic Monitor) and Indicators (2010), and IMF (2010), as these details are required to effectively convert loss estimates from around the world into present-day costs (Daniell, 2008-2010b). Again, this has been used for other natural disasters.

For volcanoes in CATDAT where there is no estimate from a previously written source, separate analysis has been done to calculate an order of magnitude for the economic losses based on historical construction costs, wages as a proportion of building damage and then a reanalysis of losses. Using the economic status of a region, a reasonable estimate has been established. In some cases, the range description developed by NGDC was used. Every one of the 950 volcanoes in the CATDAT database from 1900 onwards has an economic loss range associated with it. This is used to fill in the gaps in volcanic economic loss knowledge worldwide, to account for previously unquantified volcanic eruptions.

In the **Hybrid Natural Disaster Economic Index (HNDECI)** developed as part of the CATDAT database to compare natural disasters (including earthquakes and volcanoes etc.), components of the volcano loss (direct and indirect) are assigned an inflation adjustment measure to bring it to present day value in much the same way as a project escalation index. In this way, the total volcano loss will be defined to present day value, eliminating the error of CPI adjustment. Through the descriptions of major volcano damage costs in CATDAT and through reconstruction costs it can be seen that **50%** of the cost of a volcanic natural disaster comes from reconstruction unskilled wages. For earthquakes, this was deemed to be 33%. It can be assumed from crop loss, that greater emphasis on wage indices occurs. Thus, the HNDECI is primarily based on unskilled wage and building material trends as well as relative utility trends, life costs and other inflation measurements to bring the value forward and needs to be calculated on a country-by-country basis. Refer to Daniell et al. (2010a) for more information as to the HNDECI.

Using the HNDECI for all worldwide volcanoes to adjust economic loss to 2010 dollars, Figure 8 should show the results of cumulative economic loss for each year. In this case, the 2010 Human Development Index is used to classify the country losses with developing countries (defined as a 2010 HDI<0.87 shown in orange) and developed countries (defined as a 2010 HDI>0.87 shown in blue). The black line shows the approximate trend of cumulative annual HNDECI economic loss. It can be seen that there have been approximately $42.63 billion (2010 HNDECI Dollars) loss worldwide since 1900, with a range from $31.03-$48.36 billion (2010 HNDECI Dollars). There is still some calibration occurring, as shown in Daniell and Gottschämmer (2011) for the smaller countries in terms of HNDECI.

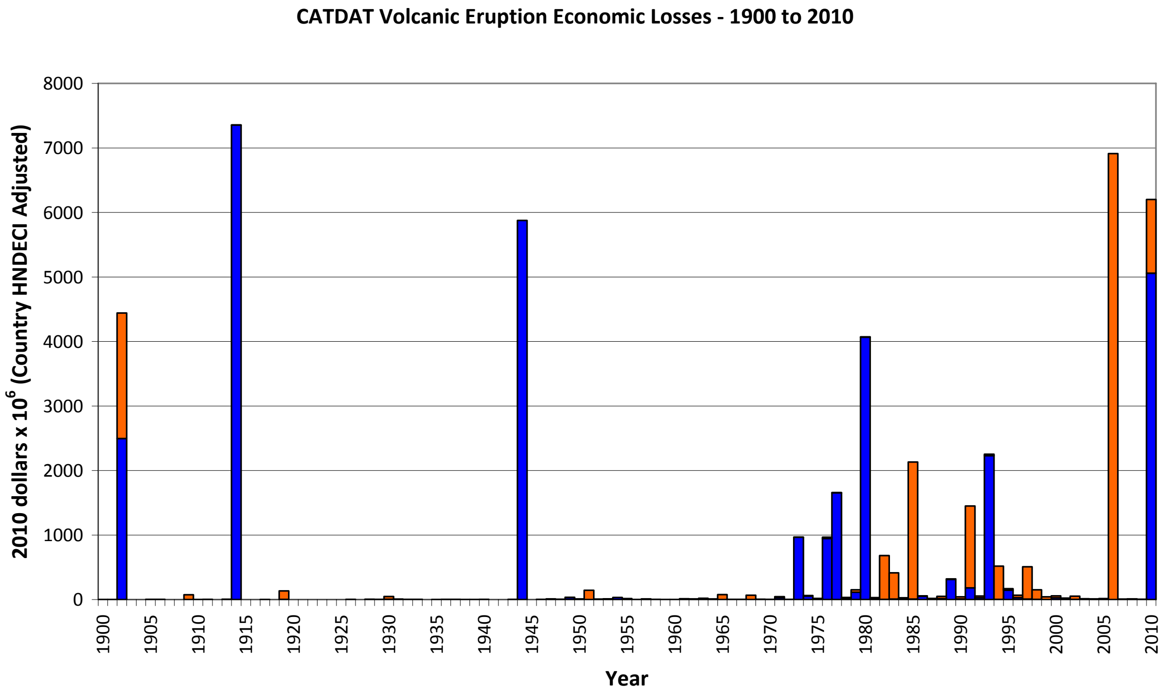

Figure 8 – CATDAT v2.77 Damaging Volcanoes – Economic Losses (2010 Hybrid Natural Disaster Economic Conversion Index adjusted) for 950+ volcanoes from the year 1900-2010 worldwide

The following is a list from CATDAT of the greatest economic losses as a function of GDP (Nominal, PPP) to compare the total economic loss at the time of disaster to the economy of the time. The median cost shown in Table 7, presented in US dollars, is the most accepted value of total economic loss at the time of the volcano as found from CATDAT through the literature. This is classified as the median cost of the event. In the full CATDAT database, there is a range of accepted loss estimates for each volcano that is not included in this report. This was generally presented in US dollar values in the literature (converted from local currency using time-of-event exchange rate). For more detail refer to Daniell et al. (2010a). The Montserrat volcanic eruption caused the evacuation of the capital Plymouth, before complete destruction of the southern half of the island. In the 1976 eruption of Guadeloupe, it was essentially the fact that the evacuation decision was taken for 3 months for life safety, thus impacting the economy of Guadeloupe greatly – but potentially saving many lives if a magmatic eruption had occurred. In terms of global GDP loss, the 1815 Tambora eruption, caused the greatest percentage GDP loss due to associated effects. This is detailed in Daniell and Gottschämmer (2011).

Table 7 – The top 10 highest ranked volcano losses since 1900 in terms of percentage of nominal GDP (purchasing power parity) – CATDAT v2.77, Daniell and Gottschämmer, 2011.

Rank	Volcano	Date	Median cost at time of event in $US	% of Nominal GDP (PPP)
1	Soufriere Hills, Montserrat	18.07.1995 25.06.1997	0.400 bn	300+
2	Pelee, Martinique	08.05.1902	0.020 bn	232.0
3	Soufriere, St. Vincent and the Grenadines	07.05.1902	0.001 bn	UK-Based
4	Soufriere Guadeloupe	30.08.1976	0.250 bn	31.5
5	Soufriere, St. Vincent and Grenadines	13.04.1979	0.0081 bn	23.1
6	Santa Maria, Guatemala	24.10.1902	0.015 bn	21.0
7	Vestmannæyjar (Helgafell), Iceland	27.01.1973	0.200 bn	20.0
8	Pelee, Martinique	30.08.1902	0.001 bn	11.9
9	Lamington, Papua New Guinea	15.01.1951	0.010 bn	4.0
10	Tavurvur, Papua New Guinea	19.09.1994	0.300 bn	3.9
	Nevado del Ruiz, Colombia	*13.11.1985*	*1.000 bn*	*1.05*

Other Assumptions

- 1902 Guatemala (up to 25 million USD, up to 35% GDP(PPP)); it is difficult to discern which losses are earthquake and which losses are volcano-related (Santa Maria).
- 1902 St. Vincent and Grenadines was under British rule, and thus, will not be calculated for PPP but should be included in the list.
- 1914 Sakura-jima eruption is also difficult to determine due to earthquakes.

4.4.2 Total Insured Losses

Within the full database, a significant amount of information on insurance losses is included. Shown below in Table 8 are the top 5 from 1900 to 2010. It can be seen that there was little impact despite the major losses from 2010 due to volcanic eruptions (i.e. less than 2% of the total losses of the year – and mostly from Eyjafjalla (USD97.6 million))! These values employ the use of many different methods encompassed in Daniell (2008-2010a, 2008-2010b, 2010e).

Table 8 – List of top 5 highest insured losses (1900-2010) in 2010 Country CPI adjusted $ international.

Rank	Volcano	Country	Date	Insured Loss (Country CPI)	Pref. Source for Event Year Loss
1	Sidoarjo Mud	Indonesia	29.05.2006	$233m	MunichRe
2	Unsen-dake	Japan	23.06.1993	$176m	MunichRe
3	Soufriere Hills	Montserrat	1995/1997	$146m	RMS, 2009, MunichRe
4	Pinatubo	Philippines	15.06.1991	$133m	MunichRe
5	Tavurvur	PNG	19.09.1994	$103m	MunichRe
6	*Eyjafjalla*	*Multiple*	*14.04.2010*	*$97.6m*	*Est.*
	St. Helens	*USA*	*18.05.1980*	*$71m*	
	Grimsvotn	*Iceland*	*30.09.1996*	*$19m*	

5 Conclusion

2010 has indeed been a larger than average year for economic losses from volcanoes. It has seen the Eyjafjalla volcanic eruption which affected around 7 million air travellers and about USD5 billion in total. In addition, the Merapi volcanic eruption in October/November caused around USD1 billion and the most homeless in the database. This years losses account for just under 25% of all economic losses since 1900 due to volcanoes. There is also much potential observed through CATDAT volcano data from the past 110 years for further insurance potential in lower HDI locations where rapid development is occurring, leading to increasing economic losses due to volcanoes. Volcanic eruptions generally occur in these rapidly evolving nations. However, when the major volcanic eruption comes, it will affect all economies!

The CATDAT Damaging Volcanoes database contains much data suitable for use in many sectors from volcanic loss estimation, to risk mapping, for insurance purposes and simply as a validated dataset to reduce the erratic values of socio-economic losses quoted wrongly throughout a number of sources. It has been shown that the traditional view that social and economic losses are increasing exponentially should be treated with caution. The dataset contains many more volcanoes with socio-economic data than other volcano databases on trend analysis and hopefully this has led to more populated trends. Large natural disaster losses are extremely difficult to quantify using a single number. Thus, CATDAT uses a lower bound, upper bound and best estimate value, using expert judgement; yet also presents all data to the user. It should also be noted that traditional databases making trends over multiple years based on year-of-event dollars or adjusting using a mass United States Consumer Price Index trend over volcano losses worldwide are incorrect. Economic loss should be calculated on a country-by-country basis and then compared. This is the same for absolute versus relative loss.

Over 1650 volcanic eruptions and incidents show over 320000 deaths since the beginning of volcano records. Great uncertainties remain however as to the effects of the Tambora 1815 and Laki 1783 volcanic eruptions, and their associated human and economic losses. It can be presumed that although the solar output was at a natural minimum, much of the 6000000+ deaths due to famine in the world, were due to the VEI 7 eruption. It was known as the "Year without a summer". Similarly this also occurred in 1783 with Laki in Iceland. Volcanoes in the 20th and 21st centuries have already caused approximately $43 billion (2010 HNDECI-Adjusted int. dollars) damage. This is 60 times less than that of earthquakes, however, we are still waiting for the relapse of a major volcanic event. If a VEI 4 eruption such as Eyjafjalla can hold European air travel to its knees and about USD5 billion in losses, imagine the effects of no worldwide air travel for days, months, years and also the crop losses.

However, like earthquakes, given the population increase around the world, there has been a significant reduction in loss of life due to volcanoes compared to what should be expected. This is with the advent of increased knowledge of volcanic processes, and safety schemes for inhabitants around volcanoes.

Many of the references for this paper are included in associated papers and abstracts and over tens of thousands of individual sources of information have been used to create the data in all the CATDAT damaging natural disaster databases.

Go to **www.earthquake-report.com**, the site of SOS Earthquakes, for further updates of current volcanic and earthquake information news and also for other CATDAT reports.

Subscribe to updates on CATDAT by emailing James Daniell at **j.e.daniell@gmail.com** or **james.daniell@earthquake-report.com.**

Man sagt oft : Zahlen regieren die Welt.
Sicher ist nur: Zahlen zeigen wie sie regiert wird.

It is often said: Figures rule the world. The only sure thing is: Figures show how it is ruled.

J.W. Goethe (1749-1832)

6 Main References for Volcanoes

There are over 2000 individual sources of information in the volcanic eruptions database but the following show the main contributors and checks that have been made.

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7 Main References for CATDAT

Given the fact that over 16000 individual sources of information have been used in the CATDAT Damaging Earthquakes database, and many other sources in the other CATDAT Natural Disaster databases, only the main CATDAT references will be shown in this list. Please refer to the following main paper or the following papers for some of these references or email me to get more details.

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2) **CEDIM Earthquake Loss Estimation Series Research Report 2011-01, http://www.cedim.de/download/2011-1_CATDAT_4.01.2011.pdf**
3) **Australian Earthquake Engineering Society Member Contribution, http://www.aees.org.au/Articles/Daniell_CATDAT_2010.pdf**
4) **PERN-M Member Contribution, http://listserver.ciesin.columbia.edu/ → follow link**

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Appendix A: Summary of the 2010 damaging volcanoes

The following section contains a summary of each 2010 volcano. More information is included in the full database; however, the section below provides a useful overview. It should be noted that much discrepancy is shown in values, and the author takes no responsibility for misuse. Most data is from other sources. Should the reader require more information, much more data on each volcanic incident is housed in the CATDAT Damaging Volcanoes database.

Simply email me at j.e.daniell@gmail.com, or use the contact details on the back page for comments.

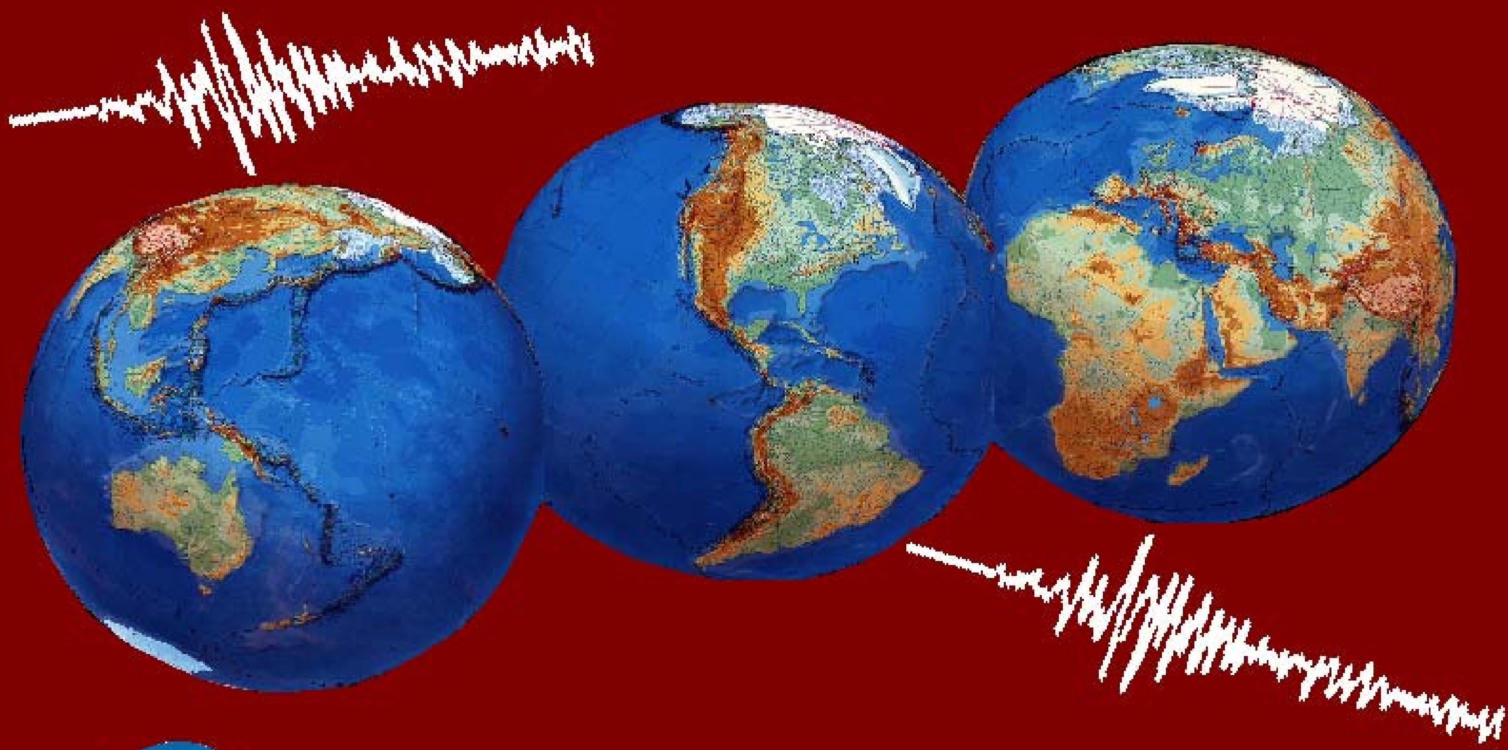
Again, I welcome any feedback, as there will no doubt be discrepancies, additions, possible other sources of information and unbeknown data to me. However, I have done my best to minimise errors.

CATDAT Damaging Volcanoes Database Summary List - 2010

Volcano Name	Date (2010)	Lat.	Long.	Elevation (m)	Type	VEI	Ctry	Old HDI	Fatality Range	Injury Range	Homeless	Evac.	Affected	Economic Loss ($m)	Aid Loss ($m)	Air Travel Disruptions
Manam	1-1	-4.08	145.037	1807	Stratovolcano	On.	PNG	0.568	0-0			1000	1000	*0.07-0.55*		
Galeras	3-1	1.22	-77.37	4276	Complex volcano	Fu	COL	0.777	0-0			900	8000	*0.19-1.41*		
Nyamuragira	4-1	-1.408	29.2	3058	Shield volcano	Ca	ZAR	0.296	0-?	Some			52096	*0.01-0.07*		
Turrialba	6-1	10.03	-83.77	3340	Stratovolcano	Ca	CRI	0.846	0-0	2		37+	60	*0.24-1.82*		
Etna	13-1	37.734	15.004	3350	Stratovolcano	Ca	ITA	0.960	0-0					*0.35-2.65*		Catania Airport
Tungurahua	15-1	-1.467	-78.442	5023	Stratovolcano	Ca	ECU	0.789	0-0					*0.2-1.47*		
Soufriere Hills	1-2	16.72	-62.18	915	Stratovolcano	Ca	MSR	0.806	0-0					*3.8-15.7*		Flights - Caribbean countries
Chaiten	10-2	-42.833	-72.646	962	Caldera	Ca	CHL	0.870	0-0					*0.26-1.98*		
Concepcion	19-3	11.538	-85.622	1700	Stratovolcano	Ca	NIC	0.687	0-0					*0.13-0.97*		
Eyjafjallajokull	31-3	63.63	-19.62	1666	Stratovolcano	3-4	ISL	0.970	2-2 , (2T)			-845+	*-7000000+*	1990.5-5050	Airline funded	105000 flights, much!
Gaua	21-4	-14.27	167.5	797	Stratovolcano	Ca	VUT	0.712	0-0					*0.14-1.08*		
Santa Maria	27-4	14.756	-91.552	3772	Stratovolcano	Ca	GTM	0.706	0-0					*0.14-1.06*		Airspace closed for 20km
Arenal	24-5	10.463	-84.703	1657	Stratovolcano	Ca	CRI	0.846	0-0					*0.24-1.82*		
Reventador	25-5	-0.078	-77.656	3562	Stratovolcano	Ca	ECU	0.789	0-0					*0.2-1.47*		
Pacaya	27-5	14.381	-90.601	2552	Complex volcano	1	GTM	0.706	1-5 , (2T, 3M)	65		1700	1700	68.39-68.39	3+	La Aurora AP
Tungurahua	28-5	-1.467	-78.442	5023	Stratovolcano	Ca	ECU	0.789	0-0	1		500	-2500+	160.22-280	20+	Guayaquil Airport
Sarigan	29-5	16.708	145.78	538	Stratovolcano	0	USA	0.950	0-0			16	16	*0.34-2.57*		
Yasur	31-5	-19.52	169.425	361	Stratovolcano	Fu	VUT	0.712	0-0				3567	*0.14-1.08*		New Caledonia domestic flights
Bezymianny	1-6	55.978	160.587	2882	Stratovolcano	Fu	RUS	0.786	0-0					*0.19-1.46*		Flight Diversions - RED Alert
Gorely	12-6	52.558	158.03	1829	Caldera	Fu	RUS	0.786	0-0					*0.19-1.46*		Flight Diversions - RED Alert
Stromboli	30-6	38.789	15.213	926	Stratovolcano	Ca	ITA	0.960	0-0					5-5		
Pacaya	9-7	14.381	-90.601	2552	Complex volcano	Ca	GTM	0.706	0-0			150	150	*0.14-1.06*		La Aurora
Tavurvur	23-7	-4.271	152.203	688	Pyroclastic shield	Ca	PNG	0.568	0-0					*0.07-0.55*		
Kilauea	28-7	19.425	-155.292	1222	Shield volcano	Ca	USA	0.950	0-0			0	0	*0.34-2.57*		

CATDAT Damaging Volcanoes Database Summary List - 2010

Karangetang [Api Siau]	6-8	2.78	125.48	1784	Stratovolcano	Ca	IDN	0.705	4-4 (4T)	5		65	65	0.68-0.68	0.05	
Galeras	25-8	1.22	-77.37	4276	Complex volcano	Fu	COL	0.777	0-0			813	8000	*0.19-1.41*		
Sinabung	30-8	3.17	98.392	2460	Stratovolcano	Ca	IDN	0.705	2-2 (1G, 1E)	31, (O=2807)		28756	-34000+	3.3-3.3	0.222	Medan Airport
Planchon-Peteroa	6-9	-35.24	-70.57	4107	Caldera	Fu	CHL	0.870	0-0					*0.26-1.98*		
Fournaise, Piton de la	24-9	-21.229	55.713	2631	Shield volcano	Ca	REU	0.809	0-0					*0.21-1.59*		
Kliuchevskoi	23-10	56.057	160.638	4835	Stratovolcano	Fu	RUS	0.786	0-0				5000	*0.19-1.46*		Flight Diversions - RED Alert
Merapi	26-10	-7.542	110.442	2947	Stratovolcano	3	IDN	0.705	353-386 (381T, 5P)	427 (O=17000)	-11500+	-350000+	-400000+	789.94-1479.75	45+	Yogyakarta and local Aps
Shiveluch	27-10	56.653	161.36	3283	Stratovolcano	Fu	RUS	0.786	0-0					*0.19-1.46*		Flight Diversions - RED Alert
Bulusan	10-11	12.77	124.05	1565	Stratovolcano	Ca.	PHL	0.700	1-1 (1G)	9		1671	14161	0.28-0.28	0.038	
Tengger Caldera	23-11	-7.942	112.95	2329	Stratovolcano	Ca	IDN	0.705	0-0		50	1000	68000++	5.55-5.55	0.28	Juanda, Saleh, local airports
Tungurahua	3-12	-1.467	-78.442	5023	Stratovolcano	Ca	ECU	0.789	0-0		2500 (698f)	2500	2500++	*0.2-1.47*		
Kizimen	13-12	55.13	160.32	2485	Stratovolcano	Fu.	RUS	0.786	0-0					*0.19-1.46*		



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