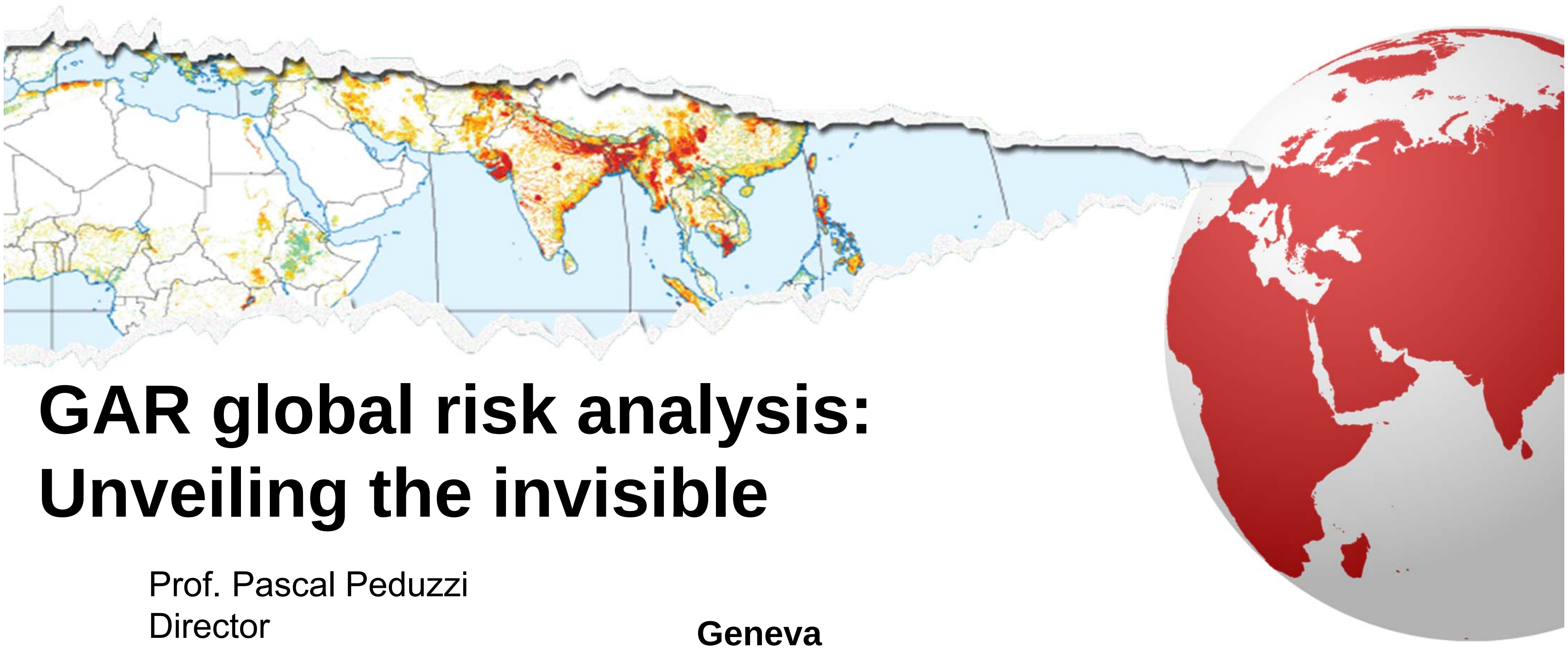
1st IAVCEI/GVM workshop
From volcanic hazard to risk assessment



GAR global risk analysis: Unveiling the invisible

Prof. Pascal Peduzzi
Director
UNEP/GRID-Geneva

Geneva
27 June 2018

The GAR reports

Contribution to 14 reports on risk & global change

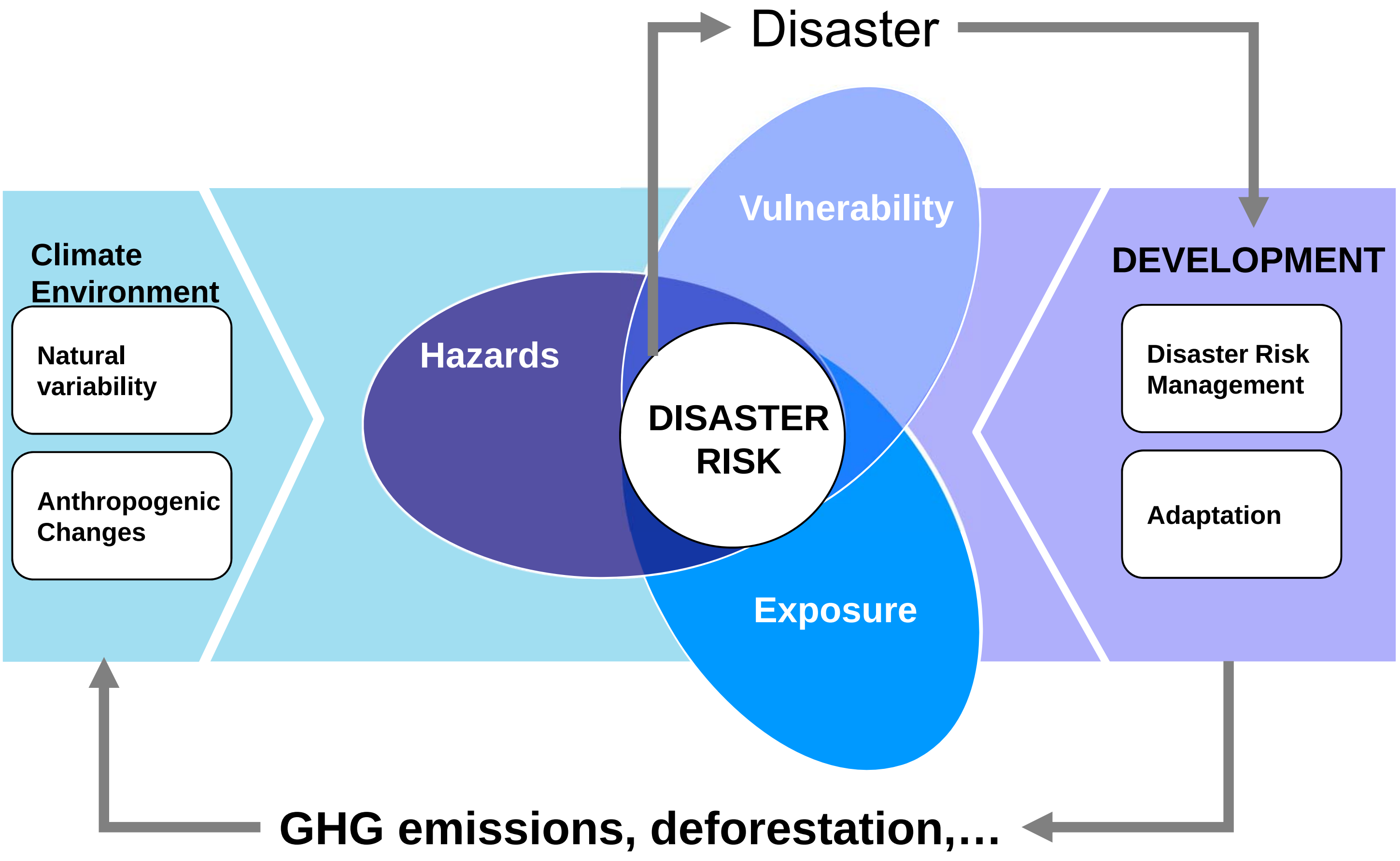
UNEP | GRID Geneva

Introduction: disasters seen as fast events

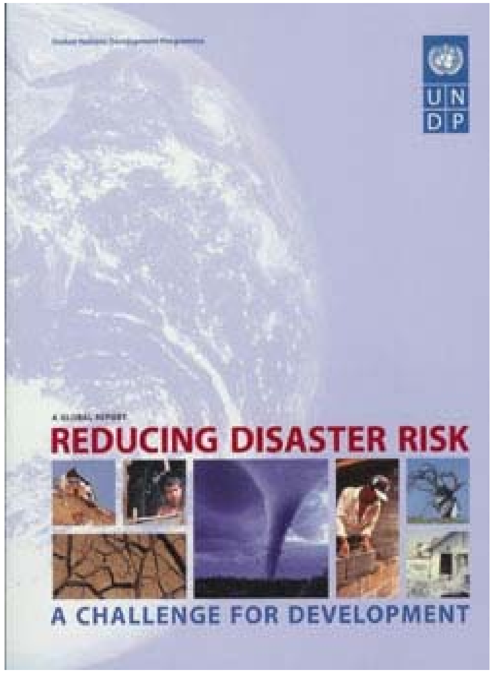
Introduction: disasters are slowly built

Disasters are the consequences of slow / continuous processes resulting from inappropriate (or lack of) choices

Special Report on Extremes (IPCC, 2012)



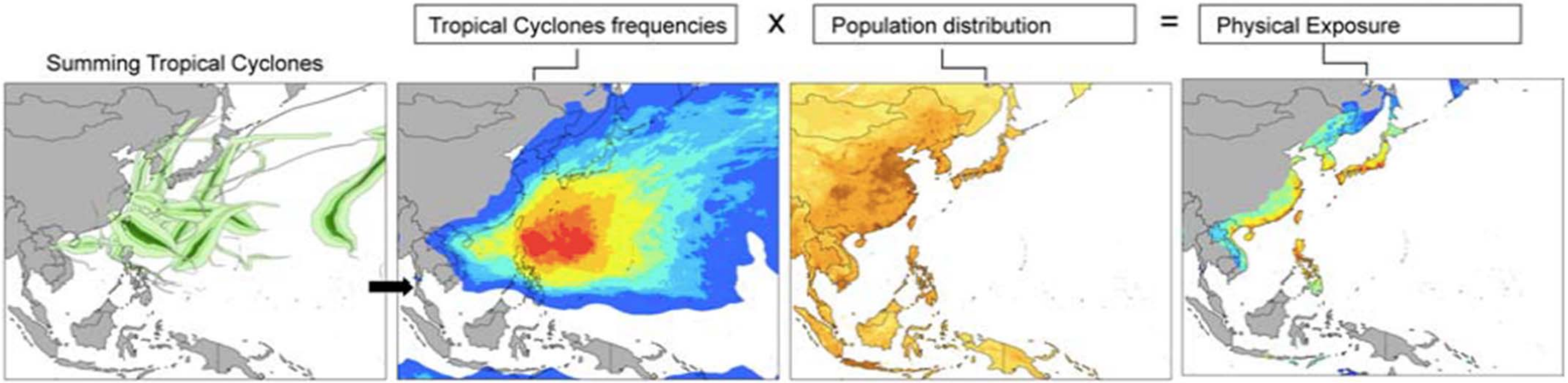
Reducing Disaster Risk a challenge for development (2001-2004)



This study was the first one which provided a global estimate for human exposure to drought, earthquakes, floods, tropical cyclones.
It did consider volcanoes:

"Volcanic eruption is important internationally, but lacks sufficient data for analysis at this time (see Technical Annex).
At an early stage, volcanic eruptions were excluded from the DRI analysis because of the need to differentiate locally between different types of volcanic hazard.
Data for such a task exists and could be compiled into an international database."

From hazard to human exposure



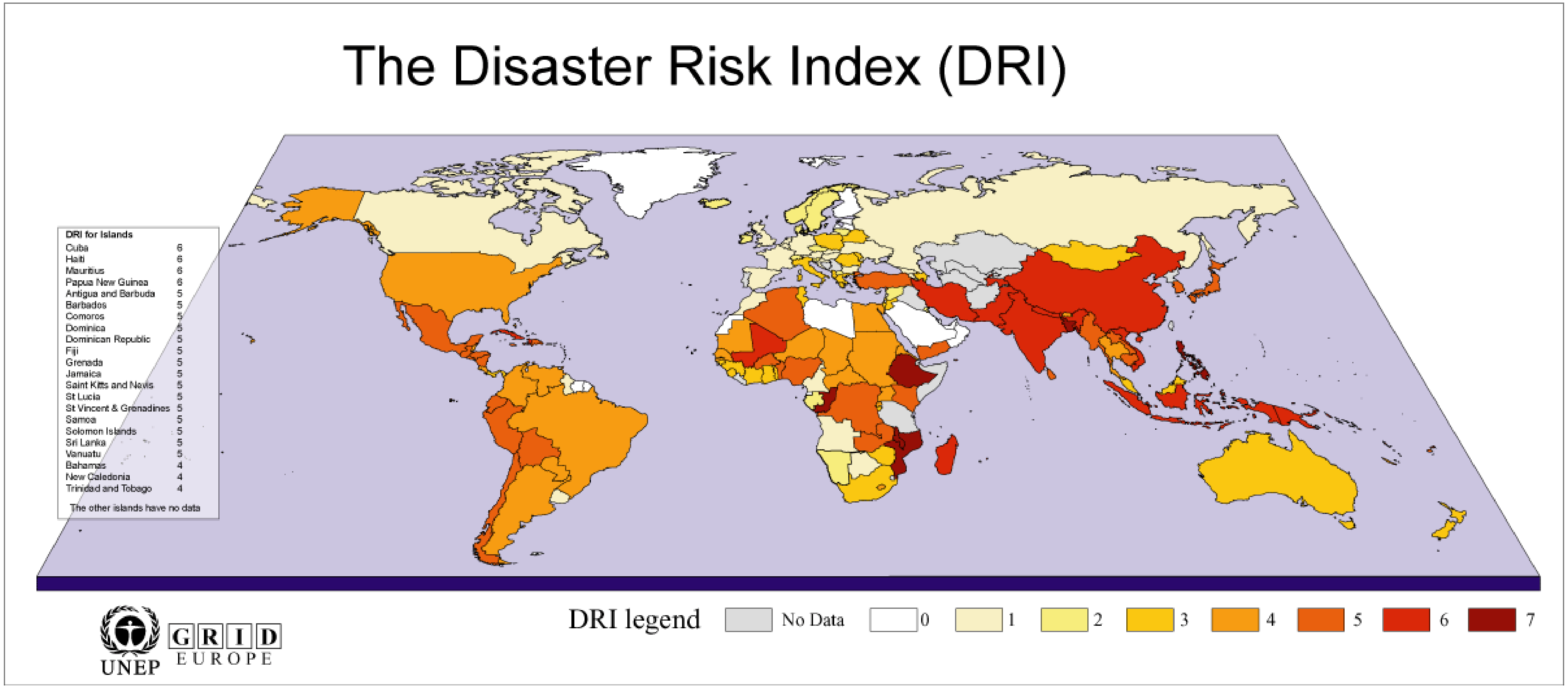
Using statistical regressions between observed losses, past exposure and socio-economic parameters: characterized mortality risk for Drought, Flood, Tropical Cyclones and Earthquakes, at the national level.

However, there were limitations:

- Flood was not well modeled
- We used the average losses over 21 year period, thus the role of Intensity of individual events could not be analyzed
- There were a need for a new approach

The Disaster Risk Index (DRI)
(2001-2004, updated in 2009)

Peduzzi, P., Dao, H., Herold, C., and Mouton, F.: Assessing global exposure and vulnerability towards natural hazards: the Disaster Risk Index, *Nat. Hazards Earth Syst. Sci*., **9**, 1149-1159, 2009.



Courtesy of P. Peduzzi and Hy Dao, UNEP, 2007

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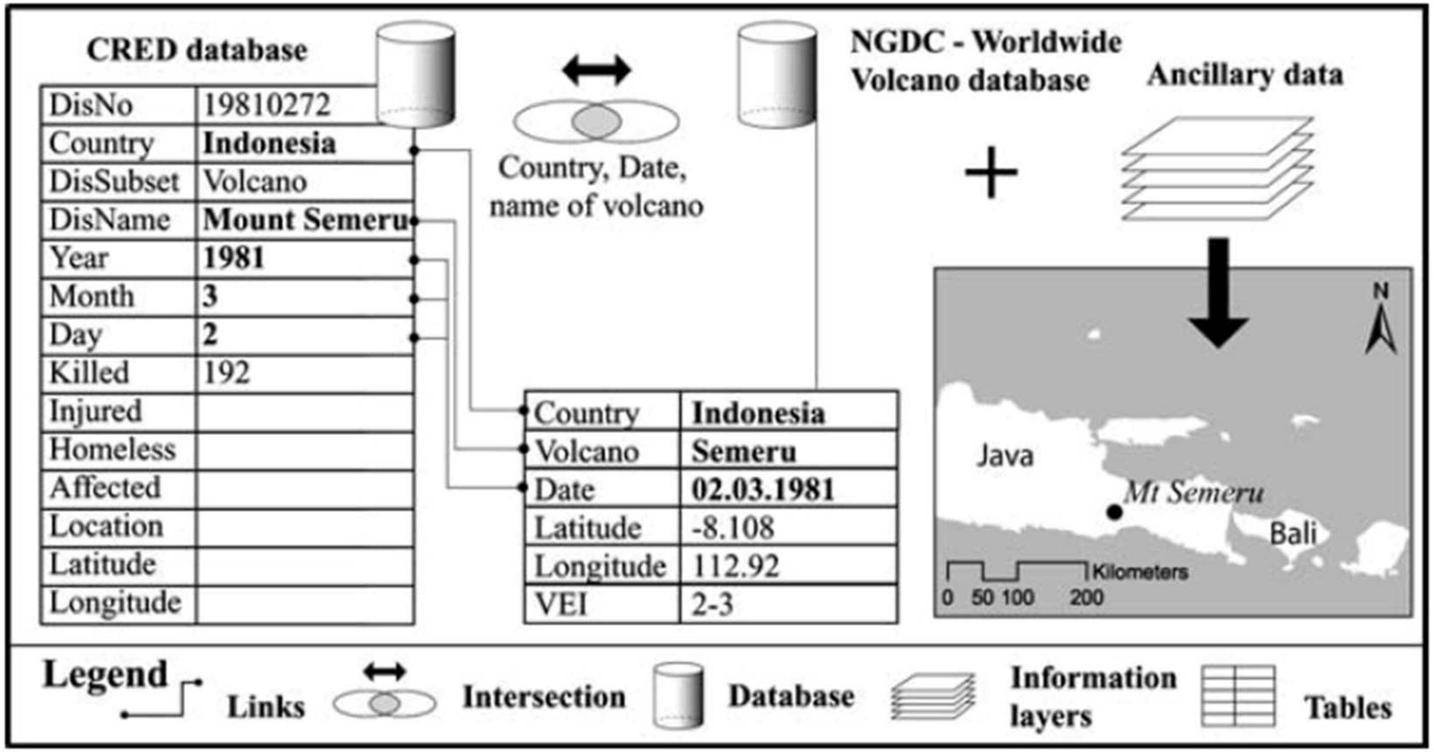
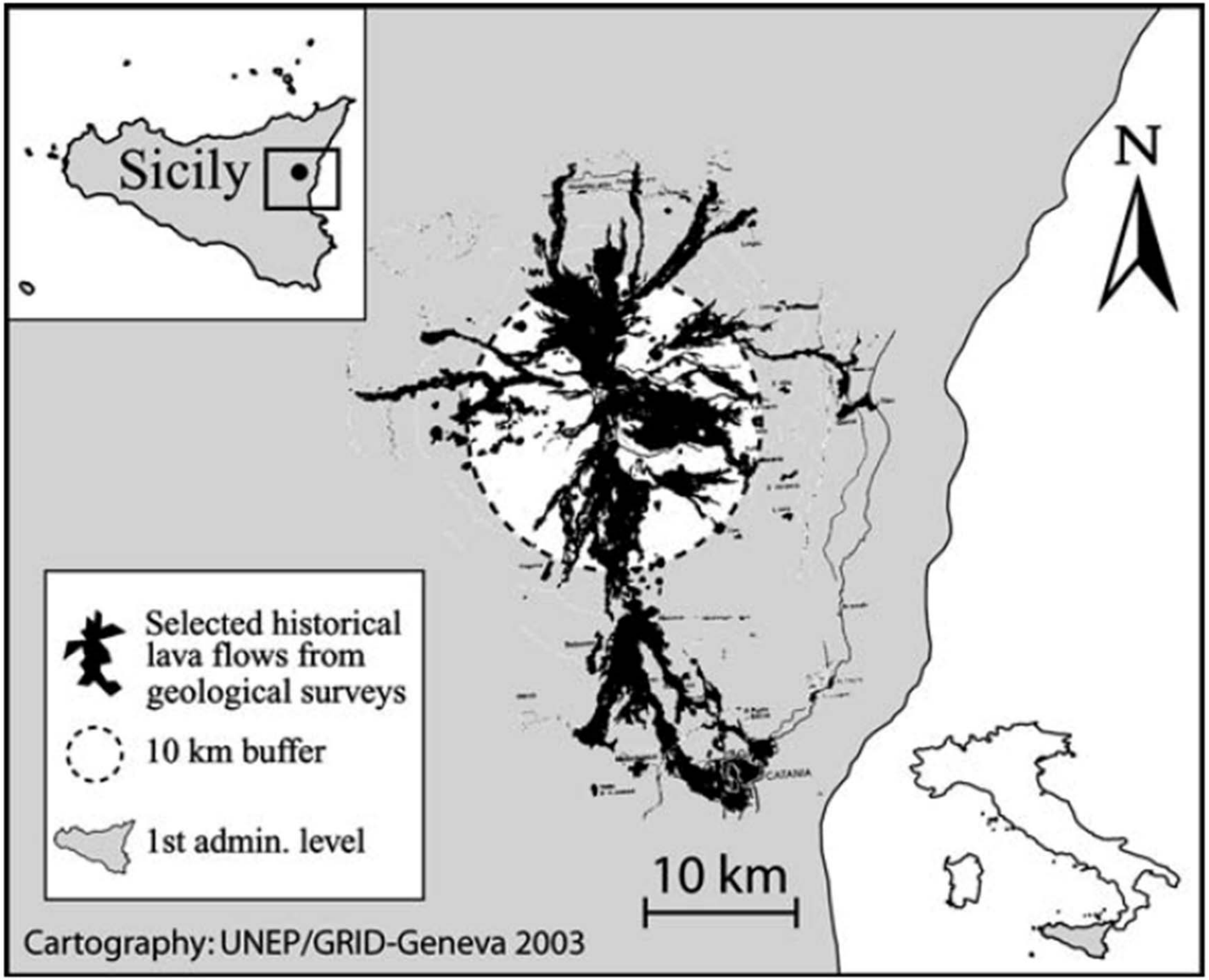
Georeferencing EM-Dat for volcanic eruptions

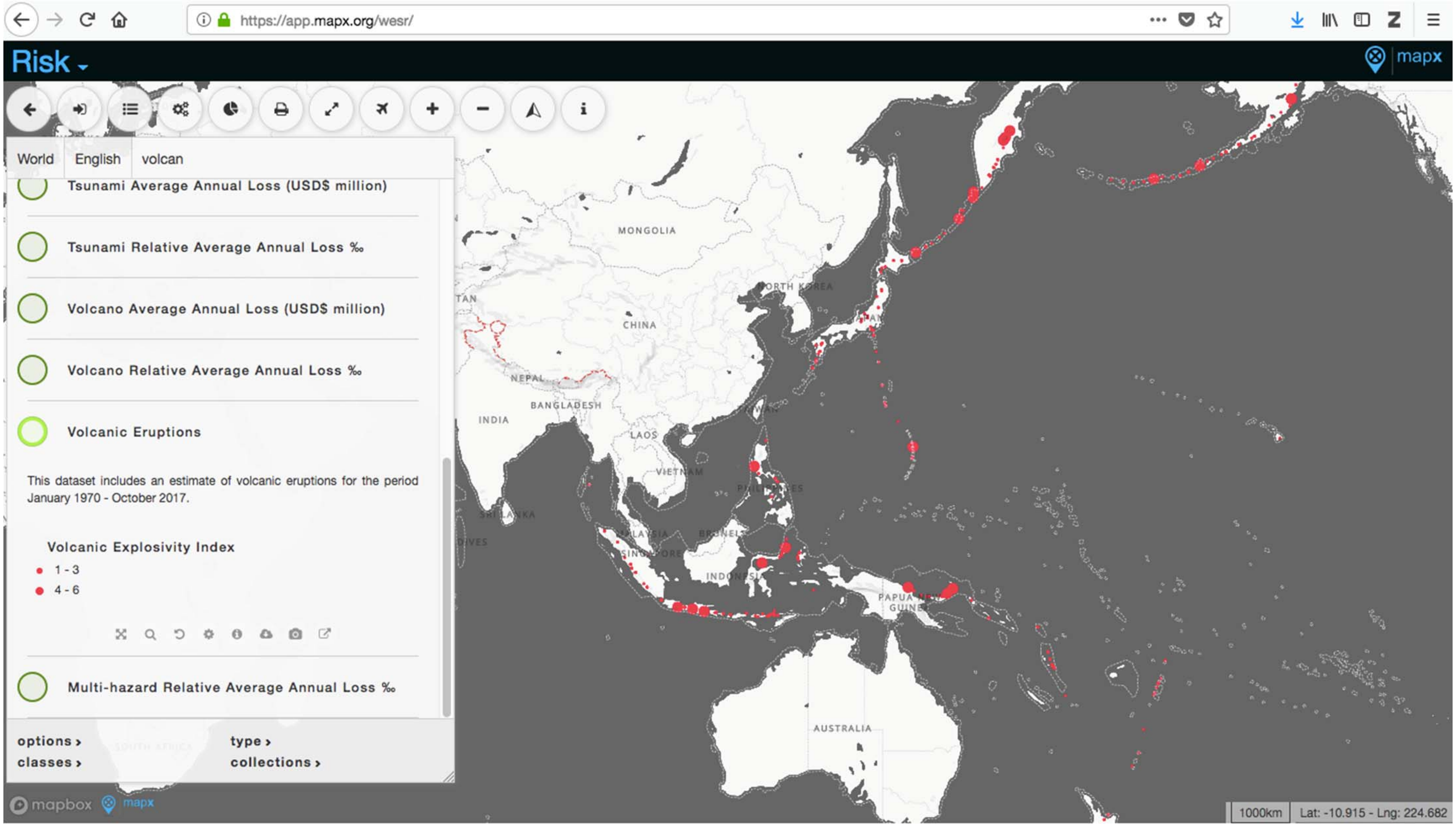


PEDUZZI, Pascal, HEROLD, Christian, DAO, Quoc-Hy. Mapping Disastrous Natural Hazards Using Global Datasets. In: *Natural Hazards*, 2005, vol. 35, n° 2, p. 265-289.



From Peduzzi et al. 2005. Fig. 8. Map of Etna VEI 2-3 events as geo-referenced using a 10 km buffer. Sources of lava flows historic map: Behncke B., Dipartimento di Scienze Geologiche, Catania (IT), http://boris.vulcanoetna.com/ETNA.html.

Global Database on volcanoes with VEI



Data source: Smithsonian Institution, Volcanoes of the world.

Map: UNEP/GRID-Geneva in http://www.mapx.org/wesr

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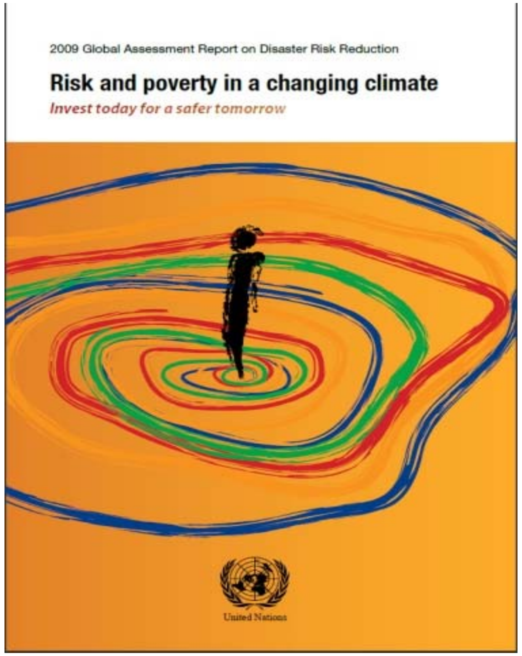
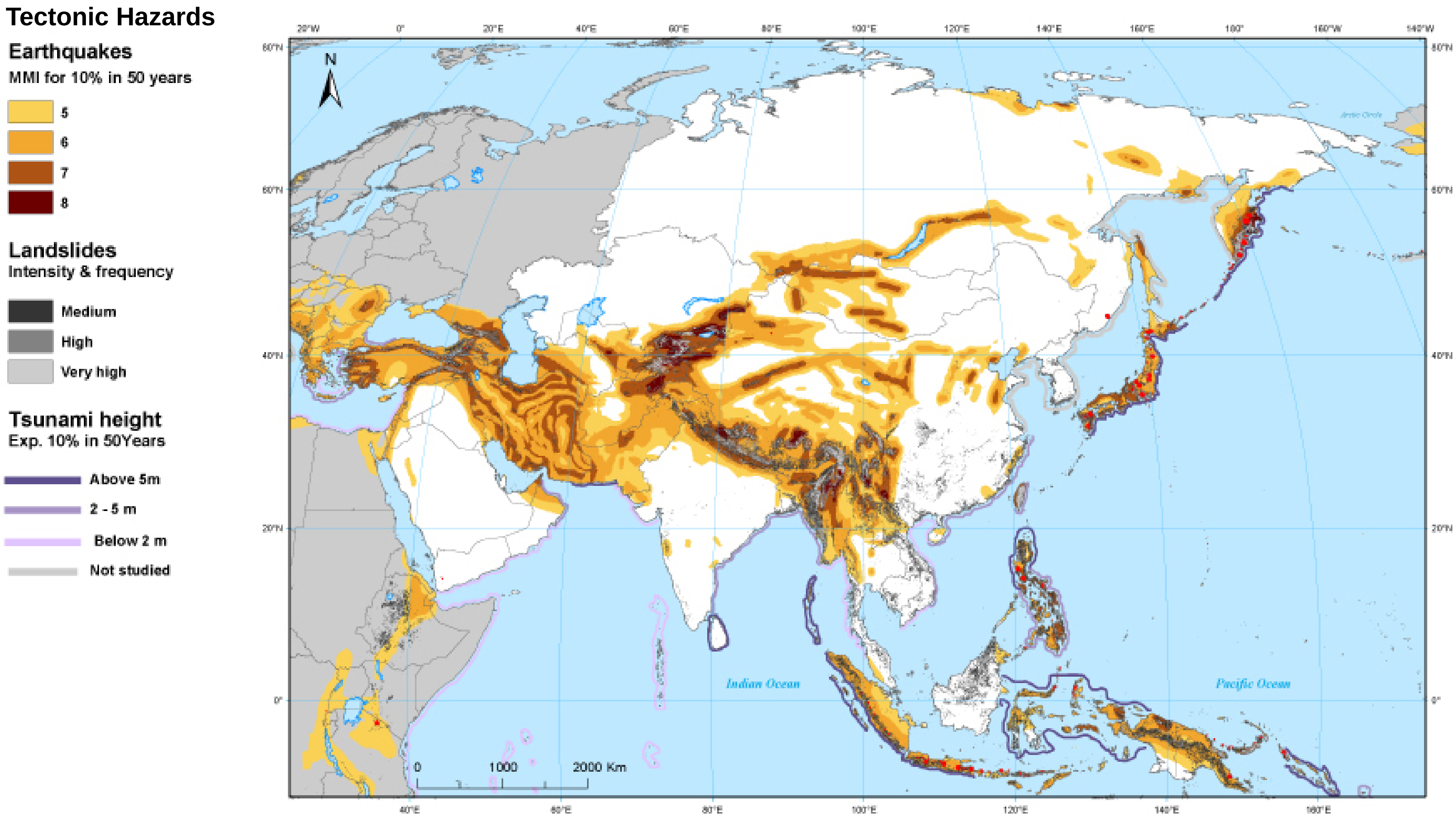
The GAR assessments (2009, 2011, 2013, 2015, 2017)



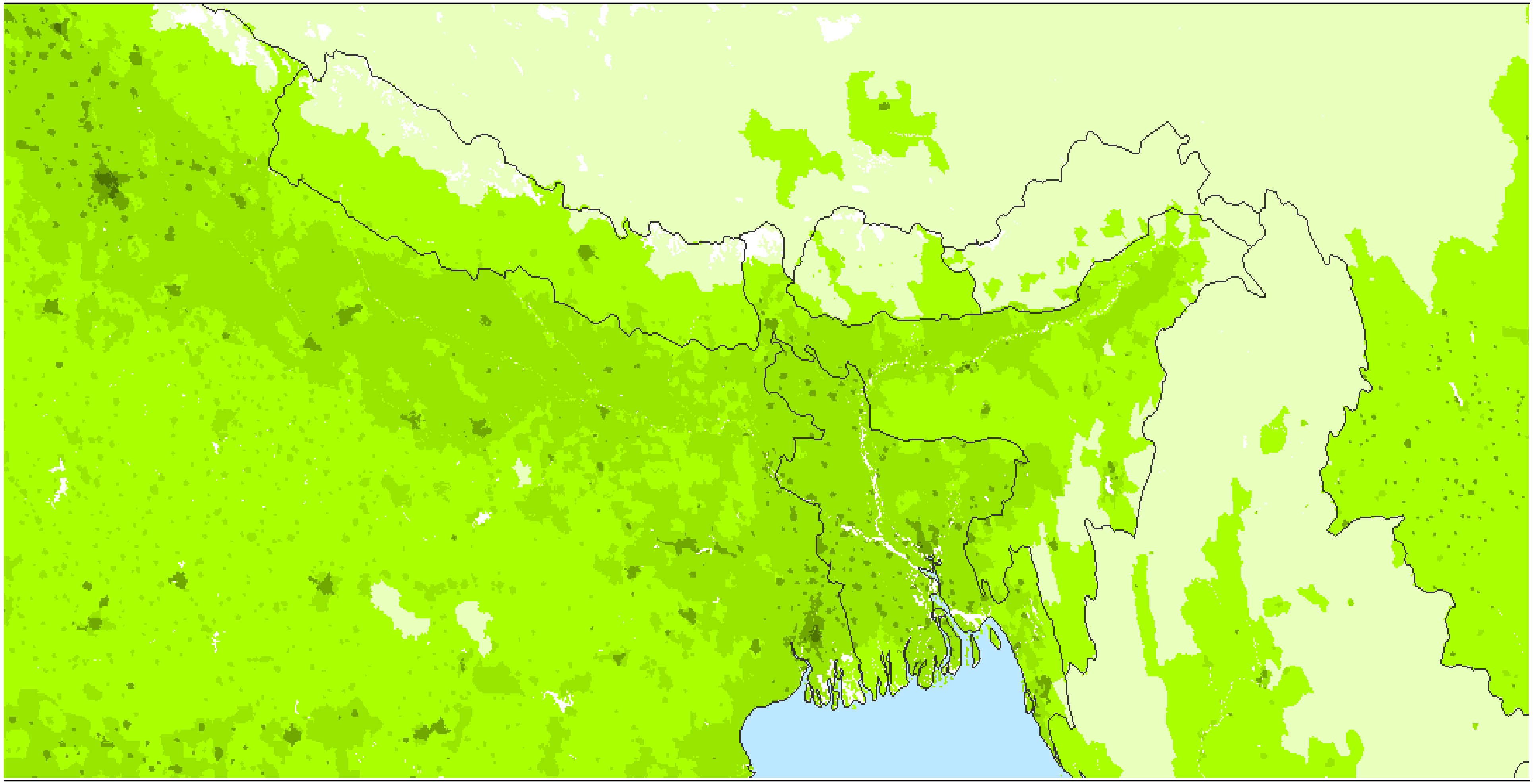
GAR 2009, understanding risk.
We used the so called "event per event Global Risk analysis" to identify the underlying drivers of risk.
This was characterised for Earthquakes, Flood, Tropical Cyclones and Landslides.
We also modeled, tsunamis and drought analysis.

New Global Hazard Datasets created for GAR 2009



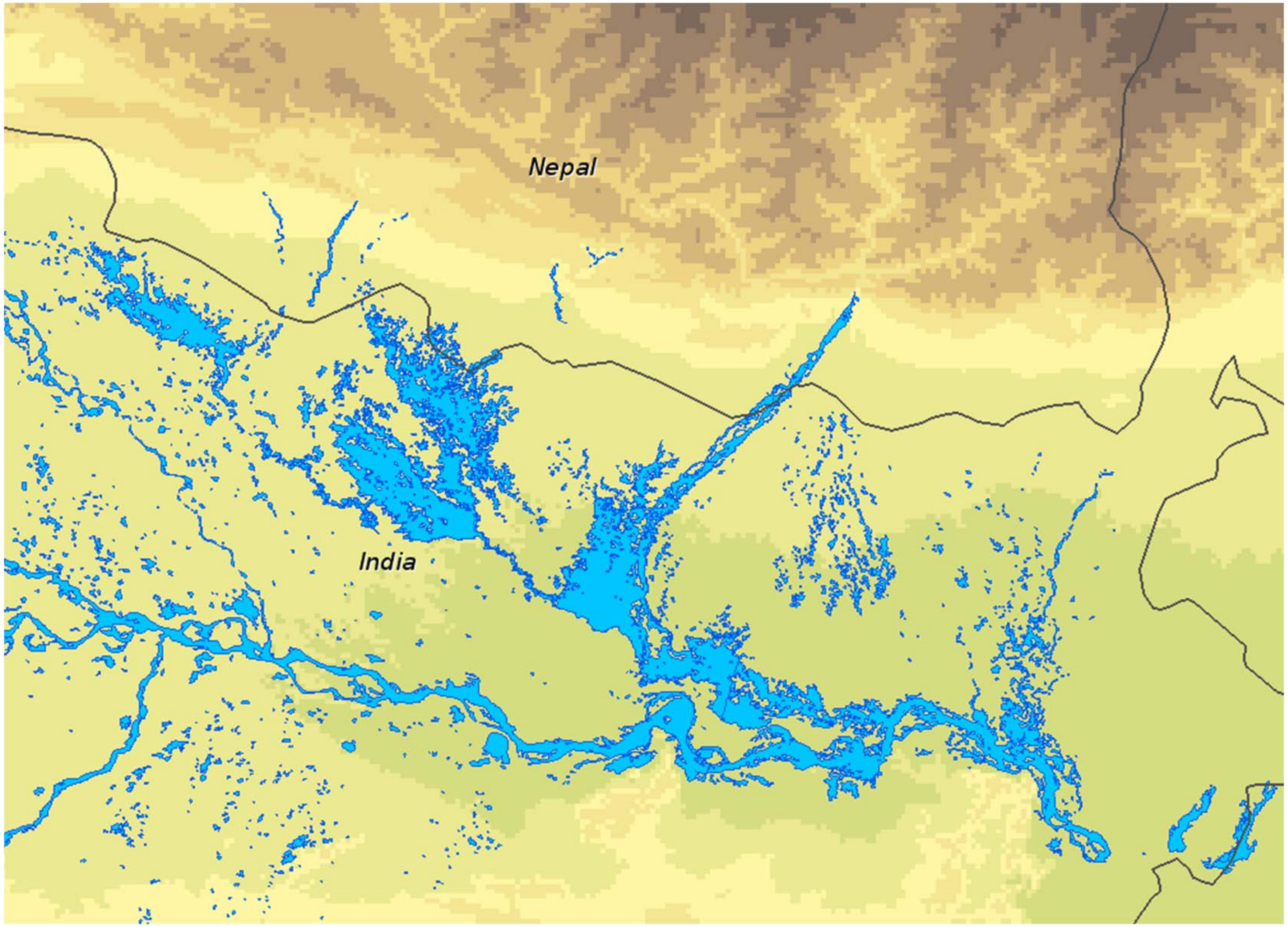
New Human & Economic exposure datasets (1 x 1 km

Population and GDP distribution Models made for every years from 1970 to 2010



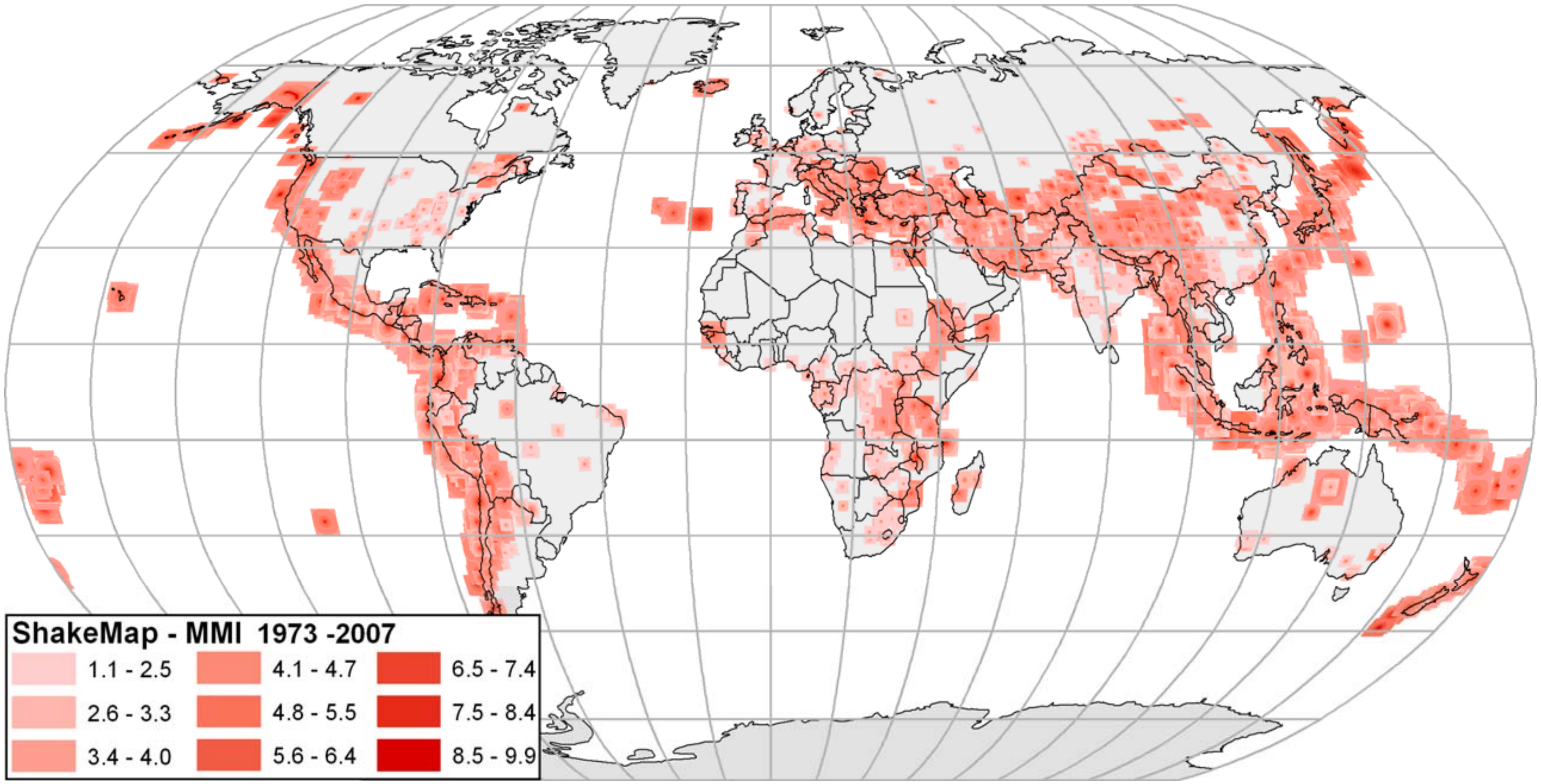
1006 Past floods as detected by satellite sensors

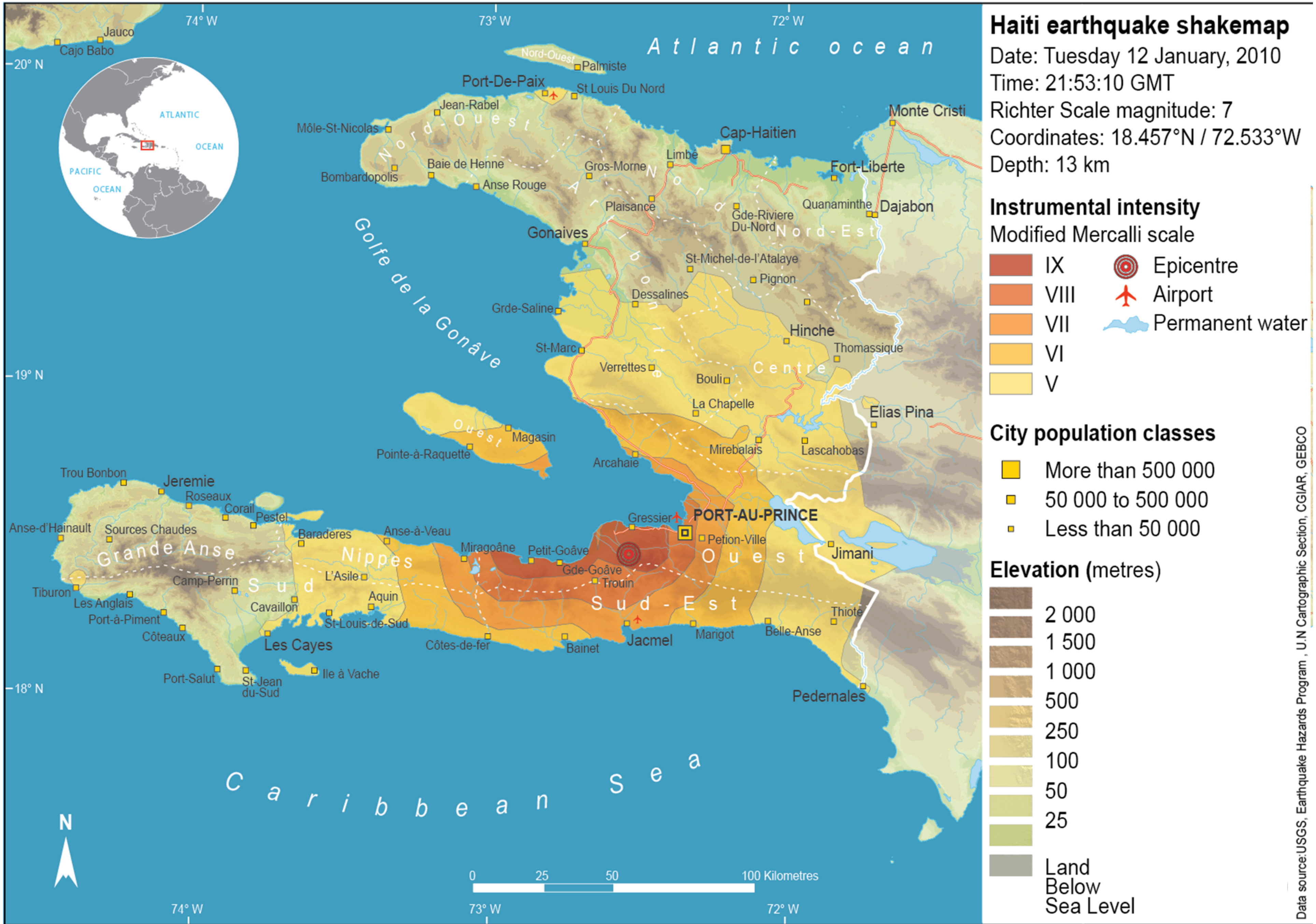
Shape	Polygon
Area	0.48742
Perimeter	147.24166
Fl_	112
Fl_id	2
Ev_id	fl2693
Iso3disno	IND20050375
Iso3year	IND2005
Glide	nodata
Iso3	IND
Id_nat	fl2693IND
Id_cat	nodata
Year	2005
Start_date	20050707
End_date	20050727
Time_gmt	nodata
Time_local	nodata
Duration	21
Severity	1.0
Magnitude	5.1
Depth_av	0.0
Depth_m	0
Area_ext	5402
Popurb_exp	380077
Poprur_exp	4773770
Poptot_exp	5153847
Crops_exp	4083
Gdp_exp	0
D_av_capi	988.9
D_min_capi	821.7
Dfo_n	85
Dead	40
Displaced	3000000
Damage	-9999
Main_cause	Monsoonal rain
Affected_s	823500
Comments	



Compilation of Past Earthquakes ShakeMaps

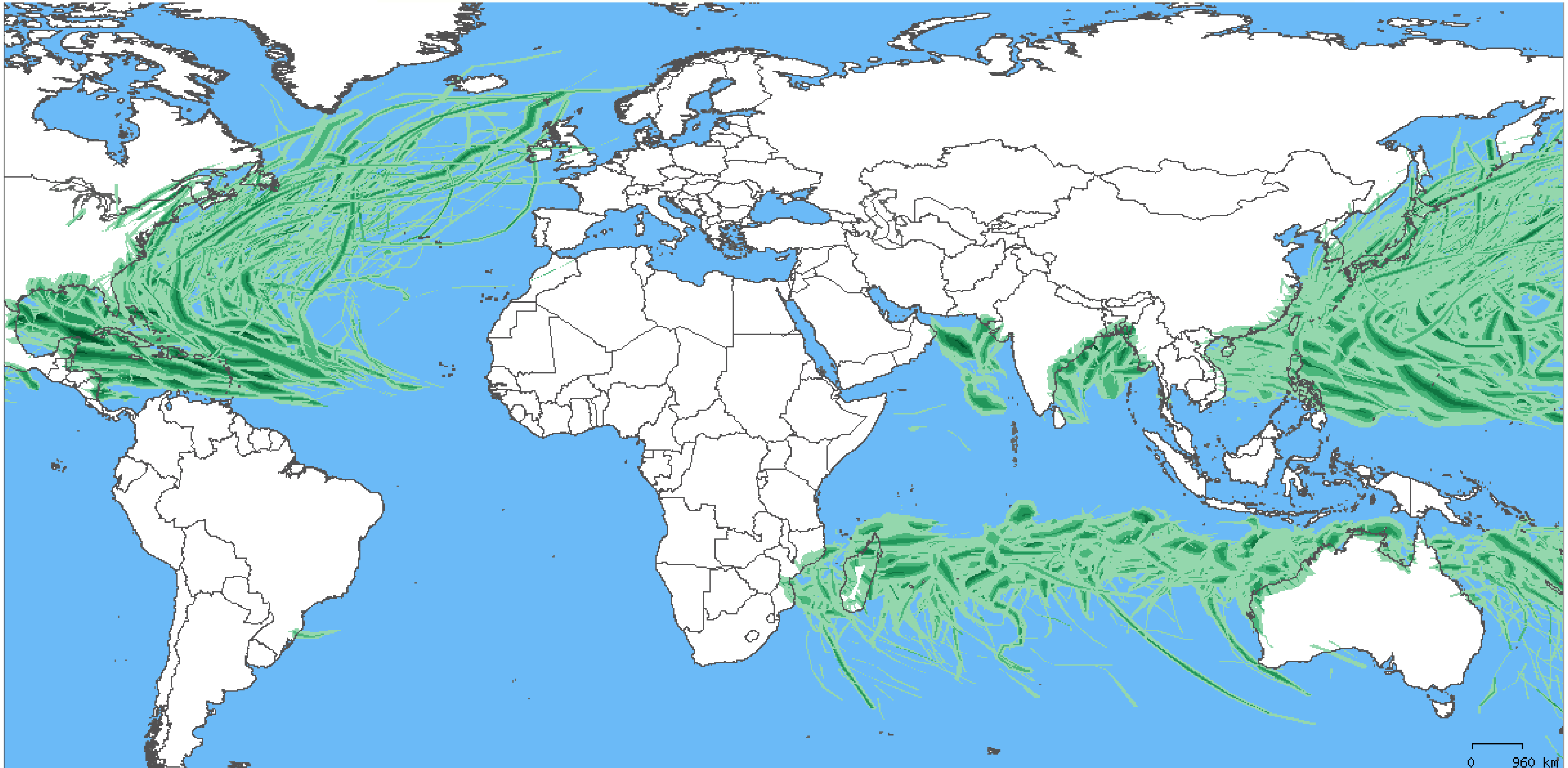
- 5686 events downloaded over the period 1973-2007




Haiti earthquake shakemap
Date: Tuesday 12 January, 2010
Time: 21:53:10 GMT
Richter Scale magnitude: 7
Coordinates: 18.457°N / 72.533°W
Depth: 13 km
Instrumental intensity
Modified Mercalli scale
IX
VIII
VII
VI
V
Epicentre
Airport
Permanent water
City population classes
More than 500 000
50 000 to 500 000
Less than 50 000
Elevation (metres)
2 000
1 500
1 000
500
250
100
50
25
Land Below Sea Level
Data source:USGS, Earthquake Hazards Program , U.N Cartographic Section, CGIAR, GEBCO
Atlantic ocean
Caribbean Sea
Golfe de la Gonâve
ATLANTIC OCEAN
PACIFIC OCEAN
74° W
73° W
72° W
20° N
19° N
18° N
0
25
50
100 Kilometres
N
PORT-AU-PRINCE
Port-De-Paix
Cap-Haitien
Gonaives
Jeremie
Les Cayes
Jacmel
Hinche
Jimani
Monte Cristi
Fort-Liberte
Dajabon
Elias Pina
Pedernales
Mirebalais
Lascahobas
Arcahaie
Gressier
Petion-Ville
Petit-Goâve
Gde-Goâve
Trouin
Miragoâne
Marigot
Belle-Anse
Thiotè
Bainet
Côtes-de-fer
Aquin
St-Louis-de-Sud
Cavaillon
Camp-Perrin
L'Asile
Anse-à-Veau
Baraderes
Pestel
Corail
Roseaux
Trou Bonbon
Sources Chaudes
Anse-d'Hainault
Tiburon
Les Anglais
Port-à-Piment
Côteaux
Port-Salut
St-Jean du-Sud
Ile à Vache
Magasin
Pointe-à-Raquette
St-Marc
Verrettes
Grde-Saline
Dessalines
Bouli
La Chapelle
Thomassique
Pignon
St-Michel-de-l'Atalaye
Gde-Riviere Du-Nord
Quanaminthe
Plaisance
Limbe
Gros-Morne
Anse Rouge
Baie de Henne
Bombardopolis
Môle-St-Nicolas
Jean-Rabel
St Louis Du Nord
Palmiste
Jauco
Cajo Babo
Nord-Ouest
Nord
Nord-Est
Artibonite
Centre
Ouest
Sud-Est
Sud
Nippes
Grande Anse

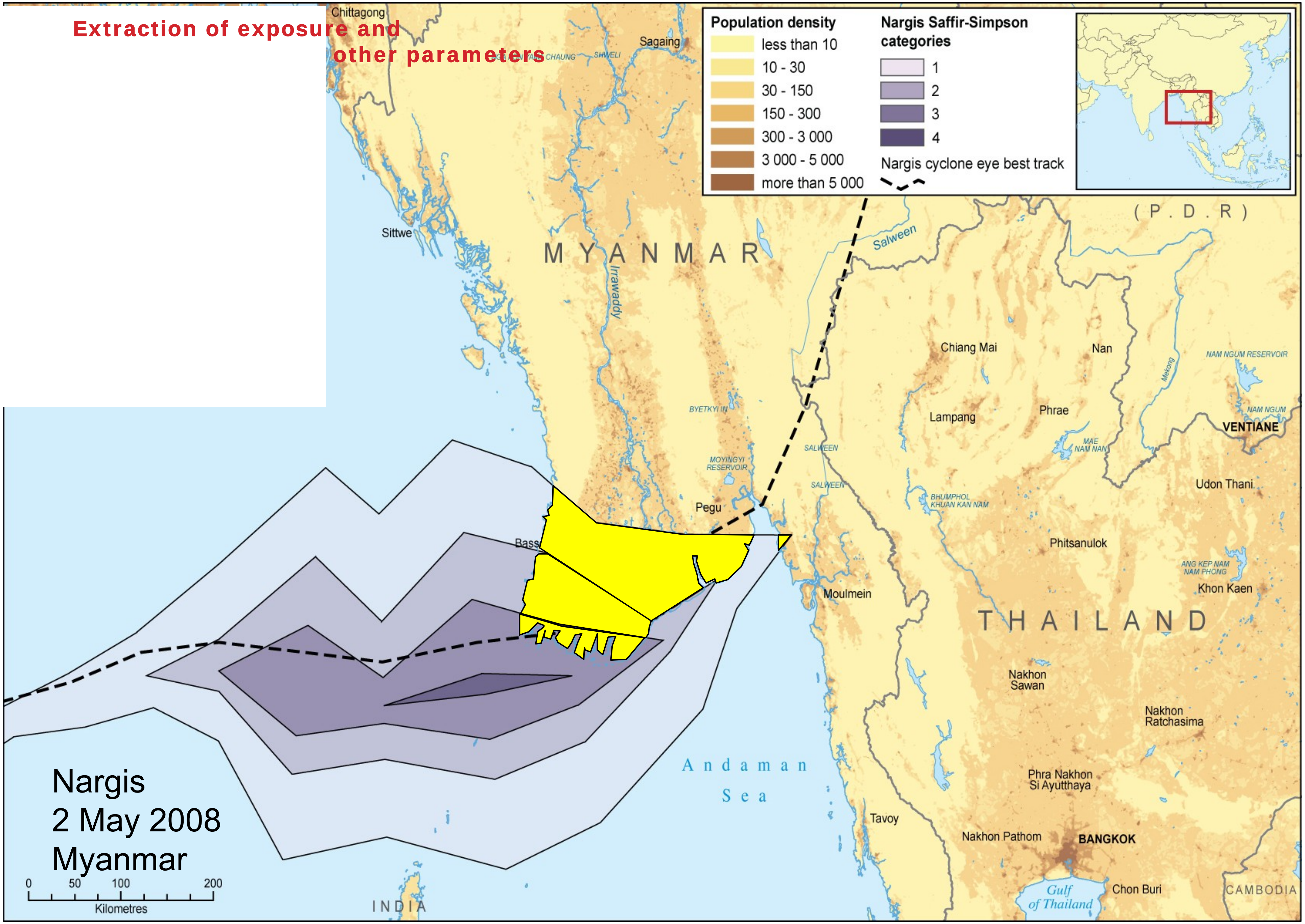
Individual past hazardous events modeling

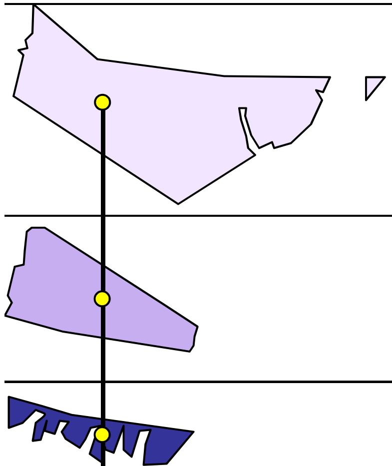
>6500 tropical cyclones events were processed
Global coverage for the period 1970 to 2009.



Geneva

Extraction of exposure and other parameters



Footprints	Category	Pop. exp.	GDP exp.	Pop.Urb exp.	GDP Urb. exp	…
	1	10,500,000	43,000,000	4,800,000	32,500,000	
	2	1,500,000	3,500,000	1,400,000	525,000	
	3	400,000	800,000	375,000	150,000	

Preview Tropical Cyclones Database

Date
Iso3

EM-DAT, CRED

Vulnerability Database 43 indicators

Date
Iso3
Killed
GDPcap
Est. damages
Voice & acc.
Governance efficiency
Radio/inhabitant
HDI
…
Urban growth

Country: Myanmar
Iso3: MMR
Date: 02 May 2008
Killed: 138,366
Damages: 4,000 US$ millions
GDPcap: 1,227 US$
Voice & acc.: -2.16
Governance efficiency : -1.608
Radio/inhabitant: 99.68%
HDI: 0.592
…
Urban growth: 2.55%

List of vulnerability parameters considered

43 indicators on:
Economy,
Demography,
Environment,
Development,
Early Warning,
Governance,
Health,
Education,
…

1 AIDS estimated deaths, aged 0-49 (% of tot. pop.)
2 non GLC2000 bare land
3 Arable and Permanent Crops - % of non GLC2000 bare land
4 Motor vehicles in use - Passenger cars (thousand)
5 Motor vehicles in use - Commercial vehicles (thousand)
6 Physical exposure to conflicts
7 Corruption Perceptions Index (CPI)
8 Arable and Permanent Crops - Total
9 Arable and Permanent Crops - Percent of Land Area
10 Control of Corruption
11 Deforestation rate
12 % of population with access to electricity
13 Forests and Woodland (% of Land Area)
14 Gross Domestic Product - Purchasing Power Parity per Capita
15 Gross Domestic Product - Purchasing Power Parity
16 inequality (Gini coefficient)
17 Human Induced Soil Degradation (GLASOD)
18 Government Effectiveness
19 Human Development Index (HDI)
20 Per capita government expenditure on health (PPP int. $)
21 # of hospital beds per 100,000 habitants # of doctors
22 infant mortality and malnutrition (though are also factored into HDI)

Equation of risk used in the study *

Risk = Hazard x Exposure x Vulnerability

- Risk: Calibrated using past disasters
- Hazard: Modelled based on physical and geographical datasets
- Exposure: Population or assets as extracted using GIS.
- Vulnerability: To be identified using multiple regression analysis.

Events footprints (8762 physical events): 5686 Earthquakes, 1106 floods, 4182 tropical cyclones). For which we extracted exposure and socio-economical contextual parameters: a database of 124,000 records (over 40 years, 208 countries, 43 parameters, in theory > 375,000 data cells, but “some” no data : 124,000 data cells).

Events with reported losses successfully georeferenced:
718 Earthquakes, 620 floods, 1525 tropical cyclones).

* UNDRO (1979), Natural Disasters and Vulnerability Analysis in *Report of Expert Group Meeting*

A multiplicative model

Simplifying the equation

$R = H \cdot Exp \cdot V$ => $R = PhExp \cdot V$

Introducing the factors and their weights

$$R = C \cdot PhExp^{\alpha 0} \cdot V_1^{\alpha 1} \cdot V_2^{\alpha 2} \ldots \cdot V_n^{\alpha n}$$

Where:

R = risk of losses from a specify hazard type

C = multiplicative constant

PhExp = physical exposure, i.e. the population exposed per year to a specific hazard

V_i = vulnerability factors (socio-economical parameters)

α_i = exponents of PhExp and Vi

Taking the logarithms

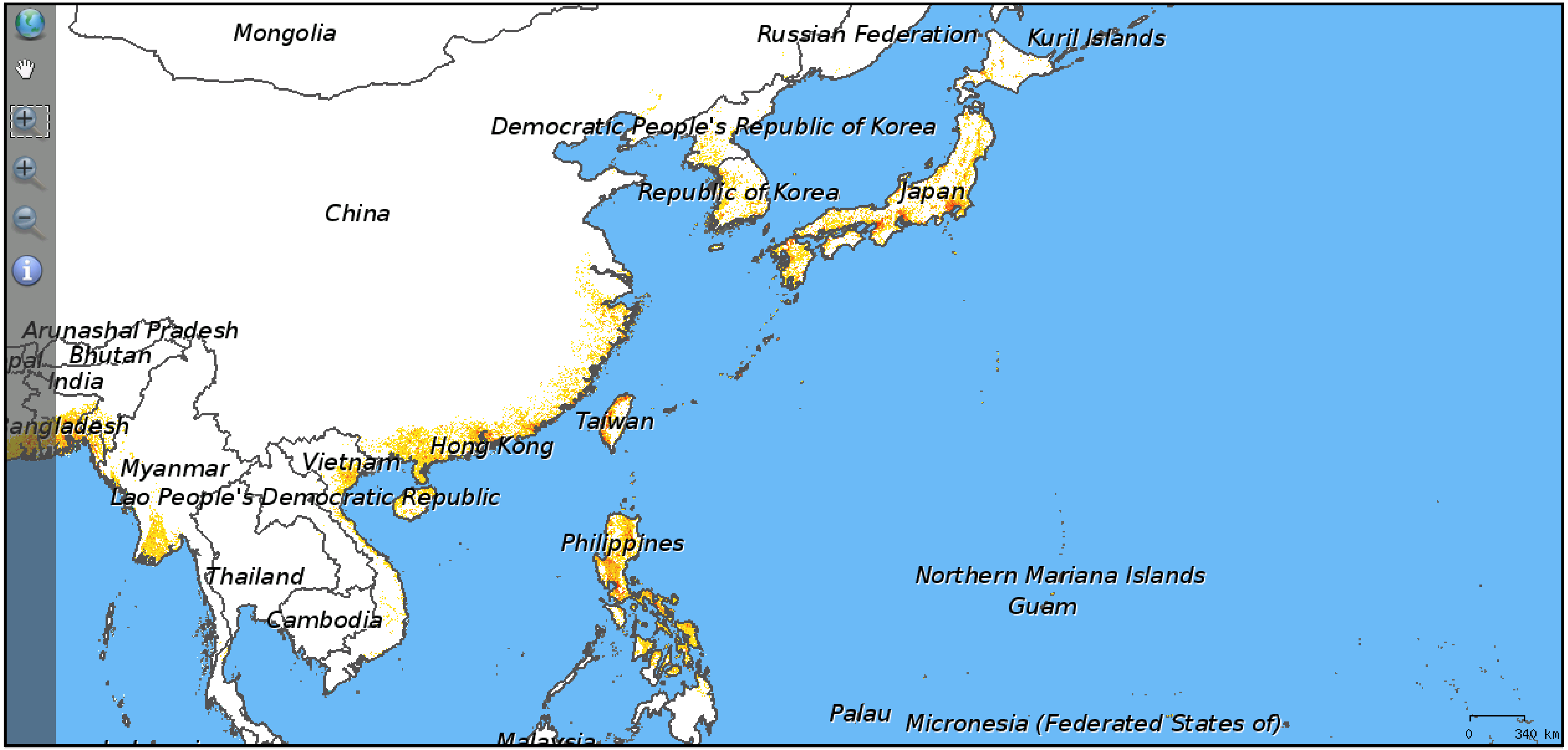
$$\ln(R) = \ln(C) + \alpha_0 \cdot \ln(PhExp) + \alpha_1 \cdot \ln(V_1) + \alpha_2 \cdot \ln(V_2) \ldots + \alpha_n \cdot \ln(V_n)$$

What are the main factors increasing risk?

- The severity of hazards
- The exposure
- Poverty (low GDP per capita)
- Poor governance (low voice and accountability)
- Rapid urban growth, when associated with low development and low governance (for earthquakes)
- Remoteness (for floods)

The role of vulnerability decrease with intensity, while the role of exposure increase!

From hazardous events to frequency and exposure



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Aggregation of human exposure at country level

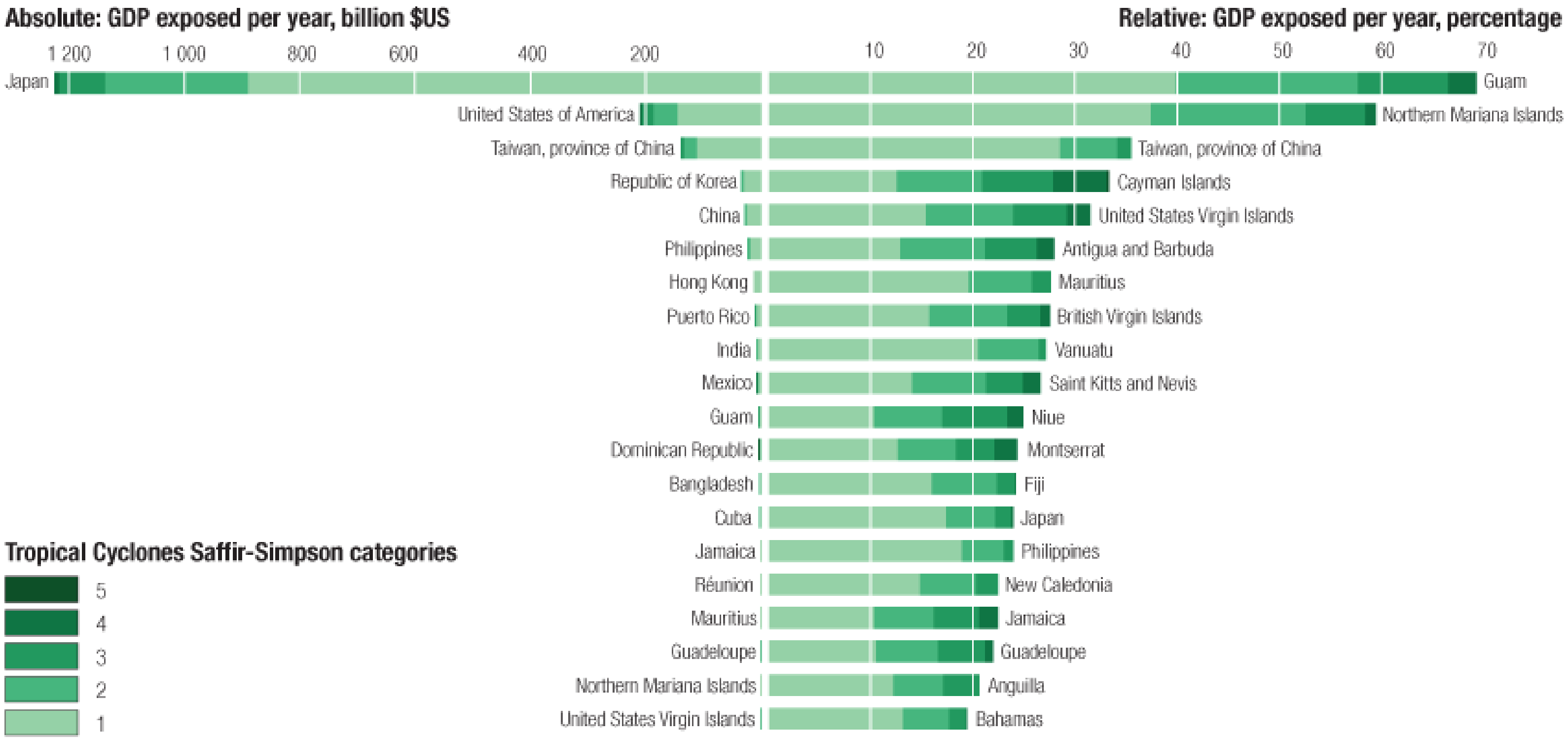
Absolute: people exposed per year

25 000 000 20 000 000 15 000 000 10 000 000 5 000 000

Relative: people exposed per year, percentage

5 10 15 20 25 30 35 40

Aggregation of economical exposure at country level



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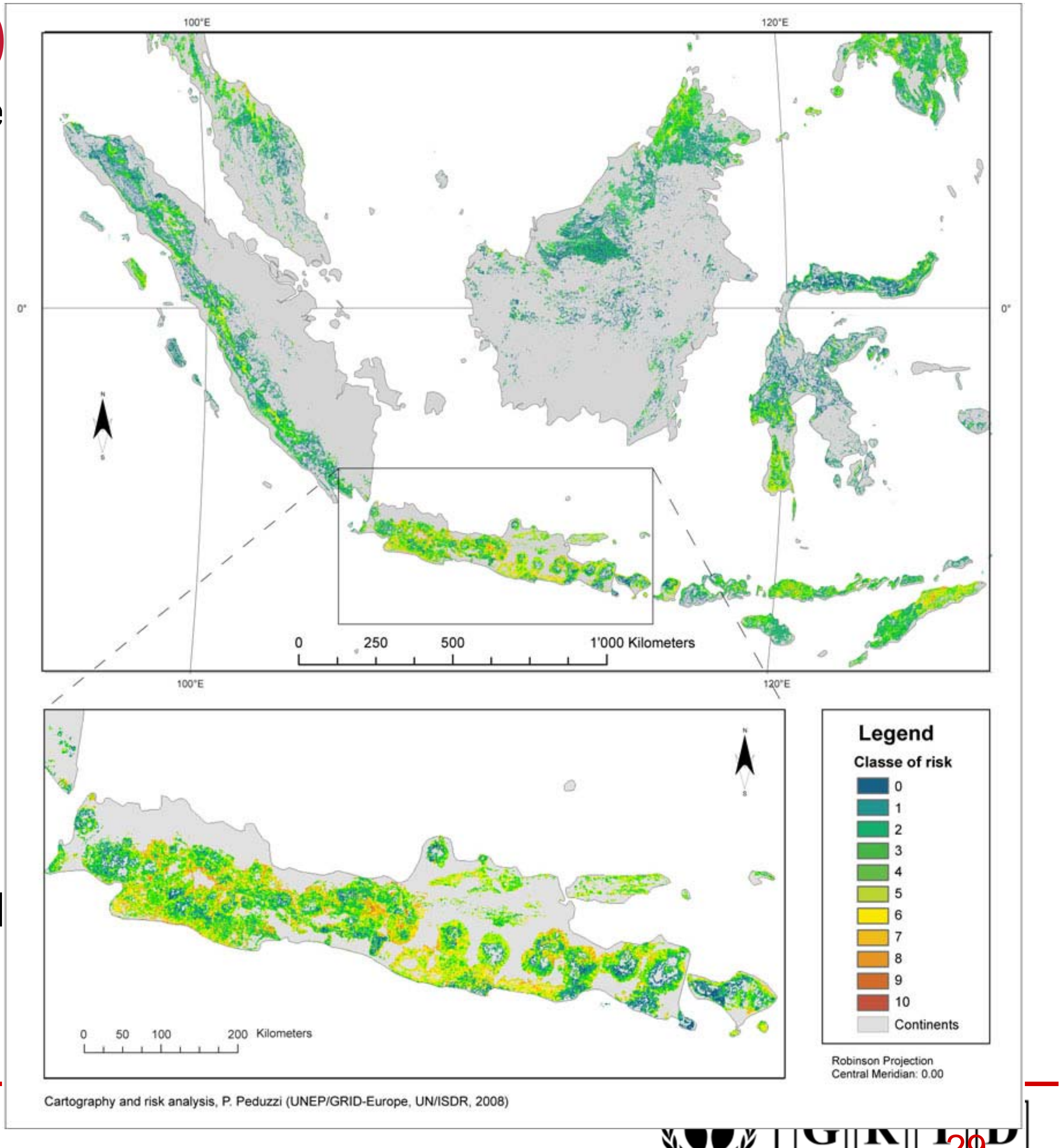
Landslides risk

Landslides (modelled for both precipitation and earthquakes)

About 2.2 million people are exposed to landslides worldwide.

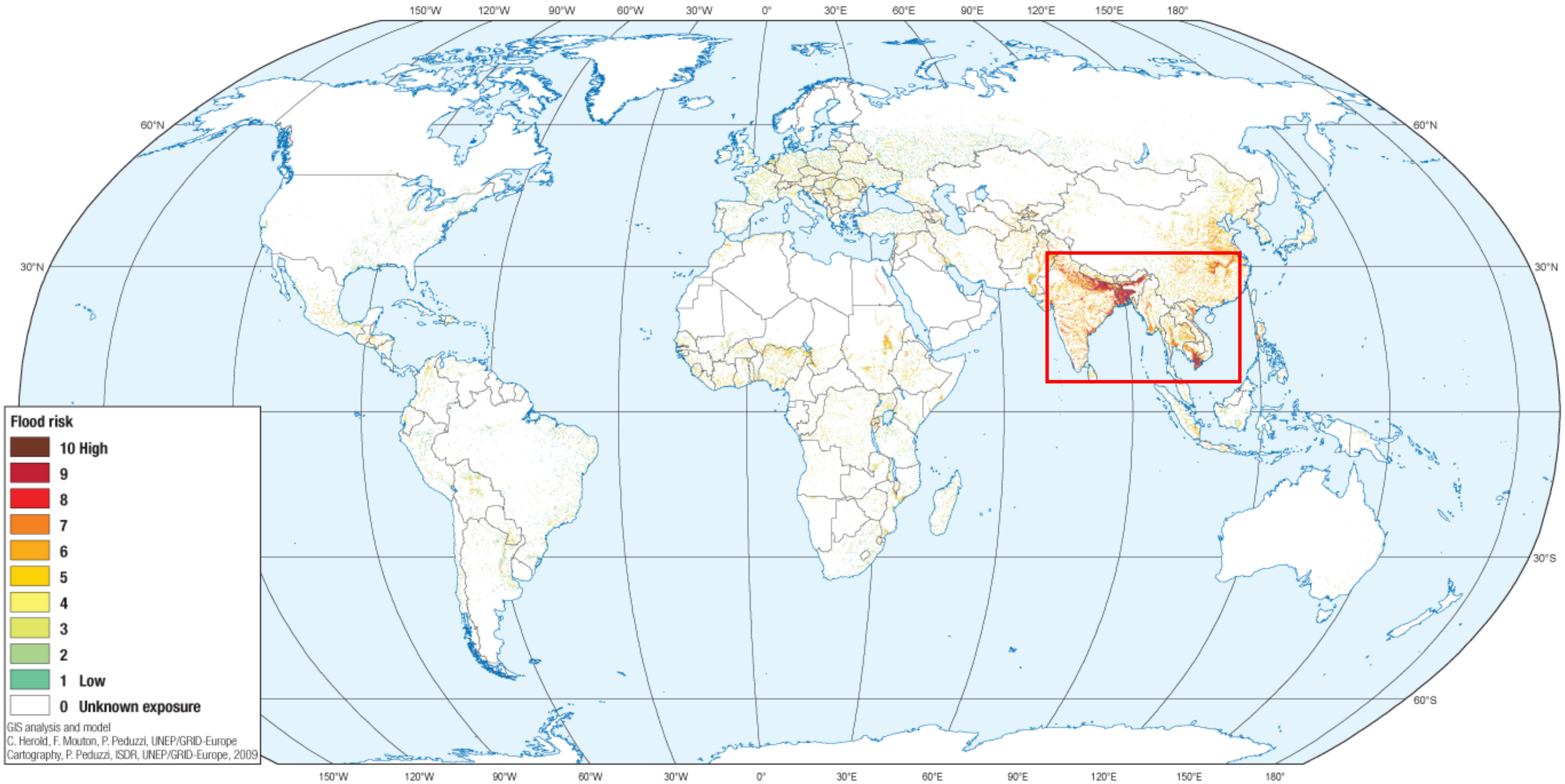
55% of mortality risk is concentrated in 10 countries, which also account for 80% of the exposure.

Comoros, Dominica, Nepal, Guatemala, Papua New Guinea, Solomon Islands, Sao Tome and Principe, Indonesia, Ethiopia, and the Philippines



Cartography and risk analysis, P. Peduzzi (UNEP/GRID-Europe, UN/ISDR, 2008)

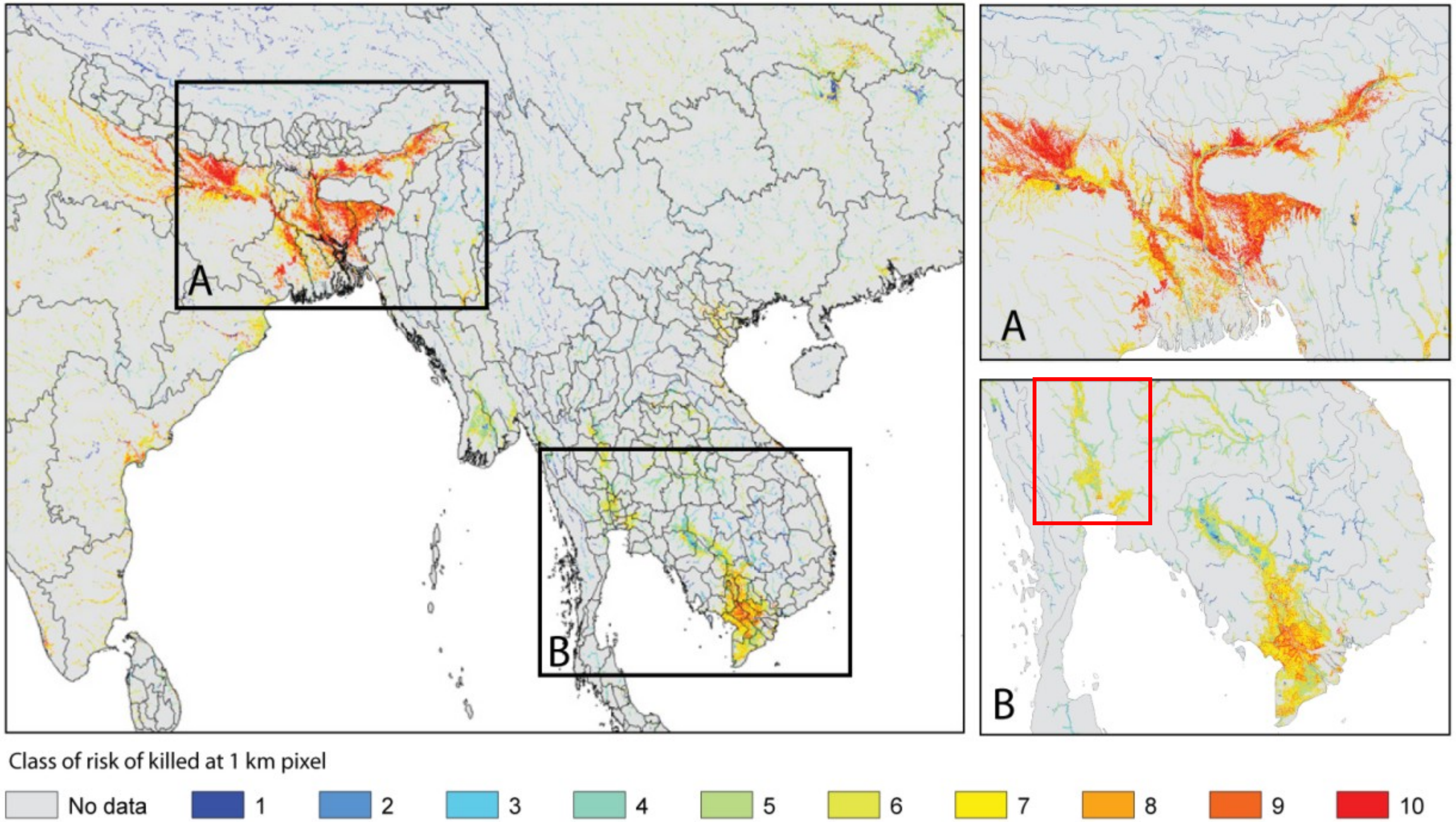
Flood risk



150°W
120°W
90°W
60°W
30°W
0°
30°E
60°E
90°E
120°E
150°E
180°
60°N
30°N
0°
30°S
60°S
Flood risk
10 High
9
8
7
6
5
4
3
2
1 Low
0 Unknown exposure
GIS analysis and model
C. Herold, F. Mouton, P. Peduzzi, UNEP/GRID-Europe
Cartography, P. Peduzzi, ISDR, UNEP/GRID-Europe, 2009

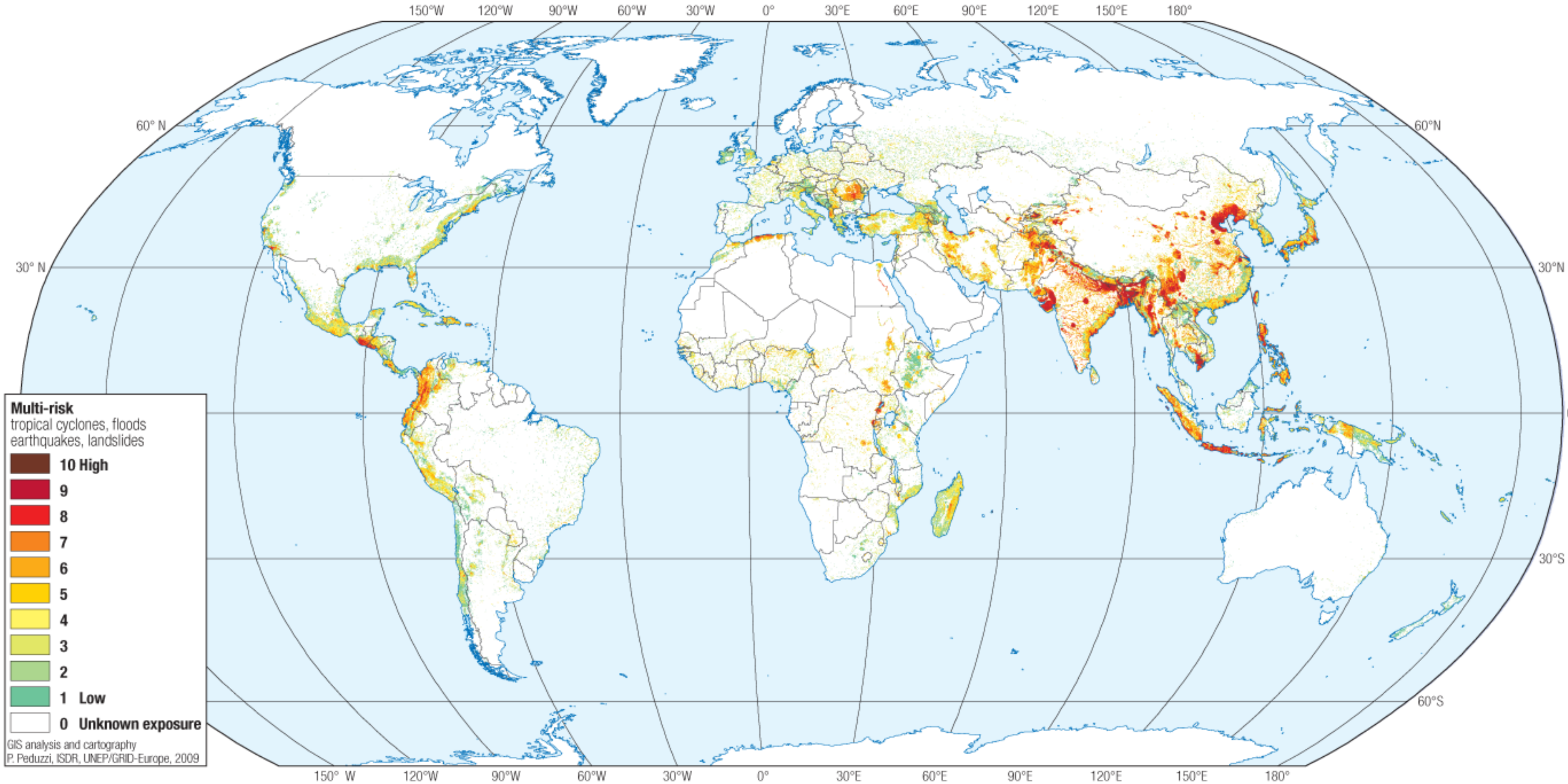
Disaster risk is intensively concentrated

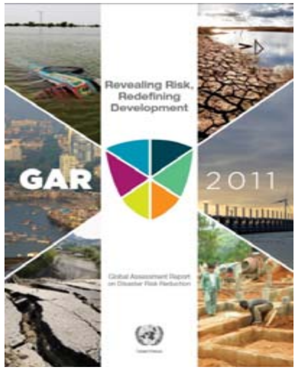
Regions of high flood mortality risk



Analysis and cartography: P.Peduzzi (UNEP/GRID-Europe, UN/ISDR), 2008

Multiple Risk

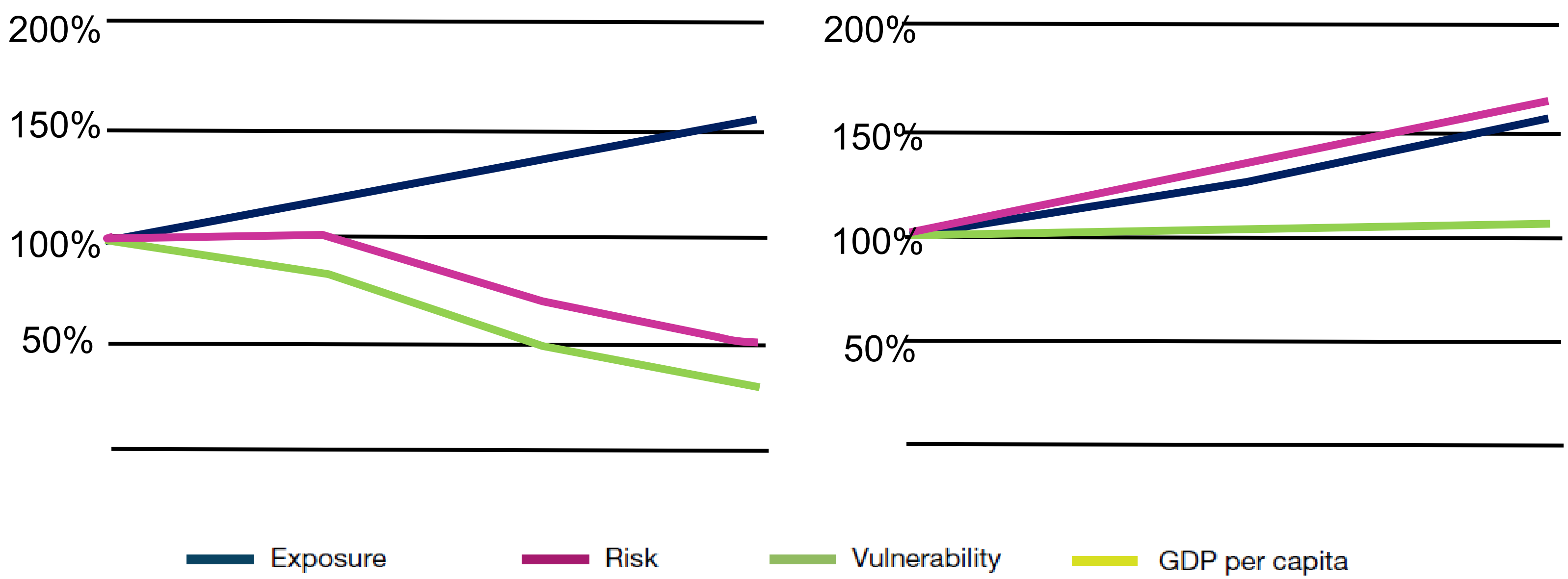




GAR 2013: trend analysis

Cyclone mortality risk

Flood economic loss risk



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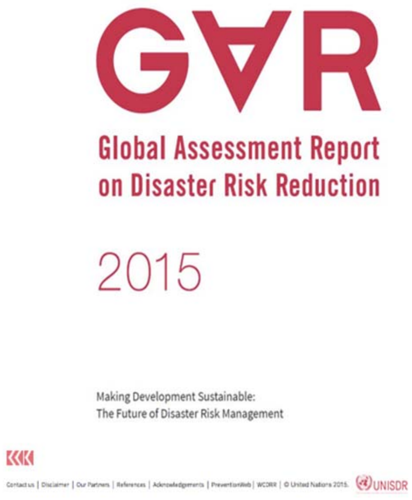
GAR 2013 and 2015 concentrated on probabilistic methodology and on economic risk



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More than 50% of world population is now urban…
… and about a third of urban population lives in slums

Vulnerability varies with the hazards and is a f(x) of intensity

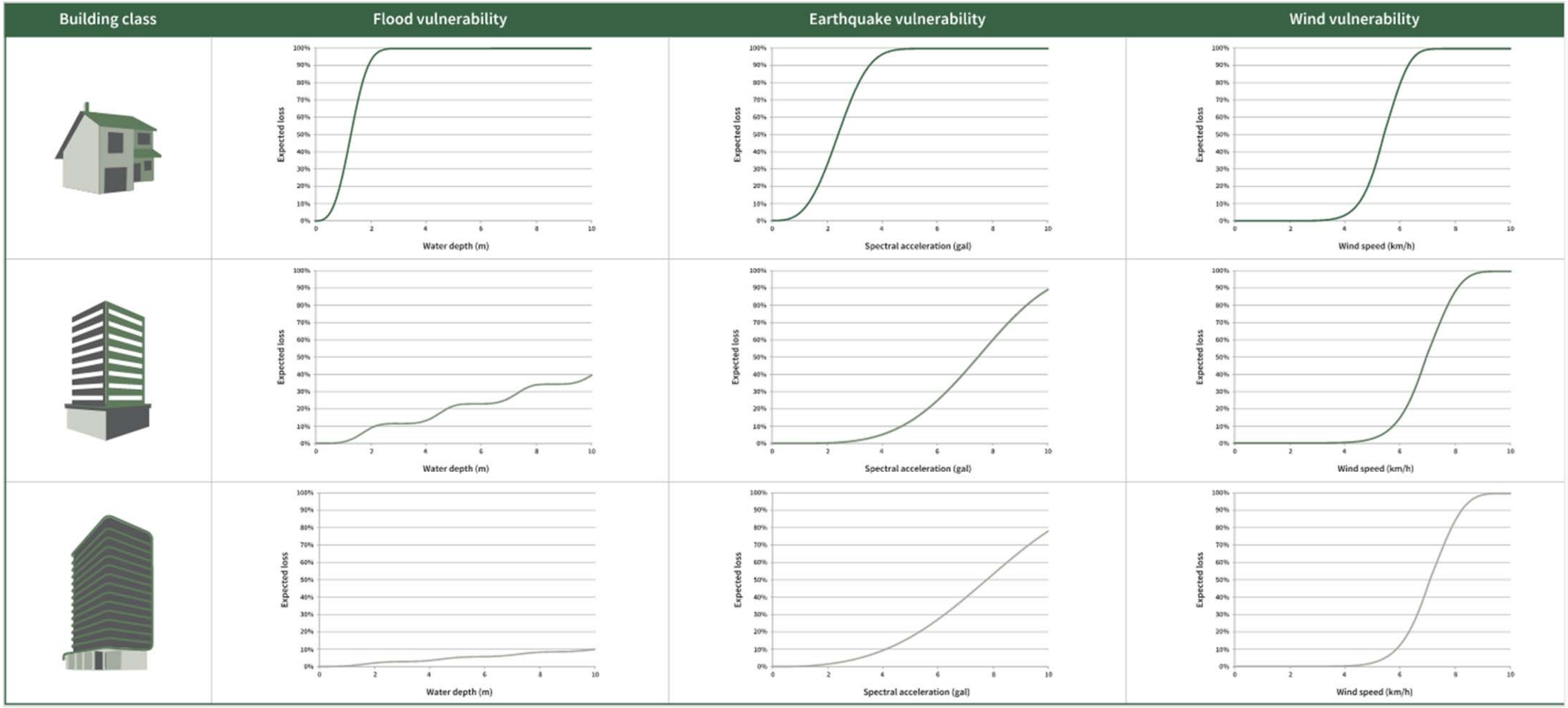
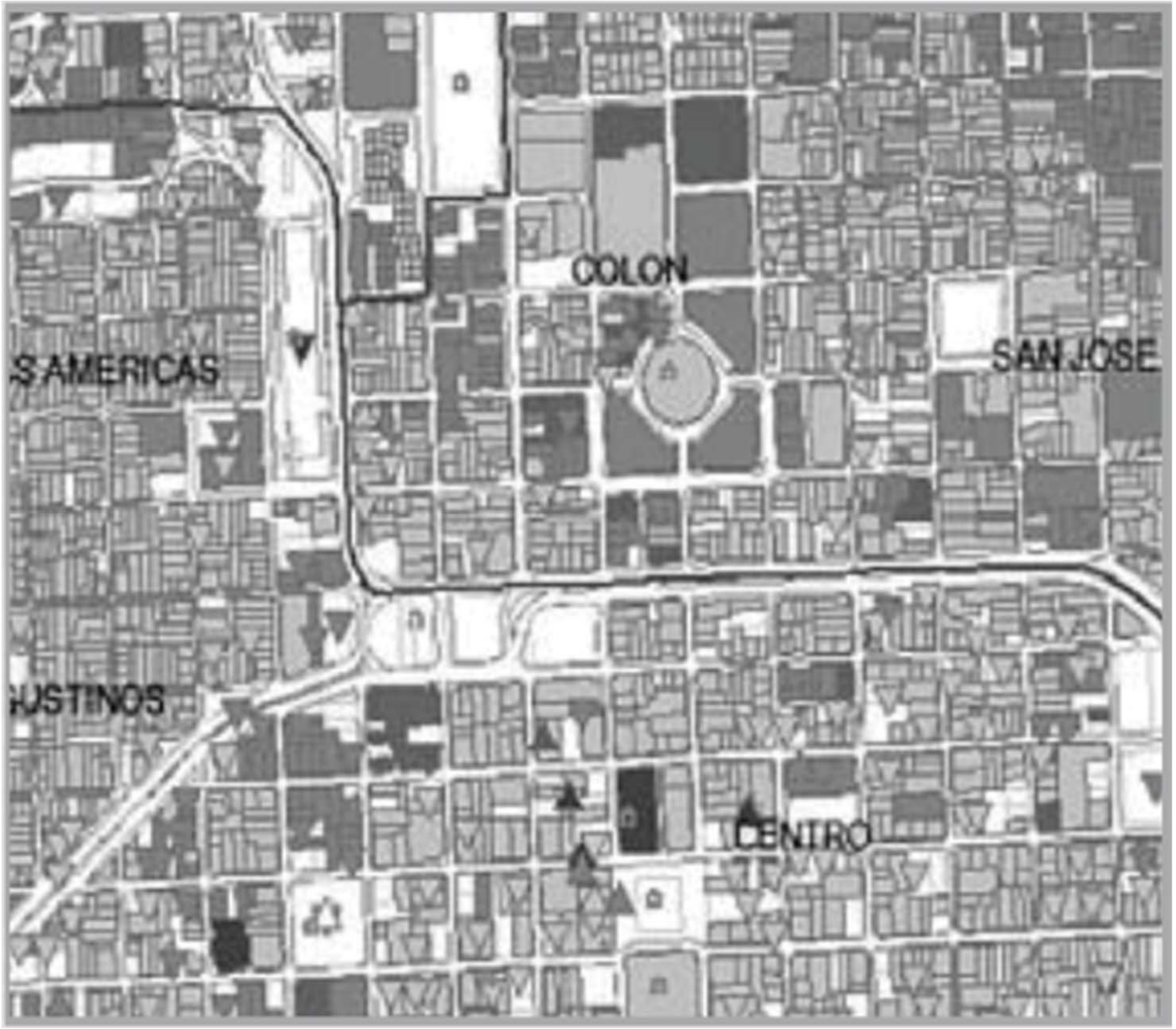
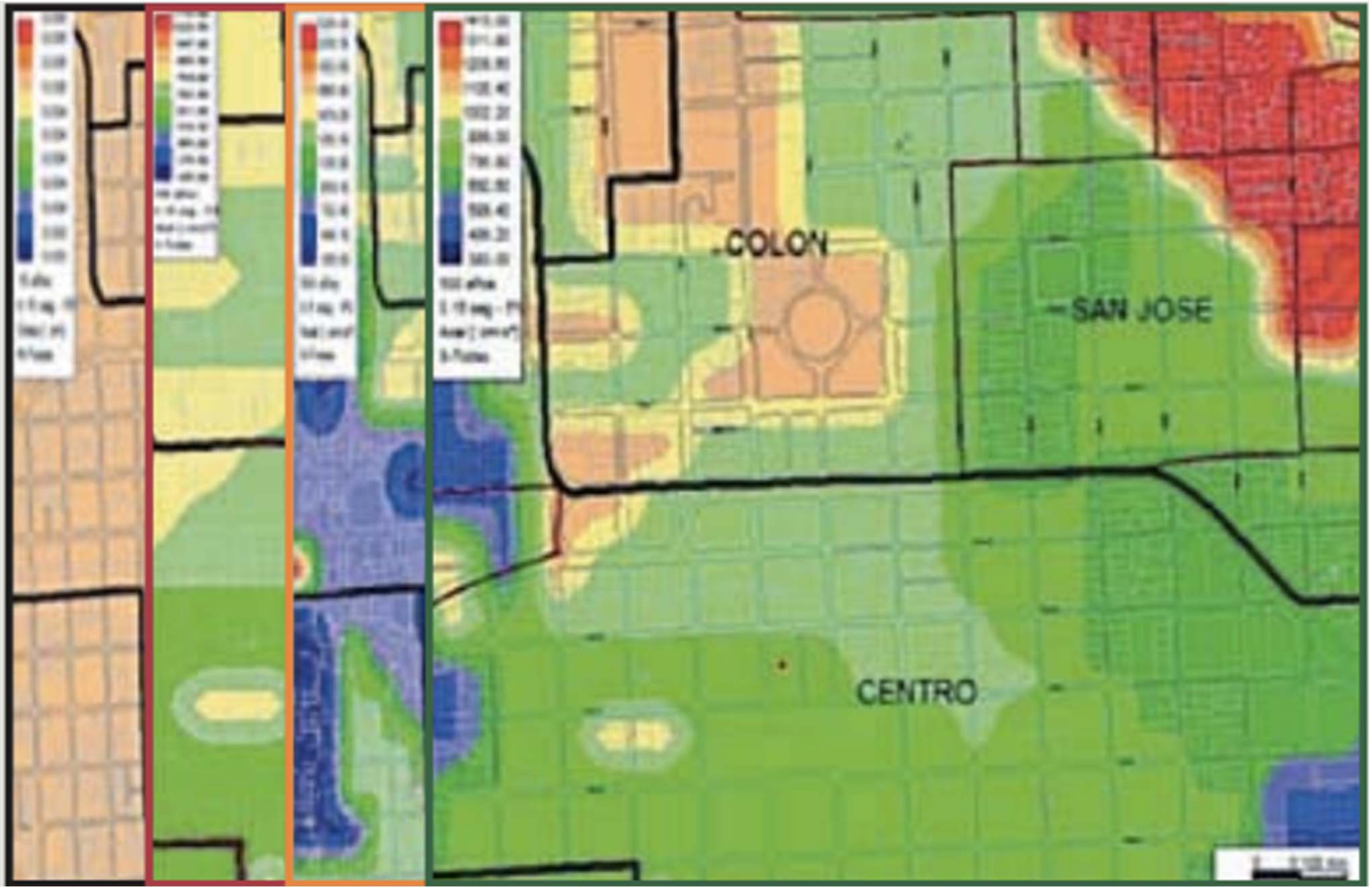


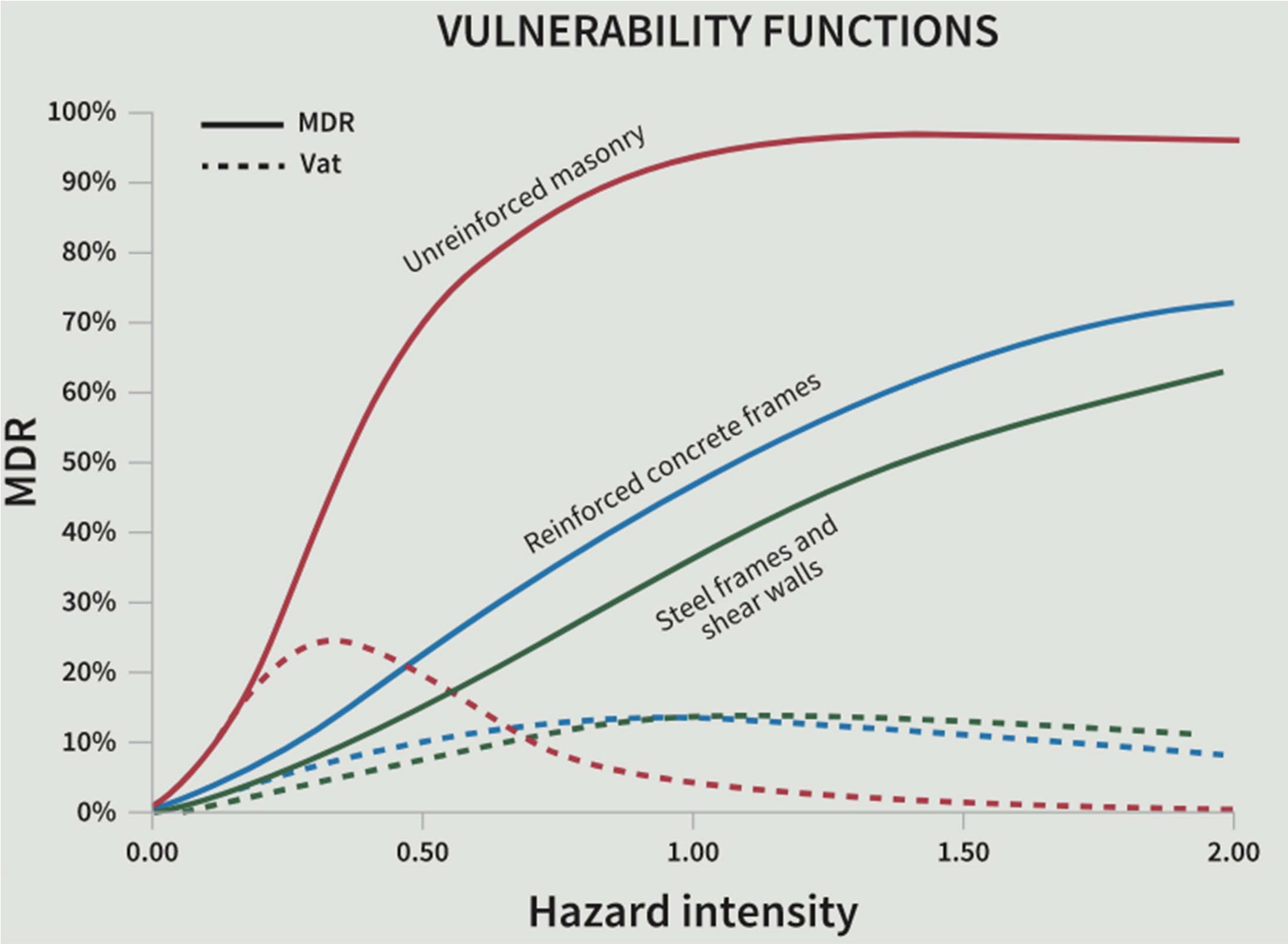
Fig.1.8 GAR Atlas 2017, adapted from Cardona et al. 2015

Exposed elements



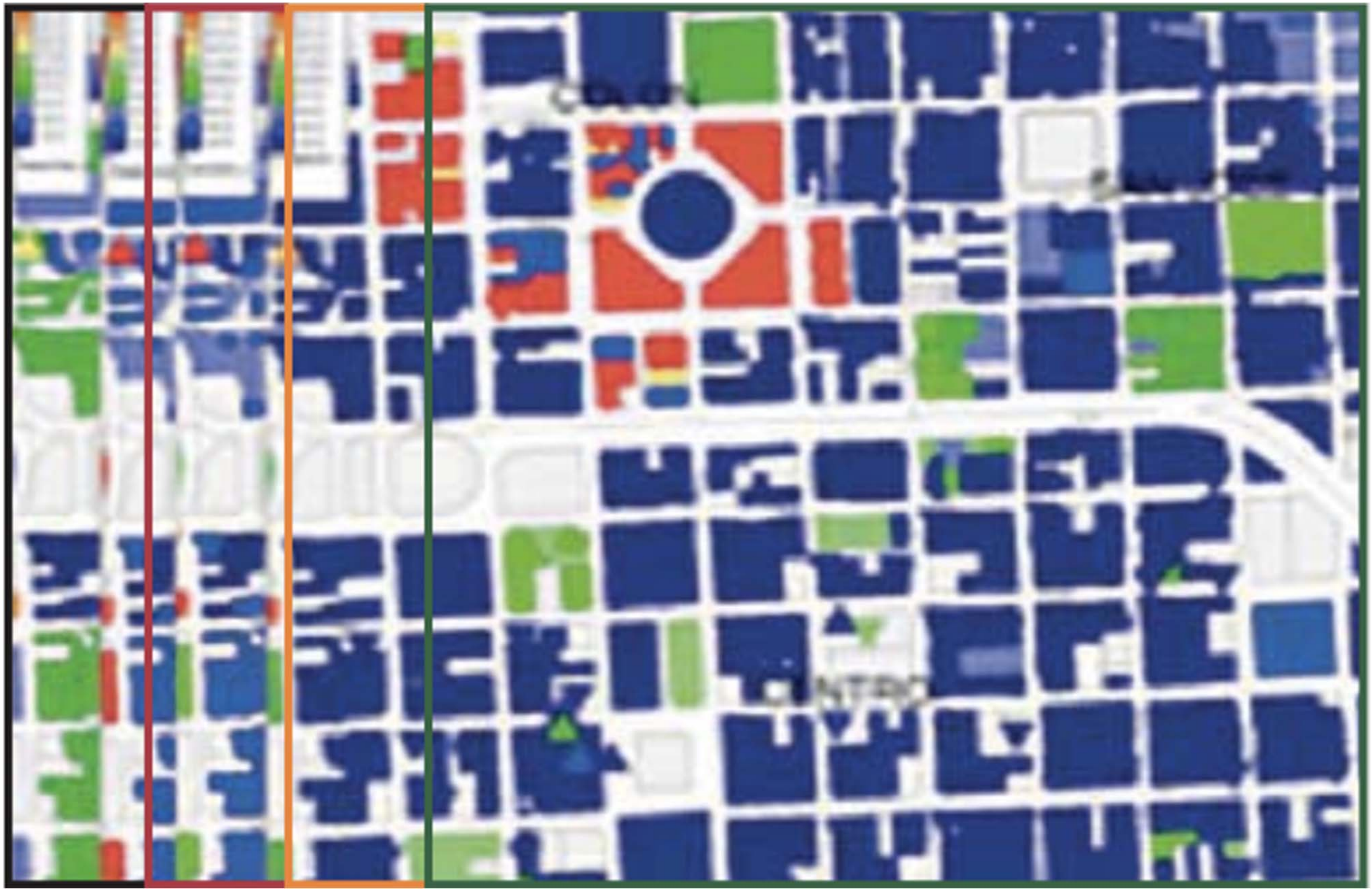
Hazard scenarios




VULNERABILITY FUNCTIONS
MDR
Vat
Unreinforced masonry
Reinforced concrete frames
Steel frames and shear walls
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
MDR
0.00
0.50
1.00
1.50
2.00
Hazard intensity

UNEP 4

Losses scenarios

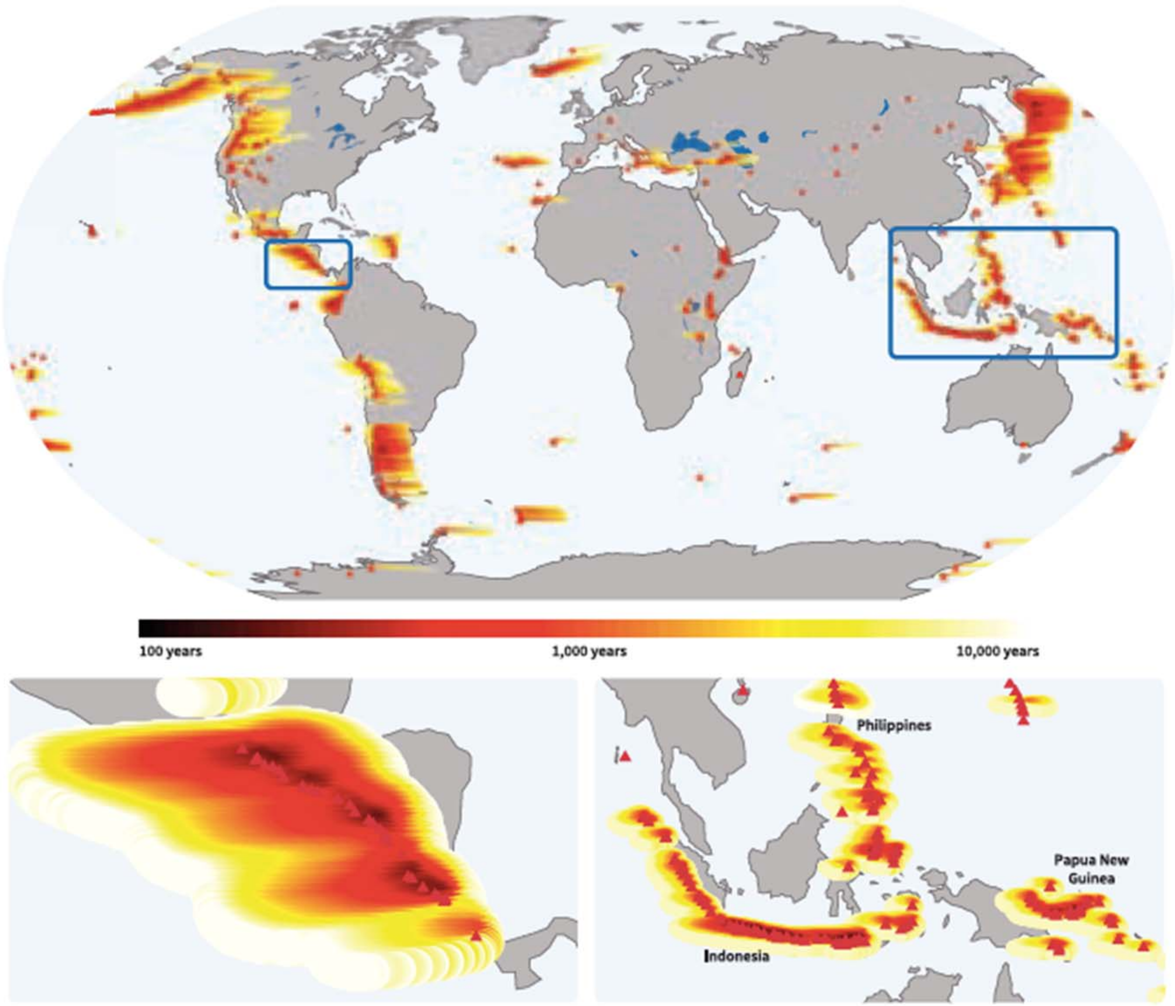


Economic risk

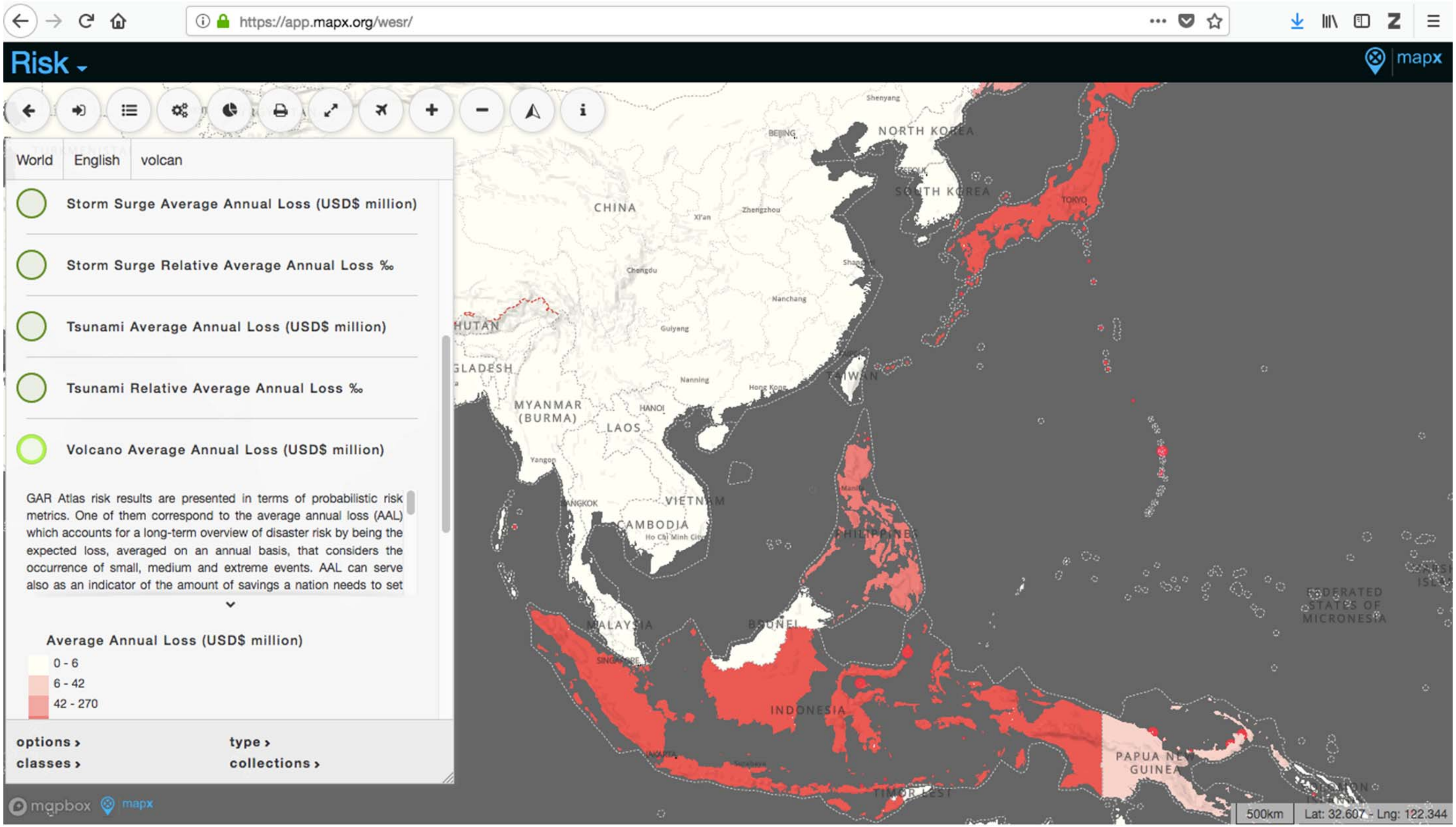
From these scenarios we can derive two figures:

- The Maximum probable loss (PML)
- The Annual Average loss (AAL)

GAR 2015, studied ash falls



Note: Displayed as the average recurrence interval of ash fall thicknesses exceeding 1 mm.


https://app.mapx.org/wesr/
Risk
mapx
World
English
volcan
Storm Surge Average Annual Loss (USD$ million)
Storm Surge Relative Average Annual Loss ‰
Tsunami Average Annual Loss (USD$ million)
Tsunami Relative Average Annual Loss ‰
Volcano Average Annual Loss (USD$ million)
GAR Atlas risk results are presented in terms of probabilistic risk metrics. One of them correspond to the average annual loss (AAL) which accounts for a long-term overview of disaster risk by being the expected loss, averaged on an annual basis, that considers the occurrence of small, medium and extreme events. AAL can serve also as an indicator of the amount of savings a nation needs to set
Average Annual Loss (USD$ million)
0 - 6
6 - 42
42 - 270
options ›
type ›
classes ›
collections ›
CHINA
NORTH KOREA
SOUTH KOREA
MYANMAR (BURMA)
LAOS
VIETNAM
CAMBODIA
PHILIPPINES
MALAYSIA
BRUNEI
INDONESIA
PAPUA NEW GUINEA
FEDERATED STATES OF MICRONESIA
500km
Lat: 32.607 - Lng: 122.344

References

De Bono, A., Mora, M.G. (2014) A global exposure model for disaster risk assessment, *Int. Jour. Disaster Risk Reduction*, **10**, 442-450.

Kundzewicz Z., Kanae S., Seneviratne S., Handmer J., Nicholls N., Peduzzi P., Mechler R., Bouwer L., Arnell N., Mach K., Muir-Wood R., Zhang X., Honda Y., Luo Y., Benito G., Takahashi K., Sherstyukov B., Brakenridge G.R., Kron W. (2014) Flood risk and climate change – global and regional perspectives, *Hydrological Sciences Journal*, **59(1)**, 1-28.

Peduzzi, P., Chatenoux, B., Dao, H., De Bono, A., Herold, C., Kossin, J., Mouton, F., Nordbeck, O. (2012) Global Trends Tropical Cyclones Risk, *Nature Climate Change*, **2**(4), 289–294.

Løvholt, F., Glimsdal, S., Harbitz, C.B., Nadim, F., Zamora, N., Peduzzi, P., Dao, H., Smebye, H. (2012) Tsunami hazard and exposure on the global scale, Earth Science Reviews, 110 (1-4), 58–73.

Giuliani, G. and Peduzzi, P. (2011) The PREVIEW Global Risk Data Platform: a geoportal to serve and share global data on risk to natural hazards, *Nat. Hazards Earth Syst. Sci.*, **11**, 53-66.

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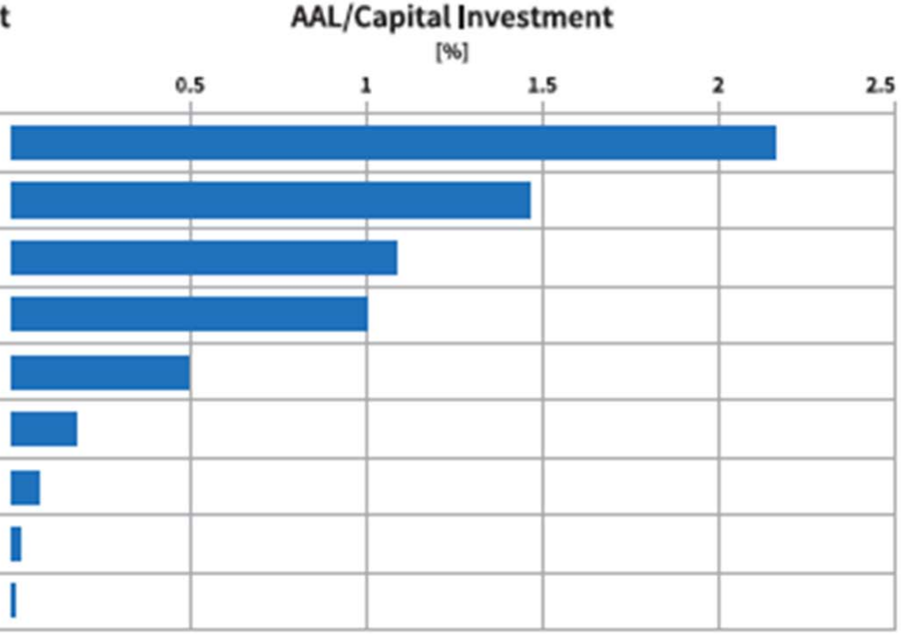
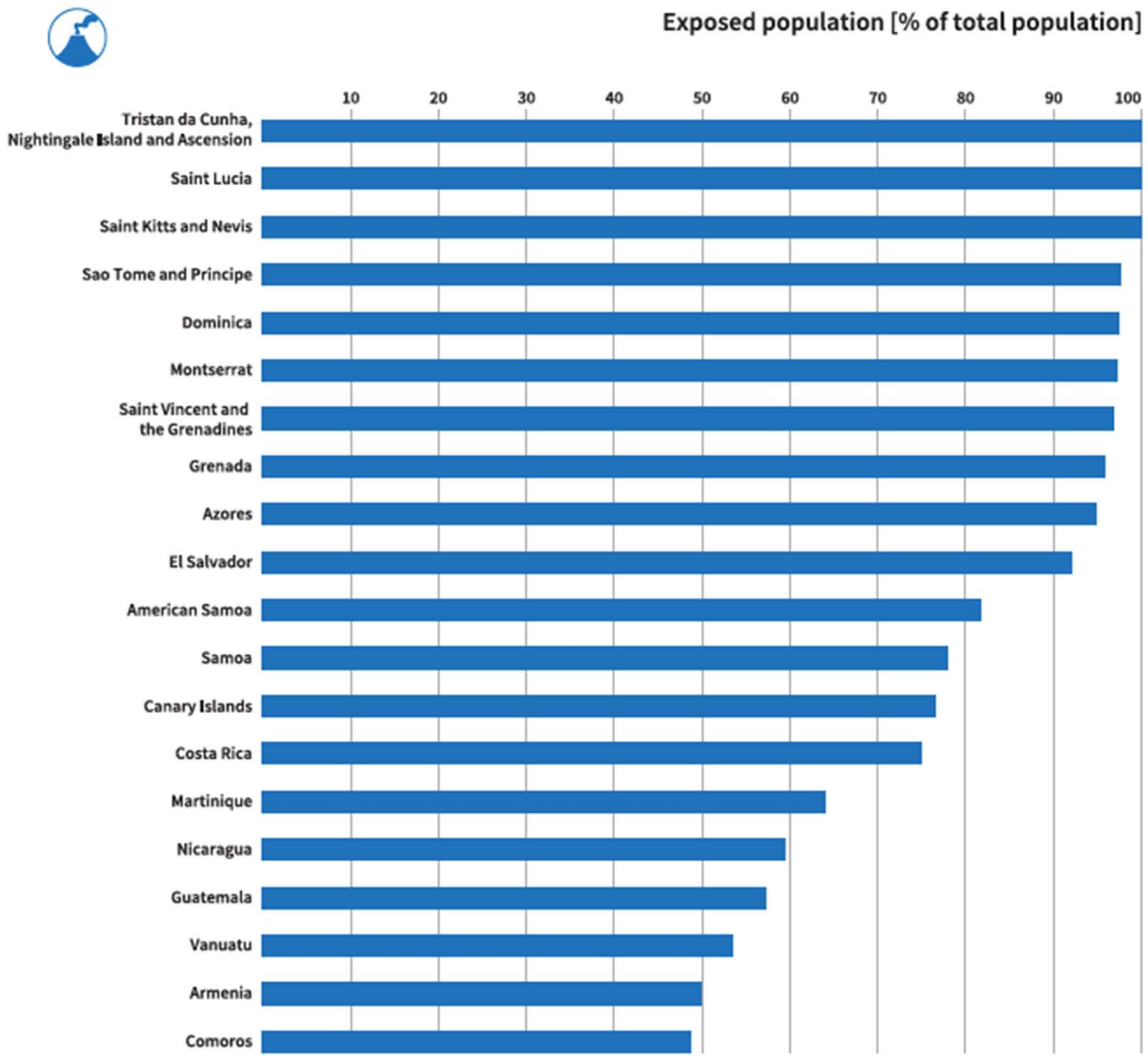
Why volcanic eruptions were not included ?

“Volcanic eruptions. The variability of volcanic hazards was too complex to be entered into a general model.
Volcanic hazard ranges from lahars linked with precipitation level, seismicity, topography and soils characteristics, to tephra falls influenced by the prevailing wind direction and strength, and phreatomagmatic eruption. Despite this complexity, much data is available for volcanic hazard and each active volcano is well described. Data needed for a global assessment of volcanic risk probably exists. But a finer resolution for elevation is needed. It would be necessary to include data on the shape and relief of volcanoes, computing slopes and hazard from lahars. Remote sensing analysis for local assessment of danger and population distribution would also be required.”

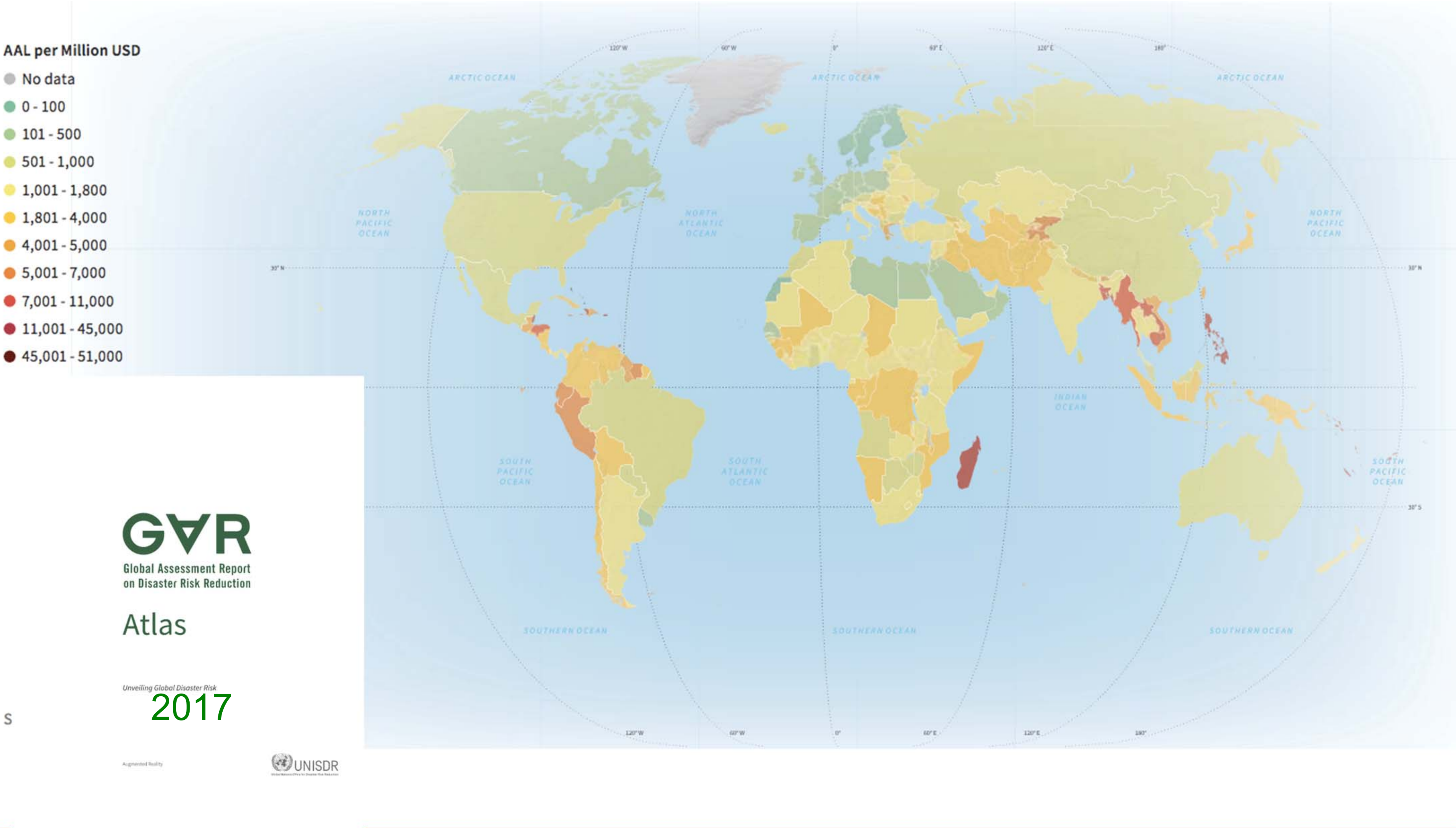
Peduzzi, P., Herold, C., Dao, H. (2005) Mapping Disastrous Natural Hazards Using Global Datasets. In: *Natural Hazards*, vol. 35, n° 2, p. 265-289.

	AAL [million US$]	Capital Investment [million US$]
Indonesia	5,929	274,944
Vanuatu	3	219
Japan	11,249	1,035,265
Philippines	558	55,645
Papua New Guinea	14	2,773
New Zealand	63	36,040
Solomon Islands	1	147
Russian Federation	88	450,239
Taiwan, Province of China	3	92,729




Exposed population [% of total population]
10
20
30
40
50
60
70
80
90
100
Tristan da Cunha, Nightingale Island and Ascension
Saint Lucia
Saint Kitts and Nevis
Sao Tome and Principe
Dominica
Montserrat
Saint Vincent and the Grenadines
Grenada
Azores
El Salvador
American Samoa
Samoa
Canary Islands
Costa Rica
Martinique
Nicaragua
Guatemala
Vanuatu
Armenia
Comoros

Global multi-hazards AAL relative to capital stock



UNEP | GRID Geneva


cm/s²
100 - 175
176 - 250
251 - 325
325 - 400
> 400
MEXICO
GULF OF MEXICO
BAHAMAS
ATLANTIC OCEAN
DOMINICAN REPUBLIC
JAMAICA
HAITI
GUADELOUPE
BARBADOS
TRINIDAD AND TOBAGO
VENEZUELA
GUYANA
SURINAME
FRENCH GUIANA
COLOMBIA
PANAMA
ECUADOR
Equator
PERU
BRAZIL
PACIFIC OCEAN
BOLIVIA
PARAGUAY
ARGENTINA
Seismic hazard
Latin America and the Caribbean

GRID Geneva


(meters)
< 1
1.1 - 3.0
3.1 - 5.0
5.1 - 7.0
> 7.1
GULF OF MEXICO
BAHAMAS
ATLANTIC OCEAN
MEXICO
CUBA
DOMINICAN REPUBLIC
JAMAICA
HAITI
GUADELOUPE
MARTINIQUE
BARBADOS
TRINIDAD AND TOBAGO
EL SALVADOR
COSTA RICA
PANAMA
SURINAME
FRENCH GUIANA
Equator
Equator
PERU
BRAZIL
PACIFIC OCEAN
BOLIVIA
CHILE
FALKLAND ISLANDS (MALVINAS)
Riverine Floods hazard
Latin America and the Caribbean

GAR 2019 and further

There are three different links between environment and risk

1) The decline of ecosystems is leading to further risk
2) The industrialization is leading to increase risk of Natech hazards.
3) New substances and pollution are adding new threats to health.

e.g. Air pollution kills 6 million per year.
New chemical substances are adding to new risk of cancer.