RISKS OF EXPOSURES OF WORLD'S CITIES TO NATURAL HAZARDS

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Outline

1. Rationale & Objectives
2. Data Sources and Methods
3. Major Findings
4. Limitations

Why Study Cities and Risk of Natural Disasters

1. Homes for half of world's population today (UN, 2012)
2. Centers of productive activities in industries and services;
    - 70-80% GDP produced in urban areas (Weiss, 2001; Dobbs et al. 2011).

    … causing environmental problems
    - 75-80% emissions of carbon dioxide by cities (Satterthwaite, 2008).
3. Natural hazards: 2000-2012, 2.9 billion people affected and 1.2 million killed, $1.7 trillion (damage) (UNISDR, 2013)
    - $73 billion in 1960s, and $630 billion in 1990s (Guin & Saxena, 2005)
4. Insufficient knowledge and awareness about risks of exposures of city population to natural hazards, environmental degradations, and climate change

Sources: 2011 WUP database (UNPD)

Objectives

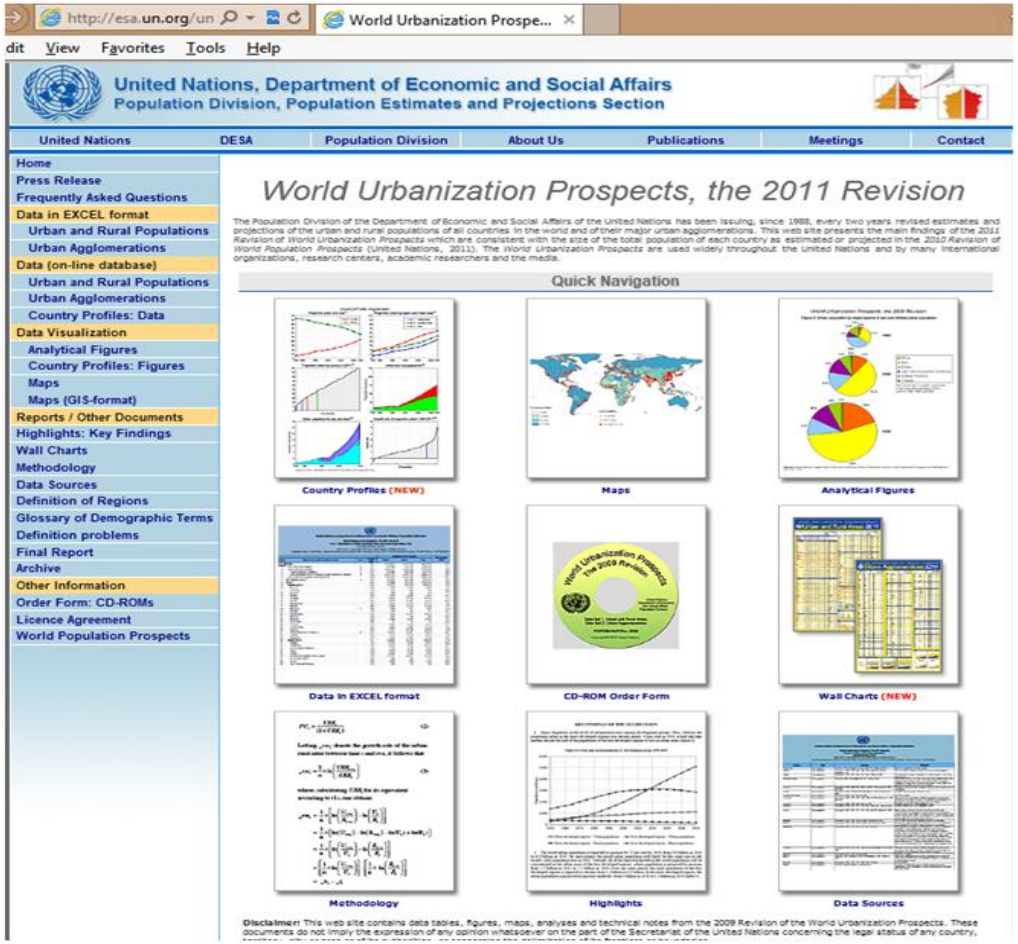
1. Investigate potential risks of exposures of world's cities to natural hazards
2. Which cities are the most exposed to the most risks?
3. Which fastest growing cities are the most exposed to higher risks?
4. What are the greatest risks the most populous cities are exposed to?
5. What largest cities have the least exposure?

Sources: 2011 WUP database (UNPD)

Data Sources: City Population

1. World Urbanization Prospects (WUP): 2011 Revision

- **633 cities** with 750K+ residents in mid-2011 + centroid & 2km buffer



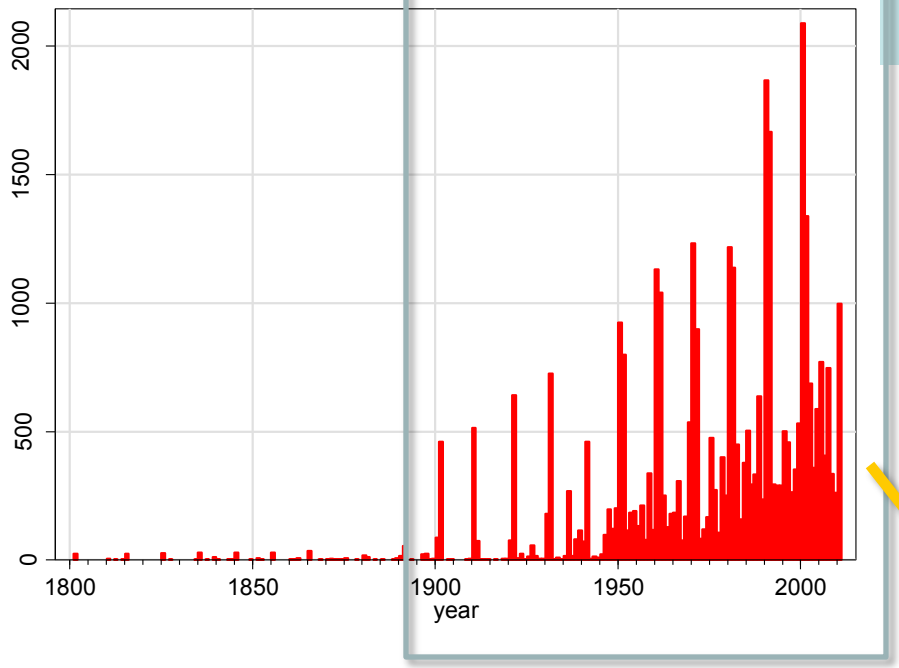
http://esa.un.org/unup/

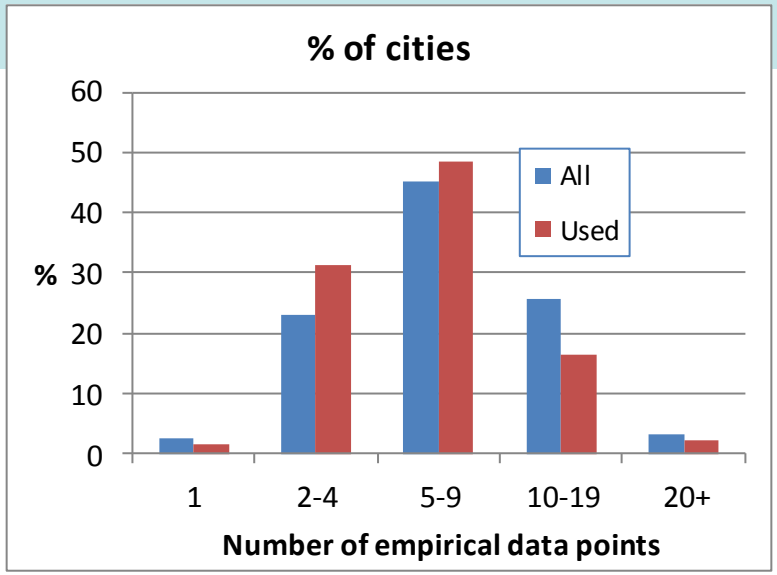
UN World Urbanization Prospects

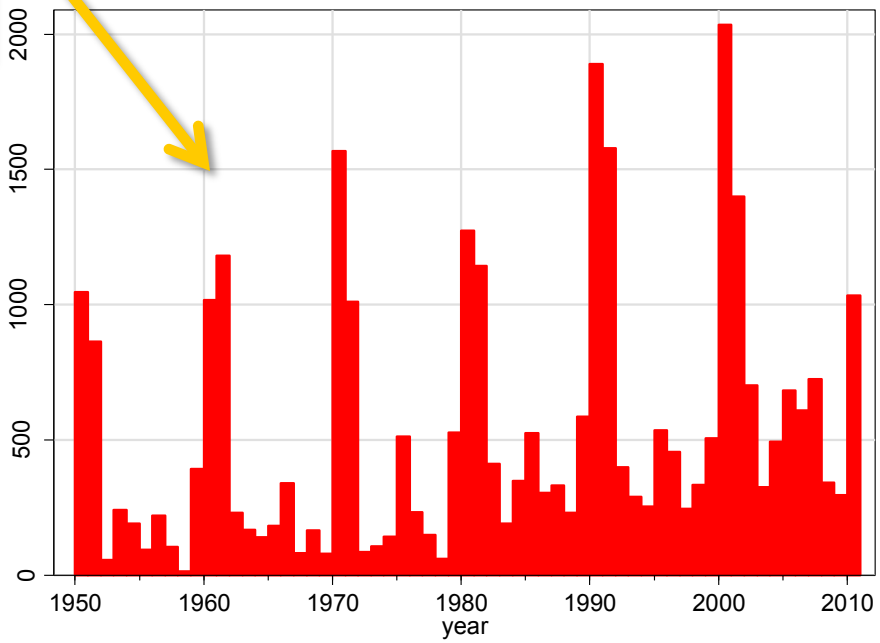
- City population data for **>5,360 urban locations** in 231 countries/areas in 2011
- Observed data points in database: >46,000
- Observed data points directly **used** for estimates and projections: >37,000 (80%)
- Published city populations (1950-2030) for urban locations with 750,000 inhabitants or more in 2011: 633 urban locations (11% of city database)

Sources: 2011 WUP database (UNPD)

WUP coverage: City Populations

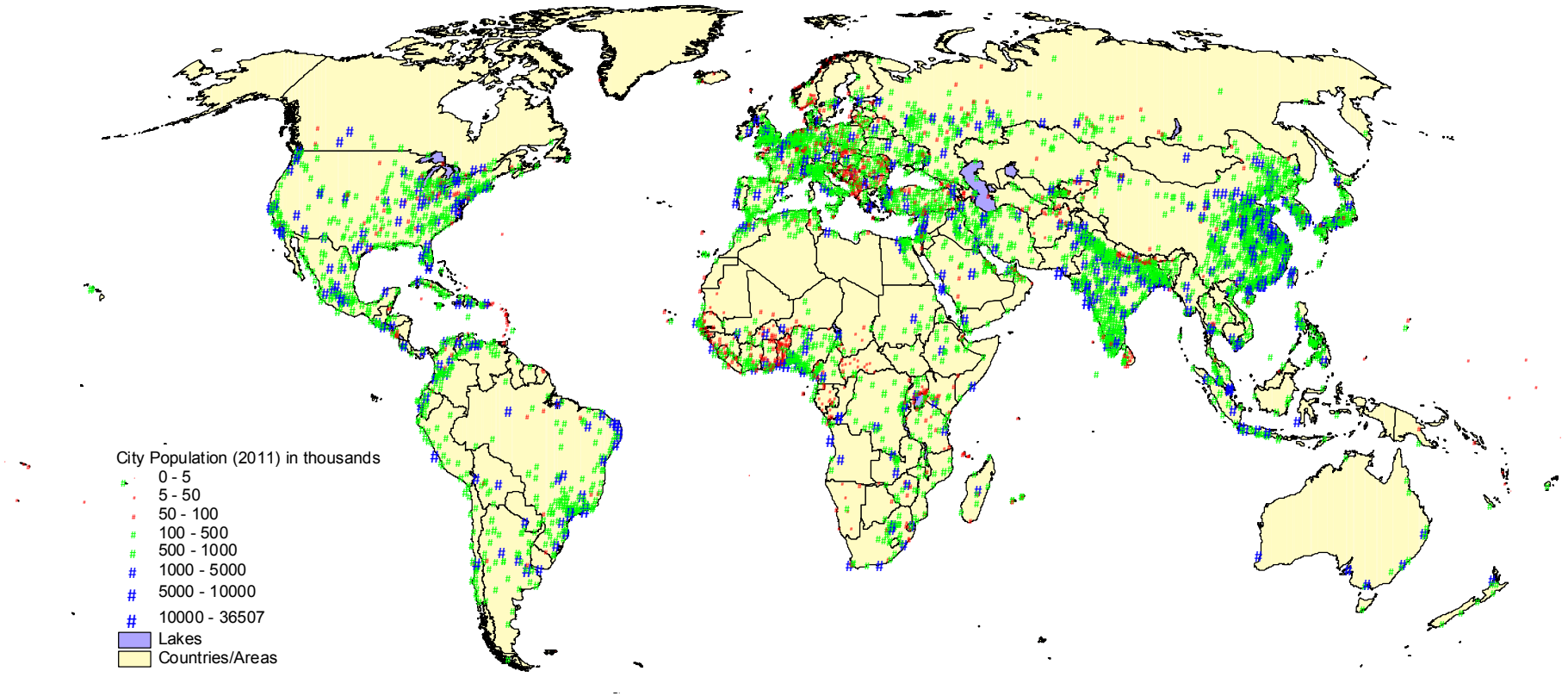






Mean number of empirical data points per city: 7 (st.dev. 4)

WUP cities by size class (2011)



Note: The boundaries shown on this map do not imply official endorsement or acceptance by the United Nations.

WUP coverage: City Populations

Size class for City pop. (2011)	Freq.	Percent	Cumul.
< 5,000	45	0.9	100.0
5,000-50,000	606	11.6	99.1
50,000-100,000	811	15.6	87.5
100,000-500,000	2,770	53.2	71.9
500,000-1,000,000	528	10.1	18.7
1-5 Millions	389	7.5	8.6
5-10 Millions	38	0.7	1.1
> 10 Millions	23	0.4	0.4
Total	5,210	100.0	

Sources: 2011 WUP database (UNPD)

Data Sources: GIS layers

(2) Spatial data on natural hazards (mainly in 1980-2000)

- **CIESIN** (Center for International Earth Science Information Network), Center for Hazards and Risk Research (CHRR); International Research Institute for Climate Prediction (IRI); Lamont-Doherty Earth Observatory (LDEO) at Columbia University; Hazard Management Unit (HMU); World Bank

  Dilley et al. (2005). Natural Disaster Hotspot: A Global Risk Analysis (http://www.ldeo.columbia.edu/chrr/research/hotspots/).

  - **6 hazards (grid cells): cyclones and landslides** (30”X30”, ~1 km at the equator**), earthquakes and volcanoes** (2.5’X2.5’, ~4.6 km at the equator**), floods** (1°X1°, ~110 km at the equator**), droughts** (2.5°X2.5°, ~280 km at the equator)
  - **grid cells are divided into deciles**:

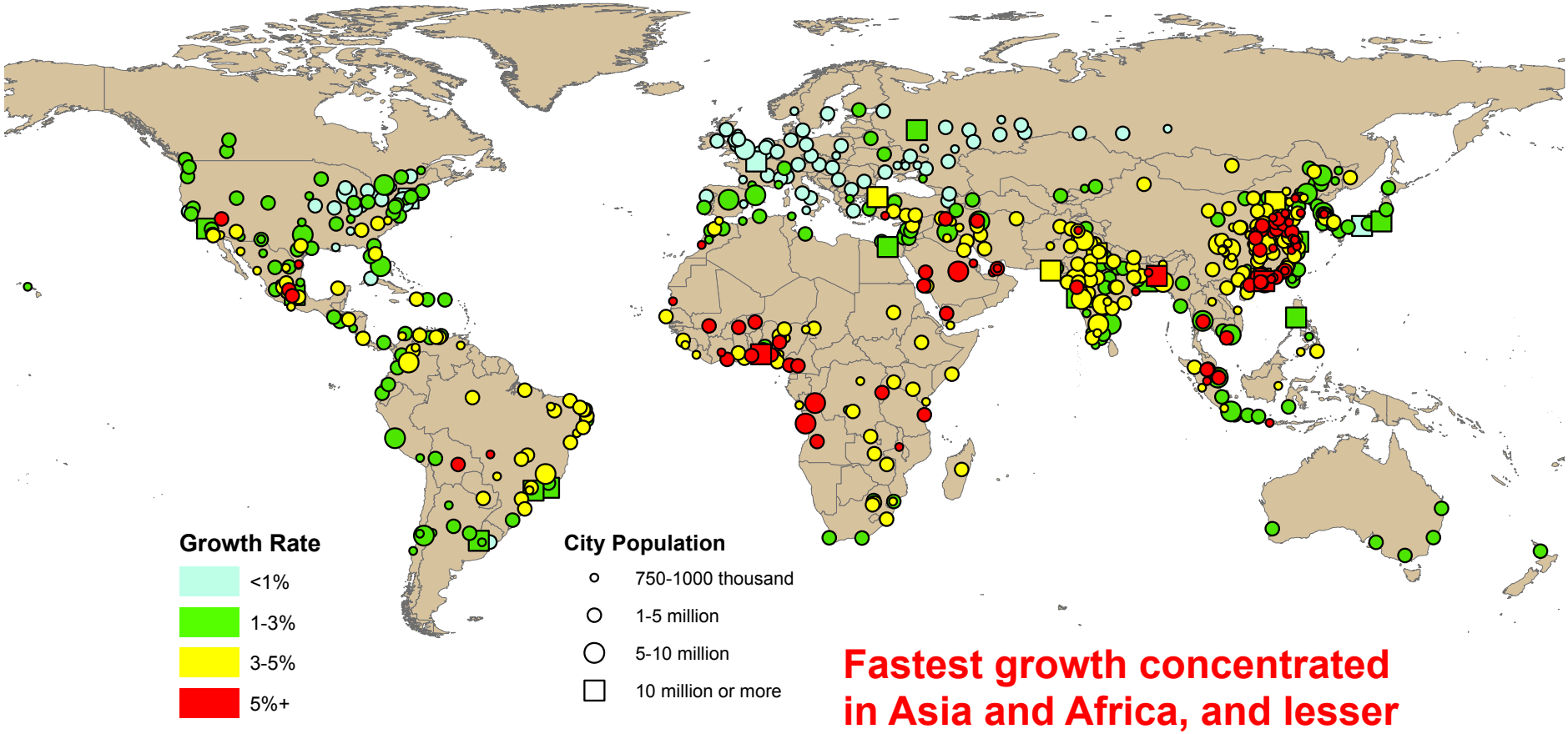
    high risk 8-10th decile;
    medium risk 5-7th decile
    low risk: 1-4th decile
  - **multi-hazard index**: summation of 8-10th decile of each hazard

(3) Coastal/Inland city classification

- **Millennium Ecosystem Assessment** (2003): coastal areas are defined as areas between 50 meters below mean sea level and 50 meters above the high tide level or extending landward to a distance of 100 kilometers from shore

1. Growth of World's Cities, 1970-2011

Distribution of cities by 2011 pop. size and 1970-2011 growth rate



Fastest growth concentrated in Asia and Africa, and lesser extent Latin America

Note: The boundaries shown on this map do not imply official endorsement or acceptance by the United Nations.

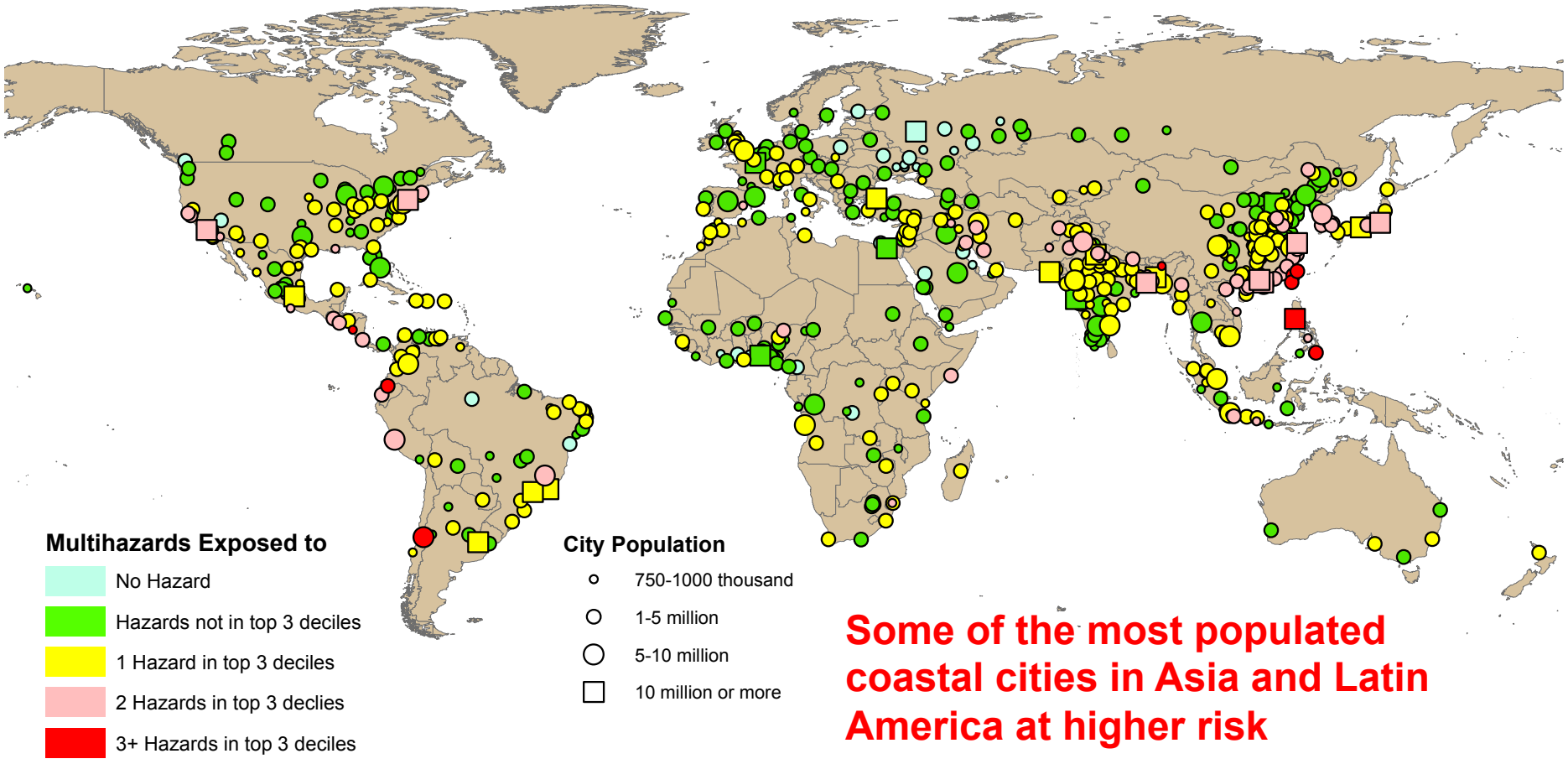
Overall exposure to natural hazards

1. Among inhabitants of major urban centers, more than 60% of city residents today at risk of at least one natural hazard

1) In 2011, 374 out of 633 cities (or 977 million people) face a relatively high risk of exposure to 1+ hazard;
2) 98 cities are exposed to 2+ hazards;
3) 17 of 23 megacities in 2011 are exposed to 1+ hazard;
4) Cities in Europe and Africa are least exposed to relatively high risks of hazards.

Exposure to multiple risks

Distribution of cities by 2011 pop. size and risks of multiple natural hazards



Some of the most populated coastal cities in Asia and Latin America at higher risk

Note: The boundaries shown on this map do not imply official endorsement or acceptance by the United Nations.

Overall exposure to natural hazards

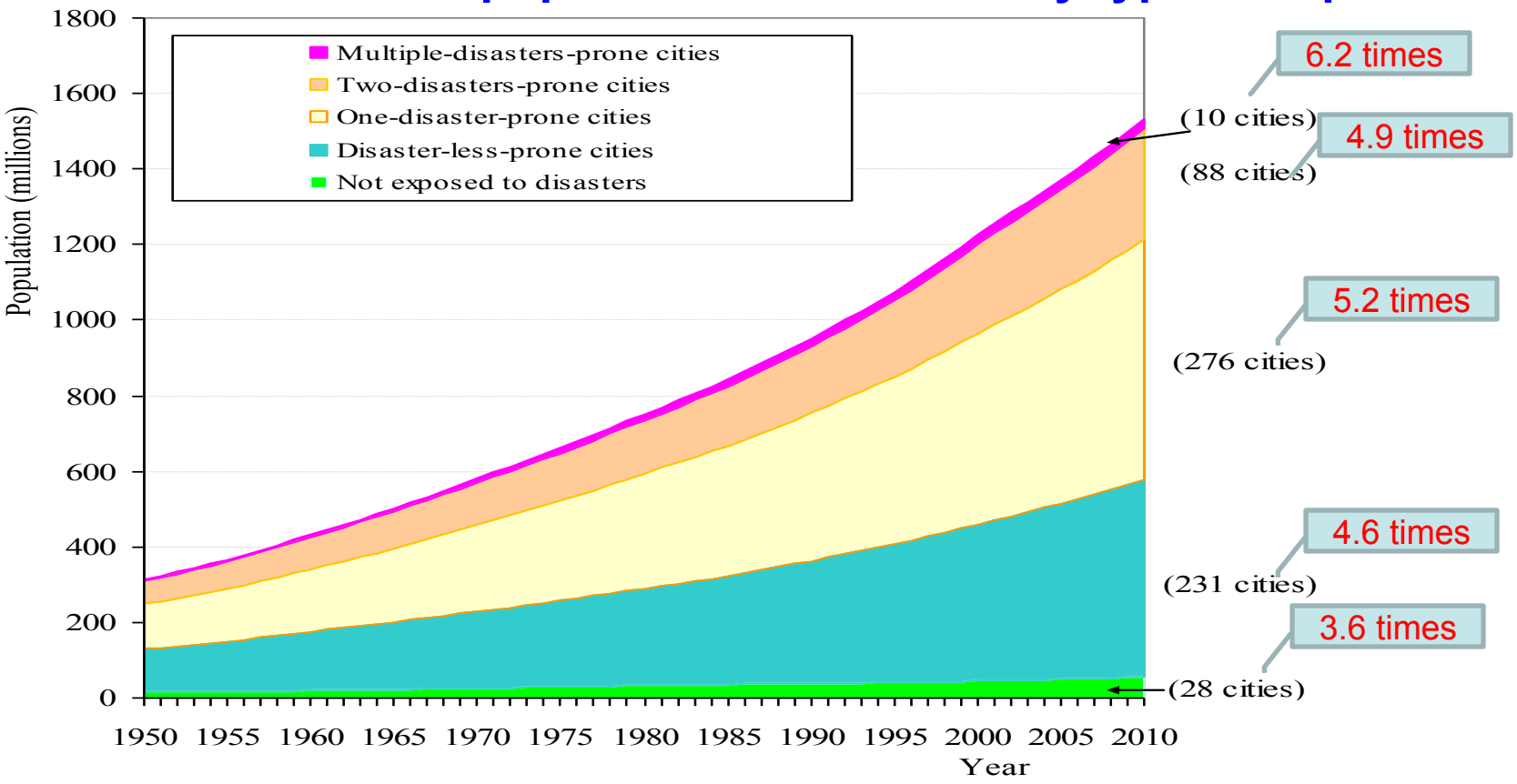
Major urban areas (750,000+ inhabitants in 2011) exposed to three or more natural hazards (8-10th risk deciles of natural disasters)

		Population (in million)			Risk decile					
	City	2011	Location	Type	Cyclones	Droughts	Earthquakes	Floods	Landslides	Volcanoes
1	Manila, Philippines	11.9	Coastal	Not Arid	8-10th	1st-4th	8-10th	8-10th	No hazard	No hazard
2	Santiago, Chile	6.0	Inland	Semiarid	No hazard	8-10th	8-10th	8-10th	No hazard	No hazard
3	Taipei, China	2.7	Inland	Not Arid	8-10th	No hazard	8-10th	8-10th	8-10th	No hazard
4	Quito, Ecuador	1.6	Inland	Not Arid	No hazard	8-10th	8-10th	8-10th	8-10th	8-10th
5	Davao, Philippines	1.6	Coastal	Not Arid	8-10th	1st-4th	8-10th	8-10th	No hazard	No hazard
6	Kaohsiung, China	1.5	Coastal	Not Arid	8-10th	No hazard	8-10th	5-7th	8-10th	No hazard
7	Taichung, China	1.2	Inland	Not Arid	8-10th	No hazard	8-10th	8-10th	5-7th	No hazard
8	Guwahati (Gauhati), India	1.0	Inland	Not Arid	No hazard	8-10th	8-10th	8-10th	No hazard	No hazard
9	Managua, Nicaragua	1.0	Inland	Not Arid	1st-4th	8-10th	8-10th	8-10th	No hazard	No hazard
10	Valparaíso, Chile	0.9	Coastal	Not Arid	No hazard	8-10th	8-10th	8-10th	No hazard	No hazard

Growing exposure to multiple risks

2.Population living in areas exposed to at least one type of natural disaster increased by 5.2 times in 60 years (vs. 4.4 times for less prone)

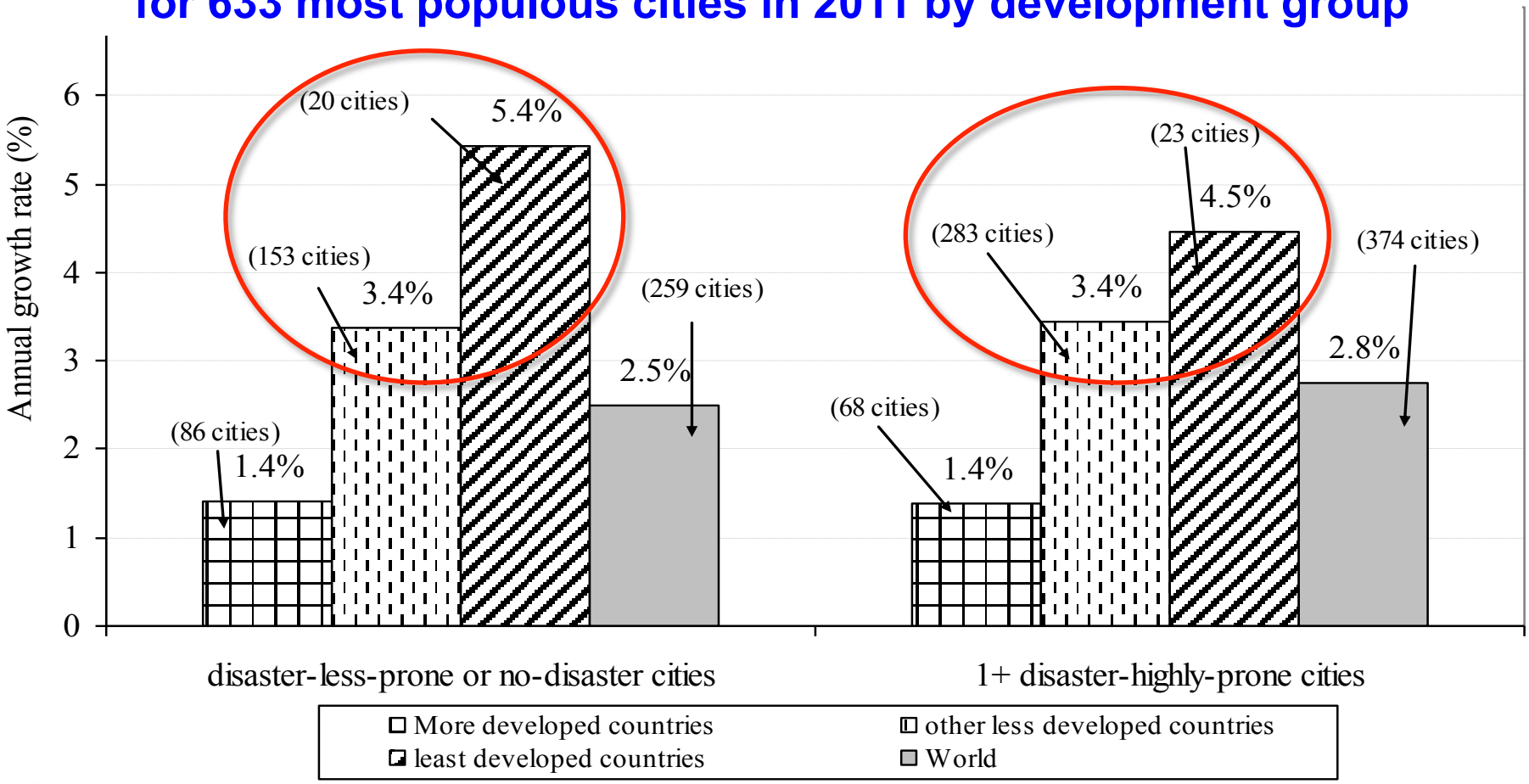
Population of the 633 most populous cities in 2011 by type of exposure



Growing exposure to multiple risks

3. Cities in less developed countries are at higher risk of natural disasters and have faster growth

Average annual population growth rate in 1950-2010 for 633 most populous cities in 2011 by development group



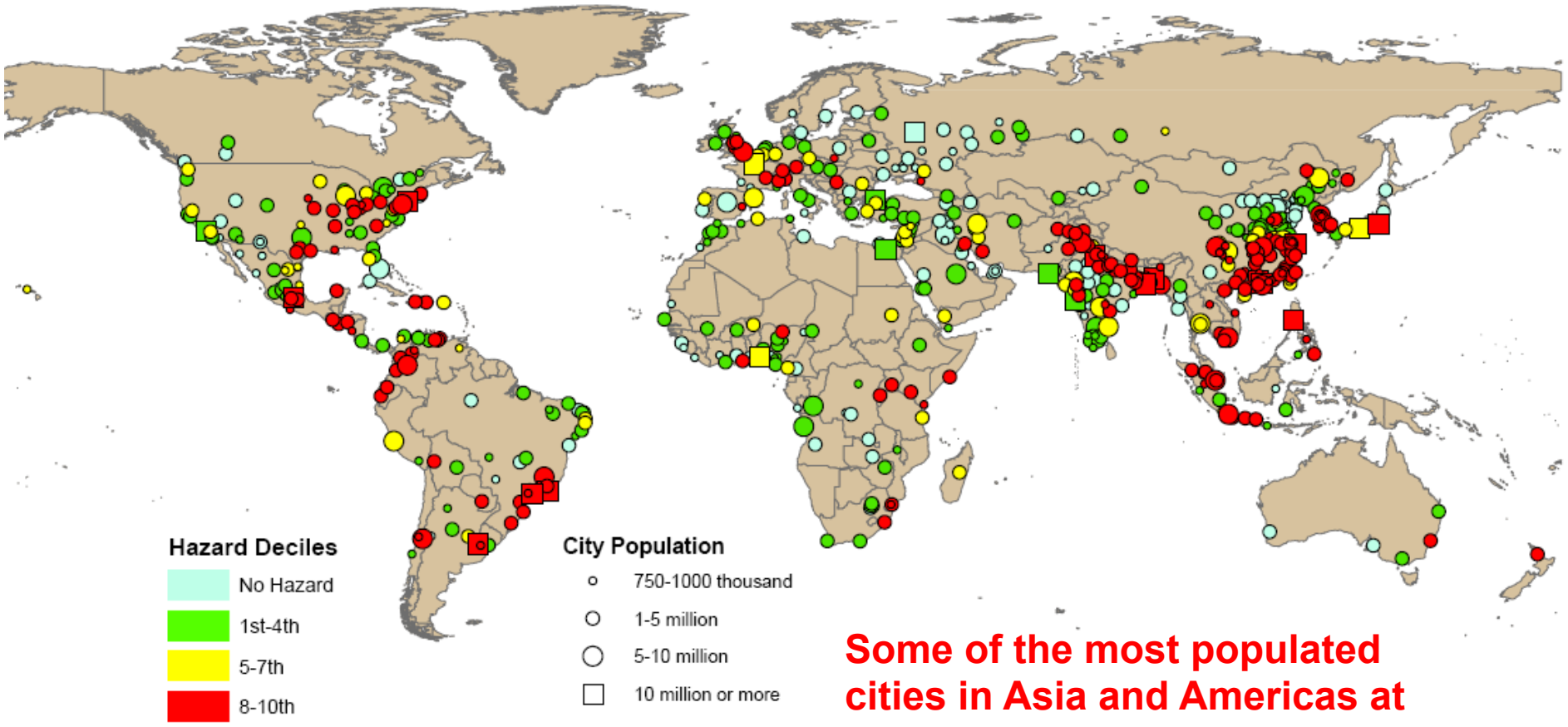
Most common risks…

4. Flooding and Droughts are the two most frequent natural hazards

1) In 2011, at least 233 of 633 cities with a relatively high risk of flooding (~ 663 million inhabitants);
2) 132 cities are located in high risks of droughts (~277 million population);
3) 68 cities exposed to high risks of cyclones (~229 million people).

Risk #1: Floodings

Cities by population size in 2011 and risks of flooding (1985-2003)



Some of the most populated cities in Asia and Americas at higher risk

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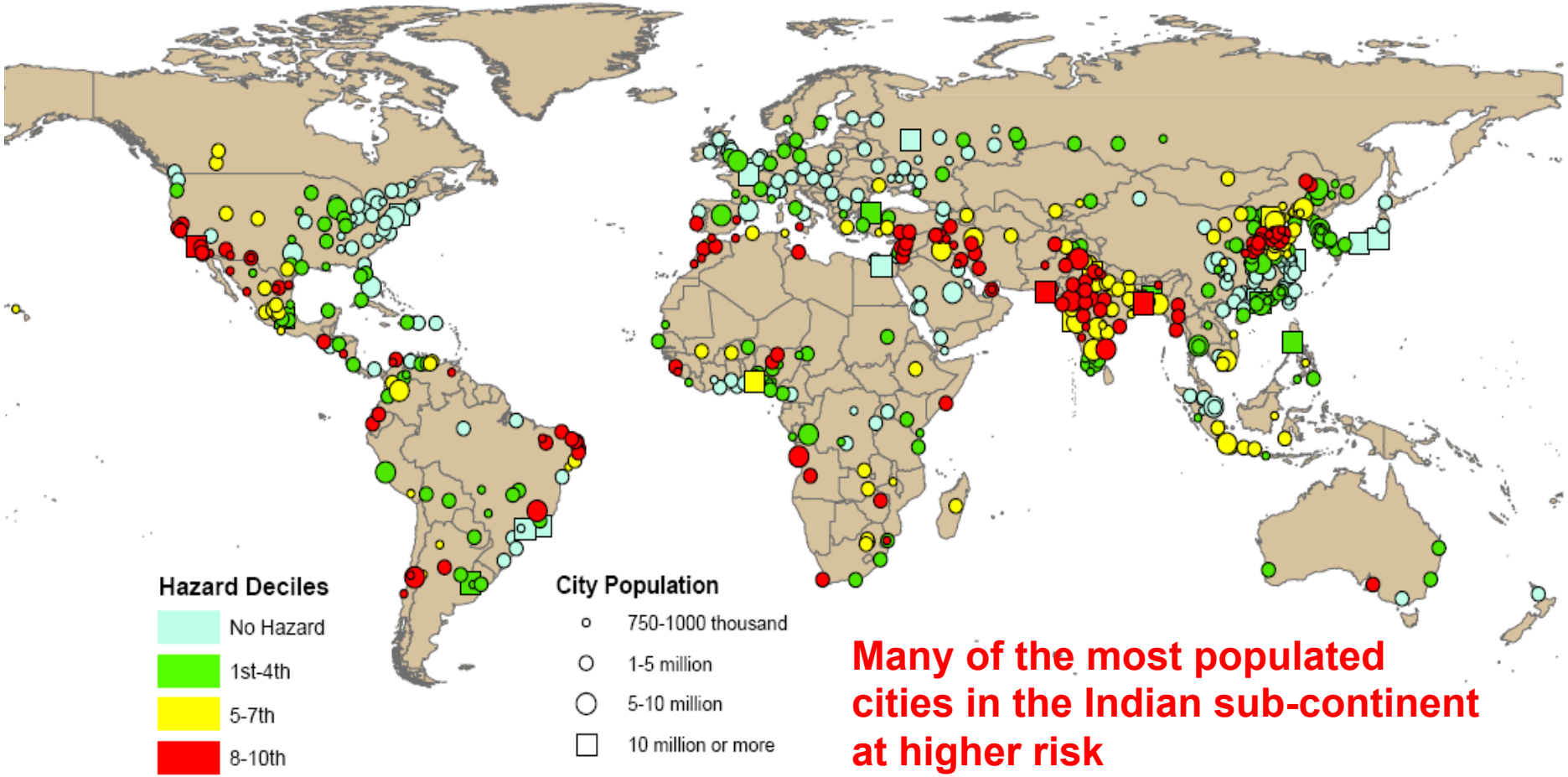
Risk #2: Droughts

Cities by population size in 2011 and risks of droughts (1980-2000)



Many of the most populated cities in the Indian sub-continent at higher risk

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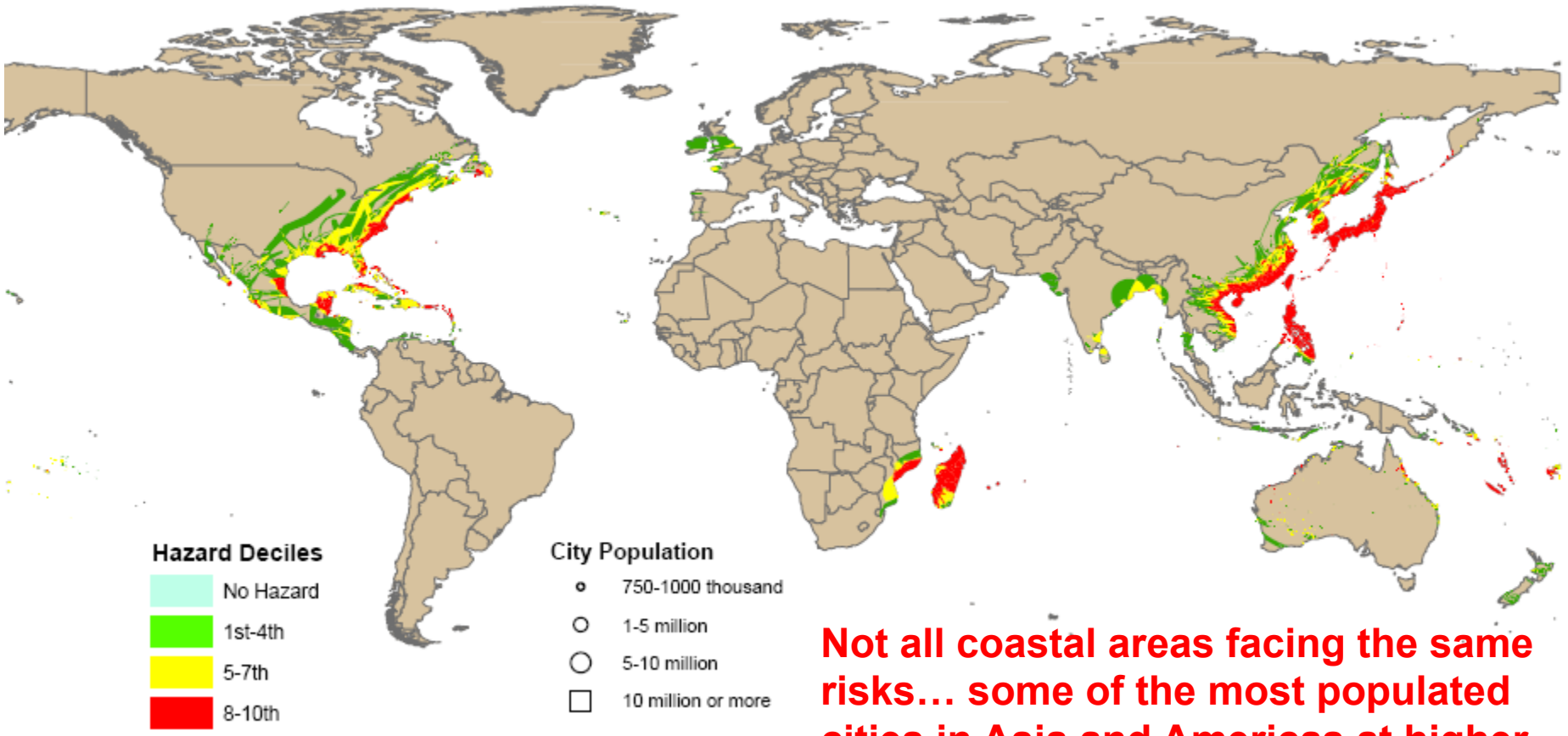
Risk #3: Cyclones

Cities by population size in 2011 and risks of cyclones (1980-2000)



Not all coastal areas facing the same risks… some of the most populated cities in Asia and Americas at higher risk

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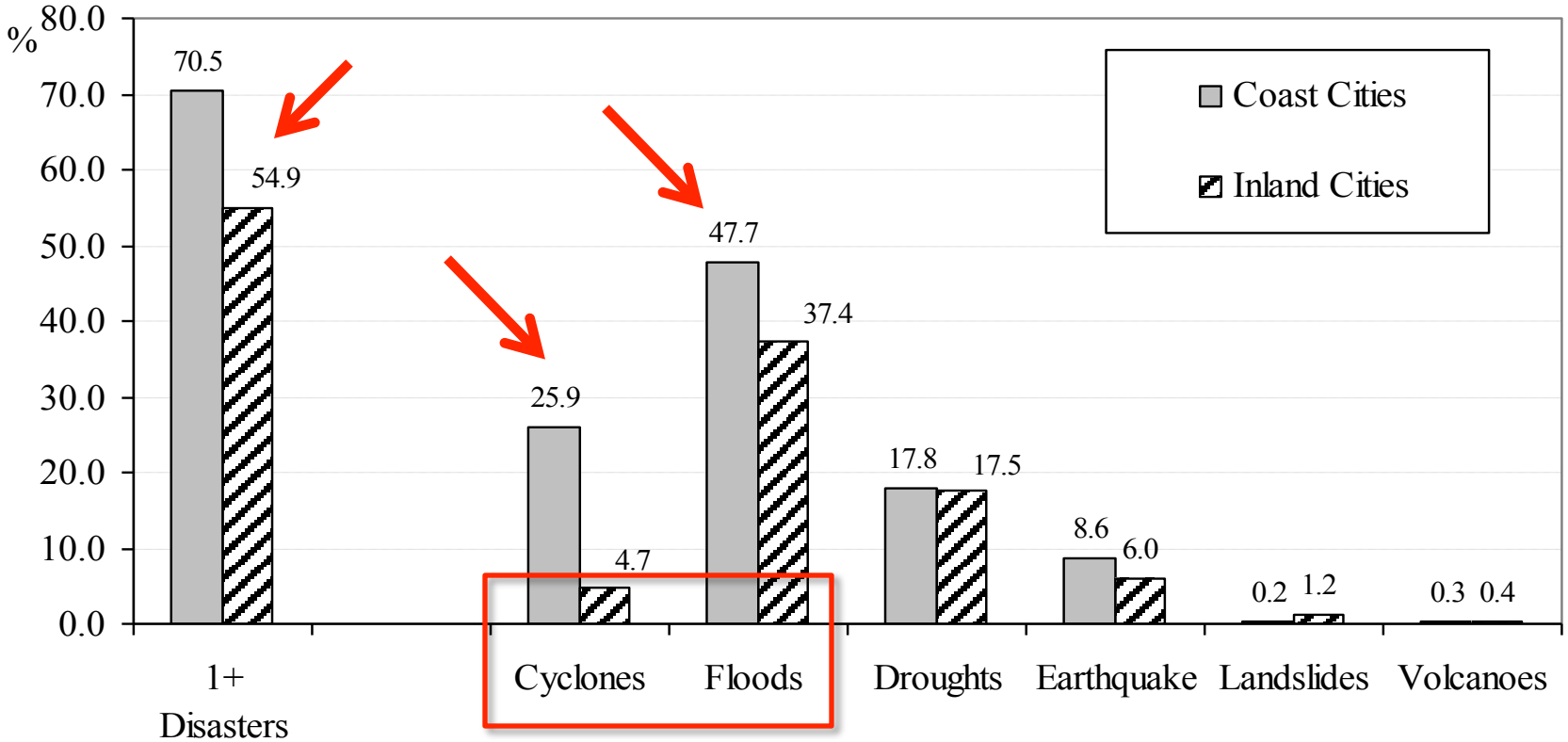
Double jeopardy: Floods & Cyclones

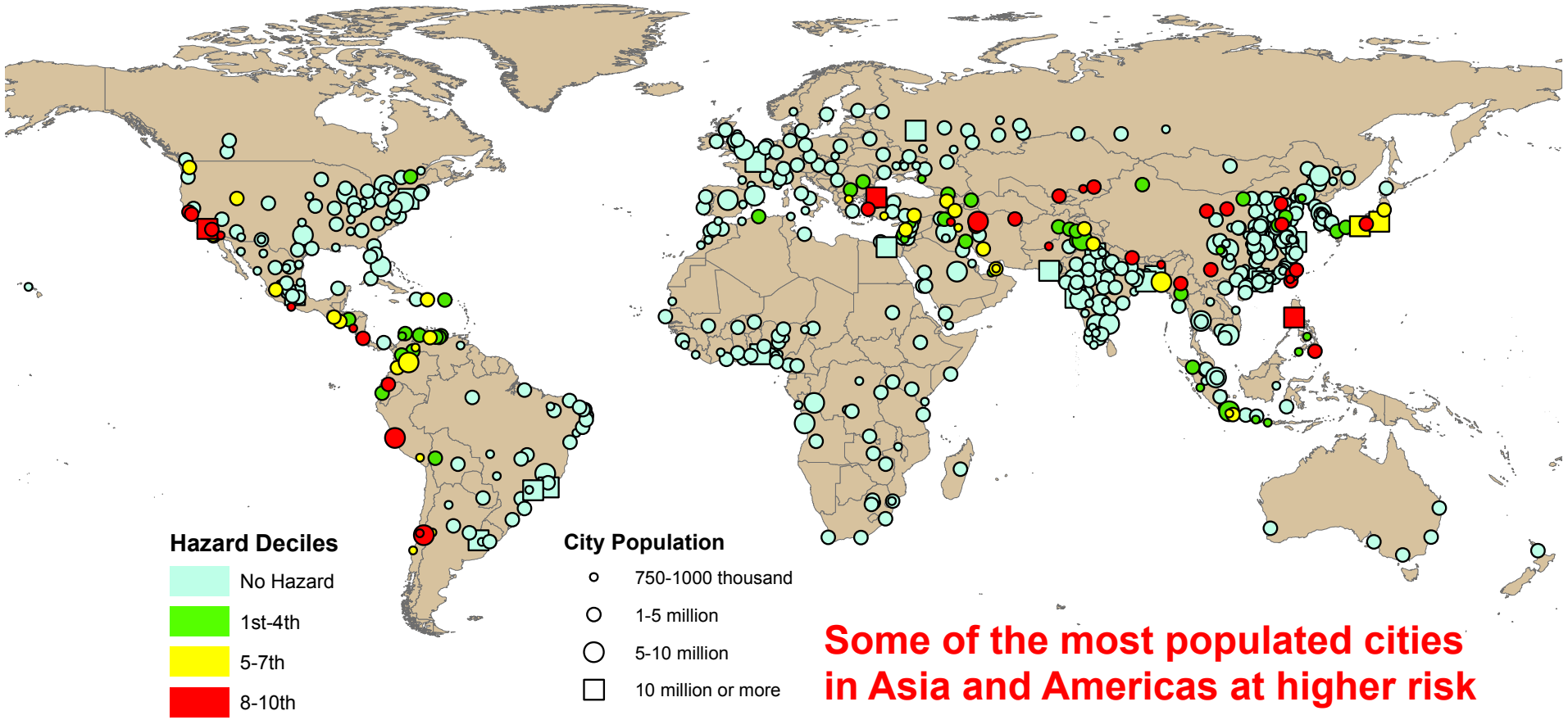
4. Coastal cities are more exposed to natural disasters than inland cities

% population at highest risk of natural hazards (8-10th risk deciles)



Risk #4: Earthquakes

Cities by population size in 2011 and risks of earthquakes (1976-2002)



Some of the most populated cities in Asia and Americas at higher risk

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Cities at high risk of natural disasters

Top 10 largest city populations in 2011 at 8-10th risk deciles by type of hazard

	Cyclones	Droughts	Earthquakes	Floods	Landslides	Volcanoes
1	Tokyo, Japan	Kolkata (Calcutta), India	Los Angeles-Long Beach-Santa Ana, USA	Tokyo, Japan	Taipei, China	Napoli (Naples), Italy
2	Shanghai, China	Karachi, Pakistan	Manila, Philippines	Delhi, India	Bandung, Indonesia	Quito, Ecuador
3	Manila, Philippines	Los Angeles-Long Beach-Santa Ana, USA	Istanbul, Turkey	Ciudad de México (Mexico City), Mexico	Quito, Ecuador	Bogor, Indonesia
4	Osaka-Kobe, Japan	Chennai (Madras), India	Lima, Peru	New York-Newark, USA	San Salvador, El Salvador	Malang, Indonesia
5	Guangzhou, Guangdong, China	Lahore, Pakistan	Tehran, Iran (Islamic Republic of)	Shanghai, China	Kaohsiung, China	
6	Shenzhen, China	Ahmadabad, India	Santiago, Chile	São Paulo, Brazil	San José, Costa Rica	
7	Seoul, Republic of Korea	Santiago, Chile	San Francisco-Oakland, USA	Dhaka, Bangladesh		
8	Dongguan, Guangdong, China	Belo Horizonte, Brazil	Kunming, China	Kolkata (Calcutta), India		
9	Hong Kong, China, Hong Kong SAR	Luanda, Angola	Nagoya, Japan	Buenos Aires, Argentina		
10	Foshan, China	Yangon, Myanmar	Izmir, Turkey	Rio de Janeiro, Brazil		

Fastest growing cities at high risk

Top 10 fastest growing city populations (750,000 or more) in 2001-2011 at 8-10th risk deciles by type of hazard

	Cyclone	Drought	Earthquake	Flood	Landslide	Volcano
1	Zhongshan, China	Nay Pyi Taw, Myanmar	Yinchuan, China	Can Tho, Viet Nam	San José, Costa Rica	Bogor, Indonesia
2	Xiamen, China	Sharjah, United Arab Emirates	Kathmandu, Nepal	Batam, Indonesia	San Salvador, El Salvador	Quito, Ecuador
3	Haikou, China	Dubayy (Dubai), United Arab Emirates	Karaj, Iran (Islamic Republic of)	Yongin, Republic of Korea	Quito, Ecuador	Malang, Indonesia
4	Jinjiang, China	Luanda, Angola	Sulaimaniya, Iraq	Zhongshan, China	Bandung, Indonesia	Napoli (Naples), Italy
5	Dongguan, Guangdong, China	Huambo, Angola	San José, Costa Rica	Xiamen, China	Kaohsiung, China	
6	Jiangmen, China	Hamah, Syrian Arab Republic	Quetta, Pakistan	Suzhou, Jiangsu, China	Taipei, China	
7	Vientiane, Lao People's Democratic Republic	Nanyang, Henan, China	Xining, China	Wuhu, Anhui, China		
8	Huizhou, China	Liaocheng, China	Bursa, Turkey	Hefei, China		
9	Jiaxing, China	Handan, China	Tangshan, Hebei, China	Kigali, Rwanda		
10	Putian, China	Zhengzhou, China	Davao, Philippines	Jinjiang, China		

Cities at low risk of natural disasters

Top 10 largest city populations in 2011 least exposed to natural hazards (no risk or 1-4th risk decile for only one natural disaster)

		Population (in million)			Risk decile					
	City	2011	Location	Type	Cyclones	Droughts	Earthquakes	Floods	Landslides	Volcanoes
1	Moskva (Moscow), Russian Federation	11.6	Inland	Not Arid	No hazard	No hazard	No hazard	No hazard	No hazard	No hazard
2	Al-Qahirah (Cairo), Egypt	11.2	Inland	Hyperarid	No hazard	No hazard	No hazard	1st-4th	No hazard	No hazard
3	Kinshasa, DR. of the Congo	8.8	Inland	Not Arid	No hazard	1st-4th	No hazard	1st-4th	No hazard	No hazard
4	Madrid, Spain	6.6	Inland	Semiarid	No hazard	1st-4th	No hazard	No hazard	No hazard	No hazard
5	Toronto, Canada	5.6	Inland	Not Arid	1st-4th	No hazard	No hazard	1st-4th	No hazard	No hazard
6	Ar-Riyadh (Riyadh), Saudi Arabia	5.5	Inland	Hyperarid	No hazard	No hazard	No hazard	1st-4th	No hazard	No hazard
7	Dallas-Fort Worth, USA	5.2	Inland	Semiarid	1st-4th	No hazard	No hazard	1st-4th	No hazard	No hazard
8	Xi'an, Shaanxi, China	5.0	Inland	Dry subhumid	No hazard	1st-4th	No hazard	1st-4th	No hazard	No hazard
9	Atlanta, USA	5.0	Inland	Not Arid	1st-4th	No hazard	No hazard	1st-4th	No hazard	No hazard
10	Peterburg (Saint Petersburg), Russian Federation	4.9	Inland	Coastal	Not Arid	No hazard	No hazard	No hazard	1st-4th	No hazard

Urban population data limitations

Practical challenges

- Data availability for urban locations
- City names in foreign languages can be easily mixed up (Chinese)
- Large amount of data (>5000+ cities) in time-series

Methodological challenges

- Lack of clear and systematic documentation/definitions
- **Definitions change** from country to country
- **Definitions change over time** (no consistency in time-series)
- Mapping national definitions into **three generic categories**:
  City proper, urban agglomeration, metropolitan areas.
- City boundaries are not drawn consistently (some cities include large rural areas, others don't)
- Neighboring cities may merge into one urban agglomeration
- Small cities / villages may become huge cities due to special development measures (Shenzhen, "airport cities")
- **Reclassification** of settlements (from village to town to city)
- **No urban extent linked to city population data** (only latitude/longitude centroid from gazetteers)

Limitations of this analysis

Urban data:

- Only cities with 750K+ population were included in this analysis
- No urban extents associated to the population data
- Used centroid (Lat/Long coordinates) with 2km (and 5km) buffer (instead of urban extents)

Natural hazards:

- Spatial resolution of some data is relatively low (e.g., about 110 km for floods, 280 km for droughts)
- Time period for some hazards is not very long nor up-to-date (mostly covering the period 1980-2000)
- Economic impacts of natural hazards were not analyzed

Suppl. Data Sources: natural hazards

- Cyclones: UNEP/GRID-Geneva PreView include more than 1,600 storm tracks in Atlantic, Pacific, and Indian Oceans covering the period from 1 January 1980 to 31 December 2000. To assess to the levels of exposure for the grid cells, the wind speeds around the storm tracks are modeled using the Holland's model and the different wind speed buffers are translated into six categories using the Saffir-Simpson Hurricane scale (Dilley et al., 2005: 27, 119).
- Landslides and snow avalanche hazards : Norwegian Geotechnical Institute (NGI) including slope, soil, soil moisture conditions, precipitation, seismicity, and temperature with incorporated data from Shuttle Radar Topography Mission (SRTM) elevation data at 30 seconds resolution (Dilley et al., 2005:29).
- Earthquakes: based on two sets: the Global Seismic Hazard Program (GSHAP) data and actual earthquake events greater than 4.5 on the Richter scale covering the period of 1976-2000 from Advanced National Seismic System. The GSHAP dataset is sampled at 1' intervals, with a criterion for shaking amplitude of a minimum peak ground acceleration (PGA) of 2 meters per square second (m/s2), for which there is a 10 percent chance of exceedance in the next 50 years (Dilley et al., 2005:27, 29-30).
- Volcanoes: Worldwide Volcano Database developed by Global and Regional Integrated Data-Geneva, United Nations Environment Programme, including 4,000 volcanic activities over nearly two thousand years from 79 to 2000 (Dilley et al., 2005:29).
- Floods: extreme flood events compiled from diverse sources and georeferenced to the nearest degree for the period of 1985-2003 from Dartmouth Flood Observatory. Data for floods are less reliable or missing in the early-mid 1990s (Dilley et al., 2005:29).
- Droughts: International Research Institute for Climate Prediction's (IRI) Weighted Anomaly of Standardized Precipitation (WASP). A drought event is counted when a grid cell (about 280 km by 280 km) has a monthly precipitant below 50 per cent of its median values of the 21-year period (1980-2000) for at least three consecutive months. (Dilley et al., 2005:29)

Dilley et al. (2005). *Natural Disaster Hotspot: A Global Risk Analysis*
http://www.ldeo.columbia.edu/chrr/research/hotspots/