Earth Observation Techniques for Natural Hazard Risk Assessment

GIZ GIDRM – Insight Moments

11.05.2022

Dr. **Christian Geiß**

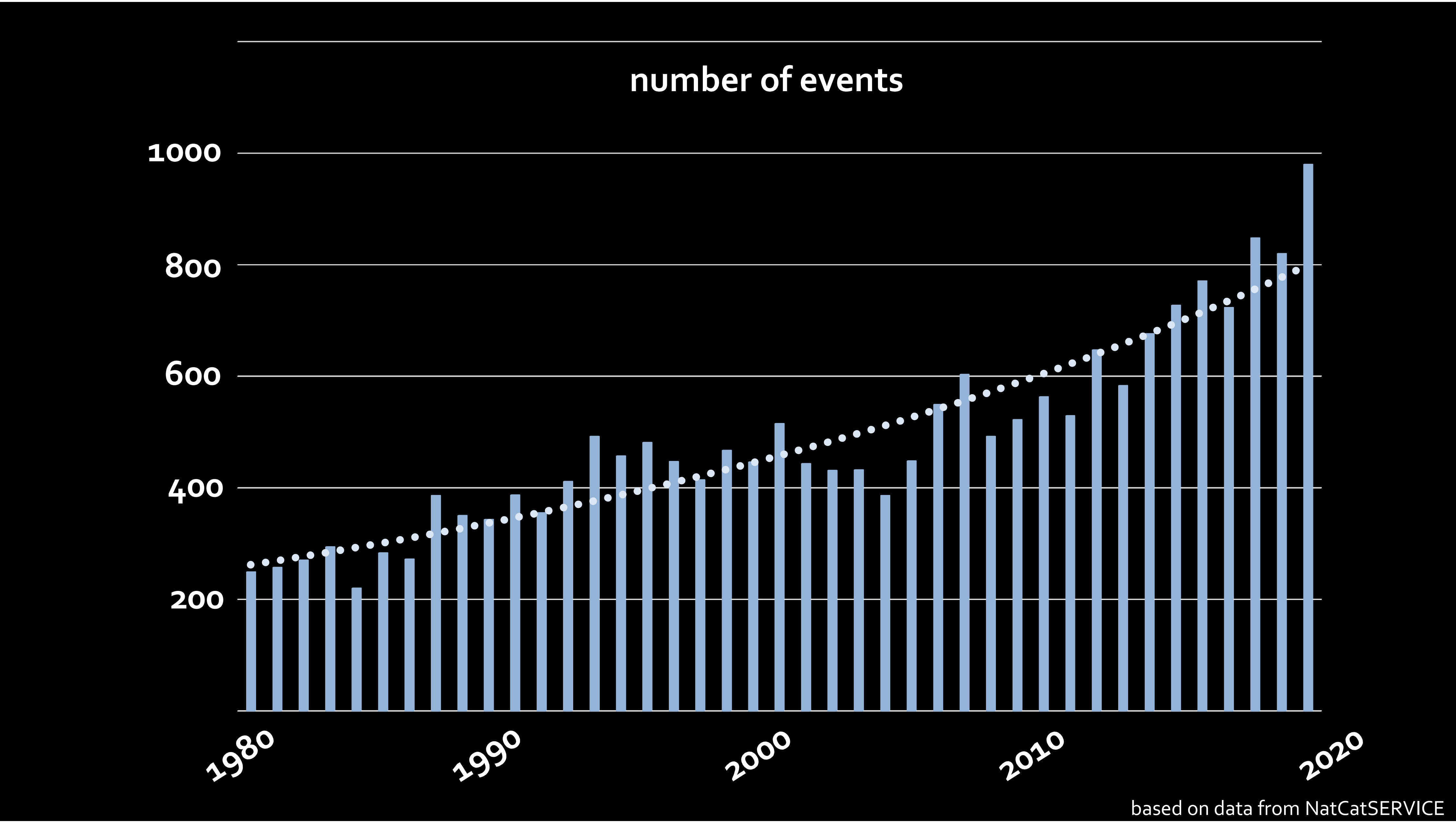
Earth Observation Center

DLR

„Risk creation is outstripping risk reduction"

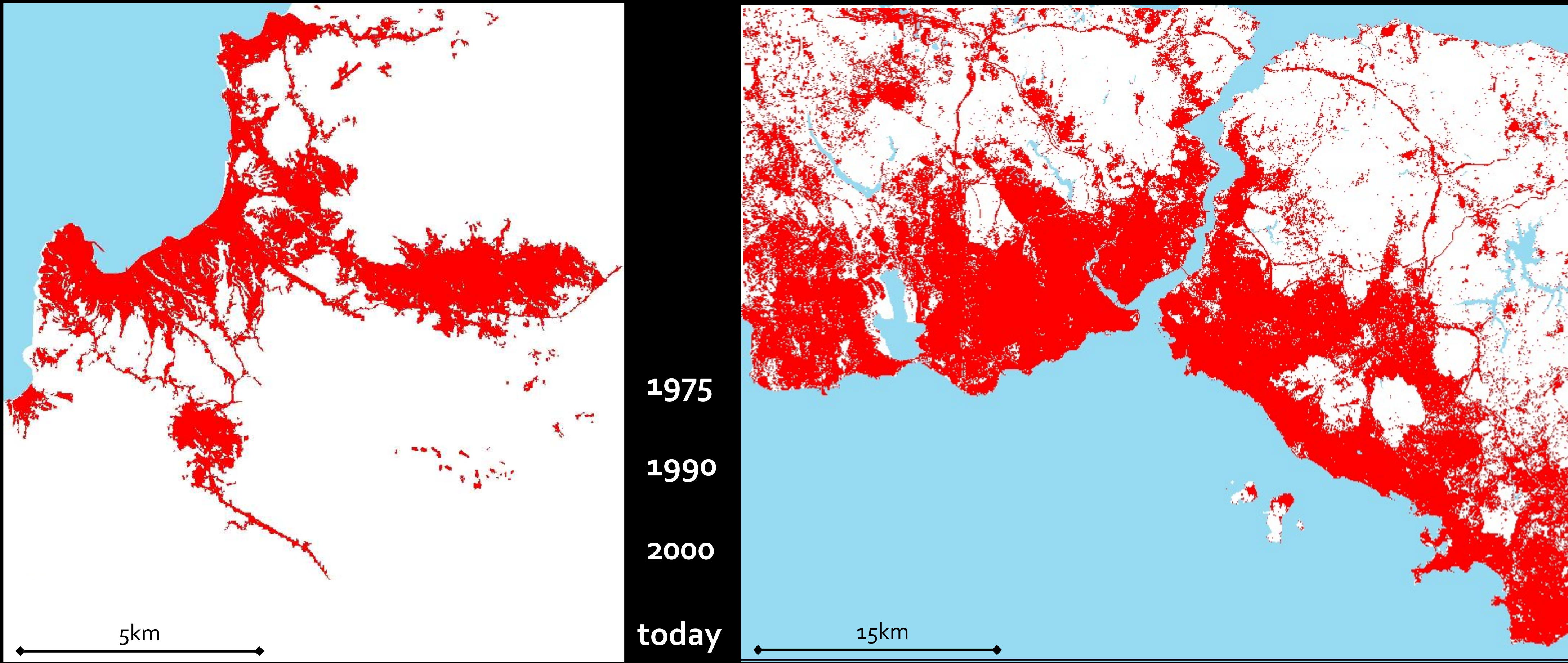
„Disasters and economic loss (…) are increasing"

United Nations Office for Disaster Risk Reduction (2022)


number of events
1000
800
600
400
200
1980
1990
2000
2010
2020
based on data from NatCatSERVICE

Valparaíso, Chile

Istanbul, Turkey

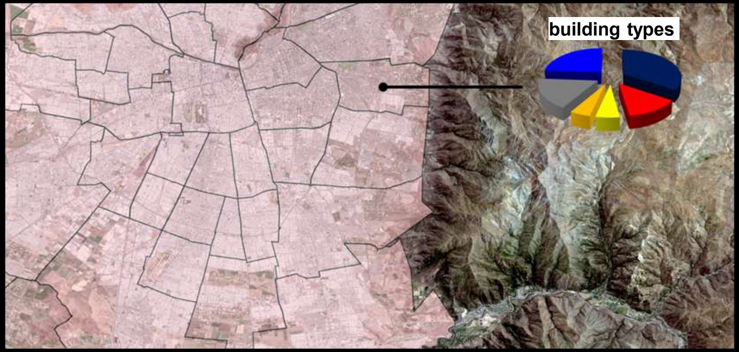


Geiß, C., Schauß, A., Riedlinger, T., Dech, S., Zelaya, C., Guzman, N., Hube, M., Arsanjani, J. J., and Taubenböck, H. (2017):
Joint use of remote sensing data and volunteered geographic information for exposure estimation – evidence from Valparaíso, Chile.
Natural Hazards, 86, 81–105.

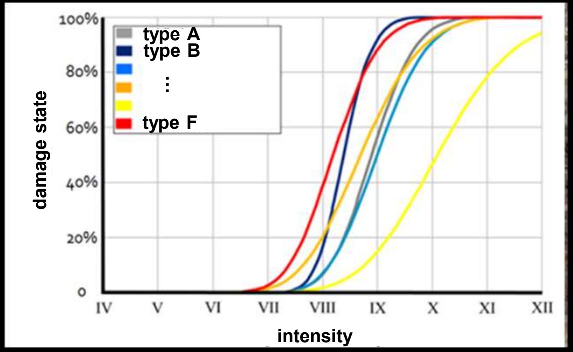
How can **risk** be **quantified**?

$$\text{risk}_{EQ} = f(hazard, \underline{exposure}, vulnerability)$$

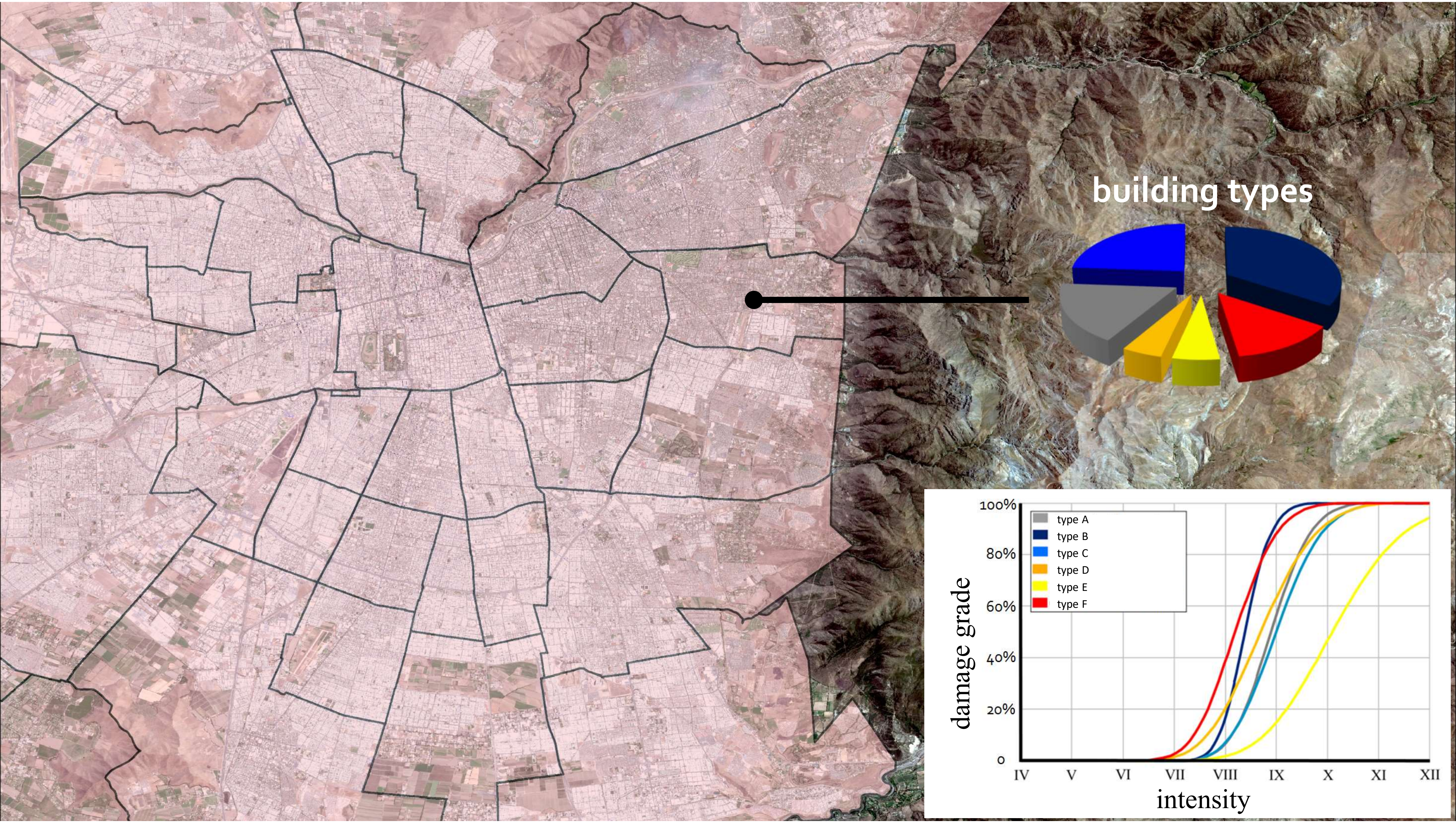
peak ground acceleration



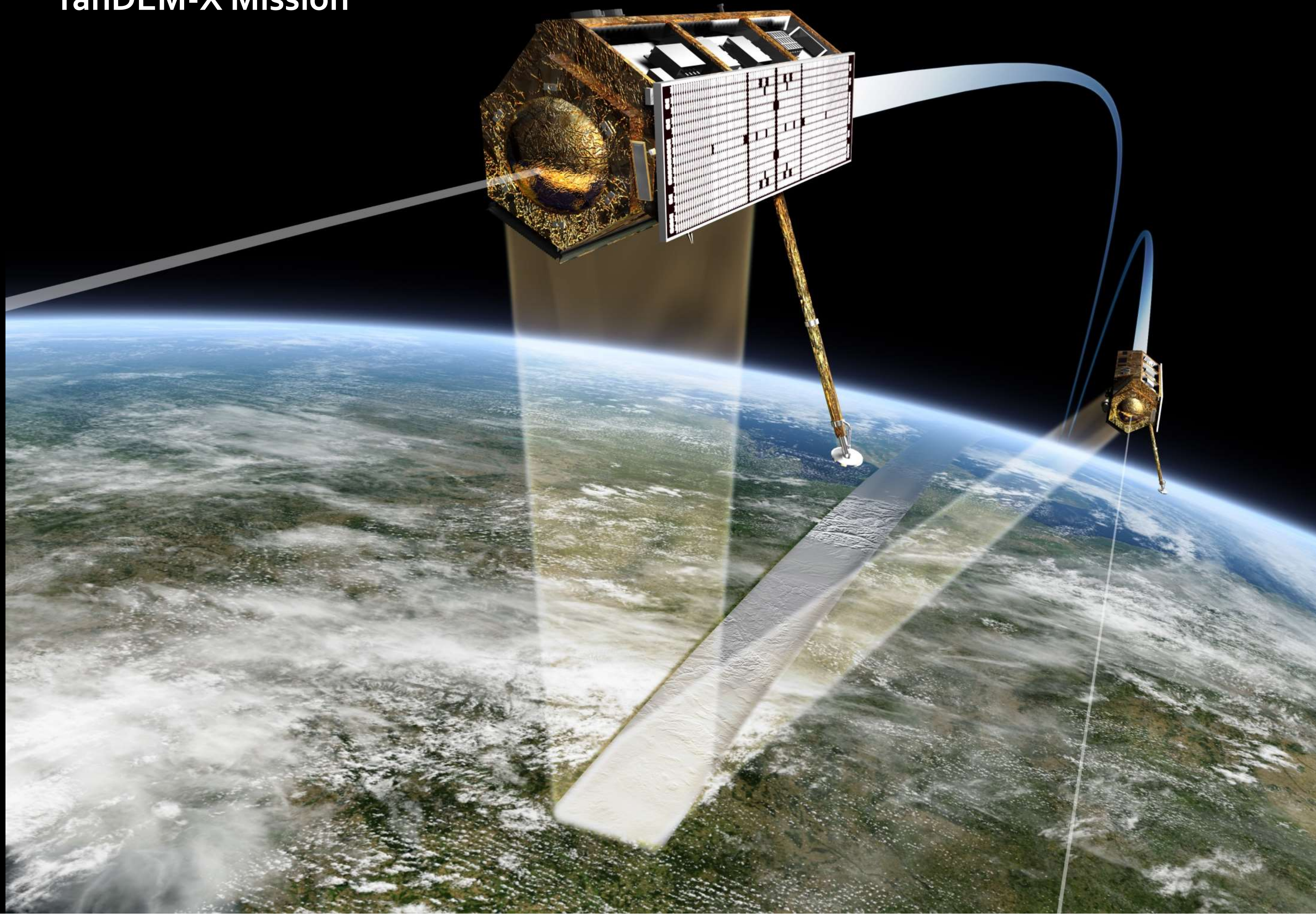
exposure

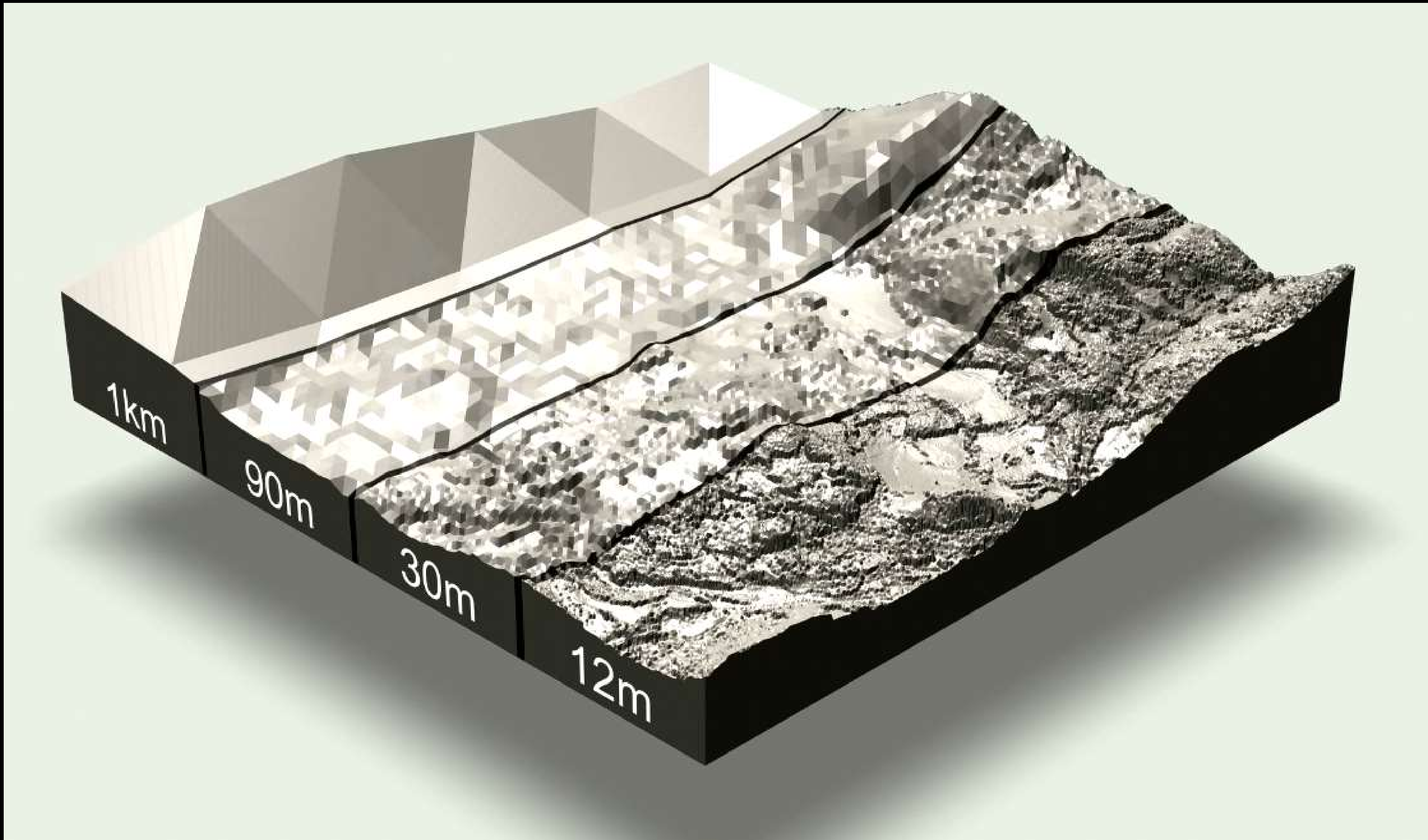


fragility functions

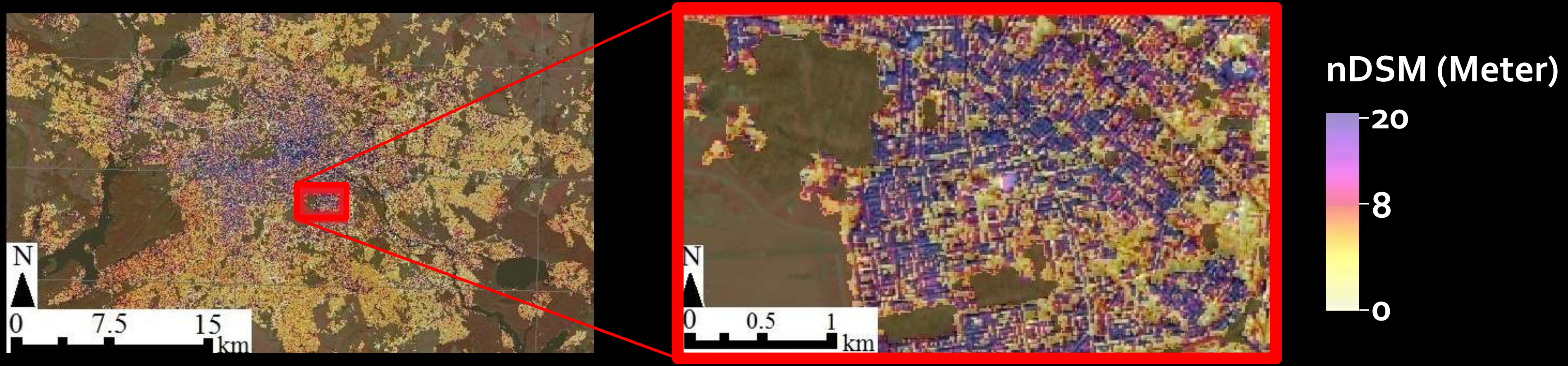

building types
type A
type B
type C
type D
type E
type F
100%
80%
60%
40%
20%
0
damage grade
IV
V
VI
VII
VIII
IX
X
XI
XII
intensity

TanDEM-X Mission




1km
90m
30m
12m

urban land cover



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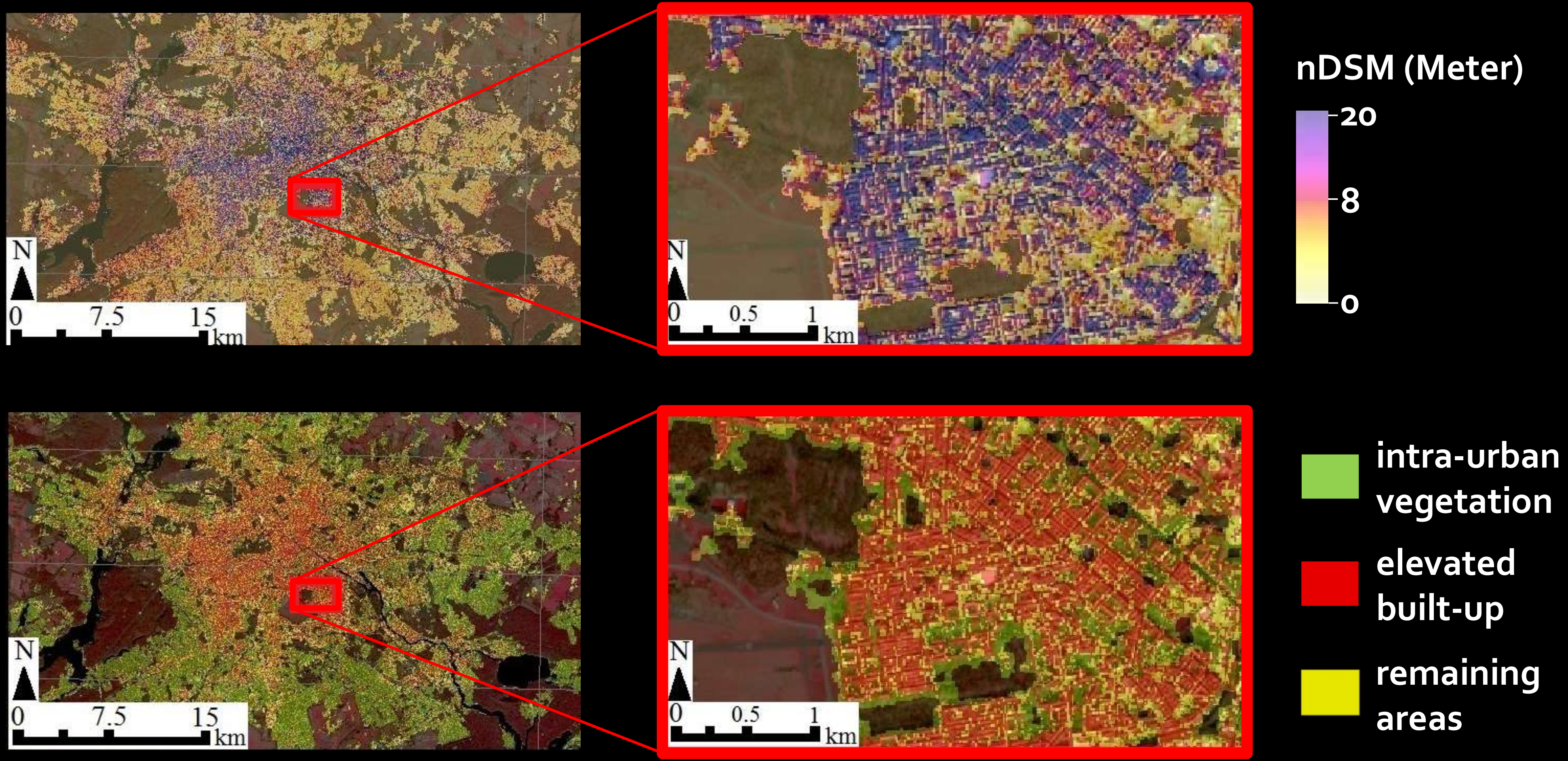

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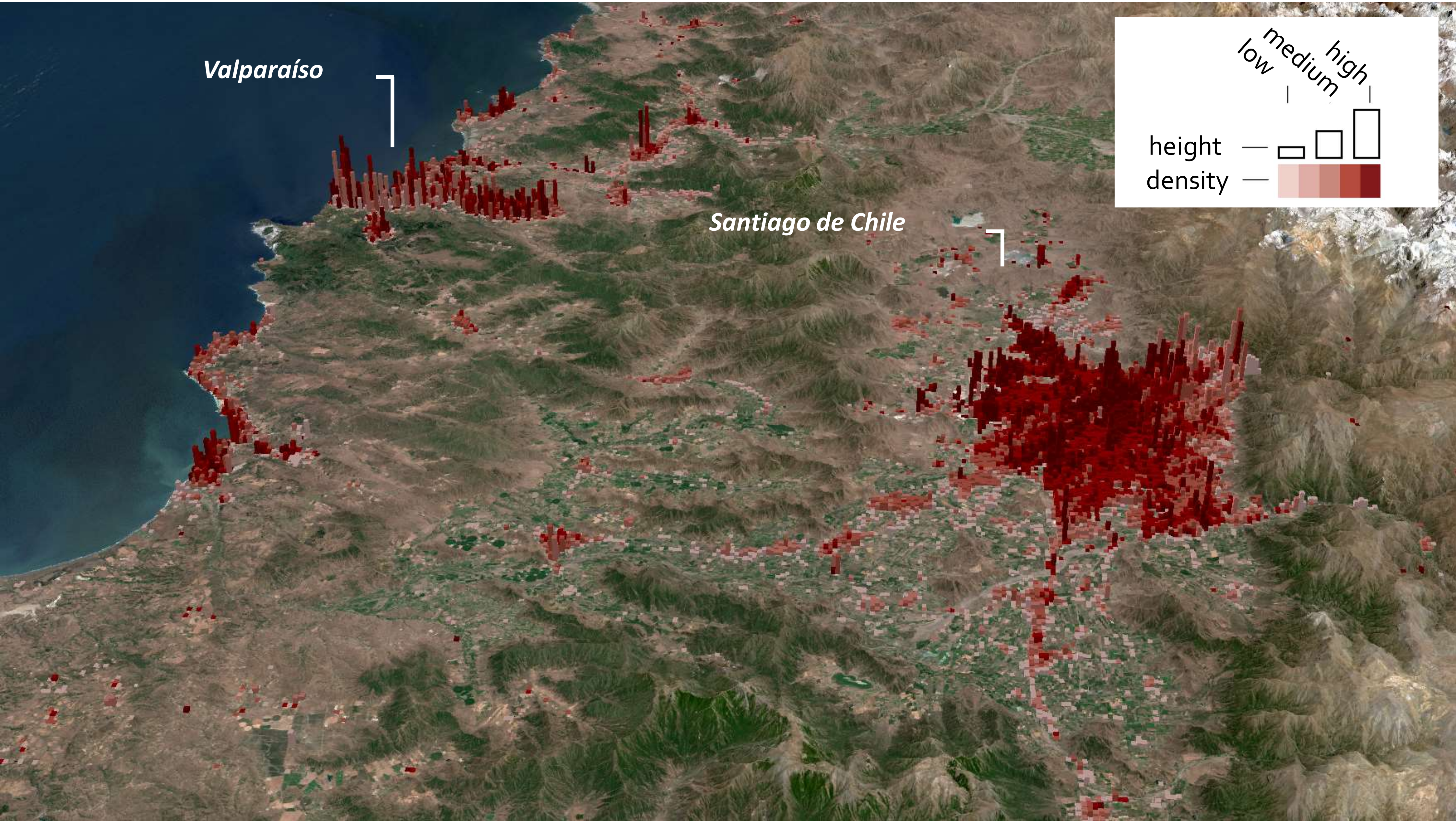
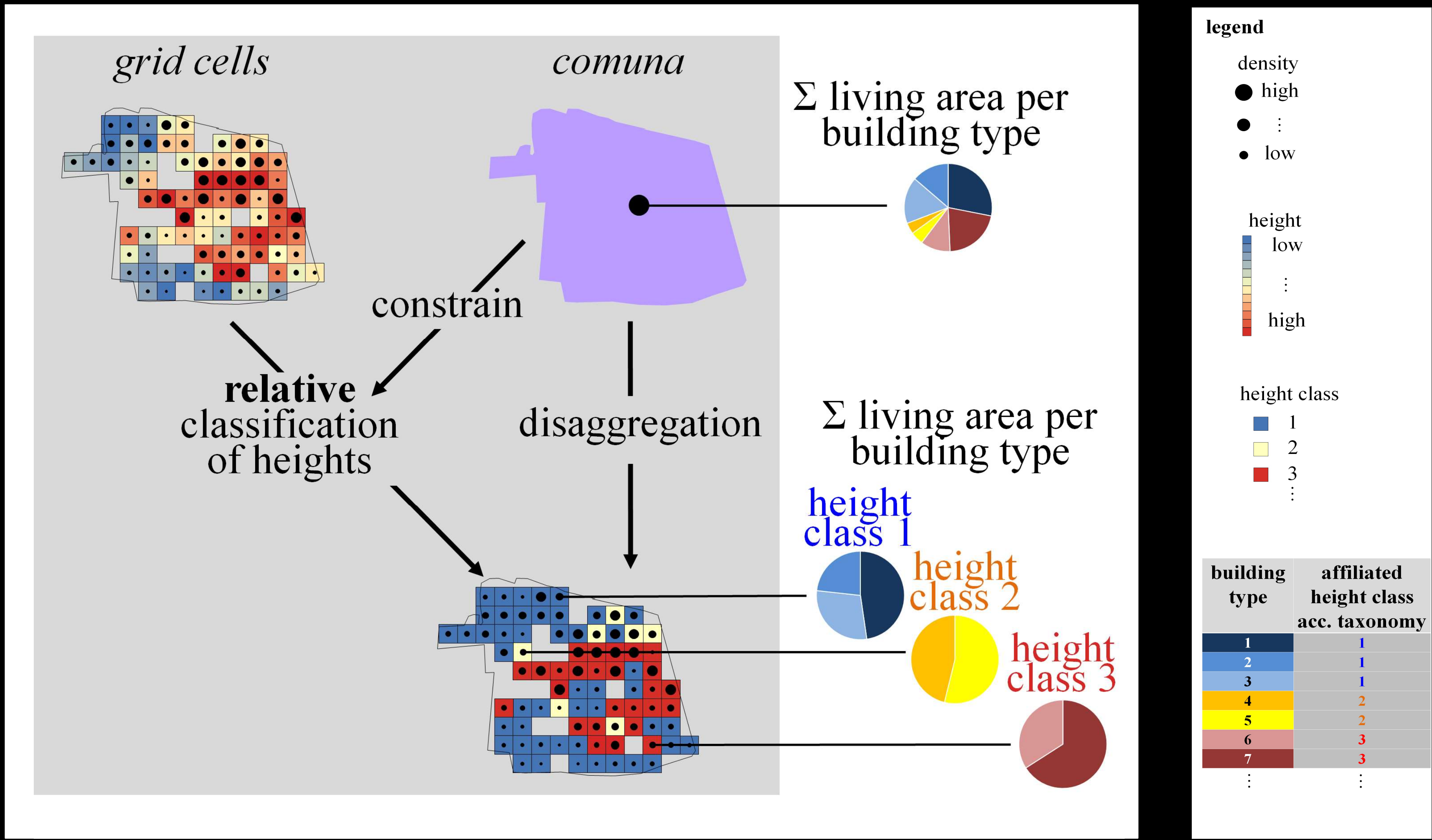

Valparaíso
Santiago de Chile
low
medium
high
height
density



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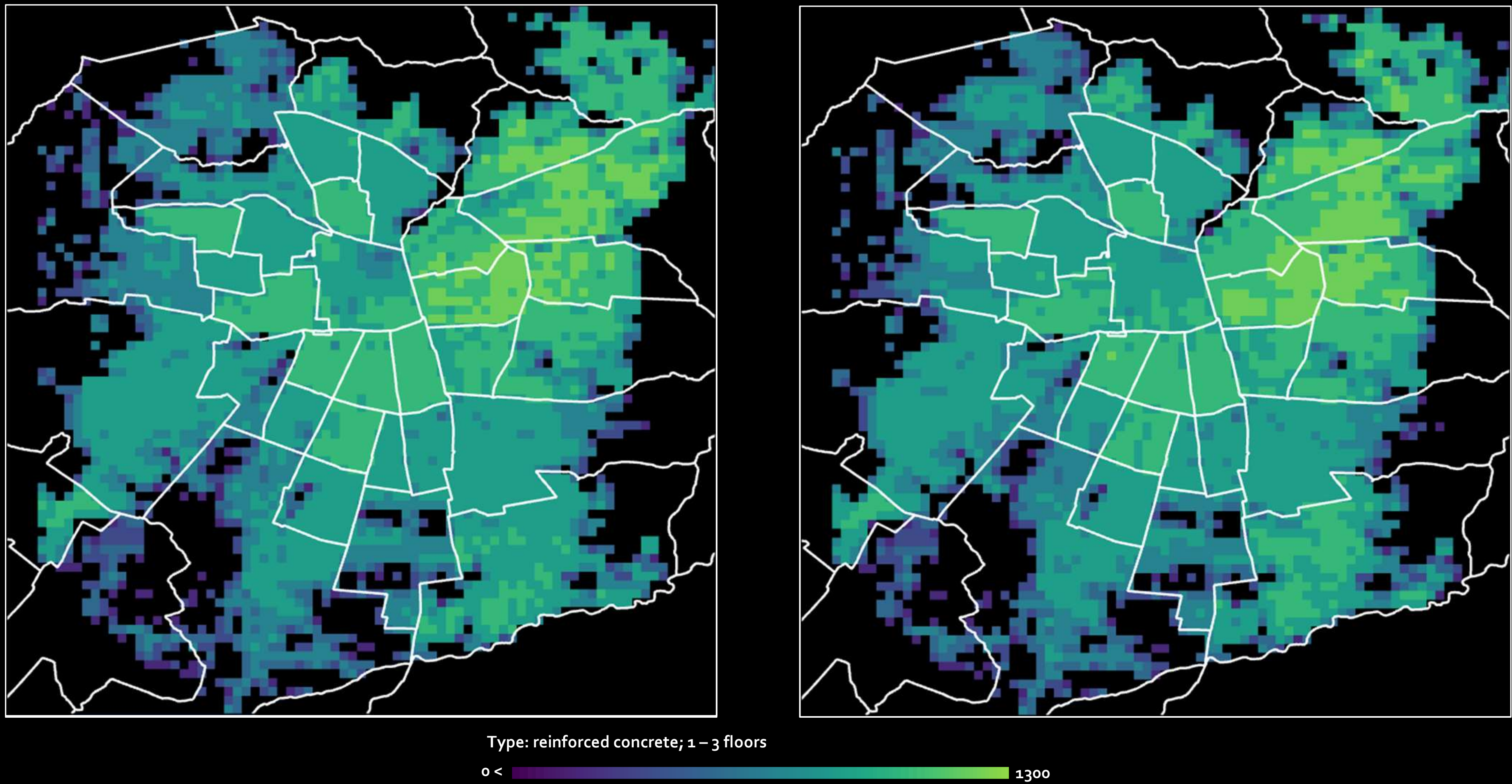
enhanced exposure model | **reference mapping**



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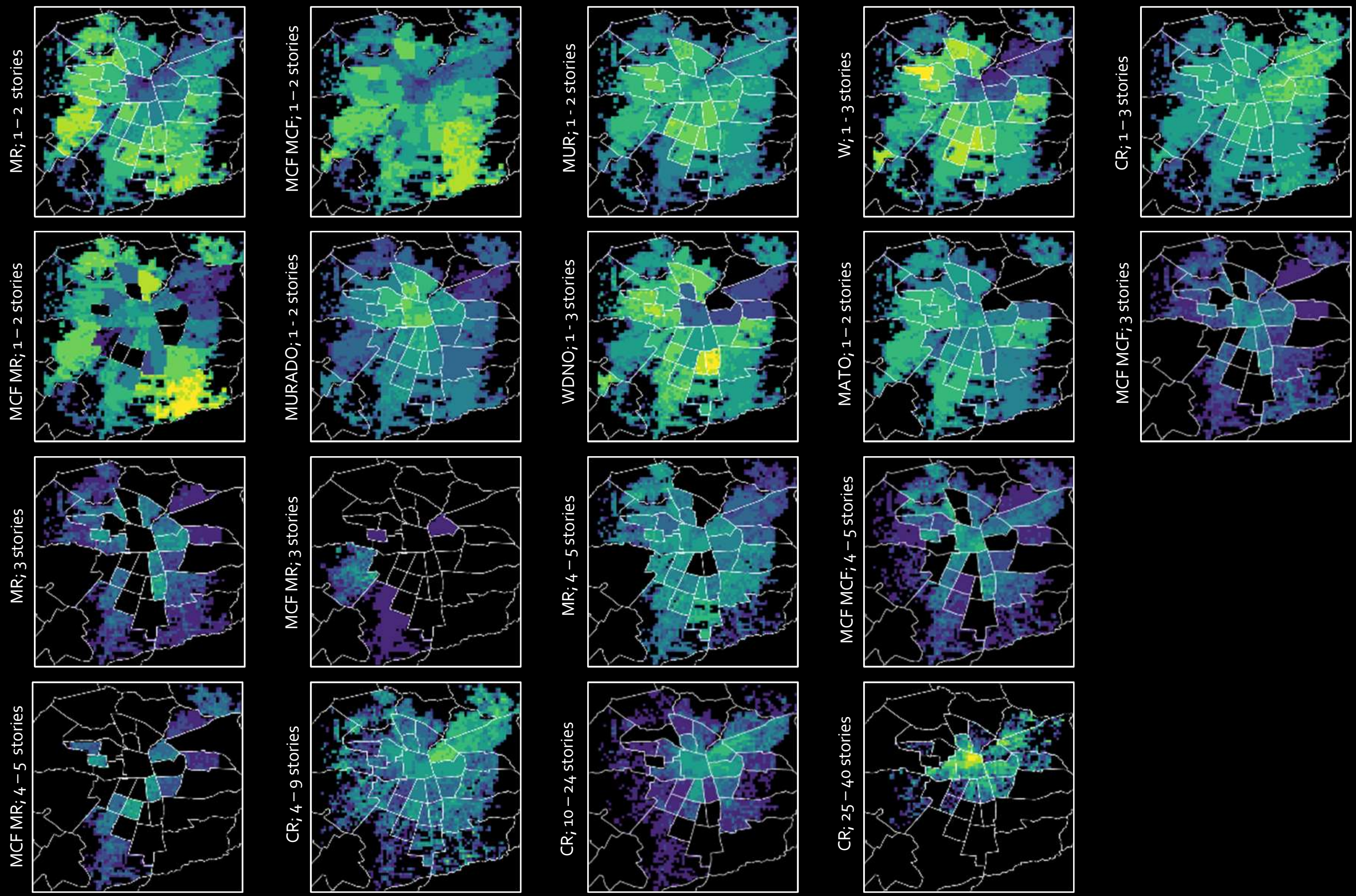

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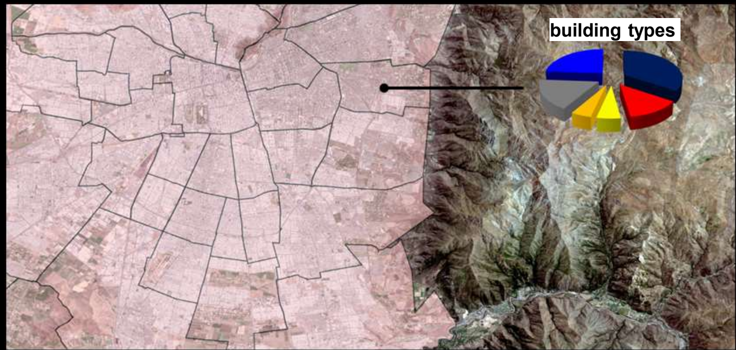
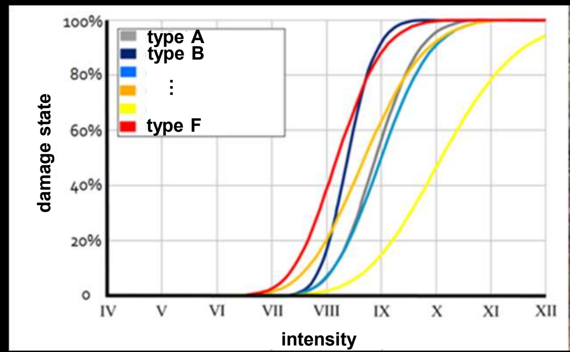
peak ground acceleration



exposure

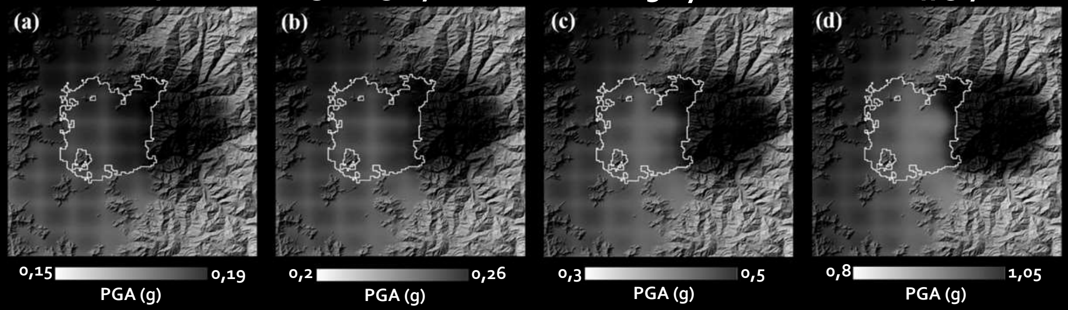


fragility functions

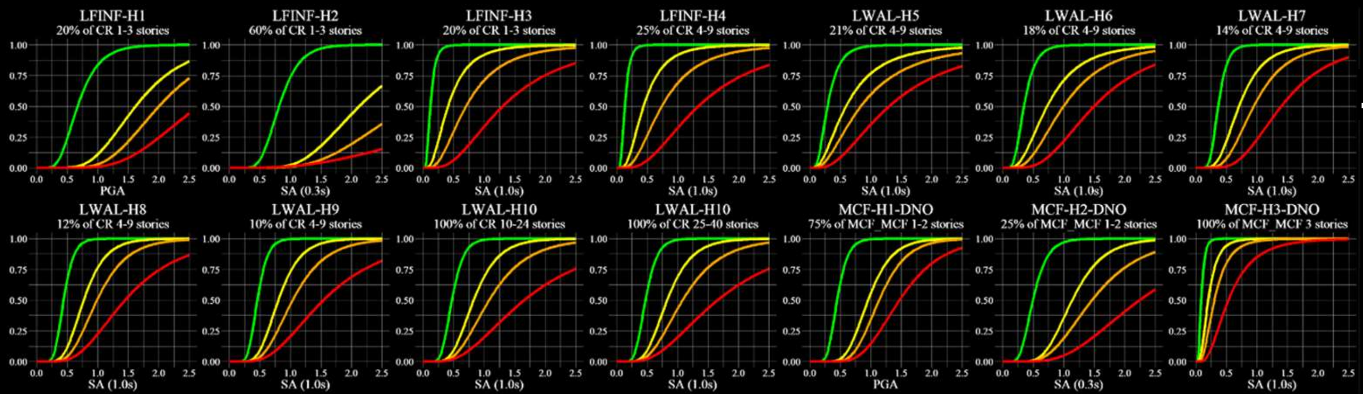
remaining risk „ingredients“

- probabilistic EQ assessment

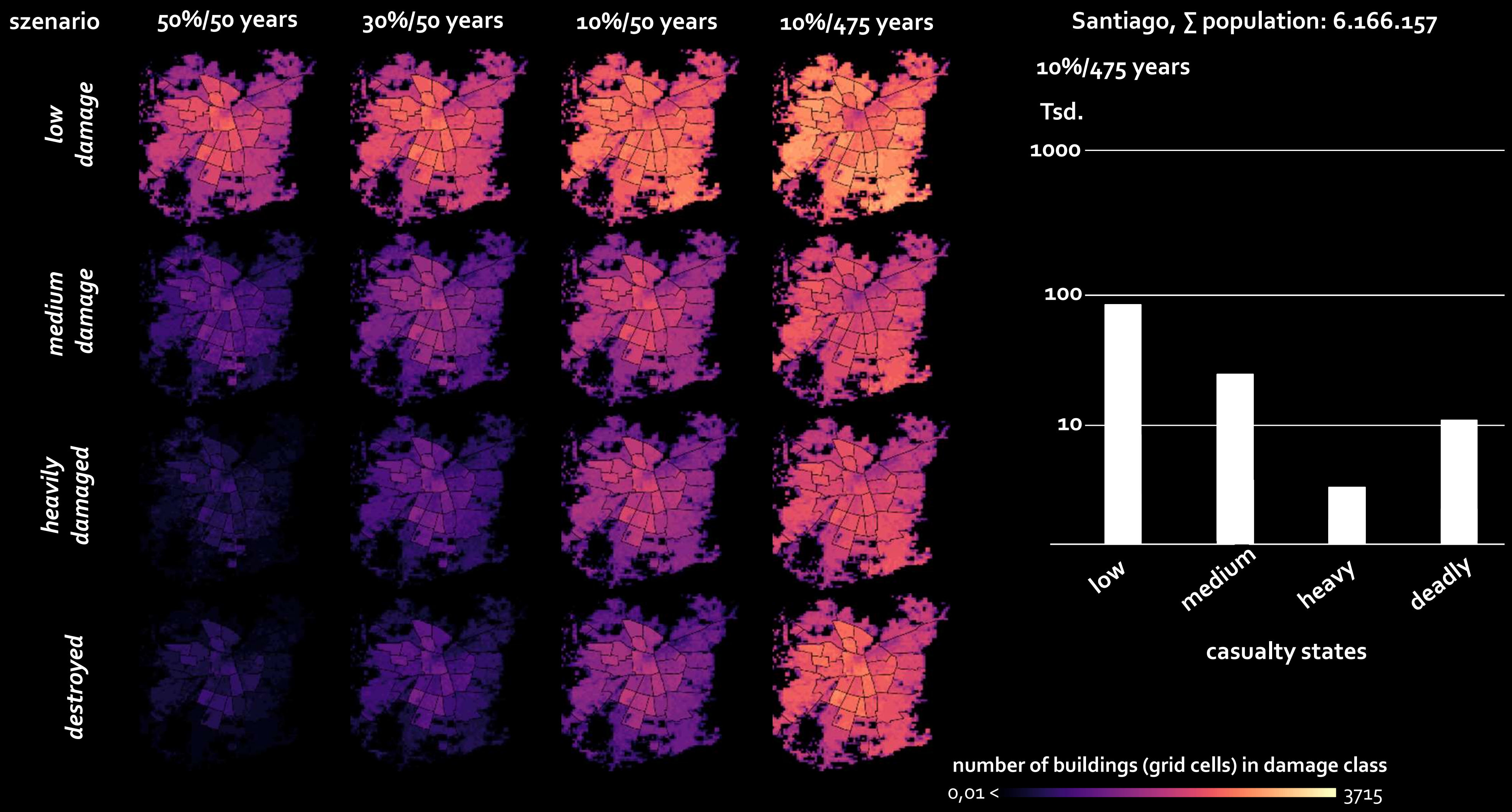
50%/50 years | 30%/50 years | 10%/50 years | 10%/475 years



- fragility functions



...



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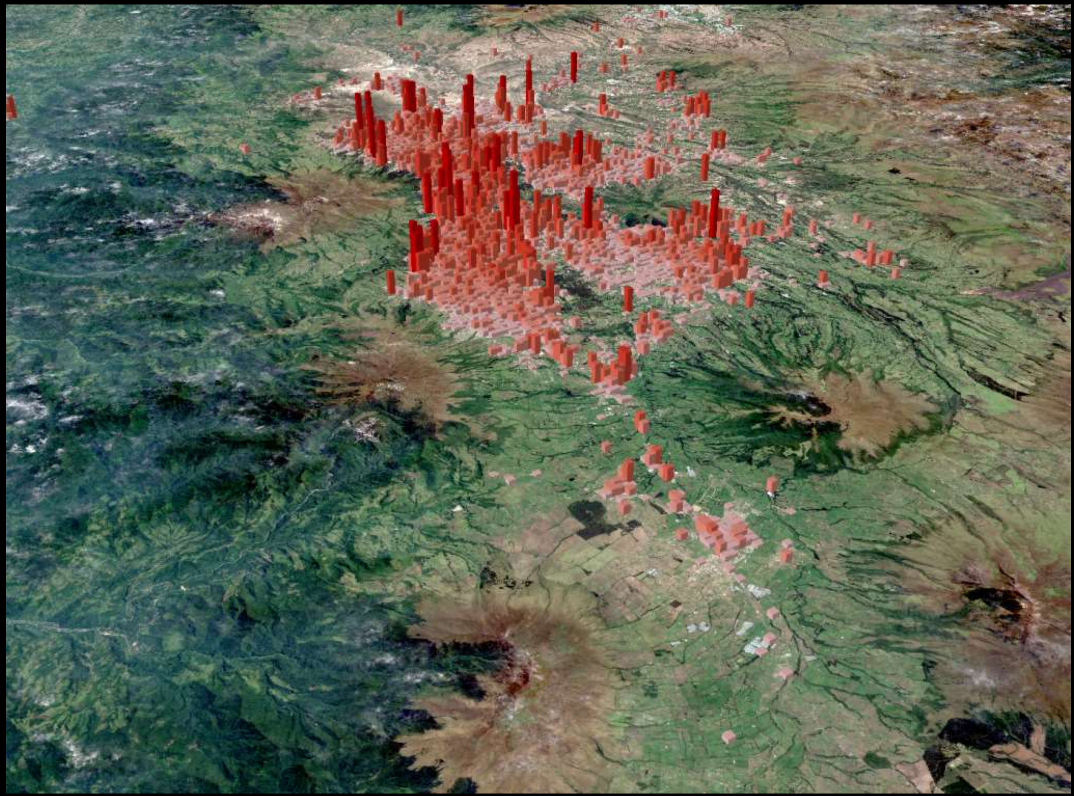
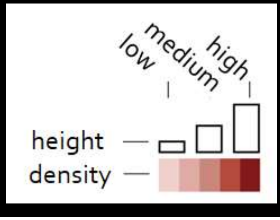
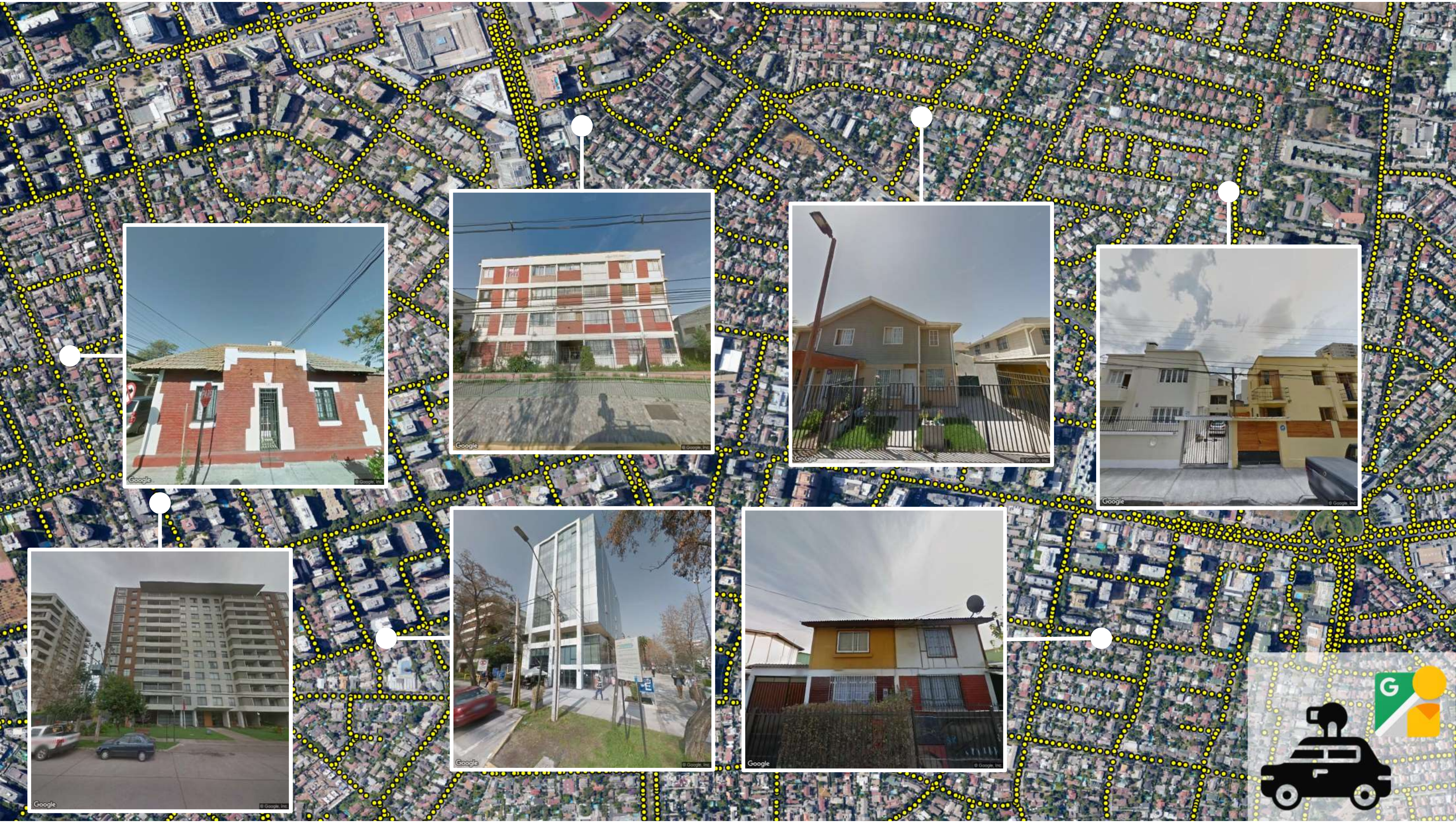
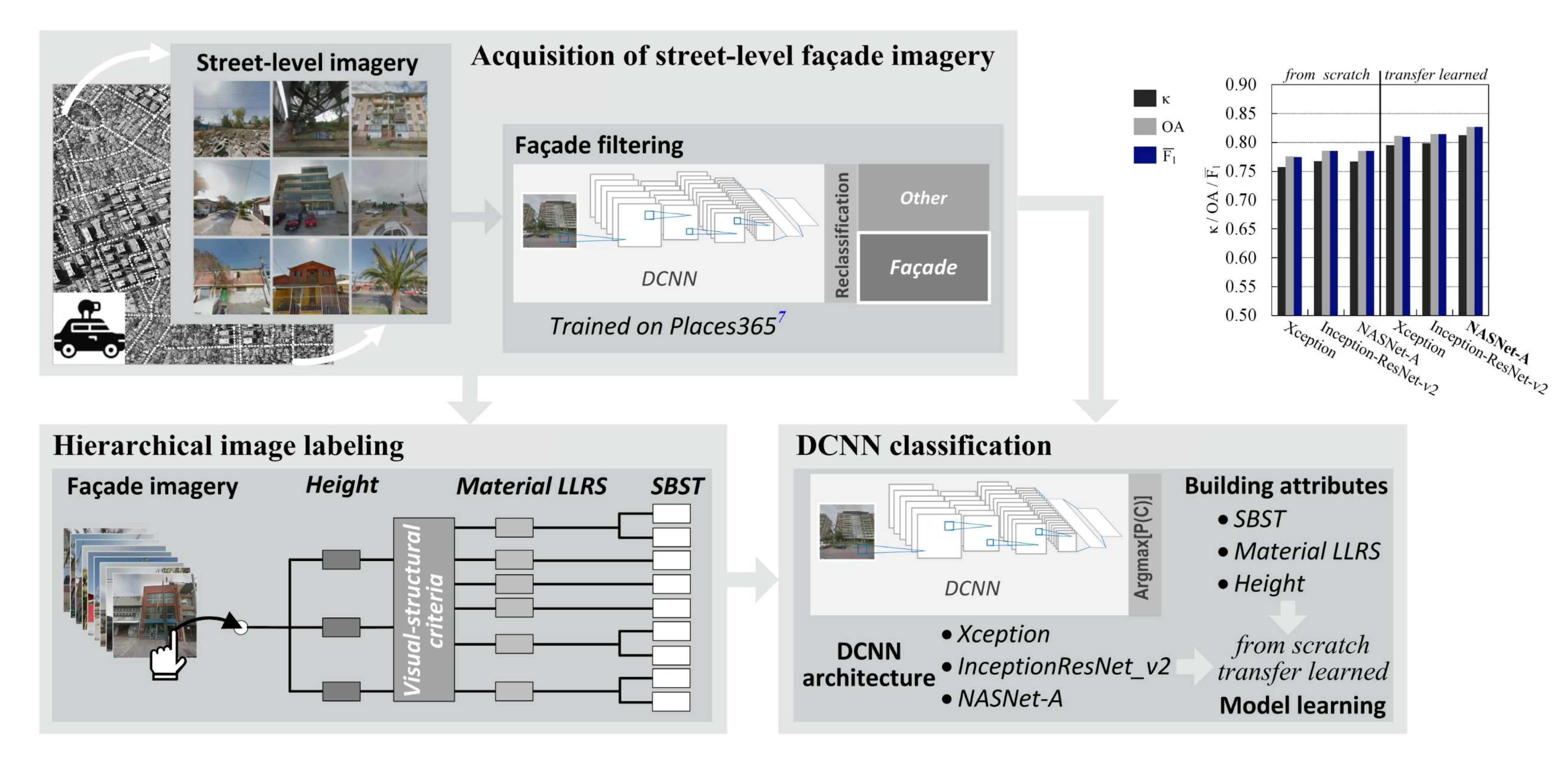
Lima, Peru

Quito, Ecuador









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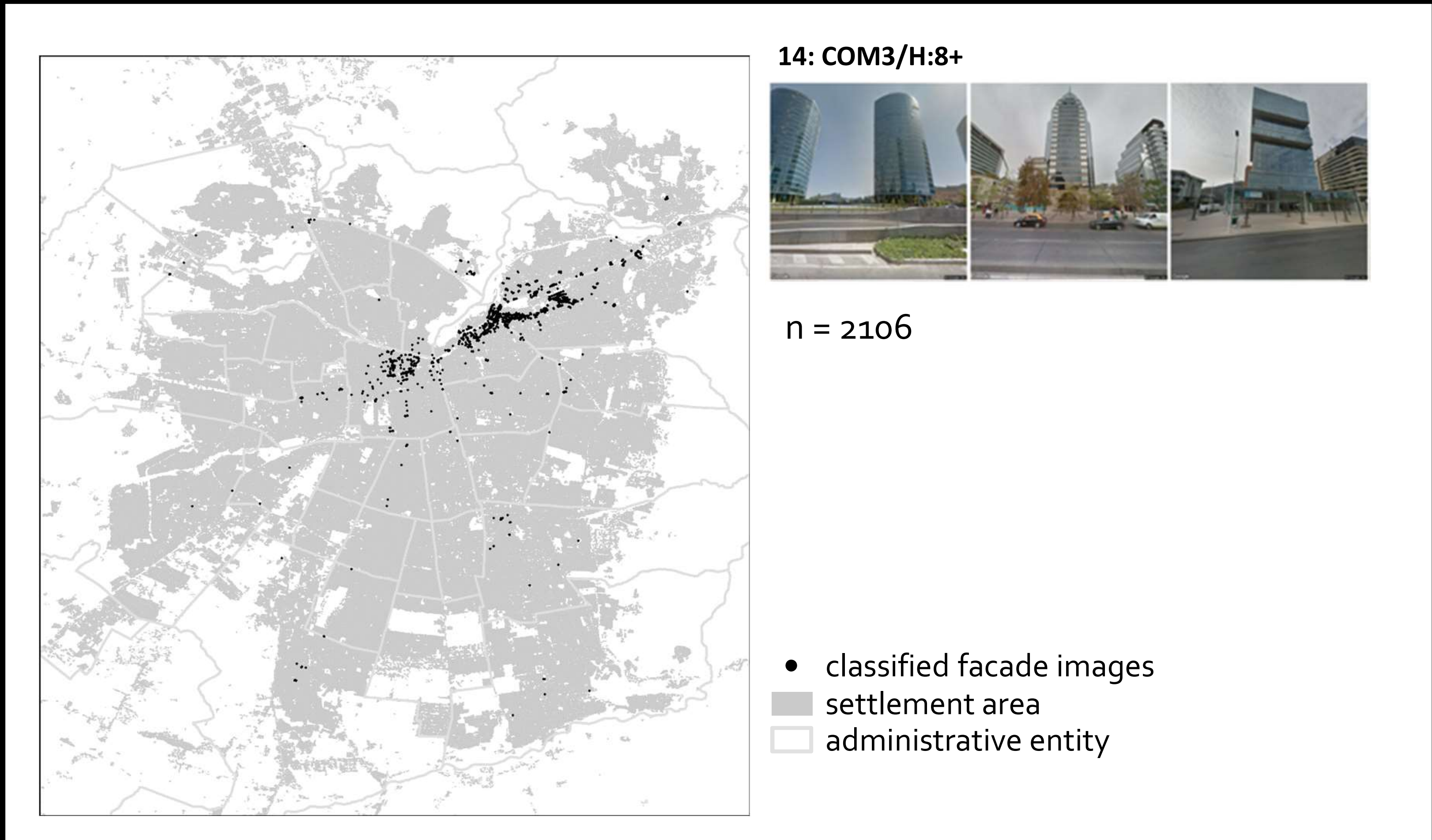
Automated building characterization for seismic risk assessment using street-level imagery and deep learning.
ISPRS Journal of Photogrammetry and Remote Sensing, 180, 370–386.

prediction of
204030
facades



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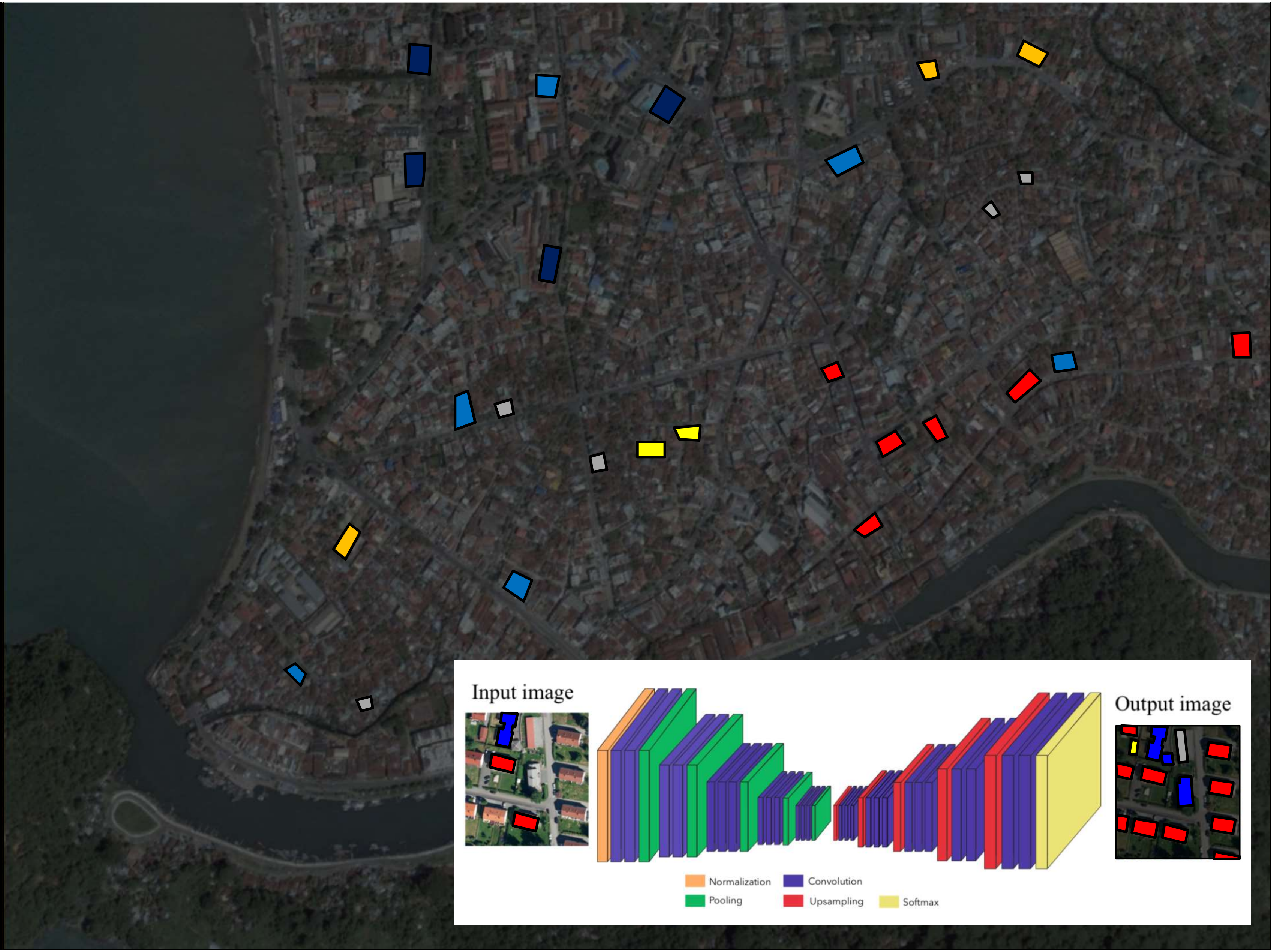
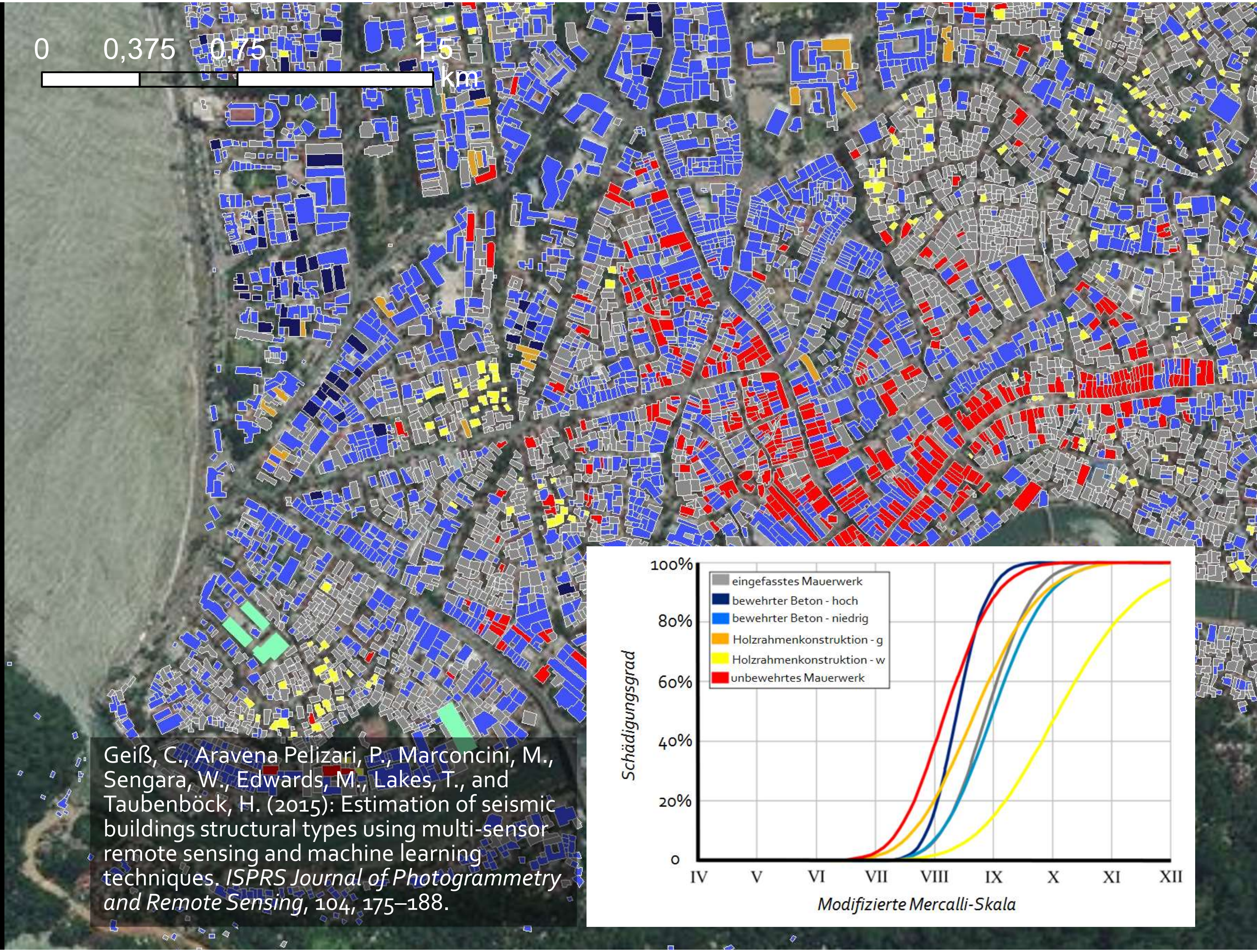
reinforced masonry
unreinforced masonry



Input image
Output image
Normalization
Convolution
Pooling
Upsampling
Softmax



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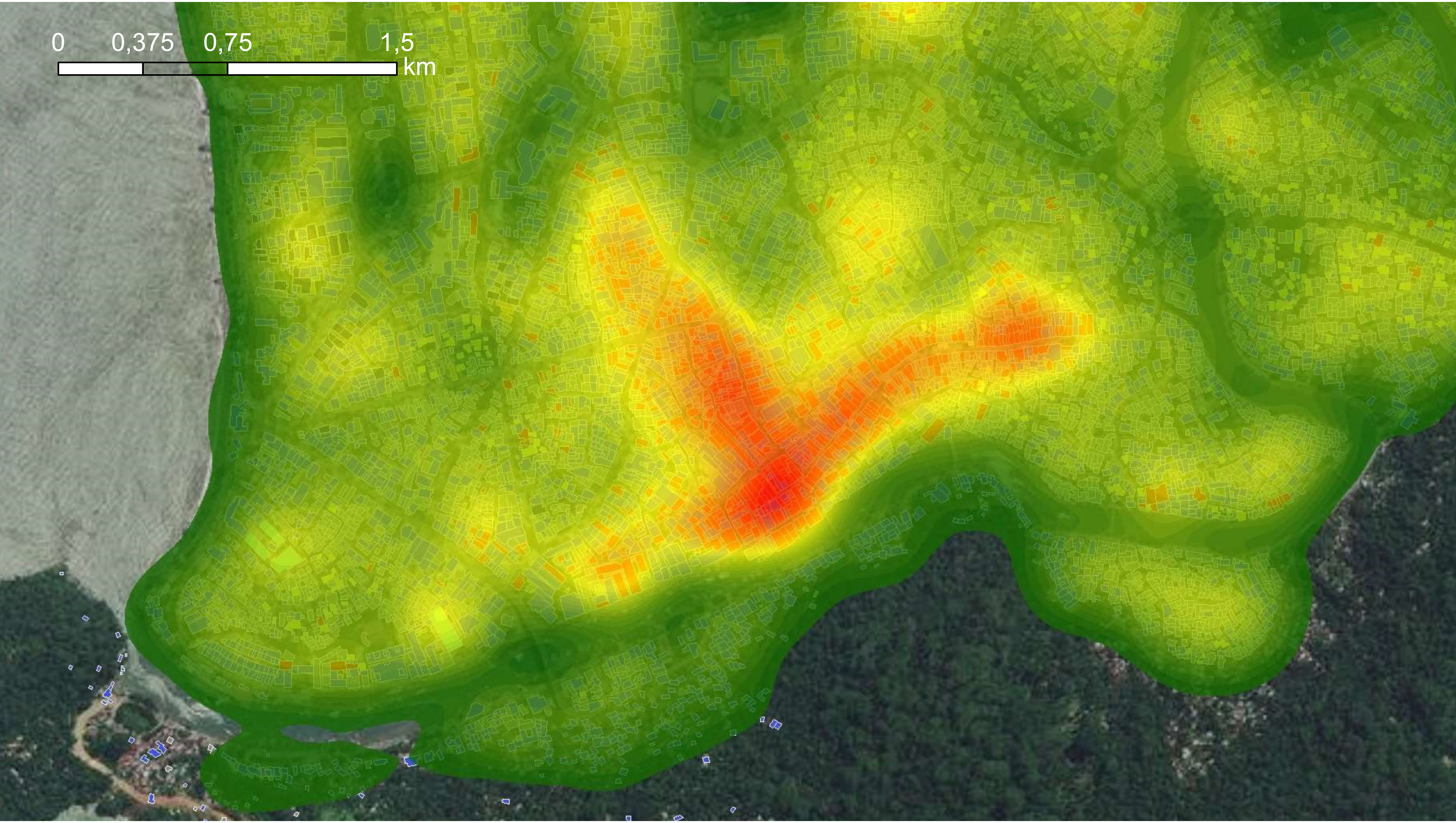
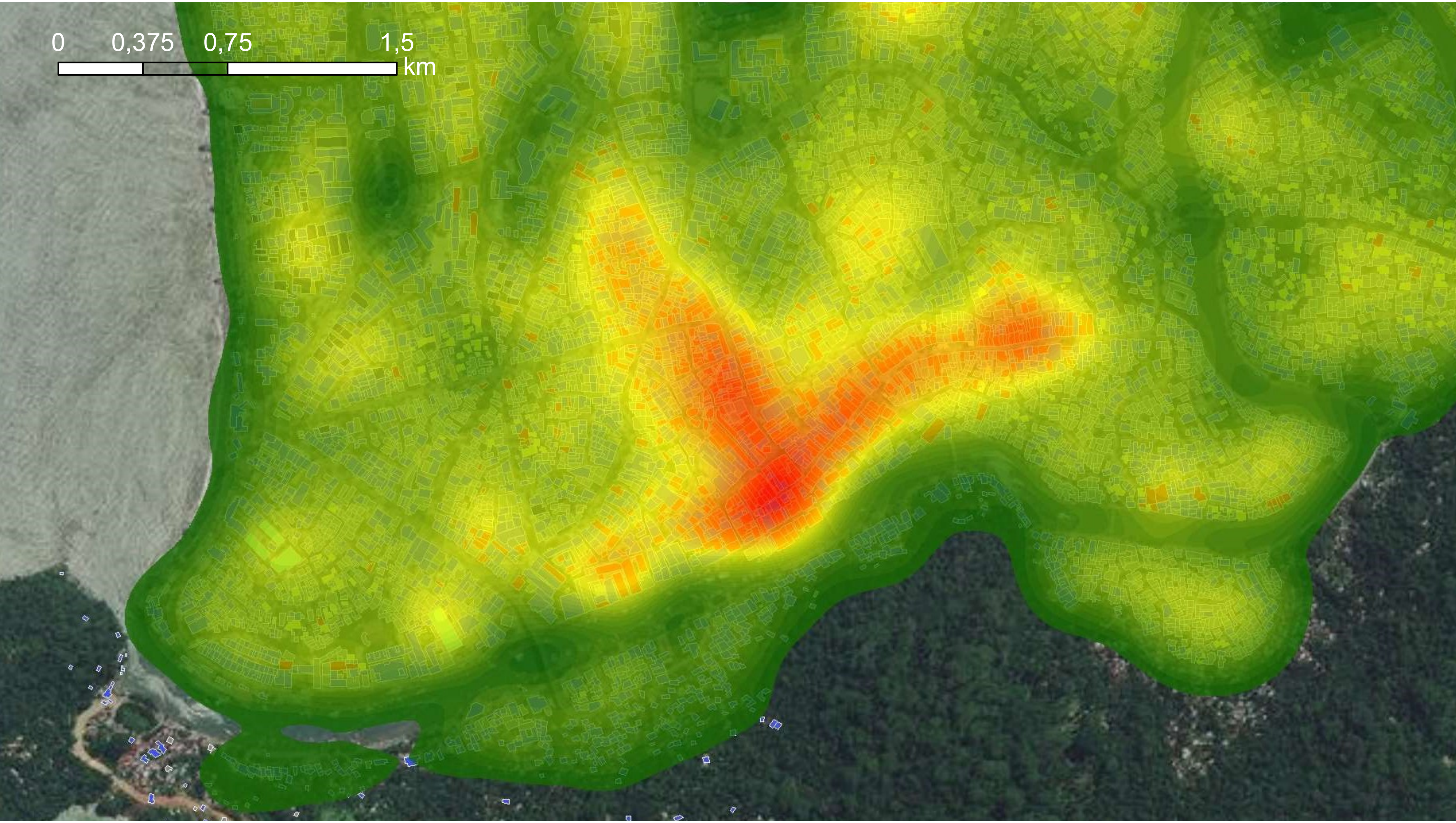

0
0,375
0,75
1,5
km



0
0,375
0,75
1,5
km

Example: Maule Earthquake, 27th Feb. 2010, 8.8 M_w

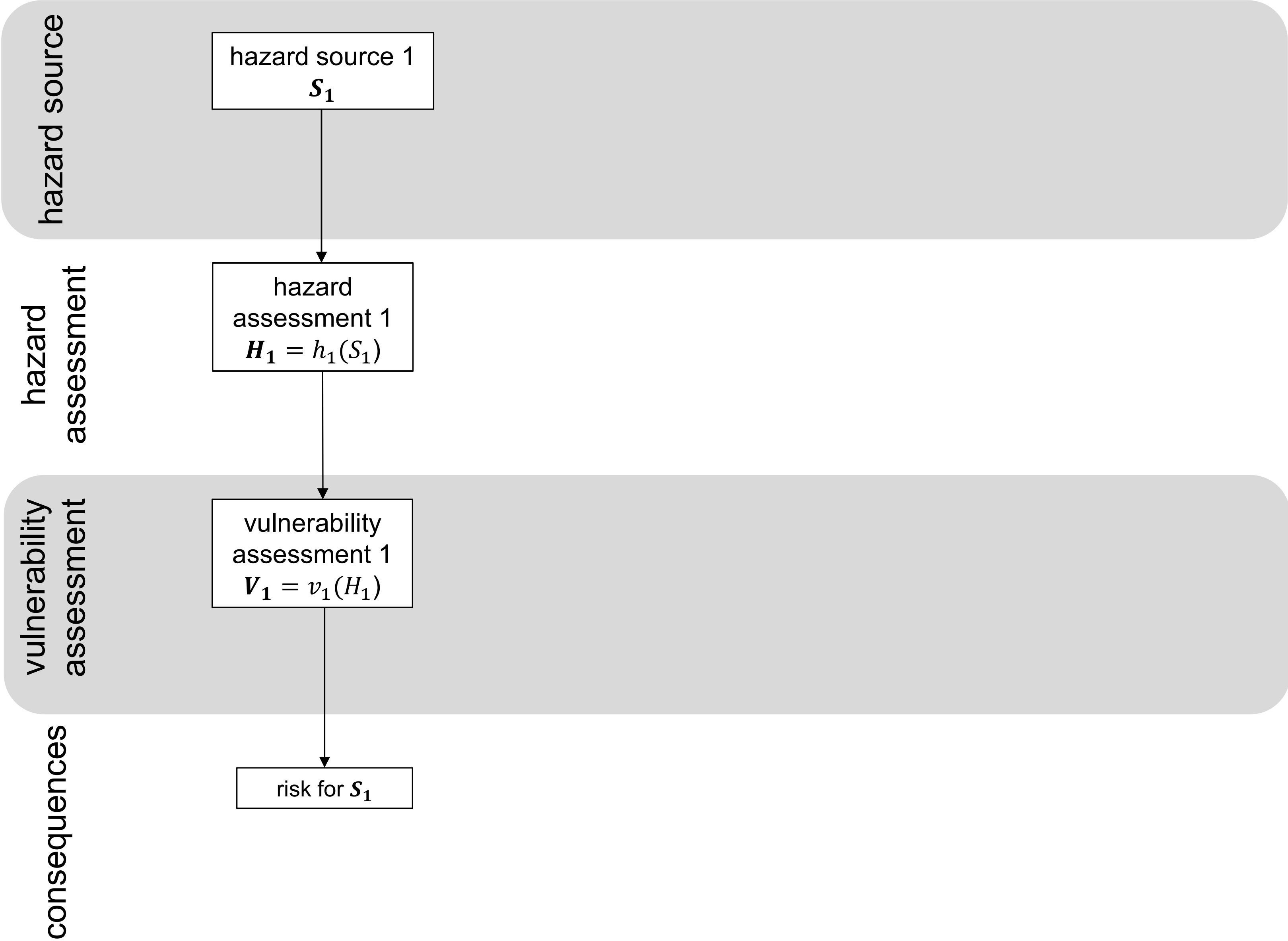
Hazard interactions

Three different types of hazard interactions

- **Concurrence of two (or more) hazard events**
- **Natural hazards triggering other natural hazards**
- **Networks of hazard interactions (cascades)**

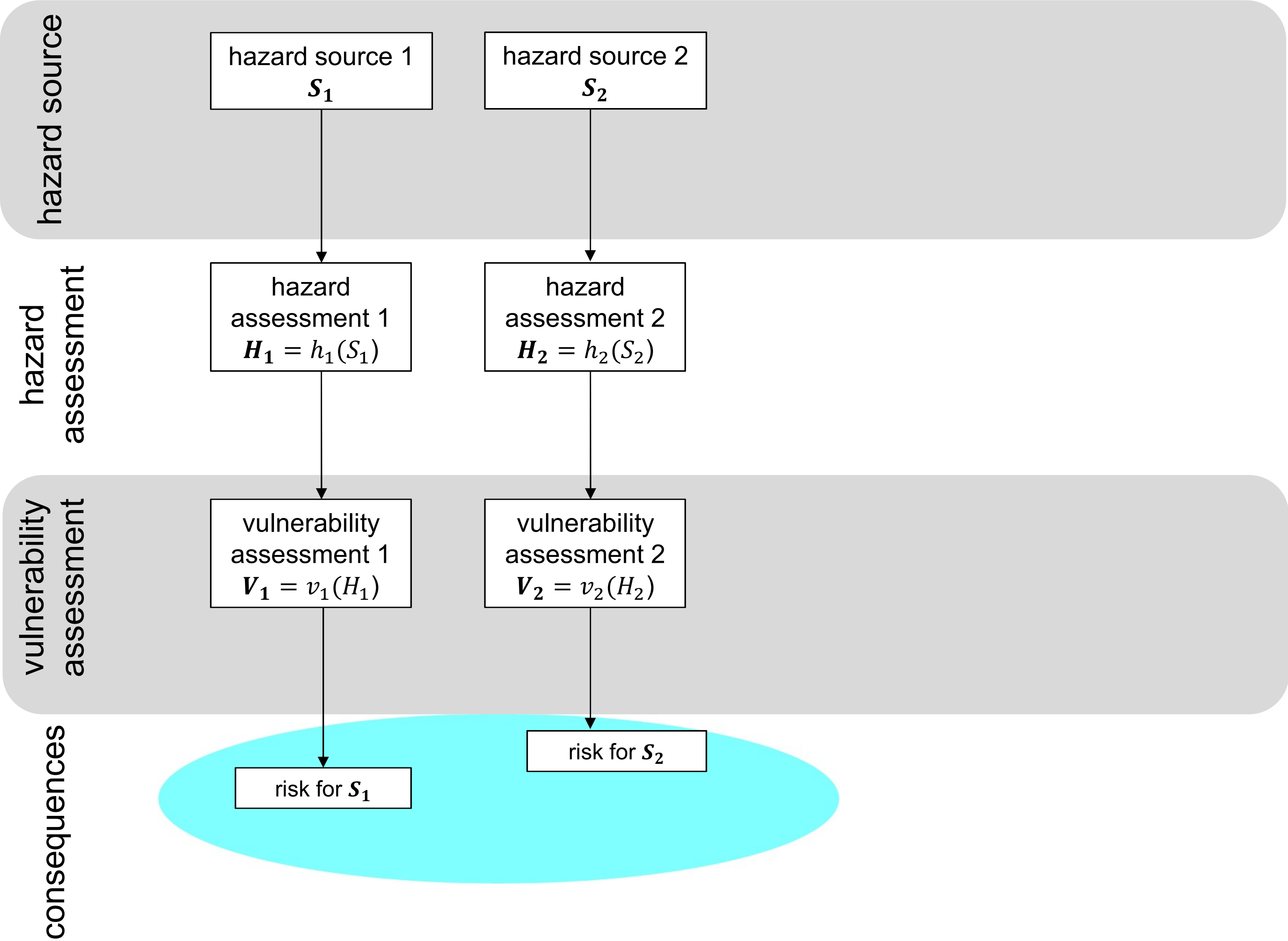
Methods

- **Single-hazard risk approaches**
  - Calculation of risk for individual hazards
    - *Missing*: no hazard interactions, single risk maps, no comprehensive view of risks


hazard source
hazard source 1
S_1
hazard assessment
hazard assessment 1
$H_1 = h_1(S_1)$
vulnerability assessment
vulnerability assessment 1
$V_1 = v_1(H_1)$
consequences
risk for S_1

Methods

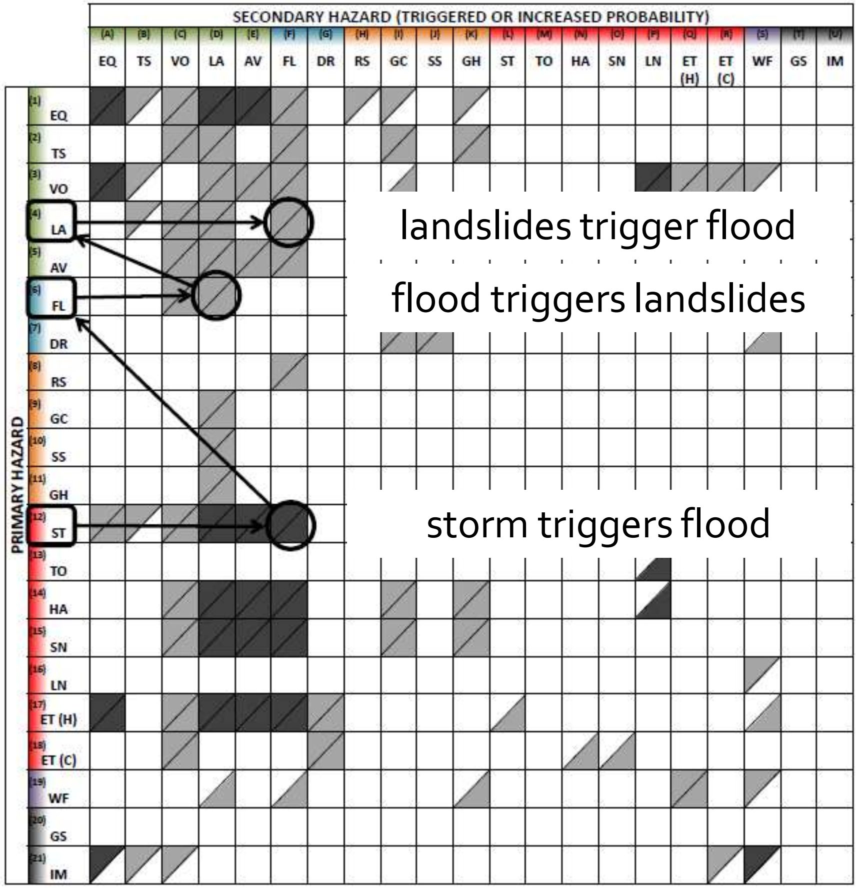
- **Multi-layer single-hazard risk approaches**
  - Calculation of risk for individual hazards
    - independent analysis of multiple different hazards relevant to a given area; computation of multi-hazard risk by e.g., **weighted overlays**
    - *Missing*: this approach does not take into account the significant interactions and dependencies of several natural hazards
    - Assumptions have to be made with respect to the „weight“ of the different layers


hazard source
hazard source 1
S_1
hazard source 2
S_2
hazard assessment
hazard assessment 1
$H_1 = h_1(S_1)$
hazard assessment 2
$H_2 = h_2(S_2)$
vulnerability assessment
vulnerability assessment 1
$V_1 = v_1(H_1)$
vulnerability assessment 2
$V_2 = v_2(H_2)$
consequences
risk for S_1
risk for S_2

Hazard interactions

- **Triggering relationships**
  - e.g., earthquake triggers landslides
- **Increased-probability relationships**
  - e.g., landslides blocking rivers and increasing the probability of floods
- **Networks of hazard interactions (cascades)**
  - e.g. earthquakes, floods, storms damage chemical plants or pipelines, causing the release of hazardous materials

What kind of cascades are possible?

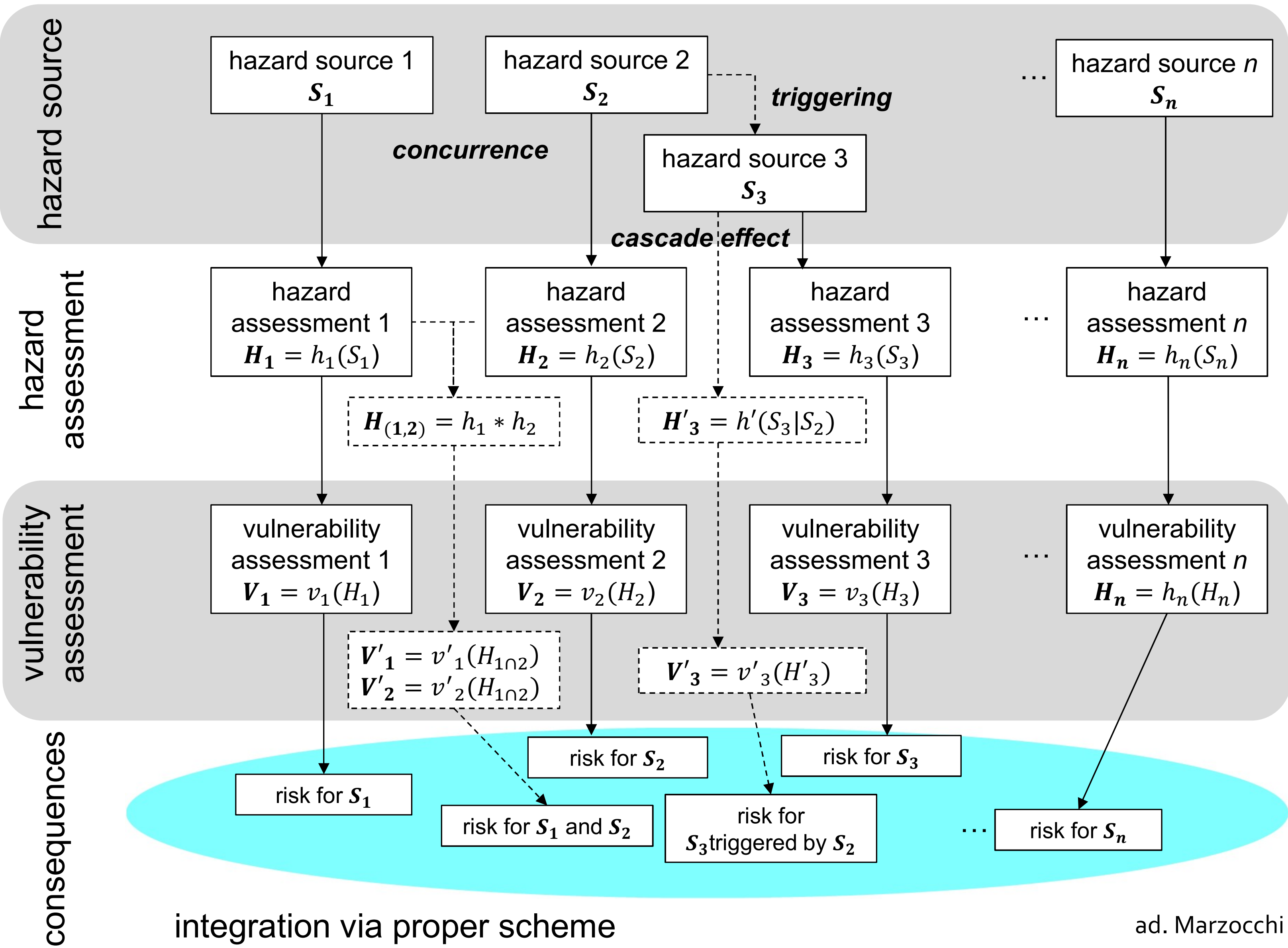


KEY		
HAZARD GROUP	HAZARD	CODE
GEOPHYSICAL	Earthquake	EQ
	Tsunami	TS
	Volcanic Eruption	VO
	Landslide	LA
	Snow Avalanche	AV
HYDROLOGICAL	Flood	FL
	Drought	DR
SHALLOW EARTH PROCESSES	Regional Subsidence	RS
	Ground Collapse	GC
	Soil (Local) Subsidence	SS
	Ground Heave	GH
ATMOSPHERIC	Storm	ST
	Tornado	TO
	Hailstorm	HA
	Snowstorm	SN
	Lightning	LN
	Extreme Temperature (Hot)	ET (H)
	Extreme Temperature (Cold)	ET (C)
BIOPHYSICAL	Wildfire	WF
SPACE	Geomagnetic Storm	GS
	Impact Event	IM

COLOUR CODE	NATURE OF SECONDARY HAZARD (FOLLOWING *ONE* OCCURRENCE OF PRIMARY HAZARD)
(light grey)	Potential for a small number of hazard events (individual or a few occurrences)
(dark grey)	Potential for a large number of hazard events (multiple occurrences)

SYMBOL	EXPLANATION
(lower triangle)	Hazard Triggers Secondary Hazard
(upper triangle)	Hazard Increases Probability of Secondary Hazard
(both)	Hazard Both Triggers and Increases the Probability of Secondary Hazard

Gill and Malamoud, 2016



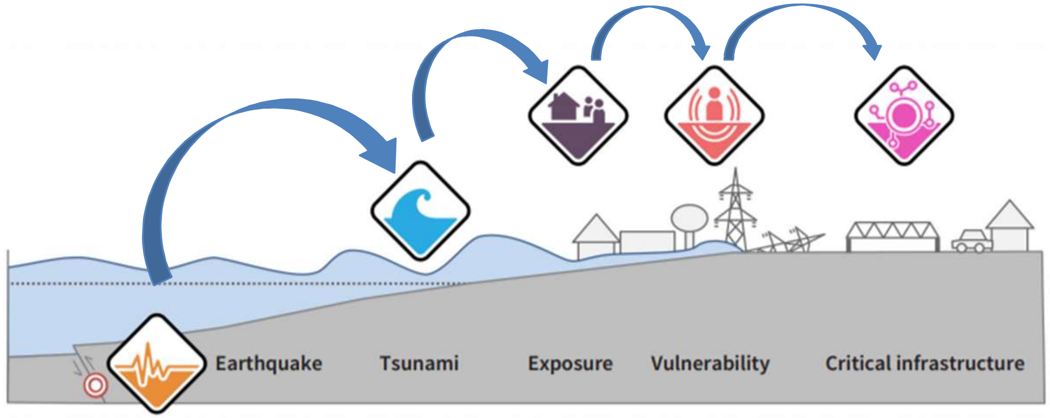
ad. Marzocchi *et al.*, 2012

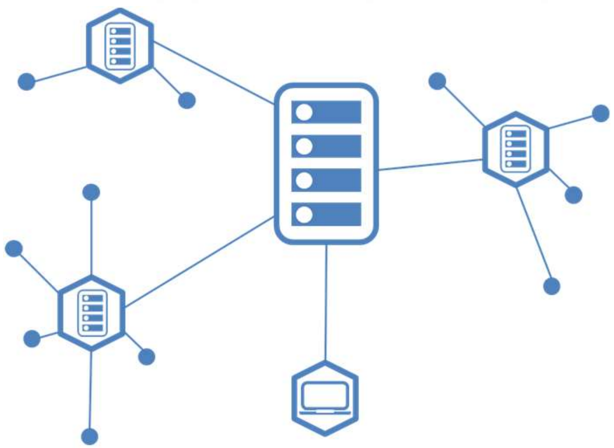
RIESGOS: A new approach to multi-risk analysis

1. **Based on multi-risk scenarios**
   e.g. Chile & Peru: Earthquake and tsunami events and their impact on residential buildings and critical infrastructure

2. **Dynamical analysis of cascading processes**
   based on users selection of parameters

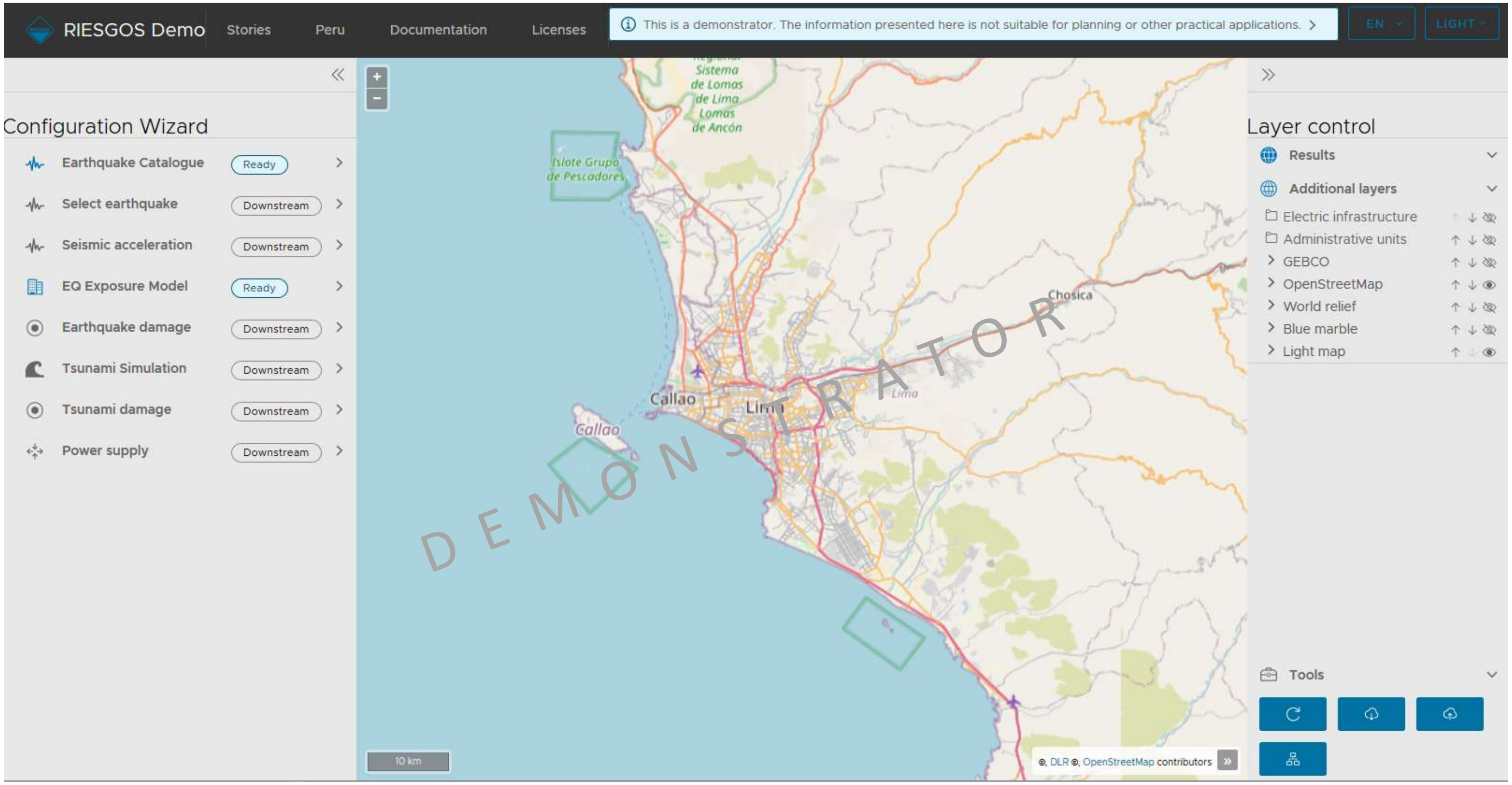
3. **Independent and distributed webservices**
   connected through a web platform (demonstrator) that serves as the interface for user interaction and visualization of results





DLR

RIESGOS: Demonstrator

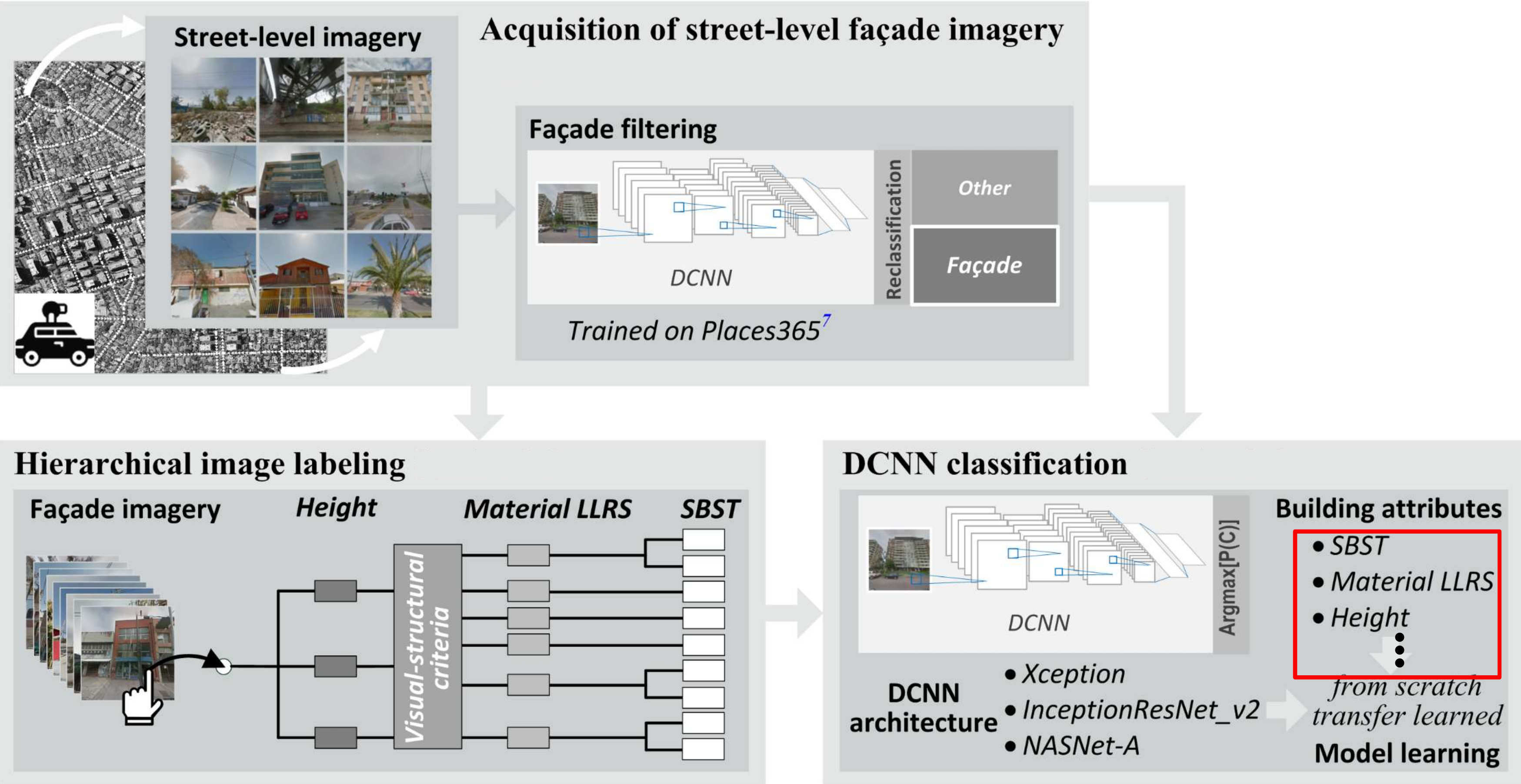


Screenshot of the RIESGOS Demonstrator

- **Modular**
  Web services may be recombined to form a chain representing a multi-risk scenario
- **User interaction**
  Users are able to select, configure, combine and run different parameters
- **Visualization**
  Display and exploration of multi-risk analysis and information

RIESGOS – hazard-independent exposure

RIESGOS – hazard-independent exposure



outlook

- Increase of certain natural hazards / population increase and urbanization increase exposure

- model complexity  monitoring capability

- risk communication for antifragile societies

references

- Aravena Pelizari, P., Geiß, C., Aguirre, P., Santa María, H., Merino Peña, Y., and Taubenböck, H. (2021): Automated building characterization for seismic risk assessment using street-level imagery and deep learning. *ISPRS Journal of Photogrammetry and Remote Sensing*, 180, 370–386.
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