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One step back for a leap forward – towards operational measurements of elements at risk

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1. Introduction to the special issue "*Geospatial data for multiscale mapping and characterization of elements at risk*"

The impact of extreme geophysical, hydrological, and meteorological events such as earthquakes and tsunamis, floods, storms, or droughts causes both enormous human and monetary losses. The NatCatSERVICE of Munich Re's database on most severe natural catastrophes documents for the years 2004 to 2015 10,304 loss events with 926,600 fatalities and 1.798 trillion US$ overall losses worldwide (MunichRE 2016). Prospectively, rapid urbanization observed in regions prone to natural hazards places more people and assets at risk than ever before.

Regarding the assessment of risks, numerous questions can only be answered in a meaningful, consistent and reliable way when using data which incorporate the spatial domain. In this manner, information about elements at risk needs to be spatially disaggregated and continuous and at the same time up-to-date and available in a standardised way. This is often not the case for many regions of the world, if suitable data are existent and available at all.

Remote sensing, Volunteered Geographic Information (VGI), and other sources of geospatial data are available at various spatial and temporal scales, and the amount of data is increasing exponentially. These data comprise local to global observations of the earth's surface with a temporal resolution reaching from daily to periodical. The overall aim of this special issue is to present and inform the multidisciplinary risk community on the latest developments, capabilities and limitations regarding mapping of elements at risk and affiliated characterization on multiple spatial and temporal scales.

This special issue on *Geospatial data for multiscale mapping and characterization of elements at risk* is closely linked to its precursor special issue in the Natural Hazards Journal on *Remote sensing contributing to mapping earthquake vulnerability and effects* (Taubenböck & Strunz 2013). Regarding the **risk component(s)** addressed, this special issue has a **narrower** focus, dealing primarily with **mapping and characterization of the exposed elements**. At the same time, the special issue clearly **widens** the utility for risk-related analysis and applications by showing **concepts, data, methods, results, and applications, regarding elements at risk, which are largely hazard-independent**. This concept is intended to address a very broad scope of researchers and stakeholders.

2. Notes on the evolvement of the role of remote sensing within natural hazard risk assessment

In general, availability of geospatial data for the analysis and assessment of risks triggered by natural hazards is constantly increasing. Digital geospatial data originate from remote sensing, commercial or administrative databases, geotagged data from social networks, mobile devices, among many others. In this section, we give a brief overview on the evolvement of the role of remote sensing, the primary data source used and discussed in this special issue, within natural hazard risk assessment. Thereby, we exemplarily focus on earthquakes, which is the hazard that is dominantly considered in the research papers of the special issue.

- **First phase: Hazard-focused analysis**

The deployment of remote sensing for earthquake hazard research can be tracked back to the first appearance of commercially available satellite images in the 1970s. Those data were used to map active faults and structures (Tronin 2006). Subsequent scientific contributions focused on the understanding and documentation of location, slip rates as well as the kinematics and dynamics of active faults on interseismic temporal scales, among others. A wide spectrum of air- and spaceborne remote sensing reaching from optical sensors to radar systems were used for this purpose (Tralli *et al.* 2005, Geiß & Taubenböck 2013). Especially differential interferometric synthetic aperture radar data proved useful in mapping and quantifying pre-seismic land-surface deformations in the amount of centimeters (Stramondo *et al.* 2007, Bayuaji *et al.* 2010).

- **Second phase: Integrative yet explorative studies on the capabilities of remote sensing for assessment of exposure and vulnerability**

The use of remote sensing for assessment of earthquake exposure and vulnerability is a less long-established field compared to earthquake hazard research. This corresponds to a changing perspective of the scientific community which increasingly considers the assessment of vulnerability and its constituent aspects as a pivotal part of a risk analysis (Pelling 2003, Turner *et al.* 2003). Thereby, the availability of new sensor systems - delivering very high spatial resolution imagery - enabled an appreciable share of remote sensing first (Geiß &

Taubenböck 2013). Notably, related studies aimed at an integrative view and considered numerous parameters for a holistic characterization and assessment of vulnerability (e.g., Taubenböck *et al.* 2008, Ebert *et al.* 2009, Prasad *et al.* 2009, Taubenböck *et al.* 2009a, Zeng *et al.* 2012). Thereby, the derivation of a wide variety of vulnerability-related parameters from remote sensing comprising for example population (e.g., Dobson 2000, Taubenböck *et al.* 2007, Chen 2010, Aubrecht *et al.* 2012), and properties of the built environment (e.g., Müller *et al.* 2006, French & Muthukumar 2006, Sahar *et al.* 2010), among others, was explored.

- **Third phase: Methodological elaboration of specific aspects of exposure and vulnerability**

With a slight temporal offset to this exploratory phase, numerous studies focused on specific aspects of risk assessment procedures and aimed to provide a deeper understanding of various details and parameters. Given the nature of remote sensing as tool for providing physical measurements of the earth's surface, especially the physical vulnerability of built environments was subject to an increasing scientific contemplation in the last decade. Since pioneering works of e.g., Sarabandji & Kiremedjian (2007), who estimate the seismic structural type of buildings based on remote sensing and ancillary information for deployment in earthquake loss estimation models, numerous studies were conducted and different approaches postulated. For instance, Taubenböck *et al.* (2009b), Borzi *et al.* (2011), Polli & Dell'Acqua (2011), and Su *et al.* (2015) characterize the built environment with remote sensing data and retrieve specific fragility functions or damage probability matrices, respectively, for designated building types. In contrast to that, e.g., Borfecchia *et al.* (2010), and Geiß *et al.* (2014, 2015) combine limited *in situ* ground truth building inventory data with features from remote sensing and use techniques of statistical inference for a complete labelling of the residual building inventory according to relevant vulnerability levels. Similar methodological principles were exploited by e.g., Wieland *et al.* (2012), Pittore & Wieland (2013), and Geiß *et al.* (2016) to assess seismic vulnerability on an aggregated spatial level to allow for covering larger areas.

3. One step back for a leap forward - towards operational measurements of elements at risk

As can be seen from the previous section, a large share of research focused on the development of techniques for mapping and characterization of elements at risk and assessing vulnerability, which are capable of providing a high level of thematic detail (i.e., aiming to provide detailed thematic information by incorporation of sufficient prior knowledge and corresponding to a holistic understanding of vulnerability). At the same time, data requirements, which incorporate e.g., very high spatial resolution remote sensing imagery and detailed *in situ* data, hamper utilization capabilities of many approaches due to availability, monetary costs and processing requirements. Moreover, local idiosyncrasies must not be bypassed and transfer of models can hardly be carried out in a non-adaptive manner.

In general, exposure can be considered as a highly tangible component of risk in contrast to the fuzzy concept of vulnerability, since it comprises assets potentially affected by a hazardous event such as people, properties, infrastructure, or economic activities (Schneiderbauer & Ehrlich 2004, Geiß & Taubenböck 2013). However, timely mapping and characterizing of those assets in a spatially continuous and detailed way for large areas remains a major challenge. In this manner, this special issue follows the governing idea to establish exposure information on various spatial and temporal scales. At the first glance this may seem as a step back since previous works could already generate detailed exposure and in particular vulnerability information. Yet, as mentioned, those approaches suffered dominantly from small-area coverage, high data costs, considerable *in situ* data collection efforts, and large processing requirements. As such, this special issue is intended as a first step towards exposure estimation approaches allowing for large-area coverage, keeping a high spatial detail and internalizing capabilities for frequent updating and monitoring. Such approaches and resulting data sets can be a leap towards significantly improved global risk models.

In this manner, this special issue contains a considerable variety of works. Pittore *et al.* present conceptual considerations and a road map for a global dynamic exposure database. Acevedo *et al.* present an exposure model for the residential building stock in Antioquia and affiliated vulnerability properties for seismic risk assessment. They rely on both cadastral information and survey data. Santa María *et al.* present an exposure model on a national level for Chile based on statistical data and refined regional models incorporating remote digital surveys and remote sensing imagery. Keeping the geographic scope in Chile, Geiß *et al.* jointly use remote sensing imagery and VGI for estimation of crucial exposure components for the city of Valparaíso with a high level of automatization. Also Qi *et al.* relay on various data sources comprising remote sensing imagery, *in situ* imagery, and crowdsourcing data for mapping of exposure and seismic vulnerability of buildings in the city of Tangshan in China. More focused on the actual application, Wyss shows earthquake loss estimations regarding the Gorkha M7.8 earthquake of 25th April 2015, which are based on a global exposure data set. Likely application-oriented, Fekete *et al.* combine VGI with other geospatial data to focus on spatial exposure in the context of flood and blackout for the city of Cologne, Germany. The special issue is closed by a comments section. There, authors from science, intergovernmental organizations, and the commercial sector give lively examples of past experiences, current best practices, and exigent future challenges and needs.

The special issue is a plea for methodological progress and the operationalized development of global (or at least large-area) exposure information using multi-source geospatial data. Connected to this is the plea for multidisciplinary thinking, as well as openness for sharing data and algorithms between different science communities. As we have seen in the past, an open dialogue always triggered a significant leap forward regarding conceptual issues, methodological developments, operational data generation, and perception of risk. Such a development appears exigent in times of for instance climate change and global urbanization process, which define unprecedented challenges for our society and environments.

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