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Review

A review of multi-risk methodologies for natural hazards: Consequences and challenges for a climate change impact assessment

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ABSTRACT

This paper presents a review of existing multi-risk assessment concepts and tools applied by organisations and projects providing the basis for the development of a multi-risk methodology in a climate change perspective.

Relevant initiatives were developed for the assessment of multiple natural hazards (e.g. floods, storm surges, droughts) affecting the same area in a defined timeframe (e.g. year, season, decade). Major research efforts were focused on the identification and aggregation of multiple hazard types (e.g. independent, correlated, cascading hazards) by means of quantitative and semi-quantitative approaches. Moreover, several methodologies aim to assess the vulnerability of multiple targets to specific natural hazards by means of vulnerability functions and indicators at the regional and local scale.

The overall results of the review show that multi-risk approaches do not consider the effects of climate change and mostly rely on the analysis of static vulnerability (i.e. no time-dependent vulnerabilities, no changes among exposed elements). A relevant challenge is therefore to develop comprehensive formal approaches for the assessment of different climate-induced hazards and risks, including dynamic exposure and vulnerability. This requires the selection and aggregation of suitable hazard and vulnerability metrics to make a synthesis of information about multiple climate impacts, the spatial analysis and ranking of risks, including their visualization and communication to end-users. To face these issues, climate impact assessors should develop cross-sectorial collaborations among different expertise (e.g. modellers, natural scientists, economists) integrating information on climate change scenarios with sectorial climate impact assessment, towards the development of a comprehensive multi-risk assessment process.

Contents

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1. Introduction

According to the report of the World Bank on the main hotspots of natural hazards (Dilley et al., 2005), about 3.8 million km^2 and 790 million people in the world are relatively highly exposed to at least two hazards, while about 0.5 million km^2 and 105 million people to three or more hazards. Climate change is likely to further increase the exposure to multiple-risks affecting the magnitude, frequency and spatial distribution of hazardous and disastrous events (IPCC, 2014). In this context, the relevance for adopting a multi-risk approach for the assessment of climate change impacts emerges from international organizations (e.g., Dilley et al., 2005; IPCC, 2012) at a range of spatial scales, including the European level (EC 2010). Also in the special report of extreme events and disasters (IPCC, 2012), the IPCC points out the relevance of adopting a multi-hazard approach in order to provide more effective adaptation and reduction measures, in the present and in particular in the future.

At the global and European level, the interest about the multi-risk assessment increased in the last decades, especially when related to applications and initiatives aimed at the assessment of risks derived from different natural and man-made hazardous events (e.g., Schmidt-Thomè, 2006; FEMA, 2011; Farrokh and Zhongqiang, 2013).

However, usually a hazard by hazard approach is considered for evaluating the consequences of individual natural and climate-related hazards (e.g. heavy precipitation events, droughts, floods, debris flows, landslides, storm surges) on vulnerable systems (EC, 2004; DEFRA, 2006; Kappes et al., 2010; Santini et al., 2010; Feyen et al., 2012; Hinkel et al., 2011). Specifically, single-risk analysis allows to determine the individual risk arising from one particular hazard and process occurring in a specific geographic area during a given period of time (Bell and Glade, 2004a; EC 2010), while it does not provide an integrated assessment of multiple risks triggered by different forces (natural and anthropogenic) (Glade and von Elverfeldt, 2005; IPCC, 2007; World Bank, 2010; Marzocchi et al., 2012).

For instance, coastal zones will be exposed to different climate change impacts and consequences, such as storms, coastal erosion, sea-level rise and saltwater intrusion (IPCC, 2007; Nicholls and Cazenave, 2010; Torresan et al., 2012). This highlights the importance to consider all these hazards simultaneously in order to approximate their dependencies and to provide a useful overview of the total risk arising from climate change for that particular coast (IPCC, 2012; Rosendahl, 2014).

Therefore, a comprehensive approach should be applied to the assessment of natural and specifically climate-related disaster risks in order to consider the whole aspects contributing to the increase of hazards, exposure and vulnerability in a multi-risk perspective (Del Monaco et al., 2007; Garcia-Aristizabal and Marzocchi, 2011). Future changes in exposure and vulnerability should be considered as key determinants of losses and should be analysed together with natural climate variability and anthropogenic climate change for the assessment of disaster risks and impacts (IPCC, 2012). The aim of this paper is to present the state of the art concerning multi-risk approaches and methods in order to provide a solid scientific support for the development of a multi-risk model (Gallina et al., submitted) addressing cumulative climate change impacts on different natural and human systems and activities. Particular emphasis is given to the analysis of natural climate variability and biophysical and environmental aspects of vulnerability, while the socio-economic dimension as well as any coping capacity of the exposed elements at risk are not considered in this phase of analysis.

Following the review of the relevant key definitions used in literature (Section 2), Section 3 and 4 provide a critical analysis and discussion about organisations, tools, projects and methodologies applied at the international level and specifically in Europe for the assessment of different natural risks. Finally, Section 5 aims to discuss the main consequences for the development of a multi-risk assessment approach related to climate change hazards, exploring the challenges posed by the integration of climate change projections in the multi-risk analysis.

2. Terminology of multi-risk

Within the general development of the International Decade of Natural Disaster Reduction (IDNDR) and the following permanently installed International Strategy for Disaster Reduction (ISDR) (Zentel and Glade, 2013), the interest and reference to the concept of multi-hazard has been first made in the Agenda 21 Conference in Rio de Janeiro (UNEP, 1992) and then in the Johannesburg Plan (UN, 2002) in which a complete multi-hazard approach was proposed for disaster management and risk reduction. Afterwards, the initiatives of analysing also the multiple risks arising from different hazards and affecting many exposed elements at risk are constantly increasing during the last years (e.g. Bell and Glade, 2004b; Glade and von Elverfeldt, 2005; Kappes et al., 2010; EC, 2011; Garcia-Aristizabal and Marzocchi, 2012a, 2012b; Kappes et al., 2012a).

A major difficulty in a new emerging discipline, such as multi-risk, is the lack of a precise definition of terms generally agreed by all different communities. However, a unified glossary is essential to minimize misunderstanding and to provide a rigorous basis for the scientific knowledge (Garcia-Aristizabal and Marzocchi, 2012a; Thywissen, 2006).

In order to avoid any confusion, Table 1 summarises the main concepts and references within the multi-risk context. These are the basis for the discussion of the analysed initiatives and methodologies.

As defined by UNISDR (2009) and IPCC (2012), the basic components that should be considered in the multi-risk assessment are: hazard, elements at risk including their exposure and vulnerability. Specifically, hazard refers to the physical phenomenon that has the potential to cause damages and losses to human and natural