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Urban thermal risk reduction: Developing and implementing spatially explicit services for resilient cities

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ABSTRACT

Elevated urban temperatures and heatwaves are a serious threat to the health and wellbeing of the continuously growing urban population and are projected to worsen under climate change. For this reason well-informed disaster risk reduction (DRR) actions, where science and technology play a key role, are required. However insufficient communication between scientific and policy-making communities (known as the science-policy gap) hampers the use of science in DRR. Hence there is a strong need to interpret existing scientific knowledge into actionable knowledge, i.e. science that is useful, usable and used. This article presents a series of services and tools that build-upon existing scientific knowledge and aim to provide actionable knowledge to authorities and citizens for reducing the risks of elevated urban temperatures. The above were implemented in the context of the European Commission's Thermal Risk rEduction Actions and tools for secURE cities (TREASURE) project, and address many of the goals and priorities for action set in the Sendai framework for disaster risk reduction (SFDRR) of the United Nations. A key policy-making user of the implemented services and tools is the City of Athens in Greece, which is one of the largest metropolitan areas in Europe.

1. Introduction

Over the past six decades (1950–2010) our planet has gone through a process of rapid urbanization, and in 2007–for the first time in history- the global urban population exceeded the global rural population (UN, 2014). This demographic trend is not expected to change and in 2050 the United Nations (UN) project that the urban population will increase to 66% of the world population (UN, 2014). To accommodate the needs of the increasing number of urban dwellers, the human reshaping of the earth has reached a truly global scale (Grimm, Grove, Pickett, & Redman, 2000; Meyer & Turner, 1992). The most clear-cut evidence of this reshaping is the extensive conversion of natural lands to impervious surfaces (i.e. driveways, paved areas, etc.), the increase of trace-gas emissions (e.g. greenhouse gases and air pollutants), and the alteration of biogeochemical cycles such as the water cycle (Grimm et al., 2000). As the world continues to urbanize −in many cases in an uncontrolled manner– the sustainable development of urban areas has become an issue of paramount importance (UN-Habitat, 2015). This is because urbanization, in spite of its advantages, induces many adverse environmental effects that jeopardize the health, safety and wellbeing of the urban population.

One of these adverse effects is the Urban Heat Island (UHI) effect, which

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refers to the elevated temperatures of urban areas compared to adjacent areas outside the urban landscape (Oke, 1982). The UHI effect is a direct result of urbanization and is associated with a range of issues, such as increased energy demand, environmental degradation, and human health (Tan et al., 2010; Uejio et al., 2011). UHIs also affect the magnitude and duration of heatwaves within cities, which can cause many excess deaths (Tan et al., 2010). In detail, heatwaves were the deadliest extreme weather events in Europe during 1991–2015 causing tens of thousands of premature deaths (EEA, 2017). The 2003 European heatwave in particular, which resulted in 25,000 to 70,000 excess deaths across Western Europe (D'Ippoliti et al., 2010; UNEP, 2004), is a stark reminder of the dangers that extreme temperatures pose to the urban population. In future, heatwaves are projected to become more frequent, more intense and longer lasting due to global climate change (Meehl & Tebaldi, 2004; Russo et al., 2014). Europe in particular emerges as an especially responsive area to anthropogenically induced climate change where the warming will continue at a higher rate than the global mean (Amengual et al., 2014; Kuglitsch et al., 2010; Meehl & Tebaldi, 2004). This fact raises the issue that to maintain an acceptable quality of life for the foreseeable future, urban areas have to be properly managed and major actions regarding the understanding, monitoring and mitigating of UHIs and heatwaves and their impact on urban population have to be adopted (Grimm et al., 2000; Wilhelmi & Hayden, 2010), e.g. heat-health warning systems and action plans (Bittner, Matthies, Dalbokova, & Menne, 2014; Sheridan & Kalkstein, 2004; WHO, 2008). Furthermore, the Paris Climate Agreement at an international level provides the framework for future international cooperation and national action on climate change (the full implementation of all mitigation actions pledged by national governments would limit average global warming higher than the agreed UN target of "well below 2 °C"; Watts et al., 2016).

A crucial issue in understanding and managing the effects of elevated temperatures on the urban population is the intra-urban variability (Basara et al., 2008; Harlan, Declet-Barreto, Stefanov, Sarah, & Petitti, 2013; Huang, Zhou, & Cadenasso, 2011; Oswald et al., 2012; Tan et al., 2010; Wilhelmi & Hayden, 2010). In particular, heat-related mortality and morbidity result from a combination of risk and protective factors from the natural, the built, and the socio-cultural environment (Smoyer, 1998; Wilhelmi & Hayden, 2010). To that end, Wilhelmi & Hayden (2010) argue that to understand the societal vulnerability to extreme heat an interdisciplinary approach that uses information from all three environments (i.e. the natural, the built and the socio-cultural) is required. Over the last decade a considerable amount of research has been carried out on the societal vulnerability to extreme heat. This body of research offers valuable insights about this problem, the most significant of which are the following: (i) the impact of extreme heat is more pronounced among vulnerable populations like the elderly and the infants (Basu, 2009; Tan et al., 2010); (ii) not all heatwaves have a similar impact on mortality and the duration and timing of each event are very important (D'Ippoliti et al., 2010; Smoyer, 1998); (iii) the heatwave risk is higher during days with high air pollution (Analitis et al., 2014); people living alone and in communities with low neighborhood stability, e.g. communities with weak social cohesion and/or high crime have a higher heatwave risk (Rosenthal, Kinney, & Metzger, 2014; Smoyer, 1998; Uejio et al., 2011); (iv) low socioeconomic status as measured by education and income is an indicator of increased risk to excess heat (Basu, 2009; Curriero et al., 2002; Huang et al., 2011; Smoyer, 1998); (v) poor housing quality, high imperviousness, and UHI hotspots have positive associations with higher mortality rates due to excess heat (Hatvani-Kovacs, Belusko, Skinner, Pockett, & Boland, 2016; Oswald et al., 2012; Rosenthal et al., 2014; Smargiassi et al., 2009; Taylor et al., 2015; Zhou, Ji, Chen, Hou, & Zhang, 2014); and (vi) air-conditioning and access to transportation can be protective factors (Hatvani-Kovacs et al., 2016; Smoyer, 1998; Wilhelmi, Purvis, & Harriss, 2004).

Understanding the societal vulnerability to elevated temperatures is crucial for disaster risk reduction (DRR) actions (Briceno, 2015). This is because, what determines a disaster is not only the hazard itself but also the population's vulnerability, exposure, and ability to cope with its effects (Aitsi-Selmi, Egawa et al., 2015; Briceno, 2015). This approach, which is a major shift from conventional pure hazard response approaches, is adopted by the Sendai framework for disaster risk reduction (SFDRR) (UNISDR, 2015). SFDRR is the new global DRR policy framework of the United Nations Office for Disaster Risk Reduction (UNISDR), which replaced the Hyogo Framework for Action (HFA) in 2015. SFDRR recognizes urbanization as a driver of risk and gives a greater emphasis on health. In detail, one of the key outcome aims of SFDRR is "*the substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries*" (UNISDR, 2015). SFDRR also enhances the role of science in DRR actions (Aitsi-Selmi, Egawa et al., 2015; Calkins, 2015). In particular, SFDRR treats science as a distinct stakeholder with a role and responsibilities, and a clear mandate to work together with governments in developing and sharing the knowledge and solutions for improving disaster resilience (Calkins, 2015).

Science and technology are essential for effective DRR actions since they enable the development of well-informed policies and decisions across the public, private and voluntary sectors by identifying a problem and developing understanding (Aitsi-Selmi, Murray et al., 2015; Calkins, 2015; Weichselgartner and Pigeon, 2015). However, the use of scientific evidence for reducing and responding to disaster risks is currently hampered by insufficient communication between the science and the policy-making communities (Aitsi-Selmi, Murray et al., 2015; Calkins, 2015; Weichselgartner & Kasperson, 2010). This problem is known as the science-policy gap and results from the unsatisfactory interpretation of existing scientific knowledge into actionable knowledge (Aitsi-Selmi, Murray et al., 2015; Wolf, Chuang, & McGregor, 2015). Another facet of this problem is the relevance gap which refers to the mismatch between the research a society requires and the research a society produces (Dilling & Lemos, 2011; Nightingale and Scott, 2007). This is due to various reasons, some of which have to do with the structure of the academic career paths that indicate a purely internal academic focus and also the increased complexity of knowledge and technology (Nightingale and Scott, 2007). This gap also highlights the need to provide a stronger role for the policy-making community in developing research questions and producing knowledge and solutions in cooperation with the scientific community (Calkins, 2015; Holmes & Clark, 2008). Overall, the science-policy gap is an important obstacle in the way to develop more effective DRR actions and can result in disheartening findings, e.g. Wolf et al. (2015) report in their work that spatial heat vulnerability assessment studies have not as yet had any substantive influence in policy-making or in the design of preventive actions. Hence, there is a strong need to improve the communication and interaction between the science and the policy-making communities and for achieving this goal the scientific community has a key role to play. This is evident in the 2015 report of the UNISDR Science and Technical Advisory Group (STAG) where it is emphasized that there is "*a recognized need for science to provide and communicate actionable knowledge with explicit links to inform effective decision making, in other words: science that is useful, usable and used.*" (Aitsi-Selmi, Murray et al., 2015).

This article presents and discusses a series of services and tools designed to provide actionable knowledge to authorities and citizens for reducing the risks of elevated urban temperatures and heatwaves. These services and tools were developed in the context of the Thermal Risk rEducion Actions and tools for secURE cities (TREASURE) project co-funded by the European Commission's Directorate-General for European Civil Protection and Humanitarian Aid Operations (DG-ECHO) and are the result of the joint efforts of an interdisciplinary scientific team consisting of epidemiologists, climatologists, Earth Observation (EO) scientists, and Information Technology (IT) developers. These tools were introduced to the policy-making community through a Table-Top-Exercise (TTX) in Palma, Spain. A key policy-