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Vulnerability of cities to extreme space weather events: A new frontier of a multidisciplinary urban research

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ABSTRACT

The vulnerability of cities to extreme solar events is an issue of increasing concern, yet relatively few detailed studies of the impacts of these events on cities have been carried out. We present a new policy for a multidisciplinary research framework aimed at coping with extreme solar events in cities. The four interrelated dimensions of the framework include prediction and warning systems; assessment of urban social, economic, and physical vulnerabilities; urban governance; and mitigation and adaptation policies. This framework will help us determine what research policies should be proposed to increase the resilience of our cities.

Keywords: Vulnerability; Sever Solar Weather; City; Climate Change

1. INTRODUCTION

Contemporary cities and their residents face phenomenal vulnerabilities stemming, *inter alia*, from social polarization, urban conflict, terrorism, natural disasters, and, most recently, climate change, which augments the likelihood and intensity of such disasters and, in addition, undermines the urban infrastructures on which modern life depends [1-3]. Separately and together these various natural and man-made threats take lives and destroy urban spaces and communities. Their destructive impacts, both those we can anticipate today and those which are as yet unknown, are likely to increase in the near future [3-5]. In recent years, there has thus been growing awareness among scholars and practitioners in a variety of fields of the urgent need for cities to increase their resilience to the threats they will almost certainly encounter. Yet, an emerging knowledge suggests that our cities may face exceptionally high risks stemming from severe space weather events [5]. However, while scientists and policy makers have become increasingly responsive to the great risks that climate change poses to our cities, they are still unaware of the disastrous impacts that extreme Sun weather, or a Tsunami Sun, may have. This emerging field of knowledge has not been sufficiently explored by various disciplines that are supposed to produce knowledge on city readiness and adaptation policies in response to severe Sun weather. Strikingly few detailed studies of the socioeconomic impacts of severe space weather events have been carried out, as indicated by the American National Research Council [6]. Moreover, almost no studies in the fields that focus on cities (such as urban planning, public policies, geography, or environmental science) have been conducted regarding this phenomenon.

2. THE IMPACTS OF EXTREME SUN WEATHER ON CITIES

A coronal mass ejection, or CME, is an extreme solar storm that is aimed at the Earth. A CME is a slow moving cloud of charged particles that can take several days to reach Earth's atmosphere. When a CME hits, the solar particles can interact with Earth's magnetic field to produce powerful electromagnetic fluctuations [5].

Some recent extreme events have caused space weather scientists to be concerned about future extreme solar events [7]. In March 1989, a large geomagnetic storm caused a voltage depression in the Hydro-Quebec power system in Canada that left millions of people without electricity for up to 9 hours [8]. During this same storm, a large step-up transformer failed at the Salem Nuclear Power Plant in New Jersey, and approximately 200 separate events were reported as affecting the North American power system [5]. During October and early November 2003, the Sun exhibited some of its strongest eruptive activity in the last three decades when enormous outbursts of energy produced intense solar energetic particle events and triggered severe geomagnetic storms [5]. In February 2011, the Sun erupted with a solar flare that

was large enough to interfere with radio communications and GPS signals for airplanes on long-distance flights [9]. On June 7, 2011, scientists observed perhaps the largest amount of solar material ejected into space. The unusual amount of material lofted up, expanded, and fell back down over roughly half the surface area of the Sun [7]. Recent events seem to be only the start of the upcoming solar maximum, due to peaks in the next several years [8]. Tom Bogdan, director of the Space Weather Prediction Center in Boulder, Colorado, states that the Sun has been "sleeping" for four or five years, and has recently been exhibiting activity, and future events could be extremely powerful [7]. NASA's Solar Dynamics Observatory suggests that the Sun's 11-year cycle of activity will reach its maximum in late 2013 or early 2014. Magnetic turbulence will peak around that time, prompting severe solar storms [7].

Contemporary cities, which are decisively dependent on advanced technologies, are especially vulnerable to the extremes of space weather because it can have a harmful impact on crucial technologies and communications, which are critical to the social and economic activities of cities. Extreme solar weather can disrupt and damage existing electric power grids, blow out transformers, disrupt transportation, communication, finance systems, government services, and potable water supply. These storms can cause the loss of perishable foods and medications due to a lack of refrigeration, can corrode oil and gas pipelines, and can degrade and, during severe events, disrupt satellite communications and global positioning systems (GPS), which have become pervasive in cell phones, airplanes, and various transportation systems [8]. The losses for cities and their businesses could be quite costly both in terms of casualties and financially [5].

To conclude, an extreme event can have a dramatic impact on urban societies. However, both the public and private sectors and civil society organizations do not recognize how severely space weather can influence society and how it can be managed to mitigate these negative effects. As we approach a new period of increased solar activity, we face some critical questions: Are our cities resilient enough to cope with an extreme solar event? How well equipped are cities, which host the vast majority of the global population, to manage the effects of space weather? A literature review suggests that there is a striking lack of conceptualization of these risks, and it is important to develop a comprehensive framework applicable to cities, which aims to mitigate these risks. Yet, a review of the literature reveals a marked absence of studies on severe solar weather and its impacts on cities. Therefore, this paper strives to propose a multidisciplinary framework for approaching and studying this critical urban field.

3. TOWARD THE RESILIENCE OF CITIES AGAINST EXTREME SUN WEATHER

Only in recent years have scholars begun to investigate and write about urban resilience. Up until quite recently, most of the literature on resilience to environmental threats has focused on disaster areas and disaster stricken communities and on poor rural communities in developing countries. Thus, there is as yet no comprehensive conceptual framework of urban resilience that takes into accounts not only environmental risks, but also challenges of solar extreme weather.

The concept of resilience goes back to studies on how ecological systems cope with stresses and disturbances caused by external factors [7]. In ecological terms, resilience is defined as "the capacity of a system to undergo disturbance and maintain its functions and controls" [10]. Recently, the term "resilience" has also been applied to human social systems [11-14]. It has been used in writing about urban eco-systems [15-20]; economic recovery [21-24], disaster recovery [2,25,26], and urban security, especially after September 11th [27]. Inspired by the concept of the resilient eco-systems, the United Nations has defined urban resilience as "the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions" (UNISDR 2010: 13).

In light of the complex challenges extreme Sun events pose to our cities and because our cities are not resilience in facing extreme space weather events, the critical mission is how to prepare cities to face the multiple challenges and uncertainties that characterize this phenomenon. Cities are complex systems with intrinsically interconnected spatial, technological and physical infrastructures with economic and social components. For this reason, attaining urban resilience *to severe Sun events* demands a "paradigm shift" toward a transdisciplinary approach that integrates a variety of urban dimensions into a unified conceptual framework for understanding vulnerability to plan a city that can face solar extreme events. The major research dimensions of this framework are the following.

3.1. Prediction and International Warning Systems

Better and more accurate forecasts will help cities prepare for the event and warn residents and all related institutions. Cities around the world should be part of an international warning system. There are many developing countries and cities that lack the basic capacity to deal with such an event. International involvement will contribute to the safety of these cities. Therefore, scien-

tific studies should be conducted to achieve on-time and accurate predictions. In addition, policy studies should be undertaken to build the international cooperation framework among nations and cities.

3.2. Assessment of Social, Economic, Physical, and Spatial Vulnerability

Studies should be undertaken to assess the various aspects of urban vulnerability as a result of a severe event. These studies should analyze and identify the types, demography, intensity, scope, and spatial distribution of risks and future uncertainties in cities resulting from severe events. How such events may affect various urban communities and urban groups should also be addressed. We assume that there are individuals and groups within all societies who are more vulnerable than others and who lack the capacity to adapt to such an event. Individuals and communities may be vulnerable to extreme solar events in different ways. Demographic, health, and socioeconomic variables affect the ability of individuals and urban communities to face and cope with environmental risks and future uncertainties. However, themain variables are income, education and language skills, gender, age, physical and mental capacity, access to resources, political power, and social capital.

3.3. Urban Governance

To cope with such an event, many stakeholders should be involved, starting from drafting mitigation and adaptation measures to the moment of dealing with a real event as well as after the occurrence of the event to reduce damages. Formal institutions, municipalities, local governments, police and security institutions, hospitals and various emergency institutions, the private sector, civil society and professional communities should all be involved in the process of establishing a resilient framework. A city that is more resilient to severe events is one in which governance is able to quickly restore basic services and resume social, institutional and economic activity after a disastrous event. Weak governance, however, lacks the capacity and competence to engage in participatory decision making. Urban governance is a crucial aspect of achieving a resilient city that can cope with such events. To enhance urban governance, there is a need to expand and improve local capacity through increasing knowledge, providing resources, establishing new institutions, enhancing good governance, and granting more local autonomy.

3.4. Mitigation and Adaptation Strategies

This dimension focuses on what strategies should be taken to lessen the potential impacts of severe solar events and what strategies and actions should be taken both while the event is occurring and afterward. What are the responsibilities of the federal, state, and local government agencies in responding to the effects of an extreme space weather event? How can public panic and fear be lessened to resume life and operations quickly and efficiently? What kind of urban planning and spatial restructuring are recommended to face such an event? What is the role of urban planning in transforming the city into a more resilient state? Planning should play a more central role in shaping all dimensions of the built environment, including physical security as well as environmental and socio-spatial policies; thus, planning has a major impact on city resilience. In other words, cities need adaptation policies to limit harm and cope with such an event. To cope with the new challenges, practitioners and policy makers must develop a greater awareness and put in place mitigation policies for adaptation or actual adjustments that might eventually enhance resilience and reduce vulnerability to expected solar events.

4. SUMMARY

This paper concludes that the critical issue of extreme solar weather and its impacts on city should be integrated to the climate change and sustainability literature [28-32] is in sum, the proposed dimensions of the multidisciplinary framework of research include critical aspects that are related to extreme solar events. The proposed multifaceted conceptual framework will help us determine what needs to be done to increase the resilience of our cities, thereby enabling us to work more effectively toward making cities safer and more secure. It is our hope that this framework will increase awareness among scholars, professionals, decision makers, and the public as a whole regarding the uncertainties and risks that our cities face. The framework includes four interrelated dimensions. First, prediction and warning systems are crucial for our knowledge regarding the occurrence of extreme solar events and for international cooperation. Second, studying and assessing social, economic, and physical vulnerabilities are important to prepare both the society and the city for an extreme solar event. Third, collaborative, flexible, inclusive and integrative urban governance is required to cope with such an event. Fourth, mitigation and adaptation strategies are crucial to lessen the impact and help people resume city life as quickly as possible.

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