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To share or not to share: Drivers and barriers for sharing data via online amateur weather networks

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SUMMARY

Increasing attention is being paid to the importance and potential of crowd-sourced data to complement current environmental data-streams (i.e. in-situ observations and RS data). In parallel, the diffusion of Information Communication Technologies (ICTs) that are interactive and easy to use have provided a way forward in facing extreme climatic events and the threatening hazards resulting from those. The combination of these two trends is referred to as ICT-enabled 'citizen observatories' of the environment. Nevertheless, the success of these citizen observatories hinges on the continued involvement of citizens as central actors of these initiatives. Developing strategies to (further) engage citizens requires in-depth understanding of the behavioral determinants that encourage or impede individuals to collect and share environment-related data. This paper takes the case of citizen-sensed weather data using Personal Weather Stations (PWSs) and looks at the drivers and barriers for sharing such data via online amateur weather networks. This is done employing a behavioral science lens that considers data sharing a decision and systematically investigates the influential factors that affect this decision. The analysis and findings are based on qualitative empirical research carried out in the Netherlands, United Kingdom and Italy. Subsequently, a model was developed that depicts the main drivers and barriers for citizen participation in weather observatories. This resulting model can be utilized as a tool to develop strategies for further enhancing ICT-enabled citizen participation in climatic observations and, consequently, in environmental management.

1. Introduction

According to the 2015 report on the state and outlook of the European Environment, floods, droughts and other weather-related extreme events are among the key risks that endanger the biodiversity, ecosystem, infrastructure and citizen's well-being in Europe (European Environment Agency, 2015). Europe suffered from more than 100 major floods between 1998 and 2004; around 700 deaths, displacement of 500,000 people and a minimum estimated insured economic loss of €25 billion are the results of these events for European countries (European Commission, 2014). Furthermore, it has been predicted that the number of people who are affected by floods (mainly driven by climate change) and also the annual monetary damage resulting from that will double during the next 70 years (Ciscar et al., 2009). Based on UNECE's report, in the best case scenario, there are four water-stressed countries in Europe, namely Cyprus, Spain, Malta and Italy; this means that around 20% of Europe's population (approximately 113 million inhabitants) live in water-stressed countries (UNECE, 2011). Water supply and wastewater operations can also be highly affected by extreme weather conditions. In such situations, water services systems (such as dams, canals, pipelines and wastewater treatment plants) can turn into elements that pose significant threats to citizens' and environment's health (Sinisi and Aertgeerts, 2011). The adverse effects of such events may not be limited to a specific location and sometimes not even the country's borders; moreover, these consequences may not be reversible or might entail huge economic investments.

In the face of such diverse weather-related hazards that are expected to be intensified by climate change (Pachauri et al., 2014; Tol, 2014), continuous and widespread observations of the weather are of crucial importance to equip authorities and citizens in at-risk locations with essential information as they have to deal with more frequent and/or more intense weather-driven hazards. Yet there are two major flaws in the traditional means of observing the weather such as Remote Sensing (RS) using satellites and in-situ observations of hydrological and

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meteorological variables. The first one is that the data acquired using these methods is not always publicly available at high resolution and density and the second one is the passive role that they stipulate for citizens in terms of understanding their environment (Lanfranchi et al., 2014). Increasing understanding of the potential of 'citizen science' in gathering data, and the rapid diffusion of Information Communication Technologies (ICTs) that are interactive and easy to use, provide a way forward in facing extreme weather events by tapping into an immense source of passion, devotion and good will but also expertise from the general public. The combination of these trends has gained popularity in many disciplines, including the environmental management domain, and is often referred to as citizen observatories through e-Participation (Wehn et al., 2015).

An example of these ICT-mediated citizen observatories are online amateur weather networks. Amateur weather observation is not by any means a new practice; in fact meteorological science was initiated thanks to the enthusiasm and interest of amateurs (Eden, 2009). The introduction of instrumental measurements in the 17th and 18th centuries and establishment of several official meteorological organizations in the 18th and 19th centuries turned these official organizations into the most widely preferred bodies for measuring and reporting weather conditions and forecasts. During the past two decades, however, the aforementioned paradigm shift towards citizen participation in environmental observations and increasing availability of user-friendly and affordable weather stations (Bell et al., 2013) once more resurfaced amateur weather observers. This was facilitated through the formation of what nowadays are called online amateur weather networks. Currently, several such networks exist and they are evolving rapidly both, in terms of the number of users as well as data visualization and reporting features. The so-called citizen contributed data that is collected using Personal Weather Stations (PWSs) and shared via these platforms can have various applications; there have already been instances of using these data to improve severe-weather warnings (Blum, 2013), event identification and separation of baseflow for small watersheds (Koskelo et al., 2012), and to verify surface precipitation (Apps et al., 2013). However, the increase in use and success of these applications are dependent on continuous and widespread involvement of citizens, the active role of citizens as the main actors of these initiatives and also trust that their efforts are valued by decision makers[1]; which in many instances are yet to be achieved.

The main objective of this paper is therefore to investigate what drives citizen participation in gathering and sharing weather-related data in order to help maximize their active and continued involvement in citizen observatories. We build on previous research in the behavioral sciences to investigate the influential factors that may affect citizens' willingness to participate in these initiatives. This paper is structured as follows. Section 2 presents a review of relevant theoretical contexts and introduces the framework used in this study. Section 3 is dedicated to details of the methods used in conducting the empirical research in the three case studies. The results of this study and the discussion of the findings are provided in Section 4. We conclude the paper in Section 5 with concrete recommendations on how to improve the current state of citizen participation in amateur weather observations.

2. Theoretical context

Collecting and sharing weather data using Personal Weather Stations is a citizen-centered and voluntary behavior that is facilitated by the diffusion of ICTs. The first step in understanding behaviors such as this, that are under an actor's direct influence, is to understand the decision making process behind it. Several decision making theories exist in the domain of behavioral sciences that may be utilized to conceptualize and understand such behaviors, namely Prospect Theory on decision making (Kahneman and Tversky, 1979), the diffusion of innovation theory (Rogers, 1968), the Technology Acceptance Model (TAM) (Davis et al., 1989), the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) and the Theory of Planned Behavior (TPB) (Ajzen, 1985).

A relevant theoretical framework for our research needs to be able to systematically investigate and explain the conditions under which citizens are willing and able to collect and share weather-related data. Prospect Theory on decision making (Kahneman and Tversky, 1979) could help us explains *how* people make decisions about their prospect and what choices will most probably be made by an idealized rational individual, but it is not able to explain the reasons behind making those decisions. The diffusion of innovation theory (Rogers, 1968) has been criticized for its so-called 'pro-innovation bias' or the idea that eventually every member of the society has to adopt the innovation (Dijk, 2005), that in this case are PWSs and online platforms. Another criticism that is closely linked to this is that the aforesaid theory may not provide the basis to explain the reasons why an innovation is rejected or not diffused (Wehn de Montalvo, 2003b). The Technology Acceptance Model (TAM) (Davis et al., 1989) and the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) are both based on the Theory of Planned Behavior (TPB). Both of these theories are simpler and more specific compared to the TPB in the sense that they have been developed to analyze the technology acceptance area; however, they both suffer from a fragmented and less comprehensive form of encompassing the 'perceived behavioral control' component of the TPB. This component helps explain behaviors that are not fully under volitional control and require factors such as resources or skills. Based on research on data sharing more generally, we already know that this component comes into play (Wehn de Montalvo, 2003b). The Theory of Planned Behavior (TPB) on the other hand is well-grounded and has been implemented previously and tested in numerous studies in diverse areas of research such as health related studies (Conner et al., 2003; Nguyen et al., 1997), environmental psychology (Koger and Winter, 2010; Stern, 2000), entrepreneurship (Kautonen et al., 2013), environmental innovation (Montalvo Corral, 2002), the ICT domain (Ambali, 2014; Kim and Shin, 2015; Teresa and María Arántzazu, 2013) and most relevant to this research, data sharing (Ngo Thu and Wehn, 2016; Plengsaeng et al., 2014; Wehn de Montalvo, 2003a,b). Despite its successful application in many studies, the TPB is sometimes criticized for being a rational choice theory that excludes implicit attitude such as affection and emotion (Bagozzi and Kimmel, 1995; Conner and Armitage, 1998; Sabini, 1995). Arguably, emotion and affection can be expected to come into play a strong role for ad hoc behavior but less so, or not at all, for planned behavior such as data sharing. The behavior of interest in our research, i.e. sharing PWS data via online platforms, is a specific case of spatial data sharing. Wehn de Montalvo (2003b) applied the TPB to study spatial data sharing behavior at organizational level as perceived by key individuals. This study resulted in development of a detailed model of spatial data sharing. Our unit of analysis, in this research, is individuals, thus we employed the basic model of data sharing as the framework for our study (see Fig. 1).

According to the basic model of data sharing, the behavioral intention of an individual to share spatial data is based on three main constructs; 'attitude' towards sharing the data that is linked with expectations about the outcomes resulting from performing that behavior; perceived 'social pressure' or beliefs about the

[1] We thank an anonymous reviewer for this addition.