Effective public service communication networks for climate change adaptation

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Abstract

Climate change adaptation is fundamentally linked to the suitability and adaptability of communication networks to confront consequences of climate change and climate-related extreme events. Communications often receive less attention yet are critical to managing adverse outcomes of climate change by emphasizing human and technological interfaces. Several cases of communication failures and ultimate successes in extreme events are diagnosed uniquely using network concepts. In these cases, communications influenced the magnitude and direction of consequences and illustrate successful learning efforts and best practices across disciplines to address communication deficiencies. The overarching research question is how two critical components of risk communication – messaging and the adequacy of communication technology – can be shaped to support adaptations to climate change to reduce its adverse consequences. Messaging and technologies act together at human-technology interfaces.

One case involved the interplay of communication technology, human capacity for understanding warnings, and mortality in a record mid-West tornado, and improvements were recommended at human and technological interfaces for more effective communication. A second case involved communications among weather scientists, government operators, and other publics about transit services in a severe New York City snowstorm, and learning occurred in subsequent storms that reduced human exposures and addressed operational changes for transit services. A third case addressed communication failures in getting services to NYC's populations in record-breaking storm-related flooding of the NYC subway system, which resulted in recommendations about information access and accuracy. The methodological approach follows case-based research techniques supported by network concepts.

These failures and the lessons learned provide key, transferrable strategies and methodologies for climate change adaptation in terms of a multi-disciplinary, network approaches for communication. Although many of the analyses emphasize technology for communications improvements, these are embedded in a larger framework of societal and inter-organizational networks that reflect human-technological interfaces.

Introduction: Rationale and aims

Communication networks play a central role in developing and supporting adaptations to climate change and extreme events, and can affect how society responds to these conditions. Communications are often hidden, receiving minimal or indirect attention yet are critical to managing adverse outcomes by emphasizing human and technological interfaces. The lack of emphasis upon communications is related to the intermediary role that communications often play in disaster management. The communication context focuses here on the risks associated with climate change and extreme events, that is, as the likelihood and magnitude of the occurrence and consequences of these conditions. In light of this focus, the general concept of communication is narrowed to risk communication. Moreover, the relationships between climate change and extreme events have been highlighted (Herring et al. 2015) as well as similarities in their outcomes. This supports an emphasis upon understanding communications in extreme events as a guide to communications for climate change.

Communication is multi-dimensional and complex, encompassing technical and social aspects. It originates in numerous, diverse disciplines. The spatial reach can be enormous, that is, the impact, need, components and participants are far reaching, often well beyond the specific physical location of a particular event. Communications occur among individuals and among organizations and groups from local to global scales. Social-psychological as well as technological dimensions often form the basis for and shape communications and these relationships have been extensively studied, benefiting from a network perspective.

<u>Risk perception and risk communication</u>

An important foundation for understanding the way risk communications are received and acted on is risk perception. Such insights include (Slovic 2000): people have strongly held beliefs (for example based on past experience) that are often difficult to change or enable adaptation to new situations; trusted sources of information tend to be believed to a greater extent; biases exist in the way people process information, for example, under some circumstances people overestimate small risks and underestimate large ones (Slovic, Fischhoff and Lichenstein 2000); and the form of information can affect how people process information, for example, numerical or quantitative information (numeracy) can be more difficult for some people than others (Peters et al. 2010). Wachinger et al (2013: 1053) have noted that trust and other factors such as experience with a risk can vary in their effects on protective action, particularly for floods and climate change, where increased perception can either reduce or heighten preparedness depending on the circumstances. Spence, Portinga and Pidgeon (2012) have analyzed public perceptions of climate change as an underlying factor in the gap in climate communication given the global nature of climate phenomena and its uncertainty, and for this reason, Spence, Portinga and Pidgeon (2012: 970) have noted the limited extent to which risk perception literature has been translated into risk communication strategies, yet they underscore the value of making these connections.

<u>Risk communication and climate change</u>

An extensive literature on risk communication has provided direction for the analysis of a number of attributes of effective communication (Höppner, Buchecker, and Bründl 2010), one of which pertains to the need to align communication strategies with communication goals. Communications often have numerous and diverse goals or purposes, namely, to disclose, inform, warn, educate, understand and reduce uncertainty, promote and encourage involvement, participation, arbitration, mediation, and negotiation to resolve differences, guide behavior, and build public trust and confidence. Orr et al (2015: 7) and Höppner, Buchecker, and Bründl (2010: 17) have also identified these goals and others. The Center for Research on Environmental Decisions (2014) has applied risk communication to climate change, taking into account those aspects of climate and extreme events that pose challenges for communication and has suggested how communications can be shaped to convey climate change information.

A number of problems in the communication of climate change risks appear in the risk communication literature pertaining to the general public and managers responsible for protecting the public from adverse consequences. Surveys have pointed to the consistently low priority given to climate change relative to other issues though its importance has been growing over time, and Pew surveys show climate change still ranking second to the lowest among other priority areas (Doherty, Suls, and Weisel January 15, 2015: 2). Communicating climate change risks is particularly challenging given climate change attributes, namely its global nature, uncertainty, and less immediacy than other kinds of problems (Moser 2010: 31). On the other hand, attributes of extreme events, which have been linked to climate change or otherwise share similar consequences, often involve the opposite attributes, namely, they are geographically specific or localized, often have highly certain onsets, and are immediate making risk communication relatively easier. This supports the fact that the climate change and extreme event linkage (Herring et al. 2015) can at least inform communication of climate change and fill a gap in ways to communicate climate change. Evidence exists that the two are in fact linked in the scientific community (Walsh et al 2014; Herring et al. 2015) and surveys identify these linkages in the minds of people to a limited extent, varying by regions of the world (Stokes, Wike, Carle 2015: 7, 21). In order to bridge the gap in climate change communications, communications in extreme event cases are used.

Approach and methodology

Several cases of risk communication failures and successes in extreme events are portrayed and evaluated here using network concepts (Newman 2010) to characterize the existence, type and direction of communication flows among nodes and across links and proximity (even virtually) of senders and recipients. The network lens provides a unique way of relating communications to technological, institutional and social dimensions of the cases, and understanding how communications often act as control points that can change the outcomes of disasters. The method of analysis borrows from research protocols for case analysis for example by Yin (2014) using an analysis of public documents within the case context. The cases generally meet the characteristics Yin (2014: 24) sets forth for case studies in reflecting real world situations, having current relevance, and where the events (phenomena) are not always clearly distinguishable from the context. Source materials used included government documents, news media interpretations, reports of oversight agencies, and where available, analyses of the cases in the peer reviewed literature. These cases illustrate how communications dramatically altered the magnitude and direction of consequences and how successful learning efforts and best practices across disciplines emerged to correct communication deficiencies.

First a generic framework for risk communications is presented and adapted to consequences of the risks of extreme events and climate change. The overarching research question is how two critical components of risk communication – messaging and the adequacy of communication technology – affect consequences and can be shaped to reduce adverse consequences of climate change.

Second, the networks of interrelationships pertinent to major public services and the communications that accompanied them are presented for key representative cases that exemplify some of the conditions expected from climate change and extreme events.

Finally, conclusions are presented in terms of ways in which consequences were and could have been reduced by virtue of changes in the nature of communications.

Results

Generic communications framework

Risk communication frameworks are traditionally portrayed as networks comprised of an initiating source or messenger, the communication, a route or channel through which the communication travels, and the recipient or receiver who is potentially in a position to act on the communication (Mayhorn and McLaughlin 2014). Other characteristics have been added to the framework, such as characteristics of the hazards and social contexts (Orr 2015: 5; Höppner, Buchecker, and Bründl 2010: 46) and behavioral modifications (Lindell and Perry 2004). Risk communications are seen as dynamic and interactive, implying multiple directions (Orr 2015: 5 citing Höppner, Buchecker, and Bründl 2010: 7 and Renn 2005: 55) and the ability to undertake changes according to stages in the event (Höppner, Buchecker, and Bründl 2010: 18).

The generic communications framework is applicable across a variety of events using two interrelated dimensions or components of the framework. First is messaging including the network structure that defines flows between messengers and recipients in terms of direction, rate and content of communications. The second component is communication technology and its deployment and how it influences messaging and can in turn shape consequences.

Messaging. Hierarchical structures of messages are a useful first step in analyzing messages and focusing on their deficiencies. The first step in the messaging hierarchy is whether messages are sent or not. Second, where a message has been sent and has been heard, the reactions of recipients can be simplified in terms of a number of major steps (Zimmerman 1988). The recipients or target populations follow the message with or without some modifications, try to get the message verified (Zimmerman and Sherman 2011; National Oceanic and Atmospheric Administration (NOAA) 2011) due to lack of trust in messengers (Slovic 1993: 678), ignore the message e.g. due to disagreement or denial (Drabek 1999)), or misinterpret the message due to biases in perception (Slovic, Fischhoff and Lichenstein 2000). Thus, the impacts of communications range from no effect to substantial effects on recipients' knowledge, understanding, attitudes or behavior. Message effects appear across levels ranging from individuals to various social groupings. The very extensive investigations of the form of messages broadly align with the human senses individually and in combination, such as visual, audible, and tactile stimuli which have advantages and disadvantages depending on the design and context (Haas and van Erp 2014). Of particular relevance to the cases reviewed is that audible sirens as warning messages alert people of an emergency but do not provide information on event cause and severity thus requiring a combination of messages. In terms of institutional trust, surveys tend to support people's trust in scientific and religious institutions over government and industry. Trust can also depend on organizational characteristics (Slovic 1993).

Technology options and deployment. Communication technologies provide essential services that support communication activities. The purposes technologies support include ongoing information transmission about hazards in general and support actions in times of emergencies. The number and type or variety of such technologies have exploded and are constantly changing (Hilbert and Lopez 2011). Cell phone sites alone have been increasing exponentially (Cellular Telecommunications and Internet Association (CTIA)) and the concentration of cell sites has also been increasing (Zimmerman 2012: 227). Communication technologies in extreme events can initially fail but then improve during recovery stages. These lessons are critical to coping with the consequences of climate change.

How people interact with communication technology depends on what people are used to relying upon. Warning systems are a common form of communication technology that played a critical part in one of the cases but was criticized for its shortcomings. Surveys indicate that people favor television networks where electric power is still available to support that. In terms of who people trust to deliver information, people tend to rely mostly on their peers or experts in their fields.

The resilience of information technologies under disaster conditions is a critical issue for their role in communication. Gauges to measure water levels during a storm, for example, are often destroyed as they were during Hurricane Sandy by flooding or wind damage. Communication services such as cell phones can become inoperative due to overloading or electric power failures. The means to harden this equipment exist to overcome many of these limitations.

Messaging and communication technologies are not independent entities, and work hand in hand for human-technology interfaces.

<u>Cases of communication disruption and adaptation</u>

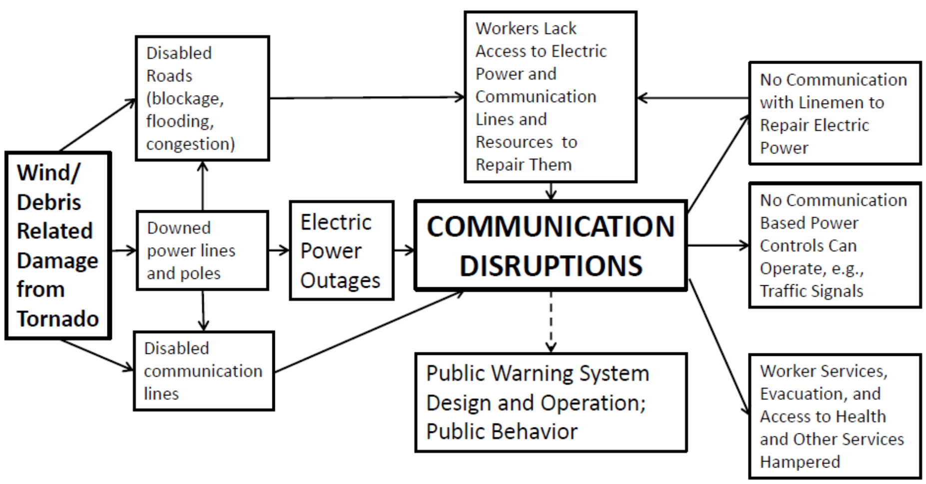
Case 1. Tornadoes: Joplin, MO, May 22, 2011

On May 22, 2011, a tornado reaching one of the highest Enhanced Fujita scale categories, EF-5 at its maximum points, descended on Joplin, MO with winds exceeding 200 mph, along a 22 mile length (6 miles of which was considered the damage path) killing 158 people and on record as one of the costliest U.S. tornadoes (NOAA 2011: 1). In 2011 Joplin, MO population was about 50,000 and population density was about 1,500 people per square mile (NOAA 2011: ii).

The two aspects of communication are explored for the Joplin case – one pertaining to the immediate effects of and attempts to deal with physical breaches in communications during response and restoration that affected messaging communication technology for warning systems used for populations at risk and the second having to do with warning system technology for populations at risk.

Messaging and communication ruptures in services and implications for response and recovery. Figure 1 illustrates the relationships among a number of events that occurred influencing the robustness and performance of communication systems and the ability of those systems to be restored in a timely manner to support effective messaging. Ripberger et al. (2015) explored perceptions in general of the accuracy of tornado warnings and response in terms protective action. They found that people's perception of the inaccuracy of warnings increased with false alarms and events that go unreported, which in turn contributed to less trust in the NWS, and resulting in taking less protective action (Ripberger et al. 2015: 54). They identified some demographic characteristics that correlated with trust in warnings, for example, the elderly are more trusting and minorities and less educated people are less trusting.

Figure 1 Communication Disruptions from the Joplin, MO Tornado of May 22 2011



Source:Adapted from Martin Penning (March 1, 2012) Linemen Rebuild Joplin After Twister's Destruction, Transmission and Distribution World
http://tdworld.com/overhead-distribution/linemen-rebuild-joplin-after-twisters-destruction
Notes: The figure only shows communication linkages that existed at the time of the event, not added afterwards. The dashed line indicates a second communication dimension related to warning system technology not shown in detail on the figure but is described in detail in the text.

Public warning system technology. A key objective of the warning systems for the exposed population was to enable people to seek shelter, which was a voluntary action. Such warning systems are critical nodes linking weather forecasting agencies such as the National Weather Service (NWS), emergency response agencies and the population at large. In Joplin, MO, siren warnings were structured to be activated by a dispatch center on the basis of weather information from the NWS rather than other more local sources and guidance for wind speed, decibel ratings, and duration from the Federal Emergency Management Agency (FEMA). Kuligowski et al. (2014: 243-246) and NOAA (2011) identified design and operational characteristics of warning systems and their effects on believability and behavior specifically associated with the Joplin tornadoes:

- Emergency communication plans existed prior to the tornadoes in the form of sirens for alerts but were not capable of voice communication.
- Sirens sounded simultaneously throughout the city, and were not interconnected between the City and the county.
- Joplin's sirens were used for both excessive wind events and tornadoes (NOAA 2011: 5) and the sounds were the same for both events creating confusion and uncertainty as to the severity of the event the warnings were communicating.
- Siren sounds differed by community which potentially created confusion especially for travelers moving among areas.
- Joplin also had a reverse 911 system where subscribers received alerts in the form of recorded messages, but volume could be a problem leading to delays so the system was not used on May 22, 2011 Kuligowski et al. (2014: 6).
- Web based systems existed but only for subscribers.
- Most communication systems required people to be proactive in seeking them out.

According to NOAA (2011) and Kuligowski e tal. (2014), communication lines were directly affected by wind damage as electric power lines were, resulting in not only physical damage to the communication lines but functional breaches due to electric power outages. Workers attempting to repair both electric power and communication lines faced transportation impediments since roads were blocked by debris. These are portrayed in Figure 1. Thus, other infrastructures such as transportation and electric power were critical nodes affecting the ability of communication infrastructure to function.

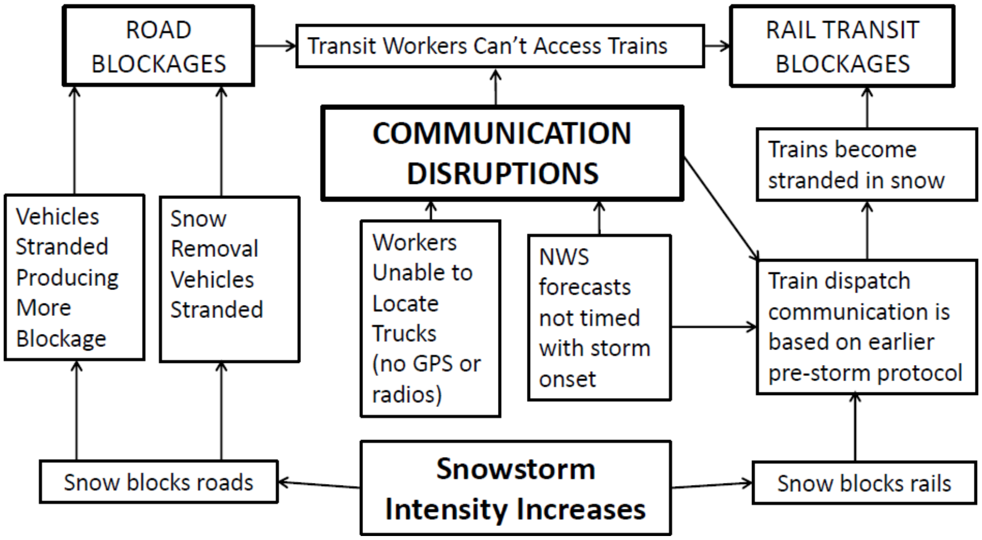
Technology and messenging operate together. The design of communications needs to emphasize lack of ambiguity and support an effective human-technology interface. The Ripsberger et al.(2015) study for Joplin emphasized as did the NOAA (2011) and the National Institute of Standard and Technology (NIST) (Kuligowski et al. 2014) investigations that reliance on warning devices did not take into account that devices served multiple purposes, for example, high wind warnings and the more dangerous tornadoes, producing unclear messages and thus reducing the effectiveness of the warnings for tornadoes.

Case 2. Snowstorm: New York City Rail Transit, December 26, 2010

Snowstorms are a type of extreme precipitation weather event. Over the weekend of December 26, 2010, New York City experienced a massive snowstorm that at the time ranked sixth in terms of snowfall accumulations in Central Park since the late 19th century, and an estimated 650 buses and 500 people in subway cars were stranded (Kluger 2011: 1). This case focuses on communication relationships as messaging and technologies used to support messages.

Messaging networks were identified between the NWS and the NYS Metropolitan Transportation Authority (MTA), internally within the MTA and between the MTA and the general population of the City. These relationships are illustrated in Figure 2. The NYC rail transit portion of the MTA system (the subways) is the focus here, though the MTA system extends beyond the City north and east (including Metro North and the Long Island Railroad), and communication issues that arose in those areas are not discussed here.

Figure 2 Communication Disruptions from Snowstorm, NYC, Rail Transit, December 26, 2010



Sources: Based on Kluger (2011), Weinstein and Funk (2011), and the New York City Council (January 10 and January 14 2011). Abbreviations: NWS – National Weather Service, National Oceanic and Atmospheric Administration; GPS – Global Positioning System.

Zimmerman (2013: 190) summarized the communication deficiencies in terms of the absence of a timely emergency declaration and worker communications vital to the snow removal activity. Evaluations of the snowstorm indicated that operating agencies relied on NWS communications that had predicted a slower magnitude and rate of snow accumulation than what actually occurred in part contributing to the delays in emergency messaging. According to NYC Council Hearings (January 10, 2011), the sequence of communications about the extent of the snowfall by NWS were as follows. An initial notification occurred on December 25, 2010 of 1-3", which was below the 6" threshold for a full alert by the NYC Office of Emergency Management (OEM). The next afternoon NWS issued a notification of 6-8" justifying a full alert by NYC OEM, however, soon afterwards, the NWS prediction was 16" with 55 mph winds, which was actually exceeded. The extent of the snowfall combined with a holiday weekend reduced the effectiveness of messages between NWS and agencies responsible for action. During the 2010 snowstorm communication linkages were not apparent between the City and travelers to discourage them from using road vehicles and to prevent them from getting stranded and blocking roads for snow removal and emergency vehicles. Communication between the NWS and the MTA did not prevent trains from being released and ultimately getting stranded.

Technology played a considerable role in the failed communications. Workers operating snow removal vehicles did not have operable and sufficient radio communication devices and locational units based on Global Positioning Systems (GPS).

In summary, the technological failures in communication were procedural. According to Kluger (2011) and the NYC Council Hearings (2011):

- Sanitation trucks which double as snow removal trucks lacked radio or GPS technologies, unable to receive or send communications about areas requiring snow removal.
- The MTA train dispatchers followed a protocol that on weekends, orders were followed on the Friday before and not updated. Therefore, Friday orders not weekend updates were used to dispatch subway trains and buses, that is, operators continued to dispatch them in spite of the storm. Communications with the general public were not clearly apparent.

When NYC experienced more storms a month or so later, many of these deficiencies in communication links and nodes had been addressed. The MTA took actions almost immediately to avoid future risk communication problems: Communication technologies were put in place at least for the New York City Department of Sanitation snow removal equipment (Zimmerman 2013). In addition, a street priority system has been implemented for snow removal, snow removal equipment has been positioned closer to where workers live, and smaller snow removal equipment is being used to access narrower streets. The City in fact experienced severe snowstorms in the weeks following the December 26, 2010 storm and a number of preventive actions were in place by then.

Case 3. Flash Flooding: New York City Rail Transit, August 8, 2007

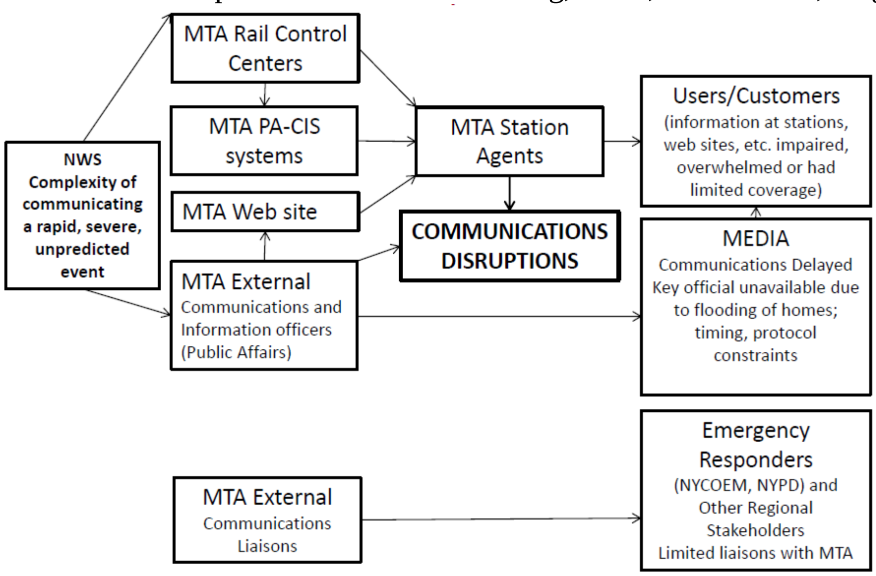
Flash floods and intense precipitation events wreak havoc on transportation systems and their users due to the suddenness, unexpectedness, and large volume of water occuring in a short period of time. They are difficult to predict due to their sudden onset. The potential effect of flooding events on the NYC subway system is reflected in the size of its ridership which the MTA (2016) reported for 2015 as reaching the 1948 record for both average weekday ridership (5.7 million) and annual ridership (1.763 billion), ranking seventh in the world for annual ridership. Three climate-related conditions associated with flooding are excess precipitation (rain and snow) exceeding the capacity of drainage systems, storm surge, and sea level rise.

- Excess Precipitation. In New York City, both average and extreme precipitation are expected to increase during the 21st century (New York Panel on Climate Change (NPCC) 2015: 31) and this is not unlike similar projections for the northeastern U.S (Walsh et al. 2016). Historically, the MTA (2007) reported that the subway system experienced numerous flooding episodes during the first decade of the 21st century alone that ranged from almost two to seven inches within a short duration of about an hour or so shutting down anywhere from 7 to 20 of its 23 lines. The August 8, 2007 storm alone was considered one of the most severe heavy precipitation events, and many of the subway lines were closed for about 12 hours. The significance of increased experiences with flooding events is that it tends to heighten people's perception of the danger though the effect could be dampened depending on what the experience actually is (Wachinger et al. 2013: 1052). Perceptions are a strong predictor of whether or not people will take protective action.
- Storm Surge. Storm surge accompanying hurricanes and other storms is another extreme event impact, which was a record event for Hurricane Sandy and was a major source of flooding of the subway lines through the tunnels and street openings.
- Sea Level Rise. Sea level rise is also expected to occur along coastal areas on the east and southern coasts of the U.S. Thus, flood related communications are critical to saving lives in the short term during flash flooding as well as in the long-term related to flood plain

location. The Regional Plan Association (2016) estimated that many critical services and developments are located in areas potentially affected by sea level rise flooding in the New York Region by 2050, including about two-thirds of energy capacity and close to half of the wastewater treatment facilities among others. Other studies have reinforced the vulnerability of NYC structures to flooding (Zimmerman and Cusker 2001, Zimmerman et al. 2015). For the subway system alone, Zimmerman (2013-2014) estimated that based on Sea, Lake, and Overland Surges from Hurricanes (SLOSH) models about a third of the NYC subway stations are in one of the four risk zones and under ten percent are in FEMA flood zones (cited from Zimmerman et al. 2015: 65). The City identified about 31 stations vulnerable to flooding (MTA 2007: 49). Many of the subway system components, in particular, its stations are in flood-prone and storm surge locations. Unlike communications for extreme events, communicating the risks of sea level rise associated with climate change has proved challenging, given the length of time over which the impacts occur.

Figure 3 illustrates some of the gaps in communications that the MTA identified during the August 8, 2007 storm event diagrammed from the MTA (2007) report.

Figure 3 Communication Disruptions from Flash Flooding, NYC, Rail Transit, August 8, 2007



Sources: Based on information from Metropolitan Transportation Authority (MTA) (September 2007) August 8, 2007 storm report. MTA, New York, NY

Messaging. The network for messaging among the actors in the flash flooding event parallels some of the generic structure that Höppner, Buchecker, and Bründl (2010: 16) outlines beginning with the weather and flood forecasters, then moving to the warners, responders and ultimately to the affected publics. The MTA identified a number of communication problems associated with that one event, attributed primarily to the unexpectedness and rapidity of the event at the outset (MTA 2007: 6). These communication gaps occurred both internally between operations and employees such as field employees and externally between MTA and the general public on the one hand and various agencies on the other hand. The communication issues arose with respect to information accuracy, timeliness, and accessibility (MTA 2007: 7).

According to the MTA, field operations apparently did not communicate with operations personnel within the MTA regarding the extent and location of the flooding, the MTA communications were weak with the general public in providing accurate information access and prompt information for the media to disseminate regarding the extent of the disruptions (MTA 2007: 6-7). The specific gaps identified primarily pertained to the lack of coverage of communication devices and other deficiencies between links in the system to support messages:

- The Station Command Center in the Rail Control Center and station field agent connectivity: relied on a “mass call” system covering only 40 out of the 900 booths for simultaneous communication (MTA 2007: 60-61)
- Field personnel (“in signal towers, local dispatchers and station agents”) and customer connectivity: various combinations of communications cover three quarters or 348 stations with 120 unserved (MTA 2007: 61-62)
- Train supervisor and personnel connectivity: supported by the “Emergency Booth Communication System”
- Station Agents and Rail Control Center supervisor connectivity
- Media and customer connectivity: Communications with the media were delayed which in turn delayed communications to the general public

NYC and the MTA have implemented a number of operational mechanisms to respond and recover from flooding to reduce the problem in both the short-term and long-term, and these have been accompanied by changes in messaging. In terms of the immediate response, NYC preemptively shut down the transit system with warnings to the public within the timeframe of warnings they receive from forecasters as well as the time it takes to shut the system down. They extensively communicated closures, and did so for Hurricanes Irene and Sandy (Zimmerman 2014). For flood reduction, flood barriers and water removal measures are adopted using pumps the system stocks or borrows. In the longer term, however, the City has had to reroute riders to make long term repairs to tunnels and equipment damaged during storms, e.g., the “Fix&Fortify” program in response to damages from Hurricane Sandy. Passenger rerouting becomes a problem for areas served primarily by a single subway line which is the subject of a separate communication protocol. Disruption of the R and the L train service to make repairs possible often over a year or two, for example, was the subject of intense public communication.

Technology. Many of the deficiencies in messaging were related to technological deficiencies. Numerous recommendations emerged from the MTA’s self-study and other assessments to address the communication problems that were primarily technological – public address systems, signage, etc.

- For the field personnel and operations link within the MTA, technological solutions were suggested used at the time such as Personal Data or Digital Assistants (PDAs) and blackberries (MTA 2007: 7) which since that time would probably be updated with smart phones. For both the MTA-media link and the MTA-user link, technological approaches and outreach strategies were identified, though different for each type of link.
- The technologies for the MTA-user link included visual (including computer based) and audible communications in the form of public address systems, electronic visual displays (“customer information screens”), more effective wireless access for customers (MTA 2007: 7-8), and additional ones in service included customer service lines.

- In 2012, the MTA expanded the visual and audio alert systems, piloting the "Help Point" program, and at that time it planned for installations at 102 stations that customers could use for assistance by connecting directly to the Rail Control Center (MTA September 21, 2012) rather than entirely through the intermediary of the MTA Station Agent. They are strengthening the RCC nodes and the liaison nodes with regional stakeholders.
- In 2015, the Federal Transit Administration awarded NYS a $52.4 million grant to strengthen communication systems at subway stations and RCCs to enhance communication links between those to nodes and between them and customers directly (New York State Office of the Governor, September 3, 2015).

Communications lessons from industrial accident cases

Industrial accidents are not directly related to climate change, however, adverse consequences experienced in these circumstances particularly with respect to technology and human-technological interfaces are often analogous to those arising in climate-related and extreme events also, and thus, reflect other potentially experiences useful for climate communications. For example, detection equipment is often not designed to reflect communication needs. Sensors for pressure, temperature and volume in industrial storage and containment structures have not detected the presence of substances in those vessels or the conditions that affect their release in some historical accidents (Zimmerman 1988). As temperatures increase from climate change, this type of technology will be critical for communications. Communication equipment is often inoperative in disasters. This occurred in some oil/gas pipeline rupture accidents (Jennings et al. 2014). Computerized data systems are only as good as their coverage of anticipated impacts. In some industrial accidents substances released were not programmed in computers, ultimately leaked, and the leakage was therefore not detectable at the control center (Zimmerman 1988).

Conclusions

Communication among individuals, social groupings, and formal organizations will continue to be an essential aspect of the reduction and avoidance of the adverse consequences of climate change and extreme events. These conditions are estimated to continue and become more severe throughout the 21^{st} century. This paper has filled the gap in the literature on climate change communications by examining communications for the risks of extreme events given the implications of extreme events for climate change.

The three cases presented use network concepts to portray relationships among communication components, and illustrate some of the communication issues and opportunities to potentially resolve shortcomings. Adaptations and protective measures occurred subsequent to the events covered that reduced future adverse consequences. Many improvements in the communication systems adopted are strengthening pre-existing communication nodes and links such as creating bypasses and reconfiguring linkages to speed up communications. Many of the measures rely primarily on expanding and updating technologies, however some explicitly address the human-technical system interface for effective messaging, which is vital for users of the technologies. In addition, Moser (2010:32) has suggested for climate change-related issue penetration expanding the audiences reached and diversifying forums, communication channels, messengers, and framings. These approaches can provide the basis for designing effective communication to potentially avoid adverse effects of climate related phenomena.

Although the suddenness of the phenomena in the three cases impeded communication and the timeliness and direction of the response, valuable lessons were learned many of which were used in subsequent events. The many dimensions of risk communication significant for climate change and extreme events are reflected in the two components addressed here – messaging and technology. Messaging needs to reflect interconnections among the various roles, adapt to the type of hazard, the social and behavioral characteristics of recipients, and the timing of or stages in the event. Technology is similarly interconnected, since the technology and the messaging need to be aligned, different technologies have different social-behavioral consequences, and the design, operation, and maintenance of technologies often reflect human error or innovation.

More specifically, the communication processes that occurred in these three cases exemplify some of the weaknesses but ultimate actual and potential improvements with respect to criteria for effective communication. Höppner, Buchecker, and Bründl (2010: 53) outline the following criteria: the existence of clear goals and a framework for communication, identification of roles or actors and the resources available to them, clear understanding of the recipients (audience) and factors that determine their responses to communication characteristics and content, and the compatibility of the technology or channels with the nature of the message, which in turn reflect audience needs. It is instructive to summarize the characteristics of communication across the three cases in light of a few of these criteria.

Uncertainty is a central factor in climate change communication (Morton et al 2011), and thus, the resolution or at least the explicit recognition of uncertainty is an important goal of risk communication. Uncertainty was pervasive in the three cases that contributed to the suddenness of the phenomena. For Joplin it was where and how severe the tornadoes would be (how long, their size and extent) given the spontaneous nature of tornadoes and the fact that communications in the form of warning sirens did not distinguish between tornadoes and severe wind events. For the NYC snowstorm, small changes in the direction or path of the storm could produce dramatically different locational outcomes. The communication of this uncertainty between the weather predictors and government agencies and weather predictors and the general public was considered deficient. For the NYC flash flooding, location and duration were not immediately certain given the sudden onset of flash floods.

Further research is required to address some of the limitations of the approach taken here. The cases provide valuable perspectives, however, they don't provide the associations between the structure of communication and adequate responses that statistical associations provide. Other research designs such as surveys also pose limitations in being primarily based on preferences that respondents express. More research is needed to continue to build more cases to enable generalizations to be made across cases, and documents such as situation reports and after action reports would begin to provide such needed guidance. Better understanding of how and why people react to extreme events and climate change need to continually be refined to understand the role of risk communication in protective behaviors, since the literature in this area is generally not decisive (Wachinger et al. 2013). Finally, problems of institutional memory exist that need to be addressed in order to carry forward the lessons from one case to others.

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