



Embedding Meteorologists and Hydrologists into Emergency Operations

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Abstract

Weather-caused disasters such as tornadoes, hurricanes and inclement weather drive a large portion of emergency management operations in the United States. Incorporating meteorological forecast information into emergency operations has been a long-standing need when the weather is either threatening or directly impacting ongoing emergency management activities during a disaster. A review of historical post-assessment reports for onsite meteorological services provided to emergency management personnel at emergency operations centers demonstrates the benefit in having weather information available to decision makers. Meteorological and hydrologic information has made it into the hands of emergency managers over the recent decades through the integration of weather forecasters into emergency operations and the development of processes such as weather watches, warnings, and advisories. As alert systems have evolved over the years, it has served to enhance timely coordination between emergency managers and meteorologists, to benefit public safety and to improve our overall capability to prepare for and respond to emergencies.

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Introduction

Weather conditions influence a variety of factors in emergency management from disruptions to supply chain logistics and travel, to the way in which a wildland fire may abruptly shift at any given moment. Due to the potential changes meteorological conditions generate before, during, and after an incident, meteorologists and emergency managers must maintain strong collaborative partnerships throughout all four phases of emergency management: mitigation, preparedness, response, and recovery. Emergency managers today know to contact the National Weather Service (NWS) office to obtain weather and water information supporting emergency management activities; this, however, was not always the case. Past weather-related disasters fueled the integration of weather forecasting with emergency management activities to safeguard both the public and first responders. Significant strides have taken place within the past ten years to standardize the process of embedding meteorologists and hydrologists into emergency operations centers (EOCs) and incident command posts (ICPs). Today, this integration provides both in-person and virtual forecasting capabilities and numerous communication modes to relay weather intelligence in support of disaster response and recovery operations.

The increase in collaboration and integration is primarily attributed to the National Weather Service's initiative in creating and maintaining a cadre of specialists ready to deploy at a moment's notice.¹ While this integration and collaboration may have not always been the norm,

lessons learned from hindsight served to slowly reveal how the embedding of meteorologists in EOCs could have significantly improved disaster outcomes years before it became more routine. For example, strong outflow winds during a concert at the August 2011 Indiana State Fair triggered the stage to collapse, killing seven people and injuring fifty-eight others. Although a ten-minute severe storm notice had been provided, emergency management did not evacuate the venue.² Had emergency managers maintained close contact with an on-site or designated meteorologist before and during the high-attendance event, a more informed decision could have been made, with far different outcomes had the call of an evacuation been made. Overall, meteorological incidents present numerous types of hazards, from the routine such as rain, wind, heat or cold to the extreme of tornadoes, hurricanes, and hail. These types of weather incidents compound the effects of other events whether natural (earthquakes, volcanic eruptions, landslides), technological (power outages, dam failures, industrial accidents), or man-made (acts of terrorism, cyberattacks, or civil disorder). Timely weather forecast information remains vital for all emergency operations regardless of the nature of the event as weather has the potential to compound and amplify the effects or put survivors and responders in danger. The Emergency Operations Center (EOC) functions as a platform for coordination that supports collaboration with meteorologists to receive that timely information.

Purpose of the Essay

This essay utilizes small-scale anecdotal overviews of events and disasters where meteorologists were utilized, underutilized, or even absent. These anecdotal overviews serve to advance the importance of meteorologist integration into emergency operations to demonstrate the value of weather information availability and accessibility supporting emergency managers in making decisions during a disaster. A subsequent discussion will examine the resources government officials possess at the local, state, tribal, and federal level to provide weather-based forecasting support for emergency response. Once we identify the resources, we will analyze the involvement of meteorologists in decision-support services in the context of best practices and lessons learned in supporting emergency managers at different levels.

Background

The Origin of EOCs Supporting Disaster-Related Events

FEMA defines emergency operations centers (EOCs) as having the following functions:

- collect, analyze, and share information;
- support resource needs and requests, including allocation and tracking;
- coordinate planning and determine current and future needs; and
- in some cases, provide strategic coordination and policy direction.³

The establishment and use of EOCs can be traced back to the Cold War era of U.S. civil defense efforts when the centers, once activated, were utilized to control, and coordinate emergency activities. While early civil defense actions envisioned EOCs for use during a possible nuclear event, the focus of EOCs changed over time as their activation and use became more commonplace

for supporting natural disaster events.⁴ The EOCs transformed from nuclear threat to natural disaster preparedness in the early days, to the present where the centers support a broad range of activities including cyber, fire, epidemic, civil unrest, and weather threat mitigation. With the stated functions, which an EOC is required to provide, EOCs become an ideal location to maintain a meteorologist presence to support decision-making and coordination activities. Emergency managers, within the EOC, gather weather information from various weather applications, both public and private including those services provided by the National Weather Service (NWS). The availability and accuracy of these weather forecast capabilities have increased over time as the NWS has evolved to integrate new and expanding capabilities from remote sensors in the air, water, and land to satellite capabilities and new supercomputers to aid in the gathering and interpretation for the massive amounts of data needed to create accurate forecasts.⁵

Meteorological and Hydrologic Service Advances through the Years

In reviewing post-event assessments from the National Weather Service regarding high impact events since 1969, there have been continuous improvements to the meteorological and hydrologic based technology services provided by the organization. The improvements, based on the service needs of emergency managers and partners aligned upon three main themes: a) the need to increase collaboration between meteorologists and their partners in emergency management, b) the importance of meteorologists working with emergency management to communicate proper calls-to-action during an emergency; and c) the importance of improving the temporal window within which meteorologists were providing updates to both emergency management and media partners who were in touch with the public and first responders.

Additionally, there were noticeable differences in preparedness and communication between meteorologists and emergency managers in the pre-2011 era for communities that frequently see severe weather, and those (particularly in the western U.S.), which don't receive frequent severe weather as discussed below.⁶ These differences decreased in the 2010s, and not surprisingly, communications between meteorologists and emergency managers tend to excel in disaster-prone communities.

The 1960s to 1970

One example of a successful collaboration resulted from the April-May 1969 Midwest Flood event and the subsequent creation of the weather warning system. The weather warning system was established through the collaborative efforts of Weather Bureau officials, Civil Defense officials, law enforcement agencies, news media, and many local, state, and federal offices to support the preparedness of local communities.⁷ This collaboration between the emergency management community and Weather Bureau served to enhance the weather warning system, as it was demonstrated to have saved lives as a success.⁸ While the Midwest Floods were deemed to have been a success between meteorologists/hydrologists and emergency management, not every event was reviewed similarly.

The Palm Sunday tornado outbreak of 1965 brought to light the need to “hold preparedness meetings in collaboration with the appropriate federal, state, and local government officials and news disseminators in order to develop emergency plans for alerting all segments of communities, whenever emergency warnings are issued.”⁹ However, when discussing short-term threats like tornadoes, every moment counts, and this remains an issue. Currently, a severe thunderstorm or tornado watch is routinely issued 0-6 hours in advance, however, warnings which serve as the immediate call to action for storm events affecting specific locations, need to be issued within minutes of local impact.¹⁰ NWS meteorologists, “regularly and effectively augment these products with other decision-supporting information based on meteorological insights, interpersonal relationships, and societal needs, but official NWS watch and warning products remain largely text-based,” and leave a gap in between watches and warnings.¹¹ Overall, from the 1960s through the 1990s, emergency managers and the public relied on the development and advancement of warning systems for meteorological and hydrologic data, with an increased capability regarding the timeliness of weather information for decision making. The development of these systems would come about over time as lessons learned from post-event assessments would serve to shape future capabilities.

The 1970s to 1980

Understandably, time remains an issue when talking about natural disasters which wreak havoc for days, such as hurricanes. During Hurricane Agnes in 1972, the nature of the event was so substantial, with \$3.5 billion in damage and more than 118 dead, that it served to prompt the public to receive direct access to flood information on an “on-demand” basis.¹² This need can best be served by either telephone or continuous radio broadcasts. Unfortunately, at the time, technology did not allow the news media to have continuous access to the latest forecasts and warnings. The lack of information hindered the media’s ability to communicate with the public and prevent public confusion about the evolving situation.¹³ Communicating to the public is critical during a disaster but so is being prepared before a disaster strikes. The importance of preparedness from meteorologists working with emergency managers was noted during the Northeastern United States blizzard of February 1978 when “NWS and local officials emphasized the importance of preparedness, the need to sensitize the people to the impact of the weather, and the difficulty of maintaining that sensitivity.”¹⁴

During the January 1982 San Francisco Bay Area Storm, barriers were identified between the National Weather Service and the emergency management community. One barrier appeared to be that weather and water information was an afterthought to immediate emergency response as “[o]fficials in the severely affected areas either did not have time, due to more urgent emergency actions, or they did not know how to communicate with the National Weather Service.”¹⁵ During this event, the presence of meteorological and hydrological support was identified as something that would have been extremely helpful for emergency response decision-makers, who were working in a rapidly evolving situation. Researchers found that:

The real-time advice and support of an operational hydrologist is an important ingredient in situation assessment and in the formulation of hydrologic advisories. This support becomes increasingly important in situations when data are scarce and flooding is occurring in areas where specific river forecast procedures do not exist. In these circumstances, hydrologists can and should provide significant assistance to meteorologists in the form of situation appraisals, judgments of storm impacts, and other advice. This draws upon the hydrologist’s experience, technical knowledge, and general knowledge of the affected area.¹⁶

Maintaining close contact with meteorologists and hydrologists in emergency situations would have supported the media, public, and government officials to make an informed and actionable decision to provide for a more comprehensive response.¹⁷

The 1990s to 2000

In the early 1990s, weather preparedness continued to improve through communications between the National Weather Service and emergency management. During this era, the internet became commonplace in homes and businesses, which changed meteorologists' communication platforms, allowing weather information to be communicated across the globe. Feedback from the December 1992 nor'easter shows that between the 1980s and 1990s, meteorologists were in frequent communication with emergency managers. However, the U.S. was starting to demand weather information in an automated manner. One of the most significant action items to come from this event was the movement "to automate the exchange of information between the NWS and the emergency management community."¹⁸

The geographical expansion of the weather forecast offices (WFOs) in the mid-1990s greatly contributed to the National Weather Service refining the services and products provided to the public. Emergency management was ready on May 3rd 1999, having anticipated a major tornado outbreak in Oklahoma and Southern Kansas. The City of Moore (OK) emergency management director broadcasted NWS warnings for the community, providing radio and television station communications warnings to reach as much of the population as was possible.¹⁹ The communication of this weather information was not just timely but was novel in terms of pre-event planning and collaboration between the National Weather Service, emergency managers, and media partners. These collaborative efforts would continue to support improved communications on changing meteorological conditions into the 2000s.

2000s to Current Day

As the United States rolled into the new millennium, the significance of networking between the National Weather Service, emergency managers and the public took center stage. Technological advancements in communications continued to support new improvements as the internet, cell phones, and other application technologies such as Nixle, a then recently developed public safety messaging platform, became more commonplace and available to users. Additionally, the rise and use of social media served to provide yet another and ever-growing communications platform on which to share information between meteorologists, emergency responders and the public.

Hurricane Isabel, in September 2003, serves as an early example where on-site coordination between meteorologists and emergency managers were deemed to have been very beneficial for a large regional high-impact event. As was noted post-event, "the FEMA Operations Center strategically place[d] personnel at the Tropical Prediction Center (TPC) during a hurricane threat for the United States to facilitate the flow of information between the two agencies."²⁰ During this event, meteorologists were not only providing their standard watch, warning, and advisory services, but were also integrating into emergency response as subject-matter experts (SMEs). At the national level, the National Weather Service "supported FEMA and state EMs by delivering twice daily, live televised briefings on the expected precipitation from Isabel."²¹

The Great Coastal Gale of 2007, a series of three powerful Pacific storms which affected Oregon, Washington, and British Columbia, occurred in an era when the National Weather Service was beginning to emphasize the need for Impact-Based Decision Support Services (IDSS) based on emergency management partners' needs. While Portland and Seattle weather forecast offices were able to communicate during this event in real time with emergency managers and partners, it was clear that not all county emergency management departments had good communications established with their local National Weather Service offices.²² The interpretive service portion of the relationship was missing for some partners, particularly with Grays Harbor County, Washington, which had anticipated a more routine storm with wind gusts from 40-60 mph. However, despite forecasts, outlooks, and briefings from National Weather Service Seattle Forecast Office which mentioned the possibility of a period of hurricane force wind gusts, the force and impact of the storm was far greater than anticipated.²³

In 2011, the National Weather Service's policy and plans began to place greater emphasis on the use of IDSS in supporting the greater needs of the emergency management community.²⁴ This was done to ensure that emergency managers would be better prepared to understand the effects of upcoming weather events so they could provide more actionable and timely information for emergency managers. Recent event reviews suggest that the agency was already heading in the direction of in-person collaboration during weather events for emergency response having recognized the benefits of a closer collaboration. In the case of the June 2012 North American Derecho (linear windstorm) across the Midwest and Mid-Atlantic, National Weather Service offices began to take steps to improve relationships with emergency managers and the media. As part of these process improvements which were constantly evolving, email briefing packages were being prepared in advance by weather personnel and were then later utilized to provide decision makers with advanced notice of severe thunderstorms taking place later in the day.²⁵ Emergency managers preferred direct interaction with the NWS and were largely able to accomplish this through other newly advanced technological developments such as NWSChat, an instant messaging program, which provided real-time communication between NWS staff, emergency managers, and media partners.

Regarding how the meteorological and hydrologic services were operating post-2011, one can look to the historic Front Range and Eastern Colorado Floods of September 2013, which significantly affected Boulder, putting homes, businesses, and roadways underwater. During this event, the NWS utilized various tools to communicate the imminent threat as it unfolded, including conference calls, one-on-one phone calls, NWSChat, and WebEOC, as an emergency management instant messaging platform, to relay timely information in near real time.²⁶ Still, some problems remained as a few counties noted the inability to interact with the NWS during peak periods of flooding.²⁷ This again revealed a gap in the communication between emergency managers and NWS offices, where near real-time integrated meteorological and hydrological support would have proven to be of significant value to decision makers.

The South Carolina Floods of October 2015 resulted in nineteen deaths and costs exceeding more than \$1.4 billion.²⁸ The NWS improved its services heading into the event with an increased ability to support emergency management organizations. Emails were distributed from NWS offices to emergency managers on a proactive basis leading up to and during key periods of concern without a formal request from emergency managers. Likewise, conference

calls between NWS staff and emergency management were a common occurrence with hydrologists included to address the influx of water associated with the unprecedented amounts of rainfall.²⁹ Notable as part of this event was the adoption and use of the incident command system (ICS) by hydrologists for the first time.³⁰

Since 2015, the NWS has prioritized the national deployment-ready program, which trains meteorologists and hydrologists in the use and structure of ICS so they can better understand their emergency management counterparts. From FEMA's perspective, the most beneficial IDSS capabilities have been the weather and flood conference calls, and briefings in support of state and local emergency management agencies.³¹

With improvements to the IDSS capabilities of NWS, the organization was better prepared to respond to events such as Hurricane Harvey in 2017, with improved communications capabilities supporting emergency managers and the public. National Weather Service forecasters were observed to have relayed timely weather intelligence information regarding weather impacts to ongoing emergency management operations during this event.³² This capability ensured that information required to make informed decisions was available as the situation evolved. While flooding was extensive during Hurricane Harvey due to a stalled weather system which inundated the region with continuous rainfall, emergency managers and the NWS worked together to communicate the importance of shelter-in-place measures based on the anticipated amounts of rainfall. Within the month, Hurricane Maria would again test communications and forecasting capabilities for an event with a constantly changing forecast track.

During Hurricane Maria, the National Hurricane Center (NHC) worked tirelessly with affected NWS offices in the Caribbean (primarily San Juan Puerto Rico office) to ensure consistent and timely communications for changing weather.³³ A secondary effort supporting numerous communities, found several of the WFO San Juan staff deployed to assist the local, state, and federal partners at the Puerto Rico Emergency Management Agency (PREMA) EOC. Despite having meteorologists embedded in the PREMA EOC however, the federal response received a great deal of criticism due to the slow response to the disaster. The criticism, while understandable at the time, was not focused on the timeliness or accuracy of the weather forecasting, but rather originated from the overstretched resources of FEMA. For Hurricane Maria, tropical experts at the NHC provide IDSS to emergency managers from nearly the start of the event, till the end, when Maria finally moved away from the North Carolina coast.³⁴

A little more than a year later, in Northern California's Butte County, the Camp Fire broke out on November 8, 2018, near the towns of Concow and Magalia. The fire reduced the town of Paradise to ashes and serves as California's most devastating fire on record with more than eighty-five confirmed deaths, and a death toll potentially greater than one-hundred, and nearly 240 square miles burned. The fire, caused by a faulty power line, was exacerbated by prevailing winds and weather patterns which fanned the flames with moderate dry winds. At the time, a Red Flag Warning (RFW) had been issued to underscore an increased risk of fire danger due to very dry fuels, low relative humidity, and gusty winds greater than 35 mph.³⁵ This warning system ensures that both firefighters and the public at large can be alerted to an increased risk for dangerous fire related weather. The warning further serves to support predictive services and decision makers as a forecast warning to ensure that a consistent and standardized weather

message is conveyed to the public. As fuels can burn rapidly once ignited, understanding the significance of a red flag warning can help elevate concerns as to the significance of a critical weather-related situation once the warning is issued. The Service Assessment for the *November 2018 Camp Fire* determined that “how to message the threat within the RFW is critical to those in the field fighting the fires.”³⁶ In the case of the Camp Fire response, the California Governor’s Office of Emergency Services (Cal OES) requested NWS meteorologists operate from the EOC from the start of the response, with the Camp Fire IMT team requesting an Incident Meteorologist (IMET) for utilization at the incident command post (ICP). Administrators deemed the IMETs as a “best practice” for the event as the ability to have trained incident meteorologists on-site at the various command posts served to support decision makers in getting real time forecasts and predictions to assist in their decision-making. The IMET program, it should be noted, has existed for over ninety years, and has deployed meteorologists to ICPs during that period to support wildland fire fighters during difficult circumstances.

Weather Intelligence for Non-Weather Emergencies

While having meteorologists involved in EOC or ICP operations remotely or on-site during natural disasters has proven to be successful, non-weather emergencies like earthquakes, oil spills, HAZMAT response, terrorism, and pandemics might very well also benefit. Weather information is important for any operation which relies on close coordination, logistics support, and for events such as support to recent COVID-19 operations where outdoor testing and treatment was conducted during good weather and bad.

The COVID-19 pandemic obviously brought about a period of unanticipated challenges here in the U.S. The pandemic impacted the consequence management activities for a wide range of operations which could be affected by weather, and in several instances direct weather support with meteorologists helped to sustain outdoor medical testing and treatment centers and the flow of vaccines when weather was a factor. Email exchanges involving meteorologists at the NWS in Pendleton, Oregon revealed that a drive-up COVID-19 clinic was nearly called off due to adverse winter weather during 2020. However, the facility was able to maintain its operations and account for weather changes with information provided by NWS to the City of Walla Walla emergency management office.³⁷ Director of Weather Services Louis Uccellini notes several examples during the COVID-19 event where NWS worked with local and state emergency managers and health providers in supporting weather updates for distribution and vaccination site efforts.³⁸ Uccellini concluded that weather intelligence helps dictate the planning and response for both short-term and long-term emergency operations, whether the incident is weather-related or not.

Recommendations

With the ongoing COVID-19 pandemic of 2019–2022, technological advancements have allowed EOCs to operate from home offices, thereby challenging the traditional paradigm of in-person command and control EOC operations. New technologies such as Zoom, Microsoft Teams, and

Google Meet have been tested during the COVID-19 pandemic offering emergency response partners the ability to enhance communications and help “see” one another’s facial expressions when communicating. While body language and other visual cues can be lost in the absence of video technology, Baker and Milutinovic have observed:

Non-verbal cues are just as crucial when communicating as the words we say. Everything from body language and facial expressions to attentiveness and engagement can indicate different thoughts and feelings—each of which can only truly be observed through face-to-face communication.³⁹

Aside from the importance of body language, being in-person allows for “[...] a sense of community [that] comes with the ability to interact and socialize, and this sets the foundation for trust, and ultimately better working relationships.”⁴⁰ Building rapport between decision-makers and SMEs such as meteorologists and hydrologists is nothing new. However, it is something that should be reinforced as emergency managers and SMEs are increasingly able to collaborate via electronic communications. This collaboration, advanced by attending meetings in person and serving together during emergency operations, helps to reinforce the bond between meteorologists, emergency management and hydrologists as force multipliers when working together before, during and after disaster events. The importance of a leader advocating for serious measurements to be taken when highly impactful weather is expected goes a long way in supporting community preparedness for incoming weather. On-site meteorologists, who can provide face-to-face communication and updates regarding weather not only helps emergency managers to understand the severity of a situation but serves to improve the relationships necessary to create a unified preparedness message for public safety

Conclusion

Weather forecasting and alert technologies have advanced greatly over the last fifty years. However, meteorologists, hydrologists, and emergency management partners must continue to remain vigilant in efforts to communicate and integrate weather intelligence into emergency operations leading up to, during and after disasters. As previously highlighted, weather impacts every operation, regardless of what caused the initial disaster. Email briefings, conference call briefings, iNWS, NWSChat, and IDSS are all excellent means by which NWS meteorologists and hydrologists can provide useful and real-time information supporting emergency managers and the public. Beyond the use of these applications however, there is no substitute for having a meteorologist on-site or virtually deployed to support events which may be considered routine, but may have a chance of becoming more extreme and complex due to changing weather conditions. Having a meteorologist deployed to support an EOC is a worthwhile investment to consider, not only during activation period, but for the entirety of an event to assist in the planning and preparation of field operations. For smaller jurisdictions where resources are thin, virtual weather support from the National Weather Service may be the best alternative to on-site support to ensure that these jurisdictions receive timely and accurate forecasting. For larger jurisdictions, having a team detailed to support its more extensive needs will be a must to ensure that both meteorological and hydrological services can be provided in support to decision makers and the public during a disaster where inclement weather is coupled to a large-scale complex event.

About the Authors

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