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WEATHER AND DECISION SUPPORT FOR EMERGENCY MANAGERS

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Presented at the 93rd AMS Annual Meeting, January 9, 2013 in Austin, Texas

Abstract:

Basic meteorological concepts and understanding play a big role in the response to this nation's natural and man-made disasters, as well as planned responses to terrorist threats against urban and rural areas. Issues such as land-sea breeze circulations, mountain and valley winds, coastal cloud cover, vertical and horizontal wind shear, normal diurnal fluctuations, and the impact of certain predictable and terrain-enhanced wind storms all play crucial roles in determining who's at risk, and what strategies are most effective in minimizing harm to people and structures. The ability of the National Weather Service with its Incident Meteorologists and decision support services, together with rapidly advancing technology in assimilating data over small time and spatial scales, provides the emergency manager or incident commander with a host of essential real-time support capabilities. This paper attempts to identify and highlight the value of these real-time support capabilities.

1. Background:

Weather-caused and weather-related natural disasters have become more frequent in the U.S. over the last 30 years (Figure 1), and their financial impact has grown proportionately. Billion dollar weather disasters affect nearly all regions of the United States when viewed over the 30-year period from 1980-2010 (Figure 2). Although some geographic areas are more prone to a particular type of disaster, such as tornadoes in the south and Midwest, hurricane landfalls along the south and east coasts, and wildfires over southern California and portions of the U.S. Southwest, nearly the entire country is at risk from one or more of such events.

The National Weather Service (NWS) has assumed a growing and important role in not only predicting weather-related events through modeling and forecast expertise as was demonstrated during Super Storm Sandy during October 2012, but also through addressing the impacts of weather on a host of human activities. These include guidance to emergency managers and the public on areas most vulnerable to damage from wind, flooding, fires and ice etc., to assessments of impacts on power grids, transportation and evacuation routes. In addition, due to political instabilities in the world and the constant concern over acts of terrorism, the NWS also plays a key role in providing data, guidance, and impact assessments to determine which populated areas are at risk in response to events of national interest, be they acts of terrorism such as an intentional toxic release, or man-made accidental releases such as might occur during a train derailment or an oil refinery explosion. The NWS's support to the emergency management community follows Department of Homeland Security and National Oceanic and Atmospheric Administration (NOAA) responsibilities identified in FEMA's National Response Framework, and is consistent with NOAA's own strategic plan goal of a Weather-Ready Nation and its objective which is to reduce loss of life, property, and disruption from high impact events.

Due to the natural tendency for emergency managers (EMs) to be principally informed in their own unique disciplines and experience, such as in

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transportation systems, law enforcement, health, first aid, fire protection and related subjects, their knowledge of basic meteorological factors is sometimes limited. Due to the urgency with which decisions need to be made to reduce loss of life and protect property, there is a tendency for EM personnel to seek simplicity rather than representativeness. This may be exhibited in such decisions as what meteorological inputs should be used in modeling assessments or what assumptions may be made about the persistence of weather conditions over the course of a day or expected duration of an event they are responding to. This has led to our motivation in writing this paper, since it is crucial that sound decision-making be based on accurate assessments, predictions and awareness of meteorological phenomena.

In general, based on the authors' experience obtained during participation in training exercises, town-hall meetings, joint response teams and terrorism early warning activities, we have found that emergency managers, responders and planners realize that weather is important to them, but they don't always know why, when, or how best to incorporate meteorological considerations into their decision-making process. The NWS is therefore committed to helping the emergency management community, and has developed many valuable tools and processes that emergency responders and incident commanders can use in making informed decisions about such tasks as determining who's in harm's way, where are the best and safest places available to establish triage and emergency operations centers, and what are the available or optimum evacuation routes.

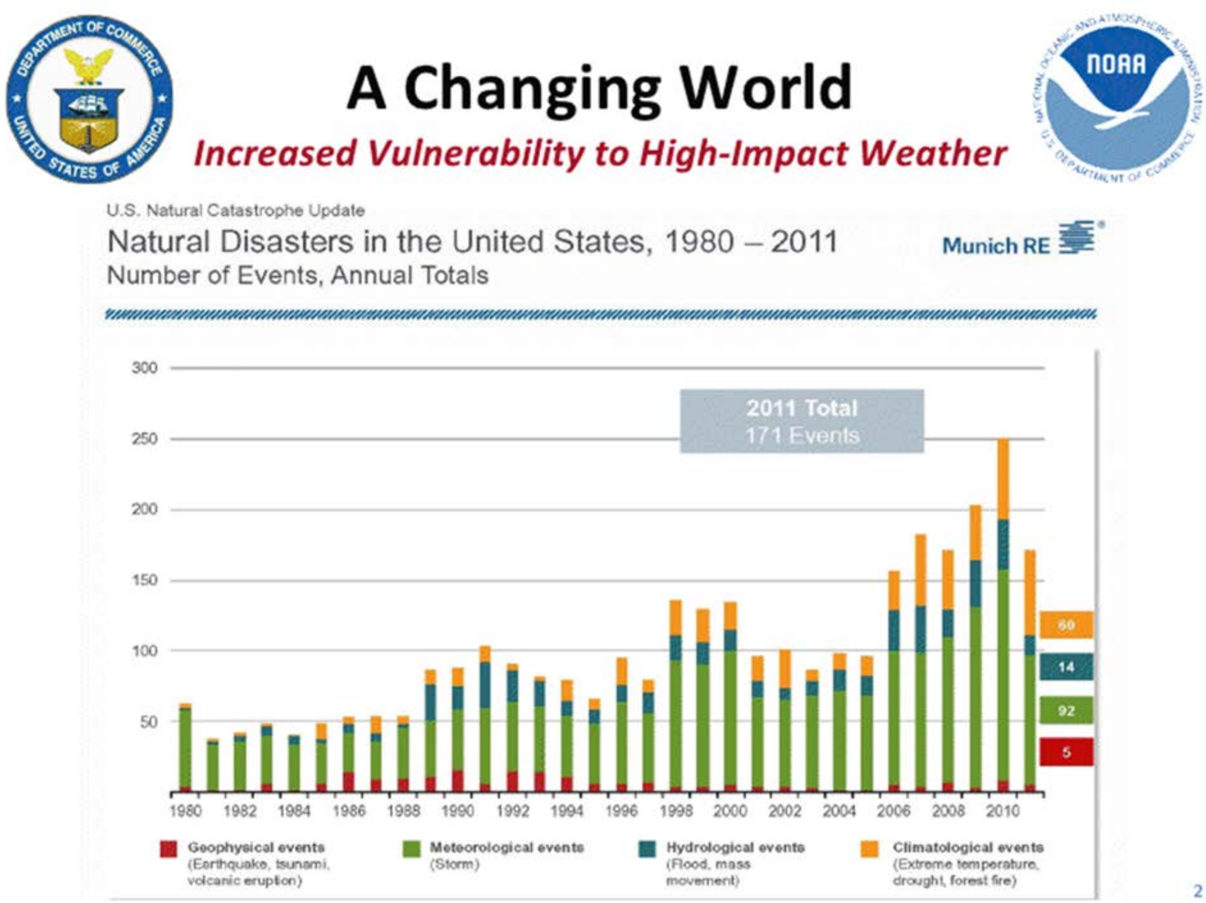


Figure 1: Natural Disasters in the United States, 1980-2011

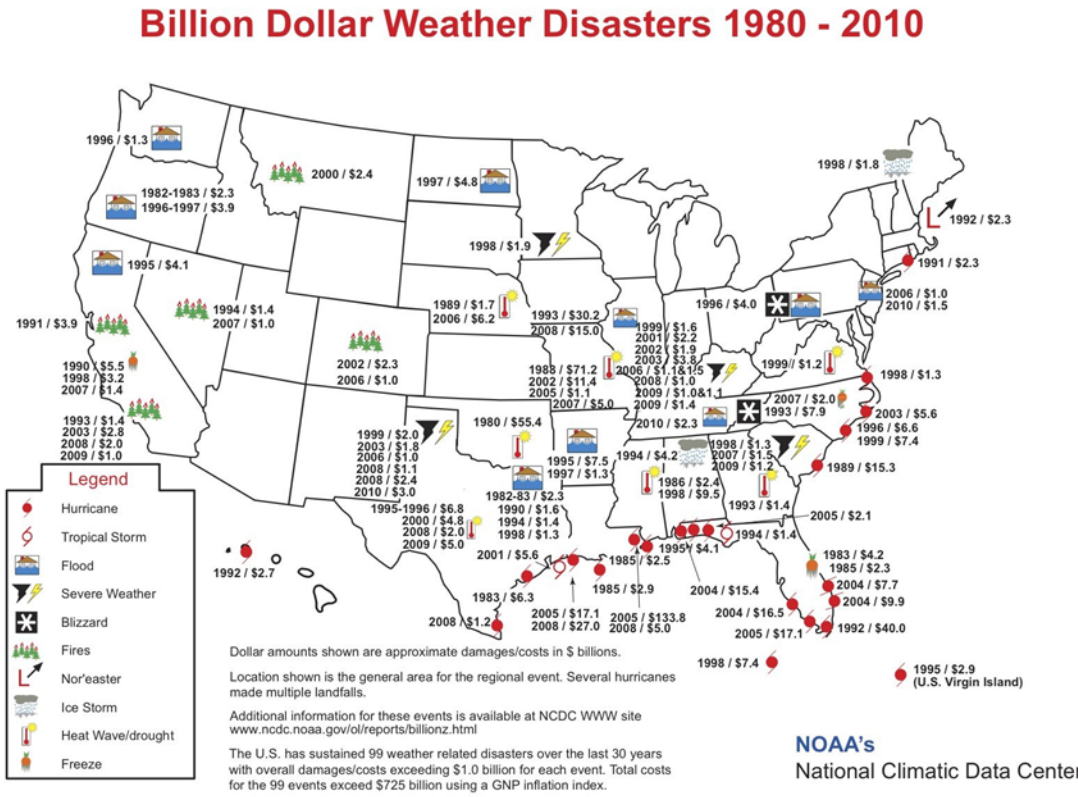


Figure 2: Billion Dollar Weather Disasters across the USA 1980-2010

2. Some 'Meteorology 101' Concepts for Emergency Managers and Incident Commanders:

Some of the most important considerations are those that relate to spatial and temporal variability of weather conditions. To the average person and those emergency management officials that are not adequately trained in meteorology, it is sometimes difficult to visualize how wind directions and speeds can vary greatly between their location and regions nearby. Or, if it is fair and windy in the morning, why wouldn't it also be fair and windy in the afternoon if no obvious weather change was taking place. Knowing that wind direction and speed are perhaps the most significant parameters in assessing which population centers are at risk from transport of a toxic cloud, correct wind assessment is vital. Starting with the basic precept that wind direction is always the direction *from* which it is blowing, EMs and responders should know that local terrain or proximity to water and coastlines have major impacts on local wind. Near beaches and coastlines, coastal eddies often occur resulting in winds that can be 180 degrees different over distances of just a few miles. Figure 3 shows typical wind variability observed in southern California in the coastal zone of Los Angeles in the presence of terrain-induced eddies.

Using a wind analysis scheme developed by Eddington, a NAVAIR Pt. Mugu meteorologist, the rotation of the surface wind flow in the vicinity of the Palos Verdes Peninsula in concert with northwest flow offshore results in significant differences in wind direction all along the densely-populated southern California coastline. Larger mesoscale eddies often termed Catalina Eddies are periodically observed in the southern California Bight south of Point Conception [Rosenthal, J. ,1972, Thompson et al ,1997]. These typically lead to moderate southeast winds over the coastal region with strong northwest winds over the outer Channel Islands. In the event of a serious oil refinery fire, knowledge of such wind variability is crucial to knowing who to evacuate and where emergency operations personnel should be placed as toxic fumes are transported away from the fire.

Other dramatic examples of horizontal wind variability in fire-prone areas of southern California include Santa Ana conditions during which extreme differences can and often do occur in both the horizontal as well as in the vertical (Figures 4 and 5). Proximity to canyons and coastal mountains typically yield northeast winds often gusting to 50-60 mph, and sometimes exceeding 100 mph. Just a mile or two away, locations can experience winds that are near calm or even southwest. Similarly, coastal or basin locations at the surface may exhibit sea breezes from the southwest or west at 10-15 mph while locations in the adjacent hills at elevations of 1,000 feet may experience the full brunt of the dry northeast flow. These conditions of extreme vertical wind shear and turbulence impact the safety and feasibility of using helicopters and fixed wing aircraft to fight fire spread with water and retardants. They also lead to rapid expansion of the fire lines when the high-velocity winds just above the surface transport burning embers that can land up to a half mile or more away, starting new hot spots beyond the original fire perimeter. This is the well-known process of spotting. Assessing which direction, and how fast the wind will be blowing throughout the day at the scene of a major wildfire requires special meteorological insight which the NWS can provide on-site and in real-time through its Incident Meteorologist (IMET) function which will be described in further detail in following sections.

A simple assumption that wind conditions will be static throughout the day doesn't match what is typically observed. No matter how strong the Santa Ana event is from an overriding synoptic standpoint, there is almost always significant impact by the daily heating cycle due to solar influence. If the Santa Ana is weak or moderate, afternoon hours will typically see slightly moister sea breeze flow replace the night and mornings' dry northeast winds along the coast and even into canyons and coastal slopes. If the Santa Ana is exceptionally strong, there is still at least a weakening of the northeast flow during afternoon hours before resumption of strong Santa Ana winds again in the subsequent evening hours.

Emergency responders and fire fighters must continuously update their assessments as the day wears on with constant monitoring of the wind through on-site measurements and use of NWS IMET capability, if available. Even in the absence of direct measurement support, emergency managers can make educated estimates of wind behavior from specialized local climatological summaries based on historical data from surrounding stations. Meteorologists at Naval Air Systems Command (NAVAIR) Point Mugu have developed graphical digital products that on a single page, depict the climatological variability of wind behavior as a function of both season and time of day so that typical diurnal factors could be quickly taken into account without a lot of analysis. An example of such a Climogram is shown in Figure 6 [Fisk, 2008].

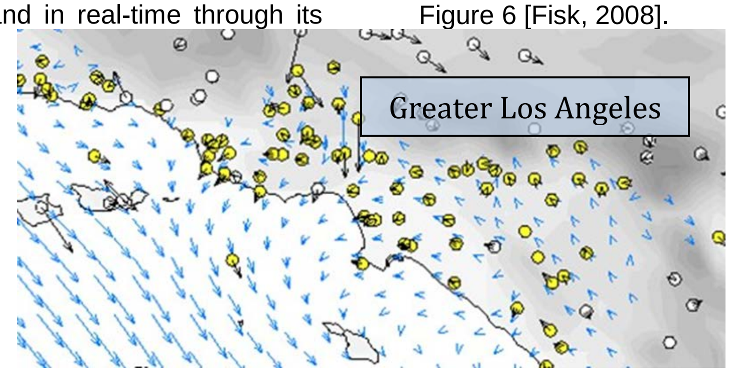


Figure 3: Modeled wind flow along the southern California coastal zone

Figure 4: Horizontal perspective of Santa Ana winds in southern CA.

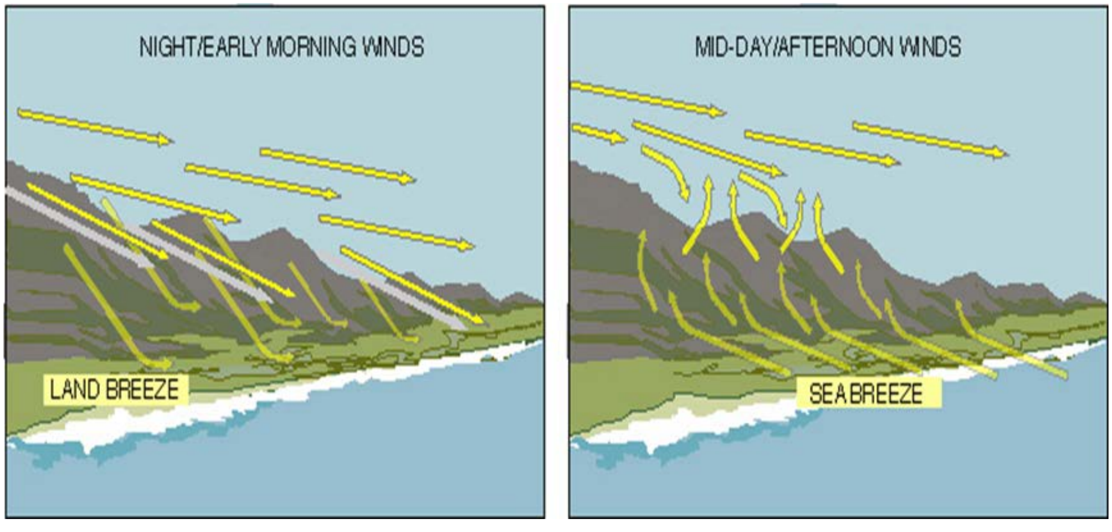


Figure 5: Vertical perspective of Santa Ana winds in coastal southern CA

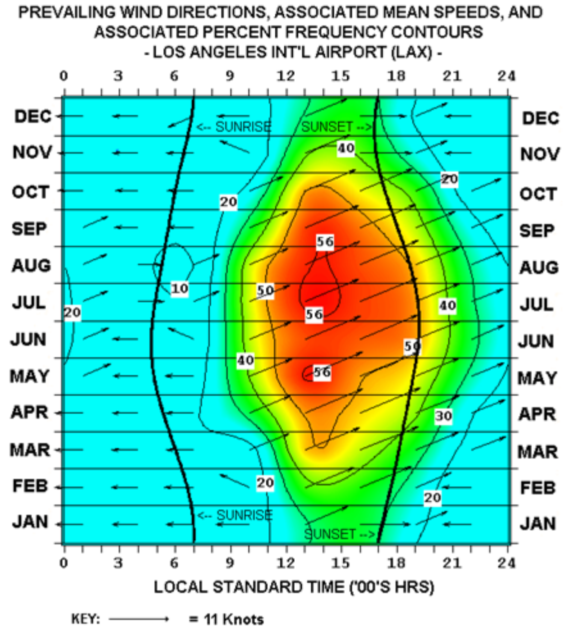


Figure 6: Sample wind Climogram for LAX (courtesy of Fisk, NAVAIR Point Mugu)

3. The Impact of Changing Winds:

In assessing the impact of weather to determine who's in harms way, and where emergency management personnel should best be stationed, a typical tactic used by emergency responders is to run a plume model to determine the expected direction and concentration of toxic cloud transport downstream away from the source. Many such models are available including HYSPLIT used by NOAA, HPAC by elements of the military, and NARAC by the Department of Homeland Security (DHS). Which one is used depends upon a combination of mission, computational capability and choice. Developed by the Lawrence Livermore National Laboratory (LLNL), a NARAC-run wind assessment is shown in Figure 7 (courtesy of LLNL) based on use during a training exercise conducted by U.S. Naval meteorologists at Point Mugu, California.

In a hypothetical release of toxic materials due to an act of terrorism, the model was run at different times of day to determine the location and concentration of cloud impacts on surrounding communities using real observed wind data as measured at the Station's airfield. Four model 'runs' were superimposed graphically to demonstrate how sensitive emergency response planning is to actual weather conditions as they progress during a day that in this case experienced only subtle synoptic changes. As shown in Figure 7, at 2100 GMT (1 P.M. local time) on November 4, 2001, based on a measured southeast wind, the hypothetical release of toxic agents would have been directed towards the coastal communities of Oxnard and Ventura. Just three hours later at 0000 GMT on November 5 (4 P.M. local time on the 4th), based on airfield observations that showed the wind had shifted to come from the southwest, the hypothetical projected plume was then in a position to severely impact inland communities of Camarillo and Thousand Oaks. Three hours subsequent to that at 0300 GMT (7 P.M. local time on the 4th), the plume model was again run, and based on observed winds that had become northwesterly, the projected plume impacts were now directed southeastward towards the coastal communities of Malibu and potentially Santa Monica.

Finally, the model was again run using winds at 0600 GMT on November 5 (10 P.M. local time on the 4th), and based on that wind observation, the toxic plume would have gone out to sea to be entrained in a prevailing northwesterly surface wind flow.

For an emergency management team trying to determine who's in harm's way, where evacuation centers should be set up, and where emergency responders and triage personnel should be placed, decisions that would have been made based only on one set of wind measurements would have been potentially catastrophic as the wind turned during the course of the day. The use of representative data is key to success, even if it requires inconvenience and multiple movements of personnel and equipment be it a real or simulated disaster response.

4. National Weather Service Support to Emergency Managers:

As an outgrowth of coordination between NOAA, DHS, and other governmental departments in response to natural disasters, the NWS has developed an ever evolving suite of support tools that can, and should be exploited in real-time for disaster response and planning. These include operationally available forecasts that incorporate the finest scale resolution of data and model predictions interpreted by professional meteorologists at the NWS Forecast Offices. These can be accessed in a number of ways via the web (www.weather.gov), spot forecasts for HAZMAT and related applications, and a variety of formats including simple narratives, tables and graphs and gridded digital data (Figure 8). Federal and State agencies, in support of emergencies, can initiate requests for special forecasts for their particular geographic response needs and the NWS will respond to those requests with predictions of up to 12 sensible weather elements in timelines out to 7 days and tailored formats that are easy to use for emergency manager decision-making.

Many of the NWS products are based on a GIS-compatible digital forecast database derived from gridded NWS forecasts with resolutions down to 2.5km. These products can be generated on-site by emergency responders to satisfy objectives that are specific to the nature of the disaster. An example of a typical product using this NWS capability is shown in Figure 9. In this scenario, the progression of wildfires can be monitored through the superposition of existing or prior fire boundaries on top of a GIS-based map of the region of interest. Also overlaid is a representation of 6-hour predicted wind directions and speeds valid at 1800 GMT on a day of interest derived from the digital forecast database. As is often the case in meteorological analyses, wind directions at grid-point locations are shown by arrows, and wind speeds indicated by the lengths of the arrows. However, color-coding provides another mechanism for emergency responders to make quick assessments of where wind speeds are greatest. By superimposing details of geography, wind direction, wind speed, and fire boundaries, more accurate assessments can be made of where fire spread is most likely, who is likely going to be impacted, and where resources should be martialed to stage the most effective fight against the advance of flames. Similar overlay products can be used subsequently to determine the most vulnerable areas to mudslides when the next major rain storm moves over burnt areas. The NWS continues to expand the application of this digital forecast capability.

In addition to automated processes established by the NWS, in-person decision support services can also be provided in some disaster scenarios depending on need and availability of personnel. These can include attendance by Warning Coordination Meteorologists (WCMs) at virtual conferences and town hall meetings, and Emergency Response Meteorologists (ERMets) in emergency operation centers where they can address critical weather issues, update forecasts, and answer questions from a variety of emergency response officials. This has been exploited successfully numerous times in recent years within the NWS, including at FEMA Joint Field Offices (JFOs) to ensure that emergency support personnel and decision makers have the benefit of the best and latest NWS guidance on weather conditions (Figure 10). Another NWS capability, when available, is the ability to send IMETs to the site of a weather-related disaster where on-site measurements and guidance can be provided to users in real time.

The NWS is also providing and experimenting with a host of other decision support products that they can push to emergency responders/planners and other selected users. These include written weather briefings, weather graphics and plain language products via partner emails when conditions seem conducive to having an impact, be it potential flooding, mudslides, severe weather, a fire hazard, or something as simple as heavy snow at low elevations impacting travel (Figure 11).

These products serve as 'heads up' guidance and warnings to the emergency response community in the face of impending weather problems. Applications can include the expected impact on transportation corridors and traffic ability in general. New capabilities under development and consideration include graphical travel web pages, statewide weather pages, and a digital data and hazard viewer. In addition, the NWS provides a succinct and colorful graphic and text 'weather story' as a part of its established web page when a significant weather event is occurring or predicted to evolve in the near future (Figure 12).

Since time is of the essence in any support to emergency response requirements, the NWS is also exploiting the use of Facebook, Twitter and YouTube to greatly expand the dissemination and availability of its warnings and forecast guidance.

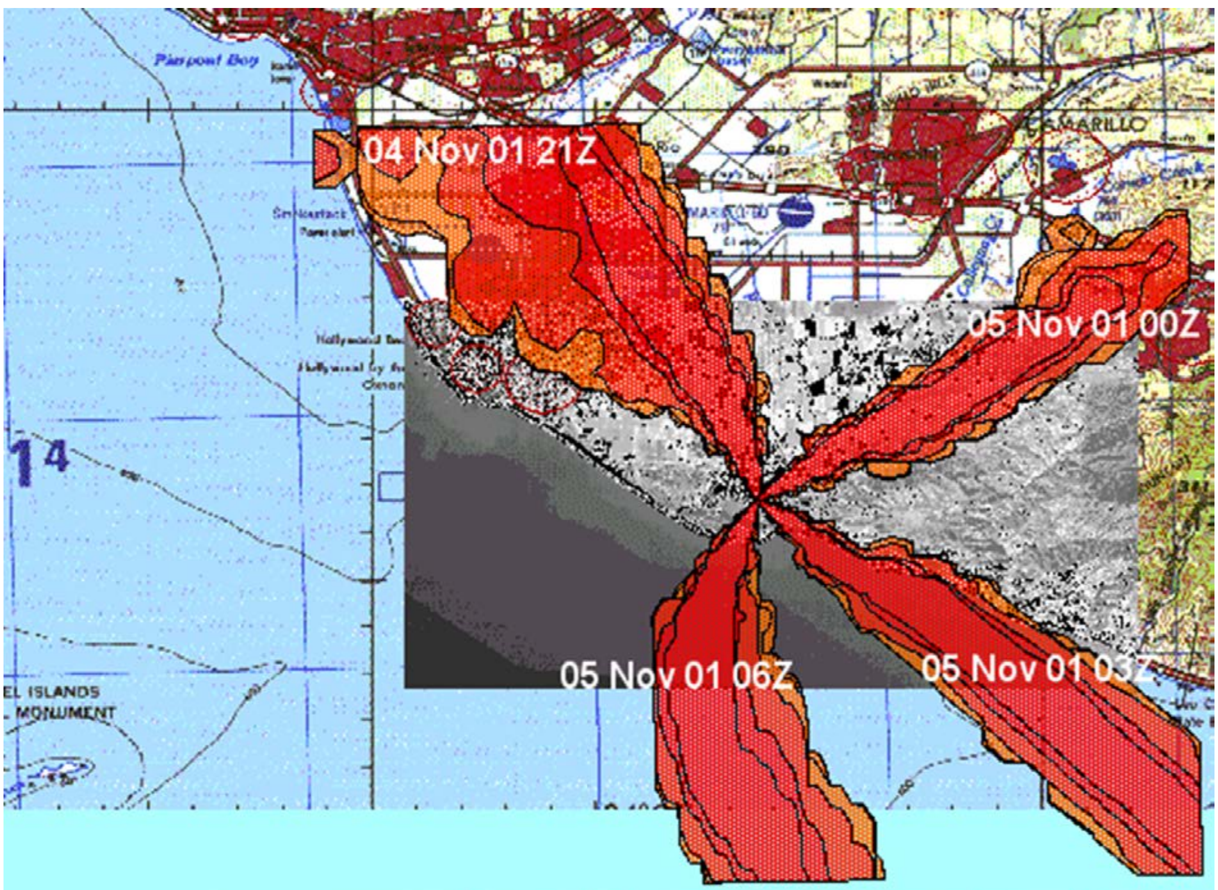
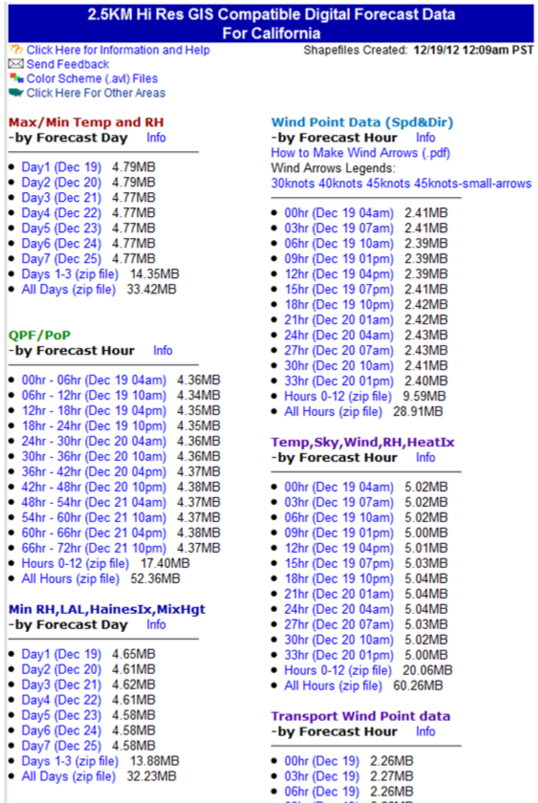


Figure 7: Superimposition of 4 separate LLNL toxic plume model runs (courtesy of LLNL)



2.5KM Hi Res GIS Compatible Digital Forecast Data For California

Click Here for Information and Help
Send Feedback
Color Scheme (.avl) Files
Click Here For Other Areas

Shapefiles Created: **12/19/12 12:09am PST**

Max/Min Temp and RH
-by Forecast Day Info

- Day1 (Dec 19) 4.79MB
- Day2 (Dec 20) 4.79MB
- Day3 (Dec 21) 4.77MB
- Day4 (Dec 22) 4.77MB
- Day5 (Dec 23) 4.77MB
- Day6 (Dec 24) 4.77MB
- Day7 (Dec 25) 4.77MB
- Days 1-3 (zip file) 14.35MB
- All Days (zip file) 33.42MB

QPF/PoP
-by Forecast Hour Info

- 00hr - 06hr (Dec 19 04am) 4.36MB
- 06hr - 12hr (Dec 19 10am) 4.34MB
- 12hr - 18hr (Dec 19 04pm) 4.35MB
- 18hr - 24hr (Dec 19 10pm) 4.35MB
- 24hr - 30hr (Dec 20 04am) 4.36MB
- 30hr - 36hr (Dec 20 10am) 4.36MB
- 36hr - 42hr (Dec 20 04pm) 4.37MB
- 42hr - 48hr (Dec 20 10pm) 4.38MB
- 48hr - 54hr (Dec 21 04am) 4.37MB
- 54hr - 60hr (Dec 21 10am) 4.37MB
- 60hr - 66hr (Dec 21 04pm) 4.38MB
- 66hr - 72hr (Dec 21 10pm) 4.37MB
- Hours 0-12 (zip file) 17.40MB
- All Hours (zip file) 52.36MB

Min RH,LAL,HainesIx,MixHgt
-by Forecast Day Info

- Day1 (Dec 19) 4.65MB
- Day2 (Dec 20) 4.61MB
- Day3 (Dec 21) 4.62MB
- Day4 (Dec 22) 4.61MB
- Day5 (Dec 23) 4.58MB
- Day6 (Dec 24) 4.58MB
- Day7 (Dec 25) 4.58MB
- Days 1-3 (zip file) 13.88MB
- All Days (zip file) 32.23MB

Wind Point Data (Spd&Dir)
-by Forecast Hour Info
How to Make Wind Arrows (.pdf)
Wind Arrows Legends:
30knots 40knots 45knots 45knots-small-arrows

- 00hr (Dec 19 04am) 2.41MB
- 03hr (Dec 19 07am) 2.41MB
- 06hr (Dec 19 10am) 2.39MB
- 09hr (Dec 19 01pm) 2.39MB
- 12hr (Dec 19 04pm) 2.39MB
- 15hr (Dec 19 07pm) 2.41MB
- 18hr (Dec 19 10pm) 2.42MB
- 21hr (Dec 20 01am) 2.42MB
- 24hr (Dec 20 04am) 2.43MB
- 27hr (Dec 20 07am) 2.43MB
- 30hr (Dec 20 10am) 2.41MB
- 33hr (Dec 20 01pm) 2.40MB
- Hours 0-12 (zip file) 9.59MB
- All Hours (zip file) 28.91MB

Temp,Sky,Wind,RH,HeatIx
-by Forecast Hour Info

- 00hr (Dec 19 04am) 5.02MB
- 03hr (Dec 19 07am) 5.02MB
- 06hr (Dec 19 10am) 5.02MB
- 09hr (Dec 19 01pm) 5.00MB
- 12hr (Dec 19 04pm) 5.01MB
- 15hr (Dec 19 07pm) 5.03MB
- 18hr (Dec 19 10pm) 5.04MB
- 21hr (Dec 20 01am) 5.04MB
- 24hr (Dec 20 04am) 5.04MB
- 27hr (Dec 20 07am) 5.03MB
- 30hr (Dec 20 10am) 5.02MB
- 33hr (Dec 20 01pm) 5.00MB
- Hours 0-12 (zip file) 20.06MB
- All Hours (zip file) 60.26MB

Transport Wind Point data
-by Forecast Hour Info

- 00hr (Dec 19) 2.26MB
- 03hr (Dec 19) 2.27MB
- 06hr (Dec 19) 2.26MB

Figure 8: Sample menu of available 2.5km GIS compatible digital forecast data

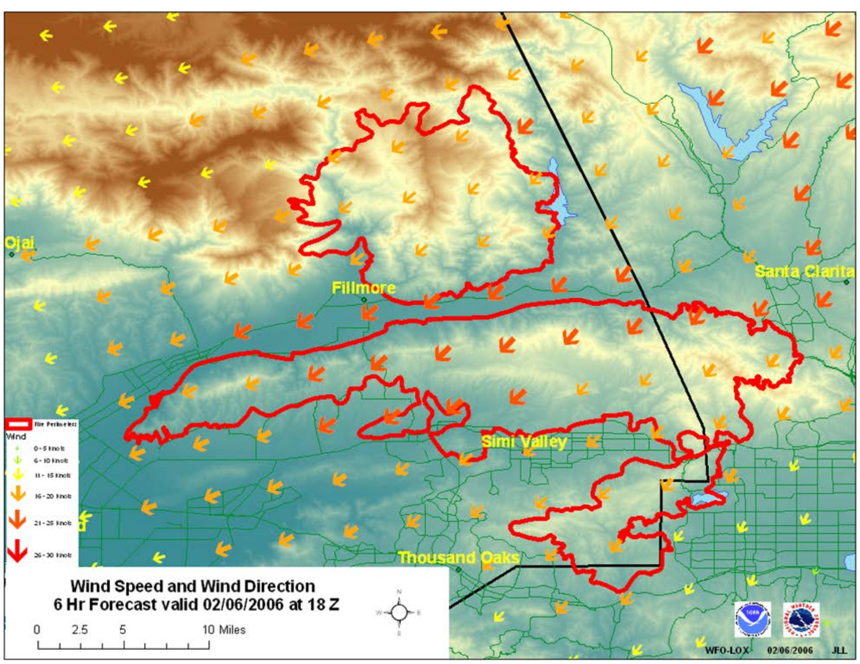
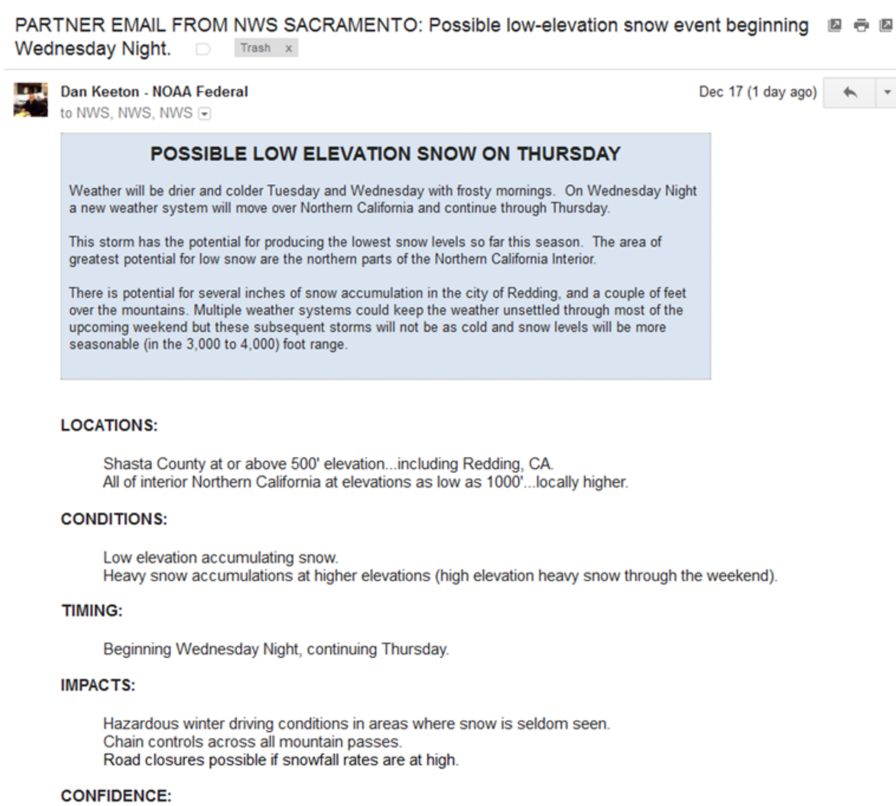


Figure 9: Sample GIS compatible digital forecast data overlaid on a GIS-based map including fire boundaries.

Figure 10: NWS briefing being provided at the FEMA JFO in Pasadena, CA in support of the FEMA/DHS-lead response to the devastating southern California wildfires of October 2007



PARTNER EMAIL FROM NWS SACRAMENTO: Possible low-elevation snow event beginning Wednesday Night. Trash x

Dan Keeton - NOAA Federal
to NWS, NWS, NWS

Dec 17 (1 day ago)

POSSIBLE LOW ELEVATION SNOW ON THURSDAY

Weather will be drier and colder Tuesday and Wednesday with frosty mornings. On Wednesday Night a new weather system will move over Northern California and continue through Thursday.

This storm has the potential for producing the lowest snow levels so far this season. The area of greatest potential for low snow are the northern parts of the Northern California Interior.

There is potential for several inches of snow accumulation in the city of Redding, and a couple of feet over the mountains. Multiple weather systems could keep the weather unsettled through most of the upcoming weekend but these subsequent storms will not be as cold and snow levels will be more seasonable (in the 3,000 to 4,000) foot range.

LOCATIONS:

Shasta County at or above 500' elevation...including Redding, CA.
All of interior Northern California at elevations as low as 1000'...locally higher.

CONDITIONS:

Low elevation accumulating snow.
Heavy snow accumulations at higher elevations (high elevation heavy snow through the weekend).

TIMING:

Beginning Wednesday Night, continuing Thursday.

IMPACTS:

Hazardous winter driving conditions in areas where snow is seldom seen.
Chain controls across all mountain passes.
Road closures possible if snowfall rates are at high.

CONFIDENCE:

Figure 11: Sample partner email about an upcoming weather event

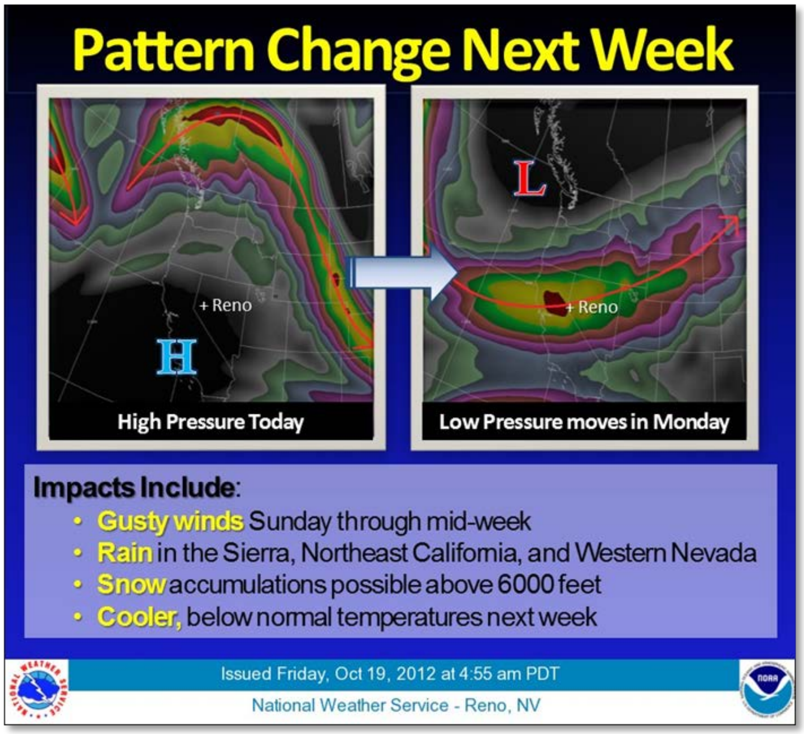


Figure 12: Sample Weather Story about an upcoming weather event

5. Conclusions:

Weather is obviously important to emergency managers, responders, Incident Commanders and planners. Unfortunately however, they don't always know how, when, where or why meteorological information and data needs to be applied during the urgency of response decision-making. Fortunately, the NWS is there to fill those support needs by providing the guidance and technology to put accurate and representative data into the hands of the decision-makers. Through the use of specially formatted new products, emergency response personnel can make much more informed decisions that incorporate such critical factors as spatial and temporal variability of weather over a region and time period of interest and speak to the expected impacts on the population at risk. Using digital databases, the NWS can push products known to be of benefit to the emergency responder community covering up to 12 parameters for up to 7 days with resolution down to 2.5 km.

When personnel availability permits, the NWS is also capable of sending Incident Meteorologists and Warning Coordination Meteorologists to on-site meetings, emergency operation centers, and scenes of disaster as appropriate. The NWS is committed to providing the best meteorological decision support services – second to none - for use in informed decision-making.

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