Lessons Learned from a HazMat Exercise
Weather Monitoring Aids Emergency Management

I. Introduction
Weather can be both a cause of disasters and a hazard in responding to them. Specific meteorological parameters impact emergency management, disaster response, and mitigation. An exercise by the State of Arizona Eastern Region illustrates how automatic weather monitoring technology can enhance preparedness and help mitigate adverse weather factors during a hazmat response.

II. Overview of the Arizona Exercise
The State of Arizona conducted a full-scale, mass-casualty exercise to test the Eastern Region's disaster mitigation capabilities including incident command, police, HazMat, communications, and decontamination. Participating agencies included the State of Arizona Division of Emergency Management, the Pinal County Office of Emergency Management, the Casa Grande Fire Department, and over 30 other agencies including emergency managers, medical teams, and fire departments wearing multiple hats.

Timing of the exercise took place on the heels of the Hurricane Katrina catastrophe, so there was considerable interest from FEMA, as well as state and federal legislators and dignitaries who attended the event.

The scenario consisted of an accident in central Casa Grande involving a large tanker truck carrying toxic chemicals. The simulated incident area was a major commercial route through the city, near several small businesses and a large residential area. Chemicals spilled from the tanker caused multiple human casualties at the scene. Casa Grande Fire Department was designated as first on-scene and therefore assumed Incident Command.

Participants were to meet at their respective staging areas at 6:00 a.m. with the exercise to commence at 7:30. Casa Grande's Incident Command Team arrived on the scene approximately 10 minutes after the simulated accident. Time delays were based on estimated response times to the site.

Western Fire, Inc., a contract fire operation with vehicle-mounted weather-monitoring capabilities, was designated as the weather coordinator for the exercise. Their job was to provide real-time weather data to Incident Command from two monitoring sites: 1) their vehicle-mounted weather station on their fire truck situated next to the Command Post and 2) a portable weather station (shown left) positioned near the accident, with a wireless data link to a laptop computer in the State of Arizona's new communications vehicle.

WeatherMaster™ Software was utilized to monitor current weather conditions, automatically log data readings, and provide an automated interface with CAMEO/ALOHA software for live plume modeling.

The Orion Nomad Portable Weather Station is deployed and operational in minutes.

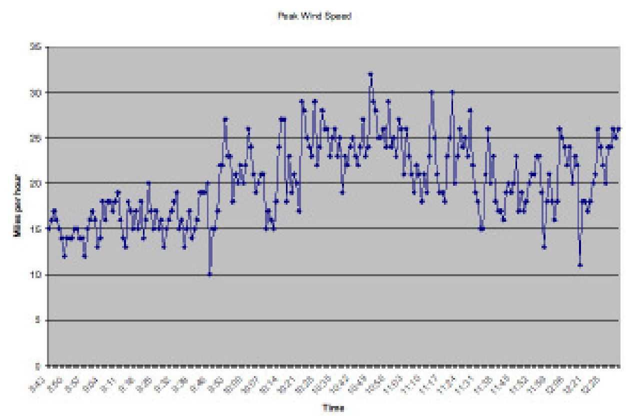
Western Fire was also tasked with providing electronic weather updates to the Pinal County Emergency Operations Center (located several miles from the incident) via the laptop computer utilizing the Communications Vehicle WIFI connection with the EOC. The portable weather station, using wireless telemetry, transmitted continuous live weather readings to four Incident site locations, keeping exercise players apprised of the changing weather conditions.

Weather conditions upon arrival: clear skies, unlimited visibility, temperature 61 °F, humidity 38%, and winds were NE (040-070° azimuth) at 7 to 12 mph. Weather conditions were recorded from 8:43 a.m. until the exercise's end at 12:34.

III. How Specific Meteorological Parameters Effect Disaster Response and Mitigation

A. Wind Direction and Wind Speed

Severe wind events such as hurricanes and tornadoes can be the cause of disasters. High winds can wreak havoc downing trees and power lines. Monitoring wind speed is especially important when operating equipment such as ladder trucks, cranes and cherry pickers.



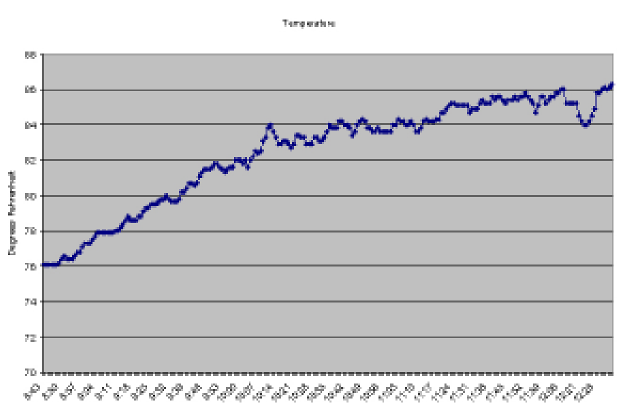
In a HazMat incident, wind speed and direction measurements are necessary to plot a toxic plume model with CAMEO/ALOHA software to help determine the scope of a contamination cloud, which affects how an accident/incident is staged and approached.

An Incident Commander's plan should always include setting up a command position upwind of the accident, then marshaling First Responders away from the contaminated corridor upon arrival. If staging, triage, and containment areas are subsequently required, these areas also should be located upwind and out of harm's way.

B. Temperature

Both high and low temperatures can cause emergencies. Cold temperatures bring on hazards ranging from road ice to blizzards. Less obvious are the hazards of warm weather which can lead to heat-related illnesses for incident crews, as well as the general public.

Temperature readings are crucial in analyzing chemical hazards, as well as managing resources.



When dealing with a chemical spill, it is important to know that different chemicals vaporize at different temperatures. Some vaporize instantly when they come in contact with air, but others vaporize at different ambient temperatures. For example, water vaporizes at 212 °F, whereas, phosphine or phosphorus hydride vaporizes at –88 °C. Also, the warmer the atmosphere, the more vapor the air can hold, intensifying a plume cloud.

When the Arizona exercise commenced, the temperature was 61 °F. It rose to a maximum of 86 °F by the end of operations. Temperature became a factor early on when at 9:44 a.m., it reached 81°F. This triggered Heat Condition 1 for a moderate workload, which meant 50 minutes of work and 10 minutes of rest (50/10 work/rest cycle). Firefighters in heavy protective clothing had to drink fluids and keep hydrated while taking sufficient breaks. This became a manpower issue when the temperature reached Heat Condition 3, 85.1°F, at which work/rest cycles became 30/30 at 11:22. By the end of the exercise at 12:30, the temperature reached 86.3°F and the work cycle was 25/35.

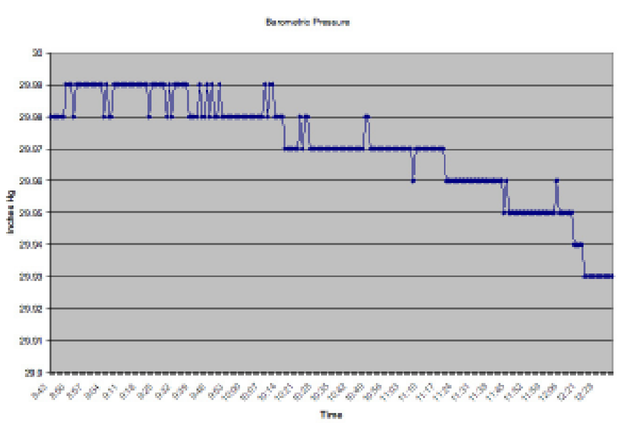
C. Relative Humidity readings indicate the percentage of moisture contained in the atmosphere with regard to 100 percent saturation. This moisture can become contaminated by toxic cloud vapor. Relative humidity measurements can help determine the density of a contaminated vapor cloud, or vapor pressure.

At the beginning of the exercise, relative humidity was 37%, and dropped to 21% by exercise end. This was not a real factor in the exercise, with the exception of responder dehydration.

D. Heat Stress Index is a calculated reading used in managing human resources – monitoring liquid intake and work/rest cycles. A combination of temperature, relative humidity, and wind speed, it provides an apparent temperature, or how hot the environment actually feels to the human body.

Normally humans perspire when the body becomes over-heated. Sweat forms on the skin and is evaporated away into the atmosphere, which is a cooling process. When humidity is high, the evaporation process is dramatically reduced due to the atmosphere's reduced ability to evaporate and absorb more moisture. To counter, the body sweats more to eliminate heat, which means liquid intake must be increased in order to prevent heat-related injuries such as heat exhaustion or heat stroke due to dehydration.

E. Dew Point Temperature indicates the temperature at which the atmosphere becomes totally saturated (100% humidity) and dew or fog may form. In a HazMat spill, when the environmental temperature reaches dew point temperature, toxic chemicals may be trapped in a low-lying saturated atmosphere causing hazardous conditions on the ground. It was not a factor in this exercise because of the arid desert conditions.



F. Barometric Pressure, a measure of air density, is a strong indicator of the upward and downward vertical air movement in the atmosphere. When pressure rises, the air aloft is inversely proportional and sinks downward. This creates higher pressure that often traps air particulates close to the surface. Consequently, if the pressure is falling, this means the air is rising upwards, allowing airborne particulates to rise and disperse into the atmosphere.

Barometric Pressure reflected stable conditions early in the exercise before dropping with the diurnal heating. As the wind conditions increased, the pressure became more unstable and dropped erratically.

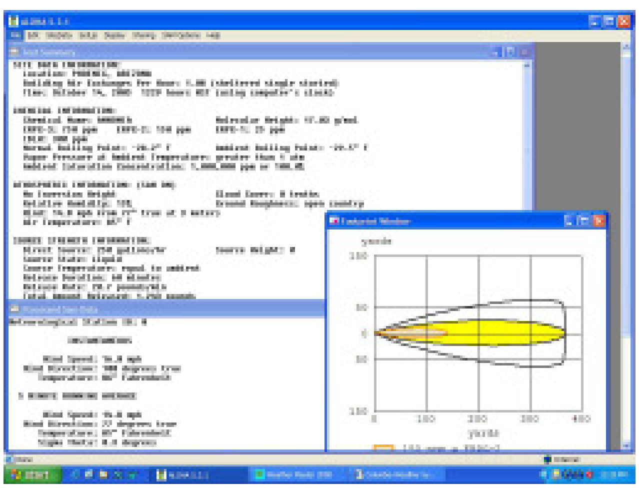
G. Rainfall washes chemicals and particulates out of the atmosphere, potentially contaminating the ground and/or ground water. It may also cause chemicals to pool and puddle creating hazardous conditions for First Responders.

Water also activates some chemicals such as phosphine which is highly toxic and can kill in relatively low concentrations. Commonly used for pest control and as a fumigating agent, it is often sold in the form of aluminum phosphide pellets, which yield phosphine gas on contact with atmospheric water. These pellets also contain other chemicals, including ammonia, which helps to reduce the potential for spontaneous ignition. If the pellets are inadvertently exposed to the elements, rainfall may cause the release of dangerous chemicals and gases into the atmosphere. There was no rainfall during the exercise.

IV. How Emergency Managers Can Optimize Their Investment in Weather Monitoring Technology
The steps below will help agencies be prepared to make the best use of their weather monitoring technology. Weather-related risks should be identified in the pre-planning stages and procedures set into place for weather station set-up and operation, data dissemination and operating under hazardous weather conditions, as well as coordinating resources with cooperative agencies.

A. Incorporate Weather Factors into Disaster Plans and Decision Aids
Upper-echelon policy makers should identify potential weather-related risks during pre-planning stages and incorporate weather data into disaster plans and decision aids. Commanders should be trained to factor weather conditions into decisions such as command site selection, approach, staging areas, and evacuation, as well as equipment and work/rest policies for crew safety. Policies should be established for operating under extreme or hazardous weather conditions.

1. Route of entry, staging and evacuation
Once Incident Command has been established with weather monitoring in place, weather information can help identify the approach route for arriving responders, help determine the type of mitigation plan, and provide an evacuation corridor for victims and evacuees. Operations should be staged from an upwind position. Dispatchers should be informed of the route of entry to the incident scene, which should be passed on to other responders. In initially staging a HazMat incident response, primary weather concerns are wind direction and speed.


CAMEO/ALOHA plume model

In spite of having live weather data during the Arizona exercise, one engine approached the tanker accident from a downwind position, which would've contaminated those assets and neutralized the responders, turning them into victims.

To create a chemical plume dispersion plot from a HazMat incident scene, site, elevation, and sun data are entered into CAMEO/ALOHA software, as well as the type, quantity, source, and character of the chemical spill. This plume model determines a toxic cloud's width and distance downwind.

However, CAMEO/ALOHA does not provide a preliminary dispersion plot and may take up to an hour to determine the downwind fallout area.

Weather software such as WeatherMaster™; offers vector wind and downwind projection plots which utilize current conditions to immediately project an initial plume corridor for evacuation of the potential contamination area and provide an entry corridor for first responders.

2. PPE - Responder Safety
Whether atmospheric conditions display heat or cold, knowledge of conditions allows for appropriate equipment choices and resource planning for the safety of the first responders.

HazMat suits do not allow for fresh air circulation and Personal Protective Equipment (PPE) can be extremely uncomfortable in extreme heat. Heat Exhaustion not only neutralizes the responder, it also diverts rescue personnel to attend to them. Automated weather monitoring provides alarm notification when user-defined thresholds are breached; alerting the need for initiating safety precaution action plans.

During high temperature conditions such as in Arizona, Heat Stress, Heat Exhaustion, and Heat Stroke are primary threats to emergency responders. Work/Rest cycles are established based on Heat Stress conditions. Under extreme Heat Stress conditions, first responders may work only 20 minutes per hour while drinking as much as two quarts of water to keep hydrated and sweating as much as 1½ to 2 quarts per hour.

Heat Related Work Rest Cycles

Wet Bulb[1] Globe Temperature (WBGT)	Heat Condition	Easy Work: Work/Rest[2] Cycle Acclimated	Easy Work: Work/Rest[2] Cycle Unacclimated	Easy Work: Water Intake Qt/hr[3]	Moderate Work: Work/Rest[2] Cycle Acclimated	Moderate Work: Work/Rest[2] Cycle Unacclimated	Moderate Work: Water Intake Qt/hr[3]	Hard Work: Work/Rest[2] Cycle Acclimated	Hard Work: Work/Rest[2] Cycle Unacclimated	Hard Work: Water Intake Qt/hr[3]
<77°F	0	60/0 Min		1/4	60/0 Min		1/4-1/2	60/0 Min		1/4-1/2
78°F		60/0 Min			60/0 Min	50/10 Min		40/20 Min		
79°F	1	60/0 Min		1/2	60/0 Min	50/10 Min	3/4	40/20 Min	30/30 Min	3/4
80°F		60/0 Min			60/0 Min	50/10 Min		35/25 Min	30/30 Min	
81°F		60/0 Min			50/10 Min			30/30 Min		
82°F		60/0 Min			45/15 Min	40/20 Min		30/30 Min		
83°F	2	60/0 Min		1/2	40/20 Min		3/4	25/35 Min		1
84°F		60/0 Min			35/25 Min			20/40 Min		
85°F		60/0 Min			30/30 Min			15/45 Min		
86°F	3	60/0 Min		3/4	30/30 Min		3/4	15/45 Min		1
87°F		45/15 Min			30/30 Min			15/45 Min		
88°F	4	35/25 Min		3/4	15/45 Min		3/4	15/45 Min	10/50 Min	1
89°F		30/30 Min			15/45 Min			15/45 Min	10/50 Min	
90°F		15/45 Min			15/45 Min	10/50 Min		10/50 Min	0/60 Min	
91°F		15/45 Min			15/45 Min	10/50 Min		10/50 Min	0/60 Min	
92°F	5	15/45 Min		1	15/45 Min	10/50 Min	1	10/50 Min	0/60 Min	1
93°F		15/45 Min			15/45 Min	10/50 Min[4]		10/50 Min[4]	0/60 Min	
94°F		15/45 Min	15/45 Min[4]		15/45 Min[4]	10/50 Min[4]		10/50 Min[4]	0/60 Min	
≥95°F		15/45 Min[4]	15/45 Min[4]		15/45 Min[4]	10/50 Min[4]		10/50 Min[4]	0/60 Min	

[1]Add **5°** WBGT to the above scale for heavy work clothing. Add **10° WBGT** for impermiable ensembles, restrictive clothing, or fire-fighting gear

[2]Rest describes minimal physical activity (ie. sitting, standing or resting; preferrably in the shade)

[3]Individual water requirements may vary by +/- 0.25 qt/hr.

[4]Mission Critical work only

[5]Heat Acclimation requires up to 3 weeks of continued physical activity under heat stress conditions similar to the anticipated work

Easy Work	Moderate Work	Hard Work
- Walking on hard surfaces with <30lb load	- Walking on hard surfaces with <30lb load	- Walking on hard surfaces with >40lb load
- Light physical excertion	- Walking on soft surfaces with no load	- Walking on soft surfaces with >20lb load
	- Medium physical excertion	- Heavy physical excertion

Source: Tinker Air Force Base, Public Safety

B. Designate Weather Coordinator

Prior to deployment, designate a team member to be the "weather coordinator." This person should be well trained in the weather station's set up procedures, operation, and integration with other programs. These responsibilities can be easily incorporated into training programs and deployment responsibilities.

In an Incident Response or HazMat team, the CAMEO/ALOHA software technician is a logical choice for designated weather coordinator because of their software expertise, system interoperability, and access to the Incident Commander and communication channels. In addition to incorporating weather data into the CAMEO/ALOHA software, the weather coordinator should be responsible for notifying the Incident Commander and emergency technicians of initial and changing weather conditions throughout the incident.

In a multi-agency exercise (or incident), this position is included in the chain of command to avoid duplication. In the Arizona exercise, this responsibility was assigned to Western Fire because of their resources and expertise.

C. Define weather monitoring capabilities

Ideally, each response team should have weather monitoring capabilities -- vehicle-mounted and/or portable. These capabilities should be defined and published so that any cooperative agencies will be aware of them.

In the event of a multiple-team incident response, the weather monitoring duties are assigned along the chain of command as with any other resource. Although the weather data was part of the Arizona exercise plan from the beginning, it was not fully utilized and coordination was a problem.

Because Casa Grande Fire Department did not have a weather monitoring capability prior to the exercise, they did not anticipate real-time weather information being provided at the scene. As “first on-scene” Incident Command that was a handicap to their effective leadership of the scenario.

While Arizona's new communications vehicle is equipped with wireless Internet capabilities and satellite communications, it did not have File Transmission Protocol (FTP) capabilities to send high-speed data to authorized Internet (IP) addresses. Therefore, instead of live data streaming to the Pinal County's EOC, they received data in the form of JPEG images and Excel data files every 15 minutes via email. In subsequent actions, this Internet connection can be automated to keep weather data continuously feeding to all emergency echelons.

In addition, the state's new communications vehicle did not have Global Positioning System (GPS) which would have provided accurate digital compass readings for wind direction measurements, as well as precise latitude/longitude coordinates and exact elevation to optimize CAMEO/ALOHA models.

D. Map the Data Dissemination Route

Procedures should to be in place to disseminate weather information during an incident – both up and down the chain of command, as well as to dispatch. All team members and upper echelon officers should be made aware of weather monitoring capabilities and reporting procedures.

In this day and age of information sharing, it is feasible to disseminate on-scene weather information to multiple agencies. Many mobile command vehicles now have satellite links, wireless Internet, and wireless Local Area/Wide Area Network (LAN/WAN) services. Real-time weather readings can be provided to all echelons of command, whether at the scene or not. Multiple on-scene agencies can receive official weather readings from a single weather station or coordinated network, rather than have multiple agencies with different weather stations providing potentially conflicting information. (The resulting confusion can cause misinformation leading to casualties.)

Weather data can be monitored via dedicated display consoles, computer software, or Internet websites. Periodic reports can be sent via email. Weather emergency notifications can be sent via email or pager.

As evidenced during the Arizona exercise, weather monitoring is crucial to the mitigation process and to the public’s safety. Arizona’s Incident Commanders should have had weather input operating procedures incorporated into their Incident Command Action Plans.

E. Practice/Training on weather monitoring equipment

Once weather monitoring capabilities are realized, it is critical that personnel become familiar with it – establish that equipment works properly, data is stored conveniently, and personnel know how to set it up and operate it.

This is simply a function of training and exercise. In addition to the weather coordinator, other team members should become familiar with the weather monitoring systems for redundant back up assistance and general understanding of how this resource fits with the overall operations.

Besides Western Fire, whose equipment was operational within minutes of arrival, several other players in the Arizona exercise had competitive brands of mobile weather stations. One team reportedly required 1.5 hours to set up their system and retrieve weather and plume modeling data. Another team never did get their station working during the exercise. In the case of a real incident, this would have diverted valuable manpower resources away from mitigating the accident and saving lives.

F. Coordinate and orient multiple data points (network)
While weather monitoring was built into the Arizona exercise plan, it did not translate into its implementation. There was no coordination of the weather monitoring resources available and no clear communication between sources of data, decision-makers, and team members.

Multiple weather readings at an incident can lead to conflicting information, especially if not all monitoring stations are set up and oriented properly. Not only is that a critical waste of valuable manpower, but it could become a serious safety issue.

One way to avoid confusion is to use network weather software. In the event of an incident or natural disaster that covers a significant geographic area, data from different weather stations positioned around the scene can be pooled together to provide complete meteorological coverage.

Automated, digital data transmission is an emerging technology that can free up critical manpower and provide multiple users with precise on-scene data. As fire departments and police operations team together to respond to an incident, weather monitoring becomes another tool in the array of available resources to be utilized and managed effectively.

V. Conclusion: Optimizing the Weather Monitoring Capability
The first Arizona statewide HazMat exercise was successful in terms of valuable lessons learned and field experience gained by working together as a team. Although anticipated in the planning stages, the weather monitoring component was not fully utilized. Had this been a real incident, casualties would have resulted from first responders entering the staging area through the contaminated corridor as well as being subject to heat illnesses in PPE under high temperature conditions.

The exercise highlighted the importance of weather monitoring for the safety of public and crew. Additional lessons learned include:

- keeping equipment operational and personnel trained how to operate it,
- incorporating weather factors into disaster plans and decision aids,
- making sure systems are in place (such as FTP and GPS) to optimize investment in automated weather monitoring equipment, and
- coordinating the use of the resource among cooperating teams and agencies.

About CWS
Columbia Weather Systems' goal is to help public service agencies leverage weather data to optimize resources and save lives. During the past decade, CWS has been at the forefront of innovation, utilizing cutting-edge technology to capture and communicate weather data wherever it is needed.

Today, hundreds of public service agencies rely on CWS weather stations to monitor and disseminate weather information to prepare for emergencies and help mitigate disasters.

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