Impact Planning Aids for Major Storms (IPAMS): A Homeland Defense Weather Disaster Decision Aid

Richard J. Szymber
Richard C. Shirkey
Army Research Laboratory
Computational and Information Sciences Directorate
Battlefield Environment Division
WSMR, NM
rszymber@arl.army.mil
Ph: (505) 678-0634
FAX: (505) 678-3385

Abstract

The U.S. Army Research Laboratory (ARL) has developed a "red-amber-green" mission planning aid for Army commanders to advise them when and where the environmental conditions currently exceed (or are forecast to exceed) levels of "marginal" or "severe" impact to their systems, operations, or personnel. This Integrated Weather Effects Decision Aid (IWEDA) is successfully deployed today with U.S. Army combat weather teams around the world for Command and Control (C2) Battle Command and Command, Control, Communication, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) mission planning applications. IWEDA will be extended to enable key government decision makers and planners to more directly and automatically anticipate and understand the critical impacts and deleterious effects caused by major storms, severe/adverse weather, and hurricanes that affect resources, infrastructure, transportation, property, safety, and lives. This extension will produce a "Impact Planning Aids for Major Storms" (IPAMS), resulting in a national concept of *"America… Staying Ahead of the Storm."*

1. INTRODUCTION

IWEDA[1] is a collection of rules with associated critical values for aiding the commander in selecting an appropriate platform, system, or sensor under given or forecast weather conditions. It provides qualitative weather impacts for platforms, weapon systems, and operations, including Soldier performance. Each system (Army, Air Force, Navy, Marines, and threat) has a list of relevant rules, which include red-amber-green (unfavorable-marginal-favorable) critical value thresholds for one or a combination of the environmental parameters that affect the system. These rules are currently extant in the Army's centralized rules database (CRDB)[2]. Criteria for the red-amber-green thresholds are given in table 1.

Table 1. Thresholds and criteria for IWEDA rules.

Impact	Criteria
Green (favorable)	Degradation < ~25% or normal effectiveness > ~75%
Amber (marginal)	Degradation = ~25% to 75% or effectiveness = ~75% to 25%
Red (unfavorable)	Degradation > ~75% or normal effectiveness < ~25%

Once the rules are compared with the weather, the results are displayed via a matrix of impacts versus. time and map overlays for the region of interest (see Figures 1 and 2, respectively). Weather data for the region of interest are supplied primarily via the Mesoscale Model version 5 (MM5)[3] or, in the near future, by the Weather Research and Forecasting (WRF) model[4]. The environmental impact rules, or critical values, for the various Army systems have been validated through the Training and Doctrine Command's organizations, field manuals and the National Ground and Intelligence Center. IWEDA rules, which interact with the weather database to determine impacts on the selected system(s), are determined from expert system concepts and are embodied in a computer database that has been tied to critical values. The critical values are defined, in a meteorological sense, as those values of weather factors that can significantly reduce the effectiveness, or prevent execution, of tactical operations and/or weapon systems. An example of such a rule would be "usage of TOW2 is not recommended for visibilities less than 3 km." In this example rule, a visibility of three kilometers (the critical value) has been coupled with a system (TOW2) resulting in a rule. We can further define this critical value, or range of values, as the point where the occurrence of a meteorological element causes a significant (moderate or severe) impact on a military operation, system, subsystem, or personnel.

Figure 1. IWEDA Weather Effects Matrix

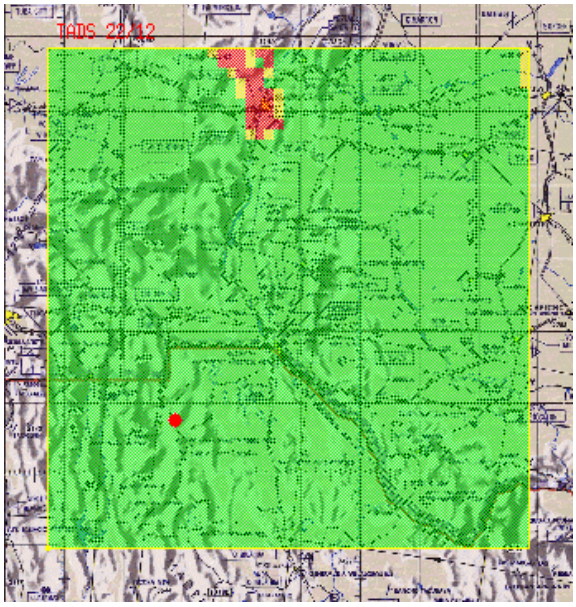

Figure 2. IWEDA map overlay for AH-64 TADS TV/DVO

We propose to extend this methodology into a new capability that can address a wide range of severe storm impacts useful to civilian emergency managers as well as to DoD installation commanders during periods of major storms. The Impact Planning Aids for Major Storms (IPAMS) will produce a dual-use, IWEDA-like Federal Government Joint Meteorological and Oceanographic (METOC) capability to specifically assess and support weather and marine disaster planning for military transportation and logistics, civilian transportation, Federal emergency planning and emergency response from national down to local command centers and related applications. The IPAMS technology will enable key government decision makers and planners to more easily anticipate and understand the critical impacts and deleterious effects caused by major storms, severe/adverse weather, and hurricanes as they threaten and impact resources, infrastructure, transportation, property, safety, and lives. IPAMS extends the former DoD "Owning the Weather" initiative developed by the ARL for Tri-Service weather applications to a national concept of *"America… Staying Ahead of the Storm."*

2. CONCEPT

The prototype test-bed system will be designed to support Homeland Security operations over the Continental United States (CONUS). IPAMS will augment the DoD Tri-Service IWEDA weather impact rules database with the impacts and warnings already identified in the Office of the Federal Coordinator for Meteorology (OFCM) Weather Information for Surface Transportation (WIST) initiative[5]. The WIST report presents a compilation of needs for weather information that have been expressed by existing and potential users of that information from the affected surface transportation communities. The transportation sectors considered were as follows:

- Roadways
- Long-haul railways
- Marine transportation systems
- Pipeline systems
- Rural and urban transit systems
- Airport ground operations.

These communities were asked the following questions:

1. Which specific weather elements (weather event or a condition) would affect their activities?
2. What information about those weather elements (spatial scale, thresholds of severity, etc.) would help to ameliorate negative consequences and exploit positive consequences?
3. When is the information needed (the lead time of forecasts or the currency of observations) to be most effective in supporting the decision processes?

Figure 3 presents the user-derived information needs that were compiled in the WIST Needs Templates and taken from that document for the subset of (Federal) highway operations. These templates, under the threshold column, contain the critical values at which a weather element affects a transportation activity or (in the case of multiple thresholds) affects it differently. This type of information is analogous to the existing IWEDA rules and can easily be incorporated into the CRDB. For example, assets (IWEDA systems, sub-systems, etc.) relate to the WIST topical headings (roadways, long-haul railways, pipeline systems, etc.). Further, looking at the first row in Figure 3, we have the meteorological conditions (in this case a severe storm cell), the critical values (≤ 20 miles), and the impact and its explanation (credibility of evacuation orders, etc.). The only remaining piece of work is to translate the action column into a red-amber-green flag. Finally, in most cases, the lead time can easily be met either by MM5, WRF or some other weather forecast model.

Weather Needs for Federal Highway Operations					
Weather Element	**Threshold**	**Forecast/Observation**	**Impacts**	**Action**	**Lead Time**
Severe Storm Cell Track—Location, Direction, Speed, Severity (proximity to route or operational area in miles, based on radar observation)	≤20 miles	Forecast and observation	Credibility of evacuation orders, loss of visibility, loss of traction, impaired mobility, lane obstruction/submersion, loss of life, property damage, loss of communications/ power, flood risk, road damage	Predict threatened area, develop warning and evacuation plans, issue evacuation orders, select treatment strategy. Mobilize maintenance personnel. Manage traffic flow (e.g., disseminate traveler information, vary speed limit, modify lane configuration, modify signal timing/ramp metering, close roadways and bridges, implement tire controls, restrict access to designated vehicle types). Operate outflow devices, remove debris, repair damage.	1-6 hours and current observation
Major Storms					
Blizzard—35 mph Sustained Winds, Visibility <1/4 mile, Blowing Snow (proximity to route or operational area in miles)	≤50 miles	Forecast and observation	Safety risks, loss of life, property damage, road damage, loss of visibility, loss of traction, impaired mobility, evacuation route delays, lane obstruction, loss of communications/power	Predict threatened area, disseminate warning information to operators and travelers, select treatment strategy. Suspend outdoor operations, implement evacuation plans, mobilize maintenance forces, repair damage.	48-96 hours and current observation
Hurricane Force Winds (wind speed in mph and proximity to route or operational area in miles)	≥74 mph, ≤50 miles	Forecast and observation	Safety risks, loss of life, loss of visibility, loss of traction, impaired mobility, evacuation route delays, lane obstruction/submersion, loss of communications/power, property damage, road damage	Predict threatened area, disseminate warning information to operators and travelers. Suspend outdoor operations, implement evacuation plans, mobilize maintenance forces, repair damage.	48-96 hours and current observation
Tropical Storm Force Winds (wind speed in mph and proximity to route or operational area in miles)	≥39 mph but <74 mph, ≤50 miles	Forecast and observation	Safety risk, potential loss of life, loss of visibility, loss of traction, impaired mobility, evacuation route delays, lane obstruction/submersion, loss of communications/ power, property damage, road damage	Predict threatened area, disseminate warning information to operators and travelers. Suspend outdoor operations, implement evacuation plans, mobilize maintenance forces, repair damage.	48-96 hours and current observation
Hurricane Storm Surge	Any	Forecast and observation	Safety risks, flood risk, loss of life, loss of traction, impaired mobility, evacuation route delays, lane obstruction/submersion, loss of communications/power, property damage, road damage	Predict threatened area, disseminate warning information to operators and travelers. Suspend outdoor operations, implement evacuation plans, mobilize maintenance forces, repair damage.	12-24 hours and current observation
General Weather/Environmental Parameters					
Air Temperature Including Maximum and Minimum (degrees F)	Variable, based on impact criteria	Forecast and observation	Air quality, loss of communications/power, precipitation type, pavement temperature, slope stability (avalanche risk), effects on snow removal/ice treatment operations	Advise operators, monitor surface moisture, modify operations.	12-24 hours and current observation
Air Temperature Relative to Freezing and Trend (degrees F and rising or falling trend)	Decrease to less than 32° or increase to exceed 32°, with moisture	Forecast	Precipitation type, pavement temperature, loss of communications/power, slope instability (avalanche risk), effects on snow removal/ice treatment operations, road damage	Disseminate early warning information to travelers and operators, monitor surface moisture, modify operations.	12-24 hours
Air Temperature (degrees F)	>85°	Forecast	Health and safety risks, engine/equipment heat stress	Advise operators, monitor personnel and equipment stress, take prescribed and precautionary measures.	6-12 hours
	>110°	Forecast	Severe and immediate health and safety danger to personnel and heat stress risk to equipment	Conduct immediate risk assesment, advise operators and supervisors to ensure continuous monitoring of personnel and equipment. Cease activities.	6-12 hours
Dew Point Temperature (degrees F)	Variable, based on temperature and impact criteria	Forecast and observation	Air quality, precipitation type, fog formation	Predict threatened area, select treatment strategy.	12-24 hours and current observation

Figure 3. WIST Needs Template for the subset of (Federal) highway operations.

Thus, we envision the IPAMS prototype system being tailored for civilian command centers that require oceanographic and meteorological data as inputs. Specific METOC observation data and high-resolution forecasts will be accessed from the National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) National Digital Forecast Database[6] (NDFD) to populate a four-dimensional environmental database. The IPAMS knowledge-based expert system will compares the environmental observations and forecast database to the critical value thresholds in its METOC impacts database. IPAMS will then display the favorable (green), moderate or marginal (amber), and severe or unfavorable (red) impacts as planning matrices for any selected location over time or spatially as a map overlay across regional areas at any specific time of interest (hypothetic examples are presented in Figures 4 and 5). These visualizations of adverse weather and major storm impacts will aid decision makers in planning and executing homeland defense and civil support missions for domestic weather disaster response and relief operations that occur during hurricanes, floods, and other environmental events. This system will ultimately support the hurricane season challenges, such as those experienced during the August 2005 Hurricane Katrina disaster, which was the costliest Atlantic hurricane in history, resulting in $84 billion in damage and causing over 1,835 fatalities. A simple example of how IPAMS could have been used here would have been to provide critical values for the wave height for the levees. Furthermore, the need for IPAMS becomes even more important as areas face increasing challenges. All the ingredients are in place for even more catastrophic hurricane events as more of the protective sand bars and beach barriers are

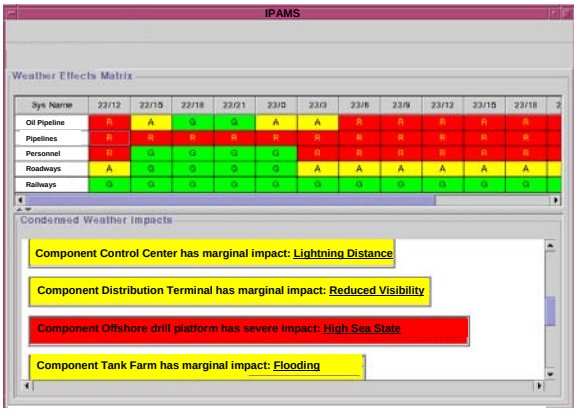

Figure 4. Hypothetical IPAMS Weather Effects Matrix

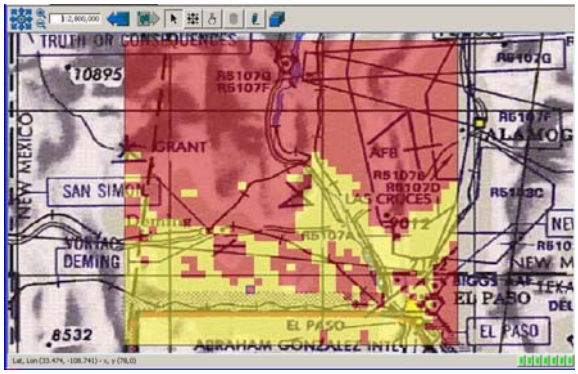

Figure 5. Hypothetical IPAMS map overlay.

destroyed/removed/altered from previous hurricanes, sea levels rise from melting polar ice due to global warming, and more people and infrastructure over-populate vulnerable coastlines.

Thus IPAMS ability to predict and assess weather impacts on the civilian and military local environment associated with severe weather-related natural disasters and emergencies will support major applications pertaining to the following areas:

- Military transportation, logistics, and resource protection
- Civilian transportation, logistics, and population safety
- Hurricanes, floods, and severe weather
- Weather hazards and marine safety.

The IPAMS system and technology will ultimately aid the Department of Homeland Security (DHS) in their planning for and response to major storm-related emergencies and disasters. IPAMS will improve the DHS capability in planning ahead for hazard mitigation to alleviate or eliminate risks to life and property from adverse weather hazard events such as the "Great Flood of 1993," the major flood that occurred in the American Midwest along the Mississippi and Missouri Rivers from April to October 1993, one of the most costliest and most devastating to have occurred in the United States, causing $15 billion in damages and 50 fatalities.

3. CONCLUSION

An automated decision aid and planning tool for major storm and adverse weather impacts over the CONUS is badly needed and could benefit the entire Nation and all Americans. Annually in the United States, major storms and adverse weather result in billions of dollars of damage and hundreds of deaths. Better preparation, response, and mitigation will save lives and property and reduce the economic costs of weather/storm-related impacts and disasters, potentially resulting in $700 million in savings per year. Furthermore, a dollar spent on mitigation saves society an average of $4, with positive benefit-cost ratios for all weather hazard types[7]. IPAMS will provide this type of capability to military and government planners and decision makers. At the core of this technological evolution has been ARL's development of the most extensive database of military METOC critical thresholds and impacts in the world. Now, with the inclusion of the OFCM WIST critical threshold values and impacts, and a newly developed database of thresholds and impacts for major storms and hurricanes and other weather-related natural disasters, IPAMS creates a capability that supports all military and civilian sectors across the United States.

REFERENCES:

1. Shirkey, R.C. and M. Gouveia, "Weather Impact Decision Aids: Software to Help Plan for Optimal Sensor and System Performance," *Crosstalk*, the Journal of Defense Software Engineering, v15 no. 12, pp 17-21, 2002.
2. https://gesportal.dod.mil/sites/crdb/ (access verified November 2006)
3. http://www.mmm.ucar.edu/mm5/ (access verified November 2006)
4. http://www.wrf-model.org/ (access verified November 2006).
5. http://www.ofcm.gov/wist_report/wist-report.htm (access verified November 2006)
6. http://www.weather.gov/ndfd/ (access verified November 2006)
7. United States Department of Commerce, National Oceanographic and Atmospheric Administration, Economic Statistics for NOAA, April 2006, Fifth Edition.