The Next Generation of Weather Impacts Decision Aids

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Abstract

The U.S. Army's second generation (GEN II) of weather decision aids includes MyWIDA (My Weather Impacts Decision Aid) and AIR (Automated Impacts Routing) applications and web services. Users may take advantage of the supplied applications or develop their own making use of the underlying web services.

MyWIDA is a rules-based expert system that can automatically identify and provide favorable, marginal, and unfavorable weather impacts on rotary and fixed wing aircraft. These impacts are presented in the form of a stop light chart overlaid on a map background and are based on operating limitations of those systems. A color-coded Weather Effects Matrix (WEM) can be queried to display detailed textual weather impacts statements/explanations for a specific location. The forecast weather information, available from numerous originating centers, is ingested through a meteorological gridded database which automatically drives MyWIDA.

AIR was designed to determine a least-cost path across multiple waypoints based on a 3D grid of adverse weather impacts. Additionally, AIR provides a mechanism to identify non-weather 3D volumes to avoid when calculating a path, thereby allowing identification of exclusion zones due to terrain, conflicting airspace, closed aviation corridors, or other user-defined conditions. AIR provides a highly-flexible and efficient route planning capability that is applicable to multiple domains, including both air and surface operations, and may be executed either as a standalone desktop application or deployed as a web service.

1. Introduction

Military operations and weapon systems are adversely affected to some extent by the environment, even those advertised as "all weather capable." The My Weather Impacts Decision Aid (MyWIDA) is the latest in a series of weather impact decision aids developed by the U.S. Army Research Laboratory (ARL) Computational and Information Science Directorate's Battlefield Environment Division. MyWIDA is a sophisticated, rules-based expert system based on thousands of identified (and validated) weather sensitivities of Army, Air Force, Navy and Marine Corps systems and tactical operations. MyWIDA's applications and underlying web services simplify the manner in which environmental impacts on military systems are determined. Multi-day weather forecasts are automatically ingested and compared with system rules subsequently identifying and providing favorable, marginal, and unfavorable weather-effects impacts in the form of a stop light chart overlaid on a map background. This impact information aids mission planners and commanders in making informed command and control decisions regarding the allocation or use of weapon systems as a function of weather conditions.

Each system, or asset, 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 Centralized Rules Data Base (CRDB) (Szymber 2008). MyWIDA's rules may also be tailored to specific missions or tactical operations thereby providing detailed weather impacts information in terms of what operations and equipment are affected, as well as when, where, and why they are affected. Criteria for the red-amber-green thresholds are given in table 1. Within the civilian community, impacts and warnings have been identified by the Office of the Federal Coordinator for Meteorology (OFCM) in their Weather Information for Surface Transportation (WIST) initiative (OFCM 2002).

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%

MyWIDA also includes the Automated Impacts Routing (AIR) application (Johnson 2011) which, for adverse weather, obstacles and no-fly zones, calculates least cost paths for user-selected aircraft or ground vehicles given a set of two or more waypoints. AIR can ingest impacts from MyWIDA or other applications.

2. Operation

MyWIDA is comprised of a collection of web services and applications. The applications are available in either HTML or Adobe® Flash®; the web services are defined by interfaces described in the Web Services Description Language (WSDL). Once the application retrieves the information about the user-selected area of interest (AOI), forecast and layers from the web services, the user selects assets of interest (upper left quadrant, figure 1). The impact calculations are then performed for the specified assets, forecasts, and layers. Once the calculations have been completed the impacts are displayed in the WEM section of the display (lower left quadrant figure 1). For each asset and forecast period, the WEM will display the highest impact level found *across the complete forecast model AOI and among all the selected layers*.

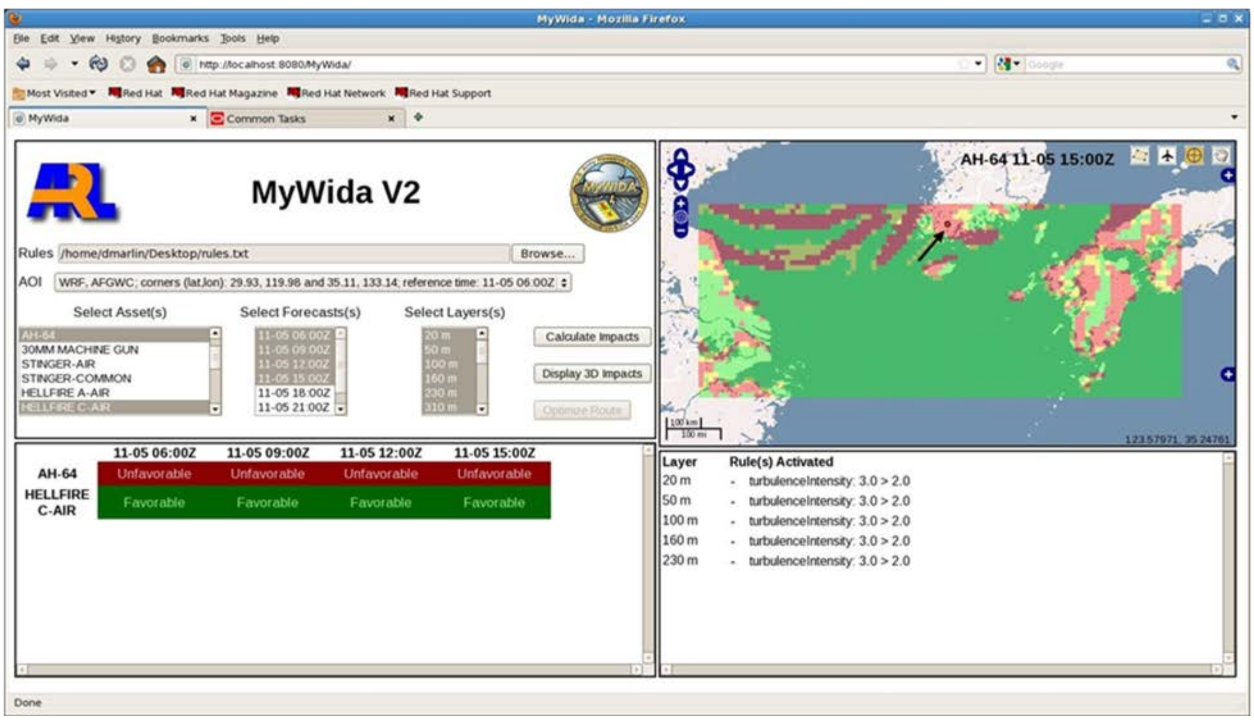

Figure 1 – The MyWIDA display (HTML version). The information section in the lower right displays the impacts by layer for the selected map location, as indicated by the small red circle (denoted by the inserted arrow) near the upper central portion of the map.

Clicking on a cell in the WEM brings up the queried system's impacts overlaid on a map of the AOI (upper right quadrant, figure 1). In turn, any point on the map can be interrogated to determine what weather impacts were invoked for the systems/assets selected (lower right quadrant, figure 1).

Weather data for the region of interest are supplied primarily via the Global Forecast System (GFS) or the Weather Research and Forecasting (WRF) model.

3. Automated Impacts Routing (AIR)

Atmospheric impacts on platforms and alternative routing options which consider environmental factors along a planned path of movement are of high importance during combat operations. Such options serve to improve survivability and movement efficiency of air and ground platforms and systems. Environmental factors which may adversely affect systems during combat operations along a projected path include adverse weather, threat activity, conflicting friendly operations, and other obstacles. ARL has developed the AIR application, which calculates optimized routes in 3D space, avoiding adverse atmospheric conditions and other obstacles during mission execution.

AIR's design allows it to be applied to both air and ground routing applications by its use of 4D data grids (3D grids over time) of "impacts." The impacts data may be areas of adverse weather or other environmental parameters that may be used to identify areas to be avoided by an air or ground platform. AIR has been developed as both a web service and as a standalone desktop computer application.

4. Impact Planning Aids for Major Storms Concept

MyWIDA's methodology can easily be expanded into a new capability that addresses 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, MyWIDA-like Federal Government Joint Meteorological and Oceanographic (METOC) capability to specifically assess and support weather and marine disaster planning for civilian transportation and logistics for 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 will augment MyWIDA's weather impact rules database by including the impacts and warnings already identified in OFCM's WIST initiative. 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?

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)	>95°	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 assessment, 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 2. WIST Needs Template for the subset of (Federal) highway operations.

Figure 2 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 MyWIDA rules and can easily be incorporated into the CRDB. For example, military assets (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 2, 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 GFS, WRF or some other weather forecast model.

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's (NWS) National Digital Forecast Database (NDFD) (NWS 2012) to populate a four-dimensional environmental database. The IPAMS knowledge-based expert system will compare 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. 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 recent hurricane Sandy disaster, resulting in over $60 billion in damage and causing over 100 fatalities. A simple example of how IPAMS could have been used here would have been to advise operators and managers to assess the safety of truck freight/cargo operators of the increased risk of collisions/spills of hazardous cargo with the need to delay, postpone, reschedule, or reroute as appropriate. 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 destroyed/removed/altered from previous hurricanes, sea levels rise from melting polar ice 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 costliest and most devastating to have occurred in the United States, causing $15 billion in damages and 50 fatalities.

5. 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 millions 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 (U. S. Department of Commerce 2006). 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.

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