WEATHER DATA VISUALIZATION - DECISION AID TOOLS FOR ARMY C4I

Donald W. Hoock [1] *

and

John C. Giever [2]

[1] U.S. Army Research Laboratory, Information Science and
Technology Directorate, Battlefield Environment Division
White Sands Missile Range, NM 88002-5501
(505) 678-5430; (DSN 258-); FAX: (505) 678-3385
E-MAIL: dhoock@arl.mil

[2] Physical Science Laboratory,
New Mexico State University
Las Cruces, NM 88003-0002
(505) 678-3280; (DSN 258-); FAX: (505) 678-3385
E-MAIL: jgiever@psl.nmsu.edu

ABSTRACT

The Integrated Meteorological System (IMETS) is the Army's battlefield C4I tactical weather system. It produces mesoscale forecasts, weather warnings and a complete 3-D Gridded Meteorological Data Base (GMDB) populated from Air Force MM5, Navy NOGAPS and Army BFM forecast models. From these data a variety of decision aid products are generated on the IMETS Weather Effects Workstation (WEW) to inform commanders of weather impacts on battlefield systems for mission planning and execution. Current visualization tools provide 2-D weather data and impact overlays that can be displayed on Army Tactical Command and Control System (ATCCS) displays using the Joint Mapping Toolkit (JMTK). In addition, the 60+ variables in the GMDB are viewable on the WEW display using the interactive Vis5D viewer. In this paper we show various visualization capabilities being explored as potential new planning decision aids. These include route displays in Vis5D for showing weather data along a 3-D path, a tactical "weather feature" for the Common Tactical Picture (CTP), and automating data ingest to the flight weather briefings. In addition, the future use of common visualization tools across the ATCCS and in particular with the Corps of Engineers terrain analysis systems, will allow weather to be better integrated into terrain and mobility decision aids. We also discuss some of the technology improvements that we expect the IMETS will evolve to as the Army tactical weather systems are made lighter and more versatile, with tailored weather applications executed or displayed on fully distributed C4I system displays at different echelons.

OBJECTIVE

With recent history and projected future requirements in mind, the U. S. Army has begun to implement a new vision for a "full spectrum" combat force. Focussing on highly flexible "Brigade and Below" force structures, the new Combat Brigades will be better able to participate not only in a conventional Major Theater War (MTW), but also in regional Stability and Security Operations (SASO). Rapid response, reduced logistics, and on-scene planning with reach back to division and above assets, will optimize the capabilities for successful employment in Small Scale Contingency Operations (SSCO), particularly in complex and urban terrain, and for confronting low-end and mid-range threats that may employ both conventional and asymmetric capabilities. Upcoming changes will impact both materiel acquisition and Army doctrine, including Brigade Combat Team (BCT) Weather Support functions.

Figure 1. Evolution of IMETS and the Weather Effects Workstation (WEW) to smaller processors.

The purpose of this paper is to begin to look at some of the various weather information and decision aid products that may be appropriate as extensions to the current Integrated Meteorological System (IMETS). The IMETS is the Army's tactical meteorological forecast and weather-effects decision aid system, currently fielded into Command and Control functions at "Division and Above" Tactical Operations Centers (TOC's), and into certain aviation brigades. In the next section we briefly outline the current capabilities of the IMETS system and the planned concepts for future lighter, smaller IMETS as shown in Fig. 1. The succeeding sections then look at various types of data visualization products that can be implemented in the near term to provide weather planning and 'nowcast' support to individual soldiers, squads, companies, battalions and brigades. These proposed products generally have no formal written requirements identified as yet, but they do build on many of the new requirements-driven capabilities that we are implementing this year for weather C4I into the Army's First Digitized Division.

The final sections explore the use of "3-D" or stereo-visualization approaches to pack more information into "2-D" image products for remote sensing and weather forecast decision aids. The practical justification for this research is that the display of 2-D image products is less demanding on the individual soldier in the field, who is now identified as a legitimate end user of weather information, than are manually-interactive, virtual 3-D visualization displays.

Therefore, for this paper and the symposium presentation we have chosen an "anaglyph" (red-blue "3-D glasses") format for these figures, although other stereo projection and observation formats are possible. This turned out to be not only interesting and rewarding, but also as a "fun" exercise to liven up a technical presentation on the last afternoon of a long conference. It does require, however, that the reader of the paper obtain a pair of "red-left, blue-right" cellophane "glasses" to view a few of the figures. Sources are readily available on the internet. Attendees of the presentation will be provided inexpensive, cardboard versions to take home.

OVERVIEW OF CURRENT IMETS

The IMETS is developed and fielded through the Army's PD-IMETS office under the PM-INTEL FUSION and PEO-C3S. R&D for IMETS' numerical weather prediction models, the information databases, and the weather impact Tactical Decision Aids (TDA's) is provided by the Army Research Laboratory. New applications are implemented by the Physical Science Laboratory of New Mexico State University under an ARL contract, and are then integrated into the Army's Battlefield Command System (ABCS) by Logicon Advanced Technologies, a PD-IMETS contractor. The goal of the latest IMETS releases is to provide the many C4I Battlefield Functional Areas (BFA's) across all the Army Tactical Command and Control Systems (ATCCS) with access to IMETS forecast and weather effects decision aids. And, IMETS workstations provide the Army's Combat Weather Teams, manned by Air Force Officers, with decision making tools that include IMETS-generated products and specially tailored weather information products transmitted via satellite to IMETS in the field from centralized Air Force Weather hubs.

Figure 2 shows a schematic of the basic components of the IMETS. The subject of this talk are products derived from software tools and models on the Weather Effects Workstation

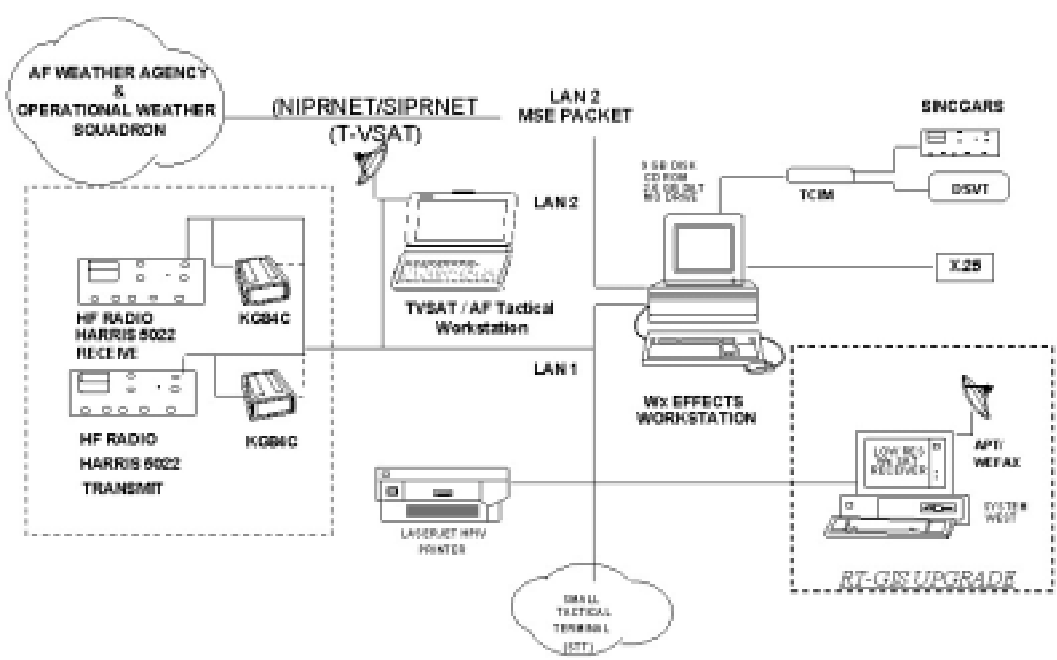

Figure 2. Schematic of IMETS work stations

(WEW). These systems are fielded in battlefield TOC's ranging from Echelons above Corps (EAC) down to Division level, and to certain Aviation Brigades. The "top-down" flow of regional forecasts arrives via the commercial Tactical Very Small Aperture Terminal (T-VSAT). These meteorological data grids originate from Navy Operational Global Atmospheric Prediction System (NOGAPS) model runs at 1 degree spacing and from Air Force Meteorological Model 5 (MM5) mesoscale meteorological forecasts at 45 km (and potentially on 15 and 5 km horizontal grids in future). The T-VSAT also provides current surface observations and vertical profile observations from around the world. As shown in Fig. 3, these data can be refined on the WEW using the Army Battlescale Forecast Model (BFM).

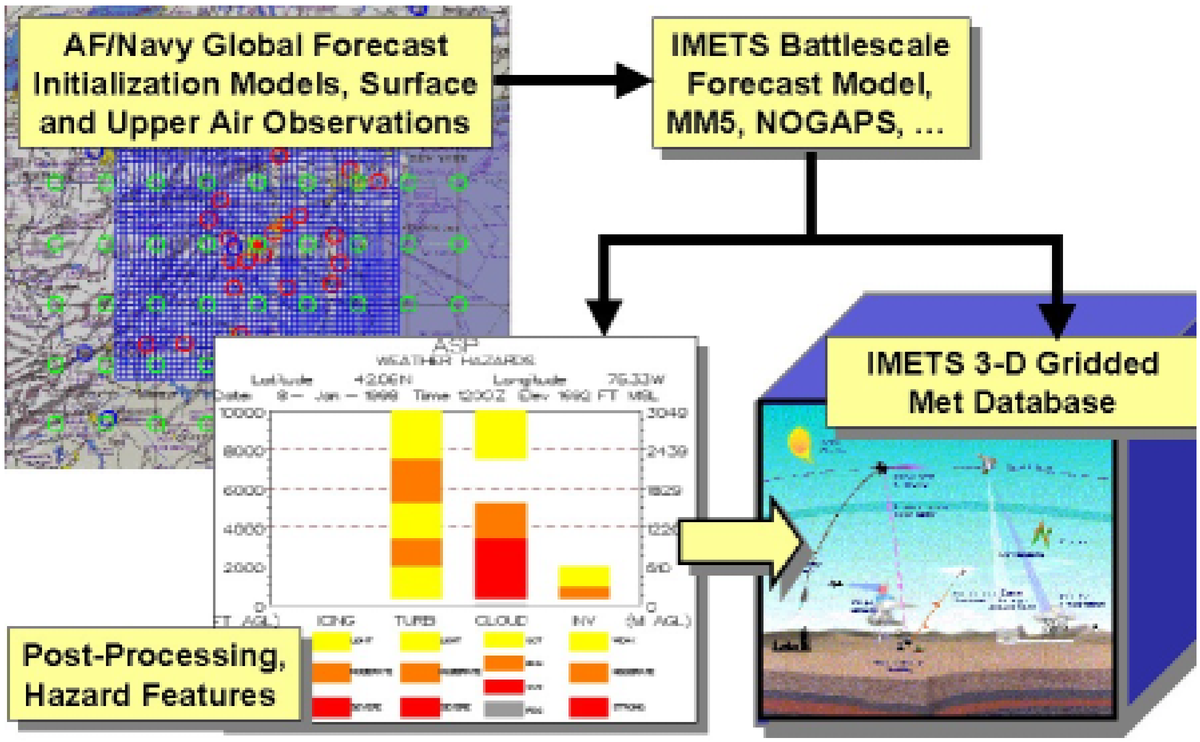

Figure 3. WEW weather forecast processing steps

BFM produces a detailed, terrain-coupled forecast at 10 km spacing (potentially down to 2 km), providing basic meteorological data from very near the ground up to 7 km in a terrain-conforming grid system. The current version of BFM for the Army's First Digitized Division produces a 24-hour forecast. While the BFM can run by itself with just local surface and vertical profile observations (providing only a local 3 to 12 hour forecast in those cases), normally it also initializes on the NOGAPS or MM5 forecast grid data. Then, because BFM is designed to "nudge" the forecast to always reproduce the NOGAPS or MM5 forecast at their input data grid locations, BFM will normally always do at least as well as those model forecasts. Numerous studies of the BFM have been made, including results presented at this conference (Haines, 2000; Henmi, 2000). The MM5 and NOGAPS forecasts are longer range, extending out to 36 and 96 hours respectively.

The data from NOGAPS, MM5 and BFM are stored as three-dimensional arrays in a Gridded Meteorological Database (GMDB). In addition, a number of weather features and

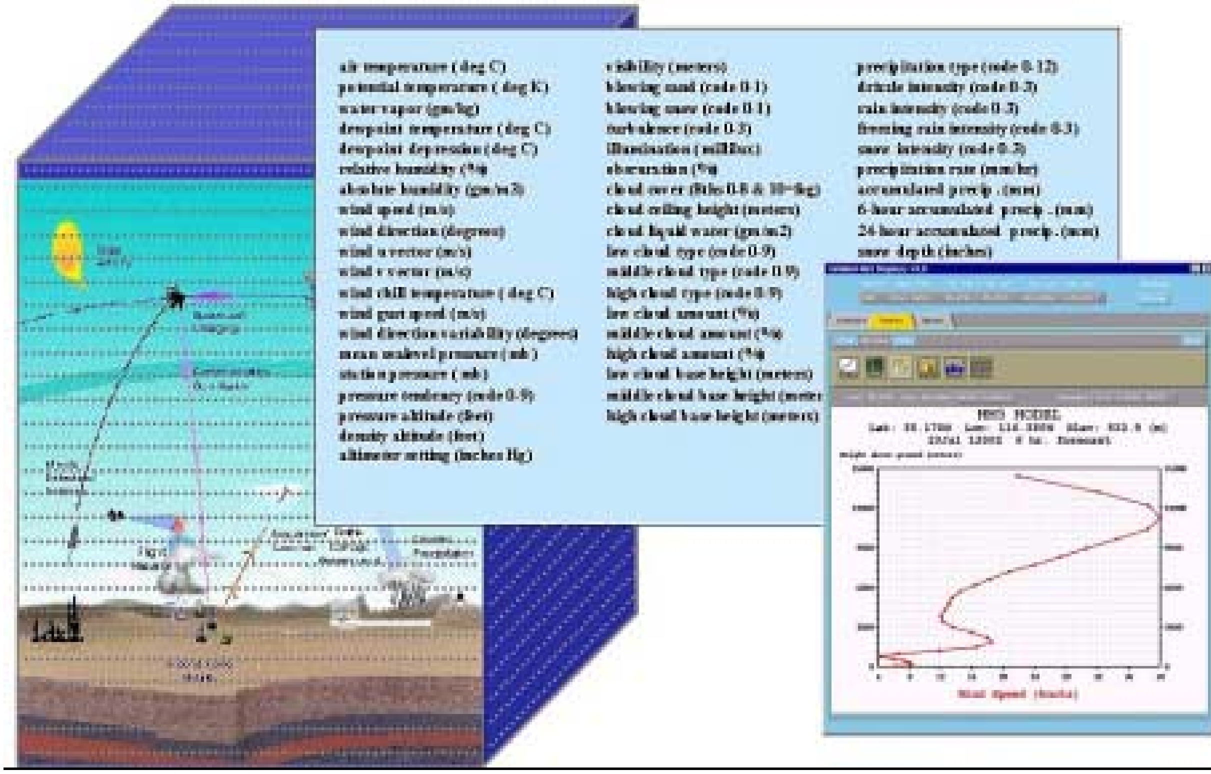

Figure 4. The IMETS Gridded Meteorological Database (GMDB)

weather hazard parameters are post-processed from the gridded forecasts in the Atmospheric Sounding Program (ASP) (Passner, 1999). These fill out the GMDB to a set of more than 60 variables as shown in Fig. 4.

The other products from the IMETS system are information and decision aid tools, and limited remote sensing products that will be expanded in the future. Some of these tools are for use by the Air Force Combat Weather meteorologists who operate the IMETS. These include skew T-log P charts, plots of profiles from the GMDB, thermodynamic parameters and input observation profiles (as in Fig. 5). The IMETS also provides various meteorological data editors, etc.

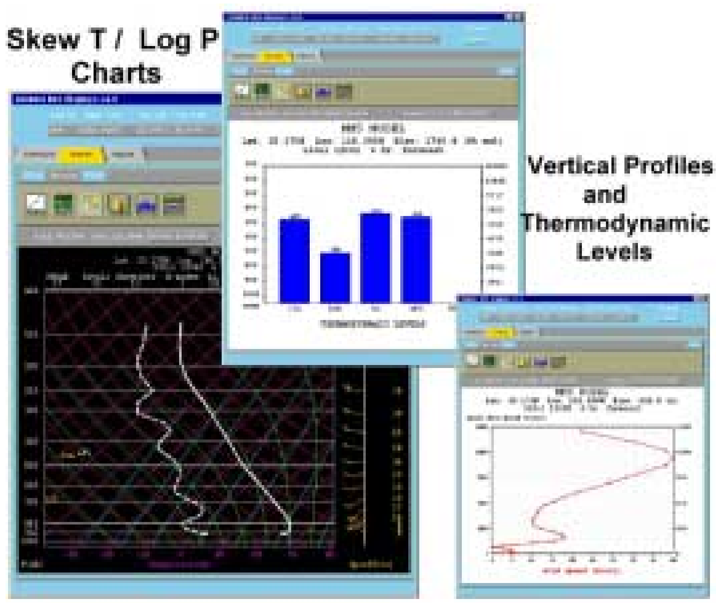

Figure 5. Some of the IMETS forecaster tools

The weather data are accessible by the various command and control functional area workstations in the TOC.

GMDB meteorological data can be displayed as overlays on common Army maps of the Joint Mapping Toolkit on these systems. Figure 6 shows an example overlay displaying a 2-D plan views of meteorological data. These overlays can include line and area contours, wind streams, etc.

The Integrated Weather Effects Decision Aid (IWEDA) produces red- amber- green weather impact warnings for many military systems and operations. The impact "rules", along with the critical value thresholds that trigger moderate or severe impact warnings can be modified for particular applications (Hoock, Torres and Sauter, 1998a) using the IMETS DIRECT weather impact editor. An example is shown in Fig. 6.

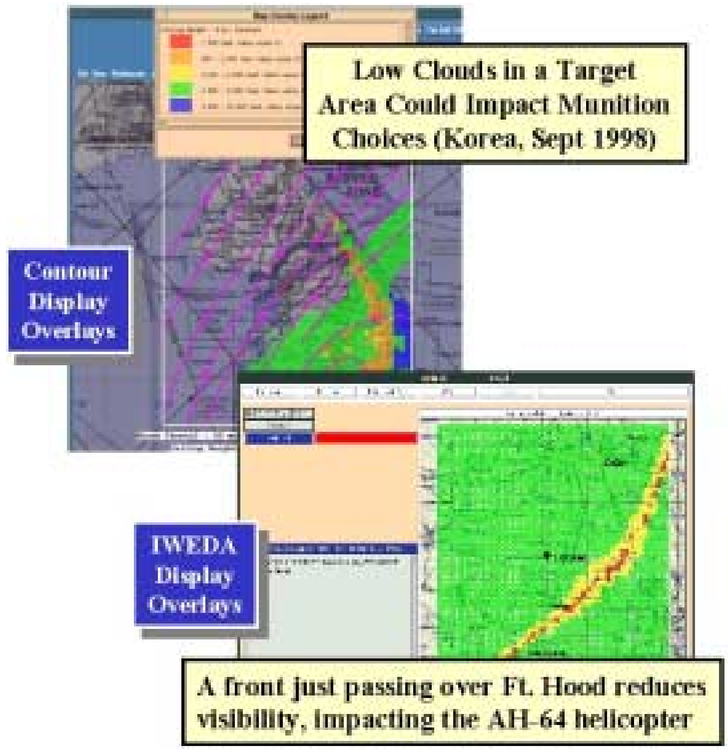

Figure 6. Weather and IWEDA overlays

Currently only simple met-sat images and loops are produced on the IMETS. As shown in Fig. 7, the analyst can annotate images and post them to an IMETS web page on the TOC network. In future the metsat data processing and product capability will be enhanced to include a number of products. These will show current clouds, precipitation, state of ground, temperatures and vegetation index. They will also provide derived quantities to support forecast and TDA model inputs, such as surface albedo and derived visibilities or aerosol events such as blowing dust. Examples of some of these products are shown in Fig. 8. An Air Force Small Tactical terminal (STT) will feed an IMETS met-sat workstation (shown in Fig. 2 as a RT-GIS upgrade to current low-res System West WEFAX.) This will make IMETS environmental processing consistent with the RT-GIS capability currently used by the Corps of Engineers on the C4I Digital Terrain Support System (DTSS).

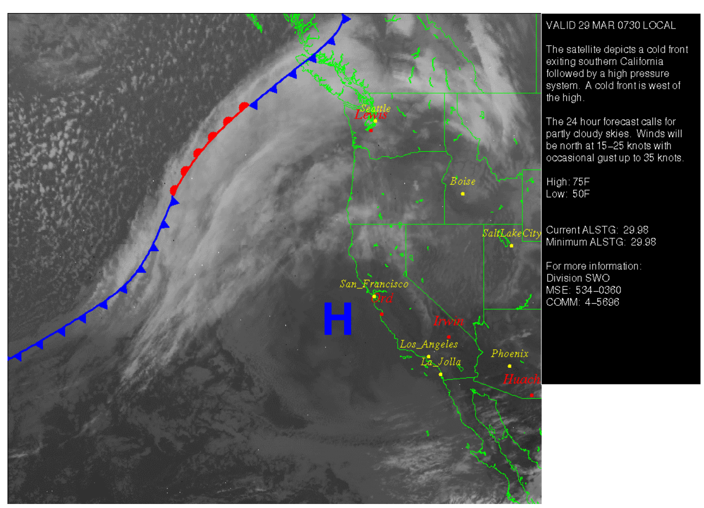

Figure 7. IMETS Homepage - annotated image

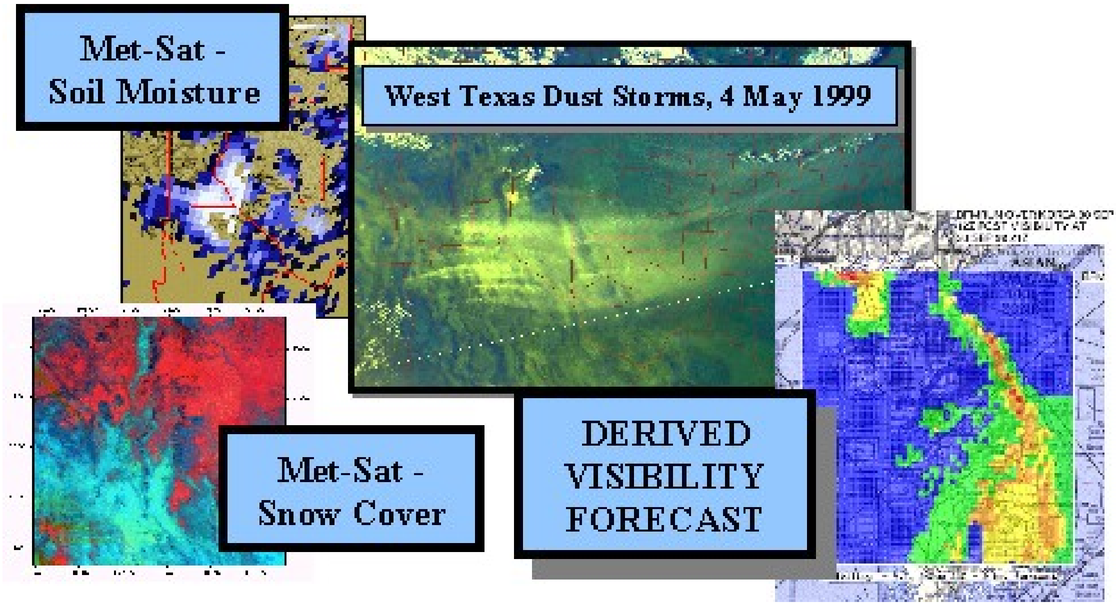

Figure 8. Future metsat derived products

Finally, the manually interactive Vis5D viewer is used on the WEW to browse and display any of the data in the 3-D Gridded Meteorological Database (GMDB). Outputs, such as those shown in Fig. 9, can be viewed on the WEW or posted to the IMETS tactical web page by the IMETS operator. While it is possible for external X-windows compatible work-stations or emulators to do a UNIX rlogin to the IMETS and to execute Vis5D, in practice this process is data intensive and slow. Furthermore, Vis5D is not an Army DII/COE graphics standard, unlike other IMETS 2-D overlays.

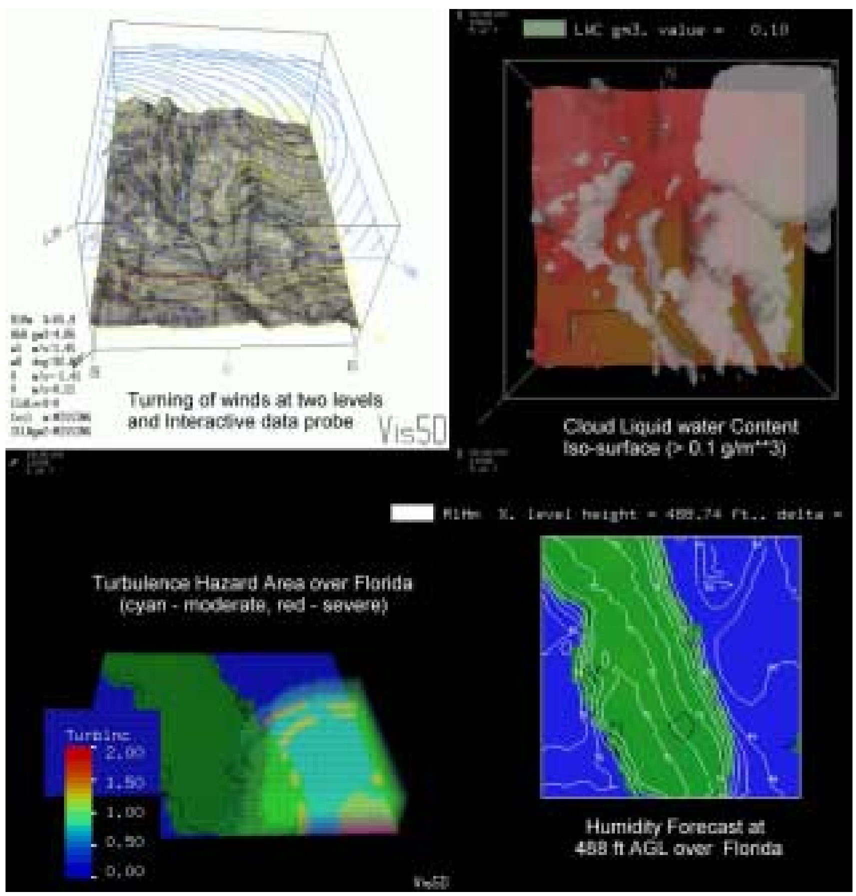

Figure 9. Standard Vis5D Viewer on IMETS

RESEARCH ACCOMPLISHED

The capabilities summarized above currently provide an excellent basis for weather intelligence at division echelons and above. Until recently, conventional assumptions for weather C4I have been that: (1) Mission planning will occur mainly at division and above. (2) Planning will focus on time frames of 24 to 96 hours; and (3) Global forecasts augmented by available surface observations, and vertical profile observations will be the main input data for forecasts over otherwise data-denied and data-sparse tactical areas.

While these assumptions and rationale will probably continue to be valid for Major Theater Wars, the new Army Vision calls for more mobile Combat Brigades. Organic data collection and mission planning may demand 20 minute decision cycles and focus on immediate objectives 3 to 6 hours in the future. Furthermore, the traditional expectation that the tactical battlefield will be data sparse may be too restrictive. Access to a variety of robotic, aerial, remote and personnel sensors for direct and inferred met observations is likely to become feasible soon. Thus, the new focus for weather products may be products developed for or at the lower echelons, perhaps down to individual soldiers, whose physiological and environmental state information may itself become available from a web of linked sensors.

The latest IMETS Operational Requirements Document recognizes an objective goal to ingest these non-conventional met observations and process them in near real-time. These will include vehicle and UAV mounted data that are neither conventional surface met observations, nor vertical profiles; incomplete meteorological data sets that include only some parameters but not others, and data taken at irregular times. Certainly a variety of remote imaging sensors from ground to space, active radars and passive radiometers observe environmental data, and one goal will be to make use of this information. And even anecdotal reports such as “It’s beginning to rain where we are” should also be considered as valuable, but perishable nowcast information. All this needs to be merged into a conceptual 4-dimensional database of arrays of meteorological and weather effects parameters, tailored unit or operation weather forecasts, weather warnings, performance impacts and inputs needed for CB defense and other models.

WEATHER REQUIREMENTS OF THE INITIAL / INTERIM COMBAT BRIGADES

Brigade Combat Teams (BCT) in excess of 3,000 personnel will probably be expected to conduct sustained, autonomous combat operations for up to 240 hours in an initial Area of Operations (AO) of 50 x 50 km, expandable up to 100 x 100 km. While it will rely heavily on “reach-back” to division TOC’s or centralized information hubs, the BCT will have a need for local decision making and generation of locally-tailored intelligence products by on-site personnel. Inside the decision making process loop at the BCT-level, combat weather personnel will recommend alternative ingress, egress, or courses of action to exploit weather intelligence as a force multiplier.

The need for quantitative nowcasts that are as consistent with ground truth as possible (and able to easily adjust to known ground truth) seems to be emerging. But the Army is just beginning a process to define weather requirements for the Initial (1-2 years), Interim (3-5 years) and Objective (10-15 years) Full Spectrum force. Some of the minimum meteorologically-driven information requirements being identified for the various company and battalion functions within the initial BCT are listed, for example, in Table 1. New technological capabilities will need to be developed to meet the spatial and time resolutions associated with this list. New weather products for route planning are particularly needed.

Table 1. Draft minimum weather requirements considered by TRADOC for BCT	
1. Onsite weather briefing capabilities	13. Cloud cover amount / height
2. Pre-deployment weather forecasts	14. Density and humidity profiles
3. NBC effective downwind messages	15. Illumination (Light, NVG)
4. Resource protection/weather warnings	16. Precipitation, rain/snow/thunderstorms
5. High-resolution metsat imagery updates	17. Temperature profiles
6. Weather Products for ABCS BFA's	18. Visibility and Tgt Acq/Lock-on ranges
7. Space weather effects on comms	19. Surface winds and upper air profiles
8. Weather inputs to trafficability	20. Icing and turbulence hazards
9. Thermal stress indices for personnel	21. Cloud free line-of-sight forecasts
10. UAV mission following/METwatch for dynamic tasking and alternative ingress/egress	22. Automated surface observations from/for UAV launch site. Take-off and recovery forecasts
11. Medevac helicopter weather forecasts	23. UAV "pilot report" weather ingest
12. Back-brief forecasts for APOE/SPOE and enroute air and sea operations	24. Radar propagation forecasts

WEATHER OVERLAYS AND GMDB DISTRIBUTION

Figure 10 shows the current "top down" flow of mesoscale MM5 and NOGAPS data, Air Force weather information products, and low resolution metsat images from the Air Force central weather hubs. The IMETS processes these data and makes the weather forecasts and weather impact data available from the Gridded Met Database (GMDB) on the local Tactical Operations Center (TOC) network. As part of the current Army Battle Command System (ABCS 6.x), ARL and PSL have developed the Weather Overlay Provider and its interface to the Joint Mapping Toolkit (JMTK). This allows the other BFA's in the TOC to display weather contours and red-amber-green impacts over their own data on their common map displays.

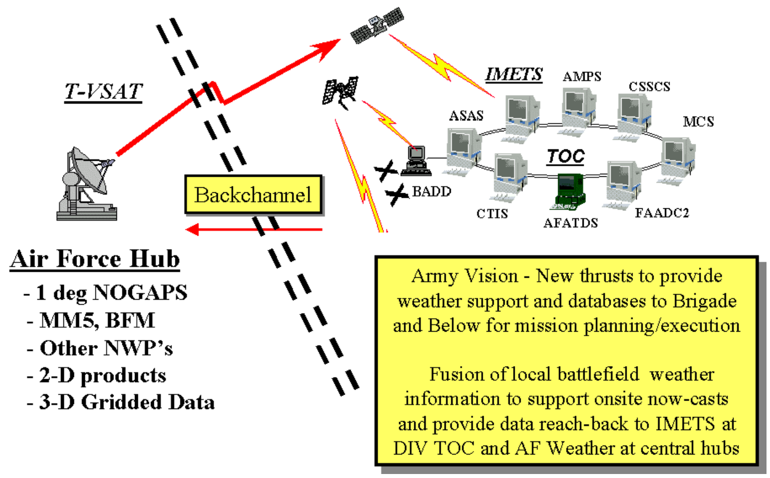

Figure 10. Weather data flow in the TOC

Under agreement with the Combat Terrain Information System (CTIS), the IMETS GMDB will share the terrain database servers

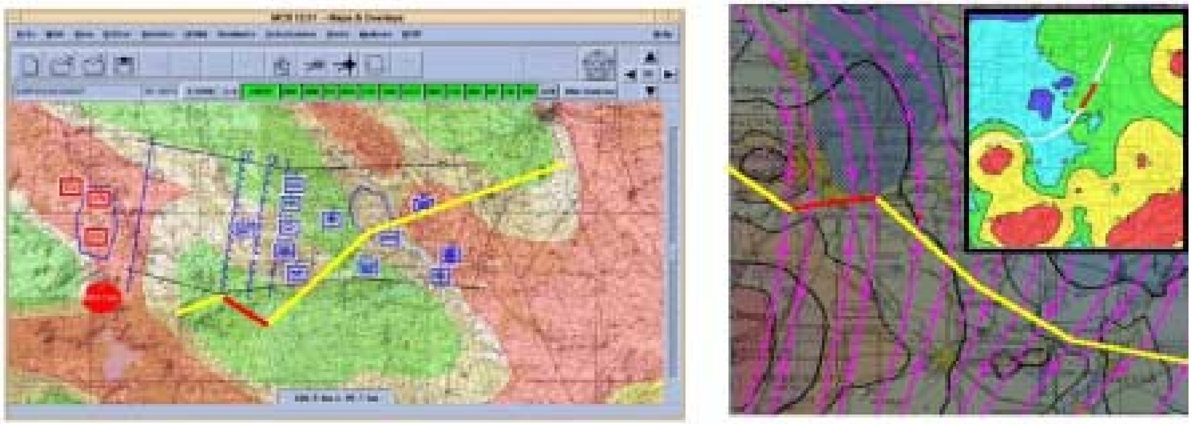

Figure 11. IMETS Overlays showing a way-point route plan view

provided by the CTIS. Since these databases will be provided across echelons, this is potentially one way for IMETS weather information and decision aids to be made available to lower echelons where a full-up IMETS is not deployed. Figure 11 shows examples of these weather overlays. One simple extension to support route planning would be to plot segments between way points (shown here in yellow with the current way point segment in red.)

COMMON TACTICAL PICTURE (CTP) WEATHER FEATURE

A new "Weather Feature" is being developed by ARL and by PSL for the Common Tactical Picture (CTP) in ABCS 6.1. The CTP is a specific type of common display for Army Tactical Command and Control Systems. It accesses the Joint Common Database (JCDB). The JCDB will replicated across echelons for use by all C4I systems. IMETS has currently been allocated room in the JCDB for a limited database of 8 basic weather parameters as shown in Fig. 12. A standard military weather symbol can be moved and clicked on to show text weather warnings, unit forecasts, and meteorological data at that symbol. For en route weather planning the symbol could be moved over a route-overlay as part of this application.

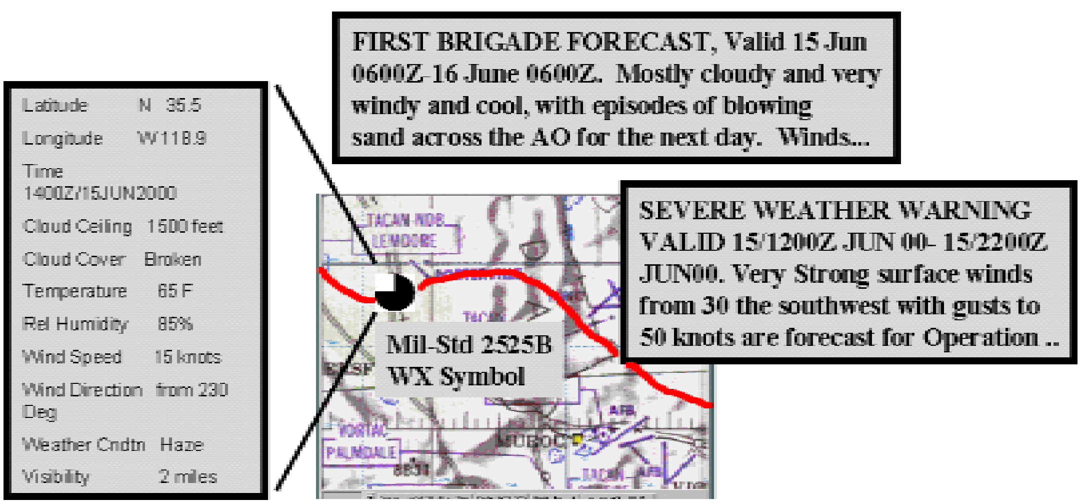

Figure 12. The Weather Feature on the Common Tactical Picture

AUTOMATED WEATHER BRIEFINGS

Probably the best example of automating a route weather briefing would be to address standard DD Form 175, the "Military Flight Plan" and DD Form 175-1, the "Flight Weather Briefing". The DD-175 defines the mission in terms of true airspeed, point of departure, departure time (Z), altitude and route of flight descriptions. The latter briefing form (part of which is shown in Fig. 13) is then traditionally filled out manually by a trained forecaster. Meteorological data for three of the five parts of the form could be automatically pulled from the IMETS gridded met database (GMDB). Part I, Mission Takeoff Data could be manually entered or automated to utilize the local met measurements at the air field or to use the forecast for the estimated time of departure. Part II, En route Data (as in Fig. 13), could be filled with data from the current IMETS GMDB, although a few of the variables will require development of additional meteorological analysis models (for example, for "visibility at flight level outside clouds"). Part III, Terminal Forecasts, could also be pulled from the GMDB, based on the location of the destination and estimated time of arrival. Note that we do not recommend eliminating the requirement for face-to-face weather briefing from the trained meteorologist. Human review and interpretation of the data will probably always be required for Parts IV Comments/Remarks and Part V, Briefing Record signatures. However, automation of data look-up and form generation could save the forecaster valuable time for analysis, discussion and contingency planning.

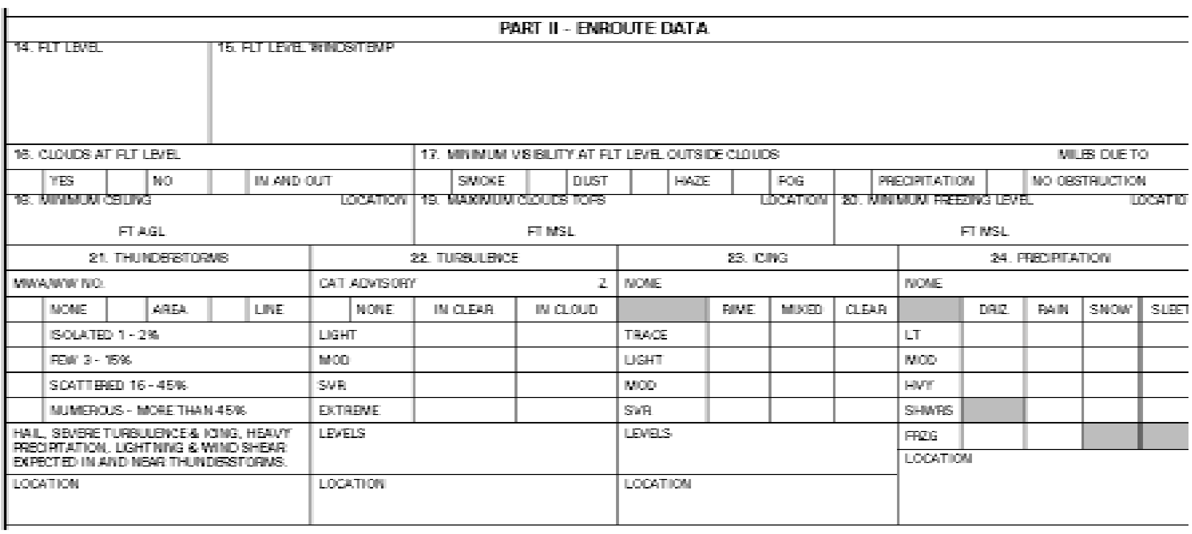
PART II - ENROUTE DATA
14. FLT LEVEL
15. FLT LEVEL WINDS/TEMP
16. CLOUDS AT FLT LEVEL
YES
NO
IN AND OUT
17. MINIMUM VISIBILITY AT FLT LEVEL OUTSIDE CLOUDS
MILES DUE TO
SMOKE
DUST
HAZE
FOG
PRECIPITATION
NO OBSTRUCTION
18. MINIMUM CEILING
LOCATION
FT AGL
19. MAXIMUM CLOUDS TOPS
LOCATION
FT MSL
20. MINIMUM FREEZING LEVEL
LOCATIO
FT MSL
21. THUNDERSTORMS
MWA/WW NO.
NONE
AREA
LINE
ISOLATED 1 - 2%
FEW 3 - 15%
SCATTERED 16 - 45%
NUMEROUS - MORE THAN 45%
HAIL, SEVERE TURBULENCE & ICING, HEAVY PRECIPITATION, LIGHTNING & WIND SHEAR EXPECTED IN AND NEAR THUNDERSTORMS.
LOCATION
22. TURBULENCE
CAT ADVISORY
Z
NONE
IN CLEAR
IN CLOUD
LIGHT
MOD
SVR
EXTREME
LEVELS
LOCATION
23. ICING
NONE
RIME
MIXED
CLEAR
TRACE
LIGHT
MOD
SVR
LEVELS
LOCATION
24. PRECIPITATION
NONE
DRIZ.
RAIN
SNOW
SLEET
LT
MOD
HVY
SHWRS
FRZG
LOCATION

Figure 13. Part II of DD Form 175-1 - Flight weather briefing

ROUTE PLANNING ADDITIONS INTO VIS5D

Vis5D is the interactive virtual 3-D data display on the IMETS WEW. To support route planning, a number of enhancements to Vis5D have been proposed and implemented, although not all have been accepted yet for field use. First, a menu-driven method to zoom the display has been added, and a prototype demonstrated that allows the database to be sectioned into quarters. This allows the user to focus on any specific quadrant in the data set. Second, a route display has been added that allows any route specified as straight-line paths between userdefined “way points” to be rendered (Figs. 14 and 15). A “snap” capability for vertical slice displays in Vis5D has been implemented so that the vertical plane can be automatically placed tangent to the current way point path segment (Fig. 14). Finally, a “probe” display mode for

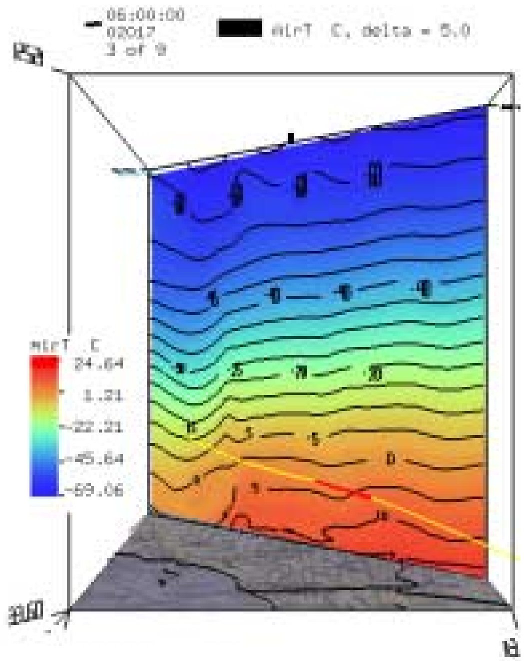

Figure 14. Vertical data plane "snapped" to route segment (red segment of yellow path)

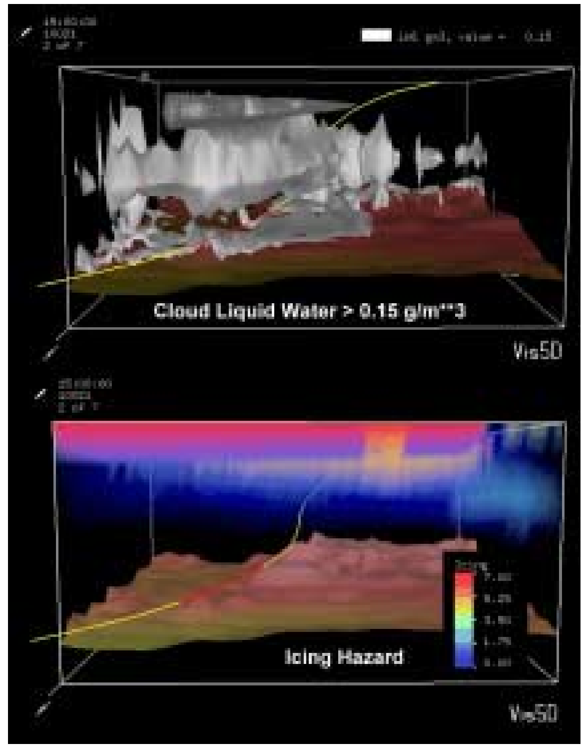

Figure 15. Way point routing in Vis5D

route segments has been written. This mode allows the user to move a slider interactively. As the slider is moved, a point is correspondingly moved along the way point segment and the met data in the GMDB corresponding to that point are printed on the display in text format.

PUSHING 3-D INFORMATION INTO 2-D IMAGES AND DISPLAYS

Information users at the lower echelons may not have the time or training to use manual virtual data browsers such as Vis5D. Furthermore, bandwidth considerations may dictate that text messages (perhaps displayed graphically at the end user’s interface), small data objects and 2-D image products will be the smaller bandwidth information formats of choice. With this in mind, we considered how the very nice capability in Vis5D to rotate the information in three dimensions might still be captured in 2-D products generated by the Combat weather Team or higher echelon IMETS.

There are several technologies, both old and new, that can be used to insert 3-D information into a flat image. The one chosen for this paper and presentation is the “anaglyph” or red-blue composite image viewed with colored filters (red for the left eye, blue for the right). Admittedly this has its drawbacks since the user may be color blind or may not want to obstruct vision with colored filters. Polarized images, flicker glasses and even stereoscopic pair viewers are alternatives. What we are only interested in here is whether there is value added. In the

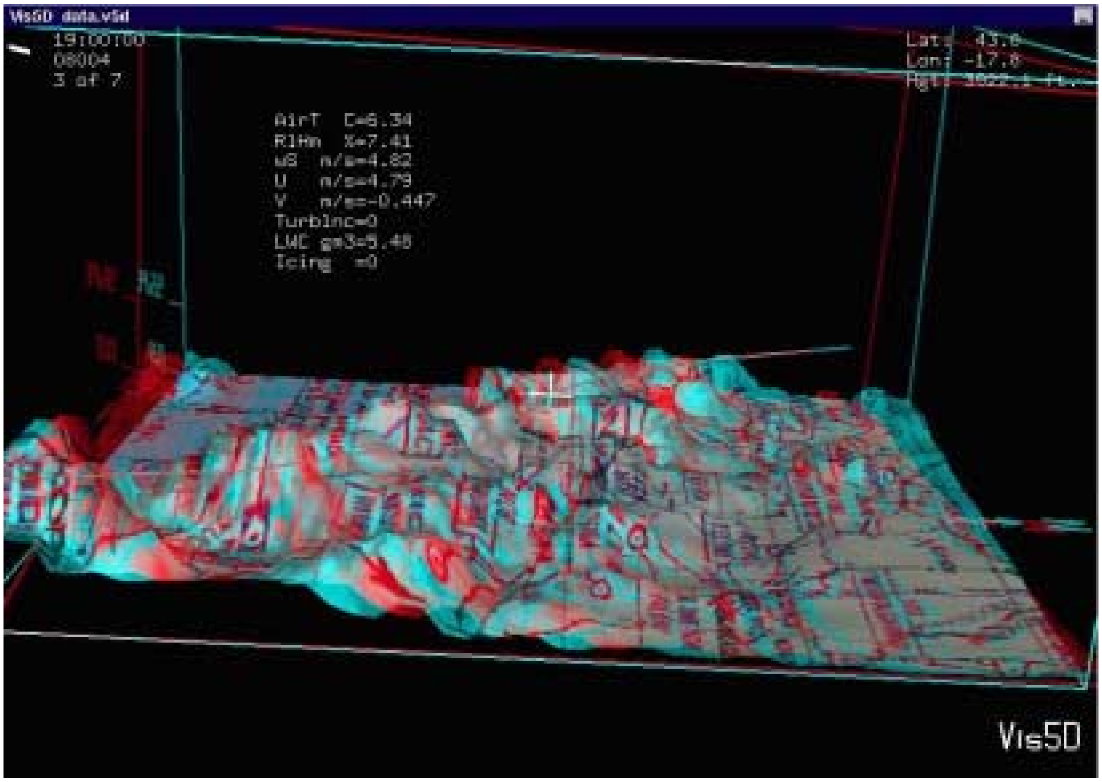

Figure 16. Probe along the route (3D image, requires red-blue glasses)

following figures we show both Vis5D and meteorological satellite imagery that has been enhanced by conversion to 3-D anaglyphs. The reader will need to obtain a pair of red-blue glasses, available at some toy stores, Edmund Scientific, or a number of good on-line stores. (Search for "anaglyph" and "glasses"). Cheap pairs costing less than 50 cents each will be handed out at the presentation of this paper.

Figure 16 shows the route planning display in "probe" mode. The met data readout is associated with the white crosshairs on this route along the coastal Yugoslav mountains. The common map is shown draped over the terrain data that was used in the BFM forecast run. Figure 17 is similar, but the map has been turned off and pseudo colors represent the shaded terrain. In viewing both figures, the reader should allow the eye-brain to relax and take in the whole image before focussing on any one element. Zooming in the page view (assuming that a color printer is not sufficient) will enhance the effects.

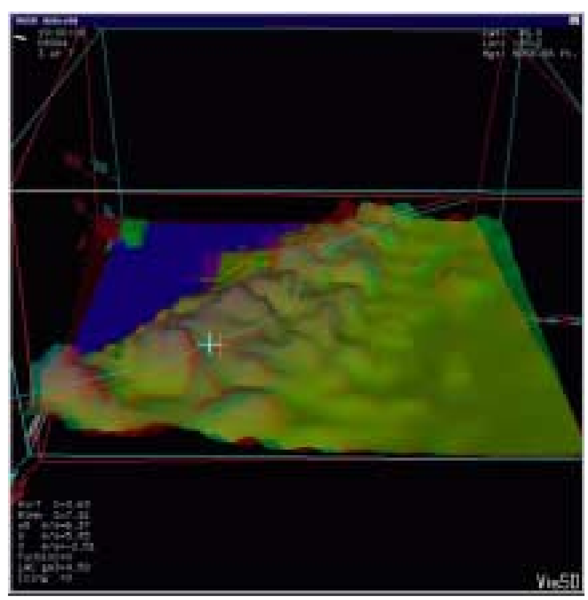

Figure 17. Probe view, Bosnia (3D)

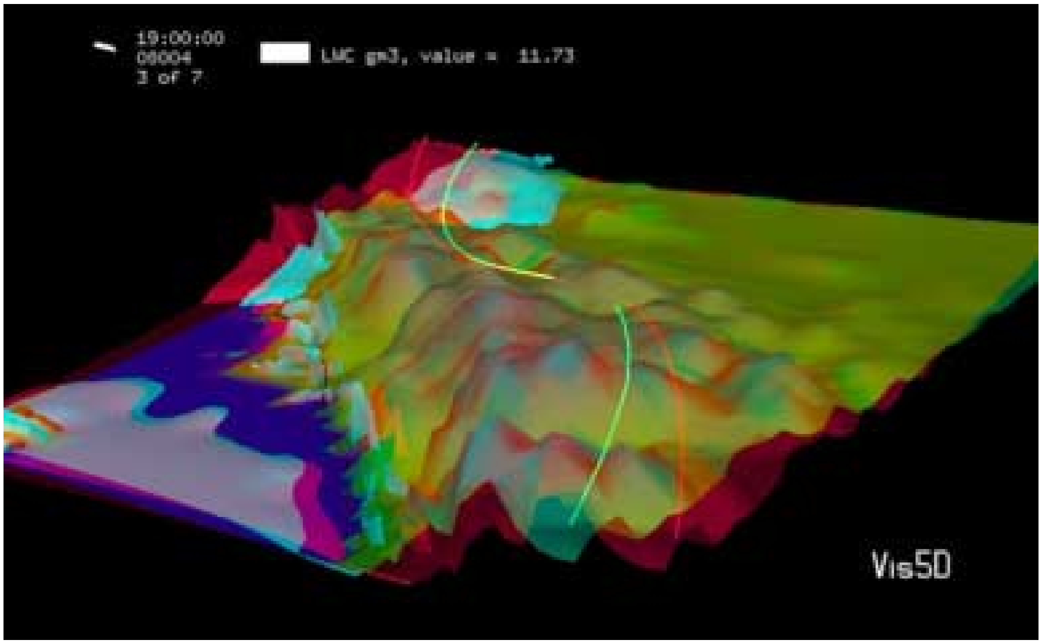

Figure 18. Extreme view of the route along the Yugoslav mountains (3D)

Figure 18 shows a rather extreme view of the path and displays iso-surfaces of liquid water content representing low stratus or fog (blue-white regions). In this case the eye must strain to try to converge the flight path lines, but the 3-D effect is striking. Figure 19 shows wind vectors for a model run over the Colorado region. Ft. Collins is near the top, just east of the front range. Denver is near the center of the image. Not only does one see the turning of the wind with height better, but also one can better visualize the effects of the mountains using the anaglyph view. This forecast corresponds to satellite imagery shown later.

Before proceeding with the other examples, let us document the simple process that was used to create these images. First, one must select image pairs that more or less represent slightly different viewpoints corresponding, for example to viewpoints from the left and right eye. The left and right images are then joined into one using the appropriate procedure below.

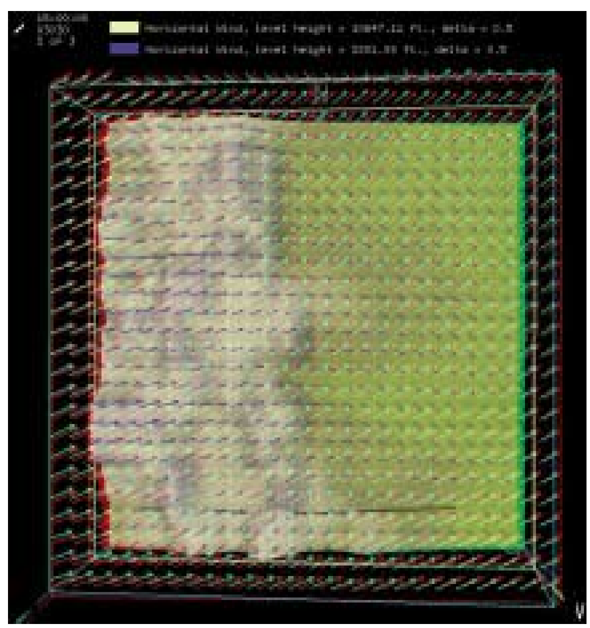

Figure 19. Winds over Colorado (3D)

<u>For two greyscale (8 bit black and white) images</u>: Simply copy the left image into the red channel, and copy the right image into both the green and blue channels of a new 24 bit RGB image. This can be easily done manually using various paint programs, for example. PaintShop Pro 4.x was used for the figures in this paper.

For two color images: Convert the images to 24-bit color if not already in this mode. Separate the red, green and blue component channels of both the left and right color images. Then form a final new image made up of the red channel from the left image, the green channel from the right image, and the blue channel from the right image.

For color graphics images or images with large bright blue or red regions: Color images of line graphics and data plots are particularly troublesome if the data are plotted as red lines or blue lines. A similar problem occurs if the image has bright blue or red regions. In these cases, try the following method to partially cross-mix the image pair colors and reduce saturation. Convert both the left and right images to 24 bit color if not already in this mode. Separate the red, green and blue component channels of both the left and right color images. Next, take a copy of the original left image and convert it directly to an 8-bit greyscale image. Average this 8-bit greyscale left image with the red channel (also now 8-bit) that was stripped out of the left color image. Place the resulting averaged image into the red channel of the final output image. Next, average the red and green channels of the right image; and place the resulting average 8-bit image into the green channel of the final output image. Finally, average the red and blue channels of the right image; and place the resulting 8-bit image into the blue channel of the final output image. The output image will have a shifted hue and will be less saturated than the original image. However, any red or blue lines in the original images should now show up in the 3-D composite.

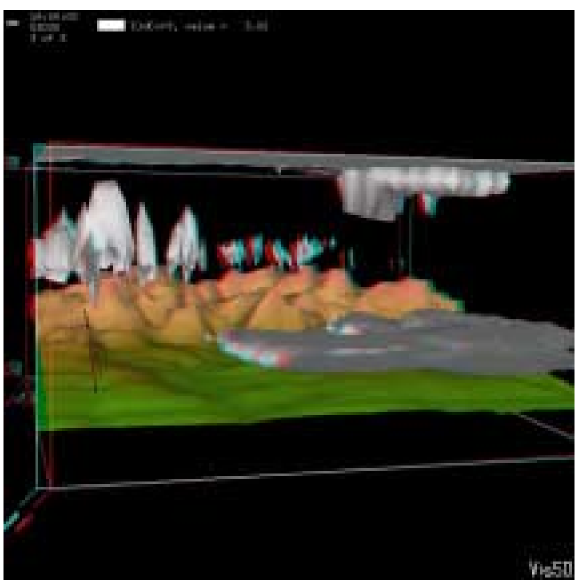

Figure 20. Cloud cover 3/8, Colorado

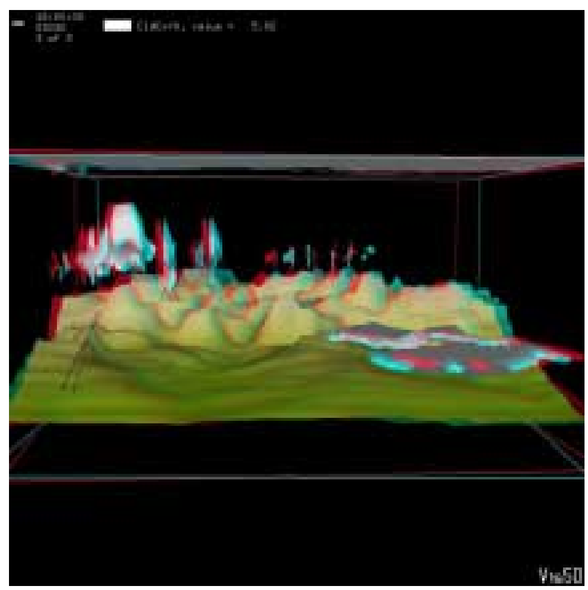

Figure 21. Cloud Cover 5/8, Colorado

Figures 20 and 21 show clouds moving through the Colorado Rockies on this date (30 March 2000). On the 29th a light dusting of snow was deposited and the skies cleared. On the 30th, snow and partial cloud cover persisted throughout much of the area. In these figures, Ft. Collins is to the right (North) behind the low lying cloud areas. The data plotted are cloud cover in eighths forecast from the IMETS BFM (3/8ths on the left and 5/8ths on the right) for approximately noon local time.

Figure 22 now shows a composite satellite image in the visible band (courtesy of the UCAR web page) showing mostly clear conditions over the Colorado rockies on 29 March, but with areas of snow on the mountains easily discerned. The two combined images are not simultaneous. Rather, they are 15 minutes apart, with the earlier image associated with the right eye (blue) and the later image in time associated with the left eye (red). This choice was made so that the geopolitical (state) boundary lines could be allowed to line up. As a result, the surface and clouds appear to be below the effective level of the map boundary. However, if one looks long enough, then the thin clouds moving in from the south east can be seen, and several convective clouds streaming to the northeast off the mountain ridges can also be picked out.

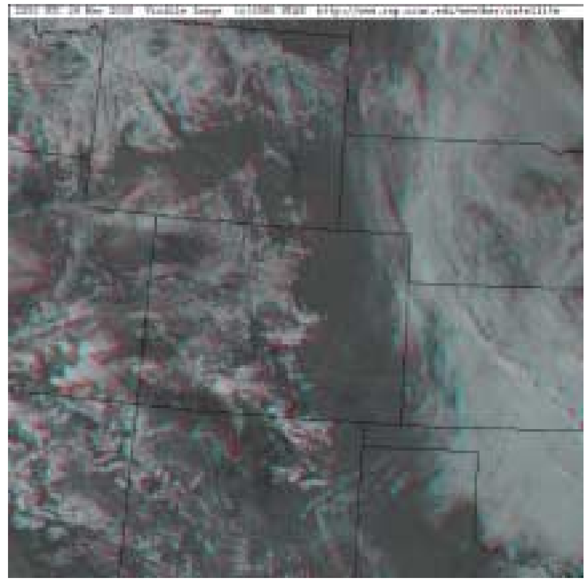

Figure 22. Snow covered Colorado Mtns

(If the resulting anaglyph images show the red and blue tinted areas as too weak to produce a good effect, then try saturating the color of the entire image. This was done in this case.)

Figure 23 is from the CSU/CIRA "Chill project" satellite image web page. It shows the conditions on 30 March at about 2 hours later than the cloud cover plots of Figs. 20 and 21. Again the image pairs are about 15 minutes apart. In anaglyph format, the image show the distinction between the open cloud free areas in the center of the state, and one can make out somewhat the heights of the clouds above the surface.

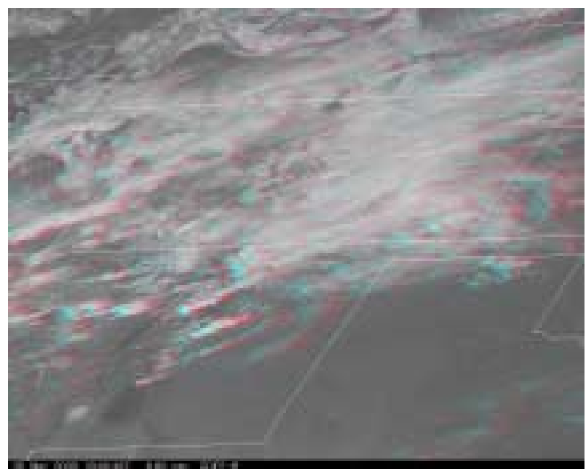

Figure 23. Slant Path – Colorado, Vis

On 29 March the weather was also active in the south-east. A tornado watch in soutwestern Alabama was in effect. Figures 24 and 25 (next page) show the region. One can make out strong convective storms in south Louisiana. Both figures are for the same image pairs. Like previous figures, the image on the left uses coincident state boundary lines. The cloud formations appear to be below the map boundaries. In Fig. 25, however, we have shifted the images by a number of ixels roughly equal to the distances that interesting cloud features have moved. This co-locates the clouds rather than the boundaries. By associating the image with the leftmost boundary lines with the right eye (blue) and the image with the rightmost

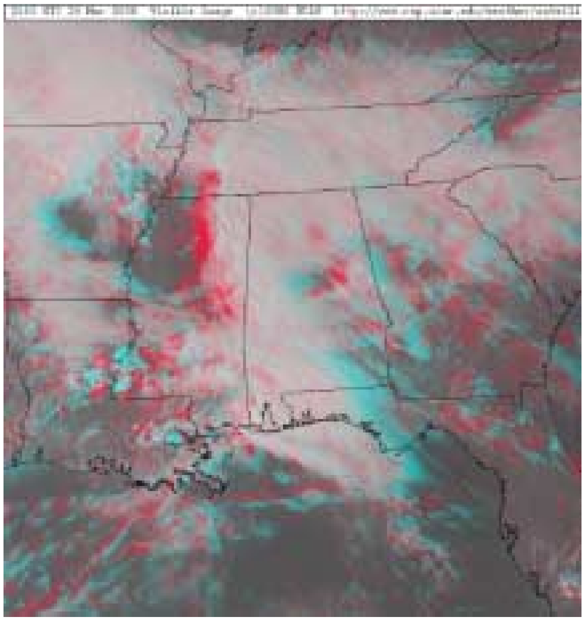

Figure 24. Fixed borders, Alabama.

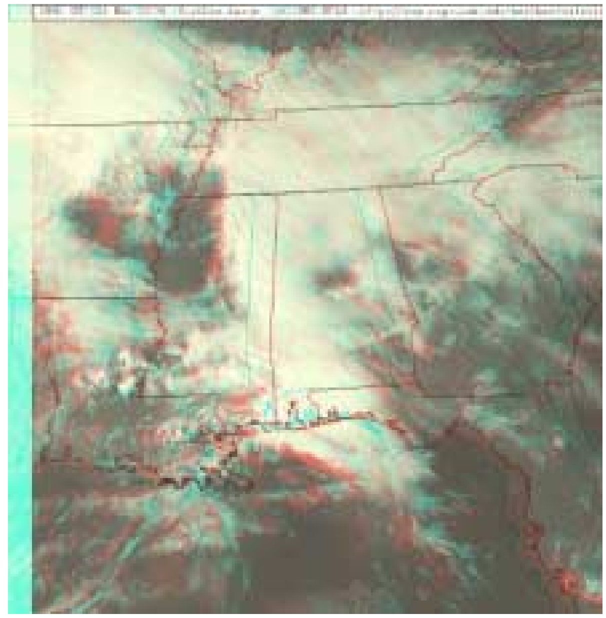

Figure 25. Shifted borders.

boundary lines with the left eye (red) one can now perceive the “map” to be at ground level, with the clouds above it. (Note: it takes a while to see this effect at first. Look for the “map” to appear a to be a flat surface a few “inches” into the figure.)

Figure 25 is also “greener” than its neighbor. This is intentional. Some red-blue glasses are darker than others, making images like Fig. 24 appear quite bluish. Figure 25 has been compensated for that type of glasses by boosting the green component. (There is some advantage to the darker blue in that there is less “bleeding” of color in the red channel by changing the hue to emphasize the green more.)

Finally, Fig. 26 shows a true stereo pair derived from images from the University of Wisconsin taken from two different satellites at the same time. This is obviously the preferred situation if possible, since it provides a truer three dimensional perspective. This is a much more involved process to co register the regions and perspectives from different satellite views. For that reason, it is less likely that Combat Weather personnel would have the time to capture and manually process image pairs in this way, except perhaps in a pre-scripted mode.

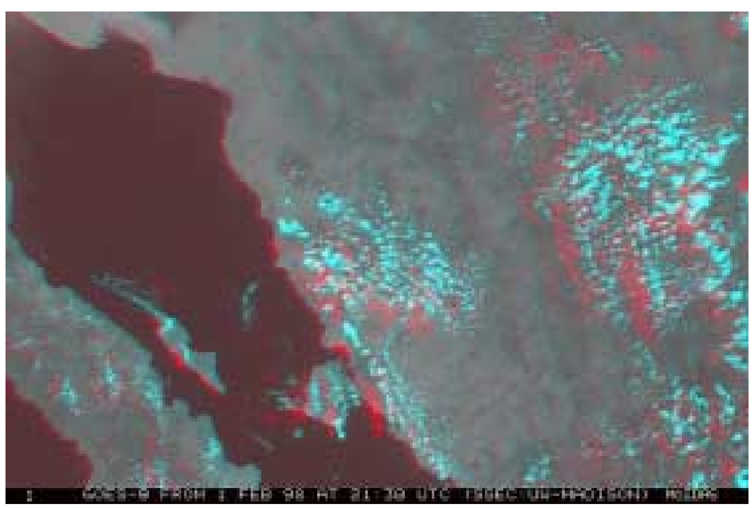

Figure 26. True stereo - 2 satellites at the same time

CONCLUSIONS AND RECOMMENDATIONS

In this paper we have described the current capabilities of the IMETS and Weather Effects Workstation. The "top down" paradigm of providing weather forecasts from central hubs down to division level may need to be augmented to support the new Army "full spectrum" brigade structures, where decision making may be pushed to lower echelons. The shorter decision cycle and nearer-term planning of operations will also tend to change the types of weather products to be more "now-cast" oriented. Local weather observations from a variety of sources may become available, including remote sensing, robotic vehicle weather sensors, UAV imagery, soldier environmental monitors, etc. Therefore, we have begun looking at the types of new capabilities that will need to be developed to support these forces. It is clear that forecast models will need a new ability to ingest non-conventional observations. And, it is clear that new weather products will be needed that are tailored for use all the way down to the individual soldier level. In this spirit, we have examined here the use of Weather Features on the ABCS Common Tactical Picture and overlays. We have looked at automating route planning weather and displaying route weather data in both virtual 3-D data environments (Vis5D). And we have looked at the potential for using enhanced 2-D images containing 3-D information.

REFERENCES

Haines, Patrick, 2000; "Development and Validation of Battlescale Forecast Model Convective Cloud Prediction Capabilities", Proceedings of the Battlespace Atmospheric and Cloud Impacts on Military Operations Conference 2000 (BACIMO 2000), Cooperative Institute for Research in the Atmosphere (CIRA), Colorado State University, Fort Collins, CO, April 25-27, 2000.

Henmi, Teizi, 2000; "Evaluation of Operational Mesoscale Models MM5 and BFM Over White Sands Missile Range", Proceedings of the Battlespace Atmospheric and Cloud Impacts on Military Operations Conference 2000 (BACIMO 2000), Cooperative Institute for Research in the Atmosphere (CIRA), Colorado State University, Fort Collins, CO, April 25-27, 2000.

Hoock, Donald W., Mario Torres and David Sauter, 1998a; "Adapting a Rule-Based Decision Aid as a T&E Range Mission Planning Tool", Proceedings of the ITEA Workshop: Modeling and Simulation, Establishing Seamless, Distributed, and Integrated Solutions to Real-World Challenges 7-10 Dec 1998, Las Cruces, NM, pp 166-180.

Hoock, Donald W. and John Giever, 1998b; "Extending VIS5D to View Very High Resolution 3-D Data", Proceedings of the ITEA Workshop: Modeling and Simulation, Establishing Seamless, Distributed, and Integrated Solutions to Real-World Challenges 7-10 Dec 1998, Las Cruces, NM, pp 793-803.

Passner, Jeffrey, 1999; "Weather Products from a Mesoscale Model", Proceedings of the ITEA Workshop: Modeling and Simulation Using Modeling and Simulation for Testing – Are We ready for the Next Millennium? 6-9 Dec 1999, Las Cruces, NM, to appear.