

**"DON'T SHOW ME ISOBARS": INTEGRATING TACTICAL WEATHER
DATA INTO MISSION PLANNING SYSTEMS1**

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1. Executive Summary

1.1. Summary Description

The goal of this project is to increase the effectiveness of Precision Guided Missiles (PGMs) and of other weapons such as Tomahawk Land-Attack Missile (TLAM) by integrating weather forecasts, aircraft-sensed weather conditions, and weather data from remote sources into the mission planning process. The benefits will be more precise targeting, better “Go/No Go” decisions, and more effective use of precision stand-off weapons.

This is a Navy SBIR research project. In the Phase I research, we examined the feasibility of providing meaningful, weather-based mission planning support for PGM mission planning, focusing on a particular air-to-surface PGM, the Joint Standoff Weapon (JSOW), currently being developed for use by the Navy and Air Force. In this study, as in Phase II, we were guided by the findings of an Integrated Product Team (IPT) convened by Naval Air Systems Command (NAVAIR) to determine the environmental effects on JSOW. We also convened a Warrior Product Team (WPT) consisting of Navy pilots with JSOW mission planning experience, to suggest and review mission planning features and displays that we developed over the course of the project.

Our principal Phase I findings were that there are weather factors which significantly affect JSOW performance, and that new tactical weather models promise to provide sufficient accuracy in predicting those factors, to significantly improve JSOW mission planning. We also determined that, while the present environmental data flow does not support mission-planning requirements, the computer infrastructure exists do so. We developed displays and mission planning aids that will allow the warfighter to deal with the weather in weapon-performance terms, rather than in purely meteorological terms.

Our Phase I study indicated two steps that need to be taken to incorporate METOC data in mission planning in a meaningful way. These are; (1) Data generated by the new, tactical weather models must be made available to mission planning modules (MPMs) via a digital interface, with minimum user interaction required, and (2) the data must be integrated into the mission planning process so that the effects of METOC factors are seen in terms of weapon effectiveness rather than in terms of the weather itself. As one pilot in the WPT put it, “Don’t show me millibars.”

In Phase II, we developed two prototypical software products to carry out these two steps. METPLAN is a software agent that automatically obtains available data on weather factors significant to a given PGM from the Tactical Environmental Data Server (TEDS) and passes those data to the Wagner Demo MPM for incorporation into the JSOW mission planning process. The Wagner Demo MPM is a mission planning module (MPM) mockup for the Joint Standoff Weapon (JSOW). The demo MPM accepts data from METPLAN, displays effects of METOC data, and assists planners in building JSOW mission plans that are optimized for the predicted conditions. This software demonstrates the handling, display, and integration of tactical meteorological data into an MPM mission planning process.

In the Phase III effort, we will build a full-capability version of METPLAN that can be hosted on various platforms, depending on the needs of the Navy and Joint commands. The important features of this software will be its ease of interface, its portability to different environments, and its ability to provide a data interface even as METOC databases and access methods evolve in the future. We will also assist MPM developers in incorporating weather data into their respective MPMs and in building weapon-specific METOC displays similar to those we developed in our demo JSOW MPM. The design for the Phase III product is shown in Figure 1

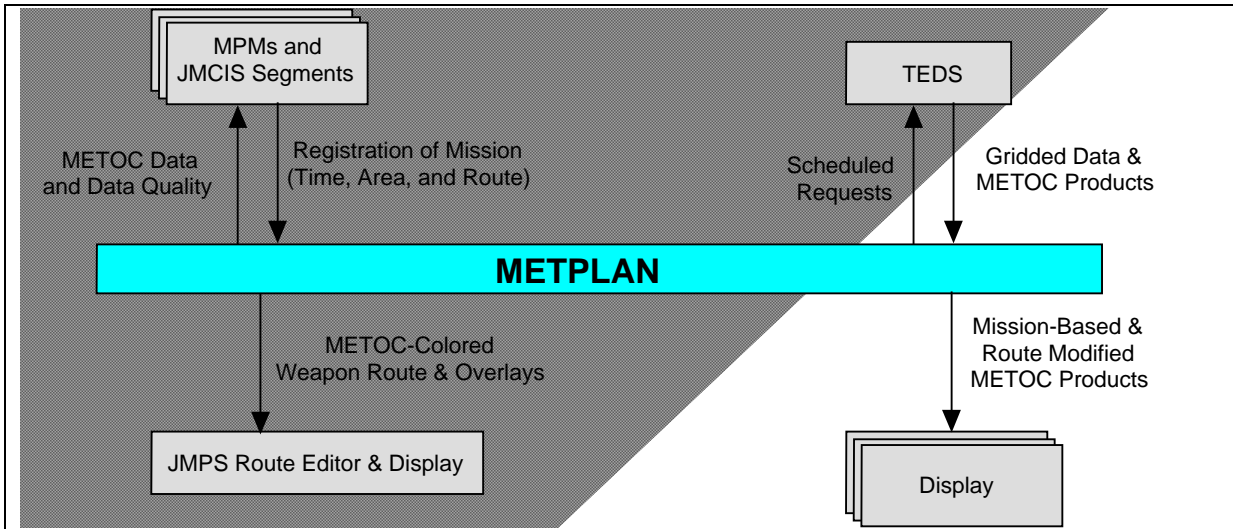


Figure 1. Phase III Structure

METPLAN will be a generic agent, suitable for use by any mission planning systems such as JSOW SLAM-ER, JDAM, and Tactical Tomahawk. METPLAN is driven by a requirements definition table that specifies the environmental variables of interest and the timeliness and model requirements that the METOC data must meet. In principle, METCAST could easily be extended to support higher-level planning, such as Strike or Interdiction Planning.

A key feature of METPLAN is its autonomous nature. Our concept is that when a mission plan is originated, METPLAN will be alerted by the MPM about the mission time, area, and (possibly) route. As with the present version, METPLAN will ascertain what applicable data is available in TEDS, and download the required METOC data from TEDS to the mission planning system with no operator action required. While the plan is valid (i.e., from the time it is first formed until a specified time after its scheduled execution), METPLAN will continually interrogate the TEDS database for more current data. After execution of the plan, METPLAN will expunge the data from the mission planning directories so that there is no possibility of using stale data in mission plans. The present METCAST capability to overlay METOC displays onto the tactical picture, or, for large-scale displays such as satellite cloud motion, to launch new windows showing the METOC product and the area of the tactical display, will be kept in the Phase III product.

The Phase III METPLAN will provide a uniform approach to integrating METOC data into mission plans, a uniform display of environment data and its effect on the weapons, and the same graphical user interface for METOC preferences and products, for all PGM weapon systems

The Phase III efforts are expected to be funded from multiple programs, including SPAWAR (PMW 185), the Joint Mission Planning System (PMA 233), and individual weapons programs such as JSOW (PMA 201), SLAM-ER (PMA 258), and Tomahawk (PMA 281).

1.2. Key Words

METOC, ENVIRONMENTAL DATA, WEATHER, MISSION PLANNING, SOFTWARE AGENTS, JSOW, JMPS, TEDS, TOMAHAWK, SLAM-ER

2. METPLAN

2.1. Phase I and Phase II Research Findings

In Phase I, we examined the feasibility of providing meaningful, weather-based mission planning support for PGMs, with focus on a particular air-to-surface PGM, the Joint Standoff Weapon (JSOW), currently being developed for use by the Navy and Air Force. Our principal Phase I findings were that

- there are weather factors that significantly affect JSOW performance;
- new tactical weather prediction models promise to provide sufficient accuracy to improve JSOW mission planning;
- while the present environmental data flow does not support mission-planning requirements for weather data, new tactical systems being fielded by the Navy and Air Force will do so; and
- displays and mission planning aids can be developed that will allow the warfighter to deal with the weather in weapon-performance terms, rather than in purely meteorological terms.

In this study, as in Phase II, we were guided by the findings of an Integrated Product Team (IPT) convened by Naval Air Systems Command (NAVAIR) to determine the environmental effects on JSOW. Further guidance was provided by a Warrior Product Team (WPT) that we convened to suggest and review the mission planning features and displays we developed over the course of the project.

In Phase II, we built a prototype Joint Maritime Command Information System (JMCIS) Segment called METPLAN, which obtains available data on weather factors significant to JSOW from the Tactical Environmental Data Server (TEDS) and makes those data automatically available to our demo JSOW Mission Planning Module (MPM). This demo MPM is a mock-up of the future JSOW Unique Product Component (UPC) of the

Joint Mission Planning System (JMPS).¹ The demo MPM incorporates the METOC data into range and altitude calculations, displays weapon-specific information about those factors, and assists planners in building JSOW mission plans that are optimized for the predicted conditions. This system demonstrates the handling, display, and integration of tactical meteorological data into the JSOW mission planning process. We also investigated extensions of these planning features to other weapons such as SLAM-ER and Tomahawk Land-Attack Missile (TLAM), as well as extensions of weather-sensitive mission-planning features to real-time JSOW launch decision-making.

The impact of incorporating METOC data into the mission planning process varies with the weapon involved, but virtually all airborne weapons will derive some benefit. In our Phase I and II studies, we examined in some detail the potential effect of incorporating METOC data into mission planning for two specific systems: JSOW and SLAM-ER. In both cases, we found that the benefit will be substantial even in very commonly encountered environments (e.g., 15-knot winds). Descriptions of these weapons are found in the sections below.

In a previous study, the authors found that there is a significant potential benefit to the Tomahawk Land Attack Missile (TLAM) from using real-time weather data in mission planning [1]. This benefit was not possible when TLAM missions were planned weeks, or even months, in advanced. Now, with the advent of Tactical Tomahawk and its near-real-time planning, those benefits can be realized.

2.2. METPLAN Features

METPLAN is a generic agent, suitable for use by any mission planning systems such as JSOW, SLAM-ER, JDAM, and Tactical Tomahawk. METPLAN is currently driven by a JSOW requirements definition table that specifies the environmental variables of interest and the timeliness and model requirements that the METOC data must meet. This concept can easily be extended to other PGMs, and in principle, METCAST could also be extended to support higher-level planning, such as Strike or Interdiction Planning.

A key feature of METPLAN is its automatic nature. In the demo version (which is not usually connected to the Internet), the required METOC data is downloaded from TEDS to the mission planning system with no operator action required other than launching the TEDS client task, using a button in the METPLAN control window. For the operational version, we envision that the TEDS client will be actuated automatically upon receipt of notice that a new plan is being developed. While the plan is valid (i.e., from the time it is first formed until a specified time after its scheduled execution), METPLAN will continually interrogate the TEDS database for more current data. After execution of the plan, METPLAN will expunge the data from the appropriate mission planning directory so that there is no possibility of using stale data in mission plans.

¹ [Except in the specific context of JMPS software design, we will use the more generic term “MPM” to describe client mission planning systems, many of which will be implemented as JMPS UPCs.](#)

Throughout this project, we have been guided by a Warrior Product Team (WPT) composed of end-users (pilots) who are intimately familiar with the requirements for PGM mission planning, especially JSOW. In their periodic reviews of our progress, the WPT made several precepts very clear. First, Navy pilots have become accustomed to the Portable Flight Planning Software (PFPS) in widespread use throughout the Navy and Air Force, and they suggested that METPLAN should run in that system. Additionally, the Joint Mission Planning System (JMPS) project announced that PFPS functionality would form the basis of JMPS. Consequently, our software is built into the PFPS environment. Second, the WPT members wanted environmental data integrated into the planning tool without them having to take any action. Third, they want, as far as possible, to deal with weather in terms of its impact on the mission rather than in purely meteorological terms. Finally, if there are weather problems, they want to be able to analyze and remedy those problems with as little effort as possible.

In addition to talking with our WPT, we reviewed a number of mission planning tools, including TAMPS (and the JSOW MPM), PFPS, and the Special Warfare Mission Planning System (SWAMPS), to garner good integration, operator-interface, and display ideas. The resulting METPLAN user interface and displays are described below.

The key display techniques are Stoplight Displays and Point-and-Click inquiries. Figure 1 shows a JSOW route generated by our demo JSOW MPM with weather-related stoplight displays from METPLAN.

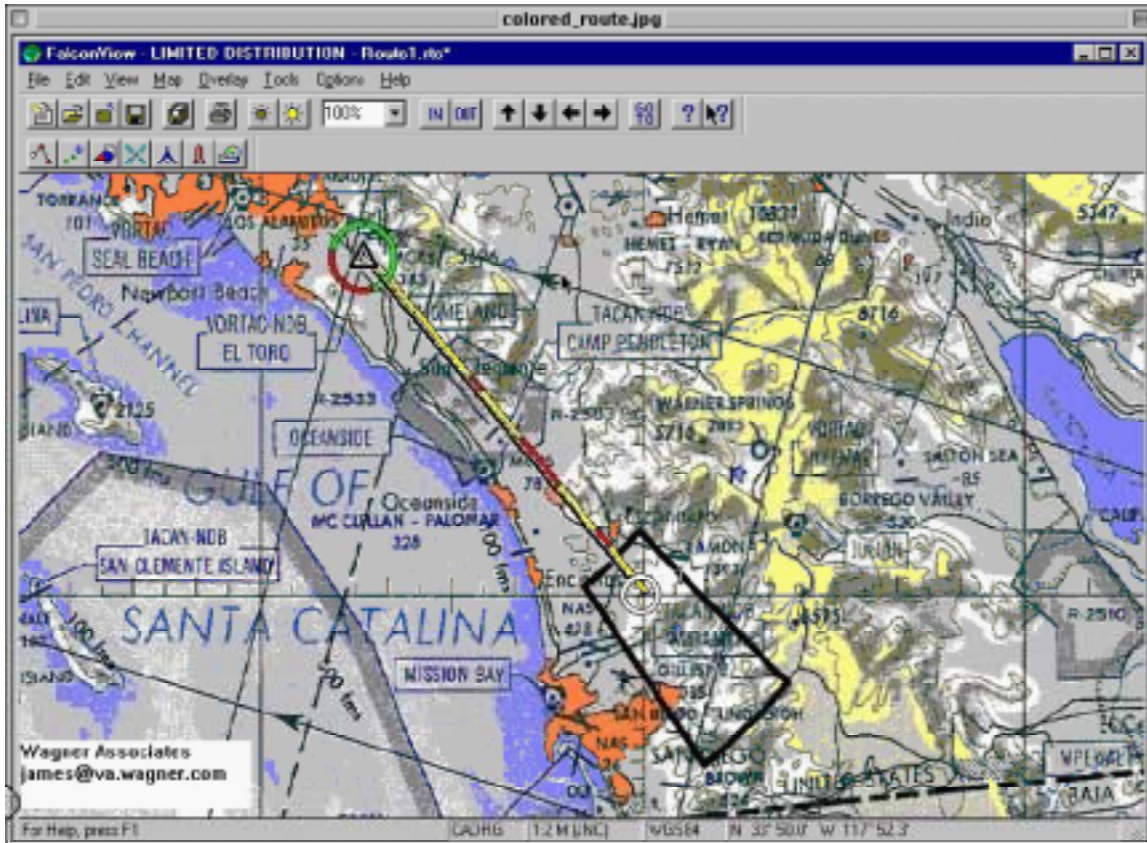


Figure 2. A JSOW Mission with Colored Route and Target Circle

Figure 2 shows a JSOW route for a strike against a target (triangular shape at top of figure) at El Toro, CA, from a weapon-release point (circular shape) southeast of the target. The symbols are generated by FalconView, the map server for PFPS, with which METPLAN is integrated. The large sector around the release point is the JSOW Launch Accessibility Region (LAR). The maximum range arc was calculated by the Wagner Demo MPM using the numerical weather forecast data extracted by METPLAN from TEDS on the day the plan was generated and valid at the planned time of missile launch.

The colored line displayed slightly to the right of the JSOW route indicates the weather conditions of interest to JSOW, along that route. The red and yellow sections of the line indicate weather conditions that are above the corresponding thresholds in the Preferences menu.²

The colored circle around the target is a JSOW-specific METPLAN display. Because of the sensitivity of JSOW-A to wind strength and direction at the target, it is extremely useful for the mission planner to be alerted when the surface-level wind at the target is strong enough to cause a problem. The circular display in Figure 1 indicates that the

² Normally, red would be reserved for conditions severe enough to seriously impair the mission, but in this case the Southern California weather rarely exceeds such levels, and so the thresholds have been set artificially low in order to demonstrate the stoplight feature.

wind is predicted to exceed the JSOW sensitivity thresholds, and is expected to blow from the southwest. The arc shows a 120-degree sector measured around the direct downwind approach direction. According to [21], JSOW munitions performance degrades severely when the weapon approaches the target from that sector (see paragraph 2.1.1).

In the case of the target circle, a red sector can only mean that the wind speed at the target is predicted to exceed the specified strength and that the red sector indicates the unfavorable downwind approach angle. A red section of the route could indicate any one of a number of weather problems. To determine the problem, the user simply points to the section in question and clicks his mouse button.

Figure 2 shows the resulting display. The "Altitude" display indicates the planned missile altitude at that point in its flight: 25895 feet above mean sea level. The user has elected to look at "High Interest (Red)" factors, and observes that the wind exceeds the red threshold at all altitudes from 40000 feet MSL down to 25000 feet. Thus, he cannot expect to extend the range of his mission by changing the altitude of flight through this area. The wind direction of around 220 degrees gives him some insight into a possible longer-range prospect, however. If he can safely launch from the direction of San Clemente Island, he may be able to take advantage of the more favorable wind direction and gain a little stand-off range for his mission. He can check this by pointing to a representative spot between San Clemente and the target and clicking there. He will get the same display as in Figure 2, without the altitude figure. Note, however, that a direct shot from the San Clemente direction would take the JSOW through the red sector on the final approach, and inserting a waypoint to avoid this might more than offset the range gains attained by flying downwind during the early stages of the mission. Because these decisions involve tradeoffs such as flight range vs. probability of success, which in turn depend on tactical constraints and target properties, they cannot be made automatically for the mission planner.

QuickTime™ and a
Photo - JPEG decompressor
are needed to see this picture.

Figure 3. Point-and-Click Weather Information

The "Icing" element of the pull-down menu of "Highest Interest" weather factors does not have an obvious solution. If the pilot wants to see what he can do about icing conditions, he must look at a larger picture. Figure 3 shows a prototype display of icing potential in the region around the mission, at the altitude the pilot has specified (about 25895 feet). In this case, there is nowhere to which he could move the approach leg to avoid the predicted probability of icing; he must either decide to scrub the mission or live with the predicted weather conditions.

If the mission planner is interested in a slightly more detailed analysis of, say, the wind direction, METCAST can supply him with graphical products from TEDS. Figure 3 shows an example product, wind streamlines. Our WPT indicated that mission-planning personnel find colored wind streamlines much easier to analyze quickly than the classical wind barbs. Note the effects of land features on the wind, as shown by the bending of the streamlines at the coast and the channeling along the coastal range just inland of Los Angeles. Wind streamline products are not yet available from TEDS, so the underlying data for Figure 3 was downloaded from the NRL-MRY website to illustrate the display.

QuickTime™ and a
Photo - JPEG decompressor
are needed to see this picture.

Figure 4. Wind Streamline Display

Figure 3 shows the area of interest, as indicated by the geographical size and position of the tactical display in Figures 1 and 2, and the line and triangle in the center of that rectangle depict the JSOW route. This is a very good idea we obtained from SWAMPS. Giving the viewer a new window that displays the area of the tactical window allows him to see the features of interest without cluttering up the tactical display. It also allows a broader field of view than the tactical one, without the necessity of scaling a picture out and then back. Our WPT members indicated that they find such scaling disorienting as compared to viewing the weather product in another window.

The streamlines of Figure 3 were colored for wind strength by NRL-MRY according to an arbitrary color scheme shown in the upper right corner. This scheme while pleasing to the METOC officer bears no import to the Mission Planner. In the operational METPLAN, we will build the streamlines from TEDS data using the same algorithms as generated the lines in Figure 3, and color them according to the thresholds for the particular weapon. This provides streamlines (or other products) that have a direct bearing on weapon performance.

In our concept of operations, the thresholds for red, yellow, and green coloring by METPLAN are changed rarely if at all. They are set according to weapon sensitivity to each weather factor, and would only be modified if the mission planners become aware of

new information about those sensitivities. Figure 4 shows a set of wind thresholds selected for JSOW-A. In this case, the user has indicated that he wants to see the downwind-approach sector colored red if the predicted wind at the target exceeds 20 knots, and yellow if it exceeds 10 knots. He is interested in coloring the arc 60- degrees on either side of the direct downwind approach. He wants to see icing listed as a problem if it is predicted at the JSOW's flight altitude, but is not interested in having precipitation or turbulence flagged. The choices on the right indicate different ways the colored route can be displayed; the choices shown in Figure 4 result in the effects shown in Figure 1.

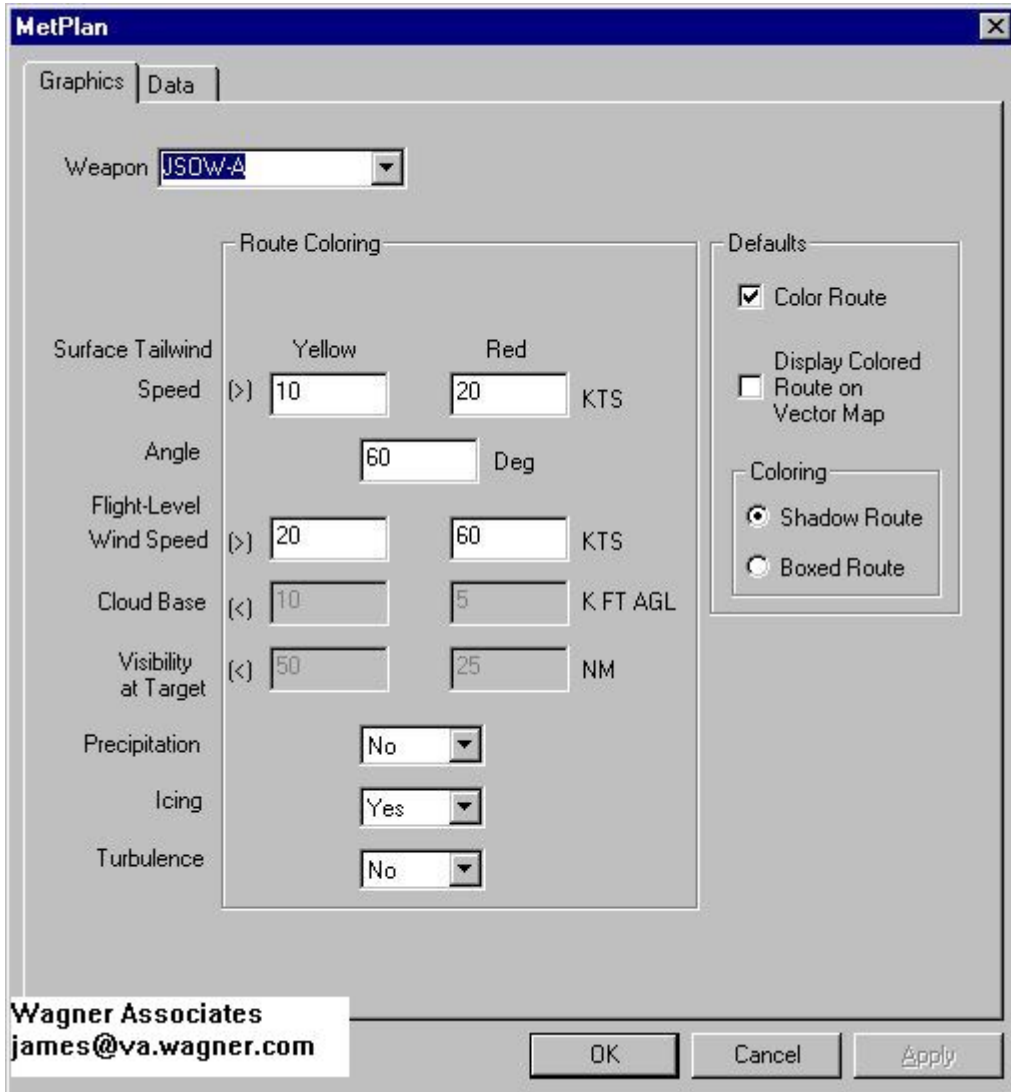


Figure 5. METPLAN Preferences Screen

Once a plan is initiated (actually, once a target has been chosen for a mission at a given time for a weapon), METPLAN searches the TEDS database for data appropriate to that weapon, valid at the appropriate time. The particular weather variables critical to that particular weapon have been defaulted too, but the user is free to select other factors as he

chooses. These factors will be added to the METPLAN Preferences screen as they are selected, and the user will be prompted to select appropriate thresholds for each. The METPLAN screen for selecting such additional factors is shown in Figure 5.

Our concept of operations for METPLAN includes a “time line” for each weather factor of interest. The METPLAN field selection screen shown in Figure 5 also allows the user to dictate the time window of interest. Here, the user had decided he wants to see all forecasts for the time interval beginning 1 hour before the scheduled mission execution time and extending 12 hours further into the future. *The button for “launch client” is only for use in the current version of METPLAN because the system is rarely online to a TEDS. This button will be removed in the operational version of METPLAN.*

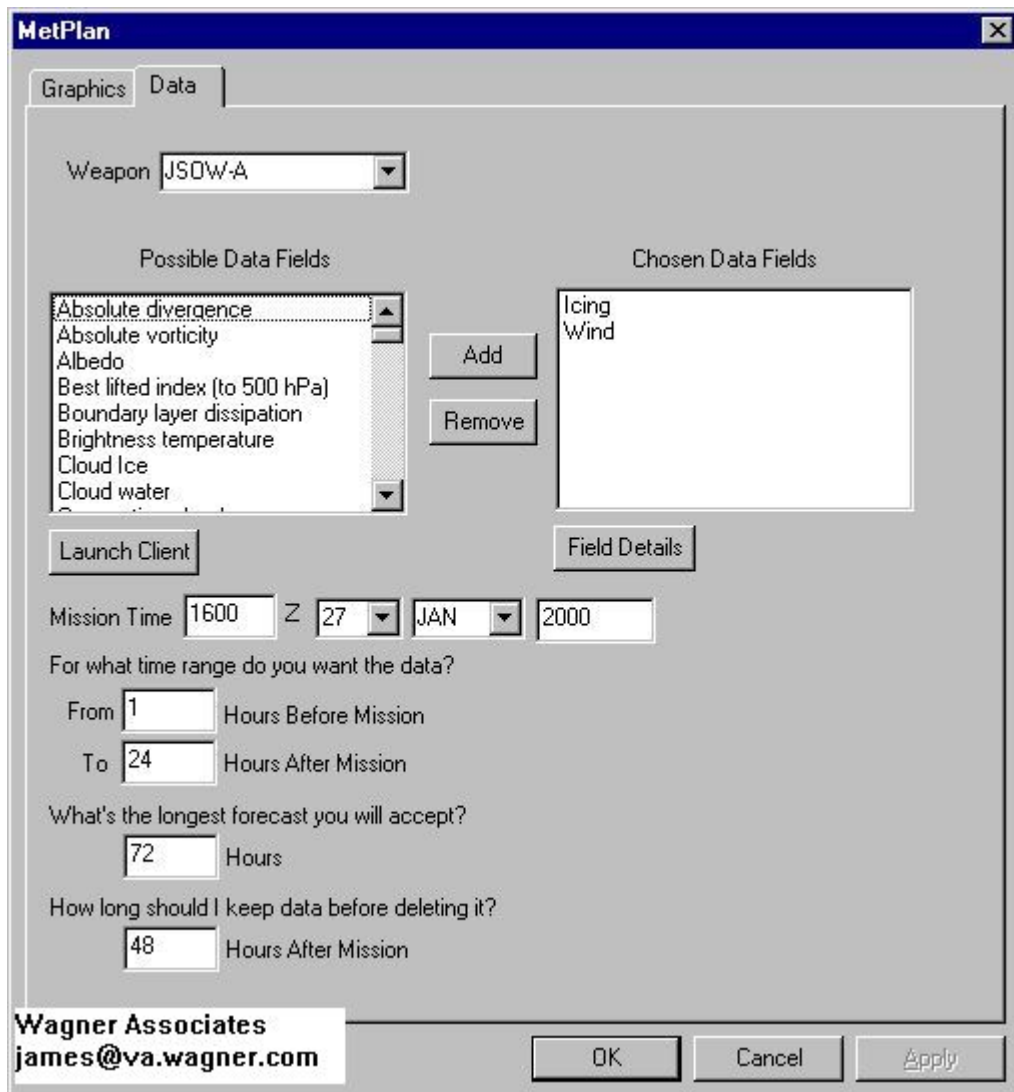


Figure 6. METOC Field Selection and Control

The architecture of METPLAN is that it operates as a separate process along with the Wagner JSOW Demo, with both processes accessing FalconView to draw on the map. This architecture, which is expected to be carried as is into JMPS, requires that each

process be controlled through a separate user interface. The METPLAN control window is shown in Figure 6. The control buttons come in two sets. The set on the left deals with METPLAN products and integrated mission planning tools; the selected button shows the same route-planning logo as appears on PFPS/Wagner Demo, and indicates that the user wants the route colored according to the weather thresholds, as in Figure 1. If that button is deselected, the route is simply drawn as a black line.



Figure 7. METPLAN Program Control

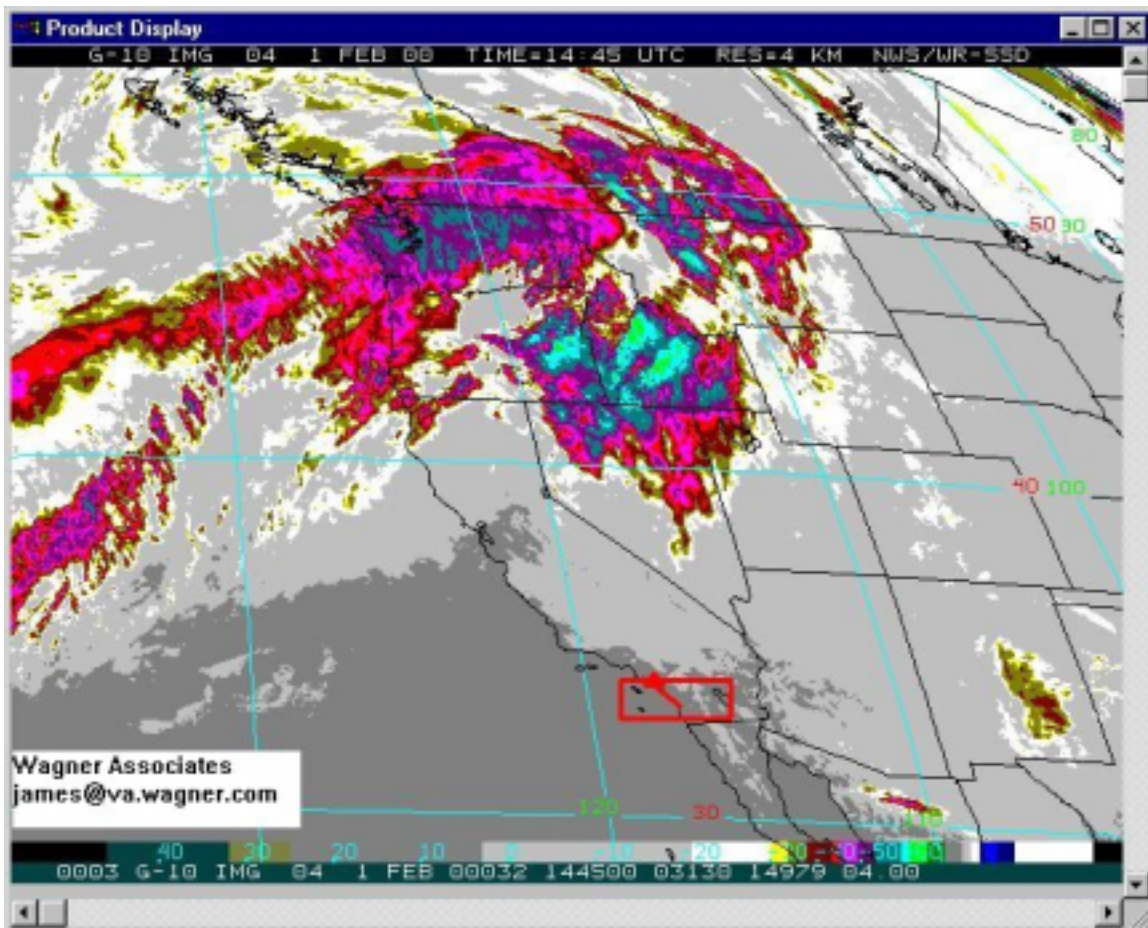


Figure 8.

2.3. METPLAN Architecture and Status

Conceptually, METPLAN consists of three parts: a TEDS client, which queries TEDS for the appropriate data; an MPM Server, which records preferences from the Mission Planning Module, puts the required data in the specified directories, and cleans up the data after the mission is concluded; a Graphics Server, which monitors the activity of the

PFPS Route Server and displays the appropriate graphics on the tactical display as required; and the Graphical User Interface (GUI), which displays the METPLAN Program Control toolbar, the Preferences screen, and the Field Selection and Control screens (Figures 4-6), and records the user's controls and preferences for use by the other parts of the program. The version of METPLAN developed in Phase II of this project lives entirely on the application side of the TEDS/Mission Planning interface.

The TEDS Client makes use of the published TEDS APIs to obtain data from TEDS. The TEDS APIs implement a client for the Informix database of TEDS, and provide routines to manipulate the data (for example, to extract a subset based on latitude and longitude constraints) once it is received from TEDS. The basic process carried out by the TEDS Client is as follows: (1) Get TEDS Catalogue for weather variables of interest to the weapon system involved (JSOW); (2) determine whether appropriate data is available for the time of the mission, and if so, which data is preferred; (3) Obtain the data from TEDS; (4) Subset the data for the region of interest; and (5) manipulate the data as required for the weapon in question (e.g., calculate probability of icing from temperature and humidity).

Functionally, the Phase II TEDS client is quite complete, and would, with minor modifications, serve as an operational program to obtain data for any weapon system. However, the Phase III version will substitute METCAST queries. METCAST, a TEDS data-access program, uses http for remote access, rather than allowing direct INFORMIX client calls into the database. METCAST can provide a single, generic interface to TEDS, a solution that improves control over TEDS access and reduces the expense of changes to the TEDS data structures. The METCAST approach has the added benefit that it uses the http port, which is almost always open in a firewall-protected system (otherwise there would be no internet access for the users of that system), instead of the INFORMIX port, which is generally not open.

The METPLAN Graphics Server is complete, for the purpose of displaying stoplight displays for JSOW, point-and-click displays for any weapon, and overlays and other products (e.g., wind streamlines) for any application. METPLAN's overlaying technique is to shade polygons with the appropriate color for the particular variable and the thresholds for that variable.

3. Phase III Plans and Recommendations

The specific objective of the Phase III project is to provide Meteorological and Oceanographic (METOC) data to all mission-planning functions in the Joint Mission Planning System (JMPS) and to other mission planning systems such as TTWCS through a single software interface called METPLAN.

METPLAN will exist as either a JMPS Framework component fulfilling a requirement to supply METOC data to all JMPS UPCs and/or as a stand alone GCCS segment for use by any non-JMPS MPM. It will be DII COE compliant, so that it can be accessed and used by any other DII COE-compliant system on the GCCS LAN.

METPLAN will automatically fetch the most recent and relevant weather products and numerical data from TEDS. It will supply those data to the client MPM, based on a one-time registration message from the client, specifying the desired interface and weapon-specific data format. The client MPM can incorporate those data in mission planning, as appropriate.

In addition to data handling and safeguarding, METPLAN will continue to provide graphical displays of the effects of the weather data on the weapon of interest and displays of the METOC products in the mission area. This feature will require no modification of JMPS UPCs, other than to send the initial registration message, because the JMPS architecture will permit METPLAN to display graphics objects on the tactical window independently. The METPLAN Preferences and Control menus are also independent of the UPC. This feature will enable developers of all JMPS UPCs to integrate METOC data into their function at minimum cost and in a uniform fashion. It will also provide a single display style for the METOC effects and products, across all weapon types.

The METPLAN approach and philosophy is to provide a single form and method for identifying UPC METOC requirements, identifying the data and products that will meet those requirements, and single method of providing a conduit for the selected data into the UPC. The current METPLAN software uses the Preferences GUI to allow the Mission Planner to select a weapon and set the limits for cautionary displays and effects. This GUI also provides a list of catalogued data and products that will be extracted from the TEDS database and made available to the UPC.

The current version of METPLAN runs in conjunction with PFPS as a single-user application. JMPS Ver 1.0 includes PFPS functionality, and we understand that JMPS 2.0 (the first version to include weapon-specific UPCs) will not only keep the PFPS functionality, but will preserve the key elements we need to run METPLAN as an independent agent. This should ease our effort to incorporate METPLAN as a JMPS Framework function, but when the lower-level design specifications for JMPS 2.0 are published in December 2000, we must modify METPLAN to conform to them.

A major task for the Phase III effort is to incorporate the requirements of weapons other than JSOW into the Preferences GUI. Each weapon/UPC will need to identify the METOC data and products needed to evaluate its mission plan. Data entry forms unique to each will need to be designed and added to the Preferences GUI. These forms include rational default values for the cautionary levels and coloring schemes for METOC products.

In Phase II, the METPLAN systems had but a single component to which it had to supply data. As a proof of concept, it was determined that a flat file structure would easily accommodate the synthetic UPC. It is not clear that such a structure will suffice for multiple UPC in an active mission-planning environment. Thus, an important feature of Phase III is the design of an efficient data cache and access software to provide the data to the UPC.

