JSIMS ENVIRONMENTAL TAILORING SERVICES (JETS): TAILORING FOR THE M&S COMMUNITY

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Research jointly sponsored by Defense Advanced Research Projects Agency (DARPA) and the Defense Modeling and Simulation Office (DMSO)

1. OBJECTIVE

On-demand tailoring of environmental data is an important objective of the Joint Simulation System (JSIMS) and has always been a desired tool within the Modeling and Simulation (M&S) community. Tailoring tools that modify environmental data are required to make detailed adjustments to a scenario prior to an exercise and to steer the training experience at run-time to meet specific goals.

In the recent past, changes made to a scenario were primarily visual and had little impact on the simulations. Now, simulation participants envision SNE control that provides the ability to affect run-time changes to a scenario. Because simulations and their operators need data and products that are consistent and derived from a common SNE, tools used to modify the Synthetic Natural Environment (SNE) should assure physical consistency across all five dimensions (time, 3-D space, and parameter). A basic goal of JETS (JSIMS Environmental Tailoring Services) was to develop algorithms that would take changes to the SNE and consistently reflect those changes through the rest of the database at an appropriate level of scientific validity. Although JETS tools have been developed for alteration of atmospheric data, the concepts can be applied to other domains such as the ocean and space. With these objectives in mind, the JETS team developed an algorithm called PFM (Pressure Field Modification) which allows for consistent correlation of user-defined edits blended with the SNE in time and space. The algorithm is based on the concept of relating variable edits to the underlying pressure field and correlating those edits with other SNE fields. The JETS project concluded in November 1999.

DARPA/DMSO funding has recently been provided to implement the JETS-PFM algorithm and demonstrate its use in a simulation framework. JETS II objectives include (a) development of a Graphical User Interface (GUI) as a means by which SNE edits can be defined and executed on a scenario, (b) development of an Application Programming Interface (API) which retrieves and replaces data in an SNE database, (c) implementation of the PFM algorithm, and (d) a data visualization tool. Figure 1 shows a schematic of the functional components of the editing process in JETS II. The JETS GUI is used to define and manage a configuration of edits to be applied to an SNE database. The GUI accepts edit parameters such as variable and edit value and spatial and temporal extent. Once an edit configuration (made up of one or more edits) has been defined, the parameters required for the PFM algorithm are saved in a configuration file. Note that, although PFM is the editing algorithm used in JETS II, other editing schemes of varying complexity could be incorporated into the process. In order for PFM to process the edits, it must access the SNE database through the JETS API. After edits are

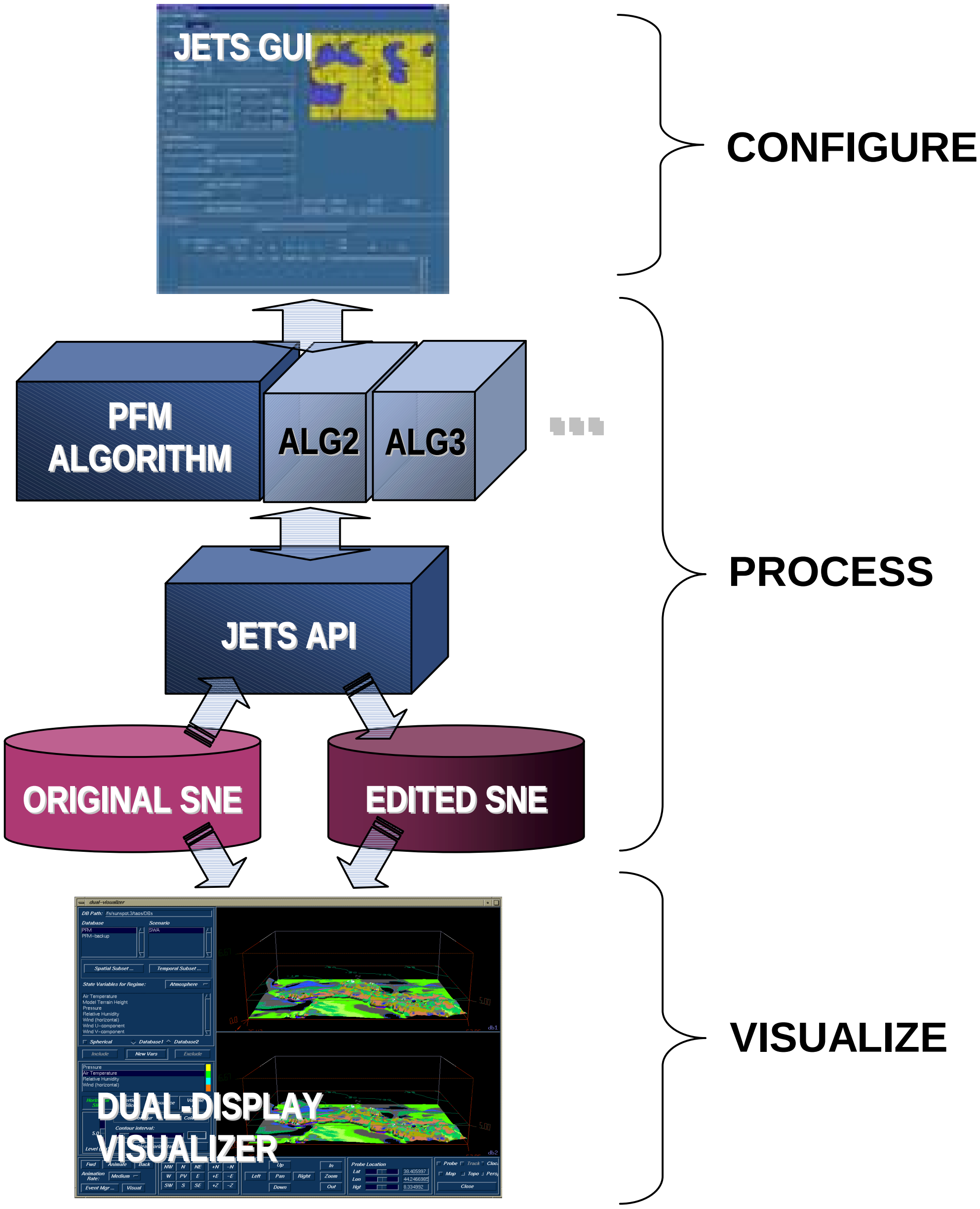

Figure 1 – Schematic showing the flow for defining and processing edits in JETS II

processed, the API is used to write changes to the original scenario back to an edited SNE file. The completion of edit processing also results in communication of that status back to the GUI. At that point, the user may open a dual-display visualizer allowing for a simultaneous view the SNE fields "before" and "after" tailoring. The visualizer accesses the original SNE and the edited SNE.

Section 2 covers each of these functional components in detail. Section 3 discusses JETS II accomplishments including examples of tailored SNE data. Finally, Section 4 offers conclusions and next steps.

2. RESEARCH

2.1 JETS Graphical User Interface (GUI)

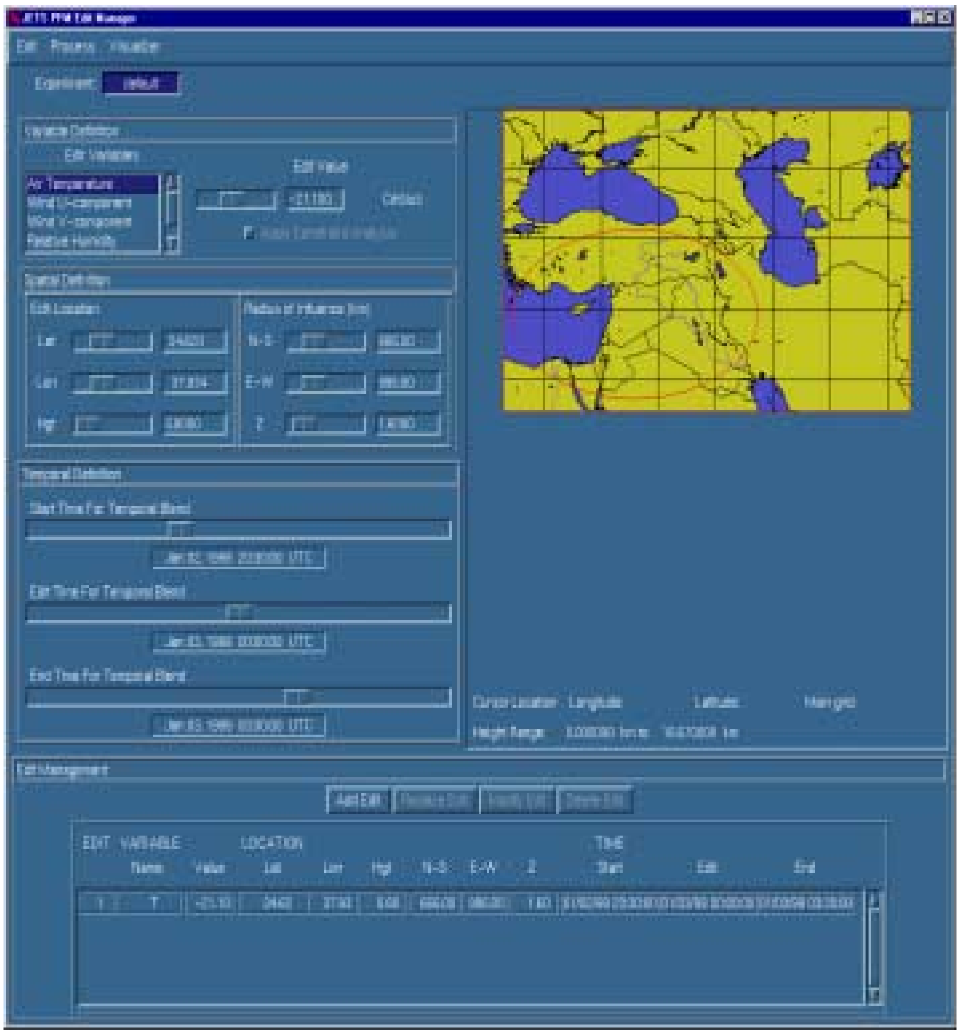

Figure 2 – JETS Main Graphical User Interface

The JETS GUI allows a user to specify one or more edits to be processed on an SNE database. The interface is shown in Figure 2. At the top of the GUI are three menus. The Edit menu is used to save and retrieve edits configurations. This menu also contains options allowing the user to define paths to input and output databases and manage edit configuration files. The Process menu is used to execute the PFM tailoring algorithm (See Section 2.3). Finally, the Visualizer menu is used to visualize the unedited or edited database individually or compare them in a dual-display mode (See Section 2.4).

Below the menus are a set of edit specification widgets used to define the nature and extent of an edit. The variable definition section is used to select the edit variable and perturbation (e.g., temperature, -10 degrees Celsius). Presently, the PFM algorithm allows for editing of 3-D gridded temperature, pressure, relative humidity, and wind (horizontal). Enhancement of the algorithm to allow for precipitation editing is underway. Once the edit variable has been defined, the user specifies the edit location and spatial "region of influence" over which the edit will be blended in three dimensions. Finally, the temporal definition is used to determine the period over which the edit will evolve and dissipate. The temporal blending is particularly useful in preventing unnaturally abrupt changes in the synthetic environment as a result of an edit. The bottom of the GUI is used for "edit management" where edits can be added, modified, replaced, and deleted. The top right corner of the interface is used to display a map of the entire SNE domain and place 2-D ellipsoidal references to each specified edit.

Prior to and during the edit specification process, the user may want to view the target database. This is done using the OASES visualizer which can be called directly from the Visualizer menu. Once the user has finalized the set of edits to be executed on an SNE, the edit specification is saved and the edits are processed. Once the PFM algorithm has completed the tailoring process, the GUI communicates the completion to the user and saves the edited database to disk. At this point, the user may use the dual-display visualizer to compare the "before and after" databases.

2.2 JETS Application Programming Interface (API)

For the JETS II effort, SNE data is stored and managed using the OASES (Ocean, Atmosphere, and Space Environmental Simulator) system. Data is stored in OASES format as a set of four-dimensional (3-D space and time) data objects. The JETS API is designed to retrieve data from the OASES database as required by the PFM algorithm, and replace edited data in a copy of the original database.

The API data retrieval process works as follows. The PFM GUI uses the edit configuration file to determine the spatial and temporal extent of the data to be edited. A data cube containing all of the required data for a single edit is passed back to the PFM code. PFM then modifies the data and returns it, via the API, to a copy of the original database. When multiple edits are performed, the results of one edit are used as the "starting point" for the next edit. Once all of the tailoring is complete, the copy of the original SNE contains all of the modifications made by PFM, and the database can be saved as the edited SNE.

This scheme was chosen because it allows for the efficient processing of edits on very large databases. Because only the "edit region" and "edit period" are operated on, the PFM code does not need to hold the entire database in memory at all times. This is particularly useful when edits are localized and when the input database is very large (high resolution and/or large spatial extent).

2.3 PFM Tailoring Algorithm

The Pressure Field Modification (PFM) algorithm has been described and documented in several published papers (Dailey, 2000; Dailey et al., 1999; Dailey et al., 1998). To bring the modification process into context, the algorithm will be briefly summarized. Figure 3 shows the basic flow of the PFM code.

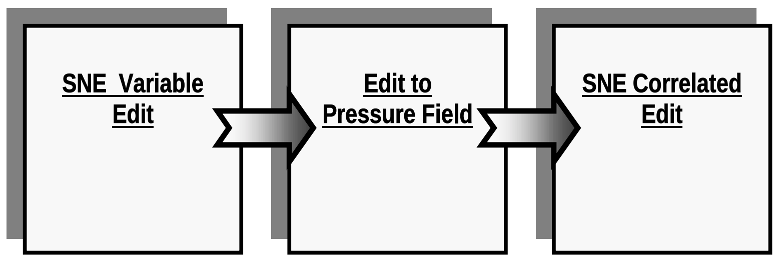

Figure 3 – Schematic representing the process of performing an edit using the PFM algorithm.

The first step is to take the SNE Variable Edit, as defined by the PFM configuration file, and modify the pressure field to reflect that change to the atmosphere. Then, using the computed modification to the pressure field, the other correlated fields are changed. This modular approach allows for simplified enhancement of the algorithm as new edit variables are added. Physical relationships (e.g., Ideal Gas Law, Hypsometric Equation) are used to determine the relationships between the edit variables and pressure. The modification process is by no means trivial. For example, a well understood relationship exists between the pressure field and the wind field (i.e., Geostrophic Equation). However, this relationship applies at upper levels where near-surface turbulent effects are negligible. Within the planetary boundary layer (PBL) where frictional effects are important to flow, the PFM code must make assumptions about what portion of the original wind field can be attributed to surface effects and adjust the results accordingly. These types of assumptions reduce the accuracy of the result but allow for an efficient algorithm that can be used in a distributed simulation training environment. The tradeoff between fidelity and usability is a recurring theme in JETS.

As new more complex fields are added to the PFM scheme, additional assumptions will be required. The goal of the algorithm, however, is to compute *one* possible physically realistic representation of the tailored environment. PFM is not designed to predict the impact of an edit on the evolution of the atmosphere. Rather, the goal is to provide the M&S community with a tool that allows for on-the-fly modification of the SNE while preserving scientific fidelity. It should be noted that a highly unrealistic edit (e.g., complete reversal of the wind direction) may result in unanticipated results.

2.3 Dual-Display Visualization

The dual-display visualizer (DDV) is a very useful tool for after-edit inspection of the data. The application's main interface is shown in Figure 4. Once PFM editing is complete, the unedited and edited databases are loaded into the visualizer and available for display. The user may view a 3-D snapshot of edited fields and manipulate both panels simultaneously. The DDV can also be used to overlay multiple variables. DDV takes advantage of many of the features of the OASES visualizer, used to display a single database.

Another useful feature of the DDV is the ability to place a “probe” anywhere in the domain and retrieve the values of selected variables at that location. The user can place the probe at the edit location, for

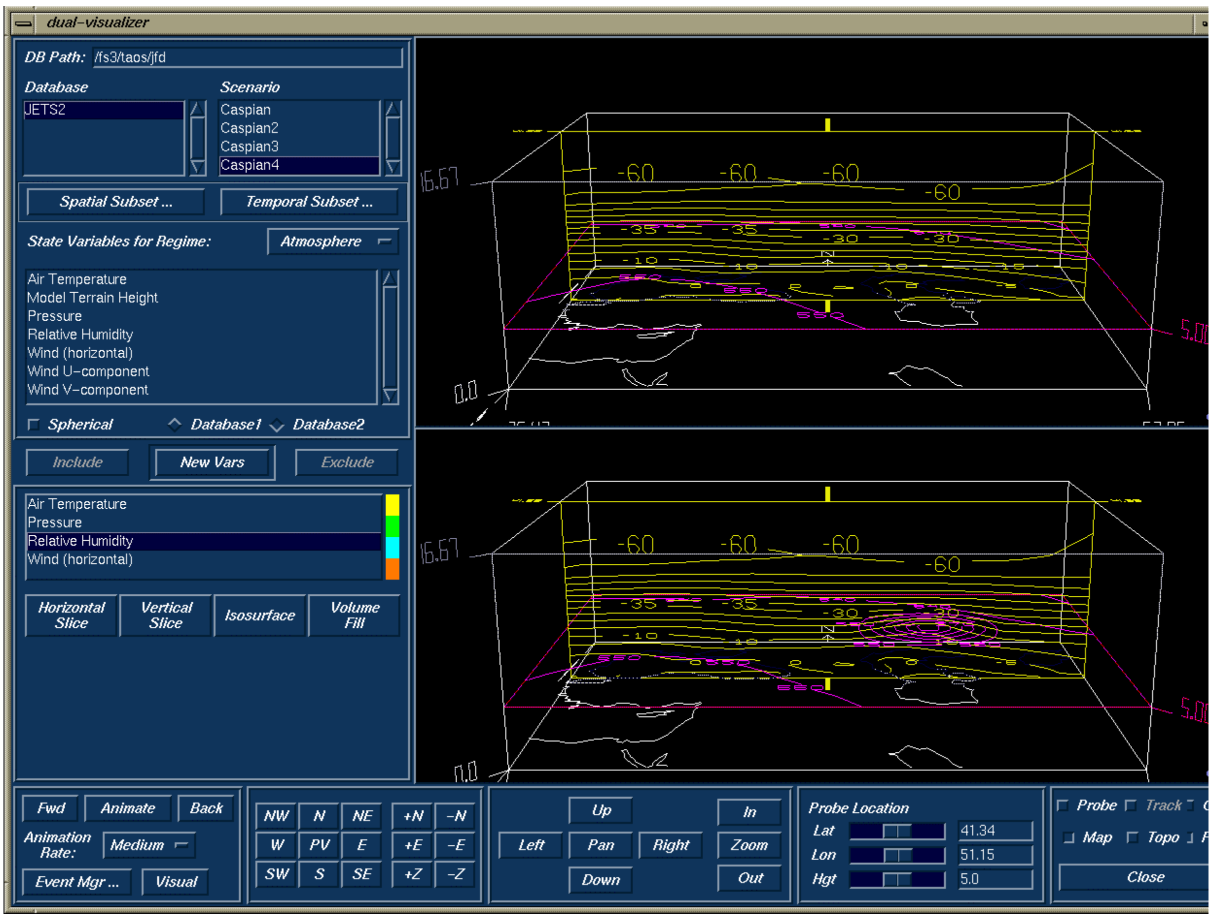

Figure 4 – The Dual-Display Visualizer

example, and verify that the requested perturbation was properly executed, and determine the impact of that edit on other variables in the SNE. An animation feature is also available in DDV to loop through the scenario.

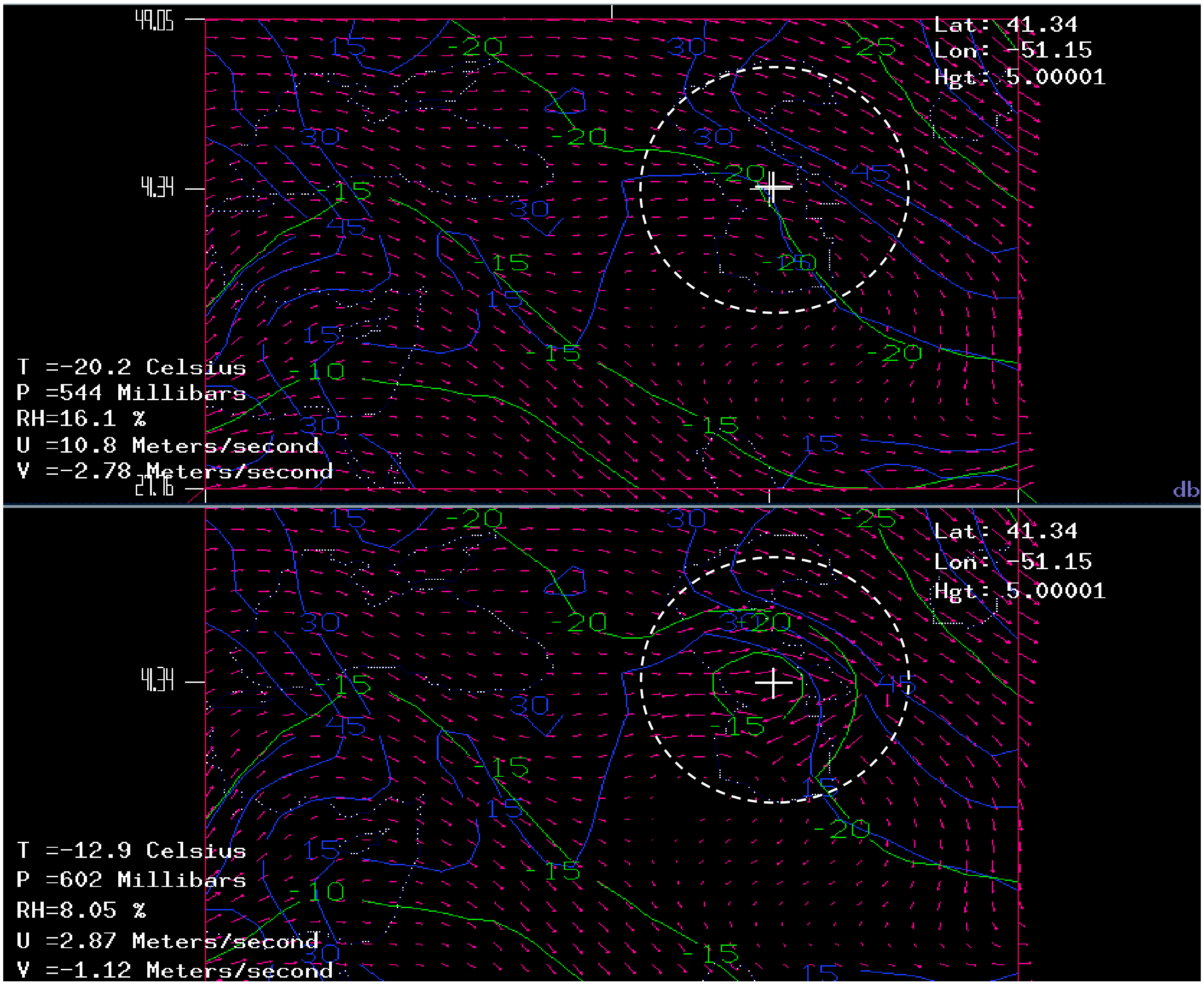

Figure 5 – Results of a 10 degree Celsius perturbation located over the Caspian Sea

3. RESULTS

In this section, two examples of tailoring an SNE are used to demonstrate the use of JETS editing technology. The first example involves an edit made to the temperature field. The second example involves an edit to the relative humidity field. The SNE used in both examples was created using the NCAR (National Center for Atmospheric Research) Mesoscale Model Version 5 (MM5). The MM5 model is run over the Middle East with roughly 1500 km extents in the X- and Y- directions with 19 vertical layers concentrated near the surface. The horizontal resolution is 90 km and the vertical resolution is highest near the surface. Data is saved every 60 minutes for a 24-hour scenario

3.1 Example of an edit to the temperature field

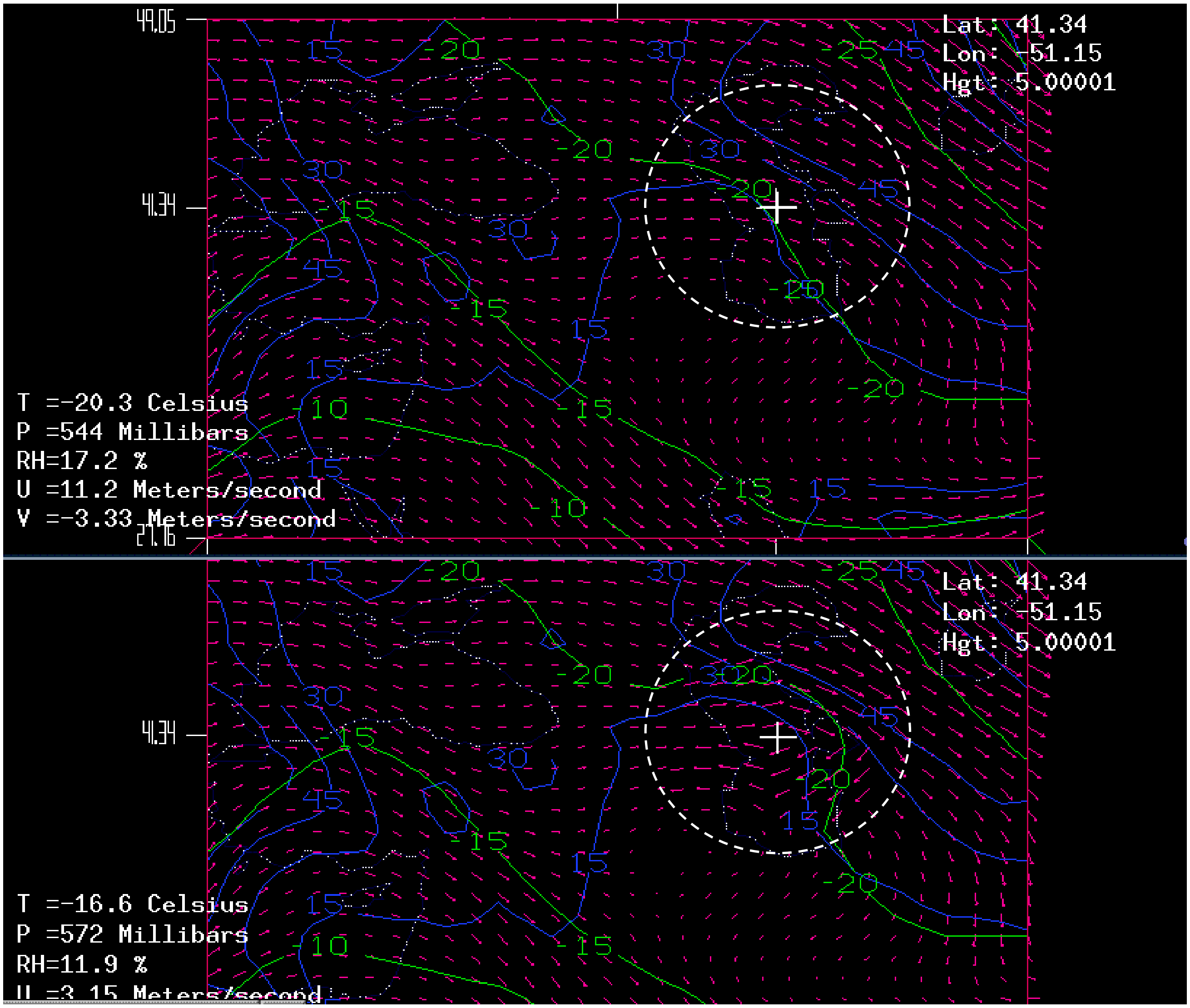

Figure 6 – Results of a 10 degree Celsius perturbations in Figure 5 but two hours prior to the edit time

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A temperature edit of +10 degree Celsius located over the Caspian Sea at a height of 5 km was blended over a five hour period with a spatial coverage radius of about 400 km and a vertical coverage of about 5 km. The results of the PFM tailoring process are shown in Figure 5. (Note: In Figures 5, 6, and 7, the top panel displays the unedited SNE while the bottom panel displays the results of PFM tailoring.)

The temperature field is contoured in green with an overlay of the wind field (red) and moisture field (blue). Note that at the edit time, the temperature has been increased at the edit location (denoted by the white crosshair) and blended within the edit region (denoted by a white dotted line). The increase in temperature without a change in moisture content results in a decrease in relative humidity. This modification to RH is not as symmetric as the temperature edit because the correlation to RH is based on a physical rather than a statistical relationship. As a result, the modification to RH is physically

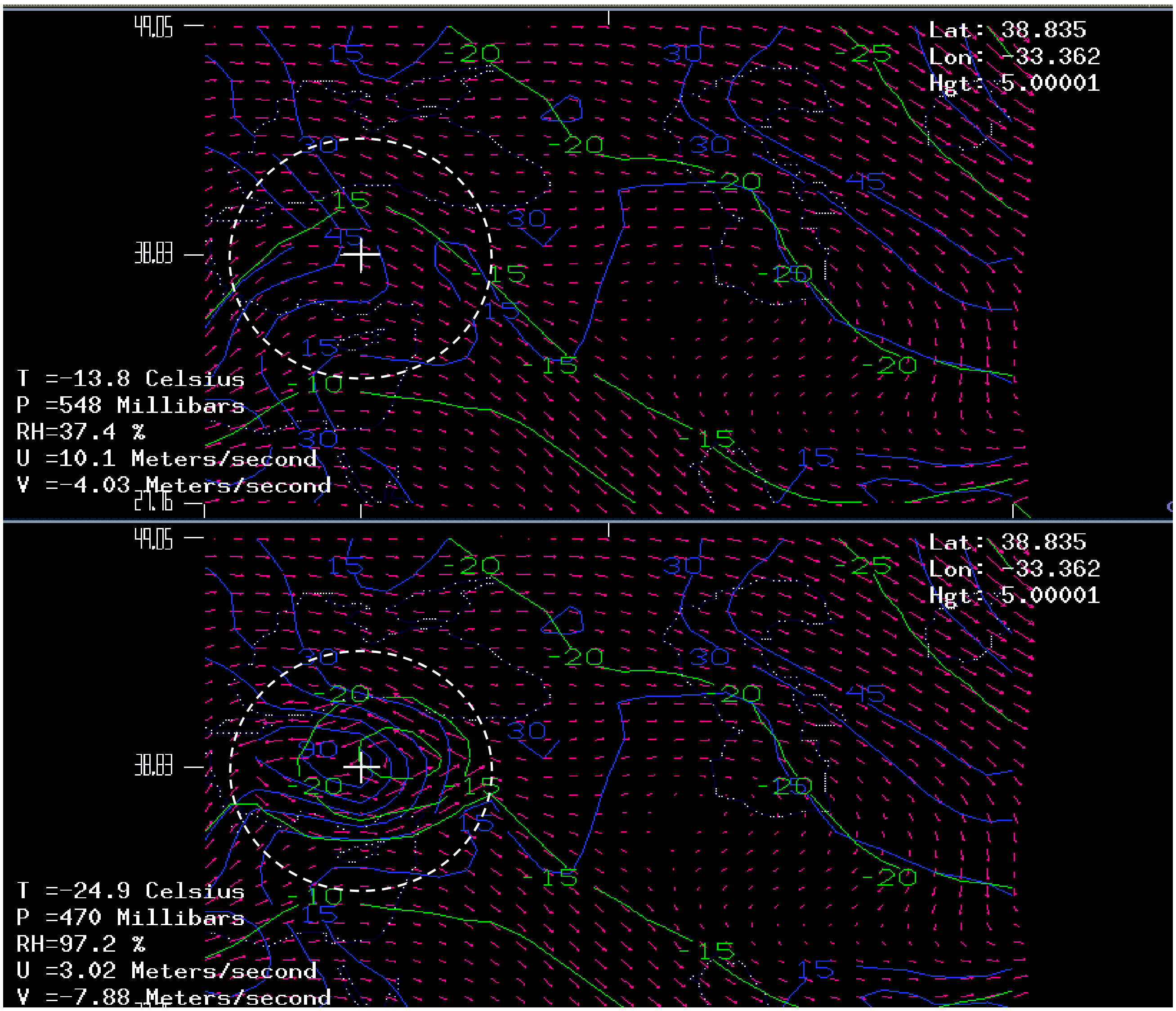

Figure 7 – Results of a 60 percent relative humidity perturbation located over Turkey

consistent with the change to temperature throughout the edit region. The temperature edit also results in an increase to the pressure field (not shown) and a resulting counter-clockwise flow around the edit location shown in the winds in the edit region. Again, the wind field is not perfectly symmetric about the edit location because the wind modification is based on a physical relationship to pressure.

The temperature field is again shown with an overlay of the wind and moisture fields in Figure 6. These panels show the fields two hours prior to the time of the temperature edit. The fields have been temporally blended to prevent an abrupt transition at the edit time. The PFM algorithm first blends the temperature edit in time and then computes the values of correlated variables at all edit times. Note that the temperature field has been modified, but the change is not as drastic as that of the edit time (Fig. 5). Analogous changes to the wind and moisture fields are evident, though they too are less drastic than at the edit time.

3.2 Example of an edit to the moisture field

A relative humidity edit of +60 percent located over the Turkey was blended over a five hour period with the same spatial and vertical coverage as in the temperature edit. The results of the tailoring process are shown in Figure 7.

Note the marked increase in relative humidity (blue) in the region surrounding the edit. The increase in relative humidity is brought about by a decrease in the temperature (green). The perturbed temperature field results in a modification to the pressure field and the resulting circulation shown by the wind vectors in the edit region.

In the case of an edit to the relative humidity field, internal constraints on the editing process must be incorporated into PFM. Specifically, since relative humidity should not exceed 100% in the atmosphere, the user-defined edit is constrained by this physical limitation.

4. CONCLUSIONS

The focus of JETS II is to provide a user-friendly tool for specifying and executing edits on an atmospheric scenario. We have shown that the JETS GUI provides a simple means by which edits can be specified and saved. The PFM algorithm reads the configuration file output by the GUI to modify the SNE in a physically consistent manner. The PFM code communicates with the database and modifies a copy of the original SNE via the JETS API. Once tailoring is complete, the GUI notifies the user of the completion status and allows the user to inspect the results using a dual-display visualizer. The DDV provides simultaneous manipulation of a 3-D image of the “before and after” databases.

The JETS application is only designed to allow for pre-exercise editing. The EnviroFed II project, sponsored by DMSO, will use an enhanced version of the JETS II tool as an OASES component application called ETS (Environmental Tailoring Services). In ETS, the tailoring scheme developed using PFM will be supplemented with a simpler though less realistic “block editing” capability. In addition, ETS will extend JETS II to provide run-time functionality. There are a variety of challenges in using such a tool during run-time including efficiency and lead-time issues. Of course, EnviroFed II will provide ETS pre-exercise tailoring capabilities as well.

We would like to acknowledge the sponsorship of the Defense Advanced Research Projects Agency (DARPA) Advanced Simulation Technology Thrust (ASTT) program and the Defense Modeling and Simulation Office (DMSO) in the research and application work related to JETS and JETS II.

5. REFERENCES

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