EVALUATING INTERACTION IN VISUALIZATION TOOLS IN METEOROLOGY

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ABSTRACT

Meteorological software is rapidly and frequently updated to keep up-to-date with current developments in the field. However, little research has been done concerning the accessibility and efficiency of such tools. In this study, we interviewed three meteorology researchers concerning their usage of the Warning Decision Support System – Integrated Information (WDSS-II) visualization tool, and then observed while completing everyday tasks using the tool. We expected to uncover a wide variety of interaction patterns during these observations. Responses and interactions were also analyzed to find the strengths and limitations of the software. We found that our participants have distinct but overlapping approaches to assigned tasks. Certain features, such as the mouseover readout, were popular with all participants, while other features were used minimally or not at all. Our findings may provide some insight that can be built upon in future studies.

1. INTRODUCTION

Visualization is a method of computing that presents information in pictorial form. It bridges the gap between a computer and the human mind, using the immense processing power of the human visual system in order to help a user quickly gain information from complex datasets (Treinish 1999). Humans' recognition of spatial and temporal patterns in particular is greatly aided by visualization tools.

Though computers have a depth of data processing abilities, visualizations capitalize on the end users' abilities to review and interpret output, and to identify potential errors. They put the analyst in charge by providing a much more convenient and easily reviewed data display than lists or paragraphs of text. In this way, visualization tools provide a balance of information and complexity. They even help to extend the user's attention span and keep a balance between working and external memory (Stasko et al 2007). Research has shown that the best interfaces are interactive, giving constant and continuous feedback (Eick 1997). Multiple window coordinations require fewer user actions and promote more obvious relationships within the data to the user (North and Schneiderman 1997).

Currently in meteorology, visualization tools are of one basic design. However, many different people are using these tools to achieve a wide variety of goals. 2-dimensional displays are the most common, but meteorologists' needs are not met by these outdated presentations (Treinish 1998). Instead of these generalized weather forecasting visualization systems, specialized tools with simple, easy-to-learn interfaces would be ideal for the specific tasks they could be used for (Hibbard et al. 1997, Treinish 1998, Treinish 1999).These specialized tools may be expensive to initially develop, but simple interfaces will lead to improved efficiency and accuracy, and will save on training costs and time in the long run (Treinish 1999).

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The current 2-dimensional and 3-dimensional animations commonly used to present meteorological information generally lead to information overload. “Change blindness” occurs when too many elements are shifting at once in an animation. The user is typically not even interested in most of the changes that are occurring. It has been shown that interaction, rather than animation, leads to easier interpretation of meteorological data. Qualitative summaries of data are often also needed to draw solid conclusions (Turdukulov et al. 2007).

In our study, we utilized the Warning Decision Support System-Integrated Information (WDSS-II) visualization tool. WDSS-II is used by both researchers and forecasters in meteorology to view archived and real-time data. It has a multi-view interface that supports coupling, can display multiple data sources at once, and provides a variety of algorithms that give it spatial and temporal advantages over similar tools in the field (Lakshmanan et al. 2006).

We conducted a study of user interaction in WDSS-II by interviewing representative members of the target user group of meteorology researchers and observing their interactions with the software. Our aim was to evaluate and model how individuals interact with multi-view visualization user interfaces. Discovering how and why researchers use these tools can provide information to both users and developers to make functionality and interaction with these tools more accessible and efficient. We predicted that different users would adopt distinct but overlapping patterns of interaction to complete common tasks using the WDSS-II visualization software. We also expected that multiple views and the display of additional radar information would increase confidence and accuracy when reviewing archived weather events.

2. METHODOLOGY

2.1 *Participants*

We aimed to study individuals who are frequent users of the WDSS-II tool, as identified by the tool’s developers because they represent a variety of research users of the tool. Users of the WDSS-II software were indentified through peer referral and word of mouth, then contacted via e-mail with a formal request to participate in the study. A total of three individuals participated in the study. These participants all considered their primary job to be that of a researcher, though they reported a variety of different goals to their research. Their everyday job activities ranged from algorithm testing and radar quality control to advising students.

2.2 *Interviews*

Participants were interviewed individually. After reviewing informed consent forms, participants were interviewed about their usage of the WDSS-II software. Questions were designed to reveal why meteorology researchers use this tool, how they use it, what issues they have encountered, and what advantages the visualization provides to them. Questions were also included to uncover more about the individuals’ jobs and verify that each participant considered him or herself to be primarily a researcher. Interviews lasted between 7 and 22 minutes, and were audio recorded for later encoding and analysis.

2.3 *Observations*

Observational research of how participants interacted with WDSS-II took place in an individual lab space using a computer running WDSS-II on a Linux operating system. We used a computer, keyboard, mouse, and 24-inch widescreen (16:10 aspect ratio with 1680x1050 screen resolution) monitor.

Participants were asked to complete a series of meteorological data analysis tasks by performing sequences of interactions that were designed to simulate typical research usage of the tool. Data for all scenarios were taken from NEXRAD Level II archives on days and times when tornados, hail, and heavy winds were reported by the Storm Prediction Center’s webpage. The data were retrieved from the National Climatic Data Center (NCDC)’s Holographic Data Storage System (HDSS) Access System (HAS). The WDSS-II ldm2netcdf command converted the data to be viewable in the WDSS-II interface. A video camera recorded the computer screen over the shoulder of each participant for later encoding and analysis. The observational task completion portion of the meeting lasted approximately one hour for each participant.

2.4 *Data Analysis*

Jones, et al. (2004) identified four key questions that should inspire the methods used in studies exploring the usability aspects of an existing product. These questions were considered while designing the study and during interpretation of the responses:

- Whether people are able to make sense of the underlying concepts in a product?
- What features do they use?
- How do existing features support what people use the product for and whether the product could be extended to add value?
- What new features or products could be developed to support discovered and currently unsupported ways of working?

Researchers transcribed interviews into word processing documents for ease of analysis. Observations were also transcribed in parts as text. Each scenario or task was viewed individually for each participant and relevant information was recorded for comparison. Unlike the content of the interview tapes, the content of the observation tapes was not completely transcribed in terms of spoken words. Instead, interactions with the interface and relevant comments made by the participants during these interactions were copied out.

After all interviews and observations had been transcribed as text, similarities and differences in the data, particularly with respect to interaction with multiple views in the interface, were sought. In interview data, responses for each question were compared. For observational data, overall approaches to using the tool were compared as well as particular interactive sequences performed in order to answer questions.

3. RESULTS

3.1 *Interviews*

The interviews provided insight into how the users of WDSS-II viewed themselves, as well as their opinions of the tool. Interviews also addressed users' typical setup and use of the tool, and the limitations they recalled it having. In some instances, short stories about a time when the tool was used either successfully or not were told by the participants in order to convey their experiences with WDSS-II. In this section, responses to interview questions have been grouped into three categories: usage, setup, and tool limitations.

3.1.1 *Usage*

We discovered that some participants use WDSS-II interface every day for their jobs, while others may go for months without using it. The frequency of usage depends not only on the individuals' overall job, but also their current projects and research interests.

The specific uses of the tool also vary greatly from user to user. Our participants reported using WDSS-II to analyze storm structures, develop new algorithms for use with the software, and analyze output from new radar technologies.

When running the software, participants work with primary focus on WDSS-II for at least an hour at a time, with 1 to 3 hours being the most common amount of runtime. Two out of the three participants said that they used a variety of other data sources and video or animation software concurrently with WDSS-II in order to supplement the tool's output. All of the participants generally make notes elsewhere; some use a word processing tool while others find that paper maps are the most suitable way to record findings.

All participants believed that they were not using the full capabilities of the tool. They felt that certain functions and shortcuts are not necessary for their research and have not had a need to learn about them. Also, a learning curve was either implied or addressed by all participants during their interviews. Depending on the user's past experience with similar tools, the amount of time spent in an inefficient learning phase of the software could range from a few sessions to several months.

A few specific functions of the tool were mentioned by participants as being particularly useful or rare. One participant felt that the vertical slice tool was not common in other meteorological tools, and that having a cross-section in certain situations was crucial for learning about the structure of storms. Another participant liked the "overall clean, easy-to-use" interface. Two individuals mentioned that the mouseover data readout was very useful, and all three participants used this function extensively during the observation sessions. All participants also addressed the perceived benefits of increased confidence and efficiency provided by being able to view data from multiple radars at once.

3.1.2 *Setup*

The physical setup for users during their typical usage of a computer running WDSS-II varied somewhat. Two monitors of 15 to 20 inches were most common, though sometimes just 1 monitor is used when doing data analysis with WDSS-II. All participants kept a keyboard and mouse accessible while using the tool. Our setup (Fig. 1) matched these criteria.

Default settings were also dependent on the user's personal preferences and necessary tasks. The user's pre-loaded maps depend entirely upon what the researcher uses the tool for. The scale of the data generally dictates which map or maps are needed. Two participants also mentioned changing the color bars in the "Edit Preferences" menu depending on the situation. Smaller scales are necessary for spotting minor differences in the data.

One participant mentioned using metric, rather than English, units since literature in meteorological research uses metric units. Another read out metric units from the tool during observation and then made a rough mental conversion to English units when evaluating the data. This suggests that measurement units are another matter of personal preference that varies from user to user.

The number of views typically opened in the tool depended entirely on the tasks the user was completing. One participant claimed to only use one window for nearly all work in WDSS-II. The other two participants said that two views was standard, and one of these two participants mentioned using up to four views when making comparisons between algorithms or while looking at multiple radars.

3.1.3 *Tool Limitations*

All participants agreed that a large amount of end user interpretation of the tool's output is necessary to gain useful results. The tool primarily displays the information, and the researcher must analyze that output.

Two of the three participants mentioned the need for 3D capabilities and felt that being able to view data in 3 dimensions in WDSS-II would make their jobs easier by allowing them to see data in a different form. This would also reduce the need to use another tool in addition to WDSS-II for viewing 3D data.

Fig. 1 A typical setup was used for the observational portion of the study: keyboard, mouse, and 24" widescreen monitor.

Two of the three participants also addressed the lack of confidence they felt in algorithms that come from unknown origins. They felt that algorithms that are produced by unfamiliar sources cannot always be trusted to be accurate. Instead, these participants preferred to use only algorithms that they had created themselves. If they chose to use someone else's product, they felt that they needed to know exactly how the algorithm worked in order to use the data it produces confidently in research.

All participants reported having occasional technical issues with the software. These were generally instances where the program would freeze or crash. All participants also mentioned that their proximity to the developers was useful in such situations. They regularly seek the developers' assistance in finding workaround or solutions to their problems. Some participants also made suggestions to the developers for future features that they would like to see in the tool.

3.2 ***Observations***

In observing the participants, we were able to gain a better understanding of how the tool was being used beyond users' verbal responses to interview questions. Details of how certain actions were performed and what habits our participants had developed became clear in this portion of the study. In this section, a few specific tasks are broken down by how each of the participants completed them. Also included are similarities and

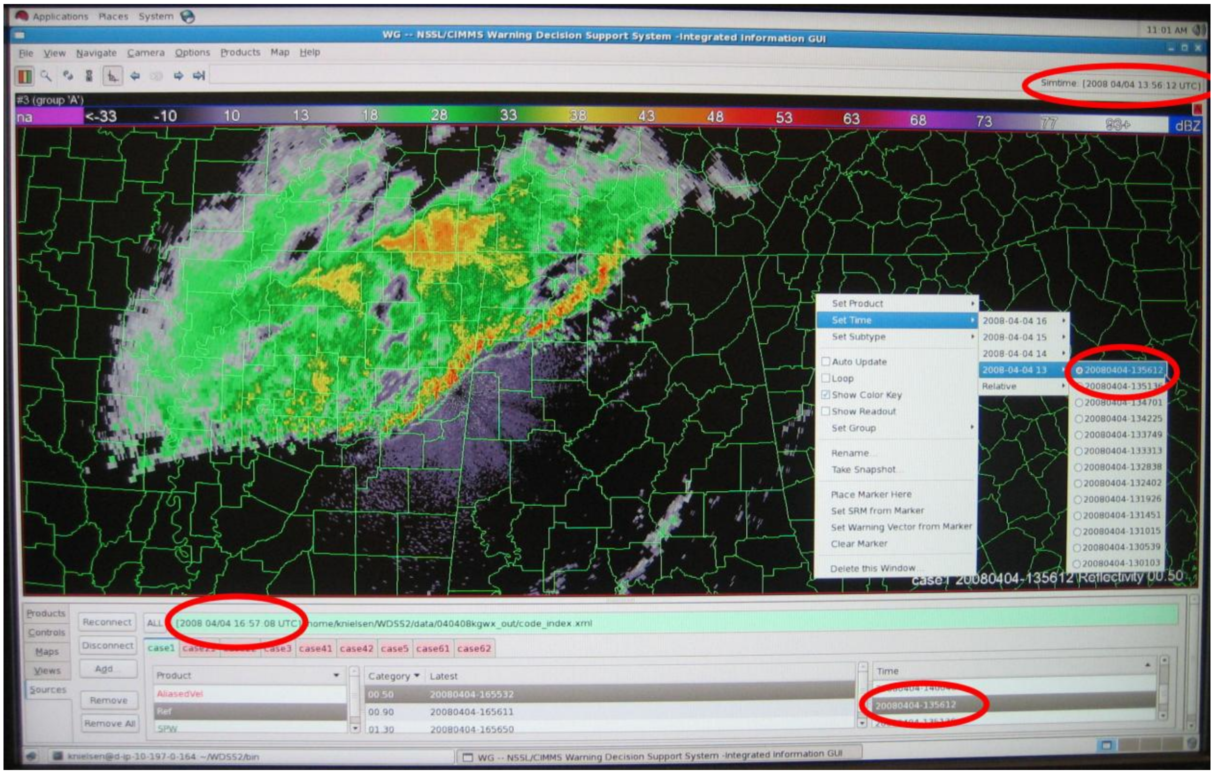

Fig. 2 The date and time of loaded data can be found in many different places in the tool. Locations mentioned by participants are indicated above.

differences that stood out to us when reviewing the entire durations of all 3 observation sessions.

3.2.1 *Date and Time*

All of the participants typically checked the location in the country and the time of year at the start of each task, without being asked. One participant commented during making a diagnosis that he did not remember a severe event at the given place and time, and that was a main reason for why he decided that there had not been one. When given data for the same date and time as given in a previous task, but with an additional radar's information, only one participant commented on having seen the data earlier in the study, and chose to examine only the newly added data because of this.

In order to identify the date and time of the data, two participants referenced the information in the lower right corner of the main view. One of these participants also pointed out the same information in the top right corner of the interface, as a "Set Time" option after right-clicking in the main window, and in the far right box in the Source tab (Fig. 2). The third participant also found the information in the far right box of the Source tab.

3.2.2 *Locating and Centering Data*

When instructed to locate and center the loaded data in the display window or windows, two participants chose to pan and zoom until locating the information. One of these participants used the wheel on the mouse to zoom in and out, while the other held both mouse buttons and slid the mouse forward and back to zoom in and out. Both participants panned by holding down the left mouse button and moving the mouse in the direction they wanted the information to move.

The third participant used the "jump to" button in the products tab. This was by far the most efficient way to find the area of interest, and most of the available data fit in the view defined by the software. If multiple views were given, this participant linked the views so that both views would show the exact same display of the information.

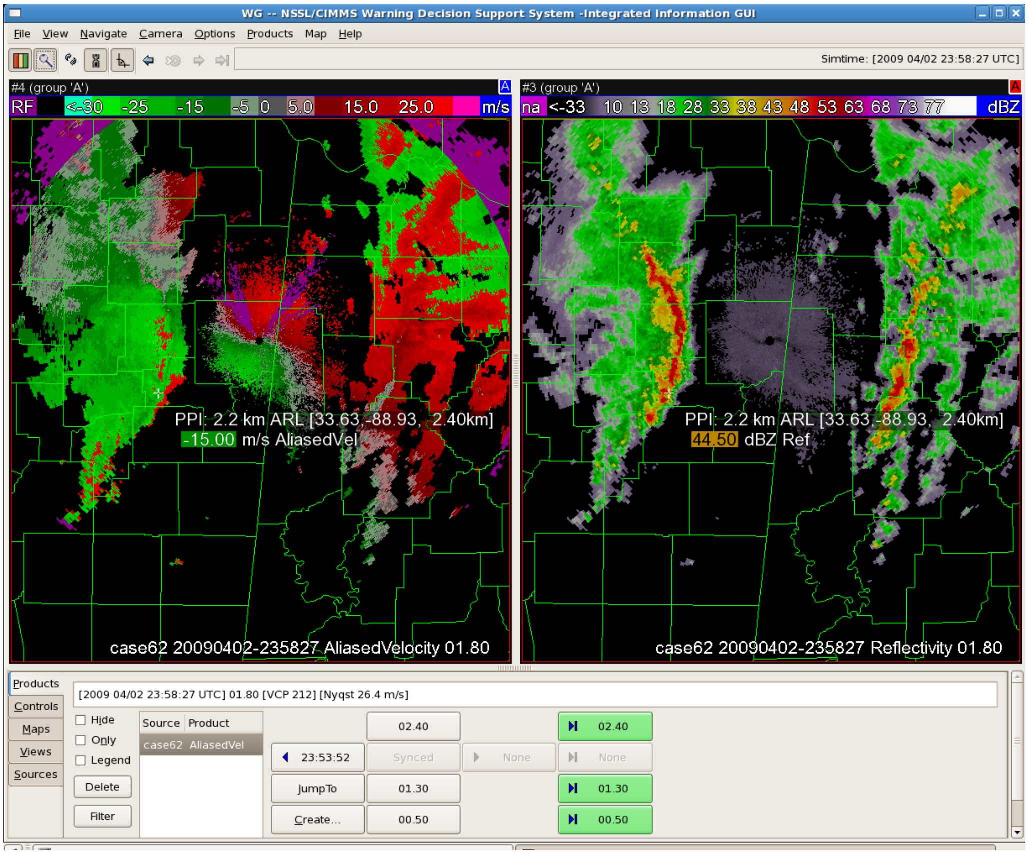

Fig. 3 Mouseover data readout allowed users to compare quantitative output across views.

3.2.3 *Identifying the Radars*

Participants had varying knowledge of the radar locations. One participant was able to give an accurate approximate location of the radar and about half of the radar names without the tool's assistance. Another participant was able to identify about half of the radars by giving an approximate location, and the third could not volunteer any information about a radar's location without the tool's assistance.

When allowed to use the tool, two of the three participants were able to turn on a "Name" option in a provided "Radar Location" map in the Maps tab. The third was unable to use the tool to gain the radars' names, but did provide the county names by turning on the "county name" option in the provided "counties" map in the Maps tab.

Two participants used the mouseover readout (Fig. 3) to learn a radar's latitude and longitude. Both participants turned on this function by click on the shortcut button on the interface's toolbar. The third participant used the "LAT" and "LON" options in the "Radar Location" map to gain this information, then checked the accuracy by turning on the mouseover data readout in the same manner as the other two participants.

3.2.4 *"Main Window"*

It was very common for users, especially those accustomed to using only one main view, to put the radar information that they focused on in the left view. During a single task, some participants switched the information in the two windows up to half a dozen times. Since the left window is the "Main Window" which view-specific commands affect, the participants' favor for left side was likely a learned behavior from the tool. Interestingly, regardless of interaction limited to this "Main Window", and regardless of whether the second view was opened by the researcher or the participant, the information of interest almost always ended up in the left view.

3.2.5 *The Loop Function*

Participants did not use the loop feature. This aspect of the tool's usage may be explained by Turdukulov et al.'s findings on "change blindness," which results from an overload of information when displayed in an animated, rather than interactive, format. If it was turned on as part of the task setup, it was turned off by the participant, and it was never turned on by any participants. Instead of using the loop, participants clicked through the times, using the buttons at both the top and bottom of the display. Some participants changed the time by selecting it in the source, especially if they were interested in the first available time.

3.2.6 *Other Functions*

The mouseover readout capability of this tool was frequently used by all participants. All participants used the shortcut button in the toolbar to turn on the readout, and two of the participants used the "Edit Preferences" menu to change which items would be read out. Sometimes participants left the readout on while focused on other aspects of the interface, while other times they turned the readout off until it was again needed.

When concerned with a single cell or a small area, participants zoomed in. Two participants used the wheel on the mouse to zoom, while one held down both mouse buttons and slid the mouse to zoom. When considering the storm as a whole, or its overall future, participants typically zoomed out to assess all of the available data.

Two participants viewed only one radar at a time, keeping the same radar active in both the reflectivity and velocity windows when 2 views were in use. When asked, these participants responded that they did this because, with both radars' data displayed, information was partially obscured and the window became cluttered. The third participant also commented on the confusion, particularly in velocity data, when information from more than one radar was being displayed.

4. CONCLUSION

In this study, we were able to answer all of the questions posed by Jones, et al. (2004) concerning the usability aspects of existing products:

Whether people are able to make sense of the underlying concepts in a product?

Participants claimed that the tool was helpful for completing their jobs, despite the large amount of end user interpretation required of the tool's output. Each participant had specific features that he or she claimed to favor, based on their usefulness for necessary tasks. Participants were able to complete all requested tasks during the observational portion of the study. We feel that these displays of confident interaction with the tool indicate that users are able to make the necessary amount of sense of the underlying concepts to use the tool effectively.

What features do they use?

During our interviews, participants mentioned a few specific features of the tool that they feel are particularly useful to them. These included the ability to create vertical slices, display multiple radars, display multiple views with the option of linking these views, and view mouseover data readouts.

The observational portion of our study provided more insight into how these features were being used. We saw multiple ways of locating loaded data and describing a radar's location. We also uncovered details of the usage of a few features that had not been mentioned during the interviews. Despite the extensive use of loops in forecasting and displays for the general public, none of our participants used the loop feature, and even turned it off when it was on. All participants also looked at the multiple tilts available for some of the radars, and all three commented on their desire to have as many tilts as possible to make a comprehensive diagnosis.

How do existing features support what people use the product for and whether the product could be extended to add value?

By observing frequent users of the WDSS-II tool, we discovered that certain features are more important to some individuals than they are to others. For example, the vertical cross-section feature was used by a researcher concerned with analyzing storm structures, but not by a different researcher with other meteorological interests.

As past research suggests, specialization of visualization tools in necessary for their effective use (Hibbard et al. 1997, Treinish 1998, Treinish 1999). In WDSS-II, algorithms provide this necessary narrowing of scope. All participants described situations in which algorithms helped them to look at particular details of their data during research.

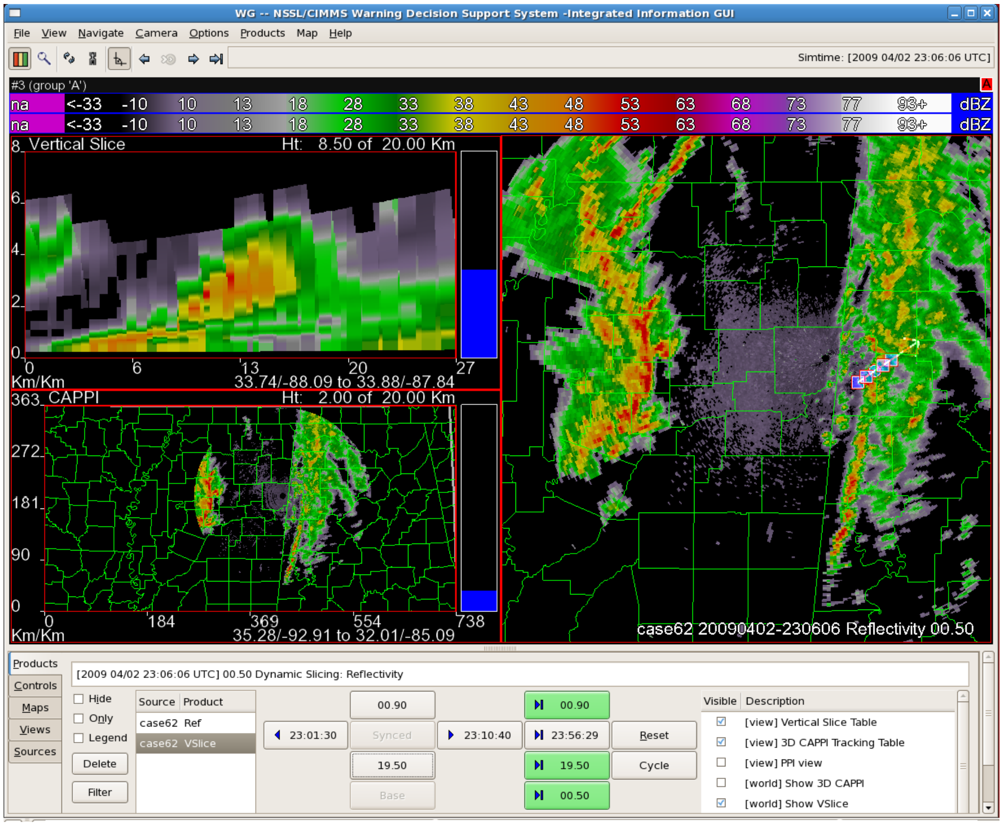

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Fig. 4 Vertical slices provide cross-sections of data of interest along a user-defined line. Participants cited this feature as a valued step toward 3D capabilities.

All of the participants also mentioned speaking directly to the tool's developers about their individual needs. Additional algorithms are constantly being developed, and confidence issues were raised by the participants. Added information about the source and details of the new algorithms may help to keep the tool up-to-date with meteorological advances while also appealing to researchers.

What new features or products could be developed to support discovered and currently unsupported ways of working?

Multiple participants mentioned the need for 3D capabilities to be added in order to keep up with other meteorological tools. Currently, the only way to view data in a 3D manner is to look at a vertical cross-section (Fig. 4) and manually move the cross section in the corresponding view while maintaining a mental catalogue of these cross-sections.

Our study was not without limitations. All participants mentioned that they normally used dealiased velocity data, rather than the aliased data that was provided in the study. One participant also commented that the tasks were unlike those he would normally complete for his job. All three participants noted the computer's limited processing abilities and the need for as many tilts as possibly to be given with the radar data. In tasks where only a limited number of tilts were given, complete diagnosis of the situation was more difficult, or even impossible, claimed the participants.

Due to our limited understanding of the context in which the software was being used and what jobs it helped users to complete, our design did not provide a comprehensive analysis of researcher's interactions with WDSS-II. This study has, however, provided an understanding that can help in the designing of future research. In such future study of this or similar visualization tools in meteorology, a larger sample with tasks and resources chosen on an individual bases or after interviews designed to understand the standard tasks participants are using the tool to complete may provide a more comprehensive understanding of how researchers interact with such tools.

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