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STATUS ON THE INTEGRATION OF THE NSSL FOUR-DIMENSIONAL STORMCELL INVESTIGATOR (FSI) INTO AWIPS

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1. INTRODUCTION

This manuscript details the status of a project being coordinated to integrate a 3D/4D base radar data display tool developed at the National Oceanic and Atmospheric Administration's (NOAA) National Severe Storms Laboratory (NSSL) into the NOAA National Weather Service (NWS) Advanced Weather Interactive Processing System (AWIPS; Wakefield, 1998). This prototype AWIPS radar display tool is currently known as the *Four-Dimensional Stormcell Investigator (FSI)*.

The FSI project is one of the many activities being coordinated between NSSL and the NWS Meteorological Development Laboratory (MDL) to assist NWS meteorologists in making hazardous weather warning decisions. NSSL is scheduled to complete the prototype version of the FSI during the summer of 2006. MDL also is on schedule to complete the work to integrate the FSI into the AWIPS Display Two Dimensions (D2D) application. Testing of the prototype at several NWS Weather Forecast Offices (WFO) will commence once the hardware and software to support the FSI is made available for AWIPS.

For detailed background information about the operational requirements and design of the FSI, consult Stumpf et al. (2005). Additional information about the FSI project, including movie animations of the FSI in use, is provided at this website:

http://www.nws.noaa.gov/mdl/dab/FSI_index.htm

This manuscript will instead provide only a brief overview of the application (including some recent screen shots), a discussion of the process that was undertaken to gain acceptance of the FSI into the operational AWIPS system, real-time test plans, training considerations, and eventual deployment in light of new operational concepts and technological advances upcoming for the NWS.

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2. DESIGN

The FSI is based on the NSSL Warning Decision Support System – Integrated Information (WDSSII; Hondl 2002) 3D display application. The FSI application allows users to dynamically "slice-and-dice" Weather Surveillance Radar – 1988 Doppler (WSR-88D) radar data using advanced four-dimensional (4D) visualization techniques.

The FSI is launched from the AWIPS D2D via the use of an interactive D2D extension in which users will point-and-click on a storm of interest. This action opens a new linked four-panel display window on the workstation, zoomed and centered on the coordinates of the mouse click, displaying the radar data source matching the D2D pane. Figure 1 shows a screen capture of the current prototype four-panel layout. The panels include:

a. *Plan Position Indicator (PPI).* The user can choose to view data on a constant elevation angle as well as draw and interact with a vertical cross-section reference line (more below). The view is locked as a zenith-pointing plan view.

b. *Constant Altitude PPI (CAPPI).* A horizontal cross-section. The user can choose the constant altitude using a slider bar, dynamically updating the CAPPI data. The view is locked as a zenith-pointing plan view.

c. *Vertical Dynamic XSection (VDX).* From either the PPI or 3DF panel, the user can manipulate the cross-section reference line and the VDX data display will dynamically update on-the-fly. The view will be locked perpendicular to the plane of the cross-section.

d. *The 3D Flier (3DF).* The radar data in this panel will be plotted as 2D textures in true 3D earth coordinates. The selected elevation angle (PPI) is plotted as a conical texture, and any vertical or horizontal cross-section textures that are being displayed in the VDX and CAPPI panels respectively will dynamically update as the user interacts with them. The user will be able to "fly" about the data in 3D fashion.

FSI components are summarized as follows:

- D2D All-Tilts “look and feel” radar volume browsing controls.
- No frame count limits (as in D2D’s “all tilts” products); access to the entire AWIPS base radar data inventory.
- Animation (looping) controls for the added 4^{th} dimension.
- Keyboard shortcuts (“hotkeys”) for selection of elevation angles, volume scan times, radar products, and other navigation short-cuts (e.g., reset to zenith view).
- Rapid panning, zooming, pitch and yaw of 3D data.
- Dynamic cross section capabilities (vertical and horizontal). Users can manipulate the location of a cross section using mouse controls, and cross-section textures will dynamically update on-the-fly in the other panels.
- Display all three radar data moments (reflectivity, velocity, and spectrum width) as well as storm-relative velocity with the ease of toggled keyboard shortcuts.
- Navigation of the radar data using *virtual volume scans* (Lynn and Lakshmanan 2002). Elevation scans from individual radars will update and replace the previous elevation scan in the virtual volume such that there is always a complete volume scan of tilts at all times. Cross sections will always contain the latest elevation scans of data and always be complete.

3. PROOF-OF-CONCEPT TESTING AND AWIPS IMPLEMENTATION

An NWS Operations and Services Improvement Process (OSIP) task was initiated for the FSI in December 2005. For those in NOAA with access to the OSIP documentation, the FSI is listed as Task 05-084:

https://osip.nws.noaa.gov/osip/projectDetail.php?projectid=05-084

The OSIP is a requirement for new applications to be integrated into NWS software systems. Via the OSIP, and through selection by the AWIPS Software Recommendation and Evaluation Committee (SREC), the FSI was selected to be implemented in the AWIPS Operational Build Version 8.2 (OB8.2), which is tentatively slated for release just prior to the 2008 convective season. 3D radar visualization technology was also considered a top priority by field meteorologists who participated in the 1st Workshop on Severe Weather Technology for NWS Warning Decision Making (Magsig and Stumpf, 2006).

Proof-of-concept testing of the FSI was originally scheduled for the spring and summer of 2006 at one WFO in each of the four CONUS regions. The software release for this testing was intended to be OB6.1. However, the fielded operating system (Red Hat Enterprise 3) and video graphics capabilities of the LX display workstations did not support the FSI software. Therefore, a decision was made to postpone the FSI alpha testing until the LX workstation capabilities could support the FSI software. This required the Red Hat Enterprise 4 operating system which would be deployed with OB7.1 in the fall of 2006.

The current fielded LX workstations do not have the video graphics card technology to support the advanced 3D visualization techniques utilized by the FSI. Fortunately, the AWIPS program is scheduling a technology refresh of the LX hardware during late 2006. MDL worked with the AWIPS contractor (Raytheon) to conduct extensive testing of the FSI and AWIPS display software with a number of video graphics cards on prototype new LX workstations. As a result, the new LX workstations will be equipped with an NVIDIA GeForce 7600 GT 256 mb PCIe graphics card to support 3D visualization in the FSI and any potential future 3D visualization applications in AWIPS.

The new LX workstations are tentatively scheduled to begin deployment to the field in the winter 2007, with operational acceptance tests (OAT) tentatively scheduled to be conducted at several WFOs by mid- to late-Fall. Therefore, we hope to coordinate our first proof-of-concept test of the FSI with the hardware OAT at the Huntsville, AL, WFO starting in October or November 2006. Feedback from this test will be used to refine the FSI application prior to the OB8.2 software development cycle, which will begin in the winter of 2007.

Other tests are planned after the release of the new LX hardware to the field during the 2007 convective seasons. These include tests at the Omaha, NE and the Norman, OK, WFOs. Additional testing is possible at WFO locations in Eastern, Western, and Pacific Regions, with locations and times still to be determined. Feedback from these tests will be used to further refine the FSI for release as a second version for OB9.1 or beyond (release schedule and SREC recommendation permitting).

The spring 2007 Norman test will be conducted under the auspices of the NOAA Hazardous Weather Testbed (HWT; http://www.nssl.noaa.gov/hwt/). HWT activities to date have traditionally been focused on the Storm Prediction Center’s (SPC) “Spring Program”. However, starting in 2007, there will be a new WFO component of the HWT focusing on the shorter-term convective weather warning needs known as the HWT Experimental Warning Program (EWP; http://ewp.nssl.noaa.gov/). The EWP is a joint effort by MDL, NSSL, and the NWS Warning Decision Training Branch (WDTB). The EWP is a vehicle for testing new hazardous weather services, products, and applications in a real-time operational setting, with specific emphasis on supporting future NWS Concepts of Operations (ConOps). Although the EWP is physically located in Norman, OK, it is intended to be a *national* testbed, with planned capabilities to simulate the technological environment of any WFO or "WFO cluster" nationwide.

In addition to these field tests, MDL is working with the Klein Associates Division of Applied Research Associates (KAD/ARA), a leading decision science company which promotes the application of Cognitive Task Analysis (CTA) methods in the design of decision support systems. We will be working with KAD/ARA to integrate expert human factors analysis into the development of the FSI. The FSI analysis will serve as a proof-of-concept project for possible use of CTA for other NWS decision support system applications.

Planned future enhancements are pending funding decisions, but include support for the display of polarimetric radar moments and Terminal Doppler Weather Radar (TDWR data). There are also plans to incorporate dynamic 3D volume rendering and 3D isosurfaces into the FSI similar to those available in other data visualization applications such as Vis5D (Hibbard and Santek, 1991). Also, the NSSL WDSSII software was designed for the visualization of many different earth-centric weather sensor data, including high-resolution 3D multiple-radar grids (Zhang et al. 2005, Lakshmanan et al. 2006) and algorithms which integrate these grids with other sensors and environmental data (Stumpf et al. 2003, Stumpf et al. 2004). The evolution of FSI from WDSSII has put the FSI in position for incorporating these new multi-sensor data and applications.

4. OPERATIONAL IMPLICATIONS OF 3D RADAR VISUALIZATION

Field tests suggest that there are some conceptual challenges to adjusting to 3D visualization. In the past, there was some limited testing of displays supporting 3D visualization in the WFOs, including the AWIPS Display 3-Dimensions (D3D; McCaslin et al. 1999; Szoke et al. 2001; Szoke et al. 2002). The WDSSII display was also tested at various WFOs over the past 4 years (Scharfenberg et al. 2005). Results from both sets of tests indicated that there was some consternation over using 3D visualization in the operational arena as users were too used to seeing data in 2D views. In surveys, some users of WDSSII also noted apprehension about using a system that was completely separate from their AWIPS systems, which they were most used to. Learning the knobology of two different display systems, one of which was not connected to their software to generate and disseminate severe weather warnings, was considered a limitation. This was a primary driver for integrating the FSI into AWIPS, and to make some of the basic radar browsing functions similar to the current D2D displays.

In May 2006, Gibson Ridge Software (http://www.grlevelx.com) released a version of their WSR-88D Level II browser known as the Analyst Edition (GR2AE) that offered 3D visualization of base radar data (isosurfaces and 3D volume rendering) in a very easy to use graphical interface. Although this interface is different from the D2D radar interface, and the software must be run outside the AWIPS environment (it is only supported in the Microsoft Windows operating system), it is starting to gain popularity in several WFOs nationwide. This suggests that 3D visualization of radar data is being embraced by a wider operational audience.

Nietfeld (2006) examines the operational usefulness of a number of applications employing 3D visualization, including those mentioned in this paper. He notes that 3D visualization has helped their WFO (and some other WFOs) learn new ways to identify severe weather signatures, as well as discover new signatures in the three basic radar data moments.

The traditional experience from the field, as well as this budding experience using 3D visualization in a (currently) small sector of WFO operations is being blended with current understanding of storm structure and evolution to aid in the development of training and education for the remainder of the NWS. In order to make quick and effective decisions, the operational meteorologist has to be well versed in the understanding of the meteorological signatures associated with severe weather from a non-traditional 3D perspective. MDL is working with the WDTB to develop this kind of training before the FSI is released nationwide. Although proper training on the knobology of the FSI is required, training will strongly focus on the science and decision-making aspects of understanding and viewing storms in 3D. This training will include innovative ways to compare storm features using only traditional 2D methods (e.g., via "all-tilts"), alongside the methods employing 3D visualization. The training is also going to link representations of hazardous weather from a remote sensing perspective to visual observations as well (Magsig et al. 2006b). The FSI will be incorporated into the Weather Event Simulator (WES; Magsig et al. 2006a) to facilitate displaced real-time warning scenarios and to provide for hands-on training.

We envision that 3D visualization of radar data will be embraced by more and more users in the field and elsewhere via the use of these new tools. Presently, work is underway to refresh the entire AWIPS software technology. It is crucial that the new AWIPS technology supports 3D visualization, and these 3D techniques are central to any new display designs for the NWS.

5. SUMMARY

The benefits of the FSI are summarized as follows:

- *Improved vertical cross-sections*: Dynamic placement and re-position of a cross-section reference line showing real-time updates to the cross-section data. Cross-sections are no longer a one-time requested RPG product, and are instead generated on-the-fly using 8-bit data.

- *Constant Altitude cross-sections (CAPPIs):* 8-bit radar data plotted at constant altitude eliminates the need to sample elevation scan data for altitude or reset elevation angle choices in four-panel displays. Cross-section control is also dynamic, showing real-time updates to the cross-section data.

- *3D visualization:* 8-bit radar data from elevation scans, vertical cross-sections, and CAPPIs are plotted as 2D textures in 3D space. A forecaster can then zoom, pan, pitch, yaw, and fly about the data in 3D.

- *Virtual Volumes:* No volume scan is incomplete. As new elevation scans are updated, they replace the old elevation scans in the virtual volume one-by-one; there are full volumes of data available at all times for cross-sections and data perusal.

- *Access to entire data inventory:* An “All-Tilts” product only allows the forecaster to peruse a sequential order of elevation scan frames. For a 32 (64) frame limit in VCP12, that only comprises 2 ½ (5) volume scans. The FSI allows the user to access any elevation scan in the radar data inventory RPS list, up to 1 or 2 hours of 8-bit data for all elevation scans.

The 3D displays are not designed to replace 2D displays, but augment them. They will reduce the amount of 2D data needed for analysis and assist meteorologists in mental 3D diagnosis. In addition to improving current capabilities, the FSI will support new enhancements (e.g., new sensor data, new multi-radar and multi-sensor applications) based on current research and technology trends. It is hoped that operational 3D visualization of radar data will allow meteorologists to discover new clues and new 3D signatures useful in the diagnosis of severe storms and other weather hazards. 3D (and 4D) visualization in meteorology is expected to provide public benefits through increased warning skill and warning service.

6. ACKNOWLEDGMENTS

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7. DISCLAIMER

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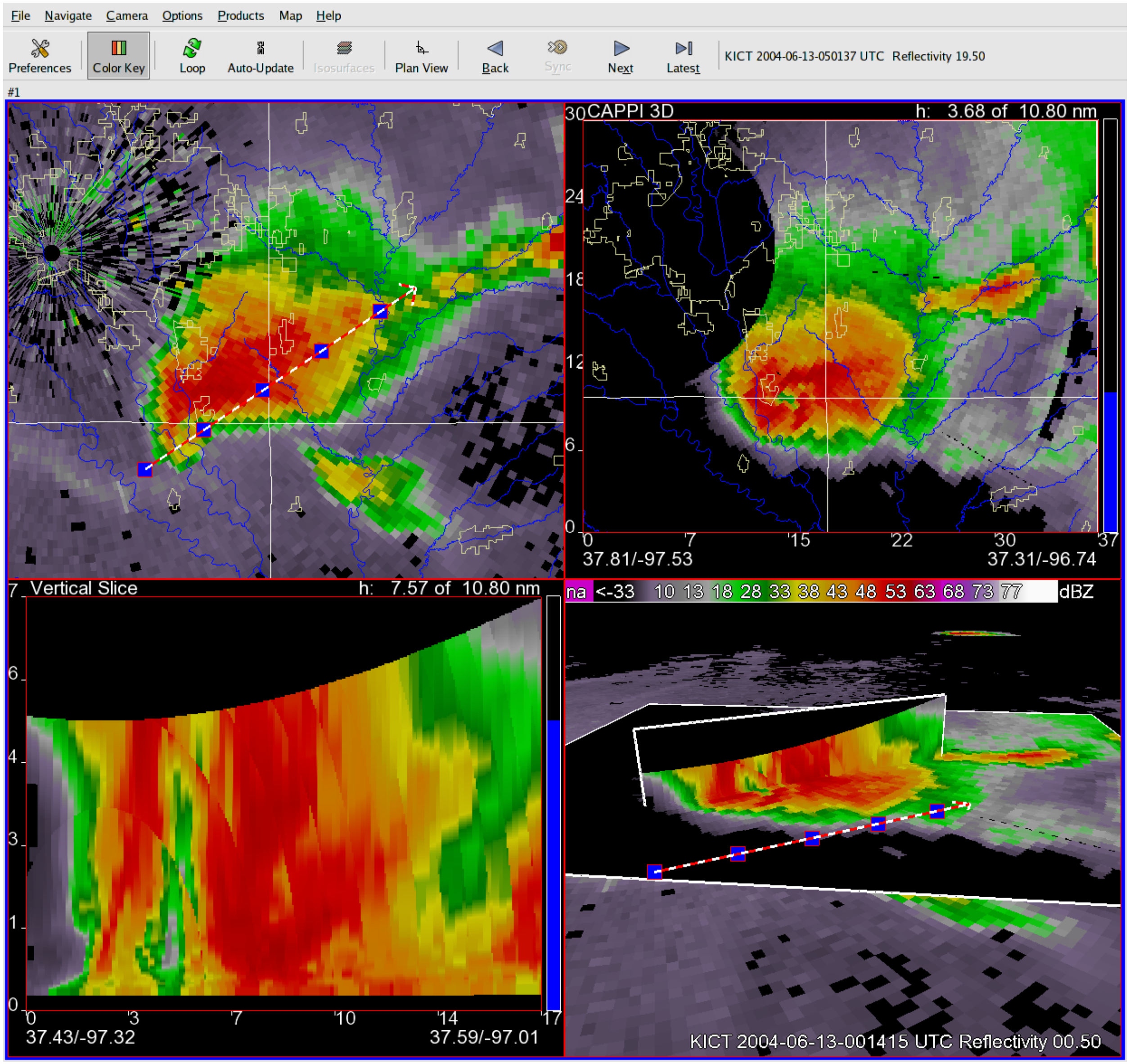

Figure 1: FSI 4-panel Display of reflectivity (dB*Z*). The upper left panel is the *Plan Position Indicator (PPI)* panel showing radar data at a constant elevation angle of 0.5°. The vertical cross-section reference line (with blue control boxes) is also shown. The upper right panel is the *Constant Altitude PPI (CAPPI)* panel showing radar data assembled from several elevation angles at an altitude of 3.68 km above radar altitude. The lower left panel is the *Vertical Dynamic XSection (VDX)* panel, showing the vertical texture of radar data assembled from the current volume scan, and corresponding to the position of the reference line in the upper left panel. The lower right panel is the *3D Flier (3DF)* panel, where textures representing elevation scan data, vertical cross-section data, and CAPPI data are shown. These three textures match the data in the other three panels, and are plotted in true 3D earth-relative coordinate space. Also shown in the bars at the top are menu options, as well as toolbar buttons. The radar data are from the KICT WSR-88D at 0014 UTC 13 June 2004. All units are in Nautical English.