Anvil Tool in the Advanced Weather Interactive Processing System

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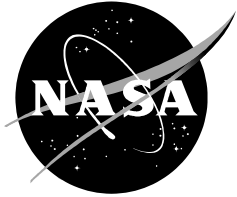
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Executive Summary

Meteorologists from the 45th Weather Squadron (45 WS) and Spaceflight Meteorology Group (SMG) have identified anvil forecasting as one of their most challenging tasks when predicting the probability of violations of the lightning Launch Commit Criteria and Space Shuttle Flight Rules. As a result, the Applied Meteorology Unit (AMU) created a graphical overlay tool for the Meteorological Interactive Data Display Systems (MIDDS) to indicate the threat of thunderstorm anvil clouds, using either observed or model forecast winds as input. In order for the Anvil Tool to remain available to the meteorologists, the AMU was tasked to transition the tool to the Advanced Weather Interactive Processing System (AWIPS).

This report describes the work done by the AMU to develop the Anvil Tool for AWIPS to create a graphical overlay depicting the threat from thunderstorm anvil clouds. The AWIPS Anvil Tool is based on the previously deployed AMU MIDDS Anvil Tool. SMG and 45 WS forecasters have used the MIDDS Anvil Tool during launch and landing operations. SMG's primary weather analysis and display system is now AWIPS and the 45 WS has plans to replace MIDDS with AWIPS. The Anvil Tool creates a graphic that users can overlay on satellite or radar imagery to depict the potential location of thunderstorm anvils one, two, and three hours into the future. The locations are based on an average of the upper-level observed or forecasted winds. The graphic includes 10 and 20 nm standoff circles centered at the location of interest, in addition to one-, two-, and three-hour arcs in the upwind direction. The arcs extend outward across a 30 degree sector width based on a previous AMU study which determined thunderstorm anvils move in a direction plus or minus 15 degrees of the upper-level (300- to 150-mb) wind direction.

This report briefly describes the history of the MIDDS Anvil Tool and then explains how the initial development of the AWIPS Anvil Tool was carried out. After testing was performed by SMG, 45 WS, and AMU, a number of needed improvements were identified. A bug report document was created that showed the status of each bug and desired improvement. This report lists the improvements that were made to increase the accuracy and user-friendliness of the tool. Final testing was carried out and documented and then the final version of the software and Users Guide was provided to SMG and the 45 WS. Several possible future improvements to the tool are identified that would increase the flexibility of the tool.

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1.   Introduction

Launch Weather Officers (LWOs) from the 45th Weather Squadron (45 WS) and forecasters from the Spaceflight Meteorology Group (SMG) have identified anvil forecasting as one of their most challenging tasks when predicting the probability of violations of the Lightning Launch Commit Criteria (LCC) (Krider, et al. 2006) and shuttle Flight Rules (FR) (NASA/JSC 2004). As a result, the Applied Meteorology Unit (AMU) developed a tool that creates an anvil threat corridor graphic that can be overlaid on satellite imagery using the Meteorological Interactive Data Display System (MIDDS). The tool helps forecasters estimate the locations of thunderstorm anvils at one, two, and three hours into the future. It has been used extensively in launch and landing operations by both the 45 WS and SMG. The Advanced Weather Interactive Processing System (AWIPS) is now the primary weather analysis and display system for SMG in lieu of MIDDS. To ensure the Anvil Tool remains available for operations, SMG tasked the AMU to transition the tool from MIDDS to AWIPS.

This report contains a brief history of the development of the Anvil Tool in MIDDS, and then describes the transition and development of software to AWIPS.

2.   MIDDS Tool Development

The Anvil Tool in MIDDS was developed by the AMU in three phases. Phase I established the technical feasibility of developing an observations-based forecasting technique using the relationship between anvil length/lifetime and the average wind velocity and moisture content in the anvil layer (Lambert 2000). In Phase II, the AMU developed a nowcasting anvil threat sector tool (Short and Wheeler 2002) that was transitioned into 45 WS and SMG operations. Using upper tropospheric wind data from current rawinsonde observations, the tool created a graphic that showed the areas where thunderstorm formation could produce anvil clouds that would threaten a user-selected area of interest. After calculating the 300- to 150-mb layer-average wind velocity, the tool created a graphic with the following features:

- 20 n mi standoff circle centered at the station of interest,

- 30 degree sector width, and

- One-, two-, and three-hour arcs in the upwind direction.

The graphic could be overlaid onto a weather satellite or radar image. In Phase III, the AMU added the capability of creating a graphic using Eta and Medium Range Forecast (MRF) model point data, in addition to rawinsonde observations (Wheeler and Short 2003).

The tool was modified again in the Updated Anvil Threat Corridor Forecast Tool task (Wheeler 2005). The software was updated to accommodate changes in the data formats of the rawinsonde observations and model forecast data. Three changes had taken place since the Phase III task:

- The operational upper-air sounding system at Cape Canaveral Air Force Station (CCAFS) changed from the Meteorological Sounding System to the Automated Meteorological Profiling System (AMPS),

- The national model names changed from Eta to North American Mesoscale (NAM) and from MRF to Global Forecast System (GFS), and

- The model data format changed from Meteorological Data to Network Common Data Format (NetCDF).

In addition, the AMU created a graphical user interface (GUI) to allow easier access to the tool. The GUI was written in a scripting language called Tool Command Language (TCL) and its associated GUI toolkit (Tk). Mr. Paul Wahner of Computer Sciences Raytheon assisted in the development. The GUI's Main Menu allowed the user to select the label position, launch complex or site, color, date and time, and data type (Figure 1). The data types included rawinsonde observations, model data, and the 50 MHz profiler observation at Kennedy Space Center (KSC). The Rapid Update Cycle (RUC), NAM, and GFS model forecasts were available.

The sites available included all of the CCAFS and KSC launch complexes, in addition to Melbourne, Florida (MLB), Edwards AFB, CA (EDW), and White Sands Missile Range (WSD), NM. The site selected is the focal point of the Anvil Threat Corridor graphic.
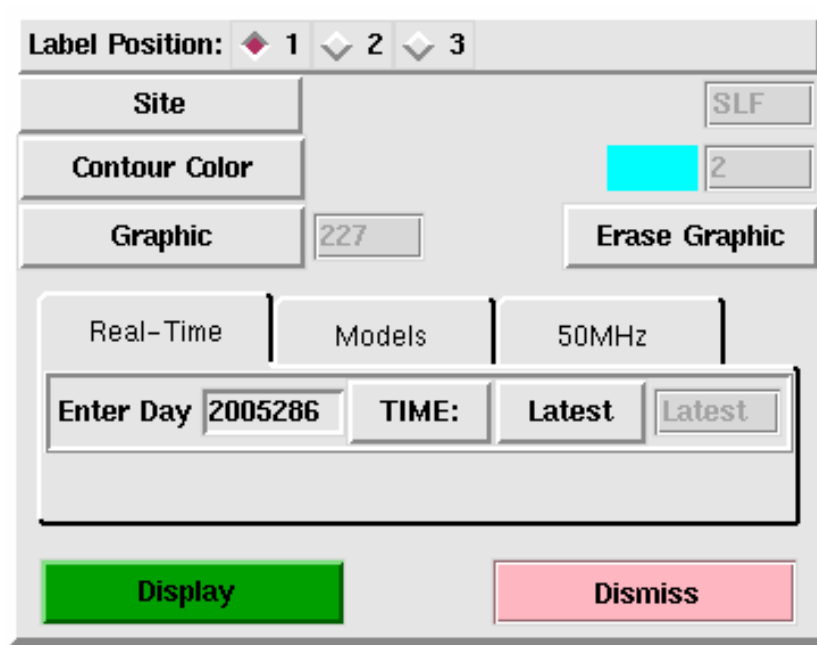
Figure 1. MIDDS Anvil Tool GUI's Main Menu.

3. Creation Of First Version of AWIPS Anvil Tool

The MIDDS Anvil Tool used code written in the McIDAS BASIC Language Interpreter (McBASI) programming language to calculate the 300- to 150-mb average wind velocity, as well as the latitude/longitude points that make up the graphic. To transition the tool from MIDDS, the AMU first rewrote the McBASI code in MIDDS into Tcl/Tk code. This became version 1.1.0 of the AWIPS Anvil Tool. When run in AWIPS, the Anvil Tool first created and displayed a data entry GUI giving the user a choice of using rawinsonde observations, model data, or 50 MHz profiler data (Figure 2). If rawinsonde or profiler data was selected, the user then selected a date and time of the observation. Otherwise, the user selected a model type (RUC, NAM, or GFS), the forecast model's initialization time and the forecast hour. The user then selected a Site, which served as the focal point of the anvil threat corridor graphic. Finally, after selecting an observation Station (or Forecast Hour if model data was used), the 300- to 150-mb average wind was calculated. After the layer-average wind was calculated, the user had the option of creating a new graphic or appending to an existing graphic. The graphic was stored as a Shapefile, which is a Geographic Information System (GIS) file standard developed by Environmental Systems Research Institute, Inc. (ESRI 1998). The Anvil Tool created the Shapefile from a list of latitude and longitude points, using version 1.2.10 of the Shapefile C library (Warmerdam 2007). The menu and product configuration on the AWIPS workstation were modified in order to view the Shapefiles. Finally, the user loaded the newly created map from the Maps menu in AWIPS.

The AMU wrote a draft Users Guide (Bauman 2007) for the Anvil Tool and provided a copy of it to SMG and 45 WS for review and testing. SMG subsequently installed the Anvil Tool on their AWIPS for evaluation and testing. The 45 WS and AMU also tested the Anvil Tool on the AMU's developmental AWIPS. The AMU collected all of the identified software bugs and desired improvements, and compiled an AWIPS Anvil Tool Bug Report.

A comparison between the AWIPS and MIDDS Anvil Tools can be seen using the CCAFS rawinsonde, which is the closest upper-air observation to the Shuttle Landing Facility (SLF), at 1200 UTC, 7 March 2007. For the CCAFS rawinsonde observation, the MIDDS tool uses data in AMPS format, while the AWIPS tool uses data in the National Weather Service upper-air format. Figure 3 shows the MIDDS graphic and Figure 4 shows the AWIPS graphic. Slight differences occur between the AWIPS and MIDDS due to the different data formats. In this case, MIDDS calculated a layer-average wind speed of 80 knots, with a wind direction of 273 degrees. AWIPS calculated a layer-average wind speed of 78 knots and a wind direction of 275 degrees.
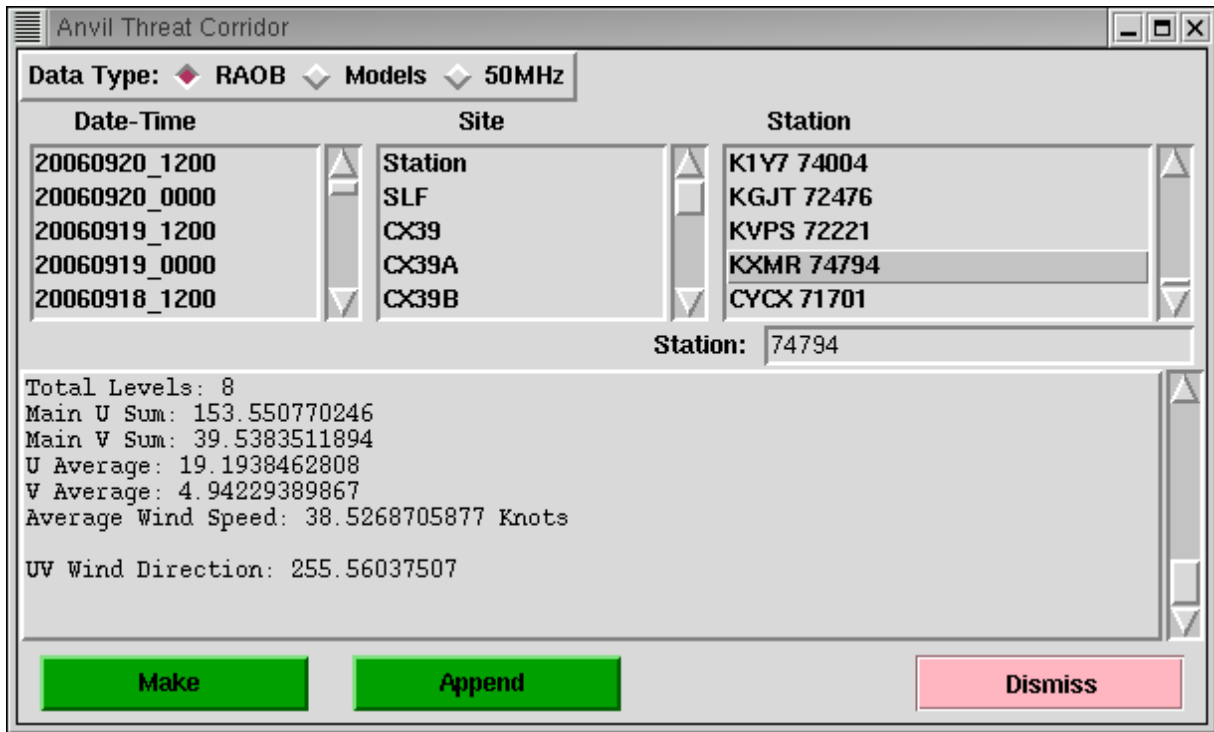
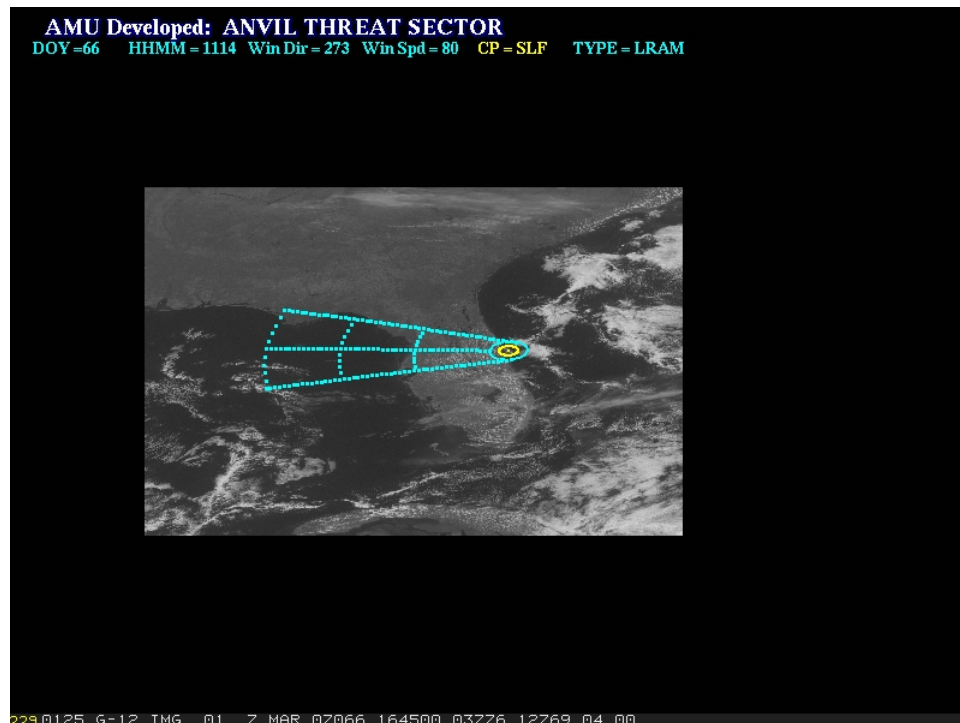Figure 2. AWIPS Anvil Tool GUI, version 1.1.0.

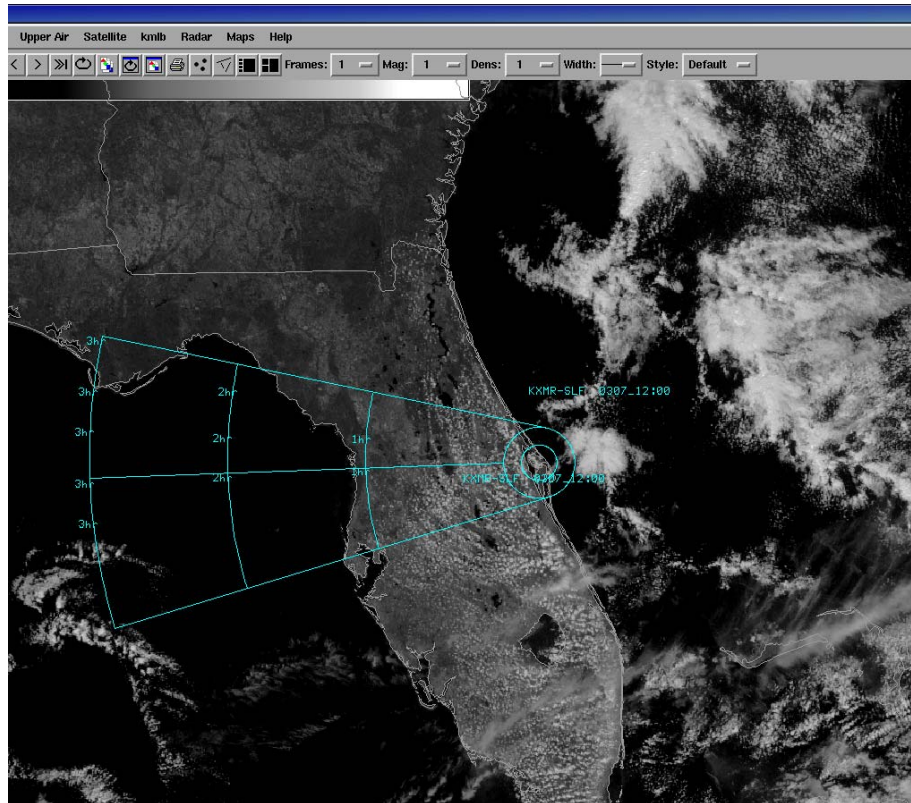Figure 3. MIDDS tool graphic for SLF at 1200 UTC, 7 March 2007.

Figure 4. AWIPS tool graphic for SLF at 1200 UTC, 7 March 2007.

4. Improvement of the AWIPS Tool

The AMU made the following changes to the AWIPS Anvil Tool software based on testing performed by SMG, the 45 WS, and the AMU:

- The user can no longer create a new map until the 300- to 150-mb average wind has been calculated,

- The text output was modified to make it easier to read,

- A refresh map feature was added. If this new feature is enabled, the user does not need to clear the current graphic and load the newly created graphic. Instead, the new graphic will be automatically displayed on the AWIPS screen,

- The map labels were modified to make them more useful and easier to read,

- Previous Date/Time and Site selections on the GUI were highlighted in red, so that the user could see which selections were made,

- When using model data, the user will no longer receive an error message when data for a forecast hour is missing. Instead, the user will receive a dialog box stating that the forecast hour was not available,

- The append map function was removed because the label only pertained to the last graphic created. In addition, it was practically impossible to differentiate between multiple graphics if they were for the same Site. Instead, three maps are available for each of the three data types. This makes it possible to view as many as nine maps together on one display,

- If there are multiple rawinsonde observations in a file, the user will be prompted to select an observation time,

- The layer-average wind calculations with the 50 MHz profiler data now use the correct units. Previously, the 50 MHz profiler data calculations used meters per second, even though the data were in knots,

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- The model grid points were adjusted so that the correct locations were read from the model data,

- The GFS vertical wind levels were previously read incorrectly,

- The tool was updated to ignore missing wind data in the rawinsonde and 50 MHz profiler observations,

- Double-clicking on a Station or Site with the left mouse button no longer creates an error,

- The radius of the inner circle centered at the Site was changed from 5 to 10 n mi,

- The maximum level of the winds in the rawinsonde and 50 MHz profiler observations was changed from 12,000 m to 14,000 m,

- The AMU's AWIPS receives 50 MHz profiler data in Range Standardization and Automation (RSA) format, while the SMG's AWIPS receives profiler data in Meteorological Assimilation Data Ingest System (MADIS) format (NOAA 2007). The Anvil Tool was modified to allow the use of both formats,

- The Anvil Tool can now display labels on the graphic to the northeast, southeast, southwest, or northwest of the Site. The label can also be positioned 50, 100, or 200 nm from the Site,

- The user has the option of whether or not to display labels on the graphic,

- Wind calculations using model data were adjusted to take into effect the difference between grid-relative and north-relative winds,

- The calculations of locations on the graphic originally used a flat-earth approximation. This introduced errors in the locations of the one-, two-, and three-hour arcs in the graphic. The amount of error increased with latitude. The tool was updated to use a spherical-earth approximation to create the graphics,

- The user has the option of displaying labels at the top, middle, or bottom positions. This prevents labels from being overwritten, and

- The AMU's AWIPS receives GFS model data at the "CONUS211" projection, while the SMG's AWIPS receives GFS model data at the "CONUS212" projection. The CONUS211 projection has a grid spacing of 80 km, while the CONUS212 projection has a grid spacing of 40 km. The Anvil Tool software was modified to read GFS model data at the CONUS212 projection.

The latest version of the Anvil Tool, 1.7.0, was provided to SMG after the software changes were completed along with a final test document (Appendix A), updated bug report, and updated Users Guide.

5.   Summary and Future Work

The 45 WS LWOs and SMG forecasters have identified thunderstorm anvil cloud forecasting as one of their most challenging tasks, when predicting the probability of lightning LCC and FR violations. The AMU developed a tool that creates an anvil threat corridor graphic, based on observed or forecast upper-level winds. This tool was successfully transitioned from MIDDS to AWIPS. This will allow SMG to use the tool on their primary forecasting system, AWIPS. However, the AWIPS in the 45 WS is not operational and the LWOs currently can only access the tool in the AMU AWIPS. They still access the tool through MIDDS.

Further development of the tool may include the following:

- Develop a 45 WS-specific version when their AWIPS becomes operational. The configuration of the AWIPS at the 45 WS will likely differ from the AWIPS at SMG,

- Automate the conversion between grid-relative and north-relative model winds. This correction is currently hard-coded for KSC/Cape Canaveral locations, WSD, and EDW. This change will allow the tool to use more locations for model data calculations,

- Automate the calculation of the closest grid point to a latitude/longitude point. This will also allow the tool to use more locations for model data calculations,

- Modify the code to use compiled NetCDF modules written in the Perl or C to allow faster access to the NetCDF data. This would significantly speed up the wind calculations when using model data,

- Allow the use of point model data,

- Allow the user to vary the vertical levels that are used in the calculations of layer-average wind velocity. The height of anvil clouds normally varies by the strength of thunderstorms and the height of the tropopause, and

- Modify the tool to create Shapefiles with the Tcl/Tk code, instead of using the Shapefile C Library. This would enable the tool to be more self-contained and decrease the number of binary files that need to be installed with the tool.

AWIPS Anvil Tool Final Test
ENSCO, **Applied Meteorology Unit (AMU)**

date – 3/5/2007
version - 1.7.0
language - Tcl/Tk 8.3
platform - RedHat Linux, containing AWIPS client software
tester - Joe Barrett, AMU
location - Applied Meteorology Unit, ROCC, Rm. 151
source code filename - anviltool.tcl

1. Startup of tool
Description: The AWIPS Anvil Tool should start up properly from AWIPS by selecting "Anvil Tool..." from the Tools menu. The GUI should have the following initial settings:

    Data Type: "RAOB"
    Refresh Map: "ON"
    Profiler Type: "RSA"
    Show Label At Circle: "Yes"
    Show Label On Frame: "Yes"
    Label Distance From Center: "50"
    Label Direction From Center: "NE"
    Circle Label Position: "Top"
    Frame Label Position: "Top"
    Make button: disabled
    Map radiobutton label between Make and Dismiss buttons: "RAOB"
    Radiobutton between Make and Dismiss buttons: "MAP 1"
    Date-Time listbox: list of all of the available RAOB files
    Site listbox: empty
    Station listbox: empty

Results: Passed.

2. Maps menu in AWIPS
Description: In the Maps menu, there should be submenus for both of the original maps (one map each for RAOB, 50MHz, and Models data types) and the current maps (three each for RAOB, 50MHz, Models data types). For the current maps, there should be submenus for RAOB, 50MHz, and Models. It should be possible to view all nine current maps at the same time.

Results: Passed.

3. Map types should change correctly
Description: When the Data Type is changed between RAOB, 50MHz, and Models, the map type at the bottom of the GUI should change accordingly.

Results: Passed.

4. Date-Time listbox should show the available files for selected Data Type
Description: The Date-Time listbox should always show the available files for the selected Data Type. Compare the files in the list box with the corresponding file directory listing. Test with the RAOB, 50MHz (both RSA and MADIS), and Models (RUC, NAM, and GFS) data types.

Results: Passed.

5. Map button should be disabled until calculations have been performed

Description: It should not be possible to create an anvil threat corridor map without first reading the input data and performing the calculations to derive a 300-150 mb layer-average wind velocity. The Make button will always create the map using the last wind calculation. The Make button should be disabled until a wind calculation has been performed. After the map has been created, the Make button will be disabled again until another wind calculation has been performed. This test should be carried out with all three data types - RAOB, 50MHz, and Models.

Results: Passed.

6. Output in the text box should be accurate and complete

Description: The output in the text box for the calculations should be complete and accurate. For each calculation, the Date-Time of the input data, the data type, the site where the plot is centered at, and the Station/Forecast Hour should be output. When creating a map, a message should be printed to the screen listing the label positions and mid-point of the plot. For the RAOB calculations, the mandatory and significant levels should be output, as well as the total number of levels and the U/V layer wind averages. For the 50MHz calculations, the significant levels should be output, as well as the total number of levels and the U/V layer wind averages. For the Models calculations, the output should include the Model type, forecast hour, number of grid points in the x/y directions, the actual grid point used, and the U/V average winds. In all cases, the layer-average wind speed and direction should be output.

For the RUC, NAM, and GFS, verify that the number of grid points in the x/y direction are correct, by comparing the text box output to output from the ncdump program. Also verify that the actual grid point used is correct, by comparing the text box output to the source code.

This test should include all data types and Sites.

Results: Passed.

7. Refresh Map function

Description: Verify that the Refresh Map function works correctly. When the radiobutton is set to ON, then the last map created should automatically load onto the AWIPS screen. If you create a new map that is already displayed, then the old map is automatically unloaded and the new map is loaded. If the radiobutton is set to OFF, then you must manually unload the current map (if it is already loaded) and load the map from the Maps menu. This should be tested with the RAOB, Models, and 50MHz data types. Test whether it works with all three maps per data type (MAP1 - MAP3).

Results: Passed.

8. Map labels

Description: Verify that the frame and circle labels on the anvil threat corridor maps are accurate and readable. Also verify that the 1, 2, and 3 hr labels are accurate and readable. Test with all data types and model types.

Results: Passed.

9. Unavailable forecast hour

Description: When using model data as input, if a forecast hour is not available for a particular model run, then the user should get a popup box saying "That forecast hour is not available." If the forecast initialization time is not divisible by 3, then only 0 and 3 hour forecasts from the RUC are available. Forecast hours are also not available when the forecast run has completed, for example mid-morning for the 1200 UTC NAM or GFS models.

Results: Passed.

10. Multiple RAOB times in a file for a particular RAOB

Description: For a particular station, if there is more than one RAOB observation in a RAOB file, then the user should be prompted to select one of the observation times. This often occurs for the XMR RAOB during launch or shuttle landing operations. It also occurs when multiple soundings are released during the day in anticipation of severe weather. Verify that the current observation is used, by viewing the output in the text box.

Results: Passed.

11. Search box

Description: Verify that the search box labeled "Station:" works correctly for the RAOB data type.

Results: Passed.

12. Wind speed in text box should be in knots

Description: Verify that the wind speed output in the text box is in knots. Test with all data types and model types.

Results: Passed.

13. Inner and outer circles

Description: The inner circle's radius should be 10 nm and the outer circle's radius should be 20 nm. Test with all data types at MLB, EDW, and WSD, by comparing the anvil threat corridor map to the Range Rings AWIPS tool. For the RAOB data type, test with KEPZ (El Paso, TX observation) instead of KWSD.

Results: Passed.

14. Label options

Description: Test the options of whether or not to show labels on the circle and frame. Test with all data types.

Results: Passed.

15. Label distances

Description: Test the label distances from the center of the plot, for 50, 100, and 200 NM. Measure distances from the station to the center of the label. Test with all directions: NE, SE, SW, NW. Label distances only need to be approximate. Show the actual distance using the Middle frame label position.

Results: Passed.

16. Distance between hour labels and direction of the anvil threat corridor

Description: Verify that the distances between the 1, 2, and 3-hour arcs are correct. Test with the RAOB data at KJAX and KMFL. Test with the model data at MLB, EDW, and WSD. Test with the 50 MHz data at the Station. Distances are measured from the outer edge of the 20 nm radius circle, using the center line through the anvil threat corridor map. Measure the distances using the Distance Bearing tool. The direction of the center line of the map should agree with the wind direction. The direction of the outside lines should be +15 and -15 degrees from the center line.

Results: Passed.
KJAX RAOB at 20070302_1200:
calculated wind speed = 102 knots
calculated wind direction = 266 degrees
distance from outer edge of circle to 1 hr arc = 101 nm

distance from 1 to 2 hr arcs = 102 nm
distance from 2 to 3 hr arcs = 102 nm
direction of center line = 265 degrees
direction of outside lines = 280 and 250 degrees

KMFL RAOB at 20070302_1200:
calculated wind speed = 54 knots
calculated wind direction = 281 degrees
distance from outer edge of circle to 1 hr arc = 54 nm
distance from 1 to 2 hr arcs = 54 nm
distance from 2 to 3 hr arcs = 54 nm
direction of center line = 280 degrees
direction of outside lines = 295 and 265 degrees

NAM 20070302_1200, 0 hr, at MLB:
calculated wind speed = 74 knots
calculated wind direction = 274 degrees
distance from outer edge of circle to 1 hr arc = 73 nm
distance from 1 to 2 hr arcs = 74 nm
distance from 2 to 3 hr arcs = 73 nm
direction of center line = 273 degrees
direction of outside lines = 288 and 258 degrees

NAM 20070302_1200, 0 hr, at WSD:
calculated wind speed = 149 knots
calculated wind direction = 272 degrees
distance from outer edge of circle to 1 hr arc = 149 nm
distance from 1 to 2 hr arcs = 149 nm
distance from 2 to 3 hr arcs = 149 nm
direction of center line = 271 degrees
direction of outside lines = 286 and 256 degrees

NAM 20070302_1200, 0 hr, at EDW:
calculated wind speed = 94 knots
calculated wind direction = 282 degrees
distance from outer edge of circle to 1 hr arc = 93 nm
distance from 1 to 2 hr arcs = 94 nm
distance from 2 to 3 hr arcs = 94 nm
direction of center line = 281 degrees
direction of outside lines = 296 and 266 degrees

50MHz MADIS 20070105_1800, 1800 UTC:
calculated wind speed = 69 knots
calculated wind direction = 246 degrees
distance from outer edge of circle to 1 hr arc = 70 nm
distance from 1 to 2 hr arcs = 70 nm
distance from 2 to 3 hr arcs = 69 nm
direction of center line = 245 degrees
direction of outside lines = 230 and 259 degrees

17. RAOB data is read correctly
Description: Verify that RAOB data is read correctly, by comparing text output to the Skew-T in AWIPS. Test with the most recent KTBW and KXMR soundings.

Results: Passed.

18. 50MHz RSA data is read correctly
Description: Verify that the 50MHz RSA data is read correctly, by comparing to the AWIPS product graphic. Compare using multiple observation times.

Results: Passed.

19. 50 MHz MADIS data is read correctly
Description: Verify that the 50MHz MADIS data is read correctly, by comparing to the output from ncdump.

Results: Passed.

20. RUC data is read correctly
Description: Verify that the RUC data is read correctly for MLB, EDW, and WSD. Test by comparing Anvil Tool output to Volume Browser (VB) output in AWIPS. Use grid-relative winds in the test.

Results: Passed.
RUC-20070302_2000 run, fhr=0
MLB
Anvil Tool:
300 mb = 73 kt, 258 deg
250 mb = 77 kt, 260 deg
200 mb = 83 kt, 261 deg
150 mb = 74 kt, 262 deg
VB:
300 mb = 73 kt, 260 deg
250 mb = 77 kt, 260 deg
200 mb = 83 kt, 260 deg
150 mb = 74 kt, 265 deg

EDW
Anvil Tool:
300 mb = 37 kt, 327 deg
250 mb = 49 kt, 286 deg
200 mb = 117 kt, 290 deg
150 mb = 81 kt, 293 deg
VB:
300 mb = 37 kt, 340 deg
250 mb = 50 kt, 280 deg
200 mb = 117 kt, 285 deg
150 mb = 81 kt, 300 deg

WSD
Anvil Tool:
300 mb = 151 kt, 271 deg
250 mb = 171 kt, 277 deg
200 mb = 158 kt, 278 deg
150 mb = 124 kt, 274 deg
VB:
300 mb = 150 kt, 270 deg
250 mb = 170 kt, 280 deg
200 mb = 157 kt, 280 deg
150 mb = 124 kt, 275 deg

21. NAM data is read correctly

Description: Verify that the NAM data is read correctly for MLB, EDW, and WSD. Test by comparing Anvil Tool output to Volume Browser output.

Results: Passed.
NAM-20070302_1200 run, fhr=24
MLB
Anvil Tool:
300 mb = 86 kt, 255 deg
250 mb = 91 kt, 259 deg
200 mb = 89 kt, 264 deg
150 mb = 94 kt, 251 deg
VB:
300 mb = 86 kt, 260 deg
250 mb = 91 kt, 260 deg
200 mb = 89 kt, 265 deg
150 mb = 94 kt, 250 deg

EDW
Anvil Tool:
300 mb = 24 kt, 304 deg
250 mb = 63 kt, 295 deg
200 mb = 114 kt, 278 deg
150 mb = 89 kt, 288 deg
VB:
300 mb = 24 kt, 310 deg
250 mb = 63 kt, 290 deg
200 mb = 113 kt, 275 deg
150 mb = 89 kt, 290 deg

WSD
Anvil Tool:
300 mb = 123 kt, 282 deg
250 mb = 153 kt, 290 deg
200 mb = 137 kt, 291 deg
150 mb = 98 kt, 293 deg
VB:
300 mb = 123 kt, 280 deg
250 mb = 153 kt, 295 deg
200 mb = 137 kt, 300 deg
150 mb = 98 kt, 300 deg

22. GFS data is read correctly
Description: Verify that the GFS data is read correctly for MLB, EDW, and WSD. Test by comparing Anvil Tool output to Volume Browser output.

Results: Passed.
GFS-20070214_1200 run, fhr=0
MLB
Anvil Tool:
300 mb = 102 kt, 271 deg
250 mb = 115 kt, 264 deg
200 mb = 124 kt, 260 deg
150 mb = 70 kt, 266 deg
VB:
300 mb = 102 kt, 270 deg
250 mb = 115 kt, 265 deg

200 mb = 124 kt, 260 deg
150 mb = 70 kt, 267 deg

EDW
Anvil Tool:
300 mb = 54 kt, 338 deg
250 mb = 50 kt, 330 deg
200 mb = 51 kt, 309 deg
150 mb = 47 kt, 291 deg
VB:
300 mb = 54 kt, 340 deg
250 mb = 50 kt, 335 deg
200 mb = 51 kt, 310 deg
150 mb = 47 kt, 290 deg

WSD
Anvil Tool:
300 mb = 107 kt, 264 deg
250 mb = 114 kt, 264 deg
200 mb = 112 kt, 266 deg
150 mb = 109 kt, 268 deg
VB:
300 mb = 107 kt, 265 deg
250 mb = 114 kt, 265 deg
200 mb = 112 kt, 270 deg
150 mb = 109 kt, 270 deg

23. U and V layer-average winds are calculated correctly
Description: Verify that the U and V layer-average winds are calculated correctly. For the RAOB data type, in the text box compare the significant and mandatory winds to the U and V winds. For the 50MHz profiler calculations, compare the significant winds to the U and V winds. For the Models data type, print out the u- and v-wind components between 300 and 150 mb.

Results: Passed.
XMR RAOB 20070303_1200
manual calculation using mandatory and significant winds -> u=82.3 kt, v=18.9 kt
Anvil Tool calculation -> u=82.3 kt, v=18.9 kt

50MHz MADIS 20070105_1800
manual calculation using mandatory and significant winds -> u=63.1 kt, v=28.7 kt
Anvil Tool calculation -> u=63.1 kt, v=28.7 kt

NAM 20070303_1200, forecast hour=0, Site=SLF
manual calculation using mandatory and significant winds -> u=83.5 kt, 21.6 kt
Anvil Tool calculation -> u=83.5 kt, 21.6 kt

24. Layer-average wind speed and direction calculated correctly from the U and V layer-average winds
Description: Verify that the layer-average wind speed and direction are calculated correctly from the U and V layer-average winds. In the text box, compare the U and V winds to the final wind speed and direction. Test with all data types; use grid-relative winds when using model data.

Results: Passed.
KJAX RAOB 20070305_1200
u=113.1 kt, v=36.7 kt

manual calculation -> wind speed=118.9 kt, wind direction=252.0 deg
Anvil Tool calculation -> wind speed=118.9 kt, wind direction=252.0 deg

RUC 20070305_1500, forecast hour=0, site=EDW
u=48.2 kt, v=18.9 kt
manual calculation -> wind speed=51.8 kt, wind direction=248.6 deg
Anvil Tool calculation -> wind speed=51.8 kt, wind direction=248.6 deg

50MHz RSA 20070222_2000, 1945 UTC
u=84.0 kt, v=-35.5 kt
manual calculation -> wind speed=91.1 kt, wind direction=292.8 deg
Anvil Tool calculation -> wind speed=91.1 kt, wind direction=292.8 deg

25. Grid-relative winds in model data should be corrected to north-relative winds
Description: When using model data as input, grid-relative winds should be corrected to north-relative winds. The Anvil Tool uses three grid points for each model type - XMR, EDW, and WSD. The following Sites use the same grid point as XMR: SLF, CX39, CX39A, CX39B, CX40, CX41, CX37, CX17, CX17A, CX17B, and MLB. The differences between grid-relative and north-relative winds vary by location. The following corrections should be added to the layer-average grid-relative winds: XMR=+5 degrees, EDW=-10 degrees, WSD=-5 degrees. Verify that these corrections are being made and that the anvil threat corridor map uses the north-relative winds.

Results: Passed.
RUC 20070305_1600, forecast hour=0, Site=MLB
Layer-average wind direction = 250.1 deg, Corrected wind direction = 255.1
On map, middle line = 254 deg

NAM 20070305_1200, forecast hour=6, Site=EDW
Layer-average wind direction = 242.5 deg, Corrected wind direction = 232.5
On map, middle line = 232 deg

GFS 20070214_1200, forecast hour=0, Site=WSD
Layer-average wind direction = 265.8 deg, Corrected wind direction = 260.8
On map, middle line = 261 deg

26. Anvil Threat Corridor maps in the northerly direction should be accurate
Description: The 1, 2, and 3-hour arcs are usually drawn from low to high angles, e.g. from 255 to 285 degrees for a layer-average westerly wind. This is not the case for northerly winds, or winds within 15 degrees of 360, assuming that 15 is one-half of the threat angle. In the case of northerly winds, the arcs are drawn from high to low angles, e.g. from 340 to 10 degrees. Verify that maps created for northerly winds are still accurate. Test with two RAOBS - one with a layer-average wind between 345 and 360 degrees, and one with a layer-average wind between 0 and 15 degrees.

Results: Passed.
20070304_1200 KTOP
Speed = 54.6 kt, Wind direction = 347.3 deg
On map: distance between arcs = 55 nm, direction of middle line = 347 deg

20070304_0000 KABR
Speed = 79.1 kt, Wind direction = 5.3 deg
On map: distance between arcs = 79 nm, direction of middle line = 5 deg

27. Compare to the MIDDS Anvil Tool
Description: Verify that the output from the AWIPS Anvil Tool is similar to that of the MIDDS Anvil Tool. Test with model and RAOB data. There will be differences due to different source code implementations.

The MIDDS Anvil Tool uses point model data, while the AWIPS Anvil Tool uses gridded model data. The MIDDS Anvil Tool uses AMPS upper-air data, while the AWIPS Anvil Tool uses mandatory and significant wind data.

Results: Passed.
NAM 20070305_1200, forecast hour=12, Site=SLF
MIDDS: speed = 77 kt, direction = 269 deg
AWIPS: speed = 75 kt, direction = 267 deg
maps covered around same area = yes

XMR RAOB 20070305_1200, Site=SLF
MIDDS: speed = 117 kt, direction = 252 deg
AWIPS: speed = 109 kt, direction = 252 deg
maps covered around same area = yes

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List of Acronyms

Term	Description
45 WS	45th Weather Squadron
AMPS	Automated Meteorological Profiling System
AMU	Applied Meteorology Unit
AWIPS	Advanced Weather Interactive Processing System
CCAFS	Cape Canaveral Air Force Station
EDW	Edwards Air Force Base
FR	Flight Rules
GFS	Global Forecast System model
GUI	Graphical User Interface
KSC	Kennedy Space Center
LCC	Launch Commit Criteria
LWO	Launch Weather Officer
MADIS	Meteorological Assimilation Data Ingest System
McBASI	McIDAS BASIC Language Interpreter
MIDDS	Meteorological Interactive Data Display System
MLB	Melbourne, Florida
MRF	Medium Range Forecast model
NAM	North American Mesoscale model
NetCDF	Network Common Data Format
RSA	Range Standardization and Automation
RUC	Rapid Update Cycle model
SLF	Shuttle Landing Facility
SMG	Spaceflight Meteorology Group
TCL	Tool Command Language
TTS	SLF 3-letter identifier
VB	Volume Browser application in AWIPS
WSD	White Sands Missile Range
XMR	CCAFS rawinsonde 3-letter identifier

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