P10.3 IMPLEMENTING THE VAHIRR ALGORITHM ON THE NEXRAD ORPG AND AWIPS

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1. INTRODUCTION

Lightning Launch Commit Criteria (LLCC) and Flight Rules are used for all launches and landings to avoid natural and triggered lightning strikes to space vehicles. Improved LLCC for anvil clouds, and an associated radar product called VAHIRR required by them, were developed using data collected by the Airborne Field Mill (ABFM) research program. The advantage of VAHIRR is that it can tell the operator which opaque anvil clouds are safe whereas the previous LLCC assumed all opaque anvils are dangerous. Details of both the ABFM research program (Merceret, *et al.*, 2006) and the science behind the VAHIRR product (Dye, *et al.*, 2006) are presented in other papers submitted to this conference.

VAHIRR stands for Volume-Averaged Height-Integrated Radar Reflectivity. It is the arithmetic product of two quantities not currently generated by the WSR-88D: a volume average of the reflectivity measured in dBZ and the average cloud thickness based on average echo top height and echo base height. VAHIRR is calculated at every horizontal position in the coverage area of the radar and can be displayed like standard two-dimensional reflectivity products such as composite reflectivity or echo tops. Work has begun on implementing the VAHIRR algorithm as a radar product within the WSR-88D Open Radar Product Generator (ORPG). Implementation of the algorithm within the ORPG will allow for continuous updates throughout the launch sequence and display on the standard NEXRAD radar console. The algorithm relies on all radar tilts of the reflectivity data within a volume scan to calculate the cloud thickness and average reflectivity values needed to compute the VAHIRR values.

The paper will include a concept of operations, the steps completed to include the algorithm in the OPRG baseline, technical challenges including a description of the implemented algorithm design and performance. Some sample output is provided although development is not complete at this time. A timeline of remaining tasks will also be provided.

2. CONCEPT OF OPERATIONS

2.1 *Use of the VAHIRR Product*

Launch (or Landing) Weather Officers (LWO) are responsible for making the go/no-go weather call for the launch or landing of space vehicles. Formal launch or landing weather constraints are in place for all space launch and landing operations. The LWO examines the observed and forecast conditions, compares them against the launch (or landing) commit criteria (LCC), and determines whether the LCC are satisfied. If the LWO is not "clearly convinced" that the LCC are satisfied, the operation is no-go.

Among the LCC used at all Government and civilian ranges under American jurisdiction are a set of rules designed to protect the space vehicle against both natural and triggered lightning. These lightning LCC (LLCC) include rules relating to flight through thunderstorm anvil clouds. Two of these rules permit flight through anvil clouds under certain circumstances only if the VAHIRR quantity is below a specified threshold. The LWO will use the VAHIRR product to assess whether these LLCC are satisfied.

The LWO will call up a display showing a map on which the ground track of the intended launch trajectory may be located. Overlaid on that map will be color coded values of VAHIRR in a manner identical to the way composite reflectivity products are currently displayed. From the display, the LWO will determine whether or not VAHIRR is below the required threshold value everywhere within 5 nautical miles of the flight track. If it meets this criterion, the VAHIRR LLCC is satisfied. If not, then the VAHIRR LLCC is no-go.

The results of evaluating the VAHIRR LLCC, along with the evaluations of the other LLCC and non-

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lightning LCC will be provided by the LWO to the Launch Director. Unless all LCC, including the VAHIRR LLCC, are go, the operation is no-go for weather. This evaluation is made continuously during the last several hours of the countdown, and must be observed as “go” at the final decision point and forecast as “go” at the time of launch or landing.

2.2 *Obtaining the VAHIRR Product*

Accessing the VAHIRR product will vary based on how the end-user sites access WSR-88D products. For sites that have a Class 1 connection to an ORPG the launch weather personnel will simply ensure that the VAHIRR product is being generated with each volume scan. For the Eastern and Western Launch Ranges the Launch Weather Officers will view the product on the AWIPS system to evaluate the LLCC. As new commercial launch facilities become activated they too will be bound by LLCC. These facilities may or may not have a Class 1 connection to a WSR-88D radar. It is assumed that these facilities will be required to have some access to radar data and a method to display the data. For these facilities the FAA Weather Information Network Server (WINS) system can serve as the source for the VAHIRR product. The WINS systems are connected to all of the WSR-88D radar sites within the US and can provide many weather data products including WSR-88D products. Coordination with the proper WINS system will be needed to ensure the VAHIRR product is scheduled as a routine product during launch days. Discussions with the FAA to accommodate this connectivity have begun. Display of the data will be the responsibility of the launch facility as well as ensuring the VAHIRR is valid within 5 nautical miles of the launch track.

3. ADMINISTRATIVE PROCESS

A well-defined process to insert an algorithm into the ORPG has been established by the Radar Operations Center (ROC) in Norman, OK. The process includes two formal meetings to establish the technical feasibility and appropriateness of the product to be included within the operational baseline.

3.1 *Technical Advisory Committee (TAC)*

The VAHIRR algorithm was presented to the TAC on April 29, 2005. The goal of the VAHIRR is to safely relax restrictive launch rules and the science and the background and science behind the change was explained. Additionally presented, was the justification for inclusion in the ORPG, a brief concept of operations, and the initial development schedule. At the time of the TAC it was expected that the VAHIRR would be included in the Build 9 release of the ORPG.

3.2 *Software Recommendation and Evaluation Committee (SREC)*

A second meeting, the SREC meeting, was held on June 15, 2005 with the ROC in Norman, OK. At this meeting all of the algorithms for the next release are evaluated for their readiness for inclusion in the ORPG baseline. Just prior to the meeting it was decided to withhold the VAHIRR from the Build 9 release. The presentation to the Committee went ahead. During this meeting there was considerable discussion regarding the inclusion of the VAHIRR in the ORPG baseline. Of concern was the concept of operations for both the current and future launch facilities as well as issues related to long-term support of the algorithm. The VAHIRR development team was given an action to clarify the CONOPS and support issues to be presented at the SREC meeting for build 10.

4. TECHNICAL CHALLENGES

The development team has been working on the implementation of the VAHIRR algorithm over the last several months and has overcome several technical challenges.

4.1 *Software Development Environment*

The ROC provides a rich set of tools called CODE, the Common Operations and Development Environment, This environment provides the current software baseline for the ORPG (except for a few proprietary algorithms), sample algorithms, visualization tools and a HCI to manage the program execution. This standalone RPG has been helpful to the developers but it required a significant learning curve to become proficient in its use. Technical discussions with ROC personnel were very helpful in understanding some of the capabilities of the system. Figures 1 and 2 below were generated using the CODE tools.

4.2 *Algorithm Development*

The VAHIRR algorithm requires access to all reflectivity tilts of a volume scan and managing the data in an efficient manner was essential to computing the VAHIRR. The reflectivity tilts are stored in a radial format, i.e. reflectivity values with respect to an azimuth and distance from the radar. The VAHIRR product is a Cartesian product with a resolution of 1 km for each grid point. The developers used the supplied algorithms to convert from the radial to Cartesian systems as much as possible but had to generate some unique conversions as well.

To compute the VAHIRR value at a grid point, a volume defined by the 5 grid points in all horizontal directions, i.e. an 11x11 grid, and the variable bottom and top cloud heights above each point defining the vertical extent, is used. The average thickness of the cloud within this volume is multiplied by the average reflectivity within the volume to compute the VAHIRR value. A two pass algorithm has been implemented where the cloud top and bottom, number of reflectivity values, and average reflectivity of each grid point is calculated on the first pass and the VAHIRR is computed on the second pass by defining the column and using the values computed in the first pass.

The cloud top is defined as the height of the reflectivity return in the highest tilt above each grid point. The cloud bottom is defined by the height of a reflectivity return in the lowest radar tilt at or above the 0C height. The 0C height value was already an adaptation value within the ORPG to compute the Hail product and is reused by the VAHIRR. Storing the average reflectivity and number of reflectivity values at each grid point reduces the amount of storage needed to compute the VAHIRR.

4.3 *VAHIRR Output Format*

The VAHIRR product uses the same storage format as the 16 color 1km composite reflectivity product. This format is already defined within the ORPG and will reduce the modifications to display systems that currently display the composite reflectivity product. It was originally planned to use existing software to store the VAHIRR product. Unfortunately the composite reflectivity storage algorithm was written in FORTRAN and the ROC prefers all future algorithms be written in the C programming language. The output routine required a significant amount of effort to implement.

5. PLAN AND PROGRESS TO DATE

Progress to date is encouraging. We have only been able to run the algorithm against a severe weather data set which is not ideal for calculating VAHIRR since the computed values are quite large. However, by examining the Figures below it is apparent that the algorithm is calculating high values where one would expect high values to be found.

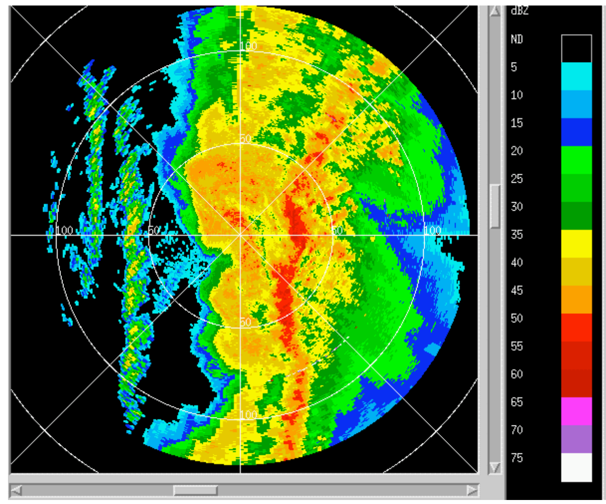

Figure 1. Composite Reflectivity Product from KMLB

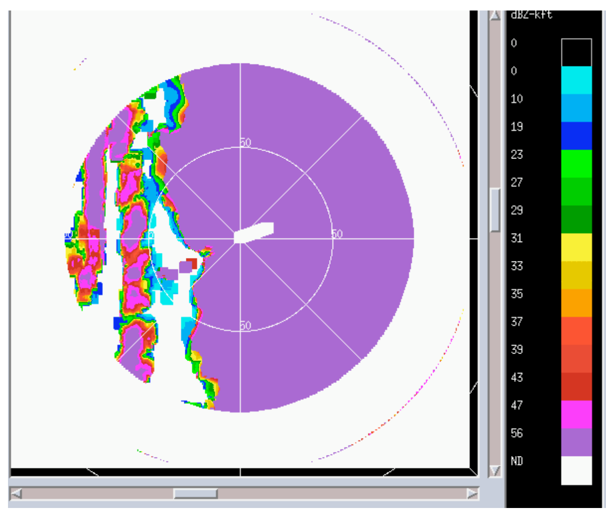

Figure 2, Calculated VAHIRR product from same KMLB data. Note the similar shapes for the clear area in the southwest part of the image. The majority of the values are purple due to the high returns of the CR image.

Remaining tasks include the generation of test data sets and software documentation. The test data will allow simple visual confirmation that the algorithm is computing VAHIRR properly. The data sets will consist of “canned” reflectivity data that will produce geometric shapes with known

VAHIRR values and will be provided to the ROC for future testing. All tasks are scheduled to be completed by the end of January 2006.

REFERENCES

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