8.3

SEVERE WEATHER WARNING APPLICATION DEVELOPMENT AT NSSL USING MULTPLE RADARS AND MULTIPLE SENSORS

Gregory J. Stumpf[1,2,], Travis M. Smith[1,2], Kevin L. Manross[1,2], V. Lakshmanan[1,2], and Kurt D. Hondl[2]*

[1]Cooperative Institute for Mesoscale Meteorology Studies, University Of Oklahoma, Norman, Oklahoma.
[2]NOAA/National Severe Storms Laboratory, Norman, Oklahoma.

1. Introduction

The National Severe Storms Laboratory has played the primary role in the development and evaluation of National Weather Service severe weather applications for the WSR-88D Doppler radar. NSSL developed many of the primary detection algorithms for the radar, and is currently developing improvements to these algorithms. The traditional WSR-88D severe weather algorithms have been designed for use with a single-radar data source. Although the algorithm guidance has led to an improvement of the National Weather Service (NWS) severe weather warning statistics, it is understood that effective warning decisions can only be made via the integration of information from many sources, including input from multiple remote sensors (multiple radars, mesoscale models, satellite, lightning, etc.). Therefore, these traditional single-radar severe weather algorithms have been updated to take advantage of additional data sources in order to reduce the uncertainty of the measurements and increase the accuracy of the diagnoses of severe weather.

The NSSL Warning Decision Support System – Integrated Information (WDSS-II; Lakshmanan 2002) has provided an invaluable development environment to facilitate the development of these new applications. In less than two years (Feb 2002 – Aug 2003), NSSL has converted its suite of single-radar severe weather detection algorithms to operate using multiple radars. NSSL has also developed a suite of new radar diagnostic derivatives, including gridded high-resolution and rapidly updating fields of vertically integrated liquid (VIL), Probability of Severe Hail, Maximum Expected Hail Size, Velocity-Derived Rotation, and Velocity-Derived Divergence. Time-integrated fields of some of the above have also been developed, including hail swath information (maximum size and hail damage potential) and velocity-derived rotation tracks. Near storm-environment (NSE) data from mesoscale model grids is automatically integrated into many of these new applications to provide even more robust diagnoses of severe weather.

2. Severe Weather Applications

The use of the WDSS-II development environment has facilitated the rapid implementation of several new severe weather forecast guidance tools as well as improvements to legacy severe weather diagnostic applications.

2.1 Multiple-Sensor Severe Storms Analysis Program

The original or legacy Severe Storms Analysis Program (SSAP) was the NSSL-developed algorithm system that included some of the severe weather algorithms that are now operational within the National Weather Service (NWS) suite of WSR-88D algorithms. The SSAP components that have been integrated into the WSR-88D include the Storm-Cell Identification and Tracking (SCIT) algorithm, the cell-based Hail Detection Algorithm (HDA), and the Tornado Detection Algorithm (TDA). One additional component of the SSAP, the Mesocyclone Detection Algorithm (MDA), is presently being engineered for the WSR-88D and will be fully integrated by the summer of 2004. A fifth SSAP component, the Damaging Downburst Prediction and Detection Algorithm

* Corresponding Author's Address: National Severe Storms Laboratory, 1313 Halley Circle, Norman, Oklahoma, 73069. Phone: (405) 366-0477, FAX: (405) 366-0472. Email: Greg.Stumpf@noaa.gov.

(DDPDA), has not been integrated into the WSR-88D system. Each of the algorithms, as implemented into the WSR-88D system or within the NSSL SSAP, operates using only single-radar data.

The Multiple-Radar Severe Storms Analysis Program (MR-SSAP; Stumpf *et al* 2002) extends the concepts of the legacy SSAP into the multiple-radar, multiple-sensor realm. The disadvantages of single-radar data are that 1) products are generated only once at the end of a 5- or 6-minute volume scan (already 5-6 minutes older than latest lowest-elevation radar data), 2) there is poor sampling at near ranges (cone-of-silence) and far ranges (radar horizon and beam broadening), and 3) all products are keyed to individual radar volume scans and radar domains (azimuth, range, elevation).

We have adapted the concepts of the single-radar SSAP to use information from multiple radars. Adjacent radars can be used to fill in cones-of silence or areas of beam blockage. Multiple radar data are mosaicked into virtual volume scans, with the latest elevation scan of data replacing the one from a previous volume scan. This method gives a complete volume scan at any point in time. We are able to generate output products in rapidly updating fashion as quickly as one individual radar elevation scan is included in the virtual volume (10-20 seconds). Presently, we run the updates at 60-second intervals for better warning management. The rapidly updating virtual volume can also run with single radar mode if coverage and outages dictate. The virtual volumes are designed to be VCP-independent, and can be integrated with other “gap-filling” radar platforms, including FAA and commercial radars. Products are keyed to a four-dimensional earth-relative coordinate system (latitude, longitude, elevation, time).

2.2 Multiple Radar SCIT and HDA

Reflectivity information from multiple radars is used to detect and diagnose storm cells. Virtual volumes of radar data containing the latest information from each radar for the previous 5 minutes are combined to produce vertical cores representing storm cells. The multi-radar reflectivity data used to construct the storm cells is diagnosed to give traditional cell-based attributes such as vertically integrated liquid (VIL). Cell-based HDA information (POSH, hail size) is also diagnosed using the combined multiple radar data, as well as NSE data from mesoscale models. The multiple-radar HDA integrates near-storm environment (NSE) data from the RUC mesoscale model analysis so that the selection of the HDA thermodynamic data is automated and has higher temporal and spatial resolution than synoptic-scale soundings. The cell-based storm and hail diagnoses are done rapidly at 1-minute intervals. Storm cells are also tracked in time (60-second intervals), attribute data are available for 60-second interval trend information, and 30-minute forecast positions are made. Cell detection and tracking is also aided by automated input of the 0-6km mean wind information from the RUC model.

2.3 High resolution maximum vertical-column reflectivity (MVR), Vertically Integrated Liquid maps

Presently, WSR-88D two-dimensional maps of maximum vertical-column reflectivity (MVR; sometimes known as “Composite Reflectivity”) and Vertically-Integrated Liquid (VIL) are presented with poor spatial (2 km Cartesian grids) and poor temporal (5-min updates) resolution. NSSL’s version has high spatial resolution using native single-radar polar grid or 0.01° latitude by 0.01° longitude multiple-radar grids. These versions also have high temporal resolution (rapidly-updating) using ‘virtual volumes’ each time an elevation scan is updated from either single or multiple-radars.

2.4 Gridded Probability of Severe Hail, Hail Size, and Hail Track Maps

The techniques used to derive popular WSR-88D cell-based hail products from the HDA have been incorporated into high-resolution gridded products similar to the high-resolution MVR and VIL products. This allows a user to diagnose which portions of storms contain large hail. Hail size data are accumulated over time to provide precise hail swath maps, showing both maximum hail size by location, and hail damage potential (combination of hail size and duration of hail). NSSL’s version has high spatial resolution using native single-radar polar grid or 0.01° latitude by 0.01° longitude multiple-radar grids. These versions also have high temporal resolution (rapidly-updating) using ‘virtual volumes’ each time an elevation scan is updated from either single or multiple-radars.

2.5 Vortex Detection and Diagnosis

More sophisticated techniques are being developed to accurately detect and diagnose rotation in radar velocity data. Present techniques search for patterns of vertically correlated azimuthal shear in single-Doppler velocity data. Current research has shown that these azimuthal shear techniques do not accurately estimate vortex location, size, and strength as well as techniques employing velocity derivatives of rotation and divergence. Traditional azimuthal shear techniques can also produce false detections along non-rotation signatures. Radial velocity values are a factor of single-radar viewing angles (one component of velocity is measured – that along the radar beam). Velocity derivatives are much less dependent on radar viewing angle, which allows for the combination of two-dimensional rotation fields from multiple radars. Two-dimensional rotation fields from single and multiple radars can also be accumulated over time providing tracks of mesocyclone features.

2.6 Motion Estimation

NSSL is currently developing a sophisticated technique segment multiple-scales of reflectivity data and to forecast the motion, growth, and decay of the two-dimensional storm fields (Lakshmanan 2003). This is not a cell tracker, but rather a forecast of 2D radar or satellite fields. Up to 60-minute forecasts of these two-dimensional products can be produced. The result also includes a high-resolution motion field that can be used to advect any two-dimensional product, such as hail, rotation, or lightning fields to provide up to 60-minute forecasts of these phenomena.

3. Application Development Environment

The Warning Decision Support System - Integrated Information (WDSS-II; Hondl 2002, Lakshman 2002) greatly facilitated the development process of the MR-SSAP. The WDSS-II system includes 1) real-time data ingest of data from multiple radars and sensors, 2) detection, diagnosis, and prediction multi-sensor algorithms, 3) an interactive prototype display designed specifically to effectively manage and provide rapid access to the most important information for decision-making (including novel 4D earth-relative base-data visualization techniques), and 4) an infrastructure to support application development, data ingest and distribution, configuration, and extensible output data formats. The Application Programming Interfaces provided within the WDSS-II development environment were utilized to provide access to time-synchronized multiple WSR-88D data streams (in offline and real-time modes), as well as to output the data in a variety of standard and extensible data formats (NetCDF and XML). The object-oriented structure of the code also facilitated the development of functions that can be reused using other data sources (such as other radars besides WSR-88D, including FAA and commercial “gap-filling” radars). The WDSS-II and MR-SSAP are designed using economical Linux systems and a variety of software development tools (e.g., CVS, Doxygen).

4. Real-Time Testing

The WDSSII and the multiple-sensor severe weather applications described here have been tested at two National Weather Service Forecast Offices (NWSFO) over the past year. The first test was at the Jackson Mississippi NWSFO and was conducted during the fall/winter 2002-2003 season (their climatological severe weather peak). The system was then moved to Wichita Kansas during the spring/summer 2003. The system was used for a number of large severe weather events, including the 10 November 2002, 4 May 2003, and 8 May 2003 tornado outbreaks. Feedback on the utility of the new applications and 4D display concepts will eventually be used in determining new direction for NWS operational system development (e.g., AWIPS).

5. Acknowledgements

Thanks go to the WDSSII development team of the NSSL (Don Bailor, Lulin Song, and Robert Toomey). This work has been primarily funded via sources from the Federal Aviation Administration, the NEXRAD Radar Operations Center, the National Severe Storms Laboratory, the National Science Foundation (Grant #9982299), and under NOAA-OU Cooperative Agreement #NA17RJ1227.

6. References

Hondl, Kurt, 2002: Current and planned activities for the Warning Decision Support

System – Integrated Information (WDSS-II). Preprints, *21st Conference on Severe Local Storms*, San Antonio, TX, Amer. Met. Soc., 146-148.

Lakshmanan, V., 2002: WDSS-II: An extensible, multi-source meteorological algorithm development interface. Preprints, *21st Conference on Severe Local Storms*, San Antonio, TX, Amer. Met. Soc., 134-137.

Lakshmanan, V., 2003: Motion estimator based on hierarchical clusters. Preprints, 19th International Conf. on Interactive Information and Processing Systems (IIPS) for Meteor., Oceanography, and Hydrology, Long Beach, CA, Amer. Meteor. Soc., (CD preprint).

Marzban, Caren, and A. Witt, 2001: A Bayesian Neural Network for Severe-Hail Size Prediction**.** *Wea. and Forecasting*, **16**, 600–610.

Stumpf, Gregory J., T. M. Smith, and A. E. Gerard, 2002: The Multiple-Radar Severe Storms Analysis Program (MR-SSAP) for WDSS-II. Preprints, *21st Conference on Severe Local Storms*, San Antonio, TX, Amer. Met. Soc., 138-141.