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The HydroMet Decision Support System: New Applications in Operational Hydrology

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1. Introduction

Weather Decision Technologies, Inc. (WDT), working with the National Severe Storms Laboratory (NSSL) has developed a custom Hydromet Decision Support System (HDSS) that has been implemented both domestically and internationally.

HDSS is a hardware/software system that uses the latest technologies in nowcasting and hydrology to provide operational users customized information from which to make real-time decisions regarding their operations. Data are ingest and integrated from sources such as radar, satellite, surface stations, rain gauges, and numerical models. Data and products are provided through a Web based display and/or three-dimensional workstation.

This paper will discuss the components and applications of the HDSS.

2. HDSS Components

The HDSS contains several components related to nowcasting and hydrology. The HDSS is a collection of algorithms either licensed from leading research organizations and subsequently enhanced and tuned by WDT or proprietary technologies developed by WDT and then deployed as part of the HDSS.

2.1 3D Mosaic Algorithm

The 3-D Mosaic algorithm, employed by WDT as part of the HDSS was developed by NSSL (Zhang et al., 2005) and the University of Oklahoma and was licensed from them. The 3D Mosaic algorithm collects data from all available radars, removes artifacts from the data, and re-samples the data to a 3D Cartesian grid. Initially, each radar is gridded from polar coordinates using a vertical adaptive Barnes interpolation scheme and gap filling to account for beam spreading with height and power density distributions. Additionally, a maximum value approach is implemented at close range to alleviate under-sampling. The system then mosaicks the individual radars and selects the preferred radar's data to be used at a given point by implementing a distance weighted mean to maximize contributions from the nearest radar.

The 3D Mosaic algorithm is a dynamic algorithm that automatically determines which radars are providing live data. If an individual radar goes down it automatically reconfigures the weighting scheme and the dynamic "look up tables" to utilize data from the remaining radars. The 3D mosaick'ed grid is 1x1 km in the horizontal with 21 levels in the vertical using increments of 500 m at lower levels. Examples of 3D Mosaic output are shown in Figures 1 and 2.

2.2 Quantitative Precipitation Estimation and Segregation Using Multiple Sensors (QPE-SUMS)

QPE-SUMS (Gourley et al., 2001) provides accumulated precipitation estimates for any period of time using sophisticated algorithms that automatically remove radar artifacts, employ differential Z-R relationships, and integrate data from multiple sensors. QPE-SUMS is exclusively licensed by WDT from SRP. For LCRA, precipitation estimates are provided on a 1 km x 1 km grid and are updated every 5 minutes. Precipitation accumulation estimates are provided for the

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past 1, 3, 6, 24, and 72 hours. Figure 3 shows an example of QPE-SUMS output. Basin average precipitation amounts are also computed from the gridded output of QPE-SUMS as shown in Figure 4.

QPE-SUMS utilizes a suite of sub-algorithms to provide rain accumulation estimates. Details of some of the sub-algorithms are provided below.

A. Bright Band Detection. Bright bands in radar data are caused by melting snow or ice as it falls to the ground. The areas of melting snow and ice cause stronger echoes and thus overestimation of precipitation estimates. One of the QPE-SUMS sub-algorithms identifies bright bands and removes the bias induced by them.

B. Determination of Convective versus Stratiform and Warm Cloud areas. Many studies have shown that Z-R relationships (radar echo to precipitation rate) are far different for areas of deep convection versus areas of stratiform rain and warm clouds. QPE-SUMS has an algorithm that uses the 3-D Mosaic field to differentiate between areas of convection, warm clouds, and stratiform precipitation so that differential Z-R relationships can be applied in each scenario.

C. Rain Gauge Only Estimates. Rain gauge only precipitation estimates are developed by using a Barnes analysis technique to analyze the data to a 1 km x 1 km grid. The Barnes analysis scheme is an inverse distance weighting scheme that utilizes an exponential weighting function. This grid can be updated as soon as new data arrives, as often as once per minute.

D. Rain Gauge Calibration. The radar estimates of QPE are adjusted on an hourly basis using both a spatially non-uniform bias adjustment technique called local gauge adjustment (LGC), and a mean field (domain) adjustment (GC). These adjustments are intended to remove non-uniform biases that may be due to improper use of Z-R relationships, range-dependency in QPEs from reflectivity profiles that decrease with height, and contamination from hail, birds, ground clutter, chaff, and other echoes from non-weather targets. For the LGC, the difference between the gauges and the radar estimates is computed at each gauge location (e.g., G-R). These differences are then analyzed to the 1x1 km QPE-SUMS common grid using the same Barnes objective analysis scheme that is utilized to determine the gauge-only precipitation estimate. In essence, this creates a grid of local biases. Finally, the local bias field is added to the radar hourly products to yield the radar-local bias adjusted QPE products. These bias corrections are also utilized to provide 5 minute updated locally bias adjusted fields. For the GC scheme a mean (1/N.R/G) is calculated on an hourly basis using all grids within the domain. The domain-wide bias is then applied to each grid. Additionally, the grid of biases will be available for display in real-time and will also be accumulated over long periods of time to allow analysis of the differences in biases in different locations.

E. Real-time Verification. WDT and NSSL have built an automated capability to verify the quality of QPE-SUMS rainfall estimates. The verification is done by comparing either hourly or daily rainfall measured by rain gauges with the QPE-SUMS estimates and results are provided in a web-based display.

2.3. MAPLE Quantitative Precipitation Forecasts

WDT has licensed from McGill University a software system called the McGill Algorithm for Precipitation Nowcasting Using Semi-Lagrangian Extrapolation (MAPLE – Germann and Zawadzki, 2002) that predicts the evolution and movement of reflectivity fields out to six hours in advance. MAPLE is a expert system/artificial intelligence algorithm that was developed and over a 10 year period. MAPLE examines a time sequence of up to six hours of past radar data to determine the movement and evolution of storms and their radar echoes. An important component of MAPLE is the capability to determine the different scales of storms and predict the lifetime of those scales based upon recent past history and the stability of the present environment. In this way, small scale storms that are predictable out to 30-60 minutes are only predicted that long, while large events that last for periods of greater than 6 hours are forecasted to maintain for that length of time.

Output from MAPLE can be utilized to produce QPF estimates of total precipitation. The same Z-R and Z-S relationships used in QPE-SUMS are applied to the MAPLE output to derive QPF. Figure 5 shows an example of a 2 hour forecast of total precipitation from the MAPLE output.

3. Summary

WDT and NSSL have deployed a Hydromet Decision Support System that provides algorithms and display systems that allow users access to high-resolution quantitative precipitation estimates and quantitative precipitation forecasts in their operational decision making process. This system provides accurate, high precision estimates of precipitation in real-time updated every 5 minutes allowing them to proactively manage their water resources and to mitigate help hydrological hazards.

Currently a system is being built that uses QPE-SUMS and MAPLE outputs with basin averaging and Flash Flood Guidance to produce a Flash Flood Prediction Algorithm. Results of this effort will be presented at the conference.

4. References

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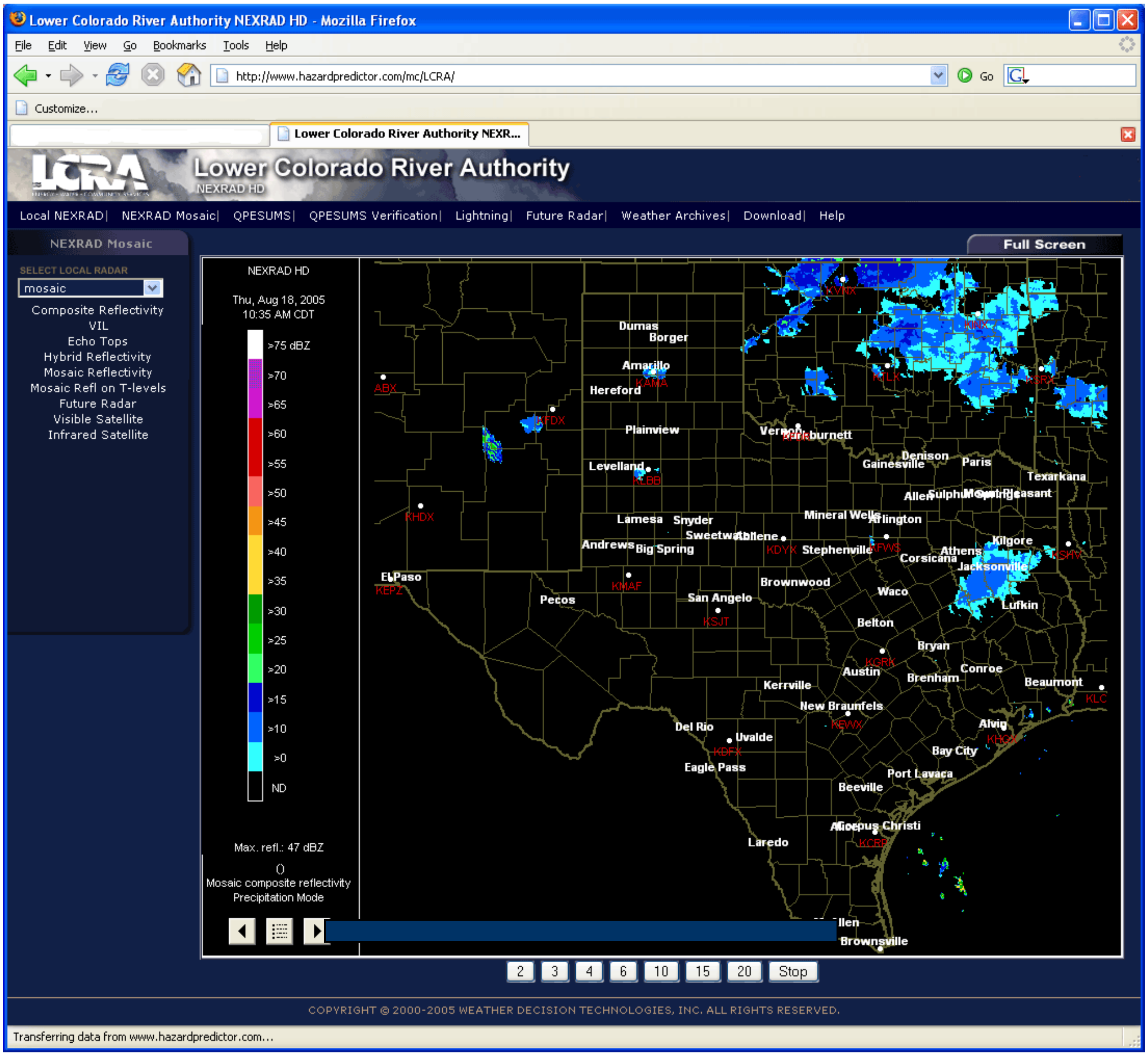

Figure 1. Example of two-dimensional mosaic product from 3D Mosaic processing shown in a Web Interface developed for the Lower Colorado River Authority HDSS.

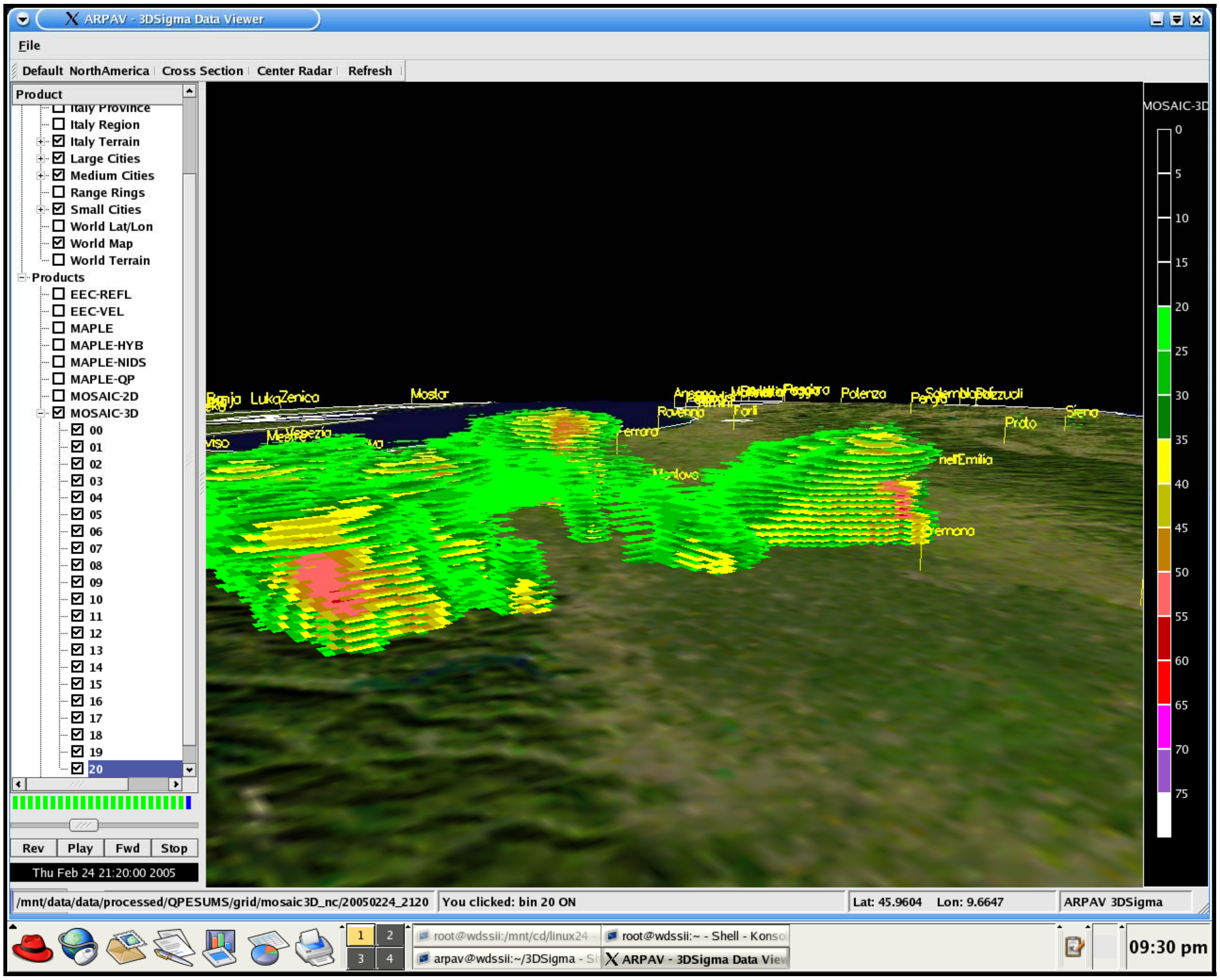

Figure 2. Example of 3D Mosaic output in 3D Sigma display showing each individual level. The user has the ability to "fly through" the data.

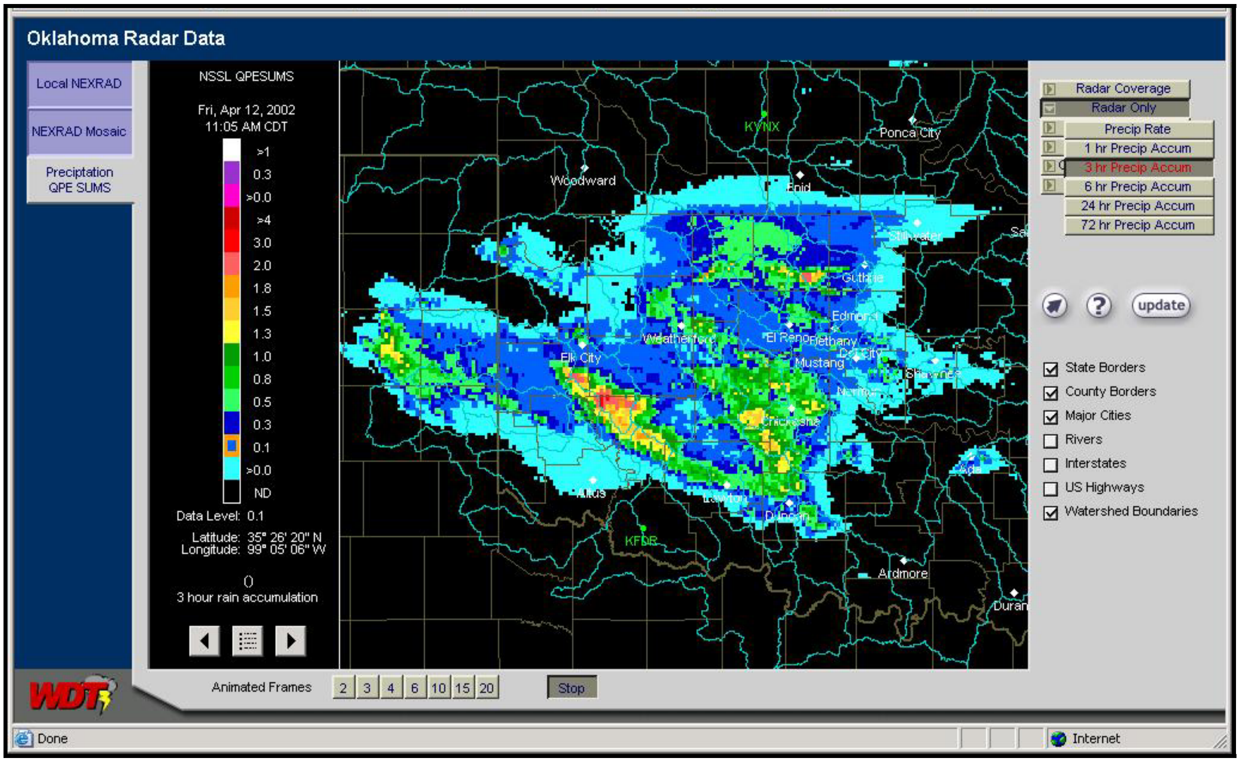

Figure 3. Example of QPE-SUMS mosaicked 3 hour rainfall estimates over Oklahoma; data from 10 radars were utilized to produce these estimates

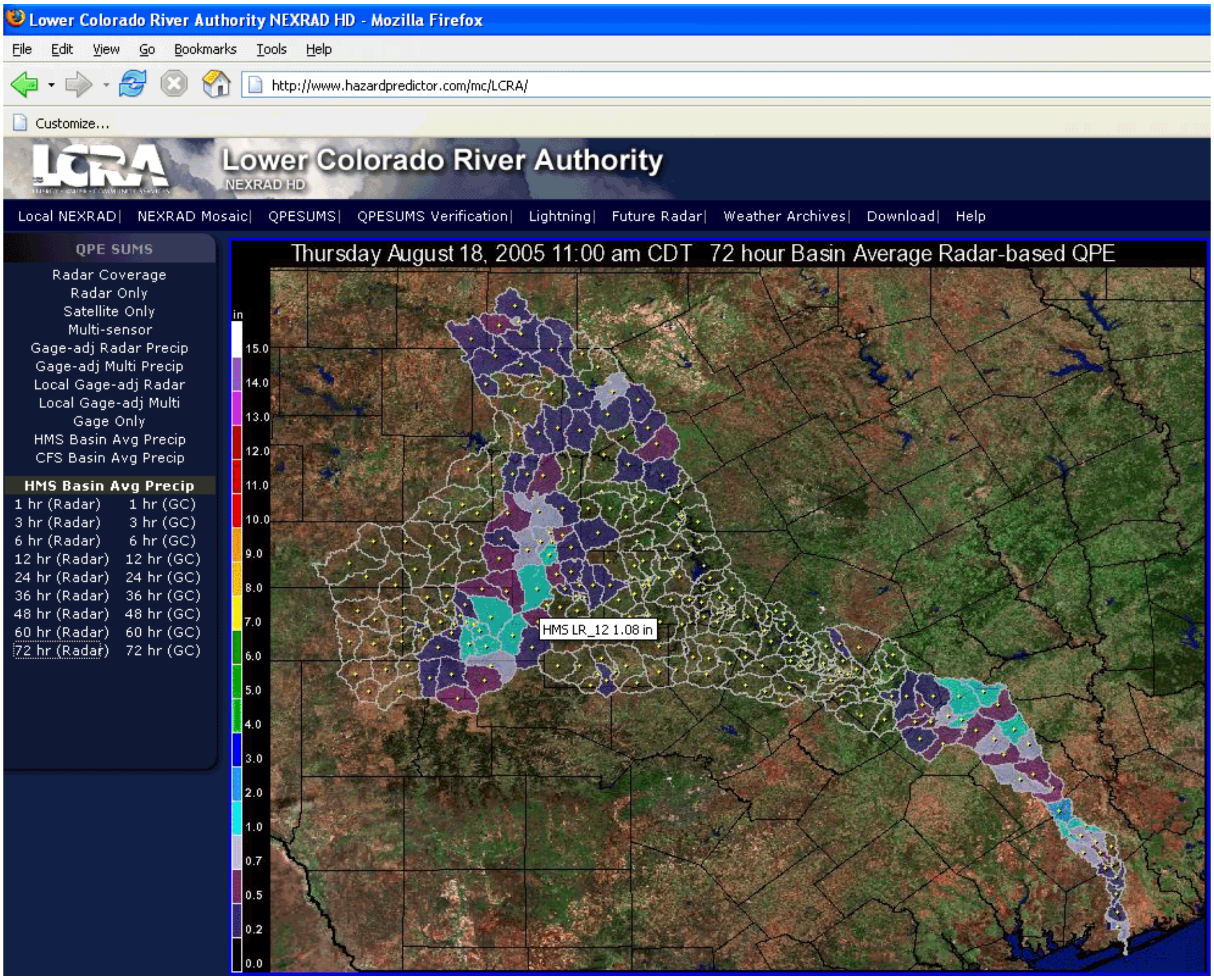

Figure 4. Example of Basin Average Precipitation Display for the Lower Colorado River Authority.

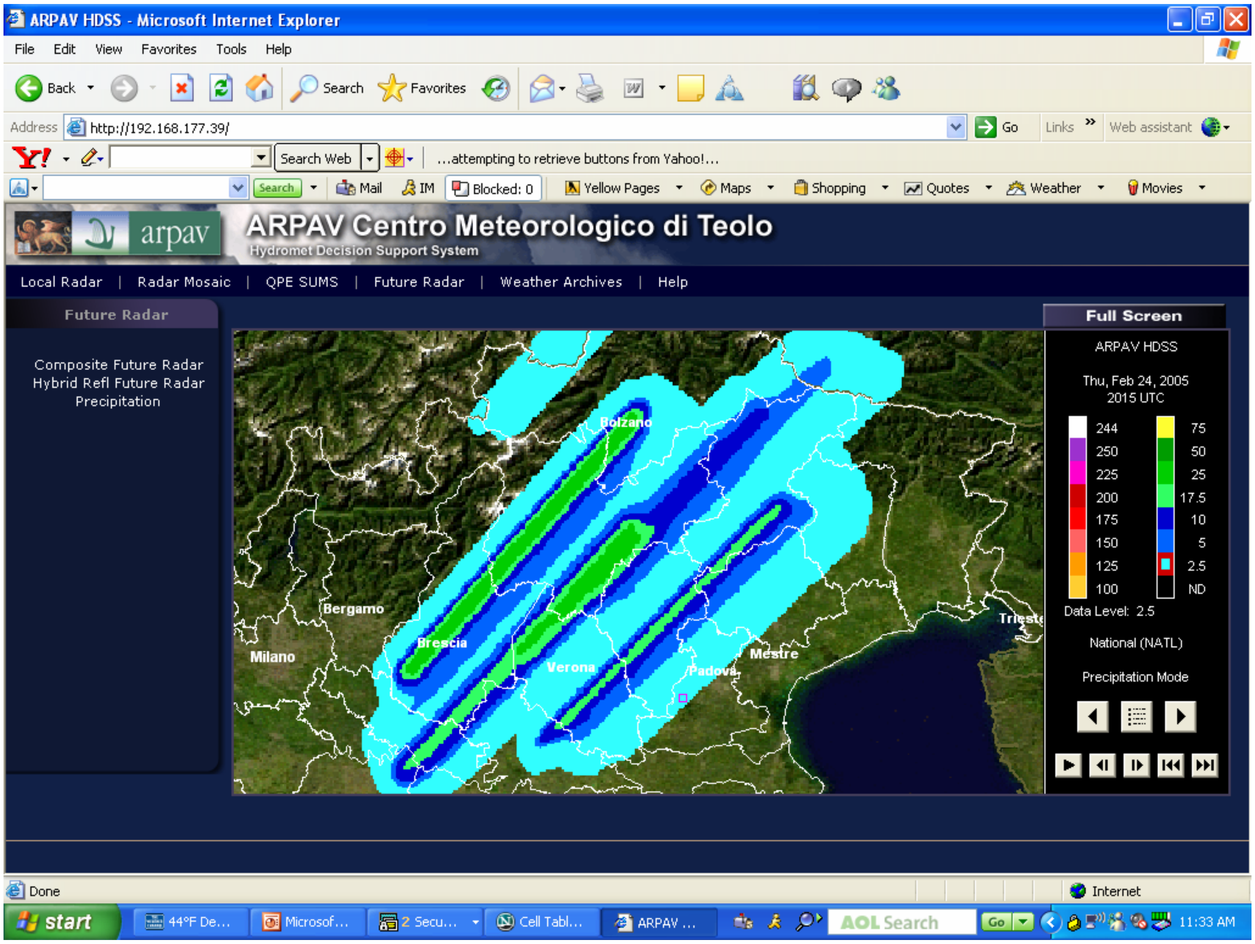

Figure 5. Example of MAPLE derived QPF over a 2 hr period shown in WxScope display from the HDSS setup in Italy. Maximum accumulations in this example are approximately 50 mm.