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Hydrometeorological Decision Support System for the Lower Colorado River Authority

***Charles A. Barrere, Jr.[1], Michael D. Eilts[1], and Beth Clarke[2]**

[1]Weather Decision Technologies, Inc.
Norman, Oklahoma

[2]National Severe Storms Laboratory
Norman, Oklahoma

1. Introduction

Weather Decision Technologies, Inc. (WDT), working with the National Severe Storms Laboratory (NSSL) has developed a custom Hydromet Decision Support System (HDSS) to support operations at Lower Colorado River Authority (LCRA).

The HDSS accesses NEXRAD Level II radar data in real-time from 22 radars covering both Texas and Oklahoma and produces a suite of products on high temporal and spatial scales, with 5 minute updates at 1 km resolution. These products include a 3D mosaic of reflectivity and a variety of precipitation accumulation estimates utilizing multiple sensors (satellite, radar, gauge, models) over multiple time periods of accumulation.

LCRA utilizes these products to support the management of their hydroelectric power generation, dams, water resources, and especially to manage potential flooding events.

This paper will describe the HDSS and each of the components of the system.

2. The Hydromet Decision Support System

The HDSS deployed by WDT includes high resolution meteorological data from numerous sources and a suite of algorithms that ingest and integrate these data to produce a series of products on a common Cartesian grid. These products are provided to LCRA's personnel through an Intranet-based display. Some products are also formatted for display in GIS software and others are converted into a Standard Hydrologic Grid (SHG) that can be directly ingested into hydrological models such as the HEC family of runoff models.

2.1 Data Sources

WDT's HDSS utilizes the NEXRAD Level II base radar data from 22 NEXRAD radars that provide coverage over Texas and Oklahoma encompassing the LCRA-defined domain (Figure 1).

*Corresponding author address: Charles Barrere, Weather Decision Technologies, 1818 W Lindsey St, Norman, OK 73069 cbarrere@wdtinc.com

The Level II radar data are the highest resolution, both temporally and spatially, and are accessed from the nationwide NEXRAD network. The NEXRAD Level II reflectivity data have resolution of 1 degree (in azimuth) by 1 km (gate spacing). The velocity data have a resolution of 1 degree by 250 meters. Data are collected in full volume scans every 4- 6 minutes in storm scanning mode. Data are either collected over 9 or 14 tilts in the vertical, dependent upon the VCP, and provide good vertical coverage. The WDT and NSSL algorithms utilize data from all available tilts to provide the best possible products. Reflectivity data precision is 0.5 dBZ and velocity data have precision of 0.5 m/sec.

In addition to the radar data, LCRA operates a rain gauge network consisting of 179 rain gauges (Figure 2) that cover an area surrounding the waterways managed by the LCRA. The rain gauge data are utilized to provide objectively analyzed rain accumulation amounts from the gauges, to remove biases from the radar derived precipitation estimates, and as 'ground-truth' to evaluate the full suite of precipitation products.

Other meteorological data used in the HDSS include NWS surface observations, United States Precision Lightning Network (USPLN, see www.uspln.com for information) detection data, WRF numerical model forecasts run by WDT, and GOES satellite data.

2.2 The Suite of Algorithms

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.

2.2.1. 3D Mosaic

The 3-D Mosaic algorithm, employed by WDT as part of the HDSS was developed by NSSL and the University of Oklahoma and was licensed from them. In short, the 3D Mosaic algorithm collects data from the 22 radars in real-time, removes artifacts from the data, and resamples 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 Grid encompasses a domain of approximately 961 x 961 km at 1 km resolution in the horizontal and 21 levels in the vertical using increments of 500 m at lower levels. An example of the output of the 3D Mosaic shown in the HDSS display is provided in (Figure 3).

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

QPE-SUMS is another technology used in the HDSS system and was developed by NSSL with support from the Salt River Project. QPE-SUMS 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 past 1, 3, 6, 24, and 72 hours. Basin average precipitation amounts are also computed from the gridded output of the algorithms as shown in (Figure 4).

QPE-SUMS utilizes a suite of sub-algorithms to provide superior 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.

2.2.3. Rain Predictor Quantitative Precipitation Forecasts

WDT has licensed from McGill University a software system called MAPLE that predicts the evolution and movement of storms with great accuracy out to six hours in advance The MAPLE system is a sophisticated expert system/artificial intelligence algorithm that was designed, developed and thoroughly tuned and tested by a group of scientists over a 10 year period at McGill University. MAPLE examines a time sequence of up to six hours of radar data utilizing highly-tuned filtering, expert system, and artificial intelligence techniques 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. WDT's Rain Predictor™ algorithm utilizes the four hour-long sequence of five-minute reflectivity estimates from MAPLE, converts all radar echoes to rainfall using the same variable Z/R relationship that are used for QPE-SUMS, and sums the five-minute images to derive accumulated rainfall in the coming one hour period. Thus, Rain Predictor produces every 15 minutes a new 4 hour forecast of precipitation on a 1 km x 1 km grid. An example is shown in (Figure 5).

3. Summary

WDT and NSSL have deployed a Hydromet Decision Support System for LCRA that provides a display system and gridded data that allows them to utilize 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 to mitigate flooding events and optimally manage their hydroelectric generation assets.

References

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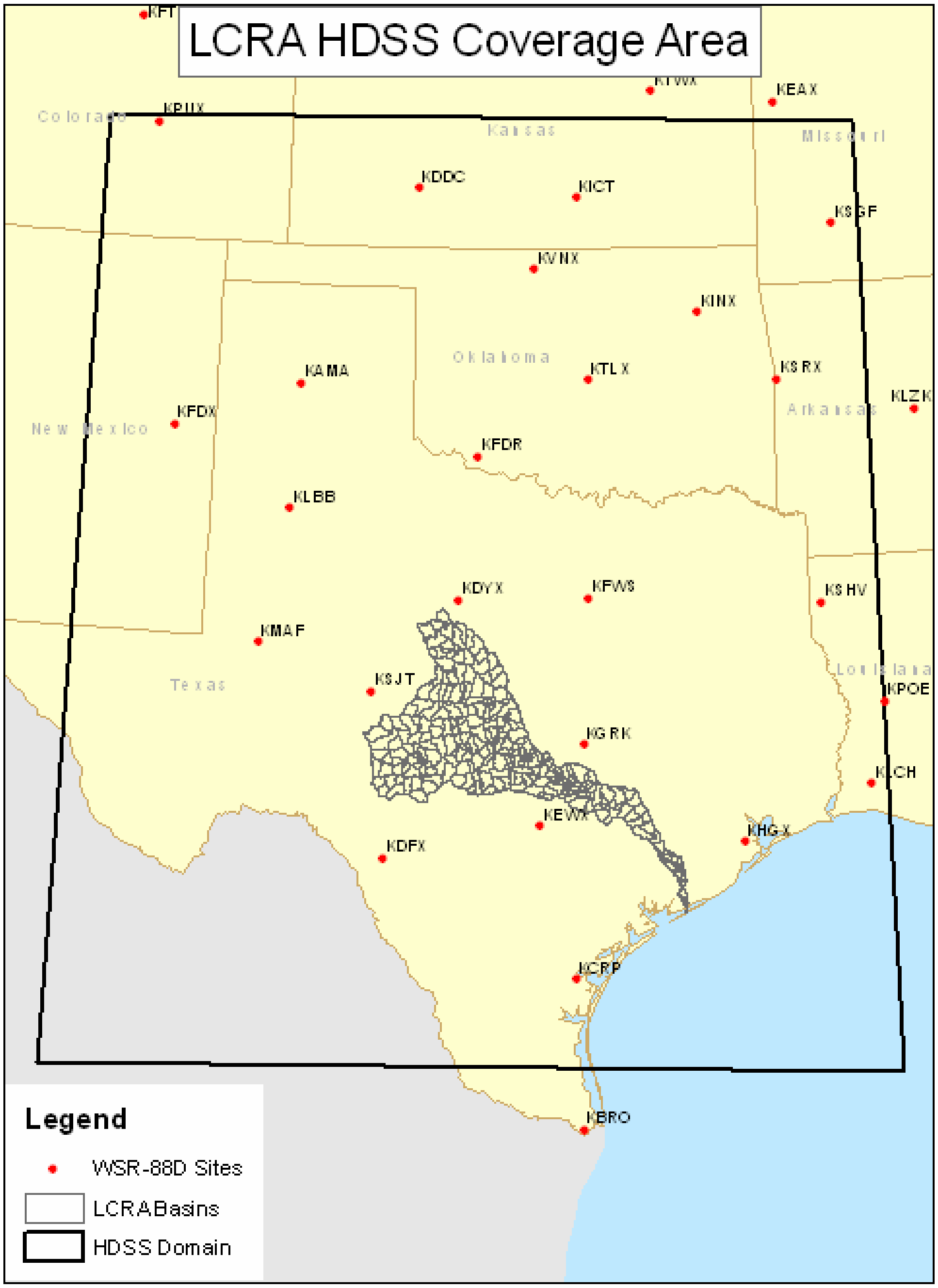

Figure 1 Diagram showing LCRA's area of interest and the coverage of the HDSS installed by WDT.

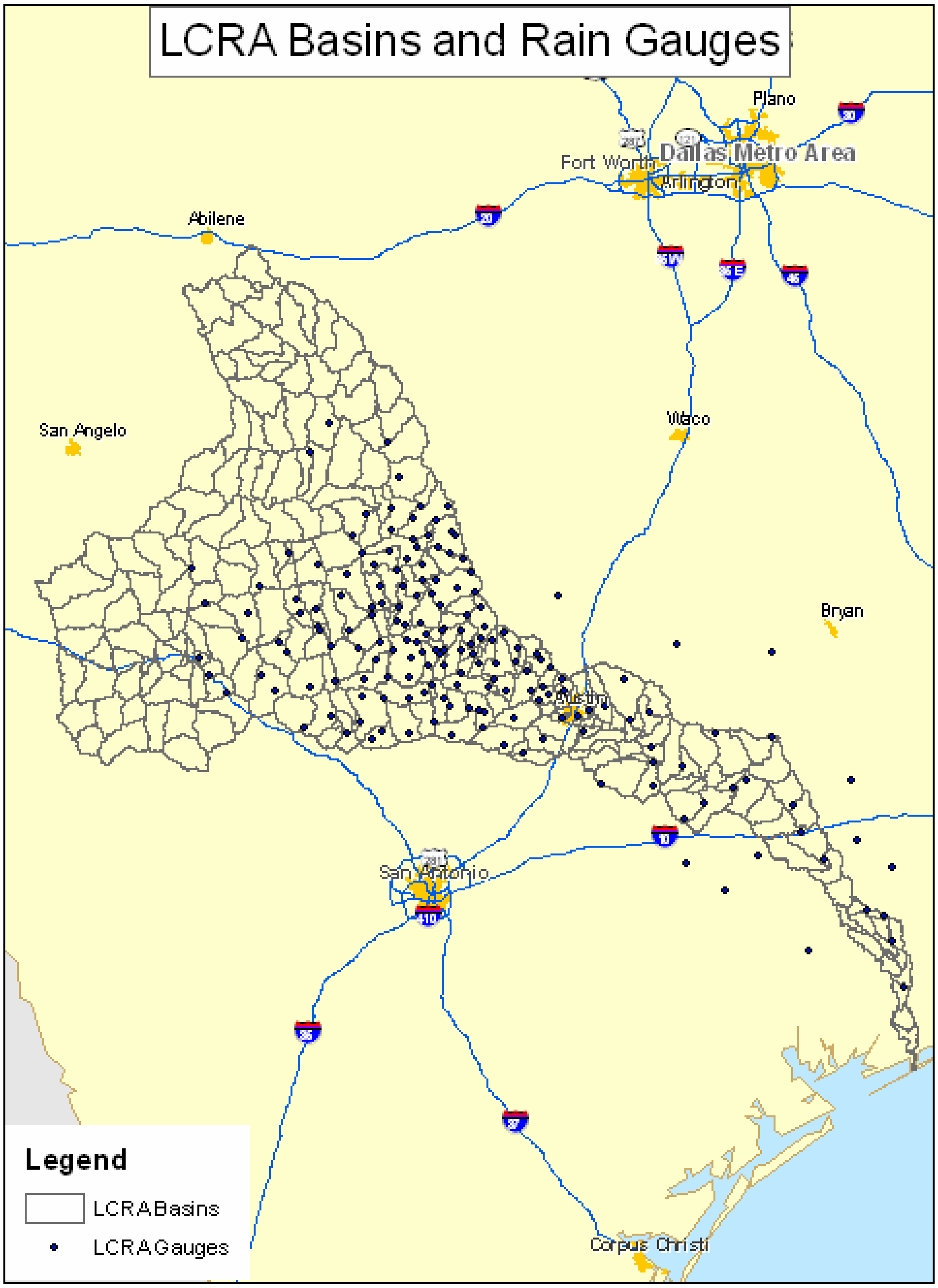

Figure 2 Map of watershed basins with rain gauge locations.

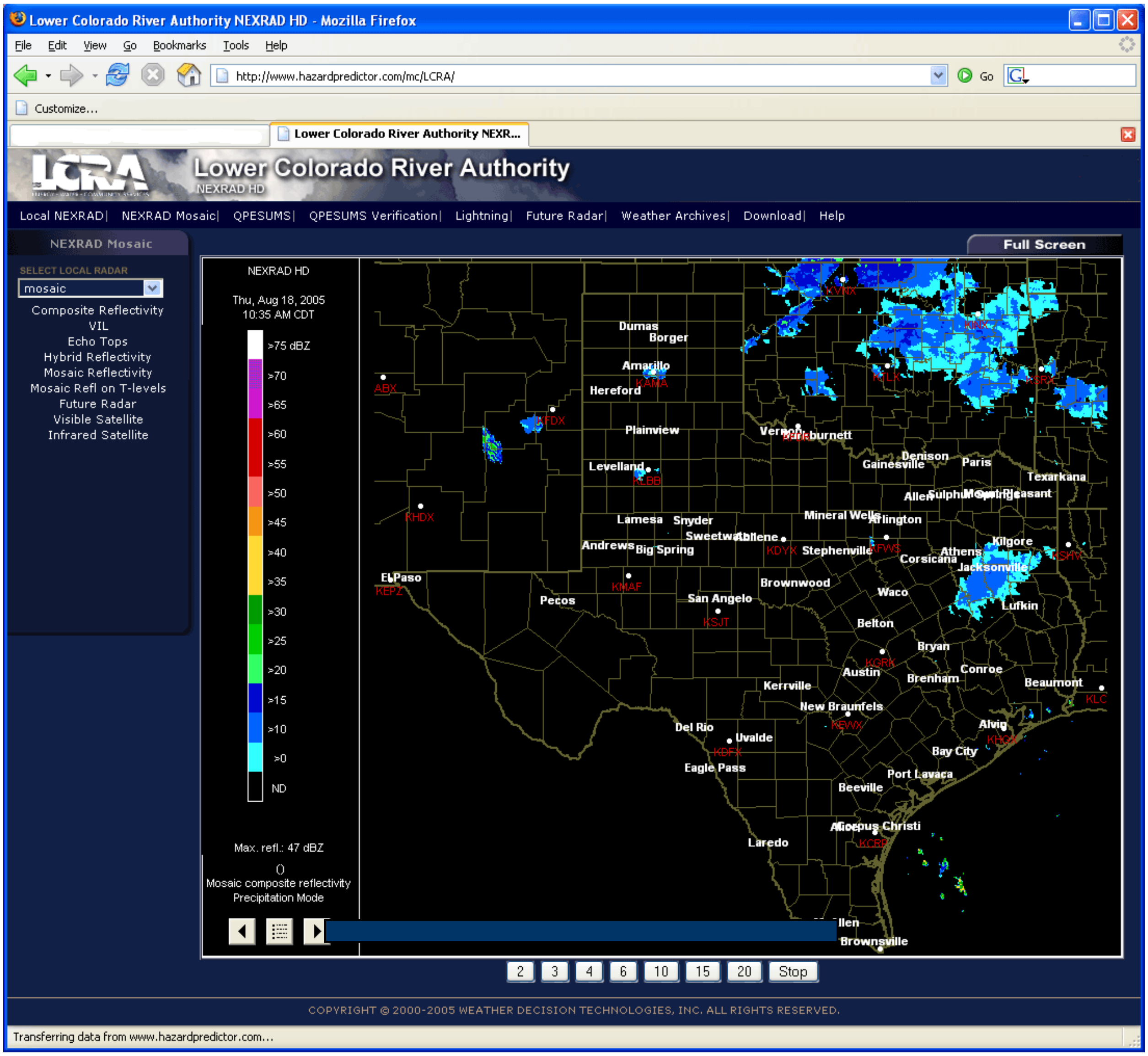

Figure 3 Example of HDSS 3D Mosaic and Web Interface

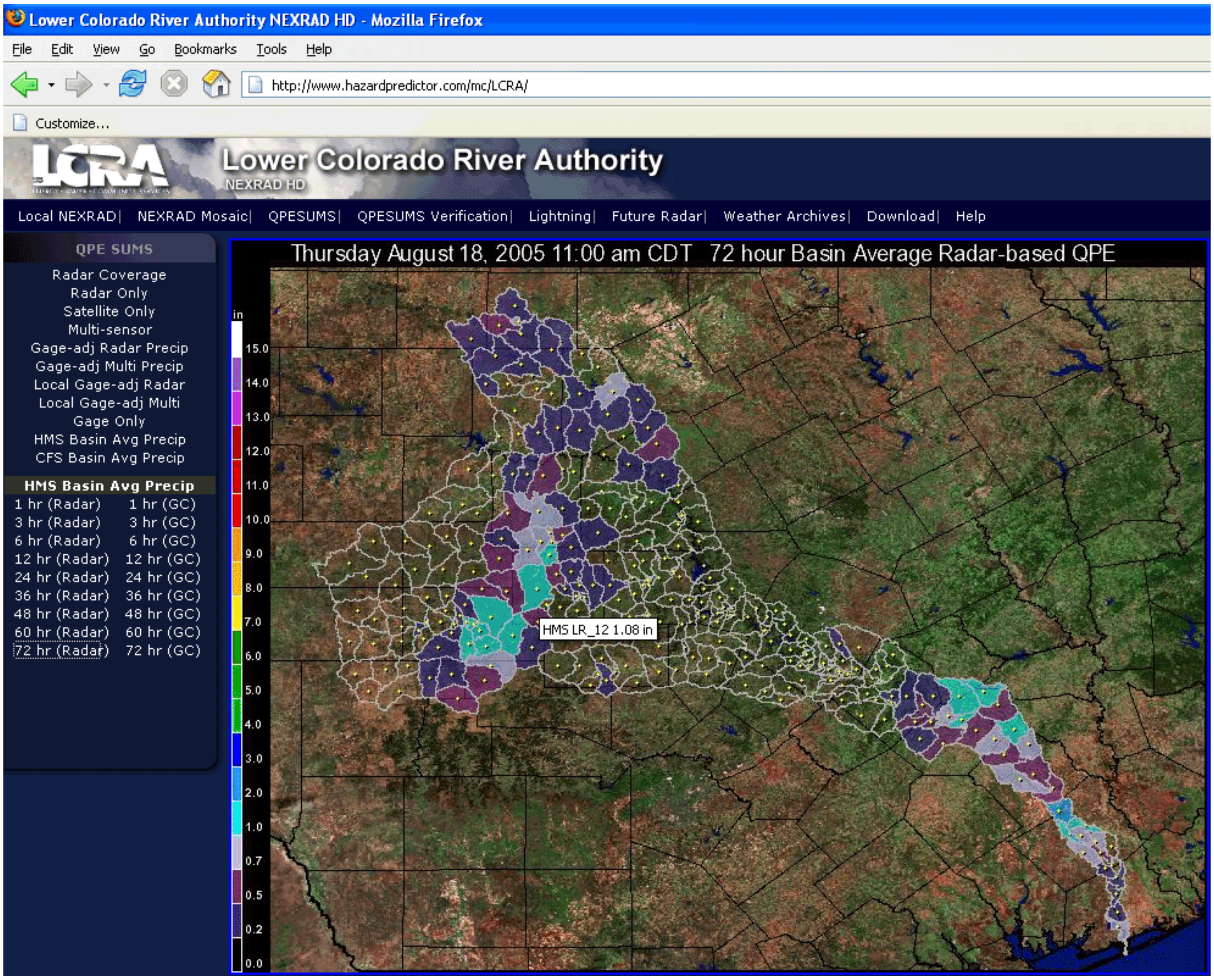

Figure 4 Basin Average Precipitation Display

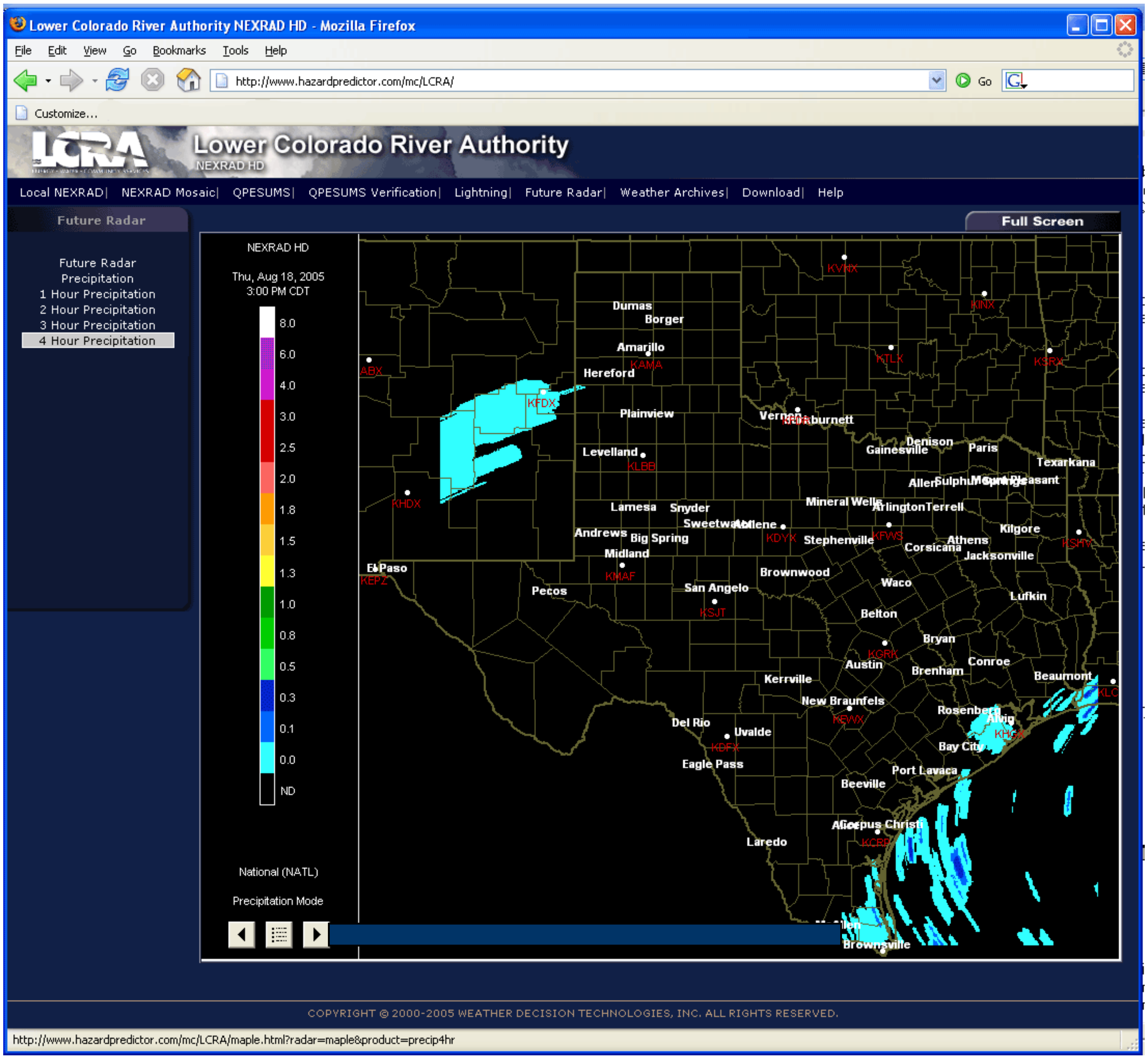

Figure 5 Rain Predictor Display