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APPLYING A MIXED TORNADO/FLOODING EVENT TO THE NEW NATIONAL WEATHER SERVICE TRAINING ENVIRONMENT

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1. INTRODUCTION

A long-lived heavy rain and severe weather event occurred 14-16 November 2001 in Central Texas. During the afternoon hours of 15 November flash flooding, main stem river flooding and tornadoes developed across central counties of the county warning area. Rainfall rates of 75 mm per hour, rainfall totals over 250 mm, and sixteen confirmed tornadoes occurred in a span of eight hours. Data from this event was captured locally and used to develop several simulations on the National Weather Service's (NWS) Weather Event Simulator (WES). The WES is an important research and training tool in NWS forecast offices that allows archived weather data to be replayed in displaced real time or interrogated in detail. An analysis of the event is presented, as well as a methodology for developing simulations from both a meteorological and hydrological perspective.

A nearly stationary strong upper-level trough to the west of the surface weather system helped provide areas of upward vertical motion and destabilization in the storm region. Satellite imagery revealed a slot of middle tropospheric dry air moving into the area from the west. Low-level satellite imagery and surface analysis revealed four distinct air masses, with their boundaries focused over areas which experienced multiple tornadoes and heavy rains. Data in the WES included an isolated supercell thunderstorm which developed two tornadoes upon crossing a weak surface temperature/moisture boundary, a bogus radar tornado vortex signature, and a series of tornadoes along a line of strong thunderstorms. Instructions with the simulation assist the forecaster in analyzing the various data fields and the radar displays. Guidance in recommended warnings is also included. The official NWS warning computer software program is available for practice warnings within the WES environment.

The data encompass the evolution of focused rains over a number of watersheds and portray the development of flash flooding, on-going and developing main stem river flooding, and the development of headwater flooding in five disparate headwater basins. Instructions with the simulation guide the forecaster in assessing both continuing and developing flash flood threats and in recognizing developing headwater flood threats. The instructions also guide the forecaster in the development of a methodology for addressing headwater and main stem flood threats and composing appropriate warnings.

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2. SYNOPTIC PATTERNS OF THE DAY

A quasi-stationary upper-level cyclone was situated over the El Paso, Texas area midday 15 November 2001, with a diffluent mid-level flow pattern evident over Central Texas. A large convective complex covered much of South Central Texas (Figure 1). Three-hour forecasts from the ETA model shifted orientation of the diffluent zone through the day with the axis remaining

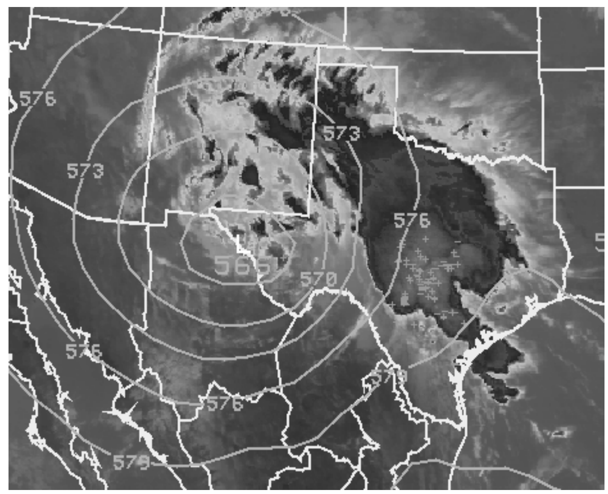

Figure 1. Synoptic situation around 1800 UTC 15 Nov 2001. 500hPa height, infrared satellite imagery, and lightning.

north-south over the central portions of the area. A moderate mid level jet (45 kts / 90 m s^{-1}) accompanied a relatively strong short wave as it moved through the mid level flow during the day. A strong low level jet (40 kts / 90 m s^{-1}) progressed eastward with the short wave system reaching the Austin/San Antonio areas between 1800 and 2100 UTC.

3. MESOSCALE PATTERNS OF THE DAY

Four air masses were evident across Central Texas midday 15 November 2001 (Figure 2). A very warm, moist air mass was situated in Southern Texas with this air spreading northward into the southern sections of the storm area. A somewhat cooler airmass lay across the southeast portions of Central Texas which had a true maritime source, the Gulf of Mexico. A drier, warm air mass lay just to the west, with its leading edge evident in a north-south line convection from Central Texas southward. A cooler, moist air mass lay across the northern portions of Central Texas. The four air masses had a general intersection in the San Antonio and Austin areas.

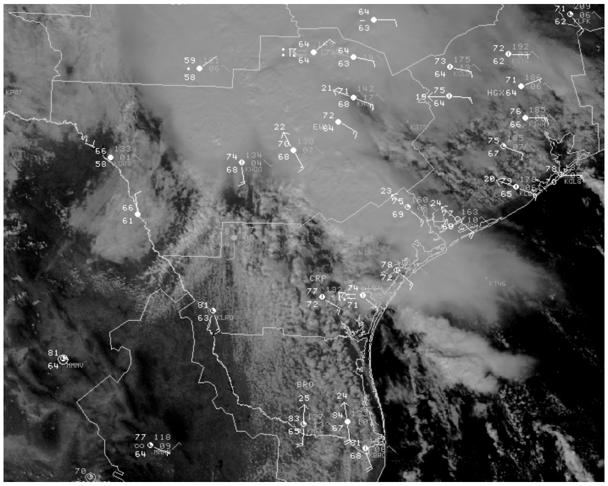

Figure 2. Visible Satellite Imagery and Surface Plot at 1800 UTC 15 Nov 2001.

Figure 3 illustrates a view similar to Figure 2, but a little higher resolution, and with a radar mosaic instead of a visible satellite image.

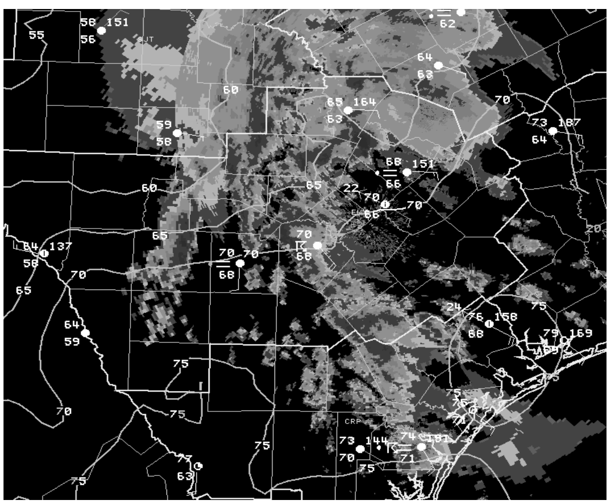

Figure 3. Radar Reflectivity Mosaic and Surface Reports around 1800 UTC 15 Nov 2001.

4. TORNADIC STORMS

As the afternoon passed, storms moved northward from the very warm humid air to the south into the marine air mass just to the north. Some of the isolated thunderstorms became tornadic. One such storm is depicted in Figure 4. The NWS WSR-88D radar algorithms detected persistent Mesocyclone (MESO) and Tornado Vortex Signatures (TVS).

Through the afternoon, sixteen confirmed tornadoes were produced as boundaries between the drier warm air mass to the west met the slightly cooler maritime air from the Gulf of Mexico. These boundaries first collided in Blanco County (upper center area Figure 3) around midday then edged eastward through the afternoon.

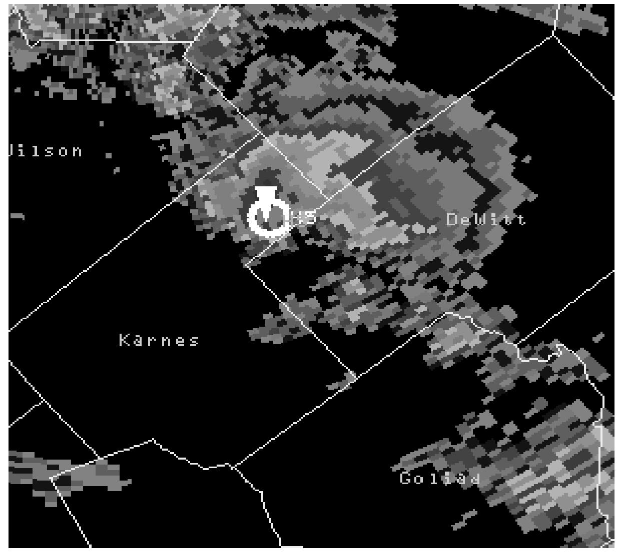

Figure 4. WSR-88D Radar Reflectivity, Mesocyclone, and Tornado Vortex Signature of a storm in northern Karnes County Texas around 1930 UTC 15 Nov 2001.

Around 2000 UTC, this convergence zone reached the Interstate 35 corridor between Austin and San Antonio and intersected with the very warm moist air moving up from the south. The tornadoes along the I-35 corridor occurred with storms that produced over 300 mm (12 in.) of rain in less than eight hours. These vortices produced persistent strong operator and radar identified TVS and MESO signatures for almost three hours.

5. FLASH FLOODING AND HEADWATER FLOODING

Flooding rains began on 14 November and continued through 17 November. Totals over the three day period were as high as 457 mm (18 in.). 100 mm amounts were common over the entire region. 200 mm totals covered large areas in seven counties with four discrete 300+ mm centers. Thirty of the thirty-three counties in the local county warning area experienced flash flooding. Main stem river flooding developed on five of the seven major river basins.

Very intense rainfall developed during the day on the 15^{th} as the boundaries of three of the air masses began to converge. Headwater flooding developed at six points during the afternoon and evening hours. Flash flooding was widespread and the majority of the fatalities attributed to vehicles in flooded waters occurred during this time. Sixteen confirmed tornadoes occurred in the same area in the same time frame.

By late morning the drier air to the west was meeting the very warm moist flow moving northward from Deep South Texas over the counties of the western Hill Country. This convergence produced intense convection over Blanco County with a 300 mm (12 in.) center over the headwaters of the Blanco River. The northern end of the convergence line produced 175 mm

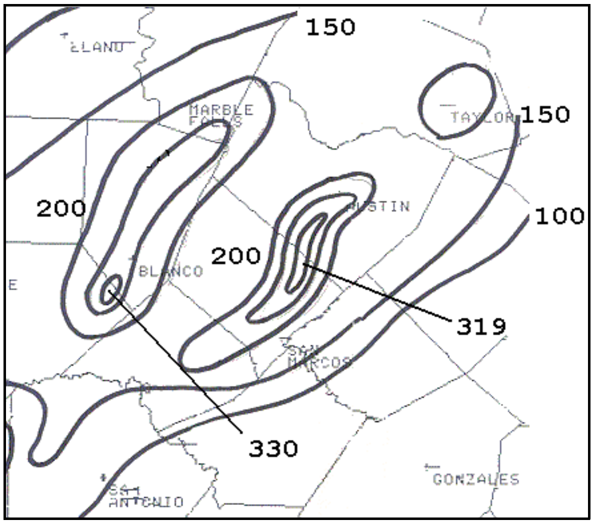

Figure 5. Total rainfall 14-15 Nov 2001. Contours in 50 mm intervals.

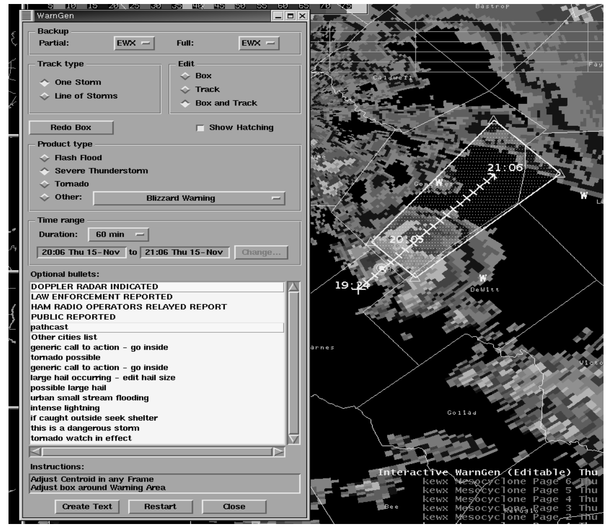

Figure 6. The NWS WARNGEN software is available to the trainee for practice inside the simulation program.

to 250 mm of rain over the headwaters of the San Gabriel River in an eight hour period.

This convergence area then moved slowly eastward with the progression of the upper low, colliding with the warm moist flow off the Gulf of Mexico roughly along Interstate 35 between San Antonio and Austin. This second convergence marked the onset of extremely high precipitation rates (75mm per hour) which continued in some locations for as long as three hours. More than 300 mm (12 in.) of rain fell in the headwaters of Onion Creek in the Austin area. The southern end of this convergence line reached Bexar County and the city of San Antonio. 100 to 150 mm of rain brought Salado and Olmos Creeks above flood stage in less than four hours.

6. DISCUSSION

Model forecasts, observations, satellite and radar imagery from this event contained a number of indicators of impending severe weather and flash flooding. The ability to capture and review this data set in displaced real time provided a unique opportunity for forecasters at the local forecast office to sharpen skills related to forecasting, radar interpretation and warning generation in respect to severe storms, flash flooding and headwater flooding in the context of a single event.

Simulations from the data set can be constructed in any number of formats targeted at a variety of goals. The WES allows the trainee to investigate synoptic and mesoscale precursor conditions prior to the event. Model data can be accessed in advance of the weather outbreak. The WES also allows the trainee to investigate small-scale features, including hourly surface plots, satellite imagery, and radar imagery. In addition to monitoring the development of severe weather and flash flooding, the software also allows the trainee to practice using the NWS warning preparation software, WARNGEN. Figure 6 illustrates the use of the WES WARNGEN software in preparing a practice warning for a tornado-producing thunderstorm. The simulations discussed here were designed as case analyses for independent study.

Two complementary but independent simulations were created from the 15 November 2001 event. Each simulation is broken into smaller time periods that can be run sequentially or independently allowing the forecaster to train as time on shift permits, or in longer dedicated blocks of time. An HTML document was created to guide forecasters through the operations of the WES, an overview of each simulation, and each portion of the event. A WES user was created for this particular event and procedures were constructed to load data appropriate to particular time frames and discussion points addressed by the simulation guide.

Simulation reference materials included warning and verification summaries, watershed boundary maps, AWIPS generated hydrographs, and hydrology text products including rainfall reports and river forecasts. These were provided as links from the simulation guide.

The Tornado and Severe Thunderstorm simulation covers a six hour period from roughly 1800 UTC through 2400 UTC November 15. It is divided into three sections of approximately two hours duration each. The dicussions focus on both basic severe weather prognosis, identification and detection, as well as more advanced topics and concepts. Ample time is allotted for users new to the simulator to become familiar with the operation and capabilities of D2D within the simulation as well as explore the archived data sets. The simulation guide moves the forecaster through a synoptic briefing, a mesoscale investigation, and several radar interpretation and warning exercises.

The Flash Flood and Headwater Flooding simulation is comprised of five sections each focusing on an individual headwater flood event. Completion of each section requires approximately one hour. The simulation guide includes an introductory briefing covering synoptic and mesoscale conditions and on-going flooding. Each section uses references available to forecasters in live events as well as hydrographs captured after the fact. The guide also contains a summary of crests and impacts for each headwater event.

The Flash Flood and Headwater Flooding simulation incorporates training in recognition of synoptic and mesoscale precursor conditions for heavy rain and flash flooding as well as basic hydrological concepts such as quantitative precipitation forecasting, mean areal precipitation (MAP) determination and the use of headwater flood guidance.

8. ACKNOWLEDGEMENTS

The authors wish to thank Robert Blaha, WFO Austin/San Antonio, for the preparation of web page links to this paper and the simulation guides.

9. REFERENCES

The WES was delivered to NWS Weather Forecast Offices in the fall of 2001. Little has been published to date concerning the implementation and use of the Weather Event Simulator.

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