The COMET Outreach Program
Sponsored by the National Weather Service

COMET Partners Final Report

University: Saint Louis University

University Researcher Preparing Report: Charles E. Graves
(replacement for recently deceased G. V. Rao)

NWS Offices: Storm Prediction Center, Norman, Oklahoma
NWSFO, Melbourne, Florida

NWS Researchers Preparing Report: Roger Edwards (SPC),
Scott M. Spratt, NWSFO Melbourne

Partners Project: Using MM5 short-term integrated kinematic fields to distinguish TC Gabrielle's (2001) mesocyclones, which produce Tornadoes from those, which did not in Florida

UCAR Award Number: SO3-38664, project extended through November 2004

Date: 10 December 2004

With the untimely death of G.V. Rao, Charles Graves agreed to complete the project as stated in the original proposal. His role has mainly been as a facilitator. Most, if not all, of the accomplishments of this work should be attributed to actions of Dr. G.V. Rao and the other members of the original proposal.

1. Summary of Project Objectives

The hypothesis for this project is that the short-range predicted kinematic fields, based on MM5 high-resolution simulations incorporating high-resolution input data, will aid the NWS forecaster by providing distinct signatures of Tropical Cyclone (TC) spawned mesocyclones producing tornadoes from those which did not.

2. Project Accomplishments/Findings

Accomplishments

Saint Louis University (SLU) obtained ARPS (Advance Regional Prediction System) Data Analysis System (ADAS) output containing high-resolution data including; the NASA mesonet tower winds, NASA Doppler wind profilers, Florida Automatic weather reporting network observations, automatic position reporting system observations, aircraft communications addressing and reporting observations, GOES visible and infrared imagery, and the Melbourne WSR-88D reflectivity and velocity

fields. This data was obtained from Jon Case of the Applied Meteorology Unit of Cape Canaveral Air Force Station.

Joshua Scheck has revamped and updated the web page for the Tropical Cyclone Tornado Group (http://www.eas.slu.edu/Comet/trop.html). This site now reflects more of the current research and findings.

SLU has succeeded in running MM5, nested at 54, 18, 6, and 2 km for TC Gabrielle (2001). The simulations all incorporated the following configuration options:

- Betts-Miller cumulus parameterization scheme
- Burk-Thompson planetary boundary layer scheme
- Reisner ice-microphysics scheme

In addition, all the simulations ingested large-scale data (i.e., NCEP-FNL) into the coarse domain for initial and lateral boundary conditions.

Several simulation configurations were run to investigate the value of introducing high-resolution data into the model. A synopsis of these simulations is given below:

Control Run:

- Ingested no high-resolution data from ADAS.

Simulation 1:

- The ADAS data replaced the MM5 lower boundary and initialization data for the two finest domains.

Simulation 2:

- The girded ADAS data were ingested via the four dimensional data assimilation (FDDA) in the finest domain only.

Simulation 3:

- The ADAS data was incorporated through nudging in the finest two domains.
- Lower boundary conditions were interpolated from the mother domain.

For SLU to analyze the MM5 output, the MM5 simulated fields were converted into GrADS format. Both through modification of the MM5-to-GrADS code and through GrADS scripting capabilities, SLU researchers were able to examine non-standard parameters expected to be useful in accessing tornadic potential. In particular, storm-relative helicity, composite reflectivity, buoyancy, and baroclinicity-induced horizontal vorticity (BIHV), were added to the standard set of available parameters.

Findings

The results from the simulations have provided several points. We observed that including high-resolution data improves the simulation. In particular the addition of high-resolution data:

- Greatly improved the representation of the vorticity field and simulated composite reflectivity.
- Increased the magnitude of vorticity maxima by a factor of three, more inline with expected values for tornadic storms.
- Improved the spatial and temporal correlation of the mini-supercells with that observed by WSR-88D radar.
- Increased storm-relative helicity substantially and was maximized in the three county area where mesocylone circulations were observed.
- At least for this study, FDDA did not produce significantly better results than observed with nudging.

However, several critical failures caution the blind use of high-resolution data. We found that how the high-resolution data is incorporated into the simulations can have huge impacts. For our particular case, the ADAS surface temperature data had a slightly different bias than the temperature generated by the MM5 (average difference of about 2°C). Therefore, our attempts to directly incorporate this data into the initialization or boundary data resulted in a large shock to the simulation. This shock had a pronounced effect, more on the low-level thermodynamics than on the dynamic fields. We adopted a nudging approach (Simulation 3) to adjust the high-resolution temperature data toward ground truth and therefore to minimize the shock to the model simulations. Sample results from the control run and simulation 3 are attached to the end of this report to illustrate these findings.

3. Benefits and Lessons Learned: Operational Partner Perspective

Roger Edwards (SPC) visited SLU in November 2003 and discussed with Professor Rao, Joshua Scheck and Krishnaraj Santhanam details on revisions to a manuscript submitted to *Weather and Forecasting* suggested by reviewers. Roger had additional discussions with Krishnaraj on various details of data assimilation and how the high-resolution data was incorporated into the MM5 simulations. Roger also presented three seminars during his visit.

Scott Spratt (NWSFO, Melbourne) attended the 26th Conference on Hurricanes and Tropical Meteorology in Miami, Florida on 4-5 May 2004. Scott used this opportunity to meet with Krishnaraj to discuss data assimilation issues and simulation strategy. Further discussions ensued concerning the improvements observed in the precipitation and vorticity fields with the inclusion of the high-resolution data. This preliminary success, suggested that such a model run could provide forecasters with subtle, yet important precursors to help refine tornado and flood threat locations and periods of occurrence. Given that NWSFO-Melbourne currently runs an experimental mesoscale model in real-time, these results could directly benefit their local forecast and warning services.

4. Benefits and Lessons Learned: University Partner Perspective

Krishnaraj and Joshua obtained invaluable experience in working with a research-quality mesoscale model. They have also benefited from the interaction with the operational community to better understand issues confronting National Weather Service forecasters. These experiences are critical for success in their future endeavors.

Joshua Scheck has completed his Ph.D. dissertation, entitled "Radar Characteristics of Two Tornadic Mesocylones Spawned by Tropical Cyclone Earl (1998) and a Study of Their Dynamics using MM5 Simulations". This research was initiated from a past COMET partner project. A copy of his dissertation will be sent to COMET shortly.

Krishnaraj Santhanam has nearly completed his Ph.D. dissertation entitled "Meso-gamma Simulations of Mesocyclones Produced by TC Gabrielle (2001) Using High-Resolution Data of East-Central Florida and MM5 Integrations." This research was directly funded by this partner project. A copy of his dissertation will be sent to COMET, upon successful completion of his degree.

5. Publications and Presentations

Scheck, J.W., 2004: MM5 Integrations of Two Tornadic Supercells Spawned by Tropical Cyclone Earl (1998), Poster presentation at the 10th Annual Graduate Research Day Symposium, Saint Louis University, 2 April 2004.

Santhanam, K., 2004: MM5 Simulations of Precipitation and Mesocyclone Dynamics Associated with TC Gabrielle (2001) Using High-Resolution Data of East Central Florida, Poster presentation at the 10th Annual Graduate Research Day Symposium, Saint Louis University, 2 April 2004.

Scheck, J.W., and G. V. Rao, 2004: MM5 Integrations and Analysis of Two Tornadic Supercells Spawned by Tropical Cyclone Earl (1998), Presentation at Missouri Academy of Science Annual Meeting, 17 April, Kansas City, MO

Santhanam, K. and G. V. Rao, 2004: MM5 Simulations of Precipitation and Mesocyclone Dynamics Associated with TC Gabrielle (2001) Using High-Resolution Data of East Central Florida, Presentation at Missouri Academy of Science Annual Meeting, 17 April, Kansas City, MO

Rao, G.V., K. Santhanam, J.W. Scheck, S.M. Spratt, B.C. Hagemeyer, R. Edwards, J. Schaefer, J.L. Case, and E. Kemp: 2004: MM5 Simulations of Precipitation and Mesocyclone Dynamics Associated with TC Gabrielle (2001) Using High-Resolution Data of East Central Florida, Presentation at 26th Conference on Hurricanes and Tropical Meteorology, 3-7 May 2004 Miami, FL.

Santhanam, K., G.V. Rao, S.M. Spratt, and B.C. Hagemeyer, 2004: Improved Rainfall Predictions Pertaining to Land-falling Tropical Cyclone Gabrielle (2001)

Based upon Ingest of High-Resolution Observational Data and MM5 Integrations, Poster presentation at National Weather Association Annual Meeting, 16-21 October 2004, Portland, OR.

Rao, G.V., J. W. Scheck, R. Edwards, and J. Schaefer, 2005: Structures of Mesocirculations Producing Tornadoes Associated with Tropical Cyclone Frances (1998), *Pure and Appl. Geophys*., Special edition on tropical meteorology, Accepted for publication.

Scheck, J.W., G.V. Rao, K. Santhanam, R. Edwards, and J. T. Schaefer, 2005: WSR-88D Investigation of Tornadic Mesocyclones associated with Tropical Cyclone Earl (1998) and a Baroclinic Boundary in Central Florida, To be submitted to *Weather and Forecasting*, January 2005.

6. Summary of University/Operational Partner Interactions and Roles

A key benefit achieved via the project was brought about from the close collaboration and professional relationships established between SLU researchers and NWS MLB forecasters. Early in 2003, four SLU researchers visited NWS MLB to discuss high resolution data sets available within east-central Florida for ingest into mesoscale-models. Following this visit, two MLB meteorologists traveled to SLU and presented seminars detailing operational practices and deficiencies common to Tropical Cyclone (TC) tornado events. A high level of interaction occurred between SLU and NWS personnel during each visit, enabling SLU students to gain a strong appreciation and knowledge of NWS radar interrogation and subsequent warning requirements during TC tornado situations. The current limitations of warning operations were stressed and the SLU team responded by using this insight to conduct a multitude of model simulations. For example, the modeling system was specifically configured to obtain realistic representations of output parameters most useful to operational forecasters (e.g. composite reflectivity, storm relative helicity, buoyancy, horizontal vorticity).

Throughout the duration of the project, SLU and NWS MLB staff frequently interacted via email exchanges and in person at conferences to examine and discuss simulated model output and to compare the results to observed conditions. The parameter configurations, which proved most accurate in the evolution of TC mesocyclone cells, were provided to NWS MLB at the completion of the project. Since a mesoscale model is currently run experimentally at NWS MLB, comparisons will be made between the results provided by SLU and the current real-time model configuration to determine if changes can be implemented to achieve improved forecast fields for TC tornado events. Such parameter modifications, if made, could pay-off through a fairly rapid transition of the Partners Project results directly into local NWS operations, likely resulting in a direct benefit to short-term forecast and warning services. Furthermore, SLU will provide graphical images of forecast fields from the simulations to NWS MLB, which will be incorporated locally into a pre-existing Warning Event Simulator (WES) case study on Tropical Storm Gabrielle

(2001) tornadoes. Once complete, the supplemented WES case study will allow NWS forecasters to train at their discretion in advance of similar events, ultimately achieving more accurate and timely identification of TC tornado situations by integrating particular parameters from mesoscale model output.

Other benefits of the project included an exposure of SLU students to the NWS local office environment, including the complexities of the operational forecast/warning program, as well as demonstrating applied research and training opportunities. In fact, over the course of the project, several students expressed interest in possible future careers with the NWS. For NWS MLB staff, the project members greatly appreciated the many open forums with SLU students, which often provided creative, well informed, and unbiased assessments and opinions concerning the tropical cyclone tornado forecasting issue. The MLB Partners Project members also benefited professionally and personally from frequent interactions with the project P.I., Dr. G.V. Rao, and greatly admired his tremendous dedication and enthusiasm displayed for the project topic.

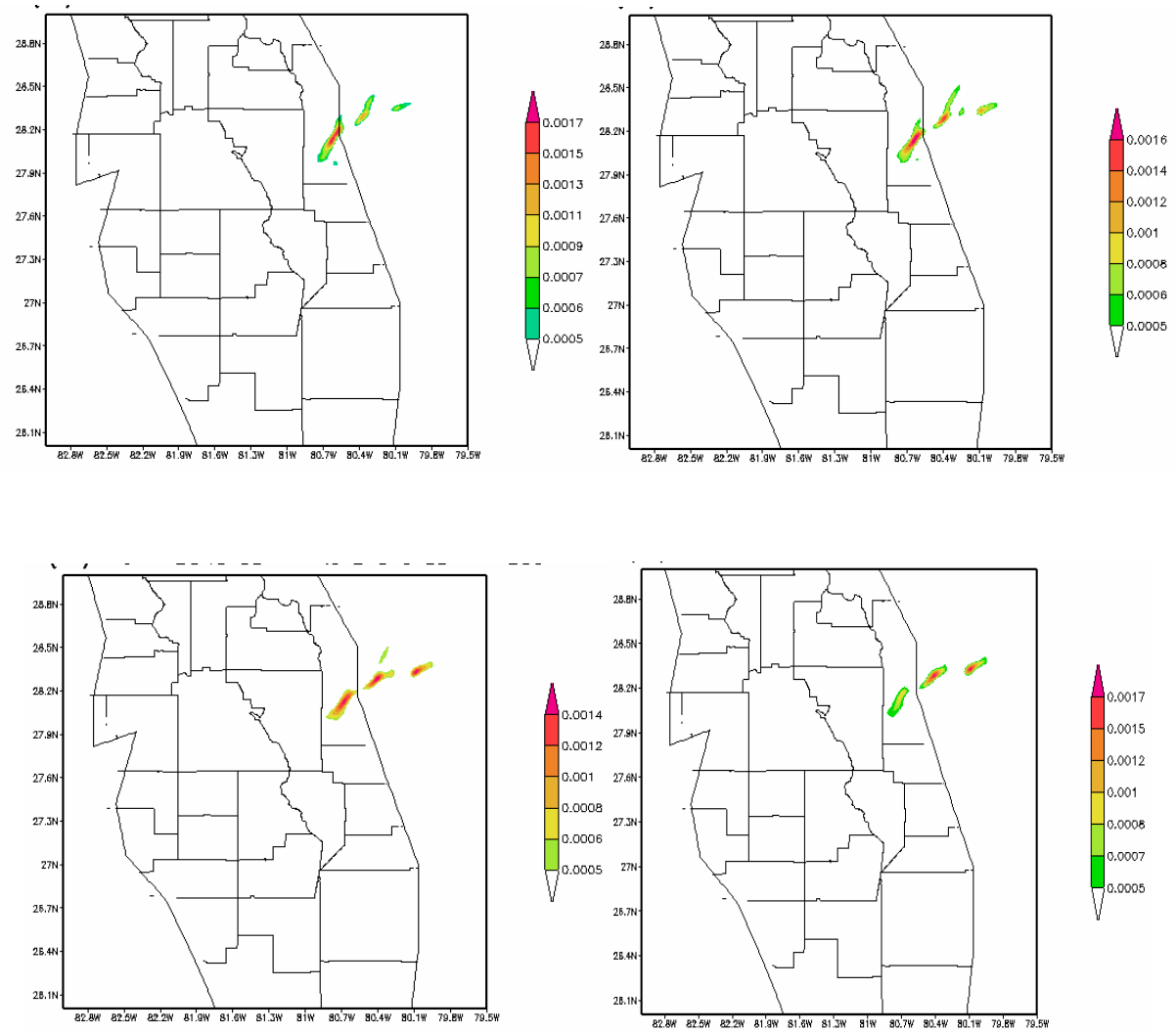

Fig 1. Simulation of vorticity (s^{-1}) in the 2-km domain at 1115, 1130,1145 and 1200 UTC respectively using high-resolution data. This simulation used Betts-Miller for cumulus parameterization in the coarse mesh and Burk-Thompson for boundary layer.

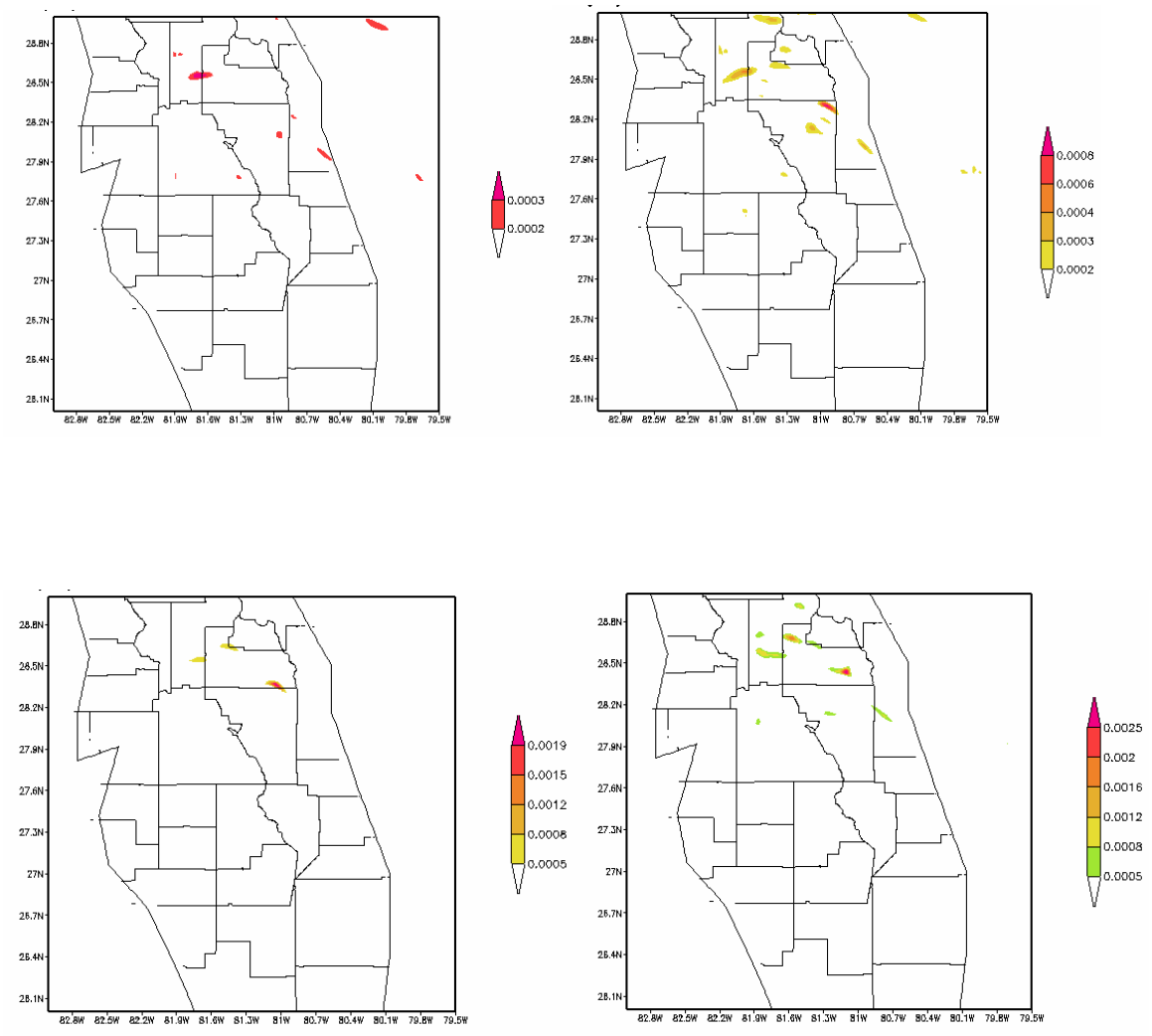

Fig 2. Same as above but without high-resolution data.

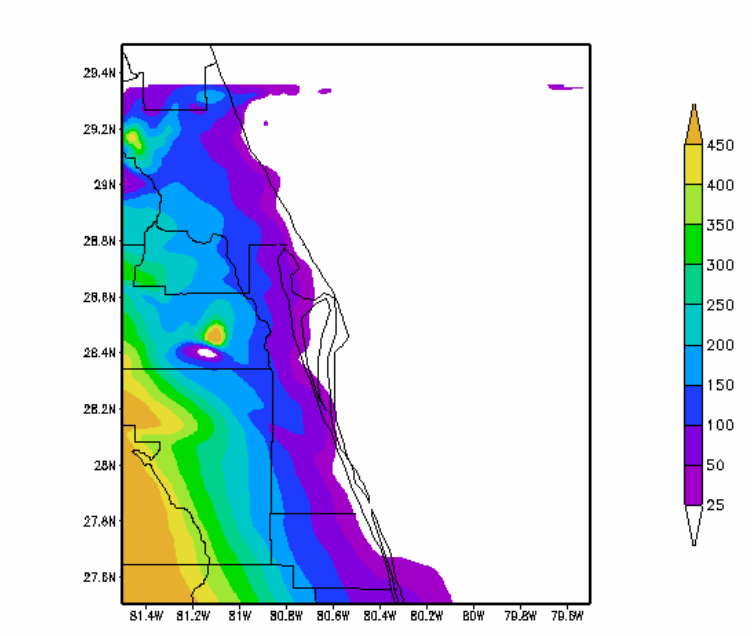

Fig 3. Storm Relative Helicity (m^2/s^2) simulation in the 2-km domain without high-resolution data. The schemes involved are same as Fig 1.

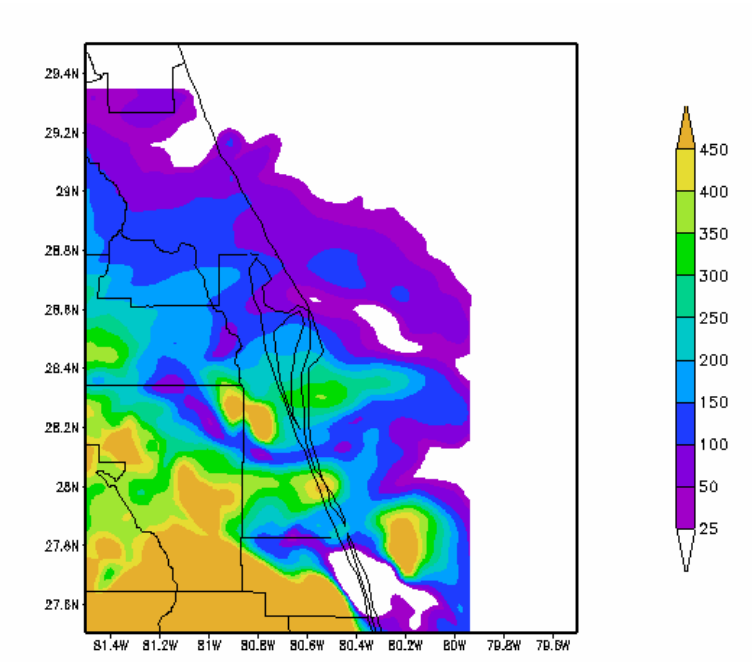

Fig 3. Same as the above with high-resolution data.