Final Report for Partners Project

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Partners Project: A Diagnostic and Prognostic Examination of a Major Flash Flood in Eastern Iowa and Northwest Illinois: 3-4 June 2002

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Section 1: Summary of Project Objectives

The primary objectives of this Partners collaboration include:

1. Accessing standard surface, upper air, GOES satellite imagery, archive level II WSR-88D, and profiler data to diagnose the 3-4 June 2002 heavy rain event over eastern Iowa and northwestern Illinois.

2. Accessing numerical model data from the Eta, RUC, and GFS operational numerical models from NCEP.

3. Developing a detailed mesoscale surface analysis of this event using surface data, satellite imagery, and WSR-88D data. Also, use RUC-II initialization data to plot basic and derived parameters (e.g., low-level moisture convergence and θ_e advection, CAPE, etc.) to determine the physical processes and sequence of meteorological events associated with this unusually heavy convective rainfall event.

4. Completing a mesoscale analysis of the 24 h (3-4 June 2002) rainfall using NCDC cooperative data and WSR-88D storm total precipitation imagery.

5. Comparing actual cell motion and storm propagation to those estimates determined from the Corfidi upwind and downwind techniques.

6. Running a workstation Eta model simulation of the event to generate a higher spatial and temporal data set to compare this model's run to the operational models' quantitative

precipitation forecasts (QPF).

7. Documenting the societal impacts of this event on the local community.

8. Evaluating the warning decision process during this event in light of lessons learned from the partners' research.

Section 2: Project Accomplishments/Findings

During the last year and one-quarter we have accomplished the following tasks:

1. On 23-24 September 2003 Jim Moore, Chuck Graves, and graduate student, Brad Mickelson, visited the National Weather Service (NWS) Davenport, Iowa office to confer with Ray Wolf and Jeff Zogg about the project. Discussions during this visit helped to set the agenda for our Partners project as we divided up tasks and set a timetable to complete various projects.

2. We downloaded all available GOES-8 satellite imagery from the Space Science and Engineering Center at the University of Wisconsin-Madison. An enhanced infrared (IR) satellite loop was created that covers the period 18 UTC 3 June to 18 UTC 4 June 2002 to track the main centers of convection.

3. WSR-88D radar data for the event were obtained from the Davenport, Iowa NWS office. At SLU we are used WATADS to look at the archive level-II data and compare it to the satellite imagery. The NWS partners used the WSR-88D imagery, along with the IR satellite imagery, to document the four major mesoscale convective systems (MCSs) which contributed to the heavy rainfall.

4. Mesoscale surface analyses were created by the NWS partners (primarily Jeff Zogg) utilizing surface data, satellite imagery, and WSR-88D imagery to identify frontal boundaries, thunderstorm-generated outflow boundaries, and a sea-breeze front from Lake Michigan. Locating these mesoscale boundaries was critical in understanding how new convection was generated during this event.

5. RUC-II initialization data were used to create plots of both basic and derived fields (e.g., 850 hPa winds, 900-800 hPa moisture convergence, 900-800 hPa θ_e advection, etc.).

6. Cell and storm motions for the four major MCSs of this event were investigated using the Corfidi method. We are also computed the actual storm motion from satellite imagery and combined it with the 850-300 hPa mean winds to derive the "actual" propagation vectors. Later, we compared the latter propagation vectors to those estimated by the Corfidi method (i.e., $-\mathbf{V}_{\text{low-level jet}}$) to test the applicability of the Corfidi vectors in this case.

7. The NWS partners documented when and where the heaviest precipitation fell and what hydrologic impact it had on the county warning area (CWA). Jeff Zogg spearheaded this part of the research effort.

8. Simulations of the event were run using the Penn State/NCAR MM5 model, as well as the workstation-Eta model. Output was converted into GEMPAK format and analyzed.

9. A preprint was created by both teams for the 20th Weather Analysis and Forecasting (WAF) Conference that took place in Seattle, Washington from 12-15 January 2004. This preprint article will form the nucleus of a manuscript for eventual publication in the *National Weather Digest.*

10. A PowerPoint presentation documenting our preliminary results was created for the WAF conference noted above. It was presented during an oral session (paper 8.5) on 12 January 2004.

11. This heavy rain case was presented at the National Weather Association 2004 Central Iowa Severe Storms Conference in Des Moines, Iowa in March.

12. This case was used in WES format for training of the NWS Davenport staff for flash flood preparedness in spring 2004. Local media also attended the training session. This was a key part of a larger local effort to increase skill in forecasting and warning for flash flood events.

13. On 5-6 July Ray Wolf and Jeff Zogg visited Saint Louis University (SLU) to discuss progress made on the project during the first six months. We spent the first day going over our surface analyses while looking at the WSR-88D imagery from Davenport, IA (DVN) to define outflow boundaries. We added the latter features to the surface analyses to create a better mesoanalysis of the surface features. We also scrutinized the hourly surface analyses for inverted troughs north of the quasi-stationary front to make sure that we had an acceptable continuity of features from hour to hour. We later examined the outflow boundaries and inverted troughs north of the quasi-stationary front to better understand the role that they played in the formation of new convection.

14. In our analysis of the WSR-88D radar data from DVN we also noticed what appear to be horizontal convective rolls (HCR) to the south of the quasi-stationary front, in the warm air, during certain time periods. The role of the HCRs in the convection north of the boundary is unclear at this time. However, the unstable air in the boundary layer associated with the HCRs was likely advected northward over the quasi-stationary frontal zone thereby influencing the convection in this region.

15. We spent several hours discussing the mesoscale convective systems (MCSs) that sequentially formed during the time period 18 UTC 3 June to 18 UTC 4 June 2002 in Iowa

and Illinois. We diagnosed basically four MCSs which we labeled 1 - 4a-b. Brad had computed Corfidi motion vectors using both the upwind and downwind methodologies. As a group we compared the MCS movements to those Apredicted@ by the Corfidi method. The downwind approximation of the Corfidi vector method appeared to better approximate MCS motion for the first two MCSs. However, as the atmosphere moistened as a result of previous convection, the last two MCSs' motion was better approximated by the upwind Corfidi vector method. MCS #4 especially displayed long periods of back-building, which contributed to the excessive precipitation in the Davenport CWA.

16. We examined cross sections of the WSR-88D reflectivities to determine whether the individual cells revealed low-centroid echoes, typical of high precipitation efficient storms. During this process, we found one cell in MCS # 4b which displayed a deep convective core, characteristic of a hailstorm, which was reported during the Iowa heavy rain event. In this case the 50 dBz reflectivity went up to about 38 kft. In MCS 3 we found another cell in the heavy rain area which displayed a classic low-centroid echo, with the 50 dBz region barely making it to the 18 kft level.

17. We constructed an outline for a manuscript, which will be eventually submitted to the *National Weather Digest*. We assigned various sections of the proposed manuscript to both the NWS and SLU partners. We are currently working on this manuscript and hope to submit it to NWD in the spring of 2005.

18. Mr. Brad Mickelson, graduate student at SLU, completed his thesis and thesis defense on 14 December 2004. His thesis is entitled, "Diagnosis and Prediction of the 3-4 June 2002 Iowa-Illinois Flood." His M.S. degree conferral date is January 2005. A copy of Brad's thesis will be sent to COMET under separate cover.

Section 3: Benefits and Lessons Learned: Operational Partner Perspective

The event under study was used as a WES case study for the NWS Davenport staff in preparation for the severe weather season. This was done on 15 March 2004.

The case was also presented by the Davenport MIC, Mr. Jim Belles, at the Des Moines, Iowa National Weather Association Meeting on 27 March. Nearly 300 people attended this conference.

A web-based component was placed on the office Intranet, which will make much of the case study data and other information available to other NWS Central Region forecast offices.

The results of this work have broadened the conceptual model of MCS flash flood-producing storms in the Midwest. This was accomplished through a seminar presentation to the entire staff and review of the preprint submitted last January to the AMS Weather Analysis and Forecasting Conference. While it is not unusual to have training MCSs over an extended period of time (usually days) over Iowa, the occurrence of 4-5 MCSs in a 27-h period is quite unusual and even unprecedented in the

WSR-88D era. The complexities of regeneration and MCS movement were discussed and contrasted with numerical model solutions.

This heavy rain event provided an opportunity for our service hydrologist, Mr. Jeff Zogg, to participate in a study which has benefited the entire forecast staff. In addition, a previously unrecognized process, described as “supertraining”, was noted as 4-5 separate small MCSs trained over the area in a 24-h time frame; resulting in significant flash flooding. Previously, our understanding and experience with flash flood-producing MCSs was generally one of large MCC-like systems repeating over the same area in concert with the diurnal cycle.

Jeff Zogg, the service hydrologist at DVN (also qualified as a meteorologist), has been active in various office research projects including a severe weather climatology and flood assessment. We have broadened his research experience into heavy precipitation, which has cross benefits to his position as service hydrologist. This experience has been key to his development toward becoming the office expert in heavy precipitation events. By example, it has also been established in the DVN forecast office that *staff members can actively participate in a leadership role in a research effort*.

This case study has been especially useful for viewing the limitations of numerical model output in extreme precipitation events. Moreover, the degree of complexity in the evolution of the 4-5 MCSs, which has become apparent via the research, was not well understood operationally during the time of the event.

Section 4: Benefits and Lessons Learned: University Partner Perspective

Brad Mickelson created a large poster based upon our preliminary work that was displayed at the Saint Louis University 10th Annual Graduate Research Symposium on 26 March 2004. As a result of this case study Brad has also mastered several software packages including Adobe Illustrator, McIDAS, WATADS, and LaTex for document preparation. Brad Mickelson was funded by this COMET Partners project and completed his M.S. thesis December 2004. A good portion of our manuscript for the *National Weather Digest* will include sections of Brad’s thesis.

This case study is being used to expand our data base of elevated thunderstorms and to further validate our elevated thunderstorm conceptual model (see Moore et al. 2004, *Weather and Forecasting*).

Our work with the Corfidi vectors during this project has heightened our awareness of the applicability of the upwind and downwind approximations for various MCS modes of propagation. In the present work we have probably applied the Corfidi vectors at a higher temporal resolution than was originally intended. In addition, we have often found it difficult to assign a single motion vector to an MCS, since over any 2-3 h time period an MCS often consists of both backward and forward propagating cells. Most importantly, we have found that the Corfidi propagation vectors, although good as estimates, cannot directly account for the presence of inverted troughs, frontal zones, and thunderstorm outflow boundaries, which can significantly alter the location of the maximum low-level moisture convergence.

Benefits of this project to SLU also include:

1. Creating a new heavy rainfall case study that will be used in the undergraduate course, Synoptic Meteorology II, as part of a laboratory exercise.

2. Diagnosing a heavy rainfall event that can be compared to mesoscale numerical models (MM5 and workstation Eta) quantitative precipitation forecasts (QPFs) to reveal the inadequacies of numerical models in forecasting mesoscale boundaries and heavy convective rainfall.

3. Developing a case study that can be shared with other NWS forecast offices at regional workshops and conferences for discussion.

4. Using this case study to expand our diagnostic capabilities by using the McIDAS software developed by SSEC and Unidata. Familiarity with McIDAS will increase it use within the Department of Earth and Atmospheric Sciences on other cases for both research and teaching.

5. Receiving WES cases from DVN to use as a tutorial for the WES software system and for instructional course work. The particular cases that SLU has received are:

    - 15-16 March 2004 northwest flow heavy snow event.
    - 16 June 2004 mesoscale flash flood event.
    - 13 July 2004 tornado with F4 damage.

We will be using these WES cases for demonstrations in the Synoptic Meteorology I and II courses. Experience gained from using these WES cases will be helpful in our efforts to produce our own WES cases based upon our case studies from our NOAA-funded CSTAR project.

An additional benefit of this COMET Partners project has been for Brad Mickelson to become acquainted with NWS forecast operations and the problems they encounter in forecasting heavy rainfall from MCSs. Brad is now actively seeking employment with the NWS upon graduation.

Section 5: Publications and Presentations

Conference Preprints and PowerPoints

SLU graduate student, Brad Mickelson, gave an oral presentation at the Second Conference on Weather

Analysis and Forecasting Issues in the Central United States (WAFICUS) in Columbia, Missouri on 6 December 2003, entitled, "Diagnostic Analysis of the 3-4 June 2002 Iowa-Illinois Flood."

Preprint prepared for the American Meteorological Society Annual Meeting (appended to this report in pdf form):
Moore, J.T., R.A. Wolf, B.L. Mickelson, J.A. Zogg, and C.E. Graves, 2004: Diagnosis and Prediction of the 3-4 June 2002 Iowa-Illinois Flood. Preprints, 20th Conference on Weather Analysis and Forecasting, Seattle, WA, Amer. Meteor. Soc., CD-ROM, 8.5.

An oral presentation of the above preprint was given on 12 January 2004. The PowerPoint is available for viewing and downloading at the following web site: **www.eas.slu.edu/CIPS/Presentations.html.**

A PowerPoint presentation of the case and results to date was given on 15 March 2004 at the NWA Central Iowa Severe Storms Conference. The presentation was essentially similar that mentioned above.

Mickelson, B.L., 2005: Diagnosis and Prediction of the 3-4 June 2002 Iowa-Illinois Flood. M.S. Thesis, Saint Louis University, 73 p.

As noted above, we are presently working on a manuscript for submission to the *National Weather Digest.*

Section 6: Summary of University/Operational Partner Interactions and Roles

During the course of this project work was divided up according to the expertise and time constraints of each partner. We also were able to schedule visits at each others' offices to discuss the ongoing work and set a time schedule for completion. The SLU crew visited the Davenport office on 23-24 September 2003, while Ray Wolf and Jeff Zogg visited the SLU campus on 5-6 July 2004. These meetings were absolutely instrumental to the success of this project. They not only helped in communicating results and questions about the data, but also opened up resource links and friendships that will continue for many years.

The Davenport forecast office partners (Ray Wolf and Jeff Zogg) spearheaded the analysis of both the surface features and output from the operational Eta model. In addition, Ray and Jeff scrutinized the WSR-88D imagery to identify the four major MCSs that contributed to this heavy rain event.

The SLU partners concentrated on computing constant pressure surface diagnostics from RUC-II initializations, sounding analyses, and processing Corfidi vectors for storm motion and propagation. They also constructed satellite imagery loops of enhanced infrared and water vapor.

During visits we were able to interactively discuss each others' contributions to the effort and find new avenues of research. For example, by examining the WSR-88D radar loops we were able to identify numerous outflow boundaries and horizontal convective rolls, which previously had not been noticed. Also, due to our operational partners' familiarity with this event, we constructed cross sections of the

WSR-88D imagery to isolate a cell which contained severe hail (> 3/4 inches in diameter). The structure of this "hailer" in the vertical was considerably different than the structure of the high-precipitation efficiency, low-centroid cell that contributed to the heavy rain in the Davenport CWA.

Another area of significant interaction was during our discussion of the applicability of the upwind and downwind approximations of the Corfidi vectors. As the SLU partners presented the Corfidi vector calculations alongside the radar imagery, discussion ensued about which form of the Corfidi vectors worked best and the limitations of said approach. Thus, our operational partners were made more aware of the fact that storm motion and propagation can change considerably during the course of a long-term (i.e., 18 h) meso-convective event. In addition, this case demonstrated that sometimes the use of one form of the Corfidi vector method (e.g., the downwind approximation) is useful early on in storm development, but as the meso-alpha scale characteristics of the atmosphere change the upwind approximation often becomes more appropriate.

Thus, this Partners project exemplifies how new insights into storm behavior and predictability can arise from the constructive interaction between the operational and academic communities.