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1. TITLE PAGE:

Response to Request for Proposals (RFP):

Title:
“Continuing Studies of Cool- and Warm-Season Precipitation Events over the Northeastern United States”

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2. ABSTRACT:

The proposal responds to the opportunity to improve operational weather forecasting in the northeastern US provided by the Collaborative Science, Technology, and Applied Research (CSTAR) Program Request for Proposals (RFP), dated 30 June 2003. The proposed research addresses those aspects of NWS Eastern Region (ER) science priorities concerned with improving the prediction of cool- and warm-season heavy precipitation events affecting the northeastern US, and builds upon the results from our currently funded CSTAR grant. Consistent with this objective, we will continue to address the following two challenging northeastern US forecast problems: 1) stratiform-dominated cool-season significant precipitation events and 2) convection-dominated warm-season significant precipitation events. A rationale for focusing on these two classes of significant precipitation events is that current operational numerical models exhibit relatively modest skill in forecasting heavy precipitation. As in our previous proposal, the proposed research will emphasize the multiscale structure, evolution and distribution of precipitation systems in relation to synoptic-scale flow regimes and the interactions of transient disturbances with the configurations of terrain and physiography of the northeastern US.

The rationale for adopting a multiscale approach is that the large-scale flow controls the location, frequency, and distribution of synoptic-scale transient disturbances determining the environment for the occurrence of heavy precipitation. The interactions of the synoptic-scale transient disturbances with the unique configurations of complex terrain and physiography of the northeastern US, combined with varying proportions of lift, instability and moisture, culminate in the unique mesoscale distributions (both spatially and temporally) of heavy precipitation that forecasters must anticipate and respond to in real time. Consistent with this adopted approach, the proposed cool-season research projects will address: 1) synoptic-scale aspects of weak-to-moderate winter storm events in the northeastern US in relation to flow regimes not generally associated with major surface cyclogenesis (e.g., split-flow regimes featuring strong warm-air advection), and 2) mesoscale aspects of heavy snow/icing events in the northeastern US in relation to coastal fronts, inertia-gravity waves, and rain/ice/snow boundaries as modulated by regional physiographic features. The corresponding proposed warm-season research projects will address: 1) northeastern US warm season severe weather emphasizing the role of terrain features and land/water boundaries (e.g., the eastern Great Lakes, coastal New England, Long Island Sound, and the Chesapeake/Delaware Bays), and 2) landfalling and transitioning tropical cyclones in relation to heavy precipitation, and coastal and inland flooding. These proposed cool- and warm-season research projects have been designed to facilitate the transfer of research findings into operations through the development of, for example, conceptual models and diagnostic software packages.

This proposal leverages the well-established programmatic assets and research infrastructure of the synoptic-dynamic group in the Department of Earth and Atmospheric Sciences (DEAS) at the University at Albany (UA) to enable the participation of a significant number of NWS personnel on CSTAR-related research of broader scope than the four core cool- and warm-season research projects enumerated above. In order to achieve this objective, a detailed framework for NWS participation and scientific transfer is proposed that allows for four categories of NWS participants, referred to as focal points, contributors, collaborators and associates. The inclusive and comprehensive nature of this proposed organizational
framework offers the NWS the potential benefits to be derived from a significant number of NWS personnel working collaboratively with the two co-PIs and four UA graduate students on research related to operational forecasting. It is anticipated that the high level of proposed collaboration will yield a successful outcome to the overall project goal of improving the prediction of cool- and warm-season heavy precipitation events affecting the northeastern US.

3. RESULTS FROM PRIOR RESEARCH:

Research conducted under the present CSTAR grant builds upon 12 previously funded COMET partners and cooperative projects awarded to the co-PIs since 1991 [Appendix (a)]. This grant has leveraged the longstanding, well-established programmatic assets and research infrastructure of the synoptic-dynamic group in the DEAS at the UA in educating generations of students who have gone on to pursue careers in weather forecasting and weather-related research. As evidence of the long-term educational impact of the synoptic-dynamic group, we note that in the last 25 years approximately 37 advanced degree recipients from the UA atmospheric science program have been, or currently are, employed by various NOAA research laboratories and the NWS. The names and affiliations of these UA advanced degree recipients are given in Appendix (b).

The objective of the present CSTAR grant has been to improve the operational prediction of cool- and warm-season heavy precipitation events over the northeastern US. To accomplish this objective, we have conducted multiscale phenomenological studies designed to advance scientific understanding and to transfer these advances to operations in a timely manner. Each study has involved the participation of a UA graduate student advised jointly by the co-PIs and by an NWS staff member, referred to as the NWS “focal point.” In addition to advising UA graduate students, NWS focal points have assumed a critical role in coordinating the transfer of research advances to operations.

The multiscale phenomenological studies comprise: a) large-scale regime transitions in relation to significant cool-season precipitation events, b) climatological and case studies of cool- and warm-season cutoff cyclones and their associated precipitation distributions, c) climatologies, composites and case studies of mesoscale precipitation systems in cool-season extratropical cyclones, and d) precipitation distributions in relation to landfalling and transitioning tropical cyclones. In the remainder of this section we will document research progress in these respective studies. Appendix (c) lists publications for the present CSTAR grant, including theses completed, conference preprints, oral presentations and CSTAR/COMET-related refereed papers.

a) Large-scale regime transitions:

Conventional forecaster wisdom is that cool-season temperature and precipitation anomalies in the northeastern US may be correlated with atmospheric teleconnection indices, particularly the North Atlantic Oscillation (NAO) and the Pacific/North American (PNA) pattern. At the outset of the CSTAR grant, it was expected that above average monthly/seasonal precipitation would be associated with the negative phase of the NAO (relatively weak Atlantic jet) and the positive phase of the PNA (eastern US trough). Contrary to expectations, UA graduate student David Groenert found minimal correlations between daily precipitation in the northeastern US derived from the UPD (NCEP Unified Precipitation Dataset) and daily NAO/PNA indices calculated from NCEP/NCAR reanalysis data over a 50-year period. Nevertheless, further investigation revealed an apparent tendency for large-scale circulation regime changes to be associated with significant precipitation events in the northeastern US. Furthermore, analysis of four significant northeast US precipitation events (12-14 Mar’93, 18-20 Jan’96, 59 Jan’98, and 24-26 Jan’00) was conducted to illustrate this apparent tendency. If confirmed by subsequent research, this apparent tendency points toward a possible operational forecast methodology for interpreting extended-range NCEP guidance for indications of significant precipitation events over the northeastern US. Ongoing research by current CSTAR graduate student Heather Archambault is directed towards quantifying the apparent relationships uncovered by Groenert through refined definitions of weather regimes and weather regime changes involving more extensive statistical analysis. Richard Grumm has served as the NWS focal point for both of these projects.

b) Cool- and warm-season cutoff cyclones:
Following the admonition of NWS staff member Ken LaPenta that “cutoff cyclones spell trouble” (from a forecaster’s perspective), we developed a series of projects to relate distributions of precipitation in the northeastern US to cool- and warm-season cutoff cyclones. As a first step, UA graduate student Brandon Smith developed an objective long-term (54 years) global climatology of 500 hPa cutoff cyclones. In addition to this important step in laying the groundwork for subsequent CSTAR research on the relationship between precipitation and cutoff cyclones, Smith performed case studies of two cool-season cutoff cyclones that impacted the northeastern US. These case studies showed that precipitation was strongly modulated by the component of the 850 hPa wind normal to the north-south oriented mountain barriers in Vermont. UA graduate student Matthew Novak applied Smith’s global cutoff cyclone climatology to 500 hPa warm-season cutoff cyclone behavior over North America and conducted two comprehensive case studies. These case studies revealed that precipitation distributions and amounts were highly sensitive to the configuration, track and motion of the cutoff cyclone. This sensitivity arises in part from physiographic features that modulate the distribution of stratiform and convective precipitation, and rapid changes between these modes of precipitation. Dan St. Jean served as focal point for Smith’s project, and Ken LaPenta and Tom Wasula participated as focal points for Novak’s project.

To further document cutoff cyclone precipitation distributions in the northeastern US, UA graduate students Tony Fracasso and Jessica Najuch are constructing composites and performing case studies of the regional distributions of cool- and warm-season cutoff cyclone precipitation, respectively. These ongoing parallel projects have focused on stratifying precipitation in a manner to determine whether a track-dependent precipitation signal exists for cutoff cyclones as they cross the complex terrain of the northeastern US. A case study is being conducted by Fracasso of a cool-season cutoff cyclone occurring in late May 2003 that posed a significant forecast challenge. Najuch is conducting a case study of a warm-season cutoff cyclone that occurred from 30 June to 1 July 1998 and tracked through the Great Lakes, producing significant severe weather in many parts of the Northeast. An objective of both of these case studies is to relate heavy convective and stratiform precipitation to orographic features, lower- and upper-level jet interactions, and to the structure, shape, and track of the evolving cutoff. Michael Evans is serving as the NWS focal point for Fracasso’s project, and Tom Wasula is the focal point for Najuch’s project.

c) Mesoscale precipitation substructure:

This project has addressed the problem of understanding and predicting cool-season heavy precipitation in the northeastern US from a mesoscale perspective. A classification scheme based on a climatology of mesoscale banded precipitation events, composites of banded and nonbanded events, and selected cool-season case studies were prepared by UA graduate student David Novak. The classification scheme revealed that single-banded events were the most common, and the result that nonbanded events also could produce significant precipitation. Further investigation of the single-banded events highlighted banded structure in the comma head portion of cyclones with approximately 80% of these bands exhibiting a majority of their length in the northwest quadrant of the cyclone. Composites were calculated for single-banded events in the northwest quadrant of the cyclone and for nonbanded events to isolate synoptic and mesoscale flow patterns associated with these respective classes. The banded composite was marked by cyclogenesis and the development of a closed midlevel circulation. The nonbanded composite exhibited a much weaker cyclone located in the confluent entrance region of an upper-level jet. A distinguishing aspect of the banded composite was the presence of deformation and strong midlevel frontogenesis northwest of the cyclone center, which coincided with the composite band position. In contrast, the absence of a closed midlevel circulation in the nonbanded composite precluded the occurrence of deformation and associated frontogenesis northwest of the cyclone. This comparison of the environments for banded and nonbanded precipitation systems in northeastern US cyclones provides another example of the LaPenta admonition that cutoff cyclones spell meteorological trouble. To put this admonition into practice, Novak developed a practical methodology and conceptual model for predicting mesoscale band formation and for alerting forecasters to the possibility of banded precipitation at various lead times. Jeff Waldstreicher served as the NWS focal point for this project.

d) Landfalling and transitioning tropical cyclones:
Landfalling and transitioning tropical cyclones continue to pose a critical precipitation forecast challenge in the northeastern US. UA graduate student Dave DeLuca is in the process of documenting the large spatial and temporal variability of heavy precipitation that accompanies landfalling and transitioning tropical cyclones. A climatology of landfalling and transitioning tropical cyclones (38 storms between 1950 and 1998) that produced at least 10 cm of storm-total precipitation has been constructed. This dataset provides the basis for stratifying rainfall distributions that occur to the left of, along, and to the right of the track of each tropical cyclone. A subset of eight storms that apparently were influenced by coastal frontogenesis and the complex terrain of the northeastern US was chosen for more detailed synoptic analysis. Subsequent analysis will explore the impact of storm-trough interactions and diabatically induced outflows in the downstream ridge/jet on the observed precipitation distributions. David Vallee is serving as the NWS focal point for this project.

4. PROJECT DESCRIPTION:

The purpose of this project is to respond to the opportunity to improve operational weather forecasting in the northeastern US provided by the CSTAR Program RFP, dated 30 June 2003. The proposed research will address aspects of the following NWS ER science priorities as stated in this RFP and will build upon the results from our currently funded CSTAR grant as summarized in section 3:

1. The roles of unique geomorphic influences on weather problems such as the type, amount, and intensity of precipitation associated with the complex terrain of the Appalachian Mountains, Atlantic Seaboard, and the Great Lakes. The interaction of these terrain features with large-scale weather systems such as winter storms, hurricanes, and closed lows.
2. The development of more accurate, region-specific conceptual models for tornado, hail, high wind (both convective and synoptic), flash flood, and localized heavy snow events. Detailed investigation of the roles of mesoscale phenomena such as gravity waves, thermal and moisture boundaries, and localized instabilities during these events. Improved understanding of low-topped severe convection and associated tornado development.
3. The relationship of landfalling tropical storms and hurricanes to severe weather and heavy precipitation resulting in flooding and flash flooding.

Specifically, the goal of this proposal is to improve the prediction of cool- and warm-season heavy precipitation events affecting the northeastern US. Toward achieving this goal, we will continue to address the two challenging northeastern US forecast problems identified in our previous CSTAR proposal: (i) stratiform-dominated cool-season significant precipitation events and (ii) convection-dominated warm-season significant precipitation events. The rationale for focusing on these two classes of significant precipitation events is that current operational numerical models exhibit relatively modest skill in forecasting precipitation amounts in excess of 5.0 cm in 12 h. For each of these two classes we will direct our efforts toward the following multiscale phenomenological research problems:

Cool Season:
1. Synoptic-scale aspects of weak-to-moderate winter storm events in the northeastern US in relation to flow regimes not generally associated with major surface cyclogenesis (e.g., split-flow regimes featuring strong warm-air advection).
2. Mesoscale aspects of heavy snow/icing events in the northeastern US in relation to coastal fronts, inertia-gravity waves, and rain/ice/snow boundaries as modulated by regional physiographic features.

Warm Season:
1. Northeastern US warm season severe weather emphasizing the role of terrain features and land/water boundaries (e.g., the eastern Great Lakes, coastal New England, Long Island Sound, and the Chesapeake/Delaware Bays).
2. Landfalling and transitioning tropical cyclones in relation to heavy precipitation, and coastal and inland flooding.

The cool-season problem will address the above-cited ER science priorities (1) and (2); the warm-season problem will address ER science priorities (1), (2) and (3). A multiscale approach is adopted for
both problems, whereby the large-scale flow controls the location, frequency, and distribution of synoptic-scale transient disturbances that determine the environment for the occurrence of heavy precipitation. The interactions of the synoptic-scale transient disturbances with the unique configurations of complex terrain and physiography of the northeastern US, combined with varying proportions of lift, instability and moisture, culminate in the unique mesoscale distributions (both spatially and temporally) of heavy precipitation that forecasters must anticipate and respond to in real time.

The adoption of a multiscale approach is based upon the co-PIs’ extensive track record in performing case studies of cool- and warm-season heavy-precipitation-producing storms (e.g., the 12-14 March 1993 Superstorm and the 4 January 1994 major cyclone event for the cool season; and the 6-7 September 1979 reintensification of tropical storm David and the 16-17 September 1999 extratropical transition of Hurricane Floyd for the warm season). These studies (Bosart and Lackmann 1995; Bosart et al. 1996; Dickinson et al. 1997; Schultz et al. 1997, 1998a,b; Bosart et al. 1998; Atallah and Bosart 2003) have demonstrated that the distribution of significant mesoscale precipitation within extratropical and tropical cyclones was critically dependent upon the interaction of the cyclone itself with the synoptic-scale flow, which in turn was influenced strongly by the nature of the anomalous large-scale flow over the preceding days.

The proposed cool- and warm-season multiscale phenomenological research problems have been designed to facilitate the transfer of research findings into operations through the development of, for example, conceptual models and diagnostic software packages. In the following subsection, we will provide a detailed framework for the transfer of scientific results into NWS forecast operations. In the subsequent subsection, we will document systematically our plans for addressing the proposed cool- and warm-season multiscale phenomenological research problems in the northeastern US.


The implementation of scientific transfer, consisting of the direct, timely and widespread incorporation of operational techniques and knowledge gained from research into the warning and forecast environment requires close collaboration between the UA co-PIs and graduate students and participating NWS personnel. Based on experience with our present CSTAR grant, we have endeavored to determine “what works” in facilitating the desired collaboration. First, we invited an NWS staff member to participate in each of the phenomenological research projects. This NWS staff member, either a SOO or an operational forecaster, had the dual responsibilities of co-advising the UA graduate student on the project along with the co-PIs and coordinating the transfer of emerging research results into NWS operations. In recognition of the unique role played by this NWS staff member in linking research and operations, this individual became known as a “focal point.”

Second, it was decided at the outset of the present CSTAR grant that the project participants would meet regularly. This decision was implemented through the efforts of Gene Auciello, MIC at the Albany (ALY) WFO, and Warren Snyder, SOO at WFO ALY, in organizing semi-annual CSTAR workshops in conjunction with the WFO spring and fall training meetings. The scope of these meetings rapidly broadened to include a research component and the participation of the wider scientific and operational communities throughout the northeastern US. The fall meeting became known as the Northeast Regional Operational Workshop (NROW), the fifth edition of which is scheduled to occur from 3-5 November 2003.

Additional successful strategies for promoting the transfer of research results into operations during the time frame of the present CSTAR grant were: a) the placement of CSTAR graduates into professional positions within the NWS (David Novak and David Groenert); b) outreach activities in the form of a teletraining/VISIT session on winter weather forecasting conducted by one of the co-PIs and hosted by WFO ALY for other NWS offices throughout the ER on 11 December 2002; c) a widely disseminated NOAA/NWS/ER/SSD report entitled, “CSTAR Impact on Forecast Operations during the Christmas 2002 Snowstorm,” that documented substantial use of CSTAR research results from David Novak’s thesis on mesoscale precipitation substructure (see section 3c); d) two teletraining/VISIT sessions entitled, “Anticipating Mesoscale Band Formation in Winter Storms,” conducted by David Novak in advance of the 2002-03 winter season; e) real-time area forecast discussions (AFDs) during the Christmas 2002 snowstorm that specifically referenced CSTAR banded precipitation research conducted at the UA and motivated by
discussion of this research at the fourth NROW meeting held on 4-6 November 2002; and f) a joint NWS/UA/NC State CSTAR workshop held in Silver Spring, MD, on 9-10 July 2003 to discuss scientific research results in the context of transfer to operations from the perspectives of the participating universities and the cooperating NWS WFOs.

Encouraged by the success of the above documented strategies, the co-PIs have decided to expand and build upon the present working model by designing an organizational structure that will allow for increased participation of NWS personnel interested in CSTAR-related research. The rationale for increasing the participation of NWS personnel beyond the present group of focal points is predicated upon our long-term experience that it is difficult to predict the outcome of any individual research project. Given this difficulty, we believe that increased collaboration across a greater number of research projects will yield a higher probability of a successful outcome to the overall project goal of improving the prediction of cool- and warm-season heavy precipitation events affecting the northeastern US. In order to apply this principle to our proposed research plan, the co-PIs and the WFO ALY SOO, Warren Snyder, met at the UA on 14 August 2003, coinciding with the onset of the massive northeastern US blackout. During this meeting the participants developed an organizational structure centered on the two cool- and two warm-season research projects enumerated at the beginning of this section that expands upon the focal point model devised during our present CSTAR project.

As stated above, our organizational structure starts with the two proposed cool- and the two proposed warm-season research projects. Each project will involve one UA graduate student who will be jointly advised by both co-PIs and the NWS focal point. In addition to the NWS focal point, each project will include a new category of NWS participant, referred to as an “NWS contributor.” The role of an NWS contributor will be to augment the efforts of the NWS focal point in performing project-related research and in activities related to the transfer of research results into operations. In order to enlarge the number of NWS personnel participating in CSTAR-related research, we propose two additional categories of NWS participants, referred to as “NWS collaborators” and “NWS associates,” respectively.

NWS collaborators will work on CSTAR-related research problems in consultation with the co-PIs and coordinate transfer of project results into NWS operations. NWS associates will work on CSTAR-related research problems independently or with other NWS personnel, and as in the case of the previous categories of NWS participation, associates will be involved in the transfer of project results into NWS operations. The rationale for creating the collaborator and associate categories is to take advantage of latent interest on the part of NWS staff members in conducting CSTAR-related research that extends beyond the scope of the two proposed cool- and two proposed warm-season research projects. The inclusive nature of this proposed organizational structure offers the NWS the potential benefits to be derived from leveraging CSTAR resources to engage a significant number of NWS personnel working collaboratively in research related to operational forecasting in the northeastern US.

In order to implement and manage the proposed organizational structure for NWS participation in the proposed research effort, WFO ALY SOO, Warren Snyder, has agreed to serve as coordinator and facilitator of the multiple NWS activities in research and transfer to operations. In addition to this role, he will consult regularly with the co-PIs on the status and progress of all NWS project-related activities.

To develop the proposed organizational structure, subsequent to meeting with the co-PIs at the UA on 14 August 2003, WFO ALY SOO, Warren Snyder, solicited a large number of NWS personnel for their potential interest in conducting CSTAR-related research. On the basis of the responses received, he formulated a comprehensive plan for NWS participation, which is included below. In addition to including the four proposed research projects to be conducted by the UA graduate students, co-PIs and NWS focal points, the “Snyder Plan” includes projects related to aviation issues, use of the workstation Eta model, an exploration of the use of ensemble forecasts in NWS operations, integration of research into operations, and various CSTAR-related cool- and warm-season phenomenological research problems, all of which will be conducted by NWS collaborators and associates as defined above. It is further noted that the projects related to aviation issues address the NWS ER science priority on developing improved methodologies for forecasting the onset and dissipation of fog and low ceilings. The topic concerned with integration of research into operations is consistent with the overall CSTAR program objective of optimizing the utilization
of interactive forecast preparation systems and gridded databases, as well as the NWS ER science priority calling for innovative approaches to formulate, produce, display, deliver and verify high resolution forecasts and products.

**Snyder Plan for NWS Participation and Scientific Transfer: 2004-2007**

**Major Foci** - Projects with graduate students advised by Co-Principal Investigators (PI). National Weather Service (NWS) Focal Points advise students on operational perspectives, and may provide datasets, suggest possible cases, or participate actively in the research and publication processes.

NWS contributors may provide datasets, suggest possible cases, share expertise, and provide input on operational implications from their local perspective to the NWS focal point, Co-Principal Investigators, and the participating graduate student. They may also do independent corollary research, or participate in the main project if acceptable to the Co-Principal Investigators, NWS focal point and Albany (ALY) SOO.

1. **Northeast Warm Season Severe Weather**
   - Identifying the role terrain features, and land/water boundaries (Great Lakes, Long Island Sound, Chesapeake Bay) have on convective development and evolution.
   - Focal Points - Tom Wasula, Ken LaPenta (ALY)
   - NWS Contributors - Robert LaPlante (CLE), Thomas Niziol (BUF), Steve Zubrick (WBC)

2. **Land Falling & Transitioning Tropical Cyclones**
   - Understanding the relationships between heavy precipitation and coastal/inland flooding to the storm systems transition from tropical to extratropical.
   - Focal Point - Dave Vallee (BOX)
   - NWS Contributors - Ron Horwood (NERFC), John Cannon, Fred Ronco (GYX), Scott Reynolds (OKX)

3. **Synoptic Scale Aspects of Weak to Moderate Winter Storms**
   - Study of significant winter events not related to major surface cyclogenesis such as, split flow regimes, warm advection, jet streak snowbursts, and mid-level frontogenesis.
   - Focal Point - Mike Evans (BGM)
   - NWS Contributors - Steve Zubrick (WBC), Alan Cope (PHI)

4. **Mesoscale Aspects of Heavy Snow/Icing Events in the Northeast**
   - Understanding the role in heavy precipitation events of, Northern Coastal Fronts, inertia gravity waves, and rain, ice, snow boundaries modulated by regional physiographic features.
   - Focal Point - David Nicosia (BGM)
   - NWS Contributor - Dave Wally (OKX)

**Collaborating Projects** - NWS Research advised by CSTAR co-Principal Investigators, with access to CSTAR infrastructure (meetings, mailing lists, networking, conferences). Coordination and supervision of these projects by WFO ALY SOO.

1. **Aviation Issues**
   - Fog Forecasting - Improving the forecast of Fog at Elmira New York.
   - Study the value of MOS and LAMP guidance. Develop composite of large scale patterns associated with fog and no fog events, and examine the utility of BUFKIT inversion heights, winds, and relative humidity at base of sounding.
   - Team - Bob Mundschenk, Michael Jurewicz, David Morford (BGM). May consider involving ASRC in this project.
   - Integrating Probabilistic Methods into the Aviation Forecast Process Apply Signal Detection Theory (Keith 2004) in creating TAFs, constructed by a probability table of critical thresholds being exceeded. These probabilities could be base lined for each forecaster and developed from IFPS Guidance.
Lead - Dan Cobb (CAR)

- Correlation of Snow Intensity to Runway Visual Range (RVR) output Correlate snow intensity critical aviation values to RVR output. This would allow more rapid decisions on closing and opening of runways, and the resultant impacts on air traffic.

Lead - Mark McKinley CWSU (ZOB).

2. Workstation ETA Projects (WSE)

- Assess the utility of the WSE in forecasting Lake Effect, synoptically forced mesoscale features, and winds. Identify WSE model forecast strengths and weaknesses. Address models effectiveness in initializing surface water temperature and or ice on Lake Erie and its sensitivity to Lake Huron’s (upstream lake) impacts on Lake Effect. Explore potential modifications of Smart Init to improve input to AWIPS. May involve collaboration with GLERL and NCEP.

Team - Thomas Niziol (BUF), Robert LaPlante & Christopher Mello (CLE), Warren Snyder (ALY), Nelson Vaz & Jeff Tongue (OKX).

- Use and assess the WSE’s ability to identify boundaries, Lake Breeze fronts, location of Lake Effect bands, areas of thunderstorm formation over CWSU Oberlin Ohio’s area of responsibility, in an effort to improve the CWSU’s ability to route air traffic.

Team - Mark McKinley - CWSU (ZOB), Warren Snyder (ALY)

- Transition of ensembles of mesoscale models to operational forecasting - Explore use of multiple runs of mesoscale models (WSE), and their utility to forecasting

Lead - Jeff Tongue (OKX)

3. Northeast Convective Flash Flood Events

- Study numerous cases, and develop techniques and conceptual models to delineate between significant and weak cases.

Team - Kenneth LaPenta, George Maglaras, John Quinlan (ALY), Paul Sisson (BTV), Alan Cope (PHI)

4. Northern New England Inverted Coastal Trough - (NORLUND Trough)

- Develop climatology, techniques, and conceptual model of NORLUN troughs to better forecast them. These occur in the absence of, or considerable distance from a surface cyclone along the Maine Coast and drop 6 to 20 inches of snow.

Team - Dan Cobb, Mike Fitzsimmons (CAR), Fred Ronco (GYX)

5. Landfalling Tropical Systems - Additional Foci

- “Outlier Systems”- Events Where Rainfall Distribution is east of center, and better forecasting recurvature and forward acceleration

Lead - David Vallee (BOX).

Associate Projects - Independent projects within NWS that are related to, or support CSTAR. They may utilize CSTAR results, data, and have access to CSTAR infrastructure (meetings, mailing lists, networking, conferences), and may require occasional interactions with graduate students and PIs.

1. Integration of Research Into Operations

- Capitalize on scientific and technological advances that result from CSTAR research. Such work could include development of AWIPS Smart Tools, AWIPS Visualizations, Operational Radar Strategies, AWIPS procedures and diagnostics, WES Cases, and Teletraining. Will require sharing of results and concepts by researchers, maybe meeting with this group. This group will probably start developing with concepts and work from CSTAR I.

Team - Eric Evenson (BTV), Josh Korotky (PIT), Greg Gerwitz, Vasil Kolec, David Zaff (ALB), Michael Jurewicz (BGM), Bill Goodman (OKX),
2. Utilize New England Pilot Project Meso-net data (hourly) to support CSTAR research.
   - These extensive new datasets are just coming online. This project goal is to make the data available to CSTAR researchers.
     Lead - Stephen Pertgen (ALY)

3. Upslope Localized Snow Events (Western Maine, Hudson Valley)
   - Study these events and attempt to develop methods to better forecast them.
     Team - Fred Ronco, James Hayes (GYX)

4. Compare and Contrast Three Ice Storms over New York
   - Compare two major and one minor ice storm. Attempt to establish significant differences.
     Team - Mike Evans and Mike Jurewicz (BGM)

5. Develop WES Simulation of 17 February 2003 Snow Event
   - Team - Mike Evans and Mike Jurewicz (BGM)

Reference:

b) Proposed Research:
In this subsection we will elaborate upon our plans for addressing the cool- and warm-season phenomenological research problems introduced in the beginning of section 4. As in our previous proposal these problems will emphasize the multiscale structure, evolution and distribution of precipitation systems in relation to synoptic-scale flow regimes and the interactions of transient disturbances with the configurations of terrain and physiography of the northeastern US.

Cool Season:

1. Synoptic-scale aspects of weak-to-moderate winter storm events in the northeastern US in relation to flow regimes not generally associated with major surface cyclogenesis (e.g., split-flow regimes featuring strong warm-air advection).

   Under circumstances where the large-scale flow is configured to favor unusually persistent upper-level ridges (troughs) over western (eastern) North America, the eastern North American trough can be locked into place with a strong blocking anticyclone situated near Greenland. This flow configuration results in a deep southerly current over the western Atlantic and allows for intense coastal cyclones to be steered poleward toward Atlantic Canada (e.g., the Superstorm of March 1993: Bosart et al. 1996, Dickinson et al. 1997; and the East Coast snowstorm of 24-25 January 2000: Langland et al. 2002, Zhang et al. 2002). Given the intensity of the coastal cyclones occurring within this flow regime and their accompanying impact on the heavily populated eastern US, this class of heavy cool-season precipitation systems has been relatively well documented. A common alternative scenario is for an anomalously strong Atlantic jet to be situated poleward of 50°N, placing the northeastern US in the equatorward-entrance region of this jet stream. Although this flow scenario does not favor intense extratropical cyclones over the eastern US, significant warm-advection-driven precipitation events are relatively common. While this behavior is well known to the operational forecast community, it is not as well documented as the former flow scenario exhibiting intense coastal cyclogenesis. Given this relative lack of attention in the scientific community to this important class of precipitation systems, we propose to investigate the occurrence of mesoscale precipitation patterns accompanying weak-to-moderate extratropical cyclones in the northeastern US.

   When the northeastern US is situated beneath the equatorward entrance region of an anomalously strong Atlantic jet, the core of the cold air mass from Canada is advected eastward over the western North Atlantic, leaving in its wake enhanced baroclinicity extending from the northeastern US eastward across the Atlantic. Dynamically, disturbances moving toward the northeastern US from the Midwest get sheared off as they approach the confluent jet-entrance region over the North Atlantic. A large-scale environment that favors trough shearing will reduce the likelihood of major coastal storminess. Despite the unlikelihood of intense cyclogenesis over eastern North America, the large-scale confluent jet-entrance region pattern can be very favorable for episodic warm-air advection occurrences. Depending upon critical thicknesses, moisture
availability, and the presence of a cold surface anticyclone near or poleward of the northeastern US, this
flow regime can be conducive to the occurrence of complex mesoscale precipitation patterns accompanying
extratropical cyclones in the northeastern US, even for cyclones of weak or moderate intensity.

The above scenario of a strong Atlantic jet stream may include a well-established branch of the
subtropical jet stream over much of the southern US, resulting in a split-flow regime upstream of the large-
scale confluent flow regime over the western Atlantic. Eastward-propagating upper-level transient
disturbances in the subtropical jet stream may interact with the cold air mass situated over the northeastern
US and Atlantic Canada. This interaction may result in a major cool season precipitation event over a broad
area in response to widespread warm-air advection beneath the equatorward-entrance region of the Atlantic
jet, prominent recent examples of which are the 19 January 1996 flooding rainstorm in the Appalachians
(Barros and Kuligowski 1998), the 5-9 January 1998 major ice storm over northern New York, New
England, and southern Quebec (e.g., Gyakum and Roebber 2001; Roebber and Gyakum 2003), and the
Presidents’ Day storm #2 of 16-18 February 2003. In the latter case, a transient disturbance in the
subtropical jet stream triggered heavy rains in California as it made landfall on 11-12 February 2003. As
this disturbance moved eastward it began to tap additional moisture from the Gulf of Mexico and the
Caribbean. This moisture was advected poleward over an exceptionally strong arctic boundary that was
situated across the Middle Atlantic States, resulting in a prolific and record-breaking snowfall from Virginia
to New England on 16-18 February 2003 in the absence of well-defined surface cyclone.

Given the relative lack of systematic documentation of warm-air advection-driven cool-season
precipitation events in the absence of major surface cyclogenesis over the northeastern US, we propose to
do the following: 1) perform a long-term climatology of split-flow regimes associated with large-scale
confluent entrance regions of the North Atlantic jet; 2) within the framework of step #1, prepare a
climatology of surface cyclones and cyclogenesis that influence the northeastern US; 3) document the spatial
patterns and intensity of significant precipitation episodes associated with individual cyclones; 4) relate the
precipitation distributions to surface cyclone track, intensity, and vertical structure, as well as to additional
factors such as season, thermodynamic stability, thermal advection, and orography; 5) develop a
classification scheme that identifies characteristic precipitation patterns associated with surface cyclones
categorized in terms of the attributes identified in step #4; and 6) construct cyclone-relative composite
analyses illustrative of the respective categories of the classification scheme developed in step #5. The
resulting composites will be used to construct a comprehensive conceptual model for precipitation occurring
in conjunction with split-flow regimes and their associated cyclones in the northeastern US. These
certitical models will provide forecasters with a heads-up in regard to the detailed characteristics of the
expected precipitation distributions in situations where numerical guidance indicates the likelihood of
significant precipitation in association with weak-to-moderate cyclogenesis in split-flow regimes affecting the
northeastern US.

2. Mesoscale aspects of heavy snow/icing events in the northeastern US in relation to coastal fronts,
inertia-gravity waves, and rain/ice/snow boundaries as modulated by regional physiographic
features.

The 4 January 1994 cyclone over the northeastern US illustrated many significant operational
forecast problems. Although this cyclone may have been a more extreme event than usual, we suspect that
almost all synoptic-scale cyclones will be associated with high-impact mesoscale weather events if only we
would scrutinize the data carefully enough (e.g., Uccellini and Kocin 1987; Homan and Uccellini 1987;
Uccellini 1990; Gurka et al. 1995; Bosart 1999; Bosart 2003). Successful numerical circulation forecasts do
not guarantee equally successful weather forecasts, because similar looking synoptic-scale flow patterns can
still be associated with significantly different precipitation distributions (e.g., Roebber and Bosart 1998). To
build upon numerical guidance, it is also crucial to anticipate how the details of the lift, instability, and
moisture patterns associated with transient disturbances interact to produce mesoscale substructure in
extratropical cyclones. For example, mesoscale substructure seems to be especially apparent when warm
fronts attempt to move poleward against entrenched shallow cold air dammed up east of the Appalachians
(e.g., Bosart and Sanders 1986; Forbes et al. 1987; Bell and Bosart 1988; Fritsch et al. 1992; Keeter et al.
1995; Bailey et al. 2003; Brennan et al. 2003). A prominent class of mesoscale substructure occurring
poleward of warm fronts in this situation is a long-lived, large-amplitude inertia-gravity wave event. Such
events have the potential of distorting and disrupting the mesoscale precipitation patterns on small time and
space scales (e.g., 11-12 February 1983: Bosart and Sanders 1986; 4 January 1994: Bosart et al. 1998).
Elevated-base thunderstorms (e.g., Colman 1990a,b; Market et al. 2002; Moore et al. 2003) also can occur
in conjunction with poleward-moving surface warm fronts as moist, unstable air is forced to ascend the low-
level dome of cold air. Frequently, these cool-season pre-warm frontal thunderstorms are observed to occur
with snow, sleet, and/or freezing rain and sometimes may accompany inertia-gravity wave events. This
observation suggests that a vigorous secondary mesoscale circulation associated with differential cooling
induced by melting snow may be important in forcing air parcels to reach their level of free convection.

Other classic examples of difficult-to-forecast cases would include the recent heavy snowstorms
that affected portions of the northeastern US, such as northeastern Massachusetts on 23 December 1997,
New England and eastern New York on April Fool’s Day 1997 (Martin 1999a,b), and parts of
this type is banded precipitation structure attributable to small moist symmetric stability and/or conditional
symmetric instability (CSI), slantwise and/or upright convection, and orographically modulated upward
motion, all occurring in the presence of lift associated with warm-air advection and frontogenetical forcing.
To build on the results of the mesoscale precipitation substructure project conducted during the present
CSTAR project (see section 3c), we propose to investigate further banded precipitation structures by means
of detailed mesoscale case studies of selected recent events as well as events of opportunity that present
themselves during the course of the project. These envisioned mesoscale case studies will enable us to
address the hypothesis from Novak et al. (2004) that the heavy precipitation signature in single band events
is related to the interaction of deep frontogenesis with a saturated environment characterized by near-neutral
moist symmetric stability. This proposed continuation of case studies of mesoscale banded precipitation
structures will allow us to address the long-standing issue of the possible importance and role of CSI in
producing the observed banding and its impact on the overall precipitation amount and distribution (e.g.,
Emanuel 1985; Sanders and Bosart 1985a,b; Martin 1999a,b; Nicosia and Grumm 1999; Nicosia et al.
1999; McCann 1999; Schultz and Schumacher 1999; Wetzel and Martin 2001; Clark et al. 2002;
Waldstreicher 2002; Graves et al. 2003). The ability to distinguish in real time between environments that
are conducive to slantwise ascent (i.e., associated with warm-air advection) in a near-neutral stability
environment, slantwise convection (i.e., associated with CSI), and those that favor upright convection (i.e.,
associated with conditional instability) will allow forecasters to issue more timely and precise short-range
forecasts of the amount and distribution of heavy precipitation.

In addition to banded precipitation features associated with extratropical cyclones, a critical
forecasting problem in the northeastern US involves the configuration and evolution of the rain-snow
boundary, both in an elevation-dependent and geographical sense. The former is concerned with so-called
elevation storms and the latter with coastal fronts (e.g., Bosart et al. 1972; Bosart 1975; Riordan 1990;
Nielsen and Neilley 1990; Fritsch et al. 1992; Riordan et al. 1995; Fritsch et al. 1998). Elevation storms
occur where the critical thickness defining the rain-snow boundary is located over regions where terrain
elevation varies significantly (e.g., the 4 October 1987 storm: Bosart and Sanders 1991). More precise
determination of the location of the rain-snow boundary will result in improved forecasts of the type,
amount, and distribution of precipitation, thereby mitigating the disruptive societal impact of these inland
events. Cool-season coastal fronts commonly occur in southern New England and the New York City/Long
Island area, and often delineate the rain-snow boundary and the axis of heavy precipitation. In the vicinity
of the rain-snow line in coastal front cases, the axis of heavy precipitation may be observed in conjunction
with mesoscale circulations forced by differential diabatic cooling associated with melting snow (e.g., Szeto
et al. 1988a,b; Coleman and Marwitz 2002). Understanding the nature of vertical circulations associated
with the rain-snow boundary in coastal fronts is a significant heavy precipitation forecasting problem that
would appear to be an ideal candidate for the application of novel visualization packages that take advantage
of existing diagnostic procedures.

As part of our proposed case studies of mesoscale precipitation structures, the opportunity exists to
develop diagnostic software packages applicable to regional-scale short-range model guidance (e.g.,
Workstation Eta) and suitable for visualizing dynamical and thermodynamic mechanisms that contribute to the character and type of precipitation associated with extratropical cyclones affecting the northeastern US. In regard to the character of precipitation, the diagnostic package will delineate the respective thermodynamic stability regimes that distinguish between upright and slantwise convection, as well as precipitation associated with warm-air advection and frontogenesis. In order to isolate the regions where precipitation would be expected to occur in a model forecast, the diagnostic package will emphasize the three-dimensional distributions of upward vertical motion and water substance in conjunction with the indicated stability regimes. In regard to the type of precipitation, the diagnostic package will indicate the topology of the 0°C isosurface in relation to topographic and frontal features. The capability exists to relate the detailed configuration of the 0°C temperature isosurface to the occurrence of snow, sleet, freezing rain, and rain. Similarly, the detailed configuration of the 0°C wet-bulb temperature isosurface may be related to the potential for the transition from liquid to frozen precipitation. Furthermore, parameters of microphysical significance may be considered, such as the atmospheric volume simultaneously exhibiting temperatures in the range of −12 to −16°C (where ice crystal production is optimized) and upward vertical motions exceeding preselected threshold values. Finally, the proposed diagnostic package will offer the capability of providing forecasters with an “inside look” at the evolution of the critical processes and features determining the formation, character, and type of precipitation in northeastern US extratropical cyclones.

Warm Season:

1. Northeastern US warm season severe weather emphasizing the role of terrain features and land/water boundaries (e.g., the eastern Great Lakes, coastal New England, Long Island Sound, and the Chesapeake/Delaware Bays).

The modulation of convection and severe weather by physiographic features such as underlying terrain and land/water boundaries, as well as by lee troughs, is an important forecast problem in the northeastern US (e.g., Farrell and Carlson 1989; Weisman et al. 1990a,b; Giordano and Fritsch 1991; Johns and Dorr 1996; Market 1996; Koch and Ray 1997; Bracken et al. 1998; Forbes and Nese 1998; Brady and Waldstreicher 2001; Wasula et al. 2002; LaPenta et al. 2003). For example, results from a study of the Great Barrington, Massachusetts, tornado event of May 1995 (Bracken et al. 1998) suggest that the north-south oriented Hudson and Housatonic River Valleys created favorable low-level clockwise-turning shear profiles that enhanced the severe weather threat, given that the large-scale pattern was already favorable for severe weather. The scientific insight gained from the Great Barrington study was used by WFO ALY to forecast northwesterly flow severe weather outbreaks in eastern New York and western Massachusetts on 3 July 1997 and on 31 May 1998 (LaPenta et al. 2003). A detailed case study analysis of the latter event (aka the Mechanicville F3 tornado event) by LaPenta et al. (2003) provides additional critical evidence that terrain-channeled southerly flow in the Hudson Valley helps to create favorable veering wind profiles for severe weather, given that the large-scale environment is conducive to supercell development. An additional factor related to terrain channeling is the modulation of the channeled flow by diurnal heating over varying terrain. This diurnal heating forces mesoscale circulations that are anchored to the terrain and that can result in heavy precipitation. Furthermore, outflow boundaries may play a role in focusing new convection or in reinforcing preexisting convection in regions of complex terrain. The overall extent to which terrain variations can alter shear profiles and create hotspots favorable for the development of severe convection, as well as channel warm, moist air to enhance convective instability in specific regions for given synoptic-scale flow patterns, also will result in the improved recognition of the signatures of terrain-modulated severe convection in the northeastern US.

The previous discussion underscores the importance of distinguishing between large-scale environments that will induce an organized convective response from those that will inhibit convection. Often the existing operational prediction models offer little help to the forecaster in these situations because the mesoscale transient disturbances aloft, as well as the detailed configurations of topography and surface heating, are not well represented and resolved in the models. In addition to its role in channeling low-level flow, the distribution of terrain features can result in patterns of differential surface heating that are favorable for focusing mesoscale low-level convergence and ascent. Recognition of these terrain-induced
patterns of differential surface heating is important for anticipating locations of convective initiation, intensification and regeneration. In the northeastern US, land/water boundaries can play an equally important role in setting up patterns of differential surface heating that can result in mesoscale frontogenesis. The mesoscale boundaries that result from frontogenesis in turn are favorable for focusing low-level convergence and ascent in preferred locations such as in the vicinity of the eastern Great Lakes, coastal New England, Long Island Sound and the Chesapeake/Delaware Bays (e.g., Market and Moore 1996; King et al. 2003). In addition to modulating distributions of differential surface heating and frontogenesis, these land/water boundaries can be associated with differential surface roughness, which not only induces low-level convergence but also modifies low-level wind shear profiles. Surface lee troughs are yet another important feature that need to be recognized in order to properly anticipate the locations of convective initiation and development in the northeastern US. These troughs act as sources of low-level vorticity and convergence, as well as contribute to differential surface heating by virtue of their coincidence with mesoscale surface temperature maxima. Identification of these aforementioned low-level mesoscale circulation features induced by underlying terrain, land/water boundaries, and lee troughs is critical in forecasting convection because of their potential to couple with mesoscale transient disturbances aloft.

Given the importance of the coupling between mesoscale transient disturbances aloft and physiographically forced low-level circulation features, we propose to do the following tasks which will provide forecasters with an enhanced capability to recognize signatures of convective life cycles over the northeastern US: 1) examine available satellite imagery and radar data for several recent warm seasons in order to identify days featuring organized convection; 2) develop a classification scheme for the various types of convection present in the sample; 3) stratify the various convective types by synoptic-scale flow regime defined in terms of prevailing flow, directional and shear profiles, and thermodynamic stability profiles; 4) refine the classification scheme through incorporation of the modulating influences of terrain, differential surface heating and differential surface roughness; and 5) perform selected case studies representative of the members of the classification scheme developed in step #4. This sequence of tasks will culminate in the formulation of a comprehensive conceptual model describing a range of scenarios for convection in the northeastern US that are modulated by the rich variety of boundary layer processes discussed in this subsection. Following the development of the conceptual model, the opportunity exists for the retrospective application of the Workstation Eta to simulate the outbreak and the initial organization of convective systems for the various elements of the classification scheme, as well as for selected individual case events studied in step #5. The end result of the application of the Workstation Eta will be the refinement of the above comprehensive conceptual model, enabling forecasters to anticipate preferred regions for the initiation of severe convection, as well as the expected type, on “convectively disturbed” days.

2. Landfalling and transitioning tropical cyclones in relation to heavy precipitation, and coastal and inland flooding.

In the context of the overall scientific problem of landfalling and transitioning North Atlantic tropical cyclones (e.g., Hart and Evans 2001; Hart 2003; Jones et al. 2003; McTaggart-Cowan et al. 2003), an important warm-season forecasting problem is how landfalling tropical cyclones contribute to heavy rain events over the northeastern US (LaPenta et al. 1995; Marks et al. 1998; Fritsch et al. 1998). Examples are the “Saxby Gale” of October 1829 (Abraham et al. 1999), Agnes in June 1972 (e.g., Bosart and Carr 1978; Carr and Bosart 1978; DiMego and Bosart 1982a,b; Bosart and Dean 1991), David in September 1979 (Bosart and Lackmann 1995), Opal in October 1995 (e.g., Henderson et al. 1999), Fran in September 1996 (e.g., Johnstone and Burrus 1998), Danny in July 1997 (Blackwell and Medlin 1998; Medlin and Blackwell 1999; Atallah and Bosart 1999), and Floyd in September 1999 (Atallah and Bosart 2003; Colle 2003). The quantitative precipitation forecast (QPF) problem posed by a decaying (or, in the case of David, reorganizing) tropical cyclone has always been a challenge. In the case of the northeastern US, there are additional complications that arise because of the complex terrain and the unique configuration of the coastline. These additional complications involve the timing of the heavy rains and the definition of the location of the heaviest rain relative to the track of the storm (recent examples include Bertha 1996; Dennis 1999; and Floyd 1999). Recent work by UA graduate students Darr (2002) and Atallah (2003) on a related
research project has established that precipitation relative to the track of a landfalling and transitioning tropical cyclone will fall to the left of the track when there is an upstream transient disturbance aloft in the presence of appreciable deep-layer baroclinicity, and to the right of the track when the large-scale environment lacks transient disturbances aloft and is relatively barotropic. (Although a class of tropical storms exists when the precipitation is primarily along-track, these storms typically occur equatorward of the subtropical ridge axis and thus would rarely affect the northeastern US.) Coastal fronts, when present, will contribute to a left-of-track precipitation signature (e.g., Floyd 1999), and downstream ridging in response to storm-induced diabatic heating, when present, will contribute to a right-of-track signature. Lower-tropospheric thermal advection is important in producing ascent in left-of-track cases (Floyd 1999: Atallah and Bosart 2003; Colle 2003), whereas upper-tropospheric differential cyclonic vorticity advection over the storm center in response to downstream ridging is the primary lifting mechanism in right-of-track cases (e.g., David 1979: Bosart and Lackmann 1995).

Important differences in mesoscale precipitation substructure are hypothesized to exist between the left-of-track and right-of-track categories for landfalling and transitioning tropical cyclones in the northeastern US. For storms moving poleward along the immediate coastline in the left-of-track category, prominent terrain features will coincide with the synoptically forced ascent region and associated precipitation distribution. In conjunction with lower-tropospheric thermal advection in a highly sheared environment, there can be a very significant orographic contribution to the overall left-of-track precipitation distribution. This orographic contribution consists of a stratiform upslope component with embedded convective elements that are preferentially enhanced by the terrain. It is also worth emphasizing that even in the case of a rapidly moving storm, such as Floyd in September 1999, heavy precipitation and associated inland flooding still may occur. In contrast, when the environment is less baroclinic and the associated deep-layer shear is relatively modest, as might be anticipated in the case of a landfalling tropical cyclone in the right-of-track category, the overall precipitation distribution will be dominated by a convective component. As an example, in this modestly sheared environment, training echoes (whereby new deep convective cells repeatedly traverse old ground covered by previous cells) and heavy precipitation can occur. The problem is exacerbated by the combination of weak flow aloft (which ensures slow-moving convective cells) and by the relative absence of baroclinicity (which ensures a tropospheric-deep unidirectional flow and training echoes). This situation was observed in conjunction with the landfall of tropical storm Dennis in September 1999, when heavy unforecast rains disrupted the morning rush hour in the New York City area well in advance of the storm, and again several days later in parts of the Northeast (including the Albany area) when the very weak remnant of Dennis interacted with ambient tropical air in the presence of complex terrain. An additional challenging right-of-track forecast problem arises when the storm track is well inland of the coast. In these cases, relatively low-elevation terrain features along the coastal plain may trigger additional convective elements that will exhibit training behavior and thus further exacerbate the heavy rainfall threat.

Other scientific issues relate to understanding the distribution of terrain-modified precipitation when thermodynamically unstable air is forced against the mountains in conjunction with landfalling and transitioning tropical cyclones. One can ask to what extent the elevation dependence of precipitation is a function of the stability profile of the moist air mass and what is the role of convection in this process. Cloud microphysical processes may be playing a key role (drop size distribution in tropical air vs. more typical midlatitude air), and the height of the freezing level may also be important in relation to precipitation-growth mechanisms. A further scientific issue, introduced in the previous warm-season research problem, is how the diurnal heating cycle over complex terrain helps to force mesoscale circulations that are often anchored to the terrain and result in excessive precipitation. Weak transient disturbances aloft can play an important role in triggering deep convection and flood-producing heavy rains, modulated by complex terrain, in ambient tropical air masses. These weak-flow heavy rain events might provide an ideal testbed for assessing how complex terrain modulates deep convection in response to the diurnal heating cycle, given relatively weak synoptic-scale forcing.

We propose to continue ongoing case-study research on the topic of landfalling and transitioning tropical cyclones. This research is expected to enable forecasters to refine the short-range QPF guidance
provided by NCEP/HPC and the National Hurricane Center (NHC) in situations of anticipated tropical-cyclone landfall and subsequent inland movement over the northeastern US. This continuing research is designed to reflect two significant operational forecasting problems: 1) the track-relative distribution and intensity of precipitation, both stratiform and convective, in relation to the coastline and to important orographic features; and 2) the question of tropical-cyclone regeneration or extratropical transition. The latter problem is especially critical because of the likelihood of significant inland and coastal flooding as well as accompanying high winds. The case study research will comprise the following multiscale components: the large-scale environment (e.g., upper-level transient disturbances, jet streaks and downstream ridges); the mesoscale environment (e.g., vertical wind shear and thermodynamic stability profiles, orography); boundary-layer and surface processes (e.g., coastal frontogenesis and diurnal heating); and microscale processes (e.g., cloud microphysics). Each of the foregoing components exhibits characteristic signatures in conventional surface and upper-air analyses, WSR-88D products, and satellite imagery. The results of the proposed case studies of landfalling and transitioning tropical cyclones will allow forecasters to anticipate, recognize, and detect distinctive sequences of events that are favorable for strong convection, significant flooding, and high winds in the northeastern US, leading to more timely and precise warnings of hazardous weather conditions associated with these systems.

5. WORK SCHEDULE:
(a) Year One:
- Begin cool-season project #1.
- Begin cool season project #2.
- Begin warm-season project #1.
- Continue warm-season project #2.
- Continue ongoing scientific transfer initiatives.
(b) Year Two:
- Continue cool-season project #1.
- Continue cool-season project #2.
- Continue warm-season project #1.
- Continue warm-season project #2.
- Continue ongoing scientific transfer initiatives.
(c) Year Three:
- Complete cool-season project #1.
- Complete cool-season project #2.
- Complete warm-season project #1.
- Complete warm-season project #2.
- Complete ongoing scientific transfer initiatives.

6. REFERENCES:


McCann, D. W., 1999: Comments on “evaluation and application of conditional symmetric instability, equivalent potential vorticity, and frontogenetic forcing in an operational forecast environment”. Wea. and Forecasting, 14, 470–472.


7. **APPENDIX:**
a) List of COMET grants


b) List of UA advanced degree recipients now working in various NOAA research laboratories and the NWS

Frank W. Alsheimer  
Title: Lead Forecaster  
NOAA/NWS  
Ruskin, FL 33570

Gerald D. Bell  
Title: Research Meteorologist  
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Camp Springs, MD 20746

W. Edward Bracken  
Title: Forecaster  
NOAA/NWS  
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Michael L. Branick  
Title: Lead Forecaster  
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Norman, OK 73069

Michael Cempa  
Title: Meteorologist  
NOAA/NWS  
Johnson City, NY 13790

Tim Coleman  
Title: Meteorologist  
NOAA/NWS  
Alabaster, AL 35007

Alan M. Cope  
Title: Science and Operations Officer  
NOAA/NWS  
State College, PA 16801

Paul J. Dallavalle  
Title: Branch Chief  
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Silver Spring, MD 20910-3283

Geoffrey J. DiMego  
Title: Branch Chief, MMB/EMC  
NOAA/NCEP  
Camp Springs, MD 20746

Michael S. Evans  
Title: Science Operations Officer  
NOAA/NWS  
Binghamton, NY 13790

David Groenert  
Title: General Forecaster  
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Richard H. Grumm  
Title: Scientific Operations Officer  
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Elliott Jacks  
Title: Meteorologist  
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Brian Korty  
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Douglas M. LeComte  
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Tiros Lee  
Title: Senior Systems Analyst  
SAIC/GSC  
NOAA/NCEP  
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Andrew F. Loughe  
Title: Associate Scientist III  
NOAA/ERL/CDC  
Boulder, CO 80305-3328

Eric Mandel  
Title: Deputy Acquisition Manager  
NOAA/NWS  
Silver Spring, MD 20910
c) CSTAR Project Publications

i) Theses completed:


ii) Preprints:


iii) PI and/or student oral presentations:


Archambault, H., 2003: Large-scale regime transition and its relationship to significant cool season precipitation events in the Northeast. Oral presentation at the NWS/UAlbany/NCSU CSTAR Workshop, 9-10 July 2003, Silver Spring, MD.


Fracasso, A., A. Aiyyer, L. F. Bosart, D. Keyser, and M. Evans, 2003: Case studies of cold season cutoff cyclone precipitation distribution. Oral presentation at the NWS/UAlbany/NCSU CSTAR Workshop, 9-10 July 2003, Silver Spring, MD.


**iv) CSTAR/COMET related refereed publications:**


LaPenta, K. D., L. F. Bosart, T. J. Galarmeau Jr., and M. J. Dickinson, 2003: A multiscale examination of the 31 May 1998 Mechanicville, New York, F3 tornado, (internal review at Eastern Region and than to be submitted to *Wea. and Forecasting*).