Agenda
Northeast Regional Operational Workshop VIII
Albany, New York
Wednesday, November 1, 2006

8:45 am
Welcoming Remarks
Eugene P. Auciello, Meteorologist In Charge
Warren R. Snyder, Science & Operations Officer
National Weather Service, Albany, New York

Session A – Winter Weather / Cool Season Topics
Session Chair – Thomas Wasula

9:00 am
The 17 February 2006 Severe Weather and High Wind Event across Eastern New York and New England
Thomas A. Wasula
NOAA/National Weather Service, Albany, New York

9:20 am
A Multiscale Examination of a Mesoscale Cyclogenesis Event in a Polar Airstream
Thomas J. Galarneau
Department of Earth and Atmospheric Sciences, University at Albany, State University of New York, Albany, New York

9:40 am
Northwest Flow - Watch Out: Experience With a Dangerous Canadian Export
David Zaff
NOAA/National Weather Service, Buffalo, New York

10:00 am
Break

10:30 am
Orographic Forcing, Stable Stratification, and a Labrador Retriever: The 4 March 2006 Snowfall in Northern Vermont
Peter C. Banacos
NOAA/NWS/Weather Forecast Office, Burlington, Vermont

10:50 am
A Multi-Scale Analysis of the Perfect Storms of 1991
Jason M. Cordeira
Department of Earth and Atmospheric Sciences, University at Albany, State University of New York, Albany, NY

11:10 am
Support for High Impact Sub-Advisory Winter Precipitation Events Along Interstate 80 in Central Pennsylvania: A Partner Project with the Pennsylvania Department of Transportation and the Pennsylvania State Police
Gregory A. DeVoir
NOAA/National Weather Service, State College, Pennsylvania

11:30 am
Lake Effect Thunder-Snows Over the Eastern Great Lakes
Robert Hamilton
NOAA/National Weather Service, Buffalo, New York

11:50 am
A Method to Reliably Predict Convective Modes (Organized Bands vs. Open- Cellular Development) in Late Season Lake-Effect Snow Events
Michael L. Jurewicz, Sr.
NOAA/National Weather Service, Binghamton, New York

12:10 pm
Improving the Understanding and Prediction of Lake-Effect Snowstorms in the Eastern Great Lakes Region - a NWS BUF and SUNY Oswego COMET Partners project
David Zaff
NOAA/National Weather Service, Buffalo, New York

12:30 pm
Lunch

2:00 pm
Anticyclones Cause Weather Too: An Understanding of Worldwide Strong Anticyclones and Anticyclogenesis
Matthew L. Doody
Department of Earth and Atmospheric Sciences, University at Albany, State University of New York, Albany, New York

2:20 pm
The Small-Scale New England Coastal Bomb of 9 December 2005: A Near-Miss Hurricane Zeta?
Lance F. Bosart
Department of Earth and Atmospheric Sciences, University at Albany, State University of New York, Albany, New York

Session B – Modeling
Session Chair – Warren R. Snyder

2:40 pm
Mesoscale Investigations and Modeling in the Northern Mid-Atlantic
Paul J. Croft
Kean University, Union, New Jersey

3:00 pm
Correlations between Observed Snowfall and NAM Forecast Parameters:
Part 1 – Dynamical Parameters
Michael S. Evans
Part 2 - Microphysical Parameters
Michael L. Jurewicz, Sr.
NOAA/National Weather Service, Binghamton, New York

3:40 pm
Exploitation of Ensemble Output at NCEP HPC
Peter C. Manousos
NOAA/National Centers for Environmental Prediction
Camp Springs, Maryland

4:00 pm
Break

4:20 pm
Forecast Performance of an Operational Meso-Gamma-Scale Modeling System for Extratropical Systems
Anthony P. Praino
International Business Machines, T.J. Watson Research Center, ACTC/Deep Computing Systems

4:40 pm
Using Wind Anomalies to Forecast East Coast Winter Storms
Neil A. Stuart
NOAA/National Weather Service, Albany, New York

5:00 pm
The Use of Ensemble and Anomaly Data during the 13-16 May 2006 New England Record Rain Event
Neil A. Stuart
NOAA/National Weather Service, Albany, New York

5:20 pm
Simulation of Lake Effect Snow using the Workstation WRF model
Daniel Leins
NOAA/National Weather Service, Cleveland, Ohio

5:40 pm
Using a Mesoscale Model to Identify Convective Initiation in an Air Route Traffic Control Center/Center Weather Service Unit ARTCC/CWSU) Environment
Warren R. Snyder
NOAA/NWS Weather Forecast Office, Albany, New York

6:00 pm
ADJOURN

Agenda
Northeast Regional Operational Workshop VIII
Albany, New York
Thursday, November 2, 2006

Session C – CSTAR Projects and Related Topics
Session Chair - Joseph P. Villani

9:00 am
The 19 April 2002 Supercell initiated by a Lake Breeze in Northwestern Ohio
Robert L. Tracey
NOAA Educational Partnership Program
NOAA/National Weather Service, Albany, New York

9:20 am
Predictability of the 22–24 January 2005 Northeast Blizzard
Heather Archambault
Department of Earth and Atmospheric Sciences, University at Albany/SUNY, Albany, New York

9:40 am
Unexpectedly Heavy Near-Coastal Precipitation Due to Mesoscale Features Induced by a Landfalling Tropical Storm
Alan F. Srock
Department of Earth and Atmospheric Sciences
University at Albany, State University of New York, Albany, New York

10:00 am
Heavy Rainfall Events Preceding the Arrival of Tropical Cyclones
Matthew R. Cote
Department of Earth and Atmospheric Sciences, University at Albany, State University of New York, Albany, NY

10:20 am
A Climatology of Tropical Transition
R. McTaggart-Cowan
Department of Earth and Atmospheric Sciences, University at Albany, State University of New York, Albany, New York

10:40 am
BREAK

11:10 am
Mesoscale Precipitation Structures Accompanying Landfalling and Transitioning Tropical Cyclones in the Northeast United States
Jared R. Klein
Department of Earth and Atmospheric Sciences, University at Albany, State University of New York, Albany, NY

11:30 am
Warm-Season Lake-/Sea-Breeze Severe Weather in the Northeast
Patrick Wilson
Department of Earth and Atmospheric Sciences, University at Albany, State University of New York, Albany, New York

11:50 am
Lunch

Session D – Warm Season Topics and Convection
Session Chair – John S. Quinlan

1:30 pm
Derecho Formation, Evolution and MCS Interactions During BAMEX
Nicholas D. Metz
Department of Earth and Atmospheric Sciences
University at Albany, State University of New York

1:50 pm
Using Ensemble Probability Forecasts And High Resolution Models To Identify Severe Weather Threats
Josh Korotky
NOAA/National Weather Service, Pittsburgh, Pennsylvania

2:10 am
The 4 August 2004 Central Pennsylvania Severe Weather Event - Environmental and Topographic Influences on Storm Structure Evolution
Joseph P. Villani
NOAA/NWS Weather Forecast Office, Albany, New York

Session E – Hydrology
Session Chair – John S. Quinlan

2:30 pm
Northern New England Coastal Flooding
John W. Cannon
NOAA/National Weather Service Forecast Office, Gray, Maine

2:50 pm
A Flash-Flood Climatology for the National Weather Service Eastern Region
Alan M. Cope
NOAA/National Weather Service, Mount Holly, New Jersey

3:10 pm
GIS Applications in Meteorology and Hydrology
John S. Quinlan
NOAA/National Weather Service, Albany, NY

3:30 pm
The June 2006 East Canada Creek Flood – Forecasting a Record Category Flood in the Absence of Real-Time Gage Data.
Robert C. Kilpatrick
NOAA/NWS, Weather Forecast Office, Albany, New York

3:50 pm
Closing Remarks
Warren R. Snyder

4:00 pm
ADJOURN

6:00 pm
CSTAR Dinner at Buca di Beppo Italian Restaurant
44 Wolf Road, Colonie, New York

NROW IX will be held November 7 & 8, 2007

The 17 February 2006 Severe Weather and High Wind Event across Eastern New York and New England

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Thomas A. Wasula and Neil Stuart

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NOAA/National Weather Service, Albany, New York

Alicia C. Wasula

Department of Earth and Atmospheric Sciences, University at Albany, State University of New York, Albany, New York~~/SUNYA~~

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Severe thunderstorms across New York and New England, are very unusual and uncommon in the Winter. For example, Albany only averages about 1 thunderstorm day every decade in the month of February. A line of severe thunderstorms producing damaging winds in excess of 50 knots (58 mph) and large hail (greater than 1.9 cm) occurred between 1200 UTC and 1800 UTC over much of eastern New York and New England on 17 February 2006. An anomalously strong low pressure system and its associated arctic cold front focused an area of severe thunderstorms that developed between 1400 UTC and 1600 UTC 17 February 2006 from the northern Catskills and Upper Hudson region in New York southwestward into northeastern Pennsylvania. This line quickly moved through the Hudson River Valley prior to 1600 UTC with over a dozen wind damage reports caused by the line of severe thunderstorms over New York and New England. Widespread wind damage subsequently followed with powerful gradient winds (numerous gusts in excess of 50 knots) in the wake of the cold front.

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Most of eastern New York and New England were in a warm sector that morning with temperatures in the 10-15°C range prior to the cold frontal passage. Eastern New York and New England were located in the favorable left front quadrant of mid- and upper-level jet streaks with strong divergence aloft. A line of convection developed in the highly sheared environment (0-6 km values in excess of 60 knots) with little instability. The 1200 UTC sounding from Albany revealed little or no instability ahead of the frontal passage, which made short term forecasting of the severe convection a few hours in advance difficult; however, the cloud to ground lightning strikes associated with the line of severe thunderstorms increased forecast awareness of the possibility of severe thunderstorms. The 850 hPa low-level jet strengthened to 60-70 kts with momentum mixing down from that level, just ahead and in the wake of the cold front. Temperatures tumbled 5-10°C with the frontal passage coupled with pressure rises of 12-16 hPa in 3 hours. Wind gusts of 52 knots and 85 knots were recorded at the Albany International and Saratoga County airports.

This talk will take a multi-scale approach analyzing the event from the synoptic-scale to the storm scale, in order to understand the environment that caused the anomalous and under-forecasted cool season severe weather over the Northeast. This event will also be compared to other narrow cold frontal rainbands produced by strongly forced low-instability lines appearing in the literature. Observational data used in the analyses include surface and upper air observations, satellite imagery, and KENX WSR-88D data. A variety of model guidance including the North American Regional Reanalysis and NAM 40km data will be shown in the presentation.

A Multiscale Examination of a Mesoscale Cyclogenesis Event in a Polar Airstream

Thomas J. Galarneau, Jr., Daniel Keyser, and Lance F. Bosart, Department of Earth and Atmospheric Sciences, University at Albany, State University of New York, Albany, New York

Occasionally, subsynoptic-scale cyclones known as polar lows develop in arctic air masses that trail precursor extratropical synoptic-scale cyclones. The characteristic scale of polar lows ranges between 500 and 1000 km, which is smaller than that of their synoptic-scale counterparts. Polar lows have been documented to occur over the northern Pacific and Atlantic Oceans when arctic air masses move over relatively warm water and produce regions of enhanced baroclinicity and deep moist convection. Polar lows occasionally can generate locally heavy precipitation and near-hurricane force surface winds. Polar lows also can form over continental regions in midlatitudes, and in conjunction with upper-level short-wave disturbances that may correspond to coherent tropopause disturbances (CTDs) of arctic origin. The relatively low height and low potential temperature of the dynamic tropopause (DT) in arctic CTDs serves to increase the likelihood that the CTD can couple with a surface disturbance in the presence of a baroclinic zone. The purpose of this presentation is to examine two polar lows that generated localized regions of heavy snow and cloud-to-ground lightning over the northeast United States on 5 April 2006.

The examination shows that the polar lows developed on the cyclonic shear side of an upper-level jet within a region of cyclonic vorticity advection associated with a CTD. The polar lows exhibited a comma cloud structure and formed within a baroclinic environment, which is consistent with the characteristics of the short-wave/jet-streak type of polar low discussed in Businger and Reed (1989). Given that these polar lows formed over land, it is suggested that a low, cold DT and steep lapse rates associated with a CTD of arctic origin may be able to mimic the effect of oceanic latent and sensible heating, which destabilizes the lower troposphere and creates an atmospheric stratification favorable for vigorous ascent and cyclogenesis.

Northwest Flow - Watch Out: Experience With a Dangerous Canadian Export

David Zaff
NOAA/National Weather Service, Buffalo, New York

Typically, meteorologists across the Great Lakes region tend to look to the southwest during the summer for indications of severe weather, often associated with warm frontal boundaries and high dewpoints. However, numerous studies have shown that some of the worst convective storms are associated with west or northwest flow aloft, particularly after the spring convection season transitions to summer.

Over Western New York, a convective outbreak under northwest flow typically occurs as a shortwave moves across the region associated with a cool upper level trough located over southern Ontario. Upper level dynamic support and lift then combine with low level convergence along lake breeze boundaries formed during diurnal heating. Sometimes the shortwave will produce convection in southern Ontario early on, which rapidly intensifies as it encounters these boundaries. The three features, a shortwave, northwest flow under an upstream upper level trough, and lake breezes, are a combination that requires forecasters to heighten their awareness for the potential of severe weather across Western New York.

Three 2006 summer severe weather events across the Metro Buffalo area occurred under these conditions. The first of the three events was markedly similar to an event that occurred on July 30, 1987, where an F2 tornado touched down in Cheektowaga, NY. This time, on June 30, 2006, an F1 touched down, only about a mile from the 1987 event and with a similar track. The second event occurred on July 23, 2006. This time a funnel cloud was witnessed in Cambria along several reports of large hail. During a third recent event, July 28, 2006, a few severe thunderstorm warnings were issued. This event was minor, with only some trees reported down in Sanborn, NY. This talk will primarily focus on the meteorological details leading up to the first case, as tornadoes in the Buffalo area clearly generate significant media attention. Comparisons between this event and the 1987 event will be discussed. Finally, comparisons between the tornadic events of 1987 and 2006 and the other recent non-tornadic events will be made. In all cases however, the message is clear: under northwest flow, watch out!

Orographic Forcing, Stable Stratification, and a Labrador Retriever: The 4 March 2006 Snowfall in Northern Vermont

Peter C. Banacos
NOAA/NWS/Weather Forecast Office
Burlington, Vermont

Orographic forcing exerts a first-order influence upon the distribution of precipitation in areas of complex terrain. In winter, the west slopes of Vermont’s Green Mountains typically receive higher snow accumulations when sufficient moisture exists in strong, low-level northwesterly flow. These episodes of upslope precipitation enhancement are often characterized by low-level cold advection, steep near-surface lapse rates, and a synoptic regime which includes a deep cyclone northeast of the region.

During the overnight hours on 4 March 2006, large snow accumulations occurred with northwest low-level flow not only in areas commonly affected by orographic enhancement, but also across the Vermont portion of the Champlain Valley, 15-25 km west of the mountains. The Burlington International airport set a daily snowfall record, with a storm total snowfall of 14.2 in (36.1 cm), and snow accumulation rates of 1-2 in/hr (2.5-5 cm/hr) for eight consecutive hours. The median snow-to-liquid equivalent ratio in the area was approximately 40:1.

This presentation offers an observational perspective on the favorable combination of large-scale, mesoscale, and microphysical factors that led to the snowfall. First, a strong high-latitude block existed near Greenland preceding the event. Second, a quasi-stationary polar vortex over eastern Quebec and Newfoundland served as a pivot point for the “retrieval” of shortwave troughs from off the Labrador coast westward and then southward into northern New England. A particularly vigorous trough, with an associated mid-level jet (up to 105 kt at 500 mb) and strong *equatorward* 925-700 mb layer warm advection, moved into northern Vermont after 00 UTC on 4 March. Third, the unusual, strong low-level warm advection from the north led to a temperature inversion below the Green Mountain ridge line. It is hypothesized that this stable stratification allowed the orographic forcing to be induced further upstream from the mountain barrier than normal, which is consistent with limited observational work from the western U.S. concerning the modulating role of static stability on upslope precipitation. Fourth, a saturated surface-700 mb layer (~ 2.5 km deep), with temperatures favorable for dendrite growth, maximized precipitation efficiency during the period of warm advection and orographic forcing.

This case illustrates the importance of various mechanisms in the development of heavy snowfall, and demonstrates that a stable thermal stratification does not necessarily preclude large snow accumulations.

A Multi-Scale Analysis of the Perfect Storms of 1991

Jason M. Cordeira and Lance F. Bosart, Department of Earth and Atmospheric Sciences, University at Albany, State University of New York, Albany, NY

The extreme weather events in the US that occurred in late October and early November of 1991, known as the “Perfect Storms”, transpired during highly amplified and anomalous large-scale flow regime transitions. This transition is exemplified through the Pacific North American index as a total positive-negative-positive transition of 8.8 standard deviations over 25 days. During the transitions the flow remained amplified and assisted in the development of two meteorologically significant and “perfect” storms. The purpose of this presentation is to document the life cycles of these twin extreme weather events via a multi-scale diagnostic analysis.

The first of the Perfect Storms began with an extratropical, baroclinic cyclone east of Nova Scotia on 28 October embedded downstream of a highly amplified mid-level trough-ridge flow pattern over the US. The cyclone’s deep circulation quickly became the foremost feature in the northwest Atlantic as it overtook Hurricane Grace to its south. The extratropical cyclone continued to strengthen to 972 hPa as it propagated westward towards the US and then subsequently weakened as it performed a counter-clockwise loop in the far western Atlantic beneath the building ridge. The warm waters of the Gulf Stream then excited convection within the center of the Perfect Storm, yielding the development of the “Unnamed Hurricane” on 2 November.

The second of the Perfect Storms began as a positive (cyclonic) upper-level potential vorticity (PV) anomaly rotating through the trough in the western US. As this PV anomaly approached the western Gulf of Mexico it induced development of a weak surface cyclone over the extreme western Gulf of Mexico. This cyclone strengthened and propagated poleward as the mid-level trough tilted negative on 1 November. A strong (1050 hPa) surface anticyclone propagating southward from Canada provided anomalously cold air (~ -3σ) that aided in giving Minnesota its earliest and heaviest snowfall totals, setting the state record for storm-total snowfall of 93.7 cm in Duluth, MN. By the end of the life cycles of these two storms, the large-scale flow regime had once again reversed.

The presented research will focus on (1) the extratropical transition of Hurricane Grace and the development of the first Perfect Storm and its subsequent tropical transition, (2) the development and life cycle of the second Perfect Storm, and (3) linkages between the two Perfect Storms including, trajectory and time series analyses, potential vorticity, and teleconnections associated with the large scale flow regime.

Support for High Impact Sub-Advisory Winter Precipitation Events Along Interstate 80 in Central Pennsylvania: A Partner Project with the Pennsylvania Department of Transportation and the Pennsylvania State Police

Gregory A. DeVoir and Richard H. Grumm
NOAA/National Weather Service, State College, Pennsylvania

In recent years the meteorological, emergency management (EMA) and law enforcement communities have gained an increased awareness of the threats associated with High Impact Sub-Advisory (HISA) winter precipitation events. HISA refers to weather phenomena including precipitation amounts (i.e., snow accumulations) which fall short of meeting National Weather Service (NWS) Advisory (headline) criteria, yet still pose a substantial hazard to the public.

HISA snow events have been responsible for a series of disastrous chain reaction accidents in Pennsylvania over the last several years. The most severe of these occurred 6 January 2004 near Bellefonte, PA, and resulted in a fiery 44-vehicle pile-up which killed 6 people and injured two dozen others. Despite forecasts calling for intense snow squalls issued hours in advance, motorists were caught off guard by sudden whiteout conditions and icy roads as temperatures plummeted behind an arctic cold front.

The NWS office in State College, Pennsylvania has built partnerships with the Pennsylvania Department of Transportation (PENNDOT) and the Pennsylvania State Police (PSP) over the past several years. The result of this effort has been the implementation of an event notification system by which affected PENNDOT districts and the PSP can be alerted for potential HISA events, sometimes days in advance. Once notified, preventative actions can be taken, including leveraging of resources and pre-treatment of roads where needed. While it is recognized that accidents associated with HISA events can never be completely avoided, it is hoped that their impact and severity in terms of loss of life and property can be mitigated through the early notification system.

The characteristics and impacts of several central Pennsylvania HISA events will be discussed. Specific details of the NWS State College PA partnership project with PENNDOT and the PSP will be presented, along with an overview of the event notification system. Ongoing and future work will focus on identifying critical event “fingerprints” from retrospective high-resolution model simulations, which may be used to anticipate HISA events with greater lead time.

Comment [MSOffice1]: What about advisories for freezing rain/sleet?

Comment [MSOffice2]: Can you really anticipate these events “days” in advance? How about “with greater lead time”.

Lake Effect Thunder-Snows Over the Eastern Great Lakes

Robert Hamilton
NOAA/National Weather Service, Buffalo, New York

Scott Steiger, Ph.D.
State University of New York, Oswego New York

Heavy lake effect snows typify winter weather across Western New York as intrusions of arctic air generate snowfall amounts that are often measured in feet. While significant snowfall is produced from these events with convective outbursts capable of producing rates of 2 to 4 inches an hour, they are usually very localized in aerial coverage.

These impressive mesoscale events are occasionally highlighted by lightning and thunder. Lightning-bearing lake effect snows across Western New York typically occur early in the winter season. The surface temperatures of Lakes Erie and Ontario are still relatively "warm" at that time of year. In addition, the depth of the surface to -10C layer is still several thousand feet thick.

Higher lake temperatures and a deeper boundary layer appear to be critical components that allow for abundant graupel production. The increased graupel is a crucial element in helping to produce an electrical charge, both by its electrostatic properties and through its role in building a static charge through frictional collisions with smaller ice particles and super cooled water droplets. Current electrification models strongly support the theory that graupel production in the -10C to -20C layer is essential for the beginning stages of lightning production. The depth of the surface to -10C layer is also extremely important in terms of allowing for charge separation.

This research has been conducted using nearly 10 years worth of sounding and ETA model data, dating from the winters of 1996-97 through 2005-2006. Results of this study on Western New York thunder-snow events suggest that if the depth of the surface to -10C is too shallow then graupel cannot be produced and lightning is much less likely. Various other convective parameters such as vertical velocity, CAPE, and equilibrium level are also examined to determine their possible contribution to lightning production in lake effect snow.

This presentation will show the importance of the lake water temperature in generating graupel which is crucial to developing an electrical charge within the lake effect clouds.

A Method to Reliably Predict Convective Modes (Organized Bands vs. Open- Cellular Development) in Late Season Lake-Effect Snow Events

By Michael L. Jurewicz, Sr.
NOAA/National Weather Service, Binghamton, New York

Lake-effect snow has long been a challenging phenomenon for operational meteorologists. This is particularly true late in the winter season, when the increased sun angle adds further complexity to the situation by altering the organization of lake-effect snow bands. Local experience indicates that late season lake-effect snow undergoes changes in structure that are closely tied to the diurnal heating cycle; cellular structures are most often observed during the afternoon and evening, while organized bands (with the heaviest accumulations) are more often observed during the late night and morning hours. However, there are instances when the structural evolutions of lake-effect snow do not follow this simple diurnal pattern; indicating there are other factors in play. The goal of this study is to identify these other factors that affect the organization of lake-effect snow bands late in the winter season.

Due to their convective nature and typically shallow depth, the overall structure of lake-effect snow bands tends to be governed by the same atmospheric principles that influence horizontal convective rolls. Prior research on these rolls, using both idealized numerical simulations and observations, indicates that their definition and intensity are modulated mainly by lower-tropospheric wind shear and boundary layer heat fluxes. Observational studies indicated that strong lower-tropospheric speed shear environments were associated with well defined lake-effect snow bands over Lakes Erie and Michigan, as well as the Great Salt Lake. Conversely, when the vertical speed shear decreased, there was a tendency for disorganized open-cellular convection to prevail. It has also been shown that increased lower-tropospheric instability (greater differential between lake surface and air temperatures), especially in the absence of pronounced vertical shear, has a similarly detrimental effect on roll organization and longevity.

For this project, archived radar images, observations, and initial-hour North American Mesoscale (NAM) model soundings were examined for the months of February, March, and April, over a four year period (2003-2006) in Central New York State. It was found that shear and instability parameters (bulk speed shear in the mixed layer and CAPE), quantified within the BUFKIT sounding program, can be used to accurately forecast convective modes in lake-effect snow situations. Based on these results, forecasters will be able to use BUFKIT soundings to be more specific with the timing of any expected changes in convective mode. Since organized banding typically produces much heavier snow accumulations than cellular convection, this will produce a significant upgrade in our ability to forecast snowfall amounts. It will also be shown that this proposed method has skill over merely considering diurnal trends in stability and their usual effect on the cohesiveness of lake-effect snow bands.

Improving the Understanding and Prediction of Lake-Effect Snowstorms in the Eastern Great Lakes Region - a NWS BUF and SUNY Oswego COMET Partners project

David Zaff
NOAA/National Weather Service, Buffalo, New York

Lake-effect snowstorms are intense, banded mesoscale phenomena that occur in late fall and winter downwind of the Great Lakes (Reinking et al. 1993 and Kristovich et al. 2000). These storms produce enormous impacts across the region. Over the eastern Great Lakes they disrupt commerce and transportation in the cities of Buffalo, Rochester, and Syracuse, as well as on major interstates, such as I-90 and I-81. These bands are often quite narrow, usually 10-20 km wide.

A wealth of research has focused on these events over the past two decades, but forecasters are still challenged with forecasting them. In particular, it is still difficult to attain accurate predictions of a lake band's timing, intensity, location, and inland extent as well as snowfall rates and snow to water ratios. The National Weather Service Forecast office in Buffalo (NWS BUF) and the Meteorology program at the State University of New York at Oswego (SUNY Oswego) have begun a year-long Cooperative Program for Operational Meteorology, Education, and Training program (COMET) designed to attempt to help meteorologists and students improve our understanding of the environmental and geographical conditions that affect these snow bands by using the Weather and Research (WRF) Model (Skamarock et al 2005).

Specifically, this project aims to 1) determine an optimal model configuration (horizontal and vertical resolution, and domain size) that improves lake effect forecasts for a variety of lake effect scenarios 2) attempt to improve forecasting the inland extent of significant accumulations 3) increase an understanding of the diurnal variability of snow band intensity and structure 4) further the understanding of the effects of topography and 5) investigate the sensitivity of lake-induced circulations to environmental factors by using the WRF model in idealized experiments. This project is in its early stages; several case studies have been selected and are being tested and rerun with the WRF model. Each case study covers a different type of lake effect event, eg, those that develop off of southwest flow vs those that develop off of northwest flow. This talk covers some of these cases, comparing the operational forecast models with NWS forecasts and storm observations. Some preliminary results of the WRF run on one case will also be discussed.

Anticyclones Cause Weather Too: An Understanding of Worldwide Strong Anticyclones and Anticyclogenesis

Matthew L. Doody, Lance Bosart, and Daniel Keyser
Department of Earth and Atmospheric Sciences, University at Albany, State University of New York, Albany, New York

Intense anticyclogenesis historically has been less studied than intense cyclogenesis, a situation that likely reflects the perception that intense anticyclones are associated with less widespread hazardous weather. However, intense cool-season anticyclones are often associated with the strongest continental cold surges and associated widespread severe cold, snow, and ice problems in midlatitudes. The purpose of this presentation is to present a global climatology of intense cool-season anticyclones and to establish the basis for an investigation of the dynamics and predictability of strong anticyclogenesis. To assist in this endeavor, anticyclone frequencies will be mapped on annual, seasonal, and monthly time scales. Continental versus oceanic and Northern Hemisphere (NH) versus Southern Hemisphere (SH) anticyclone frequencies will also be mapped.

The global gridded 2.5 degree NCEP/NCAR and ERA-40 datasets were used to perform this study. Gridded fields of sea level pressure (SLP) and 1000 hPa geopotential heights were extracted from these datasets. At each grid point a counter kept track of the number of times an SLP threshold (e.g., 1050 hPa) was exceeded. Global, NH, and SH anticyclone frequency distributions were then constructed for the specified thresholds. Annual, seasonal, and monthly anticyclone frequency distributions were mapped for the assigned selection thresholds.

A comparison of the two global gridded datasets was performed to assess analysis uncertainty. Significant differences were noted over areas of elevated terrain (e.g., Greenland) where the NCEP/NCAR analyses showed a higher frequency of intense anticyclones than in the ERA-40 analyses. This difference was noted to be true globally throughout most of the regions with higher terrain. Intense cool-season NH anticyclones populated mostly higher-latitude, snow-covered, continental regions, whereas intense cool-season SH anticyclones (1040+ hPa) dominated the midlatitude oceanic storm tracks. In the NH, intense cool-season anticyclone frequency maxima extended equatorward along the eastern margins of major topographic barriers (e.g., the Rockies). A minimum in intense anticyclone frequency was found over and to the west of major topographic barriers. Time permitting an illustrative example of intense cool-season anticyclogenesis that impacted the northeastern United States will be presented.

The Small-Scale New England Coastal Bomb of 9 December 2005: A Near-Miss Hurricane Zeta?

Lance F. Bosart
Department of Earth and Atmospheric Sciences, University at Albany, State University of New York, Albany, New York

Between 0600-1200 UTC 9 December 2005 a small-scale secondary cyclone developed just to the east of the Delmarva Peninsula. This cyclone moved northeastward along the coast and intensified rapidly (hourly pressure falls reached 10 hPa over parts of Cape Cod and the Islands) as it approached and crossed extreme southeastern New England.

Between 1700-2000 UTC, as the cyclone crossed Cape Cod, KBOX base reflectivity observations showed that a tight inner vortex had formed. Intense snowfall rates (10-15 cm h^{-1}) occurred along the bent-back frontal system in the western semi-circle of this vortex. Deep convection was observed near the center of the vortex and along parts of the bent-back frontal system where heavy snow was reported. Peak westerly wind gusts in excess of hurricane force (75 kt) were observed with the wind shift immediately behind the cyclone and near the southwest tip of the bent-back frontal system. The wind/pressure signatures seen near the center of the cyclone and the observed "eye-like" feature observed in the KBOX base reflectivity observations suggested that the cyclone possessed several "hurricane-like" characteristics. The purpose of this presentation will be to 1) document the large-scale environmental impact on cyclone formation, 2) to illustrate the cyclone's mesoscale structure and evolution, and 3) to comment on aspects of the cyclone's development that have some similarity to tropical cyclogenesis.

Mesoscale Investigations and Modeling in the Northern Mid-Atlantic

Paul J. Croft and Shing Yoh
Kean University, Union, New Jersey

The occurrence of mesoscale weather variations is of interest across New Jersey and in the immediate vicinity of the Northern Mid-Atlantic given its high population density as well as a wide diversity of land use, physiographic features, and the wide range of impacts from both hazardous weather and even “routine” conditions (e.g., local wind circulations). In an attempt to ascertain the characteristics and behaviors of these, efforts are underway at Kean University to involve students in local studies through targeted investigations and modeling of specific features and phenomena. During the past two years, students have performed investigations of characteristics and behaviors of cool season severe weather; winter season fog; spatial patterns of the air quality index in various weather regimes; October tropical cyclones; the rain-snow line; the sea breeze; and most recently summer season convective initiation and lightning patterns. Some initial results and findings on this work are presented to illustrate these efforts.

The intent has been to examine, from an operational perspective, the types of data and analyses that would best assist a forecaster in the spatial and temporal specification of the resultant sensible weather conditions and to determine how these vary with time as a function of local effects (e.g., physiography), mesoscale features, and the prevailing synoptic scale flow. Students have accessed large and diverse data in real-time, as well as from archived sets as available, to portray conditions and their variations with time and from case to case. Specific locations within the state of New Jersey were also selected so as to consider direct versus regional impacts. Composite analyses and numerical modeling (e.g., WRF), as well as the use of GIS programs and applications, have been prepared in an effort to assess the relative importance of select parameters and identify characteristics and behaviors pertinent to each investigation (e.g., initiation, distribution, evolution, movement, and coverage of convection). Initial results have provided information relevant to the identification of the family of local factors and their modes of behavior that will be useful in operational applications.

The investigations form the basis of the SECURED program (Student Educational Collective for Undergraduate Research Experiences and Development) at Kean University. They compose the Kean University Operational Undergraduate Research in Meteorology & Professional

Activities and Collaborative Training program (KU-OUR-METPACT) which continues in GROWTH (Growth through Research in Operational Weather – Training Holistically). In order to accomplish these, the Department of Geology and Meteorology has established a variety of partnerships in the region (e.g., NWS, ONJSC, Private Sector) to tailor research to operational needs and outcomes. Both external and internal (e.g., the SpF Program at Kean University) support have been sought to fund both student stipends as well as needed supplies and/or equipment relative to the research activities.

Correlations between Observed Snowfall and NAM Forecast Parameters: Part 1 – Dynamical Parameters, Part 2 - Microphysical Parameters

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Mesoscale and microscale factors that lead to enhanced snowfall in winter storms have been a topic of extensive research during the past several years. Research has shown that bands of heavy snow are often explained dynamically in terms of a thermally direct circulation associated with strong, steeply sloped lower to mid-tropospheric frontogenesis, which becomes co-located with a region of reduced or negative stability to slantwise motions. In cases of lighter but still significant bands of snow, recent research has shown that the thermally direct circulations are weaker, shallower, and less persistent than in heavier events. Based on this research, forecasters engaged in predicting snowfall have been trained to look for favorable configurations of frontogenesis and reduced or negative stability [as indicated by small or negative values of saturation equivalent potential vorticity (EPV)]. However, little guidance is currently available on how to translate the existence, intensity, and persistence of these signatures into actual snowfall amounts. Regarding the microscale, research has shown that enhanced snowfall can occur when significant lift occurs in layers with temperature structures that are favorable for dendritic snow crystal growth (dendrite-production layers). Again, except for some algorithms related to snow-to-liquid ratios, little guidance is available to forecasters on how specifically to modify snowfall forecasts based on the existence of co-located upward vertical motion and a favorable thermal profile.

The goal of this study is two-fold. First, to validate the utility of examining frontogenesis, EPV, vertical velocity, and temperature profiles for snowfall forecasting. Second, to provide forecasters with guidance on forecasting snowfall amounts, based on thresholds of intensity and persistence of these parameters. To accomplish these goals, data from 29 snow events in central New York and northeast Pennsylvania were examined. Event-maximum snowfall in these cases ranged from 4 to 34 inches. For each event a representative time and location within the area of heavy snow was identified. Data valid at these times and locations were analyzed in both cross-sectional and time-height formats. Values of relevant parameters were recorded for each event. Part one of this study focuses on correlations between snowfall and dynamical parameters such as frontogenesis, EPV, and omega. Part two of the study focuses on correlations between snowfall and factors related to precipitation efficiency, such as co-location between upward motion and a favorable thermodynamic profile

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Preliminary results will be presented that indicate that every storm in the database was associated with a 12-hour forecast of at least one layer of frontogenesis below 500 hPa, and at least one layer of negative EPV below 400 hPa. Therefore, it appears that merely identifying the existence of those two factors is not enough to allow forecasters to conclude anything about storm-total snowfall amounts. However, strong correlations were found between observed snowfall and factors that were related to depth and persistence of co-located upward vertical motion and negative EPV. The fact that these correlations were stronger than the correlations between observed snowfall and persistence and depth of upward vertical motion (EPV not considered) implies that there is significant value in looking for negative EPV in the forecast process. Strong correlations were also found between observed snowfall and maximum upward vertical motion within dendrite-production layers, while somewhat weaker correlations were found between snowfall and vertical motion alone (dendrite-production layer depth not considered). Evidence will be presented that indicates that consideration of the dendrite-production layer in the forecast process reduces false alarm rates for light to moderate snow events. Much lower correlations were found with 24-hour forecasts of many of these parameters, due primarily to a few major model forecast busts.

Details of the above correlation methodology, resulting correlations, forecasting thresholds, and threshold statistics will be presented.

Exploitation of Ensemble Output at NCEP HPC

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The use of ensemble output to support HPC operational products will be discussed including application to QPF, winter weather, medium range, and tropical cyclone forecasts. Experimental use of ensemble output will also be presented. Additionally downscaling strategies to produce high resolution grids and also a short term roadmap of intended model upgrades by EMC will be provided.

Forecast Performance of an Operational Meso-Gamma-Scale Modeling System for Extratropical Systems

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ACTC/Deep Computing Systems

In our continuing work on the implementation and applications of an operational mesoscale modelling system dubbed "*Deep Thunder*", we examine its forecast performance for several events of tropical origin over the Northeast United States. The study focused on the performance of operational nested 24-hour model forecasts, which are typically updated twice daily, for the New York City metropolitan area to 1 km resolution. Explicit, bulk cloud microphysics are included in the model predictions. All of the processing, modelling and visualization are completed in one to two hours on relatively modest hardware to enable sufficiently timely dissemination of forecast products for potential weather-sensitive applications.

In order to evaluate the quality of the forecasts produced by the Deep Thunder system at a storm-scale and its potential skill, we have identified a number of interesting cases in which systems of tropical origin impacted the tristate region. While the systems had become extratropical before reaching the geography studied, they did retain some of the structure and dynamics of their tropical genesis. We compare the model results with observational data as well as the operational availability of specific forecast products. Such performance is examined by considering forecast timing, locality, intensity and structure of convective elements of the overall system.

The Use of Ensemble and Anomaly Data during the 13-16 May 2006 New England Record Rain Event

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~~and~~

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A prolonged heavy rain event occurred in eastern New England 14-16 May 2006, resulting in record rainfall amounts and near-record flooding. The heaviest rains were observed in eastern Massachusetts, New Hampshire and southern Maine, where 8 to 14 inches of rain fell.

While the potential for heavy rain and flooding was well anticipated by meteorologists across the region, the magnitude and impact was greatly underestimated. Flood watches were issued with at least 12 hours lead time, but forecasted rainfall amounts were roughly half what was observed.

It will be shown that analysis of ensemble guidance in a variety of formats provided clues 24 to 48 hours before flooding was observed that there was an increased likelihood of more significant rainfall and flooding than deterministic forecast models were showing. For example, prolonged anomalous ensemble mean southeast winds at 850 hPa in the range of -3 to -4 Standard Deviations (SD) from normal, and precipitable water values of -2 SD from normal suggested an extended period of above normal moisture transport and low level forcing, enhancing upward motion and rainfall production. Plume displays of quantitative precipitation forecasts for 15 individual ensemble members for locations around New England also suggested a long duration heavy rainfall event.

This case demonstrates that effective use of ensemble guidance and plume displays can aid forecasters in increasing lead times and forecaster confidence for forecasting high impact precipitation events. Forecasters can then add value to forecast and warning products by including the level of confidence, in an effort to give users more specific information and more lead time to make critical decisions.

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Simulation of Lake Effect Snow using the Workstation WRF model

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Lake Effect snow (LES) events produce significant amounts of snow from mesoscale snow bands downwind of the Great Lakes during the winter months. The mesoscale nature of the LES bands produce sharp, intense gradients in snowfall that are a challenge to simulate with operational model horizontal grid spacing in excess of 10 km. The workstation version of the Weather Research and Forecasting (WRF) Environmental Modeling System (EMS) with a finer resolution of 6 km was employed by WFO Cleveland to simulate LES over northeast Ohio and northwest Pennsylvania this past winter season. Several LES events were identified and numerical model initial and boundary conditions were saved. WRF sensitivity studies were conducted by varying the model horizontal resolution from 3 to 6 km, by varying the cloud microphysical scheme, and by varying the choice of convective parameterization scheme. Model output will be verified with snow spotter observations to determine the optimal model configuration, which will be used in future simulations.

Using a Mesoscale Model to Identify Convective Initiation in an Air Route Traffic Control Center/Center Weather Service Unit (ARTCC/CWSU) Environment

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Thunderstorms account for 24% of all air traffic delays by significantly diminishing the National Airspace System's (NAS) capacity to route aircraft. The NAS is managed at Air Route Traffic Control Centers (ARTCC) by Federal Aviation Administration (FAA) personnel, who receive their weather forecasts and data from co-located Center Weather Service Units (CWSU), operated by the National Weather Service. This study provided real-time mesoscale model output from the Work Station Eta (WSEta) to one of these CWSUs located at Oberlin, Ohio. The model data was assessed to determine whether thunderstorm/convective initiation are forecastable from model fields during the first 24 hours. In addition anecdotal evidence was sought to determine the data's usefulness to the CWSU forecasters. This study, using a 29 case dataset from August 2004 to June 2005 over the Oberlin CWSU area of responsibility, identified three WSEta meteorological parameters that were credible predictors of thunderstorm initiation: hourly convective precipitation, 700 hPa omega, and 250 hPa divergence. The results from this study and the utility of the WSEta will be presented. In addition work in progress using much more accurate National Lightning Detection Network Data will be presented. These cases look at the summer of 2005 across the Oberlin CWSU and compare the model forecast of convective initiation using these parameters, and the NLDN strokes. This data looks quite promising with most of the events within one to two hours and under 100 km.

The 19 April 2002 Supercell initiated by a Lake Breeze in Northwestern Ohio

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The effects of lake breezes are very important, with many urban populaces located near the Great Lakes. Previous tornado climatologies in the Great Lakes region have implicated lake breezes as a major factor in tornadogenesis. On 19 April 2002 a lake breeze boundary, interacting with a southward moving cold front, spawned a supercell in northwest Ohio. This storm resulted in numerous hail reports, one of which was about 5 cm in diameter, and an F0 tornado.

The synoptic environment favored upward motion in the lower to mid troposphere. Divergence from the left exit region of a strong 65 ms^{-1} jet streak at 200 hPa, and cyclonic vorticity advection at 500 hPa coincided favoring the vertical development of the storm. An anomalously strong synoptic scale ridge was in place over the eastern continental United States, with 850 hPa temperatures nearly 15°C over Ohio. The impacts of this feature resulted in record-breaking temperatures of 25-30°C across the Midwest for 3 days prior to the event. An abundance of low-level moisture was also prevalent, with precipitable water values around 2.5 cm, nearly 200% of normal at that time of year.

The mesoscale environment was also very conducive for convective development. A cross section of equivalent potential temperature showed a very deep column of potential instability, with 330K theta-e at the surface, and 320K theta-e at 500 hPa, over Ohio. Surface-based CAPE values from morning soundings were also in excess of 1500 J kg^{-1}. However, deep layer shear was only marginal for supercellular development. For example, 0-6 km shear was only 15 ms^{-1} based on the Pittsburgh sounding that morning. Lake-land temperature differentials supported the development of lake breezes during the late morning and afternoon hours.

This presentation will show that the lake breezes served two purposes in creating the supercell. First, the lake breeze boundary served as a forcing mechanism for ascent. Second, northerly low-level winds behind the lake breeze boundary increased the low level shear and helicity to the necessary critical values for a mesocyclone and subsequent tornadic development. Gridded data from the NAM and experimental 1km WRF, NCDC Level-II radar data, SPC data, and NCEP-NARR data will all be used in the talk.

Predictability of the 22–24 January 2005 Northeast Blizzard

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Improving the prediction of high-impact weather such as heavy snow and strong winds associated with extratropical cyclones poses a critical scientific challenge. The 22–24 January 2005 blizzard that affected the Northeast U.S. is a recent example of a high-impact weather event that was not well forecast more than a few days in advance. Motivated by the need to identify precursors to such events, we present a multiscale case study of the January 2005 Northeast blizzard.

Data sources include the NCEP Global Forecast System (GFS) gridded model forecasts and analyses, the NCEP–NCAR gridded reanalysis, and NCEP-provided extratropical Northern Hemisphere (NH) geopotential height anomaly correlations between GFS forecasts and analyses.

An analysis of coarse-resolution (2.5°) gridded GFS model forecasts reveals that the strength of a short-wave trough over the Northeast at the time of the blizzard was significantly underforecast by the GFS model as few as two to three days prior to the event. In addition, inspection of the fine-resolution (0.5°) gridded GFS model forecasts indicates that the merger of three coherent tropopause disturbances (CTDs) over the eastern U.S. just prior to the event was inadequately resolved, likely contributing to the observed error in the position and strength of the surface cyclone associated with the Northeast blizzard.

Results suggest that the extratropical cyclone associated with the blizzard is partly attributable to dramatic changes in the NH planetary-scale flow pattern in the following ways: First, the abrupt transition from an extreme negative to an extreme positive Pacific–North American (PNA) pattern (12–17 January) resulted in a dynamically favorable flow regime for cyclogenesis near the eastern U.S. coast by establishing a deep trough over the eastern U.S. and western North Atlantic. The regime transition also facilitated an arctic cold surge over the eastern U.S. that preconditioned the Northeast for warm-air advection and heavy snow. Second, the eastward propagation of a long-lived Rossby wave train initiated over the western Pacific by an arctic CTD (18 January) may have helped spawn cyclogenesis near the Northeast coast by amplifying the planetary-scale flow pattern. Third, the rapid transition from an extreme positive to extreme negative North Atlantic Oscillation pattern (18–25 January) associated with the onset of North Atlantic blocking contributed to the development of a meridional storm track near the eastern U.S. coast. Finally, high-latitude northwesterly flow induced by the extreme positive PNA pattern helped extract a deep CTD from the arctic (21 January) that subsequently contributed to coastal cyclogenesis.

Unexpectedly Heavy Near-Coastal Precipitation Due to Mesoscale Features Induced by a Landfalling Tropical Storm

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Landfalling and near-land tropical cyclones (TCs) provide a challenging forecast problem, especially regarding major threats like storm surge, high winds, and heavy rainfall. Generally, the dangers from strong winds and storm surge weaken rapidly with increasing distance from the core of the circulation. However, the precipitation structure associated with a landfalling TC is far more variable, and is much more likely to have maxima far removed from the main circulation. These distant maxima are often found in regions where the flow around the TC is interacting with land and terrain features. Thus, mesoscale phenomena such as coastal fronts, orographic enhancement, and cold air damming can have a marked influence on the areal precipitation coverage, even while the storm is greater than 300 km away. Generally considered as cold-season phenomena associated with a high pressure system to the north, coastal fronts and cold-air damming can also be induced by a nearby low pressure system (e.g., a tropical storm) in the right position with respect to the coastline.

Atlantic Tropical Storm Marco (1990) was chosen for study because two distinct incidences of coastal frontogenesis, cold air damming, and orographic enhancement significantly alter the final precipitation distribution. Marco was responsible for greater than 500 mm of precipitation in parts of Georgia and South Carolina, although the storm never reached hurricane intensity. Marco tracked northward slowly just west of the Florida Peninsula, indicating a long period of geostrophic upslope flow over the southern Appalachians. Therefore, it appears that Marco’s associated wind field led to the formation/enhancement of mesoscale features which caused heavy precipitation and flooding during the study period. Although the inland flooding associated with coastal frontogenesis ahead of Marco most directly impacted Georgia and the Carolinas, the physical processes responsible for the flooding can occur anywhere along the East Coast in conjunction with a landfalling tropical cyclone. Synoptic upper air analyses from NCEP's North American Regional Reanalysis (NARR), NHC Best Track data, and hourly high-resolution surface data will be used to explain how the coast's topographic features combine with Marco to induce both occurrences of the aforementioned mesoscale features and thus modify the total precipitation distribution.

Heavy Rainfall Events Preceding the Arrival of Tropical Cyclones

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During recent active Atlantic hurricane seasons, observational evidence has suggested that heavy rainstorms sometimes can form unexpectedly well in advance of landfalling and near-coastal tracking tropical cyclones (TCs). The more extreme of these predecessor rain events (PREs) can cause significant flooding with little advance warning and can have even more serious implications if the TC itself later traverses the same region and additional heavy rainfall occurs. The relative frequency of PRE occurrence adds considerably to the forecast challenge prior and subsequent to TC landfall. It is therefore imperative to increase awareness in the meteorological community of the potential for PRE formation and to study the underlying physical processes responsible for when, where, and why PREs develop. The purpose of this presentation is to provide a synthesis of the important synoptic-scale features responsible for PREs with the major physical characteristics of PREs themselves. Emphasis in this presentation is placed on the 2004 and 2005 hurricane seasons.

TCs during 2004 and 2005 associated with at least one PRE were identified and analyzed using radar imagery from NCDC, NHC best-track data, and NCEP/NARR gridded datasets. Precipitation data obtained from the NPVU online QPE archive and NWS text products gleaned from online data sources were used to approximate how much rain fell during each TC/PRE event. Each TC examined showed some evidence of a peripheral moisture surge into the PRE, and each associated PRE produced 24-h normalized rainfall amounts of greater than 100 mm. A detailed data catalog was created to establish some general characteristics of each PRE.

A comparison of the PREs with a null case (Cindy 2005) showed that the Bosart and Carr (1978) schematic model of antecedent heavy rain occurring in a mid- and upper-level jet-entrance region confluence zone well downstream of Hurricane Agnes (1972) was somewhat applicable to the PRE cases. "Typical" PREs are located ~1000 km ahead of the parent tropical system, occur 1-2 days prior to the arrival of the TC at the latitude of the PRE, and last for ~12 h. Similarly, PREs are directly related to overall TC activity and have a strong tendency to form left of the eventual TC track. Frequency distributions and maps from selected cases will be presented to demonstrate these points.

A Climatology of Tropical Transition

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The importance of baroclinic forcings on tropical cyclogenesis has been a topic of investigation for several decades; however, few studies have quantitatively addressed the question, "what fraction of tropical cyclones form from extratropical precursors?". This climatology of the tropical transition (TT) genesis mechanism is based on our current understanding of the TT process and represents an attempt to analyze the importance of this genesis pathway to the overall tropical cyclone (TC) population.

Two distinct classes of TT have been identified in recent studies. Strong extratropical cyclone (SEC) TTs are characterized by the presence of a strong, pre-existing lower level vortex of extratropical origin of sufficient strength to trigger a wind-induced surface heat exchange (WISHE) process (near-surface azimuthal wind speeds on the order of 10 ms^{-1}). Initially, the presence of an upstream midlatitude trough – responsible for the development of the extratropical vortex – induces vertical shear values that preclude tropical development despite its passage over warm sea surface temperatures. However, as surface fluxes warm and moisten the boundary layer, extensive deep convection generates upper level outflow and redistributes potential vorticity in the vertical so as to minimize shear above the lower tropospheric system. Within this cocoon of low shear, midlevel convective warming leads to the development of an elevated warm core and the system's development thereafter follows a more traditional tropical trajectory. In contrast, the weak extratropical cyclone (WEC) TT pathway focuses on the concentration of convection by a precursor system that is too weak to trigger the WISHE process. Once an enhanced region of deep convection is established, the WEC TT proceeds in a manner similar to its strong counterpart.

In this study, we quantify this conceptual model of TT in order to develop a dynamically-based objective TT index. This is a necessary step in the development of a TT climatology, and itself yields insight into the classifications of WEC, SEC and more traditional tropical development pathways. The active 2005 Atlantic hurricane season is used as a training dataset in which the objective index is compared with subjective analyses of the individual storm development mechanisms. Thereafter, a climatology for all named storms from 1948 to 2004 is undertaken using data from the NCEP/NCAR Reanalysis dataset. The results of this study show that tropical systems formed along the TT pathway comprise approximately 25% of the total tropical cyclone population, suggesting that this development mode is important to the climatology. Moreover, there is a clear tendency for systems that form as TT events tend to be weaker and shorter-lived than those that develop in along tropical trajectories. This has much to do with both the geographical location of the TT events – which tend to occur at higher latitudes – as well as the sheared environment that resulting tropical cyclones encounter. A suite of composite-based analyses identify the importance of midlatitude features to a significant portion of tropical developments and lifecycles.

Mesoscale Precipitation Structures Accompanying Landfalling and Transitioning Tropical Cyclones in the Northeast United States

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Landfalling and transitioning tropical cyclones (TCs) can result in heavy rainfall and dangerous flash flooding events over the Northeast US. Complex mesoscale features found in these storms not only have exacerbated flash flooding on smaller scales, but have provided an important forecast challenge. An assumption underlying this research is that the knowledge gained from a better understanding of the physical processes controlling TC-related rainfall in the presence of complex terrain has the potential to be applied to the long-term benefit of operations. Accordingly, the purpose of this presentation is to present the results of an ongoing investigation of how the observed mesoscale distribution of heavy rainfall in landfalling and transitioning TCs is modulated by the interactions of mesoscale and synoptic-scale features in the presence of the complex physiography of the northeastern US.

A 67-storm (1950-2006) dataset of landfalling and transitioning TCs that produced storm-total rainfalls of at least 10 cm provided by David Vallee was used to identify candidate storms for our analyses. The synoptic and mesoscale characteristics of the 16 most recent storms from this dataset (2000-2006) were determined by constructing analyses of daily rainfall (1200 UTC to 1200 UTC) from the NCEP Unified Precipitation Dataset (UPD) for pre-2004 cases, the 3 h NCEP North American Regional Reanalysis (NARR) dataset, and hourly archived surface data. NCDC-archived radar imagery, NCEP/HPC analyzed precipitation maps, and the NHC best-track TC dataset also were used to investigate these cases. Selected surface and upper-air maps were constructed to identify and categorize certain synoptic and mesoscale characteristics for each case.

Preliminary results show that enhanced ascent associated with coastal frontogenesis and/or orographic lifting provided a mesoscale focus for heavy rainfall that tended to occur to the

left of the storm track in many of the cases. The interaction between a landfalling and transitioning TC, an advancing upper-level trough, and a pre-existing mesoscale boundary (e.g., a coastal front) or synoptic-scale front occurred in almost every recent heavy rainfall case examined. In some landfalling and weakening TCs that experienced minimal extratropical transition, corridors of very heavy rainfall were noted to the right of the storm track in conjunction with training convective storms.

Warm-Season Lake-/Sea-Breeze Severe Weather in the Northeast

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Thunderstorms that form along lake- and sea-breeze convergence zones over the Northeast sometimes are observed to become severe when they migrate from their source regions. These thunderstorms can pose a significant forecast challenge because they typically form under conditions of weak synoptic-scale forcing. The dynamical and thermodynamical processes, modulated by physiographic effects, that are responsible for creating severe weather from lake- and sea-breeze convergence zones are discussed through selected case studies. The results from these case studies will be shown during the presentation.

Ten cases were selected for analysis. The NCEP/NARR gridded datasets, along with data from radar, soundings, and surface observations, were used to construct the analyses. These cases were divided into two classes: pure cases where lake- and sea-breeze convergence zones were primarily responsible for initiating severe weather in the apparent absence of synoptic-scale forcing, and mixed cases where synoptic-scale forcing acted in conjunction with mesoscale forcing from the lake and sea breezes to generate severe weather. The 10-case sample includes a null event where the arrival of marine air from a sea breeze suppressed convection.

Pure cases were characterized by the absence of significant synoptic-scale forcing. Typically, pure cases featured: 1) a ridge axis at the surface or aloft, 2) temperatures (dewpoints) of at least 30°C (20°C) in the planetary boundary layer with ample heat and moisture to provide instability, and 3) weak flow with weak unidirectional wind shear. In contrast, mixed cases typically featured: 1) a trough at the surface or aloft, 2) boundary-layer temperatures ranging from 20°C to 30°C with dewpoints approaching but not exceeding 20°C, and 3) stronger flow and stronger wind shear than in the pure cases. Perhaps the most essential general finding for all cases was the prevalence of multiple synoptic and mesoscale boundary intersections. These boundary intersections served as locations where convergence and lift were enhanced to the point where deep convection was initiated.

Derecho Formation, Evolution and MCS Interactions During BAMEX

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The purpose of this presentation is to take advantage of an active deep convection period during BAMEX to provide a detailed assessment of the formation and evolution of derechos and their interactions with other mesoscale convective systems (MCSs). The first week of July 2003 (last week of BAMEX) featured twelve coherent MCSs progressing across the upper Midwest. Three of these MCSs met the derecho criteria and two are of interest here (4-5 July and 5-6 July 2003). A 20-25 knot anomalous 200 hPa jet stream was present throughout the week across the northern United States. A strong upstream blocking ridge in the eastern Pacific contributed to the favorable synoptic set-up for derechos, along with a persistent potential vorticity (PV) tail located immediately upstream of the formation of each derecho. Derecho development was assisted by transient upper-level shortwave disturbances along the PV tail that provided a source of lift, a favorable configuration of lower-level and upper-level jets, steep mid-level lapse rates, strong surface heating, deep layer shear in excess of 40 knots, and large values of surface-based CAPE.

The convective development of the two derechos was intertwined with two less severe MCSs. The earlier 4-5 July derecho formed to the south of a weak cyclone and resulted in the development of a quasi-stationary surface boundary in Iowa and Illinois along the southern edge of its significant cold pool. Radar imagery showed this derecho remained robust as it crossed Lake Michigan despite cool water temperatures, weakening only as it progressed further eastward of favorable jet support and low-level moisture. A less severe MCS subsequently collapsed in the derecho’s cold pool. Gravity waves and an outflow boundary moved eastward following the MCS’s convective demise and interacted with the quasi-stationary boundary, inducing a second MCS near the southern tip of Lake Michigan. At the same time, the 5-6 July derecho progressed eastward along a similar path across Iowa as the first derecho. The cold outflow in the wake of this second derecho reinforced the cold pool and quasi-stationary boundary left behind by the first derecho. This derecho moved eastward, merging with the gravity wave-induced MCS. The combined system weakened as it crossed the Great Lakes, moving eastward of the most plentiful moisture and jet support.

Using Ensemble Probability Forecasts And High Resolution Models To Identify Severe Weather Threats

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High resolution model data (NAM-WRF) and Ensemble Prediction System (EPS) data from the National Centers of Environmental Prediction's (NCEP) Short-Range Ensemble Forecast System (Du et al. 2004:SREF) are used to predict areas with a severe weather threat. This study illustrates the complimentary roles of high resolution model and EPS forecasts, and demonstrates the value of using SREF forecast products that depict probabilities of exceedance and joint probabilities of variables related to severe weather. Probabilities of exceedance for Convective Available Potential Energy (CAPE), Storm-Relative Helicity (SRH), height normalized (mean) shear, and the Energy Helicity Index (EHI) are examined. Joint probabilities of CAPE, effective shear, and 3 hr. convective precipitation are also considered.

NAM WRF forecasts and SREF probability forecasts are examined for a vigorous severe weather event that occurred across much of the central Mississippi and lower Ohio Valleys on 2 April 2006. This presentation will demonstrate that joint and exceedance probabilities from the SREF make it possible to clearly distinguish areas with the greatest severe weather potential.

A forecast strategy is proposed which utilizes *1)* ensemble data for assessing the likelihood, mode, and forecast confidence of a severe weather event; *2)* climatological anomalies for evaluating the historical context of an impending event; and *3)* high resolution model data for determining the magnitude of moisture, the horizontal and vertical extent of moisture, important mesoscale structures, and relevant forcing mechanisms.

The 4 August 2004 Central Pennsylvania Severe Weather Event - Environmental and Topographic Influences on Storm Structure Evolution

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Severe thunderstorms moved across portions of central Pennsylvania during the late afternoon and early evening of 4 August 2004. Initially, the thunderstorms caused straight-line wind damage in the Central Mountains and Middle Susquehanna Valley, and then evolved into tornado producing thunderstorms across the Lower Susquehanna Valley in and around the Harrisburg metropolitan area. Several significant radar features were observed, with most of the severe thunderstorms exhibiting bow echo characteristics. Some storms developed mesocyclones and consequently spawned tornadoes in the Lower Susquehanna Valley. The intensities of the tornadoes were F0 or F1, and resulted in downed trees and structural damage to homes.

The severe thunderstorms developed in a moist and moderately unstable atmosphere across western Pennsylvania early in the afternoon, as an upper level short wave trough moved eastward through the Ohio Valley. A frontal boundary across northern Pennsylvania separated cloudy and cool conditions to the north from warm and humid conditions to the south. Daytime heating with temperatures near 30^{o}C and surface dewpoints around 20^{o}C resulted in surface based Convective Available Potential Energy (CAPE) values reaching 1000 to 2000 Joules per kilogram (J/kg). The vertical wind shear was unidirectional across western and central Pennsylvania with westerly flow aloft, which contributed to the linear mode of the convection. Across the Lower Susquehanna Valley low level winds backed to a south to southeast direction in response to a weak surface low pressure center moving eastward across the region. Additionally, the topography of the area likely enhanced the development of the low level southerly wind component, which resulted in sufficient low level directional wind shear for tornadogenesis to occur.

This presentation will first focus on interrogating radar imagery from (KCCX) State College and (KLWX) Sterling to examine the significant features associated with the severe and tornadic thunderstorms. The focus will then shift to discussing factors that contributed to the convective mode transitioning from straight-line wind producing storms to tornadic, as they moved southeast into the Lower Susquehanna Valley.

Northern New England Coastal Flooding

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Forecasting storm surge and coastal flooding raises complex issues along the Maine and New Hampshire coastline. The bathymetry and the irregular configuration of the northern New England coast allows for a large range of atmospheric and tidal conditions through localized channeling effects of wind and water. Access to real-time tide data is limited to a single point in Portland Harbor, which is problematic when forecasting over a large, data-sparse coastline. Storm surge guidance is available, but can have large predictive and temporal errors. These challenges exist while the population continues to increase near vulnerable beaches. Storms pose a risk to millions of dollars in personal property damage and significantly impact the marine community.

Traditionally, forecasters base flood warning decisions for long stretches of coastline on the 12 foot flood benchmark at the Portland Harbor tide gauge. However, in an effort to better understand and predict a wide range of tide levels associated with coastal flooding, a coastal flood database was created for the period 1914 to present for Maine and New Hampshire using Storm Data Publication (http://www.ncdc.noaa.gov). This coastal flood catalogue was compared to tide archives for Portland Harbor (http://tidesandcurrents.noaa.gov). A coastal flood climatology was then created using the predicted versus observed tide levels. Storm tracks were then examined (http://www.hpc.ncep.noaa.gov/dwm/dwm.shtm) to identify predominant wind flow during coastal flood events.

The coastal flood climatology will be presented. The climatology suggests coastal flooding occurs in multi-year clusters, while moderate to severe flooding events are rare. Coastal flooding occurs over a wide variety of tide heights in Portland Harbor, as large ocean waves or freshwater flooding occasionally offset modest tidal surges. They are predominantly cold season events with a prevailing northeast wind. The peak observed storm tide usually occurs several minutes prior to the predicted astronomical high tide. Finally, unusual and extreme cases will be shown, such as the October 1996, October 1998 and May 2006 coastal flood events which were coincident with freshwater flooding.

A Flash-Flood Climatology for the National Weather Service Eastern Region

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A climatology of flash flood events has been developed for the National Weather Service Eastern Region (NWS-ER). Data for flash flood events from 1996 through 2005, for all 23 NWS-ER forecast offices, were obtained from the NWS Verification/Storm Data "Stats on Demand" web site. The data, stratified by time of day and time of year, were examined for the entire NWS-ER, and also for four "sub-regions": New England, mid-Atlantic, Ohio Valley, and South.

Results showed that flash flood frequency varied greatly around ER, from over 100 events per year in the Pittsburg area, to less than 10 per year around Caribou ME and Columbia SC. Almost half (47%) of events occurred in June July or August, and over two-thirds (71%) fell in the warm season of May through September. Diurnally, over half the events (51%) occurred during the period 1900 to 0300 UTC (3pm to 11pm EDT). This diurnal distribution was most pronounced during summer. Seasonal distribution varied somewhat by sub-region, with the Ohio Valley peaking earlier and the South later, while the diurnal distribution looked fairly similar for all four sub-regions.

To further study summertime flash floods, synoptic meteorological conditions were examined for 15-20 significant flash-flood days (10 or more events) in each sub-region during June July and August. Days with named tropical systems were excluded. Composite mean and anomaly charts were created from NCEP/NCAR Global Re-analyses and from the NCEP North American Regional Re-analyses, accessed via NOAA/ESRL web-based interfaces. Variables included pressure-height, zonal and meridional winds, temperature and specific humidity.

The resulting composites show mainly positive anomalies in moisture and meridional wind and negative anomalies in pressure-height, although there are some interesting exceptions. Synoptic patterns such as surface low pressure, mid-level troughs and upper-level jet streaks, are most similar for the New England and mid-Atlantic sub-regions, somewhat similar but generally weaker

for the South, but distinctly different for the Ohio Valley. The pattern differences among ER sub-regions will be illustrated and discussed further at the meeting, as well as the ER-wide results mentioned above.

GIS Applications in Meteorology and Hydrology

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Geographic Information Systems (GIS) are systems of hardware and software which store, retrieve, map, and analyze geographic data in relational databases. GIS uses spatial and attribute data with vector and raster data structures, and topology to create geographic data models. This allows the user to spatially analyze and display in a format which can more easily be understood and shows interrelationships that otherwise may not be apparent. GIS also allows for the representation of a third dimension which is usually elevation. The Digital Elevation Model (DEM) produced by the National Mapping Division of the United States Geological Survey (USGS) is the GIS representation of continuous elevation values over a topographic surface by a z-axis, referenced to a common datum. DEMs are typically used to represent terrain relief. Use of ESRI's Spatial Analyst extension in GIS allows for the study of locations and shapes of geographic features and the relationships between them. It is very useful for analyzing meteorological or hydrologic data in terms of geographic distribution, and for verification analyses of forecasts and warnings.

Many GIS projects have been conducted from 2000-2005 and range from verification of weather forecasts and warnings to use of GIS analyzed data in flood warnings. It will be shown how GIS should be a main component of each National Weather Service Forecast Office's (NWFO) warning verification program, and how GIS can be used to improve forecast and warning operations by giving the forecaster spatial analyzes of their forecasts and warnings. Examples of this which will be presented include variability of snow to liquid ratios during winter weather events and how this variability can be applied to improving snow forecasts, analyses of snow survey data and the use of snow density and basin average snow water equivalent in flood warnings and Winter/Spring Flood Outlooks, and a GIS analysis of 30-year climatic normals to determine the start of the growing season.

The June 2006 East Canada Creek Flood – Forecasting a Record Category Flood in the Absence of Real-Time Gage Data.

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The East Canada Creek, and in particular, the Village of Dolgeville, has long been known to have a potentially severe flood problem. A severe flood occurred there in October 1945, and other significant floods have occurred in March 1913, December 1984, January 1996, January 1998, and May 2000. WFO Albany became aware of this risk of flooding a number of years ago.

Over several years procedures were developed and refined, to make river forecasts for sites, such as Dolgeville, where adequate real-time data and guidance are not available. On 25-27 June 2006 five to ten inches of rain fell over the Mohawk Valley and Western Adirondacks. These forecast procedures were used with the Multisensor Precipitation Estimate (MPE) from the KENX WSR-88D and the WFO Hydrologic Forecast System (WHFS), in the early morning hours of 28 June to produce a stage forecast for the East Canada Creek of a little over 15 feet around noon that day.

No real-time gage readings were available. The forecast was used to issue a record category flood warning with about four hours of lead time. The forecast was about a foot too low based on measurements made by USGS at a site about 8 miles downstream. Without these methods a forecast of the height the East Canada Creek would not have been made, nor could the severity of the resulting flood been forecast. The height measured by USGS after the event was about two feet higher than the previous flood of record.