Collaboration & Research Success: NOAA/National Weather Service and North Carolina State University

CSTAR – Collaborative Science, Technology & Applied Research Program

Improving Forecasts of Topographically-Forced Weather Systems in the Carolinas and Virginia
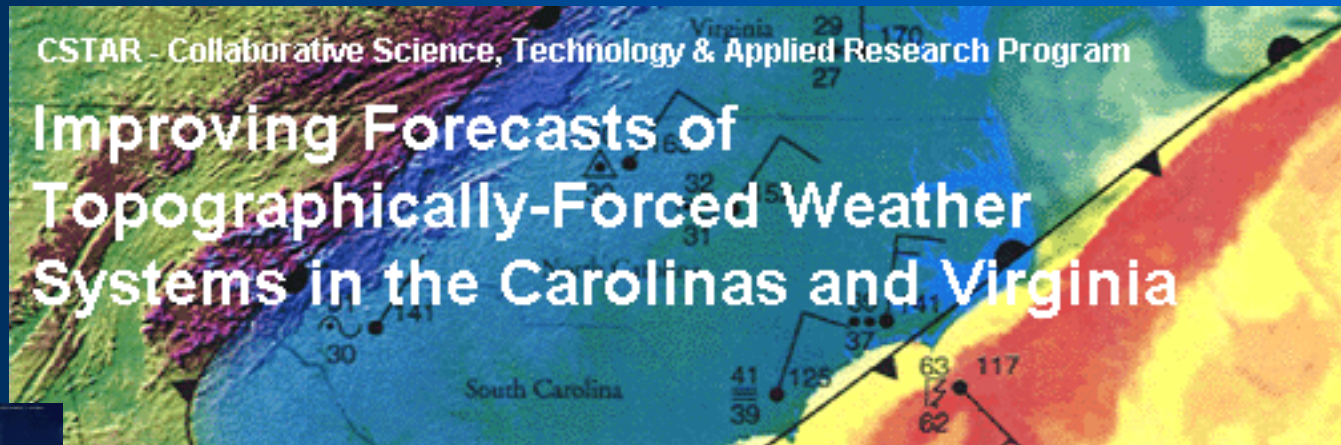
Presented by:
Gail Hartfield
NOAA/NWS Raleigh, NC

NWS-NCSU Collaborations:
A long and storied road

- ## 1970s:

  - John McClain (NWS) & Walter Saucier (NCSU)

  - Student internships

  - American Meteorological Society meetings, NCSU seminars

  - Forecast aids: winter precipitation type study, topography of flash flood

1Lt Walter J. Saucier
18th Weather Squadron
Commander

NWS-NCSU Collaborations:
A long and storied road

- 1980s:
  - The GALE Project, studying the development of Atlantic storms
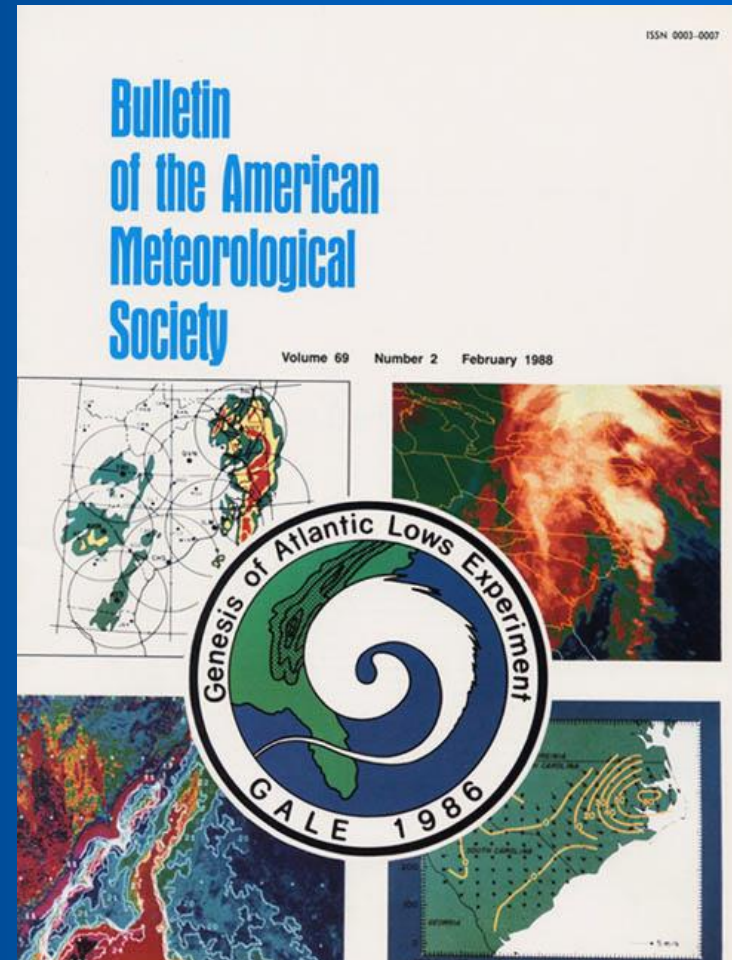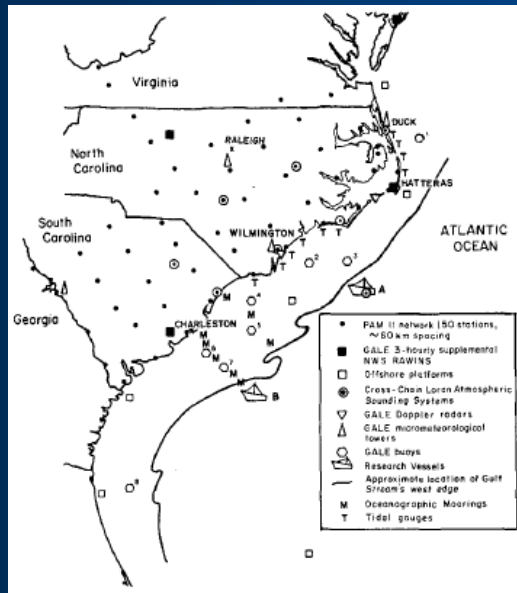
NWS-NCSU Collaborations:
A long and storied road

- 1990s:
  - The Southeast Consortium on Severe Thunderstorms and Tornadoes
    - Included intensive study of the Nov. 28, 1988 Raleigh F4 tornado ⟶
    - Paradigm for tornado outbreaks in the Carolinas/mid-Atlantic was developed
    - Conceptual models adopted by operational forecasters; computer-based tools for detection of tornado outbreaks later created
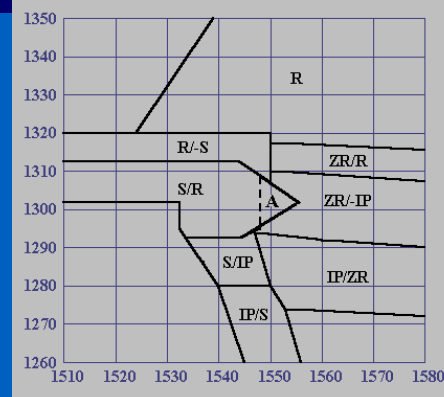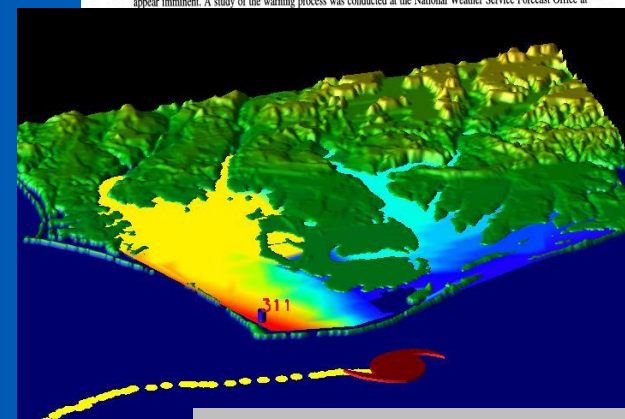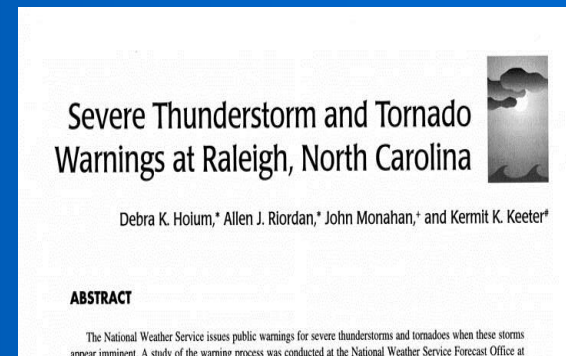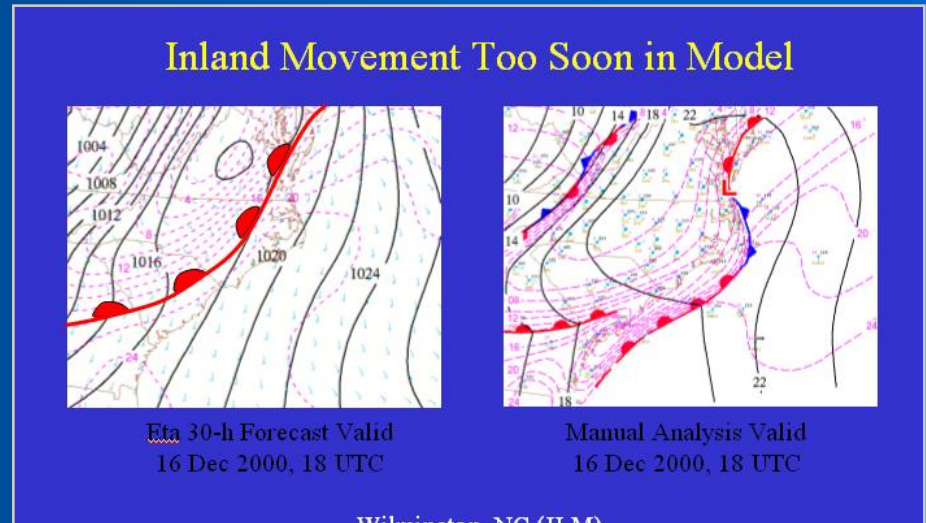

Photos courtesy of WRAL-TV

NWS-NCSU Collaborations:
A long and storied road

- 1990s:
  - Joint Severe Weather Collaboration
    - 38 students participated
    - 78 events, covering 277 hours
    - Warning decision process thoroughly analyzed
    - Benefited both students and NWS
  - Coastal flood model
  - Algorithm for determining winter precipitation type
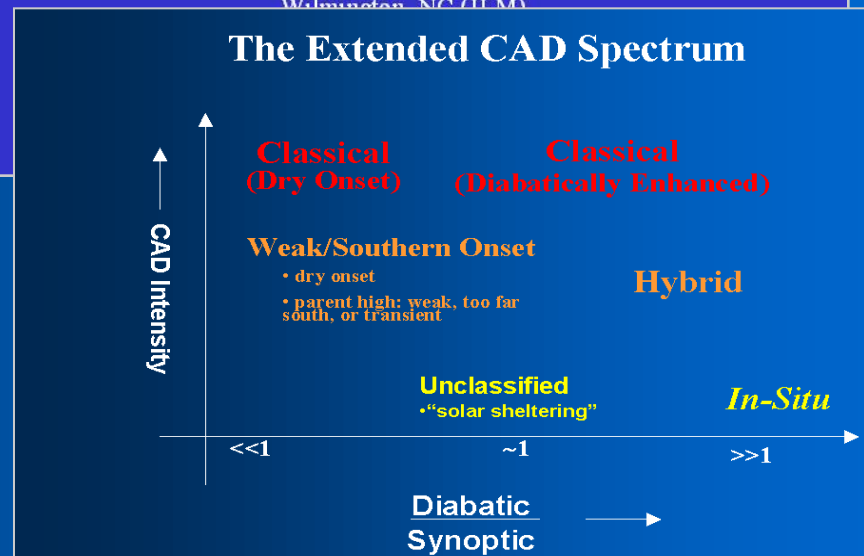 - Assessment of coastal cyclone intensification rates & development of forecast index

Severe Thunderstorm and Tornado Warnings at Raleigh, North Carolina

Debra K. Hoium,* Allen J. Riordan,* John Monahan,+ and Kermit K. Keeter*

ABSTRACT

The National Weather Service issues public warnings for severe thunderstorms and tornadoes when these storms appear imminent. A study of the warning process was conducted at the National Weather Service Forecast Office at

NWS-NCSU Collaborations:
A long and storied road

- 2000s:
  - 3 major NOAA-funded projects and other NSF and COMET projects; numerous papers & case studies published
  - Several VISITview seminars for NWS offices
  - Cold air damming climatology & development of classification system
 - Coastal front climatology & forecast aids

Inland Movement Too Soon in Model

Eta 30-h Forecast Valid
16 Dec 2000, 18 UTC

Manual Analysis Valid
16 Dec 2000, 18 UTC

Wilmington, NC (ILM)

The Extended CAD Spectrum

CAD Intensity

Classical (Dry Onset)

Classical (Diabatically Enhanced)

Weak/Southern Onset
- dry onset
- parent high: weak, too far south, or transient

Hybrid

Unclassified
- "solar sheltering"

In-Situ

<<1   ~1   >>1

Diabatic
Synoptic

NWS-NCSU Collaborations:
A long and storied road

- **2000s** (continued):
  - Assessing the effects of Gulf Coast storms on precipitation amounts in the Carolinas/mid-Atlantic region
    - Case studies led to conceptual models
    - Concepts have been applied operationally with success
  - Potential vorticity: "PV thinking" in operational forecasting


Case A (Scenario 1): December 31, 2002
Scenario 1: Upstream convection oriented parallel to flow. System propagating quickly, perpendicular to flow. (These cases would be expected to show decreased downstream precipitation as a result of interrupted moisture transport or other mechanisms.)
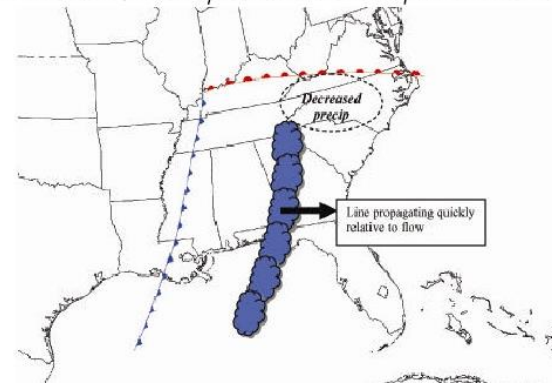
Decreased precip

Line propagating quickly relative to flow

NC STATE UNIVERSITY

The Impact of Latent Heating on Extratropical Cyclones: Using the PV Framework in Operations

Michael Brennan

NC STATE UNIVERSITY
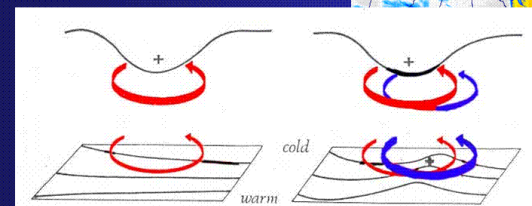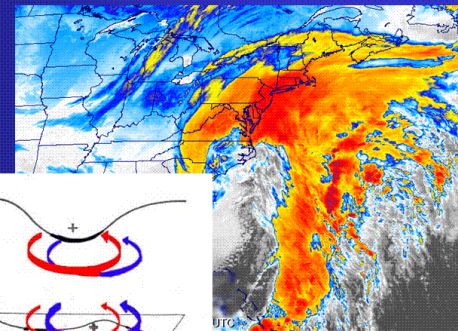
NWS-NCSU Collaborations:
A long and storied road

- **2000s** (continued):

  – Introduction to the Weather Research & Forecast (WRF) modeling system

  – Radar technique for forecasting the first lightning strikes was developed and implemented operationally

An Operational Introduction to the Weather Research & Forecasting (WRF) Modeling System

5-km WRF BMJ

NWS-NCSU CSTAR VISITVIEW PRESENTATION 12 November 2004 (updated)

RFC 10-km analysis

5-km WRF explicit
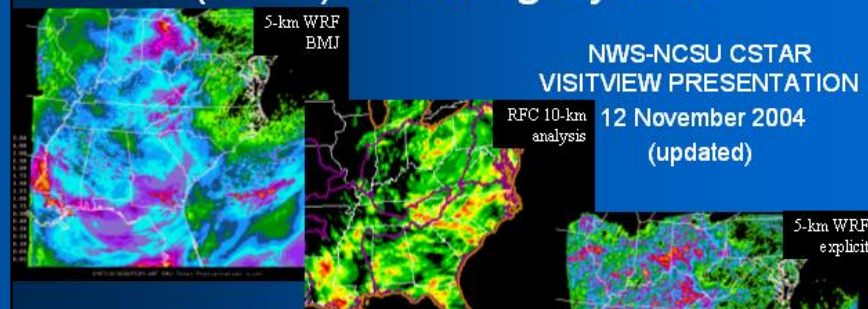
Detection Examples

Reflectivity of 40 dBZ and greater easily exceeded the -10°C and -15°C heights
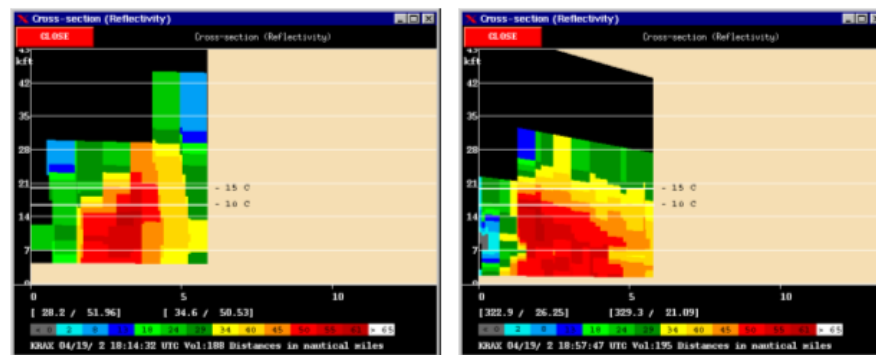
NWS-NCSU Collaborations:
A long and storied road

- **2000s** (continued):

  - Examining Multi-Scale Features that Enhance Precipitation Associated with Landfalling Tropical Cyclones in North Carolina

  - The Role of the Great Lakes in Northwest Flow Snowfall in the Southern Appalachian Mountains
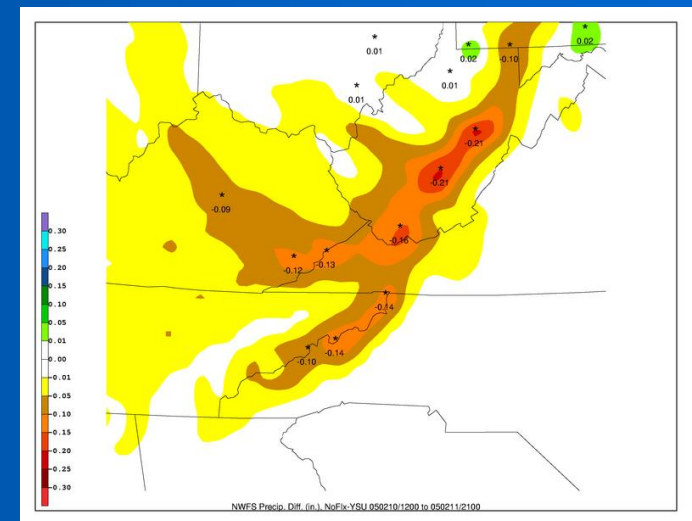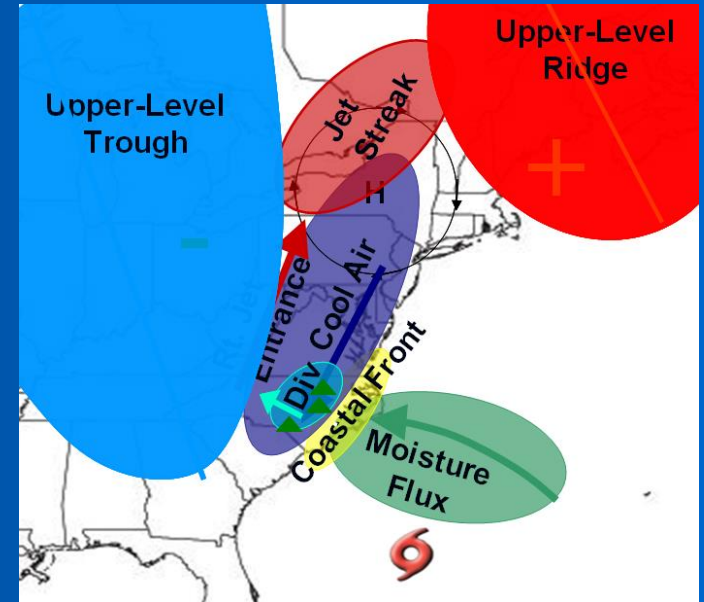
NWS/NCSU Research Focus

- Forecast Problems…for example:
  - Poor representation of coastal fronts and cold air damming by models
  - Coastal front forecast problems: inland movement, timing, sensible weather
  - Cold air damming forecast problems: development and erosion, precipitation amounts & type
  - Precipitation amounts: addressing deficiencies in the computer models in the mid-Atlantic/Carolinas
- Research Strategy:
  - Climatologies
  - Case study analysis, modeling

Visible Satellite and Surface Observations

Which Eta model component killed the stratus??

18 UTC 30 Oct 2002
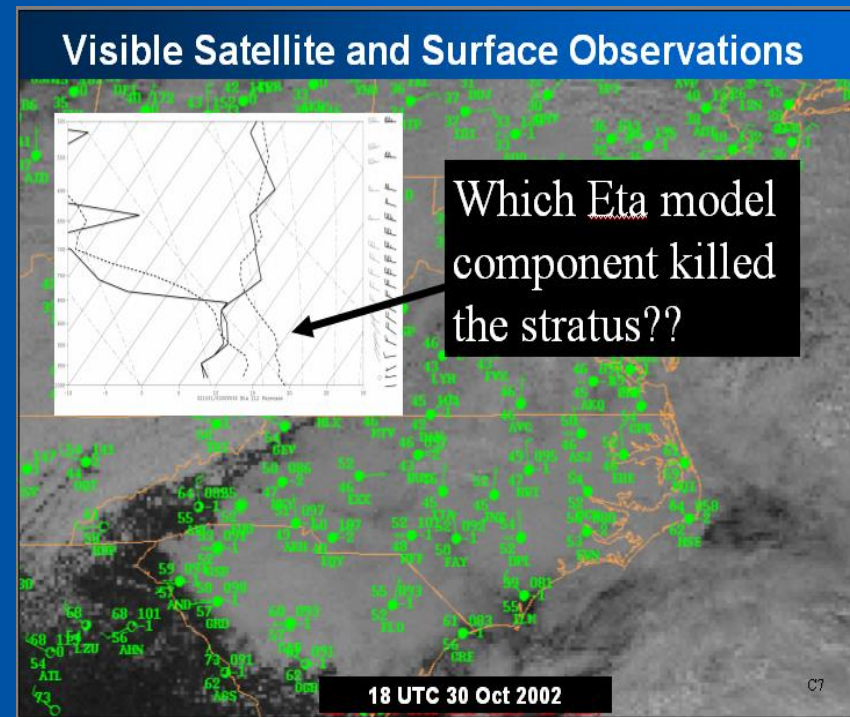
An example: How does the weather evolve as coastal front passes?
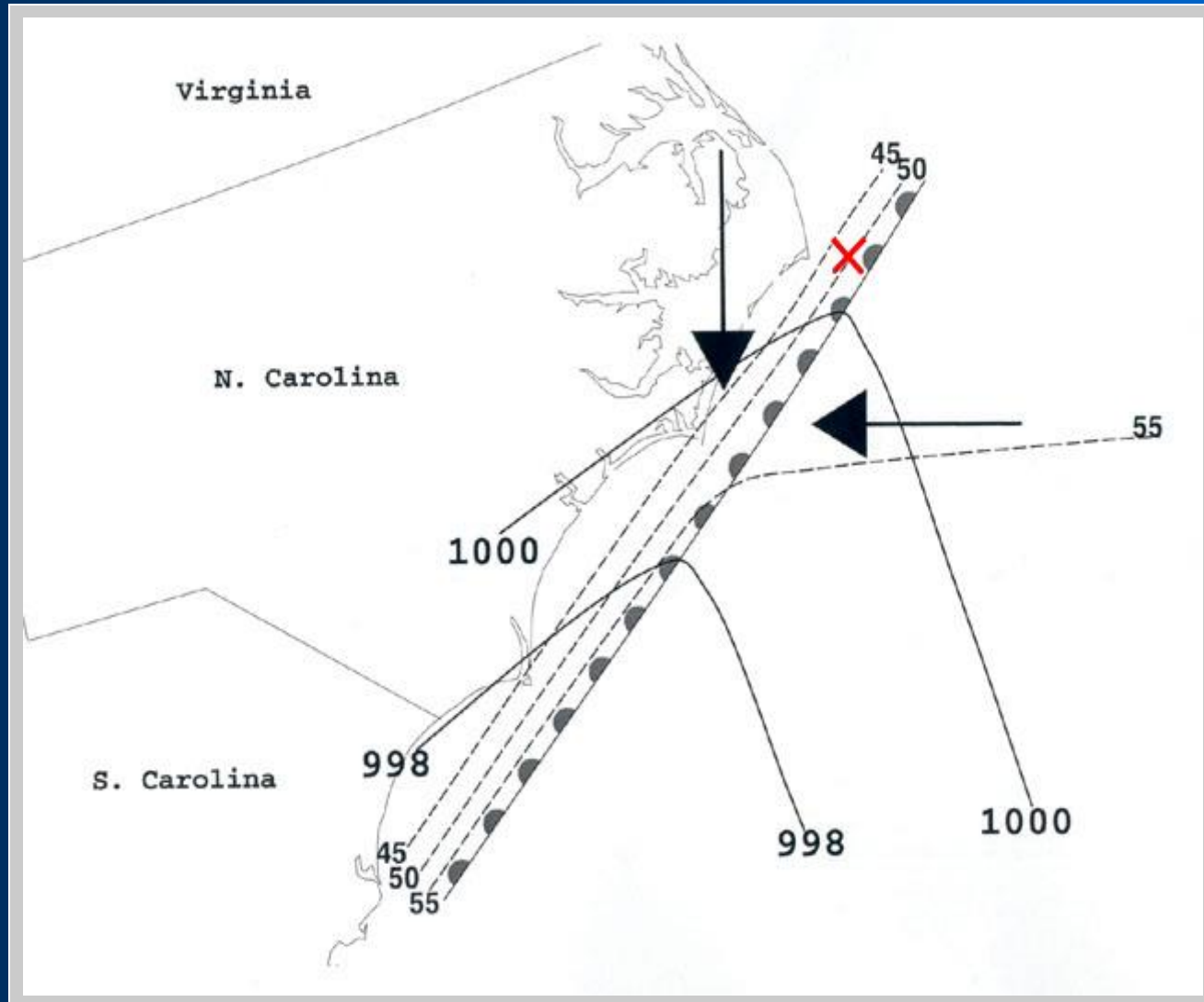
Accurate forecasts for coastal FP are critical!

CLKN7: 12/10/92 9Z

Large, rapid temperature jump…

Air Temps (C) vs Hours (Z)
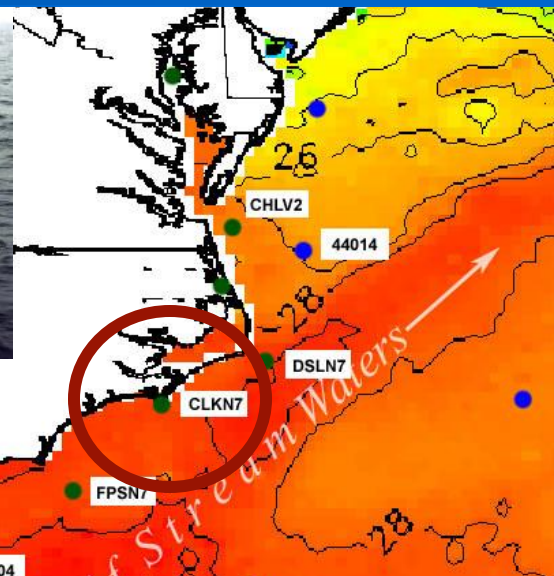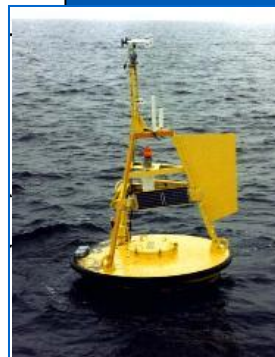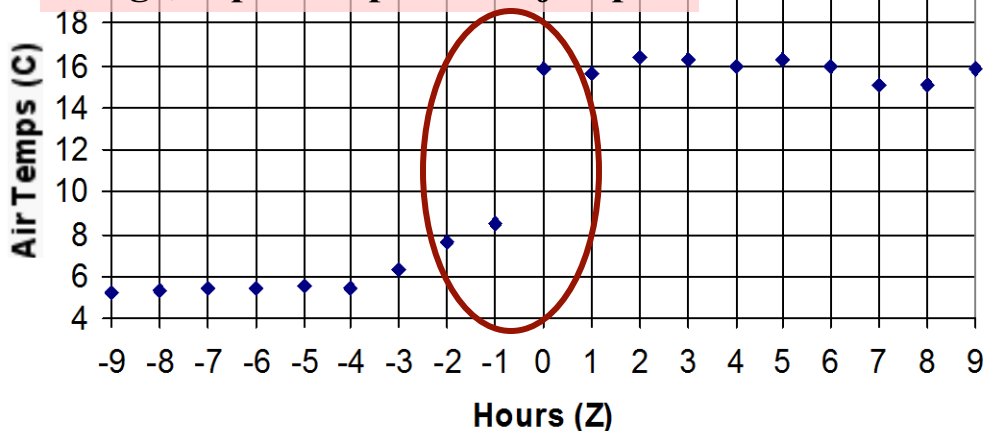
CLKN7: 12/10/92 9Z

…and drastic wind shift after CFP

Wind Direction (Degrees) vs Hours (Z)

26
28
28

CHLV2
44014
DSLN7
CLKN7
FPSN7
41004

Gulf Stream Waters

BMJ 21Z 17 Feb

KF 21Z 17 Feb
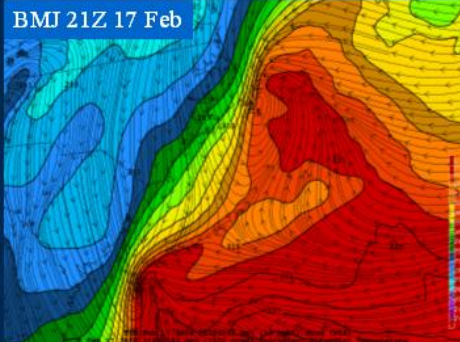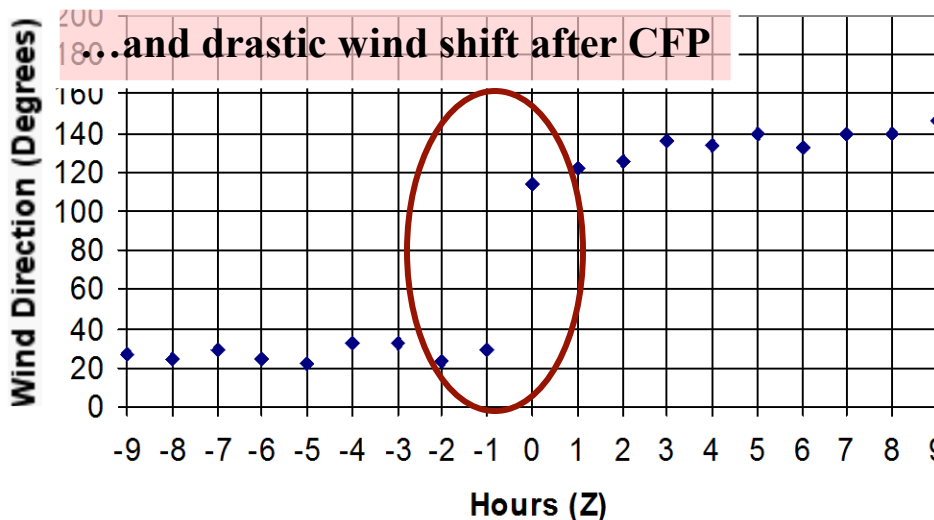
Coastal Front Representation

BMJ
- less-defined coastal front
- farther offshore
- distinct surface cyclone centers
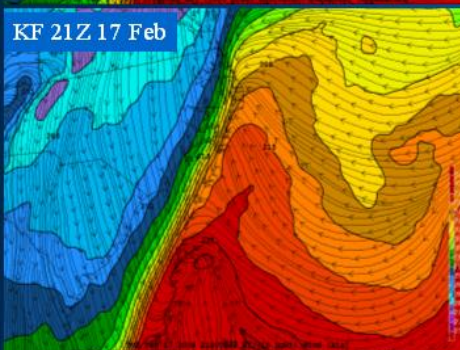
KF
- better-defined
  - stronger temperature gradient
  - more convergence
- closer to coast
- less distinct cyclone centers

C47

What have we learned about cold air damming ?

- There are many different varieties
- It is not limited to the cool season
- Weather impact (clouds, temps, weather) correlates to specific patterns, surface and aloft
- Erosion: 4 distinct synoptic scenarios & 5 erosion processes were identified


Wed, 30 October 2002, 12Z obs, Eta SLP

1) Classical, Diabatically Enhanced (CDEN)

Prominent jet shifts eastward at onset; possible subtropical jet

40 45 50 55 60   19 CDEN onset centered, time 000
250 hPa geopotential height, isotachs

Upstream trough close to damming region

Troughing west of jet; confluent flow atop high

95   99   19 CDEN onset centered, time 000
500 hPa geopotential height, ano

WAA; ridge builds north of NC; RH increases; precipitation within 6 hrs of onset time   "WET"

High north of 40°N & between 100°W and 65°W; pressure > 1030 mb; onset soon after fropa; high E-W

Research findings: cold air damming erosion scenarios

Cold-Frontal Passage:
Relatively small model error

Northwestern Low (no CFP):
Large model error

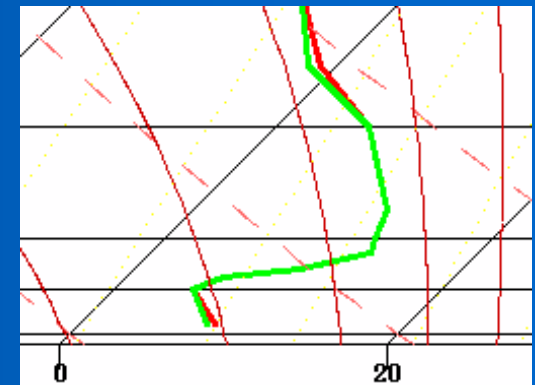*Cold-Frontal Passage*

Northwestern Low
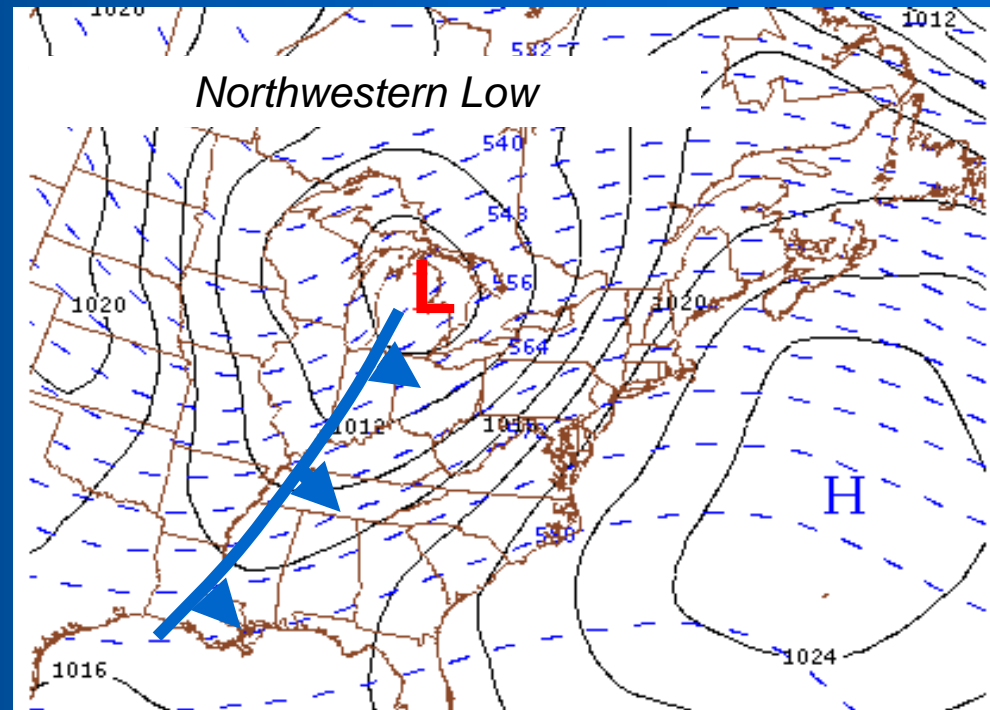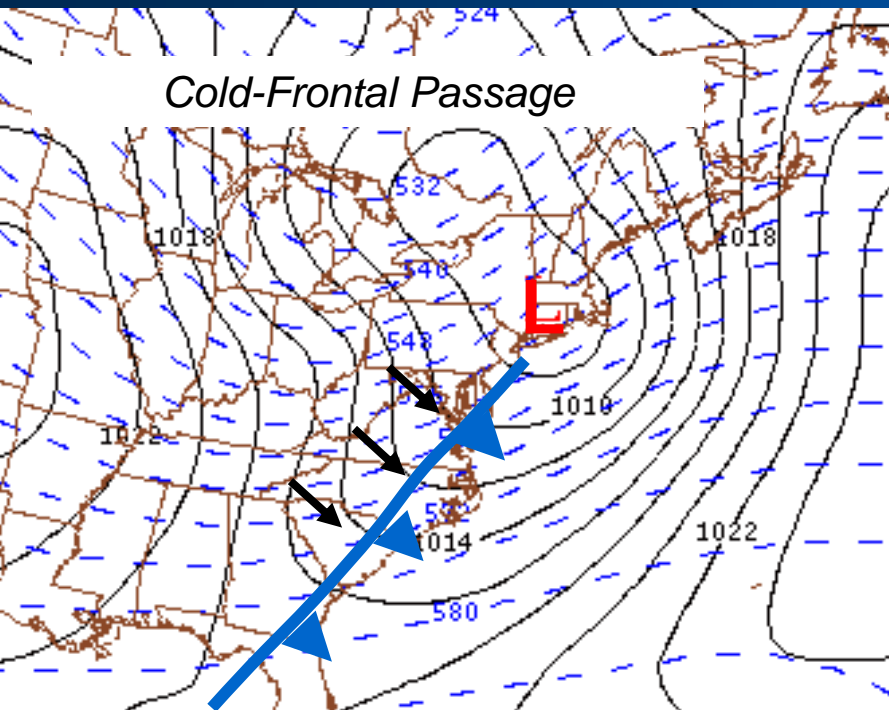
…These findings were brought <u>directly</u> into operations,
and <u>immediately</u> resulted in improved forecasts

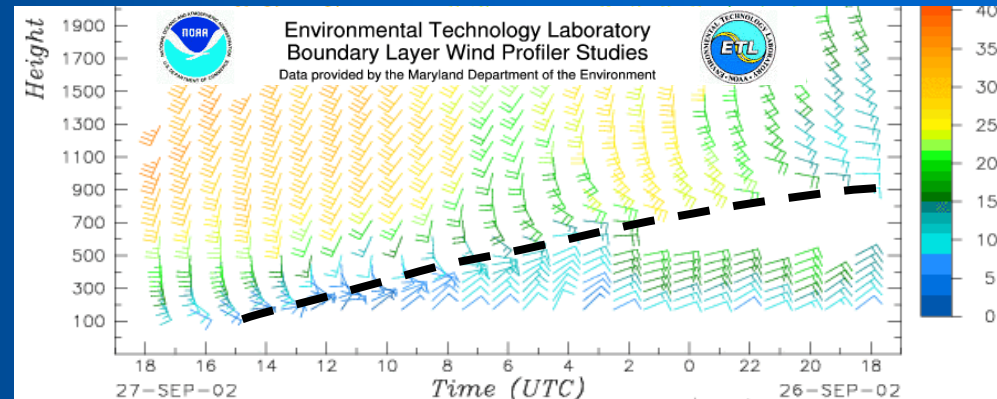# Research finding: cold air damming erosion processes

- ## Surface heating (bottom-up erosion)
  - – Eta allows excessive surface heating; premature erosion results

Red: before
Blue: after
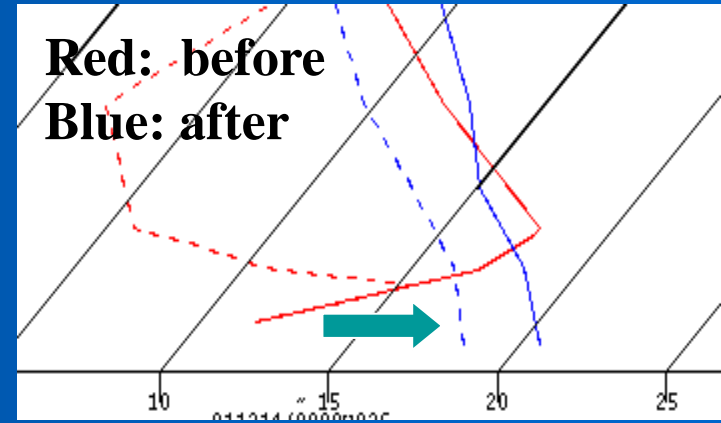
- ## Cold advection aloft (promotes mixing)
  - – Can be problematic for models

- ## Shear-induced mixing at inversion ("top-down" erosion)

Environmental Technology Laboratory
Boundary Layer Wind Profiler Studies
Data provided by the Maryland Department of the Environment

Fort Meade, MD

Winter weather computer model discoveries

- Precipitation type forecasting:
  - Comparison of techniques via case studies
  - Model discoveries: warm bias with cold air damming; cold bias with freezing rain
  - Biases depend on precipitation amounts

- Model biases:
  - Freezing rain was "misinterpreted" by one model's physics
  - Collaboration with the National Centers for Environmental Prediction (NOAA/NWS)
  - The model's bias was corrected

Freezing and Melting, Precipitation Type, and Numerical Weather Prediction

A Webcast by Dr. Gary M. Lackmann
Department of Marine, Earth, and Atmospheric Sciences
North Carolina State University

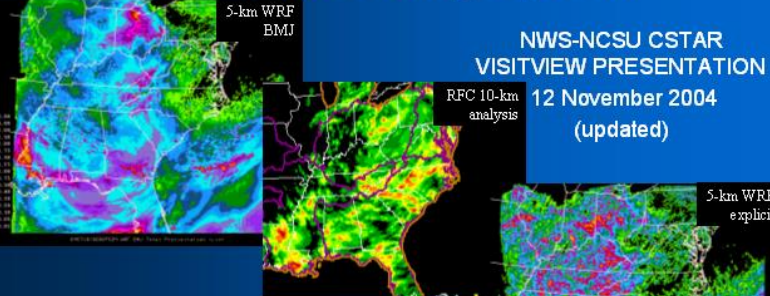Produced by the COMET® Program

NCAR Photo Library

Download Version | Click to Begin

MetEd Home | COMET Home | Northern Latitude Home
Contributors | Tech Notes | User Survey | Bibliography

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…These findings were brought directly into operations via web pages and training sessions, and immediately resulted in improved forecasts for cold air damming and ice (glaze) accrual

More research results

- Transfer of research findings via:
  - Online case studies, hard copy materials (posters)
  - Site visits, co-labs, online training sessions, webcasts

More research results

- Development of computer-based procedures to facilitate real-time application of research results

Targeted AWIPS procedures for assessing low-level potential vorticity to diagnose erroneous model QPF: COMET- & CSTAR- funded research
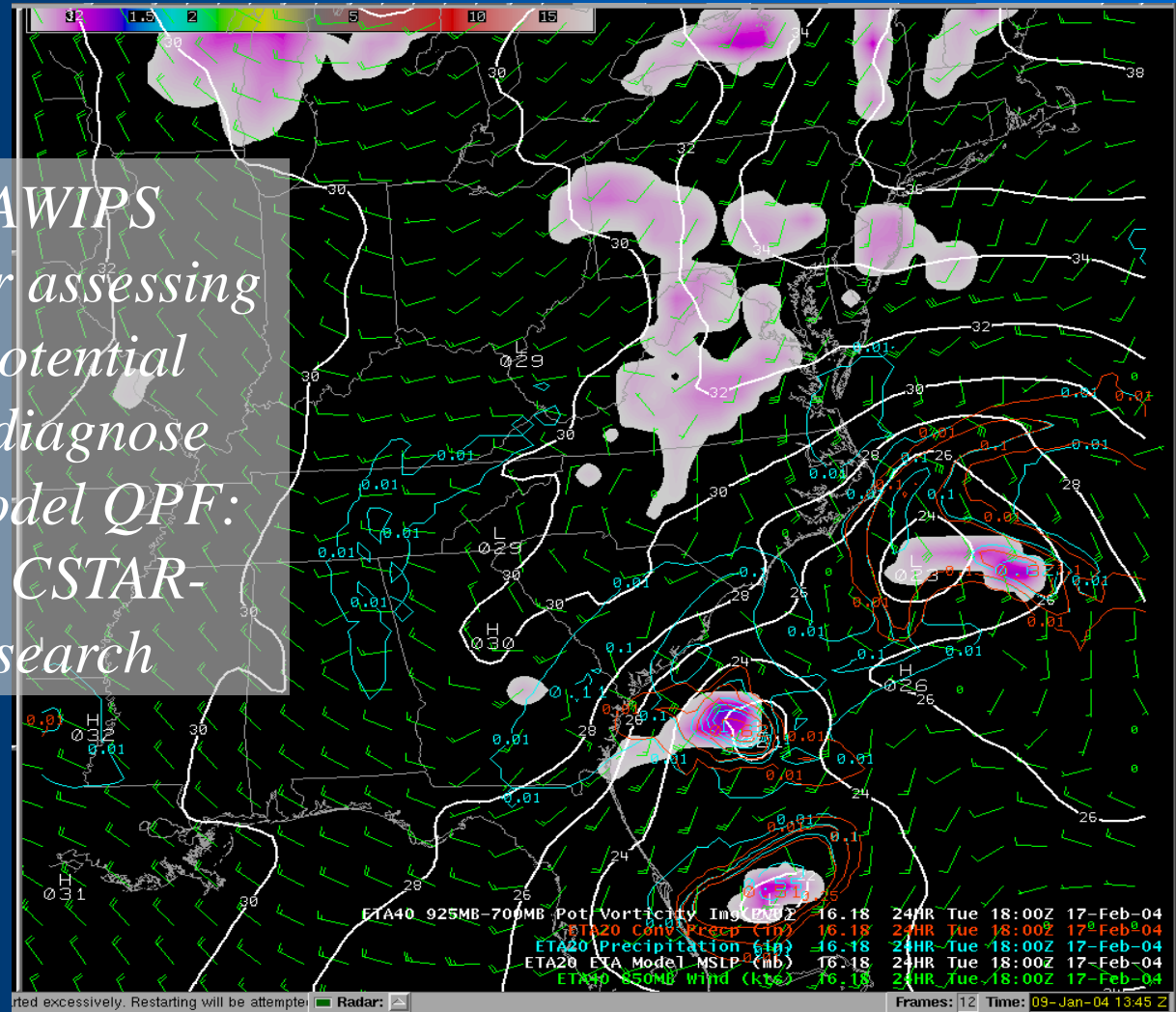
More research results

- Development of computer-based procedures to facilitate real-time application of research results

Targeted AWIPS procedures to diagnose potential for reduced convection in NC resulting from influence of upstream convection: current COMET-funded project
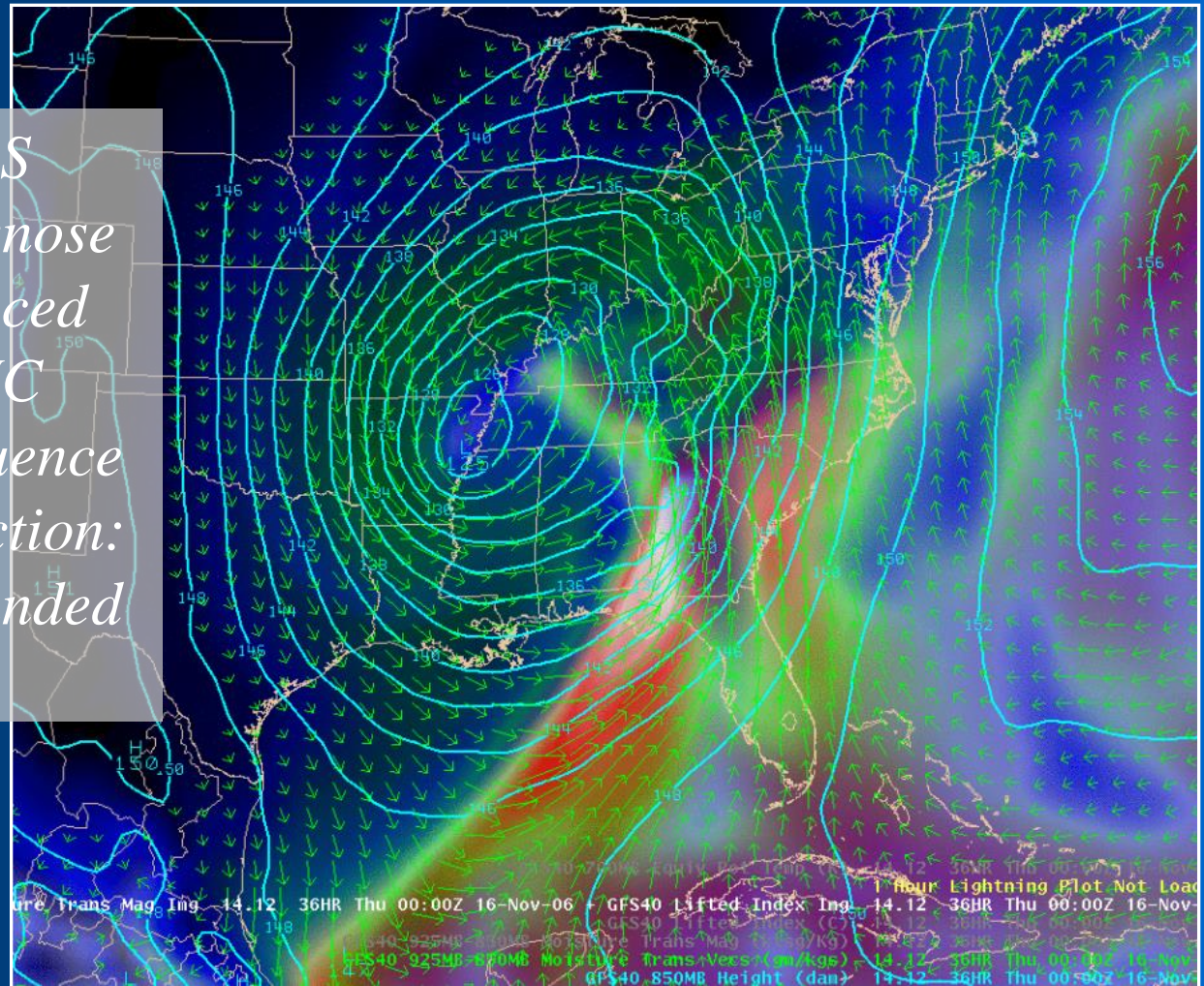
Research results

- Operational enhancements:
  - Improved pattern recognition
  - Objective detection and classification algorithms
  - Area Forecast Discussions reflect the science behind the predictions
    - *Our single most popular web page product*
  - Forecasters can now better recognize physical processes, and biases & weaknesses of models
  - Has resulted in improved weather forecasts

FXUS62 KRAH 071938
AFDRAH

AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE RALEIGH NC
235 PM EST FRI JAN 7 2005

.SHORT TERM (TONIGHT THROUGH MONDAY)...
TONIGHT...WEAK HIGH PRESSURE SLIDING OFFSHORE TONIGHT WITH LIGHT
SOUTHEAST FLOW DEVELOPING IN THE LOW LEVELS. THEN MODELS INDICATING
WARM FRONTAL (DEWPOINT BOUNDARY) LIFTING NORTH ACROSS THE AREA LATE
TONIGHT (06Z-12Z) AS LOW PRESSURE LIFTS NORTHEAST ACROSS THE
TENNESSEE VALLEY. CHANCE FOR RAIN OVERNIGHT LOOKS SLIM WITH THE BEST
CHANCE OVER NORTHWEST WHERE AREA OF LIFT/MOISTURE CONVERGENCE CROSS
TOWARD DAYBREAK. TIME/HEIGHT CROSS SECTIONS AND FORECAST SOUNDINGS
INDICATE PLENTY OF MOISTURE INTO CWA OVERNIGHT. SO WILL INDICATE
SMALL CHANCE OF SHOWERS NORTHWEST AND FAR NORTH WITH MAINLY
SPRINKLES FOR THE REST OF THE CWA. MILD TEMPERATURES WILL CONTINUE
WITH READINGS IN THE UPPER 40S TO LOWER 50S.

A FEW STRAY SHOWERS/SPRINKLES POSSIBLE FAR N EARLY SATURDAY THEN
PASSAGE OF MID LEVEL TROUGH VEERS FLOW TO WESTERLY AND DRIES COLUMN
OUT BY MID DAY. SURFACE FRONT CROSSES AREA LATE SATURDAY
AFTERNOON/EARLY EVENING.

SURFACE RIDGE OVER CENTRAL NC SUN SHOULD PROVIDE REGION WITH DRY
CONDITIONS. THICKNESSES VARY WITH ETA WARM AND NGM COOL. THIS

Surface

-8 -4 4 8 12 16   Low Impact onset centered, time 000
                  sea level pressure and anomaly
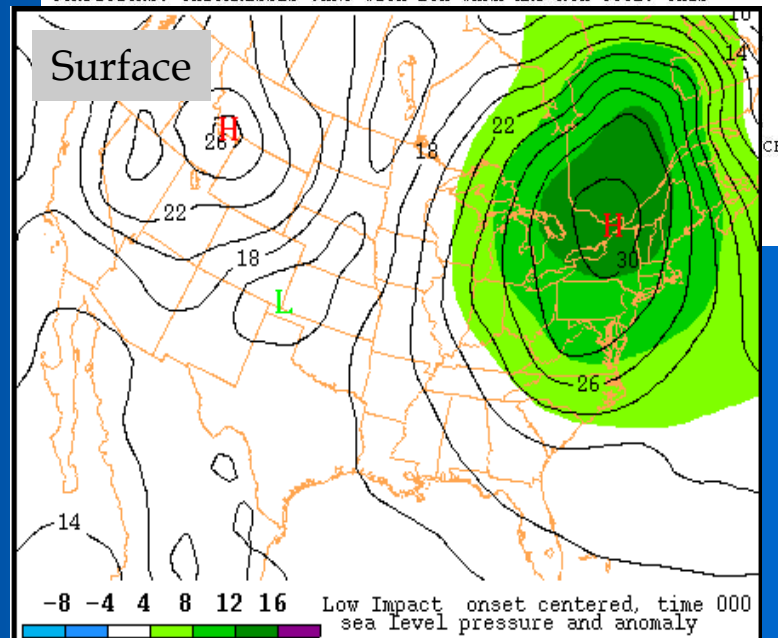
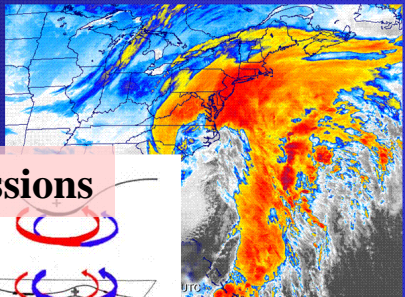# More results: Operational web pages, references, & forecast tools

Vast archive of winter, severe, & tropical case studies (contributions by NWS forecasters & NCSU students/faculty) www.erh.noaa.gov/rah/events/

The Impact of Latent Heating on Extratropical Cyclones: Using the PV Framework in Operations

Michael Brennan

NC STATE UNIVERSITY

Archived presentations from training sessions

Real-time partial thicknesses and short-range forecasts for precipitation type diagnostics & forecasting (tempest.meas.ncsu.edu/pthick/)

Group listserver for collaboration, information sharing, research updates, discussions of operational successes/failures

NCSU student internship course at NOAA-NWS Raleigh

- Credit course; began in 2004 and continues today
- Students gain real-world experience, learn typical NWS tasks
  - Collecting hydrometeorological data, data analyses, introduction to forecast/warning processes and forecast preparation methodologies
  - Students keep journal of experiences & attend various training courses

The Inaugural Class: Spring Term 2004

The NWS/NCSU Collaboration Process:
Transferring and implementing research results to achieve long-lasting benefits ("connecting the dots")

http://www.meas.ncsu.edu/nws/

Level 1 - Discover & Share (Only the beginning)

Level 2 - Demonstrate added value (So what? Show me!)

Level 3 - Operational Implementation (Practical?)

Level 4 - Mastery (By all, not a few)

Level 5 - Periodic review (A necessity)

NOAA/National Weather Service and
North Carolina State University
thank you for your interest in our collaborations!

Visit us at
http://www.meas.ncsu.edu/nws/