The Role of the Great Lakes in the 10-11 February 2005 Northwest Flow Snowfall Event in the Southern Appalachian Mountains

Blair Holloway
NOAA/National Weather Service
Greer, SC

Outline

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- Motivation
- Background Research Areas
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  - Northwest Flow Snowfall (NWFS) Events
- Objective
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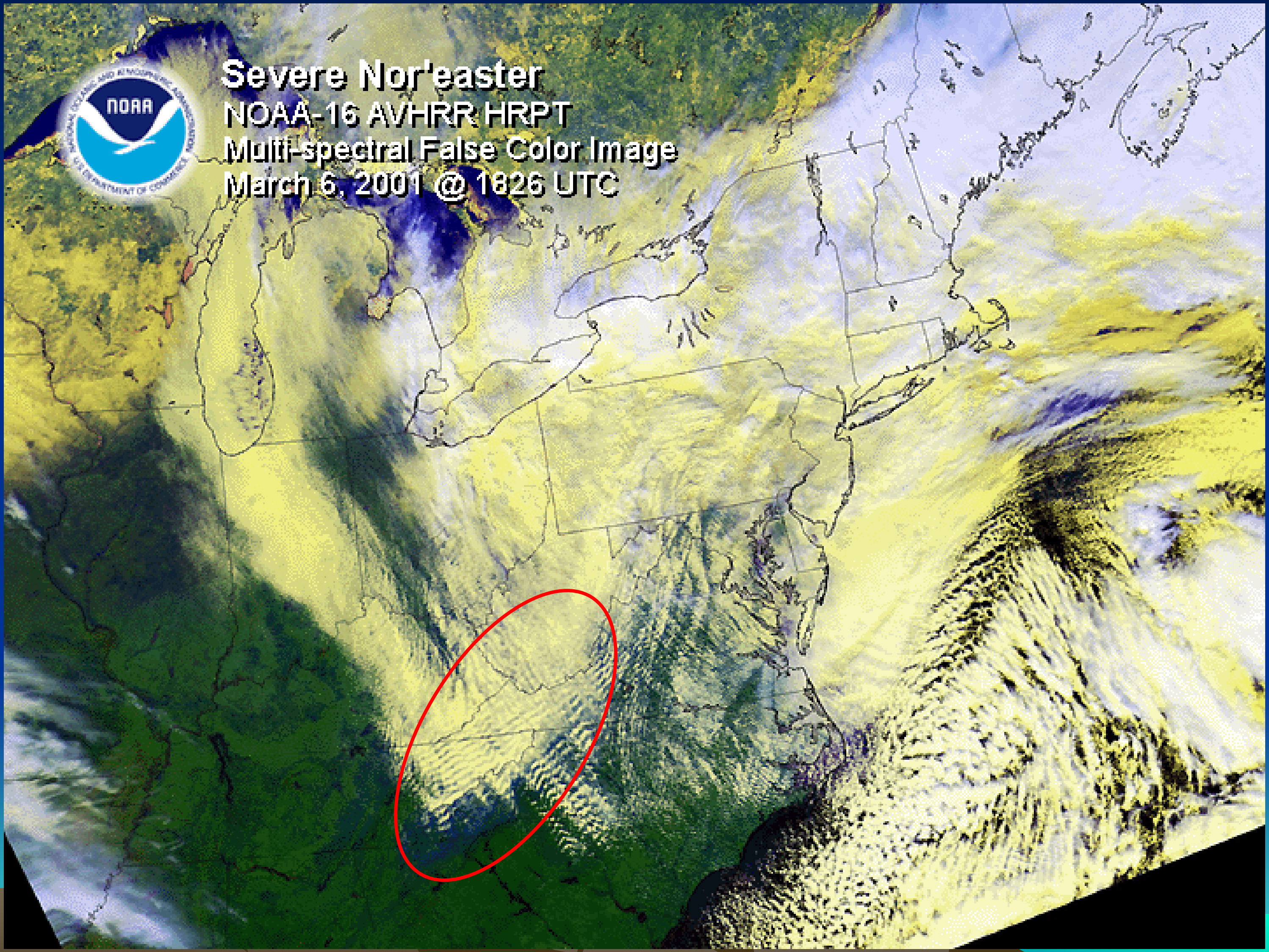
- 10-11 February 2005 Event
- Conclusions
- Future Work
- Acknowledgements

Introduction

- Snowfall accompanying upslope flow and low-level NW winds, in the southern Appalachian Mountains

What is Northwest Flow Snowfall?

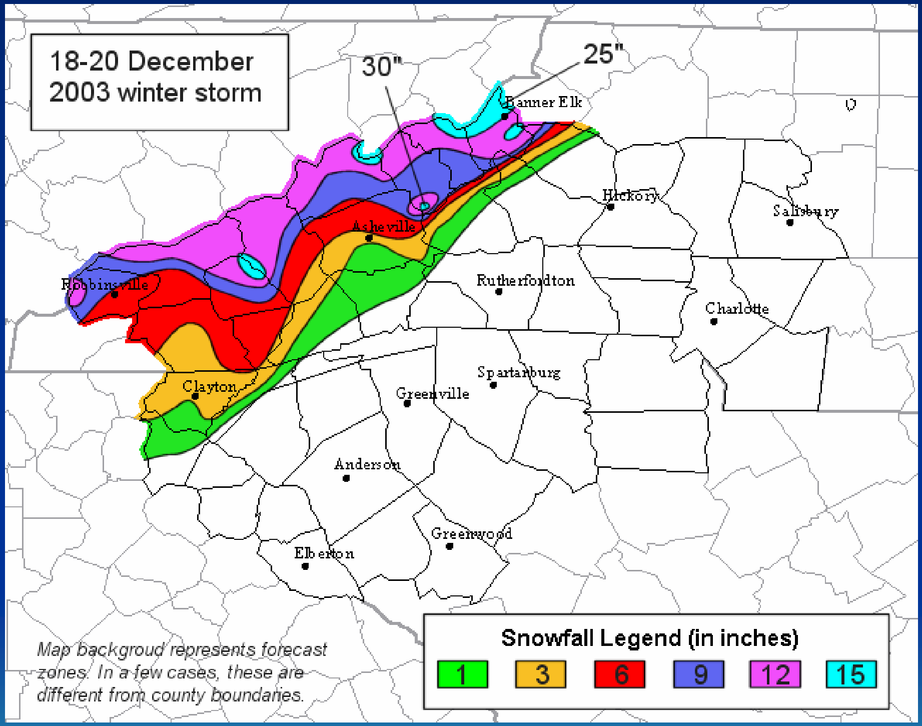
Introduction



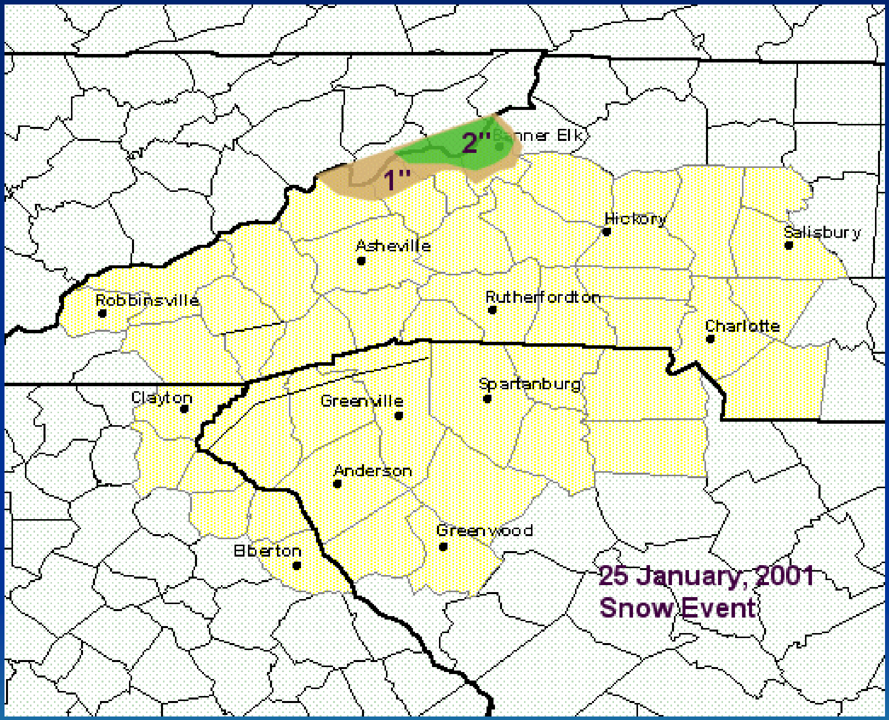
http://www1.ncdc.noaa.gov/pub/data/images/blizzard-newengland-20010306-n16rgb.gif

Introduction

Storm Total Snowfall (inches)

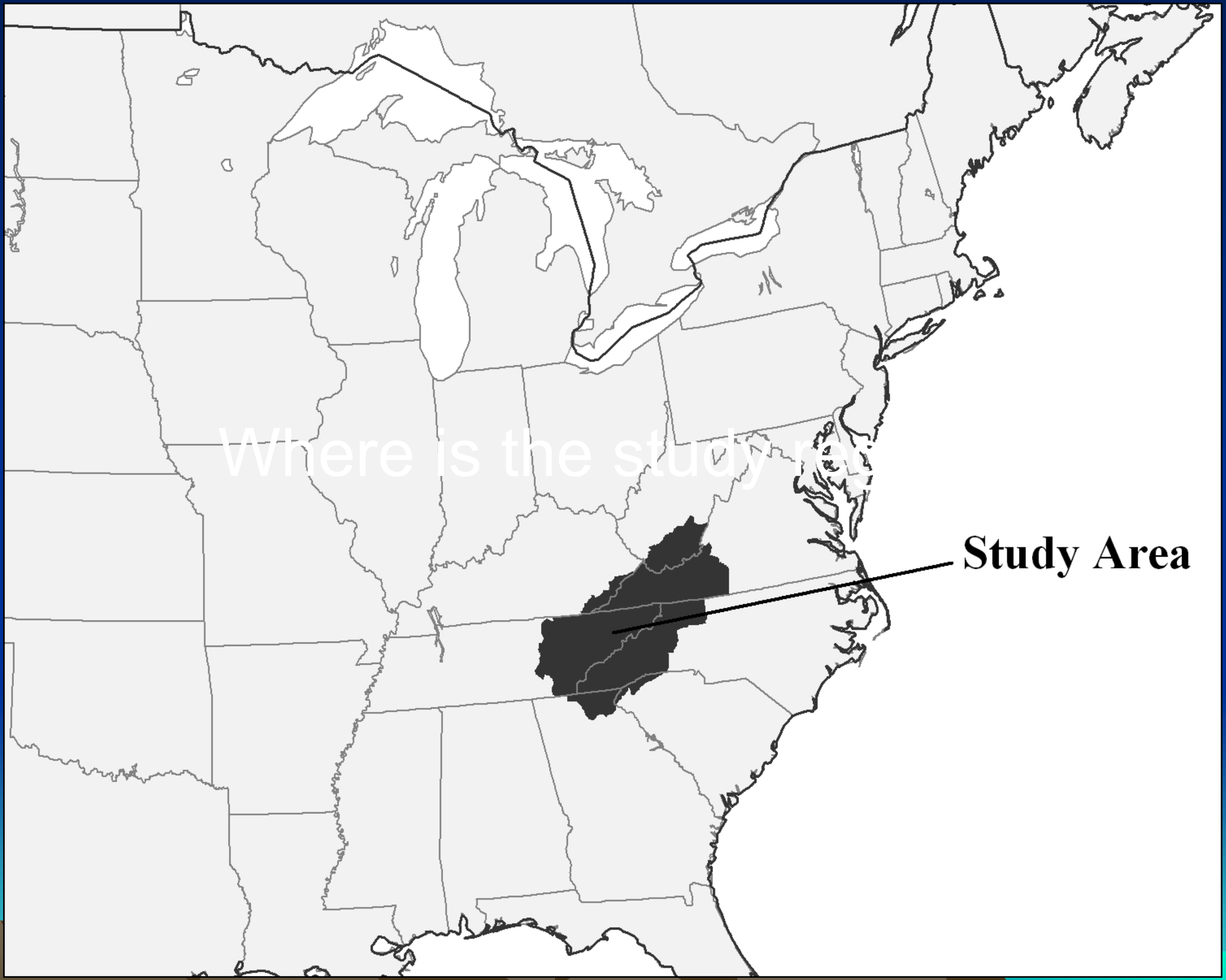


http://www.erh.noaa.gov/gsp/localdat/December_18-20.htm



http://www.erh.noaa.gov/gsp/localdat/headline/25jan2001snow/index.htm

Introduction



Graphic courtesy of Dr. Baker Perry

Motivation

- Significant forecast challenge for National Weather Service (NWS)
  - Issues include total accumulations, spatial extent, variability
- Communication with NWS through NWFS discussion group, communication with Greenville-Spartanburg staff
- Climatological studies of NWFS events done by Perry and Konrad 2004-2006 provide excellent motive
  - Identified “Great Lakes connection” (GLC)
  - But: (i) only subsidence cases, (ii) no quantification of GLC

Background Research – Flow Over Mountains

- Quantifying interaction of air flow and mountain barrier (Froude number)

$$Fr = U/NH$$

U – velocity perpendicular to mountain range
N – static stability
H – mountain height

- Great Lakes influence on Fr:
  - Destabilization increase (smaller N)
  - Moistening further increases (moist N)

- Expect more NWFS for high Fr, more flow up and over mountains

- May affect distribution, amount of precipitation

Background – NWFS Events

- Nearly 50% of average annual snowfall totals attributable to NWFS events (Perry and Konrad 2004; Perry 2006)
- Of 191 NWFS events between 1975-2000, 47.1% exhibited a Great Lakes connection (GLC) (Perry and Konrad 2005; Perry et al. 2006)
- Overall, events with GLC showed increases in composite mean and maximum snowfall totals (Perry and Konrad 2005; Perry et al. 2006)
- These results suggest that the Great Lakes can enhance snowfall in NWFS events in southern Appalachians

Objective

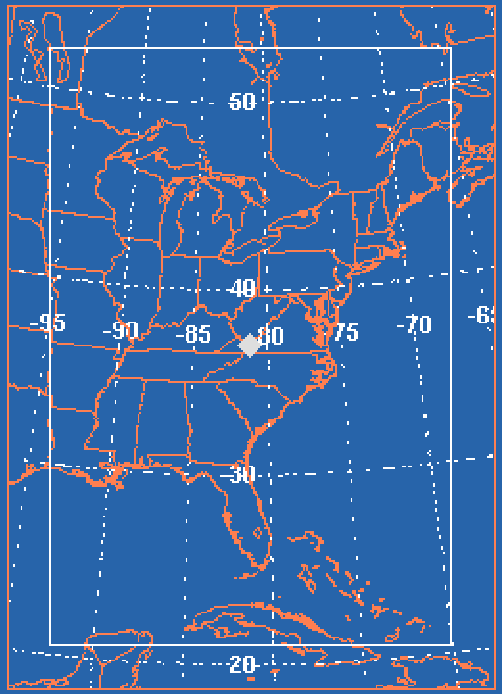
- Quantify and evaluate the role of the Great Lakes in NWFS events for select cases via model experiments using WRF.

Hypotheses

1. The Great Lakes are a major source of moisture and instability in some NWFS events and precipitation amounts would be decreased in their absence.

2. Lake-induced instability can affect the spatial extent and amount of snowfall.

Methodology – WRF Model Domain



- 150x150 size
- 24 km grid spacing
- Centered at 36.96 °N; -81.09 °W
- 0.5 degree SST data
- North American Regional Reanalysis (NARR) data used as initial and boundary conditions

Methodology – Control Run (CTRL)

- Purpose: serve as surrogate observational dataset, and basis for comparison for experimental runs

- Parameterization schemes:
  - Lin et al. microphysics
  - Yonsei University (YSU) PBL
  - Betts-Miller-Janjic (BMJ) convective
  - Rapid Update Cycle (RUC) land-surface model
  - Monin-Obhukov surface layer
  - RRTM longwave radiation
  - Dudhia shortwave radiation

Methodology – Experimental Run 2 (NOFLX)

- Purpose: increase stability between the Great Lakes and southern Appalachians
  - Determine the extent to which upstream destabilization contributed to precipitation

- Same setup as CTRL except:
  - Surface fluxes of heat and moisture set to zero across the entire model domain

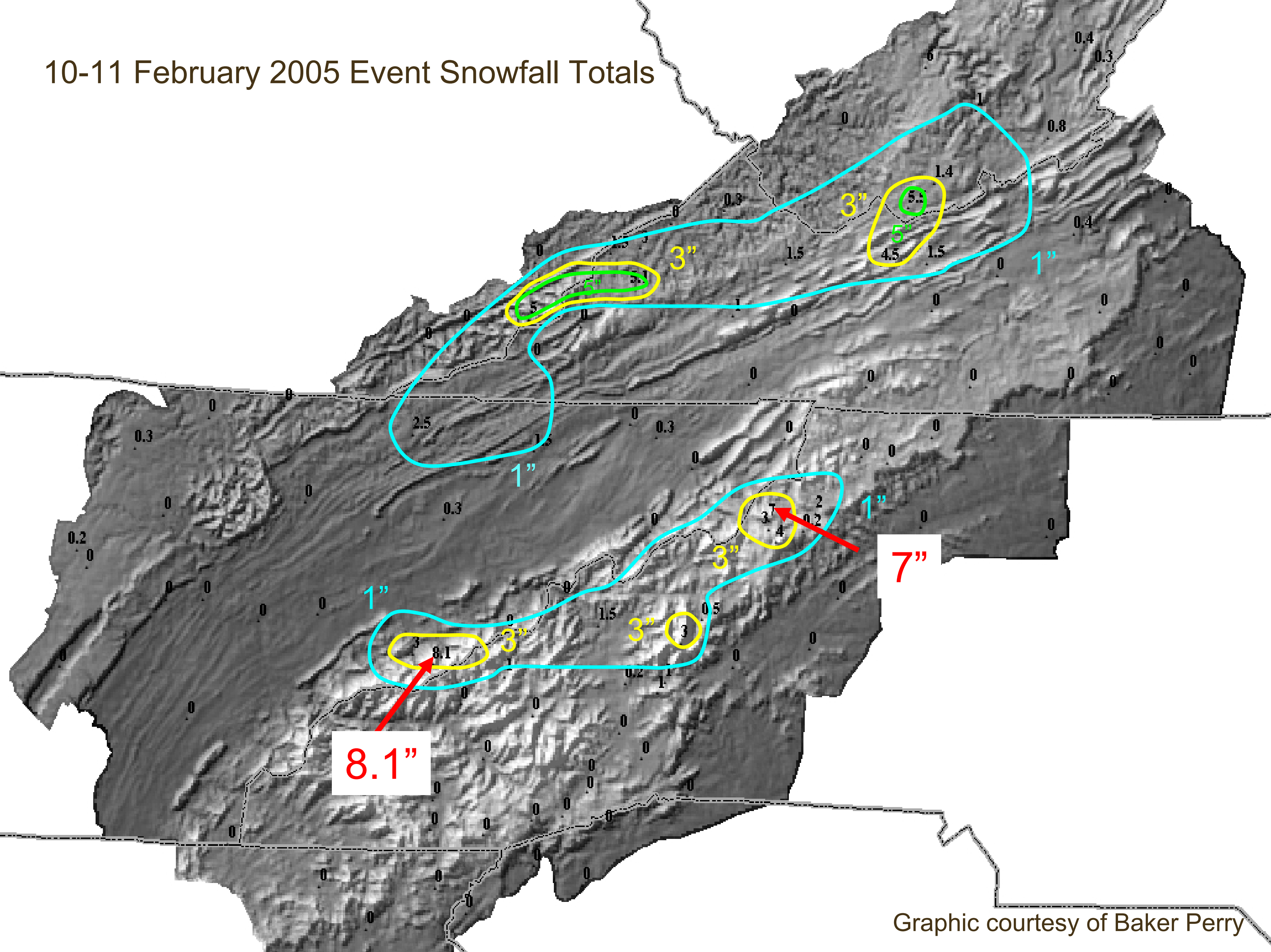
Methodology – Experimental Run 3 (LKNOFLX)

- Purpose: isolate Great Lakes, determine their contribution to moisture and instability in NWFS events

- Same setup as CTRL except:
  - Surface fluxes of heat and moisture set to zero over water

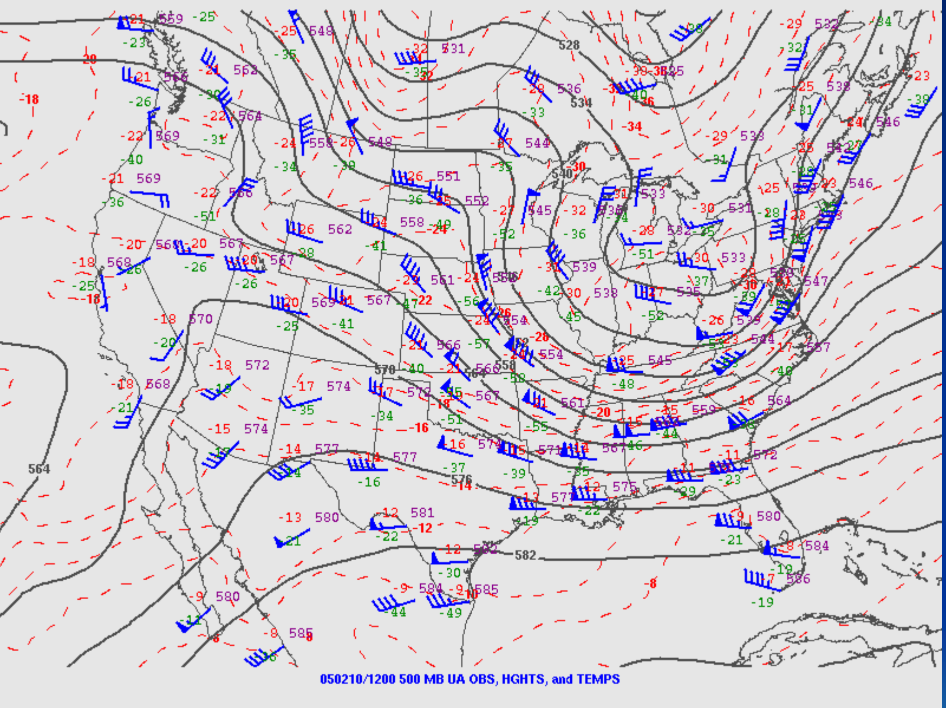
10-11 February 2005

10-11 February 2005 Event Snowfall Totals

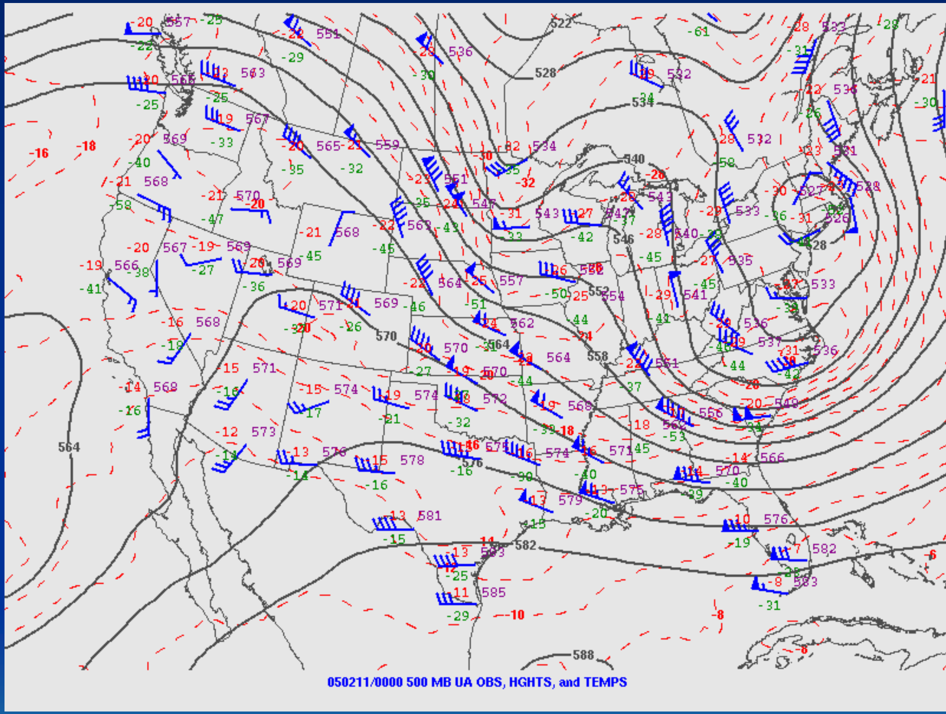


Graphic courtesy of Baker Perry

500 hPa – 10-11 February 2005

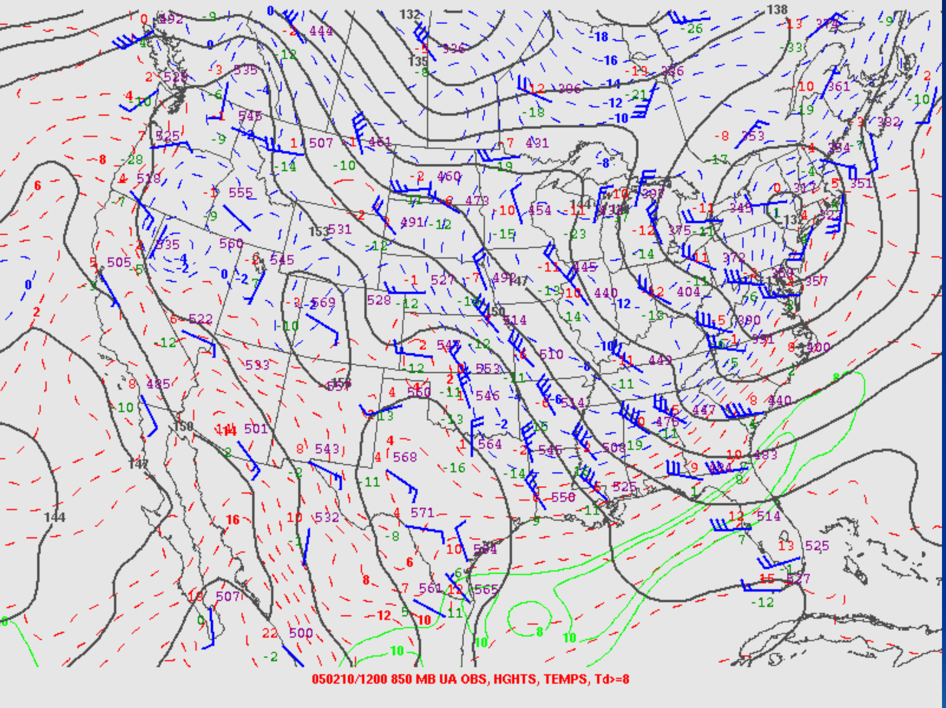


12 UTC 10 February 2005



00 UTC 11 February 2005

850 hPa – 10-11 February 2005



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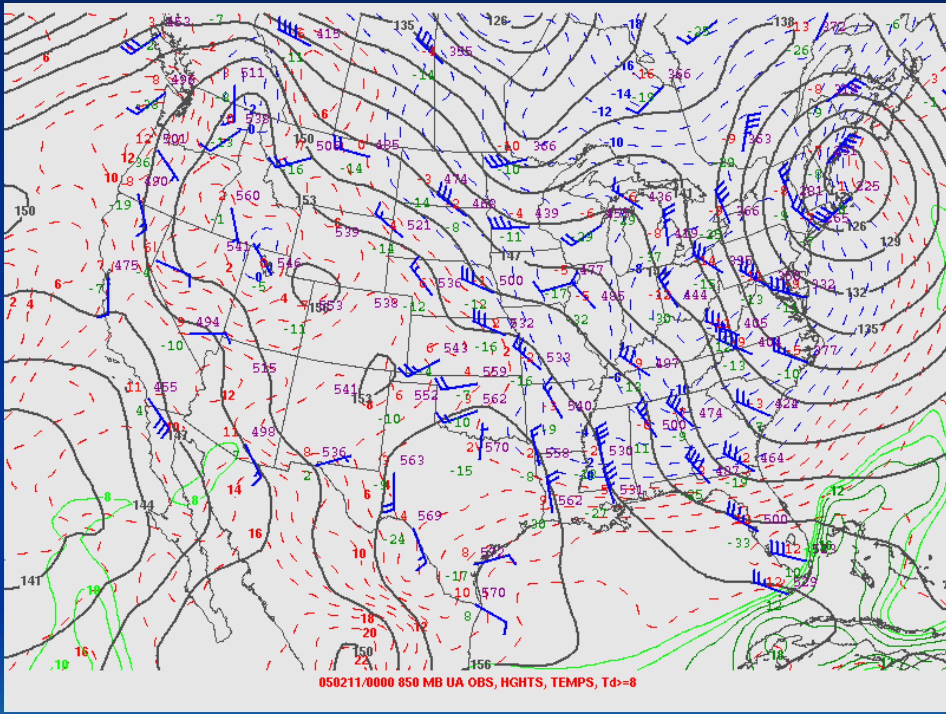
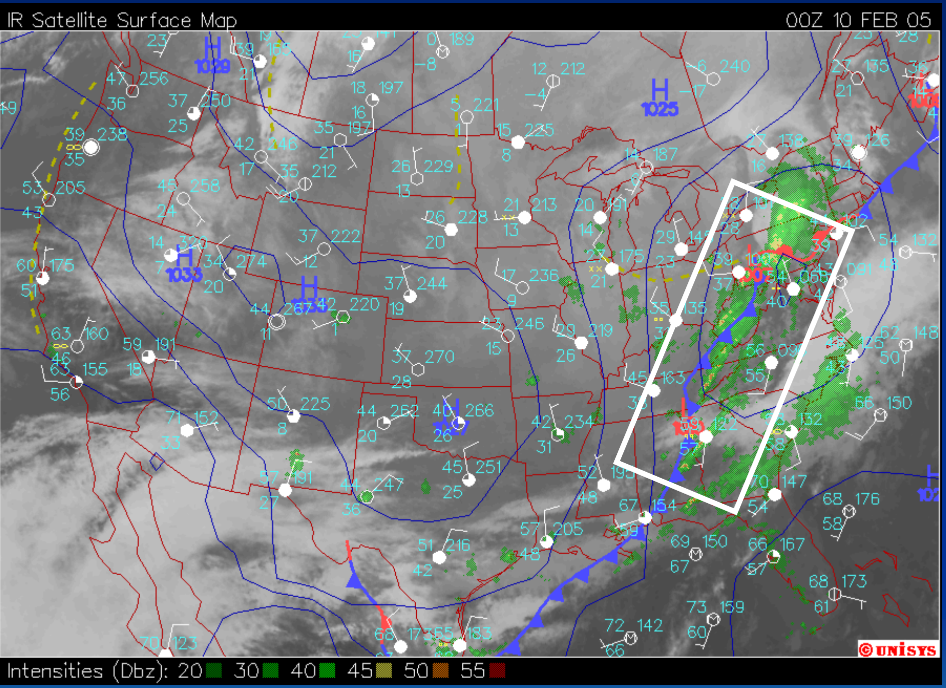


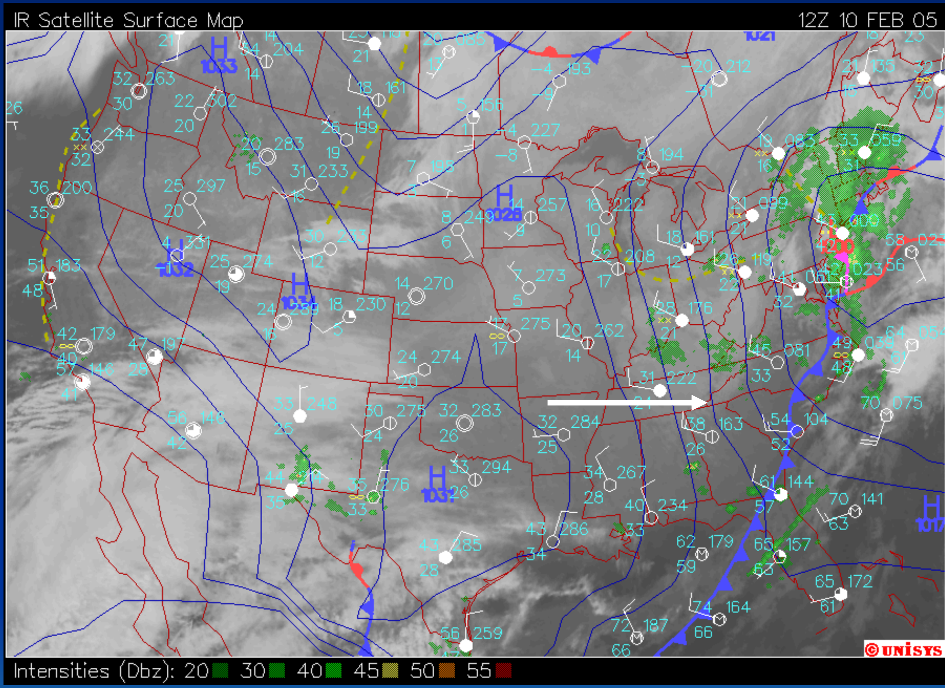
00 UTC 11 February 2005

Surface Analyses – 10 February 2005

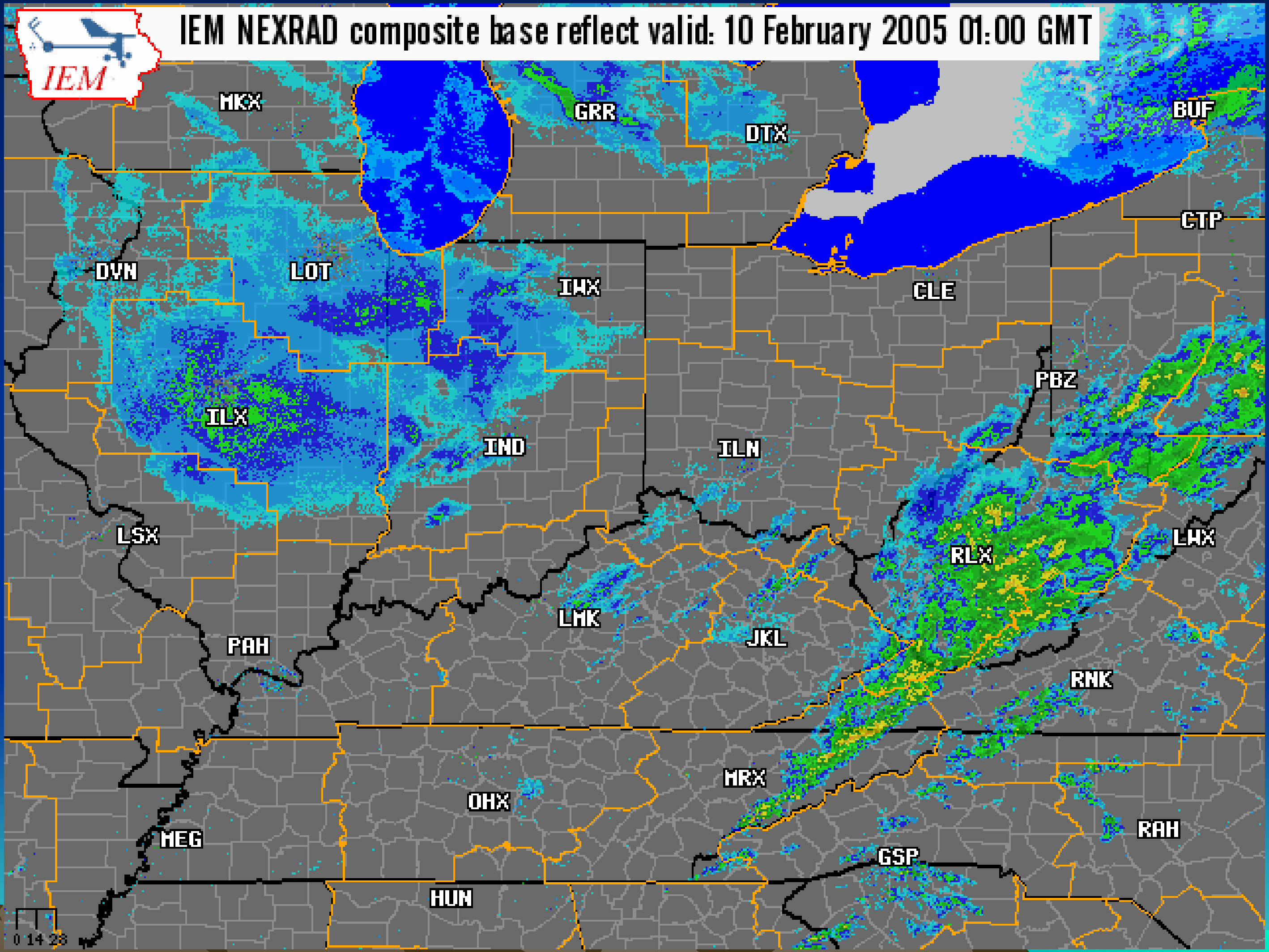
00 UTC



12 UTC



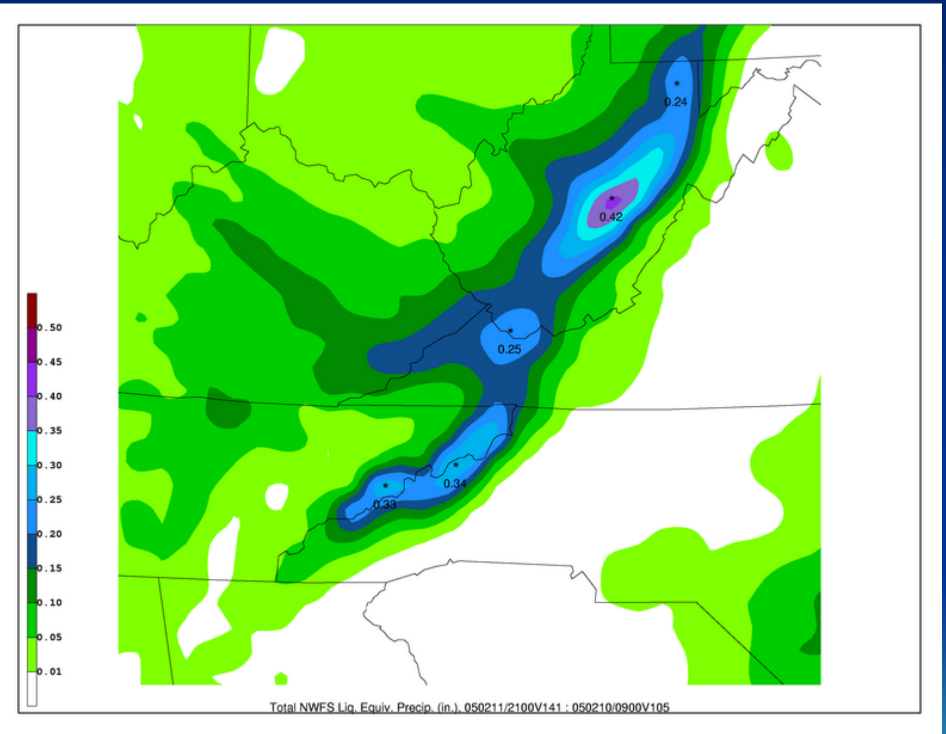
Radar – 10-11 February 2005

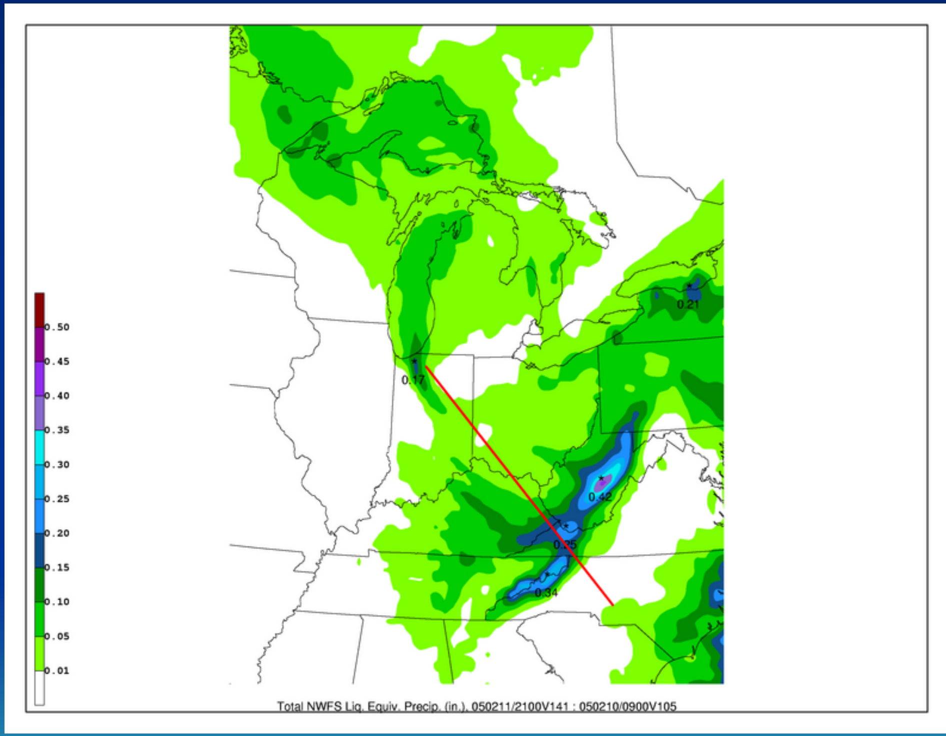


http://mesonet.agron.iastate.edu/GIS/apps/rview/warnings.phtml

CTRL – 10-11 February 2005

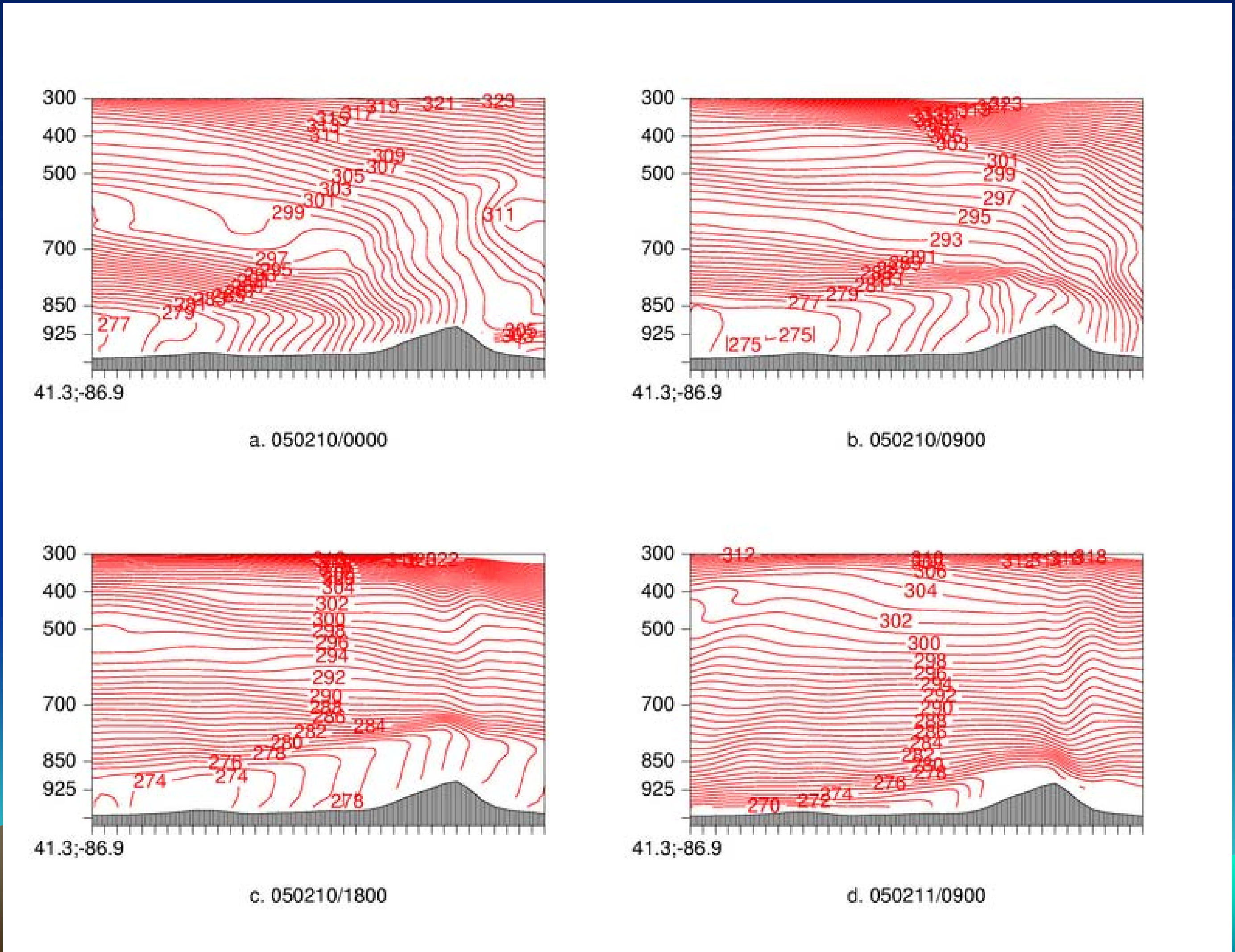
CTRL Total NWFS Precipitation (in.): 09 UTC 10 February – 21 UTC 11 February





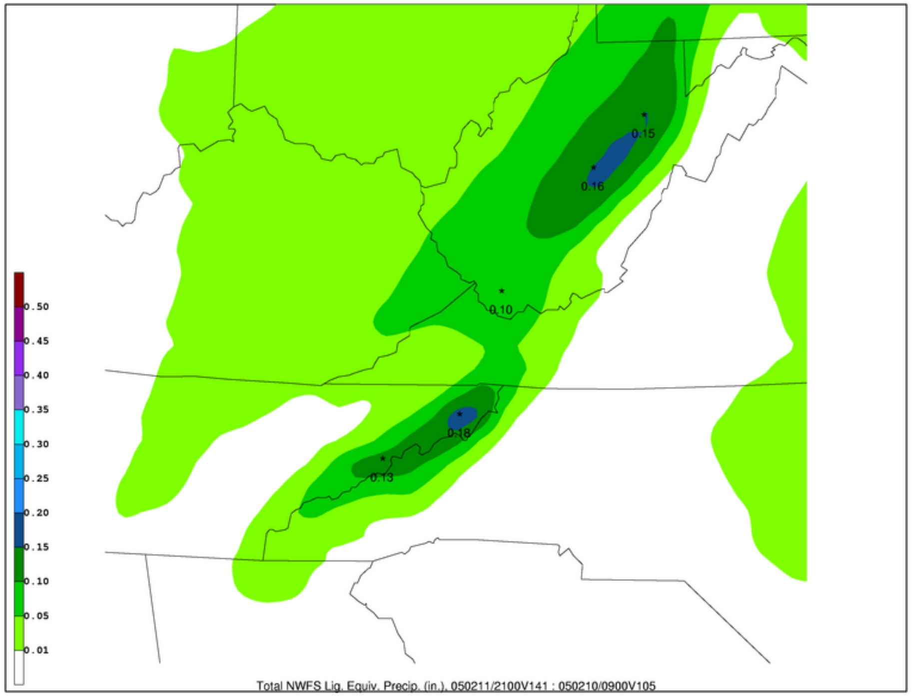
CTRL – 10-11 February 2005

Θ_e Cross-sections along plane highlighted on previous image

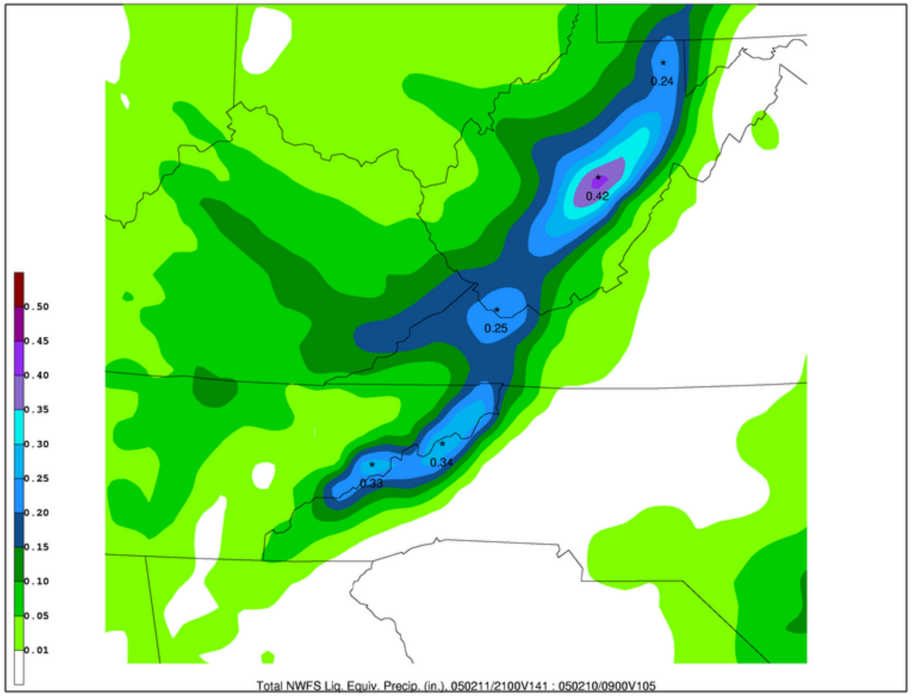


NOFLX – 10-11 February 2005

Total NWFS Precipitation (in.): 09 UTC 10 February – 21 UTC 11 February



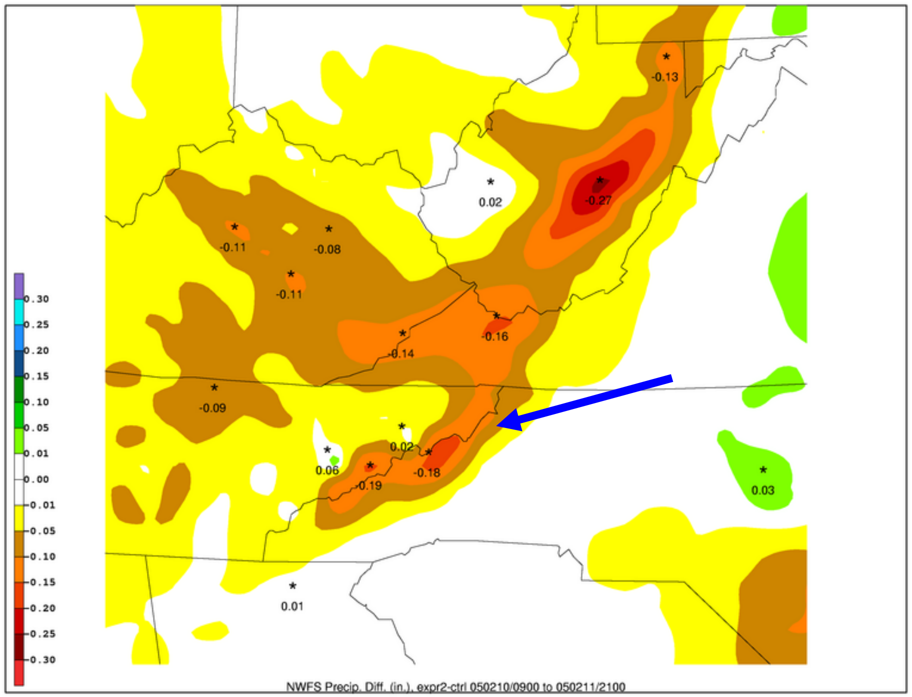
NOFLX

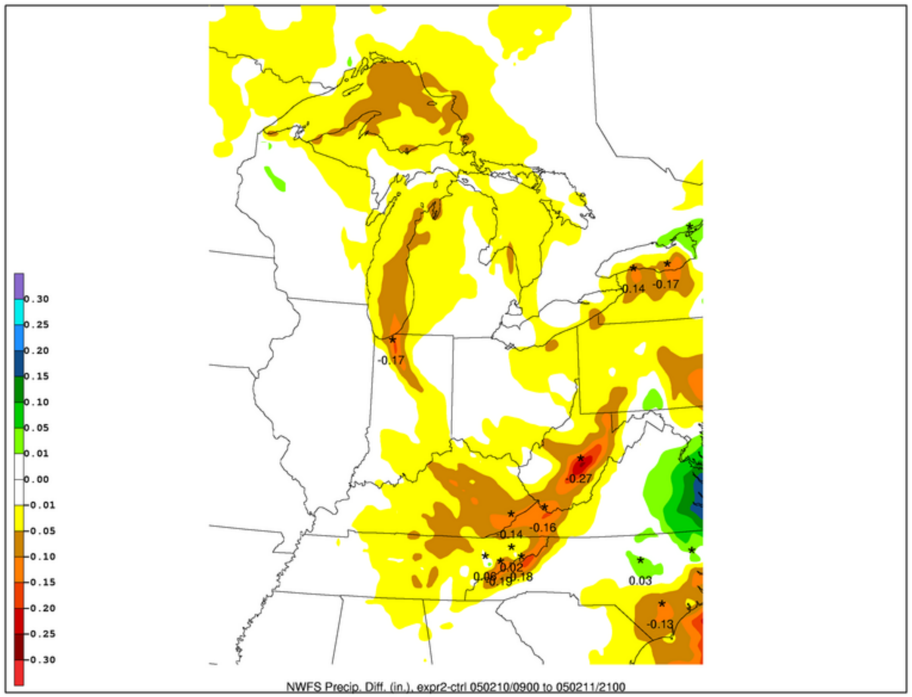


CTRL

NOFLX – 10-11 February 2005

NOFLX-CTRL Precipitation Diff. (in.): 09 UTC 10 February – 21 UTC 11 February

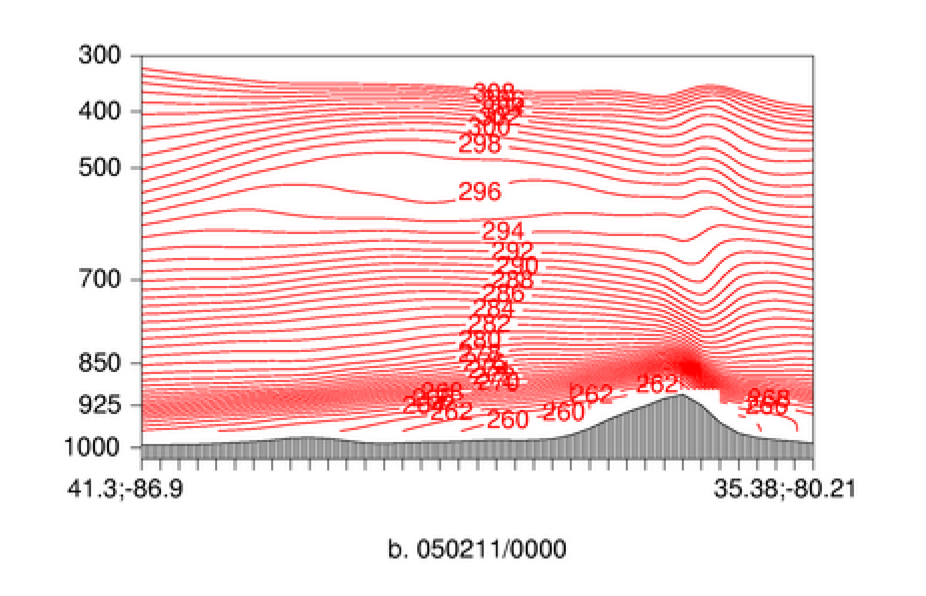




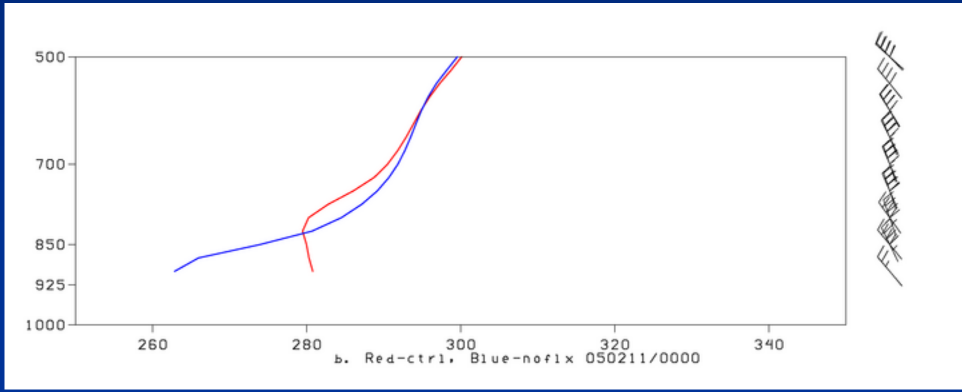
NOFLX – 10-11 February 2005

00 UTC 11 February

Θ_e Cross-section along same plane as previous

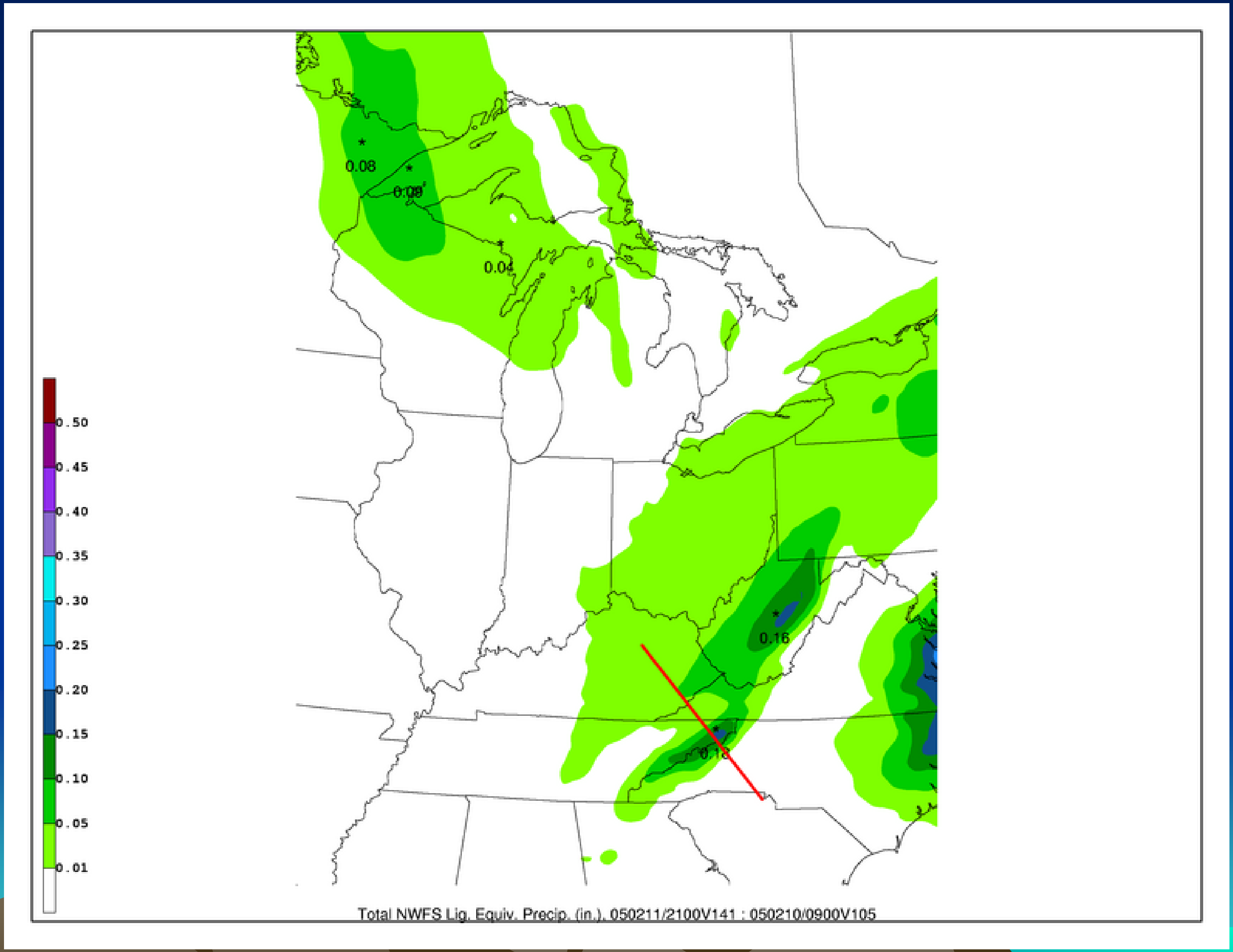


Θe Profile from Banner Elk, NC



(CTRL-red, NOFLX-blue)

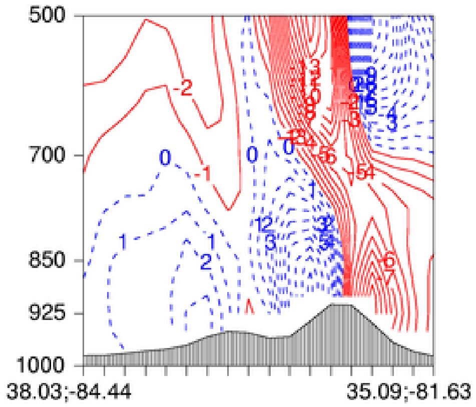
NOFLX – 10-11 February 2005



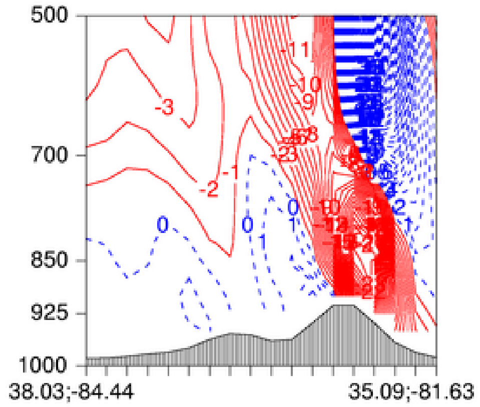
NOFLX – 10-11 February 2005

Ω (μbar/sec) profiles along plane in previous slide

CTRL



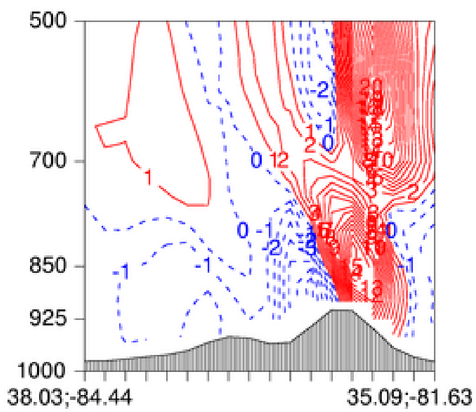
c. 050210/2100 (ctrl)



d. 050210/2100 (noflx)

NOFLX

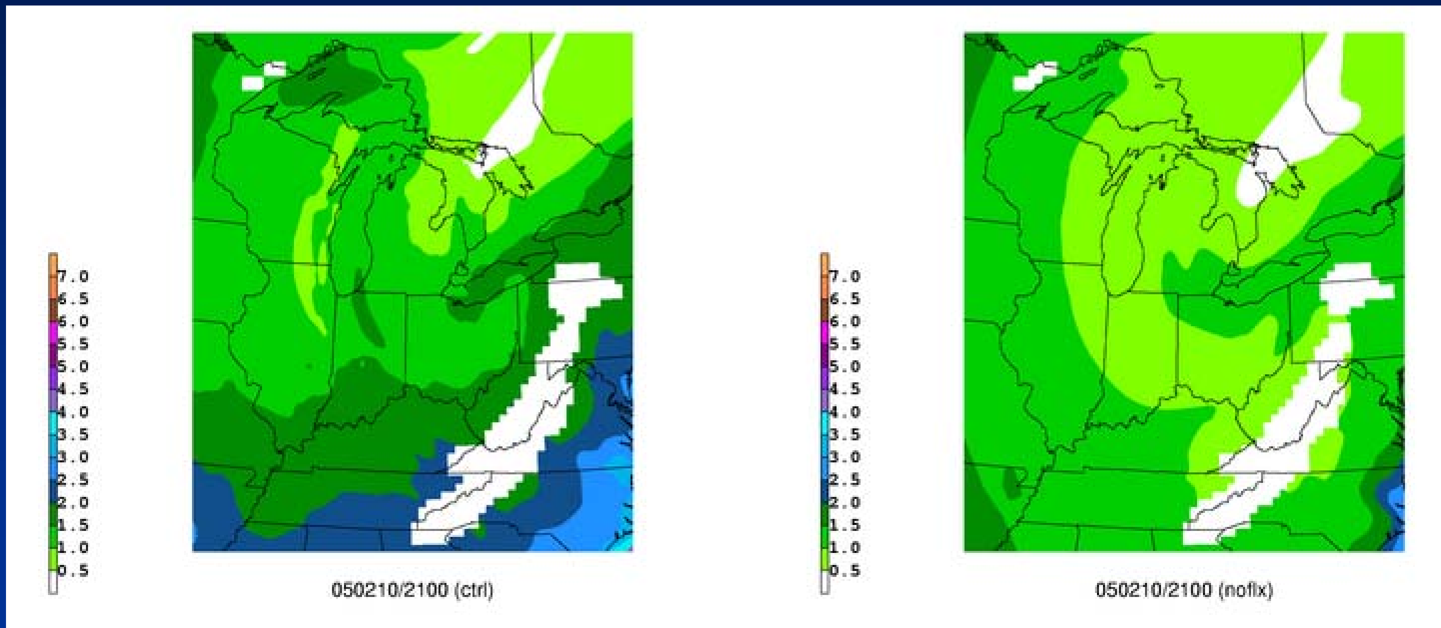
Difference Field
(CTRL-NOFLX)



b. 050210/2100

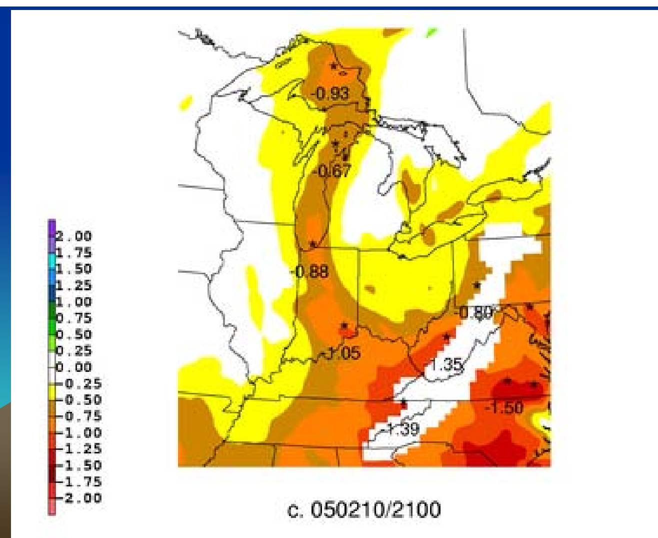
NOFLX – 10-11 February 2005

CTRL



NOFLX

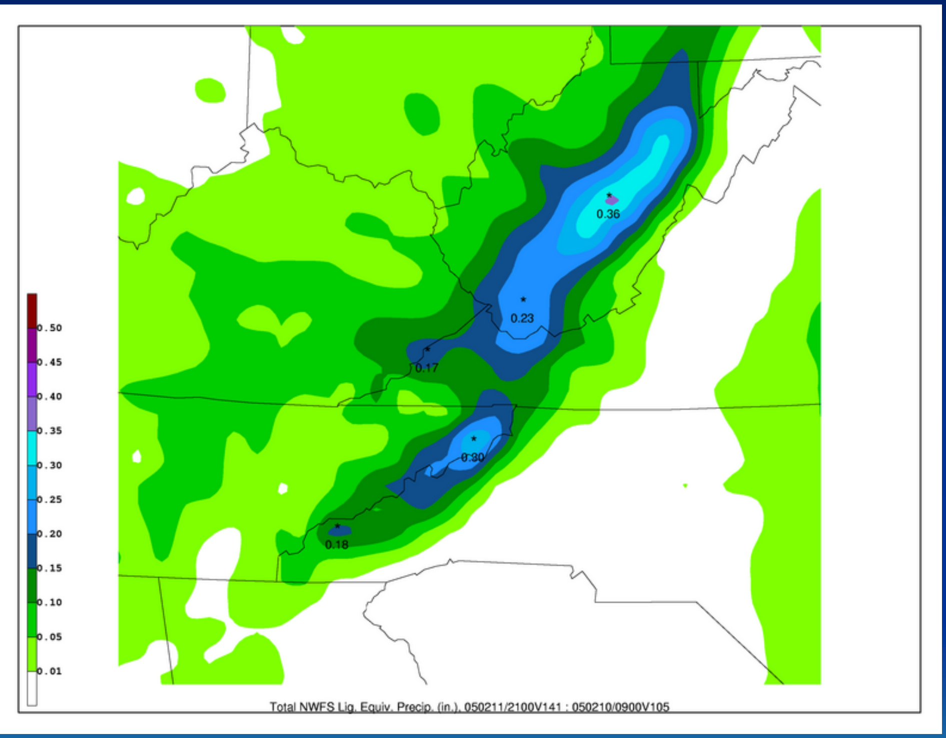
Difference Field



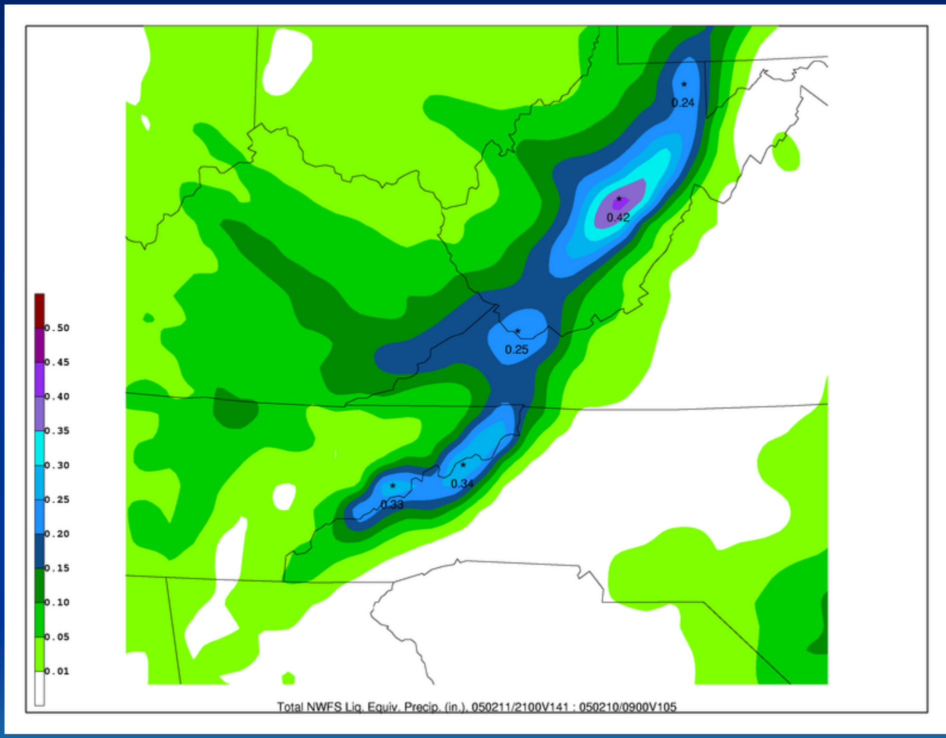
950-875 hPa layer averaged mixing ratio (g/kg)

LKNOFLX – 10-11 February 2005

Total NWFS Precipitation (in.): 09 UTC 10 February – 21 UTC 11 February



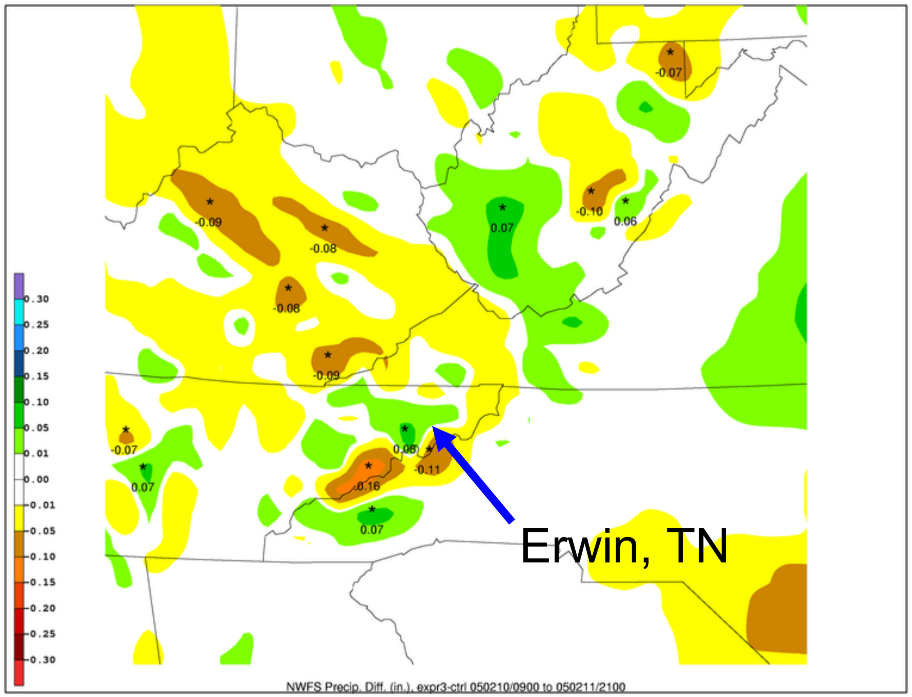
LKNOFLX

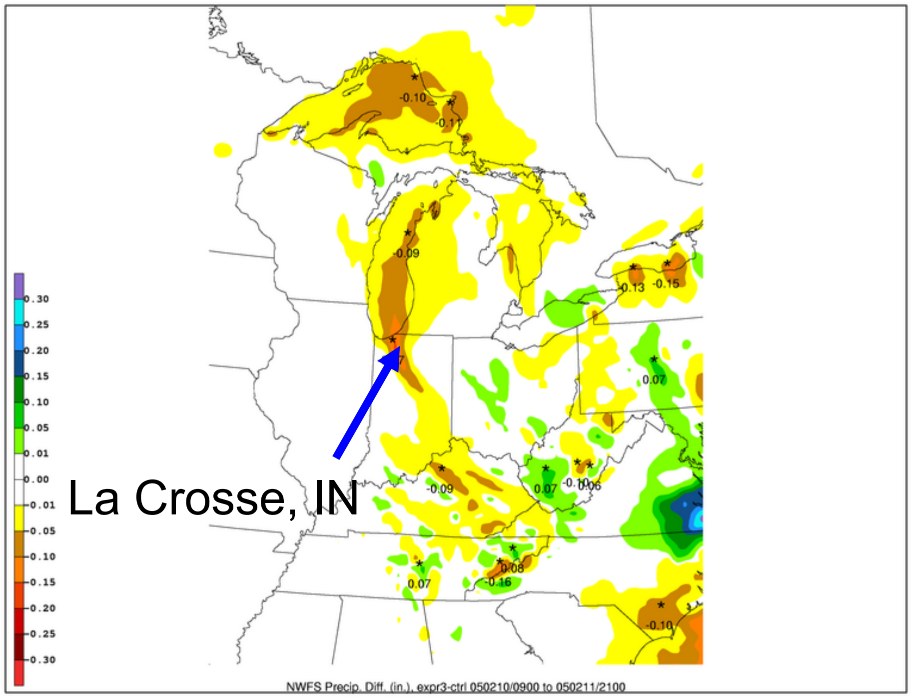


CTRL

LKNOFLX – 10-11 February 2005

LKNOFLX-CTRL Precipitation Diff. (in.): 09 UTC 10 February – 21 UTC 11 February

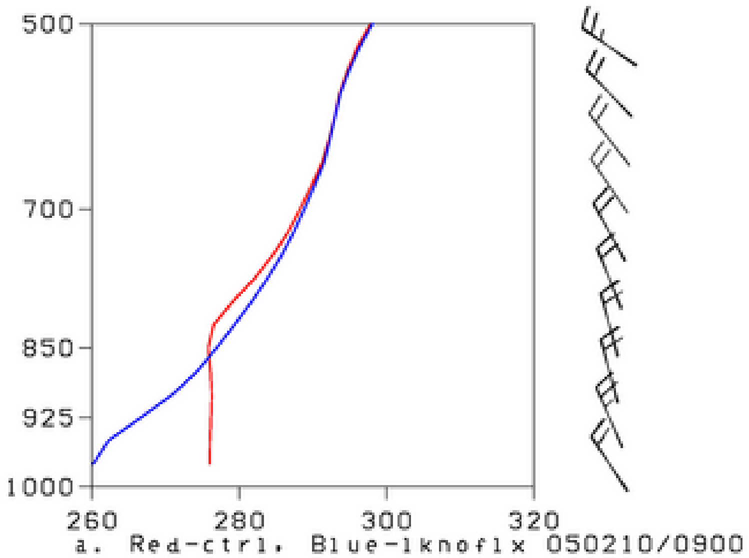




LKNOFLX – 10-11 February 2005

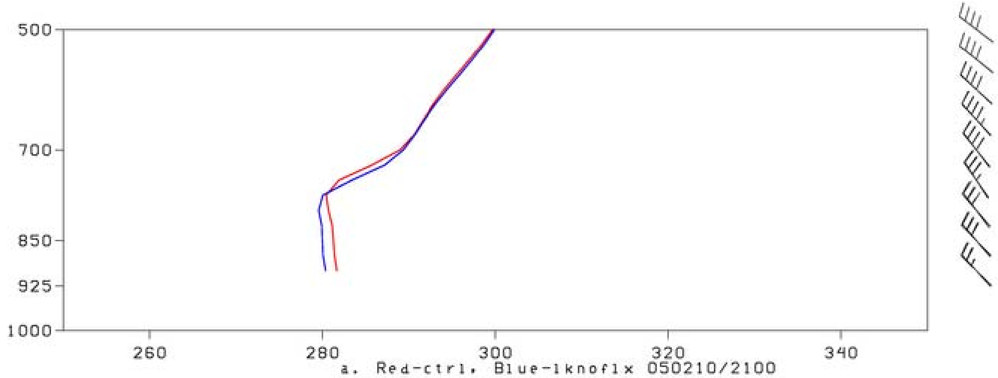
Θe Profiles **(CTRL-red, LKNOFLX-blue)**

09 UTC 10 February



La Crosse, IN

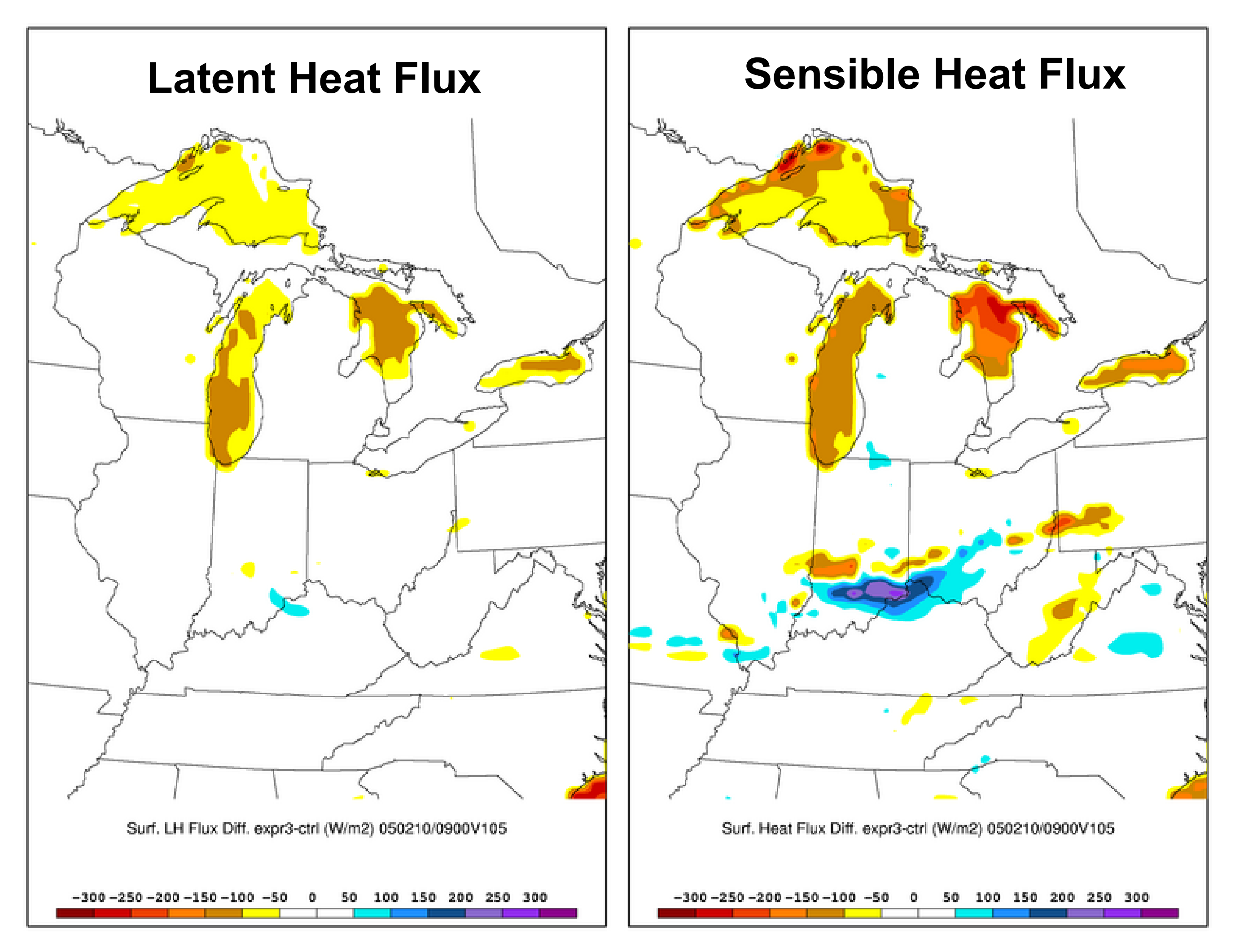
21 UTC 10 February



Erwin, TN

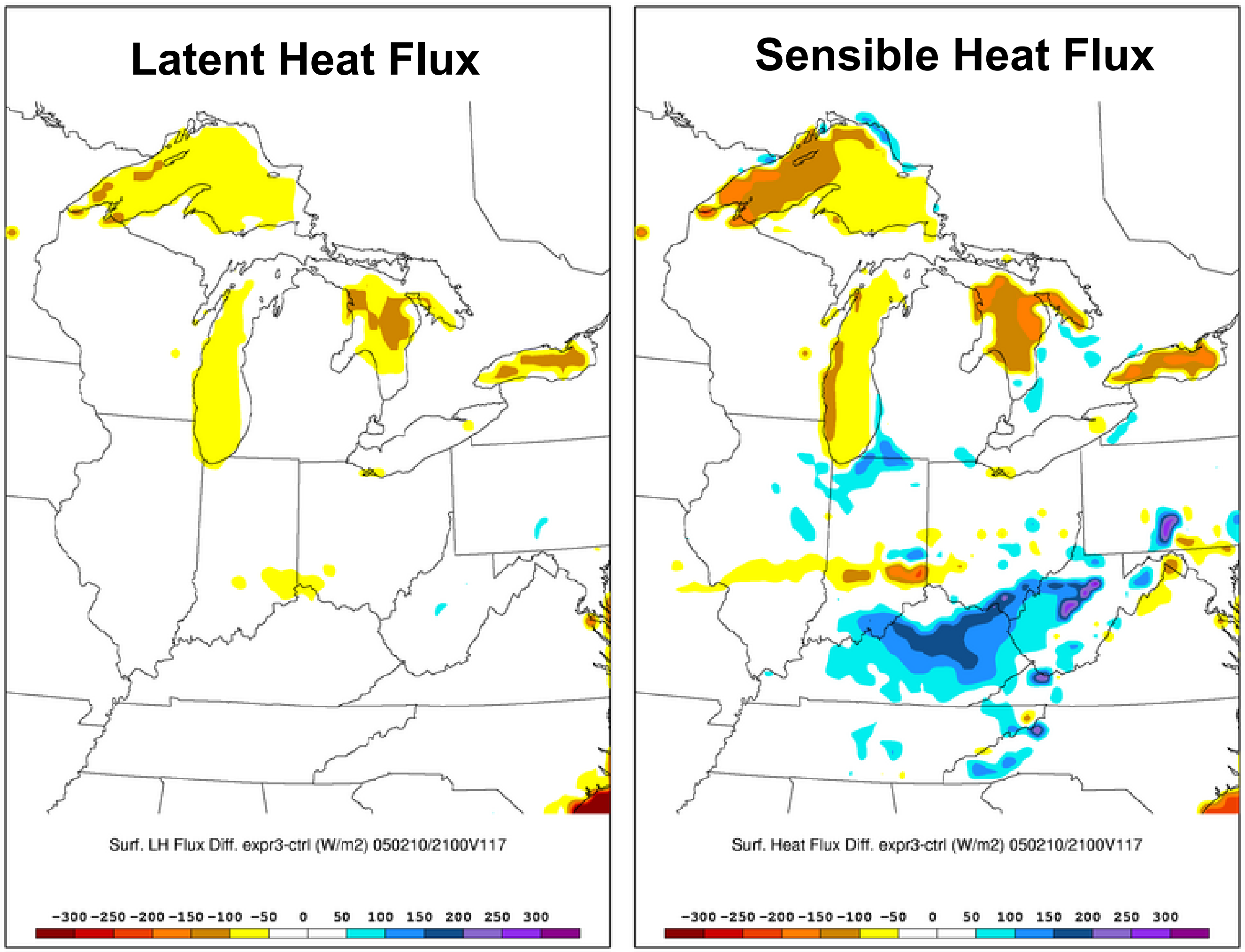
LKNOFLX – 10-11 February 2005

09 UTC 10 February Difference field (LKNOFLX-CTRL)



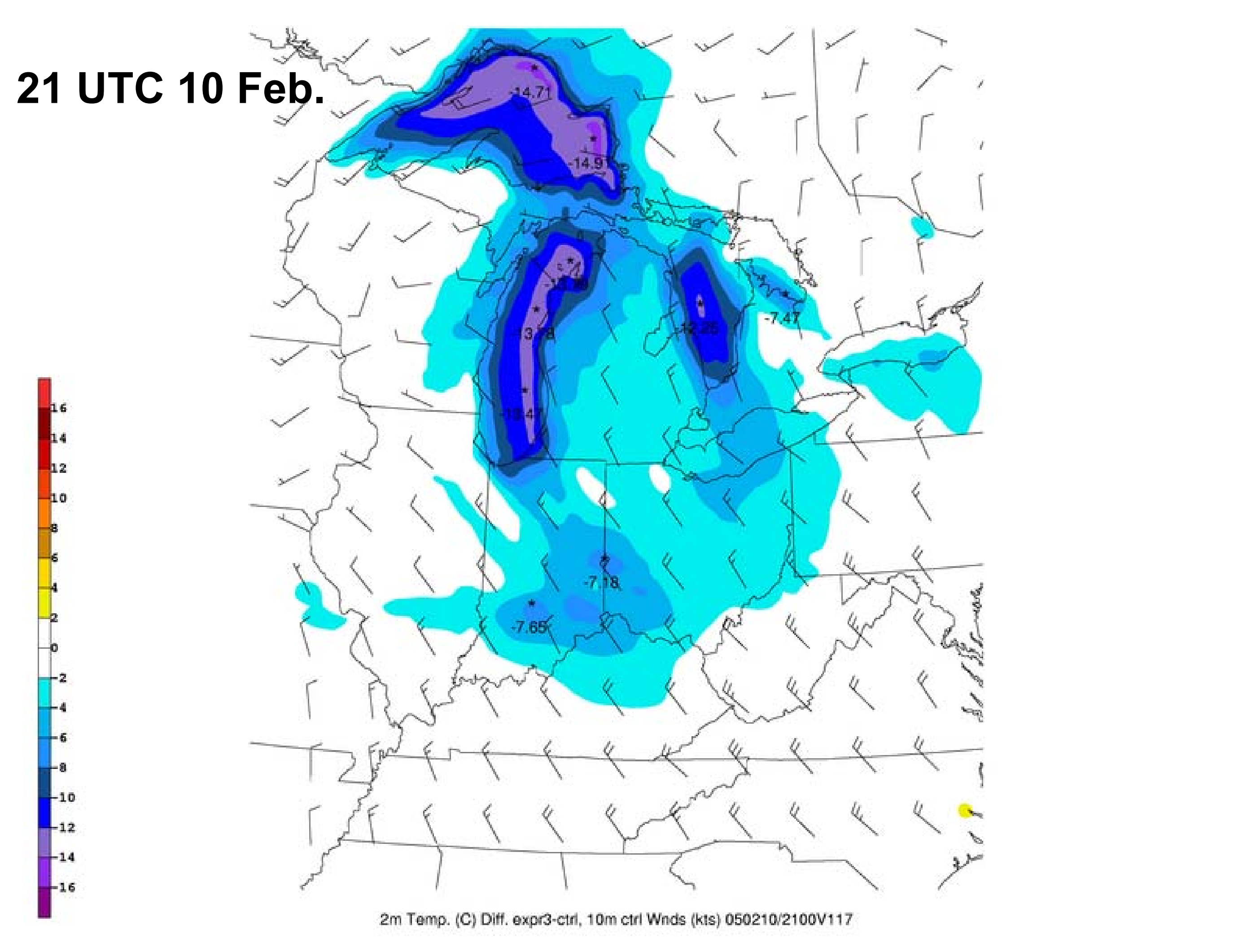
LKNOFLX – 10-11 February 2005

21 UTC 10 February Difference field (LKNOFLX-CTRL)



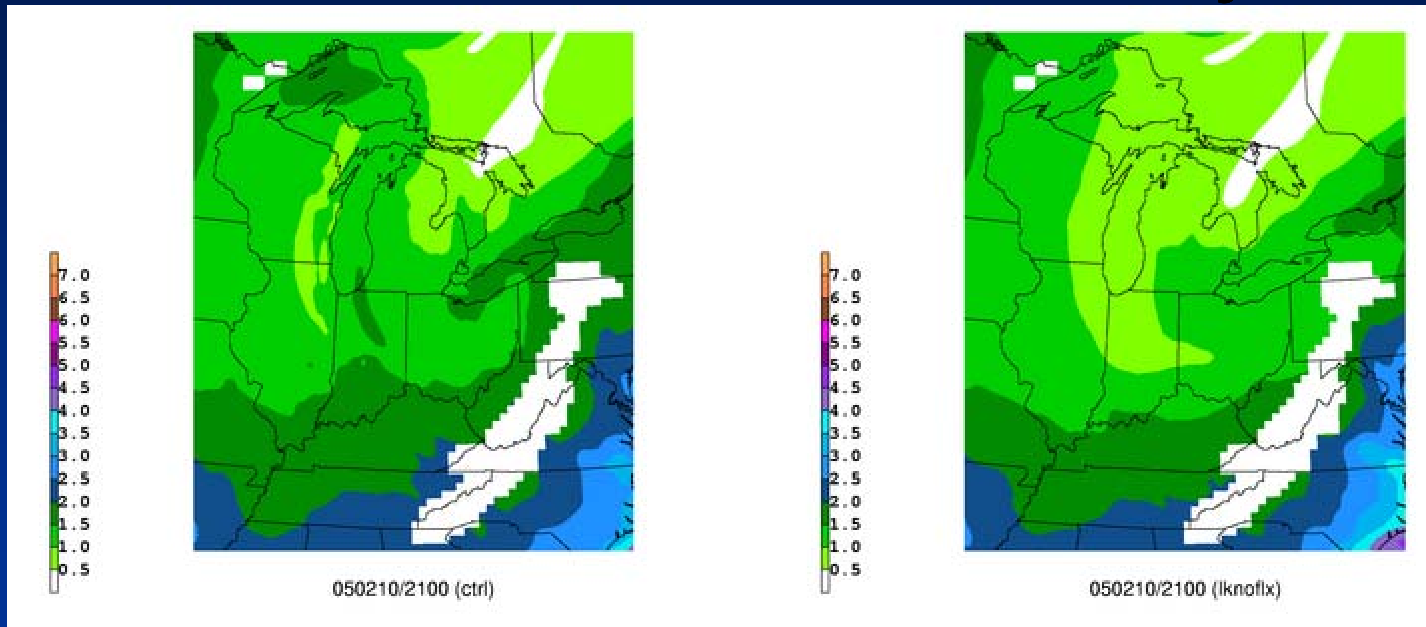
LKNOFLX – 10-11 February 2005

2m temperature (°C) difference field (LKNOFLX-CTRL) and 10m winds (kts)



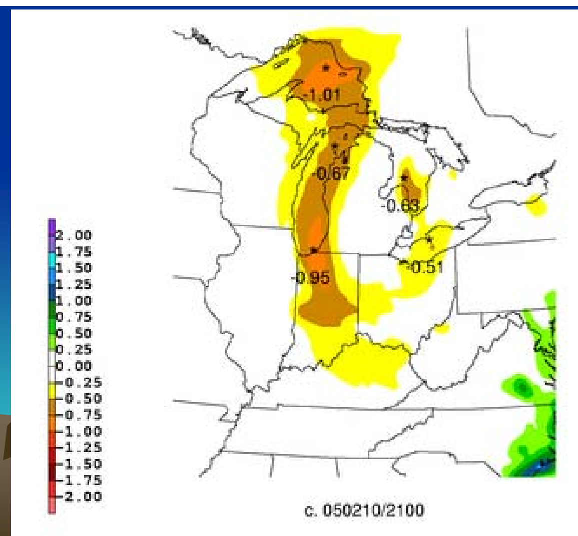
LKNOFLX – 10-11 February 2005

CTRL →



← LKNOFLX

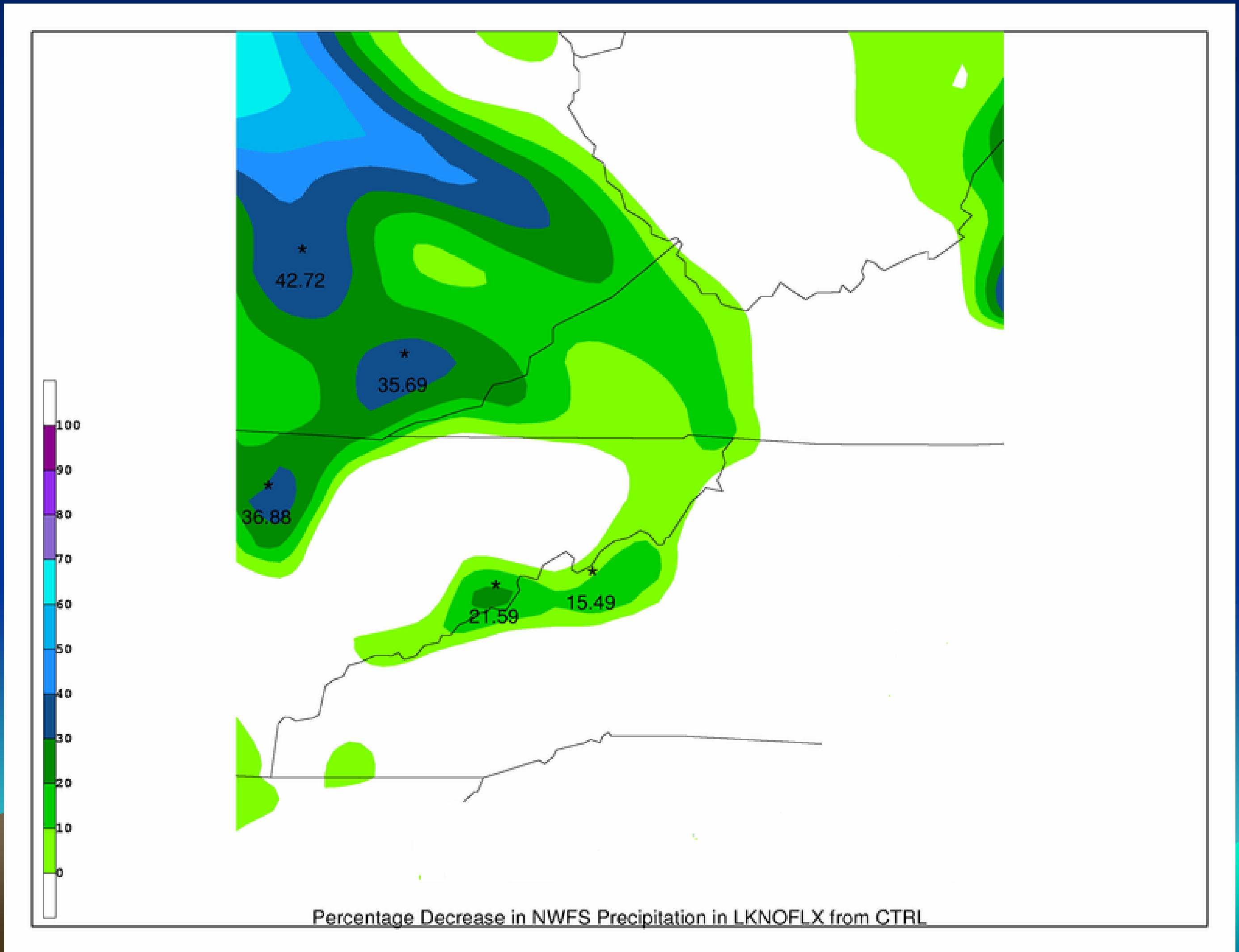
Difference Field →



950-875 hPa layer averaged mixing ratio (g/kg)

LKNOFLX – 10-11 February 2005

Percent Decrease in NWFS Precipitation in LKNOFLX



Conclusions

- Great Lakes responsible for up to 1/5 of NWFS precipitation at some locations in southern Appalachians (LKNOFLX) – less than expected?
- Great Lakes provide moisture and instability during event (NOFLX, LKNOFLX)
- When stability increased between lakes and mountains, upward vertical motion decreases on windward slopes, and NWFS precipitation is decreased (NOFLX) (consistent with lowered F_r number)
- NWFS precipitation can still occur despite a lack of convective instability between lakes and mountains (NOFLX)
- Spatial extent and distribution appears to be largely determined by terrain rather than presence and magnitude of convective instability

Future Work

- Higher resolution modeling experiments
  - Cases presented here as well as others
  - Parameterized vs. explicit convection
  - Better representation of southern Appalachians

- Further work to classify NWFS events and expected effects from each class

- Observational study of NWFS events
  - Snow-to-liquid ratios within events
  - Cloud physics and snowfall production

- Operational model climatology
  - How well do current operational models handle NWFS events?
  - What are the biases with regard to precipitation

Acknowledgements

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  - Dr. Lackmann, Dr. Raman, Dr. Lin
- Dr. Baker Perry
- NWS
  - CSTAR NWFS group, Steve Keighton
  - GSP staff

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Questions?