Long-Duration Freezing Rain Events over North America: Regional Climatology and Maintenance Mechanisms

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Background

Freezing rain (FZRA) events have produced severe damage in North America

- January 1998: >100 mm of accretion, \$3 billion damages in southern Québec[1]

Freezing rain events are ***self-limiting***[2,3]

- Latent heat absorption when snowflakes melt in warm layer (WL) erodes the WL
- Latent heat release when rain freezes at surface erodes the cold layer (CL)
- Temperature advection can offset diabatic effects, but often warm-air advection (WAA) occurs in/above CL, eroding it

One remaining question: what conditions support the persistence of FZRA for long periods despite these effects?

Research questions

1. Where do long-duration (LD) freezing rain events occur **most frequently**?
2. What **thermodynamic** conditions support the persistence of LD freezing rain events?
3. What **synoptic-dynamic** conditions support LD event persistence?

Data and methods

Datasets

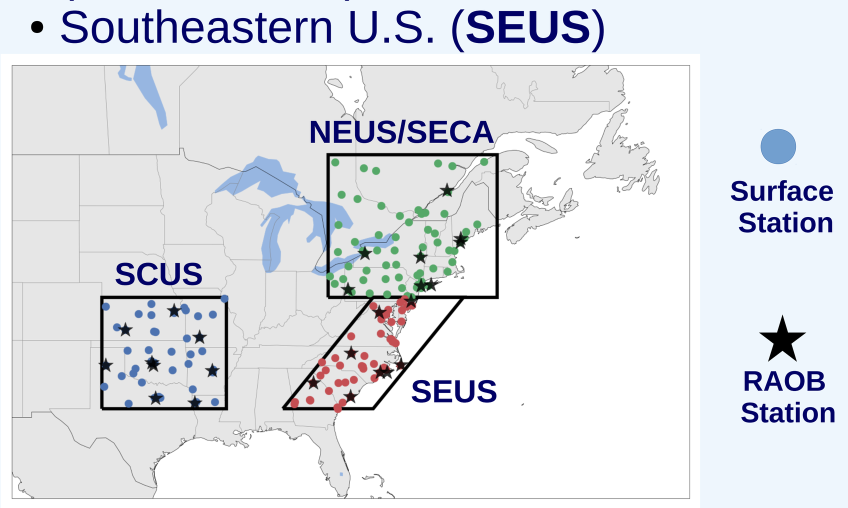
- Surface station observations – 1979-2016 (NOAA Integrated Surface Database)
- NCEP Climate Forecast System Reanalysis (CFSR)
- Sounding data (Univ. of Wyoming)

Event Definitions

- **Freezing rain event duration**
  - Hours of FZRA at a given station separated by no more than 24 hours
- **Long-duration (LD) event**
  - FZRA event of ≥ 6 hour duration
- **Short-duration (SD) event**
  - FZRA event of ≤ 3 hour duration

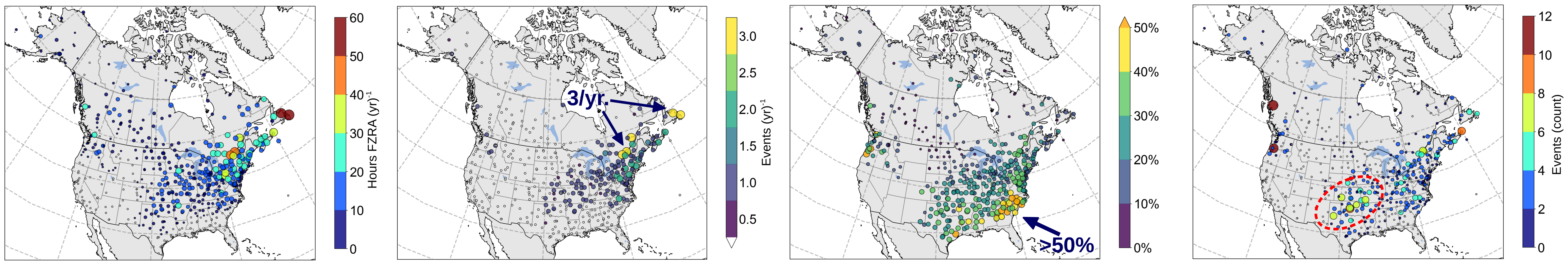
Focus Regions

- South Central U.S. (**SCUS**)
- Northeastern U.S./southeastern Canada (**NEUS/SECA**)
- Southeastern U.S. (**SEUS**)



Q1. Where do long-duration freezing rain events occur most frequently?

Median annual hours of FZRA | Median annual LD (6+ h) events | % of FZRA events that are LD | Number of 18+ h events (1979-2016)



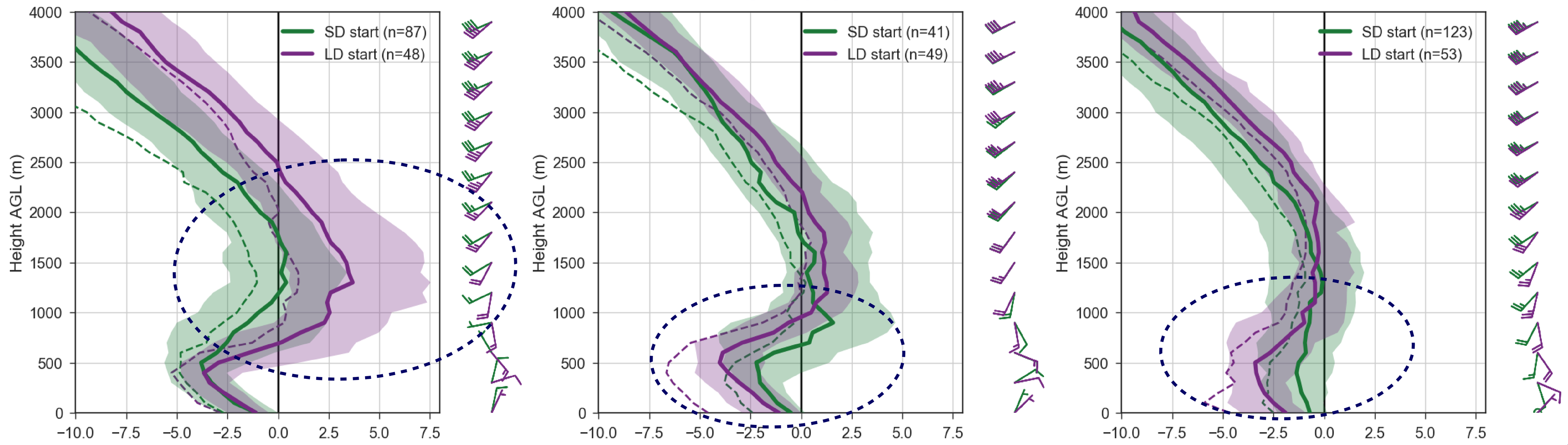
- LD events are most common over the NE U.S./SE Canada, but many 18+ h (99th percentile) events have occurred over the SC U.S.
- The SEUS, where freezing rain occurs with cold-air damming (CAD), observes more LD events than SD events (unlike other regions)

Q2. What thermodynamic conditions support the persistence of these LD events?

- All soundings within given region composited for events starting within 1 h of sounding launch
- Median T profile (solid), Td (dashed), winds (barbs), 25th-75th percentile of T (shading)

LD and SD event onset

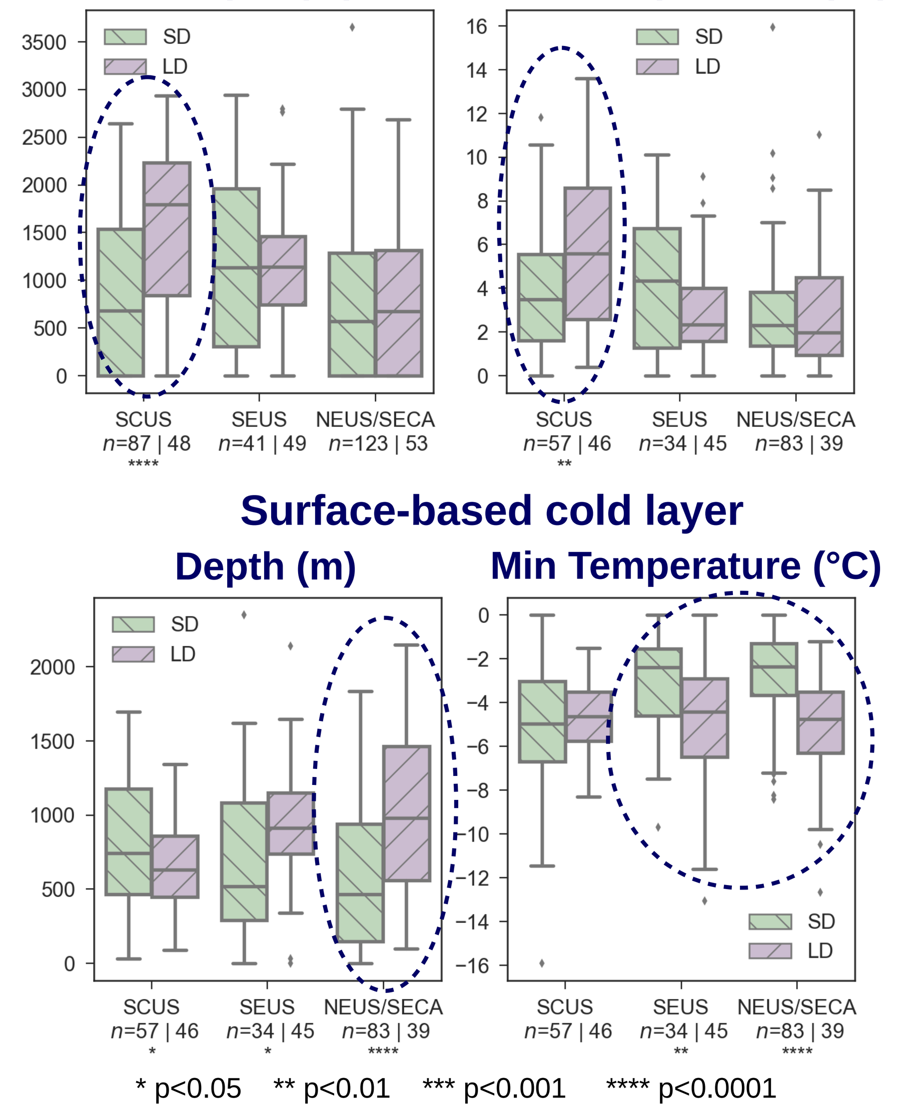
SCUS | **SEUS** | **NEUS/SECA**



Median LD (SD) values for characteristics with statistically significant differences

- **WL depth:** 1793 m (679 m)
- **WL max T:** 5.6°C (3.5°C)
- **CL depth:** 913 m (519 m)
- **CL min T:** -4.4°C (-2.4°C)
- **CL depth:** 978 m (464 m)
- **CL min T:** -4.8°C (-2.4°C)

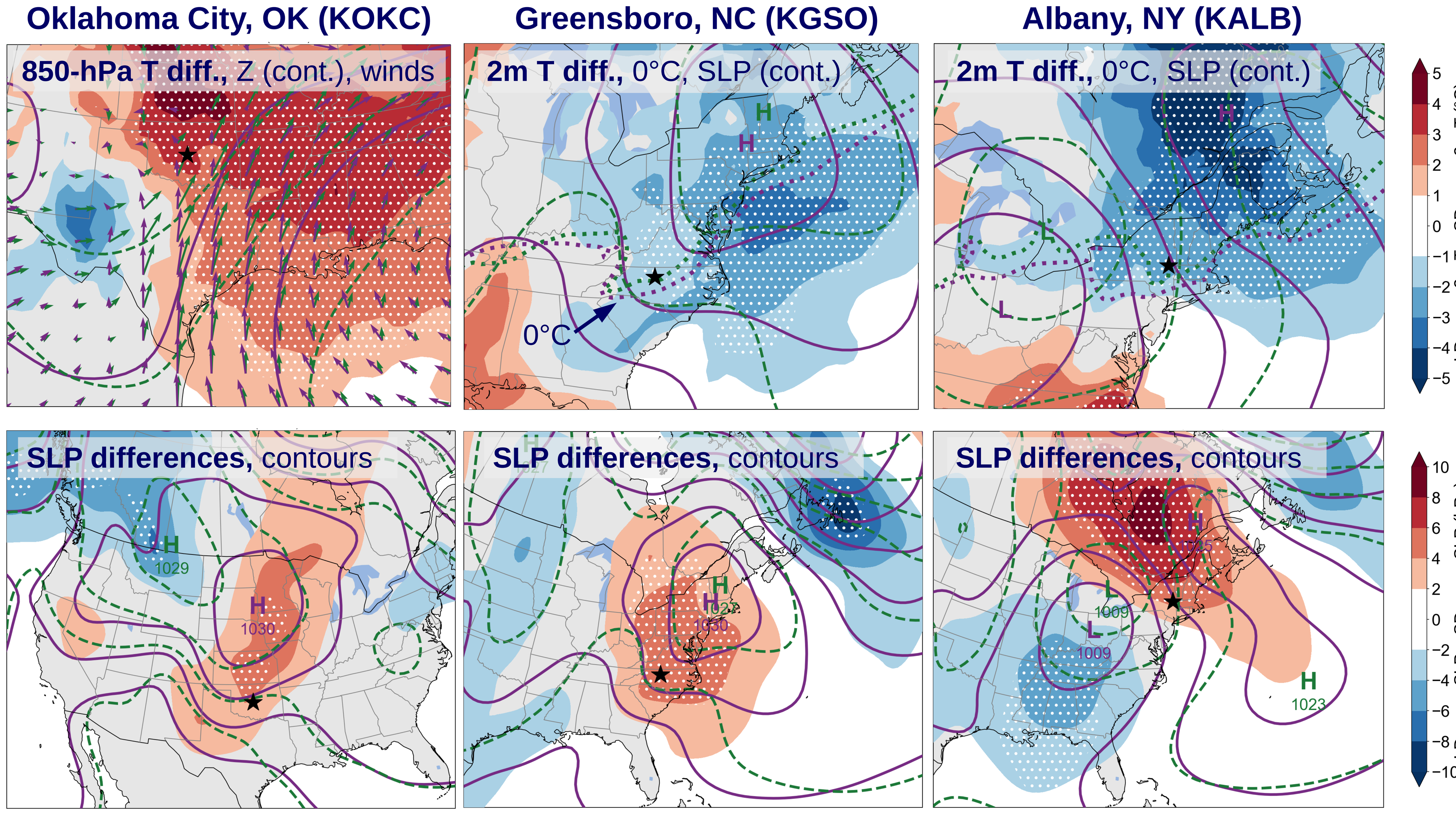
Above-0°C warm layer



Q3. What synoptic-dynamic conditions support LD event persistence?

- Composites of 30 randomly selected SD and LD cases at one representative site in each region
- Shading: LD composite mean minus SD composite mean
- Statistically significant differences at $p<0.05$ in white hatching

Oklahoma City, OK (KOKC) | **Greensboro, NC (KGSO)** | **Albany, NY (KALB)**



Conclusions

LD FZRA events are associated with regionally coherent patterns:

SCUS

- Extreme LD events assoc. w/ Arctic anticyclone, sfc. CAA behind cold front, very warm/deep warm layers
- Discerning factor in event duration is characteristics of the **warm layer**

SEUS

- CAD supports LD FZRA events
- Stronger CAD, **colder cold layer** at onset allow events to persist
- Weak cold layers are eroded quickly

NEUS/SECA

- FZRA assoc. w/ warm front, high/low position differences are important
- Weak warm layer at onset, develops via WAA just above cold layer
- **Deep cold layer** at onset allows LD events to be sustained for longer periods

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References

1. Gyakum, J. R., and P. J. Roebber, 2001: The 1998 Ice Storm—Analysis of a Planetary-Scale Event. *Mon. Wea. Rev.*, **129**, 2983–2997.
2. Stewart, R. E., 1985: Precipitation types in winter storms. *Pure Appl. Geophys.*, **123**, 597–609
3. Lackmann, G. M., K. Keeter, L. G. Lee, and M. B. Ek, 2002: Model Representation of Freezing and Melting Precipitation: Implications for Winter Weather Forecasting. *Wea. Forecasting*, **17**, 1016–1033.

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