

# What allows some freezing rain events to persist for many hours?

*A focus on dynamic and thermodynamic processes*

Christopher McCray<sup>1</sup>, John Gyakum<sup>1</sup> and Eyad Atallah<sup>2</sup>

1. McGill University - Dept. of Atmospheric and Oceanic Sciences

2. University of Arizona - Dept. of Hydrology & Atmospheric Sciences

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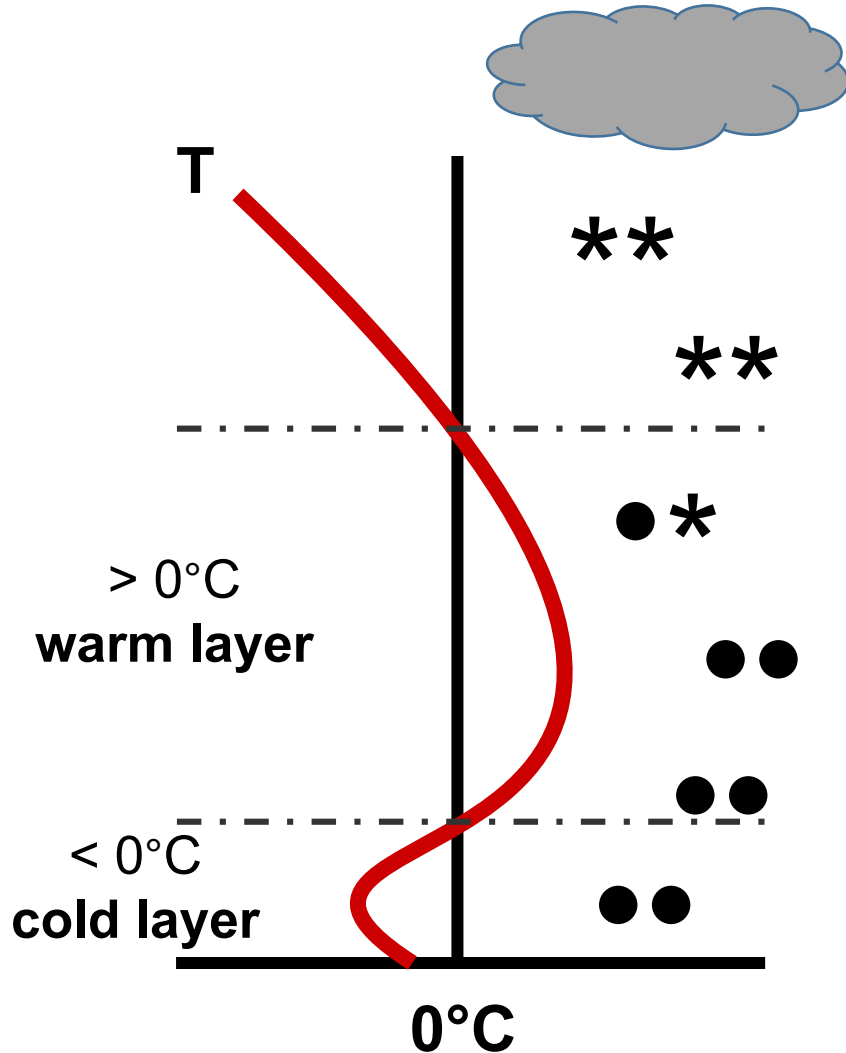
Fonds de recherche  
Nature et  
technologies

Québec 



McGill

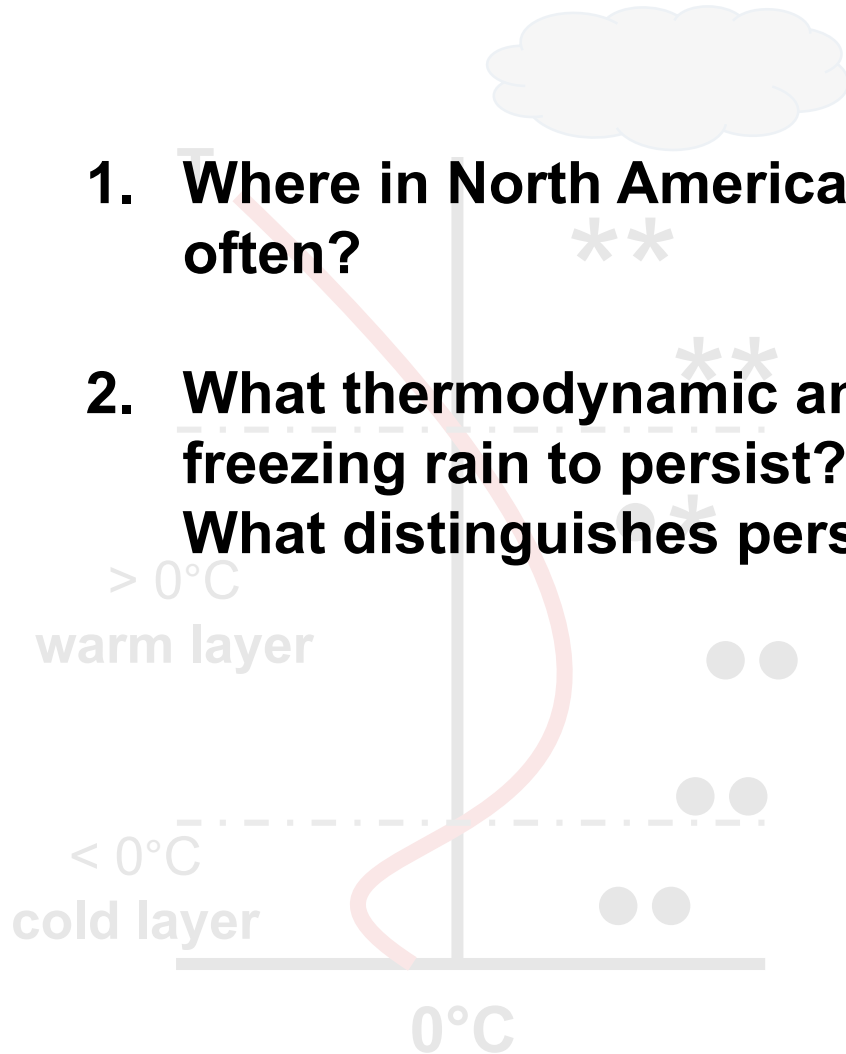
# Freezing rain can produce severe impacts, especially when it persists for many hours



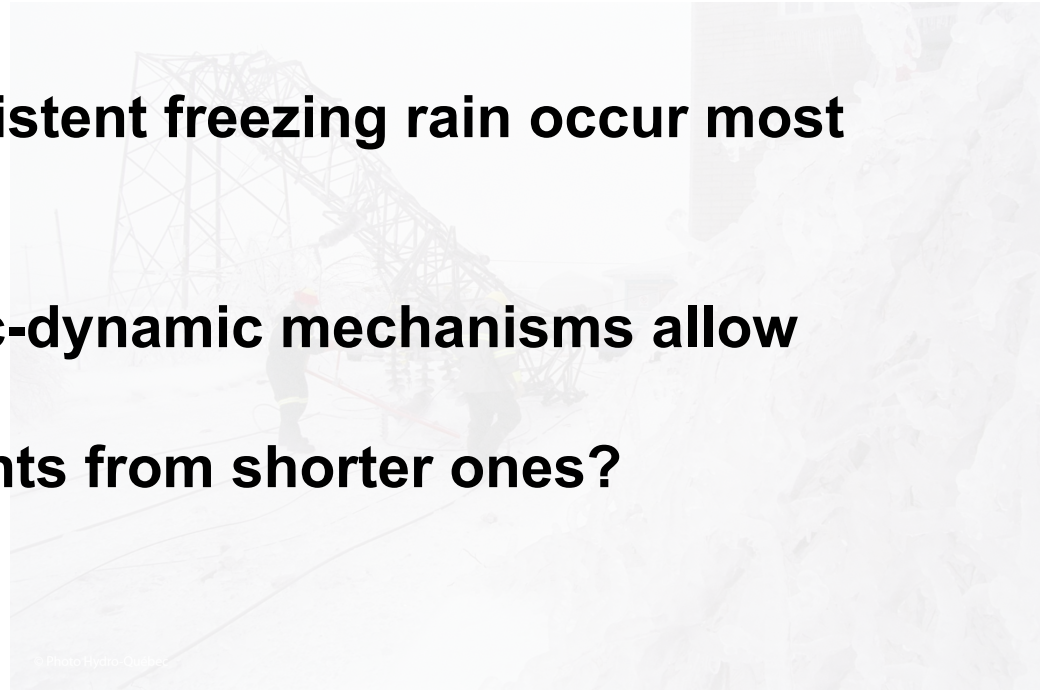
Only **11%** of freezing rain events last longer than 4 h (Cortinas et al. 2004)

# Freezing rain can produce severe impacts, especially when it persists for many hours

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1. Where in North America does persistent freezing rain occur most often?
2. What thermodynamic and synoptic-dynamic mechanisms allow freezing rain to persist?  
What distinguishes persistent events from shorter ones?



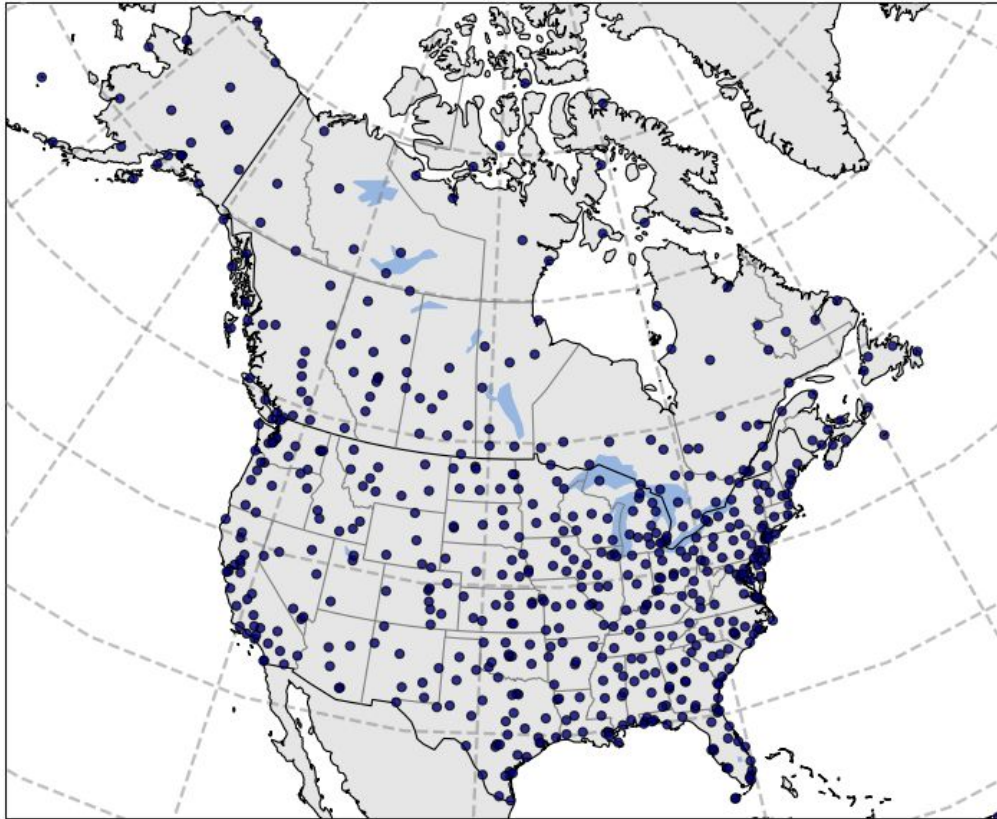
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# Data

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579 surface stations used in dataset

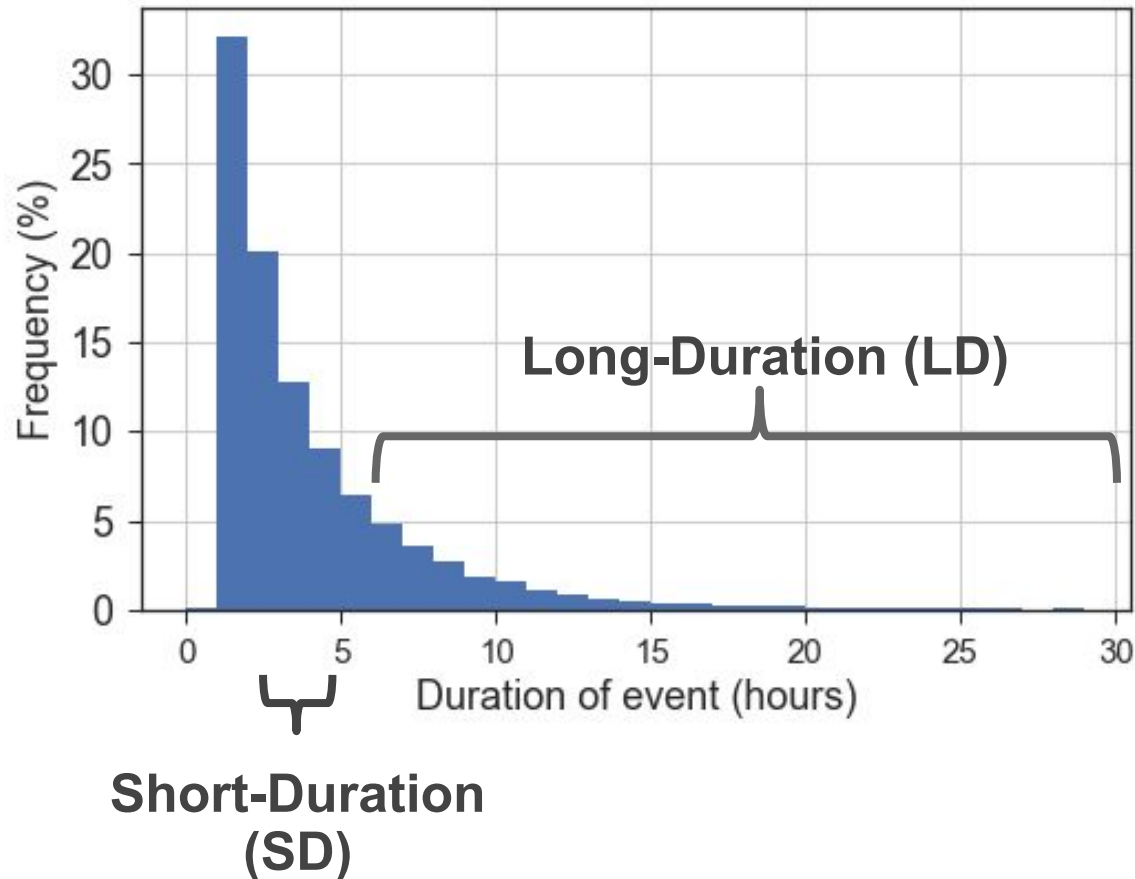


- **Surface Observations:**
  - NOAA Integrated Surface Database
  - 1979-2016, U.S. and Canada
- **Radiosonde observations**
  - Examine all soundings for events that started or ended within 1 h of a radiosonde release
- **ERA-Interim Reanalysis (Dee et al. 2011)**
  - $\approx 80$  km horizontal grid spacing
  - 60 vertical levels
  - 6-hourly
  - 1979-2019

# Event Identification

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Distribution of event duration

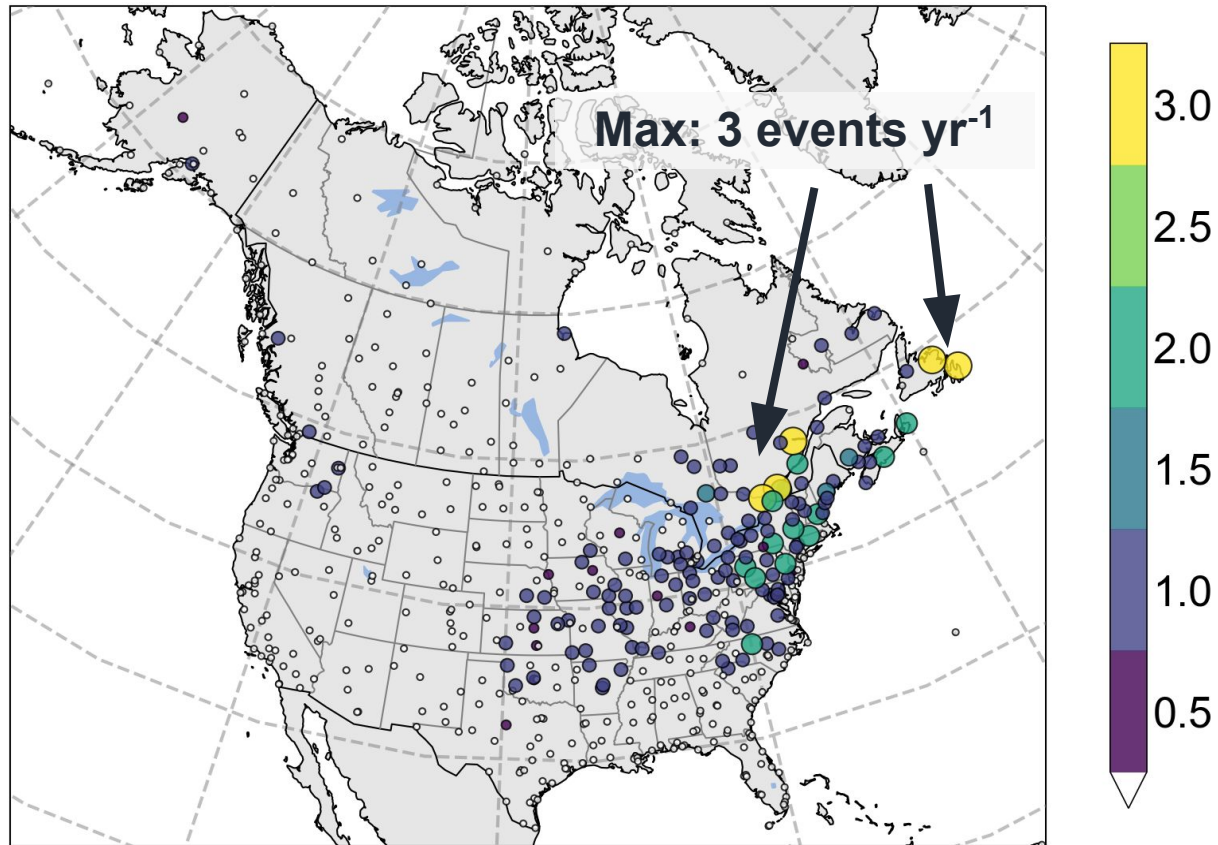


- **Freezing rain (FZRA) event:**
  - Count consecutive hours of FZRA, then combine events with <24 h between them
  - **Duration:** # of hourly FZRA observations
- **Long-Duration (LD) Event:**
  - FZRA event with  $\geq 6$  h of FZRA
  - ~20% of all events
  - Max: 61 h (Montreal, 1998 Ice Storm)
- **Short-Duration (SD) Event:**
  - FZRA event with 2-4 h of FZRA

# LD events occur most frequently in the northeastern U.S. and southeastern Canada (Median 1-3 events/year)

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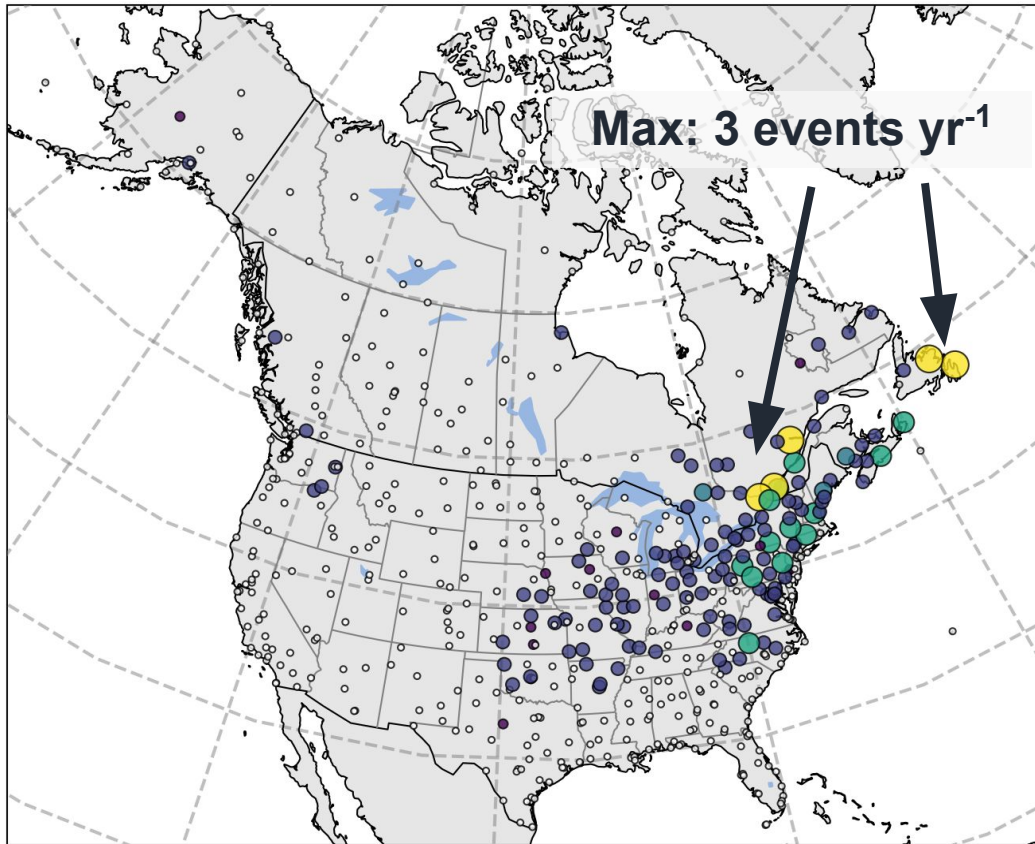
## Median Annual Long-Duration (LD) Events (1979-2016)



*Fig. 1, McCray et al. (2019, WAF)*

# The south-central U.S. is a regional maximum in frequency of the top 1% of events by duration ( $\geq 18$ h)

Median Annual Long-Duration (LD) Events (1979-2016)



Number of 18+ h FZRA events (1979-2016)

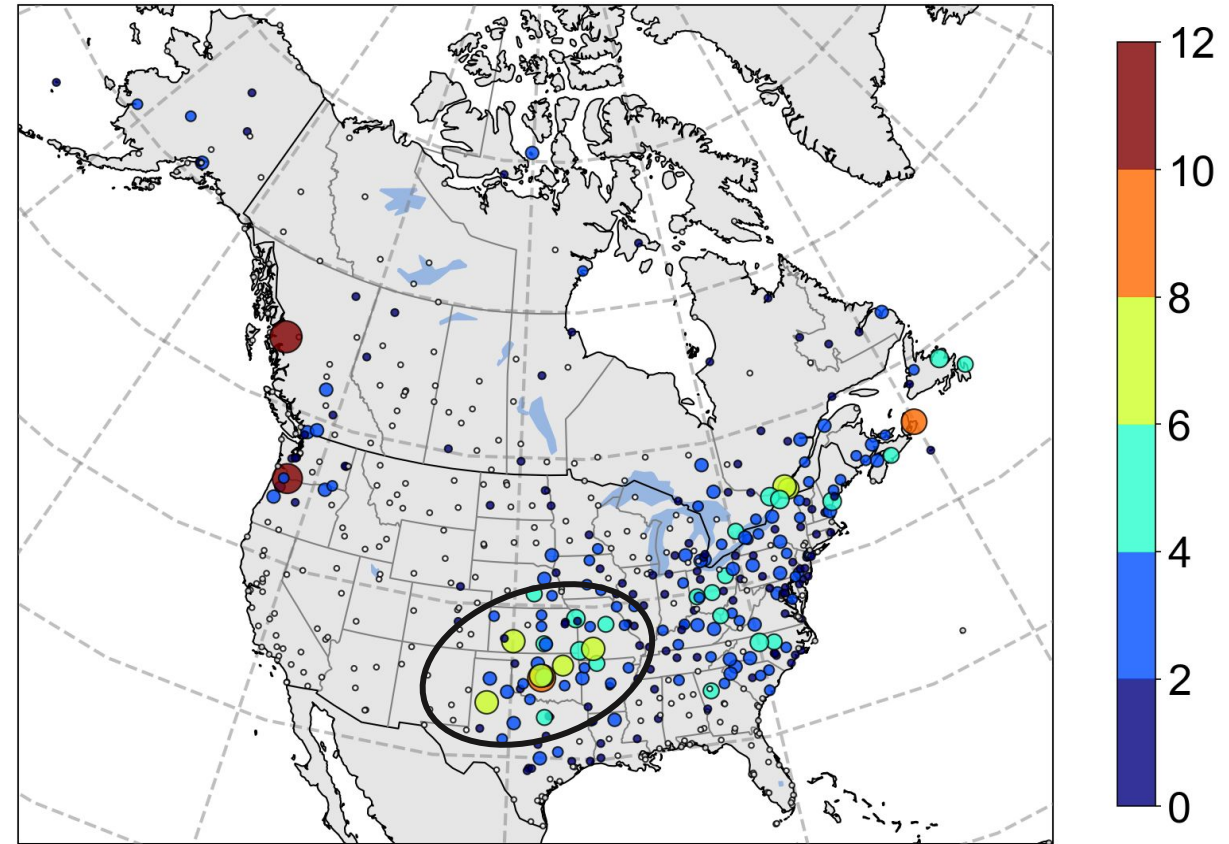


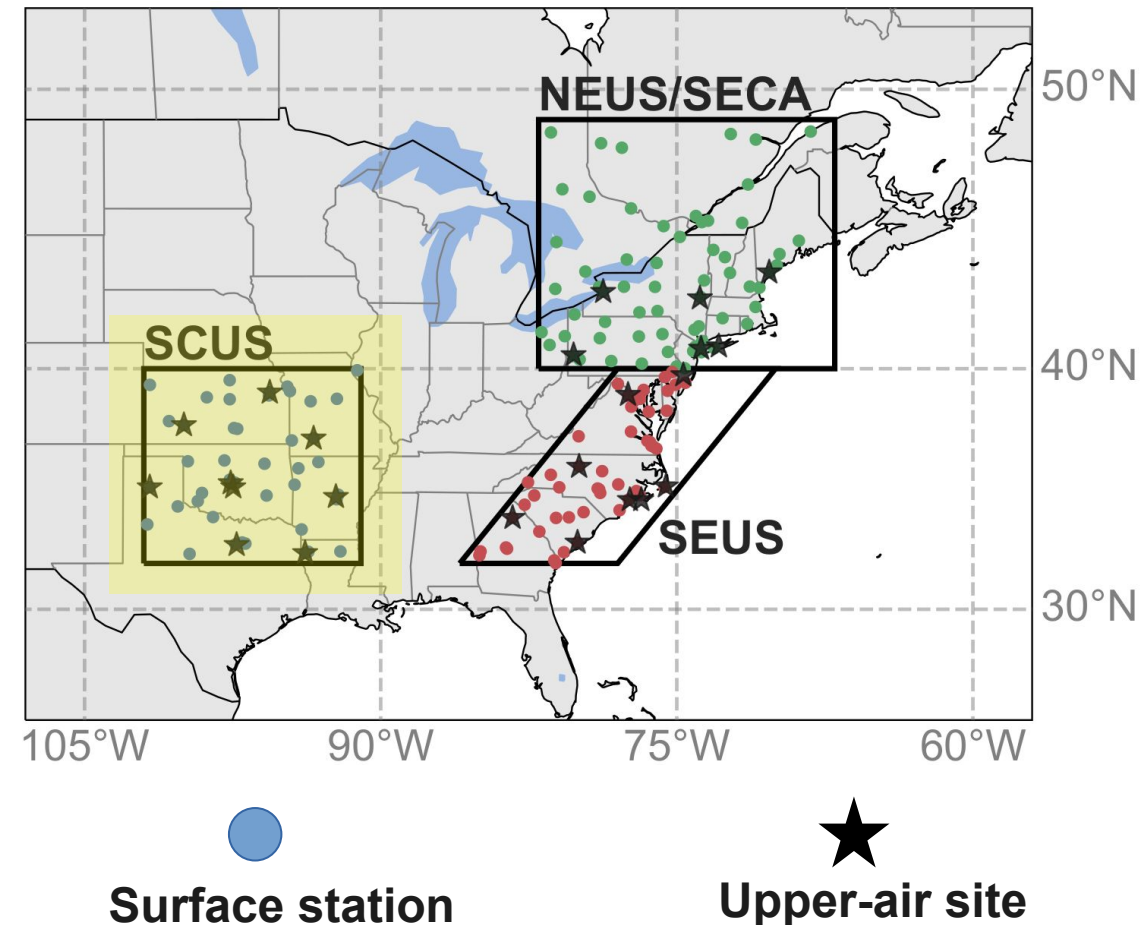
Fig. 1, McCray et al. (2019, WAF)



# We identify three focus regions to examine the causes of this climatology, focusing here on the SCUS

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- Northeastern U.S./ Southeastern Canada (**NEUS/SECA**)
- Southeastern U.S. (**SEUS**)
- South-central U.S. (**SCUS**)
  - Sanders et al. (2013, JOM) and Mullens et al. (2016, WAF) identified patterns leading to ice storms in/around SCUS
  - Both excluded weaker cases

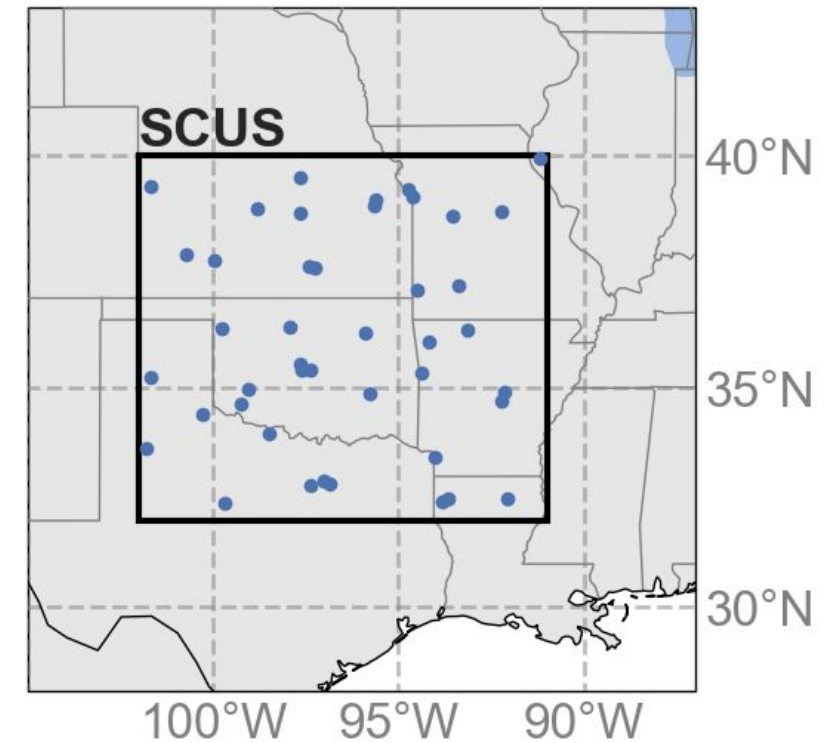




# How do synoptic patterns impact event duration in the south-central U.S.?

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- We identify cases in which freezing rain events occurred at **4 or more SCUS stations**
- Compare two categories based on the **maximum event duration** among grouped stations
  - **Short-duration (SD) grouped event**
    - Max duration **2-4 h** ( $n = 43$ )
  - **Extremely long-duration (ELD)**
    - Max duration  **$\geq 18$  h** ( $n = 42$ )
- Time-lagged composites (ERA-Interim) of each category centered on freezing rain onset time



# How do synoptic patterns differ between SD and ELD events?

-4 days

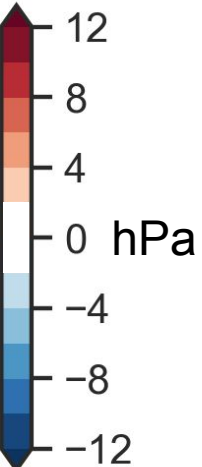
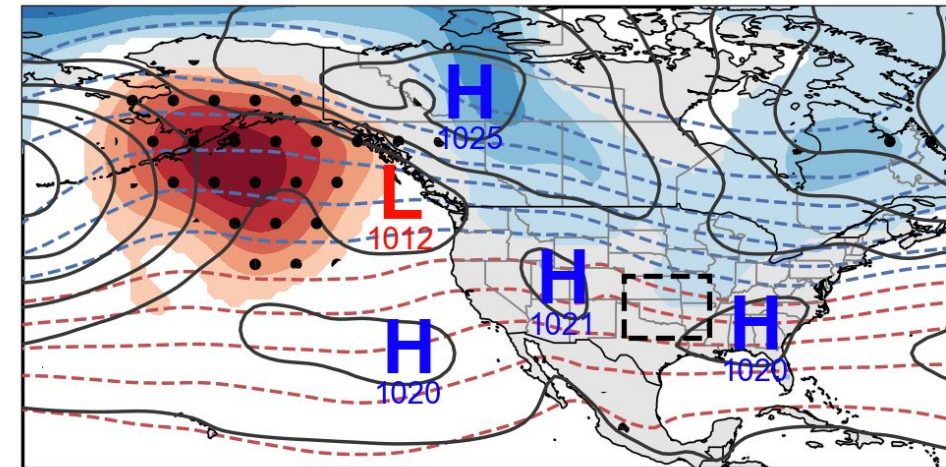
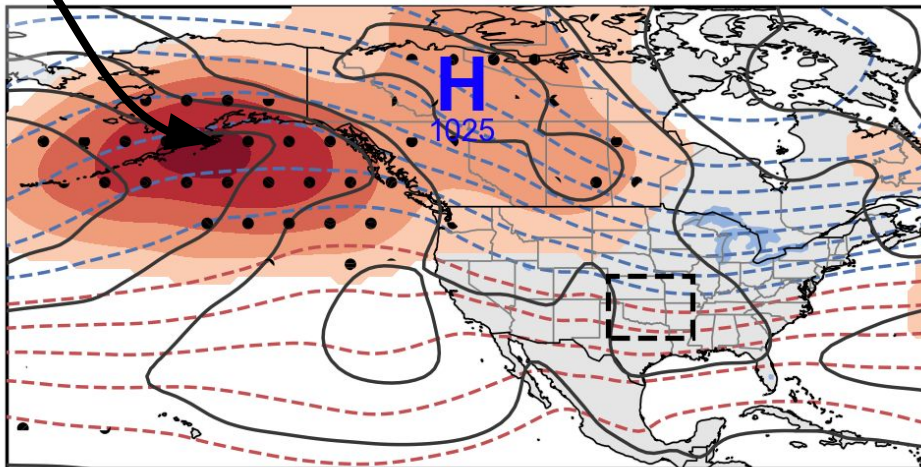
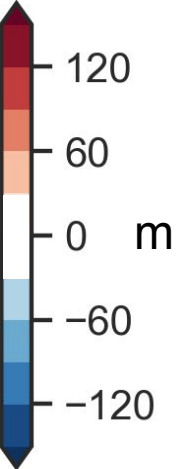
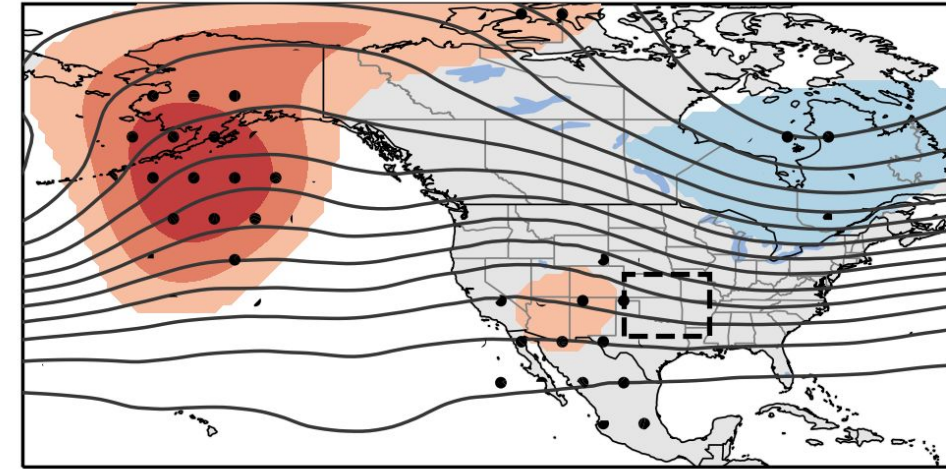
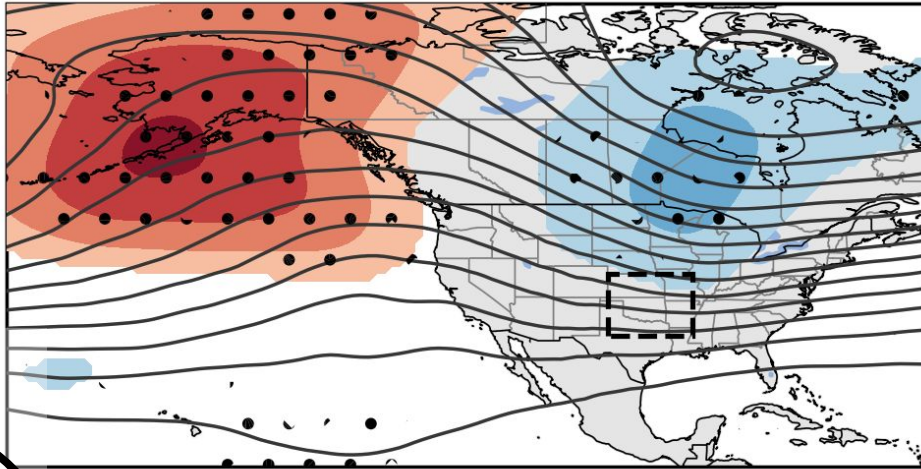
Short-duration ( $n=43$ )

Extremely long-duration ( $n=44$ )

500-hPa  
heights,  
anomalies

Stippling:  
 $\frac{2}{3}$  of events  
have anomalies  
of same sign

SLP,  
anomalies,  
1000-500-hPa  
thickness





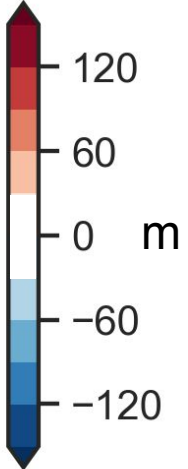
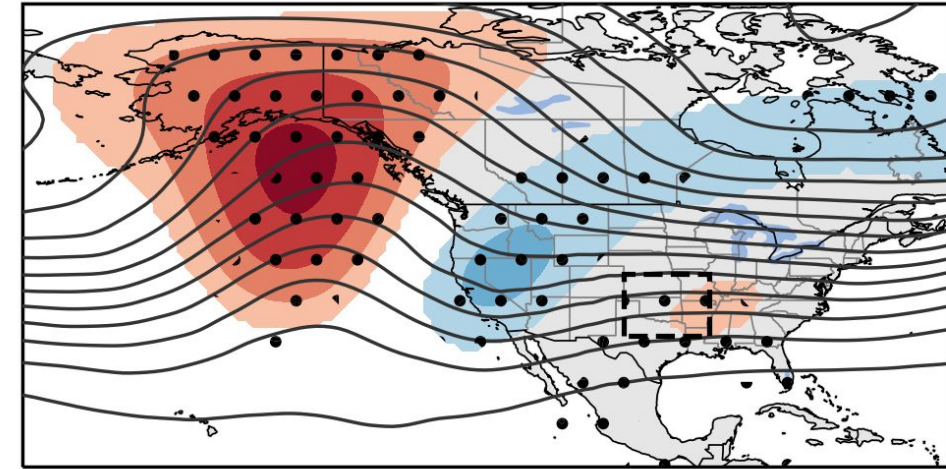
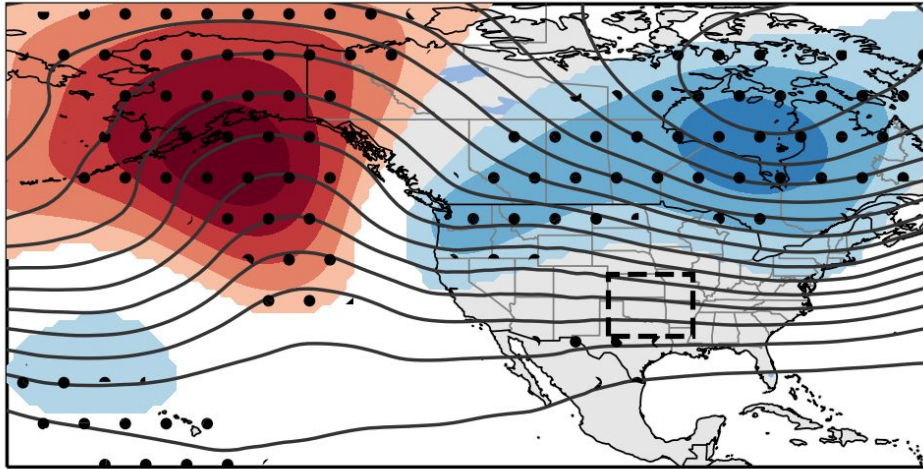
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-2 days

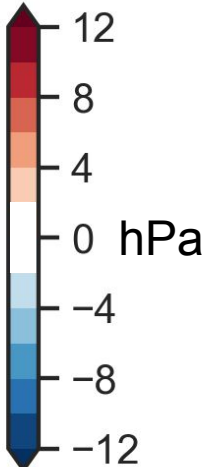
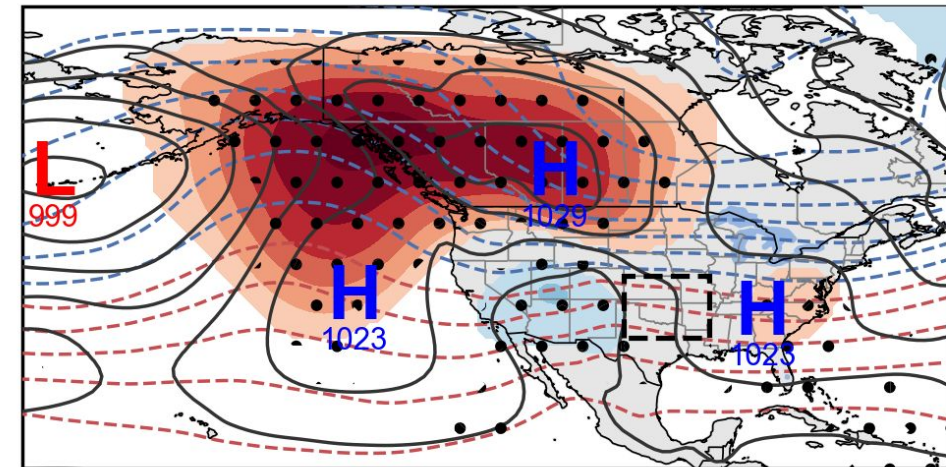
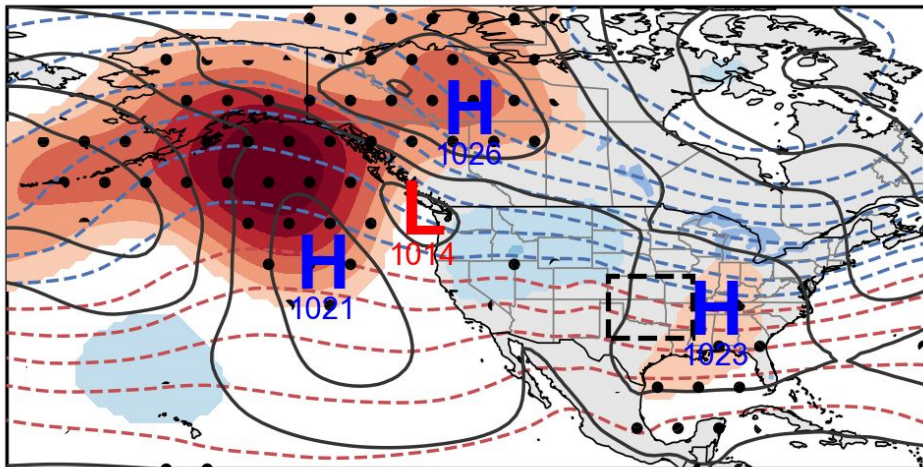
Short-duration ( $n=43$ )

Extremely long-duration ( $n=44$ )

500-hPa  
heights,  
anomalies



SLP,  
anomalies,  
1000-500-hPa  
thickness





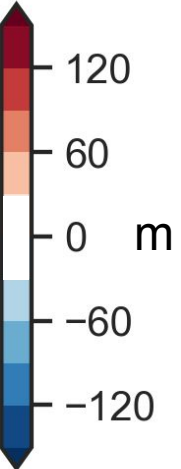
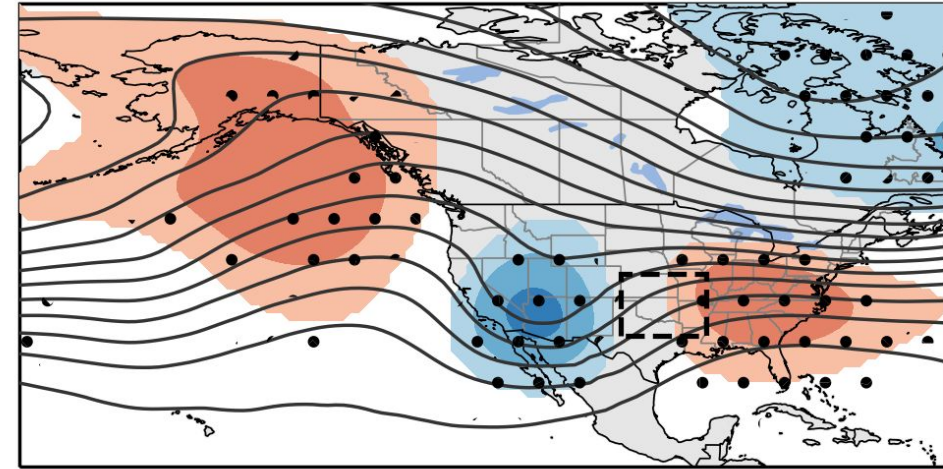
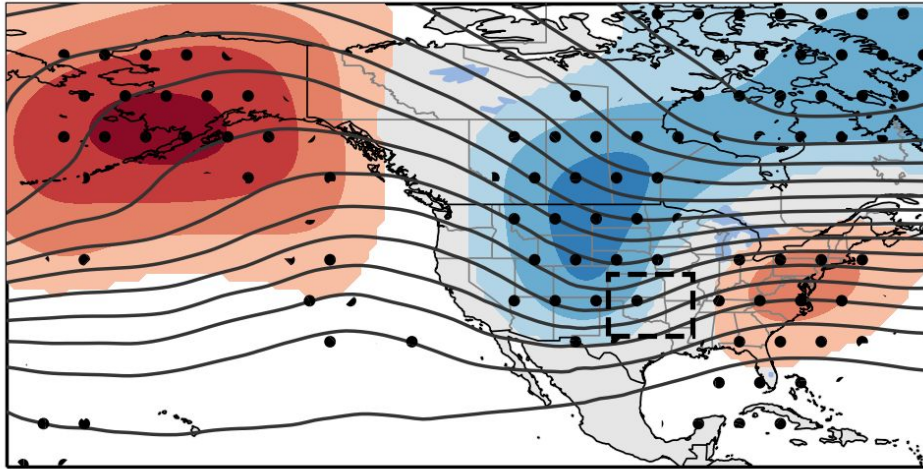
# How do synoptic patterns differ between SD and ELD events?

Onset

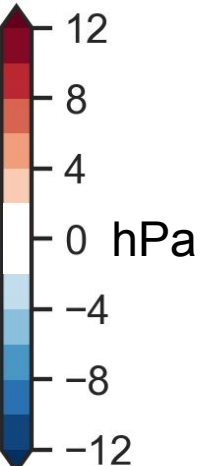
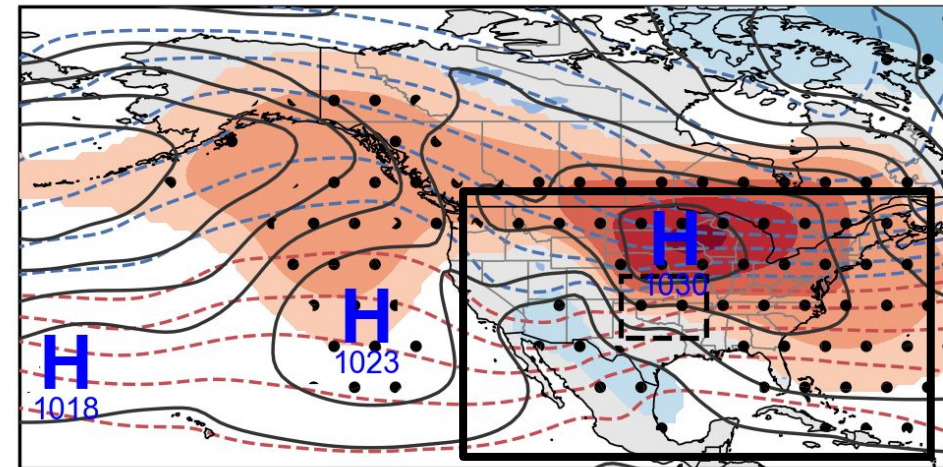
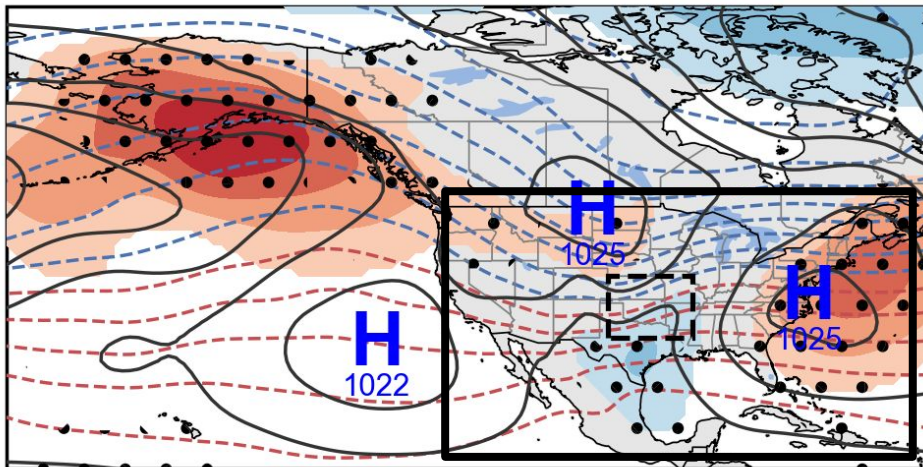
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Extremely long-duration ( $n=44$ )

500-hPa  
heights,  
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SLP,  
anomalies,  
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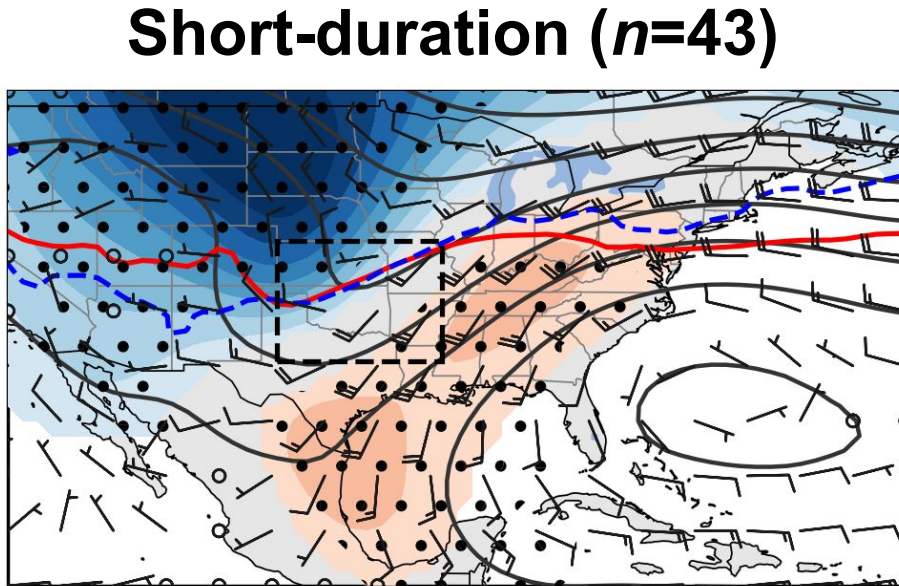
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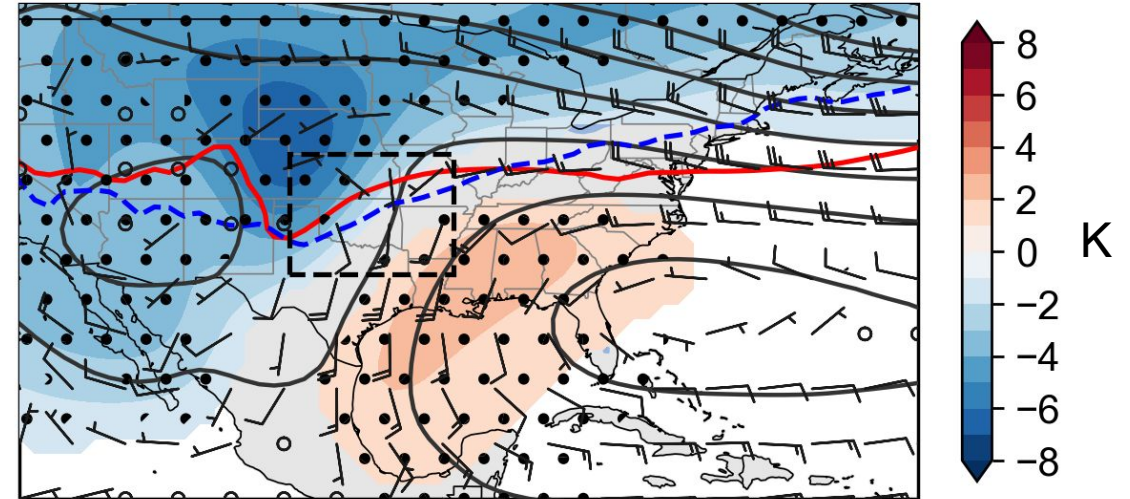
850-hPa

heights, winds,  
temp. anom.

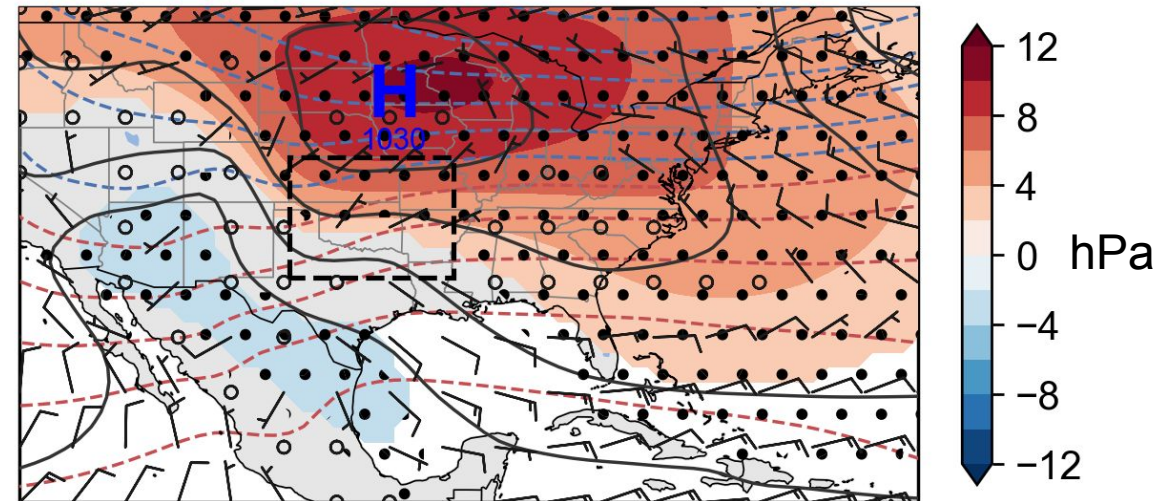
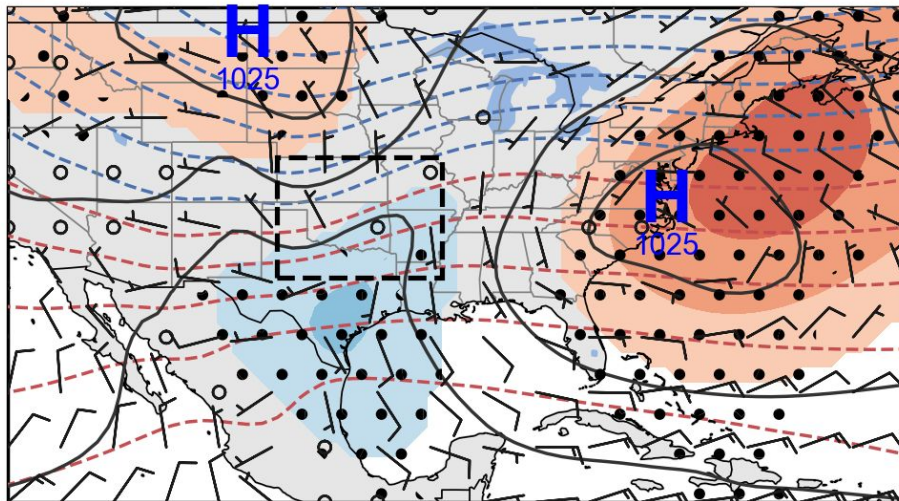
— 850-hPa  $T = 0^\circ\text{C}$   
- - 2-m  $T = 0^\circ\text{C}$



Extremely long-duration ( $n=44$ )



SLP,  
anomalies,  
1000-500-hPa  
thickness,  
10-m winds





# How do synoptic patterns differ between SD and ELD events?

+12 h

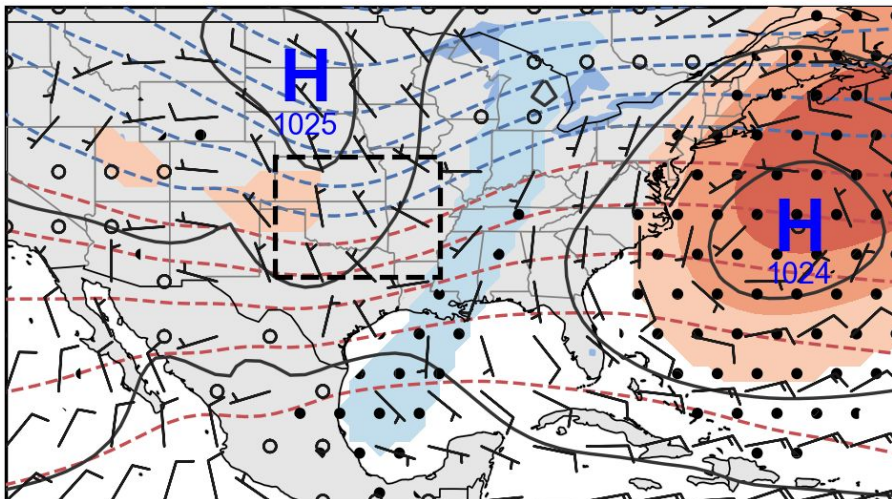
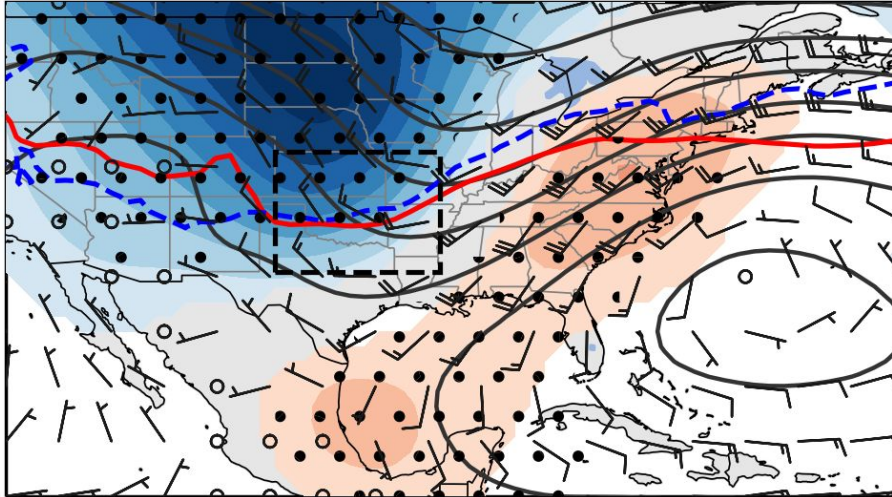
850-hPa

heights, winds,  
temp. anom.

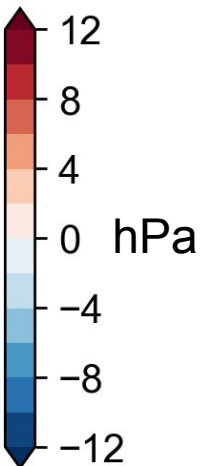
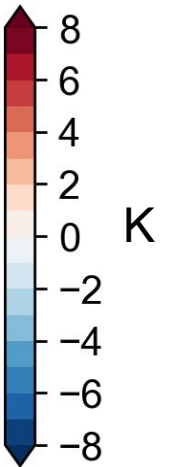
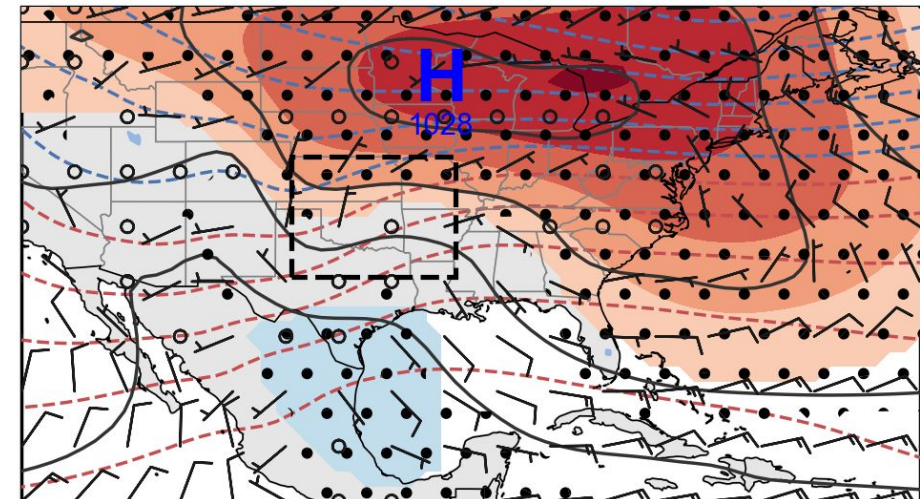
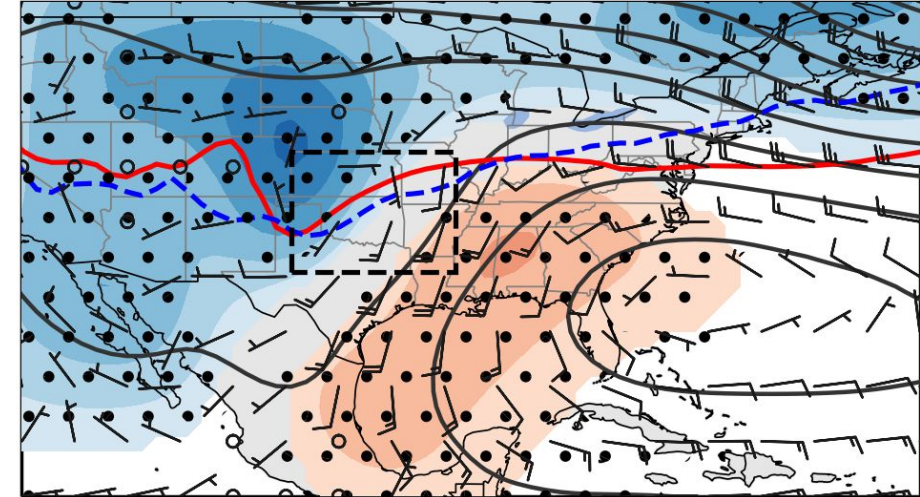
— 850-hPa  $T = 0^\circ\text{C}$   
- - 2-m  $T = 0^\circ\text{C}$

SLP,  
anomalies,  
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Short-duration ( $n=43$ )



Extremely long-duration ( $n=44$ )



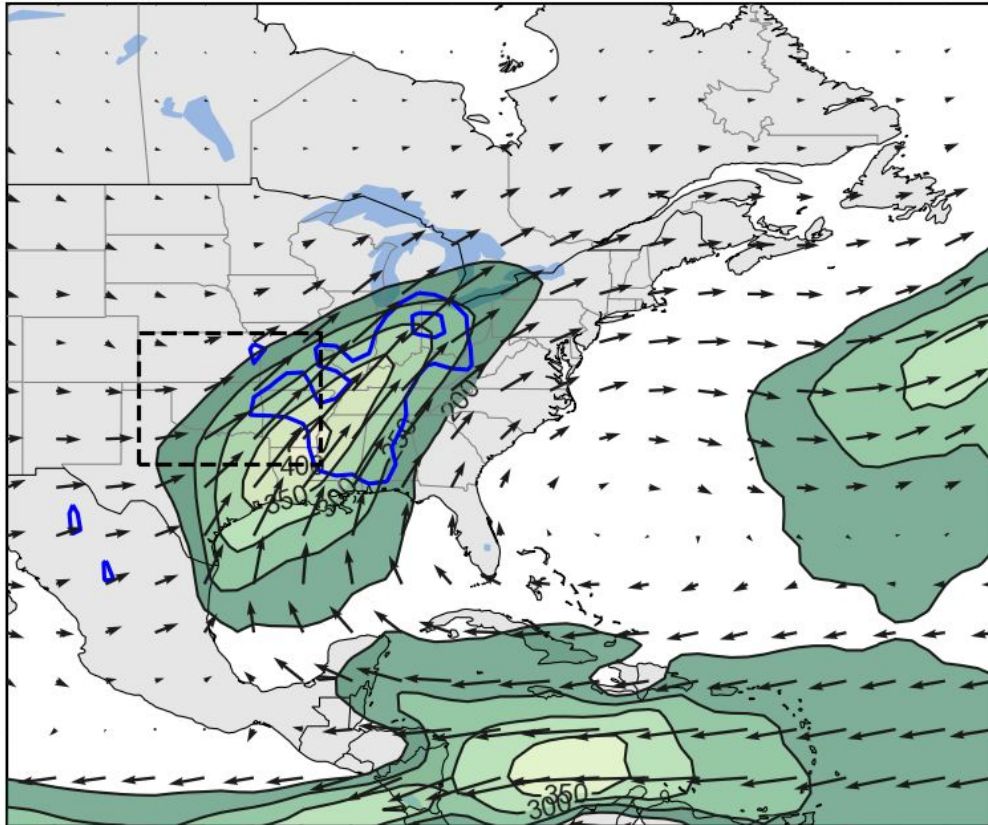


# Small differences in 500-hPa pattern have important impacts on warm layer temperature, moisture

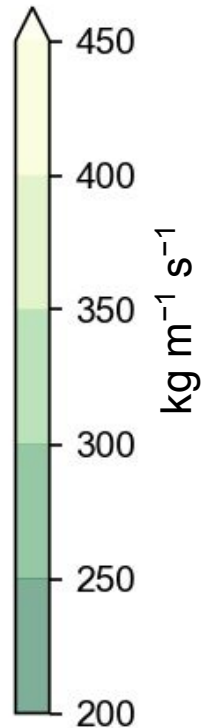
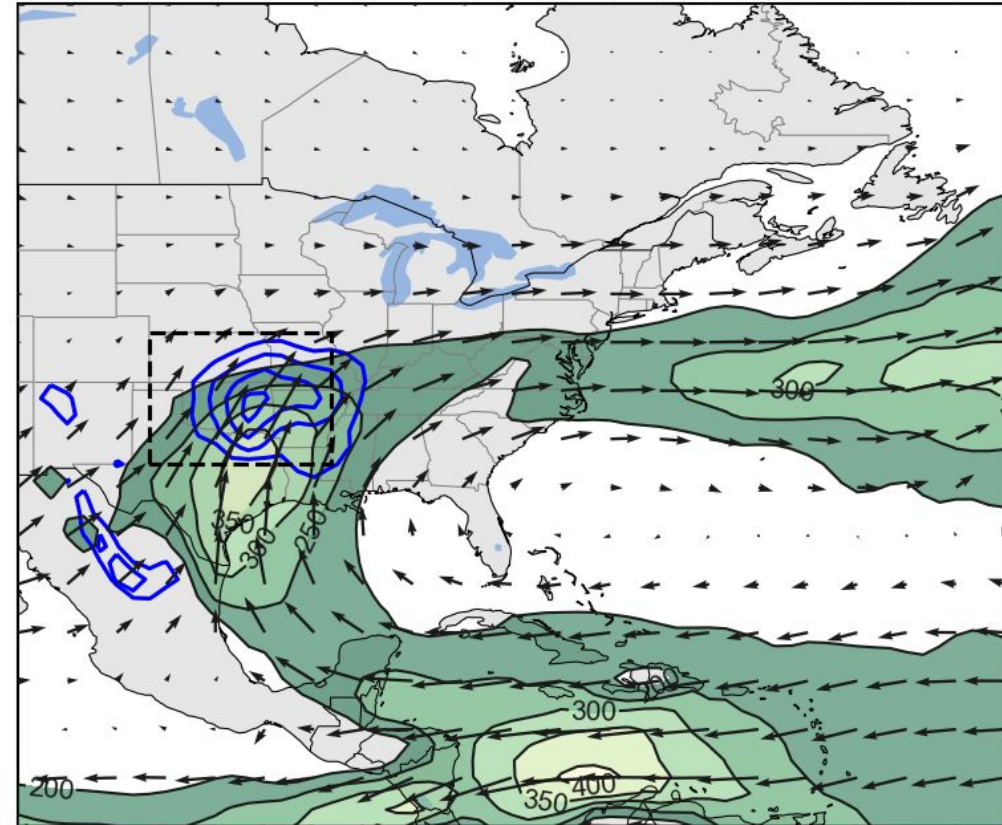
**Onset**

Composite Integrated Vapor Transport ( $\text{kg m}^{-1} \text{s}^{-1}$ , vectors/shaded)  
1000-300-hPa Moisture Flux Convg. ( $\geq 10 \text{ mm day}^{-1}$ , blue contours)

Short-duration ( $n=43$ )



Extremely long-duration ( $n=44$ )

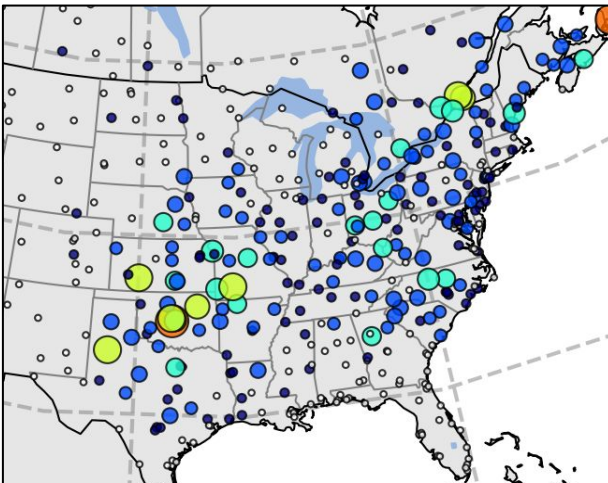


# Summary

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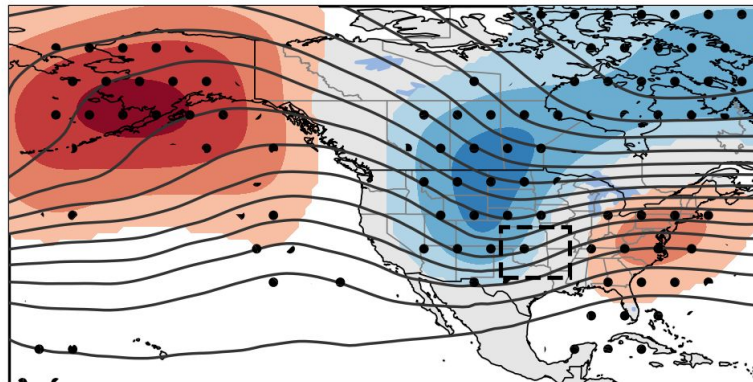
- The south-central United States has seen a disproportionate number of **extremely long-duration** freezing rain events relative to the frequency of freezing rain
- Compared with short-duration events, these extreme cases involve:
  - A **more stationary trough** over southwestern U.S.
  - Persistent **flow of warm, moist air** from Gulf of Mexico into the warm layer
- Maintenance of warm layer and sufficient moisture is key

18+ h FZRA events (1979-2016)

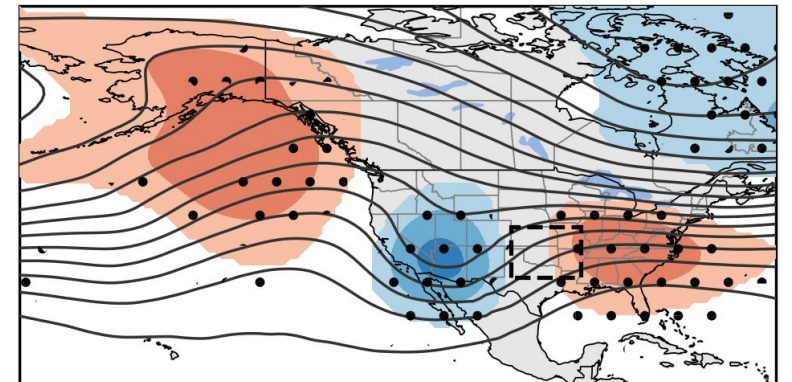


500-hPa Heights/Anomalies

Short-duration event onset



Extremely long-duration event onset



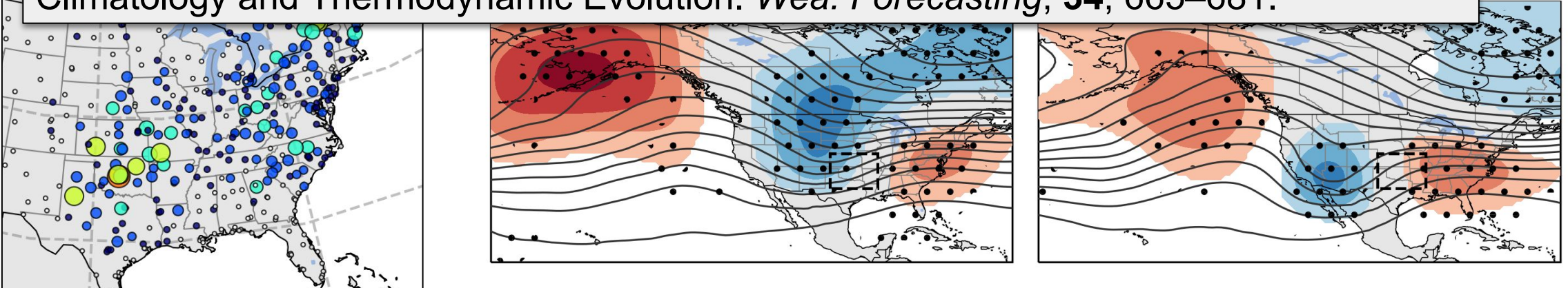


# Summary

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McCray et al. 2019: Long-Duration Freezing Rain Events over North America: Regional Climatology and Thermodynamic Evolution. *Wea. Forecasting*, **34**, 665–681.



# References

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- Sanders, K., C. Gravelle, J. Gagan, and C. Graves, 2013: Characteristics of major ice storms in the central United States. *J. Oper. Meteorol.*, **1**, 100–113.