Atmospheric and Surface Dynamics During the Winter 2021 Warm Spells in the Southern Great Plains

Taylor Grace[1], Kathy Pegion[1], and Jeffrey Basara[2]

[1]School of Meteorology, University of Oklahoma, Norman, OK

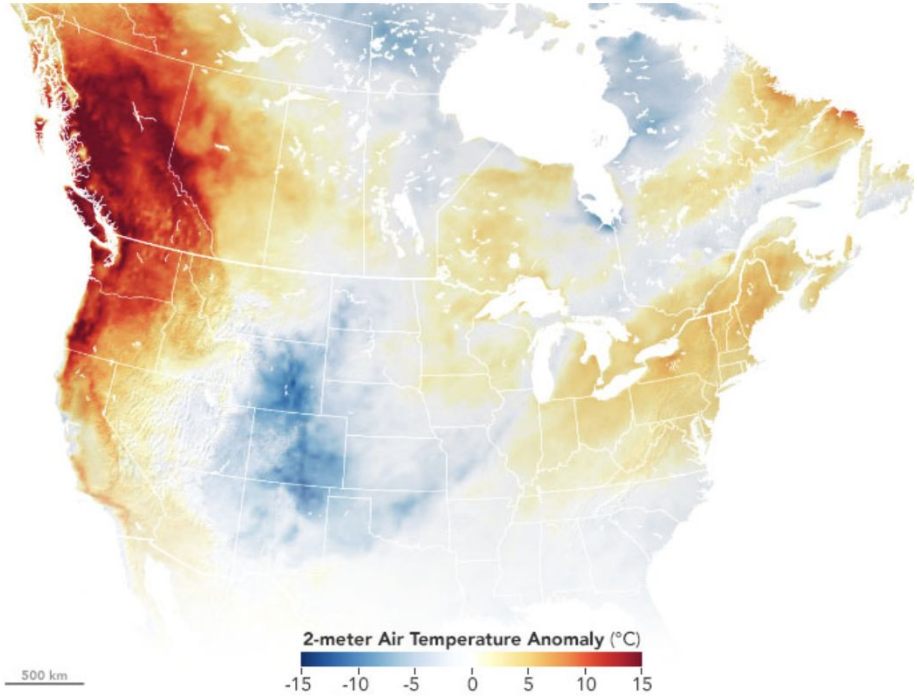
[2]Department of Environmental, Earth, and Atmospheric Sciences, University of Massachusetts Lowell, Lowell, MA

Grace et al. (2024, *in review*)

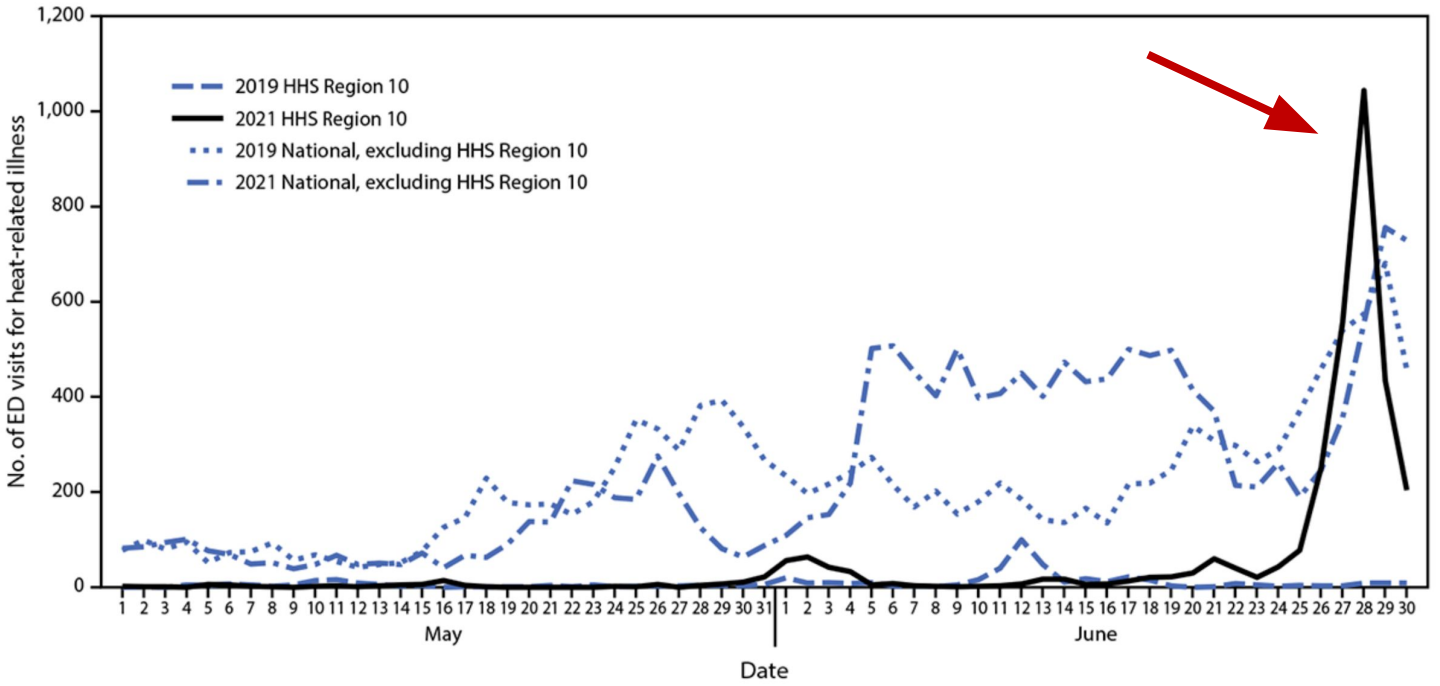
Contact: taylor.m.grace-1@ou.edu

Motivation

- Heat waves (summer season) foster detrimental impacts on **human health**, agriculture, water resources, and the energy sector
  - Example: PNW 2021 heat wave (White et al., 2023, Rempel et al., 2022, Baker & Olmos, 2021, Philip et al., 2022)



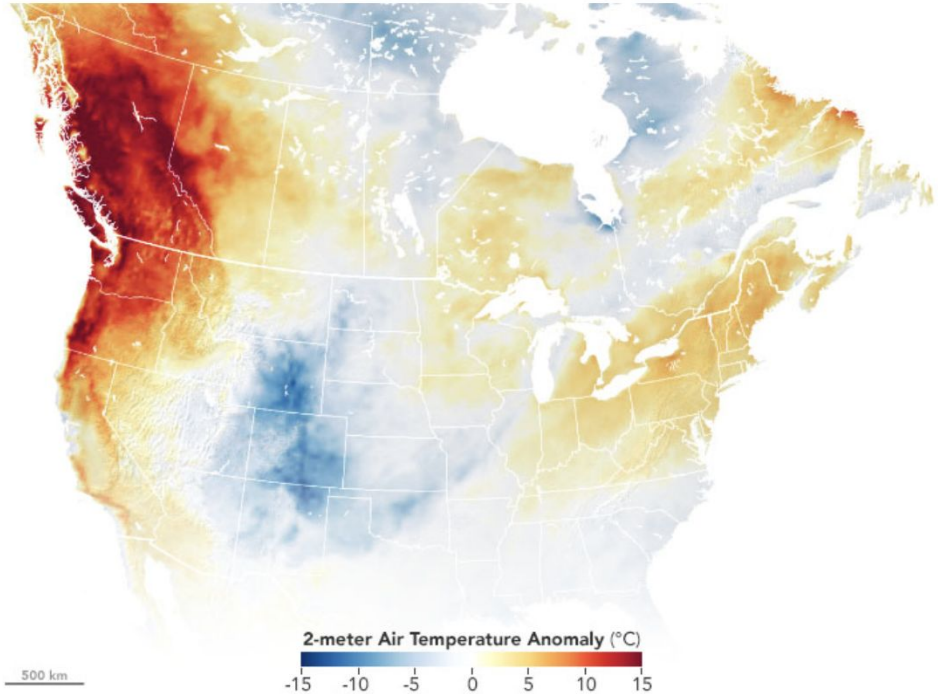
NASA 2021



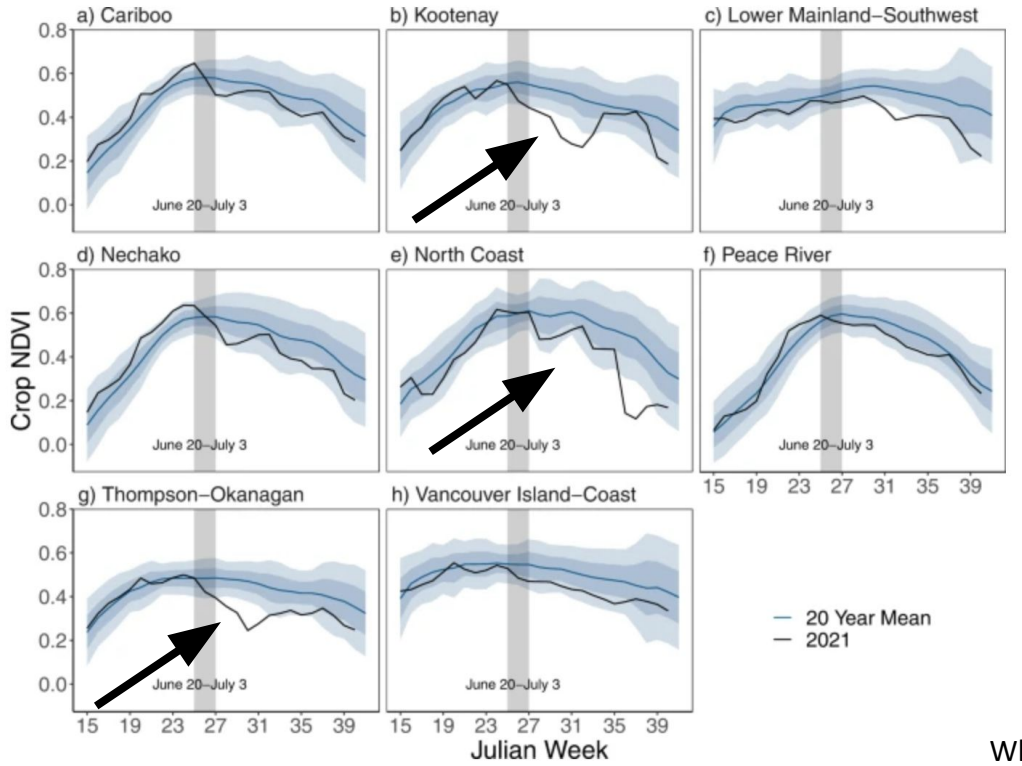
Schramm et al. 2021

Motivation

- Heat waves (summer season) foster detrimental impacts on human health, **agriculture**, water resources, and the energy sector
  - Example: PNW 2021 heat wave (White et al., 2023, Rempel et al., 2022, Baker & Olmos, 2021, Philip et al., 2022)

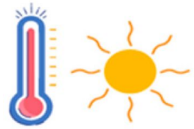


NASA 2021

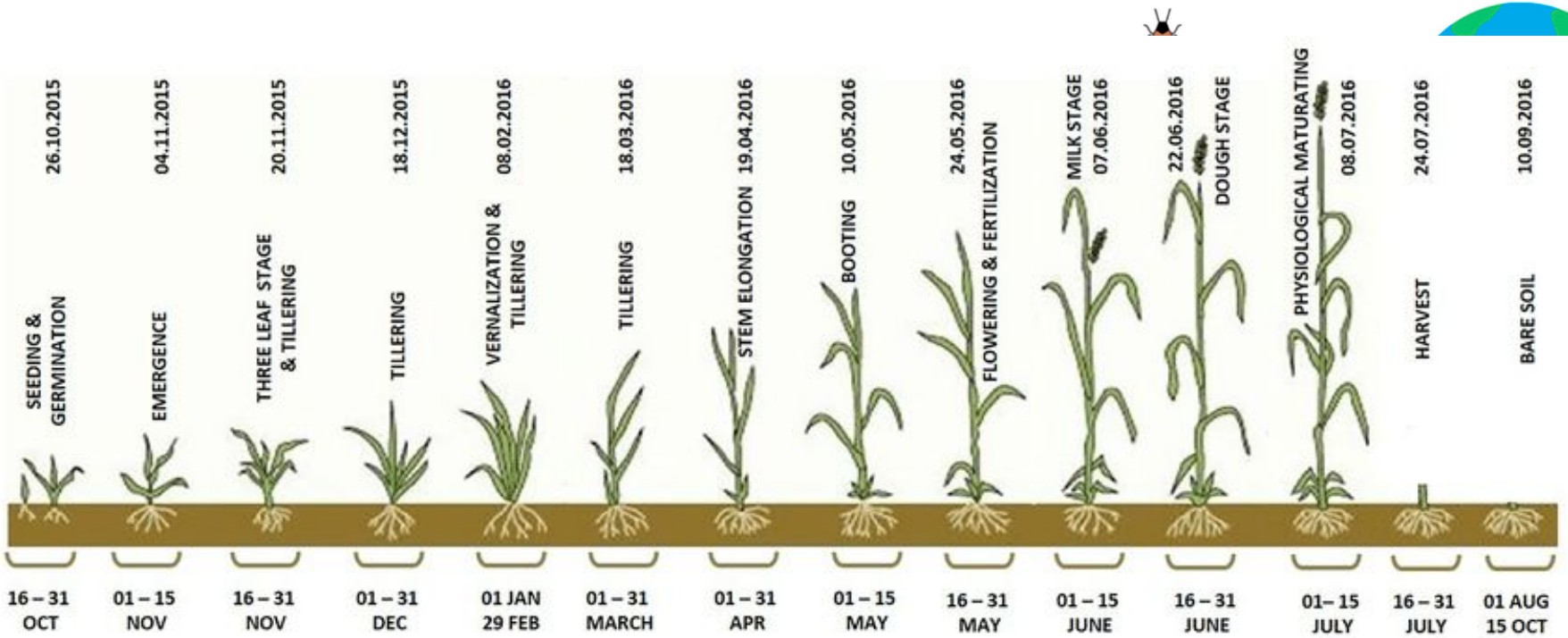


White et al. 2023

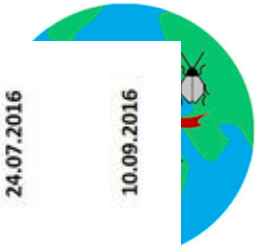
Motivation



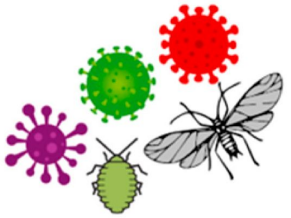
HOW DOES TEMPERATURE INCREASE AFFECTS INSECT PESTS?



Akgöz et al. 2022



ı of
range



Outbreak of plant diseases transmitted by insects

zation of
eir natural
enemies

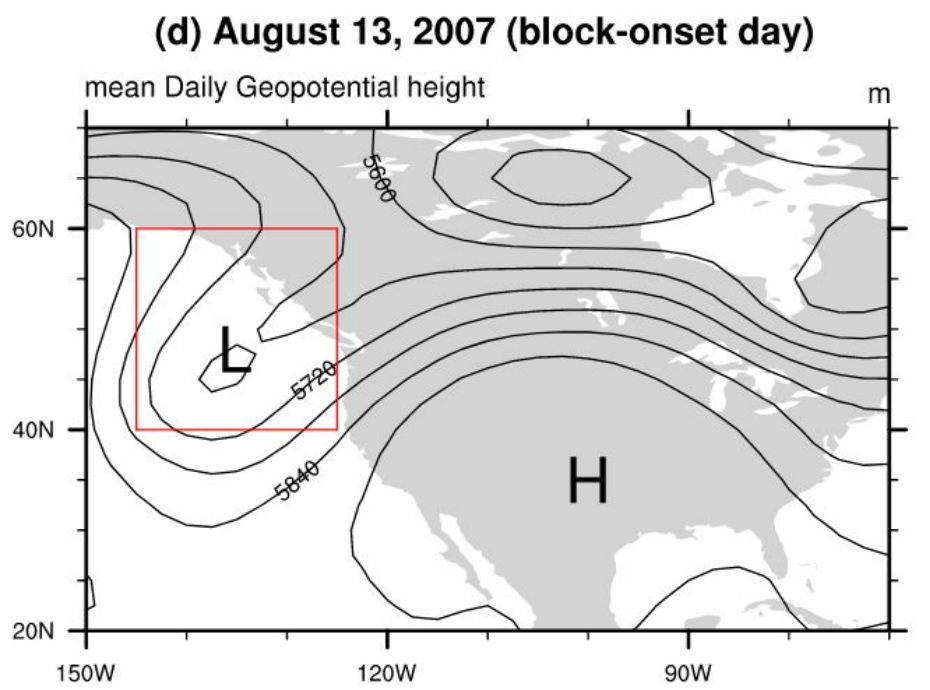
survival

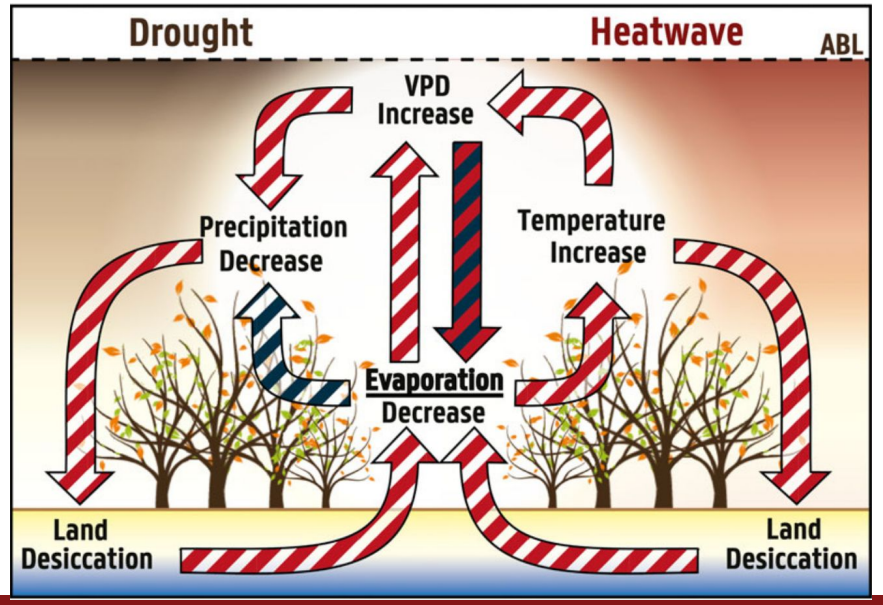
Loss of synchrony with the host plant

Skendžić et al. 2021

Drivers of Extreme Heat

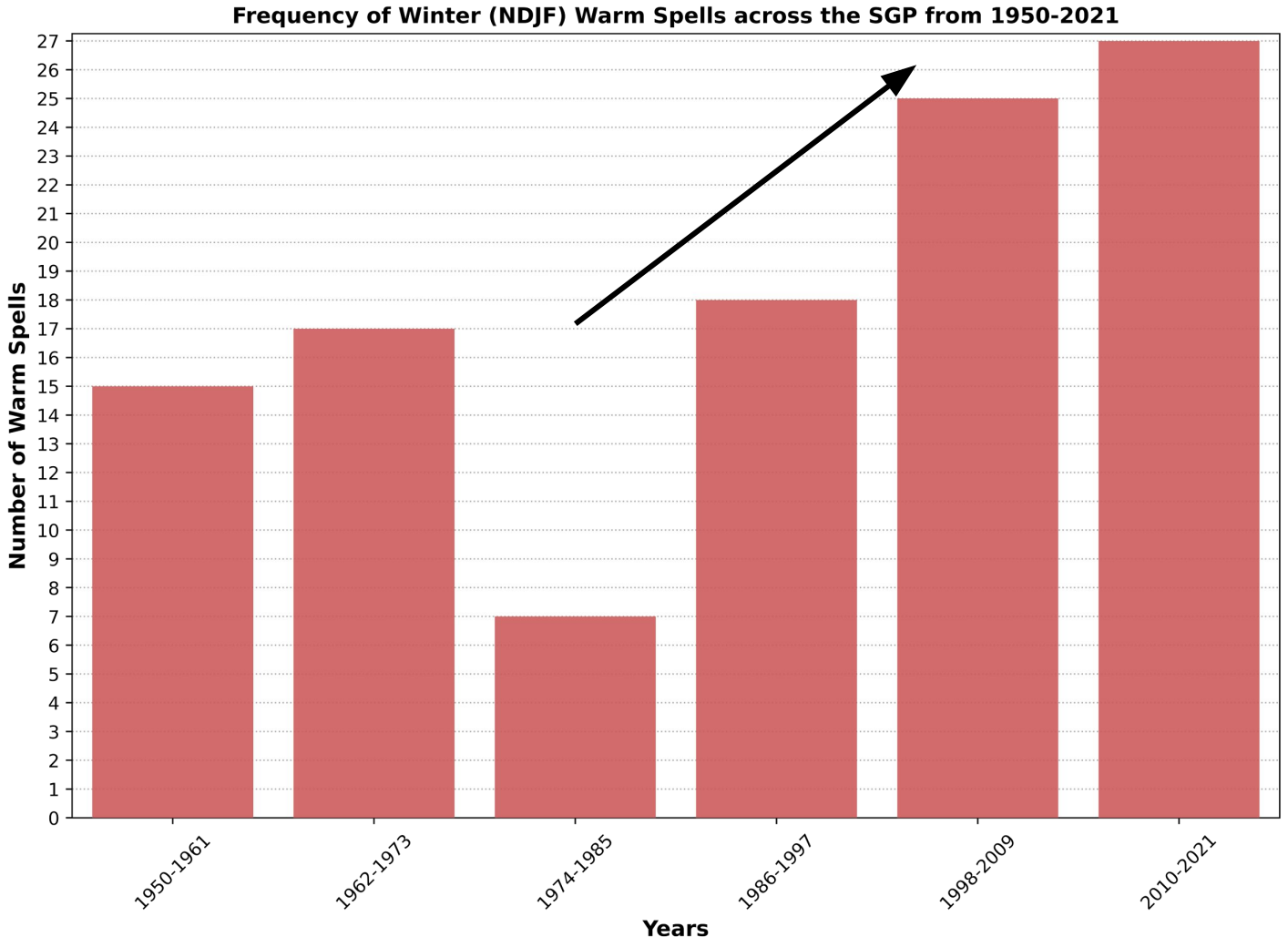
- Atmospheric blocking is the ***main driver*** of heat wave events (Dong et al., 2018, Neal et al., 2022)
- Land-atmospheric interaction feedbacks ***supplement*** extreme heat at the surface (Fischer et al., 2007, Lee et al., 2016, Miralles et al., 2019)
- Heat waves are predicted to ***increase*** in frequency, duration, and intensity (Meehl & Tebaldi, 2004, Smith et al. 2013, Shafiei Shiva et al., 2019, Domeisen et al. 2023)
- Brown et al. (2008) found a ***positive trend in the location parameter*** (i.e., center of the distribution) of maximum daily temperatures in North America **during boreal winter**





Grace et al. (2024, *in review*)

Increasing Winter Warm Spell Events



Grace et al. (2024,*in review*)

Key Question #1

What atmospheric and surface characteristics were drivers of these extreme heat periods in the Southern Great Plains during December of 2021?

Data & Methods

- Dataset: ERA-5 Reanalysis (0.5˚ spatial resolution)
- Study domain: Southern Great Plains
- Time Ste
- All varia
  standar

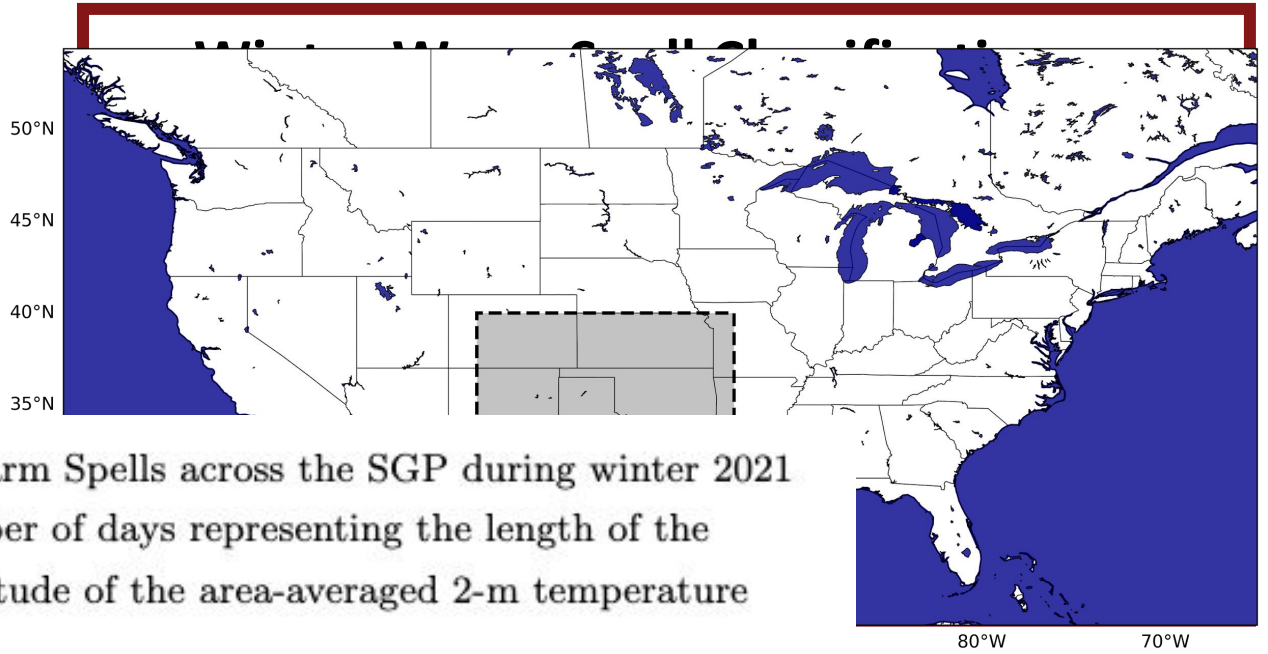
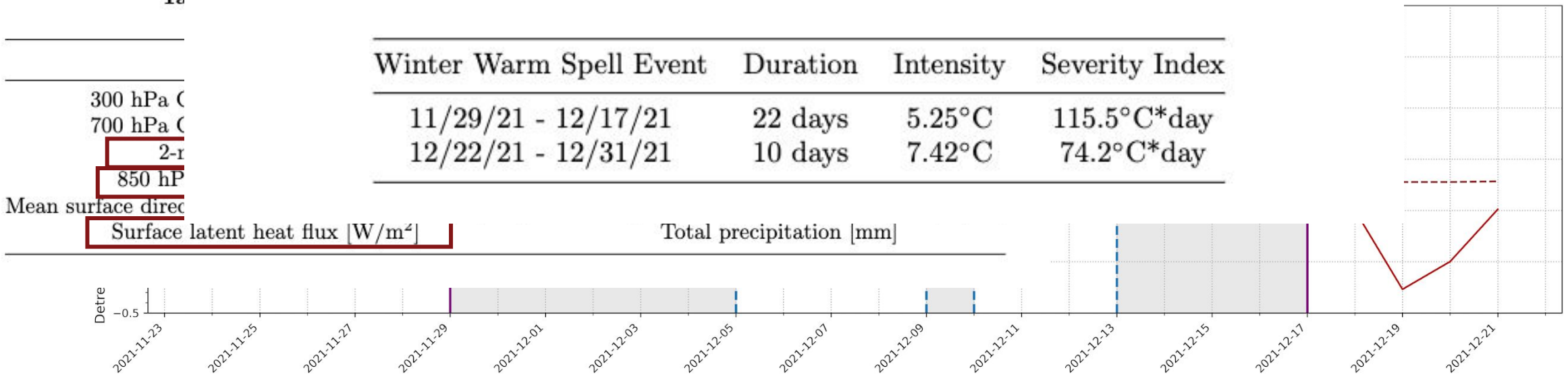


Table 2. Severity Index (°C*day) for Winter Warm Spells across the SGP during winter 2021 case study. Duration (# of days) value is the number of days representing the length of the extreme event. Intensity (°C) is the average magnitude of the area-averaged 2-m temperature anomalies during the extreme event.

Winter Warm Spell Event	Duration	Intensity	Severity Index
11/29/21 - 12/17/21	22 days	5.25°C	115.5°C*day
12/22/21 - 12/31/21	10 days	7.42°C	74.2°C*day

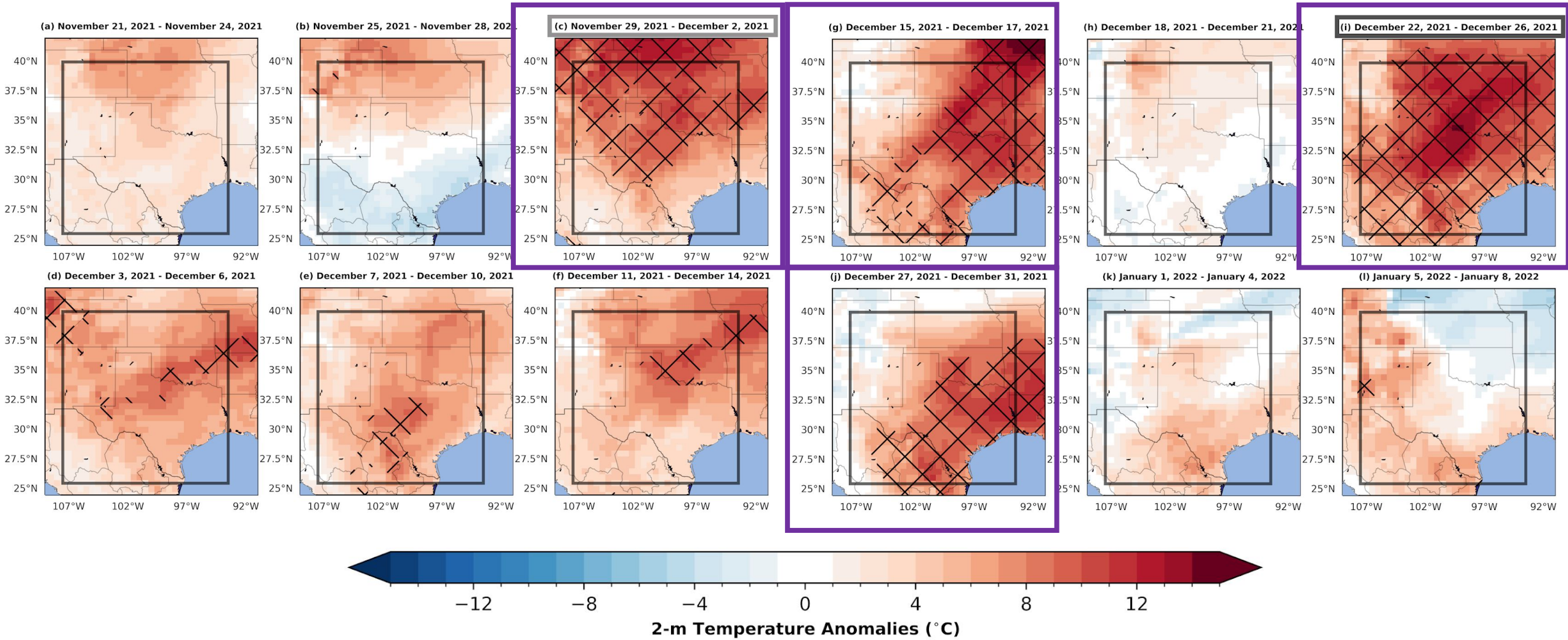


Grace et al. (2024, *in review*)

Daily Maximum 2-m Temperature Anomalies

Winter Warm Spell Event #1

Winter Warm Spell Event #2

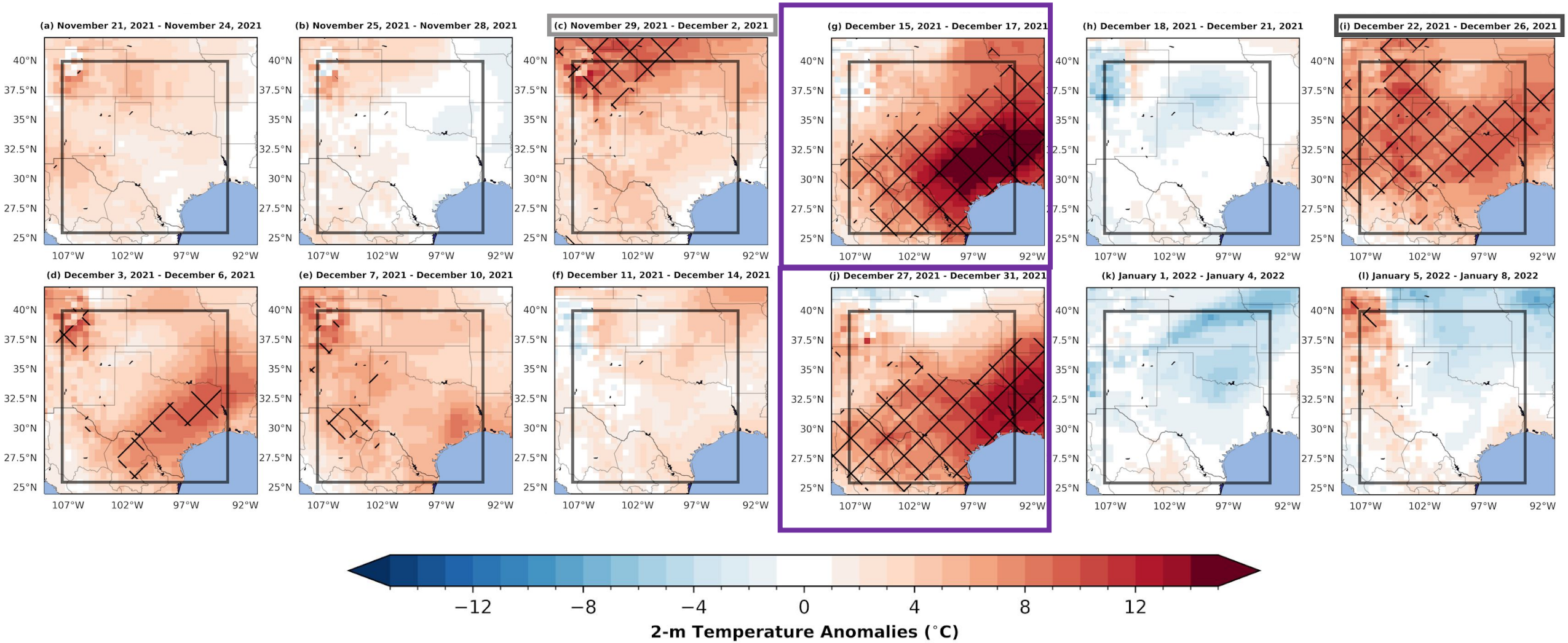


Grace et al. (2024, *in review*)

Daily Minimum 2-m Temperature Anomalies

Winter Warm Spell Event #1

Winter Warm Spell Event #2

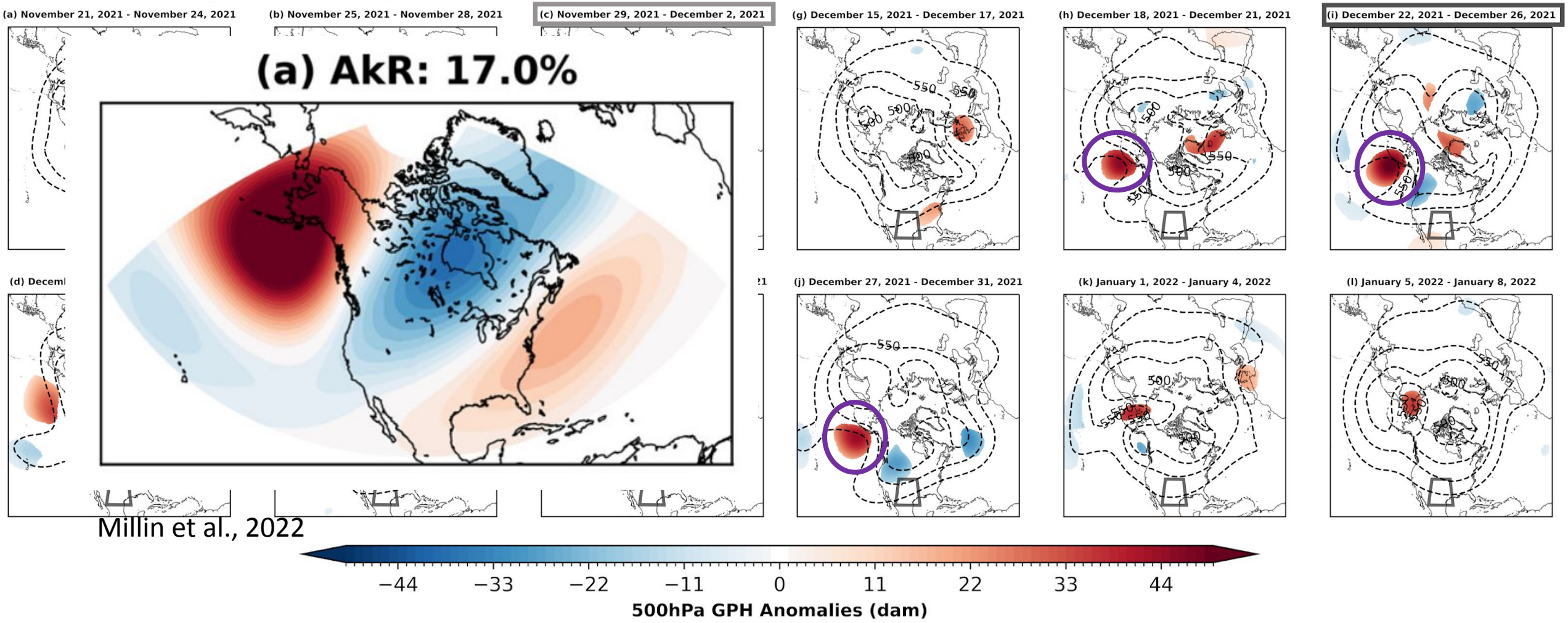


Grace et al. (2024, *in review*)

Daily 500hPa Geopotential Heights

Winter Warm Spell Event #1

Winter Warm Spell Event #2



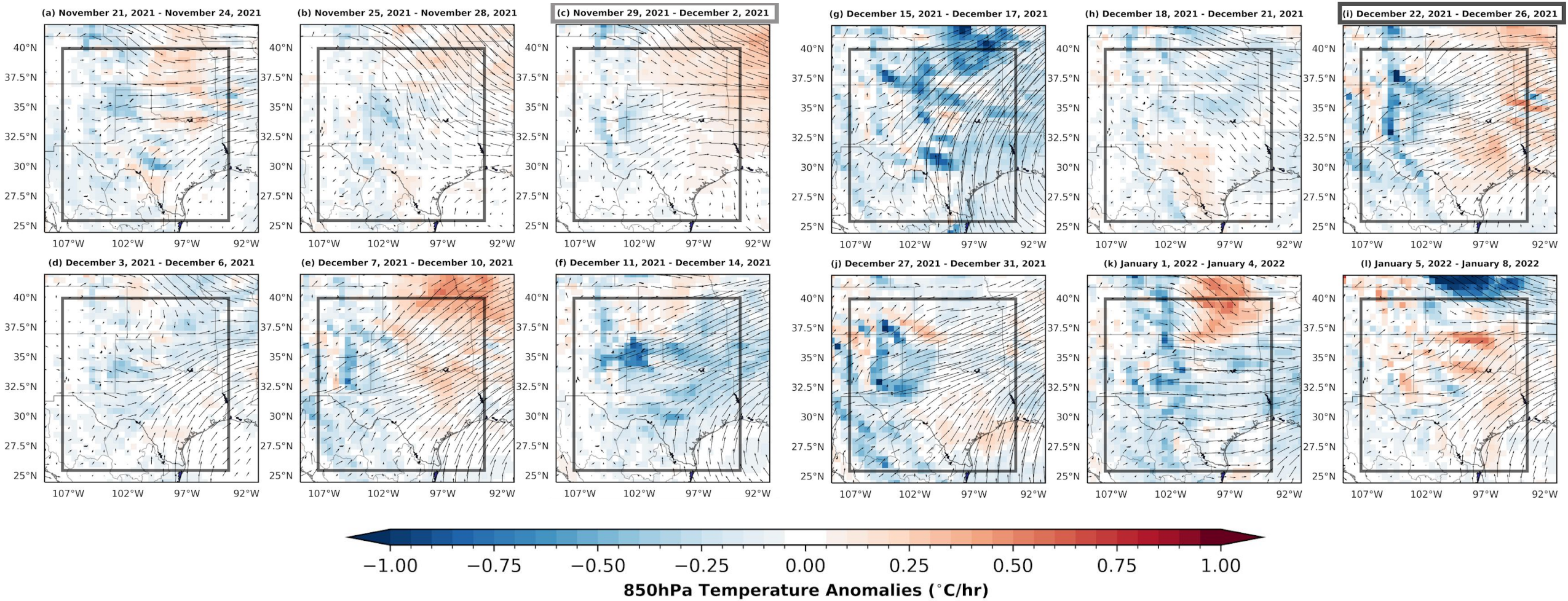
Millin et al., 2022

850hPa Temperature Advection

wind vector = 10 m/s

Winter Warm Spell Event #1

Winter Warm Spell Event #2

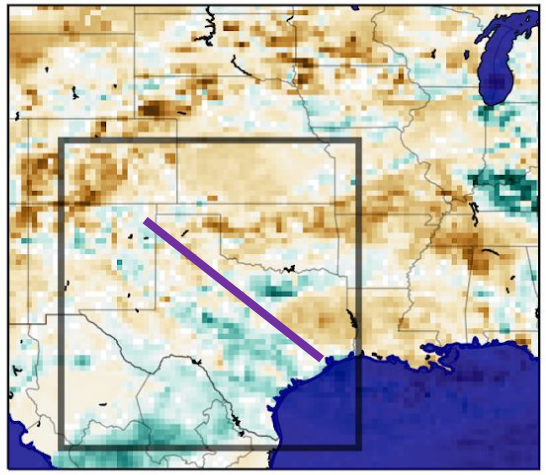


Grace et al. (2024, *in review*)

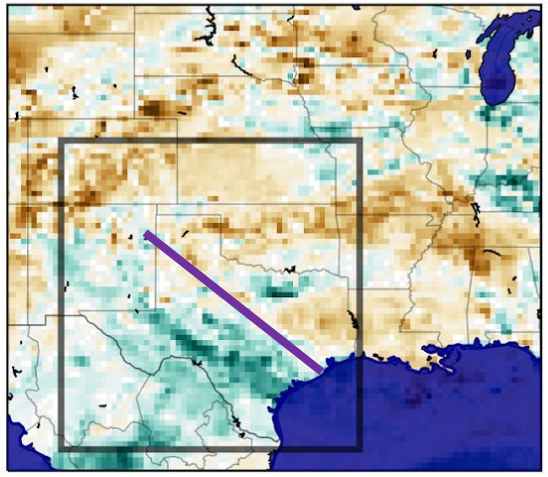
Daily Soil Moisture (0-7cm)

Winter Warm Spell Event #1

November 24, 2021 - November 28, 2021

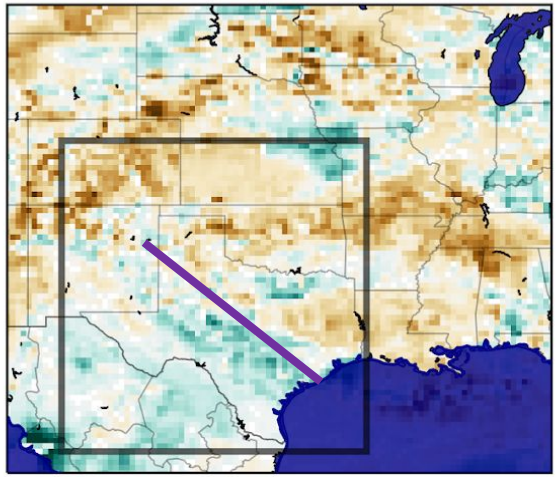


December 4, 2021 - December 8, 2021

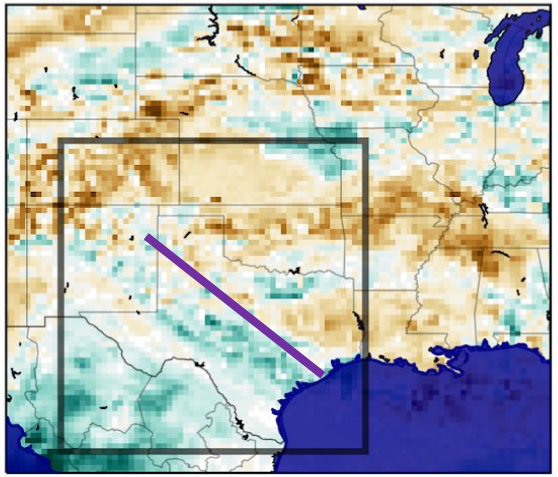


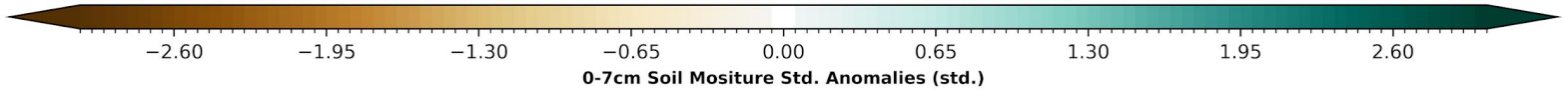
Winter Warm Spell Event #2

December 19, 2021 - December 23, 2021



December 24, 2021 - December 28, 2021



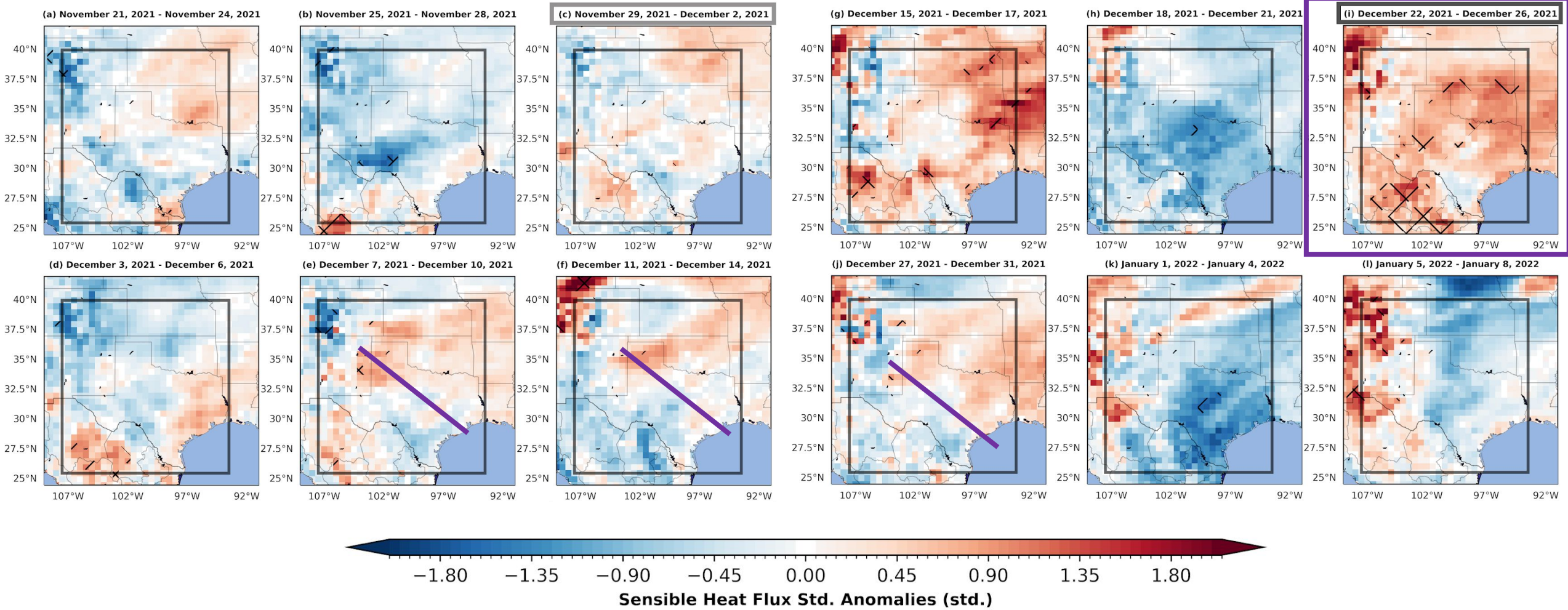


Grace et al. (2024, *in review*)

Daily Sensible Heat Flux

Winter Warm Spell Event #1

Winter Warm Spell Event #2

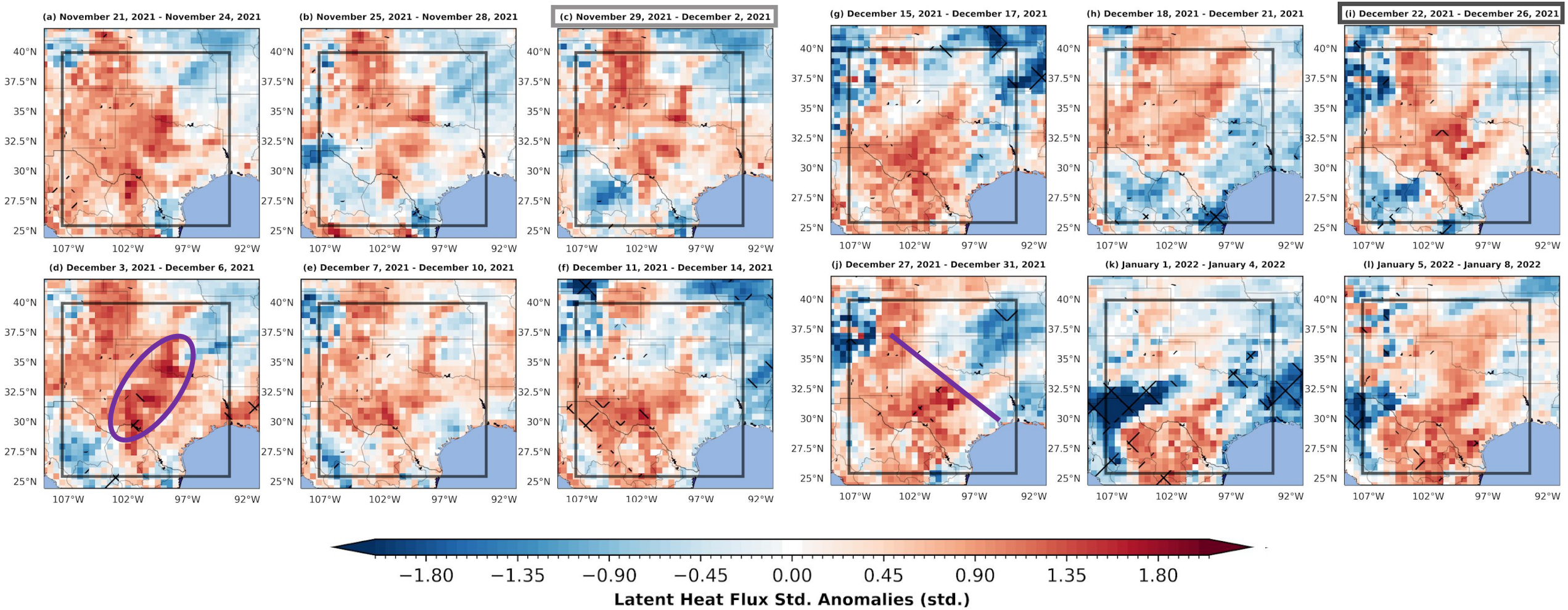


Grace et al. (2024, *in review*)

Daily Latent Heat Flux

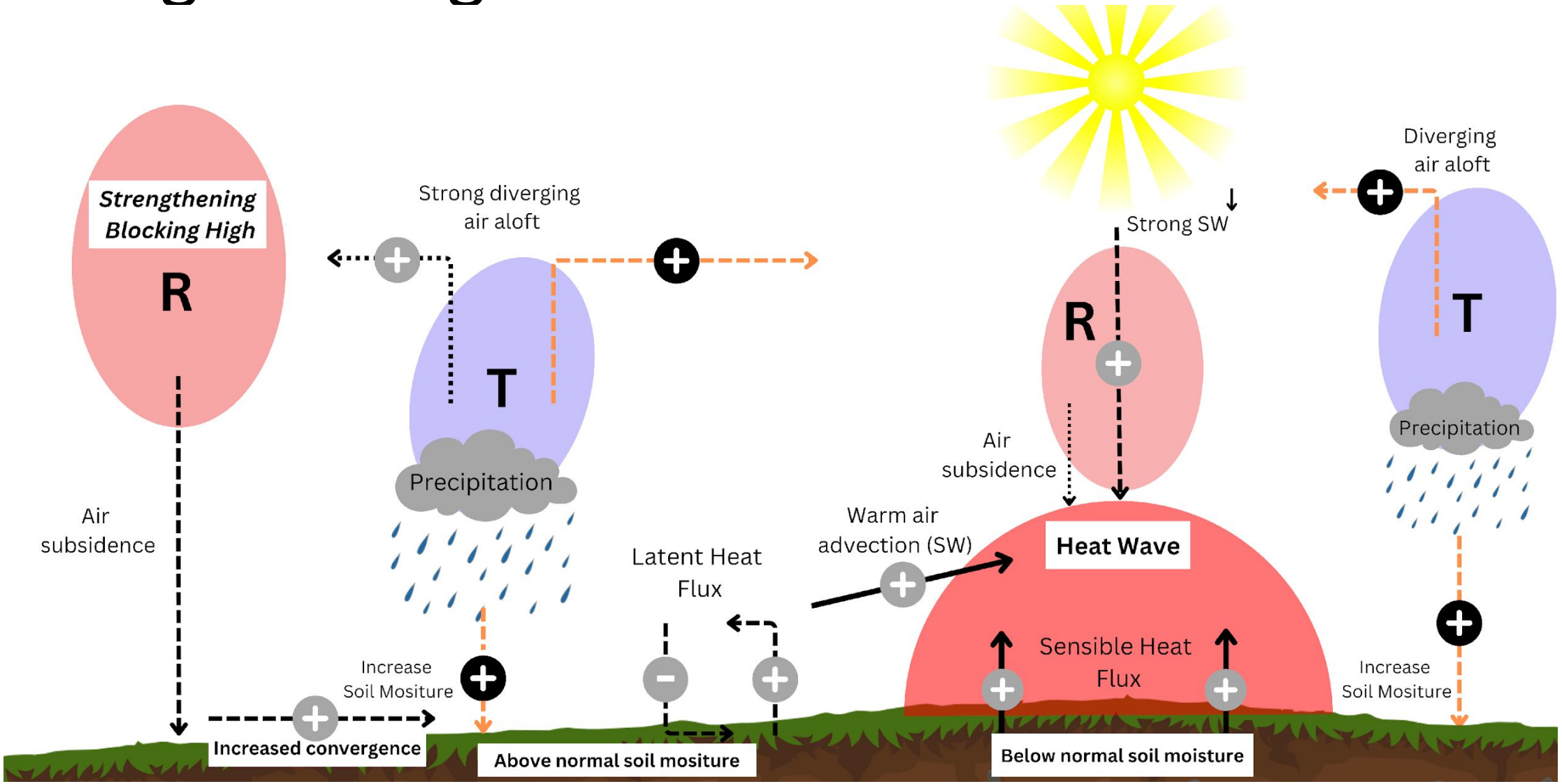
Winter Warm Spell Event #1

Winter Warm Spell Event #2



Grace et al. (2024, *in review*)

Piecing it all together…



Grace et al. (2024, *in review*)

Conclusions and Future Work

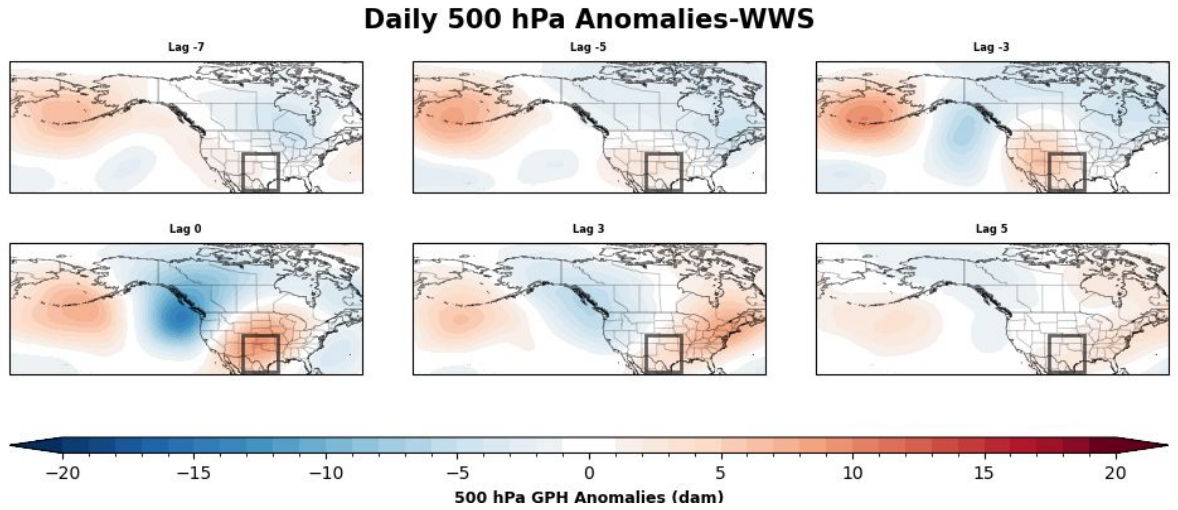
What atmospheric and surface characteristics were drivers of these extreme heat periods in the Southern Great Plains during December of 2021?

Key Findings:

1. Atmospheric blocking high (i.e., Alaskan Ridge) was not collocated with the impacted region (SGP)
2. Weak warm air advection across the SGP
3. Below normal soil moisture enhancing sensible heat flux near the surface across the eastern half of the SGP
4. Above normal soil moisture supporting latent heat flux at the surface across the western half of the SGP

Future Work:

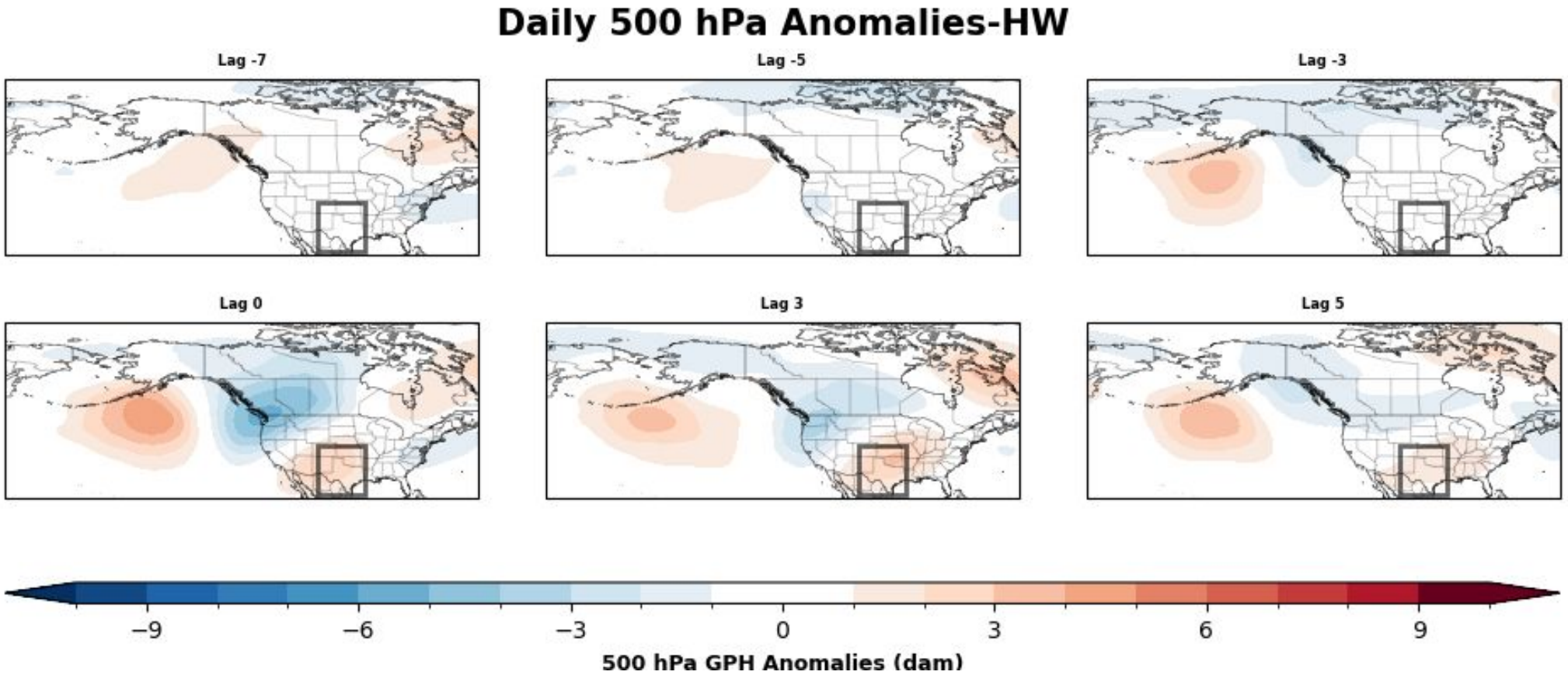
- Investigate atmospheric drivers of all winter warm spell events in SGP
- Understand the similarities and differences between SGP winter warm spells and heat wave events
- Investigate teleconnections to SGP winter warm spell events



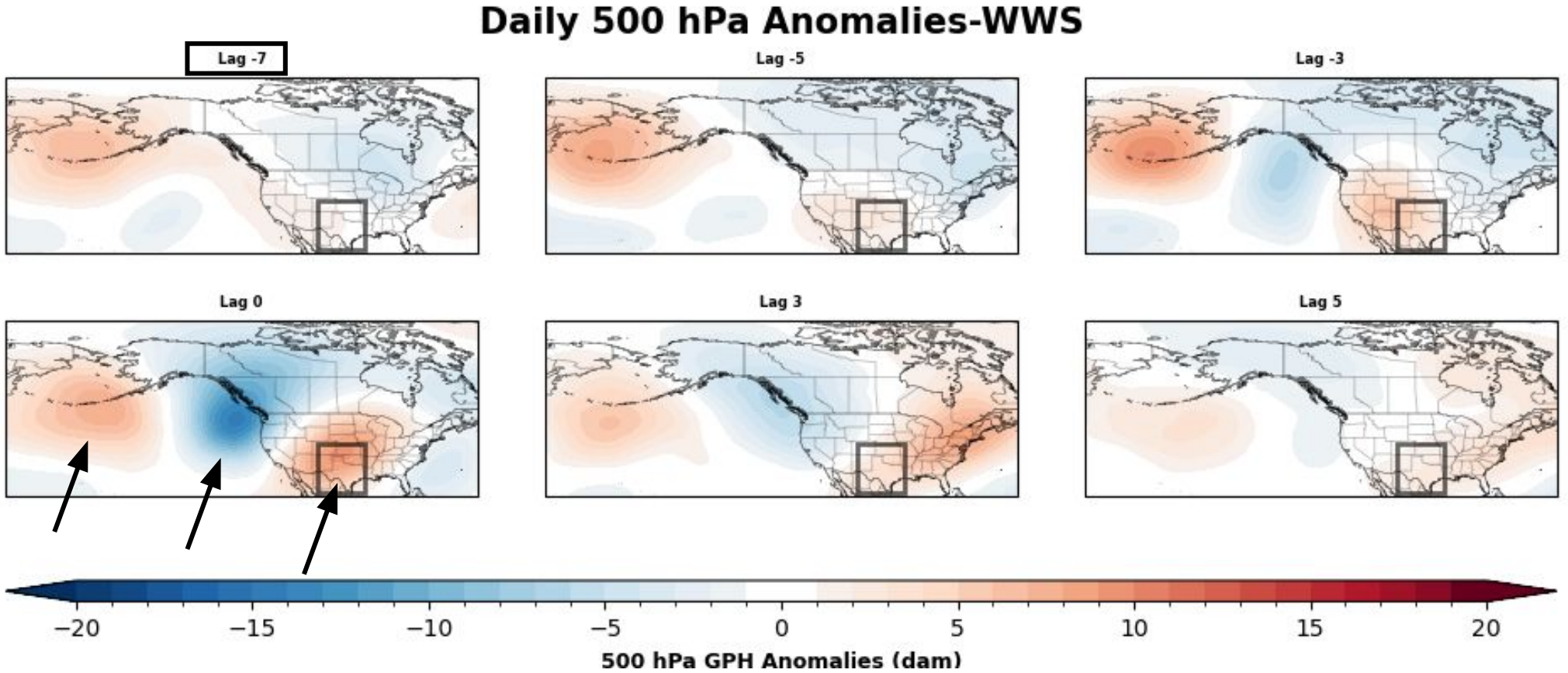
Research Goals

1. Understanding the characteristics and drivers of the extreme heat in the winter of 2021 across the Southern Great Plains
2. What are the characteristics and drivers of SGP winter warm spells compared to SGP heat waves preliminary results

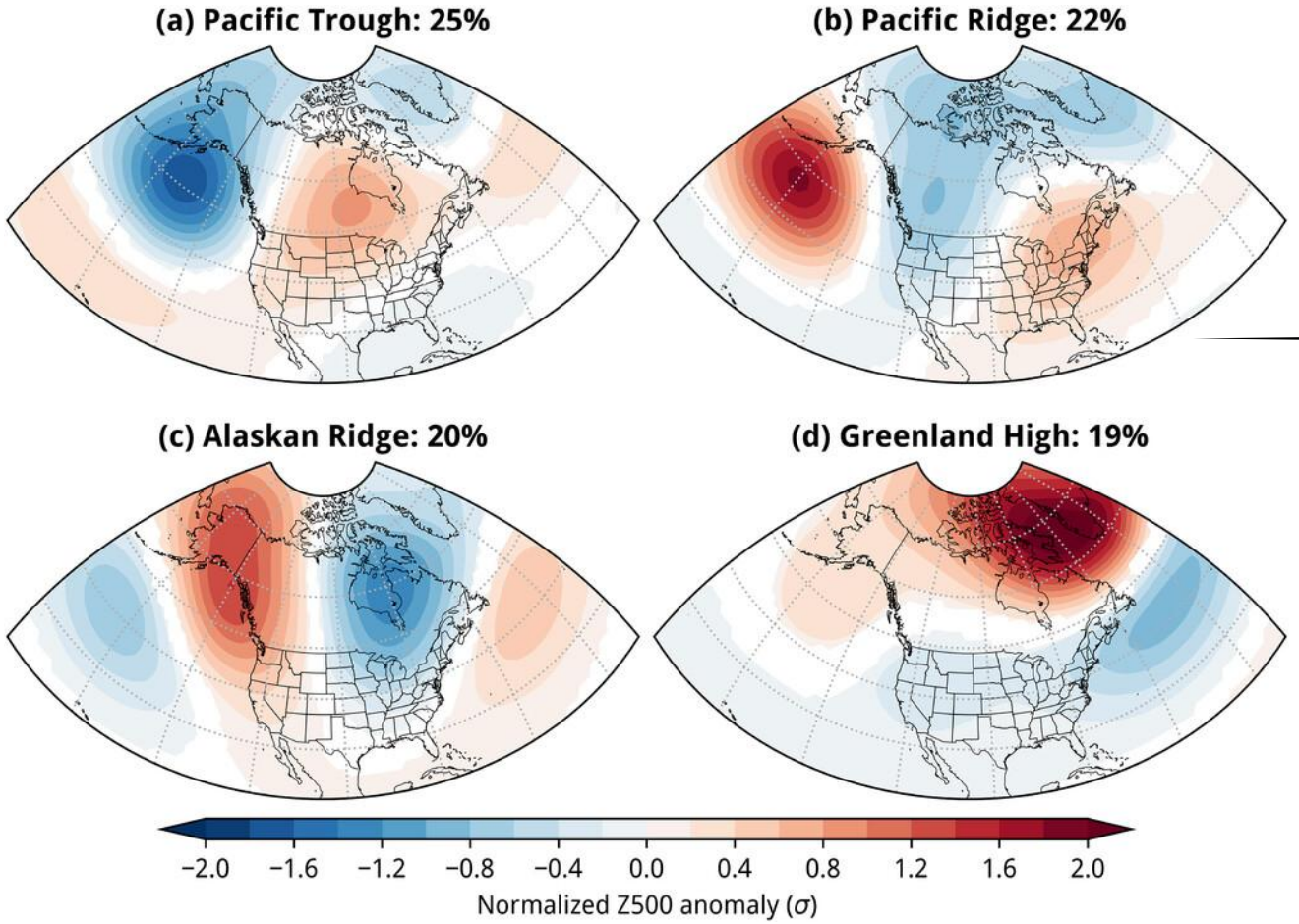
Preliminary Results (Part 2)

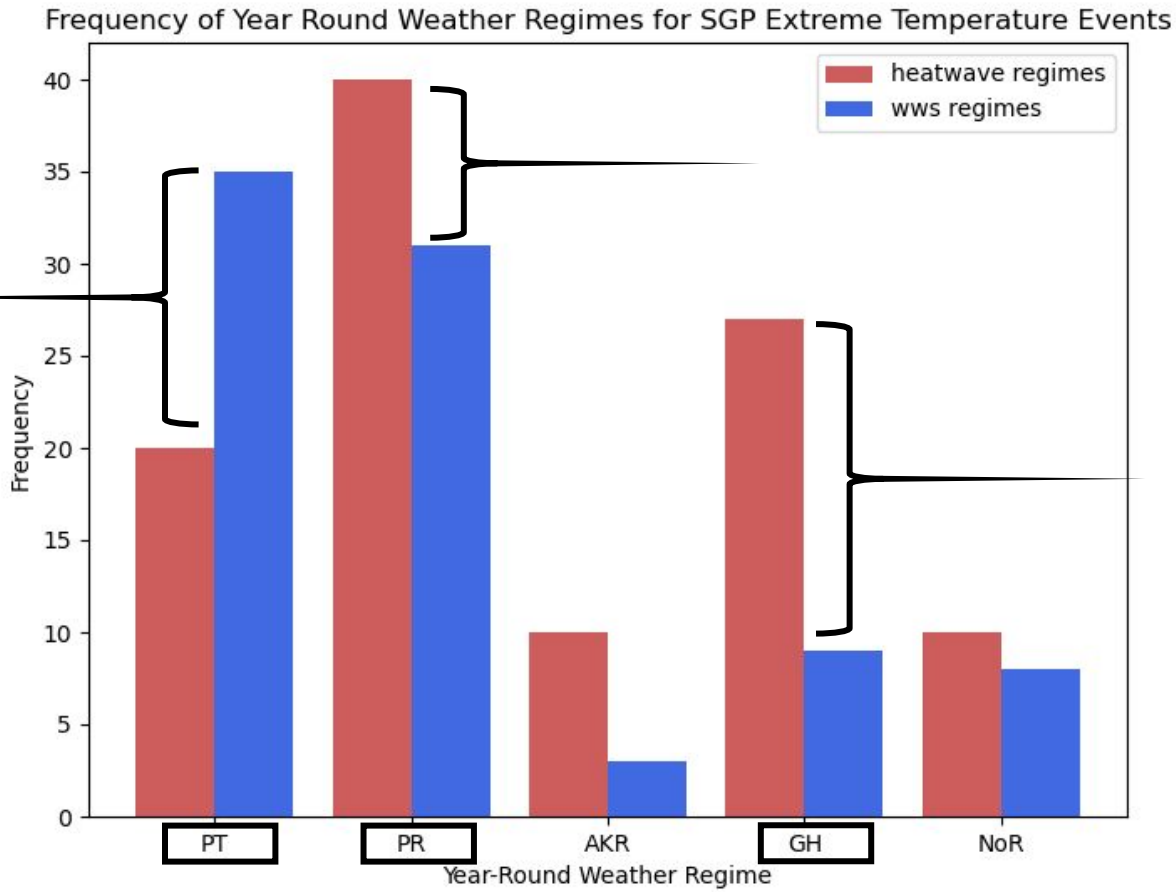


Preliminary Results (Part 2)



Preliminary Results (Part 2)





Conclusions Part 2

1. The location of the atmospheric blocking high is different compared to SGP winter warm spells and heat wave events
2. The atmospheric blocking high shows a signal around 14+ days prior to the onset of the winter warm spell event
3. Pacific Trough, Pacific Ridge, and Greenland High are important weather regimes for SPG winter warm spells and heat wave events

<u>Future Work</u>

1. Investigate teleconnections
2. Identify onset of surface characteristics

Acknowledgments and Questions

This work is supported by the National Science Foundation Established Program to Stimulate Competitive Research project Grant OIA-1946093.

Contact Info:
Taylor Grace
taylor.m.grace-1@ou.edu

References

Baker, M., & Olmos, S. (2021). The Pacific Northwest, Built for Mild Summers, Is Scorching Yet Again. The New York Times.

Brown, S. J., Caesar, J., & Ferro, C. a. T. (2008). Global changes in extreme daily temperature since 1950. Journal of Geophysical Research: Atmospheres, 113 (D05115).

Domeisen, D. I. V., Eltahir, E. A. B., Fischer, E. M., Knutti, R., Perkins-Kirkpatrick, S. E., Schär, C., . . . Wernli, H. (2023). Prediction and projection of heatwaves. Nat Rev Earth Environ, 4 , 36–50.

Dong, L., Mitra, C., Greer, S., & Burt, E. (2018). The Dynamical Linkage of Atmospheric Blocking to Drought, Heatwave and Urban Heat Island in Southeastern US: A Multi-Scale Case Study. Atmosphere, 9 (33).

Fischer, E. M., Seneviratne, S. I., Lüthi, D., & Schär, C. (2007). Contribution of land-atmosphere coupling to recent European summer heat waves. Geophysical Research Letters, 34 (L06707).

Lee, E., Bieda, R., Shanmugasundaram, J., & Basara Richter, H. (2016). Land surface and atmospheric conditions associated with heat waves over the Chickasaw Nation in the South Central United States. Journal of Geophysical Research: Atmospheres, 121, 6284–6298.

Meehl, G. A., & Tebaldi, C. (2004). More Intense, More Frequent, and Longer Lasting Heat Waves in the 21st Century. Science, 305 (5686), 994–997.

Millin, O. T., Furtado, J. C., & Basara, J. B. (2022). Characteristics, Evolution, and Formation of Cold Air Outbreaks in the Great Plains of the United States. Journal of Climate, 35 (14), 4585–4602.

Miralles, D. G., Gentine, P., Seneviratne, S. I., & Teuling, A. J. (2019). Land–atmospheric feedbacks during droughts and heatwaves: state of the science and current challenges. Annals of the New York Academy of Sciences,1436 (1), 19–35.

Neal, E., Huang, C. S. Y., & Nakamura, N. (2022). The 2021 Pacific Northwest Heat Wave and Associated Blocking: Meteorology and the Role of an Upstream Cyclone as a Diabatic Source of Wave Activity. Geophysical Research Letters, 49 (e2021GL097699).

Philip, S. Y., Kew, S. F., van Oldenborgh, G. J., Anslow, F. S., Seneviratne, S. I., Vautard, R., . . . Otto, F. E. L. (2022). Rapid attribution analysis of the extraordinary heat wave on the Pacific coast of the US and Canada in June 2021. Earth System Dynamics, 13, 1689–1713.

Rempel, A. R., Danis, J., Rempel, A. W., Fowler, M., & Mishra, S. (2022). Improving the passive survivability of residential buildings during extreme heat events in the Pacific Northwest. Applied Energy, 321 (119323).

Shafiei Shiva, J., Chandler, D. G., & Kunkel, K. E. (2019). Localized Changes in Heat Wave Properties Across the United States. Earth's Future, 7, 300–319.

Smith, T. T., Zaitchik, B. F., & Gohlke, J. M. (2013). Heat waves in the United States: definitions, patterns and trends. Climatic Change, 118, 811–825.

White, R. H., Anderson, S., Booth, J. F., Braich, G., Draeger, C., Fei, C., . . . West, G. (2023). The unprecedented Pacific Northwest heatwave of June 2021. Nat Commun, 14 (727).