The Different Stratospheric Mechanisms Influencing the Formation of Cold Air Outbreaks in the Great Plains of the United States

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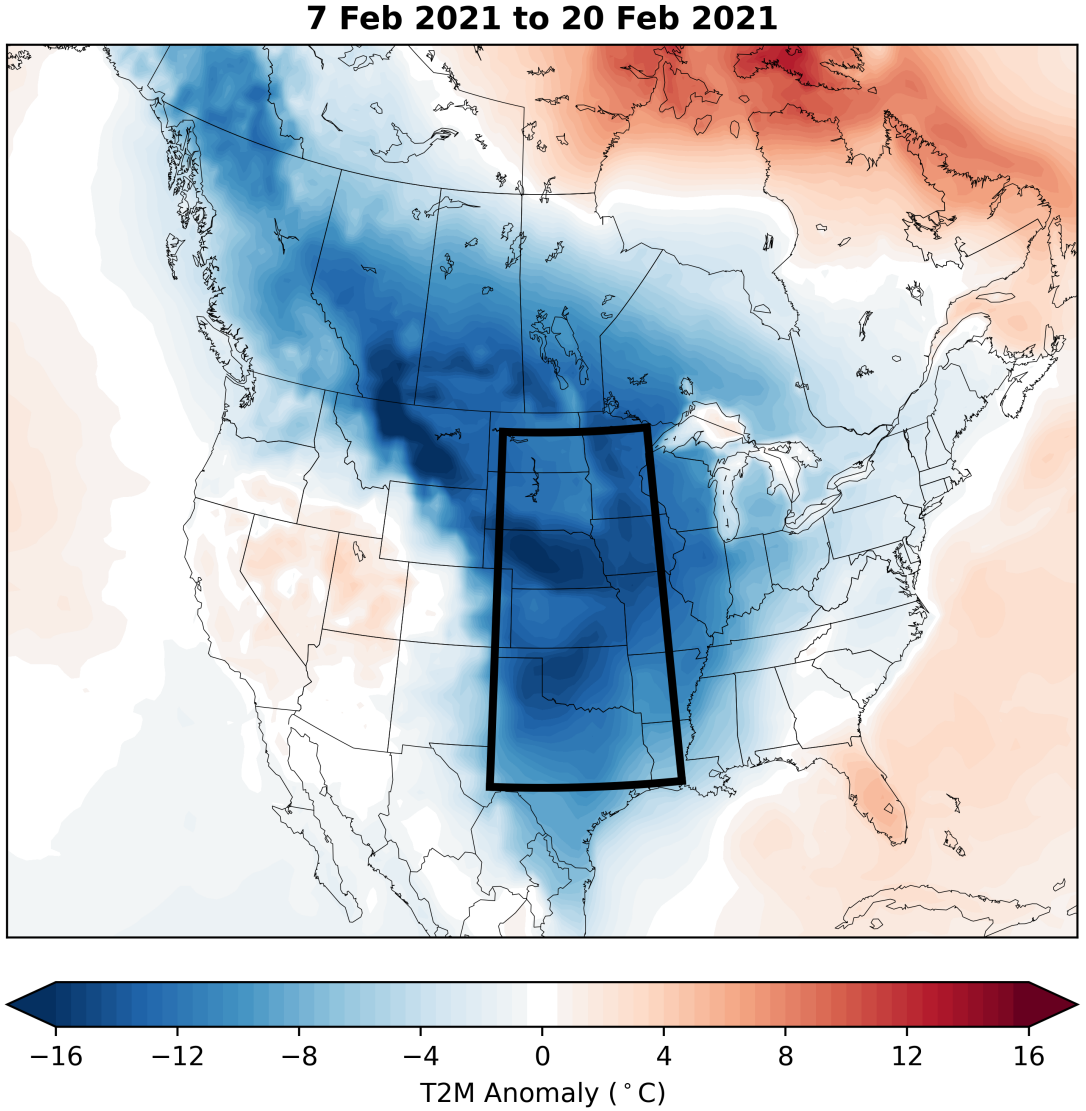
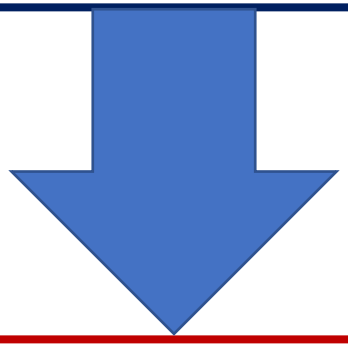
Motivation

- Wintertime cold air outbreaks (CAOs) are **high-impact** extreme events.
- The **February 2021 CAO** in the Great Plains featured **very cold temperatures.**
- **Widespread power outages** occurred in Oklahoma and Texas due to surging heating demand.



Research questions

1. What are the dynamics/characteristics of these events?

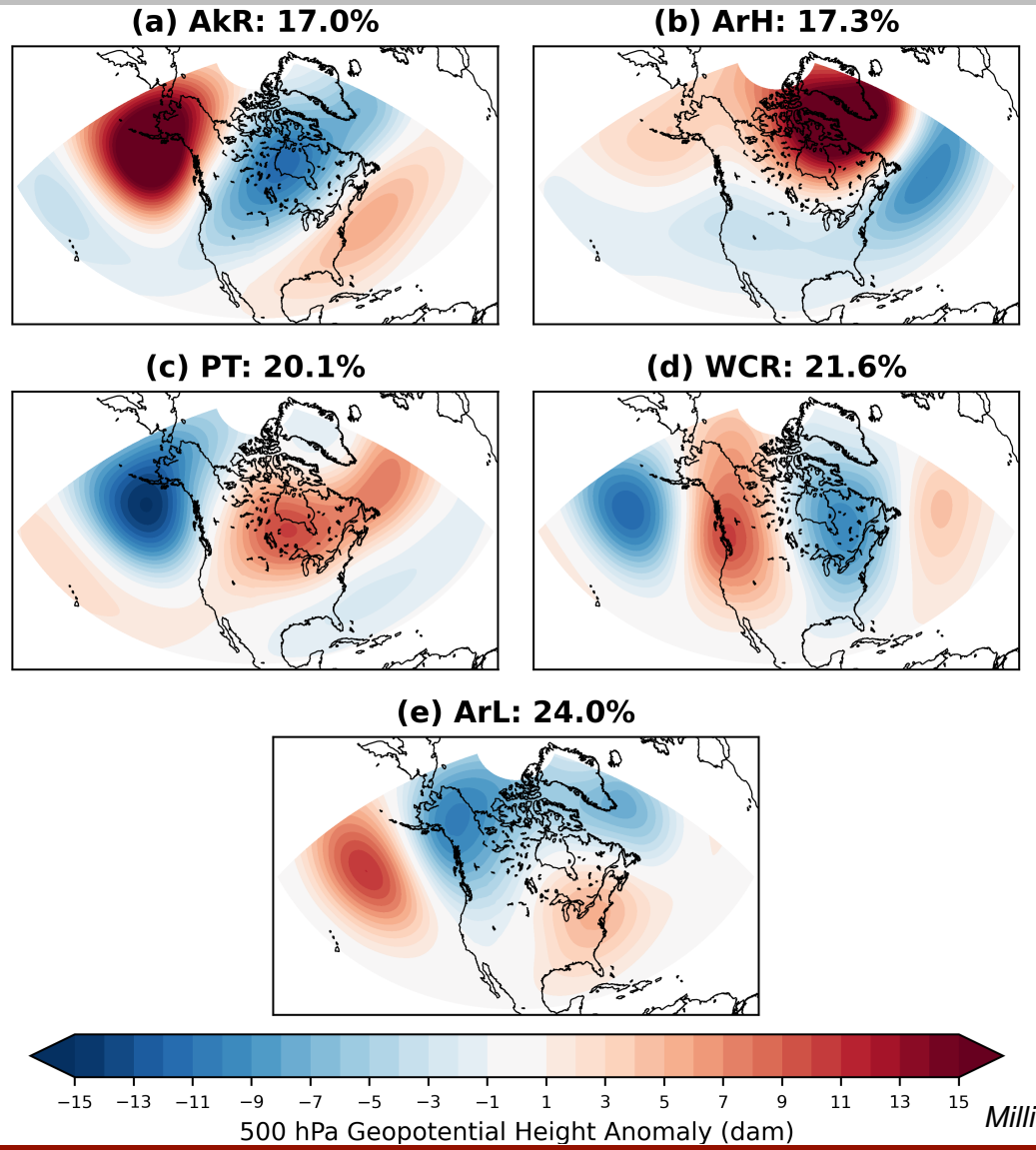


2. Is there predictability potential for these events 2-8 weeks out (i.e., subseasonal-to-seasonal timescale, S2S)?

Common North American winter weather patterns (regimes)

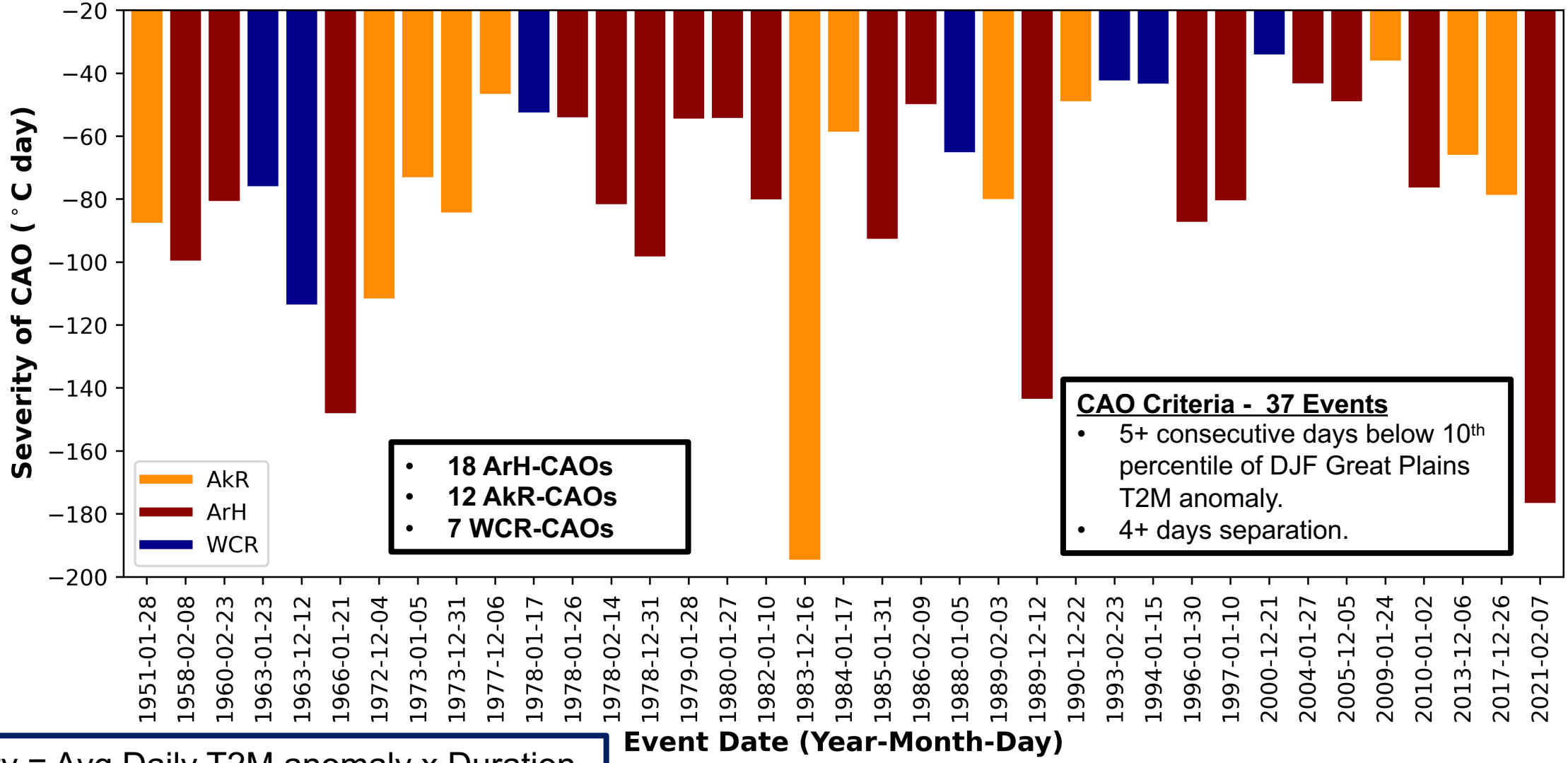
<u>This study uses ERA5 reanalysis data from 1950-2021.</u>

- Nov-March 500 hPa geopotential height anomalies are **clustered into 5 main North American weather regimes.**
- EOF and *k*-means framework (Lee et al. 2019).
- Each day is assigned a regime:
  - Alaskan Ridge (AkR)
  - Arctic High (ArH)
  - Pacific Trough (PT)
  - West Coast Ridge (WCR)
  - Arctic Low (ArL)



Millin et al. (2022), J. Clim.

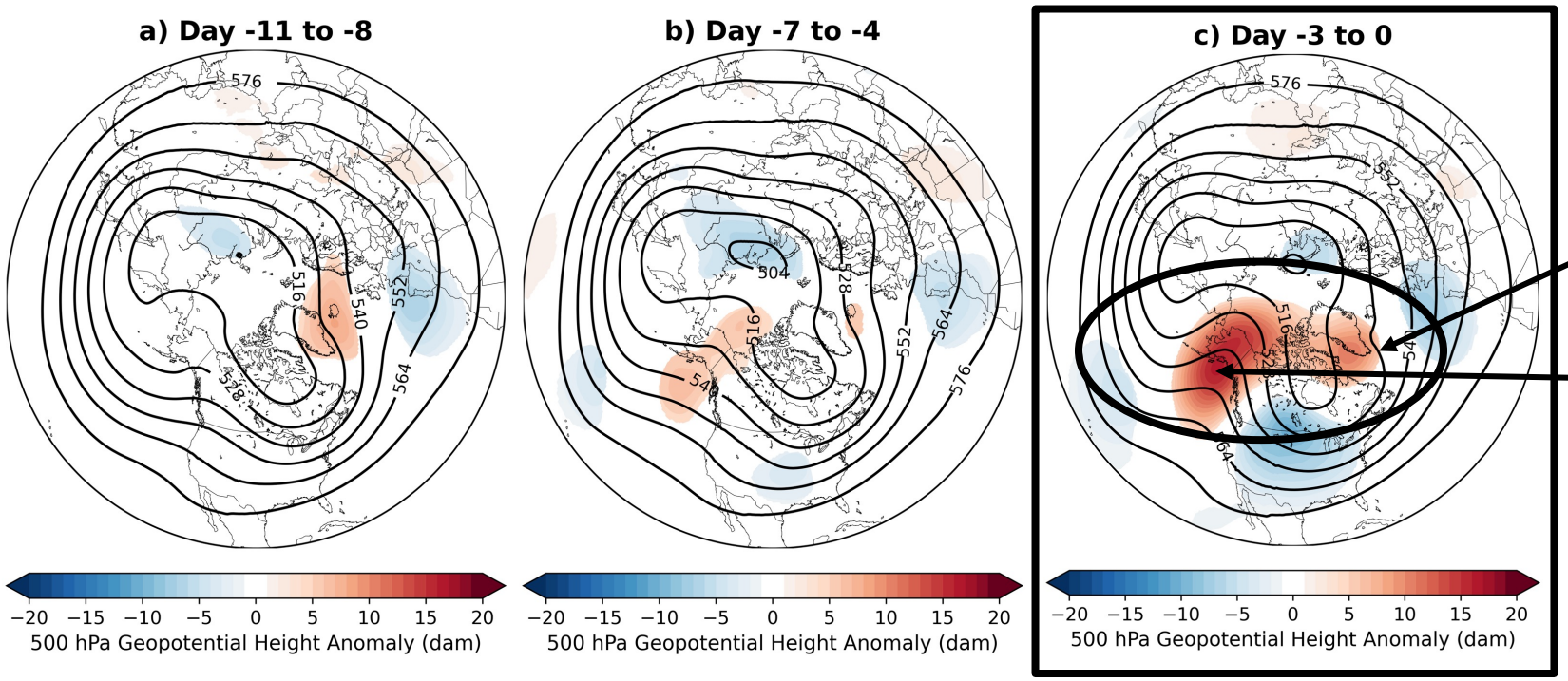
The Great Plains CAOs



Severity = Avg Daily T2M anomaly x Duration

Millin et al. (2022), J. Clim.

500 hPa GPH Anomaly Composites



Arctic High (ArH)

Alaskan Ridge (AkR)

The ArH and AkR have previously been associated with CAOs and stratosphere polar vortex (SPV) variability.

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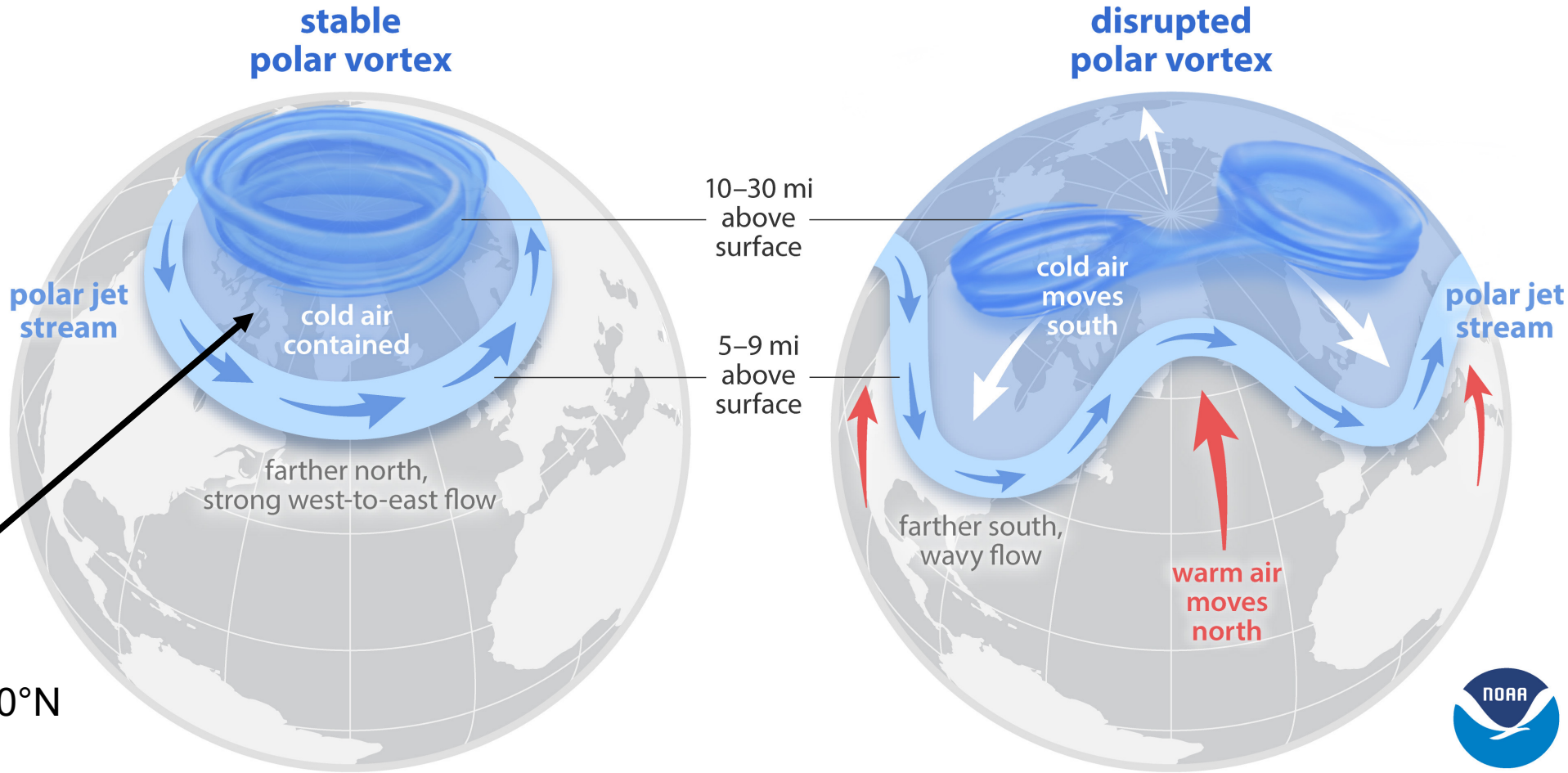
The Stratospheric Polar Vortex

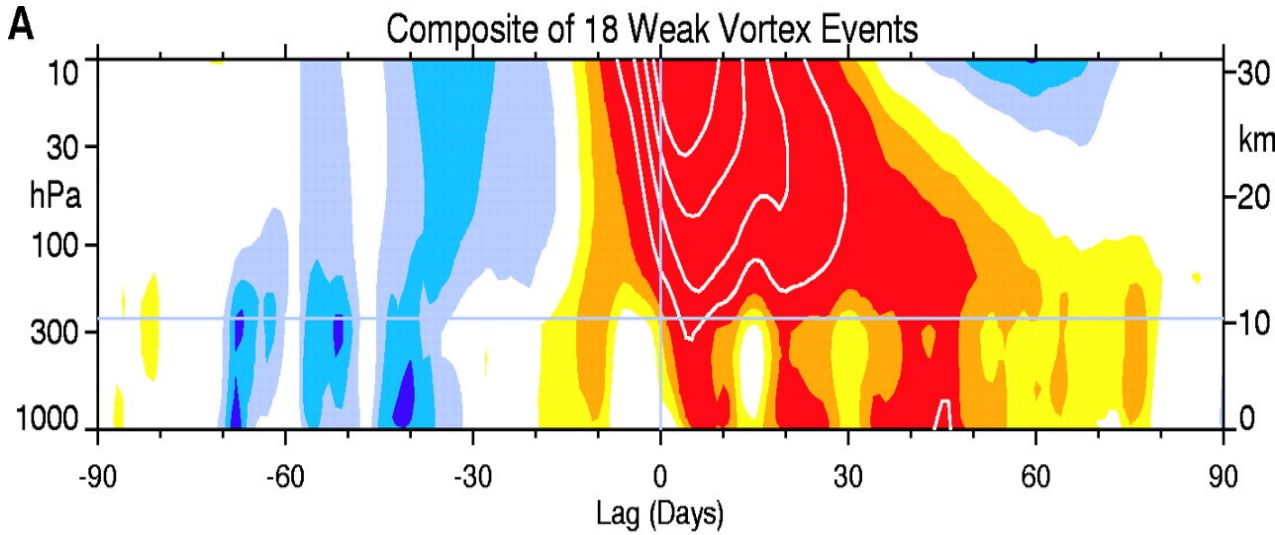


Polar cap: 60-90°N

NOAA (2021).

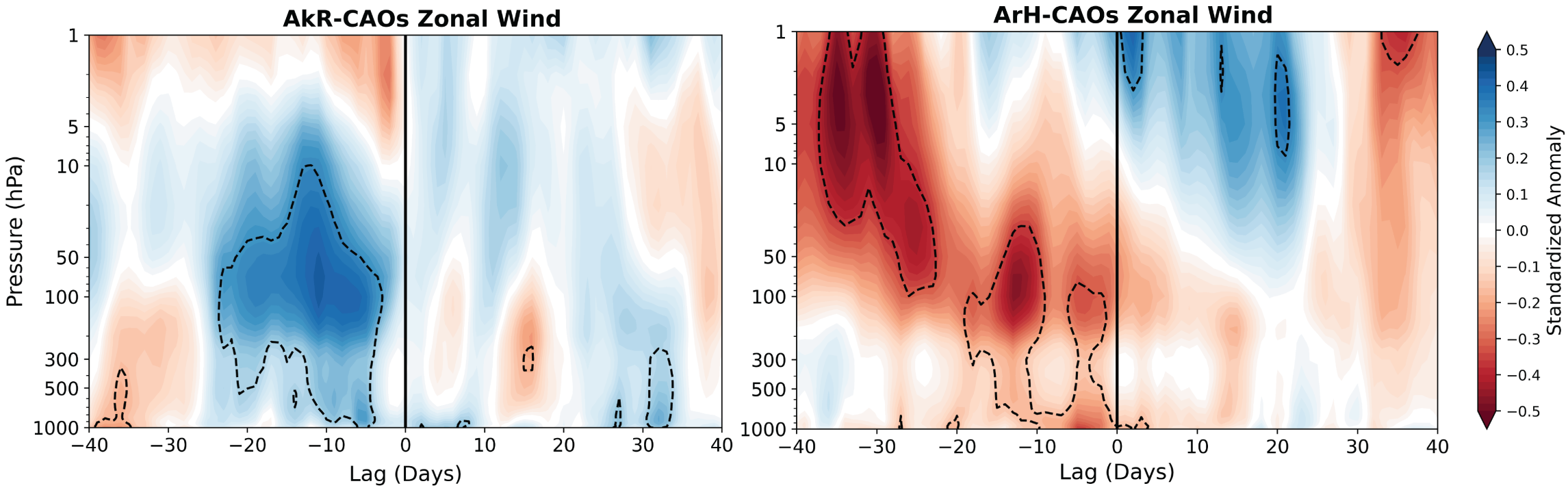
SPV variability – a tool for CAO predictability?

- **Wave driving** into the stratosphere can cause the **SPV to weaken and warm abruptly**.
- Weak vortex conditions can **propagate to the surface** on S2S timescales.
- Often, the downward propagation can result in an **enhanced risk of Northern Hemisphere wintertime CAOs**.



Baldwin and Dunkerton (2001).

SPV Variability



Strong Vortex

Weak Vortex

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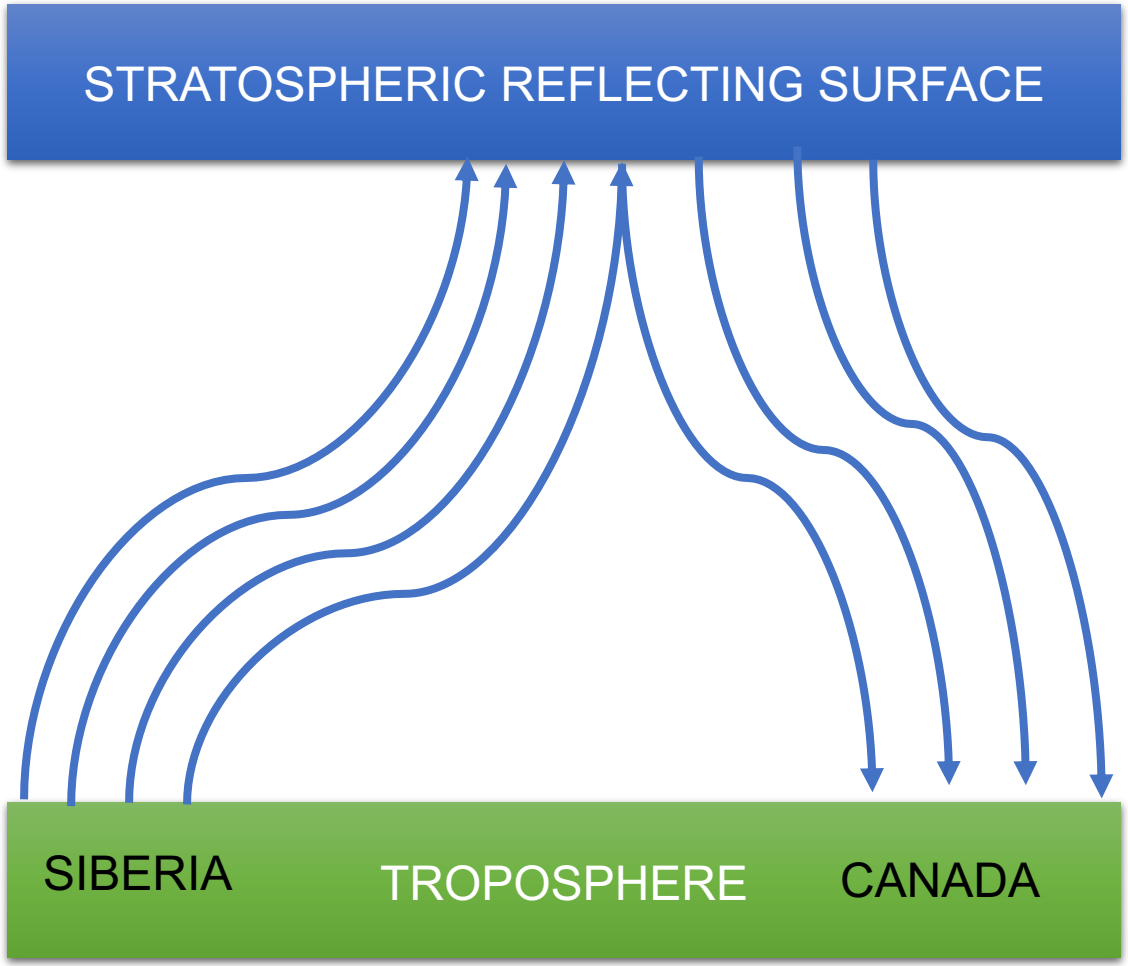
Two opposing signals suggest that **different forcing dynamics** may be occurring, with different S2S predictability potential.

Stratospheric Wave Reflection - An Additional Mechanism

- **Stratospheric wave reflection** has links with North American CAOs (Matthias and Kretschmer, 2020).
- **Upward wave activity from the Siberian troposphere.**
- The **stratosphere "acts like a mirror"** under certain configurations, e.g., peak in stratospheric winds.
- **Wave activity is reflected** into the Canadian troposphere – **enhances the wave pattern.**



Schematic for stratospheric wave reflection.

Stratospheric Wave Reflection and Great Plains CAOs

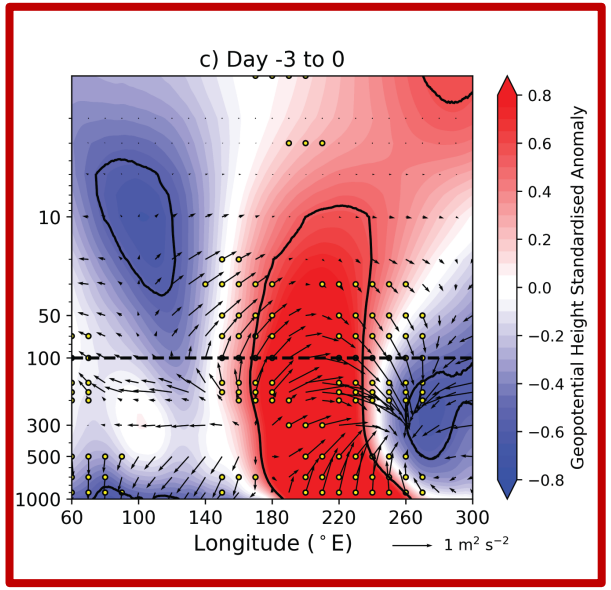
- A **rapid development of stratospheric wave reflection** occurs between Days -3 to 0 for AkR-CAOs.
- Upward waves from the Siberian troposphere into the stratosphere.
- Downward waves into the Canadian troposphere from the stratosphere.

- Such wave reflection is not seen for ArH-CAOs.

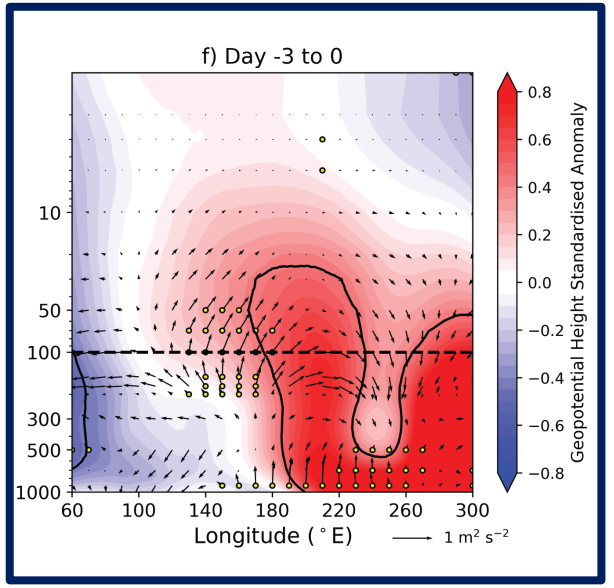
- The rapid development of wave reflection alongside a strong **North Pacific wave train** (not seen in ArH-CAOs).

→ **Tropical remote forcing?**

AkR-CAOs



ArH-CAOs



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Summary

1. The dominant onset day regimes for Great Plains CAOs were the Alaskan Ridge and the Arctic High.
2. AkR-CAOs involve a strong SPV and stratospheric wave reflection, whereas ArH-CAOs feature a longer timescale downward propagation of weak SPV conditions.
3. Both types of Great Plains CAO have potential for S2S predictability through stratospheric and/or tropical connections.

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