# Changing midlatitude wind extremes in VR-CESM

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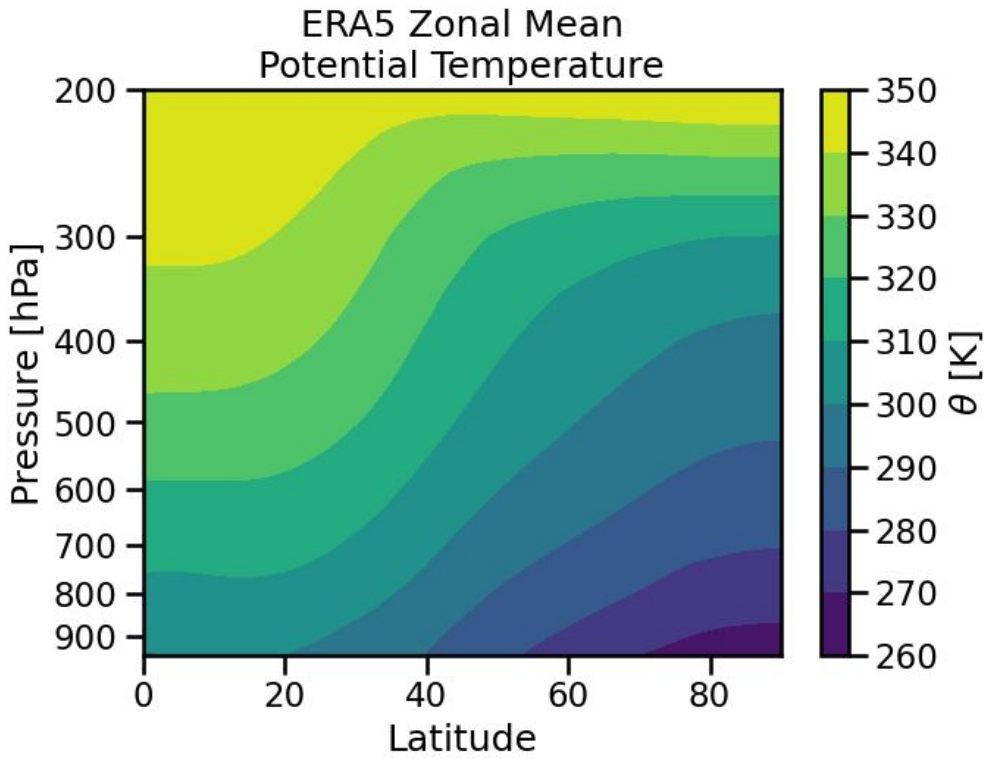
# A tug-of-war between local and large-scale changes

- **Large-scale:**
  - Midlatitude extreme winds are associated with Extratropical Cyclones (ETCs)
  - ETCs may become less common as the equator-to-pole temperature gradient weakens under climate change



# A tug-of-war between local and large-scale changes

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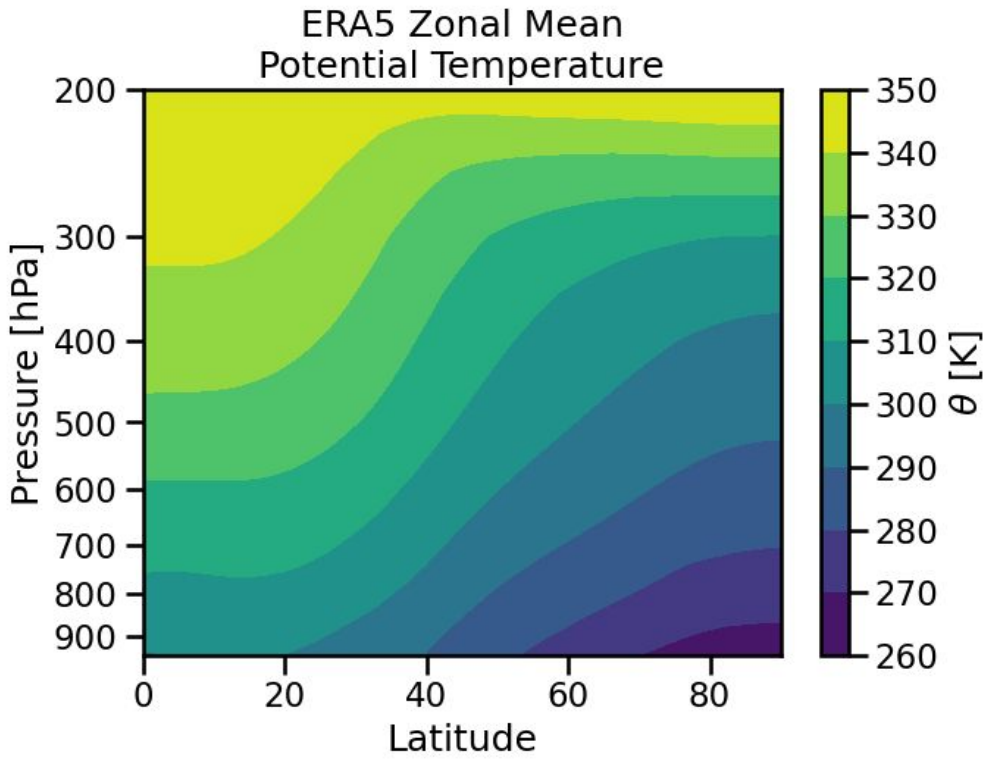
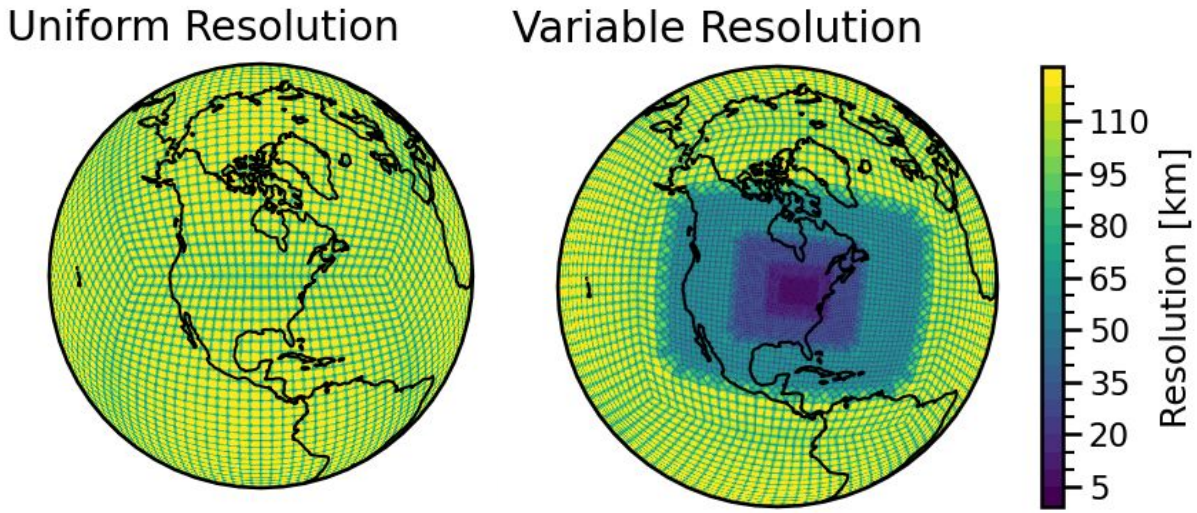
  - Midlatitude extreme winds are associated with Extratropical Cyclones (ETCs)
  - ETCs may become less common as the equator-to-pole temperature gradient weakens under climate change
- **Local-scale:**
  - Land / air heat capacity contrast may lead to increased sensible heat fluxes and reduced boundary layer stability in a warmer climate



# Extreme Wind Events in Southern Ontario (Sep.-May) (Morris et al. 2024)

| | Coarse Model | VR Model |
|---|---|---|
| ETC Strength | Decreased | Decreased |
| Extreme wind speeds | Decreased | Increased |




- Refined resolution improves the representation of 3D turbulence
- The VR model can resolve local changes to sensible heat flux and static stability
- In the VR model, local destabilization leads to increased vertical momentum mixing and faster extreme wind speeds

# Questions

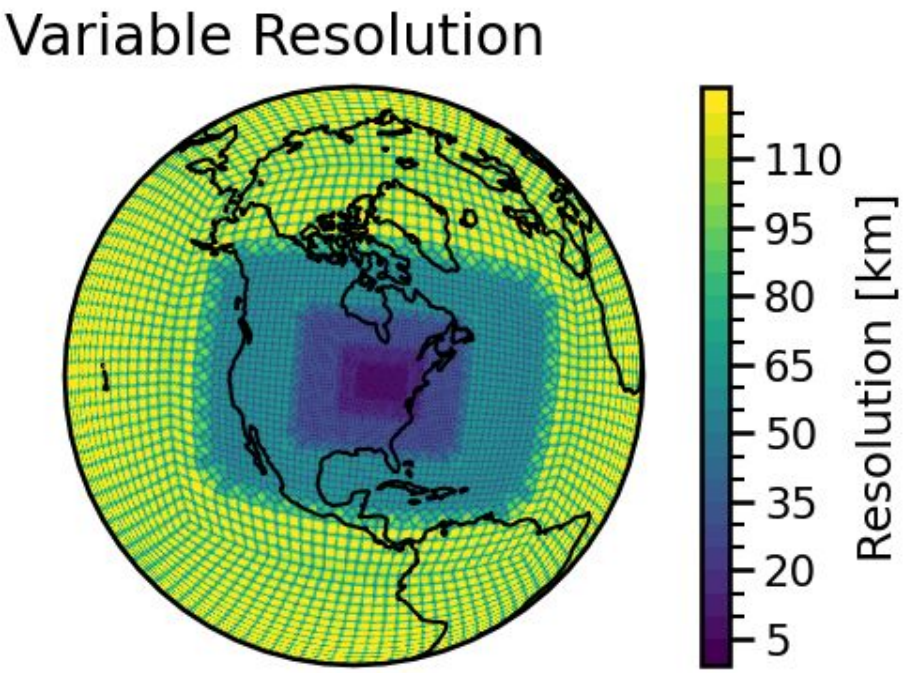
- SHFLX depends on wind speed, so a simple causal relationship is not clear

$$SHFLX = -\rho c_p c_H \overline{u}(\theta_A - \theta_S)$$

- Morris et al. 2024 did not investigate the seasonality of the climate change signal

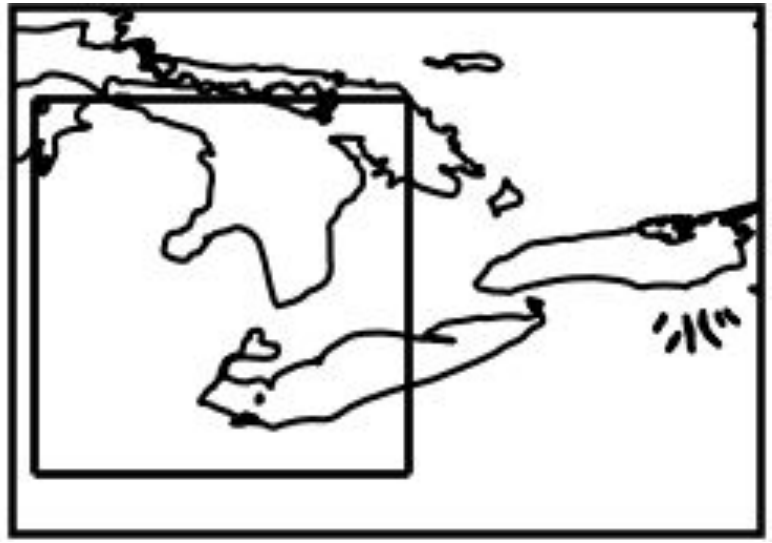
# CESM-SE Simulations

- CESM2 with CAM5 physics and CLM5
- Data from two sets of runs: **2000s** control period and **2090s** climate change scenario
- 30-year “time-slice” simulations
- Yearly recurring boundary conditions from CESM2.1.0 **F2000C5 / RCP8.5C5** component sets, including monthly prescribed SSTs and SICs
- Cubed sphere grid, with ~110 km resolution
- Refined region up to **~7 km** resolution



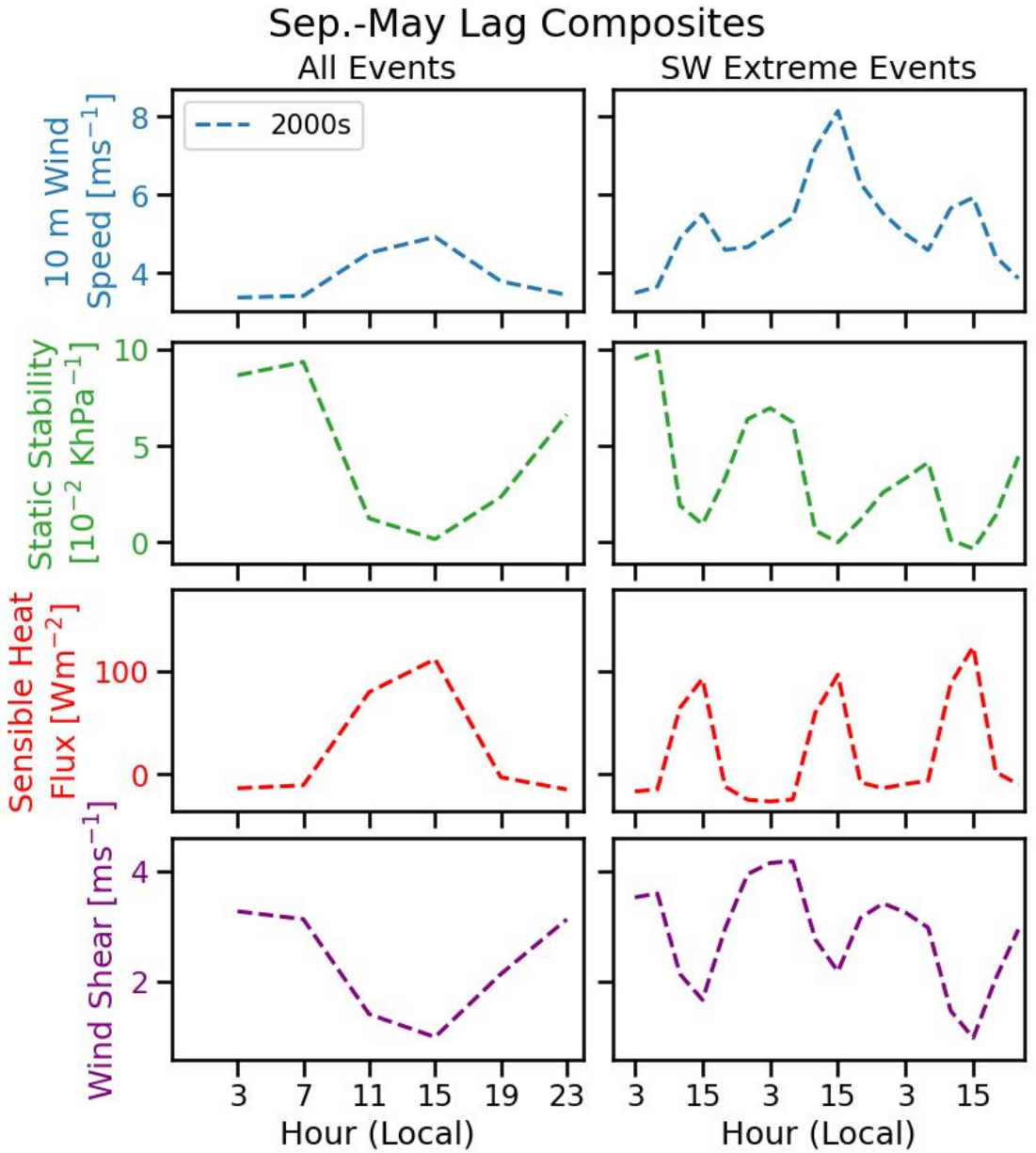
# Determining extreme wind events

- An extreme wind event occurs when the following conditions are met:
  1. **Wind Speed:** 98$^{th}$ percentile wind speed threshold at each grid cell
  2. **Area:** 25% of the region must exceed the speed threshold
  3. **Time:** If more than one extreme occurs within a 24-hour period, only the strongest is kept
- Events are categorized by wind direction (NE, NW, SE, SW)
- I focus on SW extremes



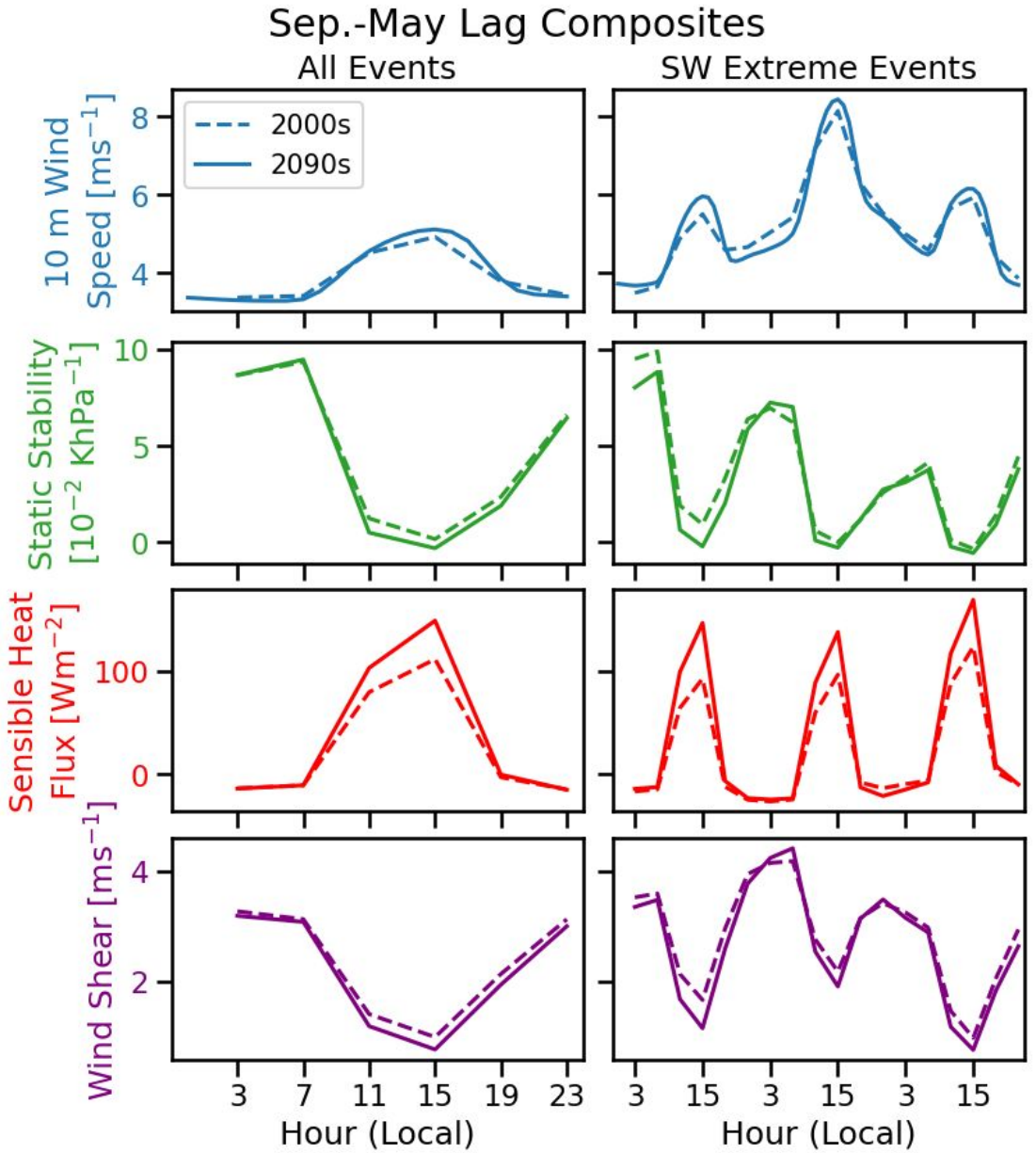
# How do extreme events compare to the mean diurnal cycle?

- The fastest winds occur in the mid-afternoon, characterized by low stability and high SHFLX
- Peak wind speeds occur following a decrease of wind shear
- Extreme wind events occur in a stronger wind shear environment



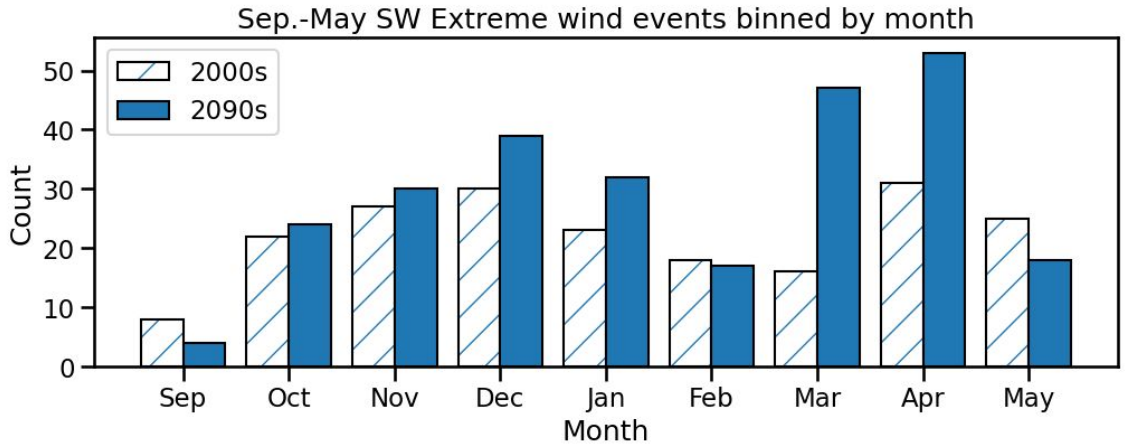
# Causality is unclear

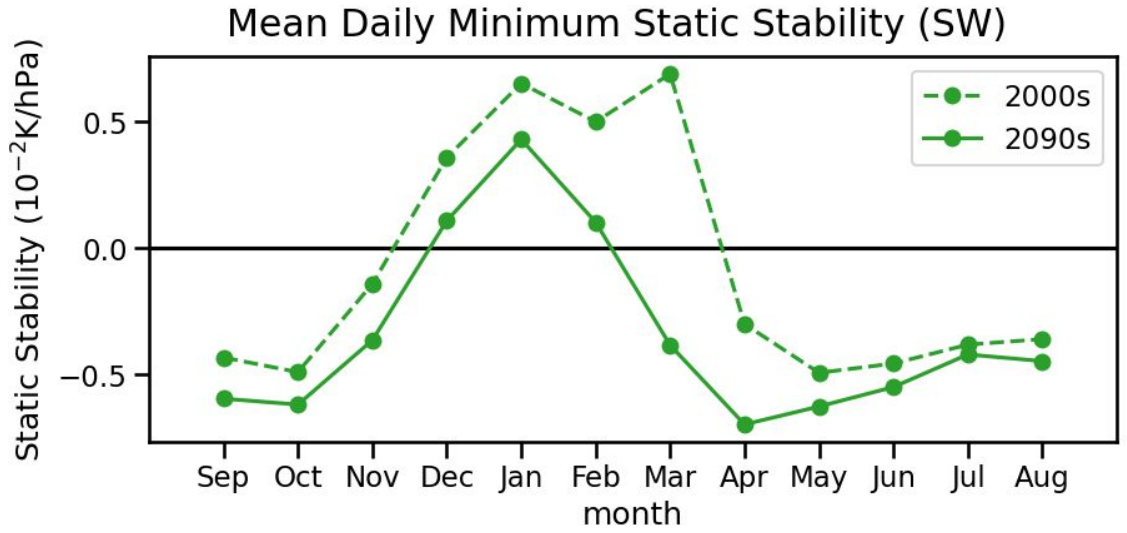
- Increased peak winds in the 2090s are coincident with reduced stability, increased sensible heat flux, and reduced windshear
- As there are no lags between these fields, a causal relationship cannot be determined



# Spring events dominate the climate change signal

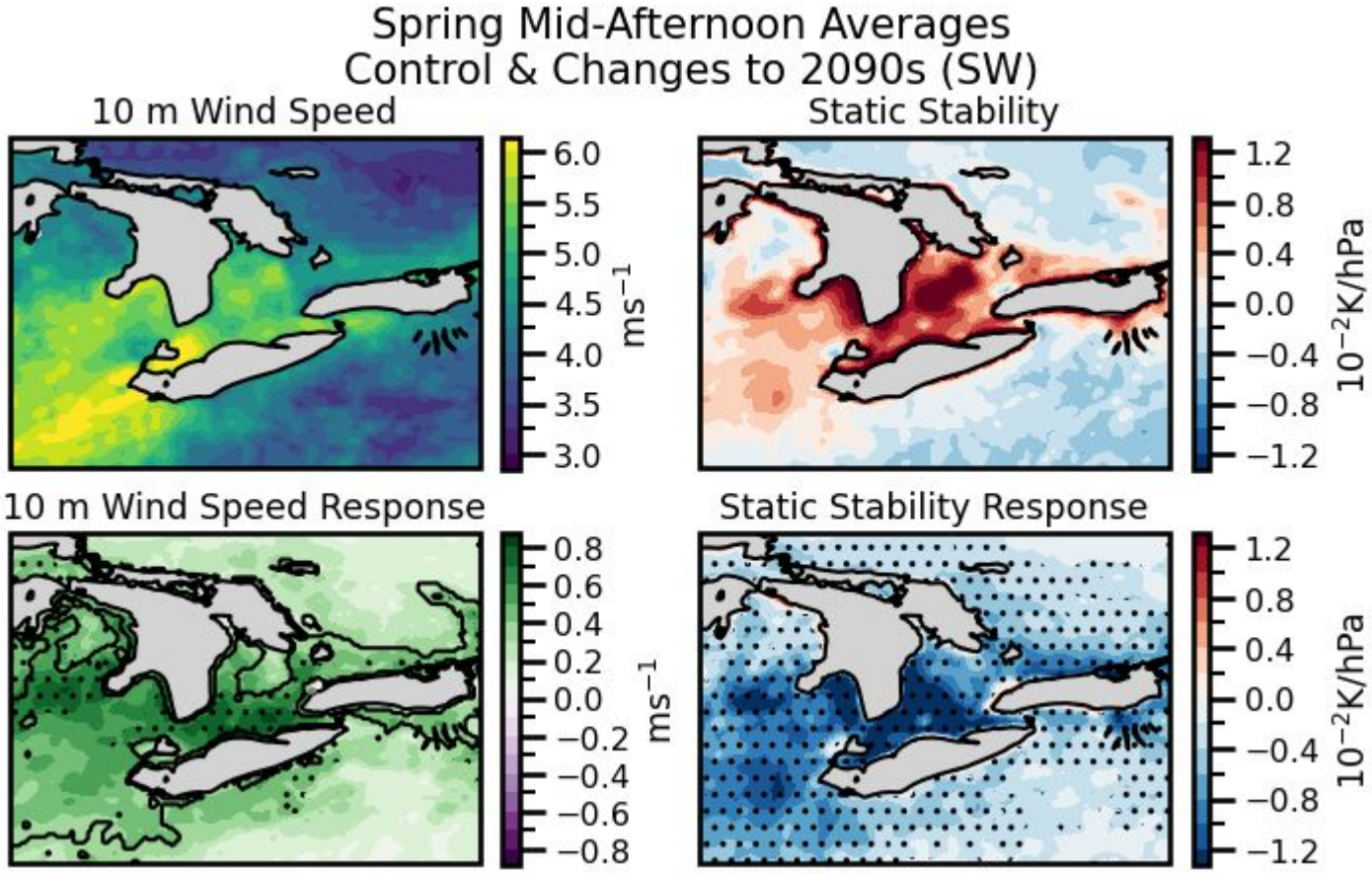
- March events more than double in frequency
- March destabilizes in the 2090s, with conditions resembling the control summer months
- Ma et al. 2025 found increased probability for destructive winds under convectively unstable conditions in Southern Ontario



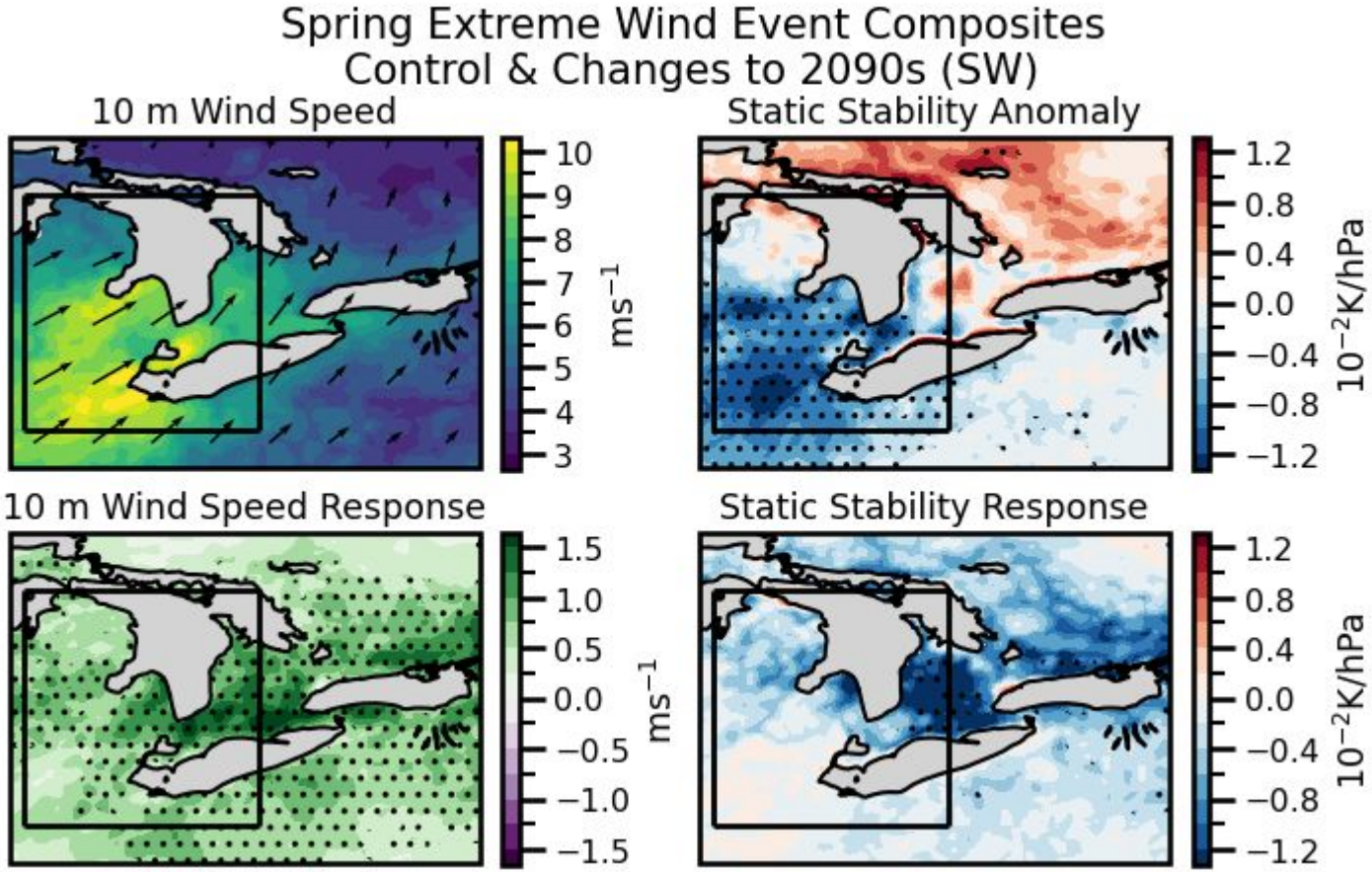
# Mid-afternoon wind speed changes with stability

- Most of the stable region in the control is destabilized in the 2090s
- Greatest increases to mid-afternoon wind speeds occur in the destabilized region



# Changes to extremes reflect changes to mid-afternoon conditions

- Extreme wind events are characterized by low static stability anomaly
- Spatial pattern in extreme wind response is similar to mid-afternoon wind response (R=0.6)
- Largest increases to extreme wind speeds are co-located with largest decreases to static stability



# Discussion

- Refined resolution leads to improved representation of local conditions associated with extreme wind speeds
- Changes to the diurnal cycle in winds speeds and SHFLX are reflected in changes to extreme wind events, but the causal relationship between these changes remains elusive
- The increase in frequency of extreme wind events can be understood in terms of the changes to daily minimum static stability
- Changes to spring season extreme wind speeds in VR-CESM appear to be controlled in part by changes to mean mid-afternoon conditions

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