



National Laboratory  
of the Rockies

# Data-Driven Analysis of Wildfire Weather Drivers Across Past and Future Conditions

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Strategic Energy Analysis Center, NLR  
ESIG Summer Workshop 2026

# Surface Wind Modelling

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Challenges for wildfire risk

# Challenges in Modelling Surface Winds

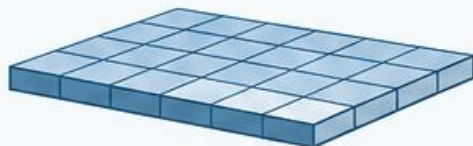
## NWP SURFACE MODEL (SIMPLIFIED REPRESENTATION)

VS.

## REAL EARTH SURFACE (COMPLEX REALITY)



REPRESENTATION  
OF THE SURFACE



Coarse grid cells (1–10+ km)  
with homogeneous surface  
properties per grid box.



Highly heterogeneous: mix of land uses, vegetation,  
topography, water, urban areas at meters to km scales.



SURFACE  
ROUGHNESS



Single roughness length ( $z_0$ )  
per grid cell.



Sub-grid variability in roughness from smooth water  
to tall buildings and hills.



TOPOGRAPHY

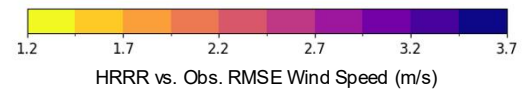
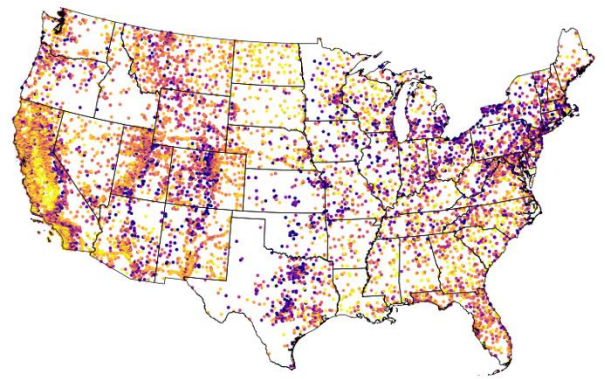
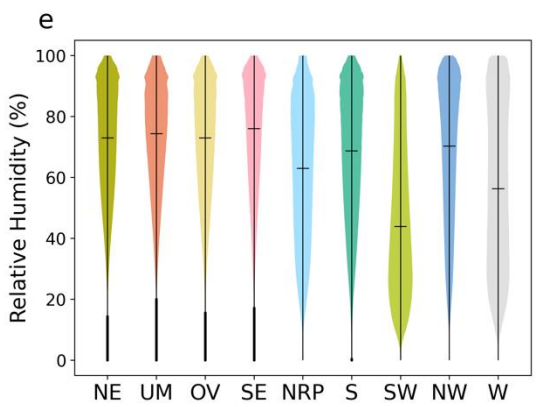
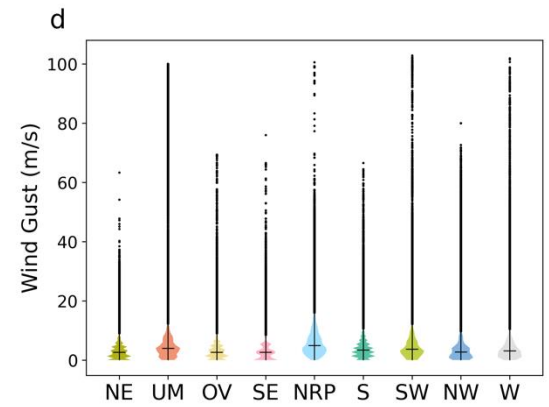
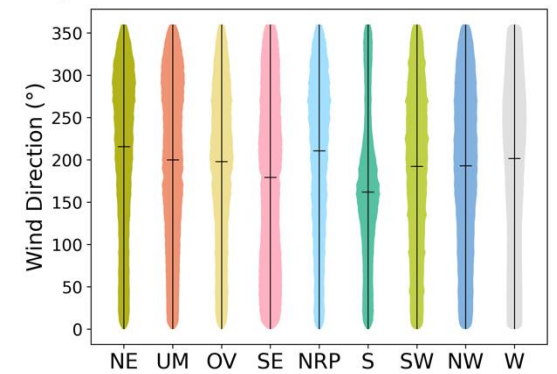
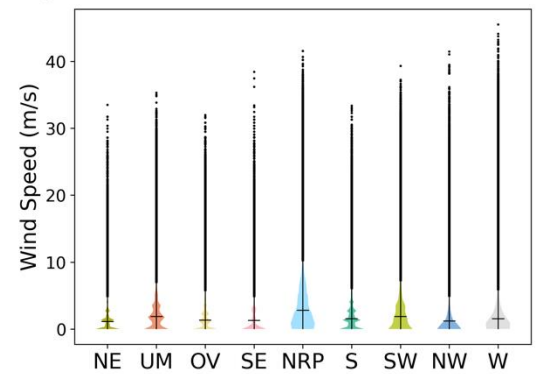
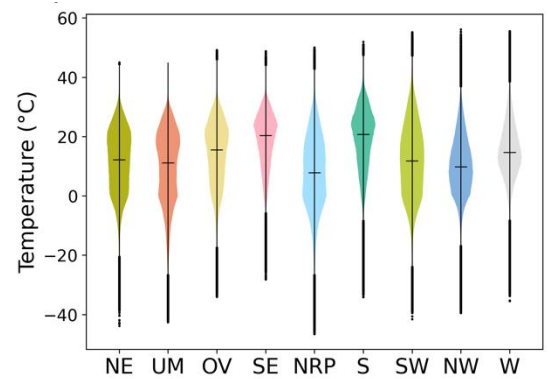


Smoothed terrain; small-scale  
hills and valleys are muted.

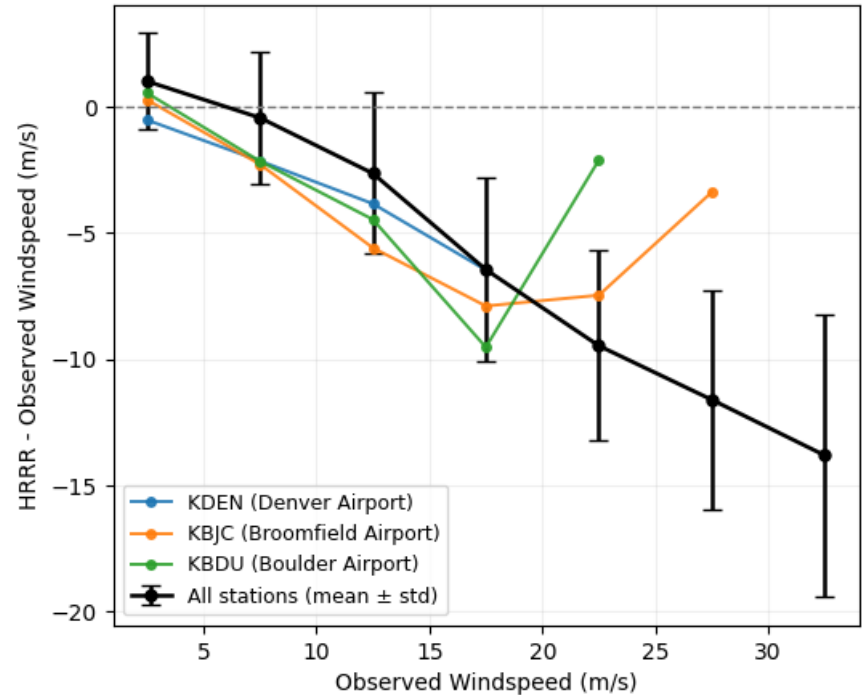
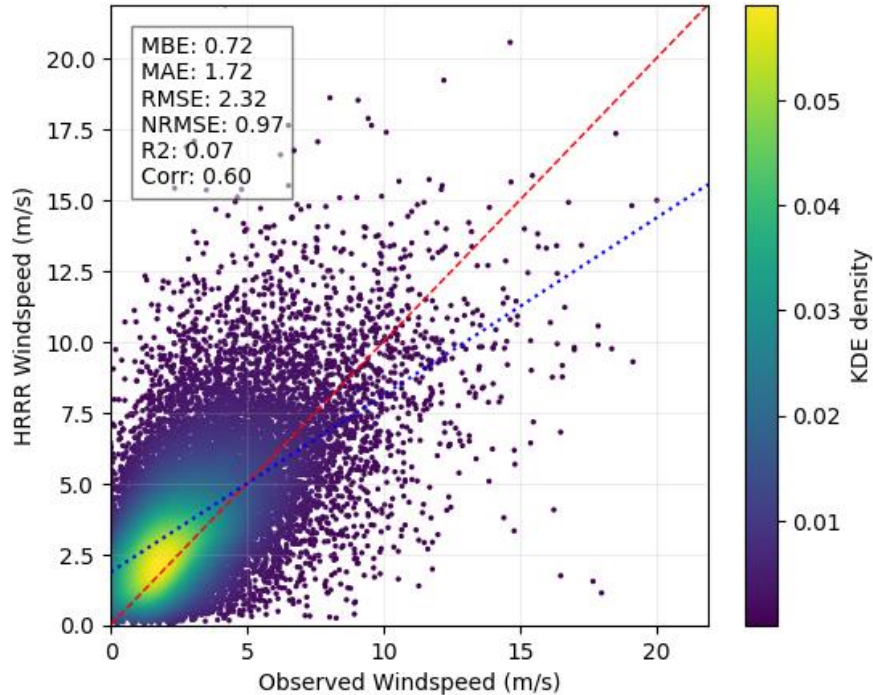


Complex terrain with ridges, valleys, slopes and  
channeling effects.

# A Benchmark Dataset for Near-Surface Observed Wind Speed Across the Conterminous United States (Bazlen et al., *in prep*)



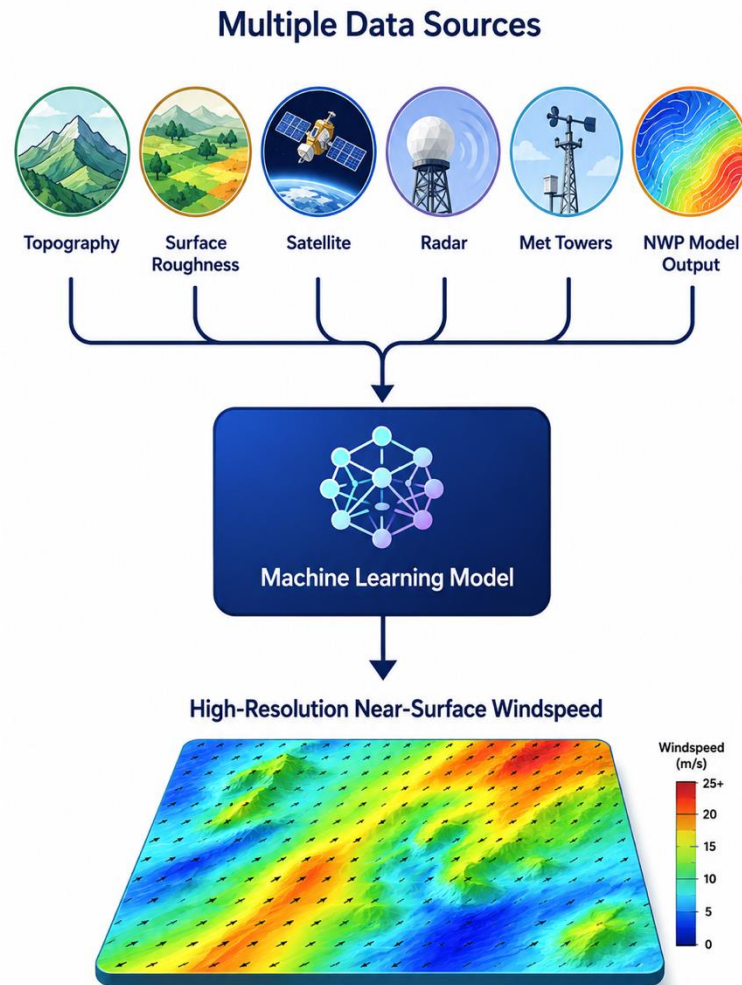
# Modelled Wind vs. Ground Measurements



- Model data taken from HRRR f02 modelled windspeed at 10m
- Based on quality-controlled data from 193 Colorado RAWS and METAR stations in 2021
- Similar results documented by [Collins et al., 2024](#)

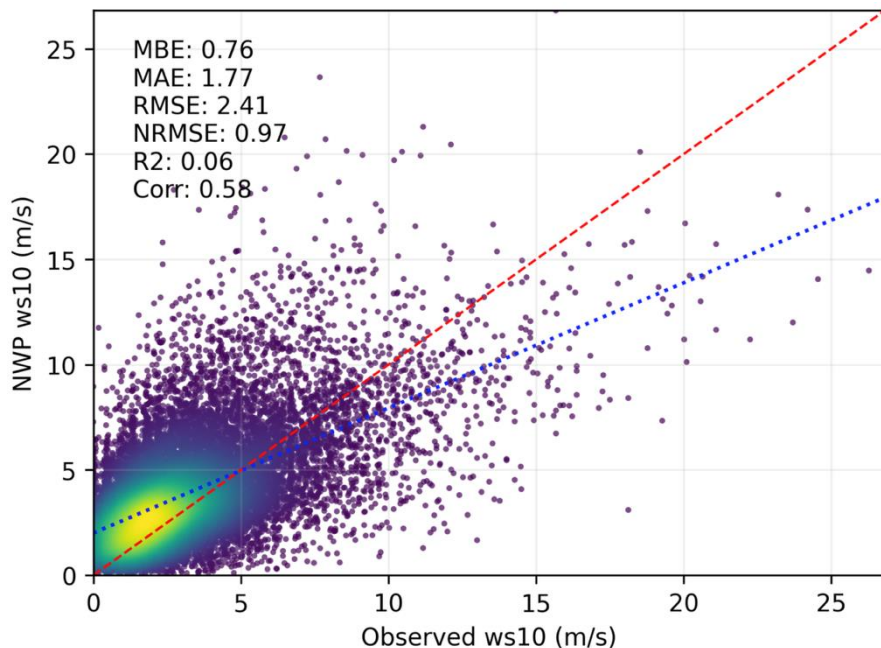
# Towards a Multi-Modal Downscaling Model for Surface Winds and Gusts

- Goal is to use all inputs available:
  - Topography
  - Surface roughness
  - Satellite
  - Radar
  - Met. towers
  - NWP
- Working on building unique features:
  - Sub-1km resolution
  - Conditional inference
  - Uncertainty quantification

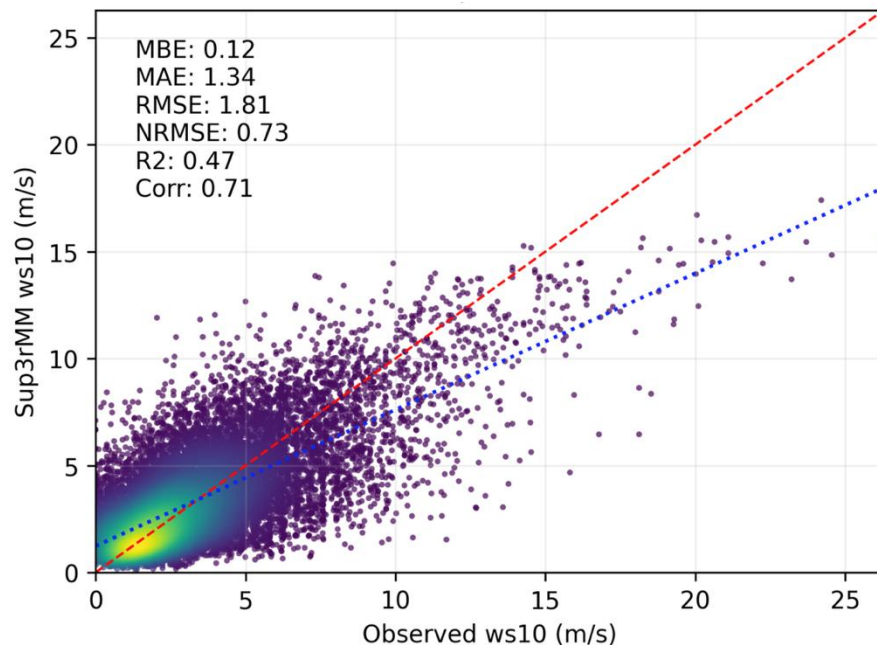


# Preliminary Results: Colorado Front Range

## HRRR



## ML Downscaling



- Substantial skill improvement with ML multi-modal downscaling
- Improved surface characterization leads to better predictions
- We still see regression to the mean and negative bias at high windspeeds

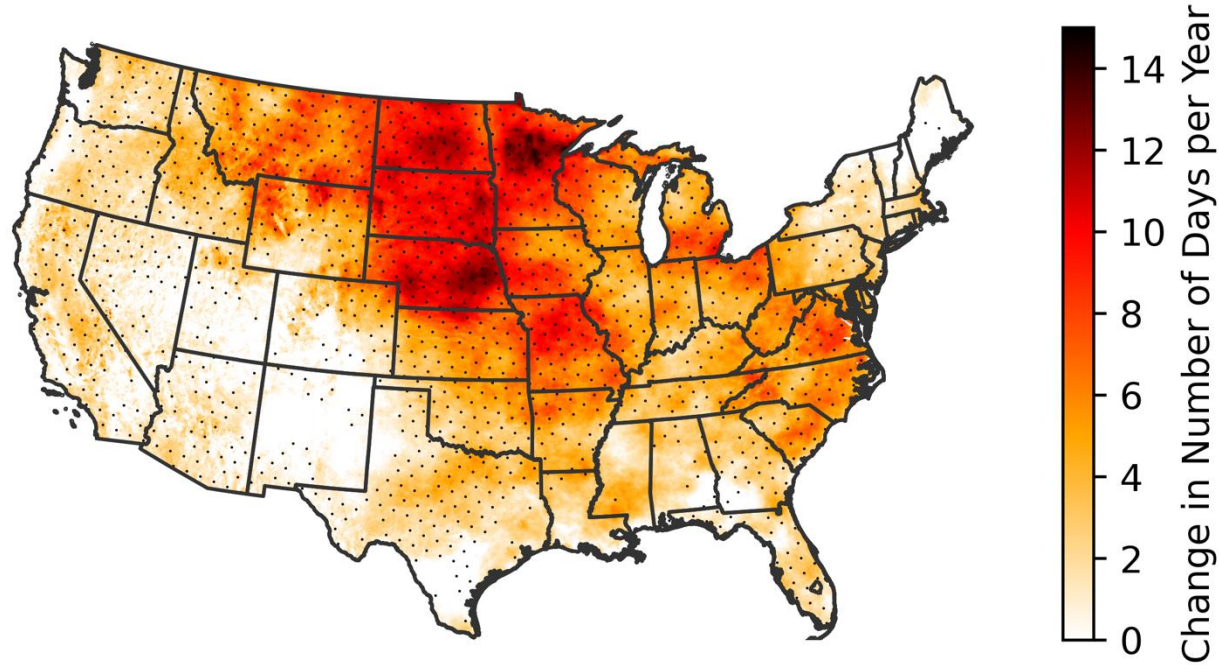
# Long Term Trends in Fire Weather

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Surprisingly dry

# Model-Projected Changes (2020-2039) in Extreme Fire Weather Days

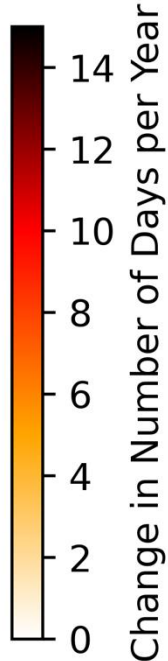
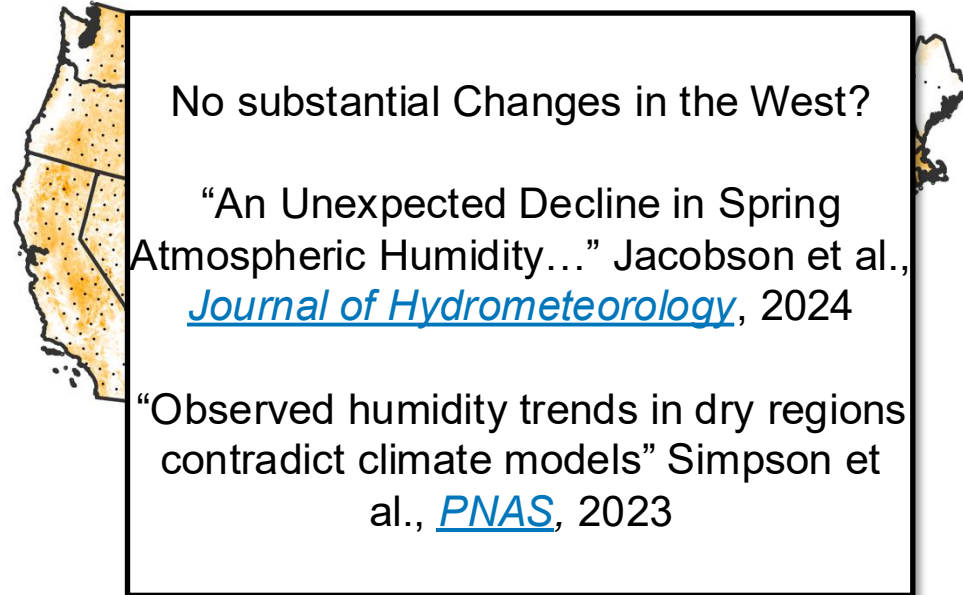
- Many large parts of the United States see modelled increases in extreme fire weather days by mid-century
- Based on the Canadian Fire Weather Index (FWI) averaged from 5x SSP2-4.5 scenarios from Sup3rCC<sup>1,2</sup>
- Stippling indicates 3/5 model agreement and statistical significance ( $p < 0.05$ )



*Extreme fire weather days are defined as greater than the 95<sup>th</sup> percentile FWI from 2000-2019 (18 extreme days per year in historical period)*

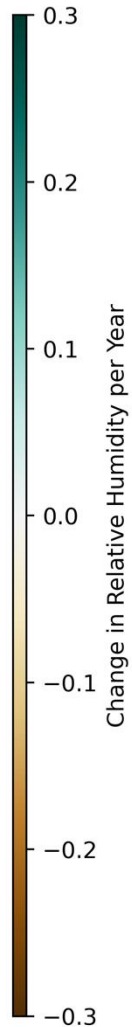
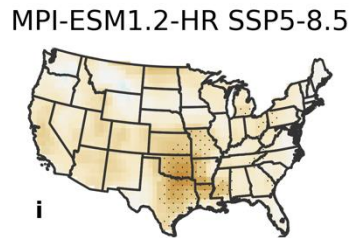
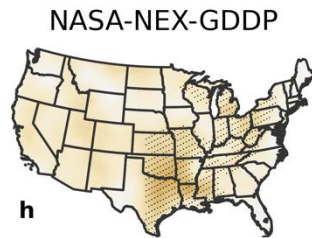
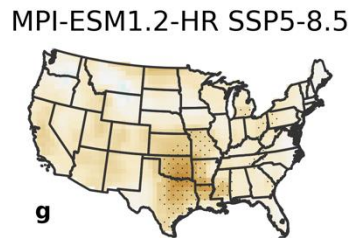
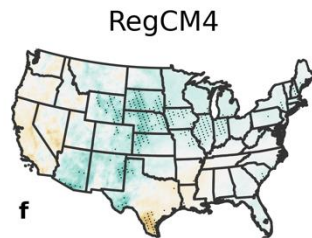
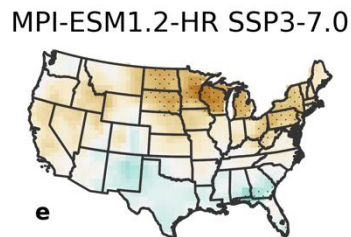
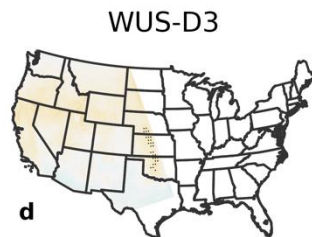
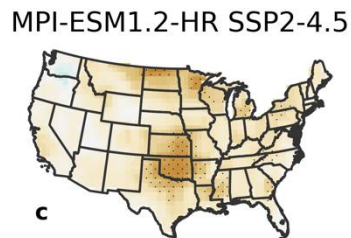
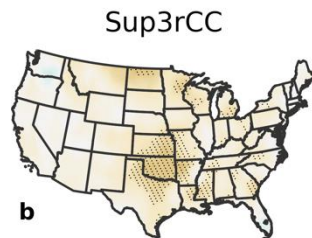
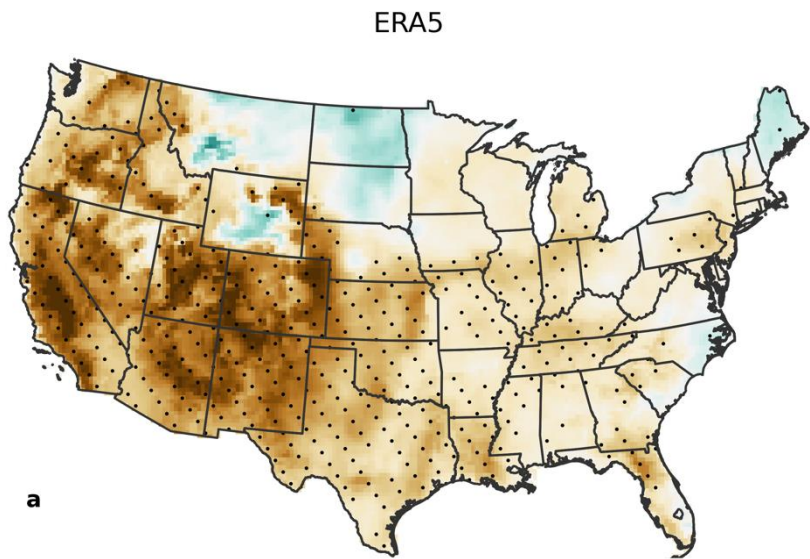
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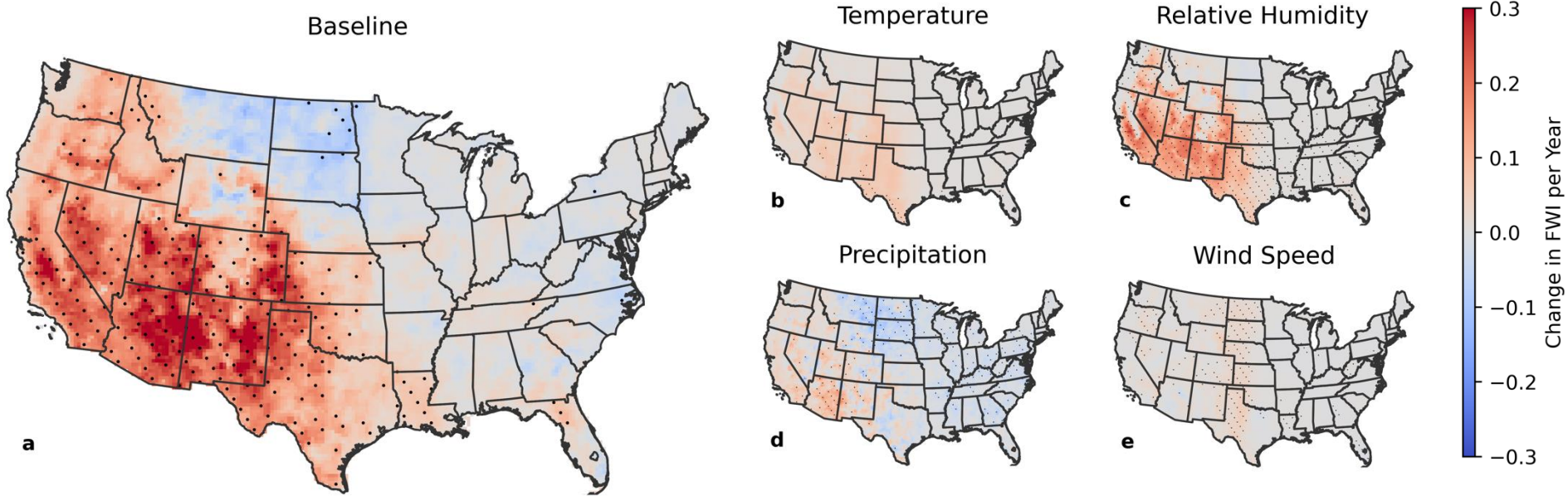


# Are We Underestimating Trends in Fuel Drying?

- We can see that in many locations in the American West, **declining trends in humidity are not reflected in ESMs or their downscaled counterpart**



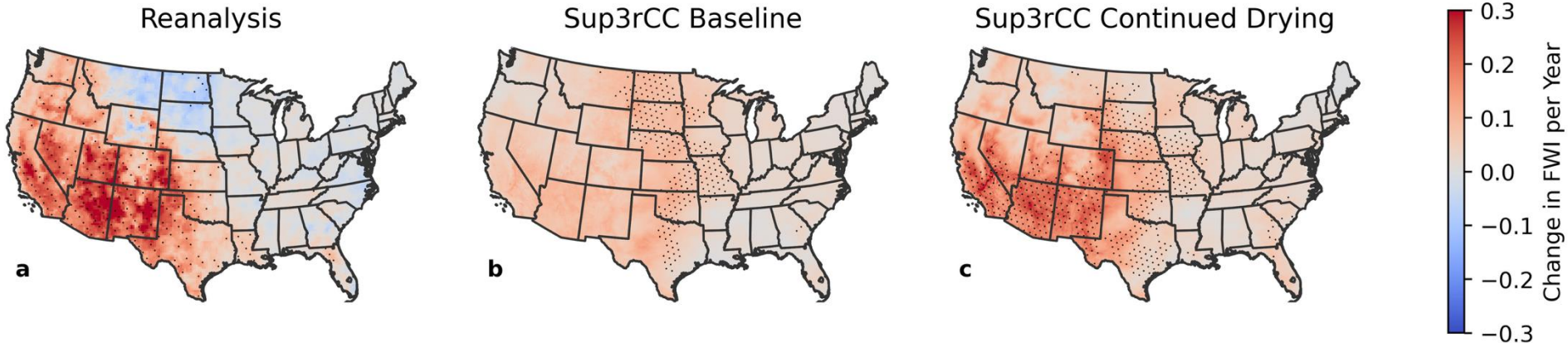
# What is the Role of Relative Humidity in Fire Weather?



- Over the last 40 years in the American West (1980-2019), **declining relative humidity has been the leading contributor to increased fire weather**, as measured by the Canadian Fire Weather Index (FWI)

# What if Drying Trends Continue?

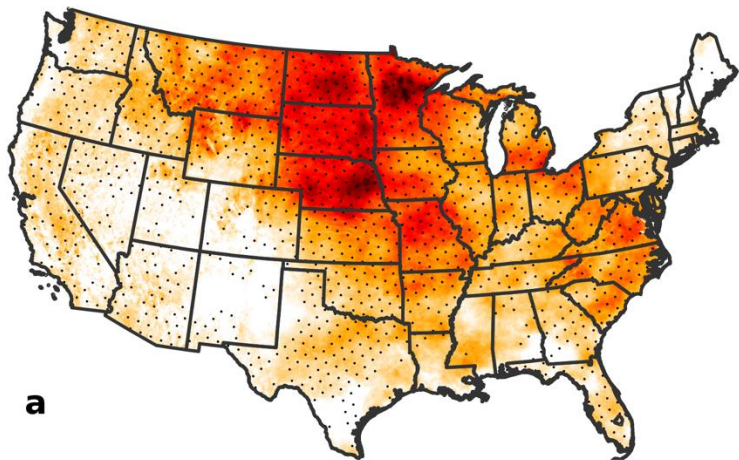
- Linear trends of FWI based on downscaled projections show little spatial variability and lower magnitude changes than we have observed in the historical record
- Correcting the relative humidity trend in the downscaled projections more closely matches our observed trends in FWI



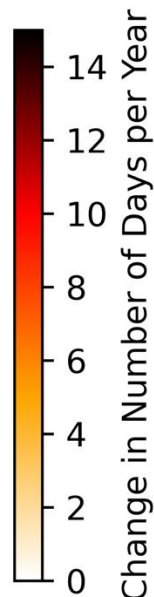
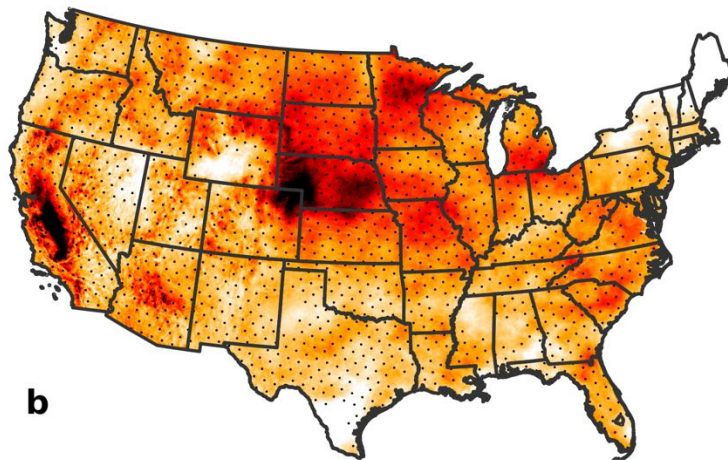
# Future Fire Weather Projections (2020-2039) with a Continued Drying Scenario

- Trend correction of relative humidity reveals western regions where ESMs have substantially underestimated drying trends

Sup3rCC Baseline



Sup3rCC Continued Drying



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## Q&A

Contact: [Grant.Buster@NLR.gov](mailto:Grant.Buster@NLR.gov)



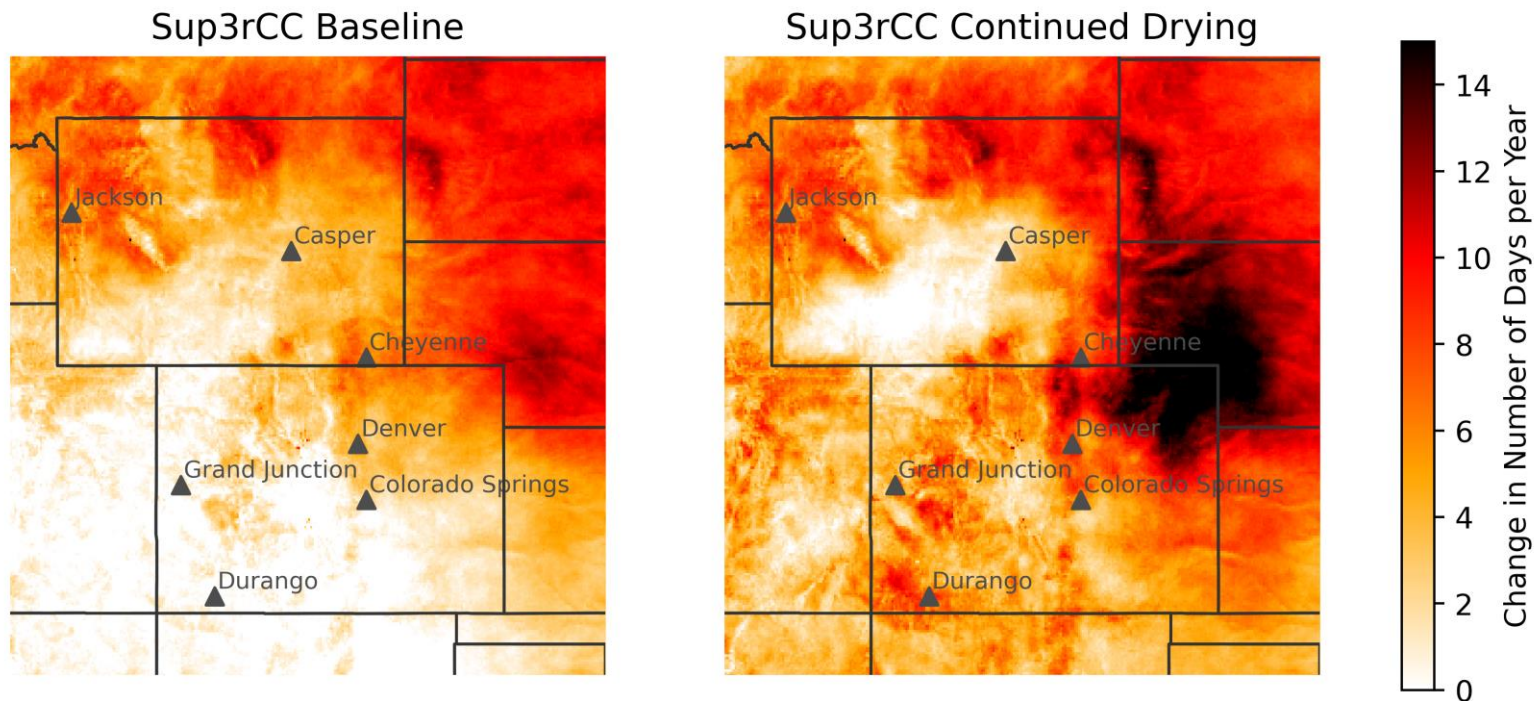
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# Appendix

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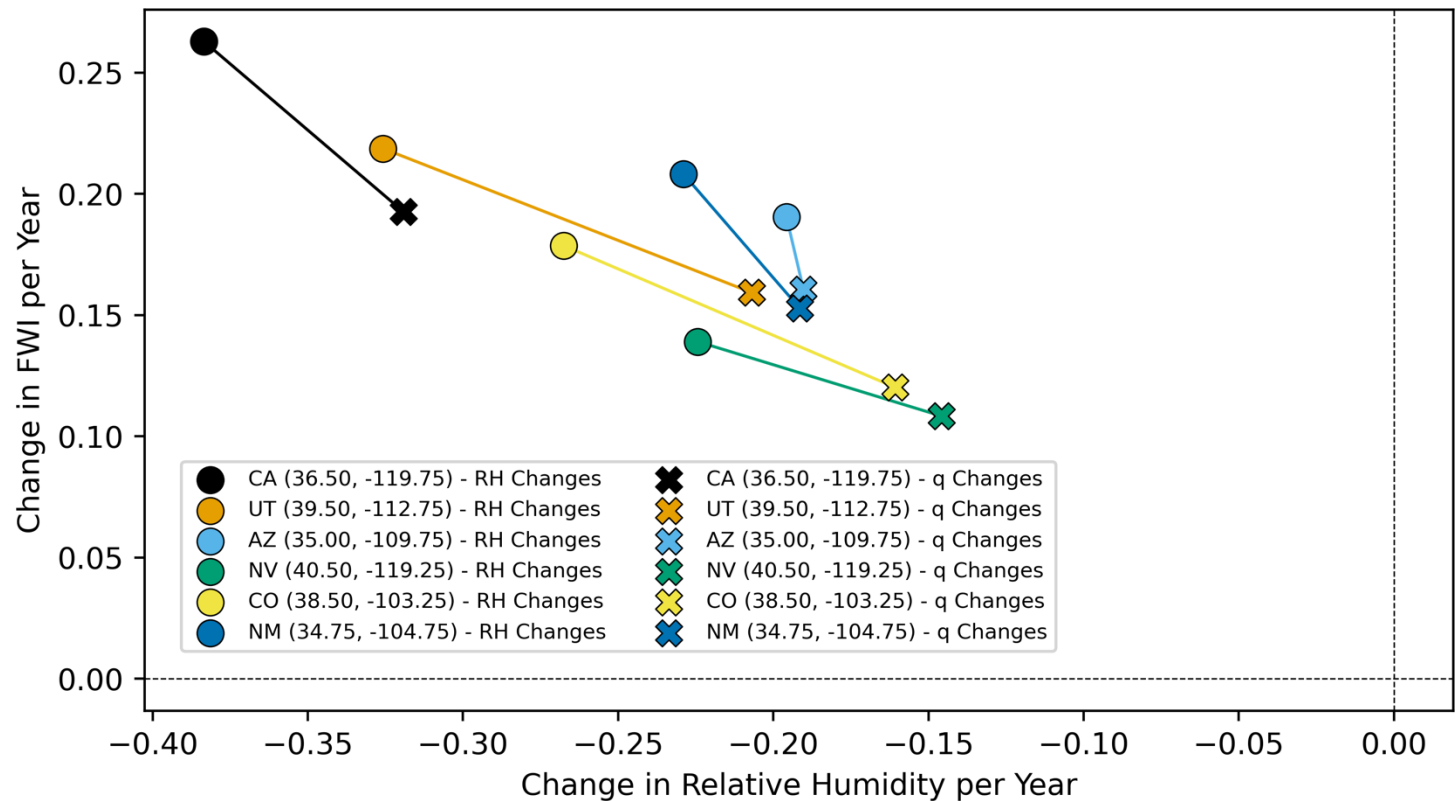
# Future Fire Weather Projections (2020-2039) with a Continued Drying Scenario

- Regions in Colorado and Wyoming are drying faster than estimated by ESMs



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# Specific Humidity (q) Changes Dominate Temperature-RH Effects



# Simplistic Linear RH Trend Correction Based on Reanalysis

