Are windstorms in the Front Range becoming more common?

Serena Lipari-DiLeonardo[1], Julie K. Lundquist[2,3,4]

[1]Department of Applied Mathematics, University of Colorado Boulder
[2]Department of Atmospheric and Oceanic Sciences, University of Colorado Boulder
[3]National Renewable Energy Laboratory (NREL)
[4]Renewable and Sustainable Energy Institute (RASEI), Boulder, CO

Correspondence: serena.dileonardo@colorado.edu

Introduction

- Boulder, Colorado is located where the Rocky Mountains meet the Great Plains, and is situated at the foothills of the Rocky Mountains 1,655 m above sea level
- Westerlies are the prevailing winds in the western US, and consequently Boulder lies on the leeward side of the mountains
- Chinook winds – also known as Foehn winds in other regions – are classified as warm, dry and typically powerful westerly winds that occur on the downward slope of large mountain ranges

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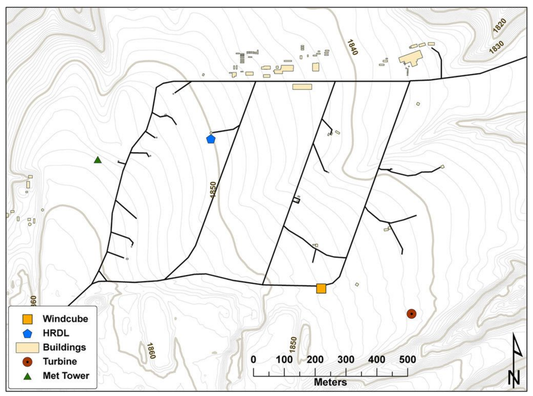
Strong downslope windstorms regularly occur in the Front Range, but the last full climatology of them was done in 1974 by Whiteman and Whiteman[1]



Map of the NWTC with the M2 site indicated by the far left triangle. (Courtesy of Joe Smith and Steve Haymes at NREL.)[2]

The Dataset

NREL Flatirons Campus (M2) Meteorological Data[3]

- Latitude: 39.9106 deg North
- Longitude: 105.2347 deg West
- Elevation: 1855 AMSL
- 1-minute 10m wind speed (m/s) and 10m wind direction (deg) from Jan 1, 2002 to Dec 31, 2021

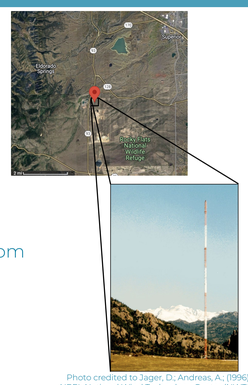
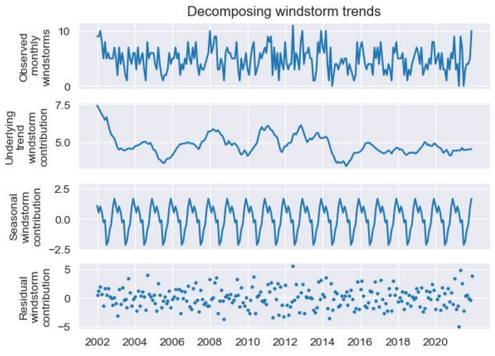


Photo credited to Jager, D.; Andreas, A.; (1996). NREL National Wind Technology Center (NWTC)[3]

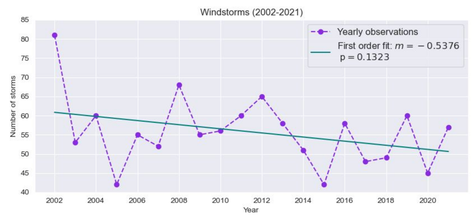
Methods

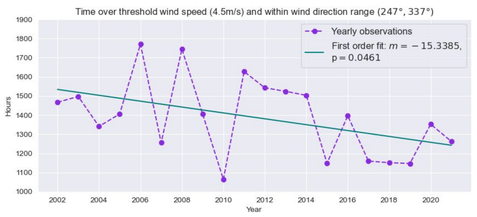
- Set windstorm thresholds:
  > 4.5 m/s, > 1 h, in [247°, 337°], lulls < 12 h
- Group data by years and classify and store yearly windstorm events
- Analyze diurnal distribution of storms
- Group data by months and assess seasonal trends
- Detrend to observe underlying trend
- Visualize yearly trends for storm properties (duration, average speed, average lull number and duration)
- Compare number of windstorms with time spent over speed and direction thresholds
- Test for significance



Results

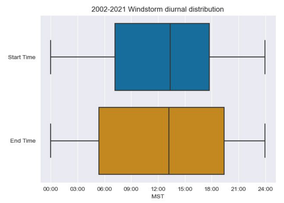
Windstorms are decreasing

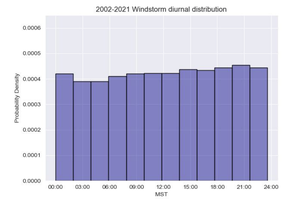




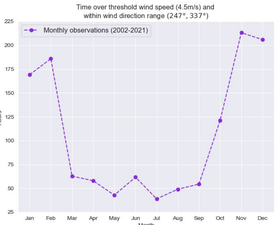
Results

Windstorms show no diurnal trend

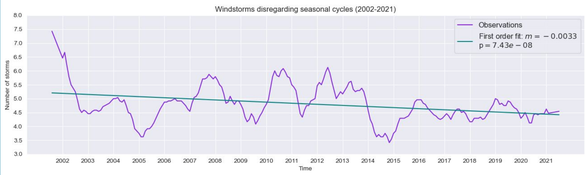




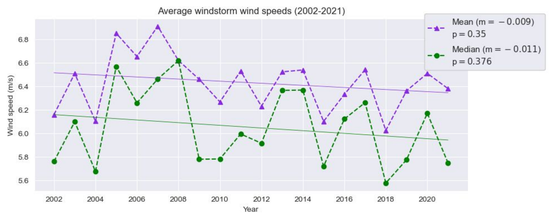
Windstorms have strong seasonal variability

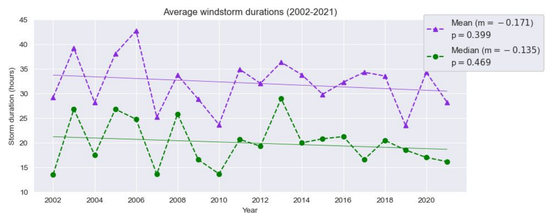


Storms occur more frequently in winter months than in summer months, as in (1,4,5).



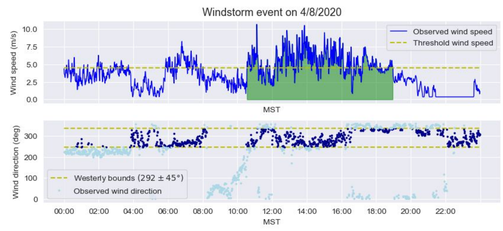
Windstorm average speeds and durations are decreasing over time





Results

Visualizing windstorm events



Conclusions

- Windstorms correspond with high wind speeds and westerly wind in agreement with the literature[1,4,5]
- Over 2002-2021, windstorms have decreased by about 1 windstorm every 25 years (m=-0.0033 storms/month, p<0.001)
- Average windstorm wind speeds and durations have been decreasing but not at a significant level (p=0.350 and p=0.399, respectively)
- Windstorms have seasonal trends, with more storm events occurring in the winter than the summer

References

[1]Whiteman, C. David, and Johanna G. Whiteman. An historical climatology of damaging downslope windstorms at Boulder, Colorado. Vol. 55. Environmental Research Laboratories, 1974.

[2]Aitken, Matthew L., et al. "Quantifying wind turbine wake characteristics from scanning remote sensor data." Journal of Atmospheric and Oceanic Technology 31.4 (2014): 765-787.

[3]Jager, D.; Andreas, A.; (1996). NREL National Wind Technology Center (NWTC):M2 Tower; Boulder, Colorado (Data); NREL Report No. DA-5500-56489. http://dx.doi.org/10.5439/1052222

[4]Shestakova, Anna A., Pavel A. Toropov, and Tatiana A. Matveeva. "Climatology of extreme downslope windstorms in the Russian Arctic." Weather and Climate Extremes 28 (2020): 100256.

[5]Nkemdirim, Lawrence C. "Canada's chinook belt." International Journal of Climatology: A Journal of the Royal Meteorological Society 16.4 (1996): 441-462.

Acknowledgements

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