Characteristics and Societal Impact Generated from the 17-19 December 25 Downslope Windstorms

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Introduction

- **Downslope windstorm**: Powerful winds that accelerate down the lee side of mountain ranges.
- Colorado has two types of windstorms(1) chinooks (warm) and (2) bora (cold)
- Impacts structural code, travel, and amplification of fire weather
- Strong westerly winds provide winds perpendicular to the Rocky Mountains to produce windstorms (Fig. 1)

This project focuses on **meteorological characteristics** and **societal impacts** of **back-to-back downslope windstorms** during **17** and **19 December 2025.**

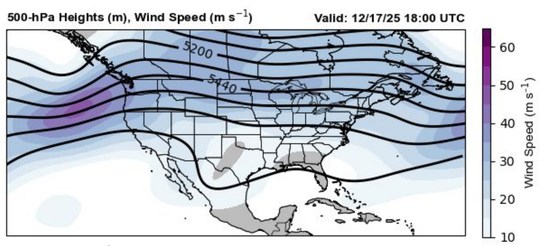


Fig 1: ERA5[1] wind speeds (shading), and geopotential height (black contours) at 500 hPa across the United States.

Methods

Data	Variable	Source	Location
Meteorological	Gust, Speed, Temperature, Direction	Synoptic Data[2]	12 Observation Sites
Power Outages	Customers with Outages	Outage Data Initiative Nationwide[3]	Counties
Air Quality	10 μg/m³ Particulate Matter (PM)	Purple Air[4]	Near the 12 Observation Sites

Table 1: Downloaded data sets from 17-19 December 2025.

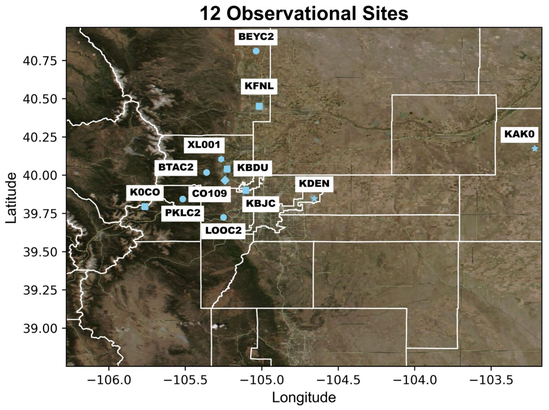


Fig 2: NASA Worldwide satellite imagery[5] of the 12 observational sites across Colorado. Shapes represent different observational networks.

Results

Meteorological Characteristics

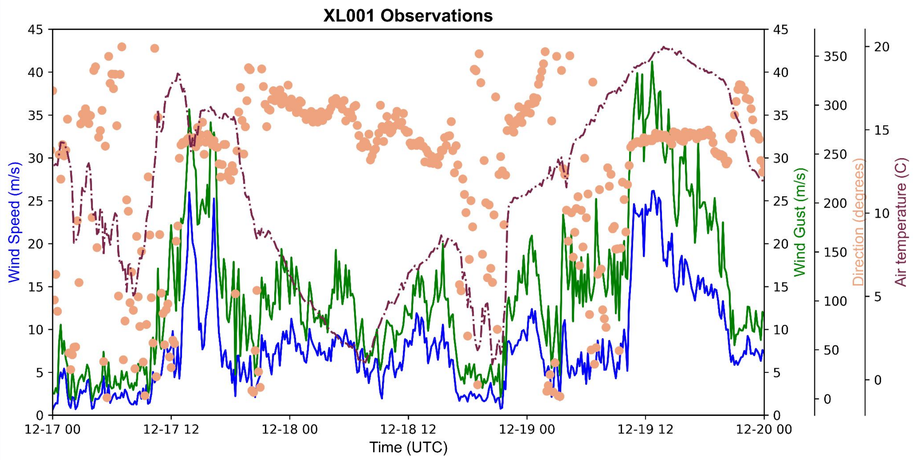
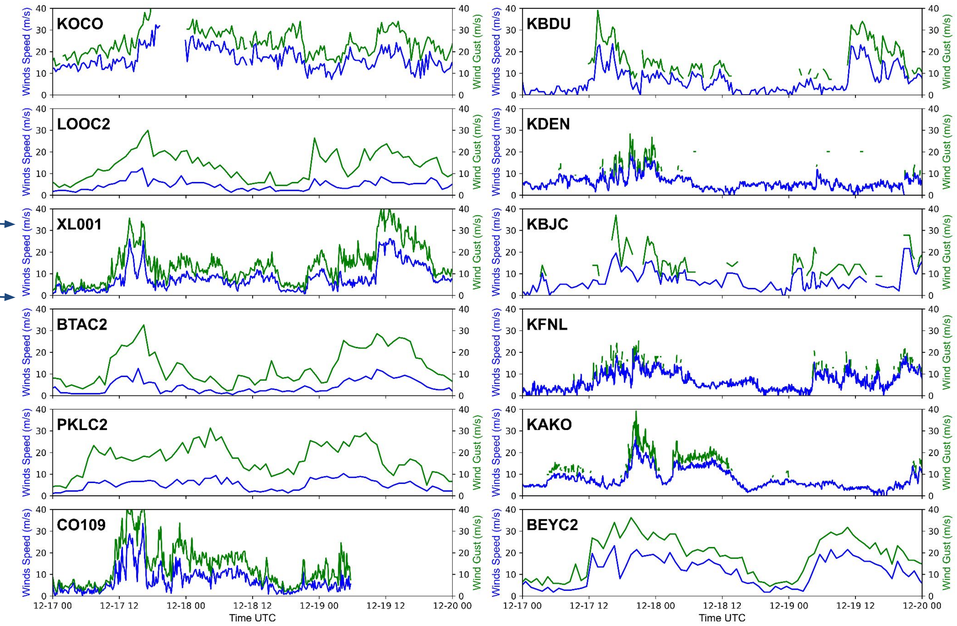


Fig 3 (above): Observational weather site XL001 wind speed (blue), wind gust (green), direction (pink),and air temperature (maroon).

Fig 4 (right): Comparison of wind speed (blue), and wind gust (green) at 0000 UTC 17 December to 0000 UTC 20 December 2025 within the three days separated by western sites (left) to eastern sites (right).



Societal Impact

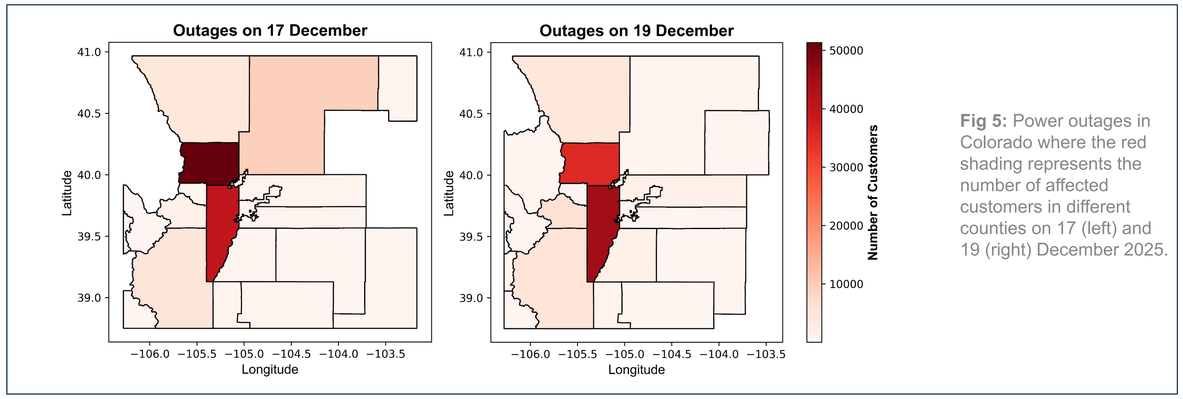


Fig 5: Power outages in Colorado where the red shading represents the number of affected customers in different counties on 17 (left) and 19 (right) December 2025.

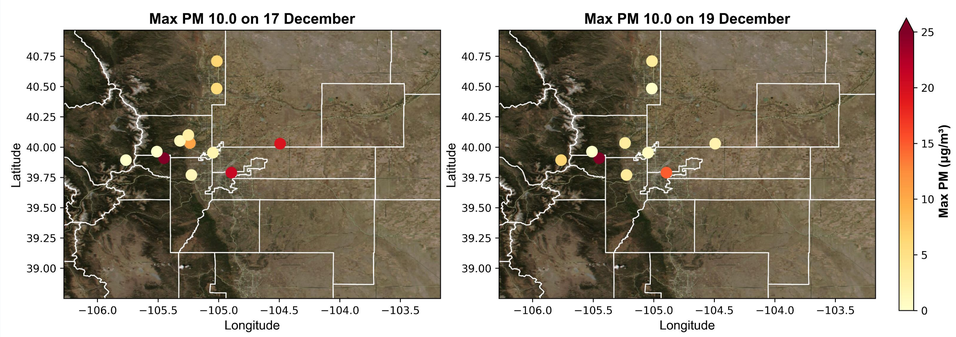


Fig 6: Maximum 10.0 μg/m³ particulate matter concentration from air quality sensors near the 12 observational sites throughout the windstorms. PKLC maximum value of 26.8 μg/m³ on 17 of December and 104.3 μg/m³ on 19 December.

Discussion

Meteorological Characteristics:

- Due to their proximity to the local topography, western sites experienced maximum **wind speed** and **gusts** sooner than eastern sites (Fig. 4)
- Maximum **westerly wind gusts** at **XL001** reached **36 m/s** on the 17 and **46 m/s** on the 19 of December (Fig. 3)
- **Increase** in **temperature** during downslope windstorms due to compressional winds (chinook) (Fig. 3)

Societal Impacts:

- Multiple counties across Colorado had **power outages**, with over **50k** customers affected in Boulder (Fig. 5)
- Boulder experienced **decreased air quality levels**, with higher PM levels observed on the 17 of December compared to 19 of December (Fig. 6)

During the 17-19 Colorado Front Range downslope windstorms, sites closest to the mountains experienced the most day-to-day impacts, including 100-mph wind gusts, power outages, and decreased air quality.

References

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Acknowledgments

I would like to give a thank you to my mentors Andrew, McKenzie, as well as the RECCS mentors and cohort. With their guidance I had the opportunity to explore atmospheric research and learn skills I hope to carry in the future.

This project was funded by EARTh Center NSF grant number 2055370