Colorado Windstorms in a Changing Climate

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Project Motivation and Focus:

- Motivated by **Boulder County Climate Change Preparedness Plan**
- Long time residents of Boulder, CO have felt that the "wind does not blow like it used to."

Purpose of this project: To observe any past trends in Colorado Front Range windstorm predictors/ingredients, and to observe future predictor trends in climate model projections, to discover if climate change will have an effect on the Colorado Front Range windstorm hazard

Fig. 1. Location of Boulder, CO on the Front Range (Google Maps)

Introduction:

- Downslope windstorms are common along the Front Range of Colorado, including the city of Boulder and vicinity
- **$20 million** in estimated damages, in January 18, 1982 storm (Vigh, 2005)
- Windstorm genesis occurs most often in the winter (Fig. 2).
- **Predictors** based on Brown's work, the NWS WFO in Boulder, and windstorm literature, including Klemp and Lilly.
    1. 15 m/s+ 700 mb wind component normal to the Front Range
    2. Shear in the 700 mb to 500 mb layer, with the ratio of 500 mb shear to 700 mb shear less than 1.6
    3. The presence of an inversion in the 700 mb to 500 mb layer (Brown, 1986)

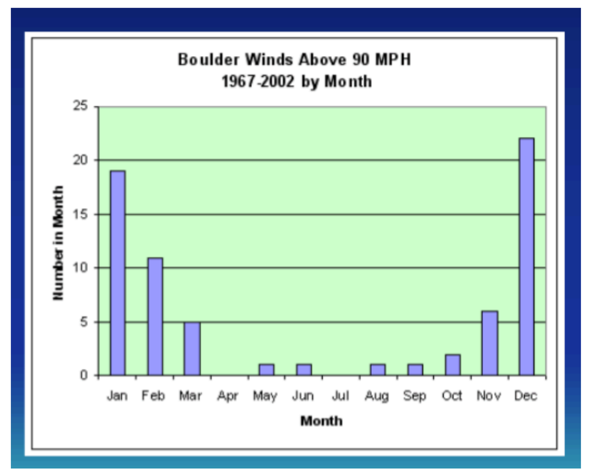

Fig. 2. Seasonal variability of windstorms, showing peak activity in winter (Vigh, 2005)

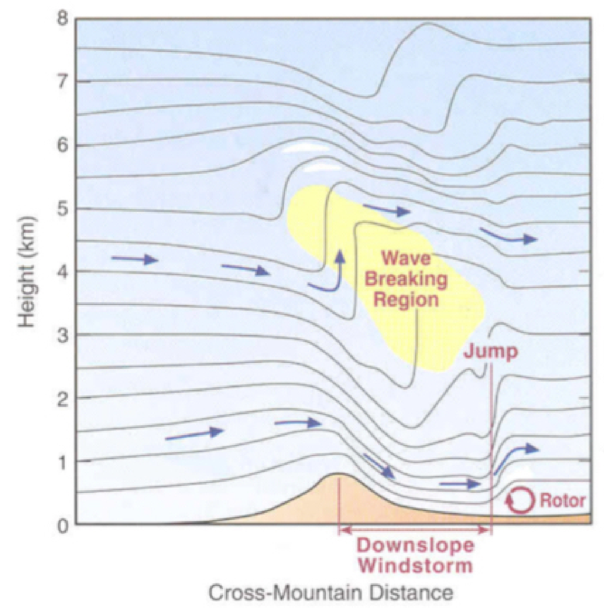

Fig. 3. Windstorm physical attributes (Vigh, 2005)

Methods:

- For validation, used NOAA NCEI severe storms database
- Since 1996, **180** "high wind" events, defined as sustained winds of 40 mph or gusts of 58 mph
- Validation of Brown's forecast model, Figs. 4-5
- Visual validation of predictor thresholds, Fig. 6
- Baseline of past 700 mb wind trend, using NCEP/NCAR Reanalysis 1 and GFDL reanalysis model (CMIP5)
- CESM climate analysis

Validation:

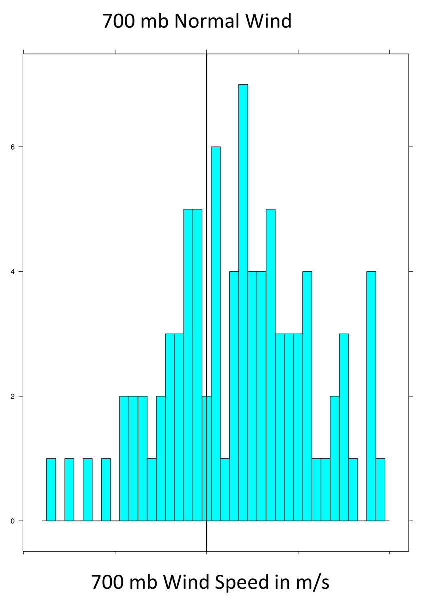

Fig. 4. 700 mb predictor distribution and threshold

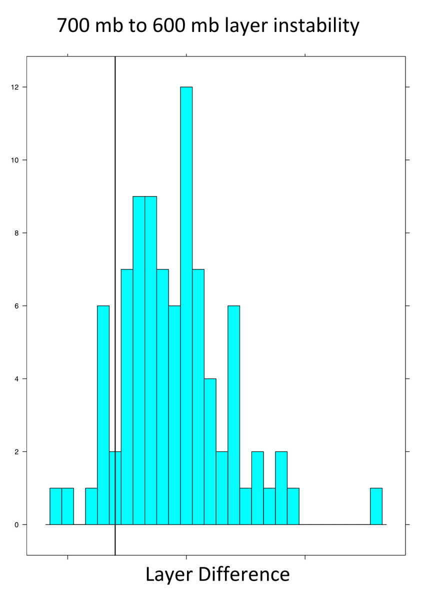

Fig. 5. 600 mb to 700 mb predictor distribution and threshold

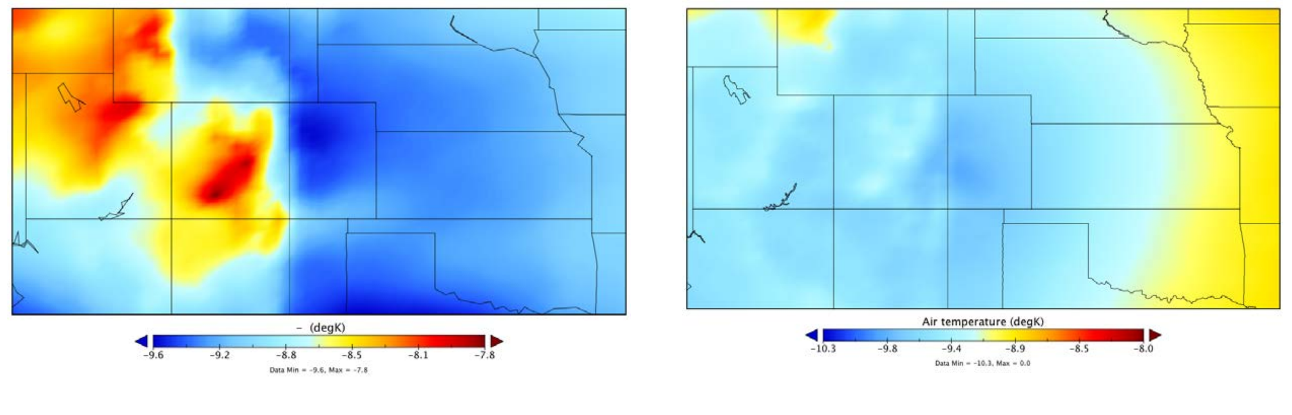

Fig. 6. 600 mb to 700 mb layer average stability in windstorms (left) and without windstorms (right).

Results:

- Downward trend in NCEP/NCAR baseline analysis of 700 mb wind predictor (Fig. 7)
- No such trend is seen in the CMIP5 GFDL (Fig. 8)
- ERA40 700 mb distribution has much shorter tail than NCEP/NCAR, failing to provide validation (Fig. 9)
- CESM annual threshold exceedance counts decrease over time frame 1990-2080, with statistical significance for 50% of the iterations (Fig. 10 and 11)

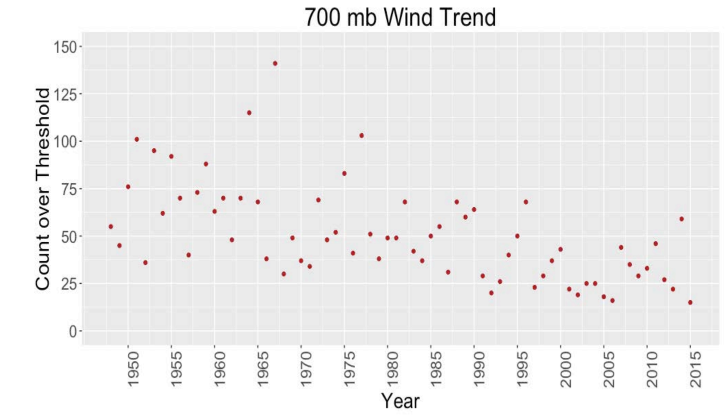

Fig. 7. Annual 700 mb wind speed exceeding threshold NCEP/NCAR

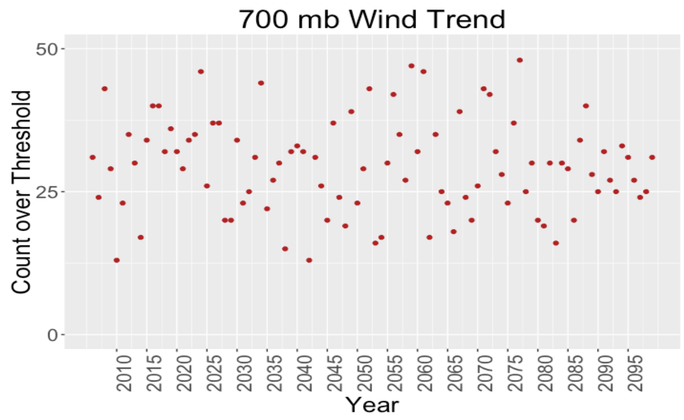

Fig. 8. Annual 700 mb wind speed exceeding threshold for GFDL

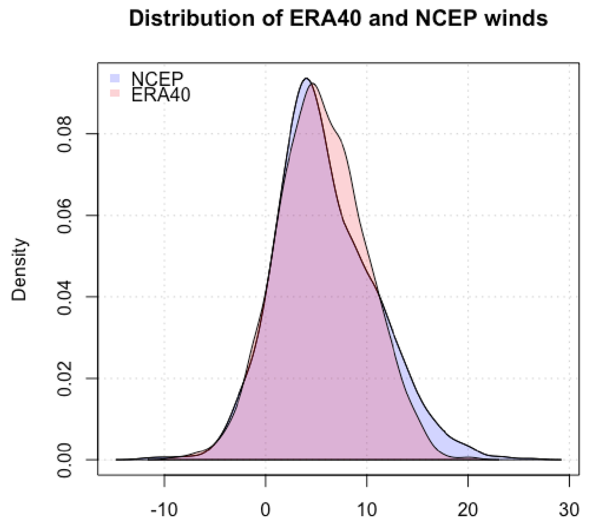

Fig. 9. NCEP/NCAR and ERA40 700 mb distribution comparison, showing ERA40's shorter tail

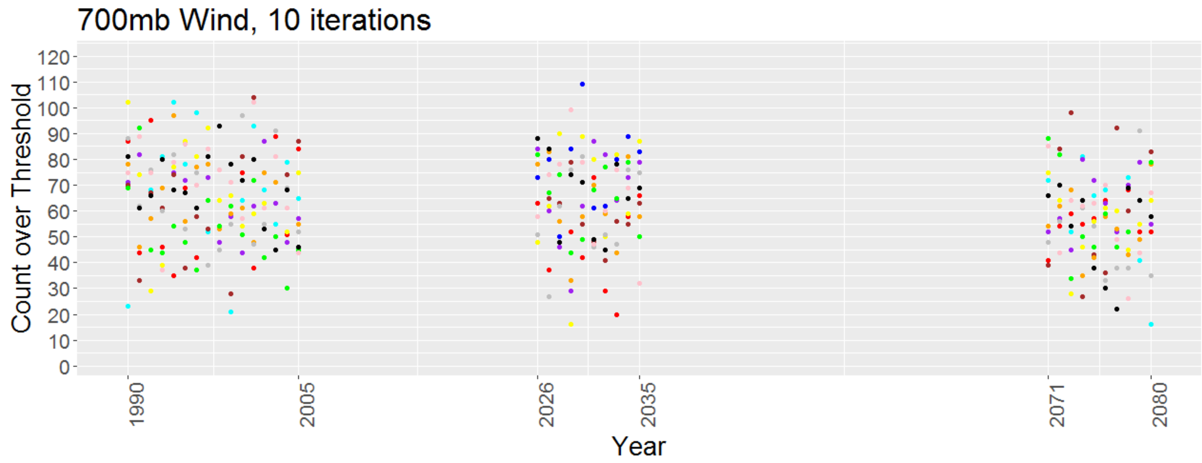

Fig. 10. Annual count of 700 mb predictor exceeding threshold in CESM for decadal slices 1990-2005, 2026-2035, and 2071-2080.

Iterations	Estimate	Standard error	p-value
Iteration1	-0.1108	0.1106	0.323
Iteration2	-0.1089	0.0880	0.225
Iteration3	-0.0460	0.0728	0.532
Iteration4	-0.0302	0.1016	0.768
Iteration5	-0.1467	0.0714	0.048 **
Iteration6	-0.1685	0.0990	0.098 *
Iteration7	0.0697	0.0821	0.402
Iteration8	-0.2469	0.0930	0.012 **
Iteration9	-0.2056	0.0759	0.010 **
Iteration10	-0.1984	0.0864	0.028 **

Fig. 11. Single linear regression t-test for all 10 iterations of the CESM over entire time of the study (decadal slices 1990-2006, 2026-2035, and 2071-2080).

Conclusion and Further Study:

- Based on the CESM analysis, the 700 mb wind, the most important predictor of Colorado Front Range windstorms, exceeds the set threshold of 15 m/s less frequently as the CESM projection introduces more climate forcing.
- **Therefore, the frequency of Colorado Front Range windstorm occurrences may decrease in the future, due to the projected decrease in the 700 mb predictor.**
- Include other 20 iterations of CESM, and consider other predictors more thoroughly

Observations:

This study would benefit from more data records for past Front Range windstorms. Lacking such data hampered the validation section. Also, if all years for the CESM were available, instead of merely the decadal slices used here, that would provide a larger sample size.

References and Acknowledgements:

Brown, J., 1986. "A Decision Tree for Forecasting Downslope Windstorms in Colorado." *Preprint Volume, Eleventh Conference on Weather Forecasting and Analysis.,* 83-88.
Klemp, J. B., Lilly, D. K. 1975. "The Dynamics of Wave-Induced Downslope Winds." *http://www.ral.ucar.edu/staff/jvigh/documents/vigh_windstorms_AT707_presentation.pdf*
Vigh, J., 2005. "Downslope Windstorms and Rotors." *http://www.ral.ucar.edu/staff/jvigh/documents/vigh_windstorms_AT707_presentation.pdf*

Many thanks to my mentors Dr. Joe Barsugli and Dr. Andrea Ray, and to my research adviser at Virginia Wesleyan College, Dr. Lydia Kennedy.
Gratitude is also due Dr. John Brown, an expert beyond peer in Colorado windstorm meteorology, and Ms. Nezette Rydell, Dr. Eric Thaler, and Mr. David Barjenbruch from the Boulder NWS office.