A HIGH-WIND PREDICITION MODEL FOR BORDEAUX, WYOMING

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1. INTRODUCTION

Southeast Wyoming is one of the windiest areas in the country during the months of October through March. The strong wind has significant impacts on commercial traffic especially along Interstates 80 and 25. One wind-prone location where road closures from blow-overs of high-profile vehicles frequently occur is the gap area of Bordeaux, Wyoming on Interstate 25 (66 miles north of Cheyenne).

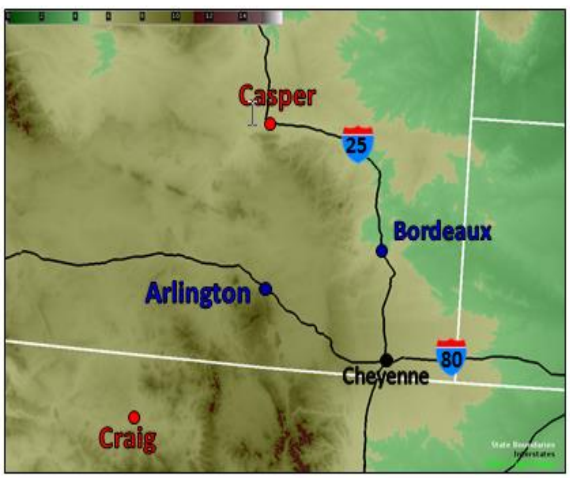

FIG 1. A map of southeast Wyoming with the gradient locations used in this study marked, along with Interstates 25 and 80.

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Forecasters at the National Weather Service in Cheyenne have commonly used the 850- and 700-mb height gradients between Craig, CO (CAG), and Casper, WY (CPR), as indicators of potential gap winds at Bordeaux. While this technique has proved beneficial in forecasting high winds, the CAG-CPR line does not bisect Bordeaux. It is possible that other gradient orientations, such as Arlington, WY (ARL) to Bordeaux (BRX), may be more useful. In addition, forecast variables other than geopotential height may provide additional predictive value.

This study has the following two objectives:

1) Conduct a statistical analysis of the CAG-CPR height gradient, ARL-BRX gradients (both height and MSLP), and winds at BRX, calculating correlation and forecasting scores.

2) Develop a high-wind statistical prediction model for Bordeaux using logistic regression. Calculate forecasting scores from the model.

2. DATA AND METHODS

2.1 WYDOT and NARR Data

Surface wind observations for this study were obtained from the BRX WYDOT site. This site is located on Interstate 25 about 66 miles north of Cheyenne. In order to focus on the wind season and avoid convective winds, only data from October through March for six years (2006-2012) were collected. Nearly continuous data every five-to-ten minutes was available over this period. Finally, the 1-hourly max wind gust was logged at 3-hour intervals.

North American Regional Reanalysis (NARR) data was utilized over the six wind seasons to compute the predictors. These predictors included height gradients (CAG-CPR, ARL-BRX) over 925-700 mb at 25-mb increments, ARL-BRX MSLP gradient, and wind at BRX over 850-500 mb. Each BRX wind gust was then matched in time to the nearest corresponding NARR three-hourly UTC predictor.

Pearson correlation values were then calculated for each predictor vs. wind gust. For this study, a high wind observation was defined as a wind gust that was greater than or equal to 58 mph (the National Weather Service high wind warning criteria). Forecasting scores (POD, FAR, CSI) for high winds were then determined for predictor thesholds.

2.2 High-Wind Prediction Model

A logistical regression model for predicting high winds was developed in a manner very similar to Lindsey et al. (2011). Logistic regression is specifically designed for creating a statistical model that outputs probability forecasts (Lindsey et al. 2011). After analysis of the NARR predictors, the following were selected as model variables: 1) The 850-mb CAG-CPR height gradient, 2) The ARL-BRX MSLP gradient, and 3) The 800-mb windspeed at BRX.

Logistic regressions (with 3 predictors) are fit to the following nonlinear equation

$$p = \frac{1}{1 + \exp(-b_0 - b_1x_1 - b_2x_2 - b_3x_3)} \quad (1)$$

where p is the predicted probability, x_n are the predictors, and b_n are the coefficients that determine the best fit. Figure 2 lists the resulting coefficients after performing the regression on the entire dataset. The normalized coefficients indicate which predictors get relatively more weight, and the raw coefficients are the ones used in (1) above and are multiplied by the predictors.

	850-mb CAG-CPR height gradient (b_1)	MSLP ARL-BRX gradient (b_2)	800-mb windspeed at BRX (b_3)
Normalized Coefficients	1.82	0.865	0.807
Raw Coefficient	0.06	0.328	0.11

FIG 2. Variables used in the linear regression model, and the resulting normalized and raw coefficients for the dataset.

3. RESULTS

Over the six wind seasons, a total of 8346 synoptic times were included in the dataset. Figure 3 shows a scatterplot of wind gust at Bordeaux versus one of the predictors (850-mb CAG-CPR height gradient). There is a positive correlation between the gradient and Bordeaux winds. The best fit line crosses the High Wind threshold of 58 mph at a gradient of around 75-80 meters. Although the correlation is good, there are several instances where high gradient values (CAG-CPR > 60 m) result in weaker winds at Bordeaux, and vice versa.

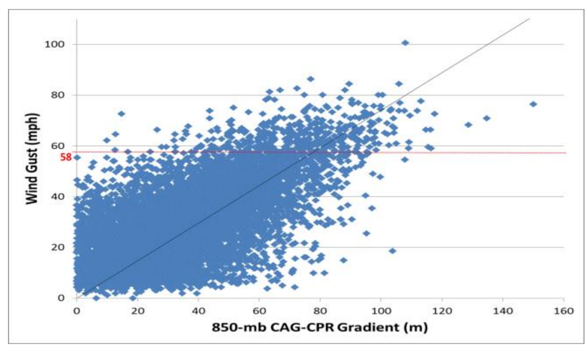


FIG 3. Scatterplot of Bordeaux wind gusts vs. the 850-mb CAG-CPR height gradient. Only positive gradient values are shown. The best-fit line is plotted in black, while the red dashed line indicates the local High Wind Warning criterion of 58 MPH.

The correlation value for the predictors at each pressure level is displayed in Figure 4. The overall correlation between the predictors and Bordeaux winds was good (0.50 – 0.65) and are statistically significant. For each predictor, the best correlations are at 850 mb compared to lower pressures. This makes sense as the elevation of Bordeaux is around 5217 feet (or approximately 850 mb). Additionally, the correlation for the ARL-BRX MSLP gradient was 0.581. It is interesting to note that the predictor with the best correlation (BRX Winds) does not produce the best forecasting scores as seen in Figure 5.

	850	825	800	775	750	725	700
CAG-CPR	0.61	0.6	0.6	0.59	0.57	0.54	0.51
ARL-BRX	0.64	0.63	0.62	0.6	0.57	0.53	0.47
BRX Winds	0.67	0.66	0.65	0.66	0.65	0.58	0.49

FIG 4. Table of Pearson correlation values for height gradient orientations (CAG-CPR, ARL-BRX) and wind speeds at BRX (BRX Winds) at each pressure (mb) level. In addition, the correlation for ARL-BRX MSLP was ***0.581***

Forecasting scores for a single predictor threshold are listed in Figure 5. The threshold values shown represent the best Critical Success Index (CSI) for that particular variable. The best CSI for a single predictor was 0.33 by applying a threshold of 70 m to the 850-mb CAG-CPR height gradient. This is quite an improvement over using 60 m at the 700-mb level (CSI of 0.257, not shown). Thus, it is recommended that if forecasters use the CAG-CPR gradient as a single predictor, that the 850-mb level is used as opposed to 700 mb. The other predictors (ARL-BRX height, ARL-BRX MSLP, and BRX wind) all show a decrease in CSI scores to around 0.23-0.25.

	850-mb CAG-CPR ≥ 70 m	850-mb ARL-BRX ≥ 40 m	MSLP ARL-BRX ≥ 5 mb	800-mb BRX wind ≥ 28 knots	Model Prob ≥ 26 %
POD	0.593	0.341	0.567	0.45	0.55
FAR	0.573	0.507	0.696	0.689	0.498
CSI	0.33	0.252	0.247	0.225	0.356

FIG 5. Table of forecasting scores (POD, FAR, CSI) for chosen variables and thresholds.

After calculating the model probabilities, it was determined that a probability threshold of 26% produced the most favorable CSI score of 0.356. Figure 5 indicates that the model results in a slight improvement over using just the CAG-CPR gradient (0.356 vs. 0.33), and does so by decreasing the false alarms (FAR). In order to understand the added utility of the model, Figure 6 was created showing the distribution of cases where model probability was greater than or equal to 26 % ("warned" events) compared to less than 26 % ("unwarned" events).

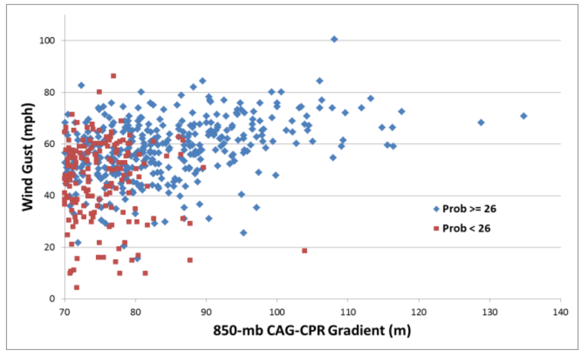


FIG 6. Scatterplot of Bordeaux wind gusts vs. 850-mb CAG-CPR gradient when model Probability ≥ 26 (blue) or model Probability < 26 (red).

Remember that using the single predictor threshold of CAG-CPR gradient ≥ 70 m, a forecaster would have warned on all the points in Figure 6. However, the model significantly reduced the number of false alarms (red points below 58 mph), especially at the lowest wind speeds. This is further illustrated by breaking the two different methods into wind speed bins in Figure 7.

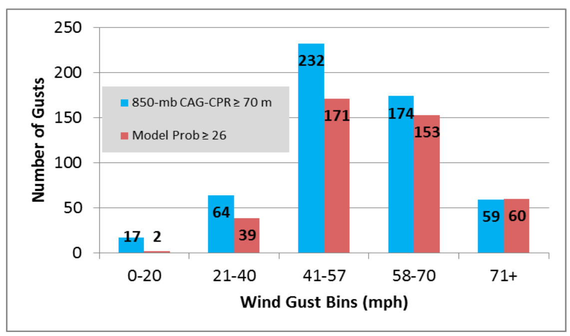


FIG 7. Number of observed wind gusts in particular gust bins when using the following methods: 850-mb CAG-CPR gradient ≥ 70 m (blue), model Probability ≥ 26 (red).

By using the model, the number of gusts at the lowest wind speed bins (0 – 40 mph) were reduced by around 50 % while gusts at the highest speed bins (greater than 70 mph) were unchanged. This is a very desirable outcome for the forecaster, that is reducing the warnings when Bordeaux winds are the weakest, and at the same time warning on the most impactful high wind events.

4. CONCLUSIONS, FUTURE WORK

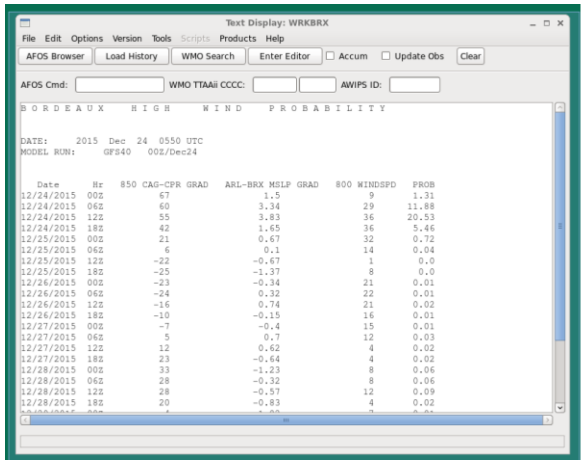
4.1 Summary

Southeast Wyoming is one of the windiest areas of the country during the cold season, and one of the more wind-prone locations is the gap area of Bordeaux, WY. This study had two objectives as stated at the beginning of the paper. First, a statistical analysis of predictor variables was conducted, computing correlations and forecasting scores. Next, a high-wind prediction model using logistic regression was developed. The following points summarize the research results:

- The overall correlation between the predictors and wind gusts at Bordeaux was good (0.50-0.65) for all pressure levels. 850 mb had the best correlations.
- As a single predictor, a 850-mb CAG-CPR height gradient ≥ 70 m produced the best forecasting CSI score. Forecasters at NWS Cheyenne should focus on the 850-mb level as opposed to 700-mb when considering the CAG-CPR gradient.
- The high-wind prediction model reduced the number of false alarms and improved CSI scores slightly. Using the model, the number of gusts at weakest winds (0-40 mph) were reduced by 50% while gusts at the highest speeds (71+) were unchanged.

4.2 Real-Time Model

A real-time version of the high-wind prediction model has been implemented to assist forecasters at WFO Cheyenne. Since NARR data is not available in real-time, the forecaster has the option to run the model using NAM or GFS forecast data. An example of output from the operational model is shown in Figure 8. For this particular GFS model run, the high-wind model shows the probability of high winds peaking at around 20.5% at 12Z on 12/24/2015. Although the forecaster would be alerted to the potential for stronger winds, since the model forecast does not reach the optimal threshold of 26 %, the forecaster would not issue a High Wind Warning in this instance.



B O R D E A U X   H I G H   W I N D   P R O B A B I L I T Y

DATE: 2015 Dec 24 0550 UTC
MODEL RUN: GFS40 00Z/Dec24

Date	Hr	850 CAG-CPR GRAD	ARL-BRX MSLP GRAD	800 WINDSPD	PROB
12/24/2015	00Z	67	1.5	9	1.31
12/24/2015	06Z	60	3.34	29	11.88
12/24/2015	12Z	55	3.83	36	20.53
12/24/2015	18Z	42	1.65	36	5.46
12/25/2015	00Z	21	0.67	32	0.72
12/25/2015	06Z	6	0.1	14	0.04
12/25/2015	12Z	-22	-0.67	1	0.0
12/25/2015	18Z	-25	-1.37	8	0.0
12/26/2015	00Z	-23	-0.34	21	0.01
12/26/2015	06Z	-24	0.32	22	0.01
12/26/2015	12Z	-16	0.74	21	0.02
12/26/2015	18Z	-10	-0.15	16	0.01
12/27/2015	00Z	-7	-0.4	15	0.01
12/27/2015	06Z	5	0.7	12	0.03
12/27/2015	12Z	12	0.62	4	0.02
12/27/2015	18Z	23	-0.64	4	0.02
12/28/2015	00Z	33	-1.23	8	0.06
12/28/2015	06Z	28	-0.32	8	0.06
12/28/2015	12Z	28	-0.57	12	0.09
12/28/2015	18Z	20	-0.83	4	0.02

FIG 8. Bordeaux high-wind model as a text product in AWIPS2. This model is being run operationally at WFO Cheyenne.

4.3 Future Work

Verification of the operational high-wind model will be performed over the next few wind seasons. Biases between the NARR data and GFS/NAM will likely exist, which will affect the model's performance. By collecting real-time GFS/NAM data using the high-wind model, these biases can be corrected. Additionally, in order to validate the high-wind model, it will be run on an independent NARR dataset over two wind seasons (2013-2014).

5. REFERENCES

Lindsey, D. T., B. McNoldy, Z. Finch, D. Henderson, D. Lerach, R. Seigel, J. Steinweg-Woods, E. Stuckmeyer, D. Van Cleave, G. Williams, and M. Woloszyn, 2011: A high wind statistical prediction model for the northern Front Range of Colorado. *Electronic J. Operational Meteor.*, **12** (3), 1–24.