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AN EXPERT SYSTEM FOR THE PREDICTION OF DOWNSLOPE WINDSTORMS IN NORTHERN COLORADO

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1. INTRODUCTION

Severe downslope windstorms (i.e., windstorms with gusts of at least 27 m/s, or 60 miles per hour (mph)) constitute a substantial threat to public safety in several population centers of the western U.S. One of these is to the east of the Front Range of the Rocky Mountains in Colorado, in particular the cities of Boulder and Fort Collins. Forecasters at the National Weather Service Forecast Office (NWSFO) in Denver are responsible for issuing watches and warnings for these events, and have found their prediction to be especially difficult and frustrating because of the highly localized and seemingly capricious nature of the phenomenon. There have been, however, significant advances in the understanding of the dynamics of downslope windstorms over the past few years (Durran 1990). Thus, windstorm prediction constitutes an appealing applied research problem, one that has some promise of having substantial operational payoff.

2. BRIEF DESCRIPTION OF THE EXPERT SYSTEM

The expert system is an outgrowth and partial merger of two separate procedures developed for Boulder (Brown 1986) and for Fort Collins (Weaver and Phillips, 1990). It was installed on a personal computer (PC) at the National Weather Service Forecast Office in Denver in November 1990, and has been operational use since that time. This expert system provides guidance regarding the "watch" component of the high-wind forecast, for periods up to 36 h ahead. Over Colorado, it uses as input NGM forecasts of several parameters. These include the geostrophic wind at 1000, 700 and 500 mb, the temperature difference between 500 and 300 mb, the sign of the vorticity advection at 500 mb, and the liklihood of there being a surface-based layer of stable arctic air over the plains of eastern Colorado in advance of or during the forecast period. All these parameters, except for the indication of Arctic air over the plains, are readily available to the forecaster through the grid-to-graph capability on the prototype Advanced Weather Information Processing System (AWIPS) workstation at NWSFO Denver. (However, it is still necessary for the forecaster to hand-enter these data for use by the PC program.)

The inhibiting effect of a surface-based Arctic airmass over the plains of eastern Colorado on the development of downslope winds is well recognized by experienced forecasters and has been examined in a modelling study by Lee et al. (1989). If the forecasters indicate that there is a possibility that such an airmass may be present at a particular time, they are queried by the program to be more specific in their assessment of the liklihood of such cold air. They are also asked to estimate how deep it will be. This is because its depth is the main factor determining whether the cold air will be scoured out, allowing high wind to reach the surface. The expert system takes the forecaster input, and incorporates the results of Lee et al. to generate a confidence level in its prediction. Both the Boulder and Fort Collins portions of the expert system make use of the "perfect prog" approach. For Boulder, this means that the predicted probability of wind gusts equalling or exceeding 40 and 60 mph (18 and 27 m/s) is based on the percent of the time these threshholds were met in the dependent data sample when observed conditions were very similar to those being predicted by the NGM. The dependent data used to derive the peak gust prediction for Fort Collins (via a formula based on stepwise linear regression) include only cases for which the wind at Fort Collins exceeded 52 mph (23 m/s). As noted above, a statement of confidence in the Fort Collins forecast is also generated by the expert system. The system is fully interactive, allowing the forecaster to rerun the forecast with different input data and requesting forecaster input as noted above regarding the cold air question. It also provides readily accessible and extensive help information and explanations of its predictions.

3. EXPERIENCE DURING THE 90-91 WINDSTORM SEASON

During the winter of 1990-91, the expert system was used by the forecasters almost every time high winds threatened. The system proved stable, with no crashes and only one or two very minor bugs noted.

In evaluating a system of this kind, it is crucial to obtain input from the forecasters themselves, as users of the system. Comments have been obtained from most of the forecasters, and are summarized below, along with some implications.

o The Fort Collins portion of the expert system output was presented differently from that of the Boulder portion. The forecasters generally preferred the format of the Fort Collins forecast, where a specific value for a peak gust was mentioned, rather than a probability of peak gust equalling or exceeding 40 or 60 mph. This is mainly because the decision of whether or not to issue a high-wind watch is based on whether a gust of at least 60 mph is expected, and is therefore made simpler (though not necessarily more accurate) when a specific maximum gust value is predicted, rather than a probability.

o For this reason and because the Fort Collins forecast appears to have performed more satisfactorily than the Boulder forecast, the Fort Collins portion of the forecast was considered more useful than that for Boulder.

o Though extensive interactive help was available through the expert system, there remained on the part of most of the forecasters a surprising amount of misunderstanding on the proper interpretation of the expert-system forecasts. It appears from talking with the forecasters that the help pages were rarely used. Also, in order to save time, the forecasters tended to circumvent those portions of the system intended to be interactive, in particular the portion dealing with the existence and depth of surface-based cold air east of the mountains. This indicates, in part, the need for more personal and hands on instruction in use of the system than was done this past winter.

The necessity of manually tabulating and hand-entering the input data limited the utility of the system. In particular, output from the expert system was impossible to obtain quickly enough to use as guidance for the morning and evening update forecasts. Therefore, it would be highly desirable to install this system on the prototype AWIPS workstation at the Denver forecast office. (In lieu of this, for the 1991-92 season, the quantitative input derivable from the NGM gridded forecast data will be generated automatically. However, the forecaster will still have to enter this input manually into the PC program.)

This past winter saw fewer downslope windstorms than usual, particularly in Boulder. This makes traditional procedures for evaluating skill of doubtful value. It is apparent, however, that the Boulder portion of the expert system, though it performed satisfactorily in indicating which situations had very low probability of producing high wind, exhibited poor ability in identifying those few situations where high wind did occur. In one case, the most severe windstorm of the year, this can be attributed in part to a poor forecast by the NGM. This points out the Achilles heel of any system that is dependent on an NMC model forecast: a poor model forecast may cause the system to fail.

This notwithstanding, the probability for gusts equalling or exceeding 60 mph in Boulder was never predicted to be higher than 35 % for any 6-h period. This is due to two factors. First, only three years of dependent data were available for Boulder at the time the probabilities were generated (by curve fitting to a four-dimensional contingency table of sample probabilities), and second, we are convinced that Boulder windstorms are inherently less predictable than those in Fort Collins, because of different physical mechanisms.

4, CONCLUSIONS

This expert system application is a good example of how theoretical advances can be brought to bear on a particular operational problem. It is, therefore, an example of applications that are desirable in the AWIPS era: those that help with a difficult local forecast problem, have a sound physical basis, make use of advanced data streams (in this case, gridded model output from NMC), are simple to use, and do not require extensive computer resources.
The PC program will be demonstrated at the symposium.

5. REFERENCES

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