AN EXPERT SYSTEM FOR THE PREDICTION OF DOWNSLOPE WINDSTORMS

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ABSTRACT

An expert system, or forecast aid, for the prediction of strong downslope wind at two locations to the lee of the Rocky Mountains in Colorado, USA, has been designed and is now in experimental use at the National Weather Service Forecast Office in Denver. This system, which runs on a personal computer, is intended to aid in deciding whether to issue a high-wind watch, a public statement that conditions will be favorable for development of damaging winds at some time during the next 12 to 36 h. Input is derived from gridded output from centrally prepared numerical forecast guidance, as well as by subjective forecaster evaluation. The system is interactive, allowing the forecaster to rerun with different input data, and providing readily available and extensive help information.

We will demonstrate the system and describe briefly its meteorological basis at the conference. We will also discuss evaluation of its operational utility based on experience over the past two years. Considerations relevant for development of similar systems for application to other locations in western United States and Canada will be discussed, along with issues arising from the use of centrally prepared model guidance as input.

Résumé

Un systéme d'éxpertise ou d'aide de prédiction, pour la prédiction des vents descendants dans deux endroits creux dans les montagnes rocheuses de Colorado, U.S.A., a été mise au point, et est maintenant à un stade expérimental dans le Service Nationale Météorologique à Denver. Ce systéme qui tourne actuellement dans un ordinateur personnel, est destiné à aider dans la prise de décision lors de la suivie d'un vent fort pour le rapport publique à faire concernant les conditions favorables aux développements pendant une période de 12 à 36 heures d'un vent devastant.

Les données d'entrées derivent du quadrillage, les sorties elles, proviennnent de la guidance de prévision numérique préparée centralisée, aussi bien que par l'évaluation subjective du météorologiste. Le système est interactif, ce qui permet au météorologiste de pouvoir retravailler avec des différentes données d'entrée, et, fournissant des informations extensives prêtes d'assistance disponible.

Au cours de la conférence nous allons démontrer et décrire d'une manière sommaire, la base météorologique du système. Nous allons aussi discuter l'évaluation de son utilité opérationnelle basée sur une expérience de 2 années passées.

Les considérations relevant de développement des systèmes similaires et de leur applications dans les autres locations de l'ouest du Canada et des Etats-Unis y seront aussi discutés, ensemble avec les issues provenant de l'utilisation de modèle de guidance préparée centralisée comme données d'entrée.

1. INTRODUCTION

Severe downslope windstorms [defined here as windstorms with gusts of at least 60 miles per hour* (mph)] constitute a substantial threat to public safety in several population centers of the western United States and Canada. East of the Front Range of the Rocky Mountains in Colorado are two of these areas, 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 their predictions are especially difficult and frustrating because of the highly localized and seemingly capricious nature of the phenomenon. There have been, however, significant advances in understanding 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 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 Denver WSFO in November 1990, and has been in 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 in advance. It uses as input gridded output over Colorado from the United States National Meteorological Center (NMC) model forecasts. This input includes geostrophic wind at 1000, 700 and 500 mb; temperature difference between 500 and 300 mb, the sign of the vorticity advection at 500 mb, and the likelihood 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 the indication of arctic air over the plains, are available to the forecaster through the grid-to-graph capability on the prototype Advanced Weather Information Processing System (AWIPS) workstation at the Denver NWSFO. (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 stable, cold 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 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 likelihood of such cold air. They are also asked to estimate how deep the cold airmass 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 this 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* is based on the percent of the time these thresholds 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*. 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 LAST TWO WINDSTORM SEASONS

Since it became available, the expert system is being used by the forecasters at Denver almost every time high winds threaten. The system has proven stable, with no crashes and only one or two very minor, correctable 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 made by most of the forecasters and are summarized below, along with some implications.

o   The expert system forecasts for Fort Collins were presented differently than those for Boulder. The forecasters generally preferred the format of the Fort Collins forecast, where a specific value for a peak gust was given, 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. (This brings up a larger issue, that of whether high-wind watches themselves would be more useful to the public if they were expressed in terms of probability rather than as categorical statements. This matter is beyond the scope of our presentation.)

o   For this reason and because the Fort Collins forecast appears to have performed more satisfactorily than the Boulder forecast, the Fort Collins forecasts were considered more useful than those for Boulder.

o   Though extensive interactive help was available through the expert system, forecasters did not use the help pages as often as expected by the system developers.

o   Interpretation of the system forecasts was a major concern of the forecasters. Since the forecasts pertained to points where the verification wind speeds used in the dependent data sample were measured, it was important that forecasters properly interpreted the system's forecasts. This was done principally by one-on-one discussions between forecasters and system developers. Once the forecasters became aware that this information was available in condensed form from the help pages, they used it to refresh their memories concerning proper interpretation.

o   To save time, the forecasters often circumvented those sections of the program where interactive input was required. In particular, the product dealing with the existence and depth of surface-based cold air east of the mountains was often bypassed by indicating there would be no such cold air in the system input.

o   During the 1990-1991 windstorm season, the necessity of manually tabulating and hand-entering the input data limited the utility of the system. However, before the 1991-1992 windstorm season, an upgrade was made to automatically generate quantitative input to the expert system derivable from model gridded forecast data. This saves the forecasters much time; they no longer need to call up several specialized products on the workstation, visually inspect them, and then write down required inputs.

During the past two years, we have seen very few windstorms east of the Front Range, particularly in Boulder. This makes traditional procedures for evaluating skill of doubtful value. It is apparent, however, that although the Boulder portion of the expert system performed satisfactorily in indicating which situations had very low probability of producing high wind, it exhibited poor ability in identifying those few situations where high wind did occur. In one case, the most severe windstorm of the past two years, this can be attributed in part to a poor forecast by the NGM. This points out the Achilles' heel of any system that requires input from an operational 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). Second, we are convinced that Boulder windstorms are inherently less predictable than those in Fort Collins, because of different physical mechanisms.

Some other topics that we would like to cover at the workshop, depending on the time available and perceived interests of the participants, include:

      o demonstration of the expert system on a PC;

      o issues involved in developing a similar system for other locations in the western
      United States and Canada, particularly along the eastern slopes of the Rockies;

      o challenges presented by use of centrally prepared model guidance as input to
      systems of this sort;

      o redesign of the present system.

4. CONCLUSIONS

This expert system application is a good example of how theoretical adva

5. REFERENCES

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* One mile per hour equals 1.609 km per hour equals .4469 m/s.