Development of Empirical Weather Forecasting Techniques for Soaring Flight

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Abstract

A method for developing empirical weather forecasting techniques is described. The method is applied to the problem of forecasting conditions favorable for the Diamond distance and record flights in eastern Colorado USA. A simple set of forecasting rules for such conditions results. The development technique is general enough that it could be used to develop equivalent soaring forecast rules for other regions.

Introduction

There is a strong need for simple empirical forecast rules for soaring weather. Such forecasting rules allow non-meteorologists to make reasonable weather forecasts based on information available from flight service stations, the web, or other convenient sources. These rules serve as a bridge between the numerical weather prediction model output provided by these sources and the GO-NOGO decision which the pilot has to make. This capability greatly enhances the soaring pilot's ability to plan flights. This capability is particularly useful for cross country and badge flights.

Pilots flying wave or ridge lift have been developing such rules for decades. For example, the Sierra Wave Project[1] developed a set of rules for predicting mountain lee waves in the Bishop California area. Indeed, most pilots who regularly plan record attempts have developed such schemes based on personal experience. However, the development of forecasting skills based on personal experience may take years. Fortunately, in most regions, it is possible to make use of the experiences of other pilots in developing forecasting techniques.

While much general information can be derived by talking with pilots and meteorologists, it is easiest to develop objective forecasting techniques from the records of a number of flights of the type contemplated. The weather patterns present on the dates of these flights can reasonably be expected to provide conditions favorable for similar flights when they recur in the future.

This note presents a simple method for developing such forecast rules by determining which factors are always present during those days on which successful flights have been made. A list of these factors is then used as a forecasting checklist. Similar techniques have been used to develop forecasting rules for severe storms[2, 3] and in a broad range of business applications[4].

Data

The first requirement to develop a forecast technique is a list containing the dates of as many successful flights as possible. As in all empirical forecast methods, nothing improves accuracy so much as having an adequate number of example cases to work from. Dates of successful soaring flights are recorded in a number of places. At the time when this method was originally developed, the early 1980s, the best source was the list of Diamond distance, record, and other long flights in "Soaring" (The Journal of the Soaring Society of America). The logbooks of a number of pilots from the region could be used if available. The most complete set of records is that kept by the Soaring Society of America of all badge flights in the U.S. Online access to such information would be invaluable in soaring forecast development. The Online-Contest (www.ssa.org/members/contestreports/OLC.htm) also is expected to be a rich source of flights.

The second requirement to develop a forecast technique is a set of relevant meteorological data for each of the successful flights. Such meteorological data are also available from a number of sources. The USA National Oceanic and Atmospheric Administration publishes a daily weather map series including: 500mb and surface maps for 1200 GMT and maximum and minimum temperature maps[5]. At the time of this writing, 2007, equivalent maps were also freely available on the web at the National Climatic Data Center and various academic and commercial weather data archives.

These sources of meteorological data were used in conjunction with flight data recorded in "Soaring" to derive a set of forecast rules for exceptional soaring days in eastern Colorado using the technique described in the next section.

Forecast rule development

The steps followed in deriving the forecasting rules are shown schematically in Fig. 1.

The first step is to define the conditions to be forecast. For example, conditions needed for Diamond distance or record flights in eastern Colorado.

The second step is to collect a sample of the dates of such occurrences. For the study of exceptional soaring days in eastern Colorado, the Diamond distance, record, and other long flight dates from seven years of "Soaring" were used. This gave a total of 29 days. At this point, it is useful to develop an occurrence climatology to guide pilots in long range planning. To estimate the number of favorable days per year, one first plots a histogram of the number of flights versus day of the week. Figure 2 shows the distribution of exceptional soaring days in eastern Colorado by day of the week for the 7 year sample period. The variation of number of occurrences is partly random but mainly due to the availability of soaring pilots and tow planes. Averaging the Saturday and Sunday flight numbers yields a value of 7 occurrences over 7 years. Thus, extending this per/day frequency to the entire week there are, on the average, at least 7 days per year suitable for Diamond distance or record flights in eastern Colorado. This average value would be low if all favorable days during the years studied were not used for recorded flights. A histogram of number of flights versus time of year, such as that shown in Fig. 3, can also be plotted. This graph is of use in long range flight planning.

The third and perhaps most difficult step in creating a forecasting rule is to hypothesize a set of predictors, that is measurable features of the atmosphere that together permit the desired soaring flight. For instance, one might expect maximum temperature, cloudbase height, or surface high pressure center positions to be related to soaring conditions. All possible predictors may not be obvious at the beginning of the study. The results of analysis of one predictor might suggest others. For example, the failure of 500mb temperature to predict favorable soaring conditions might lead one to try the lapse rate from the surface to 500mb. Consultation with experienced local pilots or soaring oriented meteorologists is useful at this stage to ensure the physical reasonableness of the predictors for soaring flight. Another important consideration is ease with which a pilot can access and assess a predictor. For example the system developed in the next section uses one predictor that requires interpretation of an upper-air weather map, something that may not be covered in all pilot training courses. If a predictor of this sort is used, simple examples should be included to train the users in recognizing the required weather pattern.

The fourth step is to relate each potential predictor to the soaring weather. There are many methods for doing this[4], but the technique discussed here uses a simple graphical method suitable for use with pencil and paper or a spreadsheet program. For predictors that can be expressed as numbers, a plot is prepared of the climatological value of the predictor versus time of year as shown in Figs 4A through 4D. The value of the predictor for each successful flight is then plotted on the graph. If a large percentage of the points lie to one side of climatological curve, such behavior of the predictor is a necessary condition for the occurrence of favorable weather conditions. Examples of such predictors can be seen in figures 4A and 4C. In contrast, Figures 4B and 4D show an ineffective predictor.

There is no guarantee that a predictor chosen in this way will be a sufficient condition for occurrence. Thus, a favorable value of the predictor does not guarantee an occurrence of a favorable weather but an unfavorable value guarantees the non-occurrence of favorable weather. This is the best that can be done with incomplete data on the dates of occurrence of favorable weather. Given enough independent predictors, however, it should be possible to achieve accurate discrimination of favorable and unfavorable weather conditions.

For pattern-type predictors, such as frontal positions, that can't be expressed as a single number, climatological data may be unavailable or time consuming to obtain. Therefore, it is more difficult to decide if a pattern-type predictor is a good predictor. Figure 5 is the composite chart of one pattern-type predictor, the 55 degree F dewpoint contour, for days of occurrence of exceptional soaring conditions in eastern Colorado. This predictor shows considerable spatial packing in the vicinity of Colorado's eastern border, indicating that its position in the region can be used as a necessary condition for exceptional soaring days in eastern Colorado. In particular, the displacement of the moist tongue well east of the Rockies and the absence of the southwest monsoon in western Colorado can be seen to be necessary conditions.

Other pattern-type predictors (not shown) are also potentially useful. For example, the relative absence of 500mb troughs from the region around Colorado on exceptional soaring days is also pronounced. In contrast, the relation between soaring conditions and the 500mb ridge position is not so clear cut although a ridge in the eastern US frequently occurs in conjunction with exceptional soaring conditions in eastern Colorado. Thus, the 500mb ridge position is at best a marginal predictor of these conditions. The surface high pressure center positions provide no information at all about soaring conditions in eastern Colorado.

After a predictor has been determined to be a necessary condition for the occurrence of favorable weather, one must determine its utility before including it in a set of forecast rules. Generally the predictor should be readily available no later than the morning of the flight. Data which can be obtained by listening to radio or television forecasts, browsing the web, or by calling a pilot briefer are ideal. Predictors involving complex concepts should be avoided to reduce confusion during telephone briefings.

If a predictor passes the test of availability, it should be written into an unambiguous forecasting rule for inclusion in the forecasting scheme. One should continue testing predictors until a large enough set of rules is developed to reliably differentiate favorable from unfavorable weather conditions. Because of the sparseness of the available soaring data sets, the only way to determine the percentage of false favorable forecasts is in flight. Several soaring season may be needed to completely test and refine a forecasting scheme.

The accuracy of a forecast technique developed using this approach will depend on both the number of flights examined and the relevance of the predictors tested. For a large enough sample of flights it is possible to eliminate most, but not all, of the effect of coincidence on the predictor selection and rule tuning process. Only validation on an independent set of flights made on different days can quantify the remaining degree of overfitting, and thus the expected rate of forecast error[4].

The errors in forecasts of this type will lie on the side of predicting too many favorable days. The more independent rules one uses the less likely a false favorable forecast will be. Independence of the individual rules can be enhanced by not including related predictors. For example, relative humidity and dewpoint depression are closely dependent while 500mb wind speed and surface temperature are more nearly independent.

The forecast rules derived for exceptional soaring weather in eastern Colorado have been prepared into a simple checklist listed in the Appendix. By following the instructions, pilots can quickly make their own objective forecast.

Conclusions

Using the techniques outlined in this paper, pilots with some meteorological expertise can derive objective forecasting rules for soaring weather. These rules can then be used by any pilot in the region to generate weather forecasts for use in GO-NOGO decisions prior to leaving home. In most locations, it will be much more practical to use this method than to maintain a supply of motivated and experienced soaring forecasters at the local weather service office.

References

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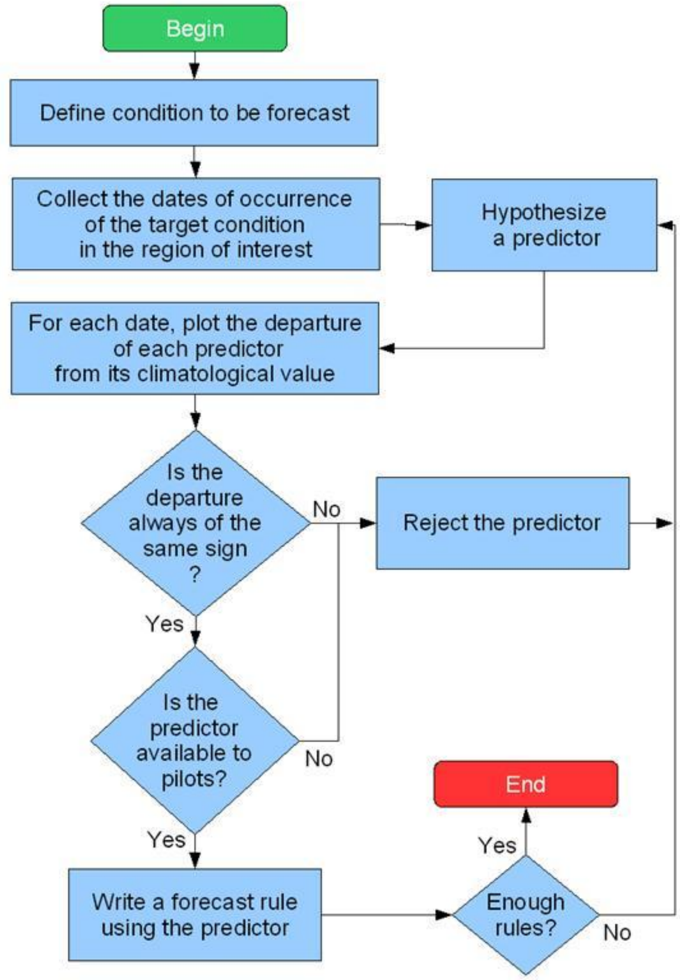


Figure 1 Schematic diagram of the steps involved in developing an objective forecasting scheme.

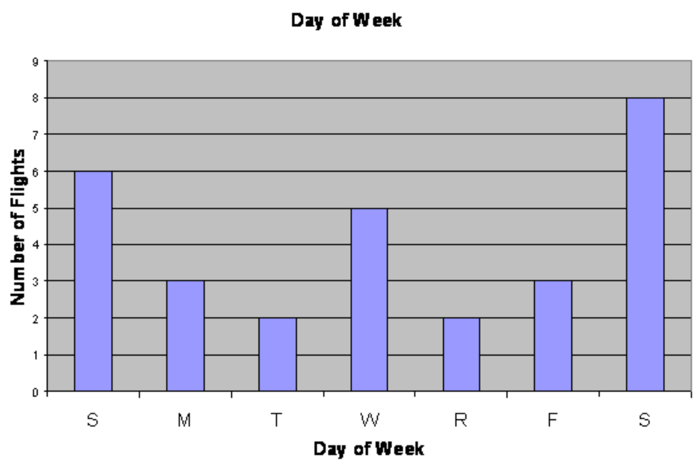


Figure 2 Histogram of the number of recorded exceptional soaring days n eastern Colorado for a 7 year period versus day of the week.

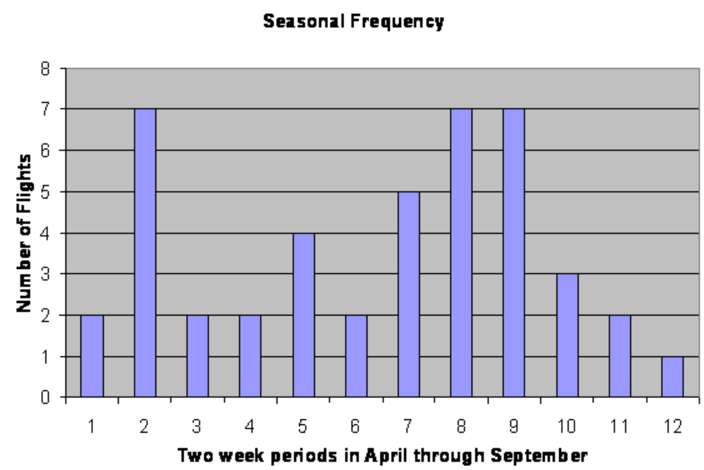


Figure 3 Histogram of the number of recorded exceptional soaring days in eastern Colorado for a 7 year period versus time of the year.

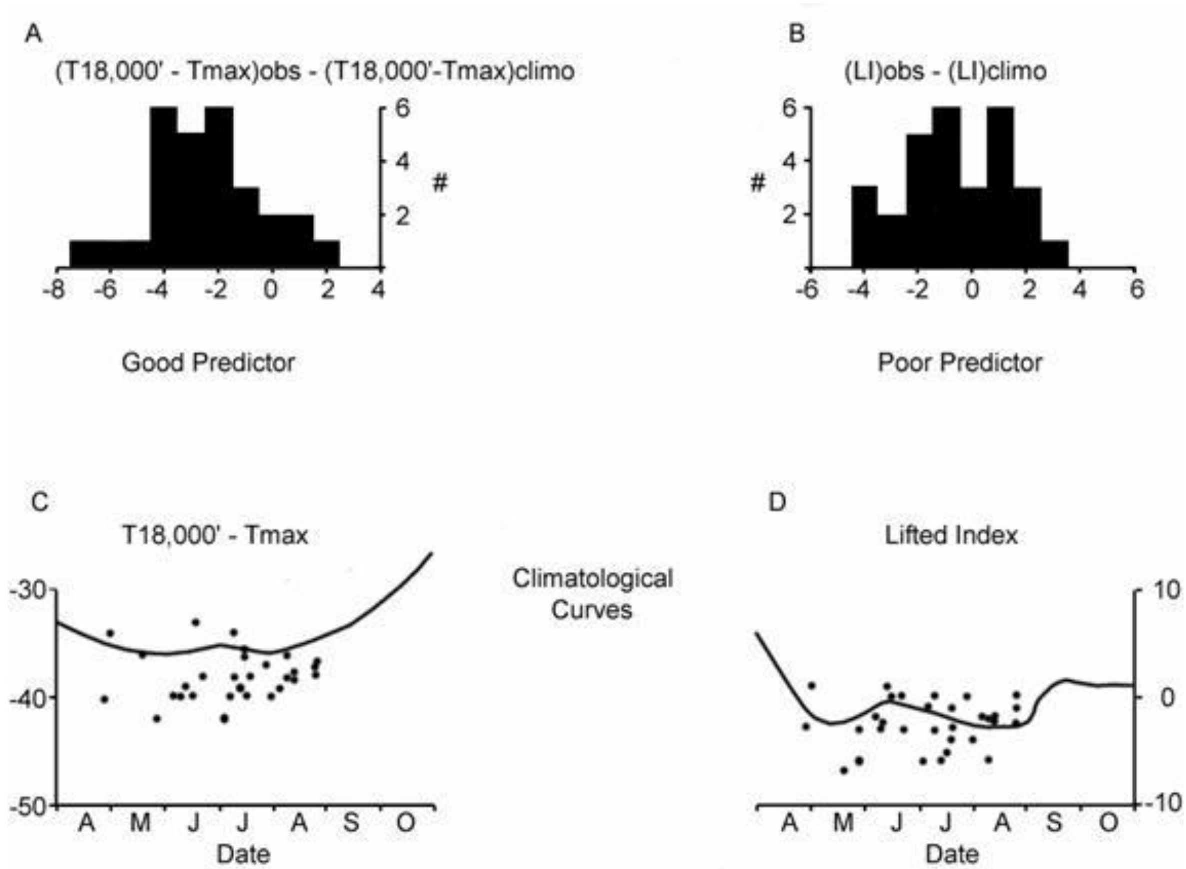


Figure 4 Predictor analysis graphs for surface to 18,000 foot AGL lapse rate and Lifted Index at Denver, Colorado for a 7 year period. A) Shows the number of exceptional flight cases as a function of departure from the climatological value of lapse rate. B) Is the corresponding plot for Lifted Index, a measure of thunderstorm intensity. C) and D) The lower graph in each pair is the scatter-plot from which these histograms (frequency plots) were derived.

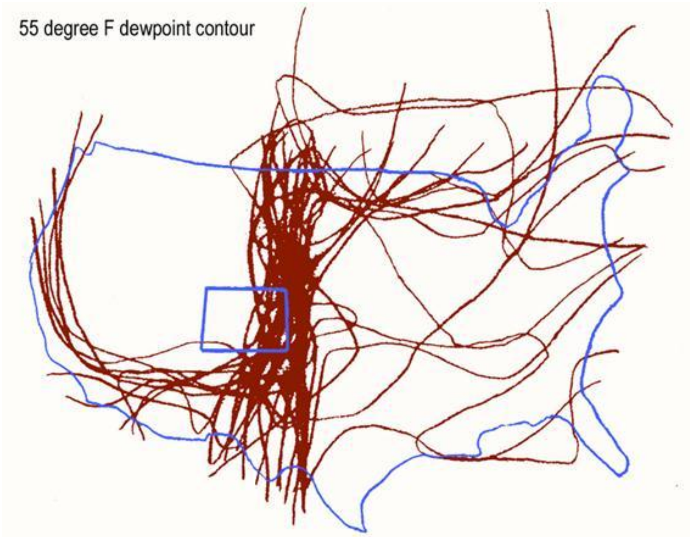


Figure 5 Map of 55 degree F dewpoint contours for days of exceptional soaring in eastern Colorado for a 7 year period.

Appendix

Forecast technique for exceptional soaring days in eastern Colorado

1. Obtain the forecast maximum temperature in degrees F for Denver from the television, radio, or the web:
   T_{MAX} =____________________

2. Call local flight service station or check the web to obtain the following information:

   Current dewpoint temperature at Denver in Degrees F: $T_{Dewpoint}$ =_________

   Forecast temperature at 18000 ft. for Denver for 1200 GMT in Degrees C: $T_{18,000}$ =____________

   Are there any dewpoint temperatures greater than 55 degrees F in the western half of Colorado:
   Yes______________________ No________________

   Are there any troughs on the 500mb (or FL180) chart between the states of Utah and Minnesota inclusive?
   Yes______________________ No________________

3. On Graph 1, cross index T_{MAX} with the date. If this point is in the "bad" region the day will NOT be exceptional.

4. Subtract $T_{Dewpoint}$ from T_{MAX} and cross index this difference with the date on Graph 2. If this point is in the "bad" region, the day will NOT be exceptional.

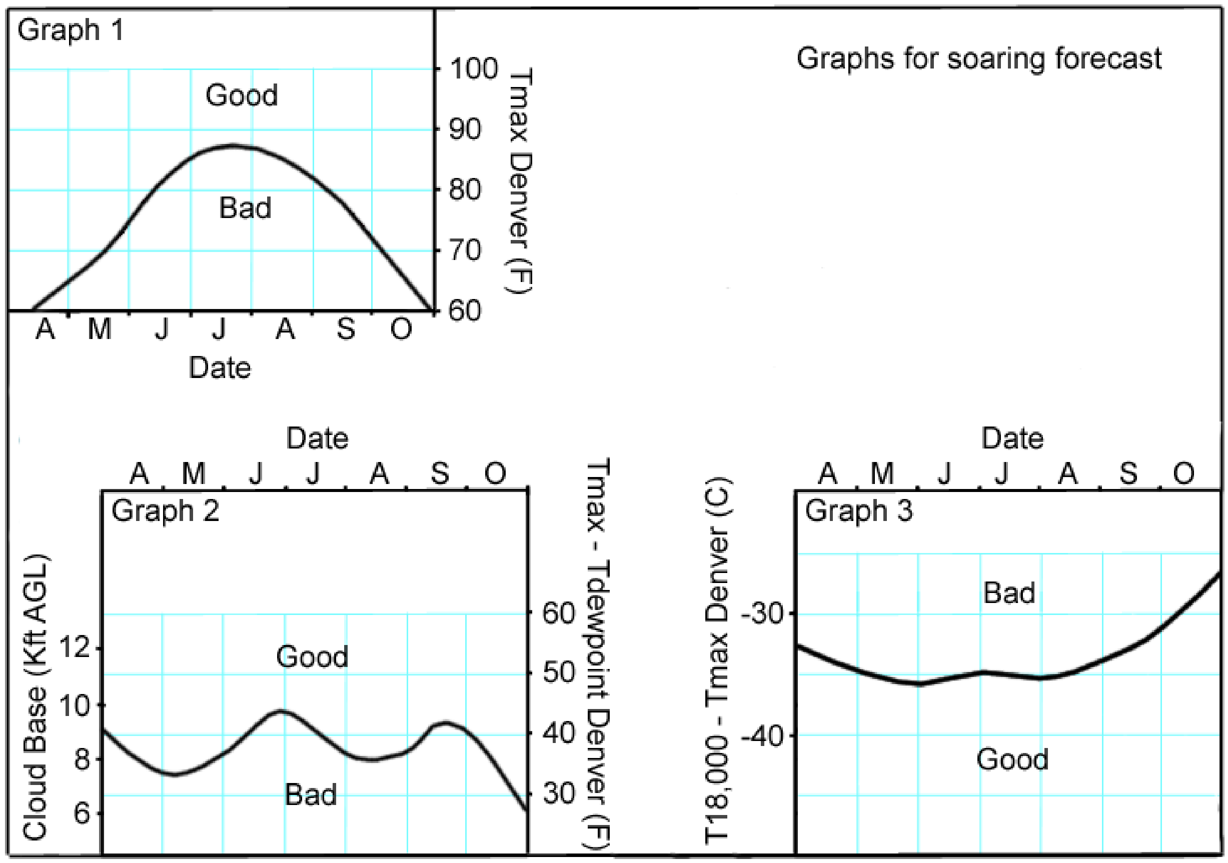
5. Convert T_{MAX} from degrees F to degrees C using the following formula:

   Degrees C = [(Degrees F – 32) x 5]/9

6. Subtract T_{MAX} in degrees C from $T_{18,000}$. On Graph 3, cross index this difference with the date. If this point is in the "bad" region, the day will NOT be exceptional.

7. If there are any dewpoint temperatures greater than 55 degrees F in the western half of Colorado, the day will NOT be exceptional

8. If there are any troughs on the 500mb (or FL180) chart between Utah and Minnesota inclusive, the day will NOT be exceptional.



Brief explanation:

Origin: This forecast scheme was developed by examination of those days on which Diamond distance flights were made in Colorado during the 1970s and 1980s. It is purely empirical, although theoretical justification can be made for the relevance of each of the predictors. Changes in climate and land use since the 1980s may have some impact on the validity of these forecasts, although the mountain meteorology upon which it primarily depends is likely to have changed less so these effects should be minor.

Interpretation: Days which meet all the above tests will be exceptional, that is Diamond distance or speed records will be possible. The fewer of the conditions met, the poorer soaring will be and the more likely it will be that thunderstorms will cause an early end to soaring.

Input: The forecast scheme works best when 1200 GMT dewpoints and 500mb charts are used. This can be done only if the forecast is made the morning of the flight. If the forecast is based on charts valid the night before, the results will still have some meaning, but will be less accurate. However, accurate forecasts can be made the night before if 1200 GMT forecast values are obtained for all parameters. Appropriate charts are available from numerous sources on the web, including the National Weather Service, Federal Aviation Administration, and various private enterprise weather forecasting firms.