FORECASTING THERMAL CONDITIONS FOR SOARING

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INTRODUCTION

Convection in the atmosphere is generally understood as buoyant air rising through a relatively cold environment. The details of these rising currents, called thermals by the soaring pilot, are not easily predicted. There is no simple guide for forecasting their sizes, shapes, or their vertical motions in a qualitative way, or the altitude to which useful vertical motions in thermals will extend. The problem of the differences in vertical velocities, or lift, between dry thermals and thermals associated with convective clouds also will be considered.

How strong convection will be, to what altitude it will extend, and what time it will begin and end is of prime importance to the soaring pilot. If thermals are strong enough and reach sufficient altitude, the soaring pilot can make a cross-country flight. If thermal conditions are to be weak, he will have to be content to make short local flights.

A great deal of work needs to be done on the subject before we can improve on present-day techniques of forecasting for soaring. It appears that very little has been written on objective methods and most of the methods used are based on individual experience. This experience needs to be recorded. From such recorded information, aviation forecasters who do not possess years of experience can improve their forecasts for soaring flight. This also needs to be done so that more forecasters will be available to prepare forecasts for the sport on a routine basis.

OBJECTIVE METHODS FOR FORECASTING THERMAL ALTITUDE AND STRENGTH

Based on the Thermal Index by Higgins (Ref. 1) and the experience of briefing soaring pilots and collecting data on their flights, an attempt has been made to arrive at a more objective means of determining the altitude to which soarable thermals will reach and the strength of these thermals.

Generally, for local soaring on weekends, soaring pilots need to know if soaring will be good, fair, or poor. For cross-country soaring and for competition flying, they need to know how high thermals will extend, how strong they will be, how early they will start, and how late they will end. Comments by the forecaster on the nature of the thermals as affected by wind shear, etc., is also helpful to the pilot (Ref. 2). Thermal streeting is also important to mention and is easy to predict when the proper wind and lapse rate conditions are present (Ref. 3).

Forecasting the Altitude of Thermals

The flight data used in this study were made by Mario Piccagli over a period of seven years (1963-1969) in the general area of Frederick, Maryland, just to the east of the Catoctin Mountain Range. A Standard Austria Sailplane was flown by Piccagli on each flight, and the altitudes he reached and the thermal strength were obtained from a recording barograph that he used on each flight. A number of meteorological variables were related to his data and the most useful relationships are included in this study.

On days when cumulus develops, the altitude to which soarable thermals will reach is generally the base of the cumulus clouds. Thermals, of course, extend into the cumulus clouds, but cloud flying is prohibited in most soaring. For this study, we will consider only thermals below cloud base. There are well-known methods for forecasting the base of cumulus clouds.

On days when only dry-thermals are forecast, several methods can be used to indicate the altitude to which they will reach. The first relationship (Fig. 1) shows the maximum altitude (h) reached in 58 flights plotted against the height of at least a -3 Thermal Index Z(-3TI).

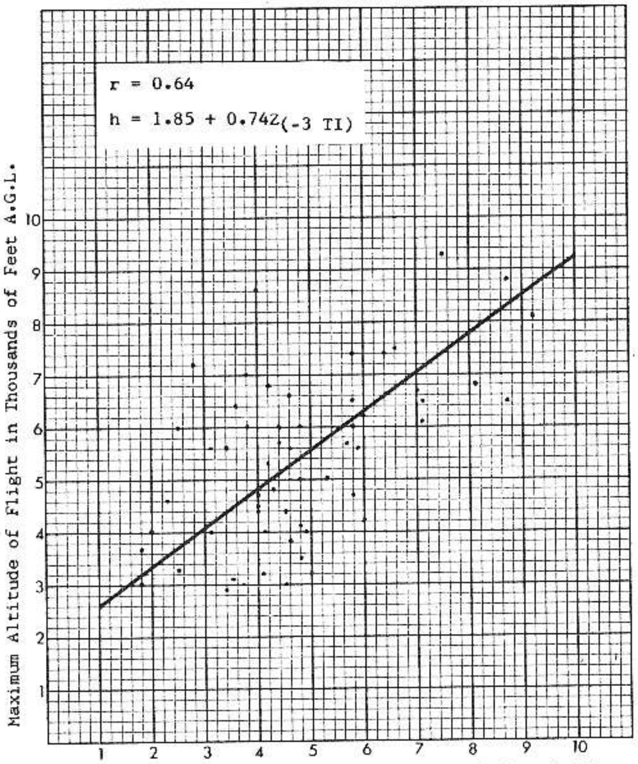

FIGURE 1. THE MAXIMUM ALTITUDE (h) REACHED IN 58 FLIGHTS PLOTTED AGAINST THE HEIGHT OF AT LEAST A -3 THERMAL INDEX Z(-3TI)

The Thermal Index (Ref. 1) is defined as the difference between the potential temperature at a given altitude and the potential temperature of the forecast surface high temperature for the day. Higgins (Ref. 1) suggests that a potential temperature increase of three degrees or greater (a TI of -3 or less) indicates a very good chance for sailplanes reaching the altitude of this difference. The data in Fig. 1 show a correlation coefficient of 0.64 which is sufficiently high to be useful in forecasting. The line of best fit on the graph is one computed by the method of least squares. This graph shows the altitude a soaring pilot could probably reach based on the amount of heating expected in the lower levels as a result of surface heating. At times, there are initial temperature profiles when this relationship does not work very well, such as when the initial lapse rate is almost dry-adiabatic for a considerable altitude. In this case, the altitude of the flight would be higher than indicated by this method. The correlation coefficient (r) and the regression equation are shown on all figures for comparison.

The second relationship for forecasting the altitude to which useful dry thermals will extend is shown in Fig. 2. This

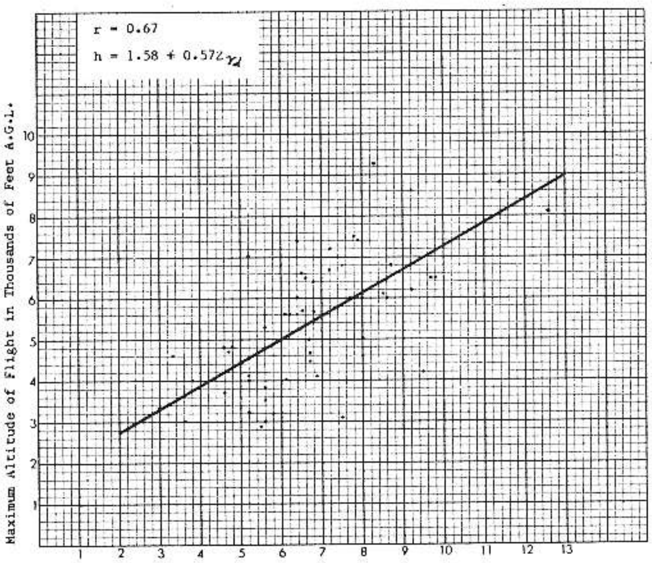

FIGURE 2. RELATES THE MAXIMUM ALTITUDE (h) REACHED IN EACH OF PICCAGLI'S 58 FLIGHTS TO THE MAXIMUM HEIGHT TO WHICH THE DRY-ADIABATIC LAPSE RATE (Z_{γ_d}) EXTENDS WITH MAXIMUM SURFACE HEATING ON A GIVEN DAY

graph relates the maximum altitude (h) reached in each of Piccagli's 58 flights to the maximum height to which the dry-adiabatic lapse rate ($Z_{\gamma d}$) extends with maximum surface heating on a given day. The data in this case produced a correlation coefficient of 0.67. This seems to work better than the Thermal Index because it can be used regardless of the shape of the initial sounding.

Forecasting the Strength of Thermals

Plotting a performance curve (Fig. 3) of Piccagli's flights produced interesting results. In relating the maximum altitude (h) to which Piccagli soared to the maximum thermal strength or lift (L) he encountered produces a correlation coefficient of 0.76. It is interesting to note that the slope of this curve compares closely with the slope of the curve by J. Warner (Ref. 4) where he relates the vertical velocity in cumulus clouds as a function of their height above cloud base. Warner found that the vertical velocity increase with height of the cloud above base was 0.7 m/sec/km (about 140 ft/min/3281 ft). The performance curve from Piccagli's data also shows about the same slope below cloud base with the data for dry thermals included.

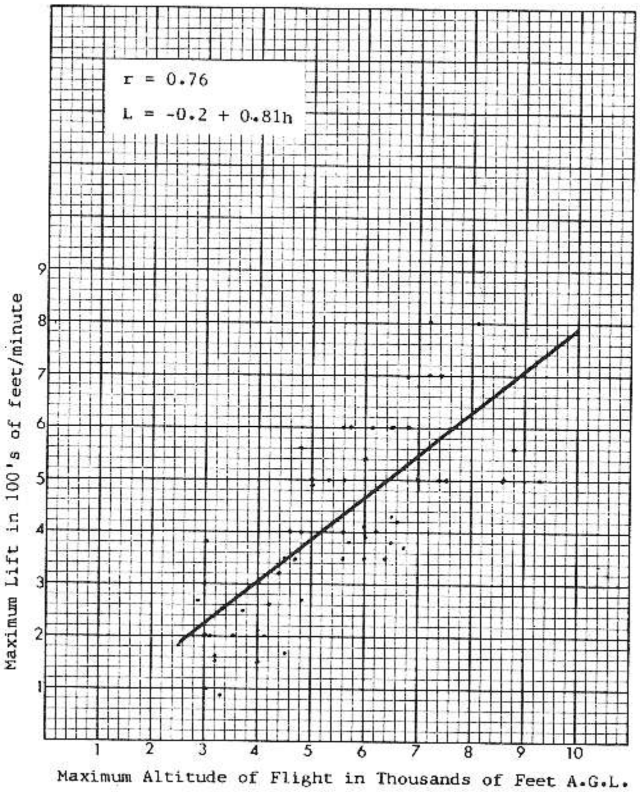

FIGURE 3. PERFORMANCE CURVE RELATING THE MAXIMUM ALTITUDE (h) TO WHICH PICCAGLI SOARED TO THE MAXIMUM THERMAL STRENGTH OR LIFT (L) HE ENCOUNTERED

In relating the maximum thermal strength or lift to meteorological data (Fig. 4), the maximum height of the dry-adiabatic lapse rate for each day was used based on maximum surface heating.

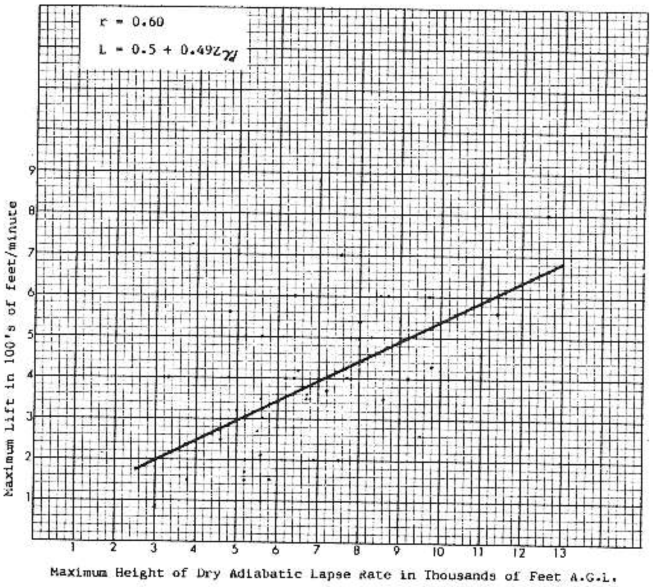

FIGURE 4. RELATES THE MAXIMUM THERMAL STRENGTH OR LIFT (L) TO THE MAXIMUM HEIGHT OF THE DRY-ADIABATIC LAPSE RATE BASED ON MAXIMUM SURFACE HEATING

This relationship produced a correlation coefficient of 0.60, a value somewhat less than that obtained in an earlier study when fewer data were available. Note that Piccagli's flights indicated that the air had to be heated enough to become dry-adiabatic to about 3000 ft before he encountered lift of 1000 ft/min or greater.

With the 58 cases divided almost evenly between days when cumulus were observed and days when only dry thermals occurred, two more relationships were examined. Soundings were used for examination of these two types of cases as well as surface weather observations. Figure 5, relating the maximum thermal strength for dry thermals to the maximum height of the dry-adiabatic lapse rate, produced a correlation coefficient of 0.60. The lowest maximum altitude of the dry-adiabatic lapse rate, giving lift of 100 ft/min or greater, was about 3000 ft.

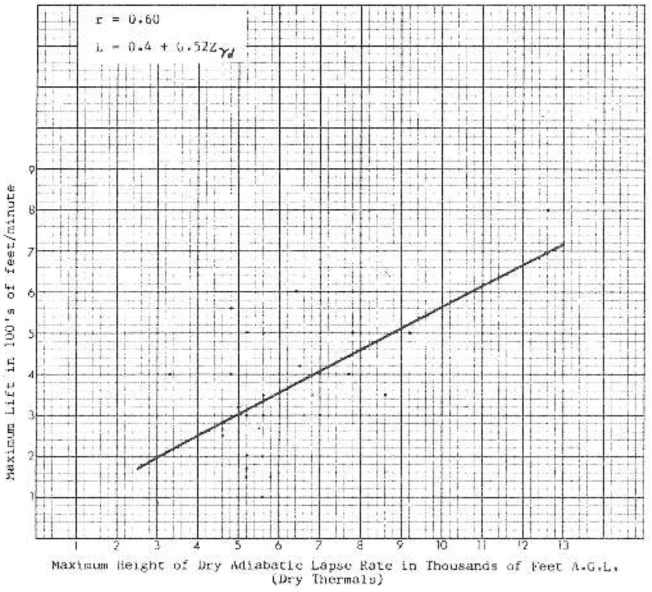

FIGURE 5. RELATES THE MAXIMUM THERMAL STRENGTH FOR DRY THERMALS TO THE MAXIMUM HEIGHT OF THE DRY-ADIABATIC LAPSE RATE BASED ON MAXIMUM SURFACE HEATING

The graph (Fig. 6), relating the maximum thermal strength (L) to the initial height of the Convective Condensation Level (CCL) as derived from the radiosonde soundings on days when cumulus were observed, produced a correlation coefficient of 0.64. It is interesting to note that the slope of this curve compares favorably with Piccagli's performance curve (Fig. 3) and also with the results by Warner. From these results, it appears that the thermal strength related to the altitude of convection below cumulus increases at about the same rate with altitude as that related to the thickness of cumulus clouds. From a forecasting standpoint, convection in the cumulus cloud is an extension of the convection below the cloud, although this is not always the case. However, some of the increase in thermal strength in cumulus can be attributed to the release of the latent heat of condensation. Soaring pilots and meteorologists have noted that thermal strength is usually stronger in cumulus clouds than below the clouds. Soaring pilots will usually find that lift is stronger in a dry thermal that extends to 8000 ft than one that extends to only 5000 ft.

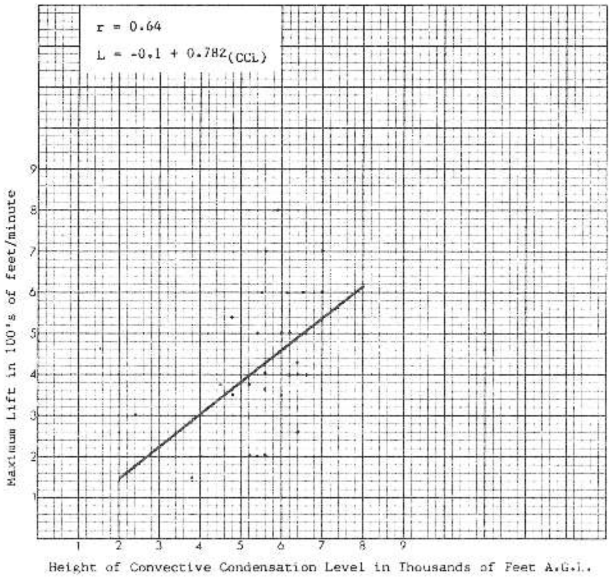

FIGURE 6. RELATES THE MAXIMUM THERMAL STRENGTH (L) TO THE INITIAL HEIGHT OF THE CONVECTIVE CONDENSATION LEVEL (CCL)

Note that in Fig. 6 the lowest cumulus base under which significant lift was encountered was about 2500 ft. Also note that the slope of the curve in Fig. 6 is greater than in Fig. 5, indicating that for a given altitude lift under cumulus will usually be stronger than for the same altitude in a dry thermal.

RESULTS AND THEIR USE IN FORECASTING

The graphs presented can be used as a tool for forecasting, and the regression equations could be used without the graphs to arrive at expected average conditions. A soaring pilot might also find some of these relationships useful in his flight planning other than during a contest. In addition to the results obtained from these graphs, a forecaster also needs to consider the following in refining the final forecast:

1. Cloud amount and type.
2. Changes in the lapse rates that may occur because of advection of colder or warmer air and moisture at critical levels.
3. Inversions and changes in inversions as a result of subsidence and moisture levels.

4. The effect of wind and wind shear on thermals (Ref. 2).
5. Wind and lapse rate conditions causing thermal streeting.
6. Convergence or divergence zones.
7. Recent rainfall over the flying area.
8. The type of terrain.
9. Type of air mass over the flying area (Ref. 5).
10. Previous day's soaring results, if any are available, help in relating soaring conditions to a particular weather pattern.

A number of variables are currently being calculated from radiosonde data through the use of high-speed computers by the National Weather Service. The CCL and the height of the dry-adiabatic lapse rate, based on maximum surface temperature forecasts, are computed. Using regression equations presented here, vertical motion (lift) could be computed for soaring flight for every sounding, and charts of iso-lift for both thermal altitude and strength could be drawn. Currently these computer calculations are not available early enough to be used for preparing a current day's soaring forecast.

Several of the graphs prepared from Piccagli's flight data have been used in soaring contests with a fair amount of success. They were used at the 1970 International Contest at Marfa, Texas, as a test. They were also used with good results at a Schweizer 1-26 Regatta in Virginia and at the Mid-Atlantic Regional Contest in September 1970 held in the Maryland-West Virginia area.

It would seem reasonable to expect better results using these graphs when forecasting over areas of relatively flat terrain as compared to mountainous terrain where convection patterns are more complicated.

If the terrain is considerably different from that where the flights were made in this study, differences in results may occur.* However, the principle involved in this study indicating the tops of soarable thermals and relating thermal strength to the vertical extent of the thermal is usable.

At the recent OSTIV Congress on Soaring Meteorology held at Zell am See, Austria, this study was thought to offer the best basis for prediction.

An aviation forecaster seriously interested in soaring meteorology should keep records of soaring flights made in his area and compare data from the flights with the relationships presented here. He might find useful variations due to mountains or special local weather patterns that affect his area. He should also seek out other useful relationships. In this way he could make improvements in the briefing services to soaring and to general aviation as well. Forecasters gaining knowledge of the soaring pilot's needs will also gain knowledge that will help in briefing and forecasting for pilots of small and large powered aircraft as well..

ACKNOWLEDGEMENT

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*Results for Fig. 2 are 2000 to 3000 ft higher over desert areas of California and Arizona.