# "DO-IT-YOURSELF" SOARING THERMAL FORECASTING

### By Russell O. Pearson

Presented at the XXII OSTIV Congress, Uvalde, Texas, U.S.A. (1991)

## INTRODUCTION

My soaring experience started at retirement, offering the enviable situation of being free to soar any day of the week. However, my home is located 90 miles from the nearest gliderport and the problem developed early on as to how to optimize my soaring fun, my four-hour round trip drives and soaring tows. The objective then became to develop a "go" or "no go" daily soaring decision at breakfast.

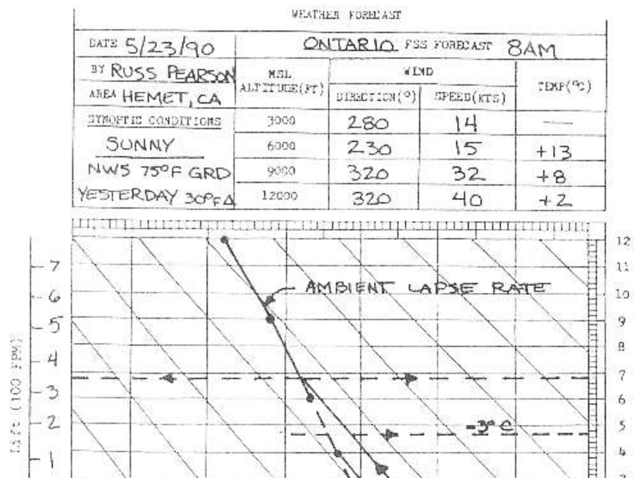
I became a student of the literature of Wallington, Lindsay, Armstrong, Higgins and Gibbs and my initial thermal forecasting utilized their suggestions with limited success, albeit, improving my soaring day selections and flight durations. My problems occurred with the use of ultra-conservative historical empirical data and the lack of availability and accuracy of local weather forecasts.

The resolution of these problems and the "do-it-yourself" soaring thermal forecasting system as presented in this paper, were developed from my data-base of thermal forecasts and flight results on 320 flying days over a seven year period. The first five flight years I flew a Blanik L-13, and the last two flight years a Schweizer SGS 1-35 primarily out of Hemet-Ryan airport in Southern California. Since the objective was to develop a forecasting method for dry thermal activity, the flight records were screened to obtain 260 results for analysis of only dry thermal flights over relatively flat areas.

## AMBIENT LAPSE RATE

The first step in thermal prediction is to identify the local ambient lapse rate or vertical temperature profile indicating the stability or instability of the ambient air. My early references Lindsay and Lacy (1), Higgins (2) and FAA (3) recommended obtaining the upper air temperatures either by local tow plane soundings or readily available 700 and 850 mb readings from the National Weather Service (NWS). Since my gliderport did not provide this as a free service, the approach of paying for five equivalent tows a week to obtain soundings for one flying day was prohibitive. My further attempts to obtain 700 and 850 mb soundings from the Los Angeles and San Diego NWS were rebuffed.

Undaunted, I remembered that winds and temperatures aloft were available during my pre-flight briefings from the FAA Flight Service Station (FSS). During 1984, I requested winds and temperatures aloft up through 18,000 feet mean sea level (MSL) from the three nearest locations for every flight made. By triangulation and comparison with temperatures aloft recorded during my flights, one Rawinsonde location (Ontario, 40 miles distant) was established as representative of the atmosphere in my local area. However, I found that only the current report given for flights before 11 a.m. was reliable for local thermal forecasting.



WEATHER FORECAST

| | | | | |
|---|---|---|---|---|
| DATE 5/23/90 | ONTARIO FSS FORECAST 8AM | | | |
| BY RUSS PEARSON<br>AREA HEMET, CA | MSL ALTITUDE (FT) | WIND | | TEMP (°C) |
| | | DIRECTION (°) | SPEED (KTS) | |
| SYNOPTIC CONDITIONS | 3000 | 280 | 14 | — |
| SUNNY | 6000 | 230 | 15 | +13 |
| NWS 75°F GRD | 9000 | 320 | 32 | +8 |
| YESTERDAY 30°F Δ | 12000 | 320 | 40 | +2 |

| SOARING | | GROUND (°F) | ALTITUDE (FT) | | MAX LIFT (FPM) | |
|---|---|---|---|---|---|---|
| | | | -3°C | ADIABAT | PLOT | CALC |
| FORECAST | TRIGGER | 76 | 11:30 | ACTUAL | 11:15 | — |
| | HIGH | 84 | 4700 | 6800 | 330 | 264 |
| | LOW | 75 | — | — | — | — |
| ACTUAL | PLOT | 83 | — | 6500 | 310 | 225 |
| | VALLEY | 83 | — | 6700 | ACTUAL = 300 | |
| | MOUNTAIN | — | — | 9200 | ACTUAL = 400 | |

FIGURE 1. Typical Soaring Forecast/Flight Record Sheet

A one page forecasting sheet was then developed with only the dry adiabatic lapse rates (5.4 degrees F/1,000 ft.) shown for clarity to record data, plot the ambient lapse rate and forecast trigger temperature and thermal heights as shown in Figure 1. It is noted that no forecast temperatures are available below 6,000 feet and the method for constructing the ambient lapse rate is to connect the 12,000 and 9,000 foot temperature points with a straight line. A straight line between 9,000 and 6,000 feet is then extrapolated to the gliderport elevation as shown in the sample of Figure 1.

## TRIGGER TEMPERATURE

Trigger temperature is generally recognized as the minimum surface temperature inducing thermals sufficient to sustain soaring flight. The historic trigger temperature utilized "...is obtained by locating a point 4,000 feet above ground level (AGL) on the sounding and lowering it adiabatically to surface; then add two degrees Fahrenheit." (Lindsay and Lacy (1).) It is noted that Armstrong and Hill (4) and Gibbs (5) also recommend this method.

However, problems occurred with the use of this historic 4,000 foot AGL determination. My observations showed that this conservatism, if adhered to, resulted consistently in launch delays of up to three hours and caused me to abort soaring trips that were later reported by friends to be good soaring days. Observations during my first year of flying (1984) resulted in the determination that the 2,500 feet AGL — ambient lapse rate intersect, without the two degree Fahrenheit (F) offset, in itself was more than adequate to sustain flight. Subsequent yearly flight records have indicated that flight was sustained 97% of the time with triggers based on a 2,500 foot AGL determination and 52% of the time based on a 2,000 foot AGL determination. These observations were based on dry sailplane launches with no water ballast.

The forecast and flight records for September 5, 1990 as shown in Figure 2 are a good example of the foregoing start delay findings. The trigger and time forecast using historic methods (Figure 2a) indicate a surface trigger temperature of 96 deg. F at 3:45 p.m., as opposed to the 92 deg. F forecast at 12:30 p.m. using the "do-it-yourself" method (Figure 2b). The actual trigger temperature (2 deg. F) occurred at 12:45 p.m., within 15 minutes of the "do-it-yourself" prediction.

Another example is shown in the forecast and flight records for May 23, 1990 in Figure 3. The trigger and time forecasts using historic methods (Figure 3a) indicate a surface trigger temperature of 81 deg. F which is higher than the NWS forecast surface temperature of 75 deg. F. In other words, I would not have made a trip to the gliderport with this forecast at breakfast time. However, the actual trigger of 76 deg. F as forecast and realized by the methods proposed in this paper (Figure 3b) resulted in a trip to the gliderport and a fun flight over over 4 hours duration. It is noted that the "do-it-yourself" trigger forecast was within 15 minutes of actual and the maximum surface temperature was off by only one degree F.

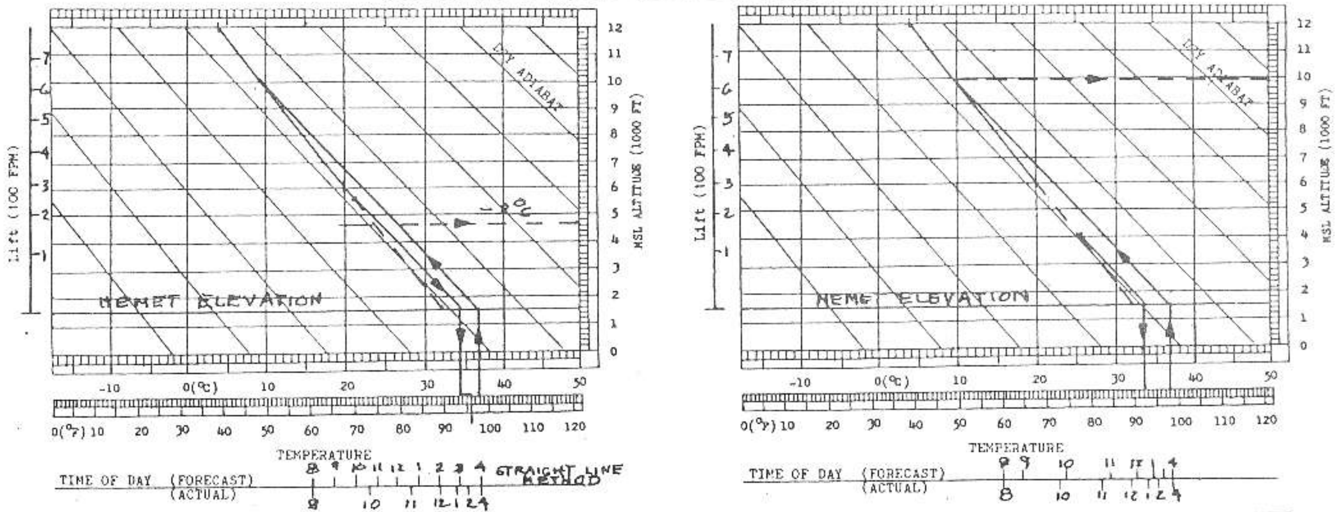
A final observation of interest is that the initial thermal activity is manifested by a slight breeze, sometimes coupled with dust devils. I have noted that the tree leaves start rustling outside the pilot's lounge area at Hemet as trigger temperature is realized. An unanswered question is: does the slight breeze initiate the thermals or do the popping runway thermals cause the breeze to start?

## ALTITUDE OF THERMALS

Thermal height predictions were initially made comparing

**FIGURE 2.** Comparison of Forecasting Methods-Thermal Altitude.

| | | | | |
|---|---|---|---|---|
| WEATHER FORECAST | | | | |
| DATE 9/5/90 | ONTARIO FSS FORECAST 7:30 AM | | | |
| BY RUSS PEARSON | MSL ALTITUDE(FT) | WIND | | TEMP(°C) |
| AREA HEMET, CA | | DIRECTION(°) | SPEED(KTS) | |
| SYNOPTIC CONDITIONS | 3000 | 340 | 8 | — |
| HAZY SUN | 6000 | L & V | | +20 |
| NWS 98°F GRD | 9000 | 170 | 9 | +12 |
| YESTERDAY 40°F Δ | 12000 | 150 | 15 | +4 |



| SOARING FORECAST | | | | |
|---|---|---|---|---|
| | GROUND(°F) | TIME | ALTITUDE(FT) | LIFT(FPM) |
| TRIGGER | 96 | 3:45 | 5500 | ACTUAL TIME 12:45 |
| HI FORECAST | 98 | 4 PM | 4700 | 150 |
| ACTUAL | 98 | 4 PM | 10 000 | 600 |

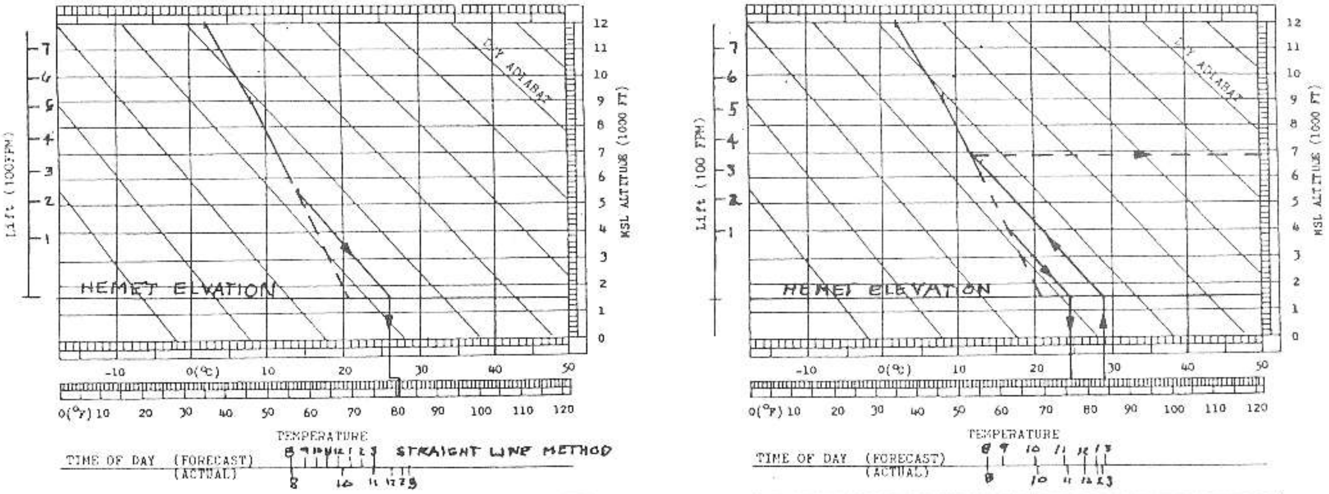
(a) Historical TI & trigger forecast

| SOARING FORECAST | | | | |
|---|---|---|---|---|
| | GROUND(°F) | TIME | ALTITUDE(FT) | LIFT(FPM) |
| TRIGGER | 92 | 12:30 | 4000 | ACTUAL TIME 12:45 |
| HI FORECAST | 98 | 4 PM | 9900 | 625 |
| ACTUAL | 98 | 4 PM | 10 000 | 600 |

(b) "Do-It-Yourself" forecast

**FIGURE 3.** Comparison of Forecasting Methods-Trigger Temperature.

| | | | | |
|---|---|---|---|---|
| WEATHER FORECAST | | | | |
| DATE 5/23/90 | ONTARIO FSS FORECAST 8AM | | | |
| BY RUSS PEARSON | MSL ALTITUDE(FT) | WIND | | TEMP(°C) |
| AREA HEMET, CA | | DIRECTION(°) | SPEED(KTS) | |
| SYNOPTIC CONDITIONS | 3000 | 280 | 14 | — |
| SUNNY | 6000 | 230 | 15 | +13 |
| NWS 75°F GRD | 9000 | 320 | 32 | +8 |
| YESTERDAY 30°F Δ | 12000 | 320 | 40 | +2 |



| SOARING FORECAST | | | | |
|---|---|---|---|---|
| | GROUND(°F) | TIME | ALTITUDE(FT) | LIFT(FPM) |
| TRIGGER | 81 | NO | — | — |
| HI FORECAST | 75 | — | — | — |
| ACTUAL | 83 | 3 PM | 6700 | 300 |

(a) Historical trigger forecast

| SOARING FORECAST | | | | |
|---|---|---|---|---|
| | GROUND(°F) | TIME | ALTITUDE(FT) | LIFT(FPM) |
| TRIGGER | 76 | 11:30 | 2500 AGL | ACT 11:15 |
| HI FORECAST | 84 | 3 PM | 6800 MSL | 330 |
| ACTUAL | 83 | 3 PM | 6700 MSL | 300 |

(b) "Do-It-Yourself forecast

the -3 deg. C and -5 deg. C Thermal Index (TI) methods proposed by Higgins (2) and Gibbs (3) with actual flight results. These methods suggest drawing a line paralleling the dry adiabatic lapse rate up from the maximum surface temperature to the ambient lapse rate intersection and backing down to a -3 or -5 deg. F difference between the ambient and the drawn dry adiabat lapse rate lines. These methods propose that this is the altitude limit for minimal soaring conditions and that indices more positive than -2 deg. F are barely capable of sustaining soaring flight. It is noted that Lindsay and Lacy (1), FAA (3), Armstrong and Hill (4) and SSA (6) also recommend this Thermal Index method.

Early flights using the TI method of thermal altitude determination appeared to be higher than forecast. In 1985, I decided to compare the results of my first 58 flight records with those of Piccagli as analyzed by Lindsay and Lacy (1) using the method wherein each line of best fit on the graph is determined by a least-squares linear regression that minimizes the sum of the squares of the deviations of the actual data points from the straight line of best fit. The line of best fit for my flights indicate altitudes much higher than TI forecast and also those of Piccagli's 58 flights as shown in Figure 4. Since my "do-it-yourself" method showed a strong correlation coefficient of 0.873 and was correct more of the time, I decided the TI method of thermal altitude forecasting was too conservative for my practical use. The flight records for September 5, 1990 as shown in Figure 2a demonstrated this conservatism in that the forecast using the TI method indicated a maximum of 4,700 feet whereas the flight altitude actually attained was 10,000 feet. The subsequent line of best fit for 260 flight results as shown in Figure 4 substantiates my early conclusions with a good correlation coefficient of 0.816.

In 1985, I discovered that most of my flights were attaining heights as forecast by projecting the dry adiabatic lapse rate up from the maximum surface temperature to the ambient lapse rate intersection as shown in Figures 2b and 3b. The subsequent line of best fit for 260 flights as shown in Figure 5 produces a correlation coefficient of 0.966, which is unusually high, and substantiates this method of forecasting attainable thermal heights. The fewer 58 flights of Piccagli, reference Lindsay and Lacy (1) did not demonstrate this approach as shown in Figure 5.

A question posed during this analysis was the impact of pilot skill level (experience) and sailplane performance on the flight height results recorded. As noted in the Figure 4 similar lines of best fit for first year flights in a Blanik versus seven years of combined experience in Blanik (medium performance) and Schweizer 1-35 (high performance) sailplanes, neither skill level or sailplane performance appear to affect the results.

**STRENGTH OF THERMALS**

A literature review revealed approximately ten methods of forecasting dry thermal strength, each of which was different, as represented by the seven displayed in Figure 6. In other words, you pay your money and you take your choice. Early on I was attracted to the "Soaring Index" method proposed by Armstrong

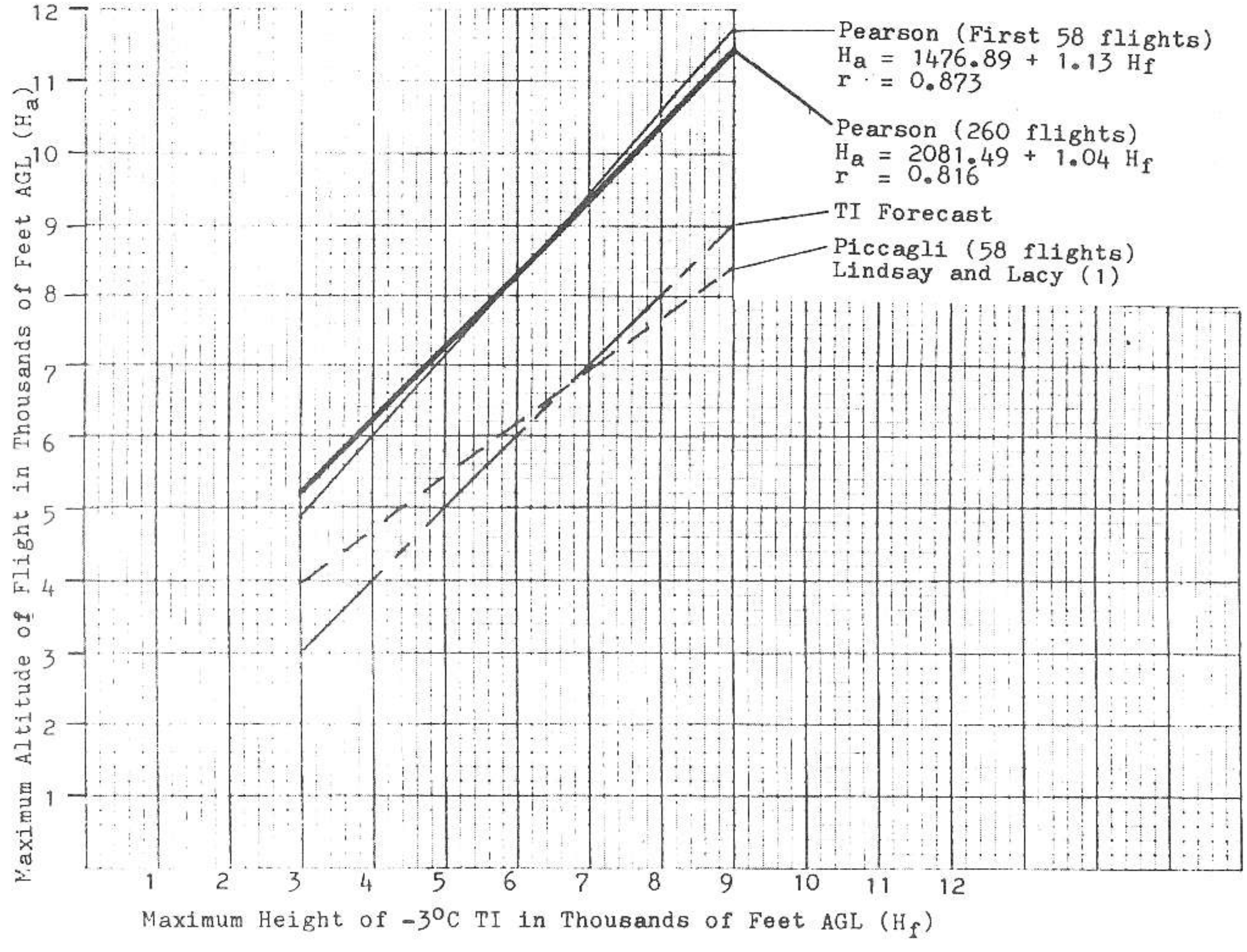


FIGURE 4. Flight Height vs. -3 Degree Thermal Index

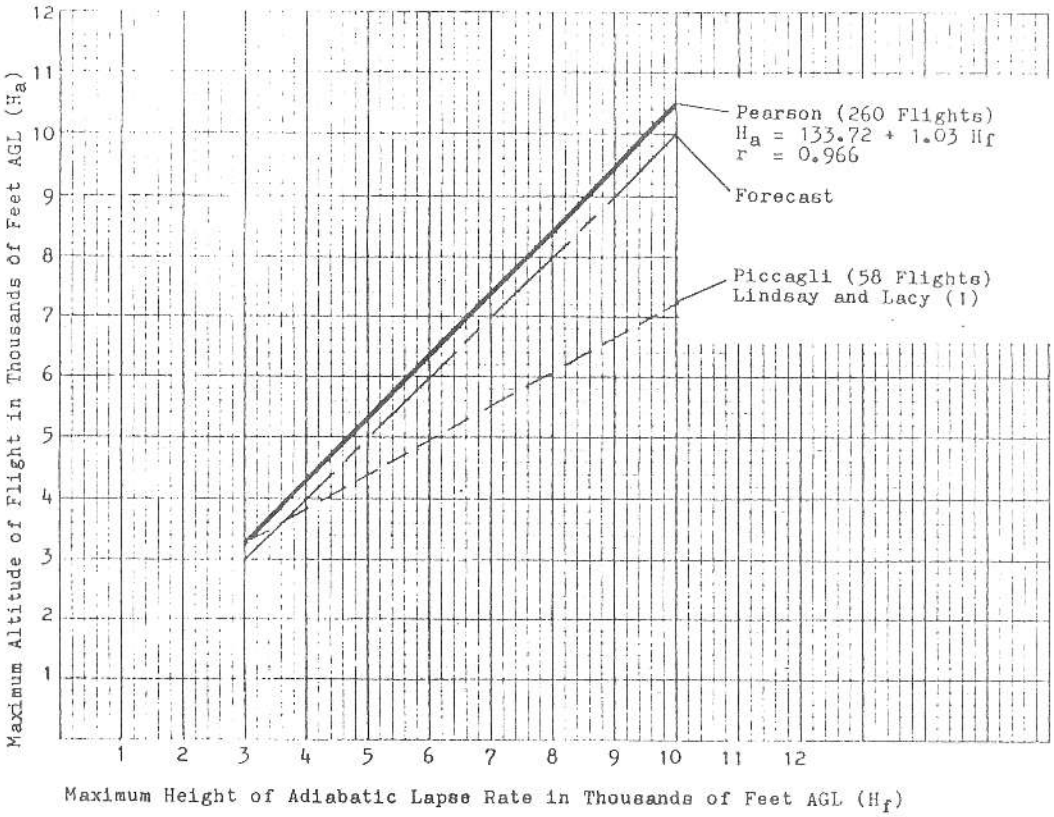


FIGURE 5. Flight Height Vs. Dry Adiabat/Lapse Rate Intersect

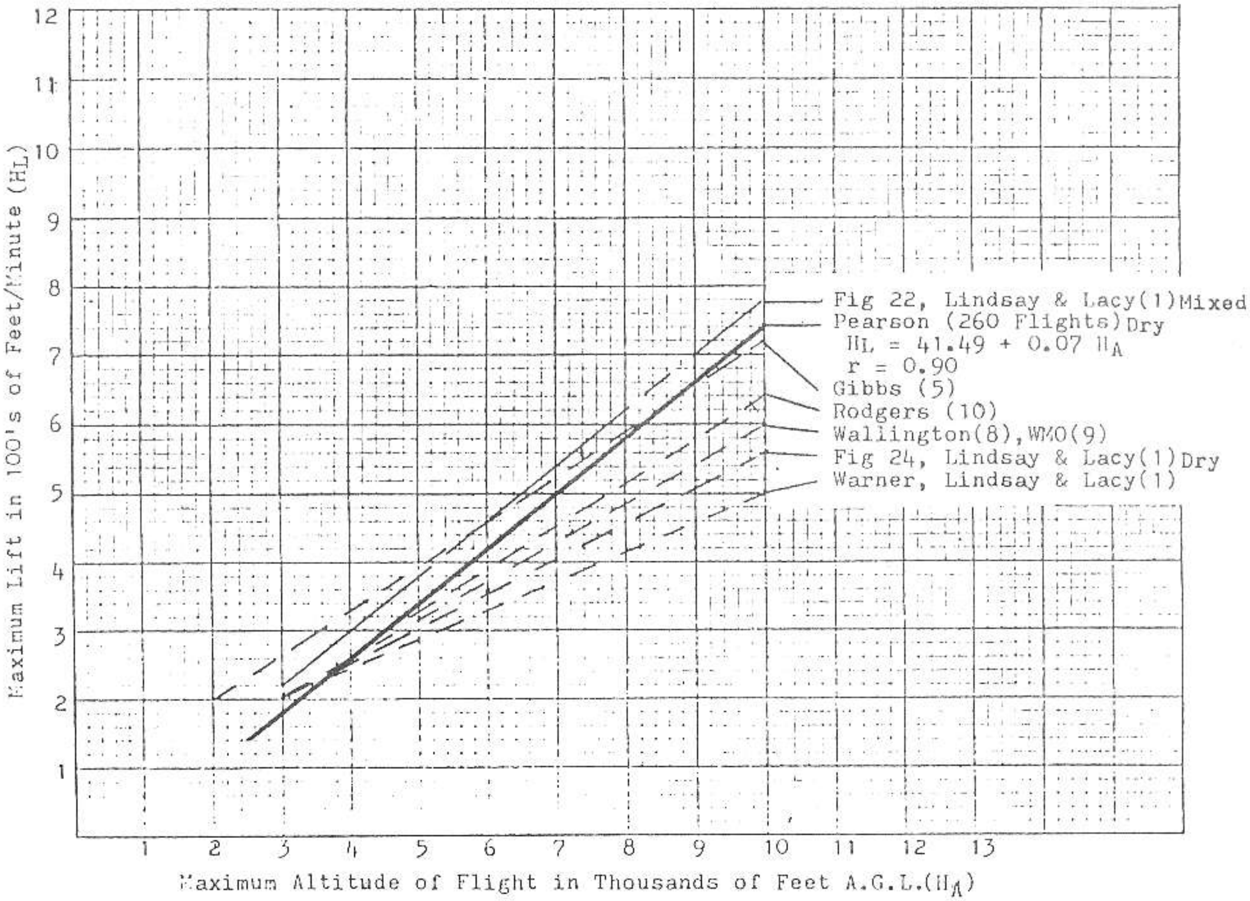


FIGURE 6. Lift vs. Flight Height

and Hill (4). This method was appealing to an engineer because of the implied precise life predictions; e.g. 264 feet per minutes (fpm) in Figure 1. I, therefore, added a column entitled "CALC" to my data sheet for calculating lift by this method. However, the implied accuracy did not match actual results. As shown in Figure 1, lift of 225 fpm was calculated vs 300 fpm actual. Figure 2 720 fpm was calculated vs 600 fpm actual.

Based on my analysis of 260 dry thermal flight results, as shown in Figure 6, I did find that the linear regression equation of Figure 22 in Lindsay and Lacy (1) and the predictions of Gibbs (5) were more accurate through the range of flight from 2,000 to 10,000 feet AGL. The high correlation coefficient of 0.90 produced by my 260 flights line of best fit confirmed the accuracy of my findings. It is observed that the slope of my dry thermal best fit is almost identical with Figure 22 of Lindsay and Lacy (1) which is based on an even mix of convective and dry thermal flight days. The correlation of these three plots in Figure 6 appears to establish my regression equation as a credible method of forecasting dry thermal lift.

The lowest maximum altitude of the dry-adiabatic lapse rate giving lift of 150 fpm or greater was 2,400 feet, as opposed to the 3,000 feet indicated in Lindsay and Lacy (1). This further substantiates my 2,500 foot AGL trigger determination. A nomograph is provided in Figure 10 for lift forecasts.

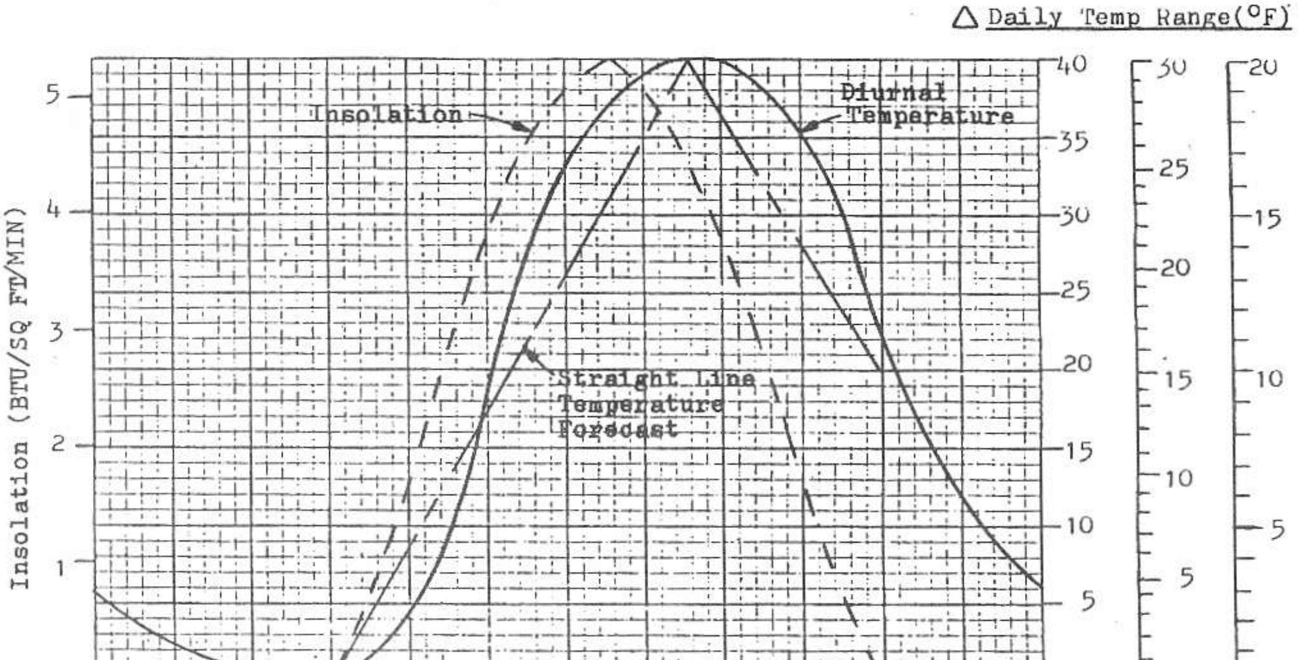
## MAXIMUM SURFACE TEMPERATURE

Finally, the most difficult predictions were maximum surface temperature and time of occurrence. It is generally recognized that a two degree or greater miss in maximum temperature prediction can make a significant difference in thermal height forecasts (Armstrong and Hill (4)). Examination of the 24-hour forecasts for my soaring area from the morning paper over a period of a year, with a wide daily temperature range, revealed that the error between predictions and actual temperatures exceeded five degrees approximately 40% of the time. In fact, the error exceeded ten degrees 10% of the time.

The historic references Armstrong and Hill (4), Gibbs (5) and Lindsay (7) all recommend relying on the NWS forecasts (see above) or using local objective aids for forecasting maximum surface temperatures. I talked to many farmers in the area (objective aid?) and found that they are not interested in actual temperatures, only the possibility of freezing. I also contacted the air pollution control district and found they were less interested in forecast temperatures than monitoring events as they occurred. Therefore, lacking the apparent privileged near-term NWS forecasts or objective aids available to meteorologists, it became necessary to develop some other method of forecasting maximum surface temperature.

Lindsay (7) suggests "The temperature curve for the previous day in the same air mass will have about the same shape, only the magnitude will vary." This observation coupled with Wallington (8) comments about diurnal temperature changes based on solar insolation led me to purchase a thermograph and install it near the gliderport to record continuous surface temperatures.

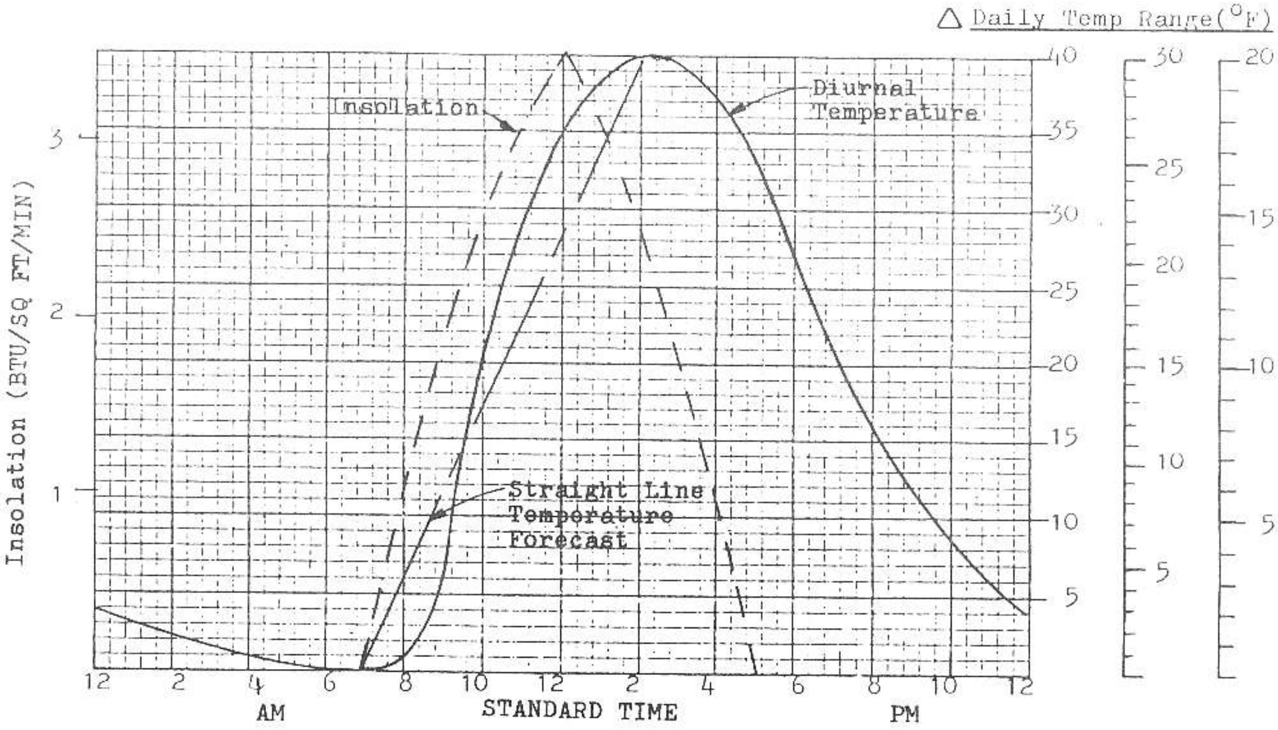
The average recorded diurnal temperatures are compared with solar insolation for Latitude 35 degrees North on Figure 7 for the Summer Solstice, Figure 8 for the Winter Solstice, and Figure 9 for the Equinoxes corrected for standard time and daylight savings time. Although the seasonal insolation rates vary, the diurnal plots are normalized to facilitate extrapolation of different daily temperature range estimates. It is noted that the temperatures lag the solar insolation by approximately one hour in the morning prior to peak, and two to three hours in the afternoon after peak. This is a completely different approach from forecasting surface temperature time of occurrence than the straight line method utilized by Armstrong and Hill (4),



Summer Solstice - June 21 - 35°N Latitude

Forecast Use - May 1 through July 31

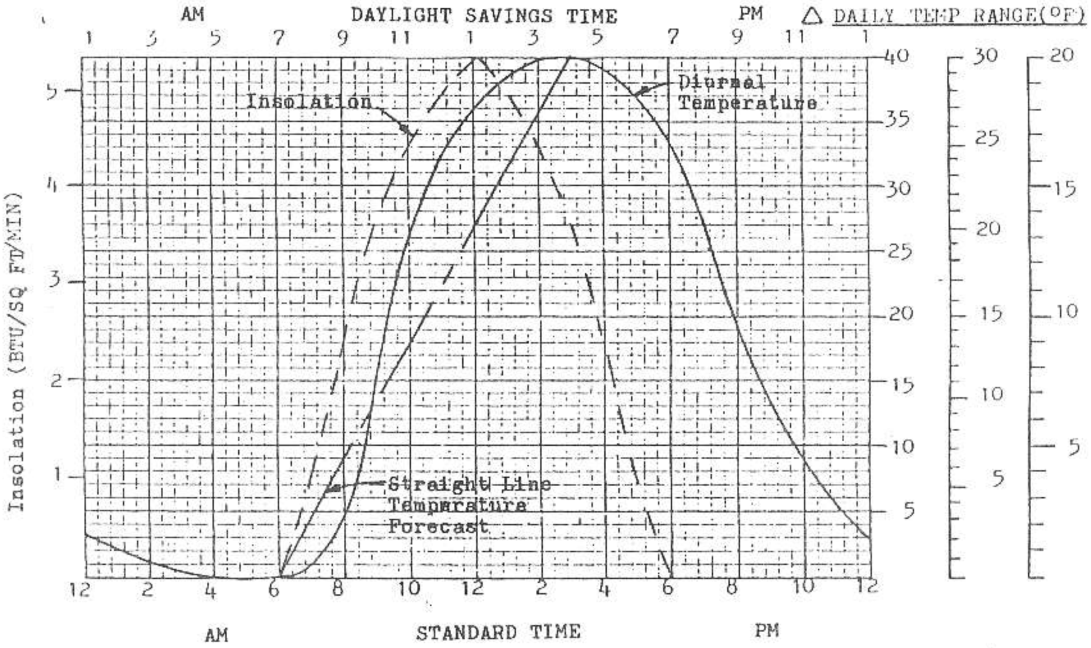
FIGURE 7. Summer Soltice-Diurnal Temperatures



Winter Solstice - December 21 - 35°N Latitude

Forecast Use - November 1 through January 31

FIGURE 8. Winter Solstice-Diurnal Temperatures



Equinox - March 21 and September 21 - 35°N Latitude

Forecast Use - February 1 through March 31 (Standard Time)
April 1 through April 30 (Daylight Savings Time)
August 1 through October 31 (Daylight Savings Time)

FIGURE 9. Equinox-Diurnal Temperatures

Gibbs (5) and others as shown in Figure 7. This illustrates why the straight-line trigger time forecasts are off by one to three hours as discussed under Trigger Temperature and shown in Figures 2 and 3. There diurnal plots were utilized to develop the nomographs shown in Figure 10 for estimating surface temperature versus time of day based on a surface temperature reading at the gliderport between daybreak and 8 a.m. and the previous day's daily temperature range. This approach has demonstrated a capability of providing maximum surface temperature predictions within two degrees and the trigger time is also predictable.

I am currently pursuing an investigation to check out this method of forecasting surface temperatures at other latitudes in the United States.

## "DO-IT-YOURSELF" FORECASTING

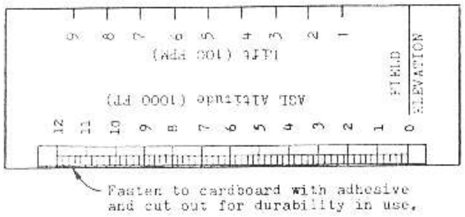
Make a copy of Figure 11 or apply a coating or transparent cover to permit multiple use. Reference Figure 1 for the following instructions.

Step 1 — Obtain a local sounding, use Direct User Access Terminal (DUAT) or call your closest Flight Service Station and ask for the winds and temperatures aloft for the area in which you intend to fly. (Remember to ask for the current reading — not the forecast.) Fill in the form at the top of the page as shown in Figure 1.

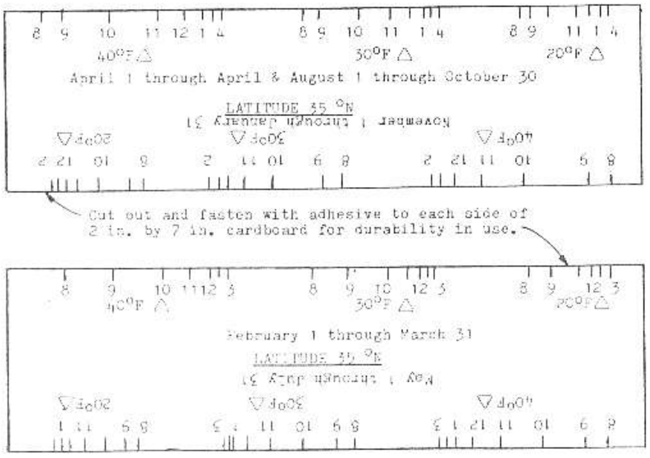
Step 2 — Plot your field elevation as shown with a horizontal line. (Example — Hemet, California is 1,512 feet above sea level.) Plot the forecast lift estimates along the vertical line provided, on the left side of the form, from the field elevation up using the template shown in Figure 10.

Step 3 — Plot the local ambient lapse rate as shown, using the data obtained in Step 1, and extend with dotted line down to field elevation.

Step 4 — Draw a line parallel to the adiabat from the intersection of the plotted or extended lapse rate of 2,500 feet above field elevation down to the field elevation. Extend the line vertically down from the field elevation and read off the ground temperature in degrees F. This is the forecast trigger temperature. Fill in the form at the bottom of page.

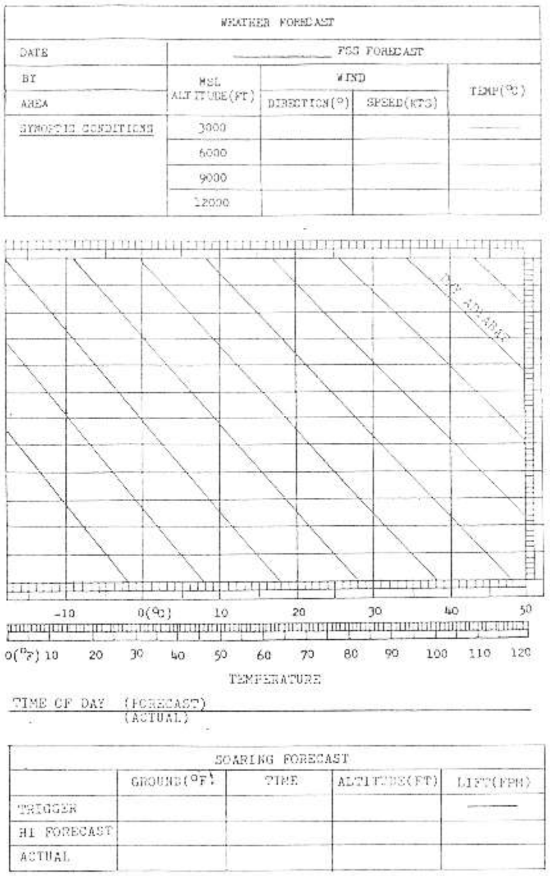


a. Lift Nomograph ( Template )



b. Diurnal Temperatures Nomographs ( Template )

FIGURE 10. Diurnal Temperatures/Lift Nomographs



| WEATHER FORECAST | | | | |
|---|---|---|---|---|
| DATE | _______ FSS FORECAST | | | |
| BY | MSL ALTITUDE (FT) | WIND | | TEMP (°C) |
| AREA | | DIRECTION (°) | SPEED (KTS) | |
| SYNOPTIC CONDITIONS | 3000 | | | ——— |
| | 6000 | | | |
| | 9000 | | | |
| | 12000 | | | |

TIME OF DAY (FORECAST)
(ACTUAL)

| SOARING FORECAST | | | | |
|---|---|---|---|---|
| | GROUND (°F) | TIME | ALTITUDE (FT) | LIFT (FPM) |
| TRIGGER | | | | ——— |
| HI FORECAST | | | | |
| ACTUAL | | | | |

FIGURE 11. "Do-It-Yourself" Forecasting Form

Step 5 — Fill in the "synoptic Conditions" portion of the form with all of the data available from the local paper or other sources. synoptic conditions include forecasts of clouds, cold fronts, haze, maximum surface temperatures, daily temperature ranges (yesterday and today) and any other weather data pertinent to the forecast.

Step 6 — Utilize the current dated temperature forecasting template of Figure 10, based on the previous day's daily temperature range, to plot forecast temperature coordinated time of occurrence on the "time of day" line below the temperature scales as shown in Figure 1.

When available, set the right hand template temperature marking directly under the reliable forecast maximum surface temperature and plot to the left to determine trigger time associated with forecast trigger temperature.

If a reliable maximum surface temperature forecast is not available, set the early morning time/template marking directly below the morning gliderport observed temperature and plot to the right to determine forecast trigger and maximum surface temperature/time relationships.

Step 7 — Draw a line vertically from the forecast maximum surface temperature for the day up to the field elevation. Draw another line from that intersection parallel with the adiabat up until it intersects the plotted ambient lapse rate and read predicted maximum flight altitude to the right and left to the left. The trigger time is forecast by projecting a line vertically down from the trigger temperature, determined in Step 4, to the time of day forecasts of Step 6. Fill in the form at the bottom of the page and go have a predictably happy soaring day.

Step 8 — After flying, note day's results for future improvements or subjective modifications to this method of forecasting and perhaps calibration to your particular flying area.

## SUBJECTIVE FORECAST MODIFICATIONS

This forecasting system is applicable to dry thermals. The system, however, is subject to the following subjective modifications which may or may not be peculiar to flying conditions at Hemet, California.

Clouds — My records indicate that cloud cover up to 4 oktas has little or no affect on forecasting results. However, with cloud covers of 4 to 5 oktas an approximate reduction of 15% in thermal height must be applied to account for reduced solar insolation effects. Thin cirrus has little influence. However, altostratus and cirrostratus are bad news and forecasts are no longer valid.

Winds — Winds up to 15 knots apparently have no affect. However, winds of 20 to 30 knots require an approximate 12% reduction in thermal height predictions according to my records.

Shear-Line Lift — We have the benefit of the Elsinore convergence at Hemet, California providing frequent shear-line lift during summer afternoons as described by Lindsay (7) and Wallington (8).

My records indicate that with forecast dry thermal altitudes of 4,500 feet AGL or below, we can expect increases in height of approximately 16% and with heights above 4,500 feet AGL increases of up to 31%. I make the observation with no attempt at explanation.

Mountains — Lindsay (7) makes the observation "As a rough estimate, one might try adding the altitude of a nearby mountain to the results from the graph and arrive at an estimate of how high he could fly over a nearby smaller type mountain." As noted in Figure 1, my data sheet included a flight record of "Mountain" heights achieved as separate from the "Valley" or gliderport heights which were utilized in developing thermal heights and strengths. The Hemet gliderport is located 20 miles west or Mt. San Jacinto (10,800 feet MSL) and this is the "Mountain" referred to. Obviously, the mountain is a target of opportunity for soaring fights by working up the surrounding ridges and smaller mountains. An average of 61 flights in dry thermal weather (no restricting cloud bases) reveal that if you could reach 5,500 feet AGL (7,000 feet MSL) over the Hemet valley floor, you could gain an additional 3,600 feet working up the mountain for a realized height of 10,600 feet MSL. This appears to me to be an exceptional correlation with, or substantiation of Lindsay's rough estimate.

Cold Front Passage — If a cold front has passed through the area in the last 24 hours or is anticipated on the day of forecast, the daily temperature range will have to be decreased by 10 deg. F in Step 6 of the detailed procedure. It has been observed that the unstable atmosphere following a cold front usually provides good soaring conditions.

Differential Temperature Advection — I have observed instability (turbulence) indications with cold-air advection; i.e. wind direction changing counterclockwise with altitude increase. These instabilities have generally resulted in higher actual flight altitudes than predicted in Step 7.

Others — The reader is referred to Lindsay (7) and Wallington (8) as excellent references to other weather phenomena affecting or occurring in conjunction with dry thermals such as wind shear, smoke, haze, recent rainfall, thermal streets, low-pressure areas, orographic lows, ridge lift and wave.

## CONCLUSION

The "Do-it-Yourself" forecasting system as developed, is not intended to supplant a formal soaring meteorological forecast if available. However, a tool is provided for the pragmatic recreational soaring enthusiast to reach a "go" or "no go" decision in less than 10 minutes at breakfast time before driving to the gliderport. In fact, the system was developed for the recreational flier who seldom flies more than 50 miles from his gliderport, and is not privileged to receive soundings and other meteorological support from the NWS or his gliderport operation. The system has a time proven correctness in dry thermal trigger temperature/time and thermal height/strength predictions in the southwestern United States.

## REFERENCES

1. C.V. Lindsay and S.J. Lacy, Soaring Meteorology for Forecasters, from the Soaring Society of America via the National Weather Service (NOAA), 2nd Edition 1976.
2. H.C. Higgins, "The Thermal Index," Soaring, January 1963, pp. 8-10.
3. Federal Aviation Administration, Aviation Weather, FAA Advisory Circular AC 00-6A, rev'd 1975.
4. D. Armstrong and C. Hill, "Mountain Meteorology," Soar Sierra, J. Joss, The Soaring Press, 1976.
5. J. Gibbs, "Thermal Prediction for the Masses," Soaring, April 1982, pp. 31-34.
6. Soaring Society of America, Soaring Flight Manual, Jeppesen Sanderson, Inc. 1980.
7. C. Lindsay, A Handbook of Soaring Meteorology, Chas. V. Lindsay, First Edition 1988.
8. C.E. Wallington, Meteorology for Glider Pilots, John Murray (Publishers) Ltd., Third Edition 1977.
9. World Meteorological Organization, Technical Note No. 158, Handbook of Meteorological Forecasting for Soaring Flight, Organisation Scientifique et Technique International du Vol 'a Voile, 1978.
10. W. Rodgers, "Weather Predictions for Soaring Pilots," Tape SSA-1003, SSA National Convention 1989.