PRACTICAL FORECASTING OF THERMAL SOARING WEATHER

by Jim Wang

"Whatever may be the progress of the sciences, never will observers who are trustworthy and careful of their reputations venture to forecast the state of the weather." - Dominique Argo (1786-1853)

Introduction

When a soaring pilot starts to venture on cross-country sojourns on a regular basis, he or she soon realizes the importance of a good weather forecast. If a badge or record is involved, selection of the right day is as important as loading the camera or winding the barograph. A simple forecast can help determine whether you should go ahead and load that film.

This article describes a number of simple procedures that a pilot can use to forecast thermal soaring conditions (ridge and wave conditions are not covered here). A minimum of theory and formulae will be covered, since most of the computations are handled by using the right charts. Nevertheless, a number of friends to whom I have described these procedures have accused me of being too much of a technician, and of turning soaring from an art to too much of a science. If you are in this camp, never fear, for Rule Number 1 of weather forecasting is that no matter how hard you try to predict the weather, it is always capable of surprises (professional meteorologists, please don't take umbrage with this statement- I speak as an amateur). More often than not, I've found the surprises to be pleasant ones.

Information Sources and Products

The hardest part of generating a soaring forecast used to be getting the requisite information. Fortunately, it's now quite easy if you have a computer and modem plus a communications program. Here are a few sources:

1. If you have an Internet link and a Web browser (such as Netscape) weather products abound. For example, Purdue University

wxp.atms.purdue.edu/skew_det.html

provides ready access to the Skew-T/log-P plots that will be described later. From Gunther Eichhorn's excellent aviation server you can get ASCII skew-T/log-P plots e-mailed to you.

acro.harvard.edu/GA/upper_air.html

Many standard aviation weather maps are available from the National Weather Service's aviation page

www.nws.mbay.net/aviation.html

or the University of Notre Dame's page

www.science.nd.edu/physics/meissner/

72293 SAN 1212Z RAOB DATA

MANDATORY LEVEL						SIGNIFICANT LEVEL			WINDS		
PRMB	HMTRS	TEMP	DPD	WDR	WDS	PRMB	TEMP	DPD	ALTD	WDR	WDS
995	SRFC	17.6	3.3	110	4	986	22.8	9.0	SRFC	110	4
1000	92					974	25.2	13.0	1000	140	7
850	1505	19.0	16.0	225	13	799	16.0	15.0	2000	170	10
700	3139	6.2	4.4	205	5	642	0.0	1.0	3000	195	12
500	5790	-13.1	14.0	240	23	595	-4.1	4.9	4000	220	14
400	7470	-20.3	13.0	235	41	565	-7.5	4.1	6000	220	10
300	9530	-37.5	10.0	240	49	553	-8.5	12.0	7000	215	9
250	10770	-44.1		245	58	518	-12.3	13.0	8000	200	8
200	12240	-51.3		255	47	417	-18.3	14.0	9000	190	6
150	14070	-62.3		265	40	287	-40.1	10.0	12000	190	2
100	16530	-67.5		275	8	221	-46.9		14000	235	5
70						143	-64.1		16000	195	7
50						112	-67.9		17000	220	14
30									19000	240	23
20									20000	240	31
10									22000	230	42
112	TROP	-67.9		265	16				25000	235	40

STABILITY INDEX: 2

MEAN LAYER WINDS: SFC-5K 185 11

5K-10K 205 8

FIGURE 1. Radiosonde sounding from Weatherbank for San Diego (SAN) at 1200Z on 12 October.

weather.html

2. If you have a computer and modem but no Internet access, Compuserve (800-848-8990) has limited weather information, but may be attractive because of the other services that are available.

3. Also not requiring Internet capability are the Direct User Access Terminal (DUAT) services. Two are available: Contel (800-767-9989) and DTC (800-245-3828). DUAT is the FAA-sponsored system for providing aviation weather. DUAT is free for registered pilots, but the data provided is not necessarily in the most convenient form for soaring information.

4. If you don't have a computer available, Flight Service Stations can provide an. expert aviation weather briefing. Much of what you need is available on the Automated FSS recording (AFSS can be reached at 800-WX-BRIEF in many areas). However, they do not routinely forecast conditions that are specific to soaring flights.

For a reasonably complete picture of what to expect as far as soaring conditions are concerned, you should try to get the following information:

• Radiosonde sounding. At 0000Z and 1200Z each day, weather stations release telemetry balloons which as they rise transmit measurements of winds, temperatures and dewpoints aloft.

• Satellite photos. Weather photos are useful for accessing general conditions and potential non-convective cloud cover. Your local TV station displays them in a rather transient form. They are also available on the Internet or Compuserve.

• National Weather Service forecasts. Although the widely broadcast ones are targeted for more prosaic uses such as picnics and softball games, NWS forecasts are useful for estimating potential maximum temperatures and the possibility of overdevelopment (also known as "rain" to picnic planners).

• Aviation forecasts. The typical AFSS forecast will include useful information on possible clouds and their altitudes, hazardous convection, visibility restrictions, and predicted winds aloft. A Flight Service briefing will also inform you of any relevant Notices to Airmen (NOTAMs).

• Upper-level analysis charts. These charts can give advance indication of approaching fronts or significant changes in the ambient air mass. They are probably the best means of long range forecasting (i.e., several days in advance) of soaring weather, as opposed to the "morning of" type of forecast to be covered in this article.

What You Want

Your objective when creating a soaring forecast is to make your best-guess estimates concerning the weather factors that are pertinent to your soaring flight, including:

1. Stability: the lapse rate, expected rates of climb, maximum altitude of convective lift, and trigger temperature. The average rate of climb you achieve will have the most direct effect upon your average speed during your flight. The maximum altitude will determine your working altitude band. The trigger temperature (and more important, its time) will determine how early you will be able to start your flight.

2. Possibility of cumulus clouds, and the altitude of cloud base. Cus will usually make your flight easier since they can mark mark areas of lift. However, if your route crosses high terrain, then for optimum speed cloud base should be at least three thousand feet above the peaks to allow a reasonable altitude band.

3. Possibility of overdevelopment. Often, clouds will develop into thunderstorms too early in the day to allow a successful long flight. It is not pleasant to round your turnpoint 250 kilometers out only to find the route home marked by lightning bolts.

4. Possibility of high clouds. Even if the lapse rates look good, high cirrus or stratus clouds can block the solar heating that is necessary to trigger thermals.

5. Winds aloft. The expected winds may affect your decision about which leg of a closed course to fly first, or which direction to proceed on a straight out course.

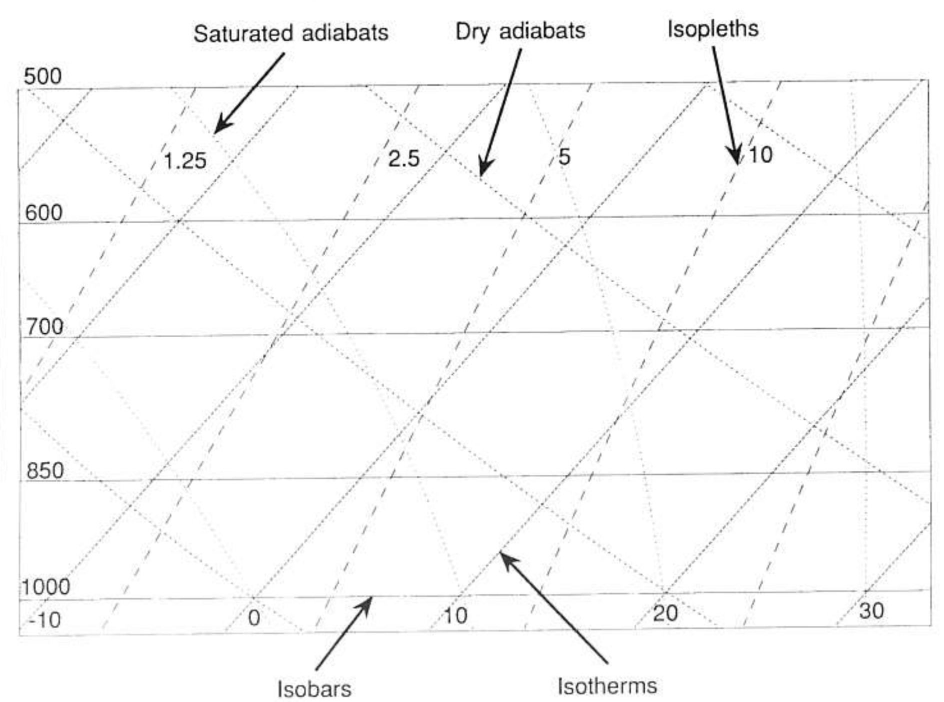

Figure 2. Features of a Skew-T/Log-P diagram. Lines of constant temperature (isotherms) are skewed at about a 45° angle, while the vertical axis is logarithmic in pressure altitude (which makes it linear in feet). Saturated (wet) and dry adiabats indicate how a lifted parcel of moist or dry air will cool as it rises, assuming no heat transfer to or from the parcel. Isopleths indicate how much water vapor a parcel of air can hold (in grams H_20 per kilogram air) at a given temperature and pressure.

6. Surface winds. Strong winds (10 knots or more) at the surface may inhibit formation of workable thermals in spite of a favorable lapse rate. Even if there is lift, it may be too fractured to allow you to climb efficiently.

7. Potential hazards, including storms, obstructions to visibility, incoming fronts, and precipitation.

Any of these factors can be of sufficient severity so as to force a no-go decision.

Sounding Data and Plots

Use a standard procedure in preparing your forecast. If you have no reason to believe that any of the factors listed above veto your flight, then start with a sounding. A properly plotted sounding will give you the best measure of the stability, the chance of cumulus clouds, and the likeihood of overdevelopment.

A typical sounding (Figure 1) reports temperature and dewpoint at mandatory and significant levels, plus the current winds aloft at round thousands of feet. The mandatory levels are standard reporting altitudes, while the significant levels are the points in the sounding that a briefer considered significant for interpretation. The altitudes themselves are reported variously as pressure in millibars (PRMB), height MSL in meters (HMTRS), and altitude MSL in feet (ALTD). The temperature at each level (TEMP) is reported in Celsius degrees, as is the dewpoint depression (DPD). The winds aloft are also reported, but these are less useful than the forecasts of winds aloft which you should obtain later. A lifted stability index is also sometimes given at the bottom of the sounding (more on soaring indices later).

The sounding data is easiest to interpret when it is plotted on a temperature-height chart. If you are lucky enough to receive your sounding data already plotted, you only need to interpret it; otherwise, you should plot your own using the temperature and dewpoint soundings. Your chart should include both saturated (wet) and dry adiabatic curves, water saturation lines (isopleths), and of course altitude and temperature axes. The most useful chart is the Skew-T/Log-P chart that Bruce Carter described in the June and July 1986 issues of *Soaring*. Those articles also included a convenient copy of the chart that is suitable for reproduction. A summary of the salient characteristics of Skew-T/Log-P charts is included here (Figure 2), but for more detail from a professional meteorologist, please consult Bruce Carter's articles.

As anyone who has completed Soaring 101 knows, the main idea is to determine how the *adiabatic* temperature lapse rate compares to the *ambient* lapse rate. As long as the temperature of a parcel of air exceeds the ambient temperature, then that parcel will be less dense than the surrounding air and it will rise. As it rises, it expands and cools due to expansion, but it doesn't transfer much energy to the surrounding air, which is what *adiabatic* means.

The ambient temperature also cools with altitude, although rarely as fast as the adiabatic lapse rate. A heated parcel of air rising from the surface and cooling adiabatically will eventually reach an altitude where its temperature equals the ambient temperature, thus limiting the maximum height of thermals.

Note that there are four temperature lapse rates which you should know: 1) the *standard* lapse rate (2°C/1000 ft.), which is the rate the ICAO standard atmosphere cools with altitude, 2) the *dry adiabatic* lapse rate (3°C/1000 ft.), 3) the *saturated adiabatic* lapse rate (1.5°C/1000 ft.), and 4) the *ambient* lapse rate determined by your sounding. In addition, there are two dewpoint lapse rates which are relevant: 1) the adiabatic dewpoint

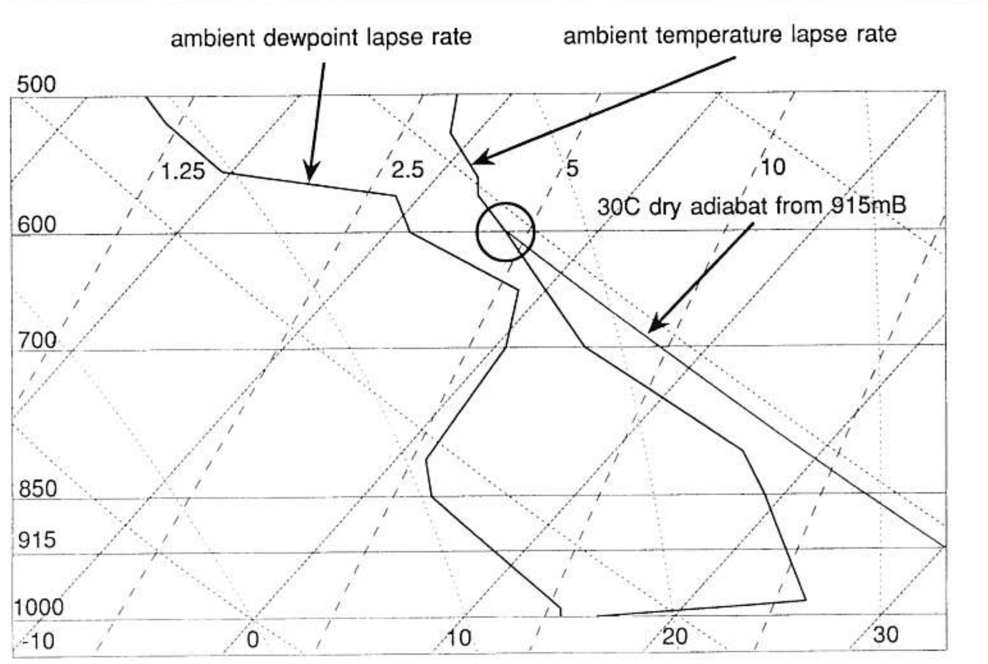

Figure 3. Lapse rates for 12 October plotted on a Skew-T/Log-P chart. Also shown is the dry adiabatic lapse rate for an airport at 915mB for a maximum expected temperature of 30°C (thin dotted line). The intersection with the ambient lapse rate occurs near the 600mB isobar, which is about 14,000 feet.

lapse rate, the rate at which the dewpoint decreases during adiabatic vertical convection (0.55°C/1000 ft.), and 2) the ambient dewpoint lapse rate (again, determined by your sounding).

The adiabatic lapse rates are set by thermodynamics, and are shown on the Skew-T/Log-P chart for various temperature/altitude combinations. Once a thermal has started to rise, its air temperature follows the adiabatic curve on the chart that is determined by the surface temperature. What varies from day to day are the ambient lapse rates and the particular adiabat that the thermal follows. Comparison between the thermal's trajectory on the chart with the ambient lapse rates yields the stability information that you seek.

If you are using sounding data, plot both the ambient temperature lapse rate and the ambient dewpoint lapse rate. Compute the dewpoint at each altitude by subtracting the dewpoint depression (DPD) from the temperature. The dewpoint curve will always be to the left (cooler side) of the temperature curve.
Once you are working with temperature-height charts, get used to refering to altitudes using pressure in millibars instead of height in feet, and impress your friends (however, be aware that the politically correct unit in today's metric world is the *hectoPascal* or hPa). Useful approximations are 850 mB ≈ 5000 ft., 700 mB ≈ 10,000 ft., 600 mB ≈ 14,000 ft., and 500 mB ≈ 18,000 ft.

Once you have a plot, you can get a quick idea of whether it will be worth driving to the airport. Make an estimate as to the maximum expected surface temperature. Follow the isotherm for that temperature up until it intersects the isobar that corresponds to your airport altitude. Hopefully, the intersection point will be to the right (hotter) side of your ambient temperature curve (if it's not, then the air is stable).

Next, follow a dry adiabat until it intersects the ambient lapse rate (Figure 3). In the example, it looks like it may be a good day since the intersection is near 600 mB (14,000 feet).

The situation is more complicated when moisture is taken into account. The same parcel of air that starts upward from the surface carries with it the water vapor present at that time. The capacity of air to hold water vapor decreases as it rises and cools. If it rises enough, the water will condense and a cloud will form.

The dewpoint is the temperature at which the air would be fully saturated given its water vapor content. The *isopleths* (from *plethora*, meaning "full") on the chart show the set of temperature/pressure combinations where the same mixing ratio of water vapor to air is fully saturated. Thus, assuming that a rising parcel of air does not exchange moisture with the surrounding air, then cloudbase can be estimated by following the isopleth of the surface dewpoint up until it intersects the dry adiabat (Figure 4). This altitude is called the *lifted condensation level* (LCL).

Alternatively, since the adiabatic dewpoint lapse rate is 0.55°C/1000 feet and the dry adiabatic lapse rate is 3°C/1000 feet, they converge at a rate of 2.45°C/1000 feet. Therefore, a rough estimate of cloudbase in thousands of feet AGL is calculated by subtracting the surface dewpoint from the maximum surface temperature and dividing by 2.45°C. In the example, the dewpoint for an airport at 915 mB (3000 ft.) is about 15+°C, so for a 33+°C maximum temperature, a cloudbase of about 7,500 feet AGL is forecast.

When water vapor condenses into clouds, heat is released and the adiabatic assumption that no heat is exchanged is no longer valid. However, meteorologists have taken the heat release into account with the wet adiabats, which have a lower lapse rate (the wet adiabatic lapse rate, which is more properly called a *psuedoadiabat*). With this model, the air continues to cool

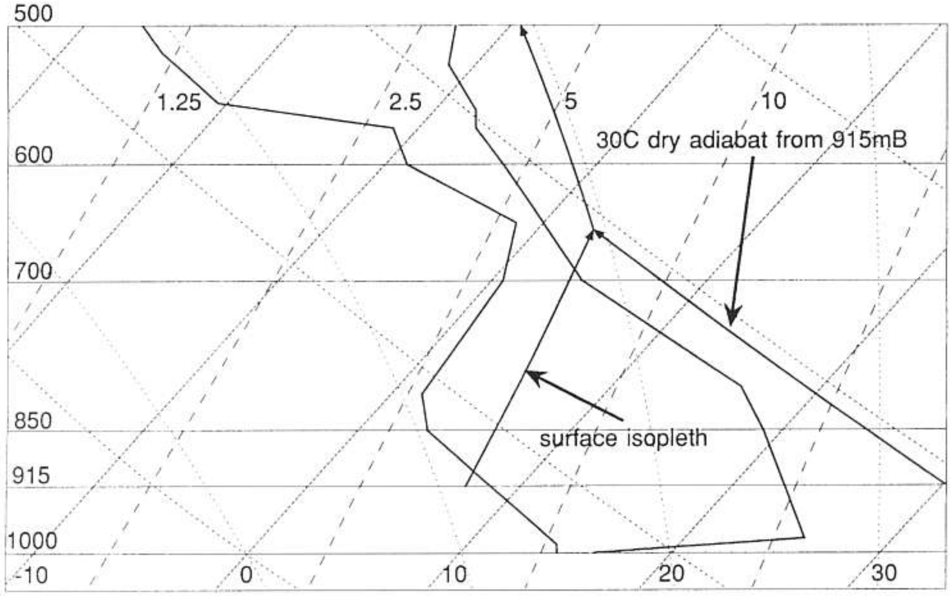

Figure 4. The cloudbase can be estimated by extending an isopleth upwards from the surface dewpoint until it intersects the adiabatic lapse rate. At this point, a rising parcel of air is fully saturated, and any further rise will result in condensation and cloud formation. In this case, cloudbase is predicted at 675 mB or about 10,500 feet. As the parcel rises above cloudbase, it continually condenses vapor and hence follows the wet adiabat. Wet adiabats have a lower lapse rate than dry because condensation heat is released as the parcel rises.

adiabatically above cloudbase but at a much slower rate than below cloudbase. A lower ambient lapse rate is sufficient to allow convection. This effect encourages the production of towering cumulus and cumulonimbus clouds. In the example, above 600 mB, the wet adiabat for our 30°C parcel continues well above the ambient lapse rate right off the top of the chart at 500 mB (18,000 feet). Thus, conditions are favorable for the formation of towering cumulus clouds and overdevelopment.

In contrast, if the air is dry at some level above the forecast cloudbase, the cloud may evaporate at the top. The clouds will then look flat with little vertical development. In this situation, be wary even in view of a good lapse rate since evaporation rapidly cools the air and strong sink may prevail between clouds.

A final note about charts: chart interpretation has many aspects, and is a continual learning experience. Print them and keep a notebook of your charts. When you fly compare the observed conditions with your forecast. After you fly, make notes on your charts as to the actual conditions and attempt to reconcile your forecast with your observations. After a year, you will have a valuable casebook of the specific conditions that occur in your area. For instance, where I fly (Warner Springs, California), the onshore wind from the ocean 35 miles west often converges with desert air from the east to provide ideal circumstances for a shear line. Combined with ambient instability, the shear line can provide excellent soaring conditions. At other times, the marine layer deepens to six thousand feet, easily flowing through the mountain passes to Warner Springs. The marine air usually brings with it a discouraging inversion. But since a deep marine layer is also easily recognized by a reduced DPD at altitude, I've often been able to save myself a trip to the airport.

Soaring Indices

Soaring indices are intended to summarize with a single number the soaring outlook for the day. They cannot give a complete picture, but since they are easy to compute and can be relevant at times, a few are listed below (this list is by no means complete).

- 850 mB - 500 mB lapse rate. Subtract the 500 mB temperature from the 850 mB temperature. Values between 22° and 34° are considered best. Less than 22° is too stable, while over 34° indicates a strong possibility of overdevelopment. Note that the "standard" decrease for this interval in the ICAO atmosphere is 26°C, and the dry adiabatic decrease is 39°.
- Showalter Index or Stability Index. The stability index is a lifted index computed by taking the difference between: a) the temperature of a parcel lifted from 850 mB to 500 mB, and b) the ambient temperature at 500 mB. This index is easy to find using the Skew-T/Log-P chart. Take the temperature at 850 mB and follow a dry adiabat up in altitude. Then take the 850 mB dewpoint and follow an isopleth up in altitude. If the two intersect, follow a wet adiabat from the intersection point up to 500 mB; otherwise, just take the dry adiabat up to 500 mB. Note the temperature of the lifted parcel and subtract it from the ambient temperature at 500 mB. Values over 12° are indicative of stable conditions; values under 2° are indicative of excessive instability and possibility of overdevelopment. The stability index is routinely computed by NWS and is may be reported with the sounding data (Figure 1).
- "K" Index. The K Index is computed as follows:

$$K = 2T_{850} - T_{500} - DPD_{850} - DPD_{700}$$

where T_{PR} is the temperature at pressure altitude PR, and DPD_{PR} is the dewpoint depression at PR.

K indices below 12° are stable, between 12° and 32° is the preferred range, while above 32° suggests overdevelopment is probable.

•Soaring Index. The soaring index is interesting since it was developed by meteorologists and glider pilots at Reno, and it is based on much empirical data. It is however slightly more complex than the other indices, and its relevance may vary in other than strong Western conditions:

$$SI = \frac{3Z}{100} + 30\,(T_{4000AGL} - T_Z)$$

In these equations, Z is the MSL altitude in feet at which the dry adiabat raised from the maximum expected temperature intersects the ambient lapse rate curve. $T_{4000AGL}$ is the temperature at 4000 ft AGL, and T_Z is the ambient temperature at Z. The soaring index is calibrated to yield the maximum expected climb rate in feet per minute for 15-meter sailplanes.

For the sounding shown in Figure 1, the 850-500 mB lapse rate is 32.1°C, the Showalter index is 2, the K index is 30.7°C, and the soaring index (assuming a 915 mB maximum temperature of 33°C) is 1275. These are all at the strong end of the desired ranges, but just below the level of probable overdevelopment. Often the soaring indices will disagree about predicted conditions, which is not surprising since each index only samples a few points in the sounding. However, if they do all agree that conditions will be booming, wind the barograph.

Other Data

If you can obtain a recent satellite photo of your area, check it for any clouds that are headed your way. Major storm systems show up well on the photos and are often proceeded by banks of high cirrus clouds. See if any are headed toward your course.

Get a winds aloft forecast (as opposed to the measured winds in the sounding) from the Internet, Compuserve (GO AWX, then type FDLO and the appropriate station identifiers) or your Flight Service Station. The winds aloft forecast also provides forecast temperatures aloft for 6,000, 12,000, and 18,000 feet. A quick check of the temperature spreads between these altitudes for a few stations in your area of interest may reveal a preferred direction of flight.

Other aviation weather products that may be of interest are terminal forecasts (FT's) if there are any reporting stations near your intended route, and area forecasts (FA's) which give a synopsis of expected general conditions over a large area.

A call to AFSS is useful after you've done your sounding since their forecasts can corroborate yours. You can compare your forecasts of cloud bases, chance of overdevelopment, and possibility of high clouds. However, like the other weather sources, the AFSS briefing requires some interpretation and you should make a practice of calling frequently to build your interpretation experience. The AFSS forecast for the example day called for isolated thundershowers and scattered clouds with bases at 12,000 feet and cumulonimbus tops to 30,000 feet. Predicted winds aloft were under 10 knots from 3,000 to 12,000 feet. The forecast for possible thundershowers and cumulonimbus is typical for good soaring days in the San Diego area. (Note: San Diego has relatively mild and localized summer thunderstorms. Do not take forecasts of thunderstorms in your area lightly unless you are familiar with local conditions.)

Summary

A forecast based upon a few simple procedures can give you a good idea of expected soaring conditions for the day. With practice, you should be able to work up a reasonable forecast in ten minutes or so. Your forecast will not be correct all of the time, but even the pros aren't always correct either. And there is no substitute for familiarity with local weather patterns. After a few months of forecasting and observation, your weather perspicuity will be much improved.

Addendum

The day presented in the example (12 October) was in fact an excellent soaring day. Fifty miles north of Warner Springs airport, cloud bases were at 12,000 feet, while fifty miles south, bases were as low as 9,000 feet (remember that the predicted base was 7,500 feet AGL or 10,500 feet MSL). The lower cloudbase to the south is indicative of moisture moving up from Mexico. The strongest lift was also to the south and required speeds of over 100 knots (in an LS-3a) to stay below cloudbase. The clouds produced some virga, but it was not extensive. No lightning was seen.

October is definitely late in the season for strong conditions like these, and had it not been for some weather intelligence, I might have missed this excellent day.

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