THUNDERSTORM!

Second of two parts—the steady state and severe storms are among the pilot's greatest weather threats

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ILLUSTRATION BY LEO GWINN AND DOUG PARKHURST

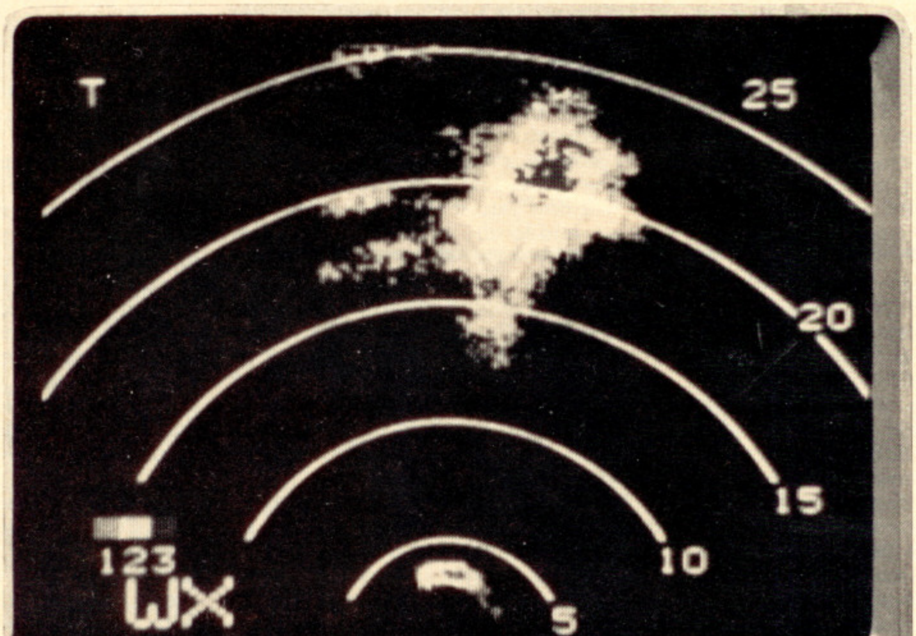
The air mass thunderstorm, discussed in Part One of this series, is the vertical, three-stage storm: it builds; the rain starts to fall as it matures; the descending rain stifles the updraft and the storm dissipates. Dangerous as it is, we have dubbed this type of thunderstorm Baby Bear, considering the even greater threat posed by the *steady state* and the *severe* thunderstorms, which we will call Mama Bear and Papa Bear, respectively.

To get the steady state thunderstorm we have to take the brakes off the air mass thunderstorm. To do this the water must be taken out of the updraft. The simple way for this to occur is to have the storm develop in an environment in which the wind changes with height. This usually means that the wind increases with increasing altitude. The more the growing thunderstorm leans, the more water will go elsewhere than right back down through the updraft, and the more it grows.

The thunderstorm that slopes can produce hail in large quantities and large chunks. I was first made aware of this by the late Dr. Fred Bates of St. Louis University, and I found it useful when serving as an Air Force forecaster in New Mexico. When I observed a thunderstorm on our radar, I would elevate the antenna and scan it vertically. If it sloped, I issued a hail warning. In many cases, of course, the storms didn't pass over my location, so I have no way of knowing if hail fell out of them. Those that did, hailed.

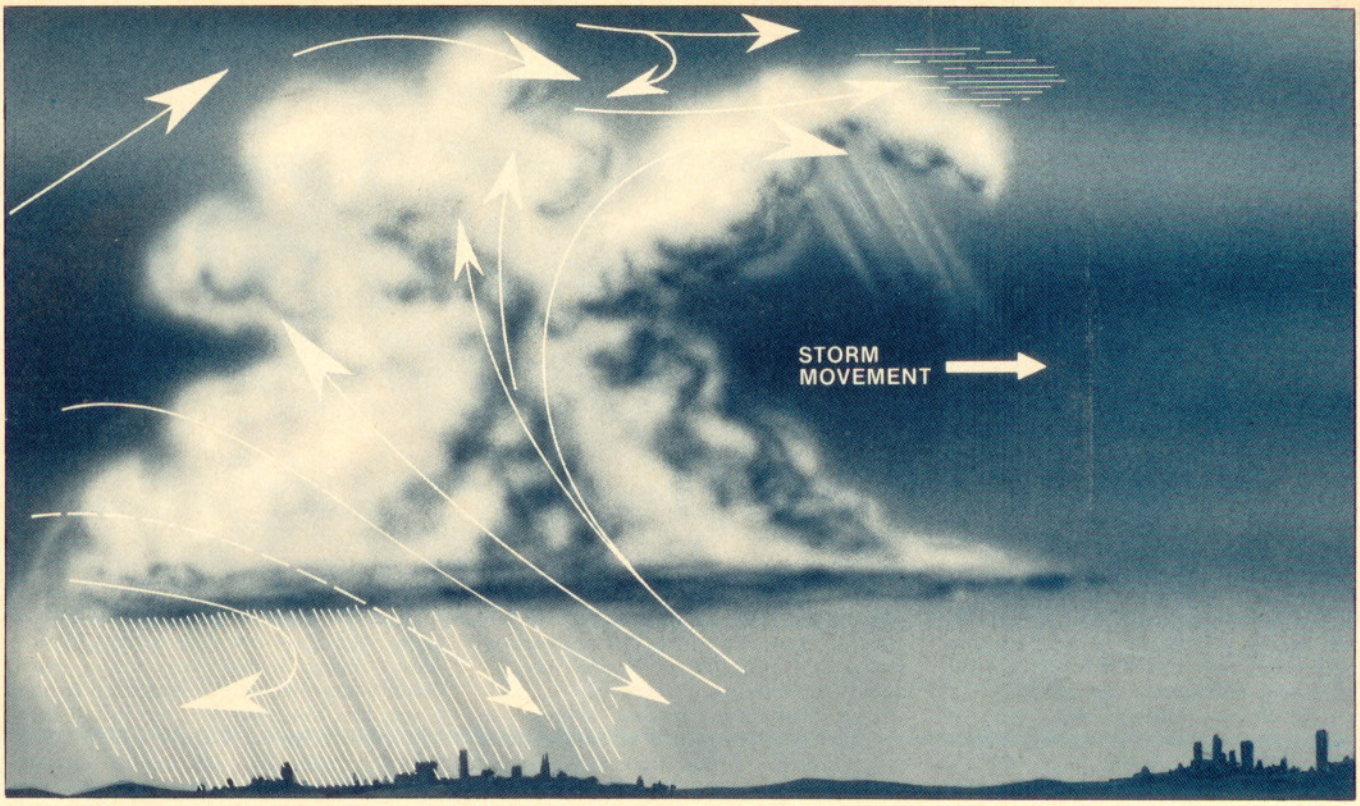
Remember, though, that I was looking for a sloping *updraft*, and using a radar set that showed returns from liquid drops, which were being copiously generated by condensation in the rising air. You may be able to tell that some given storm slopes with the old eyeballs. You also may not be able to, since there may be clouds all over the place. The fact that you don't see a slope doesn't mean it isn't there, or that hail is not present.

I mentioned that I found this sloping storm idea useful in New Mexico. Why there, particularly? Well, where would we expect to find a situation where the winds frequently increase with height? How about mountainous



RCA

The classic hook shape of a radar return indicates possible tornado activity. An RCA ColoRadar looking for "demonstration" echoes, stumbled on this one, which hit the front pages with what it did when the tornado hit Wichita Falls, Texas, early in April.



The back-sloping storm compounds the already bad situation of a steady state storm—producing hail and strong gust fronts and self-generating instability.

terrain, where low-level winds are interfered with by the rockpile? As we have seen, the maximum number of days per year with thunderstorms occurs in Florida, but hail at the surface is nearly nonexistent there. The maximum frequencies of hail days occur on the eastern slopes of mountain ranges in Colorado, Wyoming, Nevada and Utah, in areas getting around half the number of thunderstorm days as Florida.

Colorado, of course, is next door to New Mexico, which is also mountainous. Any thunderstorm forming in such terrain should be suspected as being a hail producer, and we don't have to penetrate the storm to run into it. Shafts of hail may fall from high in the storm to its rear, and from the anvil downwind of the storm. The only safe course of action is to give the storm a wide berth. The hail could be 10 miles or so from the rain underneath the anvil. A hail shaft often has a greenish appearance, and may be sighted visually. The fact that you don't see one, however, doesn't necessarily mean it isn't there or won't appear in your location if you circumnavigate only the rain.

Steady state, sloping storms do not have to have mountainous terrain. All that's required is a change of wind with height. In the mid-latitudes, the jet-stream can result in winds that increase with height over any kind of terrain. The greater the increase of wind with height, the larger and more severe the thunderstorms are likely to be, other things being equal. In the study of 55 general aviation accidents and 18 air carrier accidents, which we mentioned previously in talking about stability, the increase in wind with height was also found to be abnormally large.

A more dangerous variant of the steady state storm, which can occur anywhere that enough moisture and a vertically changing wind exist, is the back-sloping storm. This storm is an intense little low pressure area, and air will flow into it from the sides. Dry air at mid-levels, around 15,000 feet or so, may enter the storm from the rear and be invaded by rain falling out of the sloping updraft. Early in this process, the storm looks as shown above. The falling rain evaporates in the dry air, and cools the air in the process. The drag of the drops also gives this air a knock in the downward direction, resulting in a totally unstable situation.

The air is cooler than the air around it as a result of extraction of heat by the evaporating rain; it has a downward shove to start it moving; it runs into still more rain to cool it even more; it gets even more of a downward shove, and the worse it gets, the worse it gets. This kind of storm produces hail just like the more simple orographic sloping storm, which we found occurring in the mountains. It also produces a very dangerous gust front.

The air in the unstable downdraft, accelerating all the way through the cloud, roars out the bottom of the storm and moves out. The favored direction is ahead of the storm, since this is the direction of the prevailing winds that are moving the storm. Remember that this gust front is made up of cold air, cooled by evaporating drops as it came through the cloud. Thus, as it races ahead of the storm, it plows its way under the surrounding air like a cold front. The lifted air is drawn toward the storm, and now stability gets into the act again.

If the air at low levels ahead of the storm is moist and unstable, lifting ahead of the storm by the gust front triggers it into a building cloud, which in turn enters the storm and feeds the updraft. This generates a stronger updraft, which generates more precipitation, which cools more air in the downdraft, which generates a stronger gust front, which lifts more air into the storm, which feeds the updraft, etc., etc.

Gust fronts have been observed more than 20 miles ahead of the generating storms. Peak gusts in excess of 70 knots have been observed 15 miles or more ahead of the generating storm, with sustained winds in excess of 40 knots following passage of the gust front. Once again, obviously, we don't have to penetrate these storms to encounter dangerous, even catastrophic, weather. We don't even have to fly to break an airplane. Leaving it untied in the path of a steady state storm can do the job very nicely. If the wind doesn't get it, there's always the second chance that the hail will.

The steady state storm is a genuine killer, and we penetrate one at the literal risk of our lives. It also requires more respect in circumnavigating than the air mass storm. The question is, how do we know when we are looking at Mama Bear, not Baby? Some rules are as follows:

1. When in doubt, always treat the storm as a steady state storm.

2. If you know that the lifted index from the National Weather Service Stability Chart (shown in Part One of this series) in your area is minus two or a lower value, unless you have very good evidence to the contrary, treat it as a steady state storm.

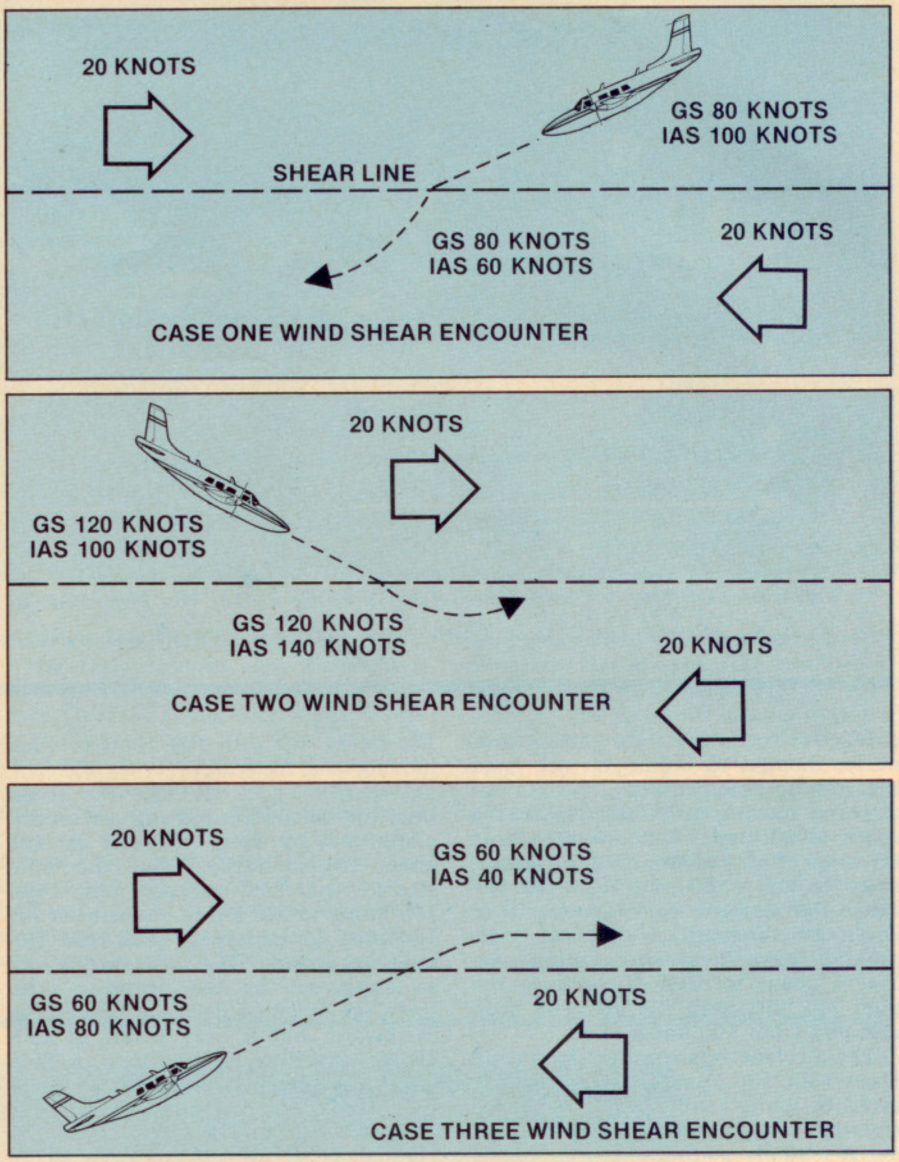
3. The gust front advancing ahead of the steady state storm and a blocking effect that such a storm produces in the upwind direction make these storms particularly inclined to form lines. This is true of all storms to some degree, but any line that forms rapidly and without plenty of space between storms should be treated as containing steady state storms. Watch the storms in a loose line and see if the individual cells top out and dissipate.

4. Try to find out what the tops are. A call to Flight Service in the area may get you some radar tops, but be sure that the information is current and not read from a radar summary chart a couple of hours old. Two hours is ancient history around building thunderstorms. Listening in to the conversations on a Center frequency in the area may get you a report on the tops. As a ball park number, regard any storm with tops above 35,000 feet as a steady state storm.

5. *Never* penetrate what you believe may be a steady state storm. This also means not to penetrate a line of storms, in the clouds and unable to circumnavigate visually, without radar. Updraft and downdraft speeds may be in excess of 6,000 feet per minute (fpm) (I have personally measured an updraft of 5,000 fpm in a cloud that had not yet reached the thunderstorm stage), and the wind shear between the drafts may be far in excess of what an airplane is designed for. This, of course, is in addition to the likelihood of encountering hail.

6. Exercise great care in taking off or landing at an airport in the path of a steady state storm. The first gust'll getcha if you don't watch out. Fortunately, the leading edge of the gust front is often visible from the air. There may be a line of blowing sand or dust, trees will lean over and dance, and tall grass will show it clearly as it advances across a field. From the ground, though, even if you're looking for it, you may not be able to see it coming until it's too late. The only good advice is to not take off if an advancing storm that you believe to be a steady state storm is within 15 miles and you don't know where the gust front is.

As if Mama Bear wasn't bad enough, Papa Bear, the full blown severe thunderstorm, is still waiting in the wings to be introduced. Let's let that wait a few minutes, though, and take some time to understand wind shear.

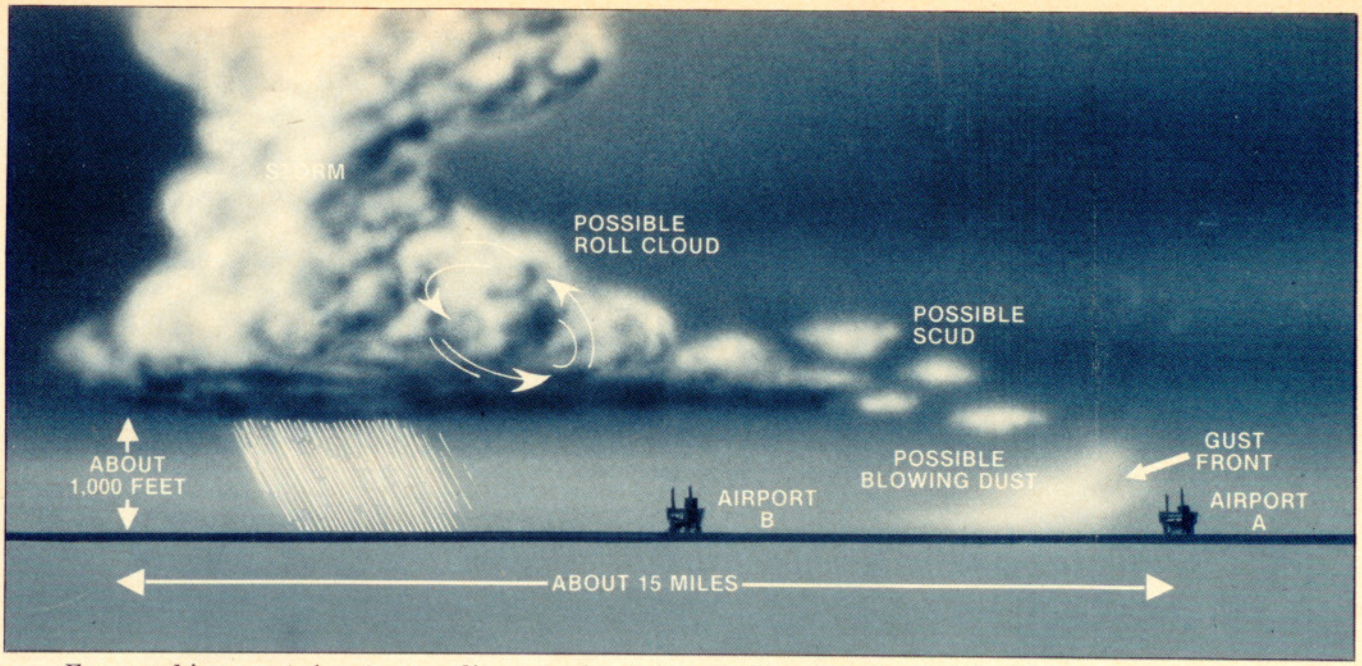


Wind shear encounters can leave your airplane about to stall out or difficult to rein in. The ones to watch out for are the ones that leave you low—and—slow.

Both wind speed and wind direction usually change with altitude. This is common and generally not hazardous. This is not what we mean by a wind shear, however. Since there are presently several definitions of wind shear around, and since we don't want any confusion, we'll make our own. What we will mean by wind shear is *a change in wind speed and/or direction which is sudden enough to cause an abrupt change in the indicated airspeed of an airplane.* Let's look at an example above.

Suppose we have two layers of air, an upper layer moving from the left at 20 knots and a lower layer moving from the right at 20 knots, with a sharp boundary between them. The boundary we will call a *shear line.* Suppose you are watching from the ground, and an airplane is coming from the right, above the shear line but descending slowly, at an airspeed of 100 knots. What you see from the ground (we will ignore the difference between indicated and true airspeed, since it has no bearing on this illustration) is an airplane moving from right to left at a ground speed of 80 knots, but it has 100 knots of wind moving over its wings.

As you watch from the ground, the airplane descends through the shear line. The wind change from a 20-knot headwind to a 20-knot tailwind is almost instantaneous. The airplane can't



Far-reaching gust front preceding steady state, or Mamma Bear, thunderstorm can produce wind shears that raise Cain with aircraft operations well in advance of the main storm.

accelerate or decelerate instantaneously, though, so what you see from the ground, momentarily, is still an airplane moving from the right at a speed of 80 knots, but now with only 60 knots of air moving over the wings, since it has a 20-knot tailwind. Because the airplane can't accelerate or decelerate instantly, you, on the ground, haven't seen anything yet. You're about to, though, because the pilot has just seen his airspeed drop abruptly from 100 knots to 60.

The airplane was trimmed for steady flight with 100 knots of wind moving over its wings and control surfaces, and that's what it wants. Whether or not it actually stalls is of little consequence. In any case, it noses down abruptly in an effort to regain its trim speed. The pilot—any pilot and any airplane—is now going to lose some altitude. How much depends on how much power he has available and how fast he uses it, because what he needs to do is reestablish steady flight by accelerating back to his trim airspeed, or at least to an airspeed that is sufficient to stop the altitude loss. If he happened to be descending toward a runway, and if the shear line happened to be just a couple hundred feet off the ground, our pilot had best hope that the alligators in the swamp short of the runway are well fed. Let's call this kind of wind shear encounter "Case One."

If the airplane was descending from left to right when it hit the shear line, the pilot would see a sudden *increase* in airspeed. You, on the ground, would see an airplane descending through the shear line at a groundspeed of 120 knots, 100 knots of airspeed plus a 20-knot tailwind. The pilot is in an airplane moving over the ground at 120 knots, but with 100 knots of wind moving over the wings.

When he goes through the shear line, you on the ground still see an airplane moving from the left at 120 knots (momentarily), but the pilot sees his indicated airspeed jump from 100 knots to 140 knots, the sum of his 120-knot groundspeed plus the 20-knot headwind. This is obviously not as dangerous as the previous case, since the airplane does not precipitate earthward, but it may result in suddently exceeding landing gear or flap-limit indicated airspeeds or in overshooting a landing and winding up amid the stumps and alligators at the far end. Let's call this "Case Two."

What we will call a "Case Three" encounter is as dangerous as Case One, perhaps even more so. Take the same wind picture we have been using, and suppose the airplane is *climbing* toward the shear line, from left to right, in the lower layer of air. Suppose it is climbing at its best-rate-of-climb speed, for example, 80 knots. This is what the pilot sees on his airspeed indicator. Standing on the ground, you see an airplane climbing at a groundspeed of 60 knots, with 80 knots of air moving over the wings.

Now the airplane penetrates the shear line, and what you see (momentarily) is still an airplane moving from left to right at 60 knots, but suddenly it has a 20-knot tailwind, and therefore only 40 knots of wind moving over the wings. That's what the pilot is looking at, 40 knots IAS. The airplane stalls but this time the pilot doesn't have any additional power to add, or at least not much. He was already using nearly all he had to climb. The wind shear will reverse itself when the airplane falls back through the shear line, but the airplane may be out of control or the sudden increase in airspeed may exceed limit speeds. If the shear line is close enough to the ground, it may not be possible to stop the descent in time.

For the sake of completeness, let's have a brief look at another possibility, "Case Four," in which an airplane climbs through a shear line and encounters a sudden *headwind*. This is not usually dangerous, since it results in a sudden increase in airspeed and rate of climb. The airplane will pitch up in order to return to its trim speed, and as long as this is controlled and indicated airspeed limits are not exceeded, there will usually be no harm done. However, a shear line is often violently turbulent and should be treated with great respect on that account, regardless of the direction of penetration.

Now let's see what the thunderstorm, particularly the Mama Bear storm with the far-reaching gust front can do. Look at the illustration above and suppose we are landing at airport A. The gust front has not yet arrived at this airport, but is approaching. The wind, however, is blowing toward the storm at airport A, feeding the updraft. This will usually be from a southerly direction, if the storm is approaching from the northwest quadrant. Let's assume that this is the case. Then, to make an approach to a runway oriented toward the south, we must fly to the north of the airport, more or less toward the storm.

We are now set up for a Case One Wind Shear Whammy, because we will very possibly enter an area above the shear line. We will start our descent toward the south in a headwind and descend through the shear line into the tailwind caused by the cold air outflow from the storm. There may be some scud marking the shear line, or a roll cloud ahead of the storm rotating violently in the shear zone. There also may be nothing visible.

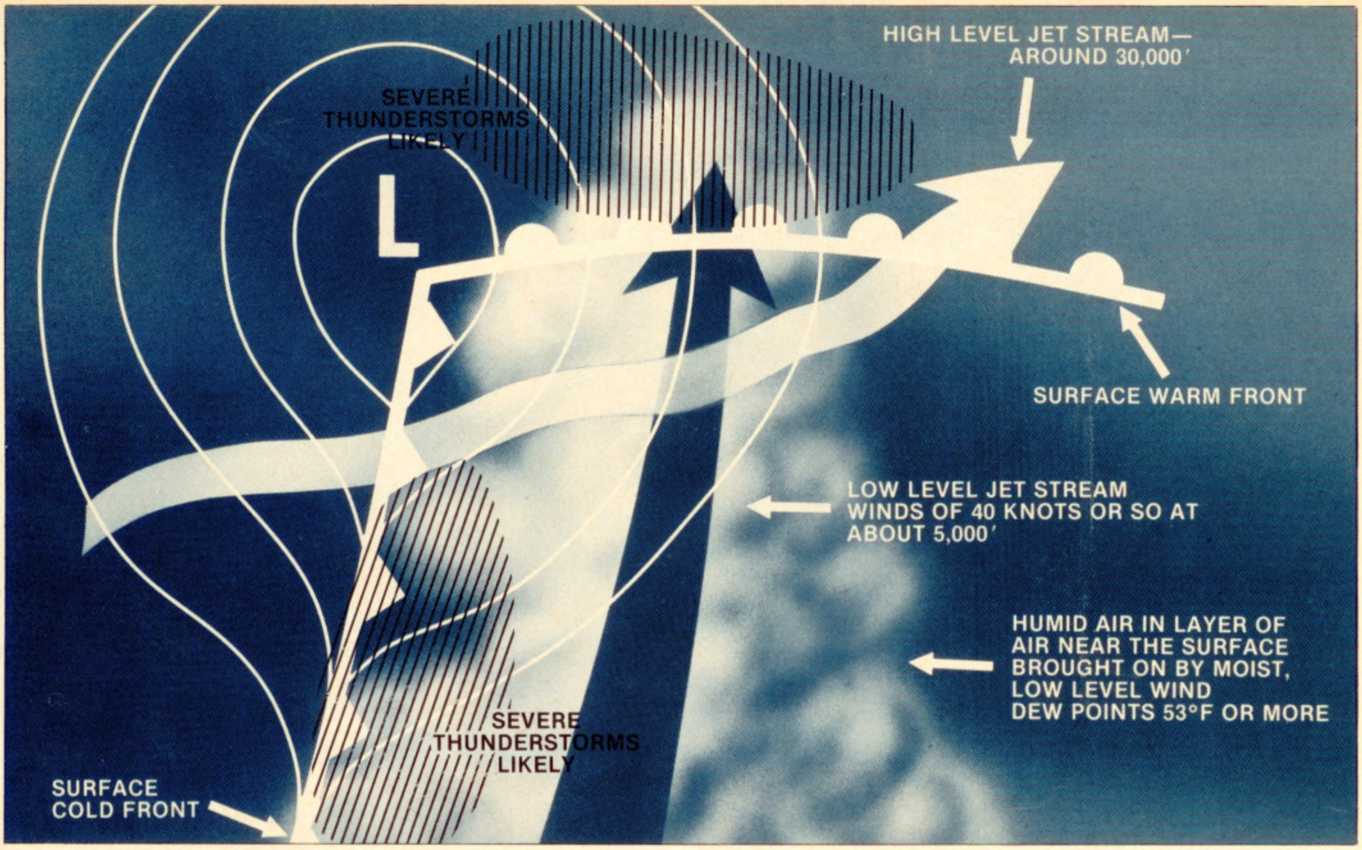
Winds in the southerly airflow at airport A and above the shear line may easily be as much as 30 knots, and winds below the shear line, in the cold outflow, as much as a steady 40 knots. This provides the potential for an airspeed loss of as much as 70 *knots*, accompanied by violent turbulence at the shear line. If we take off at airport A, we will take off away from the storm, and that's okay as long as the gust front doesn't pass while we're sitting there or on the roll. If it does, we can find ourselves hit by a gust of as much as 70 knots, and if we've already started to roll, may find ourselves attempting a takeoff in fierce turbulence with a 40-knot tailwind.

Suppose we are at airport B and the gust front has already passed, as evidenced by a strong, cold wind blowing from the direction of the storm. In the example we are looking at, this would mean that we would take off (if we elect to try) to the north or northwest. We are now set up for a Case Three Whammy, because we will climb through the shear line into the tailwind, and again have the potential for an airspeed loss, accompanied by severe turbulence, of as much as 70 knots. That, obviously, would bring the airspeed to essentially zero in some light aircraft.

The only good advice about taking off in the cold draft from the thunderstorm is Don't Do It. If you do it anyway, turn away from the advancing storm as soon as possible. If you are heading away from the storm when you penetrate the shear line, you will have converted the situation into the far better Case Four encounter. This, however, is a very risky thing to do, because you have no way of knowing how high off the ground the shear line is. If it's only a couple of hundred feet, welcome to the stumps and alligators.

A Case Two wind shear encounter would occur approaching airport B from the direction of airport A. If the winds at airport A are blowing toward the storm and the winds at airport B are away from the storm, you know that the shear line is in there someplace. This time, you can expect fierce turbulence, at least strong to moderate if not severe, and an increase in airspeed that may make landing impossible if encountered late in the approach.

For years many pilots have played tag with thunderstorms in the vicinity of their departure or arrival airports and got away with it. With experience and knowledge, we can be canny enough to watch for the gust front from the air, look for the scud or roll clouds that may indicate the shear zone, check winds from airports closer to the storm, listen to other aircraft on the frequency that may be flown by people more bold than we and are giving it a try, and otherwise make an intelligent decision as to whether we



The Daddy Bear—or severe thunderstorm—can be spawned by cold or warm fronts associated with low pressure areas, and then can generate the big one—the tornado.

are facing Baby Bear or big Mama Bear. All too frequently, however, such decisions are based on nothing but the desire to get going, or get there, and the outcome rests on the steady hands of dumb luck. *Any* airplane, and *any* pilot, can be brought down by low-level thunderstorm wind shear, and the culprit is usually Mama Bear.

There is still one more kind of thunderstorm, the big Daddy Bear of the family, the full-grown severe thunderstorm. These generally travel in packs, complete with Mama Bears and Baby Bears, and woe betide the errant aeronautical Goldilocks who dips into the porridge. These are the things that spawn tornadoes.

Severe storms require large quantities of moisture and deep unstable layers to form. Typically, we picture an advancing low pressure system in the Midwest, above. The low-level flow (in the lower 5,000 feet or so of the atmosphere) is strong and steady and right off the Gulf of Mexico. These winds are frequently in the neighborhood of 40 to 50 knots in speed, and are often referred to as a low-level jet stream. Tornadoes almost always occur in areas where the surface dewpoints are 53° F or higher.

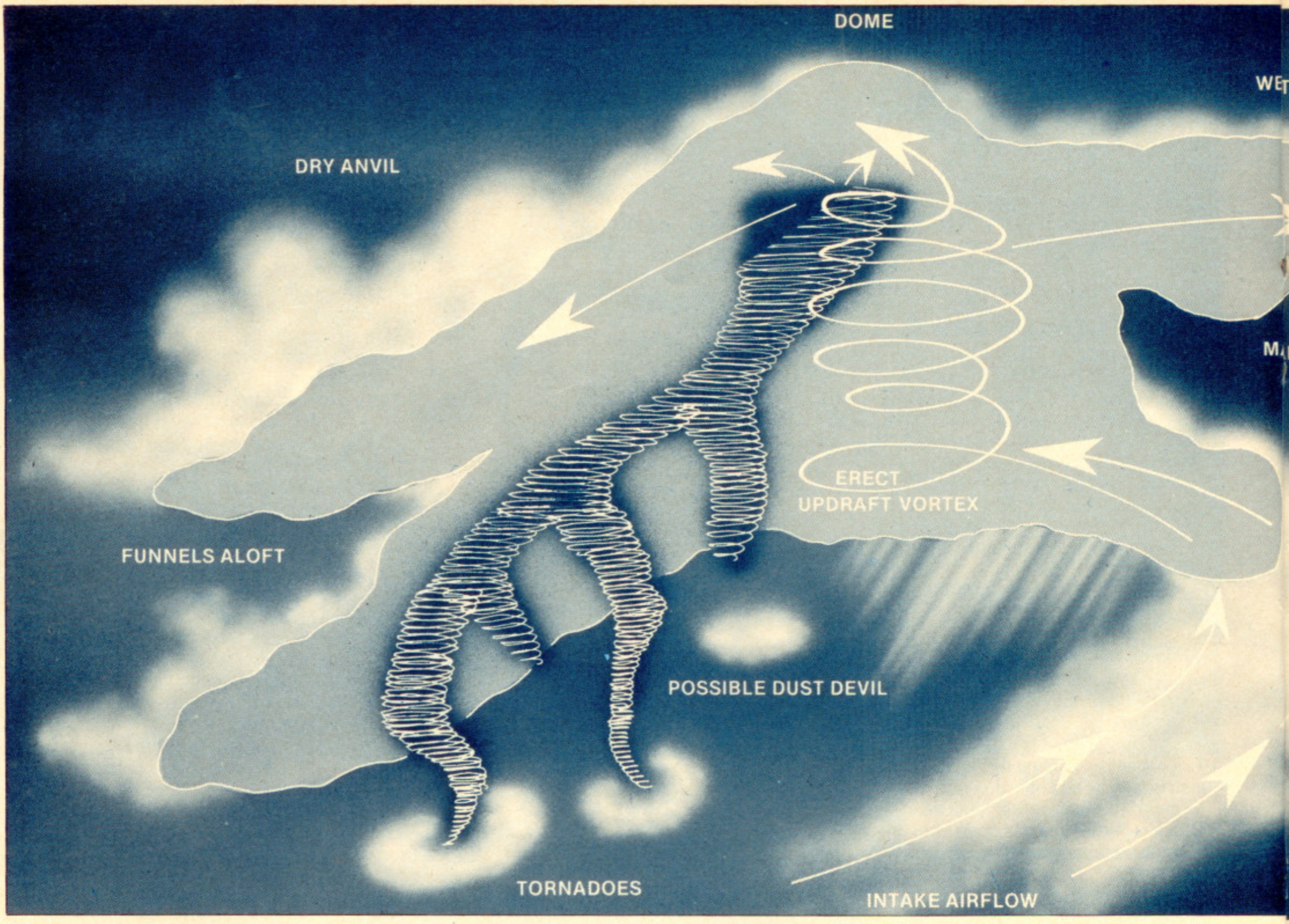
A high-level jet stream from the southwest is usually found at 30,000 feet or so, crossing the low-level jet stream at an angle when viewed from above. This results in an environment in which the winds increase and turn with height, which is perfect for the development of steady state storms. The updrafts will slope and the water brake will be off.

Once the moisture and instability are there, and the wind field is favorable for steady state storm development, all we need is lifting. This lifting is often provided, not by a cold front as you might expect, but by lifting of the low-level jet stream air over a warm front. Squall lines and severe thunderstorms can and do occur with and ahead of cold fronts, but it is well worth making the point that tornadoes often occur along the surface position of the warm front in the low pressure weather system involved. This is directly contrary to the propaganda that is served up about warm fronts in most elementary weather courses for pilots, in which the warm front is generally presented in a stable situation with minimal convective activity. A warm front, like any other front, lifts air. If the air being lifted is a warm, wet, low-level jet stream, and if the air is unstable enough and the wind changes with height enough, the result is not only thunderstorms, it may include Papa Bear, the severe storm.

These storms are usually found in squall lines, and they start life as Mama Bears, steady state thunderstorms with hail, gust fronts, ferocious updrafts and downdrafts, severe turbulence, and wind shears. As they develop into Papa Bear, they add yet another feature, the destructive tornado vortex.

One of the dangers of the tornado vortex is that it can be found in areas where you wouldn't expect it. Tornado vortices can exist aloft with no evidence at the surface, and can be found in areas with cloud tops as low as 12,000 feet. They do not have to extend vertically out of the storm, but can be entirely in cloud and almost horizontal.

As the steady state storm develops, the updraft begins to rotate (see next page). Vortices of tornado intensity can develop in and extend beneath, the cloud itself. This type of cloud can presumably exist as long as the conditions that created it (including the moisture supply) exist. The record for a single tornado path along the ground is *over seven hours*. I won't even guess how long a vortex might exist aloft. New cells can develop on the right rear flank of the rotating updraft severe thunderstorm, and these have been found to contain tornado vortices. It is here, in the flanking line to the right rear of the severe storm, that the real trap exists. These clouds are not Cb's, at least not initially. They may not appear on radar at all, and yet vortices have been seen extending from these clouds as far as 20 miles from the heavy precipitation of the thunderstorm. It is entirely possible to encounter a destructive vortex underneath this flanking line in clear air, miles from the storm and while flying



Interior of a severe thunderstorm can generate tremendous swirling forces, visible or invisible, that can make short work of anything that flies into them.

under cloud that is not raining and that is clearly not Cb.

The squall line that spawns the severe storm contains every kind of thunderstorm weather. The individual storms compete for the available moisture. Some will not become thunderstorms at all. Some will, and Baby, Mama and Papa Bear will most likely all be found in various places with updrafts in excess of 6,000 fpm, downdrafts of that or more—I have heard of one case (in which the airplane survived) of a 12,000 fpm downdraft—large hail, gusts in excess of 70 knots near the ground, severe and possibly extreme turbulence, and tornado vortices.

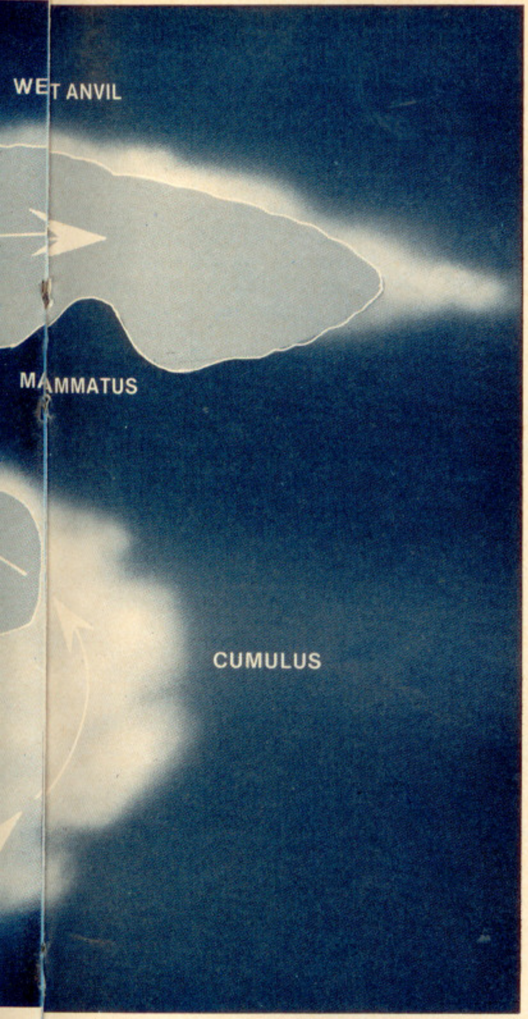
What is a tornado vortex? Everyone has seen pictures of a tornado tearing up the turf someplace in the Midwest. The width of the tube may be anywhere from a couple of hundred feet to a mile. Tubes may be found in, or under, the Cb cloud, and in or under the flanking cloud that is connected to, but not yet part of, the storm in the upwind quadrant. The tube may be oriented anywhere from vertically to nearly horizontally, and will be visible only if carrying dust or debris of some kind. The speed of the winds may be over 200 knots in the vortex, and grazing or penetrating one can create any kind of wind shear. A head-on encounter can literally lift the wings of an airplane right out of the fuselage.

There are cases on record, noted particularly by Dr. Fred Bates, in which airplanes apparently disintegrated in clear air in the vicinity of severe storms, probably due to a head-on vortex encounter. A tail-on encounter can result in an airplane suddenly finding itself going backwards relative to the wind. There is a case on record, again from Dr. Bates, in which a jet transport at about 19,000 feet in a flanking line found that its airspeed had abruptly become zero, whereupon it did the only thing any sensible airplane with no airspeed ever does. It put its nose down and got some. The airplane survived due to some beautifully sharp piloting, but the recovery pulled one engine right out of the wing.

It is probably not necessary to go on with stories of what could, and has, happened. Note, however, that these vortices very seldom contain water. Unless they pick it up from the surface, the rotation throws it all out. Consequently, since weather radar "sees" water drops, dry vortices do not appear on radar. It is possible to penetrate a squall line containing severe storms, be well away from the nearest storm echo and hit a tube.

Fortunately, this most destructive of storms is probably the most easily avoidable; NWS has a method of forecasting them. It involves the high- and low-level jet streams, low-level moisture, stability and lifting, and is one of the single most reliable methods of forecasting. The NWS issues teletype severe weather watches whenever necessary. The coverage area is normally a box, 60 nautical miles or so each side of a line between the end points of the suspect area. These boxes are then drawn on the Radar Summary Charts, which are received by Flight Service and NWS Stations.

These forecasts are verified about 40% of the time: that is, the forecast weather occurs in the box during the forecast time period. Of those that aren't precisely verified, many are near misses, with the weather ocurring a little outside the box or outside the time period. Also, for these forecasts to be verified, the weather generally



has to affect the surface. The fact that this may not happen in an individual case doesn't mean that the weather doesn't exist aloft. Therefore, avoidance of Papa Bear, the severe thunderstorm, generally means just this: when a severe weather watch is in effect, and storms have actually begun to form, *stay out of the box.* Development in these areas is so rapid (do a little arithmetic with a 6,000-fpm updraft and see what you get), and penetration is so risky even in clear air, once storms are present, that to go out of the way or wait a few hours is an insignificantly small price to pay for the assured safety it will afford.

Suppose that a severe thunderstorm occurs without being forecast, or that word of the forecast has not reached you. The VFR pilot should use the tips we discussed in the section on Mama Bear, the steady state storm, to determine that this is no ordinary storm. If you are caught in the area and have to circumnavigate what you suspect may be a severe storm under VFR, avoid it by at least 20 miles. Don't run under a cloud base upwind of the storm, most especially if the cloud is seen to have a common base with the storm. For the radar-equipped instrument pilot, a severe storm may give a couple of other clues, as follows:

1. Watch for right moving storms. A large thunderstorm echo that turns to its right, instead of moving in the direction you would expect from the wind flow, is probably a severe thunderstorm.

2. Hook-shaped echoes often indicate storms containing tornado vortices. Once again, give such storms a 20-mile berth, particularly avoiding the upwind quadrant. If possible, visually avoid flying through, or under, the upwind flanking line.

I'm not too much at pep talks, but this may be a good place for one. We are pilots, and regardless of what we fly, the Federal Aviation Regulations make us, as pilots in command, directly responsible for the safety of our airplane and the final authority as to its operation. In the case of a thunderstorm, when we believe it's time to quit we must have the backbone to do it. Passengers must be told we can't get there from here right now. If necessary, air traffic control must be told, "baloney, I'm not going in there."

It may be well to say a few words about thunderstorms that occur at night, because the subject is sometimes overlooked or treated as obscure in weather books commonly available to pilots. There is nothing basically mysterious about nocturnal thunderstorms. All three kinds of storms we have talked about here can, and do, occur at night. I don't have any data to support this, but I would guess from my experience that air mass storms occurring at night are more often unforecast than daylight storms, and that the consequent element of surprise lends a sense of the unknown to these things.

They occur for the same reasons that any other thunderstorm occurs—namely, the right combination of moisture, instability, temperature and lifting. There are far fewer thunderstorms at night than during the day because of lack of surface heating by the sun. This removes the thermal lift, which is probably the most common trigger for air mass storms, and if the ground cools off enough, it cools the layer of air near it, resulting in a warm-over-cold, stable layer. However, it's easy enough to imagine situations that can kick off air mass thunderstorms at night. Let's imagine.

If the air is moist enough, and unstable enough above what may be a shallow, stable layer near the ground, a high enough hill can always do it. If enough low-level wind springs up to move the air up the hill until a cloud forms, and if the lifting continues until the air being lifted becomes warmer than the air around it, Bingo!

Suppose air that is sufficiently moist, and is unstable except possibly in a layer near the cool ground, is moved by the wind over a relatively warm lake. Not only will the lower layer warm up and tend toward a cold-over-warm, unstable situation, it will become even more moist. A very small amount of lifting caused by rising terrain on the lee shore may then be enough to set off the action.

On the other hand, absence of wind from any other sources can be replaced by the formation of a sea breeze front at night, in which relatively cool air from the land moves offshore and plows under the moist air over the water like a miniature cold front. Once again, possible fireworks.

In the right wind field, and with enough moisture and instability, any of these storms can become a steady state storm. Steady state and severe storms can also be set off at night by more conventional lifting mechanisms —cold fronts plowing under warm, moist air or warm, moist air riding up over warm or stationary fronts. Steady state storms that form during the day can also last far into, or even through, the night.

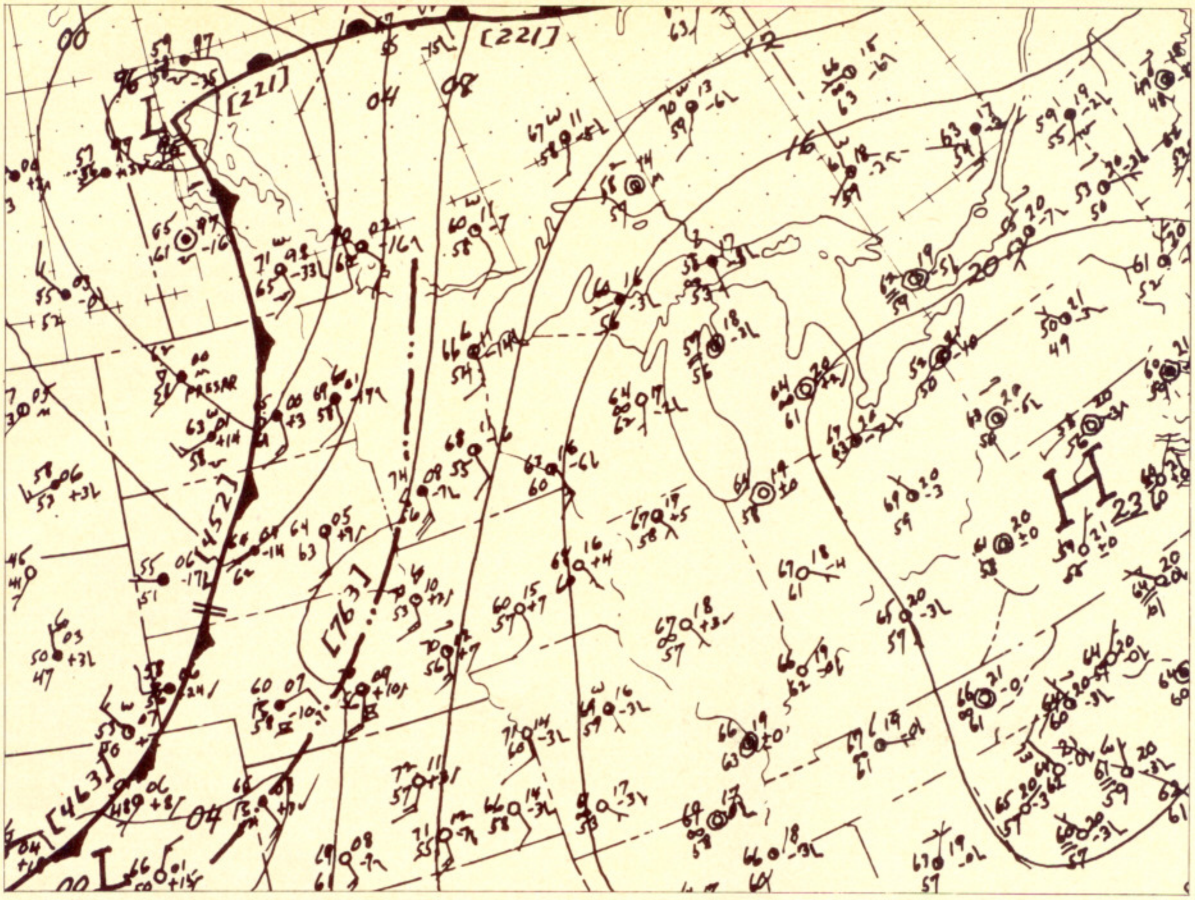
A cloud that formed during daylight may cool off at the top after sunset, again resulting in a cold-over-warm, unstable situation. A small, upper-air trough may form or move across an area where air is sufficiently moist and unstable for thunderstorms. These are hard to locate on the large scale of meteorological upper-air charts, but they are not hard to understand. They do one or both of the following:

- They act like a small vacuum sweeper in the upper air and suck up air from below, thereby providing lifting.
- They bring in cooler air aloft, and there we go again. Cold over warm.

Thunderstorms, even surprise thunderstorms, are fortunately often more easily avoidable at night than daytime storms because they broadcast their location, and frequently give a good indication of their intensity, by easily visible lightning. Once again, get on top of any haze if possible. Don't panic at the first flash of lightning, because it may be visible for hundreds of miles at night, but do start immediately to use all the means at your disposal to locate the storm. If the lightning is frequent or covers a broad area, suspect steady storms and possible squall lines and act accordingly. Don't hesitate to land if you don't like the situation.

We have said a few things in passing about weather briefings for flight on thunderstorm days, but there are some things that haven't been covered so let's take a look at how to obtain a weather briefing that'll give the confidence that comes with knowing what you're doing when you walk out to the airplane.

If possible, go in person to the flight service station, or whatever other weather source you may use, on days when the weather is questionable. A picture is indeed worth a thousand words, and you will both save time and increase your understanding of the weather on this day and all other



On the surface chart, look for such signals as a squall line (dash and two dots) preceding a cold front that warn of possible areas of thunderstorm activity.

days if you go see for yourself.

First, and this is common to all weather briefings and has been said so many times it's almost trite, take a look at the big picture. In the case of thunderstorms, first take a look at the stability chart, if you can find it. It is seldom used or asked for in weather briefings, and that's a shame. Many times you will see immediately that the chance of thunderstorms is small, and you can concentrate on other things. Other times it will alert you at once to a potentially explosive situation. In any case, it's a lot of quick and painless thunderstorm information.

Now go to the surface map. What we particularly look for here are moisture and lifting. The moist areas are the areas of high dewpoint. We pay particular attention to areas where the dewpoint is 53°F or higher, because that's the magic tornado number, and to all areas where the dewpoints are more than 40°F or so and lifting might occur. As to lifting, we look for several things. We look for large, cloudless high pressure areas where the ground will heat up in the afternoon to get thermals started. We look for fronts, and note what they have been doing for the last several hours if the previous charts are available. We look for squall lines, which often form along instability lines away from fronts.

In the example above, there is a squall line (shown by a dash and two dots, repeated along the length of the line) ahead of a cold front. This is a common place to find a squall line, but certainly not the only one. A squall line will be shown on the surface map by this dash-dotted symbol whenever it is not coincident with a front. The dewpoint is the lower-left number in each group of numbers around a station, and we see in this example that the dewpoints are in the high 50's and low 60's well in advance of the frontal system and squall line.

If it's available, a look at the low-level winds aloft chart would be handy at this point. We will look at the winds above the surface up to 5,000 feet and see if there is a general pattern of wind from large bodies of water, particularly from the Gulf of Mexico. On a day such as shown on the example surface map, it would not be unusual to find strong southerly flow from the Gulf to the Great Lakes, with still more water from the lakes being added to be lifted over the warm front at the top of the map.

The radar summary chart is next. We look for areas of organized activity, and we look at tops. We also look at the time the chart was prepared, and take the information with a grain of salt. Remember that two hours is a long, long time when you are talking about things that can grow at over 6,000 fpm. We also look at the radar summary chart for severe weather boxes, to alert us to areas where a severe weather watch was current at the time the chart was prepared.

The charts are not the latest weather, so we now go to the hourly sequence reports and check stations along our route. Having checked the weather charts, we know the direction we can expect weather that might affect our route to come from, and we also check existing weather there. We check dewpoints and existing cloud layers that might be cumulus or altocumulus. We check the remarks at the end of the reports for mention of towering cumulus or Cb's that might be within sight of any of the stations. We check pilot reports for tops of the haze and for any sightings of thunderstorms.

We must be sure to ask for, and check, convective SIGMET's. For about a year now, at 35 minutes past each hour, the Kansas City severe storms forecast center has been issuing a convective SIGMET bulletin on the teletype. If there are no thunderstorms to report, the SIGMET is issued anyway and merely says none. This is an excellent service. Unfortunately, it could have been an even better one.

In April 1978 the FAA issued what

was called a "Prototype Hazardous Weather Plotting Chart" with radials and distance circles drawn on it with respect to six VORTAC's. The chart covered the entire United States, and the convective SIGMET's gave the position of the storms with respect to the plotted VORTAC's. The purpose of the chart was to allow easy in-flight plotting of the storms by pilots receiving the SIGMET, and it was great. However, it seems to have fallen by the wayside.

Anyway, whether there is any present activity on the convective SIGMET or not, we look for severe weather watches. We may know from the box on the radar summary chart that a severe weather watch has been issued, but the absence of a box on the chart does not mean that one couldn't have been issued since, so we check. We then look at the prog charts for the time we are concerned with, and determine what the surface map is expected to look like at that time. We check these charts for expected areas of thunderstorm activity. Finally, we zero in on our destination and possible alternates by checking terminal forecasts.

This last step particularly requires bringing to bear the knowledge we have gained from our preliminary checking. The forecasts were always made some time ago, or they wouldn't be laying there on the table. Obviously, they were made by the forecaster from knowledge of weather that existed at some still earlier time. We will look at what they forecasted the weather to be right now, and see how the forecast is panning out so far.

If we are to be scared off by such things as "chance of" or "possible" thunderstorm in the forecasts, we might as well resign ourselves to walking from about April to November. If thunderstorms are definitely indicated by the forecasts, we will look for the moisture, lifting and instability that will cause the storms to develop. Things may have changed since the forecasts were made.

We also consider the possibility that the forecasts do not predict thunderstorms that *will* happen. If the moisture and instability are there, and a little lift comes along, the atmosphere won't ask permission from the forecast. Remember that, due to the scale of the data collection system, thunderstorms are often like little fish in a big net. The strands of the forecast network may have missed something that is now bumping against the strands of the current data collection net, and the fish that we could've found and didn't will be no less voracious as a result of our oversight.

The only last word in checking weather for thunderstorms is as follows: If there is a severe weather watch current, believe it! Such reports are reliable. Find out where the area is, and stay out of there. Nobody, but nobody, needs to mess with Papa Bear. □