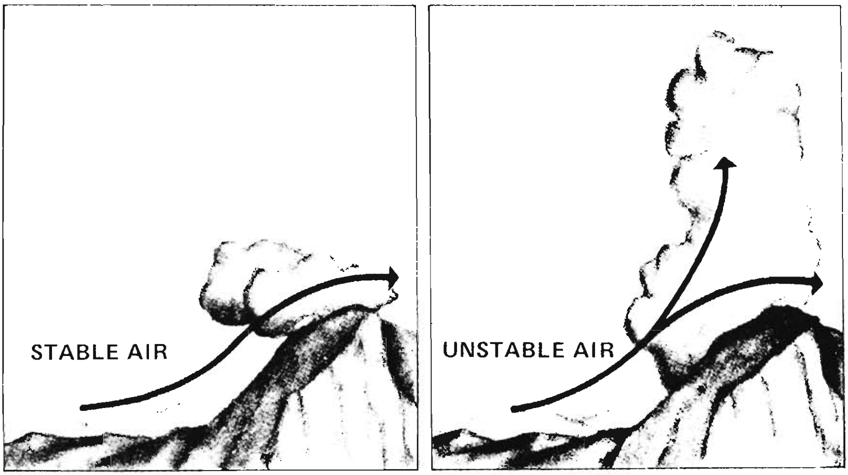


TURBULENCE

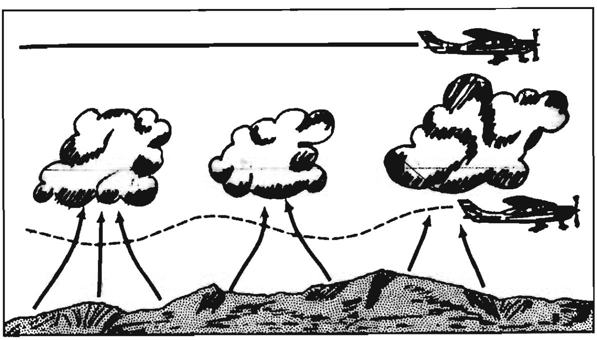
Turbulence affecting aircraft ranges all the way from a few annoying bumps to severe jolts which are capable of producing structural damage.

Since turbulence is associated with many different weather situations, a knowledge of its causes and the behavior of irregular air movements is helpful in avoiding or minimizing the effects of this disturbed air.

The atmosphere is considered turbulent when irregular whirls or eddies of air affect aircraft so that a series of abrupt jolts or bumps is felt. A large range of eddy sizes exists, but those causing the bumpiness are roughly of the same size as the aircraft.



THE EFFECT OF STABILITY ON CLOUD STRUCTURE



AVOID CONVECTIVE TURBULENCE BY FLYING ABOVE THE CLOUDS

The main causes of turbulence are:

1. **vertically moving air in convective currents,**
2. **air moving around or over mountains and other obstructions, and**
3. **wind shear.**

Determine the top of convective activity (when there are no clouds present) or determine the approximate base of the cumulus clouds by subtracting the surface dew point (60°F) from the temperature (80°F) and multiply by 2 (80—60 = 20 x 2 = 40). The approximate height of the base of the clouds is 4,000 feet.

Accounts exist throughout the history of aviation of ''freak'' air currents throwing aircraft out of control, forcing planes into mountains or other objects, and causing accidents while taxiing, landing, or taking off. Occurrences of enroute accidents of such severity are spectacular but rare, provided reasonable flight precautions are taken. Accidents near or at airports due to "unfavorable winds" are much more common. These "unfavorable" currents arise from various causes and are irregularities in the large-scale wind flow. Aircraft traversing an area of irregular flow will be continually encountering changes in wind flow. These irregular air currents are called *turbulence*. Turbulence in flight is also quite common. While annoying and tiring even to experienced pilots, it more seriously affects the comfort of passengers, often causing nausea, apprehension and even fright.

Obviously, pilots want to be able to anticipate whether turbulence is likely on a planned flight, where it will be, and what plans can be made to avoid or minimize it. There is no way of *measuring* the degree of turbulence. However, as in the case of icing and cloud tops, the best source of turbulence information is PIREPS.

Aircraft reactions to a given degree of turbulence vary with aircraft characteristics, such as airspeed and wing loading, as well as with the flight technique used. A pilot's reaction to turbulence is conditioned by a number of factors. Prior knowledge of turbulence enables the pilot to make both physical and mental preparations for the conditions. He will likely consider reducing air speed to lessen turbulence effects or some maneuvering of the aircraft to avoid the turbulent zone. Most pilots advise passengers of imminent turbulence and make sure that they are given safety instruction commensurate with the expected degree of turbulence. The pilot may gain prior knowledge of turbulence from visual observation, radar, forecasts, preflight and in-flight briefing.

Intensity of Turbulence

The pilot's judgment of turbulence severity may be influenced by the length of time his plane is subjected to it. Brief encounters likely will not be considered as significant as those lasting several minutes or longer. The pilot's experience in turbulent conditions and in various aircraft types also affects his evaluation of the intensity of turbulence. Thus, a pilot accustomed to the sharp maneuverability characteristics of a light aircraft and the way it is displaced quickly in turbulent air may regard as unimportant to his safety and comfort, turbulence which would be considered significant by the pilot flying a heavy aircraft.

From the standpoint of structural safety, the design criteria for withstanding turbulence are practically the same for all types of civilian aircraft. However, as stated earlier, there is a great difference in how different pilots would classify an encounter with a given degree of turbulence, based on their experience and the types of aircraft that they are flying.

Although true standardization of classifying intensity is not possible, it is desirable, and an attempt has been made to define and classify turbulence according to its severity on transport aircraft. Such an aircraft would be of the DC-3 class.

Specifically, turbulence is divided into four degrees of intensity—light, moderate, severe and extreme—according to its effect on the aircraft and occupants as follows:

LIGHT: Occupants may be required to use seat belts, but objects in the aircraft remain at rest.

MODERATE: Occupants require seat belts and are occasionally thrown against the belt. Unsecured objects in the aircraft move about.

SEVERE: Aircraft momentarily may be out of control. Occupants are thrown violently against the belt and back into the seat. Objects not secured in the aircraft are tossed about.

EXTREME: Rarely encountered condition in which the aircraft is violently tossed about and practically impossible to control—it may cause structural damage.

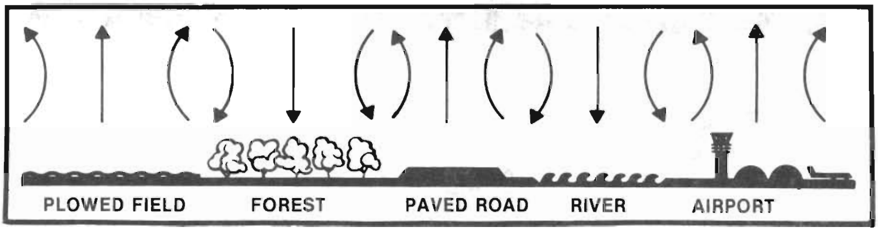
Because of the differing effects of turbulence on different types of aircraft, it is *extremely important* that you give your *type of aircraft* when reporting turbulence encountered.

Types of Turbulence:

Turbulence is divided into four general types based on the meteorological and physical properties responsible for its existence. These types are called *convective, mechanical, wind shear, and clear air.*

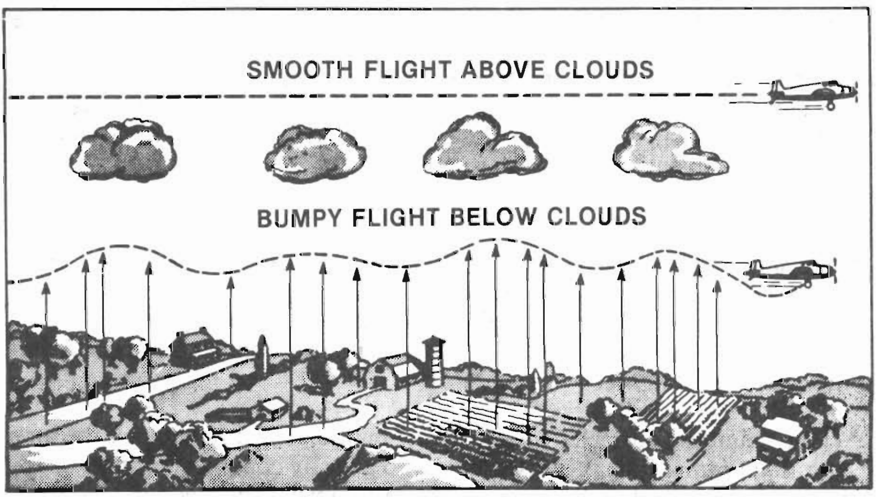
Convective Currents

Vertical currents (convection) were discussed in the section on stability. You learned that updrafts and downdrafts develop in air whenever the existing lapse rate exceeds the dry adiabatic and in saturated air when the existing lapse rate exceeds the moist adiabatic. The force driving these currents is proportional to the difference in density, which in turn is proportional to the difference in temperature between the descending air and the rising air—the greater the difference in temperature, the stronger the force accelerating the vertical current. The speed of the current is proportional to the distance through which this acceleration acts. Thus, when a large difference in temperature exists through a deep layer, the speed of the currents is much greater than when the temperature difference is small and/or the layer is shallow.

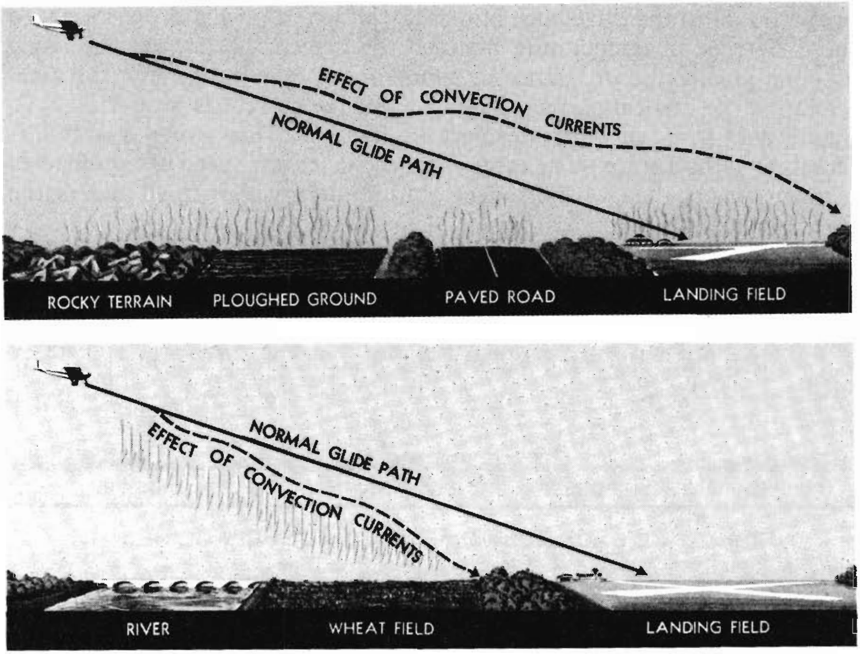


TURBULENCE CAUSED BY DIFFERENTIAL SURFACE HEATING

Convective currents, one of the main causes of bumpiness experienced by pilots flying at low altitudes in warm weather, are localized vertical air movements, both *ascending and descending*. For every rising current, there is a compensating downward current. At times, this downward current may occur over a broad area and be of a much slower speed than the rising current. As clouds form on a typical summer afternoon, there are rising currents of air beneath and within the clouds, while compensating downward currents are found in the clear air between the clouds.



CONVECTIVE TURBULENCE



THE EFFECTS OF CONVECTIVE TURBULENCE ON FINAL APPROACH (A) Overshooting (B) Undershooting

Convective currents develop in air which is heated by contact with a warm surface. They, therefore, are most active on warm summer afternoons with a light wind, since a strong wind flow tends to break up the currents. If the wind is light, bubbles of heated air form near the ground. They rise as convective currents until they reach a level where their temperature is the same as that of the surrounding air. The strength of the currents increases as surface heating increases. Barren surfaces, such as sandy or rocky wasteland and plowed fields, heat faster than ground covered by grass or other vegetation. The rough air resulting from convective currents is often referred to as "thermal turbulence."

Mechanical Turbulence

When an object is placed in a moving air current, it impedes the flow, causing the wind to go around the objects and changing its direction of flow. As the current closes in behind the object in returning to its original flow, eddy currents are set up leeward of the obstruction. These eddies are classified as *mechanical turbulence.*

Where countless obstacles such as trees, buildings and hills block the air's path, the normal flow is transformed into a vastly complicated snarl of eddies similar to rapids in a stream but more complex. These eddies tend to be carried along with the general flow. In such cases, their effects are most noticeable within a few hundred feet of the ground. When the wind blows