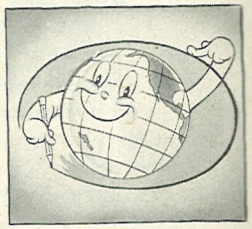
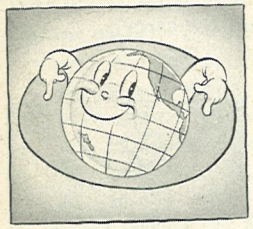
Low Pressure System—An area where the barometric pressure in the center is lower than the pressure in the surrounding region, with counter-clockwise wind circulation around the center.

Meteorology—The science treating with the atmosphere and its phenomena, especially its variations.

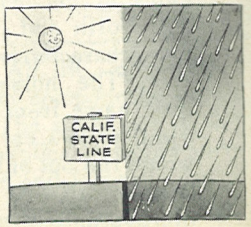
Stratosphere—The upper portion of the atmosphere in which temperature changes but little with altitude and clouds never form.



Tropopause—The narrow transition zone that divides the troposphere from the stratosphere.



Troposphere—The portion of the atmosphere below the stratosphere where weather variations take place.



Weather
The state of the atmosphere.

AEROLOGY SERIES ☆ ☆ NO. 5

THE WARM FRONT

PREPARED BY TRAINING DIVISION
BUREAU OF AERONAUTICS, U. S. NAVY

INTRODUCTION

You have been told in general about the movement of air masses and how fronts are formed. This booklet will develop for you the characteristics of one type of front—the warm front.

Don't underrate the flight problems that are involved in negotiating the type of weather conditions that are associated with the warm front. So much has been written, and there has been so much pilot scuttlebutt about the difficulties of flying *cold* fronts that there is a tendency to overlook the fact that *warm fronts bring tough operating problems*, too.

This booklet is designed to point out some of these problems for you by explaining in non-technical language how warm fronts are formed, how you can recognize them in flight, what conditions you find in the areas surrounding them, and how to fly them.

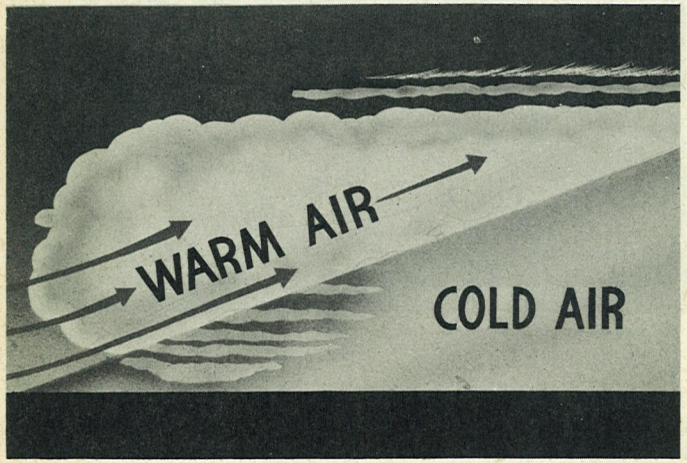
HOW WARM FRONTS FORM

A cold front is formed when a surge of cold air from the north invades a region of warm air to the south. The warm front is produced when a surge of warm air from the south invades the region of cold air in the north.

These fronts are usually associated with a low pressure system, projecting from its center like the spokes of a wheel impelled to move by the winds.

HOW WARM FRONTS FORM

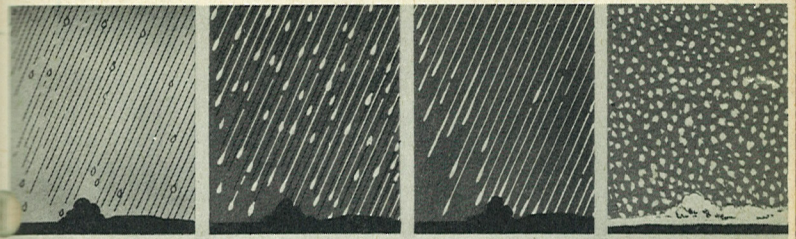
In the northern hemisphere, winds blow counterclockwise about a low pressure system; therefore the winds in the northeasterly sector of the low pressure area will be from a general easterly direction and the winds in the southern sector of the low will be from a general southwesterly direction. It is the warm southwesterly winds blowing up over the cold easterly winds that cause warm front weather because when moist, warm winds are lifted by the cold, clouds form and spread for many miles in advance of the front.



Cross Section through a Warm Front

You readily can see that with the warm air overlying the cold, the resulting temperature inversion probably will cause many peculiar conditions of weather. That is the case. The warm front brings many extensive cloud formations and practically all types of precipitation—rain, freezing rain, sleet, and snow.

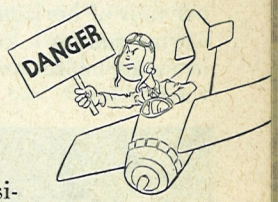
HOW WARM FRONTS FORM



You get all four in WARM FRONTS

The precipitation falling from the clouds in the warm air into the cold air wedge below causes the cold air to become saturated with moisture, and therefore low-lying clouds form in the cold air, causing low ceilings and poor surface visibility.

From the standpoint of the aviator, warm fronts present two principal hazards



The *first* of these is lack of surface visibility and ceiling. The *second* is icing, for there are two distinct sources of icing danger in the warm front area. There is a *third* possible danger—that of running full tilt into a thunderstorm hidden by the cloud layers that surround the warm front. This hazard, however, is more remote than the ever-present dangers of icing and low visibility.

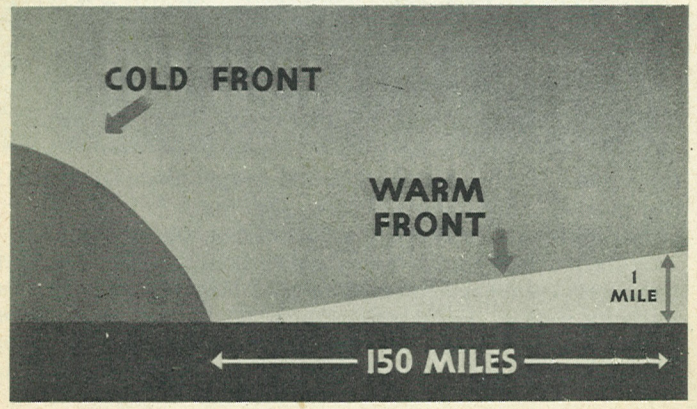
HOW TO RECOGNIZE A WARM FRONT

Warm fronts have this redeeming feature: They give you a warning when you are about to enter them. Extending over widespread areas in advance of the warm front are distinctive cloud formations which are as good as sign posts to the informed pilot, indicating what lies ahead.

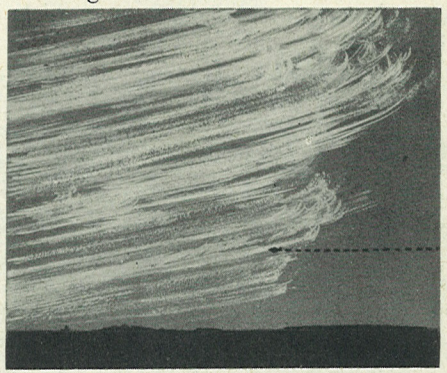
Then, too, there are significant shifts of wind and changes in outside air temperature to tell you when you have crossed the front. These are not so abrupt as in the cold front, but usually they are quite noticeable.

Let's figure out what causes these signals:

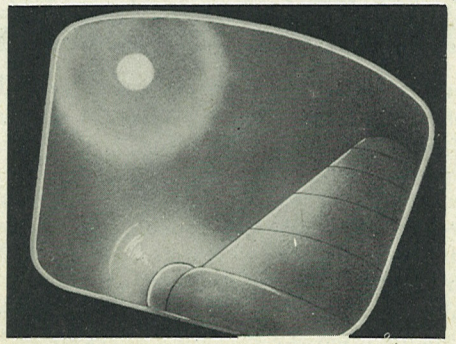
The slope of the warm front is very gentle, being about 1 to 150, or one mile up for every 150 miles horizontally. The cold front is about 1 to 40, or one mile up to every 40 miles horizontally. Therefore you have a much greater lift per unit of horizontal distance in the cold front than in the warm, and as a consequence, vertical currents and turbulence are more violent along the cold front than along the warm front.



In approaching a warm front, your first indication usually is a succession of parallel bands of cirrus clouds. Probably they will not be connected directly with the front, but they are its advance agents.



Next you encounter an overcast of cirrostratus clouds which overlies and leads the solid cloud formations that comprise the front itself. The cirrostratus cloud deck does not obscure the sky but gives it a milky cast and throws a halo around the moon or sun.



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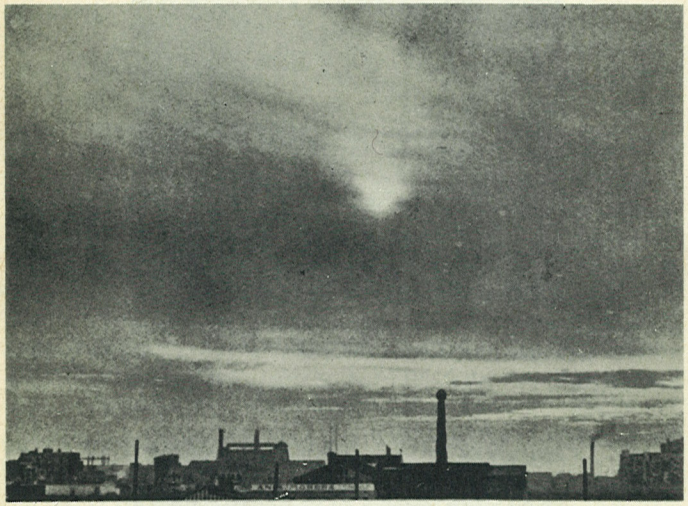
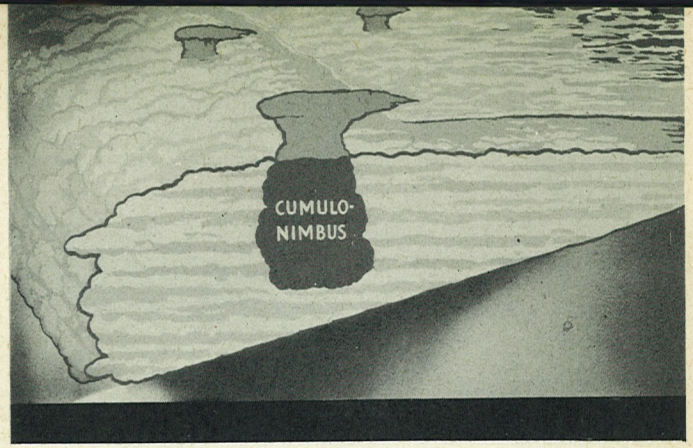
HOW TO RECOGNIZE A WARM FRONT

If you find patches of cirrocumulus in this area—the "mackerel sky" to which the old-time mariners used to refer —it is an indication that the overrunning warm air of the front is unstable, which means that you are likely to encounter heavy showers or thunderstorms which might be embedded in the warm front cloud systems.

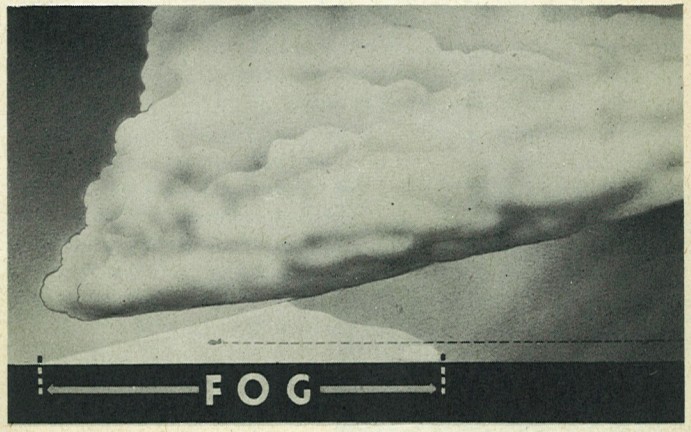


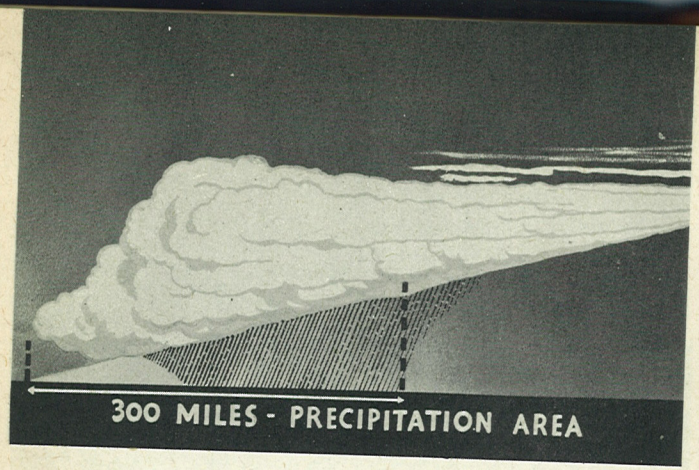
Considerably below the cirrus and cirrostratus clouds you find altostratus and altocumulus types at altitudes from 8,000 to 15,000 feet. These are the first cloud banks that are directly connected with the main warm front surface. Their form varies greatly, depending upon the type of air which is overrunning the warm front. If this air is stable, altostratus forms; if it is unstable, a turbulent deck of altocumulus combines with the altostratus. If the air is extremely unstable, scattered thunderstorms may be embedded in the altostratus and altocumulus decks.



Cross Section - Warm Front - Showing Hidden Thunderstorms

As you continue on into the warm front zone, the clouds get closer and closer to the ground. The entire cloud system increases in thickness, the various intermediate and lower level clouds merge and stratus may build all the way down to the earth's surface in the form of a fog so thick as to render landing impossible.





The warm front precipitation area may extend as far as 300 miles and the clouds may precede the front by 600 miles or more. On passing from the cold wedge of air through the warm front there will be a gradual transition from cold to warm air and a shift of wind. You are now in the warm sector of the storm.

The warm sector contains tropical air both at the surface and aloft. The air is warm and moist and the sky generally cloudy. If any rain is encountered it will be in the form of drizzle caused by turbulent or orographic uplift of the warm moist air. The wind is fairly steady in direction but sometimes gusty.

On many occasions fog may be encountered in this sector caused by the advection of the tropical air over a cold surface. The weather in general will not, however, be as bad as was encountered ahead of the warm front but any attempt to determine what conditions are to be expected must take into consideration the characteristics of the tropical air and the nature of the surface over which it is flowing.

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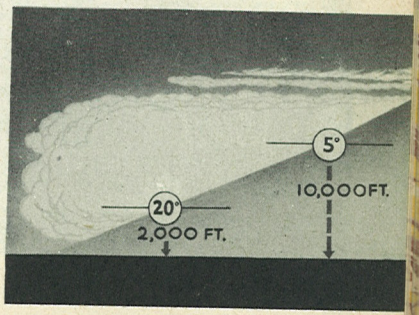
WIND SHIFTS

One of the general characteristics of warm fronts is a wind shift from southeasterly to southwesterly when going through it from the leading edge. This wind shift may amount to from 30° to 90°. The closer to the surface of the earth the greater the magnitude of wind shift. The higher you are the less the magnitude of wind shift. In any case, it is not nearly so abrupt and violent as that associated with the cold front.

Due to the slight wind shift through the warm front, the resulting turbulence is slight, in comparison to the cold front, where the magnitude of wind shift is much greater.

TEMPERATURE CHANGES

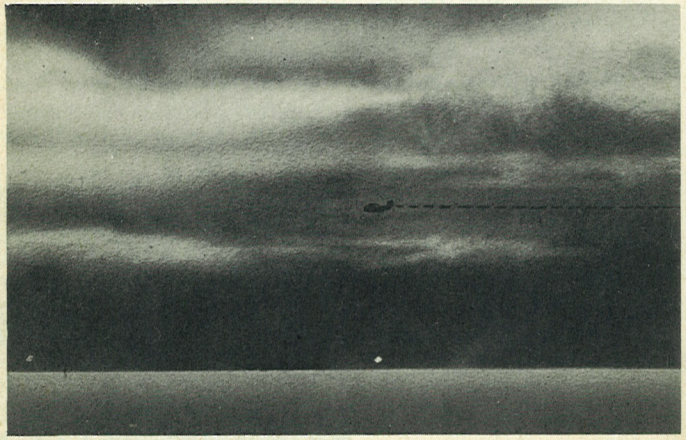
Representative temperatures are higher in the rear than in advance of the front, and therefore the line of discontinuity is easily determined on the outside temperature indicator when proceeding through the front in either direction. The nearer you are to the earth's surface the greater the temperature change will be. At 2,000 feet it may be as much as 20° whereas at 10,000 feet it may not be more than 5°.



WHAT YOU FIND WITHIN A WARM FRONT AREA

Flight operations in warm front weather are very difficult because of low ceilings and restricted surface visibility. During the winter months there is the additional hazard of ice. Operational problems are complicated because the warm front zone is extensive and moves very slowly, so that bad flying conditions persist over a given territory for many hours.

When rain begins to fall from the cloud system associated with the front, lower clouds, irregular in shape, form in the air beneath. These lower clouds cause ceilings to be lower and the precipitation itself restricts surface visibility. Within a distance of 50 to 100 miles in advance of the front, the cold air is very shallow and in this area clouds generally lie on the earth's surface, causing zero ceiling and zero visibility.



WITHIN THE WARM FRONT AREA

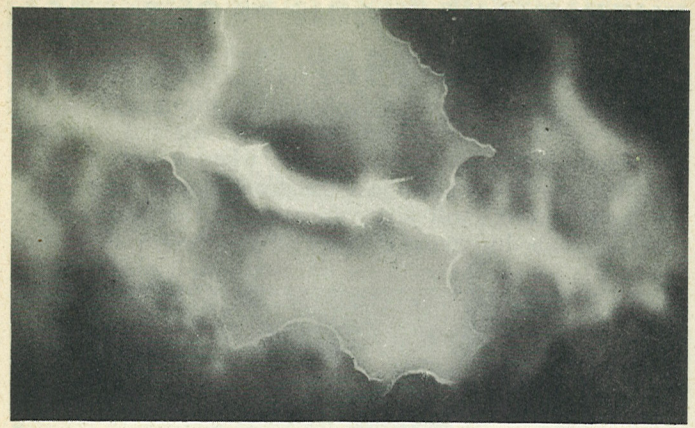
Because the clouds of the warm front are usually in layers, normally you may expect a smooth flight through them, for you do not encounter vertical currents of air and resulting turbulence. There are times, however, when scattered cumulonimbus clouds lurk in the warm front cloud system, and the thunderstorms will give you a rough ride unless your flight is planned to avoid them.

Thunderstorms lurk in the Warm Front System

Warm front thunderstorms have higher bases and usually are less violent than those associated with cold fronts, but nevertheless they can give you more turbulence than you want. They are known as "high level" thunderstorms. Actually, they are a greater problem than cold front thunderstorms because they are hidden by the more benign cloud formations, and it is often difficult to select a flight path around them.

Due to the warm front thunderstorm bases being high, the lightning discharges are generally from cloud to cloud and not from cloud to ground.

WITHIN THE WARM FRONT AREA

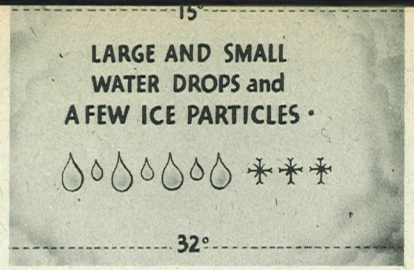


Horizontal Lightning

These flashes are violet in color, whereas low level, or cloud-to-ground lightning, is a brilliant blue-white. The horizontal flashes make it difficult to locate the centers of thunderstorms, because they illuminate the whole area and do not show a concentration in the core of the individual thunderstorms.

At the point where the base of the altostratus cloud formation is 8,000 to 12,000 feet above the surface of the earth, precipitation begins and becomes steadier as you get closer to the front. If the cold air associated with the warm front is unstable, instead of low stratus clouds and fog you will usually have a broken to overcast stratocumulus in the cold air, giving better ceiling and visibility in the precipitation area than if the air were stable. If you encounter intermittent heavy precipitation, while flying under the warm front, it is an indication that thunderstorms or heavy showers exist in the warm air aloft.

During winter, in a typical warm front system, temperatures in the cold air generally are below freezing, and temperatures in the warm air, in the lower few thousand feet, are above 32°F.

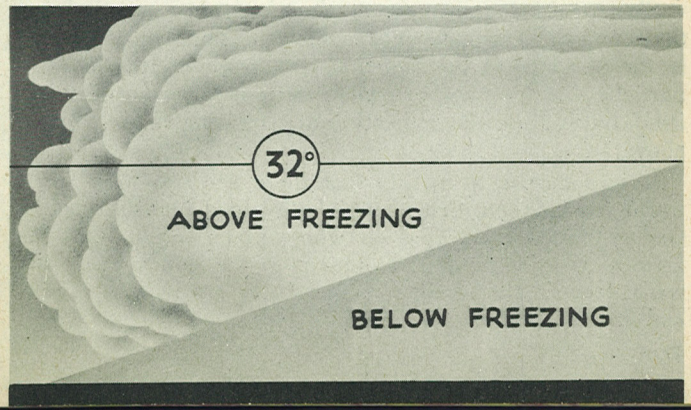


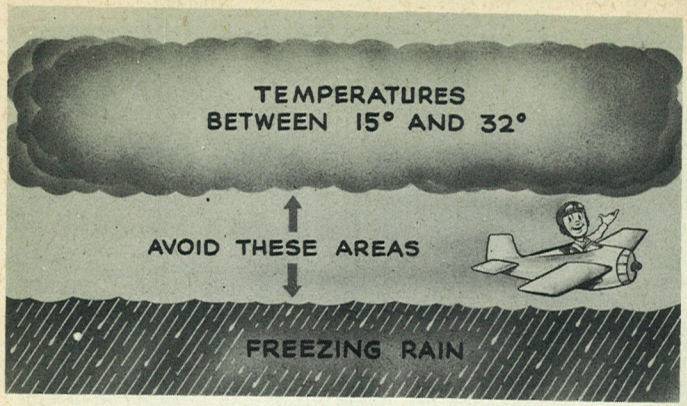
In the area where temperatures are below 15°F., the clouds are composed mostly of ice crystals and therefore only a light formation of ice is to be expected.

But in areas where the temperatures are between 15°F. and 32°F., the clouds are made up of ice particles and subcooled water droplets, the proportion of water droplets being greater at lower levels. These cause *severe* icing.

The portion of the cloud where the temperatures are above 32°F., is composed entirely of water droplets and presents no icing problem.

The type of precipitation falling from these clouds and into the wedge of cold air below is determined by the temperature of the warm air from which it falls. Under the area where the temperature of the warm air is above freezing rain will fall. These rain drops will freeze on contact with any object: This is called freezing rain and presents the most serious of all icing problems.





Under the area where the temperature of the warm air is well below freezing, snow will fall. Snow does not present an icing problem unless it is wet snow. Wet snow will stick to the plane and form ice at near freezing temperatures, in which case you should climb to an altitude where temperatures are colder and where the snow will not adhere so readily.

Between the snow and freezing rain area is a relatively narrow transitional zone. In the upper portion of this zone is a mixture of rain and snow, while the lower portion is a mixture of snow and sleet. This change is caused by the freezing of the raindrops as they fall through a considerable depth of cold air.

Sleet is also found under the freezing rain area whenever the time of fall is sufficient to allow the raindrops to freeze in the air. Due to the fact that sleet is small frozen water particles, it does not present a serious icing problem in itself, but is a positive indication of a freezing rain condition above.

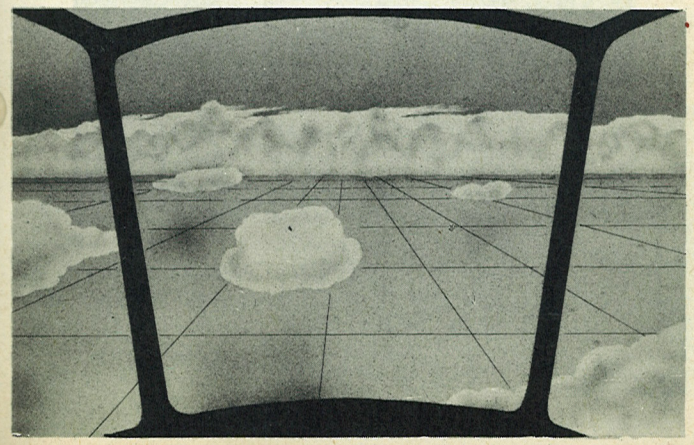
It is apparent from this that there are two areas in a warm front system that should be avoided like the plague. One is the low-lying cold air where precipitation is in the form of freezing rain. The other is in the clouds above the warm front surface where temperatures are between 15°F. and 32°F.

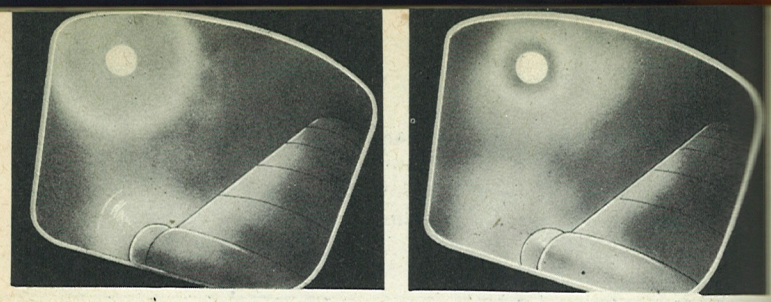
Don't get the idea that you can't pick up ice in less dangerous areas, but there the accumulation is slow and doesn't cause immediate danger. On the other hand, if you prolong flight in these areas, the ice may build up to serious proportions.

PILOT COUNSEL

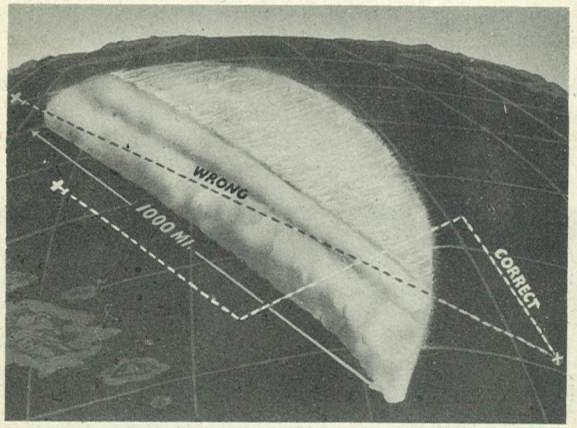
When you approach a warm front from the cold air side, you will first see the sharply defined deck of cirrostratus clouds. The leading edge of these clouds is roughly parallel to the front and therefore you can set your course to fly through the front at a right angle. This will be the shortest route through the weather band and will cut down your time on instruments and, in winter will reduce icing conditions to a minimum.

When you approach the front from the warm air side, orienting your course is more difficult, but if you are on top, usually you can see the line of clouds extending along the front and set your course at a right angle to them.





The halos that the cirrostratus clouds throw around the sun or the moon will indicate to you whether the front is approaching or receding. These halos appear only on the cold air side, and if the halo is getting bigger, it means that you are getting away from the warm front. If the halo gets smaller and smaller, narrowing down to the apparent circumference of the sun or moon, it is a sign that you are approaching the front.



A warm front may be as much as 1,000 miles in length, so a course parallel to the front and within the weather area would be the height of folly.

PILOT COUNSEL

It is never advisable to fly at intermediate levels through warm front clouds, for you are bound to be on instruments, and consequently might fly head-on into the center of a thunderstorm. You can avoid this by either of two flight procedures:

1. By flying below 6,000 feet, you usually will be under the bases of the storms.
2. By flying at 18,000 feet or higher, you can usually see the tops of the cumulonimbus clouds and choose a course that avoids them.

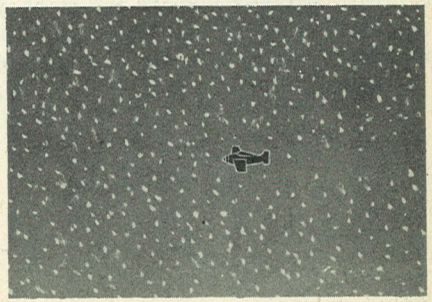
On entering a warm front area, the first appearance of precipitation is an indication that visibility and ceiling will drop rapidly.

The dangerous icing areas can be avoided by flying on top of the clouds whenever possible. If you can't do this, and you must fly within clouds at a lower level, select an altitude where less dangerous icing conditions are indicated by the temperatures or by the type of precipitation.

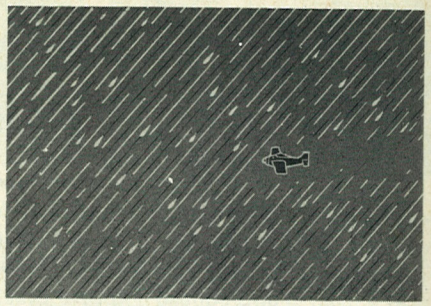
In electing to fly under a warm front the possibility of encountering freezing rain must be kept in mind. Generally over water an altitude close to the water, between 50 to 200 feet, is the most desirable.

You can tell by the precipitation you encounter what the approximate temperature is in the clouds above you.

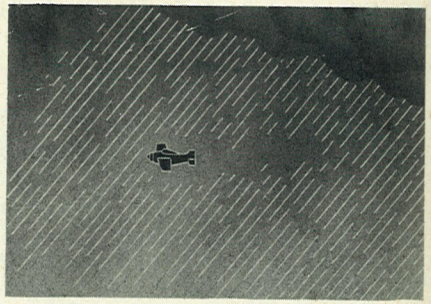
If you are flying through snow, temperatures aloft are *well below* freezing.



If you run into freezing rain, you know that the temperatures overhead are *above* freezing.



If you encounter sleet, the temperatures in the clouds above are *at* or *below* freezing. This is a positive indication of the presence of freezing rain above.



Sleet is the leading edge of the above-freezing temperatures in the warm air of the frontal system. Therefore, if your course is perpendicular to the front, you can start a rapid ascent into the warm air at this point, if the situation is such that you are unable to undertake low level flight.

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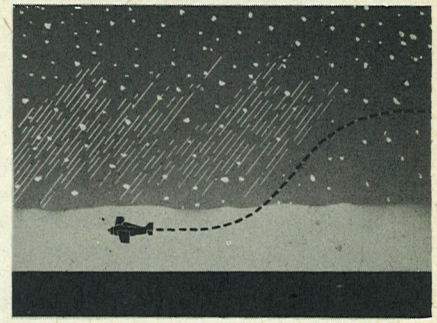

If you are flying in snow and encounter sleet, it is a forewarning that freezing rain lies ahead and above. You must make a decision immediately as to how to change altitude and avoid it. If your course is over land, usually the safest procedure is to climb rapidly, but if you are over water you can fly between 50 and 200 feet of the surface in temperature warm enough to remove the hazard of the freezing rain. There is sometimes a preferable alternative—you can turn around go back.

You cannot expect to go through a warm front in the winter months without getting some ice except over the ocean when a flight at very low levels will avoid it. There is little chance of avoiding it completely over land, but there *is* the chance of getting a minimum amount. When you fly from the cold air to the warm air side you have an opportunity to get rid of it, but that isn't true of the reciprocal course. If you already have ice on the plane, future formations will be more rapid and hazardous than if you don't have it, for sleet and snow will stick to ice more readily than to metal.

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PILOT COUNSEL

Even after you pass through the frontal system, and break out on top of the low cloud deck, it may extend for many miles out into the warm air following the front. Landings will not be so difficult in this area as on the other side of the front, but ceilings and surface visibility still may be restricted in the middle and high latitudes. These restricted ceilings and surface visibilities in the warm air are common over the open sea in all seasons and over continental areas in the winter months. Good ceilings and surface visibilities are the rule behind the warm front over continental areas during the summer (because land surfaces are usually warmer than the air above them during the summer months), and over the open sea in the lower latitudes during all seasons of the year.

Whenever you are about to fly into a warm front area give careful consideration to your flight plan before takeoff.

Don't risk entering dangerous icing areas.

Don't plan sustained flight in areas where you may get a gradual ice accumulation.

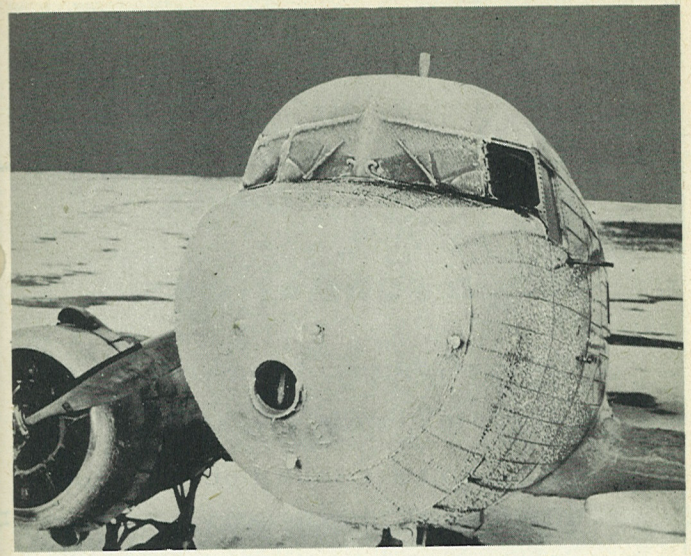
Don't underestimate the effect of ice on the performance of your aircraft, particularly when you are on instruments. If flying at any appreciable altitude it is a foregone conclusion that you are going to take some ice in flying through a warm front area. Govern yourself and your plane accordingly:

Don't over-control. • Don't perform any sharp maneuvers. Don't lose your flying speed.

Don't take a chance of barging into a thunderstorm.

Don't be misled by any current report on ceiling and visibility at your destination. Conditions may change while you are en route.

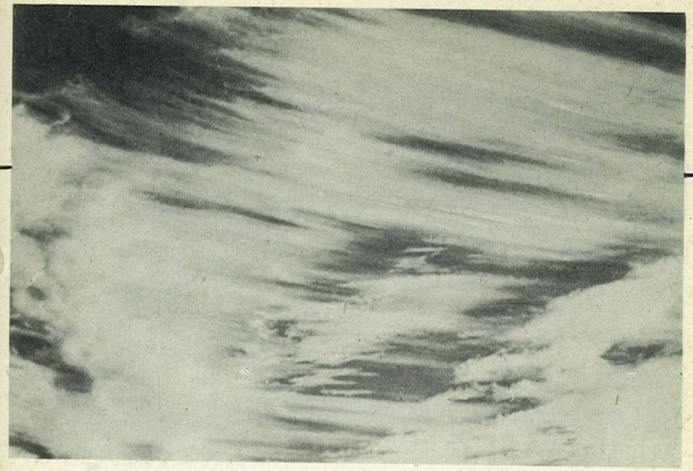
Make sure you have enough fuel aboard to reach an alternate airport outside the warm front area.



This actual photograph isn't typical, but it does give you an idea of how much ice it is possible for a plane to accumulate in a warm front.

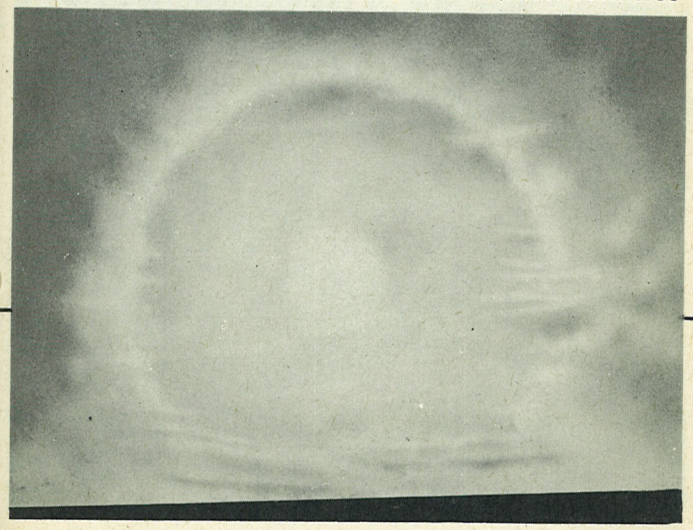
CLOUD FORMATIONS

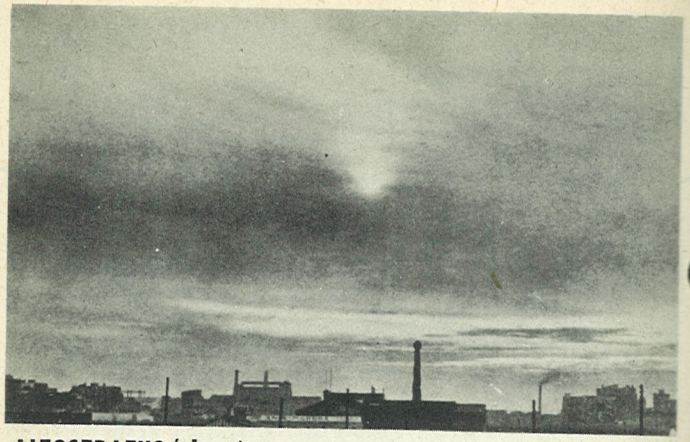
The different types of clouds you will encounter when flying the warm front are shown on the following pages. Familiarize yourself with them. They are sign posts enabling you to select the proper course to follow.



(above) CIRRUS

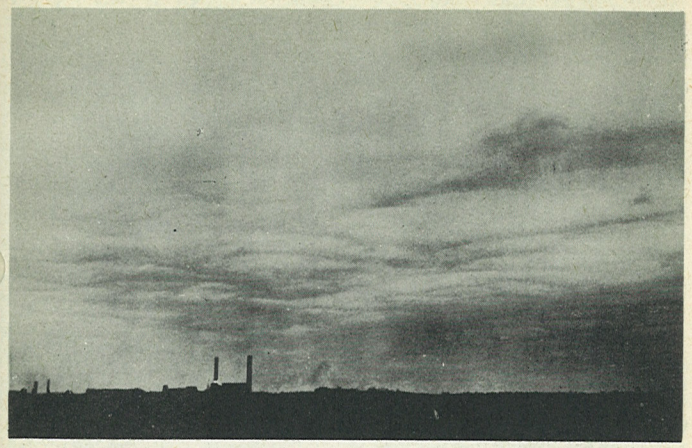
(below) CIRROSTRATUS





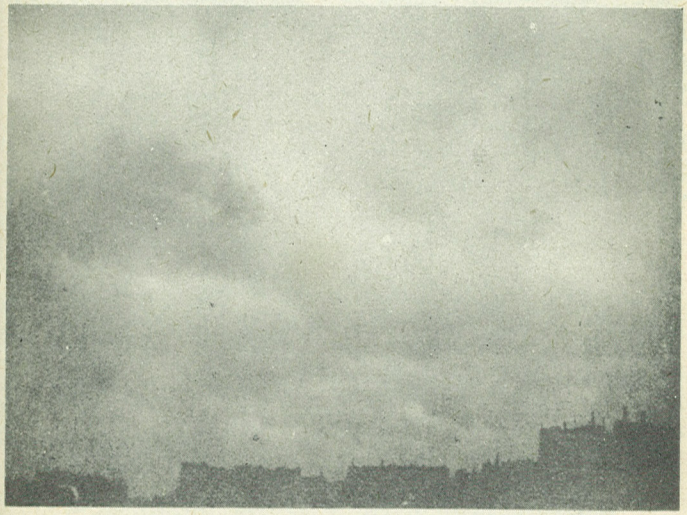
ALTOSTRATUS (above)

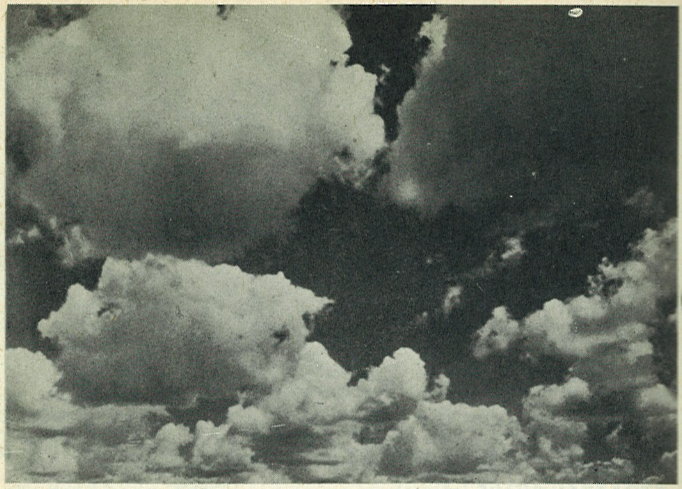
ALTOCUMULUS (below)



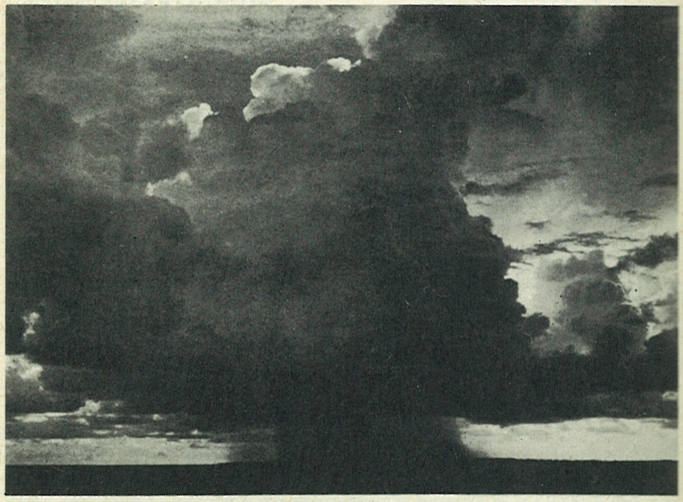
STRATOCUMULUS (above)

NIMBOSTRATUS (below)

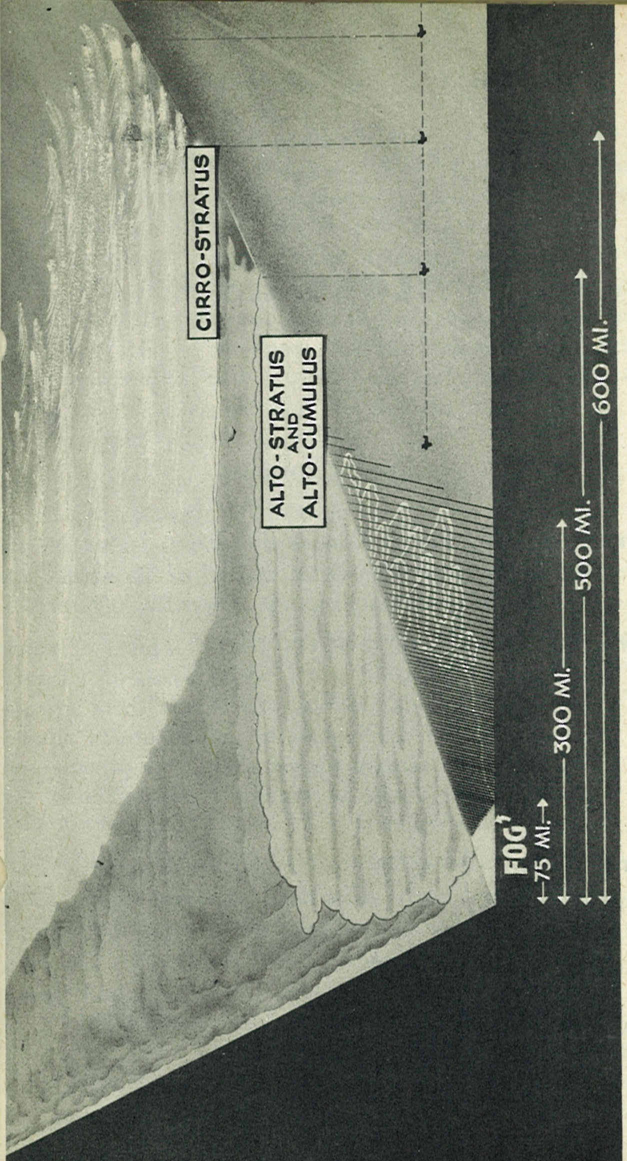




FAIR WEATHER CUMULUS



CUMULONIMBUS



THE WARM FRONT

GLOSSARY

High Clouds

Cirrus—Detached clouds composed of ice crystals, delicate and fibrous, generally white, and often of a silky appearance; formed at high levels (above 20,000 feet).

Cirrocumulus—(20,000 to 40,000 feet)—A layer or patch of clouds composed of small, white flakes, or of very small white globular masses. As a rule there are no shadows and the small globular masses are in ripples like those in the sand at the sea shore. A sky composed of cirrocumulus clouds is commonly referred to as the "mackerel sky."

Cirrostratus—(20,000 to 40,000 feet)—A thin, whitish veil-like cloud which does not blur the outlines of the sun or moon, but causes halos around them. A veil of cirrostratus gives the sky a milky appearance.

Intermediate Clouds

Altocumulus—(7,000 to 18,000 feet)—A cloud layer or a sky composed of flat, gray globular masses. The smallest elements of the regularly arranged layer are fairly small and thick, with or without shadows. These globular cloud masses may be arranged in groups, in lines, or in waves. Sometimes it is difficult to distinguish between the cirrocumulus and the altocumulus clouds, but it is helpful to know that cirrocumulus ordinarily is pure white, without shadows, and there is almost always shading between the globular masses of the altocumulus clouds.

Altostratus—(7,000 to 18,000 feet)—A thick, fibrous gray layer, sometimes bluish in color. This cloud is like thick cirrostratus, but does not form halos. At times the sun or moon may be vaguely visible with a gleam as though coming through the ground glass of your bathroom window, but in many cases they are completely hidden. Rain or snow may fall from altostratus and then the cloud layer grows thicker and lower as more clouds form beneath.

Low Clouds

Cumulus—(Defined in "Thunderstorms.")

Stratus—(Defined in "Thunderstorms.")

Nimbostratus—(Surface to 6,000 feet)—A low amorphous layer of dark gray clouds nearly uniform; finely illuminated, seemingly from inside; with steady rain or snow falling from it. Ordinarily it forms below altostratus clouds and results from precipitation dropping from the altostratus. For this reason nimbostratus usually has a wet appearance and indicates high cloud tops.

GLOSSARY

Stratocumulus—(Surface to 6,000 feet) — Layers or patches of cloud composed of globular masses, generally appearing in long rolls covering large areas. Very often the rolls are so close together that their edges join. When they cover the whole sky, especially in winter, they have a wavy appearance.

Cyclone—A system of winds, rotating counterclockwise in the northern hemisphere around a calm center of low barometric pressure. (Don't let common parlance confuse you about this. A cyclone is *not* the same thing as a tornado.)

Discontinuity—The zone that marks the separation of two masses of air having different temperatures. The discontinuity between a warm air mass and cold air mass is a front.