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DEPARTMENT OF TRANSPORT - AIR SERVICES BRANCH

METEOROLOGICAL DIVISION

METEOROLOGY

AND

OPERATIONAL FLYING

(Reprinted from M.O. 448 (A.P. 1931))

Operational flying over north-west Europe has shown that a number of points discussed in the various courses of instruction in meteorology cannot be too heavily stressed; they have accordingly been reprinted in this pamphlet, with a series of hints on flying in bad weather conditions.

CANADA

1942

METEOROLOGY AND OPERATIONAL FLYING

1. Operational importance of meteorology. In planning operations, weather conditions are often an over-riding factor, dictating what can or cannot be undertaken with a reasonable chance of success. For example, in planning bombing raids the following are some points that have to be considered; notice how often the word 'weather' occurs.

(a) Will it be possible to identify the target? Moon phase, cloud height and amount, visibility, and weather conditions all affect the answer.

(b) Can the aircraft get through without serious risk of being lost or forced down through bad weather en route?

(c) Bearing in mind weather conditions, what will be the best heights and tracks for the flight?

(d) Will weather conditions be safe for take-off from operational aerodromes?

(e) Will weather conditions at base be suitable for landing on return? If not, are there alternative aerodromes in the country where weather will be suitable?

(f) What bomb and fuel loads shall be taken, in view of wind strengths and fuel safety margin for possible diversions because of bad weather? As a case in point, in an hour's flying a Wellington uses fuel equivalent to three 250 lb. bombs.

(g) Given specified amounts and height of cloud, should attacks be high level, low level, or dive?

(h) When day bombing, and to an increasing degree by night, what suitable cloud cover is there to reduce chances of interception by enemy fighters?

2. Importance of meteorological knowledge to air crews. Unless they become squadron commanders or air staff officers, individual crew members will not have to make decisions involving the above points. But they must have enough knowledge to be able to see the reasons underlying their commanding officer's decisions, and to ask him intelligent questions based on a study made with the meteorological officer of the probable weather conditions.

In their initial enthusiasm for action, many are inclined to look on weather-study as a boring waste of time; if you are one of these, talk to an air-line pilot with 10,000 hours flying, or to a senior air staff officer of a flying command, or to a seasoned operational pilot; their views will quickly disillusion you.

The weather can be either friend or foe, and intelligent pilots and navigators use it to the best advantage as an ally. It is a noteworthy fact that the more experienced they are, the keener they become to study meteorology.

Once in flight, the aircraft captain bears the responsibility of conducting his operation and looking to his aircraft and crew safety; and the actual weather he meets (which is not always what he expects) constantly compels him to make decisions. The more he knows about meteorology, the sounder his decisions are likely to be.

Many of our best operational crews attribute a great part of their success to the fact that they have studied weather seriously. Some success is due to piloting and navigating skill, some to sheer guts and perseverance, some to good luck; but a large part is due to knowing the weather. Many a crew will fly straight through any flak barrage, shoot down an enemy, dive low over a target, and be nearly shot down themselves without turning a hair; but on running into bad weather they get the biggest fright of all. A sound study of meteorology does much to rob bad weather of its risks and frights; it can then be recognised for what it is, its extent estimated, and a plan evolved to get out of it again.

3. Examples calling for decision. Consider yourself an aircraft captain under the following conditions. You must provide good and instant answers.

(a) You are returning to base to find your aerodrome in fog. What is the best thing to do if your W/T has failed?

(b) You deal with a target and set course for home on forecasted winds. Later you find yourself a hundred miles off track. How could this have been guarded against?

(c) On reaching your aerodrome you find a summer storm is just sweeping over it, with heavy black cloud, heavy rain, violently bumpy flying conditions, and high gusty wind. Will you land quickly or wait?

(d) You are flying through clouds and the navigator reports a rapidly falling temperature. What does this suggest?

(e) In cloud, ice forms on the windscreen, or heavy ice forms on the wings, or boost begins to fall, or airscrew vibration develops with lumps of ice flying back from the blades. What should the pilot do in each case?

(f) In cloud, flying conditions are reasonably smooth but static electricity forms halos round the airscrews, or flying conditions become rough and lightning is seen around. What should the pilot do in each case?

The operational pilot or navigator who cannot answer these questions is not fully efficient, operationally or otherwise; and he had best set himself the task of going through his meteorological text again, a chapter per day.

4. The meteorological officer. Make a friend of him. Before any flight, obtain as clear an idea as possible of the winds and weather likely, and the weather changes that may take place during flight. Getting a typewritten forecast or ringing up on the telephone is good, but not good enough. Visit the meteorological office, look at a succession of weather maps if necessary, and talk to the meteorological officer. And to get the best out of these discussions, learn the forecaster's methods and language.

5. The weather map. The weather map is the foundation of forecasting. It is simply a map showing wind and weather conditions over any area of country with which one is concerned. For operations based on Great Britain the area is that which is broadly covered by operational activities - western Europe and the eastern Atlantic; at the same time the forecaster considers conditions further afield, as they may affect the operational area later on.

Maps are drawn every three hours; eight times in every 24 hours. The chart for 8 o'clock, say, is drawn up and ready for your inspection in the meteorological office between 9 and 10 o'clock. Thus at all times of the day and night there is a map to show you what the weather was only an hour or two earlier. Conditions are always changing, slowly or rapidly. Thus during a flight base-Berlin-base a belt of rain may move from Devon across to Norfolk. So before starting think of the changes likely to take place during flight. Before take-off study the weather map carefully, particularly the isobars. Most important points to remember are:-

(a) A region of low pressure means bad weather about; a region of high pressure means good flying weather except for the risk of fog or very low stratus clouds.

(b) Fronts - warm, cold or occluded - may mean bad flying weather. Always discuss them in detail with the meteorological officer.

6. Pressure. Remember the big changes that can be caused in altimeter readings by pressure alteration, not only at different places, but at a single place over a period of hours.

Be prepared for misleading altimeter readings by studying the weather map isobars before leaving on a long flight; before descent in thick cloud obtain a QFE, by W/T, from the ground.

When navigating, it is best to have altimeters set to read height above mean sea level, so that their readings can be compared with heights shown on the map. Be most careful to multiply by three map readings in metres to give approximately heights in feet.

A useful rule:-

When flying from high to low pressure you may be lower than you think; when flying from low to high, you may be higher than you think.

7. Wind. A man may get a 100 per cent. in all his examinations and be the world's best theoretical navigator, but he will still fail to find his target or base aerodrome if he does not work on the correct winds.

The meteorological officer supplies estimated winds for different heights and different parts of the track on both outward and homeward journeys; but these are only a general indication of what to expect, and under no circumstances should a navigator calculate on meteorological winds in the air unless he checks them as often as possible and finds them correct.

Therefore before flight study the pressure distribution with the meteorological officer and get a clear idea of what winds and wind changes to expect.

In flight, check wind constantly and modify calculations as necessary.

8. Isobar winds. Winds at about 2,000-3,000 ft. flow along the weather map isobars, with the lower pressure on the left hand side in the northern hemisphere.

When isobars are close together, wind is strong. When isobars are far apart, winds are light.

Sharp bends in isobars mean sudden changes in wind direction.

A glance at a series of weather mapsshows that it is one chance in a thousand that winds will be the same all along a track from England to Berlin. Indeed, any meteorological officer can probably produce past weather maps showing a change to the opposite direction and decrease or increase by 40 m.p.h. over such a track. Yet it is not unknown for navigators to sit on one wind for 400 miles expecting it to bring them over the target.

Secondly, the winds are always changing over any one place; thus an aircraft might well leave base with a SW. surface wind of 5-10 m.p.h. and return 6 hours later to find it blowing at 40 m.p.h. from NE.

9. High level winds. Wind not only changes with time and place, but with height as well. The majority of errors in navigation over a long period of bombing operations have been traced to a lack of understanding or disregard of these elementary facts.

In this connexion, it is interesting to note that wind velocity at 33,000 ft. has been observed to change from 20 m.p.h. to 110 m.p.h. in the course of a day. Readings taken over a year show that at 33,000 ft. the average wind speed is 65 m.p.h.; while on some 40 days in the year speeds of over 100 m.p.h. were recorded.

Such facts are obviously of the greatest importance to navigators;and fighter pilots should never forget that a blue sky and calm conditions on the ground do not preclude the possibility of a 100 m.p.h. wind at 30,000 ft.

Meteorological officers always give a good general indication of what to expect; but in long distance flying everything depends on the navigational use of winds found in flight.

10. Wind change results. A large number of practical rules could be given, but they are only confusing unless one makes a hobby of the subject.

The two following should be kept in mind, however:-

(i) When navigation is difficult through thick clouds or bad weather, the winds are more likely to vary rapidly than in good weather. This is unfortunate;

but the moral is that in bad weather every possible chance should be taken to fix position.

(ii) If you are in or have flown through an extensive period of bad weather and notice a considerable fall or rise in temperature, you will almost invariably drift to port off track if you work on the wind previously determined.

11. Visibility. Near industrial areas visibility is almost invariably reduced by smoke; in quiet weather perhaps to a few hundred yards. If therefore you fly for some time in generally good visibility and then run into very bad visibility near an industrial area, there is no reason to panic or to turn back. Hold a steady course in the almost certain knowledge that visibility will improve again when the area has been passed.

Smoke only affects the actual area and the leeward side. So an accurate pin-point for bombing operations is much better obtained if one approaches the area from upwind.

Light effect from moon and sun are of major importance. Therefore remember the following rules:-

(a) Visibility looking towards the moon (up moon) is very much better than with the moon behind (down moon). This is mainly because the reflection of moon-light shows up railways, rivers, canals and water; and buildings and roads to a lesser extent. Experienced crews will always bomb 'up moon' if possible.

(b) Sun effect is quite different, because of the glare; anyone who has driven a car up moon and up sun will appreciate the difference. Flying up sun in poor visibility is very trying, and in the air one may be able to see practically nothing ahead and yet be able to see 1/2 to 1 mile by looking back, down sun. Many accidents have occurred through landing up sun in bad visibility. When one has to land up sun in haze, wind is usually light; then, having particular regard to other aircraft, it is easy and advisable to land a few points out of wind to avoid the full glare and visibility reduction.

12. Fog. Fog presents the greatest problem when an aircraft returns to its base to find the aerodrome fog-bound. Usually advice can be obtained from the ground by W/T; but occasions may arise when, through wireless failure or radio traffic congestion, such advice cannot be obtained. Then the aircraft captain has to act on his own judgment. His decisions depend on petrol endurance, and on the information about the likely character and extent of fog that he got from the meteorological officer before leaving.

Radiation fog is particularly trying because above it winds are light, sky clear, and visibility excellent. It may be patchy and thin at some times, widespread and up to 1,000 ft. thick at others. If the fog is patchy, try other aerodromes; if thin, try higher aerodromes; otherwise consider heading for a part of the country for which the meteorological officer has foretold better conditions. As a rough, but by no means invariable, rule, aerodromes to the west (where the wind is usually off the sea) are likely to be clearer. A long diversion is almost always much better than circling in a small locality, hoping for a clearance. Radiation fog often thickens shortly after sunrise, and then rarely clears until several hours have elapsed.

Sea fog is often thin, and rarely more than 1,500 ft. thick. It can often be seen drifting inland across the coast as a continuous sheet. By flying downwind, inland, the odds are that one will run out of it. It may extend far inland, but never right across England. Sometimes there is a 200-500 ft. clear air gap under the sea fog (or stratus) that does not exist with radiation fog.

Hill fog occurs at high aerodromes as low cloud on high ground, and aerodromes at lower levels may well be clear.

Weigh the odds very carefully before going down through fog to 'look see'. Are you sure of the height of ground below you? Are you sure that the altimeters are reading correctly, allowing for any air pressure changes since they were last set? Remember that many good crews have flown into the ground through 'feeling for it' on the glide in fog, often because they had insufficient petrol to go elsewhere. Had these men baled out at a safe height, only the aircraft would have been lost.

13. Layer clouds. Cirrus clouds (over 20,000 ft.) are thin and interfere only with really high level operations and with sextant sights. They are worth watching as they give warning of the possible formation of condensation trails (see 'Cloud Atlas for Aviators', page 21) and of the approach of bad weather.

Medium layer clouds, the alto group lying between 7,000 and 15,000 ft., may either be broken up or 10/10, and there may be more than one layer. They usually give good cloud flying, however, and are very useful for fighter and searchlight evasion.

In them frost may gradually accumulate on the aircraft, particularly on the windscreen. They are a second warning that bad weather is ahead, particularly if they thicken and lower rapidly. Watch them carefully on long distance flights, for they will show how the weather forecast is working out.

Determine early whether it will be better to climb above them while they are reasonably high and not too thick rather than to fly on or into a bad weather system where cloud flying may be far more difficult.

Low layer clouds, the stratus and stratocumulus groups, range from 0 to 7,000 ft. Seen from below, when it is 10/10 without precipitation it is very unlikely that it will be more than 5,000 ft. thick, although there may be other layers above. If the sun or moon can be seen through them it obviously means that the layer is thin and ice formation will then be confined to a little frost.

Seen from above, a smooth top means smooth flying, and a bulging top means moderately rough flying.

If the upper level is above 4,000 ft., there will almost always be a clear air gap underneath above sea level. So descent is usually safe if one is certain of position over the sea or low-lying ground. Glide through such clouds down sun or up moon.

Remember, however, that when the temperature lies between 0 and -7°C. severe icing may be likely.

If the upper cloud level is 3,000 ft. or below, the bottom level is more likely to be on or very near the ground.

14. Heap clouds. The isolated cumulus clouds, not of great vertical thickness, met in fine weather are not very troublesome. They are rather bumpy; ice formation is usually of little consequence because it takes little time to fly through them. Visibility in these clouds is very bad.

Never trust such clouds for cover, for even when they are closely packed and almost continuous they have a habit of fading out just when cover is most needed.

Towering cumulus and cumulonimbus clouds give local showers and bright intervals when they are isolated. They are worth avoiding, as they are dense and bumpy, give noticeable ice formation, and are quite unsuitable for formation flying. They are easy to see and avoid by day and on moonlight nights.

At other times these clouds may cover large areas, and be continuous from low levels up to 25,000 ft.

They are characteristic of hot sultry afternoons, but they may occur at night and over land and sea.

They are violently bumpy, compass-course flying in them is almost impossible, and ice formation may be severe.

Lightning is always present, the compass may be permanently affected, and any parts of the aircraft, particularly the radio equipment, may be damaged unless properly earthed. These clouds give the worst flying conditions that can be experienced.

Thunderstorm clouds in the vicinity may be recognised at night by:-
(1) Humming and interference in the intercom.
(2) Considerable W/T interference.
(3) Sudden heavy downpours of rain and hail.

Thunderstorm clouds are thick and black at the base, with the falling rain. The tops, which may lie between 15,000 and 25,000 ft., are brilliantly white in sunlight and moonlight and can be recognised without doubt even fifty miles away.

15. Thunderstorms and flying. Try to avoid flying through thunderstorms by altering course and keeping a good air plot. The storms often go up to great heights and it may not be possible to fly over them. The base is low, with heavy rain, lightning and bumps below; so it is inadvisable to fly underneath if one can go round.

It is often possible to pick one's way between the tops of thunderstorm clouds quite successfully, flying all the time in clear air.

If one flies into a thunderstorm, at night for example -
(1) Earth the W/T at once; the intercom. may still be used without danger;
(2) Get out quickly by turning on to the reverse course and consider a sound course of action.

16. Electric phenomena. Night-flying crews often report striking electrical phenomena, not only in thundery weather. The airscrews may be surrounded by brilliant bluish-white halos, the wing tips may be illuminated, and sparks jump across gaps between metal fittings, such as parallel gun barrels. Whenever these are experienced, wind in the aerial and earth the radio.

These phenomena occur in daytime also, but cannot be seen so easily. A good indication that they are likely to develop is a deep humming in the intercom. which increases in volume.

These phenomena are alarming when first experienced at night, but are not in the least dangerous if the precautions outlined are taken.

17. Fronts. When two different air currents meet the warm current is forced up, and, given sufficient humidity, the lowering of the temperature causes clouds to form and precipitation to follow. Almost every weather map shows one or more fronts, marked as a red line (warm front), a blue line (cold front), or a purple line (occlusion).

Fronts differ very much in character. Thus the typical cold front may be a belt 100 miles wide, with broken cloud, whose base is at 1,000 ft., and in which flying conditions are rough; the severe cold front may take the form of a line-squall, with extreme bumpiness, hail and lightning; while a typical warm front may be a 300 mile belt with unbroken cloud layers lying between 30,000 ft. and ground level, and yet with fairly smooth flying conditions throughout.

It is impossible to look at frontal clouds from the air and decide how deep is the belt of which they form a part. Therefore before flight always discuss the probable structure with the meteorological officer, and decide beforehand on the best method of negotiating it.

18. Fronts and flying. (i) Flying under frontal clouds. This should be done only if one has a very reliable forecast indicating that such flying is safe.

It is always dangerous to fly through patches of low cloud near the ground.

Always be prepared to turn back to clear weather or to climb should the base fall too low.

Never deliberately fly under 'wet' frontal clouds near freezing level.

(ii) Flying over frontal clouds. If the aircraft performance permits this is the safer and more satisfactory procedure because an accurate course can be steered in good visibility. Remember, however, that the clouds often go up to 30,000 ft.

(iii) Flying through frontal clouds. This will frequently be necessary as a normal operational procedure. The widespread impression that a front is a serious or dangerous obstacle to flying dates from the time when cloud flying was hazardous through lack of proper instruments and de-icing equipment. With well-equipped modern aircraft and competent crews that keep their heads, flying through fronts is little more than a nuisance, provided severe bumps and severe icing are not met; and even then, by action based on knowledge, the front may be safely negotiated.

19. Navigating in frontal regions. Under such conditions pin-pointing and astro-navigation are generally impossible, and may continue so for some two to three hundred miles. The only remaining methods are:-

(1) Radio methods, which can only be used when electrical interference is small. Do not risk your radio set to get a fix or loop bearing under thunderstorm conditions.

(2) D/R. - This is the only constant method of keeping a check on position. The pilot must concentrate on flying an accurate course and keeping height and airspeed constant while the navigator keeps his D/R plot.

Frontal wind changes are obviously very important and their probability should therefore be discussed carefully before flight.

Remember that many bad errors in navigation have been traced to neglecting these wind changes, particularly on return from operations when navigators have been fatigued and less careful about their D/R.

If the navigator has no reliable winds, it is a good practical precaution to alter course to 10° starboard on entering a frontal belt.

20. Ice formation on aircraft. Long experience has shown that in the majority of cases when ice forms on aircraft there is no cause for alarm; it is harmless. The past two winters of operational flying have proved that while slight ice in the form of a thin coating of frost is quite common, serious icing is exceptional. Nevertheless there are cases on record of dangerous ice formation, and it is therefore best to know when such icing may be expected and what steps should be taken to counter this.

The types of cloud and the temperatures in which ice forms on aircraft, the effects of icing on unprotected aircraft, the mechanical measures taken to counteract icing, and the measures which the pilot may take to avoid serious icing are all discussed in detail in meteorology texts. This information cannot be condensed without omitting essentials, so no attempt will be made here to offer a precis.

It is unlikely that crews will be deliberately sent on any flight, operational or otherwise, which necessarily entails flying through serious ice conditions - dense 'wet' clouds or precipitation with the temperature within the danger range.

At times, however, they will certainly have to fly in clouds. When this happens, remember that serious icing is comparatively rare. Experienced pilots who know their meteorology will not worry, and there are some who deliberately fly through clouds to add to their experience on an aircraft type, and to pass it on to others, because they know exactly what to do when ice forms.

21. Condensation trails. Under certain conditions aircraft flying in clear air leave cloud trails in their wake. Such trails are of tactical importance for they betray the position and track of aircraft. Full information on how they form and how to prevent their formation is given in 'Cloud Atlas for Aviators', page 21.