flowing water in the stream; in cases of replacement of old gages, the zero of the old gage has been continued without change.

A considerable number of river gages now used by the Weather Bureau were installed by other branches of the public service—the Army Engineers, the Mississippi River Commission, the U. S. Reclamation Service, and the U. S. Geological Survey. Almost without exception the original zeros have been continued. The gage at Yuma referred to by Mr. Leach is a case in point. The Weather Bureau is using the gage established by the U. S. Reclamation Service, and in order to prevent confusion a note is printed in each volume of Daily River Stages to the effect that stages at that station do not indicate the volume of water in the river. In the case of Umatilla, on Columbia River, that station was established by the Army Signal Corps in 1878 and the zero was placed to correspond with low water of 1874.

In the early days of gaging rivers in this country it was a common practice to refer the zero of the river gage to the lowest known water for the gaging station.

It should be remembered that the object of Weather Bureau river gagings is primarily to secure data on which to base flood forecasts and that the gagings do not and are not intended to indicate the volume of water in the stream. It is, of course, to be regretted that it was not foreseen that the selection of arbitrary points of reference for the zero of the gages would lead to complications in the future.

SOME METEOROLOGICAL OBSERVATIONS OF A BOMBING PILOT IN FRANCE.[1]

By THOMAS R. REED, Meteorologist.

SYNOPSIS.

Smooth flying is generally found above cloud summits in summer, and bumpy air beneath them. Exceptions to this rule were so rare in the writer's experience on the western front during the summer of 1918 as to be worthy of note, and one such exception was made the subject of memoranda on the occasion of its occurrence. This was on the afternoon raid of August 29, 1918, in connection with the Oise-Aisne operations, when roughness was found at all levels. The cumuli that occupied the lower levels were left far below, but roughness was still encountered, although an altitude of 5,000 m. was reached before the lines were crossed. Phenomena, associated by the writer with the disturbed conditions in the upper air, were noted later in the appearance of cirro-stratus clouds overhead, the remainder of the journey to the objective being made between two cloud-strata—cirro-stratus above, cumulus and strato-cumulus beneath.

The term "bumpy weather" has come into such general use among aviators that it has ceased to be slang and become a proper part of aeronautical parlance. No other term expresses so succinctly the presence of atmospheric disturbances arising from convection and topography, the commonest sources of those localized turbulences that affect the piloting of airplanes. Although frequently employed by flyers in referring to undulatory movements or air swells of any kind, the conditions to which the expression specifically applies are more often attributable to convection and topography than to anything else.

Convection, of course, is most active in summer, or the warm season, while topographic influences are more likely to be felt in the winter or during the season when horizontal air currents are strongest. The height to which an uneven landscape may extend its influence depends on the ruggedness of the surface and the speed of the wind passing over it. In general a few hundred or a thousand meters of elevation will smooth out the irregularities arising from this cause, while convectional irregularities are often found in their greatest vigor at that height or above.

Pilots who were on the west front in the summer of 1918 and stayed in action until the armistice had an excellent opportunity to experience both these conditions in their most typical forms, particularly if they were engaged in the American sector where the terrain was notoriously broken. During the warm season convectional disturbances were very active, and raids were executed almost daily in spite of weather conditions. It was no unusual thing for the writer's escadrille (Breguet No. 128) to leave the Roissy airdrome on a raid during the Oise-Aisne operations when the sky was almost filled with the cumuli of an impending storm. Under such circumstances it was customary for the commandant who led the group to take us above the clouds, for although the interstices in the latter might afford only scanty vision of the landscape, and navigation therefore be difficult, the group was less liable to attack, and the problem of managing the planes and keeping a good formation was greatly simplified. The bumps were left below and we had an undisturbed medium in which to perform the journey.

Flying in group, though never employed in peace times, except for exhibition purposes, is of first importance in war, and all branches of the flying corps, whether pursuit, reconnaissance, or bombardment, must employ it on occasion or be exposed to successful attack by lurking enemy planes.

Formation flying brings home to the pilot more forcibly than any other form of air work the fickleness of his atmospheric medium. This is because the sense of motion is so purely relative that unless one has some object close at hand with which to relate his course he soon loses consciousness of his own speed, and is quite oblivious to the factor of wind velocity (and, to some extent, of direction) so long as exerted in the plane of his own movement. Even undulatory movements are not realized unless abrupt, especially if one is flying with the wind.

Vertical currents, of course, are evident enough under any circumstances, but until one finds himself flying in a group and trying to maintain a certain position with respect to other planes close at hand he does not accurately estimate all the components of movement that are agitating the air.

The greatest obstacle to formation flying is convection. The plane does not always rise or sink on an even keel, as might be supposed; more often it is pitched this way and that, one wing now up and the other down. The sensation under a thunder cloud is exactly that of an antiaircraft bomb exploding underneath you, with the difference that you don't get any shrapnel holes in the process.

Every meteorologist knows theoretically, and every pilot from experience, that bumps generally are found in and under (at least close under) cloud formations, and smooth flying above them. In an arid region one would feel the currents of convection without the attendant clouds to define their limits. Not so in France. Here clouds formed so readily that the presence and strength of vertical currents might oftentimes be safely gaged by their visible outlines, the character of the summer cumuli serving as an excellent indicator of the roughness of one's projected flight. We knew that flying below them

[1] Presented before American Meteorological Society, Washington, D. C., Apr. 22, 1920.

would mean a tussle with aileron and rudder to keep on an even keel; but that once their snowy summits were passed the fight would end and that the big bombers would glide on their way as if on a glassy sea. Exceptions to this rule were unusual enough to draw out a good deal of comment when they occurred. An excellent example of such an exception was found on the afternoon raid of August 29, 1918.

Two raids were made on that day, one in the morning and another in the afternoon. In the morning, although thunderheads were forming and we had the customary bumpy weather until they were surmounted, the usual placidity was found above. The clouds had increased by afternoon and it was so rough that only four planes out of the original 10 that started remained in the air, the others turning back before they had climbed a thousand meters. The remaining four stuck together, thinking to get through the clouds to the calm above, and the appearance of another escadrille overhead, which we joined a few minutes afterwards, encouraged us in this idea.

It is pretty work getting a formation through the clouds, requiring much twisting and turning to rise through the holes to the blue above, judgment on the part of the leader, who must guard against sharp turns or running into a cloud, and vigilance on the part of the pilots, who must keep their position and avoid collision, while being tossed about relentlessly in the upward surging and restless air.

Expectation of finding smooth sailing in the upper air, however, was not realized on this occasion. Although the region of cloud was left far below—so far that the once imposing masses of mountainous white had lost their individuality and seemed merged in a sea of petty billows—we were still encountering undulatory currents and of so marked a nature that in my notes on the raid, set down immediately afterwards, I have referred to them as bumps. In winter we might have expected overlapping currents and consequent roughness at any altitude, but to find them in midsummer and at 5,000 meters was extraordinary, and in my personal experience distinctly worthy of note. My meteorological training naturally led me to look for some development which would visibly attest the extra-local character of what was going on, so I was not surprised when cirrus clouds began to appear overhead in what had been a sky of unobstructed blue. Before the lines were reached we were sailing between two cloud strata,—a rapidly thickening cirro-stratus veil above, cumulus and strato-cumulus beneath.

The weather map for this date did not reveal any marked cyclonic developments. The barometer was high in western Europe and relatively low over the Baltic regions. The map for August 30, however, the day after our raid, bore evidence of a different character. It showed a fall in pressure over northwestern Europe and indicated the approach of a disturbance to the north of Scotland, an augury confirmed by the chart of August 31, which depicted a typical depression central in the North Sea and causing unsettled, rainy weather throughout the British Isles, the Netherlands, and northern France.

When the group moved eastward in September to take part in the Meuse operations of the 1st American Army, opportunity was afforded of doing cross-country work over a very different type of land. It was much more hilly; in fact, there was so little level or cleared ground that airdrome sites in the region around Bar le Duc, where many squadrons were clustered, were difficult to find. Flying over such a country, if it was at all wind swept, gave a pilot plenty of work to do at low elevations, especially if he were flying one of the larger types of plane. The greatest uncertainties, of course, were involved in landing. Coming to earth at express-train speed is a matter of nicety even with everything in one's favor, but to do it day in and day out on fields remarkable only for their uneveness and limited extent gives one ample familiarity with the fickleness of surface currents when distorted by irregularities of the terrain.

The plane may be almost seated, wheels and tail skid about to brush the earth, when a puff catches the ship and lifts it into the air again or tilts it sidewise, calling for the quickest action from the pilot to avert a stripped undercarriage or a scraped wing. Sometimes the only thing to do is to put on the motor and circle the field for another landing.

As regards the consideration of safety, no danger is to be feared from air bumps so long as the pilot enjoys sufficient altitude in which to maneuver. He may be tossed about and even thrown into a slip, but, given enough space and a properly lined-up ship, he can recover himself and maintain flight even under the most boisterous conditions of wind and weather. His difficulties await him as he approaches the earth. For this reason rolling ground never should be chosen for a permanent landing field. The necessities of war require the use of whatever flying fields can be found; but in the case of civilian flying, the selection of such fields should be a matter of the most careful judgment, so that the danger of accident from the principal uncertainty of present day aviation may be reduced to the minimum.

DISCUSSION.

The condition of bumpiness above, as well as below, cumulus clouds in the forward part of a cyclone may be explained as follows:

The southerly wind of the front of a cyclone rides under the upper portions of the remains of the westerly or northwesterly wind which the southerly wind has displaced at the lower levels. This upper wind is likely to be cold, whereas the lower, southerly wind is likely to be warm. During the first day that the southerly wind blows the continued fall in temperature of the upper current and the rise in temperature of the lower one frequently produces a temperature gradient which exceeds the adiabatic, and thus establishes convection between the two winds. As the difference in temperature increases, the depth of the convective layer of adjustment increases until its under boundary may reach the top of the layer of surface local convection marked by cumulus clouds. In the case described, the upper convective layer does not seem quite to have reached the lower one; if it had, the cumulus clouds would have extended rapidly to the top of the upper convective layer and gone beyond.

Mr. J. C. Edgerton, in his fully kept meteorological logs of his daily postal mail flights from Washington to Philadelphia and return in the summer of 1918, mentions several times the occurrence of "bumpy weather" in the lower levels and at intermediate levels in the morning, but very bumpy conditions from the ground to great heights in the afternoon.

When alto-cumulus clouds are visible when a southerly wind is blowing at the surface, they probably mark the top of the higher bumpy layer, just as the cumuli summits mark the top of the lower.—*Charles F. Brooks.*