

METEOROLOGY DURING AND AFTER THE WAR.

By Col. H. G. LYONS,

Acting Director of the Meteorological Office, London.

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During the past four years and a half of hostilities meteorology has, like many other branches of knowledge, been utilized in naval and military operations to a far greater extent than ever before. Consequently, there are now a large number of officers in the services who have had practical experience of the value of meteorological information when it has been prepared from sufficient data, and by men who have been thoroughly trained in the subject. It is, therefore, highly desirable that full advantage should be taken of the experience which has been gained during the war in order to meet, as adequately as possible, those demands which will be made upon meteorology in the general reconstruction which is now beginning.

In some ways the conditions which prevailed during hostilities were favorable to advances in the subject. Special facilities were given for the rapid transmission of reports; kite-balloons could furnish series of observations at various heights; aeroplanes were available to observe the temperature in successive layers of the atmosphere up to 12,000 or 14,000 feet; the velocity and direction of air-currents up to even 25,000 feet were determined by the bursting of shells fired at high angles; pilot-balloons at perhaps a hundred stations were observed four or more times daily. In these and other ways a vast store of information has been amassed which has already been utilized, but remains available for much more detailed study in the immediate future; and not the least difficult problem will be to reduce the mass of information to a manageable and orderly arrangement.

In the Meteorological Office the policy for some years had been to bring in men who had had a thorough scientific education at a university and to encourage them to devote it to the study of the many problems which meteorology had to offer. This was a great advance from the empirical treatment of the subject, and has been amply justified by the success obtained when this policy has been tested under the conditions of active service.

After the beginning of the war the need for more and more distant stations was felt, and by 1916 reports were being regularly received from Spitsbergen to the North African coast and Cairo, and from Iceland and the Azores to the Russian stations of Petrograd, Nicholaieff, Sebastopol, and Batum.

The supply of daily weather reports and forecasts to the public was stopped, but their preparation was continued actively in the Meteorological Office, where the telegraphic reports which were collected several times daily reached the number of about one hundred, and the information which they contained was compiled on working charts from which the forecasts were prepared. These were issued to the Admiralty, to various dockyards, to the Grand Fleet, various battle squadrons, submarine flotillas, etc., each of which required reports and forecasts adapted to their special needs. Similarly information was supplied to the Naval Meteorological Service for the Royal Naval Air Service, and to numerous units of the Royal Flying Corps, or the Royal Air Force as it afterwards became.

To provide information for aviators in the early morning or for use in preparing plans for the day's operations, it became necessary to take observations in the early hours of the morning, and 3 a. m. was the hour chosen

at first, but this was not found to be early enough, and 1 a. m. was finally adopted, making the observing hours 1 a. m., 7 a. m., 1 p. m., and 6 p. m. Thus a continuous 24-hour forecasting service was established, and has been maintained in operation up to the present time, to prepare forecasts and reports four times daily; and to telegraph the observations taken at selected stations to the Meteorological Section at the British General Headquarters in France, and to other stations that required them, as well as to the Meteorological Service of the French Army, and later to that of the American Expeditionary Force.

Under service conditions something simpler, plainer, and more direct in its presentation of the opinions of the trained meteorologists who prepared it than the ordinary daily weather report with its statistical data was needed. Those who had to make use of the daily weather reports were usually far too busy to wish to study the statistical material before accepting the meteorological opinions which were offered to them. They wanted a direct statement of expert opinion which they could make use of in preparing their own plans of action. The desire for such expert assistance was also shown by many requests that forecasts should be expressed in "perfectly simple and non-technical language." To this very reasonable request it is not so easy to accede as it may seem. Such expressions as "a depression advancing from the westward," "a secondary depression developing over the Channel," "an anticyclone spreading northward," are more than mere statements of fact; they convey to all who are acquainted with meteorology much additional information depending on the weather conditions described, which it would take several paragraphs to state simply and in non-technical language.

So far as meteorological conditions could be set out in plain language, this was done in these special daily weather reports, which were issued in the early morning, before noon, and in the afternoon to all who required them; and these were supplemented by special summaries, one of which dealt with the prevailing and the prospective weather conditions on all fronts where military operations were in progress, and another with the weather conditions in the various sea areas around Europe.

It was not difficult to estimate from the working weather chart what sort of forecast the enemy meteorologists would probably make on the assumption that the information from a wide area to the westward of them was not available, and this was done daily as part of the routine of the Meteorological Office. In the case of attacks by enemy aircraft it was fair to assume that his meteorological service considered the conditions to be reasonably favorable; and this was compared with the estimate of his opinion which had been formed here. Occasionally enemy forecasts were available, and these were compared in the same way. Negative evidence is not conclusive, but the impression that we gained was that little if any meteorological information of value was obtained from our area.

Many cases could be cited where operations were undertaken by the enemy which it seemed very unlikely that he would have undertaken had he possessed the information which we had here.

By the spring of 1915 two branches of the Army, the Royal Flying Corps and the Special Brigade, R. E.

(Chemical Warfare), had decided that they required the cooperation of trained meteorologists who could explain the meaning and the limits of the forecast, answer questions or give advice, and arrange for fuller or more suitable information being furnished when required.

These demands for the provision of trained meteorologists in France led to the formation of a meteorological section as a unit of the Corps of Royal Engineers, which has at first a strength of about 4 officers and 20 non-commissioned officers, but the establishment was repeatedly increased until, when hostilities ceased, it consisted of 32 officers and about 200 other ranks, and provided sections for duty not only in France but also on the Italian and Macedonian fronts, besides a reserve section at home. From a small unit at General Headquarters in France the organization developed until there was a meteorological unit with each army and one with the Independent Force, R. A. F., these units having their groups of observers and pilot-balloon stations reporting to them. The telegraphic weather reports from the stations in the British Isles, as well as those received from a large number of European stations, were at first thrice daily, and later four times daily, telegraphed from the Meteorological Office in London to the Meteorological Section at General Headquarters in France, in order that weather maps might be drawn and forecasts prepared there as might be required. This information was supplemented by data which the Meteorological Section collected from its station on the British front, and also from other parts of France through the French Meteorological Services.

In this way on the western front, and similarly at later dates on the Italian and Macedonian fronts, a network of meteorological stations was built up, which, with the addition of the data and reports furnished by the Meteorological Office, enabled the meteorological officers to supply the information which the different services required for their special purposes, to issue forecasts and weather warnings, and also, as will be seen later, to increase very materially the accuracy of the work of some of the services.

The task of providing the personnel for this military unit was no easy one, for, as has been already mentioned, the staff of the Meteorological Office was small, and outside it there were very few expert meteorologists who were available. At first three of the senior staff of the Meteorological Office received commissions for duty in France, and afterwards a number of men who had a thoroughly scientific education at a university joined the Meteorological Office for longer or shorter periods of training before being posted to the Meteorological Section, and in this way a high-grade scientific staff was formed and maintained. To a training which included especially mathematics and physics was added as much instruction and practice in advanced meteorology as could be given in the time available, and on the basis of such an education the meteorological aspect of the problems was quickly appreciated.

As time went on the scope and number of such reports and warnings steadily increased until there was a regular and continuous flow of information sent out from meteorological offices to various branches of the service for them to utilize as best fitted the operations in hand. The Royal Air Force required forecasts of weather for short periods which it could use for its reconnoitering and bombing squadrons; for day operations reports of the wind direction and velocity obtained from pilot-balloon ascents and high-angle shell bursts were communicated

from different altitudes up to 20,000 feet; for night operations information for lower levels sufficed, and the arrangements had to be modified. For high altitudes a central station could supply information adequately, but when data concerning lower levels became important, where the air turbulence set up by friction with the earth's surface became a material factor, the reports were more effectively supplied by local stations where the special conditions could be more effectively studied. For all this the most rapid means of transmission is essential; for the shorter the forecast period, and the more detailed the forecast in its information, the more rapidly must it be placed at the disposal of the aviator if it is not to mislead him. These reports were largely supplemented by telephone inquiries by those interested, and a precision was demanded which was often very difficult and sometimes impossible to attain. Success in answering these inquiries is reached by having as meteorological officers men who have an acquaintance with the physical condition of the region, and also possess such a scientific training that they instinctively proceed from cause to effect, and facts at once fall into their place in their minds. This is very different from the acquired skill of an empirical forecaster, who can never attain the same confidence in his opinion.

In chemical warfare a different set of problems was encountered. Here we are concerned with the movement of air currents close to the surface of the ground, affected by all its irregularities, diverted this way and that by obstacles, and generally in that state of irregular motion known as turbulence in which eddies form, break up, and reform, greatly complicating the conditions. At night, too, when the surface wind may die down to a calm and the ground cools under a clear sky, the colder and heavier air streams down from higher ridges into valleys and low ground. Consequently the direction and velocity of air currents along the front had constantly to be observed and studied in relation to the relief and conditions of each section; so long as the wind was favorable for enemy operations, or even likely to shift into a favorable quarter, observations, reports, and warnings were unceasingly needed.

But, besides the aviators, there are other branches which are vitally interested in the conditions which prevail in the upper air. Projectiles leave the firing point and traverse a considerable thickness of the atmosphere during their flight, reaching an altitude of about 10,000 feet for a 50-second trajectory. In its passage through the air a projectile traverses strata of different temperatures, and consequently of various densities, so that a correction has to be applied to the range tables. On a winter day, when the temperature at the surface is 3° F., the temperature at 3,000 feet, 6,000 feet, and 9,000 feet may be 15° F., 16° F., and 12° F., respectively, so that any correction based on the temperature near the ground would be wrong. Also the wind varies considerably, and often irregularly, both in velocity and direction as the ground is left, so that a correction based on mean conditions here will probably be widely different from that which should be used on any particular occasion.

These considerations led to a much wider application of meteorological information to the practical correction of gunnery than had hitherto been employed, and reports of upper-air temperature and of the velocity and direction of the wind at various altitudes were regularly prepared and transmitted from meteorological stations along the various fronts. This increased application of meteorology to ballistics raises many problems of interest and

importance, which demand for their solution the cooperation of scientific gunnery and meteorological science of the highest order.

To mention another field, the sound-waves which are recorded in sound ranging, that wonderful adaptation of the physical instruments of the laboratory to practical use on the field of battle, traverse the lower layers of the atmosphere, and as higher and higher accuracy was aimed at, it became clear that meteorological observation must be made concurrently and utilized in order to attain the desired precision.

Frequent mention was made during the war of the meteorological efficiency of the enemy's organization and of the very favorable conditions which he experienced during many of his operations; his superiority in these directions was not infrequently assumed. It is not possible to compare the effectiveness and success of the rival organizations until much more information is available and, in the discussion and investigation of past operations, the various contributing factors have been sorted out and duly weighed. No doubt Germany started with a much larger number of men who had received a scientific training in the subject, for professors of meteorology existed at several universities; the appreciation of the subject and its practical value, too, may have been more general among that nation; but, as a personal opinion, I do not believe that it attained a higher standard than our own. Many apparently did not realize that the occurrence of bad weather during operations did not necessarily mean that the commander and his staff had no information regarding the impending weather changes; but weather is only one of many factors which have to be taken into consideration, and it must often be that operations planned and prepared must be carried out whatever the weather may be, though a good forecast may at the last moment enable him to judge whether nearer or more distant objectives are likely to be attained.

There are now four State meteorological services in operation—the Meteorological Office, the Admiralty Meteorological Service, the Meteorological Section, Royal Engineers for the Army, and the Meteorological Service, Royal Air Force of the Air Ministry—and the relations and the means for cooperation between these four services will have to be worked out, and a number of considerations taken into account.

So far as the study of the weather and the issue of forecasts is concerned, short-period meteorology, as it may be called—rapidity of transmission of the observations to the central office, where they are discussed and compared, and of the forecasts, warnings, etc., which are sent from it—is the first essential, and the needs of aviation have only accentuated this. Observations should be in the central office for the forecaster's use not later than one hour after they are taken if he is to get out his reports and warnings early enough to be of effective use to aviators.

Aviation, with its prospect of long-distance communication, has rendered necessary a readjustment of meteorological relations within the Empire. Canada, South Africa, Australia, New Zealand, India, and Egypt and the Sudan have all their well-equipped meteorological services, which include networks of stations so selected as to represent most suitably the different meteorological

conditions prevailing in those regions. In each there is a scientific staff studying the problems that arise or affect the economic life of the country. Except as students of the same science, the interests of each service have been somewhat diverse from the nature of the requirements which each had to meet, but in future we must organize the provision of all information that aviation may require; and since aviators are going to pass from continent to continent and from one country to another, uniformity of some kind must be attained in respect of the assistance that meteorology is to give.

The problems that press for early investigation are too numerous to recite, but a few may be mentioned.

The relation of meteorology to gunnery must be continued and the study of the many problems involved carried on by competent men.

The air routes of aerial transport will have to be studied and all the information now available must be sorted out, investigated, and discussed in order that it may be put in the form most suitable for use by airmen. This will demand much additional observing at many places besides the discussion of existing material, but unless this is done as part of a concerted scheme much unnecessary expense will be incurred, and the results will fall far short of what they should be, since all the data must eventually be worked up in connection with that from other places, and if all are not of the same scientific standard they cease to be comparable, and must often be rejected in discussion.

Many of the stations in the Crown colonies can afford most valuable information in this connection if expert meteorologists are available to carry out the work. An observant traveler in Dahomey has remarked upon the presence of a steady northeasterly current at about 6,000 feet to 7,000 feet over the lower currents of the southwestern monsoon of West Africa, and such information, if substantiated and extended, may be of material importance in this region.

While overland observations are numerous, and have been extended by means of *ballons-sondes*, aeroplanes, etc., to very great heights, our knowledge of the atmosphere over the sea is much less complete. By means of ships equipped for the purpose, such observations can be, and have been, made in certain parts, but this line of investigation must be extended if our knowledge is to be adequate.

Besides these more evident needs of aviation there are many problems of great practical importance which merit a closer and more thorough investigation than they have yet received. Among these may be suggested those violent disturbances known as hurricanes and typhoons. Recent theoretical investigations have thrown much light on their nature, and a further study of the evidence which exists should greatly add to our knowledge of them.

Variation of rainfall is always a matter of importance, and in countries where it is barely adequate for agriculture any diminution of it is a serious matter, and such cases call for careful investigation.

The war has given a great impulse to meteorology by showing its possibilities to all, and aviation has made, and is still making, more and more demands upon it for information of every kind.