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821st ORDINARY GENERAL MEETING,

HELD IN COMMITTEE ROOM B, THE CENTRAL HALL, WESTMINSTER, S.W.1, ON MONDAY, MAY 9th, 1938, AT 4.30 P.M.

B. A. KEEN, ESQ., D.Sc., F.R.S., F.INST.P., F.R.MET.S., IN THE CHAIR.

The Minutes of the previous meeting were read, confirmed and signed.

The CHAIRMAN then called on Lt.-Col. E. Gold, D.S.O., F.R.S., F.R.Met.S., to read his paper entitled "Synoptic Meteorology; the Basis of Weather Forecasts."

SYNOPTIC METEOROLOGY; THE BASIS OF WEATHER FORECASTS.

By LIEUT.-COLONEL E. GOLD, D.S.O., F.R.S., F.R.Met.S.

WHEN you hear a weather forecast broadcast from one of the stations of the British Broadcasting Corporation or see a weather map and its interpretation in your morning newspaper, you may not realise the organisation on which the information which you receive depends. It is my purpose to describe to you that organisation and its development.

It will be convenient for my purpose, and I hope assist you in following this lecture, if I divide it into five sections:

I. The information to be transmitted. This is primarily the results of observations—both surface observations and observations of upper atmosphere. But it includes also forecasts (*see* V).

II. The form in which the information is transmitted. This is primarily a matter of codes and specifications or scales. A meteorological code differs from an ordinary code in the fact that the significance of each figure in a message depends upon the position of the figure in the message.

III. The arrangements for the transmission of the information. This is effected primarily by wireless telegraphy.

IV. The presentation of the information on charts or in tables. This is primarily a matter for internal arrangement in each service. It has international aspects.

V. The forecasts derived from the information. These also are primarily an internal matter in each service. There are certain aspects in which international arrangements are necessary.

I shall before going to Section I give an historical note, mainly about the International Meetings, which have been primarily concerned with Synoptic Meteorology since it began to be organised about 70 years ago.

History.

Until about a century ago forecasts depended on observations at a single place, and so far as the weather a short (but variable) time ahead at a single place is concerned, observation there is the best guide. I say "variable" time because it may vary from five minutes to five hours or more. On some occasions it is impossible to tell from observations at the place what the weather will be in five minutes' time; on other occasions the weather at a place can be forecasted with confidence for several hours ahead by observation at that place. I say "the weather at a single place" and "at that place" because no method has yet been devised which will convey to a person at a place B all the information which actual observation on the spot gives to an observer at place A. For example, a report of the weather at Paris does not enable a person at London on that information alone to forecast the coming weather at Paris so well as a person of equal intelligence at Paris itself can do it. Very great advances have been made in the past twenty years in this matter of reporting exactly and fully the meteorological conditions at a place; the most difficult part is the fact of the sky, the varieties of cloud, their distribution and amount. But the problem is by no means completely solved.

Even before the invention of the electric telegraph, it was realised that a knowledge of the weather over a wide area would be a better basis for a weather forecast than the conditions at a single place, and charts of isobars over Europe for each day of the year 1783, drawn naturally long after the event, were published by Brandes. The chart for March 6th was reproduced in Hildebrandson and Teisserenc de Bort's book on *Les Bases de Meteorologie Dynamique* and subsequently copied in other books on weather forecasting. It is worthy of mention, because it was not until many years after the collection of weather reports by telegraphy had commenced in the middle of the following century that the regular use of isobaric charts became established —they had, as it were, to be rediscovered.

The international arrangements for synoptic meteorology are made by the International Meteorological Organisation, which has a Commission—the Commission for Synoptic Weather Information—appointed to deal specially with this side of international work. It is indicative of the manner in which the pace of meteorology, as of other things, has changed, that in the first thirty-five years of the International Meteorological Organisation, no substantial changes were made in the arrangements for synoptic meteorology agreed upon immediately after the Congress of Vienna in 1873.

As I shall have occasion frequently to refer to the Commission for Synoptic Weather Information and the custom of indicating the Commission by the initials C.S.W.I. has become general, I propose to follow that custom in this paper.

The predecessor of the Commission for Synoptic Weather Information was the Commission for Weather Telegraphy. This was appointed in 1907,* and held meetings in 1909 and 1912. It was reappointed after the War, and since then it has held meetings in 1920, 1921, 1923, 1926, 1928, 1934, 1935 and 1937. My connection with the Commission began in 1919. The following notes indicate briefly the work which the Commission has had to do.

C.S.W.I. First Meeting.

At the meeting in 1909 the Commission considered the International Code for Weather Telegraphy which had been in operation without appreciable change since its introduction in 1874. The Commission made recommendations notably in regard to the introduction of the barometric tendency or the change of barometric pressure in the period preceding the time

* At the Congress at Vienna in September, 1873, a small sub-committee was appointed to report to the Congress on the question of Weather Telegrams. In discussing the report of this sub-committee, the British delegate, Mr. R. H. Scott, remarked that it would be very desirable to have a uniform system of cyphers for Weather Telegrams. The duty of arranging this was entrusted by the Congress to the International Meteorological Committee.

of observation. They recommended that this period should be three hours, and it has continued to be three hours until the present time. The Commission also recommended that appropriate arrangements should be made in any regulations for the control of wireless telegraphy for full facilities for the transmission of meteorological messages. These recommendations were approved and the change in the international code was introduced two years later.

C.S.W.I. Second Meeting.

At the meeting of 1912 the principal question was that of hours of observation—a question which has not yet been solved. General Rykatcheff, the Chief of the Russian Meteorological Service, pointed out that although other countries could usually choose two hours of observation approximately equidistant, which did not necessitate observations in the middle of the night, that was not practicable for his country where the difference of longitude meant differences of 9 or 10 hours in the time. The Commission recommended one set of hours—7, 13, and 18h. G.M.T.—for Central, Northern and Western Europe, and another set of hours—6, 12 and 18h. G.M.T.—for stations east of Longitude 30° E. The Commission also made recommendations in regard to the characteristic of barometric tendency, an endeavour to describe with one figure the appearance of the curve of a barograph during the period of three hours used for estimating barometric tendency.

C.S.W.I. Third Meeting.

At the meeting in 1920 the Commission began the work of post-war development which has extended until the present day. There had been a meeting of Directors of Meteorological Services in London in July, 1919, at which ideas for the utilisation of wireless telegraphy and for the revision of codes and specifications embodied in the Meteorological Annex to the International Air Convention were discussed; and this was followed by a Conference of Directors at Paris in September, 1919, at which new ideas were further diffused, though slowly. Consequently, when the Commission met in November, 1920, members were prepared for radical changes; and they made them. The code for reports from land stations was entirely revised; the inadequacy of a single figure to describe the weather was recognised and a code of 100 specifications adopted; visibility, form and amount of low and high cloud were introduced into the code and a figure added to represent approximately the height of the cloud base (or "ceiling"). Reports of rainfall and of the time of beginning of rainfall were included twice daily and the maximum and minimum temperatures were made to refer to the day and night respectively, thus terminating the ludicrous arrangement under which a minimum temperature below freezing point was often reported on, say, Thursday morning, when the preceding day and night had both been mild with temperatures of 40° F. to 50° F. (This always happened after a cold morning followed by a mild day and night.)

C.S.W.I. Fourth Meeting.

At the meeting in 1921, in London, the Commission made some minor changes in the recommendations of the meeting of 1920, but the only substantial modification was a change in the code for reports for aviation. The code recommended for abridged reports by the meeting of 1921 was :*

$$I_n I_n \quad wwVhL \quad NDDFW \quad (C_a ddF_1 S).$$

This code marked the definite intrusion of aviation into synoptic meteorology, and the first group of this code has now become a world-wide group in synoptic and aviation codes. One of the resolutions of this meeting which has an historical interest is a resolution which reads :

> "That, as Austria had now been admitted to the League of Nations, Professor F. M. Exner, of Vienna, should be co-opted a Member of the Commission."

C.S.W.I. Fifth Meeting.

At the meeting of the Commission in 1923, at Utrecht, the Commission decided to change its title from Commission for Weather Telegraphy to Commission for Synoptic Weather Information.

Among other points of interest in the resolutions taken by the Commission at this meeting were : (1) a decision to ask the different Meteorological Services to publish a description of the meteorological stations used in their collective synoptic messages ;

* For the significance of the letters *see* p. 243.

(2) a resolution expressing the hope that Russia and Italy would arrange for regular and punctual issues of synoptic reports according to the International Scheme ; and (3) a resolution recommending the issue of reports giving observations made at the intermediate times of 10 a.m. and 4.0 p.m. at selected stations on the Atlantic seaboard. This marks a further stage in the progress from the once-a-day messages of thirty years ago to the synoptic messages every three hours of the present day.

This meeting also marked the beginning of a period of six years during which the general code and, particularly, the codes for weather and cloud were continually under discussion. The French Service had never been contented with the codes for weather and cloud, and had proposed alternatives which had led other services also to make proposals for modifications in the codes. All these proposals were referred in the first instance to a special Sub-Commission, called the Code Sub-Commission, which was appointed by this meeting at Utrecht.

C.S.W.I. Sixth Meeting.

The meeting at Zurich in 1926 was the first meeting after the war at which German members were present. On this occasion the veteran Dr. Hergesell represented the German service. The principal matters discussed were (1) the question of hours of observation. On this the meeting made general recommendations to the effect that any hours selected for synoptic observations should be included in the periods 0–2h., 6–8h., 12–14h., and 18–20h. G.M.T., the times 1, 7, 13 and 19 being recommended as the standard hours. (2) The specification of the force of the wind in synoptic messages. It was agreed that the force of the wind should be reported in the Beaufort Scale and a precise specification of the scale in terms of the velocities recorded by an anemometer at a standard height in an open situation was adopted, together with rules regarding the variation of the equivalent velocities for anemometers whose heights were different from the standard. (3) It was at this meeting, too, that the principle of using three index figures for a station was adopted and a decision confirmed to send a delegation to the Radio Telegraphic Conference to be held at Washington in 1927. This meeting at Zurich, like its predecessors and successors—until the meeting at Salzburg in 1937—was characterised by fine weather.

C.S.W.I. Seventh Meeting.

The meeting of 1928 was held in London. The Commission received the report of the delegation which had attended the Radio-Telegraphic Conference at Washington in 1927.* The delegation had been successful in its main purpose of obtaining he allocation, in the European region, of two wave-lengths between 3,000 and 8,000 metres for the exchange of meteorological synoptic messages and in its second purpose of securing that radio telegrams containing observations intended for a meteorological service should be granted priority. As a result of the allocation of wave-lengths specially for meteorological messages the Commission recommended at this meeting that there should be four general collective issues for the European and neighbouring area, viz. :—

1. For Western Europe (issued by France).
2. For Central and Northern Europe (issued by Germany).
3. For Eastern Europe and Siberia (issued by the U.S.S.R.).
4. For the countries of S.E. Europe and Asia Minor.

At this meeting also great progress was made in the revision of Codes and Specifications, but this work was not completed until the meeting at Copenhagen in the following year.

Perhaps the most important resolution of the meeting was that in synoptic messages issued by wireless telegraphy for international exchange *the pressure should be expressed in millibars*, a resolution which was subsequently confirmed by the International Conference at Copenhagen in 1929. This decision put an end to the difficulties arising from the use of inches and millimetres of mercury, difficulties which led to the proposal of the British Meteorological Office fifteen years previously to adopt millibars as the unit of pressure.

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* It was at the Washington Conference that it was decided to adopt "frequencies" (kilocycles per second) instead of "wave-lengths" (metres) to denote the "note" of a radio-transmission. The proposal was considered by a Commission of the Conference which decided, after some discussion, to recommend the adoption of wave-lengths. The decision was practically unanimous. At the next meeting of the Commission, a day or two later, the question was reopened and, after a brilliant exposition of the case for frequencies by a young American scientist, Dr. Dellinger, the Commission reversed its former decision, and agreed, also practically unanimously, to recommend the adoption of "frequencies." It was one of the most interesting cases of *volte face* that I have ever seen.

C.S.W.I. Eighth Meeting.

At the meeting at Copenhagen in 1929, in addition to the completion of the revision of codes and specifications referred to, a new code was adopted for use in collective messages issued for the use of ships at sea, which brought these messages into line with the general international code. Arrangements for the main collective transmissions which had been recommended by the meeting in London were submitted to the Conference and approved with some slight modifications and extensions. The meeting at Copenhagen was mainly memorable for the struggle between what might be called the purely scientific side and the practical aviation side in regard to the form of code. In the end the aviation side carried the day, and in consequence the form of synoptic code in use at present begins by the information which is considered of greatest importance for aviation. It was not, however, possible to secure agreement on a single form of code for use all over the world, and a second form of code was adopted for use in tropical regions. In this second form of code less prominence was given to forms of cloud and no provision was made for reporting the height of the cloud base.

C.S.W.I. Ninth Meeting.

In 1934 the meeting was held at De Bilt, Holland. It was largely occupied with discussions about the symbols for representing meteorological information in synoptic charts and about observations of visibility. On both these subjects there were two schools of thought, markedly divergent.

The recommendation which the Commission made at this meeting in regard to symbols was reconsidered at the meeting at Warsaw in the following year after trial had been made of the symbols in which the greatest difference of opinion existed, namely, the symbols for amount of cloud. In the end it was impossible to secure agreement on this point, and the Conference at Warsaw therefore contented itself with noting that there were two systems in use. The recommendations of the Commission in regard to other symbols were, however, approved and are now in general use.

Another important recommendation made at this meeting was in regard to the issue by wireless telegraphy of monthly mean values of temperature and rainfall. The importance of such issues from the scientific and from the practical point of view had been emphasised at the meeting in London in 1921. But it was not until this meeting and the meeting in the following year (1935) at Warsaw that international agreement was secured on a practical working scheme.

C.S.W.I. Tenth Meeting.

Warsaw, 1935. One of the most important results of this meeting was a modification of the second of the two forms of code approved at Copenhagen, in such a way that the first four groups in this form were identical with the first four groups of the first form. Thus general agreement was secured on a single international form of code so far as the most important elements were concerned. At this meeting, too, the Commission decided to appoint Regional Vice-Presidents for different parts of the world to undertake the duty, by Regional Conferences or by other means, of promoting in the regions concerned the application of the resolutions of the International Meteorological Organisation in regard to synoptic meteorology. Another important step which the Commission took at this meeting, as a result of a proposal by Dr. Dobson, was to express their desire to see a network of stations in Europe, in North America, and in the U.S.S.R. making daily observations of ozone. The establishment of one such station is a rather expensive matter, but substantial progress has now been made towards carrying out the recommendation of the Commission which was subsequently endorsed by the Conference of Directors.

C.S.W.I. Eleventh Meeting.

At the meeting at Salzburg in 1937, the most important question was that of the exploration of the upper atmosphere by means of radio-sondes. The Commission recommended the establishment of a network of fifty stations in Europe and corresponding densities in North America and other parts of the temperate zone. Radio-sondes is the name applied to free balloons carrying specially-designed instruments which transmit messages by radio-telegraphy. These messages give the values of pressure and temperature in the atmosphere in the position which the balloon occupies at the time the message is transmitted. The outstanding importance of this method is that it enables the values of temperature and pressure at different heights in the atmosphere to be obtained in all conditions of weather and at altitudes far greater than can be normally reached by other methods. The normal height at which it is possible to obtain information by radio-sondes is about 50,000 feet, and in favourable conditions values can be obtained up to 80,000 feet. In some countries this method of investigation has already commenced and other countries are now making arrangements to carry out the recommendations made at the meeting at Salzburg.

At Salzburg, too, the code for upper wind observations was materially altered ; previously the height had been represented by one figure according to a conventional specification, and the speed given in miles per hour or kilometres per hour by two figures. In the new code the height is given by two figures (in hectometres—100's of metres), and the speed is given by one figure v_5, according to a conventional specification.

A further decision at Salzburg was to specify the symbolic forms of message by a letter F and a number. This prevents confusion between the " Forms of message " and the " Specifications," which are both usually called Codes.

There are about fifty specifications, and each of these has a number allotted to it. For example, the specification of the face of the wind is Code 30, while that of present weather, ww, is Code 92. The numbers are arranged according to a simple system, so that if further specifications are required in future, they will receive a number in the same decade as existing specifications of related elements, *e.g.*, if an additional specification of weather were introduced it would receive a number between 90 and 99.

There are also about fifty distinct forms of message. This appears a flat contradiction of my remarks about the adoption of a single international form of code at Warsaw. The contradiction is only apparent. The first four groups of the code for fixed stations are universal, but additional groups are required, and the form of these additional groups depends on whether the station is in an ordinary situation inland, or on the coast, or on a light-ship, or on a mountain. They are also different in the morning and evening. Again, there are codes for more precise reports of phenomena of special importance for aviation, and codes for reports of cloud motion, of upper winds, temperatures and forecasts, and these differ in reports from ships. The difference may only be by the addition of an extra group or groups ; there is an underlying unity of form, but it is essential for the recipient of messages to know precisely what groups are being used. The method of specification adopted at Salzburg enables this information to be given concisely. For example, the code consisting of the first four groups of the Land code is F 1, and that of the first four groups of the Ships' code is F 2, while the following $IIIC_LC_M$ $wwVhN_h$ DDFWN PPTT UC_happ RRT_xT_xE $C'_LH'H'N'_L$, which is the code for evening reports from a mountain station, is expressed simply as F 116, *i.e.*, it is derived from F 1 and belongs to the first general form of reports from land stations and is the sixth variant of that form.

I. The Information to be Transmitted.

The first stage in synoptic meteorology, as in climatology, is observation at an individual station. The word " observation " has a wide meaning. It includes the readings of meteorological instruments, and the results deduced from the readings, sometimes by a comparatively abstruse mathematical calculation. *e.g.*, when the values of the wind at different heights in the free atmosphere are derived from theodolite observations of a free balloon or when the temperatures at different heights are derived from the records of a baro-thermograph. It includes also the eye observations of form of cloud, amount of cloud, distance of visibility, and the character and intensity of precipitation and the present weather, of which 100 types are specified. In an ordinary report, excluding upper air observations, an observer must note sixteen facts, viz., atmospheric pressure, temperature, humidity, character of curve of barograph, tendency or rate of change of pressure, direction of wind, force of wind, present weather, weather since last report, visibility, form of low cloud, amount of low cloud, form of middle cloud, form of high cloud, total amount of cloud, height of base of cloud ; and twice a day he must note three more facts, viz., the amount of rainfall, the maximum or the minimum temperature and the state of the ground.

This is a formidable list, and it is not enough for synoptic meteorology to take readings of instruments and estimates of conditions : they must be comparable readings and estimates at all the stations of all the countries of the world, since all the countries of the world are now contributing to the synoptic organisation. For example, thermometers must be protected from rain and from radiation, and yet they must be well ventilated : the radiation from which protection is necessary is not only direct radiation from the sun, but radiation from or to the earth's surface and to the sky. In fact, the surroundings visible from the bulb of a meteorological thermometer must be as nearly as possible at the temperature of the air which it is desired to measure. Further, thermometers must be placed at a standard height because the temperature of the air changes, requently very rapidly, upward not only at night but also in the middle of the day. Also thermometers must be placed in a situation which is not abnormal, *e.g.*, they should not be in a hollow : if they are, an unrepresentative low temperature will be recorded. Similar considerations apply to wind. It is important that the force and direction of the wind in reports for synoptic purposes should give a good representation of the general current of air over the surface of the earth in the region where the reporting station is situated.

Again, it is necessary that the meanings of terms like mist, drizzle, sleet, showers, heavy rain, should be uniform—as you may know our English word sleet is used in America for frozen rain—hard ice-pellets instead of a mixture of snow and rain—while the word mist, intended in International codes to apply to poor visibility not quite so bad as a fog, has in some parts the significance of thick fine rain.

With a view to securing uniformity in such matters, the C.S.W.I. has drawn up a set of instructions and explanations for the International Codes for Synoptic Weather Reports. These instructions are published in the *Manuel des Codes Internationaux* Part 1 of Publication No. 9 entitled *Les Messages Synoptiques du Temps*, of the International Meteorological Organisation.

The instructions are by no means complete, and as time goes on they will be further elaborated ; but there are inherent difficulties which are not readily surmounted in getting international agreement on matters which concern the ordinary every-day language of the people.

II. The Form in which the Information is Transmitted.

It would obviously be impracticable to collect and distribute the observations of weather from hundreds of places if they were described in plain language, and it would be impossible to represent them on a chart without the assistance of symbols. A meteorological shorthand is necessary and a meteorological code and meteorological symbols. Neither shorthand nor codes and symbols appear to be particularly interesting or exciting, but the development of shorthand and codes and symbols during the past twenty years has been one of the most interesting examples of international co-operation.

I have spoken of shorthand, but the technical term used is "specification." I can indicate best by a practical example what is meant by the term specification. An accurate description of the weather at a place involves a great variety of terms: there may be rain or snow or sleet or drizzle, thunderstorm or fog; the rain may be heavy or moderate or slight. It may be continuous or it may be intermittent; or it may be short showers with clear intervals between. In the international specification of weather these varieties are arranged according to an agreed plan and are restricted to 100 varieties to which the numbers 00–99 are allocated. Thus if an observer has to report continuous moderate drizzle he uses the figures 54; if he reports continuous moderate rain he uses the figures 64; while if he reports continuous moderate snow he uses the figures 74.

This specification, the first plan of which was prepared by me in France in 1918, was discussed at a meeting in London in December, 1918. It was included practically unaltered in the Meteorological Annex of the International Air Convention of 1919. It was modified at the meeting of the C.S.W.I. in November, 1920, the principal change being to arrange the different elements rain, drizzle, snow, etc., in separate decades, *i.e.*, numbers

90–99 referred to thunderstorms
80–89 to hail or rain and hail
70–79 to sleet
60–69 to snow
50–59 to rain
40–49 to drizzle
30–39 to showers
20–29 to fog
10–19 to cloudy or overcast weather
00–09 to fine or fair weather.

This specification was used from 1921 to the end of 1929, when the present form, which was adopted at the Conference of Copenhagen, was introduced. The principal change was the introduction of a decade for sandstorms and storms of drifting snow, and the allocation of the first number in each decade 90, 80, 70, 60, etc., for the use of observers who were for any reason unable to use the detailed specification. (This allocation of the numbers 90, 80, etc., was called irreverently by certain younger meteorologists : " The Blind Man's Code.")

In the revised form the decades are arranged as follows :

90–99 thunderstorm
80–89 showers
70–79 snow
60–69 rain
50–59 drizzle
40–49 fog
30–39 sandstorms and storms of drifting snow
20–29 precipitation in the last hour, but not at time of observation
00–19 phenomena without precipitation.

I have referred to this specification at some length because it is one of the most important and one about which there has been most discussion.

In addition to the specification of weather there are

Specifications of the state of the sky, lower, middle and upper—10 types for each level.
Specification of past weather—10 types.
Specification of wind force—12 degrees.
Specification of state of ground—10 types.
Specification of character of barograph curve—10 types,

and special conventions or specifications for the other elements enumerated in the list of symbolic letters.

Among the most important of these are the Index Figures. When reports were sent by telegraph, the place of origin of the telegram indicated the station of observation. But when a large number of reports were collected in a single message, containing a long series of groups of figures, broadcast from a wireless station, it became necessary to indicate clearly to which station groups of figures belonged. It is a well-recognised principle in telegraphy and radio-telegraphy that when figures are being transmitted it is undesirable to mix letters among them. It increases the difficulty and, what is more important, the time of transmission of a message. Further, if letters are mixed among figures, the cost of the message is greatly increased.

A group of five figures counts as one word ; but a group in which one of the figures other than the first or last is replaced by a letter counts as three words. Thus it would have been uneconomic to put in the collective message the name of the station, or to have it indicated by letters. Accordingly, stations were given numbers, and these numbers were given in the collective messages and served to indicate the station to which the groups of figures following referred. At first two figures were used, and the figures were selected by the service of the country from which the message was sent. This did not prove satisfactory, and in 1926 it was decided to use three index figures for each station, and the allocation of the figures to the different stations was made by the President of the C.S.W.I. in consultation with the Directors of the Meteorological Services responsible for the stations. These index figures provided for 1,000 stations. It was clear that the number was insufficient to cover the whole world. Accordingly a group of 1,000 has been allotted to each continent or large region. Six such groups have now been allocated and the synoptic meteorological stations all over the world have now each its own International Index Figure. The groups are as follows :—

First Group—Europe.

Second Group—U.S.S.R. in Asia, India, Japan, China, East Indies.

Third Group—New Guinea, Australia, New Zealand and the Pacific Islands.

Fourth Group—North America.

Fifth Group—South America.

Sixth Group—Africa.

A complete list of the stations and their index numbers is given in Part II of Publication No. 9 of the International Meteorological Organisation.

If a message is issued which contains stations from more than one group, the stations from each group must be collected together to prevent risk of confusion.

In telegraphy a group of five figures counts as one word. (This has not hitherto applied in the United States and Canada, and in those countries the meteorological code for internal purposes has been a word code—though a figure code is used for the messages transmitted for the use of services in other continents, and it is hoped that these two countries will before long also use the standard figure code.)

Consequently meteorological codes consist of groups of five figures. It is convenient to indicate the significance of a group by symbolic letters ; in an actual message each letter is replaced by the appropriate figure. Thus a group PPPDD means that the first three figures give the value of atmospheric pressure (in millibars and tenths) and the last two figures give the direction of the wind in points reckoned from North, *i.e.*, 08 = E, 16 = S, 24 = W, 32 = N, 00 = calm.

A full and complete description of the symbolic letters used is given in the *Manual of Codes* of the International Meteorological Organisation (Publication No. 9, part I, and in Annex G of the International Air Convention).

The following is an abridged and abbreviated list :

a = characteristic of curve of barograph.
C_L, C_M, C_H = low, medium and high cloud.
D, DD, dd = direction on scales 1–8 and 1–32, 1–36.
E = state of ground.
F = force of wind in Beaufort Scale.
GG = Hour—Greenwich Time.
H, HH, h = height (above M.S.L. or above ground).
III = index number of station.
K = Swell (at sea).
LLL and *lll* = latitude and longitude.
N and N_h = amount of cloud and of cloud at height h.
PPP = barometrical pressure.
pp = change of barometric pressure in 3 hours.
Q = octant of globe.
RR = rainfall.
S = state of sea.
TT, T_1T_1, T_xT_x, T_nT_n = temperature of air and sea and maximum and minimum temperatures, respectively.
T_d = difference between air and sea temperatures.
t_w = characteristic and duration of past weather.
U = relative humidity.
V = visibility.
v_1v_1 = speed of wind.
ww, W = present and past weather, respectively.
Y = day of week.

In the first form of code adopted in 1874 by the Committee appointed at the Vienna Congress of 1873 the groups were as follows :—

$$\text{PPPDD} \quad \text{FFwTT} \quad \text{PPPDD} \quad \text{FFwTT} \quad \text{T}'\text{T}'\text{RRR} \quad \text{T}_x\text{T}_x\text{T}_n\text{T}_n\text{S}.$$

The first two groups referred to observations at 6 p.m. the preceding evening; messages were exchanged internationally only once daily, and the evening observations were therefore incorporated in the message sent in the morning. Two figures FF were used for the force of the wind and the wet-bulb temperature T′T′ was included. Three figures were used for rainfall. In British messages inches and degrees F. were used: in continental messages millimetres and degrees C. The use of the code was practically confined to Europe.

It is interesting to mention that the code was approved at a meeting at Utrecht in 1874 presided over by Buys Ballot, whose name is associated with the law " Stand with your back to the wind and the low pressure is on your left," a law which the Hydrographer of the British Admiralty, remarking that British sailors always faced the wind, preferred to have in the form " Face the wind and low pressure is on your right." At the same meeting at Utrecht it was decided to thank de Lesseps for " the numerous meteorological communications received from the Suez Canal Stations."

The system inaugurated in 1874, largely due to the initiative of the Director of the Meteorological Office, London (R. H. Scott), lasted till 1910, when a slightly revised form was introduced. Its symbolic form was nearly the same, viz.,

$$\text{PPPDD} \quad \text{F}^{\text{w}}\text{TTW} \quad \text{PPPDD} \quad \text{F}^{\text{w}}\text{TTD}_1 \quad \text{appRR} \quad \text{T}_x\text{T}_x\text{T}_n\text{T}_n\text{S}.$$

One figure only is used for wind force and two figures for rainfall. The wet-bulb temperature is omitted and new elements are introduced, viz., W = weather during the previous day: D_1 = direction of motion of upper cloud and the barometric characteristic and tendency. This code lasted until 1921, when it was replaced by the first post-war code, viz.:

$$\text{PPPDD} \quad \text{FwwTT} \quad \text{abWVU} \quad \text{C}_1\text{N}_1\text{C}_2\text{Nh} \quad (\text{RRT}_x\text{T}_x\text{r or RRT}_n\text{T}_n\text{r}).$$

In this code two figures ww are allotted to present weather, one figure is allotted to visibility, a new element, while barometric tendency is allotted only one figure. One figure is allotted for relative humidity. A whole group is allotted for cloud observations, viz. :

C_1 = form of lower cloud.
N_1 = amount of lower cloud.
C_2 = second main form of cloud.
N = total amount of cloud.
h = height of cloud base.

There is no provision for including 6 p.m. reports with the morning message ; the maximum temperature of the day is reported in the evening and the minimum temperature of the night is reported in the morning.

Finally, a figure r is allotted to indicate the time of commencement of precipitation.

A corresponding but different code was required for reports from ships. Its symbolic form was

$$\mathrm{QLLLx_1} \quad \mathit{llll}\mathrm{x_2} \quad \mathrm{PPDDx_3} \quad \mathrm{FVKdx_4} \quad \mathrm{wwGGx_5} \quad \mathrm{TTttx_6}$$
$$\mathrm{CNWrx_7} \quad \mathrm{y_1y_2y_3y_4z_1}$$

In this code the letters x y z refer to check figures which enabled the recipient of the message to ascertain if any mistake had been made in transmitting the message and to find what the correct figure should be. Such check figures are not necessary in reports from land stations because reports from neighbouring stations usually show if any mistake has been made. But they were certainly very useful when reports were received from ships far away in the ocean with no other reports of weather anywhere in the neighbourhood. When the codes were revised in 1929 these check figures were omitted to save expense.

In addition to these codes for surface observations there were codes for reports of upper wind and temperature, viz. :

Pilot II hddvv for wind,
and Temp II YYGG PPTTU for temperature.

As many groups of the form hddvv and PPTTU were given as were necessary to represent fairly the results of the observations at different heights.

These codes continued to be used until 1930, when the station code was replaced by the code now in use. The symbolic form of this code is

$$\mathrm{IIIC_LC_M} \quad \mathrm{wwVhN_h} \quad \mathrm{DDFWN} \quad \mathrm{PPPTT} \quad \mathrm{UC_Happ.}$$

Twice daily a further group is added, viz. :

$\mathrm{RRT_nT_nE}$ in the morning.
$\mathrm{RRT_xT_xE}$ in the evening.

The principle underlying the construction of this code is that the information of greatest importance for aviation comes at the beginning of the message, *i.e.*, information about the cloud, the weather, the visibility, the height of the cloud and the wind. That principle would not in itself be a sufficient justification for arranging the code for synoptic reports in this way, but there is a definite practical advantage which results from the arrangement, and this advantage, in conjunction with the principle, was held to justify the arrangement. The practical advantage is that the first three groups of this standard form are identical with the three groups of the abridged code which can be used for intermediate and supplementary reports for aviation. Such, for example, are the hourly reports from stations in and along air routes which are exchanged under the regional system which now extends over Europe.

There is a second form of code designed especially for use in low latitudes where the variations of the barometer are usually relatively small and regular, and where more precise information about the humidity is considered of greater importance. In this second form of code the first four groups are identical with those above, but the fifth group takes the form $UURRt_w$.

The new ships' code in use since 1930 has the symbolic form

$$\text{YQLLL}\quad lllGG\quad \text{DDFww}\quad \text{PPVTT}\quad 3C_LC_MC_HN$$
$$T_dKD_kWN_h\quad d_sv_sapp.$$

where D_k = direction of swell.
d_sv_s = direction of motion and approximate speed of ship.

The principle underlying this code is that the first four groups have a universal character and are the same all over the world, while the following groups can take different forms, according to the desires of the Meteorological Services arranging for the reports, or to the equipment of the ship which makes them. The nature of these groups is indicated by the figure which comes at the beginning of the first of them. In the example quoted, it is the figure 3. There are two other forms of these latter groups which have received international approval. They are indicated by the figures 6 and 9, viz. :

$$6KD_kCN\quad T_dd_sAWC_H\qquad 9SKD_kW\quad CNN_hAT_d.$$

The adoption of this principle of having universal groups and variable groups in ships' codes originated, to the best of my recollection, with Sir George Simpson.

III. The Arrangements for the Transmission of the Information.

Whether forecasting is empiric or based on fundamental principles, it is easy to see that a knowledge of the conditions over a wide area is essential to the forecaster. Complete representation of atmospheric conditions at any one time would require an infinite number of observations. Practical considerations impose the necessity of selecting a network of stations. Ideally, places ought to be selected to give the best possible representation for the district in which they are situated. Again, practical considerations make it necessary to select places at which telegraphic communication exists and at which people able to make observations can live. For example, this rules out most mountain peaks and isolated islands. Further, the network of stations cannot be a national network, it must be international. It is often said that the atmosphere has no frontiers; it has fronts or physical frontiers, where there is a change from one regime to another, but they are usually moving frontiers and are certainly not political frontiers.

Before the war the exchange of information was made by telegram. It was a very restricted exchange. For example, in London, reports were received from six or eight French stations and about the same number of German stations. To-day, reports are available for fifty or sixty stations from each of these two countries. Moreover, reports arrived very late—sometimes four or five hours or more after the time of observation—and, as we have seen in the first international code, many of the evening reports were not received from other countries until the next morning.

The first great step was made at the Peace Conference at Paris. A convention was agreed upon for the regulation of International Air Navigation and a Meteorological Annex was included in the convention in which the following general principles were incorporated. Reports from each country should be transmitted within 1½ hours of the time of observation to meteorological offices of other countries within a radius of 1,000 miles. Further, a selection of reports from a region embracing several countries should be transmitted from a central transmitting station of world-wide range within three hours of the time of observation. Although it was a long time before these principles were put into actual operation, their formulation acted as a guide and stimulus to later developments. This annex was largely the work of Major Blair, of the U.S. Meteorological Service in France, Lieutenant Rouch, of the French Meteorological Service, Group-Captain Blandy, of the Signals Department of the Air Ministry, and Lieutenant-Colonel E. Gold, of the Meteorological Office, London.

At the meeting of the C.S.W.I. (then the Commission for Weather Telegraphy) in London, in November, 1920, a timetable was prepared in which the times at which the different countries of Europe should issue the reports from their stations by wireless telegraphy were definitely specified. The times were so arranged that not more than two issues were being made simultaneously and the transmissions were completed about $2\frac{1}{2}$ hours after the time of observation. In this table the time allotted to Great Britain was the interval from 1 hr. to 1 hr. 20 mins. after the time of observation. A second table gave the number of stations which should be included in each issue—*e.g.*, 20 for France, 20 for Italy, 8 for Norway.

This scheme was generally adopted, though some modification was made at the C.S.W.I. meeting at Utrecht in 1923 to ensure a more rapid issue of the reports. This modification permitted three simultaneous transmissions instead of two, and aimed at getting the transmission practically completed within two hours of the time of observation.

Under this system it was necessary for each service to arrange for the reception of the issues from every country in order to get a complete set of reports for the whole European area. But in 1927 the C.S.W.I. sent a delegation to the Radio-Telegraphic Conference at Washington and obtained the consent of the Conference to the allocation of two wave-lengths exclusively for the transmission of Meteorological Reports in the European area. As a result of this it was decided at the Conference at Copenhagen in 1929, on the recommendation of the C.S.W.I., to change the system and replace it by the following plan.

The Northern Hemisphere was divided for the purpose of the distribution of synoptic meteorological reports into two great divisions: (1) Europe and the Eastern Atlantic, (2) North America and the Western Atlantic and Eastern Pacific. (The division is a broad one; the region within the tropics is not specifically included, nor the major part of the Pacific Ocean.) The reports from a selection of stations and ships in these regions were to be issued in abridged form in two great collective messages by Great Britain and the United States of America.

Further, the region (1) was sub-divided into two sub-regions (both of substantial extent and including many different countries), viz., 1 (*a*) Western Europe, which embraced Iceland, British Isles, France, Holland, Belgium, Switzerland, Italy, Spain, Portugal, the Azores and North Africa bordering the Atlantic and Western Mediterranean, and 1 (*b*) Central Europe, which embraced Norway, Sweden, Denmark, Finland, Poland, Esthonia, Lithuania, Latvia, Czechoslovakia, Austria, Germany and Hungary. The reports from the synoptic stations in these two regions were to be issued more frequently in complete code by France and Germany on the two reserved wave-lengths of 6,660 metres and 3,350 metres respectively. (These wave-lengths have been subsequently modified and the number increased to four. They are now 7210 m. ; 7100 m. (FLE) ; 3352 m. (DDX) ; 3005 m.)

Under this arrangement it was no longer necessary for any country to receive the individual messages for each of the other countries in Europe ; it was necessary only to receive the issues from France and Germany.

There was a further message which completed the arrangement, but which did not fall precisely into either of the two general categories mentioned. This was the collective message issued by the U.S.S.R. for the great area in Europe and Asia which is included within its regime. This message, issued from Moscow, gives reports in full code for a selection of stations distributed over the area mentioned.

The messages from France (Eiffel Tower), Germany (Berlin) and U.S.S.R. (Moscow) were issued simultaneously, while those from Great Britain (Rugby) and North America (Arlington) did not overlap the other issues. The arrangement therefore made it possible for any meteorological service with two receiving sets to get the synoptic reports necessary for a detailed meteorological map of Europe (excluding Russia) and a general meteorological map of the Northern Hemisphere, and with three receiving sets the detailed map could be extended to Russia and Siberia.

The plan was further extended at the Conference at Warsaw in 1935 by the inclusion of a third collective message for the European area, viz., a message from Rome for the Region 1 (*c*) Eastern Mediterranean, which embraced reports from Italy, Yugoslavia, Albania, Malta, Greece, Turkey, Rhodes, the Dodecanese, Libya, Syria, Palestine, Iraq and Egypt. At the same Conference it was agreed that Bulgaria and Roumania should be added to the list of countries given in the Region 1 (*b*) Central Europe.

This arrangement effectively completed the International Scheme of collection and distribution of reports in the European area, so far as the space element is concerned. We must turn for a moment to the time element.

As already mentioned, when synoptic meteorology began, observations were sent in the morning only. If evening observations were made, they were kept and added to the morning message. This was soon found to be unsatisfactory, and a selection of stations sent their evening observations in the evening so that they could be used for the weather forecasts supplied to newspapers for publication the following morning. Next, a third observation in the middle of the day was added for a few stations, but still the main network of stations reported only once daily. When the system of exchange by broadcast issues by wireless telegraphy was introduced in 1920, the reports from practically all stations were issued three times daily and reports of observations at or about 1 a.m. were issued for a selection of stations. As the application of meteorology to aviation extended, and as aviation itself developed, more frequent synoptic reports were found necessary, and to-day observations are made at most stations four times daily and at a selection of stations eight times daily; and the arrangements for international exchange of information provide for the issue of these observations within 1½ hours of the time at which they are made. For example, the collective issue of 7 a.m. observations from Paris or Berlin begins immediately after 7 a.m. and goes on continuously until 8.30 a.m. The observations are grouped in such a way that it is possible with one receiving apparatus to obtain a selection of reports from stations distributed over the whole region covered by these two collective issues. This is achieved in the following way. The stations in any country are divided into two categories A and B—the more important stations being in category A. When reports from A stations in the Western European region are being issued from Paris, reports from B stations in the Central European region are being issued from Berlin, and *vice versa*. Consequently the reports from A stations in the two areas are not being issued simultaneously and can be received by switching over from one issue to the other.

The main issues are made from reports of observations at 1 a.m., 7 a.m., 1 p.m., 6 p.m. and supplementary issues from reports of observations at 4 a.m., 10 a.m., 4 p.m., 10 p.m.

IV. Presentation of the Information.

When reports are received at a central office, although some idea of their importance might be gained from an examination of a table of the reports, it is found better in practice to decode the reports and plot them on a chart. The scale of the chart should be selected in such a way that the chart will be of manageable size, will cover a large enough area, and will permit the information to be entered on it without overcrowding. None of these conditions can be completely satisfied in practice—a compromise has to be effected. The area to be covered was until recently governed largely by the period of time which the forecasts had to cover. Forecasts for a few hours ahead for a given place can be made best by using a comparatively restricted area and a dense network of stations. Forecasts for longer periods of a day or two require a larger area and a less dense network. Recently, owing to the increase of speed and range of aircraft, it has become necessary to make forecasts for a comparatively short period of time, but covering a great distance or area ; and this has necessitated further compromise. Thus the scales of charts recommended internationally are 1/5,000,000 for dense networks over a restricted area; 1/10,000,000 for general charts for making forecasts such as those broadcast by the B.B.C. ; 1/30,000,000 for charts covering practically the whole hemisphere and used to obtain general guidance and "directives" in regard to developments in the meteorological situation. The recent compromise scales are 1/7,500,000 and 1/15,000,000.

It is customary on all the charts to show the contours of the land, and the high ground is shaded because, naturally, high ground has an important influence on the motion of the atmosphere and the weather resulting from the motion, particularly from the vertical motion.

The information entered on charts used to be entered by each of the meteorological services, according to the manner which the particular service found most convenient. But owing to the development of aviation it has become more and more necessary that charts should be the same in all countries of the world, so that the aviator who flies from one capital to another will find the same kind of chart and the same method of entering the information on it in all the places where he has to consult meteorologists or their maps. Accordingly, a method of entering the information on the charts has been agreed upon internationally. As already mentioned, figures provide an international language for use in the exchange of reports. But figures alone are not sufficient for the entries on charts. A clear picture of the meteorological situation could not readily be obtained from a mass of figures. Accordingly, the information for each station is plotted on the chart around the position of the station in a conventional way which was approved at the conference at Warsaw in 1935. Thus the wind, which is telegraphed by figures, is shown on the chart by means of an arrow, the direction of which represents the direction of the wind and the number of feathers represents the force of the wind. The remaining information is grouped according to the plan below—called the station model—in which the letters have the meaning already described in the section on Codes and are replaced in the actual chart by figures or symbols.

TABLE I.

Station Model.

Station Model.—The circle denotes the position of the station. *In the Station Model the letters have the following customary meanings :*

	C_H	(E)
TT	C_M	PPP
V ww	(N)	±ppo
T_sT_s	C_LN_h	W(w)
T_1T_1	h	(RR)

Station Model.

PPP = Pressure. pp = Tendency.
TT = Temperature. T_1T_1 = Sea Temperature.
ww = Present Weather. W = Past Weather.
a = Characteristic. E = State of Ground.
$C_LC_MC_H$ = Form of Low, Medium and High Cloud.
T_sT_s = Dew Point Temperature.
N = Total Amount of Cloud. V = Visibility.
N_h = Amount of Low Cloud. RR = Rainfall.
h = Height of Low Cloud.

Also (w) = That part of ww which refers to the last hour but not to the time of observation.
U = Humidity is alternative to T_sT_s.

Where lack of space necessitates a modification of the Station Model a deformation of it without permutation of the places allotted to the individual elements is permissible.

If only one colour is used it should be black. If two colours, black and red, are used, then red should be used for one or more of the following :—

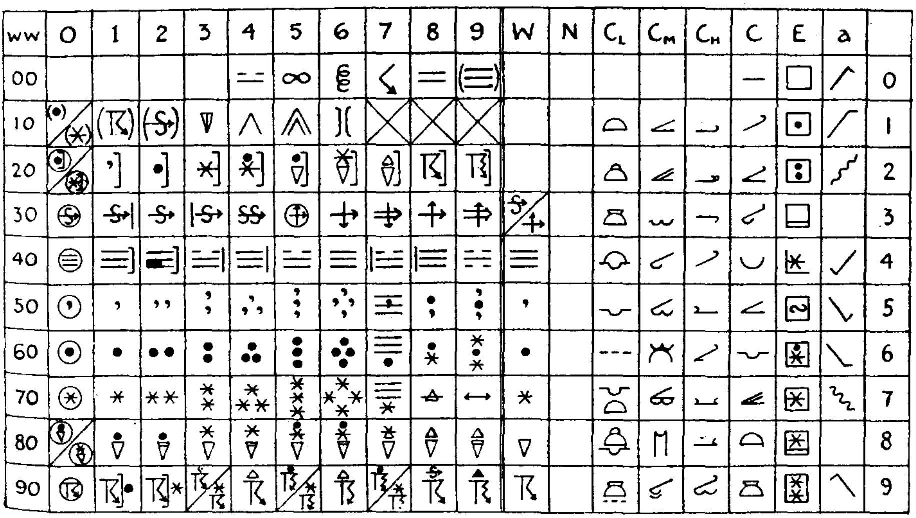
(1) For C_H. (2) For W (Past Weather). (3) for TT, T_sT_s. (4) For V. (5) for pp *when pp is negative.*

Red should *not* be used for PPP, ww, C_M, C_L, T_1T_1, N_h, h.

Thus the weather ww is represented by symbols, mainly pictorial, and arranged according to general principles, readily understood. For example, two symbols, of which one is to the right of the other, mean that the weather represented by the second symbol succeeded (in time) the weather represented by the first symbol. Two symbols, one over the other, mean that the weather represented by the one symbol was co-existent with the weather represented by the second symbol. There are also symbols for the form of the cloud and for the way in which the barometer is changing. The amount of cloud is represented by the proportion of a circle which is shaded or blacked. Figures are used for the barometer pressure, the distance of visibility, and the amount and height of cloud. Some of these are entered in black and some in red to facilitate differentiation at a glance.

The complete table of symbols is given below, Table II. It appears sufficiently complicated and may serve to indicate the technical skill required both by those who make meteorological maps and by those who interpret them.

Table II.



V. Forecasts.

It is no part of my purpose to give here an account of the principles and methods of forecasting. I am concerned only with describing why international arrangements are necessary in regard to the distribution of forecasts and what they are. For the most part, forecasts and their issue are purely local or national matters, but there are certain aspects in which they require international action.

The first is in regard to the exchange of forecasts for aviation. It was realised immediately international civil aviation commenced that a code for forecasts was essential. This was devised and has the following form :

$$\text{PREVI} \quad \text{YYGGO} \quad t_1L_1L_1L_11 \quad D_1D_1Ft_22 \quad h_1d_1d_1v_13$$
$$W_1N_1h_2t_24 \quad Y_cVL_1t_25 \quad R_1R_2L_1t_26$$

where the last figure in each group indicates the character of the information contained in the group, *e.g.*, if the last figure is 3 the group contains information about upper wind, 4 to the state of the sky, etc. This arrangement permits more than one group of each type to be used where it is necessary to do so. This is often the case, especially with groups 2, 4, 5 and 6.

YYGG = date and time.
t_1 = time to which forecast refers.
$L_1L_1L_1$ = route or area to which forecast refers.
D_1D_1, F = direction and force of wind, forecasted wind.
t_2 = time to which D_1D_1F refers.
$d_1d_1v_1$ = direction and speed of wind at height H.
$W_1N_1h_2$ = anticipated weather, cloud and cloud height at time t_2.
Y_cVL_1 = visibility and changes of visibility expected in places L_1 at time t_2.
$R_1R_2L_1$ = precipitation, its character and intensity in places L_1 at time t_2.

This code enables the forecaster to give to anyone, whatever his nationality or however remote his language, who has a copy of the decode, reasonably precise information as to what the weather conditions are likely to be along the route for which he requires the information, *i.e.*, it gives the wind in the upper air, the weather, the height of the cloud, the visibility, and the variations and changes expected. The value of the code is not only that it solves the difficulty of language, but it also serves to guide or to remind the forecaster of the elements about which it is necessary for him to give information in his forecast and of the kind of forecast which is required.

A second direction in which a code for forecasting is necessary is in forecasts for shipping. Although English is nearly an international language at sea, it does not completely meet the case, and meteorological services, such as those of Norway or Iceland, find themselves asked to repeat the forecasts, which they issue in their own language, in other languages too. A simple code has therefore been devised to enable forecasts for shipping to be given in an international form. The code is at present a trial code. It is already used in certain countries and its use is likely to extend as its value becomes more widely known. The symbolic form of the code is

IDFWV GDFWV GDFWV

when

I = an index number to represent the region concerned.
D = forecasted direction of wind.
F = forecasted force of wind.
W = forecasted weather.
V = minimum visibility expected.
G = time of commencement of weather indicated in the group.

I hope this account will give you some idea not only of the subject of synoptic meteorology, but also of the way in which the practical need for international co-operation has indicated how in this department of human activity the barriers of language and race can be and are being surmounted.

Discussion.

The Chairman said he was certain the audience would agree that they had listened to a most fascinating account of a very interesting but complicated subject. To his mind the paper opened up two distinct although related matters. There was, in the first place, the utilisation by meteorological scientists of the mass of data now available every day, for the furtherance of meteorological knowledge, for the elaboration of hypotheses and theories, and so building up an ever more complete science of meteorology. In the second place there were the technical and administrative problems of specifying the nature of the observations to be taken and the complicated questions connected with the procedure for communicating these observations in a kind of shorthand form as rapidly as possible for use in forecasting. A high degree of international collaboration was necessary for the smooth functioning of this second aspect of the subject, and Col. Gold had given an impressive account of the extent to which the nations concerned co-operated for this purpose. The Chairman's own experience of international work had been mostly in connection with agricultural science—a subject which was one of the first in which international contacts were resumed after the Great War, but in recent years he had also taken part in similar meetings in connection with meteorology, and he had been struck by the curious but perhaps comforting fact that the less important and fundamental the matter under discussion the more vehement was the controversy and the more difficult was it to secure agreement between rival proposals. Of course, at international meetings very much was done by private conversations and informal discussions taking place outside official hours, and in this connection he had been much impressed by Col. Gold's ability. No one could be more tenacious than he was in holding to a point of view that he regarded as fundamental and in persuading others to adopt it, and he felt sure that international collaboration in meteorology would not be in its present stage had it not been for his sustained efforts in this direction. On behalf of the meeting he proposed a hearty vote of thanks to Col. Gold for the interesting and important paper they had had the privilege of hearing that afternoon.

Lt.-Col. T. C. SKINNER, F.R.Met.S., asked the Lecturer to what extent the international co-operation would be affected by serious political disturbance in Europe? Would it make impossible the collection of information of vital importance to our own meteorologists? Or would it merely interrupt the distribution of information to continental countries from Great Britain? Suppose that the majority of European powers were at war, would we be able to carry on effectively without their co-operation?

Mr. L. C. W. BONACINA said that he remembered seeing a few years ago synoptic weather charts of the entire Northern Hemisphere prepared in Germany in connection with the International Polar Year 1933.

The charts were for noon G.M.T., which meant, of course, that the observations in the Pacific region referred to midnight. He asked if Col. Gold could throw light on this confused system of day and night observations, and how it was to be interpreted.

He added the following note later in writing :—" In paying tribute to the usefulness, thoroughness and comprehensiveness of the code in use by the Meteorological Office for forecasting, so clearly explained by Col. Gold, I should like as a non-official meteorologist to indicate where it seems to me it may be a little dangerous for members of the general public to think too much in terms of official codes.

The distinction, for instance, between " rain " and " drizzle " is all to the good for certain purposes, but there is a risk that by sheer pressure of circumstances and force of usage the ordinary person may cease to think of drizzle as a form of rain at all. In this way violation would be done to common language and rudimentary conceptions. Drizzle (defined as precipitation in very small drops) can be both persistent and heavy in hill districts, and has as much right to be called rain as varieties found of larger drops.

Then as to the pellets of frozen rain, which as Col. Gold said is called " sleet " in America, I do not know whether there is any official name for it, but in plain English it is one of several varieties of hail, though its mode of origin is different from that of ordinary soft hail or true thunderstorm hail. These frozen rain-drops often form severe ice-storms in the United States and are not unknown in England.

Again the Air Ministry's visibility code is no doubt of the highest utility to airmen for whom it was designed, but I think there is an increasing tendency for this code to be adopted in other fields in which it is not always so suitable. Statistics about the distribution of fog and mist, for example, based on this code must necessarily be arbitrary. A landsman's idea of a " dense fog " is different from that of an airman or a seaman.

I have merely made these comments because I feel that a non-official meteorologist is in a favourable position to see the disadvantages of the unrestricted adoption of official terms and usages.

Mr. F. Entwistle said : The previous speaker referred in his remarks to the requirements of aviation. It is not always realised, perhaps, to what extent aviation has contributed to the development of synoptic meteorology. It is very largely due to the demands of aviation services for detailed and accurate information regarding present and future weather conditions that such an intense and seemingly complex system of meteorological observations, and of the international exchange of these observations, has been built up. This intense organisation has helped not only aviation but other services and even individuals who make use of weather forecasts, for the detailed information which is now available at frequent intervals from such a large area of the globe has furthered the study of weather phenomena and has led to more accurate and useful forecasts.

I should like to endorse the remarks which have already been made regarding international co-operation in meteorology. It speaks volumes for the mutual confidence and goodwill which are invariably exhibited at international meteorological meetings that such complete agreement on the intricate details of which we have heard this afternoon has been found possible. It is indeed remarkable that representatives of so many national services can meet together with a common object before them and be prepared to compromise in order to reach unanimity.

It will have been gathered that the lecturer has been intimately associated with this international development for the last twenty years but he has not told us how much meteorology is indebted to him for the leading part he has played in the International Meteorological Organisation, particularly in regard to the aspect of the subject which he has been describing to us. That such complete agreement has been reached internationally is due in no small part to his wise leadership.

Mr. R. A. Watson Watt said: It is far from being an accidental coincidence that the advances which Colonel Gold has described this afternoon have taken place in the period in which he himself has been the recognised international leader of synoptic reporting. To his zeal and skill we owe, in very great measure, that vast increase in content, in clarity and in utility of the synoptic weather reports which pass over the international network of co-operative meteorology.

Colonel Gold has shown how a great mass of detailed " longhand " information about the state of the weather in any one place is now compressed into a " shorthand " message of great compactness. I would like to ask whether the international system is now providing, or is about to provide, for the next stage of compression. The lecturer has referred very briefly to the diagnosis and description of the general weather situation over an area in terms of cold fronts, warm fronts, occlusions and the machinery of that system which bears in some places the unlovely name of frontology. I am aware that the diagnosticians differ, here as in other professions, but I wonder whether provision is being made for the immediate interchange of information on their diagnoses as a natural extension of synoptic weather reporting.

COMMUNICATION.

Mr. J. M. SMYTH, M.Inst.C.E., wrote : In the course of work as an Electrical Engineer, the writer has had experience of many different weather conditions in Brazil, Guianas, Colombia and West Africa, and for Hydro-Electrical power work accurate records of rainfall in a given district are essential.

In the tropical regions within 10° of Latitude North and South of the Equator, the dry and wet seasons of the year are so well defined as to be capable of being forecasted within a week or two at a given period of the year, and the annual rainfall all occurs within the wet season.

During the " rains " it was noticed that the heaviest storms were always preceded by wind of hurricane force, followed in an hour or two by calm weather and sunny sky. Occasional heavy showers occurred from an apparently clear sky at this season. At intervals of a month or so, when humidity reached 90 per cent. to 100 per cent., rain would fall steadily for a week.

During the dry season, masses of heavy, thundery-looking cloud often collect, but rain never falls during this period.

Will Col. Gold kindly throw some light on these conditions, if possible, chiefly with reference to the reason why tropical weather is so well defined as to season, but sub-tropical and temperate conditions much less certain ?

Then as to thunderstorms. Has the Royal Meteorological Society any system of recording these weather phenomena ? In

U.S.A. I believe they take a series of records called "Isoceraunics" (Keraunos-thunderbolt), *i.e.*, lines based on an equal average number of "Thunderstorm Days" in different regions over the whole country for a period of years. These records are used to give some indication of the relative protection required against lightning for electric power lines, and it is not clear whether they are of use in any other direction.

Looking at such a chart of U.S.A. for the period 1904–23 (20 years), a line near the west coast from north to south shows an average of five "Thunderstorm Days" per year, being the lowest recorded. The highest average is 70 thunderstorm days per year in a small area of the State of Colorado and also along a region bordering on the Gulf of Mexico between the States of Texas and Florida.

Apart from thunderstorms, has the electrical tension of the atmosphere any appreciable effect on weather conditions, and is it possible that an instrument may be devised to measure this, just as a barometer by indicating changes in the weight of the atmosphere, is some guide in forecasting the weather ?

AUTHOR'S REPLY.

Lieutenant-Colonel GOLD said : With regard to the points raised by Colonel Skinner, the arrangements which have been described in the lecture apply only to peace-time conditions. In case of war, countries usually discontinue or restrict the issue of their meteorological reports.

Mr. Bonacina's reference to the terms rain and drizzle brings to my mind discussions which I listened to at the International Climatological Commission at Zoppot in 1935, when the Commission had before it a proposed definition of rain. It proved as difficult to define rain as it was proverbially difficult to define a cow. Mr. Bonacina's fear that the official definitions might lead to a change in the meaning of words would, I think, be justified if the official definitions differed substantially from the common meaning. My experience has been that official meteorologists have been very reluctant to use common terms with a technical meaning and have endeavoured to use technical terms where a limited technical meaning was necessary. Actually, the distinction between rain and drizzle has been made by ordinary people in this country for generations, and the meteorologist is not changing but stabilising the practice. Drizzle is technically useful as well as linguistically expressive.

I am glad that Mr. Entwistle emphasised the inter-dependence of meteorology and aviation. Meteorology is not only like chess, a game which exists for the interest of those who play it. Meteorology is also a service which exists for those who will use its results. It is the aviator who makes most use of meteorology in his work and who is prepared to spend money, so that his needs shall be met.

Mr. Watson Watt asked about the exchange of diagnoses. This is, as he says, the natural extension of the exchange of synoptic reports. But it is at present in the experimental stage. Diagnosis is actually intermediate between the weather report and the weather forecast, and it might be expected that exchange of diagnoses would precede exchange of forecasts. Actually, an international code is in use for the exchange of forecasts for aviation purposes, but the codes for the exchange of diagnoses have hitherto been national and experimental, and have not reached the stage at which international agreement on a formal code for the exchange of diagnoses has been practicable.

I am interested to see Mr. Smyth's note about his experiences in the dry and wet seasons in the tropical regions. It is rather outside the subject of my lecture. I think the main reason for the seasonal variation to which he refers is the North and South movements of the thermal equator and the consequent movements of the belts of trade winds. Broadly speaking, in the tropics north of the Equator the rainy season on land is in the middle months of the year, June, July, August, and in the tropics south of the Equator the rainy season is in December, January, February. But the division is not clear-cut. At St. Helena and other tropical ocean islands, there is rain all the year round : and the same is true of Singapore, where the lowest monthly average is 168 mm. (nearly 7 inches), and at other places on the Equator. Taking the countries Mr. Smyth mentions : at Bogota in Columbia, rain falls in every month of the year, and in substantial amounts : the lowest monthly average is in July, 52 mm. (just over 2 inches). At Georgetown, British Guiana, rain falls heavily all the year round : the smallest average monthly fall is in October, 75 mm. (just under 3 inches) ; in May, June and December, the fall is over 280 mm. (11 inches). The rainfall in Paramaribo, Dutch Guiana, is similar. At Recife, in Brazil, the smallest average monthly fall is 26 mm. (1 inch), in October, and occasionally even October has 3 or 4 inches. At Accra, Gold Coast, the smallest average monthly rainfall is 15 mm. in August, but even in August 100 mm. (4 inches) or more may fall. Thus, these places, all within 10° of the Equator, are exceptions to Mr. Smyth's statement that "the annual rainfall all occurs within the wet season."

With regard to the effect of the electrical state of the atmosphere on weather conditions, Mr. Smyth might be interested in the papers written by Dr. Bureau, of the National Meteorological Office of France, on the relation between atmospherics and fronts.

In conclusion, I should like to express my appreciation of the kind remarks of the Chairman and of the other speakers.