Popular Long-Range Weather Forecasts.

SINCE last April, forecasts of the weather for fifty days ahead have been appearing in the *Daily Mail*. The forecasts, which are prepared by Lord Dunboyne, have excited a considerable amount of interest. The question of long-range forecasts has been engaging the attention of meteorologists for some time, and they would welcome any progress in this direction, even if in the first instance the forecasts were purely empirical. Lord Dunboyne has not published any account of the principles he uses, and it is not possible therefore to study the methods of the forecasts, but only the results obtained. The forecasts are given in the form of a diagram, and it is stated in the explanation that the higher the curve rises above a datum line the greater the probability of rain, and the lower the curve falls the greater the probability of dry weather. When the curve rises sufficiently far above the datum line, and rainy weather is indicated, the area within the curve is blackened, and similarly the lower parts of the diagram are shaded to indicate that dry weather is forecast.[1] In this way the periods when wet or dry weather is expected are shown at a glance.

From the curves it is possible to read off what are here called 'forecast numbers.' The day when the curve is below the datum line has a forecast number of 1; one with a curve on the datum line a forecast number of 2; a little above gives 3; considerably above the datum line but not up to a blackened area, 4, and when the curve rises to the blackened area the forecast number is 5. To compare the forecasts with the actual weather, readings have been taken from the *Daily Weather Report* from which weather numbers have been deduced. The weather number for each day is determined as follows: 5 is a day when more than 2 mm. of rain has occurred; 4 when the rainfall is between 0·2 mm. and 2 mm.; the other numbers are for days when the rainfall is less than 0·2 mm.; 3 is a day when the mean cloud amount is 8 or more; 2 when the mean cloud is between 3 and 7·9, and 1 when the mean cloud is 0 to 2·9. These cloud amounts are the means of the cloud amounts recorded at 9 A.M., 1 P.M., and 6 P.M. This seems to be a fair way of comparing the two sets of numbers. The only doubtful case is that of weather number 3, which represents overcast skies, for anticyclonic cloud may cover the sky in perfectly dry weather, and it would be unfair to class a forecast number of 1 as a failure, when the weather that occurred was anticyclonic, merely because the sky was overcast. But such weather, though it occurs in the winter, is not much in evidence in the summer, and the period under consideration is that from April to October; during this part of the year an overcast sky may very fairly be taken as half-way between rainy and dry weather, and the above criticism would not apply.

The diagrams are given for fifty days ahead, but they are amended from time to time, and therefore the forecast for a given week made six weeks ahead may differ from the forecast for the same week as given five, four, or less weeks ahead. To take, for example, the forecast for south-east England for the week commencing July 4 (Fig. 1). When this first appears in the *Daily Mail* for May 28 it shows the curve below the datum line for all the days except July 5 and 10, on which days the curve rises just above the datum line; that is to say, the forecast was for a week with a definite but small probability of fine weather. The next forecast for the same week shows the curve above the datum line for all days with a probability of rain on July 5 and 7; this probability seems to be reduced in the next diagram, and when we come to the forecast for three weeks ahead the curve has fallen below the datum line again except at the end of the week, when it rises a

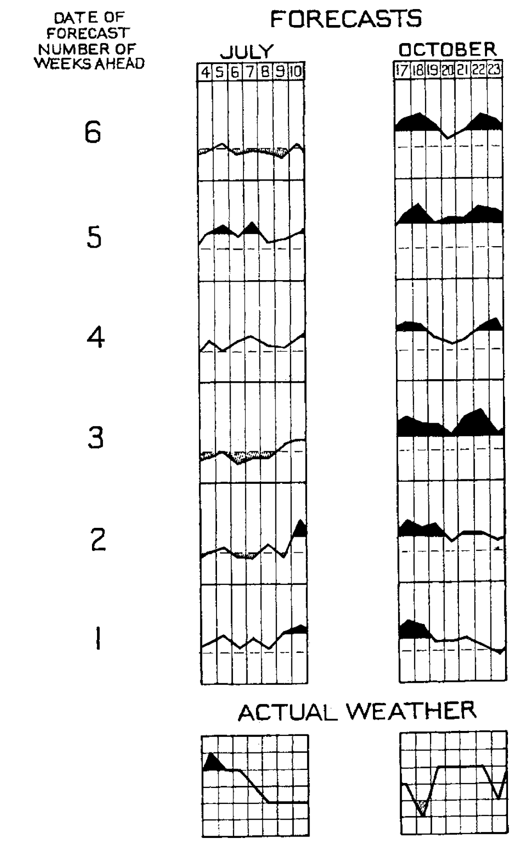

FIG. 1.

little above; for two weeks ahead a blackened area occurs on the last day, and the forecast for one week ahead is very similar. The actual weather experienced at Kew was as follows:

Date.	Rainfall.	Weather Number.
July 4	5·0	5
,, 5	2·0	4
,, 6	0·6	4
,, 7	Trace	3
,, 8	..	2
,, 9	Trace	2
,, 10	Trace	2

Another week, that commencing October 17 (Fig. 1), when it first appeared in the *Daily Mail* for September 10, gave rain as probable at the beginning and end of the week, on all days, in fact, except September 20 and 21, but the curve was above the datum line for the whole week; the next curve was above the blackened area all the week. The forecast for four weeks ahead was

[1] Some slight changes have lately been made in the diagrams, but this does not affect what follows.

very similar to the first one, but the blackened areas were reduced. The forecast for three weeks ahead had the curve again above the blackened area all the week. The next two charts kept the blackened area at the beginning of the week, but the curve fell lower at the end of the week, and in the last forecast of the series it

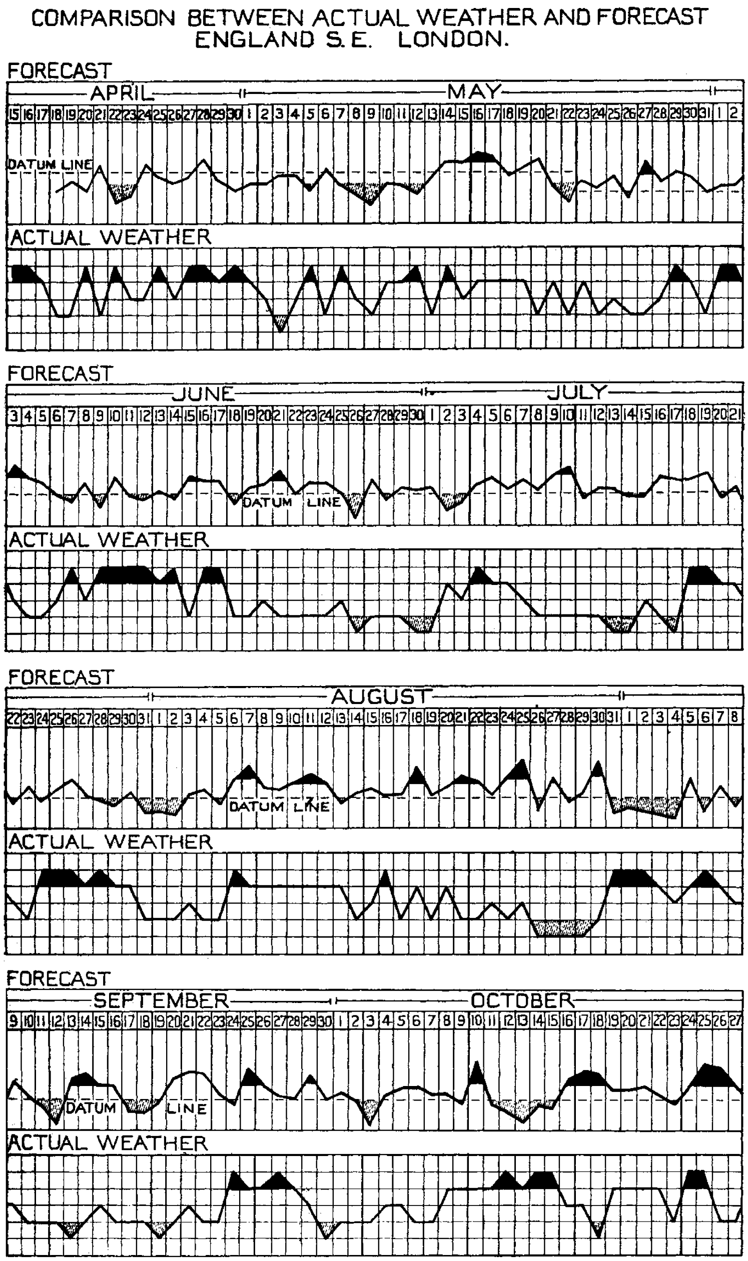

FIG. 2.

was below the datum line on the last day of the week. The following was the actual weather at Kew:

Date.	Rainfall.	Weather Number.
Oct. 17	..	3
,, 18	Trace	1
,, 19	0·3	4
,, 20	0·3	4
,, 21	1·0	4
,, 22	1·1	4
,, 23	0·1	2

These weeks were taken at random, without first looking up the actual weather that occurred, and without trying to find a case where successive forecasts differed among themselves. There are other examples where still more striking changes occurred in successive forecasts for the same week, changes much greater than would be expected from the statement that "the curves are subject to slight amendment as time advances." So little concordant with each other are the successive forecasts for the same week that it is evident that, whatever value the forecasts may have, six weeks is considerably too long a period for the methods employed.

In order to compare the forecasts with the actual weather, diagrams have been made from the weather numbers for Kew and Scilly, and have been placed below the forecast diagrams for south-east England and for south-west England respectively (Figs. 2 and 3). This method of comparing the forecasts with the weather experienced was used by Dr. W. J. S. Lockyer in a short communication sent a few months ago to the editor of NATURE, who later invited me to prepare the present article. Only the forecasts for one week ahead have been made use of.[2] An examination of these two sets of curves shows that the forecasts, though agreeing with the actual weather at times, yet on the whole show no relationship with the weather experienced. No shifting of the curves backwards or forwards in time makes any approach to a fit between the two except in a few isolated cases. The best fit is probably that for Scilly in August, but even in this case it must be remembered that if the forecasts had been chosen for more than one week ahead the curves would not have been the same as those actually shown. On the whole, there is no such general agreement between the curves of forecast and those of actual weather as would be expected if the forecasts had any sound meteorological basis.

Another way of looking at the results is to take the differences between the forecast numbers and the weather numbers; 0 would mean that the forecast was entirely successful, and 4 that it was as unsuccessful as possible. Taking the forecasts for south-east England for one week ahead and comparing them with the weather numbers for Kew, we find that there were 30 cases with a difference of 0, 72 of 1, 45 of 2, 21 of 3, and 16 of 4. Taking 0 and 1 together we get 102 complete and partial successes as against 82 that were not

[2] As no charts were issued between April 30 and May 21 the forecasts which should have been for one week ahead for the period May 2 to May 22 were taken from the chart issued on April 30. Similarly, where forecasts for six weeks ahead for the period June 13 to July 3 are under consideration they are taken from the chart issued on May 21.

		One Week. 0	1	2	3	4	Six Weeks. 0	1	2	3	4
KEW.	Actual	30	72	45	21	16	30	57	29	28	9
	Chance	35	65	44	28	12	31	52	36	26	8
	Ratio	0·9	1·1	1·0	0·8	1·3	1·0	1·1	0·8	1·1	1·1
SCILLY.	Actual	34	67	43	31	9	30	55	34	24	10
	Chance	35	62	40	33	14	31	50	33	29	10
	Ratio	1·0	1·1	1·1	0·9	0·6	1·0	1·1	1·0	0·8	1·0

a success. This means that the forecasts were successful in 55 per cent. of the cases and failed in 45 per cent. The results for Kew for six weeks, and the results for Scilly both for one week and for six weeks ahead, come out at almost exactly the same percentage. At first sight this seems a definite measure of success for the forecasts, but a further examination of the figures shows that this seeming success is illusory, since the figures are very near to those which would be expected on pure chance. The above table gives the difference between the forecast numbers and the weather numbers for Kew and Scilly both for the forecasts one week and six weeks ahead, together with the numbers which should be expected on pure chance, and with the ratio between them.

From this table it will be seen that the distribution is very close indeed to that of pure chance. If the forecasts had any measure of real success the table should show a high ratio for differences of 0 and 1, and low values for differences of 3 and 4; but there is no indication of this.

To emphasise the fact that the distribution is solely due to chance, the weather numbers have been taken for Kew and have been compared with the forecast numbers for different months, May with October, June with September, July with August, and so on; moreover, the days have been reversed, that is, the first is compared with the last day of the month, the second with the last day but one, and so on; therefore by no possibility can the weather numbers have any connexion with the forecast numbers; the differences come out as follows:—

0	1	2	3	4
35	70	45	27	7

This is in striking agreement with the legitimate comparisons, and emphasises the fact that the latter too have the appearance of being governed by nothing but chance.

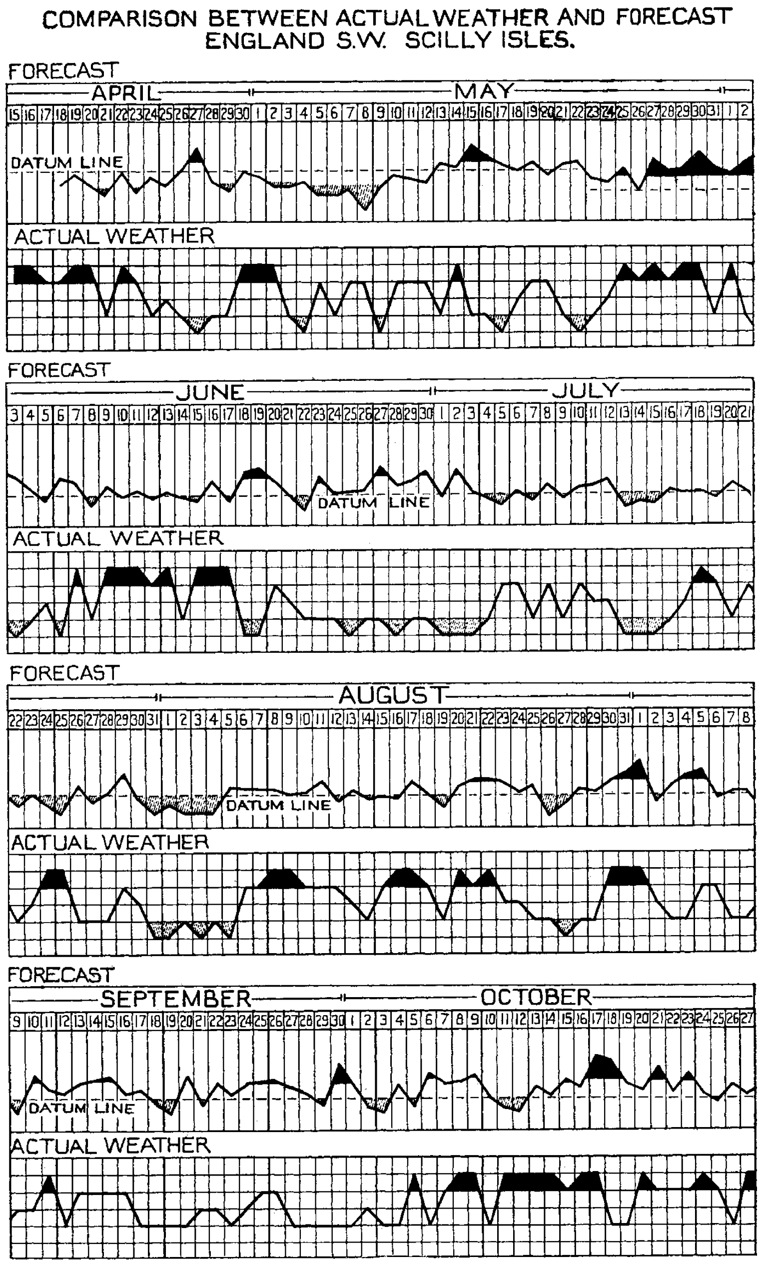

FIG. 3.

Yet another method of examining the figures is to take correlation coefficients between the forecast numbers and the weather numbers. The adjacent table gives these for each month for Kew and Scilly, and for forecasts of one week and six weeks ahead.

These coefficients have of course no significance; even the value of +0·6 for August in Scilly, standing alone, does not indicate any real relationship between the two sets of numbers.

	KEW.		SCILLY.	
	One Week.	Six Weeks.	One Week.	Six Weeks.
May	0	..	0	..
June	−0·2	−0·4	−0·3	−0·3
July	−0·1	−0·1	+0·1	+0·2
Aug.	+0·3	+0·1	+0·6	+0·4
Sept.	−0·2	−0·2	+0·4	+0·2
Oct.	−0·3	0	−0·1	−0·1

It would appear, therefore, from the foregoing considerations that the forecasts, even for one week ahead, have not any success. They are not, in fact, any better than could be obtained by purely fortuitous predictions, and they agree with what one would expect from chance in a very marked way. Nevertheless, it would be interesting to have some account of the methods used. Lord Dunboyne has made a study of meteorology for many years, and if he were to propound a theory of forecasting it would meet with due consideration from meteorologists.

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Regions of Compression.[1]

By Dr. J. W. EVANS, F.R.S.

II.

THE accumulation of great masses of sediment destroys for the time being the isostatic balance of the earth's crust, which is restored by the outward flow of the plastic sima beneath them to other areas where the amount of deposits is less, or towards mountains subjected to erosion that diminishes the superincumbent load.

As a result of this outflow the surface on which these thick deposits have accumulated is correspondingly lowered. Such a depression of a previously approximately level floor of deposition may be described as a *sedimentation subsidence.*

Thus thick accumulations tend, by the direct result of their weight, to form and fill hollows in the earth's crust, and so provide for their own preservation. Hence it is that, as the late G. W. Lamplugh pointed out, the areas in which geological formations have now their most important outcrops are those in which they were originally deposited in the greatest thickness.

Where such a sedimentation subsidence has occurred, we must distinguish two constituent parts of the resulting structure: the basal or *external* portion, consisting of the older and more consolidated rocks that formed the original floor of the area of deposition, and the *internal* deposits made up of the sediments and other materials accumulated upon the former.

The depth of the accumulated sediments, and consequently the amount of the subsidence, is greater near the foot of the mountain slopes, and gradually diminishes as the distance from the mountains increased, although at equal distances it will be thicker opposite the outflow of important rivers and less where these were absent.

At a greater distance from the region or regions of erosion, where the amount of sediment deposited was less, the accumulation of calcareous material from the growth of organisms or the precipitation of carbonate of calcium, also derived originally in the main from organic sources, must often have played a similar part in causing subsidence by their weight.

The eruption of lava and ashes will have a like result, intensified by the removal of the material from beneath. The general tendency would, however, be for the load and depression to diminish as the distance from the source increased. At the same time, the inflow of the plastic material from the area of maximum sedimentation would add to the effect of the decrease of the load. Ultimately, at a greater distance, where the deposition was still more reduced, elevation would replace depression.

In the period of comparative quiescence that intervenes between paroxysms of earth movements, resulting in folding and thrusting, the horizontal compressive forces in the earth's crust, which had (for the time being) been exhausted, are once more slowly developing and increasing in strength. At last the crust yields to the pressure where the resistance is weakest. Other things being equal, this will be where the solid crust is bent most deeply down in a sedimentation subsidence. There it is no longer flat and horizontal, and directly opposed to the forces of compression. It has consequently very much diminished powers of resistance, precisely as a pillar bent out of the vertical line is incapable of sustaining the same weight as if it were straight and erect. The weakness of the crust in the subsided area is increased by the fact that the depression of the solid floor through some thousands of feet brings the rocks into regions of higher temperature, and the increase in temperature must be accompanied by a considerable decrease in strength, while the unconsolidated deposits of the interior of the subsidence can add little or nothing to its powers of resistance.

Accordingly, it is in a tract of subsidence that the crust gives way under the forces of compression. It is true that these forces operate on the whole surface of the globe, but immediately the portion with least resisting strength yields, however slightly, the remainder of the great circle on which the yielding takes place is released *pro tanto*, adjusting itself by a movement of elastic expansion, so slow that the resistance opposed to it by the viscosity of the subjacent plastic sima is inappreciable.

It must be remembered, however, that, as already indicated, there are other horizontal forces affecting the earth's crust that may increase or diminish the forces of compression locally, and these may in some instances determine whether the crust yields at one subsided tract or another. When such a yielding has taken place, the probability of the crust giving way at another point is at once greatly diminished, at any rate for the time being.

The first effective action of such compressive forces usually antedates by a considerable period the epoch of maximum disturbance, and is as a rule very gradual and gentle, so that it merely narrows slightly and deepens the area of subsidence. The deposition of great thicknesses of a succession of shallow-water strata is usually explained as due to subsidence by way of isostatic adjustment of the earth's crust, to correct the disturbance of equilibrium from the weight of the sediments accumulated. Prof. A. Morley Davies has, however, directed attention to the fact that there is a limit to such an adjustment, because the density of the sediments laid down is less than that of the plastic subcrustal sima displaced.

Let s be the original depth of the sea, and l the

[1] Continued from p. 17.