20

The bureau of the section is authorized and requested to draw up a report on the various practices of the different sciences comprised within the International Geodetic and Geophysical Union with regard to units of measurement and to invite the cooperation of the bureaus of the other sections of the union, with the ultimate object of a common unitary system for all the sciences comprised within the union.

21

The section approves the appointment of a commission to consider the question of the use of geopotential in the geophysical sciences as the vertical coordinate in the representation of the position of a point with reference to the earth for the purposes of geodynamic problems.

The commission representing the different sections of the union is constituted as follows: Seismology, Oddone; meteorology, Shaw; oceanography, Martin Knudson; geodesy, Bulloni and Norland; vulcanology, Tanakadate; magnetism, Chapman; and hydrology, Wallen.

22

In view of the increased importance of the application of meteorological statistics of the weather to the problems of agriculture, dublic health, and other aspects of public economics, the bureau of the section is authorized to ask the International Conference of Directors of Meteorological Réseaux to receive a deputation of the section at a meeting of the directors in 1929 (which may be regarded as a jubilee celebration of the International Meteorological Congress at Rome) in order to urge the consideration of a more scientific grouping of meteorological statistics than the customary one by calendar months of arbitrary and unequal length.

And, further, upon receipt of a favorable reply, the directors of the bureau are authorized to arrange the deputation on behalf of the section.

PERFORMANCE IN LONG-RANGE WEATHER FORECASTING[1]

By CHARLES F. BROOKS

[Clark University, Worcester, Mass., August 18, 1927]

SYNOPSIS

Long-range forecasts are so much desired that any number of unqualified persons issue them without regard for criteria of performance. Among what might be called "fake" forecasts are the almanac, astrological, pseudosolar, and "mathematical" sorts, many of them calamity howls. The "prediction" of climatic normals, forecasts from phenomena on certain dates and from the behavior or aspects of certain animals or plants also belong in this category.

To be of value a forecast must be specific, limited as to place and time, and it must have a probability of more than chance verification. Furthermore, the economic consequences of failures, both in the long run and in a small sequence of years, must be reckoned. A forecast that will not hit the mark four times out of five, or at least once out of every three in succession, can not be of much value, though some claim that a forecast verified only three times out of five would be useful. The uncertainties of meteorological relationships on which any long-range forecasts can now be based are generally too great to permit reputable meteorologists to forecast on expectations of less than 75 or 80 per cent verification. A critical study of the methods now used in the attempts at scientific long-range weather forecasting and an evaluation of their relative merits for different parts of the world is much needed.

Nature of long-range forecasting.—What is long-range weather forecasting? This question at once raises thoughts of forecasting now what the weather for next month, next summer, next fall and winter will be. The long-range forecast is beyond the realm of storms already in existence and which by their movement may be likely to affect us some time next week. Long-range forecasting, dealing with the weather abnormalities of particular months and seasons, therefore, has but little in common with day-to-day forecasting or with its extension, the forecasting on Saturday what the general character of the weather during the coming week will be. (**1**)

Value of and demand for long-range forecasts.—Farmers, city people, merchants, manufacturers, politicians, statesmen, engineers, all would find many uses for general scientific weather forecasts a month or more in advance. The farmer has good need for them. In the opinion of a county farm adviser, for example:

> In general, accurate seasonal forecasting would tend to establish a more permanent type form of agriculture, insure more profitable crops, enable the farmer to replenish and maintain soil fertility and reduce somewhat the hazards of agriculture. (**2**).

For want of such forecasts, western farmers have paid a "rainmaker" thousands of dollars at a time (**3**). Business men (**4**), transportation people (**5**), and water-supply or power engineers (**6**) especially value advance indications of seasonal weather, even when of a general character. "In many lines of goods," says Douglas, "the general character of the weather has a definite and direct influence on sales; in others the effect is present but indirect; therefore, any predictions of the general character of the weather months in advance are of decided value to the business man. Without predictions the weather factor becomes guesswork." (**4**) "Waste of water could be reduced," says Rowe, "thus making it possible to increase the area of agricultural land cultivated." (**6**) In other words, reasonably dependable long-range weather forecasts would reduce the cost of living.

Fake forecasts; almanac, astrological, and others.—The fight against them.—There is no use discussing in detail here those "forecasts" of the almanac kind, detailing or generalizing, on some worthless scheme, the weather usual for each month (**7**). "Poor Robin" (**8**) and Dean Swift's satire on Partridge two centuries ago (**9**) were the opening shots of the long campaign against quack forecasters. Nor need we feel concerned when given "warnings" of weather disasters "impending" a fortnight to a year or more in advance. Howlers of such calamities have been roundly attacked by scientists time and again. In 1875 C. M. Woodward's dramatic exposé of one planetary scheme led the way for other scientific attacks in this country (**10**). Weather Bureau officials and others, notably Cleveland Abbe (**11**), and Garriott (**12**), Moore alone (**13**), and with several other officials (**14**), Wren (**15**), Walz (**16**), Marvin (**17**), Carpenter (**18**), editors (**19**) and other writers have been unsparing of their criticism of the fake or inadequate systems in use in the United States. Here during the past 10 years well over 50 long-rangers of greater or lesser repute have been publishing and, in a great many cases, accepting money for worthless or damaging forecasts. European countries also support quack forecasters in number, against whom the attacks of scientists have been as strong as in the United States (**20**). Hellmann lists 96 by name and analyzes and criticizes their methods (**20**). He characterizes such prophets as "conceited, positive, more or less fanatic, eager for a fray." He says they use the same method against critics—picking out the best hits and keeping the poor ones silent. They are self-praising; they quote

[1] Essentially as presented at U. S. Weather Bureau Staff Meeting, Washington, D. C., May 13, 1926.

letters from people in high positions, and stigmatize meteorologists and scientific societies. Their friends and protectors belong largely to the sensational daily press, which opens its columns to them and occasionally carries some propaganda in their favor. It is difficult to say whether they are honest, says Hellmann, though some surely are (**21**). Probably no country in the world is free. Walker mentions the hold of astrologers and almanacs in India, for example (**22**).

In view of the harm done by spurious warnings Cleveland Abbe was moved to write hopefully that—

> the time must soon come when a general law shall forbid the publication of weather predictions and storm warnings, especially those of a sensational character, by others than properly licensed persons (**23**).

Abbe did not say on what bases licenses could be issued, but it is not unlikely that he had in mind some consideration of the following points: (1) The candidate's training as a meteorologist, (2) his ability to demonstrate the probability of success of forecasts of the sort he proposed to make, and (3) his willingness to present to prospective customers a statement concerning his system of forecasting signed by a committee of, say, three competent scientists.

Predicting climatic normals.—Another type of forecast more respectable than the almanac or astrological guesses, but not real forecasts, is the prediction of climatic normals (**24**). Such forecasts have even been officially made. Our pilot charts, issued by the United States Hydrographic Office with the cooperation of the Weather Bureau, years ago used to carry "forecast for the month" where now they say "average conditions." The Mexican weather service formerly published "Tiempo probable durante el ano méteorologico de 19— en la República Mexicana," (8vo, 8–10 pp.) (**25**). Recently the Signal Corps meteorologist, Capt. B. J. Sherry, was issuing, toward the end of each month, a statement of the normal weather for the succeeding month, calling it a forecast. In the low latitude of Panama the weather is so steady that prediction according to normals would have a verification of 85 per cent, the hydrographer there once told the writer.

Those who predict weather from actual or supposed occurrences on special dates, "critical days," such as the equinoxes, Candlemas, St. Swithin's, or the date of first snowfall, do no better than guesswork (**26**). Hellmann has traced this type of forecasting, based on January, back at least to the eighth century (**27**).

Biological forecasts.—We are amused rather than informed or mislead by the usual autumn pronouncements of this or that old farmer or hunter who has noticed the flight of geese, examined the fur of a woodchuck, looked at a goosebone, observed the nature of a muskrat house, the abundance of nuts in squirrels' stores, and what not. (**28**). Josh Billings in his almanac, in 1870 wrote (**29**):

> When yu see 13 geese walking injun file and toeing in yu can deliberately bet yure last surviving dollar on a hard winter, and grate fluktuousness during the next seazon in the price of cowhide boots.

Some biological forecasters will seek to tell you whether the winter is to begin early or late and about when it is to end, by observing the position and relative length of the central brown division between the black ends of fuzzy caterpillars: And don't look at more than one caterpillar! Such forecasts are about as dependable as that by a Minnesota Indian a few years ago, who expected a cold winter because he saw Neighbor White Man put in a large supply of coal. John Burroughs, however, on observing Arctic birds in the northeastern United States early in December, 1917, gave newspapers a correct forecast of an extraordinarily cold winter to come.

Character and dependability of forecasts.—To say "there will be a cold winter" does not mean much. People want to know for their own locality about when the cold weather will set in; the extent to which mild periods will mitigate the winter; the average degree of cold (**30**) and the number of days and their amounts below the freezing point (**31**), and when spring will come. And they need some proof that the forecast is much better founded than ordinary guesswork. Forecasts must be specific and reasonably accurate if they are to be useful.

"Specific" and "reasonably accurate" are variously interpreted. Some consider a statement of trend up or down, from the preceding year sufficiently explicit (**32**) and 60 to 75 per cent verification a useful degree of accuracy (**33**). But a forecast based on a relationship no closer than this may be no forecast at all. Thus, Walker, in discussing "Some sources of error" (**34**), reminds us of the strong temptation to think there is a relationship if two curves run markedly parallel. The use of changes from year to year instead of the actual values results in a curious paradox. For example, he made a chance drawing of 28 trends, plotted them and then made an inverted plot and moved it one value to the right of the original. The two curves showed a 64 per cent trend relation, while that between the actual values was only 15 per cent, an amount quite useless for forecasting. Another drawing would probably have shown smaller percentages, while the average for a large number of such samplings would be 50 and 0.

On low average verifications, one must be willing to take some risk and have sufficient resources and faith to carry on through the many successive failures likely to occur. Obviously, as is shown by Walker's statement, one trouble with a verification of only 60 per cent is the chance that unrelated variations or errors in the data used may have been responsible for 10 or 20 per cent of the correspondence and that the apparent relationship on which the forecasts may be based is not real. Furthermore, it has been found that a correlation continuing for years may suddenly cease or become opposite (**35**).

Experience in Jamaica.—Most meteorologists, before they will forecast for general issue, must see indications that may be stated quantitatively, a probable vertification, as shown by 50 or 100 years of record, of not less than 75 or 80 per cent, and an extreme unlikelihood of two bad failures in succession. An experience of the late Maxwell Hall, in Jamaica, illustrates this last point:

> Forecasts for monthly rainfall were commenced in 1885 and discontinued in 1886; of these 80 per cent were correct, but the subject required more attention than I could give it, and when a large rainfall was forecast for May, 1886, which proved unusually dry, and when with an average forecast for June, 1886, heavy rains fell June 5 and 6, and floods did great damage, it was clearly time to stop this mode of forecasting (**36**).

If the rains had occurred only a week earlier, his forecast would have been a marked success. Later, another forecast failed, though based on an apparently close relationship between droughts and maximum sun spots published in *Nature* (**49**: 339):

> In 1893 I gave out that that year and the next few years would probably be drier than usual—the sun-spot maximum was then approaching, and 1891 had been unusually wet—but 1893 proved to be still wetter, and it was not until two or three years after the maximum in 1893 that drought was severely felt in certain parts of the island, and the connection preserved (**36**).

Apparently Hall made no further long-range forecasts. His record was too short. Pickering later, with a much longer series of years, confirmed Hall's experience that droughts followed rather than attended sun spot maxima (and minima), and successfully forecast the onset of the severe drought beginning in 1919 (**37**).

Experience with India's monsoon forecasts.—After early failure to achieve sufficient success in long-range forecasting in India, says Walker (**38**)—

> A preliminary examination (in 1908) led to a formula for forecasting the monsoon rainfall of the whole of India, and a relationship [2] of 58 per cent with the actual rainfall was indicated; and during the 16 years 1909–1924, the formula was fully answered by expectations. So small a relationship as 0.58 does not justify a forecast unless the abnormalities are fairly marked; but this condition has been satisfied in nine years out of the 16, and in 8 years out of the 9 the rains were in excess or defect when this was given by the formula.
>
> [Improved formulæ for northwest India and Peninsular rainfall with 0.76 correlation coefficient are now used.]
>
> As we shall need an idea of the values of relationships of this kind for purposes of forecasting, some further consideration is necessary. Taking the simplest case, in which either an excess or defect of rain is predicted, success turns on the condition that the probable error of the estimate of the amount of rain shall be less than the amount of excess (or defect) indicated by the data; and, in fact, smallness in the relationship both diminishes the amount indicated and increases the probable error of the estimate.
>
> THE BASIS OF CALCULATION
>
> If we decide that it is useless to issue forecasts that will not, on the average, be right 4 times out of 5, it follows mathematically that if the relationship be 80 per cent [correlation coefficient 0.8] circumstances will justify a forecast in half the occasion; if 70 per cent there is a 3 to 2 chance against the indication of any one occasion being definite enough; for 50 per cent the odds are 6 tol against; for 40 per cent 18 to 1; for 30 per cent 130 to 1; and for 20 per cent 25,000 to 1. So unless the relationship is of 50 per cent, occasions for a justifiable prediction will occur too rarely for practical purposes. These figures would be modified if forecasts of ["] normal ["] conditions were also made, but the general result would not be fundamentally different.

Later, Sir Gilbert Walker presented a more detailed statement and showed that for successes on the average 4 times out of 5 strong indications at certain times would justify a forecast on a much smaller correlation coefficient than when the indications were more or less uncertain. Thus while we should have to have a correlation coefficient of about 0.8 before we should be justified in making regular forecasts, a correlation coefficient of 0.5 would justify an occasional forecast having a probable success 4 times out of 5 if the forecasted departure were something over twice that required for forecasting with a correlation coefficient of 0.8 (**39**).

In conclusion, Walker says (**40**):

> It must regretfully be admitted that the majority of the methods employed in seasonal predictions have been false; and insistence on strict conformity to the rules—in other words the principles of probability is not mere pedantry. The larger variations of seasonal rainfall, pressure, and temperature are in general not isolated phenomena, but are linked up with big variations in other parts of the earth, so that there is every cause for hopefulness regarding the possibility of understanding and predicting them; but many researches needing time and money are first necessary, and it is highly desirable in the interest of meteorology that as little as possible should be done by careless work to diminish public confidence in the possibilities of long-range forecasting.

Two or three successive failures in a seasonal forecast on the strength of which farmers and business men were governing their operations would mean financial ruin to many. This could not be remedied by many more successes in subsequent years, even supposing, as would be unlikely, the users still retained faith in the forecaster. This is different from the run of the weather. Ruinous strings of years may occur, but the farmer has to take what comes next. A false prediction of a drought one year followed by even a correctly predicted drought the next would constitute a 50 per cent verification that would, if followed, be much worse than the result of a farmer's expecting and preparing for good rains both years.

Beginning with empirical forecasting.—The few dynamic principles of daily and weekly forecasting now known (**41**) are based on experience and investigations involving records of thousands of days or weeks. Corresponding principles of seasonal forecasting on physical grounds, on the contrary, can hardly be built on the 5, 10, 30, 60, or even 100 records of months or seasons of the same name, which constitute our available data, and this for only a fraction of the earth's surface. Over enormous areas we do not know what the weather is or has been. How sure could we be of a forecast for to-morrow if our first daily weather records over an area within one day's weather reach had been made only two or three months ago and not yet mapped for the whole region for any day? Though we did not know the immediate causes of the storms whose appearance and approach were reported, we should, nevertheless, be able to make useful predictions for at least portions of our area, not only from the reports from other places but also from empirically established local sequences, e. g., the normal cyclonic sequence. This appears to be the present status of long-range forecasting. Some forecasts are made for favored points, but scientific long-range weather forecasts are not yet generally available, probably not only because our records are still of insufficient length and world-wide scope to provide adequate bases for them. Meteorologists are mostly agreed that the fundamental problem of long-range forecasting is that of the physical bases of world weather, as yet not fully known, nor, indeed, knowable till the earth is far better covered with a network of stations than at present (**42**). Nevertheless, some, McEwen, for example (**43**), are using empirical rules, which, supported by a working hypothesis, can provide useful forecasts and tide us over the learning period.

Conclusion.—While the bibliography in this paper includes many references to present-day, more or less successful, scientific long-range weather forecasting, it does not pretend to cover this field even in part. A much needed investigation in scientific long-range forecasting is a critical examination of the numerous methods now or formerly employed and an attempt to determine for those found of value the probable applicability to various parts of the world.

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[2] In technical language there was a correlation coefficient of +0.58, implying that an average fraction of 58 per cent of the variations of the actual rainfall would be provided by the forecast.

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BERLAGE ON EAST MONSOON FORECASTING FOR JAVA[1]

By ALFRED J. HENRY

The author points out that curves representing the monthly mean deviations of the meteorological elements from the normal over an extensive area, that includes Australia, the Malay Archipelago, and probably the whole of the Indian Ocean, show a fairly regular periodicity in which a three-year cycle is prominent.

Like all other periodicities thus far discovered, this one breaks down; some disturbing influence reduces the amplitude of the deviations, or even destroys them altogether. The best examples of regular epochs of maximum pressure are those of 1885, 1888, 1891, and 1896, 1899, 1902, respectively, with a break between 1891 and 1896. Another series of oscillations with a distinct three-year period gave maxima in 1911 and 1914, and one might find a regular succession of maxima separated by intervals of three years from 1896 up to 1914, but from the 1914 maximum up to the present date the three-year period seems entirely lost; there is, however, one inportant maximum at the close of 1918, and others follow in 1923 and 1925.

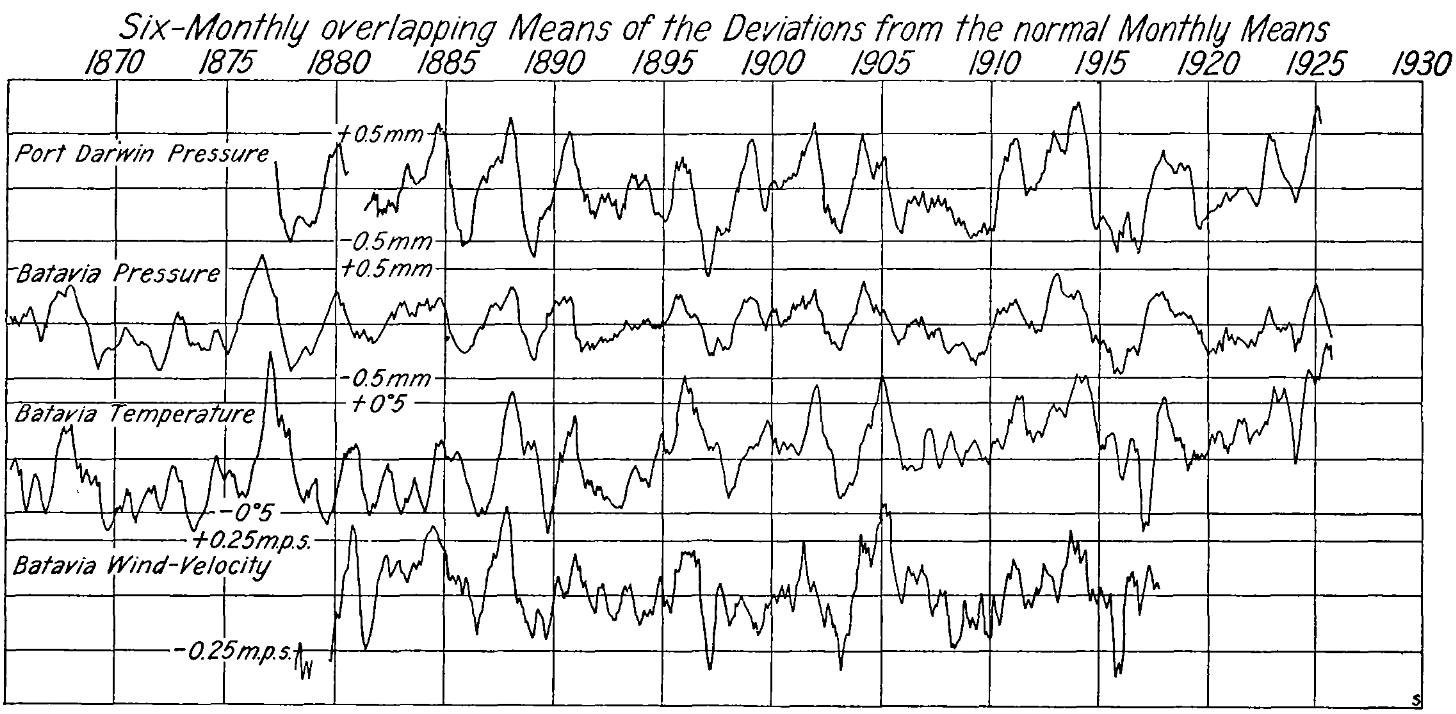

FIG. 1

Figure 1 contains a number of curves showing the march of pressure and temperature at Batavia over a period of 65 years, and for a shorter interval for other elements.

The Port Darwin pressure curve, for reasons given by Braak (1), is unique in that pressure passes from a maximum to a minimum and then to a second maximum within a period of three years.

[1] Koninklijk Magnetisch en Meteorologisch Observatorium te Batavia Verhandelingen No. 20. 1927.