

one of Arrhenius, that the force causing the apparent negation of the law of gravity is the repulsion due to the pressure of sun light.

The preceding article by Dr. S. A. Mitchell presents in a popular way the present condition of our knowledge of the subject that was first discussed, in 1619, by Kepler, whose views were considered quite plausible by Sir Isaac Newton. A more technical description of the steps by which the pressure of light has finally been demonstrated, experimentally, is given in two papers by Professors E. F. Nichols and G. F. Hull, published in the *Astrophysical Journal* for June, 1903, pp. 315-360.

As many readers of the *Review* may be surprised at the results of this computation of the effect of the pressure of a beam of light, and may wonder what the computation of the curvature of a comet's tail has to do with meteorology, the Editor would call their attention to the fact that several computations of the sizes of vapor dust particles floating in the atmosphere have led to results similar to those above given by Dr. Mitchell, so that it is quite plausible that the action of sunlight on the dust floating in the uppermost layers of our atmosphere may give rise to interesting meteorological phenomena.

The so-called zodiacal light is apparently due to the reflection of sunlight from extremely small particles arranged as a ring, which according to some authorities encircles the sun, but according to others must also encircle the earth. The Bishop's ring and other large halos around the sun are undoubtedly diffraction phenomena, produced by the action of minute particles upon sunlight; the size of the particles can easily be calculated. In the *American Meteorological Journal*, vol. 5, April, 1889, p. 539, the editor has given the formula and calculation executed by himself in 1884, when Bishop's ring was first observed in Washington. For red light and  $15^\circ$  as the radius of the halo, the diameter of the particles that caused the diffraction ring was 0.0001 Paris inch, or 2.7 microns. A micron is the thousandth of a millimeter, and is usually designated by  $\mu$ . Smaller particles would make a larger ring. In the voluminous report of the committee on the eruption of Krakatoa, at pp. 232-269, Mr. E. D. Archibald has given the views and calculations of several students of the subject. Thus, p. 248, Riggenbach and Kiessling locate the "dust" that formed the Bishop's ring and the red twilight glows at altitudes in the atmosphere varying from 5 to 22 kilometers, depending on the phases of the phenomena. On p. 257, various calculations are given as to the size of these particles, based on various views as to the optical phenomena. The figures vary between 0.003 millimeter as given by Forel, and 0.001 as given by Floeger.

It will be seen, therefore, that the red twilight glows are apparently explained on the assumption that we have floating in the upper air minute particles of a size comparable with those that Dr. Mitchell has computed for the tail of the comet of 1903. As to the exact nature of these particles, it may be that our use of the word "dust" is slightly misleading. Professor Barus, in his exhaustive researches on the condensation of vapor in the atmosphere, has shown that every substance, whether solid or liquid, is giving off emanations that are probably either molecules, atoms, or corpuscles, and that these constitute the nuclei of the condensation. These may be analogous to the particles of dust, so called, that are floating in our upper atmosphere and in interplanetary space.

We have in the aurora borealis a phenomenon that is as yet only imperfectly understood. Evidently some component of our atmosphere becomes visible. Whether that be helium or argon or nitrogen, as the spectrum suggests, or whether it be this molecular dust; whether the luminous substance causes magnetic disturbance, or, vice versa; whether the disturbance goes from the earth outward, or comes from outer space inward, are questions still under discussion.

We know that Krakatoa sent its dust outward, while meteors and comets may bring their dust to us inward. In either case, the sunlight would act upon them alike, and the study of the phenomena going on many miles above the ground can not be neglected by that modern meteorology which aims to study the whole atmosphere by every method that can be devised.—  
Ed.

#### THE PROMOTION OF METEOROLOGY.

During the recent session of the Fifty-eighth Congress, Senator Bard, of California, at the earnest request of one of his constituents, introduced a bill (Senate bill No. 5277) "To promote further discovery and research in meteorology," which was read twice and referred to the Committee on Agriculture and Forestry. The originator and special promoter of this bill, an active attorney of Los Angeles, Cal., and friend of a well known long-range planetary forecaster, announces that he desires the bill to stand on its merits. The Chief of the Weather Bureau and his staff of advisers are not able to see any merit in the bill. The promoter sent a copy to Prof. J. M. Pernter, Director of the Central Institute for Meteorology at Vienna, Austria, whose lecture on forecasting had been published in the *MONTHLY WEATHER REVIEW* for December, 1903. As Professor Pernter has sent us a copy of his reply, we take pleasure in printing the correspondence, as he suggests.

Letter from the Director of the Imperial Royal Central Institute for Meteorology and Geodynamics.

[Translation.]

VIENNA, HOHE WARTE, *May 26, 1904.*

DEAR COLLEAGUE: I learn that the Weather Bureau has translated my lecture "Allerlei Methoden das Wetter zu prophezeien" (Various Methods of Forecasting the Weather) into English, and distributed it to its observers. Some of these observers have addressed letters to me on the subject; in particular an attorney in Los Angeles has not only written, but has communicated to me a bill introduced by Mr. Bard in the Senate of the United States on March 26, 1904. In his letter this gentleman says that it was he, himself, who caused the bill to be introduced by Senator Bard. He asks whether I am not of the opinion that by means of this bill one would attain to the correct physical principles of weather forecasting? I have replied to his question and send you, herewith, a copy of my answer to be made use of as you may think proper.

However, I see that the bill, after its second reading, was referred to the Committee on Agriculture and Forestry and will, therefore, for the time being remain in conference. Were I an American, I would have my letter published in some American magazine or newspaper in order to prevent this bill from becoming law. If you think it advisable to publish it, you are at liberty to do so.

May I ask you to send me a copy of the translation of my lecture "Allerlei Methoden, etc.?"

With the highest regard, I remain, very respectfully,

(Signed) J. M. PERNTER.

Copy of the letter above referred to.

[Translation.]

CENTRAL INSTITUTE FOR METEOROLOGY AND GEODYNAMICS,

*Vienna, Hohe Warte, May 21, 1904.*

DEAR SIR: The object sought to be attained by the bill is very well considered and important; it is much to be desired that large sums of money should be devoted to the promotion of good forecasts of the weather and especially to the discovery of the physical basis of weather forecasts, since the ultimate attainment of this object is worthy, not only of the labor of the noble, but also of the treasure of the state.

While, therefore, I welcome the bill from the standpoint of the appropriation of funds for the investigation and improvement of weather predictions, still, on the other hand, the method by which it is sought to attain this great object appears to me to be very doubtful. A competition is, indeed, in itself not to be condemned, if the most competent specialists, of clear and incorruptible judgment and in independent positions, be selected as arbiters. This independence does not, however, consist in the fact, as laid down in the bill, that the three jurors in question shall not be allowed to accept any Government position, as that is quite irrelevant to the verdict, but it is much more important that they shall not be prejudiced in any way against any of the competitors. Through the provision of the bill that the judges shall not be in Government employ, the most competent specialists in America, the officials of the United States Weather Bureau, as well as those in the meteorological service of the individual States, will be excluded. Under such circumstances, it would be best for the selected universities to decline to name candidates for jurors.

Secondly, the bill prescribes that the search for the correct basis of weather forecasts shall be carried on according to the method which in my lecture I call the heuristic method.<sup>1</sup> Although this method, when used with all possible precaution, is in many cases admissible and may eventually lead to the desired goal, it ought, properly speaking, to be employed in the further pursuit of science only in such a manner that exact research will proceed in the standard way, following the genetic and causal methods, and be only incidentally occupied with the heuristic method. In other words, it is dangerous to limit one's self to the heuristic method; this method has in it an element of inaccuracy which up to this time has always manifested itself in the investigation of weather forecasts, and which is not to be eliminated notwithstanding the exact provisions contained in the bill for determining the verifications of the forecasts. It would require too much time for me to go deeper into this question. I will, however, point out the necessarily disagreeable consequences in which this competition will involve the bill.

There is no doubt but that, when this competition becomes known, many hundreds of persons will, year after year, send their prognostications to the three juror-colleagues for examination. Those poor jurors! However, these latter will be well paid and, therefore, they will perhaps be able to endure the frightful ordeal! But there can be no doubt that among the many hundreds who will send in their forecasts there will not be ten who, in case they are required to explain from the beginning the principles upon which their predictions are based, will not be rejected with derision or indignation by the jurors and forbidden to take part in the competition. Now, shall all of these utterly impossible principles—to the torment of the judges—nevertheless be allowed consideration in the investigation of the true physical basis of weather forecasts? Shall any and every one be permitted to submit weather predictions and his investigation of fundamental principles to the judges, instead of the principles on which they are based being first submitted to a preliminary test, and those only accepted which successfully pass that test? Does not logic demand that

<sup>1</sup>The "heuristic" method, as the term is used by Pernter, is not the strict, logical, inductive method, that considers all the observations first, but consists in inventing or devising a method of forecasting and then endeavoring to find agreements between the forecasts and the weather that shall establish the correctness of the principles on which the forecasts are based. It is a method that can lead to the discovery of the laws of nature only under the most fortunate and unusual combination of circumstances. To assume that the earth is round and then to test this assumption by the observation of phenomena is an example of the heuristic method. To first observe many phenomena and conclude from them that the earth must be round is the strict, logical, inductive method. To accept certain principles as being well established and then deduce their necessary consequences, even though these consequences have never been observed, is the true deductive method.—F. O. S.

the process be reversed and require that the nature of the basis be first demanded, and that only those be admitted to the competition who can furnish a rational basis and not one that from the very outset is physically impossible? One should not blindly load the judges with the great burden of a strict scientific test quite gratuitously for every would-be weather prophet. The object of the whole competition is expressly announced to be the discovery of a true physical basis for weather predictions. How can this object be attained by admitting every one to the competition, even those who have not the faintest conception of such a basis? Such a proceeding is in the highest degree objectionable.

The so-called heuristic method is in itself not entirely free from uncertainty. Not that it is impossible to handle it accurately, but because this accurate manipulation is attended with very great difficulties, which even the most experienced and most accurate investigator can overcome only with great labor. To cite only one example: The bill prescribes that the forecasts of rain shall be made for any three of the following States: Massachusetts, New York, Pennsylvania, District of Columbia, Georgia, Ohio, Minnesota, Missouri, Kansas, Texas, or California. It is, therefore, left to the observer to choose which States he will take. Now, assuming the correctness of the principles on which his forecasts are based, this would imply that he can just as easily make the prediction for all the other States at the same time, whereas, the jurors can not positively determine that the forecast is based on a correct principle if it is to be verified in three States only.

Again, it is prescribed that the prediction shall extend over the six months, March–August, 1905, or one of the succeeding years, but in every case only over a half year. This is undoubtedly far too short a period for an accurate test of any fundamental principle; in order to be able to lay claim to a strict, scientifically correct, accurate trial, these predictions should be furnished and tested for a period of at least ten consecutive years. It is quite possible that a prediction for a single year may be accidentally verified, without any bearing on the question whether a correct principle was used in making the forecasts. I remember an example often cited: The editor of a calendar in Moravia had, for the ordinary weather predictions, such as are usually introduced into weather calendars, relied upon a collaborer, who, however, failed him. In his despair he seized upon a calendar for south Africa, which he happened to have, for the year just ending, and simply copied the weather predictions contained therein into his calendar for the following year. And, behold! he had predicted the weather better than all the other calendars, and he was often appealed to as to what method or principles he had used. It would be very comical in this case to speak of his discovery of a physical basis for weather forecasts for Moravia! Or would it be correct to lay down the principle that the weather in Moravia is the same as the weather shown in the calendar for the preceding year in south Africa? Whether this really happened, however, is more than doubtful. The editor of the calendar in question was the next year convinced that he owed his luck to an accidental coincidence which did not recur in the following year.

Finally, the method for determining successful predictions which, most remarkable to say, is prescribed to the jurors in the bill will certainly never lead to the desired end. Those cases must be counted as verified which are above or below the normal rainfall and to that extent agree with the predictions. But when the rain is only a trifle above or below the normal shall this be counted as a verification? On the other hand, when it is only a trifle over or under the normal is it a failure? Should an agreement with the normal be a half verification? It may certainly be predicted that by this kind of test a decided verdict for or against can not be attained.

It seems to me most unbecoming for professional men,

nominated by universities for appointment as jurors, to receive instructions and commands from legislators who are not professional men as to what they must do in the treatment of purely scientific questions, or as to how they must proceed in a strictly scientific investigation. These specialists will certainly make use of the most exact methods, because this is their usual habit of work; the methods recommended by the bill are not in themselves sufficiently accurate, and can not be made so except by the hands of experts and by making use of necessary modifications.

Furthermore, I am of the opinion that the discovery of the correct physical basis can never be attained by a competition of this kind. This basis will never be discovered by means of experiments in predictions, which are for the most part matters of personal judgment, but only through long continued, rigidly exact, genuine research, with the aid of physical methods, by men equipped with a complete knowledge of physical, meteorological, and mathematical sciences. This is, without doubt, one of the most difficult and complex of all the problems of physics and, therefore, it can only be by means of the devotion of the most profound erudition and many years of research, combined with occasional strokes of genius, that ultimately, if ever, it will be granted to mankind to solve the problem of weather forecasting. Work, hard and thorough work for many, many years, and not a game of chance in experimental predictions, is what is required in this matter.

The method prescribed in the bill is, therefore, already quite hopeless, because it tacitly assumes that some one now living is in possession of the correct physical principles, for it is only in this case that the bill will, by the methods that it proposes, lead to the knowledge of these principles. Ordinarily, I do not like to express myself in an apodictic manner, but in this case I do not hesitate to declare that it is absolutely sure and certain that, at the present time, no human being is in possession of the knowledge of the true physical basis for weather predictions. You will say, "This is true, but if one were only in partial possession of only one of the principles that would already be an advantage." That is true, but certainly one does not need to pay such a high price for this, for all that can be accomplished by a partial knowledge of true physical principles is now being done by the meteorological institutions; and it is certain that no one knows of a single principle of importance more than those known to the experts of these institutions, who, in their predictions, certainly make use of all principles now known, as I have already demonstrated in my lecture. It therefore seems to me certain that competition, as shown by the bill, must remain entirely fruitless.

I would, however, strongly indorse a bill authorizing the devotion of \$150,000 to the prosecution of accurate, extensive investigations covering the whole subject of the improvement of weather predictions. There might be some men—let us with the present bill say three men—whom we could secure men of perfect professional education (perhaps *one*, with a sufficient number of assistants, might suffice). They should, if possible, be men of considerable reputation in meteorology, to whom the one sole duty should be assigned of investigating the true principles of weather forecasting; who should, among other things, subject the following relations to the most thorough and detailed investigation: (1.) The connection between the weather and atmospheric pressure, (2) the conditions, manner, and causes of the transition from one style of distribution of atmospheric pressure to another, from day to day, as well as for longer periods; (3) the connection of the solar and other cosmic processes with the terrestrial and especially the meteorological phenomena. The predestinate and, undoubtedly, the most suitable institution for this purpose is the United States Weather Bureau. By this means, the \$150,000 will most assuredly be expended in the man-

ner most profitable to weather forecasting and the predictions will, without doubt, make notable progress.

If, on the other hand, we follow the plan proposed by the bill, the \$150,000 will certainly be saved to the treasury, since it will never be possible to award the prize to anyone. The three jurors will be uselessly tormented and disturbed, and hindered in their own scientific investigations; and they will have to be paid \$10,000 without having discovered a prize winner, if the jurors are honorable, strict specialists.

I have replied to your questions technically, and with a sincere love of the truth, such as is to the scientist the only justification of his activity. Unfortunately, your views concerning this bill do not apparently agree with mine. I hope, however, that mature reflection will lead you to concur in my conclusions.

With the highest regard, I remain, very respectfully,  
(Signed) J. M. PERNTER.

#### RELATION OF PRECIPITATION TO YIELD OF CORN.

By J. WARREN SMITH, Section Director, Weather Bureau, assisted by WILLIAM D. GIBBS, President of the New Hampshire State College.

[Summary of an article prepared for the Year Book of the U. S. Department of Agriculture, for 1903.]

All cultivators of the soil recognize the important relation between precipitation and crop yield. Johnson said in 1870, *How Crops Feed*, p. 216 :

It is a well recognized fact that next to temperature the water supply is the most influential factor in the production of a crop.

Yet we believe that few people have any appreciation of the effect of an abundant water supply upon the ultimate yield of crops. Whitney says, *Bulletin No. 22, Bureau of Soils*, p. 63:

On the average farm the great controlling factor in the yield of crops is not the amount of plant food in the soil, but is a physical factor, the exact nature of which is yet to be determined.

Later, on same page, he says :

The results of these investigations also seem to indicate that the actual quantity of water a soil can furnish the plant, irrespective of the percentage of water actually present in the soil, has probably a very important influence on the yield.

It is self-evident that to have water furnished to the plants in any soil in sufficient quantities there must be an abundant supply available, either through actual rainfall or by irrigation. So that, other things being equal, the results of the investigations of the Bureau of Soils seem to agree with the results of experience, viz : Heavy rainfall, large yields; light rainfall, light yields. Moreover, in a latitude and at an elevation favorable for the production of crops, precipitation is more important than temperature in its effect upon the yield.

It was with something of this thought in mind that the writer of this article began the preparation of the accompanying diagrams. Yet he was not prepared for the remarkable confirmation of the theory, or the close relation between the yield of corn and the precipitation in certain definite short periods during the growth of the crop.

Inasmuch as the greater part of the corn produced in the United States is grown in the central part of the country we have considered only the following States : Ohio, Indiana, Illinois, Iowa, Nebraska, Kansas, Missouri, and Kentucky.

As the area of greatest corn production does not include all of Ohio, Kentucky, Kansas, or Nebraska, we probably should have considered only the western part of Ohio and Kentucky and the eastern parts of Nebraska and Kansas for both yield and rainfall. (Quite likely Kentucky should have been left out of the discussion altogether.) We were anxious, however, to include all the principal corn producing districts, and the data were more readily available by States than by counties.

It is not practicable to reproduce all the original diagrams in this article; hence, the three most important have been selected.