Bureau have been found valuable aids to engineers and investors. Each State is a section of the Climate and Crop Service of the Bureau, in charge of an official whose duty it is to establish stations of observation. These stations are possible through the voluntary cooperation of public spirited citizens willing to act as observers. Observations include a record of the temperature, rainfall, snowfall, cloudiness, and prevailing winds; reports are rendered monthly, and after examination and computation at the section center, the values are published in quarto form about the 15th of the following month. These printed reports, with the addition of the annual summary, furnish a convenient source of information on climatic features, and may be had free of charge upon application. A considerable number of the stations have been in operation a great many years, while reports from others cover a comparatively short period. If the monthly publication does not give a report from the locality desired, application should be made to the section director for the information, as a copy of all records made at any time within the State in question is on file; thus, in Colorado, the number of discontinued stations is three times as large as that of the stations at present in operation, although these number nearly one hundred.

Records from mountain stations being especially important in the study of precipitation, efforts have been directed, for a number of years, toward increasing the number of observers on the upper watersheds, and while the number of such observers now cooperating is larger than ever before, there is room for a great many more in every section of the arid region.

The importance of these rainfall stations is not fully appreciated by the general public. In the beginning the work of reclamation will necessarily be confined to the larger and more promising undertakings, leaving relatively small ones for later consideration. When these latter are taken in hand full information must be available regarding the rainfall and its seasonal distribution, and whether it comes in small amounts or in an occasional downpour or cloud-burst. It lies within the power of this Congress to do much to encourage persons to undertake rainfall observations in the higher altitudes of the different States. As regards the furnishing of instrumental equipment, I feel sure there will be no difficulty, for Professor Moore, Chief of the Bureau, has the hearty cooperation of the Honorable Secretary of Agriculture in all matters that will further the interests of irrigation.

HURRICANE IN THE GULF OF MEXICO.

By Capt. J. ELLIGERS, jr.

Mr. W. C. Devereaux, Assistant Observer, Havana, Cuba, forwards the following report by Capt. J. Elligers, jr., captain of the Norwegian steamship *Jason*, with reference to the hurricane of August 14 and 15. The exact location of the vessel is not known, other than as given in the extract from Captain Elligers's report:

We received a telegram at Tampico on August 11 from the United States Weather Bureau, stating that a hurricane was approaching the Mexican coast, but, as the following day did not show any signs of the approach of the storm and as our boat was new and well loaded, we sailed with a cargo of cattle at 2 p. m. of the 13th, direct for Havana. The weather was clear, with a light breeze from the east-northeast and a normal barometer. After midnight of the 13th the wind increased to a brisk breeze from the north-northeast. At 6 a. m. of the 14th, when we were about 150 miles east of Tampico, a gale suddenly blew up from the north, with heavy rain, the barometer began to fall rapidly, and the sea became very rough. The wind continued from the north with terrible force until 9 p. m. of that day, but seemed to be strongest between 12 noon and 4 p. m.; the rain fell in torrents, the air was sticky and much warmer than on the preceding day, and the sea was very rough. The barometer reached the lowest point at 8:30 p. m., one reading 29.24 and the other reading 29.13 (they were together before the storm). From 9 to 9:20 p. m. there was a dead calm; the rain had stopped, but the sea was terrible: the only thing I can compare it to is the boiling water in a mammoth kettle. At 9:20 p. m. the wind turned to south, through east, and the storm came with a sudden rush from that direction, and the wind blew with great force until 6 a. m. of the 15th. I can not estimate the velocity of the wind, but it was very high; I had to hold myself on the boat by clinging to a stanchion with both arms, and the wheelman had to stand in front of the wheel so that the wind would blow him against the wheel and not away from it.

During the 15th the storm gradually moderated, and on the 16th the hatches, which had been closed for three days, were opened and 270 dead cattle were removed from a cargo of 613. It was by far the worst storm I ever encountered, and I have been a sailor all my life.

Abstract of log of steamship Jason.

Date.	Barometer.		Remarks.
1903.	*Mm.*	*Inches.*	
Aug. 13, 2 p. m.	762.0	30.00	Fine weather; light breeze from ene.; left Tampico.
4 p. m.	762.2	30.01	Fine weather: light breeze from ene.
8 p. m.	762.0	30.00	Do.
14, 12 midnight.	762.0	30.00	Fine weather; fresh breeze from ene.
4 a. m.	760.0	29.92	Cloudy; strong breeze nne.
5 a. m.	760.0	29.92	Do.
6 a. m.	759.8	29.91	Heavy rain; wind north, blowing up suddenly to storm.
7 a. m.	759.5	29.90	Heavy rain; wind north; storm; heavy sea.
8 a. m.	759.0	29.88	Do.
9 a. m.	758.0	29.84	Heavy rain; wind north, increasing to hurricane; heavy sea; warm and oppressive.
10 a. m.	757.0	29.80	Do.
11 a. m.	756.0	29.76	Do.
12 m.	755.0	29.72	Heavy rain; wind north, hurricane; heavy sea; warm and oppressive.
1 p. m.	752.5	29.63	Do.
2 p. m.	751.0	29.57	Do.
3 p. m.	750.0	29.53	Do.
4 p. m.	749.0	29.49	Do.
5 p. m.	747.0	29.41	Do.
6 p. m.	745.0	29.33	Do.
7 p. m.	744.0	29.31	Do.
8 p. m.	743.5	29.27	Do.
8:30 p. m.	742.8	29.24	Do.
9 p. m.	743.6	29.25	Dead calm.
10 p. m.	744.5	29.31	Hurricane.
15, 12 midnight.	745.0	29.33	Do.
4 a. m.	750.0	29.53	Do.
8 a. m.	759.0	29.88	Storm.
12 m.	761.5	29.98	Strong gale.

At 9 p. m. of the 14th a great calm, and then the wind turned from north through east to south. At 9:20 the cyclone came with a sudden rush from south, glass rising. Wind blew with terrible force right up to 6 a. m. of the 15th; after that time it went slowly down to storm, strong gale, and fresh breeze at 12 midnight of August 15–16. The sea was very rough at the time and there were heavy rain squalls all the time. During the hurricane the temperature of the air was about 31° Celsius, and before the hurricane it was not more than 27°–29° in the middle of the day. Sunday morning, the 16th, the wind was fresh breeze from east and the sea very moderate.

METHODS OF METEOROLOGICAL INVESTIGATION.

By W. N. SHAW, Superintendent of the Meteorological Office, London.

An address before Section A, of the British Association for the Advancement of Science, at Southport, England, September 10, 1903.

[Reprinted from the author's corrected separate print.]

In opening the proceedings of the subsection devoted to cosmical physics, which we may take to be the application of the methods and results of mathematics and physics to problems suggested by observations of the earth, the air, or the sky, I desire permission to call your attention to some points of general interest in connection with that department which deals with the air. My justification for doing so is that this is the first occasion upon which a position in any way similar to that which I am now called upon to fill has been occupied by one whose primary obligations are meteorological. That honour I may with confidence attribute to the desire of the Council of the Association to recognise the subject so admirably represented by the distinguished men of science who have come across the seas to deliberate upon those meteorological questions which are the common concern of all nations, and whom we are specially glad to welcome as members of this subsection. Their presence and their scientific work are proof, if proof is required, that meteorologists can not regard meteorological problems as dissociable from section A; that the prosecution of meteorological research is by the study of the kinematics, the mechanics, the physics, or the mathematics

of the data compiled by laborious observation of the earth's atmosphere.

But this is not the first occasion upon which the address from the chair of the subsection has been devoted to meteorology. Many of you will recollect the trenchant manner in which a university professor, himself a meteorologist, an astronomer, a physicist, and a mathematician, dealt candidly with the present position of meteorology. After that address I am conscious that I have no claim to be called a meteorologist according to the scientific standard of section A. Professor Schuster has explained—and I can not deny it—that the responsible duty of an office from which I can not dissociate myself is signing weather reports; and I could wish that the duty of making the next address had been intrusted to one of my colleagues from across the sea. But as Professor Schuster has set forth the aspect of official meteorology, as seen from the academic standpoint, with a frankness and candour which I think worthy of imitation, I shall endeavour to put before you the aspect which the relation between meteorology and academic science wears from the point of view of an official meteorologist whose experience is not long enough to have hardened into that most comfortable of all states of mind, a pessimistic contentment.

Meteorology occupies a peculiar position in this country. From the point of view of mathematics and physics, the problems which the subject presents are not devoid of interest, nor are they free from that difficulty which should stimulate scientific effort in academic minds. They afford a most ample field for the display of trained intellect, and even of genius, in devising and applying theoretical and experimental methods. And can we say that the work is unimportant? Look where you will over the countries which the British Association may be supposed to represent, either directly or indirectly, and say where a more satisfactory knowledge of the laws governing the weather would be unimportant from any point of view. Will you take the British Isles on the eastern shores of the Atlantic, the great meteorological laboratory of the world, with the far-reaching interests of their carrying trade; or India, where the phenomena of the monsoon show most conspicuously the effects of the irregular distribution of land, the second great meteorological cause, and where recurring famines still overstrain the resources of administration. Take the Australasian colonies and the Cape, which, with the Argentine Republic, where Mr. Davis is developing so admirably the methods of the Weather Bureau, constitute the only land projections into the great southern ocean, the region of "planetary meteorology." Australia, with its periods of paralysing drought; the Cape, where the adjustment of crops to climate is a question of the hour; or take Canada, which owns at the same time a granary of enormous dimensions and a large portion of the Arctic Circle; or take the scattered islets of the Atlantic and Pacific or the shipping that goes wherever ships can go. The merest glance will show that we stand to gain more by scientific knowledge, and lose more by unscientific ignorance of the weather, than any other country. The annual loss on account of the weather would work out at no inconsiderable sum per head of the population, and the merest fraction of success in the prevention of what science must regard as preventable loss would compensate for half a century of expenditure on meteorological offices. Or take a less selfish view and consider for a moment our responsibilities to the general community of nations, the advantages we possess as occupying the most important posts of observation. If the meteorology of the world were placed, as perhaps it ought to be, in the hands of an international commission, it can be no exaggeration to say that a considerable majority of the selected sites for stations of observation would be on British soil or British ships. We can not help being the most important agency for promoting or for obstructing the extension of meteorological science. I say this bluntly and perhaps crudely because I feel sure that ideas not dissimilar from these must occasionally suggest themselves to every meteorologist, British or foreign; and if they are to be expressed—and I think you will agree with me that they ought to be—a British meteorologist ought to take the responsibility of expressing them.

And how does our academic organisation help us in this matter of more than parochial or even national importance? There was a time when meteorology was a recognised member of the large physical family and shared the paternal affection of all professors of physics; but when the poor nestling began to grow up and develop some individuality, electricity developed simultaneously with the speed of a young cuckoo. The professors of physics soon recognised that the nest was not large enough for both, and with a unanimity which is the more remarkable because in some of these academic circles utilitarianism is not a condition of existence, and pure science, not market value, might be the dominant consideration—with singular unanimity the science which bears in its left hand, if not in its right, sources of wealth beyond the dreams of avarice was recognised as a veritable Isaac, and the science wherein the fruits of discovery must be free for all the world, and in which there is not even the most distant prospect of making a fortune—that science was ejected as an Ishmael. Electrical engineering has an abundance of academic representatives; brewing has its professorship and its corps of students, but the specialised physics of the atmosphere has ceased to share the academic hospitality. So far as I know the British universities are unanimous in dissembling their love for meteorology as a science, and if they do not actually kick it downstairs they are at least content that it has no encouragement to go up. In none is there a professorship, a lectureship, or even a scholarship, to help to form the nucleus of that corps of students which may be regarded as the primary condition of scientific development.

Having cut the knot of their difficulties in this very human but not very humane method, the universities are, I think, disposed to adopt a method of justification which is not unusual in such cases; indications are not wanting which disclose an opinion that meteorology is, after all, not a science. There are, I am aware, some notable exceptions; but do I exaggerate if I say that when university professors are kind enough to take an interest in the labors of meteorologists, who are doing their best amid many discouragements, it is generally to point out that their work is on the wrong lines; that they had better give it up and do something else? And the interest which the universities display in a general way is a good-humoured jest about the futility of weather prophecy, and the kindly suggestion that the improvement in the prediction of the next twenty-four hours' weather is a natural limit to the orbit of an Ishmaelite's ambition.

Under these circumstances such an address as Professor Schuster's is very welcome: it recognises at least a scientific brotherhood and points to the responsibility for a scientific standard; it even displays some of the characteristics of the Good Samaritan, for it offers his own beast on which to ride, though it recommends the unfortunate traveller to dispose of what little clothing the stripling has left to provide the two pence for the host.

It is quite possible that the unformulated opinion of the vast majority of the people in this country who are only too familiar with the meteorological vagaries of the British Isles is that the weather does just as it pleases; that any day of the year may give you an August storm or a January summer's day; that there are no laws to be discovered, and that the further prosecution of so unsatisfactory a study is not worth the time and money already spent upon it. They forget that there are countries where, to judge by their languages, the

weather has so nearly the regularity of "old time" that one word is sufficient to do duty for both ideas. They forget that our interests extend to many climates, and that the characteristics of the eastern shores of the North Atlantic are not appropriate to, say, western tropical Africa. That may be a sufficient explanation of the attitude of the man in the street, but as regards the British universities dare I offer the difficulty of the subject as a reason for any want of encouragement? Or shall I say that the general ignorance on the part of the public of the scientific aspirations and aims of meteorologists and of the results already obtained is a reason for the universities to keep silence on the subject? With all respect I may say that the aspect which the matter presents to official meteorologists is that the universities are somewhat oblivious of their responsibilities and their opportunities.

I have no doubt that it will at once be said that meteorology is supported by government funds, and that alma mater must keep her maternal affection and her exiguous income for subjects that do not enjoy state support. I do not wish just now to discuss the complexities of alma mater's housekeeping. I know she does not adopt the same attitude with regard to astronomy, physics, geology, mineralogy, zoology, or botany, but let that pass. From the point of view of the advancement of science I should like to protest against the idea that the care of certain branches of science by the state and by the universities can be regarded as alternative. The advancement of science demands the co-operation of both in their appropriate ways. As regards meteorology, in my experience, which I acknowledge is limited, the general attitude towards the department seems to be dictated by the consideration that it must be left severely alone in order to avoid the vicious precedent of doing what is, or perhaps what is thought to be, government work without getting government pay, and the result is an almost monastic isolation.

There is too much isolation of scientific agencies in this country. You have recently established a national physical laboratory, the breath of whose life is its association with the working world of physics and engineering, and you have put it—where? At Cambridge, or anywhere else where young physicists and engineers are being trained? No; but in the peaceful seclusion of a palace in the country, almost equidistant from Cambridge, Oxford, London, and everywhere else. You have established a meteorological office, and you have put it in the academic seclusion of Victoria street. Monastic isolation may have its advantages, but I am perfectly certain it is not good for the scientific progress of meteorology. How can one hope for effective development without some intimate association with the institutions of the country, which stand for intellectual development and the progress of science?

I could imagine an organisation which by association of the universities with a central office would enable this country, with its colonies and dependencies, to build up a system of meteorological investigation worthy of its unexampled opportunities. But the co-operation must be real and not one-sided. Meteorology, which depends upon the combination of observations of various kinds from all parts of the world, must be international, and a government department in some form or other is indispensable. No university could do the work. But whatever form government service takes it will always have some of those characteristics which, from the point of view of research, may be called bondage. On the other hand, research, to be productive, must be free with an academic freedom, free to succeed or fail, free to be remunerative or unremunerative, without regard to government audits or House or Commons control. Research looks to the judgment of posterity with a faith which is not unworthy of the churches, and which is not among those excellent moral qualities embodied in the controller and auditor general. *Die academische Freiheit* is not the characteristic of a government department. The opportunity which gave to the world the "Philosophiæ Naturalis Principia" was not due to the state subvention of the deputy mastership of the mint, but to the modest provision of a professorship by one Henry Lucas, of whose pious benefaction Cambridge has made such wonderful use in her Lucasian professors.

The future of meteorology lies, I believe, in the association of the universities with a central department. I could imagine that Liverpool or Glasgow might take a special interest in the meteorology of the sea; they might even find the means of maintaining a floating observatory; and when I say that we know practically nothing of the distribution of rainfall over the sea, and we want to know everything about the air above the sea, you will agree with me that there is room for such an enterprise. Edinburgh might, from its association with Ben Nevis, be desirous of developing the investigation of the upper air over our land; in Cambridge might be found the author of a book, on the principles of atmospheric physics, worthy of its Latin predecessor; and for London I can assign no limited possibilities.

If such an association were established I should not need to reply to Professor Schuster's suggestion for the suppression of observations. The real requirement of the time is not fewer observations, but more men and women to interpret them. I have no doubt that the first expression of such an organisation would be one of recognition and acknowledgment of the patience, the care, the skill, and the public spirit—all of them sound scientific characteristics—which furnish at their own expense those multitudes of observations. The accumulated readings appal by their volume, it is true, but they are, and must be, the foundation upon which the scientific structure will be built.

So far as this country is concerned, when one puts what is in comparison with what might be, it must be acknowledged that the tendency to pessimistic complaisance is very strong. Yet I ought not to allow the reflections to which my predecessor's address naturally give rise to be too depressing. I should remember that, as Dr. Hellmann said some years ago, meteorology has no frontiers, and each step in its progress is the result of efforts of various kinds in many countries, our own not excluded. In the presence of our guests to-day, some of whom know by practical experience the advantages of the association of academic liberty with official routine, remembering the recent conspicuous successes in the investigation of the upper air in France, Germany, Austria, Russia, and the United States, and the prospect of fruitful co-operation of meteorology with other branches of cosmical physics, I may well recall the words of Clough:

> Say not the struggle nought availeth ....
> And as things have been they remain.
>
> If hopes were dupes, fears may be liars:
> It may be, in yon smoke concealed
> Your comrades chase e'en now the fliers,
> And, but for you, possess one field.
>
> For while the tired waves, vainly breaking,
> Seem here no painful inch to gain,
> Far back, through creeks and inlets making,
> Comes silent, flooding in, the main.
>
> And not by eastern windows only,
> When daylight comes, comes in the light;
> In front, the sun climbs slow, how slowly,
> But westward, look, the land is bright.

Official meteorologists are not wanting in scientific ambitions and achievements. It is true that Professor Hann, whose presence here would have been so cordially welcomed, left the public service of Austria to continue his services to the world of science by the compilation of his great handbook, and Snellen is leaving the direction of the weather service of the

Netherlands for the more exclusively scientific work of directing an observatory of terrestrial physics; but I am reminded by the presence of Professor Mascart of those services to meteorological optics and terrestrial magnetism that make his place as president of the International Committee so natural and fitting; and of the solid work of Angot on the diurnal variation of the barometer and the reduction of barometric observations for height that form conspicuous features among the many valuable memoirs of the Central Bureau of Paris.

Of the monumental work of Hildebrandsson in association with Teisserenc de Bort on clouds, which culminated quite recently in a most important addition to the pure kinematics of the atmosphere, I hope the authors will themselves speak. Prof. Willis L. Moore's presence recalls the advances which Bigelow has made in the kinematics and mechanics of the atmosphere under the auspices of Professor Moore's office, and reminds us of the debt of gratitude which the English-speaking world owes to Prof. Cleveland Abbe, of the same office, for his treatment of the literature of atmospheric mechanics.

If General Rykatcheff had only the magnificent climatological atlas of the Russian Empire to his credit he might well rest satisfied. Professor Mohn's contributions to the mechanics of the atmosphere are examples of Norwegian enterprise in the difficult problems of meteorology, while Dr. Paulsen maintains for us the right of meteorologists to share in the results of the newest discoveries in physics. Davis's enterprise in the far south does much to bring the southern hemisphere within our reach, while Chaves places the meteorology of the mid-Atlantic at the service of the scientific world.

Need I say anything of Billwiller's work upon the special effect of mountains upon meteorological conditions, or of the immense services of those who cooperate with Hann in the production of the Meteorologische Zeitschrift, Professor Pernter of Vienna, and Dr. Hellmann of Berlin; or of Palazzo's contributions to terrestrial magnetism? The mention of Eliot's Indian work, or of Russell's organisation of Australian meteorology, will be sufficient to show that the dependencies and colonies are prepared to take a share in scientific enterprise. And if I wished to reassure myself that even the official meteorology of this country is not without its scientific ambitions and achievements, I would refer not only to Scott's many services to science but also to Strachey's papers on Indian and British meteorology and to the official contributions to marine meteorology.

There is another name, well known in the annals of the British Association, that will for ever retain an honoured place among the pioneers of meteorological enterprise, that of James Glaisher, the intrepid explorer of the upper air, the nestor of official meteorologists, who has passed away since the last meeting of the Asssociation.

I should like especially to mention Professor Hergesell's achievements in the organisation of the international investigation of the upper air by balloons and kites, because it is one of the departments which offers a most promising field for the future, and in which we in this country have a good many arrears to make up. I hope Professor Hergesell will later on give us some account of the present position of that investigation, and I am glad that Mr. Rotch, to whose enterprise the development of what I may call the scientific kite industry is largely due, is present to take part in the discussion.

Yet with all these achievements it must be confessed that the progress made with the problems of general or dynamical meteorology in the last thirty years has been disappointing. When we compare the position of the subject with that of other branches of physics it must be allowed that it still lacks what astronomy found in Newton, sound in Newton and Chladni, light in Young or Fresnel, heat in Joule, Kelvin, Clausius, and Helmholtz, and electricity in Faraday and Maxwell. Above all, it lacks its Kepler. Let me make this clear. Kepler's contribution to physical astronomy was to formulate laws which no heavenly body actually obeys, but which enabled Newton to deduce the law of gravitation. The first great step in the development of any physical science is to substitute for the indescribably complex reality of nature an ideal system that is an effective equivalent for the purposes of theoretical computation. I can not refrain from quoting again from Plato's "Republic" a passage which I have quoted elsewhere before. It expresses paradoxically but still clearly the relation of natural philosophy to natural science. In the discussion of the proper means of studying sciences Socrates is made to say: "We shall pursue astronomy with the help of problems just as we pursue geometry; but we shall let the heavenly bodies alone if it is our design to become really acquainted with astronomy." What I take to be the same idea is expressed in other words by Rayleigh in the introduction to his "Sound." He there points out as an example that the natural problem of a sounding tuning-fork really comprises the motion of the fork, the air, and the vibrating parts of the ear; and the first step in sound is to simplify the complex system of nature by assuming that the vibrations of the fork, the air, and the ear can be treated independently. In many sciences this step is a most difficult one to take. What student of nature, contemplating the infinity of heavenly bodies and unfamiliar with this method of idealism, would imagine that the most remarkable and universal generalisation in physical science was arrived at by reducing the dynamics of the universe to the problem of three bodies? When we look round the sciences each has its own peculiar ideals and its own physical quantities; astronomy has its orbits and its momentum, sound its longitudinal vibration, light its traverse vibration, heat its energy and entropy, electricity its "quantity" and its wave, but meteorology has not yet found a satisfactory ideal problem to substitute for the complexity of nature. I wish to consider the aspect of the science from this point of view and to recall some of the attempts made to arrive at a satisfactory modification of reality. I do not wish to refer to such special applications of physical reasoning as may be involved in the formation of cloud, the thermodynamics of a mixture of air and water vapour, the explanation of optical or electrical phenomena, nor even Helmholtz's application of the theory of gravitational waves to superposed layers of air of different density. These require only conventions which belong already to physics, and though they may furnish suggestions they do not themselves constitute a general meteorological theory.

The most direct efforts to create a general theory of atmospheric circulation are those which attempt to apply Newtonian dynamics, with its more recent developments on the lines of hydrodynamics and thermodynamics. Attempts have been made, mathematical or otherwise, to determine the general circulation of the atmosphere by the application of some form of calculation, assuming only the sun and a rotating earth, with an atmosphere, as the data of the problem. I confess that these attempts, interesting and ingenious as they are, seem to me to be somewhat premature. The "problem" is not sufficiently formulated. When Newton set to work to connect the motions of the heavenly bodies with their causes he knew what the motions of the heavenly bodies were. Mathematics is an excellent engine for explaining and confirming what you know. It is very rarely a substitute for observation, and before we rely upon it for telling us what the nature of the general circulation of the atmosphere really is, it would be desirable to find out by observation or experiment what dynamical and elastic properties must be attributed to an extremely thin sheet of compressible fluid rotating about an axis with a velocity reaching 1000 miles an hour, and subject to periodic heating and cooling of a very complicated character. It would be more in consonance with the practice of other sciences to find out by observation what the general circulation is before using mathematics to explain it. What

strikes one most about the mathematical treatises on the general circulation of the atmosphere is that what is true about the conclusions is what was previously known from observation. It is, I think, clear that that method has not given us the working ideal upon which to base our theory.

Consider next the attempts to regard atmospheric phenomena as periodic. Let me include with this the correlation of groups of atmospheric phenomena with each other or with those of the sun, when the periodicity is not necessarily regular, and the scientific process consists in identifying corresponding changes. This method has given some remarkable results by the comparison of the sequence of changes in the meteorological elements in the hands of Pettersen and Meinardus, and by the comparison of the variation of pressure in different parts of the globe by Sir Norman Lockyer and Dr. W. J. S. Lockyer; as regards the earth and the sun the subject has reached the stage of productive discussion. As a matter of fact, by continuing this address I am preventing Sir Norman Lockyer from telling you all about it.

For the purpose of dealing with periodicity in any form we substitute for nature an ideal system obtained by using mean values instead of individual values, and leaving out what, from this point of view, are called accidental elements. The simplification is perfectly legitimate. Passing on to the consideration of periodicity in the stricter sense, the process which has been so effective in dealing with tides, the motions of the liquid layer, is very attractive as a means of attacking the problems of the atmosphere, because, in accordance with a principle in dynamics, to every periodic cause there must correspond an effect of the same period, although the relation of the magnitude of the effect to the cause is governed by the approximation of the natural period of the body to that of the cause.

There are two forms of the strict periodic method. One is to examine the generalised observations for periodicities of known length, whether it be that of the lunar rotations or of sun-spot frequency, or of some longer or shorter period. In this connection let me acknowledge a further obligation to Professor Schuster, for tacking on to his address of last year, a development of his work on the detection of hidden periodicities, by giving us a means of estimating numerically what I may call the reality of the periodicity. The other method is by harmonic analysis of a series of observations with the view of finding causes for the several harmonic components. I may say that the meteorological office, supported by the strong opinion of Lord Kelvin, has favoured that plan, and on that account, has for many years issued the hourly results for its observatories in the form of five-day means, as representing the smallest interval for which the harmonic analysis could be satisfactorily employed. Sir Richard Strachey has given some examples of its application, and the capabilities of the method are by no means exhausted, but as regards the general problem of dynamic meteorology harmonic analysis has not as yet led to the disclosure of the required generalisation.

I ought to mention here that Prof. Karl Pearson, with the assistance of Miss Cave, has been making a most vigorous attempt to estimate the numerical value of the relationship, direct or inverse, between the barometric readings at different places on the earth's surface. The attempt is a most interesting one as an entirely new departure in the direction of reducing the complexity of atmospheric phenomena. If it were possible to find coordinates which showed a satisfactory correlation, it might be possible to reduce the number of independent variables and refer the atmospheric changes to the variations of definite centers of action in a way that has already been approached by Hildebrandsson from the meteorological side.

Years ago, when Buys Ballot laid down as a first law of atmospheric motion that the direction of the wind was transverse to the barometric gradient and the force largely dependent upon the gradient, and when the examination of synchronous charts showed that the motion of air could be classified into cyclonic and anticyclonic rotation, it appeared that the meteorological Kepler was at hand, and the first step towards the identification of a working meteorological unit had been taken—the phenomena of weather might be accounted for by the motion and action of the cyclonic depression, the position of the ascending current, the barometric minimum. The individual readings over the area of the depression could be represented by a single symbol. By attributing certain weather conditions to certain parts of the cyclonic area and supposing that the depression travelled with more or less unchanged characteristics the vagaries of weather changes can be accounted for. For thirty years or more the depression has been closely watched, and thousands of successful forecasts have been based upon a knowledge of its habits. But unfortunately the travelling depression can not be said to preserve its identity in any sense to which quantitative reasoning can be applied. As long as we confine ourselves to a comparatively small region of the earth's surface the travelling depression is a real entity, but when we widen our area it is subject to such variations of path, of speed, of intensity, and of area that its use as a meteorological unit is seriously impaired, and when we attempt to trace it to its source or follow it to its end it eludes us. Its origin, its behaviour, and its end are almost as capricious as the weather itself.

Nor if we examine other cases in which a veritable entity is transmitted, can we expect that the simple barometric distribution should be free from inexplicable variations. We are familiar with ordinary motion, or, as I will call it, astronomical motion, wave motion, and vortex motion. Astronomical motion is the motion of matter; wave motion, the motion of energy; vortex motion, the motion of matter with energy; but the motion of a depression is merely the transmission of the locus of transformation of energy; neither the matter nor the energy need accompany the depression in its motion. If other kinds of motion are subject to the laws of conservation of matter and conservation of energy, the motion of the depression must have regard also to the law of dissipation of energy. An atmospheric disturbance, with the production of rainfall and other thermal phenomena, must comply in some way with the condition of maximum entropy, and we can not expect to account for its behaviour until we can have proper regard to the variations of entropy. But the conditions are not yet in a form suitable for mathematical calculation, and we have no simple rules to guide us. So far as meteorology is concerned, Willard Gibbs unfortunately left his work unfinished.

When the cyclonic depression was reluctantly recognised as too unstable a creature to carry the structure of a general theory, Mr. Galton's anticyclones, the areas of high pressure and descending currents, claimed consideration as being more permanent. Professors Köppen and van Bebber have watched their behaviour with the utmost assiduity and sought to find therein a unit by which the atmospheric changes can be classified; but I am afraid that even Dr. van Bebber must allow that his success is statistical and not dynamical. "High pressures" follow laws on the average, and the quantity we seek is not an average but an individual.

The question arises whether the knowledge of the sequence of weather changes must elude us altogether or will yield to further search. Is the man in the street right, after all? But consider how limited our real knowledge of the facts of atmospheric phenomena really is. It may very well be that observations on the surface will never tell us enough to establish a meteorological entity that will be subject to mathematical treatment; it may be that we can only acquire a knowledge of the general circulation of the atmosphere by the study of the upper air, and must wait until Professor Hergesell has carried his international organisation so far

that we can form some working idea therefrom of general meteorological processes. But let us consider whether we have even attempted for surface meteorology what the patience of astronomers from Copernicus to Kepler did for astronomy.

Do we yet fully comprehend the kinematics of the travelling depression; and if not, are we in a satisfactory position for dealing with its dynamics? I have lately examined minutely the kinematics of a travelling storm, and the results have certainly surprised me and have made it clear that the travelling depressions are not all of one kinematical type. We are at present hampered by the want of really satisfactory self-recording instruments. I have sometimes thought of appealing to my friends the professors of physics who have laboratories where the reading of the barometer to the thousandth of an inch belongs to the work of the "elementary class," and of asking them to arrange for an occasional orgy of simultaneous readings of the barometer all over the country with corresponding weather observations for twenty-four consecutive hours, so that we might really know the relation between pressure, rainfall, and temperature of the travelling depressions; but I fear the area covered would even then hardly be large enough, and we must improve our self-recording instruments.

Then, again, have we arrived at the extremity of our knowledge of the surface circulation of the atmosphere? We know a great deal about the average monthly distribution, but we know little about the instantaneous distribution. It may be that by taking averages we are hiding the very points which we want to disclose.

Let me remind you again that the thickness of the atmosphere in proportion to the earth's surface is not unsatisfactorily represented by a sheet of paper. Now it is obvious that currents of air in such a thin layer must react upon each other horizontally, and therefore we can not *a priori* regard one part of the area of the earth's surface as meteorologically independent of any other part. We have daily synoptic charts for various small parts of the globe, and the Weather Bureau extended these over the Northern Hemisphere for the years 1875 to 1879[1]; but who can say that the meteorology of the Northern Hemisphere is independent of that of the Southern? To settle that primary question we want a synchronous chart for the globe. As long as we are unable to watch the changes in the globe we are to a certain extent groping in the dark. A great part of the world is already mapped every day, and the time has now arrived when it is worth while to consider what contributions we can make towards identifying the distribution of pressure over the globe. We may idealize a little by disregarding the local peculiarities without sacrificing the general application I have put in the exhibition a series of maps showing what approximation can be made to an isochronous chart of the globe without special effort. We are gradually extending the possibility of acquiring a knowledge of the facts in that as in other directions. With a little additional enterprise a serviceable map could be compiled; and when that has been reached, and when we have added to that what the clouds can tell us, and when the work of the aeronautical committee has so far progressed that we can connect the motion of the upper atmosphere with the conditions at the surface, when we know the real kinematics of the vertical and horizontal motion of the various parts of a travelling storm, we shall, if the universities will help us, be able to give some rational explanation of these periodic relations which our solar physics friends are identifying for us, and to classify our phenomena in a way that the inheritors of Kepler's achievements associated with us in this section may be not unwilling to recognise as scientific.

[1] The Bulletin of International Simultaneous Meteorological Observations was published daily, with a monthly summary, from January, 1875, to December, 1883. The monthly summary alone was continued to December, 1889; it was continued in the MONTHLY WEATHER REVIEW to December, 1895, with the Atlantic Ocean storm tracks. The latter have been kept up by the United States Hydrographic Office and published on the monthly Pilot Charts to the present date. The daily weather maps for the Northern Hemisphere were published with the Bulletin from January, 1877, to November, 1883, but have been preserved in manuscript from January, 1875, to December, 1896, by the Weather Bureau, and since that date by the United States Hydrographic Office. The monthly charts of isobars, isotherms, and wind and storm tracks were published by the Weather Bureau up to December, 1889. The ten-year summary for the years 1878–1887, inclusive, was published as Bulletin A by the Weather Bureau in 1891.—[ED.]

CLIMATOLOGY OF COSTA RICA.

Communicated by Mr. H. PITTIER, Director, Physical Geographic Institute.

[For tables see the last page of this REVIEW preceding the charts.]

Notes on the weather.—On the Pacific slope the rains were very inconstant, being superior to the normal in some instances and inferior in others. In San José the pressure was markedly above the normal, while temperature was slightly low, with the exceptional minimum of 55.0° on the 25th (the lowest temperature observed heretofore in this month was 55.9°); the relative humidity was also less than the mean. The rainfall, 9.83 inches, occurred almost entirely during the afternoon hours, and was distributed pretty evenly through the month. Sunshine, 187.55 against a normal of 150.42. On the Atlantic slope the rainfall was markedly deficient on the coastal plains, and generally abundant in the valleys and mountains of the interior.

Notes on earthquakes.—September 19th, $5^h\ 33^m$ a. m., pretty strong shock NE–SW., intensity III, duration 4 seconds. September 24th, $2^h\ 53^m$, a. m., slight shock NW–SE, intensity II, duration 8 seconds.

THE HURRICANE SEASON.

By ENRIQUE DEL MONTE, Chief of Central Station, Havana, Cuba.

[Translation of a circular letter from the Central Meteorological Station of the Republic of Cuba, dated July 23, 1903.]

It is well known to all that the hurricane or cyclone season of the Antilles embraces a period variable from one year to another, and that the period of duration also varies with regard to its beginning and its ending, although the date of the latter is subject to more regularity than that of the former.

In fact in some years the cyclonic activity manifests itself in June (and even in May, as it happened in 1889), and continues until the end of October; in other years it begins in July and even in August, but terminates in October. This does not mean that every year there will be hurricanes which pass more or less near to us. Some years are recorded in which there has not been any real cyclonic activity, although this is rarely the case; thus during the past year there were no storms that properly deserved the name of hurricanes.

Up to this date the cyclonic activity has not commenced this year, nor does the upper current of the atmosphere appear to indicate that its beginning is near, although conditions may afterwards vary with relative rapidity and may almost unexpectedly inaugurate the hurricane season.

But whatever may be the date at which cyclonic activity begins, tropical hurricanes in their progress are subject to the two following empiric laws:

1. The place of formation of a hurricane is variable, being intimately connected with the time of the year in which storms originate.

2. The hurricane once formed advances in a route or trajectory that varies both with the different periods of the cyclonic activity and with geographical latitudes.

The practical generalization of the two laws we have just mentioned is due to the sagacity and perseverance of one of the highest authorities of modern times in matters relating to hurricanes of the Antilles (we allude to the deceased Father