to the coordinates in Hansen's tables, corrected from Newcomb's numbers.

Paris Mean Time 1897	D	π	$\Delta\alpha$	$\Delta\delta$	No. of Obs.
d. h. m.	′ ″ ″		s. s.	″ ″	
July 23 13 9	15 32·87±0·14	indeterminate	+0·30±0·01.	−0·1±0·2	36
Oct. 13 14 5	15 32·86±0·24	57′ 3″·2±1″·0	+0·31±0·02.	+0·5±0·4	29

A NEW FORM OF MIRROR FOR A REFLECTING TELESCOPE.—During the dedication exercises held in connection with the Yerkes Observatory, Dr. C. L. Poor advocated and exhibited a reflecting telescope in which the mirror is a portion of a paraboloid of revolution cut from the surface near the extremity of the latus rectum. The reflected rays then being at right angles to the incident rays, no dome would be required for such a telescope, and there would be no secondary mirror. This form of telescope was, however, recommended by Prof. Pickering more than sixteen years ago (NATURE, 1881, August 25); moreover, Prof. Schaeberle shows in the *Astronomical Journal*, No. 419, the inefficiency of such an instrument, from the following considerations. Let L denote the distance from the focus to the centre of the mirror, which is evidently inclined about 45° to the line of sight. If D denotes the minimum diameter of this elliptical mirror, the maximum diameter must be D sec. 45° if a circular cone of rays is to be used. The linear distance from the focus to the nearest and most distant points of the mirror will then be approximately—

$$\text{Least distance} = L - \tfrac{1}{2} D \sec 45^\circ.$$
$$\text{Greatest distance} = L + \tfrac{1}{2} D \sec 45^\circ.$$

If we assume $\frac{L}{D} = \frac{7}{4}$, the greatest distance divided by the least distance becomes 1″·22.

This quantity is approximately the *blurring factor* for the given ratio of focal length to aperture for this form of instrument. For a star which is only 5′ from the optical axis of the telescope, and in a place containing the longer axis of the mirror, the image will, therefore, be a line no less than 66″, or more than a minute of arc.

Exactly at the focal point this star image will be a point, but for all other positions of the image the definition will be unworkable.

RECENT RESEARCHES ON TERRESTRIAL MAGNETISM.[1]

THE science of terrestrial magnetism has on one previous occasion formed the topic of a Rede Lecture. Twenty-five years ago Sir E. Sabine delivered a discourse on this subject, with which his name will always be honourably connected. The length of time which has elapsed may perhaps justify a return to the same theme, though it must be admitted that now, as then, the study of the magnetic properties of the earth is in an early stage of development. It is true that considerable advances have been made in the theory of the nature of magnetism itself, and of its connection with electricity; but when we attempt to apply theory to explain the actual condition of the earth progress is at once checked by difficulties, many of which have hitherto proved insuperable. We have no real knowledge of why the earth is a magnet, no real knowledge as to why its magnetic state is continually changing, and thus we are compelled to spend long periods of time in collecting facts, which, though their number and complication oppress us, are still insufficient to answer some of the simplest questions that an inquirer, approaching the subject for the first time, would be sure to ask. Terrestrial magnetism is in this respect in the same stage as that occupied by astronomy during the centuries in which the data were accumulated on which Kepler and Newton worked. We have a certain grasp of the facts, but have not yet found the thread of theory which binds them together.

And in one respect the magnetician is less favourably situated than was the astronomer. The rapid repetition of the principal astronomical events made it comparatively easy to discover the laws which those events obey; but, though some magnetic phenomena run through their courses in a day, a year, or a short period of years, the greatest change of all, that which causes the magnet to point now to the east and now to the west of the geographical north, has been studied for three hundred years and is still unfinished. It is a secular variation, of which the period, if definite period there be, must be measured by ages, and centuries may yet elapse before the first cycle which man has watched will be complete.

In spite of these difficulties attempts are continually being made to draw from the facts at our disposal some more definite information as to the causes of terrestrial magnetism; to foretell the future from the present; to trace the connection between the magnetic state of the earth and the constitution of the sun or of the earth itself; and I propose, therefore, to bring before you some of the theories and speculations which are now attracting the attention of those who take special interest in this science.

The fundamental fact, or rather series of facts, from which we have to begin our investigation is a knowledge of the magnetic state of the surface of the earth. To determine this, observations have for many years past been made at many different places, at sea and on land. The general result is a matter of common knowledge. The compass needle points approximately north and south, and dips from the horizontal towards the magnetic poles of the earth.

The first and simplest hypothesis that will serve as a rough approximate explanation of these facts, is that the earth itself is uniformly magnetised, or that there is at the centre of the earth a small but very powerful magnet by which the compass and the dipping needle are controlled.

If this suggestion were adequate, we should be compelled to assume that the axis of the magnet was inclined to the axis of the earth, for the magnetic and geographical poles do not coincide. It would further follow that at the magnetic poles, where the dipping needle is vertical, the magnetic force, which determines the position of the needle, would be of maximum intensity.

But here the simple hypothesis breaks down. The distribution of terrestrial magnetism is more complex than that which can be thus explained. It is true that there are two magnetic poles, but the directive force is not greatest where the needle is vertical. On the contrary there are in each hemisphere two other points, generally called magnetic foci, at which the force is a maximum.

It is thus evident that the magnetic system of the earth might be better represented by supposing that there are within it two magnets inclined both to each other and to the geographical axis, that the foci indicate the directions of these axes, and that the magnetic pole or point where the needle stands vertical is determined by their joint action. Mr. H. Wilde attempted to imitate the magnetic state of the earth by the aid of a duplex arrangement of this kind, but even this was insufficient. He was compelled to supplement it by covering with thin sheets of iron those portions of the globe which correspond to the oceans, and with this modification he succeeded in making a capital magnetic model of the earth.

For the moment, however, I will not follow up the line of inquiry thus suggested, but will only draw attention to the fact that, in spite of all these complications, mathematical analysis supplies us with the means of answering certain questions as to the magnetic constitution of the earth, without the aid of a clear mental picture of the causes to which that magnetic state is due. Whether there be one or more independent magnetic systems within the globe, whether some portions are more magnetic than others, are points upon which at present we have but little information, but there are a few facts from which we can argue with the knowledge that the foundations of our investigation are secure.

Magnetic forces can be produced only by magnetised matter, or by electric currents, and these may either exist within the globe or be external to its surface. Some of the currents, however, may be both internal and external in the sense that their circuits pass partly through the rocks and partly through the air, and that at certain points they traverse the surface from earth to air or from air to earth. Thus the first important question with which the investigator is confronted is: Are the forces which act upon the compass produced within or without the globe? and, if the magnetic forces are in part due to electric currents, are all these currents wholly internal or wholly external, or do some of them flow in part within and in part without the earth?

With regard to the first inquiry, the great mathematician Gauss furnished us with a method by which, if our knowledge of the magnetic state of the surface of the earth is sufficiently

[1] The "Rede Lecture" delivered in the Senate House, Cambridge, on June 9, by Prof. A. W. Rücker, F.R.S.

accurate and extensive, we can determine the relative proportions of those parts of the force which are due to causes wholly external or internal respectively. It is only lately that a further attempt has been made to discover whether, in addition to these, currents from earth to air and from air to earth also exist. The credit of this attempt is due to Dr. A. Schmidt, who, taking the most recent and the most accurate facts at his disposal, deduced from them the conclusion that about one-fortieth part of the magnetic force is due to causes wholly external to the earth, and that a slightly larger fraction is produced by vertical currents; the origin of the remaining thirty-eight fortieths being traced to internal causes only.

And now it becomes necessary to say a few words as to the method by which the vertical earth-air currents may be detected. If we could perform the impossible operation of severing the north pole of a magnet from the remainder without immediately producing poles of the opposite kind in the broken fragments, the isolated pole thus manufactured would be urged northwards by the magnetic forces which are in play near the surface of the earth. If therefore a traveller were to carry such a pole with him, he would be assisted when going northwards, retarded when returning to the south. If the tour ended at the starting-point, the advantage gained when moving in one direction would in general be exactly compensated by the disadvantage of being compelled to oppose the magnetic forces during the remainder of the journey.

To this rule there is one exception. If the migrations of the magnetic pole carried it round an electrical current, so that its course passed through the circuit in which the current flows, as a thread might pass through a ring, and if the route finally led back to the starting-point without again passing through the circuit of the current, the exact equilibrium of loss and gain would be destroyed, and when the journey was over the wandering pole would either have added to or drawn upon any store of energy which it might at first have possessed.

Whether the result would be a loss or a gain would depend upon the direction in which the journey was performed relatively to the direction of the current. On this point it is unnecessary to dwell. Suffice it to say that if the amount of the loss or gain experienced by a given pole is known, the magnitude and direction of the current, whose circuit had been traversed, can be calculated. The result would not be affected by whether the current flowed from all parts of the district which the path of the pole had encircled, or was confined to a few points only; the total flow would be registered without reference to how it was distributed. If some of the currents flowed in opposite directions the excess of one set over the other would be measured.

If now a current passes at a certain point from earth to air it must return from air to earth elsewhere, completing the circuit through the soil. The course of the unburied portion may be regarded as an aerial arch, and from what has been said it will be evident that if a magnetic pole were carried round a leg of this arch the circuit of the current would be pierced, and the total upward or downward flow would be determined. The experiment, as thus described, is impossible, but, by an appropriate method, we can determine the force which would be exerted at any point on the detached north pole of a magnet of given strength, and, if this be known for a sufficient number of points on the path, we can calculate what the result would be if the imaginary conditions of the journey could be realised.

The calculations of Dr. Schmidt as to the existence of earth-air currents were based upon this principle, and were applied to the earth as a whole. Their general accuracy has been confirmed by Dr. Bauer, who supposed the hypothetical isolated magnetic pole to be carried along lines of latitude right round the earth. If, for instance, the journey were made along latitude $51\frac{1}{2}°$, beginning and ending at London, the resulting work would show the total amount of the currents which traverse the northern portions of the Northern Hemisphere between that latitude and the geographical pole. If the same operation were repeated, say on latitude 45°, a similar result would be obtained, and the difference between the two would give the average flow of the currents which traverse the surface of the earth between these two latitudes.

Of course, it must be remembered that by such a calculation we can only arrive at a mean result. If, for instance, we had proved that between these latitudes there was, on the whole, an upward current, it would by no means follow that at all points on the vast surface included between the selected boundaries the currents were flowing from below to above. The meaning of the result would be that, within the region considered, the upward were stronger than the downward currents, and that, if the excess were uniformly distributed over the whole of the surface to which the calculation applied, an average current of such and such a magnitude would be produced.

Turning from the method of detecting the vertical currents to the question as to whether they exist, there are, apart from the calculations of Schmidt and Bauer, some experimental and theoretical reasons which support an affirmative answer. We know that earth currents traverse the soil beneath us. The Aurora is evidence of electrical discharge in the atmosphere. It is conceivable that there are cross connections between these two systems. Again, if the immediate surroundings of the earth are electrically conducting, the mere rotation of the huge magnetic mass of the earth itself would cause the production of currents which at some points would flow out of, and at others would flow into the surface. The late Prof. Hertz calculated the forms of the paths of such currents for the case of a uniformly magnetised sphere rotating about its magnetic axis, and, though the fact that the magnetism of the earth is irregularly distributed forbids us to apply his calculation directly to the globe, yet the principle holds good, though the distribution of the currents would be more complex. Dr. Bauer has deduced from the calculations already referred to the average direction of flow between different latitudes.

The result is shown in Fig. 1. The directions and magnitudes of the supposed vertical currents are indicated by arrows, and points at which there are no such currents occur at lat. 43° N. and 40° S.

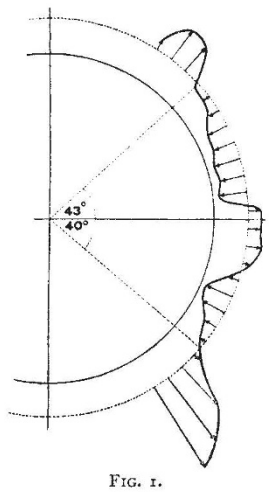

FIG. 1.

Up to this point, therefore, the argument seems all in favour of the actual existence of currents from earth to air, but the results of calculations such as these must be accepted with very great caution. Our knowledge of the magnetic state of the earth is very imperfect; we know but little of the oceans as compared with the land, and of the land but little of the less civilised regions. Whatever be the lines of latitude chosen they must pass over sea, or desert, or both; and if the assumptions made as to the magnetic conditions of these regions are incorrect, it may be that the results are due not to the physical existence of the currents, but to the inaccuracy of the data to which the formulæ were applied.

It therefore becomes important to check such large scale calculations by others which depend only on the comparatively small areas which have been minutely studied.

In 1895, Dr. Carlheim-Gyllenskiöld applied the test for the existence of vertical currents to Sweden, for which comparatively numerous observations could be utilised. The conclusion at which he arrived was that there was no evidence for the existence of the currents, except in those parts of the country where the data were so untrustworthy as to make any conclusion valueless.

In 1896 similar calculations were made for this country. Dr. Thorpe and I have recently completed a magnetic survey of the United Kingdom which is, I believe, the most complete of any which has hitherto been made of an equally large area. All our observations were made within a few years, and, therefore, the corrections for secular change were comparatively unimportant.

The survey was divided into two parts, in one of which we depicted the magnetic state of the kingdom in 1886; while the other part was devoted to a similar investigation for the epoch 1891. We were thus able to compare the results obtained at two periods, separated by a few years only, and by their concordance or disagreement to judge of the value of our conclusions. As these appear to be of some importance with regard to the question we are now discussing, I have recently repeated the calculations in a somewhat different way, and have determined the average value of the currents flowing through all the distri :ts

in the United Kingdom which are bounded by lines of latitude and longitude corresponding to whole degrees.

Thus, if starting on the meridian of Greenwich a traveller were to go due north from lat. 51° to 52°, that is from mid-Sussex to the north of Hertfordshire, then were to go due west until long. 1° W. was reached near Buckingham, thence due south along long. 1°, until when near Petersfield he turned homewards due east along lat. 51°, his route would include an area of, in round numbers, 2800 square miles, or of about 7000 square kilometres. In each such circuit the average current expressed in hundredths of an ampere per square kilometre has been determined, and the results are shown on maps both for 1886 and for 1891.

These maps are given in Fig. 2, A and B. The numbers indicate the average flow in hundredths of an ampere per square kilometre. The figures are underlined where the flow of the current is from above to below. In other cases the direction is upwards.

FIG. 2, A.

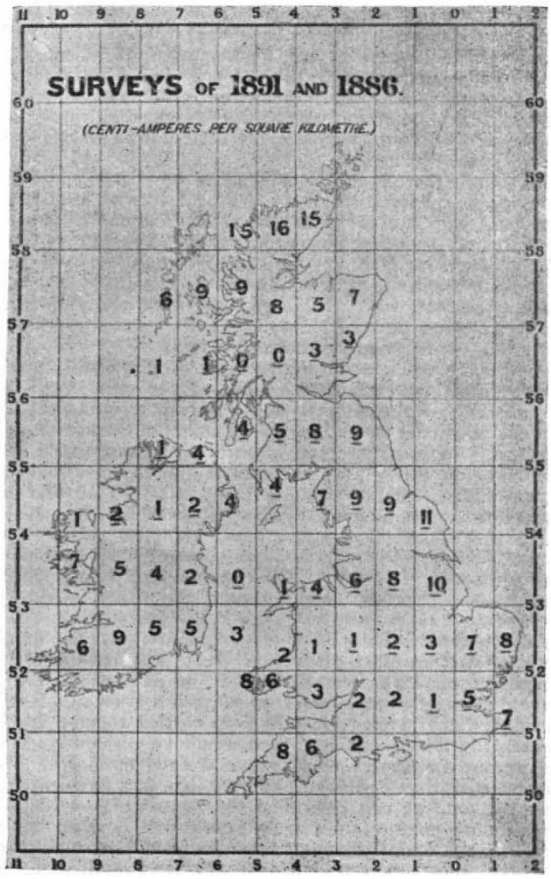

FIG. 2, B.

Fig. 2, A, shows the result for January 1, 1886, deduced from the 200 stations which were then available. In Fig. 2, B, all the facts obtained in the two surveys are worked up to a final result for the date January 1, 1891.

If we compare the two maps thus obtained from the two surveys, the conclusions arrived at are, in some respects, not very different. In both the larger currents occur near the boundaries of the land area to which the observations were necessarily confined. If the maps are to be trusted, the largest currents exist in the extreme north of Scotland, in the east of England, and in the far west of Ireland. It is also in favour of the trustworthiness of the results that in both cases the upward currents occur in the same parts of the kingdom. The figures indicate that the currents flow upwards in the far north, in the west and south, while in the midlands and the east the general tendency is from above to below.

But in spite of this apparent agreement, I am very doubtful whether these conclusions can be trusted. In the first place the currents are very minute. The whole flow of electricity passing through an area of 2800 square miles is less than that concentrated by Prof. Moissan in a few square inches within an electric furnace. The forces to be measured are so small that they must be seriously affected by the inevitable errors of observation and reduction.

Again, the observations which were made at nearly 900 places scattered all over the kingdom, are affected by local disturbances, due to quite other causes than those we are now discussing, and the magnetic state of the whole area, such as it would be if these disturbances were removed, can only be deduced by an elaborate system of averaging the results obtained at different places. This process of taking means is least accurate near the boundaries of the survey, and thus the larger currents which are indicated near the shores of our islands have probably no real physical existence, but are due only to the relative uncertainty of our knowledge of the magnetic state of the particular localities in which they appear to flow. From this point of view, therefore, it appears to be unsafe to trust to any particular figure, and that a better result will be obtained if we deal with larger areas and content ourselves with taking the mean of all the currents which appear to flow within them through the surface of the earth.

Adopting this plan, the general conclusions to be drawn from the two maps are very nearly identical. If for the moment we neglect the question as to whether the currents are flowing up or down, their average magnitude in any considerable area in the United Kingdom is about five-hundredths of an ampere per

square kilometre. If, however, we take account, as we are bound to do, of the difference of direction, treating those which flow upwards as positive and those which flow down as negative, the result would show that the mean current in the United Kingdom is about five-thousandths of an ampere per square kilometre. Of course, if we deal with considerable but smaller areas, the precise value obtained depends upon the district chosen, but this does not affect the conclusion to any important extent. Thus, for the reason I have already given, it is probable that our knowledge of the magnetic state of the central districts is better than our information as to the borders, and if we confine ourselves to the centre of the kingdom, we find that the average current is downwards in both cases, and that in 1886 it was apparently a little larger, and in 1891 a little less than one-hundredth of an ampere per square kilometre.

Even these concordant conclusions are rendered more doubtful if the two completely independent sets of results obtained by means of the two surveys for 1886 to 1891, respectively, are reduced to the same date. It is true that the magnitudes of the calculated currents are larger than those shown in the map given above, but on the whole they are so opposed in direction that the comparison compels us to reject the hypothesis of their physical reality.

I therefore feel justified in asserting that no evidence that can be relied upon points to the existence of any flow of electric currents through the surface of the British Isles, whether from below to above or from above to below. The quantities are so minute that if they existed they could barely be measured, and the results are too discordant to command assent.

Since the survey of the United Kingdom was completed, my friend Dr. Van Rijckevorsel has made a minute magnetic survey of Holland. In the case of so small a district it is more difficult to eliminate the effects of local disturbances than when the area to be dealt with is larger, and thus I doubt whether conclusions as to the flow of electrical currents drawn from Holland alone could be regarded as trustworthy. Taking them, however, for what they are worth, they indicate an upward current of about one-tenth of an ampere per square kilometre for that country. All these quantities are less than the currents which Dr. Schmidt's calculations demand. In the neighbourhood of the United Kingdom the flow should, according to his calculations, be upwards and the magnitude about fifteen-hundredths of an ampere per square kilometre. This is approached by the flow in Holland, but is from ten to wenty times greater than the average obtained over large areas in the United Kingdom.

So far, then, the question as to whether such currents really exist appears to be doubtful. The calculations of Schmidt and Bauer lead to the conclusion that when the world as a whole is investigated the answer is affirmative, but all the more accurate investigations which have hitherto been made in small areas combine to prove either that the currents do not exist, or that they are less than Dr. Schmidt's theory demands. This fact, taken by itself, is not conclusive, as Sweden, the United Kingdom, and Holland are all in the west of Europe, and it might well be that this happened to be a district in which the currents were exceptionally small; but, on the other hand, the doubt thus raised is formidable. Dr. von Bezold has recently stated to the Berlin Academy that Dr. Schmidt himself must now be added to the list of doubters; and von Bezold confirms this caution by figures which lead him to the conclusion that in all probability the results obtained from calculations which embrace the whole globe are due rather to the want of accuracy of our knowledge than of the physical reality of currents from earth to air. I should myself be sorry to pronounce a final opinion, but I must confess that I seriously doubt whether the horizontal magnetic force has been determined with adequate accuracy at a sufficient number of places in the vast regions which are covered with the sea to enable us to draw any final conclusion from areas which include them, and I certainly consider that the balance of evidence is at present opposed to the physical reality of the currents. Before we can accept the opposite proposition some evidence must be produced based on surveys as complete as those of England and Holland. Before long we shall probably have full information as to France and Maryland, and it is possible that one or other of these may furnish positive evidence sufficient to outweigh the negative results which have hitherto been obtained.

(*To be continued.*)

A PROPOSED SWEDISH EXPEDITION TO THE ARCTIC REGIONS.

A YEAR since, Dr. A. G. Nathorst, of Stockholm, read a paper before the Swedish Society for Anthropology and Geology, entitled "Återblick på Polarforskningens närvarende Ställning samt Förslag till en Svensk Polarexpedition" (a review of the present position of Polar investigation, with a project for a Swedish Polar expedition), which has since been published in *Ymer* (Årgång 1896, Heft 4, pp. 267–286), the journal of the Society. At the time of reading the paper, there seemed but little probability of a near realisation of the projected scheme; but, during the present year, the King of Sweden and certain wealthy merchants of Stockholm and Gothenburg have generously come forward and provided the funds necessary for carrying it out, and Dr. Nathorst, who will act as the scientific leader of the expedition, is now engaged in preparations for a start next year (1898).

As the result of Nansen's voyage, Dr. Nathorst thinks that there is but little probability of the discovery of fresh land areas in the vicinity of the Pole, and that the aim of future expeditions to the Arctic regions should be a thorough scientific investigation of those lands, of which at present but little is known beyond the fact of their existence. Under this head may be mentioned the west coast of Ellesmere Land and Grinnell Land and the neighbouring islands; also the shores of Jones Sound, in Arctic America. Further, large tracts of the north-eastern and north-western coasts of Greenland remain to be examined, in spite of the admirable work of the Danish, Austrian, and other exploring expeditions. But it is with Spitsbergen and the region east of it that previous Polar explorations on the part of Sweden have been most closely connected; and though no fewer than twelve different Swedish expeditions, led by such men as Torell, Nordenskiöld, Nathorst, de Geer, and others, have visited this region since 1858, and that it has been the field of work for expeditions from other countries as well, the most recent being that under Sir Martin Conway in 1896, it yet offers, in Nathorst's opinion, a rich harvest for scientific investigation.

The west coast of Spitsbergen is now fairly well known, but owing to the ice coming from the east and blockading the eastern coasts of the island, nothing has as as yet been ascertained of their geological structure. The same obstacle has also prevented observations on Stans Foreland (Edge Island), Barentz Land, North East Land, Kung Karls Land, and Ny Island; but it is probable, that given favourable conditions of the ice, a steam vessel would be able to approach sufficiently near these islands to allow of their geology at least to be made out. The exploration of these lands between Spitsbergen and Franz Josef Land is the main object of the expedition; but should this be frustrated by the prevalence of the ice, the research work would be carried on in Spitsbergen itself, and more particularly a study would be made of the raised shell-banks and terraces, evidencing a comparatively recent elevation of the land, and of the remarkable quaternary deposits which show that the climate of the island, for a certain interval after the Ice age, was warmer than at the present time. Promising botanical results might be also expected from an examination of the valleys extending from the heads of the fiords, as, for example, those in Sassen Bay, Kol Bay, and Van Mijens Bay.

A stout vessel of from 350 to 400 tons, and a crew of thirteen men, would, in Nathorst's opinion, be most suitable for the undertaking; and the scientific staff would consist of a geologist, a botanist, two zoologists, one hydrographer and meteorologist, and one for cartography and photography. It is not intended to over-winter in the Arctic regions, but the vessel would be provisioned for a year, in case of accidents. The estimated cost of the expedition is about 4000*l*. It is proposed to reach Spitsbergen in the beginning of June, and work there until the middle of August, when it is hoped the ice will allow Kung Karls Land and the other islands near it to be examined.

THE USE OF KITES IN WEATHER PREDICTION.

THE systematic exploration of the upper air by means of kites is referred to by Prof. Cleveland Abbe in the *Monthly Weather Review*, at the end of a long article upon the experiments made previous to 1893. It is pointed out that at that time the Malay kite and the free balloon were merely