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THE PRESENT STATUS OF THE THEORY OF THE EARTH'S MAGNETISM.[1]

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It is characteristic of Gauss's method of working that he published no investigation until it was either finally completed or had been developed to the highest stage attainable at the time with the material at hand. Were there any weak points, no opportunity to point these out was neglected by him. Herein lies the classic value of his works, and so, naturally, it came to pass that for many years the principal endeavor of his successors was to fill in the missing links, and that only recently attempts have been made to farther develop his methods.

In the field of terrestrial magnetism, especially, did further development of method take place but recently—hardly more than a decade ago. Since then, however, a wonderful zeal, enthusiasm, and singleness of purpose, as probably in no other branch of geophysics, have been displayed. This activity has disclosed a great number of new ideas and points of view, and has revealed a more intimate connection between terrestrial magnetism, meteorology, and atmospheric electricity than was at first suspected. This discovery, though but very recent, is leading future investigation into totally different paths from those of the earlier days.

The solution of the new problems lies rather in the fields of electricity and of atmospheric physics than in that of pure mag-

[1] Freely translated and slightly condensed from the "Physikalische Zeitschrift," 2 Jahrg., No. 7 and 8, pp. 108–110 and 119–125.

[PLATE

Arthur Schuster.

netism. This necessitates new methods of discussion and a careful scrutiny of the facts at hand. The circle of those interested in the development of our knowledge of the Earth's magnetism has thus been greatly widened. It will, therefore, be opportune to give now a brief résumé of the present status of the theory of terrestrial magnetism.

Gauss's general theory of terrestrial magnetism is one of the most complete and finished of his works. Gauss himself, however, greatly regretted that the inaccuracy of some of the data and their insufficiency did not permit a more accurate determination of his coëfficients. Improvement could only be hoped for with addition of new material, and so the first endeavors were to obtain new data and to improve the instruments and methods, Gauss, Weber, and Lamont having principal share in this development. And now, with the multiplication of data, re-computation of the Gaussian constants were undertaken. However, as these early re-computations were not accompanied by any material improvements in the representation of the distribution of the magnetic elements, the desire arose anew to improve and increase the data by new instruments and observational methods, and so resulted finally the Neumayer magnetic charts for 1885, as published in Berghaus's Physikalischer Atlas, and his re-computation of the Gaussian coëfficients.

Gauss, in his computations, and so also his successors up to this time, developed his mathematical expression to terms of the fourth order (24 terms), and on the basis of a spherical Earth. Fritche,[1] however, published, in 1897, the results of a comprehensive re-computation, in which he investigated how many terms of the series had to be used in order to obtain the maximum degree of accuracy in the mathematical representation of the distribution of the Earth's magnetism. Sixty-three constants seemed to give no material improvement over forty-eight; the latter number, however, gave a more accurate representation than obtainable with but twenty-four constants.

A new epoch in the theory of terrestrial magnetism begins with the investigations of Adolf Schmidt.[2] He revises the Gaussian

[1] H. Fritche: Die Bestimmung der Koeffizienten der Gaussischen Theorie, St. Petersburg, 1897.

[2] Ad. Schmidt: Der magnetische Zustand der Erde zur Epoche, 1885. Aus d. Archiv d. Seewarte, Hamburg, 1898.

method on the basis of an elliptical Earth[1] and, unlike his predecessors, does not regard as a final object the mere numerical and graphical representation of the distribution of the magnetic elements with the aid of the calculated Gaussian coëfficients, but rather, in the spirit of Gauss, *as the means to an end*, viz., the solution of some of the physical problems implied in the Gaussian equations. This led to the theory of the so-called "permanent magnetism of the Earth," whereby that portion is meant which is subject only to secular variations.

It had been generally known that Gauss had computed the line integral of the horizontal magnetic force around a triangle the virtices of which were three stations at which the magnetic elements were accurately known. However, the full importance, from a physical standpoint of the fact that when the integral

$$\int H \cos \theta \, ds$$

carried out for any closed circuit, results in a zero value, it implies the existence of a magnetic potential, appears to have been overlooked. If this integral does not vanish, then the existence of forces not to be ascribed to a potential would be proven. If, for example, we have electric currents passing perpendicularly through the area bounded by the curve, then we should have

$$\int H \cos \theta \, ds = 4\pi I,$$

where I represents the resultant intensity of all of the currents passing through the area. Schmidt's computations appeared to indicate that $\frac{1}{40}$ of the total magnetic intensity could be ascribed to such sources. For Germany this would imply a current of 0.091 ampere per square kilometer.

Gauss expressed the Y component of the horizontal magnetic force for points along a parallel of latitude by the harmonic series:

$$Y = l + l' \cos \lambda + L' \sin \lambda + \ldots$$

The condition $\int Y \, dy = o$ is then identical with the condition that $l = o$. The result is, that values of l for the different latitudes differ from each other, and do not vanish. In view of the uncertainty in the values of the elements along a parallel of latitude,

[1] Obtaining thereby, however, no essential improvement. His revision consisted, principally, in the fact that he did not assume, *ab initio*, as Gauss had done, the existence of a potential, whether inner or outer.—ED.

Rücker,[1] Carlheim-Gyllenskiöld,[2] and von Bezold[3] chose closed areas, bounded by parallels and meridians, in regions of accurate magnetic surveys. If λ_1, λ_2, ϕ_1, ϕ_2, are the coördinates of the vertices of the trapezoid, X_1, X_2, Y_1, Y_2 the geographical components (south-north, east-west), then we have:

$$\int H \cos\theta \, ds = \int_{\phi_1}^{\phi_2} X_1 \, d\phi + \cos\phi_2 \int_{\lambda_1}^{\lambda_2} Y_2 \, d\lambda -$$

$$\int_{\phi_1}^{\phi_2} X_2 \, d\phi - \cos\phi_2 \int_{\lambda_1}^{\lambda_2} Y_1 \, d\phi.$$

For equidistant observations the integral can readily be computed by mechanical quadratures. Thus, Bezold selected a trapezoid, embracing Middle Europe and found the value, expressed in terms of the Earth's radius, of 0.00081, or about one per cent of the value of the potential between two opposite points of the figure. Liznar,[4] for an area in Austria-Hungary, where he had made a detailed magnetic survey, found for the difference of the potential between two opposite points of his quadrilateral along one path the value 0.0271442, and along the other 0.0271396, hence a difference of 0.0000046, or 0.017% of the potential value along one path. It seems, therefore, extremely doubtful whether any part of the Earth's permanent magnetism is to be referred to vertical earth-air electric currents, at least not of the strength indicated by above-mentioned investigations (Schmidt).

This question, however, has been attacked from various standpoints, disclosing to us new views. First to be mentioned here is the investigation of L. A. Bauer,[5] who determined the distribution of the hypothetical vertical currents over the surface of the Earth by computing the integral values for narrow zones bounded by two parallels of latitude, and from them the intensity of the

[1] Cf., Vol. I, T. M., p. 77.

[2] V. CARLHEIM-GYLLENSKIÖLD: Mémoire sur le magnétisme terrestre. Vet. Ah. Förh. 27. Stockholm.

[3] W. VON BEZOLD: Zur Theorie des Erdmagnetismus. Sitzber. Berlin Acad., Vol. 48, 1897, p. 414.

[4] J. LIZNAR: Magnetische Aufnahme Osterreich-Ungarns und das erdmagnetische Potential. Met. Z. V. 15, 175, 1898.

[5] L. A. BAUER: T. M., Vol. II, p. 11, 1897.

resultant current system. He distinguished four zones, in which the upward and downward currents canceled each other, viz.: Zone 1, between 90° N.—65° N.; zone 2, 65° N.—20° N.; zone 3, 20° N.—57° S.; and zone 4, from 57° S.—90° S. As remarked above, the integration along a parallel is too uncertain to enable one to draw safely further deductions from the values obtained. Nevertheless, the investigation is of great interest, as it is still possible that electric vertical currents may play a part in the magnetic condition of the Earth, without, necessarily, appearing in the "permanent field."

It is evident, that with existence of vertical currents there would follow relations with the phenomena of atmospheric electricity, and so we find a comprehensive paper on this subject by Trabert, on the relation between the phenomena of terrestrial magnetism and those of atmospheric electricity.[1] In this paper the various theories of atmospheric electricity are examined in the light of the investigations of Schmidt and Bauer, and the author succeeds, on the hypothesis of a mechanical transference of electricity, in obtaining quantitatively a current intensity corresponding to Schmidt's value. Furthermore, Elster and Geitel have proposed, for the further investigation of this matter, simultaneous observations of the magnetic elements and of electric potential.[2] Lemström has published, in the third volume of the Finnish polar work, current intensities, measured in 1882, of currents passing from the upper regions of the atmosphere to the Earth.

For this purpose he had a metallic connection between an apparatus, consisting of many hundred points, placed on a hill, and the ground in the valley below, and thus obtained the difference of potential of the existing currents. It is a question, however, whether such currents would also exist without a metallic conductor.

The permanent value of the investigation of the Gaussian line integral is, therefore, this, that the Earth's permanent magnetic field is to be ascribed entirely to forces possessing a potential, and that this integral, hence, is a criterion of the accuracy of a given magnetic survey.

As soon as it was recognized that the fundamental premise of the Gaussian theory was a correct one, an endeavor was next made to further develop his theory. The striking irregularity in the dis-

[1] Meteorol. Zeitschr., 1898, 401–412. (Cf., Vol. IV, T. M., p. 63.)

[2] T. M., Vol. III, p. 49, 1898.

tribution of the magnetic elements is patent to any one looking at a magnetic chart. If the Earth were uniformly magnetized about an arbitrary axis, then should the mean value of the potential $V\phi$ along any parallel be equal to $C \sin \phi$. The thought lies near, that the actual distribution results from a superposition of a uniform and of a disturbance field. This idea induced von Bezold[1] to determine middle values for the various parallels and subtract these from the individual values, and, from the residuals thus obtained, he derived his "isanomalous lines of the magnetic potential." Thus arose the conception of a "normal potential." From the definition of the "anomalies" or residuals, it results that on every parallel there must exist at least two points of normal magnetism. The line connecting these points is called the "normal" of the geomagnetic potential. If dy be a meridional element, then it follows, since the normal potenial V_n for every parallel is constant, that $\frac{\partial V_n}{\partial y} = 0$. And if, V_a be the abnormal potential, hence $V = V_n + V_a$, then we also have $\frac{\partial V}{\partial y} = \frac{\partial V_a}{\partial y} = Y$; *i. e.*, "a knowledge of the anomalies for all points of the Earth suffices to determine everywhere the easterly magnetic component." Furthermore V_a consists of a constant and a readily computed term dependent upon the longitude. The constant is the value which this second term has at the point of intersection of the parallel with the "normal" of the potential. Hence "it suffices to know the easterly magnetic components for the entire Earth in order to determine the anomaly at every point without being obliged to go back first to the mean values of the potential." These laws call to mind the analogous one of Gauss, whereby it suffices to know the westerly components for all points and the northerly components along a meridian, in order to determine the potential for every point.

Schmidt[2] investigated whether there exists an axis which would satisfy the condition $V_n = C \sin \phi$ even better than the axis of rotation, but found none that specially distinguished itself in this respect.

However, the first term of the Gaussian spherical harmonic series corresponds to a uniform magnetization of the Earth, as was first pointed out by L. A. Bauer,[3] and thus a physical interpretation

[1] W. von Bezold. Der normale Erdmagnetismus. Berl. Sitzber, Vol. 50, p. 1,119, 1895. Isanomalen des Erdmagnetischen Potentials, Vol. 48, 1895.

[2] T. M., Vol. I, 1896, p. 18.

[3] Am. Jour. of Science, Vol. 50, 1895, p. 194.

of a part of the series has been obtained. Bauer[1] has, furthermore, investigated the field represented by the remaining terms. He defines the normal magnetization as that resulting from a uniform magnetization about an axis, determined from Schmidt's computations, which intersects the northern hemisphere in latitude 78° 34'.3, and in longitude 68° 30'.6, west of Greenwich, the moment of the magnetization being 0.32298 R^3, c. g. s. units.

By subtraction of the "normal" components from the observed ones, the residual field is determined; the result is a field having three principal north and south magnetic poles. It will lead us too far to discuss in detail these recent investigations. Suffice it to say that striking similarities manifest themselves between Bauer's residual field, the diurnal variation field and the mean annual isanomalous lines of temperature. Quite likely the cause of these associated phenomena are all to be referred to the distribution of land and water.

Another assumption of Gauss's, although not an essential one, was that the entire magnetic force was due to causes inside the Earth's crust. He left the possibility open, however, that a small part might arise from outside. This point was recognized in Schmidt's computations, and more recently has been investigated in another way by Liznar.[2]

Substituting in the harmonic series (Art. 17 of the Gaussian theory) for the radius vector r, the value increased by h (the altitude above the sea of the station), and neglecting powers of $\frac{h}{R}$, these results for the potential

$$V_h = R^2 V_o \,/\, (R+h)^2,$$

where V_o is the value of the potential at the surface. We have, furthermore:

$$X_h = R^3 X_o \,/\, (R+h)^3;\; Y_h + R^3 Y_o \,/\, (R+h)^3;\; Z_h = R^3 Z_o \,/\, (R+h)^3.$$

h being small in comparison to R, approximate formulæ suffice and we obtain for the variations due to altitude:

$$\triangle X = -3\frac{h}{R}X_o;\; \triangle Y = -3\frac{h}{R}Y_o;\; \triangle Z_h = -3\frac{h}{R}Z_o;$$

$$\triangle H = 3\frac{h}{R}H;\; \triangle T = -3\frac{h}{R}T_o;\; \triangle \delta = \triangle i = o.$$

[1] T. M., Vol. I, p. 169, 1896, and Vol. IV, p. 33, 1899.

[2] J. LIZNAR: Änderang der erdmagnetischen Kraft mit der Höhe, Wiener Sitzber, Vol. 107, p. 753, 1898.

Hence the angular values suffer no change, the intensities vary linearly, the assumption involved being, however, that the decrease with altitude depends alone upon increase of distance from the Earth's surface.

Liznar took as the surface values:

$$X_o = H_o = 0.21\,; \; Y_o = 0.033\,; \; Z_o = 0.4\,; \; T_o = 0.45$$

c. g. s. units, which, according to his magnetic survey, held true for $\phi = 46°\ 40'$, $\lambda = 17°.6$, and for the epoch 1890.0. The stations arranged by altitudes in three groups appeared to give results, pointing to the conclusion that there also exists a magnetic field outside of the surface, and that it would be hence necessary to reduce magnetic surveys to the same datum plane. It should be remarked that Trabert, in the paper cited above, was unsuccessful in obtaining a field, consisting of electric currents traversing the upper regions in lines parallel to the Earth's surface, which could produce quantitatively the magnetic field necessary to produce Liznar's results. This, of course, does not contradict Liznar's work. It must serve, however, to encourage further investigations in this direction, and, as Liznar proposed, the erection of an observatory at a high altitude. We may remark, briefly, that the cause of the observed decrease may, likewise, be referred to a kind of mass effect, just as we have in plumb-line deviations.

Palmieri[1] has shown that earth-currents follow the slope of hills. Such an upward-sloping current must of necessity evoke a disturbed field. To investigate this, it would be necessary to carry out line-integrals around a mountainous region.

All of the investigations thus far described pertain to the permanent magnetic field. This is, however, subject to the secular variation—a variation of which, because of insufficiency of data, we know the least. A theoretical investigation of the secular variation was undertaken but very recently. Gauss and Weber assumed a quadratic equation, but later investigators use generally a Bessel series. Such researches, however, were not very fruitful, and it is furthermore questionable whether, strictly speaking, there exists a common secular variation period. Weyer,[2] however, was more successful in his application of the Bessel series, his graphical representation of the first terms bearing some similarity to Bauer's researches.

[1] L. Palmieri: Correnti telluriche all' Osservatorio Vesuviano. Atti di Napoli, Vol. 8, No. 4, 1897.

[2] Weyer: Nova acte 58, 3, 1895.

L. A. Bauer[1] investigated that curve, which the north pole of a freely suspended magnetic needle describes in the course of time in consequence of the secular variation in declination and inclination. His first result was, that the curve, as viewed from the center of suspension of the needle, for the entire Earth, is described in the hands of a watch (exceptions being small loops). The second result reached was that nearly the same curve is described by an instantaneous circuit with the magnetic needle around the globe along the parallel of latitude. This implies that the permanent field gradually slides around the Earth. Of course this is only an approximation to the real truth which later investigations will modify.

The first step in this direction was made by the elegant theory of Carlheim Gyllenskiöld.[2] In this investigation the variation of the entire magnetic potential is considered, the author computing for this purpose, by a method of successive approximation, the spherical harmonies $h^{i,n}$, $g^{i,n}$ for twenty-three different epochs. The result of the computations was that the moment of the field remains constant, but that its direction varies with time. This is a similar result to that of Bauer's, with the exception that Gyllenskiöld could show at the same time that the fields of different order exist independently of one another, the changes in direction for the respective fields taking place according to different periods.

The changes in direction are proportional to the changes in time; *i. e.*, the various fields rotate with uniform velocity about the Earth. The magnetic potential which Gauss obtained for a definite moment of time, Gyllenskiöld develops as a function of the time. If we regard as principal axis of the magnetization of the Earth the direction of the principal moment, then there results that this magnetic axis describes about the rotation axis in 3,147 years, a cone of 23° 28′ spread.

Gyllenskiöld's numerical analysis of the observations is, however, but the introduction to his physical one. The whole system of rotating fields represents one which induces in the Earth a system of conflicting forces. And so the author continues with his investigation and reaches the result "that the coëfficients of the

[1] L. A. BAUER: Beiträge zur Kenntniss des Wesens der Säcular-variation. Diss. Berlin, 1895.

[2] V. CARLHEIM-GYLLENSKIÖLD: Sur la forme analytique de l'attraction magnétique de la terre. Astron. Jaktag. Vol. V, No. 5. Stockholm, 1896. Cf. T. M., Vol. II, p. 150, 1897.

entire field are fractions, composed of the coëfficients of that of the permanent and of the inducing field, and the angle constants are displaced by $\frac{\pi}{2n}$ with reference to that of the permanent field." He regards as inducing field a system of electric currents in the atmosphere; and applying Hertz's researches on the rotation of a magnetized sphere in such a field, he finds agreement with his theory, if the electric field of force rotates in an opposite direction to that of the Earth about its axis.

This, of course, does not yet prove the existence of such a current field, for every magnetic effect can be regarded as due to a properly distributed current system. However, the possibility of there being such currents is a great one, for Schuster,[1] likewise, was able to show that, under certain assumptions of the conductivity of the upper strata, the secular variation may be due to electric currents in those regions. In this connection should also be cited Korn's[2] researches, in which he makes use of the hydrodynamic theory of gravitation to explain the circumstance that the Earth is magnetized (principally) in the direction of the axis of rotation. So, also, Wessely's[3] idea deserves mention; he endeavored to explain the same circumstance with currents due to the orbital motion of the Earth.

In contrast to the phenomena of the permanent field, we have the so-called periodic variations, by which we understand those phenomena which appear to repeat themselves within definite periods. The character of these is defined by the number and position of the maxima and minima, and by the range; the latter, however, generally being itself subject to periodic fluctuations, so that the phenomena may not strictly repeat themselves until after the lapse of long periods. If the period be known definitely, the phenomena can be represented by suitable functions. Thus, for the diurnal variation, regarded, simply, as a function of the solar hours, a Fourier series would be used. If this phenomenon be also regarded as a function of the months, spherical harmonics would be employed, and if, in addition, it is desired to express the eleven-year fluctuation in the diurnal variation, elliptic Lamé

[1] T. M., Vol. I, p. 1, 1896.

[2] A. Korn: Entstehung des Erdmagnetismus.

[3] Wessely: Grunert's Archiv, 1899.

functions would be required. Such a mathematical representation, or harmonic analysis, as the writer has shown elsewhere, likewise expresses the physical origin of the phenomena. The period of the harmonic must, of course, be definitely known, as it may easily happen that a period may have resulted by interference. Thus, for example, it was thought for some time that there existed a relation between magnetic phenomena and the sun-rotation period (26 days). This period, however, Schuster was able to show, resulted from interfering periods. He was enabled to do this with the aid of his method of "hidden periodicities."[1]

Of the variations, the diurnal variation alone has been subjected to a Gaussian analysis of the operating forces, viz., by Schuster,[2] who assumed that the system of forces possessed a potential which rotated about the Earth in 24 hours without undergoing any change. Bezold called attention to the fact that Schuster's assumption consists of two independent parts: First, the normal daily variation is produced by a system of forces which revolves, unaltered, in the course of the day about the Earth, supposed to be standing still; and, secondly, the system has a potential.[3]

If the first premise be true, the diurnal variation is but a function of the local mean time (or longitude), and, hence, will be the same for all points in the same parallel of latitude. Von Bezold investigated this with vector diagrams, oriented with respect to the geographical meridian.

More interesting is the second premise, that the system has a potential. Two cases are possible: either the system is unalterable, or periodically alterable. In this first case the daily variation is again but a function of latitude and longitude, and simple laws pertain to the potential V_d. For example, "a knowledge of either component of the horizontal force for all points on the Earth suffices to determine the potential and all the other components at every point." The two rectangular components of H, X_d and Y_d, are, therefore, not independent of each other. Von Bezold has deduced some other laws and given an expression involving the horizontal components for testing, with the aid of the observations, the hypothesis of a daily potential.

[1] A. SCHUSTER: "On the investigation of hidden periodicities," T. M., Vol. III, p. 13, 1898; and "The possible effect of solar-magnetization," Phil. Mag. 395, 1898.

[2] ——————: The diurnal variation of terrestrial magnetism. Phil. Tran., Vol. 180 (1889) A., pp. 467–518.

[3] W. VON BEZOLD: Theorie des Erdmagnetismus, l. c.

Schuster has made a computation of the potential, and has given a graphical representation of the equipotential lines. Von Bezold, employing Schuster's figures, likewise has given a graphical representation. These diagrams bring out prominently the salient features; *e. g.*, the steeper gradients of the lines in the northern hemisphere and the existence of a positive and negative center of force in each hemisphere. The centers move about the Earth on the so-called horse latitudes and precede the Sun. All this points to meteorological influences, and quite likely we have to deal with electric currents brought about by the general atmospheric circulation.

Schuster, investigating the matter further, was enabled to show that the cause of the daily variation resides above the Earth's surface, and, probably, consists of electric currents in the upper region. He also examined the effect of the currents induced in the Earth by these atmospheric electric currents.

The Schuster-Bezold theory of the diurnal variation discloses an unbounded field of research, which is all the more interesting by reason of the fact that it promises to lead to an explanation of the correlated phenomena of terrestrial magnetism and meteorology.

Of the other variations, we possess, as yet, but few investigations, and no correlating theories. The annual variation is difficult to obtain alone, as yet, as it is affected by the secular change and by the variations in the base lines of the registering magnetometers. In view of the known law that the amount of solar radiation which falls upon the Earth increases inversely with the time during which the radiation takes place (because of the ellipticity of the Earth's orbit), it follows, that the inclination of the orbit alone can cause the annual variation of a geophysical element; therefore, also, the smallness of the annual amplitude in comparison to that of the other variations.

The 26-day period, supposed to be referable to period of rotation of the Sun, as already stated above, has been shown to be fallacious. Only the so-called eleven-year sun-spot period and the lunar diurnal variation appear to be known with certainty.

The length of the sun-spot period varies, from time to time and in full accord therewith, according to Ellis,[1] fluctuate the daily ranges in declination and horizontal intensity. It can not, there-

[1] W. Ellis: Diurnal range of declination and horizontal force and the period of solar spot frequency. Proc. Roy. Soc., Vol. LXIII, p. 64, 1898.

fore, be questioned that the two are, primarily, associated with each other, and that the thermic and electric radiation of the Sun, as affected by the spots, is the cause of this magnetic variation and of the change in number of the magnetic disturbances storms).

What is a "disturbance" has not yet been sharply defined. There probably exists two kinds of magnetic storms, such as are of cosmic origin, occurring instantaneously over a very large area, and such as take place at different times at the various stations. Adolf Schmidt[1] has, recently, been able to show that the lower atmospheric strata are traversed by electric vortices, which may be regarded as an illustration of disturbances of the second class, which are purely of terrestrial origin.

The disturbances, in general, increase with latitude, so that, as was shown by Lüdeling,[2] the Bezold vector diagrams are reversed in the polar regions. Eliminating, however, the disturbed days restores the primary direction of the curve.

Summarizing the results of the recent researches, we find: The Earth's magnetic field freed of the periodic variations and reduced to a definite moment of time is due to a potential. Upon this field is superimposed a system of forces, causing the variations and the constitution of which depends materially upon the thermic and electric radiation of the Sun. Eliminating from this system of forces all variations, except the daily, we find that, as a first approximation, it rotates about the Earth in twenty-four hours, that it may have a potential, and that it may be a function of the geographic coördinates. If we eliminate only secular changes, then it is seen that the orbital inclination of the Earth produces an annual change in this system. The secular variation causes gradually a successive displacement or sliding of the system about the Earth, and since the geographic peculiarities to be found along the various longitudes remain fixed (*e. g.*, the local peculiarities of distribution of land and water), the secular variation field consists of two parts—the displacement of the system and the effect of the permanent field. Gradual loss of the Earth's energy and the displacement of the entire solar system in space may produce further modifications.

[1] ADOLF SCHMIDT: Die Ursache magnetischer Stürme. Meteor. Zeitschr, Vol. XVI, p. 385, 1899. Cf. T. M., Vol. V, p. 86, 1900.

[2] T. M., Vol. IV, 245, 1899.

We, furthermore, see that there exists a relation between magnetic variation phenomenon and meteorological phenomenon, and the question arises how far there may exist a direct connection between them. However, the direct connection with solar activity appears to be established.

When one recalls that the results cited above are the product of the past fifteen years, it must be recognized with what zeal investigations have been carried on. Even more striking than the sudden revival of interest in magnetic research is the international co-operation of the various investigators. This fact finds its expression in the existence of the Journal TERRESTRIAL MAGNETISM in the establishment of the permanent International Magnetic Committee, and in the attempt by the various countries to conduct work according to a uniform plan; as, for example, in the case of the south polar expeditions of the coming year.