The Wingst Geomagnetic Observatory and the Development of Geomagnetism during the Past Fifty Years

Ulrich Schmucker

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1 *D, H, I* records past and present

This review of the past begins with the classical, never outdated task of geomagnetic observatories: to provide continuous and complete records of the changing Earth's magnetic field in its three components. For a long time this implied the observation of two field direction angles D and I and one field strength H; D is the declination of the compass needle against true north, I the inclination of the dip needle against the horizontal plane, and H the horizontal field intensity.

Their records reach much further back into the past than the lifetime of the Wingst Observatory. When it began to operate in 1938, hundred years had passed since the creation of the first global network of observatories under the strong influence of C. F. Gauss and W. Weber at Göttingen.

Since the sixteenth century compass and dip needle readings were made more or less regularly at various European locations. Observations of H were added much later and will be considered separately. Figs. 1 and 2 show two of the longest records in D and I, reduced from various locations of measurement near London to the site of the Greenwich Observatory. Changes in D are quite dramatic. Within the seventeenth and eighteenth century the compass needle swang here eastward by 35 degrees. Since the beginning of the nineteenth century it moves steadily backward toward an angle of zero declination. Changes in I are small by comparison. We note a continuous decrease by 8 degrees until the inclination levels off at 67 degrees at the beginning of this century.

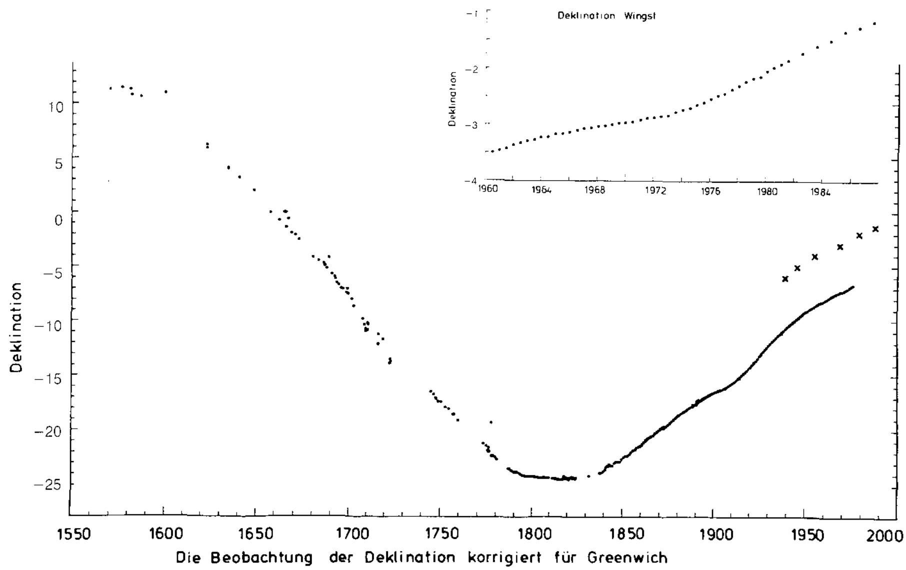


Fig. 1: Magnetic declination at Greenwich (dots) and Wingst (crosses). The inlet shows for Wingst annual means at epochs 1960.5, 1961., ... on an expanded time scale. The Greenwich curve is adapted from Malin and Bullard [1981], the Wingst values are from the Observatory yearbook 1982 with preliminary values added from 1982.5 to 1987.5.

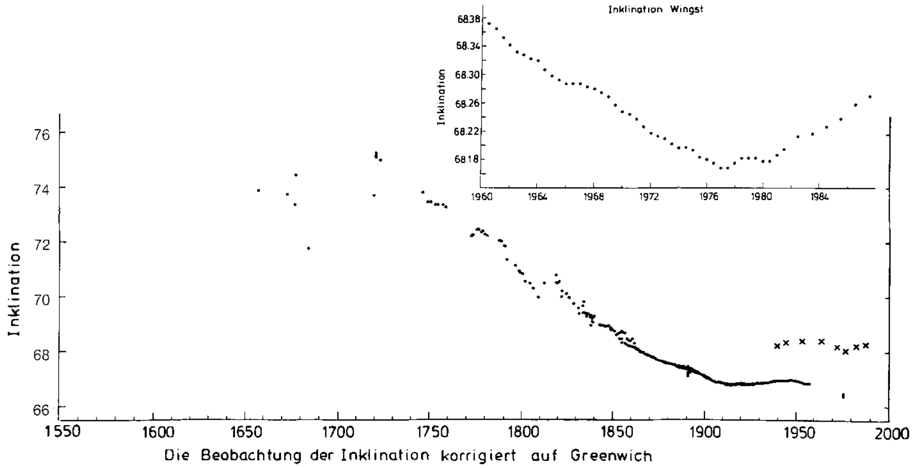


Fig. 2: Magnetic inclination at Greenwich (dots) and Wingst (crosses). Cf. legend to Fig. 1 for further explanations.

For the last fifty years observations at Wingst can be added. The similarity of the records at Greenwich and Wingst is striking. But this should be expected from the great depth of the source region of the Earth's field, almost without doubt the fluid outer core, in comparison to the distance of the two sites; this is at least 2900 km against 500 km. The Wingst records are, however, not a mere duplication of observations made elsewhere in Europe. They have their own and indispensable value, when details of secular variations are to be studied in space and time. Here are examples of on-going research with long term observatory data:

Firstly, the secular change of the Earth's magnetic field at Wingst is not exactly the same as the secular change at Greenwich. Presently, a fine spatial structure of secular variations is emerging on a distance scale, which surprises in view of the quoted depth of the primary sources. So the question arises whether there exist secondary sources at shallower depth. They could be from induction effects in an Earth's mantle of laterally variable conductivity or from a temporal change of crustal magnetization, say, under time-varying crustal tensions. None of these effects seems very likely to contribute significantly to the secular variation field. But once a regional structure of secular variations is established beyond doubt, explanations have to be sought in the indicated directions.

Secondly, secular changes do not follow at all times a smooth trend. As seen from the Wingst Observatory record in *D*, the rate of change from year to year increases abruptly from 1970 onward, a phenomenon seen also at other observatories. The abruptness of this increase is again a surprising fact. Even though little can be said about the time and distance scale, on which the Earth's field changes in its source region, an electrically conducting Earth's mantle removes by induction all fast and sufficiently widespread fluctuations. Hence, "jerks" in secular variations, which are observed at the Earth's surface coherently on a distance scale comparable to depth of the core, impose an upper limit on lower mantle electric conductivity. Present estimates are at 100 S/m, but also this needs further examination.

In coming years progress in understanding secular variations will come from global observations with satellites, repeating in particular the most successful satellite mission MAGSAT in 1979 and 1980. Ground based observations as those at Wingst are an integral part in the reduction of the satellite data, since only their records can bridge the time gap between satellite missions and can provide adequate control on fast temporal changes during the missions.

Let us turn now to the history of observations of H, which begins with the discovery of C. F. Gauss that the measurement of H can be reduced to measurements of distance, mass, and time. In a letter to W. Olbers from February 18 of 1832 which is reproduced in part in Fig. 3, he reports on his work as follows:

> "I occupy myself at present with geomagnetism, especially with the absolute determination of the magnetic intensity. Friend Weber (Wilhelm) is making the experiments according to my plan. Just as, for example, a clear conception of speed requires reference to a time and a length, so, I find, a complete specification of the intensity of geomagnetism requires reference to a weight and a length."

(Translation of the marked section from: S. Chapman and J. Bartels, Geomagnetismus vol. 2, p. 927, Clarendon Press 1940).

Fig. 4 shows Gauss' H-value for 1832 together with biannual H-determinations at Wingst from 1938 onward. Göttingen is 250 km south from Wingst and at present H is greater here by 1200 nT (= Nanotesla). The difference could have been similar in Gauss' times. Hence, by moving in Fig. 4 the Göttingen value 1200 nT downward, the Wingst record in H appears in direct continuation of the first determination of H at Göttingen, reflecting for Northern Germany an overall increase of 10 nT per year during the last 150 years.

The table in Fig. 5 is from Gauss' publication on H-determinations, made jointly by Gauss and Weber. The listed values T (for H) have to be multiplied by 10.000 to convert them into Nanotesla. Obviously, Gauss' and Weber's determinations were reproducible within ±100 nT, not counting possible effects from temporal changes. They could have been in the order of 10 nT at quiet times, but much larger during magnetic storms. The same Figure shows for comparison a similar one year sequence of H determinations, made more than a century later at the Fürstenfeldbruck Observatory in essentially the same way. The use of modern instruments provides an almost hundredfold increased accuracy, noting that from this sequence temporal changes were removed with the aid of simultaneous observatory recordings. – This was the last year that the Fürstenfeldbruck Observatory like many others used Gauss' method to determine H.

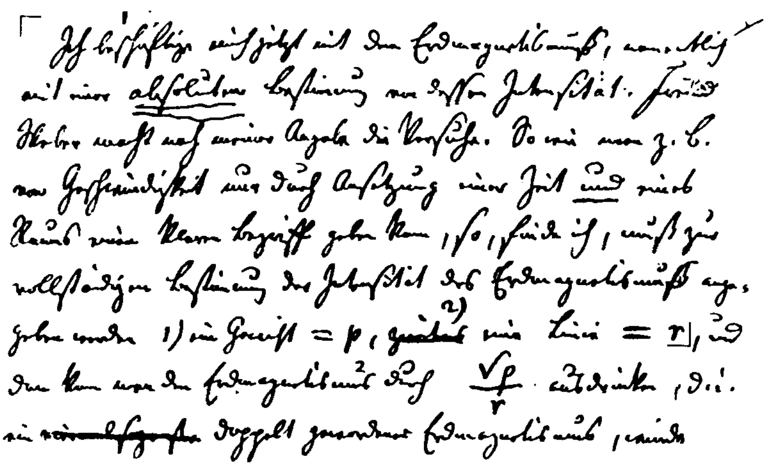


Fig. 3: C. F. Gauss writes to W. Olbers on his new concept to determine H in 1832. Handschriftenabteilung der Niedersächsischen Staats- und Universitätsbibliothek Göttingen.

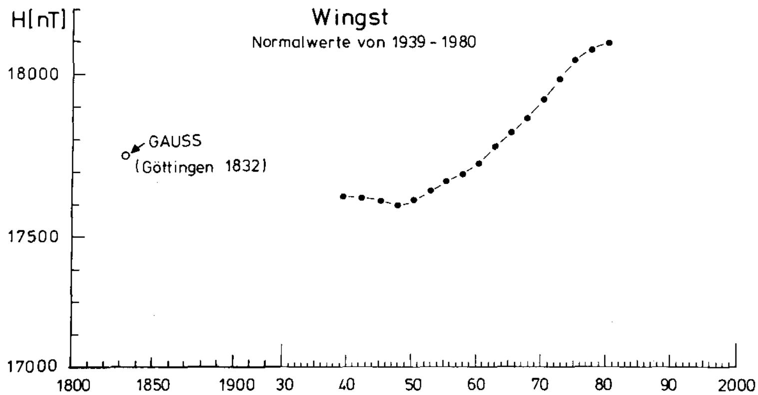
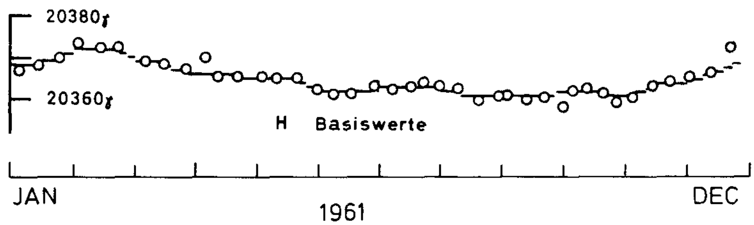


Fig. 4: Magnetic horizontal intensities at Wingst and Göttingen. Wingst values at epochs 1940., 1942., ... are from the Observatory yearbook 1982. Cf. Fig. 5 for the origin of the Göttingen value.



Numerus	Tempus, 1832	T
I	Maii 21	1,7820
II	Maii 24	1,7694
III	Iun. 4	1,7713
IV	Iun. 24-28	1,7625
V	Iul. 23, 24	1,7826
VI	Iul. 25, 26	1,7845
VII	Sept. 9	1,7764
VIII	Sept. 18	1,7821
IX	Sept. 27	1,7965
X	Octobr. 15	1,7860.

Fig. 5: Absolute determinations of the magnetic horizontal intensity H with Gauss' method. The diagram shows a sequence of determinations at the Fürstenfeldbruck Observatory in 1961, reproduced from the 1962 yearbook. The table, containing determinations by C. F. Gauss und W. Weber at Göttingen in 1832, is reproduced from Gauss [1832]. – $T = H$ in 10^4 nT.

2 The study of solar cycle variations

So far we have followed the contributions which observatories such as Wingst provide for research on the main field of internal origin. Now it will be demonstrated that long time series of observatory data contain also a small superimposed portion of external origin. Their primary connection to solar-terrestrial effects will be evident from a close relationship to the solar sunspot cycle of eleven years.

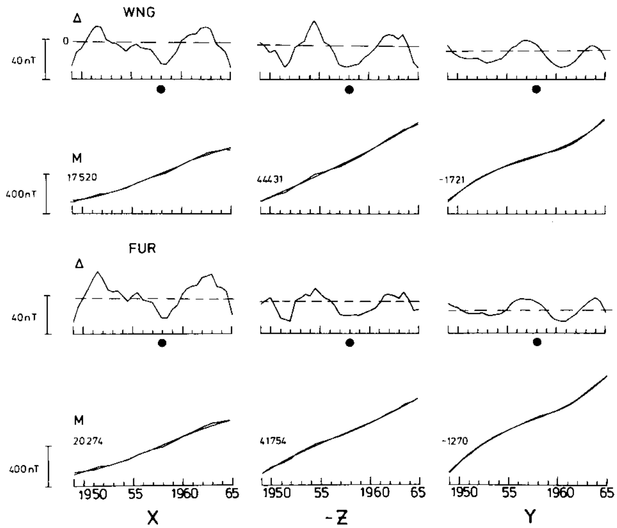


Fig. 6: Annual mean values (M) and solar cycle variations (Δ) at the Observatories Wingst (= WNG) and Fürstenfeldbruck (= FUR) for epochs 1949.5, 1950.5, ... , 1964.5.
X: north component, Z: vertical component, Y: east component. Dots mark the year of maximum sunspot number. – Note the reversed sign in the presentation of Z.

Fig. 6 shows Wingst annual mean values in the north component X, the vertical component Z and the east component Y for sixteen years from 1949 onwards, covering more than one solar cycle. The year of maximum sunspot number is indicated by a large dot. To have an independent control, the same Figure displays also annual mean curves from Fürstenfeldbruck, the second observatory in West Germany. It is located 700 km south of Wingst. For each component and observatory two diagrams are shown. The lower diagram "M" shows the annual mean values relative to the indicated base value of 1949.5. Superimposed and almost invisible is a second curve, presenting a 3rd degree polynomial least squares fit to the observed values. The upper diagram "Δ" displays, on a tenfold increased scale, the difference between the observed curve and the polynomial fit which is supposed to represent the smooth secular change of the main field within the chosen time interval. Note that this interval ends before in 1969 an abrupt change occurs in the D secular variations.

Even though the differences are quite small in comparison to the overall secular changes, they are well reproduced at both observatories. Thus, they cannot be regarded as spurious effects. This view is supported by a visible connection to solar activity: In the year of maximum sunspot number, the differences ΔX are negative, in the years of minimum sunspot number five years before and after they are positive. In Z the correlation is less clear, but appears to be reversed with positive peak values, when the number of sunspots is greatest.

Solar cycle variations of this kind occur coherently on a global scale, but details of their spatial structure and thereby of their source structure are uncertain. From the shown examples the following can be inferred:

The oscillating differences of X and Z have about the same peak-to-peak amplitude with a negative correlation. Thus, the ratio $-\Delta Z/\Delta X$ is roughly a time-independent constant near unity. This fits to the ratio $F_0 \cos\varphi / F_0 \sin\varphi$ of an uniform external field F_0 at latitude φ, when φ is near 45 degrees and when F_0 is oriented parallel to the Earth's axis of rotation, positive towards south.

Thus, the quasi-uniform field of the equatorial ring current ERC of drifting and gyrating particles, which becomes highly visible in the Dst recovery phase of magnetic storms, appears as a major external source of solar cycle variations, even though this cannot be the only one. We note at both observatories distinct and correlated differences ΔY which cannot be ascribed to an axial symmetric field such as the ring current field. It should be added that a transformation to geomagnetic coordinates, in which the ERC field is truly axial symmetric, does not make these differences to disappear. The negative correlation between sunspot numbers and ΔX implies that, as to be expected, the ring current field is strongest in times of increased solar activity, leaving it as an open question, which absolute value this field attains in years of minimum solar activity.

Another unsolved problem concerns the internal part of solar cycle variations. As a time-varying field they should induce currents in electrically conducting matter within the Earth. But in view of their slowness very high conductivities in excess of 1 S/m are needed, which places these hypothetical currents into the lower mantle from 800 km depth downward. In the simplified model of an equatorial ring current field, any internal contributions would produce at midlatitudes ΔZ fluctuations which are smaller in amplitude than ΔX fluctuations. This reflects the fact that external and internal contributions add in X and Y, but are opposed in sign in Z. The stated observation, that at least at Wingst ΔZ and ΔX amplitudes are comparable in size, implies at first sight the absence of internal contributions. The Earth's deeper mantle is then either too poorly conducting or the solar cycle variation source is too non-uniform to produce any significant induction at the 11-year period.

But again, this is the current state of knowledge. More research on solar cycle variations is needed to clarify these and other open questions on their source structure, their zero level and their internal parts. The weakness of all studies involving older data is the unsatisfactory baseline stability in Z and, in general, the involvement of diurnal variations in the derivation of annual mean values, which change also with solar activity. Progress relies completely on the continued operation of observatories like Wingst with reliable base values in all components over many years.

3 The magnetic field and its anomalies in Northern Germany

The magnetic field and its time variations are continuously observed at geomagnetic observatories. The field and its secular change in the areas between the observatories are measured during magnetic surveys. After the Magnetische Reichsvermessung 1935 – geomagnetic survey of Germany – (Bock, Burmeister and Errulat [1948] and [1956]) secular measurements in Northern Germany had been made in 1948, 1965 and 1982, the latter of which is subject of a special contribution to this volume.

A less visible service of magnetic observatories arises from the need, to remove short-term temporal changes in the Earth's magnetic field from magnetic survey data. In this way, the Wingst Observatory has had an important part, when in the thirties Northern Germany became the subject of extensive exploration work. In earlier time, this included surveys with magnetic field balances to investigate anomalies in Z, later with proton precession magnetometer to measure the total intensity. In addition, from the very beginning the Wingst Observatory has been active to conduct geomagnetic measurements at sea. When in 1947 H. Reich compiled the first complete ΔZ anomaly map of Northwestern Germany, it can be assumed that he relied extensively on the Wingst magnetograms for temporal changes, even though he used the Niemegk Observatory for zero reference. Fig. 7 reproduces from this map the region around Wingst. Except for a regional offset of −40 nT, local

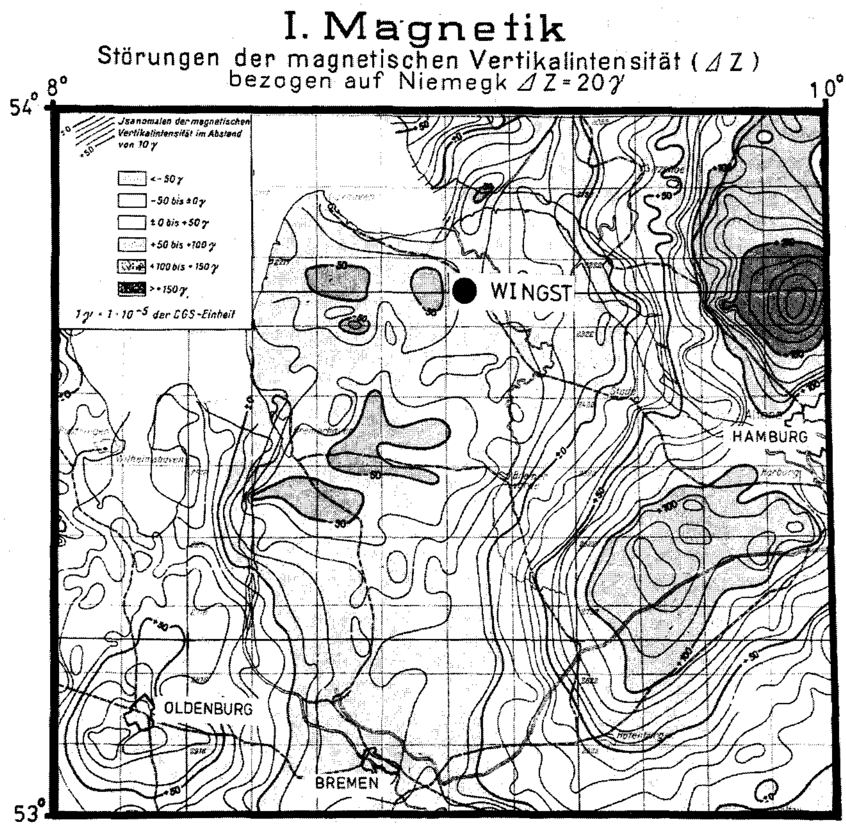


Fig. 7: Static magnetic anomalies in *Z* around the Wingst Observatory. Map adapted from: Geophysikalische Karten von Nordwest Deutschland, I Magnetik; zusammengestellt von H. Reich 1948. Reichsamt für Bodenforschung, Abt. für Geophysik.

anomalies are absent near Wingst and the site of the Observatory is well chosen in this respect. But, as this map shows, Northern Germany is not at all free of anomalies which surprises from the fact that the deep sedimentary basin here is virtually without volcanism and thus without rocks of any significant magnetism. Only in the earliest epoch of basin formation, an abundance of volcanic material was produced in the Lower Permian. But too little is known about their deep-seated distribution and present-day magnetization to estimate their contribution to surface anomalies.

So the source of these exceptionally strong and widespread anomalies is uncertain. Their 100 nT amplitudes require magnetization contrasts in the order of 1 A/m, if these sources are assumed to lie 10 to 20 km deep within the basement. It should be noted that these anomalies are at some distance from the observatory site. Thus, it can be expected that the field at Wingst represents the true dynamo field from the Earth's core with a minimum of crustal contamination.

For a quantitative proof of this statement the observed field B_{obs} is now compared in Table 1 with a synthesized internal field B_{syn}, derived from a synthesis of spherical harmonics with sets of coefficients from global ground and satellite data. The codes WMC, DGRF and GSFC stand for differently derived sets of coefficients, involving variable maximum degrees N of spherical harmonics. The comparison is carried out with respect to field intensities at the indicated epoch. Two sites in West Germany are added which like Wingst are believed to be without crustal anomalies. The Table gives two synthetic values. The upper value is from a synthesis uniformly with spherical harmonics of up to eight degrees. The second value refers to a synthesis up to the respective maximum degree as indicated. It appears that the first values agree better with the observed field intensities, indicating that series with terms of maximum degree N=8 of spherical harmonics express the dynamo field from the Earth's core in sufficient detail, at least in Central Europe. When terms of higher degrees are added, the differences between B_{obs} and B_{syn} are significantly increased, possibly because this adds not sufficiently resolved contribution from the crust.

Table 1

Observed and synthetic total field intensities

Location		Epoch	B_{obs}	B_{syn} WMC (N=12)	DGRF (10)	GSFC (13)
Wingst	53.74 N 9.07 E	1979.5	48 667	48 618 48 569	48 665 48 696	48 669 nT 48 718
Ludwig-stein	51.32 N 9.91 E	1980.	48 060	48 045 47 976	48 082 48 107	48 086 nT 48 128
Fürsten-feldbruck	48.17 N 11.28 E	1979.5	47 269	47 239 47 160	47 268 47 284	47 270 nT 47 302

Table 1 illustrates the general observation that at sites without known anomalies the field can be reproduced from a global synthesis within a few Nanotesla. Satellite missions in the future will clarify, whether remaining differences as those at the three cited locations are spurious effects or expression of large-scale anomalies on a continental scale.

4 Magnetic activity indices

Another little known service, provided by the Wingst Observatory, concerns the calculation of indices, which measure the degree of magnetic disturbance, predominantly arising in the auroral zone. Here it is important to add to observations in this zone itself data from

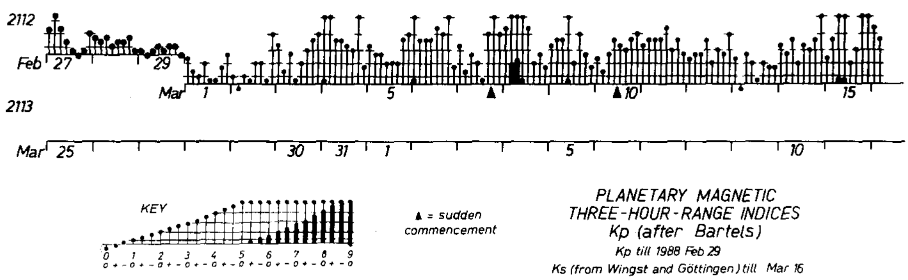


Fig. 8: Sample section of Bartels' "musical diagram" of *K*-indices of magnetic activity in 1988. February 27–29: Final planetary *Kp*-values from 13 observatories; March 1–16: Preliminary values from Wingst and Göttingen.

midlatitude observatories. Since 1951 the Wingst Observatory is among the thirteen selected "*Kp*-observatories" around the globe. Their standard magnetograms for the recording of geomagnetic variations are used to derive for every 3-hour universal time a local *K*-value of magnetic disturbance. The *K*-values of all observatories are then combined into a planetary *Kp*-index of magnetic activity.

Fig. 8 shows as an example a sequence of such indices, arranged in 27 day sections in correspondence to the rotation period of the sun, the ultimate cause of such activity. The local *K*-values are reported regularly to the Göttingen Geophysical Institute, where they are converted into planetary *Kp*-indices and distributed halfmonthly worldwide. Because of the nearness of Wingst to Göttingen, preliminary indices just on the basis of the records of Wingst and Göttingen are added for the last few days before mailing, as seen at the bottom line of the "musical diagram" of magnetic activity in Fig. 8.

After the closure of the Witteveen Observatory in the Netherlands, these are the thirteen current *Kp*-observatories, arranged from north to south:

Table 2

Lerwick/Shetland Isl.	60° 08′	N,	358° 49′	E	62.2° N[1]
Lovö/Sweden	59 21		17 50		57.8
Sitka/Alaska	57 04		224 40		60.3
Brorfelde/Denmark	55 37		11 40		55.5
Eskdalemuir/Scotland	55 19		356 48		52.1
Meanook/British Columbia	54 37		246 40		61.9
Wingst/Northern Germany	53 45		9 04		54.2
Niemegk/Central Germany	52 04		12 40		51.9
Hartland/SW England	51 00		355 31		54.2
Ottawa/Ontario, Canada	45 24		284 27		56.6
Fredericksburg/Virginia, USA	38 12		282 38		49.3
Canberra/Australia	35 19	S,	149 22		44.0 S
Eyrewell/New Zealand	43 25		172 21		47.6

[1] geomagnetic latitude

5 The North German anomaly of geomagnetic variations

O. Meyer, the observer-in-charge at Wingst from 1938 to 1954, used the Wingst records of magnetic substorms to demonstrate that there are local effects in Northern Germany of internal origin, connected to Earth currents which these substorms induce within crust and mantle. He noted that such effects reoccur in a systematic way with a $Z:H$ relationship which makes an external origin most unlikely. When during the last century the first simultaneous observations of fast fluctuation in D were made on agreed days, a striking similarity over large distances was discovered. Under the impression of such examples as shown in Fig. 9 for Europe, Gauss himself concluded that their source should be widespread overhead currents high above the ground, where some unknown process gives the air the required ability to conduct currents. This would account also for the then already known fact that very strong D-fluctuations during magnetic storms are connected to visible auroral lights.

Half a century later, when continuos observations in all three components became possible, A. Schuster [1889] proved the primary external origin for those regular variations, which have the solar day as fundamental period, but with an additional secondary part of internal origin. It could be shown that this part is explainable by induction in a spherically symmetric conducting Earth. Even though Schuster's analysis concerned very slow variations, later studies seemed to indicate that also faster substorm variations induce Earth currents mainly at several hundred kilometer depth, at least on continents because the inductive shielding by oceans was recognized.

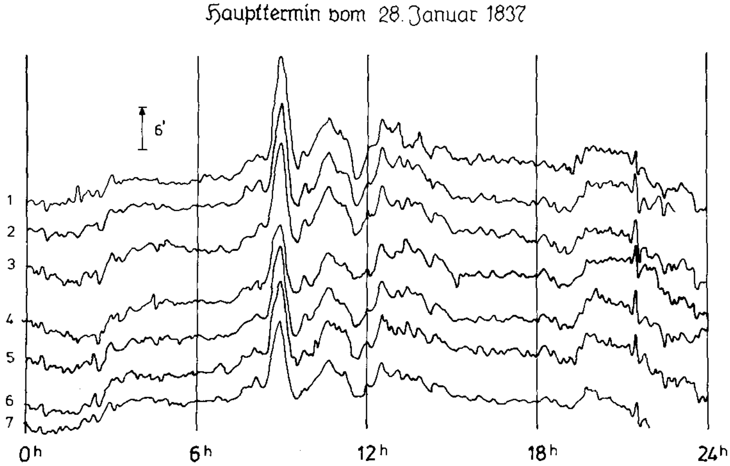


Fig. 9: 4-hours sections from the first simultaneous observations of declination changes in Europe, 1837. Shown are the time variations in *D* as obtained from the changing position of suspended magnets, read every five minutes. Observatory code: 1 = Uppsala, 2 = Kopenhagen, 3 = Altona (Hamburg), 4 = Breda, 5 = Göttingen, 6 = Berlin, 7 = Breslau. Redrawn from the original in Gauss and Weber [1838].

In the light of this generally accepted view about the deep origin of the internal part of substorm variations, Meyer's conclusion that there exist local effects in this part on a scale of tens of kilometers opened a new field of research. In a note at the end of a publication which concerned another subject, Meyer [1951] calls attention to a discrepancy, already noted by Bartels [1948], in the $Z:H$ relationship of bays between Wingst and Niemegk, the third German observatory south of Berlin. Fig. 10 shows three bay disturbances from the records of Wingst with positive deviations from the undisturbed level in all three components *D, H,* and *Z*. This was found to be typical for bays which occur before local midnight. After midnight the deviations of bay-type disturbances tend to be negative, again in all three components. Thus, the $Z:H$ ratio at Wingst is positive at all times. At Niemegk which is 300 km to the southeast, however, this ratio is negative, i. e. bays have here the same sign as at Wingst for *H*, but the opposite sign for *Z*. If this reversal in sign were due to external sources, as Bartels originally suggested, then two overhead currents north of Wingst and south of Niemegk are needed, either one seen by only one observatory and both in either eastward or westward direction. But there are no indications for such currents in observations further north or further south besides the fact that at this distance from the polar electrojet region overhead currents of such complexity are unlikely. Meyer then concludes that

> "Es wird nicht leicht sein, diesen Widerspruch zu klären, wenn man nicht einen Erdstrom zwischen den beiden Stationen als Ursache für den Effekt annehmen will."
>
> "It will not be easy to account for this discrepancy (in the $Z:H$ ratio) unless an Earth current between both stations is postulated to be the cause for this effect".

Meyer's conclusion was confirmed when the spatial structure of bay disturbances in Northern Germany was investigated with mobile recording stations. Fig. 11 gives an example from the IGY 1957/58, for simplicity only for the records of *H* and *Z*. Altogether this illustration assembles the records of a typical bay disturbances for seven European observatories and for four mobile stations. The records in *H* show the expected spatial correlation from site

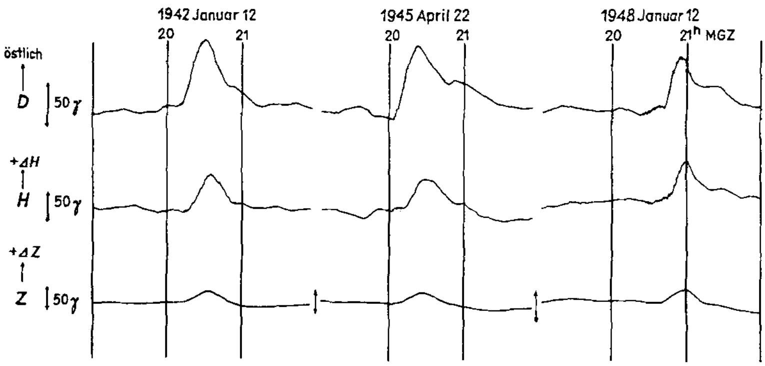


Fig. 10: Three bay disturbances with pulsations, recorded before local midnight at Wingst. Reproduced from Meyer [1951].

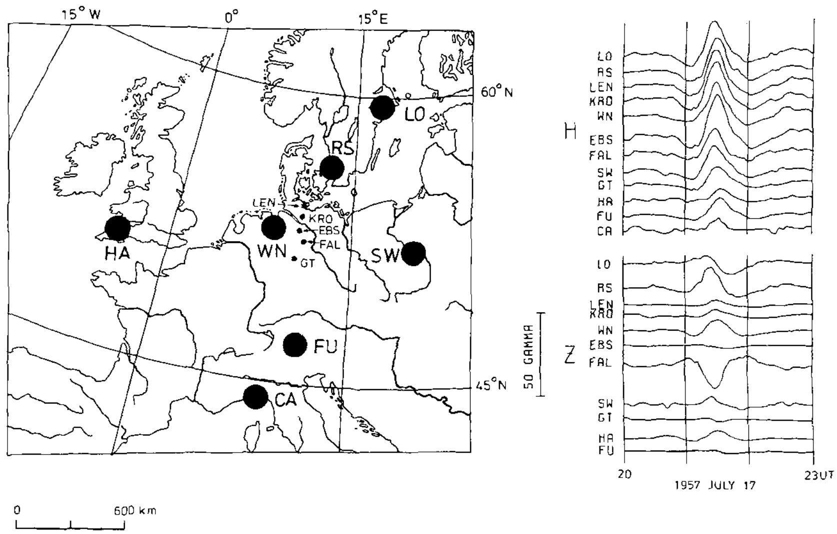


Fig. 11: 3-hours sections of *H* and *Z* records of a bay disturbance in Europe. Large dots: magnetic observatories; small dots: temporary variometer stations during the IGY. – The center of the North German variation anomaly is at EBS with zero *Z* and maximum *H* variations.

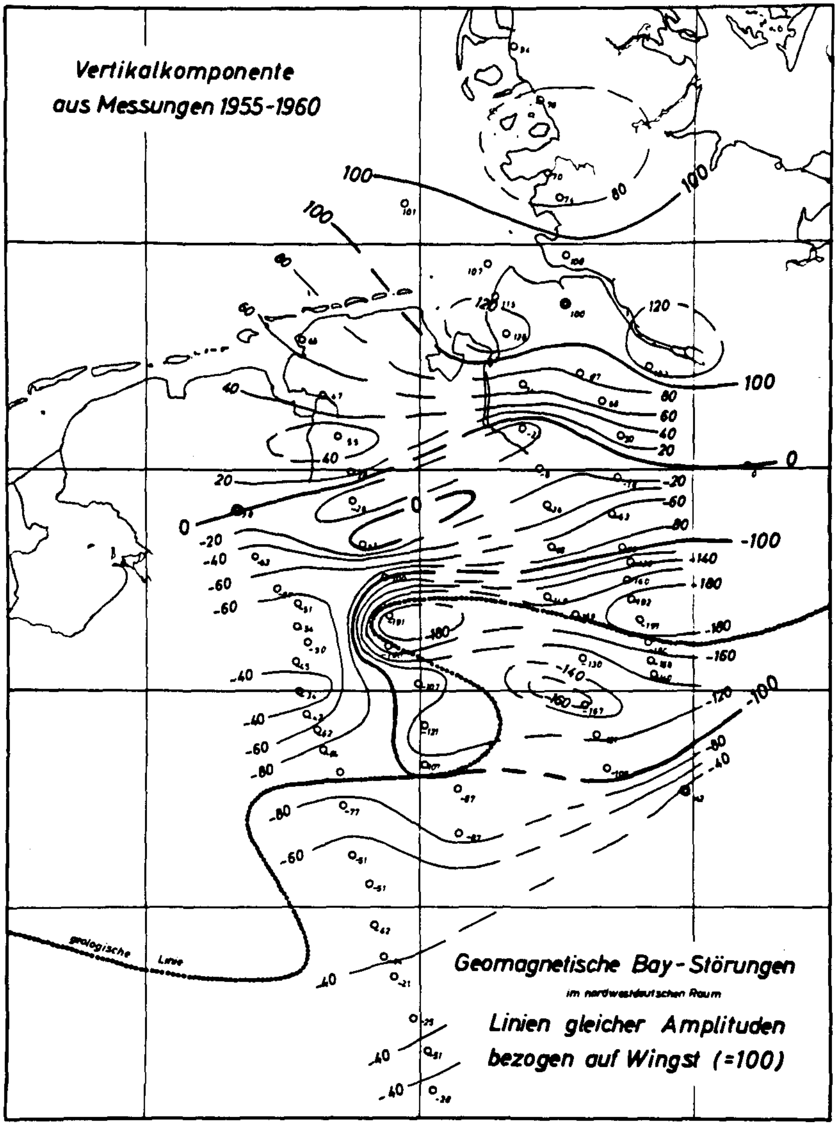


Fig. 12: Fine spatial structure of the North German variation anomaly. Local Z-amplitudes of bays, observed with one to three mobile stations at changing sites, are normalized with respect to the Z–amplitude at Wingst (= 100). Shown are isolines of relative Z–amplitudes. The zero line of no Z variations marks again the center of the anomaly, where Earth currents form a concentrated flow from west to east. Reproduced from an unpublished report by O. Meyer, 1961.

to site, but in contrast to *D* with an overall decrease in amplitude towards south, i. e. with increasing distance from the polar electrojet. In *Z*, however, the bay disturbance displays a spatially irregular behaviour. Only at the two most northern stations RS (= Rude Skov) and LO (= Lovö) can this be attributed to external source effects, at least partially. At all other sides these irregularities express effects of internal origin.

The greatest changes occur indeed in Northern Germany between WN (= Wingst), EBS (= Ebstorf) and FAL (= Fallersleben) over a north-south distance of just 150 km. The station EBS, which has no *Z*-variations at all, seems to lie exactly above the postulated Earth current, in perfect agreement with the clearly visible enhancement of *H* at the same site.

Fig. 12, which is taken from an unpublished report of O. Meyer, demonstrates that the variation anomaly in Northern Germany possesses details on an even finer scale. All this is clear evidence that shallow Earth currents beneath Northern Germany are involved, which obviously produce a substantial, but variable portion of the internal part of bay-type disturbances. But it should be observed that these currents belong to a widespread system of induced currents, existing everywhere. Their magnetic field more or less doubles the horizontal components of the external source field and reduces the vertical component *Z* to zero by compensation, where variation anomalies are absent, i. e. where conductivity is a sole function of depth. Even though the existence of variation anomalies is now clearly established and similar anomalies have been founded on all continents, nothing definite is known about their cause or about their relation to geological or other geophysical evidence for special conditions in the Earth's outermost layers. Their spatial complexity establishes a depth limit independent from all other considerations. For Northern Germany this depth limit is in the order of 10 km as seen from Fig. 12.

Further information about depths comes from the period dependence of the anomalies and from magnetotelluric observations. Both suggest for the North German anomaly that its cause is a highly conducting layer of 1 S/m between 6 km and 10 km depth, crossing the North German Basin from east to west. But no model concept exists to this date which can account for all observations from fast pulsations to slow diurnal variations in the Earth's magnetic and telluric field.

O. Meyer himself thought that younger sediments of the North German Basin down to a few kilometer depth were responsible for the observed local effects on bays because the partially well conducting sediments of jurassic to tertiary ages are absent south of the basin. Model calculation indicate, however, that contributions from induced currents within these sediments are not sufficient and not with the right dependence on period, to account for the observed effects, indicating the quoted depth range as source region. The Wingst Observatory will continue to play a major rôle in further studies toward a complete understanding of this now classic example of a geomagnetic variation anomaly.

6 Pulsation records at Wingst

Since its early years the Wingst Observatory employs induction coils to record the first time derivative of very fast field fluctuations, known as geomagnetic pulsations. They supplement the variometer records of the standard magnetograms, on which larger pulsation can be seen, but not resolved in time. Two major contributions have come from pulsation records at Wingst. The first contribution is contained in the already cited publication by O. Meyer and Fig. 13 is reproduced from it.

In its upper portion a standard magnetogram of a very quiet day is displayed with a bay disturbance, commencing shortly before 22 hours in 15° eastern meridian time. The lower portion from a simultaneous pulsation record shows on an expanded time scale that the onset of the bays is accompanied by strong pulsations in *H* and *Z*. Meyer founded by searching through the Wingst magnetograms from 1939 to 1949 that in the average about 60 bay events of this special type occur annually and established their correlation to solar particle streams interacting with the Earth's magnetosphere.

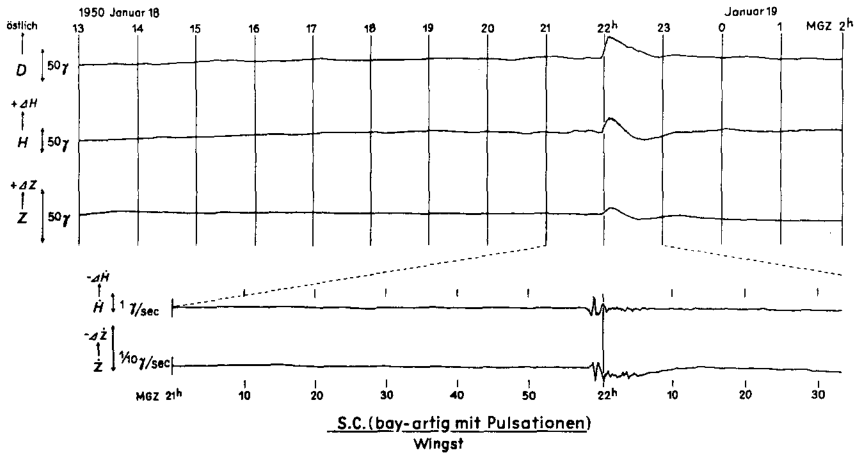


Fig. 13: Standard magnetogram and pulsation record of the Wingst Observatory, showing a bay disturbance with strong pulsations at the onset. Reproduced from M e y e r [1951].

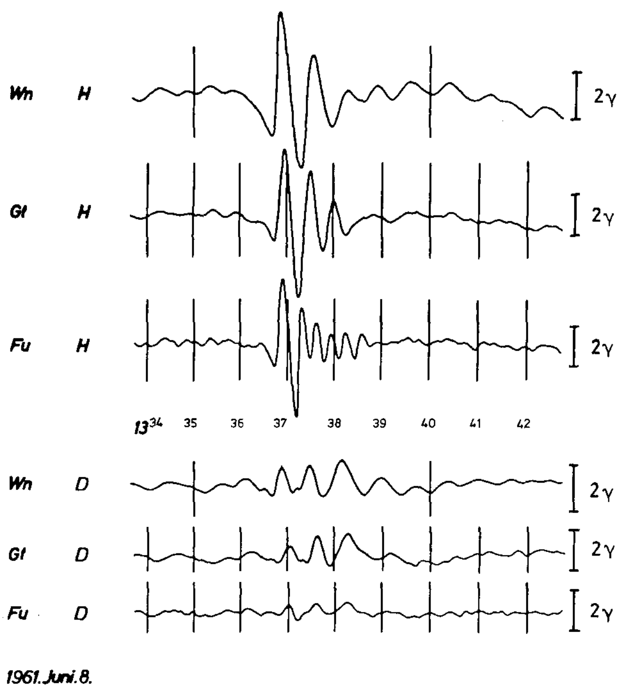


Fig. 14: 9-minutes sections of pulsation records in *H* and *D*, observed simultaneously at Wingst (= Wn), Göttingen (= Gt), Fürstenfeldbruck (= Fu). There is a pronounced southward decrease of period in *H*. Reproduced from V o e l k e r [1962].

The second contribution concerns a discovery by Voelker [1962] that the period of certain forms of pulsations varies with latitude. Fig. 14 compares the record of pulsations in *H* and *D* at the observatories Wn = Wingst, Gt = Göttingen, and Fu = Fürstenfeldbruck. They lie roughly on the same meridian in 350 km distances from each other. Vertical bars are minute marks at Gt and Fu, five minute marks at Wn. In *D* a general southward decrease in amplitude is observed, but with no change in period.

The *H* amplitude in contrast is nearly constant and the period of the *H* pulsations most clearly decreases from 40 s in the north to 25 s in the south with 35 s halfway at Göttingen. The interpretation is that *D* and *H* pulsations of this event express independent modes of presumably one source. Assuming that the *H*-mode arises, when plasma in the magnetosphere has been excited to vibrate in resonance along field lines, the observed latitude dependence of their period reflects the latitude-dependent length of fieldlines between conjugate points on the northern and southern hemisphere which in turn determines the eigenperiod of the vibrations. In the meantime observations with geostationary satellites have confirmed that indeed fast magnetic field oscillations occur in the magnetosphere simultaneously with pulsations at the ground.

This final example concludes the review of past achievements in geomagnetism associated with the Wingst Observatory. Its results on all time scales have been used most efficiently in many aspects of geomagnetic research, a number of discoveries will remain connected to name of Wingst, and its continued operation is essential for further progress in geomagnetism.

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Anschrift des Verfassers:
Prof. Dr. Ulrich Schmucker
Institut für Geophysik der Universität Göttingen, Herzberger Landstraße 180, 3400 Göttingen