PUBLICATION OF THE NETHERLANDS GEODETIC COMMISSION

GEODETIC WORK

IN

THE NETHERLANDS

1940–1953

Report presented at the Tenth General Assembly of The International Associaton of Geodesy at Rome 1954

PUBLICATION OF THE NETHERLANDS GEODETIC COMMISSION

GEODETIC WORK

IN

THE NETHERLANDS

1940–1953

Report presented at the Tenth General Assembly of The International Associaton of Geodesy at Rome 1954

GEODETIC WORK IN THE NETHERLANDS 1940–1953

I. TRIANGULATION.

1. *Introduction.*

The first and second order triangulations having been completed already in 1929 triangulation operations during the period under report consisted mainly in:

a. Determination of coordinates of new points, (newly erected towers, etc.).
b. Re-determination of coordinates of triangulation-points damaged or destroyed by the war-activities and rebuilt afterwards.
c. Determination of Laplace-points to strengthen the Netherlands-chain of the recent European adjustment and to check the accuracy of the net.
d. Computations to connect to the Netherlands chain of the recent European adjustment those parts of the first order net not included in that chain (for scientific purposes).

2. *Measurement of horizontal Directions.*

Experiments were made with a new method of pointing the telescope of a thedolite. Use was made of a method of precision-alignment, invented by Prof. dr A. C. S. van Heel of the Delft Technological University. It was proved that both the internal and the external accuracy are almost twice as high as with the classic method.

A detailed description is given in a separate report:

A New Method of Collimation with a Theodolite by P. Richardus, presented at the General Assembly at Rome.

3. *Computations.*

The following computations were made under the direction of the late Prof. J. M. Tienstra.

A. The results of the adjustment by the modified Bowie method of the Central-European Adjustment have been forwarded to the Netherlands Geodetic Commission in the form of geographic positions on the Hayford ellipsoid of 44 points of theNetherlands primary triangulation net. These points are situated in an arc (marked on map nr 1) running from Ubagsberg via Utrecht to Finsterwolde.

These data were used to connect the whole Netherlands primary triangulation to the system of the Central European Net and after that formulae were derived to transform the plane coordinates of all triangulation points in the Netherlands (which are known in Stereographic Projection on the Bessel-ellipsoid) to plane coordinates in the Universal Transverse Mercator projection. The computations applied, are explained below.

B. In the first place those parts of the Netherlands primary triangulation net, which were not included in the arc mentioned under A had to be connected with this arc. These parts have been marked on map nr 1 and are called: triangulation net East and triangulation net West. It was desirable to firstly re-adjust these two nets separately. The purpose of these adjustments was to avoid the distortion, possibly originating from the boundary conditions of the adjustment groups II and III to group I in the initial adjustment of the net executed in the years 1901—1904. Triangulation net East actually includes parts of the former adjustment groups I and III and triangulation net West parts of the adjustment groups I and II.

The data, necessary for the re-adjustment of the nets East and West are to be found in „Triangulation du Royaume des Pays Bas", Tome I, 1903 and Tome II, 1921. The triangle-and side equations could be copied for the greater part from this publication, some had to be derived. The normal equations were solved by applying an elimination method and the „Entwicklungsverfahren" by Boltz in such a manner that in net West two systems of 15 and 7 and in net East two systems of 17 and 10 normal equations had to be solved.

C. In these re-adjusted triangulation nets Eats and West the lengths of the sides of the triangles were computed and after that the geographic positions, starting from the length and the azimuth of the side Harderwijk -Urk for triangulation net East and from the length and the azimuth of the side Gouda-Gorinchem for the triangulation net West. The lengths and the azimuths of these two sides were computed from the geographic coordinates in the C.E.A.

D. The geographic coordinates of the common points of the arc mentioned under A on the one side and the nets East and West on the other side are then known in two systems viz. firstly in that of the Central European System and secondly in the System mentioned ad. C. Table no. 1 gives the differences $\Delta\varphi$ and $\Delta\lambda$ between the geographic coordinates in both systems. Afterwards the sum of the squares of the remaining differences in φ and λ was reduced to a minimum by a conformal transformation on the Hayford ellipsoid with superfluous observations.

A transformation formula to produce a conformal connection between both systems has to be set up in isometric coordinates, introducing the isometric coordinate Φ which is a function of the geodetic latitude:

$$\Phi = \ln \operatorname{tn}\left(\frac{\pi}{4} + \frac{\varphi}{2}\right)\left(\frac{1 - e\sin\varphi}{1 + e\sin\varphi}\right)^{e/2}$$

Φ can be found by means of tables in which the isometric latitude χ is given against the geodetic latitude φ. The relation between Φ, φ and χ is

$$\Phi = \ln \operatorname{tn}\left(\frac{\pi}{4} + \frac{\varphi}{2}\right)\left(\frac{1 - e\sin\varphi}{1 + e\sin\varphi}\right)^{e/2} = \ln \operatorname{tn}\left(\frac{\pi}{4} + \frac{\chi}{2}\right)$$

In this way χ can be found for a given φ and after that Φ can be computed.

The transformation formula is

$$\Phi_A + i\,\lambda_A = (\alpha + i\,\beta) + (\gamma + i\,\delta)(\Phi_N + i\,\lambda_N)$$

in which the index A refers to the C.E.A.-system and the index N to the system mentioned ad. C. λ is the geographical longitude and $i^2 = -1$. The constants α, β, γ and δ were determined by the method of the least squares, for net-West from 12 correction equations (6 common points) and for net East from 20 correction equations (10 common points). These correction-equations are:
for the isometric latitude

$$\Phi_A + \varepsilon_\Phi = \alpha + \gamma\,\Phi_N - \delta\,\lambda_N$$

and for the longitude

$$\lambda_A + \varepsilon_\lambda = \beta + \delta\,\Phi_N + \gamma\,\lambda_N$$

in which ε_φ and ε_λ represent the remaining discrepancies in isometric latitude and longitude after applying the method of least squares.

The results of this adjustment, viz. the discrepancies in φ and λ (ε_φ and ε_λ) are given in table nr. 2, expressed both in seconds of arc and in cm.

With the aid of the above transformation formulae the geographic coordinates of all primary points of the triangulationnets East and West were transformed into the Central-European system.

E. In this way the geographic coordinates in the Central European system of all primary points of the Netherlands triangulation-net were obtained and plane coordinates in U.T.M. projection were derived from them. The coordinates in the stereographic projection also being known, transformation formulae for corresponding points in both projections, were derived. As the U.T.M. as well as the stereographic projection are conformal and since it is desirable to use transformation formulae which are as simple as possible, a conformal transformation based on three common points was chosen. This transformation of second degree, however, can only be used for relatively small areas. Consequently the country was divided into 21 triangles indicated in map 2. For each triangle transformation formulae were derived separately; the results were considered of value for topographical purposes only. For large-scale surveying e.g. cadastral surveying the stereographic coordinates will be maintained.

TABLE no. 1.

Comparison of the geographical positions of the Central European Net with the geographical positions, resulting from the re-adjustment of the triangulationnets East and West. (Before transformation). Remaining differences in φ and λ.

Nr	Name	$\Delta\varphi$	$\Delta\lambda$
1.	Finsterwolde	+ 0″0156	+ 0″0715
2.	Groningen	+ 192	+ 355
3.	Ureterp	+ 138	+ 128
4.	Oldeboorn	+ 136	+ 126
5.	Wijkel	+ 63	+ 11
6.	Urk	—	—
7.	Harderwijk	—	—
8.	Amersfoort	— 44	+ 9
9.	Rhenen	— 166	+ 175
10.	Flierenberg	— 217	+ 284
1.	Berkheide	— 0″0030	+ 0″0051
2.	Gouda	—	—
3.	Gorinchem	—	—
4.	Oosterhout	+ 24	+ 39
5.	Oirschot	+ 46	+ 108
6.	Luyksgestel	+ 07	+ 191

TABLE no. 2.

Comparison of the geographical positions of the Central European Net with the geographical positions. resulting from the re-adjustment of the triangulationnets East and West. (After transformation). Remaining differences in φ and λ.

Nr	Name	ε_φ	ε_λ	ε_φ in cm	ε_λ in cm
1.	Finsterwolde	— 0″0036	+ 0″0205	— 11.1	+ 37.9
2.	Groningen	— 0 .0003	0 .0000	— 0.9	0
3.	Ureterp	— 0 .0020	— 0 .0109	— 6.2	— 20.3
4.	Oldeboorn	— 0 .0007	— 0 .0036	— 2.2	— 6.7
5.	Wijkel	— 0 .0035	— 0 .0075	— 10.8	— 14.0
6.	Urk	— 0 .0033	— 0 .0079	— 10.2	— 14.9
7.	Harderwijk	+ 0 .0059	— 0 .0089	+ 18.2	— 16.8
8.	Amersfoort	+ 0 .0072	— 0 .0016	+ 22.2	— 3.0
9.	Rhenen	+ 0 .0007	+ 0 .0097	+ 2.2	+ 18.5
10.	Flierenberg	— 0 .0001	+ 0 .0100	— 0.3	+ 19.2
1.	Berkheide	— 0″0006	+ 0″0060	— 1.9	+ 11.4
2.	Gouda	+ 0 .0005	— 0 .0020	+ 1.5	— 3.8
3.	Gorinchem	— 0 .0011	— 0 .0051	— 3.4	— 9.8
4.	Oosterhout	+ 0 .0021	— 0 .0041	+ 6.5	— 7.9
5.	Oirschot	+ 0 .0015	+ 0 .0002	+ 4.6	+ 0.4
6.	Luyksgestel	— 0 .0023	+ 0 .0051	— 7.1	+ 9.9

4. *Laplace-points.*

Until 1947 only one Laplace-point was available in the Dutch primary triangulation net. (1) Partly in view of the re-adjustment of the triangulation nets of the European countries partly to check the Netherlands primary net, three Laplace-points have been measured since 1947, namely Leeuwarden and the adjacent point Ameland in the Northern part and Zierikzee in the Southwestern part of the country. The two adjacent points Leeuwarden and Ameland were considered as a twin Laplace-point to check the external accuracy of the geodetic and astronomical observations by applying the Laplace equation between these two points; this gave a discrepancy of only 0.″12 between the forward and reverse azimuths (2).

The astronomical latitude and azimuth in Leeuwarden, Ameland and Zierikzee were already available (3). The results of the determination of longitude of Leeuwarden, Ameland and Zierikzee are to be found in (4). Leeuwarden and Ameland also in (2). See also (5).

In the primary point Goedereede, adjacent to Zierikzee, also a longitude determination was performed but an azimuth determination has not yet been carried out.

With the aid of these data the Laplace-equations between the primary points Leeuwarden (or Ameland), Ubagsberg and Zierikzee were set up. The closing-errors between these three points were as follows:

Leeuwarden	—	Ubagsberg	+ 1″.06
Ubagsberg	—	Zierikzee	— 0″.78 and consequently between
Zierikzee	and	Leeuwarden	— 0″.28

The mutual distances between these points are 260, 170 and 210 km respectively.

We may conclude from these closing-errors that a possible distortion of the primary Dutch triangulation net due to Laplace conditions not having been taken into account in the adjustment, is very small.

LITERATURE:

(1) Déterminations de la différence de longitude Leyde-Ubagsberg etc. en 1893. Publication de la Commission Géodésique Néerlandaise 1905.

(2) *R. Roelofs:* Astronomical determination of longitude in the Netherlands. Traxaux de l'A.I.G. Tome 17.

(3) Détermination de la latitude et d'un azimut aux stations Oirschot, etc. Publication de la Commission Géodésique Néerlandaise 1904.

(4) *G. J. Bruins:* Astronomische lengtebepaling in Leeuwarden en op Ameland. Tijdschrift voor Kadaster en Landmeetkunde 1951 pag. 204.

(5) *R. Roelofs:* Determination of longitude with remote quartz-clock control. Bulletin Géodésique, 1948.

5. *Adjustment of triangulations.*

Theoretical and practical investigations are carried out concerning the application of modern electronic calculating machines for the adjustment of triangulations, including the determination of the accuracy and mutual correlation of all triangulation points.

A study by W. Baarda: Some Remarks on the Computation and Adjustment of large Systems of Geodetic Triangulations, is presented as a separate report at the General Assembly at Rome.

II. GEODETIC ASTRONOMY.

In view of the International Longitude Determinations in 1957—'58 (International Geophysical Year) in which The Netherlands intend to participate by establishing an astronomical station at Curaçao (West Indies), some studies and experiments were made, a description of which is to be found in separate reports presented at the General Assembly at Rome.

Th. de Haas: A New Method and a New Instrument for the Determination of the Chronometer-correction by means of Radio Time Signals
(visual comparison of time signal and chronometer-tick, both made visible on the scope of a cathode--ray tube).

J. C. de Munck: Recherche sur la détermination précise du profil des axes de rotation. (electronic method for determining the shape of the rotation axis of a theodolite or transit instrument).

G. van Herk and J. C. de Munck: Observations of Mires without Refraction Disturbances
(elimination of refraction by pointing at a terrestrial azimuth mark through a vacuum tube).

Experimental simultaneous determinations of latitude and longitude by precise solar observations (using a theodolite provided with a solar prism attachment) are carried out to investigate the most adequate method and the accuracy obtainable.

III. PRECISE LEVELLING IN THE YEARS 1951—1953.

1. *General information.*

The length of the lines levelled in the course of this period is 955 km. The total length of the lines, levelled for the Third Precise Levelling of the Netherlands was 1220 km on Dec. 31, 1953. The mean error during the period was

$$\mu'_R = 1/2 \sqrt{\frac{1}{n_R} \cdot \left[\frac{p^2}{R}\right]_1^{n_R}} = 0.54 \text{ mm/km}.$$

As there are only very few circuits closed, no dependable value of μ'_F is available.

In the period six river-crossings were levelled, the distances being 2250, 1600, 1000, 650, 500 and 500 m. These levellings were carried out by the optical method, some of them with special measures to eliminate errors in the instruments adjustment.

A seventh rivercrossing was measured hydrostatic, the distance being 4200 m (Westerschelde).

2. *Instruments, bench marks.*

The instrument Zeiss A 1939, which was in use in the beginning of the period, was replaced in 1953. Both parties are equipped with Wild N III now. It is envisaged to use the Zeiss-Opton Ni 2 with optical micrometer, but experiments are not yet available in this country.

Six new underground benchmarks were constructed during the period. These consist of concrete piles, pressed into the bottom until they have reached the diluvial sand. The length of these piles is 22, 20, 14, 7, 6 and 4 meters.

3. *Methods.*

A party consists of 4 men, of which only one observer. The observer does one accurate reading on the rod; immediately after this he reads the auxiliary division of the same rod, without re-setting the bubble. This second reading is a check only and is not used as an observation. Two consecutive observations on the same rod being highly correlated, the method of making two accurate observations does not give a higher accuracy; it gives only loss of time, which results in a loss of accuracy.

The new method gives an accuracy (μ'_R) which is not in the least inferior to the method with two observers. Nevertheless, only after completing some circuits and determining the quantity μ'_F we will be able to say if this method is satisfactory.

No correction due to the variation of gravity is applied; this is not important in so flat a country as the Netherlands.

4. *Crustal movement.*

A number of circuits already completed in the third precise levelling will be preliminary adjusted in the end of 1954. Until then no new figures of crustal movements will be available. The crustal movements in the Netherlands are difficult to observe, as there are thick layers of clay and peat in the West of the country. The local subsidence is considerable in several cases, though it is not evident if the difference in altitude is due to subsidence of the soil or only to sinking of the building in which the benchmark is situated. Even a value of 21 cm/20 years was found. A significant crustal movement was found in Limburg, about Roermond and Venlo.

5. *Adjustment and datum of network.*

The datum of the Netherlands precise levelling consisted of the altitude of 5 marble stones at Amsterdam, placed in 1684. The only one still remaining will disappear in the end of 1954. A new underground benchmark constructed at Amsterdam in the end of 1953 will replace it.

6. *Junctions.*

Junctions with Belgium have been made recently. One junction with Nordrheinland-Westfalen was made in 1953 at Aachen. The programm of junctions with Nordrheinland-Westfalen and Niedersachsen has been held up by levellingwork necessary after the inundations in February 1953.

IV. GRAVIMETRY.

The 1951 — Report of the Netherlands[1]) gives some details of two gravity expeditions by submarine across the Atlantic:

1948: Curaçao — Paramaribo — Casablanca — Rotterdam.

1951: Rotterdam — Lisbon — Martinique — Curaçao — Key West — Punta Delgada — Rotterdam.

During the years 1952 and 1953 these observations were worked out and the free-air anomalies computed. The computation of the isostatic reduction is being made by the Geophysical Department of the N.V. Bataafsche Petroleum Maatschappij and will be completed within a few months. The stations are isostatically reduced according to the Hayford-Bowie reduction and to the Airy reduction for local compensation and for five degrees of regionality of the compensation, for crustal thickness T of 20 km and of 30 km.

The pendulums of the Vening Meinesz apparatus were checked twice over the past two years at the base-station de Bilt. No real change in length of the pendulums was found.

In 1953 the apparatus was sent to the Geophysical Department of the Cambridge University in order to make some investigations about second order corrections, by means of the slow pendulums of the apparatus. The results obtained substantiated the theory, developed by Vening Meinesz: Theory and practise of pendulum observations at sea, part II, 1941. After this the apparatus was sent to the University of California, Los Angelos Branch, to be used for pendulum observations in the Pacific.

As Heiskanen remarks in his publication: On the isostatic structure of the earth's crust, 1950, pag. 5, the N.V. Bataafsche Petroleum Maatschappij in cooperation with the Netherlands Government of Mines observed about 12000 gravimeter- and about 9000 torsion balance stations in the Netherlands. Supplementary gravimeter observations have been made in the course of the last three years in the southern provinces of the Netherlands. The results of all these observations have not yet been published.

---

[1]) (See W. Heiskanen, Rapports Généraux no 8 and no 9, Sur les déterminations du géoide par les anomalies de la pesanteur, isostasie, pag. 47 and 48).

PUBLICATIONS:

F. A. Vening Meinesz: A remarkable feature of the earth's topography, origin of continents and oceans I and II.
Koninkl. Nederl. Akademie van Wetenschappen Series B, 54, no. 3, 1951.

id. A third arc in many island arc areas.
Koninkl. Nederl. Akademie van Wetenschappen Series B, 54, no. 5, 1951.

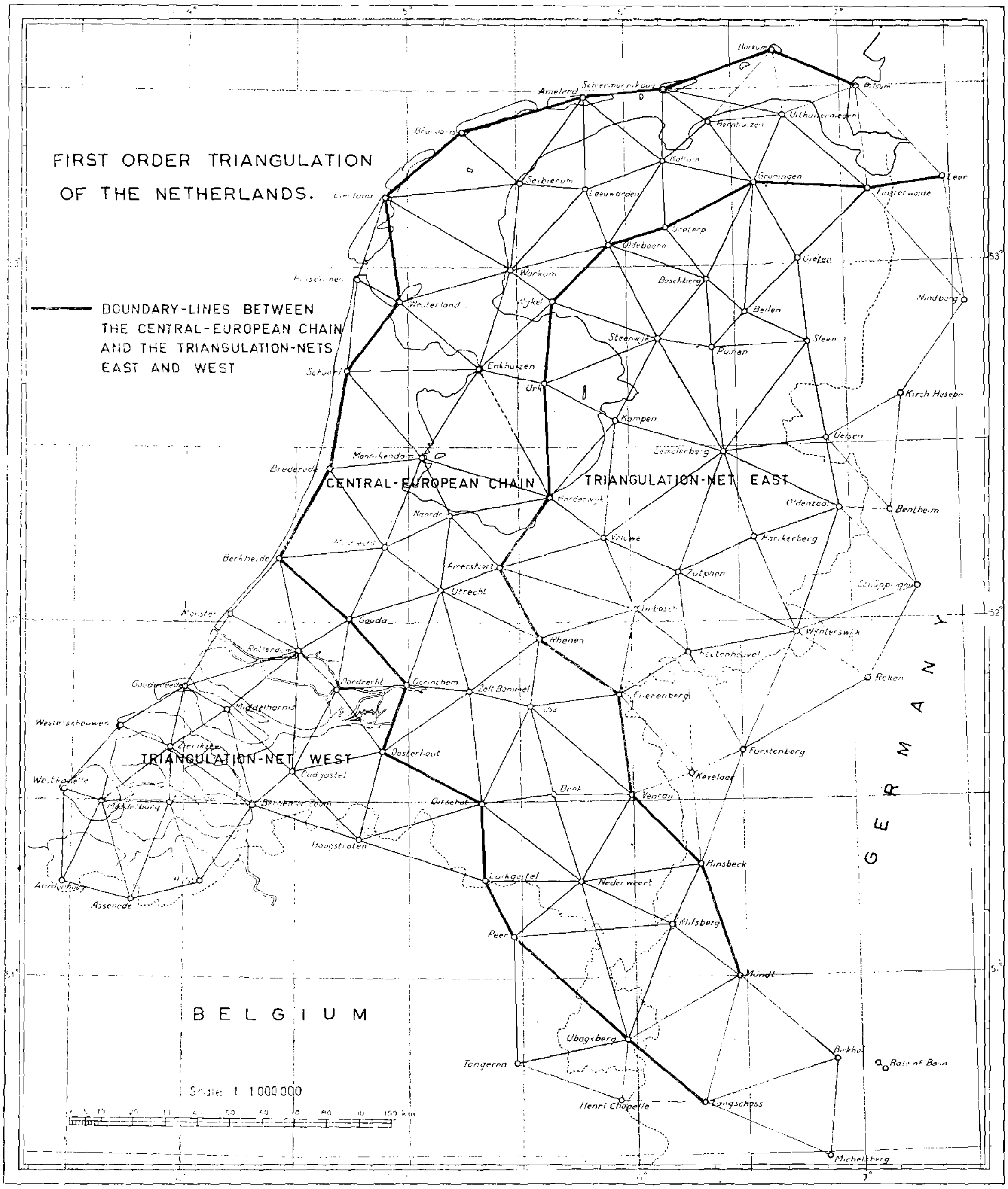
id. Convectioncurrents in the earth and the origin of the continents.
Koninkl. Nederl. Akademie van Wetenschappen Series B, 55, no. 5, 1952.

id. Physical Geodesy I and II.
Koninkl. Nederl. Akademie van Wetenschappen Series, B, 56, no. 1, 1953.

id. The second order corrections for pendulum observations at sea.
Koninkl. Nederl. Akademie van Wetenschappen Series, B, 56, no. 3, 1953.

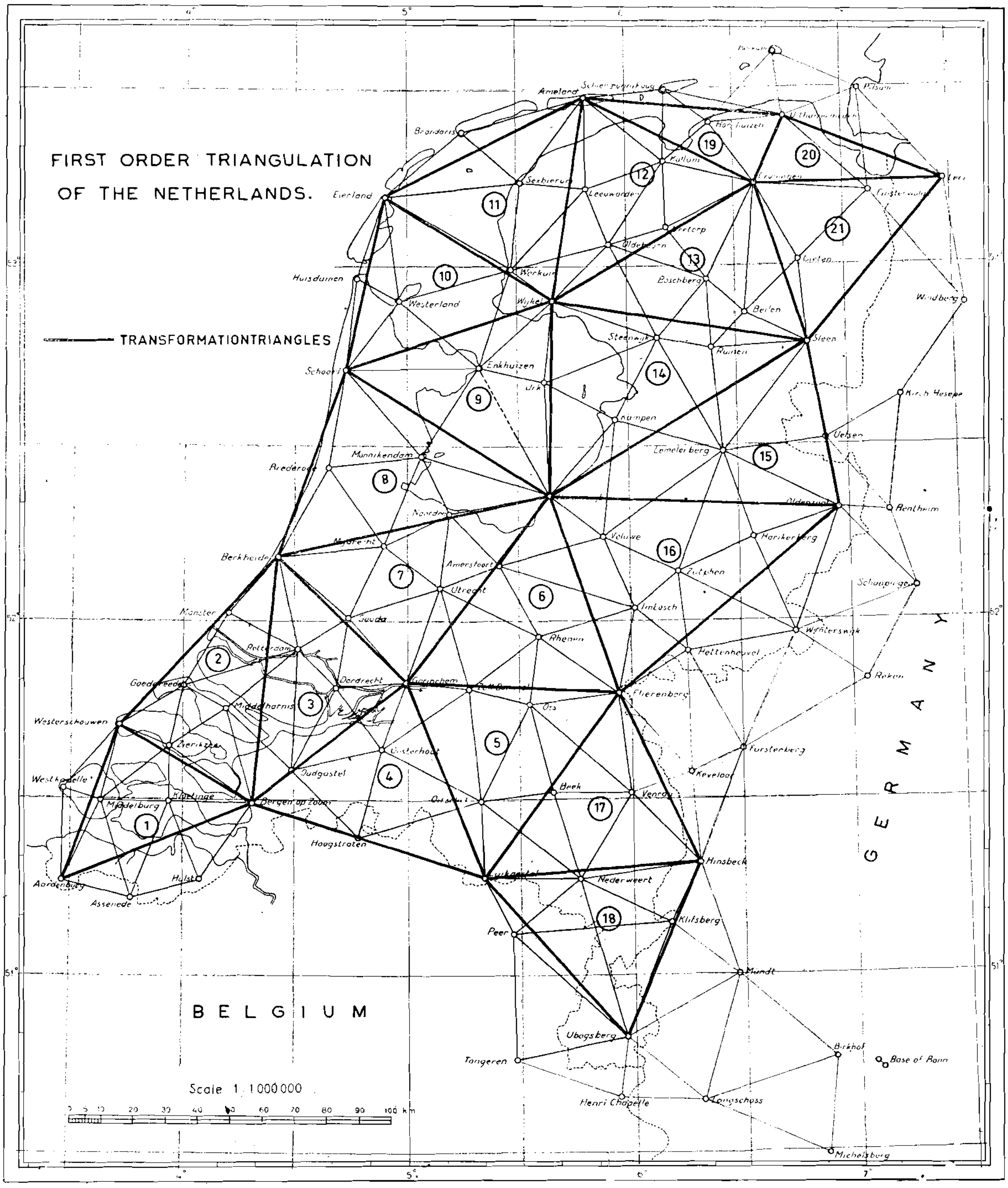
B. J. Hofman: The gravity field of the West-Mediterranean Area.
Geologie en Mijnbouw; Nieuwe serie; no. 8, 14e jaargang, Aug. 1952, pp 297—306.

MAP NR. 1



FIRST ORDER TRIANGULATION OF THE NETHERLANDS.
BOUNDARY-LINES BETWEEN THE CENTRAL-EUROPEAN CHAIN AND THE TRIANGULATION-NETS EAST AND WEST
CENTRAL-EUROPEAN CHAIN
TRIANGULATION-NET EAST
TRIANGULATION-NET WEST
BELGIUM
GERMANY
Schaal 1 : 1000000
Borkum
Ameland
Schiermonnikoog
Pilsum
Uithuizermeeden
Groningen
Leer
Leeuwarden
Oldeboorn
Drachten
Workum
Wieringen
Enkhuizen
Urk
Kampen
Steenwijk
Beilen
Sleen
Uelsen
Kirch Hesepe
Bentheim
Oldenzaal
Harikerberg
Volkwe
Amersfoort
Utrecht
Gouda
Berkheide
Monster
Rotterdam
Dordrecht
Gorinchem
Zalt Bommel
Rhenen
Zutphen
Winterswijk
Reken
Fürstenberg
Kevelaer
Venray
Hinsbeck
Mundt
Klitsberg
Peer
Nederweert
Gilsehof
Oosterhout
Bergen of Zoom
Middelburg
Westkapelle
Westenschouwen
Zierikzee
Middelharnis
Goedereede
Hoogstraten
Assenede
Aardenburg
Ubagsberg
Tongeren
Henri Chapelle
Langschoss
Birkhof
Michelsberg
Base of Bonn
Bredorode
Monnikendam
Naarden
Schoorl
Amersfoort
Imbosch
Hettenheuvel
Oss
Boek
Lutkgestel
Finsterwolde
Nindberg
Ruinen
Beschberg
Grefen
Sebrierum
Hollum
Hornhuizen

MAP NR. 2


FIRST ORDER TRIANGULATION
OF THE NETHERLANDS.
TRANSFORMATIONTRIANGLES
BELGIUM
GERMANY
Scale 1:1000000
Ameland
Eierland
Workum
Wykel
Enkhuizen
Schoorl
Munnikendam
Berkheide
Amersfoort
Utrecht
Gouda
Rotterdam
Dordrecht
Gorinchem
Middelburg
Bergen op Zoom
Hoogstraten
Oosterhout
Oss
Veluwe
Zutphen
Elterenberg
Hinsbeck
Nederweert
Peer
Tongeren
Ubagsberg
Henri Chapelle
Kampen
Leeuwarden
Groningen
Sleen
Oldenzaal
Bentheim
Base of Bonn
Michelsberg

Summary of the Work effected by the Study Group No. 6

of the International Association
of Geodesy:

Critical Study of Certain Methods of Geodetic Astronomy

by R. ROELOFS

Presented at the tenth General Assembly
of the International Association of Geodesy
at Rome 1954

Printed with financial support from the Netherlands Geodetic Commission.

Summary of the work effected by the Study Group no. 6: "Critical study of certain methods of Geodetic Astronomy"

by R. ROELOFS

1. *Introduction.*

The study group was formed in February 1953 and has the following members:

Brig. G. Bomford	—	Great Britain
Dr. P. Engi	—	Switserland
Sr. D. F. Gil Montaner	—	Spain
A. Gougenheim	—	France
Dr. G. van Herk	—	Holland (Vice-President)
H. S. Jelstrup	—	Norway
Ing. J. Loodts	—	Belgium
Prof. A. Marussi	—	Italy
Dr. G. Nikolič	—	Yugo-Slavia
Donald A. Rice	—	U.S.A.
Prof. R. Roelofs	—	Holland (President)
Prof. P. Tardi	—	France

The following paragraphs give a summary of the work done by the Study-Group and may be useful as a basis for the discussions at Rome.

2. *Determination of Azimuth.*

Dr. Engi reported the determination of the azimuths of two sides of the first-order triangulation net of Switserland, by Niethammer's „*Method* A" [1]: observation of transits of stars over the vertical plane of the terrestrial line to be determined. The stars are combined to form pairs, the sum of the zenith distances of each pair being approximately 90°. The number of pairs was 95 and 80 respectively and the standard errors in azimuth 0.″07 and 0.″10.

Dr. Engi makes the following remarks:

a. Notwithstanding the really high accuracy obtained, it is not impossible that the results are affected by systematic errors;
b. A serious disadvantage of the method in question is that it is restricted to azimuths in the vicinity ± 10° of the meridian;
c. The amount of work for preparation, execution and computation is very large;
d. It is not very probable that further azimuths in Switserland will be determined by this method.

---

[1] Th. Niethammer: Die genauen Methoden der astronomisch-geographischen Ortsbestimmung. Basel, 1947.

In a discussion on these questions M. J e l s t r u p, Prof. T a r d i and Dr N i k o l i č agreed with the points a-c, M. J e l s t r u p saying that the amount of work for preparation, etc. is too large to apply the method except in very exceptional cases and Prof. T a r d i being of the opinion that the method certainly does leave systematic errors larger than the *apparent* standard errors, but that this may be imputed to all determinations of azimuth which use stars at high altitudes and a terrestrial mark approximately in the horizontal plane; the influence of rotating the telescope about the "horizontal axis" is rather unknown — a method which is at the same time economic, reliable and precise, has not yet been found.

Although a final solution of this important problem would probably require a quite original approach, an obvious way to improve the classic methods it to determine the profile of both ends of the rotation axis.

M. D e M u n c k of the Geodetic Institute at Delft, Holland designed a new method using an electronic device for measuring small displacements [2]). The axis rotates in special pivots, provided with a "feeler", the displacements of which are measured electronically. The profile of the axis can be computed from these displacements. Measurement and computation of a profile do not take more than one hour. The standard error of the result is approximately 0.04 microns.

A variant of Niethammer's method was studied theoretically [3]) and applied experimentally [4]) by Ing. L o o d t s. His method differs with Niethammer's in that the stars of a pair, observed at opposite azimuths, have approximately *equal* zenith distances.

With this method it is desirable to observe stars at zenith distances as large as possible, anyhow larger than 45°. The zenith distances of the stars of a pair may differ 2° à 3°. Characteristic of the method is that most systematic errors, including the non-vertical position of the primary axis of the instrument, are eliminated by especially programming the observations; only the errors in longitude and time and the errors due to the width of the electrical contacts of the eyepiece-micrometer are not eliminated.

The experimental application of the method gave a standard error in the final azimuth of 0."47 from ten pairs of stars observed in four nights.

Both Ing. L o o d t s and M. G o u g e n h e i m stressed the interest of repeating the operations, applying corrections for the profile of the rotation-axis to be determined by the method and the device used by De Munck.

Nevertheless, — M. G o u g e n h e i m and Dr. N i k o l i č remark, — the fact that the "profile-correction" is a function of the zenith-distance, is in favour of observing stars at a *constant* zenith distance rather than of observations in a certain vertical plane, be it the meridian or the vertical plane of the terrestrial line in question.This constant zenith distance should be taken rather large, 75° à 80° for instance and the observations should be distributed re-

---

[2]) J. G. d e M u n c k: Recherche sur la détermination précise du profil des axes de rotation. Report presented at the General Assembly at Rome, 1954.

[3]) J. L o o d t s: La détermination de l'Azimut d'une direction par l'observation de l'heure du passage d'étoiles dans le plan vertical passant par cette direction. Report presented to the Study Group.

[4]) J. L o o d t s: Détermination d'un Azimuth Astronomique à l'Université Libre de Bruxelles, en 1952. Report presented to the Study Group.

gularly over the horizon. Evidently, all observations would require the same "profile-correction", which could be determined by De Munck's device.

The necessary introduction of horizontal circle readings is esteemed to be no impediment; it is indeed in harmony with the horizontal circle-readings to determine the angles of the triangulation in combination with which the azimuth is used.

Ing. Loodts in a comparative theoretical study [4a] arrives at the following conclusions concerning the preferable choice of a method:

a. If neither the latitude nor the longitude are known:
   Meridian transits.
b. If only the latitude is known:
   Stars (particularly Polaris) in elongation or Niethammer's Method A.
c. If only the longitude is known:
   Niethammer's Mehod B or Stars in the vertical plane of the terrestrial line at symmetric zenithdistances.
d. If both the latitude and the longitude are known:
   Arbitrary star, particularly Polaris at an arbitrary moment.

Since the influence of the inclination of the axis is eliminated in the methods ad c, these seem to be the most adequate. From a practical point of view preference must be given to the latter of these two methods.

M. Gougenheim, elaborating a paper by Sanjib K. Ghosh [5]) develops a graphical solution [6]) of the problem of determining latitude and azimuth from altitudes of a single unknown star. This solution is similar to the well-known graphical method to adjust the simultaneous determination of latitude and longitude from (equal) zenith distances of stars. Although the accuracy of the result can be improved by observing two stars, whose right ascensions differ about twelve hours, the method will still be of moderate precision only. Nevertheless it may be of interest for certain purposes.

3. *Determination of G.M.T.*

A report by Th. de Haas [7]) of the Geodetic Institute at Delft, Holland, on a new method and a new instrument for determining the chronometer correction to G.M.T. by means of radio time signals, was presented to the Study-Group and will also be presented at the General Assembly at Rome. The comparison of chronometer-tick and time-signal is facilitated by making both visible on the screen of a cathode ray tube. The actual measurement of the time-difference between tick and signal is done by bringing their images on the screen into coïncidence with

---

4a) J. Loodts: Les méthodes de détermination en campagne d'azimuts de haute précision, 1954. Report presented to the Study Group.

5) Sanjib K. Ghosh: Determination of azimuth and latitude from observations of a single unknown star. Empire Survey Review XII, 1953.

6) A. Gougenheim: Détermination de la latitude et de l'azimut par observation d'une étoile non identifiée Report presented to the Study Group.

7) Th. de Haas: A new Method and a New Instrument for the Determination of the Chronometercorrection by means of Radio Time Signals. Report presented at the General Assembly at Rome.

the aid of a calibrated electronic retarding device. The accuracy achieved is of the order of 0.001 second, while errors and uncertainties due to atmospherical and/or manmade interference with the reception of the radio time signals practically have been eliminated.

4. *Determination of latitude, longtitude and azimuth.*

A study by M. Gougenheim on the simultaneous determination of latitude, longitude and azimuth, distributed among the members of the Study Group, meanwhile has been published in the Bulletin Géodésique. We may therefore restrict ourselves here to referring to that publication [8].

5. *Refraction.*

For certain methods of determination of longitude and/or azimuth it may be desirable to refer the star-observations to a fixed terrestrial line in a certain direction, materialized by a "mire". Such a combination of star observations and mire-observations however is not homogeneous from the point of view of refraction, the former observations being only slightly affected by lateral (provided that the stars are observed at a sufficient altitude) whereas the latter observations (in which the rays of light usually pass in close proximity of the soil) may be influenced to a much larger amount, depending upon atmospheric and topographic circumstances.

MM. Van Herk and De Munck of the Geodetic Institute at Delft, Holland found and investigated a way [9]) to reduce refraction to a negligible amount by using an iron tube which is pumped vacuum after both ends have been sealed hermetically by plane-parallel glassplates. The tube is placed between theodolite and mire in such a position that the rays of light pass through the tube when the telescope is pointed at the mire. From theoretical considerations and practical experiments the authors conclude that refraction can be reduced to less than 0.″05 by using a 100 meter tube pumped vacuum to 0.76 mm Hg, which can easily be obtained by a modern pump.

It is evident that the application of this method, which requires voluminous equipment, will be limited to semi-permanent stations — for instance stations of the coming international longitude operations.

6. *Re-edition of Albrecht's Tables.*

Although according to Brig. Bomford these tables are not much used in Great Britain — I might add that the same applies to Holland — several other members of the Study Group, M.M. Loodts, Jelstrup, Gougenheim, Nikolič, expressed the strong opinion that a revised edition of these tables should be published.

The Belgian National Geodetic Commission has done excellent work by studying the various fundamental questions connected with a re-edition of the Tables and formulating a proposal, which served as a working paper for further discussions in the Study Group.

---

[8]) A. Gougenheim: Théorie et Pratique de la Méthode des Droites d'Azimuth. Bulletin Géodésique, No 32, 1954.

[9]) G. van Herk and J. C. de Munck: Observations of Mires without Refraction Disturbances. Report presented at the General Assembly at Rome.

The main fundamental questions were answered by the Belgian Committee as follows:

a. The theoretical part of the tables should be dropped, probably with the exception of the fundamental formulas.

b. The standardisation of notations is a difficult point.

c. The tables, the former editions of which cover only the latitude zône of + 30° to + 60°, should be extended to all latitudes.

d. For stations at the southern hemisphere a star of 5th. magnitude probably can play a similar role as Polaris at the northern hemisphere.

e. Certain tables could be advantageously put in the form of nomograms.

f. It is no use to insert tables which are to be found in Ephemeries or Catalogues.

g. A loose-leaf edition is to be preferred.

h. Numerical tables only; no logarithmic tables.

M. M. Jelstrup and Gougenheim generally agree with these proposals. As to the question ad *b.* M. Jelstrup recommends not to make changes in notations.[10]) He wishes both tables and nomograms as far as possible; I certainly agree with this view. M. Gougenheim recommends to insert the tables and the nomograms in two separate volumes.

M. Nikolič is also of opinion that it is indispensable to publish a revised edition of the Tables, but wishes to go considerably further by also including geodetic and gravimetric tables, tables for precession, for the transition from one fundamental system to another, tables with data on the brightest stars, on constellations, on geographical coordinates and geophysical data of all astronomical observatories, and perhaps of all the more important astronomical points of the European and American triangulation, convient sky-maps and data on observatories which emit time signals, etc.

As to the above point f M. Nikolič is of contrary opinion. He stresses the necessity of including everything that can be generalised in connection with all the methods for determining geographical coordinates which are in use at present.

The Belgian proposal reads as follows:

Table No.	SUBJECT	REMARKS
1a	Hour angle at rise and set of a star at given latitude.	To be extended to all latitudes.
1b	Amplitude at ditto.	
2	Hour angle of a star at transit over the prime vertical at given latitude.	
3	Zenith distance of ditto.	

[10]) In this connection it may be of interest to announce a paper by L. P. Lee: Conventions and generalized Formulae for the Astronomical Triangle, shortly to be published in Empire Survey Review. He suggests that the parallactic angle should be reckoned *eastward* from the *northern* direction of the polar distance or in the case of the southern hemisphere, from the *northern prolongation* of the polar distance. With this rule and the ordinary conventions for reckoning the other elements of the astronomical triangle, all the basic formulae for the northern hemisphere apply equally to the southern hemisphere.

Table No.	SUBJECT	REMARKS
4 5	Appr. computation of azimuth of Polaris. Ditto, of zenith distance.	To be revised to take account of the actual mean declination of Polaris. See also Connaissance des Temps.
6 7—8 9 10—11 12—13	Appr. computation of hour angle at given azimuth. Ditto, of zenith distance. Appr. computation of azimuth at given hour angle. Ditto, of zenith distance. Hour angle and zenith distance at transit over the prime vertical.	To be extended to all latitudes.
14 15	Transformation of mean time to sidereal time. Inverse transformation.	Less convenient as the tables in Connaissance des Temps.
16	Correction for curvature of star's track.	Very interesting. To be given in numerical values. Uccle Observatory uses more convenient tables.
17—22	Instrumental corrections for meridian transits.	Graphic representation to be envisaged. Values of table 17 are given with each star in Connaissance des Temps.
23	Time by transit of a star over the vertical of Polaris.	Too special method.
24	Time by corresponding altitudes of the Sun.	Non precise method. (for topographers)
25	Latitude by altitude of Polaris.	Similar tables in Connaissance des Temps.
26—28	Latitude by circum-meridian altitudes.	Very interesting. To be given in numerical values.
29	Latitude by transits over the prime vertical (Struve's method).	log sec t is to be found in a trigonometric table.
30	Azimuth by hour angle of Polaris.	Connaissance des Temps gives similar tables but much less precise.

Table No.	SUBJECT	REMARKS
31	Refraction.	Connaissance des Temps gives very convenient tables.
32—34	....	Do not refer to astronomy.
35	Transformation of minutes and seconds into decimals of an hour.	See Conn. des Temps.
36	Transformation of hours, minutes and seconds into decimals of a day.	

The other tables can also be found in tables of logarithms or numerical values.

M. Jelstrup made the following remarks:

Table 23: May be useful.
Table 24: Useful for provisional adjustments at remote expeditions.
Table 30: To be retained.
Tables 32-34: May be of interest for astronomers.

M. Gougenheim:

Table 23: To be dropped; very rare application.