n section A of the bibli-
ling. References without
al publications — of the

1 Introduction

1.1 Definition and Classification of Geodesy

According to the classical definition of F. R. Helmert (A1880), geodesy ($\gamma\eta$ = earth, $\delta\alpha i\omega$ = I divide) is the "*science of the measurement and mapping of the earth's surface.*" This definition has to this day retained its validity; it includes the determination of the earth's external gravity field, as well as the surface of the ocean floor. With this definition, which has to be extended to include temporal variations of the earth and its gravity field, geodesy may be included in the geosciences, and also in the engineering sciences, e.g. Nat. Acad. Sciences (1978).

Triggered by the development of space exploration, geodesy turned in collaboration with other sciences toward the determination of the surfaces of other celestial bodies (moon, other planets). The corresponding disciplines are called *selenodesy* and *planetary geodesy* (Bills and Synnot 1987).

Geodesy may be divided into the areas of global geodesy, national geodetic surveys, and plane surveying. *Global geodesy* is responsible for the determination of the figure of the earth and of the external gravity field. A *geodetic survey* establishes the fundamentals for the determination of the surface and gravity field of a country. This is realized by coordinates and gravity values of a sufficiently large number of control points, arranged in geodetic and gravimetric networks. In this fundamental work, curvature and gravity field of the earth must be considered. In *plane surveying* (topographic surveying, cadastral surveying, engineering surveying), the details of the terrain are obtained. As a *reference surface* for *horizontal positioning* the ellipsoid is used in geodetic surveying. In plane surveying, the horizontal plane is generally sufficient.

There is close interaction between global geodesy, geodetic surveying and plane surveying. The geodetic survey adopts the parameters determined by measurements of earth, and its own results are available to those who measure the earth. The plane surveys, in turn, are generally tied to the control points of the geodetic surveys and serve then particularly in the development of national map series and in the formation of real estate cadastres. Measurement and evaluation methods are largely identical in global geodesy and national geodetic surveys. Particularly space methods (satellite geodesy) enter more and more into regional and even local surveys. This also implies more detailed gravity field determination on regional and local scale.

With the corresponding classifications in the realms of the English and French languages, the concept of "*geodesy*" (la géodésie, "höhere Geodäsie" after *Helmert*) is to be referred only to global geodesy and geodetic surveying. The concept of "*surveying*" (la topométrie, Vermessungskunde or "niedere Geodäsie" after *Helmert*) shall encompass plane surveying.

In this volume, geodesy is treated only in the more restricted sense as explained above. An introduction to plane surveying is given by Kahmen and Faig (A1988).

1.2 The Problem of Geodesy

The problem of geodesy, generated from and partially supplementing Helmert's definition, may be described comprehensively as follows (DRAHEIM 1971, FISCHER 1975):

"The problem of geodesy is to determine the figure and the external gravity field of the earth and of other celestial bodies as functions of time; as well as, to determine the mean earth ellipsoid from parameters observed on and exterior to the earth's surface."

This *geodetic boundary-value problem* incorporates a geometric (figure of the earth) and a physical (gravity field) formulation of the problem; both are closely related.

By the *figure of the earth* we mean the physical and the mathematical surface of the earth.

The *physical* surface of the earth is the border between the solid or fluid masses and the atmosphere. Recently, the *ocean floor* has also been included in the formulation of the geodetic problem, being the bounding surface between the solid terrestrial body and the oceanic water masses. The extension of the problem to the oceans is designated *marine geodesy* (MOURAD 1977, SEEBER 1975). The irregular surface of the *solid earth* (continents and ocean floor) is incapable of being represented by a simple mathematical relation; it is therefore described point wise by the use of coordinates of the *control points*. On the other hand, the *ocean surfaces* (70% of the earth's surface) possess a simpler principle of formation. Under certain assumptions, they form a part of a level (equipotential) surface (surface of constant gravity potential) of the earth's gravity field. We may think of this surface as being extended under the continents and then identify it as the *mathematical figure* of the earth (HELMERT A1880/1884). J. B. LISTING (1873) designates this level surface as *geoid*.

C. F. Gauss had already referred to this surface: "What we call the surface of the earth in the geometrical sense is nothing more than that surface which intersects everywhere the direction of gravity at right angles, and part of which coincides with the surface of the oceans." (*C. F. Gauss*: "Bestimmung des Breitenunterschiedes zwischen den Sternwarten von Göttingen und Altona," Göttingen 1828), see also MORITZ (1977).

The majority of the observed parameters used in geodesy refers to the earth's *external gravity field*, whose study thereby becomes a concern of geodesy. The upper limit of space that is of interest is governed by the geodetic usage of artificial satellites and space probes, as well as the earth's moon. The physical aspect of the problem of geodesy follows from the consideration of the earth's surface and the geoid as bounding surfaces in the earth's gravity field. The external gravity field may be described by the infinite number of *level surfaces* extending completely or partially exterior to the earth's surface.

Reference systems are introduced in order to describe the motion of the earth in space (celestial system), and surface geometry and gravity field of the earth (terrestrial system). For global geodesy, the use of three-dimensional Cartesian coordinates in Euclidian space is adequate. In geodetic surveying, a *reference surface* is introduced in order to distinguish curvilinear surface coordinates and heights. Because of its simple equation, a rotational ellipsoid flattened at the poles is better suited as such a reference surface than the geoid, which is determined by the uneven distribution of the earth's masses. Particular significance is given to the *mean earth ellipsoid*, which is the optimal ellipsoid approximating the geoid. Because of its physical meaning, the *geoid* is well suited as reference surface for heights. Fig. 1.1 shows the mutual arrangement of the surfaces to be determined in geodesy.

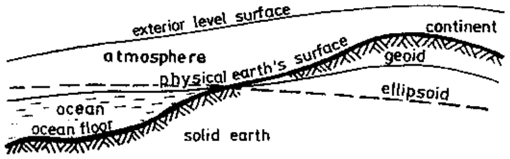

Fig. 1.1. Earth's surface and reference surfaces

The body of the earth and its gravity field are subject to *temporal variations* of secular, periodic, and abrupt nature, which can occur globally, regionally, and locally. The geodetic measurement and evaluation techniques today have advanced to the extent that they can detect a part of this change. Should average conditions be ascertained, observations must be corrected for these changes. With the detection of a part of the variations, geodesy also contributes to the investigation of the dynamics of the terrestrial body. The figure of the earth and the external gravity field are accordingly conceived as time dependent variables. This leads to the ideas of "four-dimensional geodesy" (ANGUS-LEPPAN 1973, MATHER 1973).

1.3 Historical Development of Geodesy

The formulation of the problem of geodesy expressed in [1.2] first developed in the course of the nineteenth century. However, the question of the figure of the earth had already been raised in antiquity. After the *sphere* first served as a model for the earth, the oblate *rotational ellipsoid* as figure of the earth asserted itself in the first half of the eighteenth century; cf. FISCHER (1975), BIALAS (A1982), LEVALLOIS (A1988).

1.3.1 The Spherical Earth Model

Various opinions on the form of the earth prevailed in the past; e.g. the notion of an *earth disk* encircled by Oceanus (*Homer's* Illiad, ~800 B.C., *Thales of Milet*, ~600 B.C.). *Pythagoras* (~580–500 B.C.) and his school, as well as *Aristotle* (384–322 B.C.), among others, expressed themselves for the spherical shape.

The founder of scientific geodesy is *Eratosthenes* (276–195 B.C.) of Alexandria, who under the assumption of a spherical earth deduced from measurements a radius for the earth (SCHWARZ 1975). The principle of the *arc measurement* method developed by him was still applied in modern ages: From geodetic measurement, the length ΔG of a meridian arc is determined; astronomical observations furnish the associated

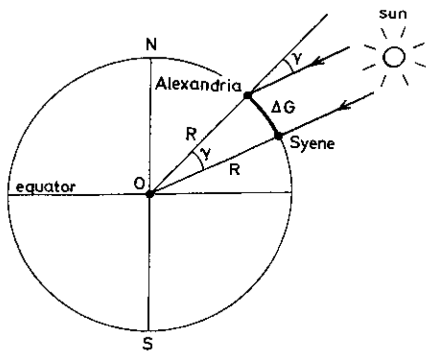

Fig. 1.2. Arc measurement of Eratosthenes

central angle γ (Fig. 1.2). The radius of the earth is then given by

$$R = \frac{\Delta G}{\gamma}. \tag{1.1}$$

Eratosthenes found that at the time of the summer solstice, the rays of the sun descended vertically into a well in Syene (Assuan, today); whereas in Alexandria, roughly on the same meridian, they formed an angle with the direction of the plumb line. From the length of the shadow of a vertical staff ("gnomon") produced in a hemispherical shell ("skaphe"), he determined this angle as 1/50 of a complete circle, i.e. $\gamma = 7°12'$. He estimated the distance from Syene to Alexandria to be 5000 stadia as taken from Egyptian cadastre maps which are based on the information of "bematists" (step counters). With the length of an Egyptian stadium as 157.5 m, we obtain an earth radius of 6267 km. This value departs from the radius of a mean spherical earth (6371 km) by −2%. A subsequent determination in antiquity is attributed to *Posidonius* (135–51 B.C.); using the meridian arc from Alexandria to Rhodes, he arrived at a radius of the earth deviating by −11%.

During the middle ages in Europe, the question of the figure of the earth was not pursued further. An arc measurement handed down by the Arabs was carried out (~827 A.D.) by the caliph of *al-Mámûn*, northwest of Bagdad (+10% deviation). At the beginning of the modern ages, the French physician *Fernel* in 1525 observed on the meridian through Paris the geographical latitudes of Paris and Amiens using a quadrant; he computed the distance from the number of rotations of a wagon wheel (+0.1% deviation).

The remaining arc measurements based on the notion of a spherical earth are characterized by fundamental advances in instrumentation technology (1611, *Kepler* telescope) and methodology. After the initial application of *triangulation* by *Gemma Frisius* (1508–1555) in the Netherlands, and by *Tycho Brahe* (1546–1601) in Denmark, the Dutchman *Willebrord Snellius* (1580–1626) conducted the first triangulation to determine the figure of the earth, HAASBROEK (1968).

In 1615 with the triangulation applied by *Snellius* to the arc measurement between Bergen op Zoom and Alkmaar (Holland), the hitherto inaccurate estimate or direct measurement of the length of arc was replaced by a procedure of high precision. This method served into the twentieth century for arc measurements and for the formation of principal control networks. For Snellius, the deviation with respect to the mean earth radius amounts to −3.4%.

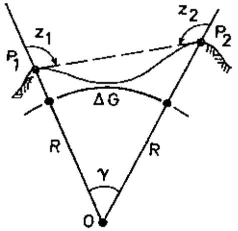

Fig. 1.3. Determination of the central angle from zenith angles

Through the initiative of the Academy of Sciences, founded in Paris 1666, France in the seventeenth and eighteenth centuries assumed the leading role in geodesy. The French abbé *J. Picard* in 1669/70 carried out an arc measurement on the meridian through Paris between Malvoisine and Amiens with the aid of a triangulation network; he was the first to use a telescope with cross hairs. The value obtained by him for the radius of the earth (deviation of +0.01%) aided *Newton* in the verification of the law of gravitation which he had formulated in 1665/66.

Another solution of the determination of the central angle, different in principle, namely by using *reciprocal zenith angles*, found application in 1645 by the Italians *Grimaldi* and *Riccioli* (Fig. 1.3). The angle may be computed from the zenith angles z_1 and z_2 observed at P_1 and P_2 according to

$$\gamma = z_1 + z_2 - \pi. \tag{1.2}$$

This procedure does not yield satisfactory results due to the insufficiently accurate determination of the curvature of light rays (refraction anomalies).

1.3.2 The Ellipsoidal Earth Model

In the sixteenth and seventeenth centuries, new observations and ideas from astronomy and physics decisively influenced the perception of the figure of the earth and its position in space. *N. Copernicus* (1473–1543) achieved the transition from the *geocentric* universe of *Ptolemy* to a *heliocentric* system (1543: "De revolutionibus orbium coelestium"), which *Aristarchus of Samos* (~320–250 B.C.) had already postulated. *J. Kepler* (1571–1630) discovered the laws of planetary motion (1609: "Astronomia nova ...", 1619: "Harmonices mundi"), and *Galileo Galilei* (1564–1642) developed modern mechanics (law of falling bodies, law of pendulum motion).

In 1666, the astronomer *J. D. Cassini* observed the flattening of the poles of Jupiter. The astronomer *J. Richer* in 1672 discovered on the occasion of an expedition to Cayenne to determine martian parallaxes, that he must shorten a one-second pendulum which had been regulated in Paris, in order to regain oscillations of one second. From this observation and on the basis of the law of pendulum motion, one can infer an increase in gravity from the equator to the poles. Building on these and on their own works, *Isaac Newton* (1643–1727) and *Christian Huygens* (1629–1695) developed earth models *flattened* at the poles and founded on principles of physics.

Newton (1687: "Philosophiae naturalis principia mathematica") obtained a rotational ellipsoid as an equilibrium figure for a homogeneous, fluid, rotating earth based on the validity of the law of universal gravitation. The flattening

$$f = \frac{a - b}{a} \tag{1.3}$$

(f for "flattening", a = semimajor axis, b = semiminor axis) in this case amounts to 1/230. At the same time, Newton postulated an increase in gravity acceleration from the equator to the poles proportional to $\sin^2 \varphi$ (φ = geographical latitude). *Huygens* (1690: "Discours de la Cause de la Pesanteur") shifts the source of the earth's attractive forces to the center of the earth and develops a rotationally symmetric equilibrium surface which possesses a meridian curve of fourth order with $f = 1/576$.

For a geometric verification of the ellipsoidal earth model, one has employed *arc measurements at various latitudes*. Namely, the length of a one-degree arc (meridian arc for a difference of 1° in latitude) in the case of flattened poles increases poleward from the equator. The ellipsoidal parameters a, b or a, f can be computed from two arc measurements [1.3.3].

An evaluation of the existing older arc measurements (*Snellius*, *Picard*, among others) led to an earth model elongated at the poles. The same result was obtained by *La Hire*, *J. D.* and *J. Cassini* (1683–1718) who extended the arc of Picard north to Dunkirk and south to Collioure (latitude difference of 8°20′). The computations from two arc segments yielded a "negative" flattening of $f = -1/95$, which can be attributed particularly to measurement errors of the astronomic latitudes. The intense dispute between the supporters of Newton and those of Cassini over the figure of the earth was resolved by two further arc measurements sponsored by the French Academy of Sciences.

Maupertuis and *Clairaut*, among others, participated in the expedition to *Lapland* (1736/37); the results of this arc measurement (average latitude 66°20′, latitude interval 57′.5) confirmed the polar flattening. In combination with the arc measurement on the meridian through Paris, revised by *Cassini de Thury* and *La Caille*, 1739/40, the result was $f = 1/183$. On a second expedition (1735–1744) to Peru (regions of today's Ecuador), an arc of average latitude 1°31′ S and 3°07′ amplitude was determined by *Godin*, *Bouguer*, and *La Condamine*. Combination with the Lapland arc led to $f = 1/210$. The flattening of the earth at the poles was thereby demonstrated by *geodetic* measurements.

A *synthesis* between the physical and geodetic substantiations of the ellipsoidal shape of the earth was finally achieved by *A.-C. Clairaut* (1713–1765) with the theorem (1743) named for him, which permits the computation of the flattening from two gravity measurements at different latitudes [3.5.2]. The practical application of this "*gravimetric method*" suffered until the twentieth century from the lack of accurate and well distributed gravity measurements and from the problem of reducing these data to the earth ellipsoid.

1.3.3 Arc Measurements

After the rotational ellipsoid had asserted itself as a model for the earth, numerous arc measurements were conducted until the middle of the nineteenth century to determine the dimension of this earth ellipsoid. The arc length was invariably obtained by triangulation. We distinguish between arc measurements along an ellipsoidal meridian (latitude arc measurement), along a parallel (longitude arc measurement), and arc measurements oblique to the meridian.

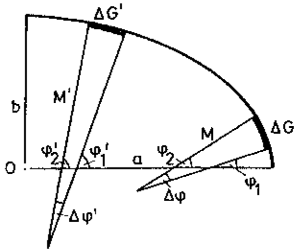

Fig. 1.4. Latitude arc measurement

For the computations in a *latitude arc measurement* (Fig. 1.4), the angles $\Delta\varphi = \varphi_2 - \varphi_1$, $\Delta\varphi' = \varphi_2' - \varphi_1'$ are formed from the observed geographic latitudes φ_1, φ_2, φ_1', φ_2'. The corresponding meridian arcs ΔG and $\Delta G'$ are obtained from triangulation networds. For short arcs one can replace the meridian ellipse by the osculating circle having the meridian radius of curvature $M = M(\varphi)$ evaluated at the mean latitude $\varphi = \frac{1}{2}(\varphi_1 + \varphi_2)$, where M is also a function of the ellipsoidal parameters a, f [3.4.2]. From $\Delta G = M\Delta\varphi$ and $\Delta G' = M'\Delta\varphi'$, a and f may be determined. The larger the latitude interval $\varphi' - \varphi$, the more accurate is the computed flattening; whereas, the accuracy of a depends in particular on the lengths of the meridian arcs.

Particular significance was attained by the measurement commissioned by the French National Assembly and carried out by *Delambre* and *Méchain* on the meridian through Paris between Barcelona and Dunkirk (1792–1798); it was supposed to serve for the definition of the meter as a natural unit of length. In combination with the Peruvian arc measurement, this yielded an ellipsoidal flattening of $f = 1/334$.

Of the numerous arc measurements carried out in the nineteenth and twentieth centuries, which were largely the foundations of geodetic surveys, we mention here only the older, historically important arcs of *Gauss* (arc measurement between Göttingen and Altona, 1821–1825, adjustment according to the least squares method) and of *Bessel* and *Baeyer* (arc measurement oblique to the meridian in East Prussia, 1831–1838). References to more recent and to some extent still currently significant works are made in the treatment of astrogeodetic methods [5.1.4].

1.3.4 The Geoid and the Ellipsoid

As *P.-S. Laplace* (1802), *C. F. Gauss* (1828), *F. W. Bessel* (1837), and others had already recognized, the assumption of an ellipsoidal earth model is not tenable under sufficiently high observational accuracy. Namely, one can no longer ignore the deviation (*deflection of the vertical*) of the physical plumb line, to which the measurements refer, from the ellipsoidal normal. By an adjustment of several arc measurements for the determination of the ellipsoidal parameters a and f, contradictions arise which exceed by far the observational accuracy.

An initial adjustment of arc measurements was carried out in 1806 by *A. M. Legendre* in his treatise "Sur la méthode des moindres carrées". *C. F. Gauss* was the first to adjust a triangulation network (in and around Brunswick, 1803–1807) by the method of least squares (Gerardy 1977).

Despite these discrepancies, numerous adjustments were undertaken until the mid-nineteenth century to determine the dimensions of the ellipsoid, whereby the deflections of the vertical, being physically caused, and hence, having systematic characteristics were treated as random observational errors. With the definition of geodesy [1.1] and the introduction of the geoid [1.2], *F. R. Helmert* made a transition to the current concept of the figure of the earth. Here, the deflections of the vertical are taken into account in the computation of the ellipsoidal parameters. The three-dimensional concept of geodesy was also introduced in that time (Bruns 1878).

Friedrich Robert Helmert (1843–1917), one of the most distinguished geodesists of modern times, was professor of geodesy at the technical university at Aachen and director of the Prussian Geodetic Institute in Potsdam and of the central office of the "Internationale Erdmessung". Through his work, geodesy has experienced decisive impulses, which until today have their effect. In his fundamental monograph (A1880/1884) *Helmert* established geodesy as a proper science (Wolf 1970).

The determination of the geoid was for about 70 years (1880–1950) a major goal of geodesy. Its importance diminished after 1945 with the development of methods for the direct derivation of the physical surface of the earth; however, its determination still remains an essential problem of geodesy. In fact, the significance of the geoid has again increased with the establishment of three-dimensional continental and global systems [5.1.2], as well as with the requirements of marine geodesy [3.3.3].

1.4 Organization of Geodesy, Literature

1.4.1 National Organizations

The problems of *global geodesy* may be solved only with international cooperation of institutes which work at a national level, together with a few international services [1.4.2]. In some countries, governmental or academy research institutes (Federal Republic of Germany: Deutsches Geodätisches Forschungsinstitut in Munich and Frankfurt, Zentralinstitut Physik der Erde/Geodätisches Institut in Potsdam; U.S.S.R.: Central Scientific Research Institute of Geodesy, Aerial Survey, and Cartography in Moscow), as well as the geodetic institutes of universities are actively pursuing *research*. The *geodetic surveys* are carried out according to the structure of the official surveying system by decentralized institutes (Fed. Rep. of Germany: geodetic survey offices of the individual states) or by central agencies (Australia: Division of National Mapping; Canada: Surveys and Mapping Branch; France: Institut Géographique National; Great Britain: Ordnance Survey; India: Survey of India; Japan: Geographical Survey Institute; U.S.A.: National Geodetic Survey, National Oceanic and Atmospheric Administration (NOAA) — formerly Coast and Geodetic Survey).

In addition to these, a number of *nongeodetic* institutions exist which in the course of their special projects are also concerned with geodetic problems; indeed, they deal with the theory, and in particular, with the collection and evaluation of data. We mention here the institutes of space exploration and of astronomy (Goddard Space Flight Center of NASA, Greenbelt, Md.; Centre National d'Études Spatiales, Brétigny-sur-Orge; Smithsonian Astrophysical Observatory (SAO), Cambridge, Mass.), geologic and hydrographic services (Geological Survey of Canada; Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover; Bundesamt für Seeschiffahrt und Hydrographie, Hamburg; Bureau de Recherches Géologiques et Minières, Orleans; Institute of Geological Sciences and Institute of Oceanographic Sciences, U.K.; U.S. Geological Survey), university departments (Lamont-Doherty Geological Observatory, Columbia Univ., New York), and military agencies (U.S.A.: Defense Mapping Agency, Topographic Center DMATC and Aerospace Center DMAAC; U.S. Naval Oceanographic Office NAVOCEANO).

1.4.2 International Collaboration

At the beginning of the arc measurements in the kingdom of Hanover (1821), *C. F. Gauss* had already expressed his intensions. According to him, this net would be connected to neighboring triangulation networks, aiming toward an eventual merger of the European observatories. Organized international collaboration originates with the instigation by the Prussian general *J. J. Baeyer* (1794–1885): "*Über die Größe und Figur der Erde, eine Denkschrift zur Begründung einer Mitteleuropäischen Gradmessung*" (1861). In 1862, the "Mitteleuropäische Gradmessung" was founded in Berlin as the first international scientific association of significance; Baeyer was its first president. After expanding to the "Europäische Gradmessung" (1867) and to the "*Internationale Erdmessung*" ("Association Géodésique Internationale"), 1886, the association developed a fruitful activity, which was especially inspired by the works of *Helmert* as director of the central bureau (Levallois 1980).

After the dissolution of the "Internationale Erdmessung" during the first World War, the "*International Union of Geodesy and Geophysics*" (I.U.G.G.) which today (1987) has a membership of 77 countries was founded in 1919. It consists of one geodetic and six geophysical associations. The "*International Association of Geodesy*" (I.A.G.) is directed by a president who is elected every four years, and who has vice presidents and a general secretary at his side. I.U.G.G. and I.A.G. meet at general assemblies at four-year intervals; in addition, numerous symposia and scientific conferences which treat special themes are organized by the I.U.G.G., its associations and commissions.

The I.A.G. consists of five *sections*: Positioning, Advanced Space Technology, Determination of the Gravity Field, General Theory and Methodology, Geodynamics. *Commissions* are established for continuing problem, whereas, transient problems are treated by *special study groups*. In addition, the I.A.G., partly in collaboration with other scientific organizations maintains permanent institutions: International Earth Rotation Service (IERS) with the Central Bureau at the Observatoire de Paris, replacing since 1988 the Earth Rotation Service of the Bureau International de l'Heure (BIH) and the International Polar Motion Service (IPMS); Bureau International des Poids et Mesures (BIPM) Sèvres; Bureau Gravimétrique International (BGI), Toulouse; International Center of Recent Crustal Movements, Prague; International Center of Earth Tides, Brussels; Permanent Service for Mean Sea Level, Bidston on Merseyside, U.K.

For cooperative programmes of rocket and satellite research, an Inter-Union Committee on Space Research (COSPAR) was established by the International Council of Scientific Unions (ICSU).

1.4.3 Literature

A survey of the recent *text books* and *manuals* of geodesy is given in the bibliography on page 235. There also, references are listed to introductory mathematical works (potential theory, differential geometry, plane and spherical trigonometry, adjustment computations) and to literature pertaining to the neighboring disciplines of surveying, as well as to astronomy and geophysics. A list of geodetic publication series is given in Bulletin Géodésique *62*, no. 3, 381–393, 1988.

Among the *technical journals*, the "Bulletin Géodèsique" issued by the I.A.G. (Springer, Berlin-Heidelberg-New York) concerns itself exclusively with geodetic problems. After each general assembly of the I.A.G., the results are compiled in a general report; whereas, national reports contain information on the geodetic activities of the I.A.G. membership countries (*Proceedings of the I.A.G. — Travaux de l'A.I.G.*). Since 1990, the proceedings of IAG-symposia will be published in separate volumes by Springer. An international geodetic bibliography is published by the Technical University of Dresden. Prompt publication of research results is possible in the "Manuscripta Geodaetica", Heidelberg-New York. Queries in geodesy are further treated in the technical journals of *surveying*. The following are mentioned in particular: "Allgemeine Vermessungsnachrichten", Karlsruhe; "The Australian Surveyor", Sydney; "Bolletino di Geodesia e Scienze Affini", Florence; "The Canadian Surveyor", Ottawa; "Geodesy, Mapping and Photogrammetry", Washington (translation of the Russian journals "Geodeziya i Aerofotosyemka" and "Geodeziya i Kartografiya"); "GPS-World", Eugene, Oregon; "Marine Geodesy", New York; "Österreichische Zeitschrift für Vermessungswesen und Photogrammetrie", Vienna; "Vermessung, Photogrammetrie, Kulturtechnik", Baden-Dättwil; "Surveying and Mapping", Falls Church; "Survey Review", Tolworth, Surrey; "Vermessungstechnik", Berlin; "Zeitschrift für Vermessungswesen", Stuttgart. Geodetic articles also appear in the *geophysical* technical literature: "Bolletino di Geofisica teorica ed applicata", Trieste; "EOS Transactions American Geophysical Union", Washington; "Geophysical Journal", Oxford (combining Annales Geophysicae, The Geophys. J. of the Royal Astronom. Society, and Journal of Geophysics/Zeitschrift fur Geophysik); "Geophysical Research Letters", Washington, D.C.; "Surveys in Geophysics", Dordrecht; "Gerlands Beiträge zur Geophysik", Leipzig; "Journal of Geophysical Research", Washington; "Reviews of Geophysics and Space Physics", Washington; "Studia Geophysica et Geodaetica", Prague, "Tectonophysics", Amsterdam.

Reports are issued by geodetic universities and research institutes and by various scientific academies, as well as by some governmental agencies. We mention here: "Acta Geodaetica, Geophysica et Montanistica", Budapest; "Acta Geodaetica et Geophysica", Beijing; "Australian Journal of Geodesy, Photogrammetry and Surveying", Kensington N.S.W.; "Bull. d'Inform. Bureau Gravimetrique Internat.", Toulouse; "Bull. d'Inform. Marées Terrestres", Brussels; "Bull. of the Earthquake Research Institute", Univ. of Tokyo; "Bull. of the Geographical Survey Institute", Tokyo; "Defense Mapping Agency, Technical Rep.", Washington D.C.; "Mitt. d. Geodät. Inst. T. U. Graz.", "Mitt. Inst. f. Theor. Geod. Univ. Bonn"; "Nachrichten aus dem Karten- und Vermessungswesen", Frankfurt/Main; "NASA Goddard Space Flight Center Rep.", Greenbelt, Md.; "NOAA–NOS–National Geodetic Survey Technical Rep.", Rockville, Md.; "Publications of the Finnish Geodetic Institute", Helsinki; "Reports of the Department of Geodetic Science and Surveying", The Ohio State Univ., Columbus, Ohio; "Schriftenreihe der Hochschule der Bundeswehr", München; "Smithsonian Astrophysical Observatory: Special Reports"; "Unisurv G-Univ. of New South Wales Rep.", Kensington, NSW; "Veröff. der Bayer. Komm. für die Internationale Erdmessung der Bayer. Akad. der Wissenschaften", Munich; "Veröff. der Deutschen Geodätischen Kommission bei der Bayerischen Akad. der Wissenschaften", Munich and Frankfurt a.M.; "Veröff. des Zentralinstituts Physik der Erde", Potsdam; "Wiss. Arb. d. Fachr. Vermessungswesen d. Univ. Hannover".