Journal of Geodesy (1997) 71: 176–188

Journal of
Geodesy

A profile of General Carlos Ibáñez e Ibáñez de Ibero: first president of the International Geodetic Association

T. Soler

National Geodetic Survey, NOS, NOAA 1315 East-West Highway, Silver Spring, MD 20910, USA

Received 27 September 1996; Accepted 2 October 1996

Abstract. The exploits of the multifaceted scientist (engineer-geodesist-metrologist) General Carlos Ibáñez e Ibáñez de Ibero (1825–1891), Marqués de Mulhacén, are recounted. A bibliography of his relevant work is included.

Geodetic history has traced the origin of its first consolidated association to 1862, when a group of visionary scientists, primarily geodesists and astronomers, backed by their respective governments, formed the *Mitteleuropäische Gradmessung* [Helmert, 1913]. This term which according to Lambert [1950] "may be translated literally, if barbarously, «The Central European Degree-measurement»" represents the first organized attempt to exchange and share on a permanent basis, geodetic advances across national boundaries. Their main intent was to connect the many scattered chains of triangles surveyed in Europe under unrelated national mapping programs and progress toward the quest of finding the actual size and shape of the earth. Notable premises set forward at that historic occasion demanded that projected goals must be apolitical in content, and that the decisions made would stand or fall exclusively based on their scientific merits and without having any binding effect whatsoever on member countries.

At the inaugural general conference held in Berlin in October 1864, a *Central Bureau* headquartered at the Geodetic Institute of Prussia, and directed by the eminent General Baeyer [see Torge, 1994; Buschmann, 1994], was recognized as the center responsible for coordinating all central European geodetic activities. This office was also in charge of performing the required work and conducting the necessary negotiations to assure the desired uniformity in the collection of geodetic and astronomic data.

At a follow-up convocation in Berlin in 1867, after Spain and Portugal agreed to join this emerging organization and in order to better reflect the multinational scope of its membership, it was decided to change its name to *Europäische Gradmessung* (European Geodetic Association). Concurrently, a *Permanent Commission* with administrative powers that supervised the Central Bureau and acted as the supreme standing scientific agency was created. Furthermore, with the intention of encouraging the exchange of ideas and ultimately having a forum to present and discuss the progress accomplished, a triennial General Conference and an annual meeting of the Permanent Commission were regularly scheduled.

As already pointed out by Lambert [1950], there was confusion as to the precise referencing of these early organizational structures due to the somewhat liberal French translation of the original German language. For unknown reasons; perhaps, to convey more universality, Europäische Gradmessung became in French: Association Géodésique Internationale. This is explicitly evident from the title pages and bilingual contents in the volumes detailing the annual proceedings of the Permanent Commission meetings where "Verhandlungen... Permanenten Commission der Europäische Gradmessung" became "Comptes-Rendus des Séances de la Commission Permanente de l'Association Géodésique Internationale pour la Measure des Degrés en Europe."

In truth, it was not until two decades later –in 1887– when the word "international" was formally added for the first time to these pioneering geodetic societies. Consequently, and in order to be consistent with the current terminology implicitly adopted by the present International Association of Geodesy [Levallois, 1980], the words "Association Géodésique Internationale," although mentioned in the proceedings of the General Conferences and Permanent Commission meetings during the interval 1875–1886, should be understood exclusively as the "Europäische Gradmessung." The French designation was so prevalent in the literature of the time, that Clark [1880, p. 36] in the first edition of his acclaimed book *Geodesy* used the term "International Geodesic (sic) Association" 7 years before this organization was officially established.

It was at the general conference in Berlin in November 1886, when the name Europäische Gradmessung was changed to *Internationale Erdmessung (Asso-*

ciation Géodésique Internationale = International Geodetic Association) to accommodate the participation of countries outside Europe. Although its membership comprised nations in Europe, Asia, and the Americas, two prominent geodetic powers, Great Britain and the United States, were not represented initially. The United States became a full member in 1889 after the U.S. Congress approved the necessary monies. Precise nomenclature was so poorly defined during those days, that in the 1889 Report of the Superintendent of the U.S. Coast and Geodetic Survey, funding is requested to pay the membership fees with these words: "For contribution to the «International Geodetic Association for the Measurement of the Earth»" [U.S. Coast & Geodetic Survey, 1890, p. 13]. However, in the same volume Davidson [1890] reporting on his trip to Paris to attend the Ninth Conference "as the Delegate appointed by the President of the United States" writes the more appropriate short terminology "International Geodetic Association." This designation remained in effect until 1917 when a new, more cumbersome wording was introduced: "Reduced Geodetic Association Among Neutral Nations." This was followed by "Section of Geodesy of the IUGG" (1920–1933); "Association of Geodesy" (1933–1946); and, finally, from 1946 to the present, "International Association of Geodesy" (IAG) [Tardi, 1963].

Having clarified the conventional naming accepted to designate the precursors of today's IAG during the years preceding the nomination of Carlos Ibáñez e Ibáñez de Ibero as the first president of the International Geodetic Association, attention will now be focused on his life and achievements.

As he is commonly known in Spain, General Carlos Ibáñez e Ibáñez de Ibero, Marqués de Mulhacén (Fig. 1) was born in Barcelona (Catalonia, Spain) on April 14, 1825 and died in Nice (France) January 28, 1891. The outstanding professional career of Carlos Ibáñez (identified hereafter by his father's surname) comprises a life virtually dedicated to geodesy and other closely related sciences. His achievements brilliantly extended the path initiated by other Spanish military scientists (among them, well known mariners Jorge Juan and Antonio de Ulloa) who fiercely devoted their energies to expand the realm of higher geodesy with a dedication and impetus of deserved worldwide recognition. Not only were the contributions of Ibáñez internationally acclaimed, but more importantly, his foresight and intervention were pivotal in forging an ingenious and well-thought course of action for the pragmatic implementation of the geodetic and mapping sciences in Spain.

Carlos Ibáñez descended from a family with prominent military heritage. His father, a lawyer and mathematician, and both grandfathers were high-ranking officers in the Spanish Army. From an early age he was tutored with a solid intellectual and humanistic background. For example, he was an accomplished polyglot, fluent in French, English, and German; and because of its similarity to his mother tongue (Spanish and Catalan), he was able to read and communicate in Portuguese and Italian.

Fig. 1. General Carlos Ibáñez e Ibáñez de Ibero

This aptitude for languages made him a popular and admired personality in European scientific circles, propelling him to prestigious international positions, both in management as well as basic and applied research. "The vast experience of this motivated scholar, the amenity of his character and his ample loyalty, has gained for Ibáñez, besides the esteem, the affection of all his peers" [Bertrand, 1891]. In fact, his accomplishments were not limited to assuring the progress of the mapping sciences in Spain, but transcended its national domain to generate an impact on geodesy and international diplomacy as a whole.

As Hirsch [1892] said very eloquently: "But it is not only Spain who has profited from the tireless work of this learned officer; it was geodesy in general, to which Ibáñez rendered his best services. Although animated by the most ardent and genuine patriotism, his liberal spirit would not admit, within the world of science, the isolated and restrictive limitations of political frontiers and, above all, national vanities. He understood from the very beginning, that in order to achieve the progress he envisioned for his own homeland, it was necessary to study and adapt the organization and procedures of the most advanced countries. It was never too late for him to repay with interest the important scientific and technological input that he had borrowed from abroad."

Following a tradition well blended within his ancestry, he enrolled in the elite Engineering Military Academy at the early age of 14. He graduated in 1843, the ninth highest in his class with the rank of lieutenant [Llave, 1953]. Being basically a scientist, Ibáñez enjoyed a peculiar military status, although he always retained his affiliation with the Corps of Engineers, rising through the ranks to Captain (1845); Commandant (1857); Lieutenant Colonel (1862); Colonel (1868); Brigadier (1871); and finally, Field Marshal (1877), which was renamed General of Division in 1889.

In 1847, in response to a special request by the Portuguese government, Spain and England sent troops to the neighboring country to subdue an incipient revolt fueled by political agitators acting from the northern city of Porto that was threatening country-wide anarchy. This uprising was pacified without bloodshed, but most significantly, during Ibáñez's stay in Portugal his unit was assigned to map the route from Porto to Tuy, and the strategic city of Valença do Minho. Thus, for the first time, he assumed responsibility of a cartographic task which would imprint on him a vocation that guided forever the course of his professional activities.

During all his life Ibáñez maintained an attitude that was unusual for a military officer of his notoriety and prestige: to be totally sheltered from the influence of political coalitions. Nevertheless, during his years as a young Captain, he was mobilized with his troops to restrain two tumultuous rallies in Madrid streets (March 28 and May 7, 1848) that had been instigated by antimonarchist elements [Paladini, 1991]. As a consequence of those actions he received a medal, the *Cruz de San Fernando*. This was the first of a myriad of honors bestowed on him by Spain and other foreign governments. Awards included the Grand Crosses of *Carlos III* and *Isabel la Católica*; and Knight of the Orders: *San Hermenegildo*, *María Victoria*, Medjidie of Egypt, Crown of Prussia, Crown of Italy, Crown of Romania, St. Anne of Russia, and *Concepción Villaviciosa* of Portugal [Ibáñez de Ibero, 1957].

He assumed the post of professor at the Engineering Military Academy in 1850, but this commitment was short lived. One year later, he interrupted his teaching duties after having been assigned a commission to visit several European military establishments and enhance his education and training on the latest techniques to build pontoon bridges. Undoubtedly, this 4-month sojourn acquainted him with the handling of new precision mechanical tools and prepared him well for the intricacies of metrology, a branch of the physical sciences at which he later excelled.

In 1852, he was named Director of the School of Pontoniers in Madrid. This same year the Spanish Royal Academy of Sciences (*Real Academia de Ciencias Exactas*, *Físicas y Naturales*) urged the Government to produce a large scale topographic/cadastral map of the nation. The best cartography available in Spain at the time was limited to regional maps of the provinces at scales of 1:200,000 (prepared by Colonel F. Coello) to complement a voluminous Geographical Dictionary compiled by P. Madoz [Alonso, 1972, p. 45].

The following year Ibáñez wrote a comprehensive pontonier's manual in collaboration with J. Modet [1853]. This work was well-received and represented the canonical text on the subject for many years. But with all certainty, the event that more than anything else was destined to shape his future also occurred in 1853 when he was selected to be a member of the newly formed Commission for the Map of Spain (*Comisión del Mapa de España*). This Commission was the answer to the pledge made 1 year earlier by the Academy of Sciences and was formed to study the feasibility of producing a detailed topographic map of the country. Thus, from that moment on, he embarked on what would culminate in an illustrious career in geodesy. It was from this platform he proposed and defended the idea of covering Spain with a dense network of triangles scaled by an accurately measured geodetic base line, following up-to-date methodologies adopted by other leading geodetic organizations.

The mathematical inclination of Ibáñez constantly drove him to look for the best scientific solutions, contrasting with simplified "practical" procedures advocated by pure military engineers. Such was the success of this energetic passion to properly modernize Spanish geodesy that he fostered a new trend among his colleagues where rigid mathematical and instrumental processes took precedent over the mere application of conventional routines. "He knew how to communicate his ardor to the young officers, who initially were his students, but soon after, his collaborators" [Milne-Edwards, 1891].

Compelled by these demanding intellectual principles, he contacted the shop of Brunner in Paris –the cradle of precise scientific instruments of the time– to manufacture under his supervision the most advanced base apparatus as arranged by the Map Commission. In 1855 and 1856, he spent several months in Paris directing its construction and determining its coefficient of thermal expansion. Later he made the comparisons, of what would become the Spanish standard of length, against the so-called Ruler ("module") No. 1 of Borda which was the main reference for measuring all geodetic bases in France since 1798 and whose relationship with the standard meter at the Paris Observatory was rigorously known [1884c].

The Spanish Rod designed by Ibáñez and Brunner [Brunner, 1857a, 1857b] was essentially a single bimetallic measuring bar with a nominal length of 4 m based on a thermometric combination of two metal strips (21 mm wide and 5 mm thick), one of platinum on top of another of brass of the same dimensions [1860; 1883d]. This apparatus belonged to the so-called "optical type" and, as such, was furnished with two independent microscope micrometers. The rudiments of replacing contact rods by optical procedures were introduced by Hassler and Tralles and already employed in Switzerland in 1797 [Hassler, 1825; Wolf, 1891].

Other accessories, such as a portable level bubble, a telescope for alignment, and several trestles to precisely place the rod and the micrometers above the ending points were included as an integral part of the instrumentation. A longitudinal shelter tent formed using several concatenated segments was also deployed and progressively moved to isolate the instruments and the observers from weather conditions.

In 1858, Ibáñez personally directed and participated in the measurement of the central geodetic base of the Spanish first-order triangulation. Located in Madridejos (Toledo) about 100 km south of Madrid, its length was determined using the instrument he helped to devise and which he thoroughly tested in Paris the preceding year. The results were of such incredible precision that Ibáñez soon gained fame and celebrity for the rigor of his scientific scrutiny [Lallemand, 1925], and his field-work received praiseworthy reviews such as "memorable operation" and *non plus ultra* [Faye, 1863].

This mastery in designing a base apparatus was going to be amply corroborated later, when Ibáñez constructed a second prototype, further improved in efficiency and manageability. Undoubtedly, this was the prolegomenon of advanced geometric geodesy in Spain and, due to the fulminant results achieved by Ibáñez with the base apparatus he designed, the justification for his meteoric career in the field. Around this time, preliminary discussions with Colonel Laussedat where held concerning the possibility of linking with large triangles the continents of Europe and Africa, a premonition of another of Ibáñez's salient milestones later in life. Laussedat was a professor of geodesy at *l'École Polytechnique* in Paris who was sent by the French Academy of Sciences to observe the field procedures used by Ibáñez while measuring the Madridejos base [Laussedat, 1859a, 1859b].

Interestingly, in 1872, a disparity of views claiming proprietary ideas (mainly who originally proposed the geodetic junction between Europe and Africa) erupted within the French Academy. This somewhat pointless, long-lived controversy is well documented in the *Compte Rendus* [Blondel, 1872; Doutrelaine, 1872; Laussedat, 1872a, 1872b; Levret, 1865, 1872; Perrier, 1872a, 1872b, 1879a]. In essence, an old idea already postulated by Biot and Arago was revived [Biot and Arago, 1821, p. xxix; Biot, 1857; Levallois, 1988, p. 86].

In 1859, Ibáñez in conjunction with some of his assistants published: "Experiments made with the apparatus for measuring bases belonging to the Spanish Mapping Commission" [1859a], followed by "The central base of the Spanish geodetic triangulation" [1859b], where they described in detail the methodology applied to accurately measure geodetic bases. These books were promptly translated into French by Laussedat and received world-wide dissemination [1860, 1865; Laussedat, 1866].

The same year, Ibáñez traveled abroad to become familiar with the latest techniques to produce large scale topographic maps. His main mission was to inspect every available alternative and select the best solution for the compilation and publication of topographic maps. He in turn was named Secretary of the Geographical Section of the *Junta General de Estadística*, in charge of the general plan for all topographic and cadastral operations in Spain.

Also in 1859 Ibáñez completed an independent check of the Madridejos base using a triangulation scheme [1863b, 1863c; Laussedat, 1864]. One recurrent query troubling geodetic contemporaries of our protagonist was whether or not the advantages of measuring a long base line were sufficiently great to warrant the expenditure of the time that it requires, or whether as much precision could be obtained by carefully extending a short base through triangulation. The Madridejos results answered unequivocally this important scientific challenge (see Table 1). The angular measurements done by Ibáñez at Madridejos demonstrated that bases of about 2 km in length could be enlarged without significant deterioration up to lengths of 14.5 km, strongly suggesting the convenience of reducing the direct measurement of bases to about 3 km.

On May 11, 1861, Ibáñez was elected a member (seat #20) of the Spanish Royal Academy of Sciences. His opening discourse, read in front of the assembly on March 8, 1863, dealt with the rapid advancements achieved in astronomic and geodetic instruments: "History of the observing instruments used in astronomy and geodesy and their influence in the progress of these two sciences" [1863a]. In Madrid in September of 1861 he married Juana Baboulène Thenié, born in Agen, France, from whom he did not have descendants. This failure to procreate probably was a contributing factor to marital tensions and ultimately caused their separation.

In 1862, he was named Secretary of the Section of Mathematics of the Spanish Academy of Sciences. Attending a petition from the Egyptian Government channeled through the French Academy of Sciences, Ibáñez accepted the responsibility of principal investigator in a research project aimed to determine the metric

Table 1. Results obtained at the Madridejo's base. All linear units are meters

	Direct Measurement	Reduced to Sea Level	Geodetic Triang.	Diff.	Relative Error
1st Section	3077.80064	3077.4611	3077.4647	−0.0036	(1:854,851)
2nd	2216.64132	2216.3990	2216.4011	−0.0021	(1:1,055,429)
3rd	2766.90856	2766.6061			
4th	2723.72313	2723.4268	2723.4241	0.0027	(1:1,008,676)
5th	3879.42634	3879.0034	3879.0054	−0.0020	(1:1,939,503)
Base	14664.49999	14662.8964	14662.9014	−0.0050	(1:2,932,580)

Note. The 3rd section was the only section measured twice. The discrepancy between the two measuremts was 0.797 mm representing a measurement relative error of 1:3,470,000.

characteristics of the rod used in Egypt to measure geodetic bases. Consequently, he collaborated with Egyptian astronomer Effendy in the calibration of the Egyptian standard of length against the Spanish Rod. Details of this operation performed at the Madrid Observatory under stringently controlled conditions were released in [1863d].

Constantly nurturing all types of scientific interests, Ibáñez expressed his views about leveling in "Study on geodetic leveling" [1864a] which was an instant success and re-edited on several occasions. Carlos Ibáñez was one of the first geodesists to propose setting up mareographs in Spain (Alicante, Santander, Cádiz) and other countries in Europe to investigate the best mean sea level surface defining a unique vertical datum to reference all continental heights [1881a, 1884e, 1890a]. Later in 1864, he was named Chief of Geodesy and Cadastre for the eastern region of Spain, encompassing the Mediterranean Catalan speaking provinces of Castellón, Valencia, Alicante, and the Balearic Islands.

Ibáñez inquisitiveness pushed him to conceive a simplified version of base apparatus. In March of 1865 he traveled to Paris to the shop of Brunner's brothers to supervise the completion of his new 4 m instrument and to determine its coefficient of thermal expansion. This was a monometallic rod of laminated iron 6 mm thick rivetted into two plates in the shape of an inverted T, with four removable contact thermometers. The upright depth was 12.5 cm and the horizontal 9.6 cm in width. As before, it was used in conjunction with two microscope micrometers, telescope for alignment, bubble level, etc. Other beneficial features introduced in the manufacture of this iron rod included: provisions to secure readiness in transportation, ease and rapidity in handling, and better stability of supports. The bar was lifted by two pairs of handles and was protected by a very strong box for transportation. All these advantages reduced the operational time in the field drastically. He was able to proceed at a rate of 200 m/hour compared with a slow 30 m/hour for the Spanish Rod previously used at Madridejos [Ibáñez de Ibero, 1945; Torroja Menéndez, 1991].

The novelty of affixing mercury thermometers to the iron bar was criticized by Davidson [1890]: "The principal source of error appears to me to rest in the unknown temperature of the bar, because I can not believe that the indications of the thermometers are to be taken as the actual temperature of the bar at any given time." "... I think the conditions adopted with the single metal bar and thermometers (thereby really introducing two metals) are unfavorable for accuracy on account of the direct exposure of the bar itself to the atmosphere and the doubtful contact of the thermometers therewith; and also the insufficiency of any such relation of the thermometers to the metal to determine its mean temperature." Davidson continued defending the methods used in the United States remarking: "In discussing with the members of the Geodetic Association the method by which the Coast Survey has measured the Yolo and Los Angeles bases, I endeavored to elicit from their claims for the practical advantages of the Ibáñez and Brunner bars." However, these statements were too premature and not fully supported by the facts. In the report that Davidson [1895] wrote about results from geodetic bases measured in the U.S., he tabulates a relative accuracy of 1:820,000 for the Yolo base but, incomprehensibly leaves blank the relative accuracy corresponding to the Los Angeles base which he measured more than six years earlier. In contrast, the average relative error of the nine base lines that Ibáñez personally measured with his instrument amounted to only 1:2,400,000 [1871a, 1881g, 1881h, 1881i, 1883c, 1884b; Hirsch and Dumur, 1888]. Even so, refinements to Ibáñez's ideas on how to improve the physical contact of the thermometers against the iron rod were suggested by authors such as Maurer [1884], but never implemented because of the introduction of invar tapes.

Later the same year Ibáñez returned to Paris to check the preparation of the lights to be deployed in the triangulation connecting the Balearic Islands project which he planned and personally directed in the field.

In 1866, he reiterated to the European Geodetic Association the feasibility of tying the geodetic networks of Spain (Europe) and Algeria (Africa) while representing Spain at the meeting of its Permanent Commission in Neuchatel. There, Ibáñez offered the collaboration of his government in pursuing one of the most coveted geodetic projects at the time: extending the meridian arc from the Shetland Islands to Africa [1866b, 1888b].

At the conclusion of the Paris Exposition in 1867, a Committee for weights, measures, and currencies (*comité des poids et measures et des monnais*) was assembled to study the suitability of creating a logical system of measures of universal acceptance. Ibáñez once more represented Spain at this germinal gathering. During the months of May to September of that year he continued the time-consuming geodetic survey in the Balearic Islands. This geodetic work comprised first- and second-order triangulation, but it was complicated by the logistics of visually connecting points between different islands. In the Summer of 1868 Ibáñez returned to Majorca to complete his geodetic activities in the islands.

On December 22, 1868, a royal decree, after recognizing its originality in design, officially baptizes the iron rod that he devised and constructed in Paris with the name of *Aparato Ibáñez* (Ibáñez's Apparatus). This instrument was used by Ibáñez himself to measure several base lines: three in the triangulation he designed and implemented in the Balearic Islands and five others strategically located across the Iberian peninsula. Furthermore, in 1880, the Ibáñez Apparatus was loaned to the Swiss Geodetic Commission to measure three geodetic bases in Switzerland.

In 1869, Ibáñez published "New apparatus for measuring geodetic bases" [1869] where he explained in great detail the different components of his second base apparatus. A sufficiently extensive accounting of this instrument and its operation can also be found in [Koppe, 1881; Westphal, 1881; Hirsch and Dumur, 1888, pp. 5–26; Álvarez and Bellón, 1889; Mifsut, 1905a, pp. 106–124, and 1905b, Figs. 38–97]. So well founded and authoritative was the Ibáñez contribution to geodetic base measurements that a description of his instrument and methods appeared in five consecutive editions of the respected Jordan's Handbook [1890, pp. 92–99; 1896, pp. 84–90; Jordan-Eggert, 1939 and 1948, pp. 119–124; Jordan-Eggert-Kneissl, 1958, pp. 448–451].

During the same year of 1869 Ibáñez traveled to Southampton to observe the comparison of his instrument against the English Yard performed by Clark [1873]. The determined length was 4.00040524 m, which represented a relative precision of 1:2,000,000 with relation to the value previously obtained by Ibáñez. From these series of experiments the first rigorous determination of the relationship between the meter and the English yard was made: 1 m = 1.09362311 Y. The results of the calibrations led Clark to write: "From this it appears that the length of the meter, as given by the Spanish bar (referring to Ibáñez's rod) agrees with great precision with that inferred at Southampton from the comparisons of the Belgian and Prussian toises."

January 4, 1870, marks the creation of the Geographical Institute of Spain initially placed under the *Dirección General de Estadística* in the Ministry of Fomento. Carlos Ibáñez was named Director General of the Institute by decree on September 12. Thanks to his balanced political neutrality he remained at the helm of this institution unaffected by sometimes abrupt regime changes which caused profound administrative reorganizations. Under his mandate the production of the General Topographic Map of Spain was launched. "The general directions, which, in accordance with the proposition of the Geographical Institute, His Highness the Regent of the Kingdom has been pleased to dictate, under the date of the 30th of September, 1870, are: 1st, that the publication shall be made on a scale of 1:50,000; 2nd, that the map shall be divided into sheets of 20 minutes' base in the direction of the parallels by 10 minutes' altitude in the direction of the meridians; 3rd, that the portion of the terrestrial surface represented on each one of the sheets shall be considered as a plane, without subjecting the map to any system of general projection" [Comstock, 1876]. This enterprise represented a colossal undertaking containing an estimated total of 1,080 quads; on the other hand, Ibáñez's goal had finally been realized: "to group in one single Department and under the same directorate, all geodetic and topographic operations" [Arévalo, 1991].

In the Summer of 1870, Ibáñez became a member of the International Commission of the Metre (*Commission International du mètre*). On Oct. 12, 1872, an election was held in Paris to choose among the representatives of participating countries the twelve members of the Commission's Permanent Committee. The record shows [Bosscha, 1876; Bigourdan, 1901, p. 313] that a ballot was taken where from a possible 34 votes the following results were registered: Foerster (34), General Ibáñez (34), Bosscha (33), Herr (33), Wild (32), General Wrede (31), Hilgard (29), General Morin (29), Chisholm (27), Broch (26), Stas (26), and Husny (18). At the first scheduled meeting of the Committee, and by unanimous decision, Ibáñez was elected president and Bosscha secretary.

From this privileged position, and until his death in 1891, Ibáñez vigorously committed himself to single objective: the international unification and applicability of the metric system. He enthusiastically defended the creation of the *Bureau International des Poids et Mesures* and its settlement in permanent headquarters at the *Pavillon de Breteuil* in Paris. This took skillful diplomatic maneuvering and an absolute conviction on the substantial benefits that such measure may contribute to simplify and ameliorate world-wide commerce. In the words of the Spanish mathematician Rey Pastor [1925]: "... For a third of a century Ibáñez became the paladin of metrology whose transcendent international effort he directs and organizes with great competence and ability."

The results of the geodetic operations in the Balearic Islands were compiled in a comprehensive volume entitled "Geodetic description of the Balearic Islands" verifying, once more, the wealth of information and the preoccupation for completeness, characteristic of Ibáñez meticulosity. There is a curious anecdote associated with this survey. Unable to program ahead a rigorous determination of longitude due to a break in the undersea telegraphic cable connecting Spain with the islands, Ibáñez decided to use the astronomic values of latitude, longitude, and azimuth previously determined by the French geodesists Biot and Arago in 1806 and 1825 at La Mola, Formentera [1871a, p. 141].

Paradoxically, the geodetic coordinates so computed were never updated –even after an accurate geodetic connection of the islands with the mainland was established in modern times [Paladini, 1969]. It seems that this contemporary decision adds unnecessary confidence to Ibáñez judgement and almost infallible credibility to the performance of Biot and Arago.

We come now to another event crucial in the life of Carlos Ibáñez. In March 1873, and by a decree of the newly installed Republican Government, the Geographical Institute took a new identity after it was combined with an office of Statistics and renamed Geographical Statistical Institute (*Instituto Geográfico y Estadístico*) "the greatest agency of its kind in the world, which was a model for similar institutions in other countries" [Appell, 1925]. It is not surprising that Ibáñez was thought to be the proper person to direct this revamped Institute and accordingly he was appointed its first General Director. Witness of the excellence he was able to inculcate among his co-workers are the profusion of accomplishments spanning the 17 years that he administered this organization, precursor of today's *Instituto Geográfico Nacional*. This was the golden age of geodesy and cartography in Spain but, although bypassed in the present article, one should not ignore the progress that Ibáñez inspired in promoting novel comprehensive statistical surveys of tremendous national significance.

Ibáñez himself described some professional aspects of the Institute in a letter quoted by Wheeler [1885]: "As to the organization of the Institute, which I have the honor to direct, it is neither all military nor all civil, but mixed; and the Institute itself is under a civil department

(Ministry of Public Instruction, Public Works, Agriculture, and Commerce)... The geodetic works of the first order have been executed by officers of Artillery, Engineers, and General Staff. Triangulations of the second and third orders are confided to certain officials chosen from a special civil corps, named Corps of Topographers, which cannot be entered except by competition, after being subject to an examination before a competent tribunal. The topographic works are executed by this same Corps of Topographers."

In Paris in the Fall of 1873, Ibáñez presided over a decisive meeting of the permanent Committee of the International Commission of the Metre. Among the topics on the agenda was the sanction of a resolution addressed to the French Government (Ministry of Foreign Affairs, Duke Decazes) petitioning support for convoking a diplomatic conference in Paris to discuss the world-wide consolidation of the metric system.

While attending the 4th General Conference of the *Europäische Gradmessung* at Dresden in 1874, and during the fourth session held on September 28, Ibáñez was elected president of its Permanent Commission [Anon., 1875, p. 7]. The results of the first round of votes among the nine members of the Commission (Baeyer, de Bauernfeind, Bruhns, Faye, de Forsch, Hirsch, Ibáñez, d'Oppolzer, and de Vecchi) went as follows: Ibáñez (4), de Forsch (3), Faye (1), and de Bauernfeind (1). The two candidates with the most number of votes passed to the final election where everyone except the candidates themselves could cast a ballot. The decisive result was: Ibáñez (4) and de Forsch (3). Ibáñez accepted his nomination as president as a "delicate obligation, he has fulfilled with dignity, impartiality and sensitivity, to the satisfaction of all Governments and their delegates" [Hirsch, 1892]. His first action as permanent Commission president was to put to good use this alternative podium, promulgating, once more, the need for a prompt assembly of an international diplomatic conference to decide the future of the metric system [Anon., 1875, pp. 8–9]. Ibáñez deserves immense credit for this unabated striving to crystallize this paramount conference which finally convened in Paris on March 1–20, 1875.

As president of the Permanent Committee of the International Commission of the Metre, Ibáñez was a plenipotentiary at the Convention of the Metre (*Conférence diplomatique du Mètre*) that ultimately ratified the meter as the standard unit of length [Jordan, 1877; Guillaume, 1902; Page and Vigoureux, 1975, pp. 225–230]. This agreement was signed by 17 of the 20 countries of Europe and the Americas present.

After the conference, during sessions held in Paris on April 19–24, the International Committee for Weights and Measures was born and Ibáñez elected its first president, a post that he would retain until his death. "He always presided with ample vision and polite authority together with great courtesy and tactful qualities required to moderate the debates of the International Committee during an age of political confrontations" [Guillaume, 1925]. The activities of the International Committee for Weights and Measures during Ibáñez's long mandate are thoroughly chronicled in *Procès-verbaux des séances du Comité International des Poids et Measures*, in the volumes comprising the years 1875 through 1891.

At the annual meeting of the *Europäische Gradmessung*'s Permanent Commission in Hamburg in 1878, he reported very proudly and with optimism about the completion of the field reconnaissance for the geodetic connection between Europe and Africa, a joint enterprise that France's F. Perrier and Ibáñez masterminded. Also in 1878, presuming his first wife dead, he was married for the second time to Cecilia Grandchamp y Rosset born in Montbrillant, Canton of Geneva, Switzerland. Their union produced a daughter and a son (Carlos Ibáñez de Ibero) who studied in Paris, was a prolific writer, became a member of the Spanish Academy of Political Sciences and, understandably, an impassioned biographer of his father [Ibáñez de Ibero, 1918, 1945, 1956, 1957, and 1963].

Some bizarre circumstances surrounding the reappearance of Carlos Ibáñez's first wife in Madrid soon after his death, claiming the General's widow's pension and the legal procedures which ensued may be consulted in Paladini [1991]. This private personal incident was used by Ibáñez's more prejudiced and acerbic adversaries to unsuccessfully attempt to discredit his reputation posthumously [Chaix, 1891].

It was 1879, when in collaboration with several Spanish [Barraquer, 1881; Merino, 1881] and French (Bassot, Defforges, etc.) scientists, Ibáñez representing Spain and Perrier representing France directed the geodetic and astronomic operations to complete the junction between the geodetic networks of Spain and Algeria. Also this year, the very first quad (Madrid) of the Topographic Map rolled off the presses. There were a total of 89 sheets printed before Ibáñez left the Institute [Nuñez de las Cuevas, 1991a]. The quality of the final product was well summarized by Hirsch [1892]: "This magnificent map represents one of the most perfect examples of modern cartography, notable because of the exactness of the information it contains, as well as the clarity of the drawings and the beauty of the engravings; the Map of Spain has been considered among the best of our times in every exhibit it participated."

In 1880, attending to a request from the Swiss Government, Ibáñez ordered the transportation of his instrument to Switzerland, and personally directed a Spanish team in the measurement, twice, of the geodetic base at Aarberg. This base, central to the Swiss triangulation, was remeasured once more immediately after by Swiss scientists. In July, 1881 the same Swiss group still using Ibáñez's Apparatus also measured two other control bases, Bellinzone and Weinfelden, twice, "the results were of a precision truly remarkable, which is a great complement for the instrument employed and the scientists involved in these measurements" [Gautier, 1893]. The average relative error of the three bases was only 1:2,273,000. A descriptive account of these operations including final conclusions were published by Hirsch and Dumur [1888].

Once the great geodetic endeavor connecting Spain and Algeria was completed, preliminary results were presented by Ibáñez and Perrier at the General Conference of the *Europäische Gradmessung* in Munich [1881c] and the Spanish [1880b] and French Academy of Sciences [1879; Perrier, 1879a, 1879b, 1879c]. A full scientific report and the vicissitudes encompassing this major geodetic venture, unique in its time, were thoroughly recounted in various publications [1880b, 1886a, 1888b; Perrier, 1887a, 1887b] where proper credit to all participants involved was apportioned. In the interval from 1882 to 1884 Carlos Ibáñez occupied the second highest scientific post in Spain when he took office as vice president of the Spanish Academy of Sciences.

As requested by the War Department (*Ministerio de Guerra*) in 1882, he published a voluminous study deliniating the military regions of Spain assigned to the different arms forces [1882]. This work contained an updated map of the country at 1:1,500,000.

In 1885, the French government conferred Ibáñez as Grand Officer of France's *Légion d'Honneur* in recognition of his efforts to disseminate the metric system among all nations. At the first assembly of the International Geodetic Association in Berlin in 1886, General Carlos Ibáñez e Ibáñez de Ibero was unanimously elected its first President, effective January 1887. "Unselfish devotion, perfect understanding of the concerns, judgement on persons and situation, firm resolutions and pleasant impartiality is what Ibáñez has displayed at this position which he occupied until his death" [Hirsch, 1892].

Major administrative issues confronted by Ibáñez during the four years of his tenure included, among others: participation with Helmert, Hirsch, and Foerster in the preparation of two sets of by-laws, one for the Permanent Commission, the other for the Central Bureau; taking an active role in increasing the membership of the International Geodetic Association which during Ibáñez's presidency announced the definitive addition of nine countries (France, Switzerland, and Serbia in 1887; Chile, Mexico, Japan, and Greece in 1888; and Argentina and the United States in 1889), the Association strongly recommended the adoption of the meridian of Greenwich as the international official meridian turning down some proponents advocating the selection of the meridian of Jerusalem; the first special financial commission was constituted; etc.

In 1887, he was elected Member Correspondent of the French Academy of Sciences in Paris. Besides belonging to the two scholarly organizations already mentioned (Spanish and French Academies), and many other scientific societies, he was inducted into the following prestigious institutions: Honorary Member, *Institut d'Egypt* (1864); *Miembro Correspondiente en el Exterior*, *Academia National de Ciencias Exactas*, *Físicas y Naturales*, Buenos Aires; *Associé*, *Académie Royale de Sciences*, *des Lettres et des Beaux-Arts de Belgique* (1885); *Ehren-Mitglieder*, *Akademie der Wissenschaften*, Berlin (1887); and Foreign Associate, National Academy of Sciences, Washington (1889).

By royal decree, on February 8, 1889, he was awarded the nobiliary title of *Marqués de Mulhacén* in recompense for his leadership in the planning and successful completion of the geodetic junction between Spain and Algeria ("for the scientific work he directed or was personally involved"). Ibáñez always resented not being able to participate directly in the observations. He climbed the 3480 m of peak Mulhacén on September 1879, but after 3 days of fruitless waiting for the weather to clear, he was forced to leave in order to travel to Paris and resume his busy schedule.

Unexpectedly, a royal decree of October 1889, abolished the autonomy of the General Direction of the Geographical and Statistical Institute, placing it under other General Directions in the Ministry of Fomento. This change eliminated direct control of the benefits generated by the Institute's inherent resources and caused quite a commotion. On Dec. 20, discontent with what he thought was a self-defeating policy, Ibáñez asked for 1-year leave of absence (later extended to 2) to travel to France, settling temporarily in Nice were he concentrated full time on his multiple international obligations, "... besides the plethora of titles and the respect of the scientific community, we owe General Ibáñez our gratitude: he loved France and deserves our devoted affection" eulogized Milne-Edwards [1891].

Ibáñez's intuition played a key role in setting up the Institute objectives, merging perfectly the fields of geodesy, topography, and cadastre. After Ibáñez's *de facto* resignation, the Geographical Institute of Spain began a long decline from which it did not fully recover until well into the 20th century. The hardships still seem to be somewhat unresolved. A former director of the Institute complained recently [Núñez de las Cuevas, 1991b]: "Due to the Administration lack of problem focusing... a century later the Institute continues without fulfilling in great part the goals projected at the time of its creation."

On December 29, 1890, the French Academy of Sciences awarded to General Carlos Ibáñez the Poncelet Prize. The members of the selection committee (Hermite, Darboux, Poincaré, and Jordan) justified the nomination with these words: "for his dedication and the intelligent direction he gave to every matter related to his involvement at the International Committee for Weights and Measures. After more than twenty years of scrupulous studies, in 1889, and according to the resolutions of (the Convention of the Metre in) 1875, the new metre standards were distributed to countries in Europe and the Americas perpetuating the acceptance of the metric system." [Anon., 1890].

On the 31st of January 1891, Ibáñez was buried with full military honors in the Cemetery du Château in Nice. The headstone bears the following inscription: *A la memoria del Excmo. Sr. D. Carlos Ibáñez e Ibáñez de Ibero*, *Marqués de Mulhacén; General de División del Ejército Español*; *Fundador y Director del Instituto Geográfico de Madrid*; *Presidente de la Asociación Geodésica Internacional y de la Comisión Internacional de Pesas y Medidas; Gran Cruz de Carlos III*, *de la*

Corona de Italia, etc. etc.; *Miembro Correspondiente, laureado, del Instituto de Francia*; *Gran Oficial de la Legión de Honor*; *Falleció en Niza, el 28 de enero de 1891*; *Concesión à perpétuité.*

Ibáñez won widespread accolades posthumously. On July 1912, a commemorative plaque was unveiled in Nice at the house where he lived the last days of his life and where death, caused by a virulent pneumonia, surprised him [Mier, 1912]. In June 1921, another plaque recognizing the merits of General Carlos Ibáñez was placed in Madrid on the façade of the building where the Geographical Institute was originally located. In 1924, the boulevard in Madrid where the new *Instituto Geográfico Nacional* was erected was named for Ibáñez; later, in 1957, a monument to the *fundador y Primer Director del Instituto Geográfico y Estadístico* was placed near its main entrance [Ibáñez de Ibero, 1963, p. 240–304]. In May 1925, a tribute honoring the centenary of his birth was observed at *la Sorbonne* in Paris. The full set of discourses [Commémoration, 1925] were published in the June 1925 issue of *Bull. Géodésique.* In June 1949, a commemorative tablet was located at the alpine refuge on the peak Mulhacén celebrating the geodetic connection between Spain and Africa [Gavira, 1950]. In October 1953, an homage to Carlos Ibáñez was dedicated in Barcelona with the occasion of adding his portrait to the Gallery of Illustrious Catalans [Llave, 1953]. A brief "biographical memoir" by Whitten [1988] appeared in "The Geodesist's Handbook-1988" honoring past presidents of the International Geodetic Association. Finally, the Spanish Academy of Sciences held public sessions in Madrid on September 28 and February 7, 1991, to celebrate the centenary of his death. A special issue under the series History of Sciences was published to commemorate the solemn act.

Above all, posterity remembers Carlos Ibáñez as the foremost crusader of his generation of causes shaping the international exchange of scientific ideas embracing the worlds of geodesy and metrology.

Bibliography

An inclusive bibliography of General Carlos Ibáñez e Ibáñez de Ibero has never been published. The following compilation is an attempt to remedy that void.

1853 (& Modet, J.) *Manual del Pontonero*, iv+379 p., 15 fold. pl., Impr. Memorial de Ingenieros, Madrid.

1859a (& Saavedra, F.) *Experiencias hechas con el aparato de medir bases, perteneciente a la Comisión del Mapa de España*, viii+235 p., Apps. cxlvii p., 7 pl., Rivadeneyra, Madrid.

1859b (& Saavedra, F.; Monet, F.; and Quiroga, C.) *Base central de la triangulación geodésica de España*, vi+300 p., Apps. cclxii p., 9 pl., Rivadeneyra, Madrid. Reprinted: Rivadeneyra, Madrid, 1865.

1860 *Expériences faites avec l'appareil à mesurer les bases appartenant à la Commission de la Carte d'Espagne*. (Translation of 1859a by A. Laussedat), vii+235 p., Apps. cxlvii p., 7 plates Dumaine, Paris.

1863a "Discurso sobre el origen y progreso de los instrumentos de astronomía y geodesia." *Mem. Acad. Cienc. Exactas Fís. Nat.*, 1ª Serie, Cienc. Exactas, **2**, 2ª Parte, 3–30, Madrid. Published separately, ii+125 p., 1 pl., E. Aguado, Madrid, 1863. Also: "El origen y progresos de los instrumentos de Astronomía y Geodesia. Discurso." 56 p., fold. map, Impr. Memorial de Ingenieros, Madrid, 1871.

1863b "Noticia de los resultados obtenidos en la medición de la base central del mapa de España: leída a la Real Acad. de Ciencias, ensesión de 30 de nov. de 1863."*Rev. Progr*, *Cienc. Exactas Fís. Nat.*, **13**, 513–519, 1 map., Madrid. Reprinted 10 p., Impr. Memorial de Ingenieros, Madrid, 1864.

1863c "Notice sur les résultats obtenues dans la mesure de la base central de la carte d'Espagne, lue à l'Académie Royale des Sciences de Madrid (Séance du 30 Novembre 1863)." *Astronomiche Nachrichten*, **61**, 339–346.

1863d (& Effendy. I.) *Comparación de la regla geodésica perteneciente al gobierno de S.A. el virey de Egipto, con la que sirvió para la medición de la base central del mapa de España*, 125 p., fold. plat., E. Aguado, Madrid. Also: *Mem. Acad. Cien. Exactas Fís. Nat.*,1ª Serie, Cienc. Exactas, **2**, 1ª Parte, 1863, ii+47–170, Madrid.

1863e "El arte de la guerra y lasciencias físico-matemáticas", *La Concordia*, **7**, 110–112; **9**, 144–147, Madrid. Reprinted: *Revista Memorial de Ingenieros del Ejército*, **18**, 57–77, Madrid, 1864; and *Asamblea del Ejército*, 2a. época, **10**, 52–59, 123–133, Madrid, 1865.

1864a *Estudios sobre nivelación geodésica*. viii+96 p., 1 pl., Rivadeneyra, Madrid. Reprinted: vii+84 p., 2 etch., 1 pl., Impr. Memorial de Ingenieros, Madrid, 1865. Also: 2nd ed., ix+90 p., 1 pl., tables, fold. diagr., Impr. Direc. Gral. Inst. Geogr. Est., Madrid, 1888.

1865 *Base central de la triangulation géodésique de l'Espagne.* (Tanslation of 1859b by A Laussedat.), viii+300 p., Apps. cclxiv p., 6 pl., 1 fold. map. Rivadeneyra, Madrid.

1866a *Estado de la triangulación geodésica de España en 1°* de septiembre de 1866. 8 p., 1 fold. map, Impr. Memorial de Ingenieros, Madrid.

1866b "Exposé de l'état des travaux géodésiques poursuivis en Espagne, communiqué à la Commission permanente de la Conférence internationale, par le Colonel Ibáñez, membre de l'Académie Royale des sciences et délégué du Gouvernement espagnol." *General-Bericht über die Mitteleupäische Gradmessung für das Jahr 1865*, 57–58, G. Reimer, Berlin.

1869 *Nuevo aparato para medir bases geodésicas.* 176 p., 3 pl., Impr. Memorial de Ingenieros, Madrid.

1870 "Exposé de l'état des travaux géodésiques poursuivi en Espagne. Communiqué à son Excellence M. le général Baeyer, Président du Bureau central de l'Association géodésique internationale, par le Colonel du génie C. Ibáñez, chef du service géodésique, membre de l'Académie des sciences et délégué du Gouvernement espagnol." *General-Bericht über die Europäische Gradmessung für das Jahr 1869*, 62–65, G. Reimer, Berlin.

1871a *Descripción geodésica de las islas Baleares*, xii+866 p., 7 fold. pl., 2 fold. maps, Rivadeneyra, Madrid.

1871b "Spanien. A son excellence M. le général Baeyer, President du Bureau central de l'Association géodésique internationale." *General-Bericht über die Europäische Gradmessung für das Jahr 1870*, 69–70, G. Reimer, Berlin.

1871c "Contestación al discurso «Reflexiones sobre la enseñanza de las matemáticas» leído por el Sr. D. Pedro Alcántara de la Llave ante la Academia de Ciencias Exactas, Físicas y Naturales el día 26 de marzo de 1871." 68 p., Aguado, Madrid.

1871d "Noticia sobre los trabajos de la Comisión Internacional del metro, leída en la sesión de la Academia del 21 de Octubre de 1872." *Rev. Progr. Cienc. Exactas Fís. Nat.*, **19**, 328–337, Madrid.

1872 "Un rapport sur les travaux géodésiques poursuivis par l'Institut géographique de l'Espagne pendant l'année 1870." *Bericht Verhandlungen Dritten allgemeinen Conferenz Europäische Gradmessung*, *Sept. 21–30*, *1871*, *Vienna*, 65–66, G. Reimer, Berlin.

1873a "Rapport sur les travaux géodésiques exécutés par l'Institut géographique d'Espagne depuis septembre 1871." *General-Bericht Europäische Gradmessung*, *Jahr 1872*, 57–58, 1 chart, G. Reimer, Berlin.
1873b "Forme et support du mètre. Rapport de la troisième commission." [with discussion]. *Annales du Conservatoire des Arts et Métiers.* **10**:87, 61–74, Paris.
1875a "Rapport sur les travaux géodésiques pursuivis par l'Institut géographique d'Espagne." *Compt. Rend. Quatrième Conférence Général Europäische Gradmessung*, *Sept. 23–28*, *1874*, *Dresden*, 83–86, G. Reimer, Berlin.
1875b "Rapport sur l'état des travaux géodésiques poursuivis par l'Institut géographique et statistique d'Espagne." *Compt. Rend. Comm. Perm. Europäische Gradmessung*, *Sept. 20–29*, *1875*, *Paris*, 219–222, G. Reimer, Berlin.
1875c "Prólogo." *Memorias del Instituto Geográfico y Estadístico*, **1** (xi+969 p., 1 fol. map), vii–xi, Aribau, Madrid.
1875d "Comparaciones de la regla de hierro laminado y de varias miras de precisión, con diversos tipos." *Memorias del Instituto Geográfico y Estadístico*, **1**, 899–923, Aribau, Madrid.
1875e "Publicación del Mapa de España en escala de 1/50,000." *Memorias del Instituto Geográfico y Estadístico*, **1**, 943–951, Aribau, Madrid.
1875f "Carte de la triangulation de l'Espagne. Premièr carte géodésique d'Espagne." *Compt. Rend. 3me session Association française pour l'avancement des sciences*, *Lille*, *1874*, 1006–1008, Imprimerie Danel, Lille.
1877a "Rapport sur les travaux géodésiques en Espagne en 1876." *Compt. Rend. Comm. Perm. Europäische Gradmessung. Oct. 5–10*, *1876*, *Bruxelles*, 125–128, 135, 1 pl., G. Reimer, Berlin.
1877b *Reseña de la novena reunión del Congreso Internacional de Estadística*, 69 p. Impr. Víctor Sáinz, Madrid.
1878a "Rapport sur l'état des travaux géodésiques poursuivis par l'Institut géographique et statistique d'Espagne pendant l'année 1877." *Compt. Rend. Cinquième Conference Général Europäische Gradmessung*, *Sept. 27–Oct. 2*, *1877*, *Stuttgart*, 309–312, G. Reimer, Berlin.
1878b. "Rapport sur les travaux géodésiques et astronomiques accomplis pendant l'année 1878 (Espagne)." *Compt. Rend. Comm. Perm. Europäische Gradmessung*, *Sept. 4–8*, *1878*, *Hamburg*, 112–115, G. Reimer, Berlin.
1878c "Prólogo." *Memorias del Instituto Geográfico y Estadístico*, **2** (x+1068 p., 7 pl.), v–x, Aribau, Madrid.
1879 "Correspondence" *Compt. Rend. Acad. Scie.*, **89**, 851, Paris.
1880a "Spanien-Espagne. Institut géographique et statistique. Rapport sur le travaux géodésiques et astronomiques accomplis pendant l'année 1879." *Compt. Rend. Comm. Perm. Europäische Gradmessung*, *Sept. 16–20*, *1879*, *Geneva*, 115–117, G. Reimer, Berlin.
1880b (& Merino, M.) "Enlace geodésico y astronómico de Europa y Africa. Notas presentadas a la Real academia de ciencias." 55 p., 1 map., Aguado, Madrid. Also: *Rev. Progr. Cienc. Exactas Fís. Nat.*, Madrid, **21**(3), 128–183.
1881a "Rapport sur l'état des travaux pour la détermination du niveau moyen des mers." *Compt. Rend. Sixième Conférence Général Europäische Gradmessung*, *Sept. 13–16*, *1880*, *Munich*, App. 8, 2 p., G. Reimer, Berlin.
1881b "Spanien-Espagne. Institut géographique et statistique" in Rapport Général de les Progrés des Travaux pour la Measure des Degrés en Europe dans l'année 1880, 41–44, *Compt. Rend. Sixième Conférence Général Europäische Gradmessung*, *Sept. 13–16*, *1880*, *Munich*, G. Reimer, Berlin.
1881c (&Perrier, F.) "Jonction géodésique et astronomique de l'Algérie avec l'Espagne" in Rapport Général de les Progrés des Travaux pour la Mesure des Degrés en Europe dans l'année 1880, 44–47, *Compt. Rend. Sixième Conférence Général Europäische Gradmessung*, *Sept. 13–16*, *1880*, *Munich*, G. Reimer, Berlin.
1881d "Prólogo." *Memorias del Instituto Geográfico y Estadístico*, **3** (xii+956 p., 12 pl., 2 fold. maps), v–ix, R. Labajos, Madrid.
1881e "Descripción y uso del aparato de medir bases." *Memorias del Instituto Geográfico y Estadístico*, **3**, 229–246, R. Labajos Madrid.
1881f. "Dilatación linal de la regla del aparato, y su longitud a una temperatura determinada." *Memorias del Instituto Geográfico y Estadístico*, **3,** 247–258, R. Labajos, Madrid.
1881g "Medición de la base de Arcos de la Frontera." *Memorias del Instituto Geográfico y Estadístico*, **3**, 259–276, R. Labajos, Madrid.
1881h "Medición de la base de Lugo." *Memorias del Instituto Geográfico y Estadístico*, **3**, 337–351, R. Labajos, Madrid.
1881i "Medición de la base de Vich." *Memorias del Instituto Geográfico y Estadístico*, **3**, 419–435, R. Labajos, Madrid.
1881j "Contestación al discurso «Aplicación e importancia del péndulo en las investigaciones de la figura de la Tierra» leído por el Sr. D. Joaquín Barraquer y Rovira ante la Academia de Ciencias Exactas, Físicas y Naturales el día 10 de mayo de 1881." 79p., Aguado, Madrid.
1881k "Discurso del Excmo. Sr. D. Carlos Ibáñez e Ibáñez de Ibero en contestación al Presidente." *Boletín Real Soc. Geográfica*, Madrid, **10**(6), 437–466.
1882 *Zonas militares asignadas a los Cuerpos del Ejécito para su reemplazo y organización de sus Reservas y Depósitos.* xx+484 p.,1 map. Impr. Direc. General Instituto Geográfico y Estadístico.
1883a "Spanien. Espagne. Rapport de Monsieur le général Ibáñez sur les travaux géodésiques." *Compt. Rend. Comm. Perm. Europäische Gradmessung*, *Sept. 11–15*, *1882*, *The Hague*, 134–139, G. Reimer, Berlin.
1883b "Prólogo." *Memorias del Instituto Geográfico y Estadístico*, **4** (xi+707 p., 6 pl.), v–ix, Impr. Direc. Gral. Inst. Geogr. Est., Madrid.
1883c "Medición de la base de Olite." *Memorias del Instituto Geográfico y Estadístico*, **4**, 99–113, Impr. Direc. Gral. Inst. Geogr. Est., Madrid.
1883d "Determinación del coeficiente de dilatación lineal de la regla de hierro laminado perteneciente al aparato Ibáñez." *Memorias del Instituto Geográfico y Estadístico*, **4**, 666–696, Impr. Direc. Gral. Inst. Geogr. Est., Madrid.
1883e (& Hirsch, A.) "Rapport sur le comparateur géodésique" [with discussion]. Comité International des poids et mesures, *Procès-Verbaux des Séances de 1882*, 28–33. Gauthier-Villars, Paris.
1883f (& Hirsch, A.; Oppolzer, V.) "Rapport sur l'unification des longitudes par l'adoption d'un premier méridien unique et sur l'introduction d'une heure universelle." 29 p. Imprimerie Royale, Rome. Also: *Compt. Rend. Septième Conférence Europäische Gradmessung*, *Oct. 15–24*, *1883*, *Rome*, 138–154. G. Reimer, Berlin, 1884.
1884a "Prólogo." *Memorias del Instituto Geográfico y Estadístico*, **5** (xi + 759 p., 6 pl., 1 fold. map) v–xi, Impr. Direc. Gral. Inst. Geogr. Est., Madrid.
1884b "Medición de la base de Cartagena." *Memorias del Instituto Geográfico y Estadístico*, **5**, 5–23, Impr. Direc. Gral. Inst. Geogr. Est. Madrid.
1884c "Base de Madridejos." *Memorias del Instituto Geográfico y Estadístico*, **5**, 97–376, Impr. Direc. Gral. Inst. Geogr. Est., Madrid.
1884d "Spanien-Espagne. Rapport sur les travaux géodésiques de l'Institut géographique et statistique." *Compt. Rend. Septième Conférence Europäische Gradmessung. Oct. 15–24*, *1883*, *Rome*, 283–285, G. Reimer, Berlin.
1884e "Rapport sur l'état des travaux faits pour la determination du niveau moyen des meres de l'Europe continental." *Compt. Rend. Septième Conférence Europäische Gradmessung*, *Oct. 15–24*, *1883*, *Rome*, App. 5, 10 p., G. Reimer, Berlin.
1886a *Jonction Géodésique et Astronomique de l'Algérie avec l'Espagne*, *exécutée en commun en 1879*, *par ordre des Gouvernements d'Espagne et de France, sous la direction de M. le Général Ibáñez pour l'Espange et le M. Colonel Perrier pour la*

France, xix+281 p., 6 pl., 5 etchings, Imprimerie Nationale, Paris.
1886b "Prólogo." *Memorias del Instituto Geográfico y Estadístico*, **6**, (xiii+801 p., 6 pl., 1 fol. map) v-xiii, Impr. Direc. Gral. Inst. Geogr. Est., Madrid.
1886c "Enlace geodésico de las Islas Baleares con el continente." *Memorias del Instituto Geográfico y Estadístico*, **6**, 5–61, Impr. Direc. Gral. Inst. Geogr. Est., Madrid.
1887 "Espagne. Progrés des travaux." *Compt. Rend. Huitième Conférence Général Association Géodésique Internationale*, *Oct. 27–Nov. 1*, *1886*, *Berlin*, 124–127, G. Reimer, Berlin.
1888a "Prólogo." *Memorias del Instituto Geográfico y Estadístico*,**7** (xi+455 p., 14 pl., 1 fol. map), v–xi, Impr. Direc. Gral. Inst. Geogr. Est., Madrid.
1888b "Enlace geodésico y astronómico de la Argelia con España realizado en 1879, por orden de los gobiernos de España y de Francia." *Memorias del Instituto Geográfico y Estadístico*, **7**, 1–288, 11 pl., Impr. Direc. Gral. Inst. Geogr. Est., Madrid.
1888c "Espagne. Rapport sur les travaux géodésiques de premier ordre de l'Institut géographique et statistique." *Compt. Rend. Comm. Perm. Association Géodésique Internationale*, *Oct. 21–29*, *1887*, *Nice*, App. 13, 3 p., G. Reimer, Berlin.
1888d (& Cebrián, P.) "Espagne" in Ferrero, A. "Rapport sur les Triangulations." 27–33. *Compt. Rend. Comm. Perm. Association Géodésique Internationale*, *Oct. 21–29*, *1887*, *Nice*, (*Supplement*), G. Reimer, Berlin.
1888e "Prólogo" in *Reseña Geográfica y Estadística de España*, xix+1088 p., p. v–xix. Impr. Direc. General del Instituto Geográfico y Estadístico, Madrid.
1888f (& Hirsch) *Comité international des poids et mesures. Premier* [→ 11e] *rapport aux gouvernements signataires de la convention du mètre sur l'exercise de 1876–1877* [→*1887*]. 11 fasc. in fol. Gauthier-Villars, Paris.
1889 "Espagne. Rapport succint sur les travaux géodésiques du premier ordre du l'Institut Géographique et Statistique." *Compt. Rend. Comm. Perm. Association Géodésique Internationale*, *Sep. 17–23*, *1888*, *Salzburg*, App. 1, 3–5, G. Reimer, Berlin.
1890a "Rapport sur l'état des travaux faits pour la determination du niveau des meres de l'Europe continental." *Compt. Rend. Neuvième Conférence Général Association Géodésique Internationale*, *Oct. 3–12*, *1889*, *Paris*, App. A.2, 11 p., G. Reimer, Berlin.
1890b "Rapport succint sur les travaux géodésiques du premier ordre du l'Institut Géographique et Statistique." *Compt. Rend. Neuvième Conférence Général Association Géodésique Internationale*, *Oct. 3–12*, *1889*, *Paris*, App. B.16, 3 p., G. Reimer, Berlin.
1890c (& Cebrián, P.) "Espagne" in Ferrero, A., "Rapport sur les Triangulations." *Compt. Rend. Neuvième Conférence Général Association Géodésique Internationale*, *Oct. 3–12*, *1889*, *Paris*, App. A.4, 12 p., G. Reimer, Berlin. The same text with updated tables also appeared in Ferrero's contribution on triangulations presented at the meetings in Brussels (1892) and Stuttgart (1898), published separately by Barbèra, Florence (1899).
1890d "Compte rendu des travaux accomplis per le Comité et le Bureau international." *Compt. Rend. Première Conférence Général des Poids et Mesures*, *Sept. 24–28*, *1889*, *Paris*, 19–29. Gauthier-Villars, Paris.

References

Alonso Baquer M (1972) *Aportación Militar a la Cartografía Española en la Historia Contemporánea.* xi+365 p., 16 pl. Patronato "Alonso de Herrera", Instituto de Geografía Aplicada, Instituto Geográfico y Catastral, Madrid.
Álvarez Sereix R, and Bellón de Arcos J (1889) *Aparato de Ibáñez para medir bases geodésicas*, 155 p., 7 fold. pl., Direc. Gral. Inst. Geogr. y Estadístico, Madrid.
Anon. (1875) "Procès-Verbaux." *Compt. Rend. Quatrième Conférence Général Europäische Gradmessung*, *Sept. 23–28*, *1874 Dresden*, 83–86, G. Reimer, Berlin.
Anon. (1890) "Prix Décernés. Année 1890. Prix Poncelet." *Compt. Rend. Acad. Scie.*, **111**, 1025, Paris.
Appell P (1925) "Discours prononcé au centenaire de la naissance du Général Ibáñez de Ibero, Marquis de Mulhacén, célébré à Paris, à la Sorbone, le 29 Mai 1925. "*Bull. Géodésique* **6**, 169–172. Also published in *Commémoration* (1925).
Arévalo A (1991) "La creación del Instituto Geográfico y Estadístico" in *Conmemoración del Centerario del General Ibáñez e Ibáñez de Ibero*, 52–77, Historia de la Ciencia, Real Acad. Cien. Exactas Fís. Nat., Madrid.
Barraquer y Rovira JM (1881) (& Perrier, F.) "Jonction géodésique de l'Algérie avec l'Espagne" in Rapport Général de les Progrés des Travaux pour la Mesure des Degrés en Europe dans l'année 1880, 47–53, *Compt. Rend. Sixième Conférence Général Europäische Gradmessung*, *Sept. 13–16*, *1880*, *Munich*, G. Reimer, Berlin.
Bertrand J (1891) "Notice sur le général Ibáñez, Correspondant de l'Académie." *Compt. Rend. Acad. Scie.*, **112**, 266–269, Paris.
Bigourdan G (1901) *Le Système Métrique de Poids et Mesures.* vi+458 p., Gauthier-Villars, Paris.
Biot JB and Arago DFJ (1821) *Recueil d'observations géodésiques, astronomiques et physiques, exécutées par ordre du Bureau des longitudes de France, en Espagne, en France, en Anglaterre et en Écosse, pour déterminer la variation de la pesanteur et des degrés terrestres sur le prolongment du Méridien de Paris; faisant suit au triosième volume de la Base du Système métrique.* xxx+588 p., 2 fold. pl., Ve. Courcier, Paris.
Biot JB (1857) "Communication de M. Biot à l'ocassion de la précédente lecture." *Compt. Rend. Acad. Scie.*, **45,** 513–514, Paris
Blondel AL (1872) "Lettre adressée a M. le colonel Levret sur le méme suject. " *Compt. Rend. Acad. Scie.*, **75**, 1749, Paris.
Bosscha J (1876) "La Commission Internationale du Mètre et la Conférence Diplomatique du Mètre.", *Verslagen en Mededeelingen der Koninklijke Akad. van Wetenschappen* **10**, 273–307, Amsterdam.
Brunner J (1857a) "Apppareil construit pour les opérations au moyen desquelles on prolongera dans toute l'étendue de l'Espagne le réseau trigonométrique qui couvre la France." *Compt. Rend Acad. Scie.*, **44,** 150–152, Paris.
Brunner J (1857b) "Aparato para la medición de bases geodésicas." *Rev. Prog. Cienc. Exactas Fís. Nat.* **7**, 158–161, Madrid.
Buschmann E (ed.) (1994) Aus Leben und Werk von Johann Jacob Baeyer. *Nachichten aus dem Karten-und Vermessungswesen* **112.** 186 p. Institut für Angewandte Geodäsie, Frankfurt am Main.
Chaix E (1891) "Note sur les travaux de général Ibáñez." *Archives des Sciences Physiques et Naturelles*, **26**, 520–524. Geneva.
Clark AR (1873) "Results of the comparisons of standard of length of England, Austria, Spain, United States, Cape of Good Hope, and of a second Russian Standard, made at the Ordnance Survey Office, Southampton. With a preface and notes on the Greek an Egyptian Measures of Length by Sir Henry James." *Philosophical Transactions of the Royal Society of London*, **163**(2), 445–469.
Clark AR (1880) *Geodesy*, xi+356 p., Clarendon Press, Oxford.
Commémoration du centenaire de la naissance du Général Ibáñez de Ibero, *Marquis de Mulhacén. Discours prononcés le 29 mai 1925*, *à la Sorbone.* (1925) 24 p., 1 lam., P. Dupont, Paris.
Comstock CB (1876) "Notes on European Surveys." *Annual Report of the Chief of Engineers*, US Army, Part 3, App. HH, 126–217, Washington.
Davidson G (1890) "Report of George Davidson, assistant U.S. Coast and Geodetic Survey, Appointed by the President of the United States as the Delegate to the Ninth Conference of the International Geodetic Association held at Paris, October, 1889" in *Report of the Superintendent of the U.S. Coast and Geodetic Survey showing the progress of the work during the fiscal year ending with June*, *1889*, App. No. 18, 493–503, Govt. Print. Off., Washington.

Davidson G (1895). "Report on Committee B, on base lines" in *Report of the Superintendent of the U.S. Coast and Geodetic Survey showing the progress of the work during the fiscal year ending June 30, 1893*, Part II, 254–271, Govt. Print. Off., Washington.

Doutrelaine LTS (1872) "Sur les indications données, des 1859, par M. Laussedat, concernant le project de la prolongation de la méridienne de France en Espagne et en Algérie." *Compt. Rend. Acad. Scie.*, **75**, 1813–1814, Paris.

Faye RH (1863) "Nouvel appareil pour mesurer les bases géodésiques." *Compt. Rend. Acad. Scie.*, **56**, 372–380, Paris.

Gautier R (1893) "Exposé historique des travaux de la Commission Géodésique Suisse de 1862 a 1892. Mesure des bases." *Bull. Société Scie. Naturelles*, **21**, 48–53, Neuchatel.

Gavira J (1950) "Homenaje a la memoria del general de Ingenieros D. Carlos Ibáñez de Ibero, marqués de Mulhacén." *Estudios Geográficos*, **11**:38, 146–150, Consejo Superior de Investigaciones Científicas, Madrid.

Guillaume Ch E (1925) "Discours prononcé au centenaire de la naissance du Général Ibáñez de Ibero, Marquis de Mulhacén, célébré à Paris, à la Sorbone, le 29 Mai 1925." *Bull. Géodésique*, **6**, 176–181. Also published in *Commémoration* (1925).

Guillaume Ch E (1902) *La Convention du mètre et le Bureau International des poids et mesures*, vii+236 p., Gauthier-Villars, Paris.

Hassler FH (1825) "Description of the aparatus for measuring base lines" in Papers on various subjects connected with the Survey of the Coast of United States. Communicated 3d March, 1820, *Trans. Amer. Philo. Soc.*, **2,** New Series, 273–286, Philadelphia.

Helmert FR (1913) "Die Internationale Erdmessung in den ersten fünfzig Jahren ihres Bestehens." *Internationale Monatsschrift f. Wissenschaft Kunst u. Technik*, **4**, 1–14, Berlin.

Hirsch A (1892) "Le général Ibáñez." *Compt. Rend. Comm. Perm. Ass. Géodés. Inter., Oct. 8–17, 1891, Florence*, 101–109. Attinger, Neuchatel. Also: Comité International des poids et mesures, *Procés-Verbaux des Séances de 1891*, 1–14, Gauthier-Villars, Paris.

Hirsch A and Dumur J (1888) "La mesuration des bases" in *Le réseau de triangulation suisse publié par la Commission géodésique suisse*, **3**, 104 p., 6 pl., Association Géodésique Internationale, Corbaz, Lausanne.

Ibáñez de Ibero C (1918) *El General Ibáñez de Ibero, Marqués de Mulhacén. Apuntes para servir a su biografía.* 30 p. Impr. P. Ortega, Barcelona.

Ibáñez de Ibero C (1945) "El Geneal Marqués de Mulhacén (Fundador de la geodesia moderna)." *Estudios Geográficos*, **6**:18, 123–153. Consejo Superior de Investigaciones Científicas, Madrid.

Ibáñez de Ibero C (1956) "La obra científica del General Marqués de Mulhacén y la unión geodésica y astronómica de España con Africa." *Archivo del Instituto de Estudios Africanos*, **9**:37, 57–75. Consejo Superior de Investigaciones Científicas, Madrid.

Ibáñez de Ibero C (1957) *Biografía del General Ibáñez de Ibero*, 24 p., Instituto Geográfico y Catastral, Madrid.

Ibáñez de Ibero C (1963) "Nota biográfica del General de División procedente del Cuerpo de Ingenieros Militares don Carlos Ibáñez de Ibero, Marqués de Mulhacén" in *Episodios de la Guerra de la Independencia*, vii+341 p., Apéndice, 247–304. Editora Nacional, Madrid.

Jordan W (1877) "International Meterconvention." Z. *f. Verm.wesen*, **6**, 278–290.

Jordan W (1890) *Handbuch der Vermessungskunde*, 3rd v., vii+549 p., Metzlerschen Buchhandlung, Stuttgart.

Jordan W (1896) *Handbuch der Vermessungskunde*, 3rd v., xx+593 p., Metzlerschen Verlag, Stuttgart.

Jordan W and Eggert O (1939) *Handbuch der Vermessungskunde*, 3rd v., 1st half, viii+590 p., Metzlerschen Verlagsbuchhandlung, Stuttgart.

Jordan W and Eggert O (1948) *Handbuch der Vermessungskunde*, 3rd v., 1st half, viii+590 p., Metzlerschen Verlagsbuchhandlung, Stuttgart.

Jordan W and Eggert O and Kneissl M (1958) *Handbuch der Vermessungskunde*, 4th v., 1st half, x+647 p., Metzlerschen Verlagsbuchhandlung, Stuttgart.

Koppe C (1881) *Der Basisapparat des General Ibáñez und die Aarberger Bassismessung.* 11 p., Eigendorf, Nordhausen. Reviewed by Schleback in *Z. f. Verm.wesen*, 1882, **11**, 95–98. Translated by Specht, G. "Measurement of the Aarberg base line in Switzerland and the apparatus of General Ibáñez." *Eng. News & Ame. Contr. Jour.*, 1884, **11**, 133–137.

Lallemand Ch (1925) "Discours prononcé au centenaire de la naissance du Général Ibáñez de Ibero, Marquis de Mulhacén, célébré à Paris, à la Sorbone, le 29 Mai 1925." *Bull. Géodésique*, **6**, 172–176. Also published in *Commémoration* (1925).

Lambert WD (1950) "The International Geodetic Association (Die Internationale Erdmessung) and its predecessors." *Bull. Géodésique*, **17**, 299–324.

Laussedat A (1859a) "Note sur les travaux géodésiques de la carte d'Espagne." *Compt. Rend. Acad. Scie.*, **48**, 473–475, Paris.

Laussedat A (1859b) "Noticia sobre los trabajos geodésicos de la carta de España." *Rev. Prog. Cienc. Exactas Fís. Nat.*, **9**, 193–197, Madrid.

Laussedat A (1864) "Sur les opérations en cours d'exécution pour la carte d'Espagne, d'après les reinsegnements donnés a l'Académie de Madrid par M. le colonel Ibáñez." *Compt. Rend. Acad. Scie.*, **58,** 70–72, Paris.

Laussedat A (1866) "Sur les travaux géodésiques exécutes en Espagne, à propos de la publication d'une traduction de l'ouvre intitulé: Base central de la triangulation géodésique de l'Espagne." *Compt. Rend. Acad. Scie.*, **62**, 1007–1010, Paris.

Laussedat A (1872a) "Note relative au prolongement de la méridienne de France et d'Espagne en Algérie." *Compt. Rend. Acad. Scie.*, **75**, 1492–1495, Paris.

Laussedat A (1872b) "Dernières observations au subject du prolongement de la méridienne de France et d'Espagne en Algérie." *Compt. Rend. Acad. Scie.*, **75**, 1746–1749, Paris.

Levallois JJ (1980) "The history of the International Association of Geodesy." *Bull. Géodésique*, **54**(3), 248–313.

Levallois JJ (1988) *Mesurer la Terrre; 300 ans de géodésie française. De la toise du Châtelet au satellite.* 389 p., Presses de l'École Nationale des Ponts et Chaussées, Paris.

Levret H (1865) "Project de liaison géodésique de la France continental avec l'Algérie" in *Memorial du Dépôt Général de la Guerre*, **9** (Supplement), 85–92, Imprimerie Nationale, Paris.

Levret H (1872) "Observations relatives à une Communication précédente de M. Laussedat, sur le prolongement de la méridienne de France en Espagne et en Algérie." *Compt. Rend. Acad. Scie.*, **75**, 1747–1749, Paris.

Llave y Sierra J de la (1953) *Biografía de Carlos Ibáñez e Ibáñez de Ibero Marqués de Mulhacén*, 16 p., Ayuntamiento de Barcelona, Barcelona.

Maurer J (1884) "Einige Bemerkungen über die von General Ibáñez angewendete Methode der Temperaturbestimmung bei der Messtange seines Basisapparates." *Z. f. Instrumentenkunde*, **4**, 269–274.

Merino M (1881) (& Perrier, F.) "Jonction astronomique de l'Algérie avec l'Espagne" in Rapport Général de les Progrés des Travaux pour la Mesure des Degrés en Europe dans l'année 1880, 53–57, *Compt. Rend. Sixième Conférence Général Europäische Gradmessung, Sept. 13–16, 1880, Munich,* G. Reimer, Berlin.

Mier y Miura E (1912) "Conmemoración Honrosa." *Revista Memorial de Ingenieros del Ejército*, **67**(7), 205–211, Madrid.

Mifsut y Macon A (1905a) *Geodesia y Cartografía*, xxi+821 p., Talleres Depósito de la Guerra, Madrid.

Mifsut y Macon A (1905b) *Geodesia y Cartografía: Atlas*, 20 pl. (Geodesy); 10 pl. (Cartography). Talleres Depósito de la Guerra, Madrid.

Milne–Edwards A (1891) "Le général Ibáñez." *Compt. Rend. Société Géographie*, **5**, 100–103, Paris.

Núñez de las Cuevas R (1991a) "El mapa topográfico nacional" in *Conmemoración del Centenario del General Ibáñez e Ibáñez de*

Ibero, 80–106, Historia de la Ciencia, Real Acad. Cienc. Exactas Fís. Nat., Madrid.

Núñez de las Cuevas R (1991b) "Historia de la cartografía española" in *La Cartografia de la Península Ibérica i la seva extensió al Continent Americà*, 279 p, 155–223. Institut Cartogràfic de Catalunya, Barcelona.

Page CH and Vigoureux P, eds. (1975) "The International Bureau of Weights and Measures 1875–1975. Translation of the BIPM centennial volume, published on the occasion of the 100th anniversary of the Treaty of the Metre, May 20, 1975." vii+248 p., illus, *National Bureau of Standards no. 420*, U.S. Govt. Print. Off., Washington.

Paladini Cuadrado A (1969) "La red geodésica española." *Boletín de Información*, **5,** 45–72, Servicio Geográfico del Ejército, Madrid.

Paladini Cuadrado A (1991) "El General Ibáñez: su personalidad militar y humana" in *Conmemoración del Centenario del General Ibáñez e Ibáñez de Ibero*, 33–49, Historia de la Ciencia, Real Acad. Cienc. Exactas Fís. Nat., Madrid.

Perrier F (1872a) "Prolongation de la méridienne de France jusqu'au Sahara, par la jonction trigonométrique de l'Algérie avec l'Espagne." *Compt. Rend. Acad. Scie.*, **75**, 1237–1244, Paris.

Perrier F (1872b) "Réponse à la Note de M. A. Laussedat sur le prolongement de la méridienne d' Espagne en Algérie." *Compt. Rend. Acad. Scie.*, **75** , 1696–1698, Paris.

Perrier F (1879a) "Extrait d'une Lettre à M. D'Abbadie, sur les opérations exécutées pour la Jonction de la triangulation de l'Algérie à celle de l'Espagne." *Compt. Rend. Acad. Scie.*, **89**, 605, Paris.

Perrier F (1879b) "Jonction géodésique de l'Algérie avec l'Espagne, opération internationale exécutée sous la direction de MM. le général Ibáñez et F. Perrier." *Compt. Rend. Acad. Scie.*, **89**, 885–889, Paris.

Perrier F (1879c) "Jonction astronomique de l'Algérie avec l'Espagne, opération internationale exécutée sous la direction de MM. le général Ibáñez et F. Perrier." *Compt. Rend. Acad. Scie.*, **89**, 941–944, Paris.

Perrier F (1887a) "Note de M. le général Perrier, accompagnant la présentation d'un Volume relatif à la Jonction géodésique et astronomique de l'Algérie avec Espagne." *Compt. Rend. Acad. Scie.*, **104**, 1817–1821, Paris.

Perrier F (1887b) "Jonction Géodésique et astronomique de l'Algérie avec l'Espagne." *Mémorial du Dépôt Général de la Guerre*, **13,** xix+355 p., 6 pl., 5 etchings, 2 maps, Imprimerie Nationale, Paris.

Rey Pastor J (1925) "El General Ibáñez de Ibero cumbre de la geodesia europea, 1825–1891." *La Nación*, Suplemento Dominical, Oct. 25, p. 7. Buenos Aires.

Tardi P (1963) "Hundert Jahre Internationale Erdmessung." *Z. f. Verm.wessen*, **88**(1), 2–10. Also in: *Festschrift zur hundertjahrfeier der Internationalen Assoziation für Geodäsie AM 12.und.13.Oktober 1962*, 29–46. Verlag der Bayerischen Akademie der Wissenschaften, 1963.

Torge W (1994) "Die Geodäsie im Übergang zur international organisierten Wissenschaft: Zum 200. Geburtstag von Johann Jacob Baeyer." *Z. f. Verm.wesen*, **119**(10), 513–522.

Torroja Menéndez JM (1991) "La personalidad científica del General Ibáñez" in *Conmemoración del Centenario del General Ibáñez e Ibáñez de Ibero*, 11–32, Historia de la Ciencia, Real Acad. Cienc. Exactas Fís. Nat., Madrid.

U.S. Coast & Geodetic Survey (1890) *Report of the Superintendent showing the progress of the work during the fiscal year ending with June*, *1889*. Govt. Print. Off., Washington.

Westphal A (1881) "Der Basisapparat des General Ibáñez un sein Verhältniss zum älteren spanischen Apparat." *Z. f. Instrumentenkunde*, **1**, 173–183.

Wheeler GM (1885) *Facts concerning the origin*, *organization*, *administration*, *functions*, *history*, *and progress of the principal government land and marine surveys of the world*, 569 p., 4 maps, 11 plates, Govt. Print, Off., Washington.

Whitten C (1988) "History of the International Association of Geodesy." *Bull*, *Géodésique*, **64**(3), 197–206.

Wolf R (1891) "Histoire de l'appareil Ibáñez-Brunnerx." *Compt. Rend. Acad. Scie.*, **112**, 370–371, Paris.