HISTORIC NOTES ON THE DIFFERENCE OF LONGITUDE BETWEEN PARIS AND GREENWICH

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Ever since the meridian of Greenwich was chosen as the international meridian, the French Hydrographic Service has had to modify the longitudes of its charts which up to then had referred to the meridian of Paris ; for this a value for the difference of the two meridians had to be adopted. This value should be fixed, however, to within at least one second of arc, for on the charts of the coasts of France on a scale of 1/45000, one second is represented by about a millimetre, and this length is such that subsequent variations of value would bring about difficulties in the accord of two neighbouring charts, if the modifications were not made simultaneously on all the charts.

But this simultaneousness was practically impossible, taking into consideration the number of charts in use, the scale of which required uniformity of the value adopted. The French Hydrographic Service has had, in fact, to spread these operations — which however are not yet entirely finished—over a certain number of years, and it was decided that except in cases determined by the funds available, the new meridian would only be placed on charts about to be or actually published.

It is interesting to recall the different values successively adopted in order to arrive at that which was employed at that period, and which appears today to have been maintained, if not as representing the most precise decision possible, at least as giving in practice a much greater accuracy for the actual needs of navigation. This value is 2°20'14".

The observatories of Paris and Greenwich, having been built more or less simultaneously in the middle of the 17th century (1), the values of the difference of longitude between London and Paris previously adopted by cartographers can only be given as historical curiosities.

The most ancient which can be mentioned is found in *l'Epitome Géographicum* of PHILLIPO FERRARI ALEXANDRIN, published at Ticini in 1605. In this work will be found, entirely written in Latin (as are all the scientific works of this period when scholars had the advantage of possessing an international language), a very extensive table of geographical positions of places of the whole world, and the difference of longitudes of *Lutetia Parisiorum* and *Londinium* is fixed at 2°39', or 10m 36s.

In 1672 BAPTISTA RICCIOLO, of the Society of Jesus, published at Venice his *Geografiae et Hydrografiae reformatae* in which are found, with a very detailed account of the methods of determination of longitudes by the eclipses of the Moon, the Sun, and Jupiter's Satellites, the only methods then in use and which had been known and used for a long time ; and a list of the sixty eclipses of the Moon observed since Ptolemy with the names of the observers and the places used for determining the differences of longitude. It shows that the results of the observations of the eclipse of March 3, 1635 allow the inference to be drawn that the difference of longitude between Paris and London is 2°00' or 8 m 00s.

In 1709 a book in Portuguese appeared at Lisbon entitled *Arte de navegar*, the author being MANUEL PIMENTAL ; this being a new edition of that published in 1699 under the title of *Arte practica de navegar*, in which will be found a table of latitudes of certain points and of their longitudes referring to the meridian of the Island of Tici. It gives London but not Paris ; but knowing that Dunkirk is almost on the meridian of Paris (2) the author concluded from this that the difference of longitude between London and Paris was 2°31' or 10m04s.

In the *Connaissance des Temps* of 1791, MECHAIN wrote "The calculations which we made in the year 1786, from several eclipses of the Sun and stars by the Moon, observed in Paris and Greenwich, had given us the difference of the meridian at 9m16s in time ; but after some new observations of the same kind and in greater numbers, it appears that this difference is very nearly 9m20s, as had been concluded by M. DE SEJOUR after the eclipses of the Sun of 1764 and 1769. Several time-pieces and chronometers transported at various times from Greenwich

(1) Paris in 1667 ; Greenwich in 1675.
(2) Dunkirk is 2'23" East of Paris.

to Paris or vice versa, by M. le Comte DE BRUHL, M. ARNOLD and ourselves, have thus given 9m20s, a small fraction more or less..."

In 1787 connection was made between points on the English and French coasts by means of a geodetic operation. Colonel BERTHAUD writes on this subject (La Carte de France, Vol. 1, p. 117): "The success of the operations of CASSINI DE THURY for the triangulation of France had led him to propose to England to extend the chain of triangles to her territory. This offer was accepted, and the English General ROY was ordered to make a series of triangles from London to Dover and thence to the French coast.

"In 1784 a base was measured with glass tubes on the plain of Hounslow Heath to the SW of London, but the operations had to be suspended for three years in order to await the completion of the angle measuring instrument being made by RAMSDEN.

"At the request of the English Government three French associates were appointed. CASSINI being dead, they consisted of his son, the Comte de CASSINI and two of his colleagues of the Academy, MECHAIN and LEGENDRE.

"Two points on the English coast, Dover and Fairlight Down, were joined by four triangles with three points on the French coast: Calais, Cap Blanc-nez and Mont Lambert. Six other triangles joined these points to the meridian of Paris at Dunkirk. Light signals and reflecting lamps were used."

The operation, commenced September the 20th, was finished October the 17th; the weather was usually very bad; happily however the nights during which the most important observations were made, that is to say, those from Dover and from Fairlight Down to Blanc-nez and Mont Lambert, were favourable.

In his note in the *Connaissance des Temps* of 1791, MECHAIN hoped that "until General ROY had put the last touch to his calculations, he would adopt, from their first results, 9m20s or 2°20' in round numbers for the difference of longitude between Paris and Greenwich."

In his memoir on the "calculations of the triangles which allow the difference of longitude to be determined between the Observatory of Paris and that of Greenwich" published in the *Mémoires de l'Académie des Sciences* (1787-1788), LEGENDRE shows that General ROY adopted a value for the flattening of 1/145, which gave him 2°19'42"; but a value of 1/178 gave 2°19'54"; and 1/320 gave 2°20'17"6, "a value which probably does not depart from the truth by more than one second". He proposes to adopt, as the least flattening appears the most probable, the value 2°20'15" or 9m21s.

In the *Connaissance des Temps* these values appear up to 1829, when, following a general revision of geographical positions of the Table made, by order of the Bureau of Longitudes, by some of its members, 2°20'24" or 9m22s was adopted for Greenwich.

This value appeared in the *Connaissance des Temps* up to 1859, when 2°20'9" or 9m21s is found, the result of a determination made by electric telegraph in 1854.

This determination was remade in duplicate in 1888, on the one hand by English astronomers and on the other by the Geographical Service of the Army. The two results, English and French, gave inexplicable systematic differences and a new determination was made in 1892, under the same conditions as the first; but again there were systematic differences between the results.

The difference of longitude admitted at the end of this work was 2°20'9" or 9m21s.

In accordance with the desire expressed by the International Geodetic Association that these operations be re-undertaken in order to dispel the uncertainty of the previous results, the Bureau of Longitudes took the initiative of making a new determination.

The preliminary negotiations took place in 1901 between Sir W.K.M. CHRISTIE, Astronomer Royal of England, and M. LOEWY, Director of the Observatory of Paris. It was decided to make two completely independent series of observations, one by two English astronomers, the other by two French.

Two identical instruments were employed and horary stars near the zenith were chosen in order to eliminate the influence of the azimuth. The inclination was determined not only with the help of a level, but also by pointing the nadir. The collimation was determined by reversing the instruments on the line of sight, on artifical horizons and on circumpolar stars. The exchange of electric signals was made twice every evening; and the difference of the personal equations of the observers was directly determined by permutation of observers and instruments between the stations.

The French observers were M. BIGOURDAN, Director of the Bureau International de l'Heure, and M. LANCELIN; those of England being Sir F. DYSON, Astronomer Royal of England, and Mr. HOLLIS.

The operations, which took place in the spring and autum of 1902, gave the figures 9m20.99s or 2°20'14.85" for the French coast, and 9m20.93s or 2°20'13.95" for the English coast.

In 1920 a determination was made by transporting some chronometers by aeroplane from Paris to Greenwich. Twelve chronometers con-

structed by the firm P. DITISHEIM were used, these having been previously kept under observation for 43 days at the National Physical Laboratory of Teddington, following the Class A test programme.

The trials being finished, the chronometers were again observed at Teddington for ten days, in a horizontal position at a temperature of 18.7° Cent., and in an orientation which was preserved as much as possible in all the later operations. They were transported to Greenwich and submitted for a week to daily comparisons with a registering chronograph.

On the 18th of May 1920, the twelve chronometers were placed in a covered aeroplane on the point of starting from Croydon Aerodrome; they were wedged in their packing case, carefully lagged and covered with woollen rugs, the whole being shut in a case which was kept in a horizontal position during the entire voyage.

All the chronometers were provided with Guillaume balances; their secondary error was negligible and the mean proportional error was less then 0.015s per degree.

The bad weather lengthened this first voyage abnormally, but for the four succeeding trips, from the 21st to the 27th of May, the mean time taken was 2h45m. The double trip Paris-Greenwich was accomplished on one occasion in a single day. The transport between the aerodrome and the observatories was made by motor car. The observations were made in Paris by M. LANCELIN, and at Greenwich by Mr. BOWYER, the calculations being made by M. LANCELIN.

The general mean of the 61 operations was 9m20.947s+0.027s or : 2°20'14.21"+0.405".

The probable error is in the same order as those of the determinations by ordinary telegraphic signals.

With wireless signals the determination of the difference of longitude between the observatories of Paris and Greenwich will be a great deal easier and more precise. In this respect the horary signals sent out daily by the Eiffel Tower could be used; up to the present this combined work has not been carried out (1).

(1) This note has been written with the help of M. le Commandant VIVIELLE, librarian of the Service Hydrographique of the French Navy, and of M. F. LANCELIN Astronomer of the Paris Observatory.