THE USE OF OBSERVATIONS FOR
ARTIFICIAL EARTH SATELLITES
IN SOLVING SOME GEODETICAL
PROBLEMS

THESIS SUBMITTED IN PARTIAL
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P R E F A C E

This thesis was carried within the frame-work of the international cooperative programme "The Great Arc, Arctica-Antractica", which is concerned with the study of the shape of Earth .

The main purpose of this work is to determine 7 absolute space directions between some stations in Africa and Europe, using satellite photographic observations.

Simultaneous photographic observations of a satellite from two stations on the Earth's surface are used to determine the direction connecting these two stations. This is done by using a purely geometrical method known as the "Simultaneous Circle Method".

The thesis comprises four chapters and an appendix :

In chapter I, a historical introduction has been given for the geodetical work through the centuries, and the different methods used in determining the Earth's radius, the triangulation nets and the various directions on the Earth's surface.

In chapter II, we have discussed the different methods for observing active and passive satellites. We have also explained the use of AFU-75 camera for such observations, as well as, the reduction of the observed film. Results of observations of different stations have been interpolated in order to be exactly simultaneous.

In chapter III, we have discussed the geometrical method (The Simultaneous Circle Method) used in determining the directions between the chosen pairs of stations in Africa and Europe.

The least-square method is used to obtain the best direction connecting each pair of the chosen stations.

A critical discussion of the final results obtained is given in chapter IV. It also involves graphical representations giving an indecation of the accuracy of the directions obtained. It shows that these directions are determined with a high degree of accuracy except in two cases owing to the lack of data available.

In the appendix the algorithm and the flow-chart of the computer programme used for the calculations are given.

It is of interest to point out that the results concerning three of the seven directions obtained were in the works of the "Fifth United Nations Regional Cartographic Conference for Africa) held in Cairo on, 28 February to 7 March 1983, under the sponsorship of the United Nations Economic and Social Council.

The Determined Directions

CHAPTER I

INTRODUCTION

CHAPTER I

I N T R O D U C T I O N

1.1- Geodesy :

Geodesy is that branch of applied mathematics which determines by observations and measurements, the size and the shape of the Earth, the coordinates of points, the lengths and directions of lines on the Earth's surface, and the variations of terrestrial gravitational field. Geodesy is generally considered to have two main branches, physical geodesy, and geometrical geodesy (Veis, G., 1980), (Massevitch et al, 1978).

Physical geodesy is concerned with the gravitational field of the Earth. It is that branch of geodesy which deals with directions and magnitudes of the physical forces that link the Earth to objects on its surface or in its surrounding space. The study of gravity is useful in determining the shape, but not the size of the Earth (Kozai, Y. 1961).

Geometrical geodesy is concerned with the size and shape of the Earth, the intercontinental ties among land masses of the Earth, and the determination of positions, lengths of lines and azimuths. In general it deals with anything related to the geometry of the Earth (Massevitch, A.G. 1977).

Problems of geometrical geodesy used to be a source of interest and concern to mankind throughout the centuries.

The size and shape of the Earth raised several interesting research problems to scientists. Various opinions of the shape of the Earth have been given in the past e.g. the notion of an Earth disk encircled by Oceans (Homer's Illiad $\sim$ 800 B.C., Thales of Milet $\sim$ 600 B.C.) Pythagoras ($\sim$ 580 $\sim$ 504 B.C) and his school as well as Aristotale (384 - 322 B.C) among other philosophers declared the idea of a spherical Earth.

The real founder of scientific geodesy is Eratosthenes (276 $\sim$ 195 B.C.) of Alexandria, who was able, under the assumption of a spherical Earth to determine the value of the Earth's radius. His estimation, which was obtained about 20 Centuries ago differs by less than 2% of the most recent values. He initiated the method of arc measurement which is still applied in recent years. In this method the length ΔG (Fig. 1.1) of a meridian arc is determined, and the corresponding central angle   is obtained, using astronomical observations. The radius of the Earth is then given by

$$R = \frac{\Delta G}{\psi}$$

Eratosthenes found that, at the time of the summer solestic, the rays of the sun descended vertically into a well in Syene (a place near Aswan) while at Alexandria which is nearly on the same meridian the rays inclined to the direction of the vertical by 7°22'. The angle of inclination can be found by observing the length of the shadow of a vertical staff. He estimated the distance from Aswan to

Alexandria to be 500 stadia, (the ancient Egyptian stade equals about 6000 feet). Consequently he estimated the Earth's radius as 6267 km, which is quite reasonable as compared with the most recent estimation of 6371 km. Since then, several trials were made to estimate the Earth's radius on the same bases as Eratosthenes (Gilluly, J., Waters, A.C. 1959).

In 1645 the Italians Grimaldes and Ricciali, calculated the central angle γ (Fig. 1.2) using reciprocal zenith angles. This angle may be computed from the angles Z_1, Z_2 observed at two different positions P_1, P_2 according to

$$\gamma = Z_1 + Z_2 - \pi$$

This procedure however did not yield satisfactory results due to the insufficiently accurate determination of the curvature of light rays cause. by refraction.

1.2- Ellipsoidal Earth :

During the sixteenth and seventeenth Centuries, new observations and ideas from astronomy and physics gave new ideas about the figure of the Earth and its position in space, N. Copernicus achieved the transition from the geometric universe of Ptolemy to a heliocentric system. J. Kepler discovered the laws of planetary motion (1609 "Astronomiconova 1619" Harmonics mundi) and Galilio Galili developed modern mechanics. In 1672 the astronomer J. Richer found an increase in gravity from the equator to the poles. Issac Newton and Christian Huygens made

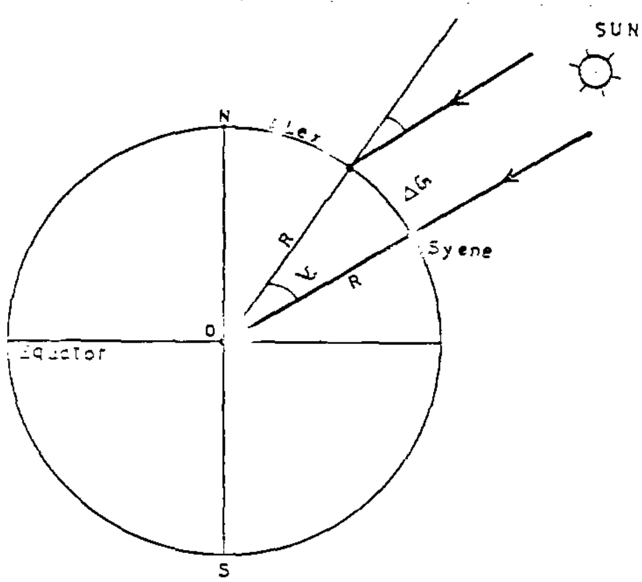

Fig. (1.1)

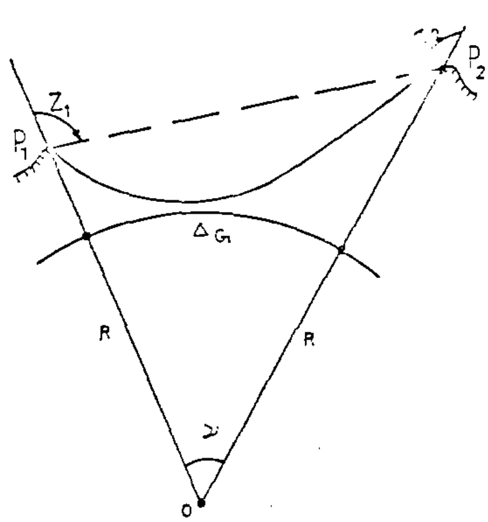

Fig. (1.2)

use of these accumulated facts and developed Earth models which are flattened at the poles (Heiskanen, W.A. 1962).

Newton (Philosophiae Natural Mathematics 1687) introduced the idea of a rotational ellipsoid as an equilibrium figure for a homogeneous fluid. The flattening of the Earth can be given by

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

where a, b are semimajor and semiminor axes of the Earth and f amounts to 1/230. Huygens (Discours de la Couse de la Pescmture 1690) shifted the source of the Earth's attractive forces to the centre of the Earth and developed a rotationally symmetric equilibrium surface which possesses a meridian curve of the fourth order with f = 1/578.

For a geometric verification of the ellipsoidal Earth model, one has employed arc measurements at various latitudes. Namely, the length of a One-degree arc (meridian arc for a difference of 1° in latitude) in the case of flattened poles increases poleward from the equator. The ellipsoidal parameters a, b or a, f can be computed from two arc measurements (Mueller, I.I. 1964).

J.D. Hire and J. Cassini obtained for the Earth an elongated model at the pole, this model extended the arc length of Picard north to Dunkirk and South to Colliaere (latitude difference of 8°20'). The computations for two arc segments yield a "negative" flattening of $f = -1/95$, which can be attributed to measurement errors of the astronomical latitudes. The dispute between the supporters of Newton and those of Casini about the figure of the Earth was setelled by two further arc measurements sponsored by the French Academy of Science.

In recent years, there have been several determinations of the dimensions of the Earth, or more strictly of the reference ellipsoid, which is a mathematical surface, representing approximatly the shape of the Earth. The most significant development in arc measuring is the classical work of Hough and others in U.S.A. The result of their work is known as the "AMS Ellipsoid" the significant part in this work lies in the length and geographical dispersion of the arcs used. Hough used four arcs, two of which are about 100° in length and they were the longest arcs ever used.

1.3- Physical Geodesy :

In studying the effect of the Earth's field on any body on the Earth's surface we must take into account two main factors : the direct attraction of the body by the Earth in accordance with Newton's general law of gravitation, and the effect of the Earth's rotation about its axis.

However, there is another annoying factor which complicates the problem. The Earth is not homogeneous, its crust