Navigation and Nautical Astronomy

Fifth Edition

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A Textbook on Navigation
and Nautical Astronomy

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CHAPTER X

CORRECTION OF SEXTANT ALTITUDES

142. Altitudes obtained by sextant are not available for use with the solution of the astronomical triangle until certain corrections have been applied to them. The errors of observations which necessitate these corrections may be grouped under the following classification.

1. The instrumental error, that is, the index error of the sextant, if one exists.

2. The atmospheric error called refraction; that is, the effect of the earth's atmosphere in causing a ray of light to deviate from a straight line.

3. The error called the dip of the horizon caused by the fact that the observer's eye must be above the surface of the earth, which causes a difference between the directions of the visible and celestial horizons.

The above three errors occur in the observations of all celestial bodies. The following apply only to bodies of the solar system.

4. The celestial bodies that belong to the solar system are near enough to the earth so that they are seen in a slightly different direction when viewed from the earth's surface than would be the case if they were viewed from the earth's center. This causes a difference between the altitudes measured from the sensible and celestial horizons. Sextant altitudes of such bodies must be corrected for this difference, called parallax.

5. The bodies of the solar system are near enough to the earth so that they appear of measurable angular size, and not as mere points of light as do the stars. In measuring their altitude it is necessary to bring their disc tangent to the horizon, so that the altitude of a point of the circumference and not the altitude of the center is measured. The sextant altitude must therefore be corrected by applying the angular semi-diameter of the body.

When the above corrections have been applied to a sextant altitude the result is the geocentric altitude of the body's center.

Index Corrections

143. The cause of the index error has been explained in connection with the description of the sextant, as well as the method of determining the sign of its application to a sextant altitude.

Refraction

144. A ray of light passing obliquely from one medium into another medium of different density will deviate from its rectilinear course; if the second medium be more dense than the first, the ray will be bent towards the perpendicular to the line of junction of the media; if less dense, it will be bent away from the perpendicular. See Fig. 1 in which ABC represents a ray of light passing from the medium X into the medium Y. PR is perpendicular to the line of junction of the two media. Y is the denser medium and the ray is bent toward PR. A ray of light from the direction PR does not cut the media obliquely and its direction is not changed.

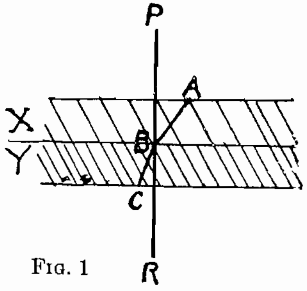

Fig. 1

The earth's atmosphere extends above the surface of the earth a distance of more than 50 miles. The density of the atmosphere is least at its upper limits and continually increases toward the earth. It may be supposed to be arranged in strata of different densities with the strata of greatest density next to the earth's surface.

In Fig. 2, O is the position of an observer on the earth's surface and the concentric curves indicate the strata of the atmosphere. Let HOR be the observer's horizon and Z his zenith. Let AO be the true direction of some celestial body. Then AOR is its altitude. BD is drawn parallel to AO. Since the body will be at such a great distance from the earth that all of its rays will be sensibly parallel in the vicinity of the observer, BD represents a ray of light from the celestial body A. It is some such ray as BD which will reach the observer at O, for as it passes through the different strata of the earth's atmosphere it will be continually bent downward and assume a curved form as shown by the curve EO. The final direction of this ray will determine the direction in which the observer sees the body. This direction will be the tangent at O to the curve EO. This tangent is shown by the line CO. To the observer at O the apparent altitude is the angle COR. The difference in these angles, that is, the angle COA, is the refraction.

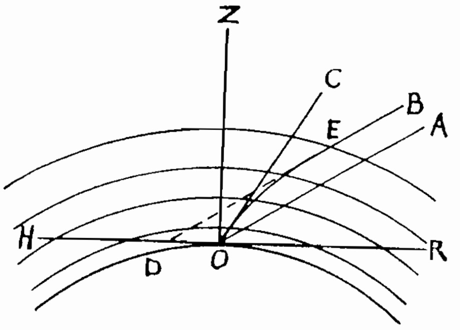

FIG. 2

The effect of refraction is always to make the observed altitude greater than the true altitude. The correction for refraction is therefore always subtracted from an observed altitude.

The light from a body in the observer's zenith will come to the observer in the line ZO. It will enter all the different strata of the atmosphere at right angles and will be unaffected by refraction. The light from a body in any other position will be affected by refraction. The effect of refraction is a maximum when the body is on the horizon. The angle of refraction indicated in Fig. 2 is greatly exaggerated for the purpose of illustration. Horizontal refraction amounts to between 34′ and 39′, varying somewhat with the state of the atmosphere.

Since refraction is caused by the differing densities of the strata of the earth's atmosphere it will vary for any given altitude of a celestial body as the density of the atmosphere changes. Since the density of the earth's atmosphere at a given time is determined by the barometric pressure and the temperature, refraction for a given altitude will vary with the reading of the barometer and thermometer.

The mean value of the refraction for an average state of the atmosphere (Barometer 30″; Fahrenheit's thermometer 50°) is recorded for each apparent altitude in Table 20A, Bowditch. Corrections to the mean refraction for various states of the barometer and thermometer are found in Tables 21 and 22, Bowditch. Two effects of refraction are set forth in the following two paragraphs quoted from Young's *Astronomy*.

> **Effect on the Time of Sunrise and Sunset.** The horizontal refraction, ranging as it does from 34′ to 39′, according to temperature, is always somewhat greater than the diameter of either the sun or the moon. At the moment, therefore, when the sun's lower limb appears to be just rising, the whole disc is really below the plane of the horizon; and the time of sunrise in our latitudes is thus accelerated from two to four minutes, according to the inclination of the sun's diurnal circle to the horizon, which inclination varies with the time of the year. Of course, sunset is delayed by the same amount, and thus the day is lengthened by refraction from four to eight minutes, at the expense of the night.

In dealing with the subject of aërial dead reckoning navigation, it is well to remember that the airplane units of the fleet are called upon to carry out sustained flight exercises, which entail the expenditure of approximately 75 per cent of the operating units' fuel. Such a safety allowance for navigational errors, established for peace-time radii of action, cannot be tolerated in time of war. The importance of intimate familiarity with standard methods of aërial position fixing, equal familiarity with standard aircraft navigational instruments and devices, and proficiency in their use, therefore, cannot be overemphasized.

314. The Drift Sight. Details of the standard Mark II, Navy Drift Sight, are shown in Fig. 15. This sight consists of a triangular-shaped base plate and scale into which plugs a post, fitted with a sighting tube. For the convenience of the observer the post is made adjustable in height, sliding on a key through the pointer, which trains in azimuth with the sighting tube. The post is locked at the desired height by means of screw *A*. The pointer is locked in azimuth by screw *B*. The sighting tube has no lenses but is fitted with two sets of beads, one set inside the bore, and one along the top axis.

In taking a drift sight, after plugging the post assembly into the base plate on the windward side of the plane, the observer concentrates his attention upon the stationary surface object to be flown over by the pilot. While the object is drawing outboard and aft, the pilot maintains a steady compass heading and speed. The observer follows the object with the sighting tube, during its apparent movement, and notes on the base-plate scale its relative bearing after thirty or forty seconds of flight. When air is gusty, and the plane rolls and yaws, discretion is required in selecting the average pointer reading as a true measure of the drift. Equipment for graphically determining the average pointer reading has been proposed and used in the past, but in service practice it has been found that it can be omitted without great inconvenience or sacrifice of accuracy.

As a variation of the above method, drift may be determined by mounting the drift sight on the leeward side of the plane and sighting on a stationary surface object ahead, and close to, the line of flight. By carefully noting any change in bearing, during the early stages of the run, the observer, by signal, can direct the pilot to a heading which, if maintained, will cause the plane to fly directly over the object; in short, the observer, by process of trial and error, finds a heading upon which the bearing of the surface reference point does not change. In this case, the drift is measured by the angle between the plane's heading and the observed bearing. A constant air speed is maintained throughout the operation.

When flying over the open sea with no stationary surface objects in view, a float light may be dropped to establish a point of reference for the drift indicator sights.

315. The Mark IV Drift Computer. (Figs. 16, 17, and 18). While the geometrical solution of the velocity triangle can be made satisfactorily by drafting methods, for airplane use some form of mechanical computer has been found desirable. The Mark IV drift computer answers the needs of the aërial navigator for this work. It was in general use in the naval service until superseded in 1934 by the Aircraft Plotting Board, Mark I.

As an explanation of the settings and manipulation of this instrument, to obtain the force and direction of the wind, and heading to steer to make a given track good, the following example is given of a problem solved by the **one-speed, two-heading method.** It is to be noted that the same problem may be solved by the **two-speed, one-heading method.** The former system, however, is preferred.

Assume that it is desired to make good a given track, for example, 0° and that an air speed of 140 knots will be maintained. A wind of unknown force and direction is acting. Head the airplane on a steady heading, near or on the required track, say 0°, and