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The Tables for Clearing the Lunar Distance

Subject: The Tables for Clearing the Lunar Distance
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This is a belated continuation of the April 28th and May 5th postings "Clearing a lunar" and "Converting a Lunar to GMT." It focuses on my Tables.

The first thing the Tables and work form do is square away the details. If altitudes were measured along with the distance, table 1 gives the adjustment to turn them into apparent altitudes of the centers. Or, if altitudes were calculated rather than measured, the "W.W." tables "uncorrect" them to turn them into apparent altitudes of the centers.

The W.W., (wrong way) tables were developed by working backward. Take, for example, the W.W. Parallax correction for the moon at 5° altitude and 61' horizontal parallax. Multiply the cosine of 5° by 61'. That gives the moon's parallax correction for a 5° apparent altitude. Taken to three decimal places the correction is 60.'768, additive. Apply that the wrong way. That is, subtract it from 5° to get 3° 59.'232. Then multiply the cosine of 3° 59.'232 by 61' to get 60.'852. Subtract that from 5° to get 3° 59.'148. Repeat another time. There's no appreciable change from 60.852, so the W.W.P. correction, rounded to the nearest tenth, is 60.'9.

Table 1 and the W.W. tables are ridiculously precise, considering how forgiving lunars are of inaccurate apparent altitudes. But they don't take up much room, and might have other uses.

The apparent altitudes of the centers, whether found with the help of table 1 or the W.W. tables, are usually designated by "m" and "s." But lower case letters don't always catch the eye. I decided to use the larger, more noticeable, "Ma" and "Sa" instead. Similar thinking affected the design of the work sheet and the other tables. Navigators aren't always wide awake and at their brightest when working observations. They make fewer blunders if they can quickly find, and unambiguously recognize, what they are looking for.

Since the true altitudes themselves are not used in the equation there's no reason to differentiate them, and (H~H) serves in place of (M~S). The (cos M * cos S)/(cos m * cos s) part of the equation was named "Q."

Substituting the above symbols for the usual ones makes the equation for clearing (given in the May 5th posting) look like this:

hav D = sqrt{hav[d - (Ma~Sa)] * hav[d + (Ma~Sa)]} * Q + hav(H~H)

Tables 2 and 3 are refraction and parallax tables: table 2 for the moon, table 3 for the other body. Refraction is for 50° Fahrenheit and 30 inches of mercury. Values agree with those in the WW II era Bowditch, where they are given to the nearest tenth of a second of arc. For convenience the tables also give, next to the refraction and parallax corrections, each body's part of Q.

To fit into tables 2 and 3 the (cos M * cos S)/(cos m * cos s) version of Q was rearranged to (cos M/cos m)(cos S/cos s). The first half answers to the same arguments as the moon's refraction and parallax, and the second half to the same arguments as the other body's refraction and parallax. To save space, everything before the first significant figure was dropped before the values were put in the tables. To prevent rounding error buildup a sixth decimal place, set off by a comma, was included.

The part that goes in table 2 is negative. The part that goes in table 3, given directly, would be positive. But in absolute value it would always be less than anything in table 2. It never exceeded 12,7, as I recall. So I applied -12,7 (if that's what it was) to everything that went into table 3, and +12,7 to everything that went into table 2. That way the two parts can be added to get the total. A clever dodge, but an old one.

Dr. Inman gets the credit for the particular arrangement of table 2. I junked my own design after examining table 34 in the 1894 print of Inman's Nautical Tables: "Corrections of the Moon's Altitude, and the Aux. Angle A."

Table 3 starts out with a 2' interval for the altitude and picks up speed until the interval reaches 1°. Ordinarily this change of interval would be a poor feature. But it doesn't matter here because there's no interpolation. Space is saved, as are page turnings.

Other than the sextant, and the observer's ability to use it, nothing is more critical to the accuracy of a lunar distance than the semidiameter of the moon. The sun's semidiameter is equally important when the distance is from him. The Almanac gives these values only to 0.'1 and in the case of the moon, not often enough. Fifteen years ago, for my own use, I penned manuscripts of what are now tables 4 and 5. These tables are based on the 1987 American Ephemeris and Nautical Almanac, the astronomers' version of the Almanac. It gives values to the nearest tenth of a second of arc.

The physical diameters of moon and earth are constant, so the ratio of the moon's horizontal semidiameter to her horizontal parallax is constant. From Ephemeris data I took the ratio to be 0.2725. But that's for horizontal semidiameter. When the moon's above the horizon she's closer, and appears larger. Directly overhead she's closer by the full radius of the earth. This effect is usually taken care of by a special "augmentation" table. To avoid the need of a separate table I concocted the formula:

Augmented S.D. = (0.2725 H.P.)/(1 - sin H.P. * sin H)

This is the basis of table 4. Entered with the approximate altitude and the nearest 0.'1 of H.P. from the Almanac, the table gives augmented semidiameter correct to the nearest 0.'03. Altitude is not at all critical for this table, so the apparent altitude can be used in place of H.

Table 5, of the sun's semidiameter, will be two days off by the year 2093, according to my figures. At that time a revision might be worthwhile.

Values in these and some of the other tables were taken to an extra decimal place so that, when added together, rounding errors don't build. It would be nonsense to interpolate between the values.

Table 6 can be calculated well enough by taking the difference in refraction caused by a change of 16' in the altitude and multiplying it by the square of the cosine of the "Angle from the Vertical."

The "K" table is made up of negative log haversines. I tried to arrange it so values could be quickly and easily found. "K" and "Q" are not initials. They are symbols, intended to be instantly picked out on the work sheet.

A problem was presented by the + sign separating "hav(H~H)" from the rest of the equation for clearing. Not easy to get around without a cumbersome table, extra trouble in calculation, or loss of accuracy. After coming up with the "inside-out critical table" which gives every value in a (fairly) reasonable number of pages, I settled on the use of Gaussian addition logs. Fortunately, subtraction logs aren't needed.

Unless you are curious about addition logs, skip the next paragraph.

Suppose you have log A and log B, and need log (A+B). Subtract log B from log A. That gives you log (A/B). Enter the table with log (A/B) and it gives you log (A/B + 1). Add log (A/B + 1) to log B and you have log (A + B). Since, in my method, "log A" and "log B" are negative and the Gaussian positive, its absolute value is subtracted, rather than added.

The "log Dec." table uses the same "inside-out" design as table 2. It gives negative log cosines for calculating comparing distances.

Table 7 is based on ten times the number of minutes of arc in a degree, that is, 2400. Entered with 31.'8 it gives log (2400/318), which is 0.8778.

Table 8 is based on the number of seconds in an hour. In the first edition this table presented the minutes across the top and the seconds down the side. This made the flow of change within the table slightly different from that in the K table and table 7. The difference led me astray one time too many. I substituted the present awkward-looking arrangement in the second edition. Once you're used to it, it works fine.

Bruce

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