

The Research and Analysis of Parallax Error Decrease in Astronomical Navigation Positioning

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Abstract—Improving the position precision will be the future development trend in astronomical navigation positioning, this article mainly introduces the influence of the parallax in the observation height of astronomical navigation positioning. Its producing principle and the corresponding error produced are analyzed and the correction to error is further researched. With the development of simulation technology, combining the simulation technology and astronomical navigation positioning accuracy analysis can make more accurate error analysis and then make navigation positioning precision and accuracy greatly improved.

Keywords-astronomical navigation, parallax error, simulation

I. INTRODUCTION

Astronomical navigation positioning is making use of marine equipment to observe the position of the stars and then to get the position of the ship by calculating the corresponding mathematical model. Therefore, celestial navigation has its unique advantages: The equipment is simple and reliable; Observation goal is natural objects and not from human's control; Don't launch any sound, light and radio and has concealment quality, etc. But because of some human's factors or external environment (such as sea conditions, eye high, temperature, pressure, visibility that is slow to change) or some other influential factors, the measurement height of object will produce certain error. Since parallax is one of the main factors that affect observation height and the resulting error may often be ignored. This article mainly analyzes the astronomical navigation positioning producing principle of parallax and the resulting error makes correction and corresponding simulation. Combining precision analysis and simulation technology makes astronomical navigation positioning accuracy improved, error further decreased and position more accurate.

II. PARALLAX ANALYSIS

The height of the object must be converted to the earth's globe height, so as to meet the astronomical navigation positioning principle of celestial height requirements. The difference of true celestial ground height $\angle BAH$ and the geocentric height $\angle BOH^\circ - p$ calls parallax. It is shown in figure1.

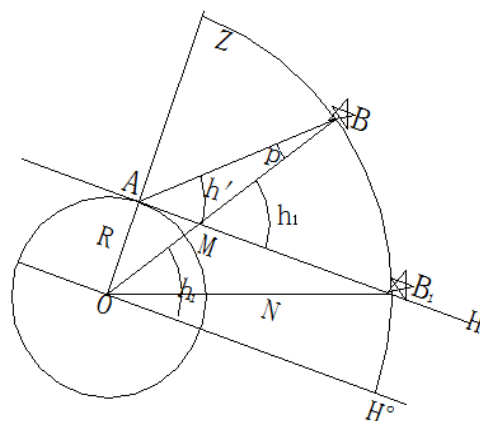


Figure1. Parallax principle

The main reason of celestial produced parallax is that the object is close to the earth and the light to the earth surface's observer and the geocentric light path is not parallel. Based on the above figure, we can get parallax correction as follows.

$AH \parallel OH^\circ$, $h_1 = \angle BOH^\circ = \angle BMH$, h_1 is exterior angle.
According to the sine theorem:

$$\frac{R}{\sin p} = \frac{N}{\sin(90^\circ + h')} \Rightarrow \sin p = \frac{R}{N} \cosh' \quad (1)$$

Through the above formula:

The closer the celestial body is, the bigger parallax is; on the contrary, parallax is smaller. For the stars, $N \approx \infty$, $p=0$.

The higher the object is, the smaller parallax is ; $h' = 90$, parallax is zero.

The lower the object is, the bigger parallax is; $h' = 0$, parallax is called horizontal parallax p .

In the spherical triangle AB_1O :

$$\sin p' = \frac{R}{N} \Rightarrow \sin p = \sin p' \cosh' \quad (2)$$

Both p and p' are small angle, we can make derivation:

$$p = p' \cosh' \quad (3)$$

Because the above parallax is mainly obtained in the average radius of the earth, the earth is the ellipsoid and the radius are different, we can make a measurement error in different sensible latitude.

III. PARALLAX ERROR ANALYSIS AND SIMULATION

In the earth's ellipsoid, a is semi-major axis, b is semiminor axis, e is eccentricity ratio, φ is observed latitude. As is shown in figure2.

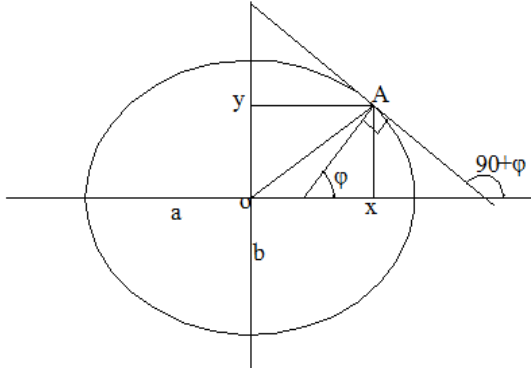


Figure2. Earth's ellipsoid

In the meridian equation of earth ellipsoid:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1 \quad (4)$$

According to the formula:

$$x = \frac{a \cos^2 \varphi}{\sqrt{1 - e^2 \sin^2 \varphi}} \quad (5)$$

$$y = \frac{a(1 - e^2) \sin \varphi}{\sqrt{1 - e^2 \sin^2 \varphi}} \quad (6)$$

Use the Pythagorean theorem:

$$OA = R_T = \sqrt{x^2 + y^2} = \frac{a \sqrt{\cos^4 \varphi + (1 - e^2)^2 \sin^2 \varphi}}{\sqrt{1 - e^2 \sin^2 \varphi}} \quad (7)$$

Because the earth's average radius is calculated through the volume equality. according to the formula:

$$\frac{4}{3} \pi R^3 = \frac{4}{3} \pi a^2 b \Rightarrow R = \sqrt[3]{a^2 b} \quad (8)$$

The actual parallax correction should be:

$$\sin p = \frac{R_T}{N} \cosh' \quad (9)$$

Using the formula(1) (2) (3) (8) (9), different observation latitude and different height make the error:

$$\Delta p = \left(\frac{R_T}{R} - 1 \right) p' \cosh' \quad (10)$$

In the shifting line positioning, the moon and the sun are used as stars. Maximum p' appears horizon. We can use the formula(10), and use matlab to program, and then make use of matlab to simulat maximum error variation with different latitude varying. In the process of simulation, h' is zero, so we ensure that the Cosine take the maximum. The result of simulations of the sun and the moon is shown in the figure 3 and figure 4.

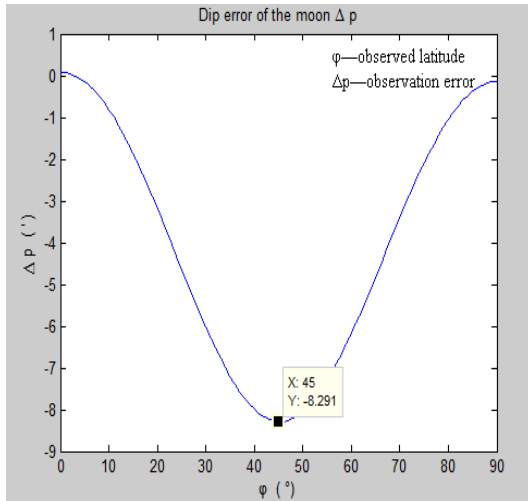


Figure3. The moon error variation with different latitude

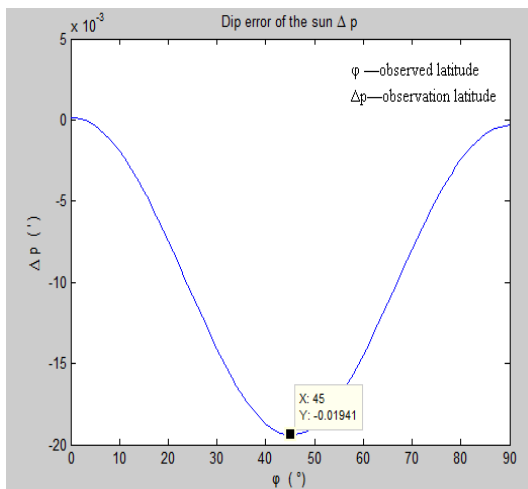


Figure4. The sun error variation with different latitude

According to the above figure, when latitude is between 0 and 45°, error will increase with the increasing of latitude; when latitude is between 45° and 90°, error with the increasing of latitude will decrease; when latitude is equal to 45°, the maximum error appears. we can find that the sun's maximum error is about 0.02' and the moon's maximum error is about 8.29'. In the process of localization, 1' is equal to about 1 kn and latitude effect on 1 kn length is small. The moon that has greater positioning error is about 8 kn, so the process of calculation can make the positioning accuracy decrease and make the measured ship's position deviate from actual position. If the error is bigger, the sailing ship on the sea may be dangerous. Accurate positioning has important significance to celestial navigation. The simulation technology application will make it possible.

By using the formula (10), we could deduce formula that the biggest error is changing with different observation height in the same latitude as follow.

$$\Delta p = kp' \cosh' \quad (11)$$

As above formula, k is the obtained results of calculation in a certain latitude. For example 45°, we could simulate maximum error variation with observation height varying. The result of simulations of the sun and the moon is shown in the figure 5 and figure 6.

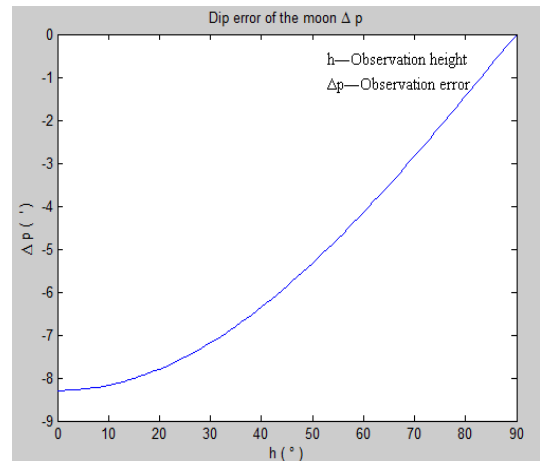


Figure5. The moon error variation with observation height

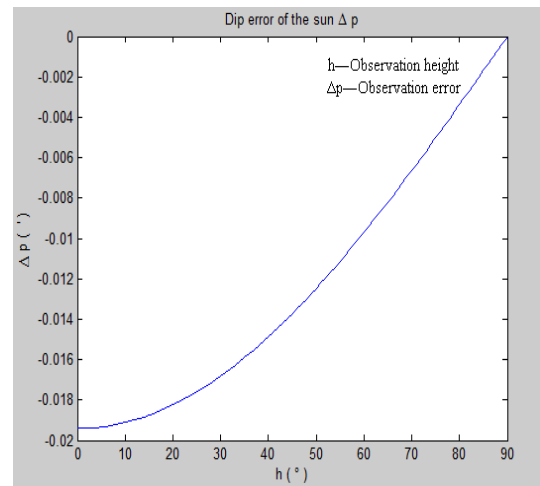


Figure6. The sun error variation with observation height

According to the above figures, when a latitude of observation is certain, the error with observation height

increasing will decrease; when the observation height is zero, the error is biggest.

IV. EXAMPLE VERIFICATION

Verification: On 2009.02.15, Tianren ship set off from the Tianjin Xingang Port to Inchon Port on the ZT₁ 12^h30^m. The height of eye e 18m, index error and device difference (i+s)=0'.0. The course CA99°, the speed V18kn, GMT1 04^h30^m26^s, the first sun altitude hs_1 38°17'.0, the solar azimuth A_1 183°, GMT2 06h17m40s, the second sun altitude 31°29'.5, solving the sun shift line position on ZT2 14 h 18m?

we could check the nautical almanac to get the sun coordinates, Declination(Dec) and Greenwich hour angle(GHA):

h_1 38°24'.6 Dec1 12°38'.4S GHA1 244°04'.6.

h_2 31°36'.8 Dec2 12°36'.9S GHA2 270°53'.1.

Using spherical triangle calculate:

ϕ 38°28'. 68N λ 119°20'. 61E

Using maximum error formula(10) through calculation:

$\Delta p_1 = 0.0144'$, $\Delta p_2 = -0.0157'$

Observation height after correction:

$h_1' = h_1 - \Delta p_1 = 38^\circ 24'.6144$

$h_2' = h_2 - \Delta p_2 = 31^\circ 36'.5957$

Using spherical triangle calculate:

ϕ 38°28'. 67N λ 119°20'. 608E

GPS data:

$\phi = 38^\circ 24'.7N$, $\lambda = 119^\circ 15'.9E$

Through the comparison, the corrected result gets closer to the actual ship position than the no correction, Error is about 0.01', 0.01 kn. Positioning accuracy is more accurate and the sailing on the sea is more safe.

V. CONCLUSION

Matlab has good numerical ability and excellent data visualization ability. The paper will make error analysis and matlab simulation technology combined, we can clearly analyse the changing rule of the error and size changing. Through the correction, the error influence on the navigation positioning will gradually decrease and it improve the navigation accuracy and promote the development of astronomical navigation positioning. We could conduct simulations of the other errors of astronomical navigation that makes a more accurate precision analysis. Based on the calculation of error, we can get a more accurate observation height and then get a more accurate ship position. At last, high-accuracy precision navigation becomes possible and benefits the progress of celestial navigation.

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