Analysis of NGSLR Mount Model Changes with Time and Temperature

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Abstract:

Because of different errors in the Next Generation Satellite Laser Ranging (NGSLR) telescope mount including misalignments, non-orthogonalities, an imperfect coordinate system and mechanical errors, a bias must be introduced into the system to compensate. These biases are determined using the Mount Model. The biases are calculated as trigonometric functions of the azimuth and elevation of the telescope's position. Over the course of time, the bias values become increasingly inaccurate for satellite tracking, and the mount model must be updated by calibrating the system based on a catalog of star positions.

The goal is to find an accurate method of determining an appropriate bias based solely on the ambient temperature and time. This would enable accurate bias determination during the period in between mount model updates as well as potentially increase the amount of time a single mount model value is applicable. The equations used to perform this function were developed using all of the mount model values since January 2008 in conjunction with the temperature data for each update. Applying the formulated equations to the past mount model data yielded results on the order of millidegree accuracy when compared to the actual mount model biases. This accuracy indicates the equations potential to be successfully implemented as a simple, effective method of determining mount biases in between mount model updates.

Intro and Background:

The Mount Model is a 22 element trigonometric equation. The equation is a function of azimuth and elevation, and its results indicate the necessary azimuth and elevation offset incorporated when ranging to satellites. The mount model is generated in a process known as a star calibration. During this process, a star camera uses a catalog of star positions to locate and aim at approximately 50 stars. Typically, the telescope will not be perfectly aligned with the star and the offset is known as a bias. This bias will vary between different stars because each star requires the mount to move to a different particular azimuth and elevation. Using the biases of the different stars and a least squares fitting method, the coefficients to the mount model equations are obtained.

Currently, the calculated mount model values are accurate for an average of 1.5 weeks. During this time, the necessary biases slowly change and the mount model values become increasingly inaccurate. Eventually, the actual value diverges too much from the originally calculated value. When this occurs, a new star calibration is conducted resulting in a new mount model values.

The purpose of this project is to determine any mount model trends due to temperature as well as time. Furthermore, the goal is to incorporate these trends to enable more accurate satellite tracking during the time between mount model updates as well as possibly extend the time a particular mount model is valid.

Method:

During the process of the star calibration, an analysis file is made containing information regarding that particular calibration. This information includes the time, date, temperature, mount model coefficients and more. Using analysis files from January 1, 2008 through June 11, 2012, I reconstructed the various mount model values in for elevations of 20° to 80° in 20° increments and azimuths from 0° to 330° in 30° increments. These values were then all averaged and scaled according to the cosine of the elevation in order to give values for the sky angle. I investigated the final values and made several trend comparisons including mount model to temperature, mount model to change in temperature, change in mount model to temperature, and change in mount model to change in temperature.

After these trends were developed it was necessary to determine which had the strongest correlation. For the azimuth bias, the apparent best fit method to simulate the mount model biases was the mount model compared to the change in temperature. This correlation coupled with the temporal trend resulted in the final equation for the azimuth bias. For the elevation bias, the apparent best fit method was simply a temporal trend.

Results and Graphs:

Eq 1 and 2 were developed to model the bias for the azimuth and elevation for the current mount position using the temperature and temporal trends.

$$\Delta Az = \frac{6.36E^{-5} * (\Delta temp) + 5.32E^{-6} * (\Delta time)}{\cos(El)} + AzMM \qquad 1$$

$$\Delta El = 1.52E^{-5} * (\Delta time) + ElMM \qquad 2$$

Where ΔAz is the angular bias for the azimuth direction, $\Delta temp$ is the change in temperature from the past mount model update to the current temperature, $\Delta time$ is the change in time for the past mount model update to the current time, $AzMM$ is the past azimuth mount model bias value, El is the current elevation position for the mount, ΔEl is the angular bias for the elevation direction, and $ElMM$ is the past elevation mount model bias value.

The past mount model values for the updates since January 2008 are depicted in Fig 1 for delta azimuth and Fig 2 for delta elevation.

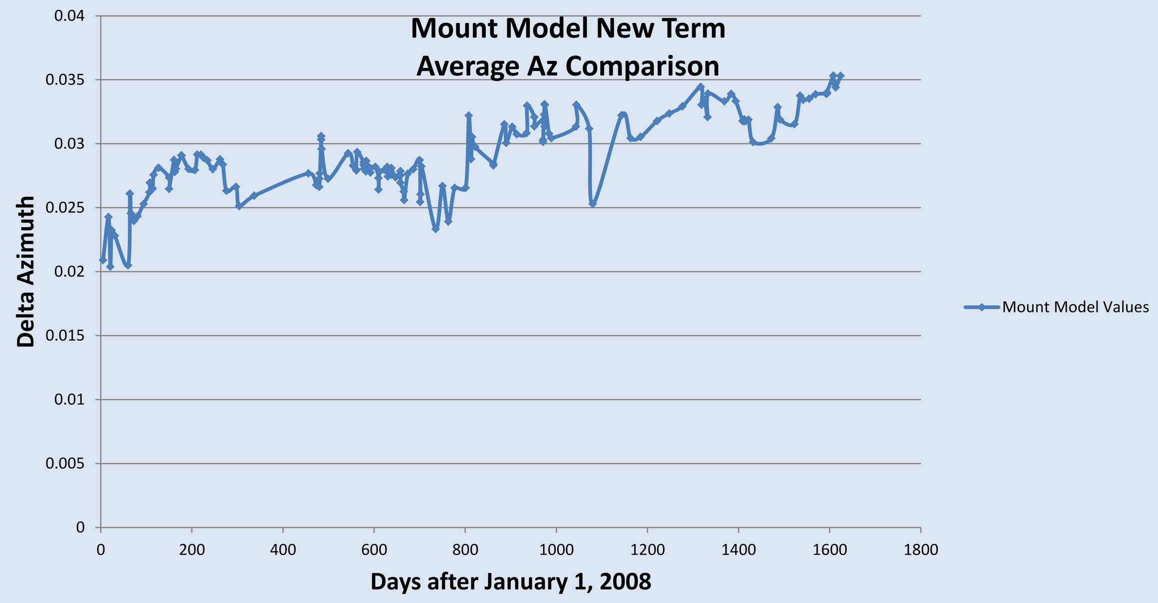

Figure 1: The necessary average azimuth biases calculated from the 10 term azimuth mount model equation for data since January 1, 2008 to June 11, 2012.

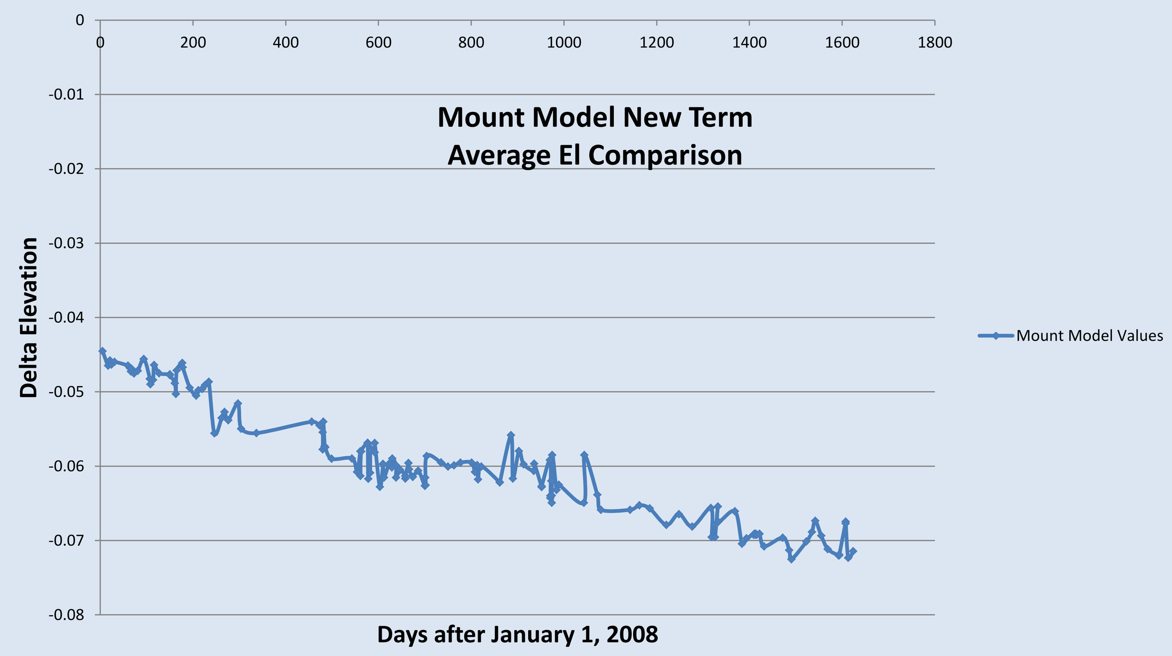

Figure 2: The necessary average elevation biases calculated from the 12 term elevation mount model equation for data since January 1, 2008 to June 11, 2012.

Using the mount model values and the temperature data associated with each update, the values for the necessary biases were closely modeled and produced in Figure 3 for azimuth and Figure 4 for elevation.

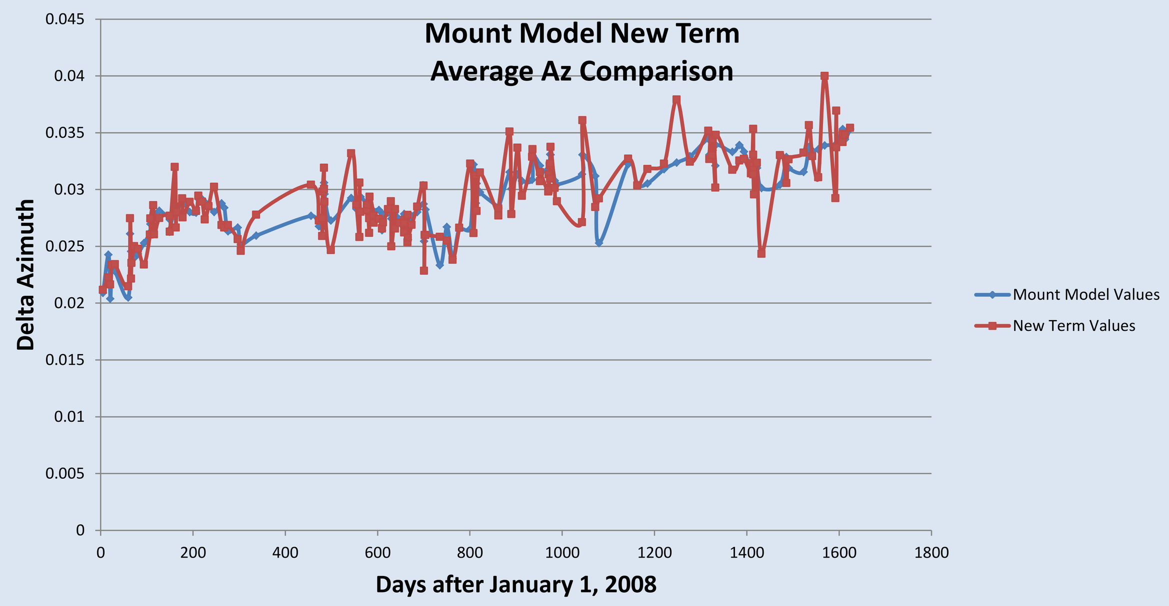

Figure 3: The necessary average azimuth bias previously calculated by the mount model updates compared to the newly developed equation based on the previous mount model value, temperature, and time. The standard deviation between the different methods is 1.843mdeg.

Results Continued:

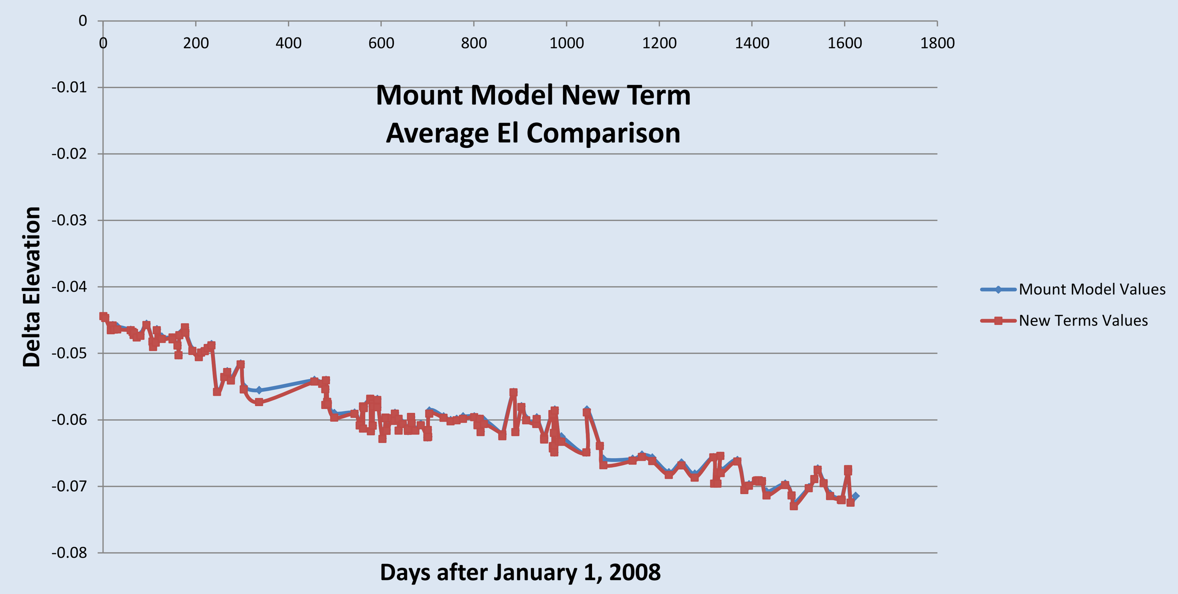

Figure 4: The necessary average elevation bias previously calculated by the mount model updates compared to the newly developed equation based on the previous mount model value and time. The standard deviation between the different methods is 2.773mdeg.

In order to determine if the new method can accurately predict values for particular positions and not just averages it was compared with the values computed by the mount model for each of the four cardinal directions. The results of the comparison are contained in Tab 1.

	Delta Azimuth (mdeg)	Delta Elevation (mdeg)
0° Azimuth	1.848	2.627
90° Azimuth	1.810	2.763
180° Azimuth	1.786	2.878
270° Azimuth	1.928	2.824
Average	1.843	2.773

Table 1: This table contains the standard deviation between the mount model biases and the new term biases for different directions as well as the average of all of the directions.

Discussion and Conclusion:

The goal of this project was to determine whether the changes in azimuth and elevation biases required for tracking satellites were functions of temperature and time. The results from Table 1 indicate that the equations developed from the trends are accurate enough to potentially provide reliable biases between mount model updates as well as increase the time that particular bias values are valid. The disadvantage of this new method is that the temperature must be constantly monitored to determine if the change in temperature produces any significant changes in the azimuth bias. Furthermore, this method introduces a complication in that it constantly refers to the past mount model bias values so it must be used in conjunction with the old method. I plan on continuing this project by attempting to develop a more accurate method including additional trends based on other factors including pressure, especially for the elevation bias. A future project would likely be to create software to incorporate this new method as a real time update for satellite laser ranging to provide accurate biases between mount model updates.