GEOCENTER VARIATIONS FROM ANALYSIS OF TOPEX/POSEIDON SLR DATA

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INTRODUCTION

The global-scale fluid-motions produce temporal variations in the Earth's gravity field and the geocenter. The geocenter variation is the motion of the origin of the Terrestrial Reference Frame (TRF) with respect to the center of mass of the Earth system. Space geodetic measurements, such as the SLR (satellite laser ranging) and DORIS (Doppler Orbitography and Radiopositioning Integrated from Space), link a satellite, which orbits about the center of mass of the Earth system, and the tracking sites, which realize the TRF. Thus, the satellite tracking data provide a unique capability for measuring the geocenter variations.

The temporal and spatial distribution of the tracking data for a satellite plays a significant role in its ability to sense the geophysical signals from the Earth. Recent estimates of the annual variations in the geocenter are at the millimeter level. To determine such small geocenter variations, centimeter level orbit fits are required in addition to the requirement for global and intensive tracking of a satellite. The TOPEX/Poseidon (T/P) satellite is nearly continuously tracked by both SLR and a globally well distributed DORIS network. The average number of SLR normal point observation per orbit revolution for T/P satellite is about 1.5 times more than that of the Lageo-1 satellite [Kar, 1997]. Using available state-of-the-art satellite force and measurement models [Tapley et al., 1994], the average laser ranging residual RMS for a 10-day TOPEX orbit fit is 2 cm, which is comparable with Lageos-2, and smaller than the RMS of 4-5 cm for Lageos-1 and Starlette. The large RMS for the Lageos-1 orbit fit is caused by the non-gravitational eccentricity excitation, which changes rapidly in magnitude with time. The complicated shape of TOPEX makes it more difficult for modeling the nongravitational forces than those spherical geodetic satellites, but adjusting the epoch satellite initial conditions along with the 8-hour $C_2$ and daily once-per-rev acceleration parameters for transverse and normal component results in a good fit to the observations. The intensive tracking of T/P satellite makes such estimation possible for reducing the orbit error. The results reported to IERS 1997 campaign for the geocenter variations from analysis of SLR tracking data to the T/P satellite is briefly discussed in following sections.

SOLUTION METHOD

The position vector, $\vec{r}$, of an Earth orbiting satellite in the inertial frame can be defined as

$$\vec{r} = \vec{p} + \vec{R}_s + \vec{r}_{cm}$$

where $\vec{r}_{cm}$ is the vector from the center of mass of the Earth system to origin of the TRF, $\vec{R}_s$ is the position vector of a tracking station in the TRF, $\vec{p}$ is the slant vector from tracking site to satellite. The unmodeled geocenter variations will result in the observation residual, which is the difference between the observed and computed slant range from the reference orbit with best fit to measurements. In this study, a post-fit approach is used to estimate the geocenter using observation residuals over a 10-day time span assuming that the observation residuals are mainly due to measurement model errors, including the geocenter variations, range biases, earth orientation parameter (EOP) errors etc. The observation residuals used in this study were based on the TOPEX reference orbit used to determine the mean sea surface topography with a RMS of 2 - 3 cm. The dynamical characters of the reference orbit are fixed. The range bias for some tracking stations over a longer time span, and the orbital element corrections and

EOP over a short arc are adjusted to reduce the orbit errors to some degree. Analysis of the 10-day time series for the geocenter variations determined from 176-cycle T/P SLR residuals shows that seasonal geocenter variations are observable, and particularly significant in the Y component. Table 1 shows the amplitude and phase for the annual (Sa) and semiannual (Ssa) geocenter variations estimated from the 15-day time series derived from T/P SLR data.

Table 1 Annual and Semiannual Variations of Geocenter from T/P SLR Data

<table>
<thead>
<tr>
<th></th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Amp (mm)</td>
<td>phase (deg)</td>
<td>Amp (mm)</td>
</tr>
<tr>
<td>Sa</td>
<td>2.1</td>
<td>309</td>
<td>4.7</td>
</tr>
<tr>
<td>Ssa</td>
<td>0.3</td>
<td>159</td>
<td>0.5</td>
</tr>
</tbody>
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DISCUSSION

A dynamic orbit fit approach was used to verify the T/P results for the geocenter variations obtained from the post-fit approach. In dynamic approach, the position vector of the geocenter is simultaneously estimated with the initial conditions of the satellite and the dynamic parameters (drag coefficients and other empirical acceleration parameters) to be the best fit to the observations. Comparison of the annual and semi-annual geocenter variations determined using TOPEX SLR data shows that the phases agree within 10 degree from the two approaches. Amplitudes are increased by approximate 40% for the annual variations in the X and Y components. A 9.8 millimeters amplitude for the annual variation in the Z component from the dynamic approach was found, which indicates that the geocenter variations in the Z component are not separable from the once-per-rev orbit errors. The interesting signals for geocenter variations were effectively absorbed by estimating the once-per-rev parameters in the process of generating reference orbit. The high frequency orbit errors cause the scattering of solution from the dynamic approach. The facts suggest that the accuracy of the current estimates for geocenter variations is limited by the aliasing effects on the geocenter variations, particular for the Z component, from the once per revolution orbit errors for T/P orbit.

In conclusion, the millimeter level magnitude of the geocenter variations is smaller than the current accuracy of orbit fit. The T/P results for the annual geocenter variations are comparable with the results from the combination of Lageos 1 and Lageos 2 [Eanes et al, 1997] except for the Z component. Improved non-gravitational force modes are required to improve the estimates for geocenter variations from satellite tracking data.

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Reference

Kar S., Long-period variations in the geocenter observed from laser tracking of multiple satellites, Ph. D. Dissertation, University of Texas at Austin, 1997.