ESTABLISHMENT OF TERRESTRIAL REFERENCE FRAMES BY NEW OBSERVATIONAL TECHNIQUES

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ABSTRACT

The use of space techniques for establishing transcontinental and intercontinental distances is progressing very rapidly. We can think of the set of station locations used in either LAGEOS ranging or VLBI measurements as forming the vertices of a polyhedron. After correcting for tectonic plate motions using an adopted model, we expect the geometry of the polyhedron to be fairly stable over periods of the order of a year. However, after some period of time, a new set of station coordinates will be required because of improved data, unexpected station motions, etc. Methods for maintaining agreement with the previous set of station coordinates in some average sense are discussed in this paper. Some of the contributions expected from other new measurement methods also are described.

INTRODUCTION

This article is addressed to the question of how we can use new observational techniques to establish worldwide terrestrial reference frames. For simplicity, the main emphasis will be on geometrical reference frames that can be established by laser distance measurements to the LAGEOS satellite and by very long baseline radio interferometry (VLBI). These two techniques are likely to be the most important ones in the 1980s for establishing basic worldwide networks of geometrical reference points. However, it should be noted that much larger numbers of points in and around seismic zones are likely to be determined with similar accuracy by observing the signals from the NAVSTAR Global Positioning System satellites. These points will have to be tied to the basic worldwide reference frames in some way.

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One of the basic reasons for establishing accurate worldwide geometrical reference frames is connected with the definition of the earth's rotation. The angular motion of such frames with respect to a conventional celestial reference frame is likely to be used in the future to define UT1 and polar motion. Any inadequacies in the reference frames thus are likely to show up as limitations on the accuracy of the UT1 and polar motion determinations. In particular, this means that the coordinates for the different stations which make observations used in determining UT1 and polar motion should be as consistent as possible. Otherwise changes in the distribution of data between different stations, either at different times of the year or over shorter periods, will lead to errors in the results.

Because of the above requirement, it appears desirable to adopt a model for the motions of the various tectonic plates for use in determining the reference system. This question has been discussed previously (Bender, 1974), and may be considered further in other papers in this volume. For example, any of the four absolute plate motion models referred to in Table 8 of Minster and Jordan (1978) might be a reasonable choice until a substantial amount of new information on plate motions from space techniques becomes available. The important point is that some of the LAGEOS ranging and VLBI stations either are or will be on the relatively high velocity Pacific and Indian plates. Without a plate motion model, the coordinates of such stations will become inconsistent with respect to other stations quite quickly.

While there definitely is a possibility that present rates of plate motions will differ from the long-term average rates determined from the geological record and other information (Bender, 1974,1978), this would require a substantial change in the picture most geophysicists have of tectonic plate motions. It appears difficult to see how the present rates of motion out in the centers of the major plates can be much different from the long-term average rates unless there is a layer in the asthenosphere with much lower viscosity than is expected from studies of post-glacial rebound. This is because the main driving forces for plate motions at ridges and rises and the viscous stresses on the bottoms of the plates are likely to be quite stable in time. For values of the order of $10^{20}$ poise for the viscosity and 100 km for the thickness of the low-viscosity part of the asthenosphere, the transient effect of even a great earthquake at the front of the plate would not propagate out to the center of the plate during typical recurrence times for great earthquakes. Thus it seems best for geodesists to regard the null hypothesis which we wish to test as being that the present rates of motion in the centers of plates are equal to the long-term average rates.

One other question which comes up frequently concerning models of plate motions is based on the fact that only relative motions of the different plates are actually observed. Fortunately, studies by Solomon and Sleep (1974), Kaula (1975), and Minster and Jordan (1978)