Tanimoto [1989] computed the orientation of the figure axis for four recent Earth models that give three-dimensional (3-D) density anomalies derived from seismic tomographic techniques. (The figure axis, or sometimes the major axis, is the principal axis of the greatest moment of inertia.) He found angular deviations, $\Delta \theta$, on the order of 0.1 degree between the computed and the nominal "North". He compared $\Delta \theta$ with the Earth's polar motion whose amplitude $m$ is only a fraction of an arcsecond. As $m \ll \Delta \theta$, he recommends $m$ be taken as the goal for constraining future improvements in 3-D Earth models.

There are three points I wish to comment on:

(i) It is inappropriate to compare $\Delta \theta$ with $m$. The polar motion essentially consists of a wobbling motion and a secular drift. The polar wobble refers to the (circling) departure of the rotation pole from the (defined as the mean pole for the period of 1900-1905). These departures are small — on the order of a fraction of an arcsecond, or less than 1 m on the surface of the Earth. But none of these should concern Tanimoto's analysis, for reasons given below.

First I'd like to stress that Tanimoto's $\Delta \theta$ is with respect to the nominal North pole (or the nominal geographic coordinates his seismic data refer to), not with respect to the rotation pole as he stated. The location of the rotation pole at any given time is of purely dynamic concern; the polar motion is caused by temporal changes in the Earth's inertia tensor and the accompanied motions, and its amplitude $m$ merely reflects the excitation and decay mechanisms in the Earth. A (static) Earth model determines its own figure axis, but says nothing whatsoever about the rotation axis. Comparing $\Delta \theta$ with $m$ is inappropriate. Yet, is it meaningful to set $m$ as the constraining uncertainty in future Earth models? The answer is still "no". The polar motion does not represent an uncertainty in the observed figure axis. The modern accuracy in the determination of the rotation axis, and hence in principle the figure axis, of the Earth is approaching 1 milliarcsecond [e.g., King, 1987], corresponding to ~3 cm on the Earth's surface! If at all, it's the latter that should be taken as the constraining uncertainty, although this seems impractical considering the systematic uncertainties and the limited spatial resolution with the seismic techniques.

(ii) It should be pointed out that the small magnitude of $\Delta \theta$ (~1 degree) is not a result of the merit of the current 3-D Earth models. It only reflects the dominance of the ellipticity $J_2$ in the Earth's density anomalies: any (reasonable) 3-D Earth model would surely result in a small $\Delta \theta$ in the presence of the dominating $J_2$. If $\Delta \theta$ is to be compared with some relevant Earth parameter, it should be with $J_2$. For example, were the Earth's $J_2$ 10 times larger, the resultant $\Delta \theta$ would presumably be 10 times smaller. The critical fact is that current 3-D Earth models are completely unconstrained with respect to the figure axis; but $\Delta \theta$ is not a very sensitive parameter for that purpose. Here I contend that the direction of the computed deviations (which Tanimoto did not give) may serve as a more diagnostic parameter in assessing 3-D Earth models.

(iii) More importantly, however, there is a similar parameter which is rather sensitive to the Earth models, namely the angular deviation (call it $\Delta \phi$, or $d\phi$) between the computed and observed orientations of the minor axis, or the principal axis of the least moment of inertia. Current 3-D Earth models are also unconstrained with respect to the minor axis; and, in the absence of other dominating effects, $\Delta \phi$ can conceivably be of any value, large or small. Moreover, it should be noted that $\Delta \phi$ is by no means less significant than $\Delta \theta$ (along with its direction) as far as the Earth's density anomalies are concerned [Goldreich and Toomre, 1969]. The observed minor axis of the Earth points to the meridian of 29.9W (in the mid-Atlantic), according to the gravitational coefficients (of harmonic degree 2 and order 2) given by, e.g., Lerch et al. [1985; see also Chao and Gross, 1987, p.585]. It should be interesting to see what the current 3-D Earth models actually predict for $\Delta \phi$.

References


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