Estimating Geocenter motions from GPS measurements

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Changes in the displacement vector between the Center of Mass (CM) of the Earth system and the Center of the Earth's geometrical Figure (CF) is the most common geocenter motion observed using modern geodetic techniques. Primarily this is due to the location on the Earth's surface of the various satellite tracking networks (DORIS, GPS, SLR, VLBI). Observations of this geocenter motion are fundamental to defining the origin of the International Terrestrial Reference Frame (ITRF) and investigating the surface mass transport between oceans, continent and atmosphere which cause this motion.

Estimates of this geocenter motion have been at various levels of agreement both between and within different geodetic techniques. Cross-technique differences can partly be put down to the broad spectrum of technique specific errors but much of the difference lies in the use of different surface tracking networks. What is required is a robust method that is relatively unaffected by the network used to sample the Earth's surface figure and hence CF. With this in mind we explore the different estimation techniques which might be used to estimate the geocenter and investigate the performance for GPS data.

We identify two methods that are currently in use; the “Network shift method” and the “Degree-1” deformation method. GPS displacements are in the CM frame since this is the gravitational center of the satellite orbits, by averaging these displacements we can estimate the translation vector (or “Network shift”) of the Earth’s surface (CF) defined by the tracking network. This technique is susceptible to orbit modeling errors and is dependant on how well the tracking network represents the Earth’s surface.

An alternative technique is to model the deformation associated with geocenter motions on a site by site basis using an elastic Earth model. Conceptually this approach can be considered as using the displacements between sites in the network rather than the displacement between sites and the Earth’s Center of Mass, the geocenter motion then follows from this “Degree-1 deformation” through the theoretical Earth model. This approach appears to be less susceptible to orbit modeling errors but is likely more susceptible to site dependant errors and aliasing from higher degree loading not considered in the model. We also consider a new third approach where we model the “Network shift” and “Degree-1 deformation” with an elastic Earth model (rather than just the deformation).

We compare and contrast different estimation methods using 7 years of fiducial-free GPS solutions from the IGS Analysis centers each of which uses different software and tracking networks. We find that the formal error for the Network shift method in the case of a poorly distributed network is largest. The Degree-1 deformation method formal error is lower in this case but for a well distributed network the formal error is comparable (this does not include other error sources such as aliasing or CF approximation) and there is little to discriminate the methods in this aspect. In terms of formal error the new method performs as well or up to twice as good in all cases suggesting it could be an improved technique for estimating geocenter motions. Comparison of actual estimates from 6 different IGS analyses with the new method demonstrates this, with an improved agreement between the geocenter motion estimates.