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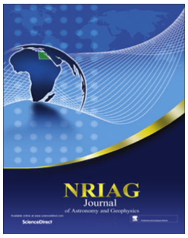

Datum maintenance of the main Egyptian geodetic control networks by utilizing Precise Point Positioning “PPP” technique

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Abstract A geodetic control network is the wire-frame or the skeleton on which continuous and consistent mapping, Geographic Information Systems (GIS), and surveys are based. Traditionally, geodetic control points are established as permanent physical monuments placed in the ground and precisely marked, located, and documented. With the development of satellite surveying methods and their availability and high degree of accuracy, a geodetic control network could be established by using GNSS and referred to an international terrestrial reference frame used as a three-dimensional geocentric reference system for a country. Based on this concept, in 1992, the Egypt Survey Authority (ESA) established two networks, namely High Accuracy Reference Network (HARN) and the National Agricultural Cadastral Network (NACN). To transfer the International Terrestrial Reference Frame to the HARN, the HARN was connected with four IGS stations. The processing results were 1:10,000,000 (Order A) for HARN and 1:1,000,000 (Order B) for NACN relative network accuracy standard between stations defined in ITRF1994 Epoch1996. Since 1996, ESA did not perform any updating or maintaining works for these networks.

To see how non-performing maintenance degrading the values of the HARN and NACN, the available HARN and NACN stations in the Nile Delta were observed. The Processing of the tested part was done by CSRS-PPP Service based on utilizing Precise Point Positioning “PPP” and Trimble Business Center “TBC”. The study shows the feasibility of Precise Point Positioning in updating the absolute positioning of the HARN network and its role in updating the reference frame (ITRF). The study also confirmed the necessity of the absent role of datum maintenance of Egypt networks.

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1. Introduction

One of the fundamental tasks of geodesy is the building and maintenance of geodetic reference networks. Geodetic networks are comprised of a set of well-defined and monument geodetic markers distributed on Earth's surface. They form the basis for investigations of the shape, dimension and gravity field on the Earth. All these quantities have to be considered as time dependent. Geodetic reference networks also are the basis for all technical and construction works in building as well as the reference frame for monitoring the stability of various large constructions.

The definition and practical realization of geodetic reference networks is changed due to progress in geodetic observation techniques. With the development of satellite surveying methods and their availability and high degree of accuracy, the problem arose, how to use these three-dimensional (3D) observations in their complexity and not to lose or reduce the information about the spatial point positions included in the measurements. When a national coordinate system is established by using high accuracy GPS positioning, a procedure designed for its regular maintenance is also required. It is aimed to ensure the quality and accuracy for the GPS control stations as they might be degraded by any intended or natural effects. If the regular maintenance is not made for those GPS sites, the geocentric reference system based on this fundamental GPS network would be distorted. However, if the maintenance is frequently carried out for those GPS control stations, it would also result in some difficulties for land planning and management as the coordinates of these control stations have to be jointly changed. Therefore, a guideline set up to carry on a stable frequency and consistent quality of maintenance for the GPS control stations in Egypt is particularly required.

Normally, for the maintenance of GPS tracking stations, the accurate coordinates of these GPS tracking stations are determined in the network adjustments integrating with part of the IGS stations whose coordinates are regularly maintained with the realization of the ITRF. When long term coordinate data sets are archived for GPS tracking stations, they can be used to investigate the time evolution. As the coordinates of the first-order GPS control stations are determined by fixing the coordinates of the GPS tracking stations in the network adjustments, the information of time evolution provided by the GPS tracking stations can be used to carry on the maintenance for the first-order GPS control stations (Rabah et al. 2015; Farhan, 2013).

In space geodetic positioning, where the observation techniques provide absolute positions with respect to a consistent terrestrial reference frame, the corresponding precise definition and realization of terrestrial and inertial reference systems are of fundamental importance. Geodetic reference frames are subject to regular maintenance for a number of reasons including the networks "densification (addition of new points)", the correction of survey blunders, unstable or disturbed monumentation, geodynamical effects such as plate tectonics and effects of crustal motion both locally and regionally, and to keep pace with ever increasing accuracy requirements.

In the classical sense, a geodetic datum is a reference surface, generally an ellipsoid of revolution of adopted size and shape, with origin, orientation, and scale defined by a geocentric terrestrial frame. Once an ellipsoid is selected, coordinates of a point in space can be given in Cartesian or geodetic (curvilinear) coordinates (geodetic longitude, latitude, and ellipsoid height). Two types of geodetic datum can be defined namely a static and kinematic geodetic datum. A static datum is thought of as a traditional geodetic datum where all sites are assumed to have coordinates which are fixed or unchanging with time. This is an incorrect assumption since the surface of the earth is constantly changing because of tectonic motion. Static datum does not incorporate the effects of plate tectonics and deformation events. Coordinates of static datum are fixed at a reference epoch and slowly go out of the date, need to change periodically which is disruptive (Chang and Tseng, 1998).

Datums can either become fully kinematic (dynamic), or semi-kinematic. A deformation model can be adopted to enable ITRF positions to be transformed into a static or semi-kinematic system at the moment of position acquisition so that users do not see coordinate changes due to global plate motions. GNSS devices that use ITRF or closely aligned systems position users in agreement with the underlying kinematic frame; however, in practice there are a number of very significant drawbacks to a kinematic datum. Surveys undertaken at different epochs cannot be combined or integrated unless a deformation model is applied rigorously, or is embedded within the data, and the data are correctly time-tagged. On the other hand, semi-kinematic datum incorporates a deformation model to manage changes (plate tectonics and deformation events). Coordinates are fixed at a reference epoch, so the change to coordinates is minimized. Many countries and regions that straddle major plate boundaries have adopted a semi-kinematic (or semi-dynamic) geodetic datum in order to prevent degradation of the datum as a function of time due to ongoing crustal deformation that is occurring within the country.

High precision GNSS positioning and navigation is very rapidly highlighting the disparity between global kinematic reference frames such as ITRF and WGS84, and traditional static geodetic datum. The disparity is brought about by the increasingly widespread use of PPP and the sensitivity of these techniques to deformation of the Earth due to plate tectonics. In order for precision GNSS techniques to continue to deliver temporally stable coordinates within a localized reference frame.

2. Transformation parameters between static and kinematic terrestrial reference systems

Transformations from kinematic ITRF to a static datum are conventionally done by either using the site velocity (measured directly or computed from a plate motion model) to compute the displacement between the reference and current epochs or by a conformal transformation augmented with time dependent parameters to account for rigid plate motion. Rigid Plate movement is conventionally defined by a rotation rate about an Euler Pole Φ, Λ and ω, where Φ and Λ are the latitude and longitude of the pole, and ω is the rate of rotation of the plate around the pole in degrees per million years. Equivalent rotation rates about the Cartesian axes (Ω_X, Ω_Y and Ω_Z) can be computed from the Euler pole definition using Eqs. (1)–(3) (Φ, Λ, and ω) are first converted from decimal degrees to radians: