TOPOGRAPHY AND CRUSTAL DEFORMATIONS

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INTRODUCTION

Deformations of the Earth's crust change the topography of the planet. Natural geodynamic processes span a very large range of time scales. Earthquakes may shift the position of sites by several centimeters horizontally and vertically in a few seconds. Continents and tectonic plates move relative to each other by several cm per year. This process has continued for millions of years but may or may not be well described by continuous linear motion. Post-glacial rebound effects, which are mainly vertical, take place over several thousands years between ice ages. They are regional and affect the extended polar caps of our planet. The topography of a coastal nation may change significantly as the accumulated vertical motion may add to several hundreds meters. The collection of natural changes that occur in the surface layers of our planet constitutes a challenge to the IERS because the terrestrial reference frame of observing sites must be continuously maintained and updated. The ITRF product is a conceptual as well as a realized basis that can be used for measuring topography and crustal deformations.

THE ITRF AND ITS RELATION TO TOPOGRAPHY AND CRUSTAL DEFORMATIONS

Topography is the surface features of the planet. The ITRF is a small, select set of points on the surface whose positions are known at some epoch(s) with particular accuracy. These points form the conceptual and realizable framework on which the topography of the planet can be defined and measured.

Crustal deformation is the change in topography arising from the accumulation of strain. It can be measured through the ITRF from the velocities of the ITRF points. Most of the velocity of an ITRF point does not come from deformation, however. The underlying system is based on the simplifying assumption of rigid tectonic plates whose modeled rotations carry the surface points along horizontally without strain. The difference between the modeled velocity and the ITRF velocity at a point arises from a mixture of deformation, model error, and observation/analysis error. Other geophysical and geodetic information is required to make the best interpretation.

A strong, reliable, well-understood ITRF is the basis for measuring topography and crustal deformation on a global scale. The ITRF is formed by combining position and velocity results from different space geodetic techniques, each having different systematic errors, spatial distribution, and temporal distribution. Collocation is the most important means by which information from different space geodetic techniques is integrated into a unified system and is the primary method for assessing the accuracy of the ITRF. Because fixed SLR and VLBI systems have generally been located for reasons other than collocation and because mobile SLR and VLBI systems have not been extensively operated for some time, the collocation between these techniques includes a number of points of lower quality. The situation with GPS collocation is potentially better, but some of the best SLR/VLBI sites do not now have GPS or have not had long, reliable GPS occupations. Many VLBI sites are also GPS sites today, but some historical VLBI sites were occupied by mobile equipment so their current quality is declining and the collocation with GPS is weak.

The use of more than one measurement technique at an observatory requires the instrument monuments or reference points to be tied together, e.g., by local geodetic survey. The quality of these local surveys may be the current limiting factor in combining space geodetic results. It would be wise to repeat such measurements from time to time to check for possible movement of monuments. This would involve a local reference network at the site. Some observatories have been built in areas of geophysical or geological activity. It may be required to considerably extend the survey area around such sites to establish if any instrument monument has movements deviating from the others. Some observatories carry out control surveys regularly, and they should be encouraged to make results available to serve the IERS and its users. Similarly local geological and geophysical information would be useful to show whether movement is consistent with expectation.

The ITRF is not static and must be continuously updated. The ITRF is defined by positions at a reference epoch and velocities, both with uncertainties. The precision of a site position at a specific epoch is a function of the error at the mean observation epoch, the error of the velocity, and the time interval between the mean and specific epoch. The quality of sites no longer occupied deteriorates as the mean observation epoch recedes into the past. This is a problem with old SLR and VLBI sites. Mobile SLR and VLBI systems could be used in the future to reobserve old sites to provide a new, longer time interval for determining velocities. Sites currently acquiring space geodetic data need to continue in order to avoid future degradation.

Recommendation 1: The IERS should make a strong effort to promote the collocation of observations, accurate local surveys, and continued (re)observations at TRF sites in order to strengthen the ITRF.

SITE HISTORY

The ITRF is a good set of site positions and velocities, but at some locations the velocities are not yet adequately known. It is desirable to know in greater detail the station history with time. Such information would reveal: 1) the time intervals for which data are available, i.e., site life time and occurrence of data breaks, 2) overlapping of periods of data for different observing techniques, and 3) episodic and other nonlinear motion present at the site. This information would allow both IERS analysts and external scientific users to evaluate the importance of each site. It is possible for analysis centers to provide this information today, and they should be encouraged to give it in a way consistent with a realization of ITRF, such as ITRF94. The time series of site positions derived by an analysis center may not be in exact agreement with ITRF94 because of difference due to data or frame definition, but the site velocities inferred from the time series should be consistent with the analysis center's own realization of ITRF. The IERS web should establish links to analysis centers to announce the existence of such information.

Recommendation 2: The IERS should encourage the analysis centers to provide time series of ITRF site positions and make this information available through the IERS web site.

UNEXPECTED STATION BEHAVIOR

The ITRF is realized by station positions and velocities. It is assumed that velocities remain constant with time, which may not be true for all sites. Counterexamples are given by observations around the earthquakes near Fort Ord and Landers. Recognition and identification of such episodic and other nonlinear motion is essential to obtaining the goal of a strong ITRF. The previous history of site positions and velocities (together with confidence information) should enable analysis centers to determine if motion components for a site at a specific epoch or some interval deviate significantly from expectations. The information is also of interest to the geophysical community. To identify causes of abnormal station behavior may require multidisciplinary efforts. The IERS should encourage and promote such studies. It is appropriate to notify the users of ITRF by means of messages on the IERS web pages and active links to detailing information.

Recommendation 3: The IERS should encourage the analysis centers to report deviating behavior of ITRF sites at the 5 sigma level or above and to attempt to identify the cause of such behavior. IERS should make such information available on the IERS web site.