Resolution on the nomenclature of space geodetic reference points and local tie measurements

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Abstract
We establish a specific but general terminology in order to clarify discussions on topics related to local tie measurements. The terminology meets the requirements of an observing system that encompasses existing International Earth Rotation and Reference Systems Service (IERS) techniques as well as other observation techniques of the Global Geodetic Observing System (GGOS).

Introduction

The continuous improvements of the space geodetic techniques DORIS, GNSS, SLR and VLBI that contribute to the International Terrestrial Reference Frame (ITRF) have now reached a precision where systematic errors in the individual techniques' internal solutions are becoming a significant source of uncertainty. Therefore, the objective to merge the individual techniques into "an accurate and stable global geodetic reference frame for the Earth that allows the interrelationship of measurements taken anywhere on the Earth and in space, [by] combining geometric positioning and gravity field-related observations, as the basis and reference in location and height" (United Nations 2015) is within reach. The combination of space geodetic techniques to support the development of the ITRF is an undertaking of the International Earth Rotation and Reference Systems Service (IERS) and its Technique Centres (TC): the International DORIS Service (IDS), International GNSS Service (IGS), International Laser Ranging Service (ILRS), and International VLBI Service for Geodesy and Astrometry (IVS). The IERS also plays a vital role within the larger endeavor of a Global Geodetic Observing System (GGOS, Plag & Pearlman 2009), and the IERS Working Group on Site Survey and Co-location (IERS 2013) is also acting for the GGOS Bureau of Networks and Observations, as well as for IAG Commission 1 Joint Working Group 1.1. With the objective of a unified observation system that supports frame requirements of 1 mm accuracy and 0.1 mm/yr stability (Plag & Pearlman 2009), the role of co-location sites becomes increasingly important. It is therefore imperative that the associated terminology is consistent and well understood throughout the whole user community in order to address remaining uncertainties and identify systematic errors. However, the current nomenclature is not unique and varies between users and techniques (IERS Workshop 2013). To ameliorate the situation we, as representatives of the individual Services IDS, IGS, ILRS, IVS, the ITRS Survey operational entity and NASA's Space Geodesy Project (SGP) in the IERS Working Group on Site Survey and Co-location, promote a terminology that is intended to be specific, yet general enough to cover all existing IERS techniques. We also stress that other instruments and techniques that add value to GGOS, e.g., tide gauges, gravimeters, terrestrial gyroscopes, and altimetry should be able to adopt the terminology and concepts. Any properties that are attributable to electromagnetism in the following text are thus inherited from the space geodetic techniques and should be understood in a more generic sense where applicable.

Motivation

Local ties are geometric vectors measured between reference points of different instruments, including the full covariance information in both temporal and spatial domain. Two general requirements for such points are that they are well defined, and that measurements of them are able to be reproduced. To meet these requirements, it is important to distinguish between the recording unit and the geometric reference point. The observational phase center and the observing instrument's geometry may be affected by electromagnetic surroundings, observational strategies, and instrument imperfections, exemplified by, e.g., pointing errors, elevation cut-offs, or telescope deformations. Whereas phase center offsets, phase center variations and other perturbations of the signals - including those due to instrumental deformations - contribute to the instrument or system error, they do not implicitly affect the relations of the geometrically defined points. When referring to a local tie, we implicitly think of a deliberate on-site action. Surveying with calibrated instruments may be a partial mean to resolve and quantify geometrical instrument variations, and uncertainties of the local/topocentric surveys can put constraints to the analysis of co-located instruments' coordinate time series in different reference frames. Any discrepancy between the topocentric measurements and space geodetic data inter-technique combinations should therefore ideally be contained within the uncertainties of the local tie measurements. Remaining differences between the topocentric local ties and the space geodesy estimates that exceed calibrated uncertainties should therefore rather be interpreted as an unsettled system error than an error in the local tie.

We have general insights as to how thermal expansion affects instrument monuments as well as how tropospheric and ionospheric variations perturb the space geodetic signals, but other effects such as movement of the pedosphere (i.e., the zone of interaction between atmosphere, biosphere, hydrosphere and lithosphere down to lithic contact) with respect to the solid Earth also need to be accounted for in order to reach the desired order of accuracy and stability. With time, we gather new insights and do not know which technical improvements will occur in the future. In order to maintain a consistent time series despite technology updates, instrument changes, etc., each site should therefore designate at least one physical marker such as a brass bolt or the like, to which all observations are related through high precision local surveys and include that in the local tie analysis. Accounting for these aspects, local ties are the vectors that connect the set of points

$$GRP \cup SM$$

where *GRP* denotes the unique geometric reference point of an instrument – reserving the word "reference" for this point only – and SM a point manifested by a site marker that preferably is attached to the lithosphere. Intermediate points, alignments, traverses, network geometries, etc., are not considered local ties per se, but should all be documented as they contribute to the elements in the covariance matrix in various ways.

Resolution

We note that considerable confusion has existed and continues to exist in defining and naming of reference points and local tie measurements used in linking the results of geometric space geodetic techniques contributing to the IERS. We realize that the confusion should be eliminated for a better understanding in discussions on topics related to local tie measurements and of the respective results.

We reiterate the following selected IERS objectives to serve the astronomical, geodetic and geophysical communities by providing

- Earth orientation parameters required to study Earth orientation variations and to transform between the ICRF and the ITRF.
- Geophysical data to interpret time/space variations in the ICRF, ITRF or Earth orientation parameters, and model such variations.
- Standards, constants and models (i.e., conventions) encouraging international adherence.

To fulfill the requirements of a common observing system that will encompass existing IERS techniques as well as other GGOS observation techniques, we interpret the terrestrial component of the reference frames to relate to the lithosphere and request:

1. that each TC defines a unique technique-specific <u>geometric reference point</u> for each contributing instrument
2. that the TCs report their data relating to the geometric reference points mentioned above
3. that each site contributing to the TCs deploys a unique physical <u>site marker</u>, preferably attached to the lithosphere and whose integrity is validated through pillar networks or the like
4. that the IERS Conventions Centre or its GGOS counterpart prescribes <u>models</u> that describe movements of the above mentioned geometric reference points and site markers with respect to the lithosphere, including but not limited to parameters such as station-specific reference temperatures, reference pressures and pedosphere dilatation.

Furthermore, we recommend:

1. that <u>local tie vectors</u> are defined as the relations that include the above mentioned geometric reference points and site markers in order to maintain consistent time series and allow transformations between the technique-specific reference frames
2. that the stations report local tie vectors as defined above, obtained by direct measurements or applying parameters relevant to the models mentioned above.

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