Mapping Matters

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Question: We often hear about ITRF datum; what is it and how does it relate to WGS84 and NAD83?

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Dr. Abdullah: In the April 2010 *PE&RS*, I introduced readers to the International Terrestrial Reference Frame (ITRF), which I used to explain the crustal movement of the Earth and its effect on the measured coordinates. The Earth's tectonic plates are in continuous motion. Such motion causes the measured coordinates of a certain time and place to drift farther and farther from their accurate values. To accurately monitor the crustal and rotational motions of planet Earth, the International Earth Rotation and Reference Systems Service (IERS) introduced the ITRS as a new geocentric reference system. The ITRS is composed of a set of three-dimensional Cartesian coordinates defined as the International Terrestrial Reference Frame (ITRF) – so actually, the datum is the ITRS, not the ITRF.

The ITRF can be understood as a realization (version) of the ITRS. Over the years the IERS published periodic modifications to the ITRS to ensure that surveyors factor crustal movements into their measured position. With each modification of the ITRS, a new ITRF is published. The initial ITRS realization, which was published in 1988 and is referred to as ITRF88, was followed by a series of ITRS realizations referred to as (ITRF89, ITRF90, ITRF97,…, ITRF00, ITRF05, ITRF08). With each new realization, the IERS publishes revised positions and velocities for a worldwide network of several hundred stations. For any geocentric reference system, the most important parameter for determining its accuracy is the distance from the center of its reference ellipsoid to the Earth's center of mass. Scientific evidence shows that the IERS determined the Earth's actual center of mass to 10 cm level, and therefore the ITRF coincides with the Earth's center of mass to Earth within that distance making the ITRS (and therefore the ITRF) the most accurate geocentric reference system ever established. In the early stages (1990s), the U.S. Department of Defense (DoD) realized the advantages of the ITRF as a global, accurate, and reliable reference frame. So they decided to align the World Geodetic System (WGS84), which originally was equivalent to NAD83(86), to follow the realizations of the ITRS or the different ITRF. This alignment caused the WGS84 to coincide with the ITRF to within a few centimeters, so ITRF-based geodetic datum, such as CORS and WGS84, are essentially the same. Several realizations of the WGS84 have evolved since the modernization program started in the 1990s. Among these are WGS84(G730), WGS84(G870), and the latest, WGS84(G1150), which are equivalent to ITRF2000. The "Gxxxx" used in these expressions denotes the GPS week that the DoD adopted the version. Adopting an ITRF-based reference system was a smart move by the DoD, since it establishes an evolving reference system that is accurate and is updated in accordance with the dynamic nature of the Earth's crust. The main reasons behind the high fidelity of the ITRS are as follows:

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1. The use of various observing techniques such as:
   a. Very Long Baseline Interferometry (VLBI)
   b. Lunar Doppler Ranging (LLR)
   c. Satellite Laser Ranging (SLR)
   d. Global Positioning System (GPS)
   e. Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS)
2. The IERS establishes different solutions, each of which are independently computed by well respected scientific organizations around the world. These solutions are either combined or used as checks against each other in order to finely adjust the reference frame.

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Adopting an ITRS-based geodetic datum offers the following advantages:

1. Supports accurate 3D positioning worldwide;
2. Taps into the responsible nature of the IERS for maintaining the ITRS and the ITRF. The IERS continuously revises positions and velocities for several hundred base stations around the globe, resulting in ever evolving reference frames (ITRF88, ITRF89,..., ITRF2000, ITRF2005, ITRF2008);
3. Provides a single standard for collecting, exchanging, and storing geospatial data;
4. Ensures compatibility between surveys, systems, and users of the data on local, state, federal, and global levels;
5. Defines and facilitates the transition to an international standard for datum definition;
6. Provides compatibility with GNSS and GPS (which are based on ITRF) tools and applications;
7. Simplifies users' understanding of datum and datum transformation; and,
8. Prevents waste through reduced replication of data (data multi-utilization) and unnecessary data transformation.

Several countries endorsed and adopted the ITRF as their reference frame and more countries are expected to follow their footsteps as the advantages of ITRF become more widely known. Here in the U.S., we use a frame fixed to North America called the North American Datum of 1983 or NAD83. Many versions have followed the original NAD83(86), including , NAD83(HARN), NAD83(CORS96) and the most recent NAD83(NSRS2007). Each new version of NAD83 introduces new challenges for users because data conversion between timeframes becomes more complicated and less reliable. Although it is geocentric by definition (when the center of the datum is close to the mass center of Earth), NAD83's center (point of origin) was proven to be about 2.2 m away from the actual center of Earth, therefore it is not a true geocentric system like the ITRF.

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Despite all the advantages that the ITRF-based system brings to users, one should mention the one disadvantage that it creates for users in the North American stable plate. Because the ITRF is based on a linear model for time evolution of station coordinates, all points in North America will be assigned a larger than usual horizontal velocity, as it is part of the global model. For example, points in central and eastern parts of the U.S. will have a horizontal velocity between 1 and 2 cm/year although they are located on a stable plate where the velocity is minimal. However, with advancements in future modeling (non-linear) and increased field measurements within the U.S. that are to be incorporated into the model, such concerns diminish with time and adopting an ITRF-based system remains a favorable choice. The U.S. National Geodetic Survey (NGS) is trusted to decide on the future of NAD83. One option would be for the U.S. to join the international community and realign the NAD83 with the latest ITRF. This change may prove wise and could establish the U.S. as a leading example for generations to come.

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