The IERS and Adjustments to Coordinated Universal Time

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Abstract

The International Earth Rotation and Reference Systems Service (IERS) plays a critical role in determining the relationship between Coordinated Universal Time (UTC) and the variable Earth rotation (UT1). Earth orientation parameters (EOPs) that describe the relationship between UT1 and UTC can be determined very accurately with low latency. For real-time users, EOP predictions are provided. The IERS EOP products are available through a variety of methods. The IERS continues to evolve to meet the future needs of its users.

1. Background

The International Earth Rotation and Reference Systems Service (IERS) was established by the International Astronomical Union (IAU) and the International Union of Geodesy and Geophysics (IUGG) in 1987. It began operations on 1 January 1988 and since then, the IERS has been providing the international community with:

- the International Celestial Reference System and its realization, the International Celestial Reference Frame (ICRF);
- the International Terrestrial Reference System and its realization, the International Terrestrial Reference Frame (ITRF);
- Earth orientation parameters (EOPs) that are used to transform between the ICRF and the ITRF;
- Conventions (*i.e.*, standards, models, and constants) used in generating and using reference frames and EOPs;
- Geophysical data to study and understand variations in the reference frames and the Earth's orientation.

2. Time and Earth Rotation

The IERS plays a significant role in the formation of Coordinated Universal Time (UTC) through its determination of EOPs. In particular, the IERS provides the measures and forecasts of a quantity called UT1–UTC. That quantity describes the difference between uniform time, as provided by atomic clocks contributing to the UTC timescale, and the variable Earth rotation angle which is related to UT1.

UTC is formulated by the Bureau International des Poids et Mesures (BIPM) using time comparisons obtained from atomic clocks and is the standard for everyday time usage worldwide. Precise time, such as that made available through UTC, is used in applications as wide ranging as navigation, communication, computer network synchronization, and transaction time tagging. It is a critical element of today's infrastructure. Modern metrological technology permits the accuracy of UTC to be measured in nanoseconds (billionths of a second).

Historically, the Earth's rotation was used to calibrate clocks, but in the 1930s clock technology had advanced to the point that the stability of clocks allowed detection of the variations in the Earth's rotation. Tides and changes in weather and ocean currents are among the causes of variations in the Earth's rotational speed. These effects are only partially predictable necessitating observational measurements to be made on a nearly daily basis. Currently, the Earth's rotation is measured using a worldwide radio telescope network through a technique called Very Long Baseline Interferometry (VLBI) (see http:// http://space-geodesy.nasa.gov/multimedia/VLBIHistoryVideo.html for a brief explanation of VLBI). By fixing the radio antennas to the Earth and observing quasars (distant radio sources), UT1 can be measured to an accuracy of tens of microseconds (millionths of a second).

3. Leap Seconds

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In an effort to provide low-precision UT1 information through UTC, the International Telecommunications Union (ITU) redefined UTC in 1972 by instituting occasional one second adjustment, called leap seconds, to UTC so that |UT1–UTC| will never exceed one second. According to ITU-R TF-460.6:

- "A positive or negative leap-second should be the last second of a UTC month, but first preference is given to the end of December and June, and second preference to the end of March and September."
- "A positive leap-second begins at 23h 59m 60s and ends at 0h 0m 0s of the first day of the following month. In the case of a negative leap-second, 23h 59m 58s will be followed by 0h 0m 0s of the first day of the following month."
- "The IERS should decide upon and announce the introduction of the leap-second, such as an announcement to be made at least eight weeks in advance."

The role of the IERS in determining when to insert leap seconds is a natural extension of its responsibility for monitoring and predicting the quantity UT1–UTC. Since 1972, there have been 25 positive leap seconds.

By keeping the difference between UT1 and UTC less than one second allows those who need only low-accuracy values of UT1 to approximate UT1 with UTC to one-second accuracy. However, for most modern applications, this one-second accuracy is not sufficient; these users rely on the IERS to provide estimates of the difference between UT1 and UTC for real-time applications. The current accuracy of IERS real-time UT1–UTC is more than four orders of magnitude better than can be obtained by assuming UT1≈UTC.

4. IERS Products

IAU and IUGG established the IERS to coordinate the observations of all Earth orientation components. As part of this process, the IERS produces a number of EOP products on different time scales. For real-time users, the IERS combines EOP observations to create daily and four-times-per-day solutions as well as EOP predictions up to a year in advance (http://maia.usno.navy.mil). All IERS products are available free of charge through different various computer transfer protocol.

A complete list of IERS products is available at http://www.iers.org. Among these products are the conventional algorithms and software, published as the IERS Conventions, that users can implement in order to utilize EOP data. All of these IERS Conventions are developed and reviewed by subject matter experts and utilized regularly in geodetic applications, which helps to ensure their quality. These IERS Conventions are made available free of charge through the web sites at http://tai.bipm.org/iers and http://maia.usno.navy.mil/conv2010.

For users that want leap second information, the IERS Bulletin C announces upcoming leap seconds (see http://hpiers.obspm.fr/iers/bul/bulc/bulletinc.dat). In general, the Bulletin C is produced in January and July and announces whether a leap second will be inserted within the next six months. Note that the ITU requires only an announcement "8 weeks in advance" of the potential leap second event.

5. Future Considerations

The IERS continues to look to the future to determine what products will be required by users over the next decade. In May 2013, the IERS held a retreat to plan future products and operations (see http://www.iers.org/nn_128276/IERS/EN/Organization/Workshops/Retreat2013.html). It is initiating plans to create new products and incorporate newer forms of input data. Among those plans is the delivery of real-time EOPs by a transfer protocol to be determined, which would provide UT1 data in a means compatible with UTC dissemination. A real-time UT1 product would provide a straightforward transition path for some users that approximate UT1 with UTC. It also has the advantage that it would provide no-cost UT1 information to UTC users with an improvement of four orders of magnitude in data accuracy.

6. Summary

The IERS has provided data, algorithms, software, and expertise to the scientific and operational communities for more than twenty-five years. To ensure that the IERS products continue to meet the requirements of users into the future, the IERS plans to create new products, using new data, and to deliver products through new methods of data dissemination. The IERS will continue to work with users to provide the needed information to support both scientific and operational endeavors.