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The Network Earth Rotation Service

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Abstract We report

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1 Introduction

Studying the variations in the Earth's rotation has to major goals: scientific and navigational. The scientific goal is to explain the variations in the Earth's rotation on a quantitative level. The navigational goal, considered in a broad sense, is to derive from observations the orientation of the Earth's in the inertial coordinate system at a given interval of time that is needed for practical applications. The navigation task in a broad sense means not only determining the course of a ship, but also solving a wide range of problems related to observations of natural or celestial bodies, for instance pointing a telescope, satellite communication, geolocation, processing space geodesy observations to mention a few. The variations in the Earth's rotation are governed by torques of external bodies and by exchange of the angular momentum between the crust and liquid core, the hydrosphere, and the atmosphere. The latter two factors are stochastic and even if the initial state could be determined with the infinite precision, the accuracy of the Earth' orientation parameter (EOP) forecast will quickly deteriorate with time.

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Since the Earth rotation variations cannot be predicted with the accuracy that is required for a number of applications, it is continuously monitored by observations from the Global Navigational Satellite Systems (GNSS), Satellite Laser Ranging System (SLR), and the Very Long Baseline Interferometry (VLBI). Individual determinations of the EOPs from these techniques are combined and smoothed, and the smoothed equidistant series are distributed to customers. This service is coordinated by the BIH since 1xxx. In 19xx the BIH was renamed to the International Earth's Rotation Service (IERS).

The original Earth's rotation service was based on optical observations that were possible only during good weather, and therefore, inevitably had a significant time lag. The bulletins with the combined EOP series were sent by mail and typically had one to two month latencies. The series were formally extrapolated, but such extrapolation over several months did not have a great value, since the errors of extrapolation increase with the increase of the extrapolation interval. The accuracy in EOP determination was improved by more than two orders of magnitude in 1980s and 1990s after the GNSS, SLR, and VLBI techniques replaced optical observations. However, the procedure of EOP products combination, extrapolation, and delivery to customers did not undergone great changes. The surface mail delivery was replaced with ftp, the latency of rapid EOP products was reduced to several days, but the approaches established in 20th century in general remained the same and became inadequate to the modern informational society.

We see two major deficiencies. A user needs know the Earth orientation either for a given moment in the past for processing old data or at a current moment of time for real time applications, or for a moment of time in a near future. Using existing service, a user needs first, download the EOP series, second, interpolate them, if necessary, extrapolate it, third, compute the Earth's rotation matrix. This requires development of a custom software. Computation of the Earth rotation matrix with the accuracy comparable with accuracy of observational is a complicated procedure. Overzealous IERS activity over last 40 years for changing definitions, notation, and short-lived standards made understanding the algorithm of the Earth rotation matrix computation very difficult even for specialists who works full time in this area. This is the area that requires improvement.

The second deficiency is that the existing algorithms for EOP forecast were historically focused on long-term predictions **refs**., 10–100 days. In our view, considering that the current EOPs are derived with the latency below 24 hours, such predictions have very limited value, since in 10–100 days new measured EOPs will be available.

This motivated us to revise the last step in the processing pipe line of the Earth's rotation service: delivery the EOPs to a customer that would be consistent with the current level of development of informational technology.

Let us consider a simple an analogy. In 1930–1990s, a common way of clock synchronization against UTC was the ear-eye method: radio-stations transmitted 6 sound signals, and a user was supposed to set manually the clock at the moment when he heard the beginning of the sixth pips. This was sufficient for setting a mechanical alarm clock. However, computer clock in modern computers connected with the Internet are synchronized without manual intervention via Network Time Protocol (NTP), which always keeps the internal quarz clock synchronization against UTC within several milliseconds. Unix operating system has system function `time` and the user-level command `date` that brings UTC to user at the current moment of time without a need to do extra work. There is a complicated infrastructure behind the NTP, but the user does not need it to know, except rare cases when the NTP failed or a user needs higher accuracy. In a nutshell, we wanted to developed infrastructure that would return the user UT1, or the Earth's rotation matrix as effortlessly as we get UTC.

First, we revised the procedure of a short-term (up to 48 hours in the future) EOP forecast, using the latest EOP results and the outputs of numerical weather models used for computation of the atmospheric angular momentum. We discuss the procedure for the short-term forecast in section 2 and introduce the algorithm for computation of the AAM in section 3. Second, we have established the Internet service called Network Earth Rotation Service (NERS). Its server and client components are discussed in sections 4 and **??** respectively. We provide results of our validation analysis o NERS in section 6 and provide concluding remarks in section 7.

In the present work, instead of using a traditional notation, polar motion and UT1, we adhere to using Euler angles E_1, E_2, E_3; instead of using notation high-frequency EOP variations and nutation, we call them together harmonic variations of Euler angles[1], and instead of using arcseconds for one component of the EOP and seconds of time for another component, we use radians for all components and rad/s for their rates. polar motion X_p, Y_p and UT1 are related to Euler angle as

(1)

and nutation delay offset in elongation and obliquity, $\delta\psi$ and $\delta\epsilon$ are

(2)

Just to remind, 1 nrad ≈ 0.20 mas ≈ 13.8 μs.

2 Short-term EOP forecast

The technique of optimal EOP forecast depends on the EOP component, accuracy of observations, and desired forecast interval. Let us firstly characterize briefly accuracy and latencies of EOP observations.

3 Algorithm for computation of the Atmospheric Angular Momentum

4 Server part of the Network Earth's Rotation Service

5 Client part of the Network Earth's Rotation Service

6 Validation of the Network Earth's Rotation Service forecast

7 Summary

References

Petrov L (2007) The empirical Earth rotation model from VLBI observations, Astron & Astrophys, 467(1):359–369, doi:10.1051/0004-6361:20065091

[1] strictly speaking they should be called quasi-harmonics variations, since their expansion contains small terms $t \times \cos(t)$, $t \times \sin(t)$, and the argument under cosine and sine contains also term of t^2, but since the contribution of these terms is small, we neglect these subtleties.