# 3.5 Product Centres

## 3.5.1 Earth Orientation Centre

This section presents the activities and main results of the Earth Orientation Centre located at Paris Observatory over the year 2011. According to the IERS Terms of Reference, the Earth Orientation Centre is responsible for monitoring Earth orientation parameters including long term consistency, publications for time dissemination (DUT1) and leap second announcements. Earth Orientation Parameters (EOP: Polar motion, Universal Time (UT1), Length of Day (LOD) and Celestial pole offsets) are available to a broad community of users in various domains such as astronomy, geodesy, geophysics, space sciences and time.

EOPs are firstly collected in the form of combined solutions derived by the Technique Centers (IGS, IVS, ILRS and IDS). Two main solutions are computed by the Earth Orientation Center: a long-term solution (IERS C01) since 1846 and the Bulletin B / C04 given at one-day intervals published monthly with a 30 day delay. Bulletin B is updated in the operational OPA solution.

An important issue is the maintenance of the consistency between the EOP system and both the terrestrial and celestial reference frames. So far, Earth Orientation Parameters and the terrestrial frame are separately computed. This leads to increasing inconsistencies between both systems. At the end of 2009, these inconsistencies were small but significant for polar motion (negligible for the x-pole component and about 50 microarcseconds for the y-pole component). All IERS reference solutions (C01, Bulletin B, C04 as well as Bulletin A derived by the Rapid Service/ Predictions Center, US Naval Observatory) were recomputed and aligned to the EOP solution associated to the current ITRF2008.

### Combined daily series: Bulletin B and 05 C04, statistics over 2010–2011

This section gives statistics (Tables 1 to 3) in term of formal errors and WRMS of the combined technique centres and individual solutions with respect to the combined solution Bulletin B and 08C04 over the period 2010–2011. Only combined solutions derived by the various technique centres (IGS, ILRS, and IVS) are used in the IERS combinations. Statistics concerning individual series are given as a feedback to the analysis centres.

### New format of Bulletin B since January 2010

Bulletin B issued by the IERS EOP Centre was more than 20 years old. Following a survey which was made in 2007 among the scientific community, a new presentation is available since January 2010. The new Bulletin B and its content description are available at <ftp://hpiers.obspm.fr/iers/bul/bulb_new/bulletinb.dat> and <ftp://hpiers.obspm.fr/iers/bul/bulb_new/bulletinb.pdf>.

*Table 1: Estimated accuracies of individual solutions compared to the combined solutions Bulletin B and 05 C04 over 2010–2011. The satellite techniques provide information on the rate of change of Universal Time contaminated by effects due to non modelled orbit node motion. VLBI-based results have been used to minimize drifts in UT estimates.*

| Individual solutions | | Estimated uncertainties | | | |
|---|---|---|---|---|---|
| | | Time | Terrestrial Pole | UT1 LOD | Celestial Pole |
| | | | µas | µs | µas |
| **VLBI – 24 h** | | | | | |
| EOP (AUS) | 01 R 01 | 3–4d | 280 | 12.5 | 160 |
| EOP (BKG) | 03 R 02 | 1–4d | 145 | 9.7 | 76 |
| EOP (GSFC) | 07 R 01 | 1–4d | 115 | 9.8 | 70 |
| EOP (IAA) | 05 R 02 | 1–4d | 150 | 11.9 | 73 |
| EOP (MAO) | 03 R 01 | 1–4d | 160 | 9.7 | 110 |
| EOP (OPA) | 07 R 01 | 1–4d | 345 | 14.2 | 74 |
| EOP (USNO) | 06 R 02 | 1–4d | 171 | 8.4 | 70 |
| EOP(IVS) * | 02 R 01 | 1–4d | 170 | 4.6 | 30 |
| **VLBI – Intensive** | | | | | |
| EOP (BKG) * | 03 R 02 | 1–3 d | | 18.0 | |
| EOP (GSFC) * | 06 R 01 | 1–3 d | | 17.3 | |
| EOP (SPBU) * | 05 R 01 | 1–3 d | | 14.3 | |
| EOP (USNO) * | 05 R 01 | 1–3 d | | 19.1 | |
| **SLR** | | | | | |
| EOP (ASI) | 03 L 02 | 1d | 230 | 54.1 | |
| EOP (IAA) | 02 L 01 | 1d | 190 | 20.6 | |
| EOP (MCC) | 97 L 01 | 1d | 200 | – | |
| EOP (ILRS)* | 05 L 01 | 1d | 170 | 38.4 | |
| **GPS** | | | | | |
| EOP (CODE) | 98 P 01 | 1d | 45 | 11.6 | |
| EOP (EMR) | 96 P 03 | 1d | 60 | 20.9 | |
| EOP (ESOC) | 96 P 01 | 1d | 75 | 13.9 | |
| EOP (GFZ) | 96 P 02 | 1d | 57 | 12.4 | |
| EOP (IAA) | 01 P 01 | 1d | 240 | 34.6 | |
| EOP (JPL) | 96 P 03 | 1d | 60 | 22.1 | |
| EOP (NOAA) | 96 P 01 | 1d | 88 | 12.5 | |
| EOP (SIO) | 96 P 01 | 1d | 55 | 19.2 | |
| EOP (IGR) * | 07 P 01 | 1d | 45 | 7.5 | |
| EOP (IGS) * | 96 P 02 | 1d | 25 | 7.2 | |

*Table 2: Mean and standard deviation in microarcsecond of the differences between various combined techniques solutions and IERS 08C04 over 2010–2011*

| EOP | IGS Comb – IERS 08C04 | | ILRS Comb – IERS 08C04 | | IVS Comb – IERS 08C04 | |
|---|---|---|---|---|---|---|
| | Mean | Standard deviation | Mean | Standard deviation | Mean | Standard deviation |
| X (μas) | –7 | 27 | 12 | 169 | –40 | 181 |
| Y (μas) | 16 | 23 | -22 | 173 | 71 | 170 |
| UT1 (μs) | | | | | 4 | 4.4 |
| LOD (μs) | 0 | 7 | -6 | 38 | | |
| $D\psi \sin\varepsilon$ (μas) | | | | | 1 | 24 |
| $D\psi$ (μas) | | | | | –18 | 27 |

*Table 3: Mean and standard deviation for Pole components and UT1 of the differences between various solutions and Bulletin B over 2010–2011*

| EOP | Unit | Bull A – Bull B | | Comb JPL – Bull B | |
|---|---|---|---|---|---|
| | | Mean | Standard deviation | Mean | Standard deviation |
| X | μas | –8 | 38 | **0** | 58 |
| Y | μas | **16** | 39 | **1** | 36 |
| UT1 | μs | –1 | 11.6 | –4 | 11.9 |

The content of Bulletin B is:

1 – DAILY FINAL VALUES AND PRELIMINARY VALUES OF x, y, UT1–UTC, dX, dY
and their respective uncertainties. Angular unit is milliarcsecond (mas), time unit is millisecond (ms).

2 – DAILY SMOOTHED VALUES OF CELESTIAL POLE OFFSETS (dPsi1980, dEps1980)
with respect to IAU 1980 precession-nutation model and their uncertainties.

3 – EARTH ANGULAR VELOCITY: DAILY VALUES OF LOD, OMEGA AT 0hUTC
LOD: Excess of the Length of day – 86400 s TAI
OMEGA: Earth angular velocity

4 – INFORMATION ON TIME SCALES: TAI–UTC, leap second announcements

5 – SUMMARY OF CONTRIBUTED EARTH ORIENTATION PARAMETERS SERIES

## Reset of Bulletin B and C04 to the new system consistent to ITRF2008, new reference solution since 1 February 2011

Maintaining a high level of consistency between the current EOP solutions with the ITRF is essential in the field of geodynamics and satellite orbit computation. The ITRF2005 was the first rigorous combination ensuring ITRF and EOP consistency, based on time series of station positions and Earth Orientation Parameters (Altamimi et al., 2008). The ITRF2008 has the same characteristics than ITRF2005. Its release was the opportunity to re-align the C04 to the ITRF2008 system. Relative to 05C04, changes in the EOP series consisted in:

1) A negligible bias in x-pole and a bias of about –50 ± 25 microarcseconds in y-pole in the sense of y (08C04) – y (05C04);

2) Changes in UT1–TAI were on the order of 2 microseconds; celestial pole offsets respectively 1, and 17 microarcseconds which are at the level of the WRMS between IVS individual solutions.

Other IERS EOP series (Bulletin B, C01) have been expressed in this new system consistent with ITRF2008. The Rapid Service/Prediction Center solutions (Bulletin A and daily) are as well expressed in the new reference system.

## Content of the 08C04 as of 1 December 2011

According to the IERS Message 198 (<ftp://ftp.iers.org/products/publications/messages/message_198.txt>) and starting on 1 December 2011, the EOP C04 series is now delivered with 30-day latency. In other words, only final definitive values will be included in it.

Users needing a long-term continuous series extending up to a recent date (including rapid solution over the most recent 30 days) have two solutions:

1) Getting the C04 solution extending until the date 30 days back and available at
<ftp://hpiers.obspm.fr/iers/eop/eopc04/eopc04_IAU2000.YY>
where YY is current two digit year

and concatenate it with the Rapid solution (Bulletin A) issued from the Rapid Service/Prediction Center available at: <ftp://maia.usno.navy.mil/ser7/finals2000A.daily>.

Due to differences in the delivery times of the two products, users should exercise caution in blending the files to ensure that there is continuity between C04 and Bulletin A.

2) Getting the new OPA EOP solution consisting of a continuous series derived from the concatenation of the C04 series and the OPA rapid solution available at:
<ftp://hpiers.obspm.fr/iers/series/opa/eopc04_IAU2000>

## Long-term series: C 01 (1846–2012)

EOP(IERS) C 01 is a series of Earth Orientation Parameters given at 0.1 year intervals from 1846 to 1889 (polar motion only) and 0.05 year interval from 1890 until now (polar motion, celestial pole offsets, UT1–UTC since 1962). For many decades, the observations were made using mostly visual and photographic zenith telescopes. Since the advent of the space era in the 1960's, new geodetic techniques were used for geodynamics. Now, the global observing activity involves Very Long Baseline Radio Interferometry (VLBI), Lunar (LLR) and Satellite Laser Ranging (SLR), Global Positioning System (GPS) and more recently DORIS.

The C 01 series was recomputed in the course of 2011 to be consistent with the reference system associated with ITRF2008. It is a composite series based on following temporal solutions:

1846–1899: Fedorov et al. (1972) polar motion solution derived from three series of absolute declination programs (Pulkovo, Greenwich, Washington).

1900–1961: Vondrak et al. (1995) solution derived from optical astrometry analyses based on the Hipparcos reference frame. The series gives polar motion, celestial pole offsets and Universal Time (since 1956).

1962–2012: BIH and IERS solutions (BIH and IERS annual reports).

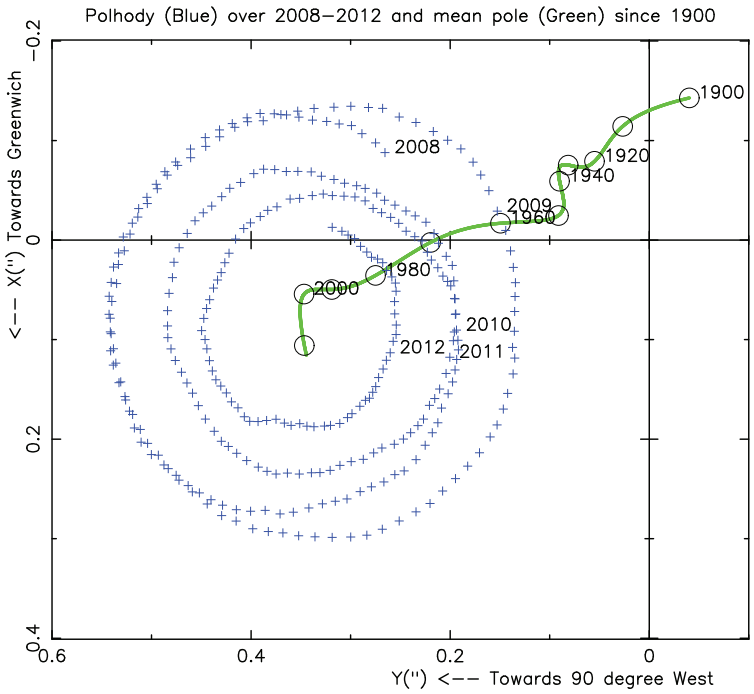



*Fig. 1: Mean polar motion over 1900–2012 and IERS C04 polhody over 2008–2012*

## Mean Pole with respect to the IERS reference origin

The analyses of the observations of space geodesy require performing the transformation between both terrestrial and celestial frames via the Earth orientation parameters. Gravity field models include the tesseral coefficients C21 and S21 coefficients. These terms describe the position of the Earth's figure axis with respect to the Terrestrial Reference Frame. This axis should coincide with the observed position of the rotation pole averaged over the same time period.

The mean polar motion is affected by a long-term drift westward (direction 70.7 degree West, rate: 4.2 mas/yr). The mean rotation axis with respect to the IERS Terrestrial Reference Frame can be considered as the long-term trend obtained after filtering out the Chandler and seasonal terms, every year from 1900 to 2012 (Shiskin et al., 1965). Figure 1 represents the polar motion over 2008–2012 and the path of the mean pole since 1900. The coefficients of the IERS (2010) mean pole model are available in Conventions 2010 (Petit and Luzum, 2010). The corresponding table is also available at the following address: <http://hpiers.obspm.fr/eop-pc/>.

After two years, it was interesting to match the extrapolated values and the updated mean pole time series. Table 4 and Figures 2a and 2b thereafter give the IERS mean pole components compared to the fitted polynomial and their differences which appear to remain limited to a couple of mas over the extrapolated period 2010–2012 .

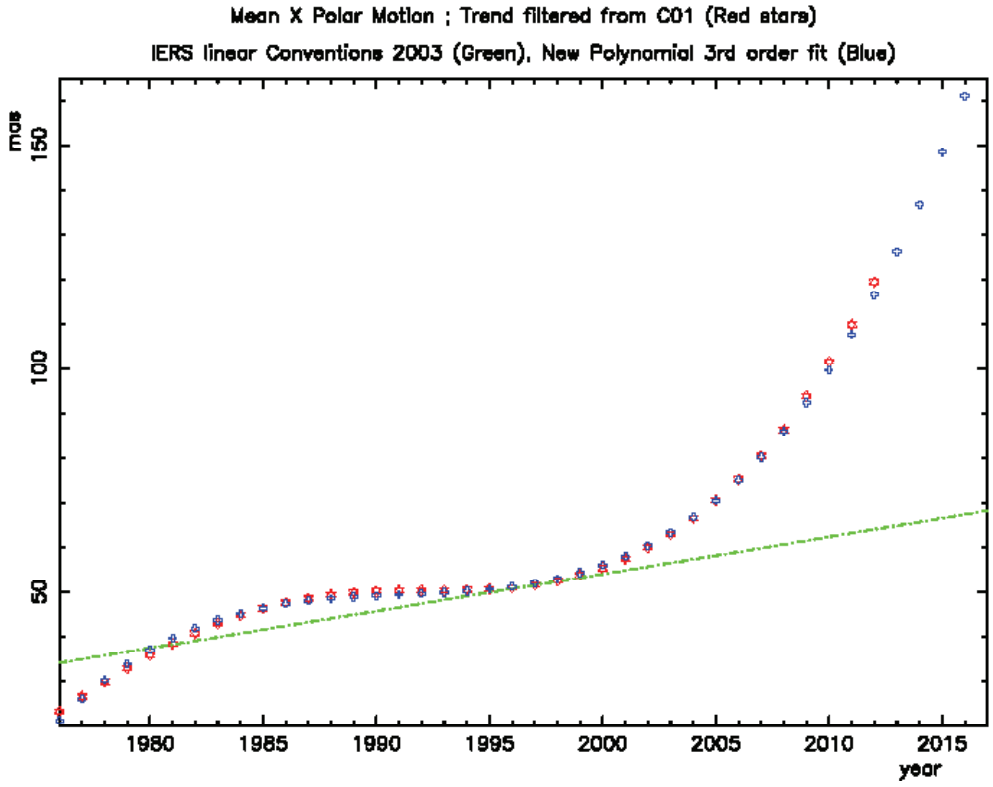
## Leap second issue. Results of the IERS survey made in summer 2011 about a possible UTC re-definition

The Earth Orientation Center is responsible for the prediction and announcement of the leap second (Bulletin C) as well as the announcement of the value of DUT1 truncated at 0.1s for transmission with time signals. This system introduced in 1972, is a good compromise to maintain UTC coupled with UT1 (Earth rotation). However some communities are arguing that this system is becoming increasingly problematic for a vast range of modern navigational and communication systems, such as satellite navigation, financial services, air traffic control and the internet.

A first survey made in 2002 within the IERS showed that 89% of users were satisfied by the current determination of UTC, including leap seconds introductions. With the increasing number of users belonging to the various communities, it was felt necessary to make a new survey to find out the strength of opinion for maintaining or changing the present system before the proposal of redefining UTC be discussed at the ITU-R meeting held in Geneva in January 2012 (Gambis et al., 2012).

*Table 4: IERS mean pole components compared to the fitted polynomial and their differences which remain limited to a couple of mas over the extrapolated period.*

| Year | X-Pole (mas) | | | Y-Pole (mas) | | |
|---|---|---|---|---|---|---|
| | Data | Polynomial fit | Difference in mas | Data | Polynomial fit | Difference in mas |
| 1976 | 23.257 | 21.157 | 2.100 | 254.129 | 254.139 | -0.010 |
| 1977 | 26.603 | 25.966 | 0.637 | 259.513 | 259.467 | 0.046 |
| 1978 | 29.817 | 30.173 | -0.356 | 264.787 | 264.706 | 0.081 |
| 1979 | 32.868 | 33.822 | -0.954 | 269.946 | 269.850 | 0.096 |
| 1980 | 35.725 | 36.954 | -1.229 | 274.981 | 274.894 | 0.087 |
| 1981 | 38.360 | 39.611 | -1.251 | 279.891 | 279.832 | 0.059 |
| 1982 | 40.751 | 41.836 | -1.085 | 284.672 | 284.660 | 0.012 |
| 1983 | 42.876 | 43.671 | -0.795 | 289.326 | 289.370 | -0.044 |
| 1984 | 44.719 | 45.157 | -0.438 | 293.858 | 293.959 | -0.101 |
| 1985 | 46.274 | 46.337 | -0.063 | 298.273 | 298.420 | -0.147 |
| 1986 | 47.540 | 47.254 | 0.286 | 302.575 | 302.749 | -0.174 |
| 1987 | 48.528 | 47.948 | 0.580 | 306.765 | 306.939 | -0.174 |
| 1988 | 49.256 | 48.463 | 0.793 | 310.839 | 310.985 | -0.146 |
| 1989 | 49.755 | 48.841 | 0.914 | 314.789 | 314.882 | -0.093 |
| 1990 | 50.064 | 49.123 | 0.941 | 318.601 | 318.625 | -0.024 |
| 1991 | 50.232 | 49.352 | 0.880 | 322.261 | 322.207 | 0.054 |
| 1992 | 50.312 | 49.570 | 0.742 | 325.751 | 325.624 | 0.127 |
| 1993 | 50.366 | 49.819 | 0.547 | 329.055 | 328.870 | 0.185 |
| 1994 | 50.458 | 50.141 | 0.317 | 332.160 | 331.940 | 0.220 |
| 1995 | 50.655 | 50.579 | 0.076 | 335.056 | 334.827 | 0.229 |
| 1996 | 51.020 | 51.175 | -0.155 | 337.737 | 337.527 | 0.210 |
| 1997 | 51.617 | 51.970 | -0.353 | 340.202 | 340.035 | 0.167 |
| 1998 | 52.502 | 53.006 | -0.504 | 342.450 | 342.344 | 0.106 |
| 1999 | 53.731 | 54.327 | -0.596 | 344.486 | 344.450 | 0.036 |
| 2000 | 55.349 | 55.974 | -0.625 | 346.312 | 346.346 | -0.034 |
| 2001 | 57.400 | 57.989 | -0.589 | 347.931 | 348.028 | -0.097 |
| 2002 | 59.919 | 60.415 | -0.496 | 349.344 | 349.490 | -0.146 |
| 2003 | 62.939 | 63.293 | -0.354 | 350.549 | 350.726 | -0.177 |
| 2004 | 66.487 | 66.666 | -0.179 | 351.543 | 351.731 | -0.188 |
| 2005 | 70.583 | 70.575 | 0.008 | 352.322 | 352.500 | -0.178 |
| 2006 | 75.244 | 75.064 | 0.180 | 351.881 | 353.027 | -1.146 |
| 2007 | 80.481 | 80.174 | 0.307 | 351.918 | 353.307 | -1.389 |
| 2008 | 86.302 | 85.947 | 0.355 | 351.830 | 353.335 | -1.505 |
| 2009 | 93.908 | 92.425 | 1.483 | 351.516 | 353.104 | -1.588 |
| 2010 | 101.602 | 99.651 | 1.951 | 350.905 | 352.609 | -1.704 |
| 2011 | 109.902 | 107.667 | 2.235 | 350.105 | 351.845 | -1.740 |
| 2012 | 119.502 | 116.514 | 2.988 | 348.925 | 350.807 | -1.882 |



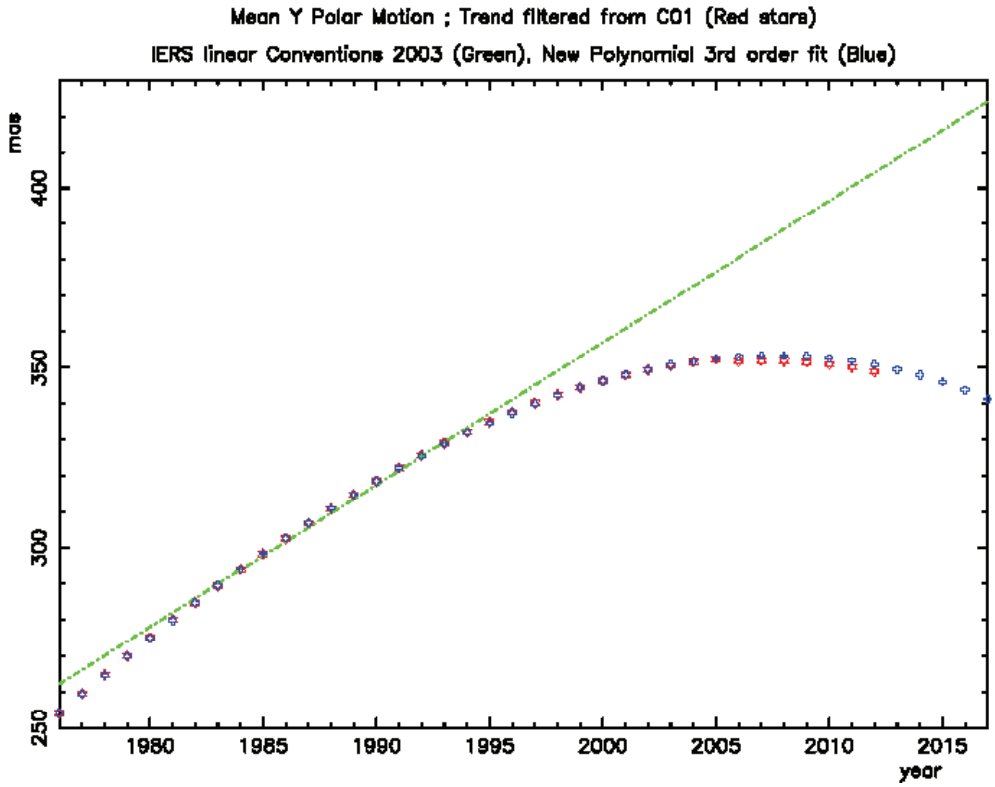




*Fig. 2a and 2b: Plots showing the good agreement between the data and the fitted polynomial. Their differences remain limited to a couple of mas over the extrapolated period 2010–2012.*

**Questionnaire to survey opinion concerning a possible redefinition of UTC**

Universal Time, the conventional measure of Earth rotation is the traditional basis for civil timekeeping. Clocks worldwide are synchronized via Coordinated Universal Time (UTC), an atomic time scale recommended by the Radiocommunications Sector of the International Telecommunications Union (ITU-R) and calculated by the Bureau International des Poids et Mesures (BIPM) on the basis of atomic clock data from around the world.

UTC is computed from TAI by the introduction of leap seconds such that UTC is maintained within 1 second of UT1. Since 1972, these leap seconds have been added on December 31 or June 30, at the rate of about one every 18 months. Since 1 July 2012, 0:00 UTC, UTC–TAI= –35s.

The objective of the survey was to find out the strength of opinion for maintaining or changing the present system.

***The options***

1. I am satisfied with the current definition of UTC which includes leap second adjustments
2. I prefer that UTC be redefined as a uniformly increasing atomic timescale without leap seconds and constantly offset from TAI. Consequently, UTC would increasingly diverge from the Earth's rotation.
3. I have another preference
4. I have no opinion or preference
5. Comments

***Results***

Figures 3a to 3d give respectively the global results and statistics concerning the domains of activities as well as the number of answers per country.

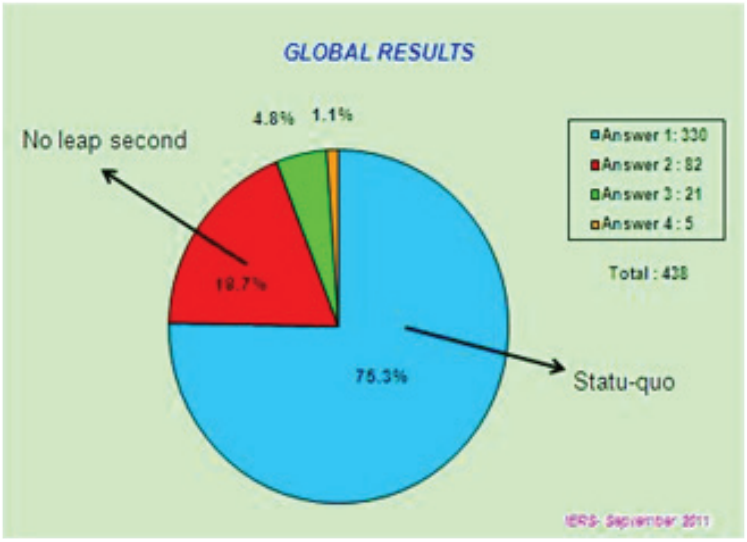



*Fig. 3a: Global results*

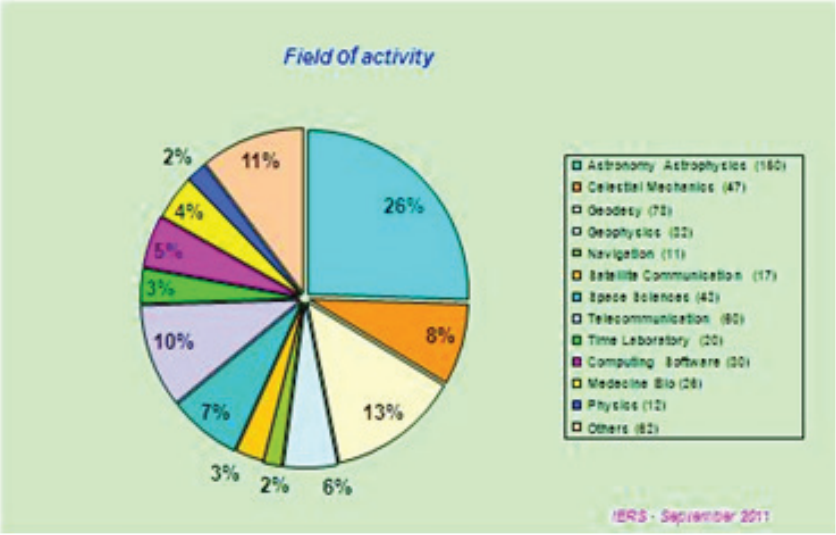



*Fig. 3b: Field of activities*

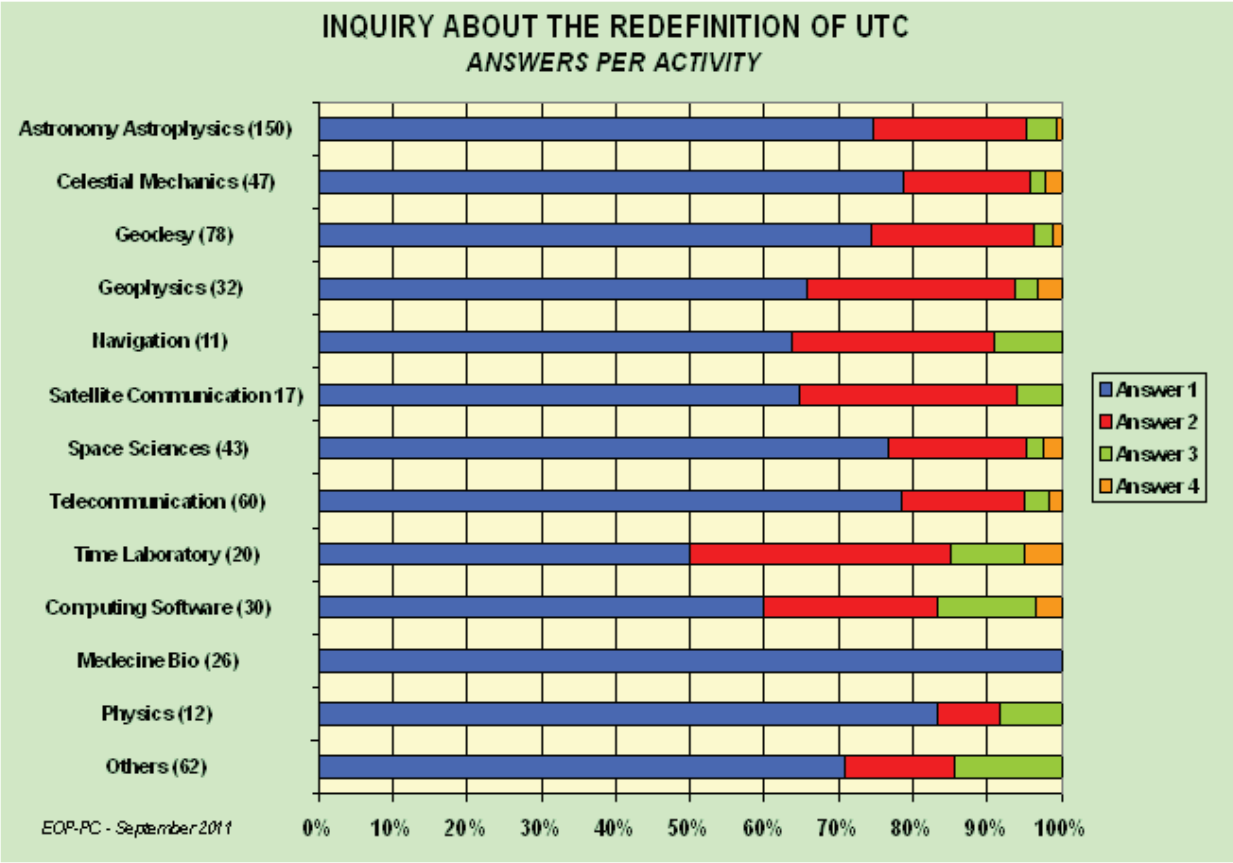



*Fig. 3c: Answers per field of activity*

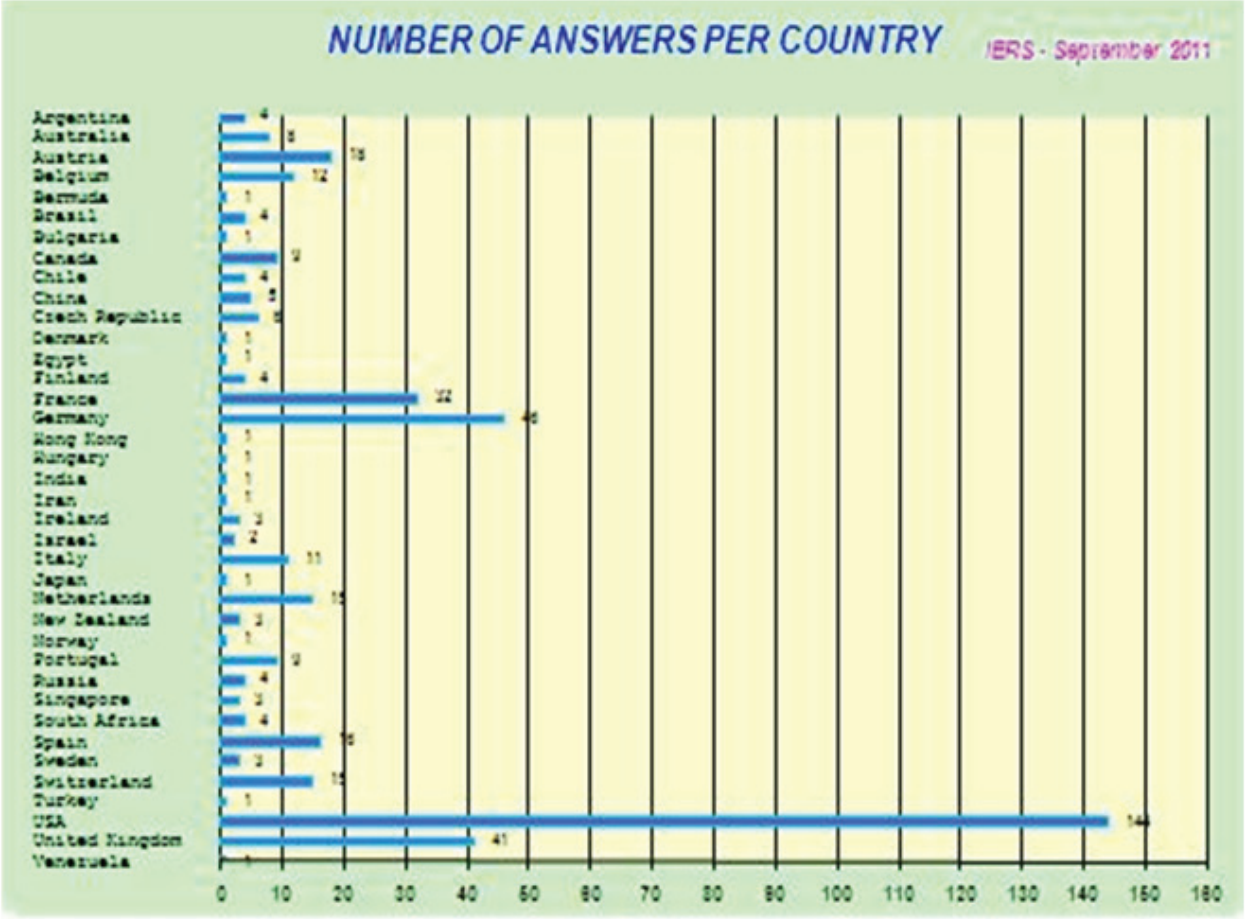



*Fig. 3d: Statistics concerning the number of answers per country*

***Summary*** The statistics mostly reflect the statements of communities of time scales users. Over the 447 answers, about 75 % are for the statu quo, i.e. no change in the current definition including leap seconds. 19 % for switching to the new UTC definition, i.e. continuous time scale no leap second, 5% for another solution mostly requiring the prediction of the leap second with a longer schedule in advance. Let us note that globally and except for the time community where 50% are for the statu quo, the rate of users for and opposite to the statu quo is similar with a majority for statu quo and this whatever the domain of activity. More details are given in Gambis et al. (2011).

Answers and comments to the questionnaire are still available at the following web site:

<http://hpiers.obspm.fr/eop-pc/questionnaire/result.php>

## Redefinition of UTC. January 2012: the leap second decision is postponed to 2015

After years of discussions within the scientific community, a proposal to fundamentally redefine UTC without leap second was discussed in January 2012 at the International Telecommunication Union (ITU) in Geneva. Delegates of 103 countries over a total of 193 countries were unable to reach a consensus, so moving the matter to a meeting in 2015. Japan, Italy, Mexico and France all supported the United States' stance on losing the leap second, while Germany and Canada, like the UK, wanted the extra second to stay.

As a result of the discussions which took place, the ITU decided that more research was needed to consider the broader social implications of losing the leap second before a decision could be taken.

More understanding on the consequences of ending the link between UTC (Coordinated Universal Time) and solar time is needed before a final decision be taken.

The ITU suggested that a study group should investigate the issue, before presenting any proposal at the next World Radio Conference in 2015. It means that for now, the world's time will continue to be linked to the Earth's rotation.

The last leap second was added on 30 June 2012.

## Dissemination of UT1–UTC through the use of virtual observatory

Information concerning UT1–UTC and the occurrence of the leap seconds are currently made available via IERS bulletins (Bulletin D and C) sent to users in ASCII format. However, this old-fashioned procedure does not satisfy automatic systems. We have investigated the way to develop a new service based on the concept of Virtual Observatory (VO). This concept, provided by the International Virtual Observatory Alliance (IVOA), allows scientists and the public to access and retrieve UT1–UTC information using on-line distributed computational resources. We derive the concept, using the XML-based VO Table format to build this UT1–UTC dedicated new service (Deleflie et al., 2011).

The scientific community working in different field and requiring in particular UT1–UTC on a regular and reliable basis can benefit from the VO concept mainly through two points. On the one hand, the concept of metadata allows to make available a single file with a description. Such tools can give a good visibility of earth orientation parameters as well as UT1–UTC derived by the IERS.

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| | |
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