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Abstract

In 2002 the OPAR Analysis Center activities focused, on the one hand, on the compliance of GLORIA software with the IAU 2000 resolutions. Various tests were performed to compare the classical and the new paradigm in the expression of the transformation from a geocentric frame to a celestial one. On the other hand, we continued the celestial frame stability analyses by studying statistical schemes to select a subset of stable objects to be used for the ICRF maintenance and the monitoring of the Earth's rotation.

1. GLORIA Software Update

The analysis of an Earth based observation of a celestial object requires an astrometric model to express the transformation from a geocentric terrestrial frame to a geocentric celestial one. One of the resolutions adopted by the XXIV General Assembly of the IAU (Manchester, August 2000), recommends the use of a new approach referring to the non-rotating origin on the equator of date, proposed by Guinot in 1979 [8], and using the celestial coordinates of the CIP [1], instead of the classical transformation which refers to the equinox of date and uses classical precession and nutation quantities.

The new transformation as well as the classical one were implemented in GLORIA in the early 1990s when the software was constructed. To comply with the 2000 IAU resolutions, the software was updated for both the new and the classical transformation following the IERS Conventions (2000) [9].

For the new paradigm, only an update was necessary of the routine that computes the coordinate (X, Y) of the Celestial Intermediate Pole (CIP) and the quantity **s** using the new developments [2] based on the IAU 2000 A model for precession-nutation. For the classical approach the precession matrix computed from the angles ϵ_0, ψ_A, ϵ_A, χ_A of Lieske *et al.* [10] together with precession corrections and offsets of the direction of the CIP at J2000 were implemented. The routine that computes the nutation matrix was updated using the IAU 2000 A model [11] and the GST routine was modified to include the IAU 2000 A precession adjustments and complementary terms in the equation of equinoxes [2].

Using the GLORIA software, various tests have been performed to verify the level of agreement between the two paradigms on the 2001 Iris Intensive sessions and the 1999 NEOS sessions [7]. The analyses showed differences less than 0.2 μas in x_p, y_p, $d\psi$ *and* $d\epsilon$, the mean values of the standard errors are 68, 59, 54 and 53 μas respectively. The differences reached 0.15 μas for UT1-UTC with a mean standard errors of 47 μas.

2. Selecting Stable Radio Sources

In a paper submitted to A&A [3] we study statistical schemes to select a subset of objects that would be used for the maintenance of the ICRF and the monitoring of the Earth's rotation. The study is based on the series of individual source coordinates derived by Fey [4] over 1979-2002.

The time series of source coordinates were obtained in three parallel analyses of the VLBI observing sessions up to May 2002. Each analysis derives time series of coordinates per session, for one third of the sources, the other two thirds being treated as "global" (i.e. with fixed positions over the total observation span). Each analysis includes a no-net-rotation (NNR) condition with respect to ICRF. To avoid inconsistencies that are due to the NNR condition realization in the three analyses, and that reach the level of 50 μas, we consider here for each source the time series of its coordinates referred to its global weighted mean.

An earlier study [6] has shown that the improvements in VLBI technology, the development of the observing network and the extension of the set of observed objects that took place in operational astrogeodetic VLBI brought the astrometric results to its current precision level towards the end of the first decade. Therefore, the selection schemes under study are applied to data after 1989.5, i.e. 3.1 million observations of 707 sources, representing 87% of the total data set.

A set of stable sources is selected in a two-step process, as follows.

1. A first selection is made on the basis of continuity criteria for one-year weighted average coordinates.
   (a) Length of observation period longer than five years.
   (b) More than two observations of the source in a given session.
   (c) One-year average coordinates based on at least three sessions.
   (d) Not more than 2 successive years with no observations, given conditions *b, c* are met.
   (e) At least half of the one-year averages available.
2. The time series of yearly values are then analysed in order to derive
   (a) a linear drift (least squares estimation);
   (b) the Allan standard deviation of a one-year sampling time.

For each local coordinate ($\alpha\cos\delta$ and δ), two partial indices are defined, as shown in Table 1. The normalized linear drift is the absolute value of the least-square derived linear drift divided by its formal uncertainty. The partial stability indices range from 1 (most stable) through 3 (least stable). Note the rejection value (10) associated to very large drifts or standard deviations. The global stability index is defined as the average of the partial indices for $\alpha\cos\delta$ and δ, i.e. four values per source. The stable sources are those which get a stablity index ≤ 2.5.

Out of the 362 preselected sources the stability scheme detects 199 stable ones, a number to be compared to the 212 defining sources in the ICRF. To test their efficiency with respect to the maintenance of the axes of the celestial reference frame that they materialize, we consider the 13 yearly differential reference frames (1990.0 - 2002.0) that are formed by the set of stable sources observed for every year. The yearly differential rotation angles $A_1(y)$, $A_2(y)$, $A_3(y)$ around the axes of the equatorial coordinate system for year y are then computed for the 13 years.

Table 1. Partial stability criteria. The values range from 1 (best) through 3 (worse), with a rejection value of 10.

Statistics	Threshold	Partial index
Allan Standard deviation (AlSd)		
	AlSd $\leq$ 100 μas	1
	100 μas $\leq$ AlSd $\leq$ 200 μas	2
	200 μas $\leq$ AlSd $\leq$ 300 μas	3
	AlSd $\geq$ 300 μas	10
|Drift| (Vel)		
	Vel $\leq$ 10 μas/year	1
	Vel $\geq$ 50 μas/year	10
|Normalized drift| (Nvl)		
	Nvl $\leq$ 1	1
	1 $\leq$ Nvl $\leq$ 3	2
	Nvl $\geq$ 3	3

Table 2 lists efficiency estimates for the selected sources, and for the ICRF defining sources. These estimates are the usual standard deviation that characterizes the scattering of the sets of rotation angles, and their Allan standard deviations for one-year and four-year sampling times that characterize their stability in time. Note that if the time series of the rotation angles has white noise, the four-year Allan standard deviation will be equal to half the one-year one (square root of one fourth in sampling time). In the case of flicker noise, both values will be equal.

Table 2. Scattering and stability of rotation angles of yearly reference frames based on 1) the 212 ICRF defining sources and 2) the 199 sources detected as stable over 1990-2002.

Source selection scheme	Nb of sources kept	Std dev. μas	Allan Std dev. 1 year μas	4 years μas
ICRF Defining	212	25.6	26.0	27.6
1990-2002 stable	199	10.8	9.4	5.9

When compared to the current ICRF defining sources, the selection scheme developed in this study achieves improved time stability of yearly reference frames. The improvement is particularly striking in the long term. This stability improvement implies improved internal consistency too.

Table 3 gives the relationship of the global stability index with two ICRF qualifiers: the source status (defining/candidate/other) and structure index computed by Fey and Charlot [5] on the basis of one map obtained during the time span covered by this study. The latter qualifies the level of position disturbance expected at the date of the map (1 for the less disturbed, 4 for the most disturbed).

Table 3. Stability index and ICRF source qualifiers

Stab.	Source status			Structure index		
index	Def.	Can.	Oth.	1	2	3-4
1	33	26	15	53	21	12
2	48	42	34	83	33	14
3	2	1	4	17	12	8
4	58	61	34	79	32	19

3. Summary

The update of the GLORIA software to comply with the IAU 2000 resolutions was made. The comparisons between the classical and the new approach showed an agreement better than 0.5 μas on estimated EOP.

We proposed a statistical scheme to select a subset of stable objects for the ICRF maintenance. Compared to the ICRF selection, it rescues a number of sources that are in fact useful for maintaining the ICRF axes directions.

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