Paris Observatory Analysis Center OPAR: Report on Activities January 1998 - March 1999

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Abstract

The OPAR Analysis Center, its organisation and technical means are briefly presented. The general scientific and operational aims of the Analysis Center are summarized. The current state of two projects that were developed during 1998 and up to 1999 March is described: the operational determination of UT1-UTC from the intensive sessions, and the studies of the stability of the celestial reference frame.

1. The OPAR Analysis Center

The team

The analysis center is run by the following team: A.-M. Gontier is the head of the group, N. Essaïfi is in charge of all the technical and database aspects, M. Feissel is participating in the scientific developments, D. Jean-Alexis is in charge of the operational analysis. There are two associated members, M. Bougeard and D. Gambis.

Characteristics of the analyses

Analyses are performed using the software GLORIA (GLObal Radio Interferometry Analysis) developed at Paris Observatory. The software package has available a number of models, including those recommended in the IERS Conventions (1996) [9]. The GLORIA modelling was compared in detail with that of MODEST [4]. The two models agree within 1 ps on delays and 1 fs/s on delay rates.

The solve segment of the software uses the SRIFT algorithm. The input data are extracted from the Calc VLBI database files (delay, delay rate), collected automatically from an IVS Data Center, preferably the Paris Observatory one. The complete observation/results database is managed with Oracle system. The computer used to perform analyses is an HP735 under Unix that will be replaced, in the middle of 1999, by an HPC200.

Main objectives of the Analysis Center

Already operational:

- Operational calculations for the Earth's orientation (intensive sessions).
- Studies of the celestial reference frame.
- Software development and documentation.

Under development:

- Operational calculations for the Earth's orientation (24h sessions).
- Multi-week operational calculations for the terrestrial frame.

Further plans:

- Provide feedback about station performance.
- Perform global, multi-year analyses.
- Participate in multi-technique combination projects.

2. Analysis of the Intensive Sessions

Results for 1998-1999

The IRIS Intensive VLBI observations obtained over 1998-1999 on a single baseline have been analysed. The program consists of 20 daily observations of about 16 sources observed on a single baseline. The following stations are used:

40441S007	Greenbank	Jan-Dec	4443 observations kept
14201S004	Wettzell	Jan-Fev, May-Jun	3947 observations kept
12734S005	Matera	Mar-Apr	563 observations kept
40408S002	Gilcreek	Jun, Oct, Nov	137 observations kept

Every two months the list of observed sources is changed except for five of them. This schedule results in two month batches with nearly constant geometry and sidereal time of observation; every Saturday, the schedule for the next bi-month is observed in addition to the current one. The observation scheme is optimised for the determination of universal time (UT1-UTC). With the available observations the four other parameters which can be estimated together with UT1-UTC from one session are the clock offset and the clock rate between the two stations, and a tropospheric zenith delay for each station.

The first date of analysis is 1998 JAN 03 (MJD: 50816.8). The data analysis uses as adopted references the ITRF97 and its velocity field for the terrestrial frame, the ICRF for the celestial frame, the EOP(IERS) C 04 series for the pole coordinates (x_{pm}, y_{pm}) and the IERS(1996) Theory of Precession/Nutation [9] referred to the ICRF [2] for the celestial pole offsets (dψ, dϵ). The UT1 results have no diurnal/semi diurnal variations (taken off using the Ray 1995 model [9]). The other modelisations are: the IERS TN 13 model [10] for the solid Earth tides, the Scherneck model [9] for ocean loading and the Niell model [11] for the troposphere mapping function.

Statistical editing of observations results in the deweighting of 15% of the observations in the average. The estimation of UT1-UTC obtained from this analysis is shown in figure 1. The global rms postfit residuals is 45 ps. The mean difference of the series with EOP(IERS) C 04 is equivalent to 0.1 mas.

Sensitivity to the adopted references

Because of the minimal geometry of a one-hour observing session, the UT1 results are expected to be sensitive to the a priori references that are adopted in the analysis as well as to the particular set of sources observed [4, 5]. Our approach is to adopt entirely the IERS references. In practice this can be done in several ways. A series of tests was conducted during 1998 to evaluate the influence of the choice of references. The successive experiments (Table 1) concerned the terrestrial frame (including the site velocity field) and the celestial pole offsets.

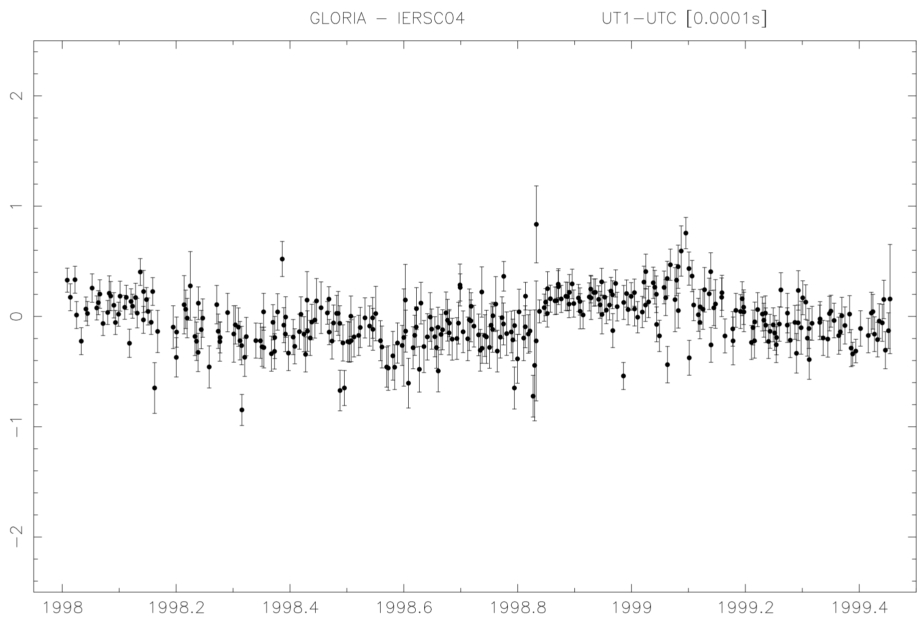

Figure 1. Estimated UT1-UTC with respect to EOP(IERS) C 04 for 1998-1999.

Table 1. Sets of a priori fixed references: terrestrial reference frame and celestial pole offsets. The celestial reference frame and the coordinates of the pole were held respectively to the ICRF and EOP(IERS) C 04. The combination corresponding to figure 1 is set #5.

	terrestrial frame		celestial pole offset
1	**ITRF94 (epoch 1993.0)**	NNR_Nuvel1A	EOP(IERS) C 04
2	**ITRF96 (epoch 1997.0)**	NNR_Nuvel1A	**EOP(IERS) C 04**
3	**ITRF96** (epoch 1997.0)	NNR_Nuvel1A	**IERS (1996) model**
4	**ITRF97** (epoch 1997.0)	**NNR_Nuvel1A**	IERS (1996) model
5	ITRF97 (epoch 1997.0)	**velocity field**	IERS (1996) model

The effects of the changes are summarized in Figure 2 where the discrepancy of the estimated UT1-UTC with EOP(IERS) C 04 are plotted under the form of weighted means for the six schedules implemented in 1998. The error bars are the standard errors of the means. Each point results from all observations of the same schedule, be it during the main time frame, or on the Saturdays in the previous schedule time frame.

The change from the sets of a prioris #1 to #2 (change of ITRF and of reference epoch for the velocities) is particularly large (30 microseconds) for the second bi-month, the only one in which Matera is used–its predicted coordinates change by about 2 cm, both in X and in Z. The rms post-fit residuals decrease by 5-10% in experiment #2. These effects suggest that the NNR_Nuvel1A velocities are not optimal to model the observations. The next change (#2, #3) consists in replacing an operational series of the celestial pole offsets by the recommended model. The differences of the estimated UT1-UTC with IERS become more consistent (decrease of the error bars by 25-30%). The results of experiments #3 and #4 suggest the presence of a seasonal difference. However, the

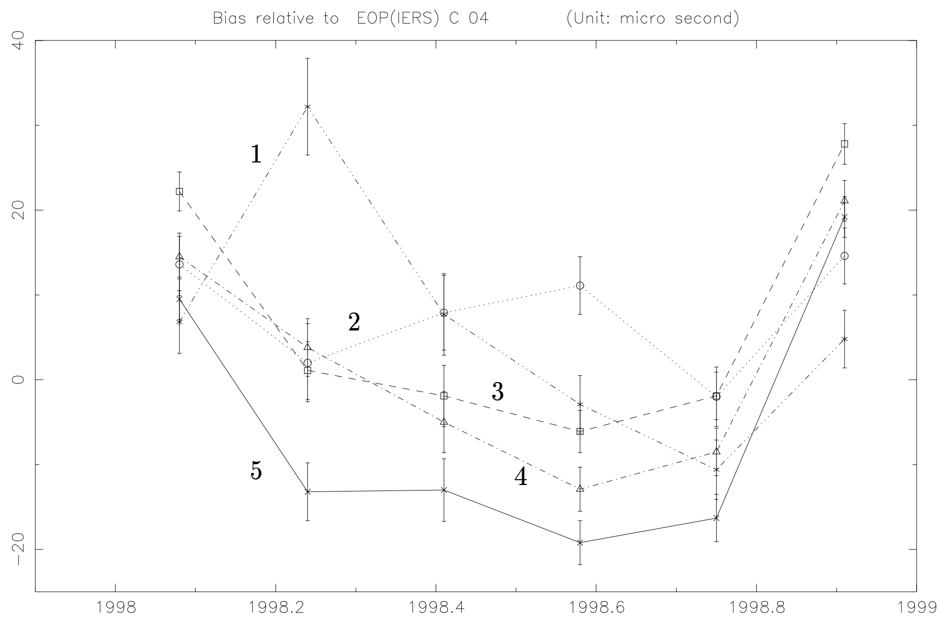

Figure 2. Weighted means of the discrepancy between estimated UT1-UTC and EOP(IERS) C 04 for the five experiments.

last change (#4, #5), that consists in the replacement of the NNR_Nuvel1A velocity field by the one determined with the ITRF, shows a different structure: the adoption of observed velocities changes by 8 microseconds the level of results involving Matera, and the possibility of systematic differences per bi-month becomes more probable. In the investigation described in the next paragraph, we found that several sources in each bi-month schedule have positions discrepancies in 1998 in the range 0.3-0.8 mas. This changes may explain part of the biases in UT1.

3. Stability of Radio Source Positions

After the adoption of ICRS by the IAU [2], studies are necessary to assess the stability of the ICRF and to prepare its future revision. This study is based on a series of source positions per session computed by M. Eubanks (ftp: casa.usno.navy.mil/navnet/frame20.arcs.iers). A total of 75000 individual positions are available for 610 sources from August 1979 through March 1999. The positions per session are expressed in a unique reference frame that is close to the ICRF. A number of sources have an observational history dense enough to build continuous time series of coordinates at a constant time-interval (e.g. 0.5 year, 1.0 year).

Figure 3 show examples of the time evolution of coordinates for three of the defining sources of ICRF, 1308+326, 1606+106, and 2145+067, under the form of weighted yearly averages referred to their respective means over 1983-1999. The error bars shown are the standard errors of the averages. The numbers of observations available each year are also shown in the plot. Those three sources were chosen because they were mentioned as having potential stability problems in the discussions for preparing a new analysis of the celestial reference frame (study group chaired by C. Ma).

A distinct feature of these time series, that is also true for the other sources, is the continuous improvement in quality with time, as can be seen from the error bars of the yearly averages. Results after the start of 1990 are quite better than those in the earlier period. However, instabilities with sizes several times the error bars are also present. This calls for a systematic study of the time series of coordinates in order to derive a statistical qualification of their time-stability.

It is reminded that the sources published with the ICRF [5] were categorized as *defining* for those with the most precise and accurate coordinates, *candidates* for those that were assumed suitable for precise astrometric purposes but need additional observations, and *other* for those judged not suitable for precise astrometric reference due to large variability in the emission structure or other observational problems, even if they had a rich observational history. This original classification is based on a number of quality criteria, such as quality of data and observational history, consistency of coordinates derived from subsets of data, and repercussions of source structure. Due to the data available, in particular source structure mapping at a single epoch, these criteria involved little consideration of time evolution.

The following is an illustration of a complementary approach, based on the Allan variance analysis [1]. In a few words, this technique allows to distinguish characteristic time variability spectra, such as white noise, flicker noise and random walk. It is applied to 65 sources for which a continous series of coordinates at 0.5 year interval could be built over 1990-1999. The results are shown in Table 2. Considering the time span of available good quality data, this qualification of stability is valid up to about five years. For comparison with the existing categories, the results are shown separately for the *Defining*, *Candidate*, and *Other* sources, roughly in decreasing order of stability. Most of the sources show a white noise spectrum over the time span studied. In such a situation, acumulating data should help improving progressively the coordinates. For the minority of sources that are found to have a flicker noise spectrum, extending the time span of observations are not expected to result in the stabilization of the estimated coordinates.

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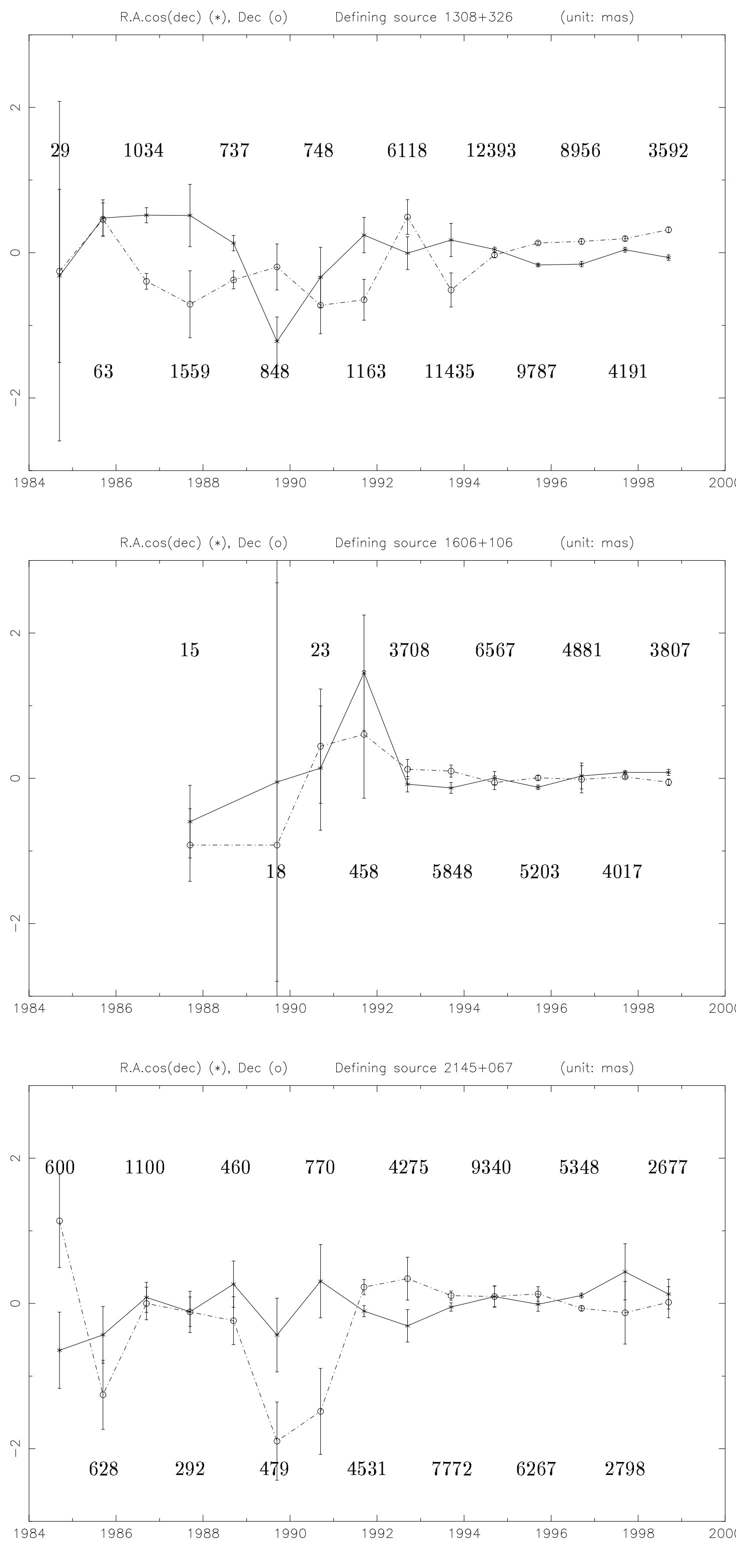

Figure 3. Yearly average coordinates for three defining sources, 1984-1999. The numbers of observations are given alternatively up and down for each year

Table 2. Stability for a one-year sampling time (unit: μas) and spectral type of radio source instabilities (1990-1999) in Right Ascension *cos(declination) and in declination.

Source	stability μas σ_α	σ_δ	stability spectrum White	Flicker	Source	stability μas σ_α	σ_δ	stability spectrum White	Flicker
				Defining					
1128+385	43	38	δ	α	2145+067	94	112	δ	α
0014+813	49	46	δ	α	1057-797	157	95	α, δ	
1637+574	53	59	α	δ	0954+658	143	121	α, δ	
0642+449	53	62	α, δ		0235+164	116	252	α, δ	
1606+106	69	61	α, δ		0637-752	252	154	α, δ	
0133+476	90	61	α, δ		1038+528	48	361	α, δ	
1308+326	92	97		α, δ	0457+024	649	592	α	δ
				Candidates					
1357+769	16	34	α	δ	1749+096	143	209	α	δ
0552+398	31	25		α, δ	2234+282	162	165	α, δ	
1803+784	45	54		α, δ	1614+051	151	229	α, δ	
0851+202	73	66	α, δ		0229+131	148	256	δ	α
1611+343	32	103	α, δ		0119+041	153	287	α, δ	
1739+522	84	100	α, δ		0458-020	101	393	α, δ	
1156+295	56	199	α, δ		0823+033	122	392	α, δ	
0528+134	117	87	α, δ		0201+113	129	334	δ	α
0202+149	86	147	α, δ		2355-106	261	936	α, δ	
0657+172	72	230		α, δ	0336-019	354	579	α, δ	
1044+719	108	114	δ	α	1244-255	315	933	α	δ
0814+425	132	203	α, δ		1519-273	588	1831	α, δ	
				Other					
0923+392	90	30	α	δ	1354+195	374	259	α, δ	
1638+398	91	88	δ	α	1921-293	190	517	α, δ	
0300+470	94	123	α, δ		2255-282	347	288	α, δ	
0735+178	84	128	α, δ		1633+382	466	323	α	δ
2200+420	85	172	α, δ		0537-441	389	583	α, δ	
2007+777	190	53	α	δ	0420-014	202	750	α	δ
1741-038	69	351	δ	α	1815-553	616	468	α, δ	
2243-123	51	558	α, δ		1622-253	563	761	α, δ	
1334-127	141	169	α	δ	0208-512	649	860	δ	α
0212+735	163	164	δ	α	0048-097	492	1031	α, δ	
0727-115	147	164	α, δ		1034-293	718	1179	α, δ	
1610-771	133	202	α, δ		1958-179	248	1153	α, δ	
1901+319	134	227	α, δ		2128-123	384	2166	δ	α
0953+254	182	201	α, δ						