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VLBI technique: impact of the change of ICRS realizations

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Abstract

In this work we investigate on the change in the International Celestial Reference System (ICRS) from the first ICRF (International Celestial Reference Frame) second extension ICRF-Ext.2 (ICRF1), to the last ICRF realization (ICRF2). At this aim we have processed a set of VLBI experiments during 27 years to estimate session-wise station coordinates, their velocities, baseline lengths and Celestial Pole Offsets (CPO) components, using as radio source reference catalog once ICRF1 and once ICRF2.

We have analyzed time series of estimated geodetic parameters and their formal errors, and the time series of the differences of the parameters estimated in the two reference source catalogs. For the analysis of the time series we have used ADEV (Allan Deviation) and its modifications.

Our findings confirm that the switchover from ICRF1 to ICRF2 yields improvements for example in the baseline lengths repeatability and in the scatter of CPO series of about 2 μas. However our results highlight also some discrepancies: the series of station coordinate differences (ICRF1-ICRF2) show significant noise at mm level and the series of baseline length differences has a bias of about 2 mm, then a time variable residual signal is present in the CPO difference time series.

Data selection and processing approach

The VLBI 24 h sessions, collected since the year 1984, were analyzed with VieVS (Vienna VLBI Software) [1], according to IERS (International Earth Rotation and Reference Systems Service) Recommendations [2] and IVS (International VLBI Service for Geodesy and Astrometry) Conventions on VLBI data processing [3].

All the sessions were processed two times using same approach, with the unique difference that the source positions were fixed once to their apriori coordinates given in the ICRF1 catalogue and once to the coordinates from ICRF2 [4]. In both analyses we used the same parametrization, and estimated the clock parameters, zenith wet delays, tropospheric gradients, Earth orientation parameters and station coordinates.

As apriori station coordinates we used VTRF2008 catalogue and for the application of datum conditions a set of reliable and globally well-distributed VLBI stations was used. No-Net-Translation and No-Net-Rotation conditions were applied with respect to the VTRF2008 solution [5].

For our time series analysis we used the estimated the position and velocity for each of the three components Radial, East, North of 17 stations, located in different geographical regions, having the largest number of observations and a long observation history, 119 baselines were analyzed in this study.

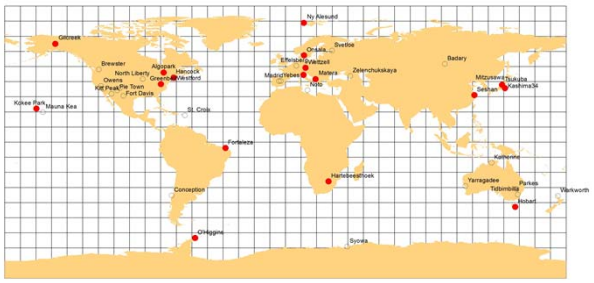

Fig. 1: Map of VLBI stations involved in the processing of VLBI experiments: in red are indicated the stations used for time series investigations.

Improvements in the switchover from ICRF1 to ICRF2

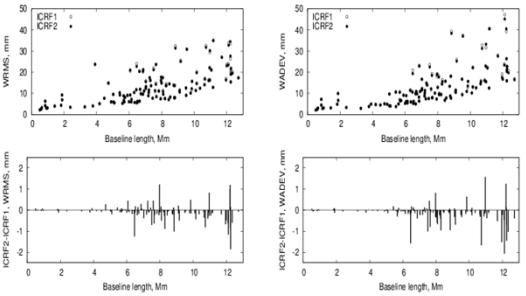

Fig. 2: Baseline length repeatability (top) and differences of repeatability estimates computed for each of the two solutions (ICRF2 fixed and ICRF1 fixed)

ICRF version	ADEV dX	ADEV dY	WADEV dX	WADEV dY	WMADEV $dX+dY$
ICRF1	192	199	102	105	147
ICRF2	190	199	99	104	144

Tab. 1: Scatter of the celestial pole offsets dX and dY time series obtained with the two ICRF versions. ADEV, WADEV, and WMADEV correspond to the standard Allan Deviation, Weighted Allan Deviation, and Weighted 2D Allan Deviation, respectively. Unit: μas

Impact on baseline lengths moving from ICRF1 to ICRF2

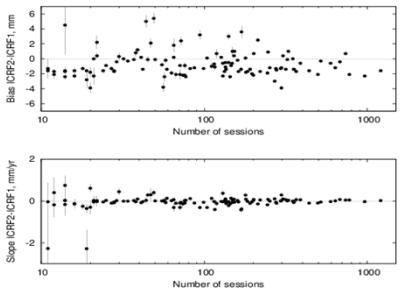

Fig. 3 Bias and slope in the differences between the baselines lengths obtained with two ICRF versions (ICRF1-ICRF2). The bias is at a level up to a few millimeters even for baselines having large number of observations (sessions).

Baseline	Sessions	Bias, mm	Slope, mm/yr
Ft – Ho	141	$+3.0 \pm 0.4$	-0.03 ± 0.07
Ft – Oh	49	$+5.4 \pm 0.7$	$+0.40 \pm 0.13$
Gc – Hh	297	-3.9 ± 0.3	$+0.29 \pm 0.06$
Gc – Ma	270	-3.0 ± 0.1	$+0.10 \pm 0.02$
Hh – G3	19	-2.8 ± 1.1	-2.28 ± 0.90
Hh – Oh	56	-3.8 ± 0.6	$+0.01 \pm 0.10$
Hh – On	94	$+3.2 \pm 0.6$	-0.31 ± 0.07
Ho – Kk	213	$+2.5 \pm 0.3$	-0.14 ± 0.06
Ho – G3	11	-1.3 ± 1.3	-2.27 ± 3.14
Ho – On	14	$+4.5 \pm 3.9$	-0.17 ± 0.53
Ho – Wz	169	$+3.6 \pm 0.8$	-0.38 ± 0.12
Ka – Wf	16	-2.3 ± 0.3	-0.14 ± 0.07
Kk – Oh	44	$+5.0 \pm 0.8$	$+0.03 \pm 0.16$
Ma – Sh	20	-3.9 ± 0.7	$+0.61 \pm 0.20$

Tab. 2: Baselines with maximum difference between ICRF1 and ICRF2. Most are baselines with southern stations, i.e. observing more southern sources presumably poorly determined in ICRF.

Impact on CPO estimation moving from ICRF1 to ICRF2

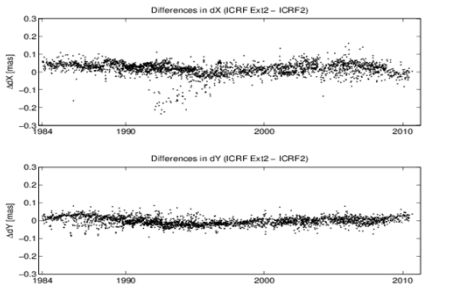

Fig. 4: The differences between CPO estimates obtained the two ICRF versions (ICRF1-ICRF2) has a time variable behavior.

	dX	dY
Bias, μas	-17.6 ± 0.6	9.3 ± 0.4
Slope, μas/yr	1.0 ± 0.1	-0.6 ± 0.1
Amplitude (18.6 yr), μas	17.3 ± 0.9	7.7 ± 0.5

Tab. 3: Differences between the CPO series computed with ICRF1 and ICRF2 show a bias from 10 to 20 μas, a residual signal is also present. It was modeled with a linear trend plus an harmonic term with 18.6-year.

Summary and conclusions

In this work we have investigated on the possible distortions due to the change from the ICRF1 to the ICRF2 materialization, as the presence of deformations could invalidate stability of ICRS and ITRS realizations or of some Earth orientation parameter. We have performed our examination computing session-wise solutions for stations coordinates, their velocities, baseline lengths and celestial pole offsets components, estimated once in ICRF1 and once in ICRF2. Our results show very small effects on station coordinates, negligible effects on their velocities and an improvement in baseline length repeatability, these results agree with previous studies of [6] based on global solutions. Anyway, our analysis based on session-wise solutions, highlights also other important effects not negligible, like a bias of a few millimeters on the mean baseline lengths and the presence of a residual signal time variable in the CPO time series. Further and detailed investigations are necessary to understand and correct these distortions on TRF and CPO estimates.

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