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Consistent Realization of ITRS and ICRS

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Abstract

This paper deals with the consistent realization of the International Terrestrial Reference System (ITRS) and the International Celestial Reference System (ICRS). DGFI computes such a common realization for the first time by combining normal equations of the space geodetic techniques of Very Long Baseline Interferometry (VLBI), Satellite Laser Ranging (SLR), and Global Navigation Satellite Systems (GNSS). The results for the Celestial Reference Frame (CRF) are compared to a classical VLBI-only CRF solution. It turns out that the combination of EOP from the different space geodetic techniques impacts the CRF, in particular the VCS (VLBA Calibrator Survey) sources.

1. Introduction

The International Terrestrial Reference System (ITRS) is realized by the International Terrestrial Reference Frame (ITRF), and the International Celestial Reference System (ICRS) by the International Celestial Reference Frame (ICRF), respectively. The two realizations are computed independently today by different institutions. While the ICRF is based on observations from Very Long Baseline Interferometry (VLBI) only, the ITRF is computed by combining observations from VLBI, Satellite Laser Ranging (SLR), Global Navigation Satellite Systems (GNSS), and Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS). Due to the independent computations and the fact that different observation data are used, the two reference frames are not consistent to a full extent. Figure 1 shows the current situation for ITRF and ICRF computation.

In order to reach consistency to a certain extent, (i) in ITRF computation the source coordinates are fixed (session-wise) to ICRF2 [1] and (ii) the VLBI-only terrestrial reference frame (VTRF) – computed together with the ICRF – is aligned to ITRF w.r.t. origin and orientation. However, there are inconsistencies between the two solutions w.r.t.:

- the scale: The scale of the VTRF is realized from VLBI observations only, while the scale of the ITRF is realized as a weighted mean of the SLR and the VLBI scale ([2], [3])
- the network geometry of the VLBI subnetwork: The geometry of the VLBI network is slightly changed in the combination due to discrepancies between the local ties and the coordinates derived from the space geodetic techniques [3], and
- the EOP: The EOP estimated consistently to the ICRF are derived from VLBI-observations only, while the EOP, i.e., the pole coordinates and UT1-UTC, estimated consistently to the ITRF are derived from the contributions of all space techniques. UT1-UTC can, in an absolute sense, only be derived from VLBI. The satellite techniques contribute to the UT1-UTC series with LOD.

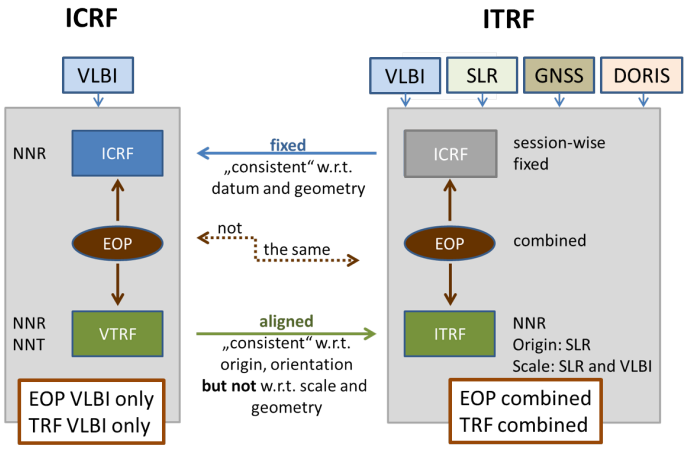

Figure 1. Situation for ITRF and ICRF computation today.

Consistent realizations of ITRS and ICRS can be reached, if both are computed together in one adjustment to which all the different observation techniques contribute (Figure 2). The geodetic datum of the solution will be realized according to the IERS Conventions [4].

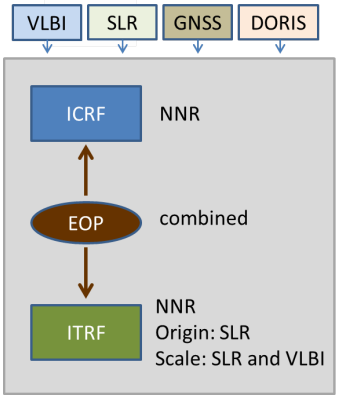

Figure 2. Consistent realization of ITRS and ICRS.

What can we expect from a common adjustment of the Terrestrial Reference Frame (TRF) and the Celestial Reference Frame (CRF)? We can expect

- Consistency between all parameters,
- An improvement of the accuracy of the EOP time series w.r.t. the single-technique series (as it is motivated e.g. by the IERS C04 series[1]), and
- Effects on the CRF (source coordinates and their standard deviations) caused by (i) on the one hand, the combination of the EOP and (ii) on the other hand, the combination of the station networks.

[1] http://hpiers.obspm.fr/iers/eop/eopc04/C04.guide.pdf

2. Consistent Realization of TRF and CRF

We performed a consistent computation of TRF and CRF based on the combination of VLBI, GPS, and SLR normal equations (Table 1), which is the result of a homogenized analysis of the observation data. The parameters included in the solution are given in Table 2. The datum parameters of origin and the scale that are also listed are implicit parameters. Altogether about 45,000 parameters are estimated.

Table 1. Input data for the consistent realization of ITRS and ICRS.

	time span	resolution	institution
VLBI	1984-2007	session-wise (24 h)	combined: IGG+DGFI
GPS	1994-2007	daily	GFZ
SLR	1993-2007	weekly	DGFI

Table 2. Parameters considered in the consistent realization of ITRS and ICRS.

	Station coord.	Source coord.	Terr. pole	Celest. pole	UT1-UTC	Origin	Scale
VLBI	x	x	x	x	x		x
GPS	x		x	(x)	(x)		
SLR	x		x		(x)	x	x

Figure 3 shows differences in standard deviation between the combined TRF-CRF solution and a VLBI-only solution at various declination angles (DE). It was found that the combination leads to a general decrease of the standard deviations of the source positions (the results for the right ascension (RA) are very similar). It can be seen from Figure 3 that for the VCS sources, which are observed by VCS (VLBA Calibrator Survey) sessions only, the decrease of the standard deviation is larger than for the non-VCS sources. This must be expected, because the VLBA network is a regional network, and the standard deviations of the positions of VCS sources are in general larger than for the non-VCS sources.

The effect of the combination on the source positions themselves is given in Figure 4. The VCS sources show larger differences w.r.t. the VLBI-only solution than the non-VCS sources. Remarkable is the systematic effect in RA, which was found to affect some of the VCS sources with a declination between $-40°$ and $+30°$ of DE. A detailed analysis of this effect shows, that about 100 sources show a difference of $|RA \cdot \cos(DE)| > 0.1$ mas w.r.t. the VLBI-only solution. Almost all of these sources are observed by VCS sessions only. However, w.r.t. the standard deviation of one single VCS source of $\sigma \geq 0.4$ mas, the systematic effect is not significant.

In order to investigate the way in which the combination of the EOP contributes to this effect in RA, three different solutions are computed: (1) combining only the pole coordinates, (2) combining the pole coordinates and LOD, and (3) combining all EOP (pole coordinates, LOD and nutation rates). In Figure 5 the results of the three solutions are compared. It shows that the systematic effect found in RA can be attributed to the inclusion of LOD in the combination. While the

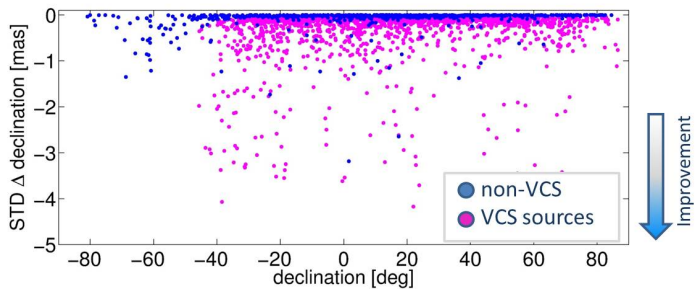

Figure 3. Change of standard deviation by declination angle due to the combination (combined minus VLBI-only).

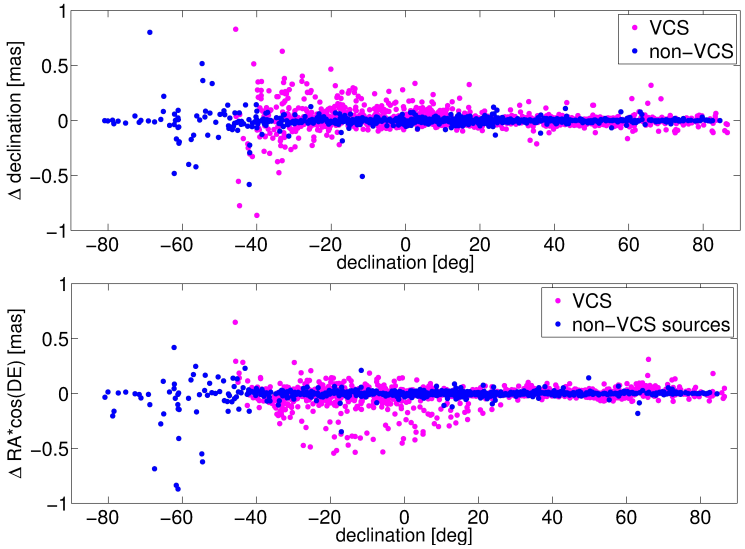

Figure 4. Differences in source positions between the combined TRF-CRF solution and a VLBI-only solution: declination (upper plot), right ascension (lower plot).

WRMS of solution (1) is 5.5 μas, the inclusion of LOD leads to a WRMS of 9.0 μas (solution (2)). The high impact of LOD combination on RA can be explained by the high mathematical correlation between the two parameters. The fact that almost exclusively the VCS sources are affected might be attributed to differences between EOP derived from a regional network and from global networks. More detailed analysis is necessary in order to understand better the effect on the individual sources.

3. Conclusions

The paper shows that a consistent realization of ITRS and ICRS from the observations of VLBI, SLR, and GPS is possible. We investigated the impact of such a common computation on the CRF. In particular, the combination of the EOP of the different techniques can affect the CRF.

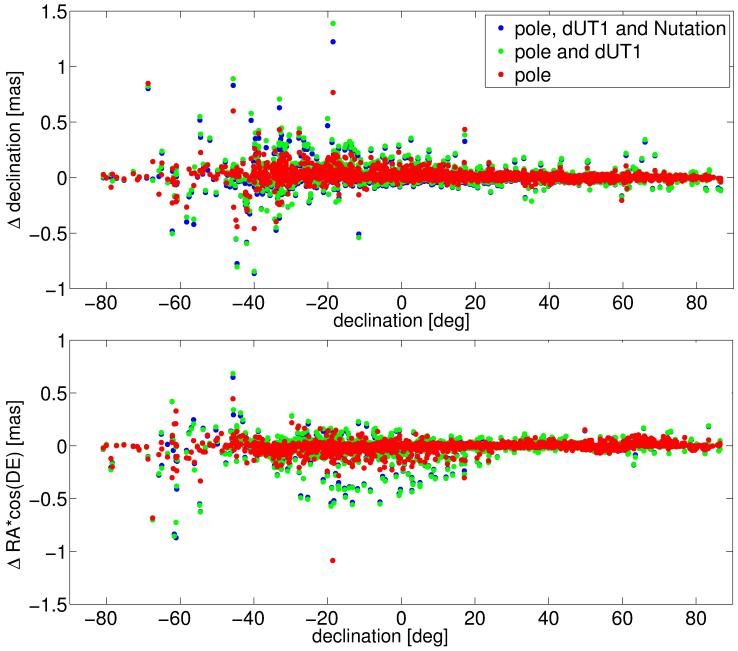

Figure 5. Differences in source positions between three TRF-CRF solutions (obtained from combining different sets of EOP) and a VLBI-only solution: declination (upper plot), right ascension (lower plot).

We found a maximum systematic effect in right ascension of about 0.5 mas for some of the VCS sources. This effect can be related to the combination of LOD. Even if it is not significant w.r.t. the standard deviation of the position of one single source, it might become significant for the frame as a whole. Further investigations are necessary in order to understand better the impact of the combination on single sources and groups of sources and their importance for the CRF.

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