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A Comparison of R1 and R4 IVS Networks

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Abstract

This study compares the two parallel 24-hour R1 and R4 networks run by the IVS since 2002. We investigate the possible influence of the network geometry as well as the consistencies between Earth orientation parameters solutions and terrestrial reference frame realized separately through R1 or R4 experiments. We point out finally that the effects of using two different networks with different geometries and observational strategies show up in the operational series. Such consequences should be carefully examined in the future.

1. Overview of the Networks

The 24-hour rapid R1 and R4 experiments are conducted on Mondays and Thursdays, respectively, since January 2002. They are the cornerstone in the production of Earth orientation parameters (EOP) through very long baseline interferometry (VLBI) on a regular basis. It has been shown that the network geometry can produce inconsistencies at the level of accuracy of the actual VLBI measurements (see e.g., [1]). Therefore, it is essential to assess the consistency of the current networks, with two main goals: to correct the errors and to orient the future VLBI network towards a more perfect scheme.

R1 and R4 parallel networks used a total of 15 stations between 2002 and 2005.5. The stations are not the same for the two networks and their rate of use is also different. Figure 1 displays the most representative sites of the R1 and R4 networks over 2002-2005.5. A strong difference appears in the geometry, especially in the spatial extension of the networks. The R1 network allows very long East-West baselines (America-Europe and Europe-Japan) and large polyhedral areas sensitive to all 3 Earth orientation parameters (x_p, y_p and $UT1-UTC$) thanks to sites in the southern hemisphere and across the five continents. The R4 network is significantly smaller, covering about a third of the Earth's surface. Sites in the southern hemisphere are poorly used, except FORTLEZA. TIGOCONC becomes sparsely used in 2003.

Figure 2 shows the number of sessions in which each station is participating over the 2002-2005.5 observing program. It appears that R4 uses quite systematically a subset of stations (WETTZELL, NYALES20, KOKEE, FORTLEZA, ALGOPARK for which the number of sessions is larger than 100) while the other sites are poorly used (number of sessions decreasing rapidly well below 20). In the R1, WESTFORD, WETTZELL and GILCREEK are systematically used, followed by TIGOCONC and HARTRAO. The number of sessions for the rest of the sites remains well above 20 excepted for 4 of them. This implies that, unlike the R4's, the R1 geometry is changing from one session to another, involving a lot of different baselines, and therefore the network geometry can be very different from one session to another.

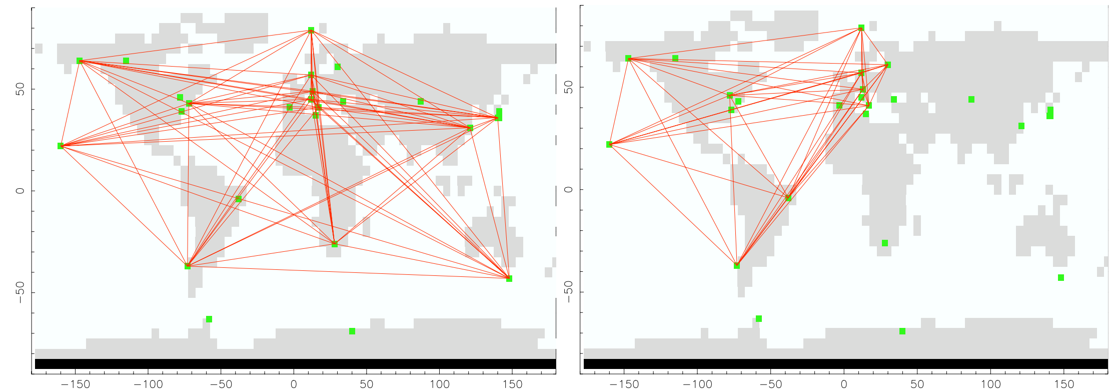

Figure 1. R1 (left) and R4 (right) networks represented with the most representative stations participating in the 2002-2005.5 observing program.

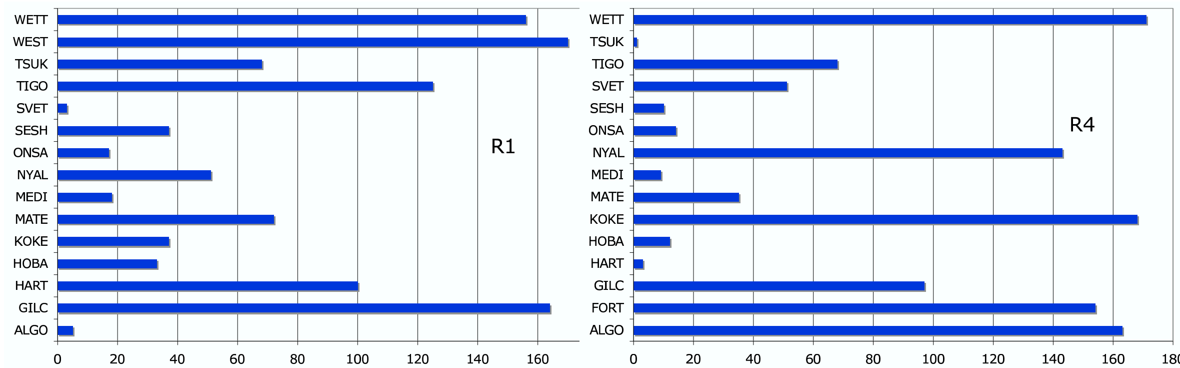

Figure 2. Number of sessions per stations in R1 (left) and R4 (right) networks over 2002-2005.5 observing program.

2. Comparison of EOP and TRF Realizations

Global solutions are run, carrying stations positions and velocities, antennas axes and sources positions as global parameters. The no-net-rotation and no-net-translation constraints on positions and velocities with respect to VTRF 2005 (Nothnagel 2005) are applied to all stations, excluding sites having known episodic motions (GILCREEK's position has been corrected in November 2002 after the Denali fault earthquake 100 miles south of Fairbanks). A no-net-rotation constraint is also applied to all the 212 ICRF defining sources. Other observed sources are estimated as global parameters. EOPs are estimated as arc parameters and compared against IERS Bulletin A ([3]). The following solutions are obtained with the CALC/SOLVE geodetic VLBI data reduction package developed at NASA/GSFC:

- EOP1, realized through the R1 experiments from experiment number 1 to 172,
- EOP4, realized through the R4 experiments from experiment number 1 to 176, and
- EOPA, realized through all the R1 and R4 experiments (348 sessions).

The CONT02 campaign is not included (note that its effect remains marginal). The EOP series are displayed in Figure 3. It appears that the current R1 experiments have residuals against Bulletin A with standard deviation similar to R4. However, EOP1 and EOP4 have different

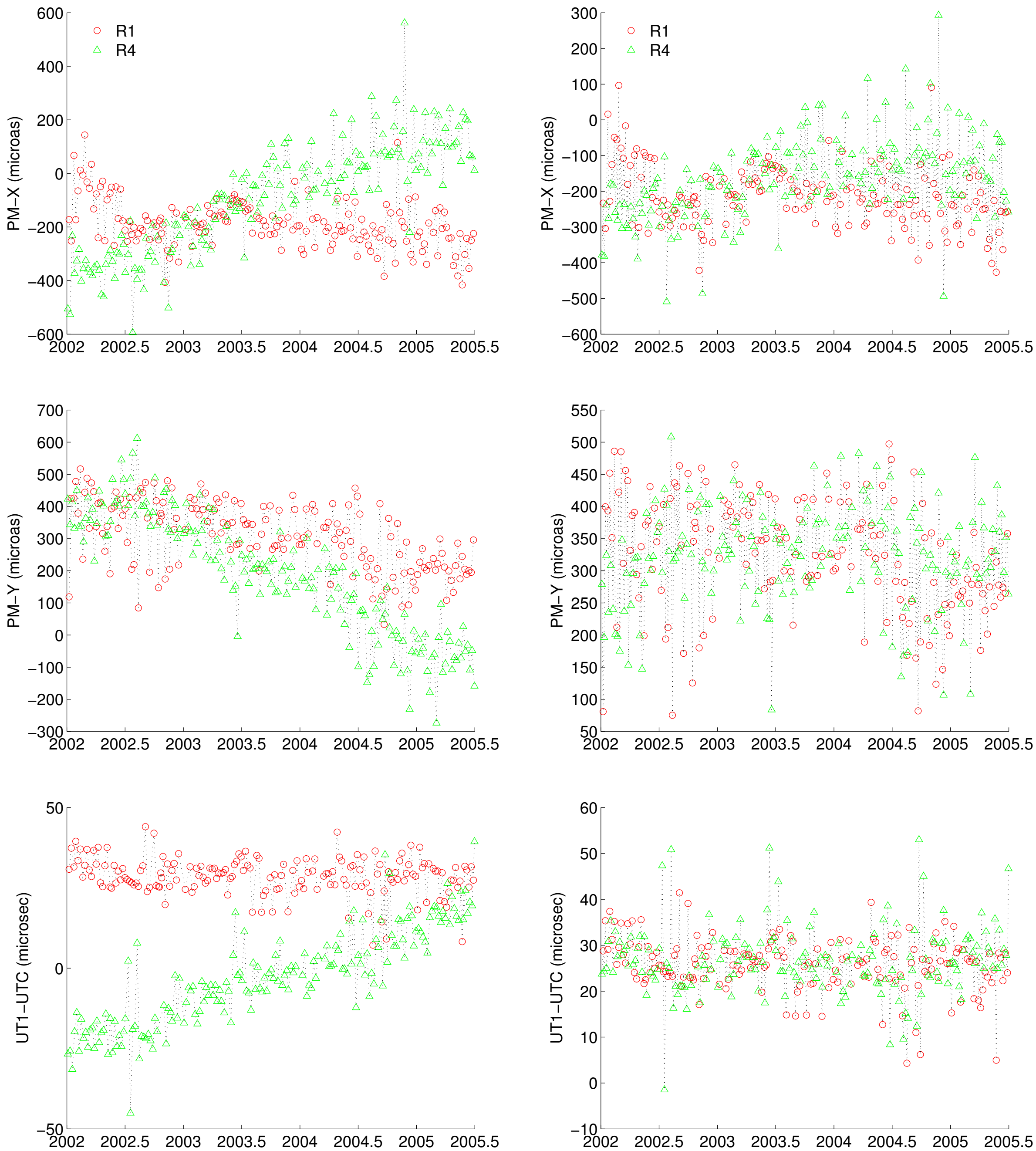

Figure 3. Differences between solutions EOP1 (left column, circles), EOP4 (left column, triangles), EOPA (right column with different markers for R1 (circles) and R4 sessions (triangles)) and IERS Bulletin A for the terrestrial pole coordinates x_p (top), y_p (middle) and UT1 − UTC (bottom) over 2002-2005.

biases and rates. The lower rates yielded by the R1-derived solution make EOP1 closer to the

Bulletin A. The differences in bias and rate between EOP1 and EOP4 can reach several hundreds of microarcseconds over a year, which is significant compared to the formal errors obtained on the EOP estimates (typically 100 μas). One must keep in mind that the two solutions EOP1 and EOP4 are obtained using the same assumptions and constraints. The only difference is the subset of stations used in the network (location of the antennas within the continents, geometry of the array, capabilities of the receivers, system failures, plate motions and faults, episodic events, etc.). It is obvious that the network and its geometry are the key parameters in the accuracy of EOP determined by VLBI among other sources of error. This raises very challenging questions and concerns which must be addressed before scheduling observations. This section seems to show that R1 experiments are "better" (in the sense that they give EOP realizations that match better the Bulletin A).

In the solution EOPA (combining both R1 and R4 sessions), it appears that the R1 and R4 x_p-components are evolving separately with a different rate. Before 2003, R4 is below R1 and this is reversed after 2003. The same phenomenon is visible also on the other components with a lower magnitude. It does reflect the differences in rate between EOP1 and EOP4.

The Helmert's parameters between individual TRF realized through solutions EOP1 and EOP4 and VTRF 2005 are reported in Table 1.

Table 1. The Helmert transformation parameters in mm for ΔX, ΔY and ΔZ, in ppm for s and in μas for α_1 and α_2, and μs for α_3, between R1 and R4-derived TRF and VTRF 2005. Formal errors are in italics.

	ΔX		ΔY		ΔZ		s		α_1		α_2		α_3	
EOP1	-1.0	*0.5*	0.7	*0.6*	-0.3	*0.5*	0.001	*0.001*	33	*305*	370	*242*	-10	*20*
EOP4	-0.6	*0.6*	0.2	*0.6*	-0.1	*0.6*	-0.004	*0.001*	-246	*208*	150	*166*	62	*31*

The determination of α_1 and α_2 for the R1 network shows significantly larger errors than for the R4's while the errors are comparable on α_3. If one remembers that the formal error is inversely proportional to the number of observations, one can explain these differences between R1 and R4 by crossing the results of Table 1 with the information of Figure 2. It has been pointed out in the previous section that a large part of the R1 sites are not used in all sessions but sparsely, and their respective number of observations is decreased. In the R4 network, a subset of sites are used regularly so that the network is almost the same in each session. A consequence is that the efficiency of R1 for the TRF determination is degraded compared to the R4. These remarks do not allow to conclude that the current R4 network is better than the R1 but they indicate:

- that a large number of sites is clearly an advantage in constraining and estimating the TRF,
- but that a changing network significantly degrades the TRF estimates.

3. Concluding Remarks

To conclude, consider a recent USNO analysis center 24-hour VLBI EOP solution ([4]) in which the other experiments are dropped (see Figure 4). The discrepancy between R1 and R4 noticed for EOPA is still present in component x_p with a weaker effect: the R4 experiments appear to be above the R1. The discrepancy is not significant for the other components.

Next, we would like to address the arguments that could be made that a limited study, such as

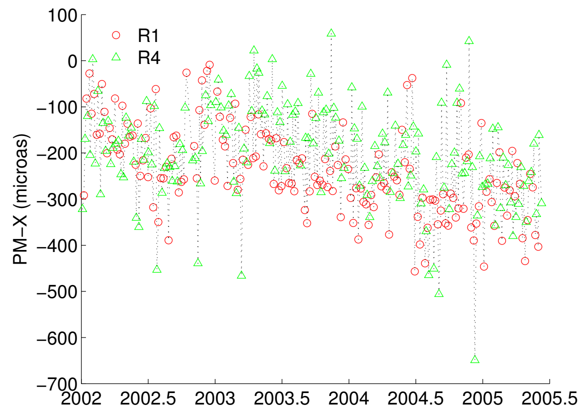

Figure 4. VLBI operational solutions USNO 2005b (x_p) represented with different markers for R1 (circles) and R4 sessions (triangles) against IERS Bulletin A.

this one, using only a small subset of VLBI sessions, is not truly representative of the long-term VLBI solutions. The argument that the long-term VLBI solutions consider many older sessions and that these additional sessions partly cancel out the effects of the inconsistencies observed here due to imperfect network is not completely valid. Many of these older experiments use similar networks (e.g., NEOS) and have their own sources of error that are not fully understood. Furthermore, this study clearly shows that the effects of these inconsistencies do show up in the operational data. Since the IVS is continuing to run these two networks in parallel and new stations will be needed to replace older ones that go out of service, the sources of errors affecting operational data must be investigated.

References

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[4] USNO 2005, maintained by the USNO Radio and Optical Reference Frame group. Available at http://rorf.usno.navy.mil/solutions/.