Effects of the datum configuration of radio sources on EOP determined by VLBI

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1. MOTIVATION

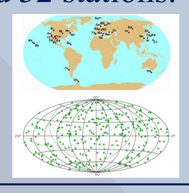
Earth Orientation Parameters (EOP) provide the rotation from the ITRS to the GCRS as a function of time. When estimating a Celestial Reference Frame (CRF) usually a number of radio sources with a long history of observations and stable positions are included in the datum definition used to define the orientation of the frame.

To estimate the International Celestial Reference Frame 2 (ICRF2), this datum is by convention the 295 defining sources determined in the ICRF2 analysis process. These sources satisfy a number of specific conditions. However, for a particular session this group of radio sources may not be the best configuration.

Using different options for the CRF datum definition, we analyze the effects on the accuracy of the EOP and the impact on the source positions.

2. INTRODUCTION

The special session 09NOV18XA was observed in the International Year of Astronomy (IYA09) in order to observe as many of the 295 ICRF2 defining sources as possible in a single 24-hour session. The advantage of this session is that it provides the positions of the sources in a single VLBI session. A typical modern session observes 50-70 sources with an observational network of 7-11 stations, while the IYA09 includes 237 sources and 32 stations. This gives a much stronger geometry to study the EOP.



	Stations	Radio Sources	Total observations	Outliers	Chi-square
IYA09	23 geodetic VLBI stations 9 VLBA stations	162 north hemisphere 75 south hemisphere	25572	95	0.9675

3. DATA ANALYSIS: Radio source and EOP adjustments

The session was analyzed with the Vienna VLBI Software VieVS applying the IERS Conventions 2010. One offset was estimated for each EOP, each station coordinate, and each radio source coordinate. Clocks and zenith wet delays were estimated with 60 min resolution and troposphere gradients with 360 min resolution. The datum definition of the Terrestrial Reference Frame (TRF) was realized by applying no-net-translation (NNT) and no-net-rotation (NNR) conditions for the stations with continuous observations and coordinates in the VTRF2008. The stations AIRA, CHICHI10 and SINTOTU were excluded due to the high scatter of the observations. The celestial datum definition was realized by applying NNR+dz conditions including different subsets of sources:

Tab.1 Celestial datum configuration

	Datum condition	Radio sources
A	NNR + dz condition Excluding sources with less than 3 observations	Defining sources (229)
B		Sources with δ>0° (161)
C		Sources with (X and S-Band) SI<3 (157)
D		Sources with -30° < δ < 30° (135)
E		Sources with 0h < α< 12h (127)
F		Feissel-Vernier sources (103)
G		Sources with 12h < α< 24h (102)
H		Sources with δ<0° (68)

- A → defining sources (reference)
- B, D, E,G,H → various geometrical subsets
- C → astrophysical subset. The structure index (SI) indicates the expected magnitude of the effects of intrinsic source structure on VLBI delay observations (Fey & Charlot, 1997).
- F → statistical subset. The Feissel-Vernier sources are selected by statistical test on the time-varying behaviour of source coordinates (M. Feissel-Vernier, 2003).

$$Overall\ formal\ error \qquad d = \sqrt{\sigma^2_{\alpha\cos\delta} + \sigma^2_{\delta} + \sigma_{\alpha\cos\delta}\sigma_{\delta}C(\alpha,\delta)} \qquad C(\alpha,\delta) = \frac{Cov(\alpha,\delta)}{\sigma_\alpha \sigma_\delta}$$

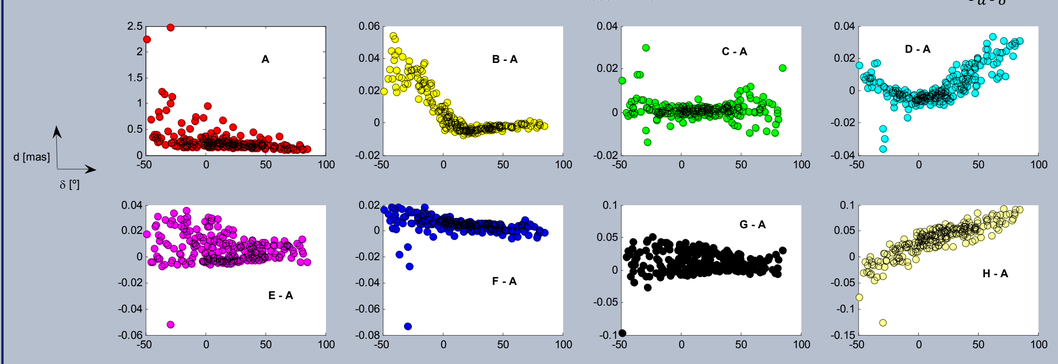


Fig.1 Overall formal error differences of the radio source positions with respect to A (first plot)

Larger variations can be found for sources of the southern hemisphere. C and F cover almost the same declination and right ascension ranges compared to A and thus show the smallest differences. Comparing approaches B and H with E and G, the impact of the geometrical restriction in δ direction is much larger than in α.

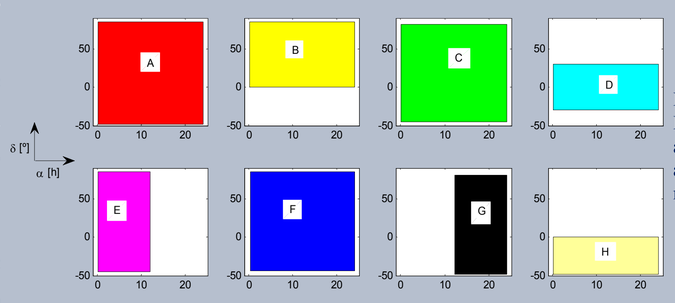
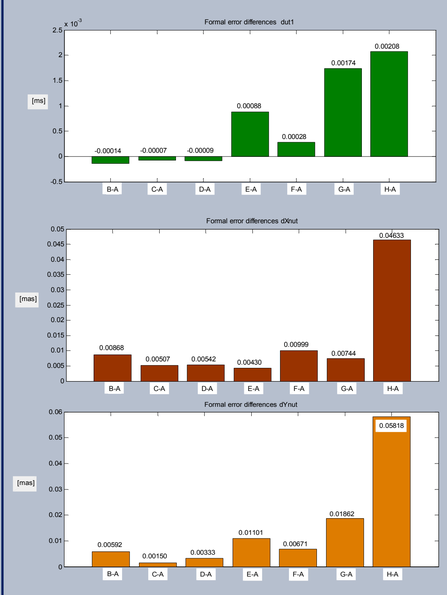


Fig.2 Declination and right ascension range

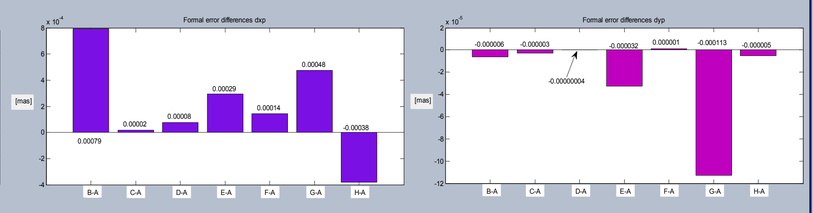
Fig.3 Formal error differences with respect to the approach A for the EOP



	A	H
C(dxp,dyp)	-0.1205	-0.1188
C(dXnut,dYnut)	-0.0403	0.1078

Tab.2 Correlation between estimates for A and H

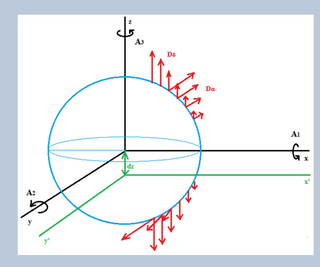
- For dUT1 the formal errors increase when the α range is limited → larger rotation angle A_3 for E and G (Fig.4) .
- A good coverage is neccessary to accurately determine the origin of right ascension defined by the x-axis.
- Concerning dXnut and dYnut, the maximal formal errors appear for approach H, where the low number of sources and the restriction of the datum to the southern hemisphere introduce a defect.
- For dxp and dyp the values are stable on the level of a few μas.



4. DATA ANALYSIS: Celestial reference frame

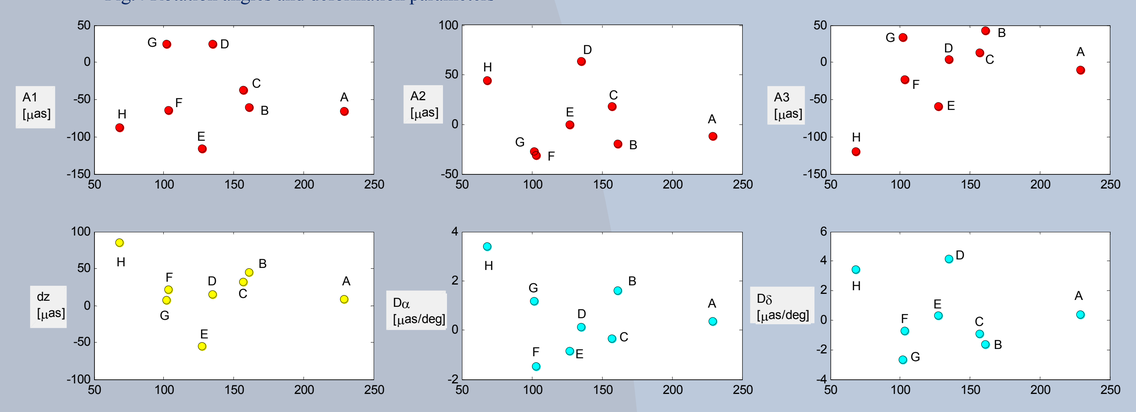
The relative orientation of two 3D frames (e.g. CRF) can be modeled by three rotation angles (A_1, A_2, A_3) around the axes. In addition, systematic frame deformations, such as shearing $(D_\alpha\delta_1, D_\delta\delta_1)$ and the translation or bias in declination (dz) can be modeled at the same time.

$$d\alpha = A_1\tan\delta_1\cos\alpha_1 + A_2\tan\delta_1\sin\alpha_1 - A_3 + D_\alpha\delta_1$$
$$d\delta = -A_1\sin\alpha_1 + A_2\cos\alpha_1 + D_\delta\delta_1 + \mathrm{dz}$$



These equations were weighted by using the inverse of the variance of the offsets $(\sigma^2_{d\alpha}, \sigma^2_{d\delta})$. We compare individual VLBI frames (Tab.1) with ICRF2 by using various subsets of datum sources (approach A, B, ..., H).

Fig.4 Rotation angles and deformation parameters



- When all the defining sources are included (A), the uncertainties of the six parameters are smallest. The approach H shows the largest rotations and deformations with an absolute value of about 120 μas for A3.
- The approach C, with good geometry but only 157 sources, shows results comparable to A, but with slightly worse uncertainties. Although the distribution of the radio sources of approach F (Fig.2) is comparable to A and C. However, this approach contains only 103 sources and the shearing parameter $D\alpha$ increases to about -1.5.
- In the cases where the geometry is restricted, the number of sources does not seem to play a significant role. The various geometrical restrictions do not show an easily explanable behaviour.

5. CONCLUSIONS

- Only 68 of 237 sources in session 09NOV18XA are in the southern hemisphere. Sources with negative declinations reach formal errors up to 2.5 mas.
- The celestial pole offsets significantly depend on the celestial datum, in particular on the geometry of the datum source distribution.
- Different criteria to assess the stability of the sources can be applied (e.g. approach F) and compared with the defining sources (A). However, in this study, all the approaches are subsets of A and thus the geometry could not be investigated independent of the number and stability of the sources.
- Southern radio sources need to be observed more often in order to get more stable positions. For some sources the structure index (SI) was not determined and thus those sources were not included in particular datum subset C.
- Increasing the number of sources in the southern hemisphere will provide a better geometry and will improve the axes stability and the EOP quality.
- The IYA09 session is very valuable for this kind of investigations.

ACKNOWLEDGEMENT

We acknowledge IVS for providing the data analysed in this study.

BIBLIOGRAPHY

A.L. Fey, D. Gordon, C.S. Jacobs (eds.) (2009). The Second Realization of the International Celestial Reference Frame by Very Long Baseline Interferometry.

M. Feissel-Vernier (2003). Selecting stable extragalactic compact radio sources from the permanent asteogeodetic VLBI program. A&A, 403,105-110(2003). Doi: 10.1051/0004-6361:20030348.

A.L. Fey, P. Charlot (1997). VLBA Observations of radio reference frame sources. III. Astrometric suitability of an additional 225 sources. The Astrophysical Journal Supplement Series, 128:17-83, 2000 May.

S. Böckmann, T.Artz, A. Nothnagel (2010). VLBI terrestrial reference frame contributions to ITRF2008. Journal of Geodesy, 84. doi: 10.1007/s00190-0357-7 pp. 201-219.

J. Böhm, S. Böhm, T. Nilsson, A. Pany, L. Plank, H. Spicakova, K. Teke, H. Schuh (2012). The New Vienna VLBI Software VieVS. Geodesy for Planet Earth, International Association of Geodesy Symposia 136. doi: 10.1007/978-3-642-20338-1_126, Springer-Verlag Berlin Heidelberg .

C. Ma, E. F. Arias, T. M. Eubanks, A. L. Fey, A.-M. Gontier, C. S. Jacobs, O. J. Sovers, B. A. Archinal, P. Charlot (1998). The International Celestial Reference Frame as realized by Very Long Baseline Interferometry. The Astronomical Journal, 116:516-546).

R. Heinkelmann, J. . Böhm, H. Schuh (2007). Effects of geodetic datum definitions on the celestial and terrestrial reference frames determined by VLBI . Proceedings of the 18th European VLBI for Geodesy and Astrometry Working Meeting.

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