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Abstract

The stability of extragalactic radio sources were further studied in 2005. Extending the Feissel-Vernier [1] study, three lists of reference sources based on progressively larger tolerances, are proposed. They include 181, 225, and 247 sources, respectively. Studies of the VLBI stations' stability were initiated. Using a new station stability analysis method [4], the noise spectrum and level of the non-linear signal in time series of station positions was characterized. We show that the non-linear signal has a white noise spectrum. The stability at one-year sampling time is better than 2 mm in the North and East directions, and 5 mm in the Up direction. The amplitude of the annual component is smaller than 1 mm in the North and East directions, and 5 mm in the Up direction.

1. Revision and Extension of the List of Stable Sources

Feissel-Vernier [1] proposed a list of 199 well observed radio sources considered stable, and 163 sources considered unstable, based on the statistical analysis of time series of source directions. An extension of the analyses was performed [2], leading to downgrading some of the sources initially considered as stable on the one hand, and to extending the list with additional sources.

A first extension concerns the sources with a relatively poor observation history. The Feissel-Vernier [1] stability detection, referred to MFV hereafter, was based on time series statistics of yearly averaged source coordinates. It has therefore the limitation of requiring time-density of observation. Over the 1990-2002 time span, 358 sources, i.e. about half of the total, were considered too sparsely observed to be submitted to the scheme. In order to learn more about their possible stability, a simplified selection scheme was applied to those sources. For sources observed in more than three sessions over more than two years, we assume that, in both $\alpha \cos\delta$ and δ, a standard deviation of the weighted mean position smaller than 0.5 μas and a linear drift smaller than 50 μas/year are an indication that the source might be stable. We thus select a set of 22 additional sources.

The second extension is based on a re-iterated computation of time series of coordinates provided by C. Ma. The MFV scheme was applied to time series of source coordinates that were derived taking subsets of the ICRF *defining* sources as the background reference. As a sizeable part of those were detected as unstable, one could not rule out the possibility that the intrinsic instability of the set of reference sources create spurious instabilities in the sources under study. A slightly modified scheme was therefore applied to time series of source coordinates derived from a global analysis where the original 199 stable sources where held fixed relative to the ICRF through a No-Net-Rotation (NNR) condition, using the CALC-SOLVE software package. The modified selection scheme includes the following rejection condition. Apparent drifts in $\alpha \cos\delta$ or δ larger than 10 μas/year, at a 5-σ significance. A set of 44 sources were detected as stable by this modified scheme.

Moreover, when the additional stability condition is applied to the time series used by Feissel-Vernier [1], the following 18 sources are found to be unstable. 0059+581, 0202+149, 0229+131, 0234+285, 0602+673, 0738+313, 0745+241, 0749+540, 1045-188, 1053+704, 1404+286 (OQ208),

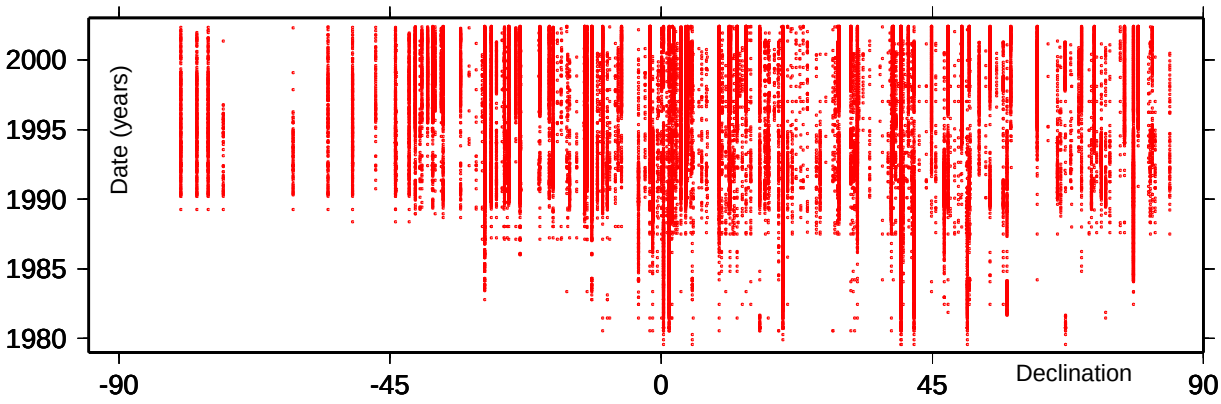

Figure 1. 1979-2002 observations of the 247 most stable sources. Each dot represents a session in which the source was observed.

1502+106, 1606+106, 1611+343, 1638+398 (NRAO512), 1642+690, 1726+455, 1738+476. The source names used here are the IERS source designations (see http://hpiers.obspm.fr/icrs-pc/icrf/icrfdico.html). The names used by the IVS are given in brackets when different. This modified scheme reduces the original set of 199 stable sources to only 181. This is the third change in the source selection.

In summary, a list of 247 sources considered stable, and thus considered suitable for the maintenance of the ICRF axes were obtained as follows.

- Adding to the MFV stability scheme the exclusion of sources with apparent drifts in $\alpha \cos\delta$ or δ larger than 10 μas/year , at a 5-σ significance and applying it to the data set used by Feissel-Vernier [1] provides a first list of 181 proposed reference sources.
- Selecting sources with low position scatter in the sparsely observed sources over 1990-2002 adds another 22 objects to the proposed reference sources.
- Applying the modified stability scheme to time series of source coordinates derived from a global analysis where the original 199 stable sources where held fixed provides 44 additional proposed reference sources.

The 247 sources are available at URL http://hpiers.obspm.fr/icrs-pc/icrf/stable_2006.txt. Their observation history is illustrated in Figure 1.

2. Stability of VLBI Station Positions

We summarize hereafter a set of statistical tests and diagnostics concerning the spectral content of time series of coordinates of IVS stations, using time series of station coordinates provided by C. Ma. The major signature in time series of station coordinates is usually modelled as a tridimensional linear drift. The horizontal component is mostly related to the tectonic plate motion, while the Up component is assumed to reflect uplift or subsidence. The remaining component ("non-linear motion") may be interpreted as noise related to local geophysical phenomena, instrumentation, or to the analysis strategies and modelling. Our analysis method is focusing on time series of residual coordinates relative to linear motion of the stations. The analysis is based on the combined use of Principal Components in the time domain (PCT) and Allan variance analysis [4].

Table 1. Stability estimators for 37 VLBI stations, 1990.0-2004.2

DOMES No	Stn	Start	End	Y	%Ms %Var	PCT1 ASdv mm	Sp	1-yr All_StDv, Noise East mm	North mm	Up mm	Mult fact	Stb ind
40424S001	1311	90.1	94.1	4	7 99%	3.5	Wh	0.7 Wh	0.1 Wh	3.5 Wh	2.42	1.8
41705S006	1404	91.9	96.9	5	11 81%	5.5	Wh	2.7 Wh	0.9 Wh	4.9 Wh	1.11	2.0
50103S010	1545	90.3	03.8	13	56* 63%	4.4	Wh	1.9 Wh	2.8 Wh	4.4 Wh	0.54	2.2
13407S010	1565	90.1	03.3	13	53* 73%	3.6	Wh	1.5 Wh	2.1 Wh	3.6 Wh	1.30	1.6
21701S001	1856	90.1	02.2	12	41 93%	10.4	Wh	1.5 Wh	2.6 Wh	10.1 Wh	2.84	3.9
21701S004	1857	90.3	03.9	13	69* 73%	14.7	Wh	2.7 Wh	11.3 Wh	13.2 Wh	1.88	6.1
40451M125	7108	93.4	03.5	10	60* 99%	19.7	Wh	1.5 Wh	4.3 Wh	19.4 Wh	0.01	7.8
40441S007	7208	95.1	00.5	5	9 93%	2.9	Fl	0.8 Wh	0.6 Wh	2.8 Wh	3.77	1.6
40440S003	7209	90.1	04.2	14	1 80%	3.1	Wh	0.7 Wh	0.6 Wh	3.1 Wh	3.31	1.1
10402S002	7213	90.1	04.2	14	21 91%	3.8	Wh	0.5 Wh	1.2 Wh	3.8 Wh	2.52	1.5
40441S004	7214	90.1	96.6	6	3 81%	1.5	Wh	1.7 Fl	0.7 Wh	1.2 Wh	1.22	0.7
14201S004	7224	90.1	04.2	14	0 85%	1.7	Wh	0.6 Wh	0.5 Wh	1.7 Wh	2.32	0.7
40408S002	7225	90.1	02.8	12	1 86%	2.5	Fl	0.8 Wh	1.0 Wh	2.5 Fl	2.99	1.5
21605S009	7227	90.3	04.2	14	49* 64%	6.3	Wh	3.8 Wh	3.2 Wh	6.3 Wh	1.11	2.8
12711S001	7230	90.1	04.2	14	38* 92%	3.2	Wh	0.8 Wh	0.8 Wh	3.2 Wh	2.03	1.5
30302S001	7232	90.1	04.2	14	2 81%	3.9	Wh	1.2 Wh	1.5 Wh	3.9 Wh	1.07	1.8
40456S001	7234	90.1	03.7	13	41 88%	4.9	Wh	0.8 Wh	1.3 Wh	4.9 Wh	4.92	2.0
50116S002	7242	90.2	04.2	14	12 71%	4.7	Wh	1.8 Wh	1.9 Wh	4.6 Wh	1.04	1.9
12734S005	7243	90.8	03.9	13	11 90%	1.8	Wh	0.5 Wh	0.8 Wh	1.7 Wh	1.06	0.7
66008S001	7245	93.1	04.1	11	81* 83%	13.6	Wh	6.7 Wh	4.2 Wh	13.6 Wh	1.03	5.4
40104S001	7282	90.5	04.2	13	17* 93%	3.1	Wh	0.8 Wh	0.7 Wh	3.1 Wh	1.98	1.2
40127M004	7296	91.5	03.4	11	74* 89%	8.4	Wh	1.8 Wh	2.6 Wh	8.0 Wh	1.62	3.1
41602S001	7297	93.4	04.2	10	7* 88%	4.2	Wh	1.0 Wh	1.1 Wh	4.1 Wh	2.25	1.8
40424S007	7298	93.5	04.2	10	0 73%	1.3	Wh	0.8 Wh	0.4 Wh	1.3 Wh	1.25	0.6
10317S003	7331	94.8	04.2	9	2 95%	2.7	Wh	0.6 Wh	0.6 Wh	2.6 Fl	3.48	1.5
12337S008	7332	94.5	03.2	8	61* 90%	9.2	Wh	2.6 Wh	5.1 Wh	8.8 Wh	0.94	3.6
21730S007	7345	98.5	04.1	5	14 66%	3.1	Wh	1.5 Wh	2.9 Wh	1.0 Wh	2.26	1.1
12717S001	7547	90.1	03.9	13	58* 90%	2.7	Wh	0.7 Wh	1.7 Wh	2.7 Wh	0.88	1.1
40466S001	7610	92.7	03.7	11	44* 84%	2.5	Wh	0.6 Wh	0.8 Wh	2.5 Wh	2.69	0.9
40463S001	7611	91.4	03.7	12	29 93%	3.4	Wh	0.6 Wh	0.6 Wh	3.4 Wh	4.49	1.3
40465S001	7612	92.7	03.5	11	40 90%	3.7	Wh	0.6 Wh	1.0 Wh	3.6 Wh	4.03	1.7
40442S017	7613	92.1	03.7	11	33 75%	1.9	Wh	0.4 Wh	0.9 Wh	2.0 Wh	2.10	0.8
40473S001	7614	93.4	03.5	10	36 95%	3.6	Wh	0.7 Wh	0.6 Wh	3.6 Wh	4.17	1.4
43201S001	7615	93.5	03.7	10	37 94%	4.3	Wh	1.0 Wh	1.2 Wh	4.2 Wh	2.23	1.9
40439S006	7616	92.7	03.7	11	43* 93%	3.1	Wh	0.8 Wh	0.9 Wh	3.1 Wh	3.40	1.6
40477S001	7617	93.6	03.8	10	36 84%	3.2	Wh	1.6 Wh	0.9 Wh	2.8 Wh	1.87	1.2
40471S001	7618	92.7	03.7	11	40* 60%	1.7	Wh	1.1 Wh	1.0 Wh	1.7 Wh	1.18	0.9

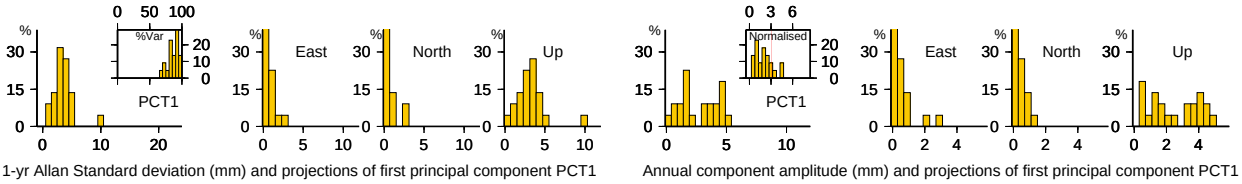

Figure 2. Distribution of the medium term stability (1-yr Allan standard deviation) and of the amplitude of the annual component in the 1990-2004 motion of 22 well observed IVS stations. The normalized amplitude is the ratio of the amplitude estimated by least squares analysis to its formal uncertainty.

The statistical quantities thus derived include medium term stability and annual signatures, scaling factors of the original coordinates uncertainties, stability indices, and various flags and criteria [3]. Table 1 gives details of the stability results found for 37 IVS stations. The meaning of the headings is as follows.

- DOMES No; Stn; Start; End; Y: DOMES Number and CDP name of the station; start and end dates of the data span, in years (first two digits of year omitted), and number of yearly averages.
- %Ms: Percentage of missing points in the time series, considering 35-d averages. The 15 stations flagged by $*$ have data gaps longer than 200 days.
- PCT1: Percentage of signal variance that it explains (%Var), Allan standard deviation for a one-year sampling time in millimetres (ASdv) - see the distribution of these quantities in Figure 2 - and noise spectrum (Sp). "Wh" stands for white noise, "Fl" for flicker noise.
- 1-yr All_StDv, Sp (East, North, Up): Allan standard deviation for the one-year sampling time of the series in the local coordinate system, in millimetres, and noise spectrum.
- Mult fact: Scale factor of the original coordinates uncertainties based on the Allan variance for the one-year sampling time. Large scale factors indicate larger underestimation of the formal uncertainties.
- Stb ind: Stability index. The most stable series have the lowest stability index.

The distributions of PCT1 Allan standard deviations and of their projections onto the East, North, Up directions are shown on Figure 2. The left part concerns the Allan variance of the non-linear signal for a one-year sampling time (independent of the annual signature, by construction) and the right part concerns the annual signature. In both cases, most of the signal is in the Up direction, with clear splitting in two populations in the case of the annual component. As indicated by the insert of the PCT1 histogram, a number of these seasonal amplitudes are significant at the 1-σ level, and a few are significant at the 3-σ level.

References

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[2] Feissel-Vernier, M., Ma, C., Gontier, A.-M., Barache, C., 2006, A&A (in press).

[3] Feissel-Vernier, M., Le Bail, K., 2006, IGS 2004-2005 Technical report (in press).

[4] Le Bail K., 2006, J. Geod. (submitted).