

IVS Memorandum 2009-001v01

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**“Some Results of Analysis of Source
Position Time Series”**

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1. Introduction

This memo is intended to contribute to two ICRF-2 preparation steps in accordance with the ICRF-2 Working Plan:

- ranking of sources by time series statistics,
- compiling list of specially handling sources.

In accordance with the ICRF-2 Working Plan, in this memo, only quantitative source stability indices are considered. Since source position variations are sometimes pretty complicated, a visual inspection still may be needed to make a final decision on the quality of a specific source (Gordon et al. 2008).

In this study we considered 33 source position time series submitted in 2007–2009 by IVS analysis centers AUS, BKG, DGF, GSF, IAA, MAO, OPA, SAI, SHA and USN. Some of initially submitted series were replaced by extended versions, some series don not contain session ID which makes them not suitable for some kind of analysis, some series contain too few sources, etc. Finally, 15 series were selected for analysis. These 15 series present various software and analysis strategies which makes them interesting and useful for comparison.

The following preliminary operations were made:

- only position with at least 5 observations were selected,
- only time series with at least 5 positions (epochs) were selected,
- for velocity analysis, only series with time span at least 5 years were selected,
- floor of 20 μ s for source position formal error was applied; this practically does not affect most of the series except the IAA ones.

2. Preliminary analysis

To better understand the result of time series analysis we tried to perform a comparison of methods used in various Analysis Centers for computation of the time series. Preliminary result is presented in Table 1 which still should be checked and completed.

Table 1. The main characteristics of source position time series.

Series software	Time span	EOP	Stations	Sources	Comment
bkg000c Calc/Solve	1984.0 2007.5	all	global	part global, part local	
dgf000f Calc/Solve	1984.0 2007.6	all	no	local with NNR and 3-param transformation (?)	
dgf000g Occam LS	1984.0 2007.6	all	no	local with NNR and 4-param transformation (?)	
gsf001a Calc/Solve	1979.6 2007.9	?	?	part global, part local	
gsf003a Calc/Solve	1979.6 2008.7	?	?	part global, part local	mobile and small networks excluded
iaa001b QUASAR	1979.6 2008.6	all	?	single session solutions for every source	
iaa001c QUASAR	1979.6 2008.6	no	no	single session solutions for every source	
mao000b SteelBreeze	1980.3 2007.3	?	?	local (?)	
mao006a SteelBreeze	1979.6 2008.7	?	?	local (?)	
opa000b Calc/Solve	1984.0 2008.0	all	no	session solutions	
opa002a Calc/Solve	1984.0 2008.7	LOD, nutation	local	part global, part local	
sai000b ARIADNA	1984.0 2008.0	?	?	session solutions with NNR for selected sources	
sha006a Calc/Solve	1979.6 2008.8	?	?	part local. part global	
usn000d Calc/Solve	1979.6 2007.4	LOD, nutation	local	part local, part global	
usn001a Calc/Solve	1979.6 2007.4	no	no	session solutions	

To get a preliminary impression about differences of the position time series produced by the participated Analysis Centers, source position time series were visually inspected. As was already pointed out in Malkin (2008b), different time series show different source position scatter and, for some sources, different long-term behavior. Two examples are given in Figs. 1 and 2. Three series mao000b, opa000b and usn001a show clear change point in DE around 2003.0 for both sources. Very similar break at the same epoch can be seen also for 0851+202, 0003–0660, 0727–115 and some other sources. Somewhat other situation can be seen for 1741–038 (Fig. 2) where two DE series opa000b and usn001a show a supplement change point around 1993.0 or maybe long-period signal. Commonly speaking, e.g. usn001a series shows strong irregular position variations for many sources, which are not seen in usn000d or most of other series.

The epoch of jump around 2003.0 may be connected with at least two events: the earthquake near Gilmore Creek and the start of regular operations at Svetloe. The first event seems to be the most important and worth careful investigation. Macmillan & Cohen (2004) and Titov & Tregoning (2005) detected an effect of the Alaska 2002 earthquake on EOP estimates. Evidently, there will be also an impact of different treatment of GILCREEK position on source coordinates. As a test, a source position time series w/o GILCREEK may be computed.

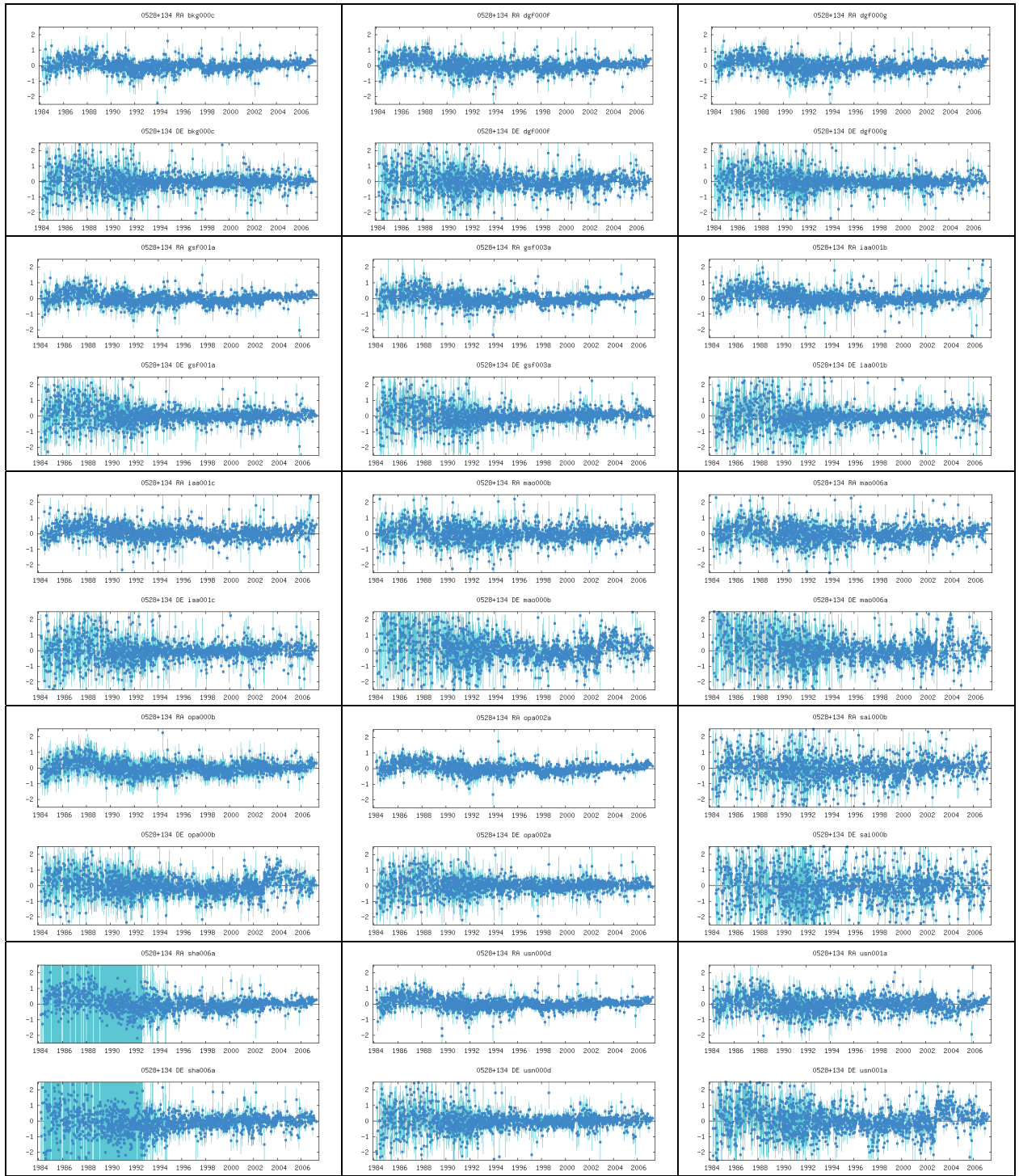


Fig. 1. Position time series for 0528+134. It should be mentioned that all the newest time series extending till 2008 (gsf, iaa, mao, opa, sha) show a clear change point, especially in RA, at the epoch around 2007.0.

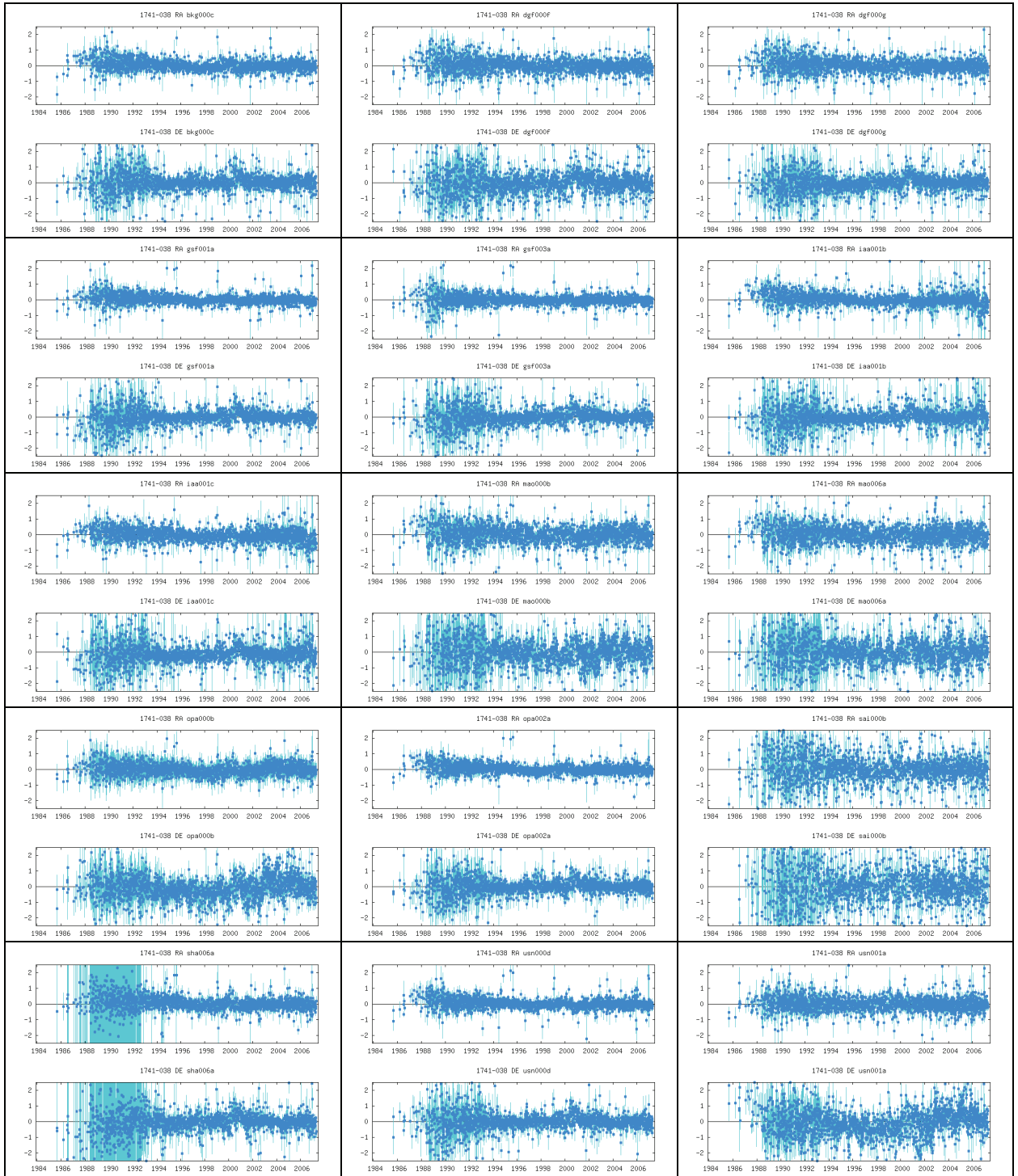


Fig. 2. Position time series for 1741–038.

There is no room in this memo to analyze all the time series. However, a conclusion can be made that the methods used for generation of source position time series considerably influence not only the scatter but also systematic behavior of source position variations. Both examples show also different noise level for different series, which will be quantified in the next section.

3. Ranking of sources by instability indices

From several scatter or instability indices used for analysis of source position time series we used two ones weighted root-mean-square residuals of the session source position w.r.t. weighted mean position, where weights are inversely proportional to the square of formal error (WRMS) and weighted Allan deviation (WADEV) computed as proposed in Malkin (2008a). The combined RA and DE (2D) results are used for source ranking.

Both used statistics, WRMS and WADEV have own advantages and disadvantages. WRMS estimate includes contribution of systematic (e.g. trend-like) and low-frequency (quasi-) periodic variations. WADEV is not affected by slow position variations; however, it may give inadequate estimate of source position stability in a case of jumps in the time series and small position variation at time intervals between jumps. To get mo general index of source position variations, composite index computed as the sum of WRMS and WADEV was used for final source ranking.

The computations were performed in two steps. At the first step, source positions for common epochs were selected from 15 series listed above. Several statistics were computed for these "common-epochs" series, two of them are presented in Table 2. The table allows us to compare the noise of each series, and later use this data for series selection at the next iteration of this work. The last row of Table 1 shows statistics for the weighted average series.

Average series was computed and used for final source ranking. Indeed, it should be considered as the first iteration only since, as shown above, systematic difference between series may exist depending on time series generation method, and these differences should be explained and eliminated. Besides, a set of time series used for averaging should be accurately selected. However, as our tests showed, this does not much influence the source ranking results, which may be more sensitive to session and time span and interval selection, cf. e.g. Tables 3 and 4 which present the results of source ranking based on WRMS+WADEV statistics of average time series computed for common only and for all epochs.

Table 2. 2D WRMS/WADEV for the most frequently observed sources and median values for all the sources, $_as$. N – number of common epochs (sessions).

Series	0552+398 N=2168	0923+392 N=1919	1741-038 N=1868	0851+202 N=1678	0727-115 N=1675	0528+134 N=1653	1749+096 N=1516	Median
bkg000c	207 / 209	316 / 251	385 / 420	324 / 330	413 / 472	362 / 370	312 / 353	457 / 515
dgf000f	235 / 233	344 / 289	547 / 546	381 / 372	558 / 585	453 / 436	433 / 433	512 / 557
dgf000g	180 / 186	302 / 248	437 / 450	296 / 306	476 / 524	368 / 368	323 / 350	442 / 499
gsf001a	161 / 161	258 / 208	294 / 316	275 / 262	365 / 410	334 / 337	234 / 261	394 / 449
gsf003a	163 / 166	254 / 203	311 / 334	273 / 273	350 / 397	321 / 321	238 / 261	400 / 456
iaa001b	200 / 210	317 / 245	413 / 426	380 / 336	442 / 495	397 / 409	303 / 348	464 / 529
iaa001c	284 / 288	340 / 289	486 / 473	386 / 384	502 / 552	425 / 444	393 / 407	522 / 585
mao000b	442 / 434	511 / 484	728 / 713	612 / 566	705 / 738	682 / 633	657 / 620	675 / 718
mao006a	486 / 463	563 / 519	931 / 803	775 / 636	937 / 889	868 / 706	857 / 709	740 / 767
opa000b	355 / 338	435 / 393	742 / 665	519 / 473	669 / 671	606 / 526	650 / 563	577 / 588
opa002a	174 / 178	278 / 218	307 / 330	284 / 270	344 / 394	328 / 330	242 / 281	382 / 430
sai000b	504 / 581	624 / 718	968 / 1113	699 / 766	1146/1372	852 / 978	789 / 915	906 / 1076
sha006a	185 / 188	249 / 217	354 / 387	278 / 278	468 / 505	389 / 366	296 / 337	446 / 501
usn000d	167 / 172	279 / 219	331 / 354	289 / 281	379 / 432	338 / 346	260 / 295	402 / 468
usn001a	445 / 429	522 / 472	722 / 711	620 / 550	670 / 693	690 / 630	660 / 620	680 / 732
Average	159 / 162	285 / 206	337 / 345	284 / 284	363 / 391	351 / 340	301 / 280	413 / 455

Table 3. Ranking of sources by WRMS+WAVEV, common sessions, 411 sources.

1357+769 0.2814	1435+638 0.5604	0336-019 0.7306	0148+274 0.9025	0201+113 1.1625	0111+021 1.5634
1300+580 0.2824	2136+141 0.5623	0836+710 0.7316	1228+126 0.9050	2252-090 1.1698	0457+024 1.5646
0059+581 0.2964	2229+695 0.5638	1954+513 0.7351	0221+067 0.9059	1555+001 1.1721	2128-123 1.5691
0133+476 0.3124	1849+670 0.5660	1633+382 0.7379	1404+286 0.9210	1023+131 1.1743	1133+704 1.5734
0602+673 0.3128	1717+178 0.5662	1144+402 0.7444	0048-097 0.9237	1548+056 1.1766	0839+187 1.5779
0552+398 0.3205	0851+202 0.5679	0716+714 0.7487	1123+264 0.9243	0636+680 1.1778	0402-362 1.5836
1807+698 0.3272	1111+149 0.5707	1637+826 0.7528	2235+731 0.9253	2008-159 1.1818	1302-102 1.6166
0749+540 0.3301	0828+493 0.5811	0736+017 0.7541	1705+135 0.9264	2335-027 1.1866	0237-027 1.6287
1448+762 0.3378	0234+285 0.5891	0727-115 0.7547	2121+053 0.9269	0539-057 1.1941	0814+425 1.6419
1739+522 0.3511	0008-264 0.5917	0637-752 0.7588	0610+260 0.9295	1215+303 1.1956	2345-167 1.6554
1751+288 0.3581	2223-052 0.5940	0754+100 0.7590	1958-179 0.9300	0013-005 1.1993	1806-458 1.6636
0642+449 0.3645	2113+293 0.5946	2253+417 0.7609	1413+135 0.9318	2155-152 1.2107	2059+034 1.6974
1039+811 0.3735	1749+701 0.5947	2021+317 0.7613	0130-171 0.9357	2021+614 1.2109	0738+313 1.7130
1800+440 0.3849	1342+662 0.5963	1928+738 0.7614	0502+049 0.9374	0409+229 1.2206	0723-008 1.7365
0955+476 0.3882	0722+145 0.6024	0805+046 0.7623	0454-234 0.9459	2227-088 1.2303	1402-012 1.7392
1803+784 0.3942	1758+388 0.6043	0536+145 0.7702	1929+226 0.9530	1104-445 1.2335	0238-084 1.7556
0224+671 0.3957	1315+346 0.6073	0600+177 0.7713	1830+285 0.9567	1255-316 1.2390	2254+024 1.7749
0035+413 0.3977	0615+820 0.6115	0556+238 0.7778	1226+373 0.9681	0406+121 1.2409	1451-400 1.7804
1417+385 0.3992	1508+572 0.6117	1124-186 0.7790	0823+033 0.9682	1614+051 1.2460	0524-460 1.7839
1044+719 0.4053	1600+335 0.6124	1652+398 0.7820	2144+092 0.9700	2243-123 1.2470	0405-123 1.8240
1639+230 0.4057	1705+456 0.6185	1504+377 0.7824	1546+027 0.9714	2344+092 1.2601	1253-055 1.8596
1655+077 0.4066	0820+560 0.6185	0123+257 0.7870	1920-211 0.9742	1522+155 1.2607	1313-333 1.8607
1611+343 0.4131	0748+126 0.6190	2254+074 0.7879	0426+273 0.9746	1705+018 1.2674	1349-439 1.8738
1638+398 0.4144	1923+210 0.6205	0601+245 0.7900	0003-066 0.9748	1213-172 1.2713	0256+075 1.9108
0110+495 0.4202	2201+315 0.6221	0322+222 0.7907	1743+173 0.9784	2230+114 1.2850	0422-380 1.9134
1213+350 0.4300	1459+480 0.6311	0003+380 0.7948	1532+016 0.9843	0420-014 1.3026	0430+052 1.9177
1011+250 0.4316	1732+389 0.6312	1342+663 0.7950	0951+693 0.9852	1004+141 1.3050	1932+204 1.9218
2037+511 0.4357	1538+149 0.6375	2351+456 0.7966	2052-474 0.9933	2251+158 1.3053	1040+123 1.9279
0804+499 0.4372	0954+658 0.6404	1746+470 0.7991	1751+441 0.9937	1354+195 1.3063	2255-282 1.9439
0149+218 0.4390	0945+408 0.6406	0215+015 0.7994	0138-097 1.0011	0239+108 1.3094	2106+143 1.9479
1221+809 0.4470	0821+621 0.6409	0151+474 0.8025	0537-286 1.0014	1921-293 1.3100	0521-365 1.9680
0917+624 0.4472	1014+615 0.6437	1502+036 0.8044	1845+797 1.0022	1510-089 1.3121	1142+198 1.9859
0202+319 0.4481	1150+812 0.6446	2234+282 0.8048	1641+399 1.0024	2030+547 1.3128	1222+131 2.0200
0219+428 0.4486	1514+197 0.6497	0920+390 0.8095	1725+044 1.0128	1458+718 1.3160	0355+508 2.0327
1738+476 0.4550	0949+354 0.6540	1045-188 0.8108	1032-199 1.0129	0104-408 1.3182	1226+023 2.0502
1547+507 0.4623	1637+574 0.6544	0554+242 0.8109	0405-385 1.0158	2320-035 1.3197	1354-174 2.1224
0016+731 0.4627	0833+585 0.6573	0657+172 0.8133	2155-304 1.0167	1145-071 1.3201	0118-272 2.1310
1128+385 0.4635	1616+063 0.6597	1147+245 0.8157	0306+102 1.0201	1130+009 1.3270	0648-165 2.1341
1418+546 0.4642	0925-203 0.6627	1116+128 0.8201	0953+254 1.0235	1354-152 1.3290	1048-313 2.1452
1726+455 0.4652	0400+258 0.6647	1057-797 0.8218	0611+131 1.0266	1706-174 1.3326	0019+058 2.1814
1053+704 0.4654	0300+470 0.6649	1038+528 0.8266	1656+053 1.0406	1451-375 1.3481	0710+439 2.1996
0812+367 0.4657	0609+607 0.6696	1519-273 0.8283	2150+173 1.0458	1351-018 1.3682	0237-233 2.2393
0805+410 0.4689	2356+385 0.6722	1954-388 0.8288	1504-166 1.0502	2143-156 1.3717	1442+101 2.2633
0014+813 0.4704	0333+321 0.6740	0859+470 0.8306	0952+179 1.0516	1030+074 1.3763	2134+004 2.4165
1842+681 0.4802	1049+215 0.6771	1252+119 0.8326	0834-201 1.0522	1908-201 1.3788	1055+018 2.4609
0607-157 0.4804	0850+581 0.6798	1012+232 0.8389	1557+032 1.0611	0007+171 1.3895	0919-260 2.6582
1053+815 0.4890	1508-055 0.6802	0119+115 0.8408	2355-106 1.0655	0341+158 1.4014	1622-297 2.8362
0010+405 0.4901	1741-038 0.6823	0829+046 0.8413	0119+041 1.0674	1237-101 1.4073	2037-253 3.2076
2209+236 0.4904	1624+416 0.6829	1020+400 0.8445	0414-189 1.0679	2126-158 1.4093	0316+413 3.9531
0923+392 0.4912	1744+557 0.6859	2318+049 0.8483	1022+194 1.0704	1038+064 1.4095	2328+107 4.5366
1823+568 0.4914	2145+067 0.6882	0342+147 0.8491	2149+056 1.0739	1443-162 1.4209	0212+735 4.7541
2319+272 0.4947	1236+077 0.6907	0955+326 0.8502	1815-553 1.0751	0656+082 1.4403	
0302+625 0.5029	0430+289 0.6909	1821+107 0.8510	0319+121 1.0775	1402+044 1.4439	
0440+345 0.5030	0528+134 0.6911	1656+477 0.8569	2210-257 1.0833	1514-241 1.4470	
0109+224 0.5079	0917+449 0.6916	1307+121 0.8592	0055+300 1.0854	2216-038 1.4487	
2007+777 0.5098	0544+273 0.6958	1936-155 0.8592	1144-379 1.0862	1222+037 1.4584	
0235+164 0.5122	2320+506 0.6972	2029+121 0.8607	0818-128 1.0894	0423+051 1.4636	
0454+844 0.5123	0202+149 0.6986	1219+044 0.8608	0338-214 1.0896	0305+039 1.4690	
0743+259 0.5194	0507+179 0.6999	0458-020 0.8627	0426-380 1.0900	1352-104 1.4696	
1324+224 0.5257	0735+178 0.7014	0745+241 0.8643	0422+004 1.0923	0150-334 1.4886	
1150+497 0.5321	0159+723 0.7073	1427+543 0.8670	1347+539 1.0955	0821+394 1.4931	
0420+417 0.5366	1308+328 0.7086	0146+056 0.8713	0742+103 1.1185	2329-162 1.4937	
0446+112 0.5417	1101+384 0.7113	0248+430 0.8725	0906+015 1.1186	0605-085 1.4956	
1749+096 0.5418	2200+420 0.7115	0208-512 0.8779	0434-188 1.1187	1243-072 1.4963	
1606+106 0.5429	1216+487 0.7124	1334-127 0.8789	2302+232 1.1314	1034-293 1.5029	
0718+792 0.5430	1738+499 0.7129	0046+316 0.8789	1406-076 1.1369	1428+422 1.5244	
0707+476 0.5434	1610-771 0.7169	2244-372 0.8815	1257+145 1.1383	1730-130 1.5315	
1030+415 0.5456	0808+019 0.7192	1424-418 0.8834	1656+348 1.1414	0106+013 1.5450	
1156+295 0.5468	2214+350 0.7195	0229+131 0.8860	1244-255 1.1501	1647-296 1.5457	
1308+326 0.5500	0537-441 0.7204	1901+319 0.8898	1622-253 1.1504	1502+106 1.5470	
1745+624 0.5524	0827+243 0.7251	0309+411 0.8943	1219+285 1.1524	1937-101 1.5495	
1642+690 0.5548	1856+737 0.7296	1240+381 0.8962	0620+389 1.1544	0317+188 1.5538	

Table 4. Ranking of sources by WRMS+WAVEV, all sessions 652 sources.

1330+476 0.1961	2007+777 0.6117	2358+189 0.8194	0201+113 1.1122	0656+082 1.4235	0521-365 1.8970
1357+769 0.2860	1022+194 0.6118	0119+115 0.8228	0341+158 1.1135	0642+214 1.4279	0859-140 1.9014
0836+182 0.2924	1150+812 0.6119	1413+135 0.8250	1213-172 1.1140	0111+021 1.4341	0415+379 1.9085
0834+250 0.3118	1954+513 0.6129	0534-611 0.8274	0522-611 1.1170	1611-710 1.4344	0524-460 1.9129
1300+580 0.3126	0234+285 0.6140	0605-085 0.8286	0539-057 1.1176	0405-385 1.4357	0637-337 1.9145
0059+581 0.3202	0812+367 0.6144	0601+245 0.8321	2149-307 1.1178	1647-296 1.4380	2233-148 1.9159
0133+476 0.3235	0748+126 0.6165	1656+477 0.8346	0506-612 1.1193	1510-089 1.4382	0831+557 1.9287
1807+698 0.3303	0821+394 0.6166	1806+456 0.8358	2230+114 1.1247	0116-219 1.4400	1239+376 1.9335
0602+673 0.3403	1754+155 0.6168	2253+417 0.8380	0537-286 1.1262	1514-241 1.4536	0919-260 1.9431
0759+183 0.3412	1342+662 0.6196	2234+282 0.8388	1101-536 1.1265	2143-156 1.4547	1104-445 1.9513
0515+208 0.3450	2229+695 0.6203	1821+107 0.8429	0130-171 1.1342	1111+149 1.4549	0425+048 1.9519
0749+540 0.3487	0820+560 0.6249	0221+067 0.8455	1251-713 1.1349	0241+622 1.4553	1048-313 1.9568
0642+449 0.3578	0302+625 0.6260	1936-155 0.8534	1219+285 1.1350	2109-811 1.4617	0534-340 1.9612
0552+398 0.3628	0536+145 0.6280	1042+071 0.8538	2335-027 1.1382	0202-172 1.4626	0232+233 1.9904
1739+522 0.3889	1538+149 0.6297	1901+319 0.8545	1020+400 1.1436	0131-522 1.4708	1222+131 1.9906
0955+476 0.3922	2150+173 0.6337	0426+273 0.8567	0248+430 1.1513	1038+064 1.4713	1328+307 2.0167
1642+690 0.3947	1749+701 0.6338	1124-186 0.8612	0235-618 1.1521	1937-101 1.4738	1519-294 2.0229
0110+495 0.4101	0707+476 0.6345	0745+241 0.8619	2131-021 1.1521	0338-214 1.4743	1420-679 2.0404
1638+398 0.4113	1508+572 0.6364	1519-273 0.8661	0814+425 1.1522	0104-408 1.4745	2255-282 2.0450
1011+250 0.4151	1624+416 0.6373	2318+049 0.8668	0834-201 1.1545	1435-218 1.4816	2037-253 2.0720
1044+719 0.4222	1502+036 0.6382	1427+543 0.8670	0039+230 1.1561	0047-579 1.4836	0826-373 2.0746
1417+385 0.4305	1717+178 0.6403	1213+350 0.8686	1511-100 1.1575	2216-038 1.4902	1433+304 2.0771
0420+410 0.4326	0400+258 0.6412	1219+044 0.8693	0422+004 1.1583	2321-375 1.4911	0332-403 2.0866
1803+784 0.4329	1216+487 0.6445	1123+264 0.8742	0406+121 1.1592	1502+106 1.4937	1012-448 2.0953
0804+499 0.4339	0430+289 0.6447	2300-683 0.8771	1130+009 1.1602	0710+439 1.5063	2331-240 2.1298
1611+343 0.4377	0212+735 0.6461	0309+411 0.8774	0138-097 1.1651	0220-349 1.5091	1929-457 2.1339
1324+224 0.4443	0322+222 0.6464	0730+504 0.8795	1555+001 1.1653	1556-245 1.5101	1354-174 2.1408
0446+112 0.4464	1101+384 0.6478	0637-752 0.8834	0007+171 1.1655	1127-145 1.5153	2355-534 2.1579
1636+473 0.4489	1150+497 0.6513	1038+528 0.8843	2155-152 1.1662	1424+366 1.5154	1143-287 2.1959
0538+498 0.4499	1147+245 0.6527	0951+693 0.8845	0305+039 1.1687	0648-165 1.5167	0511-220 2.1985
0917+624 0.4504	1923+210 0.6553	0414-189 0.8860	1824-582 1.1691	2048+312 1.5238	0056-001 2.2048
1128+385 0.4507	0333+321 0.6570	1228+126 0.8862	2023+335 1.1727	1416+067 1.5256	1511-476 2.2184
2037+511 0.4574	2250+190 0.6582	0610+260 0.8936	0506+101 1.1852	2126-158 1.5298	2054-377 2.2378
1617+229 0.4588	2200+420 0.6603	0229+131 0.8950	1614+051 1.1856	1155+251 1.5299	0529+075 2.2391
1842+681 0.4685	1744+557 0.6637	1633+382 0.8959	0440-003 1.1896	0438-436 1.5300	1038+529 2.2747
1418+546 0.4744	0003+380 0.6686	1226+373 0.8999	1954-388 1.1907	1622-297 1.5331	1055-301 2.2837
0805+410 0.4770	2351-154 0.6686	1049+215 0.9003	2355-106 1.1922	1445-161 1.5342	1253-055 2.2930
0440+345 0.4831	0549-575 0.6705	0458-020 0.9029	0530-727 1.1932	1815-553 1.5373	1245-457 2.2974
0035+413 0.4847	0736+017 0.6757	0945+408 0.9069	0723-008 1.1955	2052-474 1.5385	0743-673 2.3320
0358+210 0.4870	0123+257 0.6759	0611+131 0.9100	0823-223 1.1956	1257+145 1.5418	0108+388 2.3399
0010+405 0.4900	0912+029 0.6762	1420+326 0.9119	1557+032 1.1967	0402-362 1.5459	1142+198 2.3659
2209+236 0.4901	2201+315 0.6766	1404+286 0.9136	2353-686 1.2009	1133+704 1.5649	2058-297 2.3859
1751+288 0.4927	1417+273 0.6774	1932+204 0.9147	1428+422 1.2024	1921-293 1.5666	1451-400 2.4187
1800+440 0.4941	1514+197 0.6822	1546+027 0.9156	2005+642 1.2024	1104+728 1.5785	1016-311 2.4262
0805-077 0.4948	1435+638 0.6889	1624-617 0.9186	0430+052 1.2072	0400-319 1.5876	0002-478 2.4288
1823+568 0.4959	0808+019 0.6902	1705+135 0.9257	0208-512 1.2089	2252-090 1.5997	2227-088 2.4628
1726+455 0.4969	0821+621 0.6926	1423+146 0.9327	2149+056 1.2117	0153+744 1.6027	1349-439 2.4712
0235+164 0.5013	0716+714 0.6930	0823+033 0.9327	1237-101 1.2120	1128-047 1.6077	1128-047 1.6077
0219+428 0.5040	0403-132 0.7004	0454+844 0.9381	1548+056 1.2153	1817-254 1.6104	2314-340 2.5319
0014+813 0.5075	0954+658 0.7006	1252+119 0.9399	0405-123 1.2156	0451-282 1.6117	0711+356 2.5401
1432+200 0.5128	1308+328 0.7045	0952+179 0.9450	2008-159 1.2176	1034-293 1.6140	2254+024 2.5415
0743+259 0.5189	2356+385 0.7071	1338+381 0.9453	0319+121 1.2190	1040+244 1.6160	1412-368 2.5465
0151+474 0.5197	0528+134 0.7081	2021+317 0.9457	0906+015 1.2201	2128-123 1.6269	2030-689 2.5678
0202+319 0.5206	0107-610 0.7108	2254+074 0.9472	1758-651 1.2248	1004-500 1.6274	1226-028 2.6455
0016+731 0.5206	0850+581 0.7113	1045-188 0.9489	0256+075 1.2257	2251+158 1.6307	1725-795 2.6640
0607-157 0.5208	0547+234 0.7121	2244-372 0.9523	2204-540 1.2300	0454-463 1.6314	1633-810 2.6830
0923+392 0.5209	2029+121 0.7128	0239+108 0.9525	0112-017 1.2302	0150-334 1.6370	1226+023 2.6926
0738+491 0.5245	1144+402 0.7197	2235+731 0.9527	0013-005 1.2325	1302-102 1.6395	0912+297 2.7101
2000+472 0.5254	1746+470 0.7199	0743-006 0.9531	1032-199 1.2386	2000-330 1.6476	2059-786 2.7364
0836+710 0.5336	0215+015 0.7239	0048-097 0.9550	1831-711 1.2419	1951+355 1.6536	1806-458 2.7744
1014+615 0.5338	1741-038 0.7241	1958-179 0.9566	2243-123 1.2425	0048-427 1.6597	0122-514 2.7879
2320+506 0.5357	0600+177 0.7253	0055+300 0.9583	1443-162 1.2435	0238-084 1.6597	2134+004 2.7893
1012+232 0.5407	2017+745 0.7255	1656+053 0.9600	2328+107 1.2455	2002-375 1.6630	0629+160 2.7935
0159+723 0.5412	0202+149 0.7256	1334-127 0.9644	0423+051 1.2490	1619-680 1.6634	1021-006 2.8242
1039+811 0.5444	1637+826 0.7277	0234-301 0.9714	2059+034 1.2526	2312-319 1.6747	0920-397 2.8557
1749+096 0.5453	0828+493 0.7283	1903-802 0.9764	1727+502 1.2533	1730-130 1.6753	1451-375 2.8818
1600+335 0.5478	0615+820 0.7292	0007+106 0.9814	0252-549 1.2535	1325-558 1.6790	2005+403 2.9384
1639+230 0.5490	2144+092 0.7337	1022-665 0.9862	2344+092 1.2552	2250+194 1.7003	0629-418 2.9566
2236-572 0.5494	0827+243 0.7365	0620+389 0.9873	1004+141 1.2626	1222+037 1.7109	2306-312 2.9955
1236+077 0.5507	1240+381 0.7373	0459+135 0.9894	1657-562 1.2674	2142-758 1.7109	1604-333 3.0199
0949+354 0.5508	0754+100 0.7411	1354-152 0.9897	2325-150 1.2675	0459+060 1.7140	0118-272 3.0401
0149+218 0.5517	0444+634 0.7417	1315+346 0.9928	2021+614 1.2679	1657-261 1.7250	0733-174 3.0773
1053+815 0.5533	0300+470 0.7434	0306+102 0.9957	0334-546 1.2696	1402-012 1.7286	0437-454 3.0991
1738+476 0.5550	1406-076 0.7436	1409+218 0.9960	2008-068 1.2707	1925-610 1.7545	2102-659 3.1410
1547+507 0.5551	1347+539 0.7444	1656+348 1.0017	2320-035 1.2747	0537-158 1.7590	2146-783 3.2624
1606+106 0.5569	1342+663 0.7467	0003-066 1.0054	0738-674 1.2973	1101-325 1.7616	0518+165 3.3091

1734+363 0.5587	0502+049 0.7468	0454-810 1.0076	1156-663 1.3020	0646-306 1.7696	2352+495 3.3987
0406-127 0.5595	1504+377 0.7503	2121+053 1.0101	1402+044 1.3025	2337+264 1.7698	0405+304 3.4012
1745+624 0.5604	1637+574 0.7516	0554+242 1.0130	1641+399 1.3027	2106-413 1.7728	1345+125 3.4489
1030+415 0.5606	1929+226 0.7525	1034-374 1.0131	0008-264 1.3040	0528-250 1.7775	1105-680 3.4543
1459+480 0.5606	0650+371 0.7546	0230-790 1.0167	0317+188 1.3085	2210-257 1.7799	0335-364 3.5931
1849+670 0.5630	1057-797 0.7595	1830+285 1.0174	1023+131 1.3098	1313-333 1.7817	1607+268 3.6208
0224+671 0.5641	0920+390 0.7634	0537-441 1.0182	1458+718 1.3117	0738+313 1.7824	1116-462 3.6519
1508-055 0.5669	0458+138 0.7644	0529+483 1.0196	1622-253 1.3218	0326+277 1.7862	1826+796 3.7077
1221+809 0.5695	0336-019 0.7645	0953+254 1.0230	1040+123 1.3260	2344-514 1.7862	0503-608 3.7218
1448+762 0.5733	1751+441 0.7652	1610-771 1.0295	0237-027 1.3272	1148-001 1.7875	1156-094 3.8763
2319+272 0.5736	0657+172 0.7659	0454-234 1.0305	1030+074 1.3302	1255-316 1.8046	1454-354 3.9293
1053+704 0.5756	2145+067 0.7661	0516-621 1.0342	1354+195 1.3326	1706-174 1.8076	0237-233 4.0042
2136+141 0.5774	1856+737 0.7687	1145-071 1.0408	1424-418 1.3336	2155-304 1.8175	0026+346 4.0215
0833+585 0.5789	0507+179 0.7693	1926+087 1.0431	0818-128 1.3344	0355+508 1.8220	1236-684 4.0650
1308+326 0.5798	1215+303 0.7721	0148+274 1.0460	2329-162 1.3354	1933-400 1.8319	0236+610 4.3754
2113+293 0.5798	0046+316 0.7727	0135-247 1.0461	1243-072 1.3419	0457+024 1.8340	0316+413 4.5249
1156+295 0.5816	1532+016 0.7755	0237+040 1.0515	1549-790 1.3469	0113-118 1.8376	1043+066 4.6841
2201+171 0.5823	1116+128 0.7790	0636+680 1.0599	2051+745 1.3470	1522+155 1.8385	1718-649 4.8314
0109+224 0.5846	0735+178 0.7816	1448-648 1.0606	1351-018 1.3478	2329-384 1.8416	2128+048 4.8494
0609+607 0.5846	0859+470 0.7850	0119+041 1.0700	1015+359 1.3520	2245-328 1.8429	1947+079 4.9357
1705+456 0.5865	1652+398 0.7865	0839+187 1.0722	1144-379 1.3573	2351-309 1.8430	1031+567 5.2445
1758+388 0.5867	0805+046 0.7865	1659-621 1.0748	0422-380 1.3747	1430+365 1.8434	0134+329 6.0889
1655+077 0.5884	0544+273 0.7897	2030+547 1.0750	0037+139 1.3783	2106+143 1.8435	1322-427 7.8807
1732+389 0.5902	0727-115 0.7903	1307+121 1.0788	1424+240 1.3783	1143-696 1.8472	2005-489 8.1783
2351+456 0.5927	0829+046 0.7904	1725+044 1.0793	1129-580 1.3818	0500+019 1.8581	1323+321 12.8057
0718+792 0.5929	0409+229 0.7912	0308-611 1.0803	1143-245 1.3819	0355-669 1.8701	0218+357 47.0606
0722+145 0.5960	0556+238 0.7935	1705+018 1.0874	1352-104 1.3837	2326-477 1.8721	
0917+449 0.6005	1616+063 0.7941	1244-255 1.0939	0420-014 1.3839	0434-188 1.8726	
2223-052 0.6009	1928+738 0.8027	1055+018 1.0975	1504-166 1.4003	0426-380 1.8842	
0508+138 0.6046	0651+410 0.8031	1920-211 1.0999	1442+101 1.4084	2227-399 1.8867	
2214+350 0.6050	1743+173 0.8073	2302+232 1.1074	1908-201 1.4144	2232-488 1.8869	
0851+202 0.6085	0602+405 0.8106	0106+013 1.1090	0019+058 1.4154	0524-485 1.8902	
0955+326 0.6087	0146+056 0.8141	0742+103 1.1100	1845+797 1.4156	1935-692 1.8924	
1738+499 0.6115	0342+147 0.8145	0302-623 1.1120	0925-203 1.4167	2345-167 1.8955	

4. Sources with non-random position variations

MacMillan & Ma (2007) identified eight sources with irregular apparent motion: 0014+813, 0528+134, 0923+392 (4C39.25), 1739+522, 2145+067, 2223-052 (3C446), 2234+282 and 2243-123. In addition, visual examination of time series gsf003a, usn000d and usn001a (the latter was used for control only; as mentioned above, this series along with a couple of others show many change points in position time series) allows us to select the following sources for further investigation (as a rule, only change points after 1990.0 were considered): 0003-066, 0007+171, 0106+013, 0119+015, 0133+476, 0149+218, 0201+113, 0202+149, 0235+164, 0336-019, 0420-014, 0451-282, 0454-234, 0556+238, 0602+673, 0953+254, 1044+719, 1308+326, 1610-771, 1611+343, 1741-038, 2121+053, 2128-123, 2136+141, 2201+315.

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