



Next ICRF: Single global solution versus combination

Yaroslav Yatskiv

Main Astronomical Observatory NASU, Kiev, Ukraine

Zinovy Malkin

Central Astronomical Observatory at Pulkovo RAS,
St. Petersburg, Russia

Aim

Comparison of two approaches to generate the ICRF-2:

- **Computation of the radio source positions in a single analysis center making use of the most advanced models, software and analysis strategy.**
- **Combination of several (best) CRF realizations after investigation and accounting for their stochastic and systematic errors.**

Fundamental catalogues of star positions

FCAG → NFK → FK3 → FK4 → FK5 → FK6
(2) (1907) (1938) (1963) (1988) (1999-)

PGC → GC
(1910) (1937)

PFKSZ → PFKSZ-2
(1958) (1980)

IERS Celestial Reference Frame

1988 – now

RSC (GAOUA) sine 1991, RSC (PUL) since 2007

Combining radio source position catalogues
obtained by the VLBI analysis centers

MAO UA, PUL RAS ...

1996 – now

ICRF → ICRF-Ext.1 → ICRF-Ext.2 → ICRF-2

Single global VLBI solution

GSFC, USNO ...

GAOUA combined catalogues

Method: Kyiv arc length method (Yatskiv Y.S.
Kuryanova
A.N., 1991)

Input: Individual catalogues of radio source positions
provided by the AC

Examples: RSC (GAOUA) 91 C 02
RSC (GAOUA) 00 C 01
RSC (GAOUA) 03 C01
RSC (GAOUA) 05 C 01

Statistics of individual celestial reference frames and the GAOUA series of compiled catalogues

1991									
Frame	N	Nd	$\sigma\alpha$	$\sigma\delta$	W	$\overline{\Delta\alpha^*}$	$\overline{\Delta\delta}$	$\langle\Delta\alpha^*\rangle$	$\langle\Delta\delta\rangle$
RSC (GSFC) 90 R 01	72	6	0.11	0.20	0.60				
RSC (JPL) 90 R 02	197	6	0.39	0.55	0.17				
RSC (NGS) 90 R 01	70	6	0.16	0.30	0.23				
RSC (USNO) 90 R 02	77	4	0.18	0.25	—				
RSC (GAOUA) 91 C 02	228	59	0.75	1.15	—	-.05	.17	1.82	1.36
RSC (GAOUA) 91 C 02	228	6	0.15	0.17	—	-.02	.15	.24	.25

Statistics of individual celestial reference frames and the GAOUA series of compiled catalogues

2000									
RSC (SHA)00 R 01	636	204	0.15	0.18	0.30				
RSC (GSFC) 00 R 01	624	204	0.11	0.13	0.42				
RSC (BKGI) 00 R 01	621	204	0.15	0.17	0.28				
RSC (IAA) 00 R 03	312	81	0.13	0.20	–				
RSC (GAOUA) 00R 01	191	47	0.22	0.39	–				
RSC (FFI) 00R 01	104	41	0.13	0.11	–				
RSC (GAOUA) 00C 01	669	212	0.07	0.08	–	.00	.01	.24	.26

List of VLBI frames under consideration

Frame	N	Nd	$\sigma_{\alpha} \cdot \cos \delta$	σ_{δ}	W
RSC(BKG)03 R 01	630	161	0.06	0.08	0.38
RSC(CGS)02 R 01	457	161	0.11	0.13	0.14
RSC(GAOUA)03 R 01	1558	161	0.07	0.09	0.48
RSC(AUS)03 R 01	659	161	0.09	0.16	–
RSC(GAOUA)03 C 01	1667	161	0.07	0.08	–

RSC (GAOUA) 05 C 01

Input: 8 individual catalogues (IERS/IVS pilot project 2005)

Comparison: ICRF, RSC(GAOUA)03 C 01 and RSC(GAOUA) 05 C 01

	r.m.s. differences, d_{ij} , mas			correlations, r_{ij}			uncertainties, mas, on condition $r_{ij} \neq 0$		
	d_{12}	d_{13}	d_{23}	r_{12}	r_{13}	r_{23}	σ_1	σ_2	σ_3
All 584 common RS									
RA	0.54	0.44	0.39	-0.74	-0.45	-0.26	0.30	0.28	0.21
Decl	0.62	0.42	0.55	-0.73	-0.15	-0.56	0.31	0.36	0.25
211 common defining RS									
RA	0.32	0.35	0.26	-0.56	-0.69	-0.22	0.21	0.15	0.18
Decl	0.31	0.30	0.30	-0.52	-0.51	-0.47	0.18	0.17	0.17

Pulkovo combined catalogues

Method: Classical astrometric approach

Input: 8 catalogues obtained in the framework
of the IERS/IVS pilot project 2005

RSC(PUL)07C01

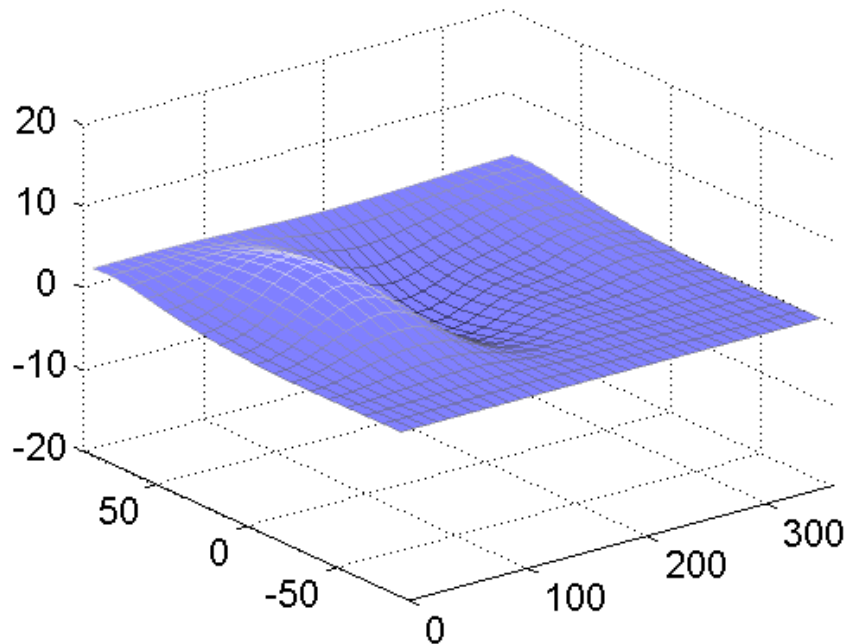
Stochastic improvement of the ICRF

RSC(PUL)07C02

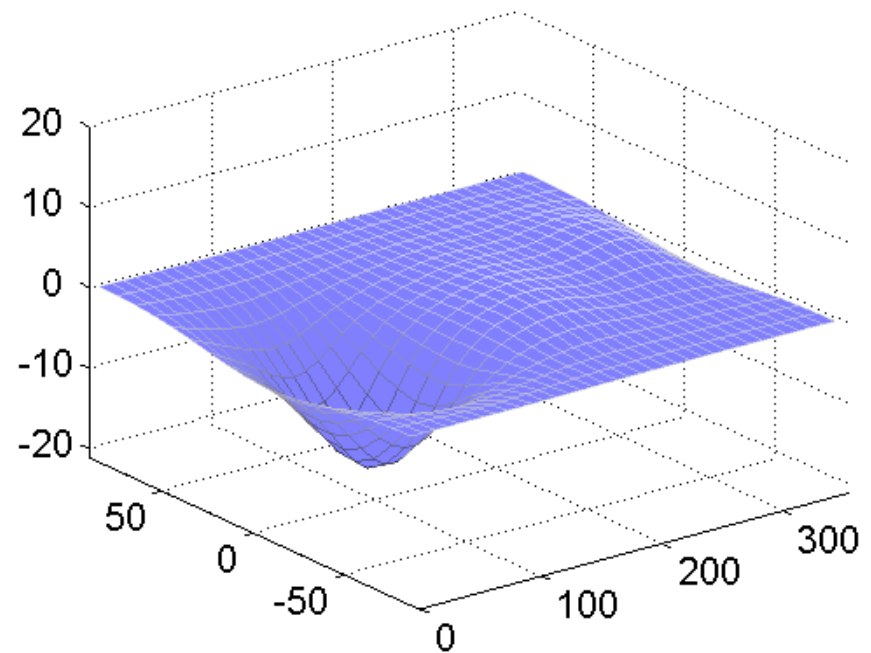
Stochastic and systematic improvement of
the ICRF

RSC(PUL)07C01 – ICRF-Ext.2

$\Delta\alpha, \mu\text{as}$

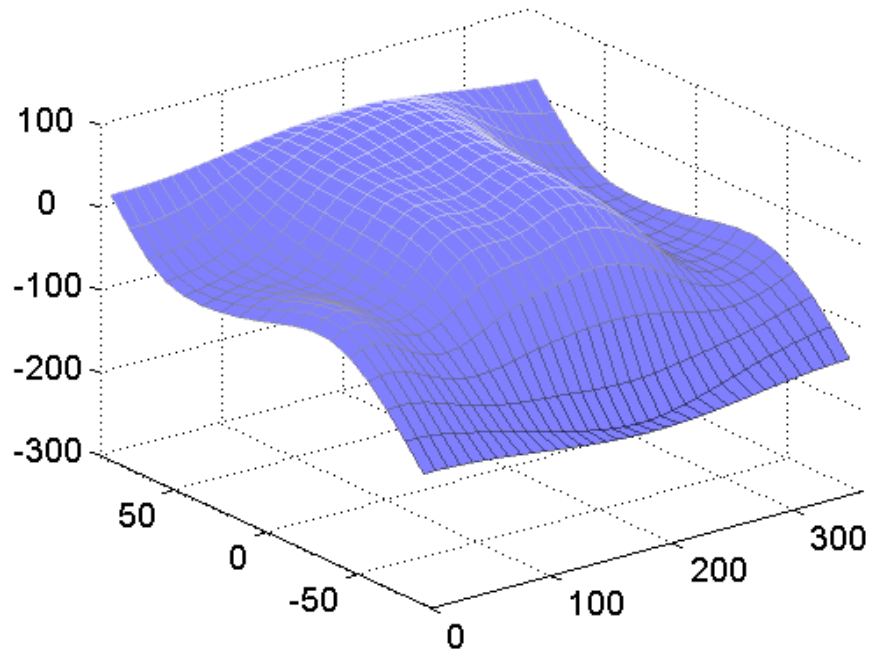


$\Delta\delta, \mu\text{as}$

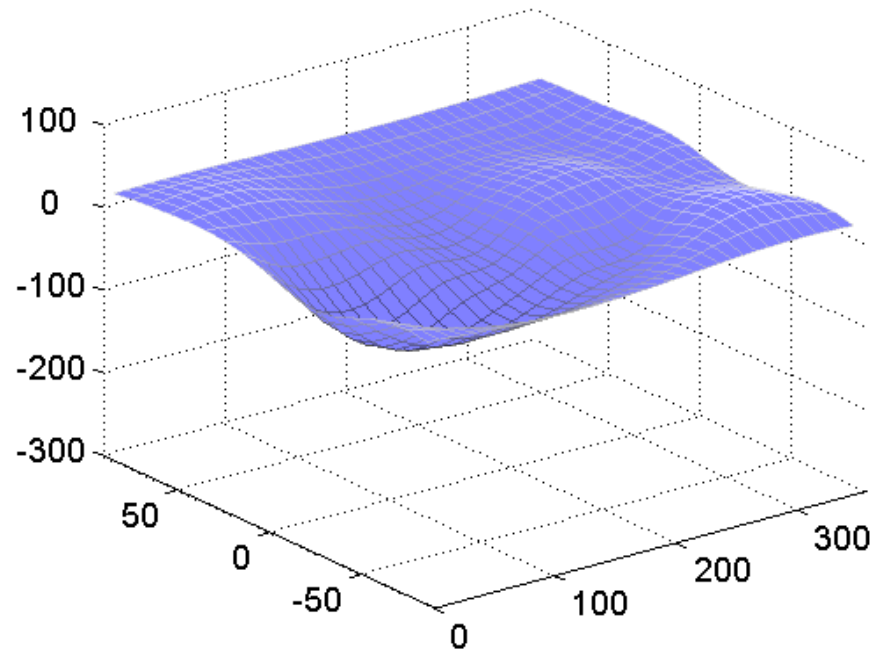


RSC(PUL)07C02 – ICRF-Ext.2

$\Delta\alpha, \mu\text{as}$

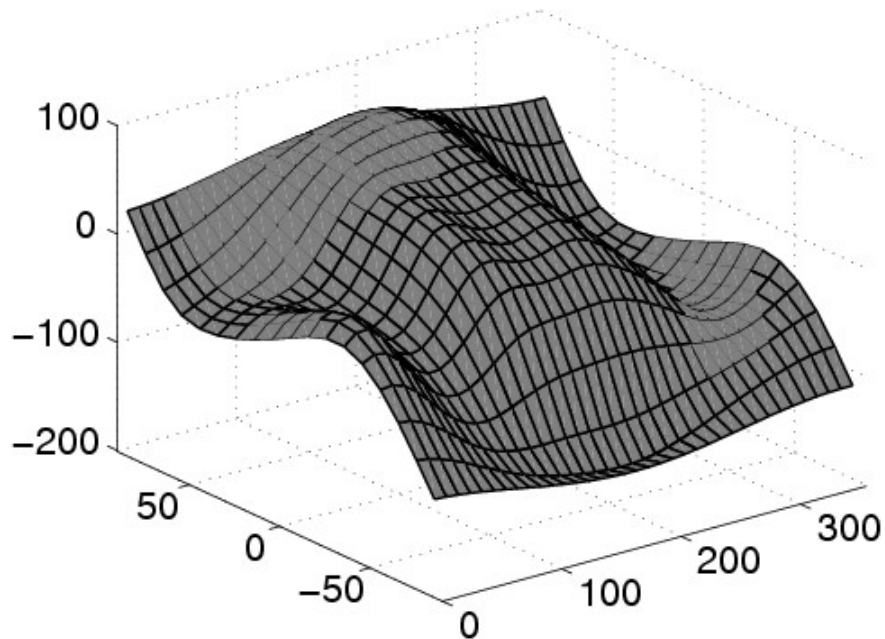


$\Delta\delta, \mu\text{as}$

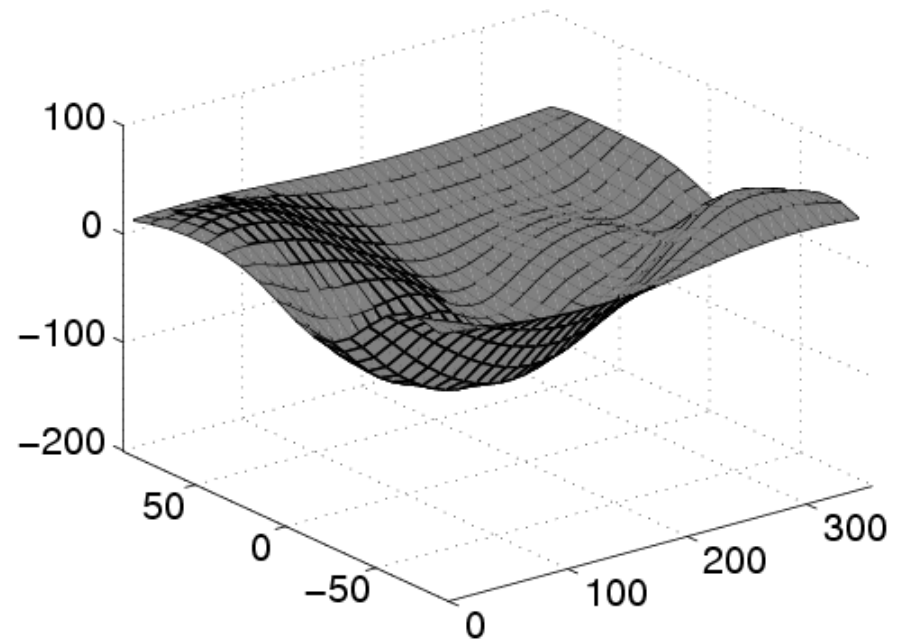


USNO – ICRF-Ext.2

$\Delta\alpha, \mu\text{as}$



$\Delta\delta, \mu\text{as}$



Assessment of the CRF quality

- 1. Systematic errors**
- 2. Stochastic errors.**
- 3. Impact on the celestial pole offset estimates.**

Relative orientation between the frames

ICRF-Ext2 – GAOUA

$$\begin{array}{llll} A_1 = -1 \pm 24 & A_2 = 1 \pm 24 & A_3 = -11 \pm 28 & (\mu\text{as}) \\ D_\alpha = -1 \pm 1 & D_\delta = 0 \pm 0 & B_\delta = 1 \pm 21 & (\mu\text{as/grad}), (\mu\text{as for } B_\delta) \end{array}$$

ICRF-Ext2 – PUL

$$\begin{array}{llll} A_1 = -1 \pm 23 & A_2 = 2 \pm 23 & A_3 = -13 \pm 27 & (\mu\text{as}) \\ D_\alpha = -1 \pm 1 & D_\delta = 0 \pm 0 & B_\delta = -1 \pm 21 & (\mu\text{as/grad}), (\mu\text{as for } B_\delta) \end{array}$$

GAOUA – PUL

$$\begin{array}{llll} A_1 = 0 \pm 7 & A_2 = 0 \pm 7 & A_3 = -1 \pm 9 & (\mu\text{as}) \\ D_\alpha = 0 \pm 0 & D_\delta = 0 \pm 0 & B_\delta = -2 \pm 7 & (\mu\text{as/grad}), (\mu\text{as for } B_\delta) \end{array}$$

Uncertainty estimations of the frames

1.ICRF-Ext2, 2.GAOUA 05 C 01, 3.PUL 07 C 02

	r.m.s. differences, d_{ij} , mas			correlations, r_{ij}			uncertainties, mas, on condition $r_{ij} \neq 0$		
	d_{12}	d_{13}	d_{23}	r_{12}	r_{13}	r_{23}	σ_1	σ_2	σ_3
All common RS 616									
RA	0.52	0.51	0.06	-0.99	-0.99	0.95	0.34	0.18	0.17
Decl	0.64	0.64	0.05	-0.99	-0.99	0.97	0.43	0.21	0.21
All common defining RS 208									
RA	0.29	0.28	0.09	-0.91	-0.88	0.60	0.19	0.11	0.10
Decl	0.27	0.28	0.08	-0.90	-0.92	0.66	0.18	0.10	0.10

S. Lytvyn (personal communication)

Uncertainty estimations of the frames

1.ICRF-Ext2, 2.GAOUA 05 C 01, 3. MAO

	r.m.s. differences, d_{ij} , mas			correlations, r_{ij}			uncertainties, mas, on condition $r_{ij} \neq 0$		
	d_{12}	d_{13}	d_{23}	r_{12}	r_{13}	r_{23}	σ_1	σ_2	σ_3
All common RS 477									
RA	0.35	0.61	0.41	-0.11	-0.87	-0.38	0.30	0.16	0.32
Decl	0.63	0.59	0.44	-0.70	-0.61	-0.14	0.38	0.30	0.27
All common defining RS 170									
RA	0.31	0.33	0.16	-0.75	-0.82	0.24	0.20	0.12	0.14
Decl	0.26	0.31	0.22	-0.51	-0.71	-0.25	0.18	0.13	0.16

S. Lytvyn (personal communication)

Uncertainty estimations of the frames

1.ICRF-Ext2, 2.PUL 07 C 01, 3. MAO

	r.m.s. differences, d_{ij} , mas			correlations, r_{ij}			uncertainties, mas, on condition $r_{ij} \neq 0$		
	d_{12}	d_{13}	d_{23}	r_{12}	r_{13}	r_{23}	σ_1	σ_2	σ_3
All common RS 477									
RA	0.35	0.61	0.41	-0.08	-0.88	-0.39	0.29	0.15	0.32
Decl	0.63	0.59	0.44	-0.70	-0.61	-0.14	0.38	0.30	0.27
All common defining RS 170									
RA	0.29	0.33	0.18	-0.67	-0.80	0.09	0.18	0.12	0.14
Decl	0.27	0.31	0.23	-0.54	-0.69	-0.25	0.18	0.13	0.16

S. Lytvyn (personal communication)

Uncertainty estimations of the frames

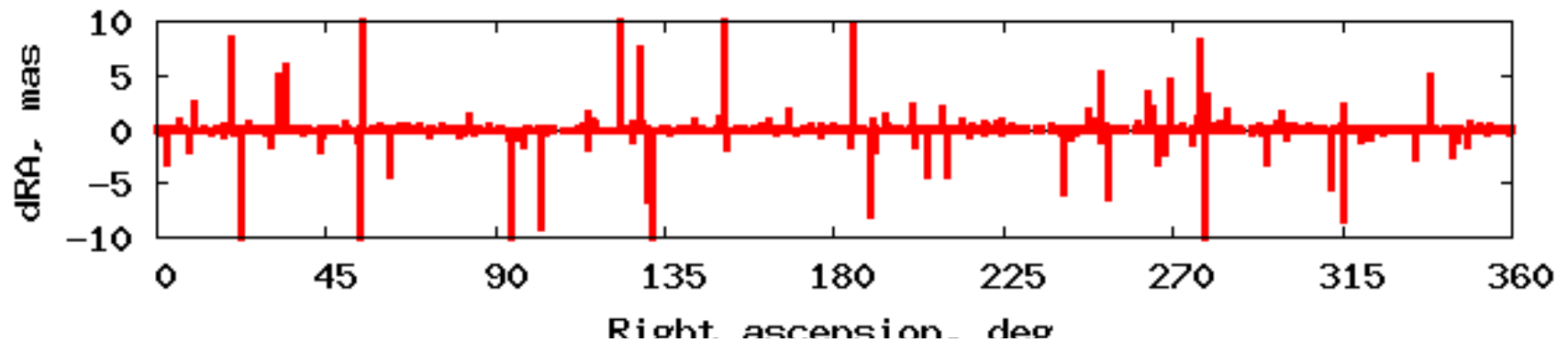
1.ICRF-Ext2, 2.GAOUA 05 C 01, 3. GSFC

	r.m.s. differences, d_{ij} , mas			correlations, r_{ij}			uncertainties, mas, on condition $r_{ij} \neq 0$		
	d_{12}	d_{13}	d_{23}	r_{12}	r_{13}	r_{23}	σ_1	σ_2	σ_3
All common RS 606									
RA	0.41	0.54	0.34	-0.46	-0.82	-0.14	0.30	0.18	0.27
Decl	0.40	0.47	0.28	-0.59	-0.79	-0.02	0.28	0.17	0.22
All common defining RS 208									
RA	0.29	0.32	0.16	-0.73	-0.81	0.19	0.19	0.12	0.14
Decl	0.27	0.31	0.19	-0.61	-0.76	-0.04	0.18	0.12	0.15

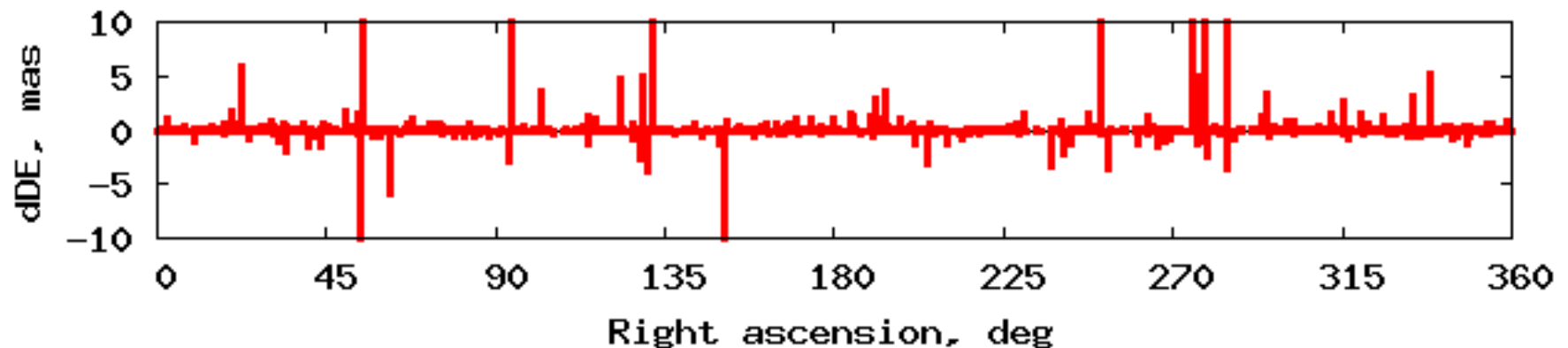
S. Lytvyn (personal communication)

ICRF-2: GSFC-USNO (all sources)

All sources, WRMS = 0.046 mas

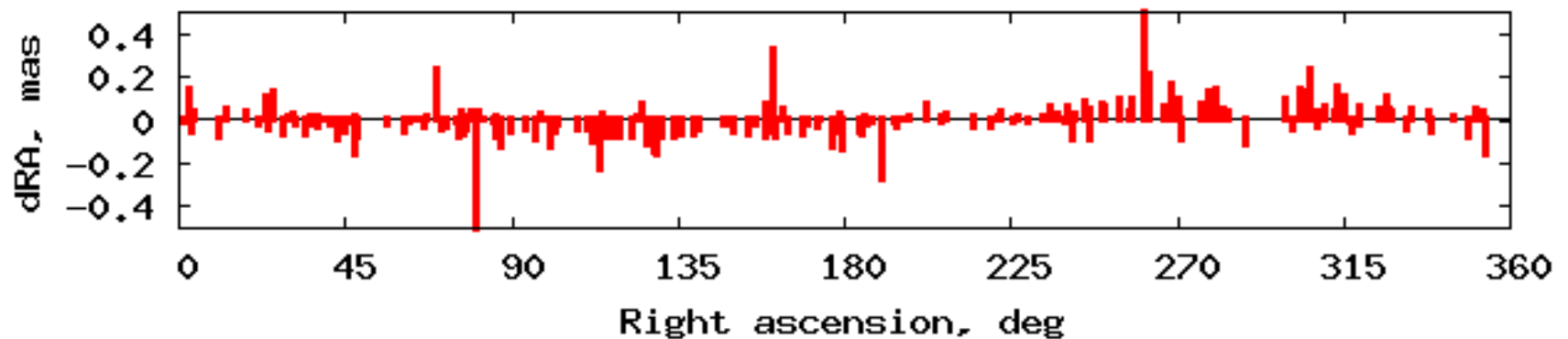


All sources, WRMS = 0.045 mas

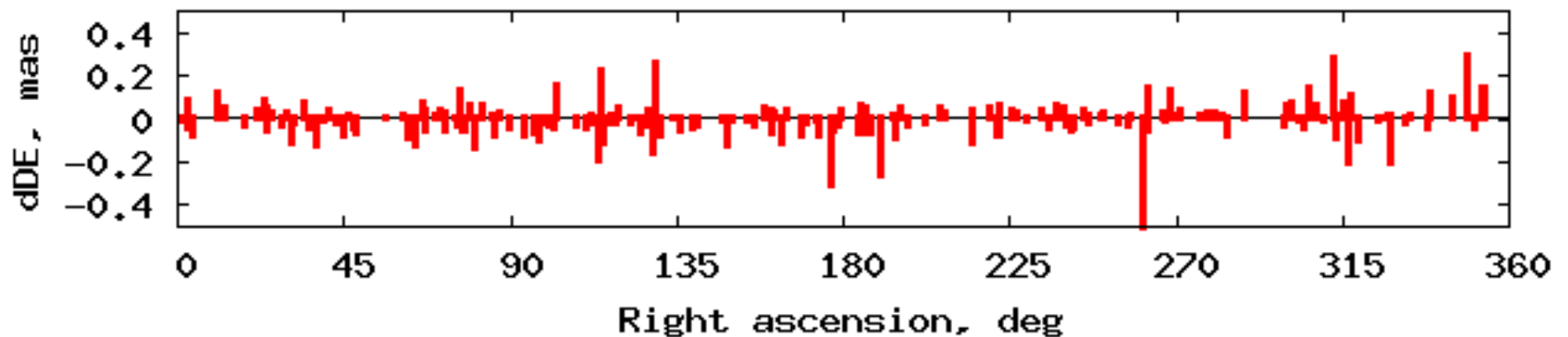


ICRF-2: GSFC-USNO (ICRF defining)

ICRF defining sources, WRMS = 0.053 mas



ICRF defining sources, WRMS = 0.038 mas



Conclusions

1. Alignments of the GAOUA and PULRAS combined catalogues to ICRF are on the level of a few microarcseconds
2. Averaged uncertainties of RA and Decl of the combined catalogues are less than those for individual catalogues and are about 0,100 mas for defining RS
3. Combined solutions are “tighter” than the individual ones

References

- Malkin Z., On accuracy assessment of celestial reference frame realizations. J. Geod., 2007 (in print)**
- Sokolova Ju., Malkin Z., On comparison and combination of catalogues of radio source positions. Astron. Astrophys., 2007 (in print)**
- Yatskiv Ya. S., Kur'yanova A.N., 1990. A new approach to the construction of a compiled catalogue of positions of extragalactic radio sources. In: Proc. 141 th IAU Symp. Pp. 295 - 296**
- Yatskiv Ya. S., et al, 2004. ICRF consistency check by comparison of the ICRF-Ext1 with the GAOUA series of RS catalogues. Proc. Journees, 2003, pp. 39 - 46**