COMBINATION

COMPILED CATALOGUE OF POSITIONS OF EXTRAGALACTIC RADIO SOURCES GAOUA 94 C 01

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Following the procedure for compiling the catalogue of extragalactic radio sources (RS) proposed by Yatskiv and Kuryanova (1990), a new version of this catalogue designated RSC(GAOUA) 94 C 01 has been constructed. The catalogue contains 504 radio sources. Estimates of internal accuracy of positions of RS and relative orientation of this catalogue with respect to other compiled catalogues are given.

Introduction

Application of the Very Long Baseline Interferometry technique (VLBI) to the determination of angular positions of radio sources has marked a new step in establishing and constructing the inertial reference frame (IRF), namely, its radioastronomical realization IRF-R. In comparison with the well-known stellar IRF realization, IRF-R has a number of advantages, which determine its stability (the extragalactic radio sources are very distant objects, and their proper motions can be neglected) and internal consistency (to one millisecond of arc). At the present time, there are several IRF-R realizations represented as sets of radio source coordinates (RSC). Original (individual) RSC catalogues obtained after reduction of VLBI observations are distinguished from compiled RSC catalogues constructed by amalgamating the original ones. The first group comprises the RSC catalogues prepared at the Goddard Space Flight (GSFC), the National Oceanic and Atmospheric Administration (NOAA), etc. Efforts have been made recently to construct compilation RSC catalogues in order to diminish positional random errors and extend IRF-R on more objects. There is a series of compiled catalogues of RS positions constructed by the International Earth Rotation Service (RSC(IERS)), Astronomische Rechen Institute in Heidelberg (CC(H.G.Walter, 1991)), and by the Main Astronomical Observatory, AS Ukraine (RSC(GAOUA)). The mutual disagreement of these compiled RSC systems is on the level of one millisecond of arc, and it can be explained by different composition of the individual catalogues and by using different methods for the compilation. Following the procedure for compiling the catalogue of RS proposed by the authors earlier (Yatskiv and Kuryanova, 1990), a new version of this catalogue, designated RSC(GAOUA) 94 C 01, has been constructed.

On the construction of the compiled catalog of radio sources RSC(GAOUA) 94 C 01

The catalog is based on the individual catalogs obtained in 1993 at the Goddard Space Flight Center (GSFC), the Jet Propulsion Laboratory (JPL), the National Oceanic and Atmospheric Administration (NOAA), the United States Naval Observatory (USNO) and the Geodetic Institute of the University of Bonn (GIUB). Some information about these catalogs, provided by IERS, is given in Table 1.

Table 1. The VLBI celestial frames used; A1, A2, A3 are rotation angles from an individual frame to the compiled one. N is the number of RS. Unit: 0.001".

Catalog	N	A1	A2	A3
RSC(GSFC) 93 R 05	449	+3.08±0.02	+0.96±0.02	-1.87±0.01
RSC(JPL) 92 R 02	333	-0.76±0.02	+0.42±0.02	+0.51±0.02
RSC(NOAA) 93 R 02	107	+0.11±0.02	+0.05±0.02	+0.03±0.02
RSC(USNO) 93 R 09	125	+0.77±0.03	+0.19±0.03	+0.05±0.03
RSC(GIUB) 93 R 01	43	+0.10±0.07	+2.44±0.08	-0.11±0.06

At the first stage we have compiled the catalogue of 39 primary radio sources which are common for RSC(GSFC) 93 R 05, RSC(JPL) 92 R 02, RSC(NOAA) 93 R 02 and RSC(IERS) 90 C 01. For this purpose internal accuracy of individual catalogues was analysed and their weights, given in Table 2, were derived according to the method proposed by the authors (Kuryanova and Yatskiv, 1992).

Table 2. Normalized weights of individual catalogs.

Catalog	Weight
RSC(GSFC)	0.226
RSC(JPL)	0.157
RSC(NOAA)	0.617

For the initial orientation of the frame RSC(GAOUA) 94 C 01, the orientation of the frame RSC(IERS) 90 C 01 was used. At the second stage the system of primary RS was extended to other sources (secondary and complementary) in catalogues under consideration. The catalogue contains 504 radio sources. The relative orientations and RMS differences of catalogue RSC(GAOUA) 94 C 01 and compiled catalogues constructed by IERS (IERS A.R.) are shown in Table 3 and Table 4.

Table 3. Relative orientation and RMS differences of RSC(GAOUA) 94 C 01 and other compiled catalogs determined from primary RS. Unit: 0.001".

Catalog	N	A1	A2	A3	$D\alpha\cos\delta$	$D\delta$
RSC(IERS) 90 C 01	37	+0.03	-0.02	-0.00	±0.218	±0.245
RSC(IERS) 91 C 01	32	-0.04	-0.10	-0.02	±0.263	±0.431
RSC(IERS) 92 C 01	39	-0.02	-0.23	-0.10	±0.220	±0.218
RSC(IERS) 93 C 01	39	+0.09	-0.08	-0.15	±0.144	±0.009

Table 4. Relative orientation and RMS differences of RSC(GAOUA) 94 C 01 and RSC(IERS) 93 C 01 determined from primary RS selected by IERS. Unit: 0.001".

Catalog	N	A1	A2	A3	Dαcosδ	Dδ
RSC(IERS) 93 C 01	166	+0.12	-0.07	-0.13	±0.123	±0.117

The average values of internal accuracy of this catalogue is given in Table 5.

Table 5. Internal accuracy of positions of RS in RSC(GAOUA) 93 C 01. N is number of RS. Unit: 0.001".

RS	Designation	N	Sαcosδ	Sδ
Primary	P,P1	166	±0.14	±0.16
Secondary	S	135	±0.38	±0.40
Complementary	C	203	±5.49	±2.22

Catalogue RSC(GAOUA) 94 C 01 is available on request from the Main Astronomical Observatory of Academy of Sciences of Ukraine.

References

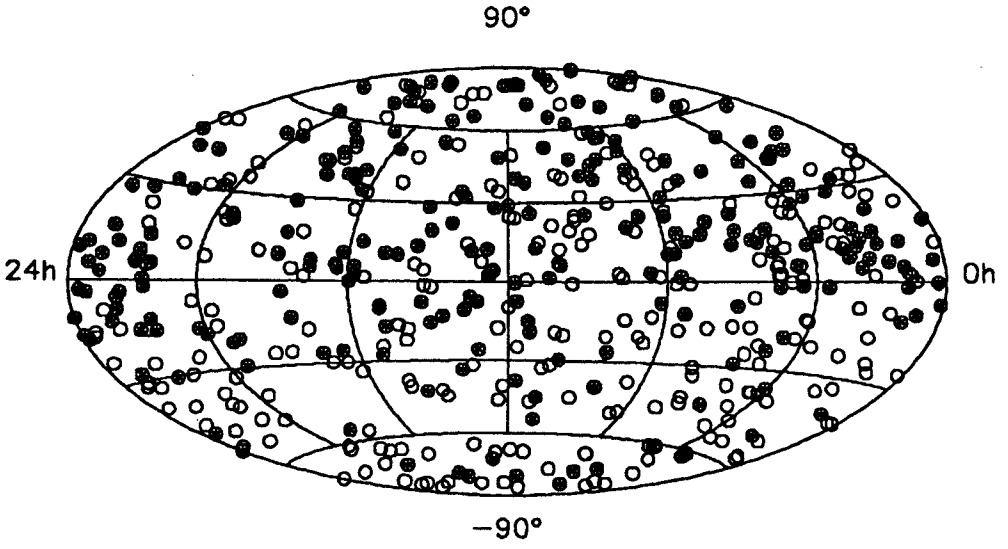
Annual Report of the IERS for 1989: 1990, Observatoire de Paris, Paris.

Annual Report of the IERS for 1990: 1991, Observatoire de Paris, Paris.

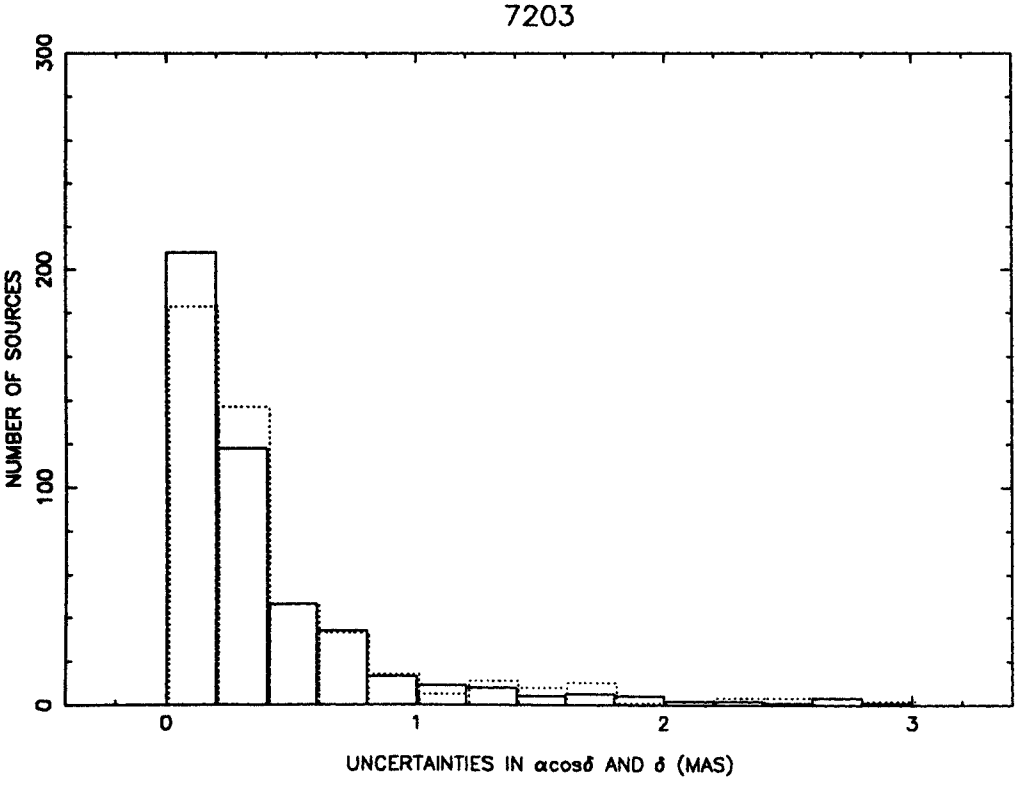
Annual Report of the IERS for 1991: 1992, Observatoire de Paris, Paris.

Kuryanova, A.N., and Yatskiv, Ya.S., 1992: The compiled catalog of positions of extragalactic radio sources RSC(GAOUA) 91 C 01, Kinematika i Fizika Nebesnykh Tel, **9**, No.2, 15-25.

Yatskiv, Ya.S., and Kuryanova, A.N., 1990: A new approach to the construction of a compiled catalogue of positions of extragalactic radio sources, in: *Inertial Coordinate System on the Sky, Proc. IAU Symposium 141*, p. 295-296.



Distribution over the sky of the 505 extragalactic radio sources of the celestial frame RSC(GAOUA) 94 C 01. Filled circles indicate radio sources with uncertainties in right ascension ($\alpha \cos \delta$) and declination smaller than 0.0003".



Distribution of the uncertainties in right ascension (full line) and declination (dashed line) of the celestial frame RSC(GAOUA) 94 C 01. 47 radio sources with uncertainties larger than 0.003" are not shown.

A COMBINATION OF EARTH ORIENTATION DATA: SPACE93

JPL 94 C 01

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A combination of independently-determined Earth orientation data has been generated from space-geodetic observations spanning 1976-1993. The approach taken is based upon a Kalman filter that was developed at the Jet Propulsion Laboratory (JPL) for just such a purpose (Eubanks 1988; Morabito *et al.* 1988). The Kalman filter is a sequential estimation technique that combines observations of the Earth's orientation in a rigorously self-consistent manner producing smoothed, interpolated estimates of UT1 and the x- and y-components of polar motion (PMX and PMY, respectively). Information about the data that have been combined is given in Table 1. All publicly available, independent determinations of the Earth's orientation by the modern, space-geodetic techniques of very long baseline interferometry (VLBI), satellite laser ranging (SLR), lunar laser ranging (LLR), and the global positioning system (GPS) have been used. Since it was desirable to combine only independent determinations of the Earth's orientation, only one LLR data set was used, namely, that determined at JPL (Newhall *et al.*, 1993), and only one SLR data set was used, namely, that determined at the University of Texas Center for Space Research (UTCSR; Eanes and Watkins, 1993). Note that the SLR UT1 results were not used in generating SPACE93 due to problems associated with separating this component of the Earth's orientation from the effects of unmodeled forces acting on the satellite causing the node of its orbit to drift. Two different data sets derived from GPS measurements were used: (1) that determined at the Scripps Institution of Oceanography from daily measurements spanning August 25, 1991 to June 20, 1992 (Bock *et al.*, 1993); and (2) that determined at the Jet Propulsion Laboratory from daily measurements spanning June 21, 1992 to January 9, 1994 (Zumberge *et al.*, 1993). Note that in both cases only the polar motion results determined from the GPS measurements were used in generating SPACE93. Three different data sets derived from independent VLBI measurements were used: (1) the approximately twice-a-week single baseline measurements made using the radio telescopes of NASA's Deep Space Network (DSN; Steppe *et al.*, 1993); (2) the measurements made under the auspices of the International Radio Interferometric Surveying (IRIS) subcommission and analyzed at NOAA's Laboratory for Geosciences (IRIS Earth Orientation Bulletin No. 120, February, 1994; note that for reasons given below only the IRIS Intensive UT1 results were used); and (3) the UTPM determinations made by the VLBI group of the NASA Crustal Dynamics Project (CDP) at Goddard Space Flight Center (GSFC) from both their

own CDP VLBI measurements and from their reduction of the IRIS and United States Naval Observatory (USNO) multibaseline measurements (Ma, private communication, 1993). Since the CDP data set used here includes UTPM values determined from the multibaseline measurements taken by both IRIS and the USNO, no separate IRIS multibaseline or USNO data sets were used in generating SPACE93.

Table 1. Data combined

DATA SET NAME	DATA TYPE	ANALYSIS CENTER	DATA SPAN	NUMBER POINTS
LLR (JPL93M01; VAR LAT, UT0)				
McDonald Cluster	LLR	JPL	22MAY76-14JAN93	390
CERGA	LLR	JPL	07APR84-14FEB93	373
Haleakala	LLR	JPL	10FEB85-11AUG90	68
UTCSR (CSR93L01; PMX, PMY)				
LAGEOS	SLR	UTCSR	19MAY76-04FEB93	1797
DSN (JPL93R01; T, V)				
CA-Spain Cluster	VLBI	JPL	26NOV79-08JAN94	489
CA-Australia Cluster	VLBI	JPL	28OCT78-05JAN94	495
CDP (GLB922)				
Multibaseline	VLBI	GSFC	04AUG79-29DEC93	1550
Westford-Ft. Davis	VLBI	GSFC	25JUN81-01JAN84	103
Westford-Mojave	VLBI	GSFC	21MAR85-06AUG90	18
IRIS (UT1MC19JAN94; UT1)				
Intensive	VLBI	NOAA	02APR84-09JAN94	2153
GPS (SIO93P01; PMX, PMY)				
Scripps	GPS	SIO	25AUG91-20JUN92	286
GPS (JPL92P02; PMX, PMY)				
JPL FLINN Analysis	GPS	JPL	21JUN92-09JAN94	521

Before combining the series, the effect of the solid Earth tides upon UT1 was removed by using the model of Yoder *et al.* (1981). Also, the model of Dickman (1993) was used to remove the effect upon UT1 of the ocean tides at the Mf, Mf', Mm, and Ssa tidal frequencies [the Dickman (1993) oceanic corrections to the Yoder *et al.* (1981) results were actually removed]. Finally, the empirical model of Herring (1992) was used to remove the effect of the semi-diurnal and diurnal ocean tides from the IRIS Intensive UT1 values since these tidal terms had been added back and were included in the released IRIS Intensive UT1 values. No subdaily ocean tidal terms were removed from any of the other series used in generating SPACE93 since none of the other series listed in Table 1 had these terms added back to them (the particular CDP series used in generating SPACE93 was a special solution in which the subdaily tidal terms had not been added back and were therefore not included in the final UTPM values; Ma, private communication, 1993).

Prior to combining the data, series-specific corrections were applied for bias and rate, and the stated uncertainties were adjusted by multiplying them by series-specific scale factors. Values for these bias-rate corrections and uncertainty scale factors were determined in an iterative, round-robin type approach wherein each data set was compared to a combination of all other data sets (except for the two GPS series which were treated separately as described below). First, a reference series (SPACE92; Gross, 1993) was used to initially correct the bias and rate of each individual series so that it agrees (in bias and rate) with the reference series. This was done for the sole purpose of initially aligning the series with each other in an attempt to reduce the required number of round-robin iterations. The stated uncertainties of the series were not adjusted at this time. Any inconsistencies introduced by using a reference series for this initial bias-rate alignment should be removed during the subsequent iterative, round-robin procedure.

After initial bias-rate alignment, the round-robin procedure was performed wherein the bias and rate of each individual series was iteratively adjusted so as to be in agreement with the bias and rate exhibited by a combination of all the other series, with rate adjustments being determined only for those series whose overlap with all the other series was great enough that reliable rate determinations could be made. The stated uncertainty of each series was adjusted by applying a multiplicative factor that made the residual of that data, when differenced with a combination of all other data, have a reduced chi-square of one. Note that the formal error associated with the residual in calculating the reduced chi-square accounts for the error of interpolation between the time of the residual and the times of other data points by using the stochastic model of the UTPM process contained in the Kalman filter. The incremental bias-rate corrections and uncertainty scale factors thus determined for each of the individual series were then applied to the series and the process repeated until convergence was achieved (convergence being indicated by the incremental bias-rate corrections approaching zero, and the incremental uncertainty scale factors approaching one). At the completion of this iterative, round-robin process, relative bias-rate corrections will have been determined that make the data sets agree with each other in bias and rate, and uncertainty scale factors will have been determined that make the residual of each data set (when differenced with a combination of all others) have a reduced chi-square of one.

When performing this iterative, round-robin procedure to determine bias-rate corrections and uncertainty scale factors, each data type is analyzed (and results reported) in the natural reference frame for that data type. For single baseline VLBI measurements this is the transverse (T), vertical (V) frame (Eubanks and Steppe 1988); for single station LLR measurements this is the variation of latitude (LAT), UT0 frame; and for GPS, SLR and multibaseline VLBI measurements this is the usual UTPM (PMX, PMY, UT1) frame.

For the purpose of determining bias-rate corrections and uncertainty scale factors, the LLR observing stations at McDonald were clustered, so that a common bias-rate correction and uncertainty scale factor was determined for all the McDonald LLR series. This was done so that rate adjustments could be made to these series.

There is not enough overlap with the other, independent Earth orientation series to allow a reliable rate correction to be determined for any individual McDonald station-derived LLR series. Thus, without clustering the McDonald stations, it would only be possible to make bias corrections to the McDonald LLR series, with consequent deleterious effects on the rate of the UT1 values prior to about 1982 in the final, combined series. Similarly, the individual DSN radio telescopes in California were clustered, as were those in Spain and, separately, in Australia, so that a common bias-rate correction and uncertainty scale factor was determined for all the California-Spain single baseline Earth orientation series, as well as for all the California-Australia series.

During the iterative, round-robin procedure, outlying data points were deleted. Before deleting any data points, a few round-robin iterations were completed in order to converge on initial values for the uncertainty scale factors. During subsequent iterations, those data points within a given series were deleted whose residual values were greater than three times their adjusted uncertainties, where the residual values were those resulting from fitting a bias and rate to the difference of that series with a combination of all other series. During the final round-robin iteration, no series contained data points whose residual values were greater than three sigma. A total of 167 data points, or about two percent of the available data points, were thus deleted from all the series.

Bias corrections and uncertainty scale factors were determined for each of the two GPS series by separately comparing them to a combination of all other, independent series after the other series had had the bias-rate corrections and uncertainty scale factors applied to them that had been previously determined for them as described above. Only bias corrections were determined and applied to the GPS series since their individual overlap with the other, independent series was not great enough to allow reliable rate corrections to be determined. During this comparison, outlying data points (i.e., those whose residual values were greater than three times their adjusted uncertainties) were also deleted.

Finally, each data set was placed within an IERS reference frame by applying to it an additional bias-rate correction that is common to all the data sets. This additional correction was determined by first combining all the data (including the two GPS series, and after applying to all the data the relative bias-rate corrections and uncertainty scale factors determined above). This intermediate combination was then compared to the IERS combination EOP(IERS) 90 C 04 (e.g., 1992 IERS Annual Report) for the years 1984-1993 in order to obtain the additional bias-rate correction required to make it (and therefore each individual data set) agree in bias and rate with the IERS combination. This additional bias-rate correction was then applied to each data set along with the relative bias-rate corrections in order to make the data sets agree with each other and be in that IERS reference frame defined by the Earth orientation series EOP(IERS) 90 C 04.

The total bias-rate correction (the sum of the relative and IERS corrections) that has been determined for each data set is given in Table 2. Except for the two GPS series (see below), the values for the bias-rate corrections given in Table 2 are the sum

of all the incremental corrections, the corrections applied to initially align the series with each other, and the additional, common correction applied in order to place each series within the IERS reference frame. The values for the uncertainty scale factors given in Table 2 are the products of all the incremental scale factors determined during the iterative, round-robin procedure. The errors in the bias-rate corrections (given in parentheses in Table 2) are the formal errors in the determination of the incremental bias-rate corrections during the last iteration of the iterative, round-robin procedure. There are no bias-rate entries in Table 2 for components that were either not used (e.g., the SLR UT1 component), or not available (e.g., the IRIS Intensive PMX and PMY components). Note that the same IERS rate correction is applied to all the data sets, including those (such as the GPS series) for which no relative rate correction could be determined. Therefore, the rate correction given in Table 2 for those data sets for which no relative rate correction could be determined is simply the IERS rate correction, but given, of course, in the natural reference frame for that data set. In these cases, no errors for the rate corrections are given.

Since the GPS series were not included in the iterative, round-robin procedure, the bias-rate corrections given in Table 2 for them are just the sum of the relative corrections that were separately determined for them (see above) and the additional, common correction needed to place them within the IERS reference frame. The errors in the bias corrections given in Table 2 for the GPS series (shown in parentheses in Table 2) are the formal errors in determining the relative corrections. The uncertainty scale factors given in Table 2 for the GPS series are just the scale factors determined for them as described above when separately comparing them to combinations of all the other, independent series.

Note that the entries in Table 2 should not be used as a measure of the relative accuracy of the Earth orientation series. No attempt was made to place the series within a common reference frame prior to determining bias-rate corrections for them. Thus, the values for the bias-rate corrections given in Table 2 include the effects upon the Earth orientation series of reference frame differences.

The final UTPM combination was generated by combining all of the data (including the GPS results) after adjusting their biases, rates, and uncertainties by the amounts given in Table 2. This final combination, spanning May 20.0, 1976 to January 9.0, 1994, is designated SPACE93 and is given as daily values at midnight of PMX, PMY, UT1-UTC, their formal errors (1 sigma), and correlations. The model of Yoder et al. (1981) was used to add back the effect of the solid Earth tides upon UT1 (the full amplitude of the tidal effect at the epoch of the time tag was added back). Similarly, the model of Dickman (1993) was used to add back the ocean tidal corrections to the Yoder *et al.* (1981) model values at the Mf, Mf', Mm, and Ssa tidal frequencies. However, no diurnal or semi-diurnal ocean tidal terms were added back. The three correlations given at each time tag are the correlations between the UTPM values at that time tag. Improvements to the observing systems (both in the hardware and software, and in the number of systems) have led to more precise determinations of the Earth's orientation. This improvement is reflected in SPACE93 by the reduction of the UTPM formal errors from about 2 mas in polar motion and 0.5 ms in UT1 during the late 1970's to their current values of about 0.2 mas in polar motion and 0.02 ms in UT1.

Table 2. Adjustments to data sets

DATA SET NAME	BIAS (mas)		RATE (mas/yr)		UNCERTAINTY SCALE FACTOR	
LLR (JPL93M01)	LAT	UT0	LAT	UT0	LAT	UT0
McDonald Cluster	1.270	1.703	-0.676	-0.225	1.012	1.301
	(0.350)	(0.327)	(0.079)	(0.086)		
CERGA	-0.289	1.635	0.075	-0.174	1.571	1.255
	(0.211)	(0.118)	(0.058)	(0.036)		
Haleakala	1.346	1.042	-0.219	-0.214	1.207	1.330
	(0.331)	(0.253)	(0.219)	(0.175)		
DSN (JPL93R01)	T	V	T	V	T	V
CA-Spain Cluster	0.626	-1.067	-0.038	-0.184	1.427	1.209
	(0.077)	(0.180)	(0.019)	(0.045)		
CA-Australia Cluster	-0.561	1.600	-0.192	0.076	1.472	1.242
	(0.053)	(0.155)	(0.014)	(0.040)		
CDP (GLB922)	T	V	T	V	T	V
Westford-Ft. Davis	2.746	-2.589	0.587	-0.192	0.659	0.811
	(1.912)	(3.285)	(0.386)	(0.656)		
Westford-Mojave	-0.659	-1.094	0.007	-0.016	3.048	0.941
	(0.214)	(0.385)				

CDP (GLB922)	PMX	PMY	UT1	PMX	PMY	UT1	PMX	PMY	UT1
Multi	0.155	-1.739	-1.617	-0.129	-0.049	-0.057	2.067	2.051	2.133
	(0.028)	(0.025)	(0.032)	(0.008)	(0.007)	(0.009)			
UTCSR (93L01)	PMX	PMY	UT1	PMX	PMY	UT1	PMX	PMY	UT1
LAGEOS	0.021	0.030	---	-0.032	-0.162	---	0.747	0.680	---
	(0.024)	(0.021)		(0.009)	(0.008)				
IRIS (19JAN94)	PMX	PMY	UT1	PMX	PMY	UT1	PMX	PMY	UT1
Intensive	---	---	1.907	---	---	0.012	---	---	1.345
			(0.027)			(0.008)			
GPS (SIO93P01)	PMX	PMY	UT1	PMX	PMY	UT1	PMX	PMY	UT1
Scripps	-1.003	-1.736	---	0.017	0.026	---	2.141	1.968	---
	(0.036)	(0.038)							
GPS (JPL92P02)	PMX	PMY	UT1	PMX	PMY	UT1	PMX	PMY	UT1
JPL FLINN	-0.717	-1.578	---	0.017	0.026	---	4.023	2.719	---
	(0.028)	(0.021)							

Reference date for rate adjustment is 1988.0

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References

Bock, Y., Fang, P., and Stark, K., 1993: 1991-1993 SIO polar motion series, in *IERS Technical Note 14: Earth Orientation, Reference Frames and Atmospheric Excitation Functions Submitted for the 1992 IERS Annual Report*, edited by P. Charlot, Observatoire de Paris, Paris, France, p. P43-P44 .

Dickman, S. R., 1993: Dynamic ocean-tide effects on Earth's rotation, *Geophys. J. Int.*, **112**, 448-470 .

Eanes, R. J., and Watkins, M. M., 1993: Earth orientation and site coordinates from the Center for Space Research, in *IERS Technical Note 14: Earth Orientation, Reference Frames and Atmospheric Excitation Functions Submitted for the 1992 IERS Annual Report*, edited by P. Charlot, Observatoire de Paris, Paris, France, p. L7-L11.

Eubanks, T. M., 1988: Combined Earth orientation series smoothed by a Kalman filter, in *Bureau International de l'Heure Annual Report for 1987*, Observatoire de Paris, Paris, France, p. D85-D86.

Eubanks, T. M., and Steppe, J. A., 1988: The long term stability of VLBI Earth orientation measurements, in *The Impact of VLBI on Astrophysics and Geophysics*, edited by M. J. Reid and J. M. Moran, D. Reidel, Dordrecht, Holland, p. 369-370.

Gross, R. S., 1993: A combination of Earth orientation data: SPACE92, in *IERS Technical Note 14: Earth Orientation, Reference Frames and Atmospheric Excitation Functions Submitted for the 1992 IERS Annual Report*, edited by P. Charlot, Observatoire de Paris, Paris, France, p. C1-C8.

Herring, T. A., 1992: Diurnal and semidiurnal variations in Earth rotation, paper presented at *AIAA World Space Congress, COSPAR Symposium*, Washington DC, August 1992.

Morabito, D. D., Eubanks, T. M., and Steppe, J. A., 1988: Kalman filtering of Earth orientation changes, in *The Earth's Rotation and Reference Frames for Geodesy and Geodynamics*, edited by A. K. Babcock and G. A. Wilkins, D. Reidel, Dordrecht, Holland, p. 257-267.

Newhall, X X, Williams, J. G., and Dickey, J. O., 1993: Earth rotation (UT0-UTC and variation of latitude) from lunar laser ranging, in *IERS Technical Note 14: Earth Orientation, Reference Frames and Atmospheric Excitation Functions Submitted for the 1992 IERS Annual Report*, edited by P. Charlot, Observatoire de Paris, Paris, France, p. M1-M5.

Steppe, J. A., Oliveau, S. H., and Sovers, O. J., 1993: Earth rotation parameters from DSN VLBI: 1993, in *IERS Technical Note 14: Earth Orientation, Reference Frames and Atmospheric Excitation Functions Submitted for the 1992 IERS Annual Report*, edited by P. Charlot, Observatoire de Paris, Paris, France, p. R33-R44.

Yoder, C. F., Williams, J. G., and Parke, M. E., 1981: Tidal variations in Earth rotation, *J. Geophys. Res.*, **86**, 881-891.

Zumberge, J. F., Blewitt, G., Jefferson, D., Heflin, M. B., and Webb, F. H., 1993: Earth orientation parameters from the Jet Propulsion Laboratory using GPS, in *IERS Technical Note 14: Earth Orientation, Reference Frames and Atmospheric Excitation Functions Submitted for the 1992 IERS Annual Report*, edited by P. Charlot, Observatoire de Paris, Paris, France, p. P33-P37.

EOP(JPL) 94 C 01 From May 1976 to Jan 1994

Number of measurements per year and median uncertainties
Units : 0.001" for X,Y; 0.0001s for UT1.

YEAR	X		Y		UT1	
	Nb	Sigma	Nb	Sigma	Nb	Sigma
1976	223	5.08	223	4.10	223	7.32
1977	365	3.48	365	2.78	365	4.81
1978	365	3.63	365	2.55	365	5.83
1979	365	3.05	365	2.36	365	4.37
1980	366	1.58	366	1.03	366	2.87
1981	365	1.33	365	1.02	365	1.86
1982	365	1.00	365	0.85	365	1.24
1983	365	0.87	365	0.82	365	0.96
1984	366	0.50	366	0.44	366	0.52
1985	365	0.42	365	0.37	365	0.33
1986	365	0.37	365	0.33	365	0.29
1987	365	0.30	365	0.27	365	0.28
1988	366	0.26	366	0.24	366	0.25
1989	365	0.25	365	0.23	365	0.22
1990	365	0.22	365	0.21	365	0.19
1991	365	0.21	365	0.20	365	0.19
1992	366	0.17	366	0.16	366	0.16
1993	365	0.20	365	0.17	365	0.20
1994	9	0.21	9	0.17	9	0.51

COMBINATION OF PRECISE OBSERVATIONS OF THE ORIENTATION OF THE EARTH

NEOS 94 C 01

[The procedure for obtaining this series is described in the IERS Annual Report for 1993, part. III].

EOP(NEOS) 94 C 01 From Jun 1979 to Feb 1994

Number of measurements per year and median uncertainties
Units : 0.001" for X,Y,$\delta\psi$, $\delta\varepsilon$; 0.0001s for UT1.

YEAR	X		Y		UT1		$\delta\psi$		$\delta\varepsilon$	
	Nb	Sigma	Nb	Sigma	Nb	Sigma	Nb	Sigma	Nb	Sigma
1979	185	1.81	185	2.56	185	2.71	0		0	
1980	366	1.91	366	1.10	366	1.79	96	1.98	96	0.87
1981	365	1.87	365	1.49	365	2.71	365	1.98	365	0.87
1982	365	1.71	365	1.72	365	1.84	365	1.98	365	0.87
1983	365	1.67	365	1.28	365	1.94	365	1.98	365	0.87
1984	366	0.94	366	0.79	366	1.18	366	0.79	366	0.30
1985	365	0.62	365	0.58	365	0.84	365	0.74	365	0.29
1986	365	0.52	365	0.56	365	0.69	365	0.67	365	0.27
1987	365	0.58	365	0.59	365	0.88	365	0.69	365	0.30
1988	366	0.45	366	0.43	366	0.79	366	0.67	366	0.25
1989	365	0.40	365	0.43	365	0.51	365	0.62	365	0.30
1990	365	0.51	365	0.51	365	0.58	365	0.59	365	0.24
1991	365	0.40	365	0.46	365	0.40	365	0.65	365	0.30
1992	366	0.18	366	0.45	366	0.33	366	0.54	366	0.26
1993	365	0.08	365	0.54	365	0.39	365	0.57	365	0.28
1994	47	0.12	47	0.12	47	0.54	47	0.30	47	0.15