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EOP Determination with OCCAM and ERA Packages

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Abstract

The EOP series were obtained with OCCAM v. 3.5 and ERA v. 7 packages from VLBI NEOS-A and CORE-A measurements for the period 1997–1999. The EOP estimations provided by OCCAM were compared with those provided by ERA. The correlations of OCCAM and ERA results with the EOP(IERS)C04 were studied. It was found that the results obtained with OCCAM agree satisfactorily with the results obtained with ERA. The differences between the EOP estimated from NEOS-A and CORE-A observations were also calculated with OCCAM and ERA. These differences were verified to be similar and of significant correlation.

1. Introduction

Recently two packages for VLBI data processing are available for the IAA EOP Service. The first of them is OCCAM, which is used in the IAA for the regular estimation of the EOP since 1997. The version 3.5 [1] is now in use. This version is an improvement on OCCAM v. 3.4 [2]. OCCAM v. 3.5 permits both EOP and station positions estimation.

The package ERA v. 7 [3] was advanced for VLBI data processing in 1998 [4]. The package makes available not only the EOP and station positions estimation but also determination of radio source coordinates and subdiurnal tidal terms in UT1.

The estimation of EOP with ERA and OCCAM from NEOS-A and CORE-A observations seems important because it helps to compare and analyze packages and might show evidence for systematical errors. In this paper the single factor statistical analysis of EOP is made. Our next step is to perform the results of multi-factor analysis of the EOP, obtained with different packages from different programs. The paper with graphical representation of result is available on the web page http://www.ipa.nw.ru/PAGE/DEPFUND/GEO/ENG/lab_e.htm.

2. Observations and Reductions

There are 155 NEOS-A and 62 CORE-A VLBI sessions accumulated for the period 1997–1999 which have been processed with OCCAM and ERA. For more detailed information on observations see Table 1.

Both ERA and OCCAM packages process the data with models compliant with IERS Conventions (1996). The station coordinates are taken from the ITRF97. Coordinates of radio sources are taken from either RSC(IAA)99R02 or for newly observed sources from NGS files.

The ERA package requires a special representation of VLBI data in the table form. To estimate EOP with ERA the observations from NGS files were databased in ERA tables. It should be noted that the ERA tables containing the required VLBI processing information are more compact than the corresponding NGS files. The coefficient of compression varies from 4.5 to 5.0 for the data

Table 1. The observations processed.

Year	Network	Period	Number of sessions	Number of observations	Number of stations	Number of radio sources
1997	NEOS-A	weekly	52	53698	7	227
1998	NEOS-A	weekly	52	58191	11	234
1999	NEOS-A	weekly	51	61217	11	252
1997	CORE-A	biweekly	23	22590	5	46
1998	CORE-A	biweekly	25	35377	6	67
1999	CORE-A	biweekly	14	18807	8	63

under consideration. In spite of this advantage the process of databasing takes time while OCCAM deals directly with NGS files.

In the ERA processing the five Earth Orientation Parameters, their diurnal linear trends and coefficients of Legendre polynomials, that approximate station clocks and troposphere zenith path delays were estimated in the least square solutions. In the OCCAM package Kalman filtering is used for estimation of stochastic parameters such as tropospheric path delay and station clocks by random walk model.

3. Comparison of the EOP Obtained with ERA and OCCAM Packages

The differences between the EOP estimations obtained with OCCAM and ERA packages were studied from NEOS-A observations for the period 1994–1999, from CORE-A observations for the period 1994–1999. They were found mostly within 1 milliarcsec for the pole coordinates X_p and Y_p and the nutation parameter $d\epsilon$, within 1.5 milliarcsec for $d\psi$ and 0.025 milliarcsec for $UT1$ (see Table 2). The EOP data for the period 1997–1996 were taken from EOP(IAA)99R01 and EOP(IAA)99R02. The graphical comparison of the differences can be found on the web page http://www.ipa.nw.ru/PAGE/DEPFUND/GEO/ENG/lab_e.htm.

The parameters of linear trend and values of rms after/before fitting are given in Table 3, columns 2–3 for each EOP. Rms value can be used as a criterion of the coincidence for the data. It is clear from Table 3 that in the sense of rms the agreement between ERA and OCCAM in Y_p, $d\psi$ and $d\epsilon$ is better for NEOS-A, in X_p and $UT1$ is a little better for CORE-A. There occur linear trends in X_p and $UT1$ EOP(ERA)$-$EOP(OCCAM) from NEOS-A differences. The linear trend in $UT1$ differences EOP(ERA)$-$EOP(OCCAM) from CORE-A can also be detected. No significant trends are found for the other differences. The correlation analysis of the differences EOP(ERA)$-$EOP(OCCAM) obtained from NEOS-A and those obtained from CORE-A shows low level of relations. The corresponding coefficients of correlation are presented in Table 5, column 1. They are evidence for the fact that there are no systematics in OCCAM and ERA.

4. Comparison of the Obtained EOP with the EOP(IERS)C04

The analysis of systematics in the differences EOP(ERA)$-$EOP(IERS)C04 and EOP(OCCAM)-EOP(IERS)C04 was carried out for NEOS-A and CORE-A. The parameters of linear trends in the EOP differences are shown in Table 4. The calculated parameters mostly coincide (within 3σ)

Table 2. The statistical characteristics of differences between the EOP (ERA-OCCAM) .

NEOS-A	$X_p(mas)$	$Y_p(mas)$	$UT1(0.1\ ms)$	$d\psi(mas)$	$d\epsilon(mas)$
min	-1.19	-1.06	-0.38	-2.14	-1.28
max	1.34	0.77	0.27	2.20	0.75
mean	-0.12	0.11	-0.07	-0.06	0.10
CORE-A	$X_p(mas)$	$Y_p(mas)$	$UT1(0.1\ ms)$	$d\psi(mas)$	$d\epsilon(mas)$
min	-0.73	-0.91	-0.23	-2.50	-0.90
max	1.20	0.80	0.18	1.72	1.29
mean	-0.05	0.07	0.01	-0.25	0.07

for ERA and OCCAM both for NEOS-A and CORE-A. The trend in X_p is revealed only for the ERA processing of NEOS-A. It can explain the trend in X_p differences in Table 3. The trend might occur because the data were taken from EOP(IAA)99R01 and EOP(IAA)99R02 obtained with ITRF96. The linear trend in Y_p is surely detected for NEOS-A with ERA and OCCAM and less surely for CORE-A. The parameters of the trend are similar that evidence for the fact that this trend does really exist. The trend can be explained by the complex effects of the input C04. The residual of trends in $UT1$ detected with ERA and OCCAM for NEOS-A is positive and explains the increase of differences in $UT1$ with time. No trend in $UT1$ was found for CORE-A. The significant value of bias is detected for $d\epsilon$ for NEOS-A.

The coefficients of correlation between differences EOP(ERA)−EOP(IERS)C04 and differences EOP(OCCAM)−EOP(IERS)C04 obtained for NEOS-A are given in Table 5, column 3. The coefficients of correlation between differences EOP(ERA)−EOP(IERS)C04 and differences EOP(OCCAM)−EOP(IERS)C04 obtained for CORE-A are given in Table 5, column 4.

The similar coefficients of correlation in Table 5, column 3-4 and *rms* from Tables 3-4 analysis make it clear that the OCCAM and ERA packages agree between each other within deviations from C04, and agree satisfactorily with C04.

5. Correlation between Observational Programs

The level of agreement of EOP estimations obtained from different networks NEOS-A and CORE-A was also studied with the OCCAM and ERA packages. The EOP obtained with ERA and OCCAM from simultaneous NEOS-A and CORE-A sessions were compared (62 sessions for the period 1997–1999). Differences between the EOP obtained from NEOS-A and CORE-A with ERA and OCCAM are shown on the web page
http://www.ipa.nw.ru/PAGE/DEPFUND/GEO/ENG/lab_e.htm. From the figure it can be concluded that these differences are similar and of significant correlation. This is evidence for systematic differences between observational programs. The correlation coefficients between the differences NEOS-A−CORE-A obtained with ERA and NEOS-A−CORE-A obtained with OCCAM are given in Table 5, column 2. The parameters of linear trends in EOP are presented in Table 3. The *rms* value characterizes the root mean square of the series, *crms*—the root mean square of the differences after linear fitting. It is easy to conclude from Table 3 that there are few significant parameters of the linear trends.

Table 3. Parameters of linear trends in the differences between the obtained EOP.

	ERA−OCCAM		NEOS-A−CORE-A	
	NEOS-A	CORE-A	ERA	OCCAM
$T_0(year-1900)$	94.01	97.08	97.08	97.08
X_p, mas,bias	-0.41 ± 0.03	-0.01 ±0.07	-0.03 ±0.11	-0.15 ±0.09
$\dot{X}_p, mas/year$	0.10 ± 0.01	-0.03 ±0.05	-0.05 ±0.07	-0.04 ±0.06
$crms/rms$	0.30/ 0.36	0.29 / 0.29	0.45 / 0.46	0.37 / 0.43
Y_p, mas,bias	0.13 ± 0.03	0.02 ±0.08	0.04 ±0.11	-0.04 ±0.07
$\dot{Y}_p, mas/year$	-0.01 ± 0.01	0.04 ±0.05	-0.08 ±0.07	-0.03 ±0.05
$crms/rms$	0.28/ 0.30	0.33 / 0.34	0.44 / 0.45	0.28 / 0.29
$UT1, 0.1\ ms$,bias	-0.16 ± 0.01	-0.05 ±0.02	-0.02 ±0.03	0.03 ±0.03
$\dot{UT}1, 0.1\ ms/year$	0.03 ± 0.00	0.05 ±0.01	0.05 ±0.02	0.05 ±0.02
$crms/rms$	0.08/ 0.12	0.07 / 0.08	0.12 / 0.13	0.14 / 0.18
$d\psi, mas$,bias	-0.04 ± 0.03	-0.08 ±0.07	0.05 ±0.10	0.02 ±0.05
$\dot{d\psi}, mas/year$	0.00 ± 0.01	-0.01 ±0.05	0.01 ±0.06	0.01 ±0.03
$crms/rms$	0.26/ 0.26	0.30 / 0.31	0.39 / 0.39	0.20 / 0.20
$d\epsilon, mas$,bias	0.10 ± 0.03	0.22 ±0.08	-0.10 ±0.10	0.06 ±0.07
$\dot{d\epsilon}, mas/year$	0.00 ± 0.01	-0.12 ±0.06	0.13 ±0.07	-0.03 ±0.04
$crms/rms$	0.27/ 0.28	0.34 / 0.35	0.41 / 0.42	0.27 / 0.27

Table 4. Parameters of linear trends in the differences between the obtained EOP and EOP(IERS)C04.

	NEOS-A		CORE-A	
	ERA	OCCAM	ERA	OCCAM
$T_0(year-1900)$	96.99	96.66	98.46	98.46
X_p, mas,bias	-0.23 ± 0.02	-0.10 ± 0.02	0.03 ± 0.05	0.09 ± 0.03
$\dot{X}_p, mas/year$	0.10 ± 0.01	0.00 ± 0.01	-0.00± 0.06	0.06 ± 0.04
$crms$	0.23	0.34	0.22	0.34
Y_p, mas,bias	0.07 ± 0.02	-0.04 ± 0.01	0.24 ± 0.04	0.16 ± 0.03
$\dot{Y}_p, mas/year$	0.05 ± 0.01	0.06 ± 0.01	0.12 ± 0.05	0.04 ± 0.04
$crms$	0.19	0.28	0.23	0.30
$UT1, 0.1\ ms$,bias	-0.02 ± 0.01	0.05 ± 0.01	0.03 ± 0.01	0.05 ± 0.02
$\dot{UT}1, 0.1\ ms/year$	-0.02 ± 0.01	-0.04 ± 0.00	-0.00 ± 0.02	0.05 ± 0.02
$crms$	0.11	0.11	0.12	0.10
$d\psi, mas$,bias	-0.09 ± 0.03	-0.03 ± 0.01	-0.37 ± 0.09	-0.15 ± 0.06
$\dot{d\psi}, mas/year$	0.01 ± 0.02	-0.01 ± 0.01	0.05 ± 0.12	0.02 ± 0.08
$crms$	0.34	0.62	0.45	0.66
$d\epsilon, mas$,bias	0.14 ± 0.01	0.04 ± 0.01	0.04 ± 0.04	-0.00 ± 0.03
$\dot{d\epsilon}, mas/year$	-0.00 ± 0.01	0.00 ± 0.01	-0.10 ± 0.06	0.03 ± 0.04
$crms$	0.15	0.23	0.24	0.30

Table 5. Correlation coefficients between the EOP differences.

	1	2	3	4
$X_p(mas)$	0.26	0.65	0.46	0.56
$Y_p(mas)$	-0.15	0.30	0.43	0.41
$UT1(0.1\ ms)$	0.34	0.77	0.75	0.76
$d\psi(mas)$	0.01	0.22	0.28	0.30
$d\epsilon(mas)$	-0.01	0.07	0.12	0.30

6. Conclusions

- The similar values of trends in EOP obtained with different packages from different programs might show evidence for systematic differences between $C04$ and VLBI results.
- Differences between EOP obtained with ERA and OCCAM both from NEOS-A and CORE-A are of low correlation and have *rms* similar to that of EOP(ERA)−EOP(IERS)C04 differences.
- The comparison of the obtained EOP with C04 shows that the OCCAM results are in a little better agreement with C04 for X_p, Y_p, $d\psi$, $d\epsilon$, than the ERA results. For $UT1$ the agreement with C04 is approximately the same for both packages.
- The accuracy of the EOP obtained from NEOS-A network for the period 1997–1999 is a little better than from CORE-A network.
- Differences between the EOP obtained from NEOS-A and CORE-A both with ERA and OCCAM are similar and of significant correlation. This shows us that these differences are caused rather by systematics between the programs than between packages. It is important to extend this study for other packages.

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