PART VII : DOPPLER SATELLITE METHODS

POLAR MOTION THROUGH 1977 FROM DOPPLER SATELLITE OBSERVATIONS

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ABSTRACT

Doppler observations of Navy Navigation Satellites have been used to compute pole positions on a daily basis since 1969. Limited results exist for the period 1964 to 1969. Based on Doppler observations from four or five satellites, the standard error for a five-day mean pole position is less than 20 cm. Comparisons are made between BIH, IPMS and ILS results and those obtained from Doppler. It is shown that the six years of reliable Doppler data since 1972 contribute little in finding the Chandler period. Using observations from the three astronomical sources over 12 years yields a Chandler period of 432.0 ± 0.2 days.

PREVIOUS WORK

The determination of the coordinates of the Earth's spin axis from Doppler observation has been described by Anderle and his colleagues in a series of publications and reports. The method of computation was briefly explained by Anderle and Beuglass (1970). A more detailed description of the observational procedures, the data reduction techniques, and error sources was given by Anderle (1973a).

Results of Doppler data analysis and comparison with other determinations are discussed in numerous places. All Doppler results are based on five-day mean values of x and y. They are tabulated and discussed for 1969 by Anderle and Beuglass (1970), for 1967 to 1970 by Anderle (1970), for 1969 to 1971 by Anderle (1972), for 1972 by Anderle (1973b), and for 1973 by Beuglass (1974). The five-day means for the years 1974 to 1977 are given in this paper. A few two-day solutions for 1964 to 1969 may be found in Anderle (1973b), Appendix F.

The above data are normally shown as plots of x vs time, y vs time, and x vs y. They are given by Anderle and Beuglass (1970) for 1969, by Anderle (1970) for 1967, 1968, 1969 and 1970, by Beuglass and Anderle (1972) for 1970, by Anderle (1972) for 1969, 1970 and 1971, by Anderle

D. D. McCarthy and J. D. Pilkington (eds.), Time and the Earth's Rotation, 263–278.

(1973b) for the period 1964 through 1967 and for 1972, by Anderle (1973a) for mid-1971 to mid-1972, by Beuglass (1974) for 1973, and by Anderle (1976b) for 1975. Plots for the years 1974 to 1977 are shown in this report.

Anderle (1976a) has also compared Doppler derived pole coordinates with classical optical solutions. He plots the differences BIH-ILS, DMA (Doppler) - BIH, and DMA-ILS for the span 1964 to 1975. He also tabulates yearly mean values for above differences as well as associated statistics. Anderle (1976b) adds the comparison DMA-IPMS and shows more detail by breaking the plots into two spans, 1964 through 1969 and 1970 to 1975.

OBSERVATIONS AND DATA REDUCTIONS

The following is a very brief description of observational data and their analysis. Details may be found in the references listed at the end of this report, especially in Anderle (1973a) and Anderle (1976b).

Observations are the Doppler shifts in the continuous radio frequencies at 150 and 400 MHz transmitted by the U. S. Navigation System satellites (Kershner, 1967). Analog combination of these two frequencies permits elimination of one large error source, namely the first order ionospheric refraction effect.

The number of satellites being observed varies between two and five depending on Navy requirements. Table 1 shows which satellites were observed, and when, for the years 1974 to 1977.

Table 1. Available Doppler satellite data (Day Numbers).

	1967-34A	1967-48A	1967-92A	1970-67A	1973-81A
1974		166-280	1-87	89-363	
1975				2-362	13-363
1976	155-365			6-364	1-157
1977	7-167	21-167	21-167	6-364	21-365

Observations are taken by as many ground stations as are operational. They increased in number from about 13 in 1969 (Anderle and Beuglass, 1970) to about 20 in recent years (Anderle, 1976b).

All observations taken during a 48-hour time span are used in a least squares solution to improve, primarily, the orbital parameters. During this process, the satellite orbits are numerically integrated by Cowell's method, that is, the Gauss-Jackson algorithm spplied to the differential equations in the rectangular accelerations. The program is normally run with a 60 seconds integration step size and order 12. The reference frame is the mean equator and equinox at the beginning of the observation span. The mathematical model contains about 480 gravity terms, atmospheric drag, radiation pressure, luni-solar solid Earth tides, with the Love number presently set at 0.26. The force field is complete enough to permit determination of the satellite's position good to about one meter.

The solution also contains, among other parameters, the coordinates x and y of the spin axis, referred to the CIO. Such two-day solutions are obtained separately for each satellite. Subsequently all two-day solutions from up to five different satellites are combined into five-day means. The latter are published by the U. S. Naval Observatory in "Preliminary Times and Coordinates of the Pole, Series 7."

The computation of pole positions based on Doppler observations originated at the Naval Weapons Laboratory, now the Naval Surface Weapons Center (NSWC). In April 1975 the responsibility of computing NAVSAT orbits, and, hence, the derivation of pole positions, was transferred to the Topographic Center of the Defense Mapping Agency (DMA). Since DMA employs the same computer programs, the transfer did not affect position results.

Over the years, there have been a number of changes in the observation station network and observation techniques (Anderle, 1973a) as well as improvements in the data reduction methods (Anderle, 1972). However, the procedures have been essentially the same since August 1971, so that Doppler results after this date are believed to be homogeneous.

DOPPLER POLE POSITIONING ACCURACY

The formal standard deviation for the polar coordinates from a two-day solution is about 5 cm during the second half of 1977. But it must be remembered that such solutions are made for each satellite separately. All two-day solutions are then combined into five-day means. Subsequently, one can compute the more realistic standard deviation of a two-day coordinate with respect to the five-day mean. That number is presently a bit less than 40 cm. The standard deviation of the five-day mean itself (standard error) has been just under 20 cm for the last two years.

The increase in accuracy from 1967 to 1977 is shown in Table 2. However, the data before and after 1972 are not immediately comparable. Polar coordinates until August 1971 were extracted indirectly from called-for corrections to station coordinates, and they were one-day solutions. Moreover, they were computed after orbit improvement, not in a simultaneous least-squares solution.

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Table 2. Preliminary yearly rms of Polar Coordinates.

	Standard Deviations (two-day solutions *)			Standard Errors (five-day means)		
	x [m]	y [m]	Av. [m]	x [m]	y [m]	Av. [m]
1967	1.65	1.78	1.72	.89	.74	.82
1968	1.48	1.60	1.54	.86	.93	.90
1969	1.51	1.27	1.40	.69	.60	.65
1970	1.25	1.15	1.20	.57	.53	.55
1971	1.16	1.39	1.28	.52	.62	.57
1972	.75	.69	.72	.37	.32	.35
1973	.38	.44	.41	.22	.28	.25
1974	.48	.50	.49	.30	.32	.31
1975	.47	.36	.42	.22	.18	.20
1976	.40	.30	.35	.20	.15	.18
1977	.41	.34	.38	.18	.15	.17

*One-day solutions before 1972

Anderle (1973a) pointed out that the principal error source in Doppler polar coordinates is due to inadequate knowledge of the Earth's gravity field. Despite recent advances, this remains true today.

RESULTS 1974-1977

Anderle and his colleagues have already published diagrams and tables summarizing polar motion during 1974 and 1975. Since some of their results were based on preliminary data, they are repeated here using final data. Final values were also available for 1976 while some 1977 results are still preliminary. They will be identified as such below.

Tabulation of Doppler Results

Table 3 is a sample containing the two-day and five-day Doppler solutions for polar coordinates. The complete tables for the years 1974 to 1977 will be published in a forthcoming NSWC report. The first two columns show the day numbers for each two-day solution. They are followed by x and y and their formal standard deviations (labelled "Standard Error") as obtained from the covariance matrix of the least-squares solution. The last two columns are the satellite designation and the nominal value for UTC-UT1. The latter information is not used in our pole position calculations.

Table 3. Sample Doppler solutions for polar coordinates.

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NWL 9 POLE
REPORT REVISION

			DAILY SOLUTION				PART-DAILY		
			POLE POSITION		STANDARD ERROR		SOLUTION		NOMINAL
	DAYS 1977		X METERS	Y METERS	X METERS	Y METERS	X METERS Y METERS	SATELLITE	UTC-UT1
	333.	334.	2.58	1.11	.05	.05	.01-947058.66	1973 81A	244000.00
	334.	335.	3.46	2.48	.04	.05	.01-953246.60	1970-67A	247000.00
	335.	336.	4.21	1.12	.05	.05	.01-947058.66	1973 81A	250000.00
	336.	337.	3.00	2.30	.05	.06	.01-953246.60	1970-67A	254000.00
	337.	338.	2.72	1.74	.06	.05	.01-947058.66	1973 81A	258000.00
MEAN	336.		3.25	1.75	.05	.05			
STD DEV	336.		.66	.55	.00	.00			
STD ERR	336.		.30	.29					
	338.	339.	2.74	1.16	.05	.05	.01-953246.60	1970-67A	262000.00
	339.	340.	2.58	1.44	.05	.05	.01-947058.66	1973 81A	266000.00
	340.	341.	2.61	1.24	.05	.05	.01-953246.60	1970-67A	270000.00
	341.	342.	2.17	1.31	.05	.05	.01-947058.66	1973 81A	274000.00
	342.	343.	3.34	1.06	.05	.05	.01-953246.60	1970-67A	275000.00
MEAN	341.		2.69	1.36	.05	.05			
STD DEV	341.		.41	.33	.00	.00			
STD ERR	341.		.18	.15					
	343.	344.	1.63	.45	.06	.05	.01-947058.66	1973 81A	279000.00
	344.	345.	1.94	.52	.07	.06	.01-953246.60	1970-67A	282000.00
	345.	346.	2.06	.46	.05	.06	.01-947058.66	1973 81A	285000.00
	346.	347.	2.05	1.33	.05	.05	.01-953246.60	1970-67A	288000.00
	347.	348.	1.26	.51	.06	.05	.01-947058.66	1973 81A	290000.00
MEAN	346.		1.82	.66	.06	.05			
STD DEV	346.		.34	.40	.01	.00			
STD ERR	346.		.15	.18					
	348.	349.	2.29	1.99	.05	.05	.01-953246.60	1970-67A	294000.00
	349.	350.	1.40	.58	.05	.05	.01-947058.66	1973 81A	295000.00
	350.	351.	.81	.83	.05	.06	.01-953246.60	1970-67A	297000.00
	351.	352.	1.17	.77	.05	.05	.01-947058.66	1973 81A	298000.00
	352.	353.	1.52	.49	.05	.05	.01-953246.60	1970-67A	300000.00
MEAN	351.		1.45	.89	.05	.05			
STD DEV	351.		.55	.59	.00	.00			
STD ERR	351.		.25	.27					

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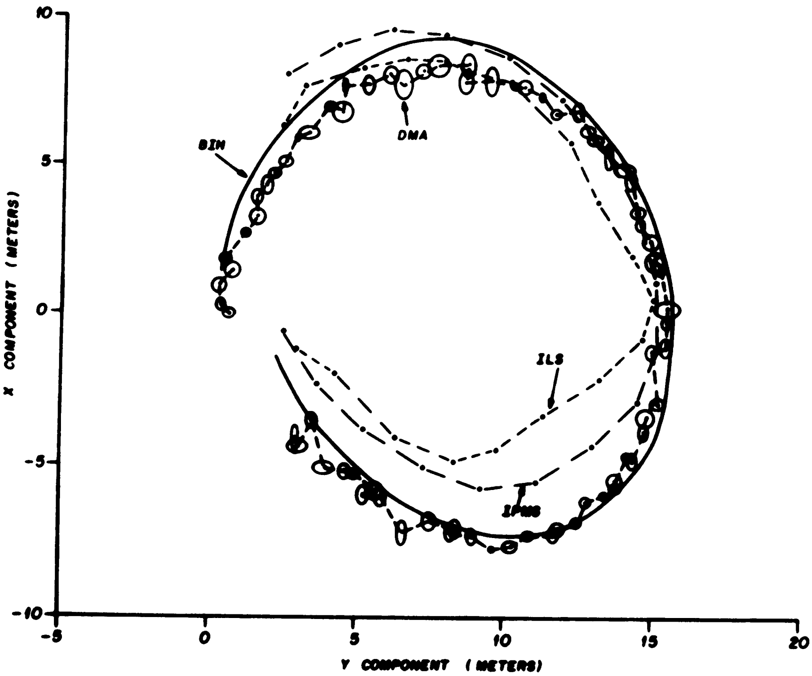

Figure 1. Pole path for 1977.

In the last three lines of each block, only the first three columns are of interest. The first column shows the day number for which the five-day average is being computed. Columns two and three show the weighted averages for x and y, where the weight is taken as $1/\sigma^2$, σ being the two-day standard deviations mentioned above. The line marked STD DEV is the weighted standard deviation of a two-day solution with respect to the five-day mean. The last line, labelled STD ERR, is the previous line divided by the square root of n. It is, therefore, the standard deviation of the five-day mean. Note that the program is presently limited to include only the first four two-day solutions for any given day in the five-day means, even though all available two-day results are listed.

Pole Coordinate Plots

The motion of the pole during the year 1977 may be seen at a glance in Figure 1. This is only a sample. Similar plots for the years 1974 through 1976 will be given in a subsequent report. The Doppler data, now labelled DMA, are easily identified by their one sigma error ellipses. These are the STD ERR of the five-day means shown in Table 3.

Also shown are the polar coordinates from three other sources, namely BIH, ILS and IPMS. They are plotted as solid lines, dashes, and alternating dots and dashes, respectively. As in earlier years, the agreement between BIH and DMA is quite good. However, it must be pointed out that the Doppler data are used, in addition to optical observations, in deriving the BIH pole position results quoted for 1977. The agreement between IPMS and BIH or Doppler is reasonably good. ILS, however, frequently differs from the other three determinations. The discrepancy reaches 3.5 m. The BIH path shown in Figure 1 appears exceedingly smooth. This is due to the fact that only "smoothed' data were available at the time the above plots were prepared.

Figures 2 and 3 permit a comparison of the various polar motion services, separated into the x and y coordinates, for the year 1976. It may be seen that the differences are larger in x than they are in y. Again, plots for the other years will be shown in a later report.

Differences in Pole Coordinates

Anderle (1976b) published plots of differences in the x and y-coordinates of the pole for the time spans 1964 through 1969 and 1970 through 1975. A similar plot, Figure 4, is given in this report for the interval 1974 through 1977, but in x only. This diagram shows the differences in the four pairs BIH-ILS, DMA-ILS, DMA-BIH, and DMA-IPMS quite clearly. By and large, the y-coordinates agree well, except for the ILS excursions in 1976 and 1977. In x, however, all four pairs show significant biases. ILS again shows some large variations with respect to BIH and DMA.

Tables 4 and 5 are a continuation of similar information published by Anderle in earlier reports. They list the yearly average difference for each of the four pairs being compared, as well as the standard deviation of the individual difference with respect to the annual mean. Individual points involving either ILS or IPMS would be 18 days apart, while DMA-BIH is formed every 5 days. Footnotes to Tables 4 and 5 contain additional information concerning data sources and reference frames.

THE CHANDLER PERIOD

It is well known that the principal periodic components of the motion of the pole are the Chandler period and the annual term. In order to determine the former, Anderle (1977, office memo) adapted an existing program to fit to the data an expression of the form

$$X_{comp} = X_o + A_s \sin\left(\frac{2\pi}{365.25}\right)t + A_c \cos\left(\frac{2\pi}{365.25}\right)t$$

$$+ C_s \sin\left(\frac{2\pi}{P_c}\right)t \qquad + C_c \cos\left(\frac{2\pi}{P_c}\right)t$$

and a similar equation for y. P_c is the unknown Chandler period, and

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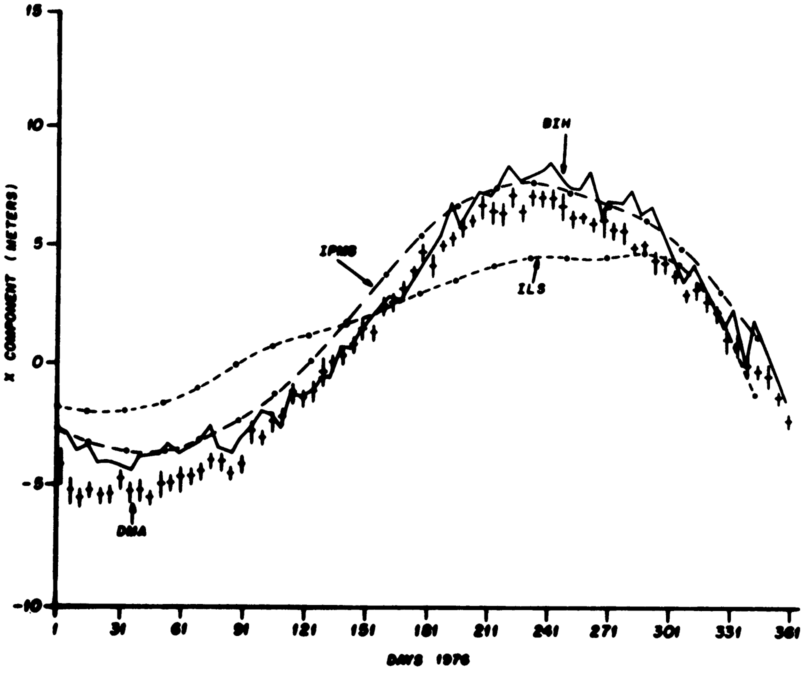

Figure 2. x component of polar motion for 1976.

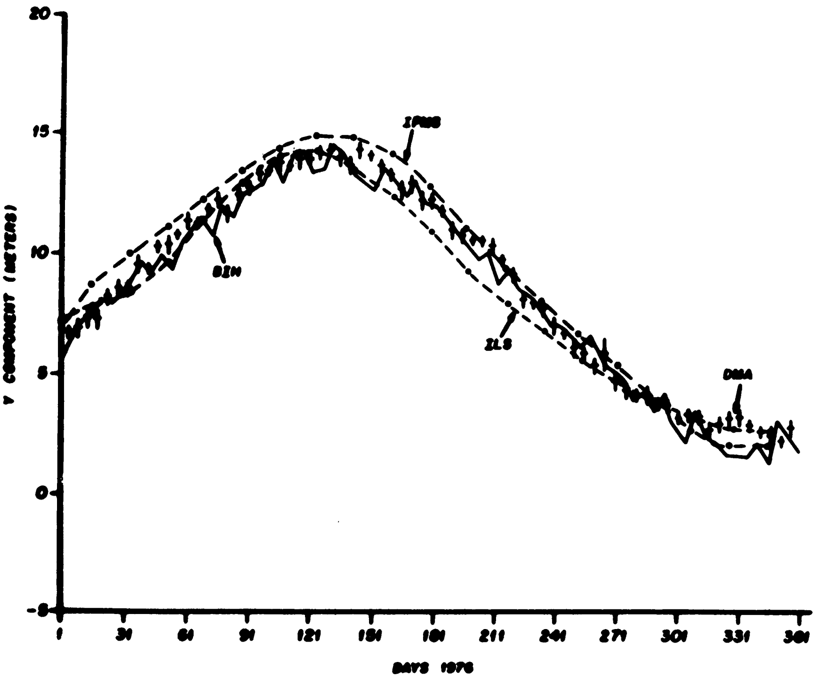

Figure 3. y component of polar motion for 1976.

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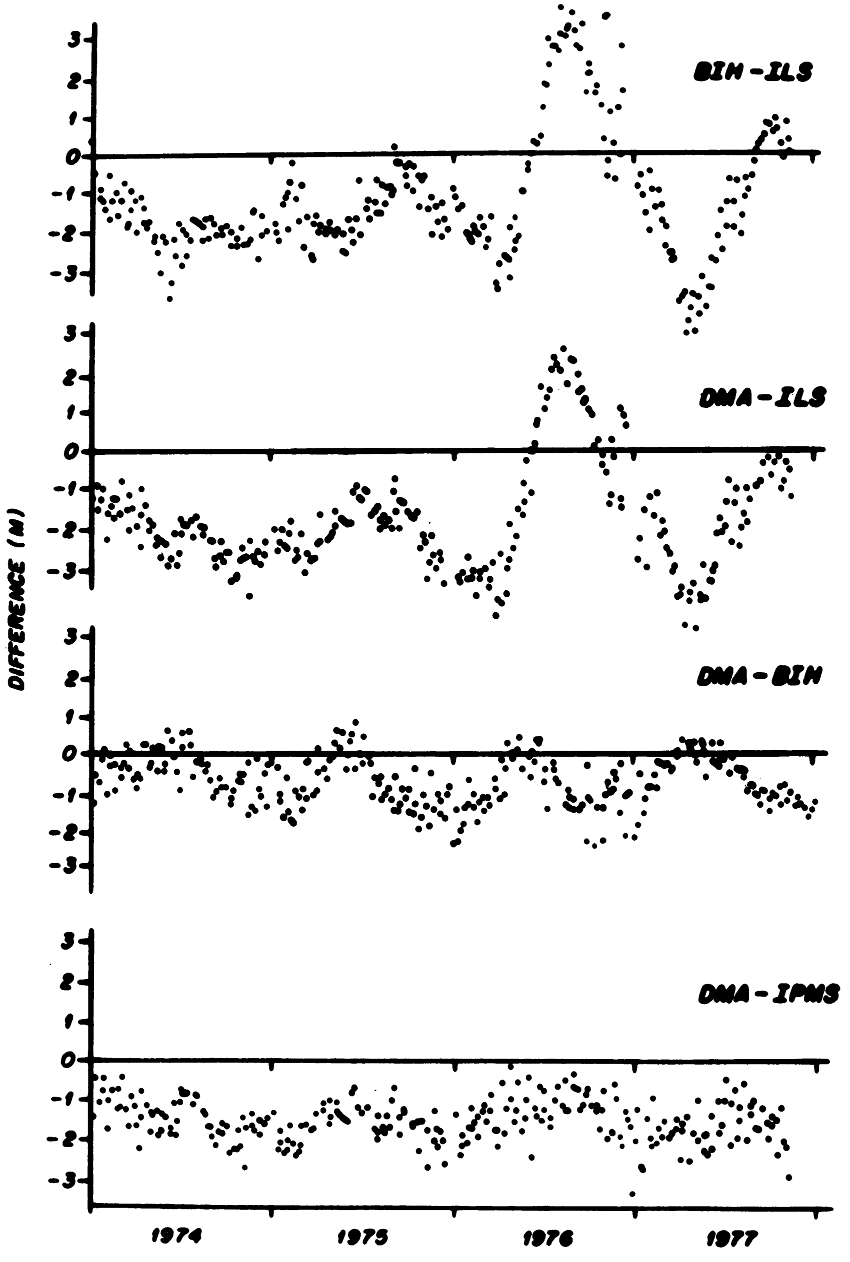

Figure 4. Differences in estimates of the x component of pole position 1974-1977.

Table 4. Average differences in pole position by year.

	MEAN DIFFERENCE (m)								STD DEV OF DIFF (m)							
	X Coordinate				Y Coordinate				X Coordinate				Y Coordinate			
YEAR	DMA -BIH	DMA -ILS	BIH -ILS	DMA -IPMS	DMA -BIH	DMA -ILS	BIH -ILS	DMA -IPMS	DMA -BIH	DMA -ILS	BIH -ILS	DMA -IPMS	DMA -BIH	DMA -ILS	BIH -ILS	DMA -IPMS
1964[1]	1.5	-.5	-1.7	.4	-.0	.3	.8	.2	1.9	1.4	1.1	1.8	1.4	1.5	1.0	1.5
1965[1]	1.6	.7	-.8	.9	.8	.8	.1	.9	.8	1.1	.5	.8	.9	1.6	.8	1.5
1966[1]	.0	-.7	-.6	-.9	.1	.7	.1	.1	.5	1.3	.8	.5	.6	.6	.9	.8
1967[1]	-.5	-.7	-.2	-1.2	-.3	-.2	.1	-.5	1.9	1.8	.9	1.9	1.4	1.9	1.0	1.5
1968	-.7	-.8	-.2	-1.5	.0	-.4	-.3	-.1	1.8	1.1	1.0	1.1	1.5	1.3	.9	1.2
1969	-.3	-1.2	-.8	-1.2	-.1	-.4	-.3	-.1	.9	1.0	1.1	1.0	1.3	1.3	.6	1.3
1970	-.4	-1.1	-.6	-1.4	.3	-.3	-.5	.0	1.0	.8	.8	.8	1.0	1.1	.8	1.4
1971	.1	-.7	-.7	-.8	-.7	-.9	-.2	-.9	.8	1.6	1.5	1.2	.9	1.4	1.3	1.6
1972	-.3	-2.0	-1.4	-1.1	.2	-.2	-.2	-.7	1.0	.9	.9	.7	.7	.9	.8	1.0
1973	-.3	-1.9	-1.5	-.9	-.2	.0	.2	-1.2	.6	1.0	1.2	.8	.5	.5	.6	.6
1974	-.4	-2.2	-1.8	-1.4	-.2	.4	.6	-.6	.5	.7	.7	.5	.5	.8	.7	.4
1975	-.7	-2.1	-1.4	-1.7	.0	.2	.2	-.3	.7	.6	.7	.5	.6	.6	.7	.5
1976[3]	-.9	-.7	.2	-1.3	.3	.5	.2	-.4	.7	2.2	2.3	.6	.5	.9	.9	.8
1977[3,4]	-.6	-2.0	-1.6	-1.7	.1	.7	.6	.3	.6	1.3	1.7	.6	.3	1.4	1.5	.7

ILS Positions are from IPMS annual report and BIH positions are final raw positions from **annual** report except as noted below.

[1]**BIH positions for 1964-1967 are smoothed astronomical positions given in 1969 and 1970 annual reports.**

[3]ILS and IPMS positions for 1976 and 1977 are from the Monthly Notes of the International Polar Motion Service (preliminary data).

[4]BIH positions for 1977 are preliminary raw values from Circular D. Note that the positions were computed using DMA data weighted solutions.

Table 5. Coordinate systems and gravity fields.

YEAR	DMA COORDINATE SYSTEM	DMA GRAVITY FIELD	SOURCE OF DMA POLE POSITION
1964	NWL-9D	NWL-9B	NWL TR-2734, 2952 (9 Mean Positions)
1965	NWL-9D	NWL-9B	NWL TR-2734, 2952 (13 Mean Positions)
1966	NWL-9D	NWL-9B	NWL TR-2734, 2952 (6 Mean Positions)
1967	NWL-8D[5]	NWL-8B NWL-8D (20 Feb)[5]	Preprint[5]
1968	NWL-8F (19 Jan)[6]	NWL-9H (18 Apr)[6]	Preprint[6]
1969	NWL-8F[7,8]	NWL-8H[7,8]	NWL TR-2734[7]
1970	NWL-9C (20 Dec)	NWL-9B (13 Feb)	NWL TR-2734
1971	NWL-9D (18 Oct)	NWL-9B[9]	NWL TR-2734
1972	NWL-9D	NWL-9B	NWL TR-2952
1973	NWL-9D	NWL-10E (2 Jan)	NWL TR-3181
1974	NWL-9D	NWL-10E	DMA Weekly Reports
1975	NWL-9D	NWL-10E	DMA Weekly Reports
1976	NWL-9D	NWL-10E	DMA Weekly Reports
1977	NWL-9Z-2 (15 Jun)	NWL-10E	DMA Weekly Reports

[5]Mean corrections of -2.06 and 1.48 m were added to 1967 NWL-8D X and Y pole positions, respectively, based on comparisons with 12 NWL-9D results given in TR-2734 and 2952.
[6]Mean corrections of -2.37 and 2.04 m were added to 1968 NWL-9D X and Y pole positions, respectively, based on comparisons with 11 NWL-9D results given in TR-2734 and 2952.
[7]Mean corrections of -.07 and -2.35 m were added to 1969 NWL-8D X and Y pole positions, respectively, based on comparisons with 12 NWL 9-D results given in TR-2734 and 2952.
[8]TR-2734 gives pole positions for 1969-1970 computed after adjusting NWL-8F latitude residuals to NWL-10D system.
[9]DMA pole positions for 1964-1966 and after August 1971 are based on simultaneous solution for orbit constants and pole position rather than sequential solutions.

the X_o, A and C are five numerical coefficients to be determined by least-squares fits. One assumes a value for P_c, obtains an expression for X_{comp} and Y_{comp}, and forms the residuals and their rms. This is repeated for several values of P_c, and a parabola is fitted to three such pairs of points. Finally, one computes the value of P_c for which the rms parabola has its minimum. Obviously, to obtain P_c directly from a least-squares solution is more elegant, but the above procedure permitted the use of existing coding.

Figure 5 depicts one of the curves discussed above. The legend shows that 12 years of data were used for the three astronomical sources, while only six years of Doppler data were available for this analysis. It can be seen that the astronomical services agree quite well. The minima are near 432 days, and they are well defined. The Doppler curve in the y-coordinate is of dubious value. It was quickly found that the short six-year time span is responsible. Solutions for the three astronomical sources over six years produced results comparable to the Doppler curve.

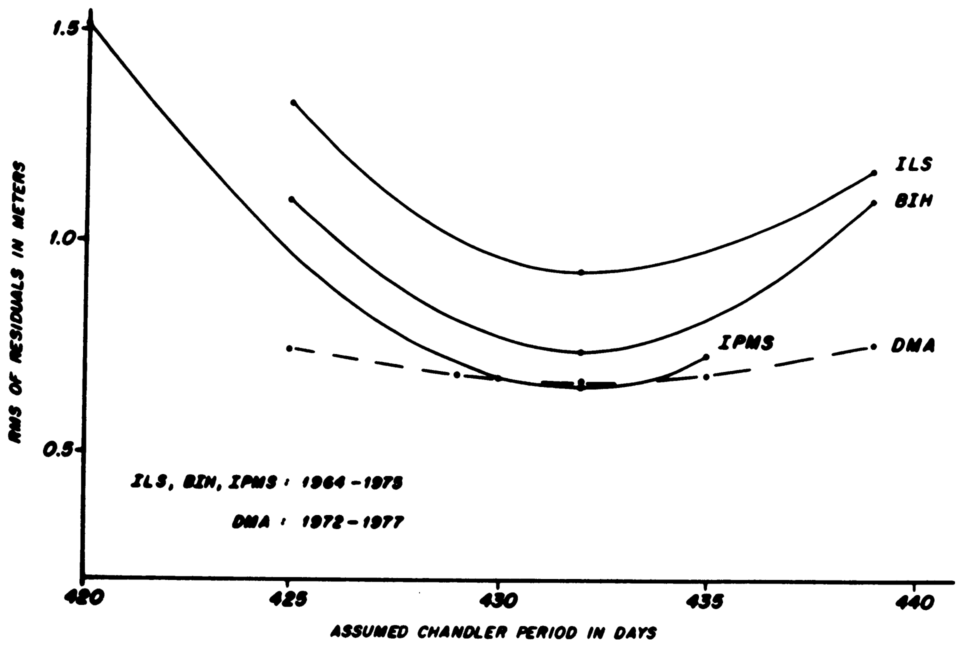

Figure 5. Residuals in y component after 5-parameter fit.

https://doi.org/10.1017/S0074180900036342 Published online by Cambridge University Press

Table 6. Chandler period.

	$P_c(x)$	$P_c(y)$	P_c
ILS	431.71	432.87	432.29
BIH	431.94	432.00	431.97
IPMS	431.77	431.79	431.78

Mean value: P_c = 432.0 ± 0.2 days.

Table 6 contains the results of the P_c computations explained above. In obtaining the averages and the mean value, unit weight was assumed. The error bound of $0\overset{d}{.}2$ was calculated from the scatter of the six individual values.

Although of questionable value, P_c was also computed from the DMA y-curve. It yields $432\overset{d}{.}2$, in reasonable agreement with our adopted values of $432\overset{d}{.}0$.

Our determination is also in good agreement with Markowitz (1976), who obtains $432\overset{d}{.}02$ ± 0.15 days. It compares reasonably well with Vicente and Currie (1976), who quote 433.2 ± 0.8 days.

The above mentioned residuals are believed to contain other periodicities. Bowman and Leroy (1976), among others, have performed a spectral analysis of the x and y-components themselves, with the following results:

Table 7. Bowman/Leroy spectral analysis.

Frequency (cycles/year)	Period (days)	Amplitude (meters)
0.85	430	5.84 ± 0.6
1.0	365	4.84 ± 0.6
1.3	280	0.49 ± 0.6
2.0	180	0.23 ± 0.6
2.5	145	0.12 ± 0.6
4.0	90	0.11 ± 0.6

Their analysis is based on five years of Doppler data. Considering our earlier difficulties with such a short time span, perhaps considerable strength could be added to the solution by including astronomical data. A particularly attractive time span would be 13 years, corresponding to almost exactly 11 Chandler cycles. However, reliable Doppler data does not yet exist for such an interval.

ADVANTAGES AND DISADVANTAGES OF DOPPLER

Doppler observations are taken day and night, and under any cloud cover. This all-weather capability is one of its major assets. Doppler data are also less sensitive to tropospheric effects than are optical observations. Moreover, they are independent of star catalog position errors. Perhaps Doppler's greatest value lies in the fact that it adds a totally independent pole position determination to the classical methods.

Systematic error due to an inadequate knowledge of the gravity field is the major disadvantage of Doppler. Results are also affected by changes in the station network and atmospheric drag variations during a two-day span. Computing Doppler pole positions is quite expensive. At the present time, however, they are obtained as by-products in orbit improvement runs performed by DMA. Finally, although TRANSIT satellites have shown remarkable endurance, their life time is finite.

FUTURE PLANS

The planning of drag-free satellites is underway at the Applied Physics Laboratory, Johns Hopkins University. Once operational, effects due to drag would be eliminated and a better gravity field could be determined, resulting indirectly in better orbits and pole positions.

The Earth gravity field is continuously being improved, especially by NASA. NSWC has also begun work on a major new geodetic solution. Other improvements in the mathematical model are planned, especially better representations of the various tidal effects.

SUMMARY

Computations of polar coordinates from Doppler observations have been performed in recent years by DMA. During the first half of 1977 as many as five satellites were observed. The standard deviation of a two-day polar coordinate solution is now better than 40 cm, that for the five-day mean under 20 cm. Agreement between the four services ranges from excellent to only fair. There are no significant problems in the y-coordinate, except a 1.5 m standard deviation in 1977 for comparisons involving ILS. The x-coordinate shows both large biases and standard deviations.

It is found that six years of Doppler data are not enough to derive a reliable Chandler period. Hence, twelve years of data from the three astronomical services were taken to compute a Chandler period of 432.0 ± 0.2 days. Residuals suggest the existence of additional periodic terms.

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DISCUSSION

S. Debarbat: Pouvez-vous donner l'ordre de grandeur du changement dans la précision avec laquelle le pôle est déterminé lorsqu'il y a changement dans l'emplacement d'une station ou changement de satellite observé?

C. Oesterwinter: I have not conducted any experiments to assess the magnitude of these effects. I guess that they would change the coordinates of the pole by only a few centimeters.

J. D. Mulholland: The 1800 terms in the gravitational field correspond approximately to a 40th degree harmonic field. Anderle reported last year that this was necessary, but later retracted. Will you please comment on this?

C. Oesterwinter: A gravitational field with around 1800 terms is required to compute SEASAT orbits of sufficient accuracy to take full advantage of its 10 cm radar altimeter.

Ya. S. Yatskiv: BIH uses the Doppler observations for determining x, y. IPMS does not. Is this the reason for the better agreement between the BIH and DMA results?

C. Oesterwinter: No. We have used the BIH results based only on optical astrometry.

D. D. McCarthy: I understand that there is a possibility that increasing solar activity may affect the Doppler results; could you comment?

C. Oesterwinter: This possibility is currently being investigated.

https://doi.org/10.1017/S0074180900036342 Published online by Cambridge University Press