VARIATIONS OF DIFFERENCES OF LATITUDES AND OF MEAN LATITUDES OF STATIONS LOCATED IN THE VICINITY OF A COMMON MERIDIAN

B. Kołaczek,* R. Galas, M. Barlik and M. Dukwicz

Institut of Higher Geodesy and Geodetical Astronomy
Warsaw Technical University
Warsaw, POLAND

Summary

Differences of latitudes and of mean latitudes of stations located along a common meridian were studied in order to find influences of local geophysical phenomena on their variations. Some correlation of variations of the mean latitude of Belgrade with the occurrence of earthquakes in the vicinity can be noticed as well as instabilities of the mean latitude of stations located near sea coasts. Some attempts at measurements of variations of the meridian component of the vertical and a discussion of spectral analysis of latitudes and of mean latitudes of considered stations are presented.

Introduction

Influence of local motions of a latitude station due to plate tectonic or local block motions as well as of local variations of the vertical on variations of latitude determined by classical astrometric methods has been noticed by many authors.[1-5] Differences of latitudes and of mean latitudes of stations located along a common meridian are especially convenient for the study of influences of local geophysical phenomena on variations of latitude because these differences are free from the influence of pole motions. A better understanding of influences of local geophysical phenomena on latitude variations can help improve the accuracy of polar motion determinations based on these data.

Analysis and conclusions

Differences of latitudes and of mean latitudes of four stations located in the vicinity of the meridian of Józefosław for the period of 1962-

*Currently at the Planetary Geodesy Department of the Space Research Centre of Polish Academy of Sciences.

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1975 were analyzed in order to study their variations. Variations of mean latitudes of a few European stations were computed for comparison. The stations and their coordinates are given in Table 1. Uccle, Paris, and Neuchatel are also located in the vicinity of a common meridian.

Table 1. Station Coordinates

Station	λ	ϕ	Station	λ	ϕ
Turku	-1^h29^m	60°27'	Uccle	-0^h17^m	50°48'
Józefosław	-1 24	52 06	Paris	-0 09	48 50
Belgrade	-1 22	44 48	Neuchatel	-0 28	47 04
Pećńy	-0 58	49 54	Hamburg	-0 40	53 36
			Potsdam	-0 52	52 23

On the basis of IPMS latitude data for these stations,[6,7] mean latitudes were computed using Orlov's filter OR 2. Additionally, filtered latitude curves were computed by spectral analysis. All detected periodic terms with amplitudes greater than the rms errors of their determinations were removed. These errors range from 0".004 to 0".010.[8] Orlov's mean latitude curves and spectrally filtered latitude curves for the above stations are shown in Figures 1 and 2. Table 2 contains a list of all periodic terms determined in the process of latitude filtering. Besides well-known terms such as the Chandler, annual, and semi-annual ones, other terms were detected. There is the strong and well-determined term with a period equal to $1^y.3$. Naito and Ishi[9] indicated the possibility that this term is caused by some oscillation of the oceans due to fluid core motions. There are a few terms with periods ranging from $0^y.4$ to $0^y.7$ which can be caused by the nearly diurnal nutation.[10,11] Terms with periods approximately equal to $0^y.95$ and $1^y.05$ can be caused by errors of the nutational constant.[12] A strong periodical term with period equal to $0^y.33$ was detected in Belgrade latitude data. It seems to be caused by a refractive anomaly because this term does not exist or it is weak in latitude data of other stations. Such a refractive term was detected by Djurovic.[13] Long-period terms with periods ranging from $2^y.0$ to $2^y.5$ and in the vicinity of $1^y.6$ are detectable. Such variations can be caused by variations of atmospheric density.[14,15] Improvement in the filtering process are necessary for further study of these terms.

Differences of Orlov's mean latitude of stations located in the vicinity of Józefosław meridian are shown in Figure 3. These variations of latitude differences reflect only the influence of local geophysical, meteorological and instrumental phenomena because the influence of

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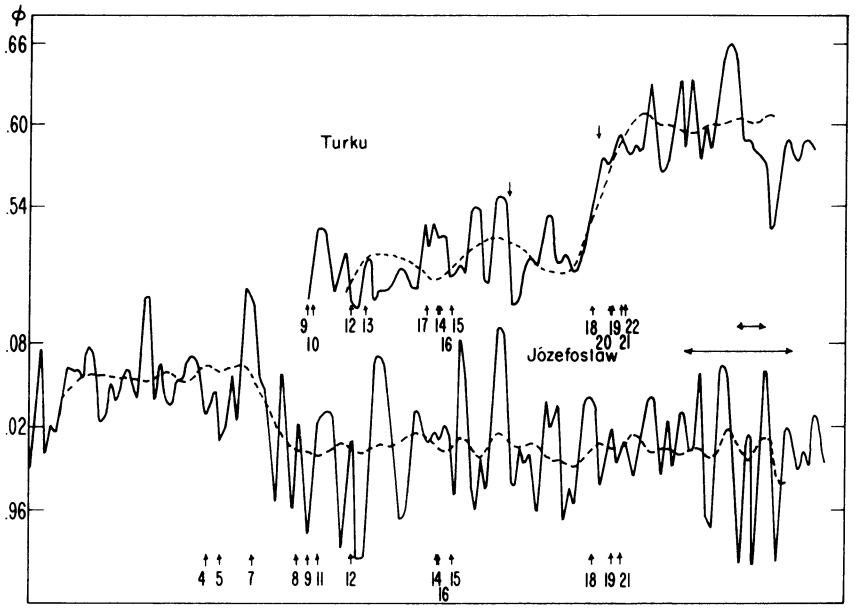

Figure 1a

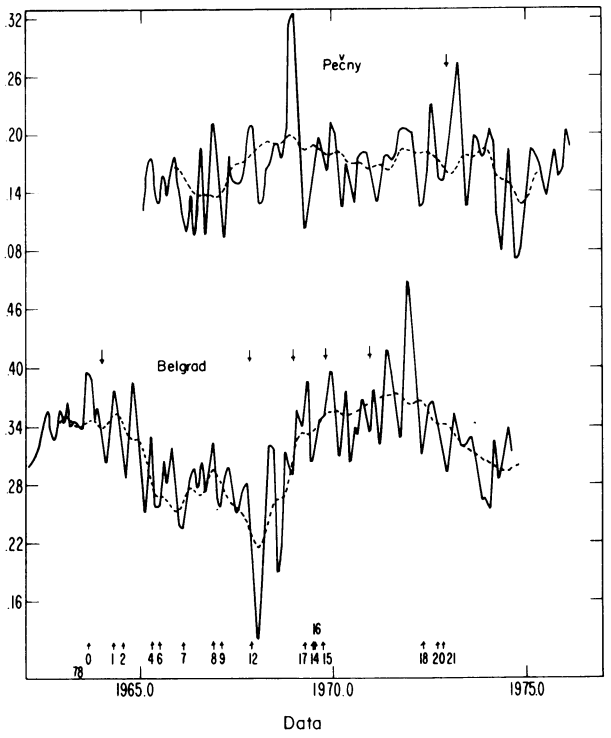

Figure 1b

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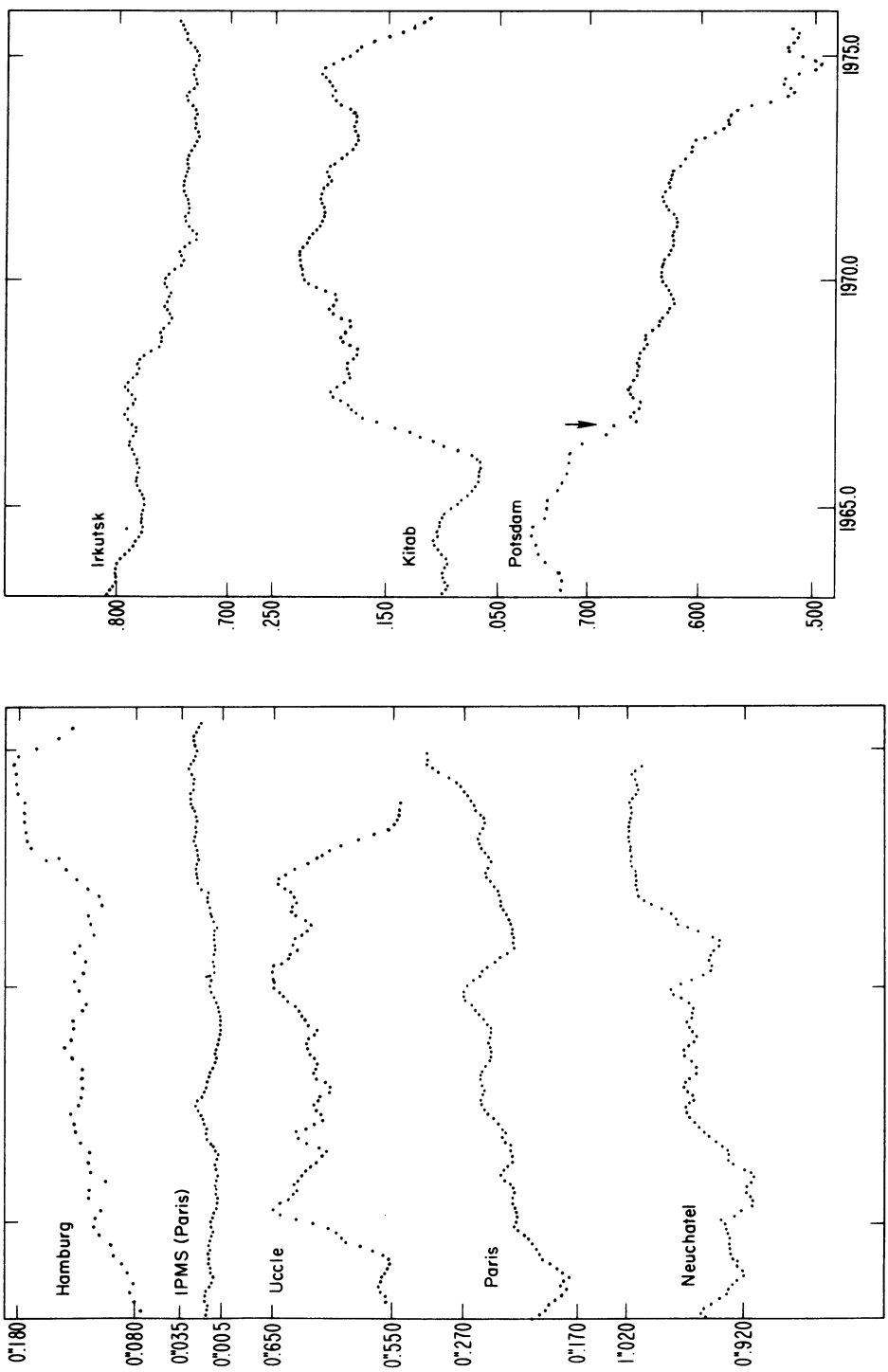

Figure 2b

Figure 2a

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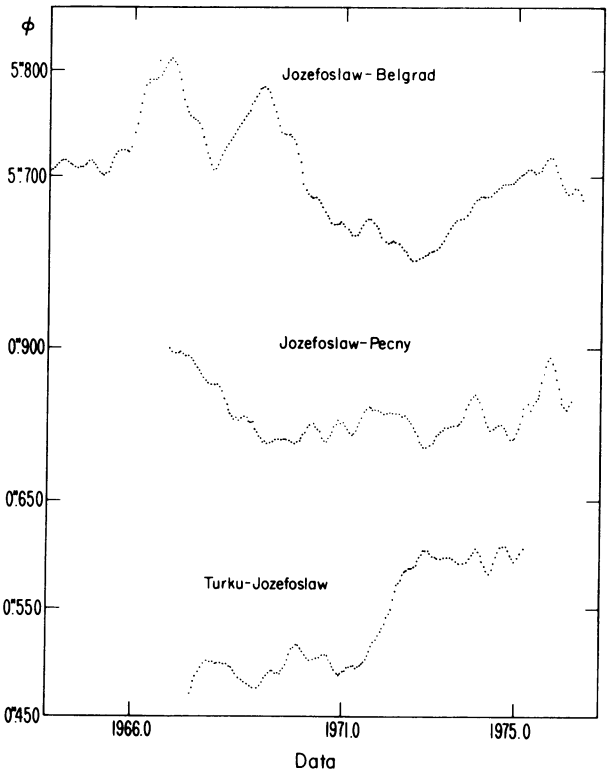

Figure 3a

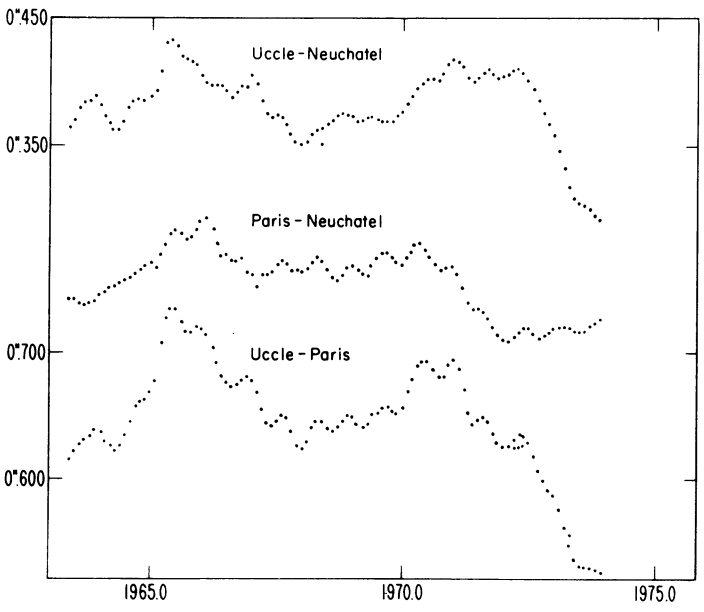

Figure 3b

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Table 2. Periodic terms of latitude variations of stations located in the vicinity of the Józefosław meridian

Józefosław		Turku		Pecny		Belgrade	
p	A	p	A	p	A	p	A
1.193	0.131	1.178	0.112	1.180	0.109	1.188	0.143
1.005	0.162	1.008	0.101	0.996	0.125	1.030	0.124
0.609	0.029	0.502	0.031	0.595	0.010	0.530	0.034
---	---	---	---	0.330	0.047	0.321	0.034
---	---	---	---	0.354	0.017	0.338	0.014
---	---	---	---	0.394	0.023	0.375	0.018
0.427	0.013	0.408	0.011	0.424	0.015	0.415	0.025
0.473	0.013	0.443	0.010	0.439	0.021	0.424	0.014
0.568	0.011	0.513	0.011	0.463	0.014	0.436	0.028
---	---	0.583	0.008	0.487	0.027	0.468	0.019
0.692	0.015	0.680	0.013	0.551	0.021	0.504	0.021
0.767	0.016	0.723	0.010	---	---	0.536	0.015
---	---	0.882	0.016	---	---	0.577	0.014
0.909	0.010	---	---	0.632	0.013	0.624	0.014
0.951	0.031	---	---	0.658	0.019	0.658	0.012
1.050	0.016	---	---	0.709	0.011	0.784	0.016
1.312	0.027	1.324	0.021	0.883	0.022	0.881	0.017
---	---	1.516	0.016	---	---	0.962	0.035
1.939	0.014	1.815	0.012	---	---	1.075	0.017
2.444	0.009	2.374	0.034	1.129	0.017	---	---
				1.334	0.029	1.268	0.034
				---	---	1.448	0.013
				1.650	0.015	1.637	0.011
				2.020	0.017	2.090	0.011
				2.507	0.015	---	---

P - period (yrs); A - amplitude (arc sec)

pole motion has been removed. Spectral analyses of the differences of latitude and of mean latitude were made. Table 3 gives all terms detected in these data. The existence of annual and semi-annual terms is obvious. There is a strong periodic term with period of about $0^{y}.85$, and there are long period terms with periods ranging from $2^{y}.5$ to $3^{y}.0$ in differences of latitudes and in mean latitudes of the stations considered. It is worth noticing that the terms with periods ranging from $0^{y}.4$ to $0^{y}.7$ which can be connected with existence of the nearly diurnal nutation are stronger in differences of latitudes than in latitudes themselves.

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Table 3. Periodic terms of the differences of latitude of stations located in the vicinity of the meridian of Józefosław. (T-Turku; J-Józefosław; P-Pecny; B-Belgrade)

T - J		J - B		J - P		P - B		T - B	
P	A	P	A	P	A	P	A	P	A
RMS = ±0".010		RMS = ±0".009		RMS = ±0".008		RMS = ±0".010		RMS = ±0".011	
---	---	---	---	0y.360	0".010	---	---	---	---
				0.400	0.010	---	---	---	---
0y.450	0".019	0y.460	0".014	0.460	0.010	0y.460	0".010	0y.440	0".011
0.500	0.037	0.500	0.029	0.500	0.010	0.500	0.021	0.500	0.016
0.550	0.014	0.560	0.022	0.550	0.025	0.540	0.009	---	---
0.600	0.034	0.600	0.022	---	---	0.580	0.017	0.580	0.019
0.640	0.016	---	---	0.640	0.024	0.620	0.013	0.640	0.017
						0.660	0.026		
0.690	0.025	0.670	0.023	---	---	0.720	0.036	0.680	0.018
0.760	0.018	0.740	0.020	0.710	0.022	0.780	0.035	0.740	0.025
---	---	---	---	0.800	0.035	---	---	0.800	0.027
0.860	0.038	0.850	0.030	0.870	0.040	---	---	0.900	0.037
0.990	0.090	1.000	0.103	1.070	0.047	1.020	0.100	1.040	0.069
1.210	0.017	1.340	0.020	1.170	0.041	1.160	0.051	1.220	0.032
1.580	0.026	1.540	0.016	---	---	1.320	0.028	1.380	0.025
						1.560	0.027	1.640	0.032
1.980	0.023	---	---	1.880	0.029	2.080	0.042	---	---
2.540	0.033	2.320	0.036	---	---			2.500	0.051
---	---	2.800	0.029	2.970	0.013	2.780	0.039	---	---

Periodic terms of the differences of Orlov's mean latitudes

RMS = ±0".005		RMS = ±0".004		RMS = ±0".002	
---	---	---	---	1.710	0".011
---	---	---	---	2.140	0.014
2.630	0".014	2.730	0".020	2.860	0.010

P - Period (yrs); A - Amplitude (arc sec); RMS - root mean square error of amplitude.

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On the basis of the analysis of variations of mean latitudes as well as of their differences, the following conclusions can be drawn:

(1) The biggest variations of the mean latitude are in Belgrade, which is located in a seismically active region. The earthquakes occurring in this area and some of their properties are listed in Table 4. In Figure 1 we can see some correlation of the occurrences of the big earthquake in Skopje[16] and a few smaller ones (Nos. 2, 4 and 6 in Table 4) with decreases in the mean latitude of Belgrade. The earthquake nearest to Belgrade, No. 12, similarly coincides with a sudden change of the mean latitude curve, but also coincides with the introduction of thermal protection for the levels. The times of occurrence of the earthquakes are marked below the curves in Figure 1, and the times of instrumental or other changes which might affect the results are marked above the curves.

Table 4. Earthquakes in the vicinity of Belgrade

Nr	Data	ϕ_N	λ_E	h (km)	M	Location
0						Yugoslavia
1	1964.04.13	45°3	18°0	5	5.5	Yugoslavia
2	07.17	38.0	23.6	155	5.7	Greece
3	1965.03.09	39.3	23.8	18	5.7	Aegean Sea
4	03.31	38.4	22.3	45	6.3	Greece
5	04.09	35.1	24.3	39	5.9	Crete
6	07.06	38.4	22.4	18	5.8	Greece
7	1966.02.05	39.1	21.7	16	5.6	Greece
8	10.29	38.9	21.1	1	5.8	Greece
9	1967.02.09	39.9	20.3	1	5.6	Albania
10	03.04	39.2	24.6	60	6.0	Aegean Sea
11	05.01	39.6	21.3	34	5.5	Greece
12	11.30	41.4	20.4	21	5.9	Albania
13	1968.02.19	39.4	24.9	7	6.0	Aegean Sea
14	1969.07.08	37.5	20.3	0	5.5	Ionian Sea
15						
16	06.12	34.4	25.0	22	5.8	Crete
17	1970.04.08	38.3	22.6	23	5.8	Greece
18	1972.05.04	35.2	23.6	14	5.9	Crete
19	09.17	38.4	20.3	33	5.6	Greece
20	09.13	38.0	22.4	75	5.8	Greece
21	11.04	38.9	20.5	13	5.6	Greece
22	11.29	35.2	23.8	37	5.6	Crete

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In the years 1964-1966, 1968-1970, 1972 seismic activity in the region of the Belgrade meridian near the Mediterranean boundary of tectonic plates was greater and correlated with variations of the mean latitude of Belgrade as well as of differences of mean latitudes between Józefosław and Belgrade.

(2) Variations of mean latitude as well as of mean latitude differences of continental stations are much smaller (Józefosław, Pecny, Paris) than for stations located in the vicinity of sea coasts (Turku, Uccle, Hamburg). It is necessary to point out the large decrease of the mean latitude of Potsdam, which has not been explained.

(3) On the basis of existing data it is difficult to explain sudden changes of mean latitudes such as in Turku in 1972, in Uccle in 1965 and in 1972, in Hamburg in 1972, in Kitab in 1966. Turku is located in the region of a large vertical motion of the Baltic sea coast, so it can be regarded as an unstable region. Kitab is located in the region of a strong refractional anomaly.

The study of influences of local geophysical and meteorological phenomena needs additional gravimetric and meteorological observations at considered stations.

(4) The spectrally filtered latitude curves show some additional details of mean latitude variations, especially in Turku, which are smoothed by Orlov's filter. Spectrally filtered latitude curves give information about mean latitude variations for all periods considered without the 1.5 or 3 year delay needed for the Orlov or BIH filter. It is important for further studies of mean latitude variations.

(5) The data considered, owing to the special choice of stations and the short period of observations, were not adequate for a study of the problem of plate tectonic motions.

Similar conclusions were reached by R. Galas in his study of mean latitude variations of stations located along a common meridian in America.[8]

Besides the investigations of mean latitude variations which were made on the basis of astronomical data at the station in Józefosław, investigations of variations in plumb line direction were undertaken by the use of gravimetric measurements. A few sets of measurements of the horizontal gradient of gravity of the meridian base of Józefosław station were made in the last year with Worden-Master and Sharpe gravimeters. The base contains three pairs of control points situated at a distance of ±14 km, ±6 km, and ±3 km from the station.

Changes of latitude of Józefosław caused by changes of gravity differences are computed by the following formula:

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$$\Delta\phi = 0''.525 \frac{\Lambda}{G} \delta\Delta g$$

where Λ, G are the Love numbers. The value of the coefficient was computed by the Veining Meinesz formula.

Results of these measurements are given in Table 5.

Table 5. Changes in local vertical

Period	$\Delta\phi$	rms error
June-November 1976	-0".0036	±0".0015
November 1976-March 1977	+0.0036	±0.0018
March-May 1977	-0.0048	±0.0012

These results show that variations of latitudes of order of 0".01 caused by variations of the deflection of the local vertical can be detected by this method. So, such gravimetric measurements made regularly with astronomical determinations of latitude at considered stations could be very useful in the study of latitude variations and of polar motion.

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