THE UKRAINIAN GEODYNAMICS SCHOOL OF ALEXANDER YA. ORLOV

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ABSTRACT. First of all a short review of the Orlov's biography is given. Afterwards some scientific achievements of A. Orlov in the field of geodynamics are discussed. Particular attention is paid on the definition of the "mean latitude" and the "mean pole of epoch" given by A. Orlov.

1. INTRODUCTION

At the end of the last century a new stage in the study of the Earth began - the planet is regarded as a complex dynamical system that responds to external as well as internal actions. It has become apparent that the observed latitude variations and tidal deformations of the Earth offer a means of determining general mechanical properties of our planet and testing its internal structure models. Alexander Yakovlevich Orlov (in Russian) or Olexander Yakovych Orlov (in Ukrainian) was among those scientists who were the first to realize this possibility *(Fedorov, 1980)*.

The life and scientific heritage of Alexander Orlov were described in several detailed papers *(Aksent'eva, 1961; Geodynamics and Astrometry (Collected Articles), Kyiv, 1980; Proceeding of the Orlov Conferences, 1980, 1986 and 1992)*. Here we remind some data from Orlov's biography (see Appendix 1) so that the reader may appraise the extent and diversity of his scientific work in which a priority trend can be easily seen - the study of the Earth as a planet by astronomical, geodetic, and geophysical techniques. This multiple approach in the Earth science was later called the global geodynamics.

The number of scientific papers written by Orlov (about 140) is not large because he was very scrupulous in publishing his investigations. Practically all his works are noted for novelty and original treatment of astronomical, seismological, and geophysical problems topical at that time. They provoked lively discussions, and above all they stimulated new theoretical and experimental investigations, including creation of new stations for the observations of latitude variations and terrestrial tides. The ideas propounded by Orlov were further elaborated by his pupils (N. Stoyko, J. Vitkovsky, Z. Aksent'eva, N. Popov, E. Fedorov, and others). Many of these ideas are still currently essential and we shall attempt to illustrate this by the examples of some problems in the latitude variability and the motion of the Earth's poles.

2. DEFINITION OF THE "MEAN LATITUDE" AND THE "MEAN POLE OF EPOCH"

When Orlov began to study the latitude variations and the motion of the Earth's poles, he had already much experience of the application of harmonic analysis to the investigation of terrestrial tides. That is why he distinguished three different notions :

initial latitude,	an arbitrary value of latitude subtracted from all the observed values of latitude;
arithmetic mean latitude,	the arithmetic mean of the values of latitude observed over a given time interval;
mean latitude for a given moment,	the mean latitude for a given moment equal to its value which it would have if there were no periodic variations of latitude.

In one of his first studies on latitude variation *(A.Orloff, 1925)* Orlov proposed a simple formula for calculating the mean latitude for the moment T = t +7.5 :

$$\psi_m = 1/20 \sum_{t=0}^{4} (\varphi_t + \varphi_{t+5} + \varphi_{t+6} + \varphi_{t+11}) , \qquad (1)$$

where the time t is expressed in units of one-tenth of a year. He noted that *"the changes of ψ_m, if existing, depend only on the slow variation of latitude, because the annual, semiannual and fourteen months' terms fall out" (A.Orloff, 1925, p.8).*

Orlov was aware of the fact that the practical realization of the notion of "mean latitude" was a difficult task, since *"nous ne connaissons que d'une facon approchée les lois des variations de latitude" (A.Orlov, 1958, p.10).* He suggested, nevertheless, that *"nous puissions les exprimer avec une précision suffisante en vue de déterminer la latitude moyenne par la somme de deux composantes harmoniques de période d'une année et de 1.2 année, du moins pour les intervalles de peu d'étendue, inférieurs par exemple à une année et demi" (A.Orlov, 1958, p.10).* The definition given by Orlov for the mean latitude was widely discussed, and several expressions (filters), more cumbersome as compared to formula (1), were proposed for the determination of the mean latitude; they were intended to take a better account of some peculiarities of 1.2 year variations and the presence the other oscillations in the spectrum of latitude variations *(see P.Melchior, 1957; V.I.Sakharov, 1957).*

As noted by E.Fedorov, *"it was not the definition of mean latitude that was discussed but the procedure proposed by A.Ya. Orlov for its determination" (E.P.Fedorov, 1980, p.15).* Nevertheless this procedure proved in action to be the most convenient and sufficiently elaborate. It was widely used in the work of the Soviet Latitude Service and some other centers where latitude observations were analyzed, the BIH in particular. Orlov believed that *"on voit donc que le Bureau Central néglige les variations continues des latitudes moyennes des stations internationales" (A.Orlov, 1958, p.13)* and referred its results to various origins of coordinates rather than to the "mean pole of epoch".

By analogy with the definition of the mean latitude, Orlov identified the "mean pole" at a given moment with *"la position que le pôle occuperait a un moment donné si ses variations périodiques n'existaient pas".* Orlov was aware that this definition of the "mean pole" is valid only in the event that the secular motion of the pole is negligible.

3. ON SLOW VARIATIONS IN LATITUDE AND THE SECULAR MOTION OF THE POLE

Orlov attached particular significance to investigations of the nature of the slow variations in latitude (ψ) discovered by him. He attempted several times to find some regularities in these variations, among them a 4-year wave *(A.Orlov, 1925)* and the secular motion of the pole. He had no doubt that the secular motion of the pole does exist, as various probable geological and geophysical processes *"doivent changer la position des axes d'inertie du Globe et provoquer un déplacement de son axe de rotation" (A.Orlov, 1958, p.14).*

Orlov put forward two explanations for the fact that this motion had not been reliably detected: *"ces déplacements séculaires des pôles, très faibles, sans aucun doute, sont masqués par les variations importantes de latitude d'origine non-polaire. D'autre part, et c'est probable à mon avis, les observations de latitude sont organisées de telle manière qu'elles ne procurent pas de données irréprochables pour l'étude des variations séculaires de latitude" (A.Orlov, 1958, p.14).*

Orlov interpreted the differences between latitude variations for observatories lying at close longitudes (Pulkovo and Carloforte, Cincinnati and Ukiah) to be the most convincing proof of the first factor, namely, the existence of large non-polar variations in mean latitudes. He calculated the differences between the mean latitudes of the Gaithersburg and Cincinnati stations and the sum of the mean latitudes of the Tschardjui and Ukiah stations, which are free of the pole motion effect. The results (Appendix 2) allowed him to conclude that *"les variations lentes de latitude enregistrées partout ont une origine non-polaire et il faut les éliminer* ***avant de déterminer les coordonnées du pôle****" (A.Orlov, 1958, p.15).* We marked out the words ***"avant de déterminer les coordonnées du pôle"*** to stress once more, following Orlov, that *"on ne peut pas affirmer, néanmoins, que parmi les variations lentes de latitude il n'y ait pas de composante due au mouvement du pôle" (A.Orlov, 1958, p.65).* To get a definitive answer to this question, *"il faut que trois stations de latitude soient établies en Amérique et autant en Asie, dont les longitudes par paire s'écarteraient le moins possible de 180°" (A.Orlov, 1958, p.67).*

At present opinions differ as to the secular motion of the pole. Some scientists hold that this motion does really exist and occurs with a velocity of about 4 mas/yr in a direction of 60-70° W. Others ascribe this result to large non-polar variations in the mean latitudes of observatories, Ukiah in particular. All thought it necessary to take into account inaccuracies in the systems of declinations and proper motions of stars when the secular and long-period motions of the pole were determined. That is why the results of reduction of time and latitude observation series in the HIPPARCOS system were expected with great interest. The results obtained by the Working Group headed by J.Vondrak were recently published, they confirmed the existence of a secular motion of the pole with a velocity of 3.39 mas/yr in a direction of 78.5° W *(J.Vondrak et al., 1998).* However, close inspection of Table 11 from that study casts doubts on the certainty of this result. There is a large scatter of linear trends in the latitude for different instruments of the same observatory or for different observatories with close longitudes (See Appendix 2). And here we want to cite Orlov once more: *"même si l'on pouvait établir l'unité du système des déclinaisons des étoiles, les changements inévitables et très considérables de la valeur du pas de vis micrométrique présenteraient une difficulté nouvelle, et peut être insurmontable, pour rattacher entre elles des séries d'observations anciennes"(A.Orlov, 1958, p.14)* and, therefore, for a reliable determination of the secular motion of the pole. The author of this paper, who belongs to Orlov's school of geodynamics, believes that we still have no definite answer to the question of the magnitude and direction of the secular motion of the pole.

4. THE CHANDLER MOTION OF THE POLE

The investigations of the Chandler motion of the pole made by Orlov in 1924-1925 were intended to find out whether its period is constant and whether there are other oscillations in the frequency band considered *(A.Ya.Orlov, 1924; A.Ya.Orlov, 1925).* The investigations were prompted by Chandler's assumption that there is a fifteen-month wave in addition to a fourteen-month wave in the pole motion. Having thoroughly studied latitude variations for some observatories, Orlov draws the conclusion: *"this suggestion of the great American astronomer seems to be confirmed, and it is to be hoped that observations of the next years will definitely show to what extent the variability of this period may be due to the interference" (Orlov A., 1925, p.30).*

Subsequently, Orlov wrote that the apparent variation of the Chandler period is caused by the fact that *"free oscillations of the Earth's axis of rotation combined with is forced annual motion... there is some evidence that terms with other periods may be present in the motion of the pole. Nevertheless, this period depends on the physical properties of the Earth only, and these properties are unlikely to have changed over the short age of the human science; therefore this period should be regarded as constant" (A.Ya. Orlov, 1961).*

Orlov was constantly concerned with the contradiction between the theoretical prediction and observation results. He returns time and again to the analysis of latitude observations, which seemed to confirm that *"the period T does not remain constant but grows with amplitude" (A.Orlov,1958, p.342).*

However, Orlov inferred that *"the values of T found from observations differ from one another only due to various impulses and disturbances ..." (A.Orlov, 1958, p.345).* In other words, in the language used today, he reasoned that the excitation of the Chandler motion of the pole is a nonstationary process and the determination of its true period is a difficult task. This topical problem still remains unsolved inspite of numerous studies dedicated to it (e.g., see review in *Ya.Yatskiv, 1996).*

REFERENCES

Z.N.Aksent'eva (1961), "Life and creative work of A.Ya.Orlov (1880-1954)", in: Selected Works of A.Ya.Orlov (in Russian), Izd. AN UkrSSR, Kyiv, vol.1, pp.7-37

Geodynamics and Astrometry, Collected Articles Dedicated to the 100th Anniversary of A.Ya.Orlov's Birthday (in Russian), Naukova Dumka, Kyiv, 1980, 166 p.

Study of the Earth as a Planet by Astronomical, Geodetic, and Geophysical Techniques, Proceedings of the I, II, and III Orlov Conferences (in Russian), Kyiv, 1982,1988,1994.

A.Ya.Orlov (1924), "On O.A.Baklund's formula for the Chandler period",Circular Odessa, *Astron. Obs.*, No.9, pp.1-2.

A.Ya.Orlov (1958), Latitude Service (in Russian and French), Izd. AN SSSR, Moscow, 126 p.

A.Ya.Orlov (1961), Selected Works in 3 Volumes, Izd-vo AN UkrSSR, Kyiv.

V.I.Sakharov (1957), "On the advantages of A.Ya.Orlov's formula for the determination of mean latitudes". In: Proceedings of the XII Astrometric Conference of the USSR (in Russian), Izd. AN SSSR, Leningrad, pp. 314-320.

E.P.Fedorov (1980), "A.Ya.Orlov: life, creative work, and scientific heritage", in: Geodynamics and Astrometry (in Russian), Naukova Dumka, Kyiv. pp.7-24.

Melchior P. (1957), "Sur la fluctuation des latitudes moyennes des stations du service des latitudes et la methode d'Orlov", *Bull. Geod.* **46**, p.22-27.

Orloff A. (1925), "Harmonic Analysis of the Latitude observations, I. Kazan, Carloforte, Greenwich". Odessa Astronomical Observatory, Gublit, Odessa, 31 .

Yatskiv Ya.S. (1996), "On the excitation of the Chandler wobble", *Artificial Satellites*, Warszawa, No 28, p. 191-199.

Appendix 1 : BRIEF C.V.OF A.ORLOV

6 April 1880	Born in Smolensk.
1898	Left a gymnasia in Voronezh and entered the physical and mathematical faculty of the St. Petersburg University.
1902	Graduated from the St. Petersburg University.
1903-1905	Sent abroad to prepare for professorship. Studied astronomy and mathematics in Paris, celestial mechanics in Lund, and seismology in Gottingen.
1905	The first scientific paper "On the determination of corrections to the elements of planetary and cometary orbits" published in "Proceedings of the Russian Astronomical Society".
1905-1906	Worked at the Astronomical Observatory of the Yur'ev (Tartu) University.
1907-1908	Worked at the Pulkovo Astronomical Observatory - observations with a zenith telescope.
1908-1912	Returned to the Yur'ev Observatory - head of the Yur'ev Seismic Station (from 1909), Teaching and first studees on the tidal deformations of the Earth (1910).
1910	Defended his Master Thesis "The First Series of Observations of Deformations of the Earth Under the Effect of Lunar Attraction Made with Horizontal Pendulums in Yur'ev".
1911	Paper on the observations of terrestrial tides at the International Seismological Congress.
1911-1912	Organized a station for observations of tidal variations of gravity in Tomsk.
1912	Visited the Yerkes Observatory with the aim to study plates with comet images.
1912	Took part in a gravimetric expedition to the Western Siberia.
December 1912	Appointed an extraordinary professor of the Novorossiyskiy (Odessa) University (ordinary professor from 1915) and Director of the Odessa Astronomical Observatory.
1912-1934	Director of the Odessa Astronomical Observatory.
1915	Defended his Doctor Thesis "Results of the Yur'ev, Tomsk, and Potsdam Observations of Luni-Solar Deformations of the Earth" in the St. Petersburg University.
1923-1924	First studies on latitude variations and motion of the pole, published in the Odessa Observatory Circulars.
1924	Took part in choosing the site for the Irkutsk Latitude Station and in the organization of latitude observations there.
1924	Proposed to create a gravimetric observatory in Poltava (created in 1926).
1924-1934	Headed the organization and operation of the Poltava Gravimetric Observatory.
1925	Introduced a new definition for the mean latitude and made a harmonic analysis of latitude variations in Kazan, Carloforte, and Greenwich.
1926	Organized a gravimetric survey of Ukraine.
1927	Elected a corresponding member of the Academy of Sciences of the USSR.
1932	Gave a lecture at the All-Union Astrometric Conference in Pulkovo: "Project of Latitude Service on Parallel 49°36'"; the project called for the organization of two more stations, in Blagoveshchensk (USSR) and Winnipeg (Canada), on the Poltava parallel.
1934-1938	Worked an the Shternberg State Astronomical Institute.
1938-1951	Headed the Poltava Gravimetric Observatory (it was evacuated to Irkutsk during World War II).
1939	Elected the member (academician) of the Academy of Sciences of Ukraine.
1941	Went to the Far East to organize the Far-East Latitude Station (Subsequently the Blagoveshchensk Latitude Station organized by his son B.A.Orlov).
1944-1948	Directed the organization of the Main Astronomical Observatory of the Academy of Sciences of Ukraine (MAO AS UkrSSR).
1948	Proposed a new definition for the mean pole of epoch (VII General Assembly of the IAU, Zurich).
1951-1952	Directed MAO AS UkrSSR.
1952	The X Astronomical Conference of the USSR approved the plan of creating the Soviet Latitude Service prepared by A.Orlov.
1952-1961	In the Poltava Gravimetric Observatory the coordinates of the Earth pole were calculated in the Orlov's system.
28 January 1954	A.Ya.Orlov died in Kyiv.
1958	The book "Latitude Service" by A.Ya.Orlov was published.
1961	"Selected Works of A.Ya.Orlov" in 3 volumes were published by the Publishing House of AS UkrSSR in Kyiv.

Appendix 2 : SLOW VARIATIONS OF LATITUDE

1. Slow variations of mean latitudes of ILS stations (*A.Orlov, 1958, p.280).*

Table 4. Differences and Sums of Mean Latitudes of ILS Stations (in units of 0.01")

Date	G-Ci	T+U
1901.0	-4.9	+2.0
1901.5	-0.5	-0.2
1902.0	+0.7	-3.8
1902.5	-1.8	-4.3
1903.0	-4.3	-1.3
1903.5	-6.2	+1.8
1904.0	-8.5	+3.3
1904.5	-8.1	+3.6
1905.0	-3.9	+2.4

(G : *Gaithersburg*, Ci : *Cincinnati*, T : *Tschardjui*, U : *Ukiah*)

2. Linear trends in the latitudes of some instruments and observatories (in units mas/cy) (from Table 11, *J.Vondrak.et al., 1998).*

a) Mizusawa

Code	A1
MZZ	172
MZL	216
MZP	-491
MZQ	-496

b) Washington

Code	A1
WA	540
W	-624
WGQ	-287

c) Grasse-Carloforte

Code	A1
CA	130
GRD	-764

d) Shanghai-Shaanxi

Code	A1
ZIA	434
ZIB	183
SXA	369
SXB	1834