

The 100th anniversary of the Poltava Gravimetric Observatory: from subtle Earth tides to seismic-tidal technology

V.P. Shliakhovyi, R.V. Shyian, 2026

Poltava Gravimetric Observatory of S. Subbotin Institute
of Geophysics of National Academy of Sciences of Ukraine, Poltava, Ukraine

Received 22 April 2026

The study of solid Earth tides is a fundamental method for investigating Earth's internal structure, enabling analysis of geodynamic processes in the lithosphere, mantle, core, and atmosphere. Over a century of advancements in tidal observation techniques has brought forth the development of equipment characterized by ultra-high resolution and sensitivity. Modern instrumental observations are also used to monitor the geodynamic state of the environment, including its local and regional geostructures. They play a significant role in monitoring deformation regimes and assessing the structural stability of critical geotechnical infrastructure.

Experimental and theoretical investigations of Earth tide phenomena have been a primary research focus of the Poltava Gravimetric Observatory of the IGPH NASU since its inception in 1926. The research program encompasses astronomical, tiltmetric, gravimetric, and extensometric observations. Studies conducted in the first half of the 20th century not only successfully confirmed Earth tides as a real geophysical phenomenon but also established them as a fundamental source of scientific information regarding the Earth's structure and internal processes. Between 1960 and 1990, the deployment of advanced equipment facilitated tidal studies at more than 40 stations in Ukraine, yielding extensive datasets for geodynamic analysis. Throughout its century-long history, the Poltava Gravimetric Observatory has made substantial contributions to the field of Earth tide research and the advancement of related technologies. This includes integrating Earth-tidal and seismic methods, which can serve not only fundamental research but also address critical practical challenges, such as monitoring the geological environment and the stability of mine workings and bridge structures, and investigating caving processes in mines.

Key words: gravimeter, gravitation, Earth tide, earthquake, seismicity, tiltmeter, technology.

Introduction. Understanding Earth's internal structure and the physical processes associated with it is fundamental to both theoretical research and geoscientific applications. However, nearly all information about our planet's interior has been obtained through indirect methods and modeling, as the Earth's depths are inaccessible under extreme pressures and temperatures. Human exploration has never exceeded depths of 15 km, and it is unlikely that direct study of the first hundred

kilometers of the Earth's interior will be feasible in the coming centuries. Consequently, all available geophysical fields and methodologies are employed to obtain such data. In this regard, the investigation of Earth tides, integrated with studies of other geophysical fields, serves as an important and effective means of probing Earth's internal structure. Currently, such observations are conducted across all continents, including Antarctica [Iwano et al., 2005], with tidal elasticity pa-

Citation: Shliakhovyi, V.P., & Shyian, R.V. (2026). The 100th anniversary of the Poltava Gravimetric Observatory: from subtle Earth tides to seismic-tidal technology. *Geofizychnyi Zhurnal*, 48(3), 65–76. <https://doi.org/10.24028/gj.v48i3.358436>.

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rameters determined at numerous stations worldwide [Boy et al., 2020]. Research integrates tiltmetric, gravimetric, and extensometric (strain) measurements alongside cutting-edge technologies such as very-long-baseline interferometry and global navigation satellite systems [Braitenberg et al., 2018]. Furthermore, advanced theoretical and analytical frameworks, computerized data processing, and sophisticated interpretation methods are continuously being developed and refined through both theoretical and experimental efforts.

The study of Earth tide variations in the gravitational field, both in magnitude and direction, as well as the resulting surface deformations, is a well-established field of geophysics with over a century of history [Melchior, 1966]. As early as 1687, Isaac Newton established that oceanic and sea tides, as well as potential tides within the solid Earth, are caused by the gravitational influence of celestial bodies, primarily the Moon and the Sun. However, while marine tides have been known since antiquity, tides within the solid Earth were only detected in the early 20th century as nearly imperceptible quasi-periodic signals recorded by horizontal pendulum tiltmeters. These instruments, based on the Hengler-Zöllner suspension, remained the primary tools for Earth-tidal research for over half a century. It was not until the second half of the 20th century that the Earth-tidal phenomena began to be recorded using high-quality instruments of a new generation. This progress was made possible by the development of precise and highly sensitive designs (tiltmeters, gravimeters, and extensometers), alongside improvements in observation techniques and technology. Currently, the accuracy in determining the parameters of major tidal waves has reached several thousandths of a percent, compared to 10 % in the 1920s—1940s. The scientific and technical research conducted at the Poltava Gravimetric Observatory (PGO) of the Institute of Geophysics of the National Academy of Sciences of Ukraine has made a significant contribution to achieving these advancements.

Earth tide and crustal tilt research at the Poltava Gravimetric Observatory. PGO was founded in 1926 on the initiative of Alexandr Ya. Orlov, a prominent scientist in the fields of geodesy, geophysics, seismology, and astronomy. Since its inception, the observatory's primary research focuses have been the investigation of Earth tides and the study of the Earth's rotational motion [Orlov, 1950]. Additionally, the PGO was tasked with addressing applied challenges, including gravimetric surveys of Ukraine's territory for mineral exploration, as well as fundamental and applied astronomical-geodetic and geophysical problems in the study of the Earth as a planet and its regional geophysical characteristics [Orlov, 1961a,b]. During its first decade, the small team of the observatory established a fundamental gravimetric point at the PGO and created gravimetric links between Poltava, Potsdam, and other key sites across the Soviet Union. They also compiled the first gravimetric map of Ukraine, which played a crucial role in the exploration of the region's mineral resources. To achieve this, A.Ya. Orlov developed a method for area-based gravity surveys that earned high acclaim from geophysicists.

Additionally, research on the Earth's rotation was initiated through observations of the bright zenith stars α Persei and η Ursae Majoris, which culminate at the zenith of Poltava's latitude. Consequently, the observatory served as the primary center for the study of polar motion for many years. In July 1927, construction was completed on a tilt station designed for prospective Earth tide research at the PGO. The facility was equipped with two Repsold-Levitsky horizontal pendulums featuring Zöllner suspensions on metal filaments, along with unique auxiliary equipment for the reliable registration of tilts on photographic paper (and later, photographic plates) [Aksent'eva et al., 1970]. This installation marked the first station of its type. Notably, due to modernizations by G.V. Levitsky and A.Ya. Orlov, this specific model of horizontal pendulum remained the primary and most dependable instrument for high-precision (at that time) Earth tide observations for

over fifty years [Matveev, 1980]. Following trial tilt observations in 1930, the observatory initiated systematic studies of Earth tides and slow crustal tilts. These research efforts were interrupted by the outbreak of World War II in 1941 and were subsequently resumed in 1948.

To analyze the tilt observations conducted from 1930 to 1941, A.Ya. Orlov applied an enhanced harmonic analysis method along with computational techniques for processing lunar geophysical phenomena using early calculating-analytical machines. The elastic tidal parameters were determined with an accuracy of approximately 10 %, leading to several key scientific conclusions. The tilt observation data revealed that, in addition to the global Earth tides, there are local distortions in the tidal deformations of the Earth's crust. It was found that the amplitude and phase parameters of tidal deformation γ and $\Delta\phi$ can vary significantly across different locations. Recall that the amplitude factor (γ) represents the ratio between the observed tidal wave amplitude and the theoretical value for a perfectly rigid Earth, characterizing the planet's elastic response. The phase shift ($\Delta\phi$) reflects the time delay in this response, caused by the Earth's internal viscosity and local environmental influences. Consequently, observations from a single station are insufficient to represent Earth's global elastic deformations. By comparing tidal data from various points, particularly those far from the ocean, Orlov concluded that local structural features of the surrounding territories and hydrometeorological conditions substantially influence both tidal and non-tidal crustal deformations. He further suggested that such methods could be utilized to address specific applied problems in geophysics.

Between 1948 and 1952, a second series of tilt observations was conducted at the PGO using the same methodology and at the same location. The results showed strong agreement with the previous 11-year data set, confirming that the elastic parameters γ and $\Delta\phi$ vary across different geographical locations due to their specific geophysical nature. It was concluded that the underlying causes of these variations required further investiga-

tion [Matveev, 1966]. To clarify the nature of these anomalies, the tiltmeter network was subsequently expanded, reaching ten stations by 1967. These observation points were established in various regions of Ukraine with diverse geological structures, including the Donbas, Kryvyi Rih, the Carpathians, and Crimea. The instruments were installed in deep mines and caves suitable for this type of tiltmeter. Due to the absence of significant meteorological disturbances, the quality of the recordings was remarkably high, even though the tidal curve amplitude and its trace width (affected by microseisms and noise) were limited to only a few millimeters.

Following the first International Geophysical Year (1957), research on the Earth tides intensified significantly at the PGO. Studies across Ukraine were organized along two mutually perpendicular profiles. The first, Sumy-Kherson (P.S. Matveev, 1960—1987), intersected the Dnieper-Donets Rift [Matveev et al., 1977a], while the second, Kyiv-Artemivsk (Bakhmut) (V.G. Balenko, 1964—1980), traversed the central part of the Dnieper-Donets Rift [Balenko, 1980]. The primary objective of this unique geophysical experiment was to obtain reliable data on the influence of deep tectonic faults on the Earth tides and to derive regional and global tidal wave parameters. Furthermore, the study aimed to evaluate the impact of the Earth's internal composition and physical properties. The concept and implementation of these observations were highly original, marking a crucial milestone in the evolution of Earth tide research and the advancement of tilt observation methodologies. The high quality of this work was facilitated by the development of sensitive, remotely controlled tiltmeters by A.E. Ostrovsky at the Institute of Physics of the Earth (IPE), their small-scale production, and the observation technology for deep pits developed by P.S. Matveev at the PGO [Matveev, 1970]. The quality and resolution of the tidal records improved significantly, with Earth tide measurements achieving percentage-level accuracy. Tidal variations began to be recorded with centimeter-scale amplitudes, and the simplification of research methodologies further

enhanced measurement precision, enabling the detection of various anomalies within the records. As a result, the PGO organized and conducted tilt observations not only along the previously mentioned profiles but also in other geotectonically diverse regions of Ukraine. A portion of this work was commissioned by industrial enterprises, such as the Ministry of Coal Industry of Ukraine. In cases involving ambiguous or particularly significant data, observations were repeated at specific intervals. For instance, when investigating the influence of caverns and collapse zones in Soledar or assessing explosion hazards in the Donbas coal mines, studies were carried out at multiple points within the chambers under investigation. The research regions for the two profiles are illustrated on a map of Ukraine, showing nearly all tidal stations (Fig. 1). Elastic tidal parameters were obtained with an accuracy of 1 % [Kutnyi et al., 2015].

Following the 1977 Vrancea earthquake, the PGO joined efforts to address the challenge of earthquake forecasting by integrating Earth tide observations with other geodynamic studies in seismically hazardous regions of Ukraine. Ukraine possesses two primary seismogenic regions, the Carpathians and Crimea, and is adjacent to the Vrancea seismic zone in Romania, located southwest of the Odesa region. Over the last decade, the Poltava region has also experienced seismic activity, with approximately twenty earthquakes recorded [Shliakhovyi et al., 2025]. Between 1980 and 1993, geodynamic tilt measurement sites were established, and systematic observations were organized in Alushta, Yalta, Sevastopol, and Feodosia (Crimea), as well as Chisinau (Moldova) and Berehove (Transcarpathians). Observations conducted along research profiles, under contract-based projects, and within the earthquake forecast-

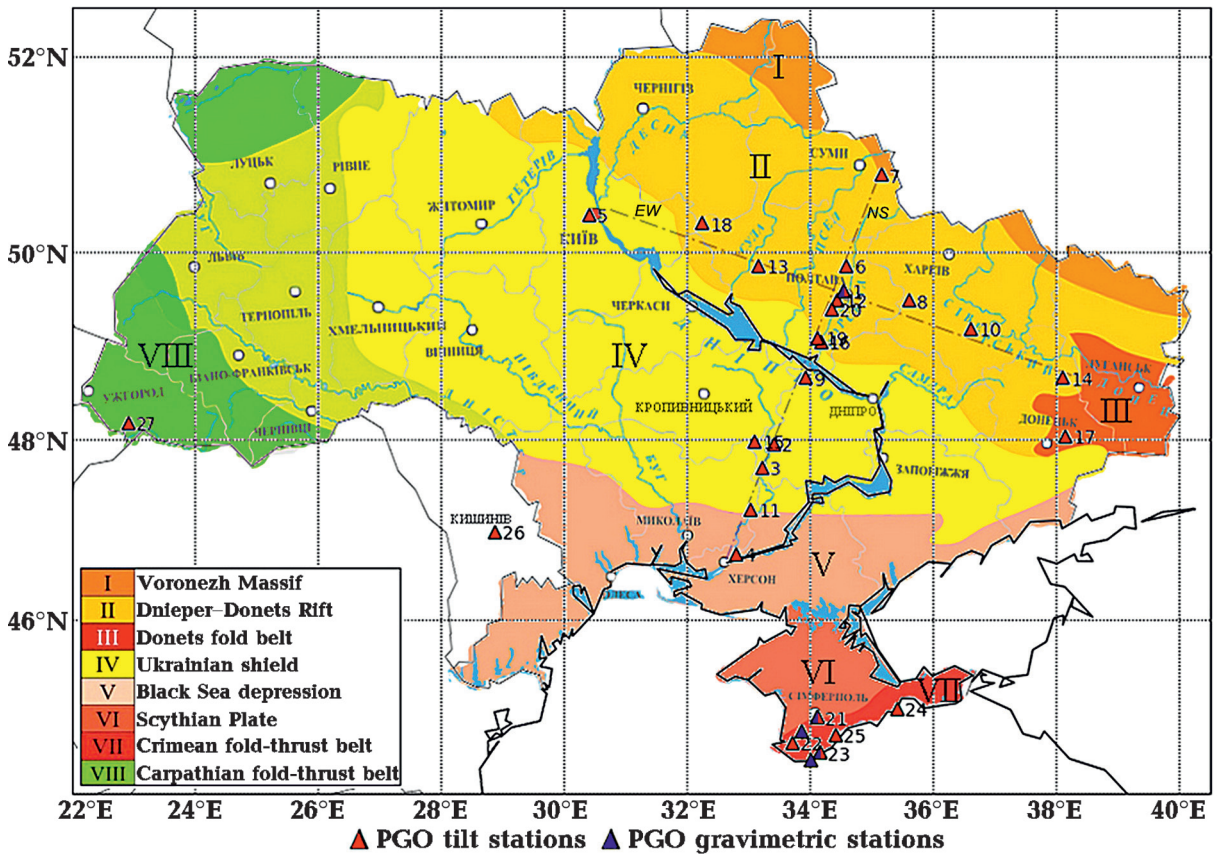


Fig. 1. PGO tiltmeter and gravimetric stations on the tectonic map of Ukraine. Profiles: NS (Sumy—Kherson, 1960—1987); EW (Kyiv—Bakhmut, 1964—1980).

ing program provided data on the behavior of elastic tidal parameters and non-tidal crustal tilts at over 40 sites across Ukraine. These data were utilized to determine the average values of the parameters γ and $\Delta\varphi$ for the main Earth tide waves, which characterize the elastic tidal deformations of the Earth in the observed regions.

During the 20th century, Earth tide observations and research conducted across several dozen tiltmeter stations (more than 40) yielded analog photographic records that captured not only Earth tides but also high-quality data on contemporary crustal movements. These records documented jump-like and other geodeformational phenomena, including hydrodynamic processes associated with borehole pumping. Key achievements from this period include the refinement of tiltmeter observation techniques (specifically within shafts) and the development of novel instrumental and methodological tools for studying crustal geodynamics. These advancements spurred the application of Earth-tidal instruments to various practical tasks; several examples are provided below. Furthermore, it should be noted that earthquake forecasting remains a fundamental yet highly practical challenge. As demonstrated in [Shliakhovyi, 1985], addressing this critical task is impossible without the implementation of seismic-tidal technologies and their integration into a network of high-precision geodynamic monitoring stations.

Investigations of gravitational and deformational tidal phenomena. Direct Earth tides manifest as variations in gravity, tilts, deformations, and surface displacements. Additionally, indirect tides occur within the Earth's body due to deformations caused by oceanic and atmospheric tides. Furthermore, «induced tides» arise within non-mechanical geophysical fields (such as magnetic, electric, thermal, and radiogenic fields) due to tidal deformations. While the first and second types of tides can be calculated with high precision, the third type has not yet been quantified and is currently studied only occasionally. For nearly 50 years, tilt measurements remained the sole method for studying

Earth tides. However, in the second half of the 20th century, it became possible to investigate tidal variations in gravity and tidal deformation phenomena. These research directions were developed intensively in Europe, the USA, Japan, and the USSR. The PGO also organized tidal-gravimetric (I.A. Dychko, 1955—1964) and deformometric (V.G. Bulatsen, 1968—1973) studies, which continue intermittently to this day. Tidal gravity variations were investigated in greatest detail by P.S. Korba (1964—1970), V.G. Balenko (1972—1996), and V.P. Shlyakhovyi (1976—1979; 1999—2022) [Aksent'eva et al., 2002]. Through gravimetric research at the PGO, the elastic parameters δ and $\Delta\varphi$ of the Earth tides were reliably determined for five sites in Ukraine (Bakhchysarai, Yalta, Simeiz, and Simferopol in Crimea, and Poltava). The gravimetric amplitude factor (δ) and the phase lag ($\Delta\varphi$) characterize the Earth's tidal response, providing essential insights into the planet's internal structure and elasticity. After introducing the necessary corrections (for marine, oceanic, and atmospheric tides, nutation, ellipticity, etc.), the Earth tide elastic parameters δ and $\Delta\varphi$ for semidiurnal waves become practically identical across all sites with an accuracy of 0.005 %. This indicates a relatively high degree of mechanical homogeneity in the Earth's interior beneath Ukraine. For the principal tidal wave M_2 , the amplitude parameter is $\delta(M_2)=1.15486\pm 0.00003$ (0.003 %) and the phase lag is $\Delta\varphi(M_2)=-0.096^\circ\pm 0.038$. These tidal parameter values correspond to the elasticity of steel (the amplitude), and to minor dissipation of elastic energy within the deep Earth's interior (the phase lag).

Between 1999 and 2005, a comprehensive capital repair and modernization of the gravimeters and registration systems were carried out, including the implementation of digital recording with 24-bit analog-to-digital converters [Shliakhovyi, 2007]. This upgrade enables high-resolution study not only of Earth tides but also of anomalies of various origins, as well as the Earth's free oscillations and other low-frequency seismic signals. Since 2005, unique gravimetric records have been obtained for nearly all great earthquakes

($M > 8.3$). Analysis of these records has revealed numerous phenomena of significant geophysical importance. The capabilities of the gravimeter and tiltmeter as a combined system for broadband recording of tidal and seismic signals within the range of the Earth's free oscillations are demonstrated in Figs. 2 and 3. High-precision broadband digital recording of powerful earthquakes using self-compensating seismic tiltmeters was established at the PGO during 1999–2001.

To investigate linear tidal deformations, an adit was constructed at a depth of 3 meters, housing a 6-meter quartz rod strainmeter. Additionally, a two-component linear extensom-

eter with arm lengths of approximately 12 and 7 meters was built in an abandoned limestone mine gallery in Crimea. In 1969, regular observations of the Earth's tidal deformations commenced (V.G. Bulatsen, 1969–1973). Based on these data, the Love and Shida numbers (h, k, l) were reliably determined for the study region. At the end of 1973, the station ceased operations as the mine was transferred to the USSR Navy. Since 2001, high-precision strainmetric and tiltmetric studies have been resumed in collaboration with the PGO at the underground geodynamic laboratory of the Taurida National University (TNU, Crimea) in Khersones. The primary instruments employed here were a differential laser strainmeter (O.V. Baborykina, TNU) and a precision self-compensating tiltmeter (V.P. Shliakhovyi, PGO). These efforts were conducted jointly by the Ukrainian State Geological Research Institute (V. Tregubenko, UkrSGRI, Kyiv), TNU, and the PGO. These operations were also discontinued in 2013 due to military reasons. Over nearly 13 years, series of observations were obtained covering tidal deformations, tilts, and other global and local geodynamic phenomena. The analysis of these data

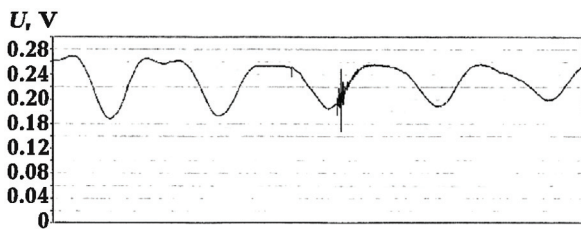


Fig. 2. A six-day tidal record obtained by the gravimeter after low-pass filtering, where a powerful earthquake is clearly visible (Tonga region, $M=7.9$, May 3, 2006, 15:26:40 UT).

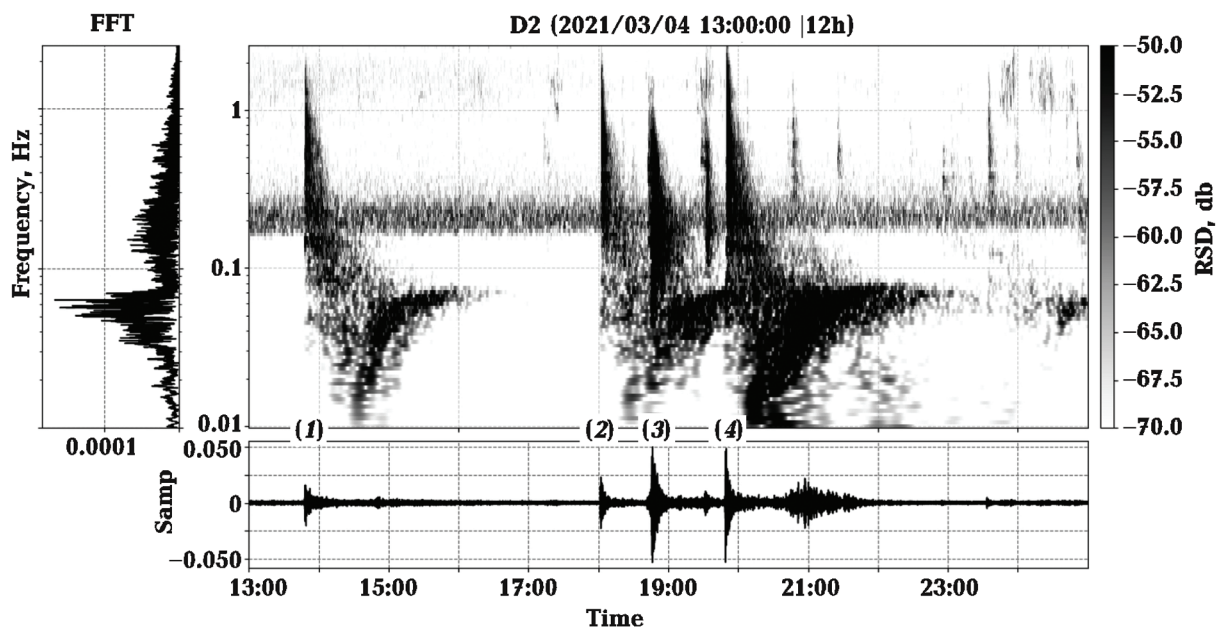


Fig. 3. Seismic tiltmeter record and the corresponding spectrogram. The 12-hour time series capture several powerful earthquakes of March 4, 2021: 1, 2, 4 — Kermadec Islands region ($M=7.3, 7.4, 8.1$); 3 — Greece region ($M=5.8$). The wide-band tiltmeter is suitable for recording both Earth tides and earthquakes.

is ongoing. Notably, parallel recordings of both slow processes and seismic-type events (earthquakes, etc.) were obtained across a wide frequency range. The PGO has made a significant contribution to the development of methods for processing and analyzing Earth tide records and other geophysical data. The key researchers in this field include A.Ya. Orlov, Z.N. Aksentyeva, P.S. Matveev, and B.S. Dubik [Matveev, 1980] and others. Theoretical problems of Earth tides were addressed by the aforementioned researchers, as well as by L. Khasilev. Several of their scientific results remain in use to this day. All Earth tide research at the PGO has been conducted in light of the theoretical and experimental studies performed in Western Europe, Japan, and other countries, as well as in close collaboration with geophysicists from the IPE. The work of R. Tomaschek, R. Lecolazet, J. Harrison, and H. Wenzel significantly influenced these efforts, and the monographs of P. Melchior serve as essential reference works at the PGO [Melchior, 1978].

Development and application of Earth-tidal technologies. The fundamental and applied significance of Earth tide research was already clear to A.Ya. Orlov during the establishment of the PGO. The study of subtle geophysical phenomena, particularly tides, necessitated the development of high-sensitivity instruments, as well as a reliable and effective methodology for experimental design, including advanced recording, processing, and analytical techniques. It can now be concluded that these investigations and systematic efforts ultimately resulted in the creation of a specialized experimental technology. As previously noted, Earth tides primarily manifest as variations in gravity, tilts, and deformations. Modern technological advancements have enabled the development of high-precision instruments for Earth tide research, some of which are less susceptible to local deformational noise. These include superconducting gravimeters, long-base extensometers, and very-long-baseline interferometry. Currently, these sophisticated and costly methods are employed to study global tidal phenomena with exceptional accuracy.

Consequently, the perceived relevance of tiltmeter research has diminished. However, tiltmeters are significantly more cost-effective than the aforementioned systems and possess a unique, highly valuable characteristic: tilt measurements are extremely sensitive to local environmental features and shifts in the deformation regime near the observation site. While this sensitivity may be viewed as an undesirable distortion of the global Earth tide, it is an extremely useful property for practical applications. It is important to emphasize that the classification of signals as useful or noise is often arbitrary; therefore, this dual nature of geophysical signals must be carefully considered.

Tiltmeters have long been utilized to address various practical challenges. Since the mid-1960s, they have been most widely used, alongside strainmeters, to assess crustal displacements and deformations during the construction and operation of large-scale hydroelectric and similar structures. Such efforts were conducted near the dams and reservoirs of major hydroelectric power plants, including the Chirkey, Sayano-Shushenskaya, Toktogul, Zeya, Nurek, and Inguri stations, among other engineering-geological sites. The primary instruments employed were Ostrovsky-type tiltmeters with galvanometric recording. Their installation and maintenance were relatively complex, and the digitization, analysis, and interpretation of the observation data remained imperfect at the time. Nevertheless, valuable information was obtained regarding the geophysics of rock massifs and the structural stability of the investigated sites. These studies demonstrated the significant potential of tilt-and-deformation Earth-tidal methods in solving highly complex practical problems. Furthermore, these projects identified methodological shortcomings and outlined directions for the further development of such research.

In the late 1970s, the PGO developed an autocompensating tiltmeter based on a photoelectric design, with accuracy and dynamic range several orders of magnitude higher than existing models [Matveev et al., 1977b]. Its operational characteristics were

significantly improved: the device can be brought to a working state within minutes and can operate under high pulse interference. This paved the way for the automation of tilt measurements. The implementation of high-precision, high-speed ADCs, along with computerization and visualization, enabled real-time monitoring, a necessity proven in practice. It should be noted that the effective resolution of applied problems cannot be limited solely to the tilt (low-frequency) signal range, as seismic signals also carry vital information regarding the properties and state of the object. Consequently, the frequency range of the self-compensating tiltmeter was significantly expanded (from 0 to 20 Hz), marking a new stage in the advancement and practical application of Earth-tidal methods: the development of seismic-tidal technologies [Shljakhovyj et al., 2011]. Due to their low cost, compact dimensions, high mobility, precision, and wide dynamic and frequency ranges, self-compensating tiltmeters are currently the most promising instruments. They are widely accessible for both scientific research and applied tasks in the field of quasi-static and seismic deformation studies. Undoubtedly, tidal gravimeters and laser strainmeters will also find application in such work, provided their mobility and accessibility are improved. The effectiveness of these technologies has been demonstrated by studies of Earth tides and other geodynamic processes near the Vrancea zone (1983—1997), in Sevastopol (1999—2013), and in the Poltava region (1998—2019), as well as by research on the Dniester River bridge (1989—1991) regarding its seismic stability. Selected results of these investigations are provided below as illustrative examples.

Between 1983 and 1997, the PGO, in collaboration with geophysicists from Moldova (Institute of Geology and Geophysics), addressed the challenge of forecasting Vrancea earthquakes. These events pose a significant threat to Ukraine and Europe due to the high concentration of environmentally hazardous and seismically vulnerable infrastructure. Self-compensating tiltmeters at the Chisinau station were used to investigate Earth tides,

slow crustal deformations, and various geophysical anomalies. During this period, two powerful events occurred in Vrancea: $M=7.2$ (August 30, 1986) and $M=7.0$ (May 30, 1990), along with eleven earthquakes with $M>4.8$. It was established that in 75 % of cases, fluctuation-type tilts were recorded several hours before events with $M>4.8$. This suggests a probabilistic nature of the preparation and rupture processes for such events and indicates that this anomalous phenomenon is a likely precursor. These anomalies are most pronounced in the north-south direction, where elastic tidal parameters exhibit an anomaly. This factor is non-random and should be utilized in the search for seismic forecasting sites. Notably, no significant fluctuations were detected prior to the earthquake of May 30, 1990, although its focal mechanism differed substantially from the others.

Another phenomenon frequently observed in tidal records is the occurrence of tilt offsets during earthquakes [Shliakhovyj, Chernyi, 2010]. These have been consistently recorded for Vrancea zone seismic events with $M>4.8$, and occasionally for lower magnitudes. However, tilt records from Chişinău revealed a noteworthy effect: for moderate seismic events ($M<5$), the offsets exhibited the same direction, whereas for two powerful paired earthquakes in May 1990, the offsets were oppositely directed and characterized by significantly higher amplitudes. This new finding is of particular importance for understanding earthquake physics. The detection of these genuine, multi-scale offsets was made possible only with self-compensating instruments, which eliminate the instrumental artifacts common in conventional tiltmeters. While other types of precursors and anomalous phenomena were identified in the Kishinev records, no clearly defined anomalies in tidal parameters or slow tilt behavior were detected immediately preceding Vrancea earthquakes. Significant tilt offsets and other geodynamic quasi-static phenomena were observed in the records of the powerful 2023 Turkey earthquakes ($M 7.8$, $M 7.4$). Even at teleseismic distances (approximately 1400 km), distinct tilt steps were recorded, with orientations con-

sistent with the focal mechanisms, alongside wave trains of ultra-long-period oscillations [Shliakhovyi et al., 2024].

Earthquake forecasting is a critical geoinformation challenge, and the necessity of its resolution is evident given the immense losses caused by these events. Analysis indicates that to significantly reduce catastrophic impact, it is sufficient to solve the problem of short-term and immediate (real-time) forecasting. This task is feasible; a warning issued even 10–30 minutes before an event can save nearly all human lives and allow for necessary planned shutdowns, substantially mitigating the potential hazards of critical infrastructure. The expertise accumulated by the PGO in addressing the Vrancea earthquakes, as well as in studying other subtle geodynamic phenomena, suggests that this problem can be resolved through seismic-tidal technologies, provided they are integrated with other monitoring methods.

The results of applied research on the seismic stability of the Dniester River bridge, conducted during tidal surveys in the Vrancea zone, are of significant interest [Shliakhovyi et al., 1994; Schliakhovyi, Schliakhovyi, 1998]. It was discovered that, under dynamic loading of the bridge structure, the piers experience deformation jumps in the slopes, which are remarkably similar to those recorded during earthquakes. This finding is of fundamental importance. Furthermore, the determination of deformation moduli and the bearing capacity of the soils adjacent to the bridge under natural, non-destructive conditions provides vital data. These parameters are crucial for assessing structural stability, and a reliable method for their determination is highly sought after by designers and operators.

Additionally, noteworthy landslide investigations were conducted in the hazardous mining zones of Soledar, Ukraine [Kutnyi et al., 2011, 2023]. Due to inadequate control over salt mining in the 1970s and 1980s, the entire city, with a population of approximately 12,000, began to sink and suffer structural damage. Under a formal agreement, the PGO initiated tilt monitoring of the deformation regime both within the mine and across the

mine fields. Both Earth tides and slow crustal deformations were studied. To mitigate these catastrophic processes, the underground workings were backfilled with rock from 1979 until 1983, which effectively halted the disastrous surface subsidence. Tiltmeter observations continued in the region until 1995, providing valuable geophysical data on how the backfilling of adits influenced the Earth tide. It was observed that the elastic Earth-tidal parameters began to stabilize, eventually reaching near-regional values, while intense non-tidal tilts were minimized. Thus, the feasibility and effectiveness of using Earth-tidal methods for monitoring large-scale geotechnical sites have been proven. In addition to the aforementioned studies, the PGO has performed various other applied research projects.

An intriguing application of Earth-tidal research methods lies in the investigation of fundamental problems in gravitation. The feasibility of recording gravitational waves using tidal instrumentation was studied at the PGO as early as 1974–1976 [Shliakhovyi, 1975]. It was demonstrated that the detection of such waves is possible provided that the resolution of these systems is increased by 3 to 4 orders of magnitude. This problem is highly relevant today. Gravitational waves have already been detected by the LIGO project, which utilizes a modified long-base geophysical laser strainmeter. However, these results require verification through independent methods. The development of a gravitational wave detector based on modern self-compensating tiltmeters, whose resolution currently reaches 10^{-11} – 10^{-12} rad and can be further improved, is an entirely feasible task. Instruments based on this technology are highly promising due to several advantages, such as the capability for frequency tuning. We are confident that recent advancements will significantly enhance their resolution, leading to a solution to this problem in the near future. The potential for such applications was considered during the development of self-compensating tiltmeters, alongside their role in seismic forecasting.

Conclusions. From its inception, PGO has primarily focused on the study of Earth tides

and their indirect effects. The goal is to obtain data characterizing the Earth's internal structure, determine tidal deformation parameters, and investigate the influence of oceanic and atmospheric tides, as well as the structural features of the crust and upper mantle, topography, caverns, and other disturbing factors. These studies were conducted using tiltmetric and gravimetric methods.

Gravimetric observations were carried out to detect subtle effects, such as potential changes in the elastic properties of the crust and mantle caused by deep-seated processes, tidal phase lag (reflecting the viscosity of the solid Earth), and the resonant influence of the liquid core on Earth tides. Experience indicates that tidal gravity observations are well-suited for characterizing the Earth's global elastic properties and are relatively independent of local geological features. The study of slow gravity variations is a crucial area of modern geodynamics. These variations may arise from changes in the Earth's rotation

speed caused by shifts in its inertia tensor, polar motion, groundwater fluctuations, and convective or other mass displacements within the crust and upper mantle.

Since the late 1950s, as the precision of tilt measurements increased, research focus shifted toward non-tidal tilts, including crustal movements, the determination of rates and directions of tectonic tilts, and the study of individual faults and the block structure of the Earth's crust. Numerous challenges remain where seismic-tidal technologies prove highly effective. These include the precise parameterization of seismic signals, particularly in the long-period range, as well as the investigation of fundamental questions in gravitational physics, the Earth's internal structure, and various other theoretical and applied issues. While only a few areas of applied research related to Earth tides have been listed, tidal observation techniques have the potential to address a much broader array of practical tasks.

References

- Aksent'eva, Z.M., Balenko, V.G., Bulatsen, V.G., Golubitsky, V.G., Pavlyk, V.G., Shliahovyi, V.P. (2002). Observations of the variations of the vertical component of gravity in the territory of Ukraine in 1955—1997. *Earth Rotation and Geodynamics*, 18(3), 195—204 (in Russian).
- Aksent'eva, Z.N., Bulatsen, V.G., & Tokar, V.I. (1970). On the reprocessing of the 11-year series of observations (1930—1941) of the Earth's surface tilts in Poltava. *Vraschenie i prilivnye deformatsii Zemli*, (2), 3—8 (in Russian).
- Balenko, V.G. (1980). *Investigation of the Earth's surface tilts along the Kiev-Artemovsk profile*. Kiev: Naukova Dumka, 176 p. (in Russian).
- Boy, J.-P., Barriot, J.-P., Förste, C., Voigt, C., & Wziontek, H. (2020). Achievements of the First 4 Years of the International Geodynamics and Earth Tide Service (IGETS) 2015—2019. In J.T. Freymueller, L. Sánchez (Eds.), *Beyond 100: The next Century in Geodesy. International Association of Geodesy Symposia* (Vol. 152, pp. 107—112). Springer, Berlin, Heidelberg. https://doi.org/10.1007/1345_2020_94.
- Braitenberg, C., Rossi, G., Bogusz, J., Crescentini, L., Crossley, D., Gross, R., Heki, K., Hinderer, J., Jahr, T., Meurers, B., & Schuh, H. (2018). Geodynamics and Earth Tides Observations from Global to Micro Scale: Introduction. *Pure and Applied Geophysics*, 175, 1595—1597. <https://doi.org/10.1007/s00024-018-1875-0>.
- Iwano, S., Fukuda, Y., Sato, T., Tamura, Y., Matsumoto, K., & Shibuya, K. (2005). Long-period tidal factors at Antarctica Syowa Station determined from 10 years of superconducting gravimeter data. *Journal of Geophysical Research: Solid Earth*, 110(B10). <https://doi.org/10.1029/2004JB03551>.
- Kutnyi, A.M., Pavlyk, V.G., Bulatsen, V.G., & Babich, T.M. (2011). The results of long-term tiltmeter observations in the salt mine of Soleidar (possible resonant effect of the liquid core of the Earth). *Geofizicheskiy Zhurnal*, 33(5), 115—119. <https://doi.org/10.24028/gzh.0203-3100.v33i5.2011.116871> (in Ukrainian).
- Kutnyi, A.M., Pavlyk, V.G., Bulatsen, V.G., Golubyskyi, V.G., Bogdan, I.Yu., Korba, P.S., Babych, T.M., & Plys, V.P. (2015). Results and analysis of the Earth's tidal observations in the territory of Ukraine. *Geofizicheskiy Zhurnal*,

- 37(2), 56—72. <https://doi.org/10.24028/gzh.0203-3100.v37i2.2015.111305> (in Ukrainian).
- Kutnyi, A.M., Pavlyk, V.G., Babych, T.M., & Plys, V.P. (2023). Dynamics of tidal parameters depending on the landslide hazard condition of the salt mine roof. *Geofizicheskii Zhurnal*, 45(3), 74—87. <https://doi.org/10.24028/gj.v45i3.282416> (in Ukrainian).
- Matveev, P.S. (1980). Development of A.Ya. Orlov's ideas on the study of tidal tilts of the Earth's surface in the research of the Poltava Gravimetric Observatory. In *Geodynamics and Astrometry: collection of scientific papers* (pp. 27—52). Kiev: Naukova Dumka (in Russian).
- Matveev, P.S. (1966). Harmonic analysis of a monthly series of Earth tide observations. In *Earth Tides* (pp. 51—79). Kiev: Naukova Dumka (in Russian).
- Matveev, P.S. (1970). On the possibility of using the results of observations tiltmetric for studies of the structure of the crust. *Vraschenie i prilivnye deformatsii Zemli*, (1), 72—86 (in Russian).
- Matveev, P.S., Golubitsky, V.G., Bogdan, I.Yu., Dubik, B.S., & Slavinskaya, E.A. (1977a). Refined values of Earth tide parameters for the stations of the Sumy-Kherson profile. *Vraschenie i prilivnye deformatsii Zemli*, (9), 16—33 (in Russian).
- Matveev, P.S., Ostrovskiy, A.E., & Shlyakhoviy, V.P. (1977b). On the efficiency of using negative feedback for stabilizing the sensitivity of a photoelectric tiltmeter. *Vraschenie i prilivnye deformatsii Zemli*, (9), 44—50 (in Russian).
- Melchior, P. (1966). *The Earth Tides* (pp. 1—25). Oxford: Pergamon Press.
- Melchior, P. (1978). *The Tides of the Planet Earth*. Observatoire Royal de Belgique, Brussels and Universite Catholique de Louvain., Pergamon Press, 610 p.
- Orlov, A.Ya. (1961a). *Selected works*: in 3 volumes. Publishing House of the Academy of Sciences of the Ukrainian SSR, Vol. II, 320 p. (in Russian).
- Orlov, A.Ya. (1961b). *Selected works*: in 3 volumes. Publishing House of the Academy of Sciences of the Ukrainian SSR, Vol. III, 243 p. (in Russian).
- Orlov, A.Ya. (1950). Poltava Gravimetric Observatory of the Academy of Sciences of the Ukrainian SSR. *Proc. of the Poltava Gravimetric Observatory* (Vol. 3, pp. 3—12) (in Russian).
- Shliakhoviy, V.V. (2007). Digital seismotidal complex of Poltava Gravimetric Observatory: technology of supervision. *Geodynamics*, 6(1), 60—66 (in Ukrainian).
- Shliakhoviy, V.P. (1975). On the detection of gravitational waves by tide-recording instruments. *Vraschenie i prilivnye deformatsii Zemli*, 8(1), 83—86 (in Russian).
- Schliakhoviy, V.P. (1985). The tidal signals in non-linear systems and the problems of the forecast of earthquakes. In *Recent Geodynamics and the Prediction of Earthquakes in Ukraine* (pp. 85—90). Kiev: Naukova Dumka (in Russian).
- Shliakhoviy, V.P., & Chernyi, V.G. (2010). Earth's tidal tilt jumps and their relationship to earthquake source's physics. *Geofizicheskii Zhurnal*, 32(4), 146—149.
- Schliakhoviy, V.P., Chernyi, V.I., & Iltchenko, A.G. (1994). Results of many years observations of tilts of earth surface near Vrancea focal zone. The Study of the Earth as a planet by methods of astronomy, geophysics and geodesy. *Proc. of the 3rd Orlov Conference, Odessa-1992* (pp. 216—217). Kiev: Naukova Dumka (in Russian).
- Shljakhoviy, V.P., Kendzera, O.V., & Shljahoviy, V.V. (2011). Registration of seismic signals by tidal devices. *Geodynamics*, 11(2), 344—346. <https://doi.org/10.23939/jgd2011.02.344> (in Ukrainian).
- Schliakhoviy, V.P., & Schlyakhoviy, V.V. (1998). Study of non-linear earth tide effects as possible precursors of Vrancea's Earthquakes. *Proc. of the Thirteenth International Symposium on Earth Tides, Brussels, July 22—25, 1997* (P. 183).
- Shliakhoviy, V.P., Shyian, R.V., & Shliakhoviy, R.V. (2024). Seismic-tidal investigations of geodynamic processes during catastrophic earthquakes in Turkey, 2023 and the problem of predicting destructive events. *17th International Conference Monitoring of Geological Processes and Ecological Condition of the Environment. European Association of Geoscientists & Engineers* (Vol. 2023, pp. 1—5). <https://doi.org/10.3997/2214-4609.2023520172>.
- Shliakhoviy, V.P., Shyian, R.V., Yelchenko-Lob-

ovska, A.S., & Shliakhovyi, R.V. (2025). Seismic activity of the Dnieper-Donetsk Basin, geodeformation fields and geotectonics of

its seimogenic zones. *Geofizicheskiy Zhurnal*, 47(2), 353—358. <https://doi.org/10.24028/gj.v47i2.322577>.

100-річчя Полтавської гравіметричної обсерваторії: від ледь помітних земних припливів до сейсмоприпливної технології

В.П. Шляховий, Р.В. Шиян, 2026

Полтавська гравіметрична обсерваторія Інституту геофізики
ім. С.І. Субботіна НАН України, Полтава, Україна

Вивчення земних припливів є фундаментальним методом дослідження внутрішньої структури Землі, що дає змогу аналізувати геодинамічні процеси в літосфері, мантії, ядрі та атмосфері. Понад століття розвитку припливних методів спостережень призвело до розробки приладів, що характеризуються надвисокою роздільною здатністю та чутливістю. Сучасні інструментальні спостереження також використовуються для досліджень і моніторингу геодинамічного стану навколишнього середовища, його локальних і регіональних геоструктур. Вони відіграють важливу роль у контролі деформаційних режимів і структурної стабільності критичних геотехнічних об'єктів.

Експериментальні та теоретичні дослідження земноприпливних явищ є одним із основних наукових напрямів Полтавської гравіметричної обсерваторії ІГФ НАН України з моменту її заснування в 1926 р. Напрями досліджень охоплюють астрономічні, нахиломірні, гравіметричні та екстензометричні спостереження. Дослідження, проведені в першій половині ХХ ст., не лише підтвердили земні припливи як реальне геофізичне явище, а й визначили їх як фундаментальне джерело наукової інформації про будову і внутрішні процеси в Землі. У період між 1960 та 1990 рр. впровадження сучасного приладобудування сприяло проведенню припливних досліджень на більш ніж 40 станціях в Україні, що дало об'ємні масиви даних для геодинамічного аналізу. Протягом своєї столітньої історії Полтавська гравіметрична обсерваторія зробила вагомий внесок у вивчення земних припливів і розвиток суміжних технологій, що охоплюють інтеграцію земноприпливних і сейсмічних методів, які можуть слугувати не лише фундаментальним дослідженням, а й вирішенню важливих практичних завдань, таких як моніторинг геологічного середовища та стійкості гірничих виробок і мостових конструкцій, дослідження обвальних процесів у шахтах тощо.

Ключові слова: гравіметр, гравітація, земні припливи, землетрус, сейсміка, нахиломір, технологія.