

ISSN 2518-170X (Online)  
ISSN 2224-5278 (Print)



«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ  
ҰЛТТЫҚ ФЫЛЫМ  
АКАДЕМИЯСЫ» РҚБ

«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ

ҰЛТТЫҚ ФЫЛЫМ АКАДЕМИЯСЫ» РҚБ

# ХАБАРЛАРЫ

---

## ИЗВЕСТИЯ

---

## NEWS

РОО «НАЦИОНАЛЬНОЙ  
АКАДЕМИИ НАУК  
РЕСПУБЛИКИ КАЗАХСТАН»

OF THE ACADEMY OF SCIENCES  
OF THE REPUBLIC OF  
KAZAKHSTAN

SERIES  
OF GEOLOGY AND TECHNICAL SCIENCES

4 (466)  
JULY – AUGUST 2024

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

---

---

*NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.*

Қазақстан Республикасы Үлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрi the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруды. Web of Science зерттеушілер, авторлар, баспашилар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енүі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

### **Бас редактор**

**ЖҰРЫНОВ Мұрат Жұрынұлы**, химия ғылымдарының докторы, профессор, КР YFA академигі, «Қазақстан Республикасы Үлттық ғылым академиясы» РКБ-нің президенті, АҚ «Д.В. Сокольский атындағы отын, катализ және электрохимия институтының» бас директоры (Алматы, Қазақстан) **H = 4**

### **Ғылыми хатшы**

**АБСАДЫКОВ Баһыт Нарикбайұлы**, техника ғылымдарының докторы, профессор, КР YFA жауапты хатшысы, А.Б. Бектұров атындағы химия ғылымдары институты (Алматы, Қазақстан) **H = 5**

### **Редакциялық алқа:**

**ӘБСАМЕТОВ Мәліс Құдысұлы** (бас редактордың орынбасары), геология-минералогия ғылымдарының докторы, профессор, КР YFA академигі, «У.М. Ахмедсафина атындағы гидрогеология және геоэкология институтының» директоры (Алматы, Қазақстан) **H = 2**

**ЖОЛТАЕВ Герой Жолтайұлы** (бас редактордың орынбасары), геология-минералогия ғылымдарының докторы, профессор, К.И. Сатпаев тындағы геология ғылымдары институтының директоры (Алматы, Қазақстан) **H=2**

**СНОУ Дэниел, Ph.D.**, қауымдастырылған профессор, Небраска университетінің Су ғылымдары зертханасының директоры (Небраска штаты, АҚШ) **H = 32**

**ЗЕЛЬТМАН Реймар, Ph.D.**, табиғи тарих мұражайының Жер туралы ғылымдар бөлімінде петрология және пайдалы қазбалар кен орындары саласындағы зерттеулердің жетекшісі (Лондон, Англия) **H = 37**

**ПАНФИЛОВ Михаил Борисович**, техника ғылымдарының докторы, Нанси университетінің профессоры (Нанси, Франция) **H=15**

**ШЕН Пин, Ph.D.**, Қытай геологиялық қоғамының тау геологиясы комитеті директорының орынбасары, Американдық экономикалық геологтар қауымдастырының мүшесі (Пекин, Қытай) **H = 25**

**ФИШЕР Аксель, Ph.D.**, Дрезден техникалық университетінің қауымдастырылған профессоры (Дрезден, Берлин) **H = 6**

**КОНТОРОВИЧ Алексей Эмильевич**, геология-минералогия ғылымдарының докторы, профессор, РГА академигі, А.А. Трофимука атындағы мұнай-газ геологиясы және геофизика институты (Новосибирск, Ресей) **H = 19**

**АГАБЕКОВ Владимир Енокович**, химия ғылымдарының докторы, Беларусь YFA академигі, Жана материалдар химиясы институтының құрметті директоры (Минск, Беларусь) **H = 13**

**КАТАЛИН Стефан**, Ph.D., Дрезден техникалық университетінің қауымдастырылған профессоры (Дрезден, Берлин) **H = 20**

**СЕЙТМУРАТОВА Элеонора Юсуповна**, геология-минералогия ғылымдарының докторы, профессор, КР YFA корреспондент-мүшесі, К.И. Сатпаев атындағы Геология ғылымдары институты зертханасының ментерушісі (Алматы, Қазақстан) **H=11**

**САҒЫНТАЕВ Жанай**, Ph.D., қауымдастырылған профессор, Назарбаев университеті (Нұр-Сұлтан, Қазақстан) **H = 11**

**ФРАТТИНИ Паоло**, Ph.D., Бикокк Милан университеті қауымдастырылған профессоры (Милан, Италия) **H = 28**

---

**«КР YFA» РКБ Хабарлары. Геология және техникалық ғылымдар сериясы».**

**ISSN 2518-170X (Online)**,

**ISSN 2224-5278 (Print)**

Меншіктеуші: «Қазақстан Республикасының Үлттық ғылым академиясы» РКБ (Алматы к.).  
Қазақстан Республикасының Ақпарат және қоғамдық даму министрлігінің Ақпарат комитетінде 29.07.2020 ж. берілген № KZ39VPY00025420 мерзімдік басылым тіркеуіне қойылу туралы күәлік.  
Такырыптық бағыты: геология, мұнай және газды өңдеудің химиялық технологиялары, мұнай химиясы, металдарды алу және олардың қосындыларының технологиясы.

Мерзімділігі: жылдан 6 рет.

Тиражы: 300 дана.

Редакцияның мекен-жайы: 050010, Алматы к., Шевченко көш., 28, 219 бөл., тел.: 272-13-19

<http://www.geolog-technical.kz/index.php/en/>

© «Қазақстан Республикасының Үлттық ғылым академиясы» РКБ, 2024

### **Главный редактор**

**ЖУРИНОВ Мурат Журинович**, доктор химических наук, профессор, академик НАН РК, президент РОО «Национальной академии наук Республики Казахстан», генеральный директор АО «Институт топлива, катализа и электрохимии им. Д.В. Сокольского» (Алматы, Казахстан) **H = 4**

### **Ученный секретарь**

**АБСАДЫКОВ Бахыт Нарикбаевич**, доктор технических наук, профессор, ответственный секретарь НАН РК, Институт химических наук им. А.Б. Бектурова (Алматы, Казахстан) **H = 5**

### **Редакционная коллегия:**

**АБСАМЕТОВ Малис Кудысович**, (заместитель главного редактора), доктор геологоминералогических наук, профессор, академик НАН РК, директор Института гидрогеологии и геэкологии им. У.М. Ахмедсафина (Алматы, Казахстан) **H = 2**

**ЖОЛТАЕВ Герой Жолтаевич**, (заместитель главного редактора), доктор геологоминералогических наук, профессор, директор Института геологических наук им. К.И. Сатпаева (Алматы, Казахстан) **H=2**

**СНОУ Дэниел**, Ph.D, ассоциированный профессор, директор Лаборатории водных наук университета Небраски (штат Небраска, США) **H = 32**

**ЗЕЛЬТМАН Реймар**, Ph.D, руководитель исследований в области петрологии и месторождений полезных ископаемых в Отделе наук о Земле Музея естественной истории (Лондон, Англия) **H = 37**

**ПАНФИЛОВ Михаил Борисович**, доктор технических наук, профессор Университета Нанси (Нанси, Франция) **H=15**

**ШЕНПИН**, Ph.D, заместитель директора Комитета по горной геологии Китайского геологического общества, член Американской ассоциации экономических геологов (Пекин, Китай) **H = 25**

**ФИШЕР Аксель**, ассоциированный профессор, Ph.D, технический университет Дрезден (Дрезден, Берлин) **H = 6**

**КОНТОРОВИЧ Алексей Эмильевич**, доктор геолого-минералогических наук, профессор, академик РАН, Институт нефтегазовой геологии и геофизики им. А.А. Трофимука СО РАН (Новосибирск, Россия) **H = 19**

**АГАБЕКОВ Владимир Енокович**, доктор химических наук, академик НАН Беларуси, почетный директор Института химии новых материалов (Минск, Беларусь) **H = 13**

**КАТАЛИН Стефан**, Ph.D, ассоциированный профессор, Технический университет (Дрезден, Берлин) **H = 20**

**СЕЙТМУРАТОВА Элеонора Юсуповна**, доктор геолого-минералогических наук, профессор, член-корреспондент НАН РК, заведующая лаборатории Института геологических наук им. К.И. Сатпаева (Алматы, Казахстан) **H=11**

**САГИНТАЕВ Жанай**, Ph.D, ассоциированный профессор, Назарбаев университет (Нурсултан, Казахстан) **H = 11**

**ФРАТТИНИ Паоло**, Ph.D, ассоциированный профессор, Миланский университет Бикокк (Милан, Италия) **H = 28**

---

**«Известия РОО «НАН РК». Серия геологии и технических наук».**

**ISSN 2518-170X (Online),**

**ISSN 2224-5278 (Print)**

Собственник: Республикансское общественное объединение «Национальная академия наук Республики Казахстан» (г. Алматы).

Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и общественного развития Республики Казахстан № KZ39VPY00025420, выданное 29.07.2020 г.

Тематическая направленность: *геология, химические технологии переработки нефти и газа, нефтехимия, технологии извлечения металлов и их соединений.*

Периодичность: 6 раз в год.

Тираж: 300 экземпляров.

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, оф. 219, тел.: 272-13-19

<http://www.geolog-technical.kz/index.php/en/>

© РОО «Национальная академия наук Республики Казахстан», 2024

### **Editorial chief**

**ZHURINOV Murat Zhurinovich**, doctor of chemistry, professor, academician of NAS RK, president of the National Academy of Sciences of the Republic of Kazakhstan, general director of JSC "Institute of fuel, catalysis and electrochemistry named after D.V. Sokolsky" (Almaty, Kazakhstan) **H = 4**

### **Scientific secretary**

**ABSADYKOV Bakhyt Narikbaevich**, doctor of technical sciences, professor, executive secretary of NAS RK, Bekturov Institute of chemical sciences (Almaty, Kazakhstan) **H = 5**

### **E d i t o r i a l b o a r d:**

**ABSAMETOV Malis Kudysovich**, (deputy editor-in-chief), doctor of geological and mineralogical sciences, professor, academician of NAS RK, director of the Akhmedsafin Institute of hydrogeology and hydrophysics (Almaty, Kazakhstan) **H=2**

**ZHOLTAEV Geroy Zholtayevich**, (deputy editor-in-chief), doctor of geological and mineralogical sciences, professor, director of the institute of geological sciences named after K.I. Satpayev (Almaty, Kazakhstan) **H=2**

**SNOW Daniel**, Ph.D, associate professor, director of the laboratory of water sciences, Nebraska University (Nebraska, USA) **H = 32**

**ZELTMAN Reymar**, Ph.D, head of research department in petrology and mineral deposits in the Earth sciences section of the museum of natural history (London, England) **H = 37**

**PANFILOV Mikhail Borisovich**, doctor of technical sciences, professor at the Nancy University (Nancy, France) **H=15**

**SHEN Ping**, Ph.D, deputy director of the Committee for Mining geology of the China geological Society, Fellow of the American association of economic geologists (Beijing, China) **H = 25**

**FISCHER Axel**, Ph.D, associate professor, Dresden University of technology (Dresden, Germany) **H = 6**

**KONTOROVICH Aleksey Emilievich**, doctor of geological and mineralogical sciences, professor, academician of RAS, Trofimuk Institute of petroleum geology and geophysics SB RAS (Novosibirsk, Russia) **H = 19**

**AGABEKOV Vladimir Enokovich**, doctor of chemistry, academician of NAS of Belarus, honorary director of the Institute of chemistry of new materials (Minsk, Belarus) **H = 13**

**KATALIN Stephan**, Ph.D, associate professor, Technical university (Dresden, Berlin) **H = 20**

**SEITMURATOVA Eleonora Yusupovna**, doctor of geological and mineralogical sciences, professor, corresponding member of NAS RK, head of the laboratory of the Institute of geological sciences named after K.I. Satpayev (Almaty, Kazakhstan) **H=11**

**SAGINTAYEV Zhanay**, Ph.D, associate professor, Nazarbayev University (Nursultan, Kazakhstan) **H = 11**

**FRATTINI Paolo**, Ph.D, associate professor, university of Milano-Bicocca (Milan, Italy) **H = 28**

---

**News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.**

**ISSN 2518-170X (Online),**

**ISSN 2224-5278 (Print)**

Owner: RPA «National Academy of Sciences of the Republic of Kazakhstan» (Almaty).

The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Social Development of the Republic of Kazakhstan No. **KZ39VPY00025420**, issued 29.07.2020.

Thematic scope: *geology, chemical technologies for oil and gas processing, petrochemistry, technologies for extracting metals and their connections.*

Periodicity: 6 times a year.

Circulation: 300 copies.

Editorial address: 28, Shevchenko str., of. 219, Almaty, 050010, tel. 272-13-19

<http://www.geolog-technical.kz/index.php/en/>

© National Academy of Sciences of the Republic of Kazakhstan, 2024

NEWS of the National Academy of Sciences of the Republic of Kazakhstan

SERIES OF GEOLOGY AND TECHNICAL SCIENCES

ISSN 2224-5278

Volume 4. Number 466 (2024), 261–273

<https://doi.org/10.32014/2024.2518-170X.440>

UDC 528.2

IRSTI: 37.31.23

© A.S. Urazaliyev<sup>1,2</sup>, D.A. Shoganbekova<sup>1,3\*</sup>, R. Shults<sup>4</sup>, M.S. Kozhakhmetov<sup>1</sup>,  
G.M. Iskaliyeva<sup>1</sup>, 2024

<sup>1</sup>Institute of Ionosphere, Almaty, Kazakhstan;

<sup>2</sup>Kazakh National Research Technical University named after K.I. Satpayev, Almaty,  
Kazakhstan;

<sup>3</sup>International Educational Corporation, Almaty, Kazakhstan;

<sup>4</sup>King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia.

E-mail: d.shoganbekova@ionos.kz

## INVESTIGATION OF LSMSA APPROACH IN LOCAL GEOID MODELING

**Urazaliyev Asset Seisenbekovich** — Senior Researcher at the Laboratory of Satellite and Geodynamic Research, LLP «Institute of Ionosphere», Almaty, Kazakhstan

E-mail: a.urazaliyev@ionos.kz, <https://orcid.org/0000-0001-7444-2897>;

**Shoganbekova Daniya Assygatovna** — PhD, Chief Researcher at the Laboratory of Satellite and Geodynamic Research, LLP «Institute of Ionosphere», Almaty, Kazakhstan

E-mail: d.shoganbekova@ionos.kz, <https://orcid.org/0000-0002-6825-4774>;

**Roman Shults** — Senior Researcher at the Laboratory of Remote Sensing and Analysis at the King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia

E-mail: roman.shults@kfupm.edu.sa, <https://orcid.org/000ccc0-0003-2581-517X> ;

**Kozhakhmetov Magzhan Serikzhanuly** — Researcher at the Laboratory of Satellite and Geodynamic Research, LLP «Institute of Ionosphere», Almaty, Kazakhstan

E-mail: m.kozhakhmetov@ionos.kz, <https://orcid.org/0009-0004-9433-8674>;

**Iskaliyeva Gulnara Maratovna** — Leading researcher at the Laboratory of Space and Geoinformation Technologies, LLP «Institute of Ionosphere», Almaty, Kazakhstan

E-mail: igm.ionos@gmail.com; <https://orcid.org/0000-0002-3183-728X>.

**Abstract.** This article presents the results of creating a gravimetric geoid model using a modified Stokes formula, implemented via the method of least squares with additive correction (LSMSA). Typically, the computation of geoid height is based on gravity measurements at points on or above the Earth's surface. However, practical limitations often restrict available gravity data to a spherical cap, leading to truncation errors. To mitigate these errors, it is essential to integrate terrestrial data with a global geopotential model (GGM). For an optimal gravimetric geoid definition, the GGM must be selected to best match the local gravity field. This selection is accomplished by comparing geodetic quantities derived from the GGM — such as potential, geoid heights, deflection of the vertical, gravity, and anomaly values — with those obtained from GNSS/levelling and terrestrial gravity measurements. This comparison reduces the impact of assumptions and approximations inherent in the Stokes method, thereby enhancing the accuracy of geoid height determination. To develop a local geoid using heterogeneous data sources (including gravity anomalies, digital high relief models, global geopotential models, and GNSS/levelling data) Least squares modification of Stokes formula with additive correction (LSMSA) method was chosen. This method is

one of the simplest and most practical approaches, which has been successfully employed in regional geoid modelling. The LSMSA approach facilitates optimal integration of terrestrial and global data, contributing to more accurate and reliable geoid modelling.

**Keywords:** least squares modifications of Stokes formula, GGM, geoid, GNSS/leveling, accuracy assessment, standard deviation

© А.С. Уразалиев<sup>1,2</sup>, Д.А. Шоганбекова<sup>1,3\*</sup>, Р. Шульц<sup>4</sup>, М.С. Қожахметов<sup>1</sup>,  
Г.М. Искалиева<sup>1</sup>, 2024

<sup>1</sup> Ионосфера институты, Алматы, Қазақстан;

<sup>2</sup> Қ.И. Сәтбаев атындағы Қазақ ұлттық техникалық зерттеу университеті, Алматы, Қазақстан;

<sup>3</sup>Халықаралық білім беру корпорациясы, Алматы, Қазақстан;

<sup>4</sup>Король Фахд атындағы мұнай және пайдалы қазбалар университеті, Даҳран, Сауд Арабиясы.

E-mail: d.shoganbekova@ionos.kz

## ЖЕРГІЛІКТІ ГЕОИДТЫ МОДЕЛЬДЕУДЕГІ LSMSA ТӘСІЛІН ЗЕРТТЕУ

**Уразалиев Асет Сейсенбекович** — спутниктік және геодинамикалық зерттеулер зертханасының ағағылыми қызметкері, ЖШС «Ионосфера институты», Алматы, Қазақстан  
E-mail: a.urazaliyev@ionos.kz, <https://orcid.org/0000-0001-7444-2897>;

**Шоганбекова Дания Асылгатовна** — PhD, спутниктік және геодинамикалық зерттеулер зертханасының бас ғылыми қызметкері, ЖШС «Ионосфера институты», Алматы, Қазақстан  
E-mail: d.shoganbekova@ionos.kz, <https://orcid.org/0000-0002-6825-4774>;

**Роман Шульц** — PhD, қашықтықтан зондтау және талдау зертханасының ағағылыми қызметкері, Король Фахд атындағы мұнай және пайдалы қазбалар университеті, Даҳран, Сауд Арабиясы  
E-mail: roman.shults@kfupm.edu.sa, <https://orcid.org/000ccc-0003-2581-517X> ;

**Қожахметов Магжан Серікжанұлы** — спутниктік және геодинамикалық зерттеулер зертханасының ғылыми қызметкері, ЖШС «Ионосфера институты», Алматы, Қазақстан  
E-mail: m.kozhakhmetov@ionos.kz, <https://orcid.org/0009-0004-9433-8674>;

**Искалиева Гульнара Маратовна** — ғарыштық және геоакпараттық технологиялар зертханасының жетекші ғылыми қызметкері, ЖШС «Ионосфера институты», Алматы, Қазақстан  
E-mail: igm.ionos@gmail.com; <https://orcid.org/0000-0002-3183-728X>.

**Аннотация.** Мақалада геоидтың гравиметриялық моделін жасау нәтижелері Стокс формуласының модификацияларын аддитивті түзетүмен ең кіші квадраттар әдісімен (LSMSA) колдану арқылы ұсынылған. Әдетте, геоид биіктігін есептеу Жер бетінде немесе оның үстінде жер гравитациясын өлшеулер негізінде жүзеге асырылады. Алайда, тәжірибеде тек сфералық қалпақпен шектелген гравиметриялық деректер ғана қол жетімді, бұл кесу қатесіне әкеледі. Осы қатені азайту үшін жердегі деректерді ғаламдық гравитациялық потенциал моделімен (ГГМ) біріктіру қажет. Геоидтың онтайлы гравиметриялық анықтамасына жету үшін жергілікті гравитациялық өріске ең жақсы сәйкес келетін ГГМ таңдау керек. Бұл ГГМ негізінде алынған геодезиялық шамаларды (мысалы, потенциал, геоид биіктіктері, тік компоненттердің ауытқуы, ауырлық күші және аномалия мәндері) ГНСС/Нивелирлеу және жердегі гравиметриялық өлшеулер негізінде алынған деректермен салыстыру арқылы жүзеге асырылады. Бұл Стокс әдісіне тән болжамдар мен жуықтаулардың әсерін азайтып, геоид биіктігін анықтаудың дәлдігін арттыруға мүмкіндік береді.

Әртүрлі деректерді (гравитациялық аномалиялар, жоғары цифрлық рельеф модельдері, ғаламдық гравитациялық потенциал модельдері, сондай-ақ ГНСС және нивелирлеу деректері) қолдана отырып, жергілікті геоидты әзірлеуде Стокс формуласының аддитивті түзетумен ең кіші квадраттар әдісімен модификациясын (LSMSA) пайдалану шешілді, бұл аймақтық геоид модельдерін анықтауда табысты қолданылатын ең қарапайым және практикалық тәсілдердің бірі болып табылады. Бұл тәсіл жергілікті және ғаламдық деректерді оңтайлы біріктіруді қамтамасыз етеді, бұл геоидты дәл және сенімді модельдеуге ықпал етеді.

**Тұйін сөздер:** ең кіші квадраттар әдісін қолдану арқылы Стокс формуласының модификациясы, ГГМ, геоид, ГНСС/Нивелирлеу, дәлдікті бағалау, стандартты ауытқу

© А.С. Уразалиев<sup>1,2</sup>, Д.А. Шоганбекова<sup>1,3\*</sup>, Р. Шульц<sup>4</sup>, М.С. Кожахметов<sup>1</sup>,  
Г.М. Искалиева<sup>1</sup>, 2024

<sup>1</sup> Институт ионосферы, Алматы, Казахстан;

<sup>2</sup> Казахский национальный исследовательский технический университет им. К.И. Сатпаева, Алматы, Казахстан;

<sup>3</sup>Международная образовательная корпорация, Алматы, Казахстан;

<sup>4</sup>Университет нефти и полезных ископаемых им. короля Фахда, Дахран, Саудовская Аравия.

E-mail: d.shoganbekova@ionos.kz

## ИССЛЕДОВАНИЕ ПОДХОДА LSMSA В МОДЕЛИРОВАНИИ ЛОКАЛЬНОГО ГЕОИДА

**Уразалиев Асет Сейсенбекович** — старший научный сотрудник в лаборатории спутниковых и геодинамических исследований, ТОО «Институт ионосферы», Алматы, Казахстан

E-mail: a.urazaliyev@ionos.kz, <https://orcid.org/0000-0001-7444-2897>;

**Шоганбекова Дания Асыгатовна** — PhD, главный научный сотрудник в лаборатории спутниковых и геодинамических исследований, ТОО «Институт ионосферы», Алматы, Казахстан

E-mail: d.shoganbekova@ionos.kz, <https://orcid.org/0000-0002-6825-4774>;

**Роман Шульц** — PhD, старший научный сотрудник лаборатории дистанционного зондирования и анализа в Университет нефти и полезных ископаемых им. короля Фахда, Дахран, Саудовская Аравия.

E-mail: roman.shults@kfupm.edu.sa, <https://orcid.org/0000-0003-2581-517X> ;

**Кожахметов Магжан Серикжанулы** — научный сотрудник в лаборатории спутниковых и геодинамических исследований, ТОО «Институт ионосферы», Алматы, Казахстан

E-mail: m.kozhakhetov@ionos.kz, <https://orcid.org/0009-0004-9433-8674>;

**Искалиева Гульнара Маратовна** — ведущий научный сотрудник лаборатории космических и геоинформационных технологий, ТОО «Институт ионосферы», Алматы, Казахстан

E-mail: igm.ionos@gmail.com; <https://orcid.org/0000-0002-3183-728X>.

**Аннотация.** В статье представлены результаты создания гравиметрической модели геоида с использованием модификаций формулы Стокса методом наименьших квадратов с аддитивной коррекцией (LSMSA). Обычно вычисление высота геоида осуществляется на основе измерений земной гравитации в точках на поверхности Земли или над ней. Однако на практике доступны лишь гравиметрические данные, ограниченные сферической шапкой, что приводит к ошибке усечения. Для уменьшения этой ошибки необходимо объединить наземные данные с глобальной геопотенциальной моделью (ГГМ). Для достижения оптимального гравиметрического

определения геоида необходимо выбрать ГГМ, которая наилучшим образом соответствует местному гравитационному полю. Это достигается путем сравнения геодезических величин, полученных на основе ГГМ (таких как потенциал, высоты геоида, отклонение вертикальных компонентов, сила тяжести и значения аномалий) с данными, полученными на основе ГНСС/Нивелирования и наземных гравиметрических измерений. Это позволяет уменьшить влияние допущений и аппроксимаций, присущих методу Стокса, и повысить точность определения высоты геоида. При разработке локального геоида с применением разнородных данных (гравитационные аномалии, цифровые модели рельефа высокого, глобальные геопотенциальные модели, а также данные ГНСС и нивелирования) было решено использовать модификацию формулы Стокса методом наименьших квадратов с аддитивной коррекцией (LSMSA), которая представляет собой один из наиболее простых и практических подходов, который успешно используется для определения региональных моделей геоида. Этот подход обеспечивает оптимальное объединение наземных и глобальных данных, что способствует более точному и надежному моделированию геоида.

**Ключевые слова:** модификаций формулы Стокса методом наименьших квадратов, ГГМ, геоид, ГНСС/Нивелирование, оценка точности, среднеквадратичное отклонение

## Introduction

There are numerous methodologies for determining the regional geoid, each employing distinct techniques, which complicates the task of identifying the optimal method for a given situation. The fundamental approaches for calculating the geoid model frequently involve various modifications of the Stokes formula to enhance accuracy and adapt to specific conditions. The Stokes formula enables the determination of geoid height ( $N$ ) from gravity data:

$$N = \frac{R}{4\pi\gamma} \iint_{\sigma} S(\psi) \Delta g d\sigma \quad (1)$$

where - is the average radius of the Earth, - geocentric angle, - gravitational anomaly, - infinitesimal surface element of integration over the unit sphere , - normal gravity on the reference ellipsoid, - the Stokes function. The Stokes function  $S(\psi)$  can be expressed in terms of Legendre polynomials  $P_n(\cos\psi)$  using their orthogonality properties on the sphere:

$$S(\psi) = \sum_{n=2}^{\infty} \frac{2n+1}{n-1} P_n(\cos\psi) \quad (2)$$

The application of Stokes' theory to calculate height anomalies relative to the reference ellipsoid encounters significant challenges:

- For the required integration, gravity anomalies must be known across the entire Earth's surface. However, approximately one-third of the Earth's surface is covered by seas and oceans. The measurement of gravity anomalies over the oceans became feasible only in the twentieth century.

- The application of the Stokes formula assumes that all masses are located below the geoid. However, gravity anomaly measurements are conducted on the Earth's physical surface, which does not coincide with the level surface. To address this discrepancy, cor-

rections are incorporated into the measured values to effectively reposition all topographic masses below sea level without altering the geoid surface. This ensures that gravity is related to the level surface. This issue, extensively discussed in the scientific literature, is known as the Earth regularization problem (Kaplan et al., 2017).

To date, one of the most prevalent methods based on the Stokes formula is the Least Squares Modification of Stokes Formula with Additive Correction (LSMSA), also known as the Royal Institute of Technology (KTH) method, developed by Professor Sjöberg. This method has gained widespread acceptance due to its effectiveness in improving the accuracy of geoid height determinations.

### **Materials and research methods**

Least Squares Modification of Stokes Formula (LSMS) is one of the simplest and most practical approaches that has been successfully used to determine regional geoid models in various fields. The LSMS method integrates various heterogeneous data such as gravity anomalies, digital high relief models, global geopotential models, and GNSS and levelling data into a single least squares-based model. This approach ensures optimal data integration, which contributes to more accurate and reliable geoid modelling.

The LSMSA method, also known as the Royal Institute of Technology (KTH) approach to accurate geoid determination, has been developed by Professor Lars Sjöberg since 1984 (Goyal et al., 2017; Sjöberg, 1984; Sjöberg, 1991; Sjöberg, 2003). The theoretical and practical aspects of this method were finalised in 2006.

This method has been successfully applied in defining various regional geoid models. In history, this method was applied in the development of the Latvian geoid model. The RMS error was 7.5 cm in the Riga area using gravimetric data and a model of the Earth's gravity field (Sjöberg, 2003). In another study, the LSMSA method was used to determine the geoid in Poland, also applying LSMSA with additive corrections to compute a new gravimetric geoid model (Janpaule et al., 2014). In addition, the LSMSA method was used in a study to determine the geoid for the territory of Iran, although the main technique mentioned was Molodensky's method [(Kuczynska-Siehien, 2016)]. Also, the effectiveness of the method was demonstrated in a study on the geoid of South Korea, which showed a significant improvement in accuracy when new land gravity and GNSS/levelling data were included (Abdollahzadeh et al., 2011). The LSMSA method has been employed for local geoid determination by integrating spherical harmonic coefficients, gravity anomalies, and topographic data to achieve high accuracy, this method has been successfully applied in various regions, including Ethiopia (Bae et al., 2012), Sweden, the Baltic States (Bae et al., 2012), and Iran (Ellmann, 2004).

The method has also performed well in areas with very complex topography and in developing regions where gravity anomaly data are limited. This demonstrates the versatility and adaptability of this method to complex conditions. The modified Stokes method provides the approximate height of the geoid :

$$\tilde{N} = \frac{c}{2\pi} \iint_{\sigma_0} S^L(\psi) \Delta g d\sigma + c \sum_{n=2}^M b_n \Delta g_n^{GGM} \quad (3)$$

$$\text{where } c = \frac{R}{2\gamma}$$

- $S^L(\psi)$  – modified Stokes function;  
 $b_n$  – modification parameters;  
 $L$  – degree of modification of the core.

Using data error estimates and certain approximations (both theoretical and calculated), we proceed to compute the geoid height, referred to as the approximate geoid height. This process is detailed in [Kiamehr, 2006].

$$\tilde{N} = c \sum_{n=2}^{\infty} \left( \frac{2}{n-1} - Q_n^L - S_n^* \right) (\Delta g_n + \varepsilon_n^T) + c \sum_{n=2}^M (Q_n^L + S_n^*) (\Delta g_n + \varepsilon_n^S) \quad (4)$$

where  $\varepsilon_n^T, \varepsilon_n^S$  – are spectral errors of ground and global gravity anomalies, respectively.

Since the true values of the error components are unknown, their estimation can be based on some standard approaches and stochastic models.

The key factor to minimise the global RMS and reduce all relevant errors in geoid modelling is a suitable choice of LS parameters.

The geoid model was computed for a test area bounded by coordinates:

$40 \leq \varphi \leq 46$  latitude and  $66 \leq \varphi \leq 71$  longitude. Calculation of height anomalies was performed according to the block diagram of the calculation algorithm shown in Figure 1. in the LSMSOFT programme. (Ågren, 2004).

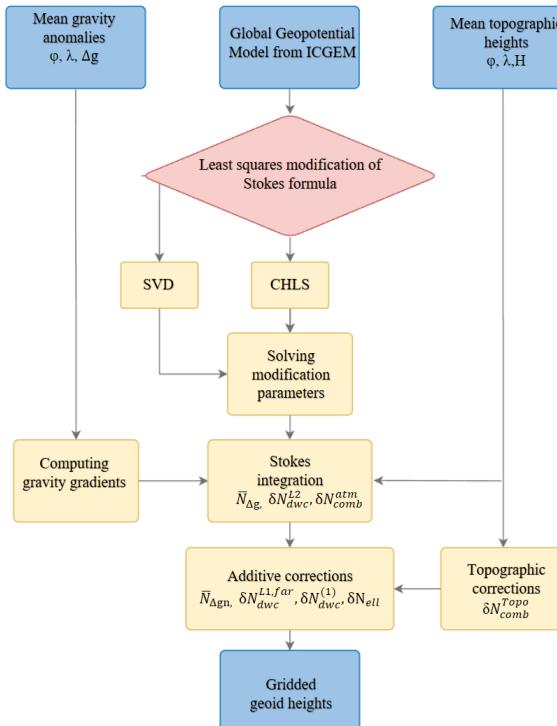


Figure 1. Block diagram of the calculation algorithm in LSMSOFT software (Ågren, 2004)

Geoid models for the test site were calculated using different maximum degrees of spherical harmonics of global gravity model (GGM) coefficients and spherical integration radii using LSMSSOFT software. Geoid model calculations included the use of XGM2019 spherical harmonic coefficients up to degrees 120, 200, 300, 400, 500, 630 with a combination of ground gravity data error variance  $C(0)$  - 0.5, 1, 3, 6, 9, 16 mGal<sup>2</sup>. The results are summarised in Table 1 and Figure 2.

Table 1 Statistics of fitting the combination of spherical harmonic coefficients with error variance of ground gravimetric data

Mmax	C(0), mGal <sup>2</sup> .									
	16		9		6		3		1	
STD	RMSE	STD	RMSE	STD	RMSE	STD	RMSE	STD	RMSE	
630	0,259	0,284	0,220	0,244	0,216	0,236	0,212	0,225	0,209	0,214
500			0,216	0,229	0,213	0,223	0,210	0,218	0,208	0,211
400									0,208	0,210
360									0,207	0,208
300									0,206	0,205
200									0,203	0,272
180									0,202	0,274

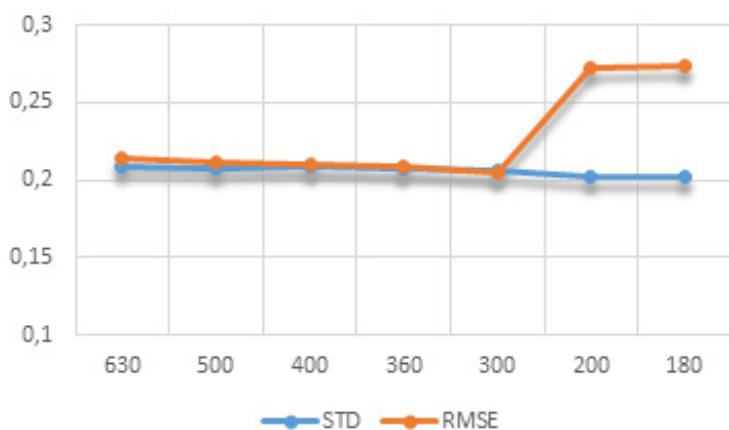


Figure 2 - Graph of statistic change with decreasing degree of GGM with error variance of ground gravimetric data  $C(0)=1$  mGal<sup>2</sup>

Based on the obtained results, value matrices were utilized as inputs for the final version of the model:

- Combination of terrestrial gravimetric - Digitized gravity maps and WGM2012 data;
- Harmonics of the global gravity model - XGM2019;

- Digital elevation model - GLO30.

The initial parameters for calculating the modification parameters were:

- Degree of modification L=M=300;
- Error variance of ground gravimetric data C(0)=1 mGal<sup>2</sup>;
- Integration cap size  $\psi=1^\circ$ .

The preliminary model of the geoid is given in Figure 3, Geoid heights for a given area vary in the range from -44 till -33 meters.

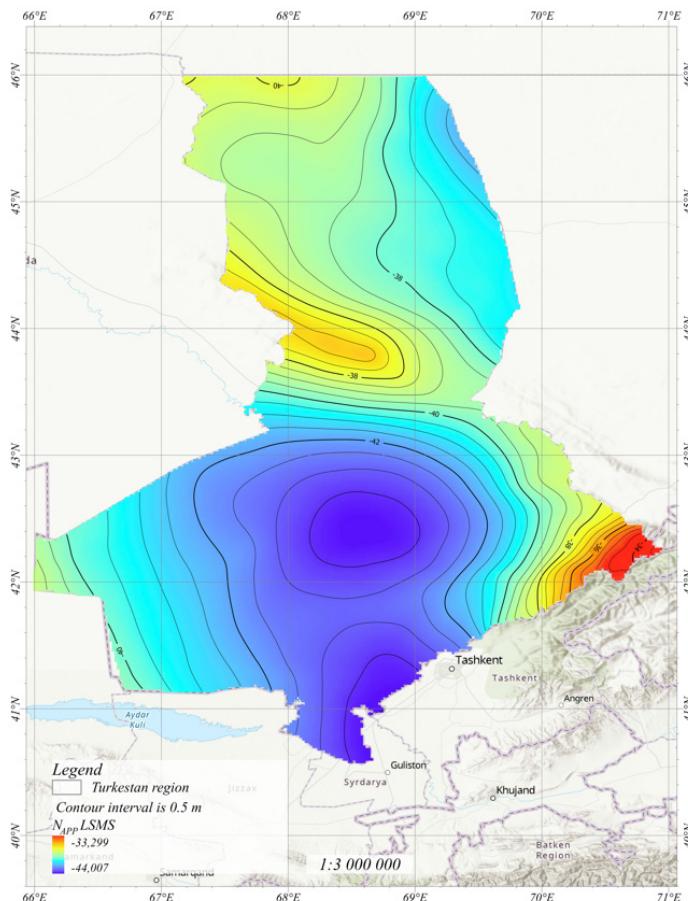


Figure 3 - Approximate geoid heights without Napp corrections (first approximation model)

*Additive corrections.* When using Stokes' formula to define the geoid, it is crucial to ensure that there are no external masses beyond the geoid and that gravity data is reduced to sea level. However, the existence of topographic and atmospheric masses above the geoid requires the addition of specific corrections to satisfy these conditions.

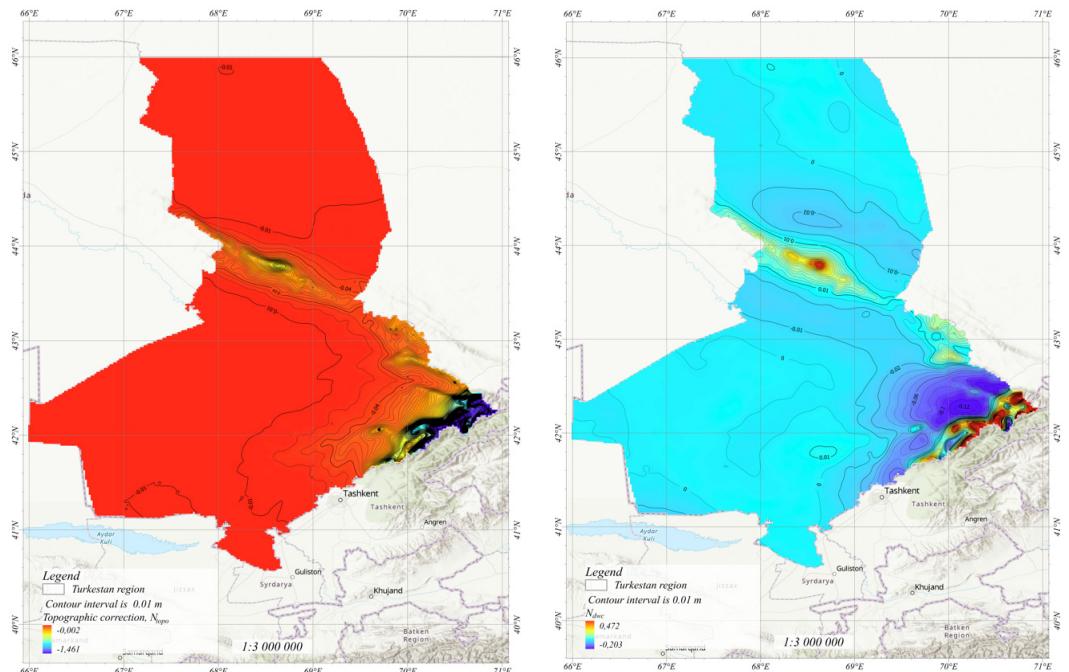
The computational procedure for estimating the final geoid height can be performed using the following formula:

(5)

where  $\delta$ - is a combined topographic correction that includes the sum of the direct

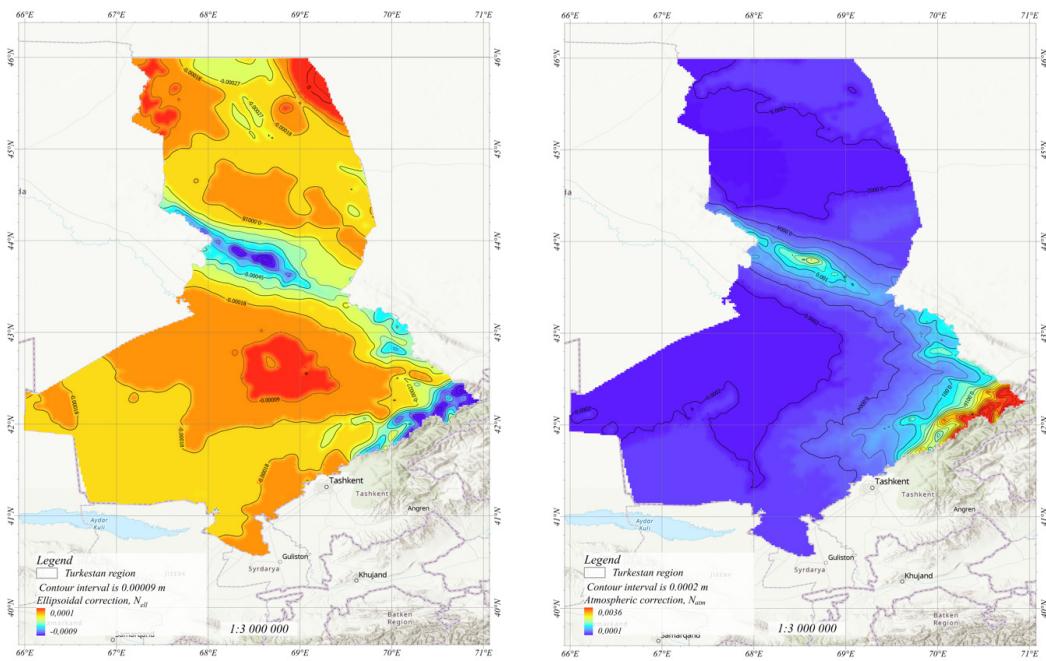
and indirect topographic effects on geoid height,  $\delta$  - downward continuation effect,  $-$  is a combined atmospheric correction including the sum of direct and indirect atmospheric effects, and  $\delta$  - ellipsoidal correction for the spherical approximation of the geoid in the Stokes formula to an ellipsoidal reference surface.

Additive corrections for the geoid model were also calculated using LSMSSOFT. The calculation results are shown in Figure 4.



a) Combined topographic correction

b) Correction for analytical continuation downwards



c) Ellipsoidal correction

d) Combined atmospheric correction

Figure 4 - Corrections to approximate geoid heights using the

a) topographic correction, b) correction for analytical downward continuation, c) ellipsoidal correction, d) atmospheric correction.

The topographic correction, illustrated in Figure 4a, ranges from -1.9671 m to -0.0004 m, with a mean value of -0.059 m and a standard deviation of 0.175 m. The minimum value of the DWC reduction is -0.458 m, the maximum is 1.102 m, the mean is 0.003 m, and the standard deviation is 0.068 m, as shown in Figure 4b. The ellipsoidal correction, depicted in Figure 4c, varies from -1.2 mm to 0.2 mm, with a mean of 0.19 mm and a standard deviation of 0.145 mm. The atmospheric correction across the study area is minimal, with values ranging from 0.1 mm to 4.2 mm, a mean of 0.48 mm, and a standard deviation of 0.55 mm, as shown in Figure 4d. The overall correction values for the test area have a minimum of -1.822 m, a maximum of 0.031 m, a mean of -0.062 m, and a standard deviation of 0.15 m.

Figure 5 illustrates the outcomes of the calculations performed using the Least Squares Modification of Stokes formula with additive corrections, the geoid model for the test area that covers an expanse exceeding 110,000 km<sup>2</sup>.

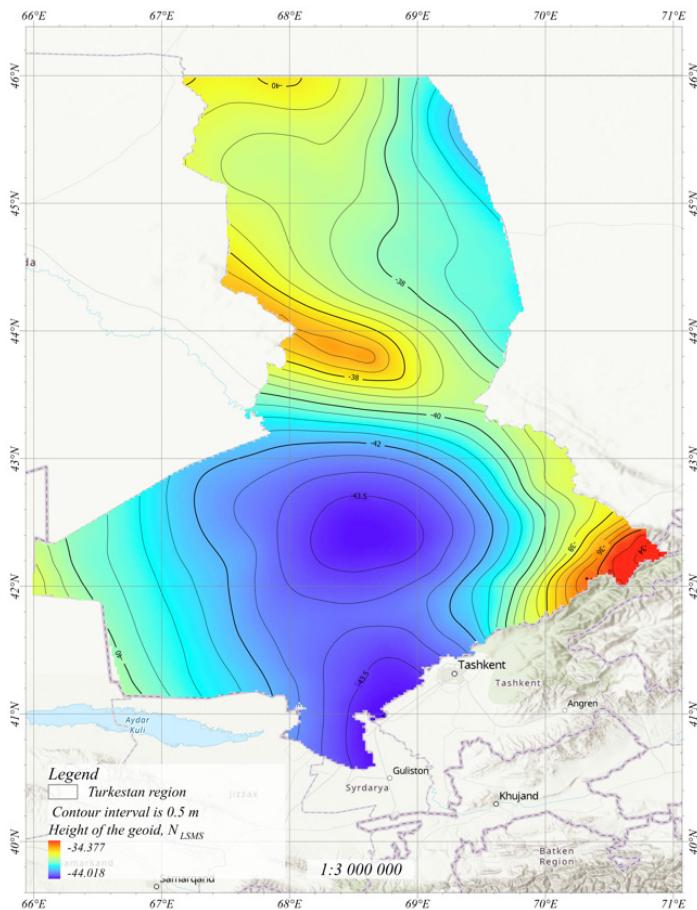


Figure 5 - Height of geoid according to the method of Modification of Stokes formula by the method of least squares,  $N_{LSMS}$

The calculated geoid heights at the test site using the LSMS method range from -48.244 m to -32.776 m, with a mean of -40.405 m and a standard deviation of 2.210 m.

## Results

The accuracy of the geoid model was assessed by interpolating heights to GNSS/levelling control points. Statistics of deviations  $N_{\text{geoid}} - N_{\text{GNSS/Lev}}$ , which are indicators of model errors at control points, are presented in Tables 2, 3.

Table 2. Statistics of differences between geoid heights  $N_{\text{GNSS/lev}}$  and  $N_{\text{Geoid}}$ , obtained from different calculation methods (unit, m)

Methods	Min	Max	Mean	STD	RMSE
N <sub>LSMS</sub>	-0,8134	0,3799	0,0002	0,2061	0,2052
N <sub>CSH</sub>	-0,8269	0,3992	-0,0156	0,2039	0,2035

Table 3: Range of values of geoid height differences  $N_{\text{GNSS/lev}}$  and  $N_{\text{Geoid}_i}$  (unit, %)

GGM	$\leq -0.4\text{m}$	$\leq -0.3\text{m}$	$\leq -0.2\text{m}$	$\leq -0.1\text{m}$	$\leq 0\text{m}$	$\leq 0.1\text{m}$	$\leq 0.2\text{m}$	$\leq 0.3\text{m}$	$\leq 0.4\text{m}$
$N_{LSMS}$	7,48	0,93	1,87	6,54	15,89	43,93	15,89	4,67	2,80
$N_{CSH}$	7,48	0,93	1,87	5,61	20,56	43,93	14,02	3,74	1,87

Table 3 shows that more than 75% of the points accuracy lies between -0.1 and 0.2, which shows good convergence.

The accuracy of a gravimetric geoid model is typically evaluated using statistical measures such as standard deviation (STD) and root mean square error (RMSE). These metrics quantify the discrepancies between the gravimetric geoid model and the geometric geoid model, providing a rigorous assessment of the model's precision (Pa'suya et al., 2022). By estimating the RMS values of the differences and considering the error ranges, the best solution for the gravimetric geoid model can be found. However, direct comparison of geoid models may not be feasible due to the presence of possible systematic errors (i.e., biases). The offset and slope of the raw data in the coordinate directions of the global system axis, representing the zero- and first-degree harmonics, are missing parameters of the gravimetric geoid. Various corrective surface models can be used to account for these systematic errors.

Table 4 - Statistics after application of the correction surface for geoid heights using the method  $N_{LSMS}$

Method	Statistics	Before correction	After correction		
			4 parameters	5 parameters	7 parameters
$N_{LSMS}$	Min	-0.813	-0.732	-0.737	-0.694
	Max	0.380	0.413	0.419	0.450
	Mean	0.0002	-9.47e-07	2.88e-11	-3.59e-09
	STD	0.206	0.201	0.199	0.195

The standard deviation of the adjusted residual values is conventionally regarded as an external metric for assessing the absolute accuracy of the geoid model. Table 4 presents a detailed statistical analysis of the results obtained by applying correction surfaces to the computed geoid model.

### Conclusion

For the initial calculation of the local geoid for the test area, the Least Squares Modification of Stokes' formula with Additive corrections (LSMSA), also known as the KTH-method developed by professor L Sjöberg, was employed. To mitigate systematic errors between gravimetric geoid heights and those derived from GNSS/levelling, four-parameter, five-parameter, and seven-parameter models were utilized. Among these, the seven-parameter model demonstrated the highest accuracy, achieving a reduction in the standard deviation by approximately 1 cm. The accuracy evaluation results showed that the method has an accuracy of 0.195 m, indicating that careful selection of data and internal calculation parameters is required. In the LSMSA method, the accuracy of the results obtained was affected by the selection of modification parameters. It was found that the earth gravity

data error was the main parameter affecting the accuracy of the LSMSA method. This indicates that it is necessary to evaluate the accuracy of gravity data. Improving the density and accuracy of terrestrial gravity data can be an effective way to improve the accuracy of the geoid model using this method.

The development of local geoid model will allow to further scale the results of research work throughout the country and introduce the methodology of building a geoid model in public and private organisations engaged in the development and use of spatial data. Since officially there are no working analogues on the territory of Kazakhstan, the developed model is relevant and competitive within the country.

**Acknowledgements:** The study was carried out with the financial support of the Committee of Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan (grant No. BR21882366).

## REFERENCES

- Abdollahzadeh M., Alamdar M. (2011). Application of Molodensky's Method for Precise Determination of Geoid in Iran. *Journal of Geodetic Science*, — 1(3). — 259–270. DOI: 10.2478/v10156-011-0004-0 (in Eng).
- Ågren J. (2004). Regional geoid determination methods for the era of satellite gravimetry: numerical investigations using synthetic earth gravity models (Doctoral dissertation, Infrastruktur).
- Bae T.S., Lee J., Kwon J.H., Hong C.K. (2012). Update of the precision geoid determination in Korea. *Geophysical prospecting*, — 60(3). — 555–571. DOI: 10.1111/j.1365-2478.2011.01017.x (in Eng).
- Ellmann A. (2004). The geoid for the Baltic countries determined by the least squares modification of Stokes formula (Doctoral dissertation, Infrastruktur).
- Goyal R., Nagarajan B., Dikshit O. (2017). Status of precise geoid modelling in India: A review. In Proceedings of 37th Indian National Cartographic Association International Congress on Geoinformatics for Carto-Diversity and Its Management, Indian Cartographer. — Pp. 308–313).
- Janpaula, I. (2014). Application of KTH method for determination of latvian geoid model. In The International Scientific Conference „Innovative Materials, Structures and Technologies” (pp. 64–68).
- Kaplan E.D., Hegarty C. (Eds.). (2017). Understanding GPS/GNSS: principles and applications. Artech house. — ISBN-13 & 978-1-63081-058-0
- Kiamehr R. (2006). Precise gravimetric geoid model for Iran based on GRACE and SRTM data and the least-squares modification of Stokes' formula: with some geodynamic interpretations (Doctoral dissertation, KTH).
- Kuczynska-Siehien J., Lyszkowicz A. & Birylo M. (2016). Geoid determination for the area of Poland by the least squares modification of Stokes' formula. *Acta Geodyn. Geomater.*, —13(1), — 19–26. DOI: 10.13168/AGG.2015.0041 (in Eng).
- Mayorov A.N. (1996). On the choice of the Stokes formula transformation. Scientific and technical collection on geodesy, aerospace surveys and cartography. *Physical geodesy*. — Moscow, TsNIIGAiK. (in Russ).
- Pa'suya M.F., Md Din A.H., Abbak R.A., Hamden M.H., Yazid N.M., Aziz M.A.C. & Samad M.A.A. (2022). Hybrid geoid model over peninsular Malaysia (PMHG2020) using two approaches. *Studia Geophysica & Geodaetica*, — 66.
- Sjöberg L.E. (2003). A general model for modifying Stokes' formula and its least-squares solution. *Journal of geodesy*, — 77, — 459–464.
- Sjöberg L.E. (2003). A solution to the downward continuation effect on the geoid determined by Stokes' formula. *Journal of geodesy*. — 77. — 94–100.
- Sjöberg L.E. (1984). Least squares modification of Stokes' and Vening Meinesz' formulas by accounting for errors of truncation, potential coefficients and gravity data. University of Uppsala, Institute of Geophysics, — Department of Geodesy.
- Sjöberg L.E. (1991). Refined least squares modification of Stokes' formula. *Manuscripta geodaetica*. —16(6). — 367–375.

**CONTENT**

<b>A.E. Abetov, A.A. Auyesbek</b> GEOLOGICAL-GEOPHYSICAL CRITERIA OF THE JEZKAZGAN ORE DISTRICT IN CENTRAL KAZAKHSTAN.....	6
<b>K. Akishev, K. Aryngazin, A. Tleulessov, L. Bulyga, V. Stanevich</b> THE USE OF SIMULATION MODELING IN CALCULATING THE PRODUCTIVITY OF THE TECHNOLOGICAL SYSTEM FOR THE PRODUCTION OF BUILDING PRODUCTS WITH FILLERS FROM MAN-MADE WASTE.....	22
<b>V.V. Gerasidi, R.G. Dubrovin, V.V. Kukartsev, T.A. Panfilova, G.V. Stas</b> BOOST SYSTEM DIAGNOSTIC PARAMETERS OF COHERENT GAS PISTON INSTALLATIONS OF MINING ENTERPRISES.....	33
<b>E.M. Elekeev, B.P. Stepanov</b> TO THE ISSUE OF EFFICIENCY OF APPLICATION OF THE SAFETY CONTROL PROGRAM AT NUCLEAR FACILITIES.....	48
<b>A.I. Epikhin, A.A. Stupina, I.A. Panfilov, V.V. Bukhtoyerov, N.A. Shepeta</b> DETERMINANTS FOR ASSESSING THE ENERGY EFFICIENCY OF A COAL MINING ENTERPRISE.....	61
<b>E.A. Efremenkov, E.S. Chavrov, E.P. Khaleyeva, V.V. Tynchenko</b> EVALUATION OF TECHNIQUES FOR DETERMINING THE LOADING OF A CYCLOIDAL SATELLITE ROLLING BEARING.....	72
<b>Zh.A. Zhanabayeva, K.T. Narbayeva, G.K. Ismailova, M.S. Ospanova, J. Rodrigo-Ilarri</b> ASSESSMENT OF THE RESERVOIRS IMPACT ON THE MAXIMUM RUNOFF OF THE SYRDARYA RIVER.....	85
<b>M.K. Jexenov, Zh.K. Tukhfatov, E.K. Bektay, R.Sh. Abdinov, G.S. Turysbekova</b> STRUCTURAL-TECHTONIC AND MINERALOGICAL STRUCTURE OF INDER LIFTING FIELD, MINING AND CHEMICAL RAW MATERIALS IN ATYRAU REGION.....	96
<b>G.M. Iskaliyeva<sup>1,2*</sup>, N.K. Sydyk<sup>1</sup>, A.K. Kalybayeva<sup>1,3</sup>, M.S. Sagat<sup>1</sup>, A. Samat</b> USE OF WATER INDICES FOR WATERBODIES IN THE ESIL WATER MANAGEMENT BASIN.....	117
<b>Z.M. Kerimbekova, A.A. Tashimova, G.I. Issayev, E.K. Ibragimova, M.Zh. Makhambetov</b> CALCULATION OF ENVIRONMENTAL AND ECONOMIC DAMAGE CAUSED BY CURRENT SYSTEMS OF SOLID WASTE MOVEMENT IN OIL PRODUCTION..	131
<b>M.Zh. Makhambetov, R. Izimova, G.I. Issayev, N.A. Akhmetov, E.K. Ibragimova</b> ECOLOGICAL-GEOLOGICAL ASSESSMENT OF TECHNOGENICALLY DISTURBED TERRITORIES OF OIL FIELDS OF THE ATYRAU REGION.....	143

<b>A.D. Mekhtiyev, V.V. Yugay, Y.G. Neshina, N.B. Kaliaskarov, P. Madi</b> FIBER-OPTIC SYSTEM FOR CONTROLLING OPEN PIT SIDE ROCK DISPLACEMENT.....	157
<b>A.S. Mussina, G.U. Baitasheva, B.S. Zakirov, Ye.P. Gorbulicheva</b> CONDITIONS FOR PREPARING THE SURFACE OF CONTACT PARTS FOR WETTIBILITY WITH MERCURY.....	168
<b>A.N. Muta, R.B. Baimakhan, G.I. Salgarayeva, N. Kurmanbekkyzy, A. Tileikhan</b> STUDY OF THE STRENGTH PROPERTIES OF SOILS COMPOSING THE GEOLOGICAL STRUCTURE OF THE KOK TOBE MOUNTAIN.....	185
<b>B. Mukhambetov, B. Nasiyev, Zh. Kadasheva, R. Abdinov, R. Meranzova</b> ADAPTABILITY OF KOCHIA PROSTRATA (L.) SCHRAD AND CAMPHOROSMA MONSPELIACA AGRICULTURAL ECOSYSTEMS ON SALINE LANDS OF THE NORTHERN CASPIAN DESERT.....	197
<b>M. Nurpeisova, G. Dzhangulova, O. Kurmanbaev, Z. Sarsembekova, A. Ormanbekova, Y.Kh. Kakimzhanov</b> CREATION OF GEODETIC REFERENCE NETWORK FOR MONITORING TRANSPORT INTERCHANGES IN SEISMIC AREAS.....	209
<b>B.T. Ratov, V.L. Khomenko, A.E. Kuttybayev, K.S. Togizov, Z.G. Utepor</b> INNOVATIVE DRILL BIT TO IMPROVE THE EFFICIENCY OF DRILLING OPERATIONS AT URANIUM DEPOSITS IN KAZAKHSTAN.....	224
<b>A.A. Tashimova, G.I. Issayev, Z.M. Kerimbekova, E.K. Ibragimova, A.M. Bostanova</b> ANALYSIS OF THE RESOURCE POTENTIAL OF SOLID OIL PRODUCTION WASTE.....	237
<b>M.K. Tynykulov, O.D. Shoykin, S.O. Kosanov, M.B. Khusainov, Zh.G. Ibraybekov</b> BIOREMEDIATION OF ZONAL SOILS IN AYIRTAY DISTRICT OF NORTH KAZAKHSTAN REGION.....	246
<b>A.S. Urazaliyev, D.A. Shoganbekova, R. Shults, M.S. Kozhakhmetov, G.M. Iskaliyeva</b> INVESTIGATION OF LSMSA APPROACH IN LOCAL GEOID MODELING.....	261

## **Publication Ethics and Publication Malpractice in the journals of the National Academy of Sciences of the Republic of Kazakhstan**

For information on Ethics in publishing and Ethical guidelines for journal publication see <http://www.elsevier.com/publishingethics> and <http://www.elsevier.com/journal-authors/ethics>.

Submission of an article to the National Academy of Sciences of the Republic of Kazakhstan implies that the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint, see <http://www.elsevier.com/postingpolicy>), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. In particular, translations into English of papers already published in another language are not accepted.

No other forms of scientific misconduct are allowed, such as plagiarism, falsification, fraudulent data, incorrect interpretation of other works, incorrect citations, etc. The National Academy of Sciences of the Republic of Kazakhstan follows the Code of Conduct of the Committee on Publication Ethics (COPE), and follows the COPE Flowcharts for Resolving Cases of Suspected Misconduct ([http://publicationethics.org/files/u2/New\\_Code.pdf](http://publicationethics.org/files/u2/New_Code.pdf)). To verify originality, your article may be checked by the originality detection service Cross Check <http://www.elsevier.com/editors/plagdetect>.

The authors are obliged to participate in peer review process and be ready to provide corrections, clarifications, retractions and apologies when needed. All authors of a paper should have significantly contributed to the research.

The reviewers should provide objective judgments and should point out relevant published works which are not yet cited. Reviewed articles should be treated confidentially. The reviewers will be chosen in such a way that there is no conflict of interests with respect to the research, the authors and/or the research funders.

The editors have complete responsibility and authority to reject or accept a paper, and they will only accept a paper when reasonably certain. They will preserve anonymity of reviewers and promote publication of corrections, clarifications, retractions and apologies when needed. The acceptance of a paper automatically implies the copyright transfer to the National Academy of sciences of the Republic of Kazakhstan.

The Editorial Board of the National Academy of sciences of the Republic of Kazakhstan will monitor and safeguard publishing ethics.

Правила оформления статьи для публикации в журнале смотреть на сайте:

[www.nauka-nanrk.kz](http://www.nauka-nanrk.kz)

**ISSN 2518-1483 (Online), ISSN 2224-5227 (Print)**

<http://geolog-technical.kz/en/archive/>

Подписано в печать 15.08.2024.

Формат 60x88<sup>1/8</sup>. Бумага офсетная. Печать - ризограф.  
15,0 п.л. Тираж 300. Заказ 4.