IRSTI 70.03.05, 89.57.35 https://doi.org/10.26577/JGEM20257728

G.M. Iskaliyeva*, A.A. Amangelgi, M.S. Sagat, A.A. Merekeyev, N.K. Sydyk, A.K. Kalybayeva

«Ionosphere institute» LLP, Almaty, Kazakhstan
*e-mail: igm.ionos@gmail.com

COMPARATIVE EVALUATION OF SRTM, ASTER, AIRBUS, AND ALOS DEMS FOR HYDROLOGICAL RESEARCH ACROSS DIVERSE TERRAIN TYPES

Digital Elevation Models (DEMs) are a key tool for hydrological modeling and water resource analysis, enabling more accurate assessment of runoff processes, precipitation distribution, and flood risks. This study presents a comparative analysis of four global DEMs: Airbus WorldDEM4Ortho, ALOS AW3D, SRTM, and ASTER GDEM, aimed at evaluating their accuracy and practical applicability across different landscape conditions, including mountainous and flat terrains. To assess model quality, state geodetic points with high-precision elevation control and topographic maps were used, providing a reliable reference for comparison. Additionally, river networks extracted from the DEMs were compared with reference data obtained from Landsat 8 and Sentinel 2 satellite imagery, allowing verification of hydrological representation accuracy.

The results indicate that Airbus WorldDEM4Ortho demonstrates the highest vertical accuracy and offers a more detailed and accurate representation of river networks due to its high spatial resolution and quality source data. The ALOS AW3D model showed comparable accuracy and hydrological reproduction, making it a worthy alternative. Meanwhile, the SRTM and ASTER GDEM models exhibit noticeable deviations, especially in flat areas, reducing their suitability for detailed hydrological modeling. Nevertheless, SRTM remains widely used due to its free accessibility, stability, and sufficient accuracy for large-area analyses. In contrast, ASTER GDEM is less suitable for high-resolution and detailed hydrological analysis tasks.

This study emphasizes the critical importance of selecting the appropriate DEM based on terrain type and specific hydrological analysis goals, as this significantly impacts the quality of risk assessment related to water resource management and engineering planning.

Key words: Digital elevation models, remote sensing, river networks, Airbus WorldDEM4Ortho, ALOS AW3D, SRTM, ASTER GDEM.

Г.М. Искалиева*, Ә.А. Амангелді, М.С. Сағат,
А.А. Мерекеев, Н.Қ. Сыдық, А.К. Қалыбаева

«Ионосфера институты» ЖШС, Алматы, Казақстан
*e-mail: igm.ionos@gmail.com

Әртүрлі рельеф жағдайларында гидрологиялық зерттеу жүргізуге арналған SRTM, ASTER, AIRBUS және ALOS жердің сандық үлгілерін бағалау

Жер бедерінің сандық үлгісі (ЖБСҮ) гидрологиялық модельдеу мен су ресурстарын талдаудың негізгі құралы болып табылады, бұл ағын процестерін, жауын-шашынның таралуын және су тасқыны қаупін дәлірек бағалауға мүмкіндік береді. Осы жұмыста төрт жаһандық ЖБСҮ – Airbus WorldDEM4Ortho, ALOS AW3D, SRTM және ASTER GDEM – әртүрлі жер бедері жағдайларында, соның ішінде таулы және жазықты аймақтарда олардың дәлдігі мен практикалық қолданысын анықтау мақсатында салыстырмалы талдау жүргізілді. Модельдердің сапасын бағалау үшін жоғары дәлдіктегі биіктік байланысы бар мемлекеттік геодезиялық нүктелер, сондай-ақ салыстыру үшін сенімді эталон ретінде қамтамасыз ететін топографиялық карталар пайдаланылды. Сонымен қатар, Жер бедерінің сандық үлгісінен алынған өзен желілерін Landsat 8 және Sentinel 2 спутниктік суреттерден алынған эталондық деректермен салыстырылып, олардың гидрографиялық бейнелеуінің сәйкестігі тексерілді.

Зерттеу нәтижелері Airbus WorldDEM4Ortho моделінің биіктік деректерінің дәлдігі жоғары екенін және кеңістіктік айырымдылығы мен бастапқы деректер сапасының арқасында өзен торларын анағұрлым нақты көрсете алатынын көрсетті. ALOS AW3D моделі де дәлдігі мен гидрографиялық бейнелеу сапасы жағынан ұқсас нәтижелер көрсетті, бұл оны балама ретінде пайдалануға мүмкіндік береді. Ал SRTM мен ASTER GDEM модельдері, әсіресе жазық аймақтарда, қуларға ие, бұл оларды егжей-тегжейлі гидрологиялық модельдеу үшін пайдалануға шектеу қояды. Сонымен қатар, SRTM моделі – ашық қолжетімділігі, тұрақтылығы және кең ауқымды аумақтарды бағалаудағы жеткілікті дәлдігі арқасында кеңінен қолданылады. Ал ASTER GDEM моделі жоғары дәлдік пен нақты гидрологиялық талдауды қажет ететін жағдайларға онша сәйкес келмейді.

Бұл зерттеу жер бедерінің сандық үлгісін дұрыс таңдаудың маңыздылығын көрсетеді. Жер бедерінің түрі мен гидрологиялық талдаудың нақты мақсатына қарай таңдалған үлгі су ресурстарын басқару және инженерлік іс-шараларды жоспарлау кезіндегі қауіптерді бағалаудың сапасына айтарлықтай әсер етеді.

Түйін сөздер: Жердің сандық үлгілері, қашықтықтан зондтау, өзендер торабы, Airbus WorldDEM4Ortho, ALOS AW3D, SRTM, ASTER GDEM.

Г.М. Искалиева*, Ә.А. Амангелді, М.С. Сағат, А.А. Мерекеев,
Н.Қ. Сыдық, А.К. Калыбаева

ТОО «Институт ионосферы», Алматы, Казахстан
*e-mail: igm.ionos@gmail.com

Сравнительная оценка ЦМР SRTM, ASTER, AIRBUS и ALOS для гидрологических исследований в различных ландшафтных условиях

Цифровые модели рельефа (ЦМР) представляют собой ключевой инструмент для гидрологического моделирования и анализа водных ресурсов, позволяя более точно оценивать процессы стока, распределение осадков и риски наводнений. В данной работе проведён сравнительный анализ четырёх глобальных ЦМР: Airbus WorldDEM4Ortho, ALOS AW3D, SRTM и ASTER GDEM – для определения их точности и практической применимости в различных ландшафтных условиях, включая горные и равнинные территории. Для оценки качества моделей использовались государственные геодезические пункты с высокоточной высотной привязкой, а также топографические карты, что обеспечило надёжный эталон для сравнения. Дополнительно выполнено сопоставление речных сетей, извлечённых из ЦМР, с эталонными данными, полученными на основе космических снимков Landsat 8 и Sentinel 2, что позволило проверить адекватность гидрографического отображения.

Результаты анализа показывают, что Airbus WorldDEM4Ortho демонстрирует наивысшую точность высотных данных и обеспечивает более детальное и адекватное представление речной сети, благодаря высокому пространственному разрешению и качеству исходных данных. Модель ALOS AW3D показала сопоставимые результаты по точности и гидрографическому воспроизведению, что делает её достойным альтернативным вариантом. В то же время модели SRTM и ASTER GDEM имеют заметные отклонения, особенно на равнинных участках, что снижает их пригодность для детального гидрологического моделирования. Несмотря на это, SRTM остаётся широко востребованной благодаря свободному доступу, стабильности и достаточной точности при анализе крупных территорий. ASTER GDEM, напротив, менее подходит для задач высокого разрешения и детального гидрологического анализа.

Данное исследование подчёркивает критическую важность правильного выбора цифровой модели рельефа в зависимости от типа рельефа и конкретных целей гидрологического анализа, поскольку это существенно влияет на качество оценки рисков, связанных с управлением водными ресурсами, и планирование инженерных мероприятий.

Ключевые слова: Цифровые модели рельефа, ДЗЗ, речные сети, Airbus WorldDEM4Ortho, ALOS AW3D, SRTM, ASTER GDEM.

Introduction

Digital Elevation Models (DEMs) are an important tool in hydrological modelling, having a significant impact on the processes of analysing and quantifying water-related risks. In this study, a comparative analysis of publicly available global DEMs is conducted to determine their applicability and performance in different modelling scenarios. Remote sensing techniques and Geographic Information Systems (GIS), in combination with digital elevation models, have proven to be highly effective in analysing drainage networks and catchment characteristics. Such methods can identify drainage patterns, flow orders and morphometric parameters with high accuracy (Joy M. A. R. et al., 2023; Elhag M. et al., 2018).

In particular, Landsat and ASTER GDEM satellite data have been successfully used to extract hydrological parameters, providing results comparable to traditional topographic maps in terms of accuracy and detail (Elhag M. et al., 2017; Rai P. K. et al., 2018; Shugulova D. K. et al., 2023). Morphometric analyses provide valuable information on catchment characteristics including drainage density, bifurcation coefficient and elongation coefficient, which play a key role in understanding catchment dynamics and planning effective water management strategies (Rai P. K. et al., 2018; Shaikh M. et al., 2021; Zhengissova N.Y. et al., 2024).

A number of studies have comparatively analysed different open source Digital Elevation Models (DEMs) for automatic extraction of drainage networks, identifying the advantages and limitations of each of the considered digital datasets. Such comparative studies are crucial to select the most appropriate datasets, considering specific regions and applications, such as floodplains with minimal elevation changes (Jamal S. et al., 2023).

ASTER GDEM, SRTM DEM and Cartosat-1 DEM have been evaluated in a part of the Kosi River basin in India using different thresholds of flow accumulation (Jamal S. et al., 2023). Among the most commonly used DEMs are ALOS, SRTM and ASTER, with ALOS showing higher vertical accuracy in mountainous areas (Chymyrov A., 2021). Hassan (Hassan I.O., 2018) noted that ALOS and SRTM are characterised by lower mean errors and standard deviations compared to ASTER. These numerical models have wide applications including hydrological modelling, elevation analysis and river network extraction (Jamal S. et al., 2023).

The accuracy of DEMs is determined by data collection technology, data processing methods and land cover types. The importance of accuracy assessment using ground control points and statistical methods is emphasised in studies to ensure the reliability of hydrological results (Chymyrov A., 2021; Hassan I.O., 2018).

In Uttar Pradesh, India, a separate study compared ASTER GDEM, SRTM DEM and ALOS DSM, where ALOS DSM provided more detailed representation of drainage networks at low flow accumulation thresholds (LN T et al., 2022). Similar studies in Brazil evaluated the performance of two computational tools, Hydrology and TauDEM, and three databases (SRTM, AGEDM and AW3D), revealing the advantage of TauDEM in drainage network extraction (Sousa Morais R.C. et al., 2016). In Portugal, drainage networks extracted from ASTER, SRTM and OpenStreetMap (OSM) were compared, evaluating their positional accuracy and completeness compared to reference data (Monteiro E. et al., 2018). All these works emphasise the importance of comparing different DEMs and extraction methods to accurately determine the structure of the drainage network.

Digital elevation models are a key tool for hydrological studies, enabling catchment modelling, analysing channel networks, and determining gradients and directions of surface runoff. Currently, there is a wide range of satellite-based DEMs, among which SRTM, ASTER, Airbus and ALOS are the most common, differing in resolution, elevation data acquisition methods and level of accuracy.

The purpose of this study is a comprehensive comparison of these digital elevation models in terms of their applicability to hydrological problems in areas with different types of relief – from flat and semi-desert to mountainous and foothill areas. This approach allows assessing the accuracy of each model's representation of the hydrographic network, watersheds and microrelief, as well as the impact of these features on the calculation of runoff and the formation of surface water flows.

Comparison of data from different DEMs facilitates a reasonable choice of the optimal model, taking into account the objectives of the study and the natural conditions of the region. The results obtained will help to determine the most accurate and stable digital elevation model for different landscape zones, which will improve the efficiency of hydrological calculations, ensure sustainable water resources management and reduce the probability of errors in water management planning.

Materials and methods

Geoinformation systems in combination with DEMs are valuable tools in hydrological research. Digital elevation models are used for processing and preparation of separate geospatial content for developed geoportals, and are the source data for automatic extraction of watercourses.

Currently, elevation data are available from several major sources and with different spatial resolutions. The main requirements for analysing DEMs were: coverage (area coverage); spatial resolution (cell size); accessibility (free cost); and consistency with selected criteria (location of reference points, streamflow characteristics). The study basin covers a vast territory, includes mountainous and flat terrain, and has a diverse vegetation cover, which presents a great difficulty in selecting and processing a suitable DEM. When analysing and comparing source data for automatic extraction of watercourses, available datasets were used: Airbus WorldDEM4Ortho, ALOS AW3D DSM (Standard), SRTM, ASTER GDEM. Their main characteristics are summarised in Table 1.

Table 1 – Main characteristics of the analysed global DEMs

Parameters	Airbus WorldDEM4Ortho	ALOS AW3D	SRTM		ASTER GDEM
			C-band	X-band	
Basic data	WORLDDEM	ALOS-2 radar images and archived optical data from the ALOS satellite	Interferometric radar image pairs obtained in 2000 by imaging from the Shuttle reusable spacecraft		Stereo pairs of optical images of the ASTER sensor of the Terra satellite
Year of creation	2011-2015	2006-2011	2003	2011	2011
Developer	Airbus Defence and Space	Japan Aerospace Exploration Agency (JAXA)	NASA, NGA (USA)	DLR (Germany)	METI (Japan), NASA (USA)
Distribution	On Limited Access (for licensed users of ESRI's ArcGIS software product)	In the public domain			In the public domain (usage restrictions apply) http://gdem.ersdac.jspacesystems.or.jp/; restrictions on use apply.
Coverage	global		60°N. – 56°S. (80 percent of the Earth's surface)		83°N – 83°S (99% of the Earth's surface)
Grid cell size	0,8´´ x 0,8´´ (24x24m)	1´´ x 1´´ (30x30 m)	1´´ x 1´´ (30x30 m for the USA territory); 3´´ x 3´´ (90x90 meters for the rest of the world)	1´´ x 1´´ (30x30m)	1´´ x 1´´ (30x30m)
Absolute height accuracy	LE90 – 4 m	LE90 – от 5 m	LE90 – <=16 m	LE90 –<=16 m	LE90 – 12-30 m
Relative height accuracy	LE90 – 2 m		LE90 – <=10 m	LE90 – <=6 m	
Source	ArcGIS Server ArcGIS Online	ALOS Research and Application Project of JAXAEORC, https://www.eorc.jaxa.jp/ALOS/en/aw3d30/data/index.htm	U.S. Geological Survey (USGS), https://earthexplorer.usgs.gov/		US National Aeronautics and Space Administration (NASA), https://search.earthdata.nasa.gov/search

Airbus WorldDEM4Ortho is a digital elevation model derived from the unedited WorldDEM and its auxiliary layers by automatic processing. WorldDEM data is based on radar satellite data from the TanDEM-X mission, funded by a Public-Private Partnership between the German Aerospace Center and Airbus Defence and Space, the Airbus Group division responsible for defence and aerospace products and services. The main objective of the mission was to create a worldwide (97% of the total land area) consistent and highly accurate digital surface model based on SAR interferometry. Data collection for the DEM began in January 2011 and was completed by mid-2015. A total of mutually overlapping 550,000 scenes were collected. Airbus WorldDEM4Ortho is given in geographic coordinates; the horizontal datum is the World Geodetic System (WGS84-G1150) and the vertical datum is the Earth Gravity Model 2008 (EGM2008). WorldDEM4Ortho is a height information layer optimised for orthorectification of high resolution and very high resolution optical and radar images (Okolie C. et al., 2024).

ALOS AW3D (ALOS World 3D Topographic-data) is compiled from ALOS-2 radar imagery acquired between 2006 and 2011 and archived optical data from the ALOS satellite. The Japan Aerospace Exploration Agency (JAXA) released a global DEM with ~30 m horizontal resolution updated void-filled version in March 2017 (Takaku J. et al., 2021).

In 2000, a radar interferometric survey was conducted from the reusable Shuttle spacecraft and an SRTM DEM was created for nearly 80% of the Earth's surface. Since 2014, global 1 angular second (~30 m) data are available through the USGS EarthExplorer interface. SRTM is one of the most used

DEMs and the data are in the public domain (Misael Uribe E. et al., 2024).

ASTER GDEM (Global Digital Elevation Model) is an advanced spaceborne radiation and reflection radiometer, it was developed jointly by METI (Ministry of Economy, Trade, and Industry of Japan) and NASA based on data from the ASTER sensor of the Terra satellite. In 2011, an improved version of the DEM, ASTER GDEM Version 2, was created by including 26,000 additional stereo pairs in the first version, increasing the horizontal and vertical accuracy of the product, adding new scenes and correcting errors. The resolution of the product is similar to that of STRM30, also using the vertical reference system EGM96 (El Mhamdı A et al., 2023).

When selecting the most appropriate DEM, the following criteria were compared: the location of the state geodetic network points on the DEM and topo map, morphometric characteristics of reference river flows extracted from the DEM and remote sensing data at the test sites. Topographic maps published in 2008-2009 by the Agency of the Republic of Kazakhstan for Land Management were used for comparison of elevation values. The topographic maps published in 2008-2009 by the Agency of the Republic of Kazakhstan on Land Resources Management were used for comparison of elevation values. According to these maps, points with established heights in mountainous and flat areas were selected.

Results and discussion

Topographic maps were brought into a single cartographic projection with DEMs. Points of the state geodetic network in the mountainous and plain areas were selected from the maps and their values were compared with the data of each DEM (Table 2).

Table 2 – Comparison of elevation values from topographic maps and DEMs

Source data	Height, m								
	Mountain area				Plain area				
Topographic map	3305.6	2547.5	1748.6	925.7	215.1	197.4	173.9	161.1	150.3
Airbus WorldDEM4Ortho	3301.5	2547.6	1744.5	930.6	212.3	195.51	172.5	162.1	151.5
SRTM	3227	2535	1740	925	210	192	170	158	150
ALOS AW3D	3301	2550	1744	929	213	196	171	161	152
ASTER GDEM	3292	2525	1740	925	221	187	176	158	145

Based on the results of height data comparison, it can be seen that Airbus WorldDEM4Ortho and ALOS AW3D DEM data have less deviation from the topographic map height values. The accuracy of the Airbus WorldDEM4Ortho DEM data value is one tenth of a meter, which makes it more detailed compared to ALOS AW3D (Figure 1). In spite of the same cell size ASTER shows worse results on the flat area, having large deviations from the reference values.

Comparison of morphometric characteristics of watercourses was carried out between the extracted watercourses from the considered DEMs and digitised conditionally reference watercourses from Landsat 8 (15 m resolution) and Sentinel 2 (10 m resolution) satellite images for 2019 at the test sites.

The analysis of works and publications on successful foreign experiments allows to reveal that the methodology of river networks creation by automatic extraction from DEM consists of certain stages. Running the algorithm according to the method is a sequence of launching the Hydrology tool group from the Spatial Analyst module or Arc HYDRO module. The same input parameters were used to extract the watercourses of the test sites from the considered datasets. The accuracy of the extracted watercourses was assessed by matching their characteristics with those of the reference watercourses.

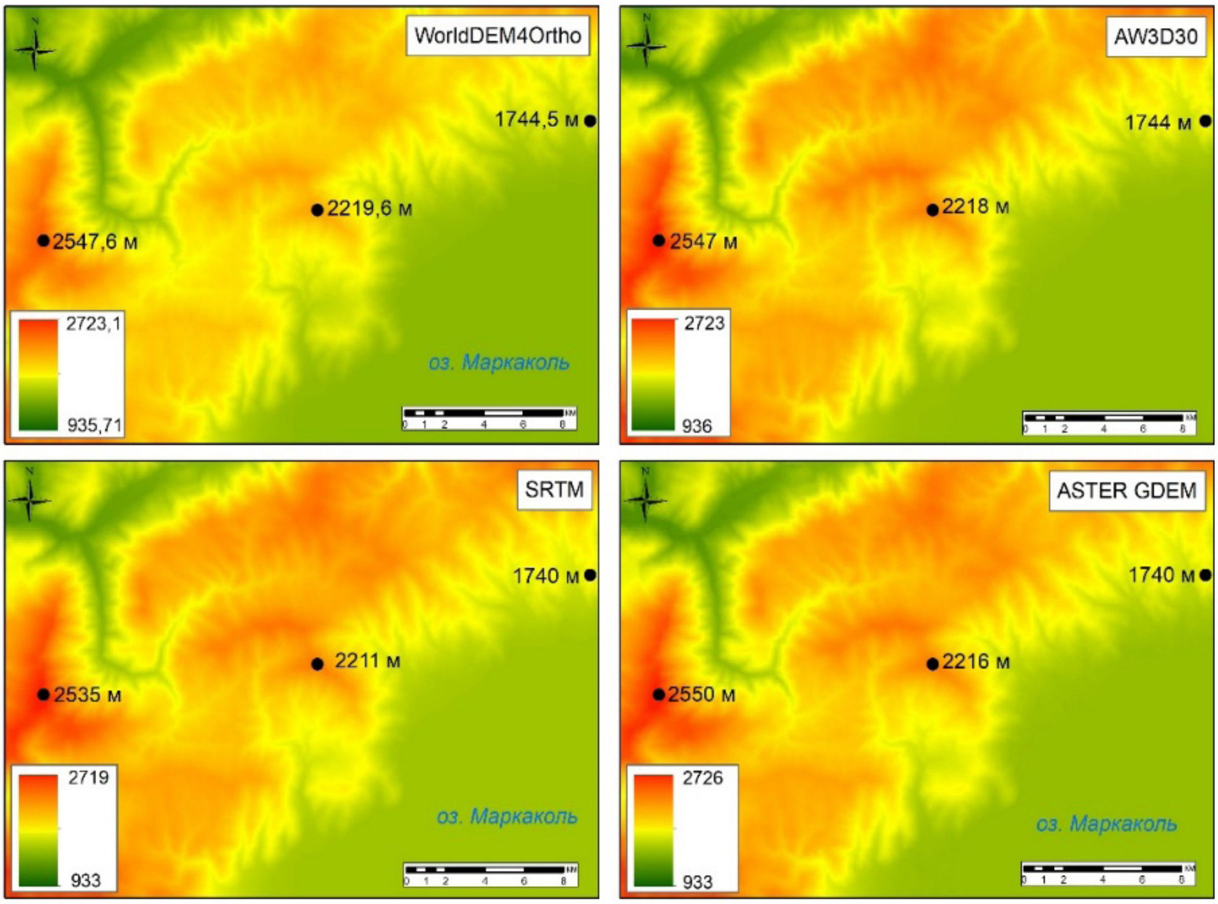


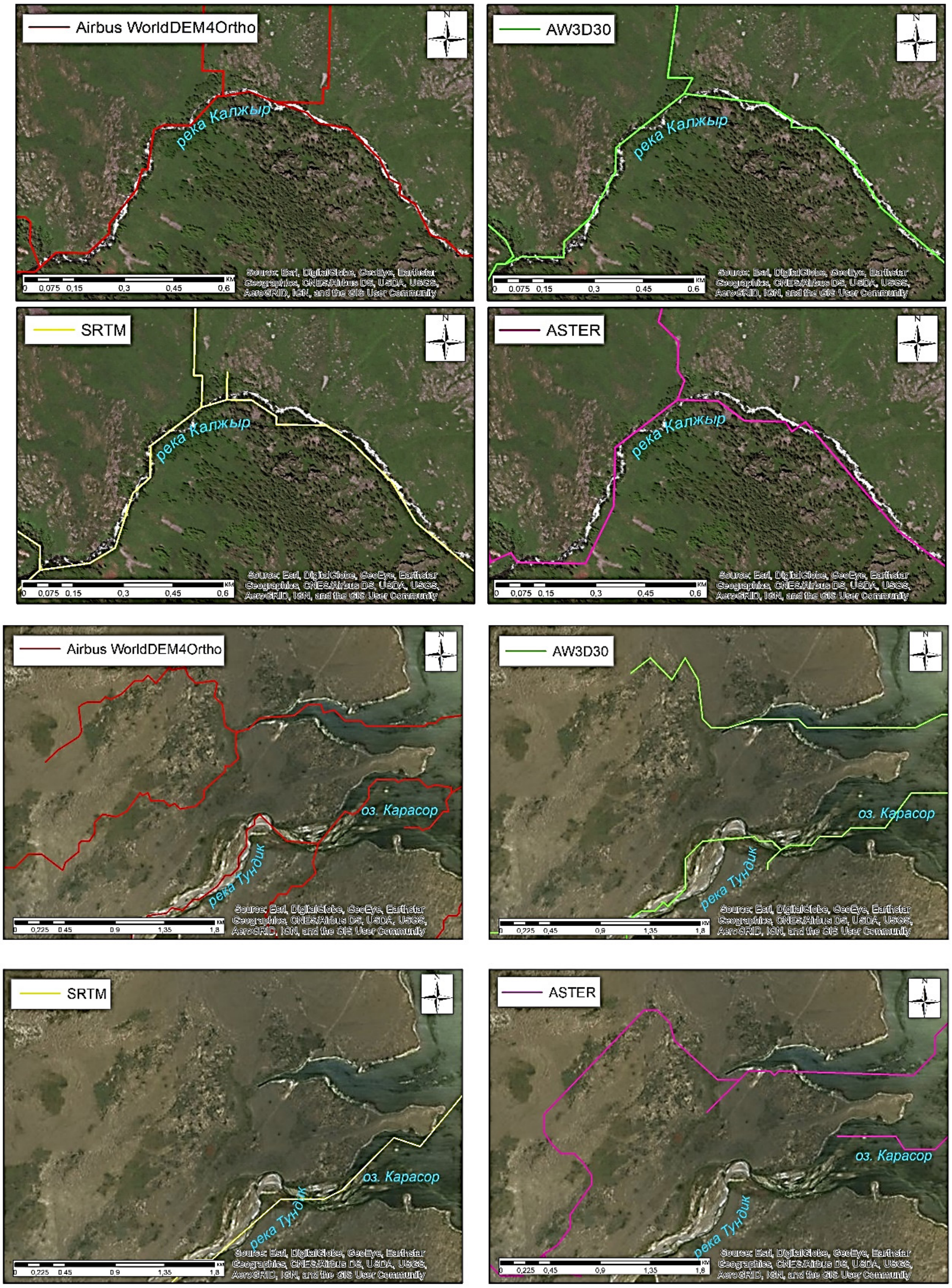
Figure 1 – Comparison of elevation values of digital elevation models

Visually in the mountainous area all elevation matrices show good results, however the rivers obtained from Airbus WorldDEM4Orth more smoothly replicate the river meandering, showing a clear river bend. The ALOS AW3D DEM gives similar results to those from Airbus WorldDEM4Orth. The watercourses obtained from SRTM and ASTER GDEM have sharp angles and some spatial inconsistencies (Figure 2a). In the plain part of the test sites, the watercourses extracted from DEM do not always correspond to the image of space images. Plain watercourses extracted from Airbus WorldDEM4Ortho DEM are more detailed and have good branching. SRTM and ASTER give the largest error in watercourse construction (Figure 2b).

Thus, according to the results of the visual analysis, Airbus WorldDEM4Ortho, having the highest spatial resolution, creates the most accurate network of watercourses.

The morphometric characteristics of watercourses were compared according to the following parameters (Table 3): length of rivers; displacement of extracted rivers from the reference river channel, total length of watercourses in the basin; and density of the river network in the basin.

To compare the morphometric characteristics of the basins, the Shukyrkalzhyr River basin (right tributary of the Kalzhyr River) with a catchment area of 297.7 km2 was selected as a reference test site (Table 4).



a)

b)

Figure 2 – Comparison of extracted rivers from DEM with satellite images:
a) on mountainous territory; b) on plain territory

Table 3 – Comparison of parameters of reference and DEM-extracted watercourses at test sites

Parameters	Baseline data	Tundik River (lower reaches)	Abyz river (left tributary of Shukyrkalzhyr river)	Tomarlybulak river (right tributary of the Kalzhyr river)
Length, km	Reference rivers	5.12	6.66	5.3
	Airbus WorldDEM4Ortho	5.01	6.04	3.96
	ALOS AW3D	4.61	5.67	5.17
	SRTM	5.11	3.96	3.71
	ASTER	-	3.65	3.69
Length discrepancy, km	Airbus WorldDEM4Ortho	0.11	0,62	1.34
	ALOS AW3D	0.51	0.99	0.13
	SRTM	0.01	2.7	1.59
	ASTER	-	3.01	1.61
Offset from the channel, m	Airbus WorldDEM4Ortho	Minimum – 10 Maximum – 90.3	Minimum – 1.5 Maximum – 30.8	Minimum – 0.7 Maximum – 38.8
	ALOS AW3D	Minimum – 19 Maximum – 250	Minimum – 2.2 Maximum – 37.8	Minimum – 6 Maximum – 43.5
	SRTM	Minimum – 65 Maximum – 276	Minimum – 7.2 Maximum – 62.6	Minimum – 7 Maximum – 40.9
	ASTER	-	Minimum – 6.4 Maximum – 64.7	Minimum – 13.8 Maximum – 86.7

Table 4 – Comparison of calculated data of the Shukyrkalzhyr River basin

№	Baseline data	Number of segments	Total length, km	River network density,km/km2
1	Sentinel 2	185	174.8	0.59
2	Airbus WorldDEM4Ortho	221	168.0	0.56
3	ALOS AW3D	105	176.5	0.59
4	SRTM	193	145.3	0.49
5	ASTER GDEM	107	119.3	0.40

The calculated data for ALOS and Airbus WorldDEM4Ortho are close to the values of the calculated data for the reference sites, while the results for SRTM and ASTER GDEM are different.

The analysis of digital elevation models showed that the most suitable for watercourse extraction from all considered DEMs is Airbus WorldDEM4Ortho, which has higher resolution and the extracted watercourses are the most consistent with the watercourses digitised from space images. The SRTM DEM also shows good results, which are suitable for both flat and mountainous areas.

Conclusion

The study concludes that among the digital elevation models (DEMs) reviewed, Airbus WorldDEM4Ortho is the most effective for hydrological modelling and water resources analysis purposes.

It provides high accuracy of elevation data and detailed topographic representation, which is particularly important for accurate representation of the hydrographic network and estimation of runoff parameters in complex mountainous and mixed landscapes. The ALOS AW3D model demonstrates comparable accuracy and can also be applied to detailed modelling tasks, providing a reliable alternative when access to WorldDEM is limited.

While SRTM remains a valuable resource, especially for regional and large areas, its limitations in accuracy and resolution become apparent in complex topography and flat areas, reducing its effectiveness for high-precision hydrological analyses. Nevertheless, its free and open access and lack of restrictions on data downloading make SRTM more accessible and convenient for a wide range of hydrological studies and monitoring where high detail may not be critical.

ASTER GDEM is less suitable for detailed hydrological modelling tasks, especially in areas with confusing topography, urban infrastructure or complex landscapes, which limits its application in accurate flood forecasting and water resources management.

Overall, the findings of the study emphasize the need for careful selection of an appropriate DEM, considering the topography and the objectives of hydrological analysis, as this directly affects the quality of flood risk assessment and the effectiveness of decision-making in water resources management.

Acknowledgement

This research is funded by the Committee of Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No. BR21882365).

Conflict of interest

There is no conflict of interest.

References

Chymyrov A. (2021). Comparison of different DEMs for hydrological studies in the mountainous areas. The Egyptian Journal of Remote Sensing and Space Science, 24(3), 587-594 https://doi.org/10.1016/j.ejrs.2021.08.001

El Mhamdı A., Aarab M., El Fariati A. (2023). Evaluation of the accuracy of open-source DEMs using GPS data. International Journal of Environment and Geoinformatics, 10(1), 41-50. https://doi.org/10.30897/ijegeo.1119695

Elhag M., Galal H. K., Alsubaie H. (2017). Understanding of morphometric features for adequate water resource management in arid environments. Geoscientific Instrumentation, Methods and Data Systems, 6(2), 293-300. https://doi.org/10.5194/gi-6-293-2017

Hamdan A., Khozyem H. (2018). Morphometric, statistical, and hazard analyses using ASTER data and GIS technique of WADI El-Mathula watershed, Qena, Egypt. Arabian Journal of Geosciences, 11, 1-15. https://doi.org/10.1007/s12517-018-4068-3

Zhengissova N.Y., Turymtayev Zh.B., Kazykanova A.K., Toktarov Zh.A. (2024). Tehnologija sozdanija cifrovoj kartograficheskoj osnovy dlja informacionno-ocenochnyh kart territorii issledovanija [Technology for creating a digital cartographic basis for information and assessment maps of the research area]. Journal of Geography and Environmental Management №4 (75). https://doi.org/10.26577/JGEM.2024.v75.i4.5

Jamal S., Ali A. (2023). A comparative study of automatic drainage network extraction using ASTER GDEM, SRTM DEM and Cartosat-1 DEM in parts of Kosi basin, Bihar, India. Journal of Umm Al-Qura University for Engineering and Architecture, 14(1), 45-56. https://doi.org/10.1007/s43995-023-00014-4

Joy M. A. R., Upaul S., Fatema K., Rezvi Amin F. M. (2023). Application of GIS and remote sensing in morphometric analysis of river basin at the south-western part of great Ganges delta, Bangladesh. Hydrol Res 54 (6): 739–755. https://doi.org/10.2166/nh.2023.087

LN T., Kumar MB S., Chikkamadaiah D. N. (2022, December). Automatic Drainage Network Extraction and Comparison of Thresholds using, ASTER-GDEM, SRTM-DEM, and ALOS-DSM: A case study of Purvanchal region in Uttar Pradesh INDIA using Remote Sensing and GIS Approach. In Proceedings of the International Conference on Systems, Energy and Environment. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4297306#

Misael Uribe E., Cruz Escamilla J., Juárez A. (2024). Evaluation of the Digital Elevation Model from the Shuttle Radar Topography Mission (SRTM) on the Papaloapan Macro-Basin, Mexico, using LiDAR as benchmark. Tecnología y Ciencias del Agua, 15(4). https://doi.org/10.24850/j-tyca-2024-04-05

Monteiro E. S., Fonte C. C., de Lima J. L. (2018). Improving the positional accuracy of drainage networks extracted from Global Digital Elevation Models using OpenStreetMap data. Journal of Hydrology and Hydromechanics, 66(3), 285-294. https://doi.org/10.1515/johh-2017-0057

Okolie C., Adeleke A., Smit J., Mills J., Maduako I., Ogbeta C. (2024). Comparison of machine learning and statistical approaches for Digital Elevation Model (DEM) correction: interim results. arXiv preprint arXiv:2402.06688. https://arxiv.org/abs/2402.06688

Rai P. K., Chandel R. S., Mishra V. N., Singh P. (2018). Hydrological inferences through morphometric analysis of lower Kosi river basin of India for water resource management based on remote sensing data. Applied water science, 8, 1-16. https://doi.org/10.1007/s13201-018-0660-7

Shaikh M., Yadav S., Manekar V. (2021). Accuracy assessment of different open-source digital elevation model through morphometric analysis for a semi-arid river basin in the western part of India. Journal of Geovisualization and Spatial Analysis, 5, 1-21. https://doi.org/10.1007/s41651-021-00089-4

Shugulova D. K. Mazhitova G. Z., Makhanova N. B., Pashkov S. V., Assylbekov K. M., Berdenov Z. G. (2023). Geoinformation modeling of the Esil river flood zone based on remote sensing data. Journal of Geography and Environmental Management №2 (69) 2023. https://doi.org/10.26577/JGEM.2023.v69.i2.06

Sousa Morais R.C., Sales M.C. (2016). Extração automática de drenagem: uma análise comparativa a partir de diferentes ferramentas e bases de dados. Revista Brasileira de Geografia Física, 9(06), 1849-1860. https://doi.org/10.26848/rbgf.v9.6.p1849-1860

Takaku J., Tadono T., Doutsu M., Ohgushi F., Kai H. (2020). Updates of 'AW3D30'ALOS global digital surface model with other open access datasets. The international archives of the photogrammetry, remote sensing and spatial information sciences, 43, 183-189. https://doi.org/10.5194/isprs-archives-XLIII-B4-2020-183-2020

Information about authors:

Gulnara Iskaliyeva (corresponding author) – PhD student of Kazakh national agrarian research university, leading researcher of the LLP «Institute of ionosphere» (Almaty, Kazakhstan, e-mail: igm.ionos@gmail.com);

Alima Amangeldi – engineer of the LLP «Institute of ionosphere» (Almaty, Kazakhstan, e-mail: amangeldialimma@gmail.com)

Madina Sagat – engineer of the LLP «Institute of ionosphere» (Almaty, Kazakhstan, e-mail: sagat.madina1@gmail.com)

Aibek Merekeyev – LLP – PhD-student at al-Farabi KazNU, Senior Researcher at LLP «Institute of ionosphere» (Almaty, Kazakhstan, e-mail: merekeev.aibek@gmail.com)

Sydyk Nurmakhambet – Head of the laboratory at LLP «Institute of ionosphere» (Almaty, Kazakhstan, e-mail: nurmahambet.s@gmail.com)

Aigerim Kalybayeva – Senior Researcher of the LLP «Institute of ionosphere» (Almaty, Kazakhstan, e-mail: kalybayeva.aigerim@gmail.com)

Сведения об авторах:

Искалиева Гульнара Маратовна (автор-корреспондент) – PhD-докторант НАО «Казахский национальный аграрный исследовательский университет», ведущий научный сотрудник Института ионосферы (Алматы, Казахстан, e-mail: igm.ionos@gmail.com);

Амангелді Әлима Азаматқызы – инженер ТОО «Институт ионосферы» (Алматы, Казахстан, e-mail: amangeldialimma@gmail.com);

Сагат Мәдина Сәкенқызы – «Ионосфера институты» ЖШС инженері (Алматы, Қазақстан, e-mail: sagat.madina1@gmail.com);

Мерекеев Айбек Айтоллаевич – PhD-докторант в КазНУ им. аль-Фараби, старший научный сотрудник ТОО «Институт ионосферы» (Алматы, Казахстан, e-mail: merekeev.aibek@gmail.com);

Сыдық Нұрмахамбет Қанатұлы – заведующий лабораторией ТОО «Институт ионосферы» (Алматы, Казахстан, e-mail: nurmahambet.s@gmail.com);

Калыбаева Айгерим Камильевна – старший научный сотрудник ТОО «Институт Ионосферы», (Алматы, Казахстан, e-mail: kalybayeva.aigerim@gmail.com).

Авторлар туралы мәлімет:

Искалиева Гульнара Маратовна (автор-корреспондент) – Қазақ ұлттық аграрлық зерттеу университетінің PhD докторанты, Ионосфера институтының жетекші ғылыми қызметкері (Алматы, Қазақстан, e-mail: igm.ionos@gmail.com)

Амангелді Әлима Азаматқызы – Ионосфера институты инженері (Алматы, Қазақстан, e-mail: amangeldialimma@gmail.com)

Сағат Мәдина Сәкенқызы – инженер ТОО «Институт ионосферы» (Алматы, Қазақстан, e-mail: sagat.madina1@gmail.com)

Мерекеев Айбек Айтоллаевич – әл-Фараби атындағы ҚазҰУ PhD-студенті, «Ионосфера институты» ЖШС аға ғылыми қызметкері (Алматы, Қазақстан, e-mail: merekeev.aibek@gmail.com)

Сыдық Нұрмахамбет Қанатұлы – «Ионосфера институты» ЖШС лаборатория меңгерушісі (Алматы, Қазақстан, эл.почта: nurmahambet.s@gmail.com)

Калыбаева Айгерим Камильевна – ЖШС «Ионосфера институты» аға ғылыми қызметкер, (Алматы, Қазақстан, e-mail: kalybayeva.aigerim@gmail.com)

Received: January 24, 2025
Accepted: May 29, 2025