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The Persian Gulf: from Ancient Maps to Satellite Images

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ABSTRACT

The Persian Gulf, as a semi-enclosed marginal sea of the Indian Ocean, has long been regarded by historical geographers and cartographers as a distinct geographic phenomenon. This study aims to integrate historical cartographical sources with satellite imagery and geographical information systems (GIS) to investigate the spatial continuity and geographical stability of the Gulf from antiquity to the present. Historical maps, obtained from the National Cartography Center of Iran (NCC) and the Circle of Ancient Iranian Studies (CAIS) and spanning from classical antiquity to the early modern period, were analyzed to document patterns of geographic depiction and labeling of the Persian Gulf across different cartographic sources. For contemporary geospatial analysis, 17 Landsat-8 and Landsat-9 scenes were used to generate a satellite-based mosaic and derive key spatial characteristics, including area, maximum length, average width, and coastline distribution in Iran, Iraq, Kuwait, Saudi Arabia, Bahrain, Qatar, the United Arab Emirates, and Oman. In addition, the geometric centroid and Standard Deviational Ellipse (SDE) were calculated to assess the overall spatial configuration and directional distribution of the Persian Gulf. The results indicate a high degree of consistency in the location, extent, and geometric characteristics of the region over time, with a pronounced spatial association along the northern coastline. The close correspondence between historical cartographic representations and satellite-derived spatial metrics highlights the continuity of the geographic feature commonly identified as the Persian Gulf. By linking ancient maps with contemporary remote sensing data, this study provides a spatially explicit perspective on the long-term cartographic representation of the Persian Gulf.

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1. Introduction

Maps have long served as fundamental tools for representing geographic space, encoding not only physical landscapes but also accumulated spatial knowledge across time (Thrower, 2008; Woodward & Harley, 1987). From early cartographic depictions based on observation, navigation, and inherited geographic concepts to modern satellite-based representations grounded in precise measurement, maps provide a unique record of how geographic features are perceived, delineated, and maintained within scientific traditions (Kraak & Ormeling, 2020; Robinson & Kimerling, 1969). Coastal and maritime regions, in particular, have played a central role in the history of cartography due to their importance for navigation, trade, and regional connectivity (Thrower, 2008). The continuity of geographic representation across different mapping eras offers valuable insight into the stability of physical features and the persistence of cartographic conventions (Woodward & Harley, 1987). In this context, examining the representation of major maritime features across both historical maps and contemporary geospatial data allows for a deeper understanding of how geographic space has been consistently conceptualized and documented over long temporal scales.

The evolution of cartography and remote sensing in the Persian Gulf illustrates a broader transition from traditional navigation-based mapping and hand-drawn charts to satellite-derived, data-driven representations. While historical maps documented this maritime region through the lenses of prevailing geographic knowledge, cultural context, and technical limitations, modern geodetic instruments and Earth observation satellites provide higher positional accuracy and analytical capability. Contemporary satellite missions such as Landsat and Sentinel now enable continuous monitoring of the Persian Gulf, providing high-resolution information on surface conditions, environmental change, and human activities (Ivanov *et al*., 2024). This technological shift has transformed the gulf from a historically mapped maritime space into a quantitatively measurable and dynamically monitored geographic system. Furthermore, the Persian Gulf's role as one of the world's most critical maritime corridors—characterized by dense shipping traffic, offshore oil and gas infrastructure, and major export terminals—has made it a focal area for applied geospatial research (Mokarram & Pham, 2025). Advances in remote sensing and machine learning have further enhanced the ability to detect, classify, and analyze marine phenomena such as oil spills and surface anomalies, particularly in the aftermath of major disturbances including the 1991 Gulf War (Ashkanani *et al*., 2025). In this sense, the integration of historical cartographic records with modern satellite-based analysis provides a comprehensive framework for understanding both the long-term geographic identity and the contemporary environmental significance of the Persian Gulf.

Beyond its historical and cartographic significance, the Persian Gulf represents a particularly suitable natural system for the application of satellite-based remote sensing and geospatial analysis. As a semi-enclosed and well-defined maritime basin with clear geographic boundaries, it can be consistently identified and observed in satellite imagery across different spatial and temporal scales (Jensen, 1996). Its strategic geographic setting, extent, and overall geometry make it an excellent case for examining spatial persistence using modern geospatial techniques (Goodchild *et al*., 2005). Moreover, the long-standing importance of the Persian Gulf in navigation, maritime trade, and regional connectivity has resulted in its frequent representation in both historical maps and contemporary scientific datasets. This continuity of representation provides a unique opportunity to link early cartographic depictions with modern satellite-based observations. In this context, remote sensing complements historical cartography by providing quantitative and spatially explicit measurements of the same geographic feature

(Campbell & Wynne, 2011).

The Persian Gulf has long functioned as a major international trade corridor, linking the Middle East with India, East Africa, Southeast Asia, and China. Historically, its primary orientation has been outward, toward the Indian Ocean, facilitating extensive maritime exchange and long-distance commercial networks (Potter, 2009). The coastal region surrounding the Persian Gulf is characterized by a hot desert climate, classified under the Köppen system as an arid environment with high temperatures, minimal annual precipitation (approximately 75–150 mm), and sparse vegetation typical of desert and semi-desert landscapes. Most of the territory within this ecoregion is bare ground or supports only small shrubs and grasses, reflecting the region's predominantly dry conditions (Ecotenet, 2023).

In antiquity, the Persian Gulf region exhibited considerable cultural diversity, encompassing several major geographic and cultural zones, along with numerous smaller subregions. These zones included: (a) southern Iran, extending from the Arvand Rud (Shatt al-Arab) to the Strait of Hormuz, a region characterized by internal diversity (which has received relatively limited scholarly attention); (b) southern Mesopotamia; (c) northeastern Arabia, comprising present-day Kuwait, Bahrain, Qatar, and the Eastern Province of Saudi Arabia, which share sufficient material cultural similarities to be considered a coherent regional grouping; and (d) southeastern Arabia, corresponding largely to the modern United Arab Emirates and Oman—the latter lying mostly beyond the Gulf's confines except for the Musandam Peninsula (Potts, 2009).

Tribal structures played a central role in the formation of modern states on the Arabian Peninsula, whose ruling dynasties largely trace their origins to tribal foundations. Tribal affiliation also remained an influential social and political factor in Iran until the mid-twentieth century and continues to hold significance in Iraq. Linguistic diversity further contributed to cultural differentiation and, at times, social division across the Persian Gulf region. Arabic, a Semitic language, predominates in Iraq and throughout much of the Arabian Peninsula, whereas Iran is characterized by an Indo-European linguistic heritage, with Persian as its official language. Nevertheless, Arabic has been widely spoken along the Iranian coast south of Bushehr, and it also constitutes the dominant language in the southwestern province of Khuzestan. Conversely, on the southern shores of the Persian Gulf, particularly in Bahrain and Dubai, communities of Iranian origin have traditionally maintained the use of Persian. Historical accounts from the late nineteenth and early twentieth centuries highlight the prevalence of multilingualism in major Persian Gulf ports, where multiple languages were common in everyday commerce. In the post-World War II era, the British diplomat Sir Rupert Hay reported that "the Persians can, nearly all, speak Arabic fluently, but few Arabs will admit to a knowledge of Persian" (Hay, 1959). This widespread bilingualism and linguistic plurality fostered a degree of mutual tolerance and cultural accommodation that characterized social life throughout the Persian Gulf region (Potter, 2009).

The Persian Gulf world is distinguished from much of the Middle East by a series of natural barriers, including mountain ranges to the north and east, extensive marshlands and lagoons at its head, and arid desert expanses to the south. Historically, communities inhabiting its shores maintained closer social, economic, and cultural interactions with one another than with populations living farther inland—a pattern characteristic of littoral societies. For millennia, the Persian Gulf functioned as an integrated regional system marked by the continuous circulation of people, goods, and religious ideas. Before the modern era, the populations of the Persian Gulf region shared a predominantly maritime culture centered on pearling, fishing, and long-distance trade, and were embedded within a broader interconnected network that included agricultural

settlements and oasis communities supporting overland caravan routes (Potter, 2009).

Numerous historical, linguistic, and cartographic studies have examined how the Persian Gulf has been represented and identified in ancient texts, maps, and international references. Collectively, this body of work highlights the long-term consistency with which this maritime region has been depicted within different geographic and cartographic traditions. Rather than revisiting this extensive literature, the present study builds upon these established perspectives by introducing a spatially explicit analysis based on satellite imagery and GIS techniques. The primary contribution of this research lies in integrating historical cartographic representations with quantitative geospatial measurements to examine the geographic continuity and spatial characteristics of the maritime feature known as the Persian Gulf.

A substantial body of scholarly research has examined the historical evolution, cultural interaction, trade networks, and external influences in the Persian Gulf region, treating it as a coherent unit of analysis rather than a fragmented space. A landmark contribution in this domain is the edited volume *The Persian Gulf in History* (Potter, 2009), which brings together perspectives from multiple historians and archaeologists spanning from antiquity to the modern era. The book explores the early historical and archaeological foundations of the region through contributions such as the study of prehistoric and early historic settlement patterns and material culture, demonstrating that the Persian Gulf area possessed distinct regional identities long before the advent of modern nation-states. Chapters dedicated to the Sasanian era and the early Islamic period further underscore the strategic and integrative role of the Persian Gulf in linking inland empires with maritime networks. The volume also highlights the institutional and external dynamics that shaped the region's history, including the impact of Portuguese, Ottoman, Dutch, and British engagements in controlling trade routes and ports along the Persian Gulf littoral, reflecting its centrality in early modern global commerce.

Additionally, historical scholarship has been enriched by works such as Arnold Wilson's *The Persian Gulf: An Historical Sketch* (Wilson, 1928), which offers one of the earliest comprehensive narratives of the region from antiquity to the twentieth century, charting socio-political developments and external influences over time. The monumental *Gazetteer of the Persian Gulf, Oman, and Central Arabia* compiled by John Gordon Lorimer (Lorimer, 1915) remains an enduring reference in regional history and geography, providing extensive encyclopedic detail on settlements, tribes, and historical geography across the Persian Gulf littoral. Collectively, these foundational works establish a multidisciplinary framework for understanding the Persian Gulf as a historically continuous, culturally interconnected, and strategically significant region, laying the groundwork for subsequent research in cartography, historical geography, and identity.

Building on this historical and geographical background, the present study aims to examine the continuity of the Persian Gulf as a distinct and well-defined geographic entity from antiquity to the present day. The northwestern coastal plain of the Persian Gulf falls within the Persian Gulf Coastal Plain Desert ecoregion and is characterized by a hot desert climate, with high annual temperatures and very low precipitation typical of arid and semi-arid environments (Ecotenet, 2023). Such climatic conditions, marked by sparse vegetation and pronounced surface contrast, create a favorable setting for satellite-based observation and spatial analysis (Alavipanah, 2004). This environmental and geographic context enables an effective integration of historical cartographic representations with modern remote sensing and GIS techniques to examine the long-term spatial continuity of the Persian Gulf. By combining evidence from ancient and medieval maps with contemporary geospatial data, this research

adopts a spatially explicit framework to analyze the stability of the region's location, extent, and geometric characteristics over time. Rather than engaging in political or ideological discussions, this study focuses on the physical and cartographic persistence of this maritime feature, emphasizing how its enduring spatial configuration has been consistently represented across different mapping traditions. Through this combined cartographic and remote sensing approach, the article highlights the continuity of the geographic entity commonly depicted as the Persian Gulf and illustrates a convergence between historical representations and modern spatial metrics in depicting a stable and recognizable maritime region.

Based on the marginal information accompanying the map, as provided by Iran's National Cartography Center (NCC), the use of the name "Persian Gulf" has a documented history spanning approximately 2,600 years. Classical scholars and geographers, including Anaximander of Miletus (c. 610–546 BC), Hecataeus of Miletus (c. 549–473 BC), Eratosthenes (c. 276–194 BC), Hipparchus (2nd century BC), Ctesias (c. 445–380 BC), Xenophon (c. 430–352 BC), Strabo (63 BC–AD 24), and Flavius Arrianus (2nd century AD), consistently and accurately referred in their writings and maps to the body of water in south of the Iranian Plateau using names whose precise meaning corresponds to the Persian Gulf .The formal introduction of this designation into cartographic tradition, however, is attributed to Claudius Ptolemy, the renowned Greek astronomer and geographer of the 2nd century AD (approximately 1,900 years ago), widely regarded as one of the founding figures of geography. Ptolemy was the first to compile a comprehensive atlas of the ancient world, consisting of 36 regional maps accompanied by a world map. Within this atlas, maps of Iran, Mesopotamia, and the Arabian Peninsula are presented, and the waters in the south of Iran are unambiguously labeled as "*Persicus Sinus*" (Persian Gulf). This term was later standardized as "*Sinus Persicus*" and became firmly established in geographical and cartographic literature. The Romans also called this sea the Persian Sea or the Persian Basin (*Aquarum Persico*). Later, the term "Sinus Persicus" was translated into other languages of the world and used in encyclopedias of different languages as: *Golfo Persico* (Italian), *Golfio Parsico* (Spanish), *Persischer Golf* (German), *Golfeul Persic* (Romanian), *Persiste Habbugt* (Norwegian), *Persisk Gilf* (Danish), *Persiska Vikem* (Swedish), *Perzsa Obol* (Hungarian), *Porucha Wan* (Japanese), *Golfe Persique* (French), *Parsits Tsots* (Armenian), *Persian Gulf* (English), *Perzishe Golf* (Dutch) and *Bacher Fars* (Hindi), all of which mean "Persian Gulf". Arab researchers and writers have also frequently mentioned the Persian Gulf in their works as "Bahr al-Farsi" or "Al-Khalij Al-Farsi" and some ancient Islamic geographers even applied the concept of the "Persian Sea" more broadly to all waters south of Iran (including both the Sea of Oman and the Persian Gulf).

2. Material and methods

Unlike review-based studies, this research employs original spatial measurements derived from satellite imagery to complement historical cartographic evidence.

2.1. Data

2.1.1. Ancient maps

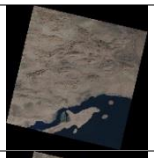
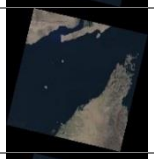
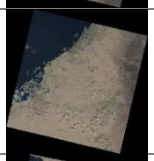
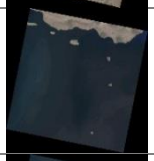
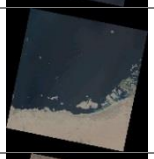
Historical maps were used in this study as primary cartographic sources to examine the representation and labeling of the maritime feature located south of the Iranian Plateau across distinct historical periods. These maps were collected from two principal archival sources: The Circle of Ancient Iranian Studies (CAIS) and Iran's National Cartography Center (NCC). The selected maps span several centuries and originate from different cartographic traditions and

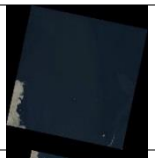
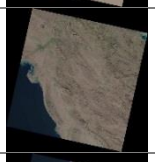
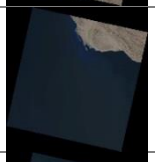
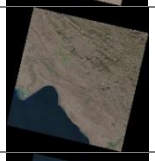
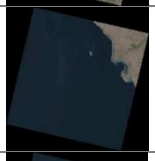
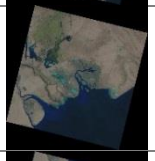
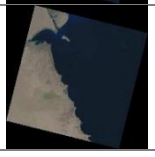
languages. For each map, the toponym assigned to the Persian Gulf was documented, along with basic metadata such as approximate date, language, and origin. Although many of the historical maps contain limited descriptive or explanatory annotations, the presence and form of the geographic name were treated as key cartographic attributes. The analysis focused on the consistency of labeling across maps produced at different times and for different purposes, independent of variations in scale, projection, or stylistic conventions. This approach facilitates the systematic comparison of historical cartographic representations with modern geospatial data within a unified analytical framework.

2.1.2. Satellite Images

The present study used 17 scenes of Landsat 8 and Landsat 9 Collection 2 Level-2 images (specifications are detailed in Table 1), obtained from the United States Geological Survey (USGS) website for satellite mapping of the Persian Gulf (Earth Resources Observation and Science (EROS) Center, 2020). Landsat Level-2 science products were generated from Collection 2 Level-1 data that satisfy the solar zenith angle threshold (< 76°) and incorporate all necessary auxiliary inputs to ensure the generation of scientifically robust products. Surface reflectance products from the Landsat 8 and 9 Operational Land Imager (OLI) were produced using the Land Surface Reflectance Code (LaSRC) algorithm version 1.5.0 (USGS, 2020).

Table 1. Characteristics of satellite images (Landsat 8 (L8) and Landsat 9 (L9)) used in the present study

No.	Satellite	Path	Row	Date	Scence cloud cover	Thumbnail
1	L8	160	041	2025/11/24	0.37	
2	L8	160	042	2025/11/24	0.67	
3	L8	160	043	2025/11/24	3.12	
4	L9	161	042	2025/11/07	0.05	
5	L9	161	043	2025/11/07	2.64	
6	L9	162	041	2025/11/30	1.79	

No.	Satellite	Path	Row	Date	Scence cloud cover	Thumbnail
7	L8	162	042	2025/11/22	0.14	
8	L9	162	043	2025/11/14	0.22	
9	L8	163	040	2025/11/29	0.61	
10	L9	163	041	2025/11/21	0.27	
11	L8	163	042	2025/11/29	1.01	
12	L8	163	043	2025/11/29	0.36	
13	L9	164	039	2025/11/28	0.13	
14	L9	164	040	2025/11/28	1.36	
15	L9	164	041	2025/11/28	0.58	
16	L8	165	039	2025/11/27	6.22	
17	L8	165	040	2025/11/27	1.92	

3. Methodology

3.1. Calculating the area of the Persian Gulf

The total area of the Persian Gulf was calculated using the "Calculate Geometry" function in ArcGIS (ArcMap). The Persian Gulf shapefile was projected to an appropriate planar coordinate system (UTM) to ensure area measurements were in square kilometers. By selecting the polygon feature and using the "Area" attribute field, the software computed the precise area of the gulf, which provided a quantitative basis for subsequent analyses of its dimensions and spatial characteristics.

3.2. Calculating the length of the Persian Gulf

To determine the maximum longitudinal extent of the Persian Gulf, the "Minimum Bounding Geometry" tool was used to generate the longest axis of the polygon. The resulting line feature was then measured using the "Calculate Geometry" function to obtain the length in kilometers, ensuring an objective measurement of the gulf's longitudinal dimension.

3.3. Calculating the average width of the Persian Gulf

The average width of the Persian Gulf was estimated by dividing the calculated area by the maximum length, a standard approach for elongated water bodies. For a more detailed assessment, a central axis (skeleton) was manually digitized using the "Polyline" tool, and perpendicular distances from the axis to the polygon boundaries were measured at regular intervals using the "Measure" tool. The mean of these distances provided a refined estimate of the average width, accounting for the irregular shape of the Persian Gulf.

3.4. Length and coastal share of the Persian Gulf countries

The coastlines of the countries bordering the Persian Gulf were extracted using the "Intersect" tool to clip each country's polygon with the Persian Gulf polygon. The "Calculate Geometry" function was then applied to the resulting coastline polylines to determine their lengths in kilometers. Coastal shares were computed by dividing each country's coastline length by the total coastline of all littoral states, allowing for quantitative comparison.

3.5. Geometric centroid and proximity of the Persian Gulf countries

The geometric centroid of the Persian Gulf polygon was computed using the "Feature to Point" tool with the "Inside" option to ensure the centroid lies within the polygon. Distances from the centroid to the coastline of each country were then measured using the "Euclidean Distance" tool, providing a spatial metric to analyze the relative proximity of each country to the geometric center and supporting interpretations related to historical naming and spatial dominance.

3.6. Directional Distribution (Standard Deviational Ellipse)

To analyze the spatial distribution and directional dominance of the Persian Gulf, a Standard Deviational Ellipse was generated. The Persian Gulf polygon shapefile, projected to an appropriate planar coordinate system (UTM), was used as the input. The Directional Distribution (Standard Deviational Ellipse) tool, set to 1 STDV, calculated the central tendency, orientation, and dispersion of the polygon. This produced an ellipse representing the main spatial trend of the Persian Gulf. Subsequently, the area of the ellipse overlapping each littoral country was extracted using the Intersect tool, allowing quantitative assessment of the

proportion of the gulf's extent within Iran, Saudi Arabia, Qatar, the United Arab Emirates, and Bahrain. This approach provides a spatially explicit and reproducible method for evaluating the concentration and directional pattern of the Persian Gulf relative to its surrounding countries.

4. Results and discussion

4.1. Ancient maps

The examined historical cartographic materials reveal a high degree of consistency in the geographic labeling of the Persian Gulf. As illustrated in Figure 1, a map produced by Saudi ARAMCO around 1952 depicts the maritime area south of the Iranian Plateau using the designation *al-khalij al-Farsi* (Persian Gulf). This map was generated for operational and technical purposes by a major regional oil company, reflecting practical cartographic requirements rather than historical, cultural, or political interpretation. In such applied mapping contexts, geographic terminology is typically selected for clarity, standardization, and functionality. The explicit use of this designation indicates that the Persian Gulf was treated as a well-defined and widely recognized geographic reference within mid-twentieth-century professional cartography. This example provides an initial reference point for examining the continuity of cartographic representation observed across both historical maps and modern geospatial datasets.

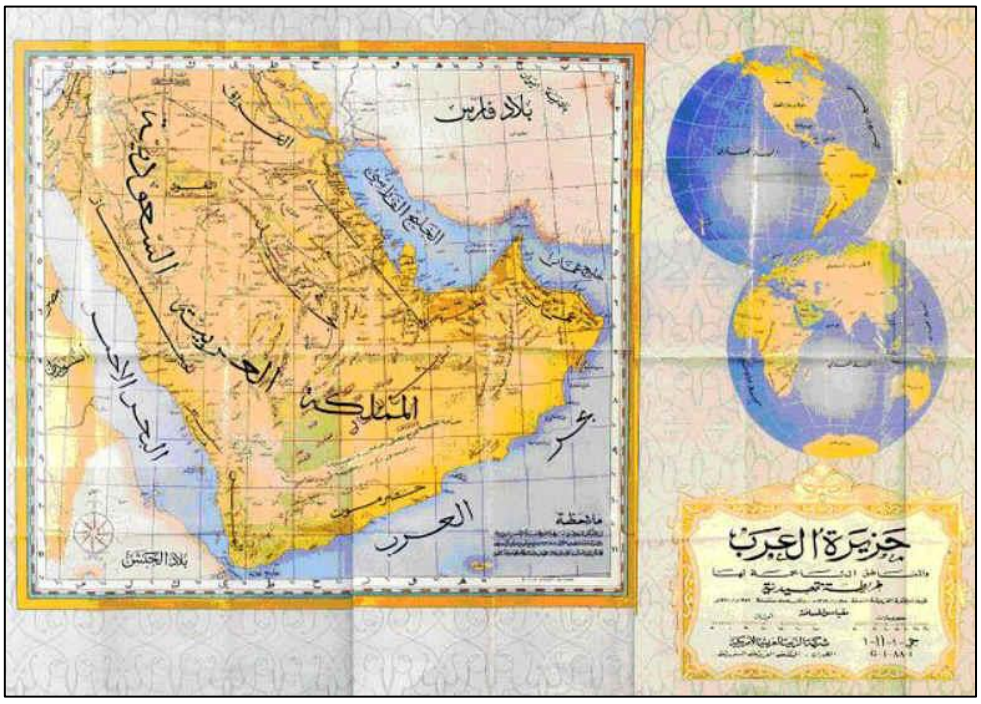


Figure 1. Historical map of the Persian Gulf (1952) labeled al-khalij al-Farsi (الخليج الفارسی), sourced from the Circle of Ancient Iranian Studies (CAIS).

Similarly, the map shown in Figure 2, an Egyptian map of Africa produced around 1908, depicts the Persian Gulf as a clearly delineated and labeled maritime feature within a regional cartographic framework. The inclusion of the gulf under the designation *Khalij al-Ajam* (Iranian Gulf) reflects the standardized toponymic conventions applied in early twentieth-century

Arabic cartography. From a cartographic perspective, the map demonstrates a consistent spatial representation of the gulf's location, extent, and orientation relative to the Iranian Plateau and the Arabian Peninsula. Despite the absence of detailed thematic information, the unambiguous identification of the gulf within a continental-scale map indicates that it functioned as a stable and well-defined geographic reference. This consistency in spatial depiction aligns with the geometric characteristics derived from modern satellite imagery, reinforcing the continuity of the Persian Gulf as a recognizable geographic entity across both historical cartographic sources and contemporary geospatial data.

Figure 2. Historical map of Africa (1908) depicting the Persian Gulf as a distinct maritime feature, labeled as Khalija al-Ajam (خليج العجم), sourced from The Circle of Ancient Iranian Studies (CAIS) (left: original map; right: enlarged view of the Persian Gulf).

Similarly, the map shown in Figure 3, one of the earliest surviving European maps from the Byzantine era dating to approximately the sixth century CE, depicts the maritime area south of the Iranian Plateau using the Latin designation *Sinus Persicus*. The appearance of this term reflects early European cartographic conventions in representing major maritime features rather than an accompanying textual narrative. Within the context of Late Antique mapping practices, the consistent labeling of this water body indicates that it was perceived as a distinct and spatially coherent geographic feature. The inclusion of this designation in a Byzantine-era map further illustrates the continuity of cartographic representation of the Persian Gulf across different historical periods and mapping traditions.

Figure 3. Byzantine-era European map (c. 6th century CE) depicting the Persian Gulf as a distinct maritime feature, labeled as Sinus Persicus, sourced from The Circle of Ancient Iranian Studies (CAIS) (left: original map; right: enlarged view of the Persian Gulf).

The sequence of historical maps presented in Figure 4 to Figure 10 spans more than three centuries and represents diverse European cartographic traditions, languages, and mapmaking conventions. Despite differences in projection, scale, artistic style, and cartographic purpose, these maps consistently depict the same maritime feature south of the Iranian Plateau with closely related toponyms referring to the Persian Gulf. This repetition across independent cartographic sources indicates a stable geographic understanding of the gulf as a distinct and well-defined spatial entity. Rather than relying on accompanying textual explanations, these maps convey continuity through spatial depiction and standardized labeling practices. When considered alongside modern satellite-derived measurements, these historical representations provide an important cartographic baseline, illustrating how the geographic configuration of the Persian Gulf has remained recognizable across centuries of mapping, thereby enabling a meaningful comparison between early cartographic knowledge and contemporary geospatial analysis. The map shown in Figure 4 (c. 1616) represents one of the early modern European cartographic depictions of the Persian Gulf, in which the maritime area south of the Iranian Plateau is explicitly labeled as *Persicus Sinus*. Produced within the context of early seventeenth-century European cartography, this map reflects the consolidation of classical geographic knowledge into Renaissance and post-Renaissance mapping traditions. Despite limitations in scale and coastal precision typical of the period, the clear identification of the Persian Gulf as a distinct maritime feature indicates its established position within European geographic understanding at the time.

Figure 4. Historical map (1616) depicting the Persian Gulf, labeled as PERSICUS SINUS, sourced from the National Cartography Center of Iran (left: original map; right: enlarged view of the Persian Gulf).

Figure 5 presents a nineteenth-century map (1831) in which the Persian Gulf is depicted with the same designation. By this period, cartographic techniques had improved in terms of coastline delineation and regional context, allowing for a more refined spatial representation of the gulf. The continued use of the established toponym demonstrates the persistence of naming conventions across centuries, even as mapping accuracy and geographic knowledge expanded.

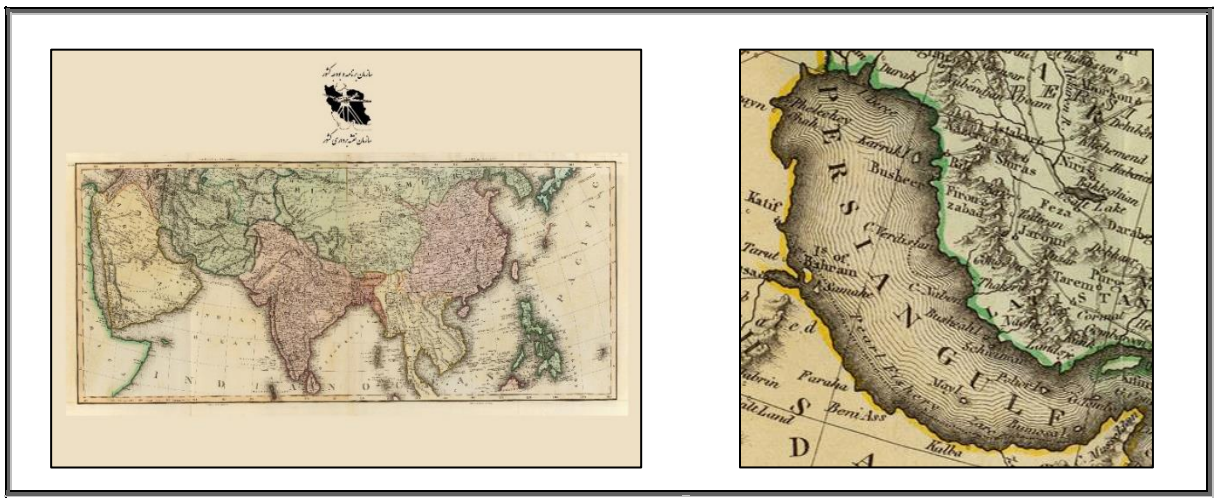


Figure 5. Historical map (1831) depicting the Persian Gulf with the same designation, sourced from the National Cartography Center of Iran (left: original map; right: enlarged view of the Persian Gulf).

The historical map illustrated in Figure 6, dated 1797, labels the maritime region south of Iran as *Sinus Persicus*. This map belongs to a late eighteenth-century cartographic tradition in which classical Latin terminology remained widely used in European mapmaking. The consistent placement and labeling of the Persian Gulf within a broader regional framework underscore its recognition as a stable and well-defined geographic entity during this period.

Figure 7 shows a mid-eighteenth-century map (1753) in which the Persian Gulf is labeled *Golfe Persique*, reflecting the adoption of vernacular European languages, particularly French,

in cartographic practice. While stylistic elements and linguistic conventions differ from earlier Latin-based maps, the spatial depiction and identification of the gulf remain consistent. This illustrates how cartographic continuity was maintained even as map language and stylistic preferences evolved.

Figure 6. Historical map (1797) showing the Persian Gulf as a distinct maritime feature, labeled SINUS PERSICUS, obtained from the National Cartography Center of Iran
(top: original map; bottom: enlarged view of the Persian Gulf)

Figure 7. Historical map (1753) depicting the Persian Gulf, labeled GOLFE PERSIQUE, sourced from the National Cartography Center of Iran (left: original map; right: enlarged view of the Persian Gulf).

The map presented in Figure 8, produced in 1817, continues the established tradition of depicting the Persian Gulf as a distinct maritime feature. By the early nineteenth century, European cartography increasingly emphasized systematic geographic representation, yet the fundamental spatial configuration and naming of the gulf remained unchanged. This reinforces the evidence for long-term stability in the region's cartographic depiction.

Figure 9 depicts an undated historical map in which the maritime area south of the Iranian Plateau is labeled The Persian Gulf. Although the exact production date is unknown, the use of

the English-language designation suggests a relatively modern cartographic context. The map's terminology and spatial representation align closely with earlier European traditions, further indicating the persistence of a standardized geographic reference across time.

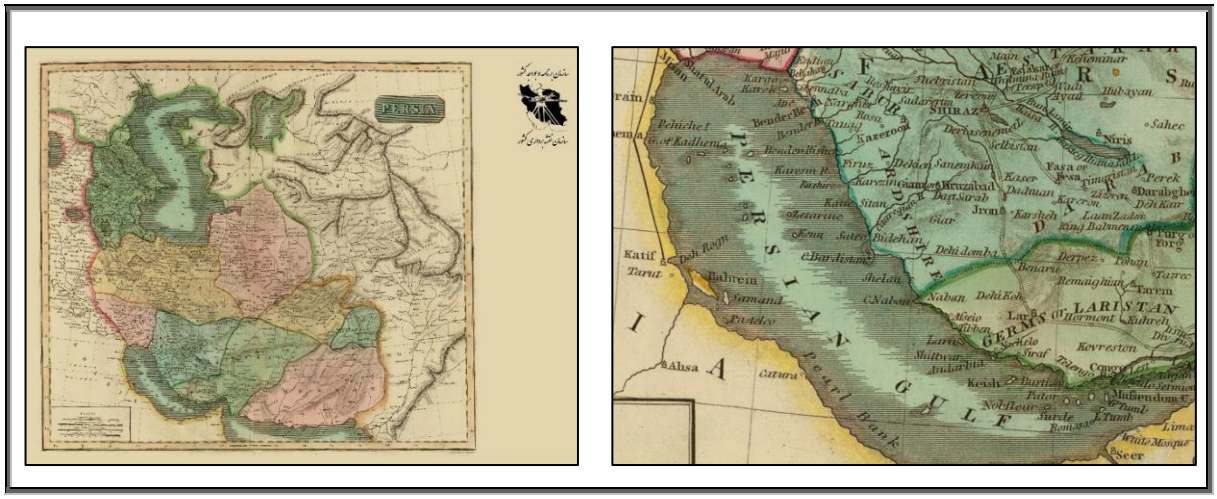


Figure 8. Historical map (1817) showing the Persian Gulf with the same designation, obtained from the National Cartography Center of Iran (left: original map; right: enlarged view of the Persian Gulf).

Figure 9. Undated historical map depicting the Persian Gulf, labeled The Persian Gulf, sourced from the National Cartography Center of Iran (left: original map; right: enlarged view of the Persian Gulf).

The late nineteenth-century map shown in Figure 10 (1892) represents a period when cartography had largely transitioned into a more scientific and standardized discipline. The clear labeling of the Persian Gulf and its integration into a broader regional map framework demonstrate that, even at this advanced stage of cartographic development, the gulf continued to be treated as a coherent and well-recognized geographic feature.

The sequence of maps from 1616 to 1892 (Figs. 4–10) establishes a clear and consistent cartographic record: the Persian Gulf is uniformly identified as such, regardless of profound shifts in mapmaking style and language. Despite variations in map projection, scale, and artistic

style, these maps uniformly depict the same maritime feature south of the Iranian Plateau using equivalent terms, indicating the long-standing cartographic recognition of a distinct and well-defined geographic entity.

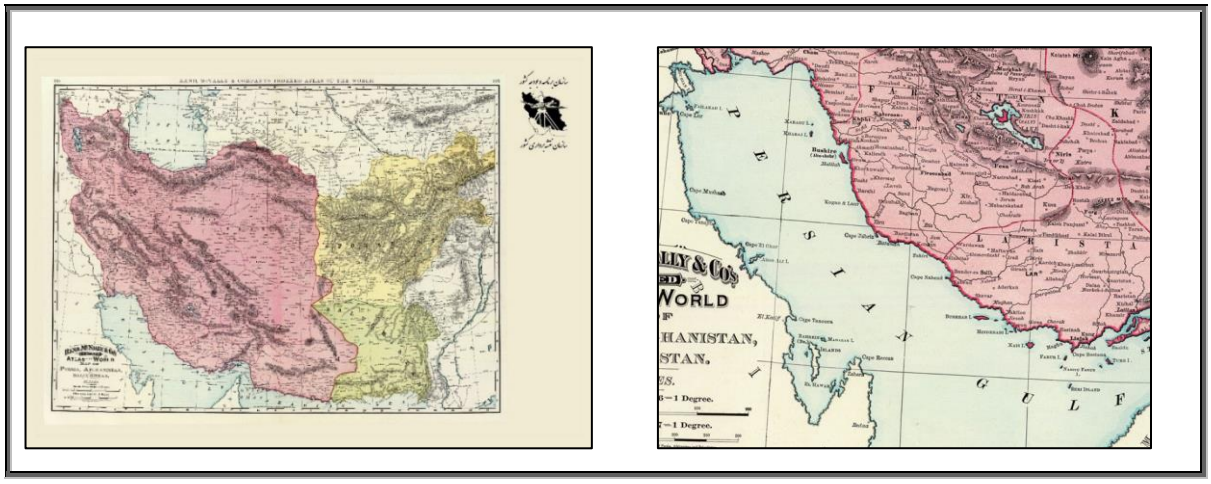


Figure 10. Historical map (1892) illustrating the Persian Gulf with the same designation, obtained from the National Cartography Center of Iran (left: original map; right: enlarged view of the Persian Gulf).

While historical maps provide essential qualitative evidence of this continuity, they are inherently limited in their capacity for precise spatial measurement. To complement these historical representations, the present study employs modern satellite imagery and GIS-based analyses to quantitatively examine the spatial characteristics of the Persian Gulf, including its extent, geometry, and coastline configuration. By linking historical cartographic consistency with satellite-derived spatial metrics, this research bridges descriptive cartographic tradition and quantitative geospatial analysis. This integrated framework offers a robust basis for understanding the enduring geographic identity of the Persian Gulf from antiquity to the present.

4.2. Satellite images

The satellite mosaic of the Persian Gulf, compiled from 17 Landsat-8 and Landsat-9 scenes using RGB bands (4th, 3rd, and 2nd bands), is shown in Figure 11. According to this map, the Persian Gulf spans an area of 238,650 km^2 between 23°–30°N latitude and 47°–56°E longitude. Its longest axis measures 929.8 km, with an average width of 265.7 km.

Eight countries—namely Iran, Iraq, Kuwait, Saudi Arabia, Bahrain, Qatar, the United Arab Emirates, and Oman—share a coastline with the Persian Gulf. Iran has the longest coastline (1,282 km), followed by Saudi Arabia (847 km), the United Arab Emirates (620 km), Qatar (462 km), Kuwait (252 km), Bahrain (138 km), Iraq (67 km), and Oman (52 km). Consequently, Iran accounts for over a third (34.5%) of the total coastline, followed by Saudi Arabia (22.8%), the United Arab Emirates (16.7%), Qatar (12.4%), Kuwait (6.8%), Bahrain (3.7%), Iraq (1.8%), and Oman (1.4%) (Figure 12). The unequal coastline distribution creates a fundamentally asymmetric spatial relationship between the Gulf and its littoral states. Iran, with the longest and most continuous share, forms the dominant northern boundary—the most extensive and spatially coherent land–sea interface. Such a configuration is significant in cartographic and geographic interpretation, as prominent and continuous coastal margins often play a central role in the spatial identification and representation of maritime features. In this context, the greater coastal extent

along the northern margin provides an important geographic framework for understanding how the Persian Gulf has been consistently delineated and referenced in both historical cartography and modern geospatial representations, without implying exclusivity or determinism.

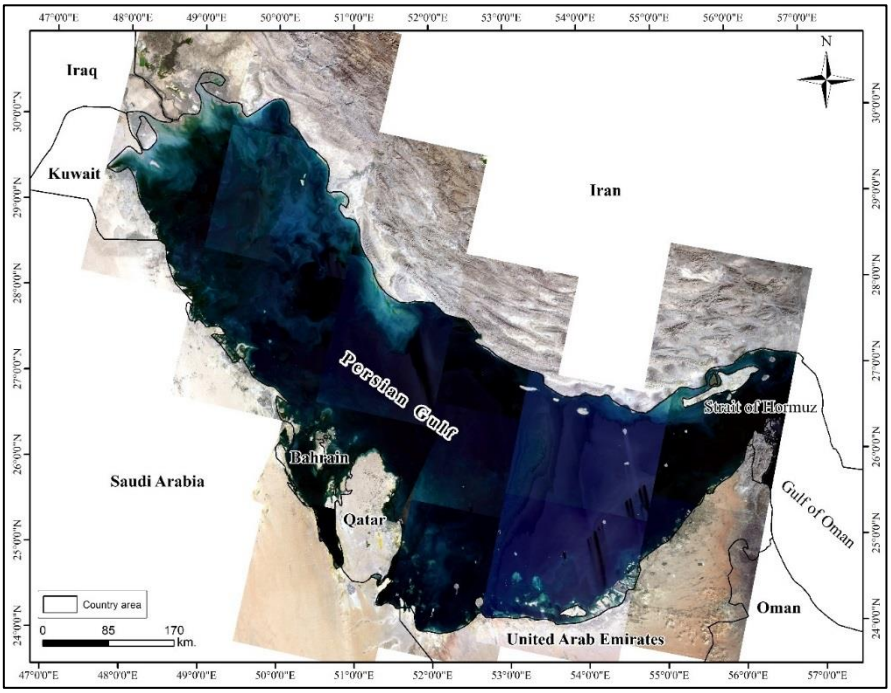


Figure 11. Satellite map of the Persian Gulf (RGB bands)

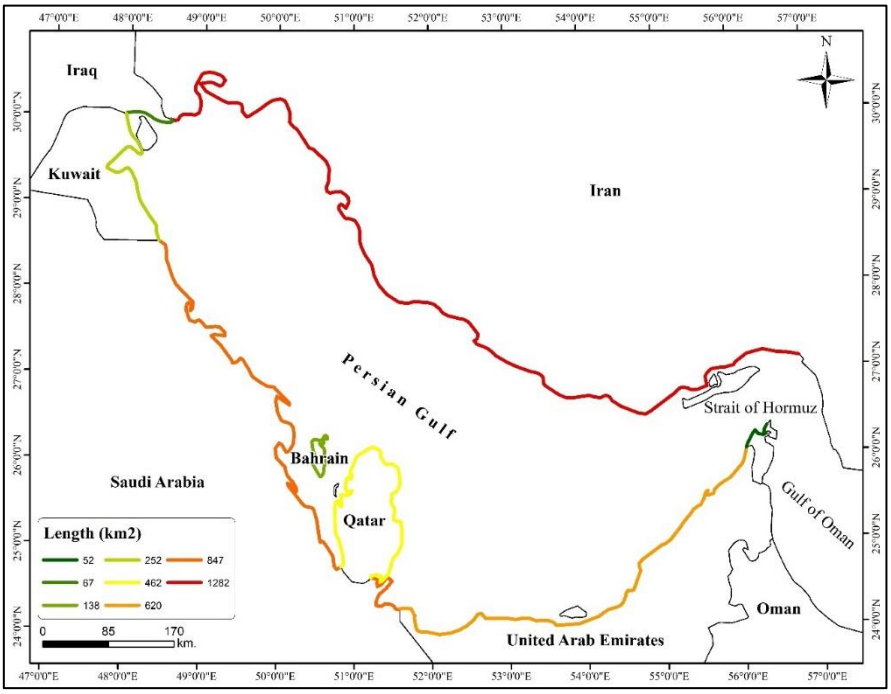


Figure 12. The length of the coastline of the Persian Gulf countries

As illustrated in Figure 13, the geometric centroid of the Persian Gulf is located closer to the Iranian coastline than to the southern littoral states. This configuration underscores the geometric asymmetry between the gulf's northern and southern margins, where the northern coast constitutes a far more extensive and continuous boundary. From a cartographic and geographic perspective, the relative position of the centroid reflects the overall shape and spatial structure of the Persian Gulf, which is influenced by the configuration of its surrounding coastlines. In this sense, the proximity of the geometric center to the northern margin provides an objective spatial descriptor of the gulf's geometry and contributes to understanding how the Persian Gulf has been consistently delineated as a coherent and stable maritime feature in both historical maps and modern geospatial analyses.

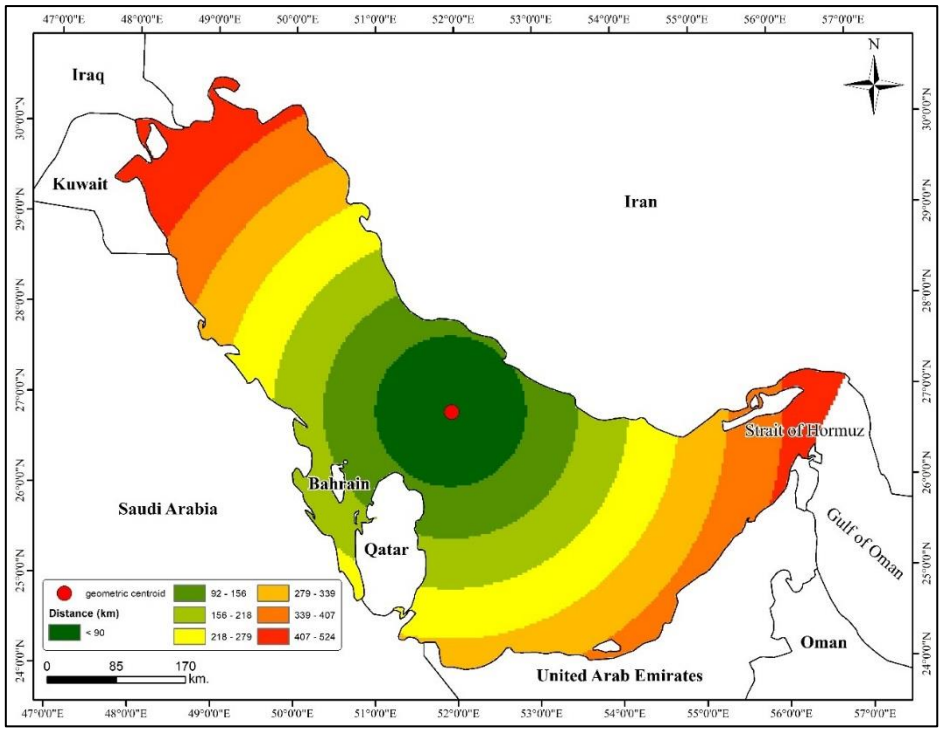


Figure 13. The geometric centroid of the Persian Gulf and its distance from the Persian Gulf countries

Moreover, as illustrated in Figure 14, the Directional Distribution (Standard Deviational Ellipse) of the Persian Gulf, derived from its shapefile, reveals a pronounced directional pattern and an asymmetric spatial distribution toward the northern coastline. The distribution of the gulf's area within the ellipse shows that 38,656 km² falls within Iran, 19,964 km² within Saudi Arabia, 8,527 km² within Qatar, 2,738 km² within the United Arab Emirates, and 640 km² within Bahrain. This spatial configuration demonstrates that a substantial proportion of the gulf's extent is concentrated along the northern margin, with the major axis of the ellipse aligned parallel to the Iranian coastline. From a geometric perspective, this pattern reflects the overall orientation and shape of the Persian Gulf as defined by its surrounding coastlines. The directional orientation and areal distribution captured by the ellipse provide a quantitative and visual representation of the gulf's spatial structure, highlighting the central role of the northern littoral in shaping the geometry and cartographic representation of the Persian Gulf across

different mapping frameworks.

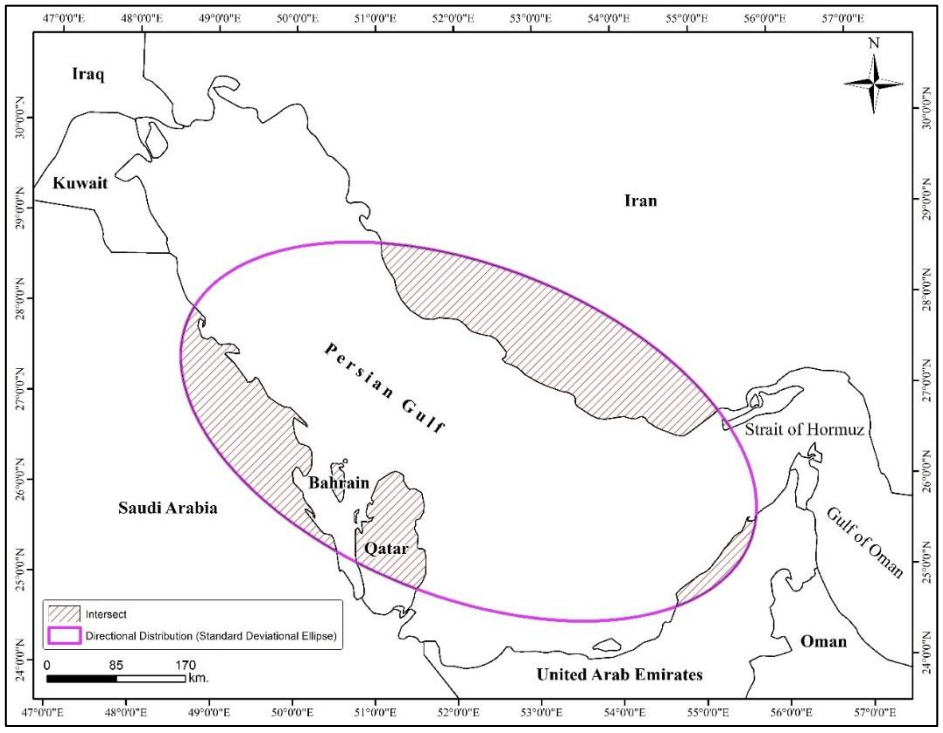


Figure 14. The Directional Distribution (Standard Deviational Ellipse) of the Persian Gulf

While historical maps illustrate long-term cartographic conventions in representing the Persian Gulf, satellite imagery and GIS-based measurements provide a complementary analytical framework by documenting the spatial stability of the underlying geographic feature. Morphometric characteristics derived from satellite data—such as area, extent, orientation, centroid position, and directional distribution—closely correspond to the form and location depicted in historical cartography. This consistency indicates that historical mapping traditions were anchored to a clearly defined and persistent maritime feature rather than to an abstract or variable spatial concept. In this regard, modern geospatial analysis offers an independent means of assessing the continuity of the Persian Gulf's geographic configuration over time. Beyond historical and satellite-based mapping, similar cartographic conventions are also evident in contemporary thematic maps produced for scientific and technical purposes. For instance, the Food and Agriculture Organization of the United Nations (FAO), in its 2015 report on the Status of the World's Soil Resources (SWSR), depicts the region using the term "Persian Gulf" in regional and global soil maps (Fao, 2015). As the primary objective of this report lies in environmental assessment rather than historical or geopolitical considerations, the use of this designation reflects its function as a standardized geographic reference within international scientific cartography.

5. Conclusions

The present study examined the Persian Gulf through an integrated analysis of historical cartographic sources and modern satellite imagery to investigate the long-term continuity and

stability of its geographic identity. Historical maps spanning from classical antiquity to the early modern period consistently depict the body of water south of the Iranian Plateau using equivalent designations, reflecting well-established cartographic conventions across different periods, languages, and mapping traditions. Complementary geospatial analyses, based on satellite-derived data, document the Persian Gulf's spatial extent, coastline distribution, and geometric properties, including its centroid location and overall directional configuration. These quantitative results reveal a coherent and asymmetric spatial structure, shaped largely by the configuration of the surrounding coastlines and particularly by the extensive northern margin. The close correspondence between historical cartographic depictions and contemporary GIS-based measurements demonstrates that the geographic feature represented in ancient maps aligns closely with the physical form observed in modern remote sensing data. By linking historical cartography with satellite-based spatial analysis, this study provides a geographically grounded perspective on how a stable and clearly defined maritime feature has been consistently represented across centuries of mapping practice. More broadly, the approach adopted here highlights the value of integrating historical maps with modern geospatial techniques for understanding the persistence of geographic features and their representation in both traditional and contemporary cartographic frameworks.

Author Contributions

Conceptualization, Mohammad Mansourmoghaddam; methodology, Mohammad Mansourmoghaddam; validation, Mohammad Mansourmoghaddam and Seyed Kazem Alavipanah; formal analysis, Mohammad Mansourmoghaddam and Seyed Kazem Alavipanah; writing—original draft preparation, Mohammad Mansourmoghaddam; writing—review and editing, Mohammad Mansourmoghaddam and Seyed Kazem Alavipanah; supervision, Seyed Kazem Alavipanah. All authors have read and agreed to the published version of the manuscript.

Data Availability Statement

Data available on request from the authors.

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Disclaimer

The authors wish to clarify that all numerical values and spatial analyses presented in this study, including measurements of area, length, width, coastline distribution, and geometric characteristics of the Persian Gulf, are derived exclusively from satellite imagery and geospatial data processed within the framework of remote sensing and Geographic Information Systems

(GIS). These results are intended solely for scientific and methodological purposes and reflect analytical outcomes based on the selected datasets and applied techniques. They do not imply any political, legal, or jurisdictional positions, nor do they represent official viewpoints or policy statements. The interpretations presented are strictly confined to the geographical and cartographic scope of the research

Ethical considerations
The authors avoided from data fabrication and falsification.

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Conflict of interest
The authors declare no conflicts of interest.

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