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SHORT NOTE

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Sea-Level Changes and its Impact on Coastal Archaeological Monuments: Seven Pagodas of Mahabalipuram, a Case Study

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Abstract The name 'Seven Pagodas' has served as a nickname for the south Indian port of Mahabalipuram since the early European explorers used it as landmark for navigation as they could see summits of seven temples from the sea. There are many theories concerning the name Seven Pagodas. The present study has compared coastline and adjacent seven monuments illustrated in a 17th century Portolan Chart (maritime map) with recent remote sensing data. This analysis throws new light on the name "Seven Pagodas" for the city. This study has used DEM of the site to simulate the coastline which is similar to the one depicted in the old portolan chart. Through this, the then sea level and corresponding flooding extent according to topography of the area and their effect on monuments could be analyzed. Most importantly this work has in the process identified possibly the seven monuments that constituted the name Seven Pagodas and this provides an alternative explanation to one of the mysteries of history. This work has demonstrated unique method of studying coastal archaeological sites. As large numbers of heritage sites around the world are on coastlines, this methodology has potential to be very useful for coastal heritage preservation and management.

Keywords Seven pagodas of Mahabalipuram · Sea level changes · Remote sensing · 3D simulation · Portolan chart

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Introduction

Mahabalipuram was a port city of the South Indian Pallava dynasty during 7th century. It is located around 60 km south of Chennai in Tamil Nadu. It is believed to have been named after the Pallava king Mamalla. Mahabalipuram has many monuments built largely between 7th and 9th centuries, and has been classified as a UNESCO World Heritage Site. The monuments include cave temples, monolithic freestanding shrines known as *rathas* 'chariots', sculpted reliefs and structural temples (Harle 1986). The sculptures are typical examples of Pallava art. Scattered ruins of structures and dressed stones have been found under water by fisherman, divers and researchers of marine archaeology (Sundaresh, et al. 2004). The Tsunami that struck the coast on Dec 26th 2004 as a result of the earthquake in the Indian Ocean washed the

sand near the beach in Mahabalipuram and uncovered some ruins belonging to the old port city.

"Seven Pagodas" is the name given to Mahabalipuram by the early European travellers (Ramaswami 1990). Since the site is on the shore with its unique temples that are visible while sailing, it rendered itself as a landmark for navigation by sea. This place was recorded in European sailors' accounts by the name Seven Pagodas. Mahabalipuram has several relief sculptures on the surface of open rocks, excavated and carved caves, and freestanding temples. But Seven Padogas refer to freestanding temples adding up to this number, summits of which could be seen from the sea. Scholars for centuries starting from William Chambers in 1778 (Chambers 1984) have speculated as to which seven monuments or temples is this reference made. Therefore, by then, that knowledge must have already been lost for some time. At present the Shore Temple built in 8th century stands at the shore, which would have been one of the seven. Whether the rest, six, are submerged or refer to ones standing further inland has been debated. At present including Shore temple there are twelve freestanding monuments dotted around Mahabalipuram.

The port city built in 7th to 9th century was much larger than what can be observed on shore at present and at that time the name Seven Pagoda dint exist. The portolan chart was made by European maritime travellers based on what they observed in 17th century. Sundaresh et al. (2004) has observed and recorded underwater remains through their study done recently in early 21st century. The present research has used the 1670 AD (closer to the period when the place might have acquired the toponym) European portolan chart to identify what they observed and recorded as Seven Pagodas at Mahabalipuram.

Materials

The 17th century Dutch portolan chart marks Mahabalipuram as "Seven Pagoda" and it illustrates seven monuments dotted along a coastline that is different from the present coastline. Recent satellite data and application of digital elevation model have been used to simulate different sea level rises factoring the topography and also study the dynamic nature of the coastline in this area by examining strand lines in multi date satellite images. Portolan charts are navigation maps that were made in Europe from thirteenth century onward. The maritime travel and trade gave rise to development of sea charts or portolan charts. Prior to the industrial era, travel by water was often easier than over land. As a result, marine channels, navigable rivers and sea crossings formed the trade routes of historic and ancient civilizations. Portolan charts were based on realistic descriptions of harbours and coasts. The word *portolan* comes from the Italian adjective *portolano*, meaning "related to ports or harbours". These charts were based on accounts of medieval Europeans who sailed the Mediterranean and Black Sea coasts. They were most often drawn on parched goat or sheep skin, and show coastal features and ports. The straight lines crisscrossing many portolan charts represent the thirty-two directions (or headings) of the mariner's compass from a given point. This is similar to the compass rose displayed on maps and charts. Navigators wished to be able to sail on what was called a rhumb-line course, or a loxodrome, i.e., to sail between two points on a constant bearing, charting their course with a straight line. On the surface of a globe such lines are curves. The portolan combined the exact notations of the text of the periplus or pilot book with the decorative illustrations. A periplus was a manuscript document that listed in order the ports and coastal landmarks, with approximate distances between, that the captain of a vessel could expect to find along a shore. The Portolan charts offered a realistic depiction of the shore, and they were meant for practical use by a mariner of the period. The portolan failed to take into account the curvature of the earth; so, they were unhelpful in crossing open ocean. The oldest extant portolan is the Carte Pisane dating from approximately 1296 (Blake 2004).

The Dutch Portolan chart 'DE CVST VAN MALEBHAER' of 1670 used in this study is from the archives of Royal Geographical Society (Fig. 1). Though the title says "Coast of Malabar", considering the features and places marked it is unmistakably the east coast of south India. In classical European accounts the word Malabar was often used to refer to south India. The place names mentioned in this portolan chart together with the modern equivalent of those that could be identified

Fig. 1 Dutch Portolan chart (1670) from the archives of Royal Geographical Society, London

Table 1 Places mentioned in the Portolan chart (north to south) and the modern equivalent of those that could be identified

Sl No.	Place names as mentioned in portolan chart	Corresponding modern names
1.	Siekrekoery	? Sriharikota
2.	Pattracatten	
3.	Criffetoer	
4.	Madraspatnam	Madras/Chennai
5.	St Thome of maliapoca	San Thome of Mailapore
6.	Couvelon	Couvelong, Taj Fisherman's cove
7.	Seve pagoodim	Seven Pagoda, Mahabalipuram
8.	Sadrempatu	Sadras
9.	Plange Bos	Bos in Dutch means forest/woods
10.	a lenprayan	
11.	Coylimaar	
12.	de Ragh	
13.	Pooleserre	Pondicherry, Puducheri
14.	Tegarepatnam	
15.	Porte Nova	Porto Novo
16.	Pagode	Temples in Chidambaram area
17.	Coldron	Koleroon/Kollidam river
18.	Treneleyaes	
19.	Trangebare	Tranquebae / Tarangambadi
20.	Carkal	Karaikal
21.	Witte Pagodt	
22.	Nagepatnam	Nagapattinam
23.	Pagodt Caryemera	
24.	Rammekens	Rameshwaram

is listed in Table 1. This portolan chart marks Mahabalipuram as Seven Pagoda and also marks seven distinctively shaped temples distributed along a shoreline. The present study compares this location as marked in the portolan chart with CARTOSAT-1 optical and stereo data to identify

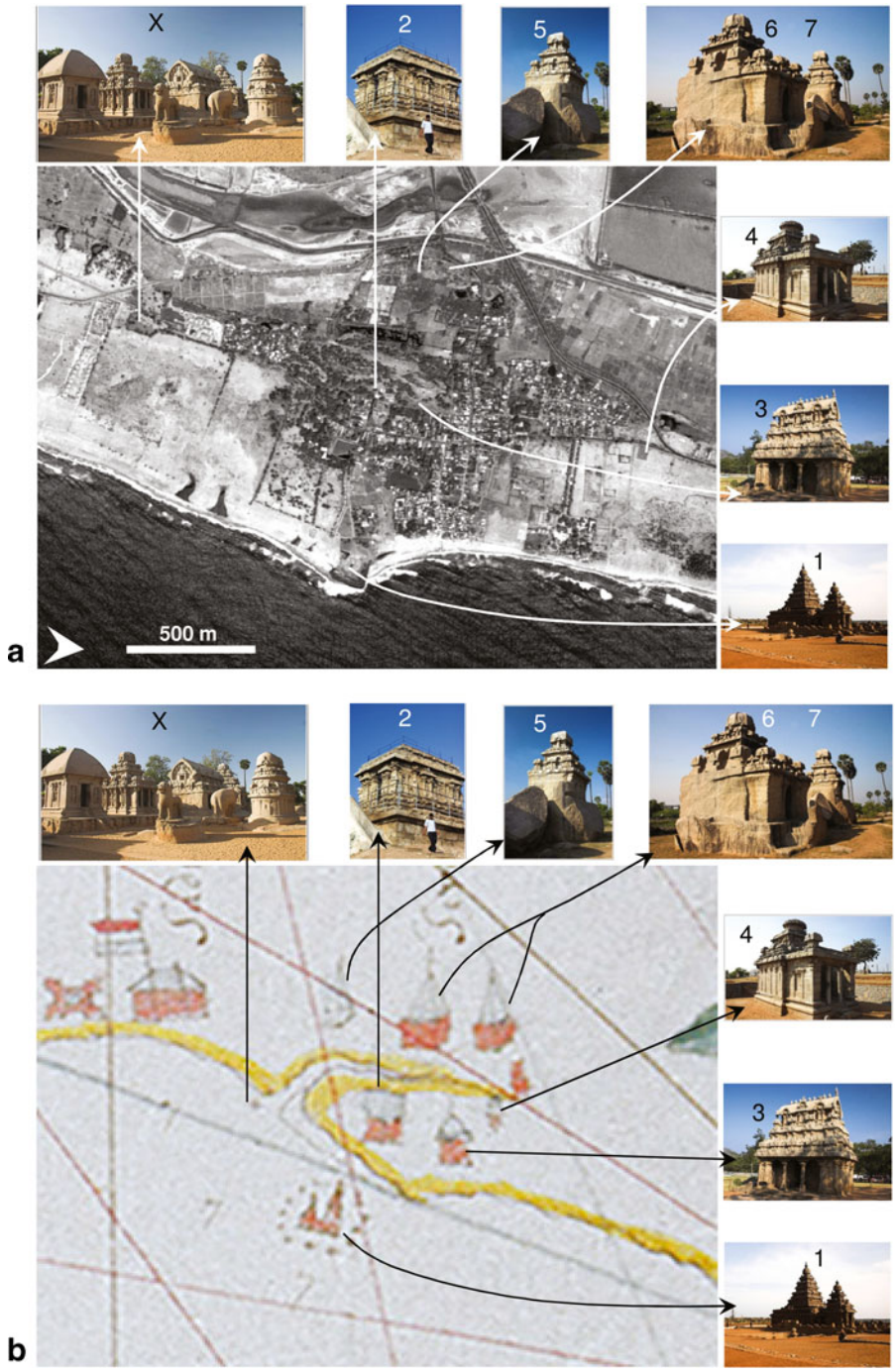

Fig. 2 (**a**) Mahabalipuram as seen on CARTOSAT-1 and the distribution of free standing monuments: 1-Shore Temple, 2-Olakkanatha or light house temple, 3-Ganesha ratha, 4-Mukunda nayanar temple, 5-Valiyankuttai ratha, 6- and 7- the two Pidari rathas, X-the five Pandava rathas. (**b**) Portion of the Dutch Portolan chart (1670) marking the Seven Pagoda and the seven monuments thereof

the Seven Pagodas. This is achieved by generating DEM, 3D models, perspective views and simulation to show views of the site that medieval mariners would have seen while sailing by.

Method

CARTOSAT-1 optical data, maps and ground photographs were used to identify all the twelve free-standing temples on the imagery (Fig. 2a). The locations of all the twelve freestanding temples were identified and marked on the CARTOSAT-1 image. The shapes of the temples from ground photographs were compared with shapes of temples drawn on the portolan chart. Each of the temples in the portolan chart is drawn with unique shape (Fig. 2b). For example a temple with two pyramid shaped towers is standing off shore in water. This can be identified with the shore temple which also has two pyramid shaped towers. It also suggests that at the time this map was made the shore temple was standing in water and the shoreline was further inland. Based on the shapes, the appropriate temples for each were identified. This helped in understanding the spatial distribution of temples with reference to each other and the current shoreline vis-à-vis the old shoreline marked in the portolan chart.

The then shoreline in the portolan chart shows a peninsula-like feature, which could be indicating topography of the area. Satellite images also throw up a feature resembling this shape (see line marked as 'All above dates' in the map in Fig. 5), which could be an old strandline. In order to investigate whether such a coastal shape could have existed 3D landscape visualization using DEM was undertaken. Another temple in the portolan chart is marked with a flat roof and is located in the middle of the peninsula. This can be compared with Olakkanatha temple (Fig. 2), which is on top of the rock near the lighthouse; it is often called lighthouse temple. In the same way the rest of the temples were identified considering their distribution on the old map in comparison with CARTOSAT-1 data. This also suggested at the time the portolan chart was made the famous five monolithic shrines called

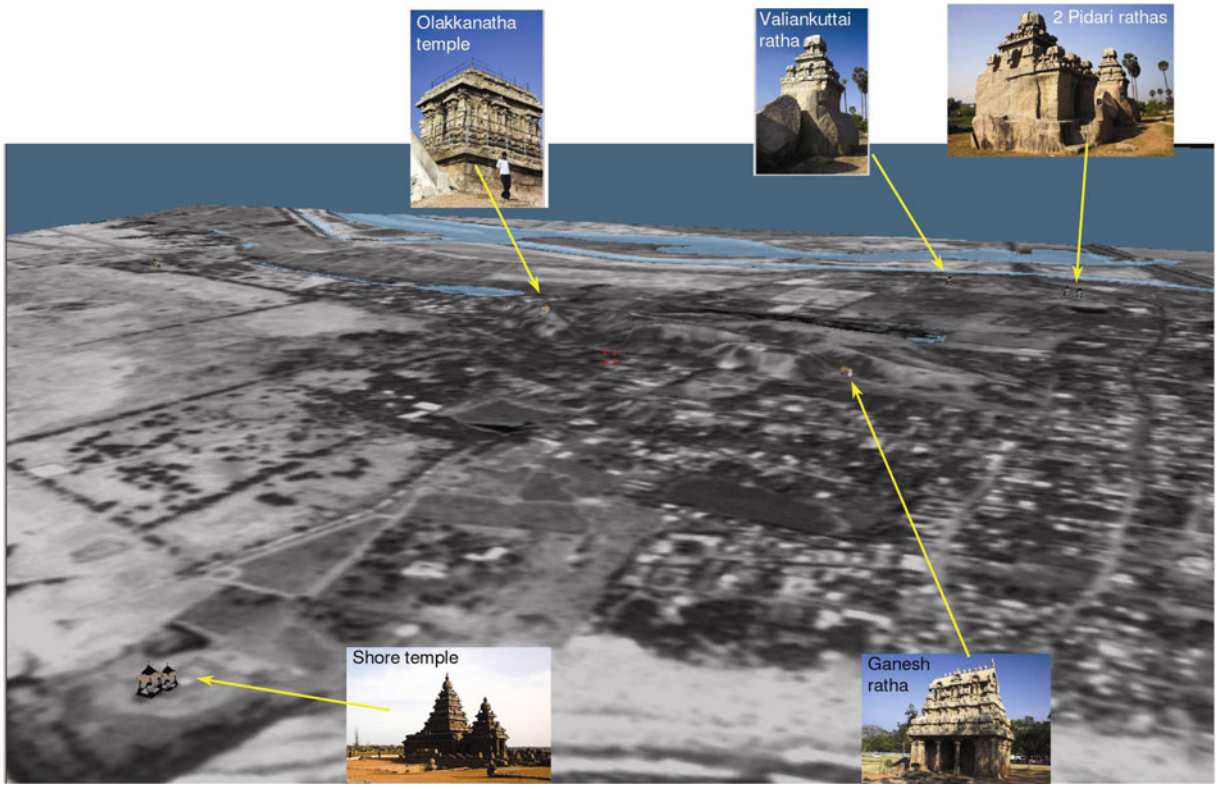

Fig. 3 3D terrain model along with embedded 3D "temple models"

the Pancha Rathas must have been submerged under water and probably under sand too.

3D visualization of landscape using different kinds of DEM has been explored (Rajani et al. 2009). In the present study the DEM of Mahabalipuram was generated using CARTOSAT-1 stereoscopic images. For surface rendition the near Nadir image of the stereo pair was draped on the DEM. The scope of the present work is to study the location of monuments in the landscape rather than architectural details of the monuments. Therefore the present work did not venture into making 3D models of architectural details of individual monuments. 3D objects (free 3D models available on www.archibaseplanet.com) resembling the shapes of temples were used by altering their size with respect to actual sizes of temple structures. These 3D "temple models" were embedded into the 3D terrain model according to their geographical location (Fig. 3). A water layer was created and raised water levels were simulated metre by metre to see the shape the shoreline would take at different levels, and consequent upon which certain monument would be submerged and some still exposed (Fig. 4). ERDAS virtual GIS module software was used for this simulation. Though the generated shoreline did not attain the exact shape of the shoreline of the old map, it did show the elevated topography of the area which is marked as a peninsula in the old map. The current topography cannot be expected to exactly match the old map for two reasons. Firstly, the then methods of mapping used could not have led to an accurate map, they were not looking from the sky but from sea or shore and what was projected as map was their inferred perception. Secondly, as the map is about 342 years old, the

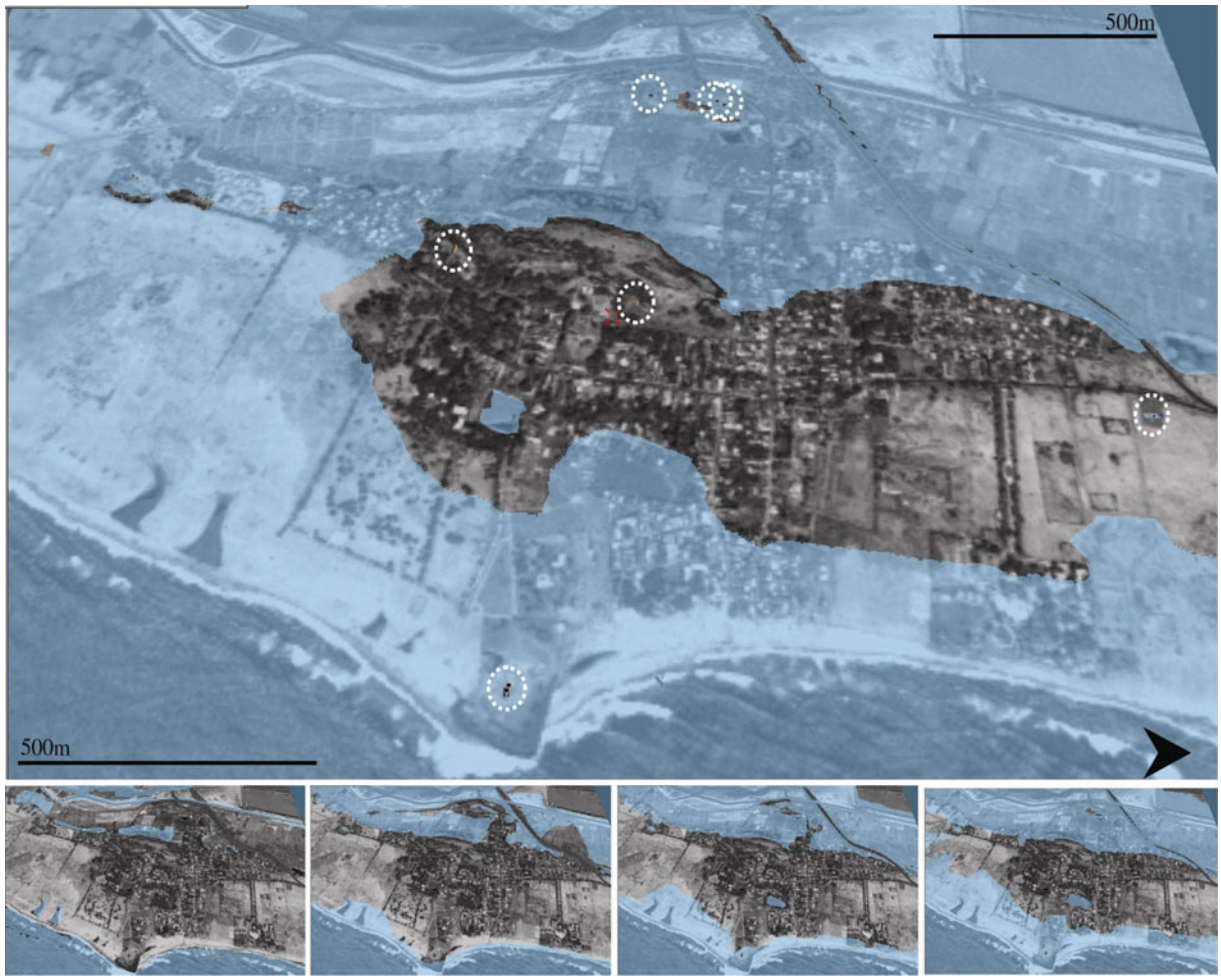

Fig. 4 3D perspective of Mahabalipuram with extent of flooding with raised water levels meter by meter

drift sand and wave action could have caused changes in the lapsed time. A "Fly Through" movie was generated simulating 3D views of the site along with simulated shoreline with the raised water level and 3D models of identified seven temples as seen from a passing ship. This was done to see if the identified temples could be noticed from the sea taking into account the topography and water level. Figure 5 shows the simulated views of the site along with raised water level and seven pagodas from three different directions from the sea. Depending on the topography of the area vis-à-vis location of the monuments, some are seen in views from south and east, but all are seen in view from north. All these views would have been considered while making the portolan chart.

Results and Discussions

This particular study represents a unique demonstration of the capability of remote sensing, particularly 3D visualization to explore coastal structures under varying sea levels. The study has identified the seven pagodas as marked on the Portolan chart of Mahabalipuram dating from 1670. This suggests that the local sea level has receded about 3–4 m in the last 342 years. The current models for rate of mean sea level change suggests a rise of about 3 mm per year (Solomon et al. 2007). However, the report also says "Sea level change is highly non-uniform spatially, and in some regions, rates are up to several times the global mean rise, while in other regions sea level is falling". Apart from the natural phenomena of sea level changes affecting the Mahabalipuram coastline, anthropogenic activity also has played a role in shaping of the current shoreline. Early 20th century studies on the condition of the Shore Temple suggested that direct lashing of sea water and sea wind had deteriorated the monument considerably. In order to protect this heritage monument, efforts for construction of Groyne wall began 1939–1940, finally it took present shape in early 1980s. This Groyne wall is the reason for the pointed shape in the present coastline beside the Shore temple in otherwise

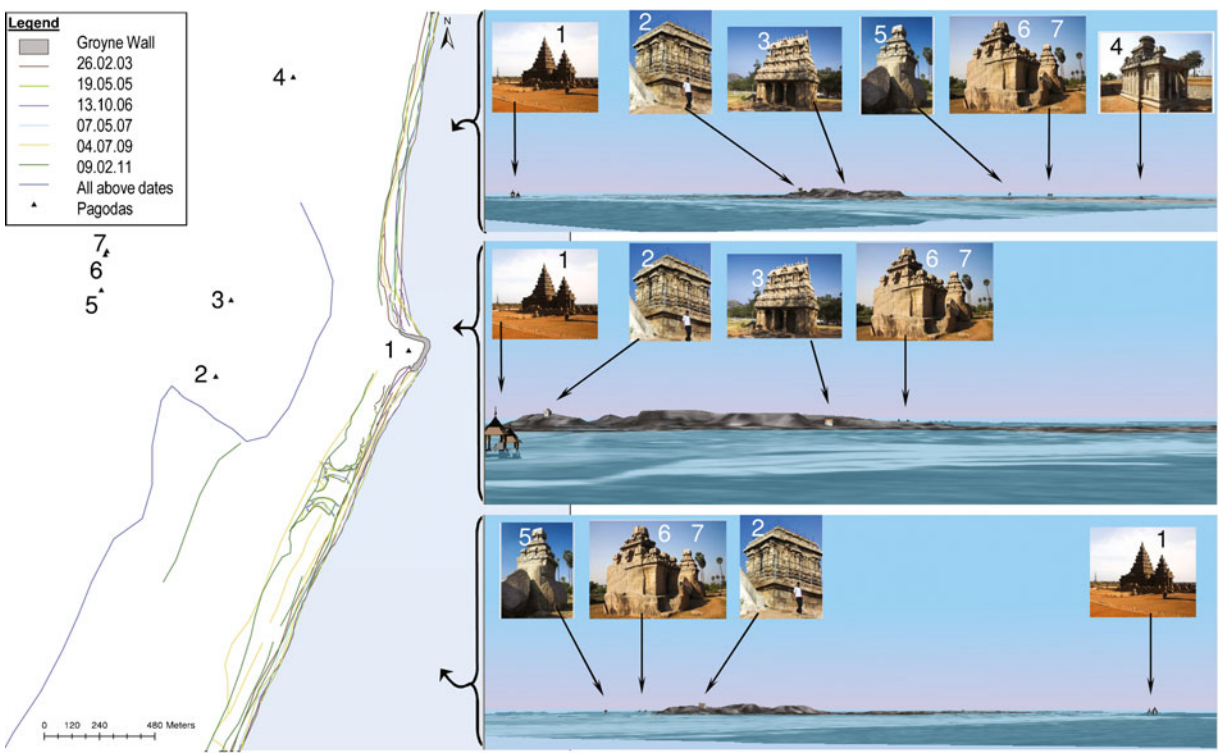

Fig. 5 Three simulated virtual reality views of Mahabalipuram from sea, recreating the scene (including the summits of seven pagodas) seen by medieval European mariners as they sailed by. On the left is a map of Mahabalipuram coastline showing the the distribution of location of pagodas, strandlines observed on multi date satellite images and also direction of the simulated views

a smooth shoreline (Narasimhaiah 1995). The map in Fig. 5 shows strandlines along Mahabalipuram coast detected in high resolution satellite images available on Google Earth of mutliple dates in the last decade. However a direct linear extrapolation of this into a 342 year time scale is fraught with complexity because of the shoreline movement not being consistently in one direction. The dynamic nature of this coast is clearly indicated by the presence and shapes of the strandlines; they also highlight the role played by groyne wall in protecting Shore Temple, but for which the Shore temple may have been in water even today.

The record of shoreline on the portolan chart could have been a transient phase, maybe affected by short-term sea level changes consequent upon local topography, wind, storm, waves and anthropogenic activities. That is probably the reason why such a shoreline with seven monuments were noticed and recorded by some and speculated upon by others, which collectively has attributed mysteriousness to the name Seven Pagodas. The site being in such a threshold between land and sea, was probably regularly inundated and therefore looked different at different times.

Conclusions

This study provides an alternative explanation for the mystery of the name Seven Pagodas of Mahabalipuram by identifying seven temples that constituted this term, which were marked on the portolan chart of 1670. This work has also demonstrated the importance and relevance of information recorded in portolan charts and also that the modern computer vision tools such as virtual GIS facilitates integration of cartographic information of different times.

In the light of past, present and predicted future sea levels, the dynamic nature of coastline is very clear. As a wealth of cultural heritage of various times from the past lies in coasts, it is important to study them and document them and take measures for preserving them for posterity. This work has demonstrated a method to use remote sensing, GIS and 3D simulation for the purpose of coastal heritage management in the context of changing climate. Digital elevation model provides a powerful tool to simulate visibility of landscape together with various scattered structures for different simulated sea levels. This in turn could be used for possible understanding for presence or absence of structure in the present epoch. This method can be applied to other areas within and outside the country. It is also important to recognise that without remote sensing and GIS tools it would not have been possible to conduct such a study and arrive at the given conclusions.

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