



# The warped sea of sailing: Maritime topographies of space and time for the Bronze Age eastern Mediterranean

Crystal Safadi\*, Fraser Sturt

Department of Archaeology, University of Southampton, SO17 1BF, UK

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## ABSTRACT

Time has consistently been regarded as the missing dimension from our renderings of space, having a significant impact on how we interpret and represent past interaction. Nowhere is this more keenly felt than in discussion of maritime mobility. This paper outlines an innovative approach to mapping maritime spaces by taking into account the performance of Bronze Age sailing ships in different weather conditions and the subsequent time of sailing journeys. The use of cartograms is demonstrated to be invaluable for reconceptualisation of maritime space and rethinking maritime connectivity in the past. This marks a step-change in approach, which has implications for regions beyond the case study area (eastern Mediterranean).

The results presented in this paper foreground meaningful differences in maritime connectivity between Egypt and the Levant during the earlier Bronze Age than are easily realised through traditional static representations. This demonstrates the significance of developing alternative representations of space/time for archaeology.

## 1. Introduction: mapping maritime space

Representations of maritime spaces and the connections they afford frequently fall into monotonous replication of spatial geography. Despite the long history of map-making, and variation in cartographic style and projections (e.g. Cunliffe, 2017: 28–34, 69–73; Harley and Woodward, 1987; Broodbank, 2013: Fig. 8.54), Cartesian maps in the twenty-first century remain imperative to archaeological interpretation and analysis. Their usage, however, raises conceptual and analytical issues. A map of Roman sea routes (Fig. 1), for instance, compared to a modern-day map of ship lanes and traffic, shows no difference in terms of how the sea and connectivity is conceived of and mediated. This poses a problem. Whilst marine transport in the twenty-first century relies mostly on machinery and powerful engines that can defy natural conditions, seafaring and navigation in prehistory involved an intricate web of rhythms, a knowledge and understanding of a range of variables that in today's world may be managed digitally. This difference in the performance of activities while being at sea inevitably results in distinct conceptions and experiences of maritime space. Accordingly, our static representations fail to acknowledge and translate that difference and complexity, which ultimately impinges on the understanding of maritime connectivity and patterns of movement in the past. The question that then arises is how to mediate maritime spaces in archaeology in

such a way as to address human variables, the rhythms of being at sea and to approximate the conceptualisation of these spaces by those engaged in the activities in the past.

This paper proposes a framework and methodology for mediating maritime spaces—mapping with cartograms—adapted from the disciplines of geography and cartography. The alternative maps presented here reflect a fundamental process associated with being at sea and imbued with human connotation: time. They build on the established understanding of waterborne movement during the Bronze Age in the eastern Mediterranean and provide a heuristic tool for the analysis of coast-to-coast connectivity. Critically, they also establish a platform for conceiving of maritime space in archaeology in new and innovative ways. This paper explores modes of mapping maritime spaces and demonstrates the significance of alternative representations to archaeological interpretation by re-evaluating maritime connectivity between Egypt and the Levant during the earlier period of the Bronze Age (the Early Bronze Age - EBA) in light of sailing space-time cartograms.

### 1.1. Maritime space

Over the last thirty years, an interest in space has gained currency in the social sciences and humanities. This 'spatial turn' has had obvious consequences since it pushed the discourse away from set objects/

\* Corresponding author.

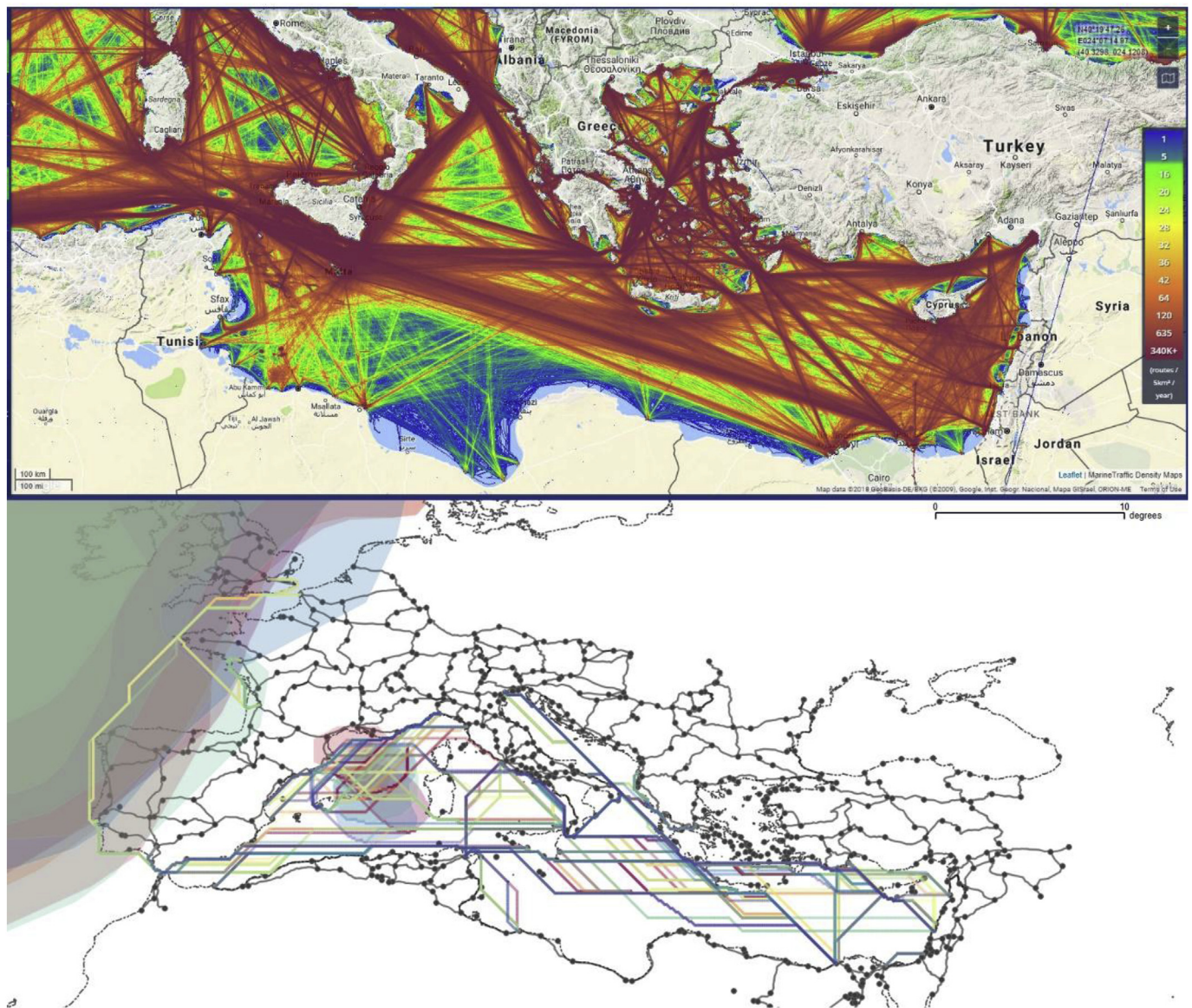
E-mail address: [c.el-safadi@soton.ac.uk](mailto:c.el-safadi@soton.ac.uk) (C. Safadi).

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**Fig. 1.** Top: Density of marine traffic lanes in the Mediterranean (Credit: Live Marine Traffic Agency). Below: Potential Roman sea routes (Credit: Meeks, 2012). Note how the Mediterranean Sea is depicted as a surface on which direct connections and routes are established for modern-day and ancient marine traffic.

definitions and imposed categories, towards an emphasis on processes and relations (Thrift, 2006: 2). Space then came to imply a dynamic one of interrelations, a space under construction, open, heterogeneous and lively (Merrimen et al., 2012; Thrift, 2003; Massey, 2005).

As Merrimen et al. (2012: 4) convey, many scholars favour working in their studies with encultured concepts, such as place, landscape and locale, rather than 'space', but the appeal of space to scholars is precisely in its heterogeneity and multiplicity, as relational, abstract, materialised and concrete. Space, therefore, not as a container or absolute, but relational and lived, is crucial to engage with in archaeological research. It shifts the focus from tasks to processes; it constitutes and is constituted by relations and productions, and here lies its power as a concept when applied to a maritime context.

Maritime spaces and navigation involve a convoluted web of rhythms, and knowledge and understanding of a range of variables. Whilst the quest for finding longitude at sea climaxed in the seventeenth-eighteenth century (see Sobel, 1995), navigating a perilous sea in prehistoric times relied on dead reckoning. Just as modern equipment and the use of digital navigation changes a mariner's perception and conception of space (November et al., 2010), so navigation

by dead reckoning involves an understanding of space processed via the mariners' mental maps. Thus, ancient seafaring comprises an active process of cognitive mapping as a means of storing information and accessing wayfinding clues. This act of cognitive mapping embraces the process of producing internal spatial representations of the surrounding environment (Pérush et al. 2000: 108), which as experiments have shown are subjective and distorted when compared to Cartesian maps (Hallpike et al. 1986: 343; see also Caquard, 2015; Ingold, 2000: 223–225). Therefore, maritime spaces as spaces of experiences, performances and relations, should not be reduced in archaeological representations and interpretations, to static models. In line with this vibrancy, mapping rather than map-making provides a framework for the mediation and translation of maritime spaces—while accounting for the rhythms involved in seafaring—their knowledge and use, which constitute fragments of a much wider, more complex relational space.

Since the mid-1980s, the view of cartography and maps as objective products of science has been challenged (Crampton, 2003; Harley, 1989; Kitchin and Dodge, 2007) and with it came the distinction between the processes of 'map-making' and 'mapping' (Edney, 2005). According to Lilley (2012: 205), while the former consists of a



conventional and narrow sense of cartography, the process of map production, the latter revolves around complex relationships and meanings and the manifold types of mappings. Mapping then becomes a medium, a mode of engagement that fosters different relations, and challenges and transforms our understanding of maritime spaces, a 'circulating reference' (Latour, 1999: 24–80; Shanks and Webmoor, 2013). Hence, mapping has the potential to alter preconceived notions of maritime space, to incorporate not only geographical variables of distances but also rhythms of activities, and to promote alternate analyses and outcomes. It is within this framework that mapping is employed in this research.

Mapping in archaeology has mainly relied on the translation of the material world onto a flat map, via the use of standardised tools and platforms such as survey instruments and Geographical Information Systems (GIS), which provide us with a repeatable mode of engagement with sites, locales and features. Nonetheless, this particular mode of engagement is not exclusive (e.g. Webmoor, 2005; Witmore, 2013: 145–147; Shanks and Webmoor, 2013). An appealing and functional approach for mediating maritime spaces involves the use of cartograms or diagrammatic maps. Cartograms are maps in which at least one aspect, e.g. distance or area, is distorted according to an element/human variable of interest (Ballas and Dorling, 2011). The distortion in cartograms is based on mathematical and statistical calculation such as bidimensional regression and aims at generating a deeper understanding and examination of research questions and problems. Unlike conventional maps, which can be characterised as equal area cartograms, any variable of interest can be the source of distortion of a cartogram and they can take many forms, e.g. linear and area cartograms (see <https://worldmapper.org/>). Linear and area cartograms started appearing in the mid-nineteenth century. The earliest known was Levasseur's cartogram of Europe from the 1870 (Tobler, 2004: Fig. 2). However, it was only in the 1930s with the work of Dr Waldo Tobler on cartographic production and automated methods that cartograms became widespread and easily drawn (Tobler, 1973; see also Henning, 2013).

The application of mapping to past maritime spaces with cartograms necessitates an understanding of the variables and processes involved in the performance of seafaring. These processes inevitably include natural rhythms such as winds and currents, as well as human variables. However, the interest here is not in rhythms and processes as independent actants, but in their relations and interactions for mapping/mediating one of the many maritime spaces. Therefore, the computation of cartograms requires a shift in focus to the dynamics of seafaring and how relations between processes affect those dynamics. This is where the two elements of distance and time, which qualify the performance of seafaring, come into play. The notion of distance, as Farr (2010: 22) maintains regarding trans-Adriatic crossings, is tangled with the passage of time. Predicting the time it takes to reach a destination was an important and difficult aspect of navigation. Seafaring-related written texts often mention the number of days' sailing when referring to distances of sea journeys (see Casson, 1995: 282–290). This is evident in the *Periploi* in which the time a trip should take and the distance between points were synonymous (Morton, 2001: 218–221). The employment of days' sailing as an indicator of distance is a corroboration of the significance of time to estimate speed, plan and undertake journeys and, most importantly, as a cognitive and realistic variable affecting the seafarers' perception and understanding of their space.

Time then glues and tangles the processes and variables unfolding in space to the performance of seafaring. Weather conditions, direction and speed of winds and currents, the vessel's characteristics, rig-plan, hull form, sailing directions, etc., all these factors and many non-quantifiable ones represent and render time, which in turn reflects how ancient seafarers might have conceived of their space while engaged in the act of sailing from one location to the other. Henceforth, mapping the maritime space in this instance equates to mapping sailing space-time for quantifiable variables. The use of cartograms, or distorted

thematic mapping, facilitates this exercise. However, not without drawbacks. Indeed, of the variables and processes rendering sailing time, such as seafarers' skills and expertise, some are non-quantifiable, and others are beyond the reach of current archaeological knowledge. Thus, the methodology here relies on quantifiable processes and relevant extant information, in the intention that mapping sailing space-time could offer a window into the intangible yet experienced world of seafaring.

## 2. Modelling space-time

With the introduction of new modes of transport, geographers and engineers engaged in the production of space-time cartograms that would cartographically represent the difference in time between different modes of transportation (see Bretagnolle, 2005: Fig. 1; Hägerstrand, 1973). More recently, the work conducted by Di Piazza (2014) employs maps based on experimental time of sea-travel by canoe, accounting for wind speed and direction, to deduce space-time cartograms for the island of Ta'u in West Polynesia. It is on similar lines to that of Di Piazza (2014) that this paper develops cartograms for the sailing space-time taking as a case study the Levantine Basin of the eastern Mediterranean during the Bronze Age. This entails a distortion of space, meaning distance, via cartograms, according to sailing time, which accounts for variables and rhythms that affect the sailing performance. In this context, the performance of a sailing vessel based on environmental conditions must be established.

Many factors influence the performance of a sea-going vessel and thereby the sailing time of a journey. Of the most important of these factors is the underlying speed of the vessel which in turn is a reflection of the rig-plan, the rigging material, the hull form, the type of propulsion, the journey's itinerary, weather and environmental conditions, human decisions, mariners' experiences and risk assessments. As Whitewright (2018: 28) discusses, the understanding of such factors, in the absence of a historical/classical handbook on maritime technology from the Bronze Age, and the lack of direct archaeological evidence revealing propulsion mechanisms, must rely on iconographic material and robust and logical interpretations/assumptions.

### 2.1. The sail and watercraft

In regards to the Bronze Age rig-plan, which is of direct relevance to how a ship performs under different weather conditions and sailing directions, the oldest documented one known to date is the single-masted square-sail. The evidence comes from the proto-dynastic period in Egypt where drawings on pots identify its use from around 3100 BC (Whitewright, 2008: 146; Casson, 1995: 12; McGrail, 2001: 19). Although the sail was known in Egypt from the fourth millennium BC, and arguably in the Arabian Gulf from the sixth millennium BC (Carter, 2006), indication of its use in the Mediterranean only appears c. 2100 BC. However, as McGrail (2001: 113) points out, it is more than likely that the sail was in use on the Levantine coast at a much earlier date, despite that the earliest depiction of its use is an eighteenth-century BC engraving on a Syrian seal. With reliable evidence, it is fair to assume that the square-sail rig was the main propulsion for Mediterranean ships throughout the Bronze Age (Whitewright, 2008: 146; McGrail, 2001: 113–114; Wachsmann, 1998: 42–47). This is further supported by depictions on Minoan seals from the 2nd millennium BC of single-masted square sails (Basch, 1987). Although these, according to Whitewright (2018: 29), possibly indicate the illustration of brailled square-sail rig that can also be traced across the 2nd millennium from Egyptian sources (Wachsmann, 1998: 251–254). Throughout the Bronze Age Mediterranean, the depictions of square-sails change from boom-footed ones, in which the lower edge of the sail is attached to a boom, to loose-footed sails with brails permitting greater flexibility and efficiency in handling and manipulating the sail (Whitewright, 2018: 30). This difference in rigging from the earlier to the later Bronze Age inevitably has

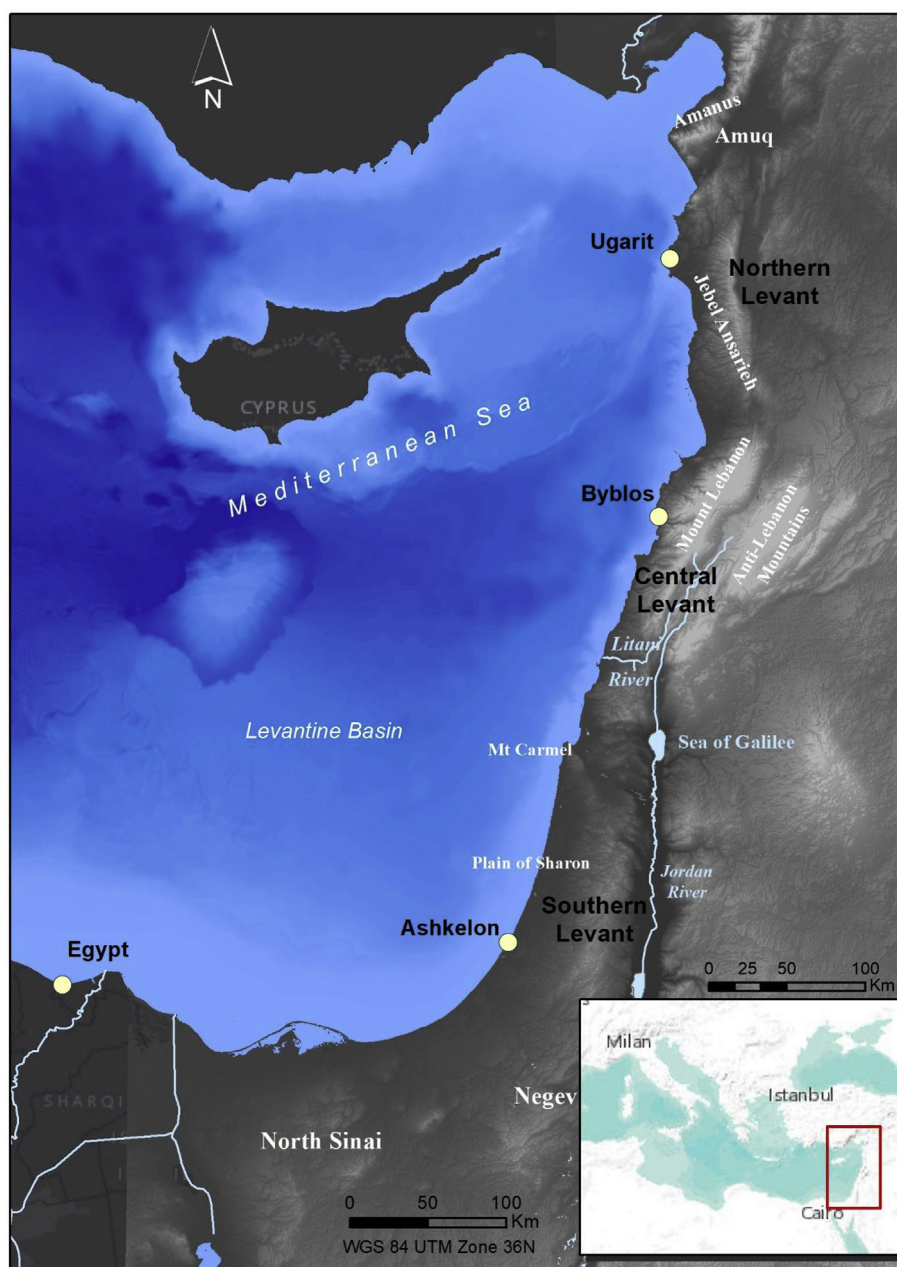


Fig. 2. The distribution of sites/departure locations on the Levantine coast (Ashkelon, Egypt, Byblos and Ugarit).

bearing on the performance of a vessel under different weather conditions. Given that this paper aims not only at mapping the space-time of the Levantine Basin of the eastern Mediterranean but also demonstrating the value of such an exercise to the evaluation of maritime connectivity during the EBA, this change in the technical details of the rigging presents an impediment to the modelling of the performance of an earlier sailing vessel, as will be discussed below, but one that is not unsurmountable for the purpose of approximating maritime space-time connectivity.

Apart from the sailing rig, the shape of the hull of a vessel plays a significant role in its performance. For instance, the 'wine-glass' shape of the Kyrenia from the 1st millennium BC is better suited to sail on upwind and crosswind courses (Whitewright, 2018: 39). Direct archaeological evidence of hull shapes, however, from the earlier period of the Bronze Age in the Mediterranean is non-existent (although for examples from Egypt and the Red Sea see Lipke, 1984; Mark, 2009; Ward, 2006; Tallet, 2012, and for the Late Bronze Age see Pulak, 1998).

In this instance, indirect evidence can shed light on maritime endeavours that took place during the EBA, particularly in relation to Egypt and the Levant, in themselves a reflection of sailing capabilities. Of these is Sneferu's inscription on the Palermo Stone (c. 2600 BC) disclosing the transport of forty ships from Byblos to Egypt (Broodbank, 2013: 291; Pritchard, 1975: 227; Sasson, 1966: 127), and the relief from Pharaoh Sahure's pyramid in Egypt, c. 2475 BC, demonstrating the first solid evidence of seagoing ships (Casson, 1995: 20–21; Mcgrail, 2001: 30). The relief portrays the return of an expedition from the Levant to Egypt. The hull is long and slender, planks are depicted edge-joined and the rig a tall narrow square sail.

The archaeological direct and indirect evidence discussed thus far proves that the earlier vessels roaming the Mediterranean were seagoing, benefiting from a boom-footed square-sail rig that is later simplified to a more efficient form with the loose-footed sail with brails (Whitewright, 2018: 30). Therefore, in the context of this research, it is the performance of square-sail ships in different weather and

**Table 1**  
Summary of observations from the experimental voyages of Kyrenia.

Wind speed (Beaufort scale)	Point of sail	Vessel speed
4–6	Broad reach	4–5 knots
4–6	Beam reach	4–5 knots
3–4	Quarter reach	3–4 knots
2–3	Broad to quarter reach	3 knots
3	Beam reach	2.1 knots

environmental conditions that determines the speed of the vessel, from which the sailing time can be derived. Indeed, the performance depends on many factors, but given the restricted data available on EBA sailing vessels, we need to resort to accessible studies and information, whilst recognising the limits that imposes on mapping sailing space-time. The following sections outline the details and data that feed into the evaluation of the performance of a square-sail vessel, subsequently the speed and time of sailing that enable the computation of distorted mappings.

## 2.2. Points of departure

The production of space-time cartograms must relate to specific locations that mark the origin of departure. Indeed, the length in time of a sailing journey is largely determined by its itinerary (e.g. number of stops). Nonetheless, the aim here is not to model sailing time between specific locations/sites, since this involves knowledge of the journey's itinerary and consideration of the movement of the vessel at sea, including choices made in respect to sailing directions and weather conditions. What this paper proposes, is a distortion of space according to how it morphs with sailing time from a particular location on specific bearings (as discussed below). For this mapping exercise, four sites that show indication for engagement with the sea during the EBA and spread along the Levantine coast were selected as markers of sailing departure. The sites were chosen in respect to their functioning as potential natural harbours during that time period (see Gophna, 2002; Safadi, 2016) and in line with the material record they reveal in relation to maritime activities, e.g. fishing practices, and/or trade connections based on the provenance of material culture. These are the sites of Byblos in the central Levant (Dunand, 1945, 1973; Lauffray, 2008), Ugarit in the northern Levant (Schaeffer, 1962; Yon, 2001; Al-Maqdissi, 2013), Ashkelon in the southern Levant (Golani, 2004; Gophna and Liphshitz, 1996), in addition to Egypt, which played a significant role with the southern and northern Levant during the EBA (Gophna and Liphshitz, 1996; Sharvit et al., 2002; Sowada, 2009). The points of departure (Fig. 2) are by no means representative of all EBA sites along the Levantine coast. However, given that the EBA period is conventionally studied by reference to the central, northern and southern Levantine sub-regions (Steiner and Killebrew, 2013), it proves systematic to select sites along those coastlines and sites whose record suggests for maritime activities (for Ugarit see Yon, 2001; for Byblos see Saghih, 1983 and Artin, 2007; for Ashkelon see Liphshitz, 2004, Braun and Gophna, 2004; for Egypt see Sowada, 2009).

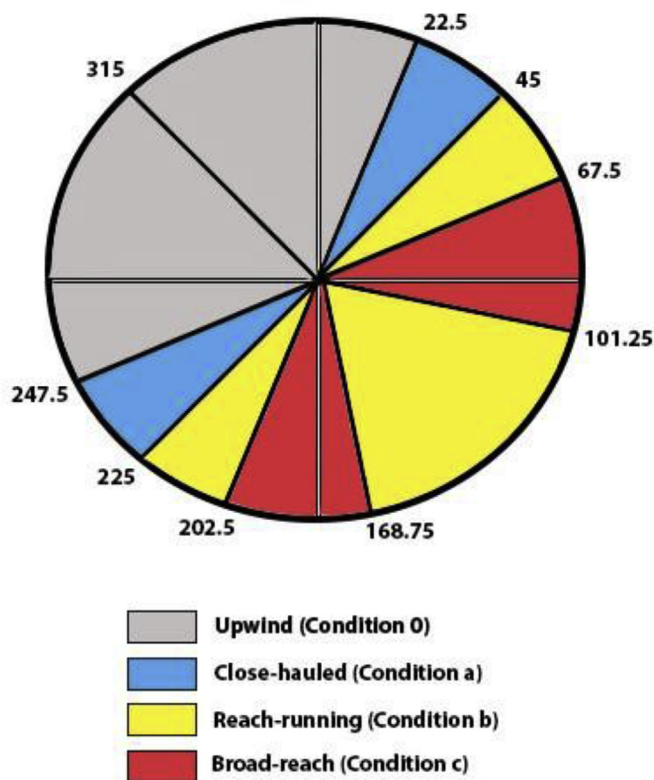
## 2.3. Sailing direction and vessel speed

Of the natural rhythms impacting on the performance of a square-sail vessel, winds and currents are of the most important given the near absence of tides in the Mediterranean Sea (Heikell, 1994: 24). The work conducted by Whitewright (2011) is of substantial importance here since it details the performance of a square-sail vessel according to wind directions, therefore binding environmental conditions to the sailing vessel. It is paramount to note, however, that Whitewright (2011) computation of a square-sail vessel performance derives from later records, beyond the Bronze Age. As such, the observations unlikely reflect the performance of an EBA boom-footed square-sail. That being said,

Whitewright's (2011) work can be employed with caution, when acknowledging that the results of this model are suggestive and permit an approximation of EBA maritime space-time deformation based on sailing time rather than represent a conclusive truth of that time period.

Whitewright's work provides sufficient information regarding the Vmg (Velocity made good) and dynamics between wind directions and sailing performance, but lacks the influence of wind speed on vessel performance. The experimental voyages of the KYRENIA II ship offer insight on this matter. The KYRENIA II is a replica of a Greek merchant ship, excavated off the north coast of Cyprus (Katzev, 1990). Summarised description on the KYRENIA II sailing speed in different weather conditions shed light on the performance of a square-sail rig (Table 1). KYRENIA II is a replica of a ship from the fourth century BC, in other words, its loose-footed brailed sail and slender hull performs differently to an EBA vessel. It does, however, remain the earliest replica to date of a square-sail vessel whose journeys have been documented and reported on. For this reason, its performance can be drawn upon but not without the necessary understanding of the implications of the results.

How a vessel performs under specific wind speed and direction is contingent on the sailing direction, for only then we can infer the point of sail according to the wind direction. A ship, ultimately, may set course on any path. Indeed, weather conditions impede that freedom of sailing, but they are not unsurmountable when an experienced crew is in charge. With the intention of an achievable mapping methodology, this paper focuses on the eight main bearings as sailing directions from a site of departure. For instance, according to Fig. 3, if a ship sails on a bearing of 315° and the wind is blowing from  $\pm 60^\circ$  from that bearing (Whitewright, 2011: 10), i.e. wind blowing anywhere from 247.5° to 22.5°, then the vessel would be sailing upwind. By restricting the direction of sailing to eight bearings, the points of sails can then be deduced according to wind direction. Henceforth, the model accounts for



**Fig. 3.** An example of the conditions of sailing on a bearing of 315°. If the wind is blowing from anywhere between 22.5 to 45 and 225 to 247.5, then sailing on a bearing of 315° will have to be closed-hauled.



**Table 2**  
Summary of Vmg in knots according to wind speed and points of sail.

Points of sail	Wind speed of Beaufort 2-3	Wind speed of Beaufort 4-5-6
Condition 0 (Upwind)	0 knots	0 knots
Condition a (Close-hauled)	0.5 knots	1.5 knots
Condition b (Reach-Running)	3.5 knots	5.5 knots
Condition c (Broad-reach)	5 knots	7 knots

four conditions in respect to points of sail. Each of those conditions in turn depends on the sailing direction and wind direction. The conditions, however, must in turn be associated with relative vessel speed. Considering Whitewright's Vmg values in relation to wind direction, and KYRENIA II observations in relation to wind speed, Table 2 outlines the Vmg values based on the four conditions of sailing, divided into two categories of wind speed, Beaufort 2–3 and Beaufort 4–6.

#### 2.4. Weather and marine data

The winds and currents of the eastern Mediterranean provide the basis of variations affecting the relative speed of vessels and sailing time (see Davis, 2001; Beresford, 2013). The models of wind speed and direction are in the form of grids of data whereby the wind speed reflects, for each grid, the value in knots, and the wind direction points to the direction the wind is blowing from in degrees (Safadi, 2016). These models offer a seasonal and daily temporal resolution, thus accounting for variations in diurnal winds. The integration of these grids in a GIS enables the computation of cost surfaces of vessel speed for the four seasons of a year and for the daily morning and afternoon temporal resolution.

As for the current, although it is relatively weak in strength in the Mediterranean (Heikell, 1994: 24), it nonetheless can reduce or increase a vessel's speed, similarly to the wind. Current data was derived from the gateway of European environmental information, Copernicus, in the form of a meridional (V) and zonal (U) current grids. Analogous to wind speed and direction, the effect of current speed and direction on sailing time was established. Arnaud (2005: 23) explains that if two ships are traveling in opposite directions at a speed of 4 knots, one with the current and one against it, whilst the speed of the current is 0.5 knots, the two ships reach a difference of 1 knot between their speeds. The one traveling with the current gains the speed of the current, whereas the speed of the one sailing against the current is reduced by the current's speed. Thus, four conditions associating sailing to current flow were formulated (Table 3).

According to the conditions put forth in relation to winds and currents, sixty-four sailing speed (Vmg) grids were generated in GIS (eight for the bearings, multiplied by four for the seasons and 2 for the morning and afternoon temporal resolution). Subsequently, time grids, generated according to Fig. 4, were employed as cost surfaces in GIS permitting the computation of sixty-four cost rasters in time (hours) for

**Table 3**  
The conditions associating current flow with sailing direction and sailing speed. Note these are the author's own assumptions as no information or study has related thus far current flow to the performance of a square-sail vessel (except for sailing with or against the current, which follows Arnaud's (2005: 23) explanation).

Sailing direction in relation to current flow	Effect of current speed on sailing speed
Against the current (Condition 0)	-Current speed
Negative current flow (Condition a)	– 1/2 current speed
Positive current flow (condition b)	+ 1/2 current speed
With the current (condition c)	+ current speed

each point of departure. These grids offer the basis for extracting the sailing time associated with image points to produce space-time deformed maps (see Supplementary Material for additional detail).

#### 2.5. Production of cartograms

The production of cartograms necessitates source and image points. Source points may be specific or random locations along a sea journey, while image points represent the image of the source points according to the newly calculated sailing time that accounts for environmental rhythms. The sailing time to reach source points, however, must be based upon a generic cost surface that does not account for winds, currents or seasonal variations. Consequently, a sailing speed of 4 knots was chosen (Casson, 1995: 282–291; Whitewright, 2011: 10). A cost raster of time was generated from the generic sailing speed surface following the step outlined on Fig. 4 for the derivation of time from speed grids, and thereafter cost distance rasters for each site/point of departure were produced. These grids then permit extracting sailing time for the source points in the process of cartograms' creation.

For each site, at least six source points on each bearing were located. Via a mere linear extension from the source points, image points were geographically located in GIS on the grid value that corresponds to the new calculated sailing time (Fig. 5). The data was then integrated in Darcy 2.0 software to produce cartograms for each site, for the four seasons and for the morning and afternoon (e.g. Figs. 6–7). Inexorably, the assumptions underpinning the modelling/mapping of cartograms, by necessity, are general ones and inherently limiting - eight points of sail, four conditions of movement, two categories of wind speed and four locations of departure. Notwithstanding, the resulting models demonstrate, as elucidated in the following sections, the significance of even such a limited set of constraints. One is compelled to imagine then the complexity and multi-faceted nature of maritime spaces with 32 points of sail, 32 current directions, 8 forces of wind, infinite landfall points and infinite variation in vessel performance.

### 3. Results and discussion

The generated cartograms offer a powerful conceptualisation of the navigable space-time of the Levantine Basin based on the selected parameters in relation to sailing performance. In fact, the methodology proposed could apply to different maritime spaces and different chronological periods, hence its significance for evaluating and understanding maritime spaces. On a general level, these deformed maps attest for the importance of such an analysis for any maritime space since on the one hand, they portray archaeologists' conceived spaces given that they are based on data that archaeologists employ, and on the other hand, they constitute a heuristic tool that can aid in better understanding the archaeological record.

The changes witnessed according to daily and seasonal temporal units are profound. For instance, the difference is evident on the cartograms of Byblos (Fig. 6) for the autumn (am) and autumn (pm). While the distortion of space from the site of Byblos during the autumn (am) brings Cyprus closer to the Levantine coast, the autumn (pm) distortion depicts the opposite, with Cyprus pushed away from that coast. The winter (am and pm) distortions on the other hand stretch out the whole Levantine coast, yet with Cyprus in close proximity to the northern Levant, not to mention the Anatolian coast which is almost superimposed with the northern Levant. Hence, winter time seems to afford an uninterrupted access for undertaking journeys across the Levantine Basin, to Cyprus and Anatolia, rather than relying on coastal pilotage along the Levantine coast and solely summer sailing. This relatively simple evaluation comparing the cartograms of one site at different times throughout the year, testifies to the nature of information that can be extracted from these mappings, but not without further analysis since, for instance, environmental rhythms may afford quicker journeys but the risk of sailing may conversely be higher. In comparison to

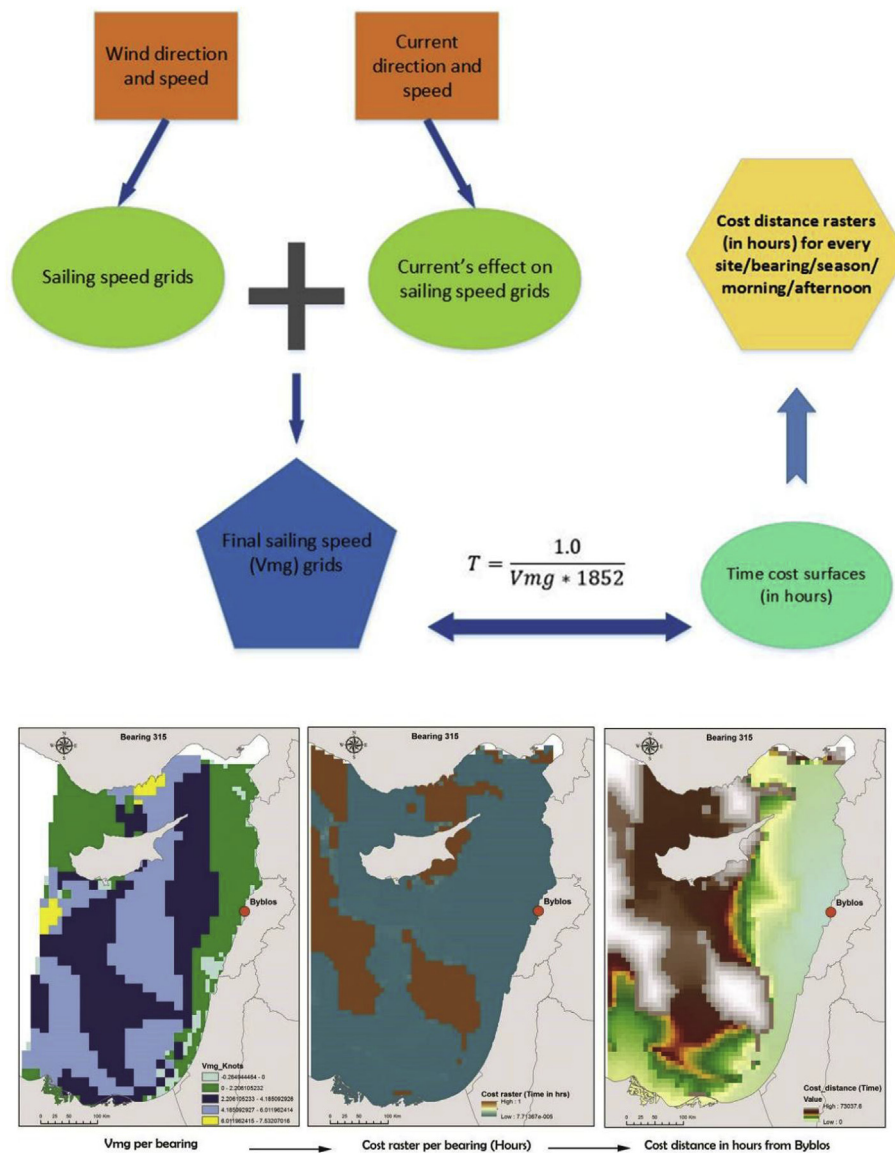


Fig. 4. Diagram describing the intermediate steps for generating the final sailing time grids and cost surfaces taking into account the effect of winds and currents.

Byblos' cartograms, the cartograms of Ashkelon (Fig. 7), during the autumn (am), show a distortion of the southern Levantine-Egyptian coast to almost one horizontal line, bringing closer the central Levantine Basin and the west of Cyprus to the coast. Henceforth, these mappings not only provide a heuristic tool to evaluate and rethink the connectivity of one site across time but allow us to compare between distinct sites. In such a way, they expand our understanding of the study area, and possibly challenge, in some cases, what we conceive of seafaring in the eastern Mediterranean.

Although these cartograms can be thought of as visually centred, providing no more than a qualitative and comparative evaluation, in fact they offer quantitative insight from deformations based on sailing time and cost between locations. One of the additional outputs of the cartogram production is a grid depicting, for each cell, its deformation value. The deformation value represents how much space was transformed according to time based on the source and image points for each departure site. Values higher than one denote the stretching of space-time, i.e. the sailing vessel is traveling at a speed slower than 4 knots. On the other hand, values less than one indicate space-time compression, i.e. the sailing vessel is traveling at a speed faster than 4 knots. These deformations enable the production of cumulative grids depicting

seasonal variations for sailing away from the coastline (Fig. 8). A three-dimensional render of the cumulative grids offers commanding representations of the maritime space-time of the Levantine Basin (Fig. 9). In these three-dimensional mappings, the sea regains its space-time volume; elevated areas signify space-time obstacles whilst depressions indicate space-time compression and facilitated waterborne movement. These three-dimensional deformations consolidate a topography of the sea, invisible to the eyes, intangible, but one that was nonetheless potentially experienced and familiar to seafarers engaged in those waters. The sea is no longer a flat surface of water, its rhythms and characteristics extend in space and time.

The exercise of mediating and mapping the sea translates one of the manifolds of spaces that seamen were part of and engaged with, but is bound by restrictions. Whilst the cartogram modelling is based on fixed points, it must be stated that boats and ships are not static, they move across the sea. Hence maritime space and time would be constantly reforming and warping according to the choices being made by the crew, in conjunction with the variables imposed on the crew. This unavoidably imposes an incredible number of variables and a massive complexity for any in-depth study and modelling of prehistoric sailing. The significance of the mapping methodology proposed in this paper

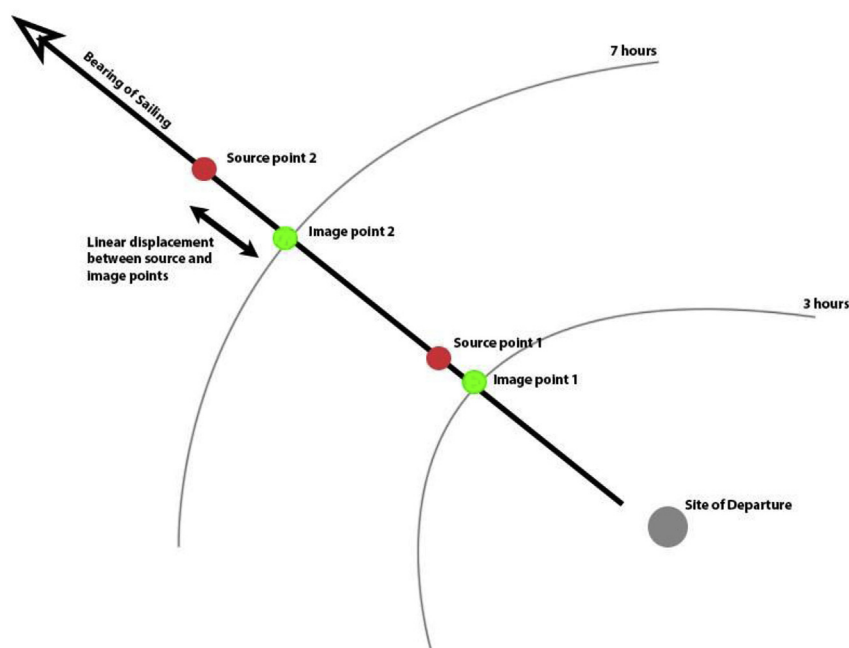


Fig. 5. The source/image points and contour lines referring to the generic sailing time from a site of departure on a bearing of sailing. Each source point corresponds to the image point by its ID. If it takes 4 h to sail from the site of departure to the first source point according to the generic sailing time (i.e. 4 knots speed of sailing), and 3 h according to the sailing time accounting for winds and currents, then the image point should be located on the same bearing but on the 3 h contour line.

however, despite its constraints, rests in demonstrating an alternative approach rather than delivering/seeking a resolution. Furthermore, the value of this mapping is in the insights it provides to archaeological interpretations, to rethinking maritime connectivity, when analysed in conjunction with the archaeological evidence.

### 3.1. Maritime connectivity during the EBA

As stated previously, despite the use of sailing performance values based on later vessels in this model, the results provide us with approximations and they shed preliminary insights on EBA maritime space-time patterns awaiting more robust evidence and experimental projects that can further inform us about sailing performance from that period.

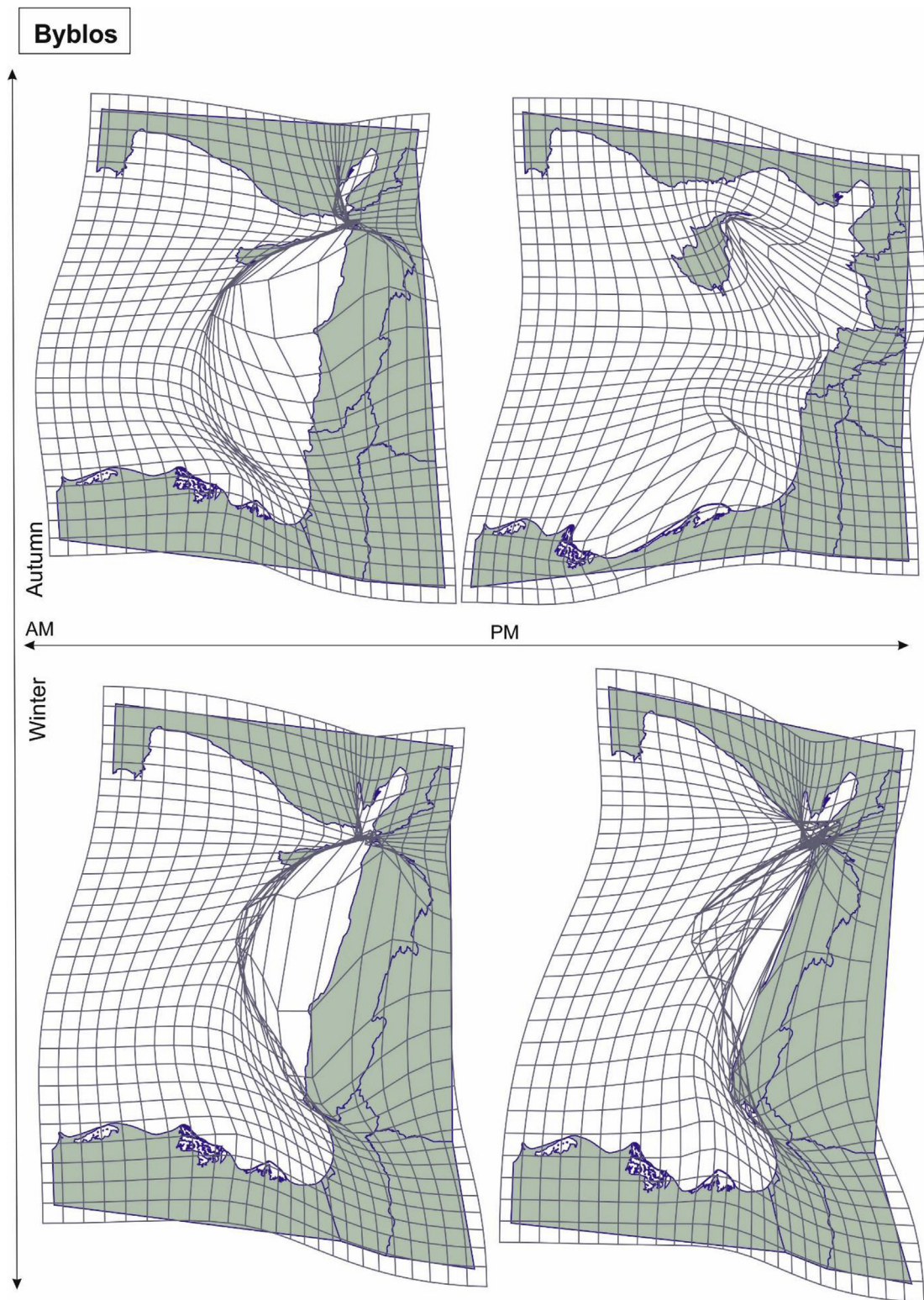
With the aim of demonstrating the value of cartograms to maritime connectivity during the EBA and the difference in deformations based on sailing time between EBA sites, cost distance grids were generated in GIS for the sites of Egypt, Ugarit, Byblos and Ashkelon, taking as input their respective deformation grids. These surfaces facilitate a comparison between the deformation costs from the sites of departures at chosen locations that would be representative of sailing destinations. The locations chosen for a deformation cost comparison comply with the EBA archaeological evidence of connectivity and affiliation, including the regions of the Aegean (Broodbank, 2000; Bevan, 2003; Genz, 2003), Anatolia (Peltenburg, 1996) and Cyprus (Knapp, 1990; Bolger, 2013). The deformation cost is a representation of sailing time, but not a direct indication of it. The computation of sailing time relies heavily on the movement of vessels at sea and the journey's itinerary, which are not the focus of this paper. The deformations on the other hand present interpolated surfaces of how space is deformed according to sailing time from specific sites on specific bearings. Based on a comparison in deformation costs at the chosen locations (derived in GIS via extracting to points the grid values of deformation cost from each site of departure for the four seasons and for the morning and afternoon) for sailing from the sites of departure, it is possible to generate a network of links of best courses of connectivity or otherwise the comparatively least-costly deformations between sites (Fig. 10). This provides us with an understanding of potential connections that are best feasible according to the parameters of the model. Worth noting, however, that the region of the Aegean, Cyprus and Anatolia cannot be

defined as a single geographic location, yet a position is required for the cost derivation. Thus, to make this achievable, a position had to be selected, and is representative of one of many possibilities of connectivity. Ideally, all coastal known sites evidencing for interaction in the eastern Mediterranean during the EBA should be integrated for deformation cost derivation. Such an endeavour can build and expand on the work presented in this paper.

#### 3.1.1. Case study: Egypt and the Levant

The case of Egypt and the Levant is a compelling one. During the beginning of the EBA, the Early Bronze I (EBI), c. 3500–3050 BC, Egypt had a strong connection with, and influence on, the southern Levant, evidenced by Egyptian and Egyptianised material found in the southern Levant (Braun, 2002), as well as Canaanite objects found in Egypt (Amiran and Gophna, 1992: 358; Kantor, 1992: 13). The Egyptian state is presumed to have spread its control to the southern Levant, where it established outposts that involved the movement of Egyptians into southern Canaan resulting in administrative centres (Sowada, 2009: 245). The platform for movement between Egypt and the southern Levant remains unclear, but more emphasis is placed on the overland route (DE Miroshedji, 2002: 40–44). However, in light of different factors including the Egyptian ceramic jar from the EBI found offshore at North Atlit Bay holding non-local shells and the cedar pieces found at Ashkelon from the central Levant (Sharvit et al., 2002; Gophna, 2002; Liphshitz, 2004), there is a strong suggestion that maritime connections between Egypt, the southern Levant and the central Levant were in place. This is not a new notion. Many scholars advocate, dubiously, for maritime connections based on long-distance trade items as early as the EBI between Egypt, the southern and northern Levant (Gophna and Liphshitz, 1996; Sharvit et al., 2002; Sowada, 2009). Nevertheless, this notion was never corroborated based on the performance of sailing vessels and on the time of sailing as modelled in this paper. The network of least-costly deformations provides additional proof and greatly reinforces the validity of maritime connections in this context. The distortions of the maritime space-time result in a pattern mimicking the archaeological evidence, hence suggesting that the facilitated maritime connections may have bridged those areas together, mediating the movement of material culture. The least costly journeys on Fig. 10 show space-time compression between Byblos, Ashkelon and Egypt. In fact, the archaeological record hints for a potential maritime connection





**Fig. 6.** Example of cartograms for sailing out from the site of Byblos on the central Levantine coast. Note how geographical distortions change throughout the seasons and in the morning and afternoon temporal windows.

between Egypt and Byblos as early as the Naqada IIC/D, c. 3450–3325 BC, based on large Cedar logs from the Lebanese mountains recovered from Hierakonpolis (Sowada, 2009: 26).

Relations between Egypt and Byblos are mostly recognised from the Early Bronze II period (EBII), c. 3050–2850 BC, when Egypt shifts its attention to the northern Levant, for the acquisition of exotic goods.

Compared to the previous EBI, the volume of Egyptian material and presence in the southern Levant contracts. The reasons for this change are unclear and remain debatable. Some of the proposed motives relate to Egypt's growing political and administrative structures that required the construction of monumental architecture and greater acquisition of goods (Oren, 1989: 403; Hendrickx and Bavay, 2002; Sowada, 2009).



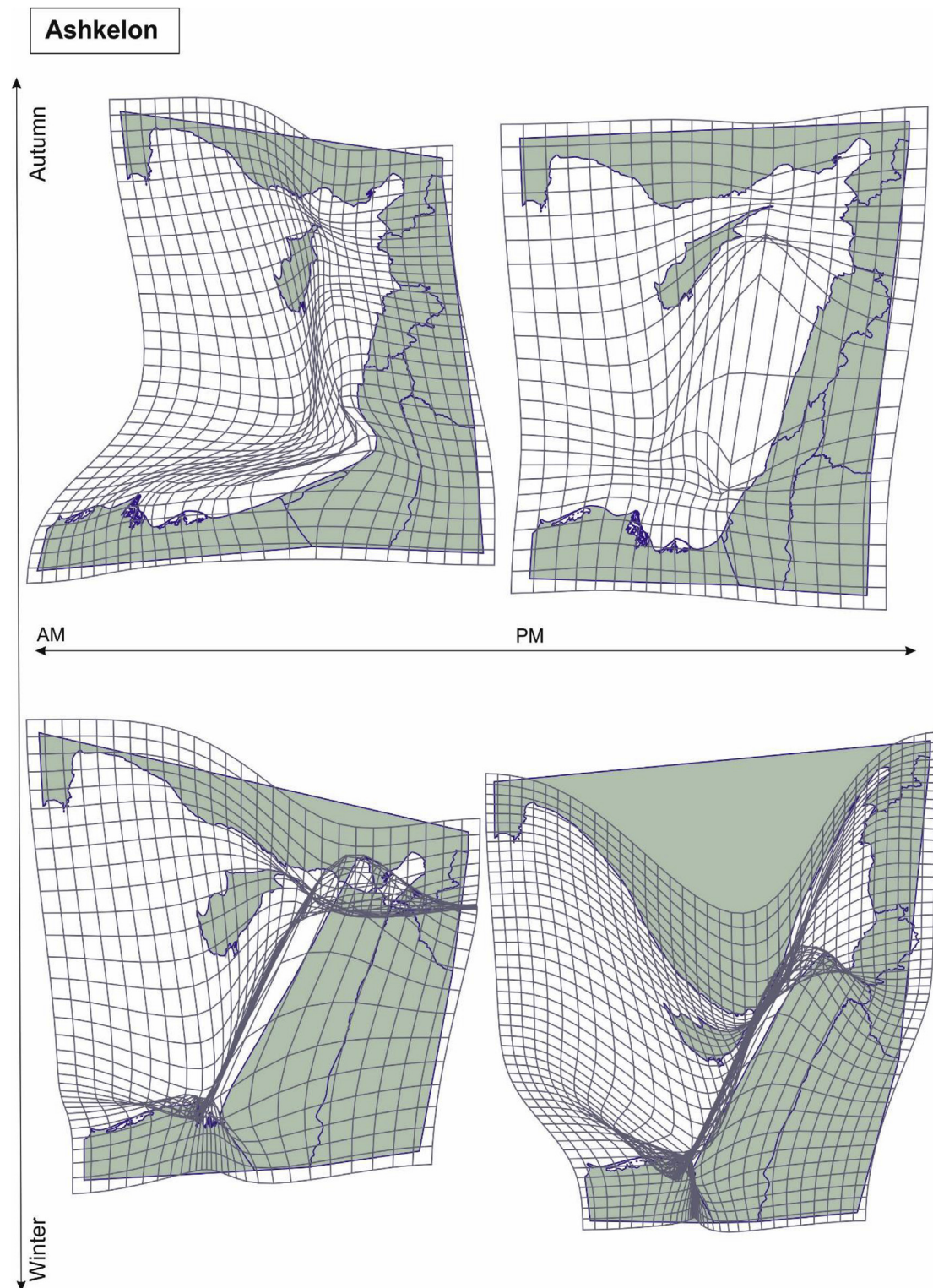
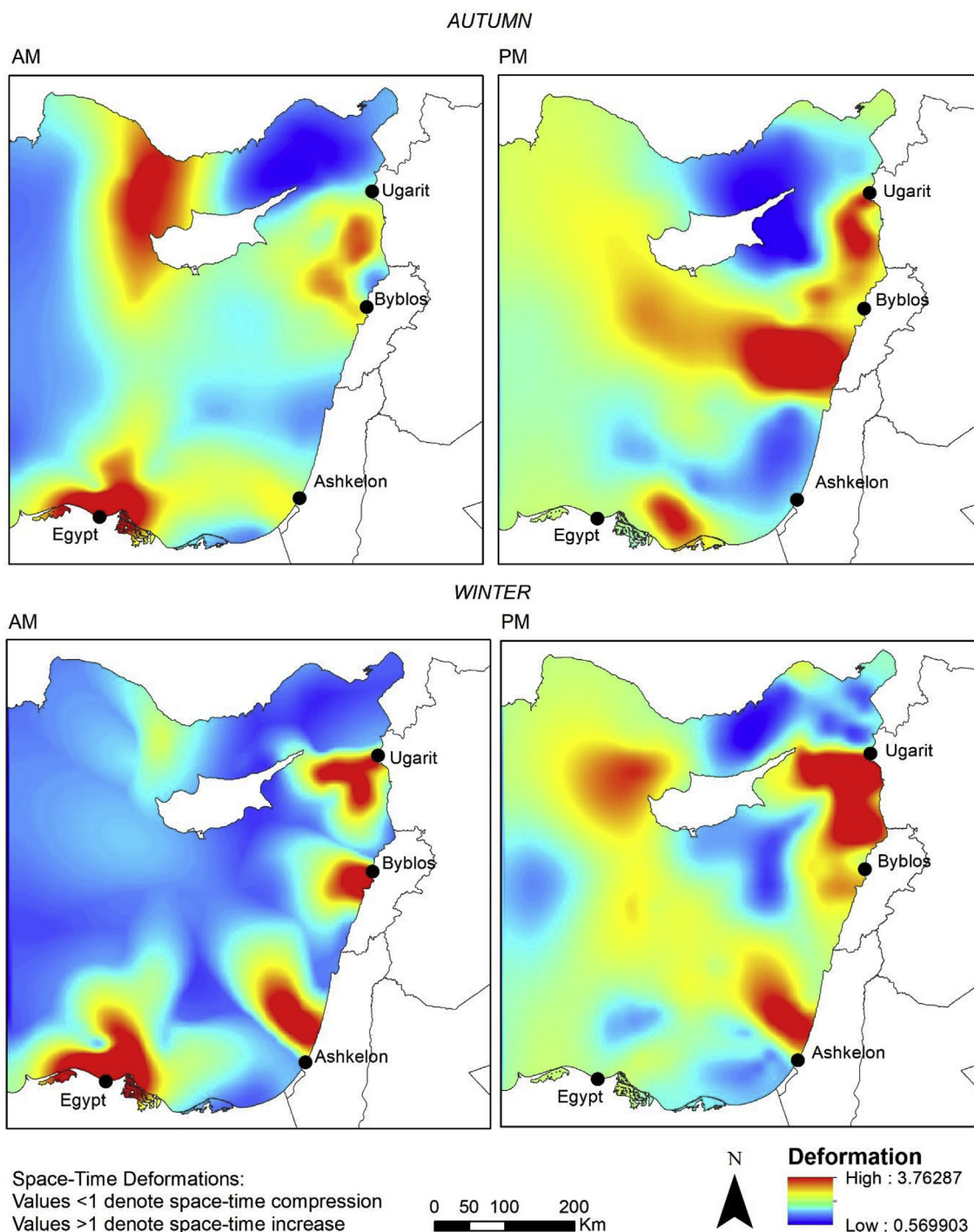


Fig. 7. Example of cartograms for sailing out from Ashkelon on the southern Levantine coast. Note how geographical distortions change according to the site of departure, in comparison to Fig. 6.

The primary motivator, however, as suggested by Sowada (2009: 30), was the large-scale seaborne traffic to ship heavy timbers and cedar from the Levantine coast, mainly Byblos (Prag, 1986: 50–60; Stager, 1992: 40; De Miroshedji, 1998; Marcus, 2002: 407–408).

The narratives regarding the relations between Egypt and Byblos have always focused on the Egyptian perspective. In other words, the instigators for these relations were thought to represent Egyptian

initiatives (e.g. Sowada, 2009: 7–15; De Miroshedji, 2002: 41–46; Ben-Tor, 1989; Wright, 1988; Ward, 1963). Such reasoning, however, only mediates one aspect of those relations and is not conclusive. Byblos already occupied a distinct location in terms of maritime accessibility to the northern Levant and Anatolia as well as the southern Levant and Cyprus (Fig. 10). The Egyptian shift of attention to Byblos may very well be labelled a Byblite growth in maritime commerce, which relates



**Fig. 8.** Cumulative seasonal deformation according to sailing time away from coastal sites of departure.

to maritime space and the connectivity it affords. Fig. 10 clearly indicates that accessing Byblos from Egypt in the Spring was least costly in comparison to Ashkelon in the close vicinity of Egypt in the southern Levant. Thus, Egypt's interest in Byblos and the transport of timber was very much expedited by the nature of maritime space and the commanding location of Byblos, occupying a position that affords an increased degree of least-costly links than any other site addressed in this paper (the number of least-costly connections based on deformations that Byblos benefits from is higher than any other site on Fig. 10, for all seasons). Accordingly, one of the many reasons behind this shift in attention that shows a strong signature during the EBII may have been the ease of maritime access to the northern Levant from Egypt and the

facilitated maritime connections from Byblos to Egypt, to the northern Levant, to Cyprus, to Anatolia and to the southern Levant, combined with Byblos' growing economic and political spheres.

This concise re-evaluation of relations between Egypt and the Levant in light of the space-time deformations demonstrates the value of this methodology to understanding maritime connectivity during the EBA. Even though the sailing performance employed in this model derives from later periods, the maritime-space time deformations deliver a preliminary approximation for rethinking EBA maritime mobility, which can only be enhanced upon.



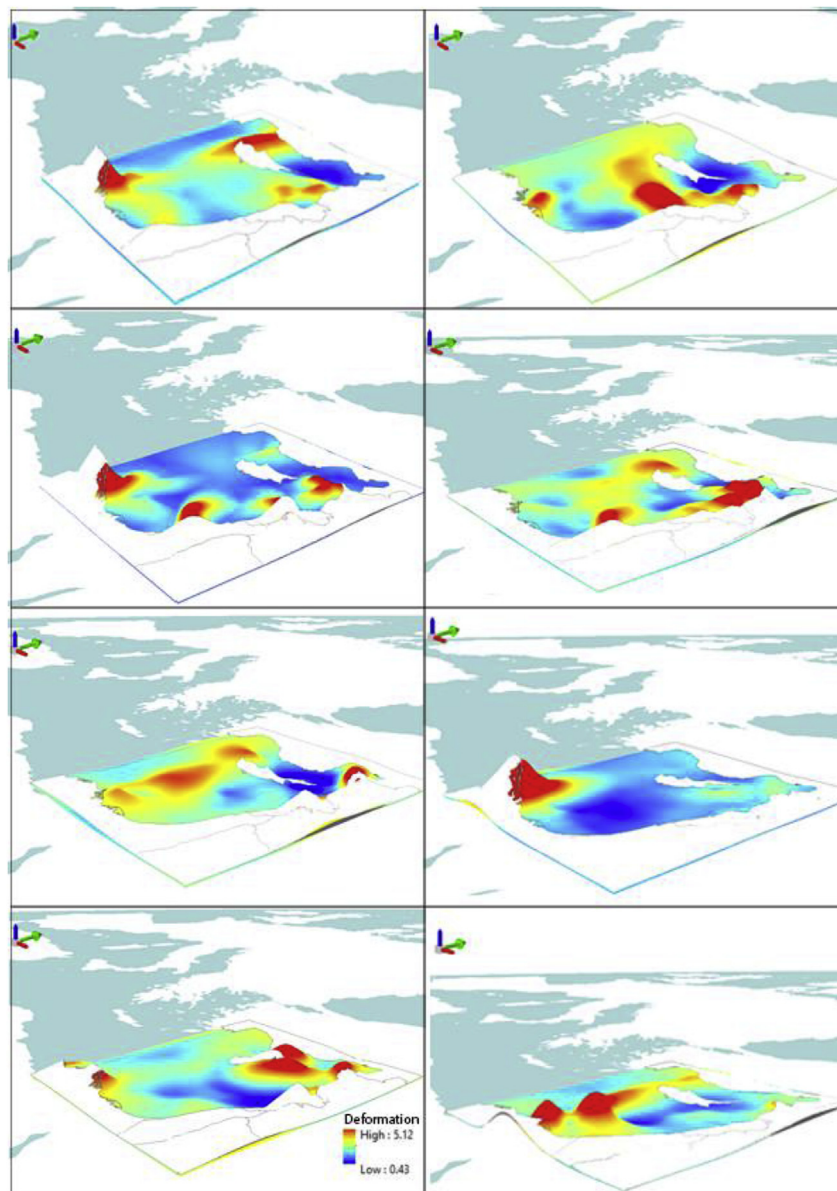


Fig. 9. Three-dimensional cumulative seasonal deformations for sailing away from Levantine coast. The sea regains its volume. Elevated areas represent time-space obstacles whereas depressions depict time-space compression.

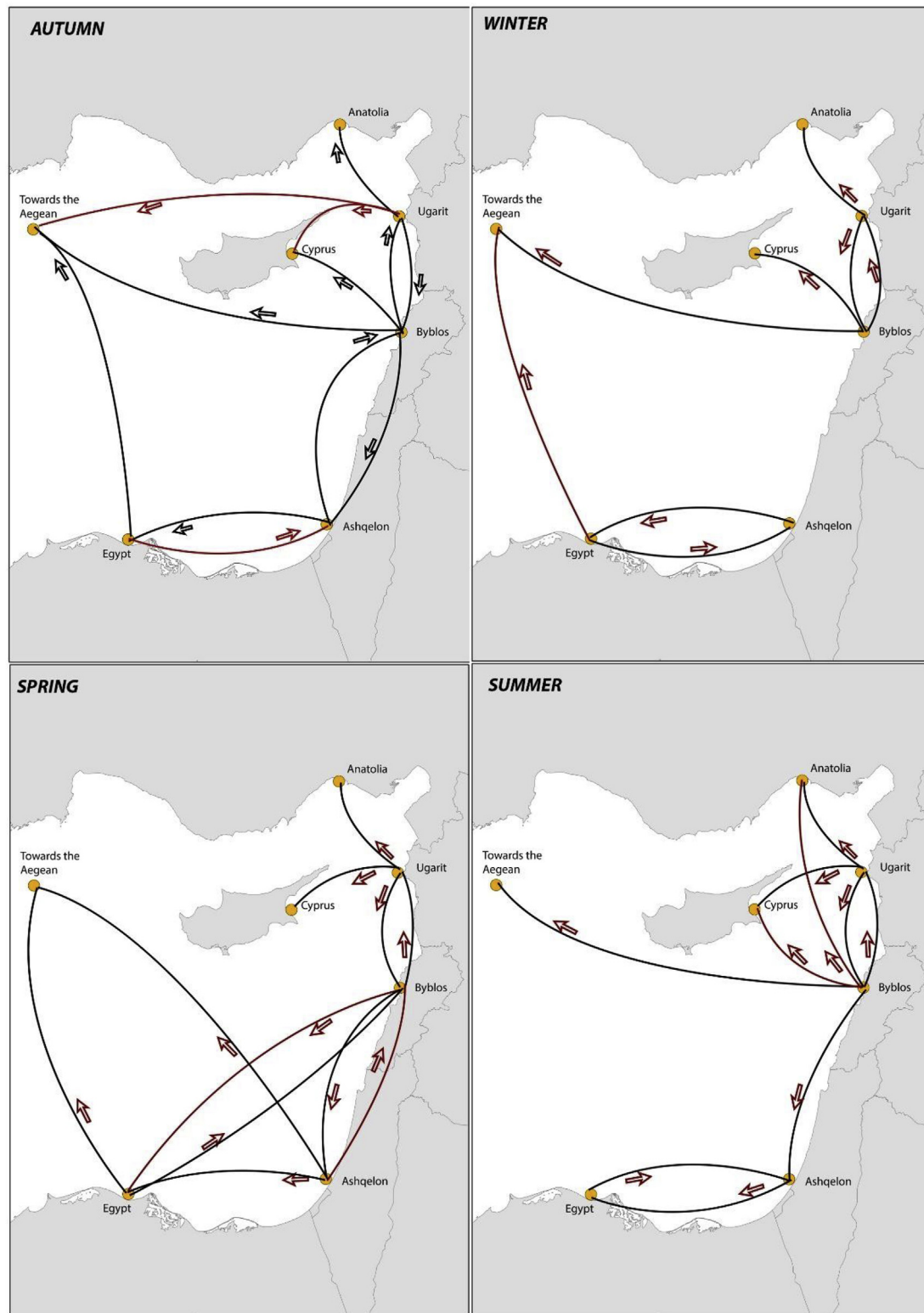
#### 4. Conclusions

Time has always been regarded as the dimension that transforms geographical space, the element required to understand maritime connections and the variable that can define interactions. Agouridis (1997: 19) points out that environmental parameters change the geographical proximity of regions and islands in respect to the potential of interaction. Knapp and Demesitche (2016: 32) account for maritime travel time based on later textual sources and, on that ground, proposed to situate Cyprus in certain maritime interaction spheres. Knappett et al. (2008: 1021) stress that travel times must replace physical distances in a maritime network. Leidwanger (2013) contributes to calculating travel time based on winds and currents. Congruently, this paper expands on the importance of time to seafarers and incorporates it in the form of rhythms; not for reconstructing specific journeys, but to mediate a relational space and a deconstructed geographical space.

This paper proposes a model for conceiving of the maritime space-time of seafaring, in such a way that Cartesian representations lose ground and space takes on new forms induced by the performance of

seafaring. The space-time representations of the Levantine Basin of the eastern Mediterranean render intangible topographies of the sea that may well have been experienced by ancient seafarers. The mapping of the sea, crucially, offers a heuristic tool with which archaeologists can study and mediate maritime spaces. On a practical and archaeological level, these deformations provide insights into eastern Mediterranean connectivity, demonstrating the presence of a facilitated network of interconnectivity that bridges internally the whole of the Levantine littoral and externally binds it with Egypt, Cyprus and Anatolia.

Despite the restrictions imposed on the model, in terms of incorporated variables and conditions, as well as in regards to adopting ship performance values from later periods and re-evaluating in that light EBA maritime connectivity, the mappings offer an alternative to generic representations that depict the sea as an unchanging surface over which maritime connections develop and unfold. In the examples of cartograms shown, the sea transforms in and with time, and, as a result, our conceptions of it must tailor for these transformations. Indeed, the cartograms and subsequent outputs are approximations and by no means conclusive, but it is in these approximations that the sea



**Fig. 10.** Network of links of best courses of connectivity or otherwise the comparatively least-costly deformations between sites. The links are not representative of the actual sailing journeys but are only an approximation of potential connectivity based on space-time deformations. For each season, both the morning (am) and afternoon (pm) links are displayed in black and red lines respectively. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

and humans regain aspects of their agencies. Furthermore, with enhanced information on ship performance during the EBA, the methodology can be re-modelled to account for not only improved resolution and data, but also additional sites and conditions, therefore permitting

further rethinking of maritime connectivity.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jas.2019.01.001>.

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