ANCIENT NAVIGATION AND MEDITERRANEAN COASTAL METEOROLOGY

Fabrizio Beninicasa, Matteo De Vincenzi, Gianni Fasano

Abstract: For a long period, Greeks, Phoenicians, and Etruscans frequented, at the same time, the Mediterranean Sea. This forced their seafaring to behave, at the same time, as pirates at sea, to break down competition, and as traders in the *emporia*, to sell their goods.
Navigation was based on the experience of sailors since there were no instruments and methods to estimate sailing parameters. The empirical knowledge of seafarers was based on the observation of environmental and astronomical daymarks, and on their ability to perceive signals from the atmosphere, and from sea animals.
Navigation was mainly carried out at such a distance from the coast as not to lose sight of it; but in the Mediterranean Sea the coasts, often mountainous, allowed to have in sight elevated points of reference, which also allowed offshore navigation.
Merchant vessels were not as fast as combat, but they could carry large loads of various types to be sold in various emporia. The average speed of a ship was around 5-6 knots, therefore the longest voyages, could require considering stops for rest and bad weather. In this case the journey required a winter stopover, and the navigation continued into the following season. Therefore, we understand the importance of "weather forecasting" which could be done with a careful analysis of the warning signs that came from the sky, from the flight of birds and the behavior of fish and other aquatic animals.

Keywords: Navigation; Ancient Meteorology; Sailing techniques; Celestial Navigation

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1. Introduction

It is not known with certainty which peoples crossed the Mediterranean first, but, for sure, the very long routes can be attributed to the Phoenicians, a population originating from the coastal strip of the Levant in the eastern Mediterranean which roughly corresponds to current Lebanon (13th century BC - 1st century AD). The Phoenicians, moreover, were the first to travel the entire coast of North Africa (see figure 1).

From the far easternmost part of Mediterranean, their place of origin, these merchants reached the far west, and around 800 BC. they passed the Pillars of Hercules[1] (Strait of Gibraltar) to Gadir (modern Cádiz, on the Atlantic coast in southern Spain). Considering the currents and winds the Phoenicians limited their sailing season to a very shorted period between late spring and early autumn, when the Mediterranean weather conditions are were almost stable [12]. D. Abulafia, in *The Great Sea* [1], shows the northerly route that they most likely followed "[…] *past Cyprus, Rhodes and Crete, then across the open expanse of the Ionian Sea to southern Sicily, southern Sardinia, Ibiza and southern Spain. Their jump across the Ionian Sea took them out of sight of land, as did their trajectory from Sardinia to the Balearics* […]" [1]. It is known that on the open sea the Phoenicians sailed at night, using the Pole Star as a reference which, for this reason, the Greeks called it the star of the *Phoenike* or *Phoenician star* [12]. Furthermore, the great help given to night navigation by beacons, precursors of lighthouses, which coastal populations kept lit in large braziers on: emergent rocks, skerries, sandbanks, and other dangers, should not be overlooked [8]. Homer, in the *Iliad*, compares the glittering shield that the god Hephaestus built for Achilles to one of these fires[2].

But it is also true that in the Mediterranean basin the coasts, often mountainous, allow high landmarks to be kept in sight even on the high seas. In the Mediterranean, in fact, the sea areas from which it is not possible to see land are very few and in areas of little interest to ancient sailors [12]. Hence our greater attention to navigation close to the coast over small or large distances, in other words small or large cabotage[3]. Greater attention that ancient sailors also had to have because sailing close to the coast, that can be more dangerous than offshore sailing. In fact, close to the coastline, there may be unpredictable rocks or currents and where the effect of the tides is felt more. For all ships, weather conditions were another risk factor because they could change suddenly and make navigation dangerous or even prohibitive.

In this paper, a sort of "immaterial archaeology", we will discuss the routes

[1] The ancient Greeks considered, at that time, the known land surrounded by an immense "river" called Ocean (*Ōkeanós* in greek): *even birds cannot fly the distance in a twelve-month, so vast and terrible are the seas that they must cross.* (Homer, *The Odyssey,* book III vv. 321-322 [21]).

[2] [Achilles] *he took the shield, / Massive and broad, whose brightness streamed as far / As the moon's rays. And as at sea the light / Of beacon, blazing in some lonely spot / By night, upon a mountain summit, shines / To mariners whom the tempest's force has driven / Far from their friends across the fishy deep,* (Homer, *Iliad* book XIX vv.450-456 [20])

[3] Cabotage: Coastal navigation or shipping especially within the borders of one country. From the French, from *caboter* to sail near the coast, apparently from the Spanish *cabo*, cape, headland, or promontory.

followed for trade and the meteorological surveys that were carried out before and during navigation. Since we cannot talk about all the cultures that, in various eras, were present in the Mediterranean, we will focus on the aspects that the seafaring of the Greeks, Phoenicians and Etruscans, in the same period, had in common. As regards to meteorology we will refer more to that developed by the Romans, who more than others made "signs" a "science", dictating rules and codifying survey procedures.

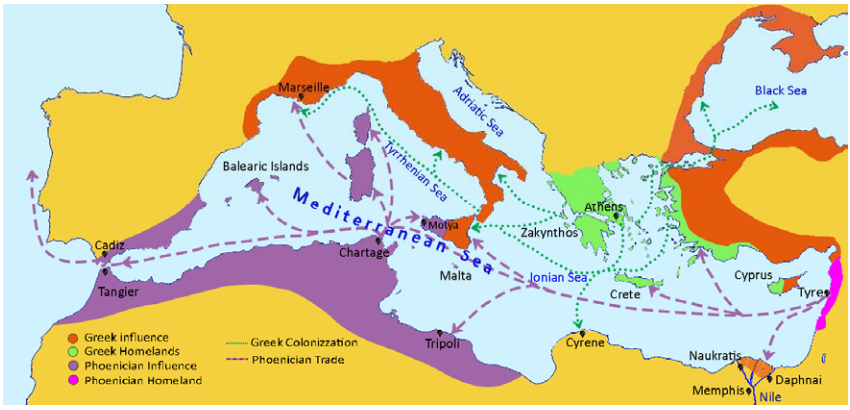

Figure 1 – The main trade routes (Graphic processing by G. Fasano).

2. The Mediterranean routes

2.1 The navigation

In ancient times, navigation was based on the experience and empirical knowledge of sailors since there were no instruments and methods to estimate sailing parameters (position at sea, direction and speed, weather, etc.). The empirical knowledge of seafarers was based both on the observation of environmental and astronomical daymarks[4], and on their ability to perceive and interpret every little signal from the atmosphere, from the wind, from the surface and from the seabed, and, as we will see, from the behavior of birds and animals that inhabited the sea areas.

The waters flowing from the Atlantic towards the Mediterranean (through the Strait of Gibraltar) generate currents. The main ones follow the coasts of Maghreb and, after passing Egypt, head towards Israel and Lebanon, reaching Cyprus; then, turning towards the west, they enter the Aegean Sea, the Adriatic and then the Tyrrhenian Sea from where, traveling along the French and Spanish coasts, they return to the Pillars of Hercules (figure 2). These sea currents have significantly facilitated sea trips within the Mediterranean because with them it was possible to navigate even in unfavorable winds.

[4] Daymarks are all those natural and artificial elements of remarkable size and height which have characteristics clearly visible and recognizable from the sea. For example, daymarks are mountains, promontories, buildings along the coast (towers, lighthouses, bell towers, etc.).

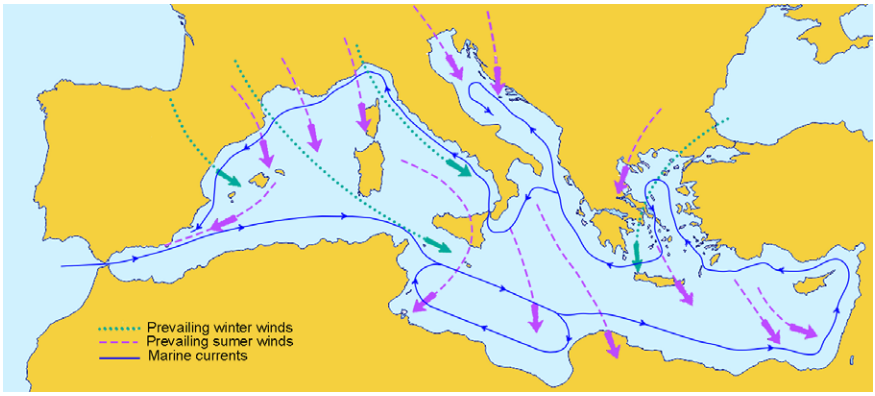

Figure 2 – Marine currents and prevailing summer and winter winds (Graphic processing by G. Fasano).

Table 1 – The winds of the Mediterranean Sea.

Origin	*Symbol*	*Greek*	*Latine*	*English*
North	N	*Boreas*	*Septentrio*	Tramontana
North-East	NE	*Kaikias*	*Aquilo*	Gregale
East	E	*Apeliotes*	*(Sub)Solanus*	Levant or levanter
South-East	SE	*Euros*	*Vulturnus*	Sirocco or Scirocco
South	S	*Notos*	*Auster*	Ostro or auster or ostria
South-West	SW	*Lips*	*Aphricus*	Libeccio
West	W	*Zephiros*	*Favonius*	Ponente
North-West	NW	*Skiron*	*Caurus*	Mistral or *Maestro*

In winter the western Mediterranean is influenced mainly by the North Atlantic weather system and in summer by the high pressure of the subtropical Atlantic, which is stationed over the Azores. The air currents in the Mediterranean region move mainly from West to East so in spring-summer the winds can be used to sail from the ports of Catalunya, Ligurian Sea, and northern Tyrrhenian Sea towards: Sicily, Sardinia, and the Levant [16]. The importance of the winds is shown by the personification that all cultures have made of them, in particular the Greeks considered the winds of divine origin, as Hesiod indicates in the Theogony [6], giving them a name in relation to the direction of origin with respect to the island of Zakynthos (Ionian Sea); while other cultures referred them to the "central Mediterranean".

All sailors knew the direction of the winds in relation to the four cardinal points (*Compass Rose*): north, east, south, west to which four intermediate winds were added (see table 1). Other names of half-winds (and successively quarter-winds) were added over time until first twenty-four and then thirty-two were classified [7].

Only the knowledge of marine and air currents allowed ancient sailors to develop navigation, rightfully considered a *téknē* (art in Greek). This art began when the "ship" was a tree trunk dug out and moved, on the water of a river or lake, by the force exerted by human being on an oar. The need to carry out longer navigations led humans

to integrate their strength with that of the wind. The sail made it necessary for greater transversal stability of the "ship", which was obtained by equipping the trunk with a lateral outrigger[5], or by widening the hull in the central area. The Egyptian ships, of which there are traces since 4000 BC, were of this second type; their hull was made of bundles of papyrus stems, tied together, and the sail was supported by two "masts", arranged in an inverted V, fixed to the sides of the hull. The sail was made with skins joined together and square-shaped, as time passed the skins were replaced by a sturdy fabric[6]. Since 2000 BC the papyrus stems were replaced by sycamore or acacia wood boards, and the support of the sail became a single central mast, which could be removed. Moreover, two short oars, with large blades, were placed at the stern to steer the ship which, thus equipped, could leave the Nile and sailing the sea. [25].

The first Phoenician ships were very similar to the Egyptian ones, but the wood used was much better. In fact, the large cedars of Lebanon, with trunks up to 40 m, allowed the manufacturing of much more robust and much larger hulls. Similar nautical structures were built by the Greeks who, however, used pine wood.

Over time, two types of vessels were designed by the Phoenicians: warships and trading vessels. The first characterized by easy maneuverability and speed, the second (of greater interest for our purpose) by a greater loading capacity of goods and people. As a result of this, the propulsion of combat ships was entrusted to sails and oars, in order to ensure speed of maneuver and movement regardless of the intensity and direction of the wind. In the latter the propulsion was mainly entrusted to the sails to minimize the crew and thus maximize the space for goods. Furthermore, in warships the hull was slender and the lower freeboard than in cargo ships, in which the hull was more rounded and higher freeboard. The Phoenician tradition was also followed by the Greeks who, however, used metal anchors [25].

The Romans modified the structure of the Phoenician ship by adding a second mast at the bow, very inclined forward, with a second square sail.

As for the rowers, they were arranged in symmetrical rows on both sides of the ship; there could have been more than one row on each side, but whether they were side by side or overlapped has not yet been demonstrated. *Experimental archeology* has shown that in both cases there could have been interference in the movements of the rowers, due to the limited space in relation to their number which could reach 150.

An accurate description of ancient ships can be found in the didactic poem *La Nautica* (tr. *The Seamanship*), by Abbot Bernardino Baldi (1553 - 1617), published in Venice (1590), in four books [5]:

- *First book*: distinction of ships, their shapes depending on use and fitting out.

[5] Catamaran from Tamil word *kattumaram* meaning tied timber. Tamil is a Dravidian language of Tamil Nadu, state of south-eastern India, and of northern and eastern Sri Lanka.
[6] In reference to sails, the most important innovation occurred with the introduction of the *lateen sail*, widely used by Byzantines in the warship dromones, and become common in the Mediterranean starting from the 5th century AD. The term is probably from Arabic and indicates a triangular sail (from french *voile latine* and in turn probably from italian *alla-trina* contracted in *latina*, also meaning easy, simple, effortless) therefore different from the square sail rigged on yards [10], [35].

- *Second book*: celestial spheres, names of the seas, tides, signs of storms.
- *Third book*: the practice of loading ships, sailing, and steering during periods of calm and stormy seas.
- *Fourth book*: the places of the world where different goods are brought.

The sources relating to ancient ships never talk about the speed of the ship, but simply indicate the length of the journey, from port to port, expressed by days of navigation. Normally in offshore navigation, in one day, a longer route was covered than in coastal navigation, where shallow waters, rocks, tides, etc., they could slow down navigation. In any case, however, weather conditions had to be considered: The good weather with regular and favorable wind made it possible to cover a longer stretch of sea than could be done in calm or rough seas. In the latter case, on the contrary, the ship had to be slowed down so that it was not overwhelmed by the sea and the wind that hit it from the stern [26].

2.2 The trade

Copper (from the 3rd millennium BC) and tin (from the 2nd millennium BC) were used to produce bronze and were at the center of the great commercial flows of the Mediterranean. Evidence of these flows are the wrecks loaded with ingots of these metals that were found in the Corsica Channel and in the Strait of Bonifacio. The iron metallurgy spread across the Western Mediterranean only in the 1st millennium BC; the rich deposits of the Elba Island, and of the facing territory of Populonia, made the northern Tyrrhenian Sea a great "industrial hub". The strong production of charcoal, necessary for the iron processing, led the Greeks to call Elba Island *Aethalia* (*Smoky Place*). The better quality of the iron ore mined from the Colline Metallifere of Etruria (Tuscany) and from the mines of the Elba Island made it preferable to that extracted from the Corsica mines. On the other hand, Corsica was rich in copper in the hinterland of Aléria (port at the mouth of the Tavignano river on the east coast); this led to the creation of favoured connections in the exchange of metals, for example Corsica exchanged its copper with iron from Populonia [31]. In the archaic Mediterranean, an area of intense traffic, trade was based on a real network of *emporia,* i.e. important trade centers located mainly on the coast, which served as markets for the collection (storage) and distribution of various goods for one or more regions [17], where Etruscans, Greeks, Phoenicians, etc. lived together, albeit in different areas.

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The merchant vessels sailed almost exclusively in the period between March and October, that is, in stable weather conditions and with clear skies which allowed night navigation by orienting themselves by the stars. Special ceremonies, addressed to the protective deities of sailors, preceded the beginning of the sailing season. Only the navigation of the large ships that sailed the high seas stopped completely in winter;

the little coasting knew no pauses. The *Acts of the Apostles* talk about the winter navigation in relation to voyage of Saint Paul and his companions to Rome: *Since the harbor was unfavorably situated for spending the winter, the majority planned to put out to sea from there in the hope of reaching Phoenix, a port in Crete facing west-northwest, there to spend the winter* (*Acts of the Apostles*, 27, 12 [33]).

Navigation followed this seasonal rhythm until the 14th century, when the use of the compass and the development of nautical charts allowed pilots to orient themselves even in overcast skies. Thenceforth, voyages began to be carried out throughout the year, although it was preferred to avoid sailing in the winter months [26].

Often on longer voyages, in the western Mediterranean and even more so in the Atlantic Ocean, warships were also used for trade purposes. This was due to the very frequent conflicts that arose between the Greeks, Phoenicians, Carthaginians, and Etruscans; they all played a dual role: pirates at sea and traders in the ports. Because of this, for the precious goods transport, which by their very nature had little volume, ships were used with little loading capacity but with characteristics such as to guarantee the possibility of both defence in the event of assault and danger, and attack in case of necessity. For this purpose, the Greeks used a ship, called *penteconter* or *pentekonter* (from the Greek *pentēkóntoros* derived from *pentēkonta* = fifty, in reference to the number of oarsmen). It was steered by means of a central stern rudder together with two lateral blades wider than an oar, a system that allowed both fast paces even on tortuous and treacherous routes, such as coastal navigation, and high maneuvering agility in ramming actions [15], [18], [30].

In the Phoenician *trireme* there was a compromise between agile maneuverability and high speed, which was made possible by small masses and dimensions combined with many rowers. In the proximity of the battle, the ship was dismasted so that the propulsive thrust remained entrusted only to the oars; the trireme was long, thin, light and with very little draft and it could easily be beached every evening.

This type of ship, with the addition of another inclined sail mast at the bow and two or more rows of oars, evolved into the *liburna* (100 AD). This model of ship was widely adopted by the Roman navy which used it for patrolling against piracy in the various provinces of the empire [9].

The ships and navigation techniques of the archaic Greek navy derived from the Phoenician naval knowledge of the second half of the 2nd millennium BC; they were substantially those described in the Homeric poems and remained unchanged for centuries. In this period, local agriculture had become so productive that, with the development of maritime trade, it allowed the foundation of new colonies on the southern coasts of the Mediterranean, particularly in North Africa.

Merchant ships were not as fast as triremes but could carry large cargoes of various types: grain, oil, wine; terracotta pots and glassware; textiles and jewelry; metal tools, millstones, and timber[7]. All this was made possible by the deep

[7] Among the various products of the trade activity, sea salt is not mentioned since all coastal populations were able to produce it independently but even if sometimes not in sufficient quantities. Another famous product of sea was *Tyrian purple* that the Phoenicians obtained from the murex, a sea snail that abounded in their coastal waters, rich in bromine, a necessary

knowledge that sailors had of sea and atmospheric currents.

The Etruscans, thanks to their availability of wood, were able to build large sailing ships that in battle, with the help of oars, could ram enemy ships. For this reason, the Greeks and Romans considered the Etruscans, as well as expert sailors and navigators, "pirates" and therefore they feared them especially when they crossed them off the western coasts of the Italian peninsula. The importance of maritime trade for the Etruscan economy is wide shown both by the artistic depictions of ships and by the models found in the tombs.

2.3 The routes

Ancient sailors, driven by the wind, cruised along straight sea routes to reach the various landing places; even in high sea crossings the basic principle was to follow the prevailing winds, which therefore influenced the main trade routes [26].

The prevailing north winds made navigation along the southern coast of the Mediterranean (North African coast) dangerous, as they pushed vessels against shoals and rocks. Navigation along the northern coasts, on the other hand, was certainly “simpler”, both due to the morphology of the coasts, where there were frequent daymarks that allowed pilots to orient themselves, and due to the presence of beaches and coves, where one could take refuge in the event of sudden storms that could occur even in summer [1]. In the Mediterranean there are few navigable sea areas without coastal landmarks, as it can be seen in the map in figure 1. The average speed of merchant vessels, depending on their type of construction, could be from 3 to 6 knots, therefore these ships could travel approximately 50 nautical miles a day, always sailing within sight of the coasts. The longest voyages, without coastal landmarks were the Ionian stretch from Greece to Sicily and from the west coast of Sardinia or Tunisia to the Balearic Islands [1].

Herodotus of Halicarnassus (ca. 484 BC - after 430 BC) and Thucydides (ca. 460 BC - after 404 BC) agreed in believing that the average speed of an ancient ship was 5-6 knots, and therefore, considering the stops due to bad weather, rest etc., for example, 15 days were needed to sail from Greece to Sicily. Herodotus wrote that longer voyages might require a winter stopover, with sailing continuing into the following season. He also pointed out that sailors were able to grow the wheat while they waited. For example, the voyage, of about 1600 nautical miles, from Tyre, the main city of Phoenicia to Cadir [8], the current Cadiz, an area rich in silver could take 90 days or more, in other words, an entire sailing season. In that case, the ship would unload and reload the goods while waiting for the return voyage, which would take place the following year [12].

Scholars have much debated what the actual routes the Phoenicians travelled. Assuming that Mediterranean currents have not changed from ancient times to the present, it seems likely that ancient sailors took advantage of the *long-distance currents* also used by modern sailors. Therefore, the route from Tyre to Cadiz would probably

element for the development of this mollusc. The richness of this element throughout the area has shown by the quantity of bromine in the Dead Sea waters, about 850 million tonnes [11].

[8] *Cadir* was the westernmost Phoenician city as it was on the Atlantic coast in southwestern Spain.

have been: north of Cyprus - the coast of Anatolia - Rhodes - Crete - Malta - Sicily - Sardinia - Balearic Islands, and along the coast of southern Spain to Cadiz. The return journey would have benefited from the current flowing back through the center of the Mediterranean, figure 2. This would give as possible the following routes: from Cadiz directly to Malta and then Phoenicia, or Balearic - Sardinia - Phoenicia, or Balearic - Carthage - Phoenicia. It is not surprising that in each of these strategic stopping points, the Phoenicians founded colonies which effectively prevented, for some centuries, trade from other cultures, such as the Greeks, who therefore frequented above all the western coast of the Italian peninsula, see figure 1 [12].

The Greek poet Hesiod (8^{th}-7^{th} century BC) stated that everything had to be done in its time, especially sailing; in *Works and days* [19] he wrote: [in winter] *If you ever get the urge for hard seafaring / When the Pleiades chased by gigantic Orion/ Fall into the misty sea, well forget it:/ All sorts of winds are whipping around then./ Too late to have a boat on the wine-colored water./ Work the earth then, remembering what I told you./ Haul your boat onto shore and pack stones;/ All around it, to keep off the wind's damp./ And pull the bilge-plug so rain won't rot the hull. /Stow all the gear and tackle of your sea-going craft/ Away in your house, tucking the sails neatly,/ And hang the polished rudder up in the smoke./ Then sit tight until the sailing season comes. (vv. 684-696)* […]/ *Fifty days after the solstice, toward the end/ of summer, the season of scorching heat,/ Comes the sailing season. (vv. 733-735)* […]/ *But the winds are easy to judge then/ And the sea's gentle. You can trust/ That swift ship of yours to the breeze/ Without a care, haul he down to the sea/ And load all your cargo./ But go as fast as you can and hurry/ Back home. Don't wait for new wine,/Or the autumn rains, or the stormy season coming on/ With high winds from the South* [Notos] *that stir up the sea. (vv. 740-749).* As seen in this passage, Hesiod underlines the importance of knowledge of meteorology for a "quite" navigation.

3. Meteorology for Mediterranean sailors

Navigation was carried out with wooden ships built in various lengths and widths with single or double propulsion, sails and rows. But in any case, the ships were unable to contrast the force of a stormy sea and therefore frequently sank if surprised by an adverse weather event, as evidenced by the hundreds of wrecks, from all historical periods, that are disseminated Mediterranean depths. It was therefore fundamental that sailors developed the ability to predict the weather. Knowing and guessing meteorological conditions was a critical part of the empirical-cognitive baggage of the ancient sailor-pilot, who had to develop a total perception of the marine environment to interpret meteorological signals [26].

For example, in the Strait of Gibraltar (figures 1), an essential gateway to exit the Mediterranean, the currents supported by the impetuous Vendaval, which blows from the Atlantic to the Balearic Islands, often forced ships not to risk crossing the strait for several days. The sailors awaited the attenuation of the Vendaval or the contrast to this by the Levant wind, which blows in the strait in the opposite direction to the first. With lack of winds, the strait of Gibraltar could remain at the mercy of the fog, equally dangerous for navigation. In any case, navigation either along the coasts or

in the open sea, or by day or by night, had to begin and continue with clear atmospheres and fair skies. For ancient sailors, however, before setting out to sea and during navigation, it was critical to know the "sea bulletin" that the deities communicated to seafarers through precursory signs of meteorological events, entrusted to the stars and animals inhabited the sea waters and the marine skies. The second book of *La Nautica* [5] is significant on these aspects.

Below are some examples of events that ancient navigators believed to be premonitory *signs* of meteorological events linked to the state of the sea. These examples are taken from Greek, Roman and Byzantine authors, in particular the Roman ones who had most developed and codified the *theory of signs*.

The coupling of Lightning and Thunder as a sign of atmospheric forecasting is attested by Aratus of Soli (315 BC - 240 BC), Theophrastus of Eresus (371/370 BC - 288/286 BC), Pliny the Elder (23 AD - 79 AD), and it is considered a sign even today. Aratus stated: *If lightning springs from all points of space, from the harsh regions of Eurus, from the regions of Notus, from the peaceful domain of Zephyr, and from the frozen sky of Bistonia* [ancient Greek town near Vistonida lake], *the sea will be rough without end or measure by a multitude of storms* [4].

In reference to the Moon, Virgil (Publius Vergilius Maro 70 BC - 19 BC) stated in the Book One of *Georgics*: […] *But if on her fourth night's rising – for this is the sign most sure –/ Through the heaven with horns unblunted she rides in radiance pure./ Then all that day, and its offspring that follow in its train/ On to the end of lie month, shall be free from wind and from rain:/ And the shipmen, from peril delivered, shall pay their vows by the sea/ Unto Glaucus, to Ino's son Melicerta, and Panope*[9]. […][24], (*Liber I*, vv. 432- 437 [34]). Again regarding the horns of the Moon, as Pliny the Elder wrote (Liber XVIII, 348 [28]), Marcus Terentius Varro (116 BC - 27 BC) stated that […] *If on the fourth day of the moon her horns are upright, this will pre-sage a great storm at sea, unless she has a circlet round her, and that circlet unblemished, since that is the way in which she show, that there will not be stormy weather before full moon* [28]. Other meteorological signs given by the Moon are specified in the second book of [5], vv. 420-439.

Clouds are meteors that, rather than indicating the weather, signaled (and still do) the presence of islands not visible from the ship, even on clear days, because they were too far away. In this case, *God willing*, a small, isolated cloud was (and still is) formed above the island. In the Mediterranean, an example is the island of Montecristo, which is not visible in stretches of sea between Sardinia and Tuscany. Obviously, this phenomenon is not due to a divine action, but it is caused by the rise of the air, along the rocky walls of the island (about 600 m), which cools down causing the vapor to condense into a small and localized “signal” cloud.

Regarding the Sun, Virgil stated in the Book One of the *Georgics* [34] that the Sun will give very specific meteorological signals: *This too shall it profit yet more to remember—when now from the sky/ He* [The Sun] *sinks, having traversed his course, full oftentimes then we espy/ Over the face of the sun the changeful colours trail./ Sea-green giveth warning of rain, flame-red of an easterly gale* [Euros in

[9] Glaucus, Melicerta and Panope were three marine deities who protected navigation.

latin]*/ But if on his ruddy fire dark spots shall begin to lie./ One seething fury of wind and cloud shall be earth and sky./ Let no man counsel me on a night like that from the land/ To laimch on the deep, nor to pluck from the shore the hawser-band!* [24], (*Liber I* vv. 450-457 [34]). Other meteorological signs given by the Sun are found in the second book of [5], vv. 386-419.

Even the Stars, the *minutest lights* of the night sky, inform us about the weather; in the second book of *La Nautica* [5] the verses 443-470 tell us that: the Night sometimes feels pity for sailors who are lost among the waves, and through the stars tells them how to act. If the Night shows you the stars, of the Ara[10] constellation, without clouds and the rest of the sky is covered by a light veil of fog, return quickly to port; if you don't do it, you will beat mercy of the sea you challenged. But if the stars on the humerus of the Centaurus[10] constellation are a little covered by clouds and the stars of Ara are bright, there is no need to fear the south wind, Ostro, but Eurus (the wind born in Aurora's kingdom) will come to your aid. There is a sign of the wrath of the sky even when the stars little by little lose brightness, and if, when the shadows envelop the earth, a star is seen falling in a long and glittering path, from that direction will come the untimely assault of proud winds.

But the surest predictors were the birds which, with their flight, were closest to the deities and were, therefore, considered their privileged messengers**.** In general: the disorderly flight of birds accompanied by screeching was a sign of a storm for sailors; the rapid flight from the sea to the land, or the gathering near the swamps and the banks of the rivers, or the appearance of many white birds in unusual places, were precursory signs of bad weather; on the other hand, the flight of birds scattered or in small groups was an indication of good weather.

The deities also used terrestrial animals to send meteorological information to human beings, but certainly not to seafarers for whom the signs shown by sea animals were more significant.

We briefly show the *meteorological specificities* of some birds and other marine animals; for the connections between some of these birds and the celestial and terrestrial divinities, see [5], second book, vv. 471-524.

- *Heron:* the disorderly flights and screeches of this migratory bird, which lives in the swamps, were a sign of a storm. Theophrastus wrote: *It is a sign of wind or rain when a heron utters his note at early morning: if, as he flies towards the sea, he utters his*

[10] The Greek astronomer Claudius Ptolemy (ca. 100 – ca. 168 AD) compiled a catalog of 48 constellations (of the 88 registered today) also observable from middle latitudes. The position of the constellations, relative to the Earth, has changed over time due to the precession of the equinoxes. In fact, some constellations, easily visible in antiquity, are today poorly visible from the northern hemisphere. Among these, we remember:
- *Ara*, (in Latin: The Altar), is a small constellation of the southern sky, visible near the tail of Scorpius. From northern hemisphere it is possible to see its main stars, but only from latitudes lower than 30° N.
- *Centaurus* it is one of the brightest and largest constellations in the sky and is visible in its entirety from the southern hemisphere or at low northern latitudes. In historical times this constellation was entirely observable even from middle latitudes.

cry, it is a sign of rain rather than of wind, and in general, if he makes a loud cry, it portends wind. (*Concerning Weather Signs* 18-21, [32]). Aratus considered the disorderly flights and the shouting of these birds when they fly from the sea towards the land to be a sign of storm. Furthermore, he considered the high-pitched voices of the heron and its rapid flights from the land towards the sea to be an omen of bad weather [23]. Callimachus of Cyrene (ca 310 BC – ca 240 BC) affirmed the quiet flights of the heron from the sea towards mainland were a harbinger of good weather [23].

♠ *Halcyons*: Virgil, evidently echoing a popular opinion about weather forecast, stated that when this sea bird, dear to Thetis, understands that the weather will be good it does not expand its wings to sun itself on the leeward beaches, while the opposite is evident when bad weather is forecast [34].

• *Swan:* Isidore of Seville (560 - 636) preserved in his works many beliefs of his contemporaries, and regarding this bird sacred to Apollo, he wrote that *Sailors say that this bird makes a good omen for them* [22], [23].

• *Coot and gull:* Theophrastus wrote *It is a sign of rain when these birds plunge under water, a sign of wind when they flap their wings.* (*Concerning Weather Signs* 26-29 [32]). Pliny stated that the voracious gulls flee from the sea or ponds when they foresee wind. According to Marcus Tullius Cicero (106 BC - 43 BC): *Grey coot in fleeing the raging abyss of the ocean, /Utter their warnings, discordant and wild, from tremulous gullets, /Shrilly proclaiming that storms are impending and laden with terrors* (Liber I, 8 [13]). Virgil, Pliny, Rufius Festus Avienius (4th century AD), Isidore of Seville also tell us about this bird.

• *Waterhen:* according to Theophrastus it is a sign of rain when this bird, or other waterfowls, flap their wings on the water of a lake or sea (*Concerning Weather Signs*, 18 [32]).

• *Goosander:* seafarers consider the frequent fluttering of this aquatic bird, its cries, its numerous dives into the water, as a harbinger of strong winds or storms. Theophrastus stated that the flight of this bird during a calm, it is a sign of coming wind [32]. According to Isidore of Seville, goosanders, when they foresee unfavourable weather, fly, with great clamour, towards the coast [23]. These popular beliefs are later reported also by several other Latin writers.

• *Dolphin:* sailors considered the frequent leaps over the sea of this beloved fellow traveler as a sign of future bad weather. According to Theophrastus, a dolphin diving near the coast and reappearing often indicated rain or storm. Plinius the Elder stated *for instance dolphins sporting in a calm sea prophesy wind from the quarter from which they come, and likewise when splashing the water in a billowy sea they also presage calm weather.* ([28], Liber XVIII). Marcus Annaeus Lucanus (39 AD - 65 AD), Isidore of Seville, Flavius Aurelius Cassiodorus (c. 485-490 - c. 580), Cicero and others also mentioned the prediction of storms from the jumps of dolphins. Even Dante Alighieri (1265 - 1321) mentioned dolphins as harbingers of sea storms: *Even as the dolphins, when they make a sign / To mariners by arching of the back, / That they should counsel take to save their vessel* (*Inferno* XXII vv. 19-21, [3]).

• *Crab and shells;* sea and freshwater crabs, and seashells have the property of predicting the weather, as reported by Pliny [28]. The sea crab comes out the sea

to avoid being dragged away by the waves and the freshwater crab abandons the banks of the river or stream for fear of being swept away by the current. Finally, seashells cling to underwater rock cavities to escape the forthcoming storm [28].

• *Pilot fish*[11]*;* Oppian of Anazarbus (2nd century AD) stated the presence of this pilot fish near ships was considered a harbinger of calm sea [27]. Claudius Aelianus (c. 175 – c. 235 AD) added that these fish warn sailors of the proximity of dry land, when it is not yet possible to distinguish it with the naked eye: [...] *when vessels are cleaving the mid-ocean these Pilot- fish swim up as though they were in love with them and attend them like a bodyguard, circling this way and that as they gambol and leap.[...] Thereupon those in control of the vessel know that they must look around for land, not because they judge by beacons but because they have been instructed by the aforesaid fish*. (Book 2, 15 [2]).

• *Octopus, squid, cuttlefish;* these marine animals can predict any change in the weather in order to take any timely action for their survival. When a storm is imminent, the squid appears most often at the sea surface and is seen continually jumping out of it. In order not to be swept away, the cuttlefish grabs the shallows of the sea depths with its tentacles. Various Greek and Latin authors talked about the prognosticating ability of the octopus, as B. Baldi wrote in his didactic poem *La Nautica*": *when the sky has a hoarse voice, the octopus leaves the bottom and rises to shore where, with its tenacious arms, it firmly holds on to the roundabouts and small stones* (Book 2nd, vv. 492-495 [5]). Theophrastus, Plutarch, Pliny and Cicero also wrote about the aforementioned movements in the imminence of storms, and about the related popular beliefs.

• *Sea-urchin;* this echinoderm can foresee gales a day or two in advance. Many authors talk about this characteristic, Plutarch, Aelian, Cassiodorus etc. We can summarize their thinking with Pliny's words: *It is said that they can forecast a rough sea and that they take the precaution of clutching stones and steadying their mobility by the weight: they do not want to wear away their spines by rolling about. When sailors see them doing this, they at once secure their vessels with more anchors.* ([29], Liber IX).

• *Black wing flyingfish* (*Hirundichthys rondoletii*); this small fish is equipped with wings that allow it to fly on the sea surface and it has a great ability to immediately foresee any change in weather. The ancients considered it as a harbinger of a storm because they were convinced that it flew out of the water to escape the imminent storms. As mentioned above, similar behaviour was attributed to squid. This popular belief is also confirmed by Pliny [28], Marcus Manilius (1st century BC-1st century AD) and Isidore of Seville.

• *Sea sponges and jellyfishes;* like the previous ones mentioned, these animals also can foresee changes in the weather. The sponges fold back on themselves to avoid being torn away from the seabed by the water vortices. The jellyfishes, predicting gales, appear in enormous quantities and flee towards calm areas [28], [32].

[11] The ancient Greeks called this fish *Pompilos*, from the name of sailor who saved the nymph *Okyroe* from Apollo who, in revenge, transformed him into pilot fish.

4. Conclusions

Navigation of the seas and oceans was attested […] *Human beings managed to reach Australia from Southeast Asia some forty to sixty thousand years ago* […]; and then expanded into the habitable islands of the "vast" Pacific Ocean, after about thirty thousand years [14]. Obviously, the ancient peoples of the Mediterranean basin also practiced navigation on this "small" sea; as highlighted by the numerous archaeological evidence, in reference to the cultures analyzed by us. The first written information dates back to Homer's *Odyssey* (around 800 BC), which tells about Odysseus and his journey home after the Trojan War; the date of the events is uncertain, but it is likely to be between 1334 BC, according to Duris of Samos (ca. 340 BC - ca. 270 BC) and 1184 BC, according to Eratosthenes of Cyrene (ca. 276 BC - ca.194 BC).

This work presents a time interval of about a thousand years, very limited compared to the history of navigation, and an equally limited space, the only Mediterranean Sea, compared to the breadth of oceanic navigation. Limited time and space, however, show frenetic naval activity both along the coasts and in the open sea. The latter was made possible by the sailors' deep knowledge of marine and atmospheric currents in terms of reliability of both direction and intensity.

In summary, we can say that the Mediterranean with its ships, for centuries, was the main center of trade, enormously exceeding, in terms of quantity and variety of goods, the land transport which went from the coastal countries to those in the interior. This primacy fell from the beginning of the modern age when the Atlantic trade routes were defined through the systematic study of the winds [14].

Sailors based weather forecasts on more imaginative, but less reliable, knowledge. However, already with the first studies of atmospheric conditions, meteorological phenomena rapidly lost their aspect of "prodigy" and only some, for which an explanation had not been reached, remained within the scope of divinatory interpretation.

Virgil in *Georgics* (1, 415-423 [34]), referring to the predictions made by animals, denies the doctrine of the Pythagoreans and Stoics, which attributed to animals a spiritual gift infused by divine care or a foreknowledge of things granted to them by Fate. He attributes the behaviour of animals to physical causes, variations in humidity and temperature, movement of clouds due to the wind, etc., clearly visible signs of meteorological changes that man himself could interpret without their help [7].

However, we had to wait until the 17th century for the beginning of a new era, in which the Galilean method affirmed the primacy of experimental measurements over apodictic deductions, linked above all to the physical conceptions of Aristotle (384 BC - 322 BC). It was with Evangelista Torricelli (1608 - 1647) that, with the experimental discovery of atmospheric pressure (1644), the foundations of modern meteorology were laid [7].

5. References

[1] Abulafia D. (2011) - *The Great Sea: A Human History of the Mediterranean*, Oxford University Press, UK

[2] Aelian C. (1958) - *On the Nature of Animals, vol. I* tr. by A.F. Scholfield, ed Loeb Classical Library, Cambridge (MA)

[3] Alighieri D. (1867) - *The Divine Comedy*, tr. by H. Wadsworth Longfellow, Ticknor and Fields, Boston.
[4] Avienus R. F. (1843) - *Description de la Terre les régions maritimes, phénomènes et prognostics d'Aratus et pièces diverse*, traduit par E. Depois et Éd. Saviot, C.L.F. Panckoucke Editeur, Paris.
[5] Baldi B. (1921) - *La Nautica*, a cura di G. Bonifacio, UTET, Torino
[6] Benincasa F., De Vincenzi M., Fasano G. (2019) - *Storia della Strumentazione meteorologica nella cultura occidentale*, CNR Edizioni, Roma,
[7] Benincasa F., De Vincenzi M., Fasano G. (2023) - *I paralipomeni della meteorologia*, CNR Edizioni, Roma
[8] Benincasa F., De Vincenzi M., Fasano G. (2024) - *The historic lighthouses of the Italian Coasts,* in Proceedings of 10th International Symposium Monitoring of Mediterranean Coastal Areas. Problems and Measurement Techniques (edited by Bonora L., Catelani M., De Vincenzi M., Matteucci G.), Livorno 11-13 June 2024
[9] Cagnat R., Chapot V. (1920) - *Manuel d'archéologie romaine II*, Picard ed. Paris
[10] Campbell I.C. (1995) - *The Lateen Sail in World History,* Journal of World History, 6 (1), pp. 1–23 http://www.jstor.org/stable/20078617.
[11] Carson R. (2019) - *Il Mare intorno a noi,* Piano B edizioni, Prato
[12] Cartwright M. (2016) - *The Phoenicians - Master Mariners*, World History Encyclopedia, www.worldhistory.org/article/897/the-phoenicians---master-mariners/
[13] Cicero (1964) - *De senectute, De amicitia, De divination* tr.by W. A. Falconer, Cambridge, Mass., Harvard University Press
[14] Conner C. D. (2009) - *A People's History of Science: Miners, Midwives, and Low Mechanicks,* Bold Type Books, New York
[15] Cordano F. (editor) (1992) - *Antichi viaggi per mare: peripli greci e fenici, testi di Annone, Scilace di Carianda, Arriano, Rufo Festo Avieno*, Ed. Studio Tesi, Roma
[16] Fantauzzo F. (1976) - *Dalla brezza all'uragano*, ETS, Pisa
[17] Fraccaro P. (1937) - *Trireme* in Enciclopedia Italiana di Scienze, Lettere ed Arti, Treccani, https://www.treccani.it/enciclopedia/trireme_(Enciclopedia-Italiana)/
[18] Herodotus (1997) - *Histories*, tr. by Rawlinson G., Quality Paper Book Club, New York
[19] Hesiod (1993) - *Works and days. Theogony,* translated by S. Lombardo and R. Lamberton, published by Hackett Pub. Co. Indianapolis, USA
[20] Homer (1870) - *The Iliad,* tr. by W. C. Bryant Boston, published by Houghton, Fields Osgood USA
[21] Homer (2003) - *The Odyssey* tr. S. Butler ed. Ann Arbor Borders Classics book USA
[22] Isidore of Seville (2006) - *The Etymologies of Isidore of Seville,* trans. and ed. by Barney S. A., Lewis W. J., Beach J. A., Berghof O., Cambridge, UK: Cambridge University Press, DOI: 10.1017/CBO9780511482113
[23] Krekoukias D. (1970) - *Gli animali nella meteorologia popolare degli antichi greci, romani e bizantini,* Leo S. Olschki Editore, Firenze.
[24] Lelli E. (2012) - *Folklore antico e moderno - Credenze greche e romane comparate con le tradizioni popolari moderne*, tesi di dottorato, Università La Sapienza. https://iris.uniroma1.it/handle/11573/918575#.XYieA2ZS-Uk
[25] Lentini M. (1984) - *Nave* in Enciclopedia Europea Garzanti, Garzanti Editore, Milano
[26] Medas S. (2004) - *De Rebus nauticis*, L'Erma di Bretschneider, Roma
[27] Oppian (1928) - *Halieutica* in Oppian, *Colluthus, Tryphiodorus*, tr A.W. Mair, ed, Loeb Classical Library, Cambridge (MA)
[28] Pliny the Elder (1961) - *Natural History,* Vol V Liberi XVII-XIX tr. by Rackham, Cambridge, Massachusetts Harvard University Press

[29] Pliny the Elder (1967) - *Natural History,* Vol III Liberi VIII-XI tr. by Rackham, Cambridge, Massachusetts Harvard University Press
[30] Pomey P. (1996) - *Navigazioni e navi all'epoca della colonizzazione greca*, pp.133-140, in Pugliese Carratelli G. (editor) *I greci in occidente,* Bompiani, Milano
[31] Rafanelli S. (editor) (2019) - *Alalìa. La battaglia che ha cambiato la storia. Greci, Etruschi e Cartaginesi nel Mediterraneo del VI secolo a.C.,* ARA ed., Monteriggioni (SI)
[32] Theophrastus (1916) - *Enquiry into plants and minor works on odours and weather sign, translated,* by A. Hort, published by W. Heinemann, Vol. II DOI: 10.5962/bhl.title.162657
[33] USCCB (2011) - *The New American Bible (Revised Edition),* United States Conference of Catholic Bishops, Washington DC, https://bible.usccb.org/bible
[34] Virgil (1912) – *Georgics (The Georgics of Virgil in English verse)*, tr. by Way A. S., London, Macmillan and co. limited, New York, The Macmillan company
[35] www.lni-sestriponente.it/vela-latina/