L'Histoire Physique de la Mer. Part III: On the Motions of Seawater

WRITTEN (1725) BY L. F. DE MARSIGLI

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ABSTRACT

Seawater movements are of three kinds: currents, waves, and tides. Observations were made five times a day for three and one-quarter months in the Strait of Cassis. Mariners' reports of a westward current outlining the Mediterranean coast of Europe are shown to be in error. Deep currents are seen, but even surface currents do not respond predictably to the wind. Wave height is proportional to wind stress. The suggestion of Robert Boyle that surface wave amplitude cannot exceed six feet is roughly correct. Higher waves were occasionally observed either where waves feel the ground or where different wave trains converge. The ebb and flow of the tide was unobservable at the location selected. Little about the motions of seawater can be established until some prince supports simultaneous observations at an ensemble of locations.

Water being naturally fluid is by consequence subject to movements, and these movements are diverse, according to the diversity of their causes. The first is perhaps the slope of some parts of the bottom of the basin. The air, which when pressed by the winds, agitates the water in proportion to its force and forms waves of various sizes, may be counted as a second. And the third finally, to which one attributes the ebb and flow of this element, is the influence of the moon. There you have the causes of the three movements that we observe in the water of the sea. I will name these three movements currents, undulations, and ebb and flow—or tides.

I have examined to what degree these movements are found in the stretch of sea where our physical study is being made. The particular place, the Strait of Cassis, seemed proper to me for this examination. I took myself several miles offshore to investigate these currents, and during three entire months, the fishermen made observations every day by my orders.

I have distinguished, through the window of my apartment and in my various navigations, undulations whose force was always proportional to that of the winds that caused them.

In order to know if there were a systematic ebb and flow, and to what degree it extended, I caused the placement of a rod, divided into a certain number of inches,[1] at the entrance of the port, as I will explain later. For the rest, I thought it appropriate, for a greater exactitude, to add to these observations those of the thermometer and of the change in weather, as they could contribute in some way to the variety of movements. They are listed chronologically in the accompanying table, including three moons and one quarter, to wit: January, February, March, and the first quarter of April. We have taken care to note all the necessary circumstances, so that they can be seen—that being the foundation of all our demonstrations, for the movement of the part of the sea we have chosen.

The currents there are of two sorts—permanent and intermittent; we see this both in the surface layers of the water and in the depths. The permanent currents at the surface are found at the mouths of the rivers and particularly at that of the Rhone, where in calm weather they are noticeable and extend 15 or 20 miles offshore. When the wind is against them, they do not advance so far, and their velocity is much weaker; when the wind is favorable to them, they extend a greater distance, but with less regularity than during the calm.

I showed in the first part of this book that there are various currents at the bottom of the sea, and I gave as an example the one at Port Miou. It would appear that changes in speed must occur there also, since so many of the causes that could contribute to changes

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[1] Originally, "pouces," a premetric French unit of measure. A pouce is 3 centimeters, so that the "40 inches" mentioned below probably means about 47 English inches.

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in speed are found at that location. But I have not been able to confirm this directly, and I have contented myself with investigating the continuity of the currents.

The most experienced mariners on the Mediterranean believe that there are two currents aligned and opposed to one another. The first goes from west to east, beginning at the Strait of Gibraltar and going the length of the coast of Africa up to the longitude of the kingdom of Candia. The second goes the opposite way, from east to west, beginning where the other finishes and going the length of the coast of Europe back to the Strait of Gibraltar, which by consequence must have its surface divided into two currents. It is certain that the first, which goes along Africa, must, at the level of Candia, make a turn to the opposite direction; for I have myself observed the continuation of this current from the Bosporus of Thrace, which forces the other to take an opposing course and to return along the coast of Europe.

This disposition of the currents, of which the most able pilots have assured me, does not accord at all with what I have observed in the Gulf of Cassis, which is a part of the coast of Europe, along which they say the current goes always westward. The list of current observations made in the Gulf of Cassis, which will be found in our table, shows the opposite; it may be that the proximity of land contributes to this difference and interrupts the continuity of the straight currents, or it may be that the structure of the basin or the reflection of the winds against the mountains that constitute this coast is the cause.

One sees then, in this table, that the currents go sometimes from east to west and sometimes from west to east; which is not expected, according to what the mariners report to us. The cause of the alternative, opposed movement does not seem to me to be easy to understand, even considering the profile of the coast of Provence, in which I find no particular reason on which to base a solid argument. It happens sometimes that these currents, principally in the summer, are completely insensible; at other times, from the water surface just to a certain depth they go to one side; and farther down another is found, having an opposite heading, and this is what the fishermen call "double currents." What is more surprising is that at the edge of the abyss during summer, and during coral fishing season, one sees a current moving with the sun, for when the sun rises, the current is going westward; at noon it courses toward the north and in the evening makes its way toward the east. I should never have believed the bizarre behavior of these currents, which the fishermen of Cassis reported to me as well as the fishermen of neighboring places, had I not seen them myself during a coral fishing trip made in this place the first day of July 1707. It was then that I truly despaired of being able to learn anything on this subject.

I tried to find out if the winds contributed to this variation but I made no advance in this direction, for in calm weather, the currents change and often become very fast so that fishermen can barely hold up their nets, and at other times, the winds being very strong, the currents were almost insensible. Several times also I saw the currents run with a speed proportional to the force of the wind, and just as often go against the wind.

That which I found most uniform was when at a certain place the currents were coming strongly from the west for two or three days there rarely failed to come a mistral wind from this same side, and when the currents were running from the east, the winds eventually blew from that side too. Nevertheless, I found irregularities even in this, so that I will not report the reflections I had made on this uniformity that I had believed to be universal.

I conclude from all these different observations that one will never establish anything definite about the currents so long as a single person works at observing them, and in a single place as I have done at Cassis. One should simultaneously place observers at all the principal capes of the coast and of the islands, who, following some agreed-upon method, would all make exact report books, both of the currents' speed and of the places where their paths turn, without forgetting the interior currents opposed to those at the surface, together with the observation of the winds, whose force should be compared to that of the currents. But since it is an expense suitable only for some prince who appreciates and protects the sciences, I shall not say another thing on this subject, and awaiting a time when one could extract some utility from our observations by these methods, I shall pass to observations of other movements.

We have called the seawater movements caused directly by the winds "undulation," since it is only attained through the cylindrical and repetitive revolution of waters pressed by the winds, to which one gives the name "ondes" (waves). This motion depends on the force of the winds and also on the various positions of the mountains, where the impetus of the winds is augmented by reflection. The latter refers mostly to the air, which stirs up the waters, making them raise themselves in cylinders of diverse sizes, proportional to the motive force of the wind.

This movement is circumstantial, for when the air is in its ordinary calm state, the sea surface is as well, and as soon as a little gust of wind is raised, the water begins to ripple gently, and in proportion as the wind grows, this kind of ripple renders itself more sensible, rising and falling in various degrees of waves in the manner seen in the first profile.

I wanted to know what was the greatest elevation of a wave in a tempest. Experience showed me that it was necessary to divide the state of waves into two: one natural and the other accidental. The natural part is uniquely proportional to the force of the wind. The accidental part arises when the waves strike one another from the front or the flank, when they follow one another with too much violence and without interruption, or when they roll on sandy beaches or against the rocks, for all of these are causes that make the waves rise farther than the wind could have done naturally.

Robert Boyle reports several observations to show that the strongest wind never penetrates farther than six feet below the ordinary horizon of the sea. It follows from that that the cylinder of water does not raise itself more than six feet above the same horizon. I have verified this experience on the beaches of Languedoc, between Maguelonne and Peyrol, where I measured the height of the waves, in tempestuous weather, on a perpendicular line above the position of the tranquil sea, and this elevation was found to be seven feet. One need not be surprised that the water in this situation rose one foot more by contact with a long stretch of sandy bottom, where the waves come to break. It is natural enough that by this violence they rise a sixth part more than at other places.

On the mountainous shores of Provence, where there are many more deep spots than in Languedoc, a Labeche wind, equally furious, made the water rise only five feet naturally, but accidental buffeting against the rocks pushed the water sometimes to a height of eight feet.

On the high seas, where the winds find a free field, the waves, which in their ordinary stormy state are not higher than six feet, can sometimes become horrible by the union of several other waves that follow each other too closely, and without a pause enter into one another, roll themselves together, and from turbulent whorls that make extraordinary storms, but commonly the water is not elevated more than five or six feet above the level of a calm sea, as one sees from the figure, where we have shown how the force of the wind penetrates the water and elevates it in proportion. Cylinder AAA is that of the wind; space BBB is the part of the water pressed by the wind that rises like CCCC above the horizon and that subsequently, by buffeting against the rocks, against sand banks, or against other waves, rises to this accidental elevation of which I have just been speaking.

On this coast the winds that cause the greatest agitation are the northwest and southwest winds, which alternate with one another in dominating, in an irregular manner, which one can observe in the table.[2] I shall not go further on this subject of the winds, even though it must form a considerable part of the science of the sea; experience having apprised me that it remains impossible to produce anything certain on this matter, so long as there are not many observers placed in different locations at the same time; for as our Mediterranean Sea is quite narrow, one remarks very often, at very little distance, two different winds coming from the diverse situation of the shores and disposition of the beaches. What I have just been arguing is something the galleys encounter almost every time they want to pass from Marseilles to Sette in Languedoc. Although they have the winds at their backs, as soon as they depart Marseilles, during the time they are advancing in the Gulf of Lyon, they find the wind at first in the southeast, then in the south, and at last in the southwest, obliging them to go back. This is why the galleys of which we are speaking prefer to pass the gulf by awaiting a little wind from the north, or else a calm.

In the accompanying table, one will see a little test of the manner in which the winds contribute to the variety of weather. For this part, and for the currents and tides, I wish we had made ten others, as I said, at the same time, in diverse places; for I repeat again, it is impossible to establish anything solid on this subject so long as one sole person works at the observations.

As regards ebb and flow, to know how it manifests itself in this sea and what creates it, I had to put in place a perpendicular ruler, long enough to touch the bottom, and to reach above the water as high as the storms could make the water rise. In the place that I chose, the ruler had to be 68 inches, and one sees its division in the profile at the side of the table.

To record the various heights of the sea, I found it convenient to begin at the upper part of the wooden rod, descending according to the order marked by the numbers, so that if the measure of the height of the water is, for example, 40 inches, one must count upward descending toward the bottom.

For a greater exactitude, I recorded whether the water was rising or falling at the hours when I was making the observations, and this difference is indicated in the table.

Of the 24 hours of the day, I chose 5, to wit: sunrise, midday, sunset, nine in the evening, and midnight, to note the height of the water according to the measuring rod.

All these observations put in order in the table show that there is no regular observable ebb and flow on the coast of Provence, at least not in the place where, during three months and the first quarter of a fourth, I so exactly observed things; having further made the comparison of the true state of the winds and currents, to know if their movements could be the cause of the absence of ebb and flow, and of all the other irregularities expressed in the table. Overall, I found nothing but an extreme obscurity. Perhaps it will be diminished by the reflections that other bright people can make, on this same table, which did cost me a lot of trouble and annoyed me not just a little. Since I have not derived any understanding that could satisfy me in any way, after all this effort, I find myself reduced to saying that there is no ebb and flow in this place but only various alterations up or down in the elevation of the waters caused by the winds and by several other irregularities associated with the irregularity of the currents.

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[2]The tables and figures mentioned by the author can be examined at Scripps Institution of Oceanography or Harvard University.