MARSİLİ'NİN İLK OŞİNOGRAFİ SEFERİ (1679-1680) VE İSTANBUL BOĞAZI YOĞUNLUK AKINTILARINI AÇIKLAMASI

MARSILI'S FIRST SCIENTIFIC OCEANOGRAPHIC CRUISE (1679-1680) AND EXPOSITION OF BOSPHORUS DENSITY CURRENTS

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ÖZET: Luigi Ferdinando Marsili'nin (1658-1730) ilk kez denizde yaptığı ölçümler gözden geçirilmektedir. Marsili deniz suyunun yoğunluğunu doğrudan ölçümlerle ilk kez büyük duyarlıkla saptamış, İstanbul Boğazı'nda akıntıları ölçerek alt akıntının yüzeyin tersine olduğunu belirlemiştir. Marsili bundan sonra kararlı bir şekilde Boğaz değişim akıntılarının dayandığı bilimsel kuramı ortaya koymuş ve modern fiziksel oşinografinin akışkanlar dinamiği temelini atmıştır.

ABSTRACT: For the first-time, at-sea measurements of Luigi Ferdinando Marsili (1658-1730) are reviewed. Marsili made the first direct measurements of sea-water density with surprising accuracy as well as the currents in the Bosphorus and observed the current reversal at depth. Based on these accurate measurements of his day, Marsili proceeded boldly to discover the scientific basis for the exchange flows of the Bosphorus Strait, laying the fluid dynamical foundations of modern physical oceanography.

INTRODUCTION

Oceanography is a scientific discipline concerned with the study of the Earth's seas and oceans, drawing on the disciplines of physics, geology, biology and chemistry. The study of the sea has always been of great importance in terms of human cultural and economic activities, which makes oceanography an applied science requiring advanced technologies. Oceanography was characterized also by a naturalistic approach until the 1980s. Scientists explored the seas and oceans with the aim above all of characterizing and classifying the currents through direct measurements of their water mass properties. The situation changed radically in the 'nineties, when measurements began to be made remotely by artificial satellites and submarine robotic instruments. Up to that point since the time of Marsili, the ocean had been measured with oceanographic cruises that collected water samples or measured temperature, salinity and other parameters directly from the ship.

Marsili's letters and travel notes from 1679-1680 are the first scientific reports of an oceanographic survey: the measurements that he made and described are the first scientific works that can be accepted as the beginnings of modern oceanography. He demonstrated that the sea could be measured quantititavely and repeatably, and recorded the results meticulously in his in travel and laboratory notes. Marsili was also the first to combine various scientific disciplines (natural sciences crossed with physics and mathematics), melding them in a way original and innovative for science. The notes and letters summarizing Marsili's scientific work on the Bosphorus Strait were reproduced in his printed treatise *Osservazioni intorno al Bosforo Tracio overo canale di Constantinopoli* (Marsili, 1681), presented to the visiting Queen Cristina of Sweden in Rome, translated into English by Soffientino and Pilson (2009). This was a decisive step in the history of modern ocean science still to develop almost three centuries later, since the measurements he made lead to the first scientific demonstration of density driven currents, providing fundamental insights into the theoretical basis of ocean dynamics (Moroni, 2003; Pinardi, 2009).

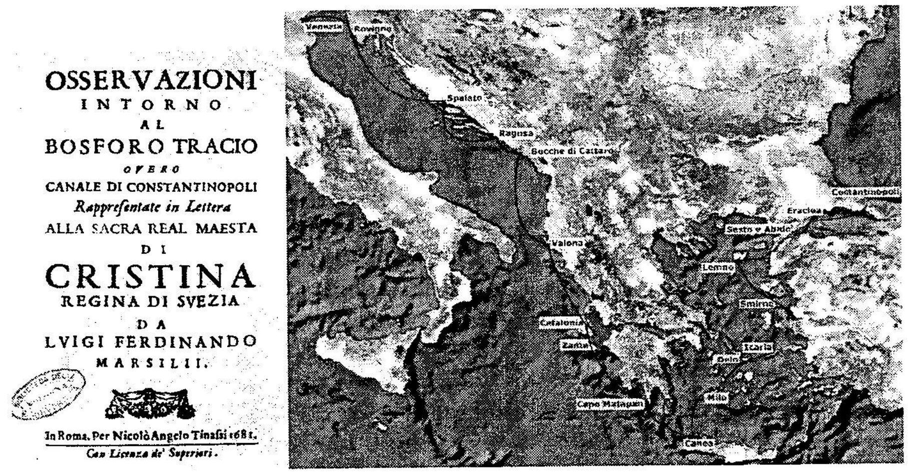

Fig.1 (a) The first page of Marsili's book '*Osservazioni Intorno al Bosforo Tracio*', (b) the path Marsili followed in his first cruise from Venezia to İstanbul (Pinardi, 2009).

Marsili's measurement technique

It is now understood that the density of in-situ water samples collected by Marsili on his voyage from Venice to İstanbul can successfully be reconstructed from the weight ("peso dell'acque") data originally reported by Marsili. This agreement between historical and modern methods of measurement, only achieved after a scrupulous search for key documents and identification of units in historical literature, made possible through recent efforts (Moroni, 2003), proves the reliability of scientific methods used by Marsili, that were in fact far ahead of his time (Pinardi, 2009).

This recent understanding is in contrast with previous studies, which assumed the measurements to be representative of salinity (e.g. Soffientino and Pilson, 2005) and disregarded exact correspondence to density due to unknown temperature of the water samples. In fact these were the first known measurements of density (weight) in the west. In the east, the hydrometer was used to determine liquid density and a strict definition for a specific weight was given by Al-Khazini of 12th century Seljuk Empire in the 'Book of the Balance of Wisdom', following his predecessor Al-Biruni of Khwarezm in early 11th century, a follower of scientific method who also experimentally determined density (Rozhanskaya and Levinova, 1996),

Using Hooke's vase to collect seawater samples (Deacon, 1971, 1982; McConnell, 1982) Marsili was capable to measure the 'specific weight' or density of the different water samples using Archimede's principle for a body submerged in a fluid. The measurement apparatus was composed of an hydrostatic ampoule that was suspended in the fluid to be measured. In order to be precise enough to measure differences between rain water and marine waters, the specific ampoule to be used had been particularly recommended by Marsili's teacher, the mathematician Geminiano Montanari of Padua University, as indicated by his written memories. This method was found to be much more accurate in comparison to a hydrometer known since old ages, capable to detect 2-3% difference between densities of seawater and rainwater, as indicated by Montanari and experimentally verified by Marsili.

Marsili achieved these results through careful and meticulous experimental fieldwork along the Venice-Constantinople route and in various places along the Bosphorus Strait – the latter having been mentioned by Galileo Galilei in his *Dialogo sui massimi sistemi del mondo* as one of the places where attention should be focused in order to understand the profound reasons for the movement of the seas.

Marsili reported the results of his experiences in Constantinople in a way that abandoned the literary forms then in use – travel books and journals, portolans and pilot books, political and historical works – and instead presented his observations in the form of a scientific treatise (we might even say a long monographic article) in which all of the many data recorded go towards the same aim: measuring the weight of water and explaining the movement of the waters in the Bosphorus Strait.

Marsili's work went to press at the end of a period that had seen a growing interest in the terraqueous globe and the complexity of natural phenomena that caught scientists' attention as a form of highly variable phenomena. Benedetto Castelli wrote in his 1628 book *Della misura delle acque correnti* (*On the measure of the water currents*):

> The truth is that this information, although of things near our senses, is often more abstruse and concealed than knowledge of things far, and far greater and more subtle is our comprehension of the movement of the planets and the periods of the stars than it is of that of the rivers and seas.

In the face of the complexity and variety with which natural phenomena manifested themselves, attempts at explaining them were manifold. Marsili proposed what was an innovative hypothesis for his times, which consisted of putting his masters' teaching into practice at sea and demonstrating that 'the sea can be measured' as in laboratory experiments of the Galilean tradition. His journey to the Levant and his eleven-month stay in Constantinople, although devised as an education in politics and diplomacy experience, were an opportunity for the young Marsili to experiment the validity of the techniques for measuring weight perfected by Galileo and his followers for use with natural phenomena.

The measuring procedure set up by Marsili allows a reliable reconstruction of the Bosphorus water density (Pinardi, 2009). His voyage from Venice to Constantinople may thus be considered the first modern oceanographic cruise where water sample undergo quantitative analysis giving information on sea water mass properties from which it is then possible to understand the Bosphorus current dynamics. Even more surprising is the accuracy of the reconstructed density measurements, highlighting the fact that the hydrostatic ampoule is a surprisingly accurate instrument, measuring very small differences.

CONCLUSIONS

The agreement shown between the values derived from data collected using modern techniques and those calculated from Marsili's measurements goes to demonstrate that Marsili's scientific method was sufficiently rigorous to allow the reconstruction of realistic values for seawater properties, even though a lack of description does not allow a perfect knowledge of the procedure used.

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