VARIATIONS IN TIME AND SPACE SCALES IN THE PHYSICAL AND BIOLOGICAL CHARACTER OF THE MEDITERRANEAN SEA

Paul E. La Violette *[1] and Robert Arnone [2]

[1] Gulf Weather Corporation, Stennis Space Center, Ms 39529 601 688 3397, USA.
[2] Naval Research Laboratory, Stennis Space Center, Ms 39529 601 688 5268, USA

ABSTRACT

The combination of satellite and in situ data form a powerful tool to use in the study of the Mediterranean Sea at varying scales of time and space. Whereas a great deal of information may be inferred from in situ data alone, the coupling of satellite with the in situ data provides a more accurate picture of what actually takes place before, during and after a series of in situ measurements. With the satellite's ability to provide broad spatial displays of surface data, the in situ measurements are no longer isolated points on the sea surface; one can see them in relation to their broader dynamic surroundings. In sample studies, we demonstrate that satellite data can be usable in such combinations not only in the single high resolution image format, but as long series of high resolution imagery, as long-term composites and finally, as graphs of long-term (multi-year) data. Recent data indicate that conditions in the Mediterranean are changing. We feel that marine studies using combinations of long-term (decades) *in situ* and satellite data are one of the most powerful tools available to provide both a baseline of comparison as well as a timeline monitor of the ongoing changes. We realize that while what we describe here is a doable methodology, there is a basic problem in the poor accessibility of satellite data to the average marine scientist. We feel that this is a critical problem that the CIESM should address.

Key-words : coastal processes, remote sensing

Introduction

Data collection by a ship at sea has long been the most accurate method of deriving information about the Mediterranean. In a span of several hours, a ship at an ocean station, using sophisticated data collection instruments can obtain detailed biological/physical data from the surface to the ocean bottom. Upon completing the station, the ship can move to another station and obtain similar data. This process repeated over a number of stations results in a powerful data set. From such data sets, marine science analysts have for years derived their view of what the Mediterranean is like. Very often these views have been presented as horizontal (*e.g.*, see Figure 1) and vertical slices of the Mediterranean showing the spatial distribution of the parameter(s) of interest to the analyst. Physical oceanographers use such views to derive the Sea's dynamic structure; biologists, to derive the distribution of organisms; and modelers, to derive the mechanisms that force the various parameters to become so displayed.

This is the classical methodology of oceanography that has been in use since the *Challenger*. It is the principal methodology in use today and undoubtedly will be so for years to come. There are, however, certain limitations to this method of data collection. Limitations that we, as marine scientists, too often do not consider in our final analysis of the data. That is, that the ship data is limited in both space and time.

Space

We often forget that the data collected at an ocean station is a collection of the actual conditions that were present at a particular point in the ocean and no place else. We often infer that the station conditions are representative of a broader area and, if there is no other data source, this inference is justified. However, we must not forget that the data is >from that station only and may be completely different from conditions just a few kilometers away from the ship. Even if a series of stations is made, there can be problems. If the studied phenomena is poorly sampled (due to either the spatial or temporal distribution of stations) then the data is worse than useless, it may well present a set of conditions that another more apropos station distribution might show to be completely different.

Time

Quite often, we try to overcome this difficulty by tighter station spacing. However, an ocean station takes time to occupy. And, once the data collection at a station is completed, it takes time to go to the next station. The new station also takes time, and the movement to the next station will again take time. If the parameter being studied is part of a dynamic ocean process, then the number of stations that can be occupied during any campaign is limited by the temporal variability of the process. It may well happen that, despite the best of plans, we cannot derive as accurate a picture of the process from the data as we would like.

Space and time

We must consider that the phenomena or event indicated by the data represents the period of the data collection. Conditions may change in several days, weeks, or even months that are starkly different from the conditions for the time the data set were collected. Seasonal and interannual changes must also be taken into account.

In this discussion, we will look at the problem as that of dealing with varying scales of space and time. We will show that any *in situ* data collection is normally limited by its spatial and temporal coverage. We will also show that this coverage needs to be expanded from immediate area and time scales to basin and short (days and weeks), long (seasons and interannually), and longer (decades) scales. To fully understand the evolution of physical, biological, optical, and or chemical processes in the Mediterranean Sea, one must use satellite and *in situ* data and models in a the integrated matrix of different scales of space and time.

As a critical part of this discussion, we will demonstrate how *in situ* sampling can be optimized using satellite data in conjunction with the *in situ* data collection. Although combined satellite - ship data analyses are fairly common in the marine science analyses published today, quite often these involve only one or two satellite images. We will show that a more intensive utilization of satellite data is needed to properly understand Mediterranean conditions.

The short term data

Figure 1 may be used as an example of the limitations of ship data isolated in space and time. This figure, part of a treatise on a multi-ship campaign in the Alboran Sea by Lanoix (1), shows a large gyre occupied the entire western Alboran during the period of a multi-ship campaign in 1964. The analysis also shows that no gyre was present in the eastern Alboran.

Lanoix's was an excellent treatise on the data he had available at the time. His study presented a gross picture of the circulation that set the stage for multiple platform operations in the sea for many years after its publication (*e.g.*, Donde Va?) (2). In 1964, the time of the multi-ship campaigns, satellite data were not available and any depiction of the circulation of the Alboran Sea could only be derived from ship data. The 1964 investigators of the Alboran had an idea of the spatial and temporal complexity of the Alboran circulation; hence, their choice of the multi-ship approach. The resulting data was what Lanoix used for his study and his final analysis reflects the limitations of the data collection methodology of the period.

In Figure 2, La Violette and Lacombe show daily satellite data of the same region, but for a different year (3). In the figure, we see that the shape of the gyre varied during the several days of satellite imagery. This variability is not disclosed by the multiple-ship analysis of Lanoix. Indeed, in the numerous studies of the Alboran since the Lanoix study, an Alboran gyre the size depicted in his analysis has never been found. Although a gyre-type circulation does exist in the Alboran, it is often found to consist of two gyres; a Western and an Eastern Alboran Gyre. In a study by Heburn and La Violette (4), both