THE USE OF VISIBLE AVHRR NOAA SENSORS IN COASTAL AND ESTUARINE STUDIES AREAS OF THE MEDITERRANEAN SEA

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Abstract

The delay in the launch of SeaWiFs has reduced the scope of turbidity and ocean energetic studies in the ocean's coastal and estuarine areas. SeaWiFs is now up and follow-on ocean color sensors (*e. g.*, MODIS, MERIS and Landsat ETM+) will soon be in orbit. This study explores the use of an interim algorithm made up of the visible channels of the NOAA AVHRR in these type studies. This study shows an unexpected dividend in that the AVHRR visible data will continue to be useful in coastal studies even after the availability of data from the new ocean color systems.

Key words : Remote Sensing, ocean color, coastal processes

Introduction

Knowing the optical variability of coastal and estuary regions is important toward understanding these regions' physical / biological processes. High concentrations of suspended sediments (from river discharges and bottom re suspension) and colored dissolved organic matter are responsible for the strong coloration of the waters in these regions. The optical signal from these sediment / biological mixes can be used alone or in combination with the thermal signal to define turbulent mixing areas, areas of strong biological activities and to trace circulation patterns. here are a number of satellite sensors that may be used to monitor these processes as well as the coastal environment in general. Those having a long proven history for such use, are two "workhorses" of remote sensing, the visible and thermal infrared sensors (for examples of their use in the Mediterranean, 1, 2, 3, 4). Although the thermal sensors have, provided a long and relatively uninterrupted data stream that may , be used to provide long-term statistical analyses of the coastal regions, the visible data steam has been relatively short; mostly limited to that provided by the Coastal Zone Color Scanner (CZCS) during the period late 1978 through mid 1986. At the time of this writing, a new ocean color sensor, SeaWiFs, has been placed in orbit after a series of prolonged delays. This sensor should shortly be providing ocean color (visible) data to the oceanographic community. (Although not available at this time, examples of the SeaWiFs data related to the Mediterranean will be presented at the CIESM meeting in Dubrovnik). SeaWiFs data will be different from that of the Coastal Zone Color Scanner (CZCS) in that the new sensor's data can be adjusted to provide high reflectance information of the shallow regions of the coastal regime. CZCS data of highly turbid regions have problems due to the red and green channels being saturated. In addition to SeaWiFs, other satellites (*e.g.* MODIS, MERIS) will be orbited in the near future that will carry sensors with ocean color data collecting capabilities that will work in the coastal environment. Thus, by the turn of the century, new data will be available. Used en suite, the repeat looks provided by this assemblage, will be highly useful in the quick-changing coastal shallows. The time spent waiting for the launch of SeaWiFs was not wasted. The easily accessed, easily processed NOAA AVHRR data has been shown to be of use in the shallow water coastal environment. This began with an algorithm developed by Stumpf (5) to derive the distribution and characteristics of highly turbid coastal regions using the NOAA AVHRR two comparatively wide (+100mm) visible channels (640 and 850 mm). Gould and Arnone (6) have modified the Stumpf algorithm to relate, remotely-sensed reflectance data to the beam attenuation coefficient at 660 mm (*i. e.*, c660), a frequently measured oceanographic parameter. Despite the extensive spectral limitations of AVHRR visible channels in comparison to those of CZCS and SeaWiFs, the use of the AVHRR data for marine research has several very practical advantages:

- AVHRR ocean color data are available now for coastal research. In this regard, the NOAA polar orbit and direct readout are ideal. NOAA 14 sees the Mediterranean shortly after local noon each day, an ideal time for ocean color research. In addition, AVHRR data can be received directly at sea and thus, can be used to control *in situ* data collection as well as be part of the post-campaign analysis.
- Unlike Nimbus 7 or Sea Star color sensors, each NOAA satellite contains identical AVHRR sensors. There has been at least one NOAA satellites in orbit since the mid 70's. When NOAA 14 reaches the end of it's operational life, a NOAA satellite with an identical AVHRR sensor will be launched. Two decades of AVHRR ocean color data are now available as a data base.
- AVHRR visible and thermal data are co-registered. Each AVHRR channel shows the same earth scene. Coincident CZCS thermal/visible coverage was available for only a short period. No thermal channel is to be on SeaWiFs. The AVHRR ability to provide temporal and spatial coincident thermal/visible data offers unique marine study opportunities.

The AVHRR algorithms have been used in a number of far ranging studies that have shown the NOAA AVHRR to be a valuable data source in the monitoring of coastal areas (*e. g.*, 7, 8, 9). An interesting aspect of these studies was to show that AVHRR data can define wind- and tidal current-induced changes in shallow waters (>5 meters). Thus, in a fashion not previously realized, the AVHRR visible and thermal data were found to be usable in small scale study of lagoons and estuaries. The data sets thus derived may be used as single images or as groups of sequential images or, as will be shown here, as statistical sets. In recent years, ocean studies utilizing both graphs and composite images of long-term satellite data have begun to emerge as methods of showing the ocean's seasonal and interannual variability (*e.g.* 10, 11). While not as spatially detailed as the instantaneous views of the high resolution daily satellite imagery, these compositing studies have provided information useful in unraveling details in the ocean's long-term variability and better defining the forces that cause this variability. This methodology has now been applied to the shallow water environment using the AVHRR visible and thermal data. When TIROS-k is launched late this year, its improved AVHRR sensor will be added to the suite of sensors available to work the shallows. So, after years of successful exploitation in the open and deep ocean, satellite remote sensing visible data (starting with AVHRR, and, as they come available, SeaWiFs, MODIS, MERIS and Landsat ETM+) are slowly coming into their own as standard tools to study and monitor the shallow water environment.

Due to the limitations of these proceedings, the examples of the AVHRR work will be limited to Figures 1 and 2. In the presentation at Dubrovnik, this paper will provide examples of the use of the c660 algorithm to 1) trace estuarine discharge and coastal flow structure and 2) provide long-term (seasonal) shallow water optical information in the coastal waters. It will show that even after the spectrally more definitive SeaWiFs et al., data become available, the dependability and easy accessibility (in reception and computer manipulation) of the AVHRR data will continue to make it a major instrument in coastal color studies. This dependability is (*i. e.*, the long term continuity of the NOAA AVHRR series) is especially emphasized in the short life span of the Japanese OCTS sensor

Examples of the C660 technique in the Mediterranean

The Gulf of Venice (Fig. 1). As stated earlier, studies of shallow water (>5 meters) lagoons and estuaries show that AVHRR data can define wind- and tidal current-induced changes. Thus, in a fashion not previously realized, the AVHRR visible and thermal data were found to be usable in studying day-to-day changes in these comparatively small regions. Note the thermal field at this time of year is relatively flat and the visible data contain the most information. The Po River Outflow (Figure 2). Unlike the other areas within the Adriatic, the area of the Po Delta always displays a strong thermal field due to the differential temperature of the river water in comparison to the Gulf waters. The coincident c660 / thermal imagery are quite similar in their general pattern characteristics, although close examination will show significant differences that reflect the involvement of different processes. The Po River outflow varies seasonally and year-to-year. Thus, there are seasons / years in which the river outflow drastically changes the composition of nearby waters and conversely, there are seasons/years when such changes are minimal. These seasonal/interannual changes can be monitored using AVHRR visible and thermal data

Conclusions

This paper demonstrates that coastal optical research can be conducted using the comparatively easily accessible NOAA AVHRR data. The following are our preliminary conclusions.

1. The algorithm of the coastal volume scattering coefficient, c660, derived from NOAA AVHRR visible channel data is effective in the study of highly turbid marine areas; in many cases marine features are revealed in the AVHRR visible data that are poorly defined by AVHRR thermal data.
2. The c660 algorithm is an excellent tracer of flow patterns and coastal water masses during seasons when sea surface temperature values are essentially homogeneous (late-spring, summer and early fall). During other seasons, a combination of the c660 algorithm and thermal images can be highly successful in studying coastal optics and dynamics.
3. The c660 algorithm is useful in studying high suspended sediment loads associated with nearshore discharge plumes and resuspensions with significant remote sensing reflectance. However, it cannot be used to resolve optical values or marine features in waters having low turbidity concentrations or reflectance. Thus, the c660 algorithm is ineffective in coastal regions with low turbidity.