N90-27157

APPLICATIONS OF ISES FOR COASTAL ZONE STUDIES

D. S. Bartlett
NASA Langley Research Center
Hampton, VA*

Introduction

In contrast to the discipline- and process-oriented topics addressed by many workshop participants, coastal zone studies are defined geographically by the special circumstances inherent in the interface between land and water. The unique characteristics of coastal zones which make them worthy of separate consideration are (1) the dynamic nature of natural and anthropogenic processes taking place, (2) the relatively restricted spatial domain of the narrow land/water interface, and (3) the large proportion of the Earth's population living within coastal zones, and the resulting extreme pressure on natural and human resources. These characteristics place special constraints and priorities on remote sensing applications, even though the applications themselves bear close relation to those addressed by other elements of this report (e.g., oceans, ice, vegetation/land use). The discussion which follows will first describe the suite of remote sensing activities relevant to coastal zone studies. Potential ISES experiments will then be addressed within two general categories: (1) applications of real-time data transmission and (2) applications of onboard data acquisition and processing. The discussion will conclude with a short summary.

Remote Sensing for Coastal Studies

A number of generic research and monitoring tasks are associated with important coastal zone processes, as follows:

1- Water circulation: The dynamics of coastal water circulation impact virtually every physical, chemical, and biological process in the coastal zone. Because of the smaller areas involved, current velocities and changes in those velocities tend to be much more rapid than in the open ocean. This is particularly true of tidally driven circulation which changes both speed and direction at time scales less than one day. This makes conventional shipboard measurement extremely difficult. Remote sensing studies of circulation generally make use of water turbidity or some other reasonably conservative, visible tracer within the surface water column to develop a synoptic picture of water mass distributions at a particular point in time. In order to follow the important changes taking place on time scales of hours and minutes, repeated imaging over hourly-daily temporal frequencies is required. Because of the characteristic spatial scales of most coastal water bodies, high spatial resolution, on the order of 50-250-m ground instantaneous field of view (GIFOV), is also frequently required although

*Now employed with the Institute for the Study of Earth, Oceans, and Space, University of New Hampshire.

coarser resolution has been used under certain circumstances. Related physical parameters such as waves and surface winds have been addressed using microwave sensors such as scatterometers.

2- Pollution: The combination of dynamic physical systems and intense human use make monitoring of pollution in coastal waters a difficult task which has benefitted from remote sensing techniques. Most such work has been analogous to the water circulation studies described above in which a known pollutant is monitored through its visible impact on water color, and the distrbution of the affected water mass is monitored through time. Some attempts to identify the type and concentration of selected pollutants through multispectral analysis have been made but such applications have not been conclusively demonstrated. Thermal effluents can be effectively monitored and their temperature estimated using imaging in the thermal infrared spectral region. Oil spills can also frequently be detected by their impact on the thermal rather than visible spectral signature of the water surface.

3- Biology: Water color can be used to map the distribution and, in many instances, the concentration of surface chlorophyll and thereby the density of phytoplankton in coastal waters. In most respects the methodology is the same as that used in the extensive studies of ocean productivity described in the workshop contribution on oceans. In the coastal zone, spectral signatures of phytoplankton are influenced by the presence of large amounts of inorganic material suspended in the water column and this can complicate analysis. Spatial and temporal dynamics of the system require higher resolution with respect to both of these parameters than is needed for ocean studies. The so-called "Coastal Zone Color Scanner" (CZCS) is, in fact, optimized for large-scale productivity studies in the deep oceans and on continental shelves. Applications in estuaries and other smaller-scale coastal environments would benefit from finer spatial resolution and, possibly, modifications to the spectral bands used.

4- Hazards: A number of hazards in the coastal zone have been addressed at one time or another through remote sensing technology. Shoreline erosion over large areas can be monitored if imagery of sufficient spatial fidelity is available. Short-term catastrophic erosion from storms is frequently documented using aerial photography and, in some cases, by orbital imagery. Ice is a hazard to shoreline communities and to navigation and extensive use of remote sensors, particularly microwave instruments, has been made for monitoring ice distribution (see contribution on snow and ice in this report). The location of toxic algal blooms, known as "red tides," has been monitored by NOAA using orbital imagery, including AVHRR data having 1-km GIFOV. In general, as with other applications, high spatial and/or temporal resolution sensors are required for coastal applications.

5- Vegetation and Land Use: Remote sensing applications in mapping land use and monitoring natural and agricultural vegetation are common and are similar to those described in the relevant contribution in this report. In this area spatial and temporal resolution requirements are not greatly different from those in non-coastal regions.

Potential Applications of ISES Real-Time Data Handling Capabilities

The dynamic nature of many important coastal zone processes make the prospect of real-time imagery from ISES extremely appealing. On the other hand, the need in many cases for high spatial resolution is not compatible with the sensors, such as MODIS, which obtain data at appropriate temporal frequencies (i.e., daily) and which are envisioned as the core of the Eos environmental monitoring system. Data from higher resolution sensors such as HIRIS and SAR would be of great interest but the narrow swaths of these instruments also lengthen the interval between data collections. In addition, the high data rates produced by these instruments restrict the amount of data which can be screened, particularly by the limited onboard capabilities of ISES. This means that coastal applications such as early warnings of pollution events, oil spills, and red tides, while technically feasible, will probably have to be limited to particular high-priority times and regions. The moderate-to-low resolution sensors collecting imagery on a daily basis will be useful for identifying large scale distributions of suspended material, for example, and directing field sampling parties to targets of interest before large changes have occurred.

There is an important trade-off in real-time applications between the efficiency and synoptic coverage of orbital remote sensing versus the higher information content which is usually associated with more conventional methods. For example, documentation of erosion in densely populated coastal regions almost always requires detailed surveys which are accurate to at least several meters. In such areas the issues of shoreline change and protection of valuable property are so important that even small events are quickly noticed and extensive local resources are devoted to in situ mapping and other detailed monitoring methods. ISES-generated real-time detection of erosion amounting to several tens of meters, the minimum detectable even with HIRIS, would be of questionable value under these circumstances, even if the information arrived a few hours or days before conventional methods could be deployed. It seems likely that similar circumstances will be encountered in a variety of instances (such as pollution detection, storm damage assessment, oil spill detection) in which orbital data may have some utility but in which the density of local observers and the importance of detailed data sets ultimately demand in situ study. In remote coastal areas where such conventional resources may not be available, the importance attached to short-term events is also likely to be much reduced, making the potential contribution of real-time orbital data problematical. One must be careful to select real-time ISES experiments which are likely to make a contribution that is not attainable using available conventional resources.

The most promising areas for real-time ISES experiments in the coastal zone will be in supporting scientific investigations through the siting of field parties and documentation of large scale environmental conditions. Some applications in early hazard warning or other environmental monitoring efforts are possible but must be selected carefully to avoid demonstrating capabilities which are already present through more conventional, information-rich means. Daily, quick-look visible and thermal IR images from MODIS of coastal regions in which field or high-resolution remote sensing studies are taking place would be very valuable. If ISES can access and transmit SAR data this could be applied to a variety of problems such as ice distributions, oil spills, and marine traffic control. The all-weather capability and pointability of SAR increases its effective coverage frequency for preselected sites and would be especially advantageous when local weather conditions make application of conventional field methods impossible.

Potential Applications of ISES Onboard Data Handling Capabilities

The massive data stream produced by the planned sensor package has the potential to overwhelm the storage and data transmission capabilities of Eos, and losses of data, particularly from high-data-rate sensors such as HIRIS and SAR, will occur when resources are required for higher priority uses. ISES could be used to alleviate this problem by recording and transmitting selected data streams outside of the allocated data system constraints. For example, planned interruptions in HIRIS data transmission might compromise a study of a coastal oil spill or of the distribution of suspended sediment, whether or not the data are required in real-time. ISES could potentially provide this data either directly to the user or to ground stations with facilities for recording the data for later use. Cloud detection algorithms within ISES, utilizing the greater coverage area and frequency of MODIS, could be used to filter requests for coverage by higher resolution sensors and direct those sensors to cloud-free areas. Capturing data which might otherwise be lost should be an important part of the rationale for ISES and, in particular, for placing the ISES capability on the Eos platform. Many real-time data requirements could be fulfilled by systems monitoring and transmitting selected portions of the Eos data stream on the ground. This will not be possible for data which never enters the Eos data system and ISES would make a valuable contribution to virtually every conceivable kind of application, coastal or not, by providing a means to acquire a selected data stream for a high-priority experiment or monitoring task.

Summary

The dynamics and intense human usage of coastal zones argue for extensive use of current and future remote sensing capabilities in environmental monitoring, enforcement, and scientific inquiry. However, coastal requirements for both high spatial resolution and frequent data collection often restrict the utility of orbital systems such as those planned for Eos. Highest priority for experiments utilizing the real-time data handling capabilities of ISES should be given to applications in which high spatial resolution is of lesser importance, such as the use of quick-look MODIS data to direct field sampling activities to transient large-scale features, or to unique capabilities, such as that of SAR to provide all-weather coastal images, which are not accessible to more conventional methodologies. ISES can also contribute to coastal, and other studies by collecting and transmitting data which would otherwise be lost because of the need to conserve Eos data handling resources. Such data would be valuable whether or not it was provided in real-time.