West Hampton, New York

PART 2. COASTAL SEDIMENT PROBLEMS

East Hampton, New York

CHAPTER 39

COASTAL PROCESSES FROM SPACE PHOTOGRAPHY

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ABSTRACT

Photographs taken from space provide a new source of data concerning coastal processes By utilizing the high vantage point and broad view orbiting space cameras can record little known large-scale processes at short time intervals Major outflow plumes, fresh-salt water "fronts", turbidity maxima and massive effluents are among the wide range of features displayed It is shown from selected examples how coastal processes can be evaluated from space photography and how the information may be of use for solving certain problems as a supplement to field and other remote sensing data By 1972 satellite photography will be available on a routine basis for many coasts of the world Engineers are urged to consider the potential for improving their information which space photography has to offer

Introduction

The "promise of space" has commanded a great deal of attention in recent years In particular, considerable credit has been given to the potential usefulness of space photography It has been asserted that space photography can record the location of fish-rich upwellings and mineral deposits, it can detect pollutants and diseased crops and inventory various natural recources, all on a global basis Though photography has contributed a great deal to our knowledge in many fields, study of coastal processes important to the coastal engineer, has been limited In recognition of this gap, this paper directs attention to space photography as a new source of information on aspects of coastal processes What coastal features can be recorded by space photography? How can processes be evaluated? And of what earthly good are space photographs to problems of coastal engineering?

Already more than one thousand photographs of coasts have been obtained from Gemini and Apollo flights which point up the possibilities of studying certain processes from space Recorded for the first time are major "fronts", massive effluents, and shelf-wide perturbations Dramatic as they are, these are only a prelude to photographs anticipated on a routine basis from the up-coming ERTS (Earth Resources Technology Satellites) program in 1972

But before we can utilize space photography we need to consider the nature of coastal features as photographic subjects and the character of space photography itself

Coastal Subjects

In contrast to terrain features, coastal features vary widely from land to water, and with depth, from surface to subsurface Beaches, tidal flats, marshes, submerged bars, grass beds, bottom sediments, slicks, and plankton blooms are among the range of subjects Varying in geometric size from a few meters to tens of kilometers and with time, hourly, daily and monthly, they present a full spectrum of rapidly changing contrasts Best understood are those features of small geometric size and relative long time scale, least known are those of large-scale which occur at short time scales Because of the very wide range and transient nature of different coastal subjects, practical problems of recording photographic information are great Not only are reflecting qualities of the subject frequently masked by atmospheric phenomena but image contrast is often lost and illumination changed within the water Our understanding of these recording vagaries is limited, and ground truth at the time of photography is seldom available It is small wonder why photography has not been extensively utilized for study of coastal processes as it has in other fields. Despite the fickleness of coastal subjects and their illumination, the orbital space camera has certain characteristics of advantage for study of coastal processes

Character of Photography.

From an altitude of over 200 km , the space camera can record more than 40,000 sq km of coast, e g Figure 1[1] Its broad view and synoptic record make it possible to examine _in toto_ large scale features of the water, wave patterns, and shoals, as well as marshland, coastal terrain and cultural features, all in a single photograph Even when only central parts of the photograph are examined, geometric fidelity is good and lighting uniform over a relatively large area, greater than 8,100 sq km. Such a quality is difficult to obtain from conventional low altitude aerial photography Because of the great distance above the optically turbulent atmosphere photographic "clarity" is good (Harvey and Myskowski, 1965), and color distortion small Whereas image scale is reduced to about 1:1,000,000 and effective resolution limited to 40-100 meters, detail "lost" by low resolution is more-or-less "integrated" into color or tone anomalies depicting major features Once in orbit the great strength of the satellite-borne camera is its ability to look at coastal phenomena at frequent intervals, once every 90 minutes to 17 days for a year or more

[1]Reproductions in color are available from the Technology Application Center, University of New Mexico, Albuquerque, New Mexico, 87106, U S A The illustrations used here do not fully portray the content of the original color photography

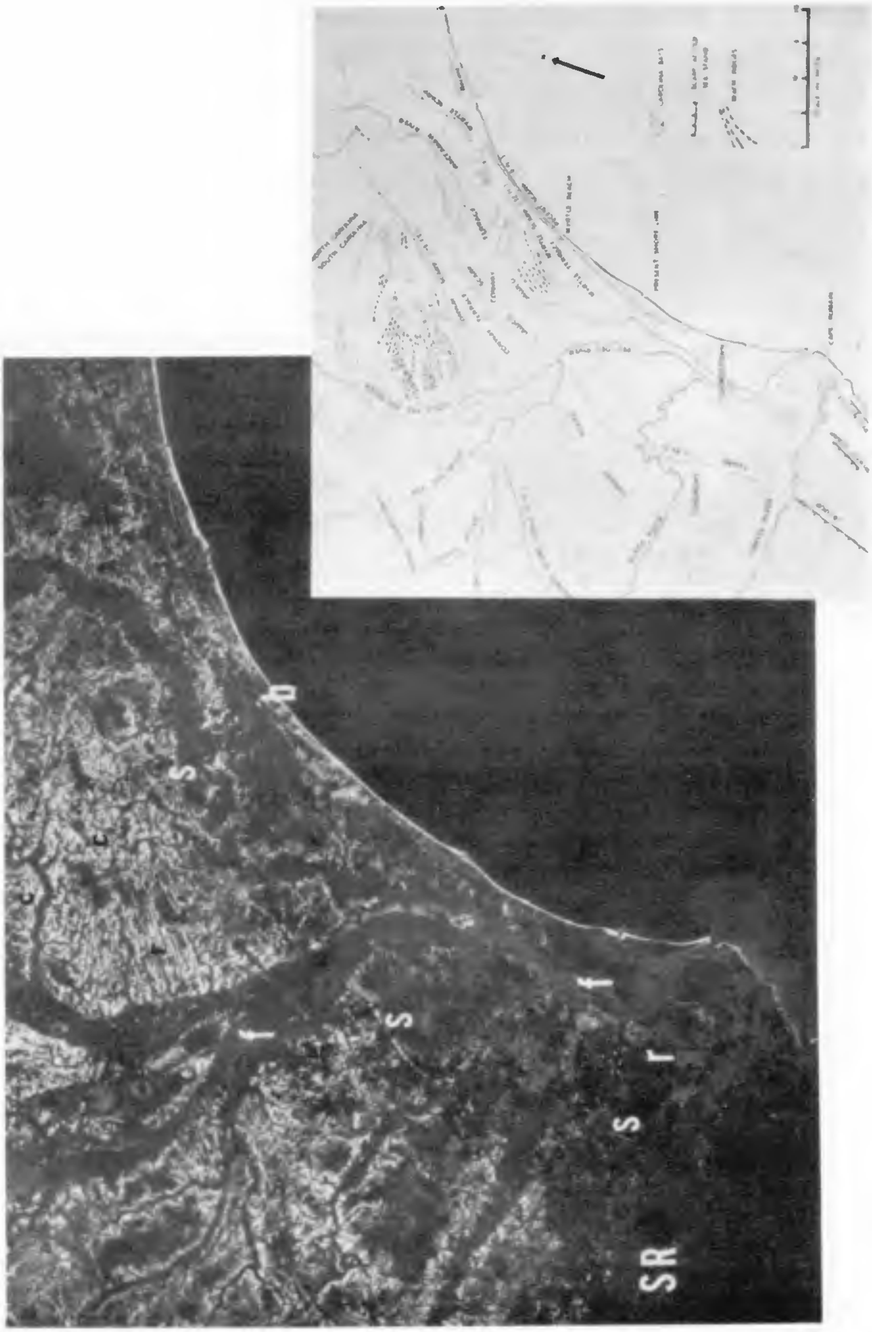

Figure 1. Apollo 9 photograph (AS9-26D-3793D) of the Atlantic coast of South Carolina, U. S. near Cape Romain. Beaches (b) extend for 100 kms along the coast while effluent plumes mark river mouths. Light tones inland are cultivated areas. Varied patterns of vegetation and cultivated areas define shoreline scarps (s) and former beach ridges (r). Marsh and tree covered floodplains border major rivers (f) and Carolina bays (c) are portrayed in a dark tone. A major water diversion is proposed, Santee River (SR). Annotated features, inset.

Waves

Because low resolution of the space camera "filters out" dimensional and directional detail, only long-period waves are recorded by photography They are observed mainly in glitter patterns around oceanic islands and continental headlands When traced to storm-generating sources with the aid of meteorological satellite photography, long period wave data is of value for forecasting waves propagated into coastal areas Amenable to analysis are refraction patterns and landward changing wave dimensions that relate to decreasing water depth and the location of shoals, and in turn to wave-stirred sources of suspended materials or turbidity Procedural details for photographic analyses of glitter patterns are given by Cox and Munk (1954) and for spectral distributions of long period waves, by Libby, et al (1969)

Coastal Morphology

Space photography is of value for portraying morphological features especially in regions where base maps are not available In remote areas like mangrove swamps and ice bound coasts they may be the chief source of information on coastal configuration Where relief changes are small and difficult to observe on the ground, many coastal features often show up more clearly on photographs For example, linear features like ancient shoreline scarps (Figure 1) can be traced for more than 150 km despite their discontinuous nature with gaps of 20 km , and subtle relief, less than 6 m The photographs reveal coastwide trends more clearly than a good map Other patterns often revealed clearly on photography include beach ridges and dunes, drainage systems, broad patterns of salt marsh, evaporite deposits, and limits of tidal flooding on flats Spatial relations of these features can be further evaluated on a regional basis in a context of major sediment sources and dispersal routes

Shoreline Changes

In keeping with traditional use of aerial photography, space photographs can be used to measure changes in shoreline configuration and thus identify major sites of erosion or accretion With proper control, scaling and rectification (Colvocoresses, 1970) different positions of the shoreline can be established by comparing common image points taken from time to time according to practices for aerial photography (Moffitt, 1969, and Langfelder, 1968) Old charts may be used to identify positions of former snorelines (Fig 2) which are comparable to those in space photographs if sufficient control is available However, relatively low ground resolution of present space photography limits application to shorelines having large changes (greater than about 300 m) over extended periods such as deltaic coasts and storm-washed beaches Frequent coverage of shorelines by future satellites could record the opening or closing of tidal inlets in the aftermath of storms so that changes can be quickly assessed and corrective measures planned

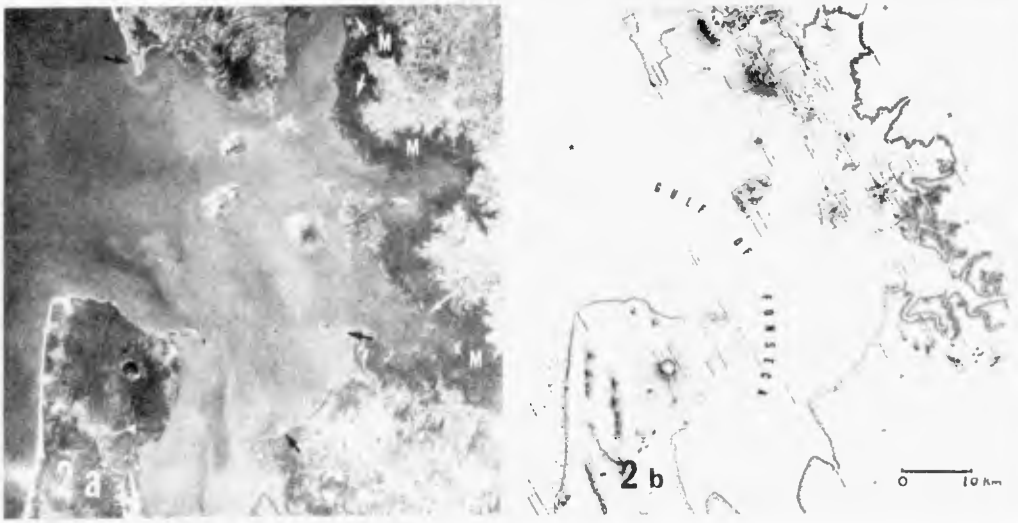

Figure 2A. Black and white reproduction of Apollo 9 color photograph (AS9-19-3019) over the Gulf of Fonseca, Pacific Coast of Honduras, March 9, 1969. Shore consists of mangroves (dark tone, M) as part of a landward extending zone 8 km wide. Locally barrier beaches (b) and spits (s) are visible. Light grey tone of the Gulf indicates turbid water supplied either by entering rivers or from wave-stirred tidal flats. Arrows directed landward indicate sites of major shoreline erosion, arrows seaward, sites of accretion.

Figure 2B. Corresponding hydrographic chart largely based on British Surveys of 1838. Depths in fathoms.

Coastal Drift:

Color and tone anomalies that record the distribution of discolored water provide a visible tracer of drift along the coast. By sensing light scattered by suspended materials in near surface water, these anomalies are fashioned into distinct patterns which reflect the direction of flow. Most obvious are seaward expanding plumes representing suspended sediment discharged off mouths of bays and rivers. Often they are prolonged downstream as "streaks" from wave-stirred bank tops or shoals. Less obvious in relation to their source are great rip-like patterns extending seaward from shore in eddy configurations (Fig. 3A) or as narrow tongues (Fig. 3B). Where opposing flows occur, "fish-hook" patterns or asymetrical interfacial waves develop. Such indicators may be used together with other data to compile a coast-wide chart of drift for an area of interest. Similar indicators may be of use to evaluate the character and direction of flow around structures like an interference eddy seaward of the jetties at

Figure 3A. Space photograph (S66-63064) taken from Gemini XII over the Texas Coast, U.S. Nov. 14, 1966. Eddy-like perturbations, (light grey tones) in the water mark offshore drift (d). In Galveston Bay (g) light tone portrays sediment discharged from a dredging operation. Debris laden outflow forms an interference eddy (e) in the coastal drift (arrow).

Figure 3B. Space photograph (AS9-26A-3728A) of the same portion of the Texas Coast, near Houston (H) March 8, 1969. Narrow tongues extending seaward (t) are in contrast to perturbations of figure 3A. Inferred coastal drift, arrow.

Galveston Bay (Fig. 3A). Within the Bay a light-colored streak marks turbid water eminating from a dredging operation. But, striking as the patterns are they are ephemeral and necessarily limited to suspended materials carried only in near surface water, often only a fraction of the total suspended load. Therefore, it seems essential to supplement the photographic record by extensive field measurements not only to gain a more complete "picture" of coast-wide drift but to "calibrate" the imagery as well.

Offshore Drift:

It was not until space photographs of the Gemini flights were available that the possibility of widespread dispersal of nearshore sediments was appreciated. First recognized by Stevenson (1967) in coastal water off Texas, turbid perturbations were traced as far as 150 km from shore. Just as rip currents relieve rising water levels in the surf zone these large scale features are believed to carry water offshore in response to a coast-wide build-up of sea level Later coverage of the same coast taken on Apollo 9 in 1969 portrays seaward extending tongues 22 km offshore A day later along the same coast (AS9-22-3464 and AS9-22-3465 not printed) after the wind had shifted from onshore to offshore with passage of a front, the tongues were largely replaced by dark masses of relatively "clear" water common to offshore areas Although the available examples are but a few snapshots of a whole "movie film" of rapidly changing drift patterns they do give an indication of widespread sediment dispersal to be expected

In another example, figure 4, a large plume leads seaward from Cape Lookout, North Carolina Seaward from the point, shoals are recorded as a light-toned shredded pattern representing large sand waves and these are interfingered with dark tongues representing tidal channels in deeper water Beyond the charted limit of the shoals, an indistinct plume extends 60 km offshore Its seaward edge is truncated by the Gulf Stream and trails northward as a narrow tongue Concentrations of suspended material sampled in near-surface water close to the time of photography were relatively low, less than 2 mg/L and materials consisted of quartz sand (60%) mixed with plankton and detritus Although the rate of drift is not recorded, the photograph shows where suspended sediment is going in relation to potential sources on the shoals or along the shore If this drift persists over the long-term, perhaps it could be utilized as an avenue of transport to discharge pollutants across the shelf and into the ocean

Utilization of photography for measurement of current speed has been successfully accomplished using stero parallox techniques with aerial photography, Cameron (1952) and Waugh (1964) It seems feasible to use a similar approach with space photography if an economical means of "seeding" currents on a large scale can be developed

Problems:

In practice the user of space photography is faced with a number of problems which must be recognized The dynamic character of the subject creates a special problem for collecting ground truth In some areas it would seem that sampling of selected sites at the moment of photography would suffice for large areas but the wide range of environments, each with characteristics of its own, and the variety of unpredictable local conditions make ground truth data collection an enormous task

In addition to understanding the subject, use of the photography depends on an understanding of various colors, tones and density anomalies in the photograph Excellent progress has been made (Ross, 1969) in developing techniques which enhance images and extract spectral data to determine water depth and turbid patterns Yet, the three dimensional character of hydrographic imagery is incompletely understood; often turbid features cannot be differentiated from bottom features. It seems sensitometric techniques have exceeded our ability to reduce imagery data to meaningful and quantitative information.

At the present stage of progress space photography is no alternative for field sampling. Instead it can assist in planning field work, extend coverage and direct it to profitable sites. The need for rapid, synoptic and timely data on a regional basis demands that new dimensions in data collection and processing be added to improve our knowledge of coastal processes.

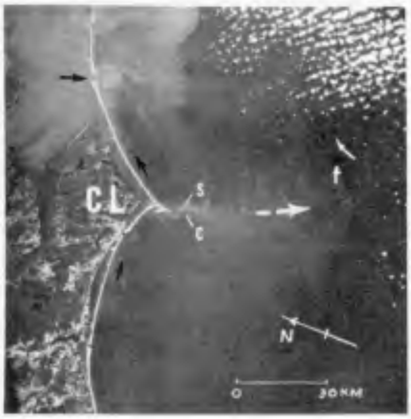

Figure 4. Black and white reproduction of color Apollo 9 photograph (AS9-20-3127) over Cape Lookout (CL), N.C. March 12, 1969. Seaward expanding plume (broken arrow) leads from shoals (s) dissected by tidal channels (c) Gulf Stream "front" (f), inferred coastal drift (arrow) nearshore.

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