N73-28347

Paper M 8

ERTS-1 OBSERVATIONS OF SEA SURFACE CIRCULATION AND SEDIMENT TRANSPORT, COOK INLET, ALASKA

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ABSTRACT

Cook Inlet is a large tide-dominated estuary in southern Alaska. Highly turbid streams enter the upper inlet, providing an excellent tracer for circulation in the lower inlet. MSS 4 and 5 images both can be used in this area to plot sediment and pollutant trajectories, areas of (probable) commercial fish concentration, and the entire circulation regime.

INTRODUCTION

Cook Inlet is one of the largest estuaries in North America. It extends almost 200 nautical miles (360 Km) northeastward from the Gulf of Alaska and is over 30 nautical miles (54 Km) wide through much of its extent (Figure 1). Depths are typically less than 20 fathoms (40 m). The hinterland is predominantly mountainous and glaciation is still extensive. Deglaciation is occurring around the upper inlet and tremendous quantities of 'glacial flour' (largely silt and clay-sized mineral grains) enter the inlet. Cook Inlet lies at about latitude 60° North, and the climate could be regarded as subarctic. There is, however, strong maritime influence and temperatures are never low enough to completely inhibit runoff. Circulation of the inlet's waters is dominated by tidal effects. In the upper inlet, tidal ranges greater than 30 feet (10 m) are not uncommon, and currents in excess of eight knots (14 KPH) are often encountered. Despite its size and extreme tidal and climatic influences, Cook Inlet appears to behave as a model high latitude estuary, and an understanding of the regime here should be useful in all estuarine circulation and mixing problem areas.

ERTS imagery is particularly well suited for the study of Cook Inlet circulation. The highly turbid runoff waters can very readily be distinguished from clean sea water on both MSS Bands 4 and 5. This information, of course,

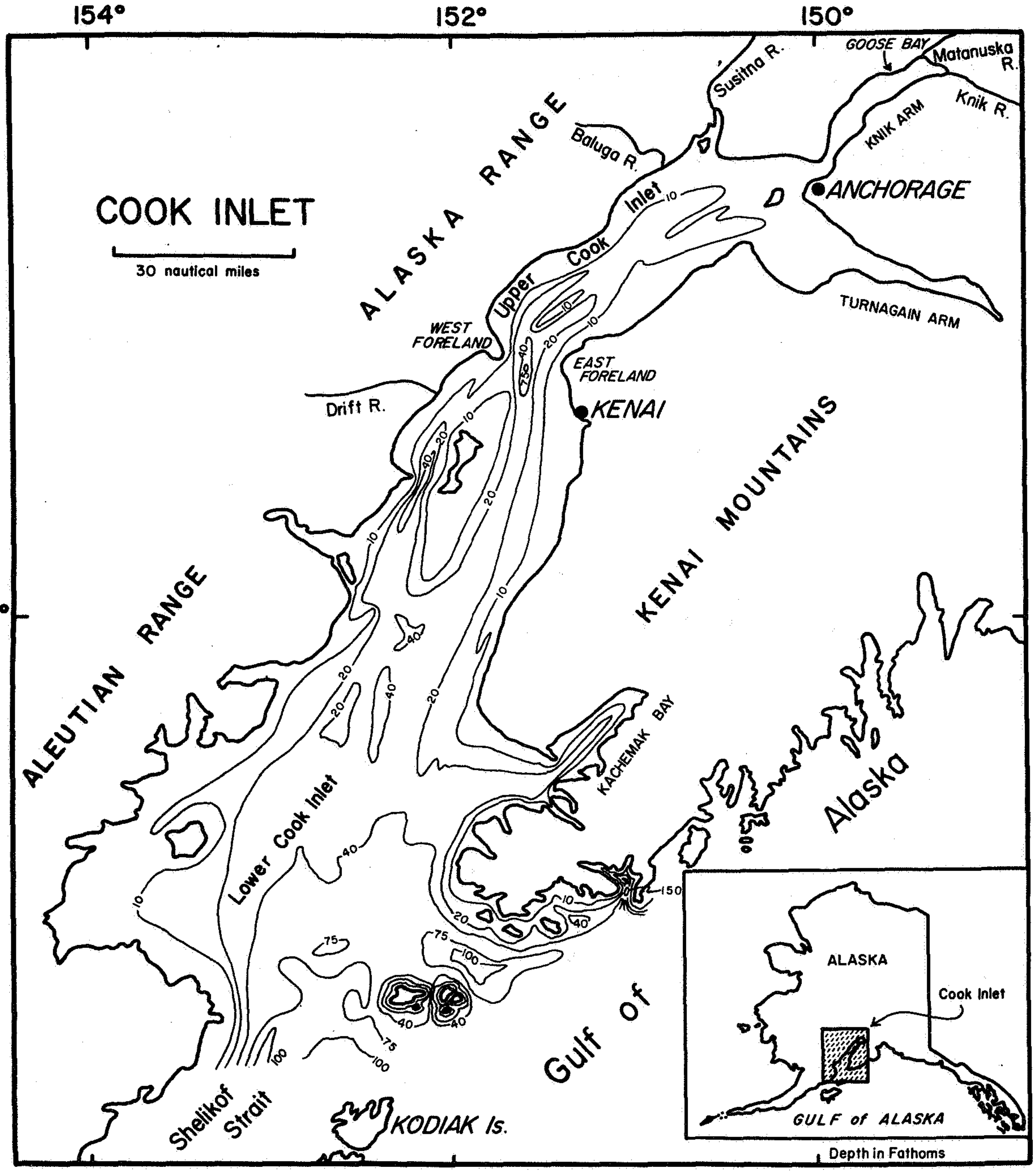

FIGURE 1. Cook Inlet, Alaska, showing bathymetry and major tributary rivers (from Sharma and Burrell, 1970).

could also be obtained from conventional aerial photography, but the size of the inlet and the speed of the tidally-controlled mixing processes make it virtually impossible to obtain a truly synoptic survey. Standard oceanographic procedures, limited by vessel and sampling speeds, are hopeless to obtain an instantaneous view of the inlet. Even ERTS requires two frames to cover the entire inlet, but these do give us a true picture, clearly defined by the turbid fresh waters, of the instantaneous circulation pattern.

Circulation in Cook Inlet is of far more than academic interest. By coincidence, the majority of the turbid waters originate from Knik Arm in the vicinity of the city of Anchorage, Alaska's population and industrial center. Offshore petroleum production also is largely confined to the upper inlet. Thus tracing the turbid waters permits us to follow in detail the trajectory of potential pollutants from these sources. As well, Cook Inlet supports a major salmon fishery. Migrations of the salmon are known to be related to water movements but little systematic study has been made of this in the inlet area. Significant fisheries for herring, shrimp, tanner and king crab are found in the normal sea waters of the lower inlet. An understanding of the circulation patterns will be important to both environmental protection and resource development and management in the entire Cook Inlet area.

DIRECT OBSERVATIONS OF COOK INLET CIRCULATION

Although Cook Inlet has been important as a gateway to the Alaskan interior since Russian times, there was relatively little navigation or systematic study of the area until quite recently. Mariners, in fact, avoided the inlet as much as possible because of its dangerous waters. The Alaska Railroad, for example, circles the head of Cook Inlet, but its major termini were at Seward and Whittier on the Gulf of Alaska. Anchorage, now the population and industrial center of the state, developed during and after World War II as a staging point between the coast and the interior. It was not until successful petroleum development in the 1950's that there was significant regular commerce in the upper inlet. Aside from basic tide height and current observations, and rather superficial bathymetric survey, oceanographic studies of Cook Inlet were non-existant until required for petroleum related engineering projects. The first large-scale studies of hydrography, sedimentation, and chemistry were conducted by the University of Alaska in the later 1960's (Kinney, Groves and Button, 1970; Sharma and Burrell, 1970). These data, with much additional biological and engineering information,have recently been compiled by Evans and others (1972).

In cooperation with the ERTS program, the University of Alaska is presently conducting an extensive series of cruises in Cook Inlet. These cruises have been scheduled to coincide with ERTS orbits over the inlet, but the only useable imagery obtained to date was collected when there were no surface observations. One cruise (25-29 September 1972) was conducted with the University's major vessel, Acona. During this cruise, complete hydrographic data as well as suspended sediment values were obtained for the entire water column, in order to provide reference figures. Additional cruises have been conducted with a smaller, chartered vessel based on Homer in the lower inlet. Sampling with the small vessel is usually restricted to the surface waters, but her speed (over four times that of Acona) permits a much larger area to be covered while the satellite is actually overhead.

Sea surface observations ("ground truth") obtained during the Cook Inlet cruises have included measurement of water temperatures, salinities, and suspended sediment load (Figure 2). These data, though clearly not 'synoptic' in the normal oceanographic sense, give us an understanding of the general water types present in the inlet. It has been found that, during the active runoff season, the water types can be easily characterized. Runoff tends to be low in salinity and very, very high in suspended load. Values greater than 100 mg/l suspended material characterize the upper inlet; the highest value reported was over 1700 mg/l from the Anchorage area. Sea water, of course, tended to have salinities ranging downwards from 32 o/oo and was relatively transparent. Water temperature shows a very decided seasonal effect. Sea water tended to be 10-12°C regardless of season, while runoff ranged from warmer than the sea in later summer (12-16°C) to considerably colder in the winter and spring (4-8° C). Suspended sediment concentrations greater than 2-4 mg/l have proven to be the most reliable criterion for rapidly distinguishing the two water masses of the inlet.

ERTS - 1 IMAGERY OF COOK INLET

The normally cloudy conditions of the Alaskan coast have severely interfered with ERTS observations of Cook Inlet. Only on one occasion in 1972 were useable images collected. Fortunately, due to the high latitude compression of orbital tracks, data were obtained for the entire inlet on two successive days, 3-4 November. The transparencies of these data, particularly the MSS 4 and MSS 5 Bands, are extremely good, and several grey shades within the turbid waters can be distinguished with the naked eye. These gradations appear to be correlable with relative concentrations of suspended material in the surface water layers. There are indications that turbid waters somewhat below the actual water surface can be detected by comparison of the two bands. Unfortunately, these subtle distinctions are not found on the enlarged prints.

A comparison of the suspended load information from the September cruise and the November ERTS image (Figures 2 and 3) makes clear the utility of the ERTS observations. The hydrographic data show a somewhat confused pattern of suspended sediment distribution, reflecting the fact that it required five

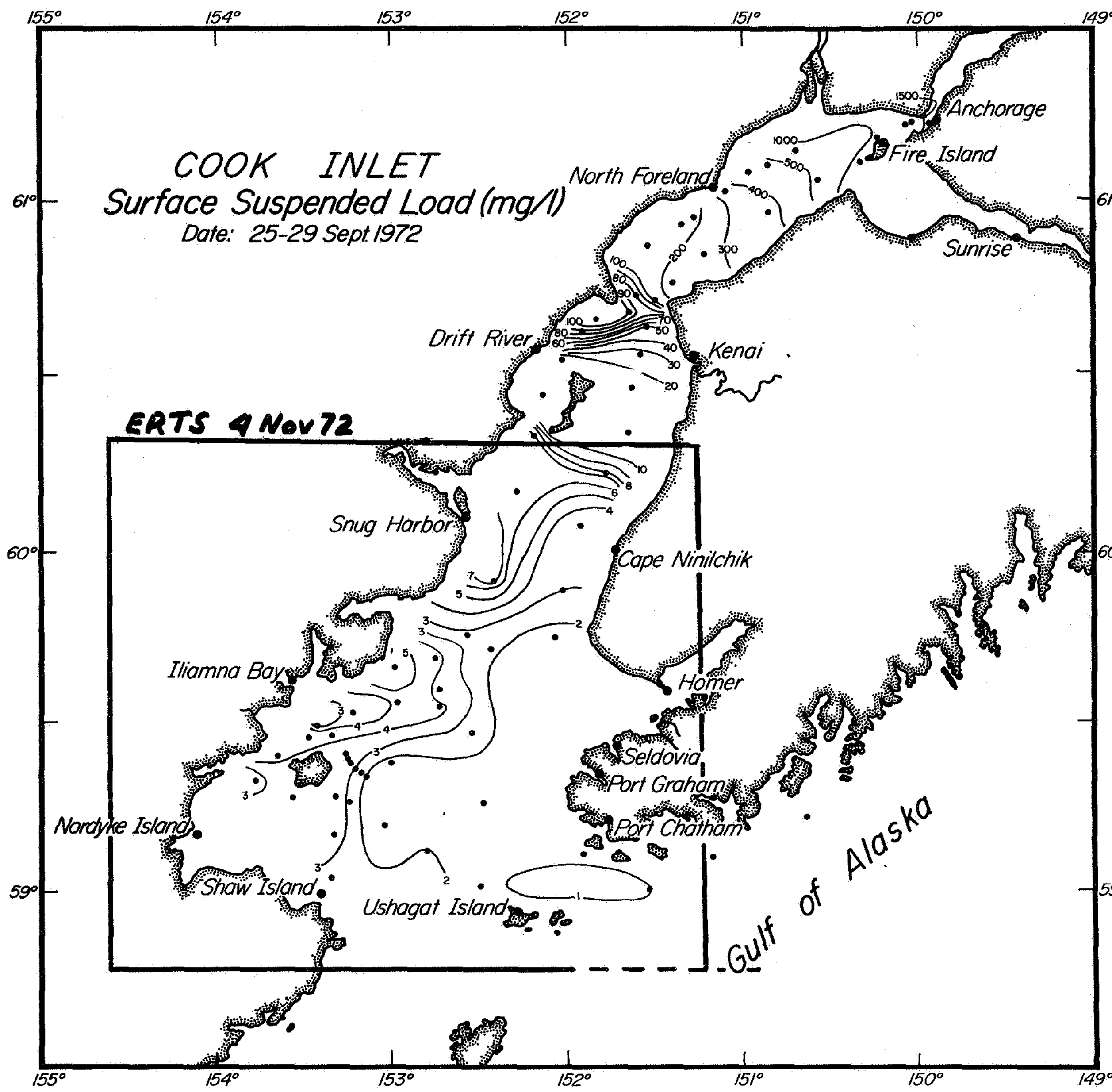

FIGURE 2. Suspended sediments in the surface waters of Cook Inlet, September 1972. Area shown in Figure 3 is outlined.

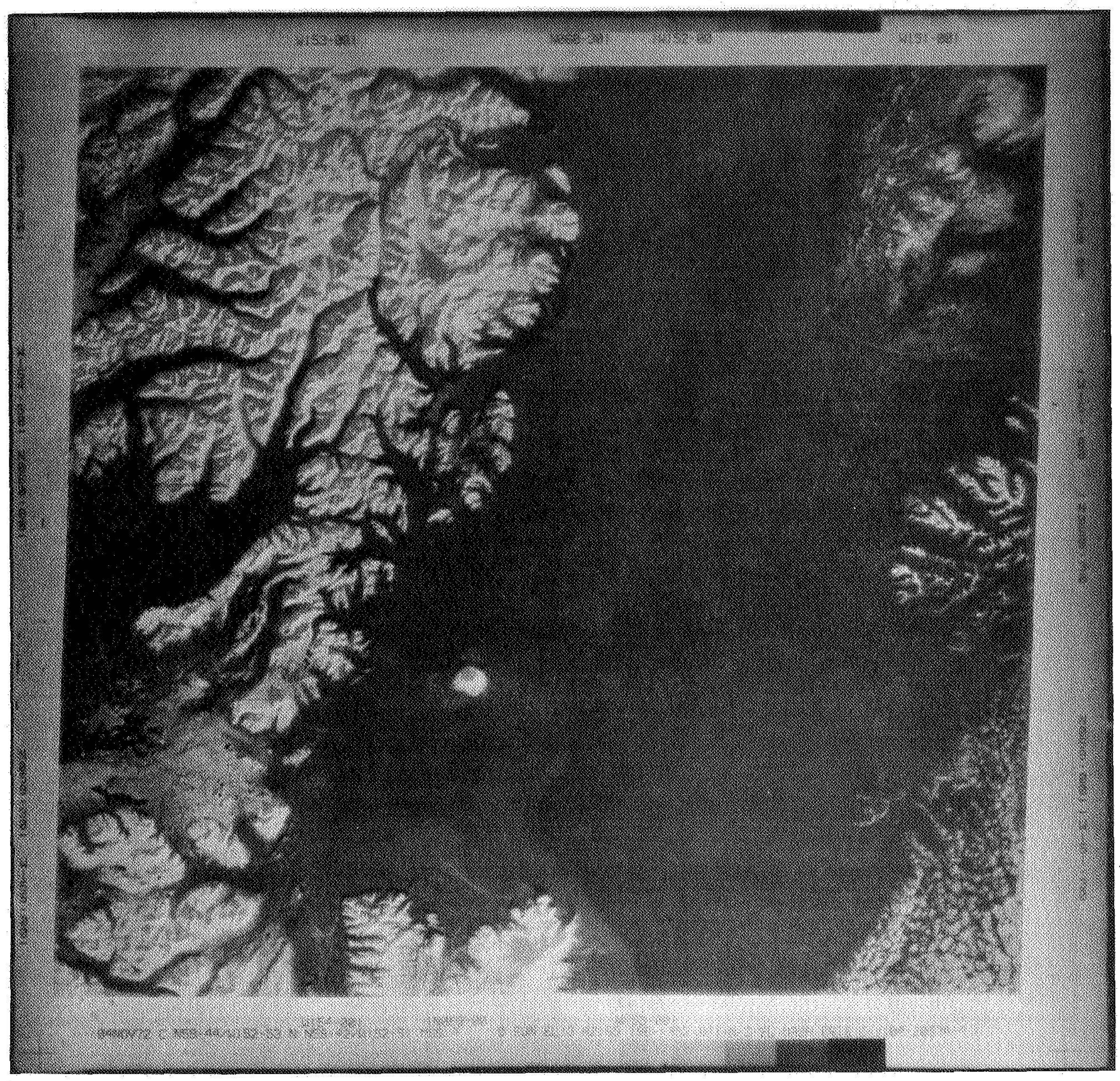

FIGURE 3. ERTS Image of Lower Cook Inlet, MSS 4 Band, November 4, 1972.

days to collect all the stations shown. The ERTS image, on the other hand, reflects accurately the conditions at one instant. It was just after low slack water in the lower inlet, and the flood is commencing. A very distinct mass of clear sea water is seen advancing up the eastern side of the inlet, extending then almost as far north as Cape Ninilchik, while turbid waters dominate the surface to the west. This pattern very clearly reflects the influence of Coriolis effect upon the circulation of Cook Inlet. This is the tendency of moving particles to be deflected by the earth's rotation toward the right in the northern hemisphere. In the ERTS image of Cook Inlet we see both the incoming and outflowing currents controlled by this effect. This picture is corroborated by numerical models of inlet circulation (Matthews and Mungall, 1972).

APPLICATION OF ERTS - 1 DATA IN COOK INLET

An understanding of the circulation regime is essential to the systematic protection and development of the resources of the Cook Inlet region. The local salmon fishery presents a good example of the relation of the fauna to the environment (Evans et al., 1972). The fish routinely enter the inlet on their spawning run and proceed with the tide, dropping to the bottom to rest when the tide sets against them. Apparently, also, they tend to mass for a time near the boundary between the clear and turbid waters before they make their final run to the spawning streams. The non-anadromous fisheries of the lower inlet -- including commercial operations for herring, shrimp, and crab, and sports fishing for halibut -- are, of course, limited by the extent of relatively normal sea water. ERTS imagery can locate the water mass boundary with precision and, with repetitive coverage, we should ultimately be able to predict its location at any stage of tide or runoff. This boundary is also important as a factor in navigation. An extensive "trash line" of floating logs and other terrestrial debris may accumulate there and create a genuine hazard to navigation. As well, emphemeral but often nasty tide rips and whirlpools may develop along the boundary.

The major input of turbid waters into the Inlet is actually from the Knik and Matanuska Rivers, both tributary to the Knik Arm above the city of Anchorage (Sharma, in progress). This coincidence permits the ERTS imagery to be used in another way. Effectively all non-solid sewage and industrial waste from the city is discharged directly into the inlet where its trajectory and sites of dispersion can easily be followed by tracing the turbid waters. Most of the current petroleum development is also limited to the upper inlet, so an understanding of the circulation will permit prediction of the behavior of any spill.

As yet, too few satellite observations of Cook Inlet circulation have been obtained to permit more than the most superficial conclusions about the regime. Both additional satellite and surface observations will be required to generate an integrated picture, however, the potential utility of the satellite system in this environment cannot be doubted. The extremely turbid inflow at the head of the inlet provides us with a unique tool to study all aspects of the circulation of Cook Inlet.

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