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PRINCIPAL SOURCES AND DISPERSAL PATTERNS OF SUSPENDED PARTICULATE MATTER IN NEARSHORE SURFACE WATERS OF THE NORTHEAST PACIFIC OCEAN AND THE HAWAIIAN ISLANDS[1/]

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16. Abstracts

ERTS multispectral scanner imagery of the nearshore surface waters of the northeast Pacific Ocean is proving to be a useful tool for determining source and dispersal of suspended particulate matter. The principal sources of the turbid water, seen best on the green and red bands, are river and stream effluents and actively eroding coastlines; secondary sources are waste effluents and production of planktonic organisms, but these may sometimes be masked by the very turbid plumes of suspended sediment being discharged into the nearshore zone during times of high river discharge. The configuration and distribution of the plumes of turbid water also can be used to infer near-surface current directions. For example, imagery of the Gulf of Alaska collected in September 1972 shows complex plumes of suspended sediment being carried westward by the counterclockwise gyre of the Alaskan current. Comparison of imagery of the nearshore water off the northern California coast from October 1972 and January 1973 shows a reversal of the near-surface currents, from predominantly south-setting in the fall (California Current) to north-setting in the winter (Davidson Current).

17. Key Words and Document Analysis. (a). Descriptors

Nearshore circulation
Suspended sediment plumes
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a. Title: Principal sources and dispersal patterns of suspended particulate matter in nearshore surface waters of the northeast Pacific Ocean and the Hawaiian Islands

ERTS-1 Proposal No. SR 209

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c. Statement and explanation of any problems that are impeding the progress of the investigation:

The informational content of interest to this P.I. and co-investigators lies in the tone contrast displayed in the water bodies imaged along the Pacific coast. Typical microdensitometer scans of positive transparency products have density ranges confined to two steps under black on the grey tablet. The variation recorded in the nearshore waters averages D = 2.20-2.45 and usually is placed between the second and third step under black on the accompanying grey scale. Because these ranges lie in the dense shoulder of exposure, the photographic product supplied by Goddard is barely interpretable by eye for our purposes. In scenes of particular interest it becomes necessary to use a time-consuming density-enhancement process to improve the photographic record. The time and cost involved require the image to be of good quality and relatively free of clouds and smog. This requirement for reprocessing considerably reduces the number of usable images that are supplied to us. To illustrate our problem we have prepared the following table classifying imagery received of the west coast of North America and the Hawaiian Islands. This imagery was gathered prior to March 1973 and is classified according to cloud cover and resulting usefulness of image for our experiment. Increasing the contrast of water scenes would give us much more usable imagery.

ERTS imagery (through February 1973)

Geographic area	Relatively cloud free	Partly cloudy (but useful)	Cloudy (not useful)
Central Calif. Coast (includes S.F. Bay)	8	5	7
N. Calif. Coast	5	10	17
Oregon Coast	1	6	4
Wash. Coast	8	8	13
Hawaii	0	5	8
SE. Alaskan Coast	3	6	9
Central Mexican Coast	18	15	17

d. Discussion of the accomplishments during the reporting period and those planned for the next reporting period:

1. The Western Regional Topographic Office of the U.S.G.S. has developed a reprocessing step for the very dark ERTS imagery that provides enhancement of the plumes of suspended sediment in the near-shore water. This process involves the shifting of the density ranges within the water from the shoulder of the D log E curve down onto the slope region. Expansion of the continuous tone is achieved through the use of direct reversal high-contrast line film, which under proper densitometric control can be converted to a wide-range, variable contrast emulsion (Allred, 1971).

Allred, W. U., 1971, Optimization of continuous tone on a reversal line emulsion by densitometric control: Am. Soc. Photogram., Proceedings, Fall Convention, San Francisco, Calif., p. 1-27.

2. Copies of imagery have been sent to cooperating investigators in Mexico for target area 4, Dr. Agustin Ayala-Castanares, and Canada for target area 6, Dr. Donald Tiffin. We are planning to compare observations on the imagery from these two areas with those being made by these two scientists and their staffs, when additional data and imagery are obtained.

3. The following NASA underflight imagery has been obtained in the last few weeks; some was requested by our project and some by other investigators, but all are proving very useful as aids in the interpretation of ERTS-1 imagery:

Date	Aircraft	Location
Jan. 4	U-2	N. Calif. Coast
Jan. 22	C-130	S.F. Bay system
Jan. 23	U-2	N. Calif. Coast
Jan. 26	C-130	Central and N. Calif. Coast

In conjunction with the Jan. 22 and 23 satellite passes and aerial underflights, water-truth measurements were made from the R/V POLARIS in south San Francisco Bay on the 22nd and in the Gulf of the Farallones on the 23rd. Water data collected included turbidity measured with transmissometer and Secchi disc, weight of filtered suspended sediment, salinity, and temperature. Preliminary analysis of these data suggests a fair correspondence between tonal changes on the imagery and changes in Secchi disc readings of as little as 0.5 m across discrete water boundaries.

4. Water-truth measurements similar to those made in January are planned as coincident to satellite passes of April 4 and 5 over San Francisco Bay and the Gulf of the Farallones. In addition, high-altitude aerial photographic coverage will be provided by a U-2 aircraft from NASA, Ames.

e. Discussion of significant scientific results.....

Repetitive ERTS-1 imagery is a potentially useful tool for studying relative concentrations and dispersal of suspended sediment discharged into the northeast Pacific Ocean during times of high river runoff. Each of the four bands of the Multispectral Scanner System (MSS) provides information of value in this study. The infrared band (0.8-1.0 micrometers) clearly delineates the shoreline and provides the best penetration through atmospheric haze. The plume of suspended sediment discharged into the ocean is seen in greatest detail on the green band (0.5-0.6 μm). The red band (0.6-0.7 μm) provides an outline of the main core of the plume, and the near infrared band (0.7-0.8 μm) shows only the immediate outlet position of the effluents with highest sediment concentrations.

The principal sources of nearshore turbid water seen on ERTS Multispectral Scanner imagery are river effluents, actively eroding headlands and coastal landslides, production of planktonic organisms, and waste effluents. Changes in the location and configuration of turbid water masses are related to variance in river discharge, intensity of surf action, and direction of nearshore currents, as well as availability of suspended particles.

Imagery of the Cape Mendocino, California area, of January 6, 1973, shows the Bear, Eel, and Mad Rivers to be the three largest point sources of suspended sediment, but waste effluent from a pulp mill also is being added to the nearshore plumes of suspended particles in the Humboldt Bay area. Because of the highly turbid and complex nature of the plumes of suspended sediment being carried north along the coast from the Eel River, which is immediately south of Humboldt Bay, this waste effluent is difficult to define even on high altitude aerial photos, but can be discerned from altitudes of less than 25,000 feet. This masking effect of the suspended sediment on waste effluents is a good reason for conducting observational underflights of the study area at the time of the satellite pass.

Besides using the imagery to locate the source of the suspended particulate matter, it is also possible to infer direction of the complex surface water movements from the distribution and shapes of turbid masses of water. For example, current directions can be inferred from the green bands of images of October 26, 1972, and January 6, 1973, of the northern California coastal waters (fig. 1). In addition to

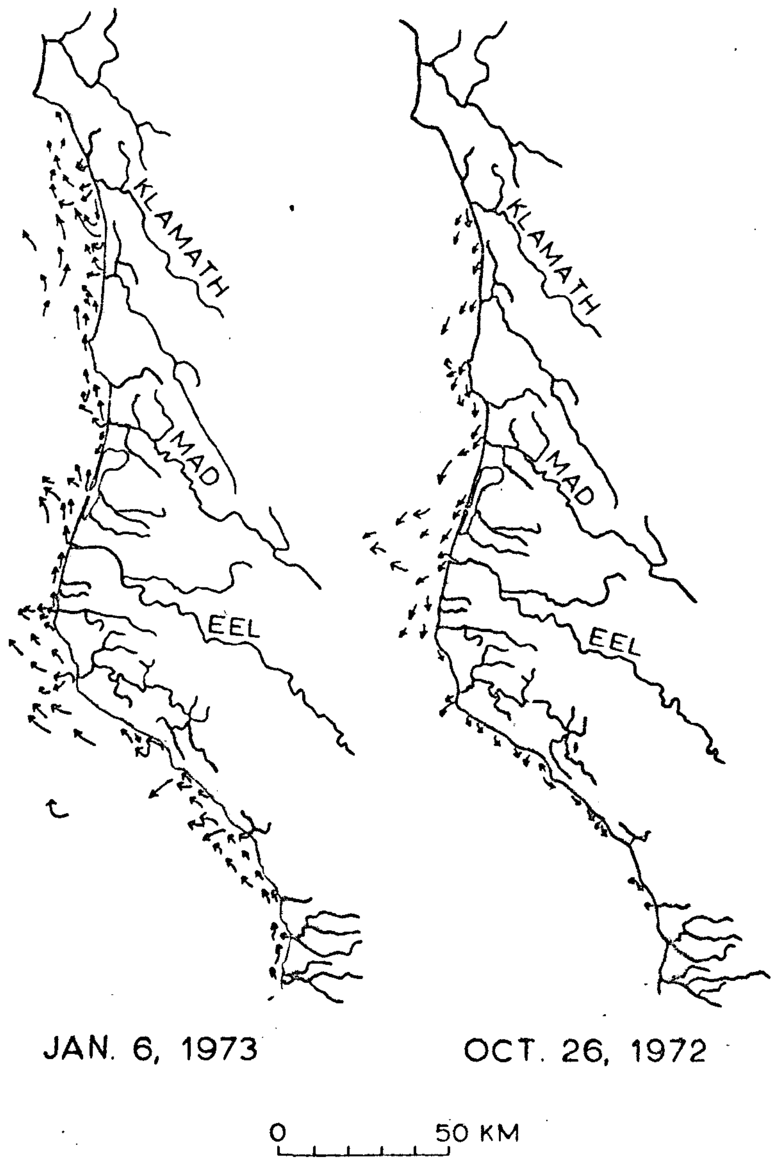

Figure 1. Seasonal reversal of current directions of nearshore, surface water along the northern California coast. Current directions were interpreted from configurations of suspended sediment plumes present on ERTS green band imagery of October 26, 1972 (no. 1095-18280 and 18283) and January 6, 1973 (no. 1167-18280 and 18283).

showing the direction of movement, we can also infer ~~a reversal in~~ water movement from predominantly southerly in October (California Current) to northerly in January (Davidson Current). This interpretation of the imagery indicates that the influence of the seasonal, north-setting Davidson Current extends to even the very nearshore water.

Imagery of the Gulf of Alaska waters taken in September 1972 also provides considerable information about source of suspended sediment and direction of nearshore, near-surface water circulation. Off the Malaspina and Bering Glaciers, southeast Alaska, the influence of several melt-water streams spaced only a few kilometers apart can be isolated and the dominant plumes traced for at least 30 kilometers from the effluent. The shapes and orientation of these plumes indicate a northwesterly longshore current. In mid-September 1972, the Bering Glacier appeared to be providing more suspended material to the ocean than the Malaspina Glacier. Offshore the movement of water is influenced principally by the Alaska Current, but complex gyres seen on the satellite images indicate additional influences such as winds and sea floor and coastal morphology.

Green band imagery of the Copper River Delta area, recorded September 24, 1972, shows the very large suspended sediment load being introduced into the Gulf of Alaska waters by the Copper River. Up to 1964, the main discharge was through distributaries at the west edge of the delta. Howevcr, now the active distributaries can be seen to be more easterly. The 1964 earthquake (cause of massive destruction in Anchorage) produced two meters of uplift in the delta (Reimnitz, 1966), and was an important factor in the distributary shift. A study of the sediment thickness off the Copper River Delta based largely on arcer profiles reported that the deltaic wedge of sediment is building **southwestward** (Reimnitz, 1966). These sediments have almost filled a former fjord, Orca Inlet, and appear to have spilled over into Prince William Sound. ERTS imagery vividly illustrates that the Copper River is the source of these sediments. Figure 2 is an interpretation of current directions off the Copper River Delta, which shows much of the Copper River suspended sediment plume moving west past Orca Inlet and into Prince William Sound.

The 18-day observation cycle of ERTS allows definition of seasonal and storm-related variations in effluent dispersal patterns. Documentation of spatial and temporal distribution of turbid nearshore surface waters observed on ERTS images, when applied to studies of coastal currents and sediment distribution patterns, can provide a better data base for planning wise use of coastal resources.

Reimnitz, Erk, 1966, Late Quaternary history and sedimentation of the Copper River Delta and vicinity, Alaska: Ph.D. Thesis, San Diego, Univ. California, 160 p.

Disciplines 5B, H. K; 7D.

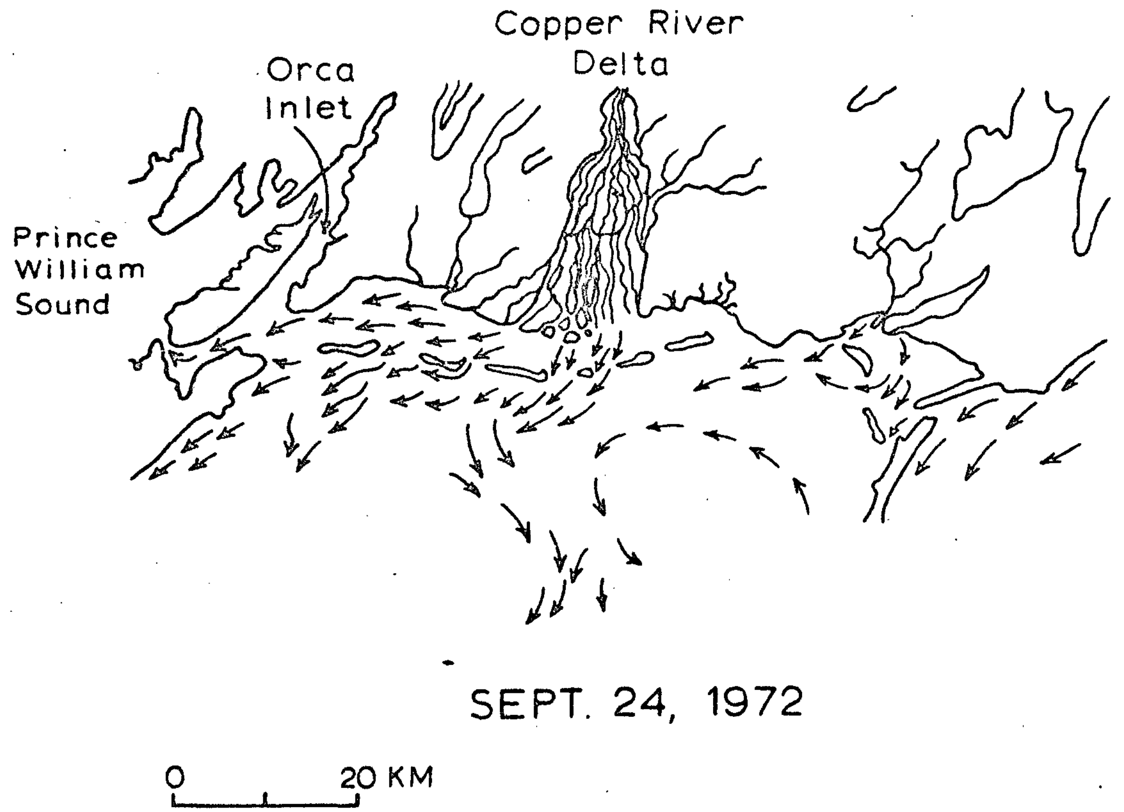

Figure 2. Westward-setting nearshore currents in the Gulf of Alaska off the Copper River Delta. Interpreted from ERTS Multispectral Scanner imagery recorded September 24, 1972 (no. 1063-20282).

f. Listing of published articles......

Carlson, Paul R., and Reimnitz, Erk, 1973, Study of river effluents and coastal water circulation off the west coast of North America using ERTS-1 data: Geol. Soc. America Abs. with Programs (Cordilleran Section), v. 5, no. 1, p. 20.

Carlson, Paul R., Janda, Richard J., and Conomos, T. John, 1973, Observations of suspended-particle patterns in nearshore north-eastern Pacific Ocean waters by ERTS-1 imagery: Symposium on Significant Results Obtained from ERTS-1, NASA/Goddard, Greenbelt, Md., p. 145.

Conomos, T. J., Peterson, D. H., and McCulloch, D. S., 1973, Seasonal nontidal drift patterns, San Francisco Bay, California: Am. Geophys. Union Trans., v. 54, no. 4, p. 303.

Peterson, D. H., Conomos, T. J., Broenkow, W. W., and Doherty, P. C., 1973, Location of density-current stagnation, San Francisco Bay estuary: Am. Geophys. Union Trans., v. 54, no. 4, p. 302.

Scrivani, E. P., and Peterson, D. H., 1973, Phytoplankton-zooplankton abundance and estuarine density-current stagnation, San Francisco Bay, California. (In Press)

g. Recommendation concerning practical changes in operations.....

None

h. A listing by date of any changes in Standing Order Forms:

None

i. ERTS Image Description forms:

None

j. Listing by date of any changed Data Request forms......

None