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Verl R. Wilmarth

*Science and Applications Directorate, Johnson Space Center, Houston, Texas*

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## SKYLAB EARTH RESOURCES PROGRAM

Verl R. Wilmarth  
Science and Applications Directorate  
Johnson Space Center  
Houston, Texas

The successful launch of Skylab on May 14, 1973, provided an unique space platform for study of the ocean, land and atmospheric phenomena of this planet earth. At an altitude of 234 nautical miles above the earth, the 100 ton experimental station orbited the earth every 93 minutes and repeats the same revolution every 5 days. In a near circular orbit, Skylab crossed major parts of the world's land masses and the Atlantic, Pacific and Indian oceans between 50° north and 50° south latitudes.

During the 171 days in space, the nine crew members surveyed selected portions of this planet with an array of sophisticated photographic, infrared and microwave sensors that have not been previously flown for earth resources investigations. These sensors formed the Earth Resources Experiment Package (EREP). Figure 1 describes the instruments and the principal use of the sensor data in study of earth. The footprint for each sensor is shown in Figure 2. The camera system consists of two parts. The multispectral camera (S-190A) is an array of six 70mm cameras boresighted so the features seen in one photograph can be simultaneously identified in the photographs from the other five cameras. With this system, images of earth features were obtained on color, color infrared, black-and-white infrared, and black-and-white film. Each photograph covers 163 Km square. The Earth Terrain Camera (S-190B) overlapped the field of view of the S-190A system and recorded information on black-and-white, color and color infrared film. Each photograph covers 109 Km square. The infrared spectrometer was boresighted with a crew-operated movable telescope for conducting radiance measurements of homogeneous areas approximately one-half kilometer in diameter. The multispectral scanner (S-192) is a 13-channel instrument capable of measuring simultaneously in the visible, reflected infrared and one channel in the thermal infrared regions of the spectrum along a 68 Km wide swath. The microwave system (S-193) combines a passive radiometer and an active scatterometer and altimeter in a single frequency of 13 GHz. This system has an 11 Km field of view and a two axis gimbal antenna for use in obtaining data 45° forward and to either side of this groundtrack. The sixth instrument is the L-band radiometer (S-194) that operates at a 1.4 GHz frequency and has a 11 Km field of view.

Although EREP was the major facility for the Skylab earth resources program, the Skylab 4 mission of 84 days provided an opportunity to add a new dimension for study of the earth by using the skills of the crew to identify, describe, interpret and photo document features and processes of interest in earth surveying programs. In conducting the Visual Observation project, 20 hours of lectures were provided the crew by a team of multidiscipline scientists and a comprehensive data package that illustrated features and outlined observation and photographing procedures was carried onboard the spacecraft.

During the three manned missions, approximately 40,000 photographs and 220,000 feet of high density magnetic tape were acquired with EREP. An additional 2000 photographs were obtained by the Skylab 4 crew to document their visual observations. The data from Skylab missions are processed at the Johnson Space Center and distributed to the 140 Principal Investigators (PIs) that represent institutions in the United States and 19 foreign countries (Figure 3). With the exception of some of the multispectral scanner magnetic tapes, all of the EREP data from the first and second manned missions have been distributed to the investigators. The data from Skylab third mission are being processed, and will be available to the PIs within a few weeks. Initial results of the investigators data analysis will be presented at a NASA sponsored conference to be held at Johnson Space Center in July 1974. Although this conference will provide an overall view and understanding of the application of Skylab results to earth resources, preliminary results from EREP and the Visual Observation project are summarized in this report.

The high spatial and spectral resolution of the camera (S-190A), S-190B) systems have provided cartographers with prime data for use in revision of topographic and photomaps, preparation of photomosaics and development of a cartographic technique for topographic mapping of remote areas such as Gran Chaco, Paraguay. The data content in EREP photography is clearly shown in this Earth Terrain Camera color photograph of the rapidly growing urban area of Phoenix, Arizona (Figure 4).

The investigator team of R. Alexander and V. Melazzo, U. S. Geological Survey, have compared the 1970 and 1972 land-use map of this

area with the 1973 multispectral camera imagery and identified areas of land-use changes. They note that most changes involve transition from agricultural to single family residences and that the EREP imagery is of great value in updating existing land-use maps in an urban setting.

At the Johnson Space Center, a cooperative program with the U. S. Department of Agriculture is underway to investigate the application of EREP multispectral photography and scanner data to the identification and measurement of crop acreage in the Holt County, Nebraska study area. On this 190A color infrared photograph taken in June 1973, in the river are circular, irrigated fields which have a quarter mile irrigation system pivoting in the center and irrigating approximately 135 acres. From this photography, crop acreage and crop vigor can be determined for use in production and commodity forecasting. Figure 6 is a 190-B color photograph of the same area; however, with three times higher resolution, more detailed information can be obtained. Note the different color shades in the circular fields which reflect variations in stages of plant growth and soil and moisture conditions. The multispectral scanner (S-192) magnetic tape data from the same area have been converted to color infrared image for comparison with the photographs (Figure 7). Although this spatial resolution of the scanner image is not as great as observed in the photographs, variations in color of the circular fields indicative of crop and soil conditions are readily determined. Because of the vast quantities of data obtained by the S-192, computer analysis are required. Figure 8 shows the computer generated map of the black outlined area shown on previous three figures. In the lower left film strip, corn is shown in yellow, grasses in red, pastures in green and all other in black. From detailed ground study conducted during the overflight of Skylab, there is a high correlation between the computer crop identification and actual crop variety.

Dr. R. Colwell of the University of California, using photo interpretation and computer processing, has demonstrated the utility of the EREP data in vegetation classification and land-use inventory in selected areas of California.

During the Skylab 4 mission, the detector assembly in the multispectral scanner (S-192) was replaced by a detector having a sensitivity of 0.8°K NE T in the thermal infrared region of the electromagnetic spectrum. The preliminary analysis of these data acquired over the Salton Sea area in California are shown in false color images (Figure 9 and 10). In the visible spectrum, the Mojave desert appears as white, Salton Sea as black and the irrigated rectangular agricultural plots near the Salton Sea as grays, greens, and tans (Figure 9). These color variations probably represent differences in crop growth and crop type. In the thermal infrared imagery, the apparent surface temperatures are indicated by color with the cooler temperatures shown as yellow and higher temperatures as shades of reds. Note that several

of the agricultural fields have temperatures near that of the Salton Sea which indicates that they were heavily irrigated during the overflight of Skylab. These data are examples of the type of information that could be applied to study of stressed crops, to search for surface indications of geothermal energy or mineral deposits, and to define freeze-thaw areas for crop forecasting.

The Skylab microwave experiments, S-193 and S-194, represent the first active system flown in space, the first measurements obtained over a tropical hurricane, and the first altimeter measurements from earth orbit. The S-193 combined radiometer/scatterometer/and altimeter system was designed primarily for oceanographic investigations in particular to determine sea surface conditions such as wind speed, wave height and precipitation areas. On June 6, Skylab passed near Hurricane Ava off the coast of Mexico, and in a solar inertial mode obtained a series of S-193 scatterometer and radiometer data. Figure 11 shows location of the eye, wind speeds, and the S-193 data points. Dr. Pierson of City University of New York, and Dr. R. Moore, University of Kansas, have completed preliminary analysis of these data and reported a reasonable correlation between the scatterometer measurements and wind speed determined by aircraft underflight (Figure 12). The radiometer data were used to determine areas of heavy precipitation which degrades the scatterometer data.

An unique opportunity occurred during the last manned mission when scatterometer and radiometer data were acquired on several passes over the largest storm system in a decade in the North Atlantic ocean. Wind speeds in excess of 60 knots, and wave heights to 75 feet were recorded by weather ship in the area. Analysis of these data are being completed by Dr. Pierson. However, preliminary results indicate the practical use of space acquired radiometer/scatterometer data in preparation of surface meteorological maps of vast areas of the ocean.

The S-193 altimeter measures accurately the distance between the spacecraft and the earth's surface and provided the first direct measurement of a sea surface depression. During the mission, several altimeter measurements were obtained over the Puerto Rican Trench. Analysis of these data shows that for about 500 Km northwest of Puerto Rico, the sea surface is depressed and reaches a maximum of approximately 20 meters over the Trench (Figure 13). Acquisitions of comparable sea level data would require extensive ship surveys.

Altimeter data were also obtained over areas of the Virginia coast for use in developing instrumentation for the geoidal satellite GEOS-C to be launched in 1974.

The third manned mission of 84 days provided the crew the opportunity to determine man's capability to study and photograph many phenomena on earth. In particular, their observations and

and photographs have provided oceanographers with information that will permit revision of ocean color charts and the location of currents and upwelling areas. Using the photographs from the first and second manned missions, Dr. Stevenson of the Office of Naval Research, identified turbulent eddies in the Yucatan current off the east coast of Central America. The general flow of the surface currents in this part of the Caribbean Sea and location of the Skylab photographs are shown on Figure 14. In the SL-2 photograph (Figure 15) the eddies appear as smooth, relatively cloud free surfaces that are 6 to 20 Km in diameter and extend to depths greater than 100 meters. In the eddies, the surface water temperature is several degrees colder than the normal sea water temperatures in the current. Towering cumulus clouds, which are white in Figure 15, generally form over the warm down wind current boundaries. The eddies are believed to represent upwelling of cold water and therefore are a potential source of fish. The SL-4 crew observed eddies in the Yucatan current and in several Atlantic and Pacific ocean currents. Dr. George Maul, National Oceanic and Atmospheric Administration, has described similar cyclonic eddies in the Gulf Loop Current in the Eastern Gulf of Mexico. The discovery of turbulent eddies in many ocean currents has required the development of new theories for modeling the atmospheric and ocean energy exchange processes.

Vast areas of the South Atlantic ocean do not have modern oceanographic charts and the location of such major ocean features as the Falkland and Brazil currents are not accurate. Because ocean currents affect weather conditions, distribution of marine life, movement of sediments and shipping courses, the observational and photographic data acquired by the third crew over the confluence of these currents have provided oceanographers with new and unique scientific information. Figure 16 shows the location of the currents. Within the Falkland current and in many other ocean areas, the crew observed the occurrence of major concentrations of plankton, a microscopic marine organism. Plankton is a basic ocean food and the location of the plankton are important in the search for potentially rich fishing areas. Figure 17 is a photograph of the Falkland current showing the "plankton bloom" as red. During the third manned mission, the crew's photography and observations of the distribution of plankton blooms in the Falkland and Brazil currents have provided for the first time information that will aid oceanographers to plot accurately the location of these currents. Similar observations and photo documentation were completed for the Humboldt current (Figure 16) and the West Wind Drift current east of New Zealand. Dr. Maul has indicated that the observations by the crew of Carr, Gibson and Pogue have added significantly to man's knowledge and understanding of the oceans.

In summary, the preliminary results of the EREP data analysis have provided information for developing future operational earth orbiting

systems which will enable resource managers to more efficiently utilize the energy resources of the world.

## EREP SENSORS

SENSOR	NO.	APPLICATION
MULTISPECTRAL CAMERA & LENS	S190 A	THERMATIC AND LAND USE MAPPING, RESOURCE INVENTORY; MEASURE OF EFFECTS OF ATMOSPHERIC SCATTERING.
EARTH TERRAIN CAMERA	S190B	HIGH RESOLUTION DATA FOR INTERPRETING EREP IMAGERY.
INFRARED SPECTRAMETER	S191	DETERMINE EFFECTS OF ATMOSPHERIC ATTENUATION AND RADIATION FROM EARTH SURFACE.
MULTISPECTRAL SCANNER 13 CHANNELS	S192	MULTISPECTRAL AGRICULTURAL SURVEYS, LAND USE DISCRIMINATION, OCEAN SURVEYS, WATER CONTAMINATION.
MICROWAVE RADIOMETER SCATTEROMETER/ALTIMETER	S193	IDENTIFICATION OF SEA/LAKE ICE, SNOW, VEGETATION AND RAINFALL PATTERN RECOGNITION, SOIL MAPPING
L-BAND MICROWAVE RADIOMETER	S194	IDENTIFICATION OF LAND/WATER AREAS

Figure 1

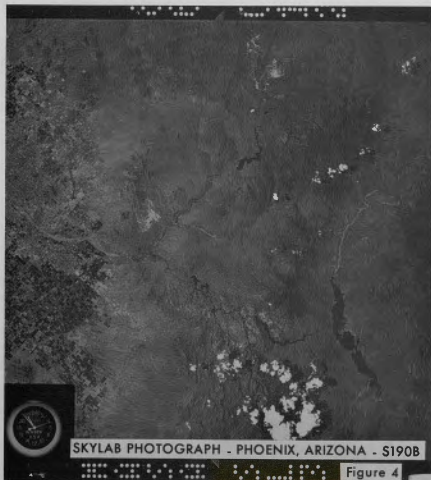


Figure 2

## EREP PRINCIPAL INVESTIGATOR PROGRAM

INVESTIGATOR AFFILIATION	DOMESTIC INVESTIGATORS	FOREIGN INVESTIGATORS
ACADEMIC	29	9
STATE	9	0
INDUSTRIAL	22	1
FEDERAL	40 (6 AGENCIES)	30
TOTAL	100	40 (19 COUNTRIES)

Figure 3



NASA-5-73-2841

# HOLT COUNTY NEBRASKA AGRICULTURAL STUDY AREA-S190A

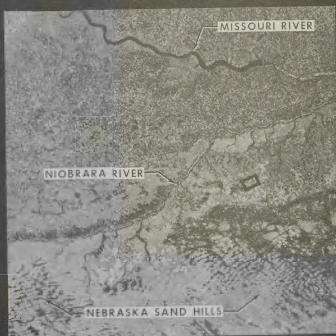


Figure 5

NASA-5-73-2838

# HOLT COUNTY NEBRASKA AGRICULTURAL STUDY AREA - S190B

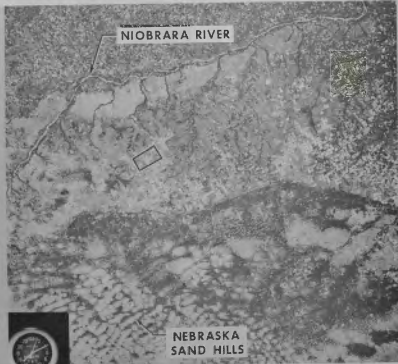


Figure 6

NASA-5-73-2830

# HOLT COUNTY NEBRASKA AGRICULTURAL STUDY AREA



Figure 7

NASA-5-73-2839

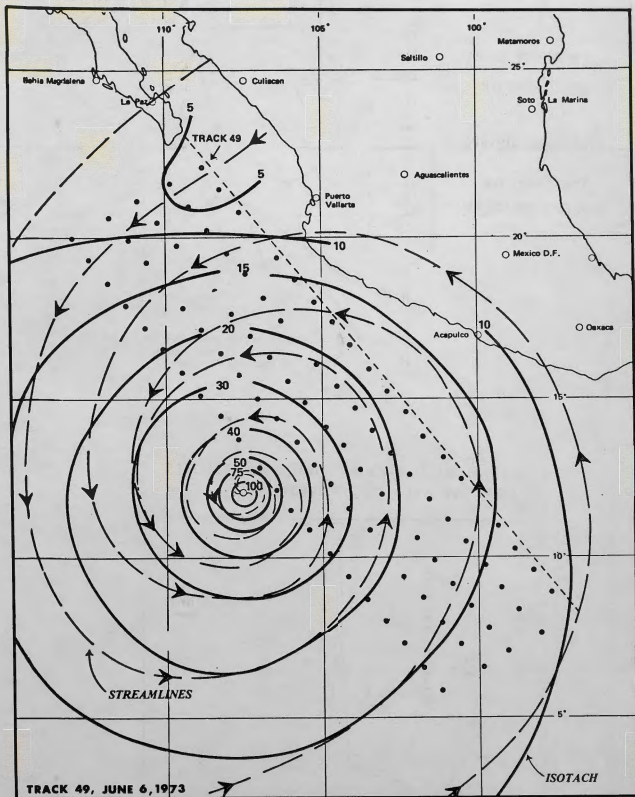
# HOLT COUNTY STUDY AREA COMPUTER CLASSIFICATION MAPS



Figure 8







# STREAMLINE and ISOTACH ANALYSIS FOR AVA

Figure 11

**RESPONSE OF  
SCATTEROMETER  
AT 52°  
OVER HURRICANE AVA  
[ASPECT ANGLE AND  
CLOUD LOSS CORRECTIONS]**

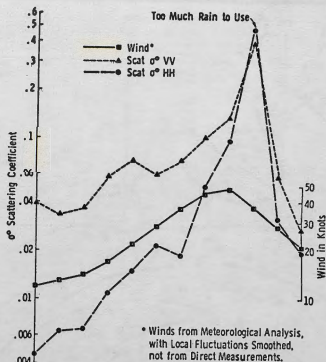


Figure 12

**SKYLAB ALTIMETER PRELIMINARY RESULTS  
FOR THE ATLANTIC/PUERTO RICO AREA**

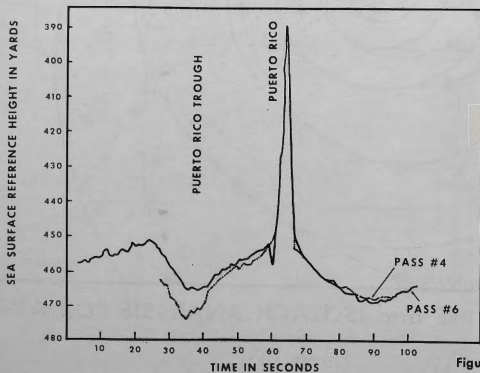
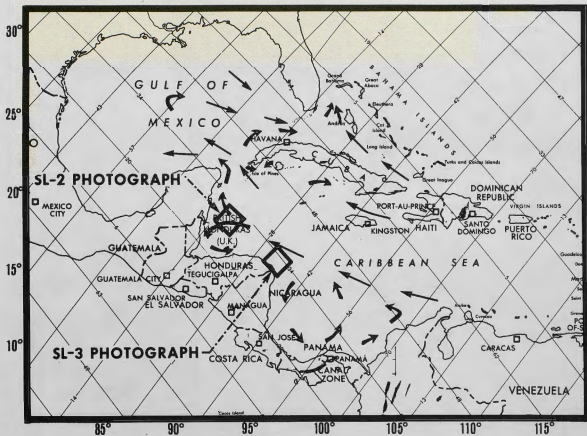


Figure 13

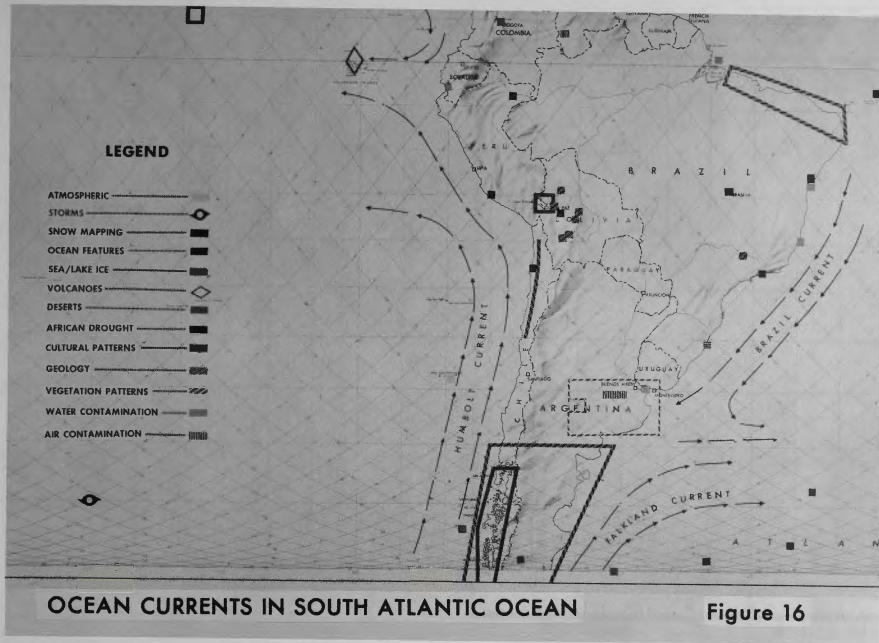


**SURFACE CURRENTS IN THE CARIBBEAN SEA AND GULF OF MEXICO**

Figure 14



**TURBULENT EDDIES IN THE YUCATAN CURRENT**



PLANKTON BLOOM IN FALKLAND CURRENT

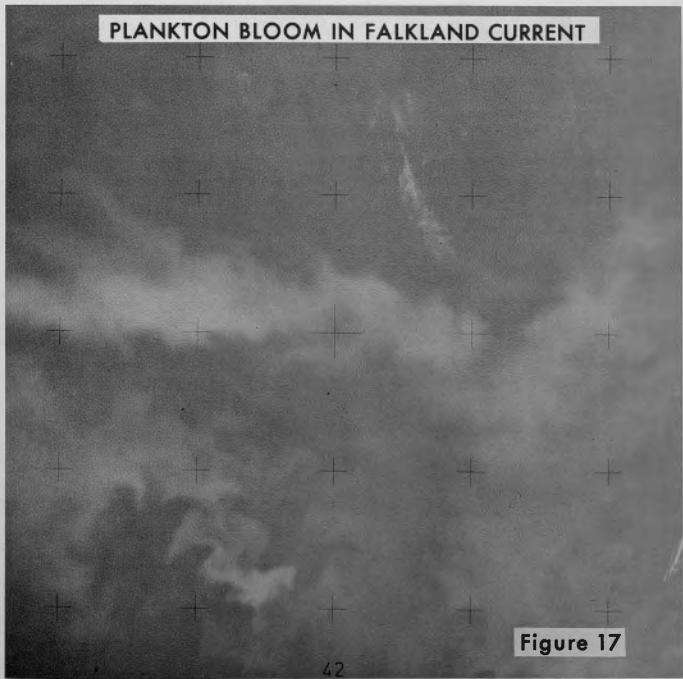


Figure 17