SAI-73-565-LJ

DETERMINATION OF AEROSOL CONTENT IN THE ATMOSPHERE FROM ERTS-1 DATA

Progress Report No. 5
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ACCOMPLISHMENTS

Significant results have been obtained during this fifth two-month period of the contract. A linear relationship, as predicted by theory, has been shown to exist between the MSS radiances over water surfaces and the aerosol content of the atmosphere. Ground-truth measurements were obtained at the Salton Sea test site in conjunction with a NASA aircraft overflight.

GROUND-TRUTH MEASUREMENTS

The NASA aircraft overflight at the Salton Sea/desert test site took place on May 23, 1973. Ground-based observations of the aerosol optical thickness were made at the time of the aircraft and satellite overpasses. The results, given in Fig. 1 with previous Volz data, show the highest aerosol content recorded during this program. No ground-truth measurements were made at San Diego in this reporting period due to cloud cover at the time of the ERTS-1 overpasses.

The photographic aircraft MSS data for one channel have been received from Houston. The data were examined, and digital data for several selected areas within the test site have been requested. Direct comparison of the aircraft and satellite data will not be readily made due to the fact that the aircraft tapes are of a different format from the satellite tapes, and a computer program has to be developed to read the data from them.

DIGITAL DATA ANALYSIS

Digital tapes for nine overpasses at the Salton Sea and four overpasses at San Diego have been received and analyzed to-date. Ground-

truth Volz measurements were made for six of these overpasses, two at the Salton Sea and four at San Diego (two others were made at the Salton Sea, but no tapes have yet been received).

Radiance-Aerosol Content Relationship

The radiances for MSS 4, 5 and 6 derived from these digital data are plotted in Fig. 2 against the aerosol content obtained with the Volz measurements. In addition, another data point obtained in the Atlantic Ocean off the African coast (21 N - 17 W) August 9, 1972, is plotted (private communication from R. S. Fraser). The radiance was determined by Dr. Fraser, and the Volz measurement was made from a NOAA ship. The radiance values are normalized to a sun angle of $\mu = .45$, using a theoretical correction based on Fig. 3 (the correction is greater than 5% only for the Atlantic point). The theoretical data for MSS 6 in Fig. 3 are derived from the calculations of Plass and Kattawar (Appl. Opt. 11, 1598 (1972)), and the same variation with sun angle is assumed for the other MSS channels for this preliminary analysis.

The results given in Fig. 2 show an excellent linear relationship between radiance and aerosol content for MSS 6. The theoretically predicted relationship is shown for comparison. It is striking that the experimental extrapolation to zero aerosol content (only Rayleigh scattering + ozone absorption) agrees exactly with the theory, suggesting that the basic Rayleigh model atmosphere calculations are good. A scatter of experimental points about the mean line is expected, of course, due to experimental errors and to variations in the aerosol type and distributions.

From this limited set of data it would appear that the problem of sun glitter is not significant. Certainly sun glitter has not been visually observed on the photographic satellite data received to-date, and the

results in Fig. 2 do not show evidence of sun glitter. (However, the NASA aircraft photographic data showed sun glitter observable from 2000 ft altitude for May 23, 1973, for which the satellite data has not yet been received). The possibility of eliminating the sun glitter problem, if necessary, by the two-wavelength technique has been preliminarily investigated by plotting the spectral variation of the ERTS radiances over the Salton Sea and the ocean and bays at San Diego. The spectral variation is shown for the nine Salton Sea overpasses in Fig. 4. Data are not shown for MSS 7 due to the inaccurate low radiance values in this channel, and due to the influence of the variable atmospheric water vapor content. These curves, and the ones for San Diego in Fig. 5-8, all have basically the same shape, suggesting that the spectral distribution of radiance over water surfaces measured with the MSS bandpasses does not vary greatly due to chlorophyll content, suspended matter and depth. The fact that none of the curves in Fig. 4 crosses another suggests that the relative accuracy of the MSS with respect to time is good.

Contrast-Aerosol Content Relationship

Ground-truth Volz measurements of the aerosol content have been made for four overpasses of the ERTS at the Salton Sea, but the ERTS digital data for only two overpasses have been received to-date. Hence, in order to investigate the contrast-aerosol content relationship for MSS 6, the linear relationship in Fig. 2 is used to determine the aerosol content from the Salton Sea radiance. These values are then treated as ground-truth values of the aerosol content. The measured values of $(C_o/C_R - 1)$ $(= f(\tau)/A')$ are then plotted against the corresponding aerosol contents. The values of both $(C_o/C_R - 1)$ and the aerosol content were normalized to a sun angle of $\mu = .45$, using the theoretical relationships in Fig. 3 and in Fig. 4 of Progress Report No. 2. The variation of the contrast

function $(C_o/C_R - 1)$ with aerosol content is shown in Fig. 9. The values of aerosol content are presented in terms of optical thickness (τ) to provide another point of information since $(C_o/C_R - 1) = 0$ when $\tau = 0$ (i. e. no atmosphere).

The results in Fig. 9 show quite a large scatter of points below $\tau = .17$. All these data points were obtained in the winter months, November through January, when there was considerable rainfall, which can affect the reflectivity of sand. The magnitude of this effect must be further investigated. The results for MSS 4 and 5 show a very large scatter of points with no apparent correlation between contrast and aerosol content.

Summary of ERTS-1 Results To-Date

The investigation of the radiance-aerosol content relationship over water surfaces is very encouraging, and suggests that this technique is suitable for sensitive monitoring of aerosol content. The investigation should be continued and expanded to include land surfaces. The contrast-aerosol content relationship does not appear so useful due to effects of weather on the reflectivity of the land surface. These effects on both the radiance and contrast methods should be investigated further.

These expanded investigations lend themselves to both new and old ERTS-1 data. The old data may be used by considering water and land areas covered by the NOAA/EPA Turbidity Network which makes Volz photometer measurements on a regular basis.

FUTURE PLANS

In the next reporting period it is planned to continue the investigation of both the contrast and radiance relationships.

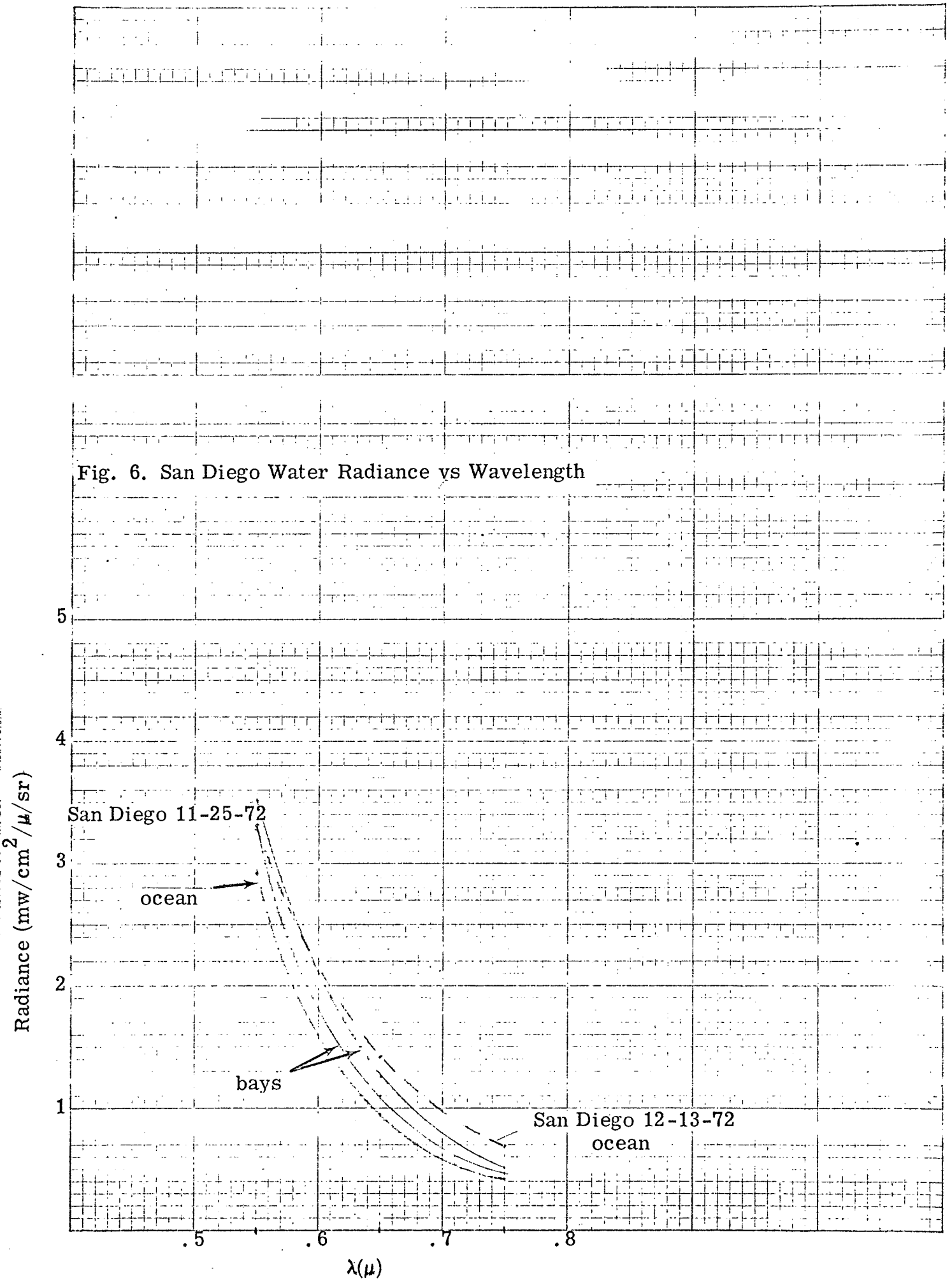

Fig. 6. San Diego Water Radiance vs Wavelength

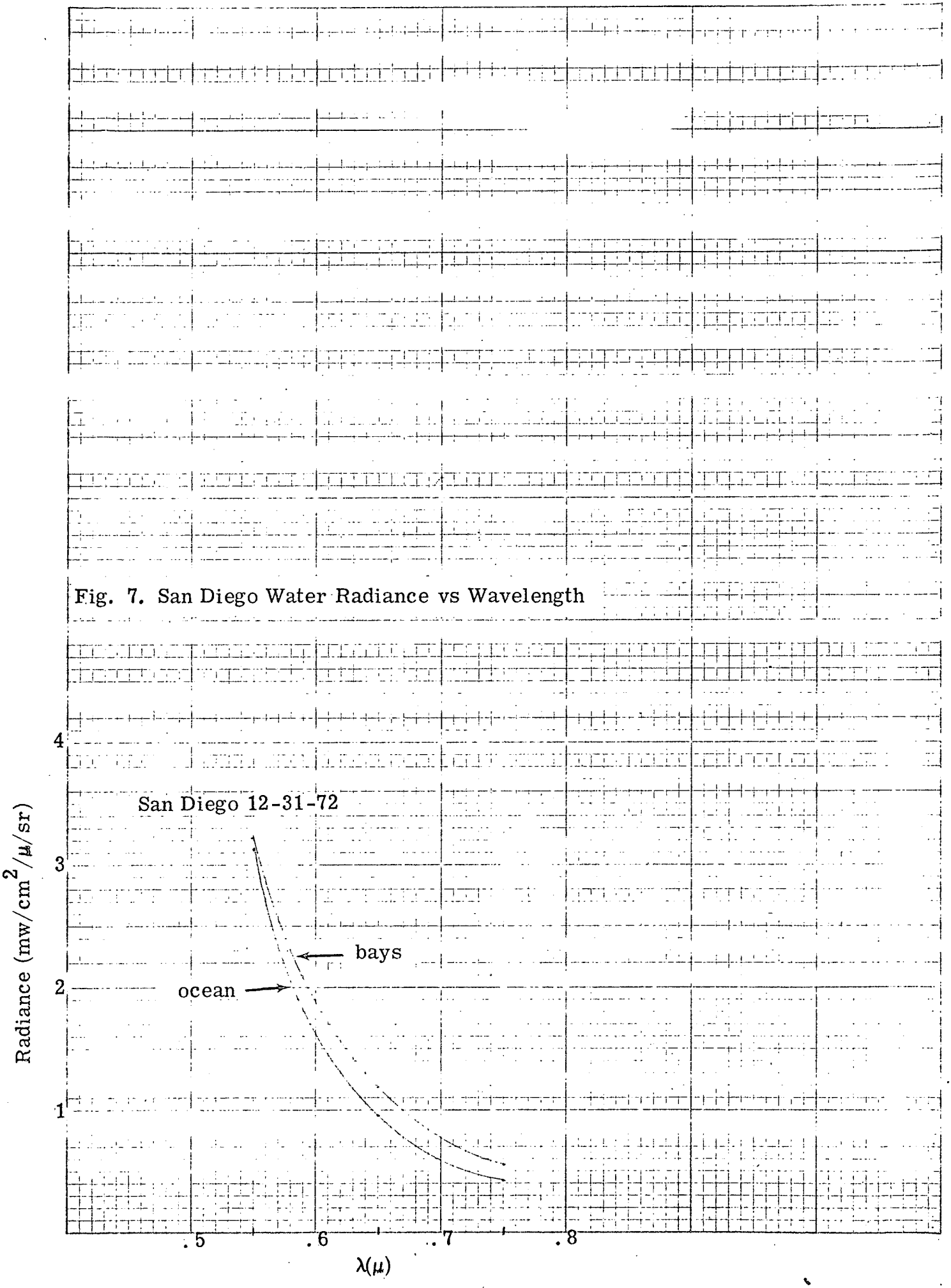

Fig. 7. San Diego Water Radiance vs Wavelength

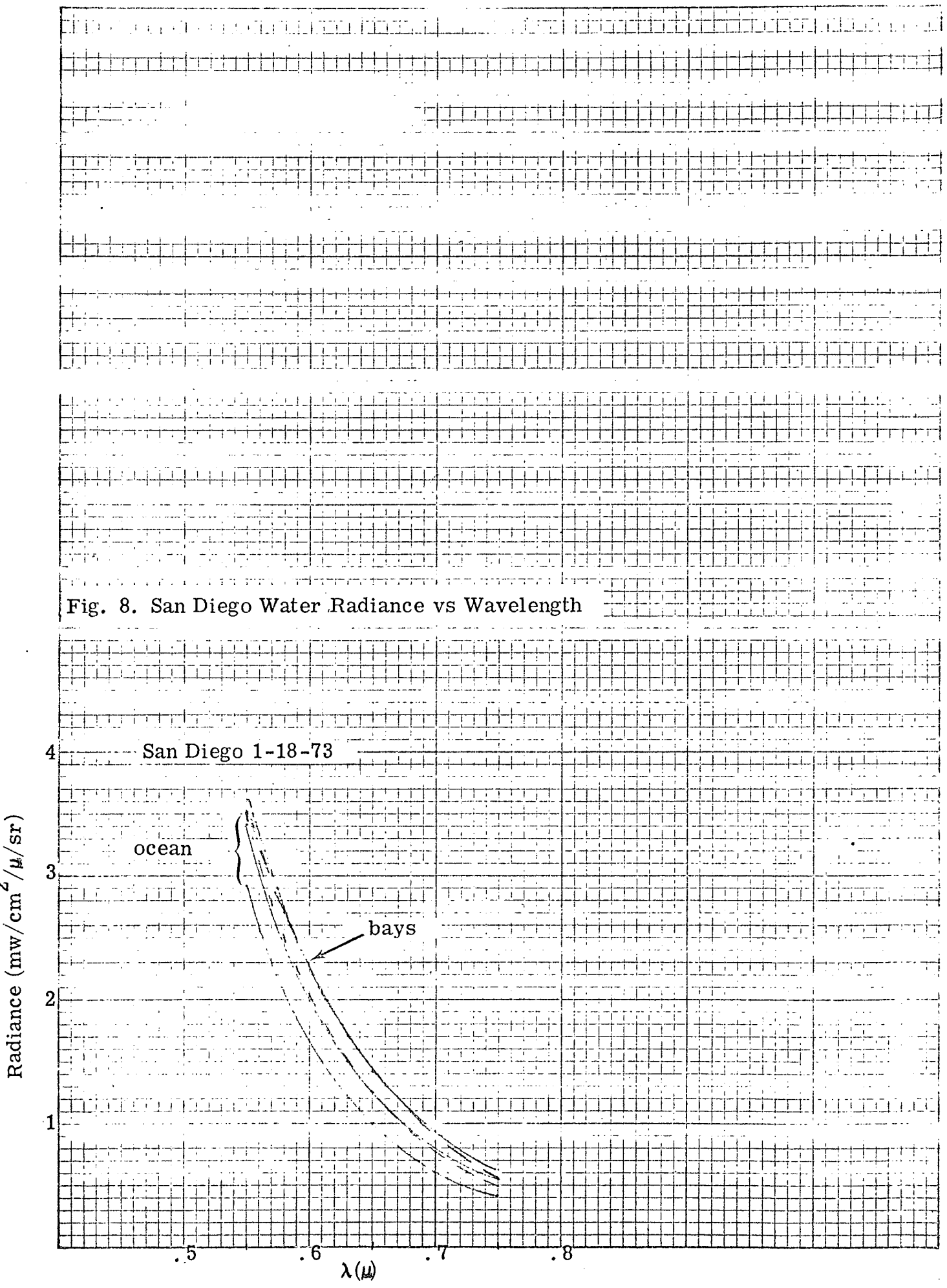

Fig. 8. San Diego Water Radiance vs Wavelength

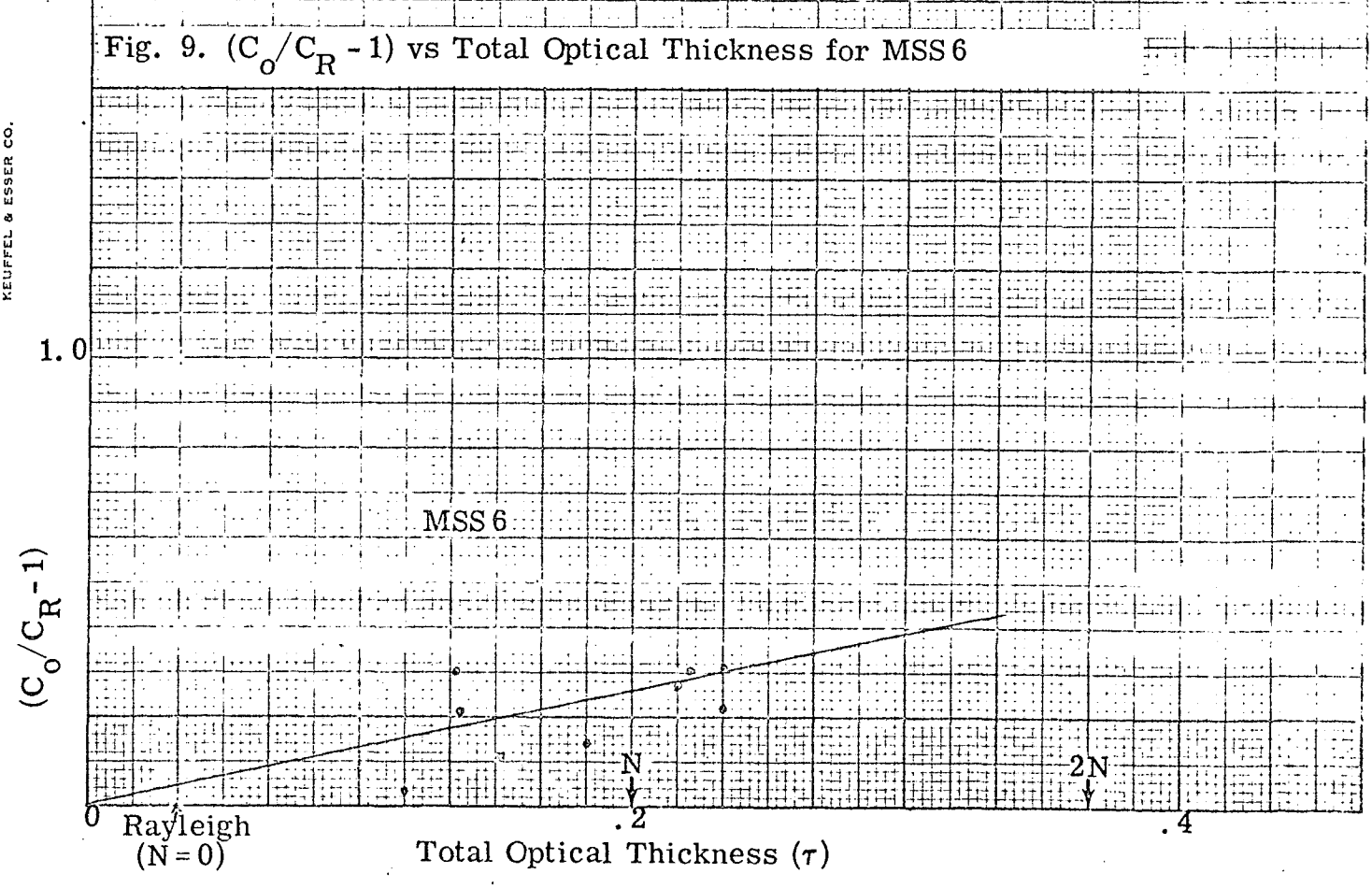

Fig. 9. $(C_o/C_R - 1)$ vs Total Optical Thickness for MSS 6

SIGNIFICANT RESULTS

Significant results have been obtained using the digital data from ERTS-1. A linear relationship, as predicted by theory, has been shown to exist between the MSS radiances over water surfaces and the aerosol content of the atmosphere measured with a ground-based Volz sun photometer. The relationship, based on seven data points, appears best for MSS 6. This relationship will enable the atmospheric aerosol content to be monitored on a global basis, once it has been verified with further measurements, and should provide the information with considerable cost-savings over a ground-based photometer network.

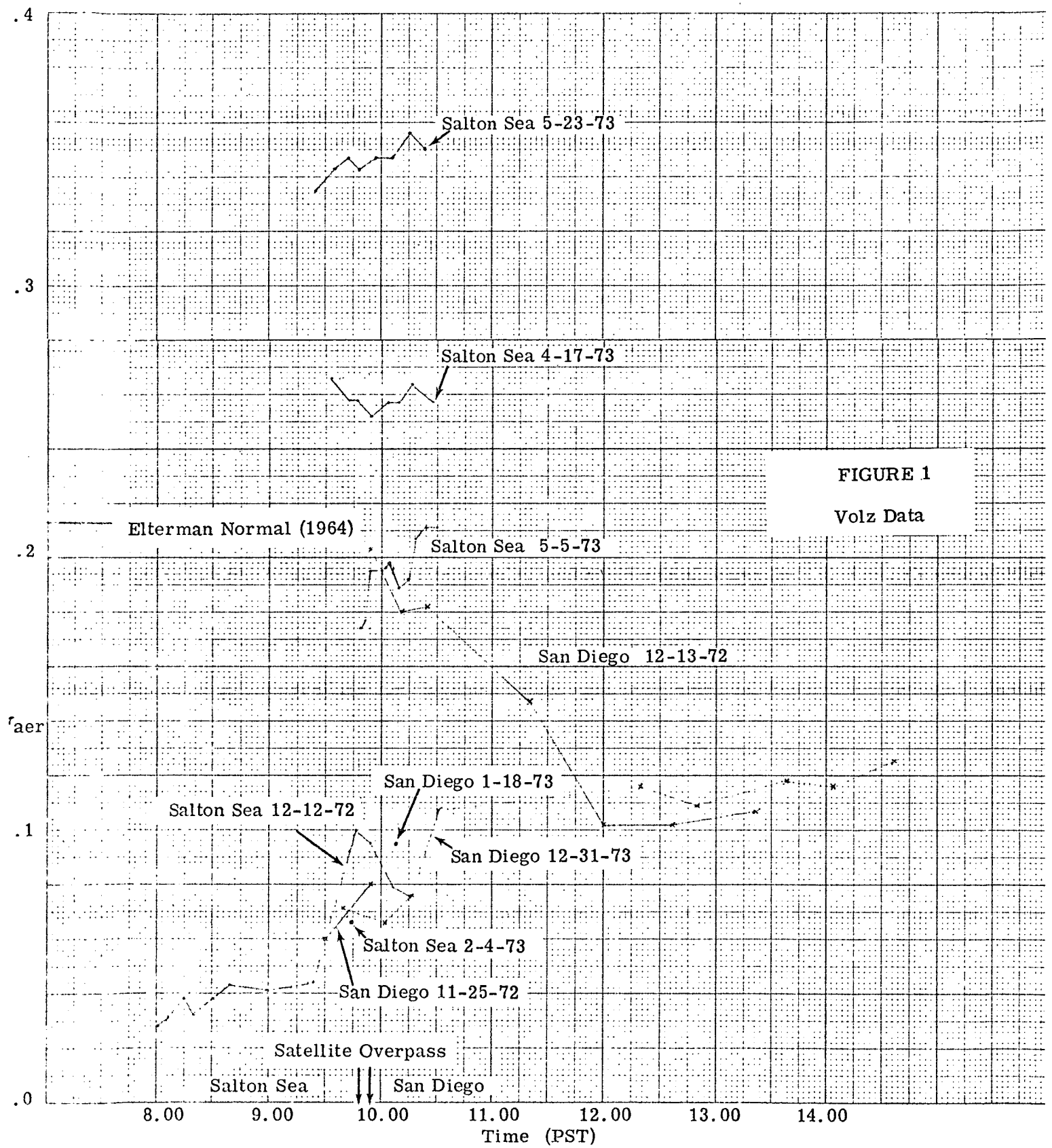

FIGURE 1

Volz Data

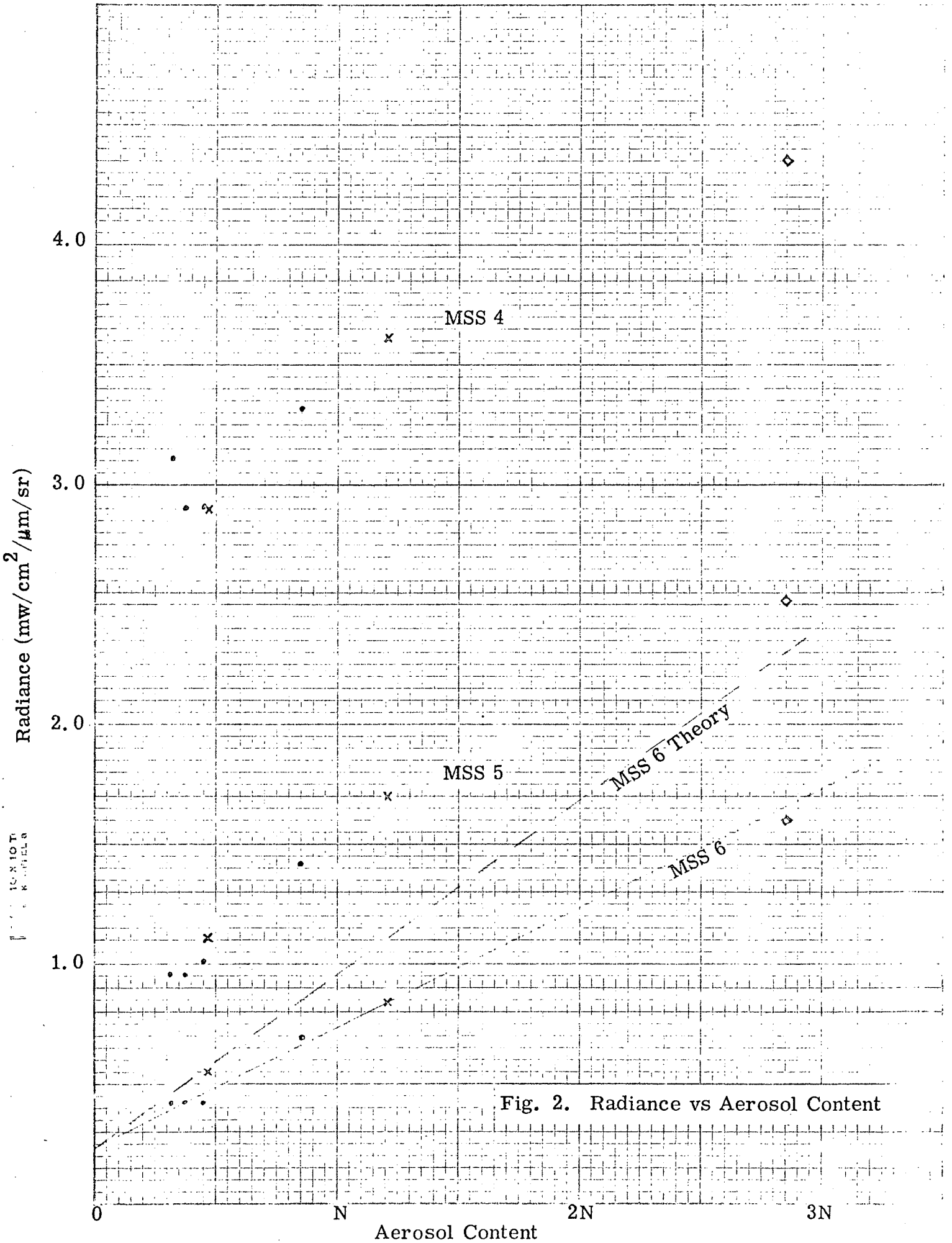

Fig. 2. Radiance vs Aerosol Content

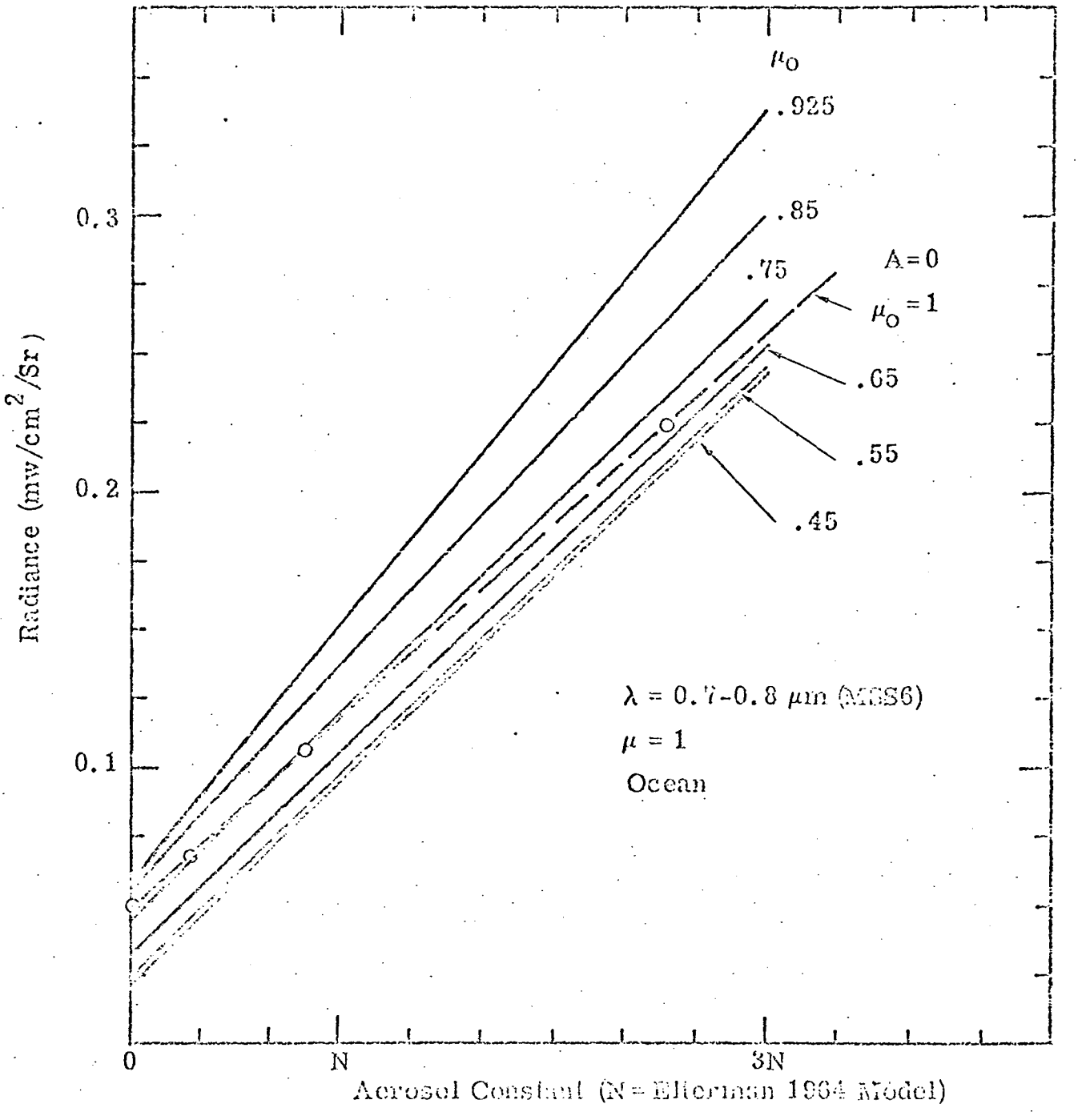

Fig. 3. Theoretical Radiance vs Aerosol Content for MSS 6

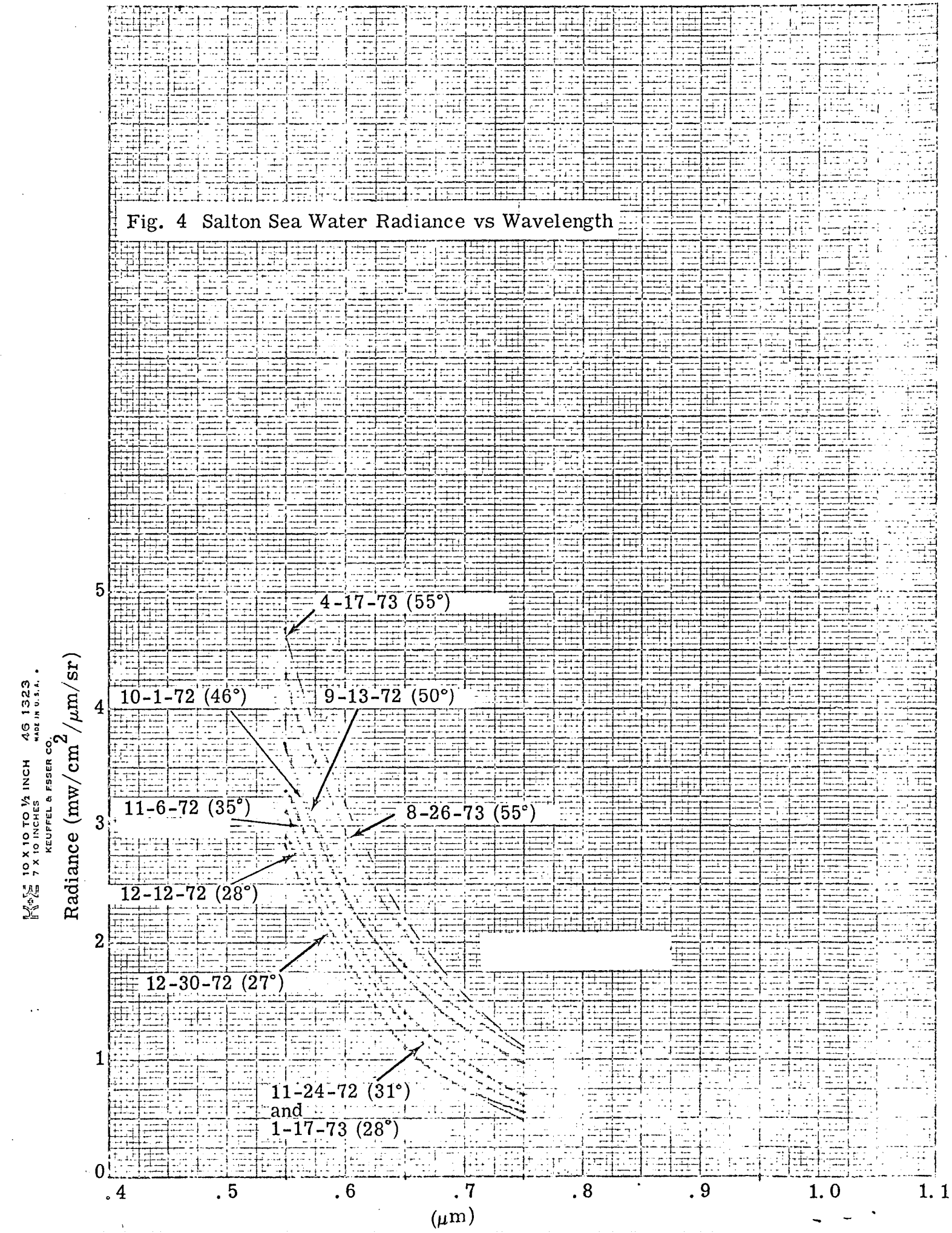
Fig. 4 Salton Sea Water Radiance vs Wavelength
4-17-73 (55°)
10-1-72 (46°)
9-13-72 (50°)
11-6-72 (35°)
8-26-73 (55°)
12-12-72 (28°)
12-30-72 (27°)
11-24-72 (31°)
and
1-17-73 (28°)
Radiance (mw/cm^2/μm/sr)
0
1
2
3
4
5
.4
.5
.6
.7
.8
.9
1.0
1.1
(μm)

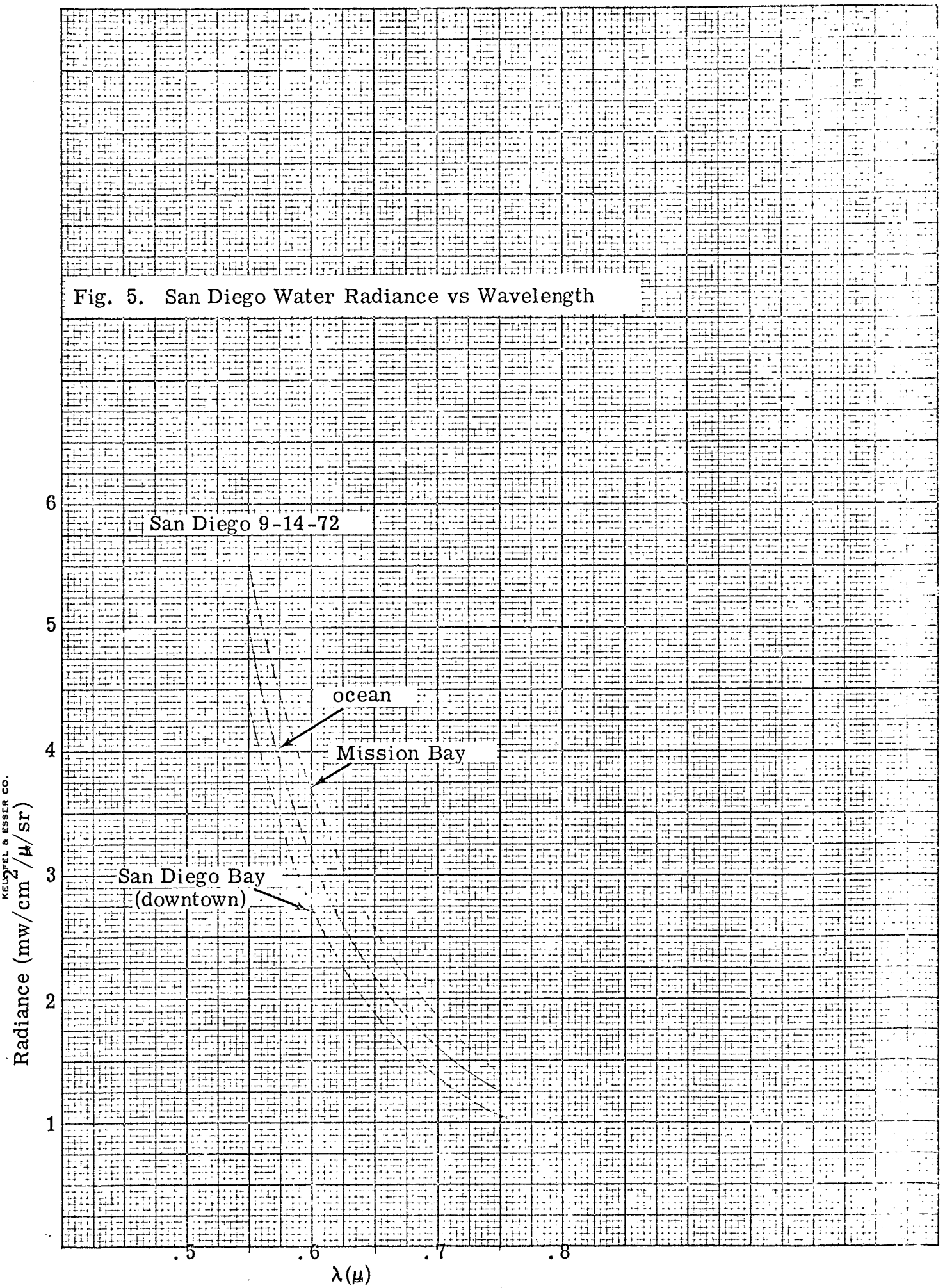

Fig. 5. San Diego Water Radiance vs Wavelength