A STUDY ON THE DETERMINATION OF THE ATMOSPHERIC AEROSOL CONTENT USING ERTS DATA

FINAL REPORT

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SUMMARY

A previous study using ERTS-1 data showed a linear relationship between the upwelling radiance over water surfaces and the atmospheric aerosol content. This study identified seven NOAA-EPA turbidity network sites, plus the NASA-Houston network within the Houston area, as being suitable for providing further data points for the relationship. Analysis of ERTS-1 and turbidity data for the period July 1972 to May 1973, found 24 possible data points. Most of these turbidity values were below the normal aerosol contents and just two high values were judged suitable for checking the relationship where data points are presently sparse. It is recommended that the study be extended to cover ERTS-1 data for the period from May 1973 to January 1975, and to include the current and future Landsat 1 and 2 coverage which provide data every 9 days at each site.

1.0 INTRODUCTION

The apparent gradual increase of particles in the atmosphere has received considerable attention in recent years due to the possible effect of atmospheric aerosols on the earth's climate. Aerosols also affect space observations of the earth and the atmosphere, and knowledge of the aerosol content and its variability is important in the interpretation of radiometric data, such as that used to determine atmospheric temperature profiles. The ERTS-1 satellite offered the opportunity of determining the feasibility of monitoring the atmospheric aerosol content on a global basis, as suggested by theoretical studies, which showed a linear relationship between the upwelling earth-atmospheric radiance and the aerosol content. This relationship was previously investigated[1], under NASA sponsorship, at two test sites, San Diego and the Salton Sea, using the MSS radiance data, with ground-truth observations of the aerosol content being made with a Volz photometer at the time of the satellite overpasses. Significant results, relating the radiance over water surfaces to the atmospheric aerosol content, were obtained. The results, summarized in Figure 1, indicate that the MSS channels, 4, 5 and 6 centered at 0.55, 0.65 and 0.75 μm respectively, have comparable sensitivity, and that the aerosol content can be determined within ± 10% with the assumed measurement errors of the MSS. However, these linear relationships are based on only eight measurements, and further data are necessary to confirm the results, particularly for high aerosol contents, and to confirm that sun glitter is not a problem.

This present study has sought to obtain further data points, by finding coincidences between ERTS-1 data and aerosol data obtained routinely by the NOAA-EPA turbidity network, with emphasis on high aerosol contents, and conditions of possible sun glitter.

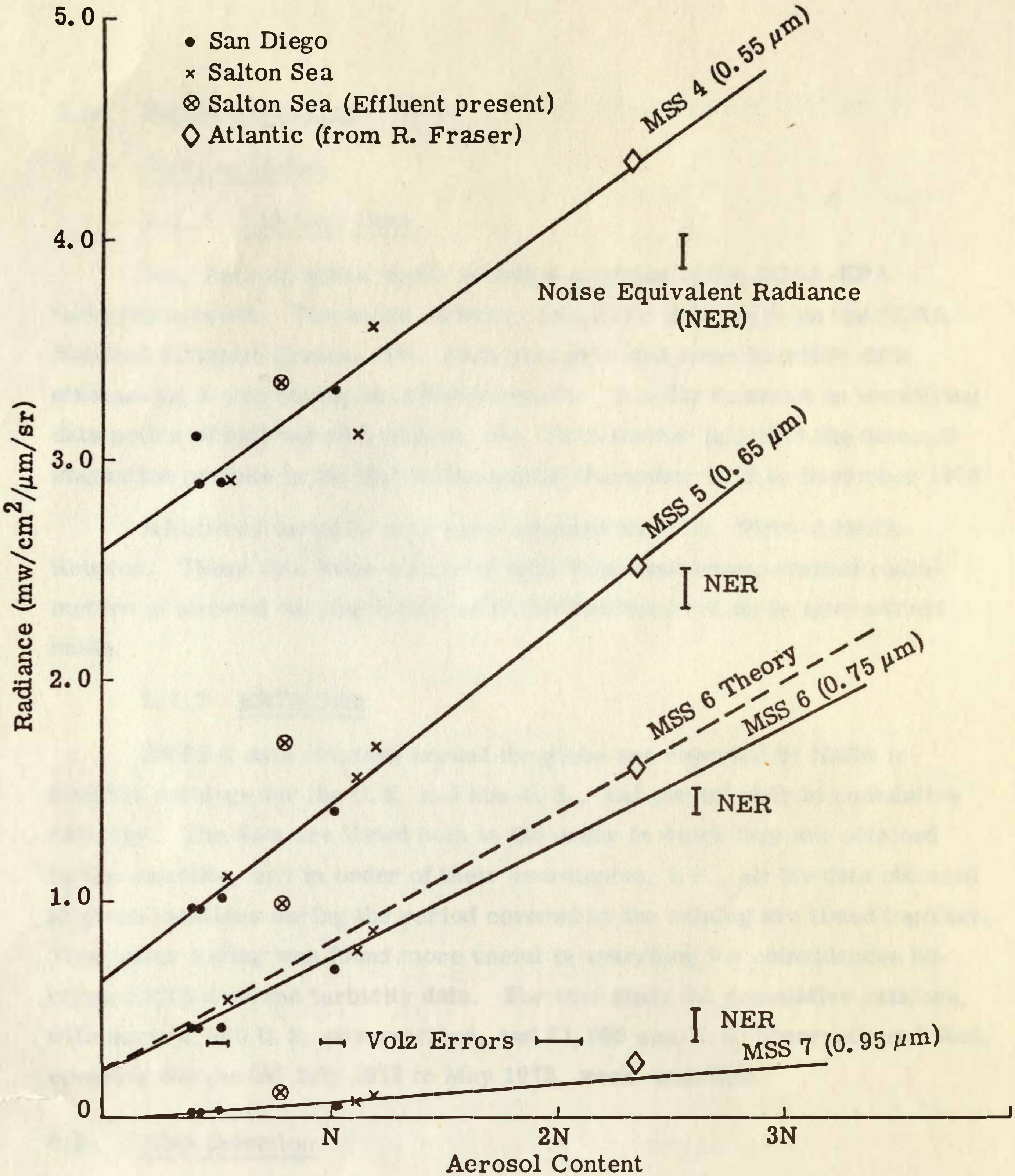

Figure 1. Radiance vs. Aerosol Content Over Water Surfaces (Normalized to sun angle $\mu = .45$)

2.0 DATA ANALYSIS

2.1 Sources of Data

2.1.1 Turbidity Data

Mr. Pack of NOAA kindly provided a listing of the NOAA-EPA turbidity network. The actual turbidity data were obtained from the NOAA National Climatic Center. Mr. Pack also provided some turbidity data obtained on a ship during an Atlantic cruise. In order to assist in identifying data points of high aerosol content, Mr. Pack further provided the dates of stagnation periods in the USA in the period December 1972 to November 1973.

Additional turbidity data were obtained from Dr. Pitts of NASA-Houston. These data were measured with Volz-type seven-channel radiometers at several varying locations in the Houston area on an intermittent basis.

2.1.2 ERTS Data

ERTS-1 data obtained around the globe are reported by NASA in monthly catalogs for the U. S. and non-U. S., and periodically in cumulative catalogs. The data are listed both in the order in which they are obtained by the satellite, and in order of their coordinates, i. e., all the data obtained at given locations during the period covered by the catalog are listed together. This latter listing was found more useful in searching for coincidences between ERTS data and turbidity data. For this study the cumulative catalogs, with some 8, 000 U. S. observations, and 21, 000 non-U. S. observations listed, covering the period July 1972 to May 1973, were examined.

2.2 Sites Selection

Initially, the locations of stations in the NOAA-EPA turbidity network were examined, and those stations which might be near a large body of water were identified. Out of 64 global stations, there appeared to be

26 potentially useful sites, 14 in the U. S. A. (including 2 in Alaska) and 12 around the globe.

Of the 12 non-U. S. turbidity stations identified as being potentially useful, it appears that 6 of them are located where the ERTS instrumentation is normally switched off. For the remaining 6 non-U. S. and the 14 U. S. stations, the cumulative catalog was examined for reported ERTS data. Only data with 80% or less cloud cover are considered. A list of dates for reported ERTS data, shown in Table 1, was sent to the National Climatic Center to obtain turbidity data as available. We submitted 153 dates, but data were available on only 41 of them. The ERTS overpass is approximately 10 a. m. local time at all places, so only turbidity data taken between 9 and 11 a. m. is considered to be useful. (The actual time of the overpass was computed for each location that was eventually determined to be useful in this study.) Under this constraint, 28 of the 41 dates had potentially useful turbidity data.

Mr. Flowers of NOAA-EPA subsequently kindly agreed to review the original list of 26 stations, and to provide more details on their location with respect to the water. His comments for each station are given in Table 2. By using these comments and by examination of topographical maps of the areas including the stations, it was found that 8 sites (2 non-U. S. and 6 U. S.), given in Table 3, are suitable for this study. The other stations were found to be within an urban area (and hence not representative of the turbidity over nearby water) or had an urban area between them and the body of water, or were no longer taking turbidity data.

The NASA-Houston turbidity data were provided for 28 days, of which 7 days were found to coincide with ERTS overpasses.

No ERTS data were taken in the vicinity of the Atlantic turbidity data provided by Mr. Pack. In addition, during the stagnation periods, there was just one ERTS overpass over a turbidity station, but on that day no turbidity observations were made.

TABLE 1. ERTS Overpasses at Turbidity Network Stations

Adrigole, Ireland	10-3-72
Andersen AB, Guam	2-16-73
Aspendale, Australia	10-22-72
	1-19-73
	1-20-73
	2-6-73
	2-24-73
Atlantic City, New Jersey	8-16-72
	10-9-72
	10-10-72
	1-25-73
	1-26-73
	2-13-73
	3-2-73
	3-20-73
	4-7-73
	4-25-73
	5-13-73
Barrow, Alaska	7-29-72
	7-30-72
	8-2-72
	8-18-72
	8-19-72
	9-5-72
	9-7-72
	9-21-72
	10-10-72
	10-11-72
	10-12-72
	3-19-73
	3-20-73
	3-21-73
	3-22-73
	3-23-73
	4-6-73
	4-7-73
	4-9-73
	4-10-73
	5-15-73
Fort Collins, Colorado	8-2-72
	8-20-72
	9-25-72
	10-31-72
	11-18-72
	12-6-72
	12-24-72
	1-11-73
	1-29-73
	2-16-73
	3-6-73
	4-11-73
	4-29-73
	5-17-73
Gainesville, Florida	8-2-72
	8-20-72
	9-7-72
	10-13-72
	10-31-72
	11-18-72
	12-24-72
	2-16-73
	3-6-73
	3-24-73
	4-11-73
	4-29-73
Grand Prairie, Texas	7-25-72
	7-26-72
	8-13-72
	8-31-72
	10-6-72
	10-24-72
	12-17-72
	2-9-73
	2-27-73
	4-4-73
	4-22-73
	5-9-73
	5-10-73
Green Bay, Wisconsin	8-2-72
	9-14-72
	9-15-72
	10-2-72
	10-20-72
	12-13-72
	2-5-73
	2-23-73
	4-18-73

TABLE 1. (continued)

Houston, Texas	8-11-72
	8-29-72
	10-4-72
	11-27-72
	2-25-73
	4-2-73
Kadena AB, Okinawa	1-8-73
	1-26-73
Miami, Florida	8-18-72
	9-5-72
	10-11-72
	10-29-72
	1-9-73
	1-27-73
	2-14-73
	3-4-73
	3-22-73
	4-9-73
	4-27-73
	5-15-73
Ramey AB, Puerto Rico	2-21-73
	10-18-73
Seattle, Washington	7-29-72
	11-14-72
	12-2-72
	1-7-73
	1-25-73
	2-12-73
	3-2-73
	3-20-73
	4-7-73
	5-25-73
	5-13-73
San Francisco, Pittsburg, Richmond — California	7-27-72
	8-14-72
	9-19-72
	10-7-72
	10-25-72
	11-12-72
	11-30-72
	12-18-72
	1-5-73
	1-23-73
	3-18-73
	4-5-73
	4-23-73
Thule AB, Greenland	3-24-73
Tin City AB, Alaska	8-1-72
	8-2-72
	8-19-72
	8-21-72
	9-7-72
	9-8-72
	9-26-72
	3-6-73
	4-12-73
	4-28-73
	4-30-73
	5-17-73
Upton, New York	7-28-72
	8-15-72
	1-25-73
	4-6-73
	4-24-73
	4-25-73
	5-12-73

TABLE 2. Comments on Turbidity Network Stations

1. Adrigole, Ireland. On Bantry Bay, Southwest tip of Ireland. Probably representative of turbidity over water most of the time. Some data problems but cause not known.

2. Andersen AB, Guam. Northern tip of Guam. With NE trade winds, data represents turbidity over water most of the time. Data very spotty following good first year.

3. Aspendale, Australia. Suburb (SE) of Melbourne. Excellent Data. Data taken at CSIRO, where they also measure turbidity with a pyrheliometer.

4. Atlantic City, N. J. Located at municipal airport about 10 miles N.W. of Atlantic City proper. Water to NE and E.

5. Barrow, Alaska. Within about 1 mile of Arctic Ocean. Don Pack could provide more details since this is one of his monitoring sites.

6. Ft. Collins, Colorado. No water. No data as far as I know.

7. Gainsville, Fla. Mid-state. Good data. Data taken by Dr. Green at University of Florida. They maintain a comprehensive radiation program.

8. Gough Island. Isolated island in the South Atlantic. Data should be good, though sparse.

9. Grand Prairie, Texas. Midway between Dallas and Ft. Worth. Good data - no water.

10. Green Bay, Wisconsin. At Austin Straubel airport at SW edge of city, 5 miles from city. (City between airport and Bay.) Good data.

11. Howard AB, Canal Zone. South side of canal. Land and mountains E-N-W. Data skimpy.

12. Houston, Texas. No data.

13. Kadena AB, Okinawa. Eastern side of island about mid-way, N-S.

14. Lajes, Azores. Surrounded by water but exact location not known.

15. Marion Island. Isolated island in South Atlantic.

16. Miami, Florida. Originally in downtown Miami; now on Key Biscayne with water on nearly all sides. Good data.

17. Pago Pago, American Samoa. On Tutuila Island at International Airport on South side of island. Land runs NE-SW so SE trade winds would bring air from ocean. This is another one of Don Pack's monitoring sites.

18. Pitcairn Island. No data.

19. Ramey AB, Puerto Rico. No data.

20. San Francisco, California. This station, along with Pittsburg and Richmond are run by the S.F. Bay Area Air Pollution Control District. The S.F. station is located in the downtown area.

21. Pittsburg, California. About 25 miles east of northern part of San Francisco Bay.

22. Richmond, California. About 2 miles north of Richmond inner harbor. Within 2-5 miles of bay from SE-W-NW.

23. Seattle. Our coordinates are for Seattle-Tacoma Airport which is about 3 miles from Puget sound. Station moved in 1970 to Redmond, north and east of original site and several miles east of Lake Washington.

24. Thule AB, Greenland. On Bay with water (ice) to west, icecap to east. Discountinued.

25. Tin City, Alaska. About 1/4 mile north of Bering Sea. Cape Prince Wales Mountains W and N. Lopp Lagoon 5 miles NW-N. Water to S, W, N.

26. Upton, N. Y. Essentially the center of Long Island. Data spotty.

TABLE 3. Tabulation of Turbidity and ERTS Data

	Turbidity	I. D.	Date
Barrow, Alaska	.70N	1239-21463	3-19-73
	1.02N	1241-21573 and 1241-21580	3-21-73
	.77N	1242-22034	3-22-73
	1.01N	1243-22090	3-23-73
	.94N	1257-21463	4-6-73
Grand Prairie, Texas	.55N	1002-16314	7-25-72
	.65N	1003-16361	7-26-72
	.72N	1255-16363	4-4-73
Miami, Florida	1.57N	1170-15232 *	1-9-73
	.93N	1242-15240	3-22-73
	1.64N	1260-15240 *	4-9-73
Houston, Texas	.94N	1072-16192	10-3-72
	.042N	1180-16194	1-19-73
	.72N	1054-16192	9-15-72
	1.19N	1073-16244	10-4-72
	.91N, .71N, .40N, 1.36N, .18N	1108-16194 *	11-8-72
	.96N, 1.44N, 1.00N	1217-16254 *	2-25-73
	3.73N	1253-16255 *	4-2-73
Pittsburg (San Francisco), California; Adrigole, Ireland; Anderson AB, Guam; Tin City AB, Alaska	No coincidences		

* B&W ERTS pictures obtained.

3.0 RESULTS

The analyses discussed in Section 2 resulted in 8 useful sites being identified, although coincidences of ERTS data and turbidity data were found for just 4 sites during the period July 1972 to May 1973. For these 4 sites there were a total of 18 days of coincidences with 24 data points possible.

These sites are listed in Table 3. The table also contains the dates when turbidity data were taken at approximately the time of ERTS overpasses, together with the turbidity values, in terms of the Elterman[2] mean value N, and the ERTS MSS identification numbers. The Elterman mean value of turbidity (total aerosol optical thickness in the vertical) N is .213 to base e at 0.5 μm, which is the Volz bandpass center wavelength. It should be noted that the Barrow, Alaska site has several days close together (in contrast to the normal 18 day period of ERTS); this is due to considerable overlap of frames on consecutive days at high latitudes, and they must all be examined in order to determine the best ERTS data for this study. Note that the Houston data show several turbidity values for two of the days; these Houston data were taken at several locations in the area on a given day, and the ERTS data must be examined carefully to determine if these variations are real or possibly due to errors. Dr. Pitts indicated that the variations are probably real since the Houston area has many industrial centers, so that the turbidity varies with location and with the wind direction.

A histogram of these turbidity values (neglecting the abnormally high 3.73 N value of 4-2-73 at Houston, which was subsequently found to be due to cloud interference) is given in Figure 2, and shows only four high values (> 1.3 N), with most of the values being less than 1.0 N.

ERTS 9 in. x 9 in. black and white prints for the 5 days of high aerosol content were obtained and examined. It was found that the 2 days

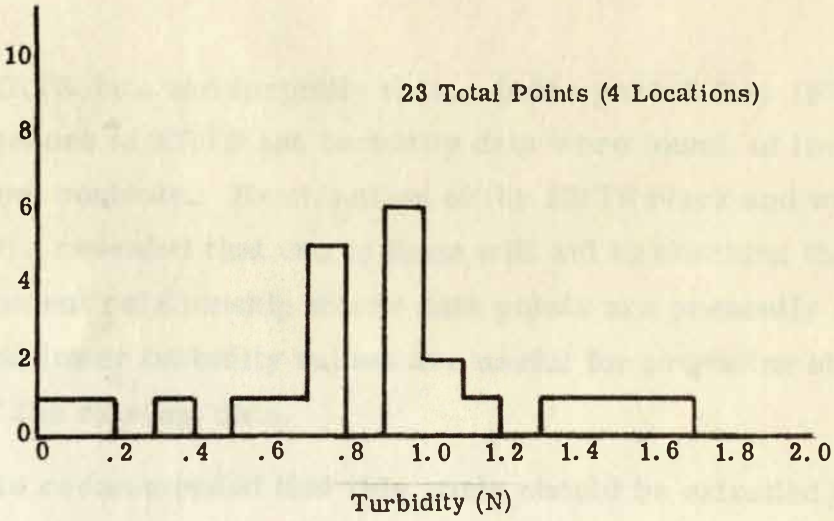

Figure 2. Histogram of Turbidity Values

at Miami are probably suitable for further analysis, and the digital data for these days will be ordered and analyzed under our NASA ERTS Follow-On Study. None of the three Houston data sets appears suitable for further analysis due to the presence of almost total cloud cover (giving the 3.73 N turbidity value which is really due to cloud rather than aerosols) in one case, and due to excessive water pollution on the other two days. This water pollution appears worse, in the black and white prints, than it did in the data at the Salton Sea with effluent present (see Figure 1).

The data in Table 3 were examined for high sun angles (zenith angle less than 30°) to investigate possible sun glitter effects. Only 2 days, at Grand Prairie (7-25-72 and 7-26-72), have high sun angles (14°). These data will be examined under the ERTS Follow-On Study.

<u>Conclusions and Recommendations</u>

This investigation has been successful in identifying seven NOAA-EPA turbidity network sites, plus the NASA-Houston network located within the Houston area, as being near to bodies of water, and hence suitable for relating ERTS data and turbidity data. In the period July 1972 to May 1973, 24 coincidences of ERTS and turbidity data were found; of these, 4 were high aerosol contents. Examination of the ERTS black and white prints of these 4 days revealed that two of them will aid in checking the radiance-aerosol content relationship where data points are presently sparse. Of course, the lower turbidity values are useful for providing statistical support of the existing data.

It is recommended that this study should be extended to cover ERTS-1 data for the period June 1973 to January 1975 so that more high turbidity values, and possible sun glitter conditions, might be obtained. In addition, the study should be expanded to include the current and future Landsat 1 and 2 coverage at these selected sites, since they will not be included in the NASA Follow-On Study. Inclusion of the current two satellites' coverage provides potential data points every 9 days instead of the previous 18 days. These selected sites could be requested to make their turbidity measurements at the actual time of the Landsat overpass to provide more weight to the data point.

Acknowledgements

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