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AIR QUALITY INDICES FROM ERTS-1 MSS INFORMATION, PR 568

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ABSTRACT

Comparison between ground based atmospheric turbidity network measurements and the average scene grayness from MSS Channel 4 data is in progress. Correlation between these two sources is promising. If continued correlation occurs for other ERTS-1 overflight dates and ground test sites, a new operational use of ERTS-1 useful to Federal, state and international organizations will become available.

1. INTRODUCTION

Over the last decade, the need to quantify the air quality of our nation has become apparent. New organizations, Federal, state and local, have been formed to manage this environmental resource. Though air quality monitoring has been carried on for decades, the sum total of these monitoring efforts at best has been sporadic, poorly planned, and very incomplete in depicting the areal and temporal features on scales larger than 20 kilometers. Major urban areas and industrial zones have been monitored by arrays of in-situ air quality sensors in which the intent was to understand the local or microscale (<20 km) distribution of the emissions and the corresponding variations of air quality; larger - mesoscale (20 - 600 km) distributions have been studied to a much lesser degree. Two or three fragments of mesoscale air quality information come to mind which bear review in order to set the stage for describing our work to date.

During the last ten years, many air quality display computer simulations have been attempted. A large number of these simulations follow a semi-deterministic approach where the pollution emissions of an urban area are mathematically modeled both areally and temporally. Transport and diffusion simulations of these emissions are performed taking into account local weather conditions and in some cases terrain.

Displays of the air quality resulting from such simulations are then compared with measured in-situ air quality and the models are then fine tuned for more faithful representations of the quantitative value of air quality. Models for handling total particulates (settleable and suspended), oxides of sulfur, carbon monoxide, etc. exist and follow the general simulation procedure described above. Experience with total suspended particulates (TSP) has shown that there is a considerable difference between calculated and measured values in the urban area and that it is largely a constant offset which is called background TSP. This background TSP is found to vary across the United States but is generally on the order of one-half of the annual urban values monitored. Such a widely distributed TSP we have chosen to call the mesoscale air quality (MAQ). Too few non-urban air quality stations exist in this country to get a firm quantitative measure of this MAQ distribution. National Oceanic and Atmospheric Administration in conjunction with the Environmental Protection Agency and the World Meteorological Organization of the United Nations have a world array of air turbidity sensing stations (approximately 50 in the U.S.) obtaining data toward understanding this mesoscale and even the macroscale phenomena. More will be said about this turbidity network data later in this report when MITRE's MAQ index efforts are described. A paper by Flowers, McCormick and Kurfis[1] related analysis of turbidity network data to mesoseale weather movements and rainfall showing the variability of turbidity over the United States.

A second insight into the MAQ has been described by Clodman and Taggart[2] where a correlation of APT pictures from the ESSA 2 satellite was compared with synoptic weather maps of the same time period. On numerous occasions when no major frontal areas were in the eastern United States and the atmospheric water vapor was negligible, large turbid areas of air were present. Clodman correlated these data with ground observations of ceiling and visibility and concluded that the ESSA 2 satellite pictures were showing large multi-state air quality disturbances.

Thus both reported efforts[1,2] have pointed to the existence of a mesoscale air quality phenomena, and our experiences with the simulations have pointed to a need for quantitative temporal and areal measures of MAQ if we are to manage our air quality control efforts wisely. In the

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[1] E. G. Flowers, R. A. McCormick, and K. R. Kurfis, "Atmospheric Turbidity over the United States, 1961-1966", Journal of Applied Meteorology, Vol. 8, No. 6, pp. 955-962, December 1969.

[2] J. Clodman and C. I. Taggart, "The Movement of Large-Scale Air Pollution Areas as determined by Satellite Photography", Unpublished paper for the Director, Meteorological Services Research Branch, Atmospheric Environmental Service, Downsview, Ontario, Canada.

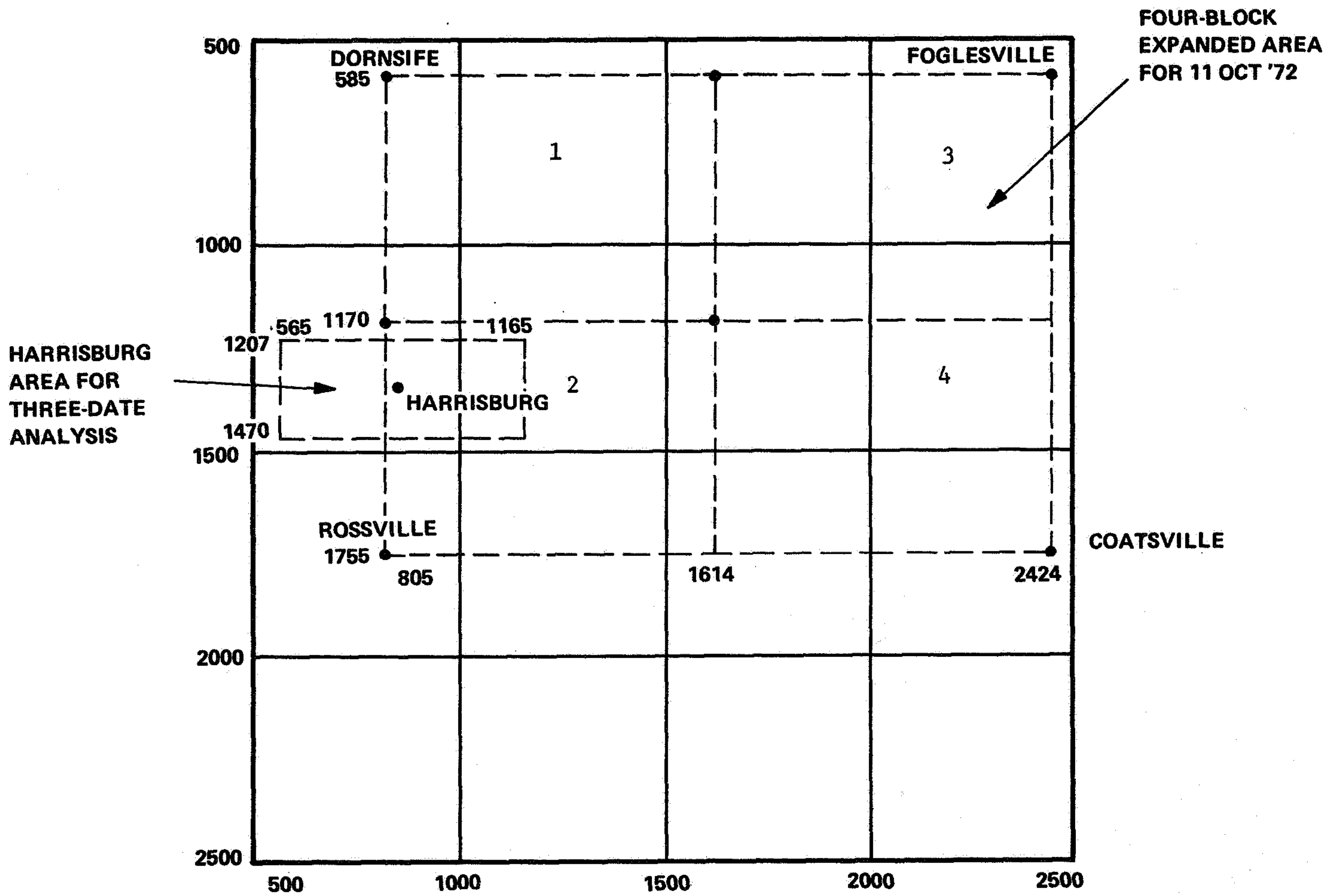
succeeding paragraphs we describe how we are attaining MAQ trends, non quantitative, areally and temporally. If continued correlations with the turbidity network and other Federal, state and local air quality assessments prove to be possible, then ERTS-1 will be a rapid means of mapping turbidity and/or MAQ. Care is required that we screen from our in-situ and turbidity network data all microscale effects. One crude measure has been to apply a population correction to the turbidity network data described below. Other corrections will be pursued in the next nine months of this investigation.

2.0 DISCUSSION

Our investigation in air quality has been in the development of an index of total air pollution burden variation (time and space); and consequently, calculation of background air quality trends from ERTS-1 data, uses two inputs. The two inputs are (1) the measure of total grayness (reflectance intensity) of one specific test area from sequential ERTS-1 overflights; and, (2) the earth observations of atmospheric turbidity (NOAA/EPA turbidity network with Rayleigh scattering and ozone absorption compensated for) over the same area on dates of ERTS-1 coverage.

The first step is to select the dates of ERTS-1 coverage in which clouds are not present over the test area. Second, compile all the turbidity network data about the test area possible. Such data are gathered on a daily (3 times per day) basis; and therefore good ERTS-1 MSS, all channels, on a relatively cloud-free day becomes the controlling factor for correlation date selection. Days in which turbidity data are not available are days of high percentage of cloud cover; thus, our ERTS data would also be of no value. On the approximately one pass over test site every 18-days schedule, we have found that 1 August 1972, 11 October 1972, and 16 November 1972 had near zero cloud cover and good ERTS imagery.

The basic analytical tool used for the ERTS-1 MSS data has been the intensity map program. The intensity map program (developed by Pennsylvania State University and called N-MAP) not only prints a thematic map of the reflectance of each channel, but also computes the average grayness statistics for the selected test site for each MSS channel. The average grayness is, of course, subject to interference by surface objects (heterogeneous nature of the test area) as well as by the total atmosphere and the sun light angle. Since both turbidity network data and the MSS data are recorded within a short time of each other (less than 35 minutes) the sunlight effect can be overlooked. Care must be taken in the test site selection for homogeneity. The Harrisburg training area boundaries are shown in Figure 1. The large, four block area shown is also being analyzed for turbidity variation on a given date.



*ELEMENT BOUNDARIES SHOWN ARE SPECIFICALLY FOR THE 11 OCTOBER 1972 MSS DATA. BOUNDARIES TEND TO CHANGE SLIGHTLY FOR DIFFERENT DATE'S COVERAGE OF THE "SAME" AREA.

FIGURE 1

AIR QUALITY TRAINING AREAS

Since the turbidity network[1,3,4] records turbidity using the Volz sunphotometer which measures a raw reflectance measure at 0.5 micrometers, we have used only ERTS-1 MSS Channel 4, which includes the 0.5 micrometer range data.

The second major input for analysis in addition to ERTS-1 intensity data, was turbidity network data. Originally operated for the National Air Pollution Control Administration (now part of EPA) by NOAA, the turbidity network reports observed and calculated readings of turbidity from sites around the world and in most states on a daily basis. The standard instrument is a Volz sunphotometer. Turbidity network data from seventeen stations about our test area (see Figure 2) for the three optimal ERTS-1 dates (1 August 1972, 11 October 1972, and 16 November 1972), and the days before and after each optimal date, have been analyzed with corresponding daily weather maps to calibrate for rainfall and frontal movement. Rainfall was found to have less than 24 hour effect, mainly lowering turbidity at a given monitoring site, and frontal movement was found to have at least a 48 hour lowering effect.[3] When analysis and calculation was completed for each of the 17 monitoring sites selected as most relevant to MITRE's Test Site 1, a fundamental vector/gradiant analysis was performed to estimate ground-measurable turbidity over Test Site 1. The figures obtained from these calculations (which essentially reflect, at a given elevation, the extinction produced by the variable amount of dust, haze, and water vapor in the atmosphere-- viz., total turbidity), have been plotted as the available ground truth information that gives an indicator of total turbidity over Test Site 1. Figure 3 and Table 1 show this information in graphical and tabular form.

Because many of the turbidity network stations are located in major metropolitan areas, a second series of calculations were made in an attempt to reduce all reporting stations to a uniform "background" standard unrelated to local sources, based mainly on the work of Larsen[5] with regard to relating total suspended particulate (TSP) to population. Larsen has shown that urban TSP approximately doubles for every order of magnitude change in population of that urban area. In our analysis all turbidity network reporting stations were scaled to a 10,000

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[3] R. A. McCormick, "Atmospheric Turbidity", Presented at 60th Annual Meeting of the Air Pollution Control Association, Paper 67-32, June 11-16, 1967.

[4] "Atmospheric Turbidity Data for the World", U. S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, Vol. 1, July - December 1971.

[5] R. I. Larsen, "United States Air Quality", Archives of Environmental Health, Vol. 8, pp. 325-333, February 1964.

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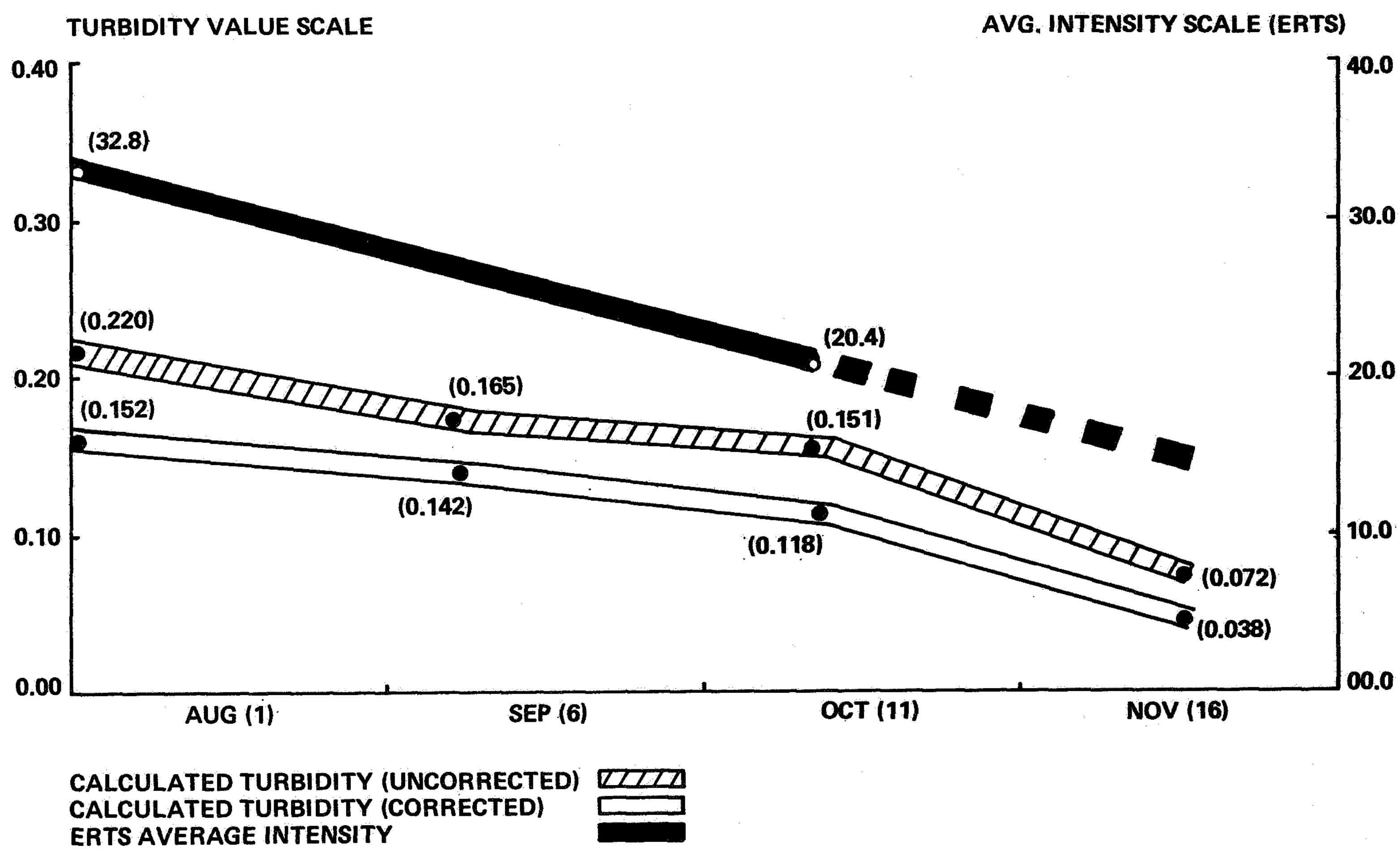
FIGURE 2
TURBIDITY NETWORK STATIONS
REPORTING DATA FOR THE MITRE ERTS-1 INVESTIGATION



COMPARISON OF ERTS-1 AVERAGE INTENSITY VARIATION WITH CALCULATED TURBIDITY VARIATION OVER THE HARRISBURG, PA. TEST SITE

FIGURE 3

ERTS-1 AVERAGE INTENSITY (CH. 4)

1 August 1972		32.8
11 October 1972		20.4
16 November 1972		24.9 (Corrected to 12.0)
11 October 1972	BLK 1	22.1
	BLK 2	24.4
	BLK 3	21.8
	BLK 4	26.4
	TOTAL (AVG)	94.7 (23.675)

CALCULATED TURBIDITY FOR HARRISBURG TEST AREA

	Uncorrected	Pop. Corrected
1 August 1972	0.220	0.152
6 September 1972	0.165	0.142
11 October 1972	0.151	0.118
16 November 1972	0.072	0.038

TABLE 1

CALCULATED TURBIDITY DATA

person population. Another choice would have been to scale to a rural population density more closely resembling a non-urban background. The many possibilities of introducing large specific error in this approach are well recognized, but it is nonetheless felt that, within an acceptable error range, useful correlations between in situ and satellite sensors will yield beneficial applications.

Our data presented in Figure 3 and Table 1 show such a trend. Comparison of ERTS-1 MSS Channel 4 data with ground truth turbidity network data for only three dates to this point in the MITRE investigation shows striking correlation, both in the scaled and raw data. As more data become available, and as analysis techniques are improved, ERTS-derived air indices and specifications for an optimal ERTS air quality monitoring system will be developed and presented.