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REMOTE DETECTION OF AEROSOL POLLUTION BY ERTS

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ABSTRACT

Photogrammetric and densitometric examination of ERTS-1 MSS imagery of Eastern Virginia coupled with extensive ground truth air quality and meteorological data has shown that the identification and surveying of fixed particulate emitters (smoke plumes) is feasible. A description of the ground truth network is included. The quantitative monitoring of smoke stacks from orbital altitudes over state size regions appears possible when tied to realistic plume models and minimal ground truth Contrast reductions over urban areas can possibly be utilized to produce isopleths of particulates when supplemented by local measurements.

I. INTRODUCTION

Reasonably cloud free ERTS-1 MSS imagery has been obtained of Eastern Virginia since launch. To date imagery has been examined both for detailed atmospheric phenomena including contrails, urban fires and smoke plumes of fixed emission sources, and for area-wide aerosol loading manifest by image contrast reduction. The development of the method by which ERTS imagery can be applied to assessment of particulate concentrations is progressing rapidly.

II. DATA SOURCES

Data sources can be subdivided for discussion purposes into those for which data is directly available to the investigators and those for which data must be generated by the investigators.

Data sources from which information is directly available include the emission inventory and ambient air quality monitoring program of the Virginia State Air Pollution Control Board (VSAPCB), local meteorological stations, urban fire departments and the FAA Air Traffic Control Office at local airports. VSAPCB emission inventory (partial listing in Figure 1) has been kindly made available to us so that we have a complete listing of all major industrial and governmental aerosol fixed emission sources in the area, together with an estimate of the quantity and quality of the effluent. The regular air quality monitoring of the VSAPCB also yields periodic information on concentrations of particulates and SO_2 at numerous sites (cf. Figure 2) in the test region, as well as continuous NO, NO_x, O_3, CO, and coefficient of haze (COH) and meteorological information at certain selected sites. Further meteorological information is received from the numerous weather stations (cf. Figure 3) that abound in the area because of the large number of naval installations. Aerosol plumes that are not predictable in location or character include those of urban and rural fires, and thus, fires in progress at the time of the satellite pass are reported to us by local fire departments. In addition, the pattern of contrails over the area at the time of each pass has to be verified by finding the location, direction, and altitude of all airplanes in the area capable of producing one.

Information generated by the investigators as ground truth correlation to the ERTS imagery includes much oblique and some aerial photography of selected smoke plumes, plus the data gathered and analyzed by three well-equipped laboratory facilities at Old Dominion University: an air pollution monitoring laboratory, a mobile air pollution and meteorological monitoring van, and an air pollution standards laboratory for the calibration of instruments and analysis of samples from the other two laboratories.

Photographic studies of particular smoke plumes are an essential portion of a ground truth program because they yield high resolution information, are subject to a large variety of photometric analysis techniques, and are relatively inexpensive. Typical photographs used by us in the past include NASA U-2 photos of the area, aerial photos from a local radio station weather helicopter, and photos taken by us from tall buildings during satellite passes. The U-2 high altitude photos show in higher resolution than ERTS imagery the spectral signature and dispersal of specific plumes under varying meteorological, seasonal and background conditions. Lower altitude aerial photos have been made by the helicopter of local radio station WTAR-AM during its twice daily traffic report flights. Finally, we have made horizon photos from the roofs of tall buildings using both regular and telephoto lenses, and on occasion using filters that match the band passes of ERTS MSS bands 4, 5, and 6.

The first of our three facilities at Old Dominion University devoted exclusively to air pollution studies is an air monitoring laboratory that is designated an official monitoring station of the VSAPCB, but that goes well beyond the instrumentation required for that task. The following instruments are currently in use for measuring air quality:

a continuous chemilumenescent ozone (O_3) and nitrogen oxide (NO, NO_2, NO_x) monitor; a continuous flame photometric sulfur compound (H_2S, SO_2) analyzer; a continuous flame ionization methane and total non-methane hydrocarbon analyzer; a twenty-four hour integration time SO_2 bubbler train; four high volume air samplers; and a two hour integration time coefficient of haze tape sampler. These instruments, sampling off a forty foot glass intake manifold provide information that is correlated to local meteorological variations. Such variations are monitored on the site by weather instruments mounted on a seventy foot tower giving continuous readings on analog recording devices of wind speed and direction, temperature, insolation, relative humidity, and air pressure.

The Mobile Air Pollution Laboratory is similarly equipped to monitor air quality and meteorological data at specific test sites, such as Wallops Island and Great Dismal Swamp, where month-long studies are scheduled for summer, 1973. This 8' x 18' trailer on tandem wheels can collect data with the following facilities: continuous monitors for ambient levels of O_3, NO, NO_2, NH_3, SO_2, H_2S, methane and total hydrocarbon; continuous temperature, wind speed and direction monitors at four altitudes to forty meters; ground level monitors of humidity, barometric pressure and insolation; suspended particulate monitors including millipore filters, high volume air samplers, and a single band nepthelometer; and PDP/8 Digital Acquisition System with teletype and magnetic tape units for instrumental control of the entire monitoring operation, and data manipulation and storage.

Both the mobile and fixed laboratory are supported by the Air Quality Standards Laboratory, which calibrates all instruments. Facilities include an isothermal gaseous permeation tube for providing metered flows of pollutants at known concentration levels for calibration of instruments, and devices for generating pure samples of each pollutant; milligram pan balances, microscopes, dessicators and ovens. Finally, elemental analysis of air filter samples can be done locally by x-ray fluorescence and x-ray diffraction, and additionally neutron activation analysis can be done using facilities at Virginia Polytechnic Institute.

III. CONCLUSIONS

Large amplitude high frequency variability of aerosols presents a serious problem which is beyond conventional economic resources for information sensing and processing. It has been concluded that the only hope for an adequate definition of pollution concentration would be through a judicious integration of the following four measurement, analysis and diagnostic approaches.

a. Conventional direct sensing systems, which would provide a quantitative input. (Air quality and meteorological data)
b. Remote imaging capabilities from aircraft and ERTS type satellites to provide the character of spatial resolution of the aerosols.

c. Numerical models, which combine the above and provide high temporal resolution.
d. Improved understanding of the constituents, their sources and interaction processes, which provide the basis for improved application of all the above.

In pursuit of approaches a, b, and c above the ground truth system has been developed, ERTS imagery has been analyzed and starts made on adopting numerical models for plume behavior so that the ERTS imagery may be quantified and the human intake level of aerosols determined. Smoke plumes generated by fossil fuel electrical plants are regularly detected. Numerous smaller industrial emission sources have been discovered and reported to VSAPCB. Contrails and urban fires have been detected. Detailed analysis of the characteristic plume geometries is being accomplished from ERTS imagery.

Computation of atmospheric diffusion coefficients from photometric analysis of ERTS imagery appears quite possible. This can be incorporated into numerical models to assess surface concentrations which will be verified by the mobile laboratory. This program can be solved backwards to provide estimates of stack emission rates and thus provide a great cost reduction in stack monitoring.

Figure 4 shows a drawing of a series of three plumes as observed on 23 September, 1973. Each is over 10 kilometers long. A densitometric scan perpendicular to the plumes symmetry axis is shown in Figure 5 . Although final analysis of imagery and ground truth is not yet accomplished, this plume (C) appears to closely follow standard Gaussian diffusion models. It is recognized that image spread may produce problems but this can be solved by examination of high contrast subjects and/or by incorporation of spread effects in plume models.

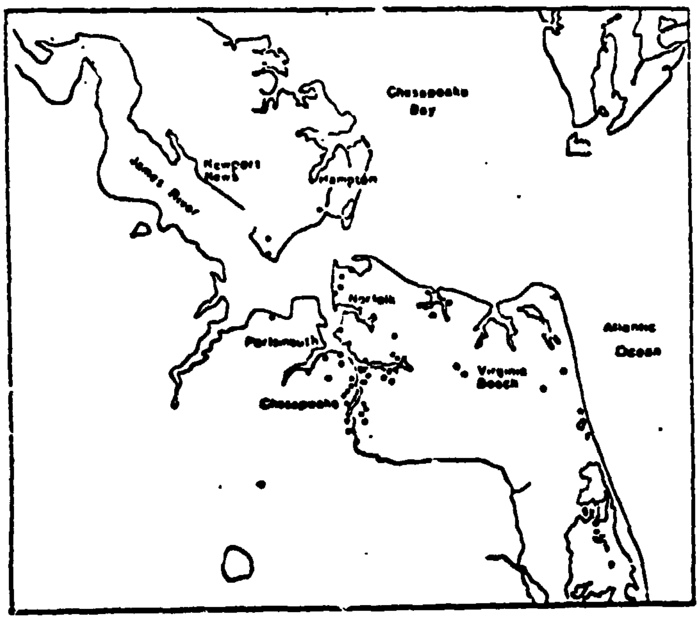

Figure 1: Locations of Major Fixed Sources of Particulate Polluters in Hampton Roads Region.

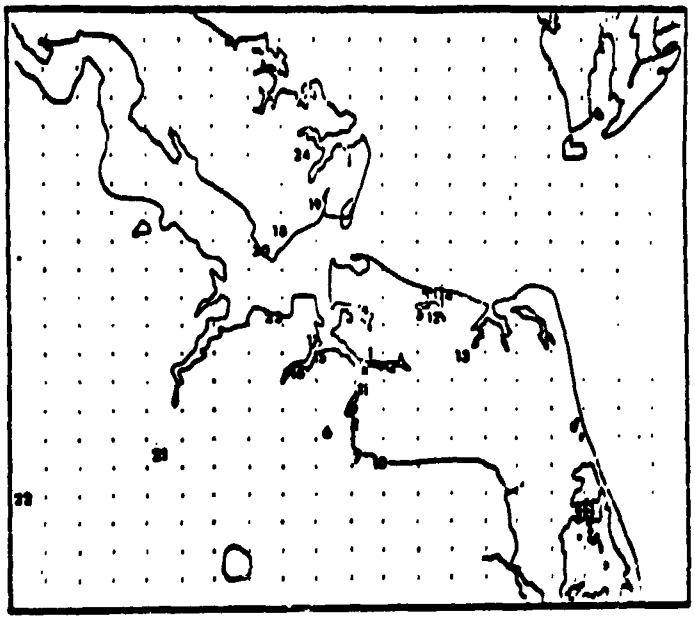

Figure 2. Locations of Major Air Quality Monitoring Sites in Hampton Roads Region (VSAPCB and ODU).

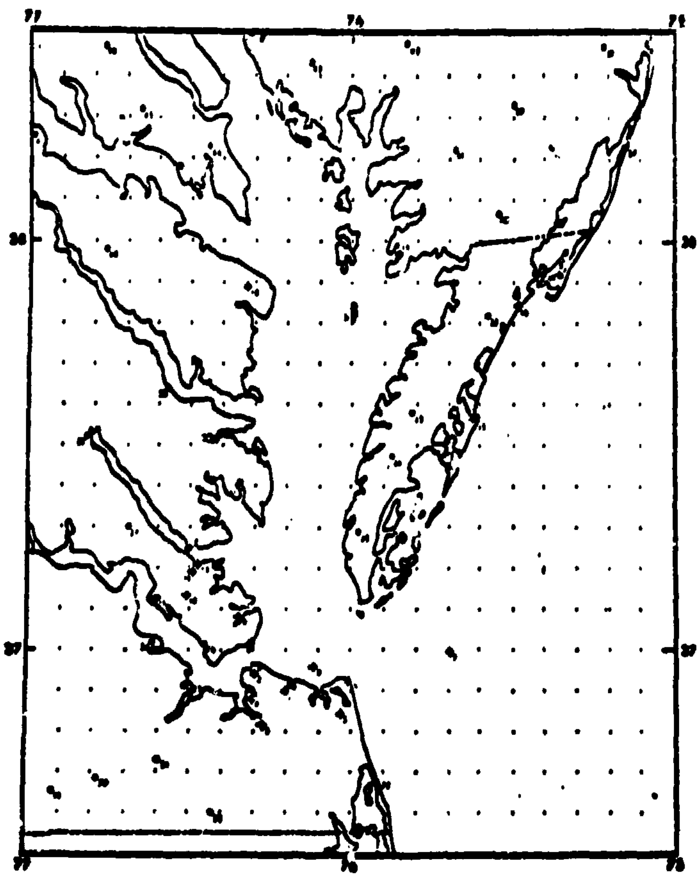

Figure 3 Locations of Meteorological Stations in the Target Area.

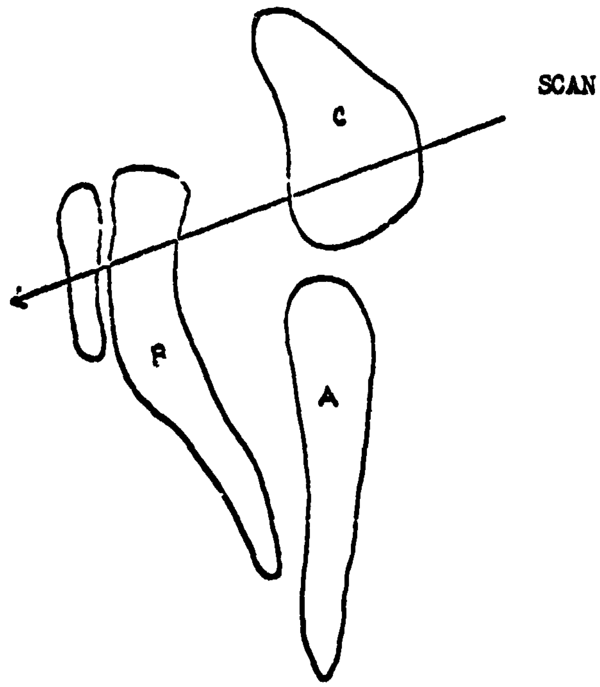

Figure 4: MSS 5 23 Sept 1972 Image I.D. 1062 15193 5
Several smoke plumes near Chester, Virginia

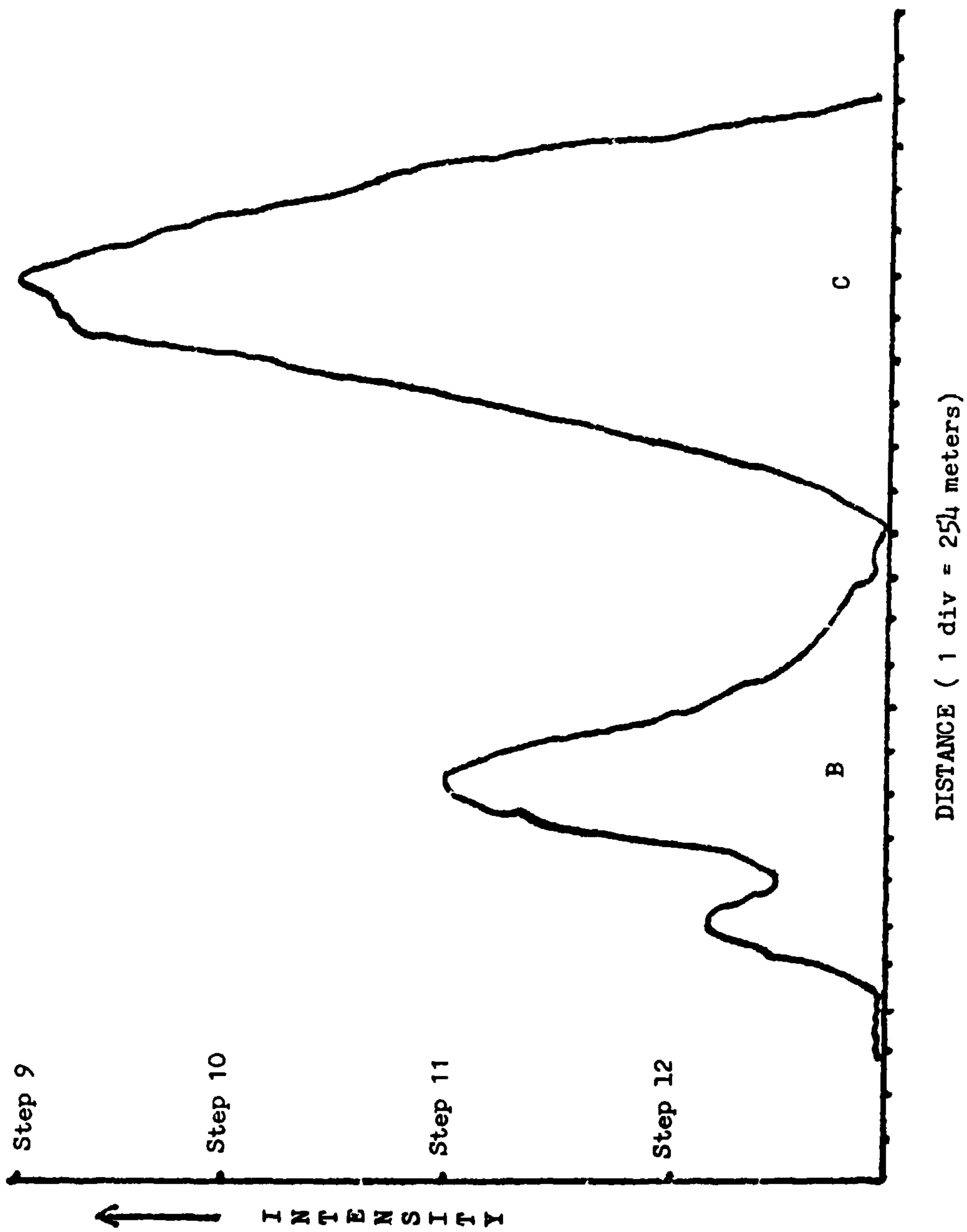

Figure 5: Densitometer Scan Perpendicular to Symmetry Axis.

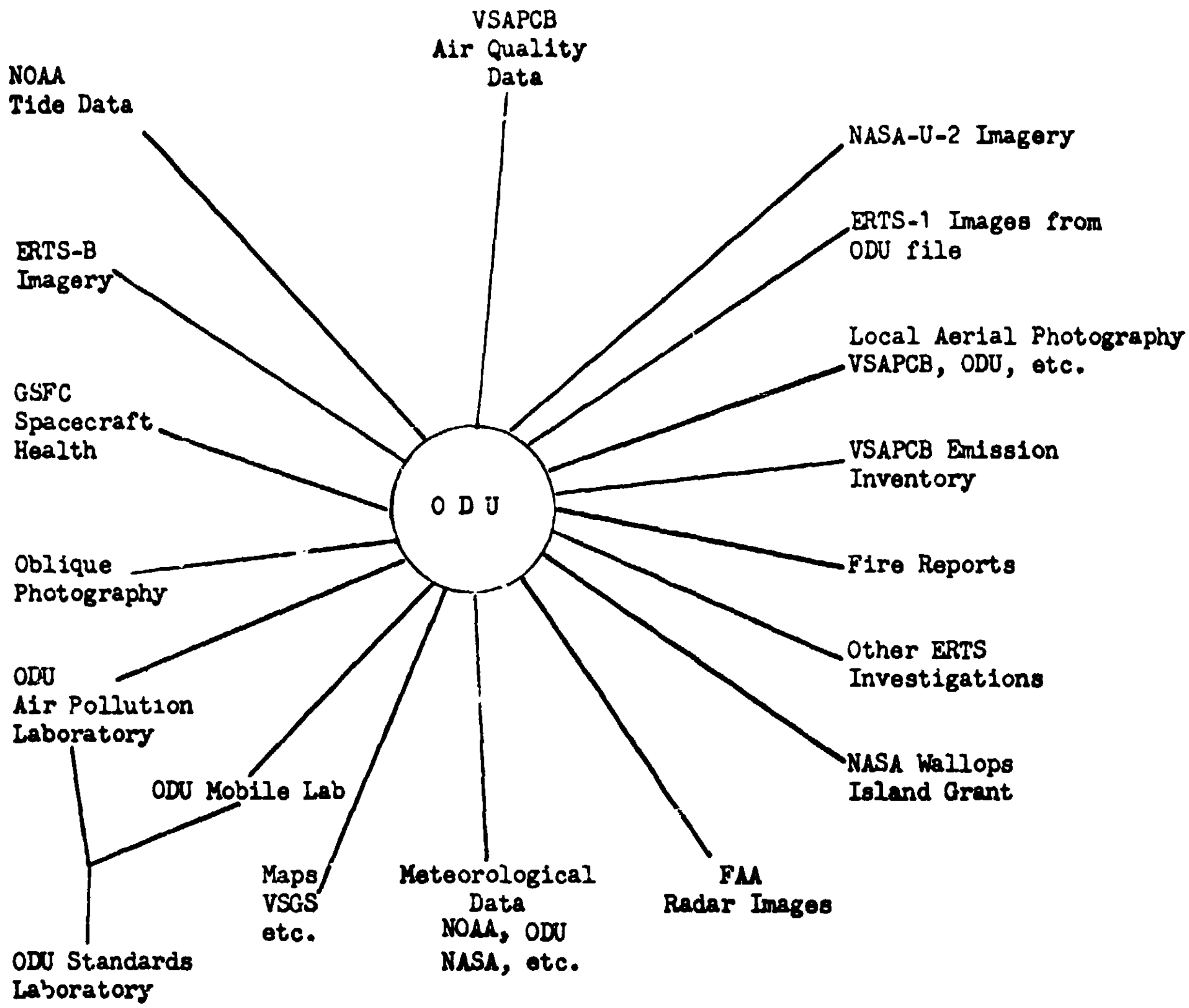

Figure 6: Data Input Sources to Earth Resources Analysis Laboratory (ODU).