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VIEWING URBAN AND REGIONAL AIR QUALITY FROM SPACE USING SPACEBORNE LIDAR

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1 INTRODUCTION

In 1994, NASA Langley Research Center operated the Lidar In-Space Technology Experiment (LITE) from the space shuttle Discovery (McCormick, 1996). For nine short days, LITE gave unprecedented global views of natural and man-made aerosols. LITE showed conclusively that important observational data on urban particulate emissions can be made from space.

In 2004, NASA will launch the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO, the mission formerly known as PICASSO-CENA), a second generation spaceborne lidar system. The polar orbit of CALIPSO will allow daily coincidences of the lidar footprint with urban areas around the globe. This paper will discuss the potential for routine observation of urban to regional scale haze from the CALIPSO mission.

2 LITE

LITE was launched on the Space Shuttle Discovery on September 9, 1994. For ten days, LITE measured aerosol structures that had only been previously investigated in relatively localized missions. A significant number of measurements were made of stratospheric and tropospheric aerosols, from desert dust, and biomass burning.

Our own work has focused on anthropogenic emissions (Strawbridge and Hoff, 1996; Hoff and Strawbridge, 1996). We have observed urban and regional scale pollution signatures in those data. In over fifty cases, we observed urban aerosol plumes downwind of these cities. Moscow, Los Angeles, San Francisco (Strawbridge and Hoff, 1996), the urban complex near northern Virginia (Hoff et al., 2001) all showed up vividly in these images. Although most of the analysis to date has been qualitative, two cases showed the potential for examining the quantitative aerosol mass in these urban plumes.

2.1 Virginia regional haze

On Orbit 117, LITE passed over the industrialized east coast of the U.S. Figure 1 shows a gray scale image of the plume seen emanating from the U.S. east coast. We have used an estimated extinction to backscatter of 43 sr^{-1} to compute the aerosol extinction in this orbit. Below the 2 km boundary layer, we found the maximum extinction to be approximately $2.9 \pm 1.2 \times 10^{-4}$ m^{-1}. The "lidar ratio" or extinction to backscatter ratio is a subject of intense study and a recent paper by Anderson et al. (2001) suggests that values of 30-60 sr^{-1} are common in the northeastern U.S. We then used an estimate of the specific scattering efficiency of 8.5 m^2 g^{-1} to convert these extinction values to mass. This value is based on our prior studies of regional northeastern hazes (Hoff et al, 1996) and from model estimates of the extinction efficiency of submicron aerosols (Charlson et al, 1991), The peak submicron aerosol concentration estimate is 60 μg m^{-3} with a boundary layer average of 34 ± 18 μg m^{-3}. Surface observations of PM2.5 mass are shown for this day in Figure 2 and the profile of mass derived from the lidar in this region is shown in Figure 3.

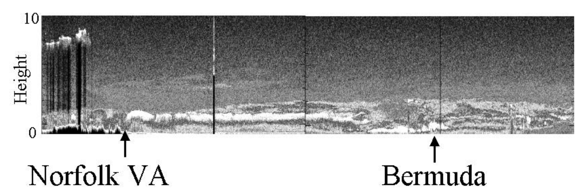

Figure 1: Lidar cross-section of the lowest 10 km of the atmosphere near Richmond, VA. on Orbit 117. The regional scale haze plume extends some 1500 km out into the Atlantic.

2.2 Taiwan

In a similar estimation exercise near the island of Taiwan, we estimated that the flux of sulfate from the island was 6.6 ± 3.0 μg m^{-3} (Hoff et al, 2001). The estimate of sulfate from the emissions rate in inventories by GEIA and a 2% per hour conversion rate during transport from Taiwan to the orbit track (20 hrs) gave 4 - 5.3 μg m^{-3} $SO_4^{=}$. The ability to estimate mass emissions from regional scale urban and industrialized sources appears to be promising from spaceborne lidar.

3 CALIPSO AND THE FUTURE

NASA will launch the CALIPSO mission in April of 2004. In a polar orbit, CALIPSO will observe all of the world's urban areas during a 16 day repeat cycle. Figure 4 shows the orbit tracks over Europe during sixteen days of the mission.

The potential to use lidar derived data from CALIPSO to give estimates of regional extinction (and with approximation regional PM mass estimates) will be

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exceptional. One can only imagine the potential of

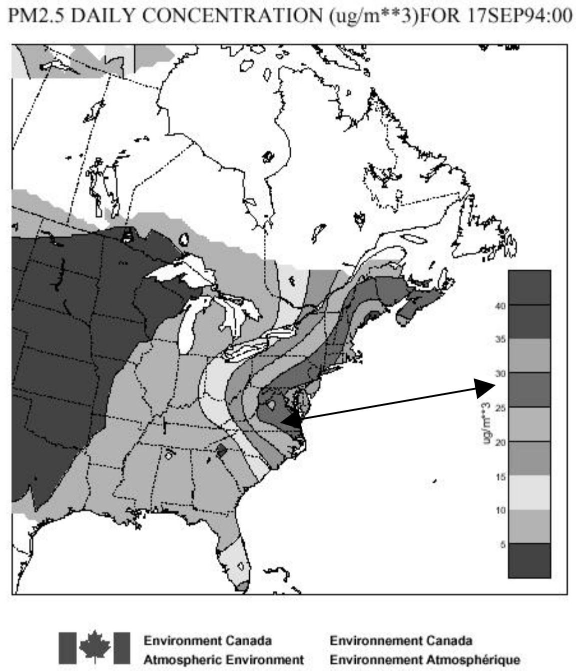

Figure 2: PM2.5 concentration from the Canadian NATCHEM-Particles database (courtesy R. Vet, MSC, Canada). The concentration near Washington, D.C. was 30-35 $\mu g\ m^{-3}$ and 25-30 $\mu g\ m^{-3}$ further south.

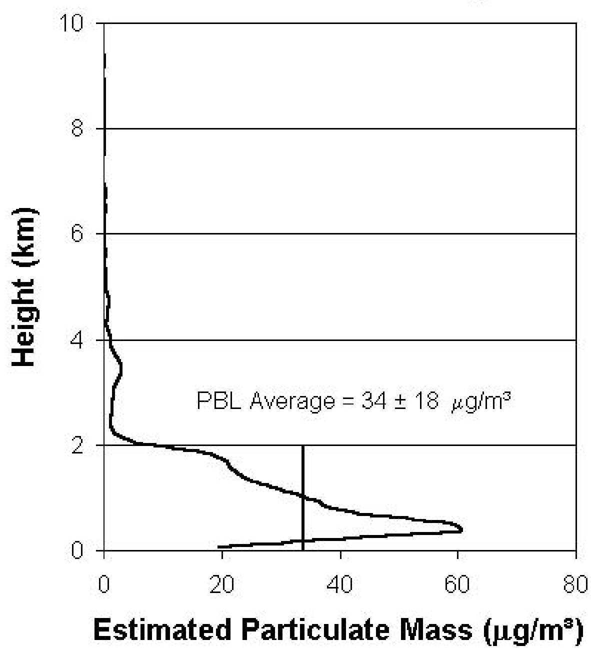

Figure 3: LITE estimated particulate mass using the specific extinction calculation above. The PBL average agrees well with the surface measurements in Virginia.

providing global estimates of particulate mass. Importantly, these estimates can be made over areas of the globe where such measurements are not presently feasible. There will need to be a recognition that these mass retrievals are just estimates due to the approximations used in converting from extinction, but for many places in the globe such data are not available at any level of confidence. CALIPSO will help focus future investigations of aerosol emissions globally.

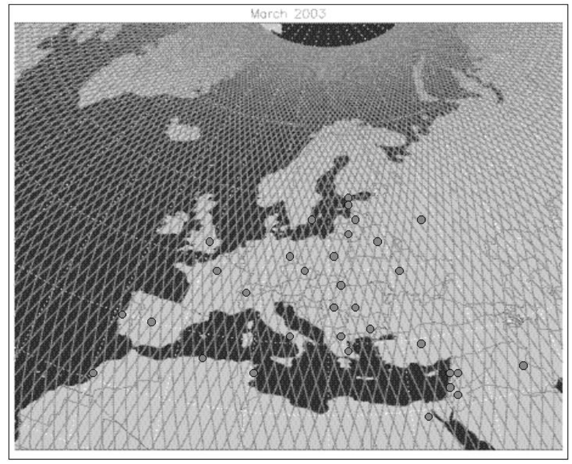

Figure 4: 16 day orbital coverage from CALIPSO showing the positions of European capitals.

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