25PA5 **THE PACIFIC '93 AIRCRAFT LIDAR EXPERIMENT**

Raymond M. Hoff, Michael Harwood and Andrew Sheppard
Atmospheric Environment Service, Centre for Atmospheric Research Experiments
R. R. #1, Egbert, Ontario L0L 1N0 Canada
Phone: (705)458-3310 Fax: (705)458-3301 Email: rhoff@cid.aes.doe.ca

One of the major uncertainties in the prediction of oxidant behaviour in the Lower Fraser valley in southwestern British Columbia, Canada, is the spatial variability of the pollutant loading throughout this area of complex topography. In many ways the Vancouver urban airshed which forms the western end of this valley (see Figure 1) is similar to the Los Angeles area in topography. The large urban area (1.5 million population) will emit pollutant precursors which will form oxidants and particulates which travel up the valley and recirculate in sea-breeze regimes. In the vertical, the extent of plumes aloft and the heights to which they are capped will strongly control the concentration of pollutants and thus the photochemistry of the region. In the horizontal, the large variation of land types (ocean, rural farmland, urban areas, and mountains) makes the dynamics of the pollutant movements challenging. This basin has the potential during summer subsidence inversions to have many-day land breeze/sea breeze events which trap the pollutants between the ocean to the west and the mountains to the east.

The Atmospheric Environment Service flew a 1.064μm backscatter lidar on the National Research Council of Canada/Institute for Aerospace Research Convair 580 aircraft during the Pacific '93 Experiment. Since this system was new and the eye-safety constraints on the system demanding, it was uncertain at the beginning of the project whether the lidar would have the sensitivity to monitor the large range of aerosol types to be encountered in Vancouver.

During Pacific '93, the experimental plan required that the lidar fly high altitude lines above 14000 ft. Eye safety is the reason for this height. An eye-safety analysis of the lidar system showed that for any observer using 50 mm binoculars viewing the lidar beam directly, the lidar (with a 7.2 mrad divergent output beam) would be eye-safe if 10000' (3000 m) of offset were maintained. In addition, however, the direct beam viewing criteria for the unaided eye required the maintenance of a 380m offset and, thus, a 1300' buffer was set between the IAR aircraft and other aircraft. Since Vancouver airspace is controlled, those other aircraft could be found up to 12500' and thus the base altitude of 14000' MSL was chosen. In the eastern end of the valley, some mountain tops were 6000' and thus with the 10000' offset, the aircraft altitude was raised to 16000'.

Airborne lidar provides a strong tool by which the vertical dispersion of pollutants aloft can be tracked in the valley. Individual particulate plumes were detected and traced away from their sources. Boundary layer heights can be inferred if the production of aerosols below the inversion is sufficient to generate a gradient at the top. Pumping of material out of the boundary layer through convective activity and orographic lift was observed. In the polluted areas around the industrial sources in Vancouver, the lidar was able to follow wide-spread plumes far up into the valley and to determine that upslope flow would carry these pollutants to the tops of local mountains and out again over the Fraser Valley. Sources of aerosol pollutants from as far south as Anacortes, Washington, were seen with regularity and some unexpected pathways of pollutant transport were identified. Several latitude-height colour cross-sections giving examples of these processes will be shown in the oral version of this paper.

Additionally, the lidar was able to determine boundary layer heights throughout the valley, even in relatively optically thin aerosol regions. Since the ultimate goal of the Pacific '93 experiment is to validate an airshed oxidants model (based on CSU RAMS or an AES community mesoscale model), the height of the boundary layer was an extremely important parameter. Figure 2 shows the results of gridding the lidar backscatter gradients through the valley on one afternoon of the study. While there is noise from some of the topography, a general increase in boundary layer height with distance inland (the shoreline internal boundary layer, IBL) is consistent with both the model expectations and sonde profiling.

One difficulty is in assimilating this large volume of lidar data. The use of colour contours (while admittedly of high visual impact) has low overall information transfer for a "quick picture" of the valley plumes. Because of this and because many of the users of these data are not lidar specialists, the lidar backscatter at 1.06 μm was scaled to extinction using a constant backscatter/extinction ratio of 0.03 sr^{-1}. The resulting integrated backscatter profiles from 1.5 km to the surface (1.5 km was the maximum height of locally generated aerosol seen in the study) were contoured to give optical depth maps such as Figure 3. In Figure 3, the optical depth has been multiplied by 1000 for ease in viewing the numbers and thus, 20 represents an aerosol optical depth of 0.02. As can be seen by the figure, the overall optical depths are not large and correspond well with the ambient visibilities (at 0.55 μm) averaging 40 km and reaching perhaps 8 km in episodes.

This scaling may be inaccurate for a true aerosol optical depth if the extinction to backscatter ratio varies widely. We do have parallel measurements on the aircraft and at the surface of the particle size distribution (from optical probes) and total scattering coefficients of the aerosol (from nephelometry) at the same time. Efforts are continuing to analyse other optical properties of the aerosol and to contribute to the speciation of the aerosols in this valley. Not surprisingly the aerosol makeup in Vancouver is similar to other west coast cities -- somewhat rich in nitrates, poor in sulphates and very rich in organics (hydrocarbons). These results and the mapping capability of the lidar may have considerable impact in defining needed reductions of emissions from major source categories in the future.

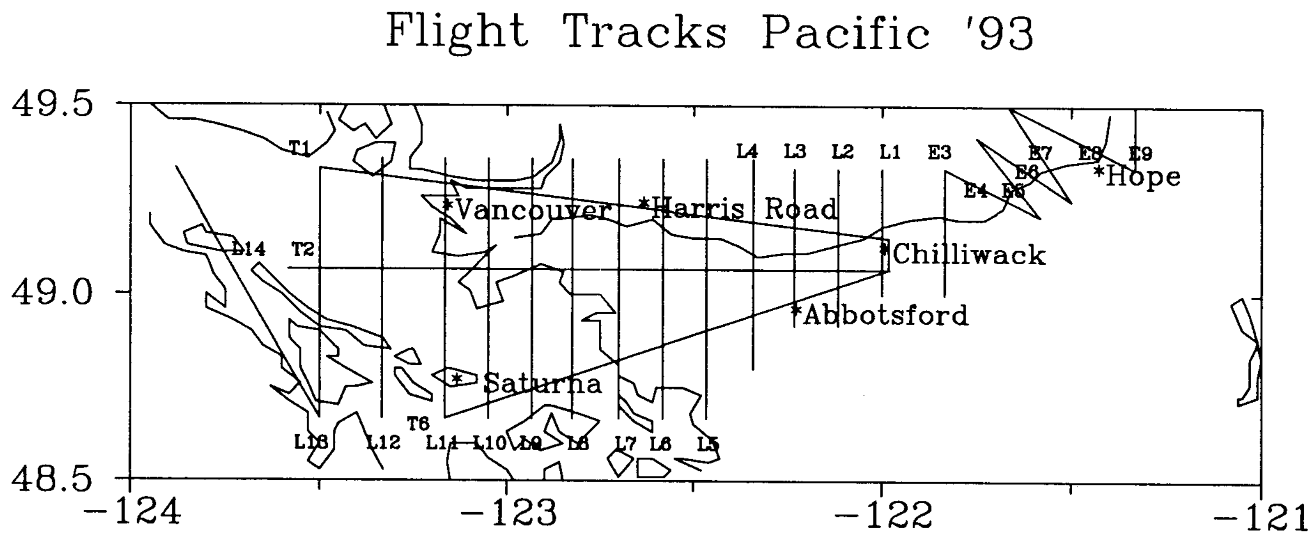

Figure 1: Flight tracks flown by the lidar in Pacific '93.

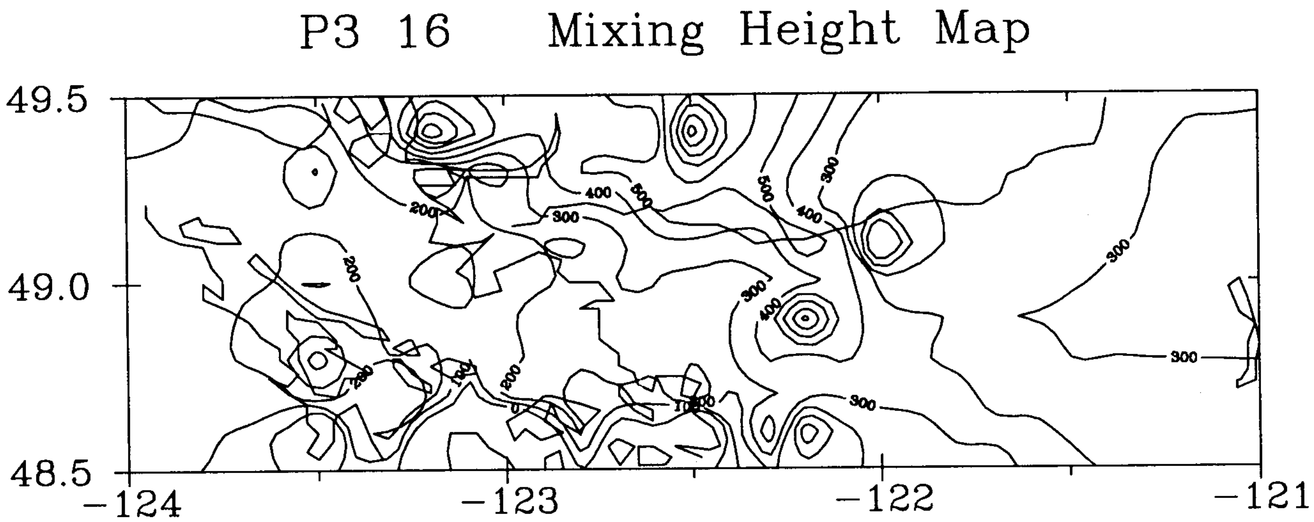

Figure 2: Mixing height contours (m) determined from the lidar backscatter.

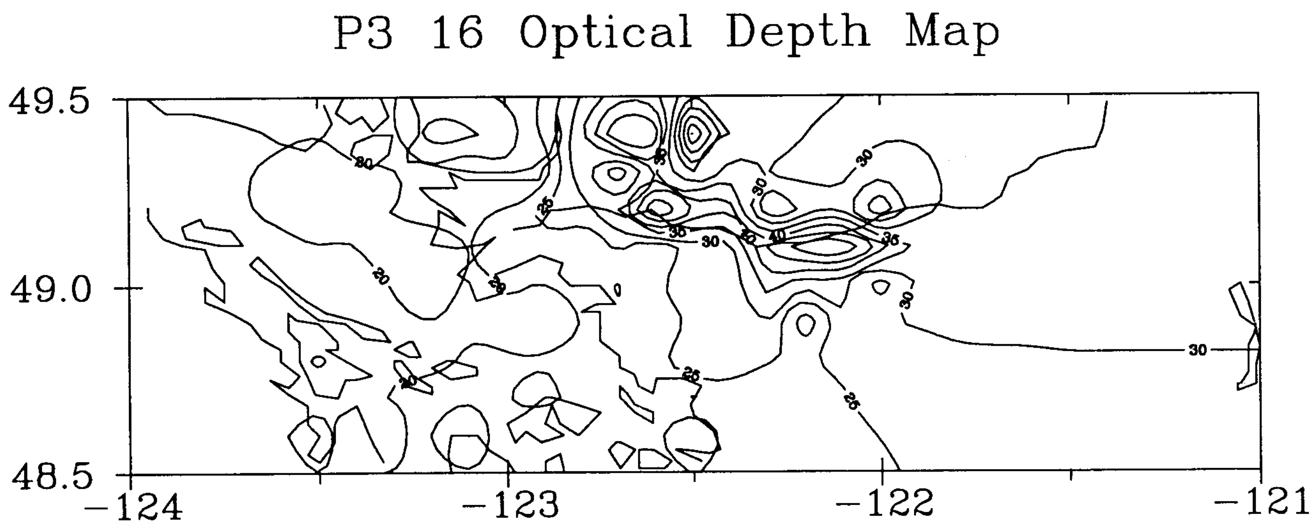

Figure 3: Estimated aerosol optical depth (at 1.064μm) from the Nd-YAG backscatter results, using a β/α ratio of 0.03 sr^{-1}.