LIDAR experiments at the Space Geodesy Facility, Herstmonceux, UK

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Introduction

We are developing a LIDAR capability, ultimately to run concurrently with satellite laser ranging measurements, at Herstmonceux, UK. Our interest is in monitoring atmospheric pollution, boundary layer heights and cirrus properties over the site. For preliminary testing we have developed a modified version of the laser ranging software and used the existing laser ranging hardware to detect backscatter at a range of heights of from one to 14 km vertically above the site. During experimental runs the C-SPAD detector is gated in few-hundred metre increments from close to the telescope to beyond the tropopause, and time-tagged single-photon backscatter events are detected. Over the experimental period of a few minutes a vertical profile of atmospheric response is mapped and various layers detected. In this paper we discuss some analysis of these preliminary results and state plans for future enhancements.

Backscatter experiments

With the telescope set towards the zenith, we gate the C-SPAD for usually 30-seconds at each height above the site, from 1000 to 14,000m and collect backscatter events. The initial height of 1000m is imposed on this experiment by the separation between the transmit-receive telescopes, whose fields-of-view begin to intersect about 800m from the mount.

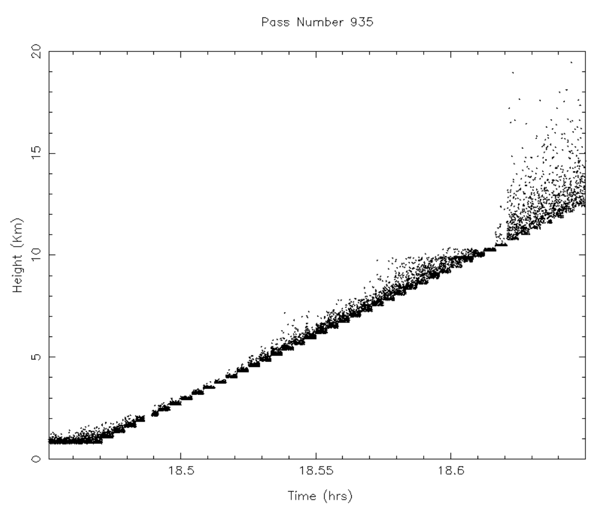

Figure 1. Raw observations of backscatter events vertically above Herstmonceux

The plot in Figure 1 shows the 'stepladder' that results when the raw event-height results are plotted against time. During the setup process at the first height, neutral density filters

(ND) were entered manually into the receiver optical path to ensure that the range gate was approximately uniformly filled with events. Thereafter, ND values were not changed.

Preliminary analysis

We carry out a preliminary analysis of the backscatter measurements by taking the raw observations and computing for each noise point its distance above the station, on the assumption that for night-time observations all data shown in Figure 1 result from laser backscatter in the atmosphere. On this assumption and, at this stage, ignoring the decrease of laser energy with height, we therefore are able to measure return energy as a function of height and thus probe atmospheric particulate density.

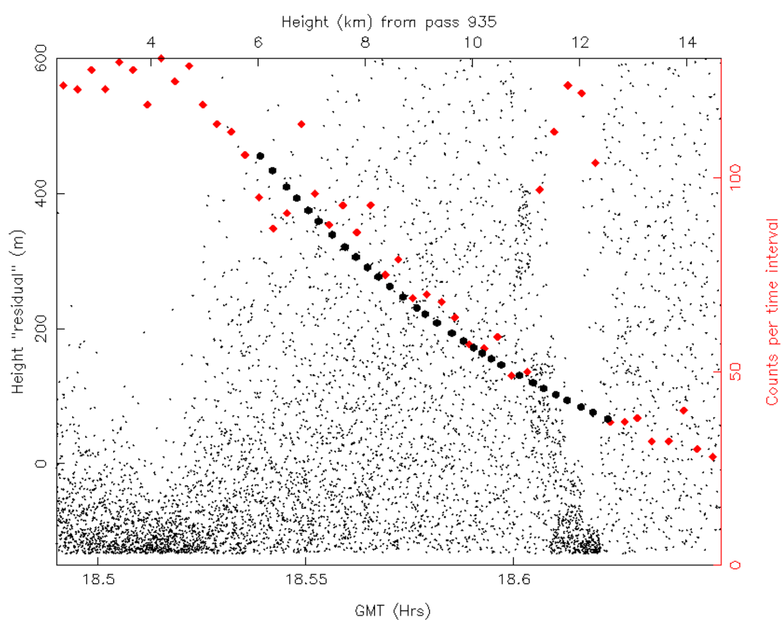

Figure 2. Backscatter events plotted as a function of time and height in the atmosphere

Figure 2 shows the results of this simple analysis applied to the observational session of Figure 1. If the degree of backscatter from the atmosphere was independent of height, the plot would show a uniform density of points. However, this is clearly not the case, and from the plot we suggest that a haze layer can be seen at about 4-5Km above the site, followed by a further layer at 12 km, probably identified with the tropopause. The red dots, plotted against the right-hand vertical axis, give the total number of events detected in each 3-minute interval throughout the experiment. We have fitted to those red points, strictly between the two haze layers (6 to 11km), the exponential decay curve shown by the black dots, and determine from it an atmospheric scale height of approximately 6km. Note that this fitted curve is extended in the plot beyond the region of the fit, through the high level layer, where it links with the observational totals for 13km and above. More work will be required to refine this analysis, in particular to estimate the decrease of laser energy with height.

Monitoring cloud and contrail optical density

In a related study, we are interested in the possibility of monitoring contrail and cirrus optical depth during standard laser ranging. The airspace over Herstmonceux is a busy flight path to Gatwick as well as a gateway into the UK for transatlantic routes, and a recent study into contrails over this part of the country (Stuber *et al*, *NATURE*, June 2006) has highlighted the importance of contrails as contributions to warming effects. However, little is known about the characteristics of contrails, and estimates of their optical depth vary greatly.

During laser ranging, the tracking software automatically maintains the average return level at single photons by inserting varying degrees of ND filters in the detector optical path. Compared with a model of the link budget for the ranging process, the degree of ND actually required to achieve single photon returns is a measure of departure of atmospheric transparency from that in the model. In particular, if the pass transits a contrail, the required change (reduction) in ND necessary to maintain single photon returns is a direct measurement of the additional optical depth of the atmosphere due to the trail.

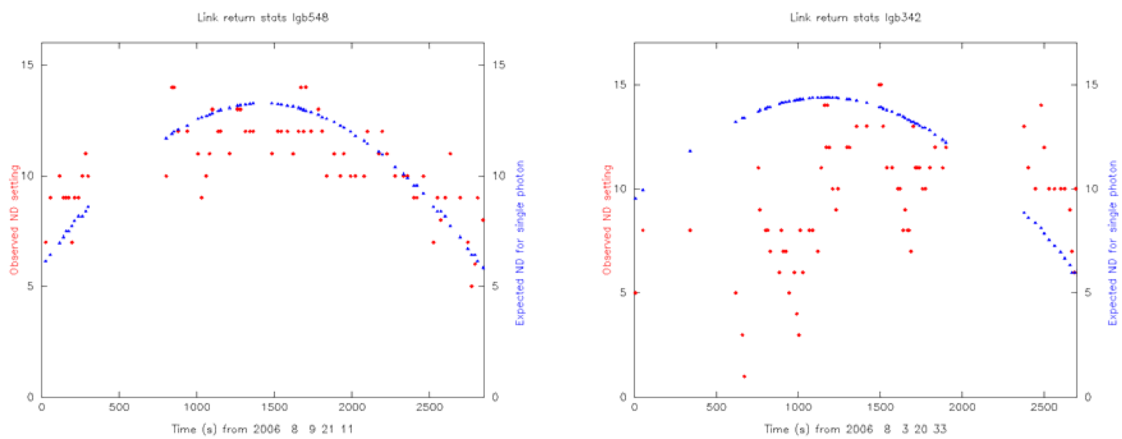

Figure 3. Comparison of theoretical (blue) and measured (red) ND required for single-photon laser return from LAGEOS-2.

The plots in Figure 3 above show two tracking instances of modelled (blue points in smooth curves) and actual ND (red, scattered points) inserted by the operating system; the left plot is in a clear sky and the right plot shows three passages of the satellite behind contrails. The clear sky data follows the predicted ND values fairly well, the small changes being due to pointing variations from optimal. During the contrail passages, ND is systematically removed and replaced, giving a profile of contrail optical density.

Conclusion.

Both the observational experiments reported in this paper are at preliminary stages. Much more work is required to improve and automate the observational methods, quantify systematic effects and analyse the results. We also plan to design and integrate on the telescope a LIDAR system that is independent of, but which will run simultaneously with, standard laser ranging operations.