P4.3 MIXING LAYER HEIGHT DETERMINATION BY MEANS OF A MODIFIED CEILOMETER

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1. INTRODUCTION

A ceilometer has been modified so as to measure the amount of light backscattered from aerosols. By studying the signal generated by aerosols trapped within thermal stratifications occurring in the first four kilometers of the atmosphere, one can determine the height of the Mixing Layer.

Such measures of the Atmospheric Boundary Layer have been carried out by other teams, using research lidars (Dupont (1991)), notably in the Paris area (Menut (1999)).

The need for continuous monitoring of the ABL's height has been demonstrated, especially for the study of air pollution crises. We show here that they can be carried out operationally by using only an inexpensive modification to an off-the-shelf (as opposed to research-grade), eye-safe, commercial ceilometer.

Furthermore, by looking at a graphical display of the backscatter signal evolving in time, some meteorological phenomena seem to display a recognizable signature. We now focus on this behavior of the signal, so as to, possibility, yield a new helper instrument for the determination of "Present Weather".

2. PRINCIPLE OF THE MEASURE

The measure is based upon the fact that the first four kilometers of the Earth's atmosphere contain several interesting components, notably water droplets and aerosol particles, whose optical properties are markedly different from the mixture of gazes which makes up its bulk. A laser beam propagating in the atmosphere will therefore have some of its light backscattered and it is this backcattered light which constitutes the signal we measure. Further processing of this signal is necessary, however to make it into something useful.

The unmodified version of the instrument, Vaisala's CT25K Ceilometer (Räsänen (2000)), emits an impulse at a wavelength of 905±5 nm (at 25 °C), and a nominal duration of 100 ns, with a repetition frequency of 5.57 kHz. Backscattered light is then measured every 100 ns over the span of 50 µs. This yields (given the speed of light in the atmosphere) a primary profile ranging from the ground up to an altitude of 25,000 feet, with a spacial resolution of 50 feet. A secondary profile is then built by cumulating 2^{16} primary profiles over a period of 11.7 s. An algorithm is then applied to this secondary profile, so as to "de-noise" it , yielding the final backscatter coefficient profile. One signal is made available every 15 s (unfortunately, in the configuration we have used, the instrument sometimes internally combines up to 9 such signals before outputting their average, in what is essentially an unpredictable manner; this will be fixed in the future).

The instrument we used has been modified to yield profiles made up of 2^8 points with a spacial resolution of 25 feet.

3. EVALUATION CAMPAIGNS

The modified ceilometer has been used for six weeks, during ESCOMPTE[◊] a large scale pollution research campaign in the south of France (Marseille/étang de Berre). This has enabled us to compare the measures with the output of a great many other atmosphere observation instruments, both in terms of classical meteorological parameters and of physico-chemicals ones.

Since October of 2001, this ceilometer is functioning (nearly) full time at Météo-France/DSO's Trappes (France) site, where it can be compared to a wide assortment of meteorological sensors. The Trappes site is arrayed with classical meteorological parameters sensors, as output by a Synoptic Network Meteorological Station, complemented by outputs of Present Weather detectors and two to four daily radiosoundings.

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[◊] http://medias.obs-mip.fr/escompte

4. DATA PROCESSING

Two types of processing have been found to be necessary:

• temporal averaging of the backscattered signal; on the one hand this is so as to attempt to minimize the distortion induced by the unpredictable averaging period of the instrument, and on the other hand this is useful to get an overall view of the daily, or pluri-day, evolution.

• non-linear transformation of the signal's dynamic; the problem here is that we have interesting information spanning several orders of magnitude, for instance aerosol backscatter result in a value in tens or hundreds of the unit, while cloud backscatter is well over thousands of the unit; we currently use the following transformation: $x \mapsto k \cdot \tanh(x/k)$, with $k = 1000$ being a good value; for some graphs, we also cut out (threshold) non-physical negative values brought about by the denoising algorithm; see the figure for an example.

These processings where put forward within considerable work on the visualization of the data. Both 2D and 3D visualizations bring valuable insights into the information generated by this instrument, and are used as a basis to the analysis and the interpretation of the data.

In the poster, the results of these measures are presented, for some typical meteorological situations.

Ulteriorly, other types of processings will be necessary to access to signature of the phenomena we are after.

5. CONCLUSION

This first evaluation of this new kind of investigation into the lower layers of the atmosphere shows that it is possible to monitor, minute by minute, both the thermical stratification of the atmosphere, and the localization of the aerosols or pre-condensation layers, in clear sky as well as when clouds are present. The modification brought to the instrument is software-only, and seems to be very promising. This modified instrument should rapidly find a place of choice among the instruments routinely used to investigate the atmosphere's lower reaches.

The main possible applications for this new instrument are urban meteorology and probably as an help to the observer for the characterization of Present Weather.

6. BIBLIOGRAPHY

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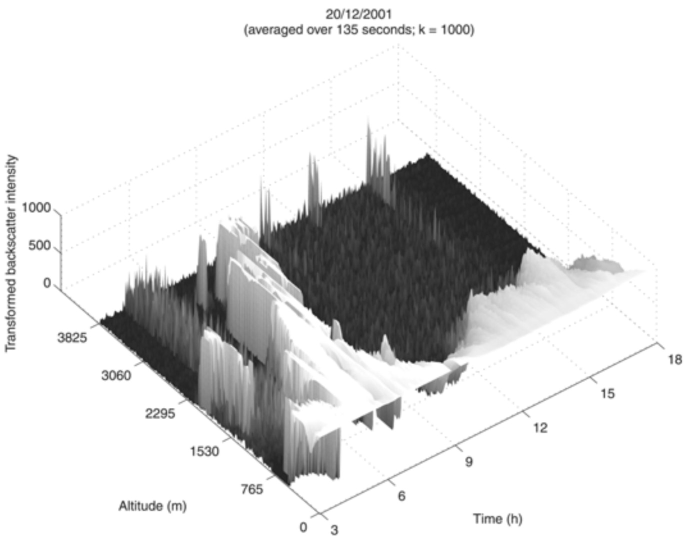

Figure: 3D visualization of backscatter data acquired at the Trappes site, showing a period of extreme visibility following a cloudy episode; time is in Universal Time, the data has been temporally averaged, non-linearly remapped and thresholded.