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RETRIEVAL OF MICRO SCALE FLOW STRUCTURES FROM DUAL-DOPPLER LIDAR DATA MEASURED IN THE URBAN BOUNDARY LAYER

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1. INTRODUCTION

In the Joint Urban 2003 atmospheric dispersion field experiment held in Oklahoma City, two coherent Doppler lidars, owned by the U.S Army Research Laboratory (ARL) and Arizona State University (ASU), were deployed to gain new insights into the boundary layer transport processes of contaminants in and around cities. This provided an opportunity to evaluate the accuracy of the four-dimensional variational data assimilation (4DVAR) method originally designed for the single lidar data retrieval. The second lidar data provided the cross-beam velocities components which are not available in the previous single lidar retrieval. One objective of this work is to determine the fidelity of the data retrieved from the single Doppler lidar and assess model errors by use of the second lidar data. The other objective is to interpret the retrieved micro-scale flow structures by comparison with the satellite ground building data.

2. NUMERICAL METHOD

The 4DVAR has been applied to retrieve micro scale atmospheric boundary layers (ABL) flows (Lin et al, 2001; Lin and Chai, 2002; Chai et al, 2002; Chai et al, 2004) and has been demonstrated to a powerful method to recover micro scale turbulent structures in the ABL. The control variables of the current 4DVAR consist of initial 3D velocity and temperature fields, as well as profiles of eddy viscosity and thermal diffusivity. Integration of the prediction model forward in time using these initial conditions and profiles produces an optimal solution of the atmospheric state that best fits both lidar observations in a least-squares sense. The uncertainty of radial velocity data is accounted for by weighting the radial velocity data with the wide-band signal-to-noise ratio (wSNR) data. The ARL and ASU lidar datasets were collected from 1802:17 to 1805:25 UTC on 11 July 2003. A computational domain of 5.5 km × 5.5 km × 2.0 km is employed in the 4DVAR analysis, as shown in Fig.1. The satellite Oklahoma City map is also displayed to illustrate the locations of the two lidars and the scope of the measurement.

3. RESULTS

The results of single ARL lidar retrieval and dual lidar retrieval are shown in Figs 2 and 3, respectively. Fig. 2 shows the fluctuating velocity field in a horizontal cross section. The shaded areas are updraft regions where *w'* >0. By comparing Fig. 2a with Fig. 2b, the fluctuating velocity structures of the single ARL retrieval are very similar to those of the dual lidar retrieval. Due to the incorporation of the ASU lidar dataset, the dual lidar retrieval provides larger coverage and exhibits more flow structures than the single ARL lidar retrieval. By comparison with the single ARL lidar retrieval, the similar flow structures pattern in overlapping region of the two lidars is magnified in the dual lidar retrieval.

From the single ARL lidar retrieval result, the coefficient of linear correlation between u_r^{ASU} (the retrieved velocities in the ASU radial direction) and u_{ob}^{ASU} (the ASU observational velocities) is 0.915. Fig. 3a also shows good agreement between u_r^{ASU} and u_{ob}^{ASU}. These results indicate the result of single lidar retrieval is trustworthy. From the dual lidar retrieval result, the coefficient of linear correlation between u_r^{ASU} and u_{ob}^{ASU} is improved to 0.990. The distribution of $u_r^{ASU} - u_{ob}^{ASU}$ is sharply peaked in Fig. 3b. By comparison with the results of single lidar retrieval, the dual lidar retrieval shows better agreement with the ASU observational velocities. As expected, the dual lidar retrieval produces better result than the single lidar retrieval because of utilization of more data.

From Fig. 1, there are a lot of interesting urban building structures in the computational domain, such as the central business district (CBD), highway, river and park. Figs. 4 and 5 are used to examine the correlation between the retrieved flow structures and urban building data. The strong updraft is observed above the downtown park in Fig. 4a. The temperature fluctuation field in Fig. 4b shows that the fluctuating temperature above the park is also high at t = 172 s. A comparison of Fig. 4a and Fig. 4b reveals a strong positive physical correlation between the vertical fluctuating velocity and the fluctuating temperature, which is expected in the ABL. Fig. 5a indicates that there was a downdraft above the CBD at t = 172 s. By comparison with Fig. 5b, the downdrafts are accompanied with the negative fluctuating temperature regions and the updrafts are accompanied with the positive fluctuating temperature regions. The retrieved velocity flow structures are similar with those of Newsom et al. (2005).

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The complete wind and temperature fields retrieved in dual lidar retrieval could be used to do further analysis about the transport process of the contamination in the urban boundary layer.

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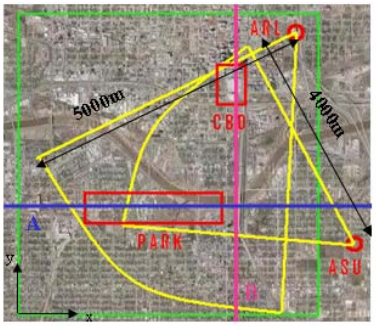

Fig. 1. The Computational domain (green lines) and lidar scan coverage areas (yellow lines) by the ARL lidar and the ASU lidar.

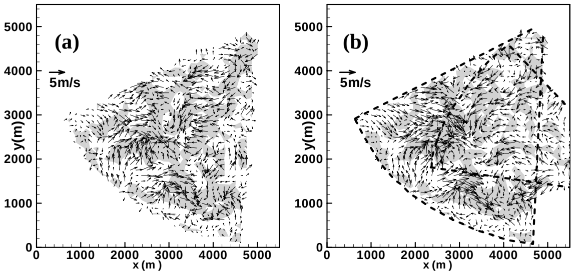

Fig. 2. The fluctuating velocity fields in a horizontal cross section at z = 200m, t=172s. (a) ARL lidar retrieval, (b) dual lidar retrieval.

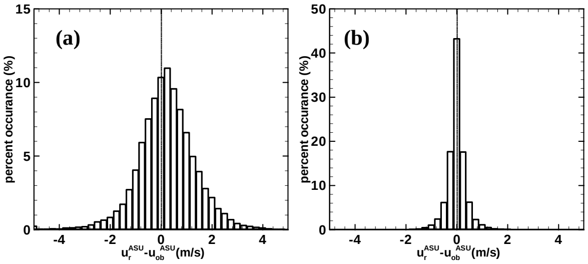

Fig. 3. Histograms of the correlation between (a) single ARL lidar retrieved data and ASU observations, (b) dual lidar retrieval and ASU observations.

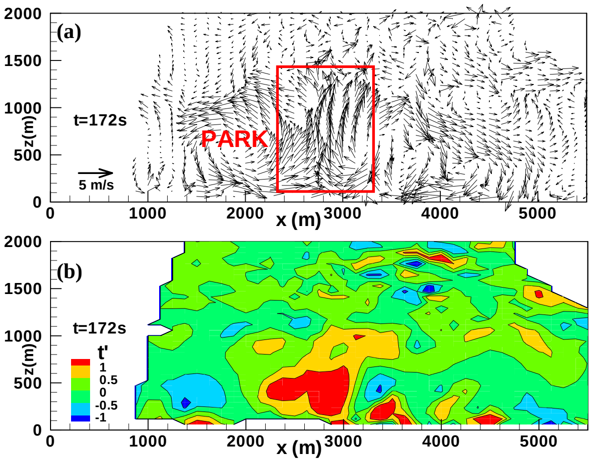

Fig. 4. (a) The fluctuating velocity field and (b) temperature field retrieved from the dual lidar 4DVAR in a vertical plane at y = 2200 m, along the blue line in Fig. 1 passing through the park.

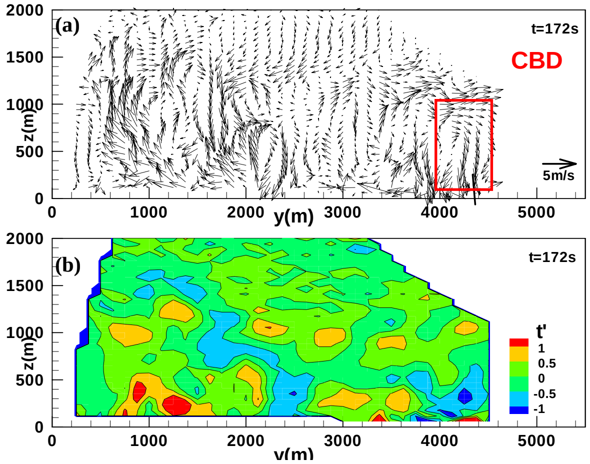

FIG. 5. (a) The fluctuating velocity field and (b) temperature field retrieved from the single ARL 4DVAR in a vertical plane at x = 4000 m, along the pink line in Fig. 1 passing through the CBD.