10.22 MIXING DEPTH VARIABILITY IN THE HOUSTON AREA DURING TEXAQS2000

Wayne M. Angevine[1,2 *], Allen B. White[1,3], Kevin Knupp[4], Richard Coulter[5], Timothy Martin[5], Christopher Doran[6], and Dan White[7]
[1]CIRES, University of Colorado, Boulder, Colorado
[2]NOAA Aeronomy Laboratory, Boulder, Colorado
[3]NOAA Environmental Technology Laboratory, Boulder, Colorado
[4]University of Alabama, Huntsville, Alabama
[5]Argonne National Laboratory, Argonne, Illinois
[6]Pacific Northwest National Laboratory, Richland, Washington
[7]Texas Natural Resources Conservation Commission, Austin, Texas

1. Introduction

Mixing depth is a fundamental, first-order control on concentrations of chemical species near the surface. Mixing depth varies on all scales, but the primary scale of interest is 10-100 km. These variations can be due to changes in the underlying land use, terrain, soil moisture and other properties, clouds, and other factors. Sea breeze circulations can also be important in coastal areas. In order to capture these variations during the Texas 2000 Air Quality Study, six radar wind profilers were deployed around Houston to measure mixing depth and winds.

Maximum mixing depths varied from day to day by more than 50%. The temporal pattern of mixing depths was generally similar at all sites except that the LaMarque site, southeast of Houston near Galveston Bay and nearest to the Gulf coast, had lower mixing depths on days with persistent southerly flow. The following discussion will concentrate on the period 25 August - 1 September, when several ozone exceedances occurred in the Houston area.

2. Results

The mixing depths are diagnosed from the profiler data using techniques described by Grimsdell and Angevine (1998) and Angevine et al. (1994). In simple convective continental boundary layers, the BL top (mixing depth) is marked by a peak in the profiler reflectivity. More complex situations require more careful interpretation, preferably aided by ancillary data.

* Corresponding author address: Wayne M. Angevine, CIRES / NOAA Aeronomy Lab R/AL3, 325 Broadway, Boulder, CO 80303; e-mail: wangevine@al.noaa.gov

Figure 1 shows mixing depths for five profiler sites on five days of the study. The morning transition from stable to convective boundary layers at the Houston sites was quite similar to those seen in continental situations. At most sites, the diurnal pattern was that of a standard continental site until at least mid-afternoon.

Midday mixing depths were similar at four of the five sites shown. Only the LaMarque site, southeast of Houston near the shore of Galveston Bay, showed significant differences at midday, and then only on 27 and 28 August. On these days the low-level winds were predominantly from the southeast or south, bringing marine-influenced air to LaMarque throughout the day. The other days had flow from directions which would bring continental air to the LaMarque site.

Mixing depths at midday were deeper at all sites except LaMarque on 25, 27, and 28 August than on 30 August and 1 September. The deeper mixing, approximately 1.5-1.8 km between 1200 and 1400 CST, was allowed by weaker capping inversions on the earlier days. The two later days had mixing depths of only about 1 km at midday.

The pattern of mixing depth in the afternoon is the subject of ongoing research. In simple, homogeneous continental conditions, the general pattern seems to be that mixing gradually decreases in depth and intensity. Profiler reflectivity patterns, however, sometimes show a band of high reflectivity remaining at approximately the height of the midday boundary layer throughout the afternoon and evening (Grimsdell and Angevine 2001). The Doppler spectral width measured by profilers can be used as a qualitative measure of turbulence intensity to aid in interpreting the afternoon behavior. At Houston, the situation is greatly complicated by the sea breeze circulation.

The sea breeze at latitudes near 30° is a large-scale phenomenon rather different from the more familiar local phenomenon found at higher latitudes (Neilsen-Gammon, this volume). Its timing is also more variable. When the sea breeze reaches a particular site, it produces deeper vertical mixing possibly followed by a reduction in mixing depth. In these data, the phenomenon is very clearly seen at LaMarque on 30 August and 1 September, where extreme reductions in mixing depth occur after the sea breeze onset. The deep mixing associated with the sea breeze onset is seen at all sites starting between 1400 and 1500 CST on 30 August (figure 2) but it is not clear whether a new mixed layer of reduced depth is formed. The increase in mixing depth is also associated with a less distinct peak in reflectivity, indicating that the humidity gradient associated with the former capping inversion has been mixed away. As a result of these complexities, it is difficult to generalize about the afternoon mixing depth behavior.

3. Summary

Mixing depths in the Houston area measured by radar wind profilers show relatively normal continental behavior in the morning. Little variation between sites is seen at midday except for the site closest to the coast (LaMarque). Day-to-day variation is more than 50%, and is probably caused by large-scale variations in inversion strength. In the afternoon, the sea breeze onset complicates the already challenging interpretation of the afternoon transition. On some days, deep vertical mixing is associated with the sea breeze onset, and a second, shallower mixed layer is formed in late afternoon at least at LaMarque.

References

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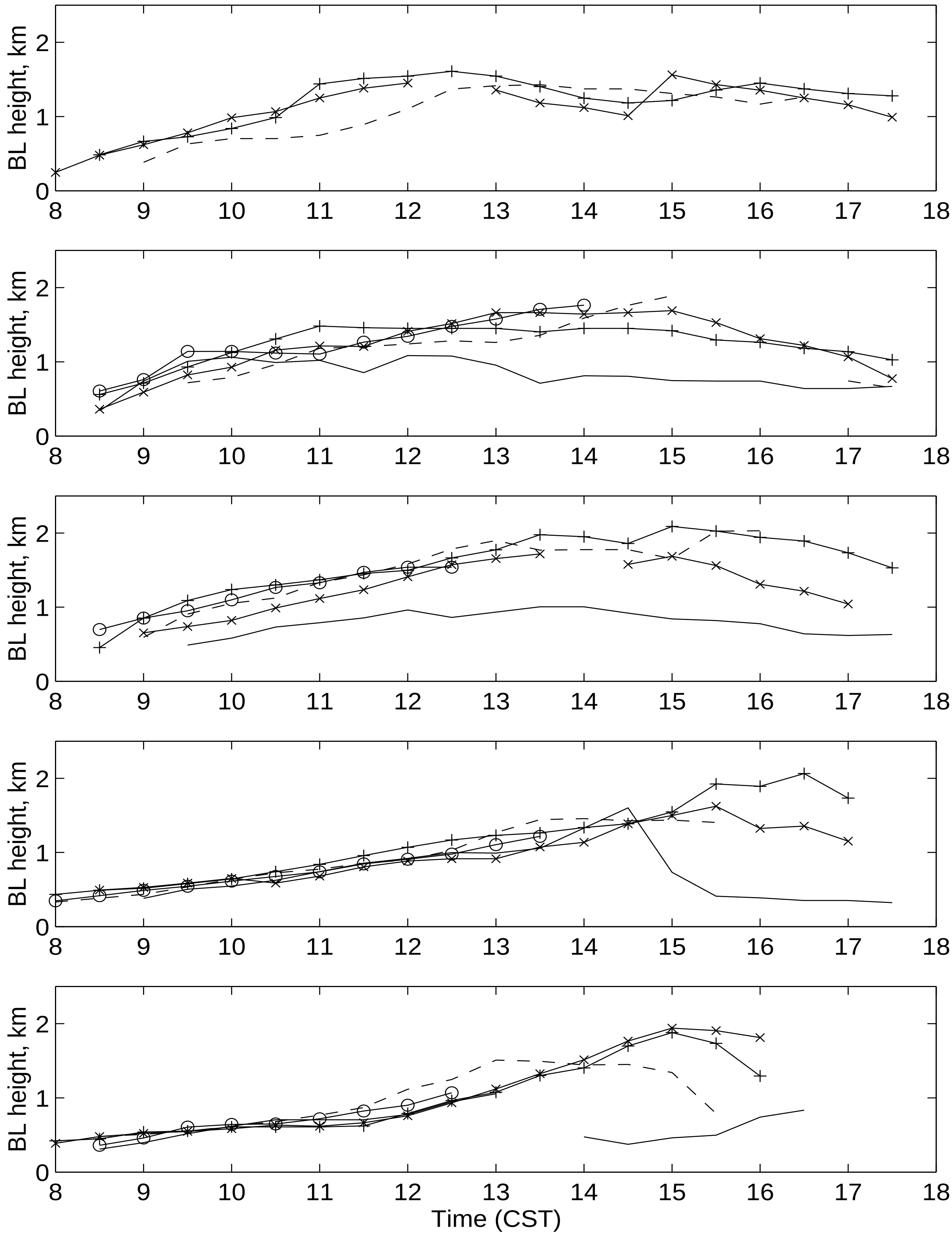

Figure 1: Mixing depths from five profilers for five days. In order from top to bottom, the days are 25, 27, 28, and 30 August and 1 September. Line types and symbols are: + = Houston Southwest, x = Ellington Field, solid line with no marker = LaMarque, dashed line = Liberty airport, o = Wharton power plant.

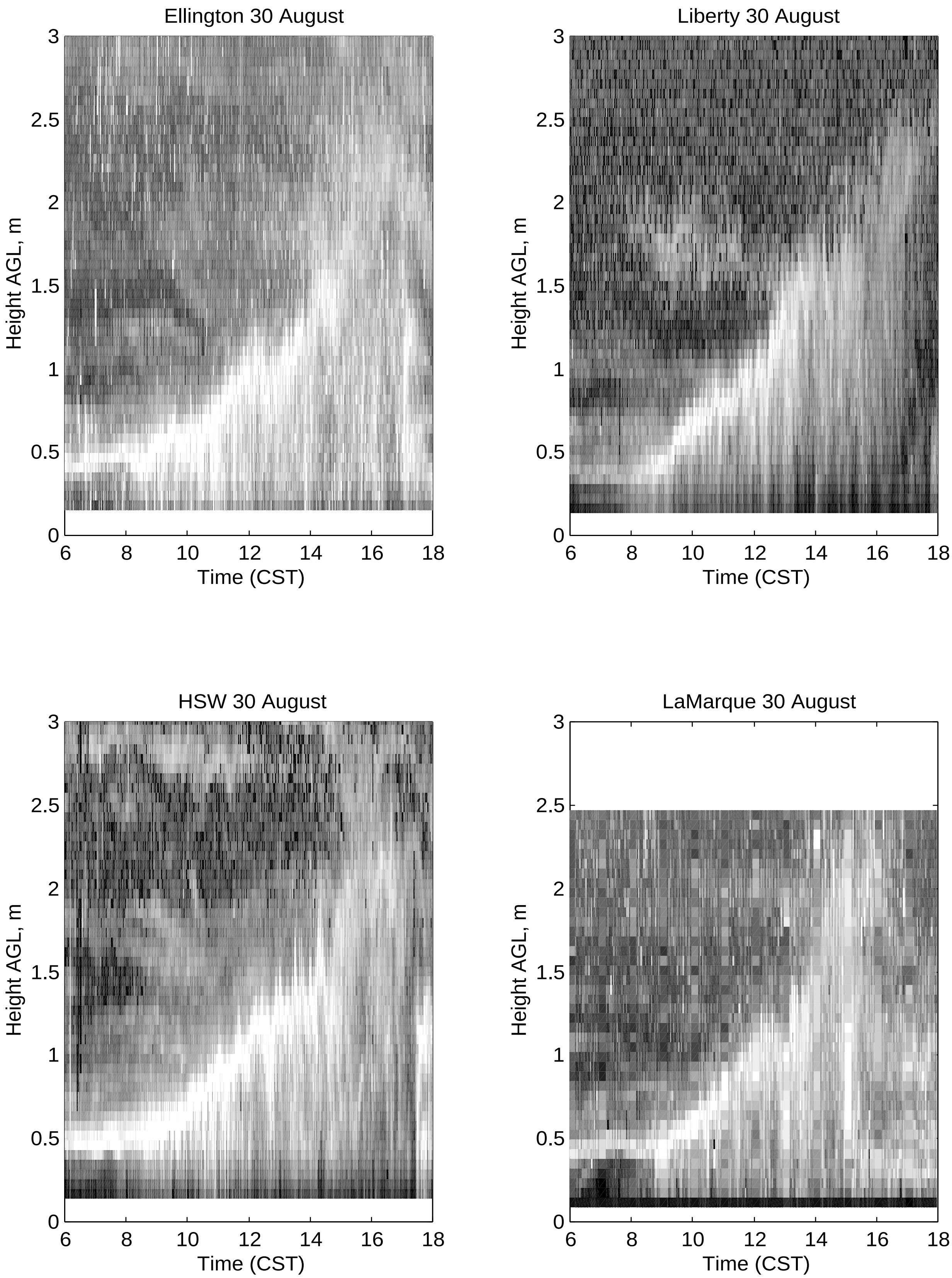

Figure 2: Profiler reflectivity patterns from four profilers on 30 August. Lighter colors indicate stronger reflectivity.