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An Observational Study of Turbulence in the SPBL

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AN OBSERVATIONAL STUDY OF TURBULENCE IN THE SPBL

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1. INTRODUCTION

Turbulence in the stable planetary boundary layer (SPBL) is complicated by intermittency, gravity waves, long time scales and meso-scale forcing. Surface features and topography are also important.

This study examines turbulence near the top of the SPBL with data taken from a network of 61 m towers. The focus is on the role of moderately complex terrain on turbulent intermittency and spatial variation.

The Savannah River Site is ~150 km from the Atlantic Ocean and is characterized by rolling forested hills and an average elevation of ~80 m ASL. Typical variations in elevation are 50 m (peak to valley) with a horizontal scale of several km. The most important topographic feature is the Savannah River flood plain, which borders the SRS to the southwest (Fig. 1). This flood plain is 3-7 km wide with an average elevation of 40 m ASL. Nine 60 meter towers are located on the SRS, generally at higher elevations (81 - 109 m ASL), except for the D tower which is in the Savannah River flood plain (elevation 43 m ASL). The CI tower differs from the other 8 towers because it collects data at 2, 18, and 36 m as well as 61 m. The TV tower, located 8 km northwest of the SRS, is instrumented at 8 levels from the surface to 300 m.

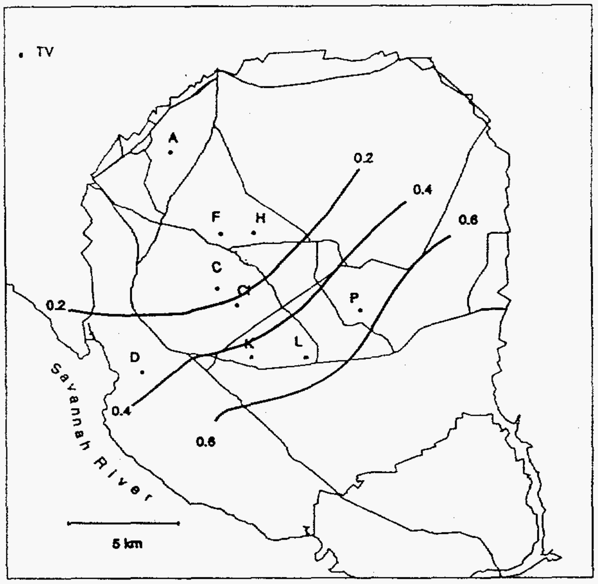

Figure 1. Map of SRS showing tower locations and contours of turbulent kinetic energy on Mar 26, between 10:15 and 11:45 PM EDT.

2. OBSERVATIONS

The Savannah River Site (SRS) routinely collects wind, temperature and humidity data. Wind and turbulence intensity are obtained from cup anemometers and bivanes. Data sampled at 1.5 sec intervals can be stored for later analysis. The distance constants for the bivanes and anemometers are 1 and 1.5 m, respectively.

A practical problem in calculating turbulent kinetic energy, TKE, in the stable boundary layer is the separation of gravity wave energy from turbulent energy. In this study the TKE was calculated with respect to 90 s means. This averaging time was selected because it is shorter than the period of most gravity waves and because it corresponds to a spectral minimum observed in the data and seen in other studies, e.g., Caughey (1982).

TKE was calculated on 4 nights. As noted in Kurzeja et al. (1991), nocturnal sea breeze fronts are a common occurrence at the SRS on stable nights and frontal passage was observed on 3 of the 4 nights . Results will be shown for two nights - one without a frontal passage (March 26), and one with a frontal passage (April 3).

3. NIGHT OF MARCH 26

The boundary layer on March 26 was moderately stable with a temperature inversion of 3-5°C, a boundary layer depth of ~130 m and west winds at sunset, which shifted to NE by 3 AM. An interesting feature in the 60 m turbulence was the maximum between 10:15 and 11:45 PM EST observed at the 4 southern towers, D, K, L, and P, but not at the northern towers, A, C, F, H (Figs. 1 and 2).

The tower data also indicated that during this period the southern towers had elevated temperatures (0.5 to 1°C), suggesting subsidence, and a stronger WNW wind direction, as listed below.

	D,K,L,P	A,C,F,H
Azimuth	295 deg	270 deg
Speed	4.8 m/s	6.4 m/s

In addition, comparison of the 60 m data with the TV tower showed that the elevated winds and TKE at the D, K, L, and P towers were similar to 90 m observations at the TV tower.

The observations suggest that the high TKE between 10:15 and 11:45 PM is due to flow of WNW air above 60 m over a cooler, transient, westerly current in the northern half of the SRS . The WNW air flow then subsided in the southern part of the SRS. The high TKE at the southern towers is thus due to the higher initial TKE in the subsiding air and enhanced directional shear as the WNW air passed over the westerly current.

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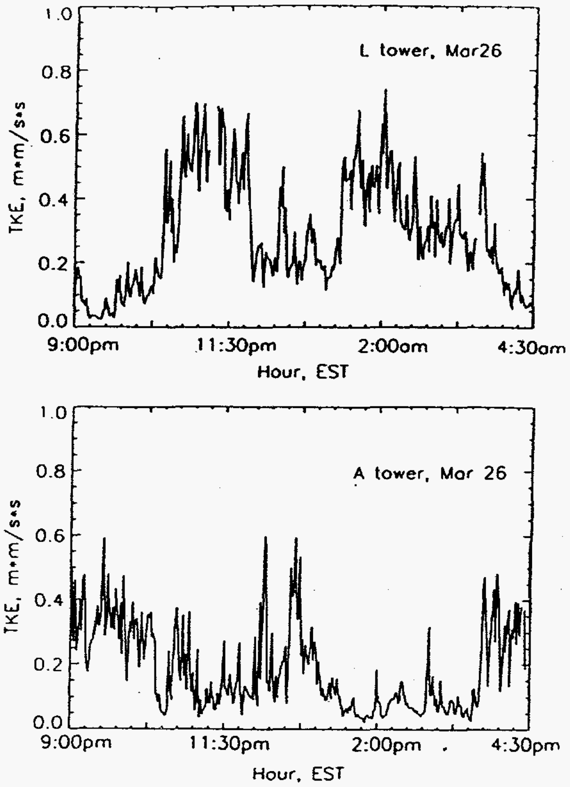

Figure 2. Turbulent kinetic energy on March 26 at the L tower, top, and at the A tower, bottom.

4. Night of April 3

On April 3 a stable boundary layer 50 m deep was established by 10:00 PM EST with a temperature inversion of 5°C and SSW winds of 5 m/s. At ~11:30 PM a nocturnal sea breeze front passed through the SRS causing a wind shift to the SE and a change in TKE from very low values to high values. The observations at eight of the nine 60 m towers were similar, as illustrated, for example, in the C tower data, (Fig.3).

The TKE at the D tower was quite different from the other towers. At the D tower, the frontal passage could easily be detected in the temperature, dew point and mean winds, but not in the TKE (Fig. 3). In addition, in contrast to the other towers, the TKE at the D tower increased before frontal passage. Oscillations in wind speed and direction with a period of ~ 3/4 hour were also observed at the D tower before frontal passage, as well as a wind shift to the south.

The different behavior at the D tower is due to its location in the Savannah River flood plain. The NW-SE orientation of the Savannah River flood plain and the generally southerly boundary layer winds caused flow in the flood plain to alternate between topographic and mesoscale control. This temporal fluctuation masked the passage of the sea breeze front and increased TKE ahead of the front.

5. CONCLUSIONS

Two examples of topographically induced variations in turbulence in the upper SPBL are discussed. On April 3, the interaction of the large scale flow with flood plain topography caused fluctuations in the local wind and increased turbulence at one tower. On March 26, elevated turbulence was attributed to the formation of a transient, low-level, current which caused subsidence of air with elevated TKE behind the current.

6 REFERENCES

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7. ACKNOWLEDGEMENT

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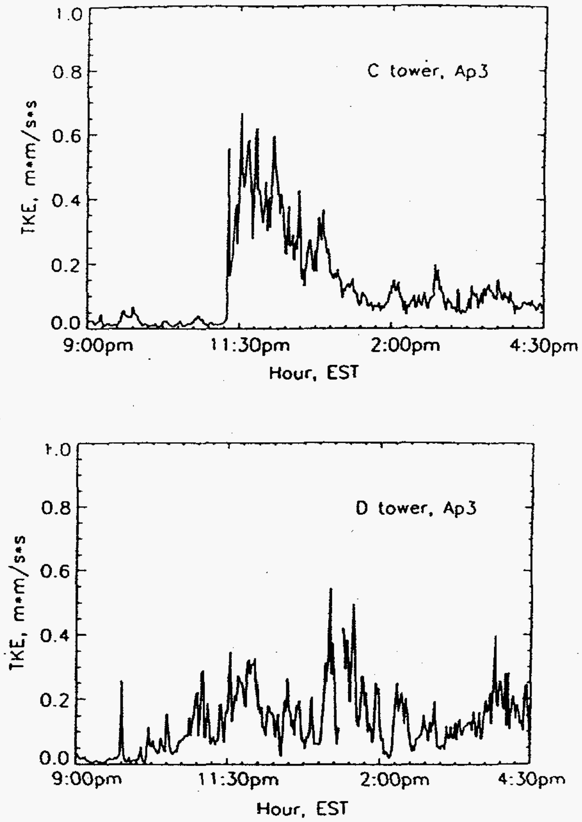

Figure 3. Turbulent kinetic energy on April 3 at the C tower, top, and D tower, bottom.