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13. ABSTRACT (Maximum 200 words)

The structure of the nocturnal boundary layer has been examined using seven levels of eddy correlation data on the main tower in CASES99 data. Turbulence generated above the nocturnal surface layer and below the nocturnal jet intermittently bursts downward toward the surface, This flow regime cannot be properly modeled within existing formulations. A z-less formulation of the transport is combined with a traditional model to improve simulation of these conditions. The relationship between advection of turbulence and local shear-generation of turbulence is examined using the network of eddy correlation stations in CASES99. Advection of turbulent patches significantly influences the relationship between turbulence and shear, as viewed using a single tower.

14. SUBJECT TERMS

Nocturnal boundary layer, cold air drainage, stable boundary layer, dispersion, turbulence, stratified flow.

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FINAL PROGRESS REPORT

STATEMENT OF PROBLEM

Through analysis of existing and new observations, re-examine basic characteristics of the nocturnal boundary layer, particularly for the poorly understood very stable case. Improve our limited understanding of interaction between drainage flows, meandering and turbulence. Improve modeling of the transport and vertical structure of the nocturnal boundary layer. Analyze existing data sets for the nocturnal boundary layer, which include eddy correlation measurements. Focus on the extensive data from CASES99 to document different vertical structure and the role of advection in order to better understand the local flux gradient relationship.

SCIENTIFIC RESULTS

The work on this project has concentrated on analysis of the wide variety of vertical structures, the behavior of the eddy correlation and construction of a new theory for the stable boundary layer, and several topics on the characteristics of intermittency and its influence on the flux-gradient relationship and similarity theory.

Our analysis has revealed two types of ``boundary-layers'' not readily accommodated with traditional modeling. First, very thin boundary layers are often observed with depths of 20-30 m. The corresponding surface layer is presumably only a few meters deep, thus eluding the resolution of most numerical models.

Secondly, nocturnal accelerations and associated mean shear, generate turbulence that is not fully coupled with the ground surface. Turbulence in this upside-down boundary layer does not scale with the boundary-layer depth nor height above the ground and is thus a form of z-less turbulence. The upside-down regime is generally temporary as downward transport of turbulence energy leads to full coupling with the ground surface. This coupling can lead to a boundary layer that is much deeper than the 60-m tower layer. However, the vertical structure of the flow and its time dependence varies substantially between nights.

We have modified a simple model of the nocturnal boundary layer where the diffusivity is originally specified only as a function of height with respect to the boundary-layer top. The modifications allow development of z-less turbulence, which does not depend on height above ground nor the boundary-layer depth. The modified model sometimes generates turbulence above the boundary layer. The modifications provide for a finite decay rate, which replaces the unrealistic instantaneous collapse occurring in the usual diagnostic relationships for the eddy diffusivity. Unfortunately, these different physical mechanisms could not be isolated from the data and the coefficients are chosen in terms of an overall subjective comparison of the model with the data. A vertical resolution of 5-m is required to produce the observed early evening very stable period.

The locally-generated z-less turbulence can produce an ``upside-down'' structure where the momentum transport increases with height, as does the eddy diffusivity. However, this feature is weak and too transient in the model compared to the observations, apparently due to elevated shear induced by mesoscale motions not capture by the model. The modeled z-less turbulence does produce a more realistic nocturnal wind maximum, without unrealistic sharp peaks, characteristic of the traditional model. The finite decay condition allows some persisting turbulence in the residual layer in the early evening, not present in the traditional model.

The above model improvements were possible without a significant increase in complexity or computer time. However, the model remains oversimplified and major differences between the model and the observations remain. The boundary layer sometimes seems non-existent or undefinable from the observations in that all of the significant turbulence is detached from the surface. The observed turbulence is strongly modulated by mesoscale variations of the wind speed on a time scale of a few hours or less, which is not captured in the model. We are currently testing several alternative models of the mixing length using CASES99 data.

Horizontal advection of turbulent patches explain about 25% of the variance of the turbulence energy at the main tower. This advective influence does not include indirect effects through advective modification of the mean shear. For many of the records, the turbulence patches and intermittency of the turbulence are poorly defined in contrast to examples in the literature. Many of the turbulence events are quite local and affect only one or two of the eddy correlations stations in the network, that is, occurs on a scale of a 100 m or less. Often the events cannot be predicted from the local Richardson number near the surface because of either horizontal advection or downward propagation of the turbulent events. Evaluation of the turbulence energy budget for these events indicates a variety of scenarios although shear-generation and dissipation are always important terms.

We have initiated work to study the influence of intermittency on the flux-gradient relationship and Monin-Obukhov and local similarity theory. The main approach is to partition the record into turbulent and non-turbulent (very weak) parts and re-evaluate the similarity only for the turbulent parts of the record. This work preliminarily indicates that the exclusion of the quiet periods reduces the scatter in the flux-gradient and changes the coefficients for very stable conditions.

PUBLICATIONS

A) REVIEWED LITERATURE

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B) PUBLICATIONS IN NON-REVIEWED LITERATURE

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C) PAPERS PRESENTED AT MEETINGS BUT NOT PUBLISHED

Mahrt, L. Gully flows in CASES99. Presented at the *Workshop on Modeling in Complex Terrain*, Jan. 2002, Corvallis, Or.

D) MANUSCRIPTS SUBMITTED BUT NOT PUBLISHED

Mahrt, L. and D. Vickers, 2002: Formulation of turbulent fluxes in the stable boundary layer. Submitted to *J. Atmos. Sci.*

SCIENTIFIC PERSONEL

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INVENTIONS

None