TURBULENCE STRUCTURE IN TEMPERATURE INVERSIONS AND IN CONVECTION FIELDS AS OBSERVED BY DOPPLER SODAR

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Abstract. The structure of turbulence in an inversion layer and in an homogeneous convective field of the planetary boundary layer is described. In the first part of the paper, we validate the sodar estimates of turbulent dissipation, by using measurements with an hot-wire anemometric system in situ. Limitations of an $\epsilon$ measurement technique using structure function calculations are given, taking account of atmospheric properties and acoustic Doppler instrumental effects.

By comparison between isopleths of backscattering intensity and of turbulent dissipation rates, we observe that in the early morning, turbulence is advected by mechanical turbulence generated by wind shear. The same mechanism seems to be operating in the case of an inversion layer capping thermal instability, when the convective activity is not too greatly developed.

A turbulent kinetic energy budget is examined using aircraft, sodar, and tower measurements. This indicates a constant turbulent dissipation profile through a deep convective layer.

1. Introduction

Knowledge of the turbulence structure associated with temperature inversions is of fundamental importance in boundary-layer modelling and in the study of the diffusion of contaminants. One advantage of acoustic sounders is that they show temperature inversion layers and their evolution in time and space. If in addition, the acoustic sounder is a Doppler sounder, one has access to quantitative measurements of some of the phenomena in the boundary layer. The following is a list of some of the works which have been published on acoustic sounders: Little (1969), Aubry et al. (1974), Estival et Aubry (1976), Mc Allister et al. (1969), Hall et al. (1974), Brown (1972), (1977), Neff (1975), Spizzichino (1974), Spizzichino et Van Grunderbeeck (1977). Recently, Gaynor et al. (1977) presented a method of estimating the turbulent dissipation rate from sodar. The same method has been explained and used by Weill et al. (1976), (1977).

In this paper, we shall examine the turbulent dissipation rate in echo layers observed by the Doppler acoustic sounder. We will first use quantitative measurements to help clarify the origin of turbulence in statically stable inversions layers as seen by sodar during the morning. Secondly, we want to benefit from simultaneous acoustic Doppler sounder, aircraft and meteorological tower measurements to
undertake a study of the dissipation rate in a convective layer and to evaluate the contribution of every term in the turbulent kinetic energy budget. At the outset, however, we shall describe the methodology used and will compare turbulent dissipation rate estimates from the acoustic sounder and from an in situ anemometric hot-wire system.

2. Sodar Methodology

2.1. Properties of the Acoustic Doppler System

We use an acoustic sounder which consists of a system of three antennas: one vertical and two slanting at 30° from the vertical (Figure 1), where the angle of the horizontal projection is 120°. The acoustic pulse lasts 100 ms, with a repetition rate of 4 s, corresponding to a range of about 650 m, with an observation every 17 m in height. The signals are digitized and a fast Fourier transform performed to calculate the Doppler shift. We selected an emission frequency \( f \), equal to 2000 Hz and a frequency band of 100 Hz for the filter of Doppler shift extraction.

The precision of the Doppler measurement is mainly a function of uncertainties resulting from the three components of the wind and the height for every antenna. These uncertainties are functions of parameters which are characteristic of sodar:

- \( f \) emission frequency
- \( \Delta f \) filter width
- \( \tau \) pulse duration = duration of a gate of analysis
- \( \theta \) elevation of antenna axis
- \( N \) pulse numbers from which the mean Doppler spectrum is calculated
- \( b_1 \) the signal width (generally near 10 Hz)
- \( \alpha \) the width of the aerial beam

Fig. 1. Geometric configuration of the acoustic sounder three-antenna system. Antennae 1 and 2 are slanting, antenna 3 is vertical, colinear to the vertical direction 3. VERTICALE PLANE
HORIZONTAL PLANE

VERTICAL
PLANE

Z

1

2

3

120°