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3.3.1 A STATISTICAL MODEL TO ESTIMATE REFRACTIVITY TURBULENCE STRUCTURE CONSTANT C_n^2 IN THE FREE ATMOSPHERE

J. M. Warnock and T. E. VanZandt

Aeronomy Laboratory
National Oceanic and Atmospheric Administration
Boulder, Colorado 80303

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INTRODUCTION

A computer program has been tested and documented (WARNOCK and VANZANDT, 1985) that estimates mean values of C_n^2 in the stable free atmosphere from standard National Weather Service balloon data or an equivalent data set. The program is based on the statistical model for the occurrence of turbulence developed by VANZANDT et al. (1981). Height profiles of the estimated C_n^2 agree well with profiles measured by the Sunset radar with a height resolution of about 1 km. The program also estimates the energy dissipation rate ε, but because of the lack of suitable observations of ε, the model for ε has not yet been evaluated sufficiently to be used in routine applications.

MODEL

There is considerable evidence that in the free atmosphere there are many thin horizontally stratified turbulent layers embedded in the large-scale laminar flow. They are thought to be due to local dynamic shear instabilities in regions where the large-scale flow itself is stable (BRETHERTON, 1969; ROSENBERG and DEWAN, 1974; WOODMAN, 1980; BARAT, 1982; VANZANDT, 1983; GOSSARD et al., 1984). The value of the Richardson number, Ri, describes the stability of the flow; it is defined as the ratio of the static stability, N^2, to the square of the vector wind shear, S, i.e., $Ri = N^2/S^2$ where N is the Brunt-Vaisala frequency. In most regions Ri is greater than its critical value, which is usually taken to be 1/4, and the flow is dynamically stable.

In the model, we make the following basic assumptions consistent with the above scenario: (1) the fine structure in N^2 and S^2 is horizontally stratified and is superimposed on their large-scale mean vertical profiles. This leads to fine structure in Ri; (2) turbulence occurs where the local small-scale value of $Ri \leq 1/4$, so that thin horizontally stratified turbulent layers are formed. Because the fine structure is not observed directly, we estimate the occurrence of turbulence indirectly by using a statistical approach. We parameterize the fine structure of S^2 and N^2, and therefore, Ri, in terms of the large-scale observable data. Because the fine structure is thought to be due to a spectrum of gravity waves (VANZANDT, 1982), the parameterization equations are consistent with gravity-wave theory. The thickness of these layers is usually a few tens of meters.

COMPARISONS WITH RADAR DATA

Vertical profiles of model C_n^2 have been compared with profiles measured by both radar and optical remote sensors. VANZANDT et al. (1978, 1981) found good agreement between profiles measured by the well-calibrated ST Sunset radar and an earlier version of the model; furthermore, they found that the model correctly tracked rapid changes of C_n^2 measured during the passage of a jet stream over the radar site. GAGE et al. (1978) found satisfactory agreement between an earlier version of the model and profiles measured at four different radar sites operating at UHF and VHF. More recently, GREEN et al. (1984) compared model profiles of C_n^2 measured simultaneously by the Sunset radar and by the double star scintillometer operated by Jean Vernin of the Universite de Nice. Excellent agreement was found between the radar and model profiles; however, at times the scintillometer measurements were less than both the radar and model values.

In all of the above comparisons the model C_n^2 profile was derived from a single balloon sounding. WARNOCK et al. (1985) conducted an observing campaign during both the winter and summer of 1982; they compared the model and radar measurements of the minimum, median, and maximum of 12 winter profiles and 22 summer profiles. The model profiles agreed well with the data in both magnitude and variability; futhermore, the calculations gave insight into the meteorological conditions responsible for the C_n^2 variability.

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