2.1B MORPHOLOGY OF THE SCATTERING TARGET - FRESNEL AND TURBULENT MECHANISMS

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Further studies of VHF radar signals from the troposphere and stratosphere revealed not only scattering from isotropic turbulence at scales of half the radar wavelength (typically about 3 m for VHF radars) but also partial or Fresnel reflection or scattering from horizontally stratified temperature discontinuities (e.g., ROTTGER, 1980). Proof for this observation was given by the large spatial and temporal coherence of radar signals. It is recognized that thin structures, particularly in the stratosphere, may be persistent over some ten seconds, which is longer than the coherence time of 3-m scale turbulence in the stratosphere (e.g., WOODMAN and GUILLEN, 1974). The vertical thickness of the structures was estimated to be much thinner than 150 m (ROTTGER and SCHMIDT, 1979). Observations over a longer time period indicate that these fine-scale structures or sheets are clumped together forming patches or ensembles of mostly downward sloping structures.

If one assumes that these fine structures are due to temperature steps or gradients rather than to very thin turbulent layers some evident similarities between the temperature fine structure of the stratosphere and the oceanic thermocline are found (e.g., WOODS, 1968). This is obvious since both the stratosphere and the thermocline are very stable regions due to the increase of potential temperature with height. ROTTGER (1980) proposed to use the same nomenclature as used in oceanography to describe the fine structure detected with vertically beaming VHF radars: the thin, persistent stratifications or laminae are regarded as "sheets" which form thicker "ensembles". Fine-scale measurements of the oceanic temperature profile showed that the sheets are thin interfacial regions separating "turbulent layers". It can be shown that radar echoes are also received from the regions between individual sheets, which are turbulent layers according to observations of the oceanic thermocline. These radar echoes are due to scattering from small-scale turbulence (3-m scale) and are normally much weaker than the echoes from the sheets. Thus, ensembles of sheets at the boundaries of turbulent layers are the typical "turbulence structures" detected by VHF radars.

It shall be stressed here that this model of atmospheric turbulence was already proposed by BOLGIANO (1968). He pointed out that vertical mixing in a turbulent layer tends to equalize the mean temperature profile so that temperature gradients are formed at its boundaries. We regard the temperature gradients as "sheets" being responsible for the enhanced and persistent echo power observed with the VHF radars. Recent theoretical investigations of PELTIER et al. (1978) yield a more detailed description of the temperature profile in a turbulent layer. There is accepted evidence that turbulence in the statically stable atmosphere is caused by Kelvin-Helmholtz instability. The essential condition for the onset of turbulence is that the Richardson number falls below its critical value, which can be due to an increase of wind shear. In Figure 1 the results of PELTIER et al. (1978) are sketched to show how temperature gradients, viz. ensembles of sheets, are formed. The original height profiles of wind velocity u and potential temperature θ are given by the curve u_o and θ_o. The temperature profile indicates high static stability because the gradient of potential temperature $\partial\theta/\partial z$ is positive. The velocity profile is characterized by a shear which gives rise to Kelvin-Helmholtz instability and yields a turbulent layer. After a typical growth time of the layer (up to some minutes), the velocity and temperature profiles are given by u_1 and θ_1. Consequently, gradients of θ occur near the top and the bottom of the turbulent layer. These gradients are sheets, according to the above-mentioned definition, which partially reflect VHF radar signals. The splitting of the shear layer ($0 \rightarrow 1 \rightarrow 2 \rightarrow \ldots$) may progress and cause the formation of multiple turbulent layers, i.e., ensembles of sheets at their boundaries. The corresponding time development of the sheets is sketched in the center part of Figure 1 and may be compared with well-known VHF radar observations.

The birth and decay of the sheets depend on the background conditions of static and dynamic stability. Only crude estimates of the lifetime of sheets can be obtained from current radar observations since the turbulence structures are advected with the wind through the radar beam. Typical times of VHF-radar observed sheets range from several seconds to minutes.

We conclude from these definitions and arguments that vertically beaming VHF radars only indirectly detect turbulent layers in the stratosphere, because they are more sensitive to the temperature gradients at the boundaries of the turbulent layers. Consequently some care must be taken in estimating turbulent transport coefficients using the characteristics of VHF radar signals such as echo power and correlation time. Further considerations on these limitations were outlined by ROTTGER (1980). It is interesting to note that recently BARAT (1982) reported about measurements of stratospheric turbulence and temperature profiles which were consistent with the model of Figure 1.

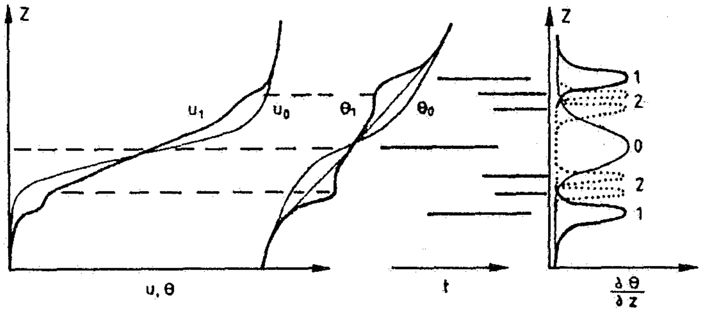

Figure 1. Formation of ensembles of sheets by Kelvin-Helmholtz instability (u and θ profiles after PELTIER et al., 1978).

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