Fine-scale turbulence

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ABSTRACT

1 Striations and fine-scale structure

Fully developed turbulence is generally viewed as a collection of eddies on a continuous range of scales ranging from the Kolmogorov scale up to the largest transporting eddies. This conceptual picture along with the energy cascade in the inertial subrange may be an oversimplification, particularly with weak-wind stably-stratified conditions. We casually and arbitrarily refer to "fine-scale eddies" as those less than 10 cm. Fine-scale turbulence is always present but not resolved by sonic anemometers since there size is less than sonic the pathlength. Quiet periods between events of intermittent turbulent mixing is sometimes interpreteded as non-turbulent but actually includes weak fine-scale turbulence and often weak turbulence on scales greater than 10 cm. The turbulence is more likely to be dominated by fine-scale structure within vegetation elements or very close to the ground but may also dominate mixing at higher levels with very stable conditions.

Surface-layer similarity theory is the basis for existing turbulence theory near the surface as well as parameterization of surface fluxes in virtually all numerical models. The fundamental assumption of surface layer similarity theory is that the length scale of the turbulence scales with height above ground due to the constraining influence of the ground surface on the turbulent eddies. The length scale is additionally modified by stability, as in Monin-Obukhov similarity.

Figure 1: Striations occur with various thicknesses. The causes of the striations are not known, but include: layers of vertical convergence (horizontal divergence), origins from surfaces of warmer temperature and flow over colder air, and, previous mixing layers where condensation occurs at the edges.

Our analysis of sonic anemometer data and fog videos reveal that the above viewpoint is not true, even as a first approximation, for weak wind stratified flow, even at 1 m above the surface (see Figures). From another point of view, the turbulence is z-less and a surface layer does not exist. Only nonstationary infrequent mixing events appear to interact directly with the ground surface, but these events only account for only part of the vertical flux.

The turbulence seems to be limited to very fine scale diffusion that blurs the edges; although some blurring due to looking through the fog and variation in the direction of the view.

This video shows the time history of some example striations. The video is sped up 16 times. In real time, the motions are very slow and barely detectable. This sped up video reveals that the striations are indeed changing partly due to weak fine scale diffusion. However horizontal advection and the use of a single camera can lead to false detection of merging and separation. pauses While wave motions seem to have little net effect on the striations, weak barely visible eddies can alter the striations. At times, sinking motions appear to reduce or eliminate the visual detection of striations possibly due to adiabatic warming and evaporation (time 300). Solitary modes at the surface, generally moving from let to right in this video can also induce weak

Figure 2: Slow flow from from left to right, on the order of 10 cm/s, shows little recognition of a fence and the road bed, approximately 1 m above the adjacent field. The flow is sufficiently stratified in this cold pool that the surface obstacles do not significantly perturb the flow. Pressure fluctuations induced by the obstacles tend to be quadratically proportional to the wind speed and thus are very small. As a result, the flow appears to be almost laminar.

Figure 3: A surface layer of fog forms in the field near the tree canopy. Fog does not form over the field closer to the camera, possibly because of greater downward mixing of dryer air, or possibly due to the history of advection of ground fog. The striations of fog at higher levels suggest only very weak fine scale diffusion adjacent to the canopy upper story but over the field.

Figure 4: Eventually, fine scale diffusion reduces the integrity of the striations.

Figure 5: Instabilities confined to a surface layer seem to feed development of a striation at the top of the layer.

mixing and modification of the striations (322). Slanting sun rays effective visualizes the striations.

1.1 Striation history

How are the striations eliminated?

1. they gradually diffuse through fine scale mixing

2. they merge with other fog elements and loose their identity

3. they advect out of the image

4. they gradually loose identify through a mixture of poorly defined mechanisms.

How do they form?

1. mixing across thin sublayers where condensation occurs at the upper edges of the layers

2. detachment of surface fog

3. instabilities across a layer deposit fog at the top of the layer leading to a striation (Figure 5).

Figure 6: Fog is diffused by fine scale turbulence generated by flow through a vineyard.

4. intensified by horizontal divergence (vertical convergence)

5. do striations occur with machine generated fog?

1.2 Natural Vegetation

Consider one example of fog drifting westward into an orchard just west of the BPP central site. Contrast the striated fog over grass (Figure **??**) with the nearby diffuse fog flowing through an adjacent vineyard (Figure 6)