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Effects of external forces on the structure of multiple thin layers in the upper troposphere as seen by imaging with the MU radar

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1. Background

At midlatitudes, strong shears associated with the edges of the jetstream are often the site of turbulent activity, seen in VHF radar data as 'layers' of high SNR and with broad spectral widths signifying a wide velocity spectrum. The origin of the turbulence is thought to be shear instability, giving rise to Kelvin-Helmholz Instability (KHI) rolls aligned with the direction of the shear. KHI has been explicitly observed in the boundary layer, and in the mesosphere with radar methods. Once turbulence rolls form and mixing takes place, sheets form at the edges of the turbulent layer and persist even after the continued mixing has made the central portions of the layer invisible to radar. It is speculated that the edge layers then become unstable and split into further layers as the originating turbulence ceases and removes the supporting force for the layers. Multiple layers which no longer have instabilities sustaining them may diffuse in less than 30 minutes, but it is possible for heating to account for longer-lived layers. Solar heating of different concentrations of molecules gives rise to temperature steps at their interfaces, which appear as radar reflection. The concentrations of molecules may occur naturally, due to density differences (hydrostatics) or due to dynamics of the wind field, arising from regions of pollution for example and advected by the wind. A stratified set of layers may therefore result from an amalgamation of different molecule concentrations orginating from a variety of different geographic sources.

2. Results

In this paper, using a high-resolution imaging algorithm, we demonstrate that sporadic layers seen by standard VHF observations are in fact part of a much more complex and persistent pattern of multiple thin layers (MTLs), with lifetimes of many days or more. Sporadic turbulent activity is observed to take place in portions of some of these layers, causing vertical mixing, and layers are seen to multiply and spread in altitude. Wind, atmospheric waves, convection, and sporadic turbulence modulate the vertical motions of the MTLs, showing that what standard VHF observations see as thicker and thinner layers are in fact the expansion and compression of MTLs relative to one another.

3. Discussion

It is important to distinguish local from non-local effects in the observed structure and motion of the layers, and also scattering from reflection. This problem has persisted since the start of VHF radar observations. Using oblique beams it is possible to distinguish reflection and anisotropic turbulence from isotropic turbulence. In the case of wave activity, reflecting sheets become sporadic in the vertical beam and appear in an oblique beam, while turbulence is visible in both vertical and oblique beams. Shear information tells us whether layers can be formed and sustained by turbulence; in some cases the turbulence source is some distance away from the radar, and the turbulence is dying out while passing over the radar. For layers with long persistence, where heating may be a source, we show some daily variations to support our hypothesis. We also show possible sources for some of the layers, using meteorological information. Since layers in close proximity in altitude may originate in widely differing locations, high-resolution imaging can be of great usefulness in environmental studies.