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P2.55 Persistent Daytime Superadiabatic Surface Layers Observed by a Microwave Temperature Profiler

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ABSTRACT

Observations of oxygen and water vapor resonances at 35 microwave frequencies were used to retrieve temperature and moisture profiles to an altitude of 10 km during the spring and summer months of 2012. The retrieved profiles have very high temporal resolution and reveal the development of the atmosphere's daytime mixed layer and its transition to nocturnal characteristics. A persistent daytime feature is a surface-based superadiabatic layer. However, only the lowest portion of this feature occasionally displays an autoconvective lapse rate, which would imply spontaneous overturning of air near the surface.

1. Introduction

Conventional wisdom in atmospheric science holds that observations of elevated superadiabatic layers should be rare and surface based superadiabatic layers are temporary features at best. Hodge (1956), e.g., notes the resistance of forecasters toward recognizing the existence of superadiabatic layers outside of the planetary boundary layer. The reasoning for these views is that a small vertical displacement under these conditions would experience acceleration in the direction of the perturbation and adiabatic expansion/compression of displaced air parcels would effectively erase the superadiabatic layer. Instrument sampling issues, such as evaporative cooling on temperature sensors upon emerging above a cloud, are often cited as causes for superadiabatic measurements. In practice, superadiabatic layers in radiosonde data are frequently flagged and/or adjusted back to adiabatic before the data are used (Slonaker et al. 1996).

However, near surface superadiabatic layers are regularly observed by radiosondes and other techniques. Takle (1983) reports on observations from an instrumented tower made over nearly six years in central Iowa. In the present study, preliminary work based on observations from a surface based microwave radiometer in Cedar Falls, Iowa, are discussed.

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2. Data collection and methods

A surface based Radiometrics MP-3000A series microwave radiometer is in operation at the University of Northern Iowa in Cedar Falls, Iowa. This instrument measures atmospheric radiation intensity at 35 frequencies (or channels) between 20 and 60 GHz. Fourteen of these channels correspond to resonance frequencies produced by molecular oxygen and 21 channels correspond to the resonance of water vapor. Emission in the oxygen channels is proportional to local temperature and density of oxygen. Emission in the water vapor channels is proportional to vapor density and temperature.

A neural network trained on data from the Davenport, Iowa, radiosonde (located about 190 km [120 miles] to the southeast of Cedar Falls) is used to retrieve temperature, water vapor, and cloud liquid water profiles at 58 height levels every 48 seconds. In this study, profiles nearest the top of the hour were used.

3. Analysis and discussion

Presented here are conditions observed on August 25, 2011. This single case is representative of near-surface conditions frequently observed by the radiometer at the University of Northern Iowa. This late-summer date was characterized by clear skies with temperatures very close to the climatological values. Profiles of virtual potential temperature sampled by the radiometer (UNI) and the Davenport radiosonde (DVN) at 12 UTC (about 30 minutes after sunrise) are presented in Fig. 1. Virtual potential temperature includes the effects of temperature, pressure, and water vapor content on the density of air. Stable conditions exist in layers where virtual potential temperature increases with increasing height. Unstable, superadiabatic conditions are found in layers where virtual potential temperature decreases with increasing height. (Note: a complete evaluation of stability in a layer should include a nonlocal analysis [Stull 1991; Czarnetzki 1996]). The UNI and DVN profiles are equally stable within about 300 m of the surface, with a profile characteristic of the residual layer between about 300 and 1700 m at DVN.

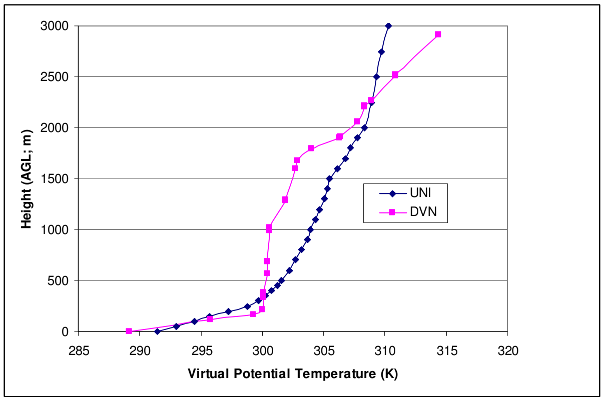


Figure 1. Virtual potential temperature (K) from the University of Northern Iowa's radiometer (UNI) and the Davenport, Iowa, radiosonde (DVN) at 12 UTC 25 August 2011.

Figure 2 presents the development of the daytime boundary layer and its transition to nocturnal conditions as measured by the radiometer. In the figure, virtual potential temperature profiles are ordered from earliest

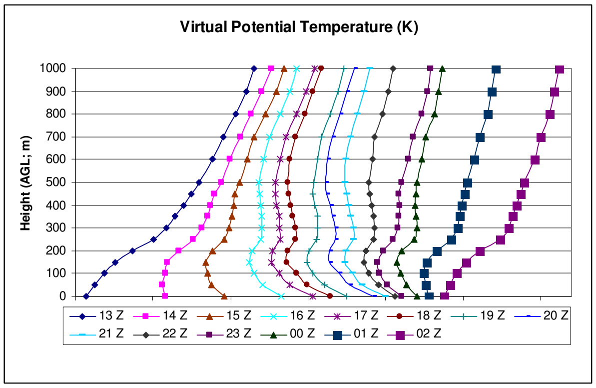


Figure 2. Virtual potential temperature (K) from the University of Northern Iowa's radiometer (UNI) between 13 UTC 25 August and 02 UTC 26 August 2011.

at the far left to latest at the far right. The nocturnal inversion transitioned to a 50 m deep superadiabatic surface layer by 1346 UTC, 139 minutes after sunrise. Takle (1983) reported an average delay of 116 minutes between sunrise and onset of superadiabatic conditions during July in the 30 m near-surface layer sampled by an instrumented tower. The profiles in Fig. 2 remain superadiabatic until the 02 UTC 26 August profile (the last superadiabatic layer occurred at 0128 UTC). The duration of near-surface superadiabatic conditions was 11 hours and 17 minutes in this case, which is comparable to the duration noted by Takle (1983) for the month of August.

The 00 UTC UNI and DVN profiles (Fig. 3) have similar structure near the surface, but differ above about 150 m. The DVN profile is nearly adiabatic (constant virtual potential temperature) from about 150 to 1100 m. The radiometer shows a stable layer capping the superadiabatic surface layer followed aloft by superadiabatic conditions between 300 and 400 m before becoming stable farther up.

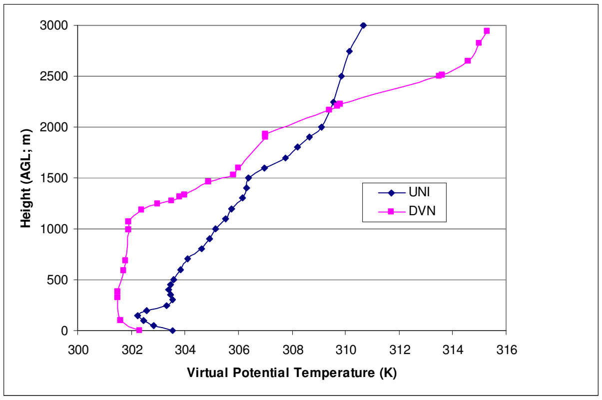
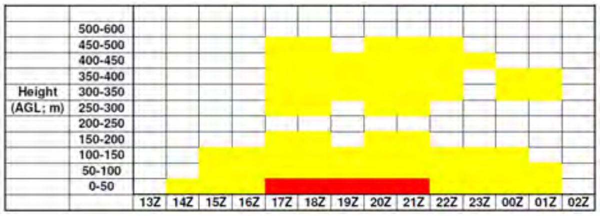


Figure 3. As in Fig. 1 except at 00 UTC 26 August 2011.

The location and development of superadiabatic layers in the profiles of Fig. 2 are shown by the yellow shading in Fig. 4. Much of the lowest 500 m of the atmosphere was superadiabatic from about 1 hour prior to solar noon (1812 UTC) through about the time of sunset that evening (0156 UTC).



Height (AGL; m)		13Z	14Z	15Z	16Z	17Z	18Z	19Z	20Z	21Z	22Z	23Z	00Z	01Z	02Z
	500-600														
	450-500					🟨	🟨		🟨	🟨	🟨				
	400-450					🟨	🟨	🟨	🟨	🟨	🟨	🟨			
	350-400					🟨	🟨	🟨	🟨	🟨	🟨		🟨	🟨	
	300-350					🟨	🟨	🟨	🟨	🟨	🟨		🟨	🟨	
	250-300					🟨	🟨		🟨	🟨					
	200-250														
	150-200					🟨	🟨		🟨	🟨					
	100-150			🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨		
	50-100			🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	
	0-50		🟨	🟨	🟨	🟥	🟥	🟥	🟥	🟥	🟨	🟨	🟨	🟨	

Figure 4. Layers with superadiabatic lapse rates (yellow shading) and lapse rates greater than the autoconvective lapse rate (red shading) between 13 UTC 25 August and 02 UTC 26 August 2011.

Red shading in Fig. 4 indicates layers in which the observed lapse rate exceeds the autoconvective lapse rate. In these layers, the air density increases with increasing height. This would imply a spontaneous overturning of air since environmental conditions could not suppress the ascent of buoyant surface parcels. Lapse rates exceeding autoconvective are only found in the lowest layer of the profiles. Their persistence between about 17 and 21 UTC imply a near-continuous replenishment of warm surface temperatures as heat is convected upward by buoyant parcels.

4. Conclusions

This work supports the hypothesis that surface based superadiabatic and autoconvective layers can be observed and the superadiabatic layers can be long-lived in the daytime mixed layer. If the initial findings are confirmed through further study, the results would indicate that observations of superadiabatic lapse rates should not be summarily dismissed as erroneous or transient.

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