P3.1

Forecasting Mixed-layer Height Over Complex Terrain

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1. INTRODUCTION

Mixing height is a critical component in determining the extent to which smoke will ventilate and disperse. Land management agencies (e.g., Bureau of Land Management, US Forest Service) frequently request mixing height forecasts (in the form of smoke dispersal) from the National Weather Service Forecast Office (WFO) in Grand Junction, Colorado (GJT) to support prescribed burn activities. The complex terrain that exists in the GJT county warning area (CWA) makes this a forecast challenge.

Smoke dispersal forecasts are based heavily upon numerical model output, as well as the most recent Grand Junction radiosonde data. However, customer feedback of forecasts have indicated that actual mixing heights are often higher than forecast mixing heights during periods of poor mixing (i.e., upper-level ridging accompanied by a subsidence inversion).

Several field programs have focused on boundary layer structure and evolution over complex terrain. One such field program was the Department of Energy's Atmospheric Studies in Complex Terrain (ASCOT) program (Clements et al. 1989). This field program took place in and around the Brush Creek Valley (roughly 50 miles north of Grand Junction). The main objective of their study was to enhance the understanding of pollution transport and diffusion associated with valley flows, focusing on nocturnal and early morning periods. More recently, boundary layer structure and evolution have been examined in urban areas near complex terrain such as the Mexico City Basin (Doran et al. 1998) and the Salt Lake Valley (Doran et al. 2002; Allwine et al. 2002). The data gathered from these two field programs show vast differences in ventilation, transport, and dispersion of aerosols during a variety of synoptic situations.

Boundary layer characteristics over mountainous terrain are presumed to differ from those over valleys (Doran et al. 1998), particularly when mixing is poor. The local radiosonde is released from WFO GJT in the Grand Valley (1472 m elevation), and therefore GJT radiosonde data may not be completely representative of the conditions over nearby mountainous terrain. Bader et al. (1987) examined the evolution of the convective boundary layer (CBL) over complex terrain in northwestern Colorado. Bader et al. found that a CBL typically developed beneath the nocturnal stable layer shortly after sunrise. The vertical growth and mixing within these CBLs eventually destroyed the elevated stable layer and coupled the terrain-driven flows with the gradient flow above ridge top. This process was found to occur earlier over mountains than valleys, as the stability is less and the stable layer shallower over mountains than over valleys.

An observational study is underway at WFO GJT to assess the difference in mixing height, for smoke management applications, between a mountain and valley location during afternoons with upper-level ridging and a subsidence layer present aloft. This focus differs slightly from the previous literature mentioned, which has investigated flows and boundary layer evolution over valley locations which are modified by the surrounding complex terrain. Special remote radiosondes have been released from a site with an elevation of 2450 m and location 13 mi south-southwest of WFO Grand Junction (Glade Park site hereafter) (see Figure 1). The

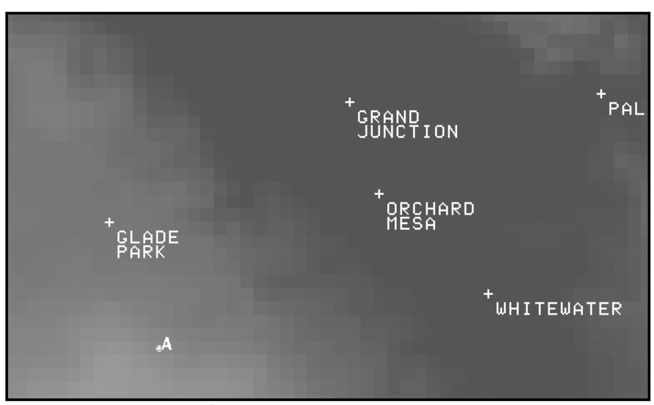

Figure 1. Map of observational study areas Grand Junction and Glade Park site (located at A). Lighter shading indicates higher elevation.

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0600 UTC MM5 (USFS) (Zeller et al. 2003) and NAM (NOAA) model-generated sounding data will be compared to observed sounding data taken 2100 UTC and 0000 UTC during such periods of poor mixing.

2. DESIGN AND EQUIPMENT

WFO GJT personnel and observational equipment have been utilized for this study. The remote release time of 2100 UTC has been chosen as it corresponds closely to the typical time of day when a maximum of mixing height is present and does not interfere with the routine 0000 UTC release from WFO GJT.

To date, two successful upper-air releases have taken place at the Glade Park site. However, low-level wind data have not been collected from the remote releases because the first several hundred meters of radiosonde ascent is below the local limiting elevation angle (i.e., the lowest reliable elevation angle of radio detection).

3. CASE STUDY ANALYSIS

Boundary layer characteristics have been examined on two separate occasions at GJT and the Glade Park site during this preliminary study. Special radiosonde releases took place at the Glade Park site at 2100 UTC on 24 May and 16 June 2006. The 1200 UTC (GJT), 2100 UTC (Glade Park site), and following 0000 UTC (GJT) soundings during each release were compared with NAM model soundings (centered on each respective release location and during the release times) generated at 12 km resolution during the 0600 UTC model run prior to the two cases presented here. The 0600 UTC model run has been chosen for this sounding comparison due to the routine use of this model for producing the smoke dispersal forecasts.

The synoptic environment during both cases was characterized by a longwave ridge building over the Intermountain West (see Figure 2) at the end of a period of intense mixing following the passage of a surface cold front.

In the 24 May 2006 case (Case 1 hereafter), a 500-hPa trough passed through the GJT CWA during the previous afternoon. By 1200 UTC 24 May, the 500-hPa trough axis was situated along the eastern slope of the Front Range. A layer of subsidence aloft is evident from the 1200 UTC 24 May GJT sounding data (Fig. 3a). This subsidence layer had a base at 620 hPa and a depth of roughly 40 hPa.

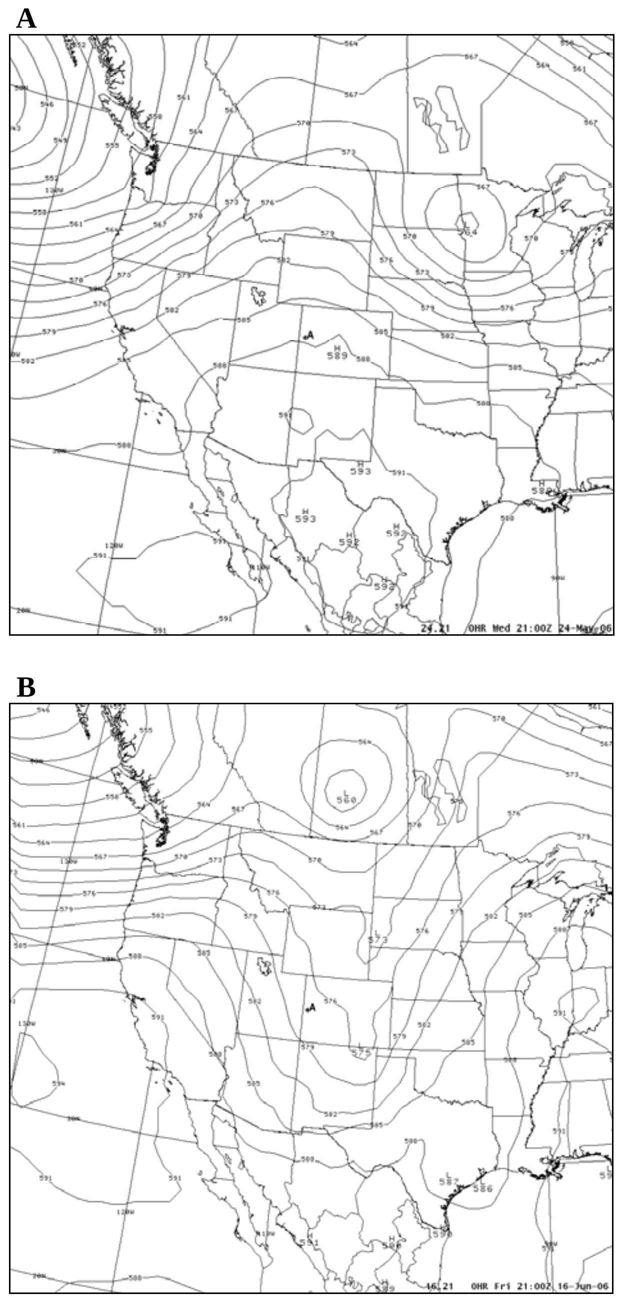

Figure 2. 2100 UTC RUC analyses of 500-hPa geopotential height (dm) during 24 May (A) and 16 June (B). Point A is the location of the Glade Park site.

In the 16 June 2006 case (Case 2 hereafter), a 500-hPa trough had passed through the GJT CWA by 1000 UTC 16 June and had reached eastern Colorado by 2100 UTC. A subsidence layer, with a base at 570 hPa and a depth of

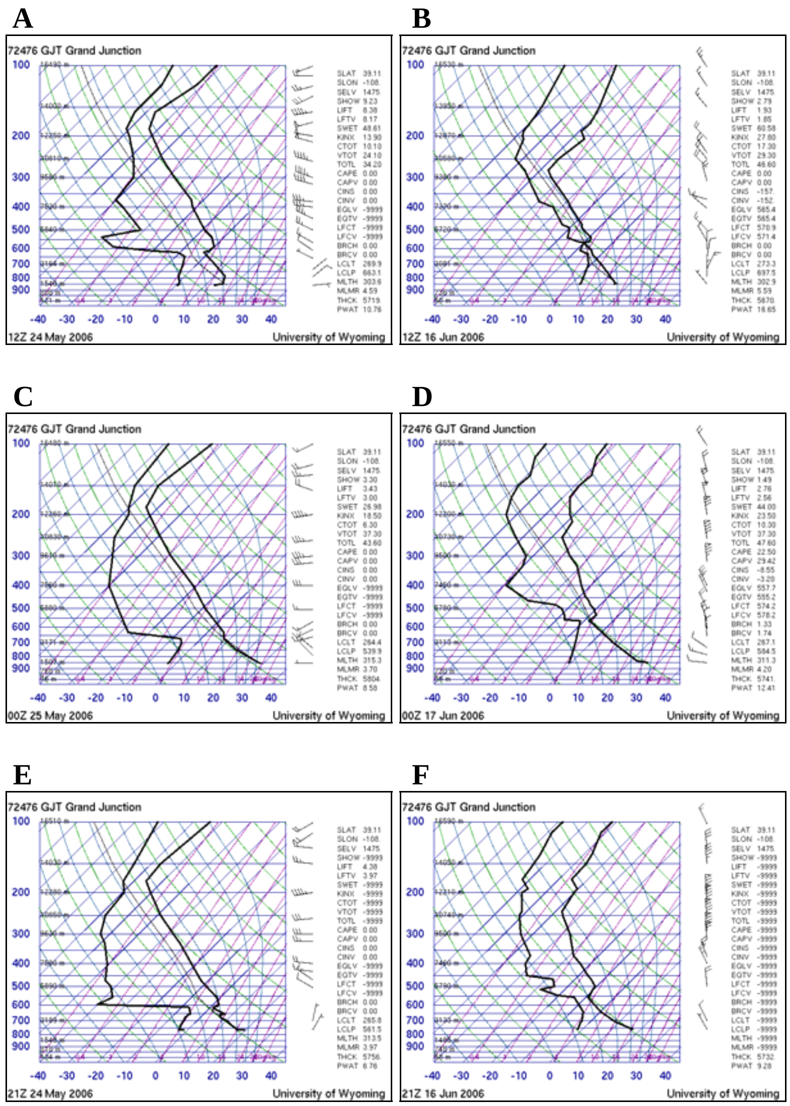

Figure 3. GJT soundings at 1200 UTC (A) 24 May and (B) 16 June and at 0000 UTC (C) 25 May and (D) 17 June. Glade Park site soundings at 2100 UTC (E) 24 May and (F) 16 June 2006 (courtesy University of Wyoming).

roughly 20 hPa, is evident on the GJT sounding released at 1200 UTC(Fig. 3b).

The GJT boundary layer characteristics during each case differs with respect to stability and moisture. Unlike Case 1, where a stable surface layer nearly 800 m deep was present over GJT at 1200 UTC, Case 2 exhibited a mixed atmosphere over GJT in the morning due to cold advection behind the trough and surface front (Figs. 3a,b). The Case 2 1200 UTC sounding had a higher mixing ratio and lower dew point temperature depression throughout the depth of the troposphere. Drying above the subsidence inversion aloft is evident in the GJT 0000 UTC soundings during both cases; however, Case 1 exhibited a very weak conditionally stable layer aloft, which replaced the subsidence inversion aloft by 0000 UTC.

The boundary layer over the Glade Park site at 2100 UTC appears to differ only somewhat with the boundary layers over GJT during the days of each respective remote release. The abrupt discontinuity in moisture that can be seen near 600 hPa over the Glade Park site at 2100 UTC during Case 1 is not evident on either the preceding 1200 UTC or following 0000 UTC GJT sounding. The strength, depth, and location of the subsidence inversion aloft seen on the 2100 UTC Glade Park site sounding during Case 1 coincides closely with the previous 1200 UTC GJT sounding, but had been nearly completely mixed out by the following 0000 UTC GJT sounding. The depth of the subsidence layer aloft over the Glade Park site at 2100 UTC during Case 2 appears to be greater than that seen in either the preceding 1200 UTC or 0000 UTC GJT sounding.

The NAM model soundings do not accurately represent some of the salient features of the GJT boundary layer in both cases. The NAM 1200 UTC model soundings suggest excessive drying throughout the depth of the troposphere compared to the Case 1 sounding released at 1200 UTC, while a surface based inversion is produced though none is evident on the Case 2 1200 UTC sounding. In both cases, the NAM soundings do not accurately reflect the depth or the strength of either subsidence inversion aloft at 1200 UTC.

The NAM model soundings are not necessarily representative of the boundary layer structure present over the Glade Park site at 2100 UTC during both cases. The subsidence layers aloft evident during both Case 1 (600 hPa) and Case 2 (550 hPa) soundings are not present on the NAM model soundings. In addition, the low-level moisture fields are much drier on the NAM model soundings than the actually soundings released during Case 1.

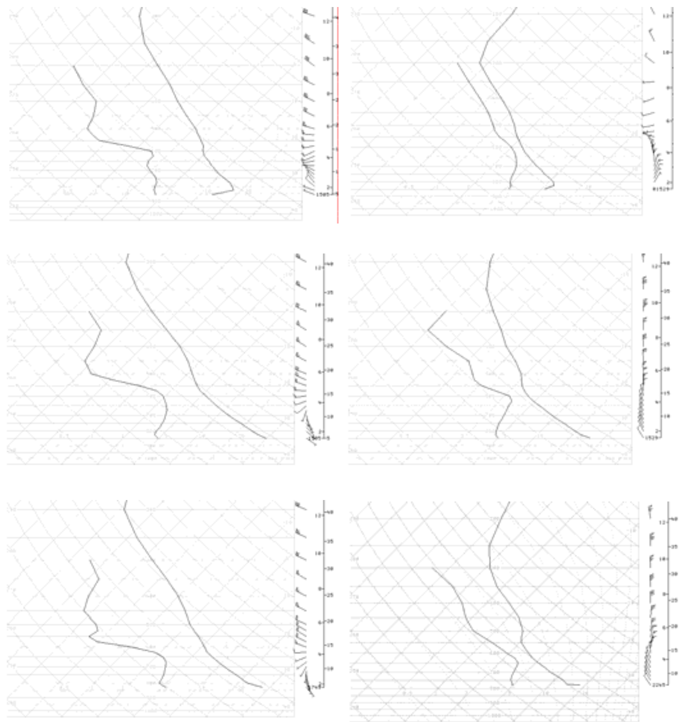

Figure 4. NAM12 (valid 0600 UTC) GJT forecast soundings at 1200 UTC (A) 24 May and (B) 16 June and at 0000 UTC (C) 25 May and (D) 17 June and Glade Park site forecast soundings at 2100 UTC (E) 24 May and (F) 16 June 2006.

4. SUMMARY AND CONCLUSIONS

Two cases of poor mixing environments over a mountain and a valley location immediately following a synoptically active period have been examined. Soundings released from a valley and mountain site have been compared to NAM model soundings produced at 12 km resolution.

This study was prompted by a need to improve WFO GJT smoke dispersal forecasts, particularly over complex terrain,. Accurate smoke dispersal forecasts are crucial for land use agencies to make decisions during prescribed burn activities.

Many of the features evident on the GJT and Glade Park site soundings are not present on the NAM model soundings. Most noteworthy during this initial study are the subsidence layers aloft evident on the soundings, while not necessarily represented on the NAM model soundings.

Further analysis of mountain and valley boundary layers near GJT and mixing height applications will be shown at the conference. A comparison of MM5 model runs produced at the USFS Rocky Mountain Center to the two cases present here will presented at the conference as well.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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