A HIGH-ELEVATION TORNADO OVER NORTHERN ARIZONA

David O. Blanchard*
NOAA/National Weather Service
Flagstaff, AZ 86015

1. INTRODUCTION

Mountain tornadoes, although uncommon, have been documented over the years across the western states. Recently, a tornado occurred over the San Francisco Peaks of northern Arizona. This group of volcanic summits includes Humphreys Peak—the highest point in Arizona at 12,633 feet. This tornado occurred within a short time and distance of the regularly scheduled rawinsonde resulting in a quality proximity sounding.

2. ENVIRONMENTAL OVERVIEW

The environment that produced the tornado was similar to the composite environment shown by Blanchard (2008) for tornadoes in northern Arizona (Fig 1). A weak closed low was moving eastward from the west coast with Arizona located in the surface warm sector (Fig. 2). Both low-level and deep-layer shear were large with values corresponding to the 4th and 2nd quartiles, respectively, as shown in Rasmussen and Blanchard (1998; hereafter RB98). Instability was marginal and this has also been shown to be typical of northern Arizona tornado environments.

The tornado (Fig. 3) occurred approximately 15 km from and within 90 minutes of the regularly scheduled rawinsonde launch (Fig. 4) from the National Weather Service Forecast Office in Flagstaff, Arizona. This is the fourth high-elevation tornado proximity sounding taken from the Flagstaff NWS office in the past decade (Table 1).

Data collected by the KFSX WSR-88D radar (not shown) indicated the tornado likely occurred between 0023 and 0032 UTC 15 September 2011.

3. TORNADO DAMAGE

The tornado formed over the gently sloping terrain west of the San Francisco Peaks (Fig. 3) and then moved up the west flank of Humphreys Peak. Damage was isolated along the early portion of the path at around 9000 feet. As it moved up the mountain, damage increased in both intensity and coverage with the peak damage occurring near 9800 feet. Higher up the mountain isolated damage continued until the tornado dissipated near 10500 feet. This makes this the third highest documented tornado[1] in the United States.

Most of the damage was classified as DOD3 and DOD4 (i.e., snapped trunks or uprooted trees) resulting in an EF-scale (WSEC 2006) rating of EF1. A small patch of damage was likely at the upper bound (UB) of the DOD3/DOD4 ratings, however, which would elevate this to an EF2 rating.

The worst damage occurred as the tornado crossed the Humphreys Trail—a popular hiking trail. The damage inflicted upon the mountain might not have been noticed as quickly—or surveyed as easily—had it not passed over a heavily used hiking trail.

4. COMPARISON WITH OTHER EVENTS

A comparison of sounding parameters for this event with other tornado proximity soundings near the KFGZ rawinsonde site is presented in Table 1.

Most notable is the marginal buoyant instability present; two of the four events are less than 100 J kg^{-1} and none exceed 500 J kg^{-1}. These compare with the 1st quartile for the TOR category shown in RB98. They are also consistent with the composite results of Blanchard (2008) in which the mean instability was a Lifted Index of –1.

Wind shear, on the other hand, compares favorably with the results of RB98. The BL–6-km shear compares with the 2nd and 4th quartiles of RB98 for the TOR category. Storm relative helicity in the 0–3 km layer is comparable to the 4th quartile for all events.

Two of the four events reported here were nocturnal (2, 3); one occurred shortly after sunrise (1); and one occurred during the afternoon hours (4). All exhibited strong low-level and deep-layer vertical shear. These events, then, are all characterized by a marginal instability—strong shear environment; these are typical of the environments described by left-hand-sides of the instability-shear diagrams shown in Brooks et al. (1994;

* Corresponding author address: David O. Blanchard, NOAA/National Weather Service, P. O. Box 16057, Bellemont, AZ 86001. E-mail: david.o.blanchard@noaa.gov

[1] Recent reports indicate another high altitude tornado occurred this summer in the mountains of Colorado and may now be the third highest event.

their Fig. 5), Johns and Doswell (1992; their Fig. 18), RB98 (their Fig. 9), and others. Further, the nocturnal events are similar to the results presented by Kis and Straka (2010) for their nocturnal tornado climatology with marginal instability coupled with strong shear.

5. SUMMARY

A high-elevation tornado occurred in close spatial and temporal proximity to the 0000 UTC 15 Sep 2011 rawinsonde launched from the National Weather Service office in Flagstaff, Arizona. A comparison of the large-scale environment indicated that it was similar to the composite pattern for cool-season tornadoes across northern Arizona. Further, this was the fourth proximity rawinsonde collected from this site in the past decade. A comparison of thermodynamic and wind shear parameters showed that these were all marginal instability—strong shear environments.

REFERENCES

Blanchard, D. O., 2008: Synoptic environments associated with tornadoes in northern Arizona. Preprints, 24th Conference on Severe Local Storms, Savannah, GA. Amer. Meteor. Soc. [Available online at http://ams.confex.com/ams/pdfpapers/141836.pdf]

Brooks, H. E., C. A. Doswell III, and J. Cooper, 1994: On the environments of tornadic and nontornadic mesocyclones. Wea. Forecasting, 9, 606–681.

Johns, R. H., and C. A. Doswell III, 1992: Severe Local Storms Forecasting. Wea. Forecasting, 7, 588–612.

Kis, A. K., and J. M. Straka, 2010: Nocturnal tornado climatology. *Wea. Forecasting*, **25**, 545–561.

Rasmussen, E. N., and D. O. Blanchard, 1998: A baseline climatology of sounding-derived supercell and tornado forecast parameters. *Wea. Forecasting*, **13**, 1148–1164.

WSEC, 2006: A recommendation for an enhanced Fujita Scale (EF-Scale), Wind Science and Engineering Center, Texas Tech University, Lubbock, Texas 79409-1023, 111pp. [Available online at http://www.depts.ttu.edu/weweb/Pubs/fscale/EFScale.pdf]

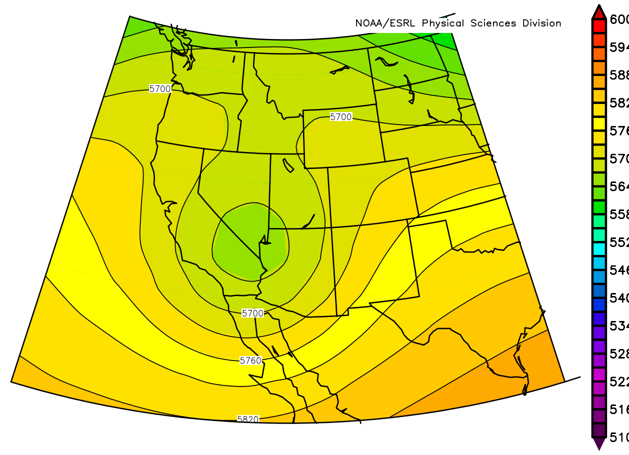

Figure 1. Composite 500-mb height field for tornado events across northern Arizona.

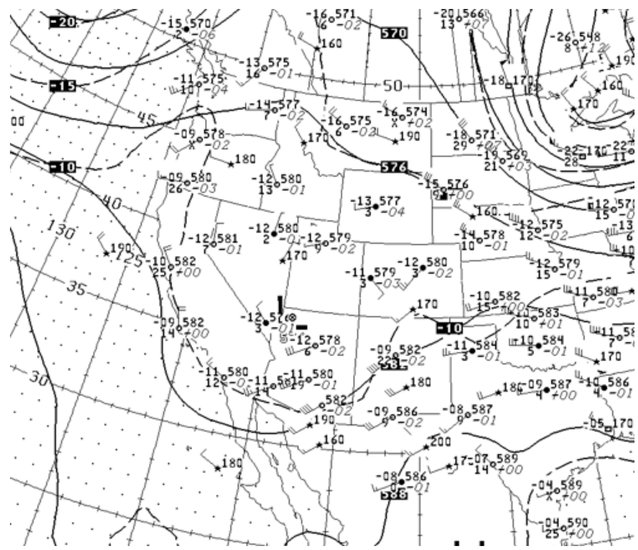

Figure 2. 500-mb analysis for 0000 UTC 15 Sep 2011 showing the closed low approaching Arizona.

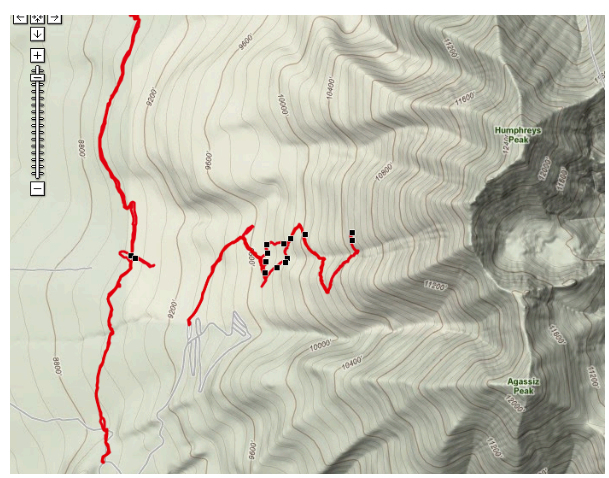

Figure 3. Terrain map of Humphreys Peak and the tornado damage path. Surveyed damage points are shown by small black squares; red lines are trails used to access the damage.

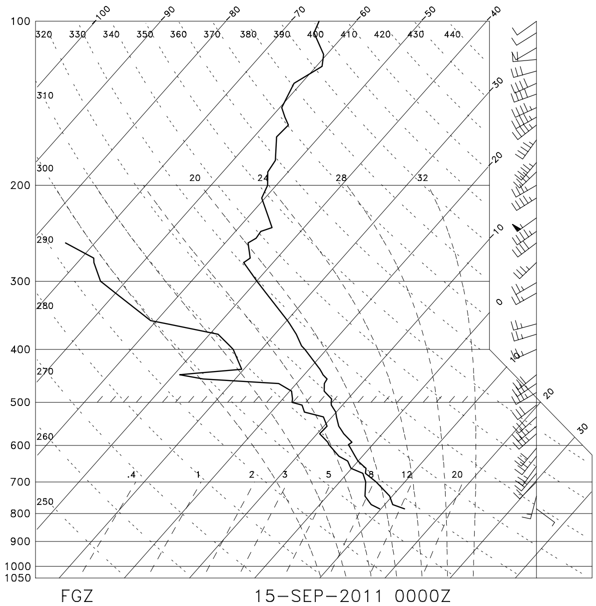

Figure 4. Upper air sounding taken at KFGZ at 0000 UTC 15 Sep 2011.

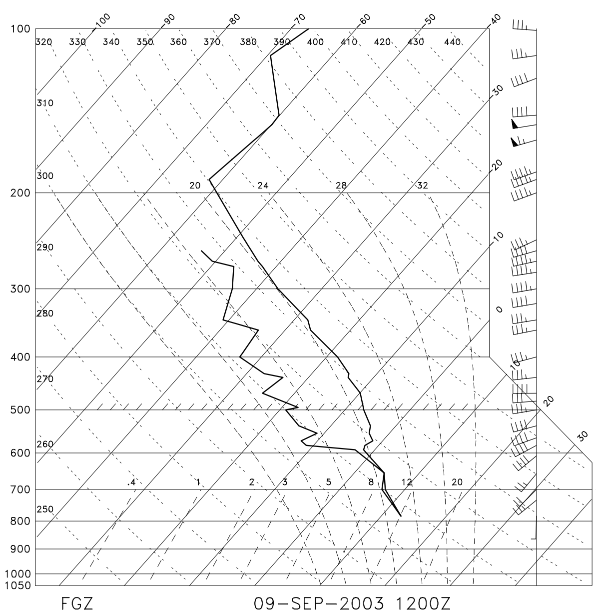

Figure 5. As in Fig. 4 except for 1200 UTC 09 Sep 2003.

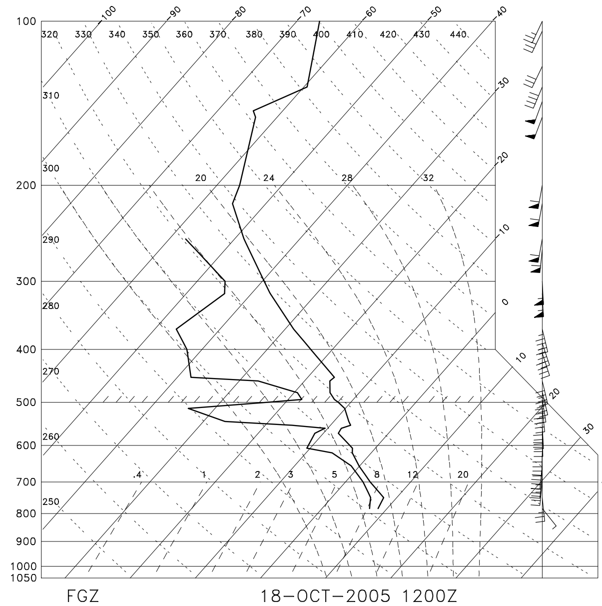

Figure 6. As in Fig. 4 except for 1200 UTC 18 Oct 2005.

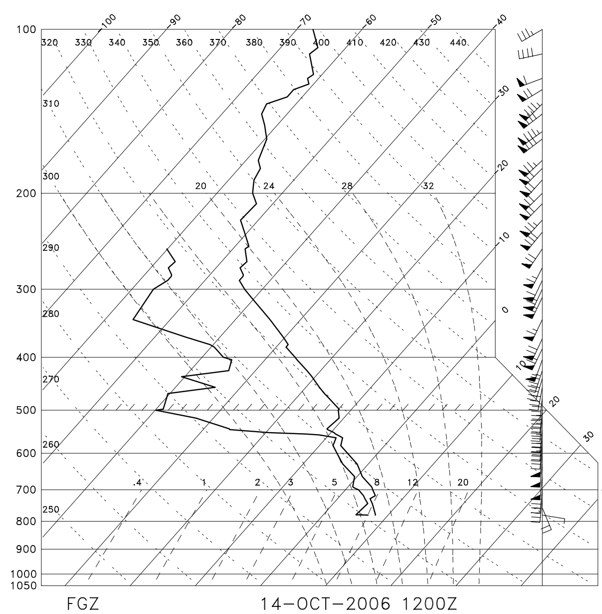

Figure 7. As in Fig. 4 except for 1200 UTC 14 Oct 2006.

Table 1. Shear and stability parameters for four tornado proximity soundings taken at KFGZ. Subscripts refer to the depth in kilometers above the ground through which the calculation is performed. Q-values in parentheses refer to the quartile to which these values compare with the results presented in Rasmussen and Blanchard (1998) for the tornado (TOR) category.

Parameter	1. 1200 UTC 09 Sep 2003	2. 1200 UTC 14 Oct 2006	3. 1200 UTC 06 Oct 2010	4. 0000 UTC 15 Sep 2011
CAPE (J kg^{-1})	18 (*)	87 (Q1)	446 (Q1)	341 (Q1)
SRH_{0-3} (m^2 s^{-2})	421 (Q4)	364 (Q4)	504 (Q4)	302 (Q4)
Mean $Shear_{0-4}$ ($x10^{-3}$ s^{-1})	8.6 (Q3)	7.8 (Q2)	10.4 (Q4)	8.2 (Q3)
BL–6-km shear (m s^{-1})	17 (Q2)	36 (Q4)	28 (Q4)	16 (Q2)
VGP (m s^{-2})	0.04 (*)	0.07 (*)	0.22 (Q3)	0.15 (Q1)
Proximity	<5km; ~3h	< 10km; ~2h	<1km; ~1h	<15km; ~1.5h

* Value is less than the minimum for the TOR category in RB98.