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P12.7 FORECASTING SEVERE WEATHER ALONG THE MOGOLLON RIM CONVERGENCE ZONE

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1. INTRODUCTION

With the nation-wide deployment of the WSR-88D Doppler radar, it has become apparent that there are many regions of the country with persistent, terrain-modified surface wind flows. The Flagstaff, Arizona, Doppler radar has been instrumental in documenting the presence of a persistent convergence zone located in the lee of the Mogollon Rim. The Rim is a crescent-shaped feature that arcs from the north-central part of Arizona southward through the Flagstaff area, thence eastward to the New Mexico border where it merges with the White Mountains (Fig. 1). Leeward of the higher terrain (typically 6500 to 8000 feet) of the Rim is the Little Colorado River (LCR) valley (generally 5000-5500 feet). This valley drains southeast to northwest from the higher mountain terrain along the Arizona–New Mexico border to the Colorado River in northern Arizona.

Under weak to moderate strength ambient flow, the winds in the LCR valley behave much as described by Whiteman and Doran (1993) in their study of the relationship between the winds within a valley and the synoptic scale flows. They note that “the ambient winds, which are in geostrophic balance above the valley, will be channeled by the valley side walls so that, within the valley, the winds will align with the valley axis. The valley wind direction depends on the sign and magnitude of the component of the ambient wind projected along the valley’s axis.” Further, they indicated that “winds are predominantly along the valley axis but with sudden shifts in direction when geostrophic winds shift across a line normal to the valley axis.”

The LCR valley often produces southeast surface drainage winds overnight that persist into the morning and early afternoon. Days with light to moderate southwest flow result in a southeast valley flow superimposed upon the drainage flow. This combined flow then interacts with the ambient southwest flow and is associated with the genesis of the Mogollon Rim Convergence Zone (MRCZ). The MRCZ typically forms on the east side of the Rim as the terrain drops into the river valley and the synoptic-scale southwest winds interact with the southeast drainage winds of the valley.

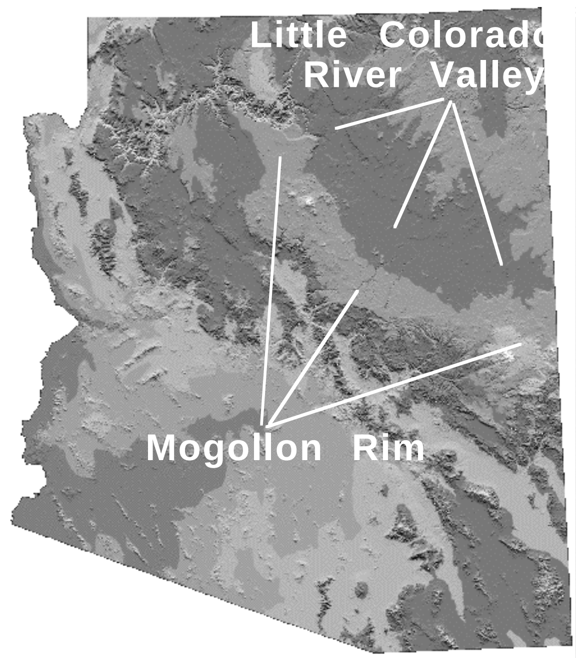

Figure 1: Image showing terrain and elevation over the state of Arizona. The Mogollon Rim and Little Colorado River Valley are noted.

When the ambient flow becomes westerly or northwesterly, the flow in the valley will reverse direction and blow from the northwest, in agreement with the results of Whiteman and Doran (1993).

Radar, satellite, and surface observations have shown that this convergence zone is a preferred region for the genesis of thunderstorms during the late spring and summer months. As has been shown with other terrain-induced convergence zones, there is often a zone of enhanced vertical vorticity (Szoke et al 1984, Brady and Szoke 1989, Szoke and Brady 1989) that is usually on the order of a kilometer or two in horizontal scale. The MRCZ, then, is similar to other terrain flows such as the Denver Convergence Vorticity Zone (DCVZ), which are often associated with higher frequencies of severe thunderstorms producing both large hail and non-supercell tornadoes (Szoke et al 1984, Brady and Szoke 1989, Wakimoto and Wilson 1989, Wilczak et al. 1992, Roberts and Wilson 1995, Lee and Wilhelmson 1997).

Often present on these boundaries are low-level circulations with typical differential velocities of 5 m s^{-1} over 0.5–1.0 kilometers. The NSTs typically form in association with an intensified low-level circulation, presumably owing to stretching of air columns in the vertical beneath the vigorous convection that develops along the boundary (Brady and Szoke 1989, Lee and Wilhemson 1997).

There have been a few documented NSTs along the MRCZ and there are probably a larger number of events that go unreported or even undetected. The next section presents a few examples of the MRCZ and a discussion of their forecast implications.

2. CASE STUDIES

In this section are presented various radar presentations of the MRCZ. One case shows synoptic southwest flow over the Rim with easterly flow in the LCR. A second case shows a westerly flow case with stronger northwest flow in the LCR. Additional cases are also discussed.

a. 17 March 2000

Northwest flow developed over the southwestern United States in the wake of a short-wave trough that traversed the region the previous day (Fig. 2). Although the environment was far too dry to support convection, a well-defined MRCZ developed during the day, as shown in Fig. 3. The convergence zone lies between KFLG and KINW. Ambient flow is from the northwest at 5 m s^{-1} while valley flow is enhanced and is 12 m s^{-1}. This wind flow results in a convergence zone with anticyclonic vertical vorticity.

b. 09 May 2000

Southwest flow dominated the region during this period as a long-wave trough was located upstream in the eastern Pacific. Winds aloft were predominantly from the southwest in the lower troposphere, becoming more westerly in the middle and upper troposphere (Fig. 4). The southwest winds in the lower troposphere resulted in a valley flow from the southeast at 5–8 m s^{-1}. Winds at KINW were from the southeast earlier in the day (not shown) and became light as the MRCZ moved over the station. In this event, the vorticity is cyclonic along the convergence zone.

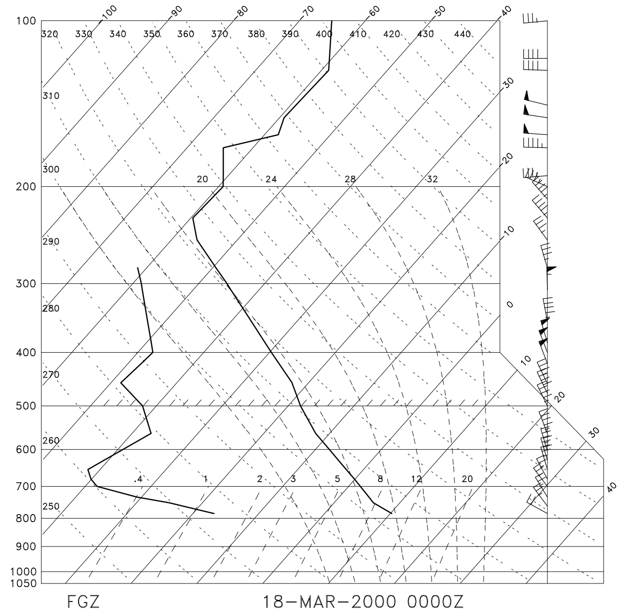

Figure 2: Skew T–ln p plot from Flagstaff, Arizona (FGZ) taken at 0000 UTC 18 March 2000.

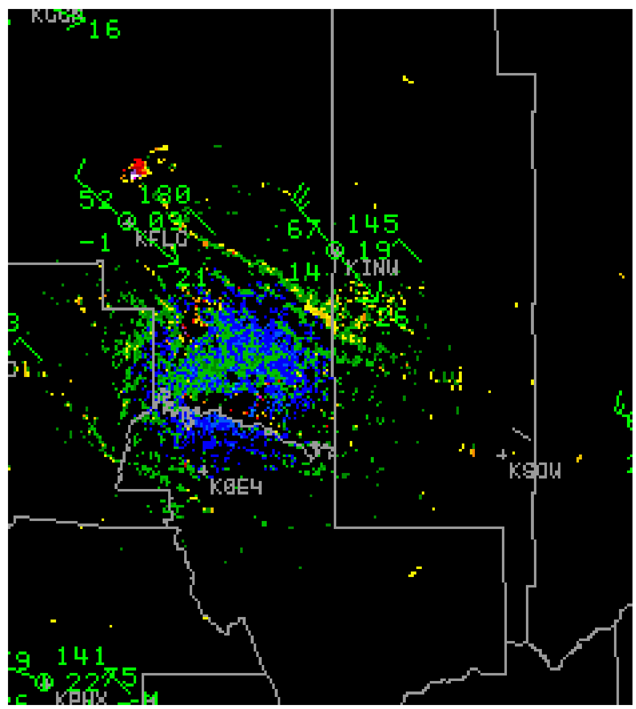

Figure 3: WSR-88D image taken at 2117 UTC 17 March 2000. The convergence zone can be clearly seen lying between Flagstaff (KFLG) and Winslow (KINW). Station plot uses standard notation.

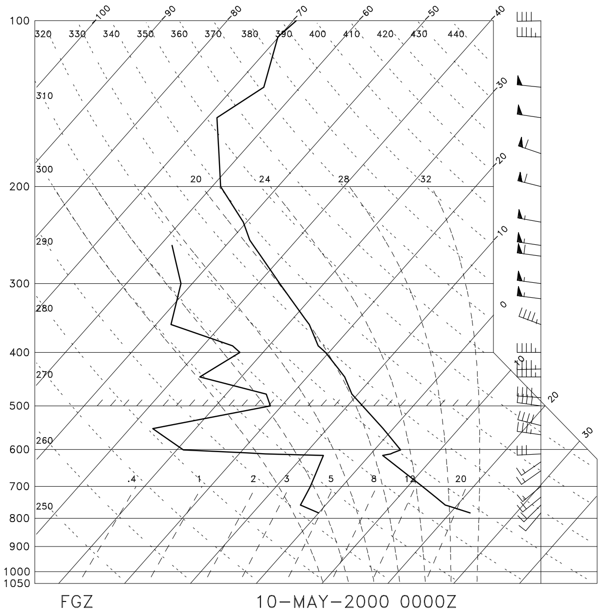

Figure 4: As in Figure 2, except for 0000 UTC 10 May 2000.

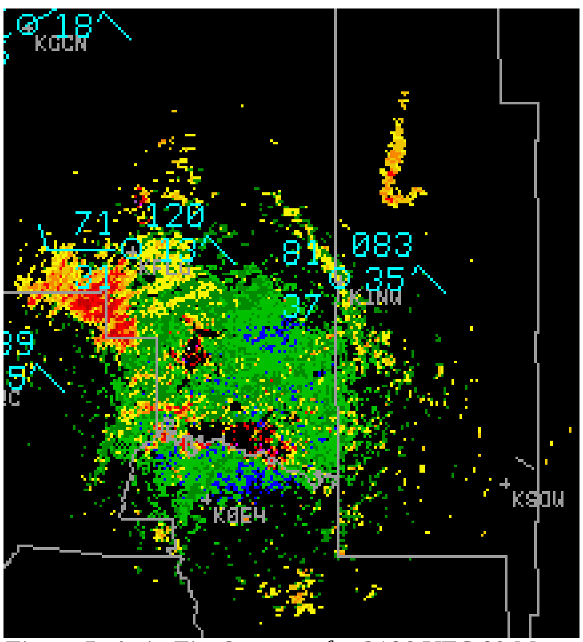

Figure 5: As in Fig. 3, except for 2106 UTC 09 May 2000.

c. 27 May 2000

A large anticyclone dominated the southwestern United States and Arizona during this period giving rise to light southwesterly flow in the lower troposphere, and northwesterly flow above that (Fig. 6).

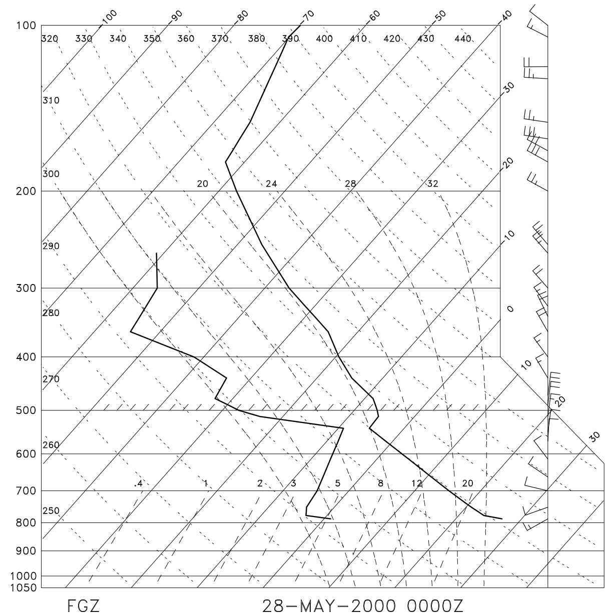

Figure 6: As in Fig. 2, except for 0000 UTC 28 May 2000.

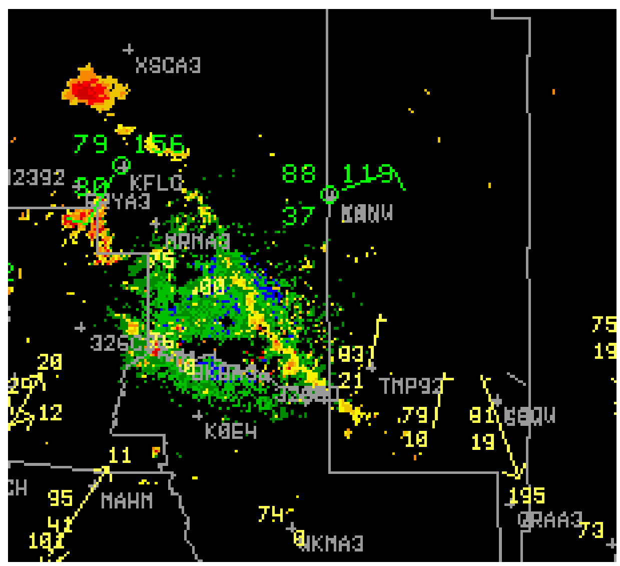

Figure 7: As in Fig. 3, except for 0126 UTC 28 May 2000.

The convergence zone formed farther west on this day as the wind direction in the LCR had a stronger easterly component, with some sites reporting winds of north and northeast (Fig. 7).

d. June 16, 1997

On this day, a nonsupercell tornado (NST) was observed by the author while in the vicinity of Winslow, Arizona (KINW). Southwest flow dominated the region as a trough resided offshore and a weak anticyclone was located over northern Mexico. No radar data was available for this case. Observations indicated that convection was occurring on a line roughly oriented from the southeast to the northwest, suggesting that the MRCZ was at least partially responsible for the location and initiation of early convection. The tornado was typical of many NSTs in that it was first observed as a small dust column with no obvious connection to the parent towering cumulus and cumulonimbus. After ~5 minutes, a small funnel was observed and the dust column reached approximately 1/2 the distance from the ground to the cloud. Because the funnel extended only a small distance below the cloud, this tornado could easily be mistaken for a large dust devil. In fact, anecdotal information in this region and in others where NSTs occur suggest that this misidentification may happen fairly often. For this reason, it is believed that the tornado numbers in the LCR may be severely undercounted.

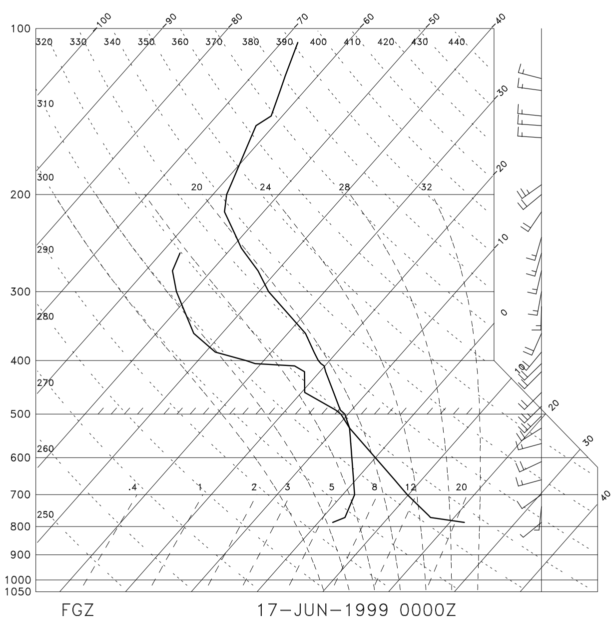

Figure 8. As in Fig. 1, except for 0000 UTC 17 June 1999.

3. SUMMARY

The Flagstaff, Arizona WSR-88D Doppler radar has been instrumental in documenting the presence of a persistent convergence zone located in the lee of the Mogollon Rim, known locally as the Mogollon Rim Convergence Zone (MRCZ). This terrain-induced flow is similar to others that have been previously studied and well documented. Some of these terrain winds, most notably the Denver Convergence Vorticity Zone (DCVZ; Szoke et al. 1984), have been shown to be associated with higher frequencies of severe thunderstorms that are capable of producing both large hail and non-supercell tornadoes. Satellite, radar, and surface observations have shown that the MRCZ, too, is a preferred region for the genesis of thunderstorms during the late spring and summer months. The WSR-88D has played an important role in identifying this feature and alerting forecasters to the possibilities of NSTs and other severe weather occurring in this region.

4. REFERENCES

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