National Weather Service

Upper Level Lows and the Monsoon

Although the North American Monsoon has been researched extensively since 1990, there are several components that are still being explored. One of them involves fairly large, subtropical, upper level disturbances that interact with the monsoon. These upper level lows behave very differently than ones which travel west-to-east with the jet stream and affect Arizona during the winter. These subtropical upper lows move east-to-west, tend to be strongest in the upper levels of the atmosphere, and tend to generate more precipitation on their outer edges than near their centers. It is also unusual for these lows to generate a surface low pressure system or surface front. This makes them virtually impossible to track using surface information alone. Fortunately, they can be tracked using upper level observations and especially water vapor satellite imagery **(Figure 1)**.

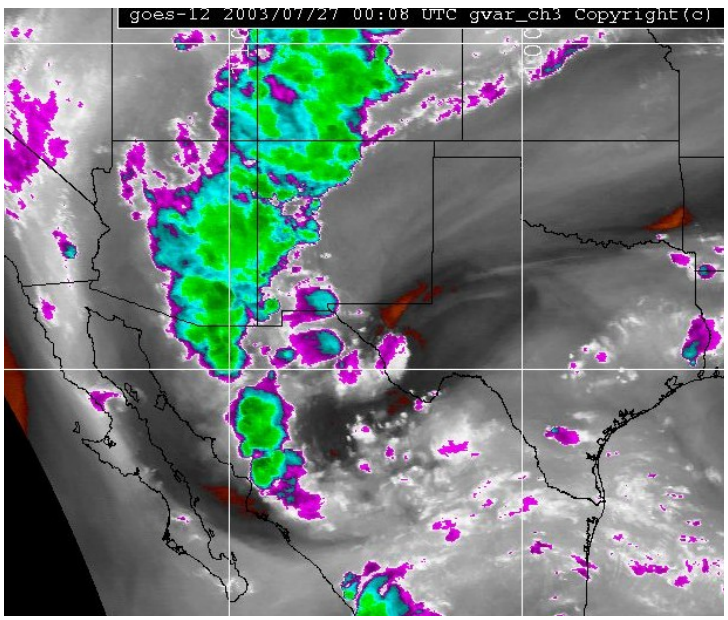

Figure 1: Water vapor satellite image of a subtropical upper low, moving west from Texas toward Arizona, 508 pm MST, July 26, 2003. This low triggered a major severe thunderstorm outbreak across southeast Arizona.

These subtropical upper lows are known to produce heavy precipitation in other parts of the U.S. (Whitfield and Lyons 1992) and the world (Kelley and Mock 1982). These upper lows have also been known to enhance monsoon-related thunderstorms in Australia (Keenan and Brody 1988). However, during the North American Monsoon Experiment, it became apparent that these lows are a primary driver of thunderstorm outbreaks across northwest Mexico and the southwest U.S. (NAME Science Plan 2004). This was confirmed in several post-NAME studies (Pytlak, et al. 2005; Pytlak 2006;

Englehart and Douglas 2006; Douglas and Englehart 2007). The studies also showed that unlike other parts of the world where the thunderstorms tended to develop on the west sides of the lows while the east sides remained quiet, large thunderstorm outbreaks can occur anywhere near these upper lows, especially when the approach the high terrain of the Sierra Madres or southern Rockies.

An idealized depiction of these upper lows is in **Figure 2**. As one of these lows moves west across the southern Plains of the U.S. or northern Mexico, the flow at jet stream level over the monsoon region is forced to diverge. This causes the air underneath to begin to rise and cool. The resulting large scale lift, combined with the mountains and monsoon moisture, causes thunderstorms to develop and grow into large Mesoscale Convective Systems (MCSs). Because the winds aloft also increase as a subtropical upper low approaches, wind shear usually increases, which allows thunderstorms to last longer than usual, move farther west into the deserts, and survive well into the night. If one of these upper lows passes directly overhead, sinking air at the center may briefly cause a downturn in thunderstorms. However as it moves off to the west, the counterclockwise flow around it will usually drag more moisture north and trigger yet more thunderstorms on the back side.

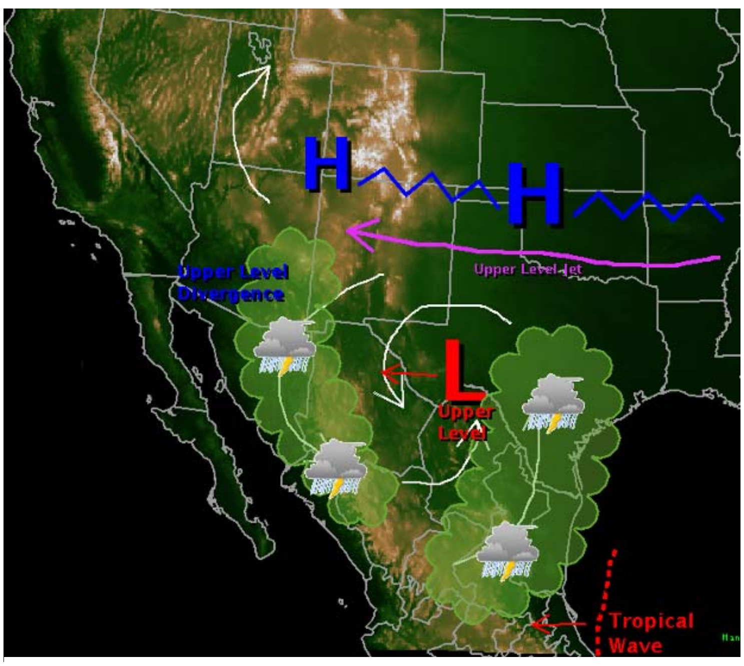

Figure 2: Conceptual hypothesis of a subtropical upper tropospheric low moving west into the North American Monsoon regime. From Pytlak, et al. 2005.

Forecasting these upper level lows, and the thunderstorm outbreaks they can produce, remains a challenge. This hypothesis is still being researched, and it is unclear how strong or large these upper lows have to be to produce thunderstorm outbreaks. The amount of available moisture and the exact placement of the upper level high center are both critical, and not all of these upper lows ignite widespread thunderstorms. However, one study by Bieda, et al. (2008) supports the ideas that these upper lows enhance thunderstorm coverage and intensity, cause them to develop earlier in the day, and cause them to persist later into the night. Another study underway by Bosart, et al. (2007) suggests that many of these upper lows start their lives as upper level jet stream disturbances in the northern U.S., and can be better-tracked by monitoring the height of the tropopause (the temperature inversion which separates the lower- and middle atmosphere at about 50,000 feet). As the research into these features continues, we hope to improve our ability to forecast severe thunderstorm and flash flood outbreaks farther in advance.

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