National Weather Service

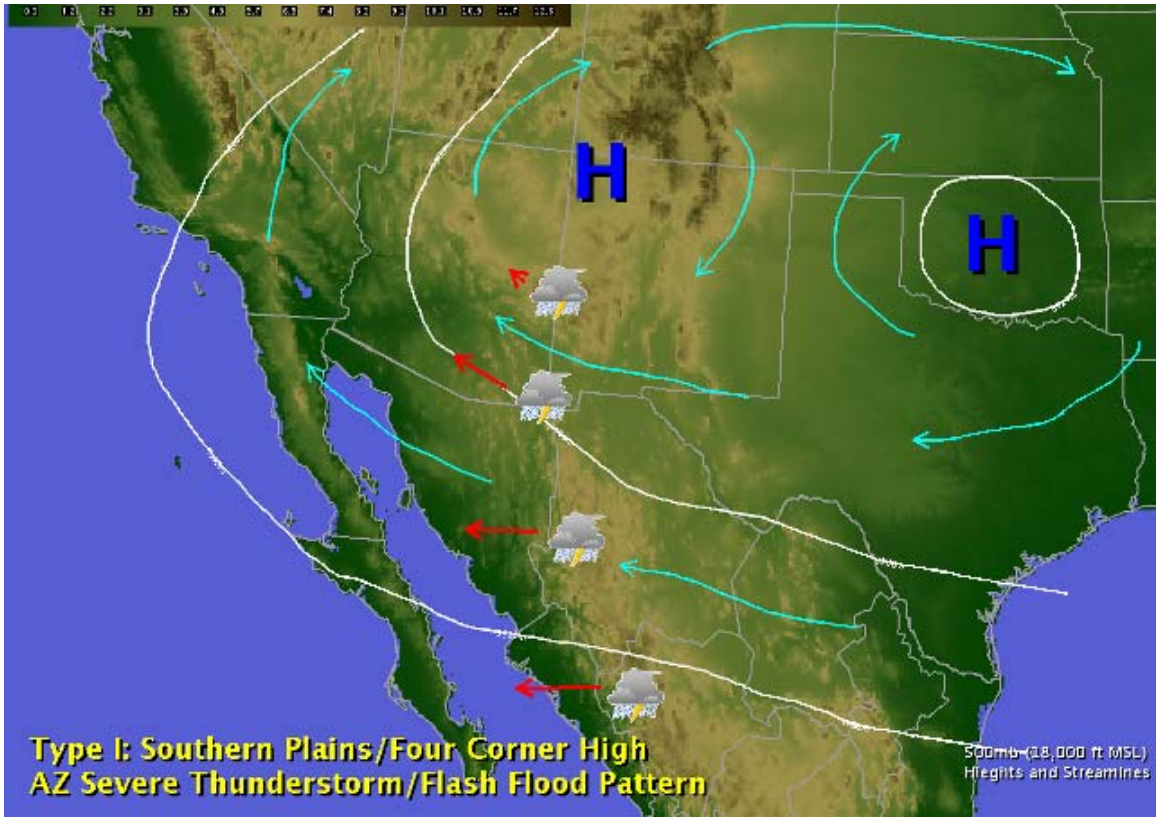
Summer Severe Thunderstorm Patterns in Arizona

In the 1990s, three general, large-scale weather patterns were identified which are favorable for producing severe thunderstorm and flash floods in central Arizona. (McCollum 1993, Maddox et al. 1995). Because of the lack of a dense, statewide severe weather spotter network, the research focused on mainly the Phoenix Metro Area. It also focused on just July and August from 1978 to 1990. Since then, a much better spotter network and rapid population growth has greatly expanded our severe weather database, particularly in the southeast and along the Mogollon Rim. The new data has confirmed that these three patterns support severe thunderstorm and flash flood outbreaks over much of the state. However, the additional data suggest that a fourth pattern, which tends to occur late in the monsoon season, produces its share of damaging winds, hail and flash flooding as well.

Type I: Southern Plains/Four Corner High

This is the most common severe thunderstorm pattern for southeast and south central Arizona, especially early in the monsoon. In this situation the monsoon ridge sets up over the southern Plains and extends west to the Arizona-Utah border. A secondary high usually develops near the Four-Corner region. When this happens, mid level temperatures across southern Arizona cool, low level moisture increases from the south or east, and winds between 10,000 and 20,000 feet increase out of the east. This causes thunderstorms to tilt slightly, and allows them to maintain themselves for longer periods of time while organizing into lines or clusters. If the lower levels of the atmosphere are rather dry, straight line winds and dust storms are a major concern. If the lower levels are moist, flash flooding becomes a problem as well.

Initially, thunderstorms on Type-I days form on the mountains and spread east-to-west or southeast-to-northwest. Thunderstorms on the Mogollon Rim and in the White Mountains tend to remain where they develop, while the storms in the mountains of southeast Arizona or northern Sonora tend to move into the valleys and eventually the low deserts. As these storms move progressively farther to the north or the west, they typically encounter a more stable atmosphere and dissipate. When a Gulf Surge is underway, though, the atmosphere remains unstable as the storms move into the lower deserts. In these instances, storms may continue to travel all the way to the Colorado River Valley.

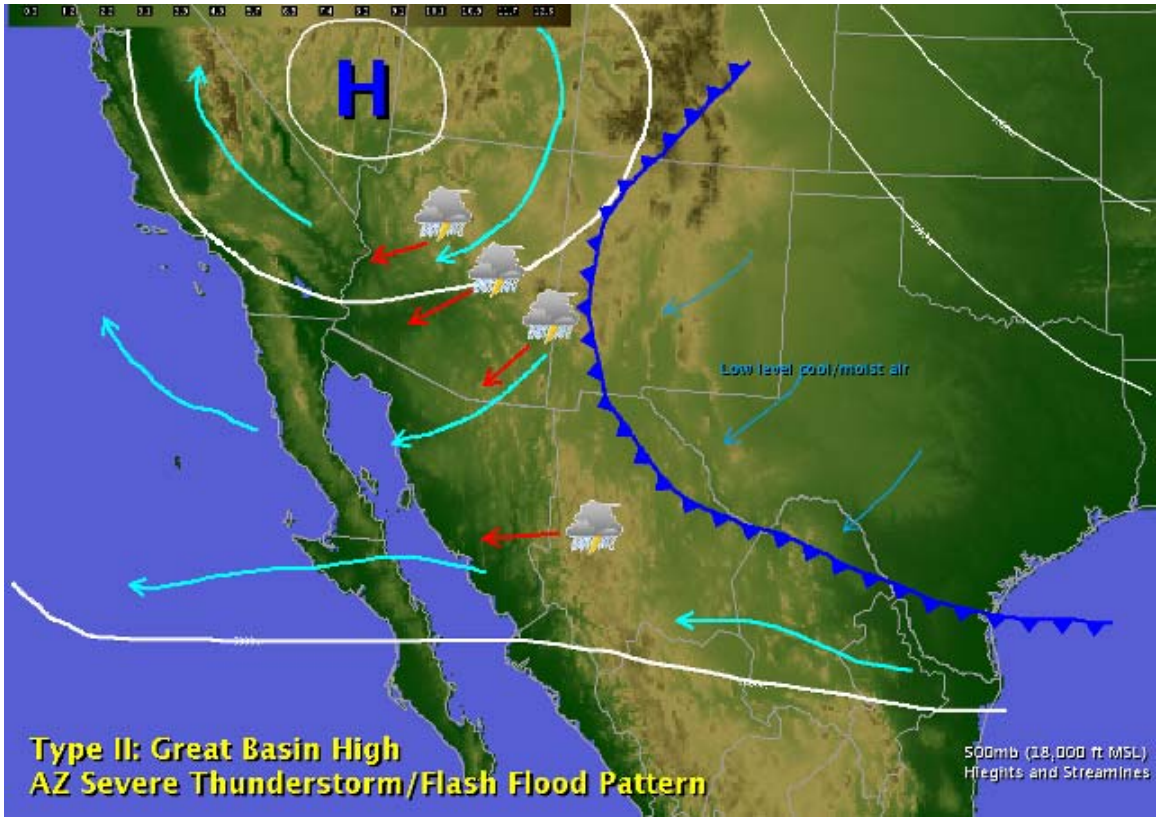


Type I: Southern Plains / Four Corner High

Type II: Great Basin High

This severe thunderstorm pattern is less common, and tends to occur during the height of the monsoon. In this situation the monsoon high migrates unusually far northwest into the Great Basin of southwest Utah or southern Nevada. Over the eastern U.S., an unusually deep upper level trough develops which sometimes pushes a cold front south through the Plains and west toward the Arizona-New Mexico border. The clockwise circulation around the upper level high causes winds between 10,000 and 18,000 feet increase out of the northeast over Arizona.

As the thunderstorms develop on the mountains, the Mogollon Rim readily forces them to organize into squall lines, which are then pushed southwest by the winds aloft into the deserts. The northeast winds aloft usually bring drier air into Arizona, so if the drying is deep enough, the thunderstorms may dissipate before moving very far away from the higher terrain. However, if there is only drying aloft and low level moisture remains plentiful, the downdrafts associated with these lines of storms can become large and severe. Areas most susceptible to Type II events are those immediately downwind from the Rim or White Mountains of east central Arizona, including: the Phoenix Metro Area, the Gila River Valley, and the valleys of Yavapai County. The changing wind direction and speed with height also helps to sustain the thunderstorms for even longer periods than in Type-I patterns, which can allow them to persist well into the night as they move southwest through Tucson and the Colorado River Valley.



Type II: Great Basin High

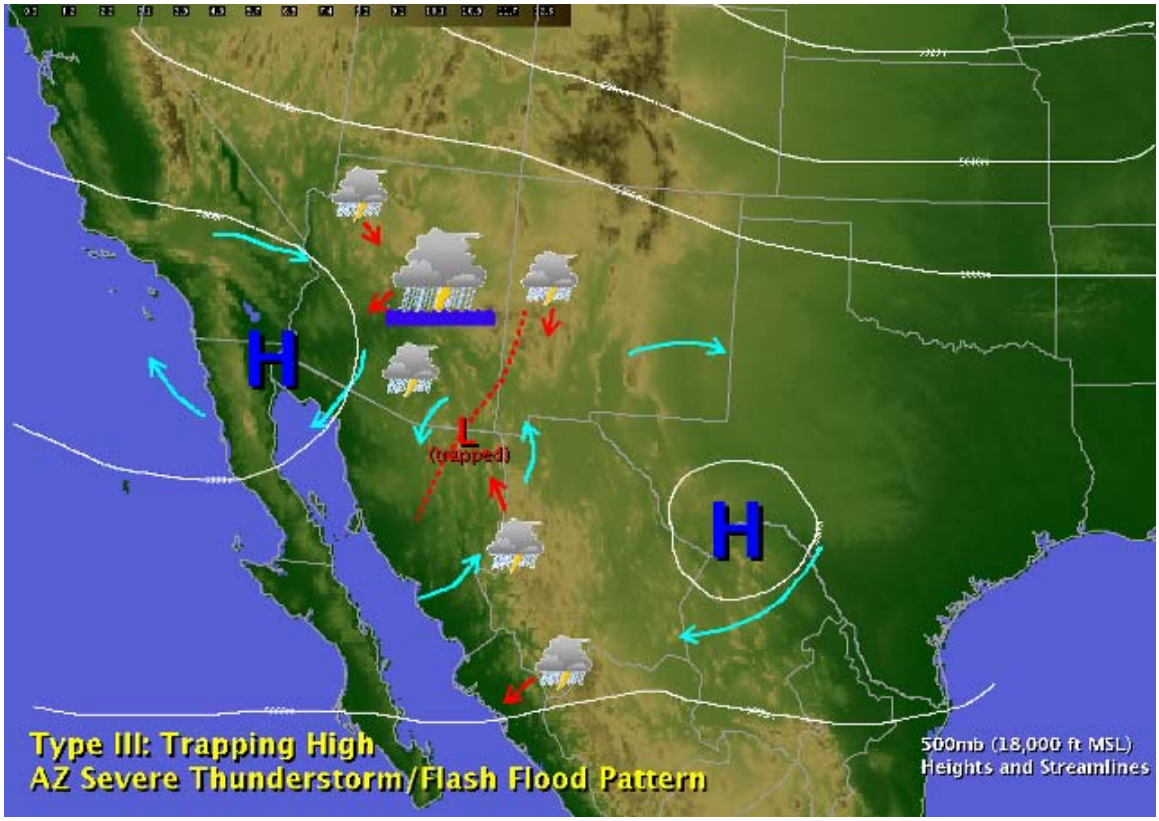
Type III: Trapping High

This pattern is quite different than the other two in that the monsoon ridge is weaker and suppressed father to the south – sometimes extending along the U.S.-Mexican border. The ridge will sometimes break into two separate centers with one over south Texas and the other over northern Baja. If this occurs either in June or September, the ridge placement tends to block moisture coming north from Mexico. However during monsoon peak, moisture still finds its way into Arizona from the south and east. Meanwhile, upper level disturbances can move into the region from several different directions, and either slow down, or become trapped within the ridge and stall. The presence of a weak upper low keeps temperatures aloft relatively cool, and the entire atmosphere unstable.

Winds aloft in Type III patterns are usually very light. Though thunderstorms are not particularly well organized due to the lack of wind shear, they tend to move slowly or remain relatively stationary. Moisture becomes trapped over the region, which only causes more slow-loving thunderstorms to develop. This rather stagnant situation will end when either the high strengthens and causes mid level temperatures to warm, or winds aloft increase.

This pattern, which tends to develop most often in late July or August, can result in flash flooding and isolated. In fact, the atmosphere can remain so moist and unstable that thunderstorms may not follow the typical diurnal pattern of developing in the afternoon and fading a couple of hours after sunset. The most notorious and recent example of what this pattern can do occurred between July 26 and August 1, 2006. An

upper level disturbance stalled between breaks in a weak monsoon ridge along the International Border. Widespread flash flooding plagued much of Arizona for several nights in a row which resulted in millions of dollars in damage.



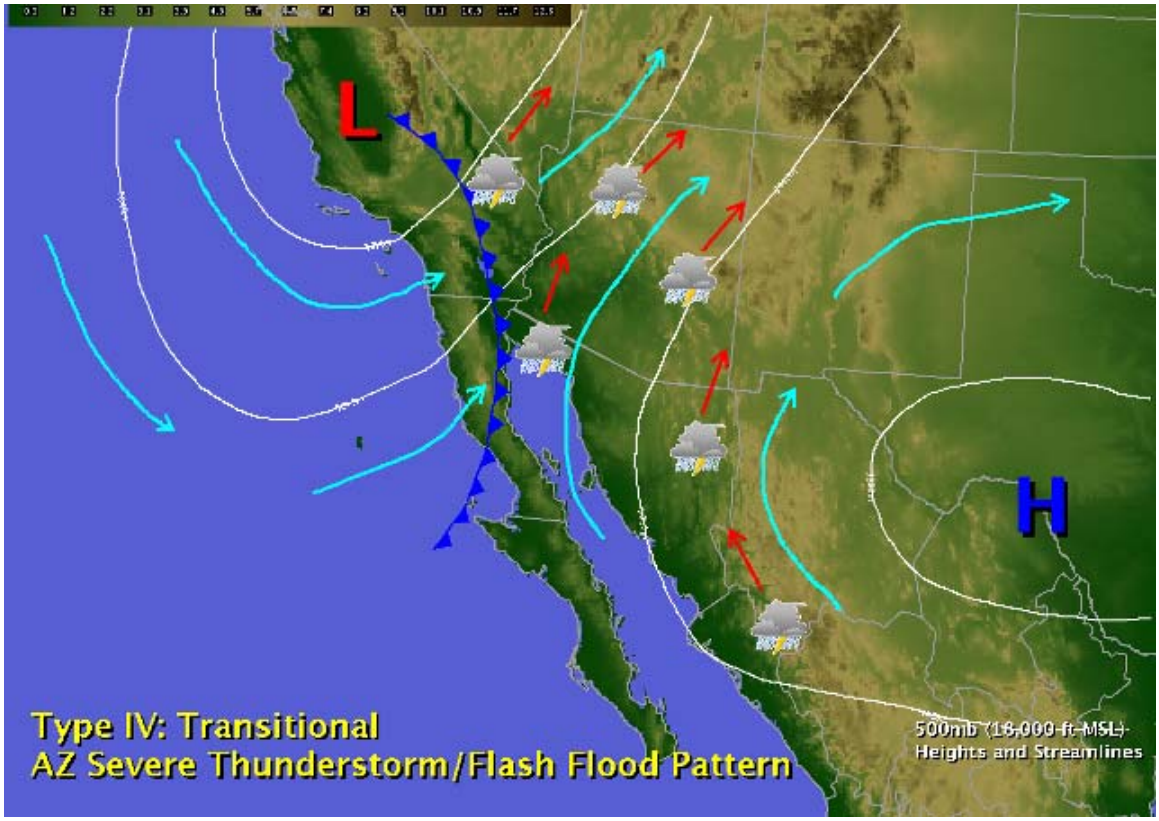
Type III: Trapping High

Type IV: Transitional

This pattern does not need the monsoon itself to generate severe weather in Arizona. It tends to develop sometime in late August or September, and usually acts on moisture that was transported into Arizona during the monsoon season. This pattern is called "transitional" because winds aloft shift from the tropical easterlies back to the southwest or west. This typically happens as the subtropical high weakens and shifts southeast into northern Mexico or the Gulf of Mexico, and a trough of low pressure develops near the West Coast. This trough is sometimes accompanied by a weak surface cold front, which helps to organize thunderstorms development.

Surface winds ahead of these upper level troughs usually remain out of the south or southeast, while upper level winds shift to the southwest or west. The resulting wind shear can cause squall lines, or rotating, supercell thunderstorms to develop. This pattern is actually similar to the conditions that trigger severe weather in the Great Plains during the spring and summer. Tornadoes are uncommon in Arizona, but this is the one pattern most likely to support stronger ones, especially from the Phoenix area north into the Rim Country and along the Utah border. Large hail can also be a problem in these situations, in addition to the damaging winds. Type-IV patterns can also cause flash flooding if the front moves slowly, or if the front taps into a tropical system well to the south. Once the

trough and associated cold front passes through Arizona, dry westerly flow at all levels of the atmosphere usually overspreads the region. After a Type-IV event, the weather usually turns quiet across Arizona for several days, and may even signal the end of the monsoon.



Type IV: Transitional

References:

Maddox, R.A., McCollum, D., and Howard, K., 1995: Large-scale patterns associated with severe summertime thunderstorms over Central Arizona. *Wea. Forecasting*, 763-778.

McCollum, D.M., 1993: Synoptic-scale patterns associated with severe thunderstorms in Arizona during the summer monsoon. M.S. thesis, School of Meteorology, University of Oklahoma, 166 pp.