Anomalous Timing of Rainfall at Tucson International Airport During July 2006

John R. Glueck
WFO Tucson, Arizona

Introduction:

Rainfall during the North American monsoon season in Tucson, Arizona normally occurs during the late afternoon to early evening hours. On a few days during the summer, thunderstorms will occur overnight and into the early daylight hours. The 2006 monsoon will be remembered for the number of consecutive days in late July and also a day in September in which heavy rain occurred between midnight and 9 am. This led to flash flooding and significant flow on the rivers, creeks and washes across eastern Pima County in southeast Arizona, especially in late July. This paper will take a look at the hourly distribution of rainfall recorded at the Tucson International airport during July 2006 versus the 1948-2005 average.

Data:

Hourly rainfall data for the Tucson International Airport, between June 15th and September 30th from 1948 through 2005, was obtained from the National Climatic Data Center (NCDC, http://www.ncdc.noaa.gov). Data from 2006 was obtained from daily Tucson ASOS printouts that are archived at WFO Tucson. This data was broken down into three separate time periods (midnight MST to 9 am MST; 9 am MST to 3 pm MST; and 3 pm MST to midnight MST) to show the diurnal differences in rainfall amounts that was recorded. Hourly total rainfall averages for the period of record (1948-2005) were calculated for the entire summer thunderstorm season (June 15th to September 30th) and also on a monthly basis. Each time period had percentage (%) of total rainfall calculated versus the 1948-2005 average, both on a seasonal and monthly basis. Additional calculations were done to compare the observed 2006 monthly and seasonal rainfall versus the 1948-2005 average.

North American Monsoon:

The monsoon is defined as the "seasonal shift in wind" that brings significant increases in humidity and rainfall to an area that is normally dry. In Arizona, this seasonal shift from a dry regime to a wet regime normally takes place between June to mid-July (Figures 1-2).

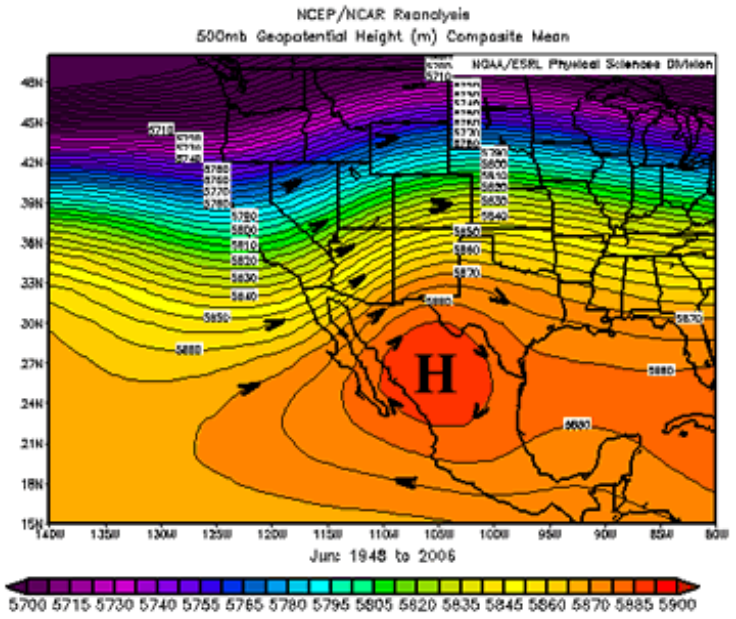
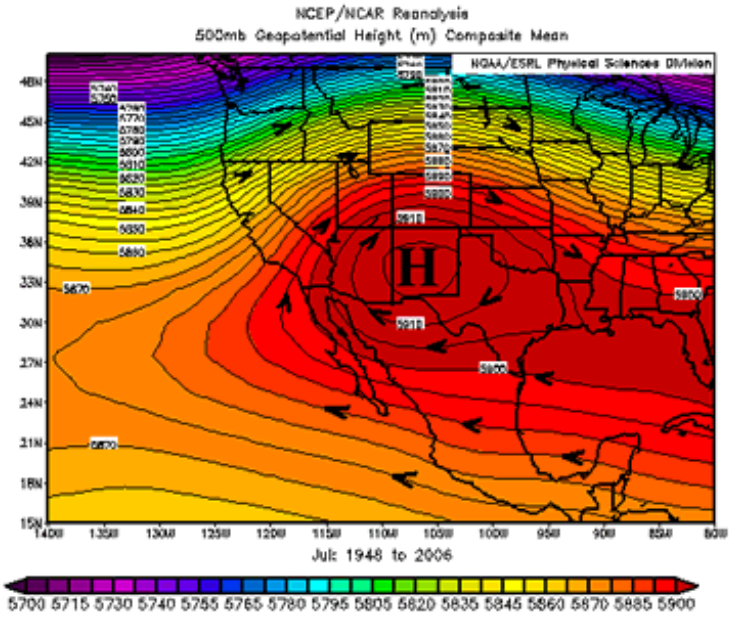


Figure 1: 500 MB mean height chart for June



b)

Figure 2: 500 MB mean height chart for July

Source: CDC reanalysis website http://www.cdc.noaa.gov/

In 2006, the first monsoon day in Tucson was on June 28th, which was the first of three consecutive days of the daily average surface dew point being 54 degrees F or higher (Figure 3).

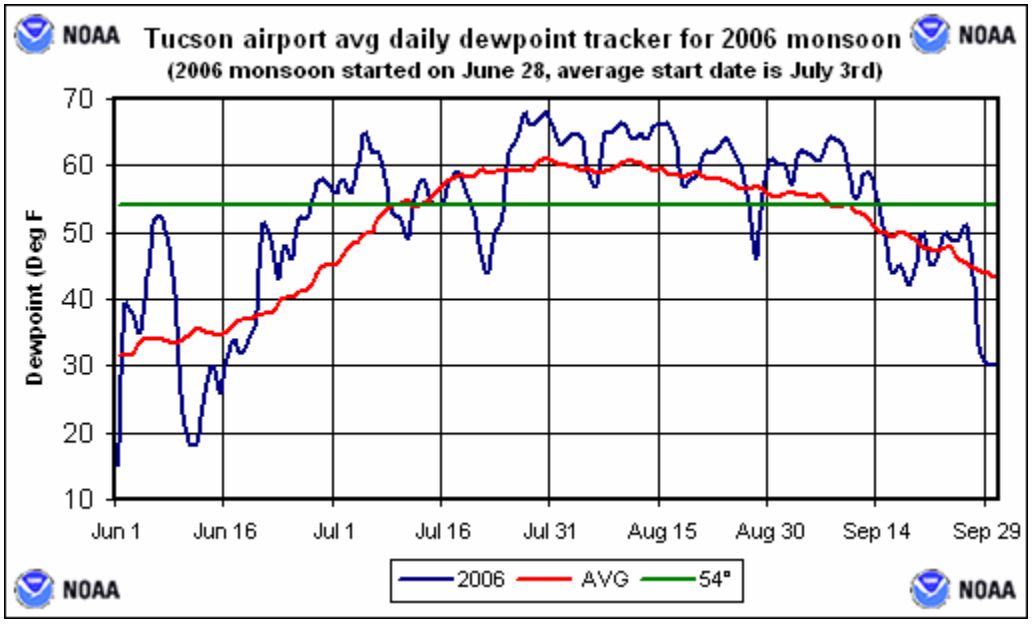


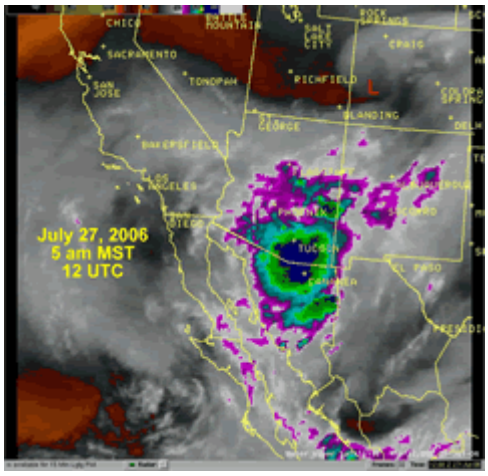
Figure 3: Average daily surface dew point for Tucson International airport in 2006. **Source:** NWS Tucson website http://www.wrh.noaa.gov/twc/monsoon/2006.png

During the first three to four weeks of the 2006 monsoon, thunderstorm activity was generally occurring during the mid-afternoon to the early evening hours, with a majority of the measurable rain being recorded in this time frame. During the final week of July, Tropical Storm Emilia, which was off the southern Baja coast, initiated a Gulf Surge which brought considerable low-level moisture into Arizona on July 24th. The remaining moisture from Emilia eventually moved north across the state on the July 25th and July 26th. On July 26th an upper level disturbance became cut-off from the main upper level flow and became quasi-stationary over the northern half of New Mexico between July 27th and July 31st before lifting into the central plains **(Figure 4)**. The flow around this low put southeast Arizona in an unusual north to northwest flow aloft, instead of the normal east to southeast flow aloft. Thus, thunderstorms that formed between Flagstaff and Phoenix in the late afternoon to early evening hours were pushed south southeast into a more moist and unstable atmosphere across southeast Arizona.

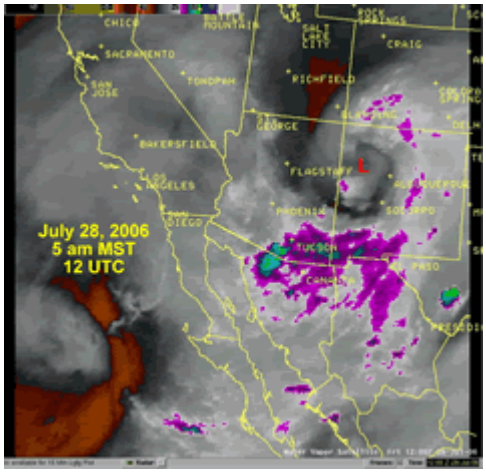
Event:

Figure 4 (A-F) showed the 5 am MST (12 UTC) GOES-11 water vapor imagery from July 27th through August 1st. **Figure 4A** (5 am MST July 27th) showed a developing upper low in southwest Colorado with a large MCS over southeast Arizona. **Figure 4B** (5 am MST July 28th) showed that the upper low had moved into northwest New Mexico with a decaying small MCS southwest of Tucson. **Figure 4C** (5 am MST July 29th) showed that the upper low in northwest New Mexico made little movement, while a small MCS was near Tucson. **Figure 4D** (5 am MST July 30th) showed that the upper low had moved east toward Albuquerque, while another small MCS was near Tucson. **Figure 4E** (5 am MST July 31st) showed that the upper low was still near Albuquerque, while an MCS was moving through Tucson. **Figure 4F** (5 am MST August 1st) showed

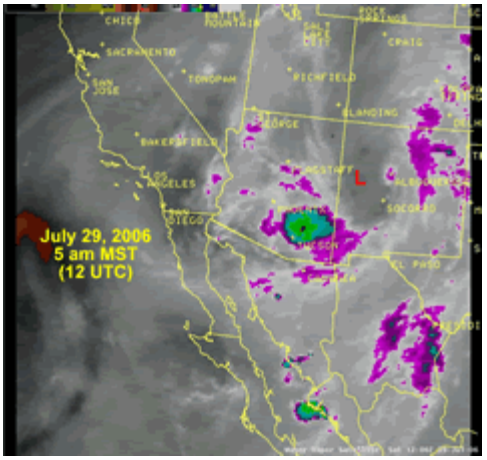
that the upper low had weakened and moved northeast while drier southwest flow aloft had moved into western Arizona. Little activity was over southeast Arizona.



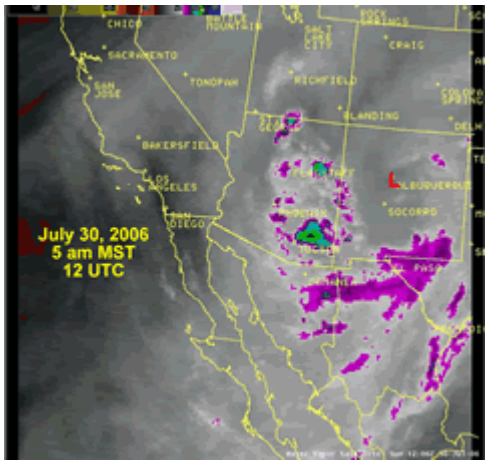
4A)



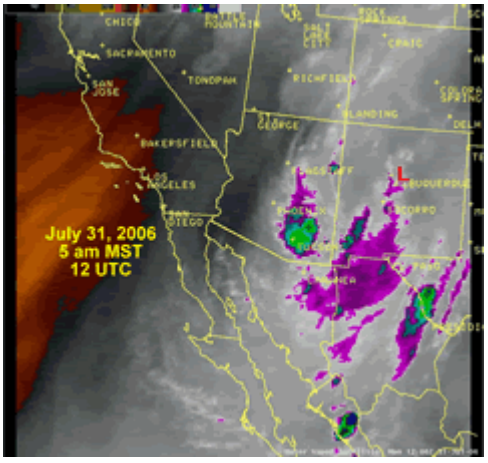
4B)



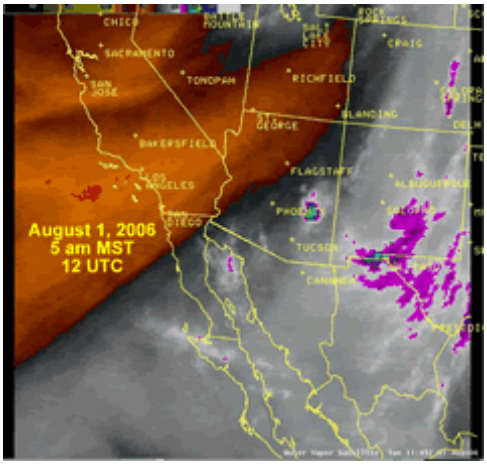
4C)



4D)



4E)



4F)

Rainfall:

The graphic below shows the hourly breakdown of July rainfall recorded at the Tucson International Airport versus the 1948-2005. You can easily see the significance of the amount of rain that was recorded between midnight and 9 am during July 2006. **Table 1** below Figure 5 shows the hourly breakdown between midnight and 9 am from July 27 through July 31st

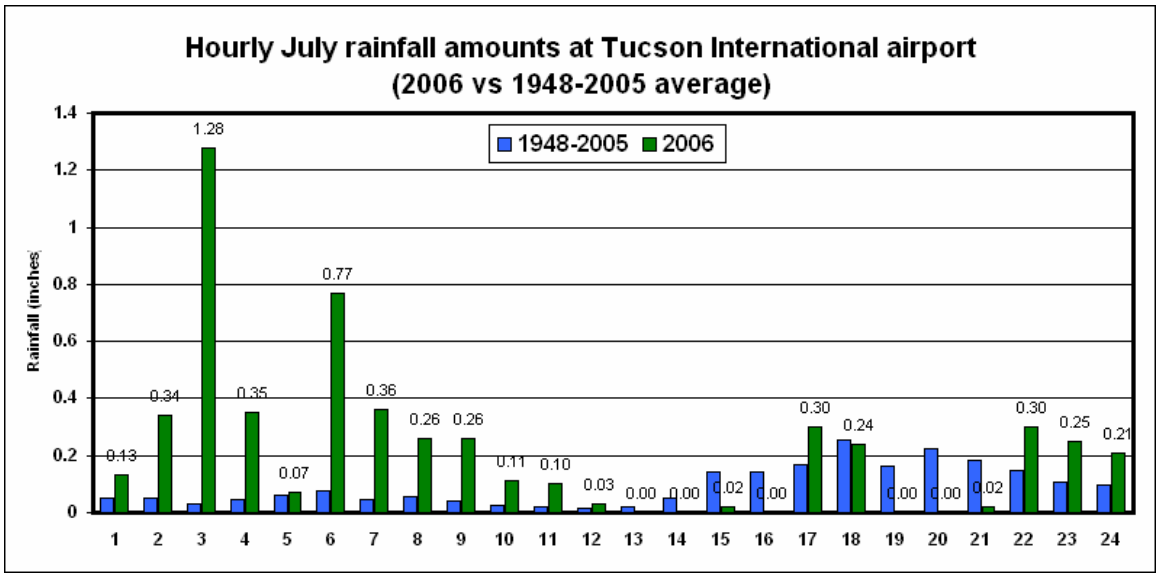


Figure 5: July hourly rainfall, 2006 versus 1948-2005 average

Table 1: Hourly rainfall between midnight and 9 am from July 27th through July 31st

Date	Midnight - 1 am	1 am – 2 am	2 am – 3 am	3 am - 4 am	4 am – 5 am	5 am – 6 am	6 am – 7 am	7 am – 8 am	8 am – 9 am
July 27th				0.05”	0.07”	0.01”	T	0.04”	0.02”
July 28th	0.01”	T	T	T					
July 29th	T	T		0.04”	T	0.72”	0.23”	0.21”	0.24”
July 30th			T				T	0.01”	
July 31st	0.01”	0.10”	1.26”	0.25”	T	0.04”	0.13”		
5 day total	**0.02”**	**0.10”**	**1.26”**	**0.34”**	**0.07”**	**0.77”**	**0.36’**	**0.26”**	**0.26”**

Nearly four inches of rain (3.83”) was recorded at the Tucson International Airport from July 27th to July 31st with the heaviest rain occurring between midnight and 9 am on July 29th and July 31st. Over 92% of the 3.83” of rain that was recorded in this five day period fell between midnight and 9 am. On average (1948-2005) during July, only 21% of measurable rainfall is recorded between midnight and 9 am. Thus July 2006 had a **438% difference** in overnight rainfall when compared to the 1948-2005 average.

Data (part 2):

Tables 2 through 4 below show the breakdown of the % of rain and total rainfall for three time periods (midnight to 9 am MST; 9 am to 3 pm MST and 3 pm to midnight MST). The left hand column is for the % of rain recorded, while the right hand columns are for the total amount of rain that was recorded. Each time period below has an explanation that highlights important facts from 2006 versus the 1948-2005 average

Table 2: Midnight to 9 am MST time period

Over 5 inches of rain was recorded at the Tucson International Airport during the 2006 Monsoon between midnight and 9 am which is over 4 inches above the 1948-2005 average. Most of this rain was recorded in July, where 71% of July's rain was recorded versus the 1948-2005 average of 21%.

Midnight to 9 am MST	% of rain		Rainfall	
	1948-2005 average	2006	1948-2005 average	2006
Monsoon	**18%**	**53%**	**1.10"**	**5.37"**
June (15-30)	4%	0%	0.01"	0.00"
July	21%	**71%**	0.46"	3.82"
August	14%	14%	0.32"	0.42"
September	23%	**71%**	0.31"	1.13"

Table 3: 9 am to 3 pm MST time period

The only thing that stood out in this data time period was that almost an inch of rain was recorded in August versus the 1948-2005 average of slightly over a quarter of an inch.

9 am to 3 pm MST	% of rain		Rainfall	
	1948-2005 average	2006	1948-2005 average	2006
Monsoon	**15%**	**12%**	**0.91"**	**1.22"**
June (15-30)	24%	0%	0.04"	0.00"
July	13%	5%	0.28"	0.26"
August	12%	31%	0.27"	0.93"
September	24%	2%	0.32"	0.03"

Table 4: 3 pm to midnight MST time period

35% of the 2006 monsoon rainfall was recorded in this time period versus the 1948-2005 average of 67%. July only recorded 24% of its rainfall during 2006 versus the average of 67%. However, rainfall totals were close.

3 pm to midnight MST	% of rain		Rainfall	
	1948-2005 average	2006	1948-2005 average	2006
Monsoon	**67%**	**35%**	**4.02"**	**3.61"**
June (15-30)	72%	100%	0.13"	0.19"
July	67%	**24%**	1.49"	1.32"
August	74%	55%	1.68"	1.66"
September	53%	**28%**	0.72"	0.44"

Conclusions:

The 2006 summer thunderstorm season will be best remembered for the amount of rain that occurred in late July between midnight and 9 am MST, normally a quiet weather time in the summer, versus the normal late afternoon/early evening thunderstorm activity. Sufficient dynamics combined with enough moisture and instability and appropriate steering winds can cause thunderstorms at any time of the day or night. Forecasters should be prepared for weather patterns that differ from the norm like the one that affected southeast Arizona for five consecutive overnights in late July. Only two other thunderstorm seasons, 1958 and 1990, were similar with July nocturnal activity. It is an event that will always be remembered.