Storm Interrogation

AWOC Severe Track
ICSvr 3-IV-C
Radar Rainfall Estimation

Thanks to Matt Kelsch for helpful input and for reviewing this material.

Radar Rainfall Estimation

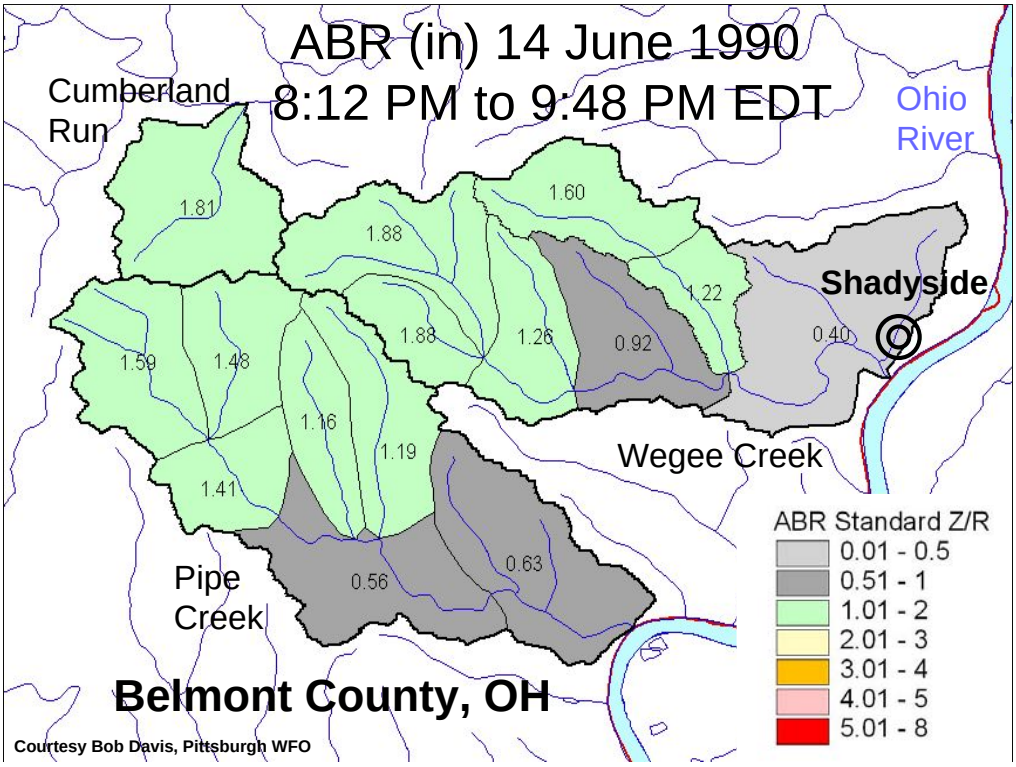
Objectives:

- Understand how inaccurate Z/R relationships at the RPG can result in a missed flash flood detection
- Know how to anticipate warm rain processes

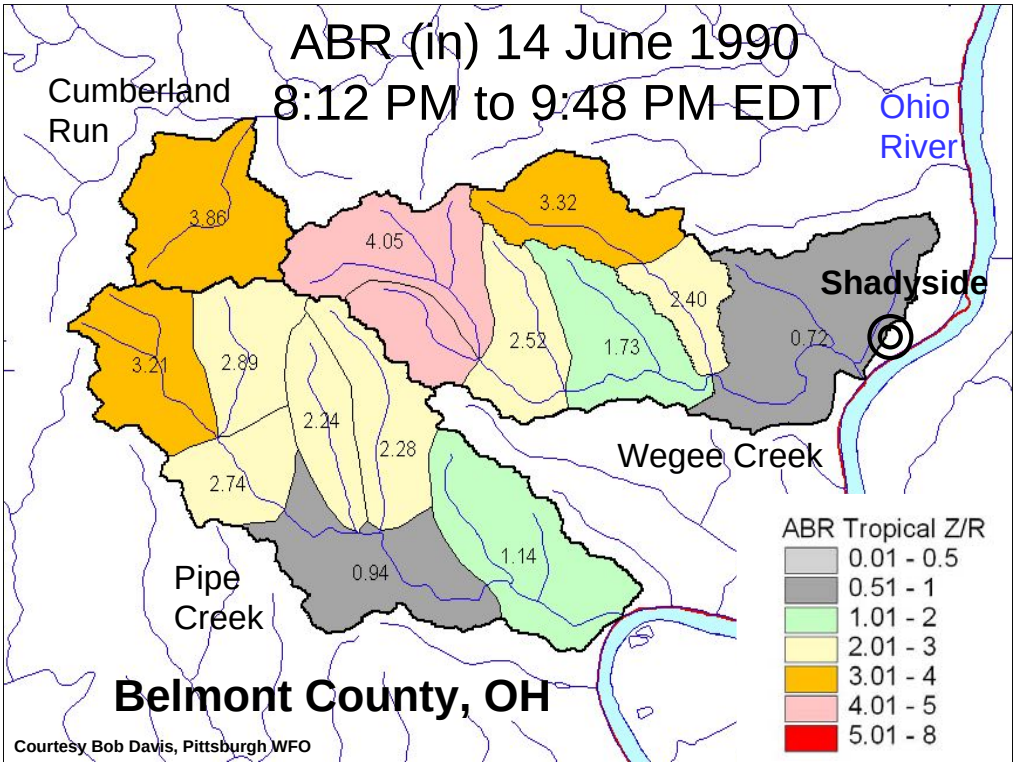
Z/R Relationship

- The standard Z/R relationship ($300R^{1.4}$) may underestimate precipitation by 50% in warm rain process-dominated storms (Davis 2004)
- Failure to switch to a tropical Z/R can lead to a failure to detect a flash flood: Shadyside Ohio

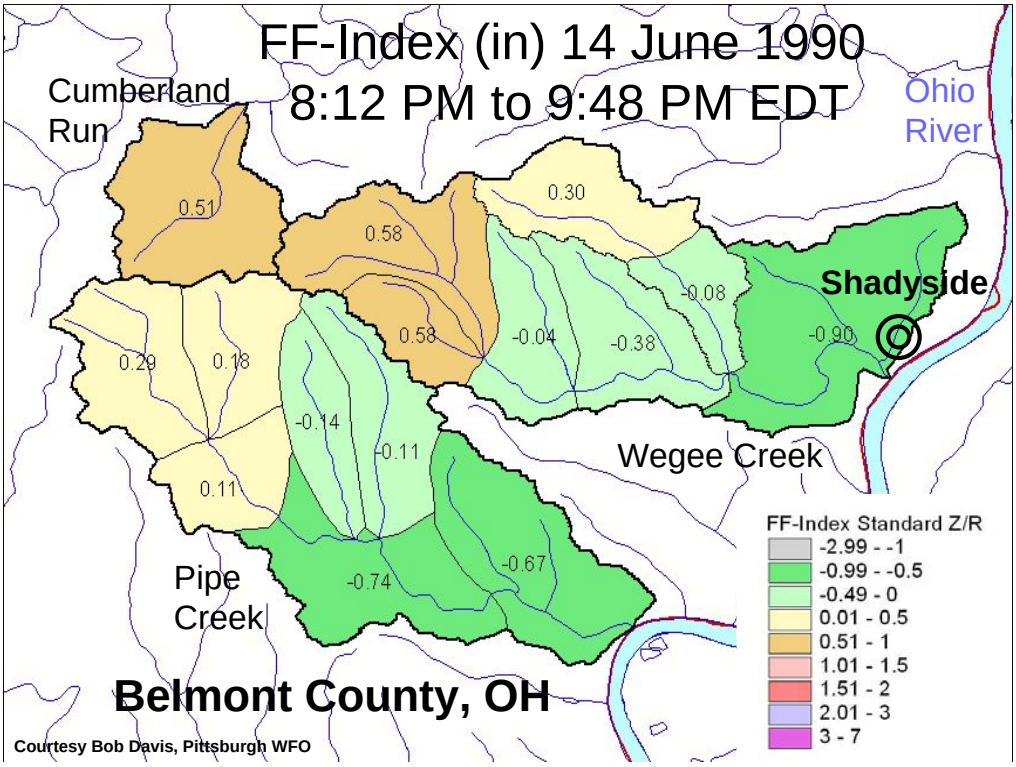
Knowing when to switch to a tropical Z-R is not a clear cut decision since there is no way to measure drop size distributions in convective storms. However, there are several clues to pick up on in the data that will help determine whether warm rain processes are dominant. We'll discuss those now.



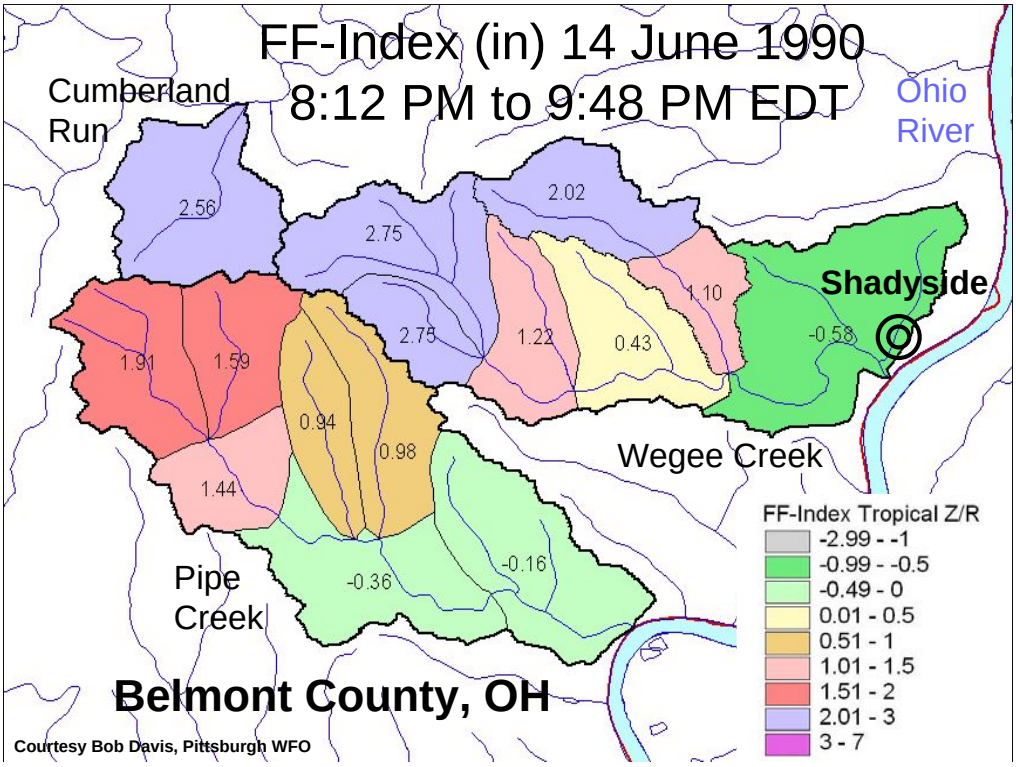
Shadyside Ohio ~90min ABR using the standard Z/R relationship



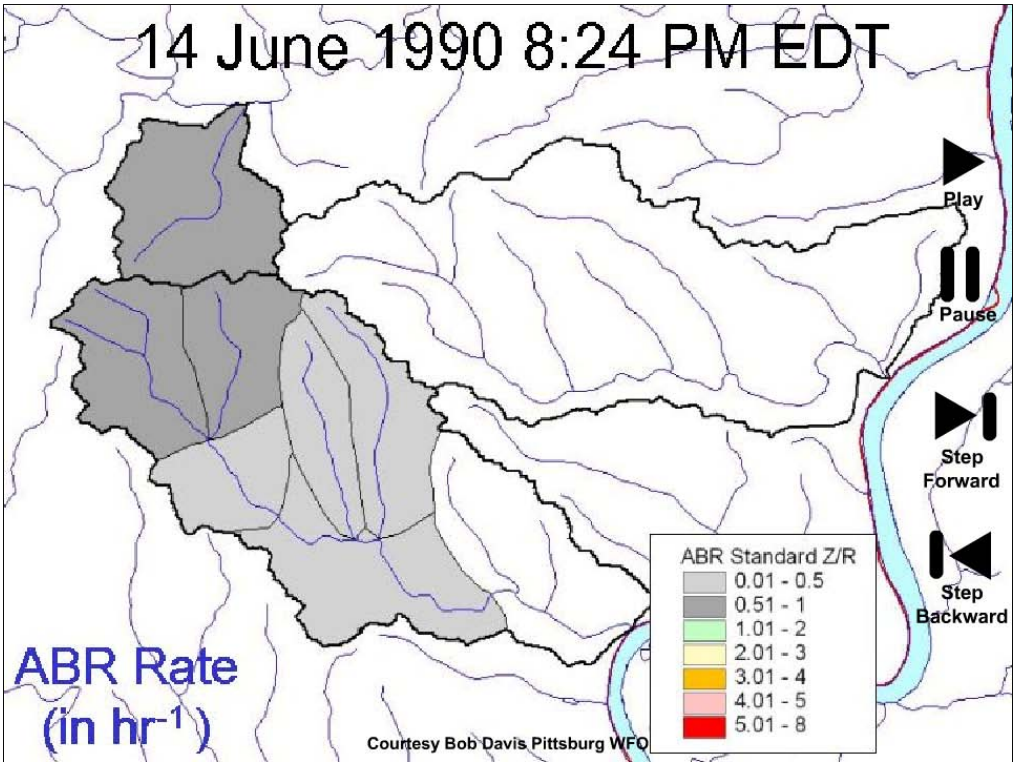
Shadyside Ohio ~90min ABR using the tropical Z/R relationship. Amounts are over twice as much in many instances.



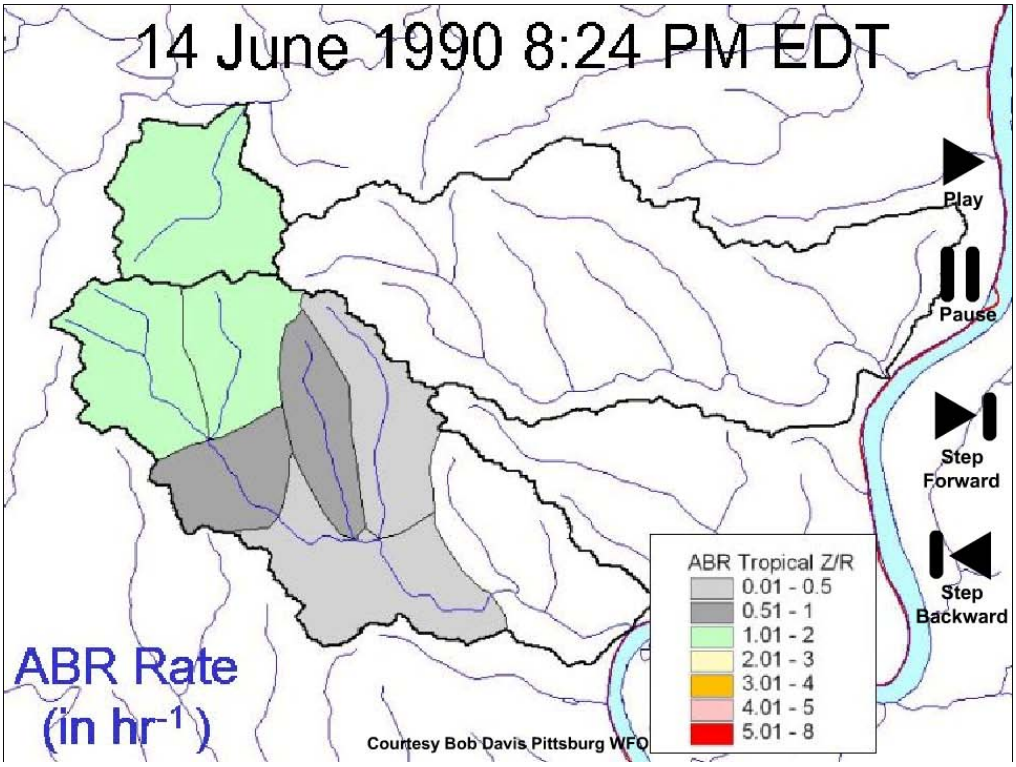
Flash flood index for the same basins, using the standard Z/R



Flash Flood index using tropical Z/R, over 2 in many sports and approaching FF3.



These loops display the large differences in rainfall rate and FFI over the ~90 minute time period. The rain that fell was from warm rain process-dominated storms and the rainfall totals matched the totals with the tropical Z/R relationship. The Standard Z/R did not detect a flash flood, while the tropical Z/R had more accurate rainfall totals and thus caught the magnitude of the flash flooding in Shadyside.



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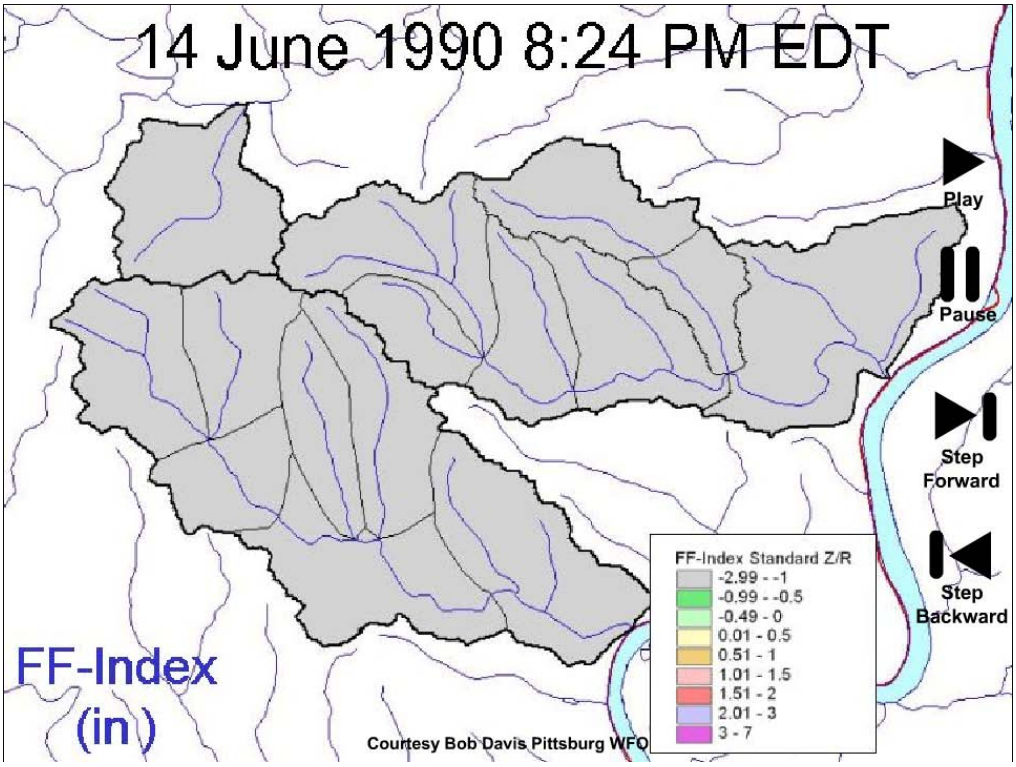

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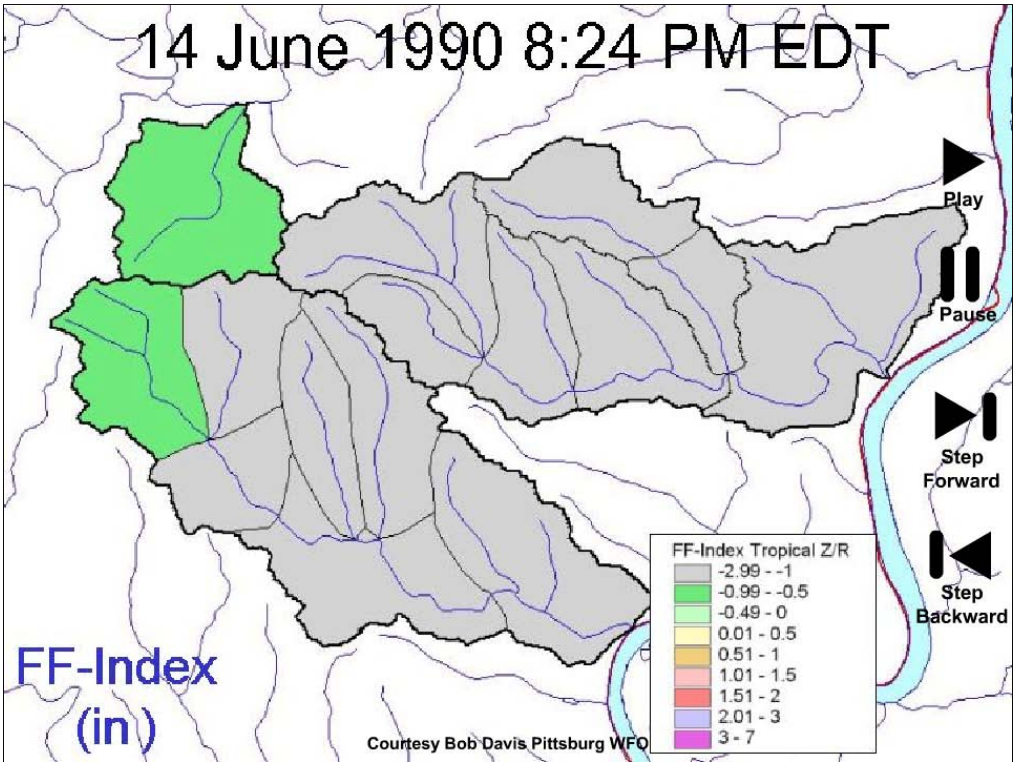

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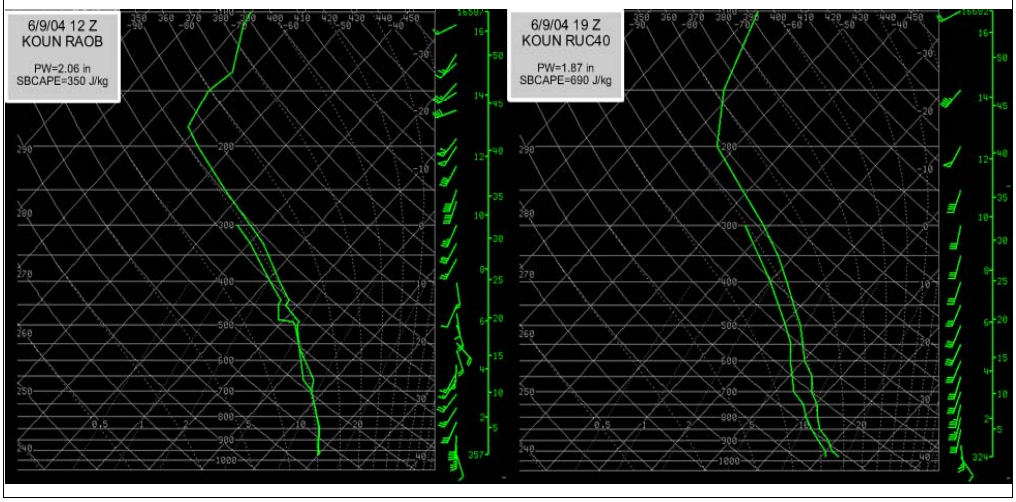
Anticipating Dominant Warm Rain Process Convection

- The sooner you can key in on warm rain process dominated convection, the quicker you can switch to tropical Z/R and help detect flash flood-producing rain
- Environmental assessment is most important, then supplement with real-time data signatures

Environmental assessment is most important if you are going to catch the warm rain processes quickly. There are several environmental clues to key in on when determining whether a certain storm is going to display warm rain process characteristics.

Anticipating Dominant Warm Rain Process Convection

- Assess the environment



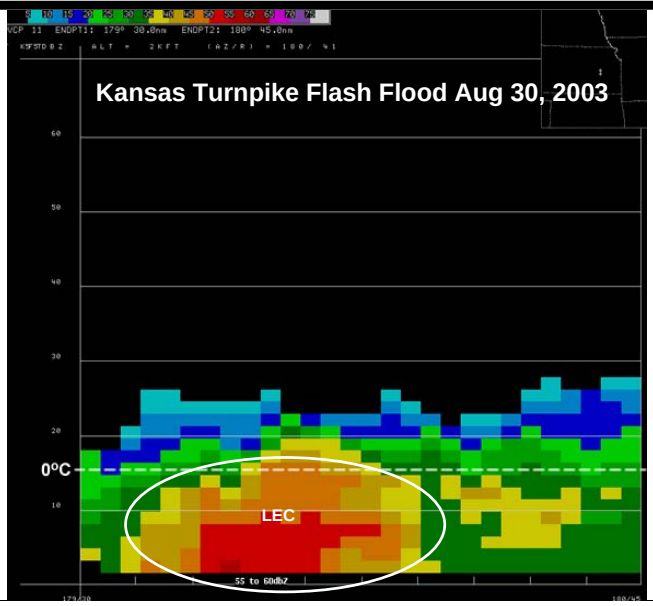
These two soundings have characteristics of a warm rain process environment: Very high PW, especially relative to climatology, little to no CIN, thin CAPE and the CAPE shouldn't be very high (1000 J/kg or less is all that is required), absence of dry air at any level, low wind shear, very deep warm cloud depth. You can look at real-time data to assess whether storms are feeding off the moisture rich environment and becoming warm rain dominant. This environment could certainly be characterized as tropical even hours before any rainfall occurs, preparing the forecaster for the possibility of switching to tropical Z/R.

Warm Rain Processes Real-Time Data Signatures

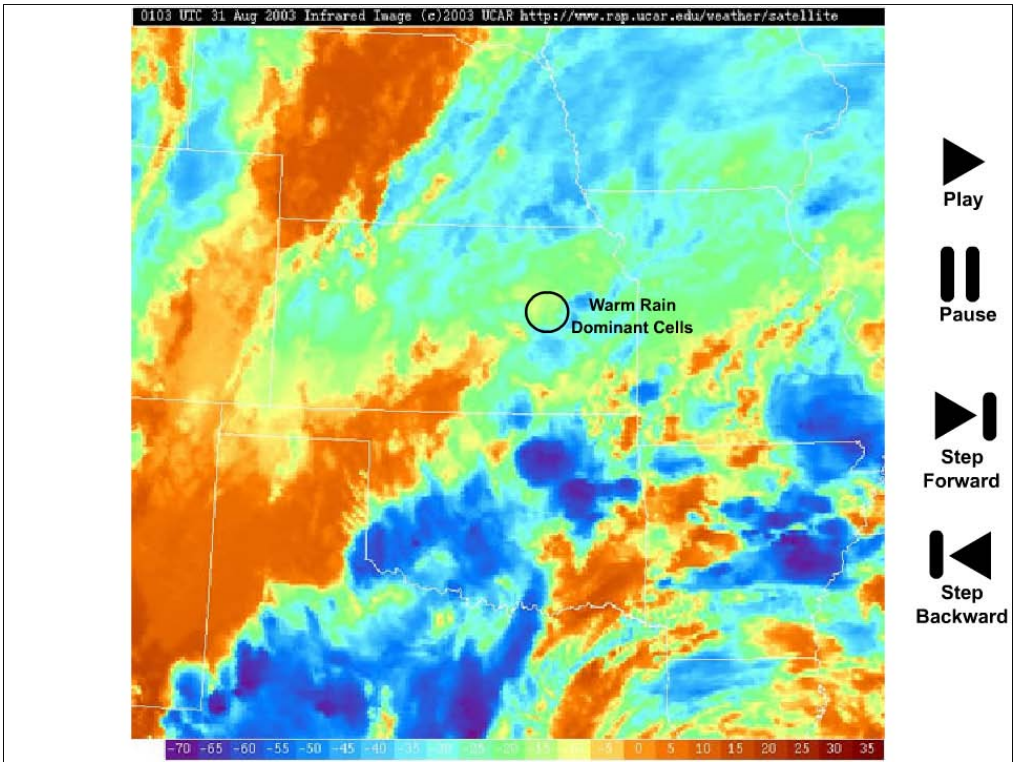
- Look for reflectivity structures, satellite, and lightning data
  - IR Satellite: Cloud tops “warm”
  - High reflectivity concentrated below the in-cloud freezing level (low echo centroid)
  - Lack of significant lightning

3 methods of helping to determine whether a certain batch of convection is dominated by warm rain processes. Reflectivity is certainly the most useful to determine this.

Warm Rain Processes
Radar Signatures

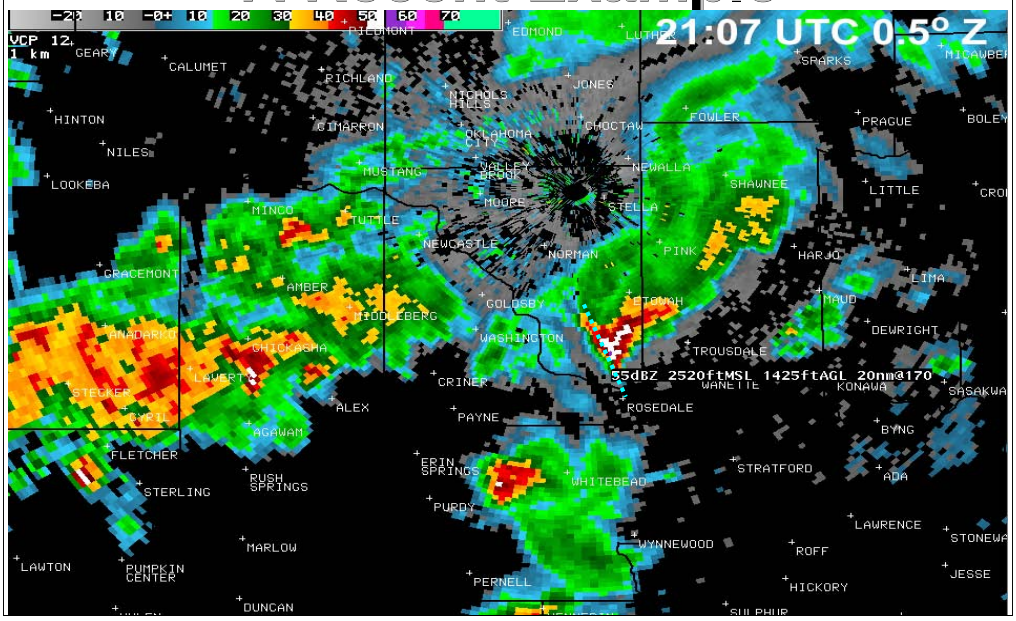


This is an example of a Low Echo Centroid (LEC) radar siganture. Maximum reflectivity is confined to the lowest tilts, and typically most of it is warmer than 0°C. One can assume that since nearly all the reflectivity is warmer than freezing, that it is all liquid and thus collision/coalesence is dominated the precipitation process. Tropical Z/R would be required anytime the environment and an LEC signature is sighted. There was no lightning with this storm, futher evidence that the dominant mode of precipitation formation was warm rain.



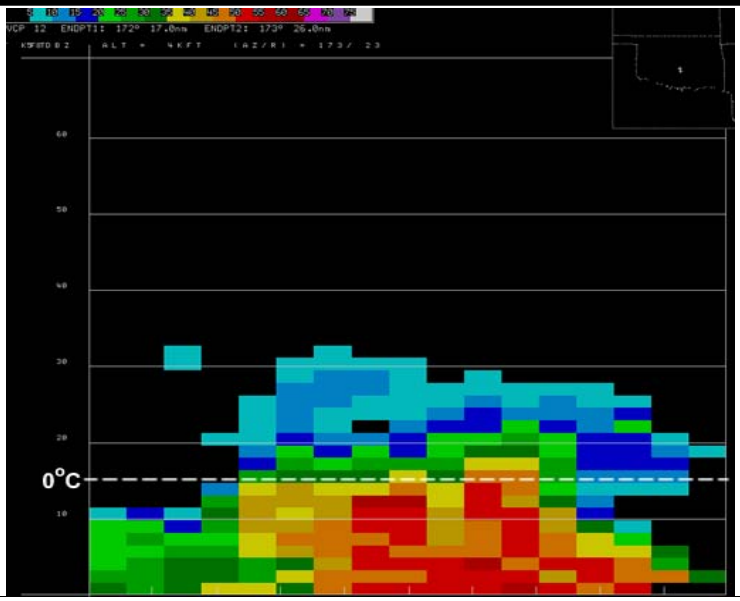
This satellite loop shows the "uneventful" appearance of warm-rain process dominant convective cells. You cannot discern their features from satellite other than to see that they are very innocent looking on IR satellite. Visible satellite would likewise appear to be innocent-looking, with a lack of any crisp cloud tops, nothing overshooting, certainly no enhanced-V signatures.

Warm Rain Processes
A Recent Example



You've already seen the environment for this day with the 2 soundings a couple of slides ago. So there is a large batch of precip to the southwest of the radar, and 2 cells to the south, both exhibiting moderate rotation in the lowest levels and hook echoes from time to time. 55-60 dBZ exists, but how can you be sure there is warm rain in there? Cut a cross section through the core (which is the turquoise dotted line) to find the following:

Cross Section through Warm-Rain Supercell



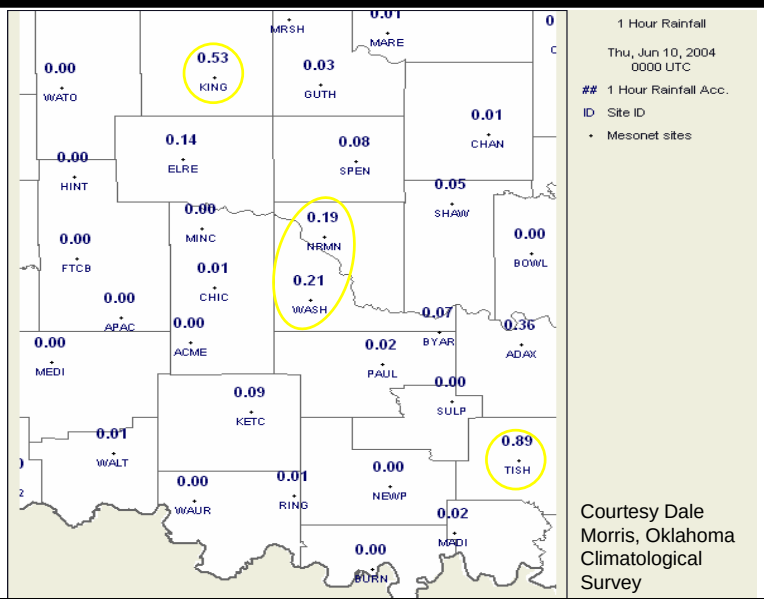
This is an example of a warm-rain process and LEC signature on a supercell storm. Not only were tornadoes a threat, but flash flooding as well because of intense rainrates. Fortunately, the storm moved NE at 25 mph and significant flooding did not occur. WDTB Instructor Jim Ladue was on this storm, verifying the complete lack of lightning and hail within this storm.

Rain Gage Comparison

- When available, compare rain gage to radar rainfall amounts
  - when comparing gage rainfall amounts to radar, remember that they measure different things

Radar measures an “average” rainfall amounts across a large 2.2 nm squure grid. A rain gage measures rainfall amounts at a point location, which can vary widely over small distances. With this in mind, rain gages are still very useful to determine the bias in the radar estimate. Spotter reports of rainfall are very useful in many instances.

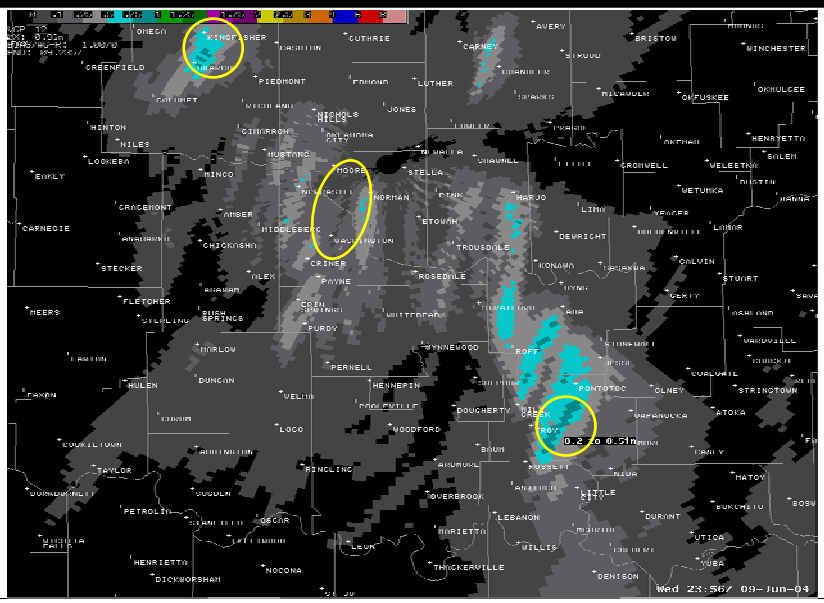
Rain Gage Comparison: Back to Example



Courtesy Dale Morris, Oklahoma Climatological Survey

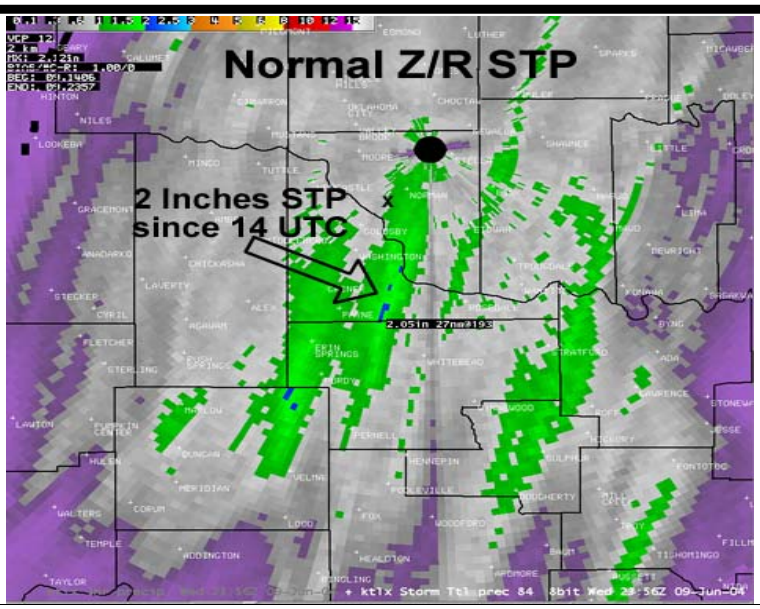
Here is an example of comparing radar estimated rainfall with a mesonet of rain gages using the Oklahoma Mesonet and the "warm rain process dominated supercell" we've been looking at. Checking to see if rainfall is accurate can be tough, even with a mesonet as can be seen in this example. Focus on the one hour precip accumulation at the 4 gages outlined in yellow.

Rain Gage Comparison: Back to Example



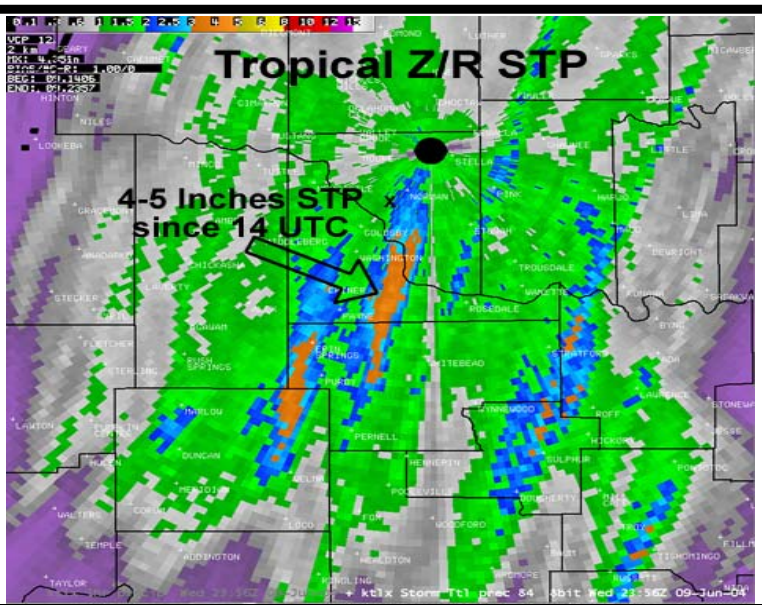
The southern most maxima is closest to being directly over a gage, and even with a mesonet it is tough to compare to radar because the gages simply aren't underneath the strongest rainfall, as is especially evident in the center oval, the the maximum rainfall southeast of either the Washington or the Norman mesonet gage. Rainfall at the southern oval is underestimated by 50%, this is using the standard Z/R, and in this event warm rain processes appeared to be dominant.

Switching Z/R can make a Difference



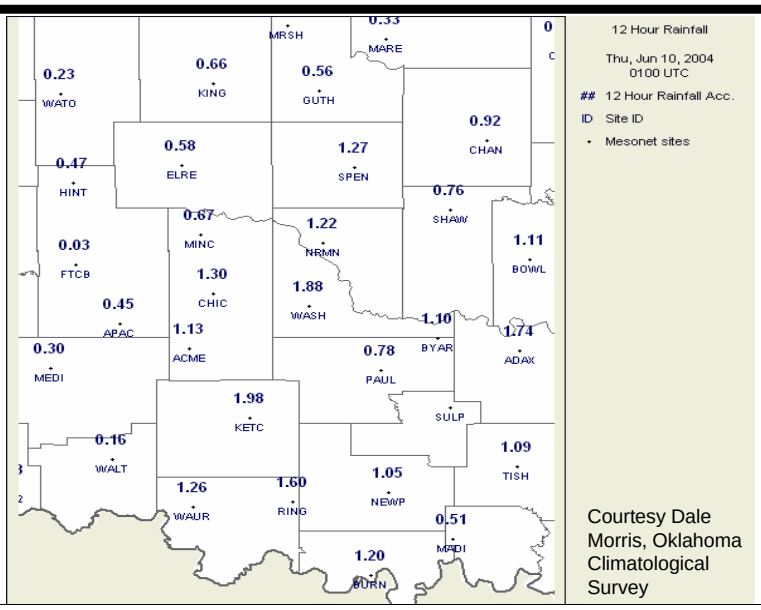
This is STP beginning at about 14 UTC using the normal 300R^1.4 convective Z/R. The X is the location of WDTB member Paul Schlatter's rain gage.

Switching Z/R can make a Difference



WDTB employee Paul Schlatter had 2.4 inches at point X in the image over roughly the same time period, clearly showing that normal convective Z/R underestimated rainfall amounts by 50%. He stood outside during the heavy showers, and reported low visibility, moderate rain with extremely heavy amounts of smaller drops, no lightning (NDLN verifies this). T/Td was 74/73 throughout the heaviest showers. Switching to tropical Z/R certainly would have resulted in accurate rainfall estimates on this day as this image implies.

Switching Z/R can make a Difference



Courtesy Dale Morris, Oklahoma Climatological Survey

Here are the storm totals over the same time period as the previous 2 images. Unfortunately, no gages exist in the axis of heaviest rainfall, but the gages even over the lighter rainfall amounts were much more accurate with the tropical Z/R than the standard Z/R.

Z/R Relationship Caveats

- Rarely a clear cut decision to switch to tropical Z/R
- Not all storms are created equally: Certainly true of DSDs within storms and across the radar umbrella
- Significant overestimate in storms that are not warm rain process-dominated

There is so much uncertainty inherent in the process and within microphyhsical aspects of convective storms that switching to a tropical Z/R in the interior portions of the U.S. is rarely an easy decision.

Both Fort Collins and the KS turnpike flash floods had other storms within the radar umbrella that were not warm rain process-dominated storms. Thus, if one were to switch to a tropical Z/R, those storms that were not warm rain process dominated would have a significant overestimate in rainfall totals and rates. Even warm rain process dominated storms may not have DSDs that are close to the ones used in the tropical Z/R, meaning even when you switch to tropical Z/R for a warm rain-process dominated storm, rainfall amounts and rates may still be inaccurate due to uncertainly in the actual DSD.

Summary

- Radar rainfall estimation contains many important sources of errors that affect FFMP

- Failing to quickly and properly anticipate warm rain processes and then switch to tropical Z/R can result in failure to detect a flash flood