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Topic: Flash Floods

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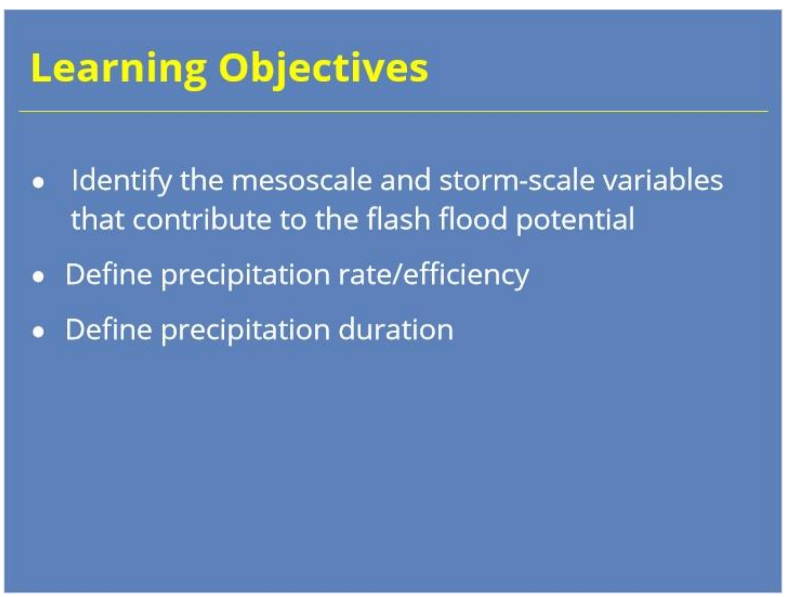
Flash Flood Meteorology

Title Slide

Notes:

Hi my name is Melissa Lamkin, and welcome to our lesson on Flash Flood Meteorology.

Learning Objectives



Notes:

Here are the learning objectives for this lesson. Please take a moment to read through the objectives, and press next to continue.

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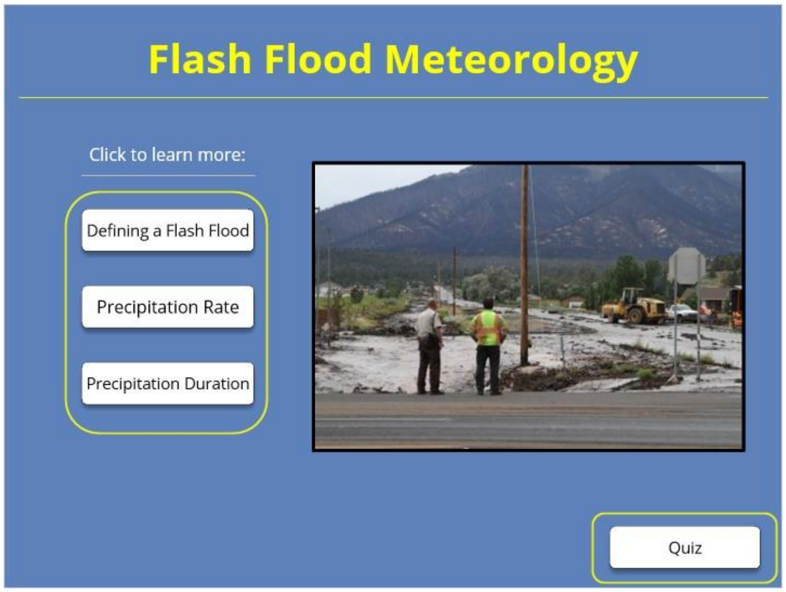
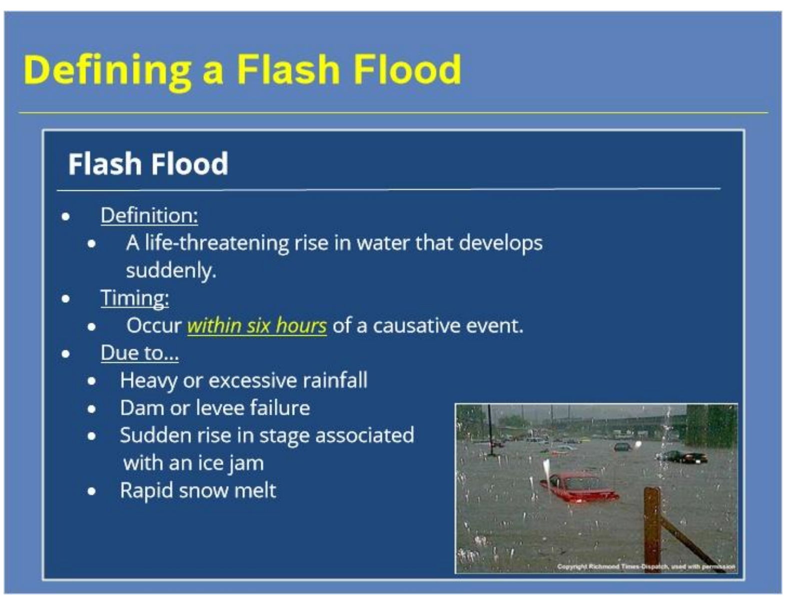
Homepage



Notes:

Welcome to the homepage for this lesson. From here, you can click on these three buttons to learn more about Defining a flash flood, precipitation rate, and precipitation duration.. You must click through all three sections to complete this module. Then, once you feel comfortable with these materials, take the quiz by clicking the button at the bottom right of the screen.

Defining a flash flood



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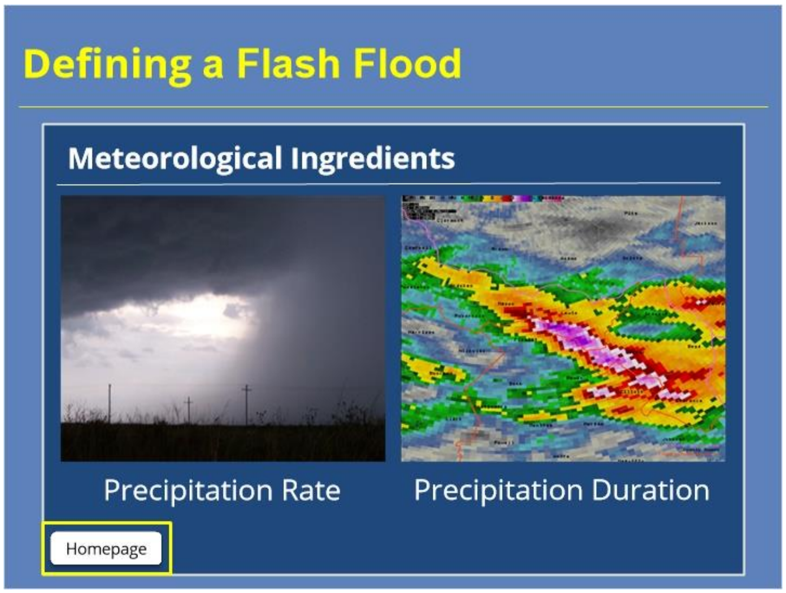
Notes:

To guarantee that we are all on the same page, I want to make sure we understand how a flash flood is defined. It is a life-threatening rise in water that develops suddenly. Flash floods can begin as quickly as minutes after a causative event, or up to six hours after. And they can occur from a variety of events, such as heavy rainfall, dam failures, ice jams, or rapid snow melt. For the purpose of these lessons, we will focus on flash flood events related to heavy rainfall. Press next to continue

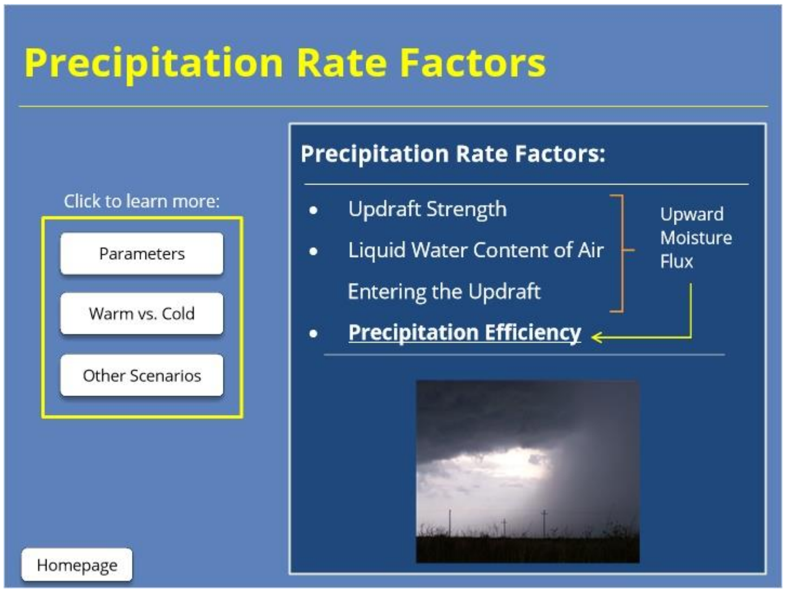
Defining a flash flood



Notes:

When it comes to the meteorological aspects of flash flooding, the two most important things to consider are the precipitation rate and the precipitation duration. Press the button to head back to the homepage and we'll step through the factors that influence the precipitation rate and duration.
Click the button below to return to the homepage.

Precipitation Rate



Notes:

PRECIPITATION RATE FACTORS:
There are several factors that help determine the precipitation rate. The updraft strength and the liquid water content of the air that is entering the updraft contribute to the upward moisture flux into a storm. The percentage of that moisture flux that returns to earth as precipitation is what is referred to as precipitation efficiency. To put it simply, the higher the precipitation rate, the more efficient the storm.
For our purposes, we are mostly concerned with how efficient the environment is during an event, and we will use precipitation efficiency to define precipitation rate throughout this lesson.
Factors that influence precipitation efficiency include the presence of ideal environmental parameters, warm or cold rain processes, as well as a few other scenarios that we'll discuss towards the end of this section. Please click through each of the topics on the left, and click the homepage button when you are done. You must complete each section to move on with the lesson.

Please click through each of the sections before moving on

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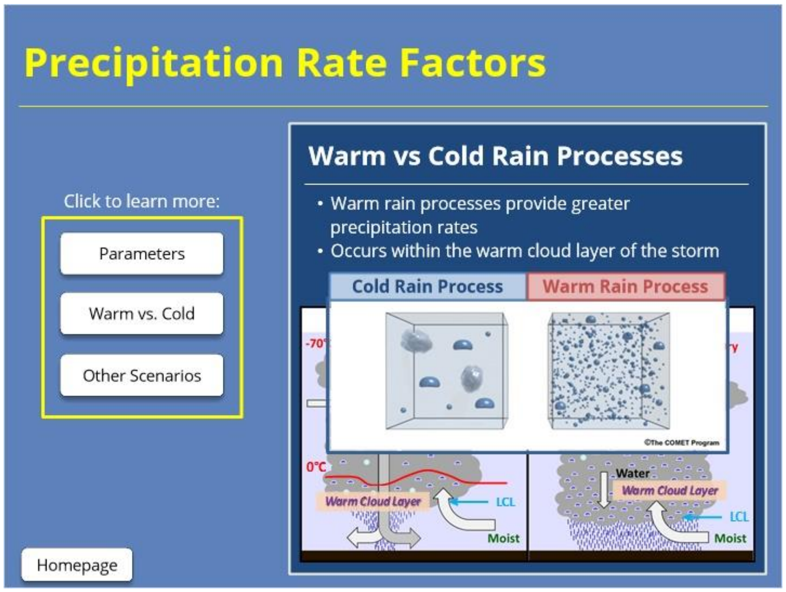
Cold vs Warm Rain Process (Slide Layer)



Notes:

Cold vs Warm Rain Process
Now that I've introduced the main parameters you can use to assess precipitation efficiency, I want to take a step back and show how they can work together. This can be explained by talking through the differences between convection dominated by warm vs cold rain processes. It is important to determine whether precipitation forms through collisions and coalescence within a warm rain process or deposition and the Bergeron Process (the collision of ice crystals) in a cold rain process to decide which is the predominant precipitation production method.

Looking at convection derived from a continental airmass, you can see that the LCL is relatively high while the in-cloud freezing level is quite shallow. The vertical separation between the LCL and freezing level is defined as the warm cloud layer, and where warm rain processes occur. However, the warm cloud layer is generally not very deep with this type of convection, along with lower precipitable water values and lower relative humidities. Within a strong CAPE environment, hydrometeors will be lofted beyond the warm cloud layer, where they will become frozen (resulting in the formation of hail) and become subjected to evaporation due to mid and upper level dry air entrainment. This region is where the majority of the hydrometeors undergo cold rain processes.

Now focusing on the convection influenced by a warm maritime airmass, you notice that the LCLs are relatively low, and the in-cloud freezing level is much higher. Therefore, you have a greater warm cloud layer. The weak CAPE profile allows for the majority of the hydrometeors to remain below the freezing level. The moist vertical profile with higher precipitable water values and low to mid level relative humidities also helps in diminishing the effects of evaporation and dry air entrainment. Here, warm rain processes will dominate precipitation production.

Comparing the resulting precipitation at the surface, you can see the dominant cold rain processes from the continental airmass yields a small quantity of rain drops that are generally large in size and can also include hail stones. The dominant warm rain

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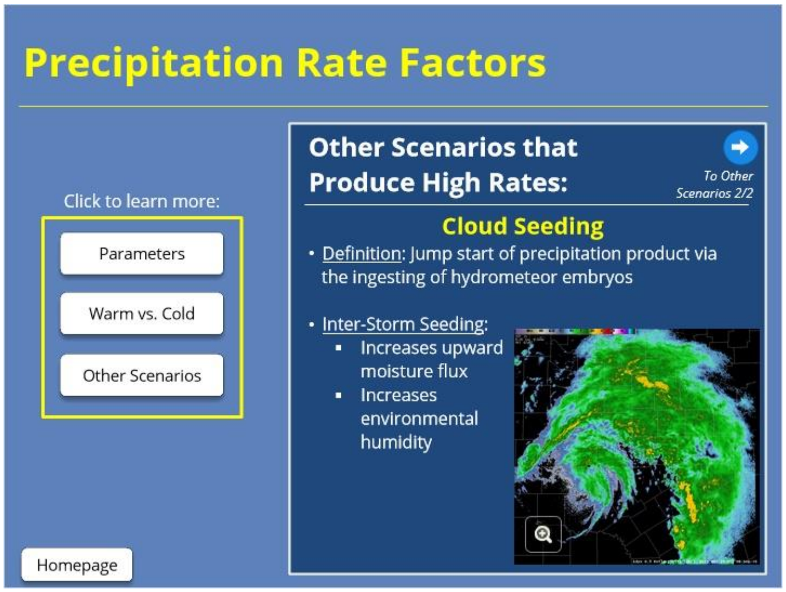
processes in the maritime airmass has a substantial quantity of raindrops. So, the warm rain process results in a greater precipitation efficiency and greater precipitation rates.

Other Scenarios I (Slide Layer)



Notes:

OTHER Scenarios 1: CLOUD SEEDING
One scenario that can also result in high precipitation rates is cloud seeding. We will focus on inter-cloud seeding here. This is the process where precipitation production is jump started by the updrafts ingesting hydrometeors from other storms. This helps increase the upward moisture flux and increase the local environmental humidity. In this example, an intense rain band forms with the remnants of Tropical Storm Hermine over central Texas. The combination of the tropical environment and the inter-cloud seeding enhanced rainfall production in an already efficient precipitation environment. Widespread rainfall totals of 6-10 inches were common with this system.

Click the button in the top right corner to continue on to other scenarios part 2

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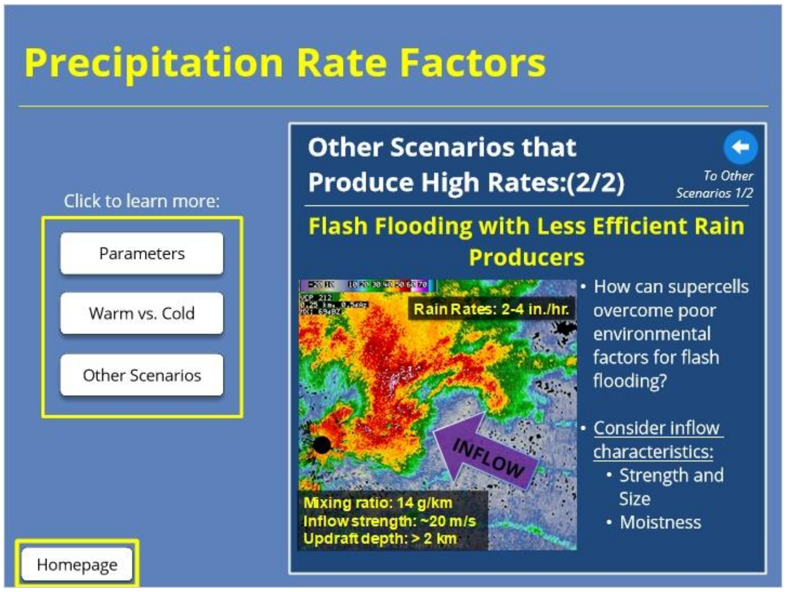
Other Scenarios II (Slide Layer)



Notes:

OTHER SCENARIOS 2: FLASH FLOODING WITH LESS EFFICIENT RAIN PRODUCERS:

The key to high precipitation rates with supercells is understanding why supercells are such a threat despite poor precipitation efficiencies and at times swift movement. Looking at this high-precipitation (HP) supercell near Midland, TX, this storm is in an environment where the profile is moist up to 700-mb and is considerably dry above it (The warm cloud layer is about 9,000 ft.). So, this storm is undergoing processes such as dry air entrainment and evaporation.

However, the storm has a very strong, moist updraft with it. It is ingesting very moist air (mixing ratio of 14 g/kg) at about 20 m/s. The updraft is wide and has a vertical depth of over 2 km. So, even though this supercell existed in an environment characterized by dry air above 700 mb, the storm produced rain rates of 2-4 inches per hour and fatal flash floods in the city of Midland. This shows that the factors that give HP and classic supercells a lower precipitation efficiency - like high CAPE and low PWs - can be balanced by other factors, such as large values of low-level moisture inflow. And this is a good reminder that you don’t need every one of the precipitation efficiency factors to be favorable to get high rates. Some may be neutral and others downright unfavorable. But we give them all to you so you know what to look for to assess the whole picture.

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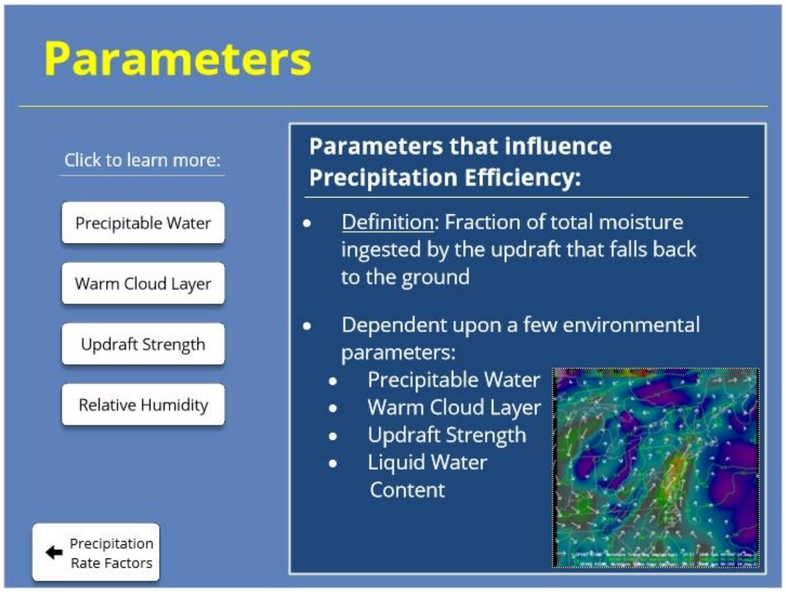
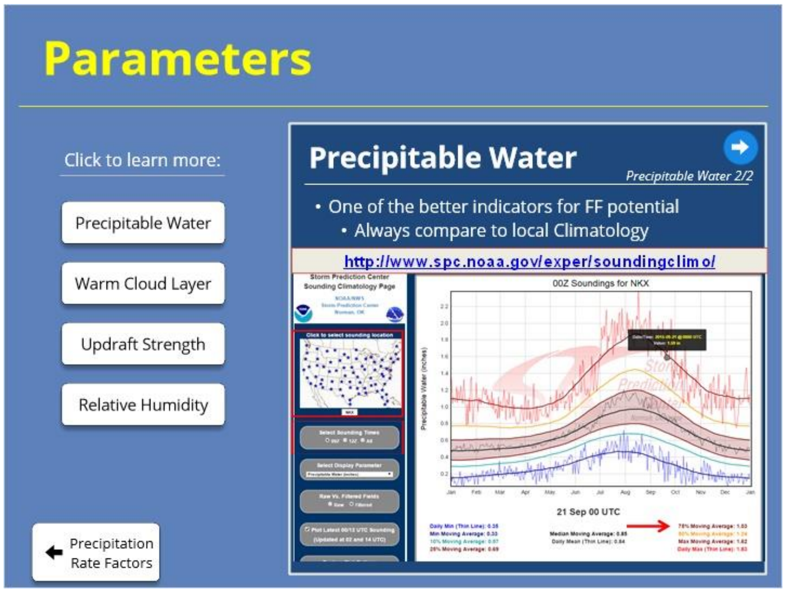
Parameters



Notes:

PARAMETERS:
Precipitation efficiency is defined as the fraction of total moisture ingested by the updraft that returns as precipitation. Precipitation efficiency cannot be quantified in real time, so you will need to examine a number of factors to infer an efficiency. These factors include the vertical moisture profile of the atmosphere, the depth of the warm cloud layer, the updraft strength, and liquid water content.
You must click through each of the parameters to move on. When you are done, click the button in the bottom left corner of the slide to return to the Precipitation Rate Factors slide.

Precipitable Water 1 (Slide Layer)



Notes:

PRECIPITABLE WATER 1/2:
A good way to get a feel for your vertical moisture profile is by looking at Precipitable Water, which is defined as the the depth of water in a column of the atmosphere, if all the water in that column were precipitated as rain. It is generally given in inches, and varies based on location and time of year. The Storm Prediction Center (SPC) hosts a PW Sounding Climatology Page with observed PW values for every sounding site across the CONUS. These values can be compared to model PW values to give a sense of their normalcy. Heavy precipitation events that lead to flooding or flash flooding tend to have PW values that are above the 75th percentile, meaning they are above 75% of all values at that given location and time of year. Use the URL to access the PW climatology page.
Click the arrow in the top right corner to move on to part two

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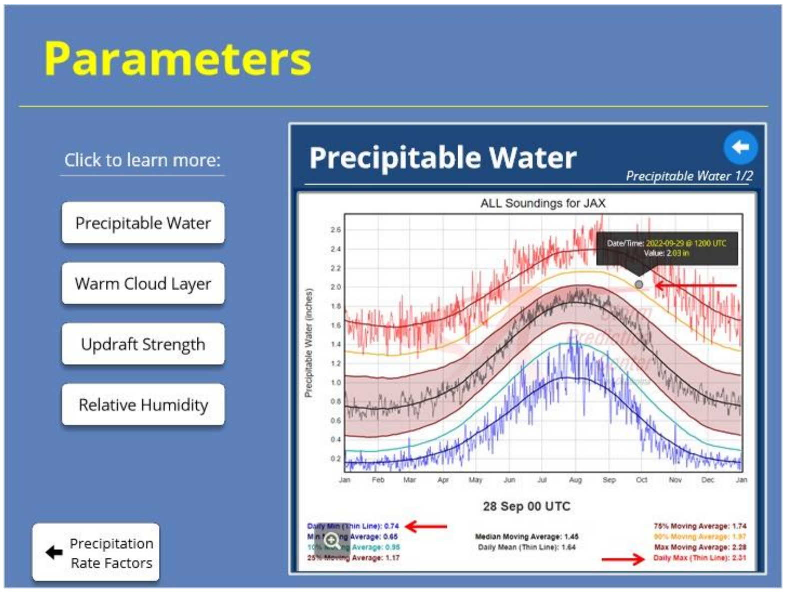
Precipitable Water 2 (Slide Layer)



Notes:

PRECIPITABLE WATER 2/2
Let's walk through an example using the SPC site. You can find the point sounding climatologies that make it easy to compare model or observed precipitable water (PW) values. Begin by navigating to the desired sounding location, and select a sounding time. The plot now shows the daily minimum, several moving percentile averages, as well as the daily maximum for each day of the year.
Let's use this 12Z sounding climatology plot for the KJAX radar near San Diego. When I overlay the latest sounding information, we see the current value is 2.03 inches. This is near the 80% moving average of 1.97 inches for this day. Historically on this day, the median PW is 1.45 inches, so we are a bit higher than that.
Heavy precipitation events that lead to flooding and flash flooding have values that are above the 75th percentile and usually approach the 90th or maximum moving averages.

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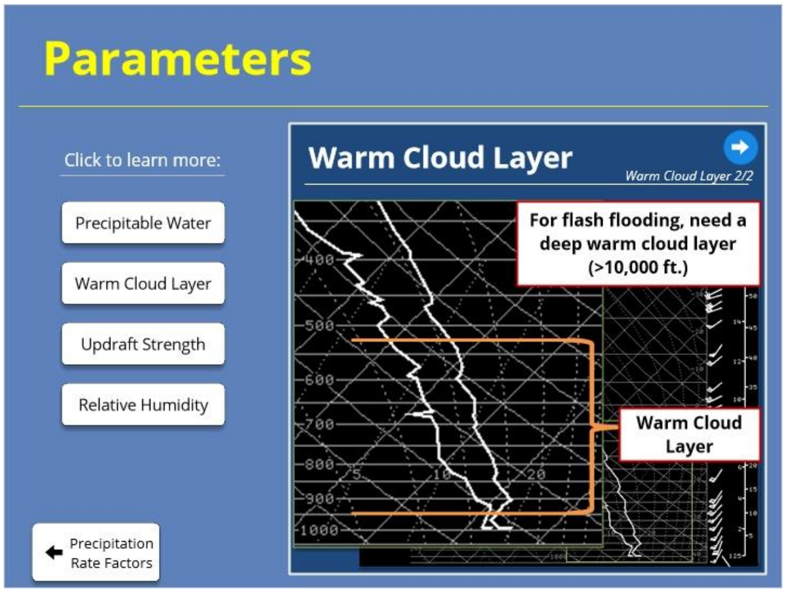
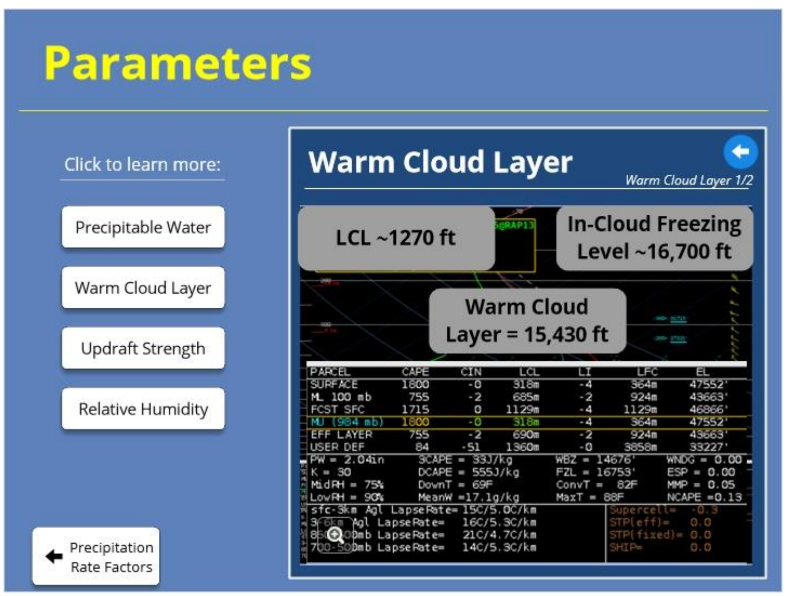
Warm Cloud Layers (Slide Layer)



Notes:

WARM CLOUD LAYER (1/2):
The Warm Cloud Layer is the layer between the LCL and Freezing Level. The depth of the Warm Cloud Layer matters because - for heavy rain potential - we care about how much space a parcel has to undergo warm rain processes (i.e. collision and coalescence). Warm rain processes are more efficient than cold rain processes, therefore, we like to see deep warm cloud layers when looking for heavy rain potential. We define a deep warm cloud layer as roughly 10,000 ft or greater. Click the arrow in the top right corner to move on to part two

Warm Cloud Layers 2 (Slide Layer)



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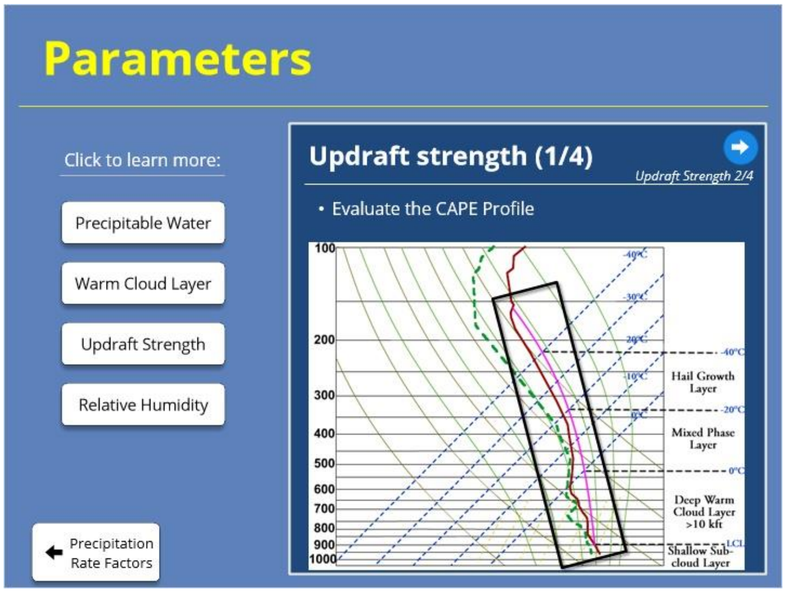
Notes:

WARM CLOUD LAYER 2/2: Example
We can calculate the warm cloud layer using NSHARP to identify the LCL and freezing level heights, either reading it directly from the sounding seen here, or we can use the table below to find these values. Looking at this example in NSHARP, we can see that our LCL is 388 m, or 1273 ft and our Freezing level is 16752 ft. The difference in height between the LCL and in-cloud freezing level will be our warm cloud layer, and in this example, our warm cloud layer is over 15,000 ft. So we would consider this a deep warm cloud layer since it is over 10,000 feet, and as a reminder, having a deep warm cloud layer is very important for flash flood forecasting.

Updraft Strength (Slide Layer)



Notes:

UPDRAFT STRENGTH 1/4:
For flash flooding, you can use CAPE to help assess precip efficiency because it indicates the instability in the atmosphere. We focus on MUCAPE because - for heavy rainfall - it doesn't matter at what level the parcel is lifted from.
An ideal CAPE profile is long and skinny so that a parcel lifts gradually, allowing more time for warm rain processes to occur. We want you to focus on this qualitative interpretation as it can tell you the most about the nature of your event. But, you may be asking yourself how much CAPE is ideal. Well, the thresholds aren't exactly cut-and-dry, but here are some general things to think about. Use the blue arrows to click through Unfavorable, Neutral, and favorable CAPE profiles.

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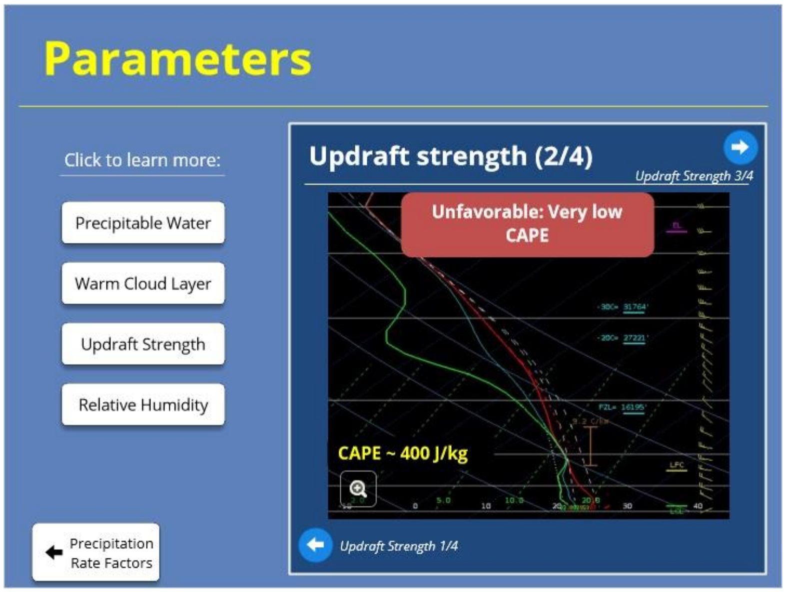
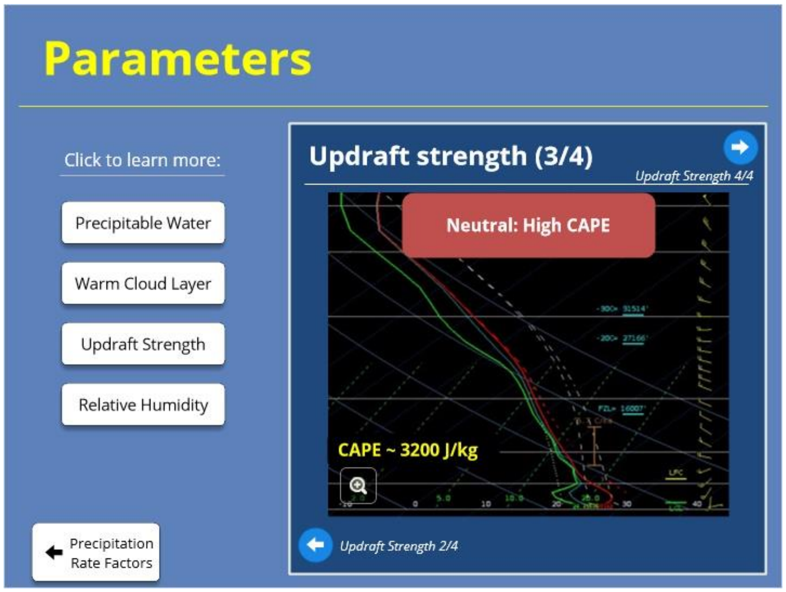
Updraft Strength - low (Slide Layer)



Notes:

UPDRAFT STRENGTH 2/4: Unfavorable CAPE
--Here we see an example of a very low CAPE profile: When CAPE is too low, there just isn't enough instability to warrant heavy rainfall. Rely on training storms for a chance for flash flooding. In this example, our CAPE is about 400 J/KG, below our desired threshold and has quite a short profile.
Click the arrow in the top right corner to move on to part three

Updraft Strength - high (Slide Layer)



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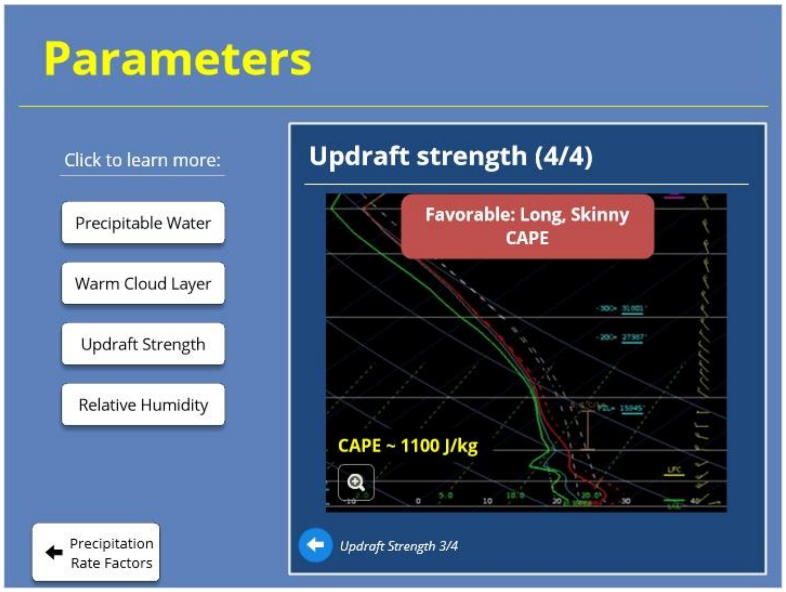
Notes:

UPDRAFT STRENGTH 3/4: Neutral CAPE
--Here is an example of a neutral CAPE profile: A high CAPE environment lends itself to more explosive lift that promotes cold rain processes and hail formation. However, that doesn't mean heavy rain won't occur. There are many instances where severe storms produce enough heavy rainfall to cause flash flooding. It's just not *as* ideal as the long, skinny set-up described before. In high CAPE environments, keep an eye on storm motion to assess whether training is required. In this example, our CAPE is about 3200 J/kg, which is quite a bit higher than our threshold, and doesn't have that skinny profile we’re looking for.
Click the arrow in the top right corner to move on

Updraft Strength - favorable (Slide Layer)



Notes:

UPDRAFT STRENGTH 4/4: Ideal CAPE
--Finally we have an example with an idealized long, skinny CAPE profile: This is the most favorable set-up for warm rain processes to occur which leads to efficient rainfall-producing storms. Generally, this sweet spot is between 500-2000 J/kg, based on the literature. This example has about 1100 J/kg CAPE, and as you can see, it has a long, skinny profile indicating a higher threat of flash flooding.
To summarize, we place less importance on the thresholds for CAPE and instead we want to focus more on the overall shape profile.

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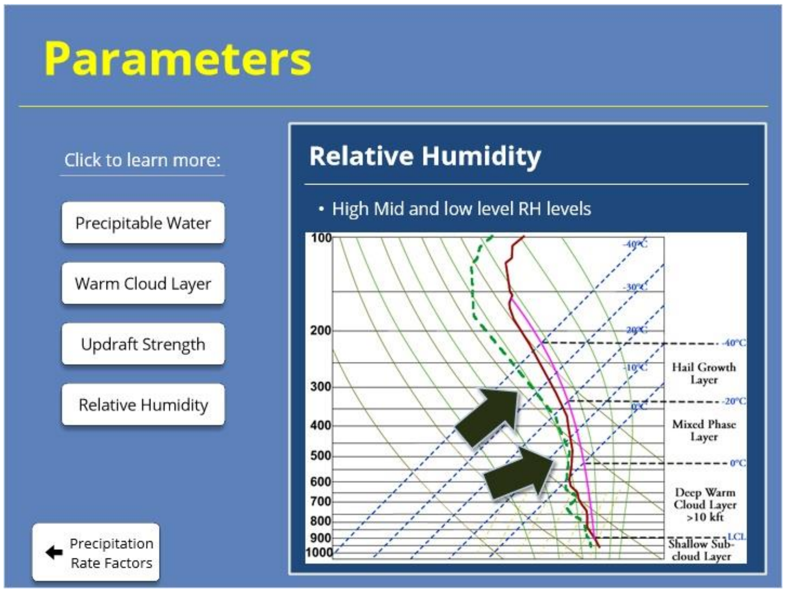
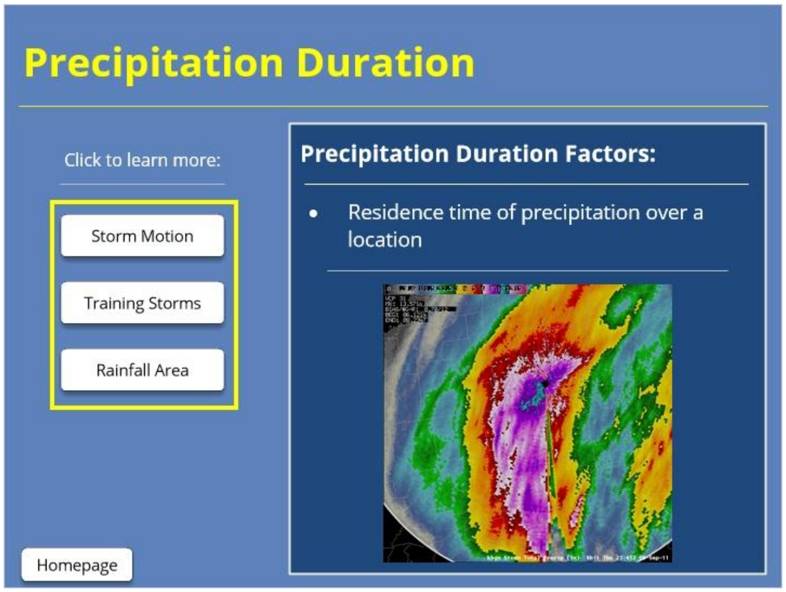
Relative Humitidy (Slide Layer)



Notes:

RELATIVE HUMIDITY:
Finally, we consider the Relative Humidity at low and mid levels to help assess saturation. In this sounding, you can see that it is very moist at all levels. Notice how there is a lack of dry air at the mid and upper levels. For flash flooding, we are specifically looking for mid and low relative humidities greater than 70%.

Precipitation Duration



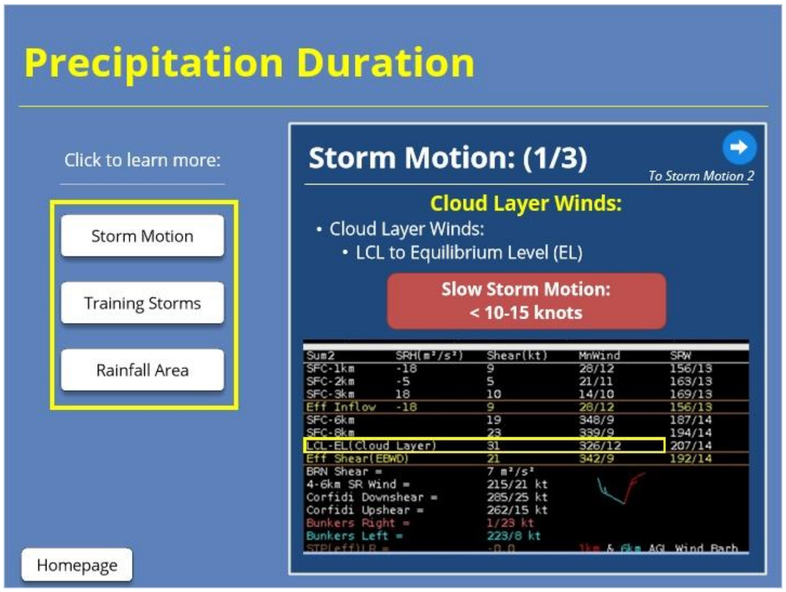
Notes:

PRECIPITATION DURATION:
Now that we have examined the meteorological variables that influence the precipitation

rate, let's examine the other meteorological factor that can influence the flash flood potential: precipitation duration.

When we talk about duration, we are talking about the residence time of precipitation over a location. There are a number of things that affect the duration of rain over a specific area, such as storm motion, training storms along with slow moving boundaries, and rainfall area. Click through each one of these sections to see how they can impact precipitation duration. Again, you must click through all the sections, and press the homepage button when you are ready to move on.

Storm Motion (Slide Layer)



Notes:

STORM MOTION1/3: STEERING LAYER FLOW:

Storm motion is a significant factor when it comes to precipitation residence time over an area. Obviously, slower storm motions lead to longer durations. But what would you look for to determine storm motion?

One factor to look at is the cloud layer winds. We define the cloud layer as the LCL to the Equilibrium Level (or EL). In NSHARP, this parameter is provided, as shown here. Generally, we consider slow storm motion to be less than 10-15 knots.. Again, we can you NSHARP to identify the Cloud layer, or LCL-EL winds. In this example, we can see that the LCL to EL winds are 12 kts.

Click the button in the top right corner to continue on to Storm motion part 2

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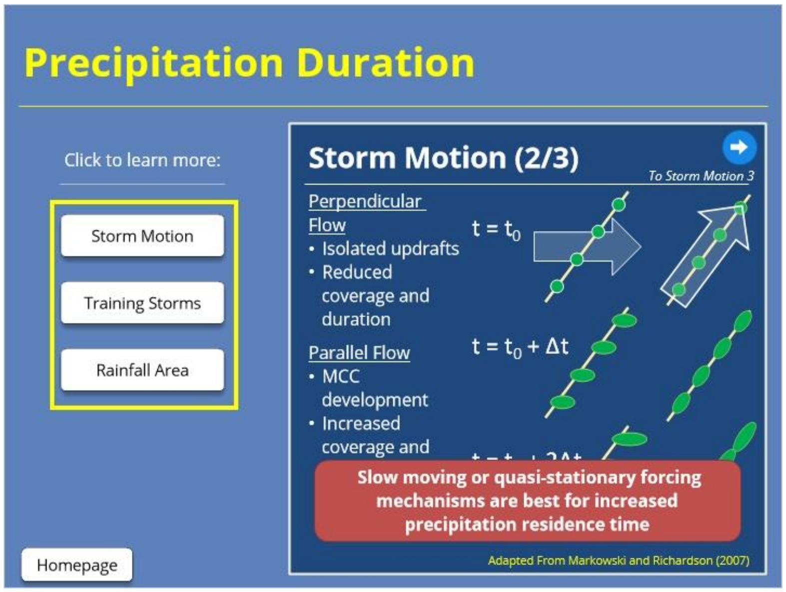
Storm Motion 2 (Slide Layer)



Notes:

STORM MOTION 2/3: RESPECT TO FORCING:
Forcing mechanisms play an integral role in the development and motion of convection. A forcing mechanism can range from fronts to outflow boundaries to topographic features. How storms form and move along a boundary can determine whether you have isolated updrafts or consolidated line segments and mesoscale convective complexes (MCSs).
Recall the work of Markowski and Richardson. Flow that is perpendicular to the forcing will lead to isolated updrafts, which in turn will have reduced areal precipitation coverage and smaller precipitation durations. Flow that is more parallel to the forcing will lead to linear convective formation. This will increase precipitation coverage and duration. Slow moving or quasi-stationary forcing mechanisms are best for increased precipitation residence time over an area.
Click the button in the top right corner to continue on to Storm motion part 3 STORM

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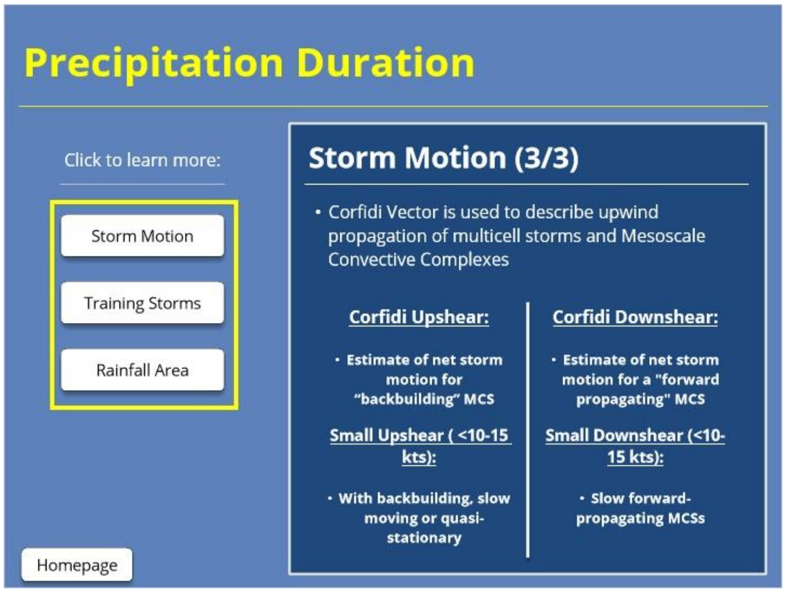
Storm Motion 3 (Slide Layer)



Notes:

MOTION 3/3: CORFIDI VECTORS VECTOR:
When dealing with multicell storms and mesoscale convective complexes (MCSs), the Corfidi Vectors can help describe the propagation of multicells and MCSs. The "Corfidi Upshear" vector is an estimate of net storm motion for a "backbuilding" MCS, where the low-level storm inflow is subtracted from the mean wind. The "Corfidi Downshear" vector is an estimate of net storm motion for a "forward propagating" MCS where the low-level storm inflow is added to the mean wind. Small Corfidi Upshear vectors - less than 10-15 kts - means that if there is a backbuilding component, then the complex will be slow moving or even quasi-stationary. Small Corfidi Downshear vectors indicate slow forward-propagating MCSs. Either one can be bad for flash flooding because they increase the residence time that the system may sit over an area.

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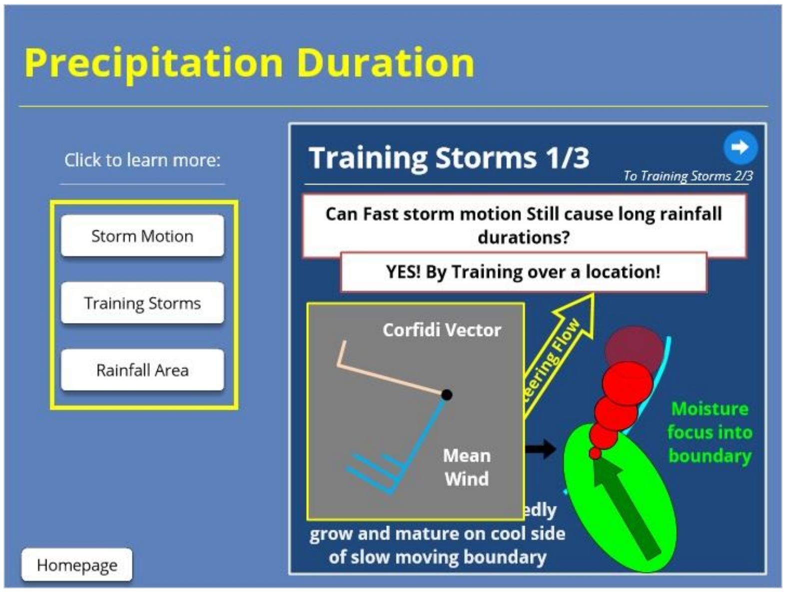
Training Storms (Slide Layer)



Notes:

TRAINING STORMS 1/3:
So far, we have talked about slow storm motions. What if storm motions are relatively fast? Can we still get large durations of rainfall? The answer is definitely yes.
If storms are training over the same location, it is easy to get the adequate duration for flash flooding to occur. One way is to have storms continuously propagate along a slow moving boundary. In this diagram, you have a SW-NE oriented boundary with an area of focused moisture transport. With enough lift and instability, convective cells will develop, move along the boundary, and dissipate. This cycle will continue so long as the boundary motion, moisture, instability, and trigger remain constant.
If you were to examine the vectors of this case, the mean flow parallels the boundary with expected storm motion of 25 kts. The Corfidi Upshear Vector shows that with back building storms (upwind propagation), this system will move to the east at about 5 kts. This will allow for ample precipitation duration for flash flooding.
Click the button in the top right corner to continue on to training storms part 2

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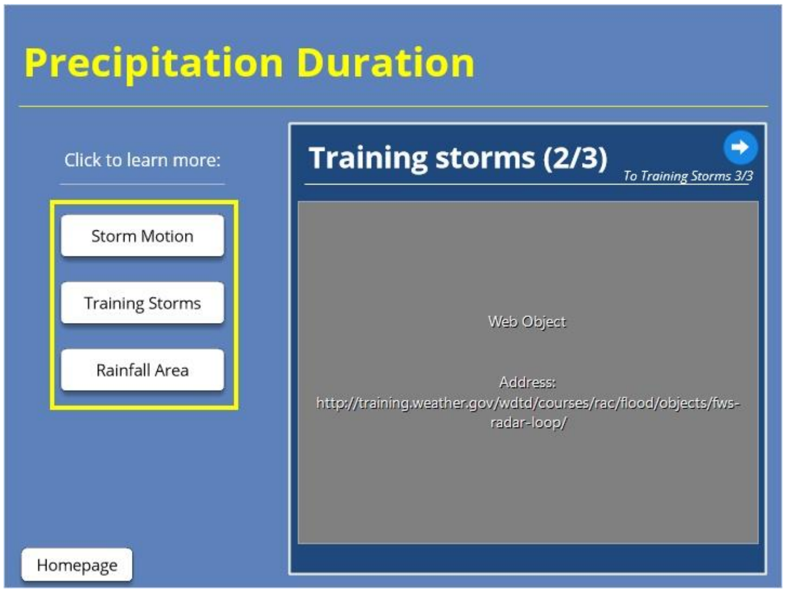
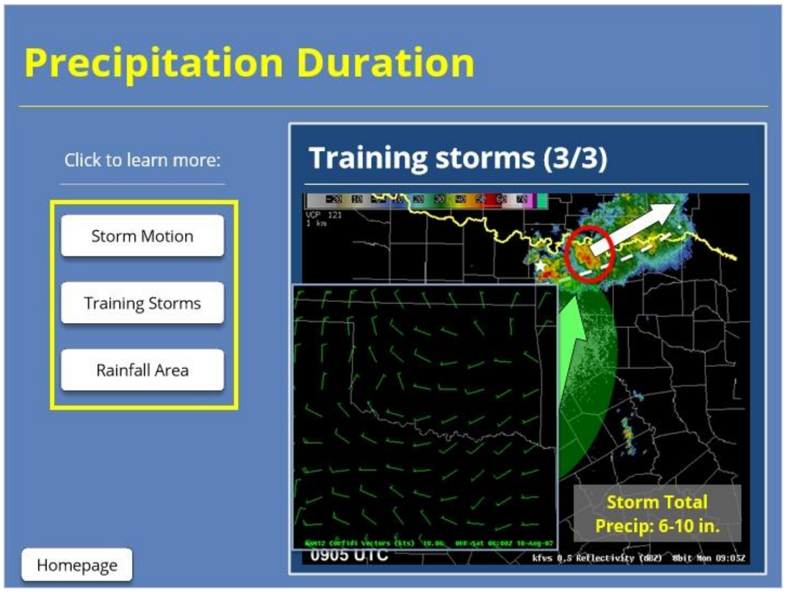
Training Storms 2 (Slide Layer)



Notes:

TRAINING STORMS 2/3:
Here is an example of training storms that led to significant flash flooding. In this case from the Dallas/Fort Worth office, a series of storms train over the northern part of Texas near the Red River. This loop shows 5 ½ hours of radar data from KFWS. The star on the map shows the relative area of maximum focus and continuous development. Note how the storms train over the same area until a substantial cold pool develops for forward propagation.
Click the button in the top right corner to advance to the analysis of this event when you are done viewing this loop.

Training Storms 3 (Slide Layer)



Notes:

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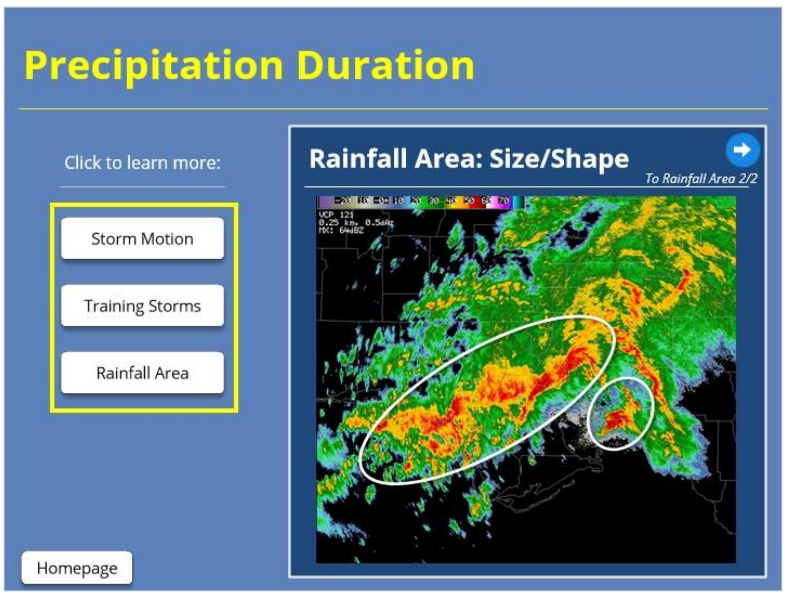
TRAINING STORMS 3/3:
This event was created from a remnant mid-level circulation and boundary where a small vorticity maximum around the southern periphery is providing focus along the axis of forcing. The 1200 UTC sounding from Dallas/Fort Worth showed a very moist southerly 850 mb winds at 35 kts. You saw that storms initiated along the boundary where the forcing was maximized and then moved off to the ENE. However, the area of storms barely moved over a four hour time period. As you see here in the Corfidi Vectors, the overall forecasted motion of the system is around 5 kts.
During this event, some areas received over four inches of rain in less than two hours, and storm total precipitation of 6-10 inches. There were six fatalities from these flash floods. Grayson County, which is circled in red here, had approximately 450 water rescues from vehicles and homes. There were hundreds of other water rescues in the surrounding counties.

Rainfall Area (Slide Layer)



Notes:

RAINFALL AREA: Size and Shape
The last piece of the flash flood meteorology puzzle is to look at the size and shape of the precipitation area. We will start with looking at the size of the rainfall area. Using the Tallahassee, FL radar, you can see a supercell southeast of the radar. Supercells and pulse storms are small in size, and depending on movement, will generally have a small residence time over one location. Linear convection, like the complex to the west, covers a much greater area. Therefore, the residence time of rainfall over a specific point is increased.

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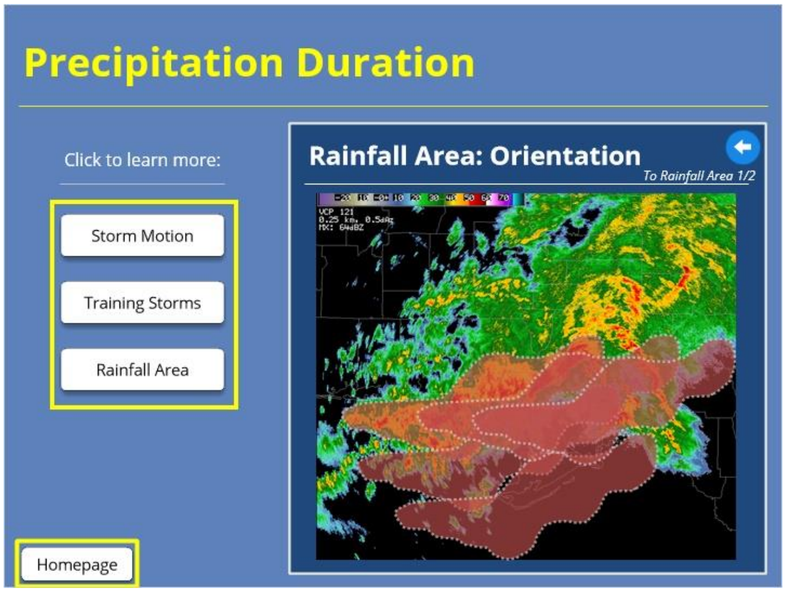
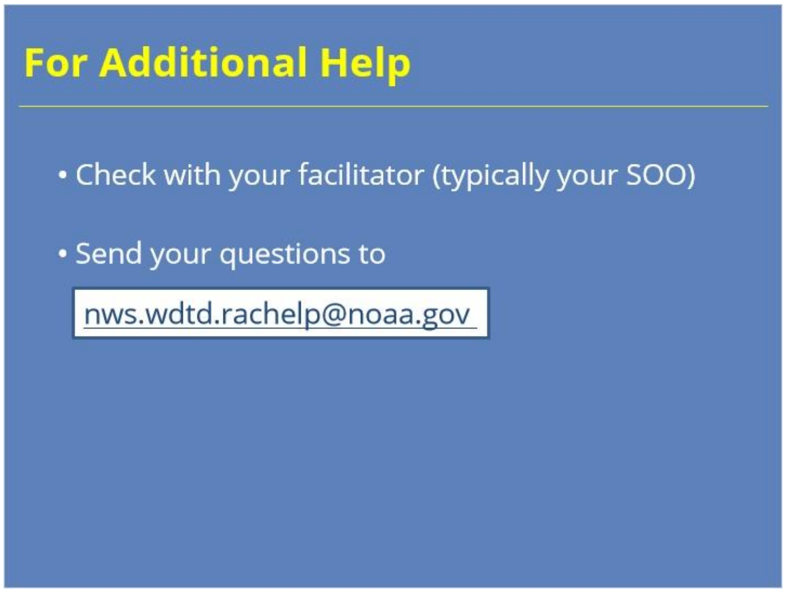
Rainfall Area 2 (Slide Layer)



Notes:

RAINFALL AREA 2/2: Orientation
The next thing to look at is the orientation of the precipitation area with respect to the motion path. Let’s assume that this convection highlighted here is moving towards the south at a constant speed of 40 mph. If we were to assume that the width of the area is approximately 20 miles, then the residence time of the moderate to heavy rain is about 30 minutes.
Now let’s assume that this linear complex is moving to the east at 40 mph. If we were to assume that the length of the area is about 120 miles, then the residence time over this area is closer to three hours. With this event, the complex was moving towards the east and produced 4-7 inches of rain around the Tallahassee area.
Click the button to return to the home page.

For Additional Help



Notes:

For additional help, check with your facilitator (typically your SOO) or send your questions to the listserv e-mail address here.

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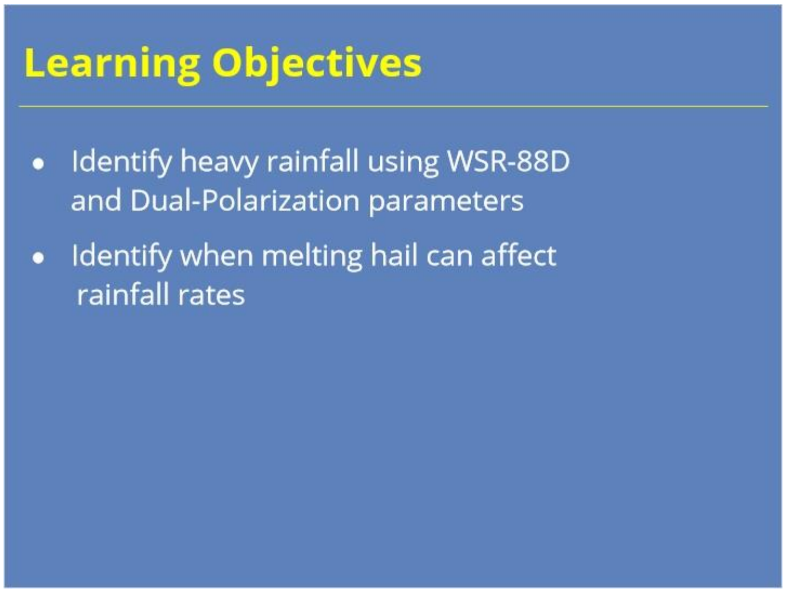
Dual-Pol Signatures for Heavy Rainfall

Title Slide

Notes:

Hi my name is Melissa Lamkin, and welcome to part 2 of Flash Flood Meteorology, focusing on Dual-Pol Signatures for Heavy Rainfall.

Learning Objectives



Notes:

Here are the learning objectives for this lesson. Please take a moment to read through the objectives, and press next to continue.

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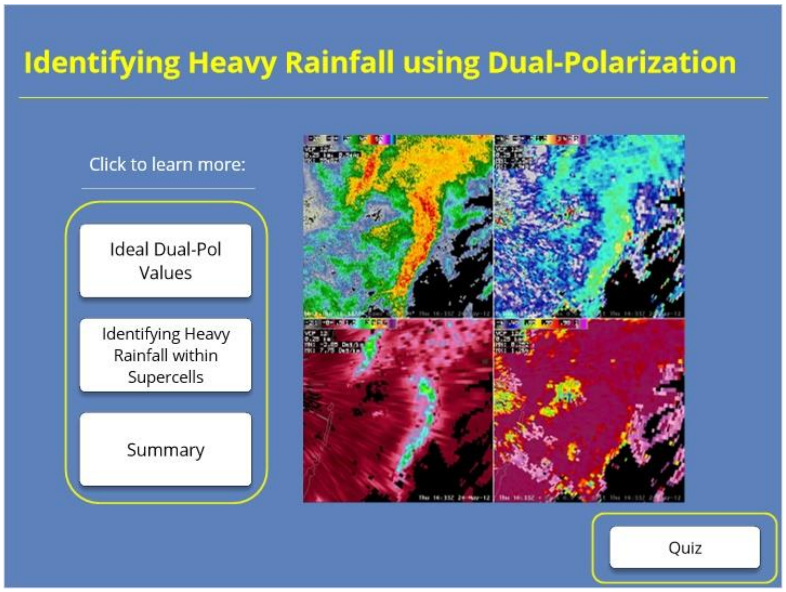

Notes:

Welcome to the homepage for this second lesson on flash flood meteorology. Dual-Pol technology has been incorporated into the WSR-88D network since 2011. One of the main reasons the radars were upgraded to include it was because of the promise of better radar-estimated rainfall, or Quantitative precipitation estimation (QPE). This lesson will dive into several Dual-Pol parameters and what they mean for heavy rainfall identification, as well as show some applied examples. Once you have gone through both sections and you feel comfortable with these materials, take the quiz by clicking the button at the bottom right of the screen

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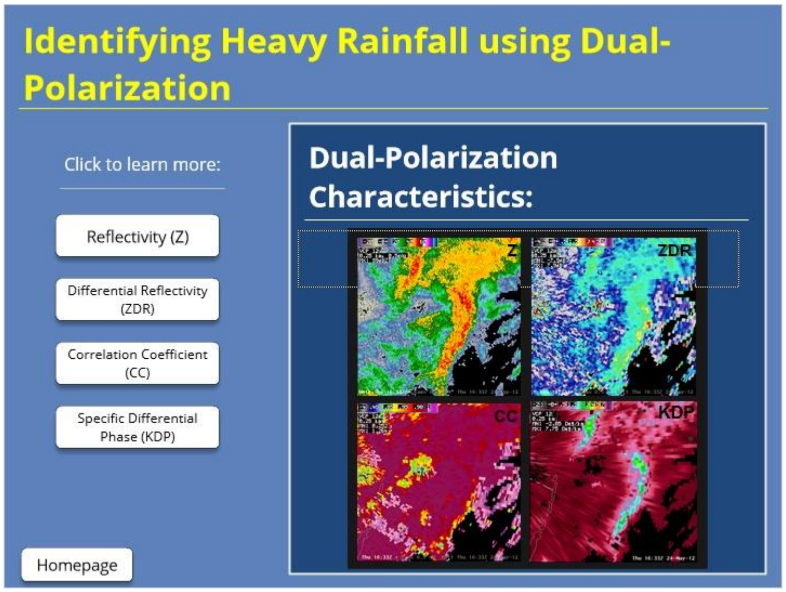
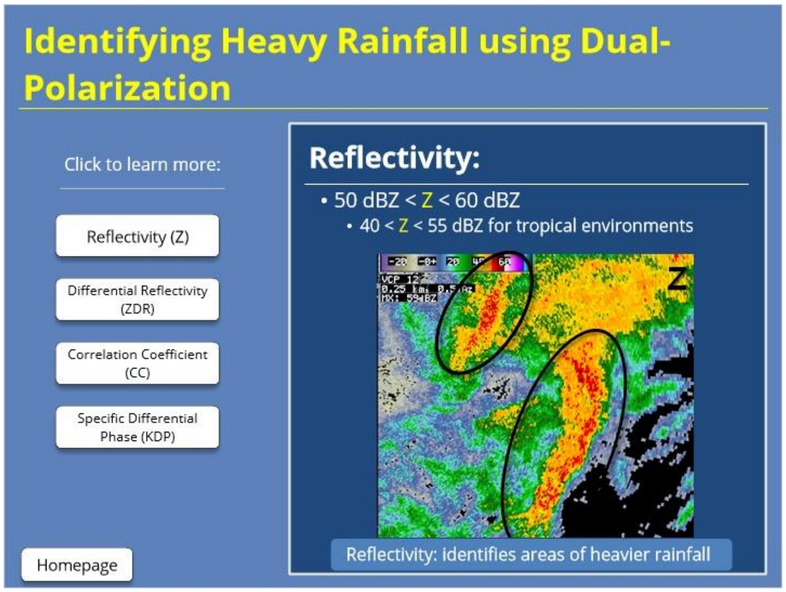
Ideal Dual-Pol Values



Notes:

Identifying Heavy Rainfall using Dual-Polarization:
The Dual-Pol parameters shown here can help pinpoint areas of greater precipitation rates. This signature is from the Miami, FL radar and was related to a tropical disturbance that eventually became Tropical Storm Beryl. Click through each of these to see what thresholds are ideal for heavy rainfall.

Reflectivity (Z) (Slide Layer)



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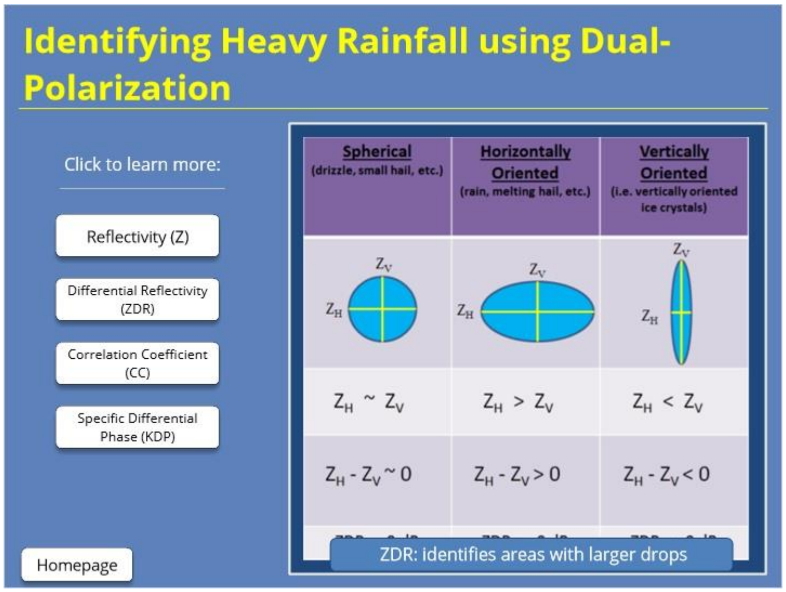
Notes:

REFLECTIVITY:
Starting with the reflectivity (Z), look for areas of enhanced values, generally in the 50-60 dBZ range; 40-55 dBZ for tropical environments. Too much higher than that, and you're in the realm of identifying hail. Too much lower, and the power returns aren't enough to warrant high rates. Here, we are highlighting two areas of enhanced values.

Differential Reflectivity (Slide Layer)



Notes:

DIFFERENTIAL REFLECTIVITY:
Now examining the differential reflectivity (ZDR), or the difference between the horizontal and vertical reflectivity factors, look for ZDR values between 2.0 and 5.0 dB, and 0.5-3.0 dB for tropical environments. Remember, there is a strong relationship between the raindrop size and ZDR where the greater the ZDR values, the larger the raindrop diameter. This is due to the pancake-like nature of raindrops. In tropical environments, raindrops tend to be small because of higher freezing levels and relative humidities. Therefore, you usually have to look for high reflectivity values in the same area as elevated ZDR. When the two are assessed together, it denotes a high concentration of small drops. In this example, since we are dealing with a tropical environment, the ZDR values are around 1.5 dB. Combine that with the high reflectivity values, you have a high concentration of small rain drops here.

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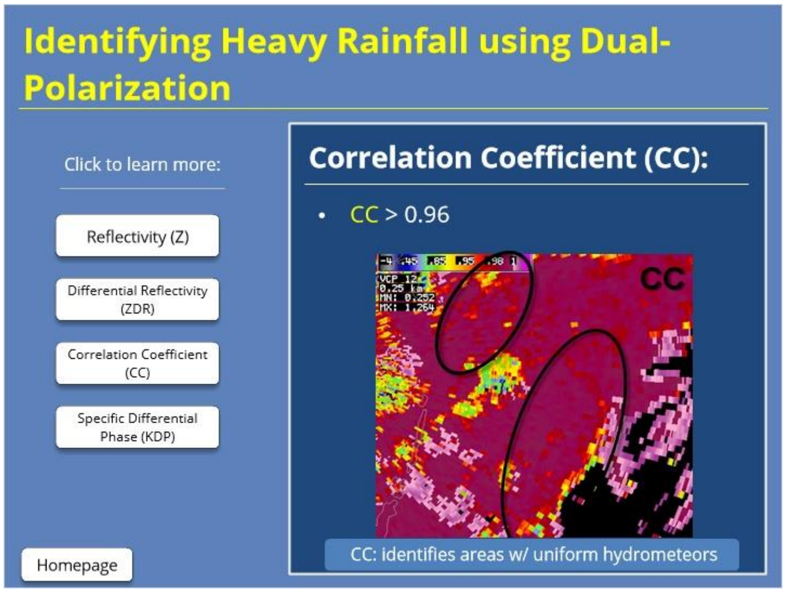
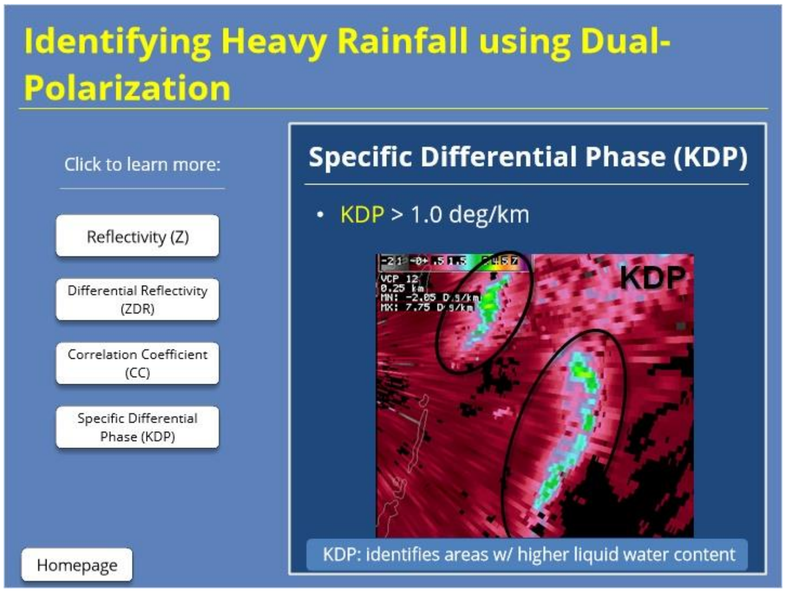
Correlation Coefficient (Slide Layer)



Notes:

CORRELATION COEFFICIENT:
Moving on to the correlation coefficient (CC), you should see very high values (above 0.96). This means that the hydrometeors being sampled are uniform. Generally, such high values are only possible with liquid hydrometeors, so high CCs are a good indication of rain. As you can see here, the areas with greater reflectivity have a CC of around 0.99, meaning all the precipitation here is uniform rain.

Specific Differential Phase (KDP) (Slide Layer)



Notes:

SPECIFIC DIFFERENTIAL PHASE:
Last but definitely not least, specific differential phase (or KDP) is your best parameter to identify heavy rainfall. In fact, there are rain rate relationships that use KDP, specifically in high-rate

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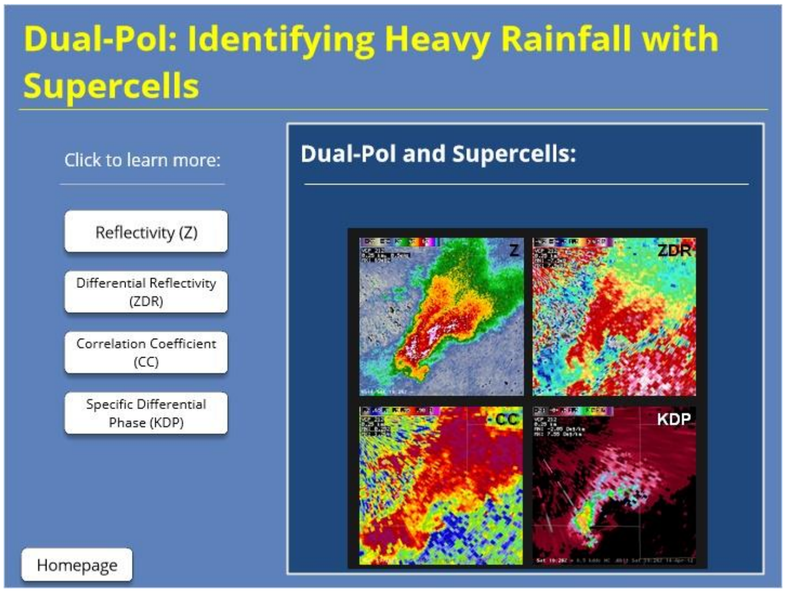
environments. Its whole purpose is to sample liquid water content within the radar beam by prioritizing the horizontal channel. For heavy rainfall, we look for values of 1.0-4.0 deg/km. Higher KDP values mean a large concentration of drops, and secondarily, denote larger drops themselves. Since we know this is a tropical environment and the ZDR values suggest small rain drops, then this means we are dealing with a larger concentration of rain drops, and thus, greater precipitation rates. This is a great example of warm rain processes producing very efficient rain rates.

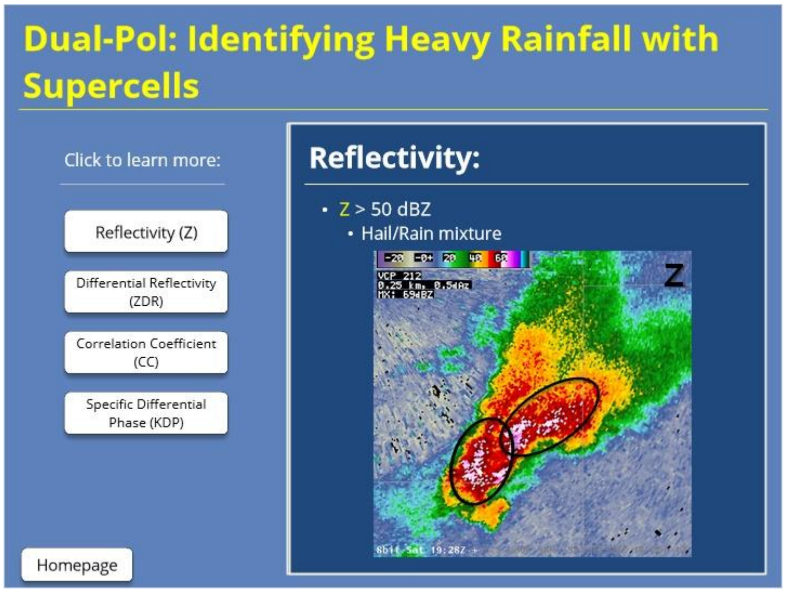
Dual-Pol: Identifying Heavy Rainfall with Supercells



Notes:

DUAL POL: IDENTIFYING HEAVY RAINFALL WITHIN SUPERCELLS
Since we have looked at what an efficient rainfall producer would look like with Dual-Pol, let’s take a look at what an inefficient storm would look like. For this example, we will use a supercell viewed from the Dodge City, KS office during the April 14, 2012 outbreak. Supercells can produce heavy rainfall - and frequently do - but because they have such strong upward motion, your heavy rainfall areas are also likely to be near areas with hail. Therefore, we must pay attention to slightly different thresholds in our Dual-Pol parameters. Click on each one to learn more.

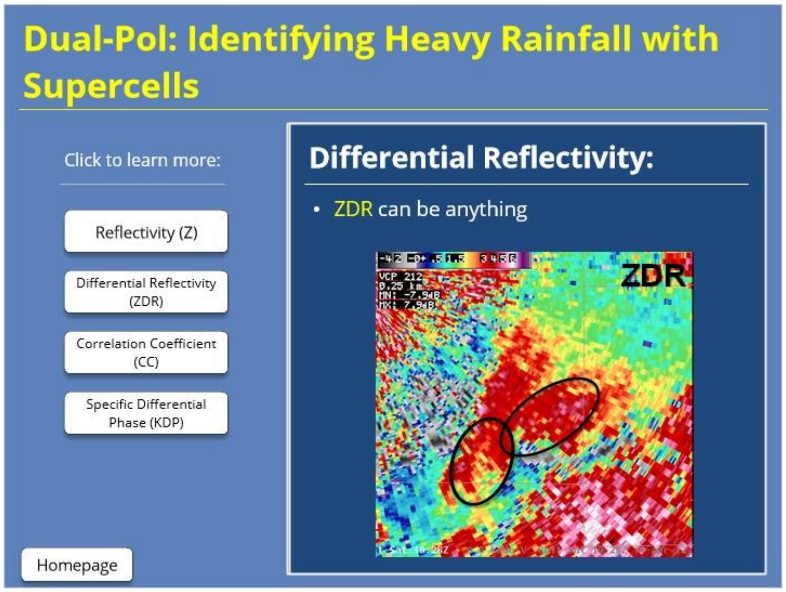
Reflectivity (Z) (Slide Layer)



Notes:

REFLECTIVITY:
Starting again with reflectivity (Z), you still need to look for areas with elevated values, greater than 50 dBZ, to find the highest rates. Here, we have highlighted two separate areas within this supercell. Because of the very high Z values, these areas are probably areas of rain/hail mix.

Differential Reflectivity (Slide Layer)



Notes:

DIFFERENTIAL REFLECTIVITY:
For differential reflectivity (ZDR), ZDR values can be anything because of hail contamination. Severe hail can bring ZDR values to near or below 0 dB while melting hail can have values up to 6 dB. Melting hail can cause such large ZDR values because hail can grow larger than even a big raindrop. So when it starts to melt, its size amplifies the ZDR signal. In our areas of high

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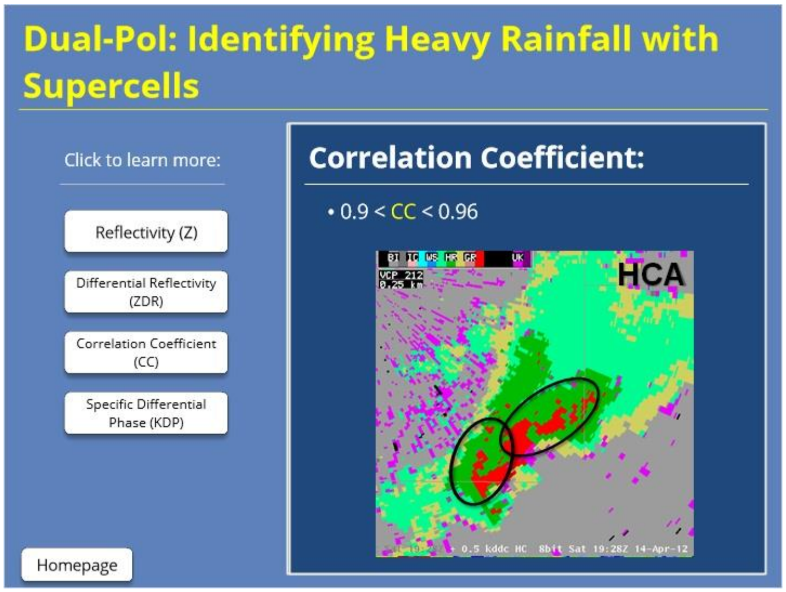
reflectivity, we are getting some pretty high ZDR values. This indicates the presence of very large raindrops, but likely some melting hail, as well.

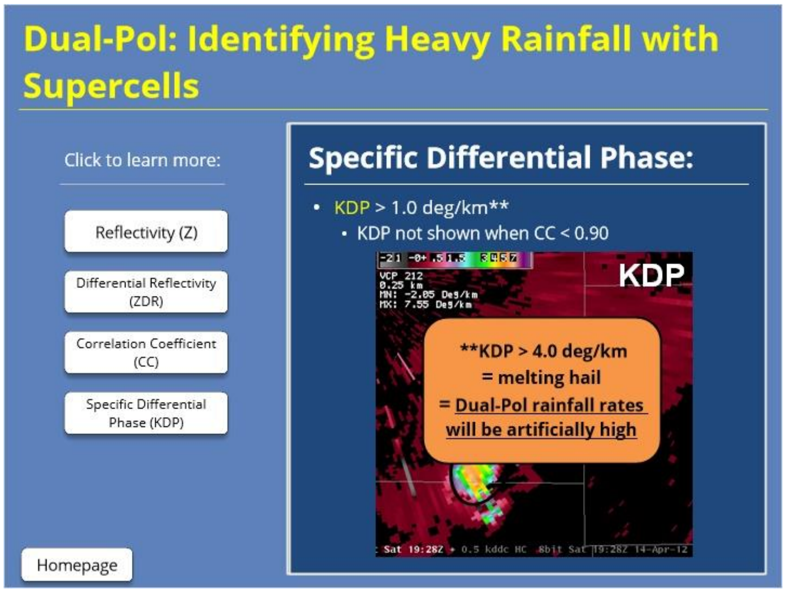
Correlation Coefficient (CC) (Slide Layer)



Notes:

CORRELATION COEFFICIENT:
Since we are dealing with areas of non-uniform precipitation types, correlation coefficient values will be below 0.96 in areas of rain/hail mix. Generally, stick with areas above 0.9 to identify the heavy rain pockets within the storm. Here, we see values ranging between 0.9 and 0.95, with some lower values within the forward flank downdraft. Now overlaying the hydrometeor classification algorithm (HCA), you can see where the radar is classifying the rain/hail mix in red.

Specific Differential Phase (KDP) (Slide Layer)



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Notes:

SPECIFIC DIFFERENTIAL PHASE:
Finally, for specific differential phase, still look for values greater than 1.0 deg/km, as seen here. But recall from the idealized thresholds that we put a cap of 4.0 deg/km for KDP. This is because the more extreme values, like the area of 4.0-7.0 deg/km near the rear flank downdraft, are a result of melting hail. The melting hail artificially increases the KDP values because the radar is fooled into thinking they're really large drops. This can have quite negative results on rain rate calculations in these areas, and we frequently see high-biased rainfall because of it. So I can't stress this enough…When you see KDP greater than 4.0 deg/km in areas of rain/hail mix, know that your Dual-Pol rainfall rates will be artificially high. Yes, you still should focus on those locations for the highest rates, but don't trust the rate or QPE output directly. Mentally hedge estimates down in these locations.
Finally, you may notice some areas where KDP isn't calculated. Recall that KDP values will not display in areas of CC less than 0.90. This is a good gut check that's built into the 88D Dual-Pol algorithm because if the radar beam is *too* nonuniform, it doesn't even want to estimate liquid water content.

Summary

Summary:

Dual-Pol Variable:	Use for Identifying Heavy Rainfall:	Ideal Values:	Supercell:
Reflectivity (Z)	Differentiate between high/low precipitation rates as well as hail	50 dBZ < Z < 60 dBZ	Z > 50 dBZ
Differential Reflectivity (ZDR):	Estimate drop size	2.0 dB < ZDR < 5.0 dB	ZDR can be anything
Correlation Coefficient (CC):	Identify uniform hydrometeor shape	CC > 0.96	0.9 < CC < 0.96
Specific Differential Phase (KDP):	Identify liquid water content	KDP > 1.0 deg/km	KDP > 1.0 deg/km* *KDP > 4 = Melting Hail

Homepage

Notes:

Throughout this lesson, we've examined how to use the Dual-Pol parameters to help us identify areas of heavy rainfall. Using reflectivity we looked at how we can use reflectivity to identify areas of high- and low-precipitation rates, as well as areas where we might see hail. ZDR can be useful for estimating drop size. For correlation coefficient, we can use this parameter to identify uniform drop sizes or non uniform shapes when looking for hail. Finally, KDP is our best parameter to identify heavy rainfall by identifying areas with a higher concentration of drops, as well as areas of melting hail in supercell environments.

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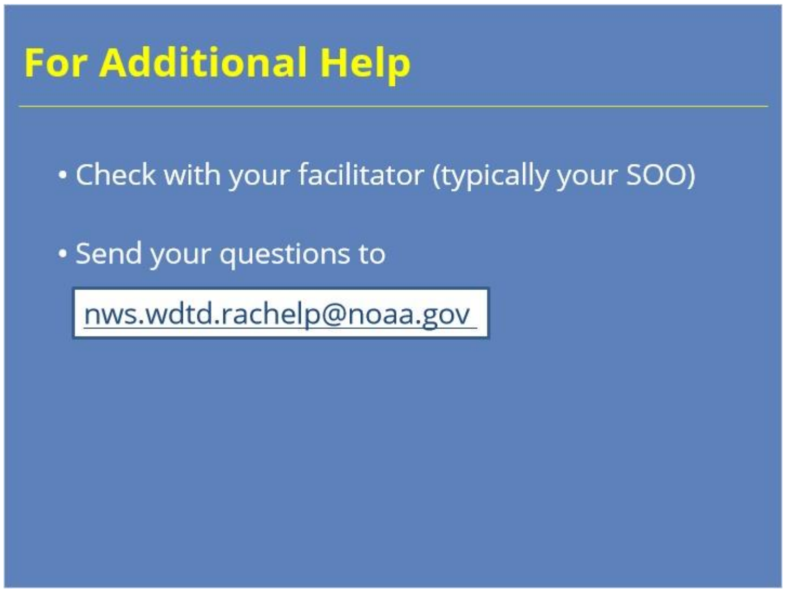
For Help

For Additional Help



Notes:

For additional help, check with your facilitator (typically your SOO) or send your questions to the listserv e-mail address here.

Overview of Precipitation Sources in AWIPS

Introduction

Notes:

Welcome to an overview of precipitation sources in AWIPS! My name is Katy Christian and I'll be your guide through today's module.

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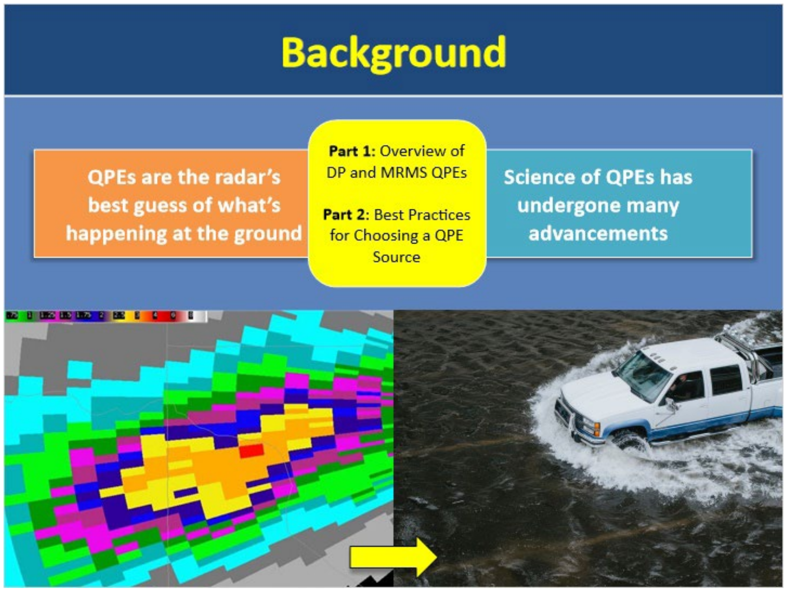
Background



Notes:

In flash flood operations, quantitative precipitation estimates (or QPEs) are one of your most important tools because they provide the radar's best guess of what's happening at the ground. The science of calculating QPEs has been evolving for many years, leading to rapid advancements and various algorithms, all trying to do the same thing...match rainfall totals happening at the surface.

This module is part 1 in a two-part series that will cover your QPE sources in AWIPS and best practices for choosing a source. Part 1 will be your one stop informational shop for both your QPE sources in AWIPS. Part 2 will then refer to the information in this lesson to outline some best practices for choosing a QPE source in warning operations.

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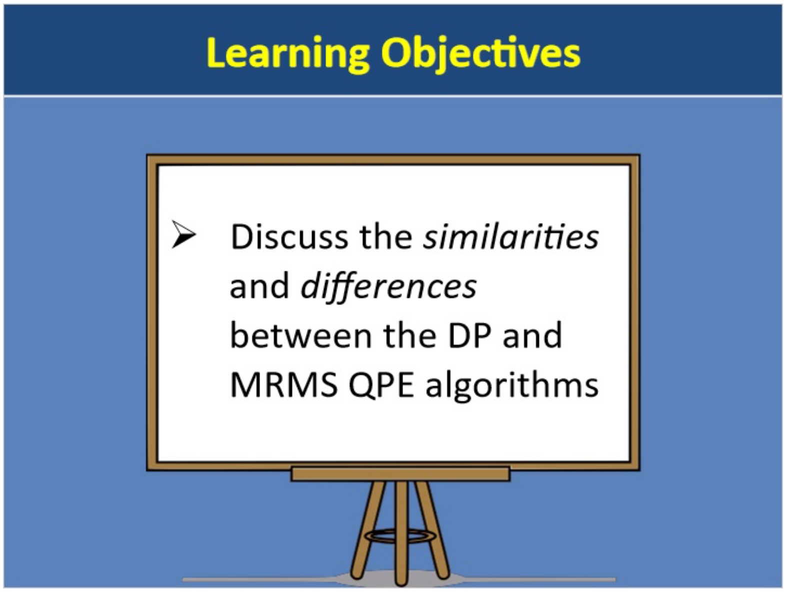
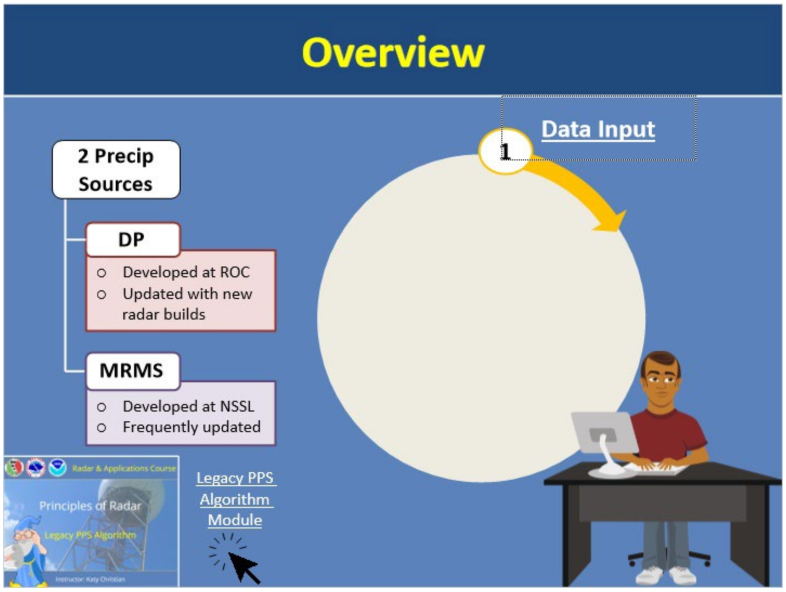
Learning Objectives



Notes:

Come quiz time, you should be able to discuss the similarities AND differences between the DP and MRMS QPE algorithms.

Overview



Notes:

Let's say you're assigned to work the hydro desk and need to start monitoring precipitation amounts - where do you even start? In AWIPS, you essentially have 2 different precipitation sources to choose from: Dual-Pol or MRMS. As a quick reminder, the DP QPE Algorithm was developed at the Radar Operations Center and has gone through a continuous cycle of updates - typically with every new radar build that comes out. MRMS was developed at NSSL and is a mosaic product. It is also constantly being refined and updated. Now you may be aware of a third source called Legacy PPS and here is a lesson that discusses it. As the name implies, this source has become quite archaic and rudimentary that we don't recommend you use it anymore.

With that being said, we need to have a fundamental understanding of how both the DP and MRMS QPE algorithms compare in terms of their similarities and differences so that we're not just blindly picking a source and using it. We'll start by working through the life cycle of these algorithms so we can see at what points they differ. Click on the first lifecycle icon to get started on your journey.

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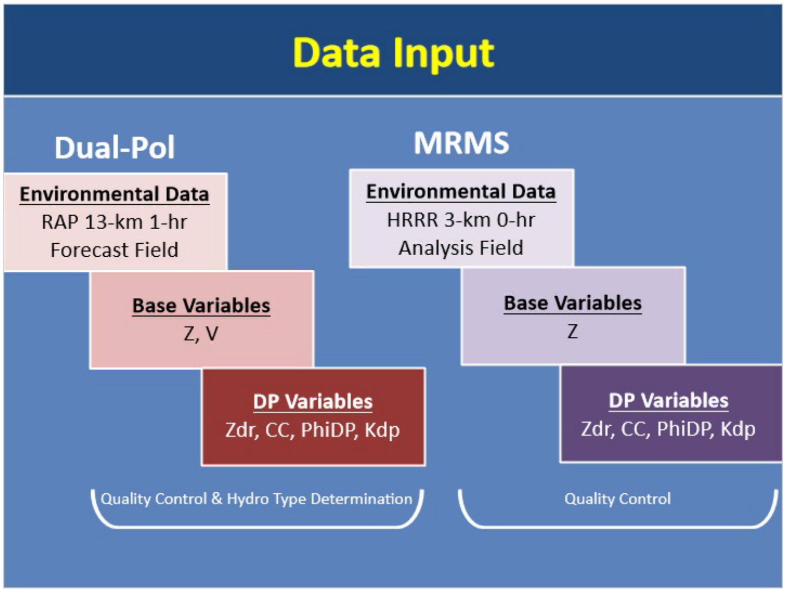
Data Input



Notes:

Every good QPE algorithm starts with data input. The DP QPE algorithm uses input from the RAP 13 km 1-hr forecast field for its environmental data source. It also uses base and DP variables including Z, V, Zdr, CC, PhiDP, and Kdp to aid in its quality control steps as well as determine hydrometeor types.

MRMS uses 3D environmental model data from the HRRR 3 km 0-hr analysis field, including the temperature field, freezing level height, and the surface wet bulb temperature. It also uses the following base and DP variables to aid in its quality control steps: Z, Zdr, CC, PhiDP, and Kdp. Remember that MRMS is pulling this radar data from multiple radars since it’s a mosaic.

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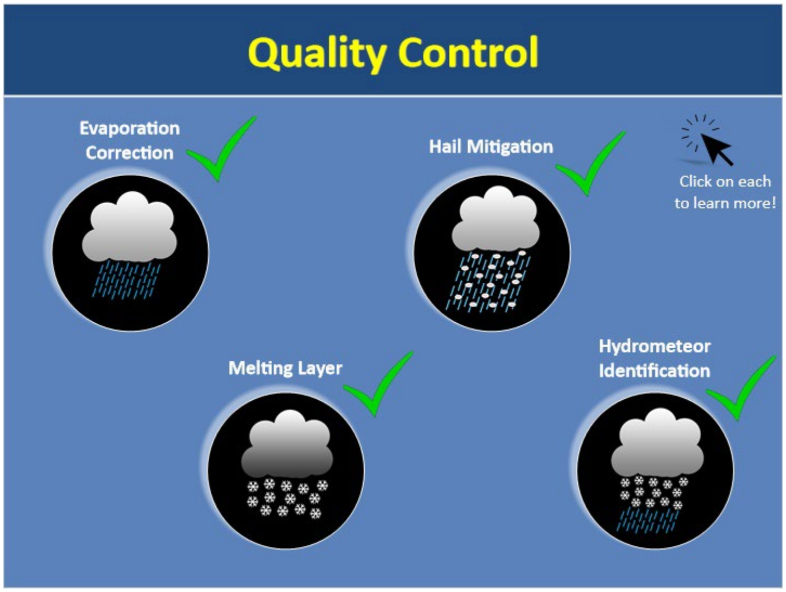
Quality Control



Notes:

Both MRMS and DP QPE Algorithms have various quality control measures built into them to help produce the most accurate precipitation estimates possible. Click on each one to learn more.

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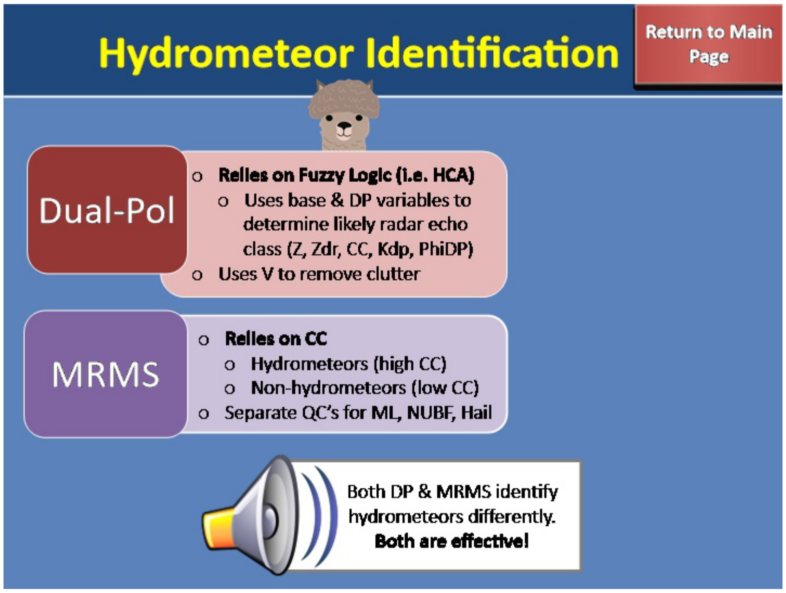
Hydrometeor Identification (Slide Layer)



Hydrometeor Identification:
Both DP and MRMS have their own ways of differentiating between hydrometeors and non-hydrometeors. DP distinguishes non-meteorological from meteorological echoes through fuzzy logic. More specifically, the Hydrometeor Classification Algorithm, or HCA, uses base and DP variables listed here to determine the type of radar echo. DP also uses a clutter filtering algorithm to remove any clutter that has a small radial velocity component (in other words, is stationary). MRMS uses correlation coefficient to distinguish between hydrometeors (characterized by high CC) and non-hydrometeors (characterized by low CC). Then it uses a series of "exception filters" to reintroduce or further remove echoes that were misclassified initially. These filters uses a variety of 3D reflectivity and environmental data, as well as horizontal/vertical consistency checks. So taking a step back, both DP and MRMS have their own unique ways of distinguishing between hydrometeors and non-hydrometeors and both methods have been found to be effective.

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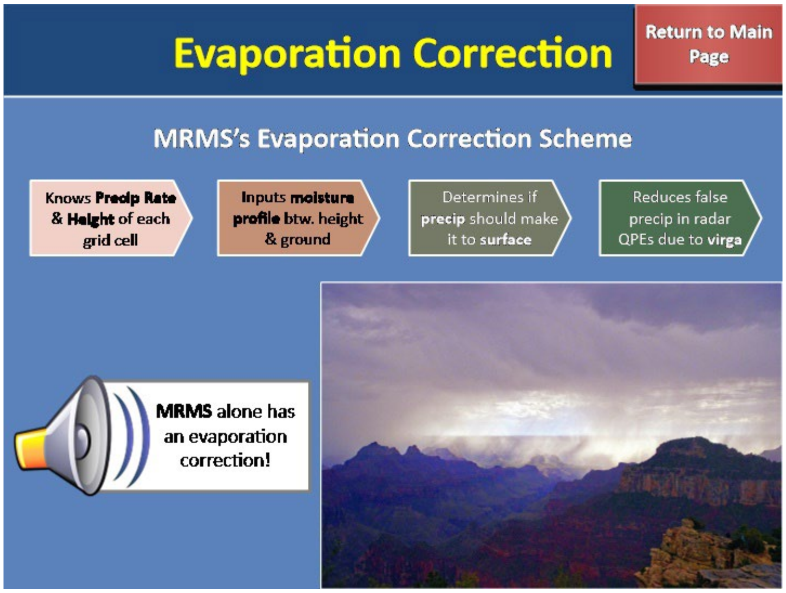
Evaporation Correction (Slide Layer)



Evaporation Correction:
One quality control measure that is unique to MRMS is that it applies an evaporation correction scheme to the mosaicked rain rate field. It works by knowing the precipitation rate at each grid pixel AND the height at which it was derived. It then inputs the moisture profile between that height and the ground to determine if that precip should make it to the surface. This helps to reduce false light precipitation in radar QPE due to virga. This evaporation correction scheme is unique to MRMS and does not exist within the DP QPE algorithm.

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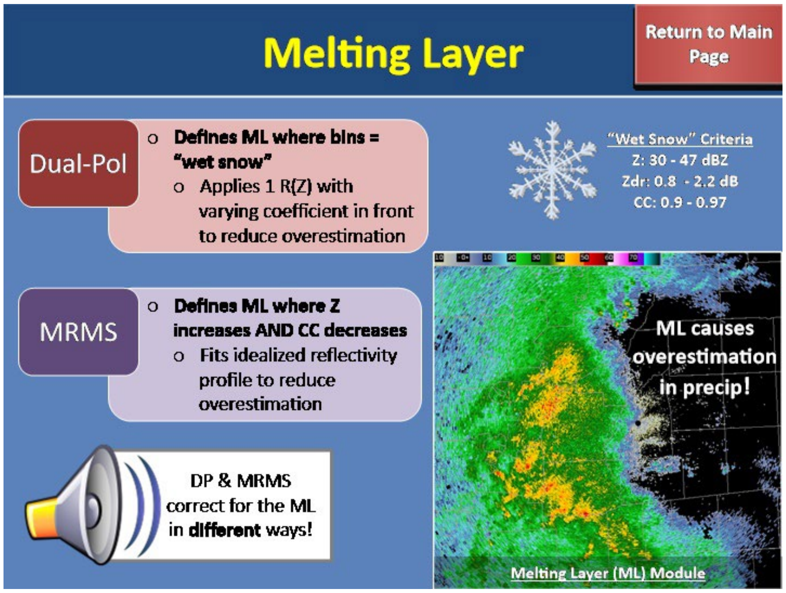
Melting Layer (Slide Layer)



Melting Layer:
The next quality control measure in both precip algorithms deals with the melting layer. Remember that the melting layer is a pain in the butt to precip algorithms because it causes an overestimation in precipitation due to Rayleigh scattering being violated here. To deal with this, both DP and MRMS have quality control measures in place. The DP QPE essentially defines the melting layer as anywhere bins are identified as "wet snow" according to predetermined criteria shown here. It will then apply the R(Z) relationship with the constant multiplier out front in an attempt to adjust for overestimation in the melting layer. For more details about the Melting Layer Detection Algorithm, refer to the lesson shown here.

In contrast, the MRMS QPE algorithm goes about identifying the melting layer in a much different manner. It starts by checking the radial profiles of Z and CC, and where Z increases and CC decreases, it will identify that region as the melting layer. It then will fit an idealized reflectivity profile to that area and apply a correction to the reflectivity to reduce overestimation. As you can see, both DP and MRMS attempt to correct for overestimation in the Melting Layer but do so in very different ways. We'll talk more in the next lesson about which method is more advantageous.

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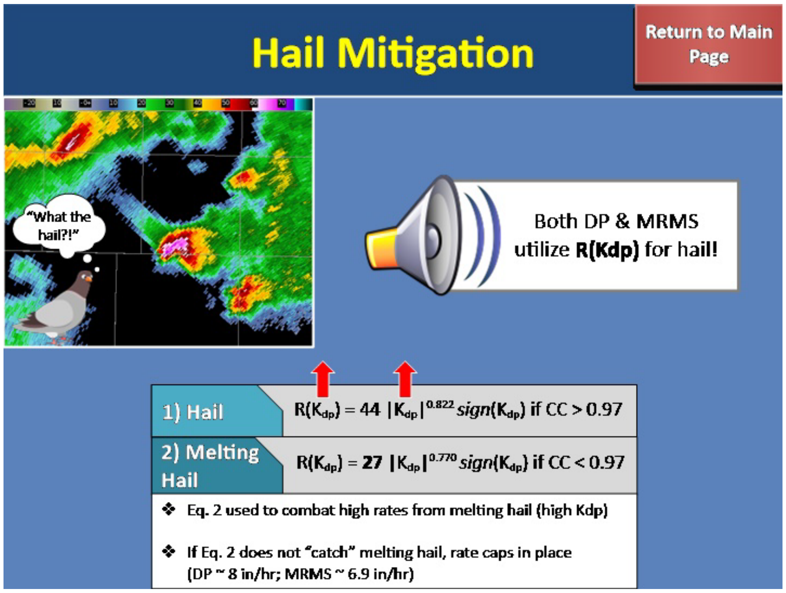
Hail Mitigation (Slide Layer)



Hail Mitigation:
Because hail causes a high bias in precipitation rates, both DP and MRMS QPE algorithms have their own ways of mitigating it. Since KDP is mostly immune to hail contamination, in areas of potential hail, both DP and MRMS utilize the R(Kdp) equation that is shown here. Notice that I said KDP is mostly immune to hail. In cases where there is melting hail, KDP values can end up being very high which results in the R(Kdp) pushing out unrealistically high rain rates. Thankfully though, both DP and MRMS have a way of dealing with this situation through utilizing a modified form of the equation if CC < 0.97. This modified form greatly reduces high rain rates that can occur as a result of melting hail when KDP is very high. As a secondary backup in case anything sneaks past this threshold, an upper limit is also in place and that is shown here.

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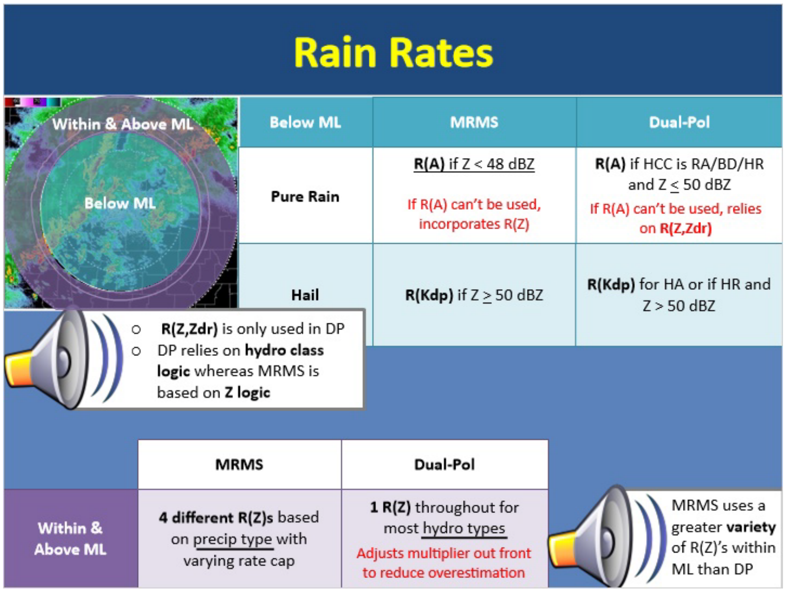
Rain Rates



Notes:

Alright, let's take a look at what rain rate relationships are used by both DP and MRMS QPE algorithms to produce precipitation estimates. Since the most significant differences between the two occur once you start to get within the melting layer, let's start with below the melting layer first and work our way up.

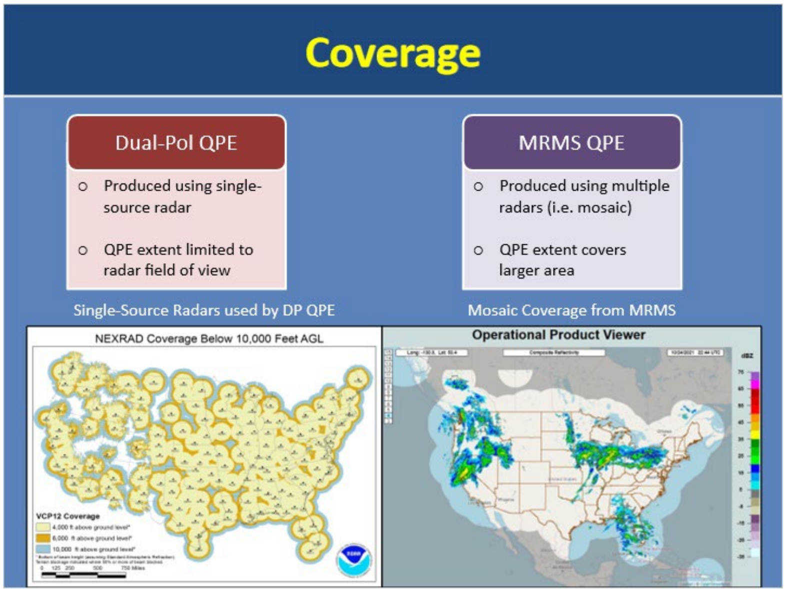
Below Melting Layer:
For MRMS, it applies R(A) in areas of pure rain, where pure rain is restricted to below the melting layer where Z < 48 dBZ. If R(A) cannot be computed, it will use a combination of R(A) and R(Z) where the cool season R(Z) is applied east of 105W and the Marshall-Palmer relationship is applied west of 105W. And lastly, it applies R(Kdp) in areas with potential hail, where potential hail is anywhere Z > 50 dBZ.

For DP, it applies very similar rain rate relationships below the ML as MRMS. It applies R(A) for pure rain, so anywhere the HCC identifies RA, BD, or HR when Z < 50 dBZ. It uses R(Kdp) for areas with a rain/hail mix (HA) and for heavy rain when Z > 50 dBZ. The one major difference is that the DP QPE also uses the R(Z,Zdr) relationship unlike MRMS which does not use this relationship at all. R(Z,Zdr) is used for pure rain classifications for a thin portion that is still below the ML as defined by the radar beam center where R(A) cannot be used there due to its sensitivity to ice contamination. Additionally, the DP QPE will default to using R(Z,Zdr) anytime R(A) cannot be computed.

So the two most important differences below the ML are: 1) R(Z,Zdr) is the only rain rate relationship that is used in DP and NOT in MRMS and 2) DP relies on hydro classifications to help determine which rain rate to use whereas MRMS is strictly based on reflectivity logic.

Within & Above Melting Layer:
Now, once you get within and above the melting layer, this is where things really start to diverge between MRMS and DP. For the DP QPE algorithm, it just uses one R(Z) relationship (the Convective relationship) throughout and will decrease or increase the single multiplier out front according to the designated hydro class. In contrast, MRMS uses 4 different R(Z) relationships (West Cool Stratiform, Marshall-Palmer, Convective, and Rosenfeld Tropical) according to precip type within and above the melting layer and it also varies the rate cap applied as well. Note that both MRMS and DP lean on precip type designation once within and above the melting layer.
The biggest difference though is that MRMS uses a variety of R(Z) relationships as well as varying the rate cap whereas DP just uses 1 R(Z) relationship. For a complete look at when each of the rain rate equations are used in both DP and MRMS, please see the "Resources" tab for more info.

Coverage



Notes:

QPE from the DP algorithm is produced using a single-source radar. Because it uses a single-source radar, its QPE extent will be limited to that of the radar field of view, typically 200 miles.

The MRMS QPE is produced using multiple radars. Because MRMS is a mosaic, it can better account for surrounding radars to use the most representative beam at any given location. As a result, its QPE extent can span a larger area.

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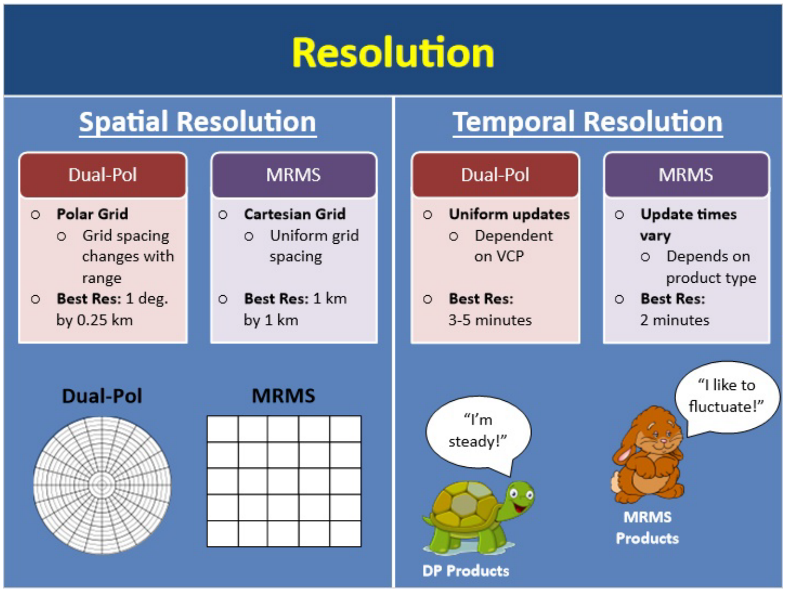
Resolution



Notes:

When it comes to the spatial and temporal resolutions of DP and MRMS, there are differences between the two.

For spatial resolution, DP is on a polar grid whereas MRMS is on a cartesian grid. What this means is that the grid spacing for DP will change with range from the radar whereas MRMS will be uniform throughout. This difference can cause a small offset in values between the two that you may notice especially when doing zoomed-in comparisons. With that being said, at its highest, DP has a spatial resolution of 1 degree by 0.25 km. MRMS has a spatial resolution of 1-km by 1-km.

As for temporal resolution, DP is simply dependent on the VCP used and has a typical temporal resolution of 3-5 minutes. In contrast, MRMS's temporal resolution varies depending on the product. At its highest, MRMS products have a temporal resolution of 2-minutes whereas other products are only updated once every hour.

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Precipitation Products: Part 1

Precipitation Products

	Dual-Pol Radar-Based QPE Products	MRMS Radar-Based QPE Products
Reflectivity	Digital Hybrid Reflectivity (DHR)	Seamless Hybrid Scan Reflectivity (SHSR)
Precip Type	Hybrid Hydro Class (HHC)	Surface Precipitation Type (SPT)
Precip Rate	Digital Precipitation Rate (DPR)	Surface Precipitation Rate (SPR)
Hourly Totals	One Hour Accumulation (OHA)	Radar Only QPE (1-hr)
Longer Totals	Storm Total Accumulation (STA)	Radar Only QPE (3, 6, 12, 24, 48, 72-hr)
	Digital User-Selectable Accumulation (DUA)	✗
Click on each highlighted product!	Rainfall Rate Classification (RRC)	✗

Notes:

When it comes to radar-based precipitation products, both DP and MRMS have nearly identical products. Here is a table of DP and MRMS radar-based precip products that you will likely use in warning ops. You can see that DP and MRMS have nearly identical products with the exception of the bottom two that are highlighted. These products are unique to DP. Click on each of these unique products to learn more and when you're done, click "next" to continue.

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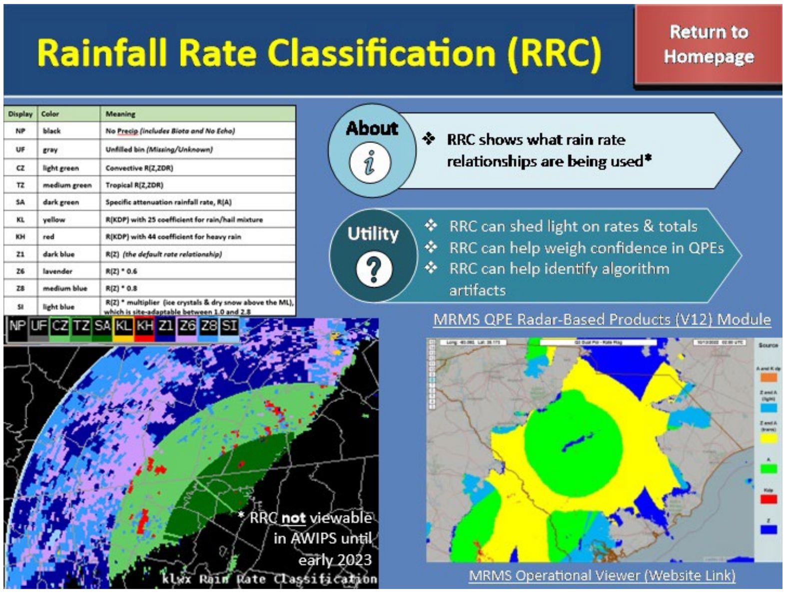
RRC Product (Slide Layer)



RRC Product:
Additionally, with Build 21, DP added the Rainfall Rate Classification Product, or RRC, that shows you exactly what rain-rate relationships are being used over the radar field of view. This is particularly helpful during operations as knowing what equations are being used can help you understand why your rates and totals are the way they are. It can also help you weigh confidence in your QPE amounts. For instance, we know that R(A) and R(Kdp) have a smaller error than R(Z) and R(Z,Zdr) if correctly applied, so anywhere we see those equations being used to produce our rates and totals, we can have higher confidence in our QPE amounts there. Lastly, RRC can help you spot any ring-like artifacts that are more a result of the algorithm than the actual distribution of precipitation. Although MRMS has a very similar product called the QPE Rate ID, it is not currently in AWIPS due to SBN bandwidth limitations but for more info, please see this lesson (MRMS QPE Radar-Based Products (Version 12)). You can also find it on the web as shown here.

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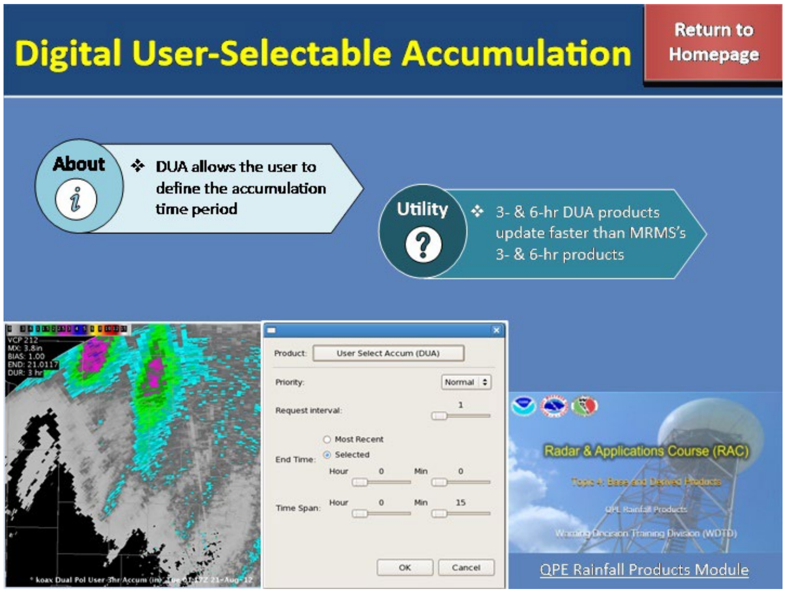
DUA Product (Slide Layer)



DUA Product:
Unique to DP is the Digital User-selectable Accumulation product, or DUA, that allows you to select the time period over which you want precip to accumulate by adding a request to the RPS list. It's advantageous to manually add the 3- and/or 6-hour DUA products to your RPS list if you have space as they update much faster than MRMS's corresponding 3- and 6-hour accumulations products as we'll discuss shortly. For instructions on how to manually add additional QPE durations to your RPS list, please see the following module (QPE Rainfall Products) or ask your radar focal point.

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Precipitation Products: Part 2

Precipitation Products (Continued)

	Dual-Pol Radar-Based QPE Products	MRMS Radar-Based QPE Products
Reflectivity	Digital Hybrid Reflectivity (DHR)	Seamless Hybrid Scan Reflectivity (SHSR)
Precip Type	Hybrid Hydro Class (HHC)	Surface Precipitation Type (SPT)
Precip Rate	Digital Precipitation Rate (DPR)	Surface Precipitation Rate (SPR)
Hourly Totals	One Hour Accumulation (OHA)	Radar Only QPE (1-hr)
Longer Totals Click!	✓ Storm Total Accumulation (STA)	Radar Only QPE (3, 6, 12, 24, 48, 72-hr)
	Digital User-Selectable Accumulation (DUA)	✗
	Rainfall Rate Classification (RRC)	✗

Notes:

Now, you may be thinking, “Okay, great, they basically have the same products, that’ll be easy to remember” BUT (and yes, there’s always a “but” just when things seem simple), I’m here to tell you that for the longer totals, how frequently they update and how they accumulate totals varies between the two and this can actually impact your operational use of them which we’ll discuss in a later module. For now though, click on the highlighted row to learn more and when you’re done, click “next” to continue.

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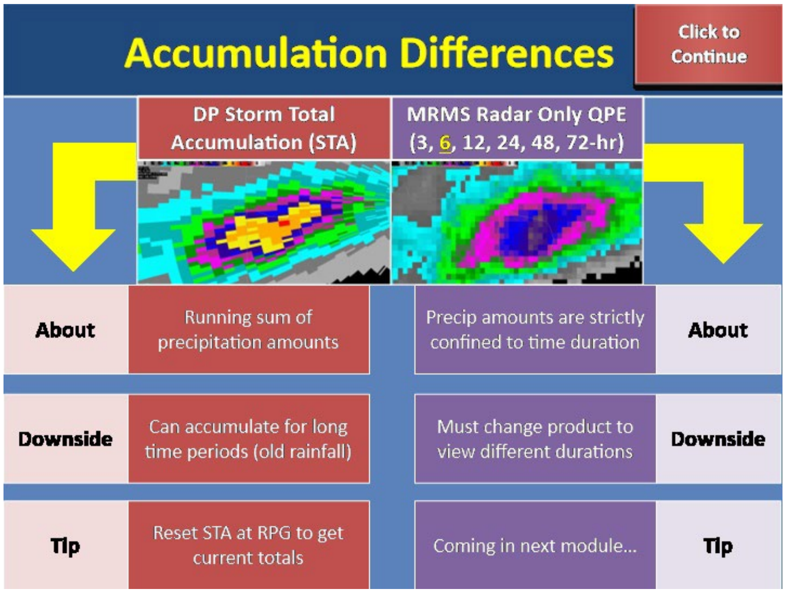
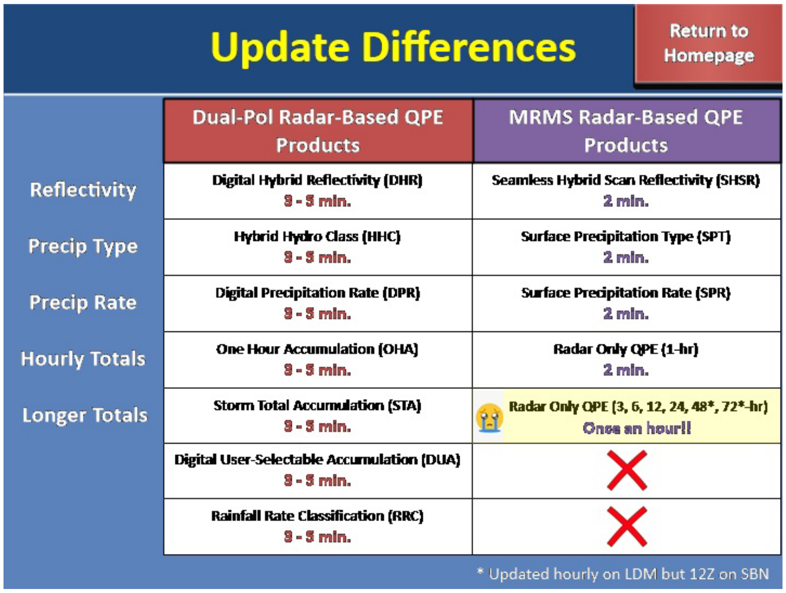
Accumulation Differences (Slide Layer)



Accumulation Differences:
When you're using the storm total accumulation product for DP, it's important to know that it accumulates in a fundamentally different way than any of MRMS's accumulation products that are longer than 1-hour. The DP STA is a running sum of precip amounts and starts accumulating when reflectivity and aerial extent thresholds have been met. One downside of this is that when you have such low thresholds over a wide coverage area, this can lead to the STA accumulating for long periods of time, especially during events that are multi-day and/or have lingering precip that takes a while to exit the area. Because the STA product won't have a chance to reset on its own, this can end up negatively impacting your interpretation of the STA product. So, if you anticipate future precipitation over your CWA, it's a good practice to proactively reset the STA product at the RPG as this ensures the storm totals will be relevant to your current event. If you need help with resetting DP STA at the RPG, talk to your radar focal point or see the RPG HCI Controls lesson included in the resources tab for a walk through of how to do so.

Now let's talk about how this differs for longer-term MRMS accumulation products shown here. For MRMS, we often use the 6-hour product as a proxy for storm total accumulation. This product differs from DP in that it is strictly confined to precipitation within the last 6-hours. So with MRMS, one potential downside is that you have to switch between different products depending on what duration you're concerned with. We'll talk more about some best practice tips for dealing with these accumulation nuances in a later module but for now, just keep in mind these differences between MRMS and DP.

Update Differences (Slide Layer)



Update Differences:
For each product, here are the update times. Take a minute to note the differences between DP and MRMS products. In particular, notice how MRMS's precipitation accumulations that are longer than 1-hour only update once - at the top of the hour. This is a drawback when using these during an active rainfall event because you want the most up to date accumulation amounts. But if you happen to look at these products way past the top of the hour, you may not be getting the full picture. And in the flash flood world, even minutes of precip data can help to accurately anticipate the flash flood threat. As with the accumulation nuances, we'll discuss how to wisely navigate these update nuances in a later module but for now, keep them in mind as areas where DP and MRMS differ.

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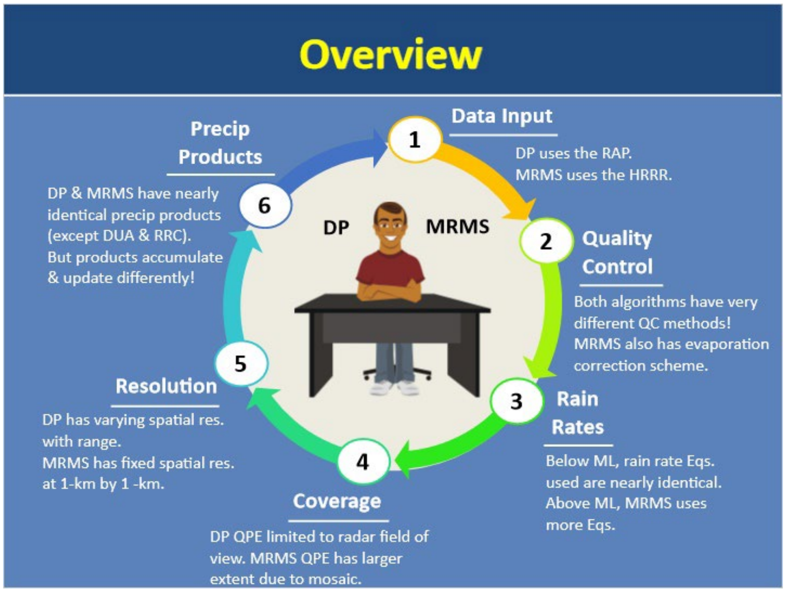
Summary



Notes:

Congratulations on completing the life cycle for both DP and MRMS QPE algorithms! I know that was a deluge of information so let's recap everything before the quiz.

For monitoring QPE amounts, you have 2 excellent QPE algorithms at your disposal: DP and MRMS. Both algorithms take in a variety of data with the biggest difference being that DP uses the RAP 13 km 1-hr forecast field while MRMS uses the HRRR 3 km 0-hr analysis field. Both algorithms have various quality control measures built into them to produce the best estimates possible. Both DP and MRMS have their own unique ways of distinguishing between hydrometeors and non-hydrometeors, identifying the melting layer, and limiting high bias rates due to hail as shown here. MRMS also has an evaporative correction scheme to prevent false precip due to virga. Rain rates are then applied accordingly, with both algorithms using nearly identical rain rate relationships below the melting layer. Once within and above the ML, MRMS uses 4 different relationships with several varying rate caps while DP just uses 1 Z-R throughout. Since the DP QPE is a single-source radar algorithm, its QPE coverage will be limited to the radar field of view while MRMS, being a mosaic, has a much larger QPE coverage. Because DP is on a polar grid and not a cartesian grid like MRMS, its grid spacing will change with range whereas MRMS will be fixed at 1-km by 1-km. And lastly, both DP and MRMS have nearly identical radar-only precipitation products with the exception being the two shown here that exist within DP. It's important to remember that while both DP and MRMS products are identical, how they update and accumulate varies and this can impact your operational use of them as we'll see in a later module. Speaking of the next module, it's time to take the quiz so you'll be ready for Part 2 where we'll take all this information and see how it impacts you choosing your precipitation source operationally.

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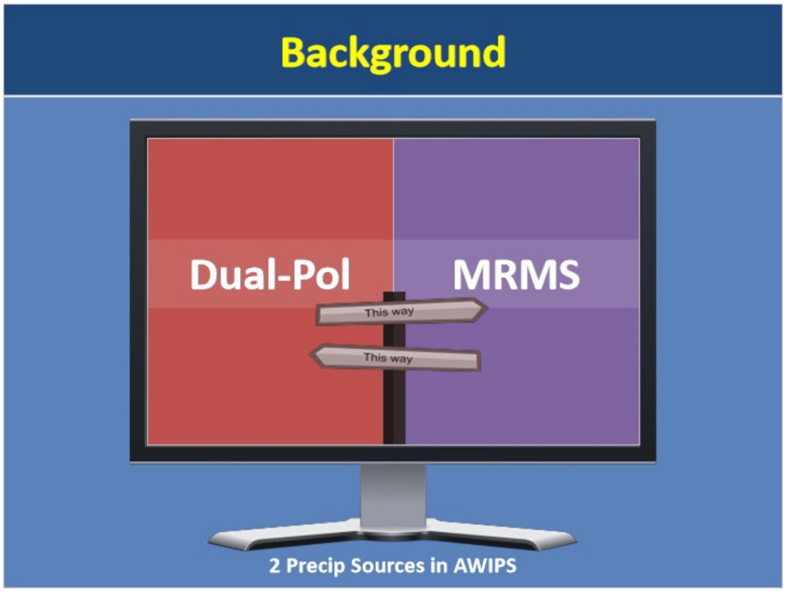
Best Practices for Choosing a Precipitation Source

Introduction

Notes:

Welcome to best practices for choosing a precipitation source! I'm Katy Christian and will be your guide through today's module.

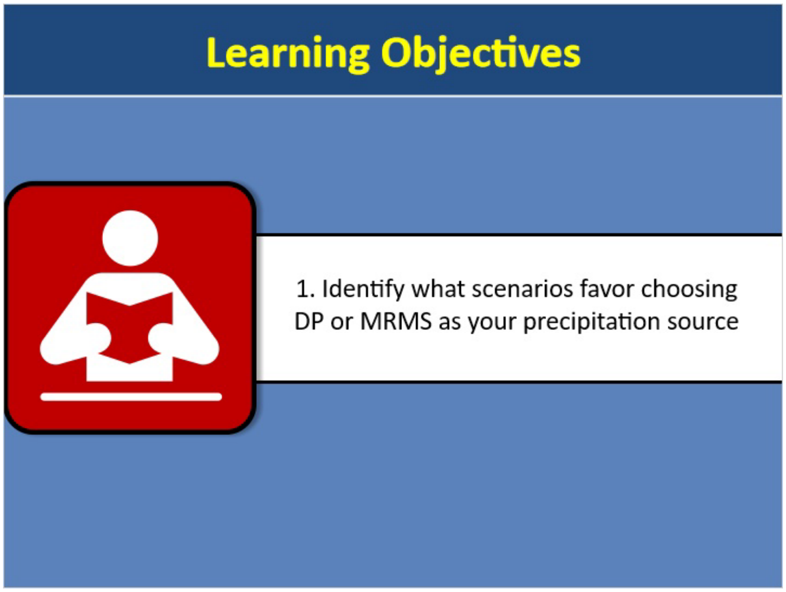
Background



Notes:

In the last module, you got to learn about your two precipitation sources available in AWIPS for QPE analysis - DP and MRMS. We talked through their algorithm lifecycles and the major points at which they are similar and different. Now that you know the ins and outs of both, we are going to outline some best practices that will help you decide which precipitation source to choose when working the hydro desk.

Learning Objectives



Notes:

Come quiz time, you just have 1 objective to master and that is to identify what scenarios favor choosing DP or MRMS as your precipitation source.

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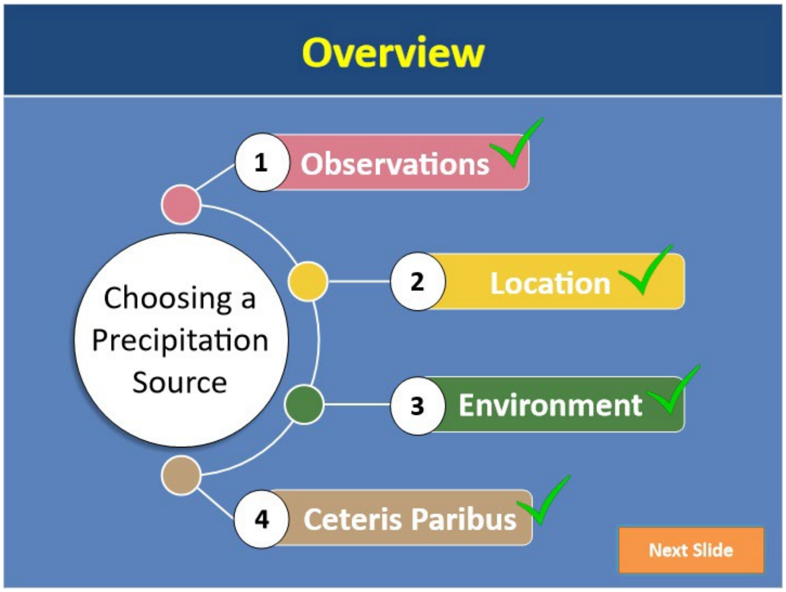
Overview



Notes:

When it comes to choosing between MRMS or DP as your precipitation source for QPE analysis, there are really four main topics you should consider. Click on each number to reveal each topic and learn more. When you're done exploring each topic, click "next" to continue.

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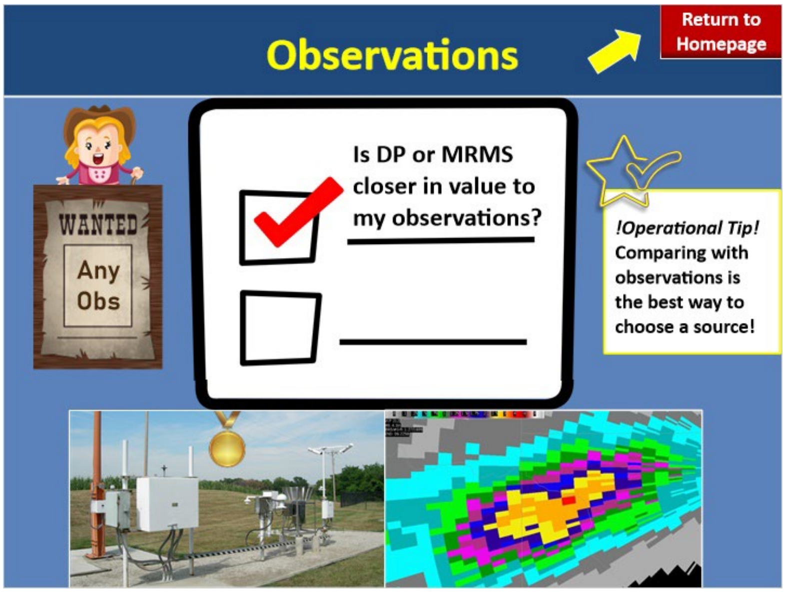
Observations



Notes:

Observations are the most important topic to consider when deciding which precipitation source to use. This is because observations can be thought of as ground truth compared to radar estimates. So the first place you should always start when choosing a precipitation source is to ask yourself: Is DP or MRMS closer in value to my observations? Because the process of comparing observations to your precip source is so important and there are nuances involved that we discussed earlier related to MRMS and DP accumulation and update times, the entire next module is devoted to this topic alone. But for now, just know that utilizing observations to help you choose your precip source is the most robust method as you'll be starting off with the source closest to reality.

Now for all of you in the great gauge void of foreverdom (i.e. the Western U.S) you're probably inwardly laughing at the concept of having ANY available ground truth to compare to. Heck, you're lucky if you have good radar coverage! Thankfully, there are other things that can help you choose between DP and MRMS in the absence of observations. Click "return to homepage" to further explore these.

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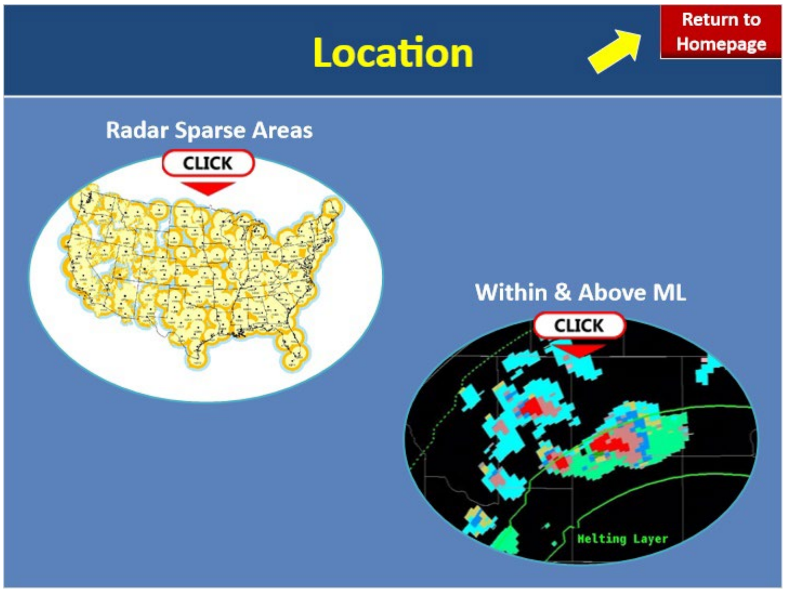
Location



Notes:

In the absence of gauges, another topic that can assist you in choosing a precipitation source is the location of your precipitation estimates. Specifically, there are two locations that matter - if your precip is in the melting layer and if your precip is in radar sparse regions. Click on either icon to learn more.

Radar Sparse Areas:
In locations with sparse radar coverage, it may seem an easy answer to choose MRMS as your precip source to start out. After all, MRMS uses multiple radars, each adding value through their own respective viewing angle. This can greatly reduce issues that occur when just using a single-source radar alone. These include the cone of silence, range degradation, and terrain blockage. Further, in areas with poor radar coverage, a single-source radar source may not be able to detect precipitation echoes whereas a mosaic can pull from other radars to get a more holistic picture of what's going on. As a best practice, if you are in an area with poor radar coverage or in a situation where precipitation echoes are far from the radar, it's advantageous to start out with the MRMS QPE as nearby radars can add further value to precipitation estimates using their additional viewing angles compared to just a single-source radar alone.

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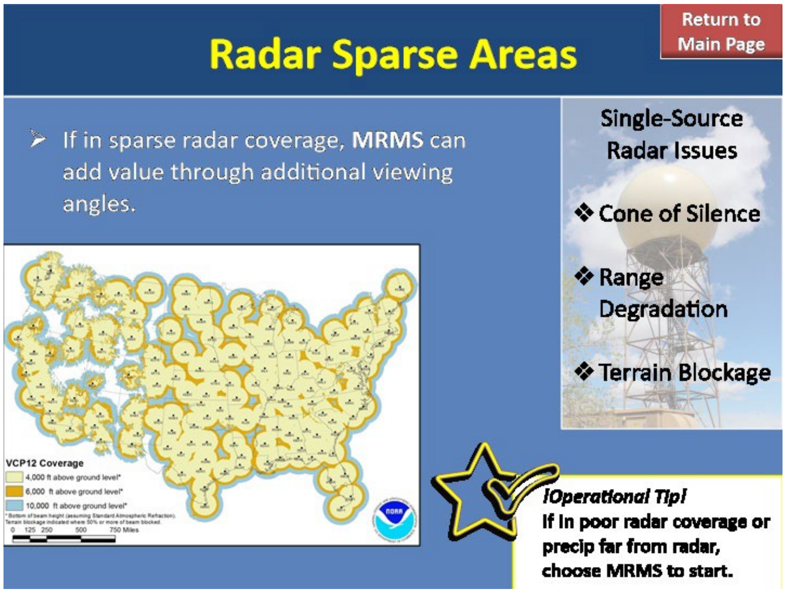
Sparse Radar Areas (Slide Layer)



Radar Sparse Areas:
In locations with sparse radar coverage, it may seem an easy answer to choose MRMS as your precip source to start out. After all, MRMS uses multiple radars, each adding value through their own respective viewing angle. This can greatly reduce issues that occur when just using a single-source radar alone. These include the cone of silence, range degradation, and terrain blockage. Further, in areas with poor radar coverage, a single-source radar source may not be able to detect precipitation echoes whereas a mosaic can pull from other radars to get a more holistic picture of what's going on. As a best practice, if you are in an area with poor radar coverage or in a situation where precipitation echoes are far from the radar, it's advantageous to start out with the MRMS QPE as nearby radars can add further value to precipitation estimates using their additional viewing angles compared to just a single-source radar alone.

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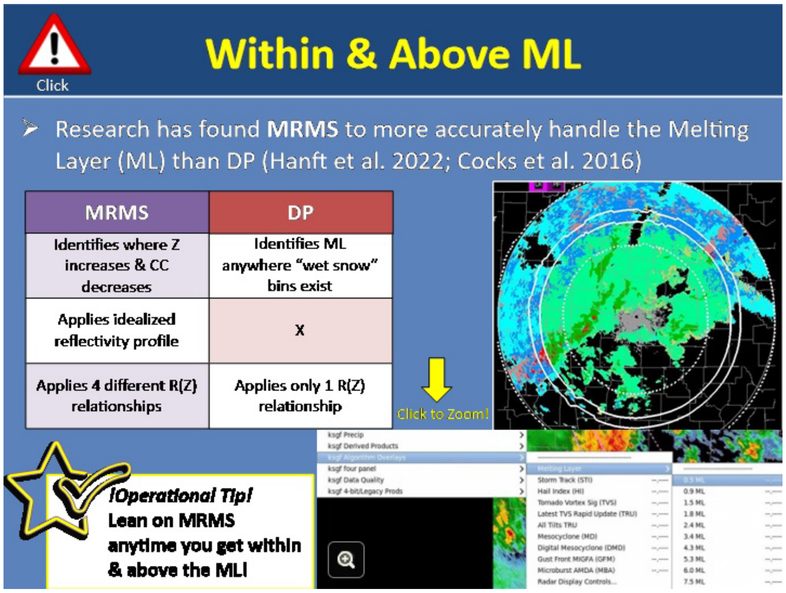
Within & Above ML (Slide Layer)



Melting Layer:
Recent research has found the MRMS QPE algorithm to more accurately handle the melting layer than the DP QPE algorithm (Zhang et al. 2022; Cocks et al. 2016). If we think back to the previous module, we learned how MRMS is able to better capture variations in ML intensity by noting areas where Z increases and CC decreases and then applying an idealized reflectivity there to prevent overestimation. DP's method of identifying the ML isn't as advanced as this. Further, DP simply applies one R(Z) relationship with a varying coefficient out front throughout the ML whereas MRMS allows up to 4 different R(Z) relationships to be used depending on precipitation type. Because of these reasons, it's a best practice to lean on MRMS anytime you get within and above the melting layer.

But how do you know where the melting layer begins? Well, here is where the MLDA exists in your AWIPS menu. We recommend having hydro procedures that overlay the melting layer rings to help maintain situational awareness. Additionally, you'll notice how these rings correlate to HHC classifications in the DP logic where you can see the sudden switch in hydrometeor identification to graupel, snow, and ice once you enter the melting layer. And in this entire region, DP will be using only one crude R(Z) relationship with a varying coefficient out front to account for overestimation due to the ML. So, it's much better to lean on MRMS for QPE amounts here instead of DP. Now unfortunately, MRMS does not have a simple overlay such as this. Instead, there are a few non-SBN products you could view online or via the LDM, and these are included in the "resources" section.

Below the ML, MRMS and DP perform similarly with the exception of one caveat that is actually very important for you to be aware of. Go ahead and click on the "caution" icon to learn more.

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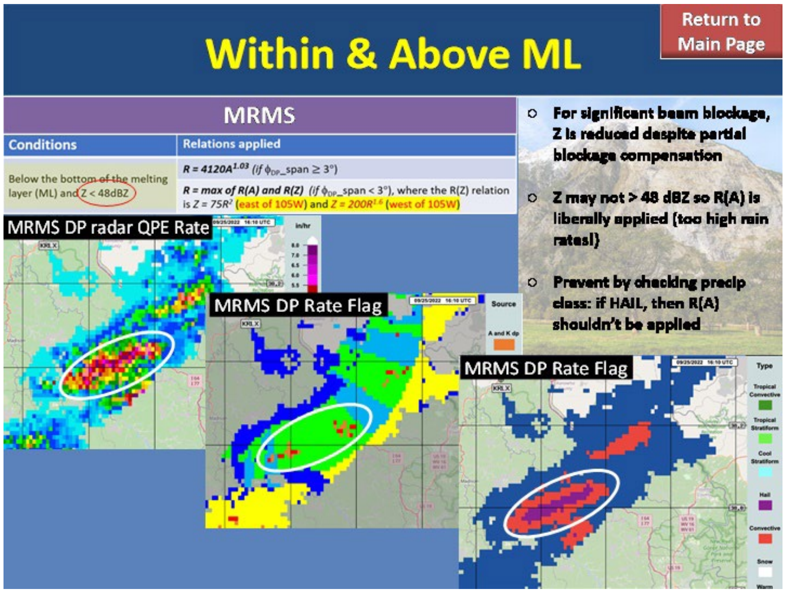
Melting Layer Continued (Slide Layer)



Melting Layer (Continued):
Remember that the R(A) equation used for calculating rain rates is only used below the ML in both MRMS and DP due to its sensitivity to ice contamination and as a result, everything is assumed to be pure rain so rates are allowed to be very high, up to ~8.0 inches per hour! The problem arises when R(A) is incorrectly applied and this can happen with MRMS in areas of severe beam blockage below the melting layer. In areas with severe beam blockage, only partial blockage compensation is applied which can result in Z being lower than it should be. As a result, Z may not get above 48 dBZ, allowing R(A) to be widely applied and resulting in high rain rates. A way you can avoid being fooled by these high rain rates is to check the precip classification in MRMS. If it shows hail in this area, then R(A) is incorrectly being applied and you shouldn't trust those rates. Here is an example of this scenario. SE of KRLX, there is severe blockage. When this storm moved into that area, notice the 5-7 inch/hour rates that occurred as a result of R(A) being applied. But looking at Precip Type, these occurred in areas of Hail where we know R(A) cannot be applied due to sensitivity to ice. So I would be wary of these values and either hedge those estimates down substantially or instead choose DP as my precip source.

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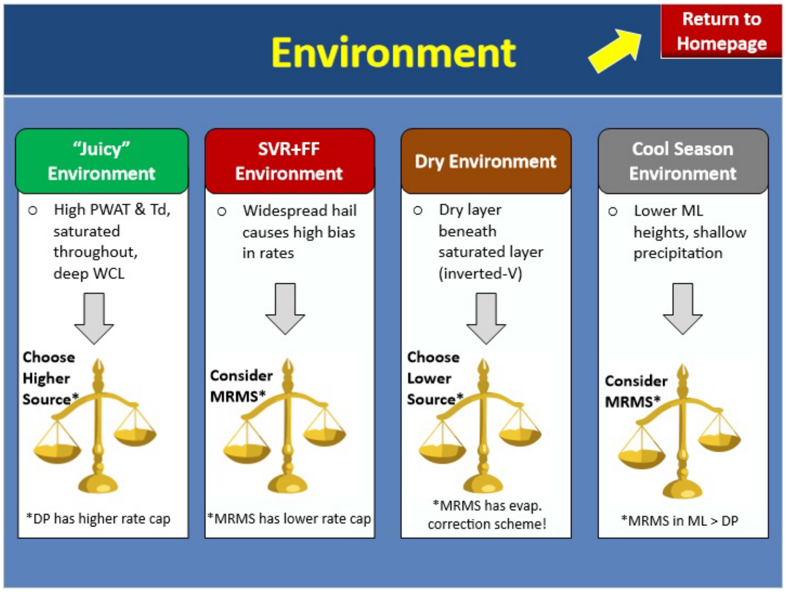
Environment



Notes:

With no ground truth, another topic to help you choose a precipitation source is what sort of atmospheric environment you are in. Let's talk through this with 4 different scenarios.

In situations where the atmosphere is very juicy - and by that I mean anomalously high precipitable water, high dew points, very saturated sounding, deep warm cloud layer, etc. - you know that when storms develop, they will be very efficient at producing high amounts of precipitation. In these situations, consider choosing whatever source is pushing out higher totals to reflect what the atmosphere is capable of until you can get ground truth to tell you otherwise. For instance, DP has a higher rate cap than MRMS so you may consider choosing DP to best keep up with storms that are very efficient at producing high rates. These sorts of "juicy environments" are very common during a landfalling tropical cyclone or in a tropical air mass.

On days where the environment is conducive to both severe and flash flood hazards, there's a good chance you'll be getting hail added to the mix. Remember that hail can cause a high bias in your rates and lead to an overestimation in precipitation over time. With this in mind, consider choosing MRMS as it has a lower rate cap of 5.9 in/hr compared to DP's rate cap of 8 in/hr. This will help keep in check the high rate bias due to hail.
In environments where the atmosphere is intruded by drier air, such as on this sounding where you have a dry sub-cloud layer beneath a saturated layer, the overall precipitation efficiency of storms will be low so consider choosing whatever source is producing lower totals to help compensate for this until you can get confirmation otherwise. Out West, this is very common where virga can lead to misleading precipitation echoes on radar. Remember though that you previously learned how MRMS has an evaporation correction scheme that determines if precipitation should make it to the ground based on the height of precip and the moisture profile beneath it. This correction scheme is only implemented in MRMS and DP does not have an equivalent. Because of this, in environments where virga is common, it's helpful to lean on MRMS as it can help reduce false light precipitation in radar QPE because it has this evaporation correction scheme unlike the DP QPE.
During the cool season, the environment is characterized by lower melting layer heights which means more of your precipitation will start to be within the melting layer. As discussed earlier, once you start to get within and above the ML, MRMS has been shown to perform better than DP so go ahead and choose it as your source. Further, overshooting of shallow precipitation is also common during the cool season months and MRMS can help "catch" some of these echoes since it's a mosaic and pulling in multiple different viewing angles from surrounding radars.

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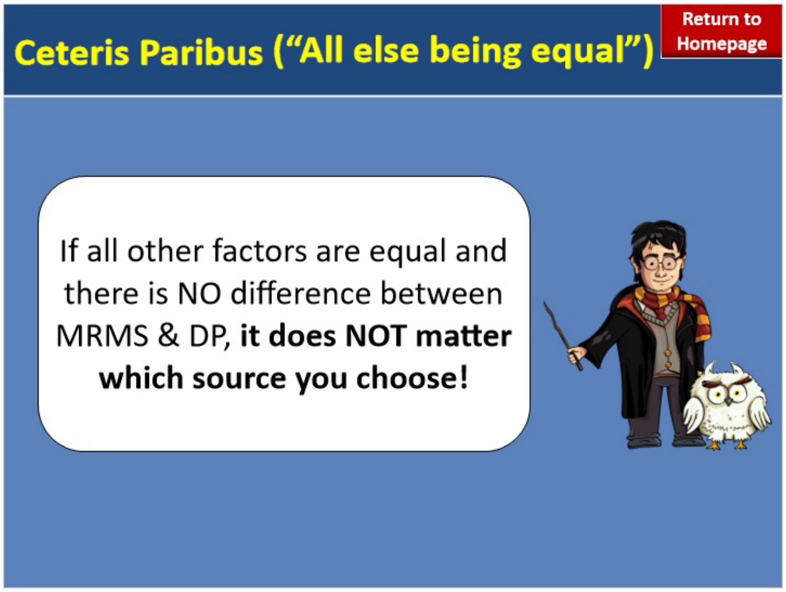
Ceteris Paribus



Notes:

Alright, you're probably wondering what the heck this means other than sounding like a possible wizarding curse from a very famous wizard. It is actually Latin for "all else being equal" and is the concept of what you should do when all the previously mentioned considerations do not help you choose between a source because there is no difference or leaning one way or another. In these cases when there is absolutely no difference between DP and MRMS, it does not matter which source you use. Just pick a source and move forward with it until any of the topics we previously discussed can sway you otherwise. You can always easily switch between DP and MRMS as your precip source mid-event so it's not a one and done decision. So the most important thing to remember? When Ceteris Paribus occurs, just pick a source and move on.

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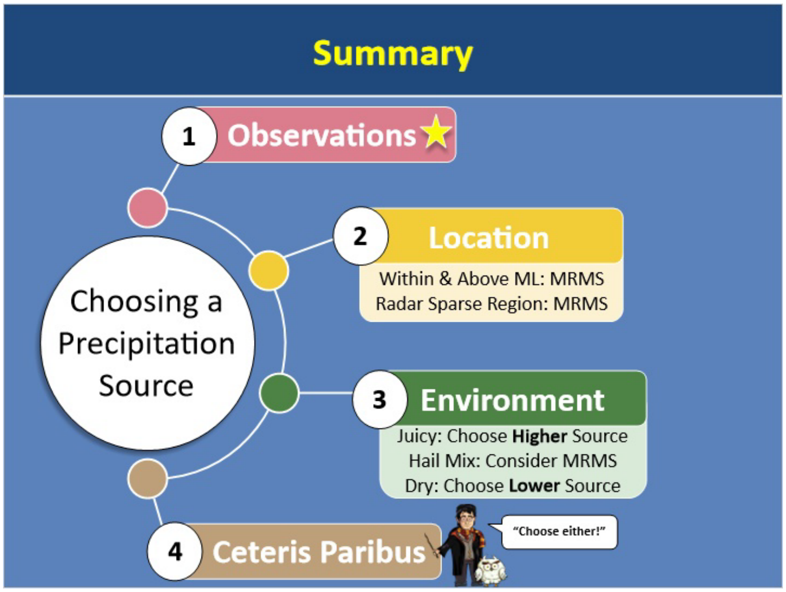
Summary



Notes:

Now I know we covered several topics to think about when choosing a precipitation source so let's quickly recap everything.

Observations are THE number one best way to help you choose between MRMS and DP. However, they're also the number one thing we need more of across the U.S.

If you do not have obs to compare with, think about where your precipitation is location wise. If you're within and above the ML, lean on MRMS for precipitation amounts as it has been shown to better handle the ML and also allows a variety of R(Z)'s to be used there. Further, if you're in a radar sparse region, choosing a mosaic like MRMS can help pull in additional viewing angles compared to a single-source radar alone.

Also think about the environment you're in and how this may sway you towards choosing one source over another. In juicy environments, choose the higher source; in hail-prone environments, choose MRMS as it has a lower rate cap; and in dry environments, choose whatever source is lower. Also remember that out West where virga is common, MRMS has an evaporation correction scheme that can help remove false precip echoes from QPE.

And finally, if none of these factors point towards one source over the other, invoke ceteris paribus and just choose a source and run with it. Speaking of running with it, it's time for you to take the quiz so go ahead and click "next" when you're ready!

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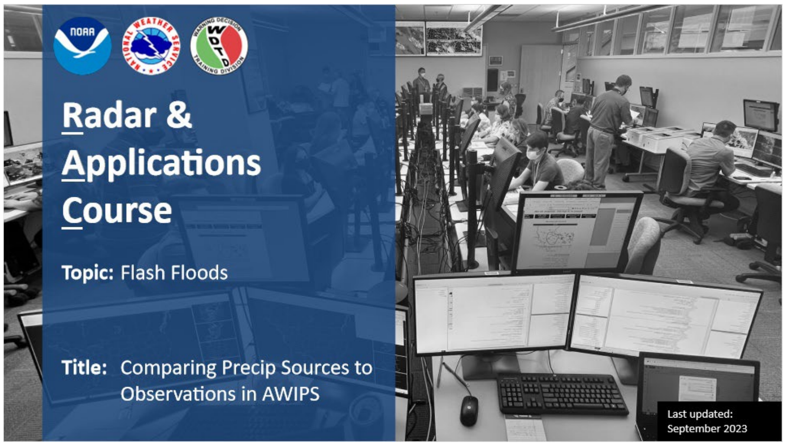
Comparing Precip Sources to Observations in AWIPS

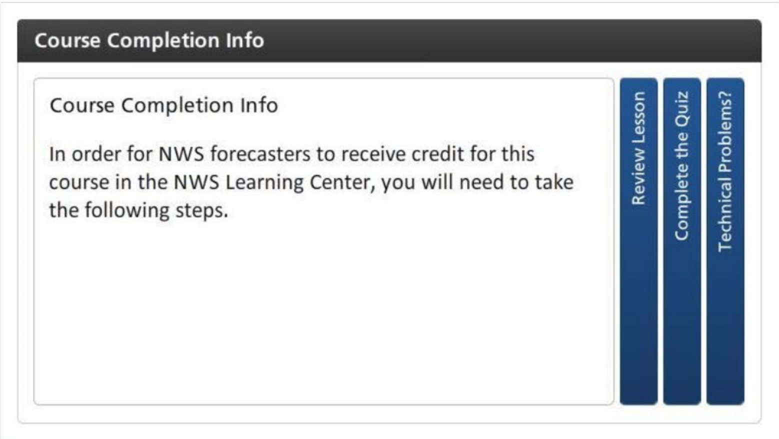
1.1 Introduction



Notes:

Hi, my name is Jill Hardy and welcome to this lesson on how to compare precip sources to observations in AWIPS. This process will help you better assess heavy rainfall during flash flood warning operations.

1.2 Course Completion



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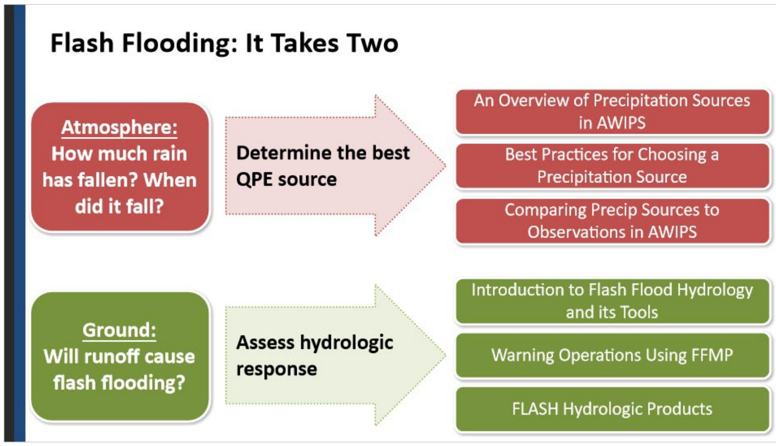
1.3 Flash Flooding: It Takes Two



Notes:

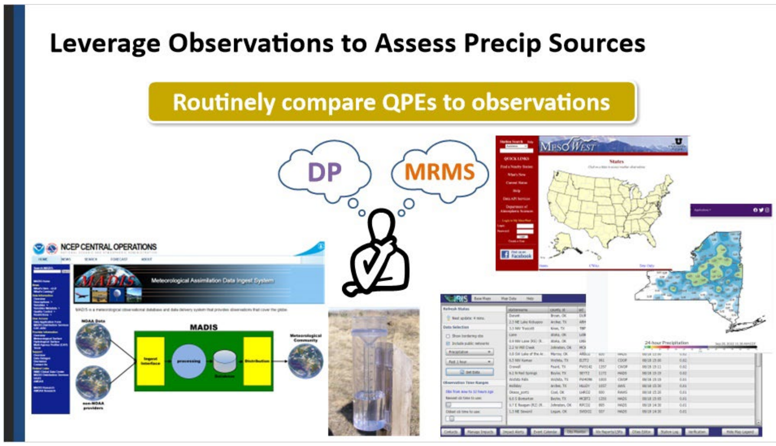
When considering a flash flood threat, there's really two parts to the problem. The first part covers the atmosphere and asking “How much rain has fallen and when did it fall?”. Part two considers the ground response and assessing: "Will the runoff cause flash flooding?" This lesson will focus on Part 1. To answer these questions, you need to identify the best QPE source during any given event. There’s a lot of information related to precip sources, so we’ve broken it up into multiple lessons.

These lessons cover the similarities and differences between your two main precip sources -- Dual-Pol and MRMS. This is a good foundation and should be taken first. This lesson will focus on comparing those precip sources to surface observations. This is an important part of choosing the best source because – when you have them – observations are the best indicators of what’s happening at the ground.

Part 2 – assessing the hydrologic response – is covered in the lessons shown here.

But it’s always good to remember that flash flooding is affected by both components. And you – the forecaster – must do your best to use the tools available for both to identify the overall threat.

1.4 Leverage Observations



Notes:

Okay, so how do you know whether to choose DP or MRMS? It simply depends on which source seems to be capturing the nature of your current precip event. The best way to truly know which source is doing the best at any given time is to routinely compare them to observations throughout the event. It is not unusual for the optimal precip source to change across your CWA and with time.

Now is a good time to mention…Generally speaking, when we refer to "observations" in this lesson, we're referring to gauges that collect rainfall information. Gauge information that's in AWIPS is the easiest source of ground truth to compare to QPEs since it can be sampled directly. This includes anything that comes through MADIS. For example, METARs, national Mesonets, CWOP sites, and HADS gauges. Additionally, offices may ingest RAWS, DOT, non-federal AWOS, IFLOWS, and ALERT networks, to name a few.

However, many gauge networks aren't in AWIPS. So most offices have web interfaces, such as IRIS, MesoWest, state Mesonets, and private data

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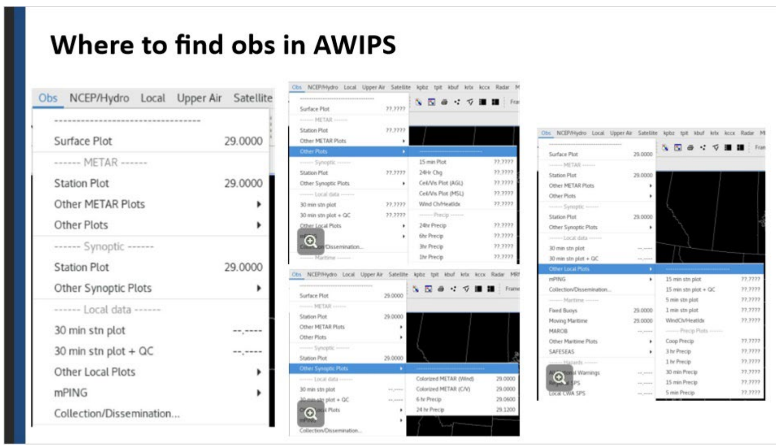
webpages to look at other gauges.

Talk to your local hydro focal point about what networks are offered in your area, both in and out of AWIPS.

1.5 Obs in AWIPS



Notes:

The rest of this lesson will talk through how to compare QPEs to gauges that are in AWIPS. So it's probably good to know where this gauge information is located. It's in the Obs menu under several different sub-menus.

As you can see, the gauges can come in various accumulation durations. So the next few slides will talk about comparing them with QPEs of various durations.

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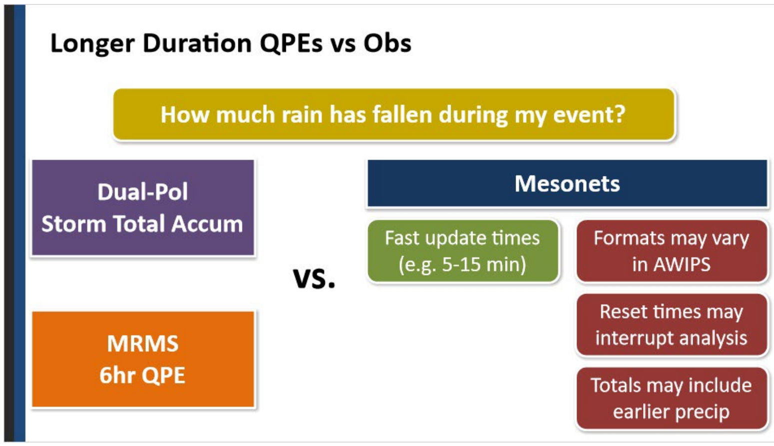
1.6 Longer Duration QPEs and Obs



Notes:

First, let's talk about comparing longer-duration QPEs to observations. We start here because it's a good way to see the big picture...How much rain has fallen during my event? This is ultimately what we're trying to figure out and what we want to relay in our warning text when the time comes.

For Dual-Pol, we use the Storm-Total Accumulation (or STA) product which is a running total that updates with every volume scan. MRMS, unfortunately, does not offer this type of product, so instead, we use the 6-hour QPE as a proxy.

Now, what gauges do we compare them with? If you've got them, local Mesonet stations work well since they report 24-hour running totals. These networks can be useful because they have fast update times, which is nice during a high-rate event. Any other fast-reporting, long-duration accumulation networks also work well.

But keep in mind that the format of the data may vary between networks, including whether they read out in inches or millimeters. Also, the networks can reset at different times, which may interrupt your interrogation of the data. For instance, if the network resets at 00Z, you could be in the middle of an event when the totals zero out.

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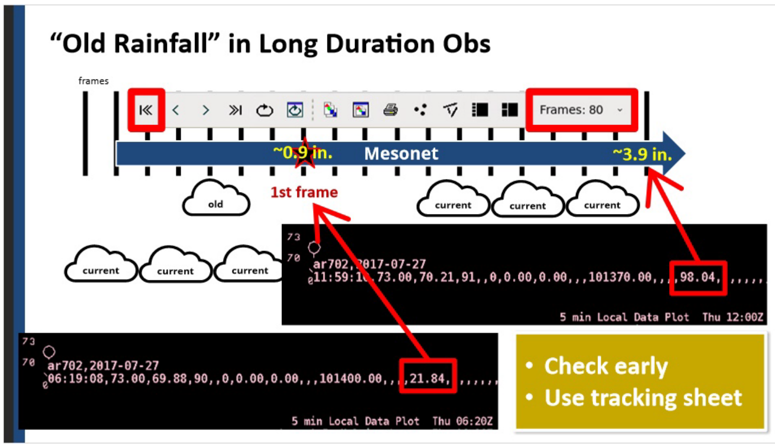
Finally, because they are 24-hour totals, the totals could include precip from the previous day that's not useful during your current analysis. Let's talk more about how to tackle this on the next slide.

1.7 "Old Rainfall" in Obs



Notes:

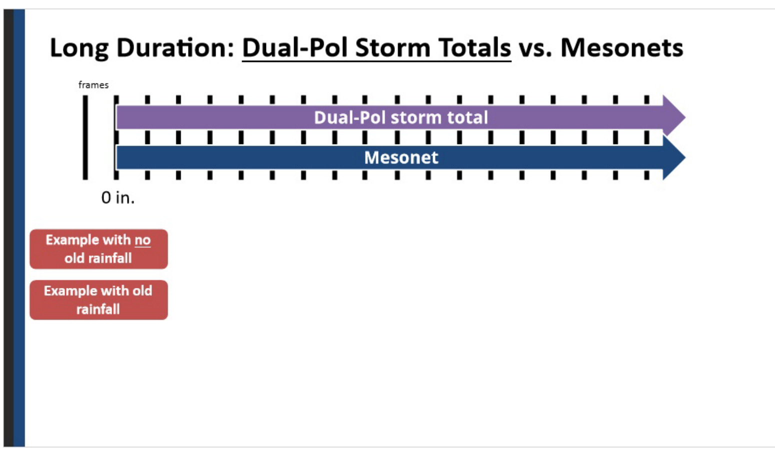
To best understand whether there's "old rainfall" in your gauge totals, set your frame count to be something large and go back to the first frame. Sample your gauge at that earlier time to see if there's rainfall in the total. If so, we usually don't really care about it during our current event since it fell hours and hours ago. And we'll want to subtract it out of our current total. A situation when you may not want to do this is when you're in the middle of a long event with major flash flooding. Then some of those previous amounts may be useful to relay. But if you're at the beginning of a new event, these steps are helpful.

Take this example...At the current time, 12Z, the mesonet has a total of 98mm, or about 3.9 inches. When we go back to an earlier frame at 0620Z, we see that about 22 mm, or 0.9 inches, of rain is already there. Therefore, only 3 inches fell in the last 6 hours that contributes to our current flash flood threat.

Since this can quickly become a lot of mental math for a lot of different gauges, we recommend checking on these gauges early in an event to see your starting values. If there's pre-existing rainfall in the totals, it may help to jot down these amounts so you know what is adding to it during YOUR event. In the Resources, we have provided a tracking sheet that you can download and use in operations.

Now let's talk about comparing these totals to DP and MRMS.

1.8 DP vs Long Duration Obs



Notes:

Because the Dual-Pol Storm Total product is a running total that updates with every volume scan, it can be really helpful to compare to mesonets that also update frequently. In an ideal situation, both the storm-total and the mesonet begin at zero and accumulate up together in the current event. Other times, either or both will have "old rainfall" that needs to subtracted out. Click on the boxes to see examples of each scenario.

No Old Rainfall: At the current time, 1135 UTC, the mesonet reads ~150 mm, or ~6 inches. Dual-Pol Storm-Total has 5.3 inches. If we go back to the first frame, we see that both the mesonet and DP begin with almost nothing. It's negligible. Therefore, our assessment at the current time is easy. Dual-Pol is

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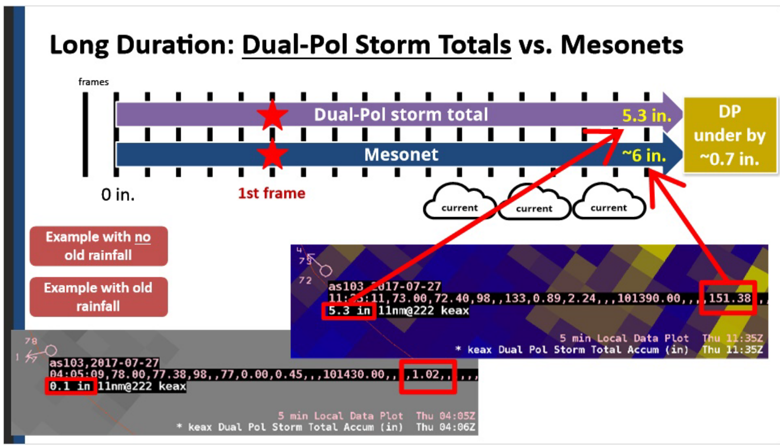
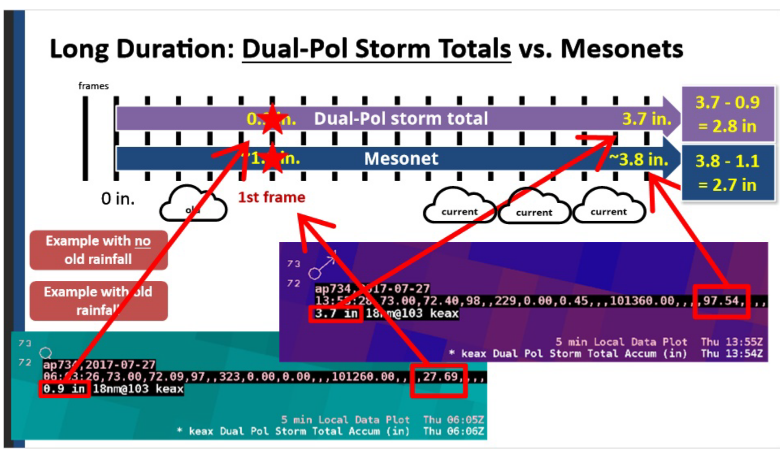
under-estimating – by about 0.7 inches - compared to the gauge.

Old Rainfall: At the current time, 1355 UTC, the mesonet reads ~98mm, or 3.8 inches. Dual-Pol Storm-Total has 3.7 inches. Going back to the first frame, both the mesonet and DP QPE begin with some old rainfall we have to subtract out. The mesonet has 28 mm (or 1.1 inches) and DP is 0.9 inches. Once you do this math, it shows both are almost exactly the same, around 2.7-2.8 inches. This gives us confidence that DP is sampling the nature of this event quite well.

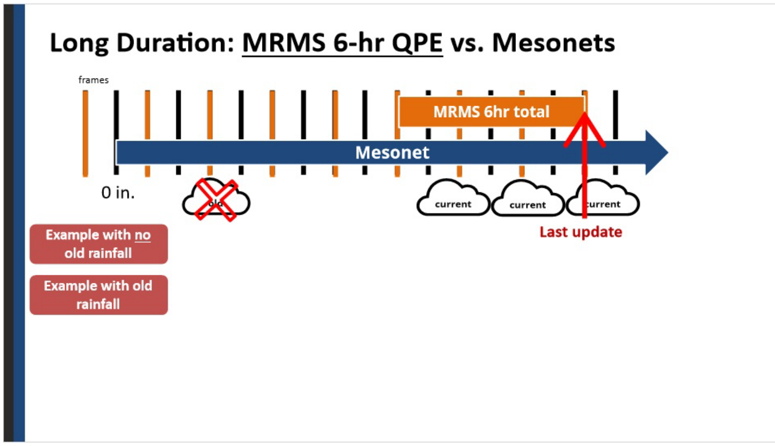
Easy Comparison (Slide Layer)



Old Rainfall Problem (Slide Layer)



1.9 MRMS vs Long Duration Obs



Notes:

The MRMS comparison has to be handled a little bit differently than Dual-Pol because of the way the product is calculated and updated.

For one, since it is simply a total of the most recent 6 hours of rainfall, the good news is you don't have to worry about "old rainfall" in the MRMS totals. Just sample out the values and interpret them directly. However, the caveat with MRMS is that it's only updated at the top of the hour. So you have to be careful of *when* you look at the data because – during an event with high rainfall rates – the MRMS 6hr total can quickly become out of date. We recommend checking your MRMS totals at the top of every hour during an event to get the best sense of "How much has fallen".

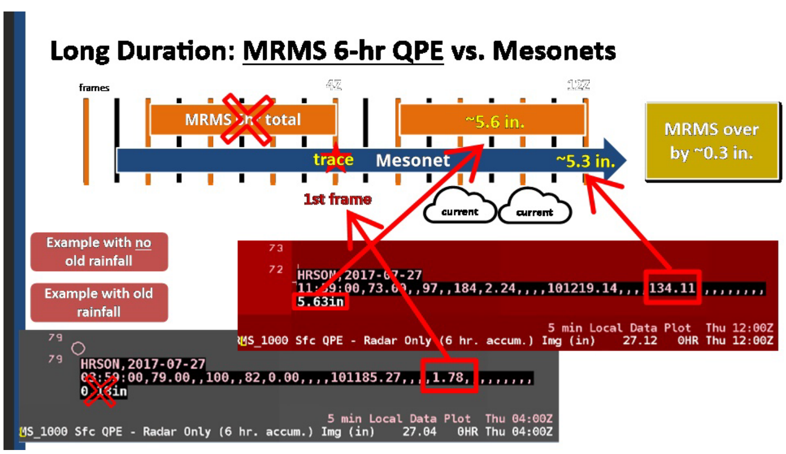
Now, when it comes to comparing MRMS to mesonets, the "old rainfall" problem still comes into play for the mesonet, since that's a running total. Let's again discuss an easy case and one with "old rainfall".

No Old Rainfall: At current time, 12Z, we see the mesonet recorded 134 mm, or 5.3 inches. MRMS, which also updated at 12Z, has a 6hr total of 5.63 inches. If we go back to the first frame, which is 04Z, we ONLY focus on the mesonet to see whether it has old rainfall. Because at 4Z, we don't care what MRMS had in its 6hr total. It doesn't matter during our – more recent - event window. But at 04Z, the mesonet shows trace amounts that can be ignored. Meaning, we trust that the 5.3 inches at the current time fell during our event. Therefore, MRMS is slightly over-estimating, by about 0.3 inches.

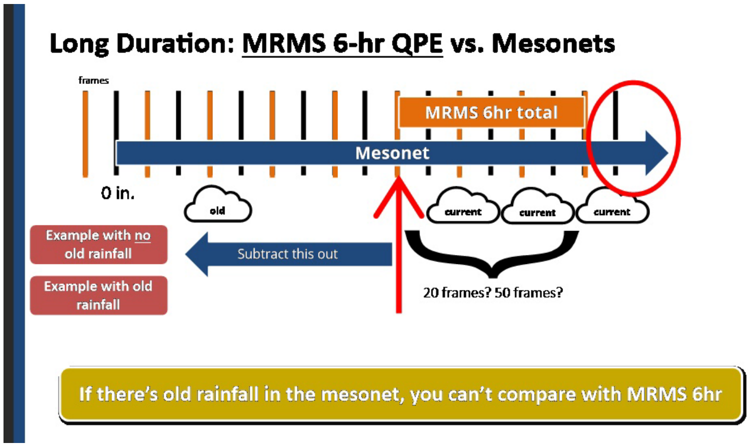
Old Rainfall: When there's "old rainfall" in the mesonets, we simply have to ignore this comparison, and here's why. Since the MRMS total is only the most recent 6 hours of data, you would have to be very careful about the exact frame you went back in time in order to only subtract out mesonet data from exactly 6 hours ago and before. This isn't easy because frame counts change based on the frequency of the volume scan, which is a factor of the VCP. I can't tell you that "100 frames is always 5 hours" or something like that. It's ever-changing. Additionally, what if you're doing this past the top of the hour? That's even more frames of data you'd have to account for.

We know it's not feasible to do this kind of stuff in the midst of a flash flood event, nor do we want you to. So to make it easy, we simply say...If there's old rainfall in the Mesonet data, you just can't compare it with MRMS 6hr totals to get a sense of QPE bias. In these situations, you will have to lean on your 1hr comparisons or other rules of thumb to understand how MRMS is doing.

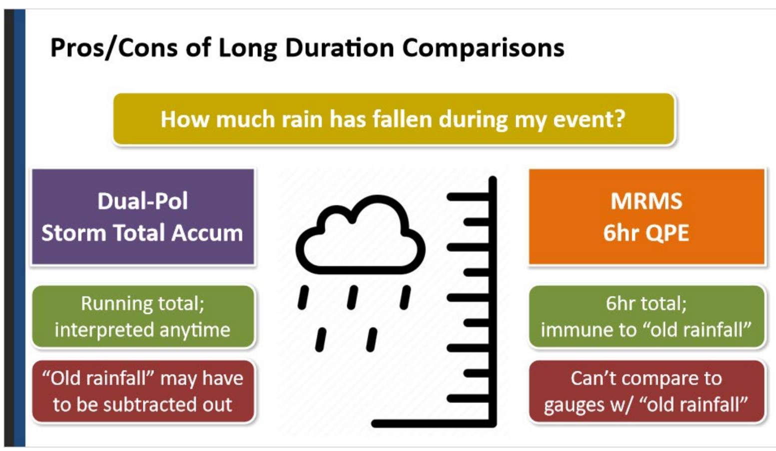
No Old Rainfall (Slide Layer)



Old Rainfall (Slide Layer)



1.10 Pros/Cons of Long Duration Comparisons



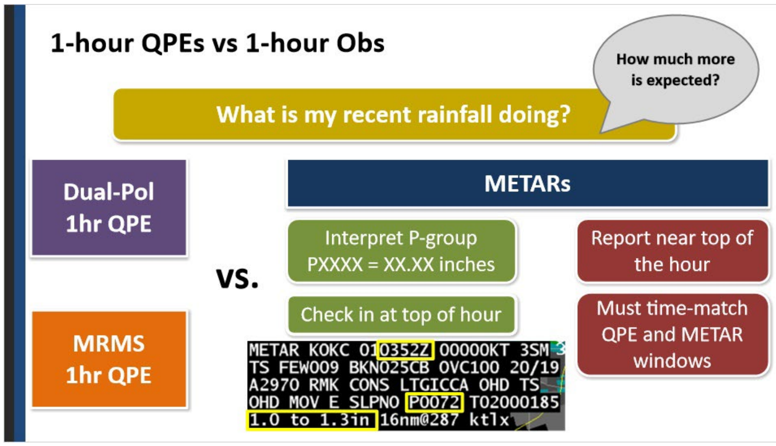
Notes:

So to summarize the pros and cons of long duration comparisons.

DP has a running total that can be interpreted at any time. However, it might have old rainfall that needs to be subtracted out of the totals.

MRMS is a recent 6hr total – only updated at the top of the hour - that's immune to old rainfall. However, it cannot be compared against gauges if the gauges have old rainfall.

1.11 1hr QPEs and Obs



Notes:

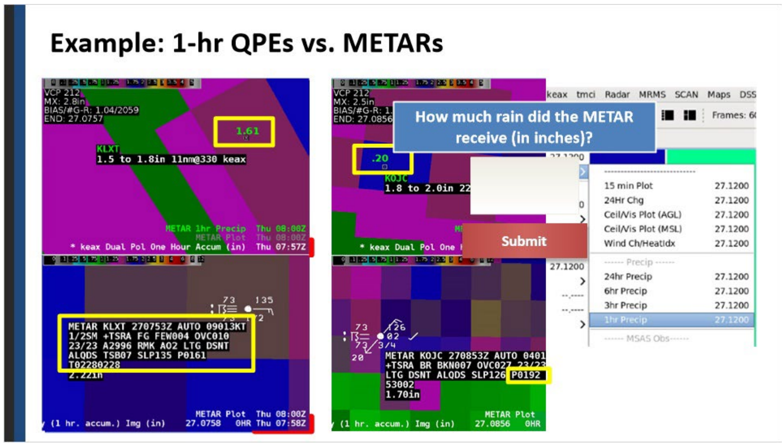
Okay, next up are the one-hour comparisons. We care about the one-hour totals – in addition to the storm totals – because they give us a sense of what the most recent rainfall is doing. They can be just as insightful during a heavy rainfall event because they can help you see short-term trends that may help in determining “how much more rainfall to expect” in your warnings.

I know I just put you through a ringer with the storm-totals. But luckily, the one-hour comparisons are MUCH easier. This is because both DP and MRMS have a running 1hr QPE product that updates every volume scan. That means you can treat them the same way when you’re interpreting their output.

In terms of what to compare them to, METARs are a great source of 1hr precip data. To find the precip total, look for the P-group. The 4 digits correspond to rainfall in inches, using this conversion. In this example, the METAR reported 0.72 inches.

There are a couple of things to watch out for when interpreting METAR data. For one, METARs only report near the top of the hour. In this example, the METAR reported at 0352Z. So 0.72 inches fell from 0252Z to 0352Z. Because of these hourly updates, think about checking in with your METARs at the top of every hour to see if there’s any new information. Sometimes you might forget or not get a chance to look right when they come in. That’s okay! When this happens, just make sure to match your QPE time with the METAR end time, which may require you to go back a few frames. This ensures that the QPE 1hr window matches the METAR 1hr window so we’re comparing the same period. In this example, with time-matching, the 1-hour DP QPE estimated 1.0 to 1.3 inches, meaning it was overestimating by a quarter to half an inch. This information can be useful as you go through the event because you may start hedging down some of your DP estimates to account for this bias.

1.12 Example of 1hr Comparison



Notes:

Let’s take a brief moment to practice these concepts. At WDTD, we have a really handy 4-panel procedure where DP 1hr is on the upper left and MRMS 1hr is on the lower left, with METARs overlaid. This makes quick comparison between them very easy.

In this example, the METAR came in at 0753Z. So we made sure that our QPE times match 0753Z as close as possible. Now let’s look at the P-group. How many inches fell? [Insert quiz question]

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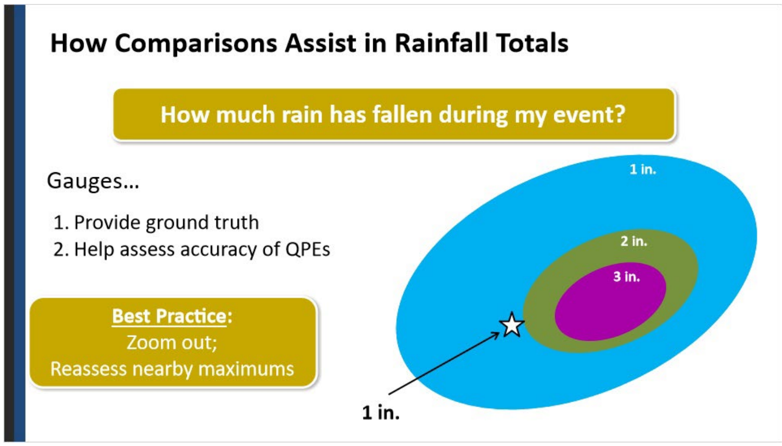
If we look at DP, it says 1.5-1.8 inches fell, so it's doing pretty well. Meanwhile, MRMS says 2.22 inches fell, which is much higher than our observation. Using this information moving forward in the event, you may lean towards using DP since you have higher confidence that its QPE totals may be more indicative of what's happening at the ground.

A quick note: There's a handy little METAR Precip overlay available in the Obs menu. This can be helpful to quickly identify METARs that have worthwhile precip totals. We recommend something like this in your procedure…Where you have the overlay on one panel and the full METAR on the other. We still need the full METAR because 1) we still need to see the time the data came in, and 2) sometimes the overlay can be wrong, like when a special comes in. Here's an example of that.

1.13 Biases and Rainfall Totals



Notes:

Before we continue on, I want to remind you of the big picture. Ultimately we want to answer the question "How much rain has fallen during my event?" Take this example where we have a QPE maximum of 5 inches. If you wanted to draw a warning for this area, what would you put in your total? "4-5 inches have fallen"? How do we know that's correct?

Well, we know looking for gauges can help because…1) they provide ground truth and 2) they can help assess the accuracy of your QPEs.

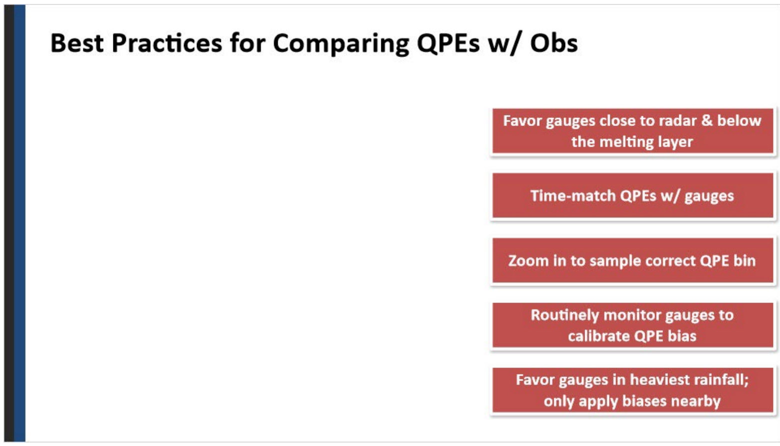
#1 is great anytime. If you have a gauge that says 1 inch fell, awesome! You now know you can put at least that much in your warning.

But what happens if that gauge is located here? Well, now that gauge is saying 1 inch fell, but in an area where your QPE says 2 inches (maybe even close to 3 inches) should have fallen. So your QPE is overestimating. Okay, that’s good information. So what do you do with it?

Go back to the big picture…How much rain has fallen? Well, because of the potential overestimation, instead of saying “4-5 inches”, I may be more inclined to say “2-3 inches”. At least until I get more ground truth that says otherwise.

So just remember….When doing a gauge comparison, zoom out and think about what it means to the overall picture. Just because we found one gauge with an inch of rain doesn't mean that’s what we put in our warning. It’s a nugget of information to help reassess our maximums. It’s easy to get hyper-focused on these small scale comparisons and forget what it means to your warning decision.

1.14 Best Practices for Gauge Comparison



Notes:

Now that you've had a chance to understand the fundamentals of comparing your QPEs with gauges, please click through some best practices:

--Put more weight in gauge comparisons that are closer to the radar and below the melting layer. At long ranges, there are two things to think about:

1)For one, precip estimates can be a lot less representative of what's happening at low levels. Consider the depiction below, where a radar estimate at 250 miles away could be overshooting the storms.

2)Because of this, it makes comparisons with ground observations less trustworthy. In this example, you wouldn't want to apply that long-range information to radar data at short range because they are sampling different parts of the atmosphere.

Here is an image of METARs and Melting Layer rings overlaid. All of the gauges located within the first dashed line are entirely below the melting layer. These are your most trustworthy gauges to compare with QPEs.

--Don't forget to time-match your QPE display with your gauge observations. Here, the METAR sent its one-hour total at 0853, so I set MRMS as close as possible which was 0856.

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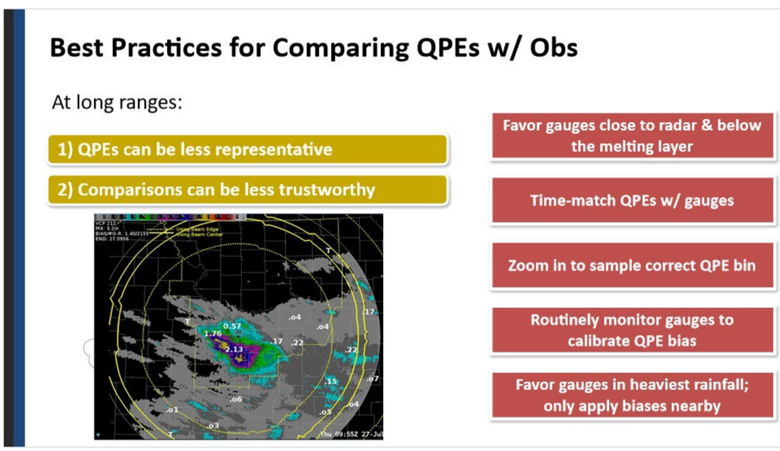
--Don't forget to zoom all the way in when you do these comparisons, to ensure you've got the right radar gate.

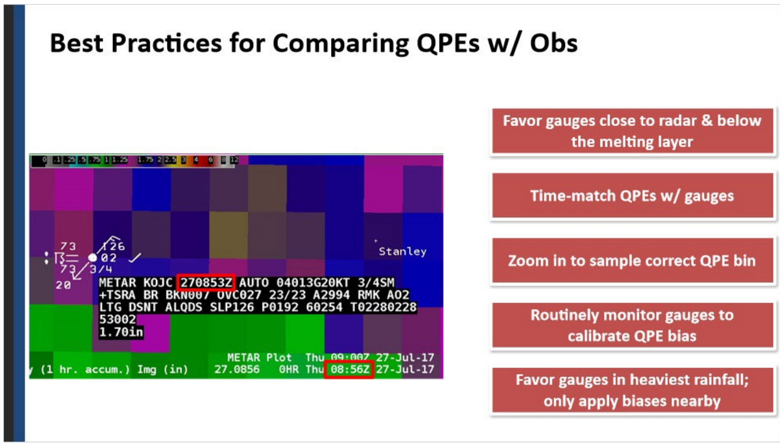
--Routinely monitor your gauges to calibrate your QPE bias. This could be every hour for METARs or checking in more frequently with Mesonets.

--Finally, favor gauges that received higher rainfall amounts to help you calibrate your biases. Ultimately, we care about the maximum totals the storms are capable of, so let’s focus there. In this example, I would have higher confidence in comparisons with these METARs versus the surrounding ones. Similarly, only apply biases to nearby rainfall. Don't expect a bias that you calculated in a convective core to necessarily hold true in a stratiform region, or across your CWA.

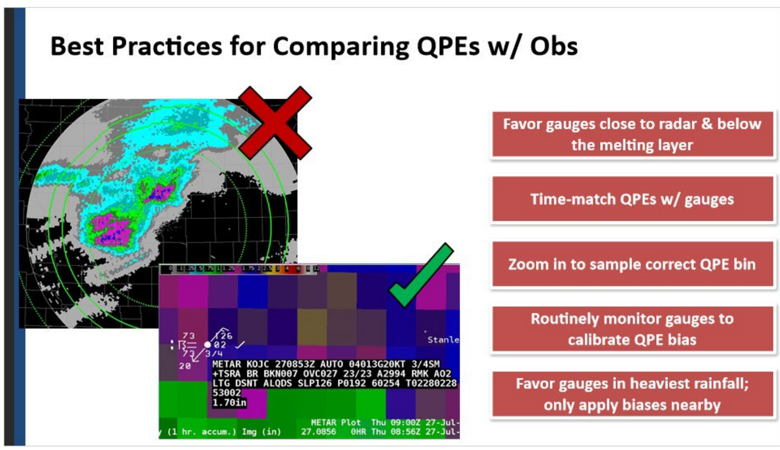
Favor gauges (Slide Layer)



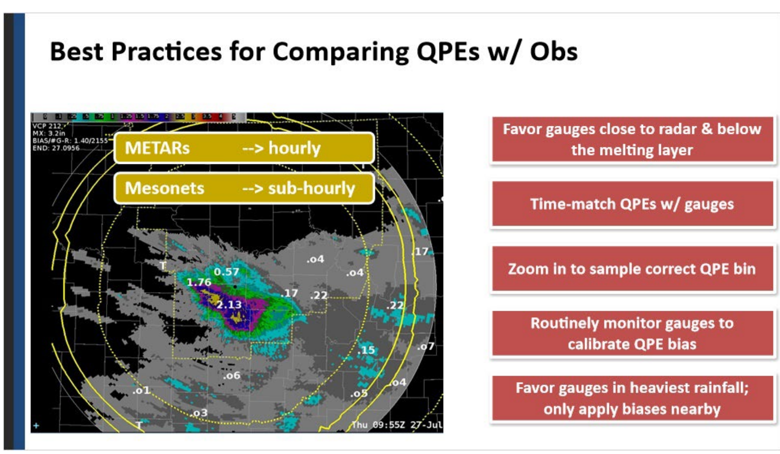
Time match (Slide Layer)



Zoom (Slide Layer)



Monitor (Slide Layer)



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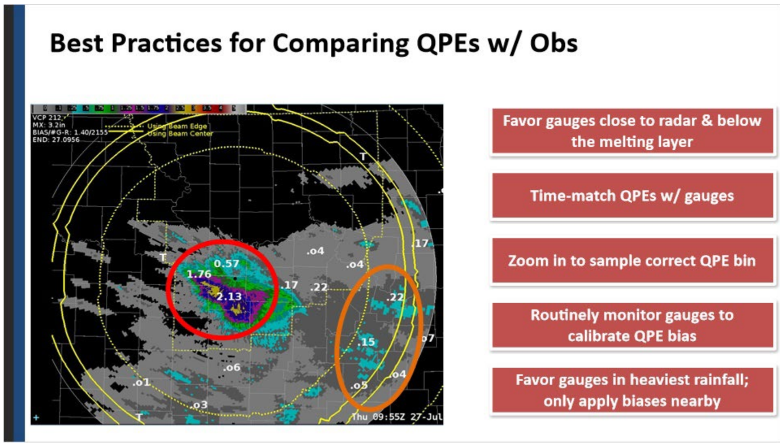
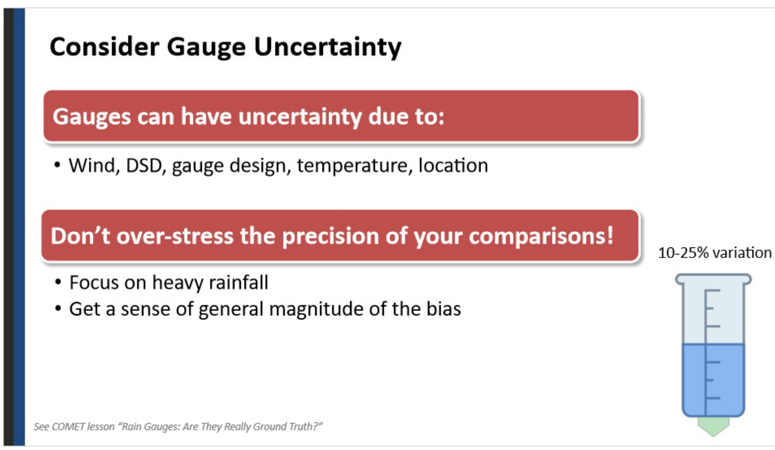
Regime (Slide Layer)



1.15 Consider Gauge Uncertainty



Notes:

A quick note: Just as we know there's uncertainty with radar estimates of rainfall, there is also uncertainty with gauge estimates of rainfall. This is outside the scope of this lesson, but keep it in mind when doing your comparisons. Gauges can underestimate due to factors like wind, drop size distribution in storms, the mechanisms of the gauge itself, temperature, and location of the gauge.

From the COMET module "Rain Gauges: Are They Really Ground Truth?", it's within reason to see anywhere from 10-25% variation of gauge totals, simply due to the factors listed above. The COMET site is linked in the Resources.

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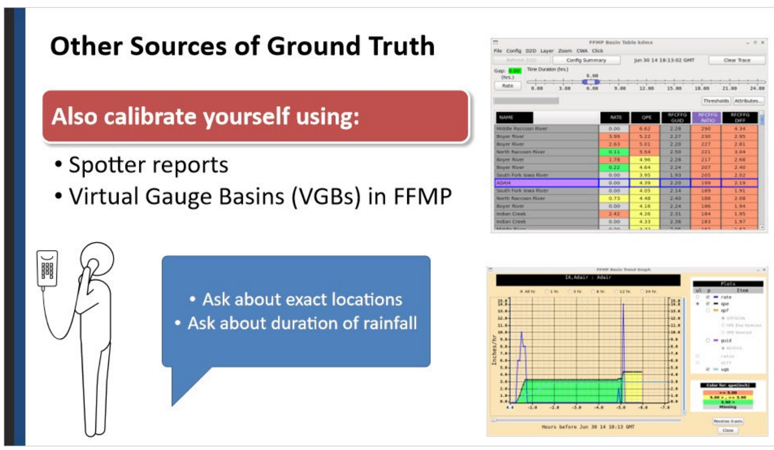
So the takeaway here is this: Don't over-stress the precision of your QPE-to-gauge comparisons. Focus on areas receiving heavy rainfall to do your comparisons, since these areas will have the highest impact on flash flooding. Yes, some of the variation can be attributed to uncertainties, but getting the general magnitude of whether you're off by, let's say, a half an inch or 1-2 inches is useful in your decision-making.

1.16 Other Ground Truth



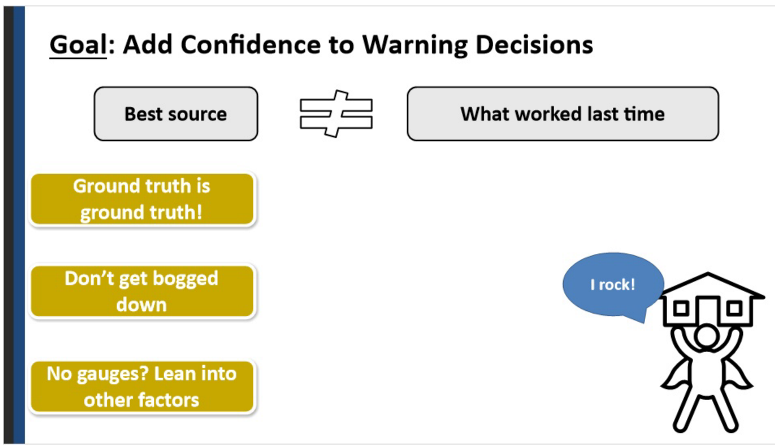
Notes:

Additionally, consider other sources of ground truth if you’ve got them.

In addition to automated rain gauges, you may receive rainfall information in the form of reports. This can also be helpful in the middle of an event. Try to get exact locations. Ask if they know how long it took to accumulate the rainfall. Talk to your local hydro focal point for other useful information to collect.

Finally, the Virtual Gauge Basins (or VGBs) feature in FFMP is also a convenient way to compare a QPE source to observations. This process is a little more involved, so refer to the lesson in WOC Flash Flood to learn more.

1.17 Other Factors to Help Add Confidence



Notes:

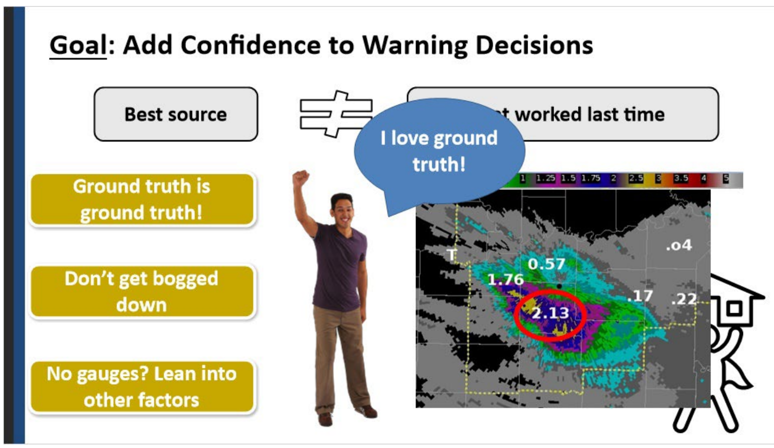
With all of this, I want to take a moment to step back and say: The whole purpose of picking the "best" precip source for each event is so you can have the most confidence in your precip estimates as you make warning decisions. It's important that you make an informed decision, and not just "what worked last time". Click on each of these for more confidence boosters.

Ground Truth: Any decent gauge hit is still ground truth! And if it's in the area of heavy rainfall, even better! You know what to put in your warning text, simple as that. In this example, we can say at least 2 inches fell in our warning. And since it looks like it missed the maximum just a little bit, I have added confidence of saying "2-3 inches have fallen" in my warning.

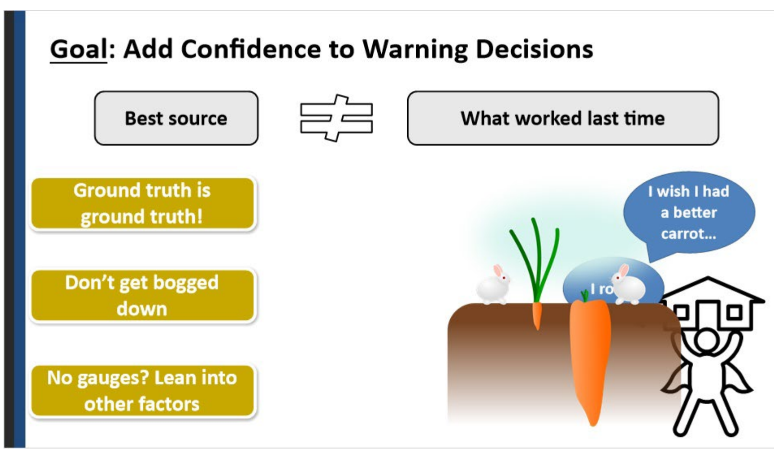
Bogged Down: Familiarize yourself with this process, but don't get bogged down in it. There's uncertainty in both QPEs and gauges. We're just trying to get sense of over- or under-estimation, and a ballpark magnitude.

No Gauges: But I also recognize that there will be many, many times when you won't have ground observations or reports to help you calibrate. And when that happens, it's okay to lean on other tools in your toolbox and rules of thumb. This is where the previous lessons come into play. Knowing some of the basic ins-and-outs of Dual-Pol and MRMS can help you make informed decisions in the absence of ground truth.

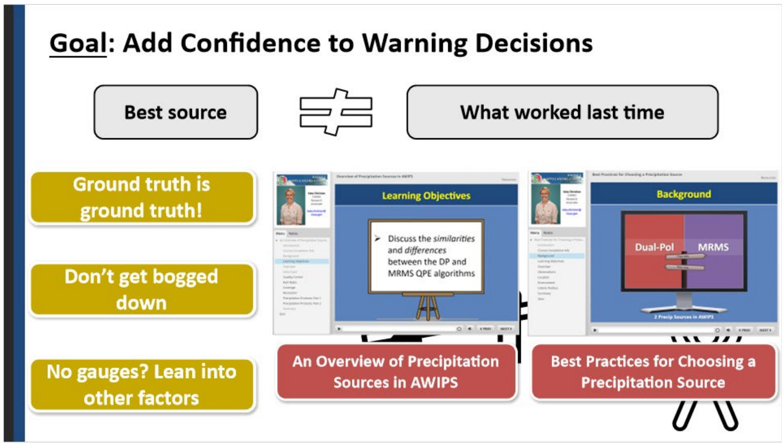
Ground Truth (Slide Layer)



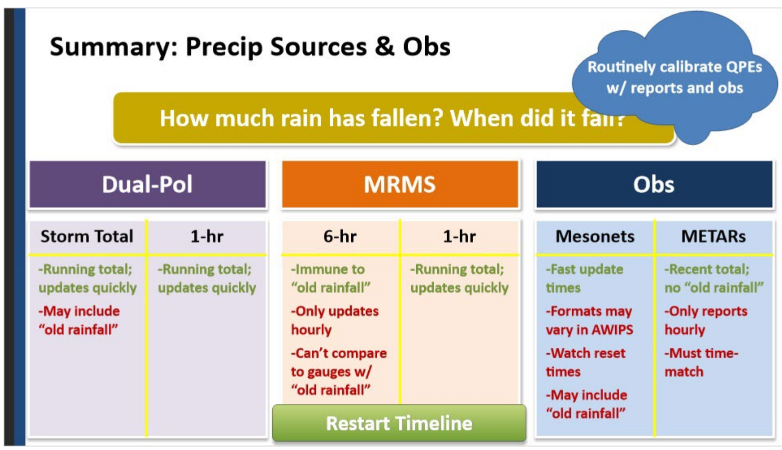
Bogged Down (Slide Layer)



No Gauges? (Slide Layer)



1.18 Summary



Notes:

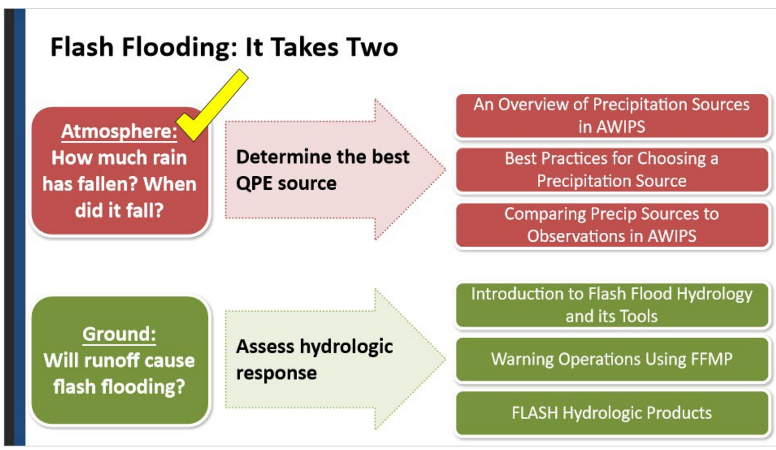
So to quickly summarize: The whole purpose of comparing QPEs to observations is to answer the questions "How much rain has fallen and when did it fall?"

Since gauge observations report in various ways, we must compare them to QPEs in various ways. Long duration QPEs are best compared to long duration obs, like mesonets, and help us see the big picture of "how much has fallen". METARs are useful 1hr gauges, so we compare them to 1hr QPEs. This helps us understand the latest threat. When doing any of these comparisons, keep in mind some of the pros and cons. Feel free to take a moment to re-read through these.

It is also important for you to be routinely calibrating QPE using reports and surface observations, since new information is always coming in. Even in the middle of an event, a good gauge hit can provide very valuable information about both QPE biases and rainfall totals for warnings.

That's the end of this lesson. When you are ready, move onto the next slide to take the quiz and receive credit on the LMS.

1.19 Flash Flooding: It Takes Two



Notes:

Alright, you've tackled Part 1 of the flash flood problem. Knowing your sources and picking the best one based on the nature of the event and observations.

Next up is the ground response...Will the runoff from your rainfall cause flash flooding? Please visit the following modules to learn about your hydrologic tools!

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Introduction to Flash Flood Hydrology and its Tools

Introduction

Notes:

Welcome to this lesson over flash flood hydrology! In the module titled “Flash Flood Meteorology”, we discussed the meteorological side of flash flooding, but today we are going to talk about the other side that is equally just as important - that is the hydrological side.

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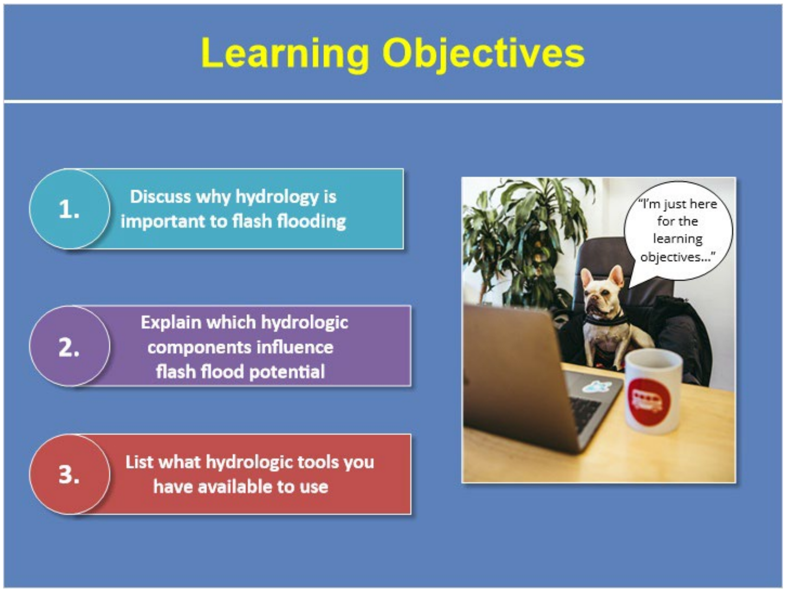
Learning Objectives



Notes:

So what are you expected to learn today? After completing this module, you should be able to discuss why hydrology is important to flash flooding. Next, you'll need to explain which hydrologic components influence flash flood potential. And lastly, you need to be able to list what hydrologic tools you have at your disposal to aid in diagnosing the hydrologic side of flash flooding.

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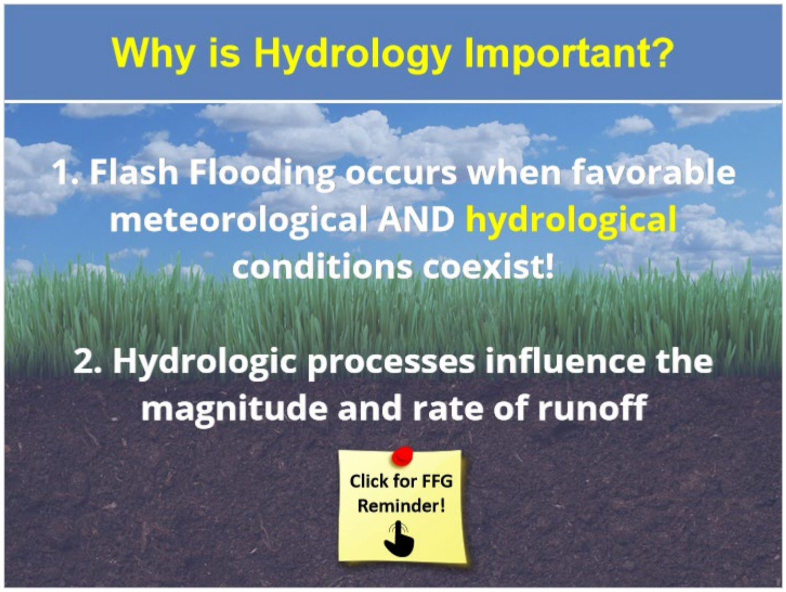
Game Time!

Notes:

Okay, before we dive in, let’s play a quick game to get you ready! Below are snapshots from scenes in three different movies - the iconic Singing in the Rain scene, Pride Rock under the reign of Scar in Lion King, and Isengard under attack from Lord of the Rings, the Two Towers. In each of these scenes, there is some aspect of hydrology on display, but only one of them has hydrology playing a MAJOR role in causing flash flooding and ultimately affecting the outcome of the movie plot. Your job is to guess which scene where you think hydrology played a MAJOR role in affecting the plot outcome. Once you’ve made your selection, click next to submit your answer!

Why is Hydrology Important?



Notes:

Okay, I know you are probably curious to see what the answer is but before we get to that, we need to spend some time talking about how hydrology influences flash flood potential. Remember from the "Flash Flood Meteorology" module that heavy precipitation results when rainfall rates are high over the same geographic region for a long period of time. However, what you need to know is that not all heavy rainfall results in flash flooding! This is because flash flooding occurs when the favorable meteorological AND hydrological conditions coexist. In other words, precipitation amounts may be considerably high, but flash flooding may not occur due to hydrological factors not being favorable.

Next, hydrologic processes are important to account for because they influence the magnitude and intensity of runoff associated with flash flooding. So if you want to properly account for runoff potential, you've got to consider the hydrology.

Now, before we go any further, throughout the remainder of this module, we will be referring to Flash Flood Guidance off and on so if you need a quick overview or reminder on what it is and how it works, feel free to click here. If you don't need a refresher, go ahead and just click "next."

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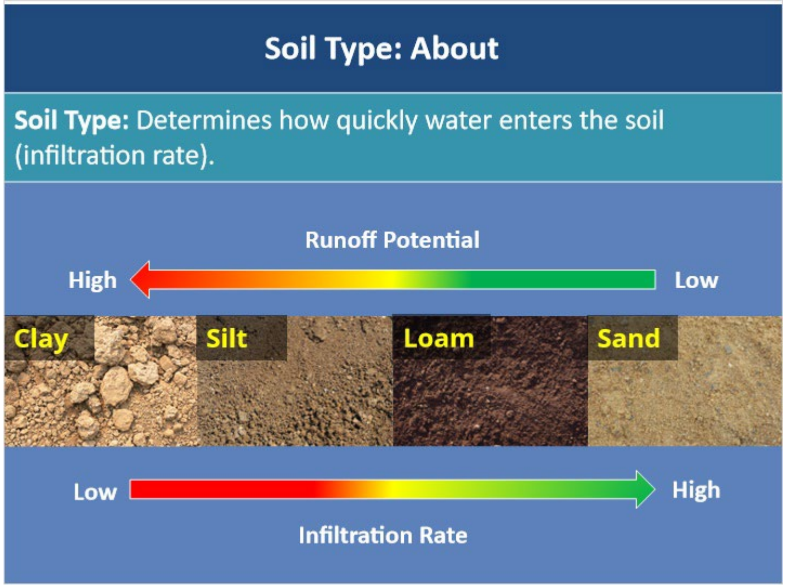
Soil Type: About



Notes:

The first hydrologic factor that influences flash flood potential is the soil type. The type of soil is important because it determines how quickly water enters the soil, referred to as infiltration rate. A low infiltration rate means that the soil is not able to absorb water quickly and as a result, runoff will occur much faster. Of the common soil types, clay has the lowest infiltration rate followed by silt meaning that these soil types have a high runoff potential. In contrast, soil types such as loam and sand have a high infiltration rate, meaning that they are able to absorb and process water at a high rate so the potential for surface runoff is lower. So the type of soil in your CWA is actually important to be aware of as it can either help to enhance or reduce runoff potential!

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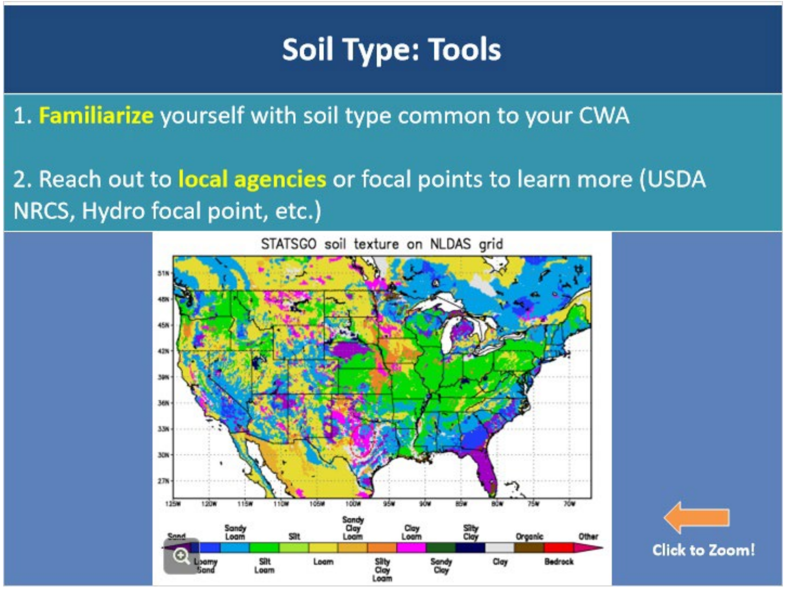
Soil Type: Tools



Notes:

As for what tools are available to help you in this area, the first is to familiarize yourself with the soil type that is most common in your CWA. Take a look at the figure here that shows the distribution of soil types across the U.S. Remember how a portion of central Texas is often referred to as “flash flood alley?” Well, one of the many reasons that region is especially susceptible to flash flooding is due to widespread clay soils there that have low infiltration rates, meaning that surface runoff occurs much faster. Knowing the soil type that is most common across your CWA can help you be aware of what areas absorb and process less water and will be at a higher risk for rapid surface runoff. This figure is included in the “Resources” tab so feel free download it and take note of your CWA’s common soil types.

Another optional tool is to reach out to your local agriculture agencies, such as the USDA Natural Resources Conservation Service, to get more detailed and specific info and maps about soil types in your area. Your hydro focal point can also help point you in the right direction as well.

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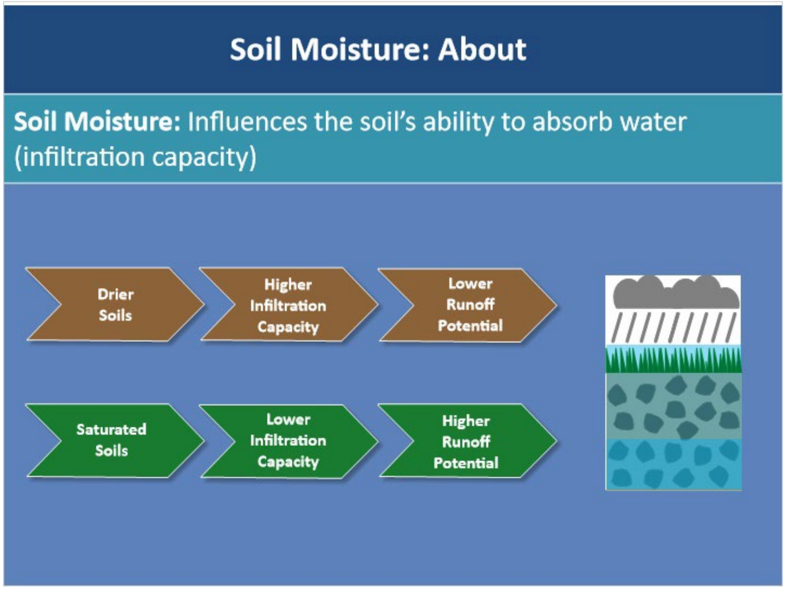
Soil Moisture: About



Notes:

The next soil characteristic to pay attention to is the soil moisture - is the soil dry or saturated? Soil moisture matters because it affects the soil's ability to absorb water, or its infiltration capacity. For example, soil that is saturated due to recent rainfall has a low infiltration capacity, meaning that it is not able to accept any more moisture and any precipitation falling at the surface will very quickly become surface runoff. In contrast, soils that are dry have a high infiltration capacity and are able to take in moisture, resulting in less surface runoff. It's important for you to be aware of what areas have recently received high amounts of rainfall, as this means that the soil's infiltration capacity there may be used up and flash flooding can occur very easily.

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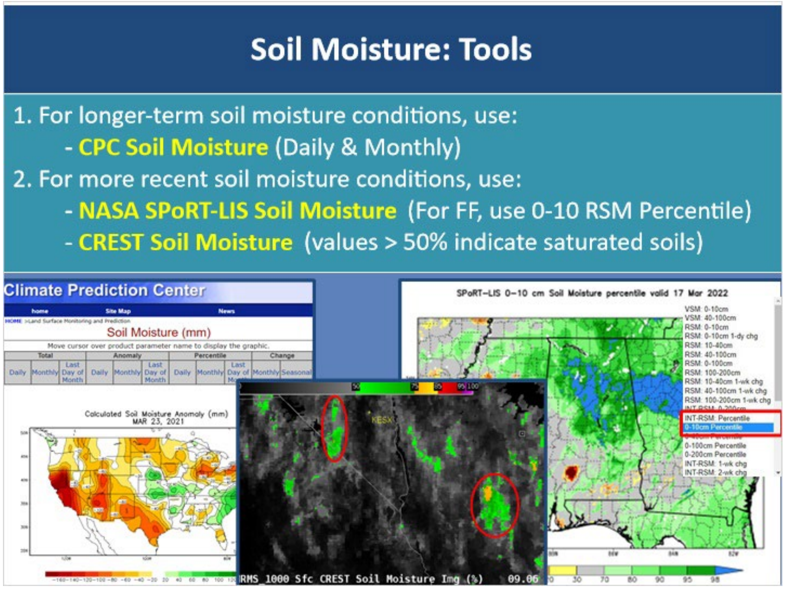
Soil Moisture: Tools



Notes:

So what tools do you have at your disposal to help identify saturated soils? For longer-term soil moisture conditions, check out the Climate Prediction Center's Soil Moisture webpage to quickly get a feel for what your soil moisture conditions are like on monthly and daily timescales.

For a more recent snapshot of soil moisture through varying soil depths, NASA SPoRT has a plethora of available products that are updated every 6 hours and have a 3 km spatial resolution. For flash flood applications, we recommend using the 0-10 cm relative soil moisture percentile product as it is based on climatology and takes into account soil type and saturation.

And lastly, for a finer temporal resolution product, check out the CREST Soil Moisture product as it updates every 10 minutes. Due to its quick update time, you can use CREST soil moisture to spot potential problem areas, especially if you have more storms coming upstream. We here at WDTD recommend paying attention to areas of greater than 50% soil moisture to identify areas primed for flash flooding. These locations have less capacity for extra moisture, and thus, will react quickly if more rainfall occurs. If you want to learn more about this product in specific, please refer to the WDTD FLASH products course where it'll be covered in more detail.

Website links to both the CPC and NASA SPoRT soil moisture products are included in the Resources tab so feel free to check those out.

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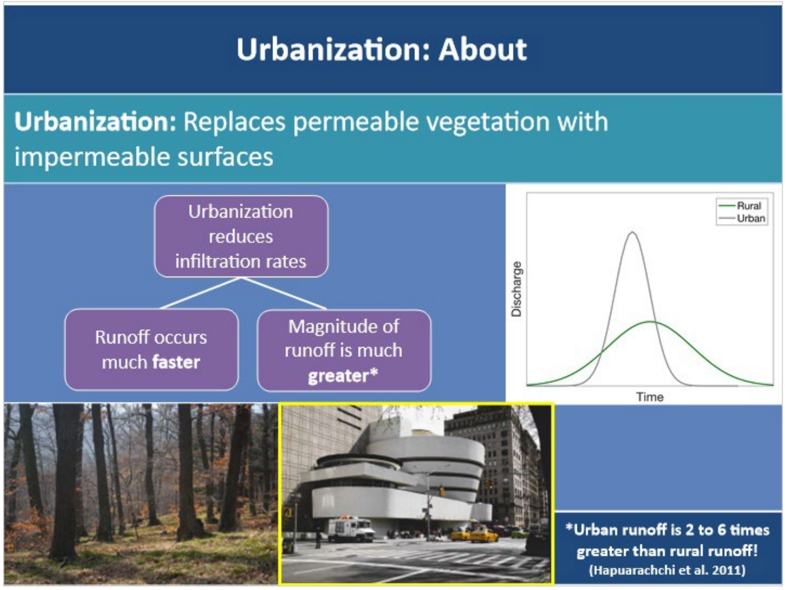
Urbanization: About



Notes:

Now that we've talked about how soil characteristics affect flash flood potential, let's take a look at which land surface characteristics are important to consider beginning with urbanization. So how does urbanization influence flash flood potential? Urbanization essentially replaces natural permeable vegetation surfaces with impermeable surfaces, such as sidewalks, buildings, and concrete. This is a problem because impervious surfaces are very poor absorbers of water compared to vegetation. For example, when heavy precipitation falls on vegetation and soil, some of that rainfall is partially absorbed. However, when rainfall occurs over urban areas and falls on roofs and sidewalks, rainfall cannot infiltrate those surfaces and is directly converted to runoff! In other words, urbanization reduces infiltration rates and allows runoff to occur much faster over urban areas than non-urban areas.

Not only does runoff occur much faster over urbanized areas, but the magnitude of that runoff is much greater. Think about the picture shown here - storm sewers, roads, roofs, and stream channelization culverts all force runoff to occur more quickly and at a much greater magnitude due to the combination of all of these! The figure to the right illustrates this. Peak discharge for urban areas occurs much earlier and faster compared to rural areas. Additionally, the magnitude of discharge for urban areas is also much greater than rural areas. To give you an idea, studies have found that urban runoff is two to six times greater over urban areas compared to rural areas! So the important thing to remember is that urbanized areas greatly increase the potential for flash flooding!

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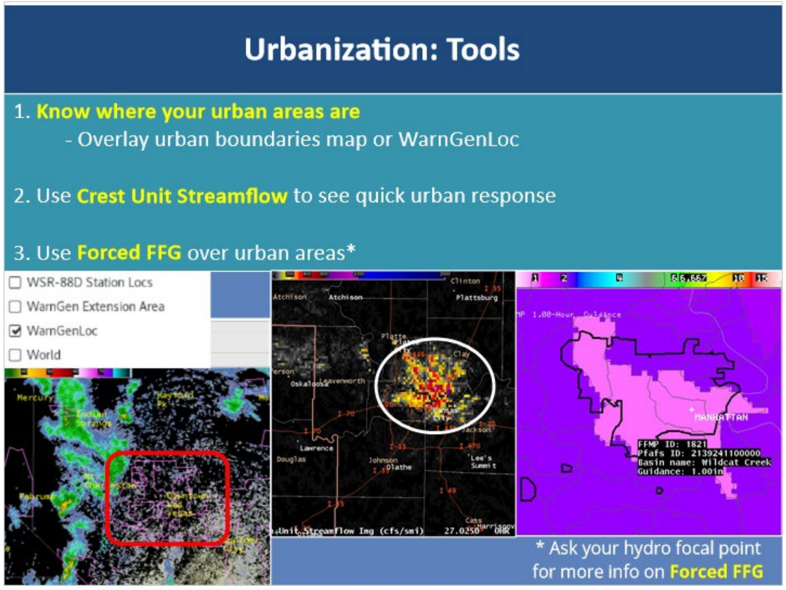
Urbanization: Tools



Notes:

So what are some tools that you can use to properly anticipate the urban flash flood threat? One of the first and most important tools you have at your disposal is to KNOW where your urban areas are as these will typically be the first to go in terms of flash flooding. Oftentimes it may only take an inch of rain in an hour to start causing havoc over metro areas. One way to help draw your attention to those areas is to overlay an urban boundaries map on your flash flood bundles. If you don’t have a local map for this, don’t worry! WarnGenLoc is a default AWIPS map of all the WarnGen city locations. When either of these maps are overlaid, it will highlight your urban bounds and can help you remember where your most vulnerable urban areas are.

Next, CREST Unit Streamflow is an excellent hydrologic tool over urban areas because it includes an imperviousness parameter. This parameter helps the model react more quickly to rainfall in urban areas since it recognizes the higher runoff potential. To learn more about the applications of this product, please refer to the ‘FLASH Best Practices’ module.

Lastly, you can use the forced FFG tool to set flash flood guidance to be a certain value over your urban areas. For example, if you know that one of your cities typically begins to flash flood anytime you get more than 1 inch of rain in an hour in that basin, you can manually set or force your 1-hour FFG to be 1-inch over that area. Feel free to talk to your hydro focal point to learn more about this option.

Using all these tools together can help you remember to not forget the serious risk that urbanization poses to enhancing the flash flood potential.

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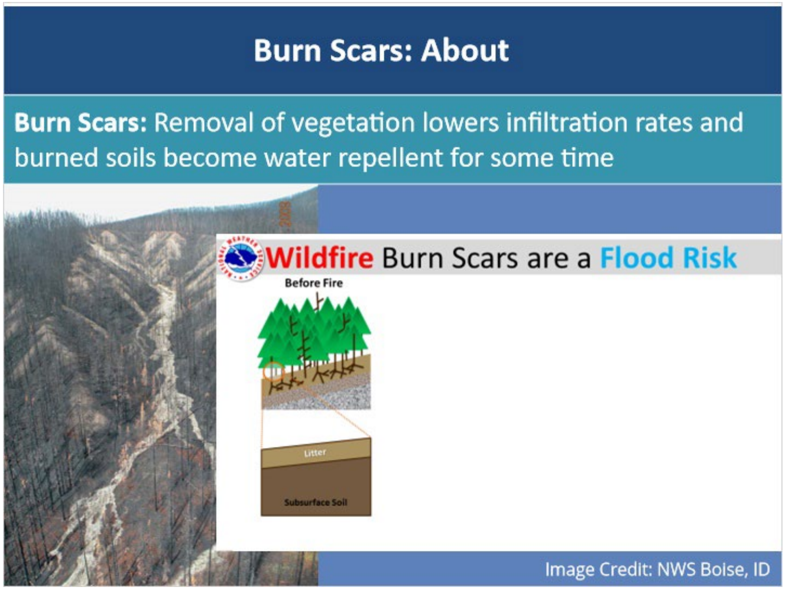
Burn Scars: About



Notes:

Another land surface characteristic that presents an enhanced flash flood risk is areas that have recently been burned by wildfires, known as burn scars. The issue with wildfires lies in the aftermath effects on the land surface. Vegetation that normally acts to intercept and delay water entering the soil is removed during wildfires so burn scar areas have a much lower infiltration rate. Additionally, soils that have been burned by wildfires are extremely water repellent, and are equivalent to a slab of concrete. To make matters worse, soils remain hydrophobic for some time after the wildfire - in some cases, up to 2 years after!

To further illustrate the post-wildfire effects on flash flood potential, take a look at the schematic shown here. Here are typical conditions before the wildfire where, at the top of the soil, you have a layer of organic material referred to as litter, which is essentially any leaves or materials that have fallen from trees or vegetation. Beneath the layer of litter, you have the subsurface soil which varies according to geographic region. During a wildfire, vegetation and the layer of litter is burned and transformed into a water repellent compound which condenses on top of the cooler soil layer below. Ash and burned soil prevent the soil beneath from absorbing water. As such after a wildfire, the soil is not able to absorb any water during periods of heavy rain and essentially acts as a slab of concrete. Rapid surface runoff and flooding results over burn scar areas and in some cases, mud and debris flow may result from the leftover burned debris and ash.

Burn scars are some of the scariest flash flood threat areas because even moderate rainfall rates can see rapid, deadly impacts due to these land surface characteristics.

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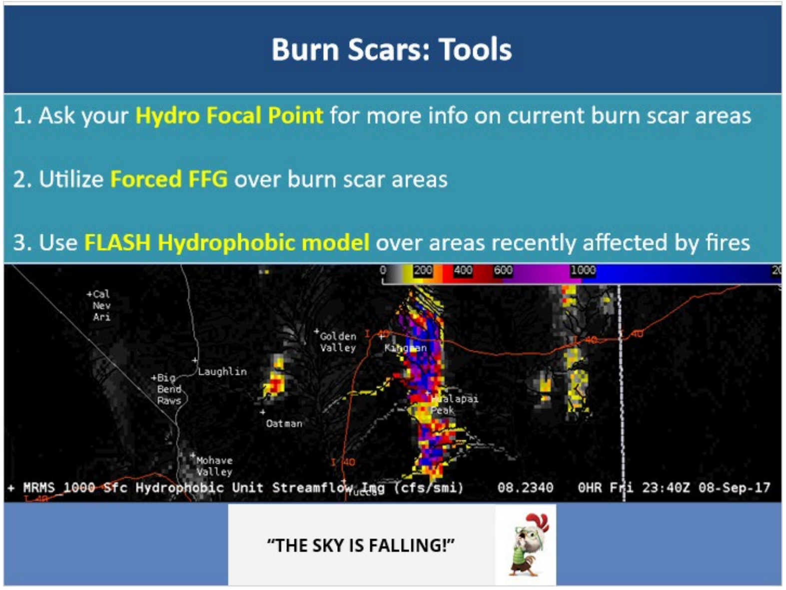
Burn Scars: Tools



Notes:

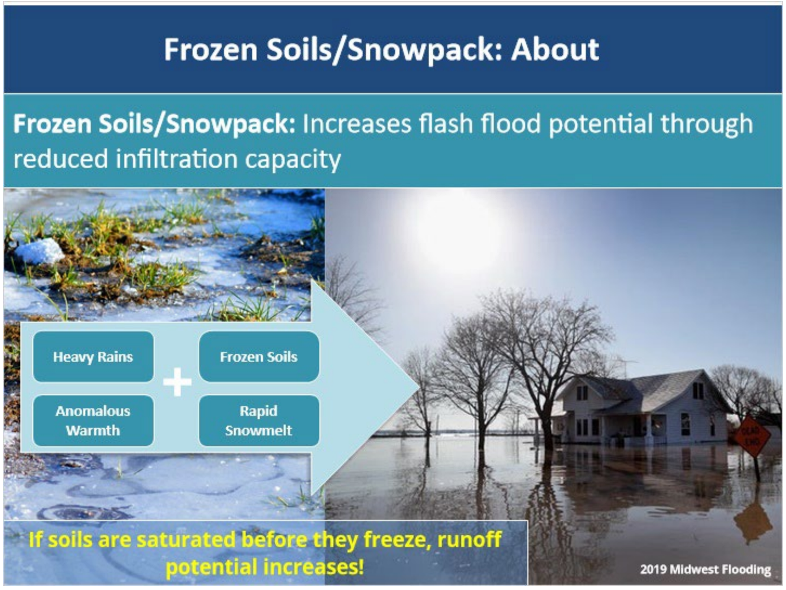
The first tool for dealing with burn scars is to be in contact with your hydro focal point about any areas in your CWA that have been recently affected by wildfires. You should become familiar with the location, impact areas, and rainfall thresholds for each burn scar.

Next, as we mentioned for urban areas, you can use Forced FFG over your burn scar areas to manually set the amount of rainfall needed over a certain amount of time for flash flooding. In many cases, it only takes half an inch of rain in an hour over burn scar areas to start causing serious problems. Making sure you use forced flash flood guidance over these areas to properly reflect that will help you not miss some of the most vulnerable areas.

Lastly, the FLASH product suite has a hydrophobic model that you can make use of over burn scar areas. The hydrophobic model essentially converts any rain that falls directly to runoff so it will often have an end of the world appearance. However, for newer burn scars where hydrophobic soil is prevalent, this model's output can be fairly realistic and can help quickly identify threat areas.

For more details about burn scar flash flooding, we have an entire lesson devoted to operational best practices and tools specific to this topic and the link is included in the "Resources" tab.

Frozen Soils/Snowpack: About



Notes:

While more a result of season, frozen soils and snowpack are the last land surface characteristics I want to mention. Frozen soils have a reduced infiltration capacity which can enhance runoff. The runoff potential is even higher too if the soils were saturated before the soil froze. This is often the case if you have an anomalously wet fall but then all those saturated soils freeze during the winter months.

Likewise, heavy rain falling on snowpack has nowhere to percolate and can also help to melt the snowpack, especially if the snowpack is already near the melting point. While rain on snow events are more often associated with longer term flooding events, that can be an antecedent condition for flash flooding later on.

A memorable example of this sort of situation was the historic Midwest floods of 2019. Heavy rains coupled with anomalously warm temperatures lead to rapid snowmelt and because the soils underneath were still frozen, they were not able to absorb any of this excess moisture, leading to historic runoff and flooding over the region.

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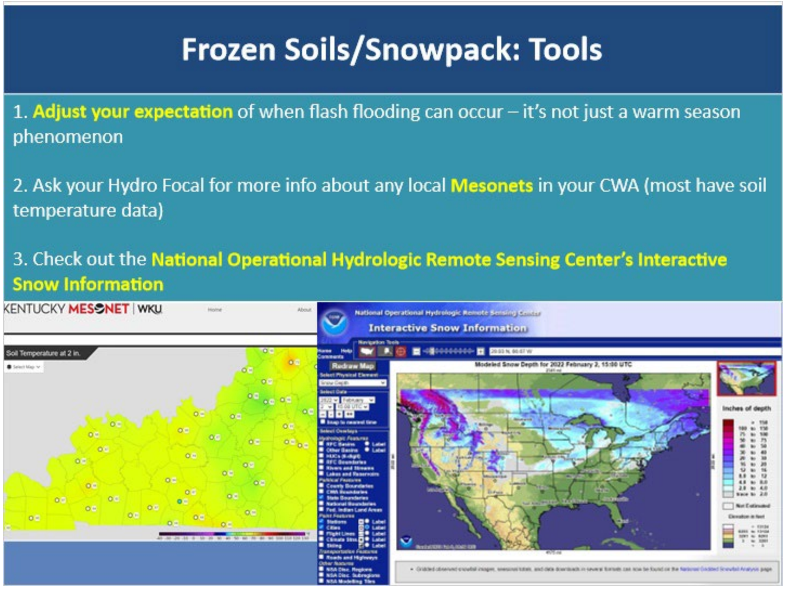
Frozen Soils/Snowpack: Tools



Notes:

So how can you be equipped to handle these sorts of situations? The first and most important tool is for you to mentally adjust your expectations of when you think flash flooding can occur. If you view flash flooding as just a warm season phenomenon, these sorts of events will catch you off guard. It's important to remember that flash flooding can happen even during the winter months!

Next, it's important to have a general feel for what your soil temperatures are like if you have a setup that is suggestive of flash flooding. While there unfortunately isn't a nationwide soil temperature monitoring system, be sure to check with your hydro focal point if you have any local Mesonets in your CWA at your disposal as these most often have soil temperature readily available for you to use.

Lastly, the National Operational Hydrologic Remote Sensing Center has a plethora of snow related observations, products, and datasets readily available and the website link is included in the "Resources" tab in case you are interested.

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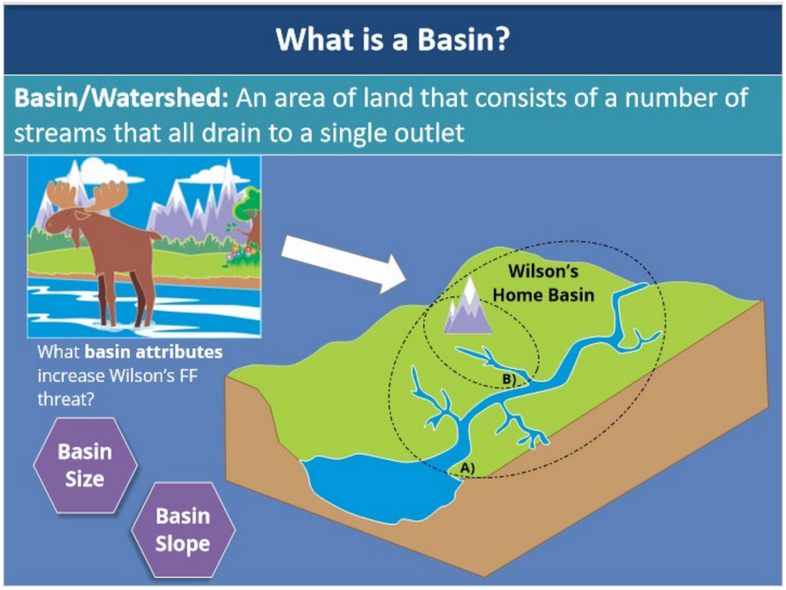
What is a Basin?



Notes:

Okay, before we delve further into discussing basin attributes, we first need to understand what a basin or watershed even is! Let's say Wilson the Moose lives in this lush green land area shown here that consists of multiple streams that run into a main river. Eventually, the main river drains to a single outlet, referred to as Point "A" shown here. A basin is simply the area of land that consists of all the streams that drain to a single outlet. Now, basins can be further divided into smaller basins as shown by the dashed line. The letter "B" now marks the outlet point for this smaller basin where Wilson spends a majority of the time. So, what basin characteristics here can increase Wilson's flash flood threat? In general, there are two - basin size and basin slope.

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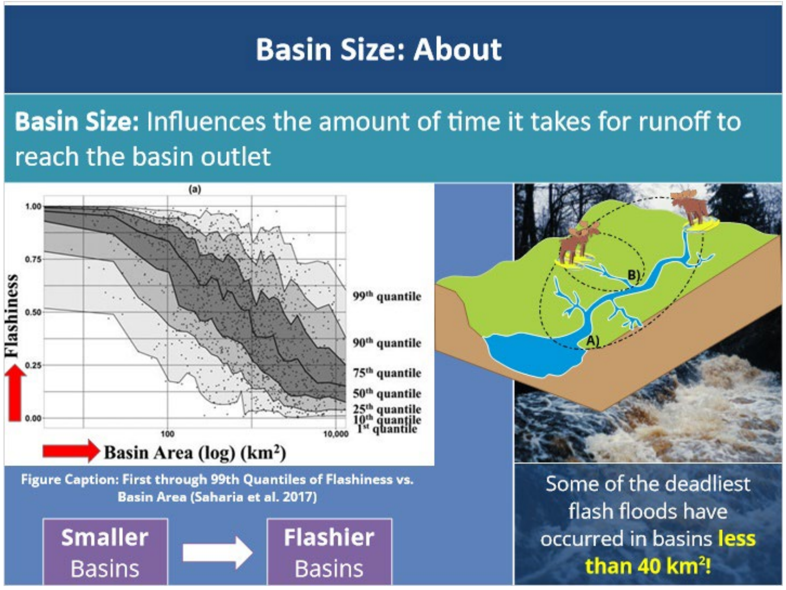
Basin Size: About



Notes:

Okay, let's talk about the influence of basin size by taking a look at this figure from a study in 2017 that examined how various climatological and geomorphological variables affect flash flood severity across the U.S. Here we have basin area on the x-axis plotted against flash flood severity, referred to as flashiness, on the y-axis. What this study found was the smaller the basin, the greater the potential for fast and extreme runoff to generate flash flooding. In other words, smaller basins are more prone to flash flooding than larger basins.

Why is this the case? When basins are smaller in size, like Wilson's home basin, runoff reaches the outlet point much quicker due to having less distance to travel downstream. As a result, the rate of discharge at the outlet point will be much greater and that basin will flash flood more quickly. In contrast, runoff in larger basins has a longer distance to travel and takes longer to reach the outlet point. While basins can range in size from as small as 5 km^2 to as large as 1000 km^2 or even larger, some of the deadliest flash floods in history have occurred in basins less than 40 km^2. So, it's very important to pay attention to where your smaller and therefore, more vulnerable basins are.

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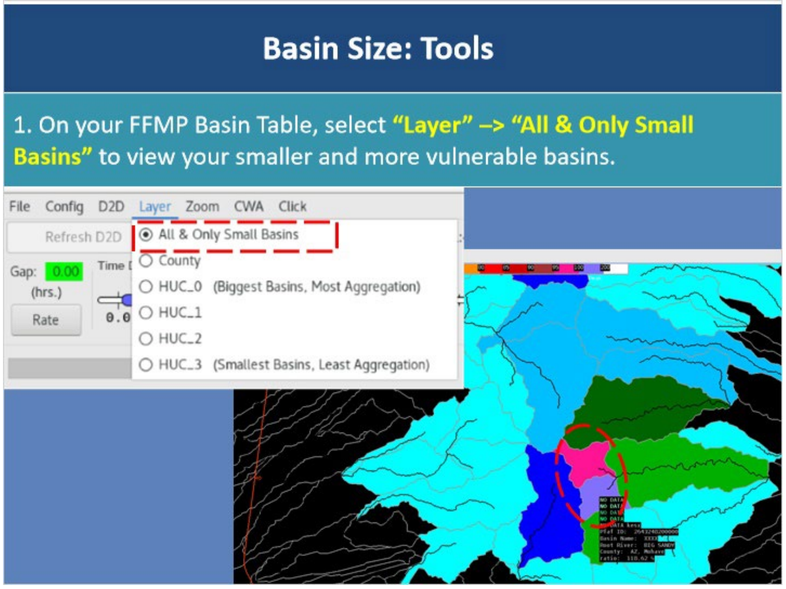
Basin Size: Tools



Notes:

As for what tools you have at your disposal, this is where FFMP comes in as a great tool to help you mentally keep track of where your smaller basins are! To view basins in FFMP, be sure to change your "Layer" view to be "All and Only Small Basins." When you select this display option, it will allow you to visually keep track of your smaller and therefore more vulnerable basins as shown in this image here.

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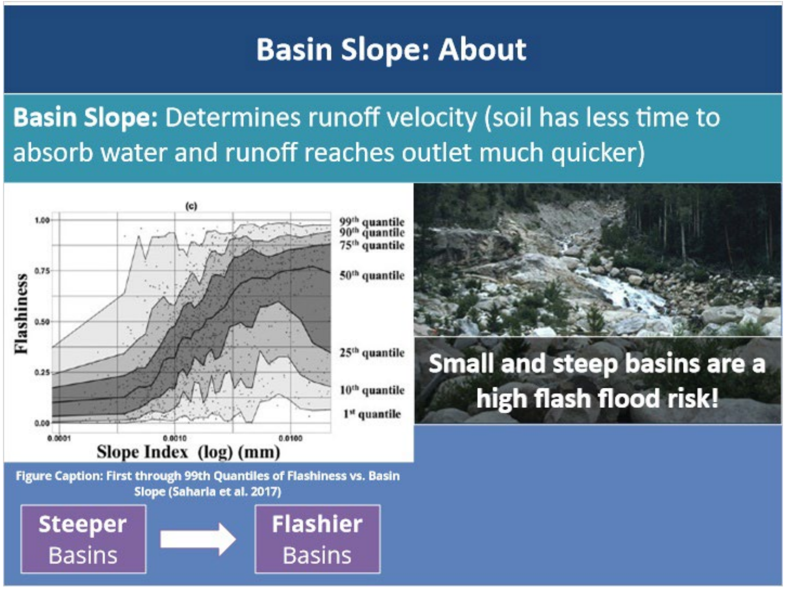
Basin Slope: About



Notes:

The next basin characteristic that can affect flash flood potential is the actual slope of the basin, where slope is defined as the measured change in elevation along the main stream channel. As before, the study we previously mentioned also looked at basin slope and the results were as you'd expect - the steeper the topography of the basin, the more flash flood prone it is. Basins with steep slopes result in higher velocity runoff such that the soil has less time to absorb water. Runoff will then reach stream channels and the basin outlet much quicker, resulting in an increase in runoff rate and magnitude!

Interestingly, the study found both basin slope and basin area are equally important contributors as to how flashy a basin was. So, the overall takeaway is that small, steep basins are at a much higher risk for flash flooding than larger, flat basins.

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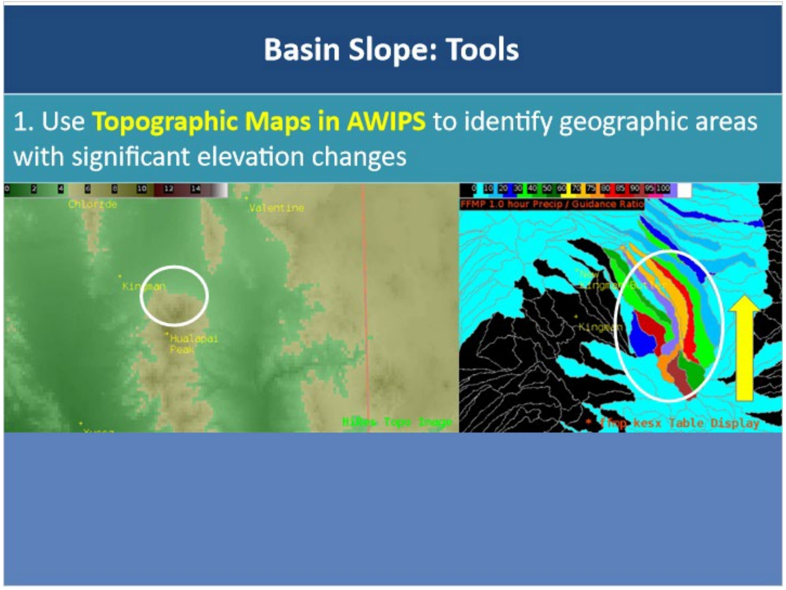
Basin Slope: Tools



Notes:

Since FFMP does not display slope information for individual basins, the best tool you have at your disposal is to rely on topographic maps in AWIPS to identify geographic areas with significant elevation changes in your CWA. You can use that knowledge in tandem with the FFMP basin display to help you identify small steep basins that are particularly at risk for flash flooding. In this example, notice the series of long, thin basins. These basins are on a mountainside that has eroded in such a way that there are channels flowing down it. This is a prime example of flashy basins that are small and very steep.

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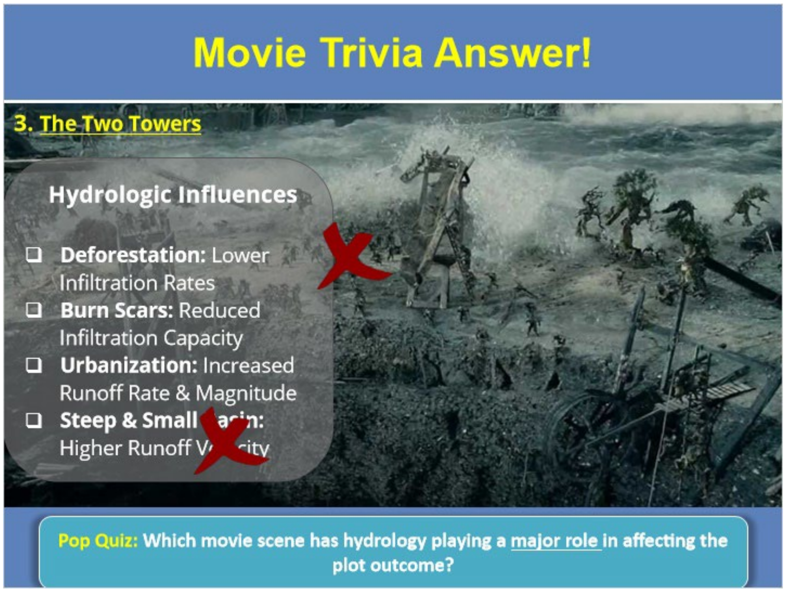
Applied Example



Notes:

Now that you have a solid framework for understanding what hydrologic factors affect flash flooding, let's return to our movie trivia question at the beginning of this module. Remember that we wanted to know which of these movie scenes illustrated where hydrology played a MAJOR role in causing flash flooding and ultimately affecting the outcome of the movie plot. Ready for the answer? If you chose the Isengard scene from Lord of the Rings, the Two Towers, you're correct!

In this iconic scene, hydrology actually played a major role if you think about it! Recent removal of vegetation and deforestation across Isengard acted to reduce infiltration rates drastically. Burn scars across the region from burning of vegetation resulted in water repellent soils and reduced infiltration capacity. Recent expansion of impermeable urban surfaces for evil purposes resulted in increased runoff rate and magnitude! Lastly, Isengard is located within a very steep basin which further increases the flash flood threat. Putting all of these factors together, it's no surprise that severe flash flooding occurred when Treebeard and his fellow colleagues broke the dam upstream! One could say that hydrology played a major role here at the turn of the tide for the battle of middle earth.

While urbanization definitely increased the flash flood potential in the ironic Singing in the Rain scene, Gene Kelly wrapped up his solo before things got to flash flood emergency level so that one is out. Lion King didn't quite make the cut because the drought and resulting widespread dry soils brought on by Mufasa's reign actually helped to absorb all the rain that fell upon Simba's return, preventing widespread flash flooding and allowing for a smooth-ish transition of power between the two. Okay, now that I've hopefully got your attention, let's summarize everything we've learned so that you can be prepared for the final quiz!

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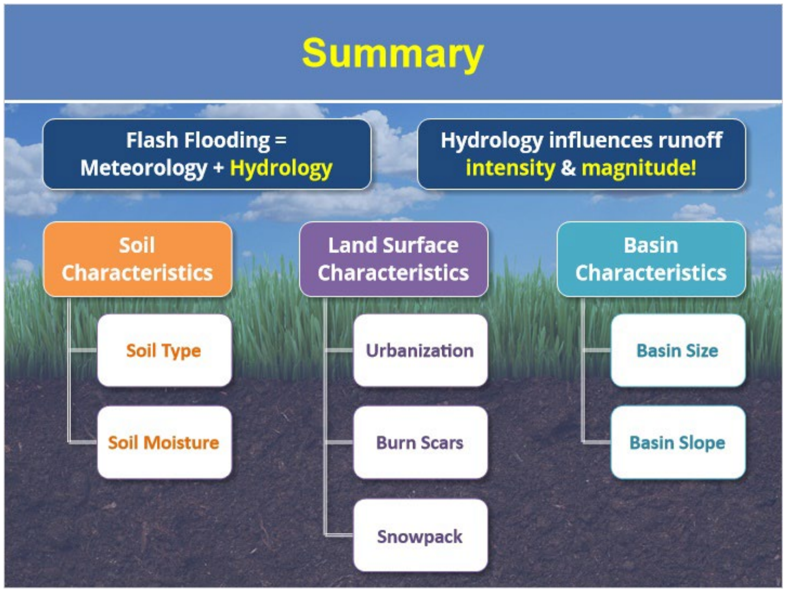
Summary



Notes:

Alright, let's quickly recap everything we've learned so far. Firstly, remember that flash flooding occurs when both meteorological AND hydrological conditions are favorable! Next, hydrology plays a major role in determining the intensity and magnitude of surface runoff! So, if you want to do flash flooding right, you've got to consider the hydrological side! As to what hydrologic factors impact flash flood potential, we focused on three different areas. Firstly, soil characteristics such as soil type and soil moisture impact how quickly water can enter the soil and how much water the soil can hold. Next, it's important for you to mentally be aware of certain land surface characteristics, such as urbanization, burn scars, and snowpack, as all three of these increase the intensity and magnitude of surface runoff! Lastly, be sure to pay attention to basin size and slope, with smaller more steep basins presenting a heightened flash flood risk. We also talked about several tools you can use in AWIPS and beyond to help you account for these hydrologic factors.

Okay, it's time to shine and show how much you've learned through acing the upcoming quiz! When you're ready to take the quiz, go ahead and click "next."

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Hi, my name is Jill Hardy and welcome to this lesson which will focus on using FFMP to diagnose a flash flood threat.

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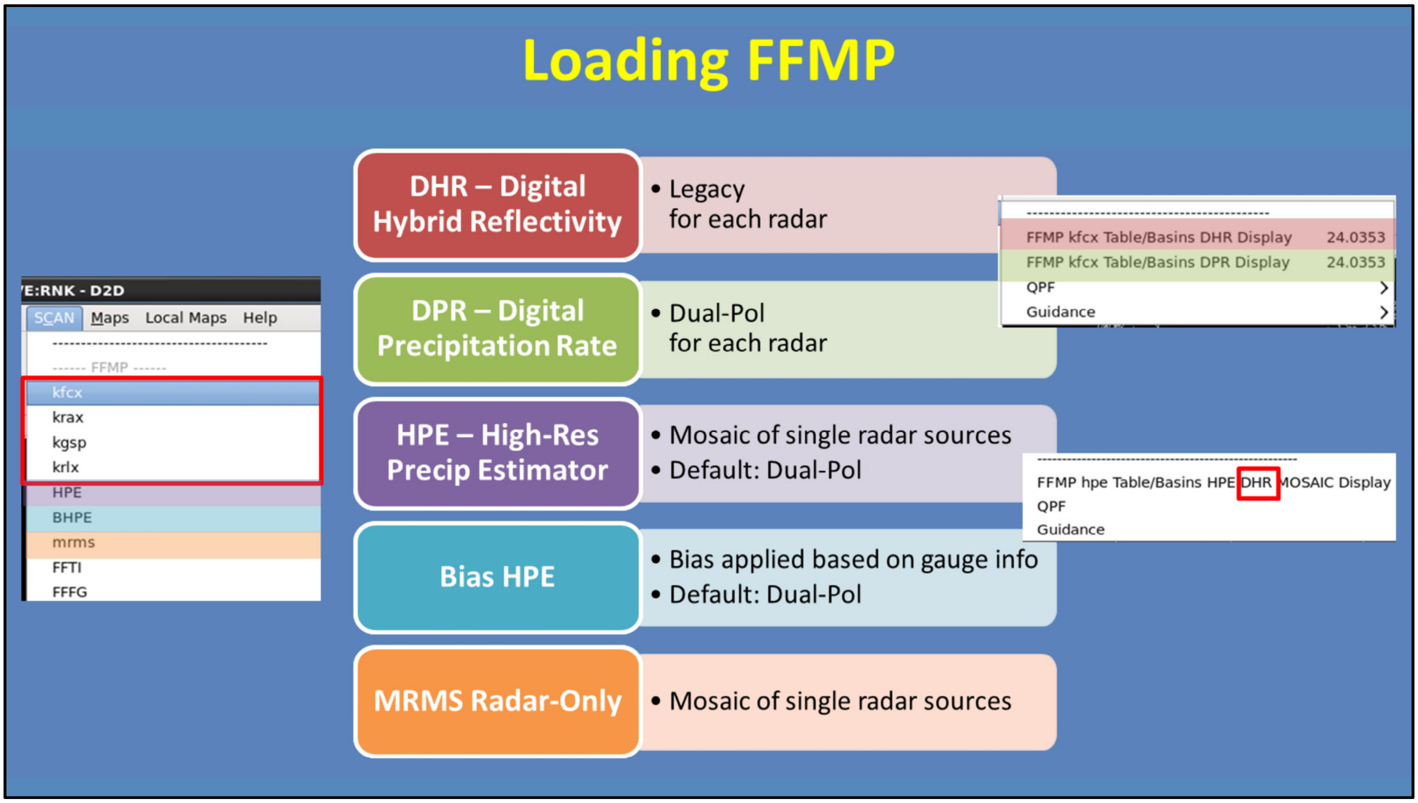
Learning Objectives

- By the end of this lesson, you will be able to:
  - Identify when to use All and Only Small Stream Basins versus County layer
  - Identify why QPE, Ratio, and Diff are useful for flash flood decision-making
  - Interpret QPE, Ratio, and Diff in FFMP
  - Interpret the Basin Trend Graph, specifically the all-hours graph
  - Identify when to use downstream trace in FFMP in warning decision making

Here are the learning objectives for this lesson. When you have finished reading them, please continue to the next slide.

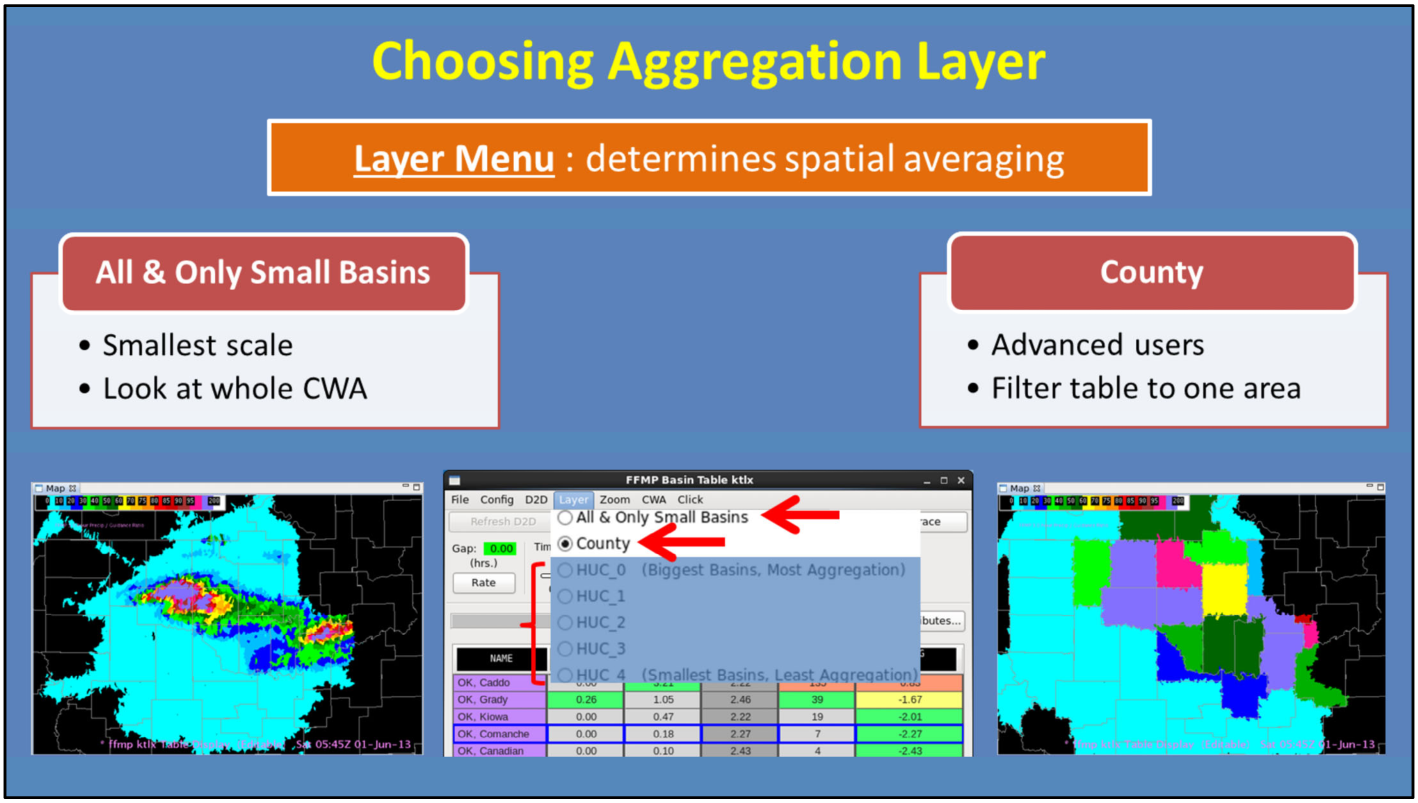


First thing's first: loading FFMP with your desired precip source from the SCAN menu.

The single-radar products are available under the menu referenced by the radar name. As seen here, under each radar submenu, there is the DHR source (which is Legacy), and the DPR source (for Dual-Pol).

Next, since the HPE and Bias HPE products are mosaics, they are identified as HPE and BHPE on the SCAN FFMP menu. Keep in mind there's a labeling error for these products. Both use Dual-Pol in their creation, however, their submenu reads "DHR MOSAIC". Just be aware that this is a typo.

Finally, the MRMS Radar Only mosaic is also available from the SCAN FFMP menu.



One of the most important steps in using FFMP is choosing the aggregation layer, which defines what spatial scale FFMP averages the QPE and FFG. The two layers we will focus on for flash flooding are the All & Only Small Basins and County.

When you first open FFMP and begin your flash flood interrogation, we recommend starting with the “All and Only Small Basins” layer option. This will give you a simple look over the whole CWA on the most relevant hydrologic scale to see what basins stand out in QPE, ratio, or diff.

As you become more advanced with FFMP, you can switch to using the “County” layer option to organize the basins in the FFMP table by county. This is done to make it easier to find particular basins and virtual gauge basins. There are a lot more settings to pay attention to when using county layer, though, so just be careful. The HUC layers are collections of small stream basins for larger scales and are not used frequently for flash flood decision making.

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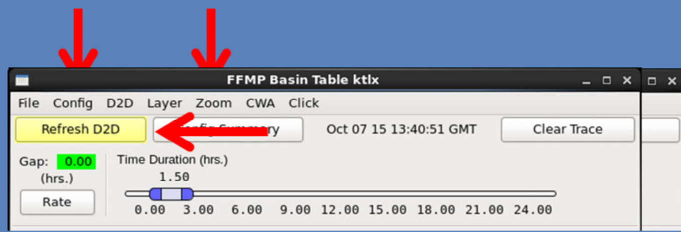
FFMP Recommended Settings



	All & Only Small Basins	County
Zoom Menu: zooming options when aggregation layer is clicked		
Maintain Layer	OFF	OFF
Only Basins in Parent	OFF	OFF
Config Menu: display options		
Link to Frame	ON	ON
Worst Case for Aggregate	ON	ON
Auto-Refresh	ON	ON

There are several FFMP Table menu options that can enhance your D2D display, as well as your FFMP basin table display.

First, the Zoom menu controls how FFMP zooms into smaller basins when an aggregation layer is clicked in the table. In either “All and Only Small Basins” or “County” layer, we recommend these options be turned off. They do not have an effect on your display when using “All and Only Small Basins”. But if you use “County” layer, and the “Maintain Layer” option is OFF, the D2D will show the individual basins (instead of just the whole county). Setting “Only Basins in Parent” to OFF allows any neighboring basins outside of the county to be displayed in D2D, so you can see flash flood threats crossing the county line.

Next, the Config menu helps with general display of the data. The “Link to Frame” ensures the D2D and the table are kept in sync when stepping through multiple frames.

Next is the “Worst Case for Aggregate” option. This option only comes into play when you have chosen a layer larger than “All and Only Small Basins”. When turned on, this option sets the values in the FFMP table to show the “worst case” value for **any** basin within the larger aggregate layer. However, be aware that the “worst case” values may not always be within the same basins (which can make interpretation tricky).

Finally, there is the Auto-Refresh option. This automatically updates the D2D display with any configuration changes made to the FFMP table. We recommend this be turned ON. However, if you notice performance problems with FFMP, you may consider turning it OFF. When it is off, you need to remember to click on the “Refresh D2D” button to manually update the display after making changes.

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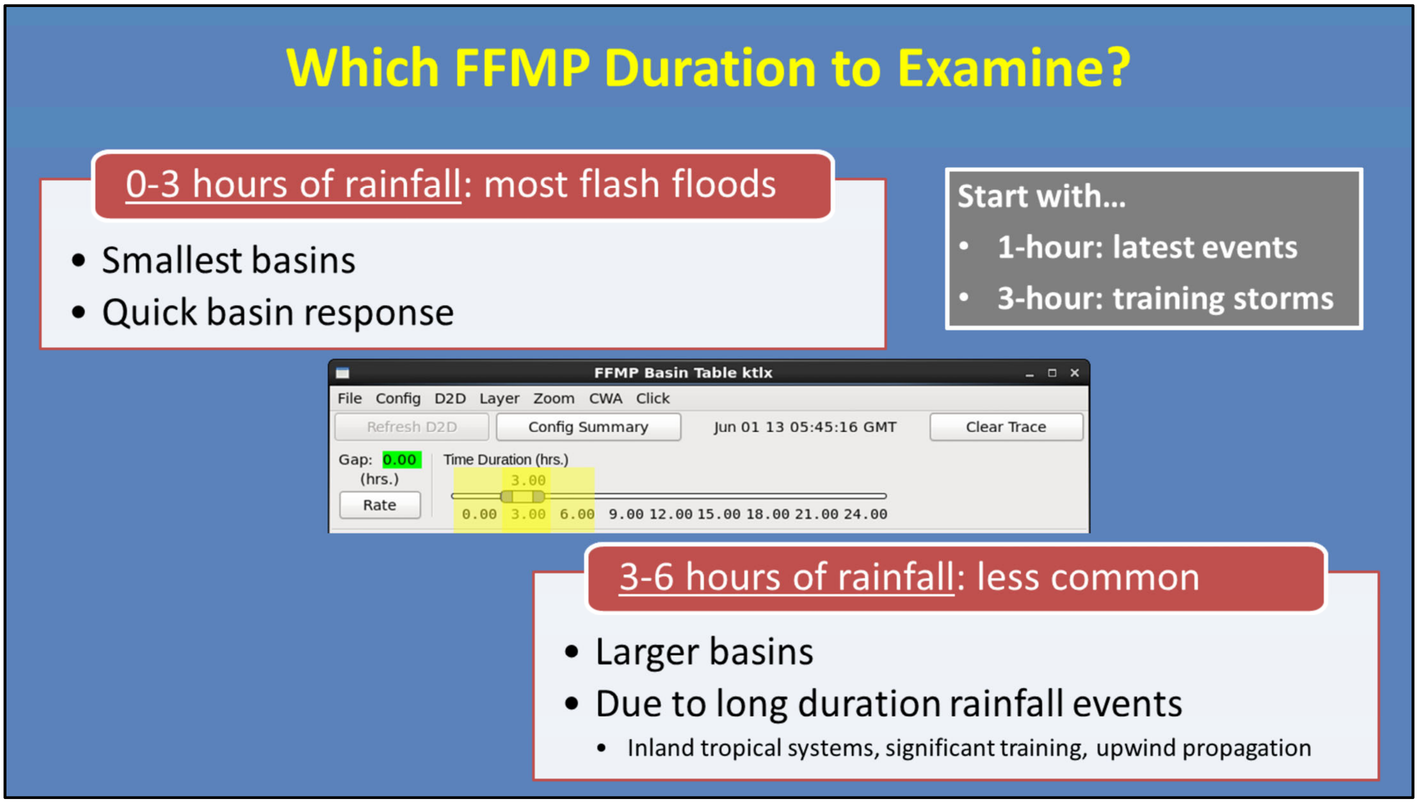
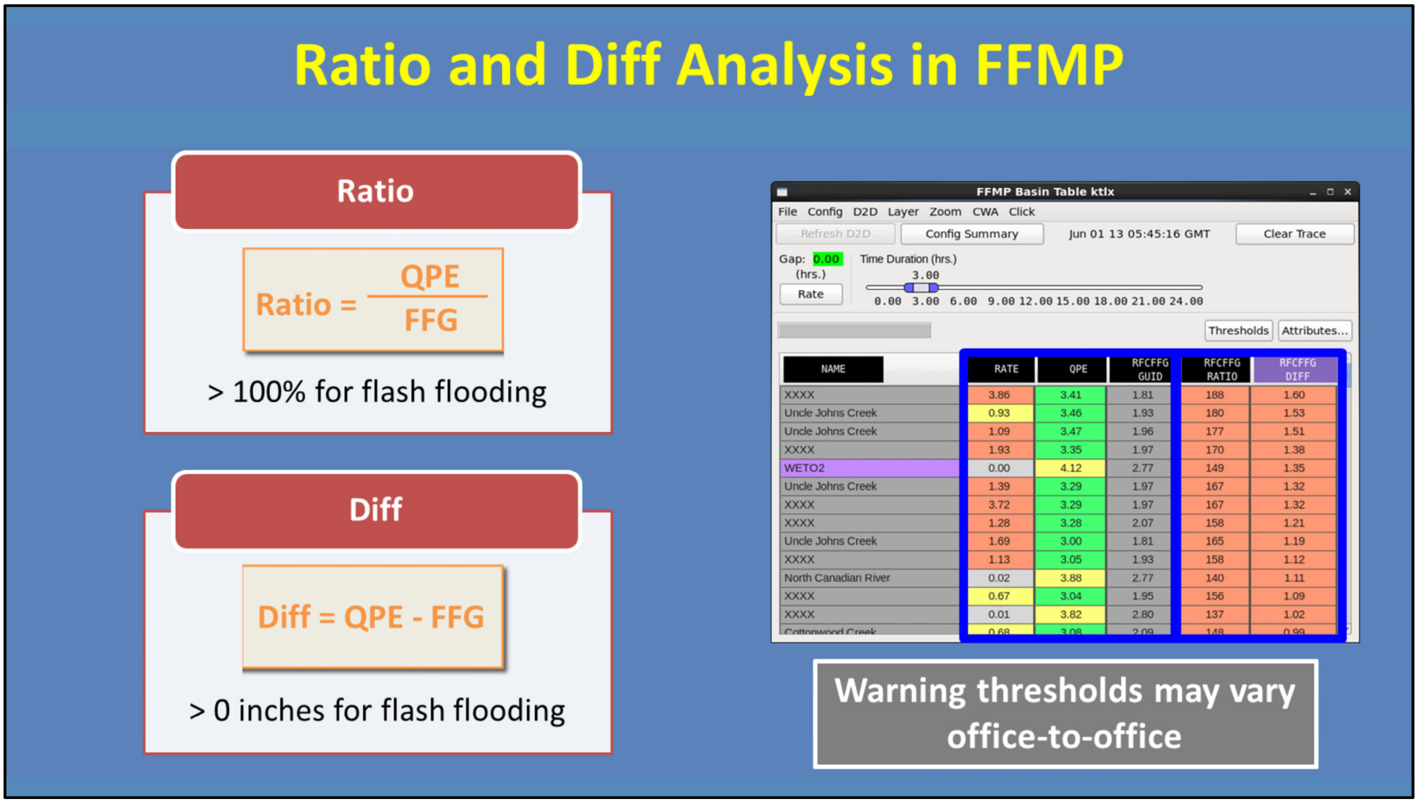


Now that we have reviewed the FFMP settings, let's talk about what durations are good to examine.

The majority of flash flood events take place due to less than 3 hours of rainfall, sometimes less than an hour of heavy rainfall. This is because they occur in very small basins. These tiny basins have quick responses to the rainfall, and thus inundate rapidly. Therefore, we suggest you focus on the 1-hour duration for the latest events, and the 3-hour duration for training storms. The duration slider bar feature in FFMP makes this easy to do.

However, certain meteorological environments are conducive to flash flooding larger basins, and thus require a longer duration to get things going. Inland tropical storms, significant cell training, and upwind propagation along a quasi-stationary boundary are examples of long duration heavy rainfall events that may result in flash flooding of large basins. In these types of set-ups, in addition to looking at 1 and 3 hour duration, it would be wise to also check out the 6-hour duration.



Okay, so you have your settings the way you want, and you know the duration you want to examine. So what should you look at? In addition to instantaneous rate, basin-averaged QPE, and basin-averaged FFG, FFMP has two other options for what can be displayed in the table: Ratio and Difference.

By default, these two take into account the Flash Flood Guidance values, and thus, are useful for analyzing exceedance threat. So let's take a look.

For Ratio, it is QPE divided by FFG. So, as Ratio approaches and exceeds 100%, that means QPE is near or exceeding FFG, and thus, the theoretical flash flood threat increases. To calculate the Difference, it is QPE minus FFG. So as Diff approaches zero or becomes positive, similarly, the theoretical flash flood threat increases.

But remember, all QPE sources have uncertainty and RFC FFG accuracy varies significantly across the country and over time. So you may find that ratio and difference warning thresholds vary from office-to-office. For instance, at some WFOs, flash flooding may typically start at 0.5 inches over FFG while another may start near flash flood guidance. But let's take a minute to review an example of QPE, ratio, and difference values.

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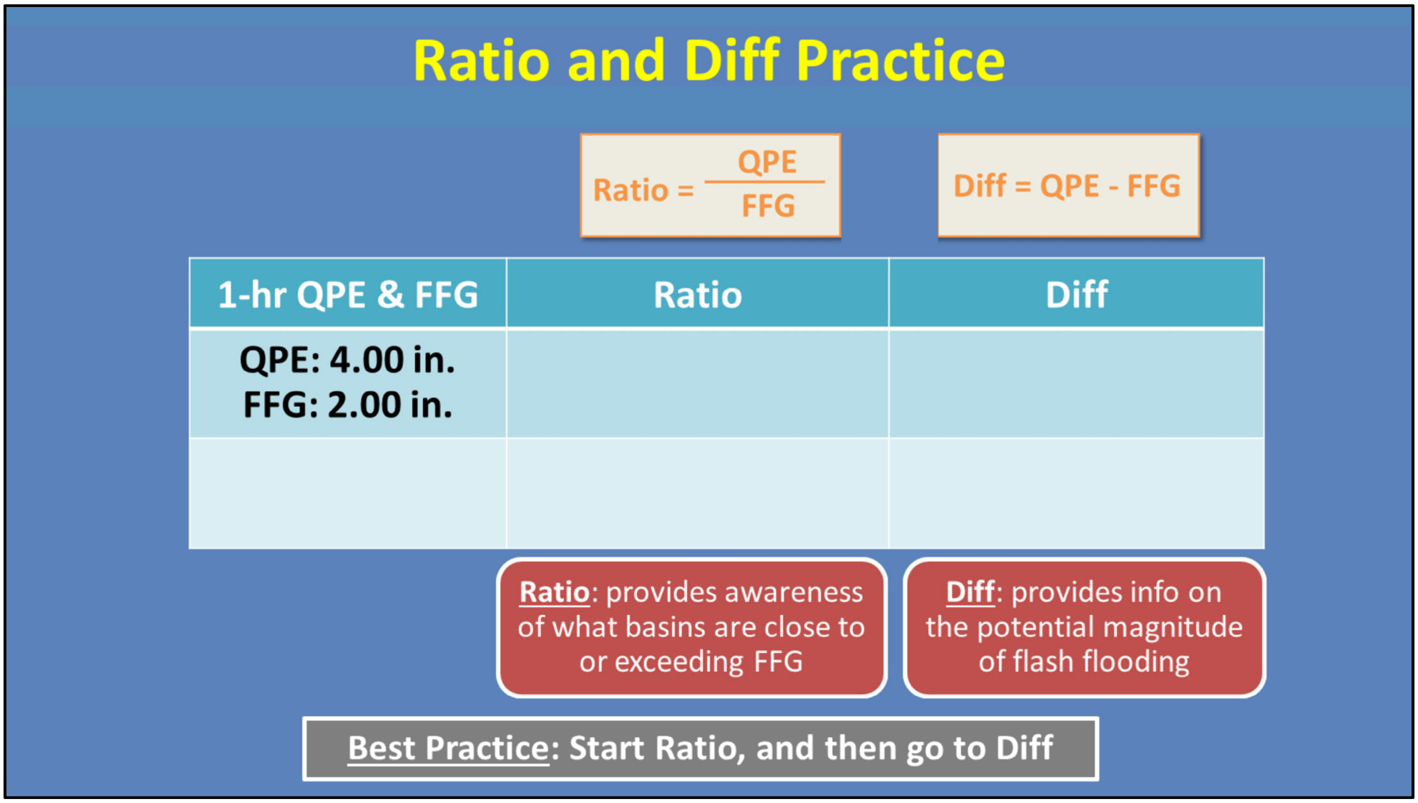

Alright, let's say we have a hypothetical basin that has basin-averaged rainfall of 4 inches in one hour, and the flash flood guidance is 2 inches in one hour. Thus, the Ratio would be 200%, and the Diff value would be 2 inches. Now imagine that for a different rainfall event, the same basin receives 1 inch of rain in an hour, and the FFG is only 0.50 inches.

The Ratio is still 200%, but the Difference is now 0.5 inches. This Ratio value could lead you to believe a significant flash flood was possible, as in the first case. However, comparing the two Difference values, the 1st event would have much more significant flash flooding given that FFG was exceeded by 2 inches, rather than only 0.50 inches during the second event.

Ratio can be used as a quick awareness tool for basins that are close to or already exceeded flash flood guidance. While, the Diff values give information on the potential magnitude of the flash flooding.

After identifying your areas of precip using QPE, we recommend that you start with viewing the Ratio, in order to pinpoint areas that may be approaching or exceeding FFG. Then, switch over to the Difference to tell how much you are over or under in those areas.

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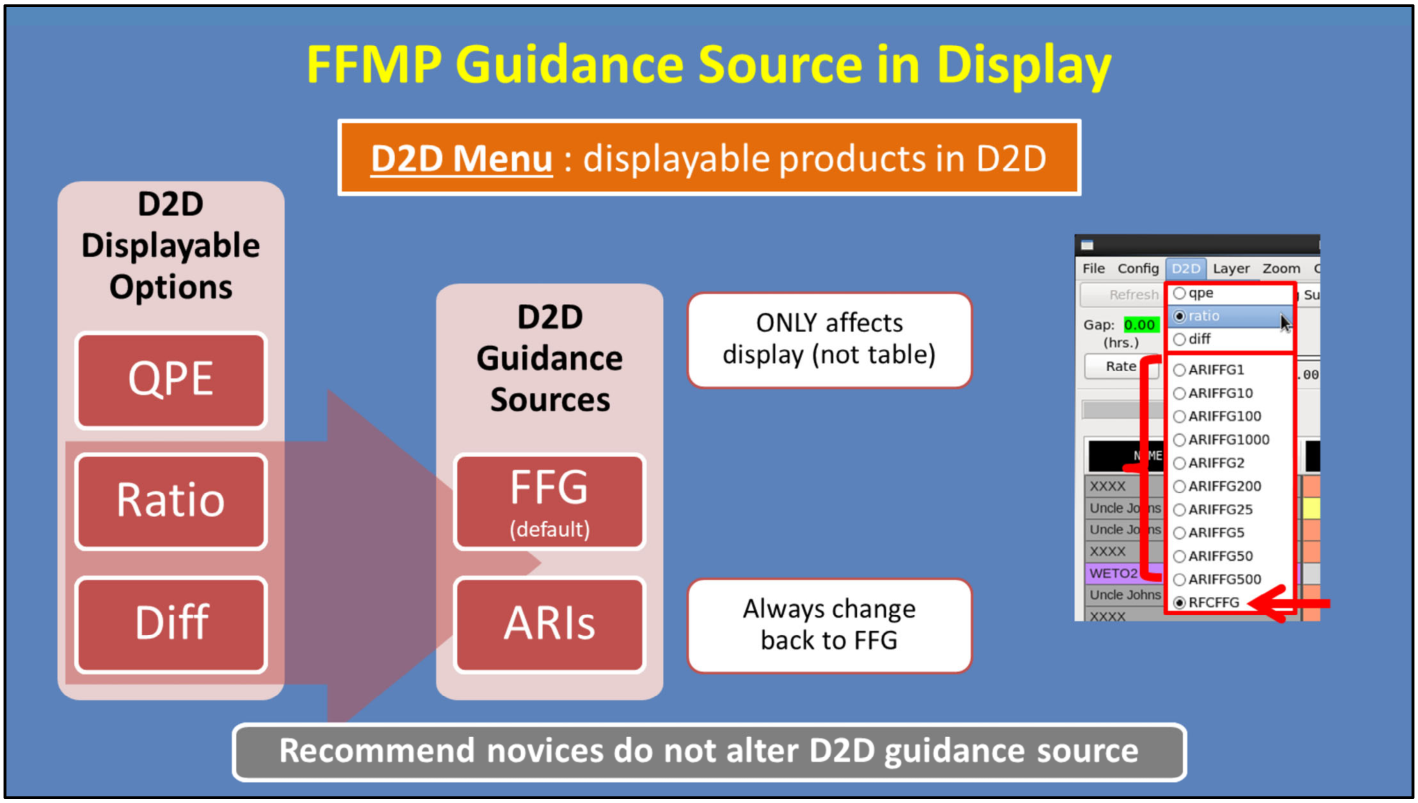

The last menu to discuss is the D2D menu, which determines what is being displayed in D2D. The three options are QPE, Ratio, and Diff, with the default being QPE.

Based on the best practice from the previous slide, it is usually good to start with QPE to get a feel for the high precip areas, and then move to Ratio and Diff to analyze the flash flood threat. When you switch the D2D menu option from QPE to Ratio or Diff, FFMP wants to determine what guidance source is being used for the ratio calculation. The default is RFC FFG, as shown here.

However, Average Recurrence Intervals (or ARIs) are a new guidance source option in FFMP. To force the D2D display to show ratio (or diff) calculated against ARI, simply choose one of the various ARI options. Keep in mind this change ONLY affects the display, and not the table values. Therefore, it can become confusing if you set the *display* to use ARIs to calculate ratio and diff, but your *table* uses FFG. So do NOT forget to always switch your D2D display back to FFG once you are done with the ARIs.

There is a lot to learn about ARIs before you start using them in AWIPS. For novices, we recommend you do not use ARIs in FFMP, and therefore do not alter the D2D menu guidance source. Rather, wait until you take WOC Flash Flood to learn more.

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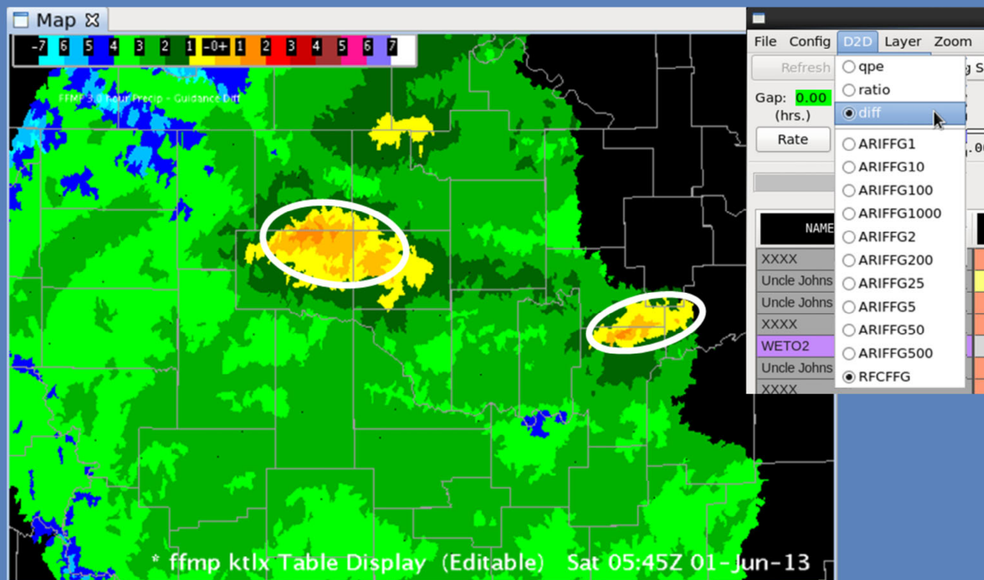
Example: QPE, Ratio, and Diff



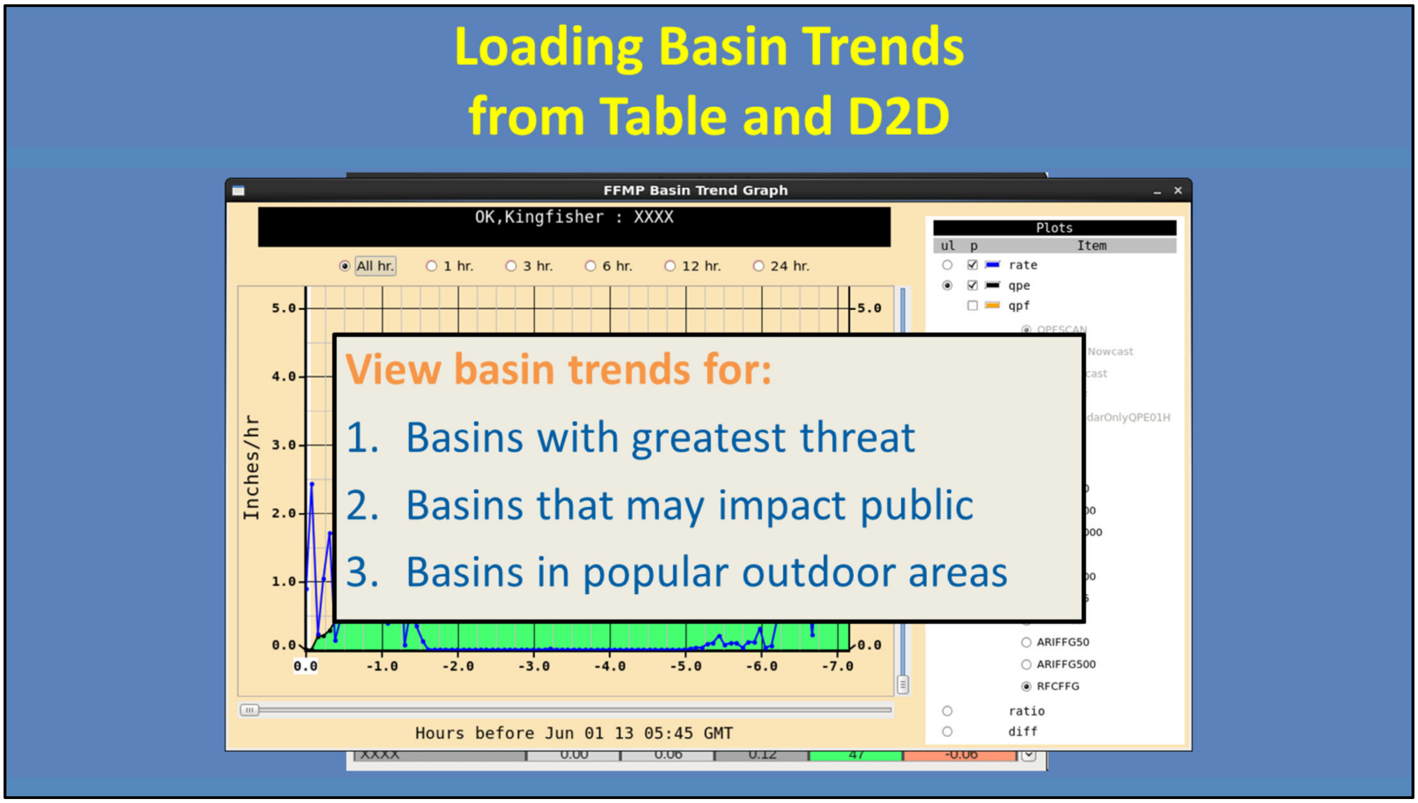
Here is an example of how to interpret the D2D options.

So FFMP defaults to displaying QPE. Simply looking at this output, we see there is a large area of greater than 1 inch in three hours, with isolated areas having upwards of 3 inches of rain in three hours. This information is useful for situational awareness, however it does not tell us anything about the hydrological response.

Therefore, your next move is to look at the Ratio product. Remember, for this, we are interested in areas that are approaching or have exceeded 100%. If rain is continuing in the area, then also consider the areas of 80 and 90%, since they are close to exceeding FFG. With this methodology, we have narrowed our threats to the circled regions.

Finally, use the Difference display to see by how much FFG has been exceeded. In this example, within our areas of interest, we have generally exceeded FFG within 1 inch. But there are some areas exceeding by 1-2 inches, which is where the more significant flash flooding threat is located.

So you see how this process helps you narrow down your flash flood threat, while providing details on magnitude that may be useful when considering your warning text.

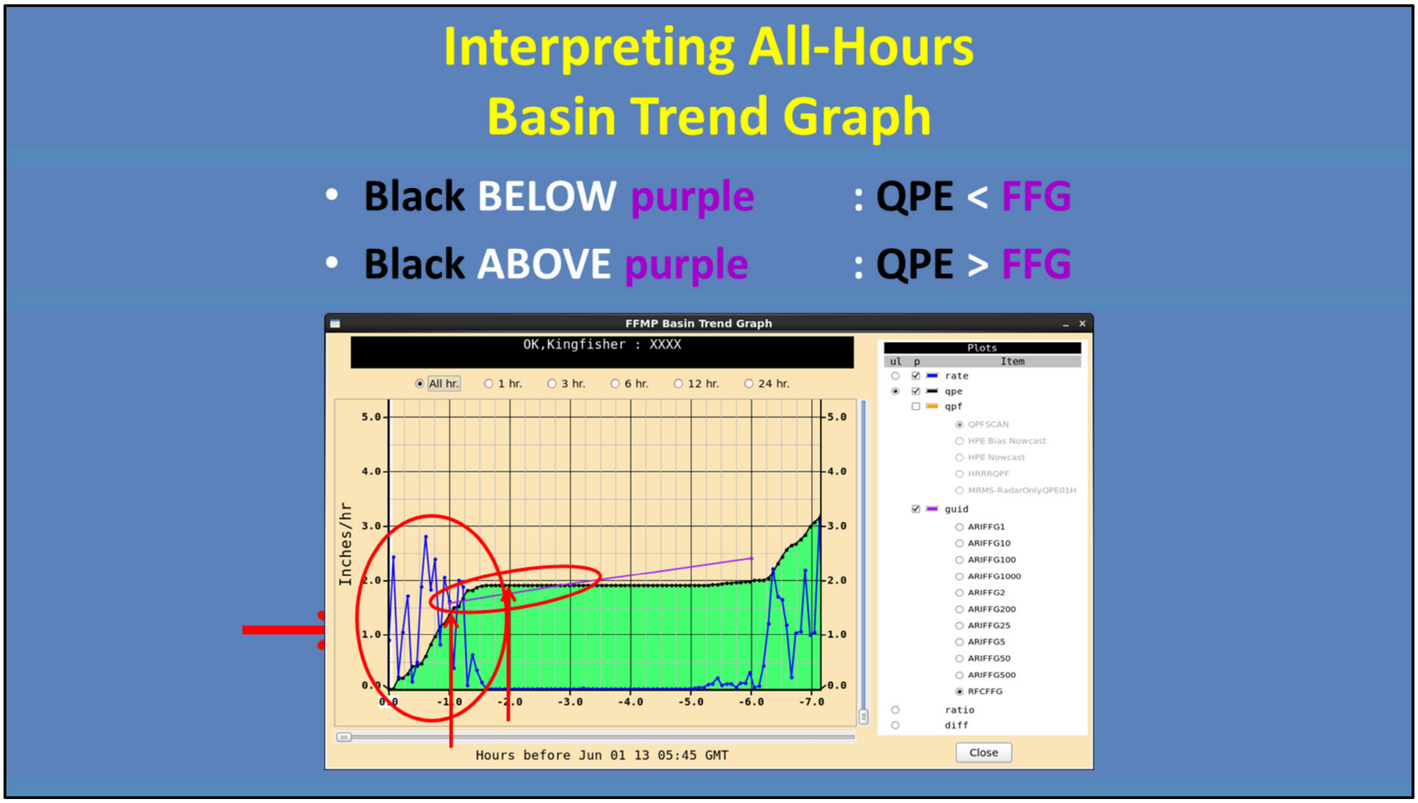


By this point you have zeroed in on the primary threat areas using Ratio and Diff and by monitoring rain rates. The next useful functionality in FFMP are basin trend graphs.

To load a Basin Trend, there are two options: First, you can load it by right-clicking on a basin name from the basin table. Second, you can set the Click menu option to "Basin Trend", then go to the D2D pane with FFMP and make the display "editable" (by middle clicking on the text in the legend), and then right-click on any basin in the display to load a basin trend for that basin.

Because there could be tens of thousands of small basins in your localization, it is best to focus on basins that: 1) have the greatest current or projected threat; 2) perhaps those basins that might significantly impact the general public (like urban basins); or 3) basins in a National Park that normally contain numerous hikers and campers.

Basin trend graphs are critical to interpreting information on the timing and relationship between the QPE and guidance for different durations. And with time, you will become more familiar with using them. We'll start you off with an example on the next slide.



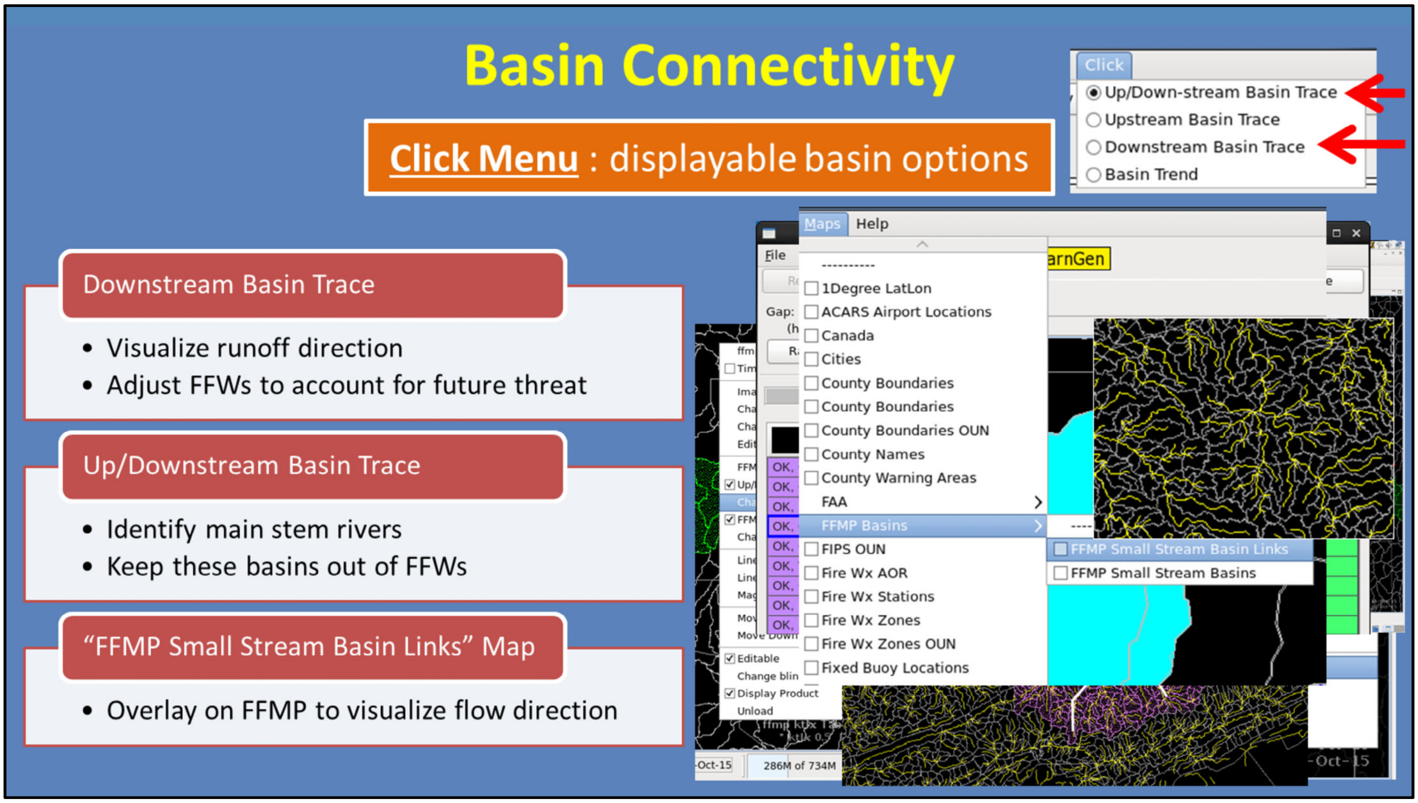
Okay, let's take a look at this basin, which is only three-hundredths of an inch away from exceeding the 3-hour FFG and is currently experiencing instantaneous rain rates of 0.89 in/hr. As a warning forecaster, I would like to know when within the three hours that 1.90 inches of QPE fell, so I right-click on the basin to load a basin trend graph shown here.

First, you want to look at the blue line, which is the instantaneous rate trend. Each blue dot represents the instantaneous rate for a particular volume scan. From this we see that rates of ~ 2 in/hr occurred primarily over the last 1.5 hrs, and there was no precip 3 hrs ago and 4 hrs ago.

Next, the black line is the precip accumulation for different durations. You will notice the accumulations increase every time there is an instantaneous precipitation rate > 0. The instantaneous rate is multiplied by the volume scan time step in order to increase the accumulation. To interpret this line, we see about 1.3" has accumulated over the 1-hour duration, while 1.9" have accumulated over the most recent 2-hour duration. We see the 1.9" accumulation lasts through the 5-hour duration, because there was no precip falling between 2 and 5 hours ago.

Finally, there is the purple line, which shows FFG for the 1-, 3-, and 6-hour durations. Whenever the black QPE line is BELOW the purple FFG line, QPE is less than FFG for that duration interval. When the black line is ABOVE the purple line, QPE is greater than FFG. Here, QPE is always below FFG, except for durations between 1 and 3 hours where FFG is exceeded by about 0.25" for the 1.5-hour duration. This may be enough to cause flash flooding, particularly since the instantaneous rates are continuing at the current time, and the longer duration FFG values (like 3- and 6-hour) are going to be exceeded more and more as that continues.

Now we're going to take a few minutes and let you have some practice with basin trend graphs. The following quiz is NOT graded.

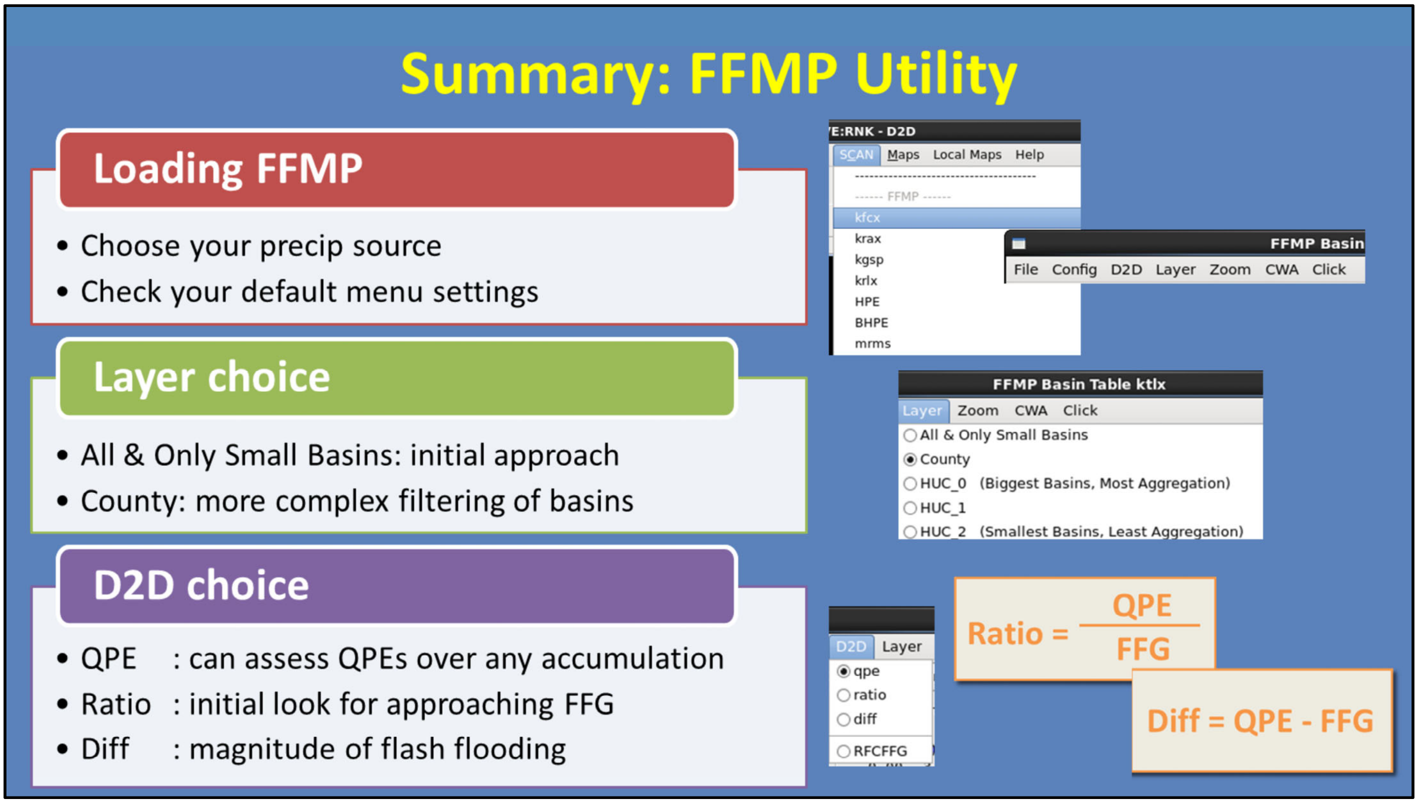


Finally, FFMP allows you to see basin connectivity on the D2D display as configured in the "Click" menu. Once you have pinpointed your current threat area, it is important to look downstream to see where the runoff will go. If the current accumulation is great enough and the downstream basins are flashy, those downstream basins can have flash flooding even without receiving a drop of rain. Knowing this can help you adjust your warning polygons to account for the future threat.

To do this, simply select "Downstream" from this menu, and then go to the D2D display and make the FFMP display editable. Once editable, your right-click button will highlight all basins downstream of the basin you selected. If it is hard to see the highlighting, you can change the color of the trace, like I did to green. And whenever you want to get rid of your trace or change the type of trace, simply "Clear Trace" on the FFMP Table.

Additionally, you may want to identify major main stem rivers. Since they typically don't *flash* flood, this may help you pull basins out of your warning. To do this, use the upstream and downstream option from the menu. Here is an example where the star denotes the selected basin. You can see the large area upstream of the basin that is feeding into that point. And then where it goes downstream to the north.

Finally, you can also visualize flow by overlaying the "FFMP Small Stream Basin Links" from the Map menu in D2D. I made them yellow in this graphic.



Because FFMP has a number of unique strengths, we focused this lesson on using it to its fullest in flash flood warning operations.

First, when loading FFMP, make sure to follow the guidance in the "Choosing Your Precip and Guidance Sources" lesson to consider all of your available precip sources. Also, make sure the menu settings across the top of the FFMP table are what you would like.

Next, start using the All & Only Small Basins layer to identify areas where QPE is approaching or exceeding FFG. You may change to County layer when you need more complex filtering of basins in the table.

Within FFMP, D2D can be configured to show any one of three options. QPE allows you to assess things like HPE, Bias HPE, and MRMS accumulation durations that aren’t usually readily available. The ratio product is one the best ways to identify areas of flash flooding threat so we recommend starting there, and using Diff to help assess the potential magnitude of flash flooding.

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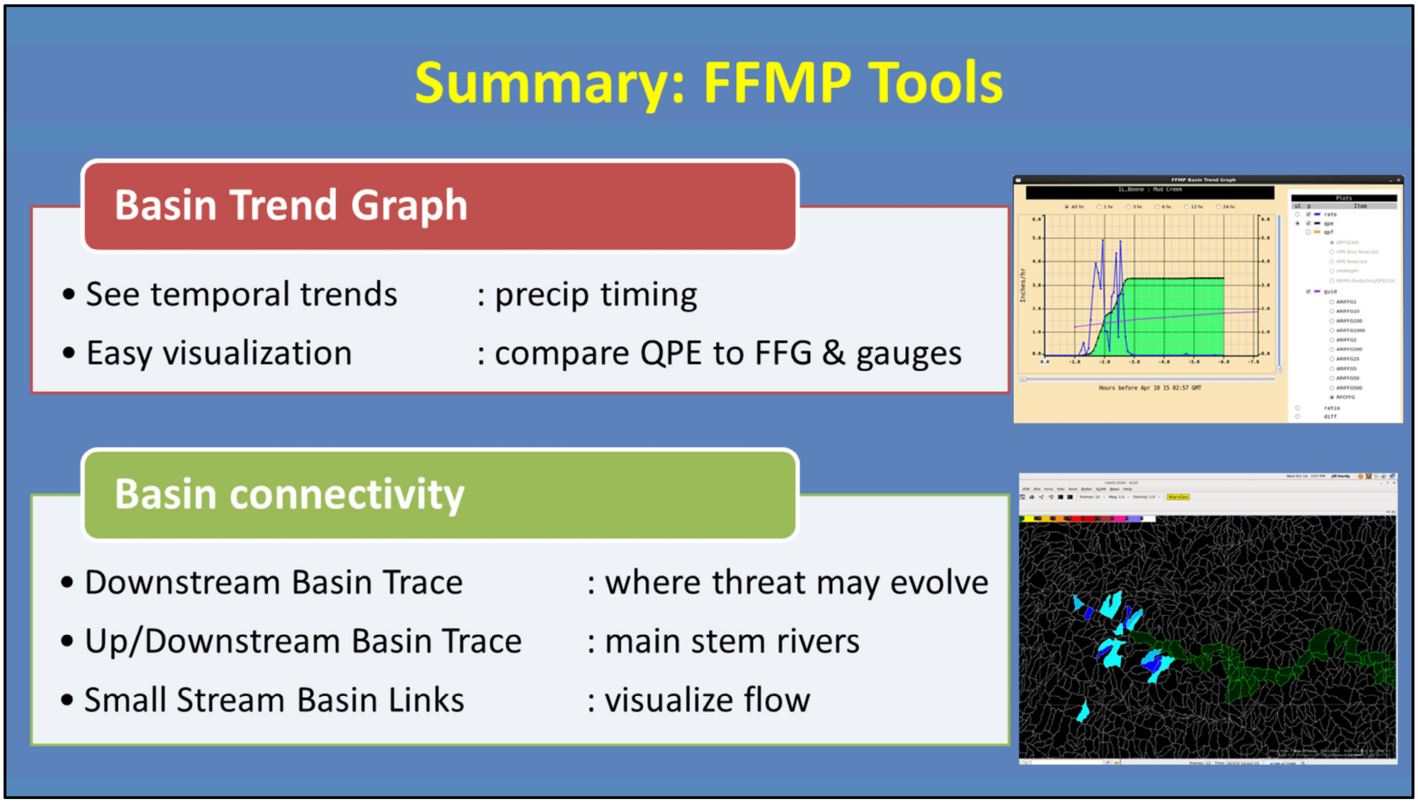


FFMP has a lot of useful functionality, as long as you know how to use it.

The Basin Trend Graph allows you to see temporal trends for rainfall rate, accumulation, and Flash Flood Guidance for a selected basin. As well as, provides easy visualization when comparing QPE to FFG, and to gauges when using VGBs.

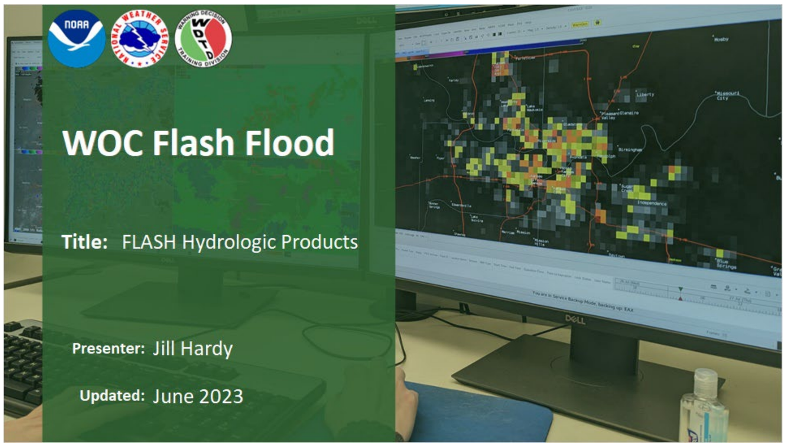
FFMP also has basin connectivity features to help identify where the flash flood threat may be evolving, where main stem rivers exist versus headwaters, and how to visualize flow outside of FFMP.

This concludes this lesson. When you are ready, please move onto the next slide to take the quiz and receive credit on the LMS.

FLASH Hydrologic Products

1. Introduction

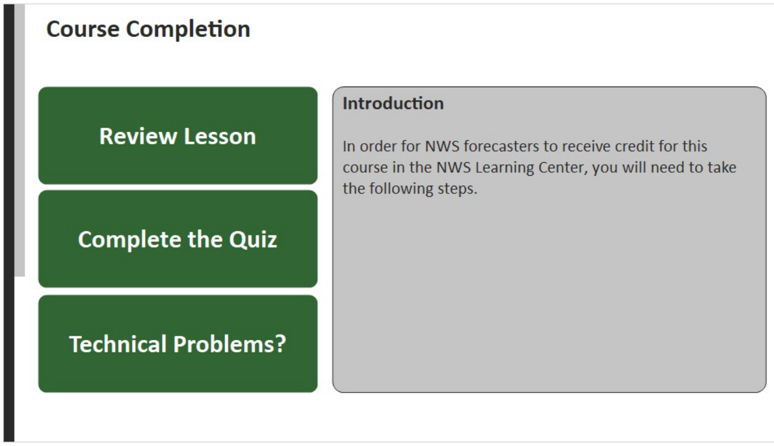
1.1 FLASH Hydrologic Products



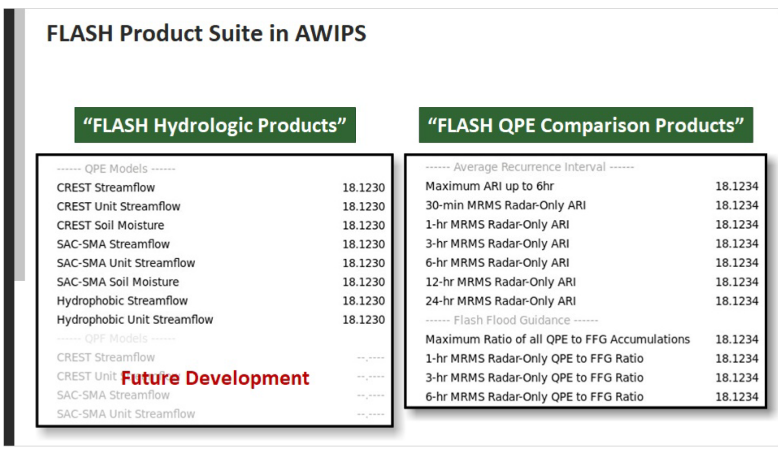
Notes:

Hi, my name is Jill Hardy and welcome to the FLASH Hydrologic Products lesson. In this lesson, we will provide some background in the creation of the hydrologic products in FLASH, as well as the applications for using them in flash flood operations.

1.2 Course Completion



1.3 FLASH Product Suite in AWIPS



Notes:

Before we begin, here is the entirety of the FLASH product suite in AWIPS. In this lesson, we will focus on the hydrologic products. But please visit this lesson to learn more about the QPE comparison products.

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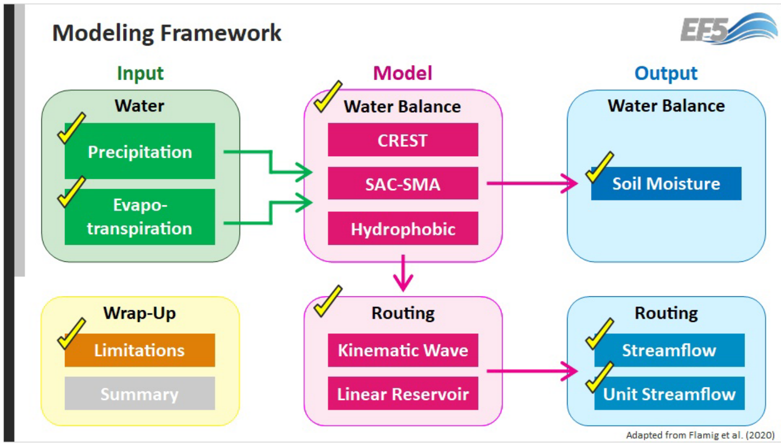
2. FLASH Hydrologic Products

2.1 EF5 Framework



Notes:

To help us better understand the FLASH system and its suite of products, we're going to use its modeling framework as our roadmap. That framework is called EF5 or the Ensemble Framework for Flash Flood Forecasting. EF5 is a platform that allows multiple hydrologic models to be run using a common set of inputs to produce a common set of outputs. For the FLASH project, EF5 was configured as shown for the needs of the National Weather Service and will be the focus of this lesson. But to learn more about EF5 in general, please check out their website and paper linked in the References section.

Alrighty, so let's talk through this schematic of the FLASH system. Notice the inputs…Precipitation and evapotranspiration. Together, they provide the estimated amount of water that must be accounted for at the surface. To do this, water balance models are used. Water balance models try to model things like how much water infiltrates into the ground versus runs off at the surface. Additionally, they model how much of the subsurface water is stored away towards the soil saturation and how much is turned into below-ground excess (also known as interflow). But once these water balance models provide the amount of runoff, that water has to go somewhere. That’s where the routing schemes come in. These schemes use various elevation maps and flow direction maps to model where the water is going, how fast it will get there, and the magnitude of the flow. The result is what you’re used to hearing about…discharge or streamflow. This streamflow is calculated at every grid cell, taking into account water coming in from every upstream cell, as well as what’s getting sent into the downstream cells. And unit streamflow normalizes the flow by the area that feeds each grid cell, and we’ll talk more about that later.

Now that you’ve seen the big picture, we’re going to spend the rest of this lesson talking through the different pieces of this process that can affect how you use and interpret FLASH products. We will begin with the inputs. Please select one to move on.

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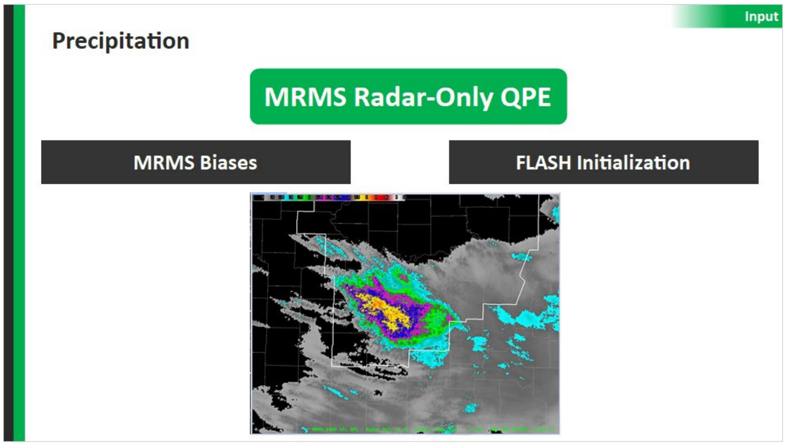
2.2 Precipitation



Notes:

Since flash flooding is predominantly triggered by heavy rainfall, FLASH relies solely on radar-estimated rainfall – or QPE – as its precipitation input. Regardless of the model being used, the precip input is always the MRMS radar-only QPE, which updates every 2 minutes. Please click on the black boxes to learn more.

QPE BIASES: Since MRMS is the only rainfall feeding the system, its biases directly impact the FLASH system. This is very important for understanding the FLASH suite of products. If MRMS QPE is underestimating, that's going right into FLASH. If it's overestimating, it's going right into FLASH. We harp a lot on understanding your precip sources and their biases, and this is another reason why. It'll help you better interpret your FLASH output. So a best practice, as always, is to compare your MRMS QPE to observations when you can. Additionally, review the lessons below to understand more about the MRMS QPE system and how to assess its biases in the absence of ground truth.

INITIALIZATION: So how is the FLASH system initialized with this rainfall information? FLASH is run every 2 minutes using MRMS QPE to create the ARI and Ratio products. For computional reasons, the hydrologic products run every 10 minutes, but that could get faster in the future. For each initialization, the prior 30 minutes of MRMS rainfall rates are input into the system. Now, this may not seem like a lot of rainfall – and it isn't. The way FLASH gets around being too computationally expensive is what's known as a "hot start". Instead of running the models for a really long time to lead up to the current time, model states are saved – such as soil moisture – and used as a starting point. So as an example…The current time is 03Z. FLASH takes MRMS rainfall rates from 0230-0300Z as its precip input. Additionally, the 0230Z run of the system is used to "hot start" the underlying hydrologic parameters. This method keeps the FLASH system to a roughly 8-minute latency, meaning our 0300Z products will come out around 0308Z. This is why the FLASH system is so useful in flash flood operations, because of its short latency.

But that's not to say there aren't limitations to the system.

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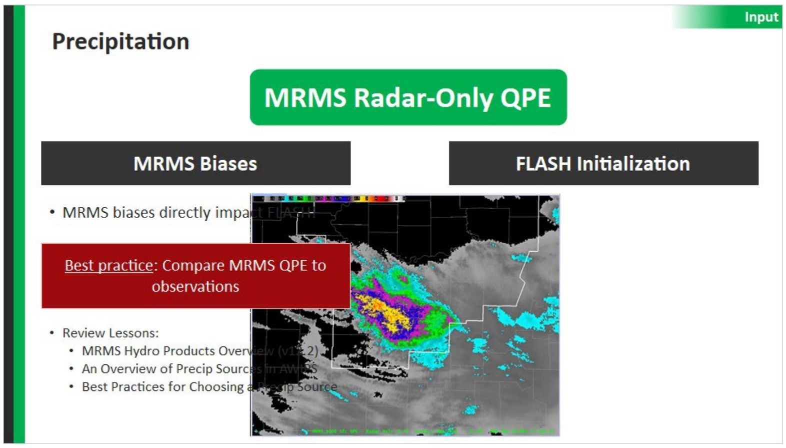
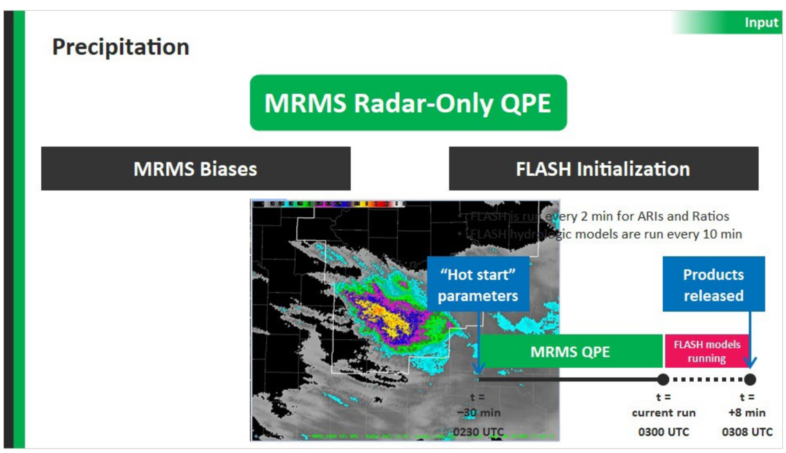
In order to run so quickly and over the whole domain, many assumptions have to be made within the model states. We'll touch on those later.

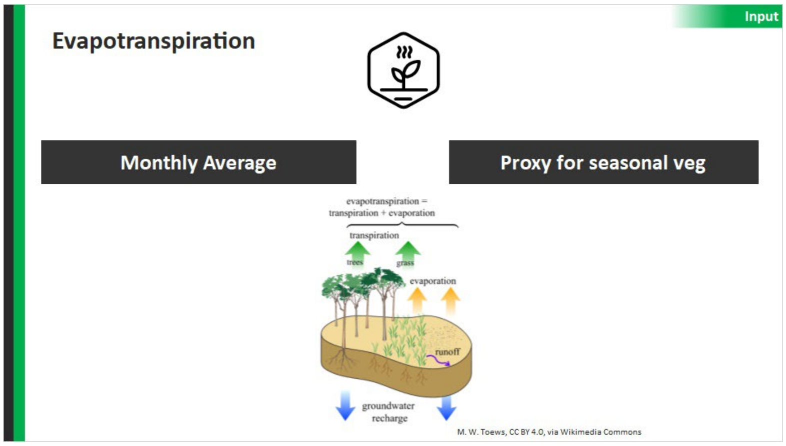
MRMS Biases (Slide Layer)



FLASH Initialization (Slide Layer)



2.3 Evapotranspiration



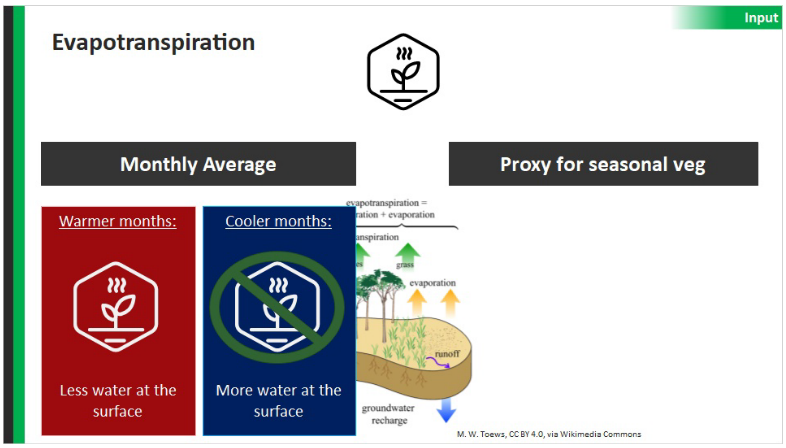
Notes:

Besides QPE, evapotranspiration (or ET) is the only other factor that impacts the amount of water that makes it through the system. Here are a couple tips for how ET can impact what you see in FLASH.

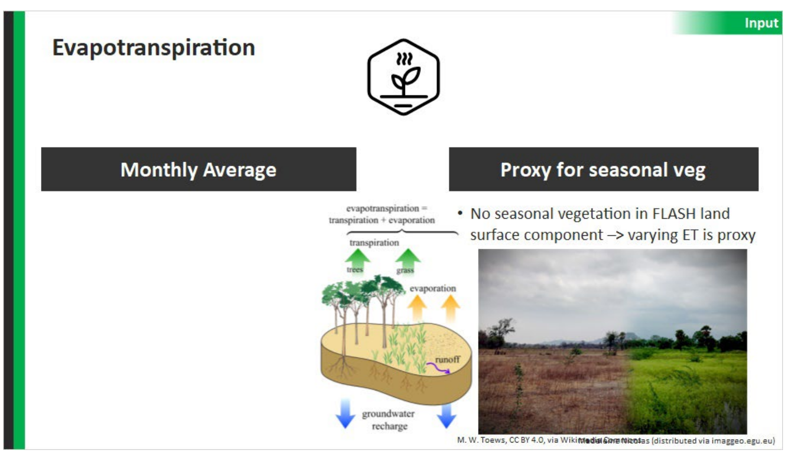
MONTHLY AVERAGE: First, the ET used in FLASH is a monthly average. This keeps the computational time down, but it simplifies the process. In warmer months, ET will cause water losses into the atmosphere thus decreasing what could turn into runoff. In cooler months - when vegetation is dead or dormant - ET does not sweep away this moisture, thus allowing for more to reach the ground.

PROXY: With that in mind, ET is the best proxy for seasonal vegetation that the system has. Due to computational reasons, the system doesn't account for seasonal vegetation in the land surface component, but it does allow for varying ET throughout the year and based on location.

Monthly Average (Slide Layer)



Seasonal Veg (Slide Layer)



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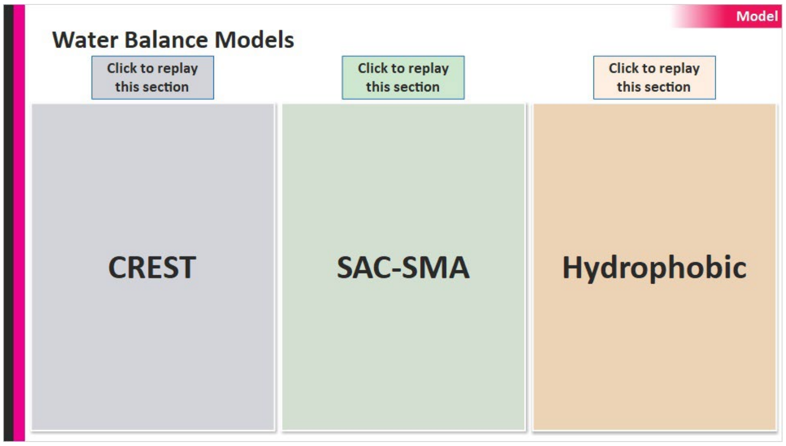
2.4 Water Balance Models



Notes:

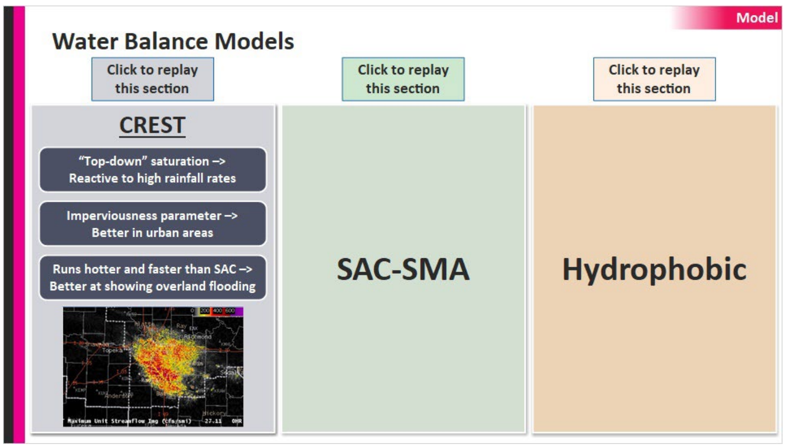
The next step in the system is to feed the initialization details – including rainfall – into the water balance models. Recall that these models simulate how the water is infiltrated and/or runoff at each grid cell. In order to do so quickly – and at large scales – these models are all conceptually based, meaning they rely on predetermined parameters guided by various physiographic properties. We aren't going to discuss the specifics of the models here, so please refer to the references to learn more. Click on each model to see how it impacts the FLASH system.

CREST: CREST has a "top-down" saturation method, meaning it generates runoff from what can't infiltrate at the surface. This means CREST is quite reactive to high rainfall rates because they will quickly exceed the infiltration capacity of the soil. Additionally, it has a "percent imperviousness" parameter which helps the model take into account urban areas that have less infiltration capacity. So if your CWA has urban footprints that are susceptible to flash flooding, CREST is more likely to do better in these areas. Because of these features, CREST runs a little hotter and faster than SAC, and does a better job showing a quick ponding response, also known as overland flooding. This quick response gives you a great first guess on areal coverage of potential flooding.

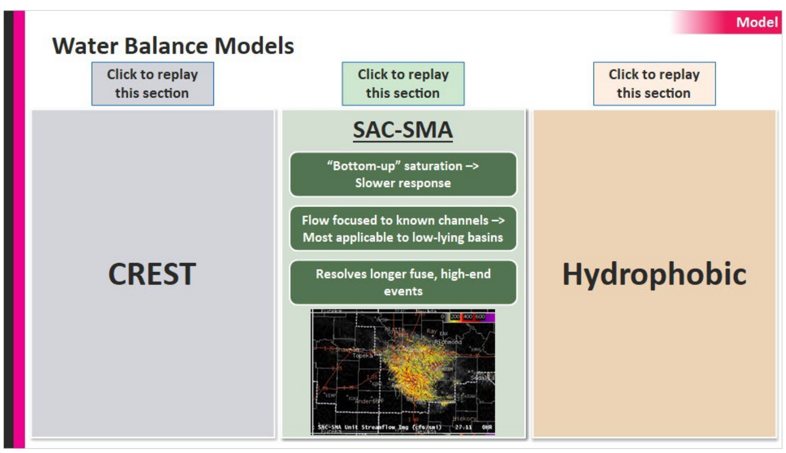
SAC-SMA: SAC-SMA was included in the system since it is a model used by some RFCs. SAC differs from CREST in that it saturates from the bottom up, meaning it generates runoff from the excess after the soil has reached saturation. Because of this, SAC-SMA tends to have a slower response. And that flow tends to be more focused in known channels. It may be most applicable to natural low-lying basins. But it is good at resolving slightly longer fuse, high end flash floods.

HYDROPHOBIC: The Hydrophobic model is actually the CREST model except it does not allow any infiltration into the underlying soil layers. It is more-or-less the “worst case scenario” model, where all rainfall turns into runoff. In this sense, it will almost always show a response, and usually a little earlier than the other two models. So if you're interested in visualizing the initial response or where the potential flood wave may go, the hydrophobic model could be useful. Also, areas with burn scars may find that the hydrophobic model best captures the threat.

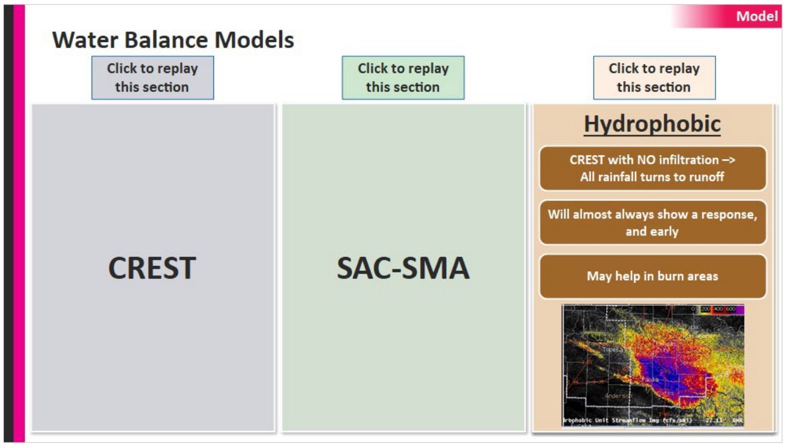
CREST (Slide Layer)



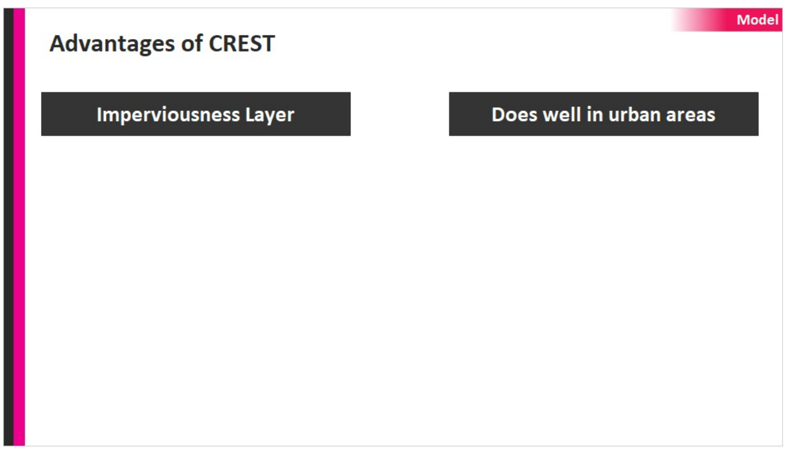
SAC-SMA (Slide Layer)



HP (Slide Layer)



2.5 Advantages of CREST



Notes:

As discussed on the previous slide, between CREST and SAC, CREST will oftentimes show the faster overland response. For flash flood operations, this an important feature that has caused us to lean into the CREST model as our preferred model. Let's briefly touch on a few reasons why.

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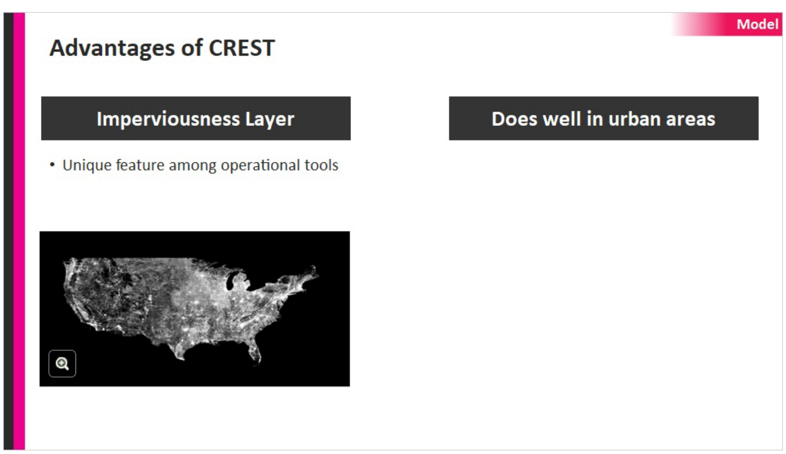
IMPERVIOUSNESS LAYER: First and foremost, the CREST model has a percent imperviousness layer. This is a unique feature among operational tools, including the RFC flash flood guidance (FFG) products. Here is an image of the layer, produced from the National Land Cover Database. The link to download it is in the Resources.

URBAN AREAS: In part due to the imperviousness layer, CREST does well in urban areas, as been shown in Gourley et al. (2017) and Gerard et al. (2021), both linked in the Resources. In particular, Gerard et al. used the latest Dual-Pol based MRMS QPEs, making it the most relevant study for what's currently available in operations. It found that CREST Unit Streamflow hit warning criteria within 30-40 minutes of the onset of heavy rain rates, with peak values within 50-70 minutes.

Imperviousness (Slide Layer)



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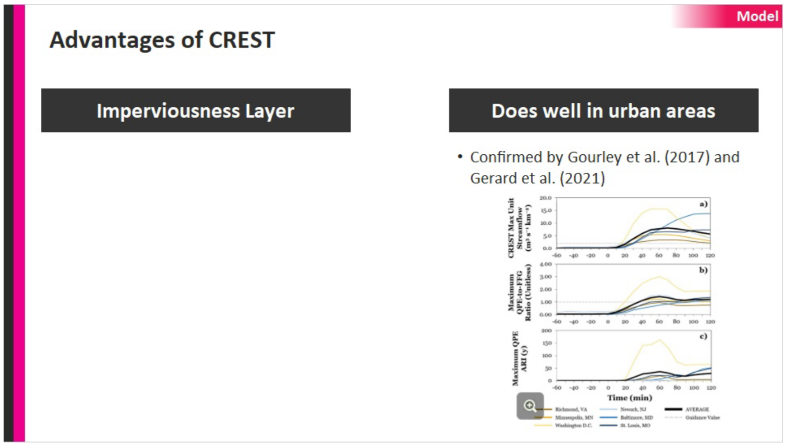
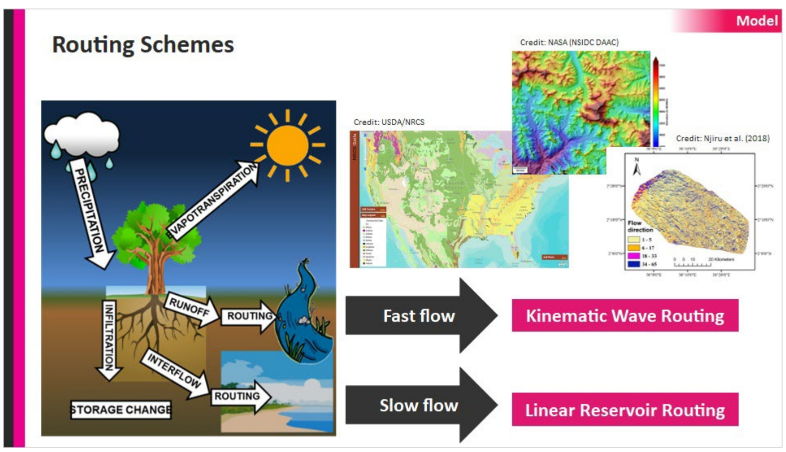
Urban Areas (Slide Layer)



2.6 Routing Schemes

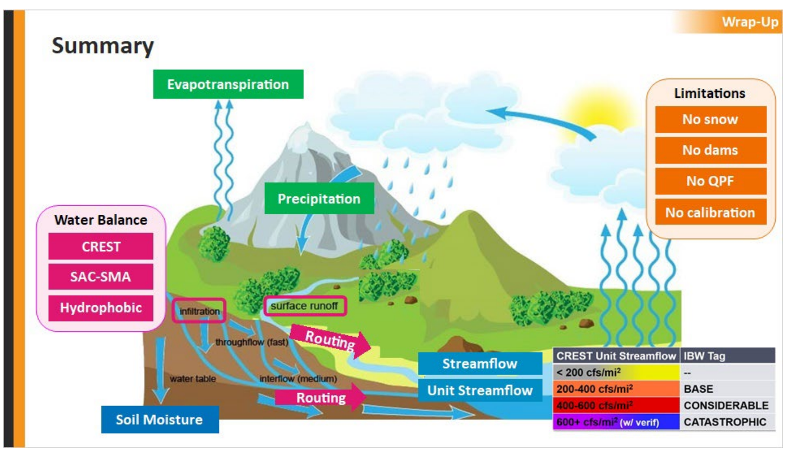


Notes:

Once each water balance model creates an estimate of the amount of excess water for each grid cell, it must route that water downstream. To do this, the models provide two types of flow. The first is “fast flow”, or excess water that routes quickly on the surface (i.e. runoff). The second is “slow flow”, or excess water that routes below the surface (also called interflow). Each of these flow types is modeled differently, so I’ll leave the details for the interested reader.

But in order to get the proper flow, details related to both the basin geometry (such as basin area and slope), as well as ground characteristics (such as soil texture and soil depth) are modeled. Additionally, digital elevation maps (DEMs), flow direction maps (FDMs), and flow accumulation maps (FAMs) determine flow speed and direction.

2.7 Summary



Notes:

So let's summarize using a more real-life diagram of the water cycle. This represents the EF5 system.

We begin with our inputs…Precipitation (in the form of MRMS QPE) and evapotranspiration (in the form of monthly averages) provide the estimated amount of water reaching the surface. Once the water reaches the surface, it is modeled using three water balance models – the CREST, SAC-SMA, and Hydrophobic. These models attempt to determine how much of the water infiltrates into the ground and how much runs off at the surface. And each one does it slightly differently. As part of this process, the Soil Moisture product is created by both the CREST and SAC-SMA models. This product shows how saturated each grid cell is, which can help you determine how much more water the ground can take on. Areas with high soil moisture tend to react more quickly to additional rainfall because their “buckets” are near full. Next, the system uses a couple routing schemes that help move the surface runoff and interflow downstream. These schemes use various elevation maps and flow direction maps to model where the water is going, how fast it will get there, and the magnitude of the flow. The final result is the Streamflow product which can be used to visualize main steam channels and downstream direction. From that, the Unit Streamflow product is created by normalizing by basin area. This helps you focus on high flow in smaller basins, and is the most useful product for diagnosing and warning on flash floods. Using the recommended thresholds for flash flood warnings has proven successful nationwide, but always calibrate to local differences.

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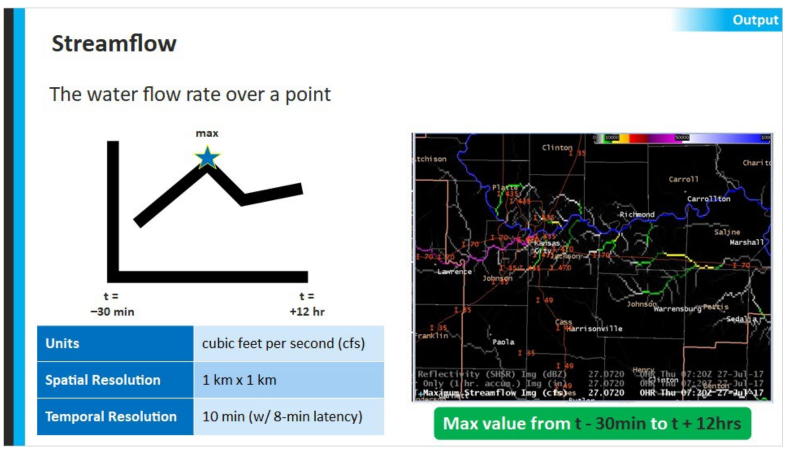
While the FLASH hydrologic products have proven useful in operations, there are some limitations to be aware of, such as no snow, dams, QPF, or calibration in the system. But with that, you are done with this lesson! Feel free to review any material before moving on to take the quiz and receive credit on the CLC.

2.8 Streamflow



Notes:

The final result is discharge, or as we call it, streamflow, which is defined as the water flow rate over a specific point. As such, it is given in cubic feet per second (or cfs).

The main purpose of this product is to model streamflow, similar to what you see in hydrographs.

In the FLASH product suite, the streamflow product displays the maximum value anywhere between the

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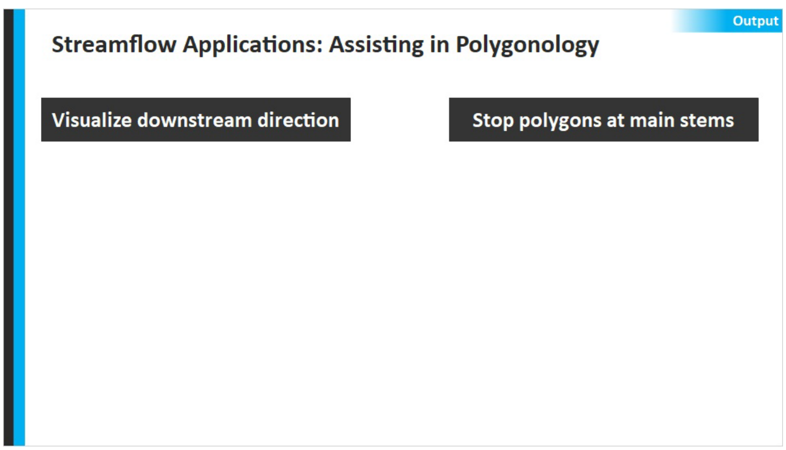
period of -30 minutes prior to valid time to up to 12 hours after valid time based on the runoff and routing of the model. This allows you to see the highest output from the model at every pixel up through the next 12 hours to help you get ahead of any short term flooding.

Take this example in the Kansas City metro. With our recommended colormap, you can see the main channels are highlighted. Especially the largest river – the Missouri – is in blue, with all of its tributaries feeding into it.

2.9 Streamflow (Applications)



Notes:

While not as useful for flash flood detection, the Streamflow product can assist in your Flash Flood Warning polygonology. Click on each to learn more.

VISUALIZE: For one, it's easy to visualize the downstream direction without opening a map layer or FFMP. Here's an example of the CREST Streamflow product with a colormap we've created that focuses your attention on the main stem rivers. From this, it is easy to see everything flowing into the Missouri River. Once you determine the downstream direction, you can use it to hedge your warning in the downstream direction. This can be particularly useful in areas where flash flood effects can be displaced from rainfall (like in the desert SW, for instance). So you will just have to learn how far downstream works for your area and its impacts.

STOP: It can also help you visualize main stem rivers to determine where to stop your warning polygon. In this example, notice how the strongest Unit Streamflow signal exists south of the Missouri River. Most of that is quickly entering the Missouri and will not pose a flash flood threat to any other downstream areas. So if we look at the town of Richmond, for example, and we assume the rain has moved out and there’s no more coming, then Richmond probably doesn't need to be in a warning. A best practice could be to have streamflow toggled with unit streamflow to help see this. Additionally, some offices overlay the FFMP stream links map to do the same thing.

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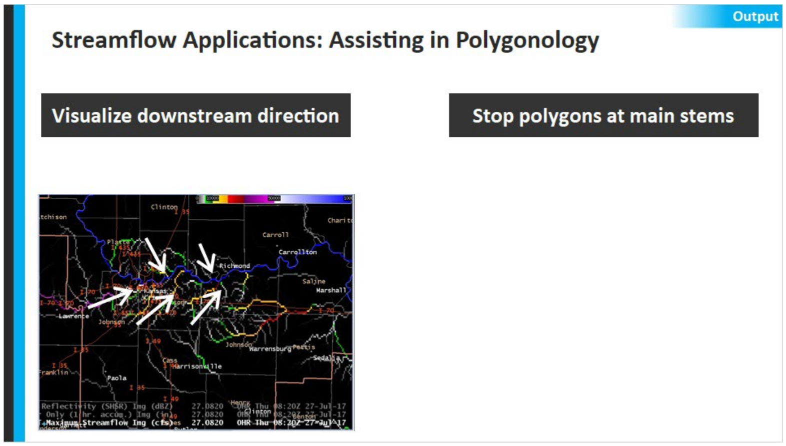
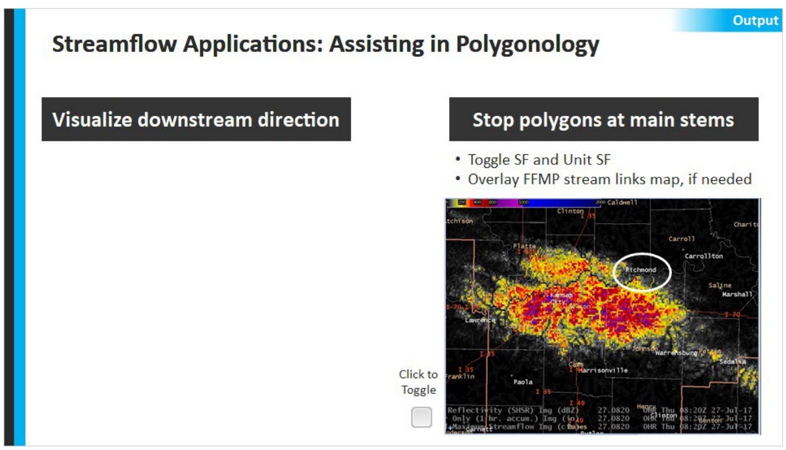
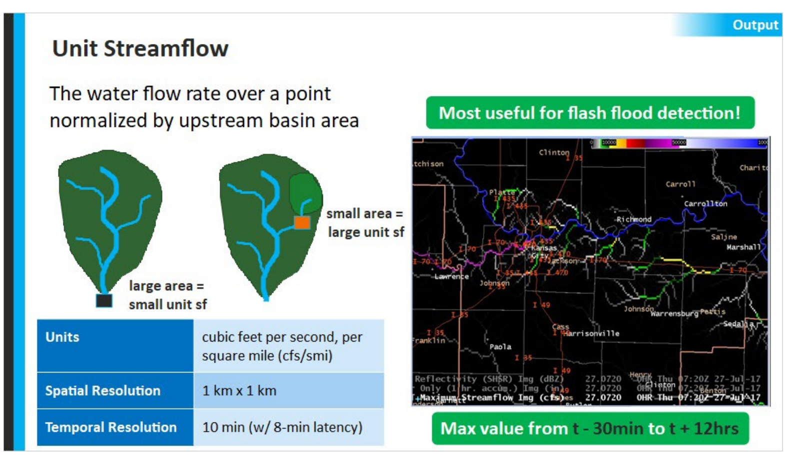
Visualize (Slide Layer)



Stop Polygon (Slide Layer)



2.10 Unit Streamflow



Notes:

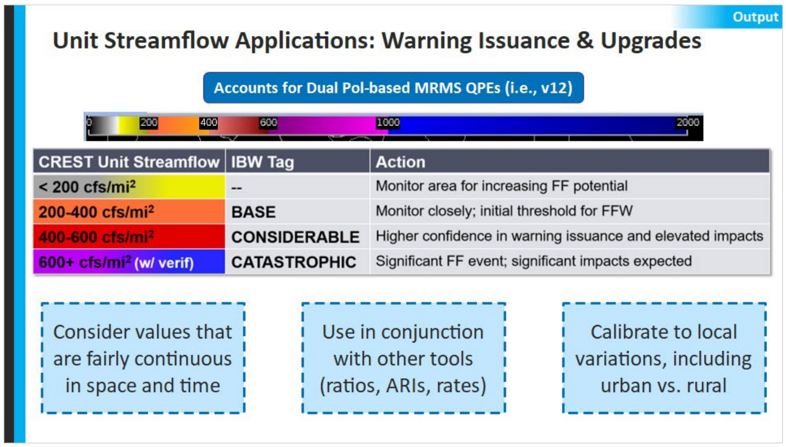
The Unit Streamflow product is simply the water flow rate over a point, normalized by the upstream basin area that feeds into it.

The main purpose of this product is to highlight more susceptible flash flood areas. Normalizing by basin size dampens the signal of major river channels, and focuses the signal on high flow in small basins. In this schematic, the black pixel would have to divide by that whole area feeding into it, making for a small unit streamflow value. But the orange pixel on the right only divides by a subset of the area. If a lot of rain was happening there, it could result in a large unit streamflow value.

Here is an example of Unit Streamflow. Notice how the Missouri River that was so prominent on the Streamflow product is now completely muted. Instead, our attention is brought to the smaller basins. These basins either usually don’t have flowing water or are so small that they react quickly to heavy rainfall. This makes the Unit Streamflow product THE most useful for flash flood detection.

Just like the Streamflow product, the Unit Streamflow you see is the maximum value for the period from minus 30 minutes prior to model runtime to 12 hours after model runtime.

2.11 Unit Streamflow (Applications1)



Notes:

Since the implementation of impact-based flash flood warnings, numerous studies have looked into using CREST Unit Streamflow criteria to inform IBW decisions. Below is the latest guidance from WDTD. It’s important to note that this guidance does take into account the use of Dual-Pol MRMS QPEs in CREST. This is meant to be a starting point, so please check with your local hydro focal point to see if your guidance deviates from this.

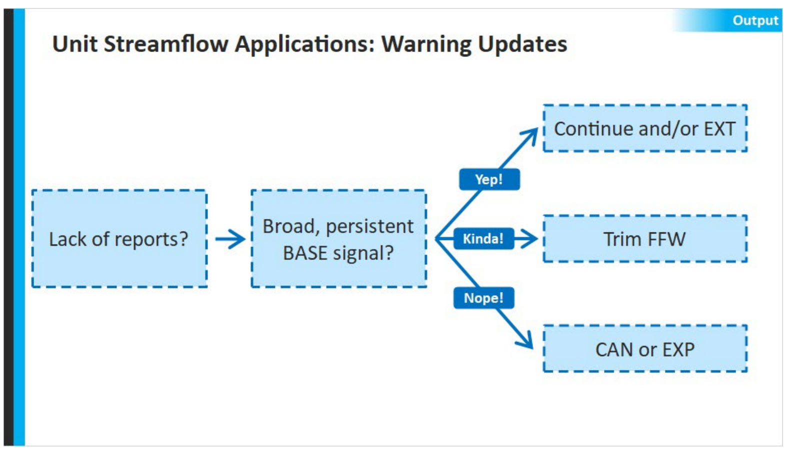
Now, in order to interpret these values properly in warning decision-making, there are some things to keep in mind:

--For one, ALWAYS look for these values over a fairly continuous area, and over a couple cycles. FLASH tends to look a little pixelated, so make sure to step back and look at the broader pattern while using the product.

--Next, always use Unit Streamflow in conjunction with other flash flood tools during your warning analysis. This can include ratios, ARIs, high rates, etc.

--And finally, calibrate yourself to local variations, including urban vs rural signals, as well as dry vs wet antecedent conditions.

2.12 Unit Streamflow (Applications2)

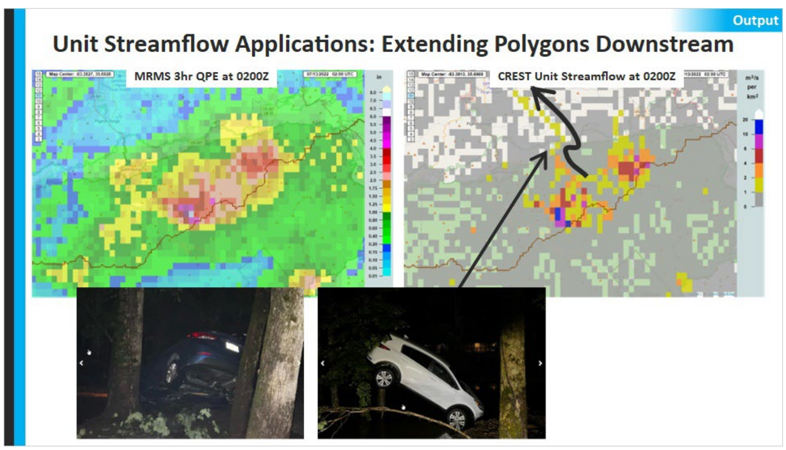


Notes:

In addition to giving you higher confidence in issuing or upgrading a warning, some WFOs have found CREST Unit Streamflow useful once the warning is already out, but you're not getting much verification.

Maybe it's the middle of the night and reports are hard to come by. Look at CREST Unit Streamflow to see if the BASE warning criteria is still being met. If so, let the warning ride. If not, you may consider ending the warning. Or, if some areas are, but others are not, you can consider trimming it down. But only do so if you don’t think those areas will ramp up again during the remainder of your warning.

2.13 Unit Streamflow (Applications3)



Notes:

The Unit Streamflow product can also highlight small basins experiencing anomalous impacts away from the main precip area. This is a result of normalizing by the basin area, as well as having good routing schemes that send the water downstream.

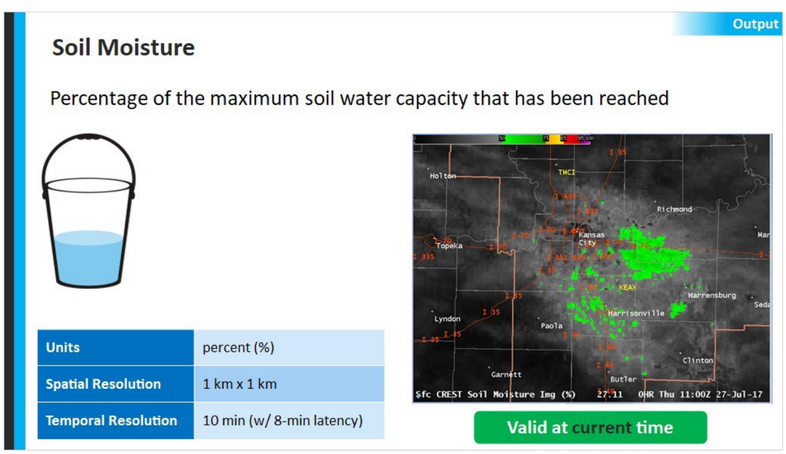
Take this example from July 2022. 3-hr MRMS QPEs totals were upwards of 6 inches in the Great Smoky Mountains.

When you look at CREST Unit Streamflow, notice the tell-tale “finger” coming out of the main signal to the north. This signal not only helps you identify downstream direction, but also how far downstream anomalous flow could be occurring. This could help you extend your polygon the right distance away from the core signal.

In fact, a campground at this location ended up having significant impacts from this event. Luckily, no injuries or fatalities.

Looking for this type of signal can be especially useful out west where impacts frequently occur far from the rainfall.

2.14 Soil Moisture



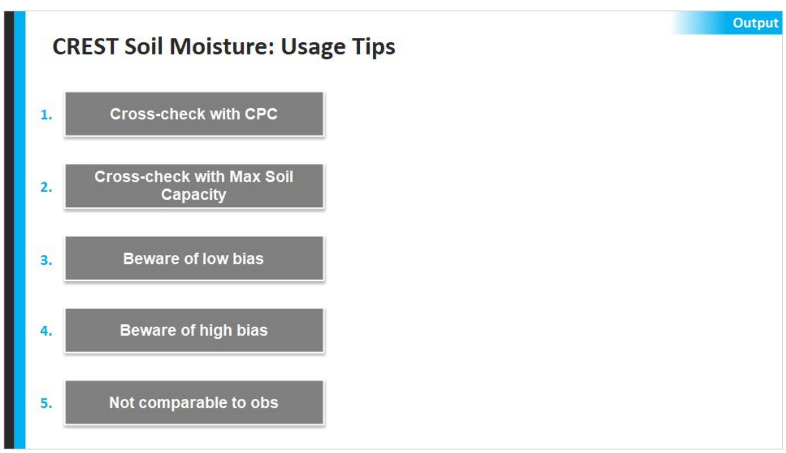
Notes:

The Soil Moisture product is the percentage of the maximum soil water capacity that has been reached for a given grid cell.

It can be thought of as a bucket that is filling up. Once the bucket is full, the grid cell is 100% saturated and cannot take on anymore water.

This product is generated after the rainfall has been put through the water balance models. It is simply a model state, valid at the current model run time. Therefore, it should not be interpreted as a forecast of soil saturation, just the here and now.

2.15 CREST Soil Moisture: Usage Tips



Notes:

Here are some extra tips for interpreting the Soil Moisture product.

CPC: If you are concerned about the accuracy of the Soil Moisture product, NSSL recommends you first compare it to the CPC product. It’s a good way to cross-check what you’re seeing.

WATER CAPACITY: If you’re interested in how quickly CREST may saturate in your area, check out the “Maximum Water Capacity” parameter. This parameter controls how much water is needed for a grid cell to fill up. Low values indicate shallow soil depth to bedrock, such as a mountainous area. It can be helpful to better understand whether you’re in an area that saturates quickly or slowly.

LOW BIAS: NSSL acknowledges a potential low bias with CREST Soil Moisture in the north and in the winter and spring months due to the lack of snow processes accounted for in the system.

HIGH BIAS: Alternatively, NSSL acknowledges a potential high bias in the winter months in areas that also have shallow soil depths. In the winter, evapotranspiration doesn’t get rid of as much moisture. So that moisture gets stored in the soils and doesn’t deplete as quickly. This can lead to high Soil Moisture values in areas where the soil column is shallow.

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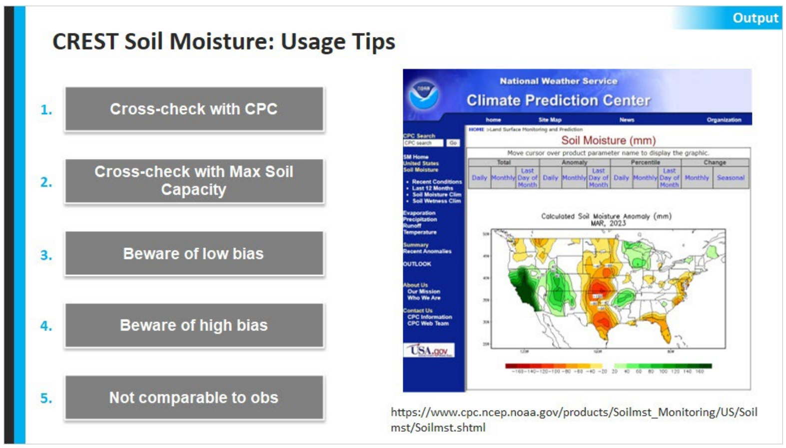
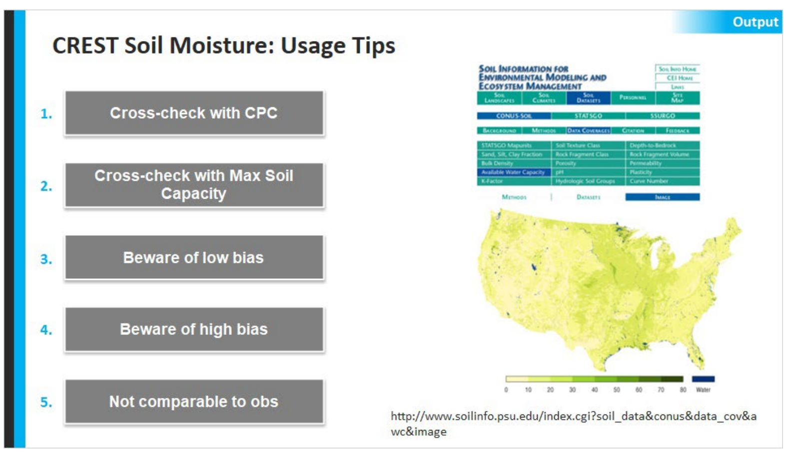
POST PROCESSING: The Soil Moisture product does not involve any post-processing, so it may not be representative of in situ, or remotely sensed soil moisture observations. You will just want to keep this in mind as the events unfold.

CPC (Slide Layer)



Max Soil Capacity (Slide Layer)



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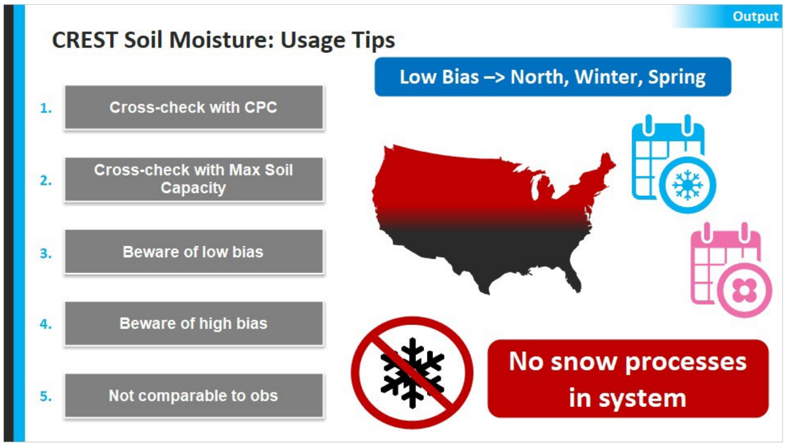
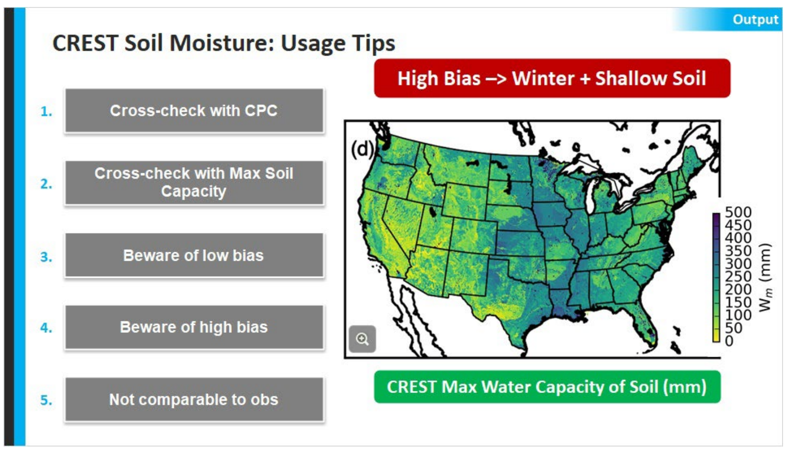
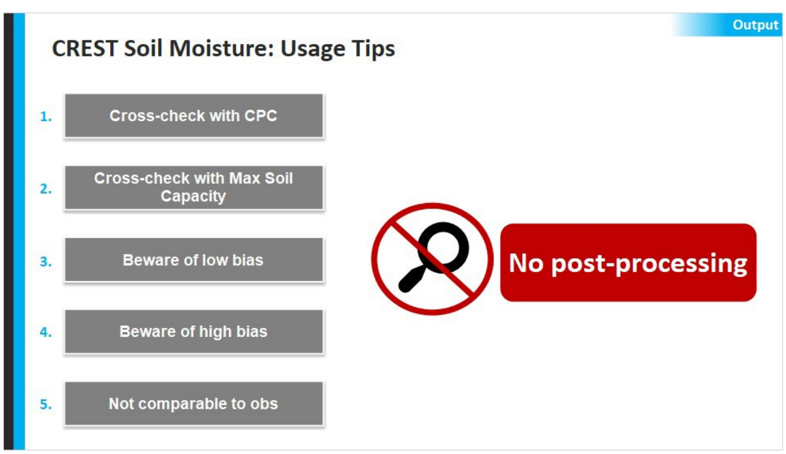
Low Bias (Slide Layer)



High Bias (Slide Layer)



Post Processing (Slide Layer)



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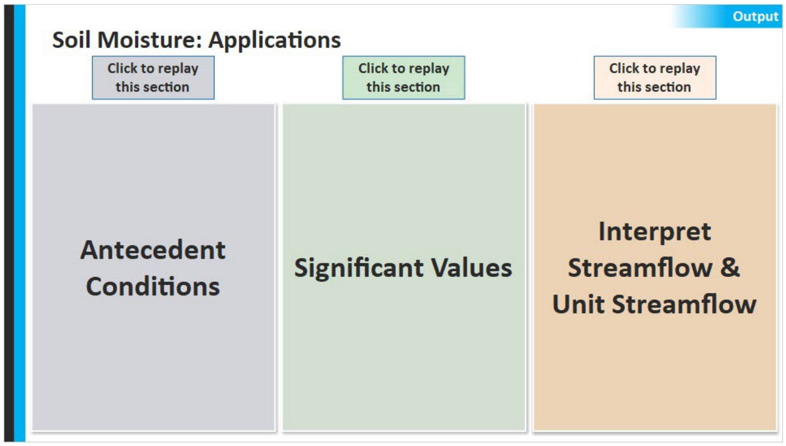
2.16 Soil Moisture (Applications)



Notes:

Click on each button to learn about applications of the Soil Moisture product.

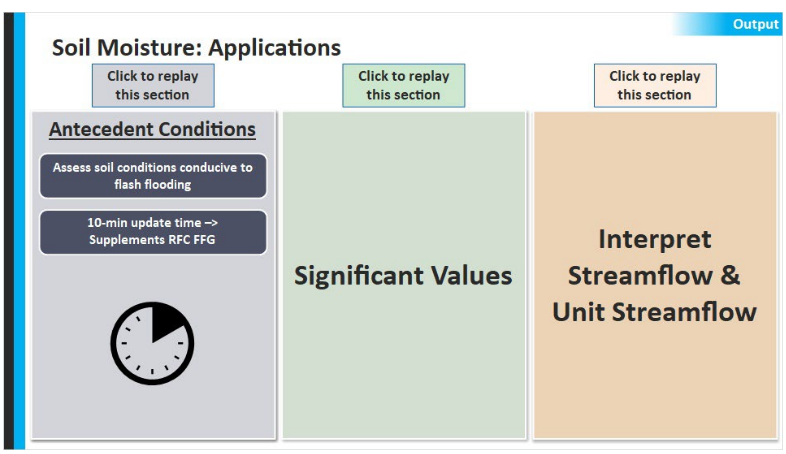
ANTECEDENT CONDITIONS: The primary application in warning operations is to diagnose the antecedent conditions conducive to flash flooding. Since it is a 10-min updating product, it is a great supplement to Flash Flood Guidance, which is usually only updated every 6 hours. In this sense, it may help you mentally extrapolate areas where FFG should be lowered, but isn't due to its slow update time.

SIGNIFICANT VALUES: Some offices have found that areas with recent or active rainfall will have values greater than 50%, which is a good threshold to consider for elevated flash flood threat. However, do not interpret the values exactly. This product is best used in a qualitative manner, to help you examine the spatial extent of saturated areas.

INTERPRET STREAMFLOW: It is also useful in interpreting the Streamflow and Unit Streamflow products. If you look at Soil Moisture first and find areas of higher saturation, then you can expect that additional rainfall in those areas will likely produce higher flows. This can help you get ahead of your streamflow signals.

So a quick best practice...Start by looking at the Soil Moisture to analyze antecedent conditions and expected streamflow response.

Antecedent (Slide Layer)



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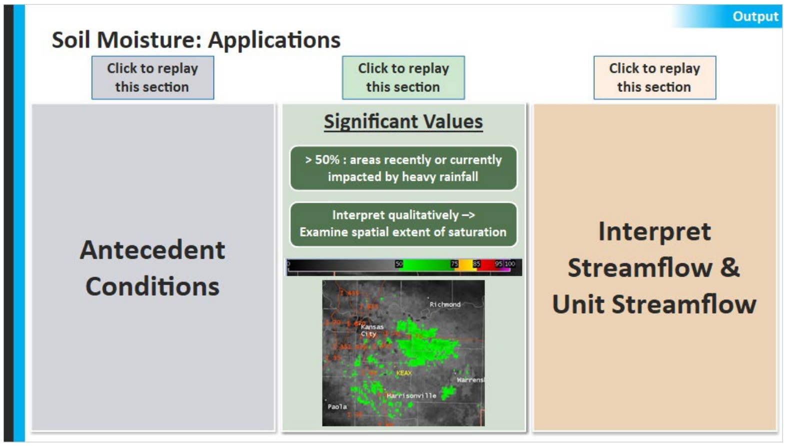
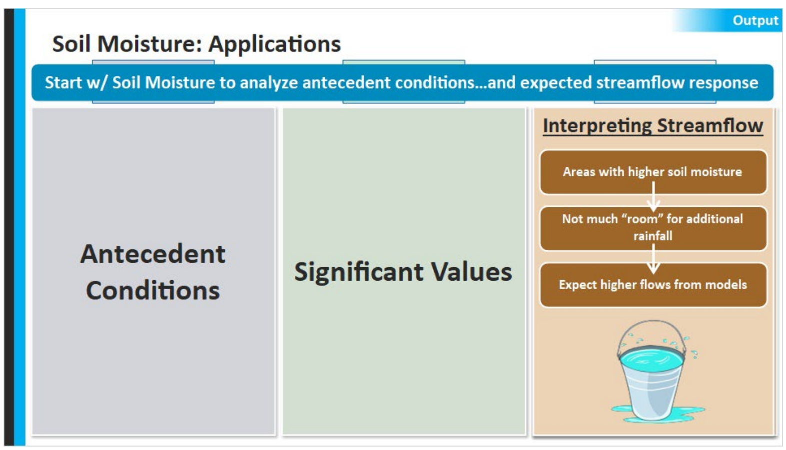
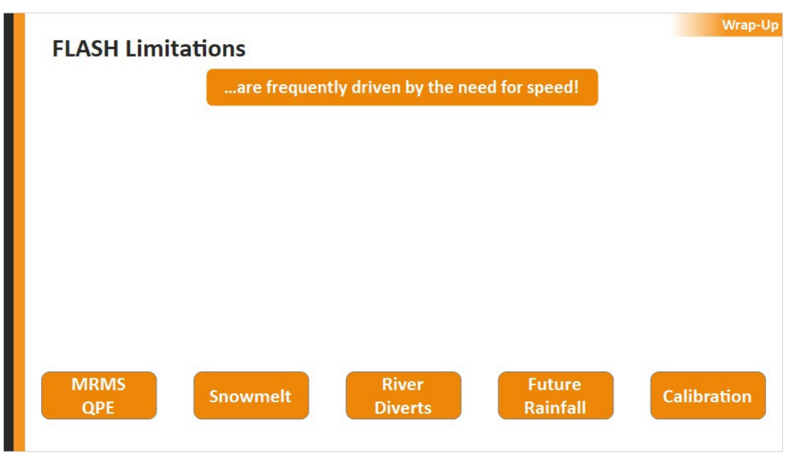
Sig Values (Slide Layer)



Interpret (Slide Layer)



2.17 FLASH Limitations



Notes:

There are some limitations of the system worth briefly discussing. Note that many of these limitations are driven by the need for speed. Running these complex models takes a lot of computational resources…which equals time. Just to run the hydrological processes we discussed in this lesson results in the minimum 10-minute updates. For flash flood diagnosis, there is a trade-off between latency and complexity. And it’s a tough balance. With that being said, please review the topics below.

MRMS QPE: As mentioned earlier, all of the limitations associated with MRMS radar-only QPE still apply. So please take the time to understand your MRMS limitations, as well.

SNOW MELT: In its current operational form, EF5 does not account for snow processes when modeling runoff. Therefore, things like snow pack, snow melt, and frozen soils are not modeled. This can have an impact both geographically – like in the high-elevations of the intermountain west – as well as seasonally. In fact, all water balance models tend to underestimate in the Intermountain West due in part to the lack of snow in the models.

REGULATED BASINS: The current version of the system also does not have dams or other human-created hydraulic structures in its calculations.

FORECAST RAINFALL: All rainfall forcing is shutoff at the initialization time. There is no QPF currently used in the system.

CALIBRATION: Modeled flow is not calibrated in realtime using actual streamflow data from the USGS gauging sites, so discrepancies between model flow and actual flow can exist. While a limitation, this was the intent of the system because the focus is on providing flash flood threat information in overland areas which do not typically have gauge instrumentation.

MRMS QPE (Slide Layer)

Snowmelt (Slide Layer)

Diversions (Slide Layer)

Forecast Rainfall (Slide Layer)

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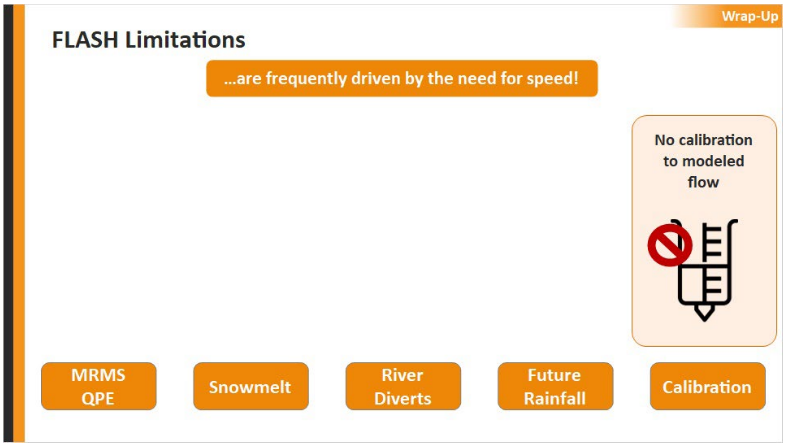
Calibration (Slide Layer)



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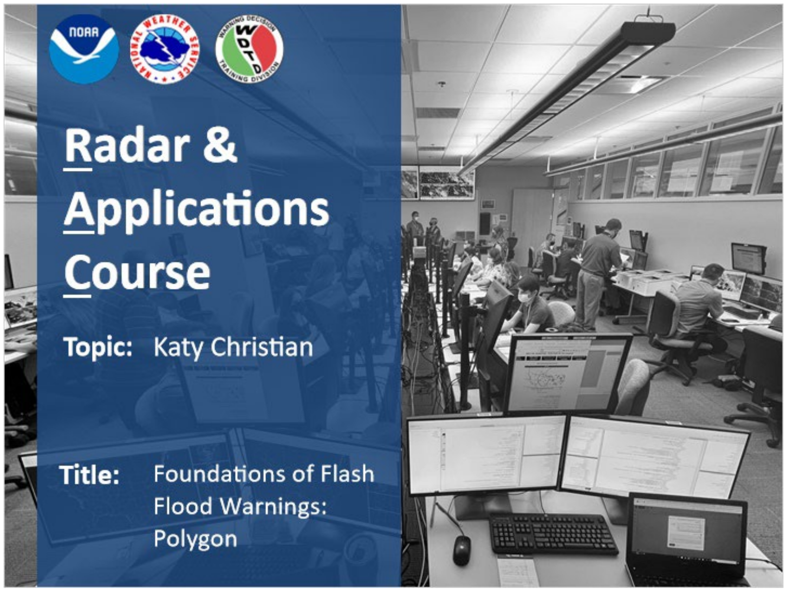
Foundations of Flash Flood Warnings: Polygon

Introduction



Notes:

Welcome to Foundations of Flash Flood Warnings! My name is Katy Christian and in this module, you'll get to practice the actual mechanics of issuing a FFW in a safe and controlled environment.

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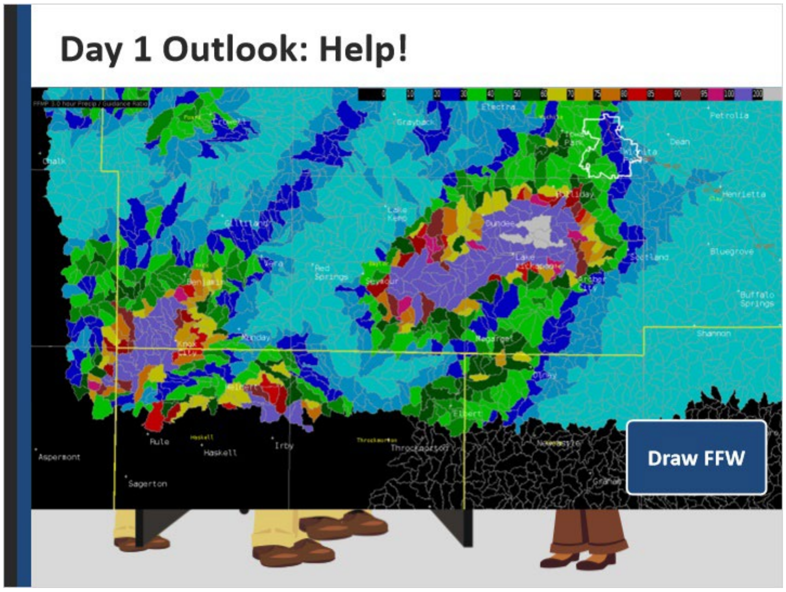
Day 1 Outlook: Help!



Notes:

So here's the situation: It’s your last day in a long-line of shifts before your much needed vacation but of course, it’s a severe+flash flood sorta day. You walk into work and your MIC says you’ll be working the hydro desk today due to staff shortages. The only problem is, it’s been a year and a few modules since you’ve worked hydro. After a brief internal panic attack, you quickly get to work and within a few hours, concepts from previous training are starting to trickle back slowly. It’s to the point now where on the severe side, all hell is breaking loose and keeping everybody else busy. Thinking you’ve been spared, you start to see the following signal in your FF bundle and you decide it’s time to get a FFW drawn up. Click on the “Draw FFW” button to be redirected to a GoogleSlide where you’ll get to practice drawing up a FFW given the shown signal. If you’d prefer to draw it up on paper, I’ve also attached a PDF to the Resources tab that you can print off to draw it up the old school way with your favorite pen or pencil. Regardless of whichever method you choose, once you’re done, come back to this slide and hit “next” to continue.

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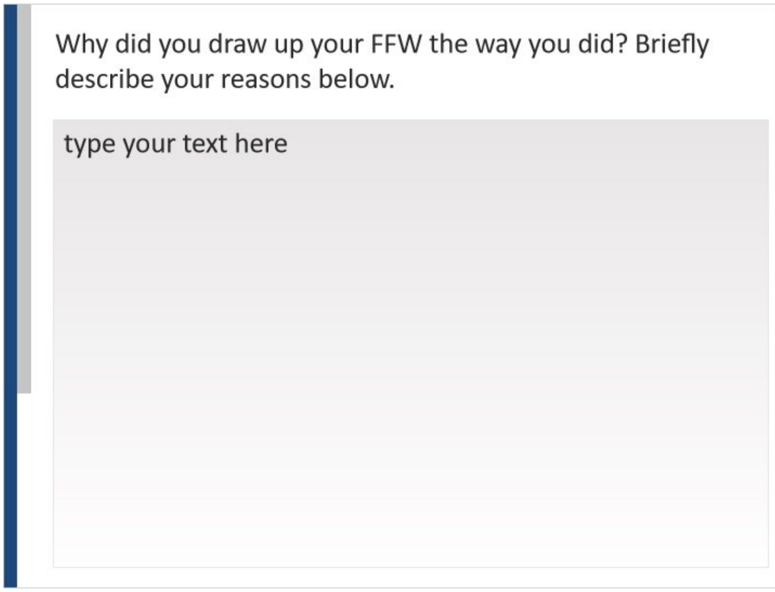
FFW Polygon: Survey



Notes:

Before moving on, I want you to explain why you drew up your warning the way you did. Note that these responses will be recorded so no gibberish or I'll know and you'll get coal in your weather ;)

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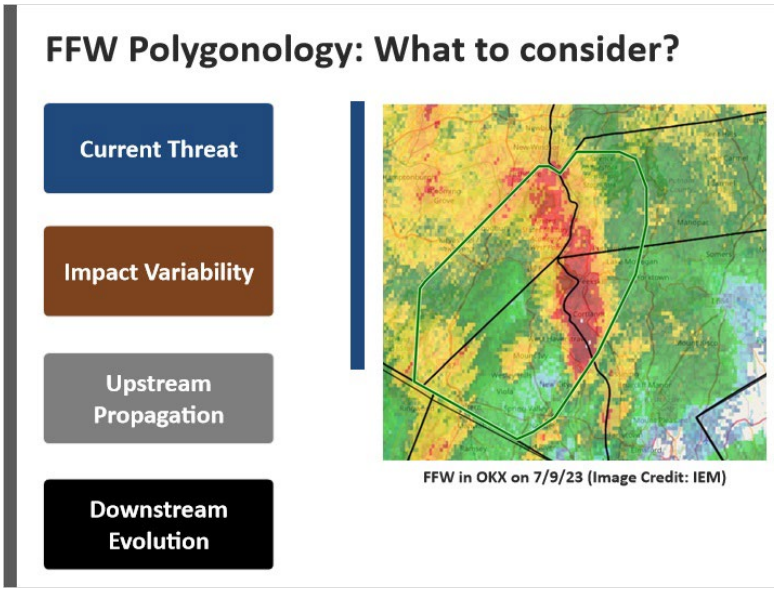
FFW Polygonology: What to consider?



Notes:

Alright, you've drawn up your FFW and are likely wondering, "Did I do it right?" When it comes to FFW polygonology, there are four considerations you need to keep in mind when drawing up your FFW to get it right per say. You need to be sure you're covering the current threat, the variability in impacts, the upstream propagation, and the downstream evolution. Go ahead and click on each of these to learn more and when you're done, you'll get another shot at drawing up your FFW.

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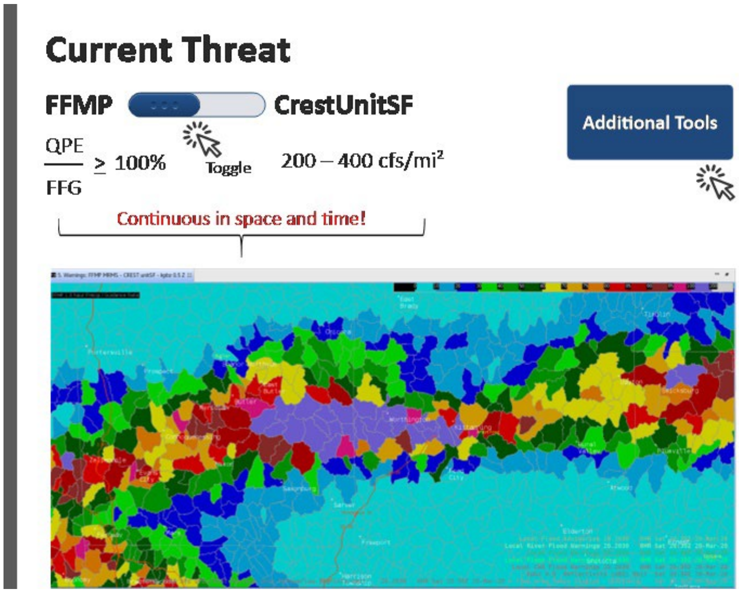
Current Threat (Slide Layer)



Current Threat:

This one may seem painfully obvious at first - of course you want to draw your FFW polygon around the flash flooding - but HOW you do that is what I want to focus on here. In earlier lessons, you learned about how both FFMP and Crest Unit Streamflow are extremely helpful hydrologic tools for diagnosing where the current FF threat is. That is why we here at WDTD recommend using both of these tools to help you know where to draw your FFW polygon. To quickly recap from earlier lessons, remember that with FFMP, you're looking for basins where the ratio of QPE to FFG is close to or > 100% and with Crest Unit Streamflow, you're looking for values between 200-400 cfs/mi^2 for a base FFW. With either of these hydrologic tools, these thresholds should be fairly continuous in space and time and not an isolated basin or pixel - that's being too jumpy and it makes me nervous. Since FFMP and Crest have different strengths and weaknesses, using BOTH of them together will give you the best shot at comprehensively capturing the current threat area with your FFW polygon. As a side note, we recognize there are some offices, especially out West, where RFC FFG is not regularly issued so your use of FFMP is more restricted - go ahead and click on the button to see what additional tools can assist you.

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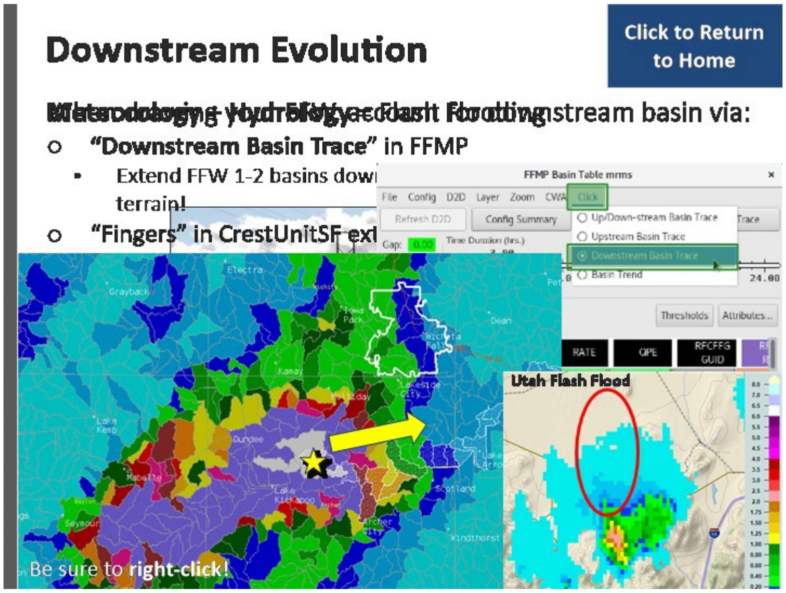
Downstream Evolution (Slide Layer)



Downstream Evolution:
Because flash flooding involves both meteorology AND hydrology, this causes complications in which somebody can experience the impacts of flash flooding even if it’s not directly raining overhead. This can occur anywhere you’ve got steep terrain that allows for rapid flow downstream - I’m talking to you Western offices! Thankfully both FFMP and CrestUnitStreamflow have ways for monitoring which way the water will flow. In FFMP, by enabling the downstream basin trace option, this will allow you to see which direction water will flow when it falls into a particular basin. Let’s go ahead and practice this now using the example you just drew your FFW up on. In the image shown here, select the “Click” menu and choose the “Downstream Basin Trace” option Now that you’ve got that set, go ahead and right click on the basin marked by the star to see which direction water in that basin will flow downstream. For that basin, when rain falls in it, runoff will flow downstream to the east/northeast as shown by the white hatched colors. With that knowledge, you will want to expand your FFW to the east/northeast when drawing it up to account for this downstream flow. Now ideally, you’d want to click on several more basins to get a bigger sample size but for this example, I just had you choose one. As a rough rule of thumb, we say that in areas of relatively flat topography, extend your FFW 1-2 basins in whatever direction the downstream flow is. However, for more mountainous topography, you will definitely want to extend it several more basins downstream due to the high potential of mud and debris flow from

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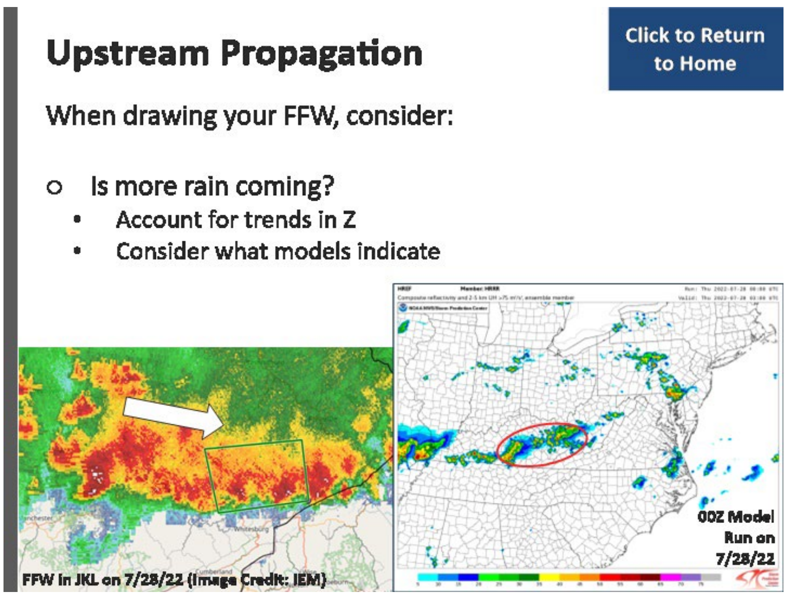
upstream rainfall.

CrestUnitStreamflow can also assist you in highlighting which way the downstream flow is. It'll appear in what we refer to as ghost-like fingers as potentially creepy as that may sound. In this example, you see these faint finger-like extensions extending northward from the area of highest crest unit streamflow and rainfall as shown here. This is telling you that the water is flowing downstream to the north. Seeing that, you'd want to extend your FFW in that direction when drawing it up.

Upstream Propagation (Slide Layer)



Upstream Propagation:
It's tempting when drawing up your FFW to get tunnel visioned and just cover the area of immediate threat. However, after drawing up your FFW, it's really important to zoom out and take an Oliver Twist perspective of "May I have some more please?" In other words, "Is more rain coming?" If the answer is yes, be sure to expand your FFW to account for this future rainfall. You don't want your warning to be so tiny that you keep having to tack on additional polygons with every little wave that scrapes the edges of your initial warning. As you'll see here shortly, FFWs are 3-hours in duration by default so you'll need to consider trends in upstream reflectivity and/or short-term models to appropriately draw your FFW.

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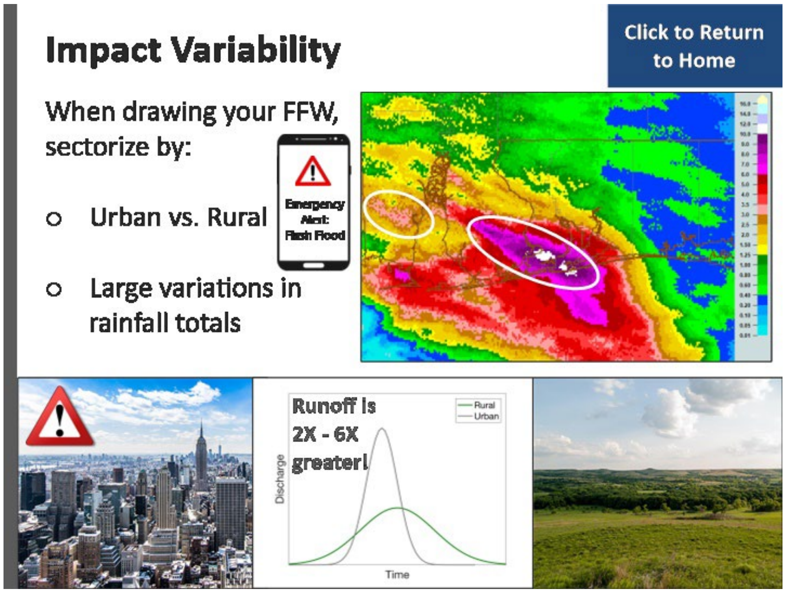
Impact Variability (Slide Layer)



Impact Variability:

If the impacts from heavy rainfall were all the same, it'd be straightforward to cover the area of concern with one FFW polygon. However, things aren't always this nice and dandy especially when you are dealing with urban vs. rural areas. Remember from earlier modules that urban areas are one of THE most vulnerable areas as runoff here is two to six times greater compared to rural areas. So, when you are drawing up your FFW, you should be intentional to sectorize your polygons based on urban vs. rural footprint as the impacts will be different between the two. As you'll see in the next module, this will also allow you to easily target upgrading the IBW tag with your FFW over urban areas instead of sounding off the alarm for areas that aren't experiencing as substantial impacts and potentially upsetting someone with a napping baby.

Next, if you are dealing with a wide range in rainfall totals over a spatial area, like in this example here, you can bet your bottom dollar that the impacts from 2-4 inches of rain will be much lower than 8-10 inches. In this case, you should be intentional to sectorize your FFW polygons when drawing them up so one warning covers the lower end totals and another covers the higher end totals. Now, it's absolutely normal to have variation in rainfall amounts across one FFW polygon but if you start to end up with drastic variations like we have here, it's a good idea to draw two separate FFW polygons to address

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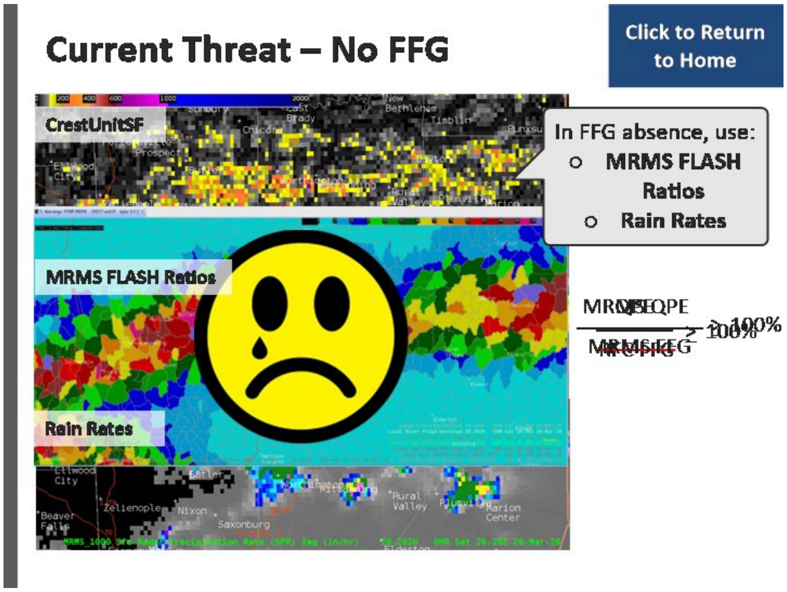
the different impacts and messaging needed between the two.

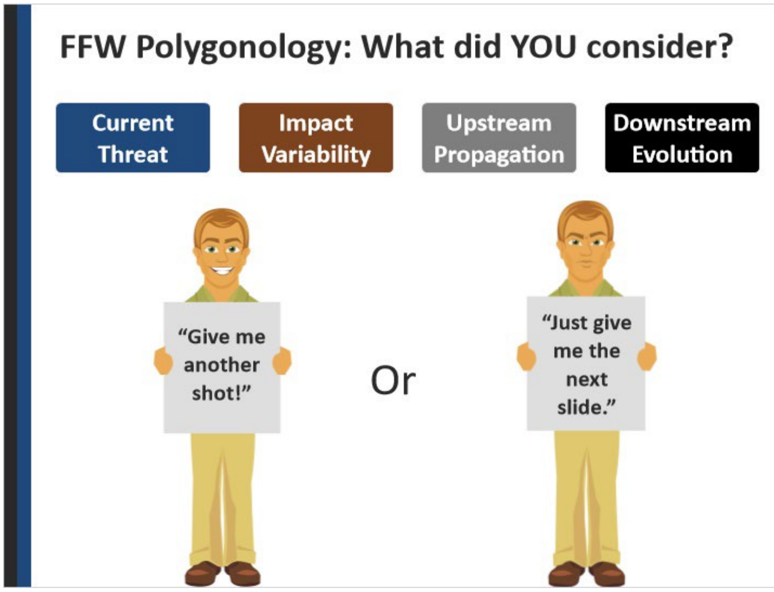
Current Threat - no FFG (Slide Layer)



Current Threat – no FFG:

When RFC FFG is not available, you won't be able to view ratios in FFMP because the denominator is not available. However, one tool you can use in tandem with CrestUnitSF as a substitute is the MRMS to FFG ratios that are part of the FLASH product suite. You can view these ratios because even if the nationally issued RFC FFG isn't available, MRMS has their own FFG values they pull from so it's a nice backup to have. Additionally, a lot of flash flooding out West is heavily rain rate driven so viewing the instantaneous rain rates will also help you identify where the current threat is.

Interaction: Drawing FFW



Notes:

Okay, now that you know what you should consider when drawing up a FFW, would you have drawn up your previous warning any differently? If your answer is "yes", click on the "Give me another shot" to redraw it based on your recently accumulated knowledge. However, if you're happy with your warning just the way you drew it earlier, click on "Just give me the next slide" to move on.

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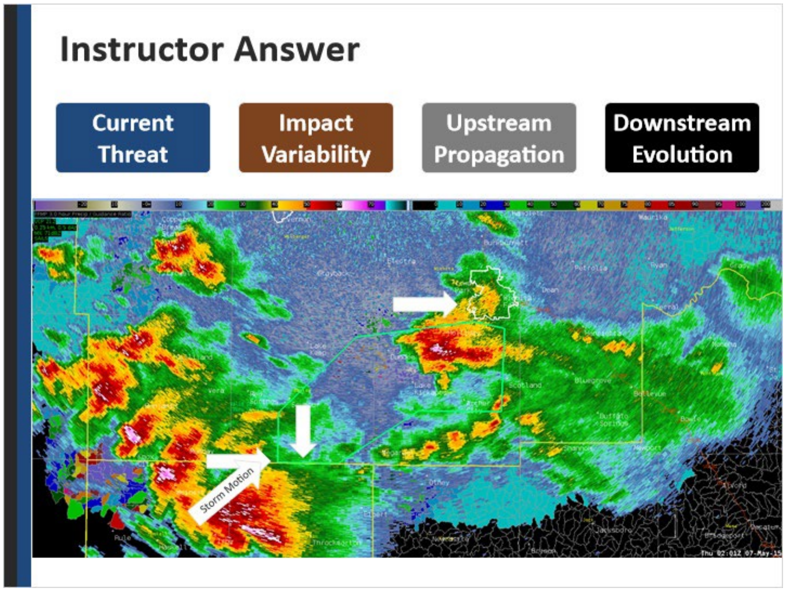
Instructor Example



Notes:

Just so you have something to compare to, I wanted to show you how I drew up my FFW using those 4 considerations we talked through starting with the current threat. Toggling between FFMP and CrestUnitSF, I noticed that the spatial footprint of CrestUnitSF was much smaller than the FFMP so I made sure to use both to help shape my polygon so I wouldn't miss any areas that needed to be covered. In FFMP, I included basins close to or exceeding FFG and in CrestUnitSF, I made sure my warning covered the main footprint. As for impact variability, this is a pretty rural area so I intentionally stopped my polygon extent right at the Wichita Falls city boundary shown in white because I know the impacts there will be more heightened and I'd rather draw a separate warning to be able to message accordingly as well. As for upstream propagation, I noticed we have more storms coming in reflectivity so I oriented my polygon in the direction of their movement as well as pulled it to the south in anticipation of future heavy rainfall there that will only fill in the response there. As for downstream trace, I noticed using the FFMP downstream basin trace tool that most water was flowing to the east/northeast so I hedged my warning a few basins downstream in that direction - not going too crazy because it's as flat as an earth conspiracy theory here. I noticed a few basins on the southwest side of my polygon all flowed directly to the south so I gave myself buffer room in that direction there as well. Lastly, I pulled my polygon on the southwest side all the way to

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the CWA border in yellow so there wouldn’t be any awkward gaps that would likely fill in once storms moved through.

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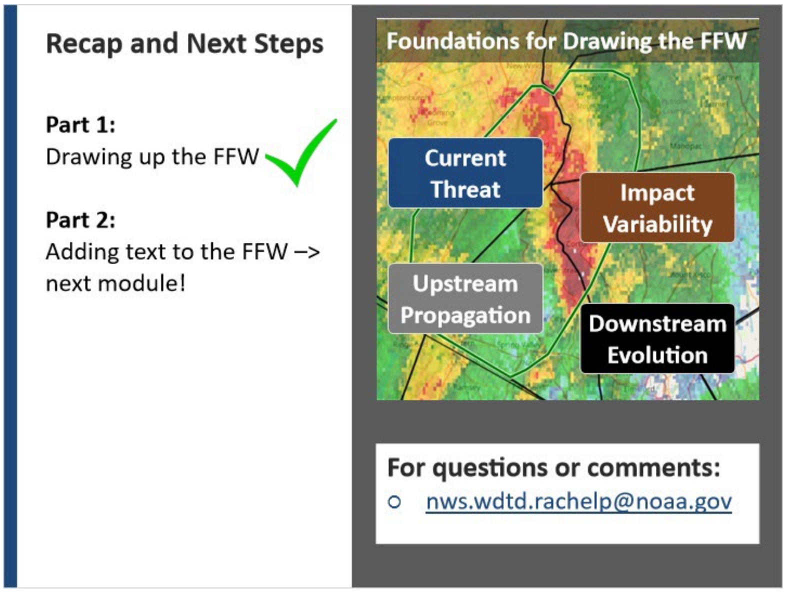
Summary



Notes:

So you've got your FFW drawn up - you're halfway there! The 2nd foundational part of a FFW is populating the text details of the warning which you'll get to do for your warning in the very next module. For now though, I want you to keep in mind those four considerations when drawing up your FFW: Cover the current threat, sectorize by variability in impacts, anticipate upstream propagation, and account for downstream evolution. If you have any questions, feel free to contact us at the email address listed below but otherwise, click "next" to take the quiz.

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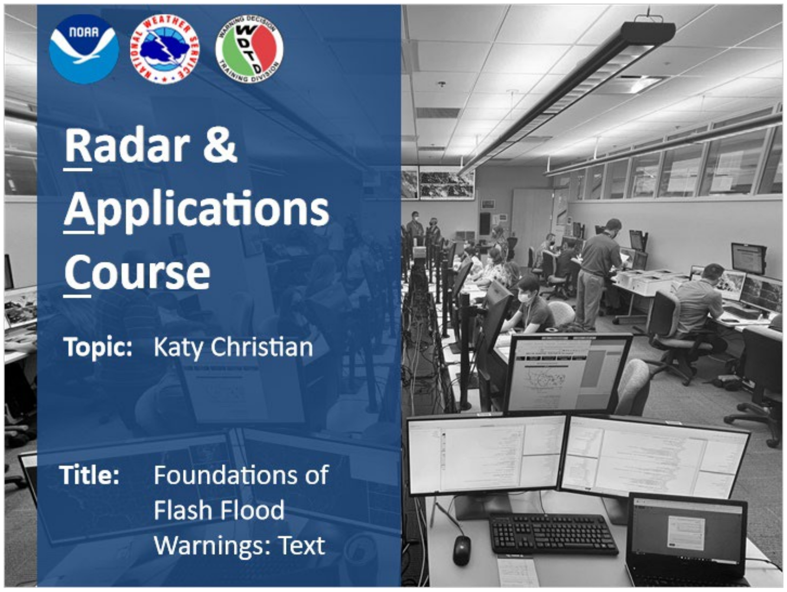
Foundations of Flash Flood Warnings: Text

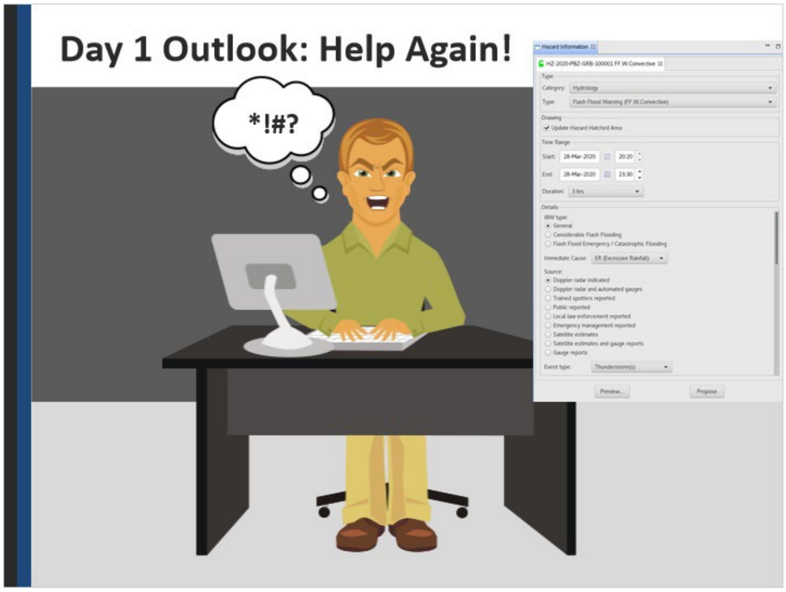
Introduction



Notes:

Welcome to Foundations of Flash Flood Warnings! In the previous module, you got to practice drawing up your FFW polygon. In this module, you are going to practice adding the text details to that FFW.

Day 1 Outlook: Help Again!



Notes:

So you just drew up a nice looking FFW polygon and are feeling pretty good about where you're at. However, all this changes when the Hazard Services Dialog box appears and requires you to populate the text details of your FFW - what in Bernoulli's Theorem do all these options mean and which ones should you select? Let's quickly discuss the most important text options you should always include in your FFW text before you do so for real.

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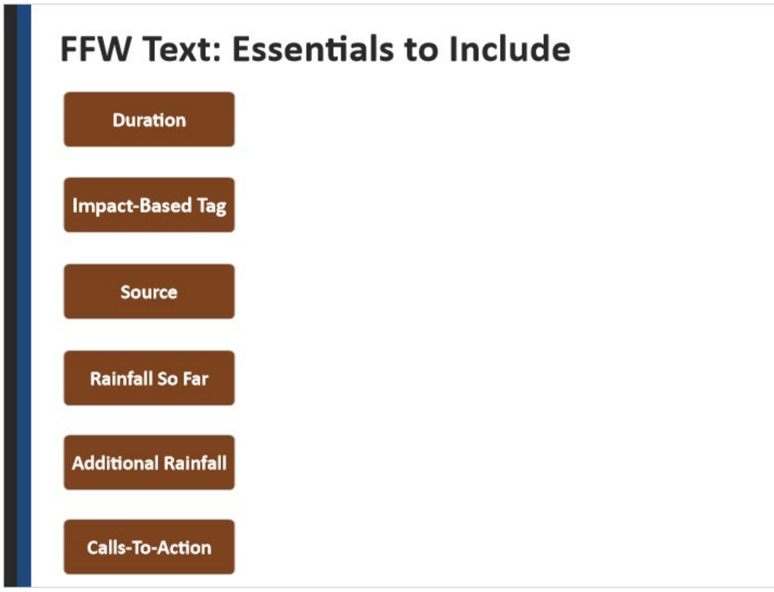
FFW Text: Essentials to Include



Notes:

Populating your FFW with text information is your opportunity to tell the story about this FFW to your public. And with that comes essential pieces of information you need to communicate to your public about the flash flood warning. Click on each of these to learn more and when you're done, you can move on.

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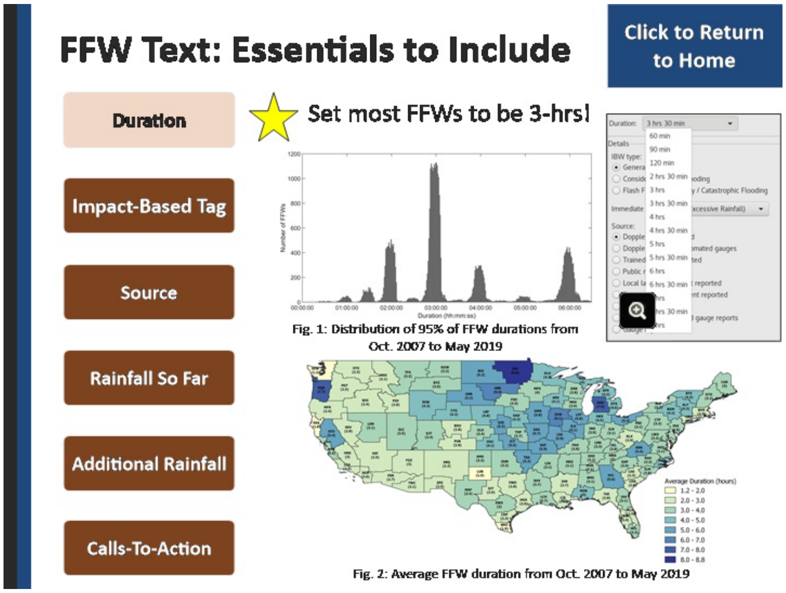
Duration (Slide Layer)



Duration:

You always need to let your public know how long the flash flooding is expected to last. In Hazard Services, it will give you a range of default durations from as short as 1 hour to as long as 8 hours. As seen in this image, FFW durations vary greatly across the CONUS depending on the cause of flash flooding, local hydrology, and different WFO best practices as a result. For example, FFWs due to dam failures last much longer than those just due to heavy rainfall. If we take a look at the distribution of 95% of FFWs over the period of analysis, we see that most FFWs are issued around hourly durations, with 3-hour warnings being the most common. With that being said, in the absence of unusual circumstances, a best practice is for your FFW to be 3 hours in duration. For a starting point, this allows one hour for the event to begin and the rain to fall, one hour for runoff and the stage to crest, and one hour for the flash flood to recede.

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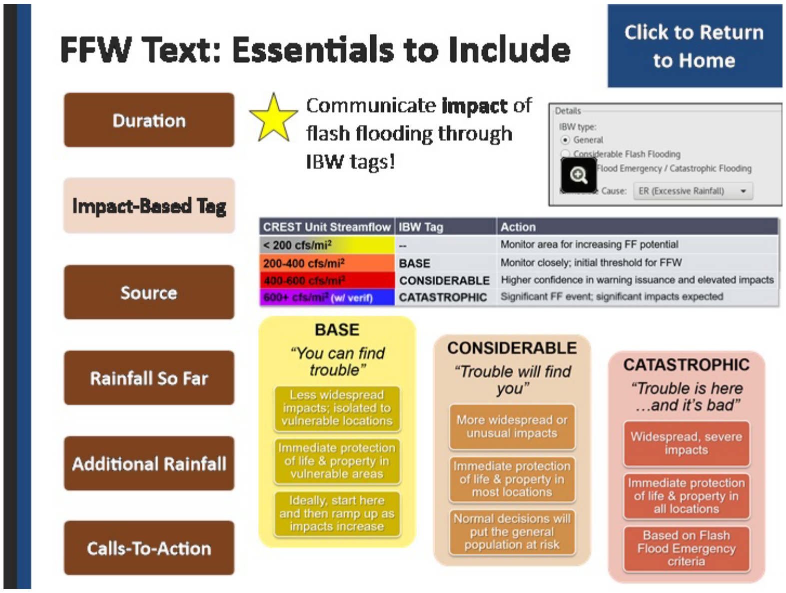
IBW Tag (Slide Layer)



IBW Tag:

Another piece of information to communicate to your public about your FFW is how impactful the flash flooding is. And the way we do this in Hazard Services is through Impact-Based Warning tags as shown here. Now, we have an entire module devoted to this topic very shortly so I don't want to spill all the beans unless they're coffee. However, what you should know for now is that base FFWs are designed for the majority of nuisance flash flooding that affects those vulnerable low-lying spots and impacts to the public are not widespread. Through a lot of research, base FFWs are typical when CrestUnitSF values are around 200-400 cfs/mi^2 and these values are continuous in space and time. "Considerable" is an important leap up because this tag sounds off the wireless emergency alerts for folks. This tag is designed for flash flooding that is more widespread where people doing everyday activities are starting to be at risk. CrestUnitSF values are typically around 400-600 cfs/mi^2. And lastly, "Catastrophic" is the most rare of all and is designed for situations where anybody, no matter what they are doing, are experiencing life or death impacts from flash flooding. CrestUnitSF values are typically greater than 600 cfs/mi^2. Be intentional when choosing your IBW tag as that tells the story to the public of how impactful the flash flooding is.

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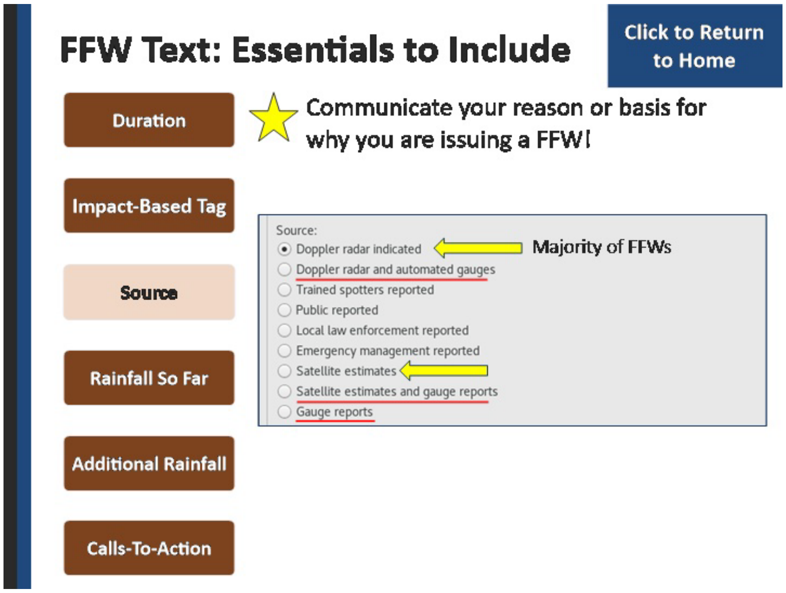
Source (Slide Layer)



Source:

It’s important to communicate what your reason is for issuing a flash flood warning in the “Source” section of Hazard Services. For a large majority of FFWs, your source will be “radar-indicated” because radar QPEs are what you are going off. However, there may be times when your radar is down but you get a valuable gauge report that would lead you to believe based on its amount alone that flash flooding is likely. In these cases, “gauge report” is definitely your reason! In other words, if the rain gauge is what helps you make the decision to issue a FFW, it’s perfectly acceptable to choose those options that include gauge in the source wording. On a side note, let’s also hope you never have to use satellite-based or that means we are really hosed in terms of available tools left! However, it may come down to that especially for you folks up in Alaska where it’s tough to come by available obs.

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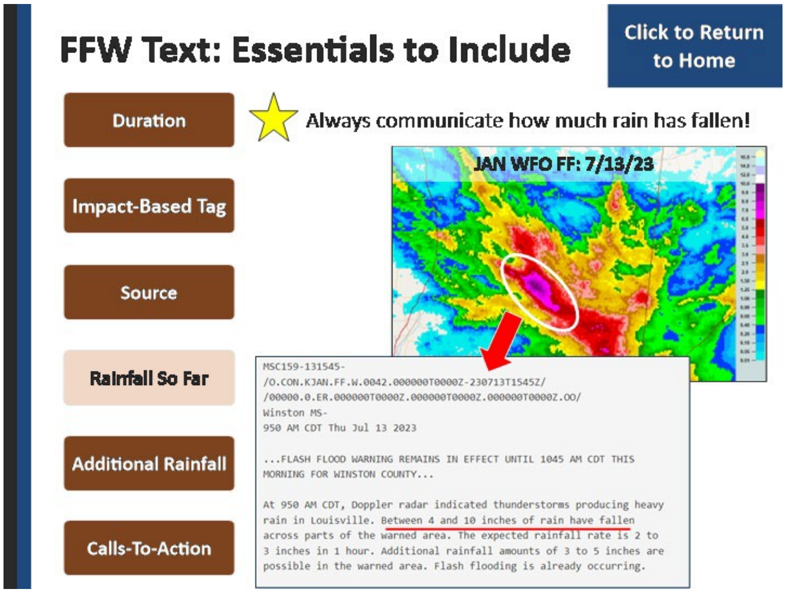
Rainfall So Far (Slide Layer)



Rainfall So Far:

It’s absolutely vital that you communicate to your public how much rain has already fallen. Without this piece of information, it really undermines why you are even issuing a FFW to start with. You should go into Hazard Services with that rainfall amount in mind and ready to go!

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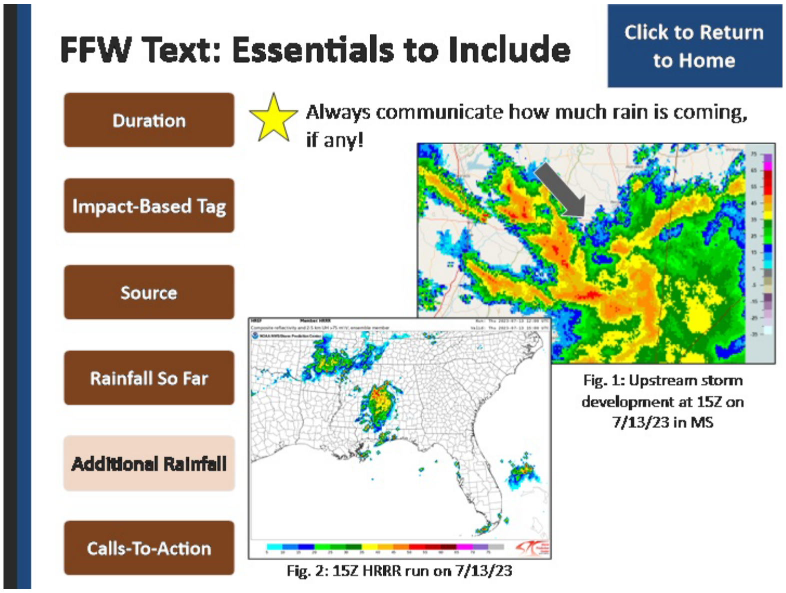
Additional Rainfall (Slide Layer)



Additional Rainfall:

You should always communicate to the public how much more rain is expected during the warning duration that way they have a sense of how the event is expected to progress - for example, is this a one and done sorta deal or will it be raining cats and dogs for a long time? You can estimate additional rainfall by looking upwind to see what QPE amounts storms that are coming have been producing and by keeping a close eye on model projections and trends.

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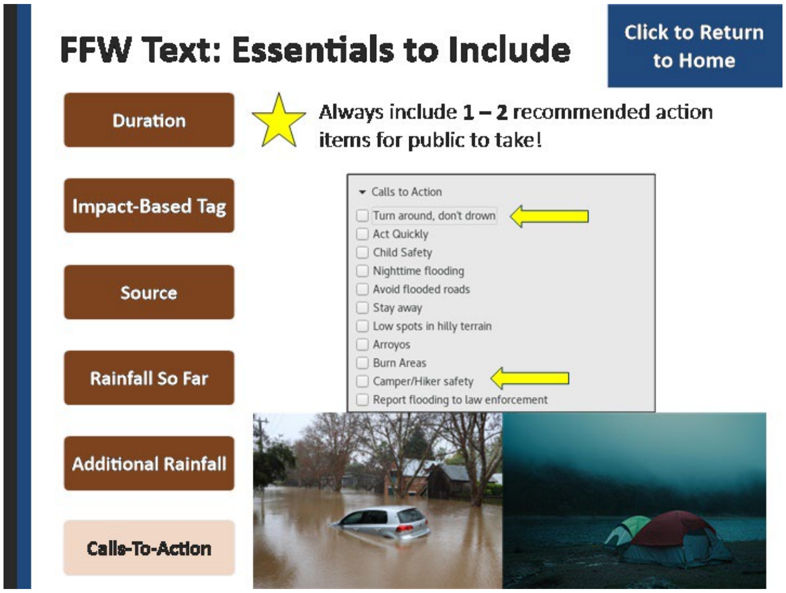
CTAs (Slide Layer)



CTAs:
Call-to-action statements are your chance to communicate to the public what specific actions they need to take to protect themselves as these can vary depending on the situation. Since most FF fatalities are vehicle related, selecting “turn around, don’t drown” is a good one to continue hammering that message in. Likewise, if your FFW is over a recreational area, the “Camper/Hiker safety” option would be relatable for people there. Choose whichever CTA communicates the most relevant and specific steps someone can take to protect themselves but remember to only just select 1 to 2 MAX or else it just bogs down the NOAA weather radio and dilutes the overall message.

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Hazard Services: A Few Nuances

Notes:

Hazard Services: A Few Nuances:

In addition to FFW text essentials, I’d be remiss if I didn’t give you a heads up about several nuances you are about to encounter in Hazard Services. Click on each of these so you know how to navigate these here shortly.

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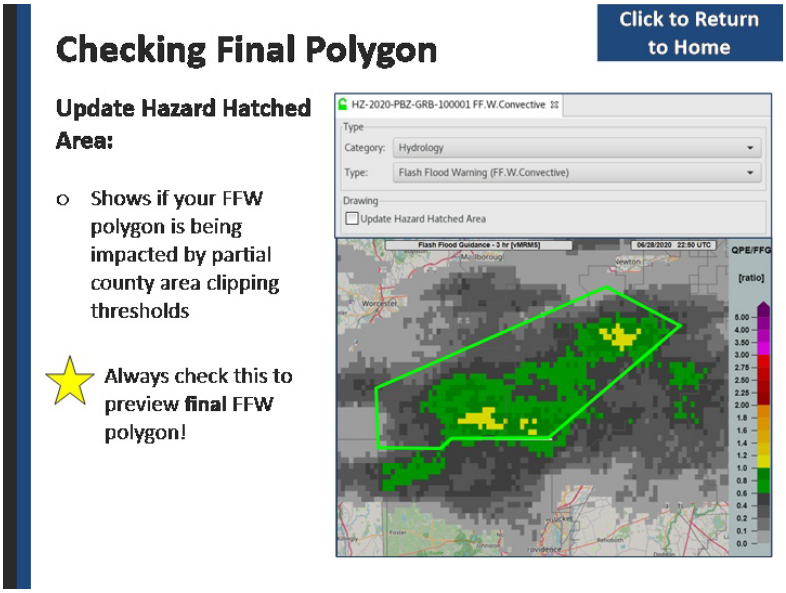
Checking Final Polygon (Slide Layer)



Checking Final Polygon:

At the very top of your Hazard Services dialog box, there's a lonely unnoticed but very important checkbox referred to as "Update Hazard Hatched Area." When you check this, it will show you if your FFW polygon is being clipped due to not covering a certain threshold of a county area. In the image shown here, go ahead and click on the checkbox above to see this in action. Notice how the FFW polygon gets clipped back to the county border shown in white. If you didn't want this to happen, you'd have to make your FFW polygon bigger until it surpassed the local county area clipping threshold percentage. Clicking on this box will always ensure you are viewing the final FFW polygon so don't forget about it!

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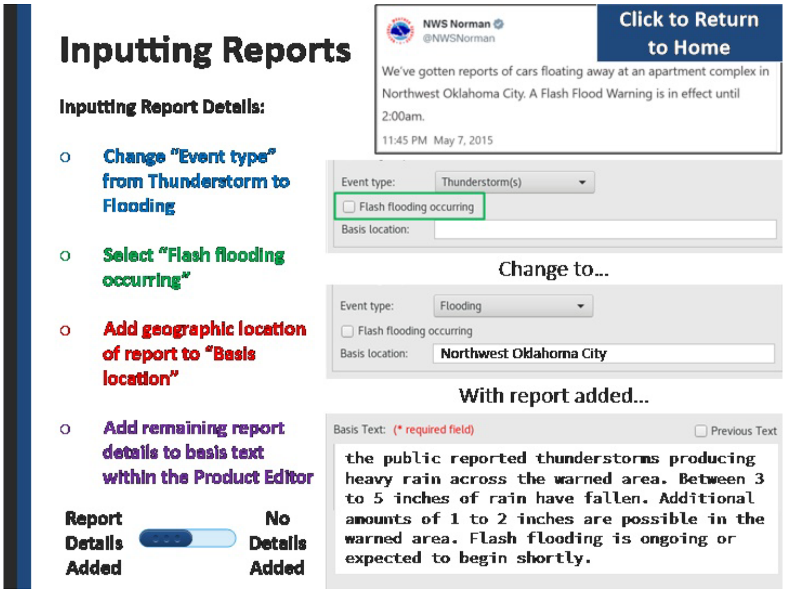
Inputting Reports (Slide Layer)



Inputting Reports:

Let's say you get a report via Twitter and want to include it in Hazard Services. When inputting reports, there's several specific options you need to select in Hazard Services to get your text right. Firstly, under "event type", you want to change it from "Thunderstorm" to "Flooding" because the report is verifying flooding, not thunderstorms. Further, it cleans up the wording of your text as you'll see here shortly. Next up, you should always select the "flash flooding occurring" checkbox when you get a report because that report is verifying your warning! Next, when a geographic location is listed in the report, like "Northwest Oklahoma City" in this example, you should type that in the basis location. Note that JUST the geographic location of the report goes here and nothing else. You will type all the other report details in the basis text portion of Hazard Services as shown here. So in the case of our Twitter example, I've added "cars are floating away" in the basis text because that's an important piece of info the public needs to hear. Without these key options and details added, your FFW text will be vague and not helpful to the public. Take a minute to look at this by toggling between our example and then an example where none of these details were added - it's quite rubbish so I don't recommend it.

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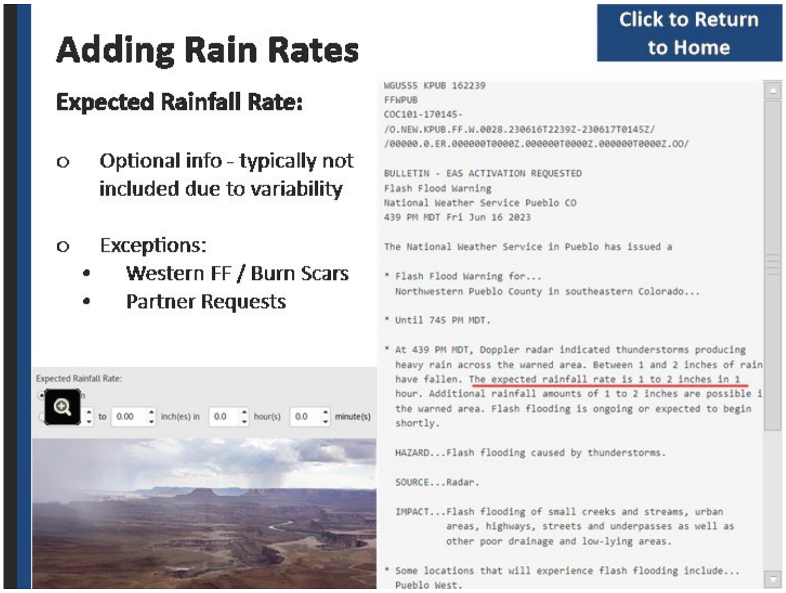
Adding Rain Rates (Slide Layer)



Adding Rain Rates:

Remember from FFW text essentials, we said to always include how much rain has fallen and how much more to expect. Rain rates on the other hand are optional for you to include. Because rain rates are instantaneous and change quite a bit from volume scan to volume scan, we typically don't include them. However, there are some cases where they're used often. In the Western United States, a lot of FF there is heavily rain rate driven and knowing rain rate info is also critical over burn scars. In these cases, including the expected rainfall rate in your text will be helpful to your public and partners. Take a minute to scroll through this FFW text example from Pueblo, CO and note where the rain rate info is listed in the text. In addition to the Western U.S., your partners may also request you to include rate info especially for high-profile events where this info is critical to their decision making.

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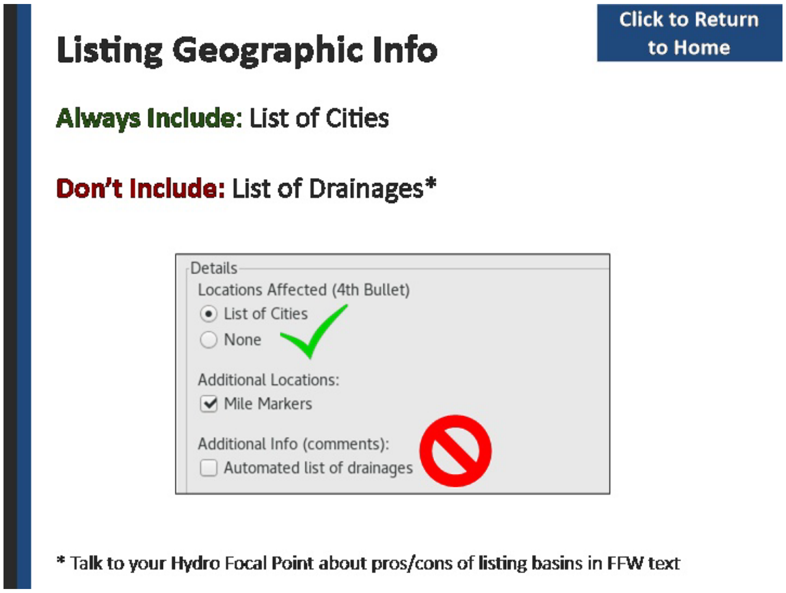
Listing Geographic Info (Slide Layer)



Listing Geographic Info:

In Hazard Services, be sure to always select "list of cities" to include in your FFW text details. Likewise, we recommend NOT selecting the "automated list of drainages" because this will include every single basin and/or stream name that falls within the FFW polygon. The list can get quite extensive and will clutter up your warning text. However, if you are interested in the pros/cons of using this option, feel free to talk to your hydro focal point.

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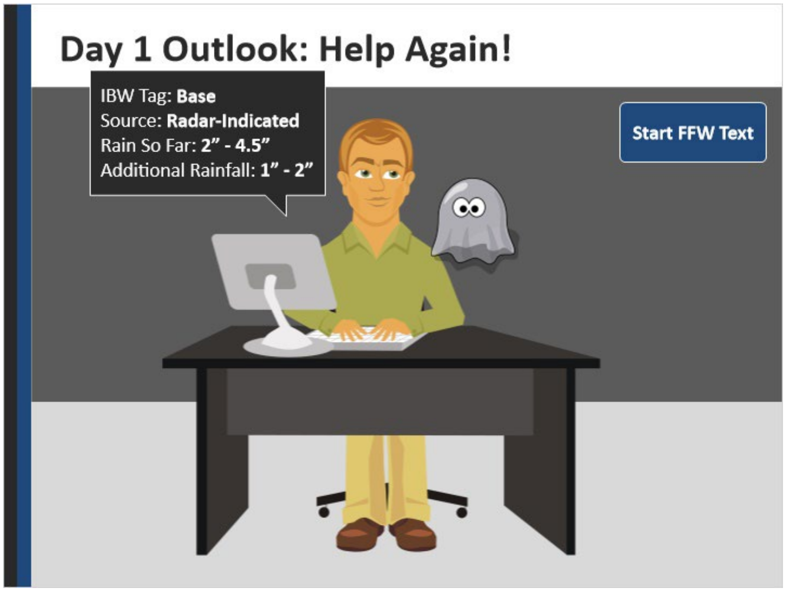
FFW Text: Exercise Overview



Notes:

Now that we've got things squared away, it's time for you to add text details to your FFW just like you would in real life! Except that if you start to go off course, I'll be playing the role of your conscience who will audibly appear out of nowhere to help guide you back on track. On the left is info related to your FFW that you drew up earlier - this will also be available to you as you work through adding text details in Hazard Services. Go ahead and click on "Start FFW text" to get going.

FFS Text: Exercise Overview

Notes:

Hooray, you successfully issued your FFW with helpful and relevant information to your public! 45 minutes pass and you receive a report that verifies your warning - boo ya baby! Additionally, in the last 45 minutes, your rainfall totals are now up to 5 inches. Armed with this report and updated rainfall amounts, it's time to issue a flash flood statement - click on the button to begin!

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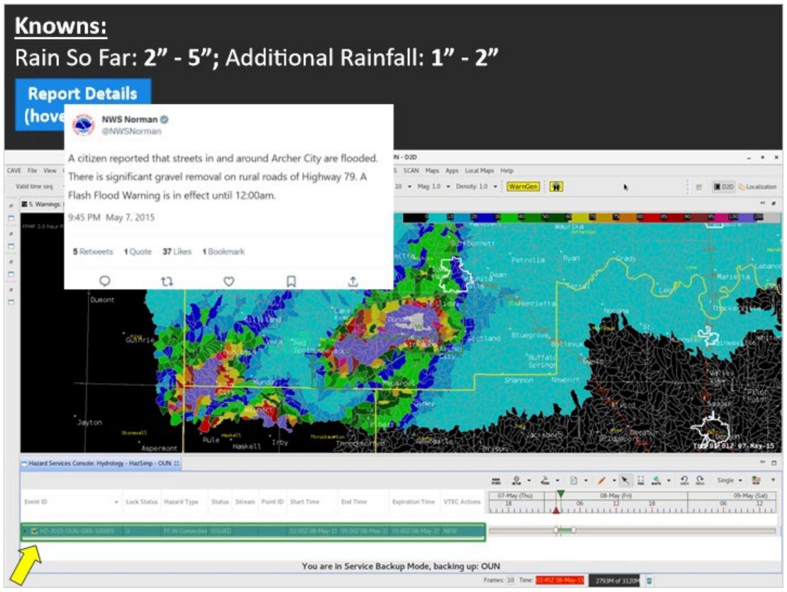
How to FFS



Notes:

To update the text information of your FFW, or in other words, issue a Flash Flood Statement, simply double click on your warning in the Hazard Services Console and it will pull it up. Go ahead and double click now.

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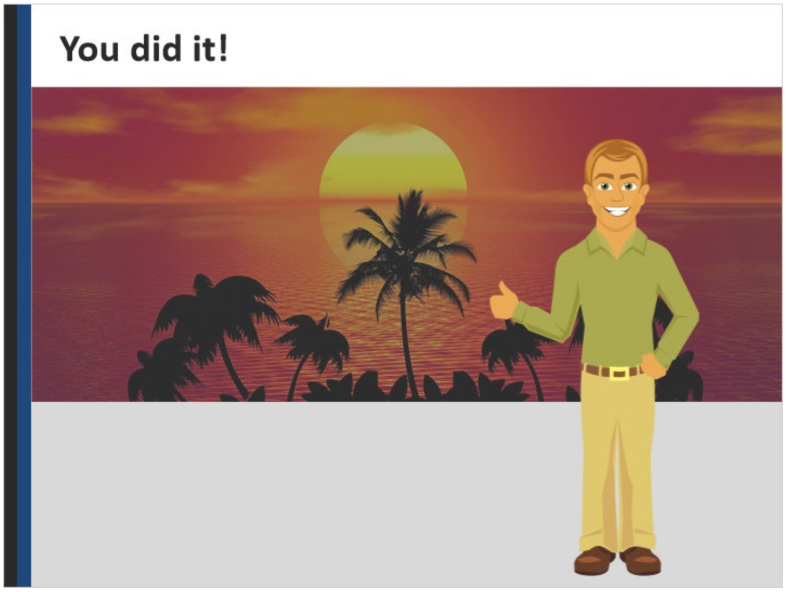
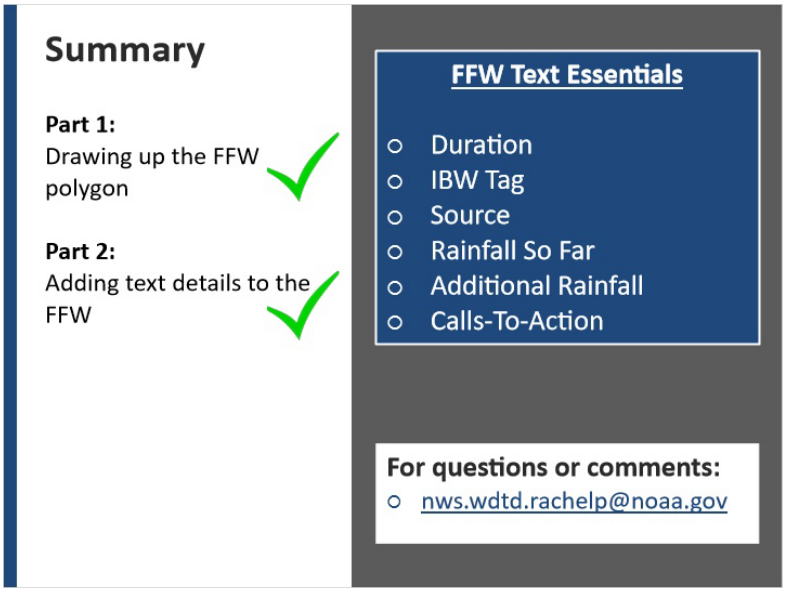
Finishing the Shift



Notes:

With your FFS out, your work here is done and the clock says it's time for you to escape to your much needed vacation (i.e. being done with this module). Click "next" to wrap things up.

Summary



Notes:

You've finished learning about the last foundational part of a FFW which is the text. Remember to always communicate how long the warning will last, the severity of it, the basis for it, how much rain has already fallen, how much more to expect, and what actions the public can take to protect themselves If you have any questions, feel free to contact us at the email address listed below but otherwise, click "next" to take the quiz.

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Implementing Impact-Based Flash Flood Warnings

JILL HARDY

LAST UPDATED: DEC 2019

Hi, my name is Jill Hardy and welcome to this lesson about impact-based flash flood warnings.

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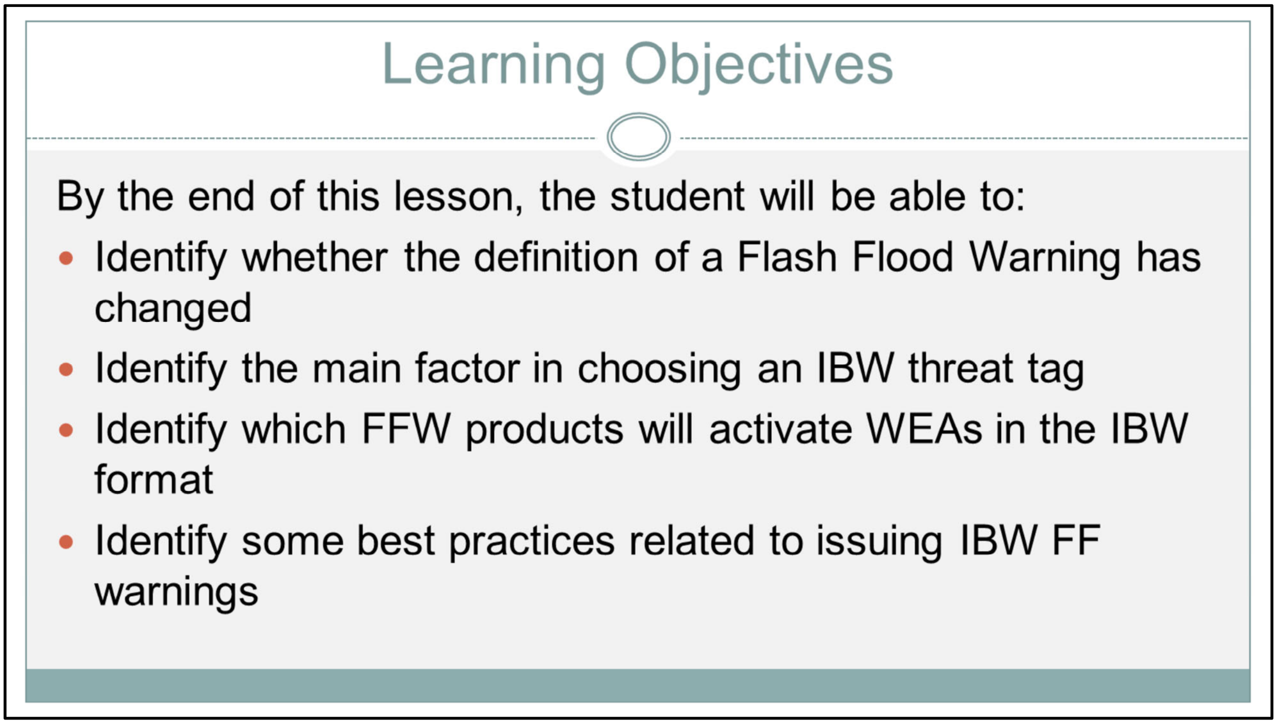

Here are the learning objectives for this lesson. When you have finished reading them, please move onto the next slide.

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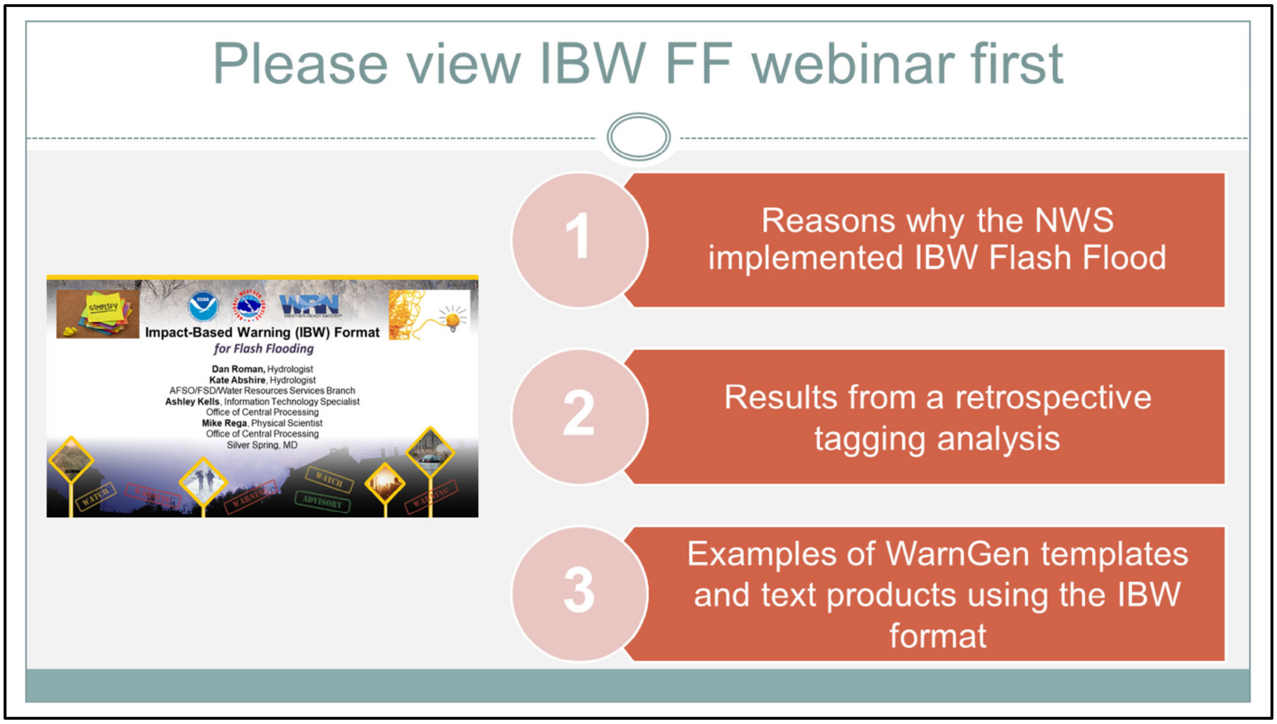
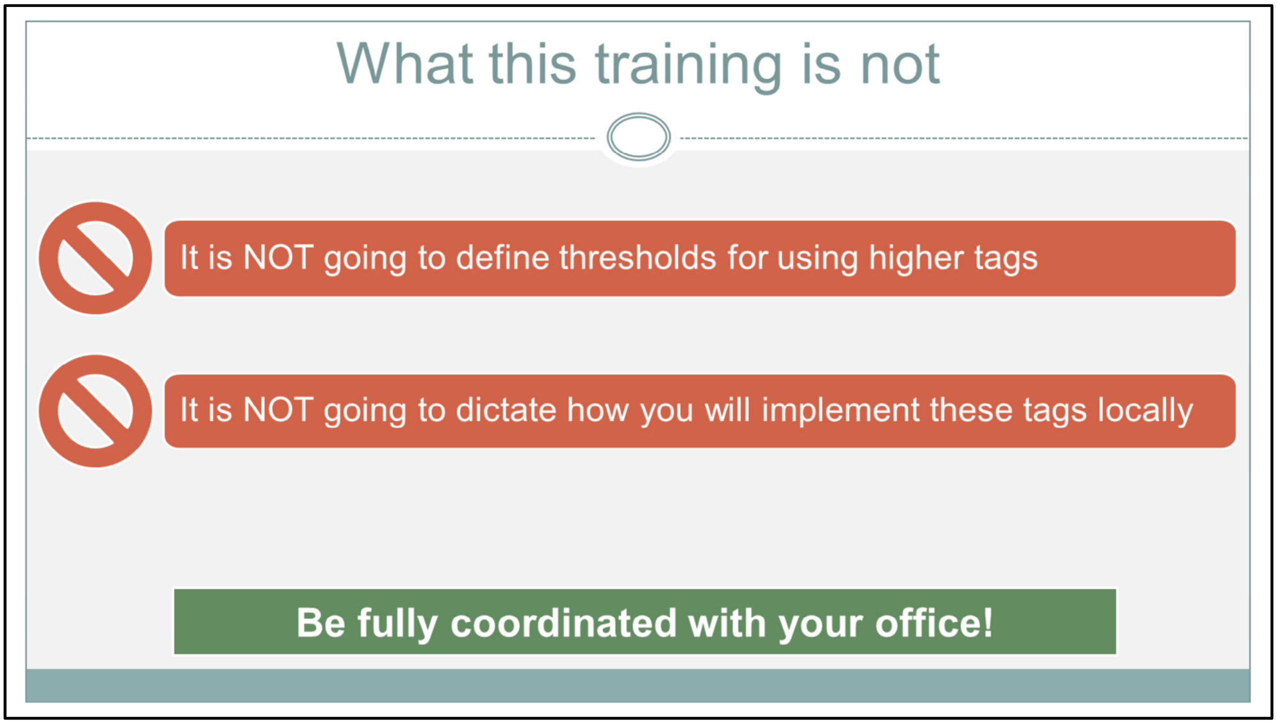


This lesson is meant to build on material covered in the webinar from Fall 2019. The webinar discusses reasons why the NWS implemented IBW FF, results from a retrospective analysis, and then examples of WarnGen templates and text products using the IBW format. If you haven't taken that webinar, we highly recommend you do so before continuing on with this lesson.



This lesson is meant to give you general guidance about using the impact-based warning format for flash flooding. This lesson is NOT going to define various thresholds in AWIPS tools for using higher tags. And it is NOT going to dictate how you will implement these tags locally.

Ultimately, using the IBW tags for flash flooding should be guided by local and regional best practices, so make sure your office is fully coordinated on this effort.

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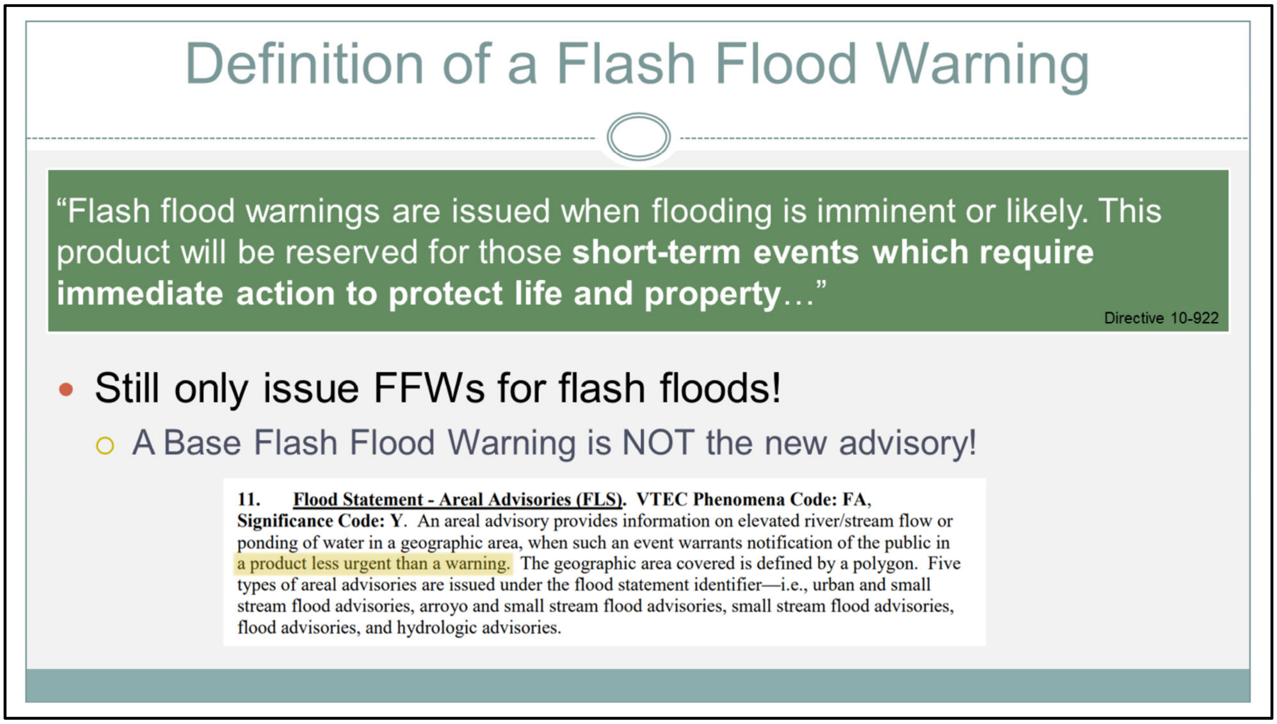
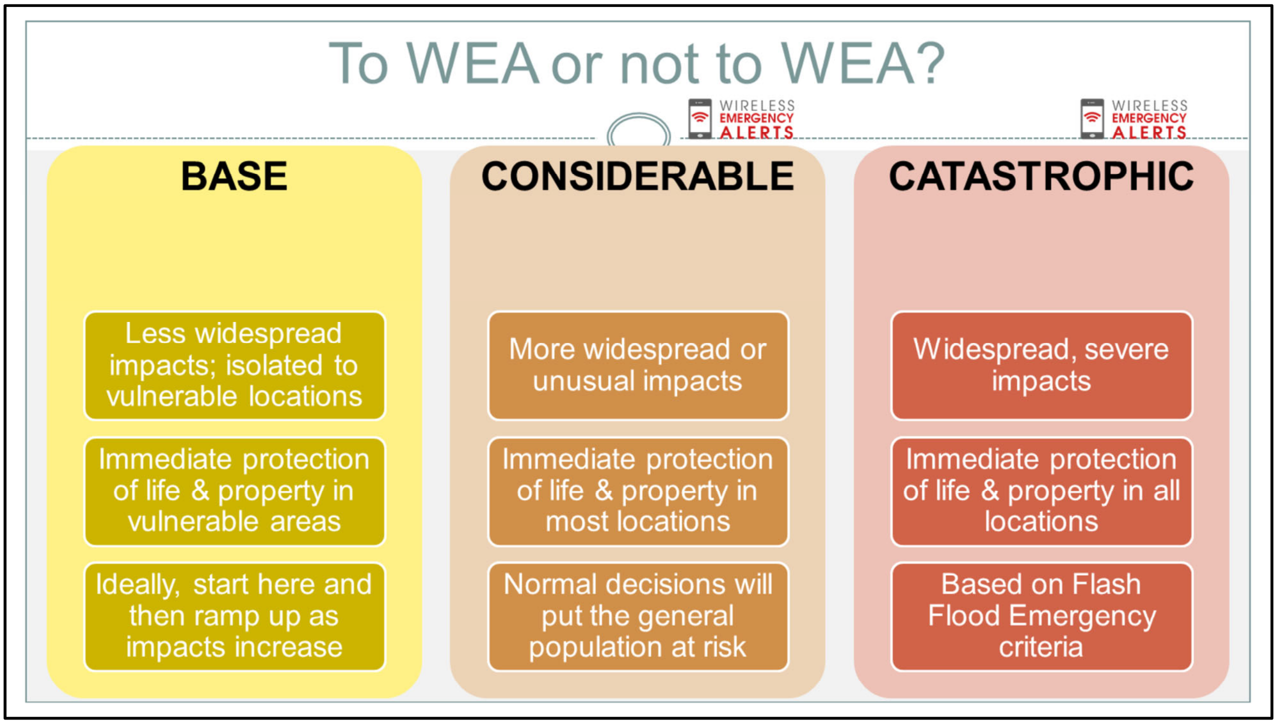


I think it's important to begin with a reminder of the definition of a Flash Flood Warning, taken from Directive 10-922:
"Flash flood warnings are issued when flooding is imminent or likely. This product will be reserved for those **short-term events which require immediate action to protect life and property**…"

This definition has not changed! Forecasters should strive to only use the FFW product when this criteria is met.

Also, a BASE Flash Flood Warning is NOT the new advisory. Advisories, by definition, are used in situations that are less urgent than warnings. You still want to save FFWs for events that require the immediate action to protect life and property.



So let's just cut to the meat of this discussion. Most likely, THE key factor in how local offices will implement IBW FF is whether you want the warning to activate the Wireless Emergency Alert (or WEA). Base warnings will not trigger the WEA, while Considerable and Catastrophic tags will.

So then you may be wondering, "Well, if FFWs are supposed to be issued when there is imminent threat to life and property, how do I discern between a warning that deserves a WEA and one that does not?" And, frankly, that is the toughest decision you have to make based on the way IBW FF has been implemented. But here's a little anecdote that helped us think through the *general* guidance.

A Base FFW: You're saying "You can find trouble if you're looking for it."
A Considerable FFW: You're saying "Trouble will find you."
A Catastrophic FFW: You're saying "Trouble is already here, and it's bad."

So let's talk this out more…In most situations, a Base FFW may have less widespread impacts or are isolated to vulnerable areas. In those vulnerable areas, there's an immediate need to protect life and property (for instance, at a creekside campground). But impacts generally may not affect folks who are staying home or driving on more developed roadways. If folks venture into low-lying areas, then they could "find trouble". But generally-speaking, the majority of people who are staying put or sticking to main areas will experience minimal impacts. Ideally, most warnings fall into this category, at least to start. Then, as potential impacts increase, the warning can be upgraded. So let's talk about what that looks like.

When you ramp up to a Considerable FF, you're saying that more widespread or unusual impacts are imminent or occurring, and that immediate protection of life and property is needed in most locations. This is where "trouble will find you". Even normal decisions can put you at risk. Staying put doesn't necessarily mean you're safe. Water could begin entering homes and businesses and major roads are seeing impacts.

And then finally, a Catastrophic FF is only used for Flash Flood Emergencies. Widespread, very severe impacts are occurring. All locations in the warning are at risk. Trouble is already here and it's extremely dangerous no matter where you are or what you're doing.

So yes, every FFW should be treated with life-threatening precautions. But I think the general takeaway to help decide which tag to use is based on the *circumstances* in which you can get into a life-threatening situation. In most situations, in most CWAs, a base warning is likely enough to alert the vulnerable populations and media without over-alerting the average person. Once you step up to either of the tags that activate the WEA, you're wanting everyone to know that impacts are more widespread and severe.

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Let impacts drive your decisions

You know your stakeholders' needs and your hydrology

Do what's best for your CWA to protect life and property

Even with the guidance on the previous slide, let the *impacts* of YOUR area drive your decisions.

Ultimately, YOU know your stakeholders' needs and the hydrology of your area. And you can provide the best service by knowing the impacts that require heightened language in the warnings.

Additionally, recognize that neighboring offices may use the IBW tags a little differently than you. Every office has different stakeholders and hydrology…Always do what's best for your area to properly protect life and property.

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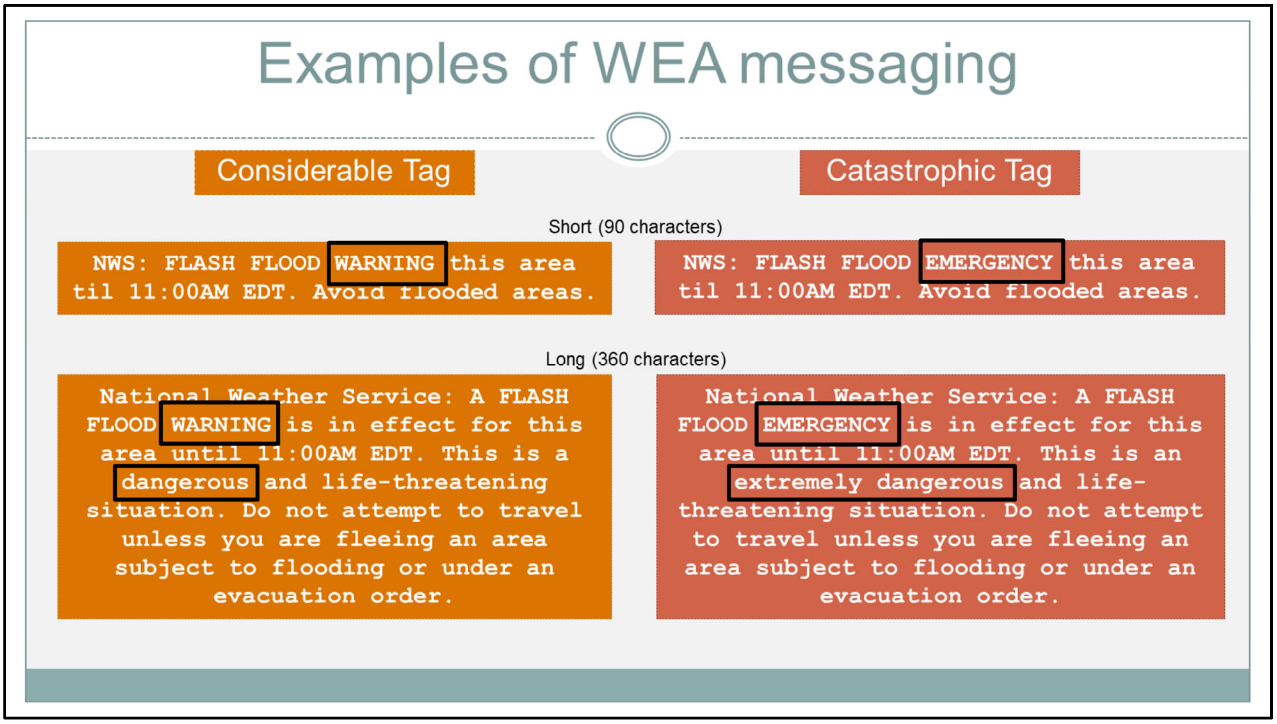
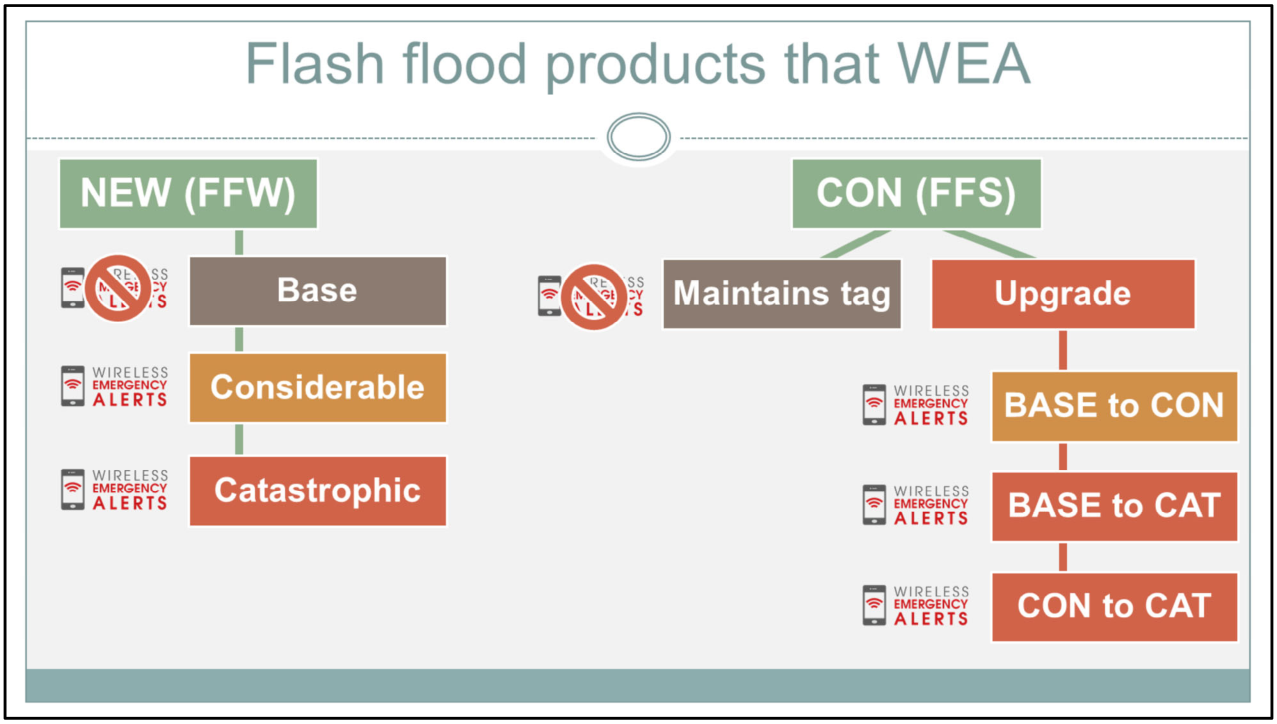
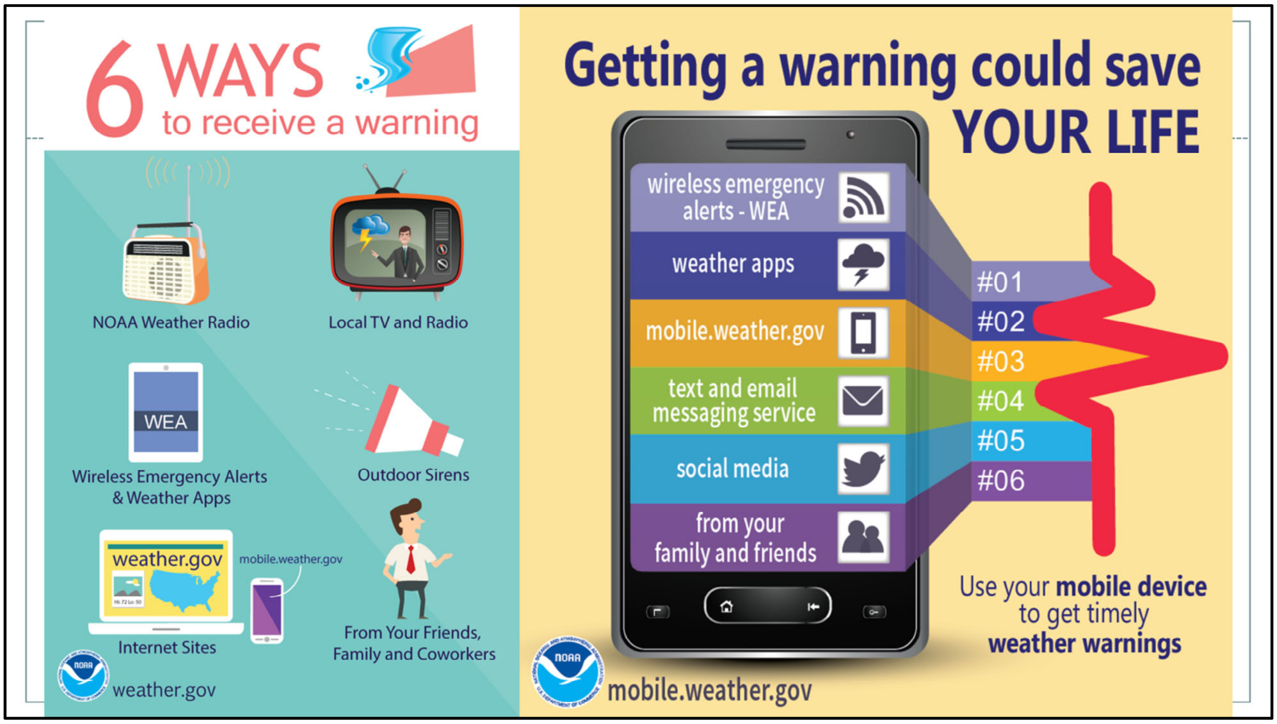


Here are the updated WEA messages for both the Considerable and Catastrophic tags. Note that the only differences are the words WARNING versus EMERGENCY, and the addition of "extremely" dangerous in the 360-character text.

These messages are also available in Spanish. Move onto the next slide when you are ready.



Here's a quick chart to remind you what does and does not activate the WEA. WEAs only activate on new warnings with Considerable or Catastrophic tags, or follow-up statements that UPGRADE in tag. Be aware that Flash Flood Statements that maintain the same tag as previously will not activate the WEA.



Regardless of whether you activate the WEA or not, don't forget that a Flash Flood Warning is the Weather Service's most impactful flood message. And there are several other ways that message can be disseminated. So always make your flash flood warning decisions with care and purpose.

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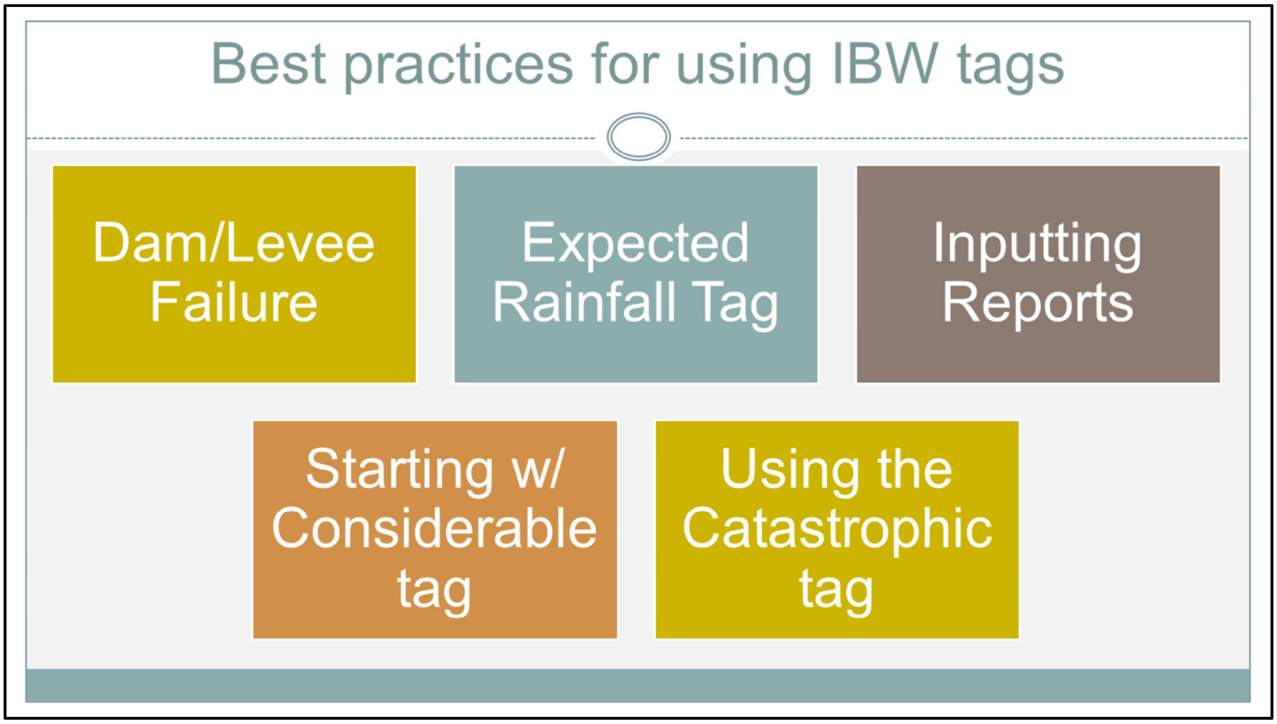

During the rest of this lesson, I am going to focus on some best practices related to using the IBW tags. Again, these are only recommendations and can vary based on local practices. I'll talk about:

--How to handle dam and levee failures
--What to do with the Expected Rainfall tag
--Where you should input reports
--When you could start with a Considerable tag right off the bat
--And how to handle a Catastrophic tag

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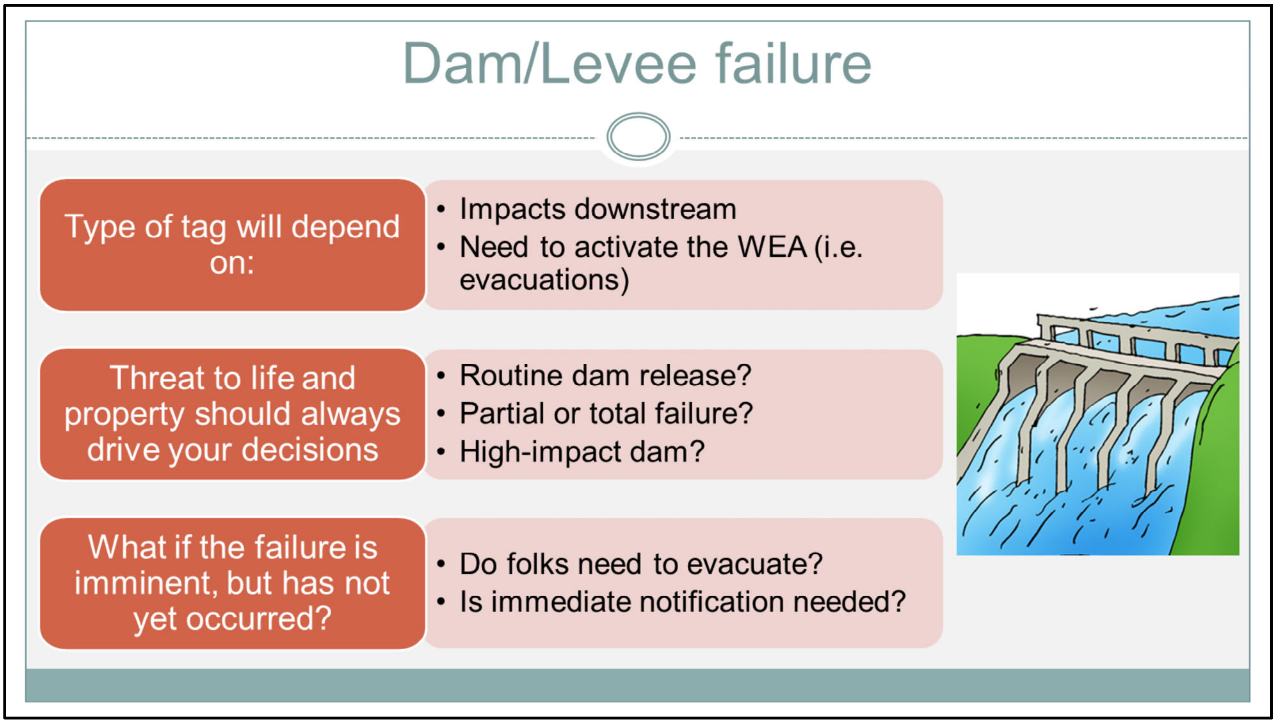

In the specific case of a dam or levee failure, IBW tagging changes nothing from what I stressed earlier. The type of tag depends on: the expected impacts downstream and whether you need to trigger the WEA to give immediate alerts.

As always, the imminent threat to life and property should drive your decisions. Is it a routine dam release that will elevate stream levels but not outside what residents are accustomed to? Is it a partial or total dam failure that requires immediate response to seek higher ground? Additionally, is it a high-impact dam with many people downstream?

One question we've heard a lot is what to do if the dam or levee failure is imminent but has not yet occurred? Again, the potential downstream impacts should drive your decisions. Do you need to notify people downstream to evacuate? Does the threat require immediate notification to protect life and property? If so, going Considerable or Catastrophic is totally warranted. If it's a small dam where officials can preemptively shut down a road or two and no one's house is going to be flooded, then you could probably stick with Base.

As always, use professional judgment and air on the side of safety.

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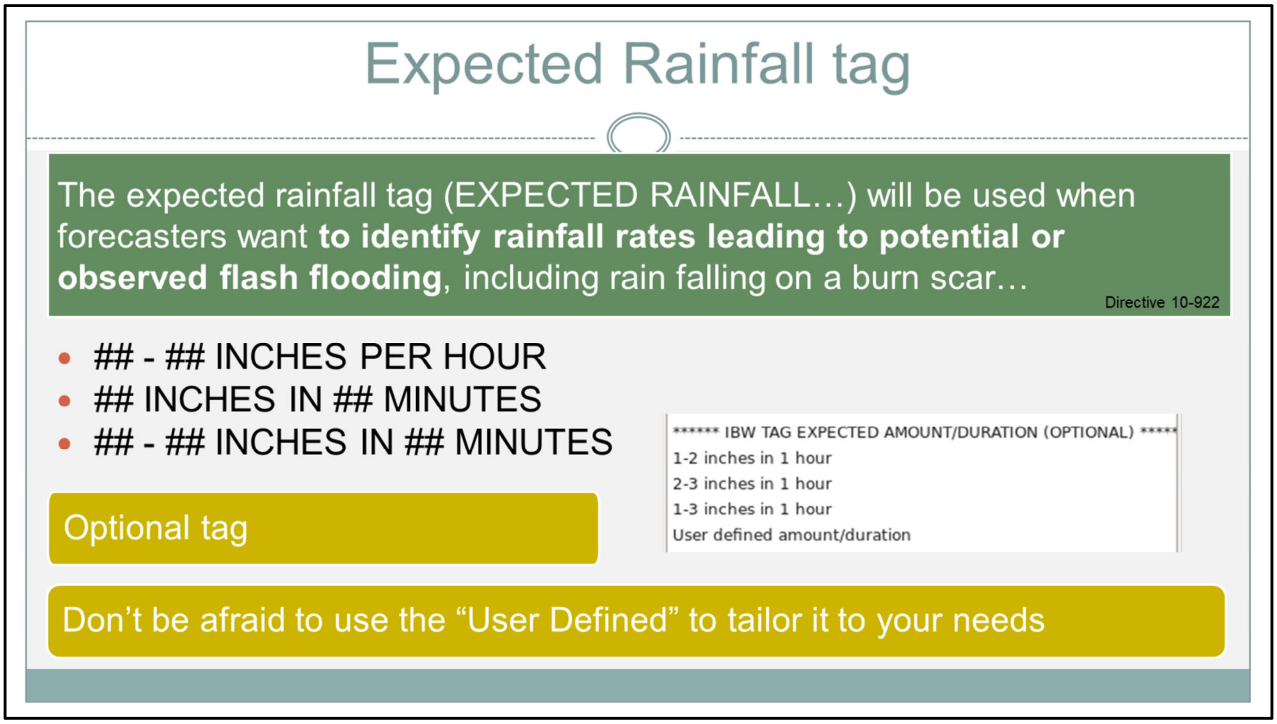

Since the Expected Rainfall tag is also new, here is the definition of how it should be used: The expected rainfall tag (EXPECTED RAINFALL…) will be used when forecasters want to identify rainfall rates **leading to potential or observed flash flooding**, including rain falling on a burn scar…"

Oftentimes, the rainfall *rate* is more important than the total rainfall when it comes to what's driving the flash flooding. This tag should be used to describe the rainfall **leading to** flash flooding.

There are several formats this information can be given, and they are shown here.
- ##-## INCHES PER HOUR
- ## INCHES IN ## MINUTES
- ##-## INCHES IN ## MINUTES

Keep in mind that this is an OPTIONAL tag. It's there to help you relay useful information, not to force you to make statements without having enough information to support them.

Also, don't be afraid to use the "User Defined" option to tailor the amounts to what you need. Again, it's there to help you quickly share useful information.

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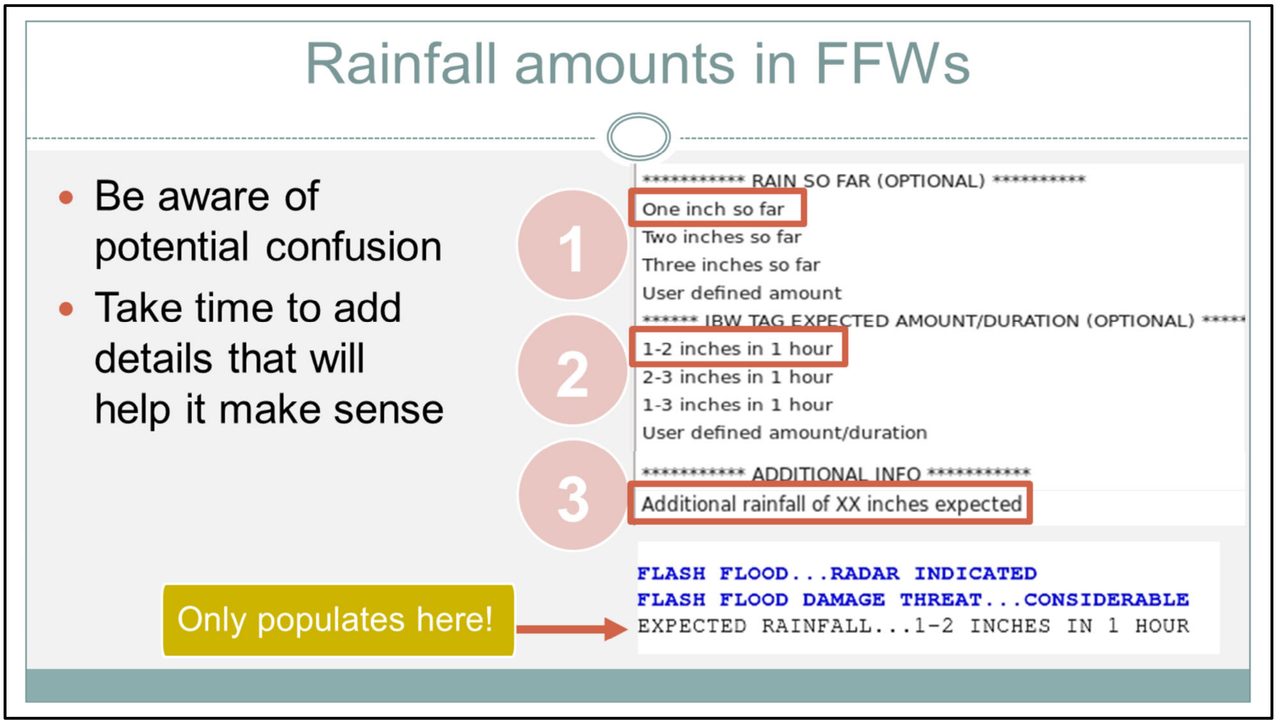


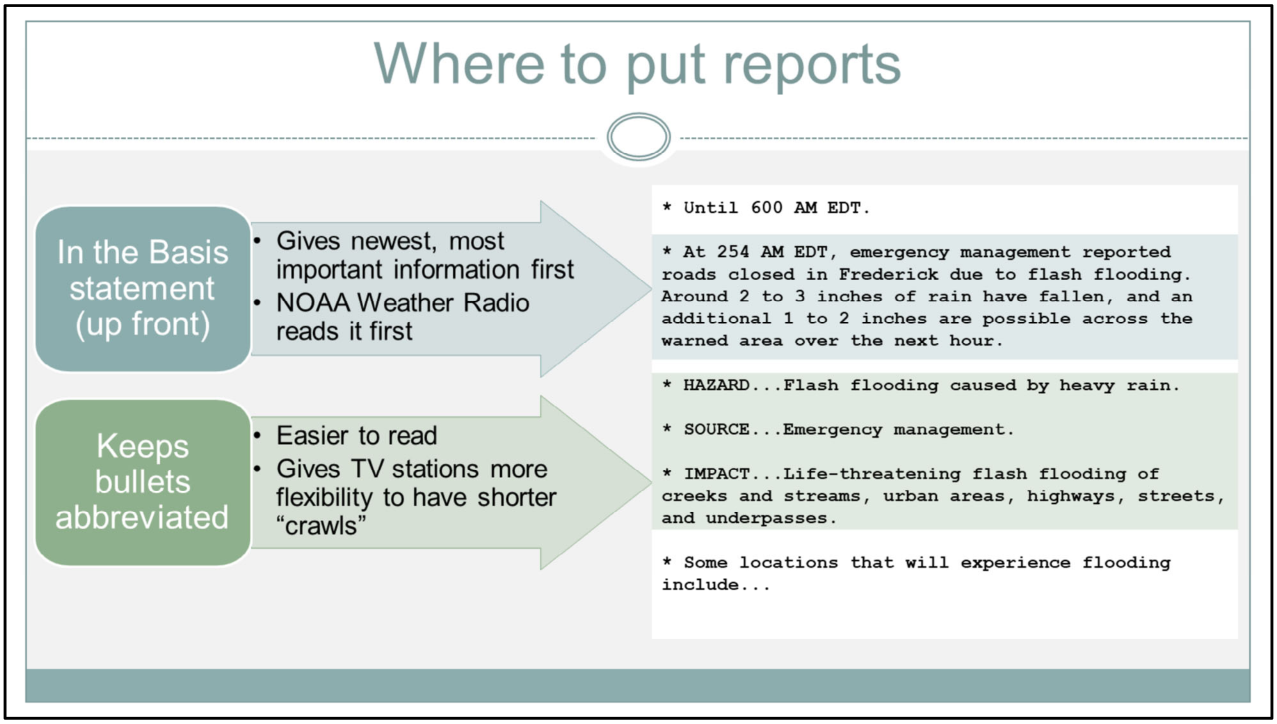
It's also important to realize that with this new Expected Rainfall tag, there are now 3 places in a Flash Flood Warning where you can talk about rainfall totals:

1) Rain so far
2) The IBW Expected Rainfall tag, and
3) Additional rainfall expected

And maybe you're starting to realize how confusing this could become. Take this scenario: You are about to issue a warning for an urban area. It's received about an inch of rain in the last couple hours, and you see more rain coming. The incoming rates will lead to another 1-2 inches in an hour, so that's why you're pulling the trigger on a warning now. Since your warning is going to last 3 hours, you estimate that a total of 3 more inches is expected over the warning duration.

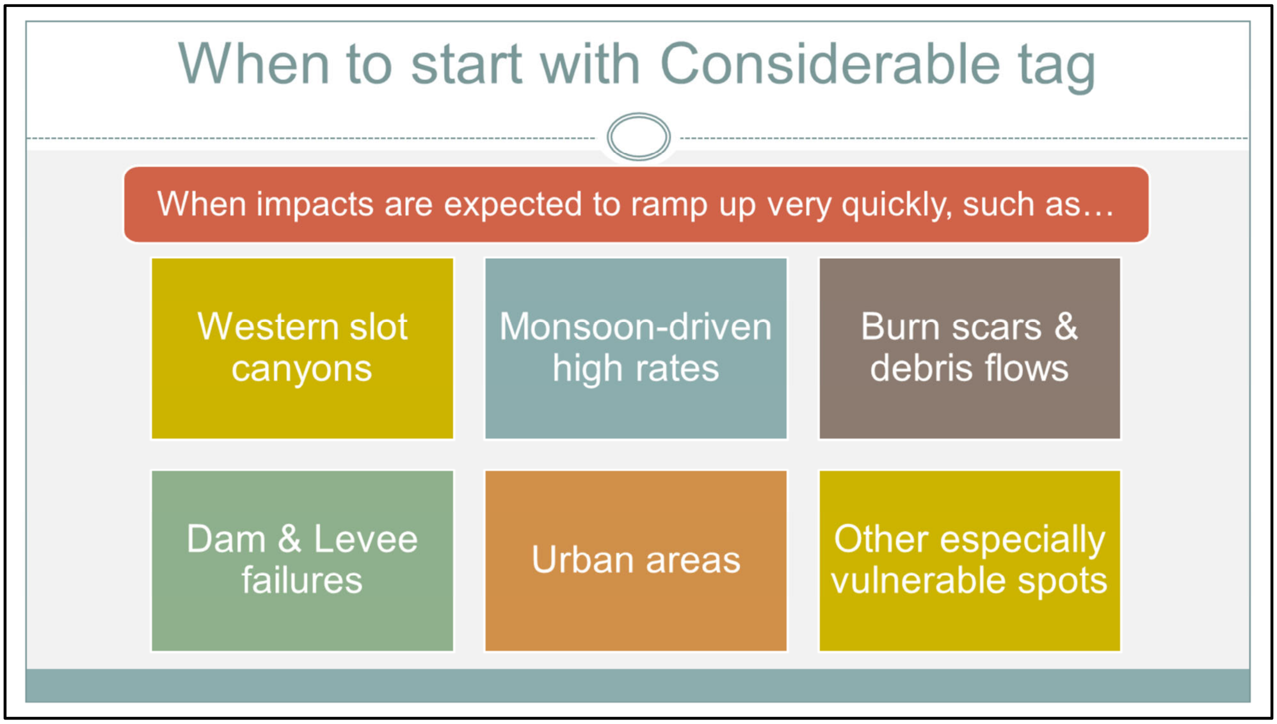
All of this is valid information, but do you see how having 3 different amounts in your text could be confusing? And to add to that, the "Expected Rainfall" tag ONLY populates at the bottom of your warning by default. So if you don't manually type it in, the body of your warning will say "additional amounts of 3 inches over the warning duration", but the tag at the bottom says "expected rainfall…1-2 inches in 1 hour."

So just be aware of this potential confusion. If you’re going to relay this information, take the time to add the details in the text that will make it make sense for the users.



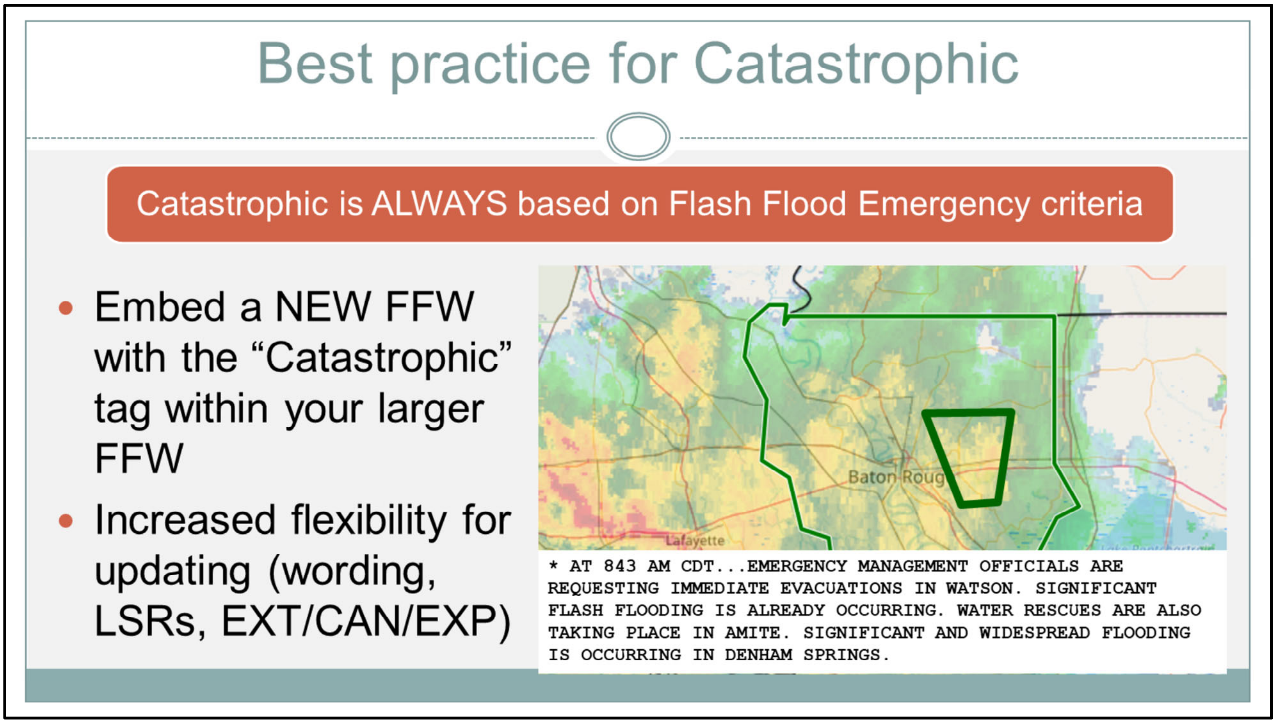
I wanted to take a moment to give a best practice related to where to input reports in the warning text. Traditionally, LSRs are given in the Basis statement up front. And in the IBW world, we don't think this should change. Putting LSRs up front gives the newest, most important information first. And it's what the NOAA Weather Radio will relay first.

We think keeping the bullets in a clean, abbreviated format is easier to read and it gives TV stations (and other apps) more flexibility to pull out concise information for shorter crawls.



There are certainly instances where starting immediately with a Considerable-tagged warning is warranted. And these instances are when you know impacts will ramp up very quickly, such as…
--western slot canyons
--monsoon-driven high rate events
--burn scars & debris flows
--dam & levee failures
--big urban areas
--and other especially vulnerable spots that you have knowledge of.

You know the needs of your partners and the public…If alerting quickly is needed, do so.



Again, the use of the Catastrophic tag is contingent on Flash Flood Emergency criteria being met. Usually, it takes time for these impacts to arise, so you may start off with a Base or Considerable warning that eventually needs to be upgraded. But there are many times when not everywhere in the warning needs to be alerted to Emergency conditions. Take, for instance, this example from the Slidell WFO. Where the initial warning polygon was based on repeated rounds of heavy rainfall moving over the Baton Rouge area.

Shortly after this warning was issued, the office opted to create an embedded Flash Flood Emergency for several towns east of Baton Rouge. In these scenarios, you want to focus the elevated wording (and WEAs) to the areas that truly need it. We recommend issuing a NEW FFW with the Catastrophic tag that's embedded within the larger polygon.

This will activate the WEA in the areas receiving the higher impacts. This also gives you more flexibility to update the wording and reports, and to extend and cancel the respective warnings when needed. In this example, emergency management was requesting evacuations and reporting water rescues in certain towns, and the targeted warning helped relay that information.

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I hope this lesson gave you a better foundation for using impact-based Flash Flood Warnings. But it definitely shouldn't stop here. More importantly, have more conversations at the office about local practices. Some topics worth discussing include:
--What tags would have been used for past (even notable) events?
--Are there thresholds in various tools that traditionally lead to higher impacts that can help guide you during an event?
--What are the needs of your partners?
--Of the public?
--And are all the forecasters on the same page when it comes to office best practices?

Thank you for watching this lesson. When you are ready, move onto the next slide to take the quiz.