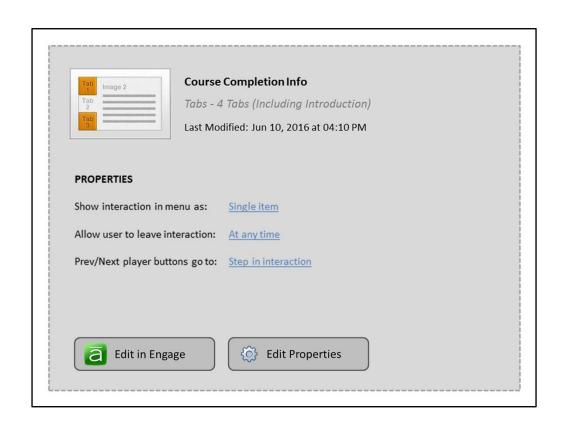


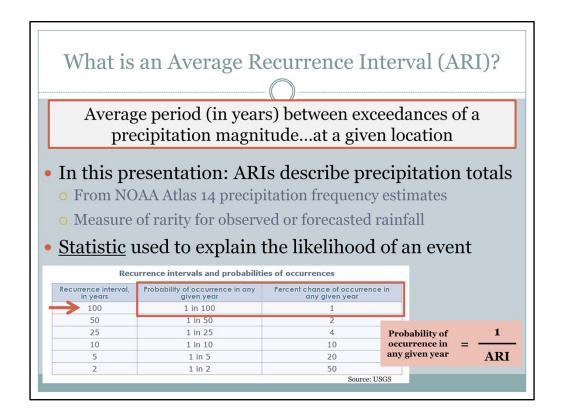
Hello. My name is Jill Hardy, and welcome to this module about the NOAA Atlas 14 Average Recurrence Intervals (or ARIs) dataset. This is Part 1 of 2, and will introduce the ARI dataset that is available in AWIPS-2, as of the 16.2.1 build. Part 2 will focus on how to use ARI data in AWIPS, as well as some tips on how to effectively interpret ARI data for flash flood decision-making in FFMP.



# **Learning Objectives**

- By the end of this lesson, the student will be able to:
  - o Identify the definition of an average recurrence interval (ARI)
  - Express the probability of occurrence of a rainfall amount given an ARI
  - o Differentiate between rainfall and flooding ARIs
  - o Identify how NOAA Atlas 14 ARIs are calculated
  - o Identify limitations of higher ARIs
  - Identify how to correctly communicate frequency estimates with ARIs
  - o Identify the geographic limitations of Atlas 14 data
  - Interpret Atlas 14 ARI data and confidence interval information

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



First, what is an Average Recurrence Interval (or ARI)? ARIs can be used to describe all kinds of events...rainfall, floods, earthquakes. In its most general sense, an Average Recurrence Interval is simply the *average* time period (in years) between exceedances of an event, at a given location.

For this presentation, we will focus on ARIs that describe precipitation totals, specifically, those derived from the NOAA Atlas 14 precipitation frequency estimates dataset. So if we reformat the definition to fit our needs, then we can say that rainfall ARIs describe the average period (in years) between exceedances of a precipitation magnitude...at a given location.

In this sense, observed or forecasted rainfall can be compared to ARIs to provide a measure of rarity of the rainfall.

So let's say you get 10 inches of rainfall over a 12-hour period, at your location. How rare is this? The ARI data tells you it is a 100-year rainfall. So what does a 100-year rainfall mean? Using the table below, there a few ways to explain this information. The first is to use the ARI, which is 100 years. However, the better way is to take the inverse of the ARI (in this case, 1 over 100), and say "the probability of this rainfall occurring *in any given year* is 1 in 100", or a 1% chance.

So just keep in mind, an ARI is actually a *statistic* used to explain the likelihood of an event. A "100-year" rainfall can occur more than once in 100 years. It can occur twice, or ten

times, or not at all. It's just that the *likelihood* of a rainfall of that magnitude occurring is 1%, in any given year.

http://water.usgs.gov/edu/qafloods.html

#### Atlas 14 ARIs are NOT...

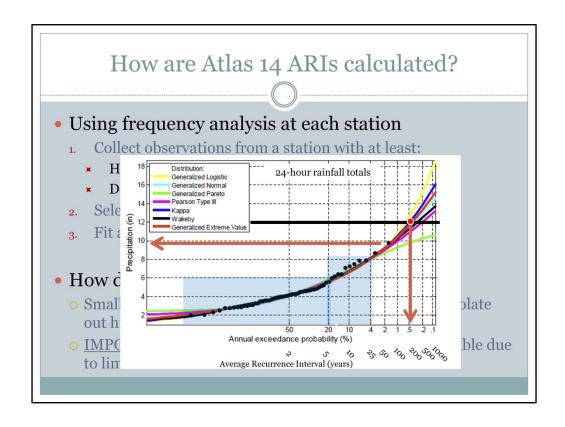
- ...return periods (or recurrence intervals) for flood events!
  - A 10-year rainfall is NOT the same as a 10-year flood
- Do NOT always show one-to-one relationships with flood events!
  - o A 50-year rainfall does NOT always cause a 50-year flood
    - Factors like basin size, duration, antecedent soil conditions, land use, etc. can make a big difference

To reiterate, the Atlas 14 ARIs available in AWIPS describe precipitation events. So given this, Atlas 14 ARIs are not...

...Return periods (or recurrence intervals) for flood events! A 10-year rainfall is NOT the same as a 10-year flood. Atlas 14 ARIs assess the rarity of a *precipitation* event, while flood return periods are based on streamflow and stage height of a particular basin.

And they do NOT always show one-to-one relationships with flood events. A 50-year rainfall doesn't always cause a 50-year flood. Why? There are many factors other than precip that can change the likelihood of flooding. For instance, how big is the basin that rainfall is falling over? What is the duration of the rainfall (30 min? 24 hours?)? Is the soil already saturated? And so on...

So just keep these differences in mind when interpreting the data.



So now that we've introduced what the Atlas 14 ARIs are, and are not, let's discuss how they are calculated.

The process is called frequency analysis, and it is conducted at each observing station. First, observations are collected from a station with at least 20 years of hourly data, and/or 30 years of daily data. Next, over the entire period of record of the station, the most extreme rainfall observations are selected for each duration. Finally, a frequency distribution is fit to the extreme observations. From this distribution, you can estimate the probability, as well as the ARI.

However, the real takeaway here is not understanding the nitty-gritty of this process, but rather, how you can get estimates of "1000-year rainfall events" with only 20 to *maybe* 150 years of data? The short answer is...because of the fitted distribution!

Take, for instance, this probability plot pulled from the NOAA Atlas 14 Volume 9 documentation. Each black dot represents a 24-hour rainfall observation, and each line represents a potential distribution that you could choose to fit the data.

Notice how many observations there are for the low-end, 1-5 year rainfall events, and just how strongly correlated they are to each other. From 5-25 years, observations become more sparse and noisy. And above 25 years, there are only 2 observations, with the max being about 10 inches. But, let's say you were interested in the probability of exceeding 12 inches in 24 hours. What do you do without any observations that high? Well, you fit one of

the distribution lines to the data. **The red one is used for the NOAA Atlas 14 dataset, so let's pick that one.** Then you can extrapolate out the statistics. In this case, there is a 0.5% chance of 12 inches in 24 hours occurring *in any given year*, or rather, it has an average recurrence interval of 200 years.

In short, this method assumes that a relatively small period of record is enough to extrapolate out higher recurrence intervals. However, the most important thing to keep in mind: higher ARIs, once you get above 10-25 years, are less reliable due to the fact they were calculated using little to no observational data over that time span.

## NWS Directive 10-922: Wording of Frequency Estimates

1.6 Appropriate Terminology for Expressing Event Frequency. When describing past, current, or expected flood or precipitation events in reference to annual probability (frequency), the terminology "T-year event" will not be used anywhere in a product. Instead, use "X percent annual chance event," where X = 100 × (1/T) percent. For example, use "1 percent annual chance flood" instead of "100-year flood." In addition, events should not be cited as having an estimated annual chance of less than 0.2 percent (frequency greater than 500-year) because the limited period of precipitation and stream flow records make such probabilities highly uncertain. When flood or precipitation frequencies are cited, they should be attributed to the agency which developed them. However, the best practice is to compare past, current, or expected events to previous events rather than an event with a certain annual probability.

Do not say – "100-year event"

Could say – "1% annual chance" (but only up to 0.2%)

Could say - "Similar in severity to..."

 ARIs are likely more useful in building confidence during extreme rainfall events

http://www.nws.noaa.gov/directives/010/010.htm

In fact, to reiterate how important it is to properly relay event frequency information to the public, the NWS Directive 10-922 provides some guidance.

Specifically, it states: "the terminology 'T-year event' will not be used anywhere in a product. Instead, use 'X percent annual chance event'..."

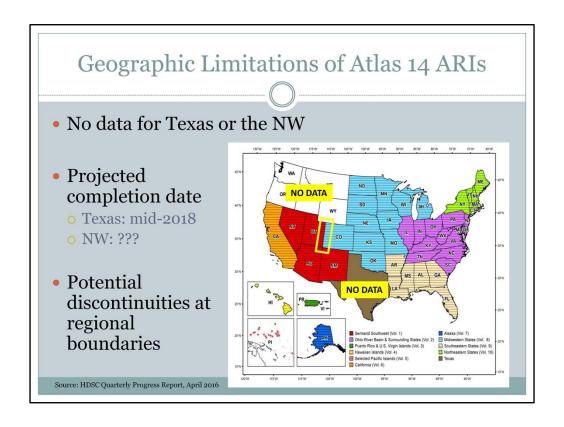
This can be used interchangeably with saying "X percent chance of occurring in any given year", whichever you prefer.

Additionally, the Directive reiterates what we discussed on the previous slide: "events should not be cited as having an estimated annual chance of less than 0.2 percent (greater than 500-year) because the limited period of precipitation...records make such probabilities highly uncertain."

Finally, there is a best practice: "Compare past, current, or expected events to *previous* events rather than an event with a certain annual probability." Remember, ARI data is *estimated*. It is more meaningful to put an event in context with past experiences, if there are similar circumstances (like hydrology and duration).

In summary, do not say "100-year event". You could say "1% annual chance", but only for events up to 0.2%, or 500-year. And even that may not be a particularly useful way to communicate the rarity and significance of the event. But in some rare instances where you know of similar historical events, you could say something like "this rainfall is similar in severity to..."

Rather than influencing the text in your products, ARIs are likely going to be more useful in building confidence when diagnosing extreme events.



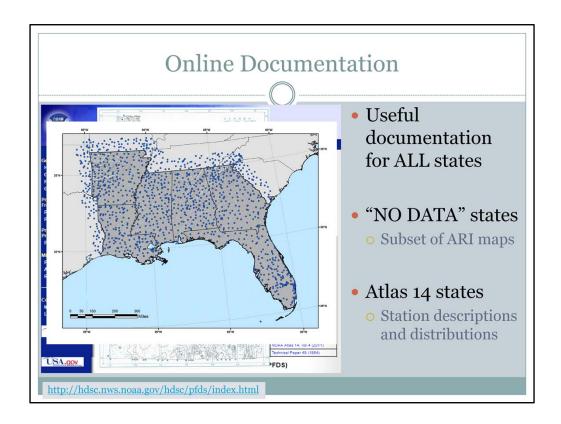
Before we go any further, it's important to note some of the geographic limitations associated with the Atlas 14 dataset.

For one, ARI data is NOT available in Texas or the Northwest at this time, as shown in the image below. The Hydrometeorological Design Studies Center (HDSC) within the National Water Center has been updating the precipitation frequency estimates regionally (as denoted by the color-coding in this image), and thus, some areas are still in the process of being completed.

Based on the Center's quarterly report from April 2016, Texas is projected to be completed by mid-2018. However, at this time, there are no plans to complete the northwest states.

Another limitation is: for regions that are complete (which are all of the hatched areas in this image), you may see discontinuities at regional boundaries (like Utah and Colorado, for instance). This is due to slight differences in calculations between regional analyses. So keep this in mind when interpreting the data across *certain* state borders.

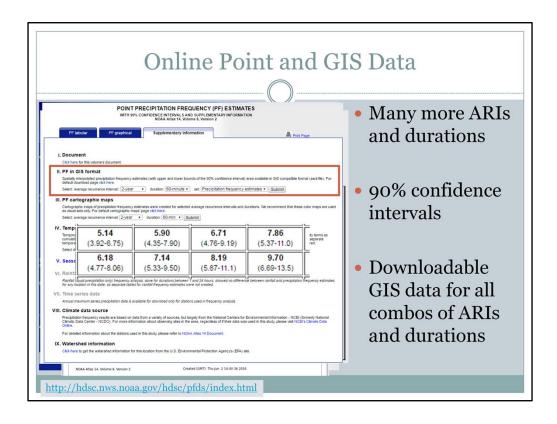
http://www.nws.noaa.gov/oh/hdsc/current-projects/progress/201604 HDSC PR.pdf



The Hydrometeorological Design Studies Center website, specifically its Precipitation Frequency Data Server, is a great resource about the NOAA Atlas dataset, with supplementary information that should be used in conjunction with what is available in AWIPS.

For one, there is documentation for ALL states located on the Documents page, here. For Texas and the five Northwest states, this documentation provides useful information that just hasn't been processed into grids yet. Take, for instance, this map from the Atlas 2 Volume 5 document. It shows Idaho's 10-year ARI for the 6-hour duration. So just be aware that there is still data out there for these states to use, you just have to find them in the PDFs!

Now, for the Atlas 14 states which *have* been processed, the PDFs still provide helpful details. There are tables with descriptions of every station used in the analyses, as well as maps (like this one) showing their distributions.



The Precipitation Frequency Data Server also allows you to access ARI point and GIS data, a lot of which is not available in AWIPS.

Beginning at the homepage, simply click on any of the dark blue states, and you will open an interactive map. From here, there are multiple ways you can sample the map to get point-based frequency estimates, including...entering a lat/lon, selecting from the station list, and moving the crosshairs to the desired location.

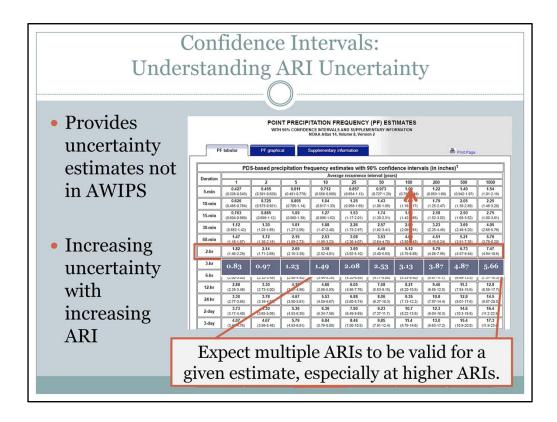
Once you have selected your location, the table below the map will automatically update with the corresponding frequency estimates. Notice how many durations and ARIs there are available here. This is one of the main advantages of the online server, because your AWIPS-2 workstation only has a subset of these created into grids. We will talk more about which ones are available in AWIPS in Part 2.

Another BIG advantage is the inclusion of confidence intervals with this data. Notice the 90% bounds below each value. These are not available in AWIPS, but can be REALLY important when interpreting the data. We'll talk more about this on the next slide.

The other two tabs also have useful information. The "PF graphical" tab plots the data in a few different ways that we encourage you to explore.

Finally, the "Supplementary Information" tab provides a variety of additional data, with probably the most useful being downloadable GIS grids for ALL combinations of ARIs and

durations.



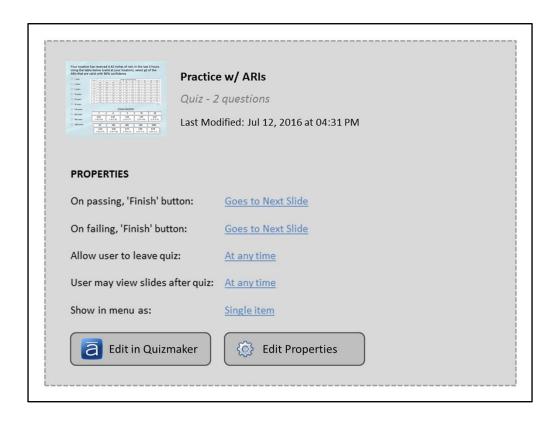
As mentioned on the previous slide, the online server provides 90% confidence intervals with all of its point data. This information is very, very useful when it comes to interpreting the ARI data because it provides uncertainty estimates, which are not apparent when using ARIs in AWIPS.

For example, let's use this table for a specific location in Oklahoma. If this location receives 5 inches of rain in two hours, how rare is this? If you just used 5 inches, you'd probably say it's around a 100-year rainfall. However, look at the confidence intervals. The *average* rainfall for a 100-year ARI is 5.12 inches, but the bounds of the 90% confidence interval shows it could be as low a 3.75 inches, or as high as 6.88 inches. Now look at the rest of these values...5 inches falls within the 90% confidence level for a 25-year rainfall ALL THE WAY to a 1000-year rainfall! So...how rare is it? Hard to say, huh? Understanding this overlap in estimates is the key to interpreting ARI data, because you may think something is a 100-year event, when it could really be much higher or lower.

Also note that there is increasing uncertainty with increasing ARI. Low ARIs have smaller, tighter confidence intervals than higher ARIs. Let's use our two-hour duration again. Here are the widths of each of these confidence intervals, in inches. Notice how the range of values increases with ARI, especially above 50 years. This makes sense based on what we know about how these ARIs were calculated. The more extreme ARIs have less observational data with which to base their estimates, therefore, the confidence in these estimates is lower, making the range of possible values higher.

Keep in mind that these uncertainty estimates will vary significantly throughout the country. Some areas may not have as much overlap as this example, or even more. So take the time to understand how they look in your area.

The bottom line of all this is: Expect multiple ARIs to be valid for a given precipitation estimate, especially at higher ARIs.



So let's have you play around with some of this data. These questions are not graded.

## Summary: What are Atlas 14 ARIs?

- Average period between exceedances of an event at a given location
  - o Gives a sense of rarity to any past, current, or future event
  - Calculated via statistical methods
- Atlas 14 ARIs...
  - Explain the likelihood of exceeding a precipitation magnitude, over a defined duration
  - Compare with observed and forecasted rainfall
  - Wording: "X-percent annual chance"

So to recap...An average recurrence interval is a general term used to describe the average period between exceedances of an event, at a given location. Their purpose is to give a sense of rarity to any past, current, or future event. They are calculated using statistical methods that help explain the likelihood of something occurring, especially when there is little to no observational data with which to compare.

For the Atlas 14 dataset, ARIs specifically explain the likelihood of exceeding a precipitation magnitude over a defined duration. Their practical use is to compare with observed and forecasted rainfall. And when using ARIs operationally, it is best practice to explain events in terms of its "X-percent annual chance", rather than by "X-year event".

#### Summary: Shortfalls of Atlas 14 ARIs

- Currently, no gridded data for Texas and the Northwest
  - Use online documentation for some useful information
- Potential discontinuities at regional borders
- A singular value is misleading
  - o Significant uncertainty, especially at higher ARIs
  - o Online interactive webpage has confidence information

There are several shortfalls of the Atlas 14 dataset, which we discussed in detail the second half of this lesson.

For one, as of August 2016, there are no gridded data for Texas and the Northwest. However, you can still use the online documentation to see a subset of ARI maps, as well as station details.

Second, because ARIs are calculated regionally, there may be discontinuities at certain state borders. Keep this in mind when interpreting values across these borders.

Finally, in AWIPS, you will only see singular values of precip estimates. This is misleading due to the significant uncertainty that exists with this dataset, especially when considering higher ARIs. So don't forget that you have the online interactive webpage with confidence information that can help you during post-event analysis, and for general self-calibration.

This concludes Part 1: Introduction to Average Recurrence Intervals. Before moving onto Part 2, which explains how to use ARIs in AWIPS-2, go onto the next slide to take the quiz and receive credit on the LMS.

