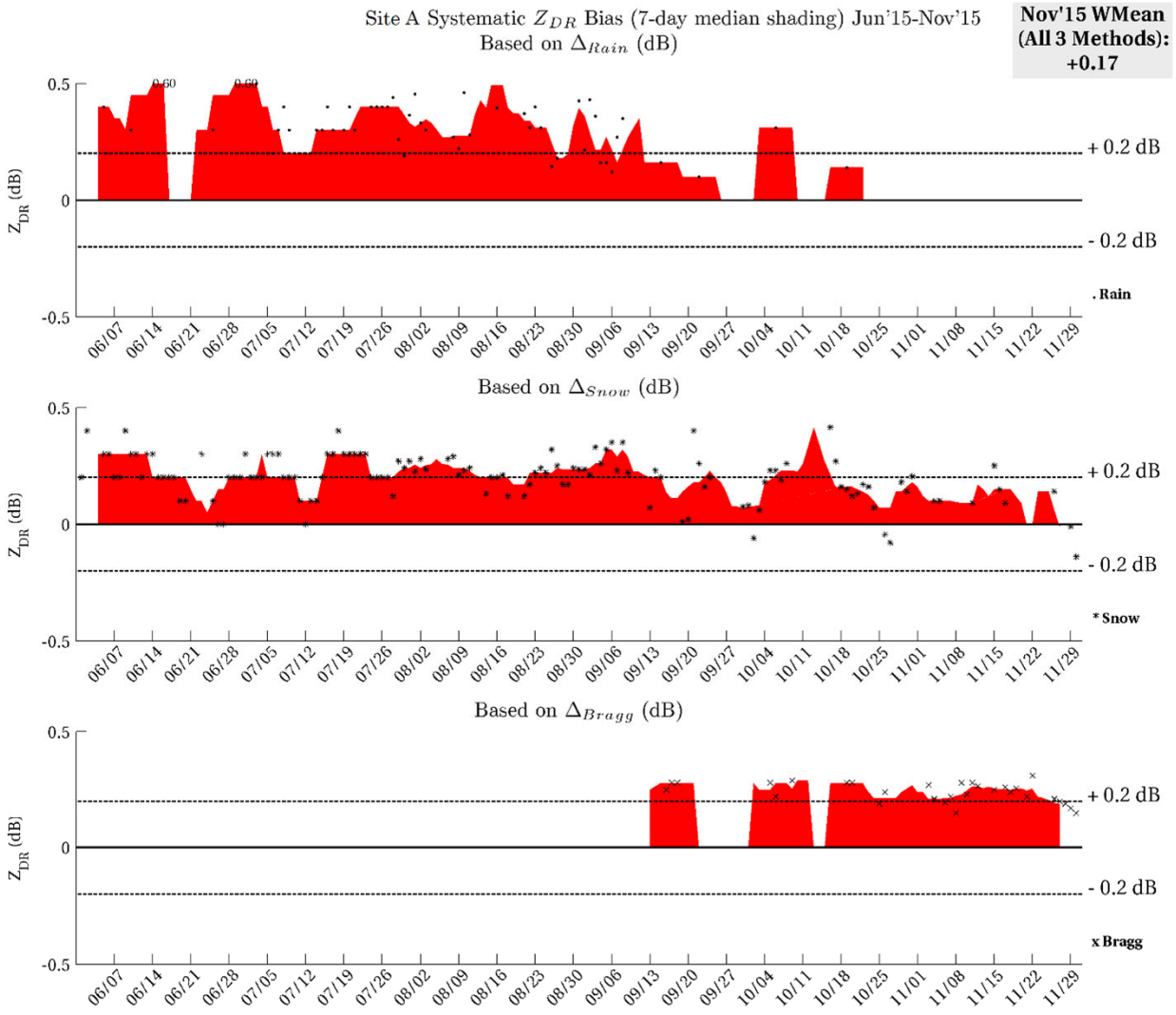
How to Interpret Z_{DR} Shade Charts

Lindsey M. Richardson, W. David Zittel, Dan B. Frashier, Amy E. Daniel, and Jessica A. Schultz

Build 20

What's a Shade Chart?

- A graphical way to monitor Z_{DR} bias from a **single** radar site
  - Information from the most recent 6 months



What's a Shade Chart? (Cont.)

- Based on 3 independent external target methods:
  - Light Rain
  - Dry Snow
  - Bragg Scatter
- Event characteristics are different between the methods

Why do we care about Z_{DR} Bias*?

- Z_{DR} bias shows the amount of error in ZDR Offset
- Z_{DR} bias can have adverse affects on Quantitative Precipitation Estimation (QPE)
  - A positive Z_{DR} bias results in underestimation
  - A negative Z_{DR} bias results in overestimation
- Z_{DR} affects other products as well
  - Melting Layer Detection Algorithm (MLDA)
    - Particularly “wet snow”
  - Hydrometeor Classification Algorithm (HCA)
    - Specific Z_{DR} thresholds for categories

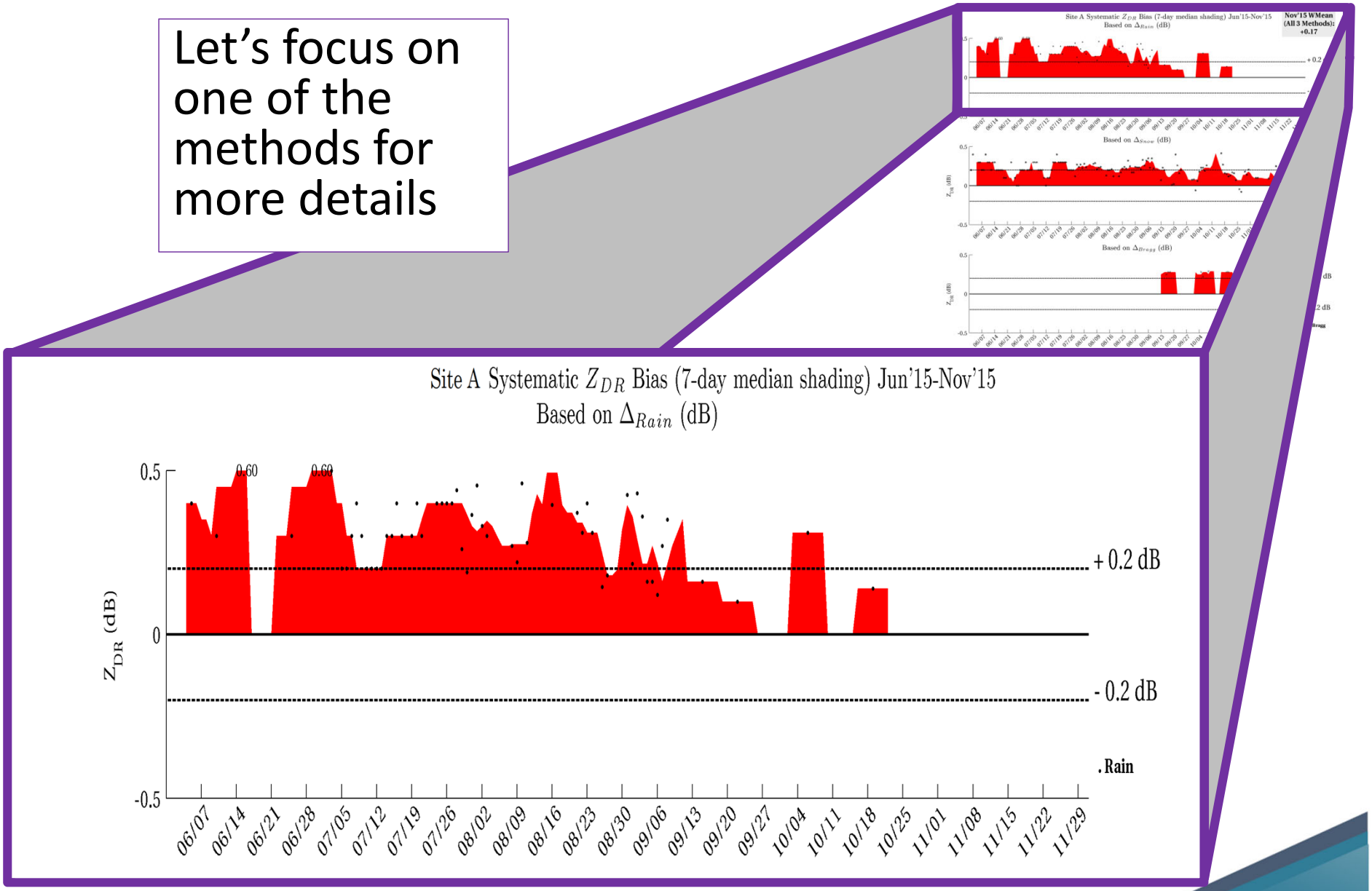
* This is not the same as ZDR Offset but is related

Why external targets?

- External targets act as an estimation metric independent from the built-in hardware estimates
  - Additional measurement to verify built-in hardware results
- Methods work with operational scanning strategies and products

What's on a Shade Chart?

Let's focus on one of the methods for more details

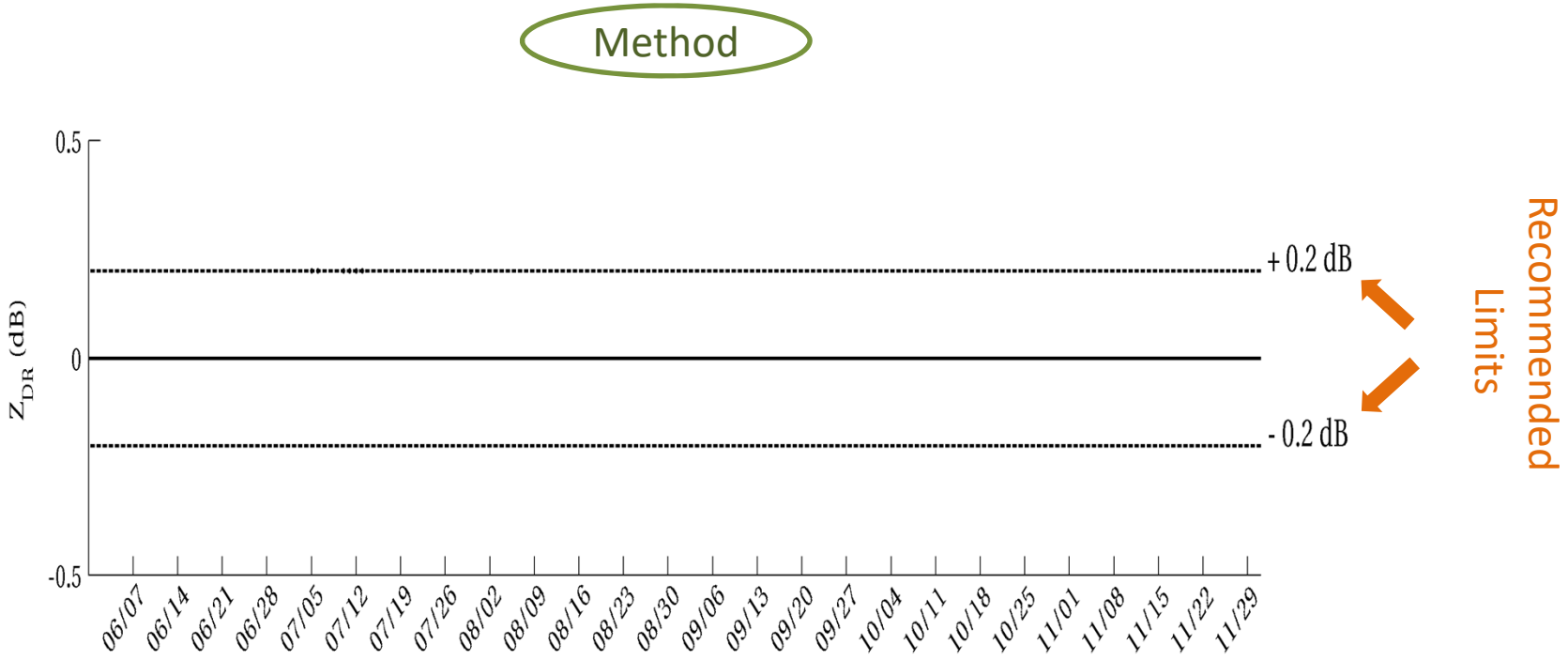


Did you notice?

- The dashed lines?
- The black numbers at the top of the shading in places?
- The gap in shading?
- Each subplot contains information from an independent method?
- The chart has a trend in time?

Let’s focus on a single subplot and explore these details

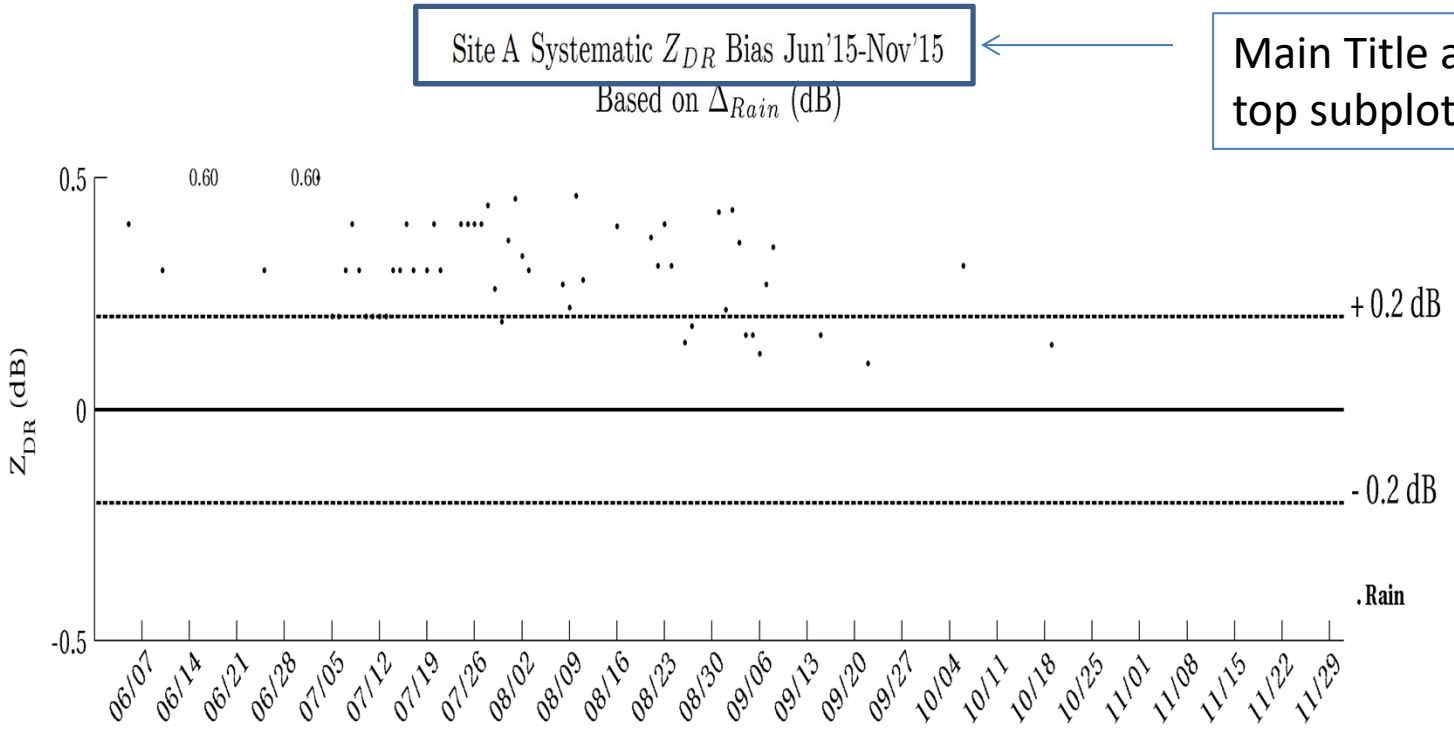
Layout of Each Subplot



Time (6 Months Ago -----> Past Month)

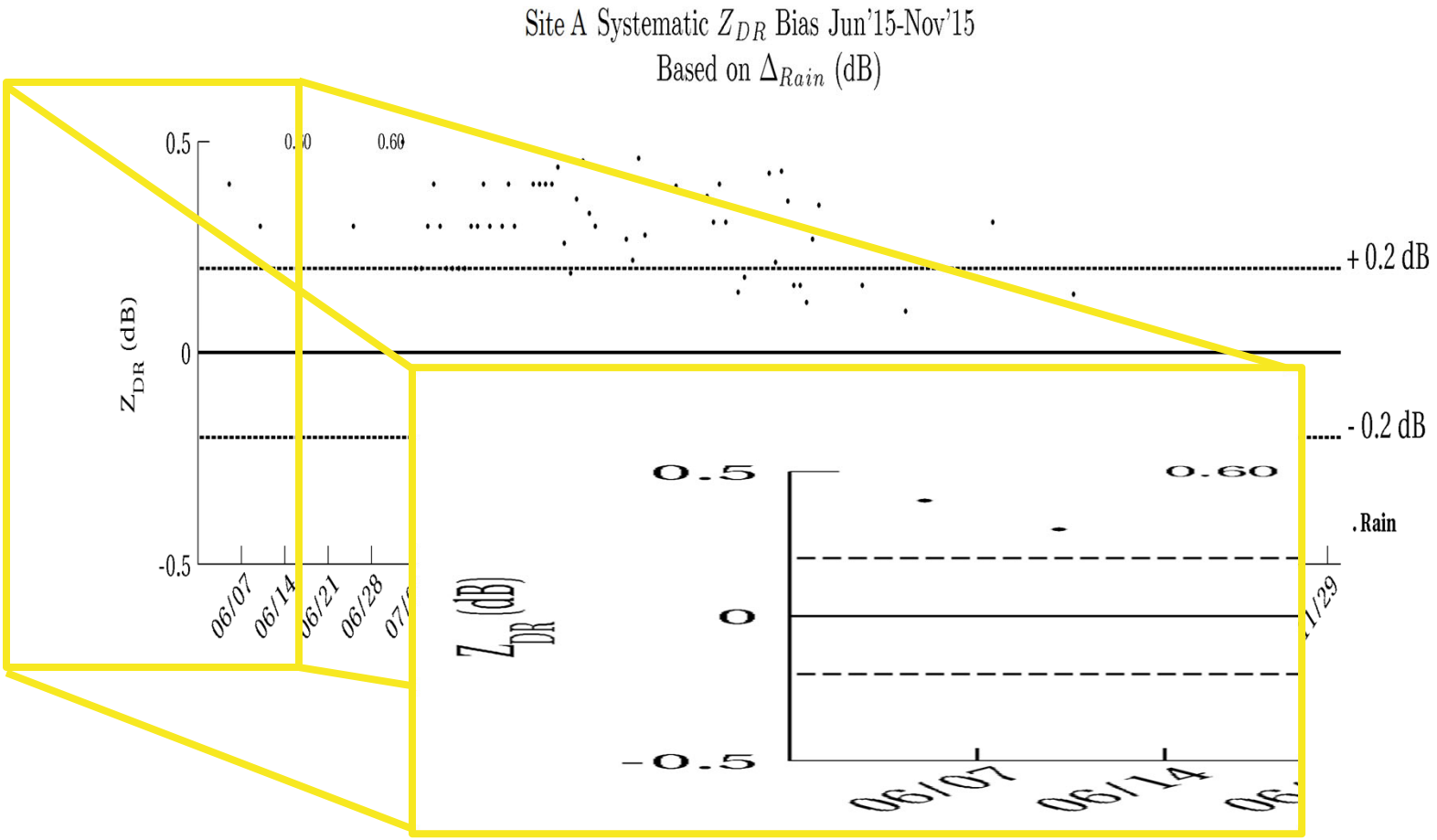
Most Recent 6 months of Data

Z_{DR} Bias Estimates from Events



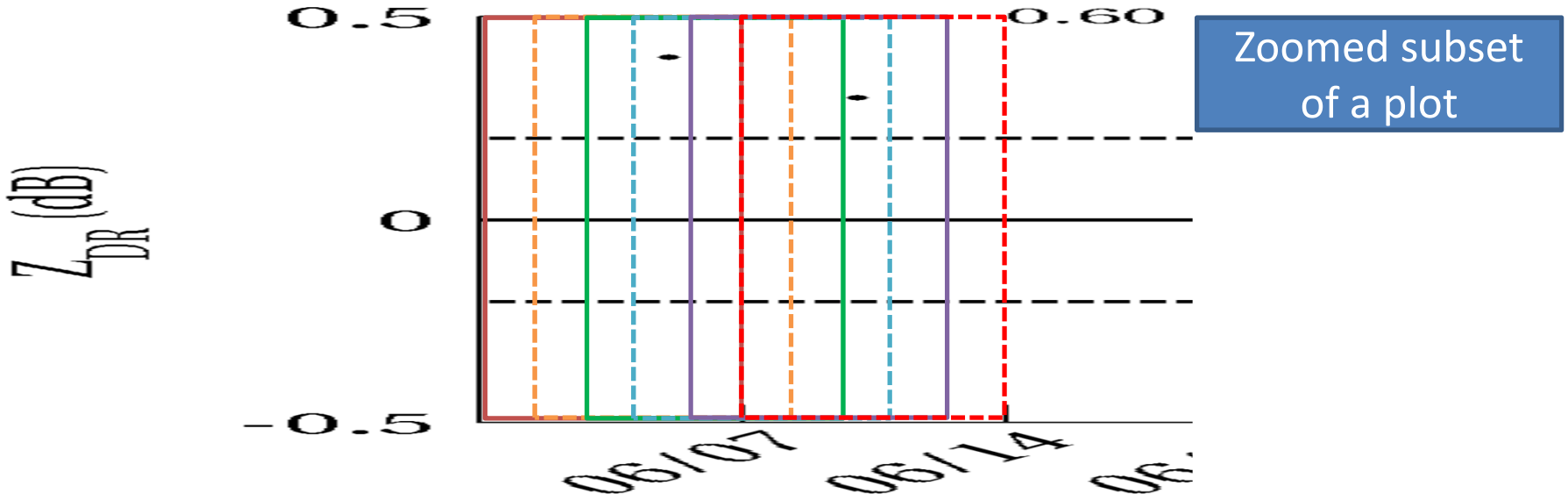
- Many, highly-varying scatter points
  - Events may vary greatly from one to another
  - Events are defined per method in later slides
- Events are OK, but what if we took a 7-day median?

Grouping for Shading



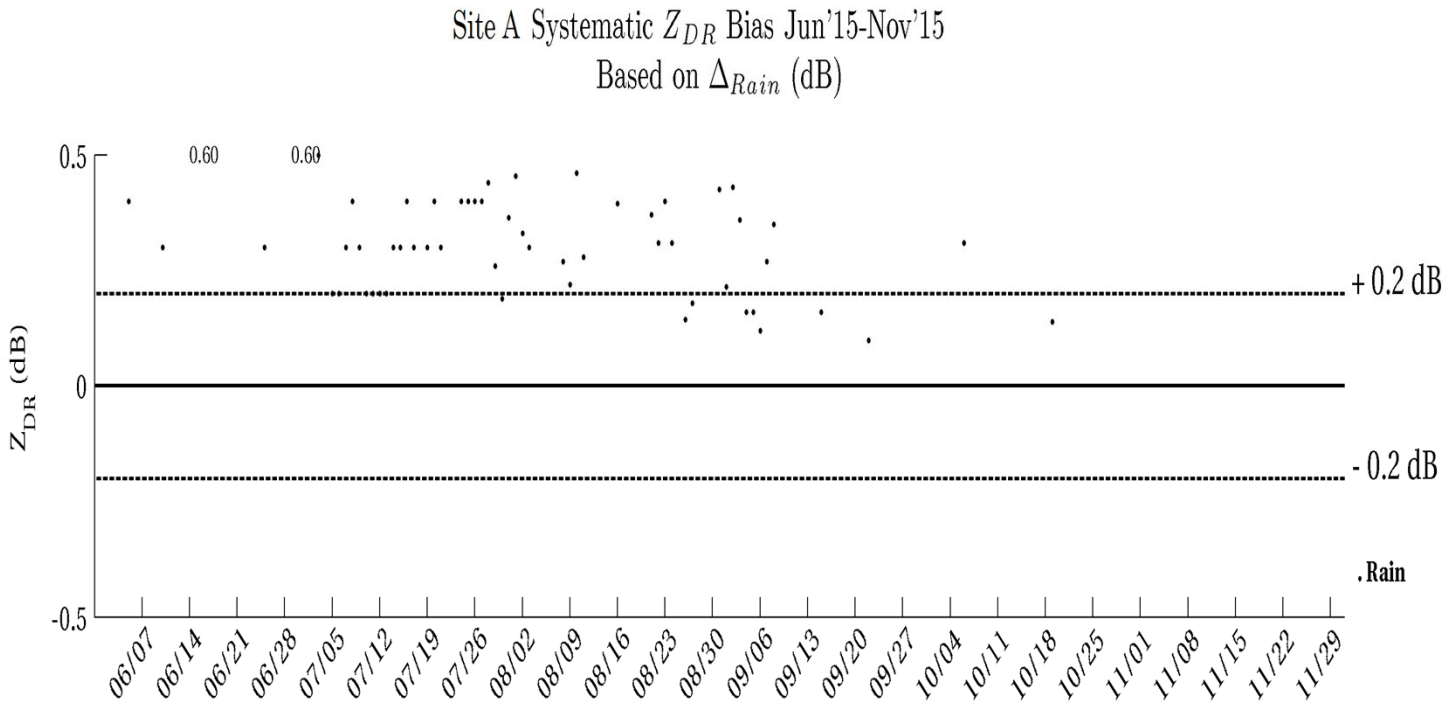
Zoom in to focus on smaller time scale

7-Day Running Median



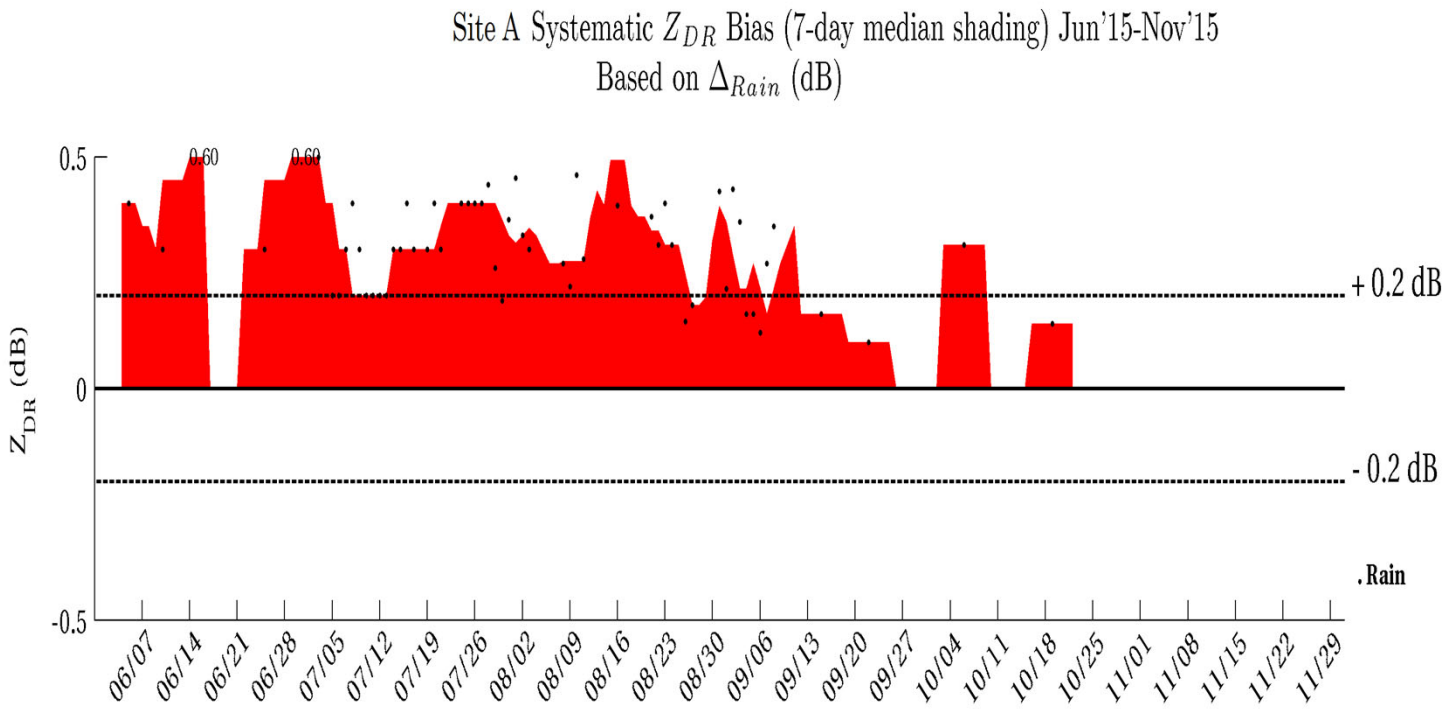
- For each 7-day grouping, a median is calculated from the points
  - Days 1-7, 2-8, 3-9, etc.
- Shading vertex placed on middle day of 7-day set
- Each of the colored boxes above represent a separate set

7-Day Median Calculation



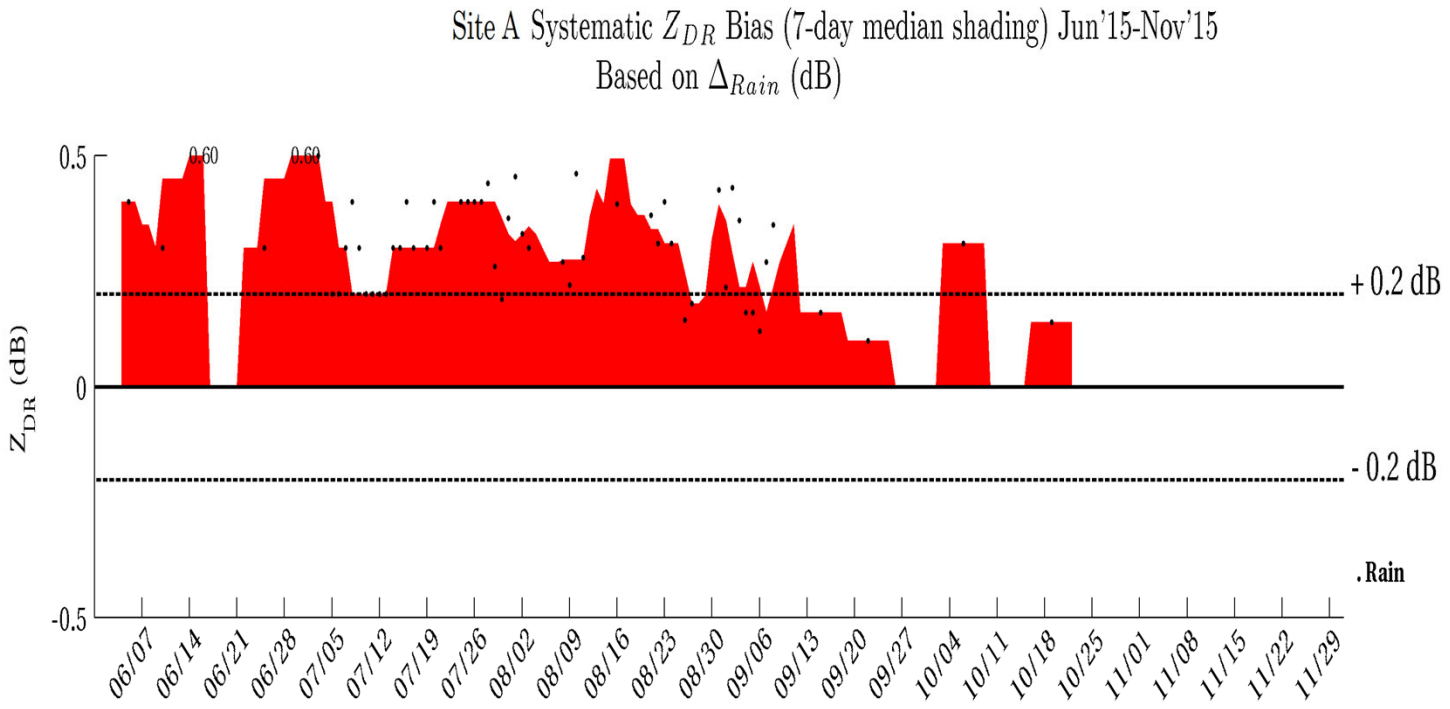
Go from just having points…

7-Day Median Calculation



…to having shading.

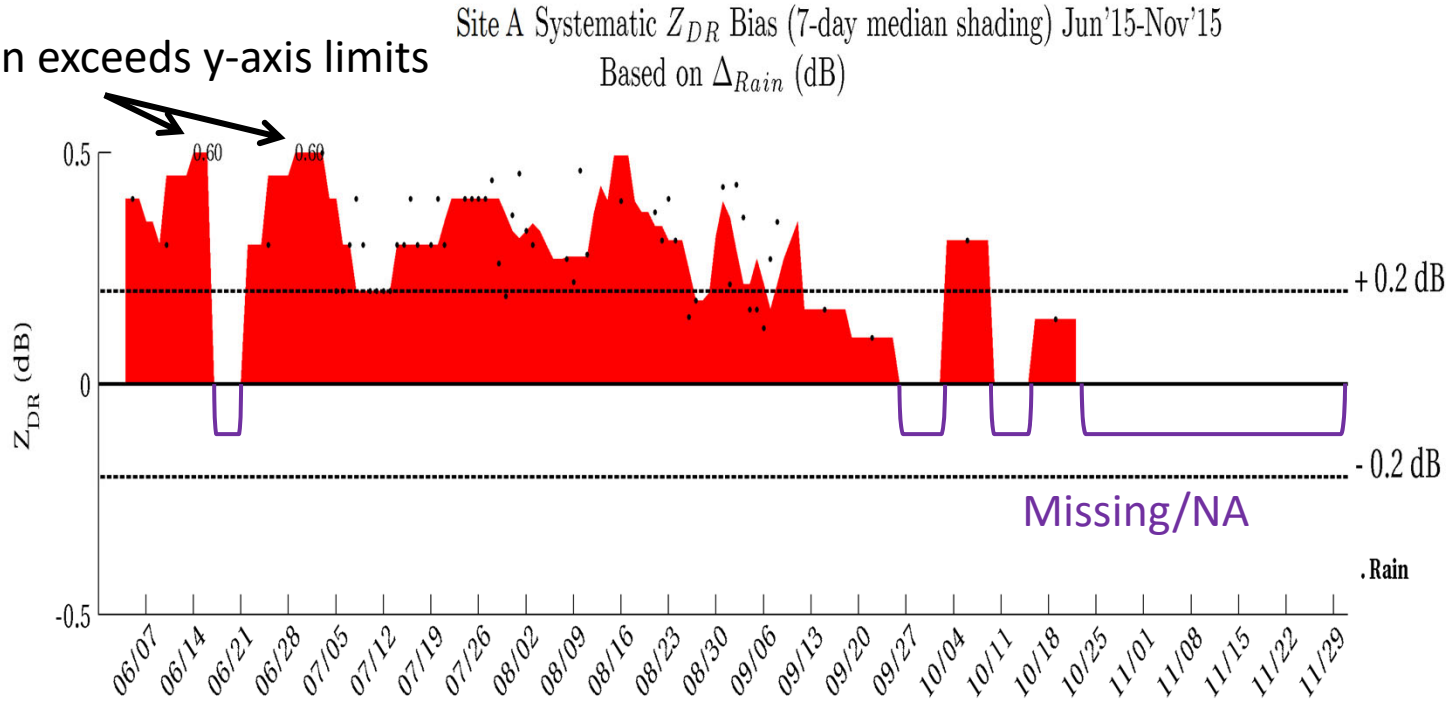
7-Day Median Shading



- Long-term median trend shows a continuing bias
  - Positive (red-shaded) values are considered warm or high
  - Negative (blue-shaded) values are considered cool or low
- Sites are beyond recommended limits if the shading is regularly above (below) the dashed 0.2 dB (-0.2 dB) line

7-Day Median Shading Cont.

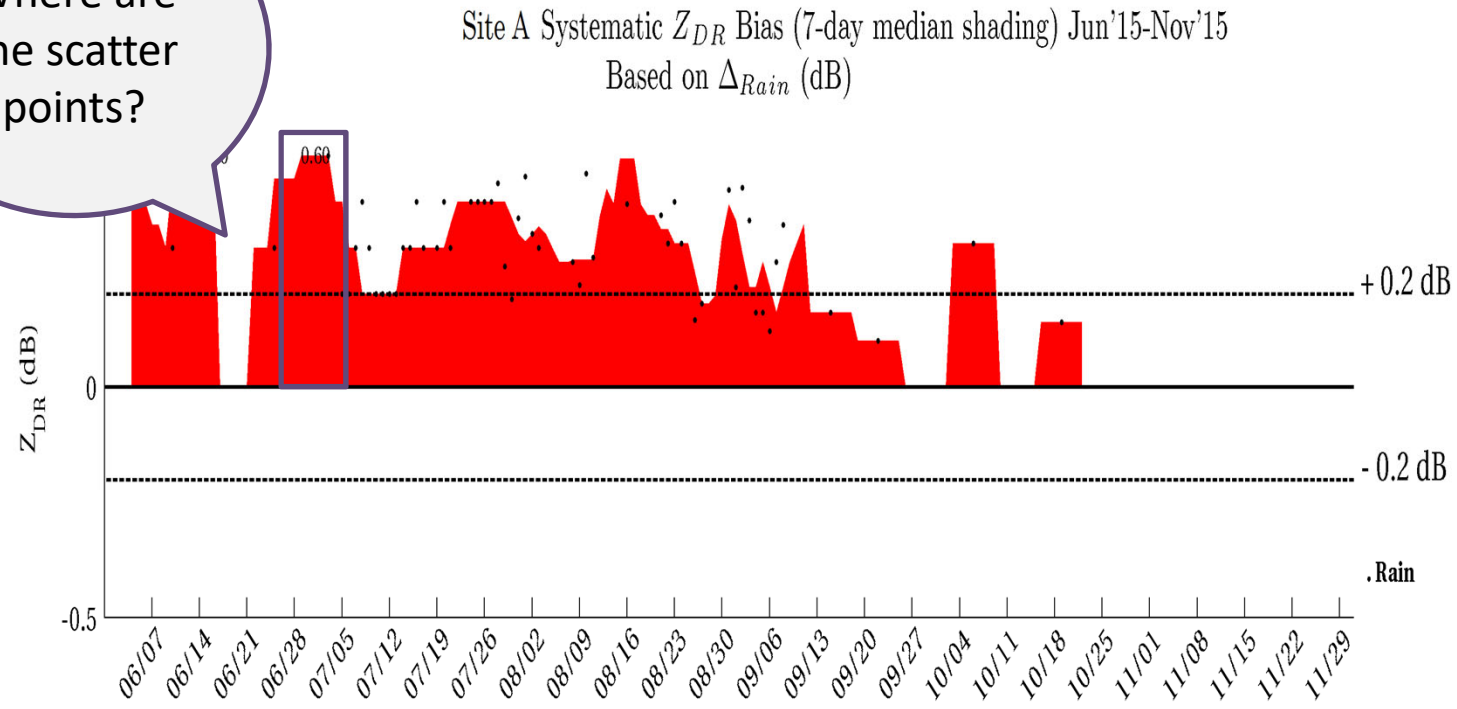
Median exceeds y-axis limits



- Medians beyond the y-axis limits are shown as a number near the top
- No shading means the data is either missing, not available, or equals 0.0 dB exactly
- Will interpolate if only missing one shade value between two valid points

7-Day Median Shading Cont.

Where are the scatter points?



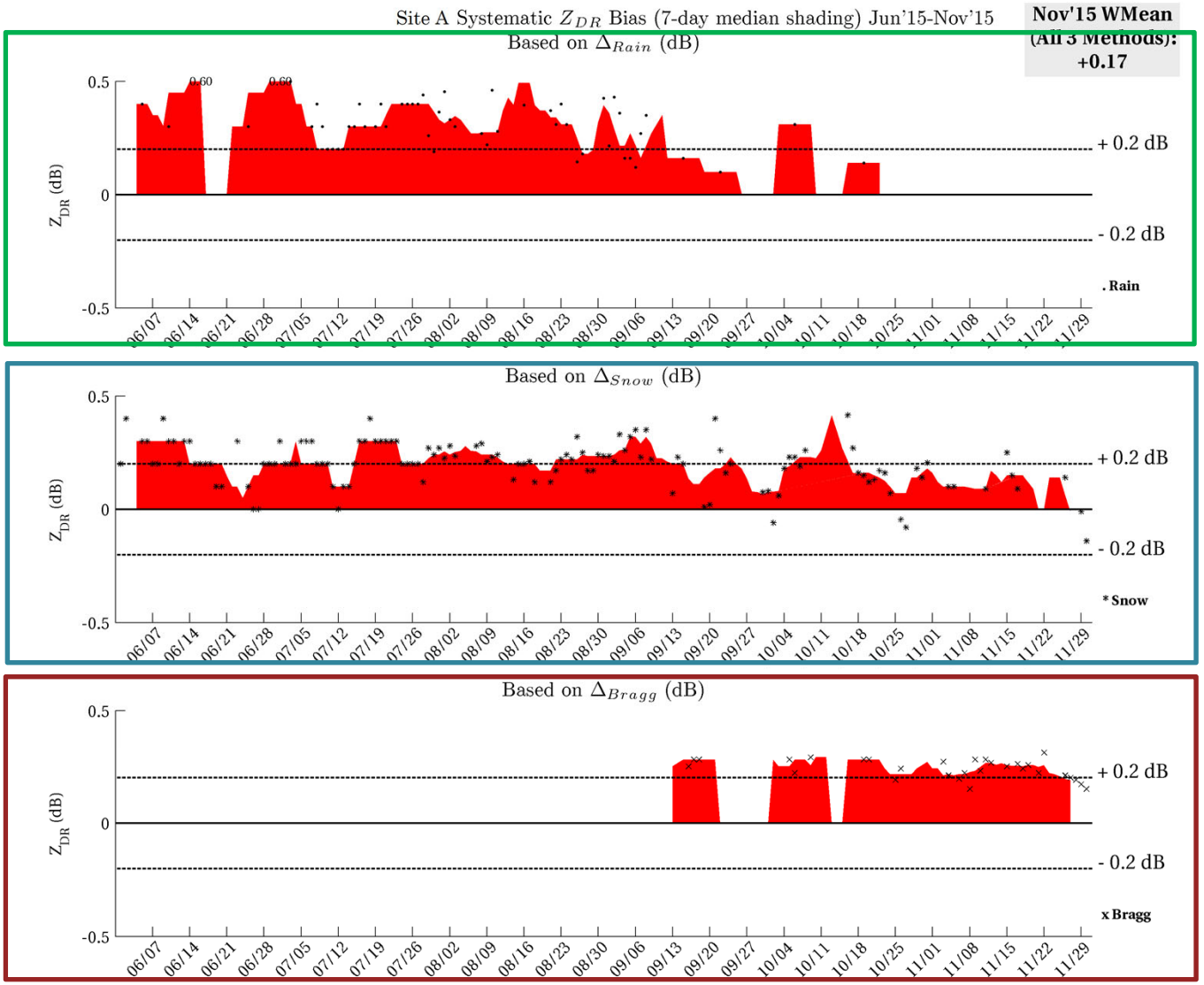
- Event scatter points outside of the y-axis limits (±0.5 dB) are not shown
- Recall that **median** values from shading outside of the limits are represented by the black numbers at the top

Compare Trends from Multiple External Target Methods

Light Rain

Dry Snow

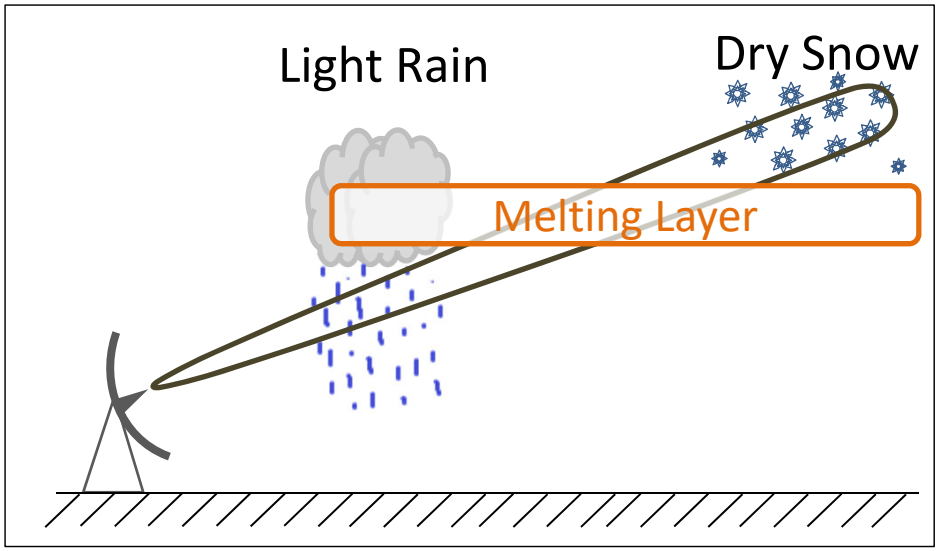
Bragg



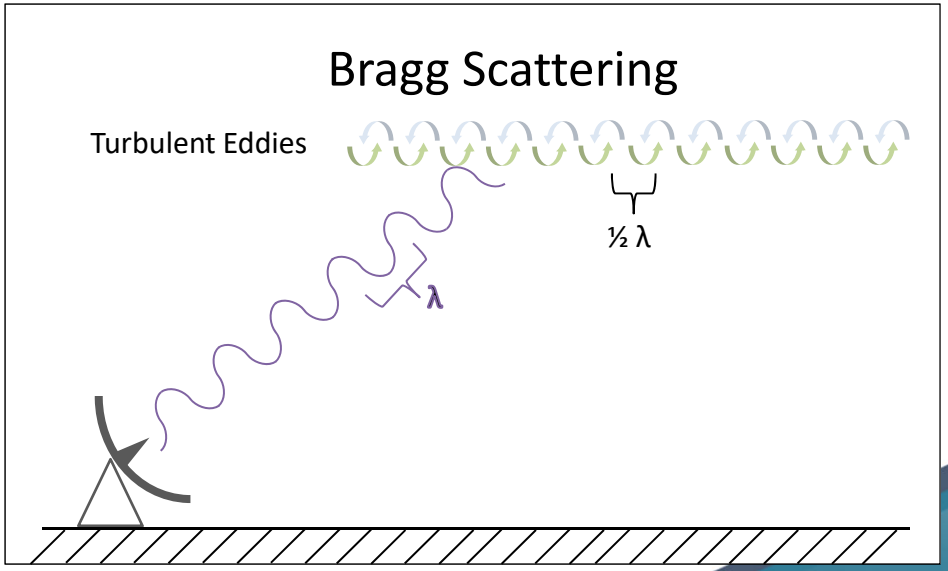
What do the methods detect?

Each method is independent and includes distinct caveats

- 2 Methods Related to Precipitation:
  - Light Rain (liquid precipitation)
  - Dry Snow (frozen precipitation)



- 1 Method Related to Clear Air
  - Bragg scattering associated with refractivity gradients



Click here to skip method details and jump to interpretation

Light Rain Method

- Light rain has characteristics of slightly-wide (slightly-oblate) spheres
- Base Filters:
  - SNR >= 20 dB
  - 19.0 < Z < 21.0
  - 0.98 < ρ_{HV} < 1.00
  - Range Gate must at least 1 km below the bottom of the Melting Layer
- Additional Filters
  - Total Range Gates that pass Base Filters >= 600
  - 0.125 <= ZDR_{IQR} <= 0.35 dB
  - 0.0625 <= ZDR_{MEDAD} <= 0.25
  - 15.0 <= Z90th <= 23.0 dBZ
  - 8.0 <= Z_{IQR} <= 16.0 dB
  - 0.3 <= PHI_{IQR} <= 3.3 °

Light Rain Method Cont.

- Daily Median (scatter points on chart)
  - An estimate is calculated each volume via: ZDR Mode – ZDR Intrinsic
    - ZDR Intrinsic for Light Rain in this reflectivity range is **0.25 dB**
  - The most recent 12 volumes are averaged together
    - Both the single volume and 12-volume average can be found in the RPG Status Log or in the ASP on lines that begin with "ZDRBE"
  - For a single date (based on UTC time), the median of the 12-volume averages defines the Daily Median
- Convective processes and other particle contamination can bias Z_{DR} estimates high
- Intrinsic ZDR Subtraction factor can bias Z_{DR} estimates low

* The ASP is a product version of the RPG Status Log available from archive sources such as NCEI.

Dry Snow Method

- Only uses range gates classified as Dry Snow (dry aggregates) by the Hydrometeor Classification Algorithm (HCA)
  - Dry aggregates appear similar to spheroids when they fall
  - Snow does NOT have to be reaching the surface
- Base Filters:
  - Range > 20 km
  - 15 dBZ < Z < 25 dBZ
  - Elevations > 1°
  - SNR >= 20 dB,
  - $0.98 < RHO_{HV} < 1.0$
  - PHI < 100°
  - Range gate must be within the first 1km completely above the melting layer
- Additional Filters
  - Must have at least 600 Z_{DR} range gates that pass filters per volume
  - Standard deviation Z_{DR} < 0.5 dB

Note: Aggregates are clumps of frozen precipitation (particularly ice crystals)

Dry Snow Method Cont.

- Daily Median Events
  - An estimate is calculated each volume via: ZDR Mode – ZDR Intrinsic
    - ZDR Intrinsic used for Dry Aggregate Snow is **0.20 dB**
  - The most recent 12 volumes are averaged together
    - Both the single volume and 12-volume average can be found in the RPG Status Log or in the ASP on lines that begin with "ZDRBE"
  - For a single date (based on UTC time), the median of the 12-volume averages defines the Daily Median
- Can be estimated at the same time as a rain Event as long as dry aggregate snow is observed above the melting layer
- Dendrites and Platelets can bias Z_{DR} estimates high
- Subtraction factor can bias Z_{DR} estimates low

Bragg Scatter Method

- Bragg distinguished by refractivity gradients generally caused by turbulent eddies
  - Often found at the top of the Convective Boundary Layer and Marine Boundary Layer
- Base Filters:
  - 10-80 km in range only
  - $Z < 10$ dBZ
  - $|V| > 2$ m/s
  - $W > 0$ m/s
  - SNR < 15 dB
  - $0.98 < \rho_{HV} < 1.05$
  - Elevations 2.4-4.5°
- Additional Filters:
  - Must have at least 600 Z_{DR} range gates that pass filters per volume
  - Z at the 90th percentile =< -3 dBZ (precipitation filter)
  - Inter-Quartile Range (IQR) < 0.9 (biota filter)

Bragg Scatter Method Cont.

- Daily Median Events
  - An estimate is calculated each volume via: ZDR Mode – ZDR Intrinsic
    - ZDR Intrinsic used for Bragg Scatter is **0.00 dB**
  - The most recent 12 volumes are averaged together but only if there are at least 10,000 range gates of potential Bragg estimates in those 12 volumes.
    - Both the single volume and 12-volume average can be found in the RPG Status Log or in the ASP on lines that begin with "ZDRBE"
  - For a single date (based on UTC time), the median of the 12-volume averages defines the Daily Median
- Precipitation contamination can bias Z_{DR} high
- Return from Bragg scattering has a weak signal, and if noise is comparable to the signal it could bias the estimate towards 0.0 dB
  - Assuming the noise estimates are similar in both H and V channels

Method Availability

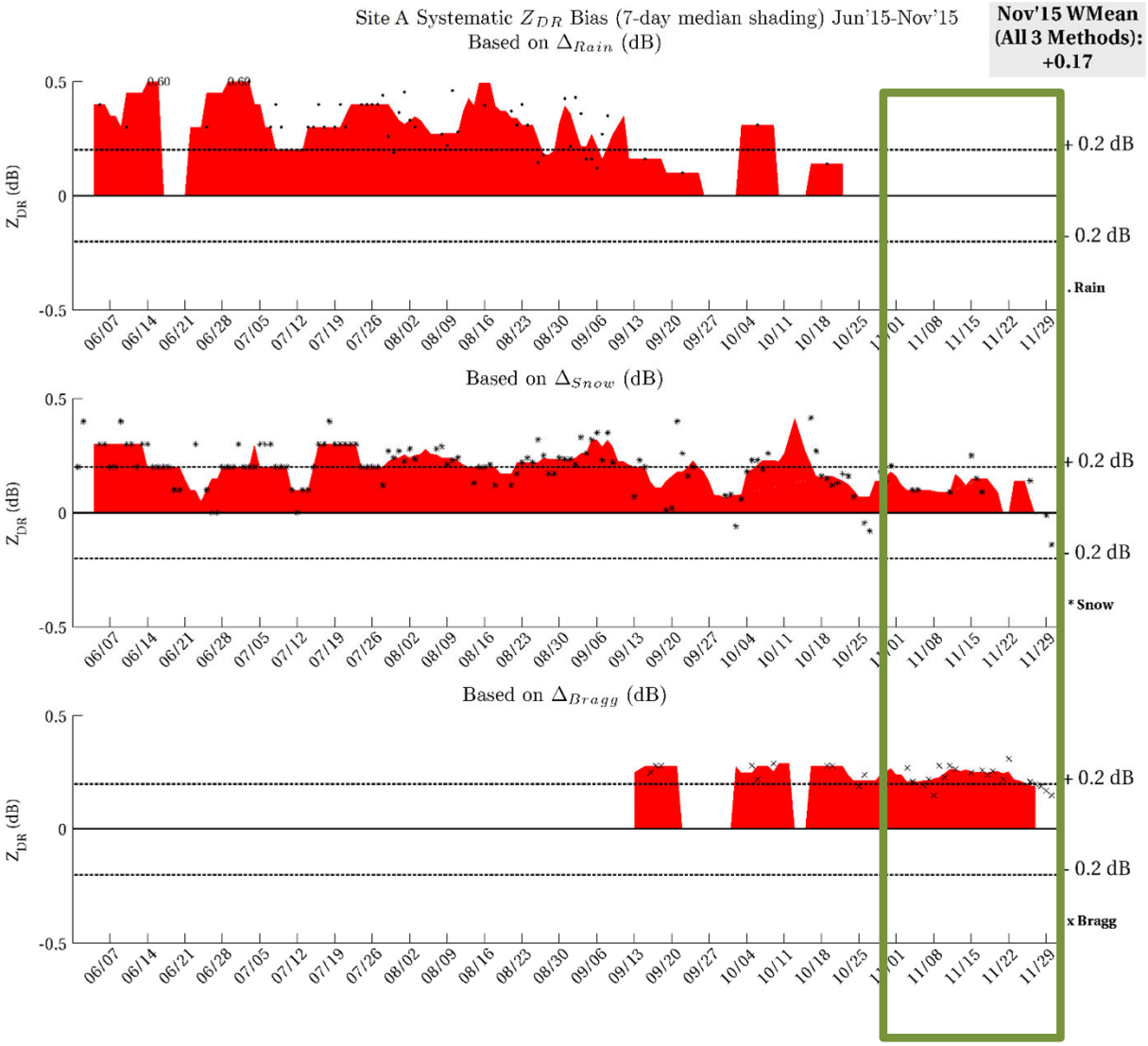
- Light rain is less available during the cool season, especially at northern continental sites
- Dry snow can be found year round at most sites
- Bragg scatter less available due to stringent filters
  - Also less available in the warm season due to biota (bugs, birds, etc.) contamination

Rely on More Than One Method When Possible!

- When all 3 methods show a similar bias, there is high confidence in the indicated bias
  - All methods are not always available
- The **trend** is the important aspect
  - Recommend **at least two weeks** of data to establish a baseline

Full-Chart Recap: Compare the Methods

- Z_{DR} is high (above and near the positive limit) for the majority of the time in all three methods
- Focus on most recent month
- Compare with previous months for overall trend



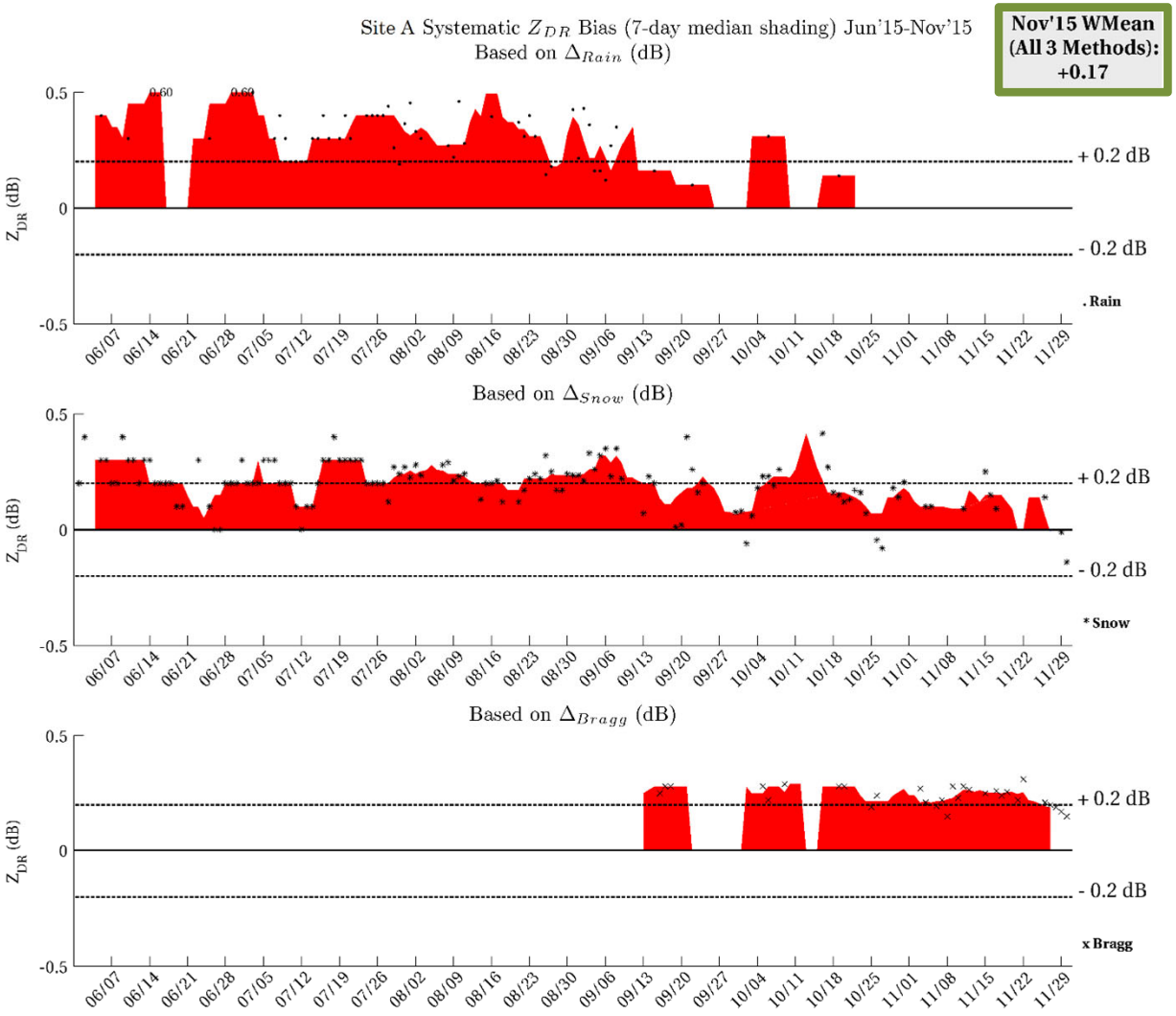
Monthly Summary

- The median of each method is calculated for the most recent month (not shown)
- These medians are then used to calculate a Weighted Mean (WMean) Estimate (displayed in the top-right box)
  - Weights are based on method estimation accuracy
    - Bragg scatter: 42% weight
    - Dry Snow: 33% weight
    - Light Rain: 25% weight

Note: Volume-based Weighted Means using the same weights are shown on ZDRBE Status lines.

Monthly Summary

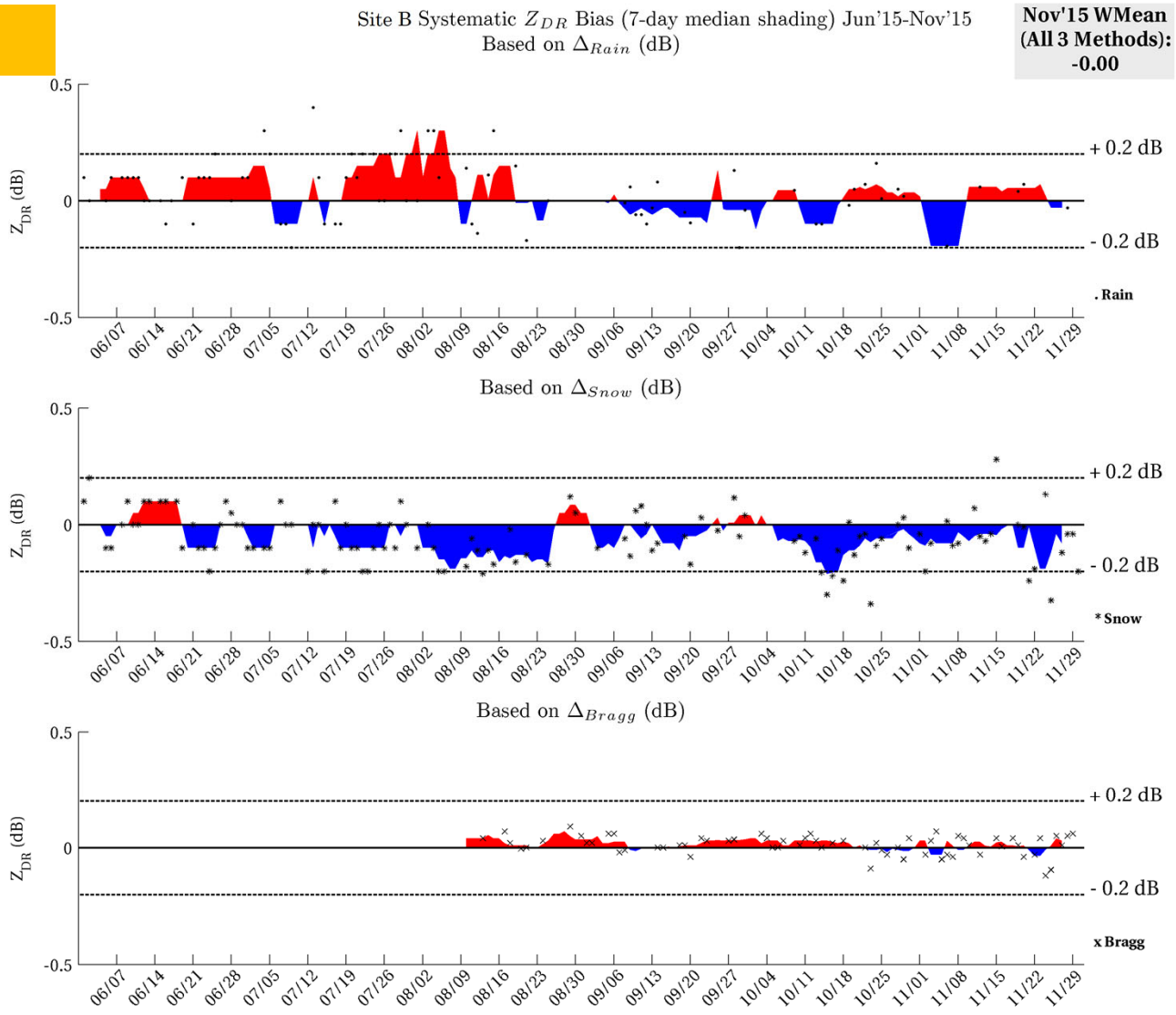
- The monthly WMean box is color coded (matches shade color when beyond-recommended-limits)
- It will say NaN (Not-a-Number) if there are no estimates for an entire month



Shade Interpretation: “Good” Site

Within Limits

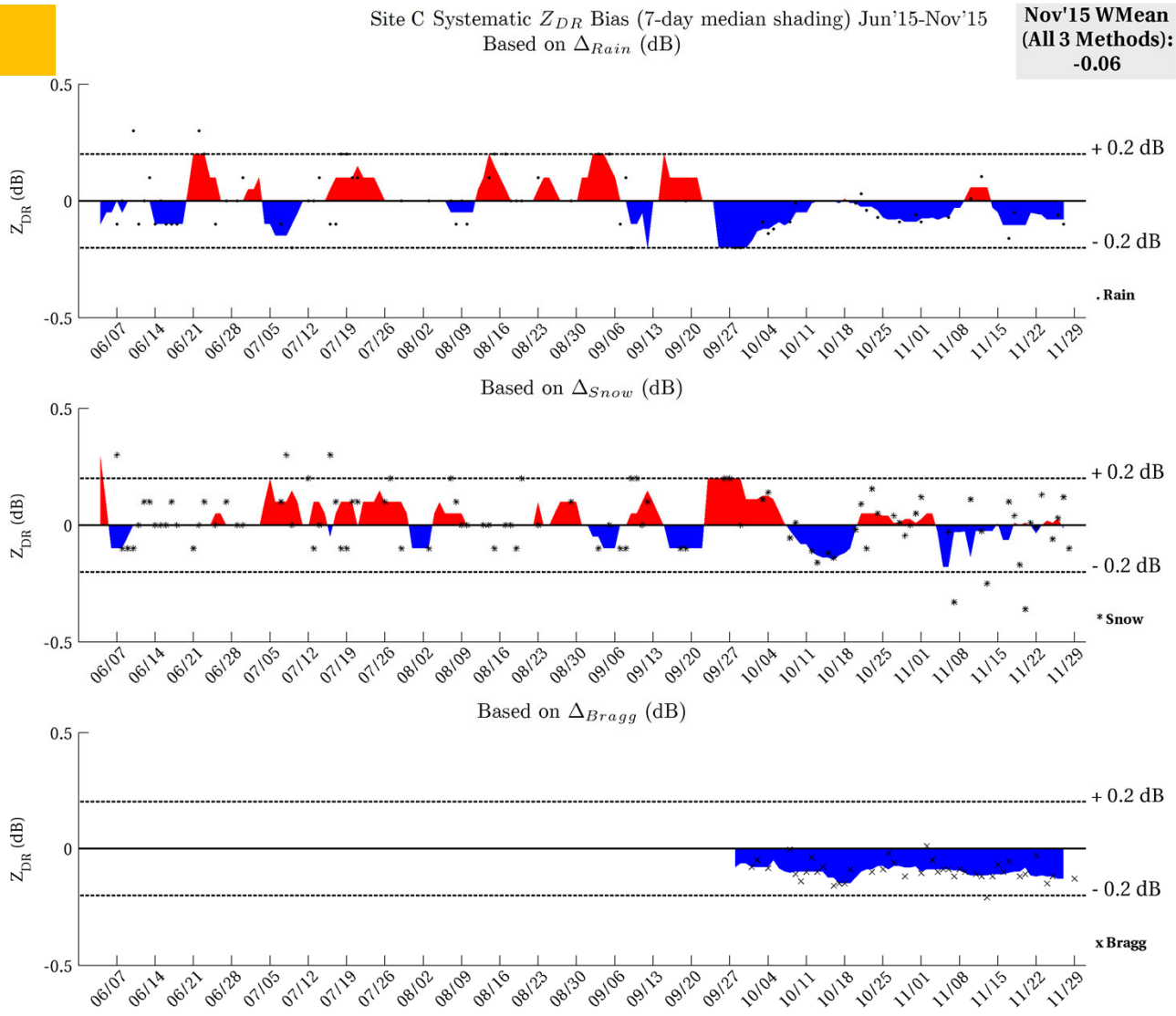
Close to zero and within recommended limits for all methods



Shade Interpretation: Another “Good” Site

Within Limits

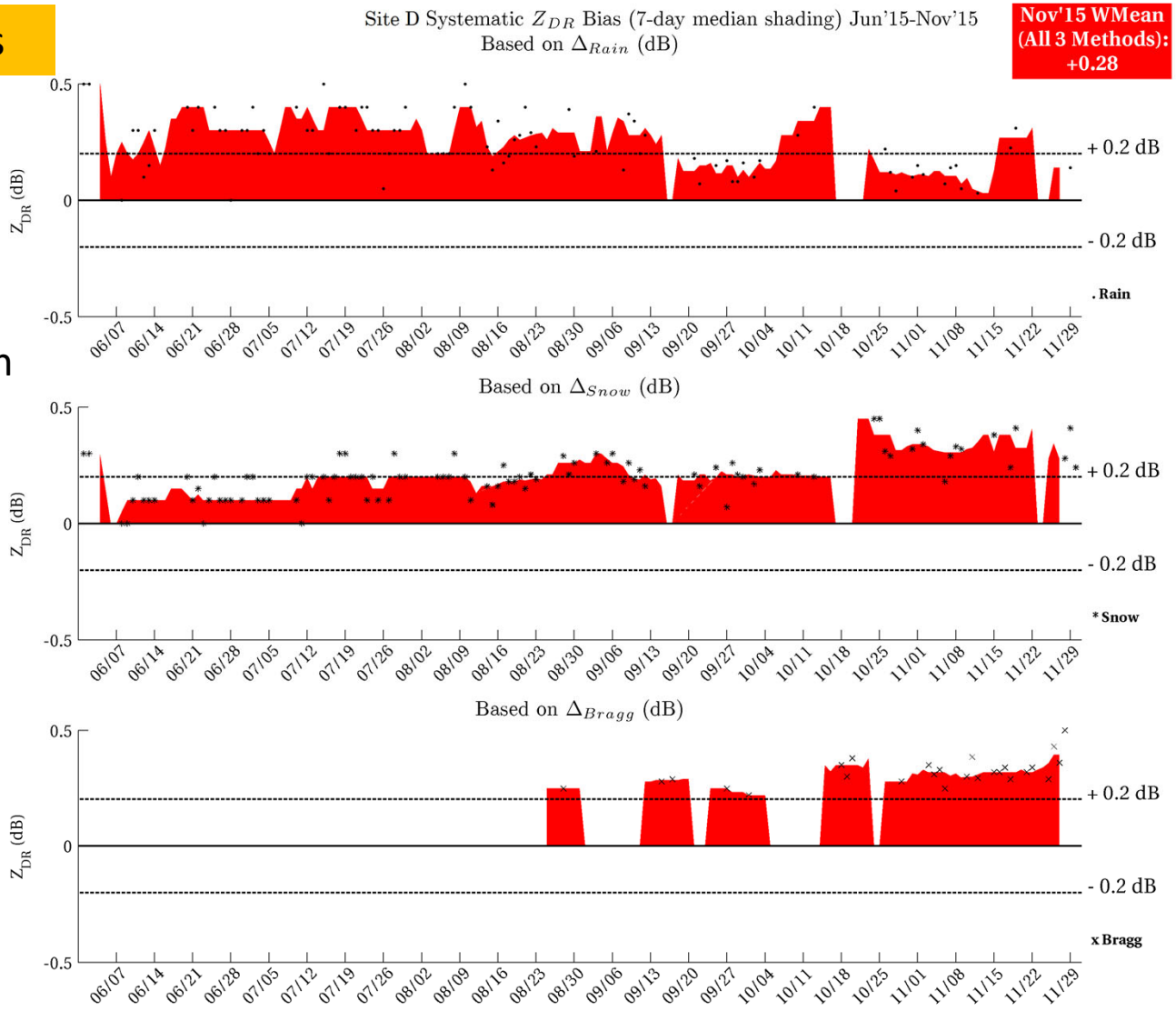
Alternating red/blue around zero (within limits) is OK



Shade Interpretation: Warm Bias

Beyond Limits

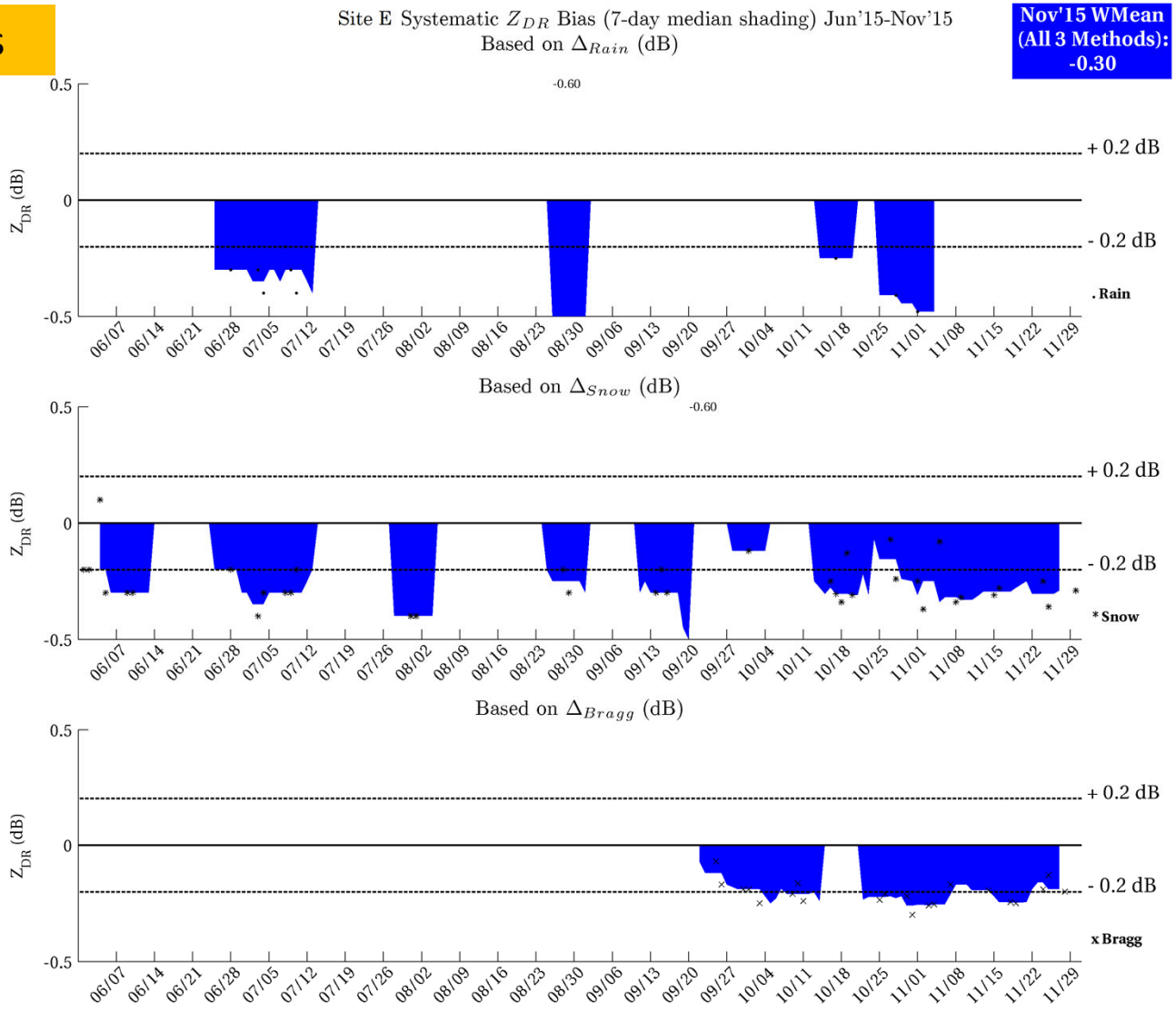
A warm bias causes QPE underestimation



Shade Interpretation: Cold Bias

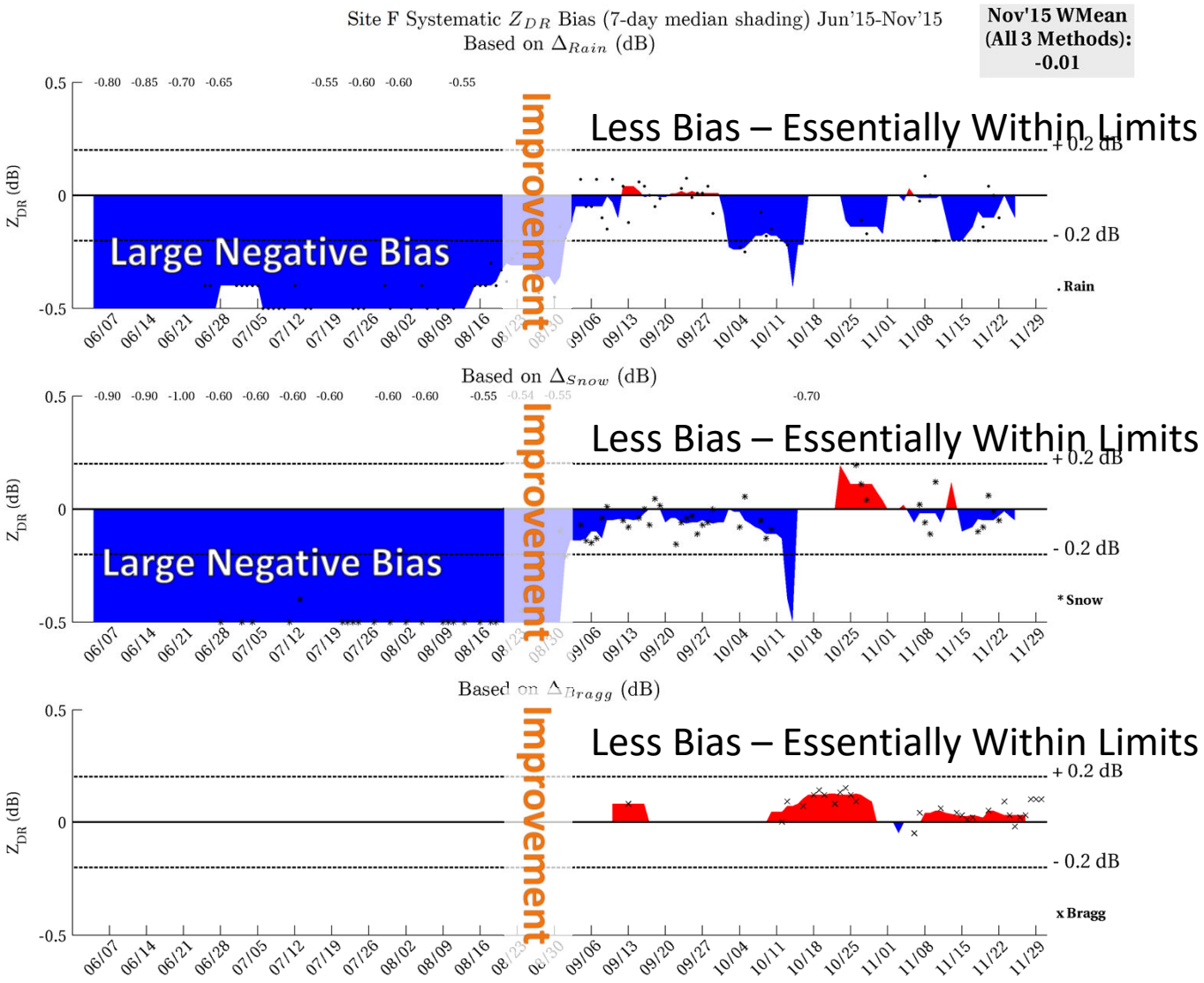
Beyond Limits

A cold bias causes QPE overestimation



Shade Interpretation: Site Improves

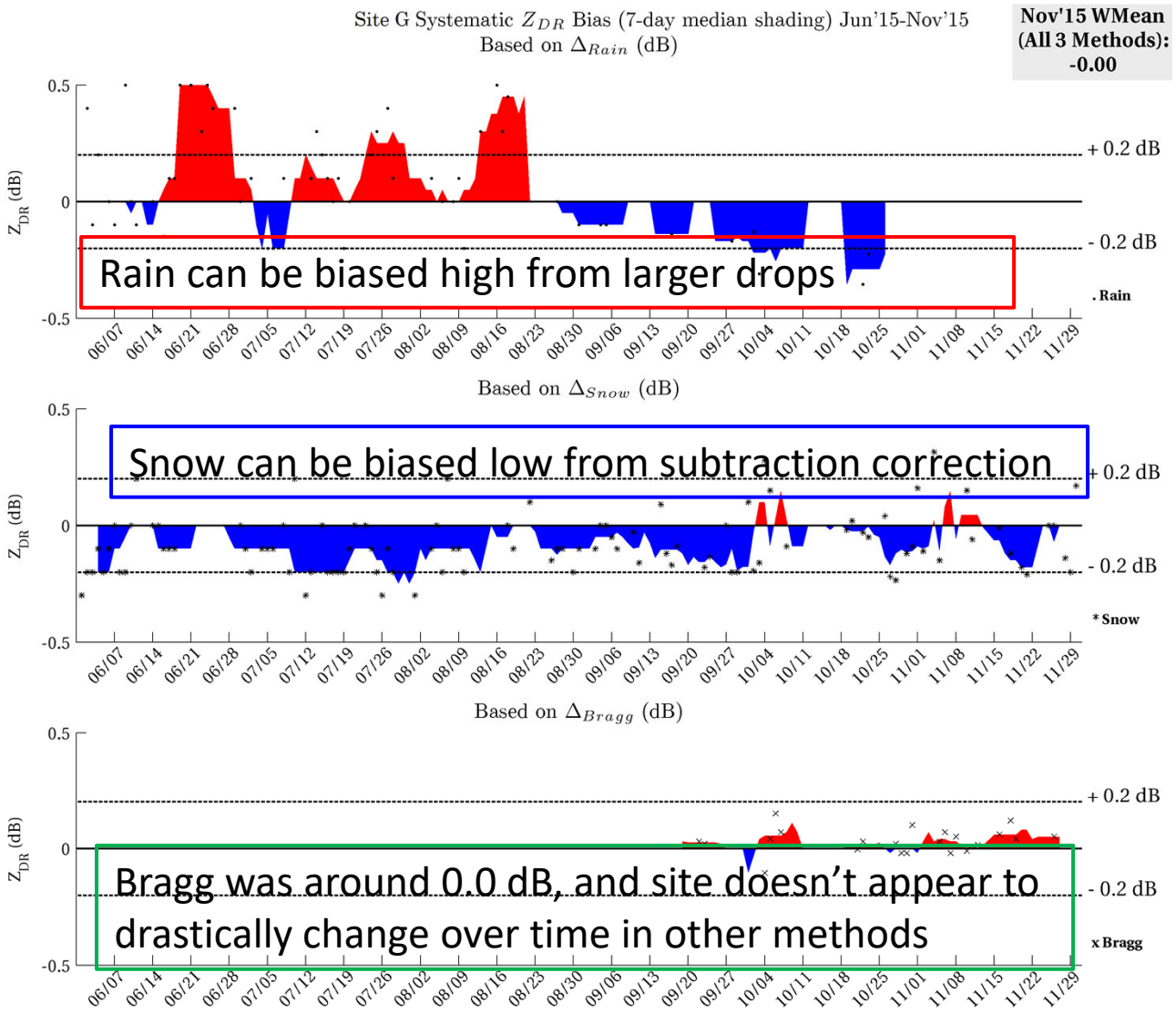
Site had a large negative bias and improved closer to within limits



Shade Interpretation: Disagreement

Disagreement possible due to the independent method caveats

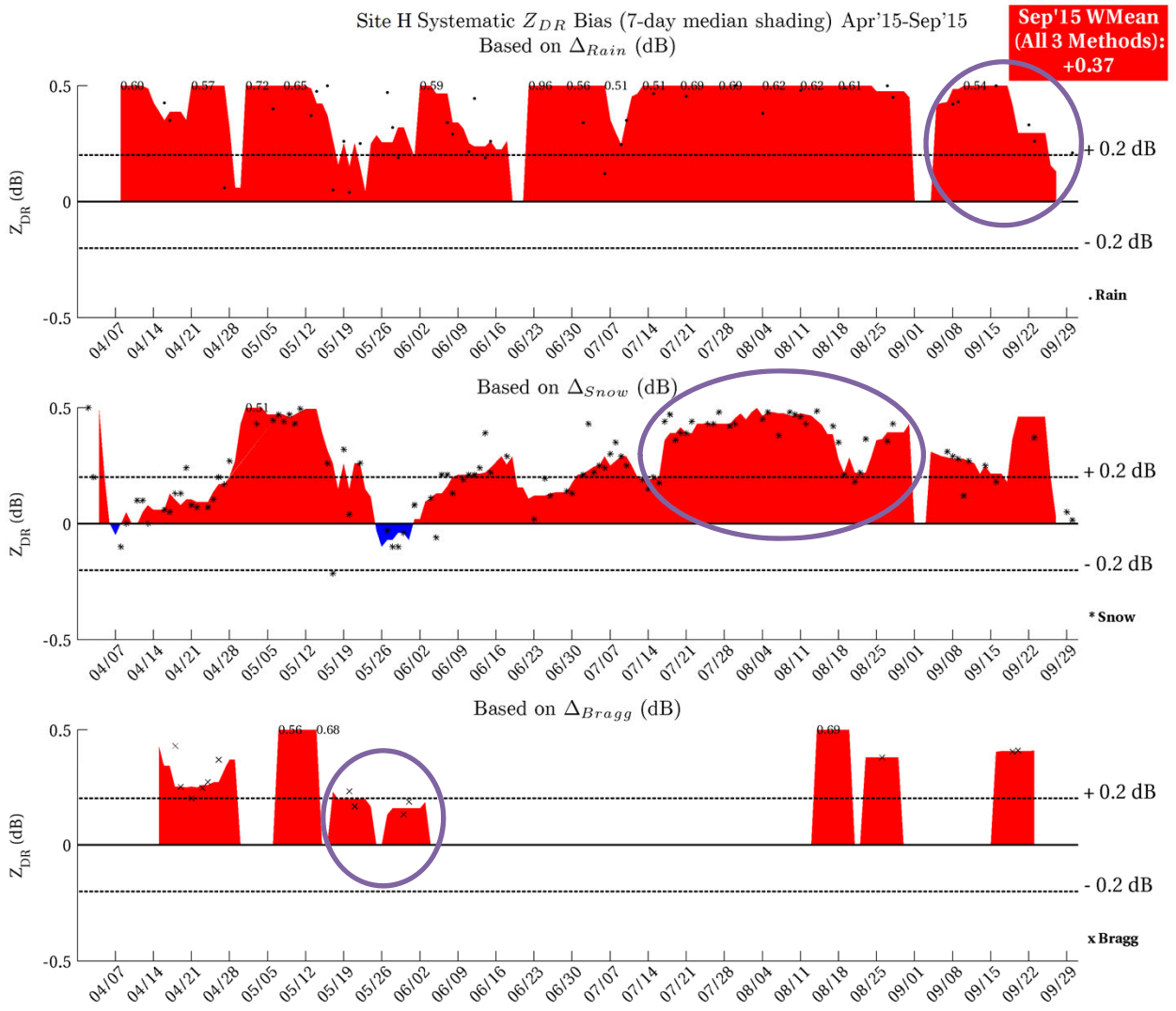
- Site bias is likely around 0.0 dB in this case
- Within limits on both sides, so less priority to take action



6-Month Time Window

- Shading features are consistent for a given month

Site H
End Month:
September

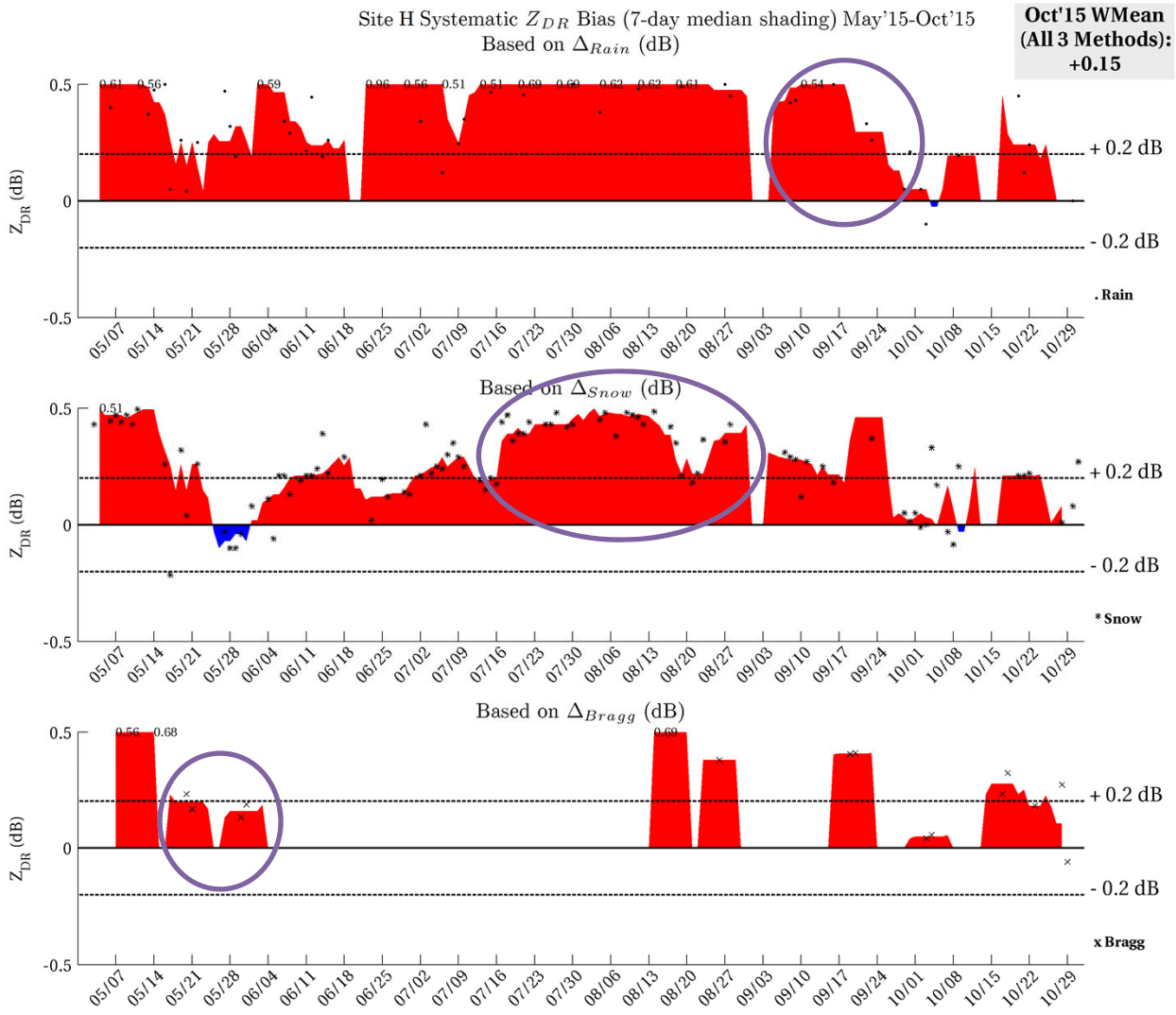


Note how the circled areas move with time in the next two slides

6-Month Time Window

- Features move to the left

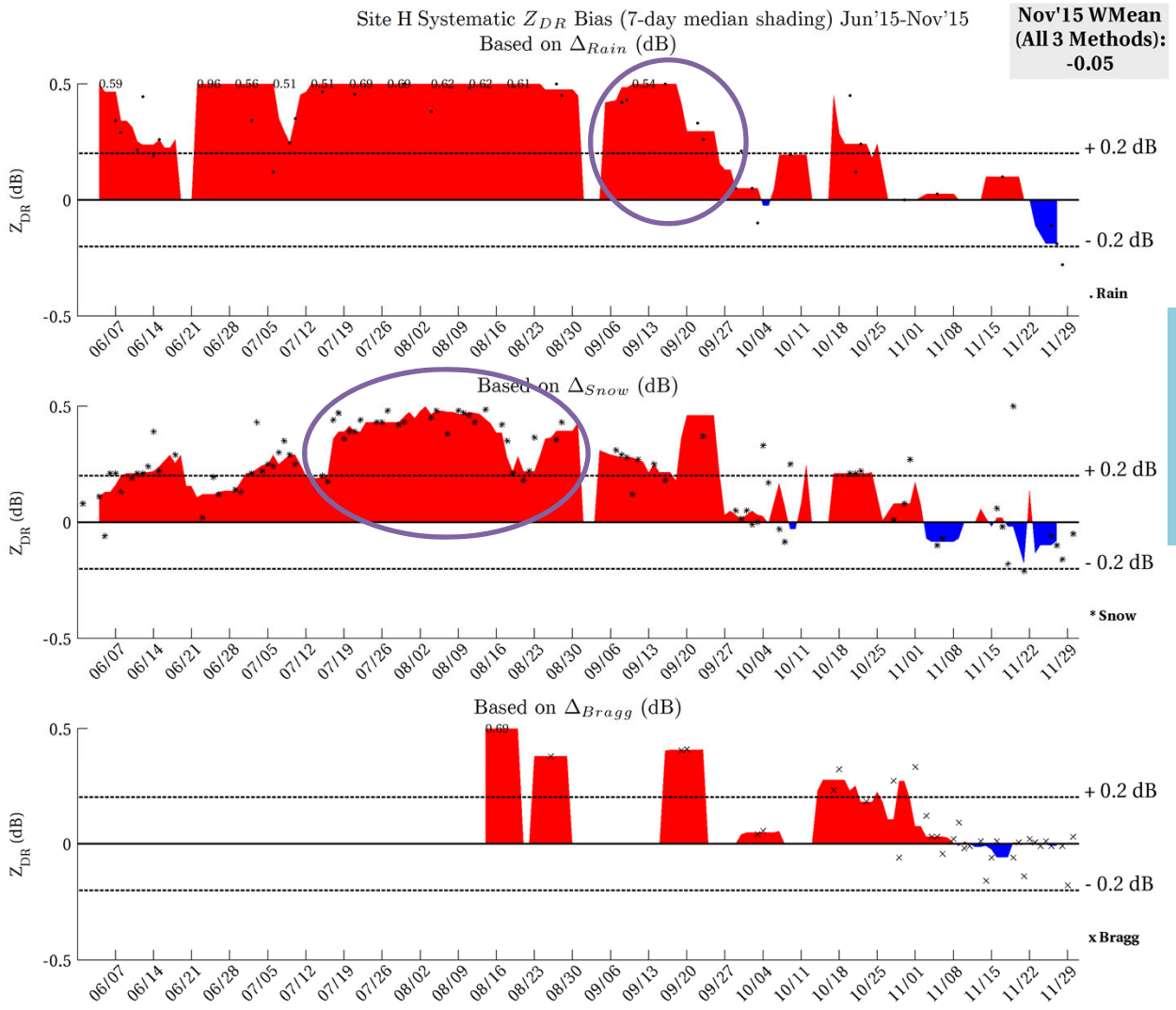
Site H
End Month:
October



6-Month Time Window

- Some features move off with the moving time window

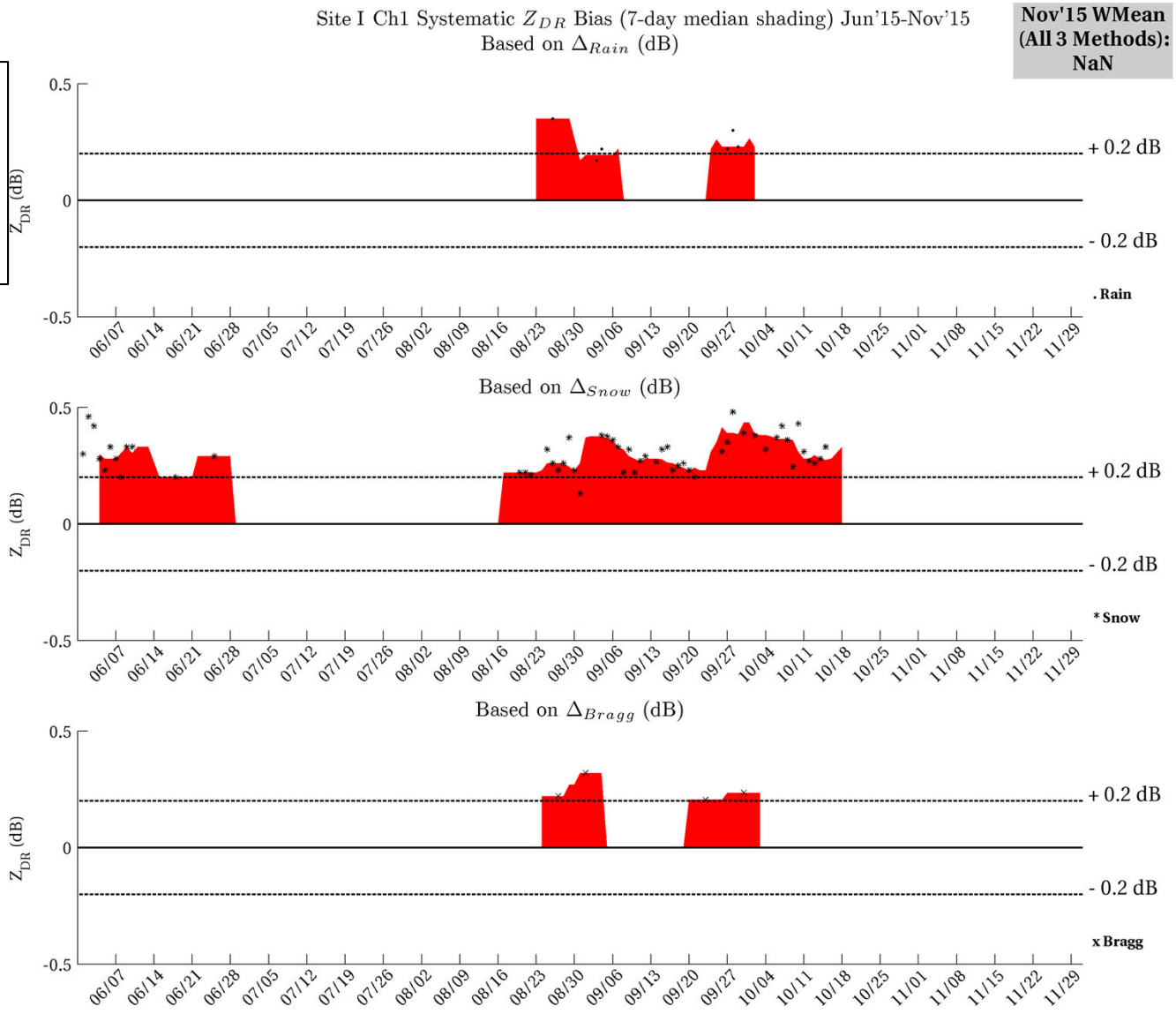
Site H
End Month:
November



Previous months are archived and available

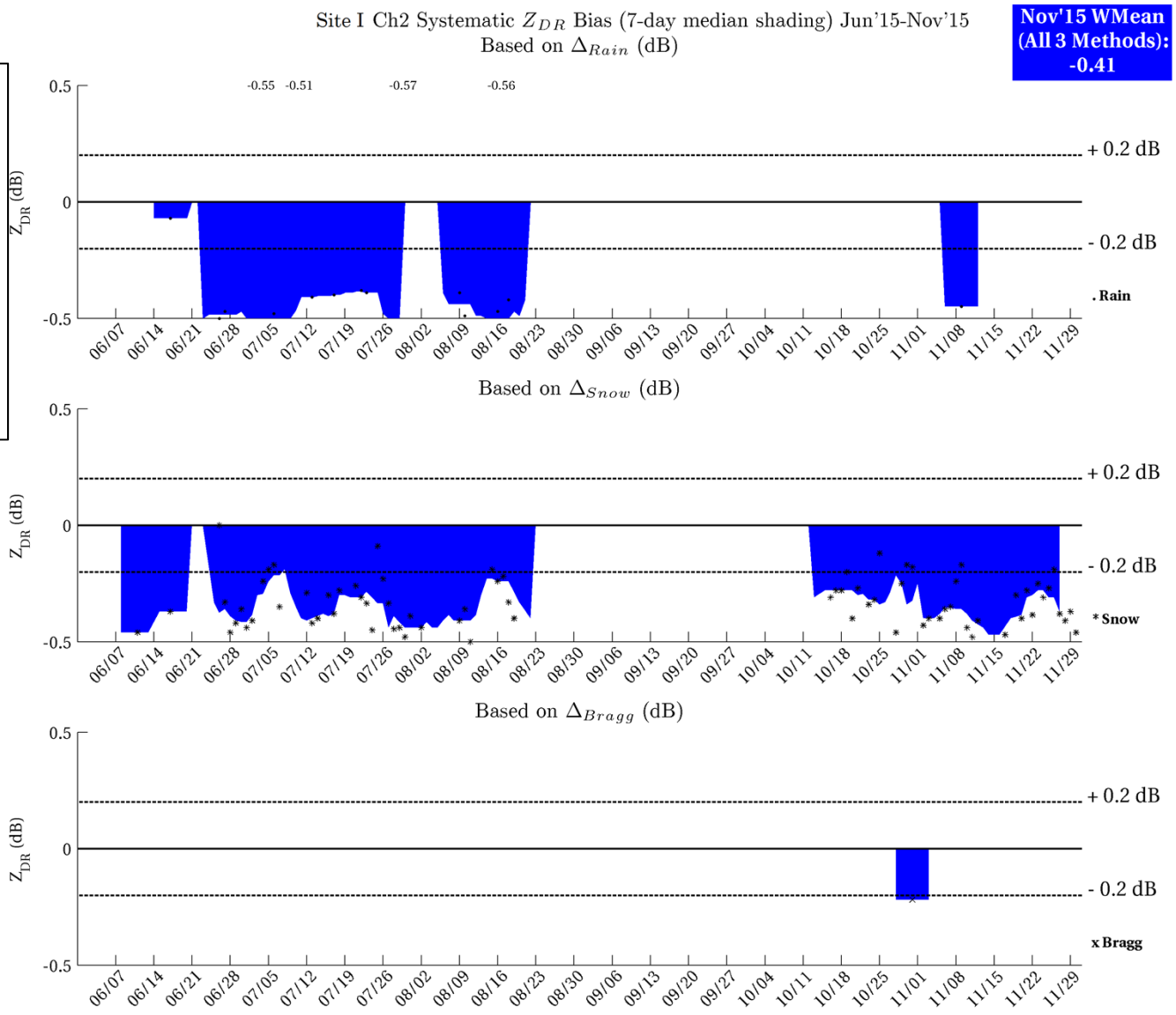
Redundant Sites (Ch1 Example)

Attempt to isolate estimates per channel
- The ROC will send charts for each channel



Redundant Sites (Ch2 example)

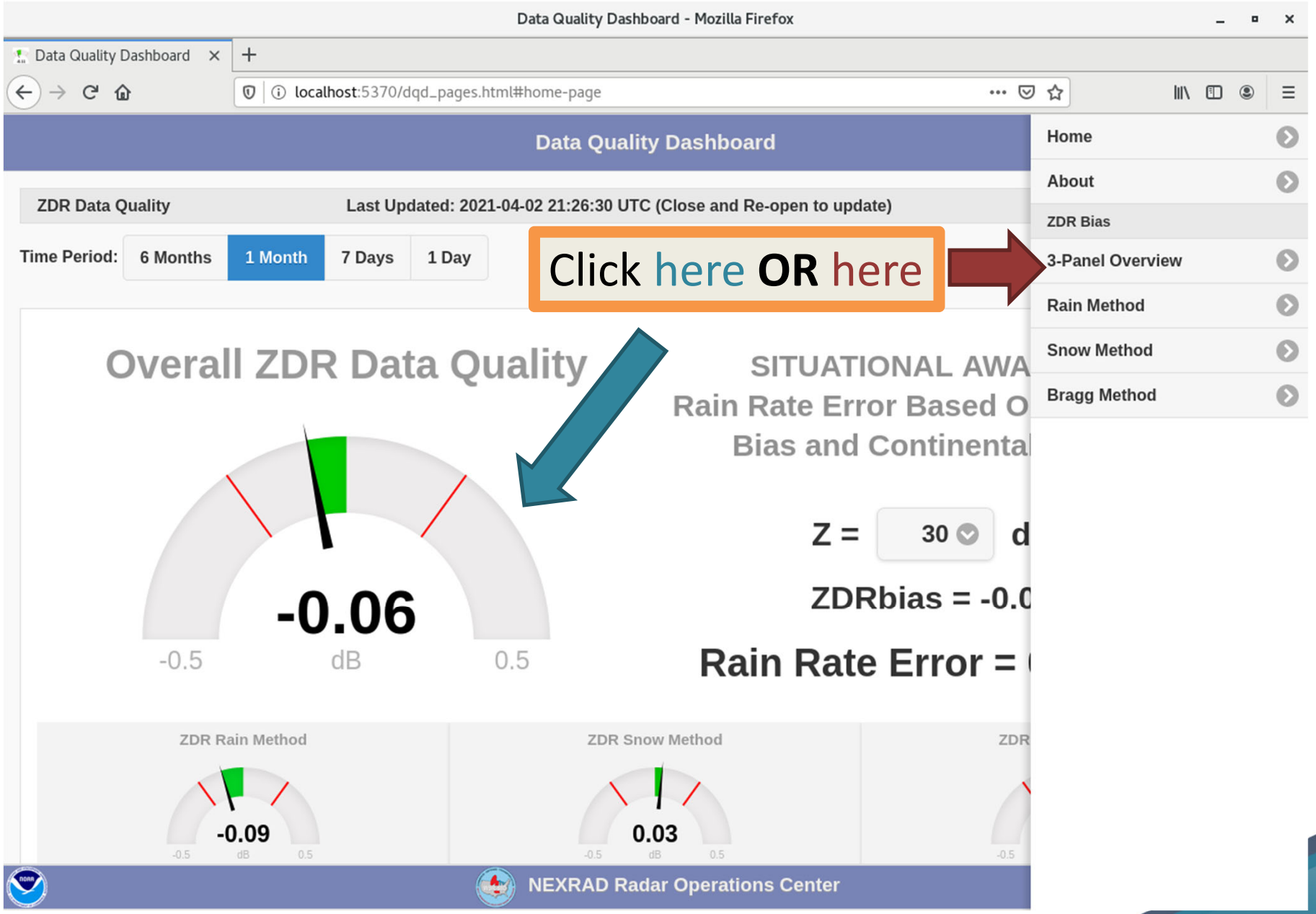
Sometimes the plots only have info in one Channel. This may be a plotting error if the site is routinely switching channels as suggested.



Shade Chart Availability

- Shade Charts are available from the ROC webpage under the Hotline section:
  - https://www.roc.noaa.gov/WSR88D/Operations/Hotline.aspx
- They are also available with more frequent updates via the Data Quality Dashboard
  - Click on the big Main Gauge or select from the menu

Shade Chart in DQD



Summary

- A shade chart is a quick way to assess if a site has a Z_{DR} bias and the approximate magnitude of the bias
  - Sites with biases outside of the **±0.2 dB** range are considered to be **Beyond Recommended Limits**
  - Z_{DR} bias adversely affects several products, especially QPE
- Charts can help track when maintenance was performed and if it helped (e.g., had a large bias and was corrected to within limits)
  - Can also see if a site has a new or drifting hardware issue (e.g., site was within limits and jumped to a large bias)

Summary Cont.

- We are still exploring the details of the external target methods!
  - External targets are an independent, extra metric to the built-in hardware estimates that work with operational scanning strategies and products
  - Each method has unique caveats and variability in accuracy
    - Some aspects of variability remain unknown
- By using multiple methods, there is higher confidence a site does or does not have a bias

Within Limits is OK!

- Achieving an exact Z_{DR} bias estimates of 0.0 dB can be difficult because the variability of the methods and built-in hardware often exceed ± 0.1 dB
  - The trend of median bias estimates falling within ± 0.2 dB should be sufficient for most algorithms and visual analysis

Extra Information

- Read publications and more by visiting the WSR-88D Hotline site: http://www.roc.noaa.gov/WSR88D/Operations/Hotline.aspx
- Other articles can be found at ROC Papers: http://www.roc.noaa.gov/wsr88d/PublicationsROC.aspx