How to Interpret Z_{DR} Shade Charts

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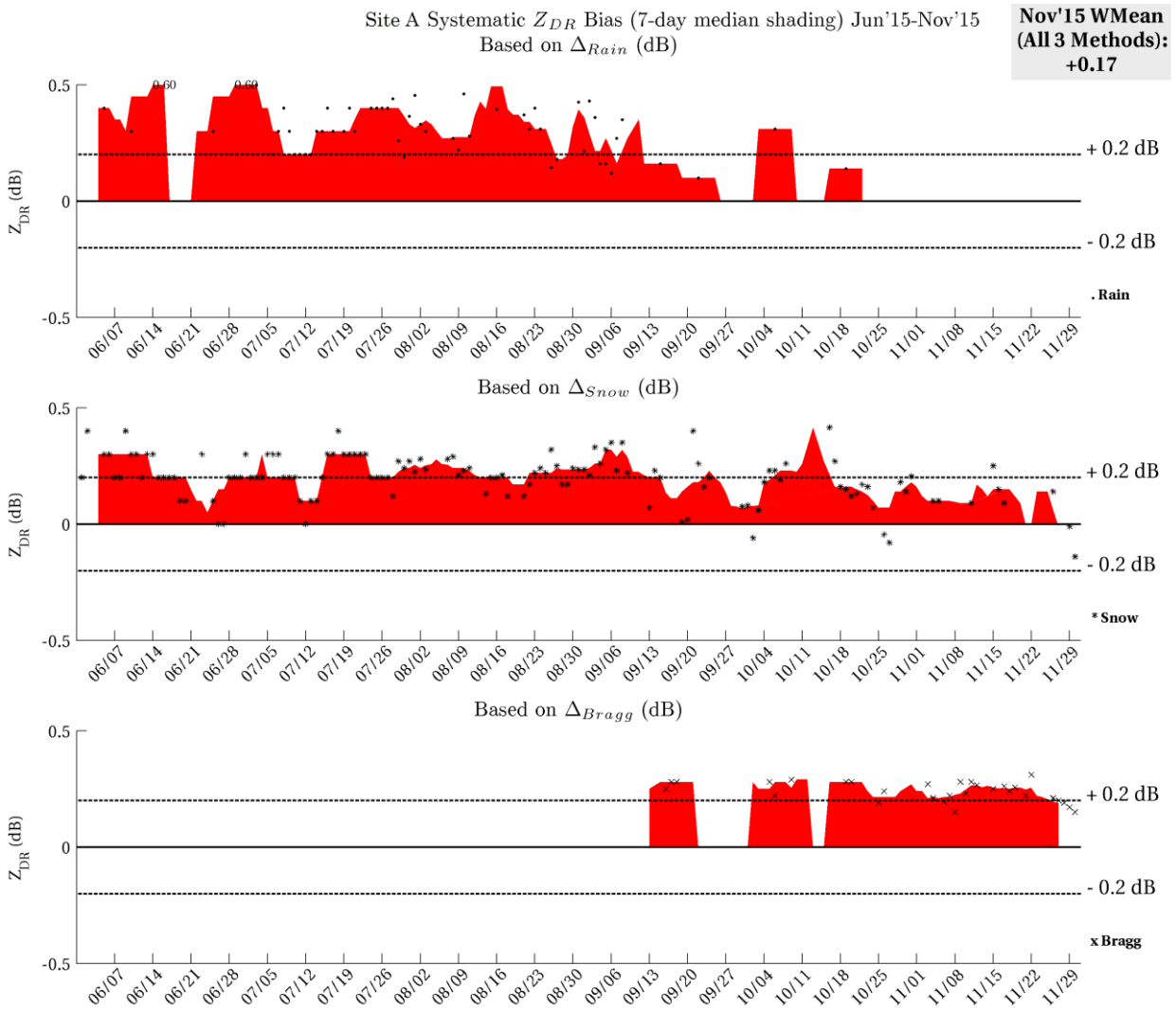
What's a Shade Chart?

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



What's a Shade Chart? (Cont.)

- Based on 3 independent external target methods:
  - Light Rain
  - Dry Aggregate 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

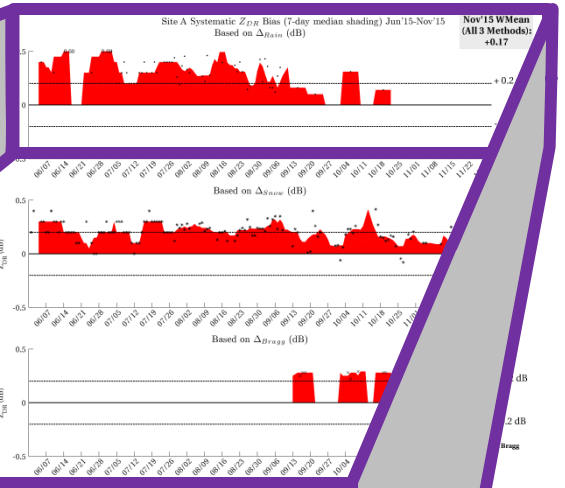
* This is not the same as ZDRB (ZDR Offset)

Why external targets?

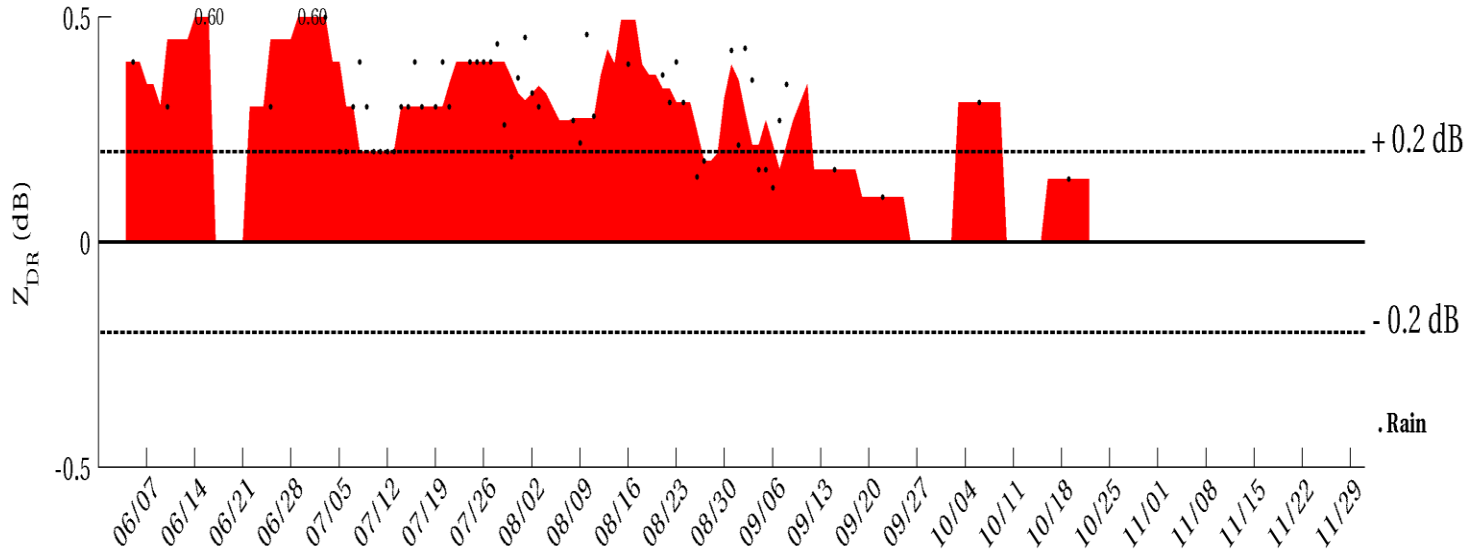
- External targets act as an estimation metric independent from the built-in hardware estimates
  - Additional measurement to verify built-in hardware results
- Methods work with operational scanning strategies and products

What's on a Shade Chart?

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



Site A Systematic Z_{DR} Bias (7-day median shading) Jun'15-Nov'15
Based on Δ_{Rain} (dB)

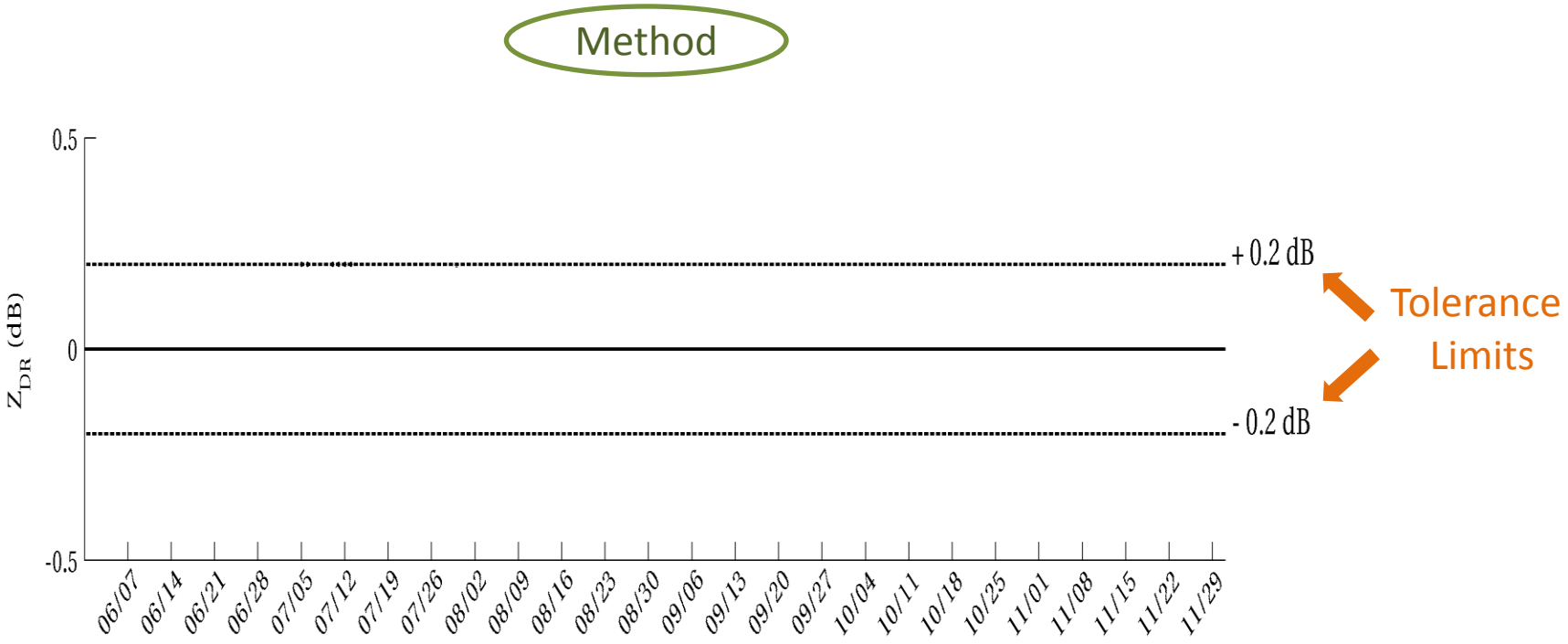


Did you notice?

- 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

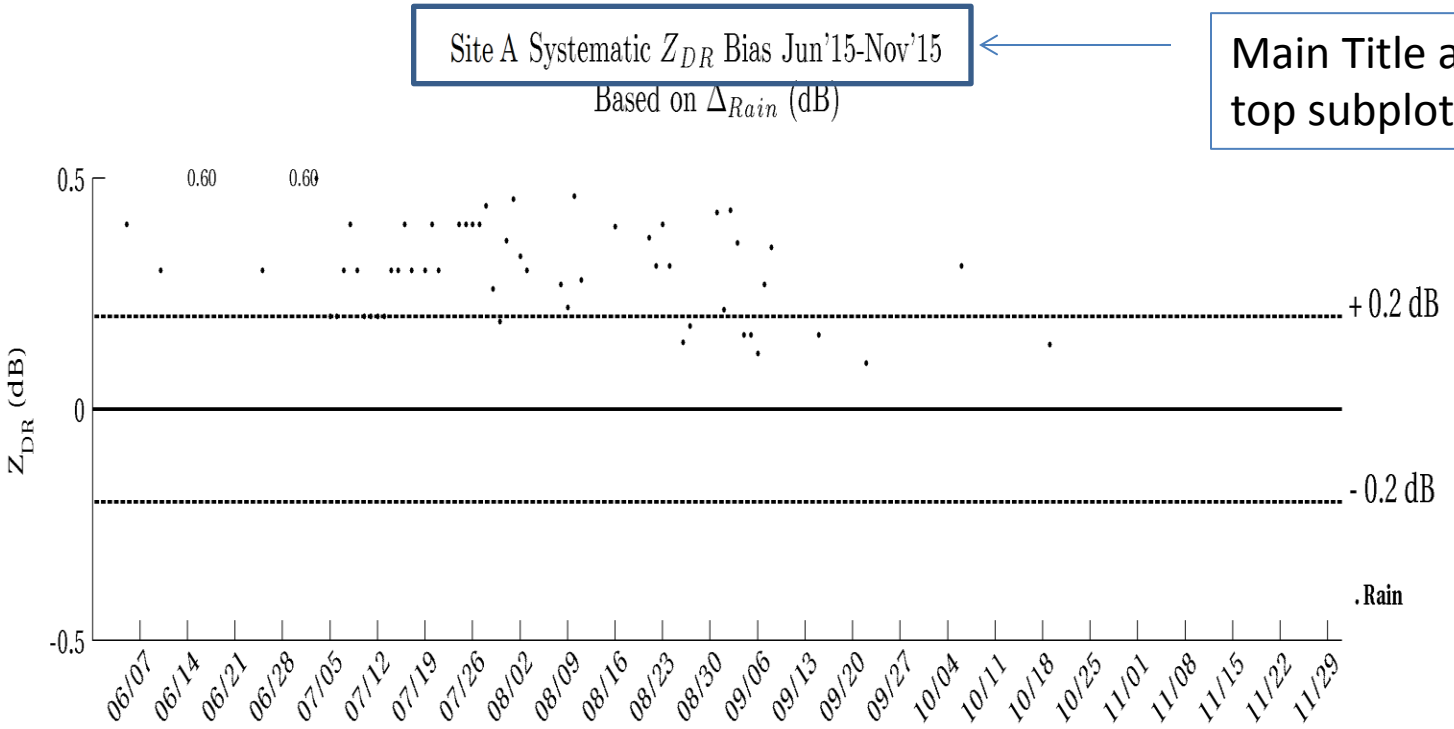
Layout of Each Subplot



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

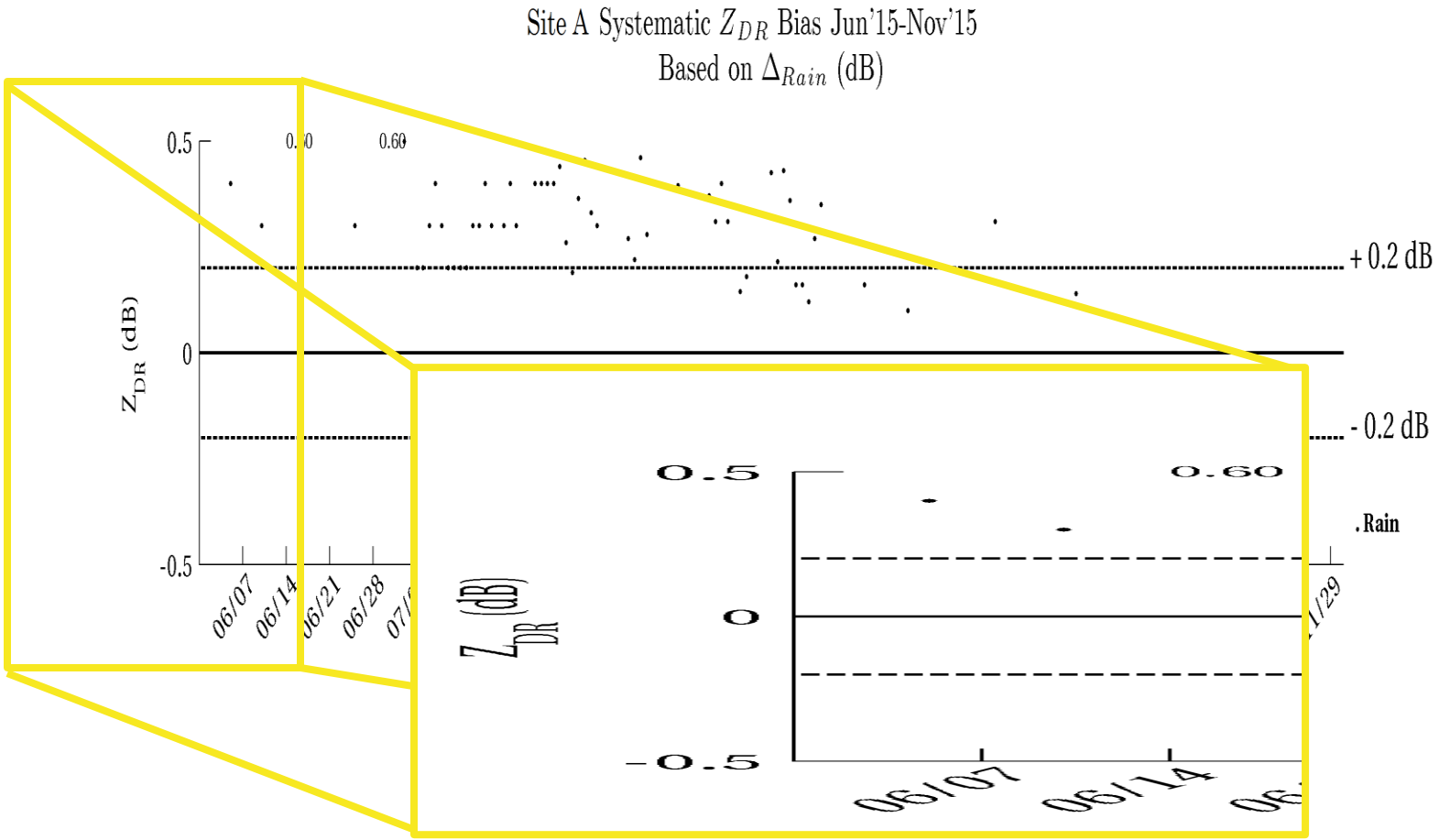
Most Recent 6 months of Data

Z_{DR} Bias Estimates from Events



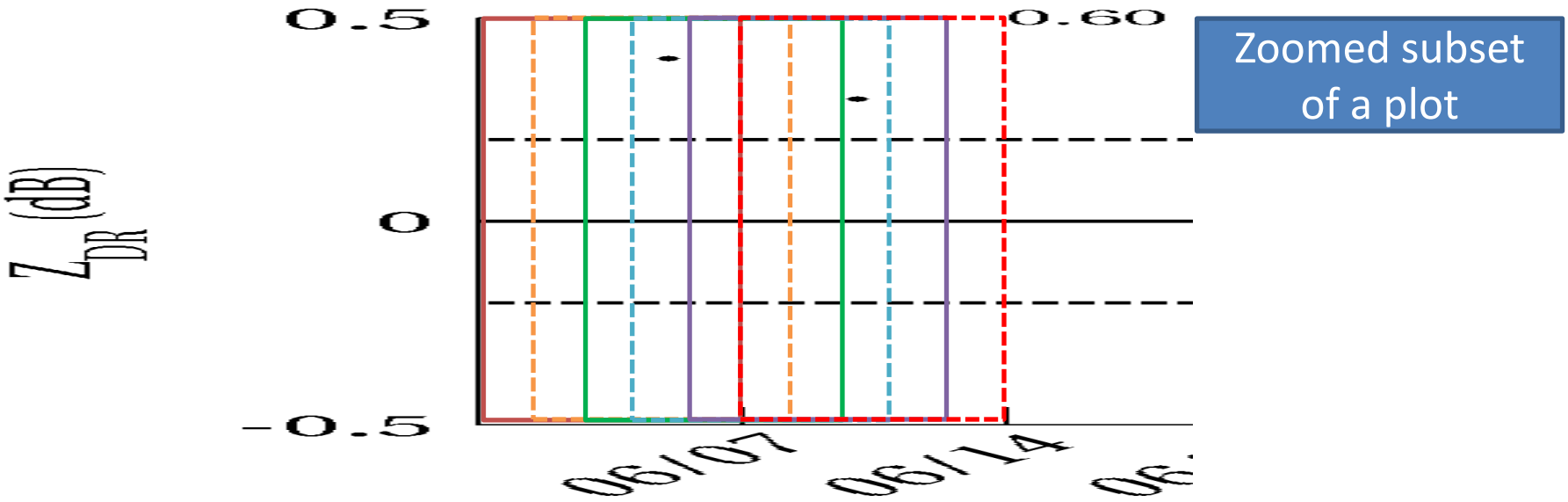
- Many, highly-varying scatter points
  - Events may vary greatly from one to another
  - Events are defined per method in later slides
- Events are OK, but what if we took a 7-day median?

Grouping for Shading



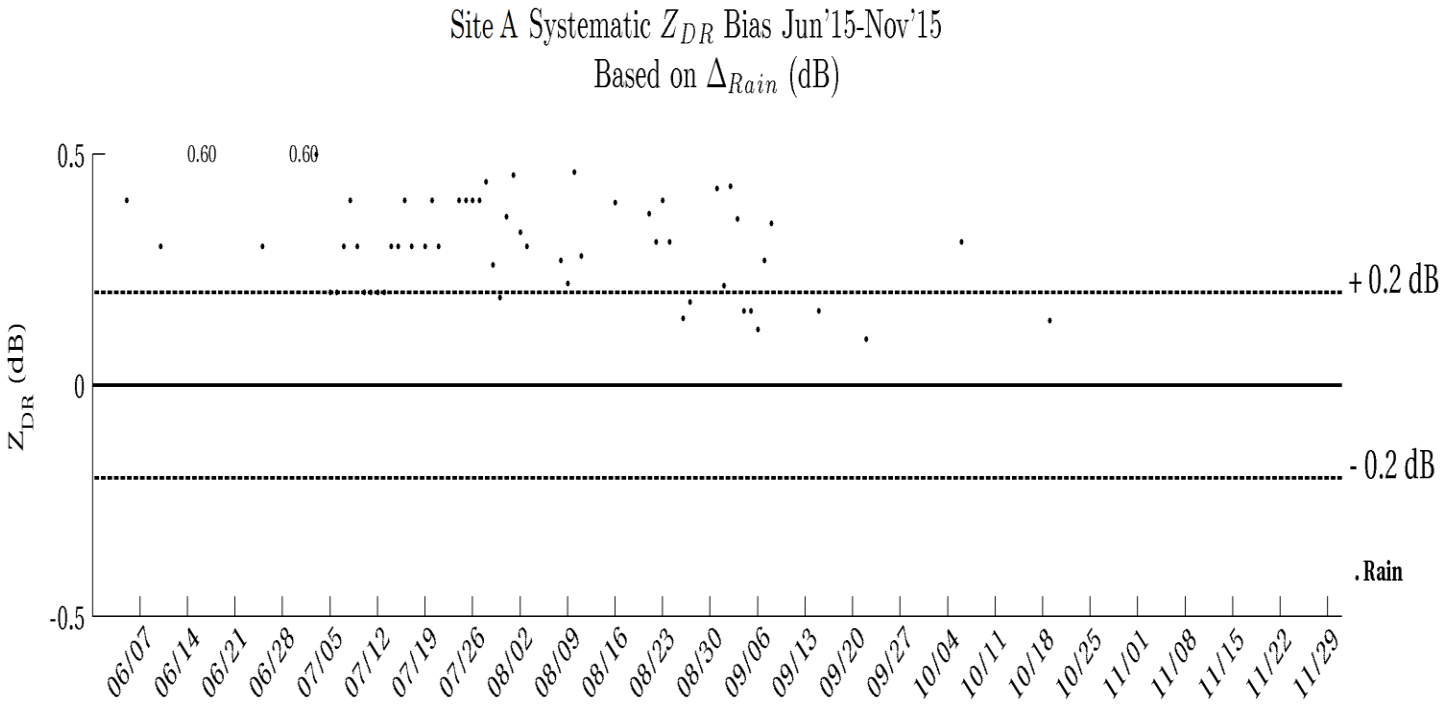
Zoom in to focus on smaller time scale

7-Day Running Median



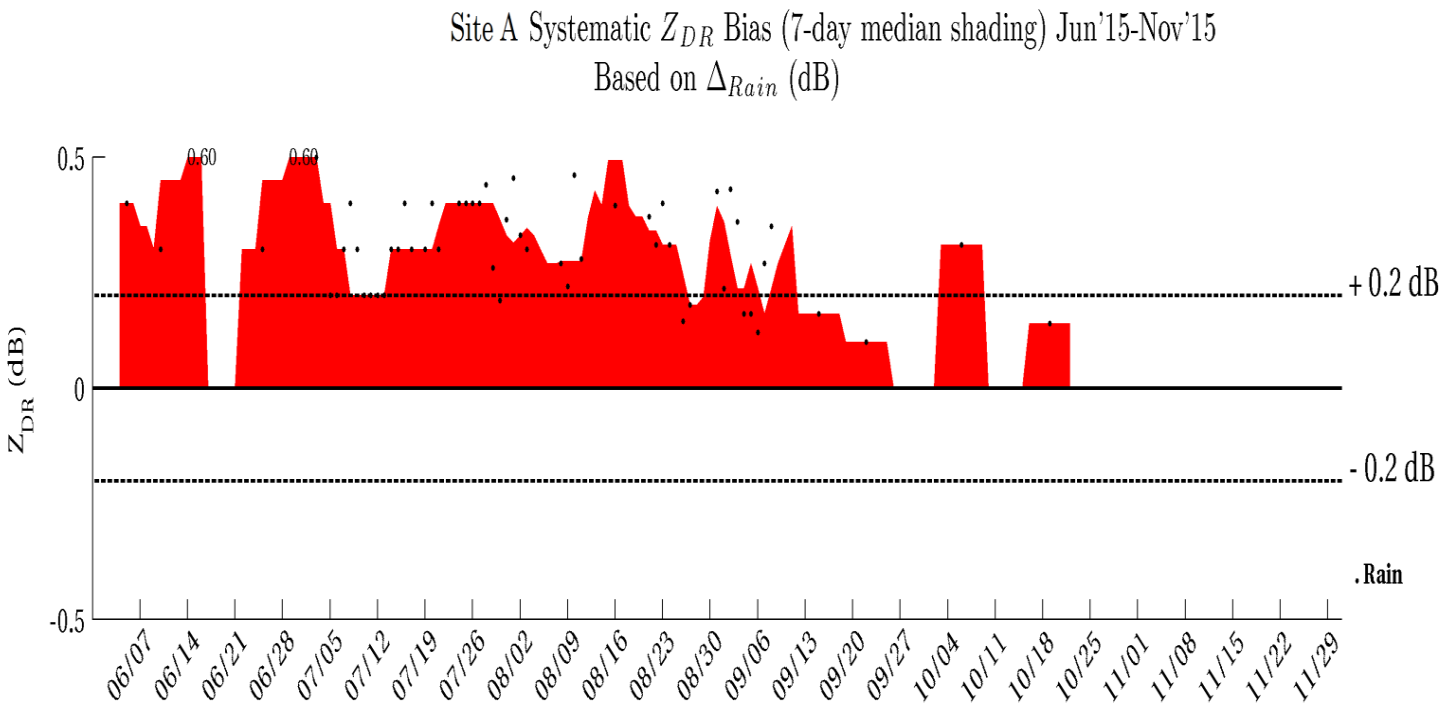
- For each 7-day grouping, a median is calculated from the points
  - Days 1-7, 2-8, 3-9, etc.
- Shading vertex placed on middle day of 7-day set
- Each of the colored boxes above represent a separate set

7-Day Median Calculation



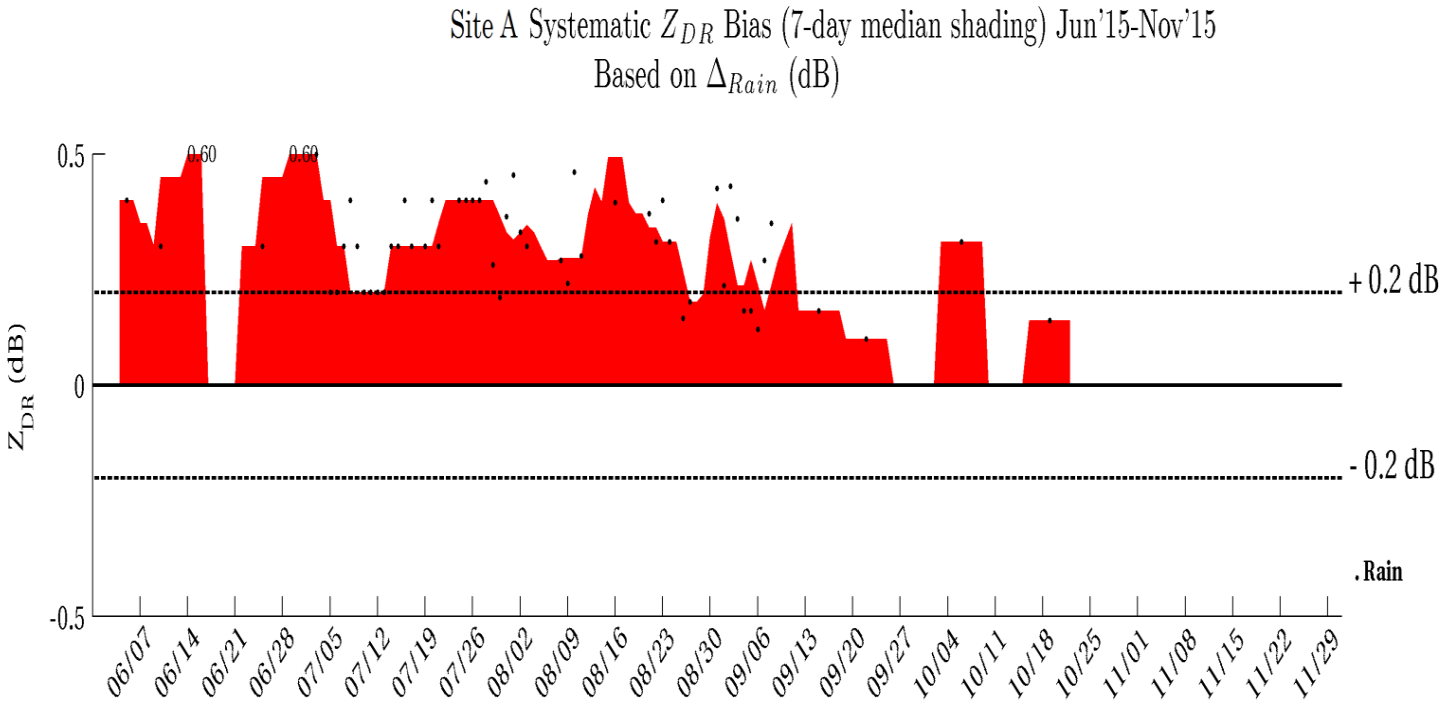
Go from just having points…

7-Day Median Calculation



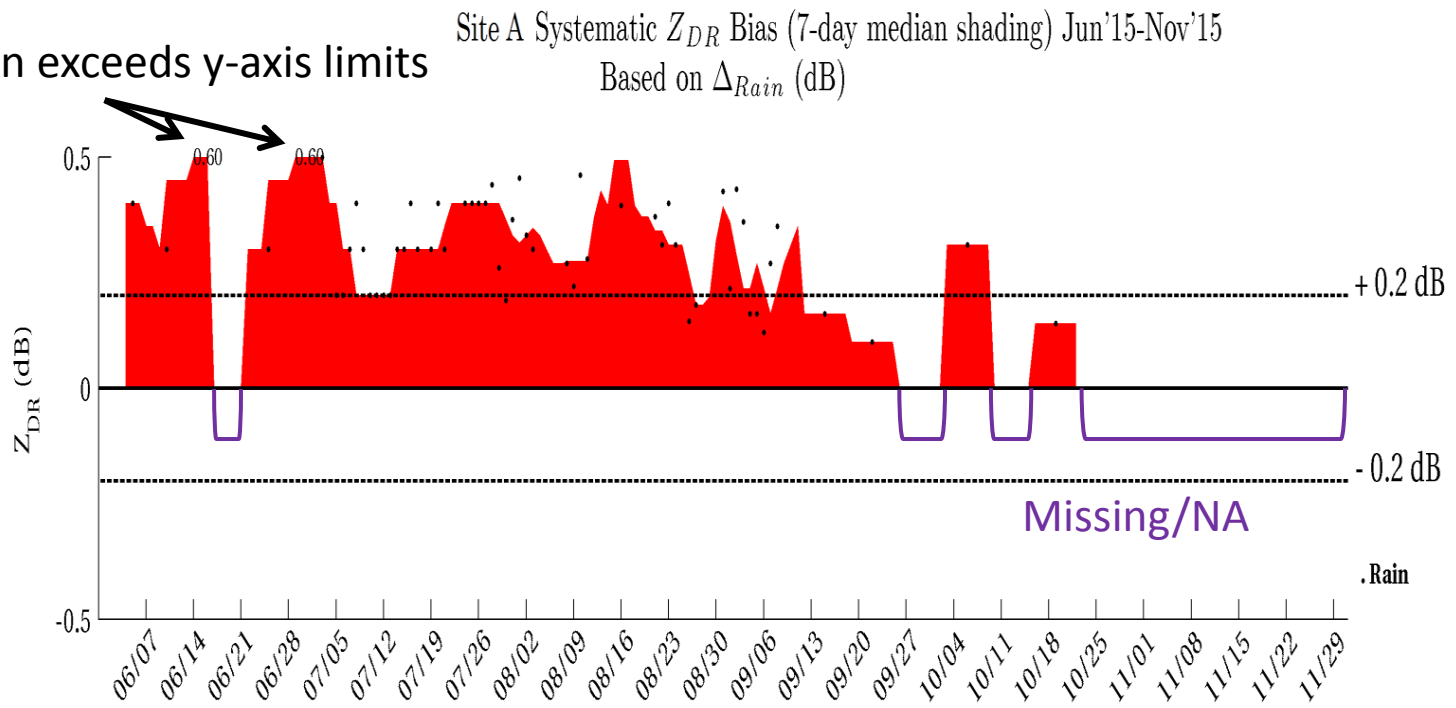
...to having shading.

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 considered out-of-tolerance if the shading is regularly above (below) the dashed 0.2 dB (-0.2 dB) line

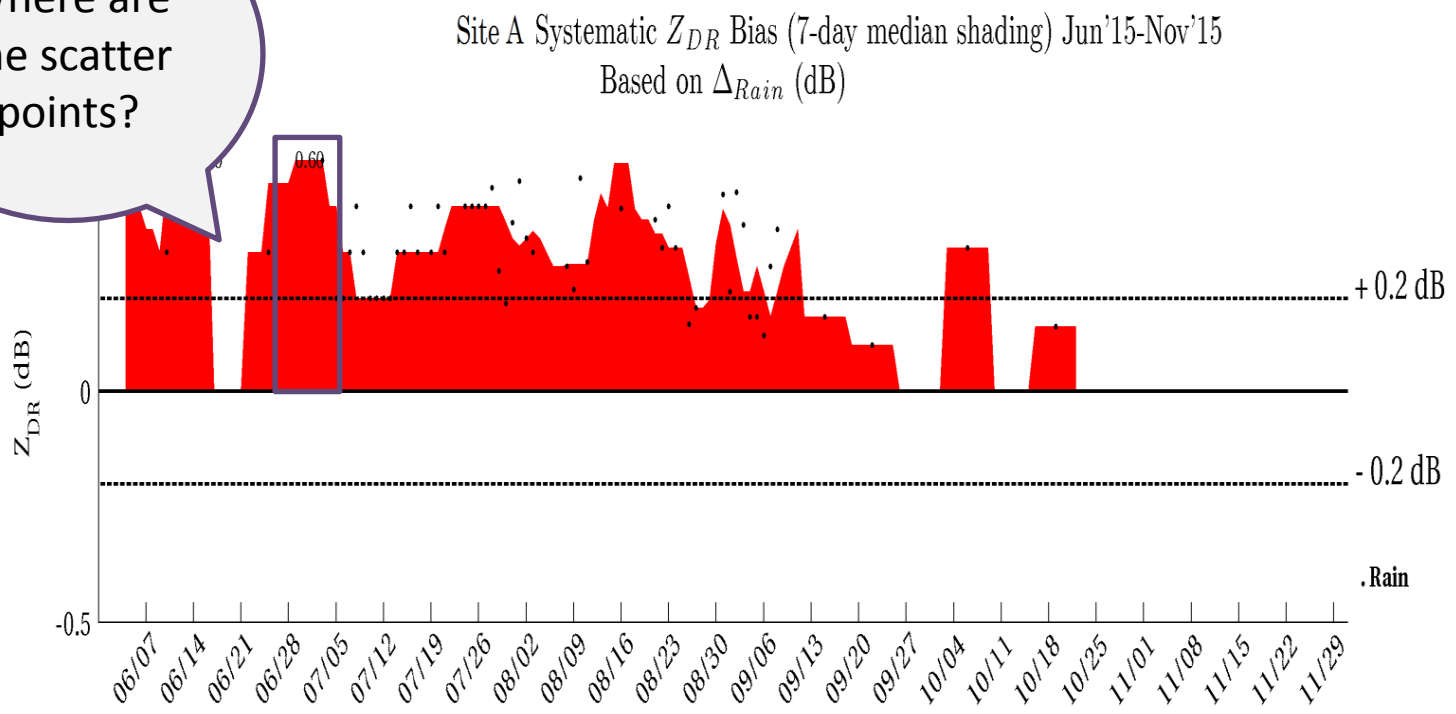
7-Day Median Shading Cont.



- 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?



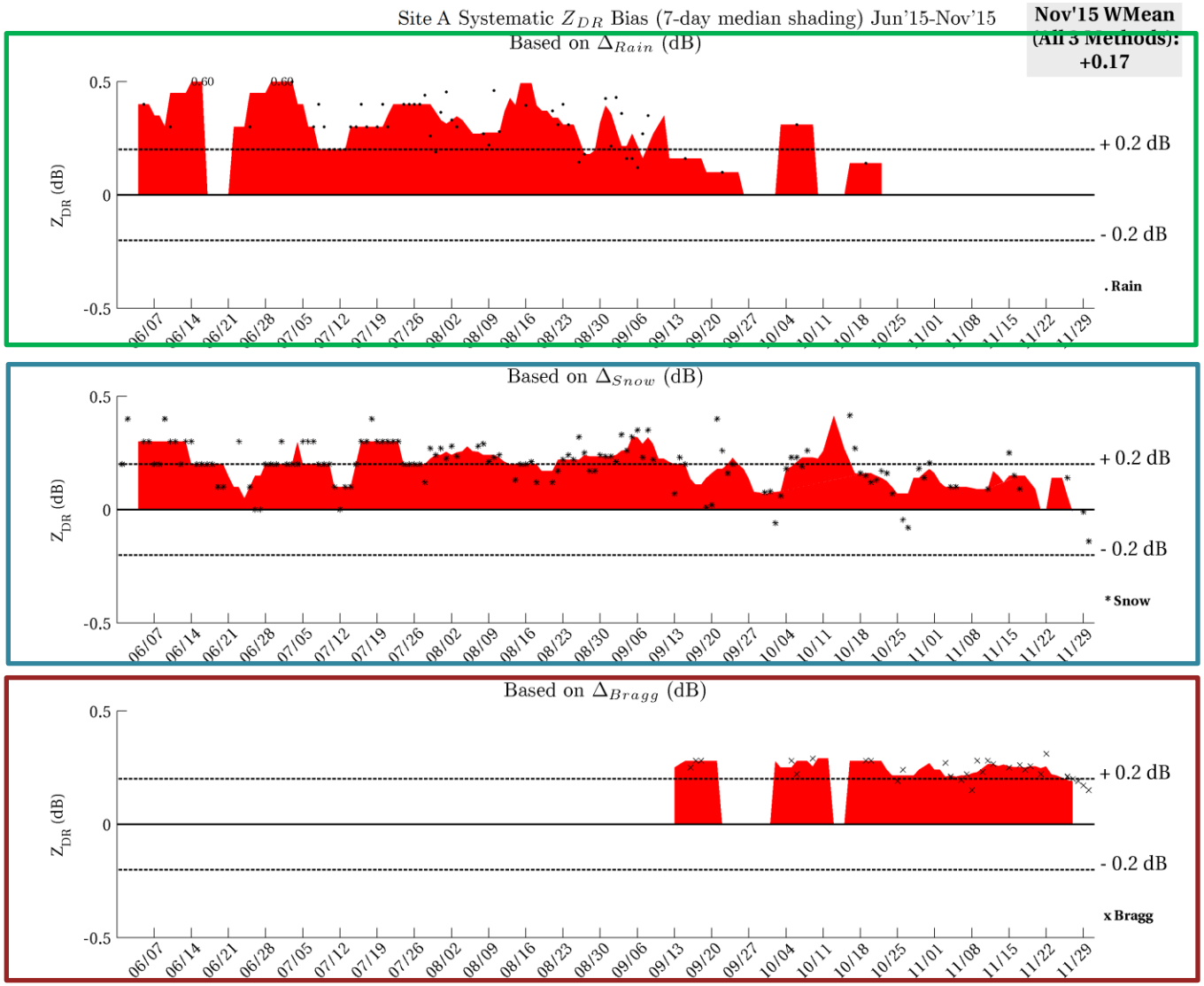
- Event scatter points outside of the y-axis limits (±0.5 dB) are not shown
- Recall that **median** values from shading outside of the limits are represented by the black numbers at the top

Compare Trends from Multiple External Target Methods

Light Rain

Dry Snow

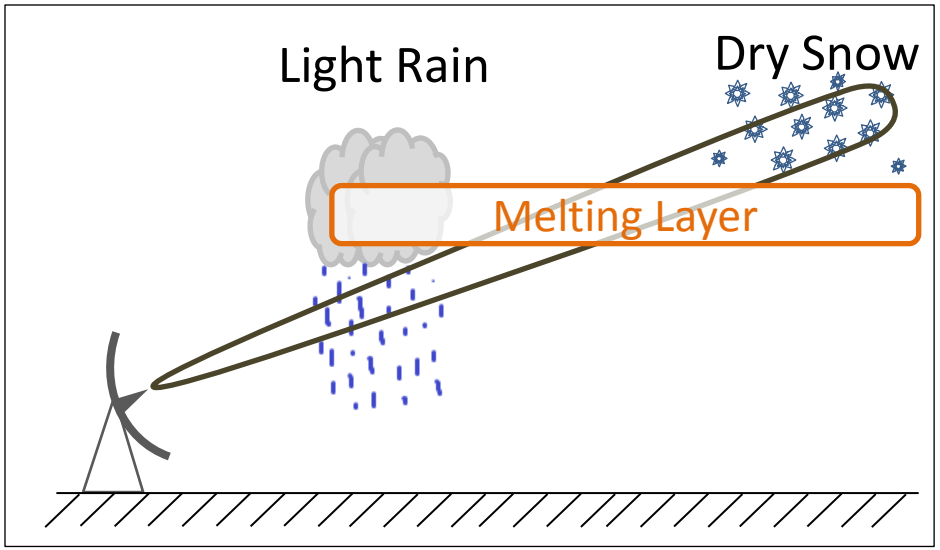
Bragg



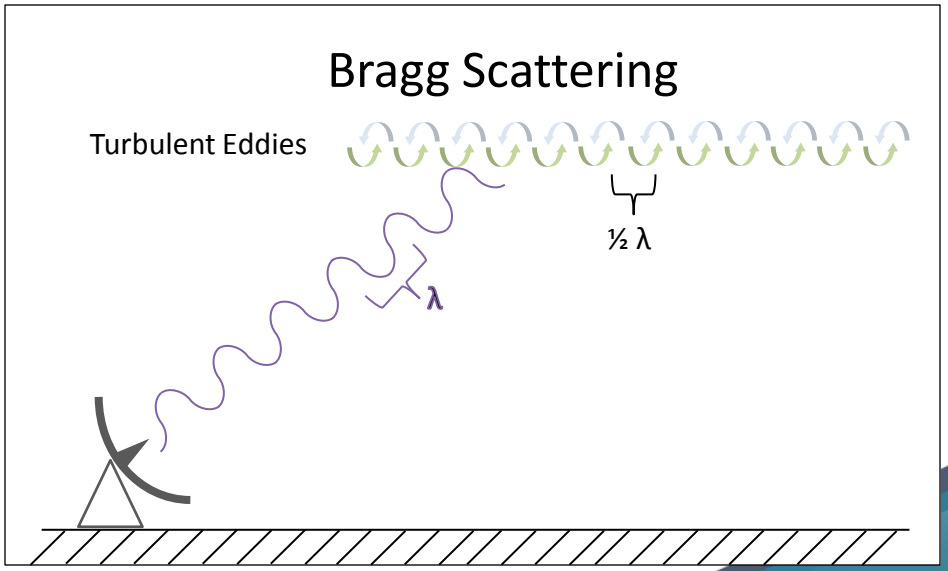
What do the methods detect?

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

- Medians are calculated for six separate reflectivity (Z) categories
  - Categories are inclusive and set as (in dBZ):

19.0-20.5	21.0-22.5	23.0-24.5	25.0-26.5	27.0-28.5	29.0-30.5

  - A correction factor (in dB) based on climatology is subtracted from the median of each category:

0.23	0.27	0.32	0.38	0.46	0.55

  - Subtraction correction can bias Z_{DR} low

Light Rain Method Cont.

- Daily Median (scatterpoints on chart)
  - Median of the 12-volume average values reported in the ASP* message (ZDR Stats)
  - The 12-volume average uses the most recent 12 volume scans
    - Results from the six separate categories are averaged each volume scan into a single number
- Filters include:
  - Range > 20km
  - Elevation > 1°
  - Heights up to 1 km below the melting layer
  - SNR ≥ 20
  - $0.98 < \rho_{HV} < 1.05$

* The ASP is a product version of the RPG Status Log

Dry Aggregate Snow Method

- Estimated only on bins classified as Dry Snow by the Hydrometeor Classification Algorithm (HCA)
  - Snow does NOT have to be reaching the surface
- Extra filters:
  - Range > 20 km
  - 15 dBZ < Z < 25 dBZ
  - Elevations > 1°
  - SNR ≥ 20 dB,
  - $0.98 < RHO_{HV} < 1.0$
  - PHI < 100°
  - Bins must be completely above the melting layer
  - Must have at least 500 Z_{DR} bins that pass filters per volume
  - Standard deviation Z_{DR} < 0.5 dB

Dry Aggregate Snow Method Cont.

- Daily Median Events
  - Median of the 12-volume averages, reported in the ASP, of the Z_{DR} values that pass the filters
  - Subtract **0.2 dB** (climatological value of dry snow) to get the Event bias
- Can be estimated at the same time as a rain Event as long as dry aggregate snow is observed above the melting level
- Dendrites and Platelets can bias Z_{DR} high
- Subtraction correction can bias Z_{DR} low

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

Bragg Scatter Method

- Bragg distinguished by refractivity gradients generally caused by turbulent eddies
  - **Intrinsic Z_{DR} = 0.0 dB** (no subtraction correction needed)
  - Often found at the top of the Convective Boundary Layer and Marine Boundary Layer
- Filters:
  - VCP 32 and 21 only (may allow others soon)
  - 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 2.5-4.5°

Bragg Scatter Method Cont.

- Additional filters:
  - Z at the 90th percentile ≤ -3 dBZ (precipitation filter)
  - Need at least 10,000 bins that pass filters
  - Inter-Quartile Range (IQR) < 0.9 (biota filter)
- Daily Median Events
  - The mode of the histogram is calculated each volume
  - 12-volume average of the modal values is reported in the ASP under ZDR Stats (Bragg)
  - Medians of 12-volume averages count as the daily event

Bragg Scatter Method Cont.

- 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

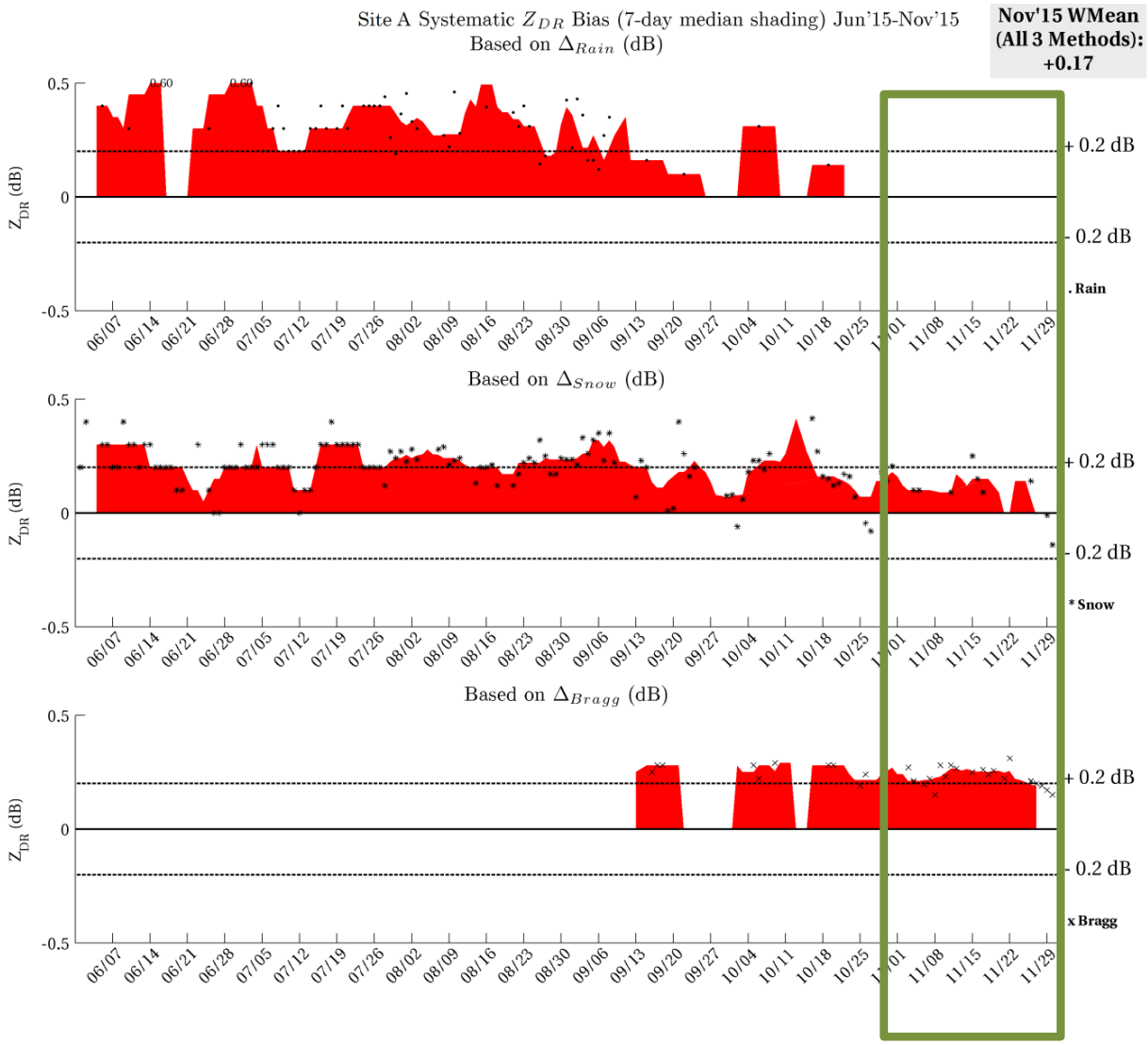
- Light rain is less available during the cool season especially at northern continental sites
- Dry aggregate snow can be found year round at most sites
- Bragg scatter less available due to stringent filters
  - Also less available in the warm season due to biota contamination

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** should be realistic regardless
  - Need **at least a month** of data to establish a baseline

Full-Chart Recap: Compare the Methods

- ZDR is high (above and near the positive tolerance level) for the majority of the time in all three methods
- Focus on most recent month
- Compare with previous months for overall trend

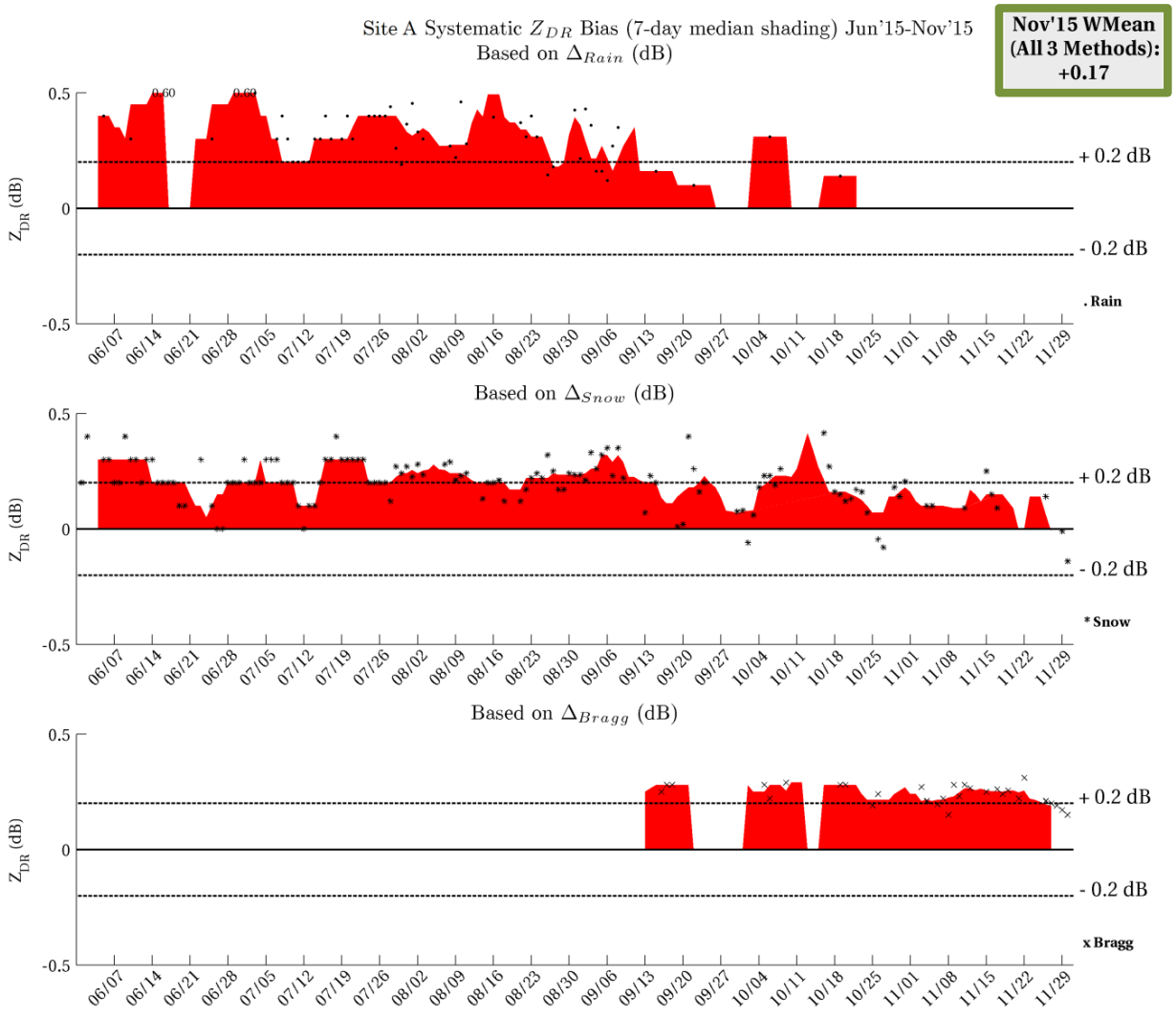


Monthly Summary

- The median of each method is calculated for the most recent month (not shown)
- These medians are then used to calculate d Weighted Mean (WMean) Estimate (displayed in the top-right box)
  - Weights are based on method estimation accuracy
  - Bragg scatter is given the most weight, snow the next most, and rain the least

Monthly Summary

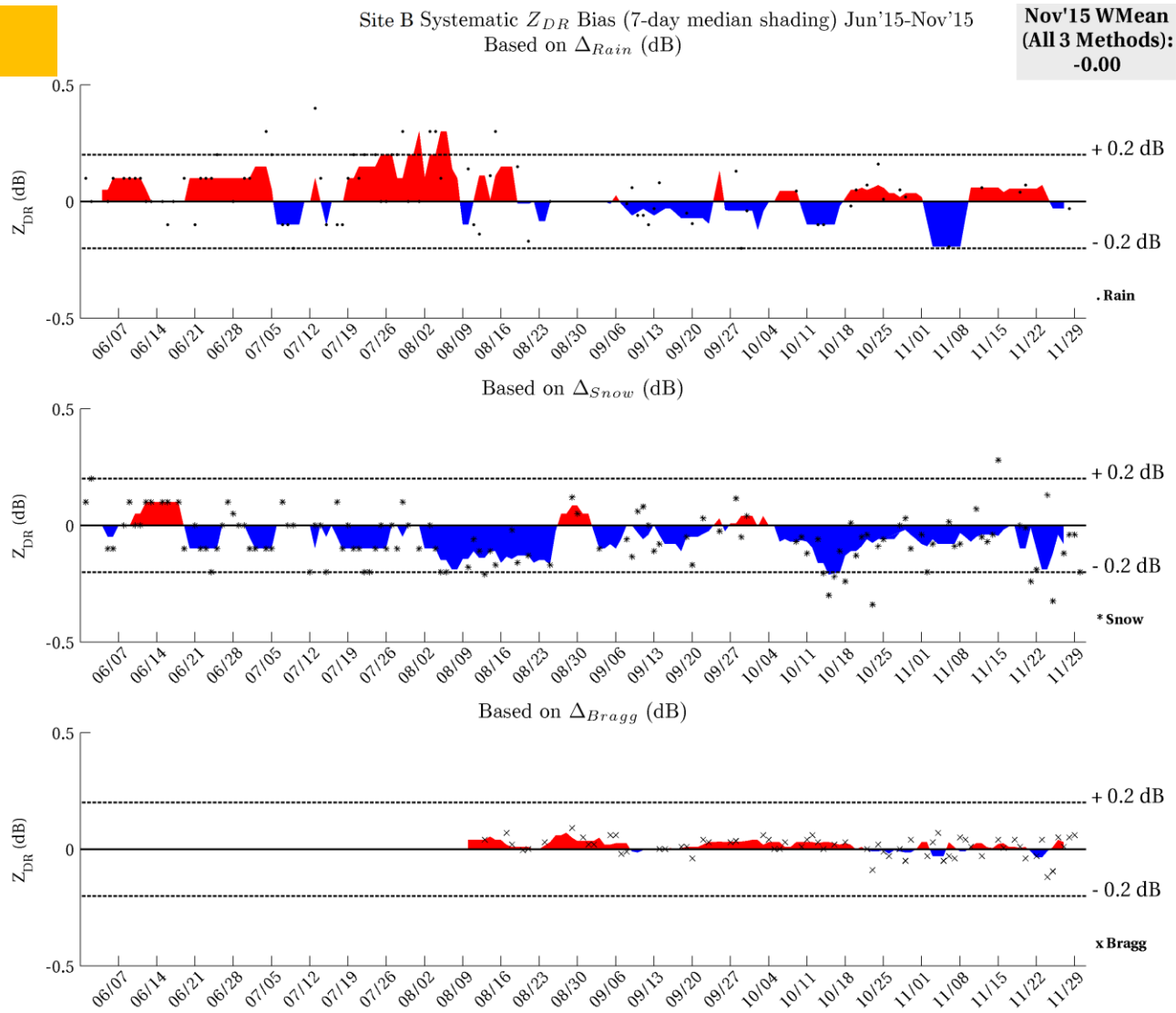
- The monthly WMean box is color coded (matches shade color when out-of-tolerance)
- It will say NaN (Not-a-Number) if there are no estimates for an entire month



Shade Interpretation: “Good” Site

In Tolerance

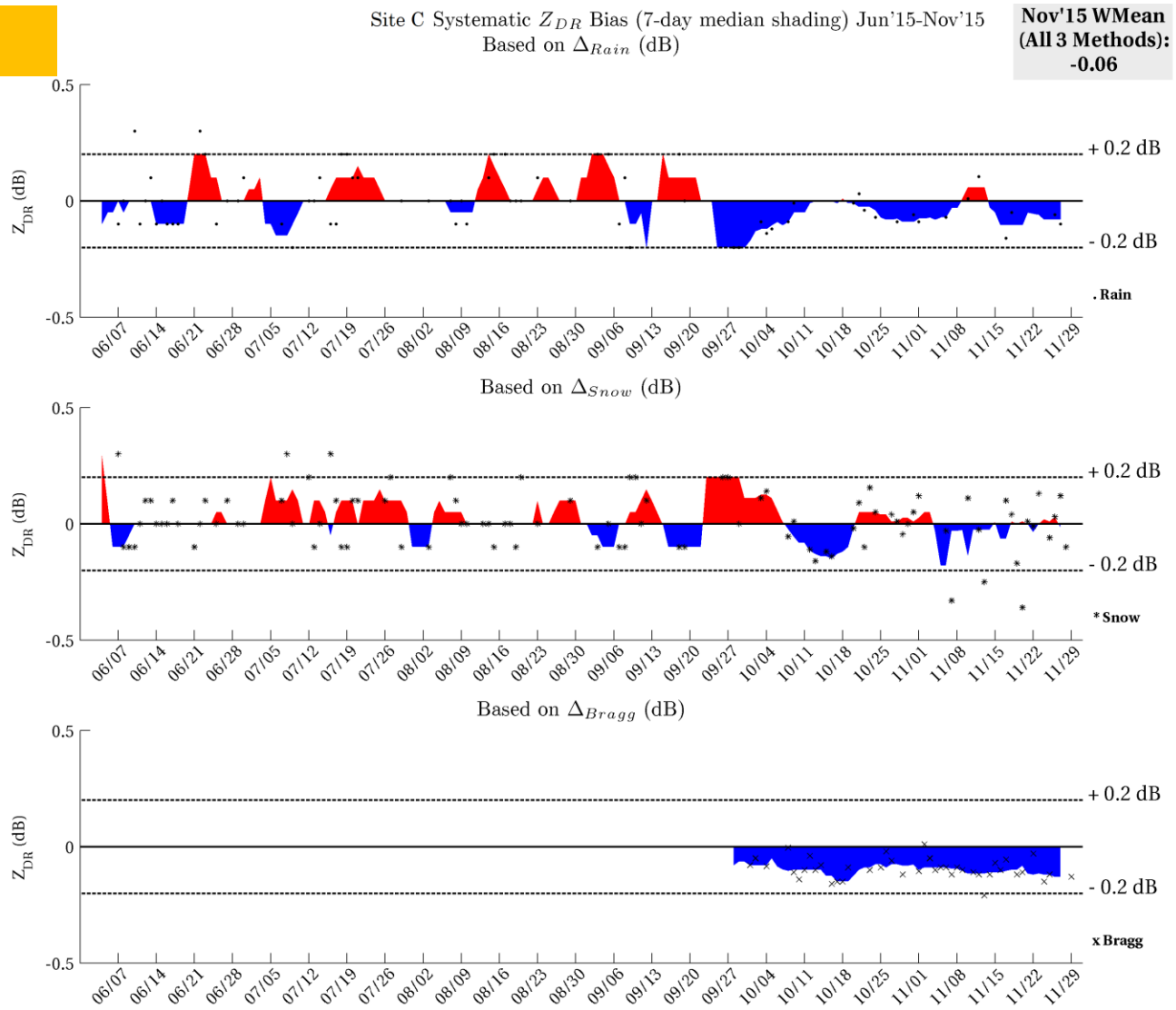
Close to zero and within tolerance limits for all methods



Shade Interpretation: Another "Good" Site

In Tolerance

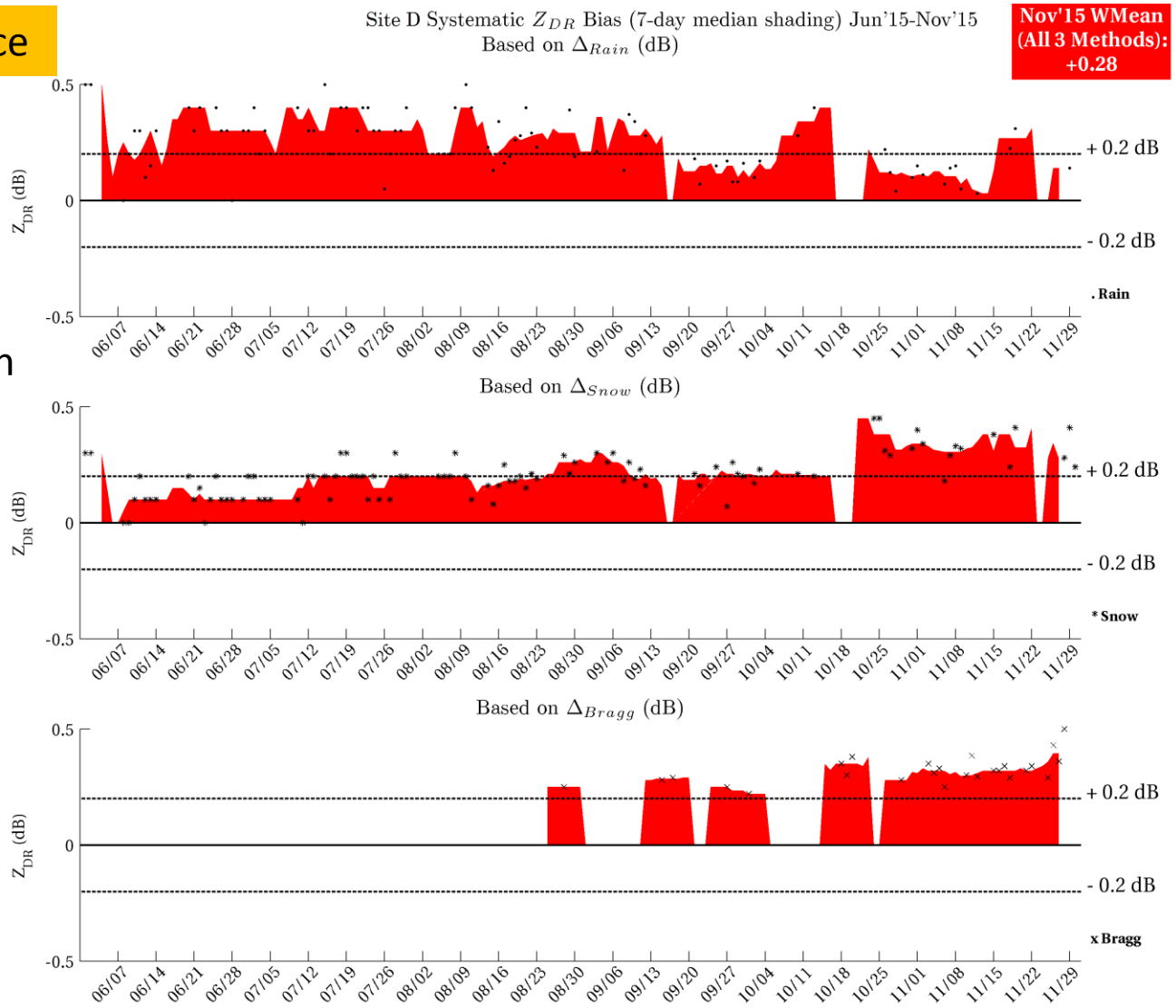
Alternating red/blue around zero (in tolerance) is OK



Shade Interpretation: Warm Bias

Out of Tolerance

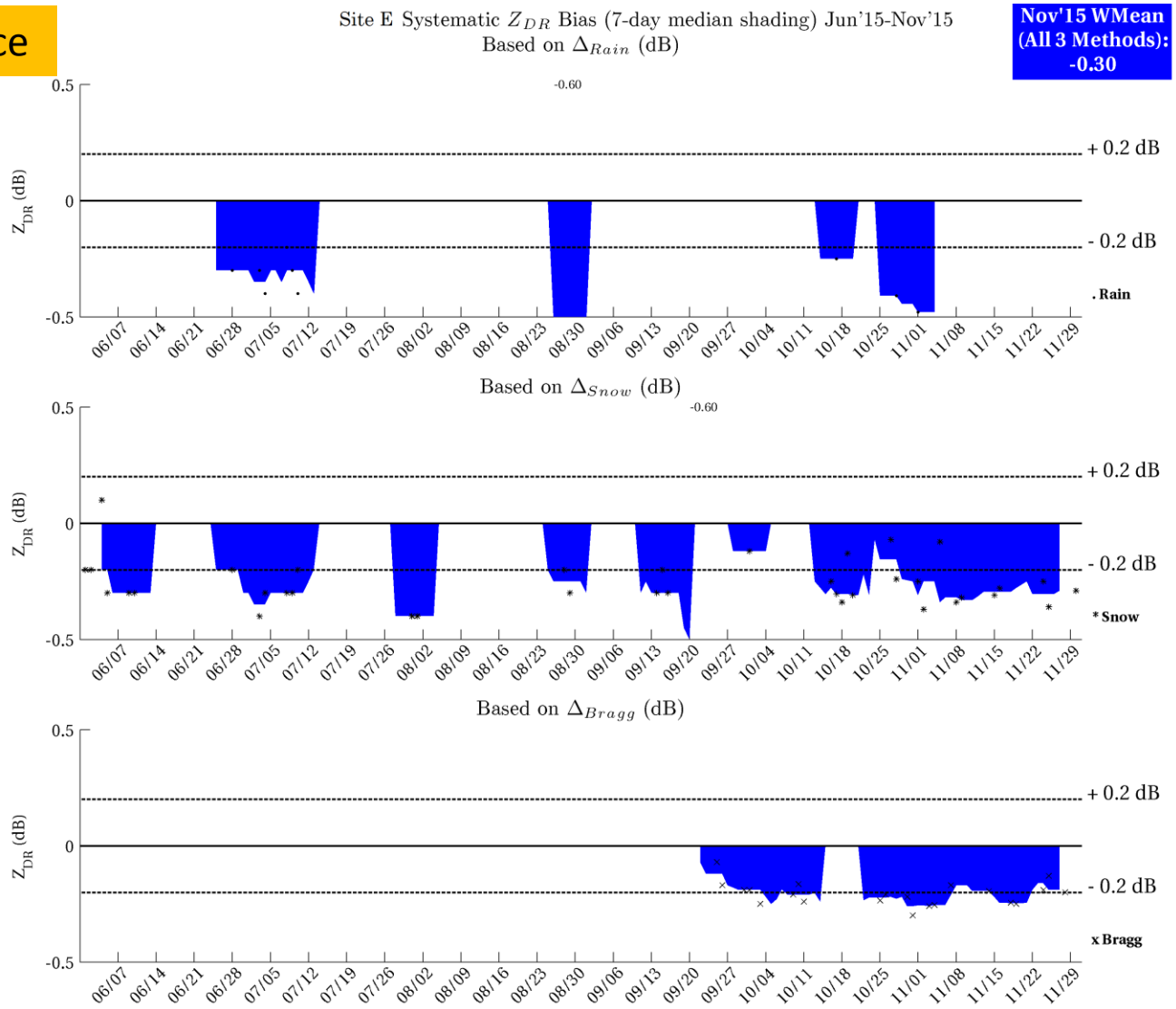
A warm bias causes QPE underestimation



Shade Interpretation: Cold Bias

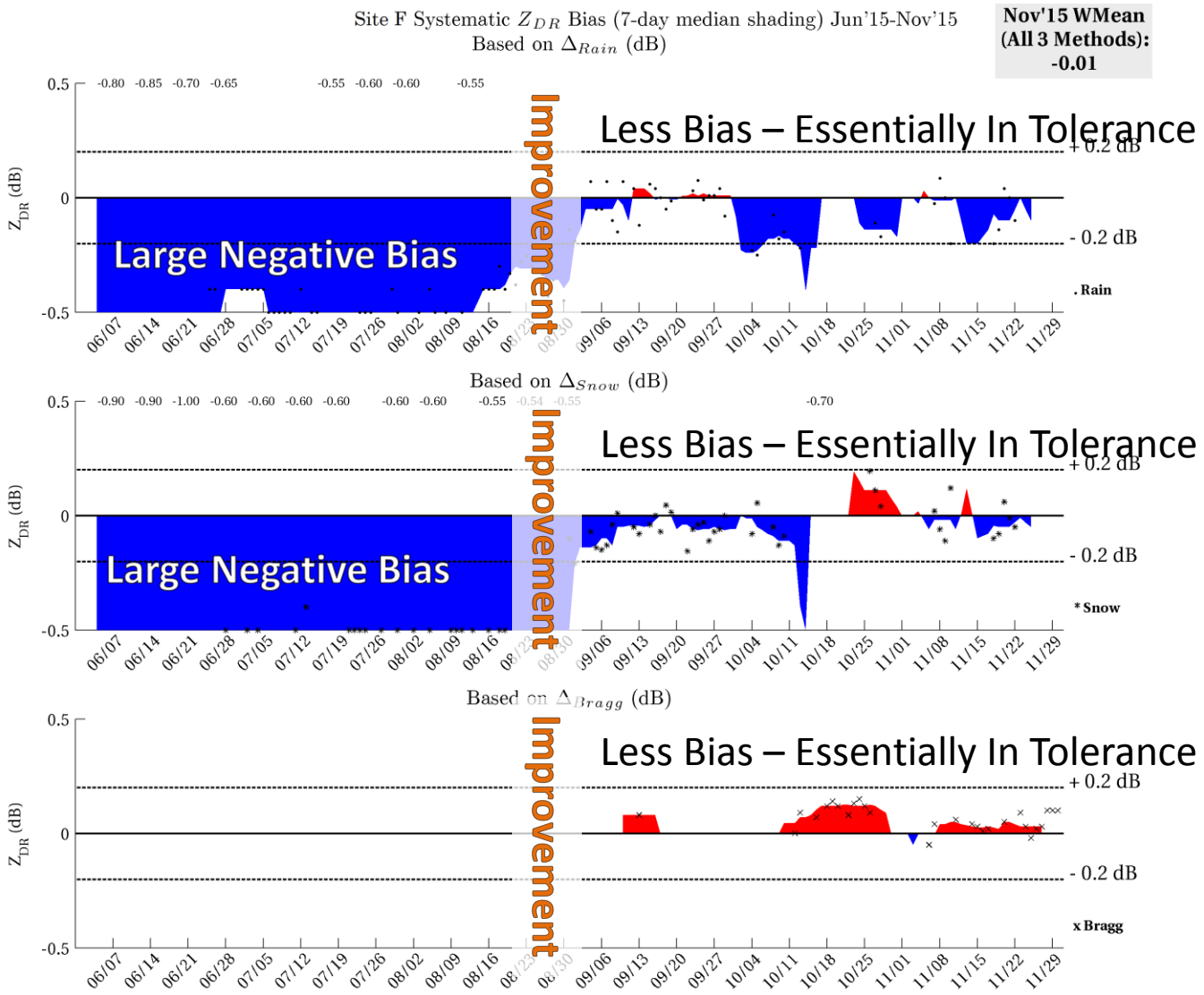
Out of Tolerance

A cold bias causes QPE overestimation



Shade Interpretation: Site Improves

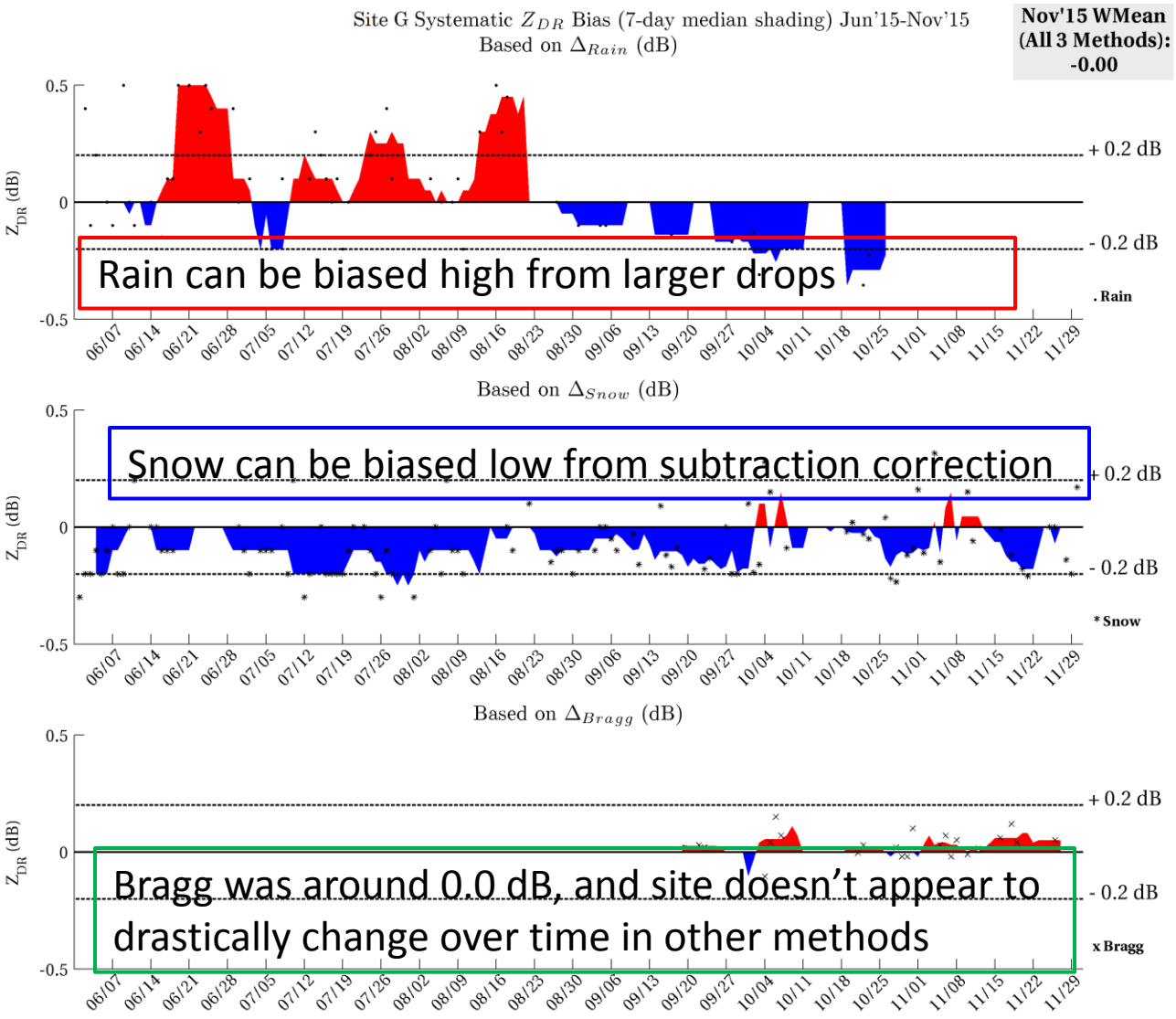
Site had a large negative bias and improved closer to tolerance



Shade Interpretation: Disagreement

Disagreement possible due to the independent method caveats

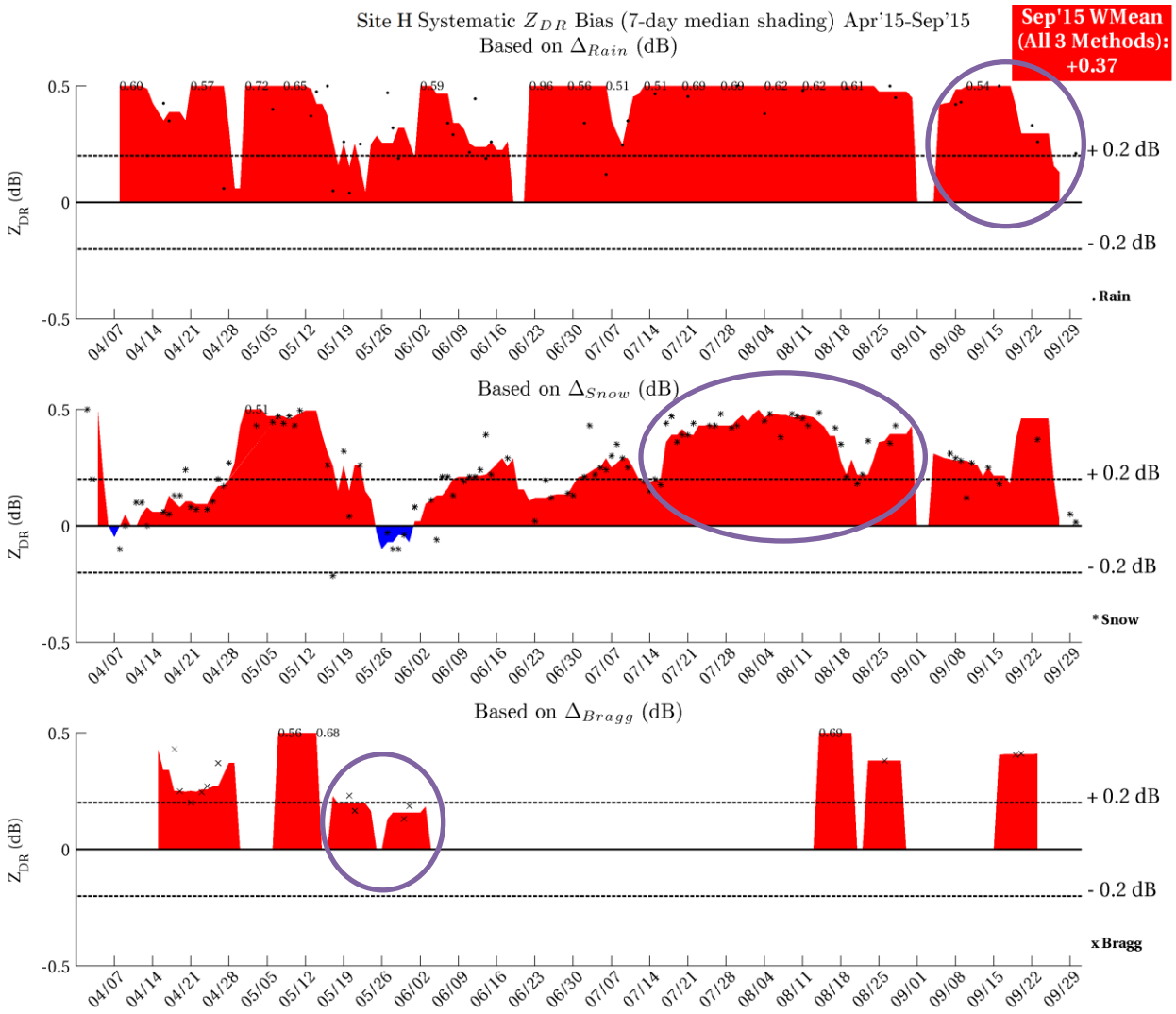
- Site bias is likely around 0.0 dB in this case
- Within tolerance on both sides, so less priority to take action



6-Month Time Window

- Shading features are consistent for a given month

Site H
End Month:
September

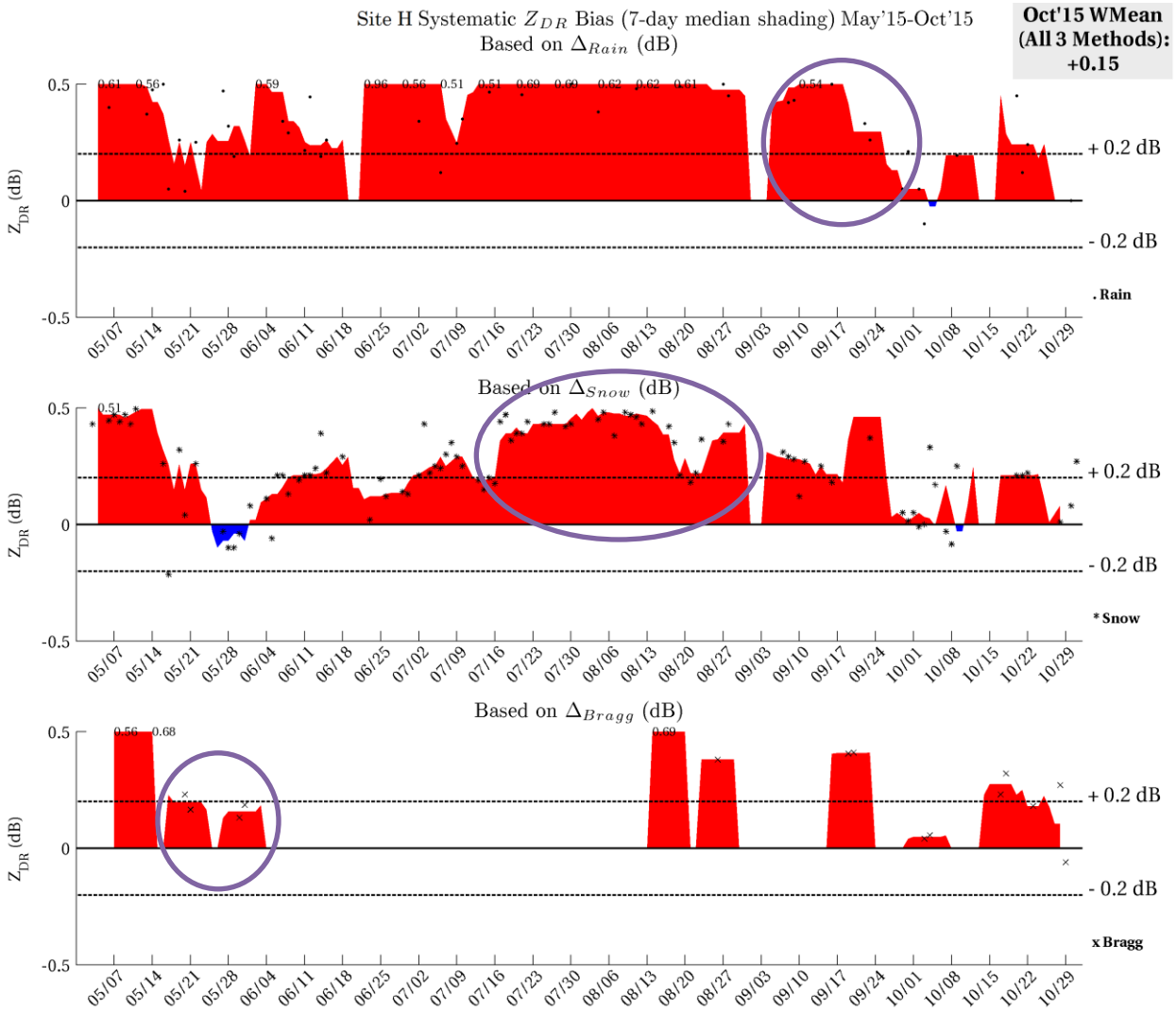


Note how the circled areas move with time in the next two slides

6-Month Time Window

- Features move to the left

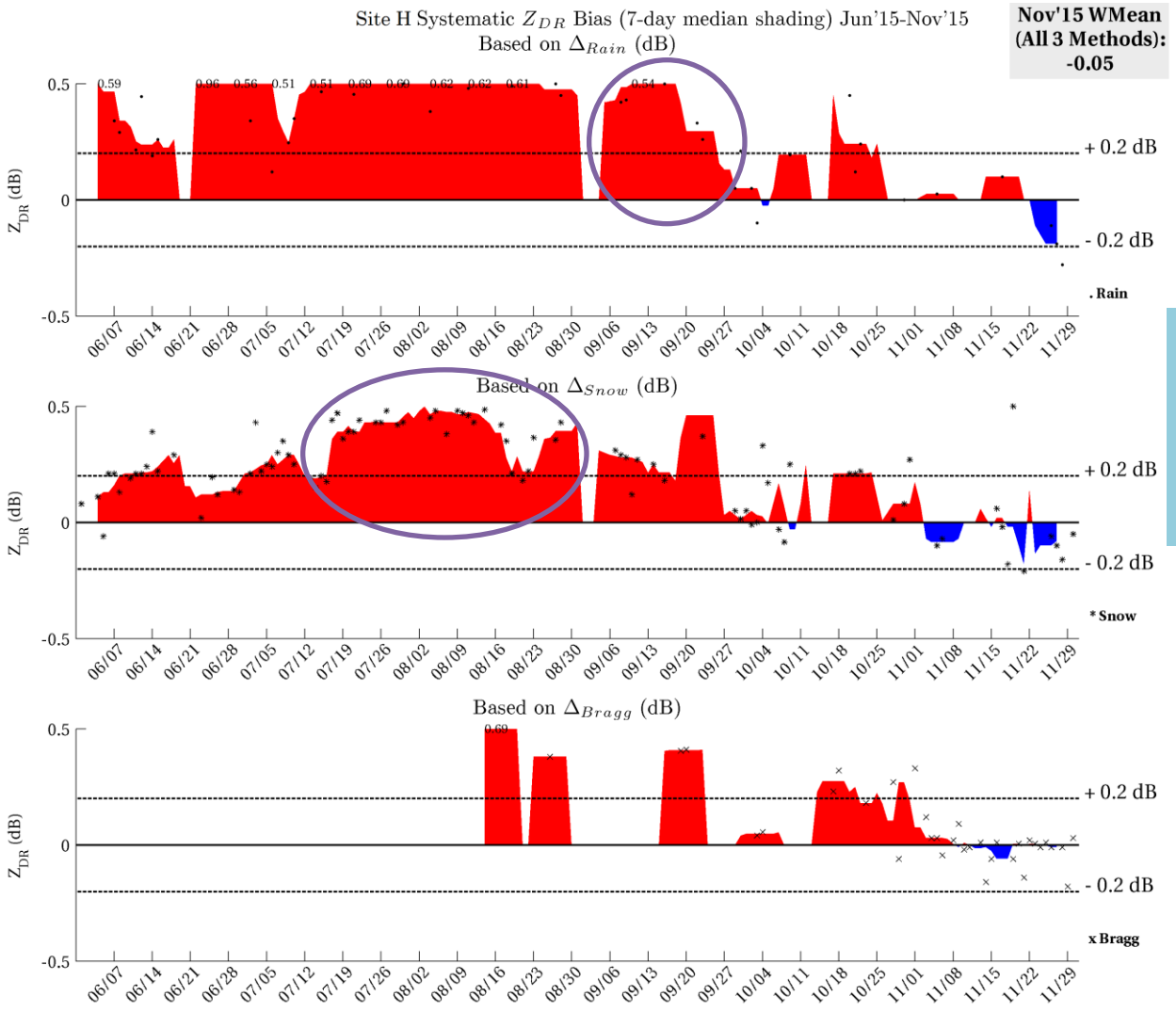
Site H
End Month:
October



6-Month Time Window

- Some features move off with the moving time window

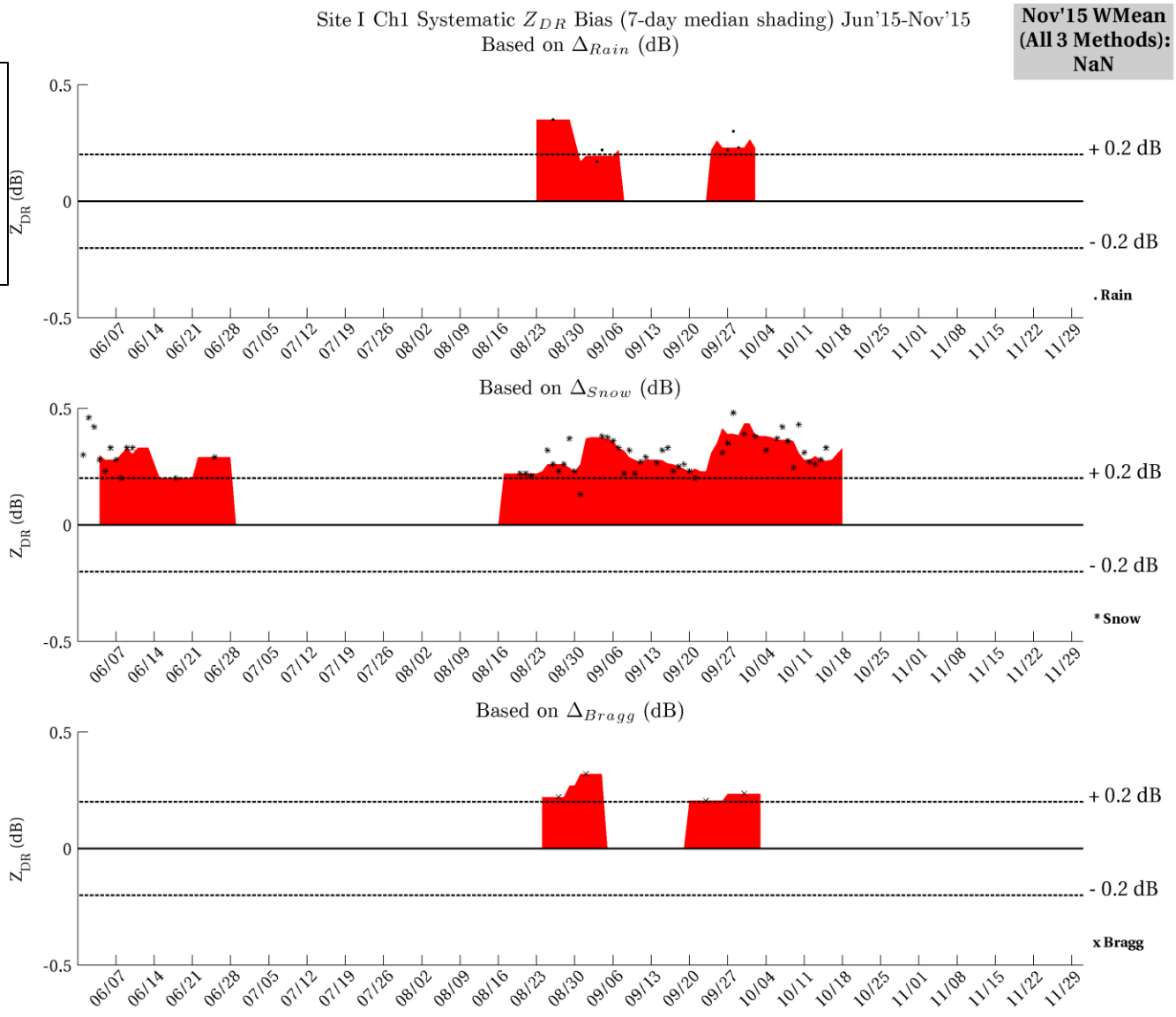
Site H
End Month:
November



Previous months are archived and available

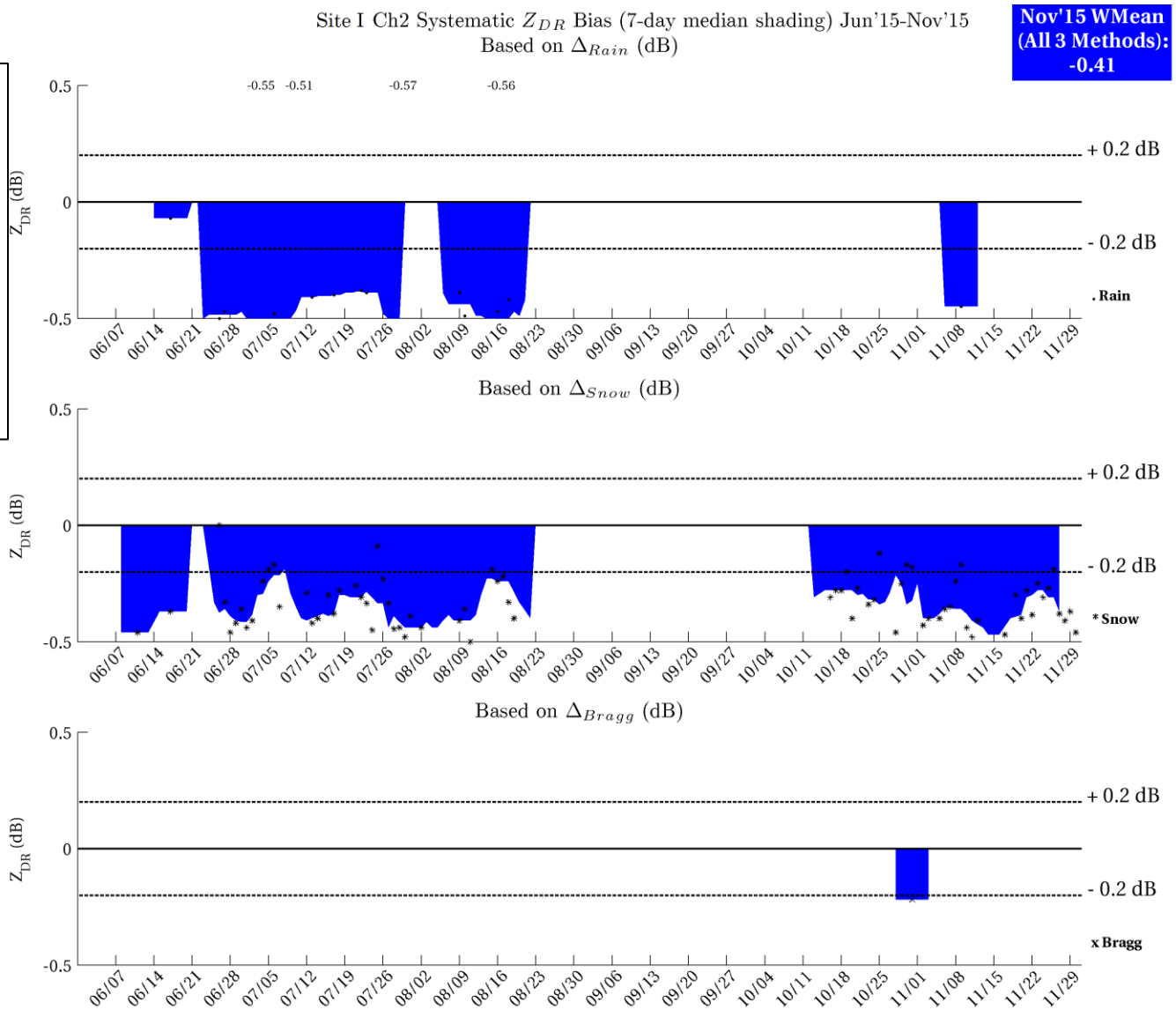
Redundant Sites (Ch1 Example)

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.



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 **Out-of-Tolerance**
  - 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 tolerance)
  - Can also see if a site has a new or drifting hardware issue (e.g., site was in tolerance 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 Tolerance 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
- Some articles can be found at ROC Papers: http://www.roc.noaa.gov/wsr88d/PublicationsROC.aspx