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

Method

Recommended Limits

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

Site A Systematic $Z_{DR}$ Bias Jun’15-Nov’15
Based on $\Delta_{Rain}$ (dB)

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

Site A Systematic $Z_{DR}$ Bias Jun’15-Nov’15
Based on $\Delta_{Rain}$ (dB)

Go from just having points...
7-Day Median Calculation

Site A Systematic $Z_{DR}$ Bias (7-day median shading) Jun’15-Nov’15
Based on $\Delta_{Rain}$ (dB)

...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.

- 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.
• 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

Site A Systematic $Z_{DR}$ Bias (7-day median shading) Jun’15-Nov’15

Based on $\Delta_{\text{Rain}}$ (dB)

Nov’15 WMean (All 4 Methods):
+0.17

Based on $\Delta_{\text{Snow}}$ (dB)

Light Rain

Based on $\Delta_{\text{Bragg}}$ (dB)

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 $\geq 20$ dB
  – $19.0 < Z < 21.0$
  – $0.98 < \rho_{HV} < 1.00$
  – Range Gate must at least 1 km below the bottom of the Melting Layer

• Additional Filters
  – Total Range Gates that pass Base Filters $\geq 600$
  – $0.125 \leq Z_{\text{DR}_\text{IQR}} \leq 0.35$ dB
  – $0.0625 \leq Z_{\text{DR}_\text{MEDAD}} \leq 0.25$
  – $15.0 \leq Z_{90\text{th}} \leq 23.0$ dB
  – $8.0 \leq Z_{\text{IQR}} \leq 16.0$ dB
  – $0.3 \leq \text{PHI}_{\text{IQR}} \leq 3.3^\circ$
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 90$^{th}$ percentile $\leq -3$ 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

![Graph showing comparison of $Z_{DR}$ methods with shading and annotations](image)

- Nov'15 WMean (All 3 Methods): $+0.17$ dB
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

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

Rain can be biased high from larger drops

Snow can be biased low from subtraction correction

Bragg was around 0.0 dB, and site doesn’t appear to drastically change over time in other methods
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:

• 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

Overall ZDR Data Quality

SITUATIONAL AWARENESS
Rain Rate Error Based On Bias and Continental

\[ Z = 30 \text{ dB} \]

\[ \text{ZDRbias} = -0.06 \]

Rain Rate Error = 0

Click here OR here

NEXRAD Radar Operations Center
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 $\pm 0.2$ 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:

• Other articles can be found at ROC Papers:
  http://www.roc.noaa.gov/wsr88d/PublicationsROC.aspx