11.2 Geographical and Seasonal Availability of Light Rain, Dry Snow, & Bragg Scatter to Estimate WSR-88D $Z_{DR}$ System Bias

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American Meteorological Society 31st Environmental Information Processing Technologies
Goals

• Measure system $Z_{DR}$ bias with accuracy $\pm 0.1$ dB when the true $Z_{DR}$ is $\pm 1.0$ dB
  – Important for Quantitative Precipitation Estimates
  – Best we think we can do currently is measure biases of $\pm 0.2$ dB

• Understand the availability of external meteorological targets geographically and seasonally with which to measure system $Z_{DR}$ bias
Methods for Estimating WSR-88D System $Z_{DR}$ Bias

- Hardware based (ZDRB)
  \[ Z_{DR}(offset) = 2 \times ANTB + RCB + TXB = ZDRB \]
  *Antenna Bias (ANTB) checked periodically, Receiver Bias (RCB) checked each volume scan, Transmitter Bias (TXB) checked every 8 hr*

- Meteorological echo-based $Z_{DR}$ bias
  - Light rain
    - $Z_{DR}$ averaged for reflectivity between 19.0 and 30.5 dBZ
    - Below melting layer by at least 1 km but above 1° elevation
    - Median of 3-6 hours continuous sampling taken as event bias
  - Dry snow
    - $Z_{DR}$ averaged for reflectivity between 15 and 25 dBZ, SNR ≥ 20 dB
    - Other filters for $RHO_{HV}$ and $PHI_{DP}$
    - 1 km above melting layer and above 1° elevation
    - Median of 3-6 hours continuous sampling taken as event bias
Methods for Estimating WSR-88D System 
$Z_{DR}$ Bias (cont’d)

• Meteorological echoes (cont’d)
  – Bragg scatter
    • Now limited to 2 hour window 17-19 UTC fleetwide – 1 daily estimate possible
    • Continuous monitoring done on 17 sites for Jan, Apr, Jul, & Oct for this study
      
      *Continuous bias estimate will become available fleetwide in May 2015*

    • Limited to 2 volume coverage patterns (21 & 32) – 9 possible
      – Used most often for clear air
    • Elevations 2.5 to 4.5 deg for sensitivity
    • Filters on $Z$, $V$, $W$, SNR, & $\text{RHO}_{HV}$
    • Other filters for light precipitation & biota contamination
    • Mode of >10,000 bin histogram of $Z_{DR}$ values taken as event bias
    • In this study we take one event per day even with continuous monitoring
KCBW Shade Chart October 2013 – September 2014

Caribou, ME (KCBW) Systematic $Z_{DR}$ Bias (7-day median shading) Oct’13-Sep’14
Based on $\Delta_{\text{Rain}}$ (dB)

**Light Rain**

Are missing obs normal, natural variability, or atypical?

**Dry Snow**

Bragg scatter may be contaminated by light precip

**Bragg Scatter**

Are missing obs normal, natural variability, or atypical?
KCBW ZDRB – Weather Estimated $Z_{DR}$ Bias Comparison
October 2013 – September 2014

Spuriously high Wx bias estimates from Bragg scatter and dry snow events may be off chart.

For this Site, system $Z_{DR}$ bias estimates from hardware ZDRB are mostly within 0.1 dB of median of weather-based bias estimates.
Are missing obs normal, natural variability, or atypical?
For this site, differences in system $Z_{DR}$ bias estimates between hardware ZDRB and weather-based bias estimates with time increase over time.
Percent of WSR-88Ds With 1 or More Events per Month for Each Weather Method

Note the reversal of frequency of events for light rain and Bragg scatter seasonally.
About 1/3 of fleet is outside of ±0.2 dB regardless of Wx method used.

A site may have only 1 event for any given month
October rain events are limited to east of the Rockies, Hawaii, & Puerto Rico. Is this the norm?

Both KILN & KJGX are low (-0.51 & -0.73, respectively). Are they equally valid?
Events are generally sparse everywhere except Puerto Rico and some Gulf of Mexico sites.

**KILN had 11 events**;

**KJGX only 4 events**.

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**US Nexrad Map Number of Events (Light Rain Method) - October 2013**

- **KILN**: 11 events
- **KJGX**: 4 events

**Legend**
- Pink: $X > 20$
- Orange: $10 < X \leq 20$
- Light blue: $0 < X \leq 10$
- Gray: $X = 0$

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**Notable Regions**
- **Alaska (AK)**
- **Hawaii (HI)**
- **Puerto Rico (PR)**
July dry snow events are prevalent everywhere, even Hawaii, & Puerto Rico. Is this the norm?

KSOX, KLBB, & KJAX are high (0.76, 0.41, & 0.84, resp.). Are they equally valid?

Legend (dB)
- $X \geq 0.20$
- $0.20 > X > -0.20$
- $X \leq -0.20$
- NaN
Events are generally plentiful everywhere except Hawaii, Puerto Rico, Southern California. KSOX had only 6 events; KLBB had 22 events & KJAX had 29.
January Bragg scatter events exist in most of contiguous US but nearly non-existent outside the contiguous US. Is this the norm?

KCBW seems a good estimate (0.0 dB). KTLX is low (-0.56 dB).
January Bragg scatter events are in fact infrequent in most of contiguous US except The south and East.

KCBW has only 1 event.

KTLX has 14 events.
January 2014 2-Hour (17-19 UTC) vs. Continuous Bragg Scatter Sampling for 17 WSR-88Ds

<table>
<thead>
<tr>
<th>ICAO</th>
<th>WSR-88D Site</th>
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<tbody>
<tr>
<td>KIWA</td>
<td>Phoenix, AZ</td>
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<tr>
<td>KOTX</td>
<td>Spokane, WA</td>
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<tr>
<td>KEYX</td>
<td>Edwards AFB, CA</td>
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<tr>
<td>KUDX</td>
<td>Rapid City, SD</td>
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<td>Oklahoma City, OK</td>
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<td>KILN</td>
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<td>KLGX</td>
<td>Langley Hill, WA</td>
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<td>Eureka, CA</td>
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<tr>
<td>KLCH</td>
<td>Lake Charles, LA</td>
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<td>KJGX</td>
<td>Robbins AFB, GA</td>
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<td>KGRR</td>
<td>Grand Rapids, MI</td>
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<td>KCBW</td>
<td>Caribou, ME</td>
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<td>PAIH</td>
<td>Middleton, AK</td>
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<tr>
<td>PHMO</td>
<td>Molokai, HI</td>
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<tr>
<td>TJUA</td>
<td>San Juan, PR</td>
</tr>
</tbody>
</table>

Number of Days with Bragg Scatter System Bias Estimates
Selected WSR-88D Sites - January 2014

- 17-19 UTC 2-Hour Window
- Continuous Monitoring
No. of Days with Bragg Scatter Estimates, Jan ‘14, 17-19 UTC Time Window

No. Events
- $X > 10$
- $5 < X \leq 10$
- $0 < X \leq 5$
- $X = 0$

Alaska (AK)
- KLGX 2
- KOTX 1
- KBHX 2
- KEYX 0
- KIWA 0

Hawaii (HI)
- PHMO 5
- PAIH 5

Puerto Rico (PR)
- TJUA 0

KGBX 2
- KUHX 10
- KPEX 3
- KPUX 0
- KUOX 2
- KTLX 14
- KIWA 0
- KCBW 1
- KGRR 4
- KILN 1
- KTLX 14
- KLCH 14
- KJGX 6

Gulf of Mexico
No. of Days with Bragg Scatter Estimates, Jan ’14, Continuous Monitoring

No. Events
- $X > 10$
- $5 < X \leq 10$
- $0 < X \leq 5$
- $X = 0$
Summary / Conclusions

• The dry snow method provides high availability geographically and seasonally but also shows high variance of estimates
• Light rain is most prevalent during the summer months and sparse during the cool seasons
• Bragg scatter during the 2 hr (17-19 UTC) time window is more common fleetwide during the cool season but really is most prevalent in the southern and eastern US. Contamination from biota and limited use of VCPs 21 and 32 may also limit number of events
• Computing Bragg scatter continuously (24/7) increases the number of days with Bragg scatter events almost 4-fold
Thank you!
Questions?

Email: walter.d.zittel@noaa.gov

For the full year’s set of monthly maps for each weather method click on the link below and then click on **Supplemental maps** for this conference paper.

[www.roc.noaa.gov/WSR88D/Applications/AppsPapers.aspx](http://www.roc.noaa.gov/WSR88D/Applications/AppsPapers.aspx)
Backup Slides
Light Rain Method

• $Z_{DR}$ medians are calculated for six separate reflectivity ($Z$) categories from 19.0 to 30.5 dBZ for each volume scan
  – A correction factor (in dB) based on climatology is subtracted from the median $Z_{DR}$ of each category:
    
    \[
    \begin{array}{cccccc}
    0.23 & 0.27 & 0.32 & 0.38 & 0.46 & 0.55 \\
    \end{array}
    \]

  – The average of the six categories within this time frame is computed

  – Spatial filters include:
    • Range > 10 km
    • Height at least 1 km below the melting layer
    • Elevation > 1.0°

• “Events” must have continuous coverage over 3-6 hrs
  – Can have multiple events per day
Dry Aggregate Snow Method

• Estimated only on bins classified as Dry Snow by the Hydrometeor Classification Algorithm (HCA)

• Extra filters:
  - $15\text{ dBZ} < Z < 25\text{ dBZ}$
  - Elevations $> 1^\circ$
  - SNR $\geq 20\text{ dB}$
  - $0.98 < \text{RHO}_{HV} < 1.0$
  - PHI $< 100^\circ$
  - Bins must be completely, but no more than 1 km above the melting layer
  - Must have at least $500\ Z_{DR}$ bins that pass filters per volume
  - Standard deviation $Z_{DR} < 0.5\text{ dB}$
Dry Aggregate Snow Method Cont.

• 3-6 hr Events
  – Average of the $Z_{DR}$ values that pass the filters
  – Subtract 0.2 dBZ (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 $Z_{DR} = 0.0 \text{ dB}$ (no subtraction correction needed)
  - Often found at the top of the Convective Boundary Layer

- Filters:
  - VCP 32 and 21 only currently (may change to allow more)
  - 10-80 km in range only
  - $Z < 10 \text{ dBZ}$
  - $|V| > 2 \text{ m/s}$
  - $W > 0 \text{ m/s}$
  - 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 $\leq -3$ dBZ (precipitation filter)
  – Need at least 10,000 bins that pass filters
  – Inter-Quartile Range (IQR) $< 0.9$ (biota filter)

• 2 hr Events
  – Currently only 17-19 UTC

★ Will be potentially available every volume scan in Build 16 (12-volume running average of the $Z_{DR}$ mode)
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
Percent of WSR-88Ds With Estimated System $Z_{DR}$ Bias $< \pm 0.2$ dB for Each Weather Method
Jul 2014
Snow Events

No. Sites: 153
No. Events: 3366

Snow ZDR (dB)
US Nexrad Map Number of Events (Bragg Method) - January 2014, 17-19 UTC

No. Events

- $X > 10$
- $5 < X \leq 10$
- $0 < X \leq 5$
- $X = 0$

- Alaska (AK)
- Hawaii (HI)
- Puerto Rico (PR)

- KCBW
- TJUA
- PHMO
- PAIH
- KPUX
- KTLX
- KILN
- KGRR
- KJGX
- KLCH
- KOTX
- KKGX
- KIWA
- KEYX
- KBHX
- KLGX
- KEXX
- KUUX
- KUDX
- KUEX
US Nexrad Map Number of Events (Bragg Method) - January 2014, 17-19 UTC

No. Events
- $X > 10$
- $5 < X \leq 10$
- $0 < X \leq 5$
- $X = 0$

Circled sites show events from continuous monitoring.

Puerto Rico (PR) 24
Hawaii (HI) 13
Alaska (AK) 24
Example of Bragg Scatter Milwaukee, WI, November 10, 2013, 18:04 UTC, 2.5° Elev.
Total Bias = RXB + TXB + 2ANTB

RXB - test signals - each volume - must know test signal bias and coupler losses
TXB - sampled power - 8 hours - must know power sense bias and coupler losses
ANTB - solar scans - monthly - must include RXB to derive antenna bias
Measuring the Biases with built in test equipment (BITE) and solar scans

Receiver bias checked each volume scan

Transmitter bias checked every eight hours (performance check)

Antenna bias checked periodically with a solar scan

the test signal and power sensing equipment biases must be known and corrected