9B.5 METHODS FOR IDENTIFYING SYSTEMATIC DIFFERENTIAL REFLECTIVITY (Z_{DR}) BIASES ON THE OPERATIONAL WSR-88D NETWORK

Jeffrey G. Cunningham, W. David Zittel,
Robert R. Lee, and Richard L. Ice
Radar Operations Center, Norman, OK

Nicole P. Hoban
University of Missouri, Columbia, Missouri

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Goal

Improve performance of dual polarization quantitative precipitation estimates (QPE) by reducing absolute systematic Z_{DR} bias

Note: Absolute Z_{DR} bias of 0.1 to 0.2 dB produces a 10 - 30% QPE error!

Objectives

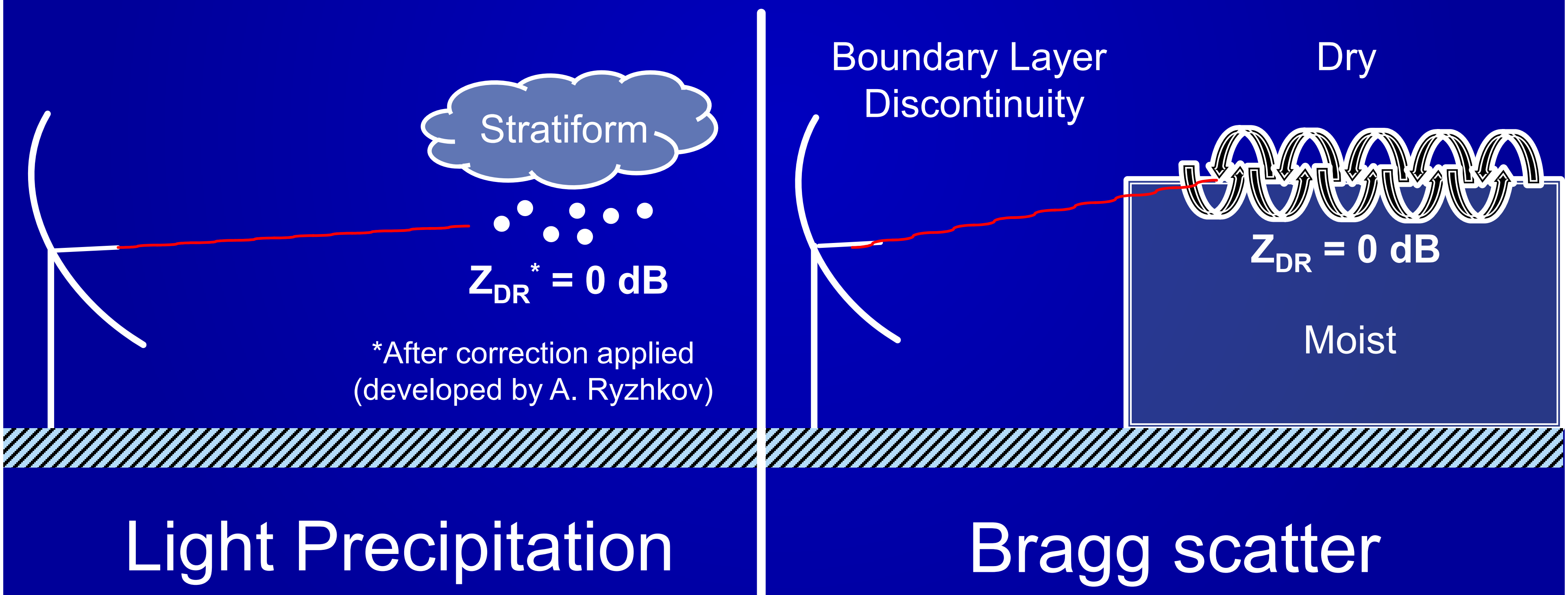
1. Develop automated observational methods that evaluate the performance of the current WSR-88D system Z_{DR} calibration method

2. Present fleet-wide statistics from the observational methods

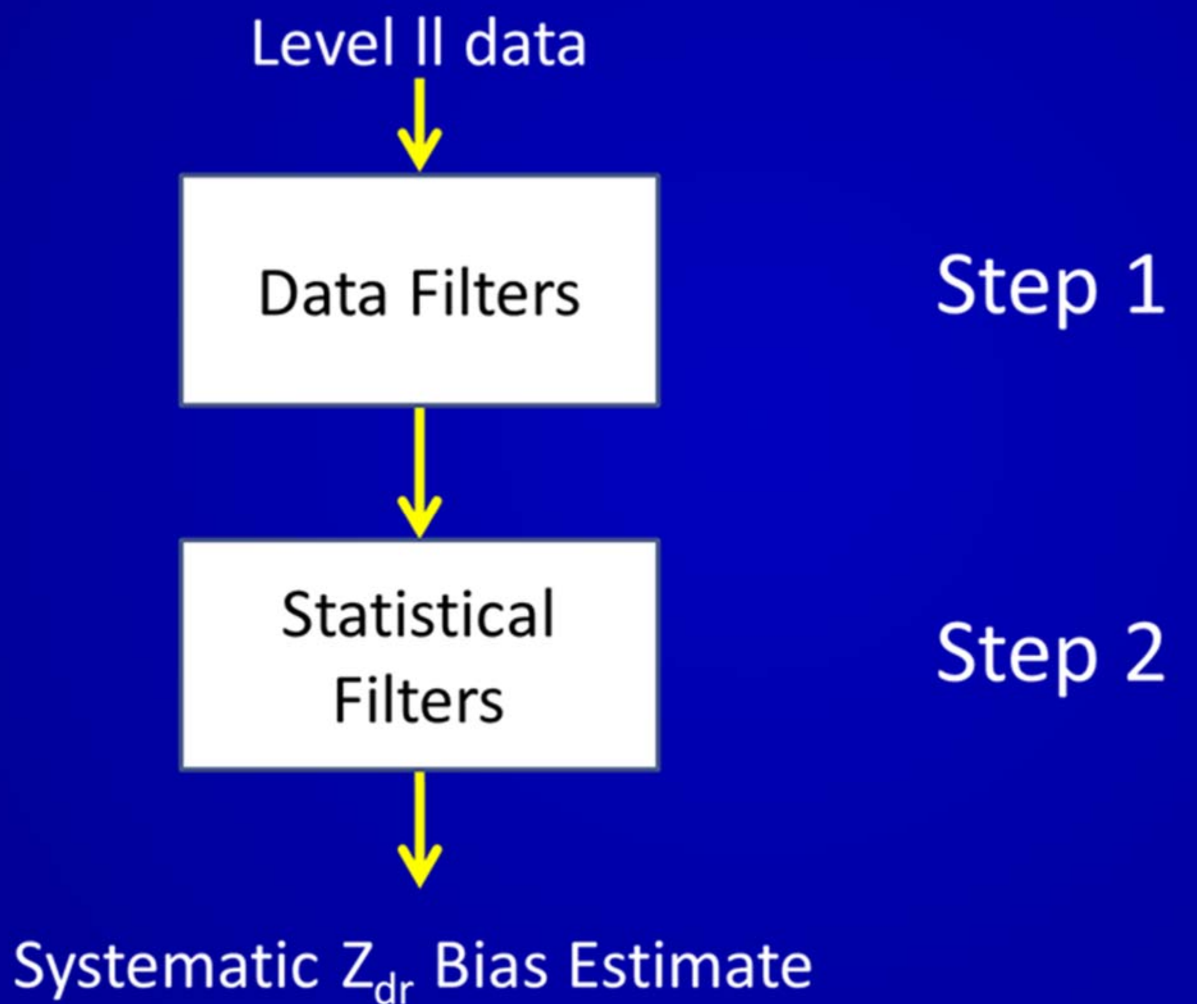
3. Combine these methods to isolate & correct sources of biases

Observational Methods to Identify Total Systematic Z_{DR} Biases

Data collected on targets with intrinsic Z_{DR} = 0



Observational Methods are Automated with Operational Scanning Strategies



Observational Methods to Identify Total Systematic Z_{DR} Biases

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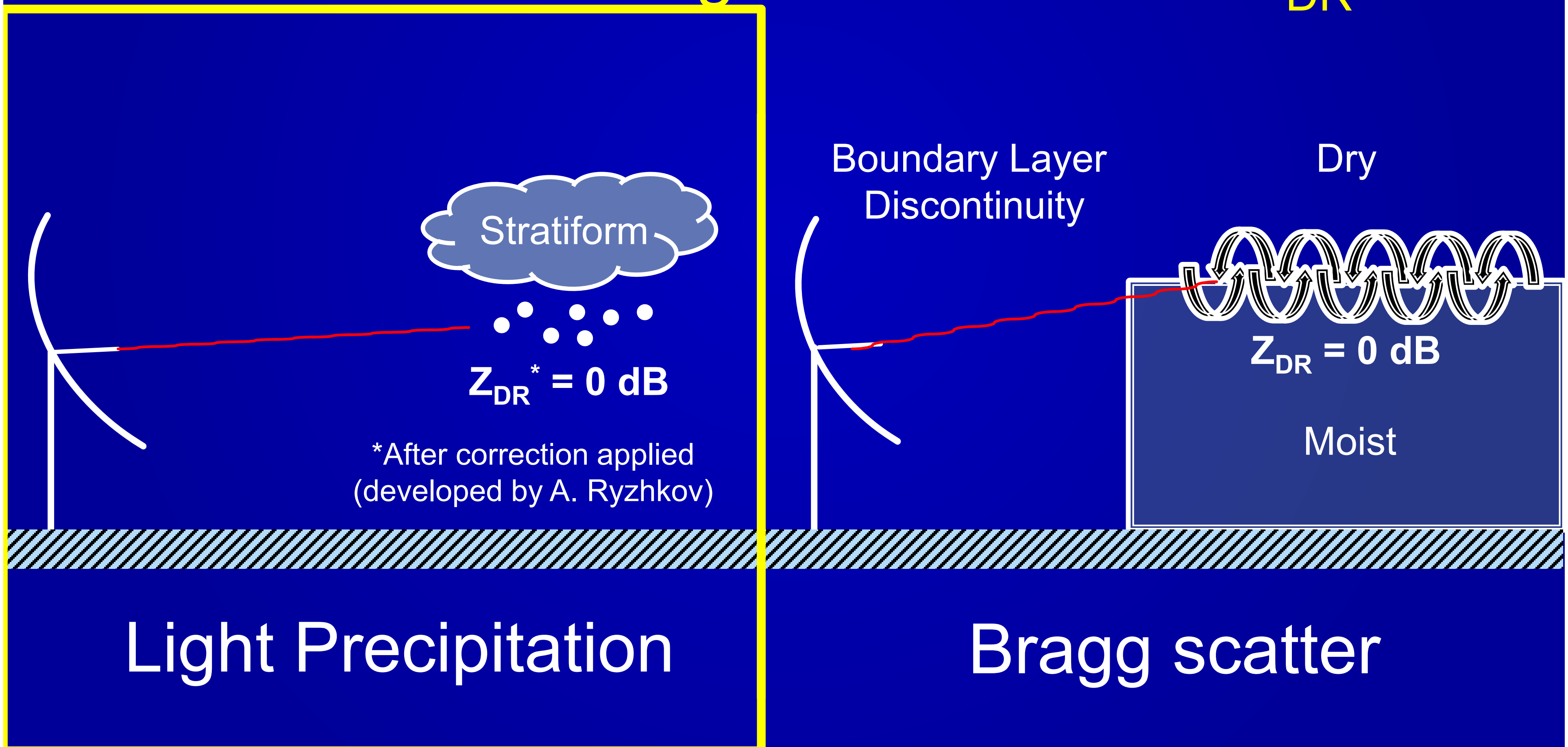
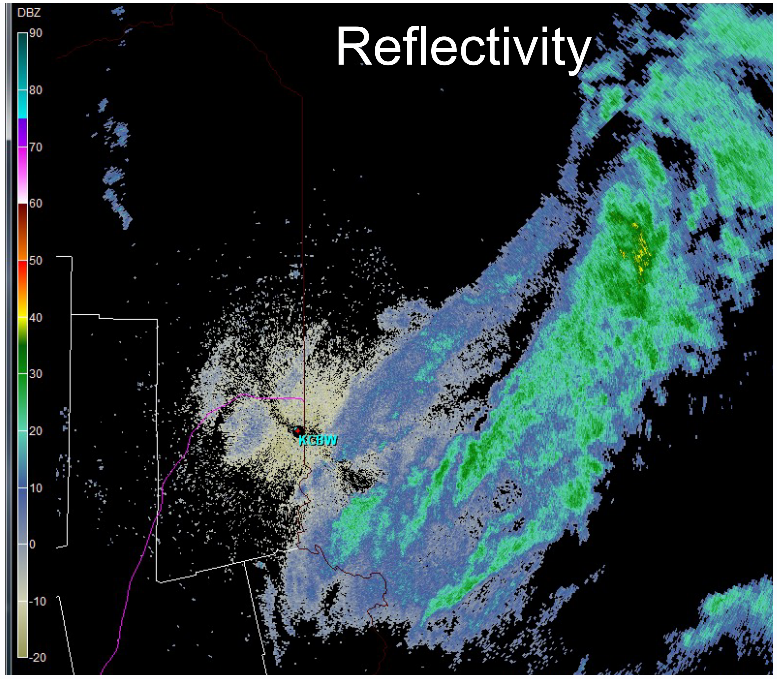
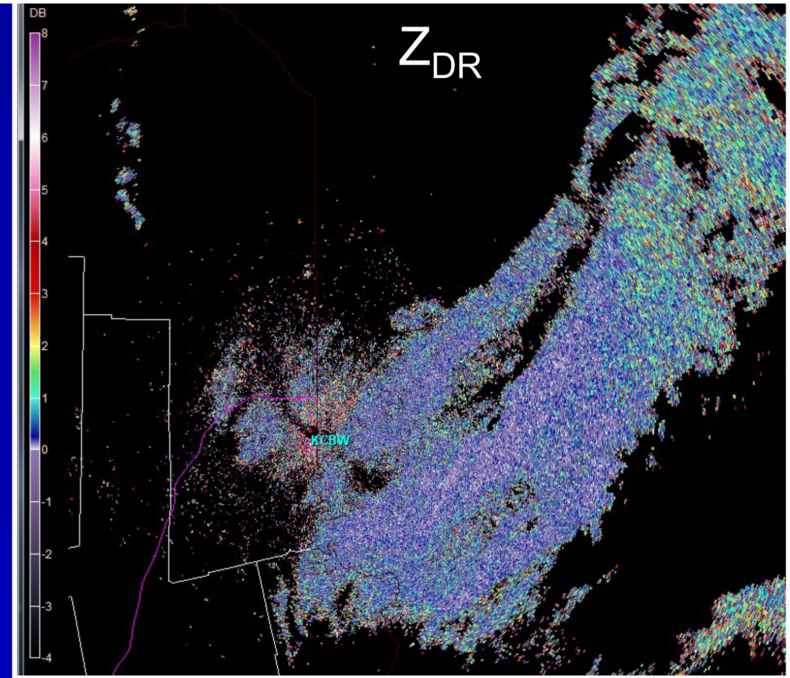
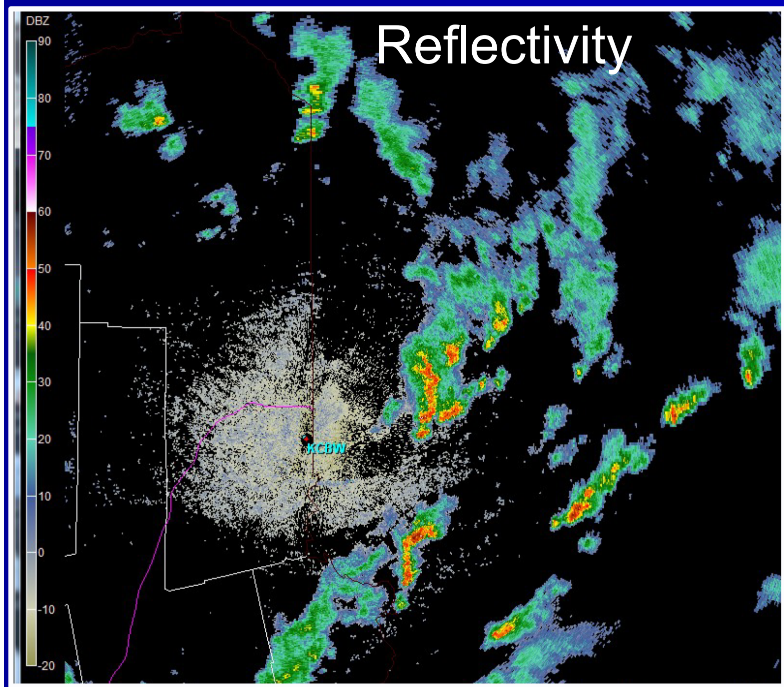




Stratiform

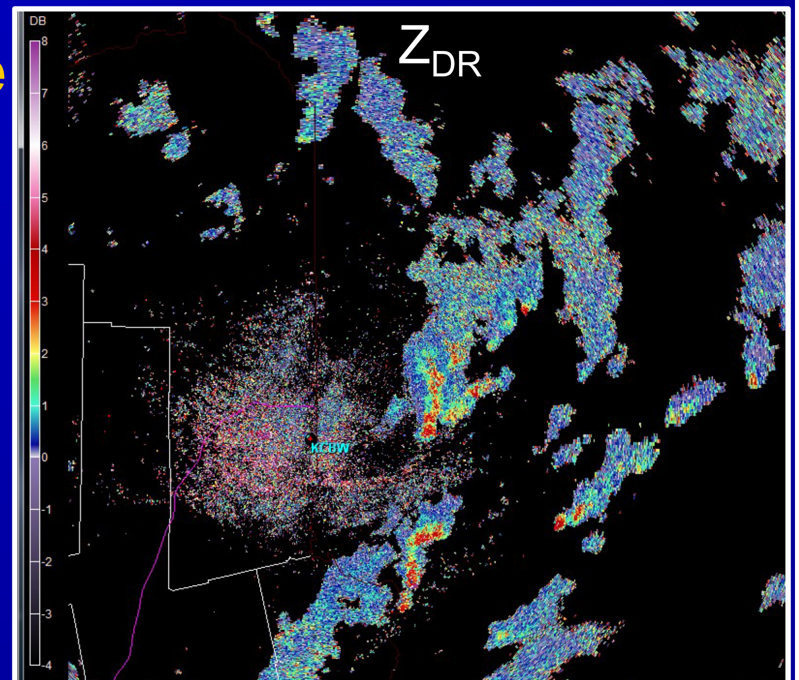
Caribou
KCBW
10 Aug '13
04:30 Z

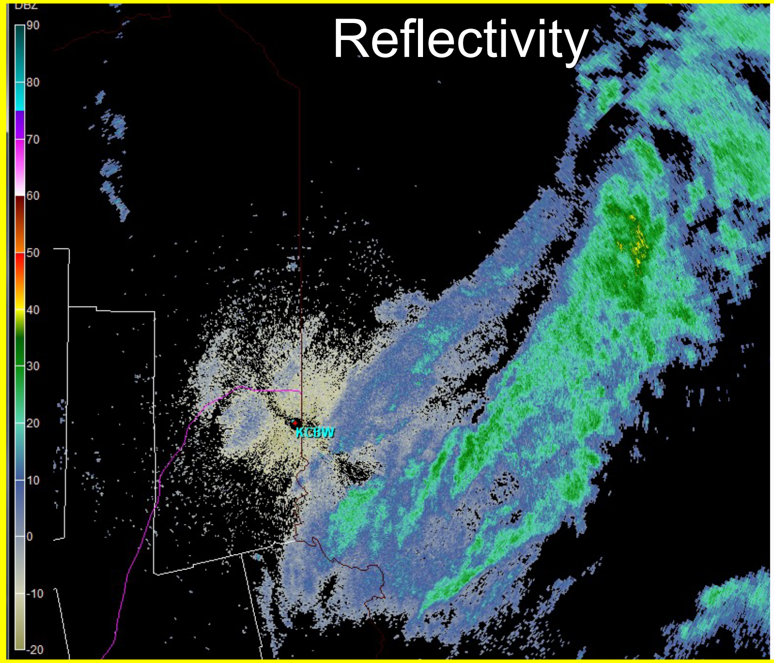




Convective

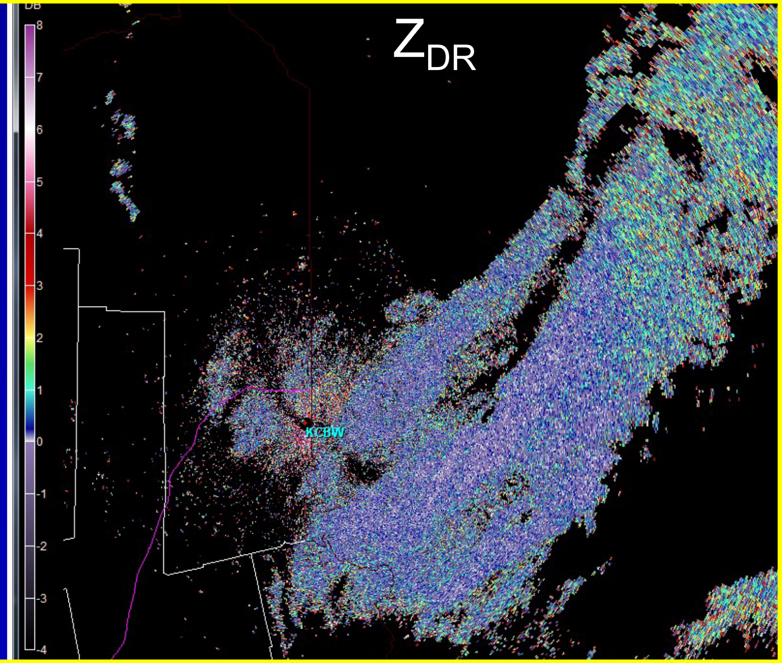
Caribou
KCBW
3 Aug '13
19:22 Z

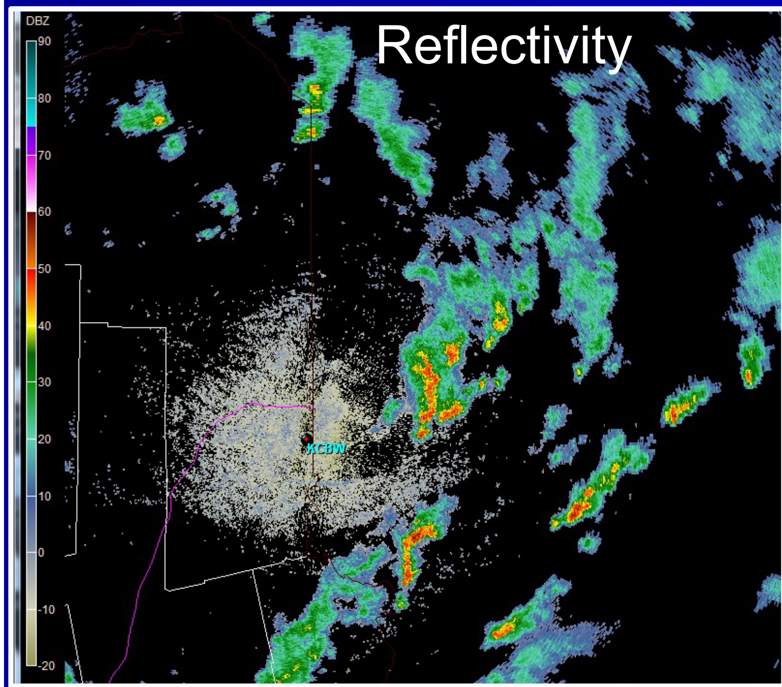




Stratiform

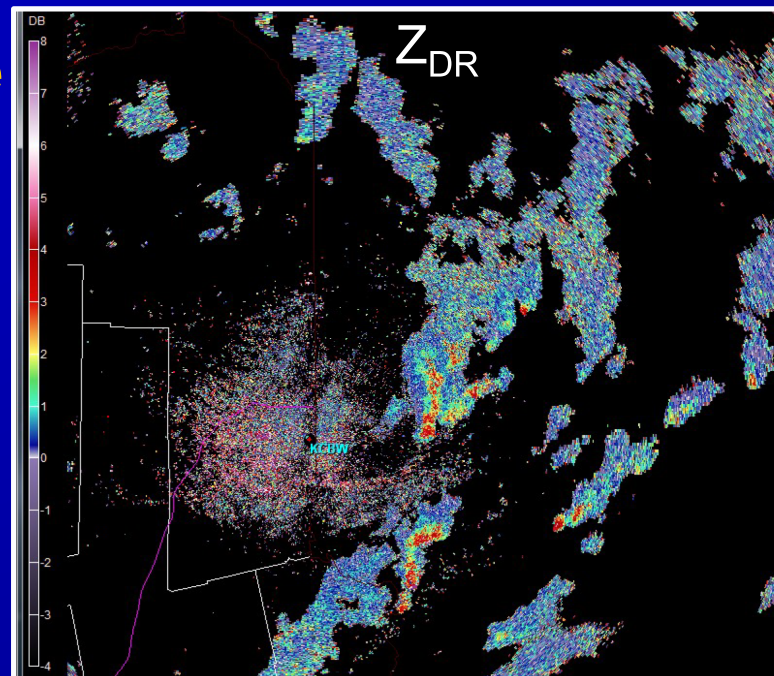
Caribou
KCBW
10 Aug '13
04:30 Z

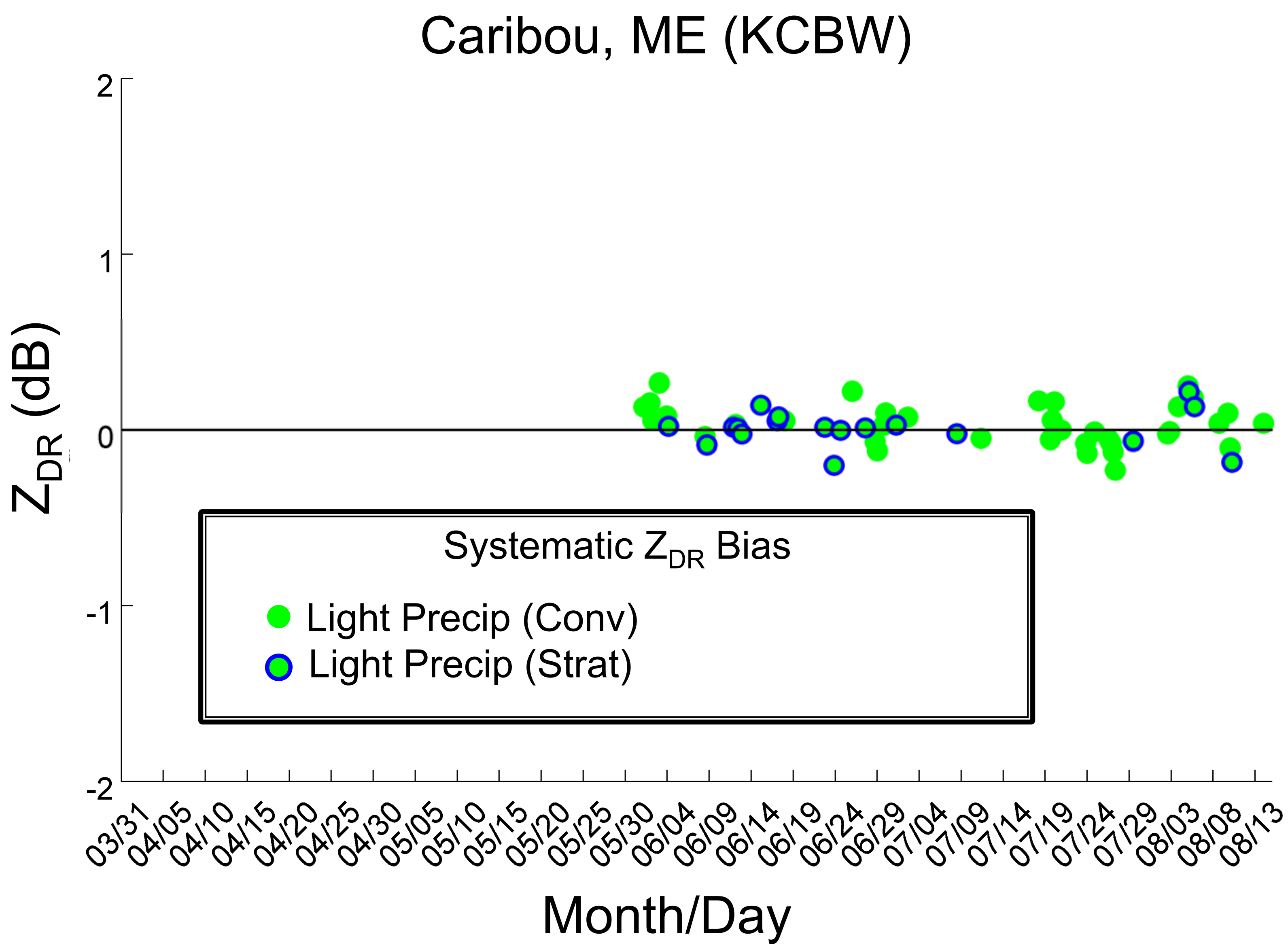


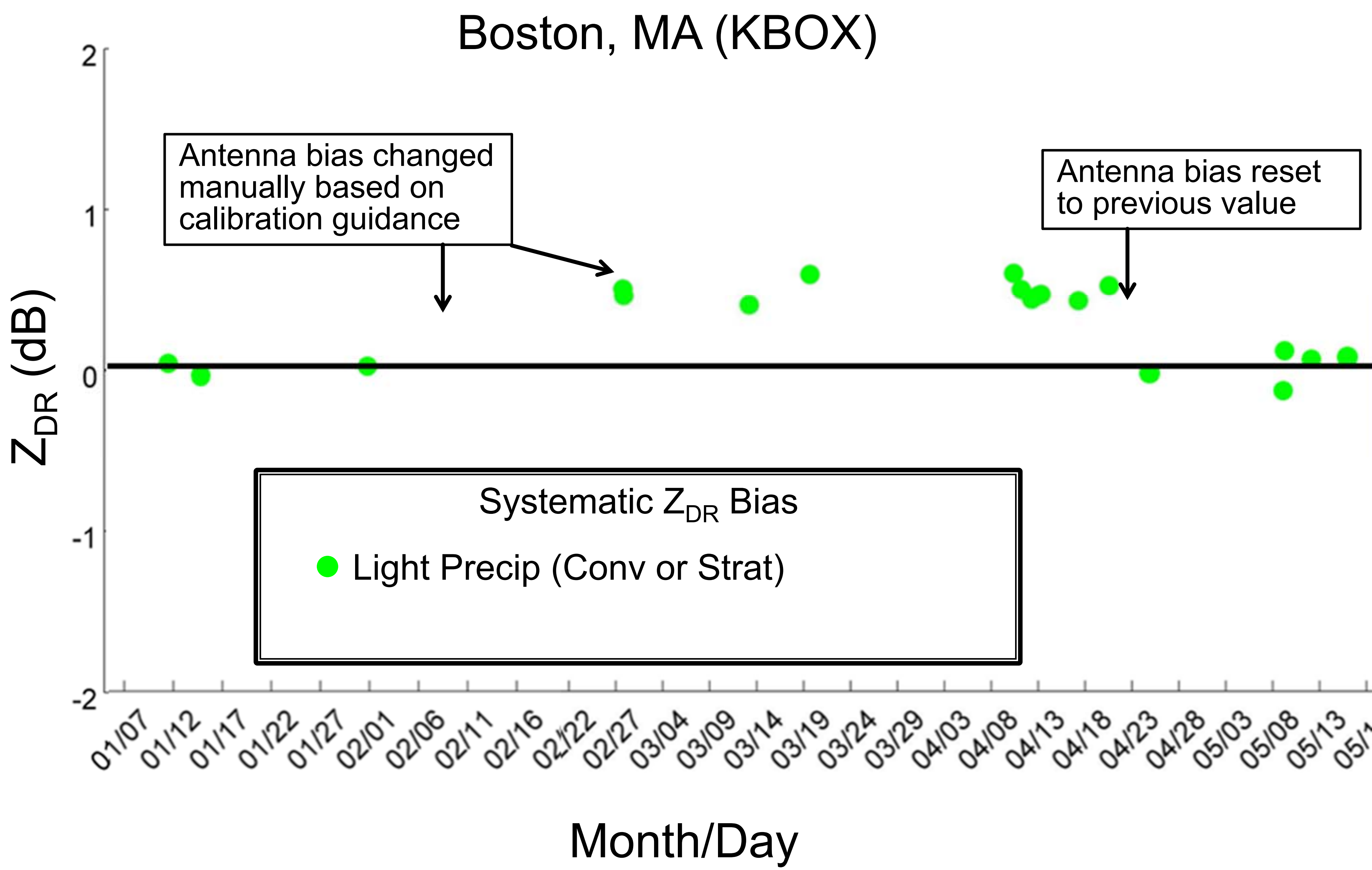


Convective

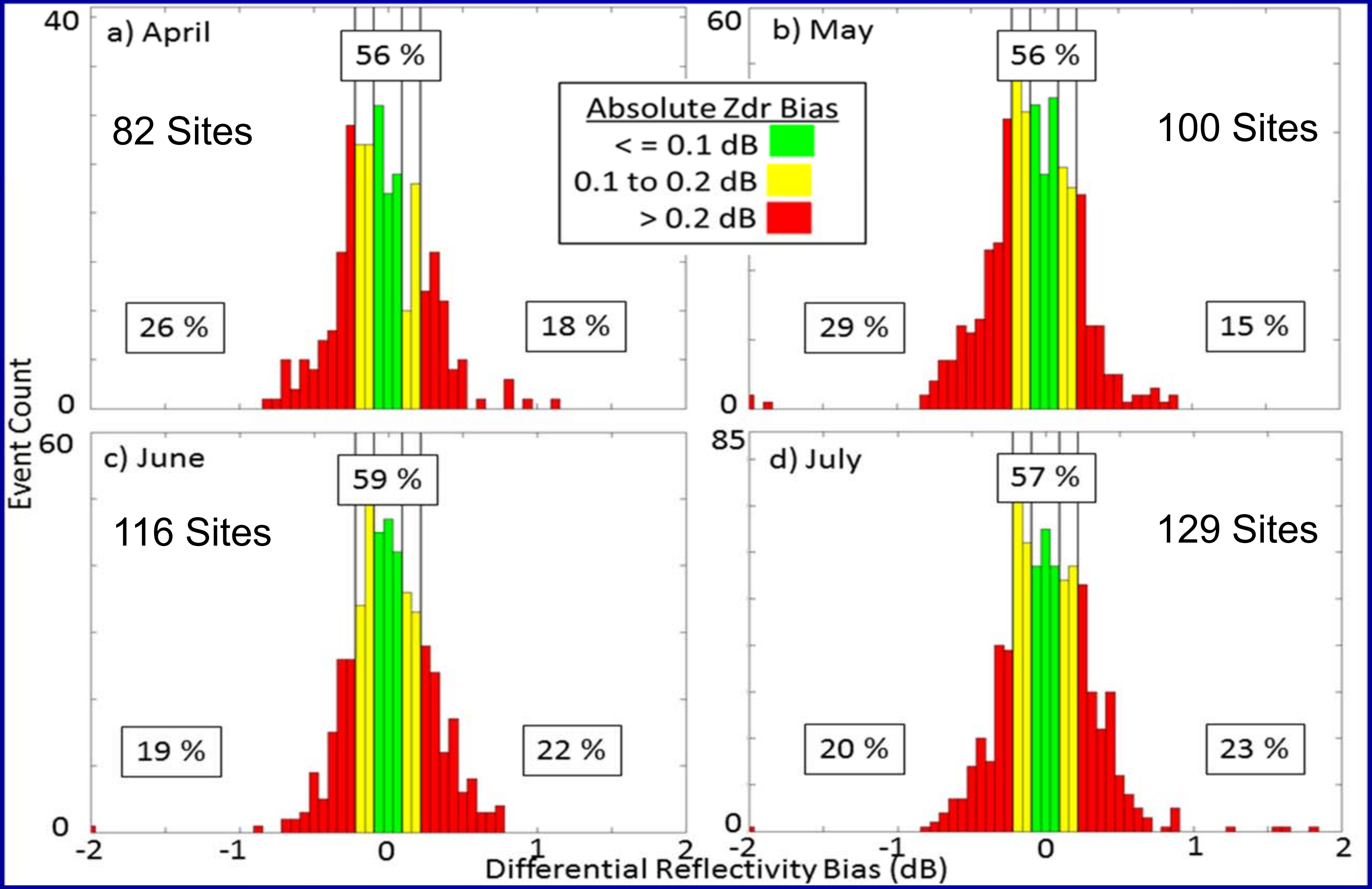
Caribou
KCBW
3 Aug '13
19:22 Z



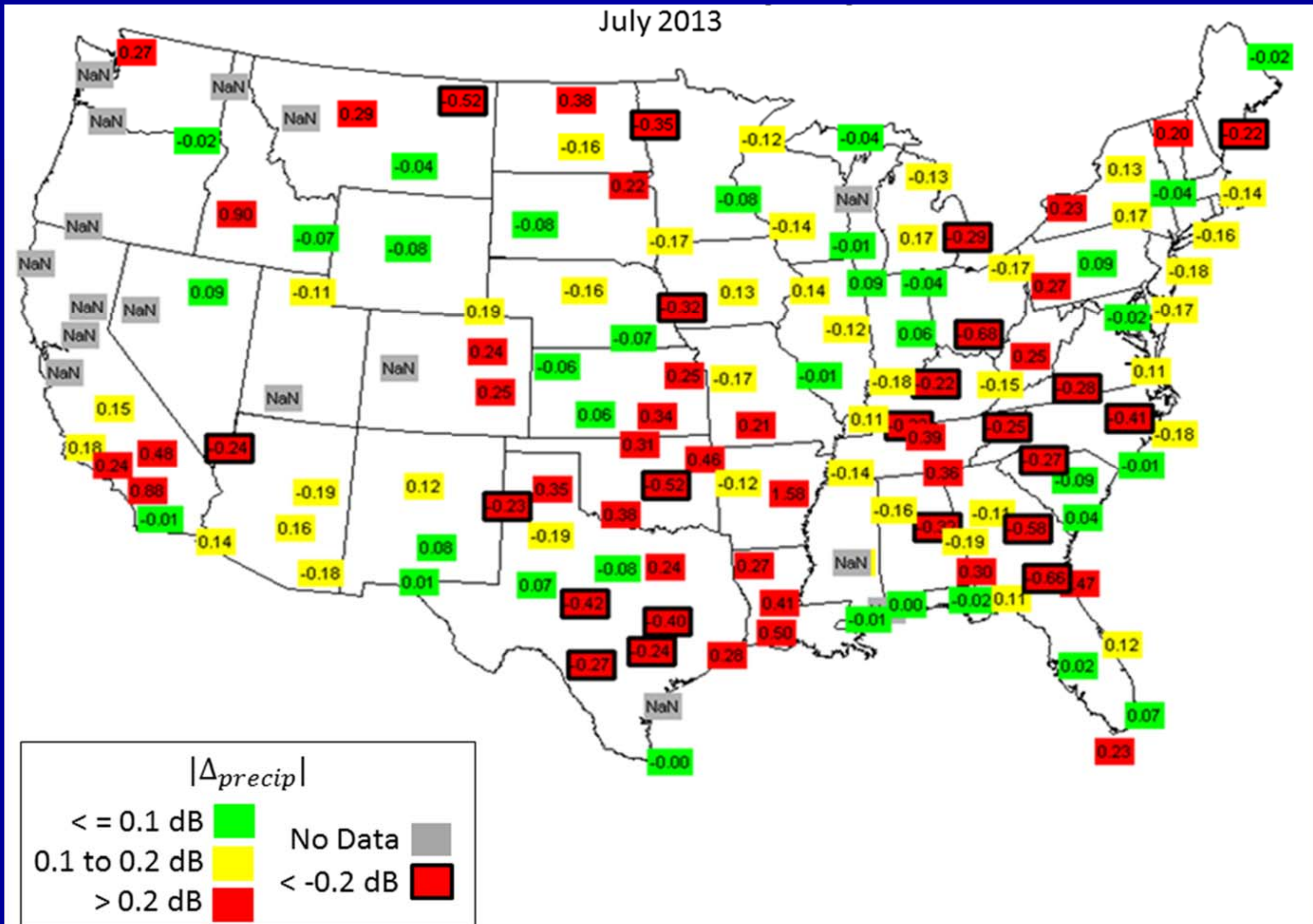

Caribou, ME (KCBW)
Z_{DR} (dB)
2
1
0
-1
-2
Systematic Z_{DR} Bias
Light Precip (Conv)
Light Precip (Strat)
03/31 04/05 04/10 04/15 04/20 04/25 04/30 05/05 05/10 05/15 05/20 05/25 05/30 06/04 06/09 06/14 06/19 06/24 06/29 07/04 07/09 07/14 07/19 07/24 07/29 08/03 08/08 08/13
Month/Day


Boston, MA (KBOX)
2
1
0
-1
-2
Z_{DR} (dB)
Antenna bias changed manually based on calibration guidance
Antenna bias reset to previous value
Systematic Z_{DR} Bias
Light Precip (Conv or Strat)
01/07
01/12
01/17
01/22
01/27
02/01
02/06
02/11
02/16
02/22
02/27
03/04
03/09
03/14
03/19
03/24
03/29
04/03
04/08
04/13
04/18
04/23
04/28
05/03
05/08
05/13
Month/Day

Fleet-wide Systematic Z_{DR} Biases (based on Light Precip. Method)

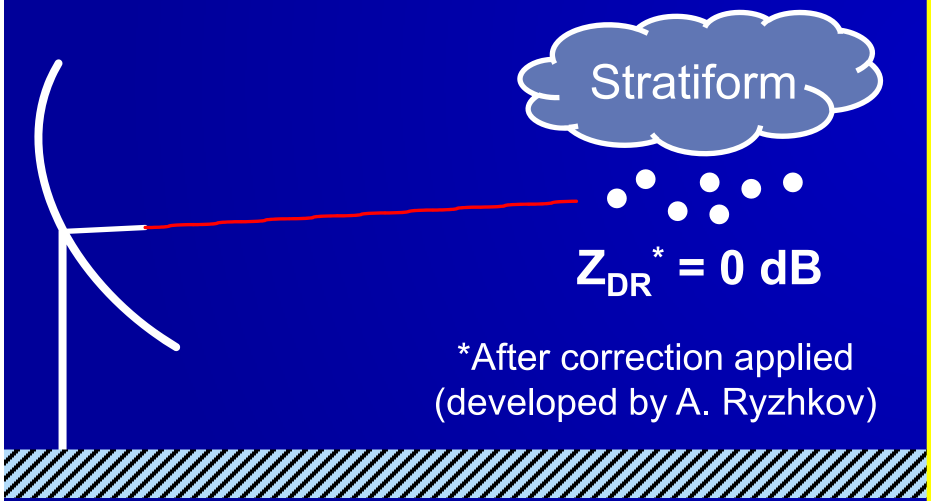


Light Precipitation Estimated Biases

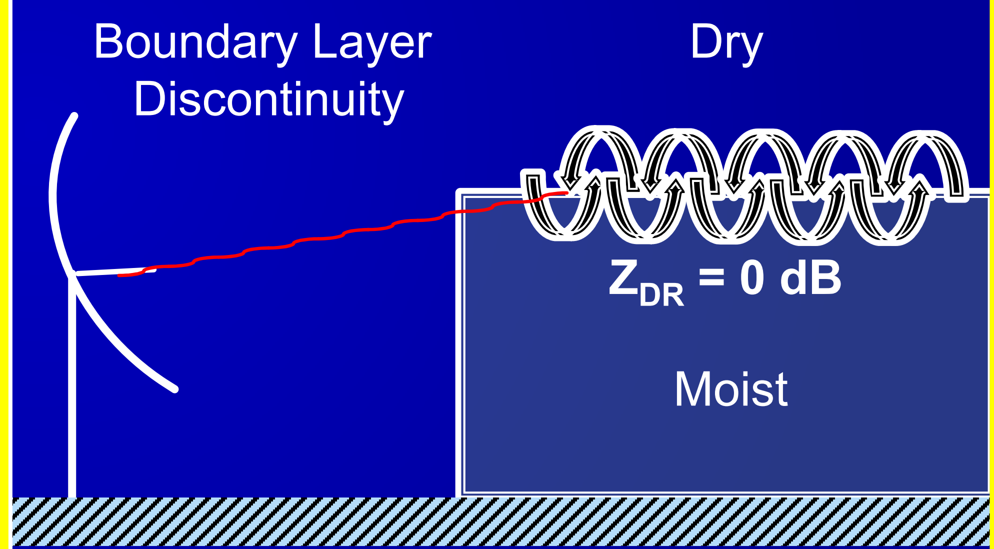


Observational Methods to Identify Total Systematic Z_{DR} Biases

Data collected on targets with intrinsic Z_{DR} = 0



Light Precipitation



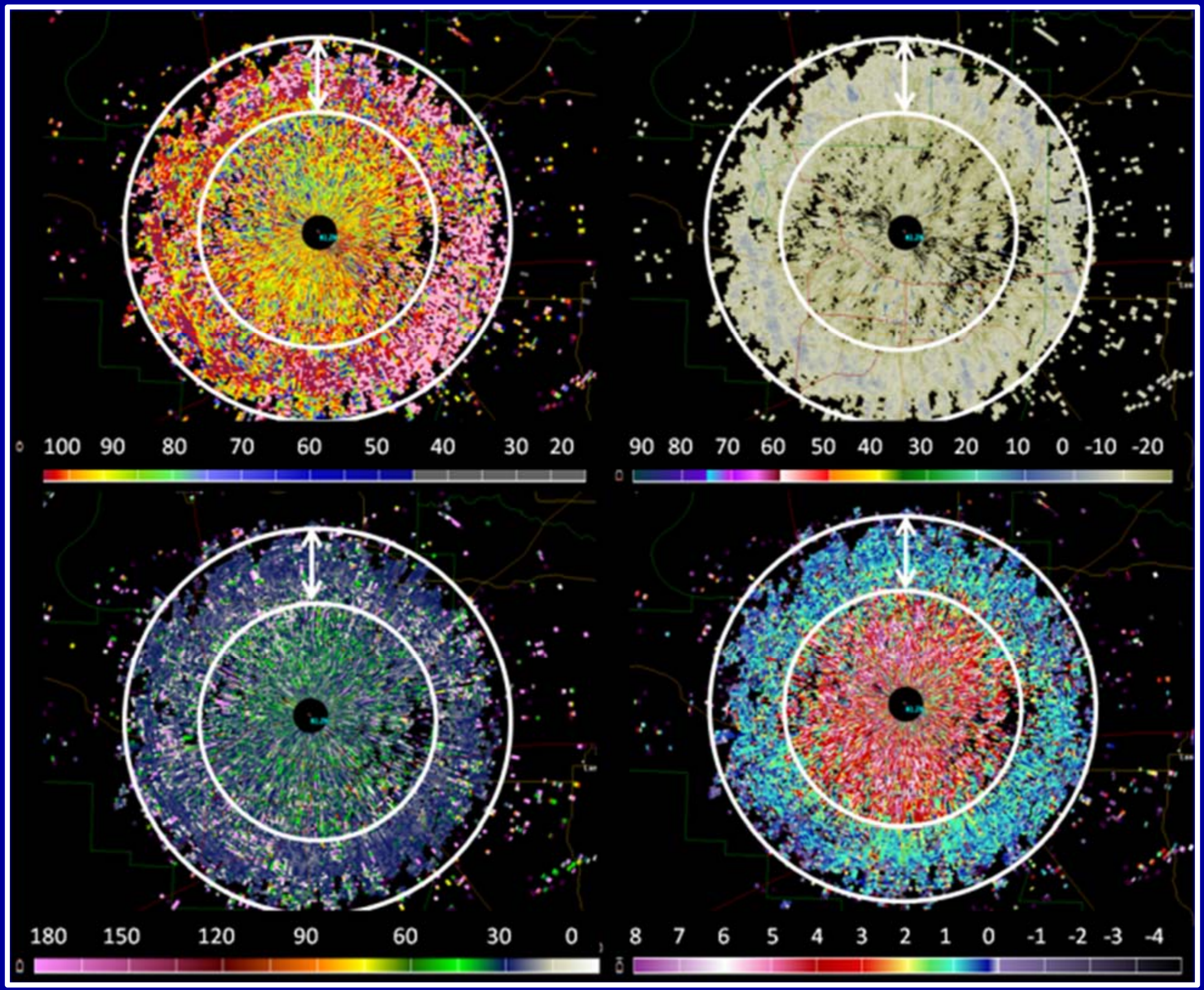
Bragg scatter

Bragg Scatter Example – Little Rock, AR KLZK, 12 May 2013, 15:43Z, 3.5° Elev.

Rings at ~15 and 25 km

Correlation Coefficient > 0.98

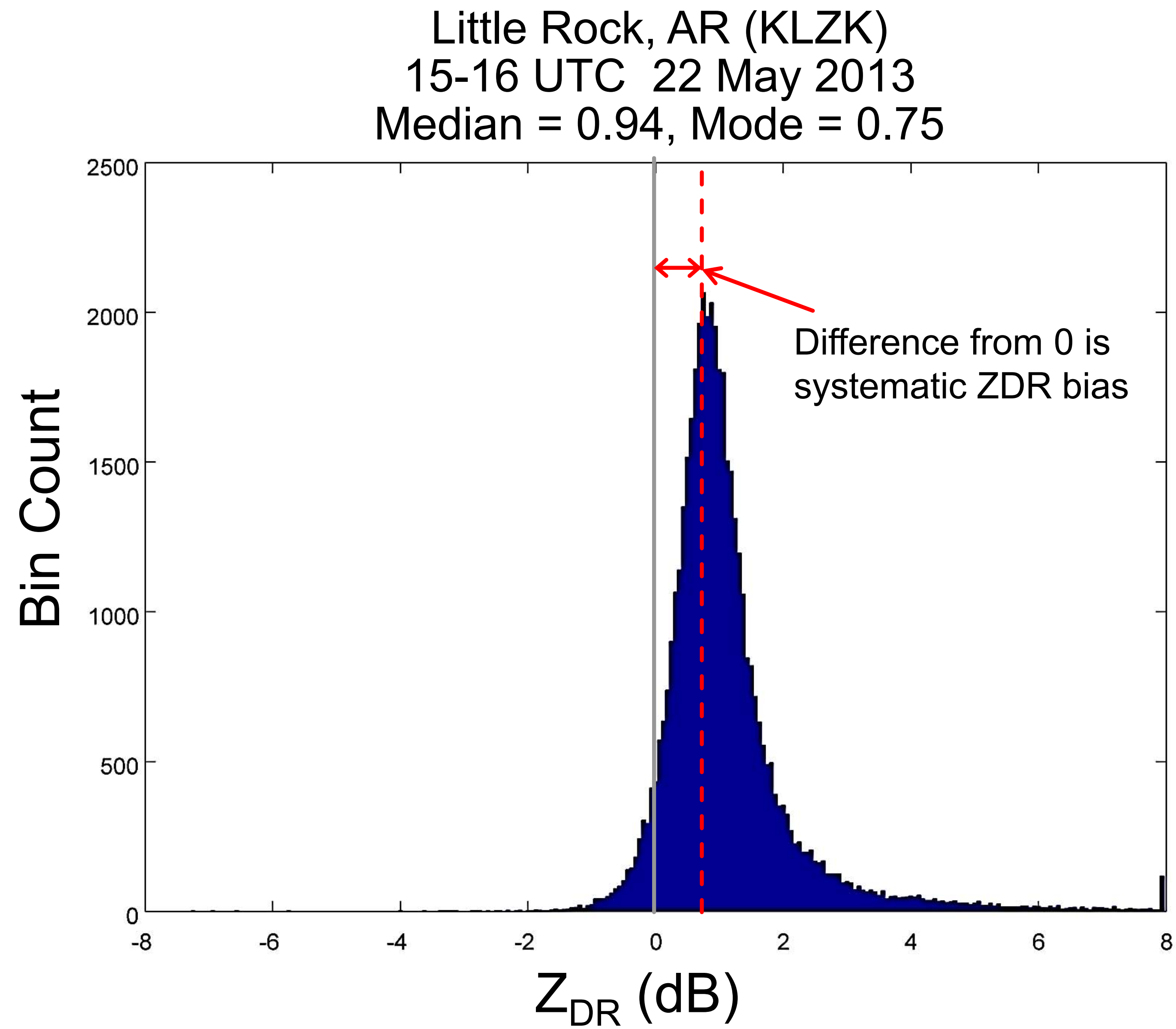
Reflectivity < 10 dBZ

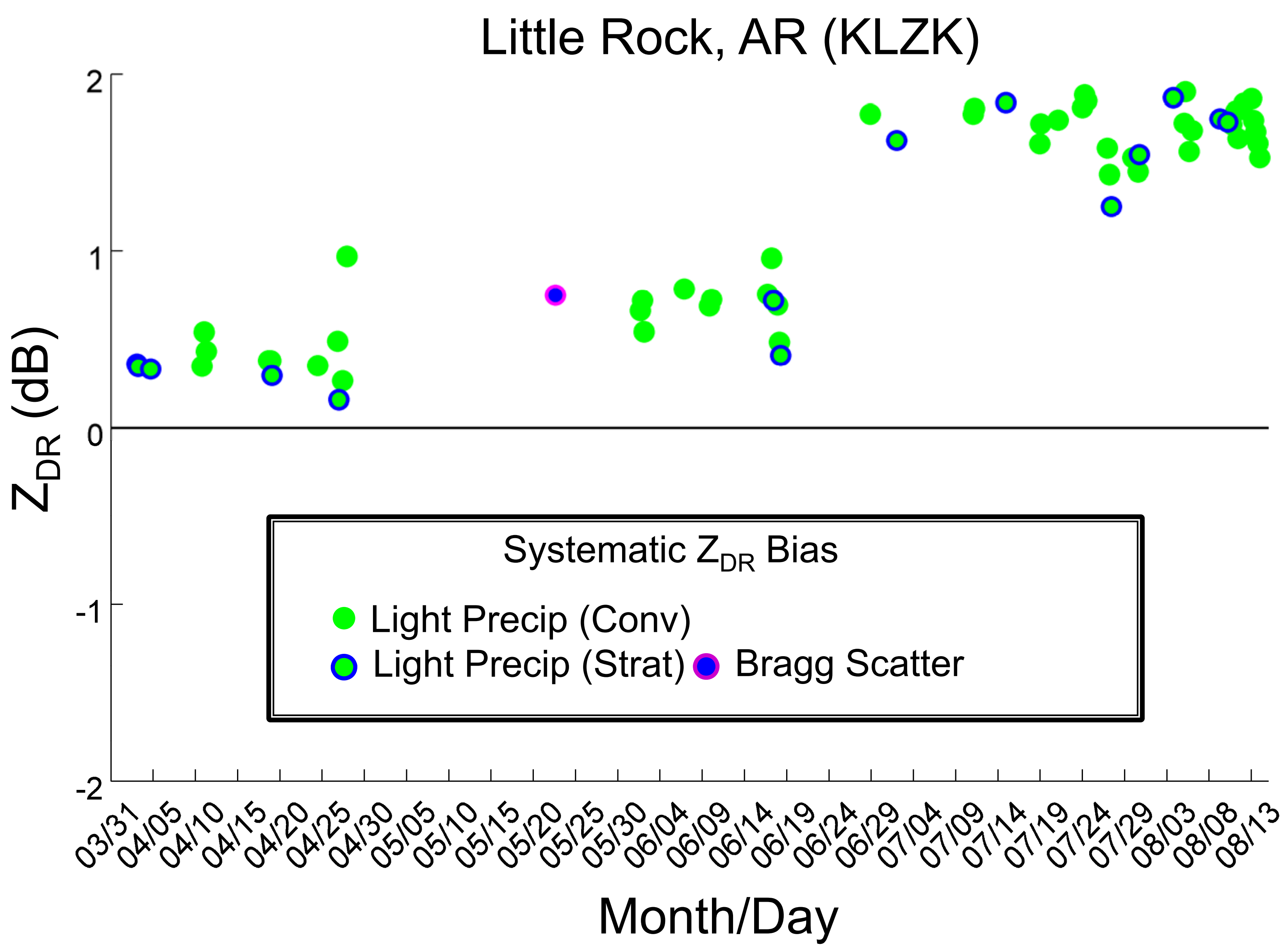


Differential Phase ≅ Initial system Φ_{DP} ≅ 25°

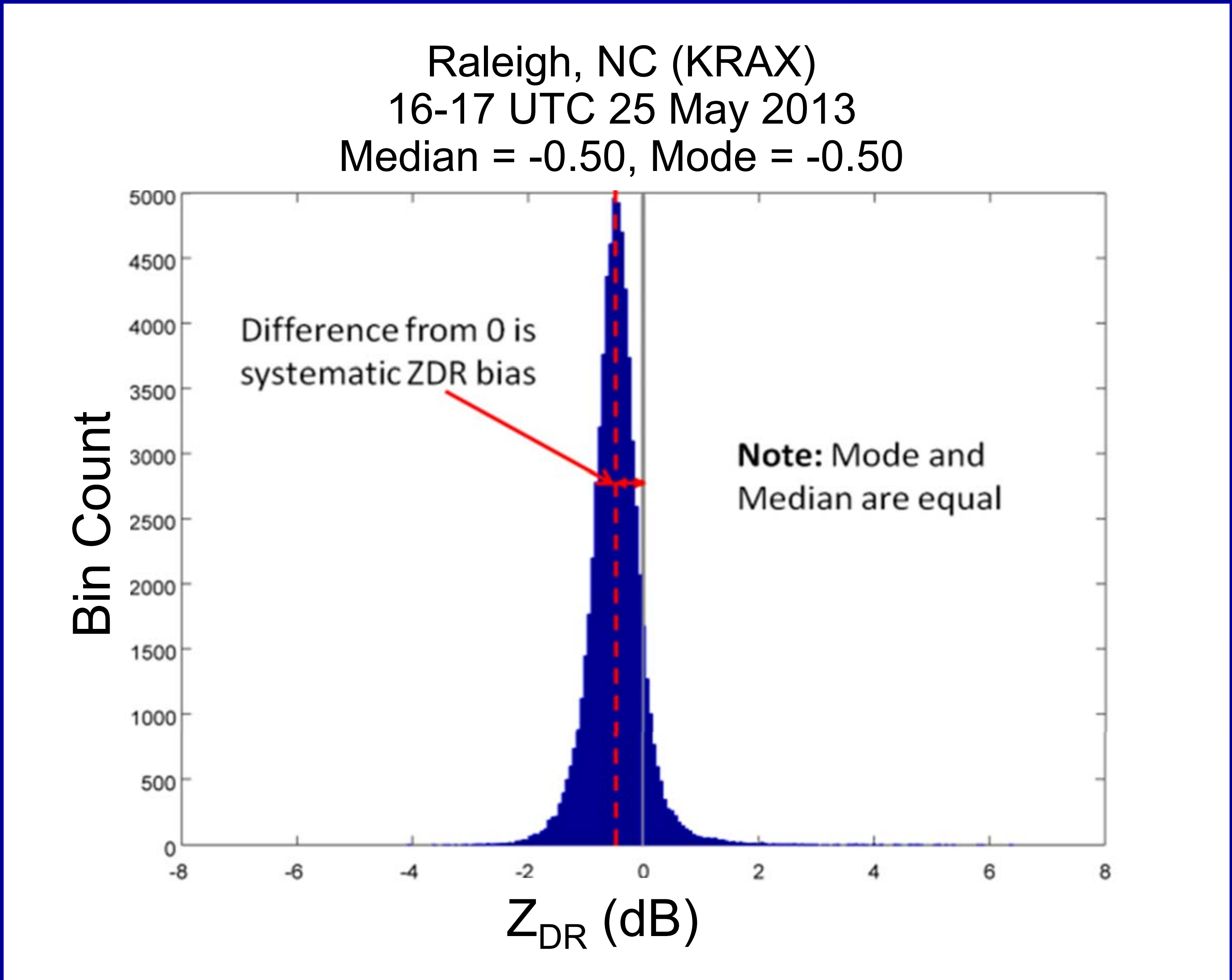
Differential Reflectivity ≅ 0 dB

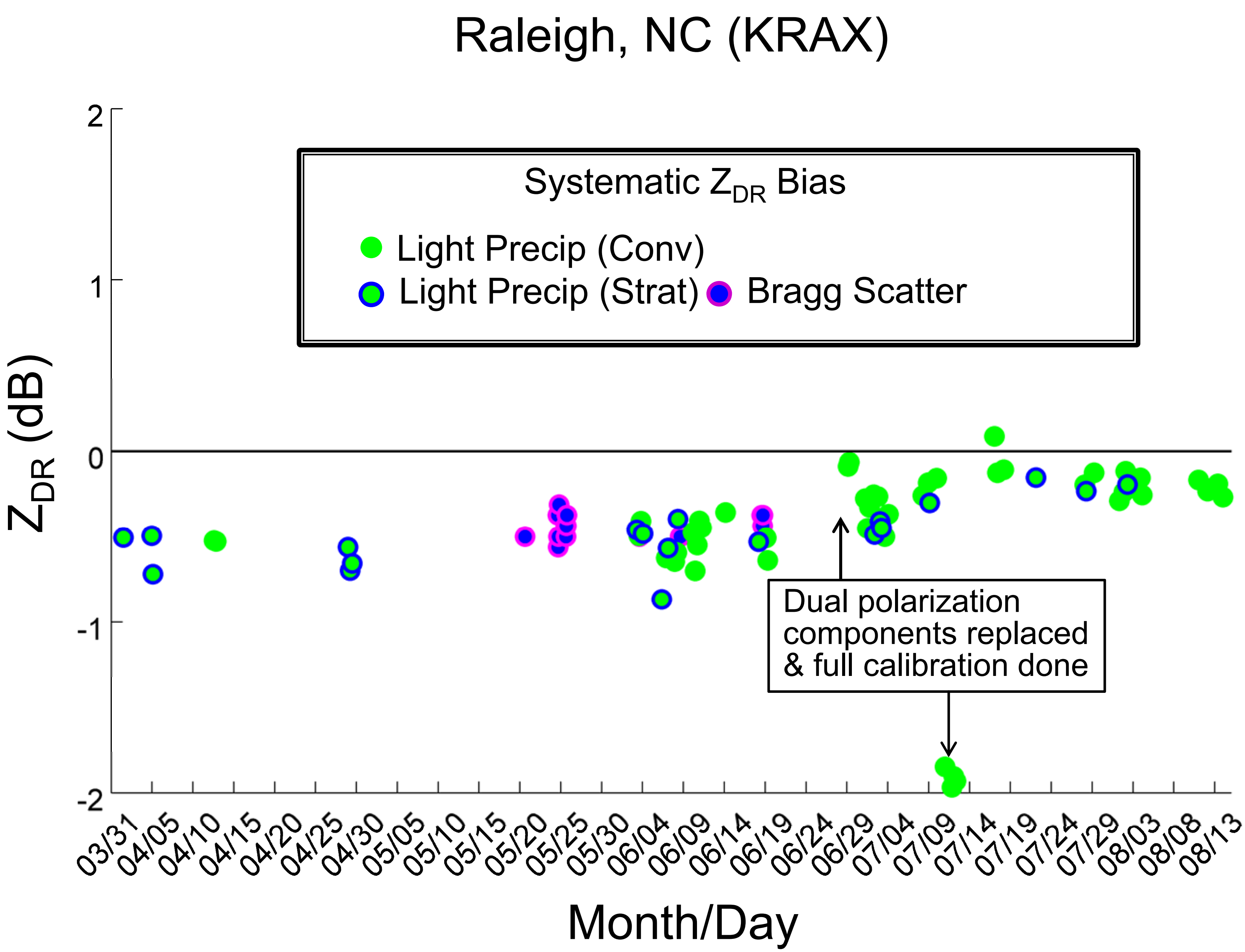
Bragg Scatter Histogram




Little Rock, AR (KLZK)
2
1
0
-1
-2
Z_{DR} (dB)
Systematic Z_{DR} Bias
Light Precip (Conv)
Light Precip (Strat)
Bragg Scatter
03/31
04/05
04/10
04/15
04/20
04/25
04/30
05/05
05/10
05/15
05/20
05/25
05/30
06/04
06/09
06/14
06/19
06/24
06/29
07/04
07/09
07/14
07/19
07/24
07/29
08/03
08/08
08/13
Month/Day

Bragg Scatter Histogram





Raleigh, NC (KRAX)
Systematic Z_{DR} Bias
Light Precip (Conv)
Light Precip (Strat)
Bragg Scatter
Z_{DR} (dB)
2
1
0
-1
-2
Dual polarization components replaced & full calibration done
03/31
04/05
04/10
04/15
04/20
04/25
04/30
05/05
05/10
05/15
05/20
05/25
05/30
06/04
06/09
06/14
06/19
06/24
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07/14
07/19
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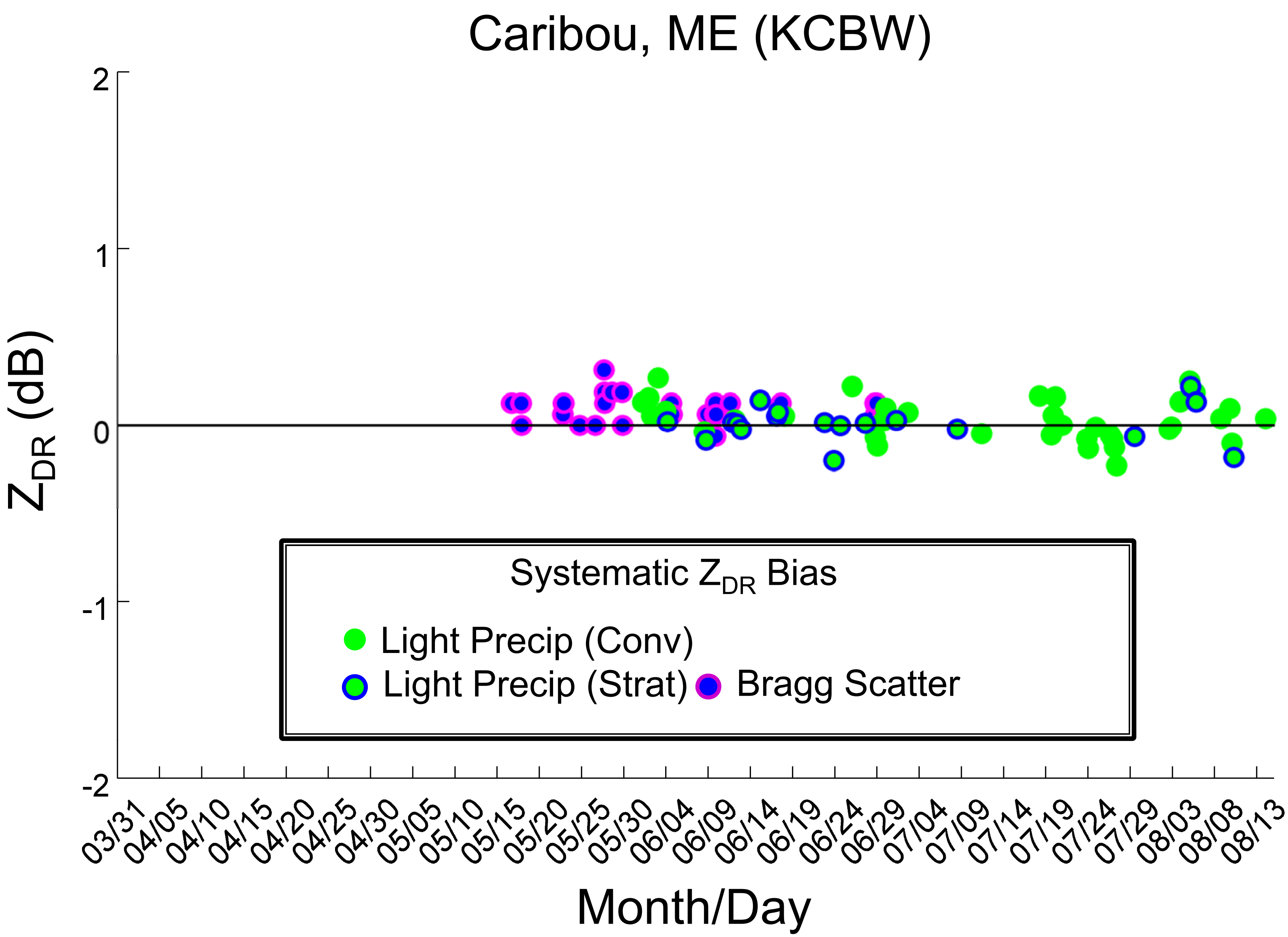
07/29
08/03
08/08
08/13
Month/Day


Caribou, ME (KCBW)
Z_{DR} (dB)
2
1
0
-1
-2
Systematic Z_{DR} Bias
Light Precip (Conv)
Light Precip (Strat)
Bragg Scatter
03/31 04/05 04/10 04/15 04/20 04/25 04/30 05/05 05/10 05/15 05/20 05/25 05/30 06/04 06/09 06/14 06/19 06/24 06/29 07/04 07/09 07/14 07/19 07/24 07/29 08/03 08/08 08/13
Month/Day

Summary

1. The light precipitation method indicates that 56-59% of cases (54-58% of sites) have a Z_{DR} bias within ±0.2 dB for April-July 2013

2. The Bragg scatter method is a viable alternative to the light precipitation method

3. The light precipitation or Bragg scatter method, when combined with the sunspike method (not shown but described in paper) and data logs, can isolate component problems

Challenges

1. Reduce the variance of Z_{DR} biases across the WSR-88D fleet
   a) Maintenance procedures (barn door vs. mouse hole)
   b) Hardware limitations (connectors, antenna positional accuracy)
2. Refine observational methods
   a) We know our methods do not provide estimates within 0.1 dB reliably
   b) Many observations required to establish bias
   c) Large changes to bias seen quickly; trends require many observations to discern
3. Geographical / climatological limitations

Thank you – Questions?

Backup Slides

Z_{DR} Calibration Equations

Total Systematic Z_{DR} Bias $\Delta_{total} = \Delta Rx + \Delta Tx$

Receive Path Bias $\Delta Rx = rx_{bias} + ant_{bias}$

Transmit Path Bias $\Delta Tx = tx_{bias} + ant_{bias}$

Methods for estimating Δ_{total}

- Current engineering method (Δ_{cal}) $- realtime\ adjustment$
  - Ideally $\Delta_{cal} = \Delta_{total}$
- Observational (volume scans)
  - Light Precipitation (Δ_{precip})
  - Bragg scatter (Δ_{Bragg})

Estimating ΔRx

- Sunspikes
  - $ZDR_{sunspike} = ZDR_{Level2} + \Delta_{cal} = rx_{bias} + ant_{bias} = \Delta Rx$

Light Precip Data Filters

Parameter	Filter
VCP	11, 12, 121, 211, 212, 221, 31, 32
Elevations	> 1.0°
Range	> 20 km
Reflectivity	19.0 to 30.5 dBZ, 2 dB Steps
Correlation Coefficient	CC > 0.98
Melting Layer	1 km below ML Height
Signal-to-Noise Ratio	S/N > 20 dB
Adjusted Median Z_{DR}	> 200 bins / step*
Average Z_{DR}	Adjusted Median per category
Volumes Averaged	12

*

Z (dBZ)	20	22	24	26	28	30
ZDR (dB)	0.23	0.27	0.32	0.38	0.46	0.55

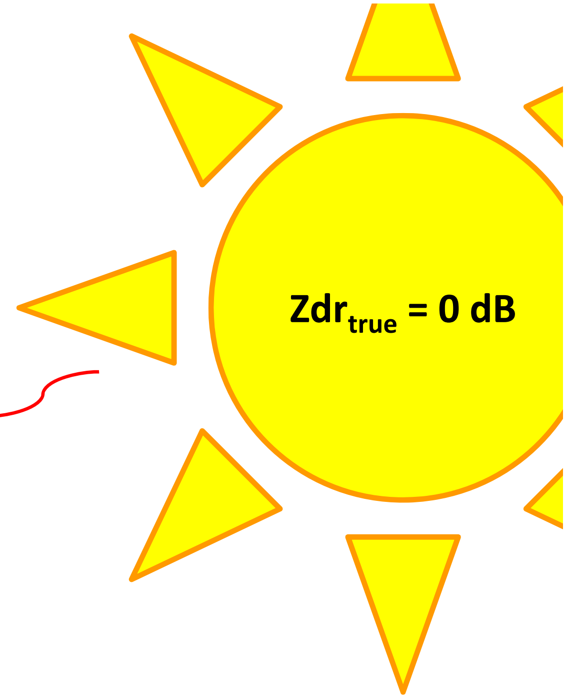
Additional Data Filters

Parameter	Filter
Big Drop Contamination Test	< 40 bins with 40 dBZ or higher above melting level
Stratiform Test	
Weak Reflectivity	10 to 30 dBZ
Strong Reflectivity	> 30 dBZ
Signal-to-Noise Ratio	> 20 dB
Ratio weak to total reflectivity bins (x100)	80%
Duration per Plotted Point	Median over 3 hrs

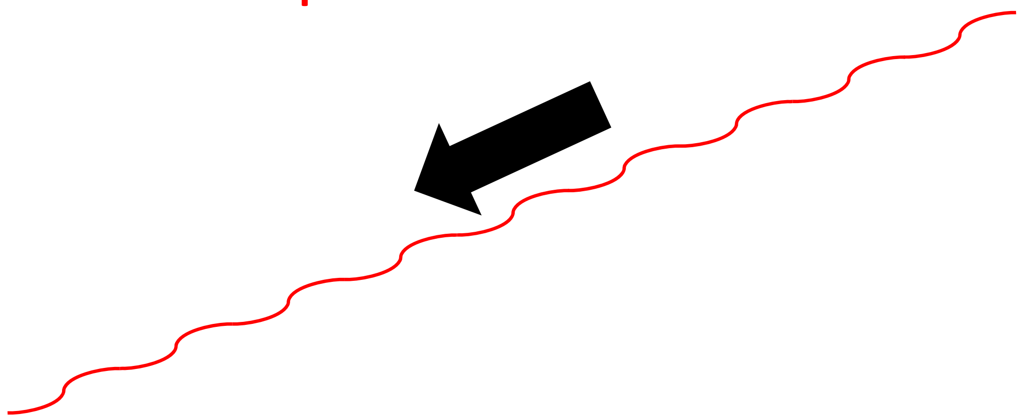
Bragg Scatter Data Filters for Z_{DR}

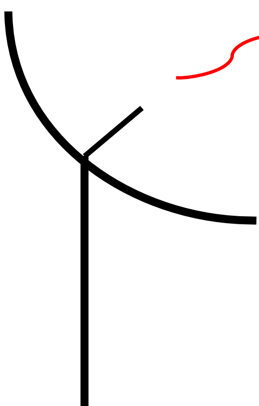
Parameter	Filter
VCP	21,32
Elevations	2.5° & above (batch modes)
Range	10 to 100 km
Reflectivity	-32 < Z < 10 dBZ
Correlation Coefficient	0.98 < CC < 1.05
Velocity	V < -2 or V > 2 m s^{-1}
Spectrum Width	W > 0 m s^{-1}
Signal-to-Noise Ratio	0 < S/N < 15 dB
Differential Phase	25° < Φ_{dp} < 35°
1 Hour Histogram	≥ 35,000 bins
Yule-Kendall Index Symmetry Test	≤ 0.1

Using Sunspikes in Level II Data to Monitor Z_{dr} Bias



Assumption: Sun is unpolarized



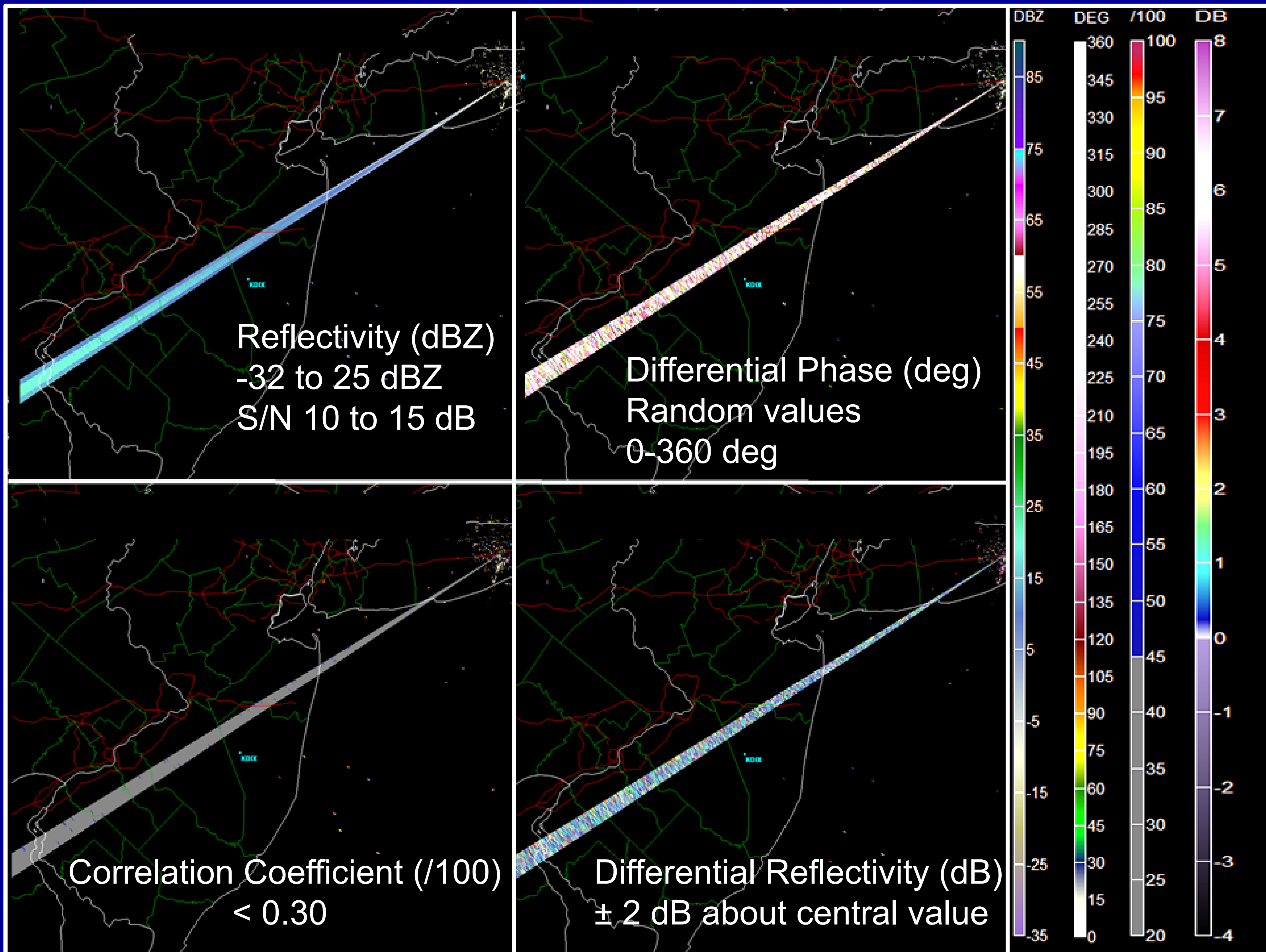


Receiver and Antenna (Ant) Bias Only

No Transmit Path (Tx)

$$ZDR_{meas} = \overset{0}{ZDR_{intrinsic}} + \boxed{rx_{bias} + ant_{bias}}$$

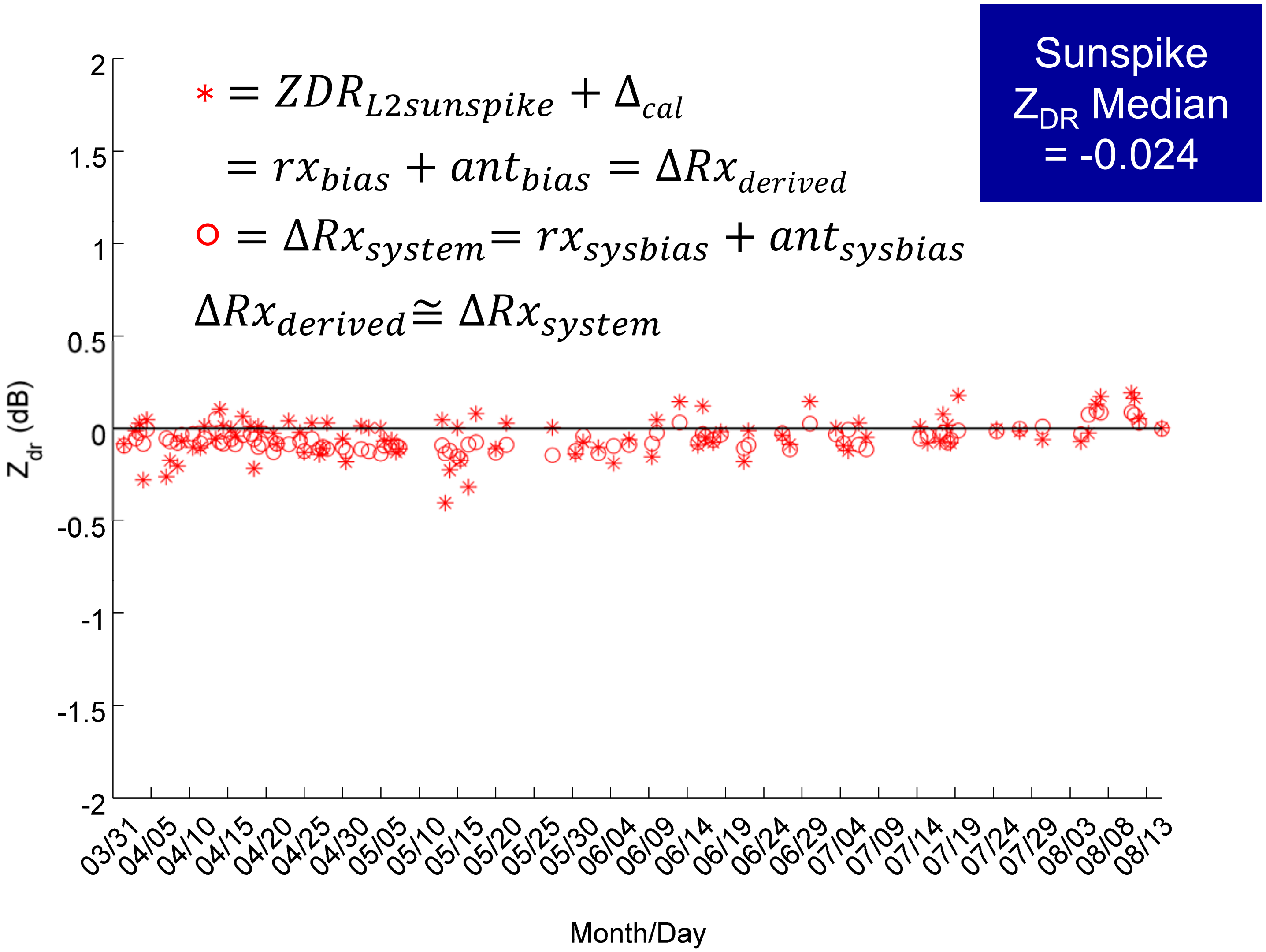
Sunspike: KOKX 13 Dec 2012, 21:11Z



Sunspike Data Filters for Z_{DR}

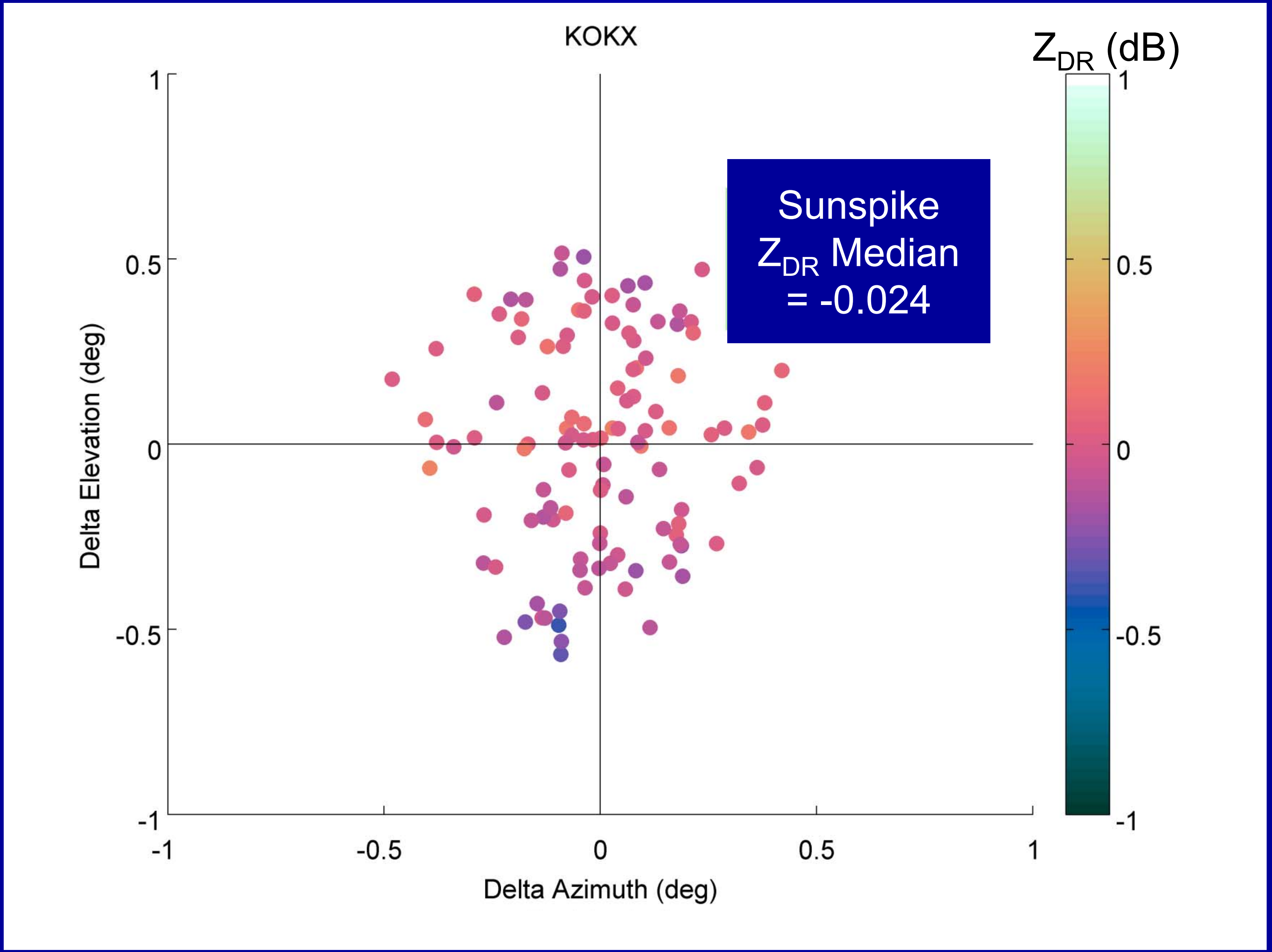
Parameter	Filter
VCP	31,32
Elevations	1.5°, 2.5° (surveillance cut)
Range	20 to 460 km
Signal-to-noise Ratio	> 10 dB & < 15 dB
Bin Count	> 1000
Volume Scans	3 closest to target elevations morning & evening
Radial	Best positional match

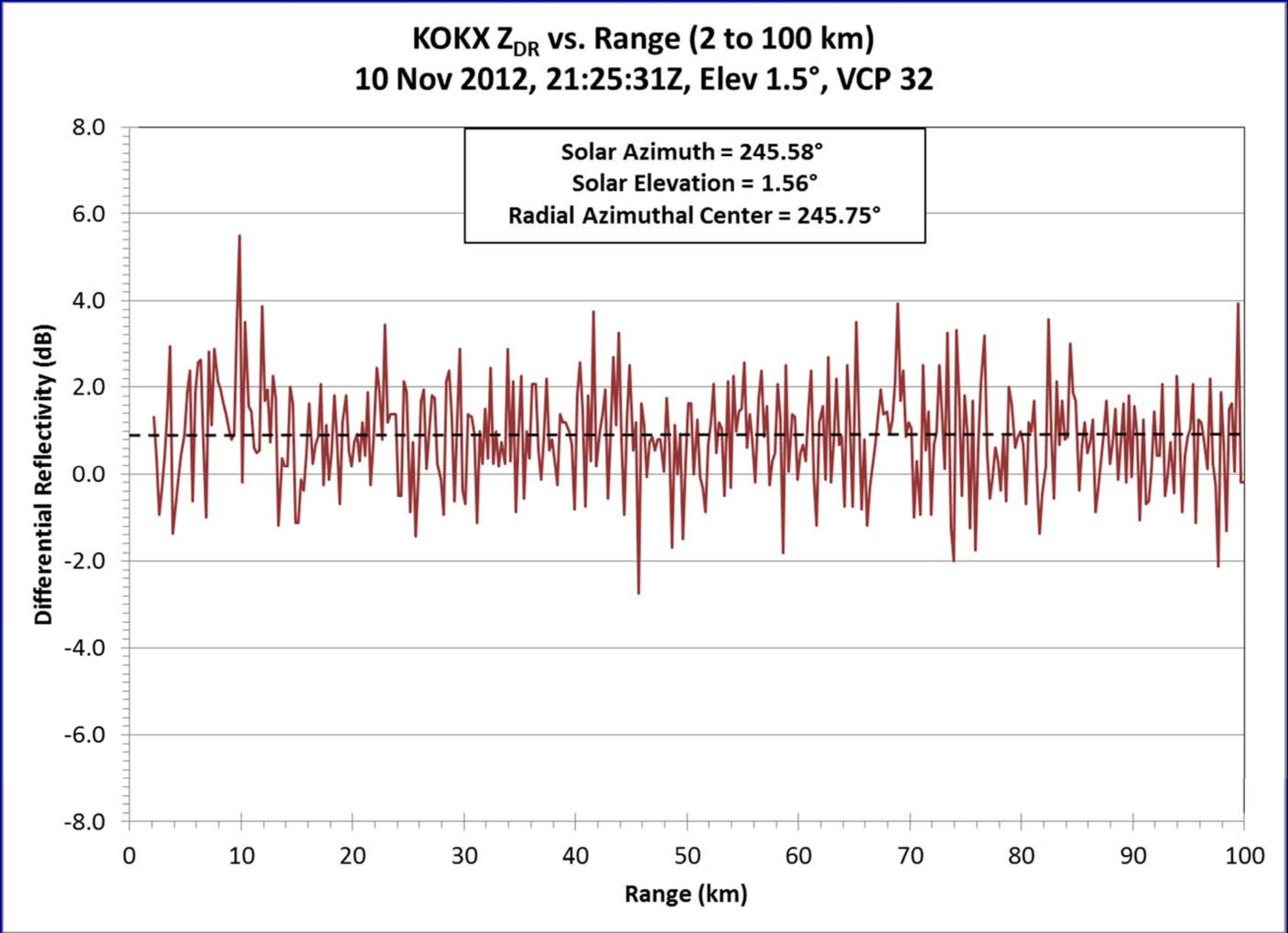
Upton, NY (KOKX) Sunspike Time Series March 31, 2013 to August 13, 2013



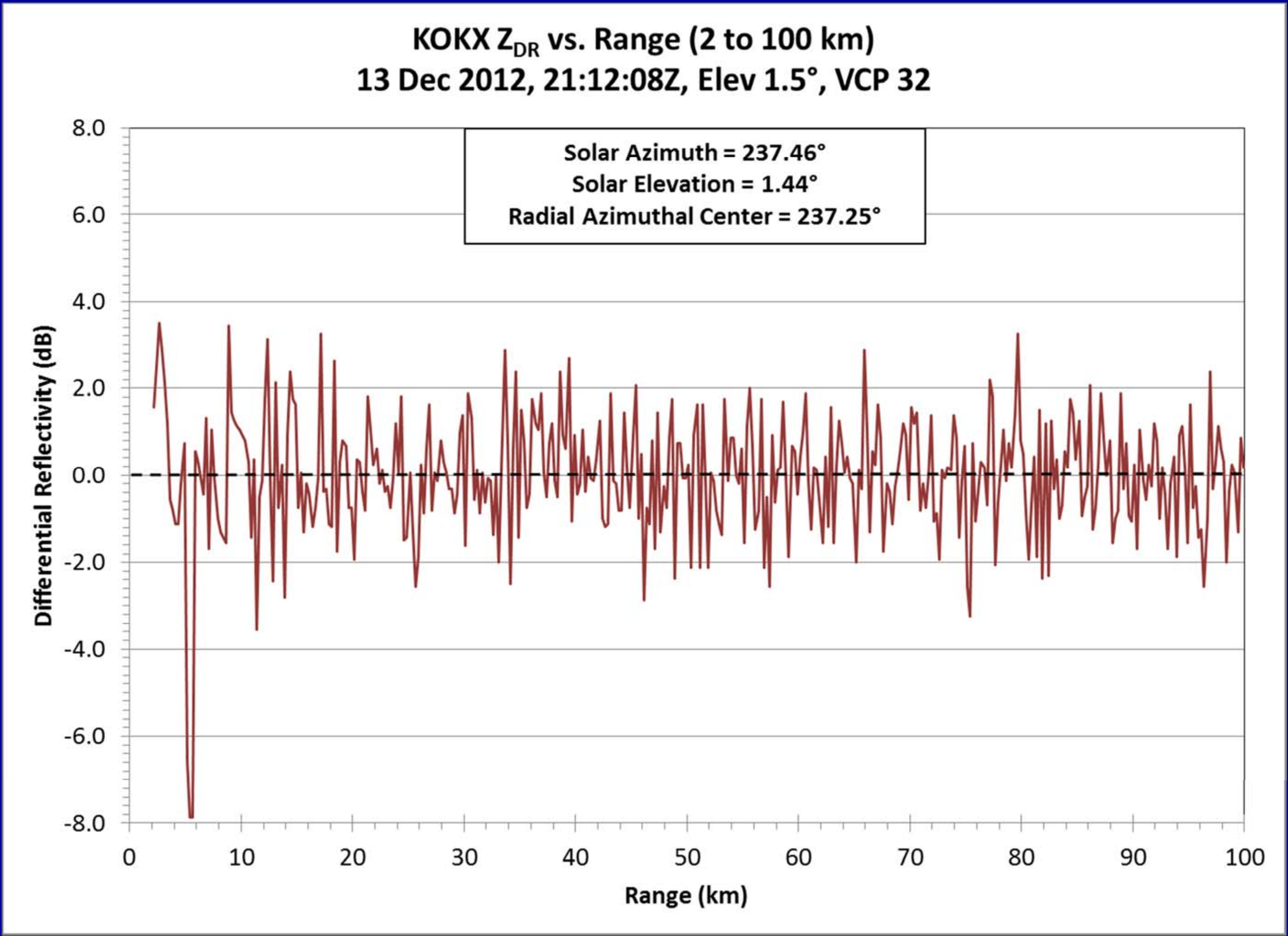
Derived Rx Path Bias (Red Stars), Baron Rx Path Bias (Red Circles)

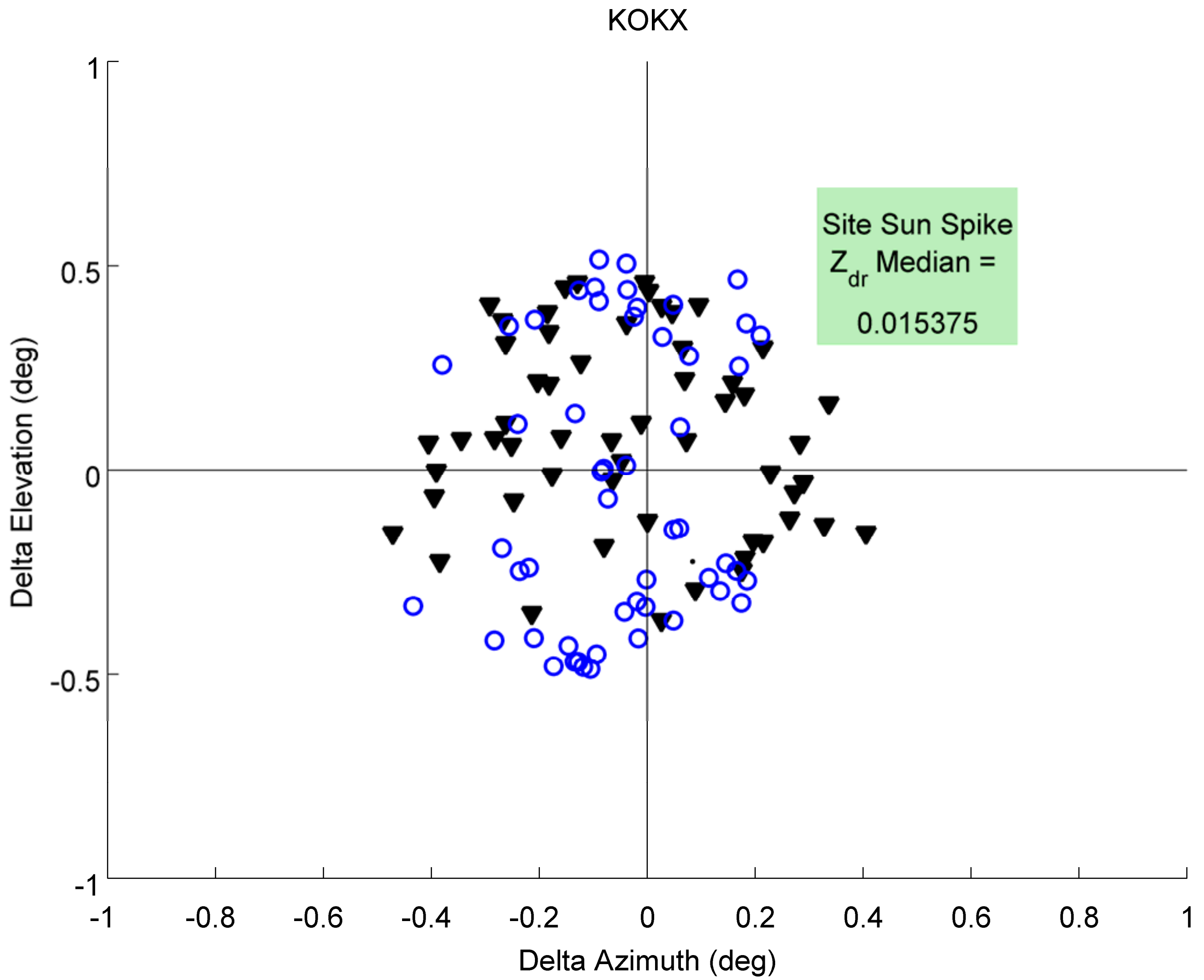
Sunspike / Antenna - Δazm vs. Δelev
KOKX March 31, 2013 to August 13, 2013



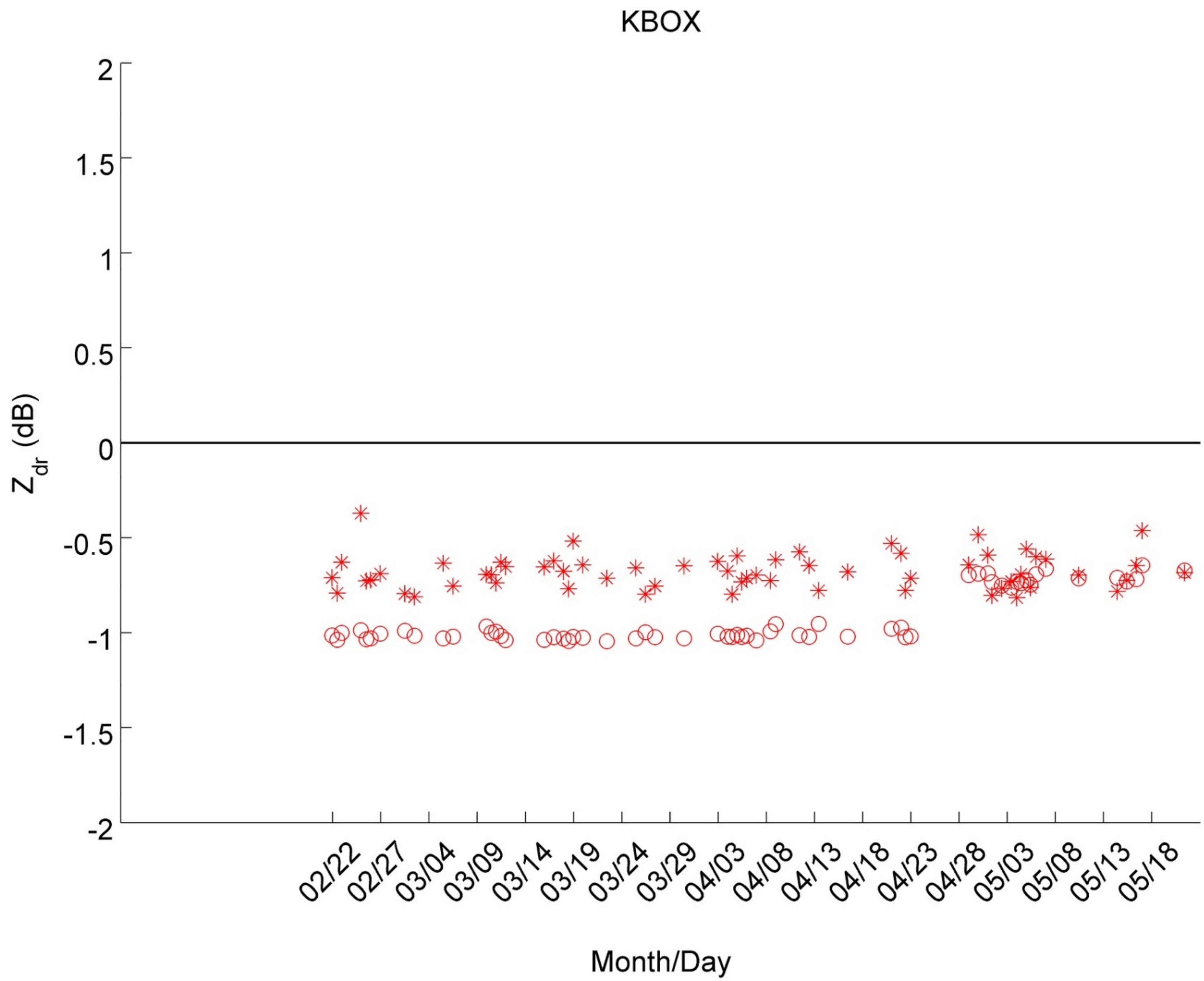


KOKX Z_{DR} vs. Range (2 to 100 km)
10 Nov 2012, 21:25:31Z, Elev 1.5°, VCP 32
Solar Azimuth = 245.58°
Solar Elevation = 1.56°
Radial Azimuthal Center = 245.75°
Differential Reflectivity (dB)
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
0
10
20
30
40
50
60
70
80
90
100
Range (km)


KOKX Z_{DR} vs. Range (2 to 100 km)
13 Dec 2012, 21:12:08Z, Elev 1.5°, VCP 32
Solar Azimuth = 237.46°
Solar Elevation = 1.44°
Radial Azimuthal Center = 237.25°
Differential Reflectivity (dB)
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
0
10
20
30
40
50
60
70
80
90
100
Range (km)



Upper 50th (Black Upside Down Triangle), Median (Black Dot), Lower 50th (Blue Circle)



Actual Rx Path Bias (Red Stars), Baron Rx Path Bias (Red Circles)

Contributions to System Z_{DR} Bias

Total System Bias = Rx Path Bias + Tx Path Bias

$\Delta Rx = rx_{bias} + ant_{bias}$ (Rx Path Bias)

$\Delta Tx = tx_{bias} + ant_{bias}$ (Tx Path Bias)

Hardware Method

Component in the system ZDR offset	Parameter	How it is measured
RCB (rx_{bias})	Hpow, Vpow	Routine receive measurements using CW calibrated signals
	R293, R294	Factory measured
	R297	Cross-and-straight measurements
TXB (tx_{bias})	Hps, Vps	Routine power sense measurements
	R295, R296	Factory measured
	R298	Cross-and-straight measurements
SMB (ant_{bias})	Psh, Psv	Suncheck measurements
	RCB	See the first table entry

Melnikov and Zrnic (2013 MOU Report)