Differential Reflectivity (Z_{DR}) Calibration: The Devil is in the Details

by
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Alarm free does not mean the radar is well calibrated or that the data quality is good.

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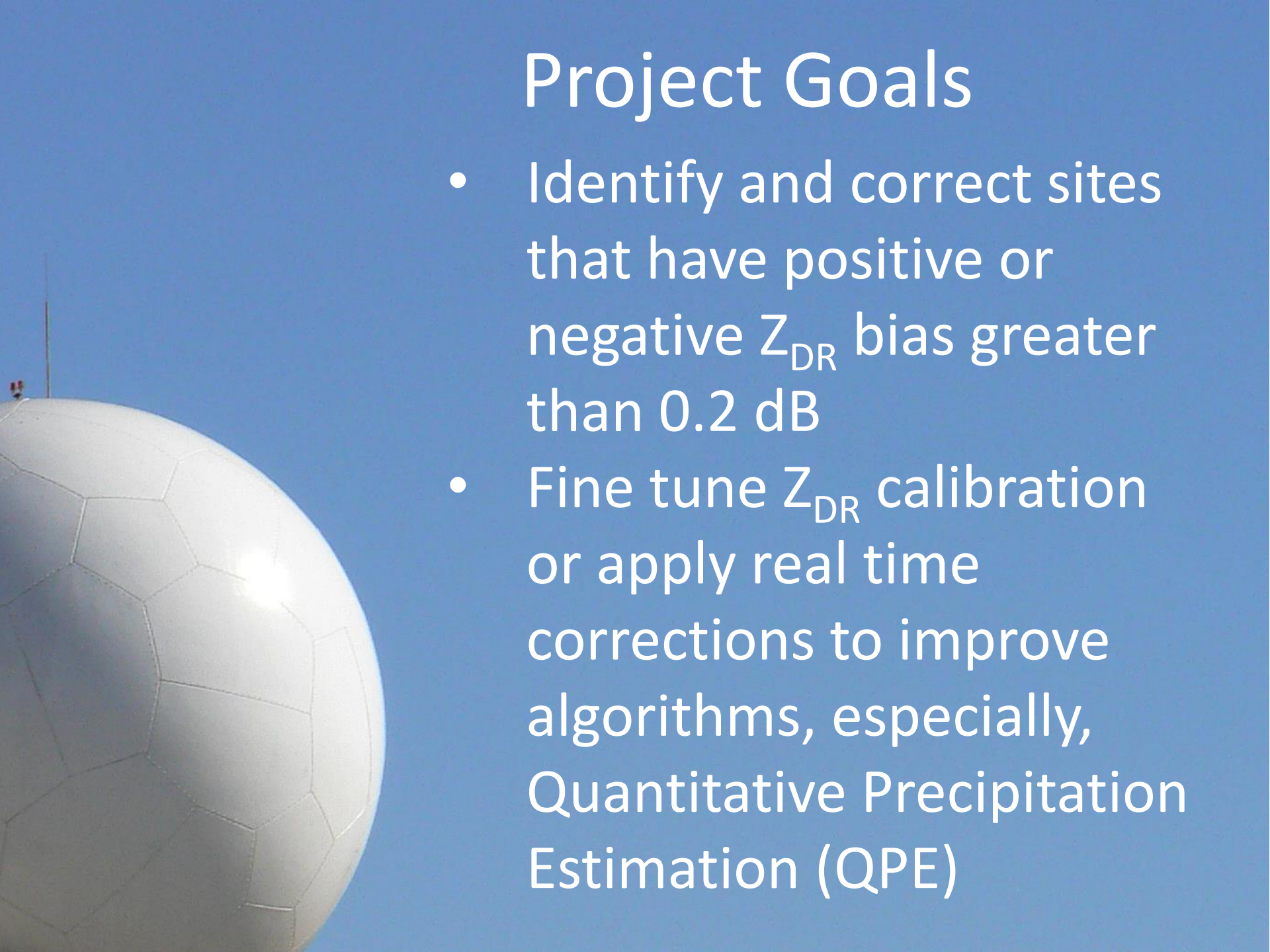
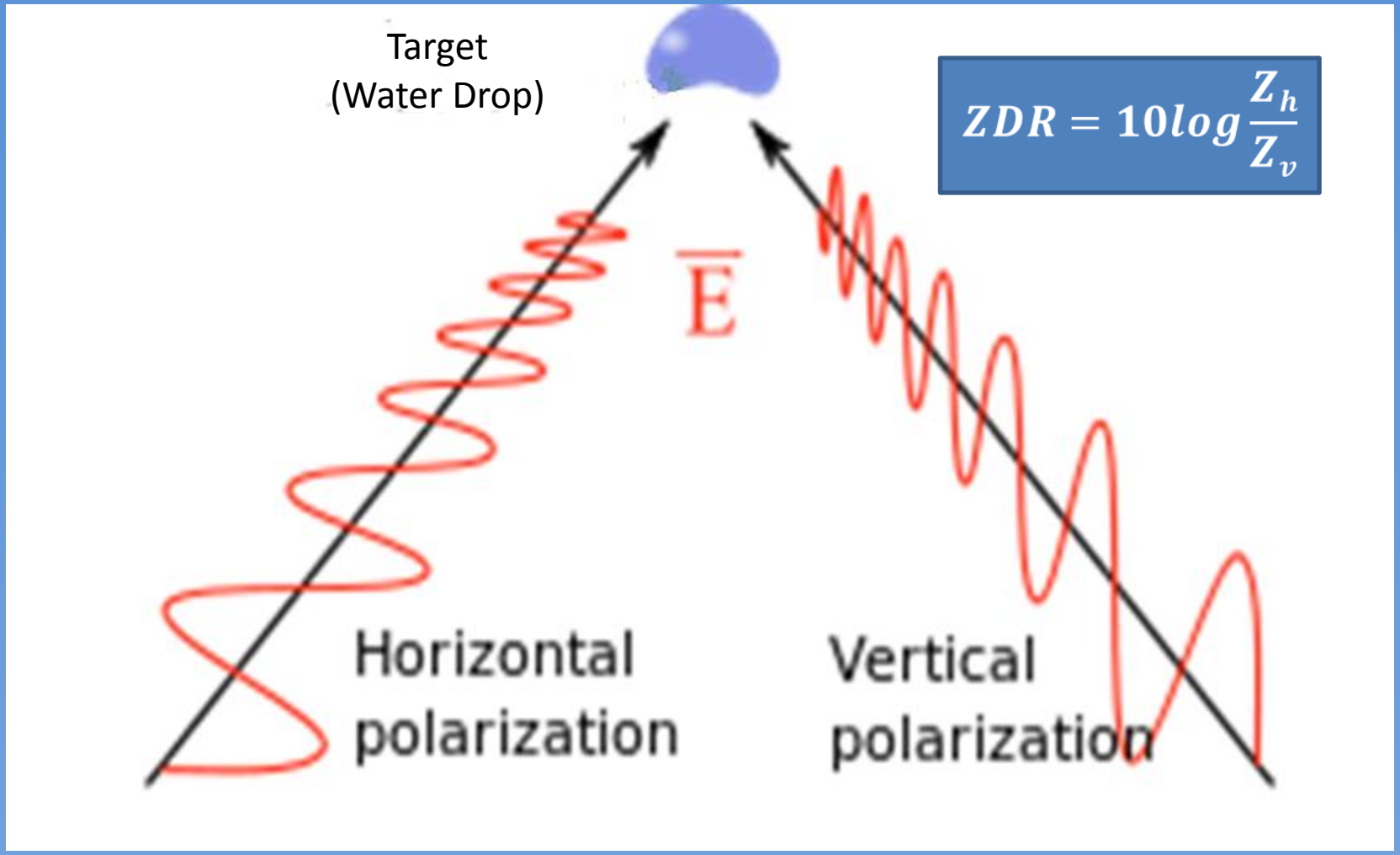


Project Goals

- Identify and correct sites that have positive or negative Z_{DR} bias greater than 0.2 dB
- Fine tune Z_{DR} calibration or apply real time corrections to improve algorithms, especially, Quantitative Precipitation Estimation (QPE)

Differential Reflectivity (Z_{DR})



Z_{DR} Calibration

- No single procedure, hardware adjustment, or adaptable parameter …
- Z_{DR} is calibrated when system as a whole is calibrated

Total
System Bias = Rx Path Bias + Tx Path Bias

Motivation

- A systematic Z_{DR} bias value <|0.1 dB|, is critical for accurate precipitation estimation
- A Z_{DR} bias of ±0.125 dB => 10% error in the WSR-88D Qualitative Precipitation Estimate

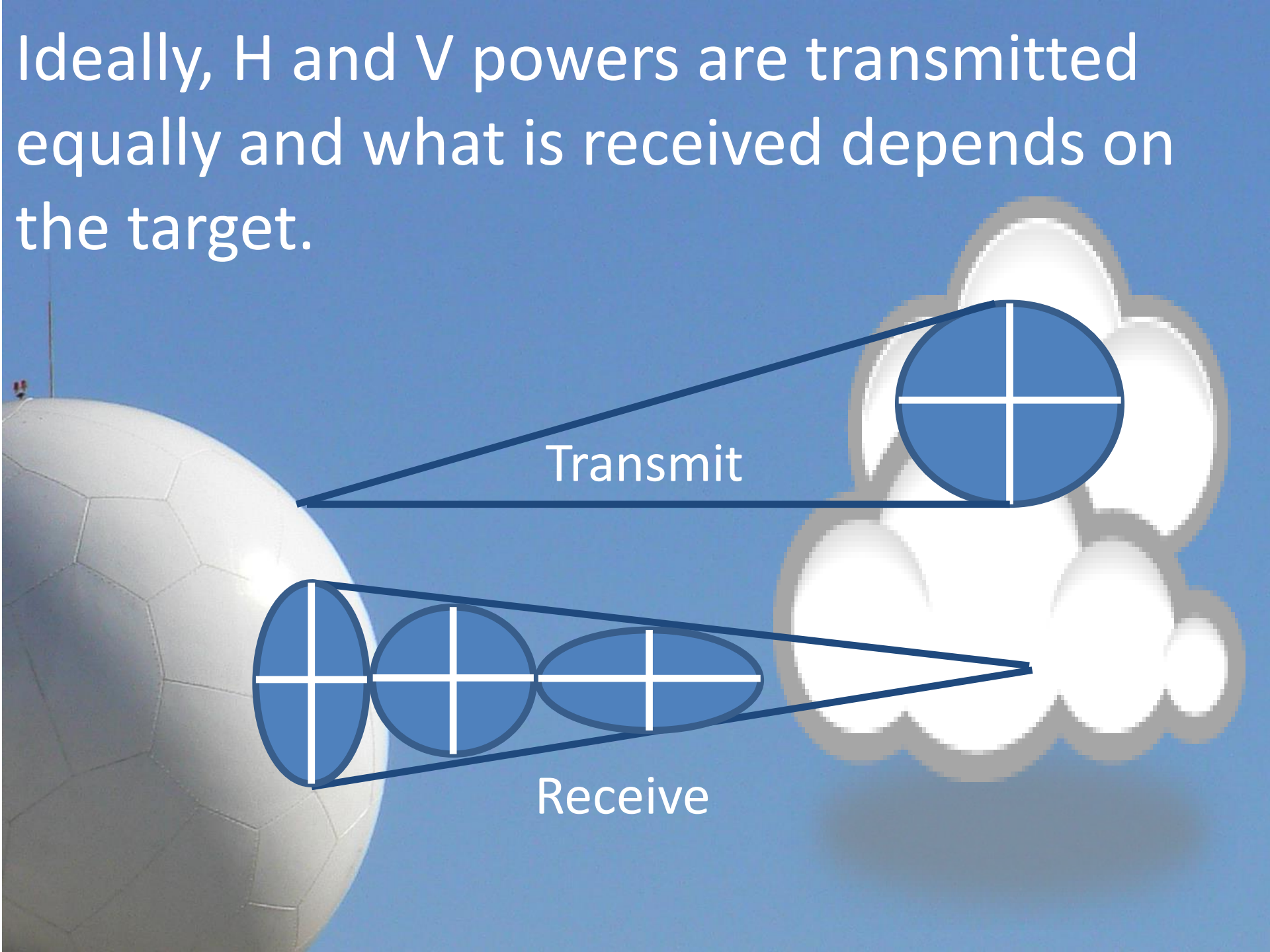
Monitoring Methodology

- Apply the Sherlock Holmes Technique
  - Use filters to avoid targets that have non-zero Z_{DR} bias values
- Estimate Z_{DR} bias from external targets with intrinsic Z_{DR} values of zero.
- Maintain radars to reduce / eliminate systematic Z_{DR} bias

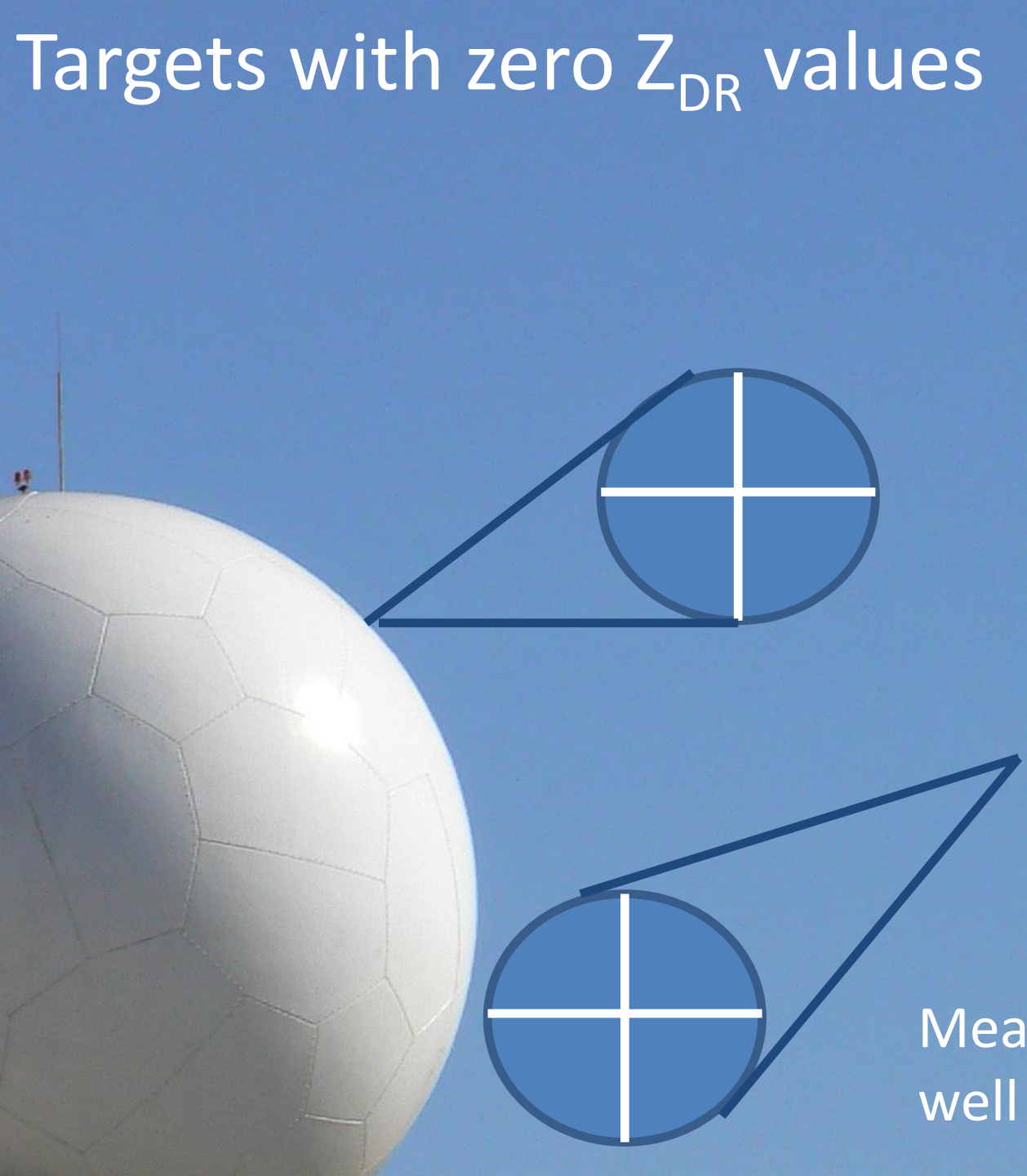
Approach

- When WSR-88D radars transmit horizontal and vertical pulses of equal power …
- Targets that have intrinsic Z_{DR} values of zero should generate a ZDR bias of zero
  - Drizzle
  - Return from Bragg scattering
  - Return from the sun
  - Corrected Z_{DR} from light rain and snow

Ideally, H and V powers are transmitted equally and what is received depends on the target.



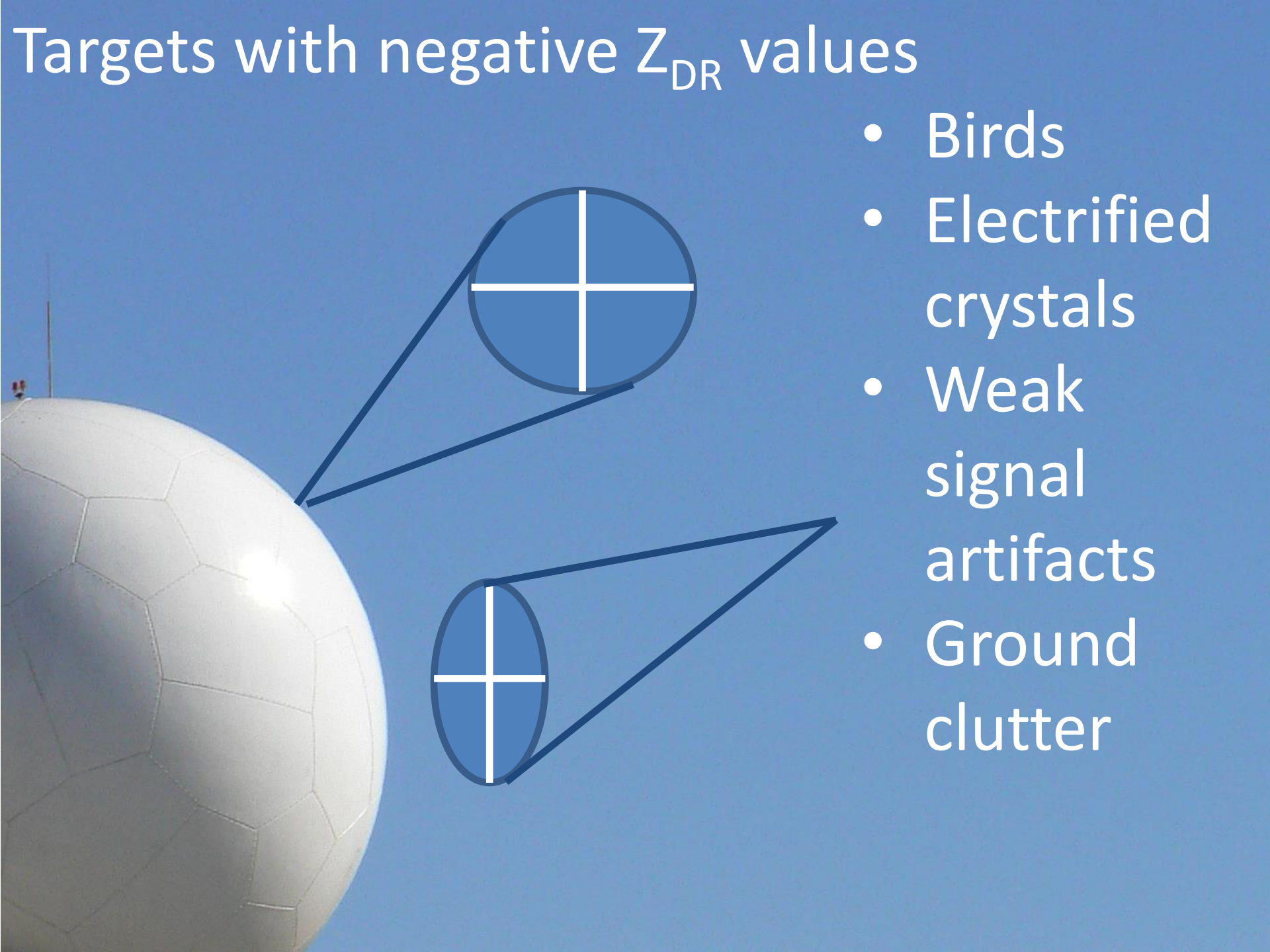
Targets with zero Z_{DR} values



- Drizzle
- Corrected light rain
- Corrected snow
- Bragg scattering
- Sunspikes

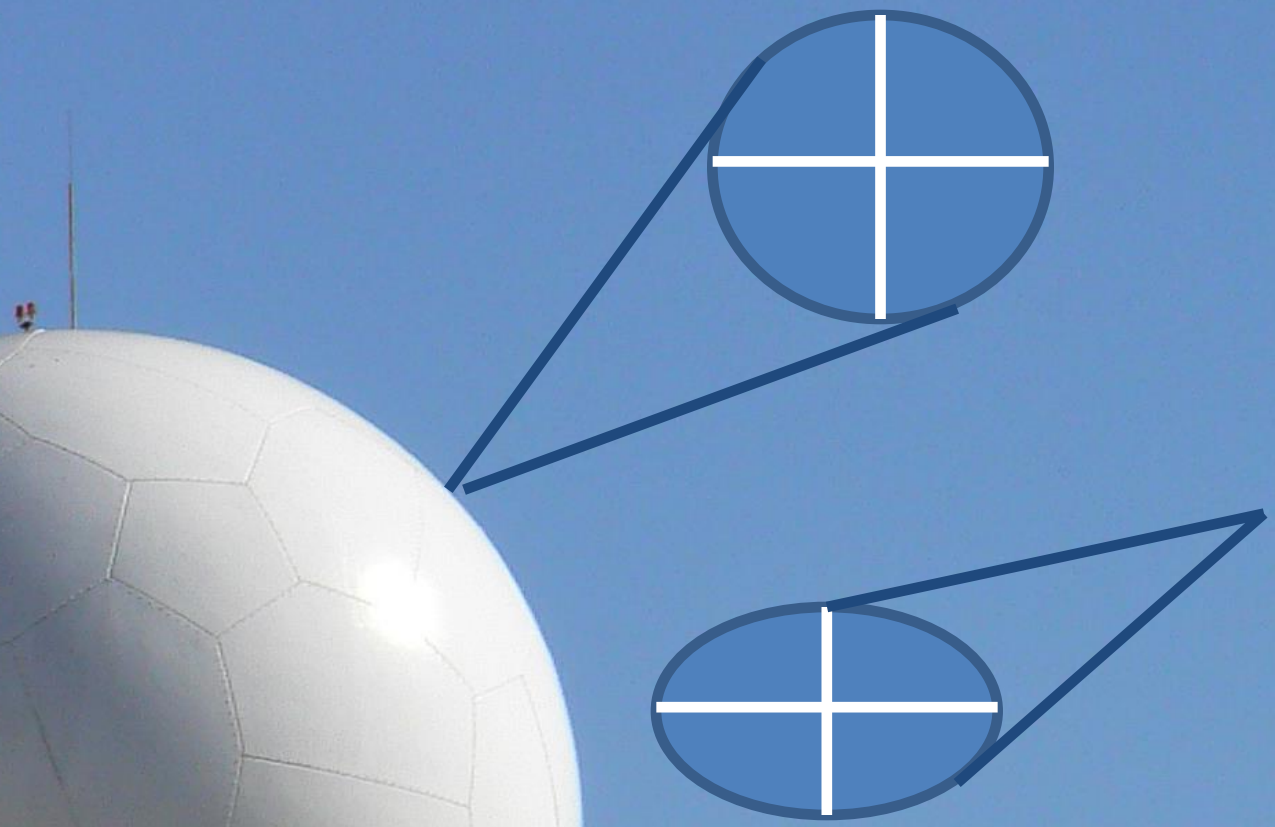
Measure Z_{DR} values using well calibrated radars.

Targets with negative Z_{DR} values



- Birds
- Electrified crystals
- Weak signal artifacts
- Ground clutter

Targets with positive Z_{DR} values

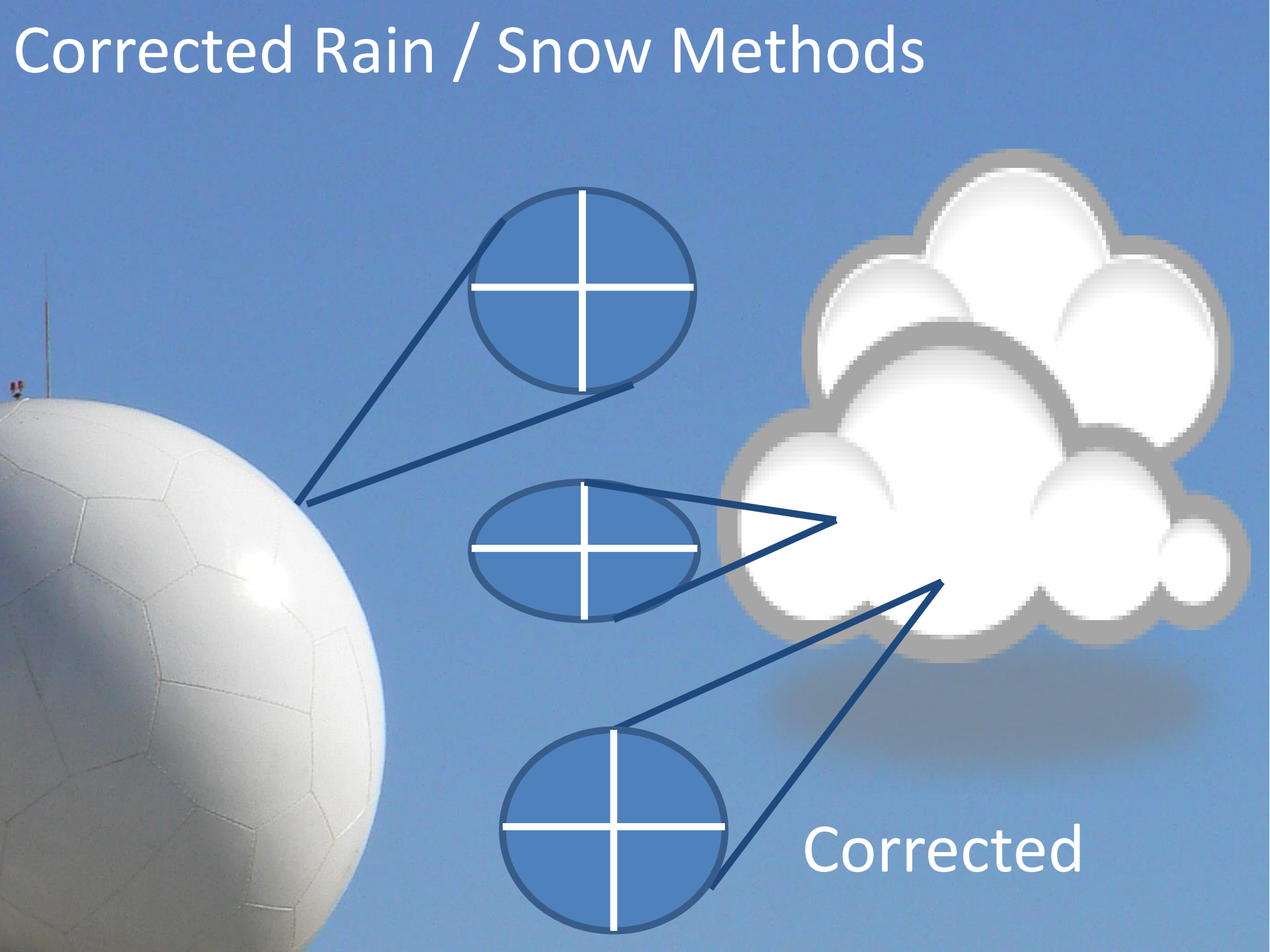


- Birds
- Bugs
- Large drops
- Weak signal artifacts
- Rain on radome
- Ground Clutter
- Uncorrected rain and snow

Apply the Sherlock Holmes Technique 'Eliminate all other factors, and the one which remains must be the truth.'

- Filter away unwanted targets
- Remaining targets should have intrinsic Z_{DR} values of zero
- Identify any systematic ZDR bias for all radars in the WSR-88D fleet

Corrected Rain / Snow Methods



Z_{DR} bias affects both transmit and receive path.

Data Filters for Rain Method

- High elevation angles to avoid ground clutter
- Sample smaller drops in stratiform rain
- Don’t sample when rain is on the radome
- Correct for small drop Z_{DR} values

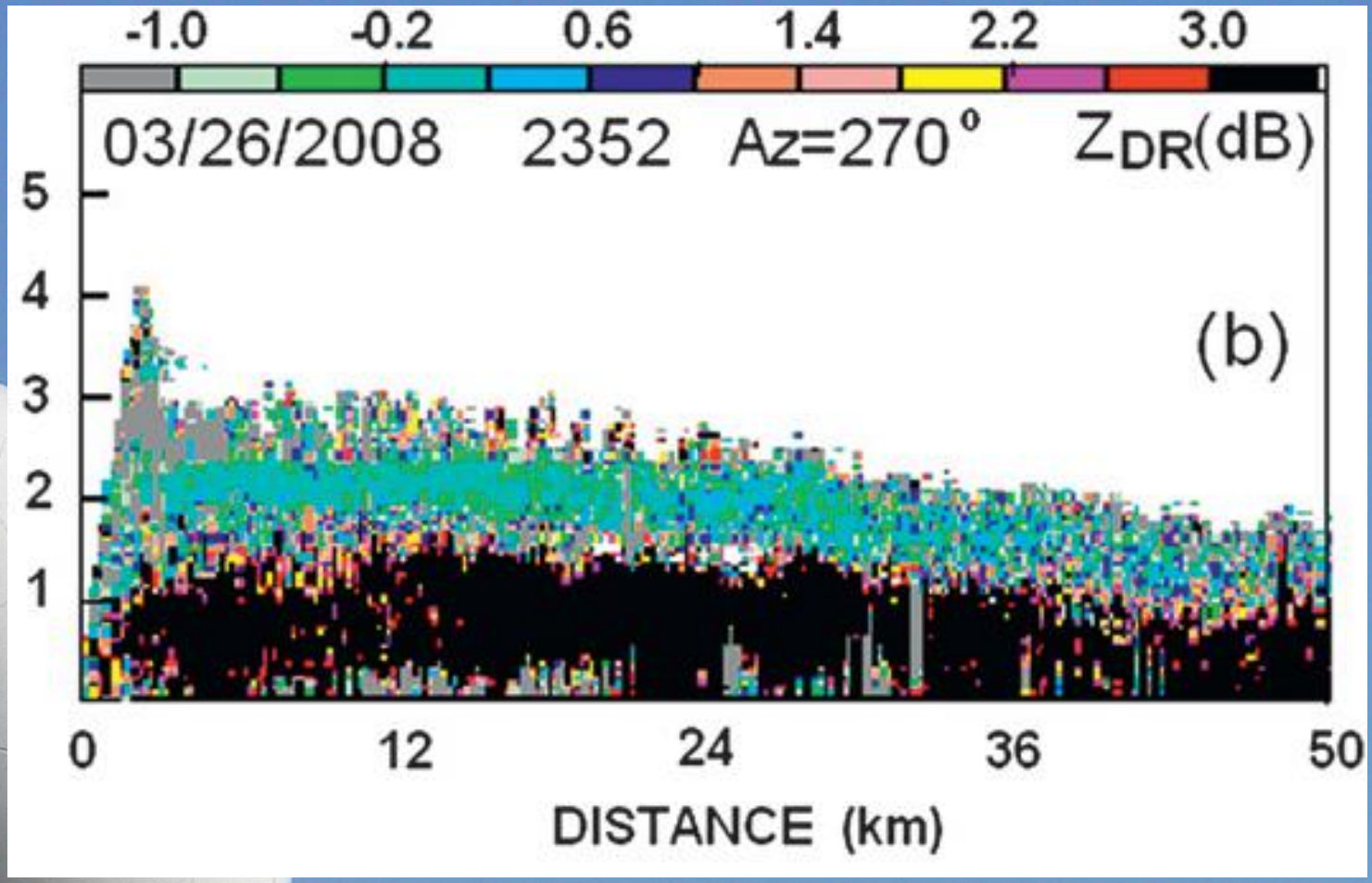
Z_{DR} bias affects both transmit and receive path.

Snow should exhibit only positive ZDR values.

Data Filters for Snow Method

- Sample only dry snow to avoid bugs and rain
- PHI to avoid convection and electrified crystals
- Rho to sample regions of uniform particles
- Correct for snow's slightly positive Z_{DR} values

Bragg Scattering



Melnikov et al. (2011)

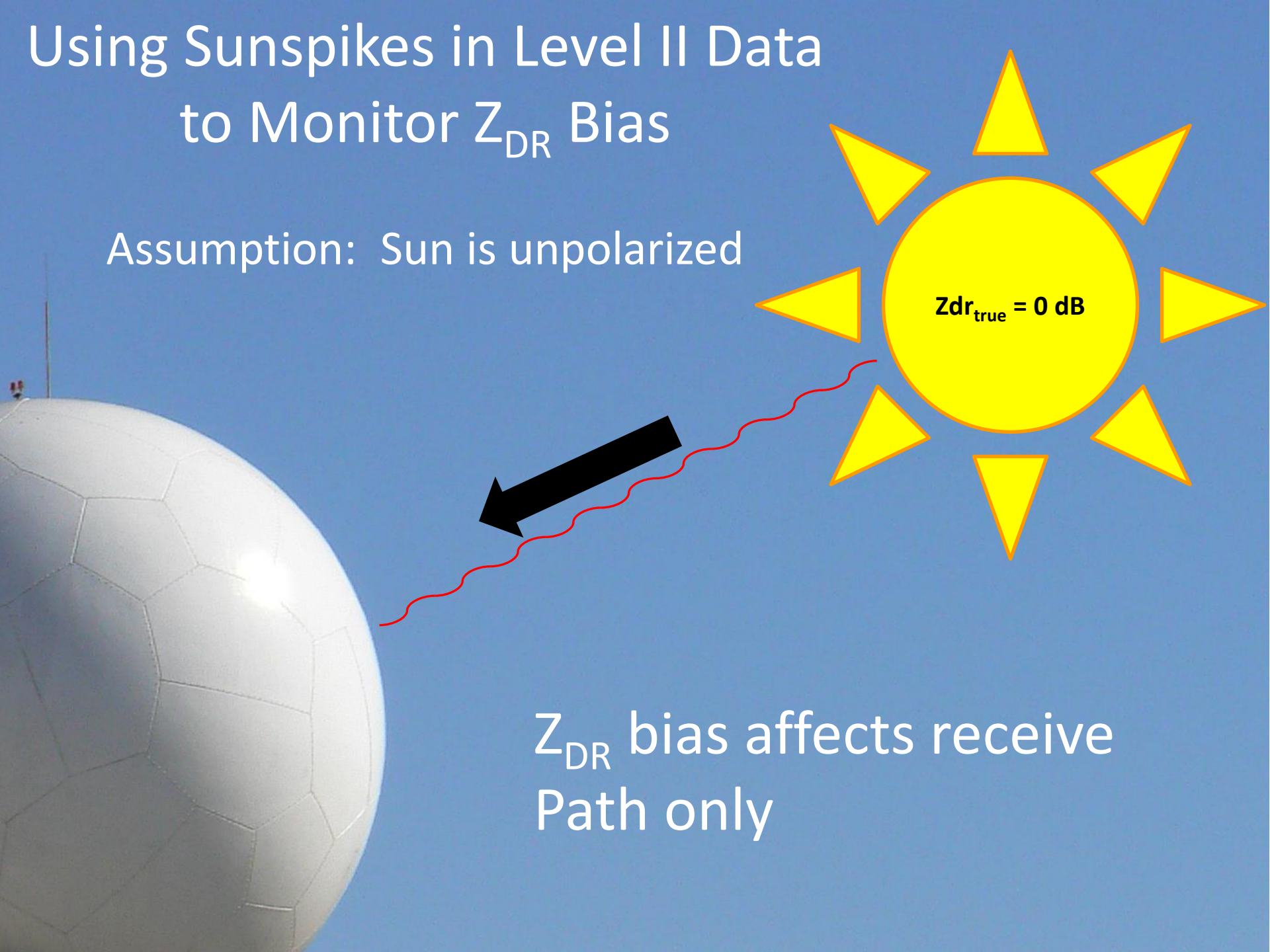
Z_{DR} bias affects both transmit and receive path.

Data Filters for Bragg Scattering Method

- Sample clear air only
- Small reflectivity values
- Velocity and spectrum width to avoid ground clutter

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

Assumption: Sun is unpolarized



Z_{DR} bias affects receive Path only

Z_{DR} bias affects only receive path.

Data Filters for Sunspike Method

- Clear Air VCP's
- Signal to Noise Ratio to avoid weak signal artifacts
- Large Bin Count for sufficient number of samples
- Sample 3 closest volume scans morning and evening

Dry Snow
Bragg Scattering

Low Z_{DR} Values

- ~~Electrified crystals~~
- ~~Birds~~
- ~~Radars~~
- ~~Weak signal artifacts~~
- ~~Ground clutter~~

Zero Z_{DR} Values

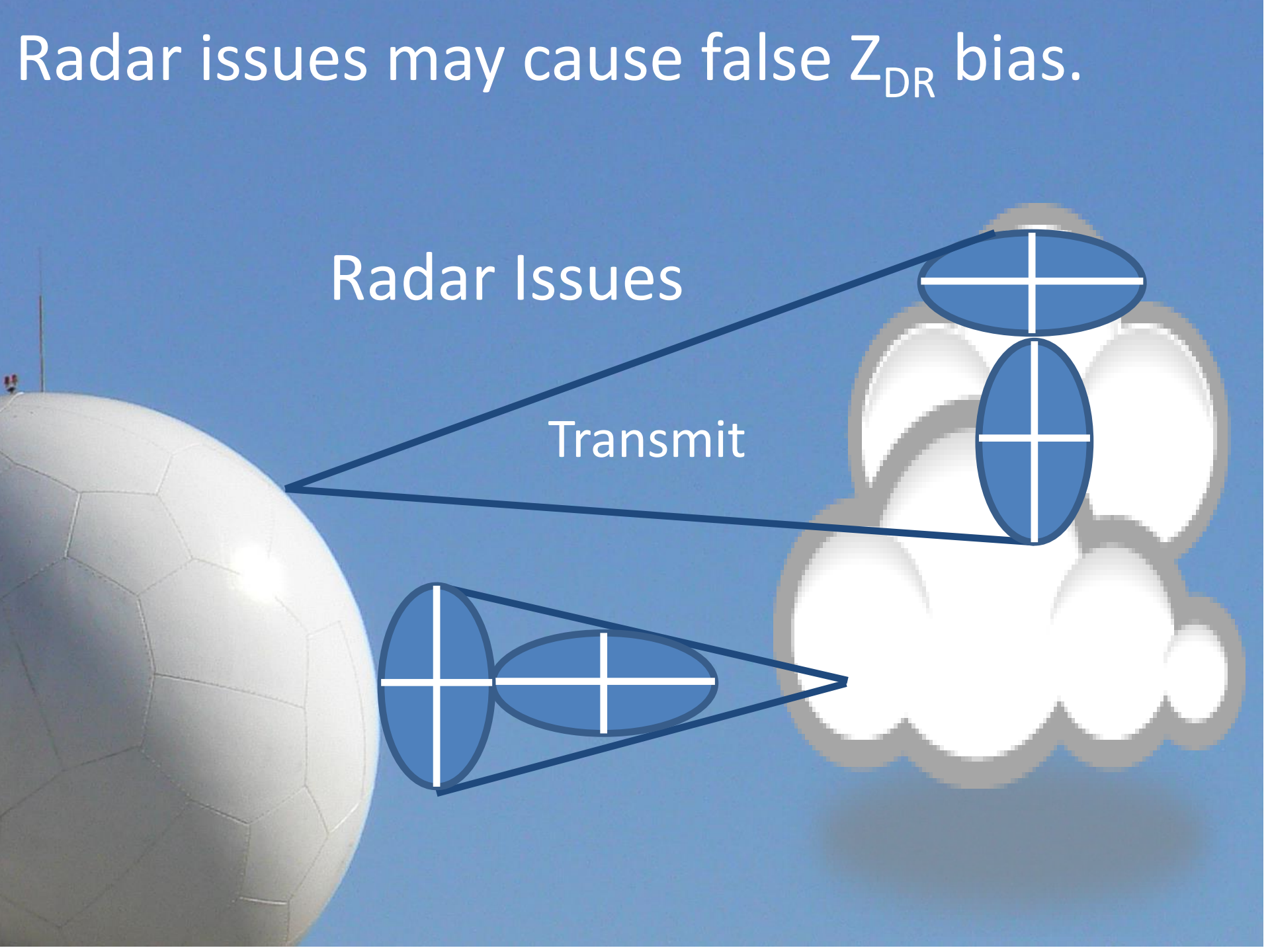
- Drizzle
- Corrected light rain
- Corrected snow
- Bragg scattering
- Sun spikes

Light Rain
Sunspike

High Z_{DR} Values

- ~~Birds~~
- ~~Bugs~~
- ~~Large drops~~
- ~~Radars~~
- ~~Weak signal artifacts~~
- ~~Rain on radom~~e
- ~~Ground Clutte~~r
- ~~Uncorrected rain and snow~~

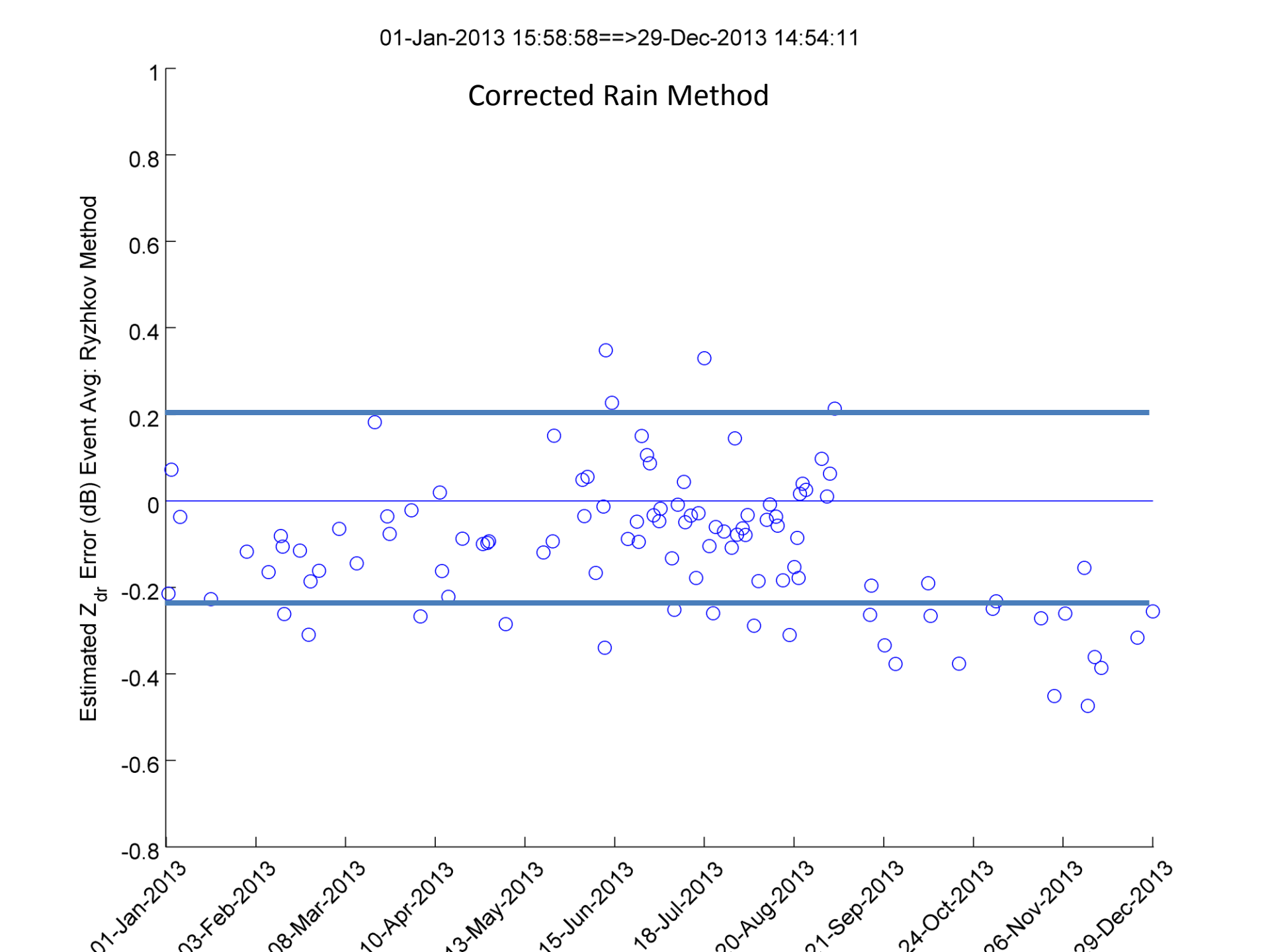
Radar issues may cause false Z_{DR} bias.

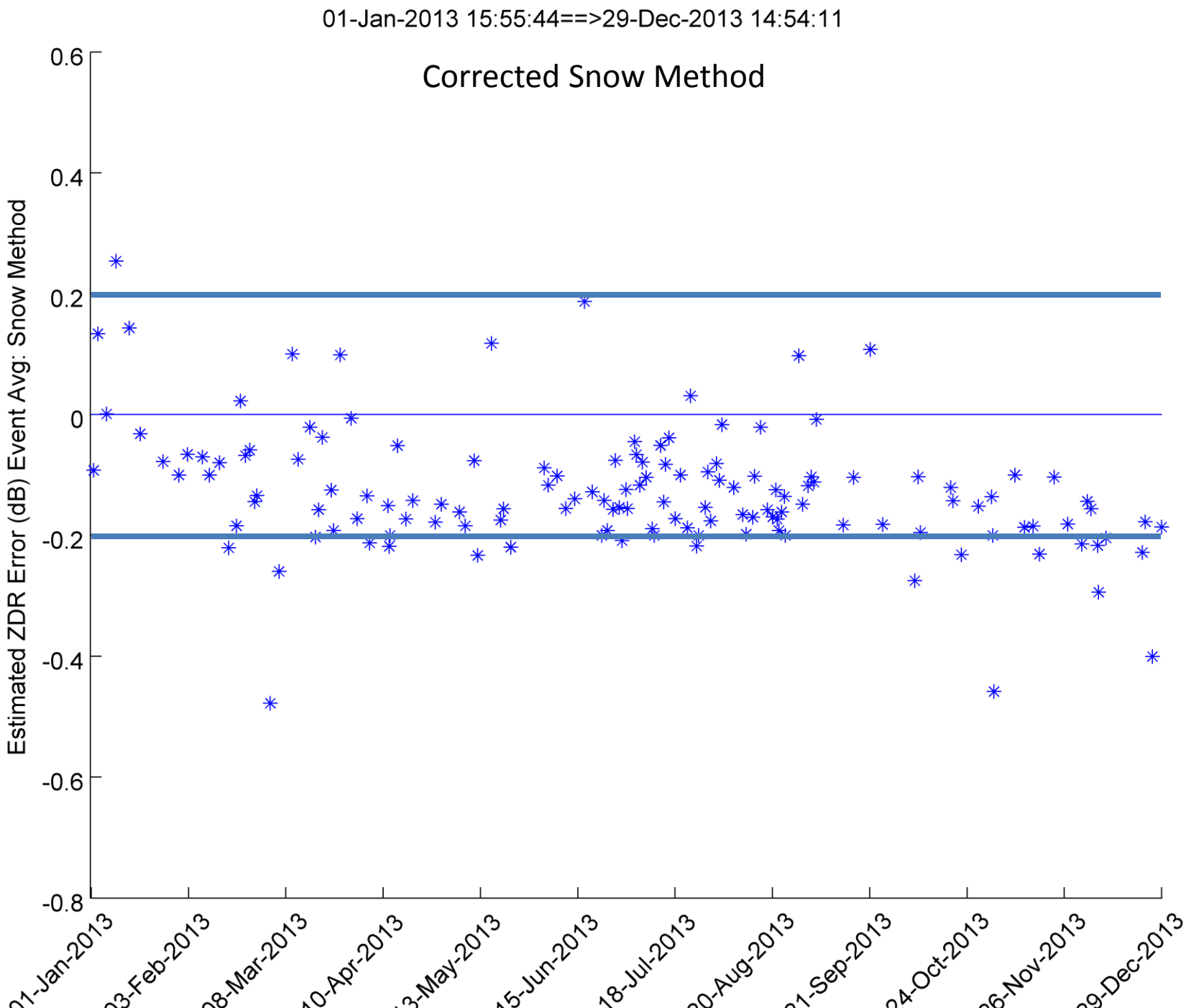


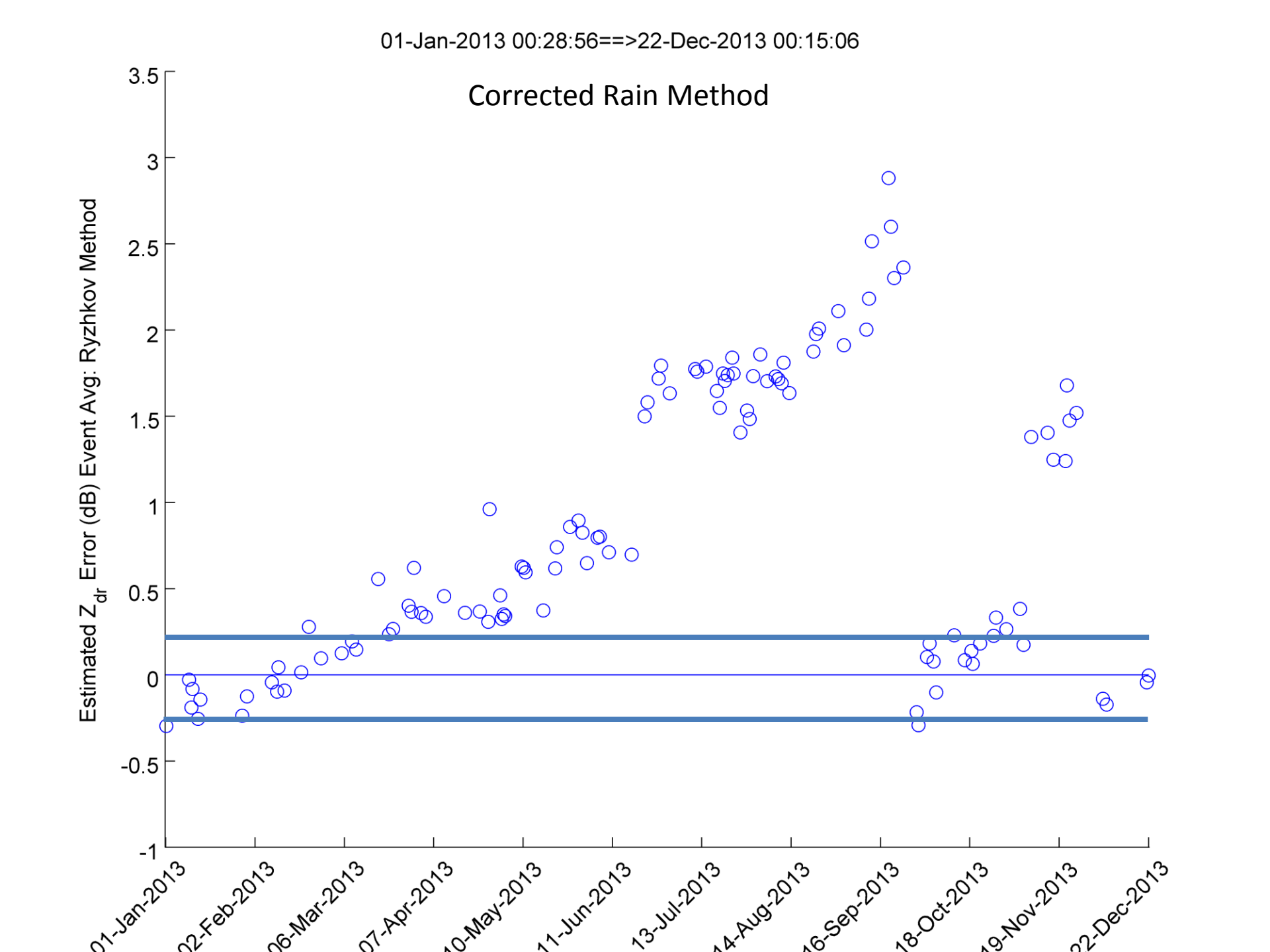
Radars

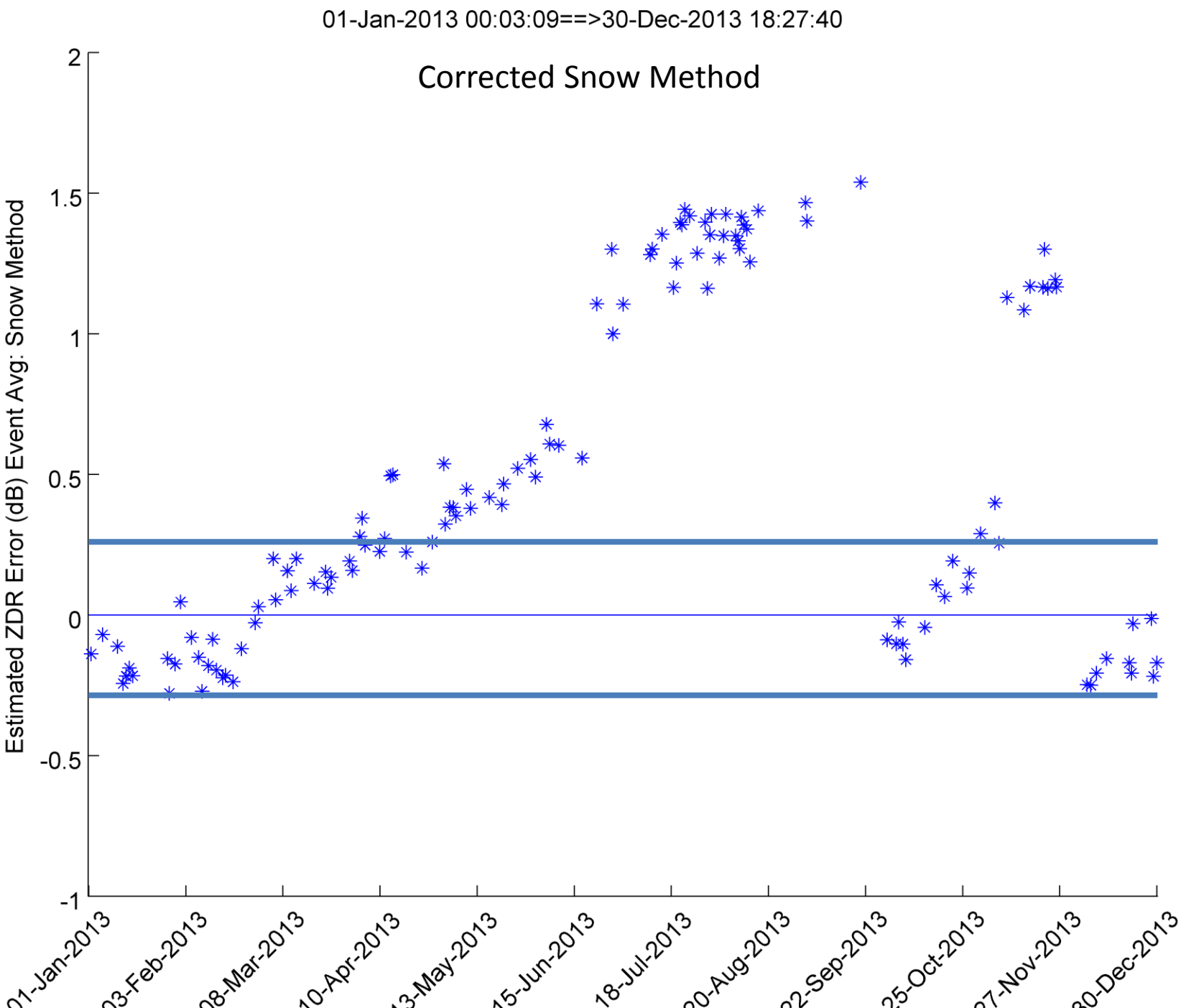
Currently, there are no alarms to alert for these conditions.

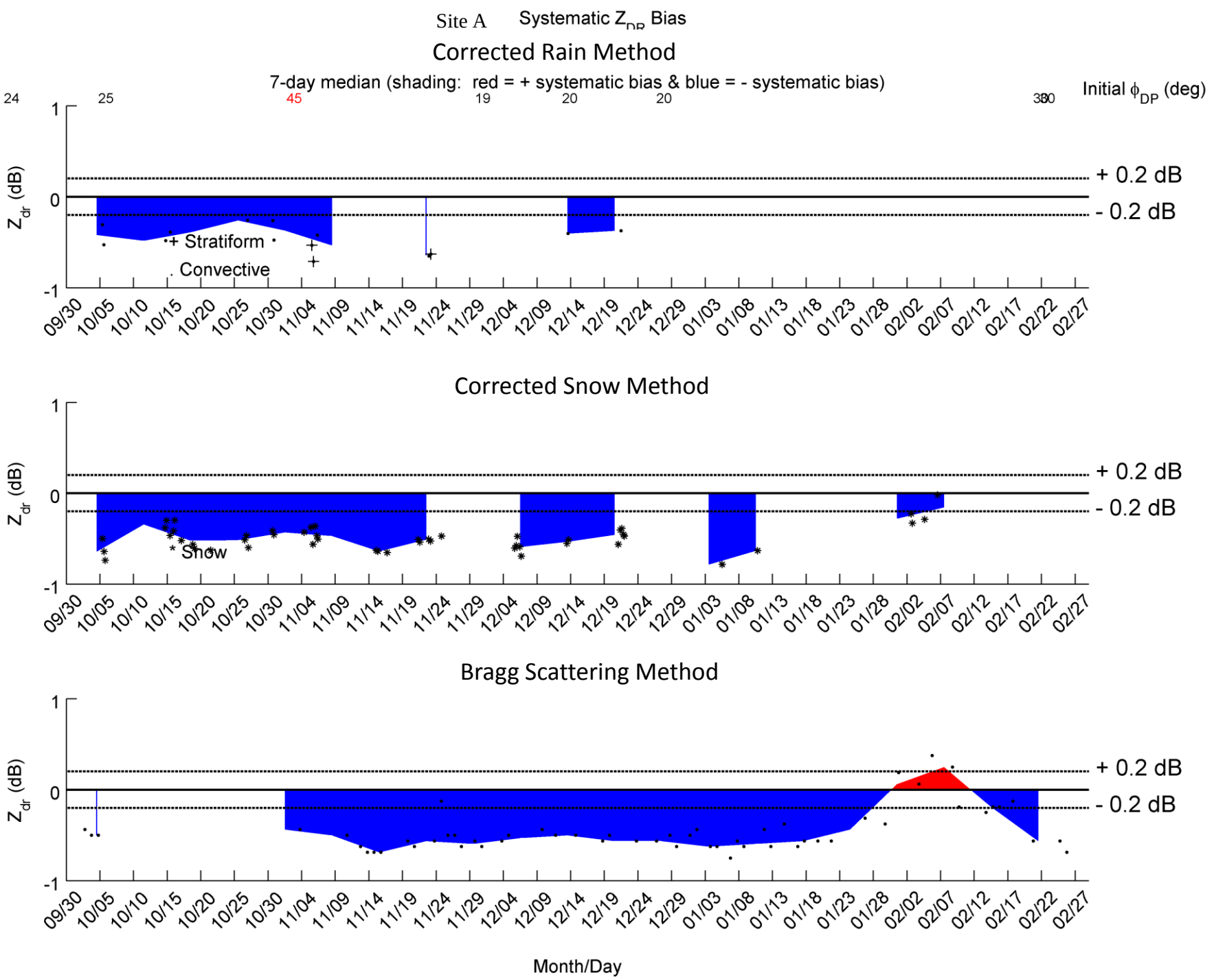
- Hardware Problems
  - H and V power not equal
  - Low transmitter power
  - 30 dB coupler
  - Pointing errors (elevation package)
  - Azimuth rotary joint
  - Cables (connections and connecting)
  - Bull gear
  - Pedestal dynamic issues
  - Test equipment
  - Power sensor
- Human Error
  - Wrong parameter settings
    - Antenna gain
    - Mis-calibration
    - ISDP incorrect
- Non-optimal wx during install for proper calibration and setup

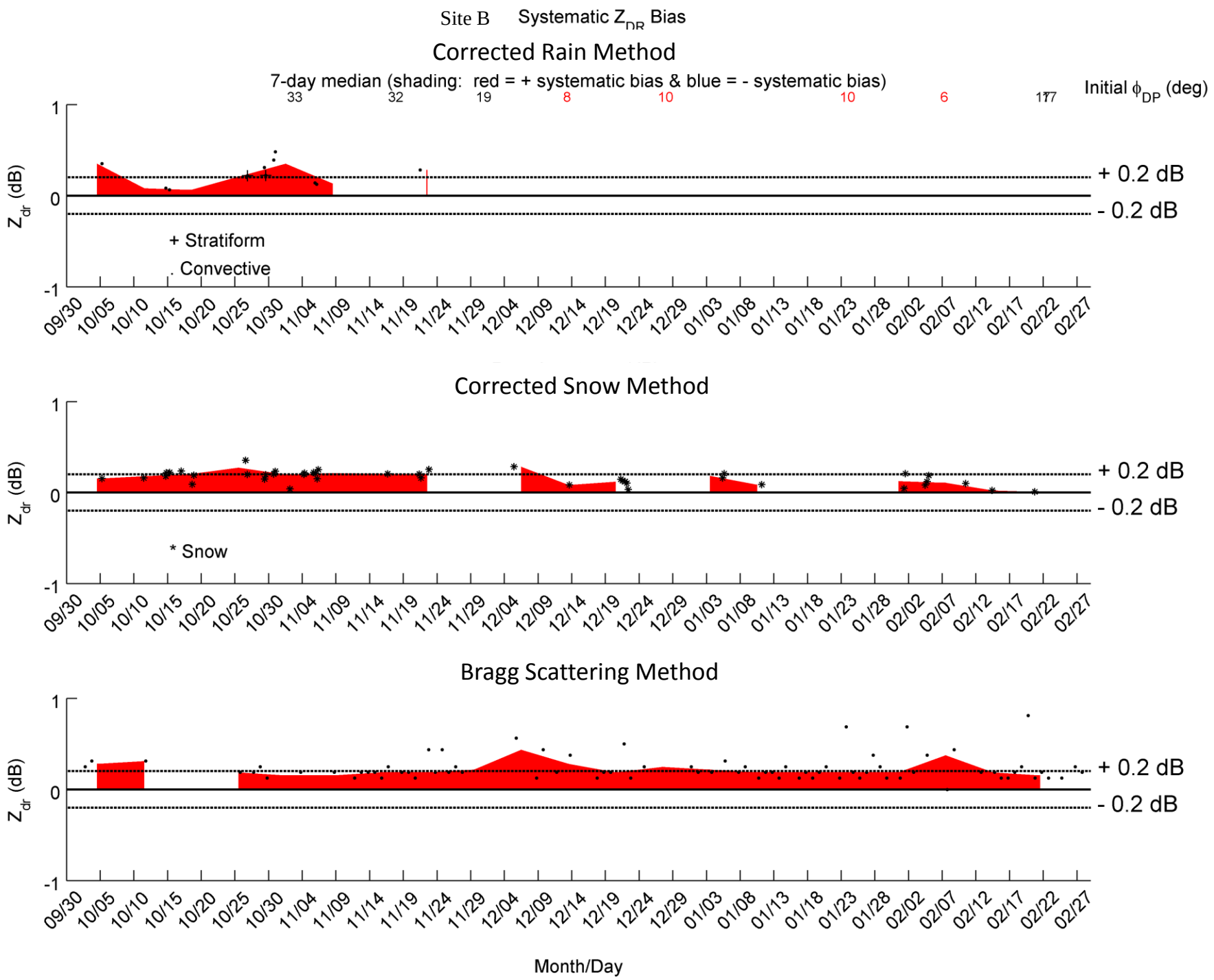

01-Jan-2013 15:58:58==>29-Dec-2013 14:54:11
Corrected Rain Method
Estimated Z_{dr} Error (dB) Event Avg: Ryzhkov Method
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
01-Jan-2013
03-Feb-2013
08-Mar-2013
10-Apr-2013
13-May-2013
15-Jun-2013
18-Jul-2013
20-Aug-2013
21-Sep-2013
24-Oct-2013
26-Nov-2013
29-Dec-2013

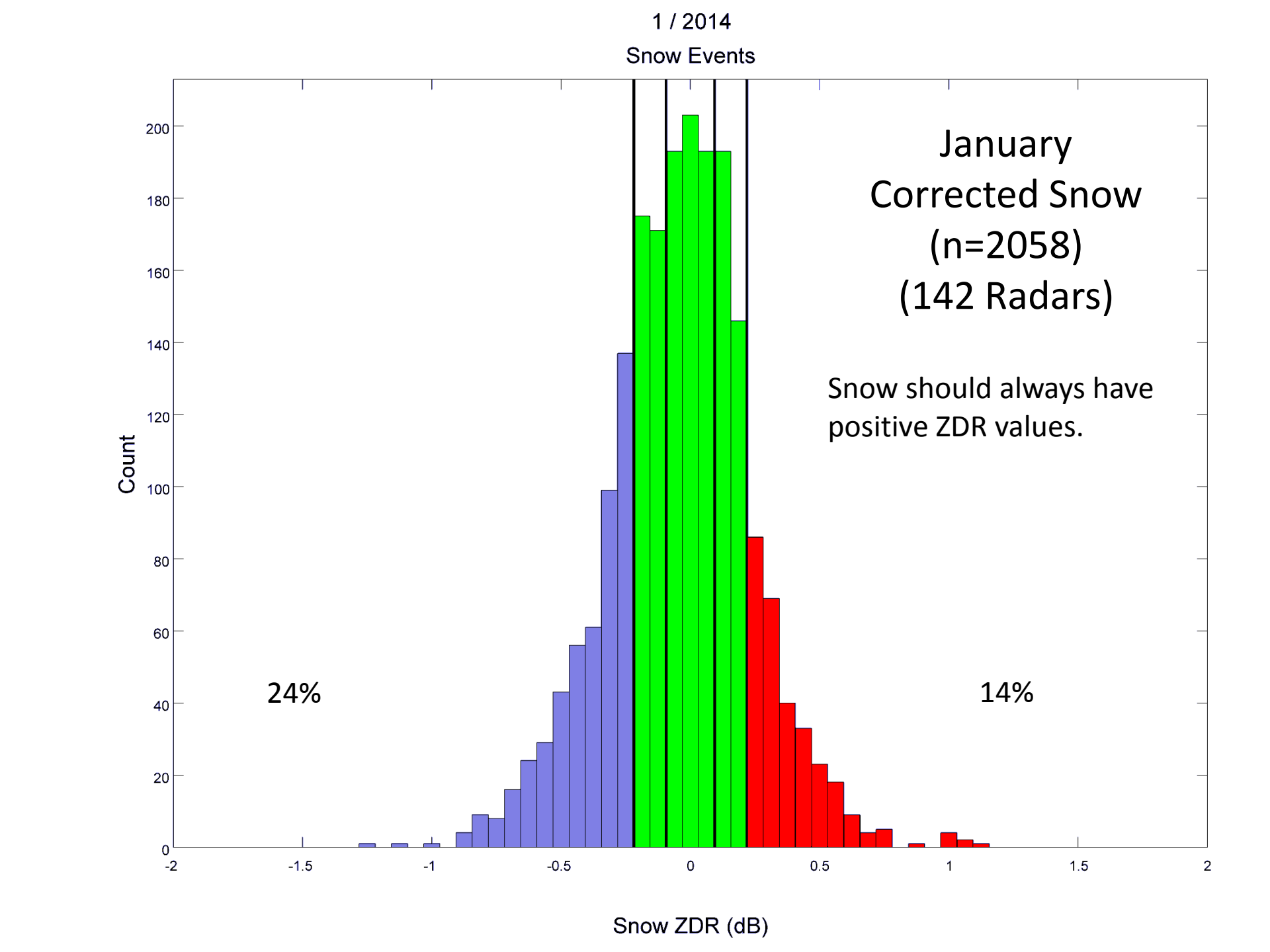

01-Jan-2013 15:55:44==>29-Dec-2013 14:54:11
Corrected Snow Method
Estimated ZDR Error (dB) Event Avg: Snow Method
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
01-Jan-2013
03-Feb-2013
08-Mar-2013
10-Apr-2013
13-May-2013
15-Jun-2013
18-Jul-2013
20-Aug-2013
21-Sep-2013
24-Oct-2013
26-Nov-2013
29-Dec-2013


01-Jan-2013 00:28:56==>22-Dec-2013 00:15:06
Corrected Rain Method
Estimated Z_{dr} Error (dB) Event Avg: Ryzhkov Method
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
01-Jan-2013
02-Feb-2013
06-Mar-2013
07-Apr-2013
10-May-2013
11-Jun-2013
13-Jul-2013
14-Aug-2013
16-Sep-2013
18-Oct-2013
19-Nov-2013
22-Dec-2013


01-Jan-2013 00:03:09==>30-Dec-2013 18:27:40
Corrected Snow Method
Estimated ZDR Error (dB) Event Avg: Snow Method
2
1.5
1
0.5
0
-0.5
-1
01-Jan-2013
03-Feb-2013
08-Mar-2013
10-Apr-2013
13-May-2013
15-Jun-2013
18-Jul-2013
20-Aug-2013
22-Sep-2013
25-Oct-2013
27-Nov-2013
30-Dec-2013


Site A
Systematic Z_{DR} Bias
Corrected Rain Method
7-day median (shading: red = + systematic bias & blue = - systematic bias)
24
25
45
19
20
20
30
Initial ϕ_{DP} (deg)
Z_{dr} (dB)
+ 0.2 dB
- 0.2 dB
Stratiform
Convective
Corrected Snow Method
Snow
Bragg Scattering Method
09/30
10/05
10/10
10/15
10/20
10/25
10/30
11/04
11/09
11/14
11/19
11/24
11/29
12/04
12/09
12/14
12/19
12/24
12/29
01/03
01/08
01/13
01/18
01/23
01/28
02/02
02/07
02/12
02/17
02/22
02/27
Month/Day


Site B Systematic Z_{DR} Bias
Corrected Rain Method
7-day median (shading: red = + systematic bias & blue = - systematic bias)
33
32
19
8
10
10
6
177
Initial ϕ_{DP} (deg)
Z_{dr} (dB)
+ 0.2 dB
- 0.2 dB
+ Stratiform
. Convective
Corrected Snow Method
* Snow
Bragg Scattering Method
09/30 10/05 10/10 10/15 10/20 10/25 10/30 11/04 11/09 11/14 11/19 11/24 11/29 12/04 12/09 12/14 12/19 12/24 12/29 01/03 01/08 01/13 01/18 01/23 01/28 02/02 02/07 02/12 02/17 02/22 02/27
Month/Day


1 / 2014
Snow Events
January
Corrected Snow
(n=2058)
(142 Radars)
Snow should always have positive ZDR values.
24%
14%
Count
Snow ZDR (dB)
0
20
40
60
80
100
120
140
160
180
200
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2

Alarm free does not mean the radar is well calibrated or that the data quality is good.

ROC personnel are monitoring data quality from all sites and investigating the addition of data quality alarms.

Z_{DR} affects may algorithms but QPE is especially sensitive to proper calibration.