S-Pol Data Quality Processing for PECAN

Mike Dixon, Bob Rilling, Eric Loew, John Hubbert, Scott Ellis

Earth Observing Laboratory

National Center for Atmospheric Research

Boulder, Colorado

2016/03/25

Contents

[1 Project time-line 3](#_Toc444432197)

[2 Monitoring 5](#_Toc444432198)

[3 Calibrations, noise levels, system stability 6](#_Toc444432199)

[3.1 Calibrations 6](#_Toc444432200)

[3.2 Noise monitoring 8](#_Toc444432201)

[3.3 Sun monitoring using sun scans 9](#_Toc444432202)

[3.4 Sun monitoring using solar spikes during routine scanning 12](#_Toc444432203)

[3.5 Clutter power monitoring 13](#_Toc444432204)

[4 Reflectivity calibration 16](#_Toc444432205)

[4.1 Reflectivity calibration check using self-consistency 16](#_Toc444432206)

[4.2 Reflectivity calibration check using the Dodge City NEXRAD (KDDC). 19](#_Toc444432207)

[4.3 Evaluating the reflectivity bias 21](#_Toc444432208)

[5 Zdr bias estimation 22](#_Toc444432209)

[5.1 Estimating Zdr bias using the cross-polar power method and vertical pointing 22](#_Toc444432210)

[5.2 Zdr dependence on temperature 24](#_Toc444432211)

[5.3 Estimating Zdr bias using measured Zdr in irregular ice and dry snow regions 25](#_Toc444432212)

[5.4 Temperature dependence of measured Zdr 31](#_Toc444432213)

[6 Creating the QC data set 34](#_Toc444432214)

[6.1 Corrections applied for QC data set 34](#_Toc444432215)

[6.2 Verifying the differences between the field and QC data sets. 35](#_Toc444432216)

[6.3 Verifying the Z calibration using the self-consistency method 36](#_Toc444432217)

[6.4 Verifying the Zdr corrections using the ice and Bragg methods. 37](#_Toc444432218)

[6.5 Analysis of scan angles vs. scan strategy 39](#_Toc444432219)

[7 Fields in the QC data set CfRadial files 42](#_Toc444432220)

[8 Software applications used for processing QC data 46](#_Toc444432221)

[9 Acknowledgements 47](#_Toc444432222)

[10 References 47](#_Toc444432223)

# Project time-line

The NCAR/EOL S-Pol S-band radar operated at the McCracken site, SW of Hays Kansas, for the Plains Elevated Convection At Night (PECAN) field project during May, June and July of 2015. PECAN formally ran from June 1 to the morning of July 16 2015.

The radar was installed at the McCracken site in early May, and was up and running in test mode by May 21 2015. During the period May 21 to May 28, testing and calibration was carried out, and the system was prepared for 24-hour operations during the field project. The antenna control program was tested with the scans specified by the S-Pol PIs.

In order to improve sensitivity, it had been decided to run the radar with a 1.5 microsecond pulse. The calibrations carried out before the project began were all performed for this pulse width. However, problems with arcing in the waveguide during the project required that the pulse width be reduced to 1.0 microseconds – this was done on June 7.

The radar was ready for operations on May 28 and started collecting data in a pseudo-operational mode.

Formal operations began on June 1, and ran until midday local time on July 16.

Table 1 below provides details the date/time of events of significance for data quality purposes:

| **Date** | **Time UTC** | **Notes** |
| --- | --- | --- |
| 2015/05/28 |  | Initial setup and calibration complete. Antenna scan testing in progress |
| 2015/06/01 |  | Project operations begin |
| 2015/06/03 | 21:18 | Stopped operations. Problems with antenna azimuth drive oil pump and waveguide arcing. Decreased xmit power by 0.7 dB (from 9.4 dBm to 8.7 dBm on top of cabinet) to prevent arcing. |
| 2015/06/04 | 01:52 | Back up and operational |
| 2015/06/04 | 07:58 | Antenna breaker tripped, scan stopped, radar down. |
| 2015/06/05 | 15:00 | Installed nitrogen bottle for waveguide pressurization, to mitigate arcing. |
| 2015/06/05 | 20:30 | Reduced xmit power to avoid arcing. Reduced by 1.4 dB, to 8.0 dBm on top of cabinet. Found various power supply-related problems. Found 140V DC in transmitter cabinet, even with power off. Radar down. |
| 2015/06/07 | 13:00 | Changed pulse width to 1.0 microseconds, to reduce likelihood of arcing. Recalibrated for 1.0 us pulse, peak power 86 dBm = 400 KW. |
| 2015/06/07 | 22:40 | Resumed operations at reduced power. |
| 2015/06/08 | 18:10 | Antenna breaker tripped. Scan stopped. |
| 2015/06/08 | 20:53 | Resumed scanning. |
| 2015/06/09 | 17:27 | Stopped scan. Replaced rotary joint damaged by arcing. Adjusted transmit power back up to normal, ~87.5 dBm. |
| 2015/06/09 | 21:10 | Performed calibrations, solar scans |
| 2015/06/09 | 22:00 | Resumed operations. |
| 2015/06/10 | 16:30 | Stopped radar for air conditioner repair. |
| 2015/06/10 | 19:00 | Replaced transmitter trigger amplifier. Radar down. Transmitter power down by 2.3 dB, H power 85.5 dBm, V power 85.25 dBm at couplers. |
| 2015/06/10 | 23:00 | Radar operated intermittently due to temperature problems. |
| 2015/06/11 | 05:30 | Shut down due to over heating of transmitter, from AC problems. |
| 2015/06/12 | 02:20 | Started scanning at reduced power. |
| 2015/06/12 | 07:40 | Shut down. |
| 2015/06/12 | 19:20 | Back up and operational at reduced power. |
| 2015/06/13 | 00:00 | Tuned transmitter for new trigger amplifier. Back up to full power ~87.5 dBm.  Operational. |
| 2015/07/01 | 05:58 | Angle problem with PMAC - scan stopped automatically. Reset sixnet and PMAC. |
| 2015/07/01 | 07:50 | Restarted scan with 0.4 degree error in elevation so files needed to be fixed later (this was done) |
| 2015/07/01 | 16:50 | Fixed angle problem, scanning normally. |
| 2015/07/12 | 00:00 | Scan ran overnight with extra 10 deg. RHI. This was removed from scan strategy at 15:30. |
| 2015/07/12 | 15:30 | Normal operations. |
| 2015/07/16 | 17:35 | Operations complete. Started post-operation calibrations. |

Table1: PECAN operations timeline for S-Pol QC purposes.

# Monitoring

At S-Pol during PECAN, we monitored a wide range of variables, including transmitter power, ambient temperature at the site, the dish temperature, and various temperatures in the transmitter container. See figure 1 below.

The power trace in the top plot shows the time period of compromised operations, from June 5 to June 14.

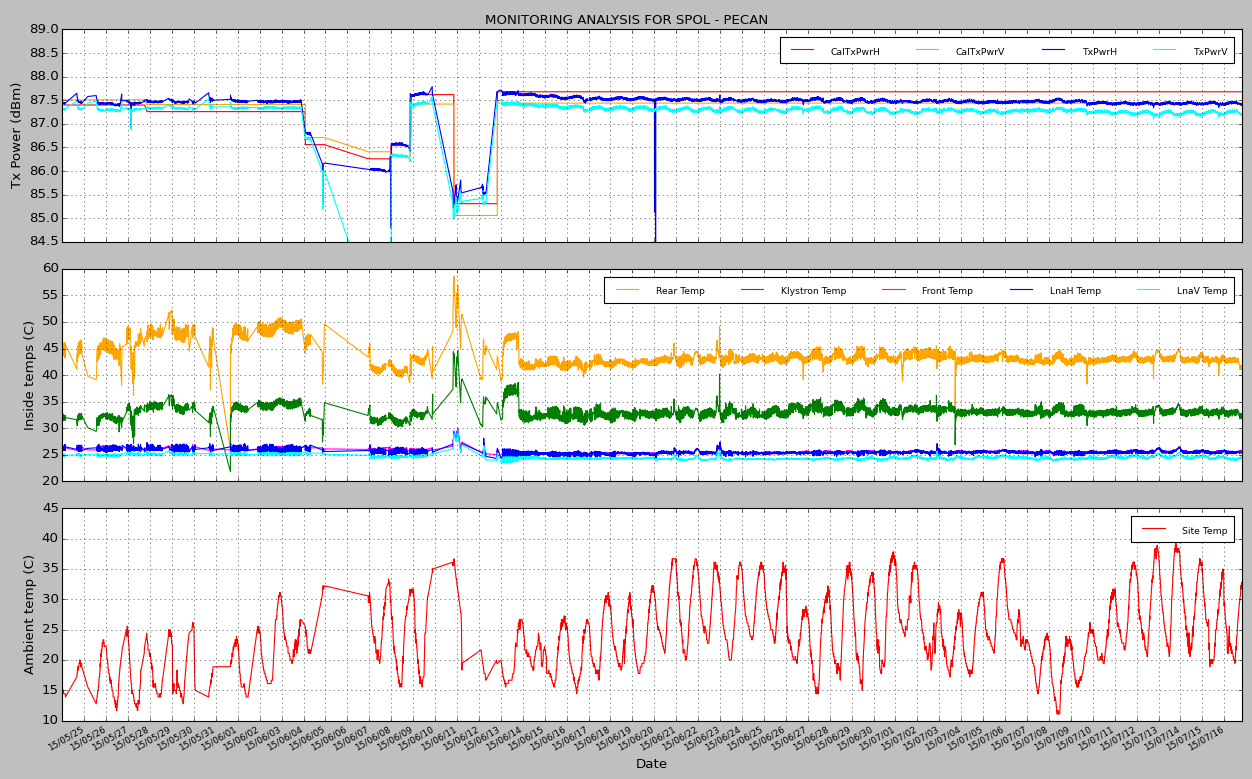
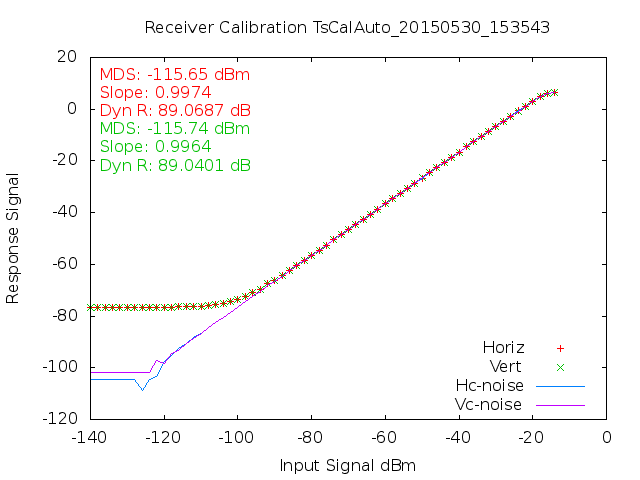


Figure 1: Site and radar monitoring for S-Pol at PECAN  
Top panel: measured transmit power, compared with calibrated transmit power.  
Middle panel: temperatures in the transmitter container.  
Bottom panel: site temperature – dish temperature if available, otherwise weather station temperature.

# Calibrations, noise levels, system stability

## Calibrations

Calibrations were carried out prior to the project, in the middle of the project (June 10) after the transmitter was repaired, and at the end of the project.



time: 2015/05/30 15:35:43

wavelengthCm: 10.68

beamWidthDegH: 0.92

beamWidthDegV: 0.92

antennaGainDbH: 44.95

antennaGainDbV: 45.32

pulseWidthUsec: 1.5

xmitPowerDbmH: 87.48

xmitPowerDbmV: 87.35

twoWayWaveguideLossDbH: 1.16

twoWayWaveguideLossDbV: 1.44

receiverMismatchLossDb: 1.3

radarConstH: 68.9149

radarConstV: 68.5849

antennaGainDbH: 44.95

antennaGainDbV: 45.32

noiseDbmHc: -76.5757

noiseDbmHx: -76.2161

noiseDbmVc: -76.5831

noiseDbmVx: -76.1107

i0DbmHc: -115.655

i0DbmHx: -115.612

i0DbmVc: -115.744

i0DbmVx: -115.710

receiverGainDbHc: 39.0796

receiverGainDbHx: 39.3958

receiverGainDbVc: 39.1613

receiverGainDbVx: 39.5989

baseDbz1kmHc: -46.74

baseDbz1kmHx: -46.6966

baseDbz1kmVc: -47.1586

baseDbz1kmVx: -47.1238

powerMeasLossDbH: -21.19

powerMeasLossDbV: -20.93

couplerForwardLossDbH: 36.9

couplerForwardLossDbV: 36.7

dbzCorrection: -1.75

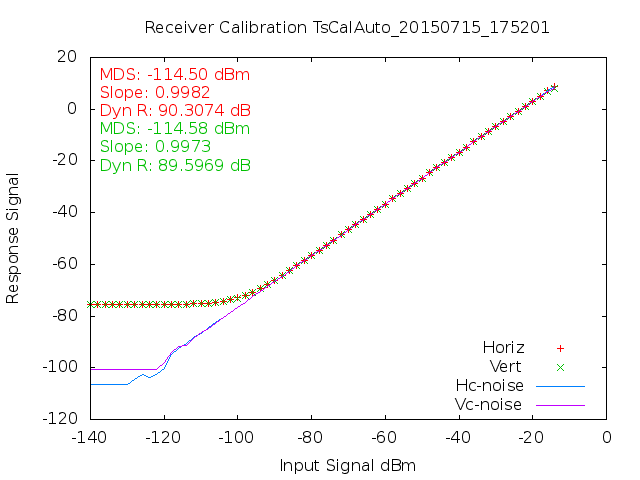
zdrCorrectionDb: 0.28228

ldrCorrectionDbH: 0

ldrCorrectionDbV: 0

systemPhidpDeg: 90

Figure 2: Receiver calibration at start of project, 2015/05/30, pulse width is 1.5 microseconds



time: 2015/07/15 17:52:01

wavelengthCm: 10.68

beamWidthDegH: 0.92

beamWidthDegV: 0.92

antennaGainDbH: 44.95

antennaGainDbV: 45.32

pulseWidthUsec: 1

xmitPowerDbmH: 87.4647

xmitPowerDbmV: 87.234

twoWayWaveguideLossDbH: 1.16

twoWayWaveguideLossDbV: 1.44

twoWayRadomeLossDbH: 0

twoWayRadomeLossDbV: 0

receiverMismatchLossDb: 0.37

kSquaredWater: -9999

radarConstH: 69.7611

radarConstV: 69.5318

antennaGainDbH: 44.95

antennaGainDbV: 45.32

noiseDbmHc: -75.4624

noiseDbmHx: -74.9898

noiseDbmVc: -75.4799

noiseDbmVx: -74.8832

i0DbmHc: -114.508

i0DbmHx: -114.410

i0DbmVc: -114.581

i0DbmVx: -114.433

receiverGainDbHc: 39.0461

receiverGainDbHx: 39.4198

receiverGainDbVc: 39.1013

receiverGainDbVx: 39.5497

baseDbz1kmHc: -44.7474

baseDbz1kmHx: -44.6485

baseDbz1kmVc: -45.0494

baseDbz1kmVx: -44.9011

powerMeasLossDbH: -21.19

powerMeasLossDbV: -20.93

couplerForwardLossDbH: 36.9

couplerForwardLossDbV: 36.7

dbzCorrection: -1.5

zdrCorrectionDb: -0.123006

ldrCorrectionDbH: 0

ldrCorrectionDbV: 0

systemPhidpDeg: 90

Figure 3: receiver calibration at end of project, 2015/07/15, pulse width 1.0 microseconds

For QC purposes we used 2 reference calibrations: (a) on 2015/05/30 for the 1.5 microsecond pulse, and (b) on 2015/07/15 for the 1.0 microsecond pulse. (The calibration performed on June 10 exhibited a different receiver gain and is considered unreliable). These 2 calibrations have very similar characteristics. As expected, the measured noise power for the 1.5 microsecond pulse is lower than that for the 1.0 microsecond pulse. For the 1.5 microsecond pulse, the horizontal co-polar noise power is -115.655 dBm, while for the 1.0 microsecond pulse this value is -114.508 dBm, 0.86 dB higher.

## Noise monitoring

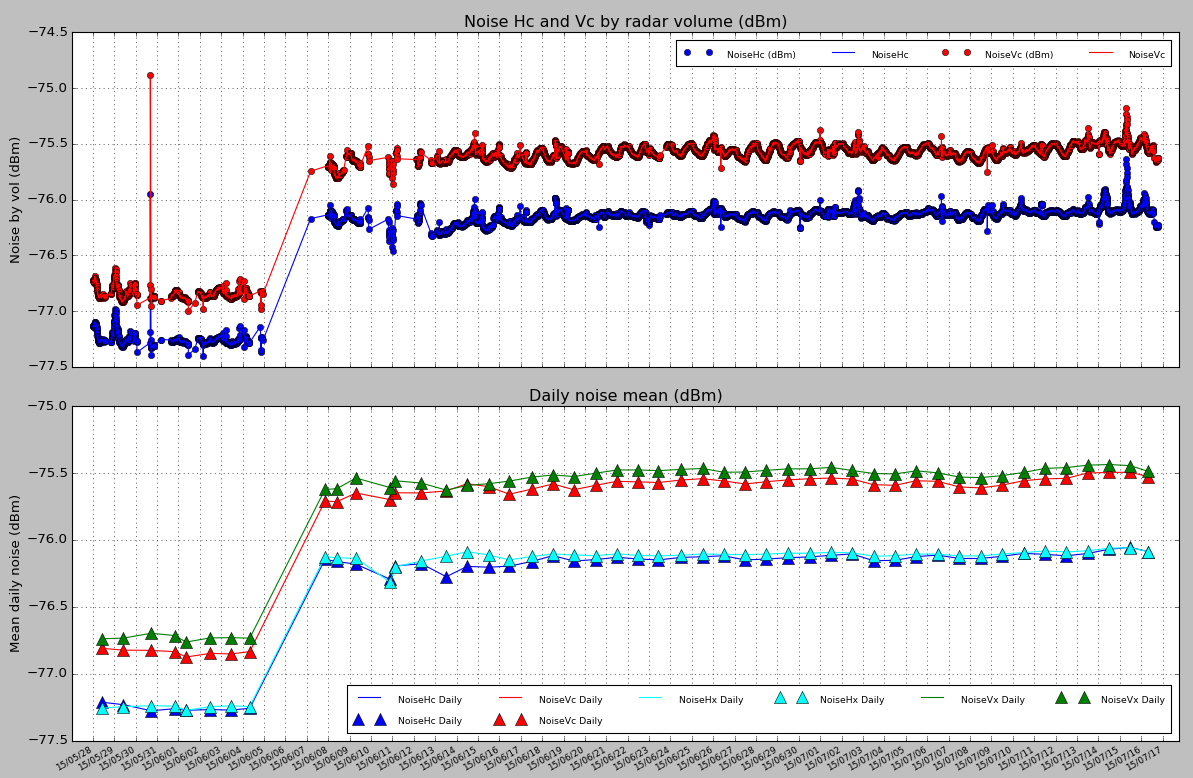


Figure 4: Receiver noise powers computed from the radar moments

During the QC analysis, we computed the receiver noise powers for each of the 4 channels: HC – horizontal channel co-polar; VC – vertical channel co-polar; HX – horizontal channel cross-polar; VX – vertical channel cross-polar.

The noise powers are reasonably constant throughout the project, indicating that the receiver was stable. The change in noise power from June 6 to June 8 corresponds to the change from a 1.5 to a 1.0 microsecond pulse, and shows a difference of about 1.1 dB. The is due to a smaller receiver bandwidth when using a 1.5 microsecond pulse.

## Sun monitoring using sun scans

Solar scans – sector box scans across the sun – were carried out routinely through the project, when possible.

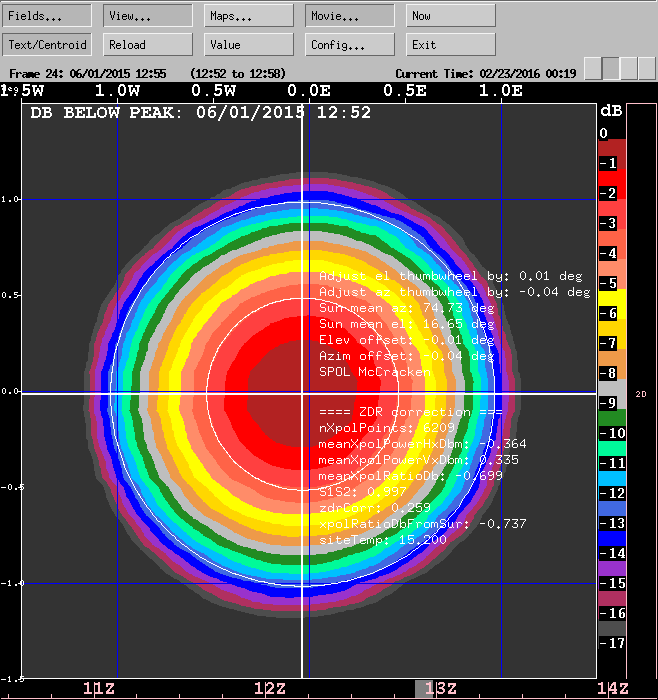
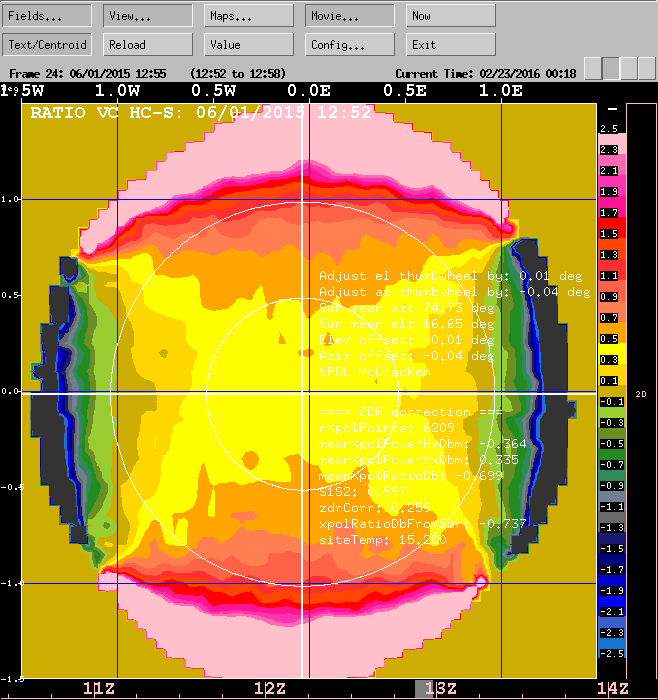


Figure 5a: Results from example sun box scan, 2015/06/01 12:52 UTC.

Left: Power (dB) below solar peak power. Right: Ratio of Vc/Hc power (dB), i.e. solar Zdr pattern.

These solar scans have 3 purposes:

1. To check the antenna angle alignment. The white cross shows the actual sun position, while the blue grid shows the idea sun position.
2. To compute the Zdr bias using the cross-polar power method in combination with the solar scans.
3. To check the reflectivity calibration and/or the receiver gain stability.

As can be seen from the figure, the antenna alignment was good – the alignment error remained below 0.04 degrees for the duration of the project.

The inner white circle is at 1 degree from the center, and the outer white circle at 2 degrees.

The Zdr pattern (Figure 5a right above) shows a gradient, especially outside the 1-degree circle. This is the result of a mismatch in the beam shape between the horizontal and vertical channels – see figure 5b below. The horizontal channel shape is quite circular, while the vertical channel shape is stretched in the vertical sense.

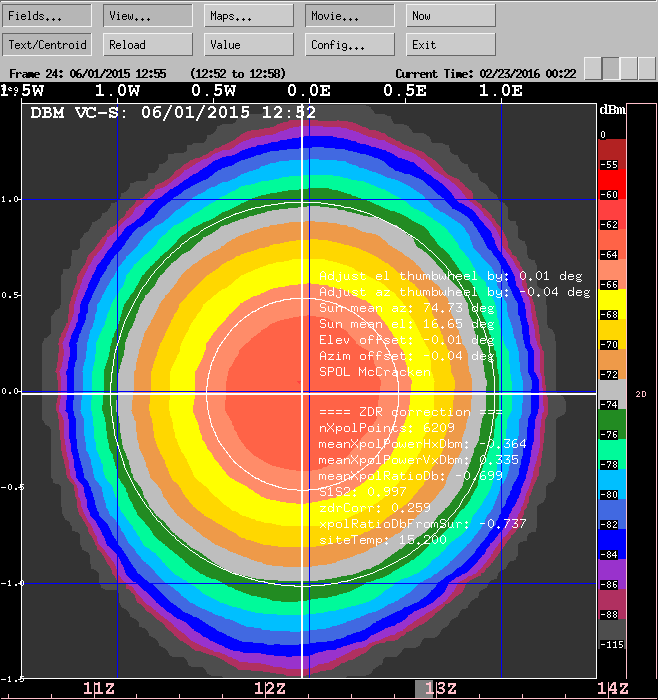
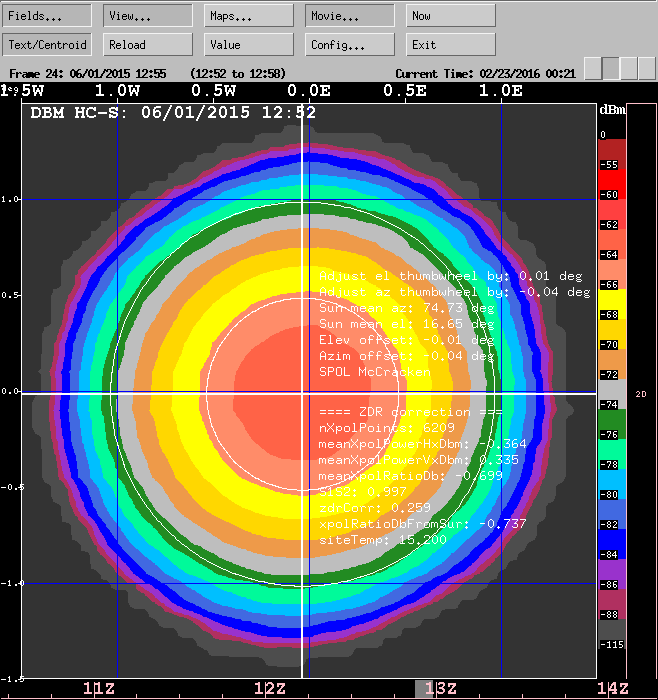


Figure 5b: Sun box scan, 2015/06/01 12:52 UTC.

Left: Horizontal polarization co-polar power (dB). Right: Vertical polarization co-polar power (dB).