SMART-R during DYNAMO: A Technique to Diagnose Elevation Angle Errors

Robert A. Rilling and Courtney Schumacher
National Center for Atmospheric Research / Texas A & M University

The Problem

Mobile and transportable radars are increasingly in use for observations during field experiments. These radars can be quickly moved to regions of interest, and sometimes even operated while in motion. Not all mobile radars are fitted with automatic systems for platform leveling. Additionally, limited options for site selection and preparation can result in a shift of the platform during operation.

During DYNAMO, SMART-R (the Shared Mobile Atmospheric Research and Teaching Radar) experienced off-level issues while operating on a sandy spit, largely surrounded by water (Fliegel, 2011). During post-field analysis, the DYNAMO radar community also found a SMART-R elevation angle bias.

Possible Approaches

• Off-level problems found in azimuthally dependent echo top heights
• Elevation bias found via statistical comparison of echo tops and direct comparison of shallow echoes between SMART-R and nearby S-Pol

Above methods require information from another radar or long-term integration of project data. Neither approach has the potential to provide an accurate time-history of change in the off-level or an accurate determination of elevation bias and whether the bias was constant with elevation.

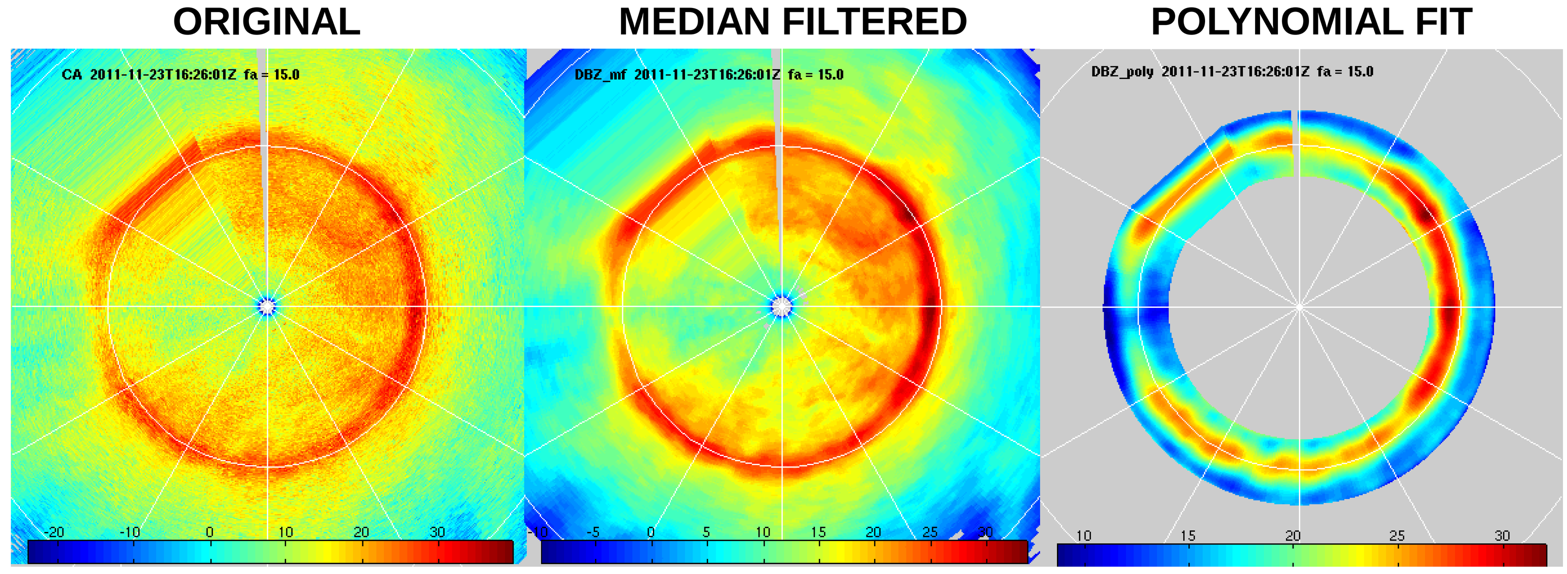
Careful analysis of bright band has the potential to overcome these limitations.

Analysis can be performed on a single scan volume. For constant elevation angle scanning, the bright band appears as a circle of high reflectivity, with that circle centered on the radar (this assumes that there is no actual tilt to the atmospheric melting level). As the radar elevation angle increases, the apparent diameter of the circle decreases. If the radar platform is off-level, the bright band becomes slightly elliptical, and the ellipse is no longer centered on the radar.

An Example

Data are first smoothed, then windowed, and a polynomial fitted to the remaining data. Note that the smeared beams to the NW are an artifact caused by a blanked sector.

ORIGINAL **MEDIAN FILTERED** **POLYNOMIAL FIT**



Procedure

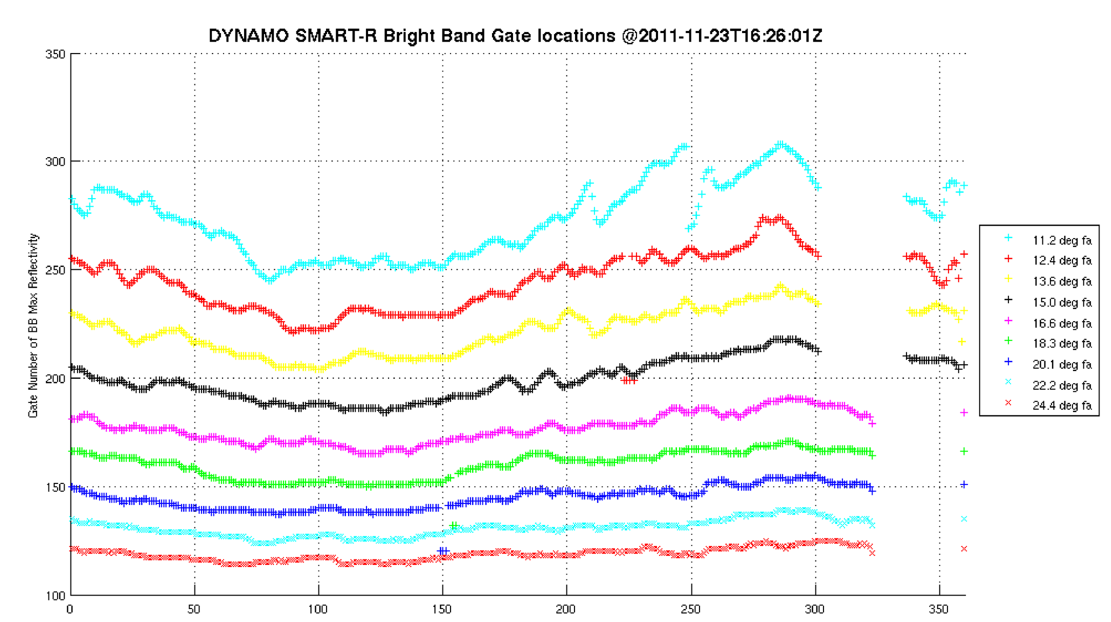
- Periods of circular bright band (BB) at high elevation tilts were found (23 November, 24 October, and 21 December 2011 were best cases)
- BB height carefully estimated using nearby S-Pol RHI scans
- Reflectivity data for high (>11°) SMART-R PPI scans windowed for BB
- SMART-R data smoothed using a 5x5 (azimuth x range) median filter
- Polynomial fit made to reflectivity data through the BB for each radial, and the gate of maximum reflectivity determined as a function of azimuth
- Using the azimuthally-dependent range to the center of the BB, along with the S-Pol determined (or an estimated) BB height, apparent elevation angles to the BB were found
- Original, uncorrected elevation angles compared to apparent elevation angles, and a true correction to the original elevation angle computed

Last step assumes the following error equation applies for each elevation scan:

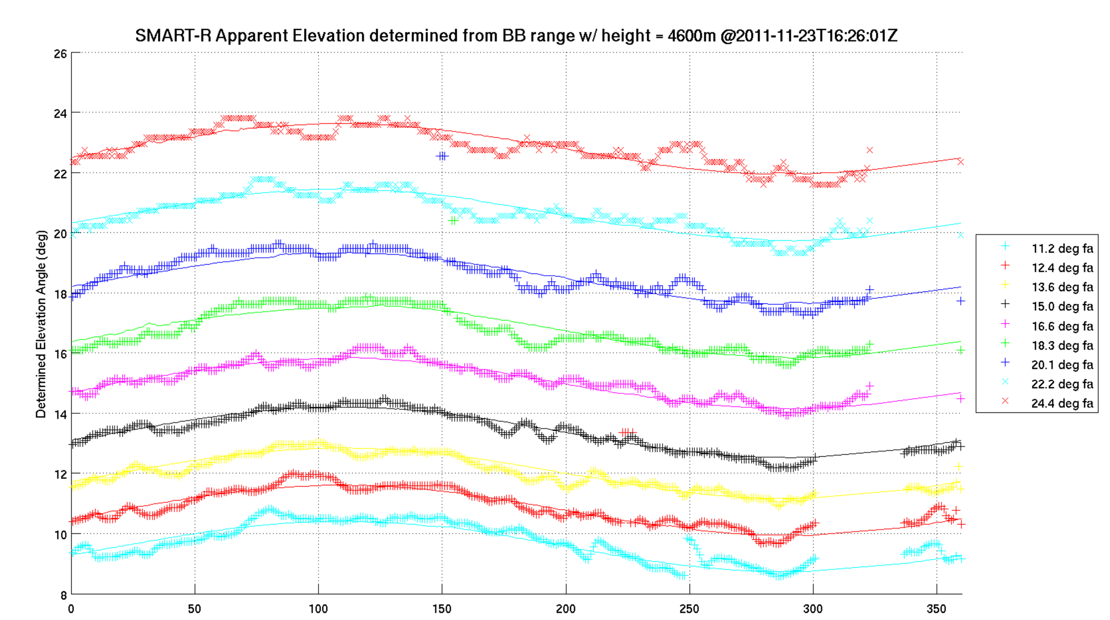
$$E_{error} = E_{apparent} - E_{original} = b1 * \cos(\text{azimuth} - b2) + b3$$

E is an elevation angle
b1 is the amplitude of the off-level angle
b2 is the direction of maximum off-level
b3 is the elevation bias

Analysis (for 23-Nov-2011)



Gate locations of BB as determined from smoothed and fitted reflectivity data. Scans used range from 11 to 24 degrees elevation.



Apparent elevation angle of BB, determined from BB range (previous plot) and known or approximated BB height. The lighter, smoothed line shows the line of best fit after outliers are removed.

Best-fit Information (BB Analysis for 20111123 ~16:34Z)

for bb_height = 4700 m

	b1	b2	b3
11.2 deg	0.8709	295.0518	1.2802
12.4 deg	0.8455	289.5133	1.2881
13.6 deg	0.8205	288.7979	1.3508
15.0 deg	0.9352	291.9410	1.3136
16.6 deg	0.8295	293.9027	1.1703
18.3 deg	0.8892	287.2169	1.2145
20.1 deg	0.9263	282.3572	1.0958
22.2 deg	0.8017	288.6839	1.1158
24.4 deg	0.8177	286.8654	1.0706
std_dev	.049		.103
All deg	0.8566	289.5471	1.2122

for bb_height = 4600m

	b1	b2	b3
11.2 deg	0.8558	294.8698	1.4945
12.4 deg	0.8270	289.5095	1.5259
13.6 deg	0.8022	288.7967	1.6146
15.0 deg	0.9142	291.9444	1.6086
16.6 deg	0.8107	293.9040	1.5053
18.3 deg	0.8683	287.1575	1.5879
20.1 deg	0.9044	282.3622	1.5136
22.2 deg	0.7820	288.6845	1.5839
24.4 deg	0.7726	287.6103	1.5777
std_dev	.051		.047
All deg	0.8359	289.4705	1.5574

The analysis for BB height = 4600 m shows the smallest standard deviation in b3, and is therefore considered the better estimate.

Conclusions

Analysis of three cases produces the following aggregate equation:

$$E_{corrected} = E_{orig} - [\, 0.78 * \cos(\text{azimuth} - 283) + 1.5 \,]$$

With the exception of the bias term, this compares extremely closely to the original Fliegel equation of:

$$E_{corrected} = E_{orig} - [\, 0.75 * \cos(\text{azimuth} - 285) \,]$$

It is furthermore concluded that the elevation bias does not change with a change in elevation angle. There is insufficient evidence to firmly conclude that the correction coefficients changed over the course of the deployment.

Recent physical measurements of the SMART-R mounting configuration closely confirm the size of the elevation bias (C. Schumacher and class, Texas A&M University, 7/2013)

A Note on Reflectivity Calibration of SMART-R

Initial reflectivity comparisons to TRMM PR and nearby S-Pol showed that SMART-R was "running hot" by 8 dB. Since we have concluded that SMART-R was pointing high by 1.5°, another reflectivity comparison must be performed. Initial, unpublished results by the authors indicate that the original 8 dB correction should only be approximately 4 dB (this work will be continued).

Acknowledgments

Many individuals contributed directly and indirectly to this work. We'd particularly like to thank our funding agencies, the US National Science Foundation and the Japan Agency for Marine-Earth Science and Technology. Any opinions, findings, conclusions, or recommendations are those of the authors, and do not necessarily reflect the views of the sponsoring agencies.

References

Fliegel, J.M., 2011: Quality control and census of SMART-R observations from the DYNAMO/CINDY2011 field campaign. Thesis, Office of Graduate Studies of Texas A&M University.

Contact Info: R. A. Rilling, rilling@ucar.edu
C. Schumacher, cschu@tamu.edu

AMS 36th Conference on Radar Meteorology, 16-20 September 2013, Breckenridge, CO