SMART-R Data set DYNAMO/CINDY 2011

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1.0 DATA SET OVERVIEW

Time Period: 2 OCT 2011 - 9 FEB 2012
Located on Addu Atoll, Maldives
LAT: 0.60752 S
LON: 73.09575 E

2.0 INSTRUMENT DESCRIPTION

SMART-R is a truck-mounted C-band, Doppler radar. The radar is on a diesel International 4700 4x2 flatbed truck with an extended cab, which houses the controls for the radar and onboard computers. The antenna is an 8' diameter solid parabolic reflector with shock-mounted center feed horn and radio frequency absorbing struts. It provides a 1.5 degree beam width and approximately 40 dB gain. The transmitter has 250kW peak power and four selectable pulse durations from 0.2 - 2.0 microseconds. It has a duty cycle of 0.001 and a selectable PRF of 300 - 3000 Hz. It has horizontal polarization and a solid-state high voltage power supply and modulator. The processer is a digital SIGMET RVP-8 signal processor with a selectable clutter filter, gate spacing, multiple PRF velocity dealising, and multiple quality control thresholds. Data collected is stored locally on a Linux hard drive until it can be transferred to other media such as a DVD or external hard drive. Other SMART-R specifications can be found in Table 1. Please refer to Biggerstaff et al. (2005) for more information on SMART-R.

Table 1:SMART-R Characteristics. From Biggerstaff et al. (2005).

SMART-R Characteristics	
Subsystem	**Description**
Transmitter	Frequency 5635 MHz
Type	Magnetron; solid-state modulator and high voltage power supply
Peak power	250 kW
Duty cycle	0.001
Pulse duration	Four predefined values selectable from 0.2 to 2.0 μs
Polarization	Linear Horizontal
Antenna	2.54 m diameter solid parabolic reflector
Gain	40 dB (estimated)
Half-power beam	Circular, 1.5° wide
Rotation rate	Selectable from 0-33 deg s^{-1}
Elevation range	Selectable from 0°-90°
Operational modes	Pointing, full PPI, RHI, sector scans
Signal processor	SIGMET RVP8

3.0 DATA COLLECTION AND PROCESSING

a) Description of Collection Techniques

SMART-R operated on a 10-min scan cycle, starting at minute 0, 10, 20… of every hour, for six total scan cycles per hour. Three range-height indicator (RHI) scans out to 100 km directed over the DOE second ARM mobile facility (AMF2) site at Gan International Airport were performed at the beginning of each 10-min cycle at azimuth angles 146°, 147°, and 148°, with elevation angles up to 60° (on 21 Nov 2011 at 1030 UTC, RHI scans were changed to 0°, 90°, and 147°). Following this, a surveillance scan was performed at a 0.5° elevation out to 300 km. At about two and six minutes after the beginning of each 10-min cycle, a full volume scan of 13 elevation angles was performed out to 150 km (Volumes A and B); the two scans were then interleaved to create a single merged volume scan for each 10-min period. Table 2 specifies angles for the full volume scans and other aspects of the SMART-R scan strategy.

Table 2 : SMART-R scan strategy.

Scan Type	Pulse Duration (μs)	Gate Length (m)	PRF (Hz)	Nyquist Velocity (m/s)	Rotation Speed (°/s)	Max Range (km)	Elevation Angle (°)
RHI	0.6	100	1500	20	12	100	0-60
SURV	1.5	125	500	6.7	18	300	0.5
VOL	0.6	100	1000	13.3	24	150	See Below
	Volume Scan Elevation Angles (°)						
VOL A	0.5, 1.0, 2.3, 3.6, 5.2, 7.0, 9.0, 11.2, 13.6, 16.6, 20.1, 24.4, 29.5						
VOL B	0.5, 1.6, 2.9, 4.4, 6.1, 8.0, 10.1, 12.4, 15.0, 18.3, 22.2, 26.8, 33.0						

b) Description of Processing Techniques and Quality Control

The IRIS software used by SMART-R creates raw SIGMET files for each RHI, surveillance, and full volume scan (separate files for Volume A and Volume B). The raw files are created in polar coordinates. Besides using NCAR's REORDER to convert surveillance scans into Cartesian coordinates, no other processing was done on the surveillance or RHI files, including any form of quality control.

To process the full volume scans, the SIGMET files are first converted into Universal Format (UF) using the National Aeronautics and Space Administration's (NASA) Radar Software Library (RSL). On occasion, a UF file cannot be created due to a corrupted RAW file; this is discussed in Section 5. Then, the two 4-min UF files per 10-min scan cycle are merged; the two 13-tilt volume scans are combined to form one 26-tilt for each 10-min cycle (the 0.5° occurs in both scans). In the event that one or both UF files are not created, either because SMART-R was turned off or a corrupted RAW file was created, no UFMERGE file will be created for that time period.

Once UFMERGE files are created, they are run through a quality control algorithm (Houze et al. 2004). The algorithm has Signal Quality Index (SQI) filters set at 0.2 below 4 km and 0.1 at and above 4 km to further remove noise and second-trip echo. Also included in the quality control adjustment is a calibration correction. SMART-R ran hot compared to S-PolKa, and a comparison with TRMM PR data revealed an offset of approximately 8 dB. Following the quality control algorithm, reflectivity data is corrected for attenuation using a routine based off of code provided by Colorado State University (CSU). This corrects artificially low reflectivity values that result from beam power loss after the beam goes through a region of high reflectivity.

It became clear during preliminary processing runs of the data that SMART-R had an apparent tilt. Given the direction of the tilt, it was most likely the front left tire that sank. Following the attenuation correction, the apparent tilt is corrected for by using a version of NCAR's Radx software developed by Mike Dixon. It employs user-defined inputs for the direction and the degree of the tilt and corrects the data in a similar way that aircraft radar data is corrected using pitch and roll information.

A subjective value of 285° was selected as the direction of the tilt based on echo top maps. Tuning of the degree of tilt resulted in an average value of 0.75°. While it appears the degree of tilt increased from October through February, it was not a significant change and thus a constant correction was selected.

The penultimate stage of raw to NETCDF processing interpolates the files from polar to Cartesian coordinates using NCAR's REORDER. The result is a three-dimensional NETCDF file with 2-km horizontal resolution and 0.5-km vertical resolution. The radius of influence is set to 1.5 km in the horizontal directions and 1.2 km in the vertical direction. There are 40 vertical levels, ranging from a 0.5 km constant altitude planned position indicator (CAPPI), up to a 20 km CAPPI.

Lastly, SQI filtering is performed again. During the conversion to Cartesian coordinates, some of the fields get blended onto nearby points resulting in some false echo reappearing; thus a second round of SQI filtering is necessary. The filters are set at 0.225 at and below 5 km, and 0.15 above 5 km. These values are set slightly higher than those used during the quality control algorithm because of the transformed coordinate system

4.0 DATA FORMAT

Raw Data: Raw folder separated by date
filename: SR1yymmddhhmmss.RAW****
Contains all raw data collected during campaign, including times when SMART-R was not radiating or files were corrupted.

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CDF3D.tar - Tar of all CDF3D SMART-R data placed into date directories.
file name: ddop.1yymmdd.hhmmss.cdf

SMART-R merged volume scans on a Cartesian grid. Grid spacing is 2km x 2km x 0.5 km. There are 40 vertical levels from 0.5 km to 20 km. These files have undergone a -8 dB calibration correction, quality control filtering, attenuation correction, and tilt correction. The tilt was corrected 0.75 degrees towards azimuth 285°. Data ranges From 2 OCT 2011 through 9 FEB 2012. Data from 2 OCT 2011 through 27 OCT 2011 have significant second trip echo that was not removed as SQI was not being saved at the time.

Fields:
CZ: Corrected Reflectivity (dBz)
VR: Radial Velocity (m/s)

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CDF-surv.tar - Tar of all surveillance scans placed into date directories.
filename: ddop.1yymmdd.hhmmss.cdf

Surveillance scans on a Cartesian grid out to 300 km placed into date directories. Directory CDFsurvofbadCDF contains surveillance scans for instances where there is no corresponding CDF3D file. **NO QUALITY CONTROL HAS BEEN PERFORMED ON ANY THESE FILES.**

Fields:
DZ: Reflectivity (dBz)
VR: Radial Velocity

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SMARTRuf.tar – Tar of SMART-R merged volume scans in uf format.
filename: SR1yymmddhhmmss.uf

These files have undergone an -8 dB calibration correction, quality control filtering, attenuation correction, and tilt correction. The tilt was corrected 0.75 degrees towards azimuth 285°. Data ranges from 2 OCT 2011 through 9 FEB 2012. Data from 2 OCT 2011 through 27 OCT 2011 have significant second trip echo that was not removed as SQI was not being saved at the time.

All fields corrected for tilt
VR: Radial Velocity
CZ: Reflectivity following calibration and quality control algorithm
CA: Reflectivity following attenuation correction
CA field is most corrected reflectivity Field for UF files. Use this for analysis.

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Products – All in NETCDF format
The following files come from the processing completed on 26 June 2012. Data is on a 151x151x1 grid and at z=3.0 km for CONVSF and RAIN files. For data from 2 OCT 2011 through 27 OCT 2011, the surveillance scan VR field was used as a mask to remove second trip echo from the data set.

CZ field from CDF3D files is reflectivity used to create these files. This is the final corrected reflectivity field. This CZ field in not the same CZ field in UF files.

ECHOTOPS
echotop.tar
ECHOTOPS - Contains echotop height data for each scan. z-spacing = 0.5 km

filename: echotop_yymmdd.hhmmss.cdf

Fields:
dBz10 - Height data using a 10 dBz threshold
dBz20 - Height data using a 20 dBz threshold
dBz30 - Height data using a 30 dBz threshold
dBz40 - Height data using a 40 dBz threshold

Convective/Stratiform Separations
For convective/stratiform separations:
0 = no rain
1 = stratiform rain
2 = convective rain
3 = weak echo (will be classified as 0)

convsf.tar
CONVSF - Contains convective/stratiform separation using Steiner et al. (1995) algorithm for each scan.
filename: convsf_yymmdd.hhmmss.cdf

Fields:
convsf : convective/stratiform separation

convsf3d.tar
filename: convsf_3d_yymmdd.hhmmss.cdf

CONVSF3D - Contains convective/stratiform separation using Steiner et al. (1995) algorithm followed by a separation using echotop height data for each scan. This algorithm attempts to capture more shallow, isolated convection that was classified as stratiform in the Steiner et al. (1995) algorithm.

Fields:
convsf3d : 3d convective/stratiform separation

RAINRATES
rainrate.tar
RAIN - Contains rainrate data and reflectivity(CZ) for each scan
filename: rainrate_yymmdd.hhmmss.cdf

Fields:
rainr : rainrate
reflectivity : reflectivity

convsf_rain.tar
RAINCONVSF - Contains convective/stratiform rainrate data for each scan.
filename: convsf_rain_yymmdd.hhmmss.cdf

Fields:
rainr : rainrate
strat : rainrate of only stratiform portions as defined using Steiner et al.
conv : rainrate of only convective portions as defined using Steiner et al.
rainr3d : rainrate (should be same as rainr)
strat3d : rainrate of only straiform portions as defined by 3d conv/strat separation
conv3d : rainrate of only convective portions as defined by 3d conv/strat separation

convsf_rain_1hr.tar
RAINCONVSF1HR - Contains hourly rainrate data. Adds together indivdual scans when enough are available in a given hour
filename: convsf_1hr_yymmdd.hh.cdf

Fields:
rainr_add : hourly rainrate
strat_add : hourly rainrate of only stratiform portions as defined using Steiner et al.
conv_add : hourly rainrate of only convective portions as defined using Steiner et al.
rainr3d_add : hourly rainrate (should be same as rainr)
strat3d_add : hourly rainrate of only straiform portions as defined by 3d conv/strat separation
conv3d_add : hourly rainrate of only convective portions as defined by 3d conv/strat separation

convsf_rain_24hr.tar
RAINCONVSF24HR - Contains daily data by adding together hourly data
filename: convsf_24hr_yymmdd.cdf

Fields:
rainr_add_24hr : daily rainrate
strat_add_24hr : daily rainrate of only stratiform portions as defined using Steiner et al.
conv_add_24hr : daily rainrate of only convective portions as defined using Steiner et al.
rainr3d_add_24hr : daily rainrate (should be same as rainr)
strat3d_add_24hr : daily rainrate of only straiform portions as defined by 3d conv/strat separation
conv3d_add_24hr : daily rainrate of only convective portions as defined by 3d conv/strat separation

NOTE: Hourly data will not be created if too many scans are missing in a particular hour, and daily data is created from the hourly files. Therefore, adding together individual files for a day, may result in a slightly different result than using the daily file.

5.0 DATA REMARKS

a) Data Quality

Due to blockage from a tree line to the west of SMART-R, most of the low-level data in that direction is generally not useful. A good 180 degree mask to use for the data is to only include data from azimuth 338-158 degrees in the clockwise direction. No mask has been applied to any of the data supplied here.

As stated above, only full volume scans have under gone quality control processes to 'clean' the data. The volume scans still have a few elements of anomalous propagation from the atoll to the north of Addu, mostly in the month of January, but this appears to have a negligible affect on the data.

b) Missing Data

SMART-R was shut down for routine maintenance every other week, which included an oil change. Table 3 lists planned shutdowns of SMART-R during the campaign.

SMART-R had instances when it stopped radiating. These instances are listed in Table 4. Raw files created during non-radiating periods are still in the 'raw' data set, but further processing was not done on these files.

On occasion, a UF file cannot be created due to a corrupted raw. These instances are listed in Table 5. Corrupted raw files are still in the 'raw' data set, but further processing was not done on these files

Table 3: Planned shutdowns for SMART-R.

Planned Shutdowns of SMART-R			
Date	Time	Missed Merged Files	Notes
2 Oct 2011	0530-0559	4	Communications Maintenance
6 Oct 2011	0440-0459	2	Drifting Clock Reset
13 Oct 2011	0410-0429	2	Drifting Clock Reset
15 Oct 2011	0540-0649	7	Oil Change
29 Oct 2011	0900-0939	4	Oil Change
12 Nov 2011	1002-1109	7	Oil Change
21 Nov 2011	1050	1	Scan Strategy Edit
26 Nov 2011	1020-1215	12	Oil Change
11 Dec 2011	0840-1006	9	Oil Change
25 Dec 2011	0800-1219	26	Oil Change / RVP8 Issue
29 Dec 2011	0612-0639	3	RVP8 Testing
8 Jan 2012	0851-0939	5	Oil Change
8 Jan 2012	1731-2359	40	Generator Issue
9 Jan 2012	0000-0939	58	Generator Issue
13 Jan 2012	0521-0739	14	Low Fuel
15 Jan 2012	0956-1030	4	Software Issue
22 Jan 2012	1051-1149	6	Oil Change
6 Feb 2012	0900-1009	7	Oil Change

Table 4: Occurrences when SMART-R stopped radiating in addition to the planned shutdowns in Table 3.

Occurrences when SMART-R stopped Radiating			
Date	Time	Missed Merged Files	Notes
6 Oct 2011	1700-2359	42	Continued into 7 Oct 2011
7 Oct 2011	0000-0339	22	
19 Nov 2011	0400-0439	4	
8 Dec 2011	1920-2119	12	
14 Dec 2011	1600-1829	15	
7 Jan 2012	1600-1839	16	
8 Jan 2012	0341-0719	22	
8 Jan 2012	1351-1719	21	

Table 5: Corrupted SMART-R raw files causing UF (and NETCDF) files to not be produced for that timestamp.

Corrupted Files			
Date	Time	Missed Merged Files	Notes
2 Oct 2011	1951	1	
3 Oct 2011	0025, 0141, 0352, 1835, 2235	5	
4 Oct 2011	0301, 0515	2	
23 Oct 2011	0355, 1835	2	
26 Oct 2011	0235	1	
28 Oct 2011	0251, 1321, 2205	3	
30 Oct 2011	0301, 0331, 1615	3	
31 Oct 2011	0301	1	
1 Nov 2011	0135, 0231, 0335, 0941, 1001, 1015, 1021, 1045, 1051, 1055, 1151, 1201, 1205, 1221, 1231, 1251, 1255, 2105	15	18 total 'bad' UF files but some occurred in same 10-min period resulting in only 15 Missed Merged Files
2 Nov 2011	1815, 2245	2	
3 Nov 2011	0111, 0251, 1131	3	
7 Nov 2011	1841, 2041	2	
8 Nov 2011	0111, 0335, 0451, 1556	4	
9 Nov 2011	1735	1	
10 Nov 2011	1231, 1241, 1251	3	
16 Dec 2011	0521	1	
22 Dec 2011	0701	1	
26 Dec 2011	0431	1	
3 Feb 2011	1425	1	
4 Feb 2012	1341	1	
7 Feb 2012	0001, 1255, 1355	3	

c) Final full volume data set

Table 6 lists the number of full volume NETCDF files created for each UTC day. A day with no errors or shutdown will have 144 files. Overall, SMART-R had a 97.8% collection rate for full volume scans.

Table 6: Number of NETCDF files created by UTC date. A day with no interruptions will have 144 files.

Date	Files	Date	Files	Date	Files	Date	Files
2 Oct	139	4 Nov	144	7 Dec	144	9 Jan	86
3 Oct	139	5 Nov	144	8 Dec	132	10 Jan	144
4 Oct	142	6 Nov	144	9 Dec	144	11 Jan	144
5 Oct	144	7 Nov	142	10 Dec	144	12 Jan	144
6 Oct	100	8 Nov	140	11 Dec	135	13 Jan	140
7 Oct	122	9 Nov	143	12 Dec	144	14 Jan	144
8 Oct	144	10 Nov	141	13 Dec	144	15 Jan	140
9 Oct	144	11 Nov	144	14 Dec	129	16 Jan	144
10 Oct	144	12 Nov	137	15 Dec	144	17 Jan	144
11 Oct	144	13 Nov	144	16 Dec	143	18 Jan	144
12 Oct	144	14 Nov	144	17 Dec	144	19 Jan	144
13 Oct	142	15 Nov	144	18 Dec	144	20 Jan	144
14 Oct	144	16 Nov	144	19 Dec	144	21 Jan	144
15 Oct	137	17 Nov	144	20 Dec	144	22 Jan	138
16 Oct	144	18 Nov	144	21 Dec	144	23 Jan	144
17 Oct	144	19 Nov	140	22 Dec	143	24 Jan	144
18 Oct	144	20 Nov	144	23 Dec	144	25 Jan	144
19 Oct	144	21 Nov	143	24 Dec	144	26 Jan	144
20 Oct	144	22 Nov	144	25 Dec	118	27 Jan	144
21 Oct	144	23 Nov	144	26 Dec	143	28 Jan	144
22 Oct	144	24 Nov	144	27 Dec	144	29 Jan	144
23 Oct	142	25 Nov	144	28 Dec	144	30 Jan	144
24 Oct	144	26 Nov	132	29 Dec	141	31 Jan	144
25 Oct	144	27 Nov	144	30 Dec	144	1 Feb	144
26 Oct	143	28 Nov	144	31 Dec	144	2 Feb	144
27 Oct	144	29 Nov	144	1 Jan	144	3 Feb	143
28 Oct	141	30 Nov	144	2 Jan	144	4 Feb	143
29 Oct	140	1 Dec	144	3 Jan	144	5 Feb	144
30 Oct	141	2 Dec	144	4 Jan	144	6 Feb	137
31 Oct	143	3 Dec	144	5 Jan	144	7 Feb	141
1 Nov	129	4 Dec	144	6 Jan	144	8 Feb	144
2 Nov	142	5 Dec	144	7 Jan	128	9 Feb	144
3 Nov	141	6 Dec	144	8 Jan	56		

6.0 LIST OF REFERENCES

Biggerstaff, M. I., et al., 2005: The Shared Mobile Atmospheric Research and Teaching Radar: A Collaboration to Enhance Research and Teaching. *Bulletin of the American Meteorological Society*, 1263-1274

Steiner, M., R. A. Houze, Jr., and S. E. Yuter, 1995: Climatological Characterizations of Three-Dimensional Storm Structure from Operational Radar and Rain Gauge Data. *Journal of Applied Meteorology*, **34**, 1978-2007