



Monitoring Z_{DR} bias & offset adjustments of new Canadian S-band radars

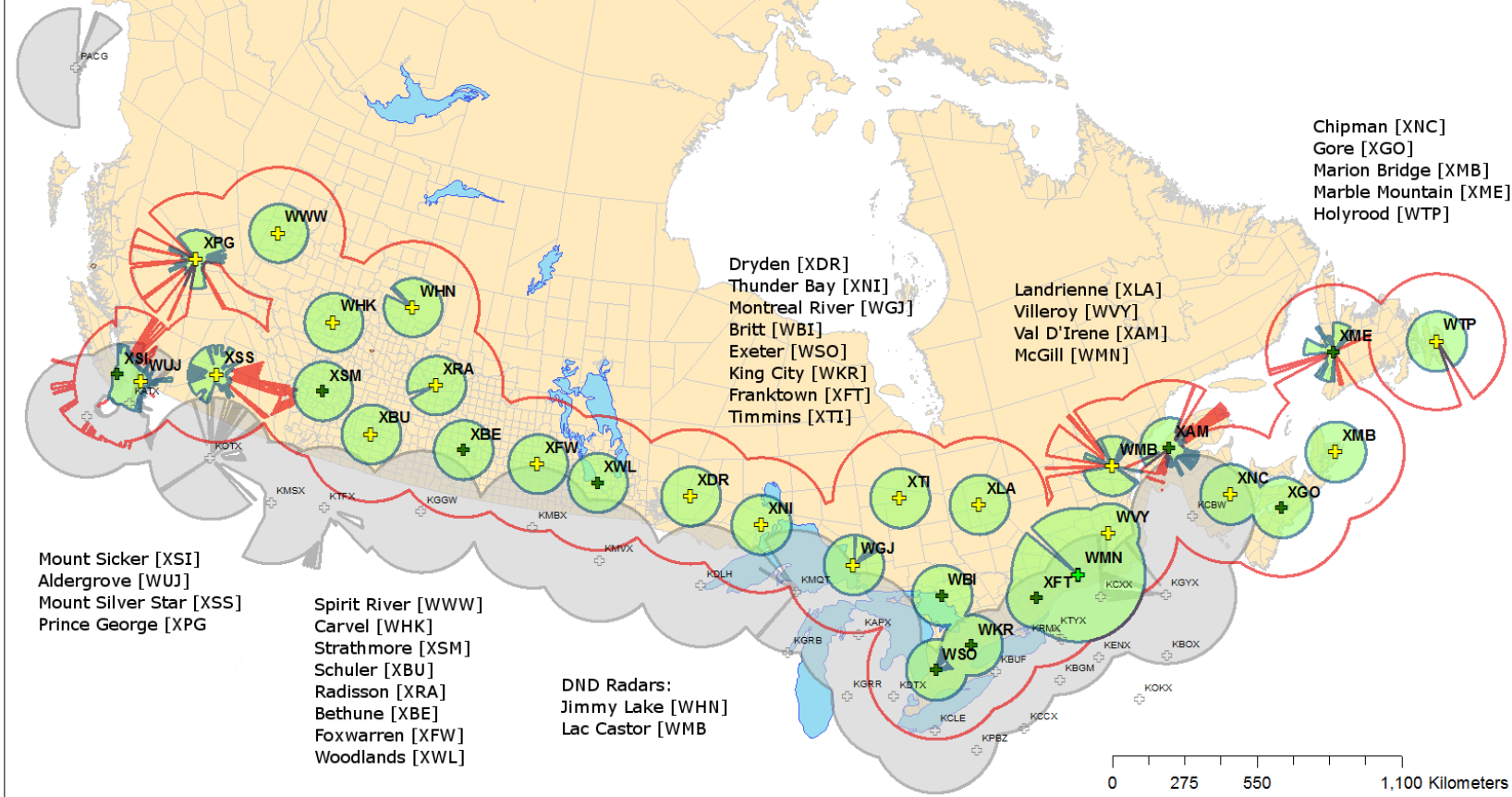
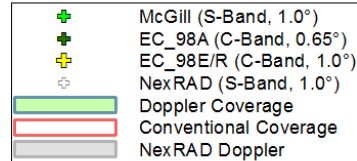
WXRCalMon 2021, Toulouse, France

November 18, 2021

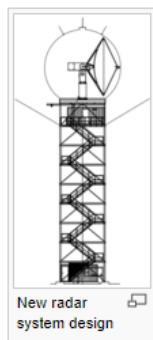
Stephen Holden, Daniel Michelson, Sudesh Boodoo,
Norman Donaldson, Peter Rodriguez,
Qian Li, Peter Leibiuk



Canadian Radar Network: pre-2016



Canadian S-Band Radar: Leonardo 1700S



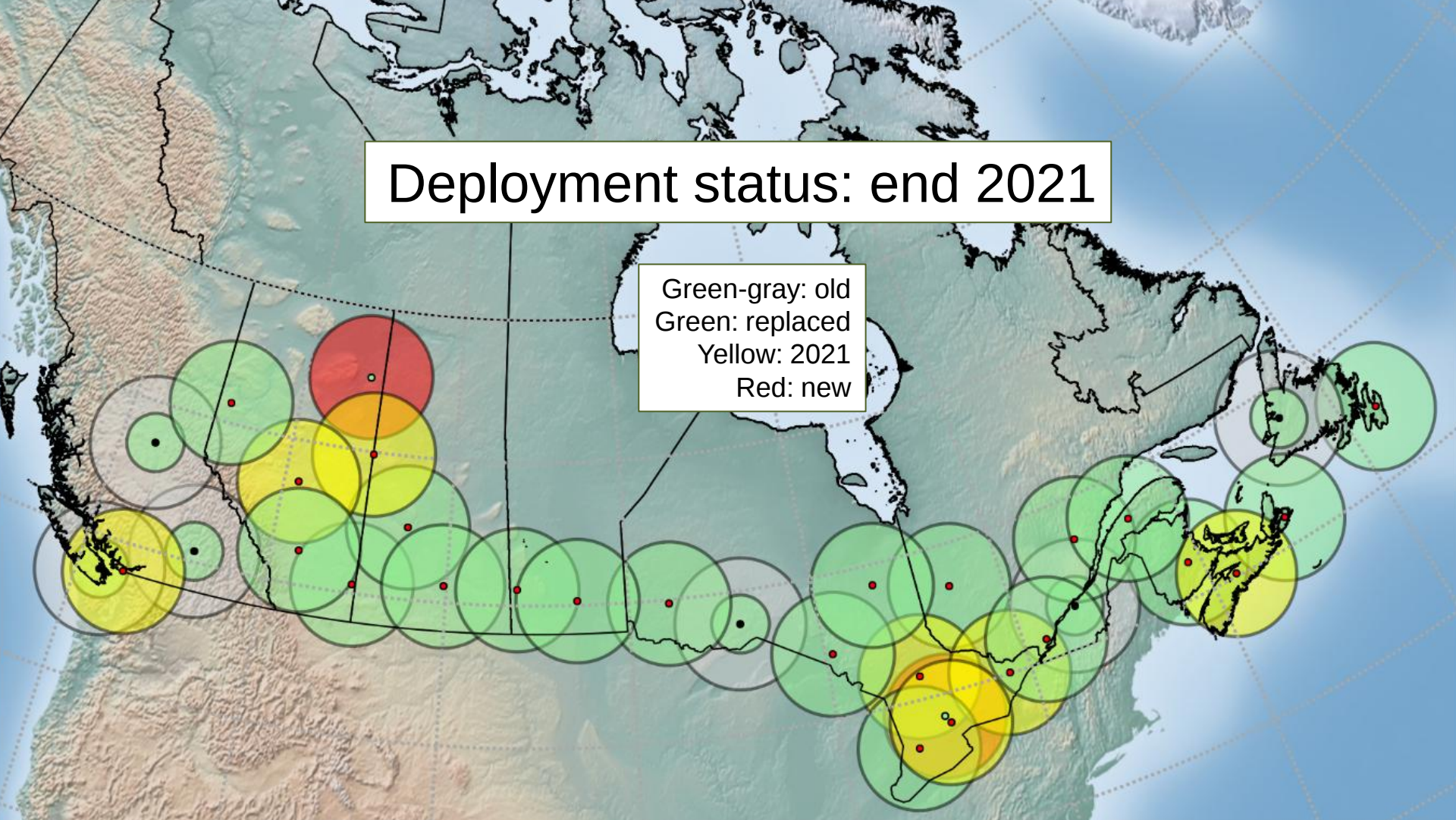
The new radars use Selex ES's operationally proven 1700S klystron radars, with enhanced sensitivity for winter severe weather. The main characteristics include:

- **Dual Polarization technology:** More information on the shape and fall mode of different kinds of hydrometeors, improved rain rate estimation, and overall data quality.
- **S-Band frequency:** Improved measurement precision at long ranges during heavy precipitation events.
- **240 km Doppler range:** 2x the current C-Band range.
- **Physical dimensions:** 9.15m parabolic antenna dish, 11.8m radome, Steel lattice tower (16-28m, site dependent).
- **Lower Operational Costs:** Reduction in scheduled maintenance frequency from 6/year to 2/year.
- **Enhanced Reliability:** Extensive lightning protection, built in system redundancy, remote calibration utilities.

	98A (Andrews)*	98E (Enterprise)	98R (Raytheon)	1700S (Selex)
<i>Operating Band</i>	C-band (5.6-5.65 GHz)			S-band (2.7-2.9 GHz)
<i>Antenna Diameter</i>	6.1 m	4.2 m	4.2 m	9.15 m
<i>Antenna Gain</i>	49.2 dB	43.0 dB	42.9 dB	45.8 dB
<i>Beam Width</i>	0.62°	1.1°	1.1°	0.88°
<i>Radome Diameter</i>	9.1 m	5.5 m	5.5 m	11.8 m
<i>Polarization</i>	Single Pol, H-only *King and Exeter Radars are Dual Pol			Dual Pol (H+V - STAR)
<i>Transmitter (Tx)</i>	Magnetron / 250 kW			Klystron / 1 MW
<i>Tx/Rx Location</i>	Ground level at base of tower			Below Radome
<i>Reflectivity Range (Typ.)</i>	250 km			300 km
<i>Doppler Range (@48m/s)</i>	120 km			250 km
<i>Receiver (Rx) Resolution</i>	12 or 14 bit			16 bit
<i>Min. Detectable Signal</i>	-107 to -115 dBm			-112 to -122 dBm
<i>Signal Processor</i>	RVP7/8			GDRX
<i>Operating System</i>	Linux			
<i>Monitoring Software</i>	BITEX - Radmon			RAVIS®
<i>Maintenance Interval</i>	6 / year			2 / year

Deployment status: end 2021

Green-gray: old
Green: replaced
Yellow: 2021
Red: new



Radar Data Processing: **BALTRAD** and **CARDS**

- CARDS is the operational “Canadian Radar Decision Support” software that processes raw radar data.
 - BALTRAD (github.com/baltrad) is open source “community-based weather radar networking” and data processing software, which we run in parallel for some additional products, e.g. for radar data assimilation.
 - Canada uses BALTRAD to detect and extract solar ‘hits’ from operational radar scans and use them to determine antenna pointing accuracy, power levels and their stability, and in estimating receive side Z_{DR} bias.
 - Methods developed by *Asko Huuskonen, Iwan Holleman* and co-authors
 - C code from *Iwan Holleman*
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LEONARDO™ Z_{DR} OFFSETS

- From Leonardo's "GDRX® Signal Processing User Manual" - Release 5.0
 - System Z_{DR} offsets are added to raw values to produce output data
 - Receiver offsets updated by system during fine raster scans
 - Transmitter offsets updated by system during calibration/maintenance
 - Birdbath offset automatically updated (if enabled) by a system script
 - Manual offset can be changed by end-users
 - $ZDR_{OFF}[dB] = ZDR_{SYS} + ZDR_{MAN} + ZDR_{BIRD_BATH}$
 - ZDR_{BIRD_BATH} is optional offset measured by script at 90° EL angle
 - ZDR_{MAN} is manual user adjustment
 - This is the value ECCC adjusts
 - ZDR_{SYS} = calculated/controlled offset from radar sub-systems
 - i.e. $ZDR_{SYS} = OFF_{TX_SYS} + OFF_{TX_MAN} + OFF_{RX_SYS} + OFF_{RX_MAN}$
-

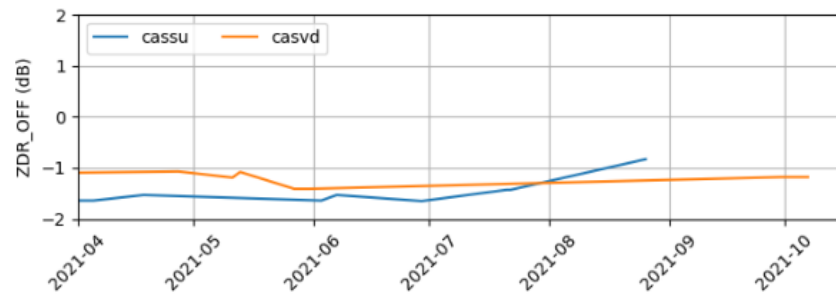
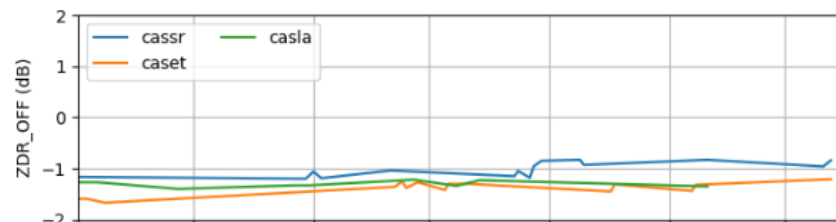
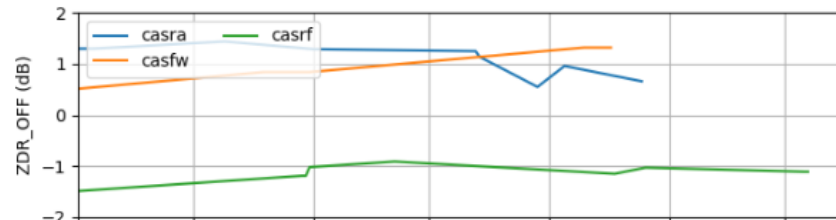
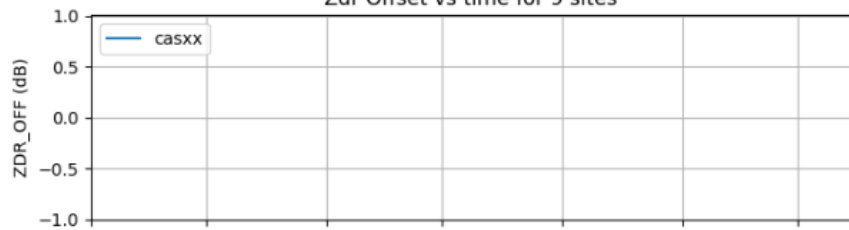
LEONARDO™ Z_{DR} SYSTEM OFFSETS

- System Z_{DR} offsets are captured from all radars into a central Analyst™ database, which we are able to access
 - We use Python code to connect to this central DB and extract all Z_{DR} Offsets in use at each individual radar
 - Data is only stored in database for up to 90 days
 - The current Z_{DR} offset values are copied locally to an Excel spreadsheet for several uses
 - We are able to independently plot Z_{DR} parameters to monitor changes over time (stability) and detect issues
 - Provides historical record of changes since the Analyst™ database flushes older data
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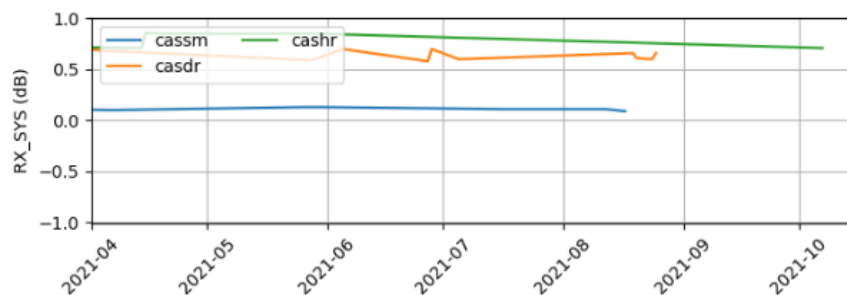
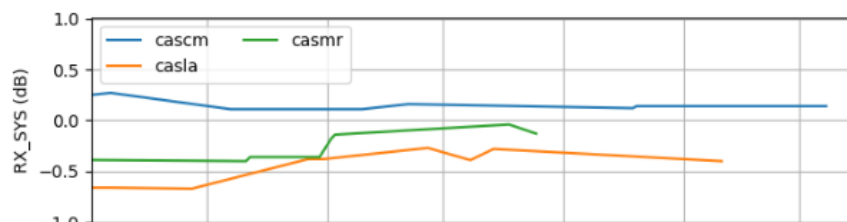
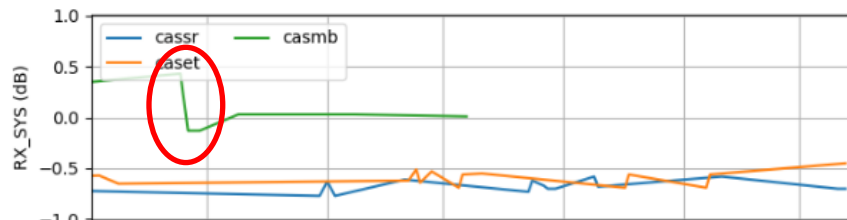
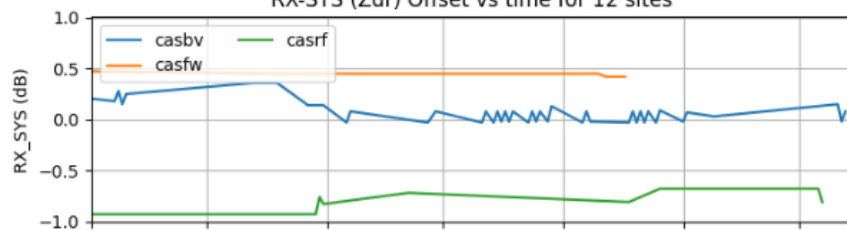
History of Z_{DR} System Offsets for Dryden S-Band Radar

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AC	AD	AF
1	CASDR (CAS-14)																													
2			ZDR Total Offset (Ravis)	ZDR(off)							ZDR Differences	OFFSET (TX_SYS)												Tx Cal Pwr (H)	Tx Cal Pwr (V)	Tx Cal Pwr (H)	Tx Cal Pwr (V)	TxPwr H-V	TxPwr H-V	Antenna Gain Diff.
3	Date	IQR			ZDR(sys)	OFF (TX_SYS)	OFF (TX_MAN)	OFF (RX_SYS)	OFF (RX_MAN)	ZDR(man)	ZDR(bird bath)		L(TX)h	P(TX)h	G(ANT)h	L(TX)v	P(TX)v	G(ANT)v						[kW]	[kW]	[dBm]	[dBm]	[kW]	[dB]	[dB]
4													[dB]	[dBm]	[dB]	[dB]	[dBm]	[dB]												
5	27-07-2020	Py-Analyst		0.08	0.08	0.08	0	0	0	0	0	-0.08000	0.008005	0.663	87.03	46.16	0.595	87.04	46.09					504.66	505.8	87.03	87.04	-1.164	-0.01	0.07
6	30-07-2020	Py-Analyst		0.87	0.874	0.08	0	0.69	0.104	0	0	-0.87000	0	0			0								0	0	0	0	0	0
7	07-08-2020	Py-Analyst		0.99	0.984	0.08	0	0.8	0.104	0	0	-0.99000	0	0			0								0	0	0	0	0	0
8	12-08-2020	Py-Analyst		0.81	0.814	0.08	0	0.63	0.104	0	0	-0.81000	0	0			0								0	0	0	0	0	0
9	22-08-2020	Py-Analyst		0.99	0.994	0.08	0	0.81	0.104	0	0	-0.99000	0	0			0								0	0	0	0	0	0
10	28-08-2020	Py-Analyst		0.89	0.894	0.08	0	0.71	0.104	0	0	-0.89000	0	0			0								0	0	0	0	0	0
11	29-08-2020	Py-Analyst		0.89	0.895	0.01	0	0.6	0.285	0	0	-0.89000	0	0			0								0	0	0	0	0	0
12	31-08-2020	Py-Analyst		1.03	1.035	0.01	0	0.74	0.285	0	0	-1.03000	0	0			0								0	0	0	0	0	0
13	01-09-2020	Py-Analyst		0.89	0.895	0.01	0	0.6	0.285	0	0	-0.89000	0	0			0								0	0	0	0	0	0
14	06-09-2020	Py-Analyst		1	0.995	0.01	0	0.7	0.285	0	0	-1.00000	0	0			0								0	0	0	0	0	0
15	Oct 1, 2020	lgr file	1.02	1.015	1.015	0.01	0	0.72	0.285	0	0	0.00000	0.008005	0.663	87.03	46.16	0.595	87.04	46.09					504.66	505.8	87.03	87.04	-1.164	-0.01	0.07
16	20-10-2020	Py-Analyst		0.89	0	0.01	0	0.6	0.285	0	0	0.00000	0	0			0								0	0	0	0	0	0
17	31-10-2020	Py-Analyst		1	0	0.01	0	0.71	0.285	0	0	0.00000	0	0			0								0	0	0	0	0	0
18	01-11-2020	43772		1	0	0.01	0	0.71	0.285	0	0	0.00000	0	0.663	0	46.16	0.595	0	46.09					504.66	505.8	0	0	0	0	0
19	06-11-2020	Py-Analyst		0.9	0	0.01	0	0.6	0.285	0	0	0.00000	0	0			0								0	0	0	0	0	0
20	17-11-2020	Qian		1	0	0.01	0	0.7	0.285	0	0	0.00000	0	0			0								0	0	0	0	0	0
21	28-11-2020	Py-Analyst		0.89	0	0.01	0	0.6	0.285	0	0	0.00000	0	0			0								0	0	0	0	0	0
22	27-11-2020	Py-Analyst		1	0	0.01	0	0.71	0.285	0	0	0.00000	0	0			0								0	0	0	0	0	0
23	2021-03-26	Py-Analyst		0.35	0	-0.01	0	0.71	0.285	-0.6	0	0.00000	0	0			0								0	0	0	0	0	0
24	2021-04-06	Qian		0.35	0	-0.01	0	0.68	0.285	-0.6	0	0.00000	0	0			0								0	0	0	0	0	0
25	2021-05-28	Py-Analyst		0.58	0	-0.01	0	0.59	0.285	-0.29	0	0.00000	0	0			0								0	0	0	0	0	0
26	2021-06-05	Py-Analyst		0.69	0	-0.01	0	0.7	0.285	-0.29	0	0.00000	0	0			0								0	0	0	0	0	0
27	2021-06-27	Py-Analyst		0.56	0	-0.01	0	0.58	0.285	-0.29	0	0.00000	0	0			0								0	0	0	0	0	0
28	2021-06-28	Py-Analyst		0.68	0	-0.01	0	0.7	0.285	-0.29	0	0.00000	0	0			0								0	0	0	0	0	0
29	2021-07-05	Py-Analyst		0.58	0	-0.01	0	0.6	0.285	-0.29	0	0.00000	0	0			0								0	0	0	0	0	0
30	2021-08-19	Py-Analyst		0.36	0	-0.01	0	0.66	0.285	-0.575	0	0.00000	0	0			0								0	0	0	0	0	0
31	2021-08-20	Py-Analyst		0.31	0	-0.01	0	0.61	0.285	-0.29	0	0.00000	0	0			0								0	0	0	0	0	0
32	2021-08-24	Py-Analyst		0.3	0	-0.01	0	0.6	0.285	-0.575	0	0.00000	0	0			0								0	0	0	0	0	0
33	2021-08-25	Py-Analyst		0.2	0	-0.16	0	0.66	0.285	-0.575	0	0.00000	0	0			0								0	0	0	0	0	0
34	2021-10-18	Py-Analyst		0.52	0	-0.16	0	0.75	0.285	-0.355	0	0.00000	0	0			0								0	0	0	0	0	0
35	2021-10-19	Py-Analyst		0.42	0	-0.16	0	0.65	0.285	-0.355	0	0.00000	0	0			0								0	0	0	0	0	0
36				0	0							0.00000	0	0			0								0	0	0	0	0	0
37													0	0			0								0	0	0	0	0	0

Zdr Offset vs time for 9 sites

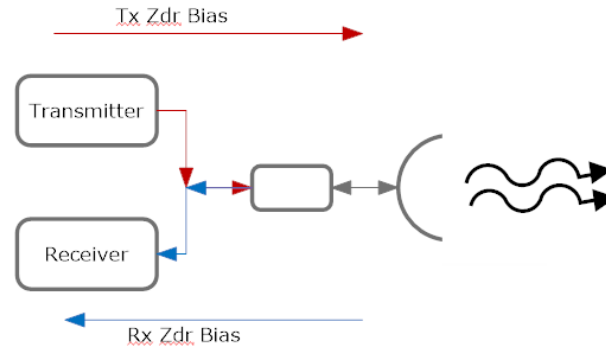


RX-SYS (Zdr) Offset vs time for 12 sites



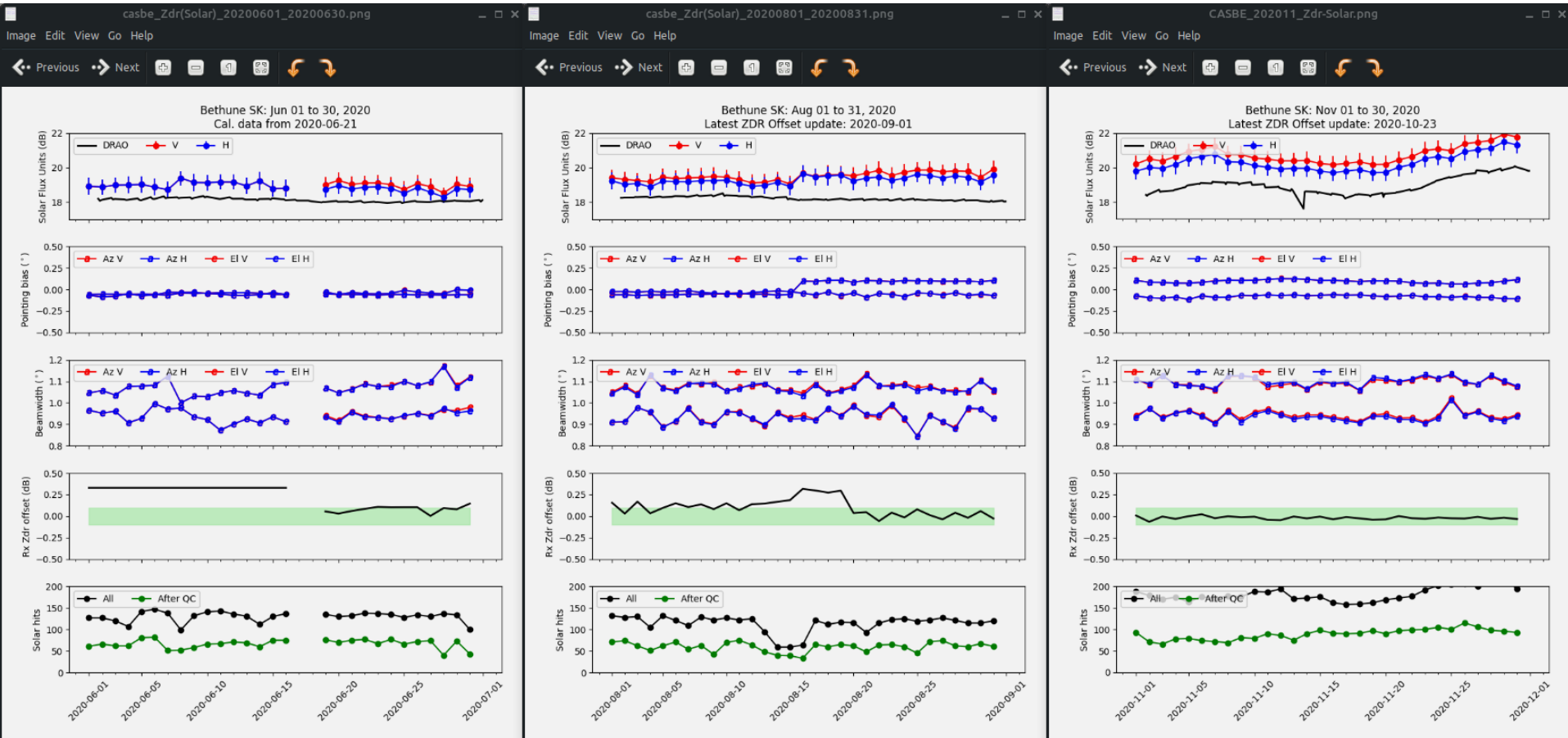
ECCC Tools estimate biases

- Reported Z_{DR} Data (ZDR_0) = Raw Z_{DR} Data (ZDR_s) + system Z_{DR} offsets (ZDR_{OFF})
 - So Raw Z_{DR} Data (ZDR_s) = $ZDR_0 - ZDR_{OFF}$
- Solar hits extracted using BALTRAD contain only Rx Z_{DR} biases
- To determine and plot residual Rx Z_{DR} bias, we take the reported solar flux and remove all Tx, User and BirdBath system Z_{DR} offsets



- $Rx\ Z_{DR}\ Bias = Z_{DR}\ of\ Solar_Flux_{BALTRAD} - (ZDR_{TX} + ZDR_{MAN} + ZDR_{BIRDBATH})$
 - Where $ZDR_{TX} = OFF_{TX_SYS} + OFF_{TX_MAN}$ (Recall that $ZDR_{SYS} = OFF_{TX_SYS} + OFF_{TX_MAN} + OFF_{RX_SYS} + OFF_{RX_MAN}$)

Bethune Solar (RX-Only) Bias Plots: Jun, Aug, Nov 2020



Operational Total Z_{DR} Bias Estimation

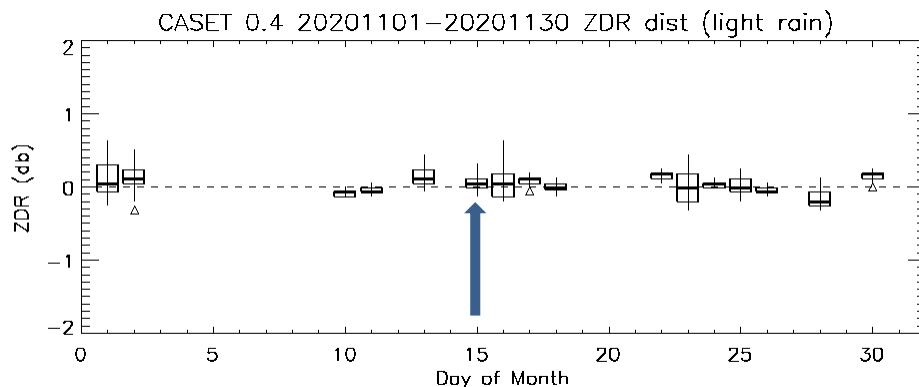
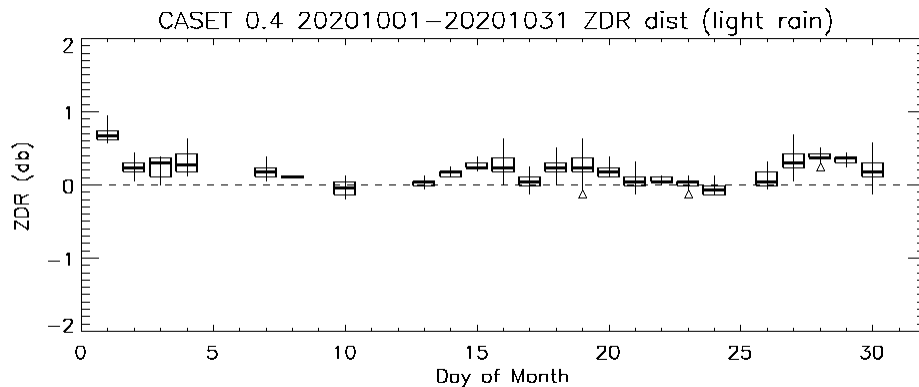
We search for 'light rain' events from operational data, to estimate overall system Z_{DR} bias over daily, weekly and monthly periods.

i.e. when raindrops should be roughly equal dimensions in both H & V

Find data in lowest EL scan, using following thresholds:

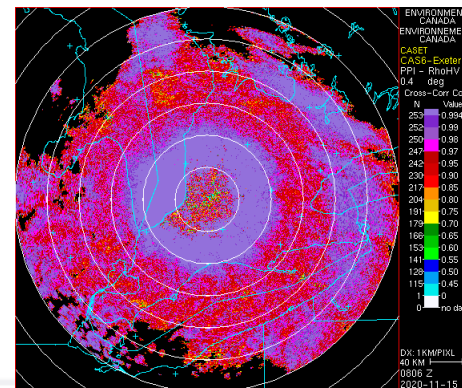
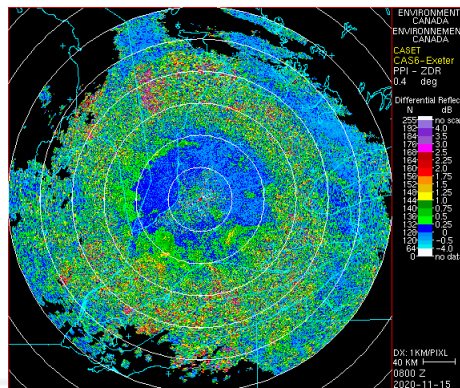
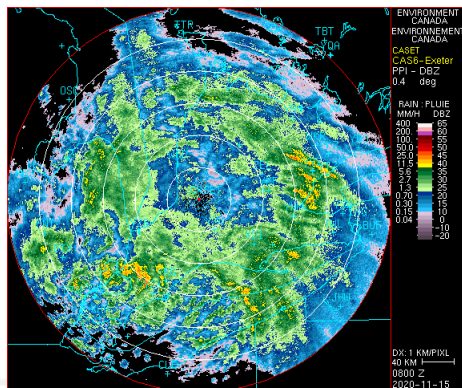
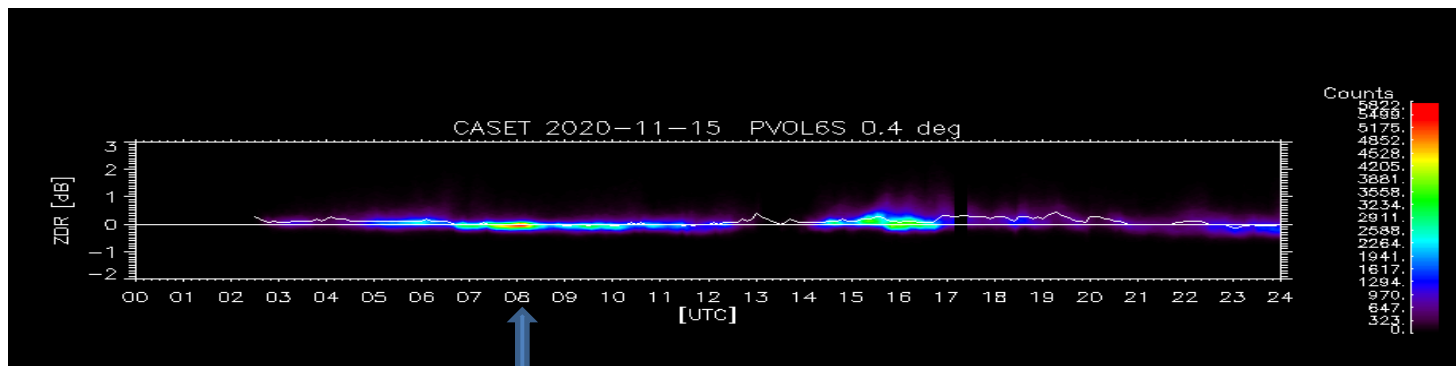
- $Rho_{HV} \geq 0.98$
 - $dBZ_{lo} = 10$ dB and $dBZ_{hi} = 20$ dB
 - Velocity (absolute value) ≥ 0.1 m/s
 - $SQI \geq 0.3$
 - Max Φ_{iDP} change along ray $\leq 20^\circ$
 - Range ≥ 20 km and ≤ 120 km or $\leq$ range of lower boundary of melting layer from models - 500 m
 - Bin count meeting above criteria ≥ 500 bins
-

Exeter, Ontario Rain Z_{DR} Bias (System total) Plots: Oct – Nov 2020



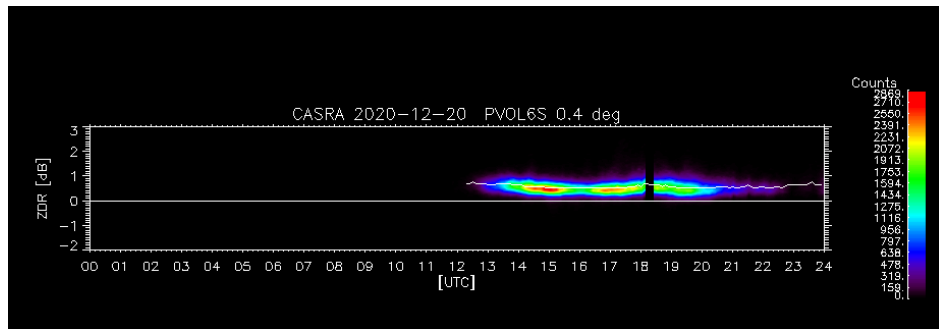
- Total system Z_{DR} bias is estimated.
- Would like to achieve Z_{DR} calibration ± 0.2 dB (final limit ± 0.1 dB desired)
- Little or no estimates during cold season
- Use of natural targets where intrinsic Z_{DR} is close to zero.
- Small raindrops fit the criteria, but must be carefully selected.

Exeter, Ontario Rain Z_{DR} Bias Nov 15 2020.



Well defined melting at ~80km range ring on 0.4 deg PPI.

a)



b)

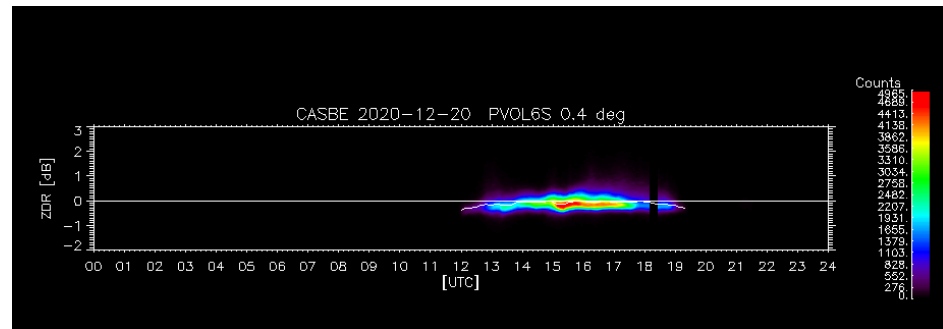


Figure 2. a) CASRA estimated Z_{DR} bias over 24 hours done scan by scan. The estimated bias at 1500Z is about 0.4-0.5 dB for CASRA.

b) CASBE estimated Z_{DR} bias over 24 hours done scan by scan. The estimated bias at 1500Z is about -0.1 dB for CASBE.

Snapshot of Receiver and Overall Z_{DR} Bias Estimates

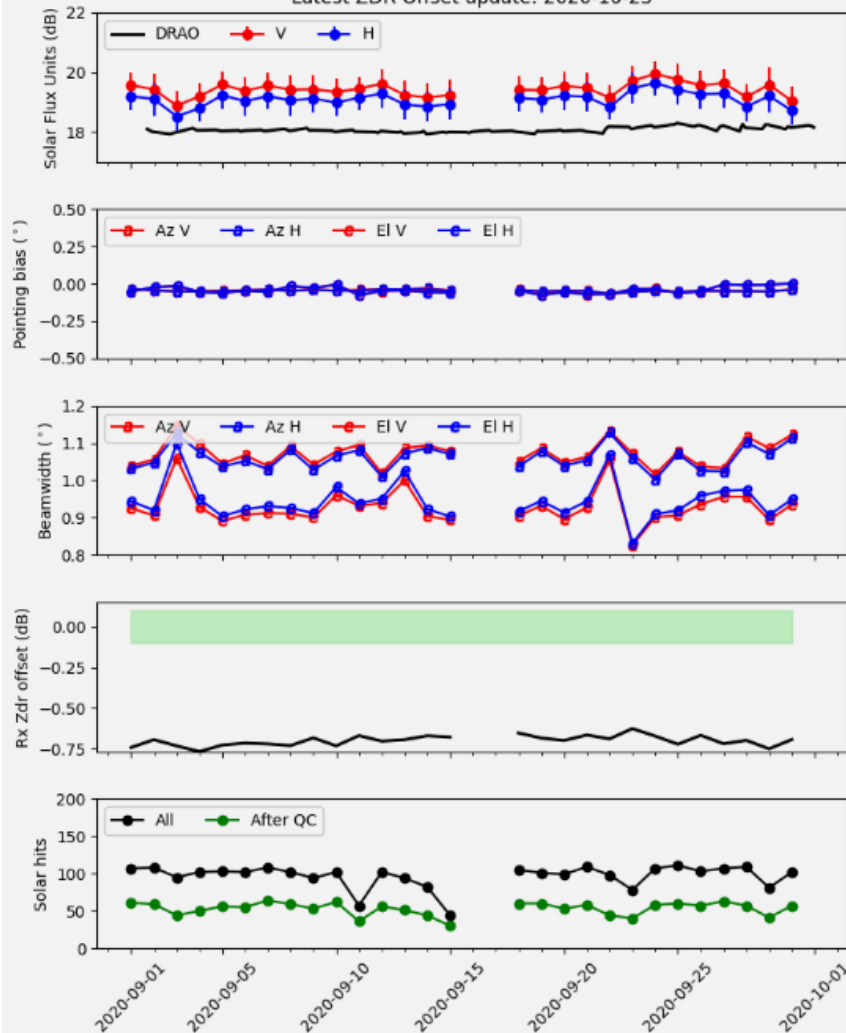
Solar Hit Zdr Results											Rain Data Zdr Results										
Average Zdr for solar data from most recent QEDX_MAN adj. (or Jan 1, 2020, whichever is later) to June 2:			June 2020	July 2020	Aug 2020	Sep 2020	Oct 2020	Nov 2020	Dec 2020	Jan 2021	rain zdr biases	May 2020	June 2020	July 2020 (Avg)	'Aug 2020 (Median)	'Sep 2020 (Median)	'Oct 2020 (Median)	'Nov 2020 (Median)	'Dec 2020 (Median)	Jan 2021	
CASBE	N/A		0.0419	0.0531	0.1019	0.0625	-0.1548	-0.0280	0.1680	-0.0228	CASBE	-8.0600	0.0175	0.1123	0.2500	-0.0600	-0.0300	-0.1250	-0.0600	-0.1550	
CASBV	0.2911	(from Jan 1)	0.3196	0.3017	0.2530	0.2376	0.2135	0.1163	0.1124	0.0997	CASBV	0.0000	0.1454	0.0709	0.3200	0.4400	0.3200	0.0000	0.3800	0.1250	
CASCM	-0.6587	(from Apr 2)	-0.7233	-0.7424	-0.7400	-0.6988	-0.0701	0.1702	0.1982	0.1893	CASCM	-0.1200	-0.2190	-0.2900	-0.3800	-0.3450	0.3800	0.6900	0.8200	0.8200	
CASDR	N/A		N/A	N/A	N/A	0.1028	0.0553	0.0084	0.0396	0.0135	CASDR	N/A	N/A	N/A	0.6300	0.5700	0.6300	0.8800	0.5350	N/A	
CASET	0.0760	(from Jan 1)	0.0410	0.3950	0.0871	0.0625	-0.1548	-0.0280	0.1680	0.1595	CASET	0.3200	0.3950	0.4083	0.3800	0.4400	0.1900	0.0000	0.0600	0.0350	
CASFW	-0.0532	(from Jan 1)	0.0463	0.0358	0.0318	0.0468	-0.2614	-0.1372	0.0270	N/A	CASFW	-0.6900	-0.7482	-0.7300	-0.4750	-0.5700	-0.7250	-0.3800	-0.2500	-0.2150	
CASLA	0.2274	(from Apr 2)	0.2236	0.2284	0.2324	0.2241	0.2144	0.1954	0.2269	0.2260	CASLA	0.5700	0.4923	0.4710	0.4400	0.5000	0.8200	0.8800	0.9500	0.7600	
CASMB	0.2004	(from Jan 1)	0.1739	0.1622	0.1969	0.2130	0.1893	0.1614	0.2171	0.2030	CASMB	0.0600	-0.0800	-0.0550	0.0000	0.0000	0.0000	0.0600	0.0650	0.0600	
CASMR	-0.2049	(from Jan 1)	0.7488	0.7408	0.7265	0.7382	0.7659	0.0626	-0.0017	-0.0235	CASMR	-1.0700	-1.2125	-0.8633	0.7600	0.7600	0.7600	0.2850	0.2500	0.1300	
CASRA	0.1474	(from Apr 2)	0.2131	-0.9594	0.0464	0.0824	0.3429	0.1172	0.1204	0.1083	CASRA	0.3800	0.4464	-1.2171	-0.2500	0.0000	0.5050	0.5700	0.5100	0.6000	
CASRF	-0.0974	(from Apr 2)	-0.0702	-0.0750	-0.0573	-0.0884	-0.3679	-0.0885	-0.1107	-0.1170	CASRF	0.3200	0.2818	0.2969	0.3200	0.3200	0.0950	0.1300	0.3500	N/A	
CASSM	0.1973	(from Apr 2)	N/A	0.1736	0.1725	0.1966	0.1767	0.1356	0.0206	0.0155	CASSM	0.6300	0.6181	0.6420	0.6600	0.6900	0.8200	0.7600	0.6600	0.5700	
CASSR	-0.129	(from Jan 1)	-0.1475	-0.0968	0.2099	0.2673	0.3944	0.3264	0.0811	N/A	CASSR	0.1300	0.1000	0.0950	0.4400	0.5000	0.7600	0.3800	0.4100	0.3500	
CASSU	N/A		N/A	N/A	N/A	0.0581	-0.0162	-0.0121	0.0213	0.0220	CASSU	N/A	N/A	N/A	-0.2200	0.2500	0.1600	0.2500	-0.0600	0.1900	
CASHR	N/A		N/A	N/A	N/A	0.0000	0.0000	0.0000	0.0000	0.0730	CASHR	N/A	N/A	N/A	N/A	0.0000	0.1300	0.1900	0.3800	0.1300	
CASSF	N/A		N/A	N/A	N/A	N/A	0.0000	0.0000	0.0000	0.0178	CASSF	N/A	N/A	N/A	N/A	N/A	0.3500	0.5700	0.4100	0.1900	
CASVS	N/A		N/A	N/A	N/A	N/A	0.0000	0.0000	0.0000	N/A	CASVS	N/A	N/A	N/A	N/A	N/A	0.0000	0.0600	0.0000	N/A	
CASWL	N/A		N/A	N/A	N/A	N/A	0.0000	0.0000	0.0000	0.0620	CASWL	N/A	N/A	N/A	N/A	N/A	0.1900	0.2500	0.1900	0.2500	
CASVD	N/A		N/A	N/A	N/A	N/A	0.0000	0.0000	0.0000	0.0537	CASVD	N/A	N/A	N/A	N/A	N/A	0.7600	0.3800	0.4400	0.5700	
CASCV																					
CASBI																					
CASET																					
CASKR																					
CASLC																					
CASSS																					
CASGO																					
CASLL																					
CASPG																					
CASMM																					
CASFM																					
CASJL																					
CASAG																					

	A	B	C	D	E	F	G	H	I
1									
2					Current ZDR MANUAL		Current ZDR_BIRDBATH		Updated ZDR MANUAL (assuming no chg to BirdBath)
3	CASBE:	218cas7			-0.22		0		-0.0650
4	CASBV:	218cas2			0		0		-0.1250
5	CASCM:	218cas9			0		0		-0.8200
6	CASDR:	218cas14			0		0		#N/A
7	CASET:	218cas6			-0.4		0		-0.4350
8	CASFW:	218cas3			0		0		#N/A
9	CASLA:	218cas10			0		0		-0.7600
10	CASMB:	218cas8			0		0		-0.0600
11	CASMR:	218cas11			0		0		-0.1300
12	CASRA:	218cas1			0.4		0		-0.2000
13	CASRF:	218cas4			-0.321		0		#N/A
14	CASSM:	218cas12			0		0		-0.5700
15	CASSR:	218cas5			0		0		#N/A
16	CASSU:	218cas13			0		0		-0.1900
17	CASHR:	218cas15			0		0		-0.1300
18	CASSF:	218cas16			0		0		-0.1900
19	CASTS:	218cas17			0		0		#N/A
20	CASWL:	218cas18			0		0		-0.2500
21	CASVD:	218cas19			0		0		-0.5700

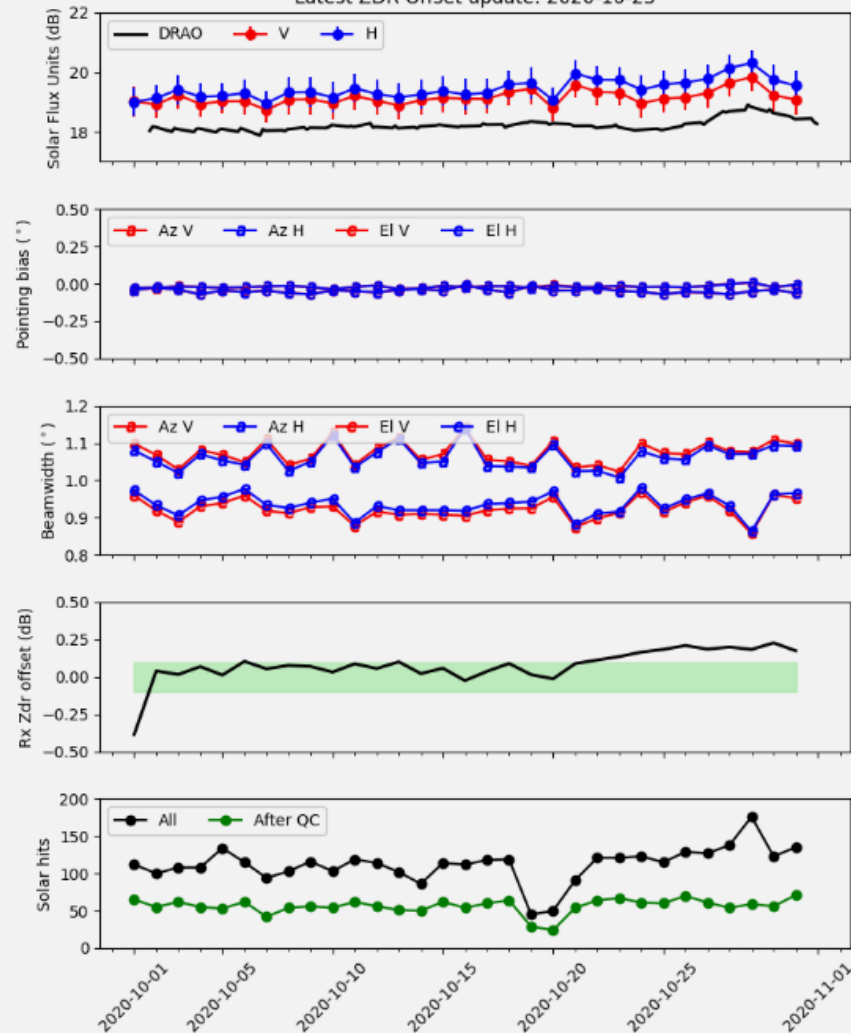
Adjustments made recently (all from 0, based on new test code considering ML):

CASCM = -0.7 CASDR = -0.6 CASLA = -0.8 CASSM = -0.7

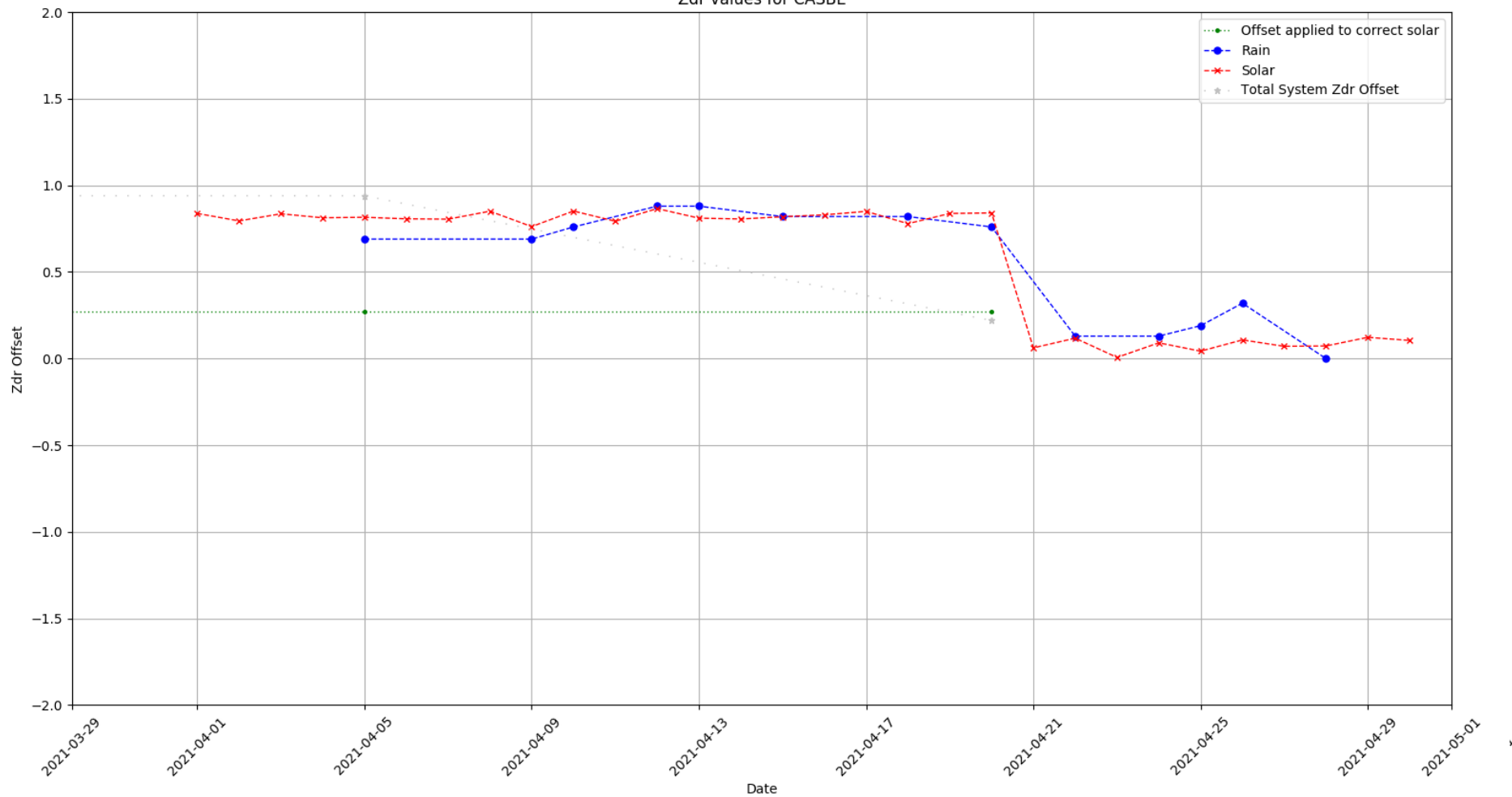
Chipman NB: Sep 01 to 30, 2020
Latest ZDR Offset update: 2020-10-23

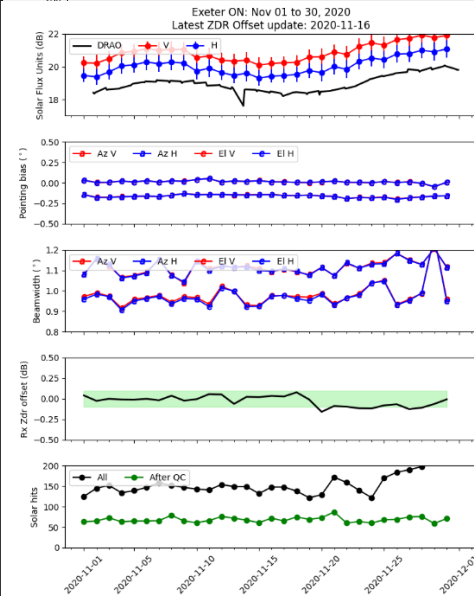
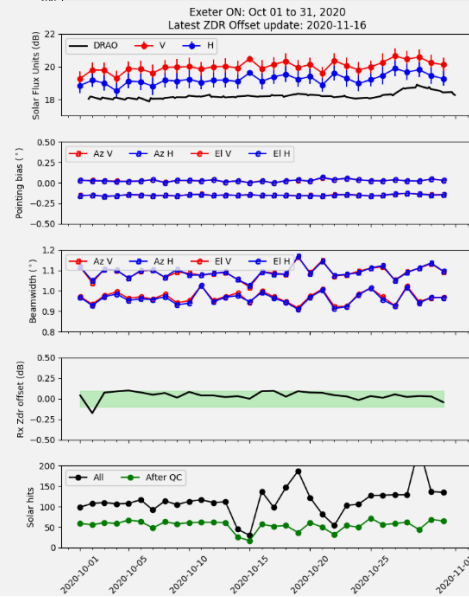
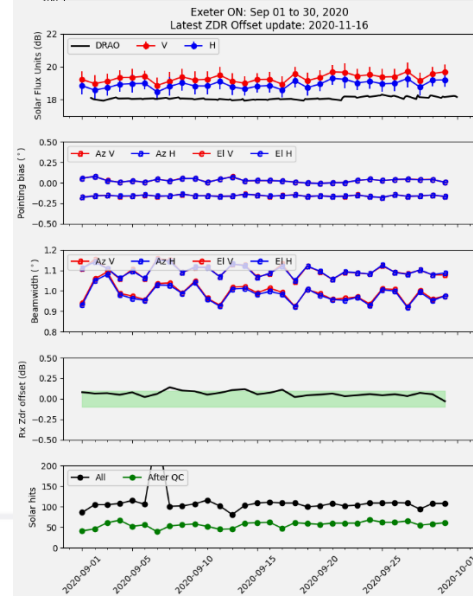
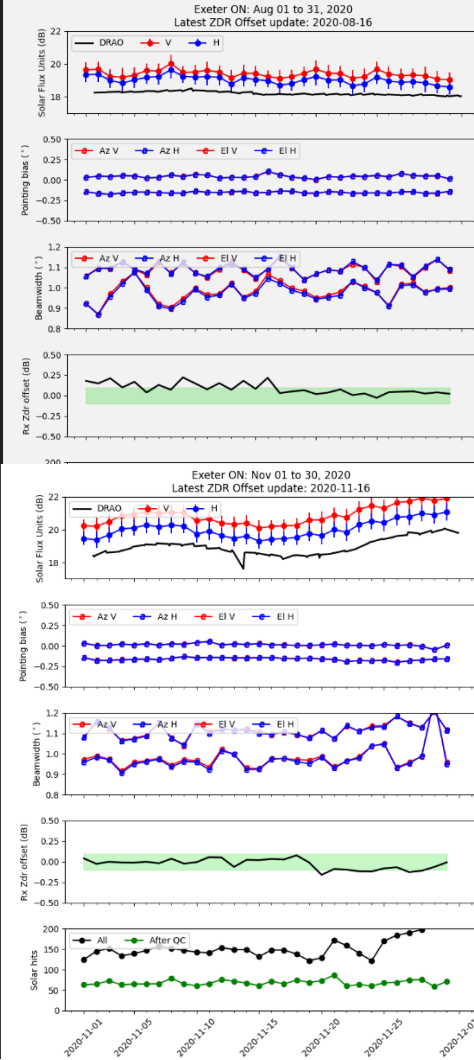
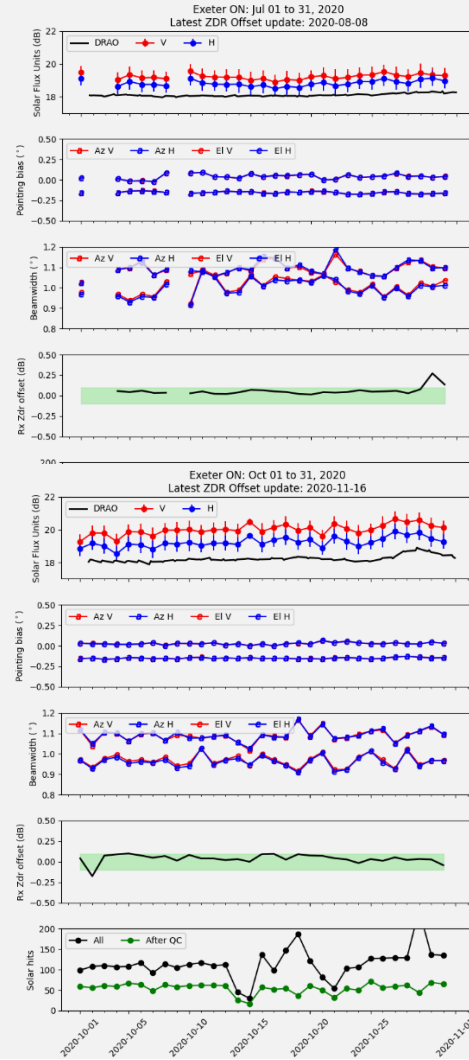
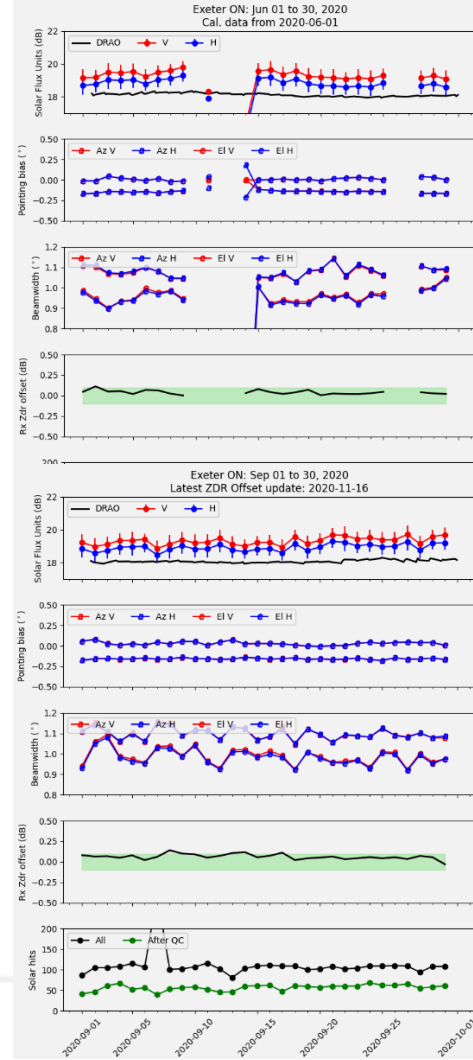


Chipman NB: Oct 01 to 31, 2020
Latest ZDR Offset update: 2020-10-23



Zdr values for CASBE





Next Steps...

- ☐ Refine the methods and outputs presented here
 - ☐ Add additional methods, e.g. Inter-radar matching (in prep)
 - ☐ Identify output metrics suitable for populating a system monitoring dashboard (i.e. Radar system Quality Assurance – QA)
 - ☐ QA includes helping monitor the system with respect to whether data are acquired within tolerances required by downstream applications
 - ☐ Transfer methods to operations
-

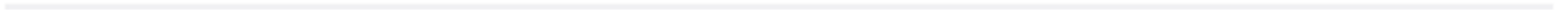
Questions?

Thanks to:

- Tameem Hassan, Miguel DeVera
(Canadian Weather Radar Replacement Project)
 - Larry Dusolt, Wayne Mercier, Todd Benko
(Atmospheric Monitoring Division)
-

2021 ZDR bias estimate monitoring

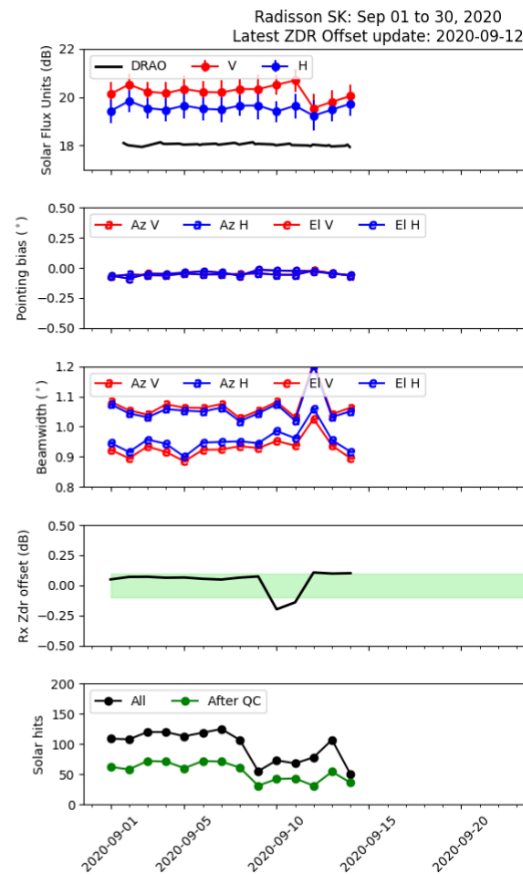
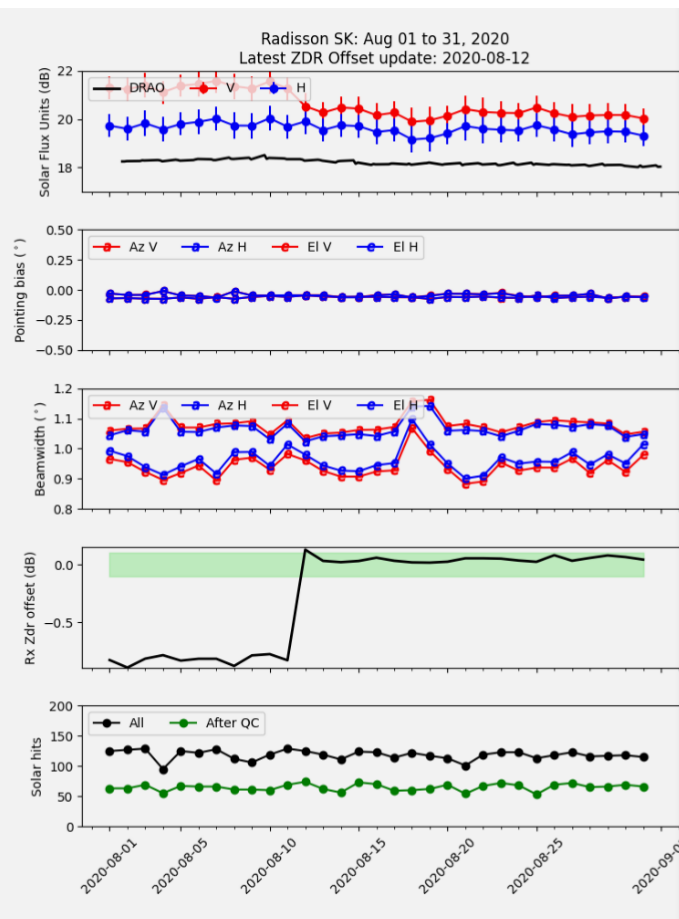
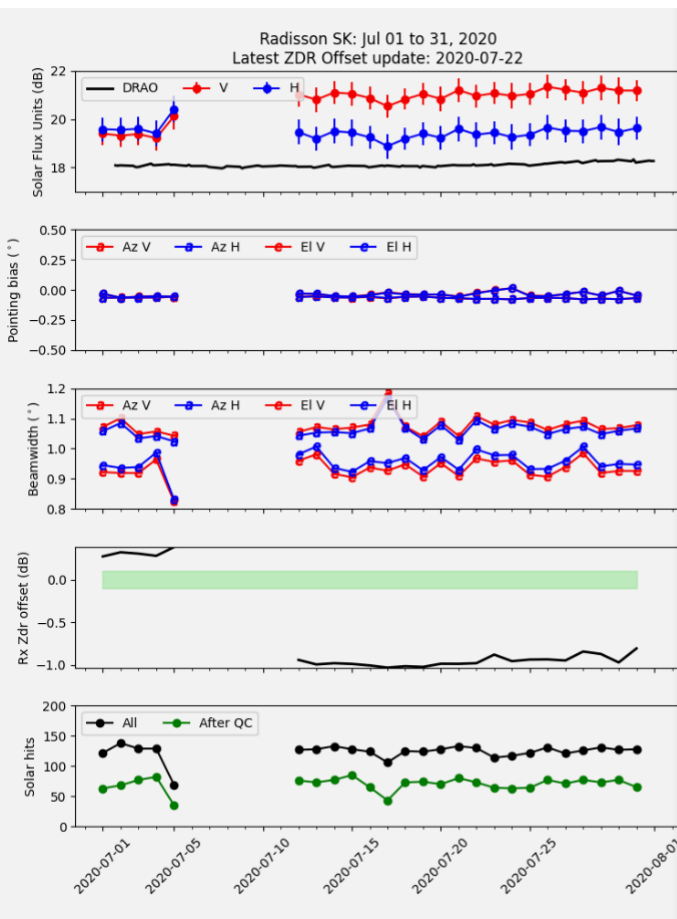
Additional Slides



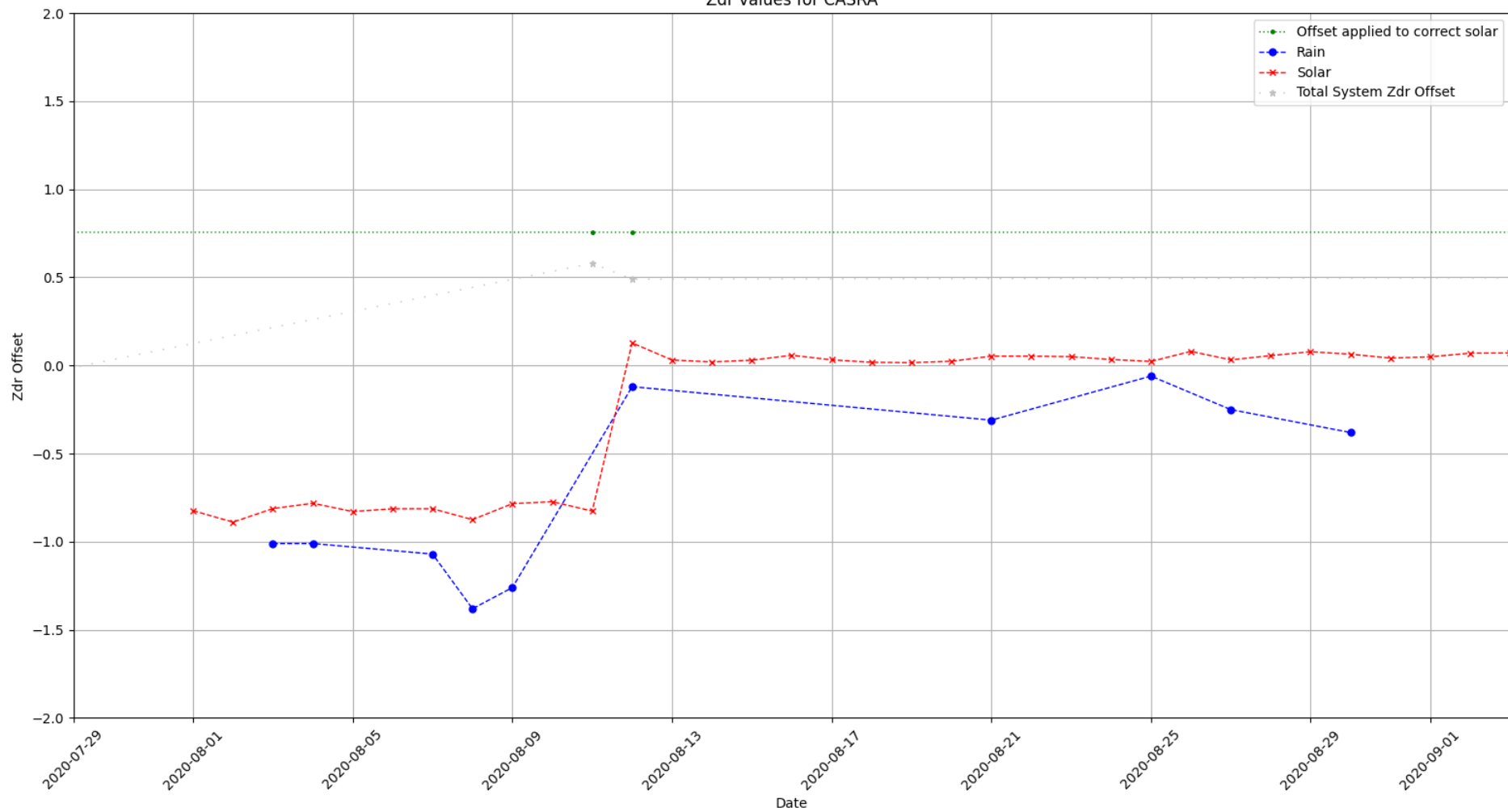
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1														Rain Bias				
2	5 Letter ID	ID's Verified	LDO ID		Current ZDR_MANUA L		Current ZDR_BIRDBAT H		Updated ZDR_MANUAL (assuming no chg to BirdBath)		If BB changed to '0'		ZDR Solar Bias	# of data points used for current		ZDR Est. Bias		Diff (New - Old) <Zdr_Man>
3	CASBE:	✓	218cas7		-0.22		0		-0.3500		As Col. I		0.15	10		0.13		-0.1300
4	CASBV:	✓	218cas2		-0.32		0		Fine Raster or repair needed 1st!		N/A		0.71 ▲	N/A		0.00		#VALUE!
5	CASCM:	✓	218cas9		-0.01		0		-0.4500		As Col. I		0.01	9		0.44 ▲		-0.4400
6	CASDR:	✓	218cas14		-0.355		0		-0.4150		As Col. I		0.13	12		0.06		-0.0600
7	CASET:	✓	218cas6		-0.4		0		-0.4000		As Col. I		0.01	11		0.00		0.0000
8	CASFW:	✓	218cas3		-0.155		0		-0.0650		As Col. I		0.11	6		-0.09		0.0900
9	CASLA:	✓	218cas10		-0.485		0		-0.4250		As Col. I		0.04	10		-0.06		0.0600
10	CASMB:	✓	218cas8		0		0		0.0000		As Col. I		0.11	10		0.00		0.0000
11	CASMR:	✓	218cas11		-0.25		0		-0.3800		As Col. I		0.07	11		0.13		-0.1300
12	CASRA:	✓	218cas1		0.08		0		Fine Raster or repair needed 1st!		N/A		-0.28 ▼	N/A		0.06		#VALUE!
13	CASRF:	✓	218cas4		-0.071		0		-0.3210		As Col. I		0.16	13		0.25 ▲		-0.2500
14	CASSM:	✓	218cas12		-0.45		0		-0.6100		As Col. I		0.10	10		0.16		-0.1600
15	CASSR:	✓	218cas5		0		0		-0.2500		As Col. I		0.19	11		0.25 ▲		-0.2500
16	CASSU:	✓	218cas13		-0.32		0		-0.2900		As Col. I		0.00	10		-0.03		0.0300
17	CASHR:	✓	218cas15		0		0		0.1900		As Col. I		-0.04	10		-0.19		0.1900
18	CASSF:	✓	218cas16		-0.25		0		-0.2500		As Col. I		0.04	13		0.00		0.0000
19	CASTS:	✓	218cas17		0		0		#N/A		N/A		#N/A	N/A		0.00		#N/A
20	CASWL:	✓	218cas18		0		0		-0.1900		As Col. I		0.04	11		0.19		-0.1900
21	CASVD:	✓	218cas19		-0.32		0		Fine Raster or repair needed 1st!		N/A		-0.30 ▼	N/A		-0.82 ▼		#VALUE!
22	CASCV:	✓	218cas21		0		0		#N/A		N/A		#N/A	N/A		#N/A		#N/A
23	CASBI:	✓	218cas31		0		0		#N/A		N/A		#N/A	N/A		0.06		#N/A
24	CASFT:	✓	218cas22		0		0		Fine Raster or repair needed 1st!		N/A		0.23 ▲	N/A		0.03		#VALUE!
25	CASKR:	✓	218cas20		0		0		0.0600		As Col. I		0.11	11		-0.06		0.0600
26	CASMA:	✓	218cas24		0		0		#N/A		N/A		#N/A	N/A		#N/A		#N/A
27	CASSS:	✓	218cas26		0		0		#N/A		N/A		#N/A	N/A		#N/A		#N/A
28	CASGO:	✓	218cas23		0		0		0.0600		As Col. I		-0.02	12		-0.06		0.0600
29	CASSN:	✓	218cas28		0		0		#N/A		N/A		#N/A	N/A		#N/A		#N/A
30	CASPG:	✓	218cas30		0		0		#N/A		N/A		#N/A	N/A		#N/A		#N/A
31	CASMM:	✓	218cas32		0		0		#N/A		N/A		#N/A	N/A		#N/A		#N/A
32	CASFM:	✓	218cas27		0		0		#N/A		N/A		#N/A	N/A		#N/A		#N/A
33	CASCL:	✓	218cas29		-0.45		0		-0.3300		As Col. I		0.10	10		-0.12		0.1200
34	CASAG:	✓	218cas25		0		0		-0.2850		As Col. I		0.05	14		0.29 ▲		-0.2850
35	CASXX:		218cas33		0		0		#N/A		N/A		#N/A	N/A		#N/A		#N/A

2021 Monthly Z_{DR} bias estimates

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	
2	Solar Hit Zdr Results														Rain Data Zdr Results															
3	Solar Zdr Biosses	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Latest	Rain estimated Zdr Biosses	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Latest		
4	CASBE	-0.0227	N/A	0.9318	0.0801	0.0873	0.1024	0.1056	0.1225	0.1249	0.1392	0.1458	N/A	0.1458	CASBE	0.0000	N/A	0.6800	0.1300	0.0300	0.0600	0.1300	0.1300	0.1300	0.1900	0.1300	0.1300	N/A	0.1300	
5	CASBV	0.1097	N/A	0.1353	0.2187	0.2315	0.1352	0.1301	0.0945	0.0524	0.7111	0.7145	N/A	0.7145	CASBV	0.5700	N/A	0.3800	-0.1900	-0.1900	0.3200	0.3200	0.3200	0.5700	0.0000	0.0000	N/A	0.0000		
6	CASCM	0.1841	N/A	-0.5100	0.1662	-0.1448	-0.0789	-0.0602	-0.0020	0.2685	0.0956	0.0107	N/A	0.0107	CASCM	0.7900	N/A	0.0000	-0.0600	-0.3800	-0.1200	-0.3100	-0.2500	0.0600	0.3500	0.4400	N/A	0.4400		
7	CASDR	0.0194	N/A	-0.5170	0.0292	0.0062	0.0129	0.0343	0.0169	0.0898	0.1517	0.1256	N/A	0.1256	CASDR	0.7600	N/A	N/A	-0.1900	-0.3100	0.1300	0.2500	-0.1200	-0.1900	-0.0600	0.0600	N/A	0.0600		
8	CASET	0.1470	N/A	0.1080	0.1275	0.1117	0.1602	0.0541	-0.0265	-0.0033	0.0040	0.0080	N/A	0.0080	CASET	-0.3800	N/A	0.0000	-0.0600	-0.0300	-0.0600	0.0600	0.0600	0.0600	0.0600	0.0000	N/A	0.0000		
9	CASFW	-0.0434	N/A	-0.2025	-0.0416	-0.0372	-0.0196	-0.0109	-0.0065	0.1104	0.1078	0.1120	N/A	0.1120	CASFW	-0.4100	N/A	-0.6900	-0.5700	-0.5700	0.0600	0.0600	0.5700	0.6300	-0.1200	-0.0900	N/A	-0.0900		
10	CASLA	N/A	N/A	-0.5757	0.2171	0.2256	0.0633	0.0828	0.0754	0.0532	0.0535	0.0369	N/A	0.0369	CASLA	0.9450	N/A	0.3200	-0.0600	-0.1900	-0.2500	-0.1900	-0.2500	-0.3100	0.1300	-0.0600	N/A	-0.0600		
11	CASMB	0.2132	N/A	0.2219	0.2106	0.1979	0.1735	0.1559	0.1406	0.1509	0.0979	0.1071	N/A	0.1071	CASMB	0.0600	N/A	0.0000	-0.0600	-0.0300	-0.0600	-0.0300	0.0000	0.0300	0.0000	0.0000	N/A	0.0000		
12	CASMR	0.0631	N/A	0.1167	-0.0129	-0.0318	0.0567	0.0682	0.0661	0.1072	0.1381	0.0717	N/A	0.0717	CASMR	0.1300	N/A	0.1300	0.2500	0.2500	0.0600	0.1600	0.1300	0.1300	0.1300	0.1300	N/A	0.1300		
13	CASRA	0.1576	N/A	0.0200	0.1685	0.2106	0.1469	0.1194	-0.1864	-0.2746	-0.2764	-0.2813	N/A	-0.2813	CASRA	0.6300	N/A	N/A	0.3200	0.3800	0.3200	0.3200	0.3800	0.0000	0.0000	0.0600	N/A	0.0600		
14	CASRF	-0.0534	N/A	-0.2353	-0.0487	-0.0463	0.2227	0.2127	0.1763	0.0815	0.1390	0.1611	N/A	0.1611	CASRF	0.1300	N/A	0.0650	-0.1900	-0.2500	0.3800	0.3800	0.3200	0.1900	0.1900	0.2500	N/A	0.2500		
15	CASSM	0.0221	N/A	-0.6620	0.0217	0.0307	0.0361	0.0427	0.0728	0.0984	0.1086	0.0996	N/A	0.0996	CASSM	0.6300	N/A	-0.2500	-0.1200	-0.2500	0.0600	0.0600	0.1300	0.1300	0.1900	0.1600	N/A	0.1600		
16	CASSR	-0.0429	N/A	-0.0255	0.0180	-0.0023	-0.0047	0.0146	0.2966	0.3022	0.2100	0.1870	N/A	0.1870	CASSR	0.3200	N/A	0.0950	0.1300	0.0600	0.1300	0.1300	0.3800	0.3800	0.2850	0.2500	N/A	0.2500		
17	CASSU	-0.0060	N/A	0.0295	-0.0382	-0.0325	-0.0310	-0.6800	-0.0480	-0.0185	0.0124	-0.0030	N/A	-0.0030	CASSU	0.1900	N/A	0.1300	0.1900	0.0650	0.1600	1.2600	0.2500	0.3200	0.0950	-0.0300	N/A	-0.0300		
18	CASHR	0.1222	N/A	0.1293	0.2168	0.3076	0.1188	0.0944	0.1182	0.1033	-0.0123	-0.0393	N/A	-0.0393	CASHR	0.1300	N/A	0.0600	0.1900	0.1900	-0.1200	-0.1200	-0.1200	-0.1200	-0.1900	-0.1900	N/A	-0.1900		
19	CASSF	-0.0230	N/A	-0.0157	-0.0139	0.0040	0.0714	0.0826	0.0640	0.0636	0.0281	0.0406	N/A	0.0406	CASSF	0.2550	N/A	0.1300	0.1900	0.0950	0.2500	0.2500	0.1900	0.0300	0.0000	0.0000	N/A	0.0000		
20	CASTS	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	#N/A	CASTS	0.2500	N/A	-0.1200	N/A	N/A	-0.0600	0.0600	0.2500	0.1300	0.0600	0.0000	N/A	0.0000		
21	CASWL	0.0647	N/A	0.0733	0.0999	0.0896	0.1067	0.1062	0.0787	0.0295	0.0461	0.0363	N/A	0.0363	CASWL	0.1900	N/A	0.0600	0.0600	0.0600	0.0600	0.1300	0.1300	0.1300	0.1300	0.1900	N/A	0.1900		
22	CASVD	0.0274	N/A	0.0607	0.0191	0.0127	0.0382	0.0301	0.0205	0.0379	-0.3590	-0.3004	N/A	-0.3004	CASVD	0.6000	N/A	0.4400	0.3800	0.3200	0.0000	-0.0300	0.0000	0.0000	-0.8200	-0.8200	N/A	-0.8200		
23	CASCV	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	#N/A	CASCV	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	#N/A	
24	CASBI	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	#N/A	CASBI	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.0600	N/A	0.0600	
25	CASF7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.2034	0.1936	0.2012	0.2275	N/A	0.2275	CASF7	N/A	N/A	N/A	N/A	N/A	0.0600	0.0950	0.1300	0.0600	0.0600	0.0300	N/A	0.0300		
26	CASKR	N/A	N/A	N/A	N/A	N/A	0.0980	0.1262	0.1054	0.0955	0.1123	0.1071	N/A	0.1071	CASKR	N/A	N/A	N/A	N/A	N/A	N/A	-0.4700	-0.0600	-0.0600	-0.0600	-0.0600	N/A	-0.0600		
27	CASMA	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	#N/A	CASMA	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	#N/A	
28	CASSS	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	#N/A	CASSS	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	#N/A	
29	CASGO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	-0.0126	-0.0628	-0.0185	N/A	-0.0185	CASGO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	-0.1900	-0.1200	-0.1550	-0.0600	N/A	-0.0600
30	CASSN	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	#N/A	CASSN	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	#N/A	
31	CASPG	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	#N/A	CASPG	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	#N/A
32	CASMM	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	#N/A	CASMM	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	#N/A
33	CASFM	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	#N/A	CASFM	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	#N/A
34	CASCL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.1193	0.0998	N/A	0.0998	CASCL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.4400	-0.1900	-0.1200	N/A	-0.1200	
35	CASAG	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	-0.1111	0.0194	0.0471	0.0471	CASAG	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.1300	0.3200	0.2850	N/A	0.2850		
36	CASXX	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	#N/A	CASXX	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	#N/A



Zdr values for CASRA



Zdr values for CASFW

