Interactive comment on "Meteorological observations collected during the Storms and Precipitation Across the continental Divide Experiment (SPADE), April–June 2019" *by* Julie M. Thériault et al.

Julie M. Thériault et al.

hilarysmith11@gmail.com

1) I found a couple of things lacking in Section 3 (Data collection) that should be addressed. The most significant is the lack of discussion about the data quality control. I found a remark somewhat buried in the README file on the repository stating that "most" files have not been processed but it is unclear if this means that no quality control has occurred in "most" files. This needs to be better stated in the manuscript, either as a general paragraph, or in the sections that describe the individual instruments/systems. Another useful piece of information that should be included where

possible and where appropriate is the description of the accuracy and/or uncertainty of the measurements. These have substantial value to data users.

Response: All data files have not been processed and no quality control has been performed by the authors, except for the MRR-2 files, which have been processed using Maahn and Kollias (2012). The following sentence was added to section 3.1: "Only the MRR-2 files were processed and quality controlled using the Maahn and Kollias (2012) algorithm. All other data files have not been processed nor quality controlled by the authors, and are the output of the instrument or manufacturer's software. Thank you for the comment in regard to the accuracy and/or uncertainty of the measurements. It has been added in a supplementary Table in Appendix A, Table A2 in the manuscript (Figure 1 in author's response). The accuracy of the instruments were found in the user's manual of each instrument. For all instruments except the LiDAR, only the variables found in user's manual are listed. For the LiDAR the information is from the user's manual as well as from Mariani et al. (2020). A sentence was added in section 3.1: "The appendix also includes a table giving the uncertainty of each instrument (Table A2).". The Table is reproduced below. Also, the information in section 3.1 is now the introductory paragraph of section 3. The sub-section numbering is used for the instrument descriptions.

Additional reference: Mariani, Z., Crawford, R., Casati, B., and Lemay, F.: A Multi-Year Evaluation of Doppler Lidar Wind-Profile Observationsin the Arctic, Remote Sens., 12, 323, https://doi.org/10.3390/rs12020323, 2020.

2) An instrument\site table would be useful in Section 3 indicating which instruments are installed at each site and an indication as to what each instrument measures.

Response: This information is included in Appendix A, Table A1. A sentence was added in section 3.1. "A complete list of all instruments used and their locations is given in Appendix A, Table A1."

3) Unless I missed it, I don't see mention anywhere in the manuscript or on the reposi-

tory about the time zone for the date timestamp. I realize that discussion of date ranges, etc in the manuscript are stated in UTC but the time zone of the timestamp should be explicitly stated in both the manuscript and the metadata on the repository.

Response: All data that have been submitted to FRDR are in UTC, which is explicitly stated within the data files as well as the attached readme file. The following sentence was added at the end of section 3.1: "All data available in the repository are in UTC.".

4) Comments from supplement:

Line 21: "In other storms" seems a little vague. How about "Often, storms propagating across the divide results in significant precipitation on both sides".

Response: It has been modified accordingly.

Line 38: The sentence is: "This dataset will serve as a baseline for future work on atmospheric conditions over major orographic features by comparing the varying conditions on either side of a large topographic feature."

Response: It has been rewritten as: "This dataset will be used to study atmospheric conditions associated with precipitation events documented simultaneously on either side of a continental divide.".

Line 69: This section seems a bit out of context here. I understand the need but it seems out of place to introduce the previous study and results before introducing the study area. In fact, you may want to move this discussion to the introduction to serve as the impetus for the current study.

Response: Thank you for the suggestion. • Sub-sections 2.1 and 2.2 have been moved to the introduction before the paragraph stating the objective of the manuscript. • Section 2.3 is now the only information in Section 2, which is called 'Site description".

Line 82: Maybe "Study Region and Climatology" would be more appropriate? That

would also differentiate this section more from the more descriptive discussion of the study "sites" in the subsequent section.

Response: Thank you for the suggestion. As mentioned in the previous comment, Sub-sections 2.1 and 2.2 have been moved to the introduction before the paragraph stating the objective of the manuscript.

Line 90: Good word :)

Response: Thank you.

Line 93: Delete "in the high mountains"

Response: It has been deleted.

Line 102: I found this sentence just a little awkward. How about "Whitfield and Pomeroy (2016) showed that flooding due to rain-on-snow events occurred more frequently in the late 19th and early 20th centuries than it does in the more recent period." Response: It has been modified accordingly.

Line 106: This might read better as "The study region consisted of two main areas separated by the continental divide."

Response: It has been modified accordingly.

Line 107: Just a note on a bit of confusion that a reader might encounter in these two paragraphs. You say here that there were two field sites on the eastern side, but there were actually four. Perhaps here is where you need to call these "primary sites". In the 3rd paragraph in this section, you say that there were four sites, but your table lists 5. I think you just need to clean this up a bit.

Response: The section was re-organized to present the main and secondary sites on the eastern side and the main site on the western side. It also takes into account the following five minor comments. It now reads as follows:

"The study region consisted of two main areas separated by the continental divide. Table 1 summarizes information on the SPADE field sites. On the eastern side, there were two main field sites and two secondary sites. The main sites were: (i) Fortress Mountain Powerline (FMP) at 2076 m ASL and (ii) Fortress Junction Service (FJS), located in a high elevation valley (1580 m ASL) along Alberta Provincial Highway No. 40 (Fig. 1). FMP was chosen as it is the primary field site in the Canadian Rockies Hydrological Observatory (https://research-groups.usask.ca/hydrology/science/research-facilities/crho.php#Overview), operated by the University of Saskatchewan Centre for Hydrology, and is already well instrumented with hydrometeorological equipment. It is the site of long-standing research (Smith et al., 2017; Conway et al., 2018; Schirmer and Pomeroy, 2020). A maintained road from FJS up to FMP allowed researchers to collect meteorological data during a precipitation phase transition along the mountainside. The frequent phase transition between FJS and FMP justified having two main sites located at valley floor and at higher elevation. Select data were also gathered on an intermittent basis at two secondary sites but not simultaneously. These were (i) from the University of Calgary Biogeoscience Institute (BGI) at 1418 m ASL located on the eastern side of the continental divide, off Alberta Highway No. 40, ~25 km north of FMP; and (ii) from the Storm Mountain Lodge (SML) at 1723 m ASL that was used temporarily on 7 June 2019 in anticipation of a forecasted significant precipitation event. SML is located approximately 5 km east of the continental divide, near the midway point between the Fortress Mountain and Nipika Mountain Resort sites, along BC Highway 93 (Fig. 1).

The Nipika Mountain Resort (NMR) site was located in a valley on the western side of the divide and was chosen to be comparable to FJS on the eastern site of the divide (Fig. 1). It approaches the latitude of the Fortress Mountain area and has an elevation of 1087 m ASL. NMR is easily accessible via an active logging road off the Banff-Windermere Highway (BC Highway 93). This area has a paucity of active meteorological stations and basic weather instruments were deployed on 21 September 2018, well before the start of the field experiment, to collect baseline data."

Line 113: new sentence

Response: The sentence was: "well instrumented with hydrometeorological equipment and is the site of long-standing research (Smith et al., 2017; Conway et al., 2018; Schirmer and Pomeroy, 2020)."

The text now reads as follows: "well instrumented with hydrometeorological equipment. It is the site of long-standing research (Smith et al., 2017; Conway et al., 2018; Schirmer and Pomeroy, 2020)."

Line 114: Delete "Moreover"

Response: It has been deleted.

Line 115: What does this mean?

Response: The text was "A maintained road from FJS up to FMP allowed researchers to collect meteorological data during transition regions along the mountainside".

It has been changed to the following sentence for clarity: "A maintained road from FJS up to FMP allowed researchers to collect meteorological data during a precipitation phase transition along the mountainside. The frequent phase transition between FJS and FMP justified having two main sites located at valley floor and at higher elevation."

Line 116: This needs clarification

Response: The following has been removed for clarity. "FJS and FMP were chosen to collect wind flow data that would allow the comparison of precipitation amounts from the valley floor to above ridgetop."

Line 121: This sentence is a bit awkward. Since you only have one site on the western side of the divide, how about "The Nipika Mountain Resort (NMR) site was located in a valley on the western side of the divide and was chosen to be comparable to FJS on the eastern site of the divide (Fig. 1)."

Response: The sentence has been changed accordingly.

Line 131: You should add site abbreviations here somewhere

Response: The abbreviations were added to Table 1.

Line 136: Since you use site abbreviations in the text, it would be useful to add them to the figure caption text as well.

Response: The site abbreviations were added to the caption of Figure 1. It now reads: "Figure 1: Map of the SPADE field campaign domain in British Columbia and Alberta with the location of the field sites (white dots), which are Nipika Mountain Resort (NMR), Storm Mountain Lodge (SML), Fortress Mountain Powerline (FMP), Fortress Junction Service (FJS), and the University of Calgary Biogeoscience Institute (BGI), the major city of Calgary (grey dot), and the continental divide (red line). Local rivers are shown in blue and labelled. The inset map shows the SPADE field campaign area (red outline) in relation to western Canada."

Line 146: This sentence is a bit confusing. "The FMP site, also known as the Fortress Mountain Snow Laboratory within the regional Canadian Rockies Hydrological Observatory, and some of the instruments located at FMP, but not used in the SPADE campaign, are described in Smith et al. (2017), Conway et al. (2018), and Schirmer and Pomeroy (2020)." It may not be necessary However, if you leave it here, it needs to be re-worded. Perhaps "The FMP site is also known as the Fortress Mountain Snow Laboratory and operates within the regional Canadian Rockies Hydrological Observatory. Other projects and instrumentation at this site are described in...".

Response: The sentence has been changed accordingly.

Line 153: Besides the photos, and the descriptions below, I suggest a summary table list the instrument name, what sites that it is installed at (which might be redundant since I believe you state that the sites are identical except for the LiDAR), and what the instrument measures. This should probably match what is contained in the repository.

Response: This information is contained in Appendix A, Table A1. See response to comment #2 for the Table.

Line 165: Is this just an SR50 or is it an A or AT model? Response: It is (just) a SR50 model and is shown in Figure 3a in the manuscript (Figure 3 in author's response).

Line 166: You need to be more specific as to the reference level. Is above ground + or - ?

Response: The sentence has been clarified to "... soil and snow temperatures at a depth of 17 cm below ground (i.e. -17 cm) and heights of 15 cm and 33 cm above bare ground (T109).".

Line 190: Section 3.6: Precipitation gauges. "Just a note here. I don't see any discussion about adjusting solid precipitation measurements for systematic undercatch. I think at least the impact of this should be mentioned. Âż

Response: A sentence has been added at the beginning of section 3.6. The sentence is as follows: "No adjustment for wind under-catch of solid precipitation was performed on the archived data. We acknowledge that this would affect the data and they should be used with caution."

Line 214: Technically, "B" should be superscript

Response: It has been changed.

Line 212: Just wanted to confirm that this is true for both generations of Pluvio gauges: "every 6 s with a resolution of 0.001 mm (OTT, 2010)."

Response: Thank you for the information.

Line 214: Pluvio 1, 1 should be subscript.

Response: It has been corrected.

Line 215: My understanding is that the Pluvio1 output mimics a tipping bucket tip every

0.1 (?) mm while the Pluvio2 has several output options. Will you describe any of this? I think a knowledgable data user may be interested in what Pluvio2 output(s) you are archiving and if you do any data filtering.

Response: We have archived the following outputs: Intensity (real-time), Accumulation (real-time/non real-time), Accumulation (non real-time), total accumulation (non real-time), bucket content (real-time), bucket content (non real-time). No filtering/processing has been applied to these data. A sentence has been added to sub-section 3.6.3.

Line 220: I know what you mean here but a reader may not. It somewhat implies that the orifice was at ground level. I think you want to say the "the orifice was levelled with respect to the ground".

Response: The sentence has been revised to:"…lumber base and the orifice was levelled with respect to the ground…".

Line 222: delete frequencies to depth

Response: The new sentence is: "The CR1000X data logger was configured to sample the period average frequency from each vibrating wire sensor, this frequency is used to compute the average amount of liquid equivalent precipitation of the three sensors and the standard deviation across them.".

Line 224: Are you archiving precipitation amounts as bucket weight differentials or are just archiving the bucket weights? Any discussion about data processing?

Response: The Geonor_Depth_Average has been archived and is the average of bucket weight from the three sensors and the StdDev corresponds to that average. It is indeed unprocessed aside from using the sensor calibration factors to convert raw frequencies to weights (in mm water). A sentence has been added for clarity. It reads: "The resultant time series obtained from the bucket weight describes cumulative precipitation, including the average and standard deviations of the three sensor depths". Line 267: This sentence gets awkward and needs to be broken up. The sentence is

"Three MRR-2 instruments were used in this study and were deployed at FMP installed at a height of z = 533 cm above bare ground; vertical resolution of Δz = 200 m), prior to the field campaign, FJS (z = 235 cm; Δz = 35 m) on 24 April 2019, and at NMR (z = 273 cm; Δz = 200 m) on 1 May 2019 for the duration of the field campaign (Fig. 3j)." The sentence has been updated as follows: "Three MRR-2 instruments were used in this study and were deployed at the 3 main sites: 1) at FMP installed at a height of 533 cm above bare ground with a vertical resolution of 200 m, 2) at FJS installed at 235 cm above bare ground with a vertical resolution of 35 m, and 3) at NMR installed at 273 cm above bare ground with a vertical resolution of 200 m (Fig. 3j)."

Line 272: You need to clarify what this means. I think you can just say that the output is in NetCDF format.

Response: Yes, that is correct. The sentence has been clarified to: "… and available in NetCDF format". Also the section has been re-organised for clarity as requested in comment #1. We moved the following sentence before introducing the MRR-PRO. "The MRR-2 retrievals were processed with a noise removal algorithm (Maahn and Kollias, 2012) to increase the instrument sensitivity to -14 dBZ and, therefore, enhancing the detection of light solid precipitation." Then, the MRR-2 is discussed, followed by the MRR-PRO.

Line 323: measured with?

Response: It has been clarified that these data were measured with an OTT Pluvio1. The new sentence is: "During this time, a total of 15.3 mm of precipitation was collected at FMP by the Pluvio1,…".

Line 324: Measured with?

Response: It has been clarified that these data were measured with a Geonor. The new sentence is: "…this is in contrast to the 1.4 mm of precipitation collected at NMR by the Geonor with an average…"

Line 347: It would be useful to label the plots with the site abbreviations. Ditto for Figure 6

Response: The abbreviations were added directly to the plots in Figures 5 and 6 in the manuscript. They are shown in Figures 4 and 5 in the author's response.

Sensor	Model	Measurements	Accuracy
Doppler LiDAR		Doppler velocity	< 0.3 m s^{-1} (uncertainty)
		Backscatter coefficient	SNR-dependent
		Intensity	SNR-dependent
		Depolarization ratio (ice/water)	SNR-dependent
	Halo Photonics Streamline XR	Vertical wind profile (u,v)	0.27 m s^{-1} (uncertainty)
Optical Disdrometer	OTT Parsivel 1	Size of falling particles	±1 size class (0.2 to 2 mm), ± 0.5 size class (>2 mm)
		Speed of falling particles	±1 size class (0.2 to 2 mm), ± 0.5 size class (>2 mm)
	OTT Parsivel 2	Size of falling particles	±1 size class (0.2 to 2 mm), ± 0.5 size class (>2 mm)
		Speed of falling particles	±1 size class (0.2 to 2 mm), ± 0.5 size class (>2 mm)
Micro Rain Radar	Metek MRR 2	Doppler raw spectra	0.53 dB
		Reflectivity (Ze)	0.53 dBZ
		Doppler Velocity (W)	0.109 m s^{-1}
		Spectral Width (σ)	0.09 m s^{-1}
	Metek MRR Pro	Doppler raw spectra	0.25 dB
		Reflectivity (Ze)	0.25 dBZ
		Doppler Velocity (W)	0.09 m s^{-1}
		Spectral Width (σ)	0.09 m s^{-1}
Weather Station	Vaisala WXT 520	2.65 m wind speed	± 3% at 10 m s^{-1}
		2.65 m wind direction	± 3°
		Atmospheric pressure	± 0.5 hPa (0 to + 30°C), ± 1 hPa (-52 to +60°C)
		Temperature	± 0.3°C (at +20°C), ± 0.25°C (at 0°C)
		Relative humidity	± 3% (0 to 90% RH), ± 5% (90 to 100% RH)
		Accumulated rainfall	better than 5%
	Vaisala HMP155	Temperature	0.226 + 0.0028×reading (-80°C to +20°C), 0.055 + 0.0057×reading (+20°C to +60°C)
		Relative humidity	-20°C to +40°C of ± D40(1.0 + 0.008×reading)
	Hobo pro V2 Temp/RH U23-001	Temperature	± 0.21°C from 0°C to 50°C
		Relative humidity	10% to 90% of ± 2.5%, and of ± 5% above 90%
	HC2-S3-L	Air Temperature (Average)	± 0.1°C at 23°C
		Relative Humidity	± 0.8% at 23°C

Fig. 1. Summary of the instruments' accuracy. They were found in the user's manual of each instrument. For all instruments except the LiDAR, only the variables found in user's manual are listed.

Location	Coordinates		Elevation	Access to AC Power	Dates during field campaign
	Latitude (° N)	Longitude (° W)	m ASL	Y/N	
Fortress Mountain Powerline (FMP)	50.824	115.197	2076	Y	2019-04-26 to 2019-06-25
Fortress Junction Service (FJS)	50.786	115.161	1580	Y	2019-04-26 to 2019-06-25
Nipika Mountain Resort (NMR)	50.612	115.801	1087	N	2018-09-21 to 2019-06-22
Storm Mountain Lodge (SML)	51.253	115.999	1723	Y	2019-06-07 to 2019-06-08
Biogeoscience Institute (BGI)	51.027	115.034	1418	Y	2019-04-25 to 2019-06-05, 2019-06-09 to 2019-06-25

Fig. 2. A summary of the field sites that were used during the field campaign including information about their location, elevation, access to AC power, and dates that instruments were operational.
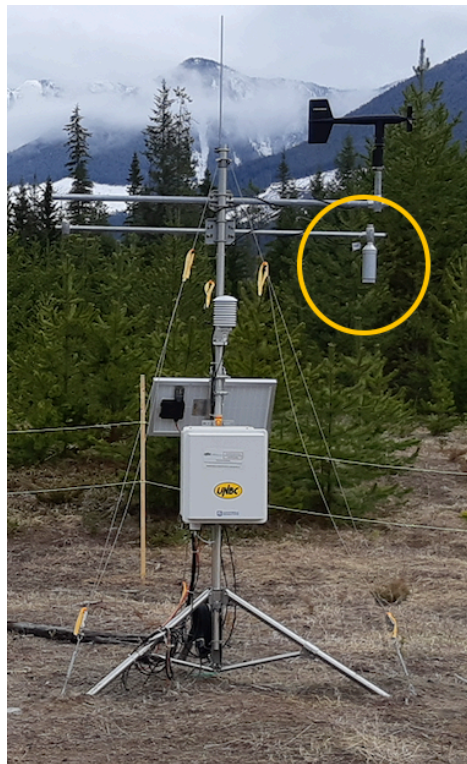
Fig. 3. Photo of the weather station at Nipika Mountain Resort with the SR50 circled in yellow.
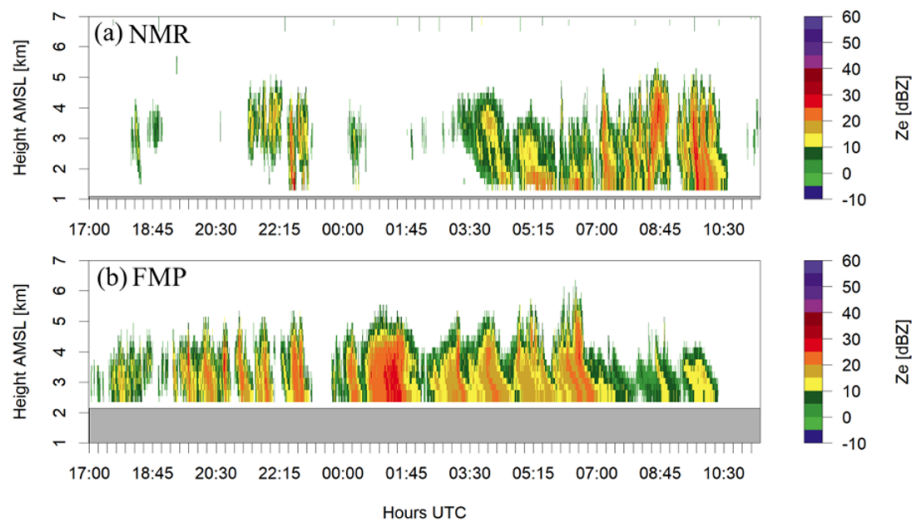
Fig. 4. MRR-2 vertical profile of reflectivity (Ze) from 1700 UTC 4 May–1130 UTC 5 May for (a) NMR and (b) FMP. The grey shading is below ground level.
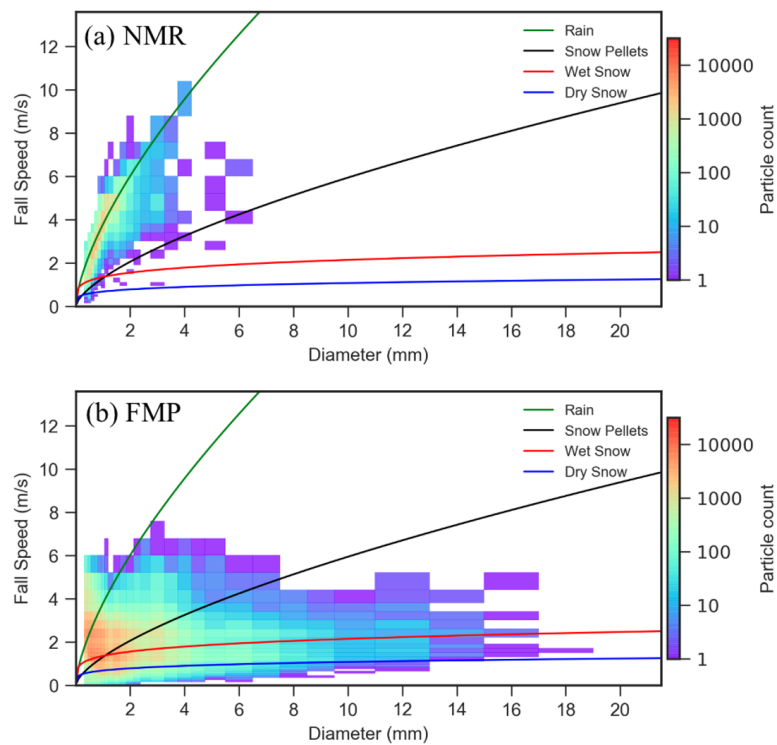
Fig. 5. The particle diameter and fall speed distribution of hydrometeors from 1700 UTC 4 May–1130 UTC 5 May at (a) NMR and (b) FMP.