Responses to Referee comment #2 :

Review of HESS-2018-131 Precipitation characteristics and associated weather conditions on the eastern slopes of the Rocky Mountains during March-April 2015 Julie M. Thériault, Ida Hung, Paul Vaquer, Ronald E. Stewart, and John Pomeroy

The authors would like to thank the reviwers for the constructive comments.

This paper presents an analysis of field observations collected in the Canadian Rockies during a 2-month period to better understand how precipitation reaching the surface formed. The authors looked at how precipitation was impacted by flow regimes aloft and could group all their events as being either dominated by westerly or easterly flows. The analysis has a strong focus on the characteristics of solid precipitation. This is a nicely written paper, based on sound data and nicely illustrated.

My main concern is that there is a disconnect between the motivation of the paper (the need to study precipitation extremes in the Rockies) and what the paper is really about. I understand that when you plan a 2-month field campaign, your chances of capturing an extreme event are very small. I also understand that undertaking such a field campaign is particularly demanding and that there is clearly a need for a unique dataset like this one.

The introduction of the manuscript has been rewritten. It is as follows.

"Western Canada is characterized by complex and rugged terrain where precipitation and associated weather conditions are highly variable (for example Stoelinga et al., 2013). This includes the eastern slopes of the Rocky Mountains, which have a continental climate subject to extremes that fluctuate from severe drought (Hanesiak et al., 2011) to extensive flooding (Pomeroy et al, 2016). Westerly flow from the Pacific Ocean brings heavy precipitation to the west coast of British Columbia while producing dry and warm conditions on these eastern slopes. During the spring, large-scale weather patterns are favourable for easterly, upslope winds that sometimes lead to extreme precipitation events. An example is the flooding in June 2013, which was one of the most catastrophic events in Canadian history (i.e. Liu et al 2016, Kochtubajda et al 2016). Previous floods such as in 2005 (Flesch and Reuter 2012, Shook 2016) rivalled the 2013 event in terms of impact.

The type of precipitation reaching the surface on the eastern slopes of the Canadian Rockies varies greatly throughout the cold seasons (Harder and Pomeroy, 2013). As summarized in Liu et al. (2017), the mean annual amount of precipitation (1960-2013) for Banff, Alberta, located ~60 km northwest of Kananaskis, is 61.7 mm. But it is not clear which month receives more precipitation as it is evident that June is the wetter month for Calgary, Alberta (located 100 km east of Kananaskis, Figure 1). Rain-snow transitions at lower elevations generally occur in March and April. Snow-water-equivalent (SWE) at higher elevation reaches a maximum in May and lowers rapidly in June and early July (Pomeroy et al., 2016). For example, catastrophic *events such as the 2013 Alberta flooding arose in part because most of the precipitation fell as rain on mountain sides and this acted to melt the existing snowpack and accentuate runoff.*

The evolution of the snowpack depends strongly on the air temperature as well as the amount and types of precipitation reaching the surface. For the period 1950-2012, winter mean temperatures have increased by 3.9°C (DeBeer et al. 2016) with very little change in precipitation in the eastern slopes of the Canadian Rockies. With the changing climate, it is critical that precipitation be well understood, including its phase, in this area because of its impact in the regional hydrological cycle. In 2008, a field experiment focusing on the changes in precipitation amounts and elevation along a transect perpendicular to the foothills was conducted, the Foothills Orographic Precipitation Experiment (Smith 2008). This experiment defined precipitation-elevation relationship using surface meteorological stations.

There is a nonetheless a need to improve our understanding of the atmospheric conditions leading to precipitation as well as the characteristics of the precipitation itself in this area. To address this, a field experiment was carried out in March-April 2015 in the Kananaskis Valley (Figure 1) to obtain critical information such as particle characteristics at the surface as well as atmospheric conditions leading to precipitation events. By utilizing this information, this study aims to better understand the precipitation characteristics and associated atmospheric driving mechanisms on the eastern slopes of the Canadian Rockies during the spring. Some of the specific scientific issues include placing the observing period into a longer-term context, quantifying the temporal variability of precipitation (and its detailed features) at the surface in relation to conditions aloft, and understanding the roles of accretion and sublimation on the precipitation reaching the surface.

The manuscript is organized as follows. Section 2 describes the field project and the instrumentation deployed. Section 3 describes the events documented and specific case studies. Section 4 focuses on the characteristics of the precipitation and associated atmospheric conditions and the precipitation processes are presented in Section 5. Section 6 places the results into perspective by comparing its findings with other studies across Canada. Section 6 provides the conclusions."

Still, I do not understand why out of the 17 events included in the analysis, more than 50% are less than a mm. Actually, 8 of the 17 events are less than 0.2 mm! There is an important fraction of the paper dedicated to the 31 March 2015 event, where a total of 0.03 mm of water equivalent was observed.

Mistakes were found in the accumulated precipitation shown in Table 1. A revised version has been made. The authors are sorry about this and we really appreciate the reviewer finding this error. The accumulated precipitation at Hay Meadow was used for consistency. When less than 0.2 mm was recorded, it is indicated as a trace. The revised Table 1 is as follows.

Table 1: A summary of the events and instrumentation over the March-April 2015 observing period at the KES site. For each event, the mean temperature (T) and relative humidity (RH) are given. The amount and types of precipitation (Amount pcpn) at the surface were rain (R), mixed

(M) and/or snow (S). The observed type was at KES and the amounts shown are at Hay Meadow (HM, Marmot creek). The amount of precipitation was adjusted using Smith (2007). A trace is when accumulated precipitation is <0.2 mm. The direction of the flow field aloft (Type event), which was either an easterly flow event (E) or a westerly event (W), is also indicated. A X indicates when each instrument was operating. These are the surface manual observations (SMO), the surface meteorological station (SMS), the optical disdrometer (OD), the Micro Rain Radar (MRR2), the microphotography setup (MP) and the sounding system (SS).

Num	Event	$\bar{T}$ [°]	$\bar{RH}$ [%]	Amount pcpn [mm]	Type pcpn	Duration [h]	Type event	SMO	SMS	OD	MRR2	MP	SS
1	15-16 March			11.3	S	21	E			X		X	
2	21-22 March			1.9	R→M→S	11	W	X	X	X		X	
3	23 March			1.2	S→M	3	E	X	X		X		X
4	28 March	5.7	82	4.0	R→M	6	W	X	X	X	X		X
5	30 March	6.1	67	trace	R	2	W	X	X		X		X
6	31 March	7.0	58	2.0	R→M	3	W	X	X	X	X		X
7	1-2 April	0.8	54	4.4	S	9	E	X	X	X	X		X
8	4-5 April	-0.5	83	3.0	S	15	E	X	X	X	X	X	X
9	6 April	-0.5	62	0.3	S	6	W	X	X	X	X		X
10	11-12 April	2	63	2.2	S	20	W	X	X	X	X	X	X
11	14-15 April	3.2	76	7.9	R→M→S	11	W	X	X	X	X	X	X
12	17 April	12.4	52	0.4	R	2	W	X	X	X	X		X
13	18 April	1.6	79	5.1	R→M→S	16.75	W	X	X	X	X	X	X
14	22-23 April	9.9	42	1.1	R→S	7	W	X	X	X	X		X
15	24-25 April	6.3	49	1.6	S	11	W	X	X	X	X		X
16	25-26 April	3.4	65	0.6	M→S	6	E	X	X	X	X	X	X
17	29 April	10.6	46	1.4	R→M→S	10	W	X	X	X	X		X

First, what is the measurement uncertainty of the precipitation gauge?

The uncertainty on the precipitation gauge is relatively low because wind speed was less than 5 m/s and most of the solid precipitation was rimed particles, which has a better collection efficiency than dry snow (Thériault et al., 2012). Also, wind speed and directions at KES were not at standard heights. For clarity, we, decided to use the precipitation measured at Hay Meadow, which was adjusted for wind speed following Smith (2007). The precipitation distribution and timing is different than KES but the data are consistent among them.

Second, from a hydrological standpoint, what is the interest?

The interest from an hydrological point of view is to quantify the type of precipitation to know if the particles y are solid, liquid or mixed phase. This will impact their interaction with the surface *and determine, for example, if the precipitation runs off directly into rivers directly or accumulates onto the snowpack.*

Also, on line 8 of p.4, we are told that the cumulative precipitation for the March-April 2015 period is 73 mm. If I sum the precipitation amount of all events listed in Table 1, I get 19.29 mm. Where are the missing 53.71 mm?

There was a mistake in the data. The cumulative precipitation at Hay Meadow is 68.9 mm. During our project (15 march to April 30, 2015), we measured documented events that produced 47.4 mm at Hay Meadow. We missed precipitation events from 1-14 March 2015. Note also that precipitation accumulation may be different at KES but Hay Meadow give a good indication of when the precipitation occurred.

I would suggest to remove all the events that are less than 1 mm and to rewrite the introduction (less emphasis on extremes and 2013 flooding) so that I better matches with the actual objectives of the paper.

The authors had considered removing events with less than 1 mm of precipitation. We decided, however, to keep all events in the analysis because the focus is on characterizing precipitation reaching the surface. If the instruments captured some particles and the observed reported precipitation, we need to consider them.

I have two additional remarks. p.8, l. 5-6: why is this the case? Explain briefly.

When non-accreted snow falls through the atmosphere, it melts faster than rimed snow. It will then produce only rain, whereas snow pellets can melt partially producing a combination of precipitation types (rain and mixed phase particles, for example).

p.9, l. 14-22: Why discuss studies in northern Canada? I would rather focus on other studies looking at precipitation in mountainous terrain.

We discussed atmospheric related studies that also examined instances of low precipitation rates at the surface. It happened that these were from northern Canada although most were also affected by strong topography. A sentence in the first paragraph has been added.

"Most of the solid particles found during March-April 2015 were rimed or were mixed with unrimed particles even under relatively dry surface conditions. These findings related to precipitation events associated with low intensity and rimed snow can be compared to the findings of some previous studies in other regions experiencing similar cold season precipitation."

A paragraph on other studies in complex terrain has been added. The following paragraph would the fourth paragraph of section 6.

"Other field projects were also conducted over complex terrain (i.e. MAP, Steiner et al, 2003; OLYMPEX, Houze et al. 2017) but few focused on the type of precipitation, in particular, the characteristics of solid precipitation. It is possible however to document the degree or riming automatically using a Multi-Angle snowflake camera (MASC, Garrett et al, 2012) as proposed, by Praz et al. (2017). They documented solid precipitation and the associated degree of riming in Antarctica."