We have used the following enumeration of reviewer comments below: R1C1 = Reviewer 1 comment 1. Reviewer comments are in black and author responses in blue.

Reviewer 1:

R1C1 The authors find that, overall, high intensity melt events are more effective in producing groundwater recharge in dry regions. This is in line with previous investigations (Jasechko Taylor, 2015) and could be stated more clearly in the abstract and conclusions.

Response: We have added to our concise summary of previous work on rapid melt leading to more effective recharge in dry regions to lines 404 to 409 of the discussion and have added the references below to round out this finding.

"Prior research has demonstrated strong seasonality in groundwater recharge, attributable to thresholds in input intensity (Jasechko and Taylor, 2015) and seasonal differences in evapotraspiration (Jasechko et al., 2014; Jasechko et al., 2017). We had hypothesized based on additional research (Hunsaker et al., 2012; Langston et al., 2015; Barnhart et al., 2016; Li et al., 2017; Hammond et al., 2018a) that input concentration along with evapotranspiration seasonality, would be the primary reason for elevated *Q* and *D* from snowmelt relative to rainfall. "

Jasechko, S., S. J. Birks, T. Gleeson, Y. Wada, P. J. Fawcett, Z. D. Sharp, J. J. McDonnell, and J. M. Welker: The pronounced seasonality of global groundwater recharge, Water Resour. Res., 50, 8845–8867, doi:10.1002/ 2014WR015809, 2014.

Jasechko, S., Wassenaar, L. I., and Mayer, B.: Isotopic evidence for widespread cold-season-biased groundwater recharge and young streamflow across central Canada. *Hydrological processes*, *31*(12), 2196-2209, 2017.

Jasechko, S., and Taylor, R. G.: Intensive rainfall recharges tropical groundwaters. *Environmental Research Letters*, *10*(12), 124015, 2015.

R1C2 The abstract is not very concise since it is not entirely clear from the abstract alone what was unknown beforehand and what the study confirms.. Currently, the abstract seems more like a list of everything that was done in the study and it is hard to get the key take away points. The authors might want to reduce the abstract length and condense the key take away points..

Response: The abstract has been shortened and now has less detail on methods so that take away points receive more emphasis.

R1C3 The paper mostly shows how streamflow generation and groundwater recharge depends on snow fraction. As has been shown in past (Barnhart et al., 2016; Musselman et al., 2017), snowmelt rates (i.e. melt intensity) and not snow fraction control hydrologic partitioning. The study would greatly benefit from reporting additional insights about how streamflow generation and groundwater recharge depend on snowmelt rates in the different climate regimes, and from a comparison of the model results with previous observation-based studies.

Response: We do address input rate at the event time scale (Figure 4). In annual time scale analyses, we used the input concentration index, which has some relation to input rate but is more appropriate for annual time scale analysis. Snow fraction is still a useful variable to consider at the annual time scale because it indicates the relative importance of snow in different climates. This study extends what is shown by Barnhart et al., 2016; Musselman et al., 2017 on the importance of snowmelt to generating runoff and deep drainage using detailed soil profiles modeled at a daily timestep. Indeed, the rate of input, and concentration of this input in time, makes snowmelt an efficient generator of runoff and deep drainage with heightened importance in dry regions.

We provide a brief comparison of runoff and deep drainage magnitude from this study to previous research on lines 517 to 524:

"60-80% of deep drainage has been shown to occur as preferential rather than interstitial flow (Wood et al., 1997; Jaynes et al., 2001; Sukhija et al., 2003), although the amount of preferential flow varies substantially between climates and soils. The magnitudes of fluxes in our simulations are consistent with observation studies, however, lending more confidence to the simplified modeling approach. Simulated annual *D/P* for dry climates (~0.05) is similar to values reported from observations (Wood et al., 1997). The simulated *Q/P* (~0.0-0.9) vs snowmelt fraction plots from HYDRUS-1D simulations follow the same general increasing pattern (r = 0.41) as observed *Q/P* (~0.0-1.0) vs SP in Hammond et al., 2018a (r = 0.39)."

Additionally, the discussion contains extensive referencing relating study findings to observation based studies:

Lines 393 to 395:

"This is consistent with previous studies showing that snowpack development and subsequent melt tend to occur when soils are at elevated moisture contents due to lower *ET* (Liu et al., 2008; Williams et al., 2009; Bales et al., 2011)."

Lines 413 to 417:

"In the simulations shown here once subsurface storage is zero, *D* will plateau, and *Q* will increase with further input due to the saturation excess mechanism. This is consistent with observations of saturation excess overland flow documented in the elevation bands of many SNOTEL sites (Newman et al., 2004; Eiriksson et al., 2013; Kampf et al., 2015)."

Lines 434 to 436:

"Prior field-based studies have also documented SWE that is similar in magnitude to the maximum amount of water storage in the upper meter of soil (Bales et al. 2011) and have shown that reducing soil depth increases surface runoff and deep drainage (Smith et al., 2011)."

R1C4. The authors do not consider rain-on-snow and mixed precipitation events in this analysis. This is probably because they work with SWE data obtained directly from the SNOTEL network, and do not use a snow model. It might be useful to mention the different event statistics in the text (eg: how much of the annual precipitation is in the form of mixed events). This should also be mentioned as a limitation in section 4.2 (which would probably benefit from a change in the title, "limitations" instead of "uncertainties").

Response: We agree that this additional information (how much of the annual precipitation is in the form of mixed events) would be helpful for the reader in interpreting the results of our study, and we will add this information both in relevant results and discussion sections on the subject of limitations.

We have added the table below to supplemental materials which provides the fraction of input each year as rain, snow and mix (rain on snow) averaged for all years at each site and then the average for all sites:

Table S6. Fraction of input from rainfall, mixed and snowmelt by site for all years and across all sites for all years.

Site	Rain fraction	Rain on snow fraction	Snowmelt fraction
352	0.23	0.45	0.32
375	0.18	0.37	0.45
396	0.39	0.52	0.10
418	0.12	0.45	0.43
428	0.15	0.51	0.34
462	0.11	0.67	0.22
481	0.32	0.52	0.16
553	0.25	0.20	0.54
559	0.45	0.43	0.12
679	0.11	0.54	0.35
697	0.21	0.54	0.25
766	0.18	0.70	0.12
778	0.46	0.27	0.27

833	0.42	0.45	0.13
848	0.15	0.48	0.38
All sites	**0.25**	**0.47**	**0.28**

In the methods section, we have added text (lines 232 to 235) relating this new information:

"To focus on differences between rainfall and snowmelt, only events with entirely rainfall or entirely snowmelt input were considered in this analysis; mixed events were excluded, though mixed input accounts for an average of 47% of annual input across all sites and years (Table S6)."

With a brief reminder in the results (lines 300-301):

"This event analysis only considered binary snowmelt or rainfall events."

And in the discussion section we provide this guidance in interpreting event and annual analyses on the influence of rain vs snow (lines 431 to 432):

"Consequently the annual analysis includes combinations of rain, snowmelt, and mixed input, whereas for event analysis we analyzed only events that were exclusively snowmelt or rainfall-dominated."

R1C5 P1 L24: Snowmelt fraction is not a commonly used term. Can instead write snowmelt as a fraction of annual precipitation. Alternatively, snowmelt fraction can be defined a priori and then be used.

Response: We define snowmelt fraction on lines 253 to 254, prior to its use throughout the results and discussion sections:

"We also report the maximum SWE and snowmelt fraction as the annual total snowmelt divided by annual total input,"

We have repeated this definition at the terms first use in the results section (lines 303 to 305):

"At the annual scale, input at all sites is a mixture of rain and snowmelt. To examine the importance of snow to partitioning, we used snowmelt fraction, defined as the fraction of snowmelt to total precipitation, and input concentration index (ICI)."

R1C6 P2 L57-58: The phrase "rainier futures" is a bit awkward. Remove?

Response: This sentence has been reworded (lines 52 to 54), and now reads:

“Daily snowmelt rates typically do not reach the extreme intensities of rainfall (Yan et al., 2018), meaning that most areas (i.e. the Cascades) are predicted to receive more intense water inputs with more winter rainfall, whereas some other areas (i.e. Southern Rockies) will likely experience a decline in input intensity with snow loss (Harpold and Kohler, 2017).”

R1C7 P2 L74: “energy hinders.. “. Do you mean that solar radiation is low during early melt and not supportive enough to drive vegetation growth, assuming snow melts very early? Then how will the growing season length increase? Should be clarified.

Response: We have clarified this statement (lines 77 to 82):

“A transition to earlier, slower, and lesser snowmelt may increase overall evapotranspiration losses (Kim et al., 2016; Foster et al., 2015; Trujillo et al., 2012) while simultaneously decreasing the water use efficiency of conifer forests during snowmelt (Knowles et al., 2018). However, even at a well-studied location in Colorado the projected effects of shifts from snow to rain on tree water use and carbon uptake differ between modeling (Moore et al., 2008; Scott-Denton et al., 2003) and observational studies (Hu et al., 2010; Winchell et al., 2017).”

R1C8 P3, line 82: “moisture content on north-facing slopes”: moisture content of the snow pack, of the soil? This requires a reference

Response: This sentence now reads (lines 87 to 92):

“Aspect modifies the snowpack energy balance, leading to higher sustained soil moisture content on north-facing slopes compared to south-facing slopes with the same input (in the northern hemisphere; Williams et al., 2009; Hinckley et al., 2014; Webb et al., 2015; Webb et al., 2018); landscape evolution due to wetter conditions on north-facing slopes may lead to deeper profiles and more deeply weathered rock conducive to deep drainage in some locations (Hinckley et al., 2014; Langston et al., 2015).”

And is supported by the following references:

Williams, C. J., McNamara, J. P. and Chandler, D. G.: Controls on the temporal and spatial variability of soil moisture in a mountainous landscape: The signature of snow and complex terrain, Hydrol. Earth Syst. Sci., doi:10.5194/hess-13-1325-2009, 2009.

Hinckley, E. L. S., Ebel, B. A., Barnes, R. T., Anderson, R. S., Williams, M. W. and Anderson, S. P.: Aspect control of water movement on hillslopes near the rain-snow transition of the Colorado Front Range, Hydrol. Process., doi:10.1002/hyp.9549, 2014.

Webb, R. W., Fassnacht, S. R. and Gooseff, M. N.: Wetting and Drying Variability of the Shallow Subsurface Beneath a Snowpack in California's Southern Sierra Nevada, Vadose Zo. J., doi:10.2136/vzj2014.12.0182, 2015.

Webb, R. W., Fassnacht, S. R. and Gooseff, M. N.: Hydrologic flow path development varies by aspect during spring snowmelt in complex subalpine terrain, Cryosphere, doi:10.5194/tc-12-287-2018, 2018.

R1C9 Variable names should be in italics (examples: L101-102, L138-145). The usage of semicolon (;) in lines 101 and 102 is incorrect and reading these sentences is difficult. Please check the usage of the semicolon throughout the paper.

Response: We have changed variable names to be in italics throughout the text, except for standard variable names snow water equivalent (SWE), potential evapotranspiration (PET), etc. which are multi-letter variables that are non-italicized as specified in the HESS manuscript preparation description (https://www.hydrology-and-earth-system-sciences.net/for_authors/manuscript_preparation.html).

One exception to the general HESS rules has been made. Under strict HESS formatting evapotranspiration would be written E_{T}, but we feel as this implies a lesser contribution of transpiration to the summed term, so we present evapotranspiration as ET throughout.

Inappropriate use of semicolons has been corrected throughout.

R1C10 P3 L105: The water balance equation is written in terms of volumes rather than fluxes, which is unusual; a change to fluxes (with the change in storage over a time increment,deltaS/deltat) seems more appropriate.

Response: The water balance can be written in terms of volumes or fluxes. In the manuscript we state that the equation applies for a given interval of time (line 111):

"Over a given time increment, partitioning can be tracked using the water balance (equation 1)."

R1C11 P3 L101 vs P4 L140: In L101, runoff is defined as lateral export of water from the domain. In L140, runoff is defined as overland flow resulting from saturation- or infiltration excess . Please clarify how runoff is defined and make it consistent throughout the manuscript.

Response: Runoff in this 1-D study is input that does not infiltrate, which may be due to infiltration or saturation excess as discussed on lines 316 to 318 on page 9:

"This partly relates to lower near-surface saturation in all rain scenarios where the mean fraction of annual runoff from saturation excess is 88% when all input is rain as compared to 97% with historical rain and snow input."

We have added this sentence directly after our study questions and water balance equation in the introduction (lines 109 to 111):

"Throughout this study, the term runoff refers to non-infiltrated input which laterally exists the domain due to infiltration or saturation excess mechanisms."

R1C12 P6 L221: Mention what percentage of annual precipitation is accounted by mixed events

Response: This sentence now reads (lines 232 to 235):

To focus on differences between rainfall and snowmelt, only events with entirely rainfall or entirely snowmelt input were considered in this analysis; mixed events were excluded, though mixed input accounts for an average of 47% of annual input across all sites and years (Table S6)

R1C13 P7 L230: for the calendar year or the hydrological year? If the calendar year: how is the snow carryover handled?

Response: Calculated for the water year, lines 242 to 245:

"At the annual scale, soil water input and partitioning components (rain, snowmelt, Q, ET, D) were totaled for each water year, and the change in water year storage (S) determined by subtracting the values of S at the end of the year from the value at the beginning of the year. In addition to S, mean saturation (Sat) at each observed depth was calculated as the average annual VWC divided by soil porosity."

R1C14: P7 L242-244: Define PCI and ICI indices with the possible range and mentioning what increasing PCI/ICI values mean

Response: PCI and ICI are defined on lines 255 to 257:

"Following the methods for computing the precipitation concentration index (PCI), which represents the continuity or discrete nature of input through time (Martin-Vide, 2004; Raziei et al., 2008; Li et al., 2011), we computed the input concentration index (ICI) using snowmelt and rain input."

We have added common ranges of the PCI and what it represents in greater detail (lines 257 to 259):

"When calculated with daily data on an annual basis, PCI commonly ranges between 0 and 100, where higher values correspond to precipitation that is irregularly spaced in time and low values correspond to precipitation evenly distributed throughout the year (Cortesi et al., 2012)."

R1C15 P7 L253 and following: it is not clear what was tested via indicator-variable regression; what is indicator-variable regression? Which results are based on this?

Response: We have added additional clarification to define indicator-variable regression and note which results use this on lines 269 to 275.

"Additionally, for question 2 we tested the pairwise difference in linear regression slopes using the regression with interaction test in JMP (SAS-based statistical software) to determine whether the rate of change between explanatory and response variables differed by climate or soil depth grouping. By comparing the slopes of regressions run on standardized data, it is possible to assess the influence of independent variables on dependent variables in different groupings. In this study, we use this test to assess the influence of snowmelt fraction of input and input concentration index on runoff and deep drainage response for all, wet and dry groupings as well as soil texture groupings."

Tables S4 and S5 present the results of this analysis as described on lines 308 to 309:

"The ranges of *Q/P* are higher in wet than in dry climates, though dry climates show greater rates of change with increasing snowmelt fraction and input concentration (Table S4)."

R1C16 P9 L327: Not clear based on the second panel of Figure 8a that you can arrive at this conclusion.

Response: We have updated text corresponding with this figure to indicate how much earlier response is in loam and sandy loam profile, and that the 100 cm VWC and deep drainage response is more frequent for these profiles (lines 346 to 353):

"For the example time period shown in Figure 8a, the 100 cm depth in loam and sandy clay loam profiles wet up each spring during snowmelt 5 days prior to the sandy loam profile, and they generated deep drainage earlier and on more occasions than sandy loam due to higher water retention. The latter soils ultimately reached the highest annual *D/P* values at higher Sat100 values, leading to more runoff generation via saturation excess, whereas the drier conditions in sandy loam led to more infiltration excess runoff. While this example time period and site displays noticeable differences in cumulative response between soil textures, when the data for all sites and years are combined few significant differences in annual partitioning between soil textures emerge (Figures 6,7).”

R1C17 P10 L371: Also mention Figure S2 which shows that a transition from snow-dominated regime to a rain-dominated regime may increase the amount of deep drainage. The Figure S2 is probably worth including in the main paper.

Response: We have added the reference to Figure S2 on line 410, but believe Figure S2 should stay in supplemental information as it is only an example at one site.

“In this study, changes from snow to rain both increased and decreased *D/P* (Figure 6, Figure S2), and *D/P* was not correlated with either snowmelt fraction or ICI in wet climates.”

R1C18 P11 L388 – 390: Which figure is this argument based on? If it is based on Table 3, please reference it in the text.

Response: We have added reference to Figure 6 and Table 3 to lines 397 to 401:

“Forcing all input into the extreme case of all rain produces substantial declines in runoff efficiency (Dry: 0.13 vs. 0.04; Wet: 0.46 vs. 0.29) (Table 3, Figure 6), likely because the input becomes less concentrated in time for the all rain scenario, allowing more *ET*. We also hypothesized that the effects of changing snowpacks would be greatest in dry climates, where soil saturation is less frequent.”

R1C19 P11 L402: How do the relative amounts of Q and D change? It is more useful to state how they change than simply mentioning they change.

Response: We have similar information on lines 391 to 393:

“Multiple lines of evidence confirm snowmelt as a more efficient runoff generator on average than rainfall. At event scale runoff efficiency was elevated for snowmelt because of the 22% greater input rate and 17% wetter soils than rainfall.”

We have added similar references to lines 397 to 401, providing relevant percentages of Q and D:

"Forcing all input into the extreme case of all rain produces 67% declines in runoff efficiency (Dry: 0.13 vs. 0.04; Wet: 0.46 vs. 0.29) (Table 3, Figure 6), likely because the input becomes less concentrated in time for the all rain scenario, allowing more *ET*. We also hypothesized that the effects of changing snowpacks would be greatest in dry climates, where soil saturation is less frequent."

Lines 421 to 423:

"Soil texture and depth generally did not change partitioning at the annual time scale as much as the varying climate scenarios (Figure 6), with the exception of changes in the shallowest soils (1x depth to 0.5x depth results in 12% *Q* increase, 180% *D* increase)."

R1C20 P11 L406: Incorrect figure citation.

Response: This figure reference referred to the precipitation axis range on Figure 3, but for clarity we have instead presented as follows (lines 426 to 428):

"The soil depths ranged from 106-127 cm, which with a porosity of 0.4 gives a storage capacity of 42-51 cm, large enough to store the mean annual precipitation in some dry watersheds."

R1C21 P13 L458: Figure S2 does not show difference between model runs using daily vs hourly inputs. Incorrect figure citation.

Response: This reference has been changed to Table S2 (line 492):

"Comparisons of results from simulations using daily vs hourly input demonstrate similar timing of response, but greater cumulative surface runoff from hourly simulations and greater cumulative deep drainage from daily simulations (Table S2)."

R1C22 Usage of the phrase "input concentration" is a bit ambiguous (eg: L203, L376). The authors use concentration in terms of length of melt period or temporal clustering of events. However, it can also be misunderstood as the intensity of melt. This should to be clarified in the text.

Response: Input concentration was defined early in the manuscript on lines 211 to 215 and 255 to 257. We have also checked for consistency in our use of the term "input concentration" throughout the text to ensure that the term always refers to temporal clustering of input.

Lines 211 to 215:

"Second, to examine the effects of input concentration, the temporal clustering of input through time, we artificially produced intermittent input (four five-day periods of low magnitude) and concentrated input (one twenty-day period of high magnitude) of the same annual total for one wet (559) and one dry (375) site using the loam profile (1056) for all years of data."

Lines 259 to 261:

"Our use of the terms input concentration and the input concentration index refer to the temporal clustering of input in time, and do not refer to the intensity of melt."

R1C23 There are a number of very long sentences in the paper which can be reframed to make the text easier to read. Some examples are: L81-85: This can be broken into two sentences. L116-120: The sentence can be shortened or converted into two sentences. L438, 464: The use of phrase "biased wet" does not sound right. L466: Reframe the sentence

Response: We agree and have edited the manuscript throughout to remove unnecessarily long sentences.

R1C24 Figure 2: What does different shades of gray mean? Is it related to hydraulic conductivity?

Response: We have clarified the figure caption to make it clear that shades of grey are only meant to show different soil layers, but do not imply characteristics of that layer:

"Different layers in each soil profile are represented as shades of gray. Shading does not indicate any property of the soil layer."

R1C125 Figure 3: In the second panel of (B), the y-axis label does not correspond with the figure label description. In the y-axis label, S/P is written whereas in figure label, ΔS/P is written.. What can we learn from panel B? Would it be interesting to present a Budyko-plot instead?

Response: Panel B sets up use of normalized response throughout rest of paper. The Y axis has been changed to ΔS/P. We believe the existing plots in Figure 3 show the hydroclimatic variability captured at the sites without the need for an additional Budyko plot.

R1C26 Figure 5: Put correlation values in the figure

Response: We have added these values to the figure.

R1C27 Figure 6: * means P-value of <0.5. Did the authors mean to write < 0.05? Its uncommon to report p-value of < 0.5. The same p-values have been reported in Tables 3, S3, S4 and S5.

Response: Yes, should be <0.05, we have corrected this.

R1C28 Figure 8: Instead of plots of Q and D, might want to show cumulative plots of Q and D as not much can be clearly seen in Q and D plots. Increase contrast between lines corresponding to 1.5x and 2x of soil depth.

Response: We have increased the contrast between lines corresponding to 1.5x and 2x of soil depth and substituted cumulative response lines instead of raw response on this figure to aid in visualization.

Reviewer 2:

R2C1 The submitted manuscript is a contribution to new ideas in the hydrologic sciences. Understanding the partitioning of soil water, runoff and deeper percolation below the root zone are important to understanding weathering, plant water use, stream water source and travel time distributions. I really enjoyed this paper. It is generally well written and well cited. I recommend the paper for acceptance with minor revisions. Specifically, I have no recommendation for additional modeling efforts. My main criticism are (1) I feel the key points are not well defined for the reader, and (2) the "Discussion Section" a bit repetitive of the results. Instead, the paper would benefit from more insight (compare and contrast) of this work with previous literature results and thoughtful hypotheses for how more complex boundary conditions may influence results (i.e. future work). Instead, I feel the reader gets bogged down in detailed results (that are in the Results section) and the key points are sort of lost.

Response: We agree that we needed to better emphasize key points that emerge from our work and we have worked to remove redundancies from results and discussion sections to focus on several key points:

- Snowmelt is a more efficient runoff generator than rainfall due to both higher input rates and higher antecedent moisture
- Deep drainage also tends to be higher with more snowmelt, but its connection to input type is weaker because soil storage buffers the effects of changing input

- When soil storage is lower than mean annual precipitation, surface runoff and deep drainage substantially increase
- Soil texture modifies daily wetting and drying patterns but has limited effect on annual runoff and deep drainage
- In dry climates snowmelt produces greater concentration of input in time, which also increases runoff and deep drainage

Highlighted sections of the results and discussion have been reworked to emphasize the key points listed above.

We have added detailed discussion on the effects of chosen boundary conditions, transient LAI, complex topography, and lateral flow detailed in responses below.

We have also added discussion of how more complex boundary conditions may influence results for future research, please see response to R2C7.

R2C2 I very much enjoyed the Introduction. It is well written. I especially enjoyed your section on soil conductance, diverging patterns in growing season length. Consider looking at and adding Knowles et al., 2018 GRL paper (doi.org/10.1002/2017GL0706504) to the Intro. The introduction should provide the reader with some hint at the limiting assumptions of a 1D approach, as I found it took too long to mention complex topography and lateral flow in my initial read through. Only in the Discussion Section “Uncertainties” is this brought to the attention of the reader with a fairly nice review. I recommend bringing some of this literature review to the Introduction. In addition to rooting depth, I suggest some discussion of how above-ground vegetation influences snow accumulation and melt rate.

Response: After looking at Knowles et al., 2018, we agree that it is a good addition to the introduction. We have added reference to this work on lines 77 to 80:

“A transition to earlier, slower, and lesser snowmelt may increase overall evapotranspiration losses (Kim et al., 2016; Foster et al., 2015; Trujillo et al., 2012) while simultaneously decreasing the water use efficiency of conifer forests during snowmelt (Knowles et al., 2018). “

We have also introduced the limitations of the 1-D modeling approach in the introduction (lines 118 to 119), though believe the review of limiting assumptions should remain in the discussion:

“The 1-D modeling approach allows for isolated comparison of climatic and edaphic factors on input partitioning; it is a simplified approach that neglects lateral redistribution of water.”

Please see the response to R2C7 below for added vegetation influence discussion.
R2C3 Page 5, line 151: Did you explore sensitivity of PET derived from a coarse grid of 4Km, as this is likely not representative of a single SNOTEL site given mountainous terrain.

Response: We did not explore the sensitivity of PET from the 4km product. The gridded products is likely more representative of conditions at some sites than others, but we aimed to apply a uniform approach across all sites. The SNOTEL sites do not have measured values of PET, so we do not have information on realistic PET values. We have commented on this issue in the discussion section (lines 494 to 496):

"Additionally, SNOTEL sites do not have measured values of PET, so we relied on a modeled 4km gridded product (Abatzoglou, 2013), which may better represent some sites than others. It was beyond the scope of this study to perform a sensitivity analysis of PET data source."

R2C4 Page 6, line 190: I am ok with the conceptual model but I think one needs to consider the implications of removing the lower boundary effects on the solution through free drainage in the discussion. Specifically, I am thinking of Brantley et al., 2017 paper where she nicely states in the abstract, "water can also flow laterally in the shallow subsurface as interflow in zones of permeability contrasts. Interflow can also be perched or it can occur during periods of high regional water table".

Response: We fold our response to this specific comment into this reviewer's subsequent comment R2C7 Our response to the subsequent comment includes additions to the discussion relevant to lower boundary conditions (including Brantley et al., 2017), transient LAI, complex topography, and lateral flow.

R2C5 Page 11, line 392, "once subsurface storage is at capacity, D will plateau and Q will increase with further input due to the saturation excess mechanism". This is a very interesting conclusion, can you provide more evidence through previous research that this result is a physical representation and not a result of the model construct.

Response: Kampf et al. 2015 show that soil moisture plateaus when saturation overland flow occurs. We do not know of other studies showing rates of deep drainage in relation to soil saturation as this is mostly inferred from hydraulic gradients.

Kampf, S., Markus, J., Heath, J. and Moore, C.: Snowmelt runoff and soil moisture dynamics on steep subalpine hillslopes, Hydrol. Process., doi:10.1002/hyp.10179, 2015.

This is discussed in relation to model results in the discussion on lines 413 to 417:

"In the simulations shown here once subsurface storage is zero, *D* will plateau, and *Q* will increase with further input due to the saturation excess mechanism. This is consistent with observations of saturation excess overland flow documented in the elevation bands of many SNOTEL sites (Newman et al., 2004; Eiriksson et al., 2013; Kampf et al., 2015)."

R2C6 Page 11, line 409, interesting result that soil water storage<mean annual precipitation, and you do provide the Smith et al., 2011 reference. But I would like to see more literature on the soil storage capacity, D and Q relationship; perhaps bring in how this might influence where D is generated (or not generated) across the watershed.

Response: We support the idea proposed by the reviewer to think spatially about the ratio of annual precipitation to soil storage and its linkage to where deep drainage may or may not be generated. We have added further discussion related to the interaction of topography, surface water inputs, vegetation, soil profile depth, etc. on controlling spatial variability of subsurface storage and deep drainage on lines 424 to 435:

"Altering soil profile depth and the associated root zone depth produced the largest effects on *Q/P* and *D/P* from 0.5x to 1x depth. The responsiveness of fluxes to changes in soil depth from 0.5-1x may relate to storage capacity relative to input. The soil depths ranged from 106-127 cm, which with a porosity of 0.4 gives a storage capacity of 42-51 cm, large enough to store the mean annual precipitation in some dry watersheds. When this storage was reduced by half to 21-25 cm, it is smaller than the mean annual precipitation at the wetter sites, increasing the likelihood of soil saturation that leads to *D* and *Q*. Consequently, the change in profile depth from 0.5 m to 1 m represents a shift from annual input greatly exceeding profile storage, to storage approximately accommodating annual input. At the sites used in this study, mean annual *P* ranged from 0.8 to 11.3 times the storage of the 1x soil profile, and peak SWE ranges from 0.1 to 5.9 times the storage. Prior field-based studies have also documented SWE that is similar in magnitude to the maximum amount of water storage in the upper meter of soil (Bales et al. 2011) and have shown that reducing soil depth increases surface runoff and deep drainage (Smith et al., 2011)."

And lines 440 to 452:

"Therefore, in this 1-D approach, soil depth exerts a stronger control on annual total input partitioning to *Q* and *D*, whereas soil texture has limited effect on annual partitioning but can affect the timing of partitioning and water availability during different times of year. In natural landscapes, texture differences can result in spatially variable soil moisture (Williams et al. 2009; Kaiser and McGlynn 2018). Combined variations in soil texture and depth within a watershed may result in significant differences in soil moisture storage across the basin (Bales et al, 2011), resulting in substantial differences in response throughout a watershed. The distribution of soil water storage capacity across the watershed likely exerts a strong control on locations where surface runoff, streamflow generation, and deep drainage are most efficiently generated especially in dry watersheds where soil moisture is generally low except during snowmelt (Atkinson et al., 2002; Seyfried et al., 2009). Additionally, unsaturated soil water storage may be the dominant control on streamflow activation during dry periods, while total input depth is the dominant control on streamflow generation during wetter periods (Farrick and Branfireun, 2014). Combining the role of soil storage capacity in space and time, areas in dry watersheds with storage similar to peak SWE may be most likely to experience reductions in deep drainage with continued slow loss."

R2C7 Page 12, line 416. Consider renaming this section from Uncertainties to something like "Limiting Assumptions" as you do not actually address uncertainty mathematically. While this section is fairly complete, consider speculating on how your results may be different by including (a) transient LAI (look at Kim et al., 2018, GRL doi.org/10.1029/2018JG00438) for some discussion ideas on phenological response to warming induced earlier green-up, (b) potential lower boundary condition controls imposing on the solution – i.e groundwater, (c) complex topography of slope and aspect and (d) lateral flow.

Response: We agree with the suggested change in title for this subsection.

We also appreciate the suggested added speculation on transient LAI, effects of lower boundary controls, and complex topography, and inclusion of lateral flow.

In addition to references already included in this section and in the introduction, we have added the following references to the discussion to more fully address assumptions of our approach as compared to other works as enumerated below, and speculate on how our results might be different if these changes were incorporated.

1) Transient LAI:

Introduction lines 77 to 82:

"A transition to earlier, slower, and lesser snowmelt may increase overall evapotranspiration losses (Kim et al., 2016; Foster et al., 2015; Trujillo et al., 2012) while simultaneously decreasing the water use efficiency of conifer forests during snowmelt (Knowles et al., 2018). However, even at a well-studied location in Colorado the projected effects of shifts from snow to rain on tree water use and carbon uptake differ between modeling (Moore et al., 2008; Scott-Denton et al., 2003) and observational studies (Hu et al., 2010; Winchell et al., 2017)."

Kim, J. H., Hwang, T., Yang, Y., Schaaf, C. L., Boose, E., & Munger, J. W. (2018). Warming-Induced Earlier Greenup Leads to Reduced Stream Discharge in a Temperate Mixed Forest Catchment. *Journal of Geophysical Research: Biogeosciences*, *123*(6), 1960-1975.

Discussion lines 459 to 463:

“Changing static LAI has a substantial effect on soil moisture dynamics (Chen et al., 2014), though model performance to match simulated and observed soil moisture does not necessarily improve with the assimilation of dynamic LAI values (Pauwels et al., 2007). Incorporating site specific constant LAI from field measurements or remotely sensed data may have improved model performance especially during spring green up and fall senescence and is recommended for future site specific studies.“

2) Lower boundary conditions:

Lines 476 to 486:

“Our modeled domain included an extended “bedrock” or regolith layer to 10 m depth to allow for deep drainage without lower boundary effects. The choice of lower boundary condition affects the simulation of soil moisture and water balance partitioning with free drainage generally resulting in lower soil moisture, evapotranspiration and runoff than with a no-flux boundary condition controlled by an impervious layer or fluctuating water table (Chen et al., 2018). The effects of lower boundary condition are generally seen in deeper layers of the soil profile and during transition periods between soil water input events when capillary rise can influence transpiration and deep drainage (Leterme et al., 2012; Brantley et al., 2017). Though a no-flux boundary condition may be appropriate for sites where relatively shallow water tables exert a strong influence on soil moisture dynamics, the inclusion of a no-flux lower boundary for the sites in this study would have made simulations wetter, furthering the difference between observed and modeled VWC.”

Chen X D, Liang X, Xia J, She D X. 2018. Impact of lower boundary condition of Richards' equation on water, energy, and soil carbon based on coupling land surface and biogeochemical models. *Pedosphere.*28(3): 497–510.

Leterme, B., Mallants, D., & Jacques, D. (2012). Sensitivity of groundwater recharge using climatic analogues and HYDRUS-1D. *Hydrology and Earth System Sciences*, *16*(8), 2485-2497.

Brantley, S. L., Lebedeva, M. I., Balashov, V. N., Singha, K., Sullivan, P. L., & Stinchcomb, G. (2017). Toward a conceptual model relating chemical reaction fronts to water flow paths in hills. *Geomorphology*, *277*, 100-117.

3) Complex topography and lateral flow

Lines 501 to 512:

"Topography affects both soil moisture and snow patterns (Western et al., 2004; Liator et al., 2008; Williams et al., 2009; Brooks et al., 2015), and it leads to lateral surface or subsurface flow, which can be important in redistributing water downslope along the soil snow interface (Webb et al., 2018) and within the shallow subsurface (Kampf et al., 2015, Kim et al., 2016). Lateral redistribution of water thus leads to spatially variable patterns of input, storage, runoff generation, and *ET* at the hillslope to watershed scales (Brooks et al., 2015). While simulating only vertical flow is reasonable for SNOTEL sites located in relatively flat forest openings, 1-D simulations will tend to be biased wet because they do not allow any lateral redistribution. A progression of the work shown here would be to simulate 3-D flow (ex. Weiler et al., 2007; Seyfried et al., 2009) and examine the spatial variability in effects of snow loss. For example, a decline in deep drainage near a ridge line, where flow paths are predominantly vertical could reduce subsurface flow emergence at downslope locations, and this decreased groundwater emergence may reduce *ET* in areas where vegetation is reliant on the emergence of deeper flow paths."

Western, A. W., Zhou, S. L., Grayson, R. B., McMahon, T. A., Blöschl, G., & Wilson, D. J. (2004). Spatial correlation of soil moisture in small catchments and its relationship to dominant spatial hydrological processes. *Journal of Hydrology*, *286*(1-4), 113-134.

Litaor, M. I., Williams, M., & Seastedt, T. R. (2008). Topographic controls on snow distribution, soil moisture, and species diversity of herbaceous alpine vegetation, Niwot Ridge, Colorado. *Journal of Geophysical Research: Biogeosciences*, *113*(G2).

Williams, C. J., McNamara, J. P., & Chandler, D. G. (2009). Controls on the temporal and spatial variability of soil moisture in a mountainous landscape: the signature of snow and complex terrain. *Hydrology and Earth System Sciences*, *13*(7), 1325-1336.

Brooks, P. D., Chorover, J., Fan, Y., Godsey, S. E., Maxwell, R. M., McNamara, J. P., & Tague, C. (2015). Hydrological partitioning in the critical zone: Recent advances and opportunities for developing transferable understanding of water cycle dynamics. *Water Resources Research*, *51*(9), 6973-6987.

Kim, J., and B. P. Mohanty (2016), Influence of lateral subsurface flow and connectivity on soil water storage in land surface modeling, J. Geophys. Res. Atmos., 121, doi:10.1002/2015JD024067.

Weiler, M., and J. J. McDonnell (2007), Conceptualizing lateral preferential flow and flow networks and simulating the effects on gauged and ungauged hillslopes, Water Resour. Res., 43, W03403, doi:10.1029/2006WR004867.

R2C8 Page 14, line 485. Your last sentence is not very strong, "water managers should develop strategies to mitigate . . ..". It should contain some qualifications based directly on your analysis.

Response: We agree with the reviewers assertion and will update this sentence to read along the lines of what is shown below:

Original:

“Although more work is necessary to translate these finding to streamflow response, water managers should develop strategies to mitigate impacts of reduced streamflow generation in places that are at risk for shifts from snow to rain.”

Update (lines 547 to 549):

“Although more work is necessary to translate these findings to watershed-scale streamflow response, the findings highlight the importance of precipitation phase shifts on runoff generation and groundwater recharge.”