Major comments

The manuscript entitled "Spatially-distributed tracer-aided runoff modelling and dynamics of storage and water ages in a permafrost-influenced catchment" by Thea I. Piovano et al. developed a new permafrost feature that facilitates fully distributed simulations of hydrological storage dynamics and runoff processes, isotopic composition, and water ages within the Spatially distributed Tracer-Aided Rainfall-Runoff (STARR) conceptual model. The new feature is definitely very interesting to readers and a great advancement. One of the most important findings in this paper is that "Results from the model output correspond with previous field investigation and hydrograph separation studies that indicate relatively old water (pre-event) dominates runoff generation during spring freshet." This result corresponds to findings by Suzuki et al. (2006b, 2018). This implied that further global warming might reduce permafrost coverage and speed up the hydrological cycle. Overall, authors need to revise the manuscript before its publication. Although there are some issues, I recommend that this paper be published after a few revisions are made.

My main concerns are as follows:

(1) First, there is a very important discrepancy in stream δ^2H between the model simulation and observation data during snowmelt season. The δ^2H in snow is low enough to be comparable with the δ^2H in the stream; however, the trend in the latter is the complete opposite of the observations, because observed δ^2H increases while the simulated δ^2H decreased during the entire snowmelt season. I think that this is a critical flaw in the model because snowmelt water should primarily contribute at the beginning of the snowmelt season, when the surface soil is frozen. In a permafrost region, the active layer—which is a seasonal frost layer above the permafrost—strongly controls peak discharge (see, for instance, Yamazaki et al., 2006) and material transport (for instance, Suzuki et al., 2006a). Most researchers are interested in how seasonal active layer depth affects water age and isotope composition. I think that Suzuki et al. (2006a) showed that δ^{18}O, which had a strong linear correlation with δ^2H (for instance, Piovano et al., 2018), clearly increased during a snowmelt period. This suggested that the trend in a small Siberian basin

would be similar with changes in the Granger basin. Thus, I believe that the new STARR feature has some problems in terms of isotope ratio estimation in permafrost influenced basins. Please add some discussion in this aspect.

(2) Second, I recommend that you emphasize how the permafrost and active layer affect water age and snowmelt runoff generation. To justify the role of old water in the permafrost regions, please consider previous studies in the Siberian watershed, such as Suzuki et al. (2006b), Yamazaki et al. (2006), and Suzuki et al. (2018).

(3) Third, it would be better to add an additional comparison of water age during a snowmelt from the previous study (Piovano et al., 2018) against the present study to evaluate the effects of permafrost with respect to the generation of snowmelt runoff. Otherwise you might discuss the effect of permafrost on water age using an additional experiment with and without seasonal changes in field capacity.

(4) Fourth, I agree with your conclusion that "*Results from the model output correspond with previous field investigation and hydrograph separation studies that indicate relatively old water (pre-event) dominates runoff generation during spring freshet. The relatively flashy nature of spring freshet in this largely frozen alpine catchment may seem counter-intuitive to this finding, yet water stored within the catchment from the previous year is the main source of stream water at the end of the melt season and explains isotopic damping of the signal.*" I think that this finding is coincident with Suzuki et al. (2018) in terms of continental-scale Arctic river basins. Thus, I recommend that you add how the role of permafrost in keeping water frozen during winter can mitigate the speeding up of the hydrological cycle (rainfall/snowfall to discharge).

Finally, please edit your text more carefully. For instance, please consider rewriting lines 17-21 on page 8 because those sentences are not clear. In addition, please add the word "liquid" to the figure 6 caption.

Reference:

Piovano, T. I., Tetzlaff, D., Ala-aho, P., Buttle, J., Mitchell, C. P. J. and Soulsby, C.: Testing a spatially distributed tracer-aided runoff model in a snow-influenced catchment: Effects of multicriteria calibration on streamwater ages, Hydrol. Process., 32(20), 3089–3107, doi:10.1002/hyp.13238, 2018.

Suzuki, K., Konohira, E., Yamazaki, Y., Kubota, J., Ohata, T. and Vuglinsky, V.: Transport of organic carbon from the Mogot Experimental Watershed in the southern mountainous taiga of eastern Siberia, Nordic Hydrology, 37(3), 303–312, doi:10.2166/nh.2006.015, 2006a.

Suzuki, K., Kubota, J., Ohata, T. and Vuglinsky, V.: Influence of snow ablation and frozen ground on spring runoff generation in the Mogot Experimental Watershed, southern mountainous taiga of eastern Siberia, Nordic Hydrology, 37(1), 21–29, doi:10.2166/nh.2005.027, 2006b.

Suzuki, K., Matsuo, K., Yamazaki, D., Ichii, K., Iijima, Y., Papa, F., Yanagi, Y. and Hiyama, T.: Hydrological Variability and Changes in the Arctic Circumpolar Tundra and the Three Largest Pan-Arctic River Basins from 2002 to 2016, Remote Sensing, 10, 402‑, doi:10.3390/rs10030402, 2018.

Yamazaki, Y., Kubota, J., Ohata, T., Vuglinsky, V. and Mizuyama, T.: Seasonal changes in runoff characteristics on a permafrost watershed in the southern mountainous region of eastern Siberia, Hydrol. Process., 20(3), 453–467, doi:10.1002/hyp.5914, 2006.