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Interactive comment on "Spatio-temporal Patterns of High Mountain Asia's Snowmelt Season Identified with an Automated Snowmelt Detection Algorithm, 1987–2016" *by* Taylor Smith et al.

Anonymous Referee #1

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In this paper, the authors use passive microwave data to identify snowmelt onset, snowmelt end and snowmelt period over the High Mountain Asia (HMA) region. They verify the results of an automated algorithm by comparison to manually identified dates in the microwave signal and find it matches to within 5 days. They then use the algorithm to calculate the melt onset, end and period over 29 years and evaluate trends across the region. The paper is well written and provides a long-term record of snowmelt trends across a region where snowmelt is a critical source of water supply. They use an existing method for identifying melt, but apply new techniques for detecting onset and end, as well as a hierarchical clustering method to identify spatial patterns in the data. This paper contributes to the literature in an understudied area of

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the world.

My main feedback is that the lack of validation data for this technique raises a number of questions. It would be useful to see validation of the approach in this region that would lend confidence to the results, independent of the microwave data. Some possible data sources that could be used include snow covered area from MODIS or VIIRS to estimate snowmelt end dates. Discharge data, if available, could be used to verify the onset of melt by evaluating the rising limb of the snowmelt hydrograph. Similarly, it may be possible to examine shifts towards earlier melt timing by looking at the hydrograph centroid. (See Regonda et al. 2004, Seasonal Cycle Shifts in Hydroclimatology over the Western United States, Journal of Climate, Vol. 18). Alternatively, temperature data may provide some verification of onset dates. If these data are not available, then demonstrating the approach in an area with data would be useful.

General comments:

1. The 36 GHz signal saturates out in deep snow, which I expect much of this area experiences. How does that affect the gradient ratio approach, since the difference may remain fairly constant for much of the season? How do you know you're selecting the actual maximum XPGR?

2. Related to question 1, the XPGR seems to follow the calculated SWE signal. How does the calculated SWE compare to general estimates of SWE in the region? Is it reasonable, or is there evidence of signal saturation?

3. It is interesting that some of the trends change after 2002, when several additional instruments begin to be available and are included in the analysis. Is it possible that differences in the sensors are causing different results?

4. Following on question 3, in section 2.3 the method used to merge the datasets for the hierarchical clustering analysis is described. Was this merged dataset also used in the snowmelt tracking analysis? If not, then explain why differences in the sensors

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wouldn't impact the estimated melt onset and end dates. If yes then this description should be included earlier.

5. The manual selection of dates based on the time series seems subjective. It would be useful to include additional information on how those dates were selected. For example in Figure 3 – in both 2009 and in 2010 there were two peaks of similar magnitude during the winter season. In 2009 the one closer to the end of the season was selected despite appearing less than the earlier one. In 2010 the one very early in the season was selected despite there being an almost equal peak later on. The description in section 3.1 should be clearer.

Specific comments:

1. Page 3, Line 25: why was this algorithm chosen over the other methods referenced in the introduction?

2. Section 2.1: additional background information on passive microwave detection of snow and snowmelt is needed, specifically on how the signal is affected by liquid water in the snow at different frequencies.

3. Page 4, Line 7: Was SWE calculated using the Chang algorithm on Tb from the different sensors? Or are you using the SWE products developed for the different sensors? Adding the equation would be useful. How do you combine multiple sensors when available?

4. Page 5, line 2: Not sure what is meant by "regularize".

5. Page 5, lines 23-25: How does the standard deviation of the melt onset date vary spatially? It seems this approach would work best in high elevation/deep snow regions, whereas along the edges in lower elevation where the snow is more ephemeral there might be more error. This would also affect estimates of melt period.

6. Page 6, line 8: Where you say, "snow is present for less than a month on average." Are you referring to the snowmelt period or the entire snow season? That sounds like

the entire season, but everywhere else is referring to melt period.

7. Page 6, line 24: You say, “As can be seen in Figure 3, inter-annual variation in snowfall can cause large disparities in the yearly dates of snowmelt onset and end.” Based on Figure 3 there doesn’t appear to be a lot of variability – the peak SWE is around 100mm each year. Are you referring to timing of snowfall events?

8. Figure 1. Can you identify on the overview map the location of the sample data shown in figures 2 and 3?

9. Figure 4: What do the gray areas on the plateau represent? Provide an explanation, similar to figure 6.

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