Response to Reviewer #2

Overall Comments

This paper presents a new inventory of 255 active rock glaciers in the Uinta Mountains, Utah, from velocity maps of InSAR. The authors compared their inventory to the previous studies and discussed several aspects of the datasets, including the geomorphic and dynamic patterns, temporal displacements on the selected three rock glaciers, possible responses to climate changes, and the hydrological implications. This study shows the strength of InSAR for mapping and investigating active rock glaciers, although it is not the first one. The study also gives insights into how the unique climate change pattern in Uinta Mountains, which is different from the other places like European Alps and Asian Himalaya, would influence the dynamics of the rock glaciers there. The paper is overall well written and structured and can be accepted after minor revisions. My concerns mainly lay in the methodology part. Some details of the data processing need to be clarified or explained.

No.	Comment	Response
1	*The uncertainties of the surface velocities from InSAR should be evaluated. Significantly, the centimeter-level magnitude of velocities of rock glaciers presented here should be carefully interpreted because the atmospheric errors always reach such magnitude. The author asserted that they use the ERA-I global weather model to mitigate tropospheric delay in Sentinel-1 interferograms. However, the correction performance of the low-resolution ERA-I data may degrade at the small-scale targets like rock glaciers.*	Concur. We examined the InSAR stacks carefully with and without the atmospheric correction and ensured the rock glacier deformation signals were consistent. In addition to using the TRAIN software package to reduce atmospheric InSAR noise, we mitigated atmospheric effects significantly by averaging multiple interferograms to create the stacks we used to calculate rock glacier velocities. Furthermore, we carefully selected local stable reference such as bedrock outcrops and parking lots which cancels out spatially correlated signals at distances exceeding the separation between these pixels. To better explain our uncertainties, we will add a sentence or two evaluating atmospheric errors in detail to the paragraph in the discussion where we discuss the limitations of our methods (lines 307-326). We will also quantify the InSAR velocity of stable hillslopes throughout the Uintas and report this as the mean and standard deviation uncertainty.
2	*The author compared their InSAR-based inventory to the inventory of Munroe et al. (2018), whose inventory method should be also summarized in the paper. Munroe et al. (2018) may compile both the active and inactive rock glaciers, while this study only compiles the active ones.*	Concur. We will add a sentence to the introduction briefly summarizing the inventory method used in Munroe (2018) (Line 78). Munroe (2018) states: "Rock glaciers were identified by scanning the bases of steep bedrock slopes and talus, searching for locations where the normal smooth talus profile is interrupted by a notably steep-fronted bulge with reduced lichen cover, where the talus appears wrinkled, and where

		furrows and other evidence of movement are apparent. Areas exhibiting these characteristics were delineated as polygons in ArcMap GIS.”
3	*The sensitivity of InSAR LOS measurements vary with respect to the aspects of rock glaciers. This may explain why little correlations were found between the InSAR LOS measurements and the topo-climate factors. The authors may calculate surface velocities along the downslope directions of rock glaciers and then probe the correlations.*	We did consider projecting rock glacier motion along the downslope direction. We decided against it because 1) we would be required to assume the rock glaciers were moving exactly in the steepest downslope direction based on DEMs made decades ago, which could introduce significant error, and 2) we don’t think it would ultimately reveal a relationship between rock glacier velocity and topo-climatic factors. As far as we are aware, rock glacier velocity is often not well correlated topo-climatic factors because velocity depends on many variables (ice content, pore pressure, thickness, etc…). We further note that there is no relationship in our data between aspect and elevation, slope, rock glacier area, precipitation, or (with our low-resolution temperature data) temperature.

Specific Comments

No.	Comment	Response
1	*Line 81 Add sub-title for section 2, e.g., '2 Study area and InSAR analysis.'*	As per reviewer #1’s suggestion, we plan on splitting this section into Section 2: Study area and Section 3: InSAR analysis.
2	*Line 91 Does 'Average precipitation' refer to the mean annual precipitation?*	Yes! We will revise the sentence to read: “Mean annual precipitation (MAP) in the Uintas between 1981 and 2010 ranged from 45 to 107 cm (Fig. 2c)”
3	*Line 125 The author stated that "To improve spatial resolution, selected one-year interferogram pairs were reprocessed with a USGS 3DEP DEM with 10 m pixel spacing". Which year of the image pairs were selected? Also, if the high-resolution DEM with 10 m spacing is available, why did the author remove the topographic phase using the SRTM data that has a coarser resolution (~ 30 m).*	Our ascending stack included interferograms: 20160921 20170922 20160921 20170910 20160927 20170922 20170805 20180731 20180731 20190807 Our descending stack included interferograms: 20160902 20170828 20160902 20170909 20160926 20170921 20170804 20180730 20180730 20190806 We can include these lists of the interferograms in each stack in the appendix.

		Computational limitations prevented us from processing all interferograms with the 10 m DEM. Instead, we used a 30 m DEM initially, then reprocessed our best interferograms with the 10-m DEM. Section will be revised to read: "To improve spatial resolution, selected one-year interferogram pairs were reprocessed with a USGS 3DEP DEM with 10 m pixel spacing. Computational limitations prevented us from processing all interferograms with the 10 m DEM."
4	*Line 146 Please elaborate on how did you address the average annual velocities from the ascending and descending stacks of 1-year interferograms since the observations from ascending and descending SAR data have different looking directions. Furthermore, from my understanding, should average annual velocities be improved by averaging three-year InSAR observations, rather than only using the 1-year data.*	We calculated 75th percentile LOS velocity for each rock glacier using both stacks. The larger of the ascending and descending values is used to represent rock glacier velocity in our data analysis (line 153-154). We avoided processing 3-year pairs, in part because we wanted to avoid unwrapping errors. See line 320: very long-baseline interferograms would be likely to introduce inaccuracies.
5	*Line 160 Please indicate the local reference points for phase unwrapping in Fig. 3 for the three selected rock glaciers.*	Concur. We'll add reference points to Fig. 3.
6	*Line 100 Please give a short summary of the inventory method used by Munroe et al., (2018), and the method for estimating the storage water of the rock glaciers.*	Concur. See response to general comment #2. See lines 394-394 for a brief summary of the method for estimating water content used by Munroe, (2018).
7	*Line 217 Rock glacier velocities cannot be correlated with 'morphology.'*	By morphology, we're referring to whether the rock glacier is tongue-shaped or lobate. To be more clear, we will edit this line to read: "No metric of rock glacier velocity is significantly correlated with rock glacier area, elevation, slope, aspect, or rock glacier type (Fig. 7a, Fig. A2)."
8	*Line 282 LOS velocity is a projection of real ground 3D velocity along the Satellite side-looking direction. It seems arbitrary by simply saying 'LOS measurements underestimate the true 3D velocity'.*	Since rock glacier motion is never entirely along the look direction, LOS velocity will, in practice, always be an underestimate of the rock glaciers' true 3d surface motion. We think this is important to mention, since it partly explains why our velocity estimates are low.
9	*Line 300. Please note that the correlation analysis between surface velocities and topo-climate factors requires that the surface velocities are in the same direction. The non-correlation pattern may also arise due to the diverse aspects of the rock glaciers.*	Characteristic rock glacier velocities were calculated by taking the 75th percent value of the velocity values within a rock glacier body. Two values were generated for each rock glacier, one derived from the ascending and another from the descending stack. The larger

		(in terms of magnitude) of the ascending and descending values is used to represent rock glacier velocity in our data analysis. Before attempting to correlate rock glacier velocity estimates with topo-climatic factors, we also took their absolute value. While our estimates for rock glacier velocity are derived from different LOSs, this shouldn't have much effect on our ability to correlate topo-climatic factors with velocity, since we are considering only the magnitude of rock glacier motion here.
10	*Line 315 The statistical differences between this study and Munroe et al. (2018) may also be a result of the two studies' different inventorying methods. Munroe's (2018) inventory consists of both active and inactive rock glaciers, while this study only includes the active ones.*	It is possible that in reality there are relatively more north-facing inactive rock glaciers than inactive rock glaciers facing other directions, which would explain why the Munroe (2018) inventory, which contains active and inactive rock glaciers, has a higher proportion of north-facing rock glaciers than our active rock glacier inventory. However, we don't have a reasonable explanation for why more inactive rock glaciers would face north than other directions. It seems more likely that we simply underestimated the number of north-facing active rock glaciers due to InSAR's insensitivity to motion along the azimuth direction.
11	*Line 374 The presence of 155 inactive rock glaciers supports this claim.*	Looks like the comment here may be missing?

Figure Comments

1	*Figure 5. Add captions for Fig. 5c.*	Concur. We'll add a sentence that reads: "(c) aspect of steep slopes (>10˚) of the Uinta Mountains, for reference."
2	*Figure 8. More displacement time series points are expected to be shown as 26 ascending, and 32 descending SAR scenes have been used to perform the SAR time series analysis. In comparison, it seems that no more than 20 displacement points are shown in (a-c).*	See line 159-160: "Interferograms with low overall coherence were manually removed from the time series." For clarity, we'll add a sentence to the same effect to the Figure 8 caption.

Thank you very much for your comments!