Response to Reviewer #3

Overall Comments

In this manuscript the authors used satellite SAR interferometry to identify and monitor active rock glaciers in the Uinta Mountains (Utah, USA). Velocity maps derived from Sentinel-1 data were considered to generate an inventory of active rock glaciers. A number of relationships with topographic and climatic drivers were calculated and analyzed. Mean LOS velocities are in the order of a few cm/yr. The paper is very well structured and written. However, there are some important missing information that should be included in a revised version.

No.	**Comment**	**Response**
1	*Line 10: According to the ongoing work of the IPA Action Group: Rock glacier inventories and kinematics (https://www.unifr.ch/geo/geomorphology/en/research/ipa-action-group-rock-glacier) regarding the definition of standard guidelines for inventorying rock glaciers (https://bigweb.unifr.ch/Science/Geosciences/Geomorphology/Pub/Website/IPA/Guidelines/V4/200507_Baseline_Concepts_) the following updated categorization of activity are proposed: - An active rock glacier shows coherent downslope movement over most of its surface. As an indication, the displacement rate can range from a decimeter to several meters per year. - Transitional rock glacier shows little to no downslope movement over most of its surface. As an indication, the average displacement rate is less than a decimeter per year in an annual mean over most of the rock glacier. Downslope movement must not be confused with subsidence. The rock glaciers in the study area seem thus to be rather transitional and not active.*	Concur. According to these proposed definitions, most of the actively creeping rock glaciers we identified can be categorized as transitional by virtue of their slow velocities. We will add a sentence to Line 30 of our introduction: "Rock glaciers with slow movement (<10 cm/yr) only detectable by measurement and/or restricted to areas of non-dominant extent have been defined as transitional and evolve towards an active on inactive state according to their topographic and climatic setting (IPA, 2020)" We will revise our language throughout the paper to refer to rock glaciers moving at <10 cm/yr as transitional.
2	*Line 25-26: Also the other way round is valid: rock glaciers might be considered as indicators of climate change, see again the work of the IPA Action Group: Rock glacier inventories and kinematics and in particular the Task 2 activities "Rock glacier kinematics as an associated parameter of ECV Permafrost", https://bigweb.unifr.ch/Science/Geosciences/Geomorphology/Pub/Website/IPA/RGK/200121_RockGlacierKinematics_V1.0.*	Concur.
3	*Line 65-75: Add further references, e.g.: Strozzi et al. Detecting and quantifying mountain*	Concur. We will add these references.

	permafrost creep from in situ inventory, space-borne radar interferometry and airborne digital photogrammetry. Int. J. Rem. Sens. 2004, 25, 2919–2931. *Barboux et al. Inventorying slope movements in an Alpine environment using DinSAR. Earth Surf. Process. Landf. 2014, 39, 2087–2099.* *Rick et al. Detection and inventorying of slope movements in the Brooks Range, Alaska using DInSAR: A test study. In Proceedings of the GEOQuébec 2015: 68th Canadian Geotechnical Conference and 7th Canadian Permafrost Conference, Quebec City Convention Centre, Québec, QC, Canada, 20–23 September 2015.* *Necsoiu et al. Rock glacier dynamics in Southern Carpathian Mountains from high-resolution optical and multi-temporal SAR satellite imagery. Remote Sens. Environ. 2016, 177, 21–36. Strozzi et al. Monitoring Rock Glacier Kinematics with Satellite Synthetic Aperture Radar, Remote Sens. 2020, 12(3), 559.*	
4	*Line 125: Why only selected one-year pairs and not all?*	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."
5	*Line 136-145: This methodological part is not well explained: - What do you mean at l. 136 with "InSAR velocity maps"? One ascending and one descending? Or for all the InSAR pairs analyzed (see Table in the appendix)? - What do you mean by "a clear and relatively high LOS velocity signal"? Be more precise and quantitative. - See IPA guidelines for the definition of the activity classes (first point above). - What do you mean by "delineated"? Manually or automatically?*	We used velocity maps derived from all the analyzed InSAR pairs to generate our inventory. We typically relied on one-year pairs more, as displacement signals in one-year pairs were much larger than any signals related to atmospheric noise. However, in the case of fast-moving rock glaciers that may have caused decorrelation errors in one-year pairs, shorter baseline interferograms were frequently used as well.

		By “clear and relatively high LOS velocity signal” we mean that rock glaciers obviously displacing at a faster rate than their surroundings were considered active. We did not use a specific velocity threshold to determine whether rock glaciers were active. As long as pixels over the surface of the mapped rock glacier body showed a clear and consistent displacement signal in a direction consistent with the downslope direction, and the surrounding pixels did not, we considered the rock glacier to be active. We manually delineated rock glacier boundaries in QGIS. We will revise this section to read: “All resulting InSAR velocity maps were used along with Google Earth imagery, the USGS 10 m DEM, and the previous Uinta rock glacier inventory (Munroe, 2018) to generate an active rock glacier inventory in QGIS 3.10. Rock glaciers displaying a clear and relatively high LOS velocity signal with a sign suggesting downslope movement were considered active or transitional (Fig. 2). Boundaries of rock glaciers were manually delineated on the basis of morphology and InSAR-derived movement pattern. Slope, aspect, and elevation of features in the rock glacier inventory were calculated in QGIS from the 10 m DEM. Rock glaciers were classified as lobate or tongue-shaped (Barsch, 1996) based on morphology, and as “North Uintas” or “South Uintas” based on their location relative to the east-west trending spine of the mountain range (Fig. 2). A non-parametric Kruskall-Wallis test was used to establish significance of differences between groups.”
6	*146-148. What is the difference between these “average annual velocities” and those of the previous section? How were these maps computed? Which pairs were considered? They could be highlighted in the table of the appendix. Any weighting (e.g. time interval, coherence) in the average?* *What is shown in Figures 2 and 3? The velocities of l. 136-145 or those of l. 146-148?*	These average annual velocities were calculated from stacks made from the velocity maps mentioned in the previous section (Line 136). These stacks (one ascending and one descending) were computed by averaging 1-year pair velocity maps, ignoring “NoData” values. 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 will include these lists of the interferograms in each stack in the appendix (Table A2). There was no weighting in the average. All interferograms used were one-year pairs. We used a coherence threshold of 0.3 during interferogram processing to remove low-quality data. The "No Data" values produced as a result were ignored when averaging velocity maps to create the stacks. Lines 146-147 will be revised to read: "Average annual velocities for rock glaciers were calculated in QGIS using velocity maps derived from ascending and descending stacks of 1 year interferograms (Fig. 2). These stacks were calculated from the one-year pairs with 10 m pixel spacing (Table A2). Average LOS velocity magnitudes were calculated by taking the mean of the absolute value of velocity values over the surface of each rock glacier." Figures 2 and 3 both show the InSAR velocity map stacks. The caption for Figure 2 will be revised to read: "Uinta Mountains study site. (a) Hillshade map of the Uinta Mountains overlaid with InSAR average velocity stack from descending track 27. The caption for Figure 3 already includes that average velocity stacks were used in the figure.
7	*Line 204: A threshold for inactive rock glaciers was not defined. Please be precise, considering also the indications of the IPA working group.*	We did not use a specific velocity threshold to identify inactive rock glaciers. When the pixels over the surface of a mapped rock glacier body did not show clear and coherent displacement

		visually distinct from the displacement of the surrounding pixels, the rock glacier was considered inactive. In practice, our slowest “active” rock glaciers move at rates >0.9 cm/yr, very close to the 1 cm/yr threshold used by the IPA action group to separate inactive rock glaciers from transitional rock glacier. We will add a sentence to our methods section beginning on Line 140 that states: “Rock glaciers identified in the previous inventory that showed no coherent and distinct deformation in our InSAR velocity maps were classified as inactive.”
8	*Line 207: What is the min. detectable size of an InSAR signal?*	InSAR can be used to accurately estimate displacement down to the millimeter scale. See: Bürgmann, R., Rosen, P. A., & Fielding, E. J. (2000). Synthetic aperture radar interferometry to measure Earth’s surface topography and its deformation. Annual review of earth and planetary sciences, 28(1), 169-209. The smallest spatial area we considered to have a clear and coherent signal indicating rock glacier activity was 5,000 m^2. We will add a sentence to that effect to Line 140.
9	*Line 212-214: Add a reference to these statements.*	These are our own observations of Uinta rock glaciers. For clarity, we will revise Line 212 to read: “We observed that Uinta rock glaciers generally have…”
10	*Line 219-221: As observed in other regions, please add appropriate references.*	We included references for seasonal changes in rock glacier motion observed in other regions in our introduction, Lines 42-43.
11	*Lines 236-239 and 295-298: Again, better define what is an active rock glacier, in particular considering the recent IPA guidelines. In this region we are probably at the limit of permafrost occurrence, small activity is possibly linked to the presence of permafrost.*	See response to Comment 1. We will adopt the language of the IPA action group throughout the document.
12	*Line 320: Why were these apparently wrong estimates (40 cm/a in 12 days versus 4 cm/a in 1 year) not masked out?*	1) There is no conclusive evidence that movement of this particular rock glacier caused unwrapping errors. It is possible that these discrepancies could be the result of particularly strong seasonal changes in

		velocity. We didn’t feel that removing this data was justified based on the evidence that we had. 2) These apparent errors only appeared to impact a very small number of rock glaciers in our inventory (<5). They are unlikely to have a large impact on our velocity estimates.
13	*Line 333: … and else where, add references*	Concur. We will revise the sentence to read: It’s likely that this observation period was too small to capture possible long-term trends in rock glacier motion, as have been well-documented in the Alps and other regions (Delaloye et al., 2008; Kääb et al., 2007; Kaufmann and Ladstädter, 2007; Roer et al., 2005; Vonder Muehll et al., 2007; Eriksen et al., 2018; Necsoiu et al., 2016).
Thank you very much for providing comments!		