A method of mass balance estimating of the mountain glaciers using the SAR data C-band spaceborne SAR observations

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Abstract

The mountain glacier changes are believed to currently provide significant responses to global climate change and strongly influence human welfare in the arid or semi-arid region, where water supplies are predominantly from glacier melt. Meanwhile, glacier mass balance has direct contribution sea level rise, declining water resources, runoff and disaster of glacier lake outburst. So the accurate estimation of mass balance at high spatial and temporal resolution is very important. Although traditional ground-based techniques exist for measuring glacier mass balance directly and inter-annually, they tend to be labor-intensive, expensive and provide very limited spatial coverage. SAR observations offer direct means of monitoring changes in surface elevation over the mountain glacier and can achieve centimeter-level accuracy. In this study, we developed a method to utilize observations of the glacier surface deformation to derive the thickness changes, and then calculated the mass balance using SAR observations. The paper demonstrates the feasibility of the presented method to obtain and analyze the mass balance of the mountain glacier.

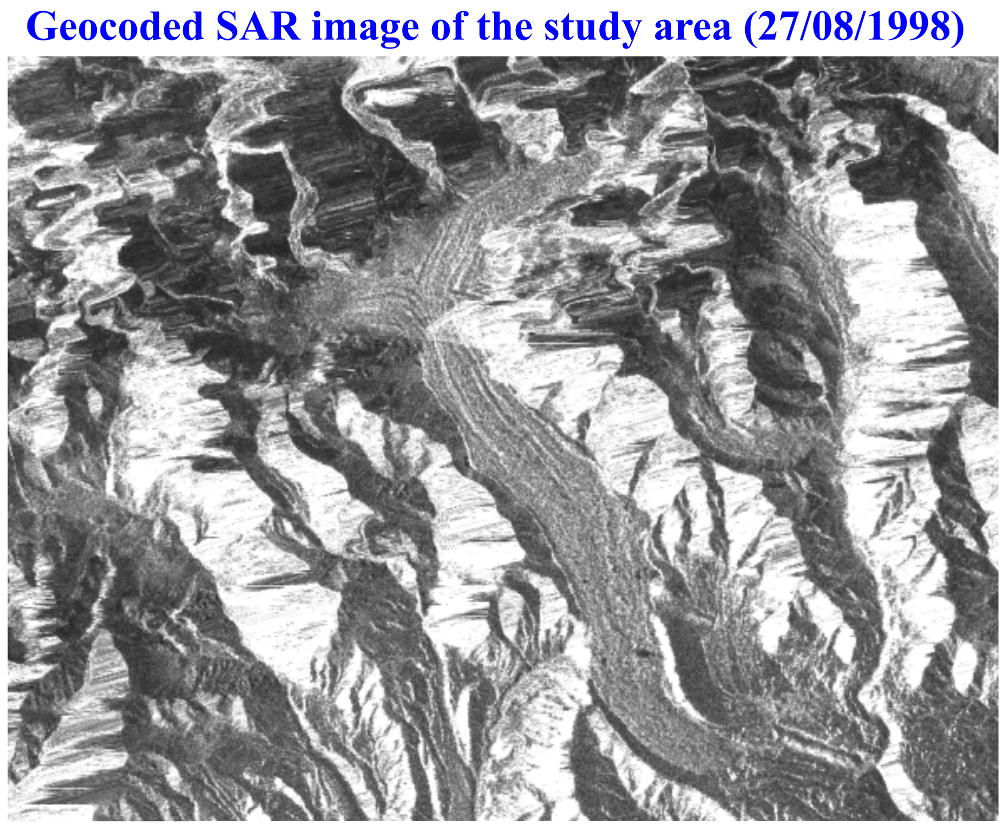
Study area and data

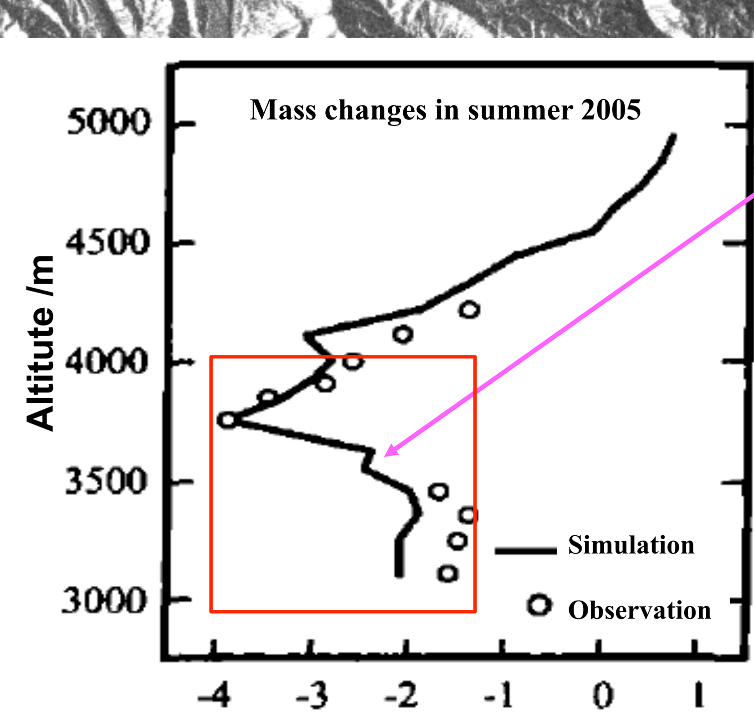
The study area local in Koxkar glacier (41.42 °N-41.53 °N and 79.59 °E-80.10 °E) in Tianshan Mountains, China, which is a typical Tuomuer-type glacier originating from Mt. Koxkar (6,342 m a.s.l.), and flows southeast to the terminus of 3,020 m a.s.l. The glacier extends 25.1 km in length and covers an area of 83.56 km^2. The equilibrium line occurs at 4,300 m a.s.l. in the icefall from whose foot a 15.5-km-long, debris-mantled glacier tongue appears. The supraglacial debris covers an area of about 19.5 km^2, which accounts for 83% of the total ablation area, with thicknesses ranging from less than 0.01 m on the upper reach of the ablation area and on ice cliff faces to more than 3.0 m near the glacier snout.

Tandem Data from ERS-1/2

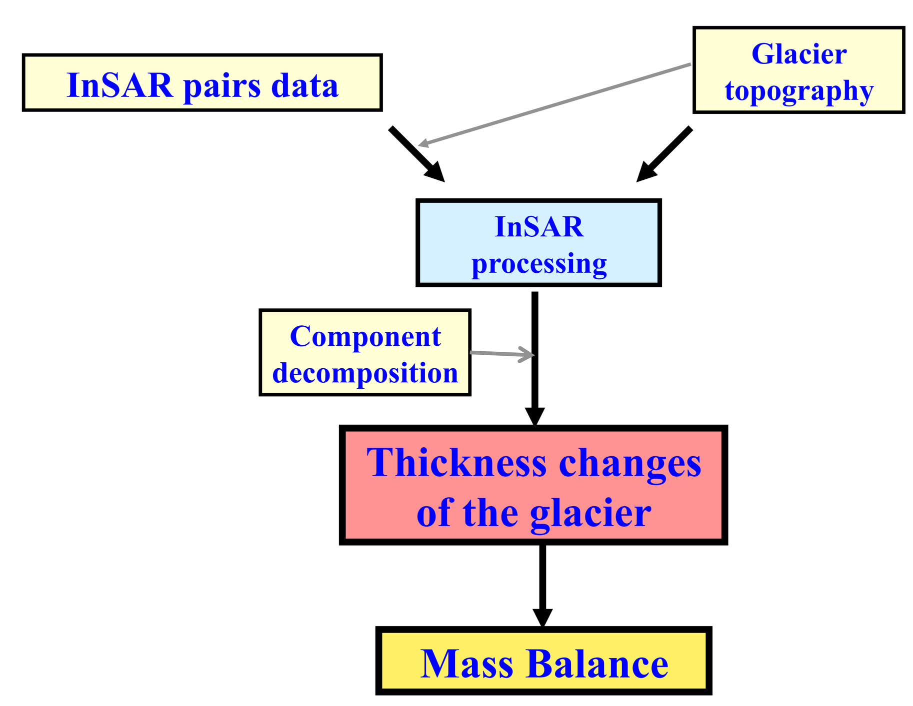
Satellite	Date
ERS-1	1998/08/27
ERS-2	1998/08/28
ERS-1	1999/03/19
ERS-2	1999/03/20
ERS-1	1999/06/03
ERS-2	1999/06/04

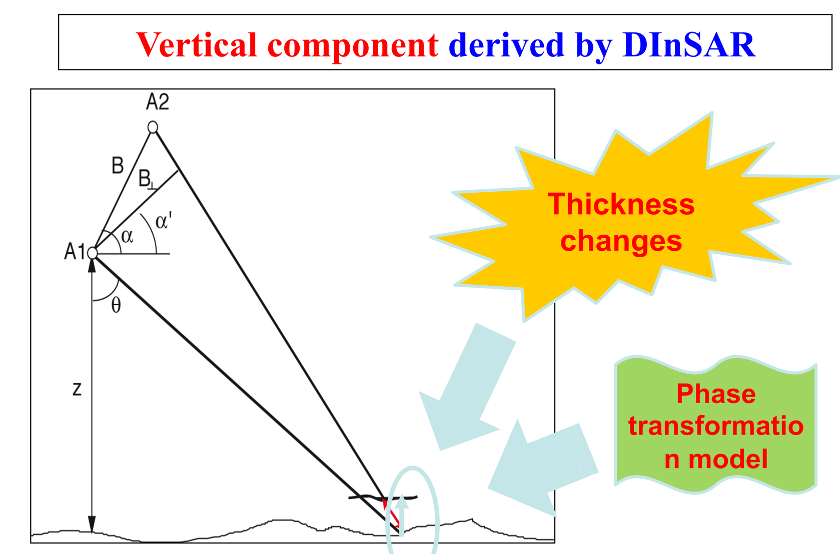
Geocoded SAR image of the study area (27/08/1998)





Methods & Results





$$\Delta_{\mathrm{mass}\,(w\ or\ s)} = \Delta H_{ice} \times \rho_{ice}$$

ΔH_{ice} :Thickness Changes of Glacier
ρ_{ice} :Ice Density

Fig. 1 Workflow of mass balance calculation from SAR .

Due to the gap of the SAR observations, we only derive the mass balance of the ablation area of the Koxkar glacier (from 3800 m to 3100 m).

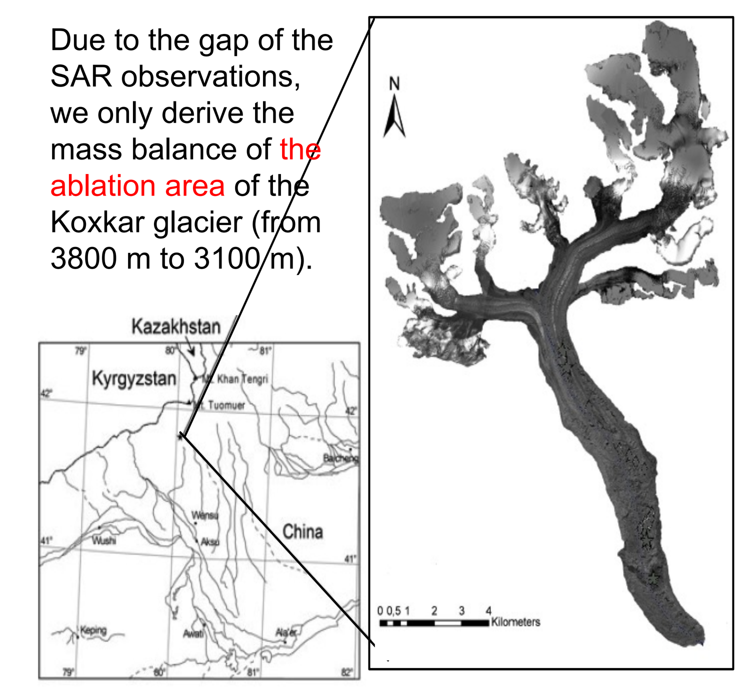
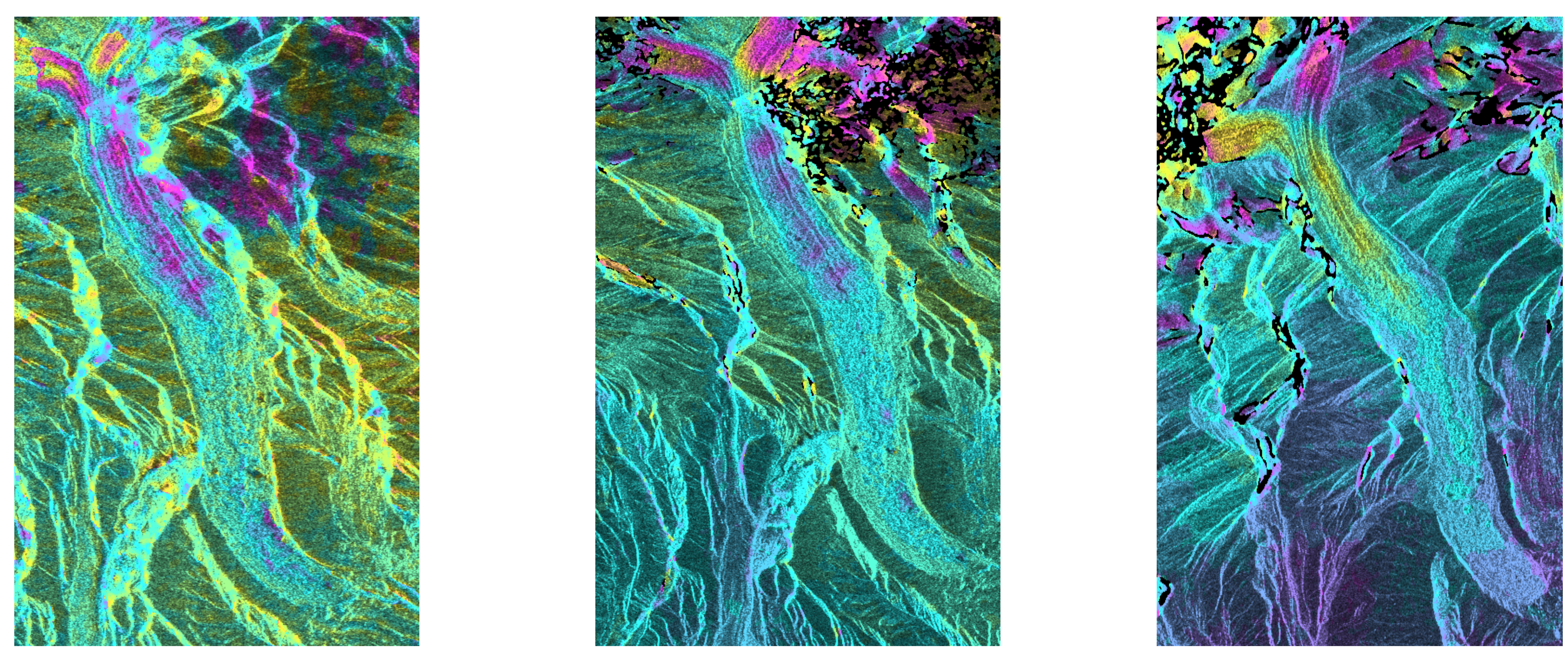


Fig. 2 The Koxkar glacier in Tianshan Mountains, China



1998/08/27-1998/08/28 1999/06/03-1999/06/04 1999/03/19-1999/03/20

Fig. 3 Interferogram of SAR pairs at study area in different date.

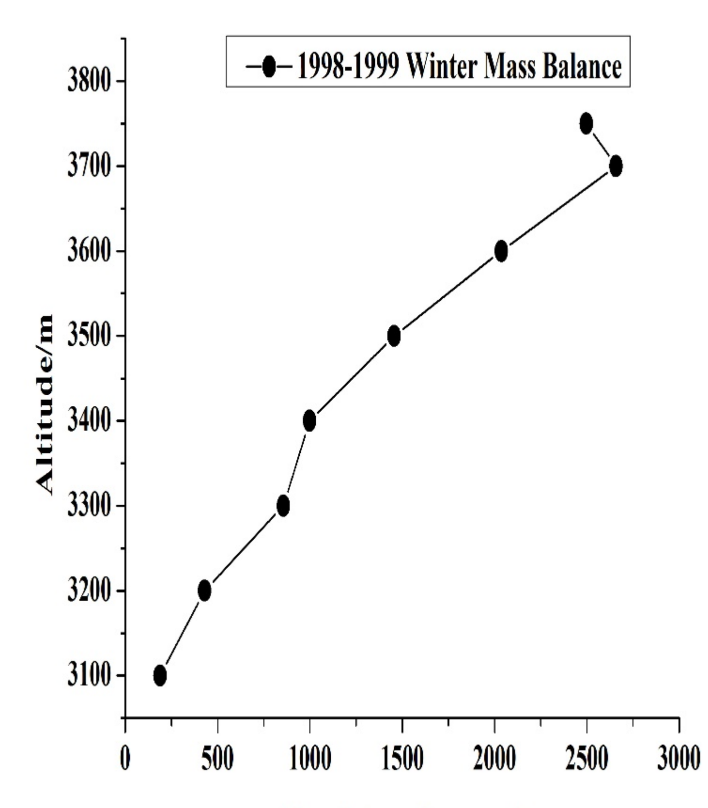


Fig.4-1 Mass changes along the different elevation(Winter)

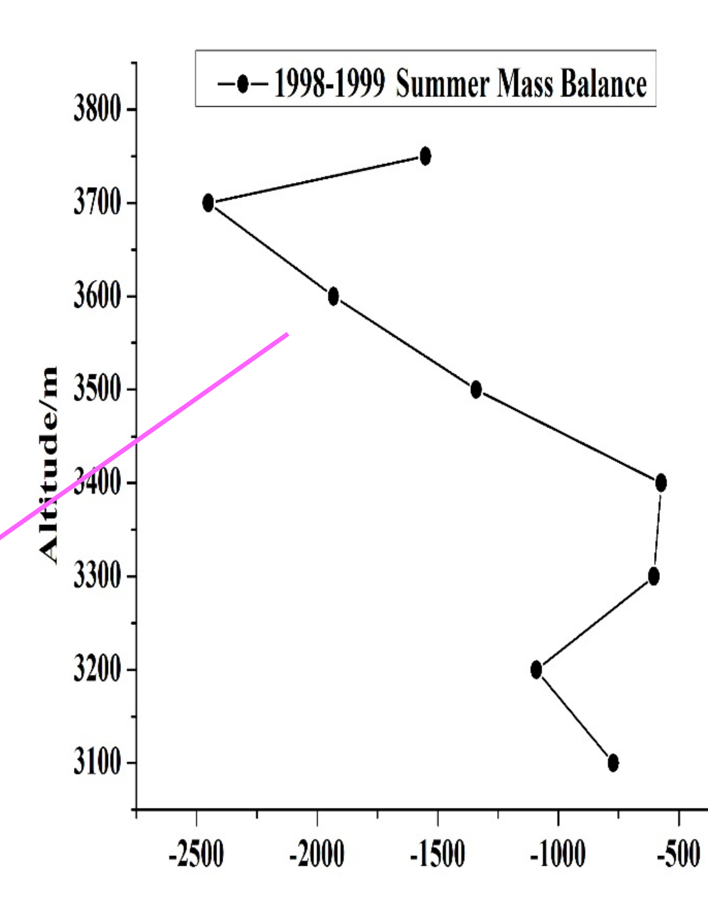
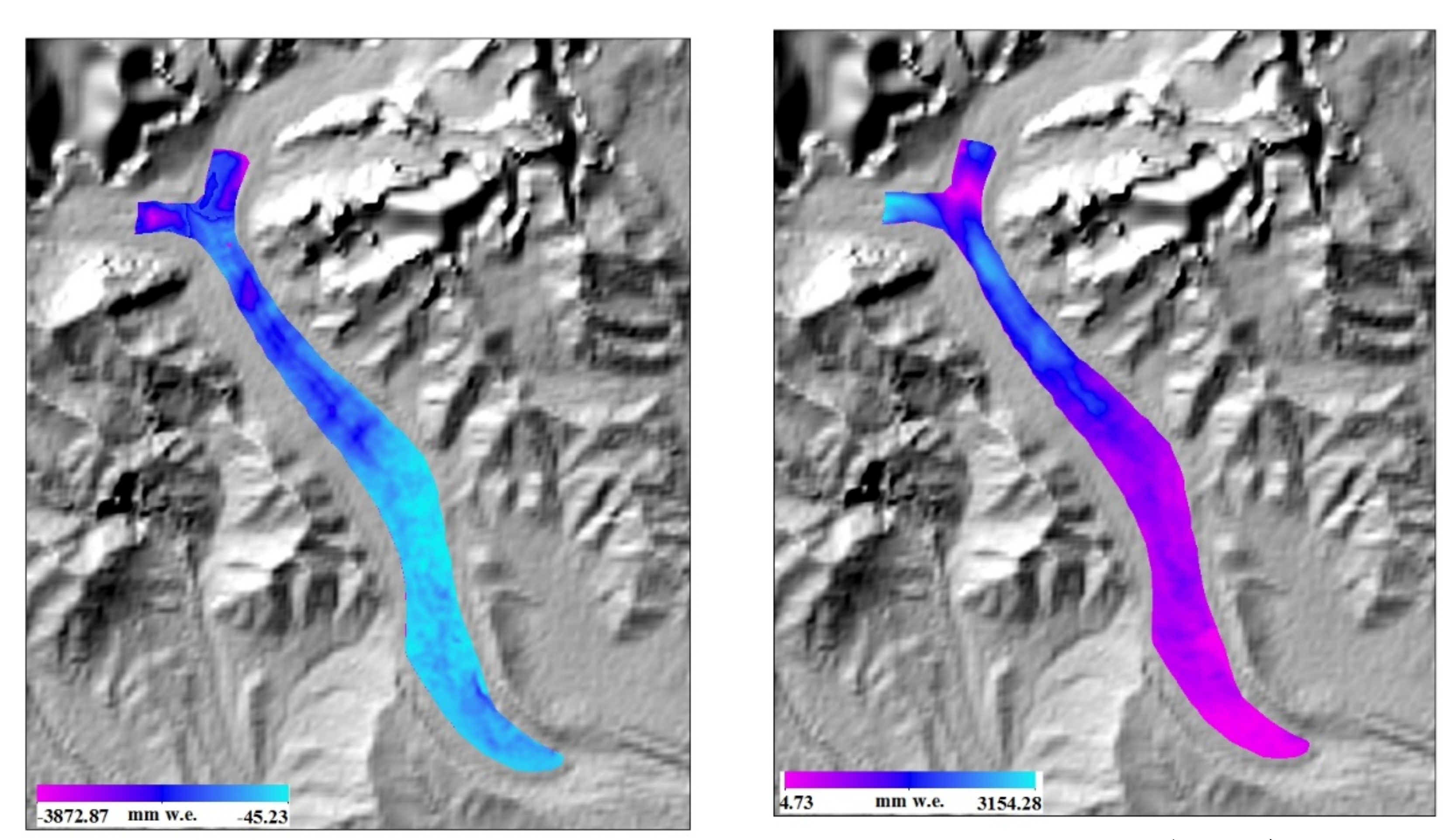


Fig. 4-2 Mass changes along the different elevation(Summer)



Summer mass changes（Negative） Winter mass changes（Positive）

Fig.5 Mass changes in ablation area of the Koxkar glacier in summer and winter.

Conclusions

- *The radar signature provides some possible to monitor the thickness change.*
- *According to the validation, our test study shows that the result is reasonable.*
- *The method developed in this study can be used to accurately extract glacier mass balance.*
- *This method provides a possible way for estimating annual mass balance of large region(compared to the field survey).*
- *The short temp-baseline SAR pairs is necessary for enough coherence，new satellite constellation may provide more valuable data.*