Precision comparison of different offset-tracking methods at sub-pixel level for glacier velocity study

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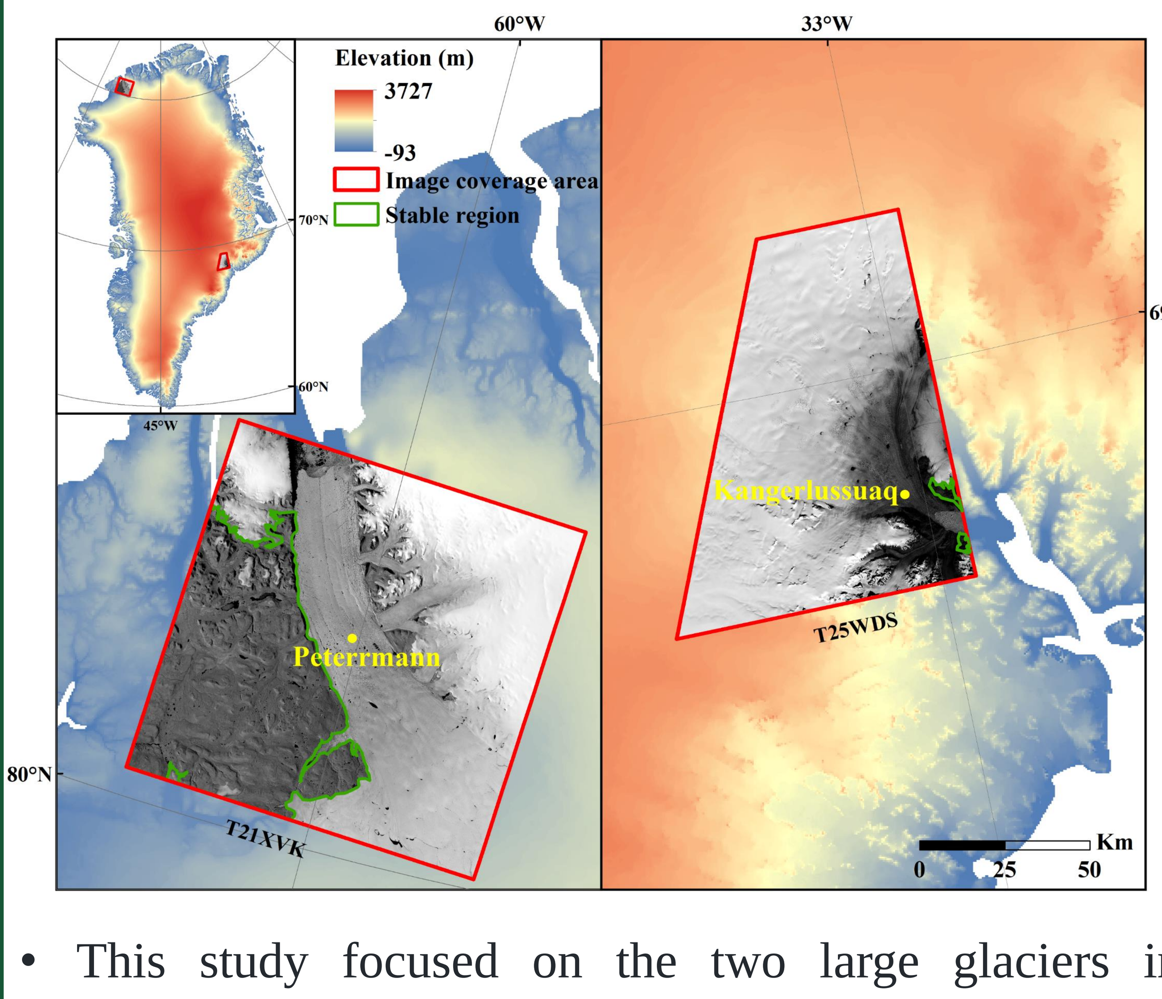
Abstract

Glacier velocity fields are typically derived through offset- tracking applied to optical and/or SAR remote sensing images. Correlation algorithms extract the pixel-level offset, which can then be refined to a sub-pixel level using various interpolation techniques. However, the accuracy of these interpolation algorithms incorporated in different offset-tracking software has relatively limited in terms of evaluation or comparison. In addition, the lack of in-situ observations to confirm the sub-pixel precision of derived offset can cause uncertainties. For above reason, a digital image processing method was used to evaluate the precision of various software and algorithms. The study aimed to assess the sub-pixel precision of derived offset and suggested an algorithm to correct possible offset tracking bias. This will ultimately help improve the accuracy of glacier velocity fields, which is crucial for climate change research and hazard assessment.

Introduction

- Offset-tracking utilizes optical and/or SAR images and is a primary method for monitoring glacier velocity. This technology obtains pixel-level offsets through cross-correlation methods and achieves sub-pixel accuracy through interpolation algorithms, such as theoretically optimal Sinc interpolation, Bilinear and Bicubic interpolation.
- Field measurements of glacier velocity are difficult to obtain and are not suitable for verifying the accuracy of sub-pixel level algorithms. Therefore, this study analyzes the accuracy of offset-tracking using image processing methods.
- Currently, there is limited research evaluating the sub-pixel registration accuracy of offset-tracking and the potential systematic errors that may exist. Furthermore, there have been few attempts to correct the possible sub-pixel level systematic errors.

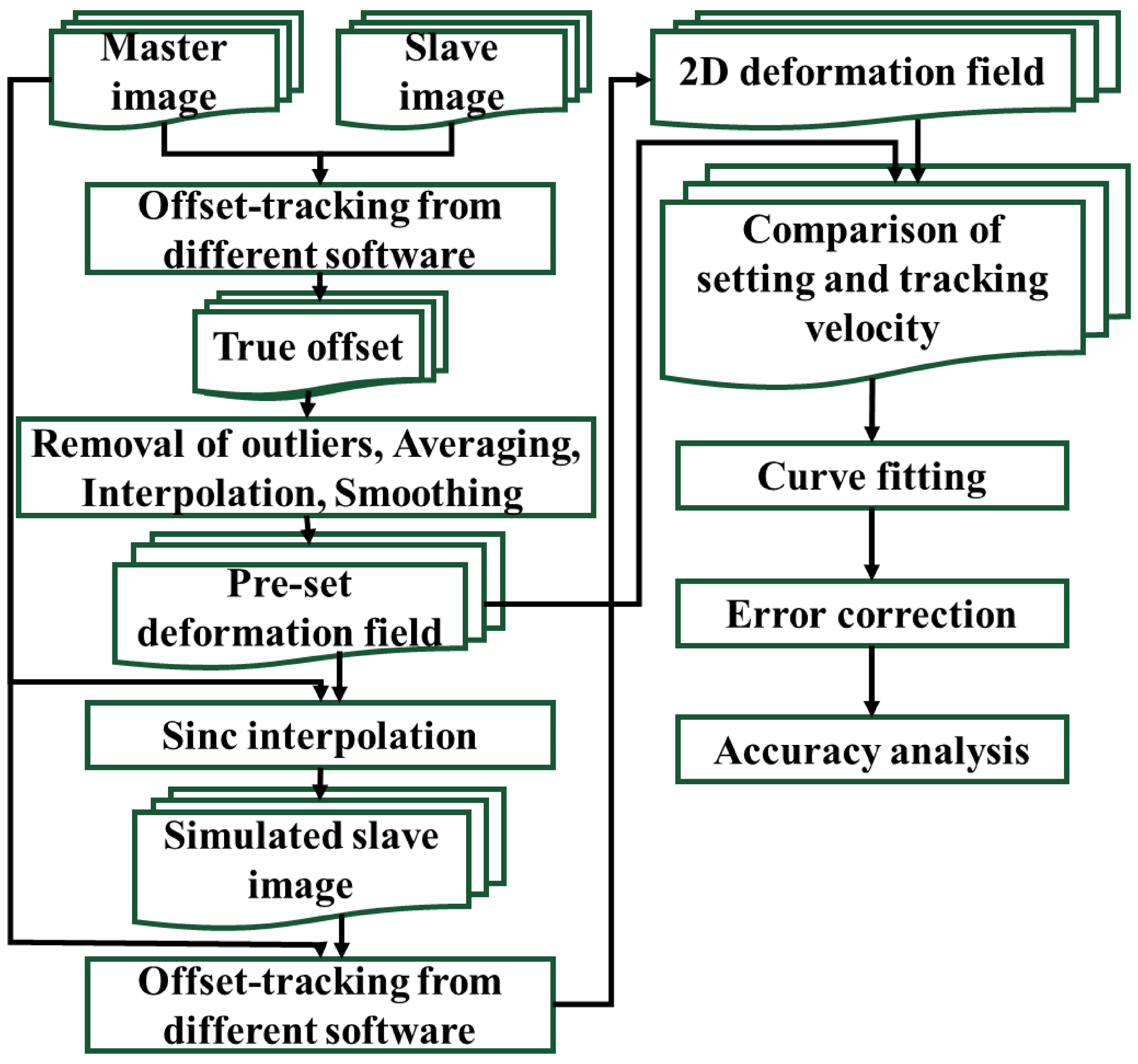
Study area



- This study focused on the two large glaciers in Greenland with opposite flow directions, Petermann and Kangerlussuaq.
- Sentinel-2 data from 07-08/2020 was used. Each of the two study areas had 3 pairs of images, totaling 6 pairs.
- The Sentinel-2 data has been orthorectified using an external DEM, allowing for direct application of the offset-tracking for calculating glacier velocity.

Methods

- This study compared the accuracy of four offset-tracking algorithms: COSI-Corr, autoRIFT, ImGRAFT (CCF-O), and ImGRAFT (NCC), through simulation experiments. It discussed whether there is systematic error in their registration accuracy and proposed corresponding correction methods for this error.



Results

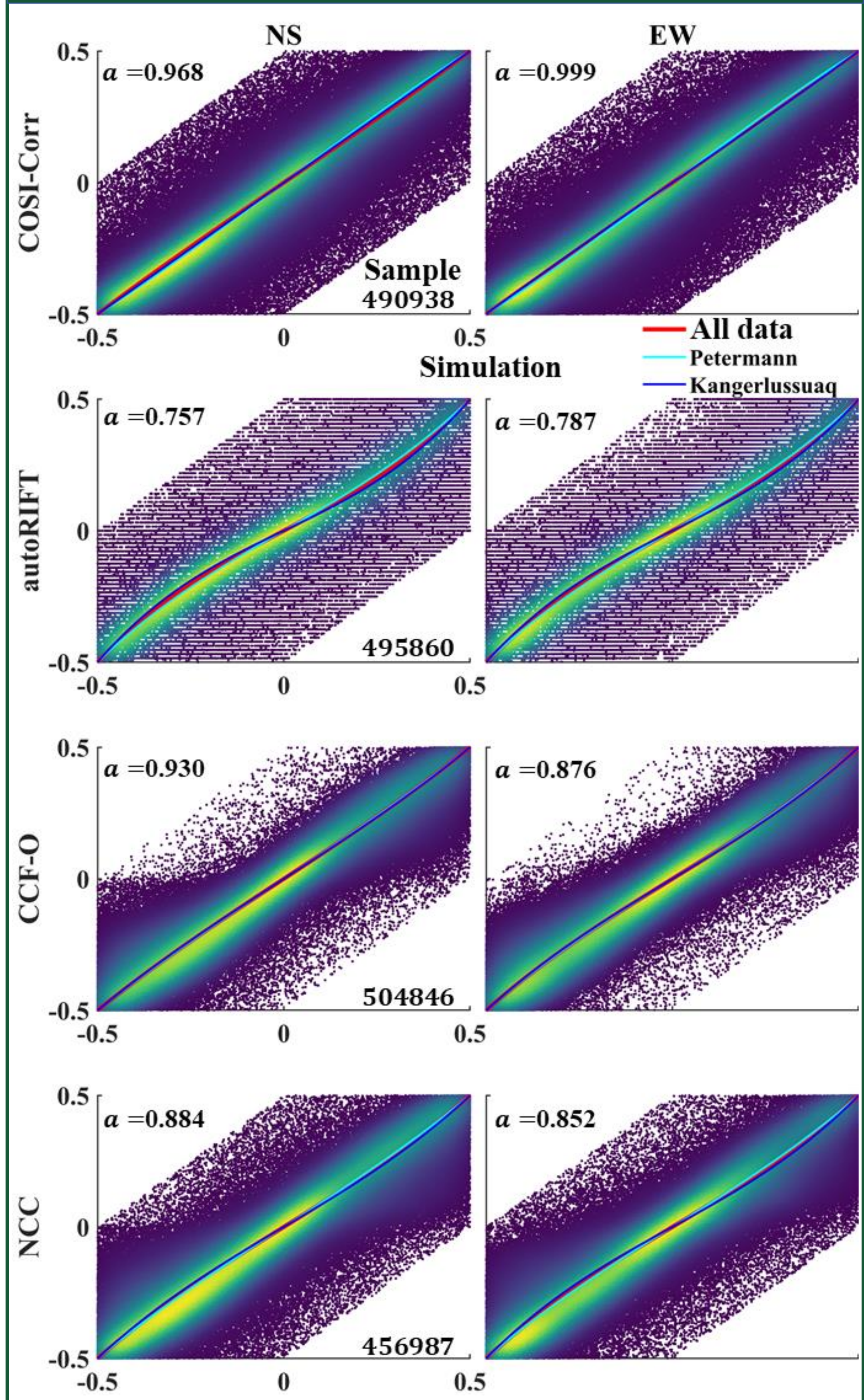


Fig. Scatter plot of the fitting. The x and y axes is the values obtained by taking the modulus of the pre-set deformation field and the glacial region offset-tracking results with respect to 1.

- The offset results of were uniformly fitted with a curve to determine the parameter a of the fitting function $y=ax+4(1-a)x^3$. The closer the fitting curve is to the line $y=x$ ($a=1$), the smaller the system error of the algorithm.
- The results indicate that COSI-Corr has the smallest system error and no need for correction. The autoRIFT algorithm has a smaller a value, resulting in a noticeably curved fitting curve and significant system error.

Results

- For sub-pixel level system errors, the offset results can be corrected by using the inverse function obtained from fitting the curve, and the corrected offset can be obtained. Based on the offset results and the corrected offset, the Root Mean Square Error (RMSE) before and after correction can be calculated by comparing them with the pre-set deformation field. The red color indicates an improvement in accuracy after correction.

Table 1. RMSE (px) before and after correction for Petermann.

Image Pair	Correction	autoRIFT		CCF-O		NCC	
		NS	EW	NS	EW	NS	EW
0706_0716	before	0.0536	0.0454	0.0905	0.0754	0.1107	0.0945
	after	0.0500	0.0412	0.0899	0.0748	0.1093	0.0948
0711_0721	before	0.0525	0.0452	0.0800	0.0825	0.0920	0.0929
	after	0.0445	0.0393	0.0790	0.0806	0.0909	0.0914
0716_0726	before	0.0504	0.0456	0.0842	0.0808	0.0932	0.0894
	after	0.0431	0.0397	0.0834	0.0787	0.0928	0.0885
All data	before	0.0519	0.0454	0.0845	0.0798	0.0976	0.0922
	after	0.0454	0.0400	0.0837	0.0782	0.0966	0.0915

Table 2. RMSE (px) before and after correction for Kangerlussuaq.

Image Pair	Correction	autoRIFT		CCF-O		NCC	
		NS	EW	NS	EW	NS	EW
0706_0716	before	0.1348	0.1249	0.0903	0.0925	0.1269	0.1310
	after	0.1303	0.1201	0.0900	0.0901	0.1265	0.1288
0716_0726	before	0.1207	0.1203	0.0868	0.0943	0.1192	0.1217
	after	0.1165	0.1157	0.0869	0.0932	0.1192	0.1198
0820_0830	before	0.1249	0.1272	0.0995	0.1078	0.1307	0.1403
	after	0.1190	0.1224	0.0984	0.1038	0.1295	0.1368
All data	before	0.1269	0.1243	0.0925	0.0979	0.1257	0.1312
	after	0.1220	0.1196	0.0921	0.0953	0.1252	0.1286

Discussion

- Since the true offset between two images is unknown, it is not possible to effectively remove incorrectly matched pixels in the actual correction process. This study mainly explores the sub-pixel level accuracy of different offset tracking algorithms and corrects for possible systematic errors. However, the correction for systematic errors can be ignored in cases where high accuracy is not required, especially for COSI-Corr and ImGRAFT software.

Conclusion

- Different sub-pixel accuracy errors exist in different offset-tracking software, and they are determined by the interpolation algorithm used.
- Taking into account the computational efficiency and offset-tracking accuracy, it is recommended to use autoRIFT in combination with sub-pixel level correction methods. After correction, autoRIFT can achieve a best single-direction RMSE of 0.039 pixels.

Major Reference

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