SUB-PIXEL PRECISION IMAGE MATCHING FOR DISPLACEMENT MEASUREMENT OF MASS MOVEMENTS USING NORMALISED CROSS-CORRELATION

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1. Introduction

The Normalised cross-correlation is the most widely used area-based image matching method for measuring displacements of earth surface masses such as glacier flow, rockglacier creep and landslide. One of the drawbacks of NCC is that its precision is limited to a pixel, thus varying with the size of the pixel. A number of techniques have been used to achieve sub-pixel precision in matching of mass movements using the normalised cross-correlation algorithms (e.g. Crippen and Blom, 1991; Scambos et al., 1992; Yamaguchi et al. ,2003), although without rigorous comparison of their performances. This study (Debella-Gilo and Kääb, 2010) compares the performances of two fundamentally different approaches to reaching sub-pixel precision in mass movement detection and measurement from repeat remotely sensed images, namely interpolation of image intensities to sub-pixel precision prior to matching and interpolation of the correlation surface after matching to locate the peak at sub-pixel precision.

2. Methods

Three pairs of aerial orthoimages over glacier flow, rockglacier creep and rock sliding with temporal baseline of approximately one month, 13 years and 30 years, respectively, were used. These images were downsampled to five different coarser resolutions. One additional resolution pyramid pair was created by manual translation of one image to use it as translation-only control. The original image pairs were matched to measure the displacement magnitude and direction. Using the same matching points the coarser resolution images were matched. In the first approach, the coarse resolution images were interpolated to different sub-pixel precisions using **bi-cubic convolution before matching**. In the second approach, the coarse resolution images were matched at pixel precision and the correlation surfaces were interpolated using: 1) **bi-cubic convolution**, 2) **parabolic curve fitting and 3) Gaussian curve fitting**.

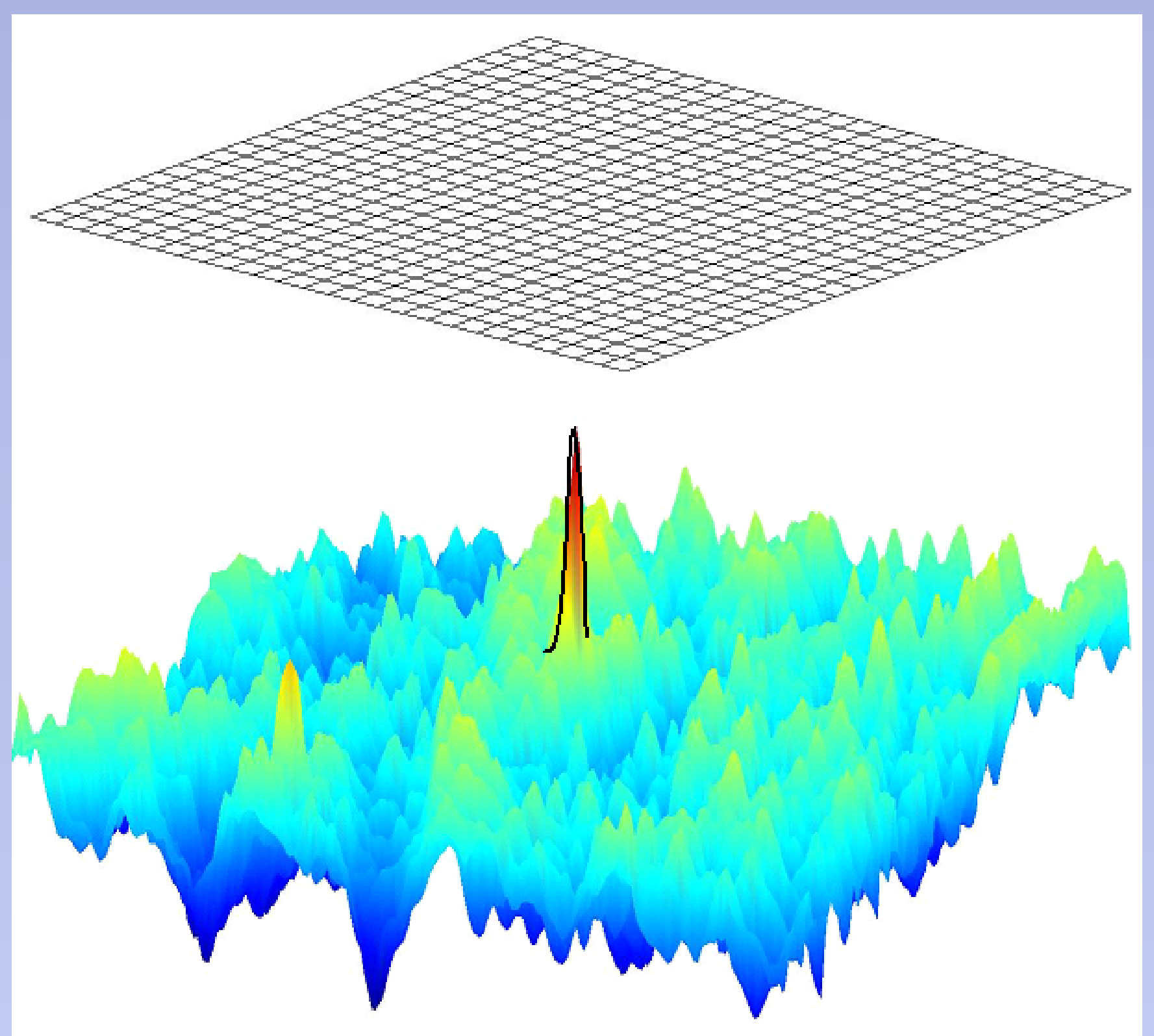

Fig 1. The correlation surface together with the peak, the bi-cubic mesh (top) and the parabola or Gaussian curve fitting the correlation peak.

The peak of the correlation coefficient was then relocated at sub-pixel precision. The performances of the algorithms were evaluated as follows: 1) by measuring the deviation of the matching points from that of the original high resolution images and computing their mean, i.e. mean deviation. 2) by measuring the deviation of the matching points from that of the same resolution original images to know how much the sub-pixel algorithms model the resolution they are supposed to model.

3. Results

Table 1. Summary statistics for the displacement magnitudes and average velocity of the mass movements and the translation-only control image as estimated from the matching of the high-resolution original ortho-images

Mass movement	**Temporal gap**	**Mean displacement (m)**	**Maximum displacement (m)**	**Standard deviation of displacement (m)**	**Maximum velocity (ma^{-1})**
Aletsch Rock slide	30 years	1.5	4.2	0.45	0.14
Muragl Rockglacier	13 years	2.4	5.8	1.20	0.45
Ghiacciaio del Belvedere Glacier	1 month	12.22	18.83	5.0	226
Control		7.50	7.50	0	7.50

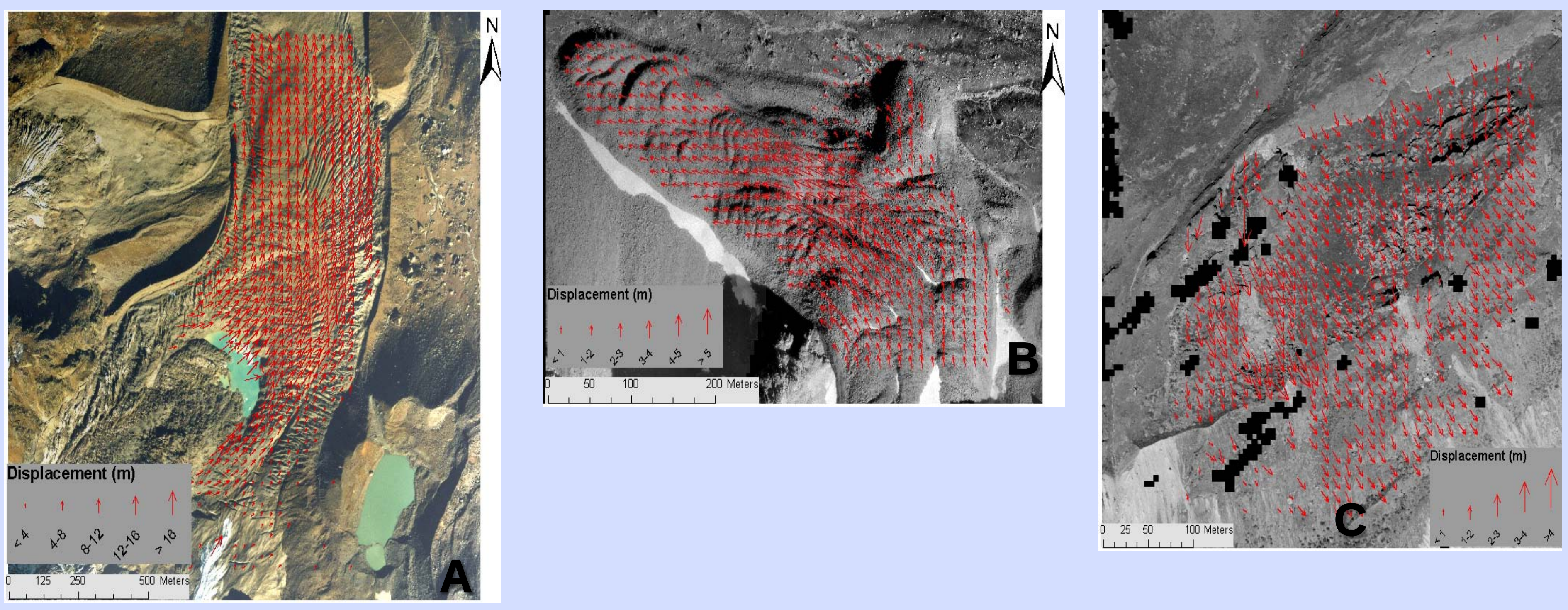

Fig 2. Displacement vectors on the Ghiacciaio del Belvedere (A), Muragl rockglacier (B) and Aletsch rock sliding (C). Images displayed are of time2.

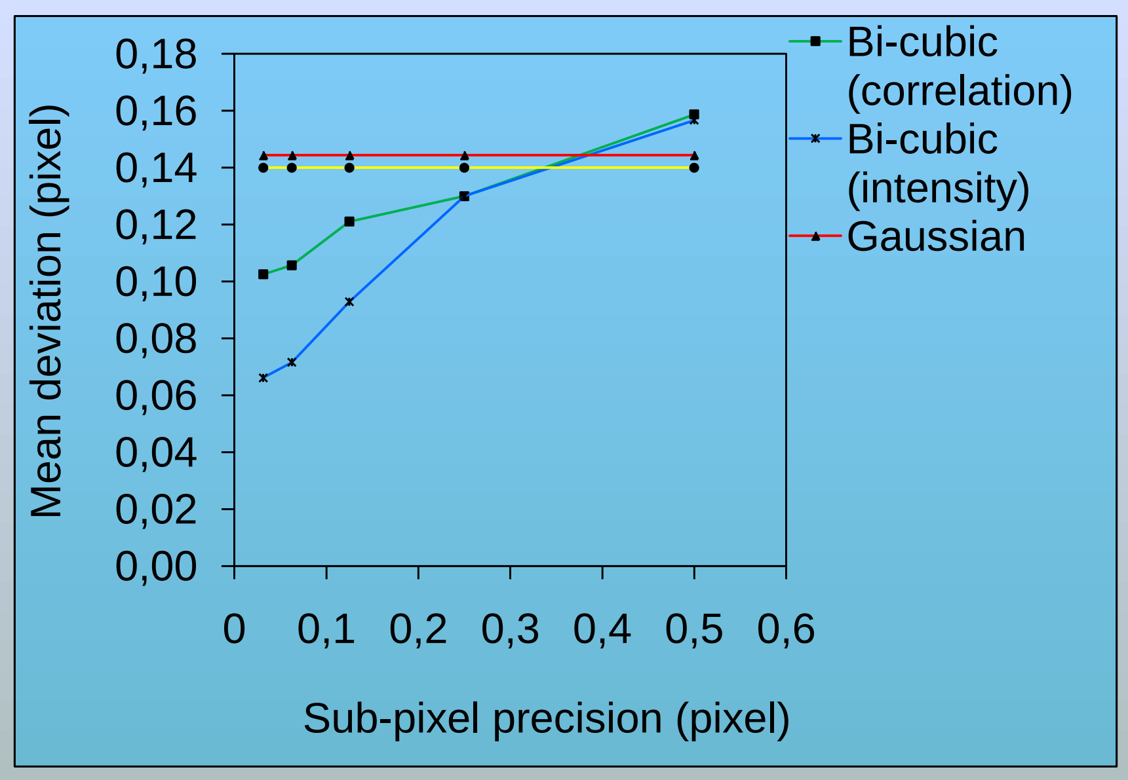

Figure 3 Accuracy of the different sub-pixel precision approaches for the control set expressed as the mean deviation of the matching positions from that of the reference high-resolution original ortho-images

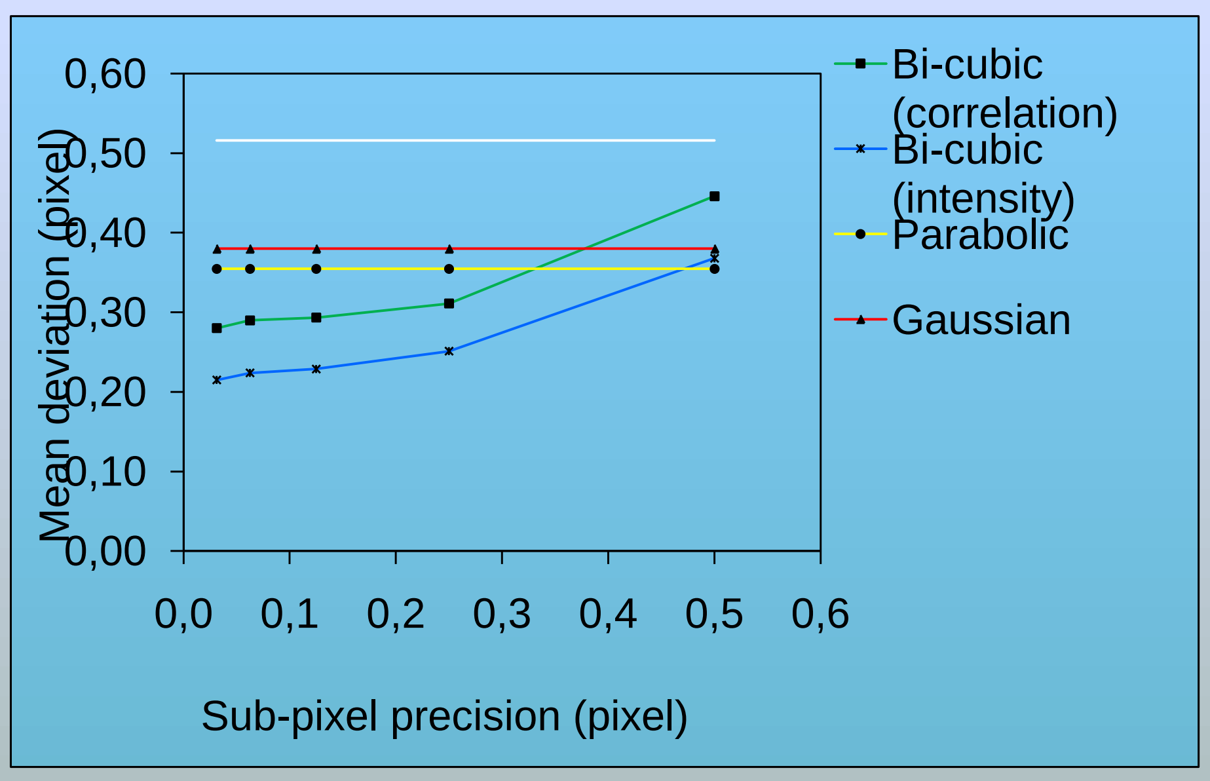

Figure 4 Accuracy of the different sub-pixel precision approaches expressed as the mean deviation of the matching positions from that of the reference high-resolution original ortho-images (averaged for the three mass movement types)

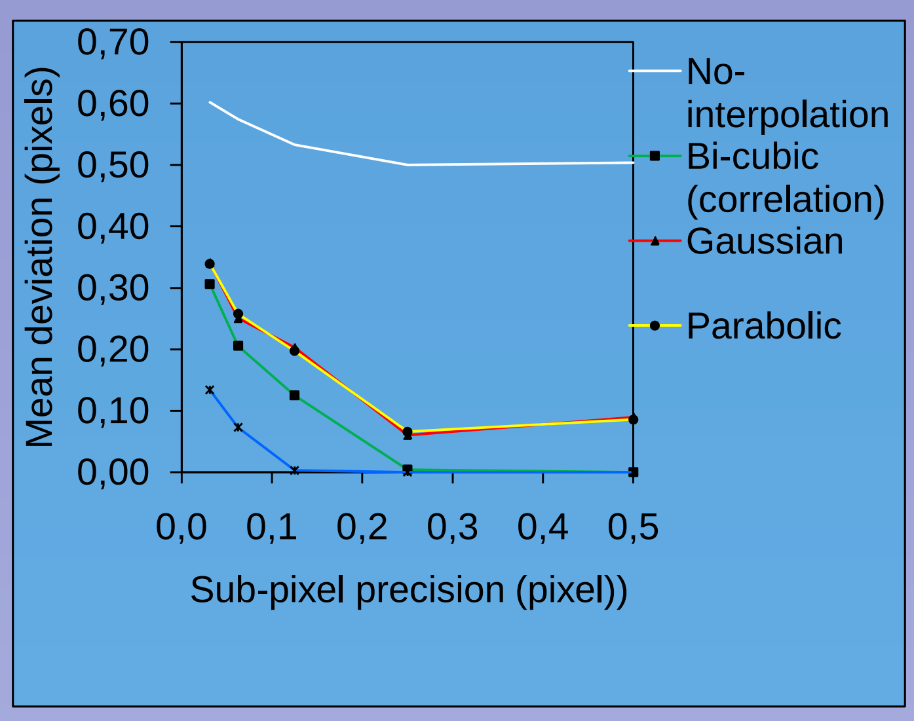

Figure 5 Relative performance of the different sub-pixel approaches for the control set expressed as the mean deviation of the matching positions from that of the same resolution original image

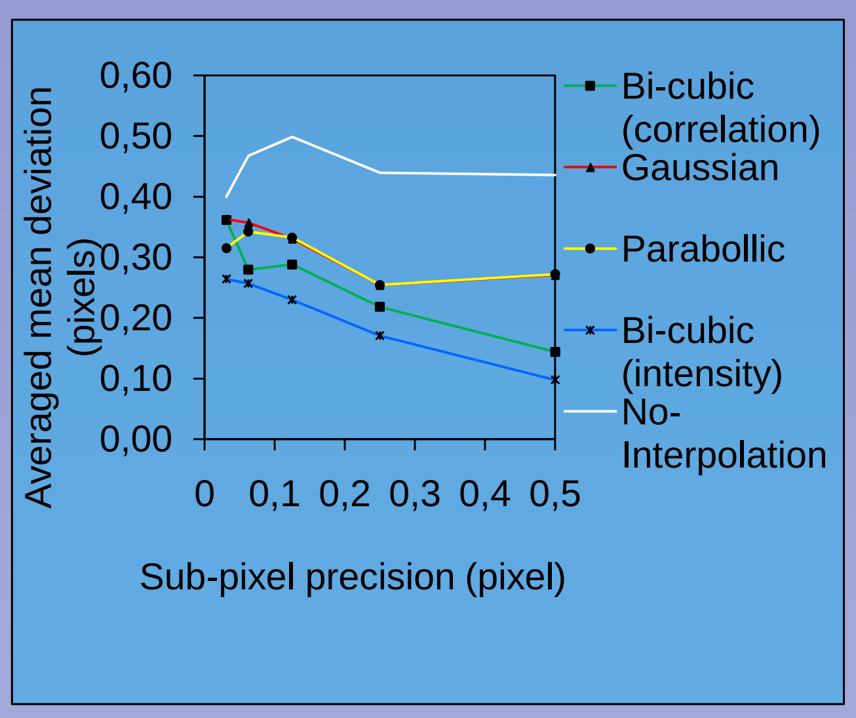

Figure 6 Relative performance of the different sub-pixel approaches expressed as the mean deviation of the matching positions from that of the same resolution original image (averaged from the three mass movement types investigated)

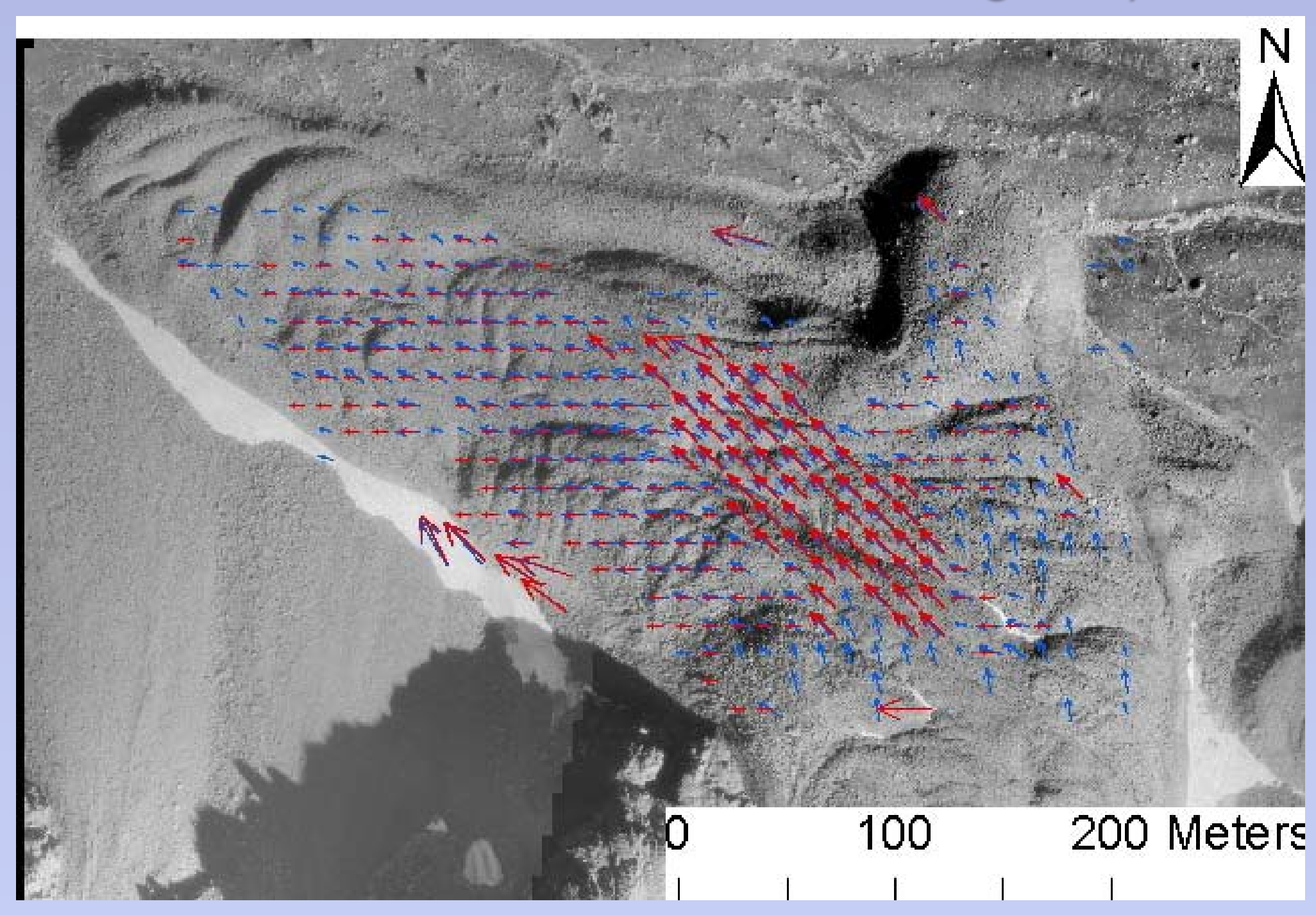

Fig. 7. Displacement vectors depicting the difference in detected movements when the metric pixel size is decreased through intensity interpolation. Red vectors are made by matching images of pixel size 3.2 m. Blue vectors are made by matching the images after interpolating the images to pixel size of 0.4 m.

4. Conclusions

To achieve sub-pixel precision in displacement measurement of mass movements from repeat spatial domain optical images, interpolating image intensities to a higher resolution using bi-cubic interpolation prior to the actual image correlation performs better than both interpolation of the correlation surface using the same algorithm and peak localisation using curve fitting. Correlation peak localisation using Gaussian and polynomial algorithms are inferior in such applications.

Interpolation to sub-pixel precision improves both the accuracy and detectability of earth surface mass movements. Interpolation to sub-pixel precision beyond 1/16th of a pixel does not improve the accuracy much as the signal-to-noise ratio of the measurement decreases.

5. Acknowledgements

The research was conducted at the Geosciences department of the University of Oslo and financially supported by the Norwegian Research Council through CORRIA project (no. 185906/V30). The orthoimages are based on airphotos by Swisstopo and CNR-IRPI. The authors are very grateful to all of the institutions.

6. References

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