Estimating the Velocity of Muldrow Glacier during a Surge Event using Synthetic Aperture Radar Imagery and Dense Optical Flow

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Background

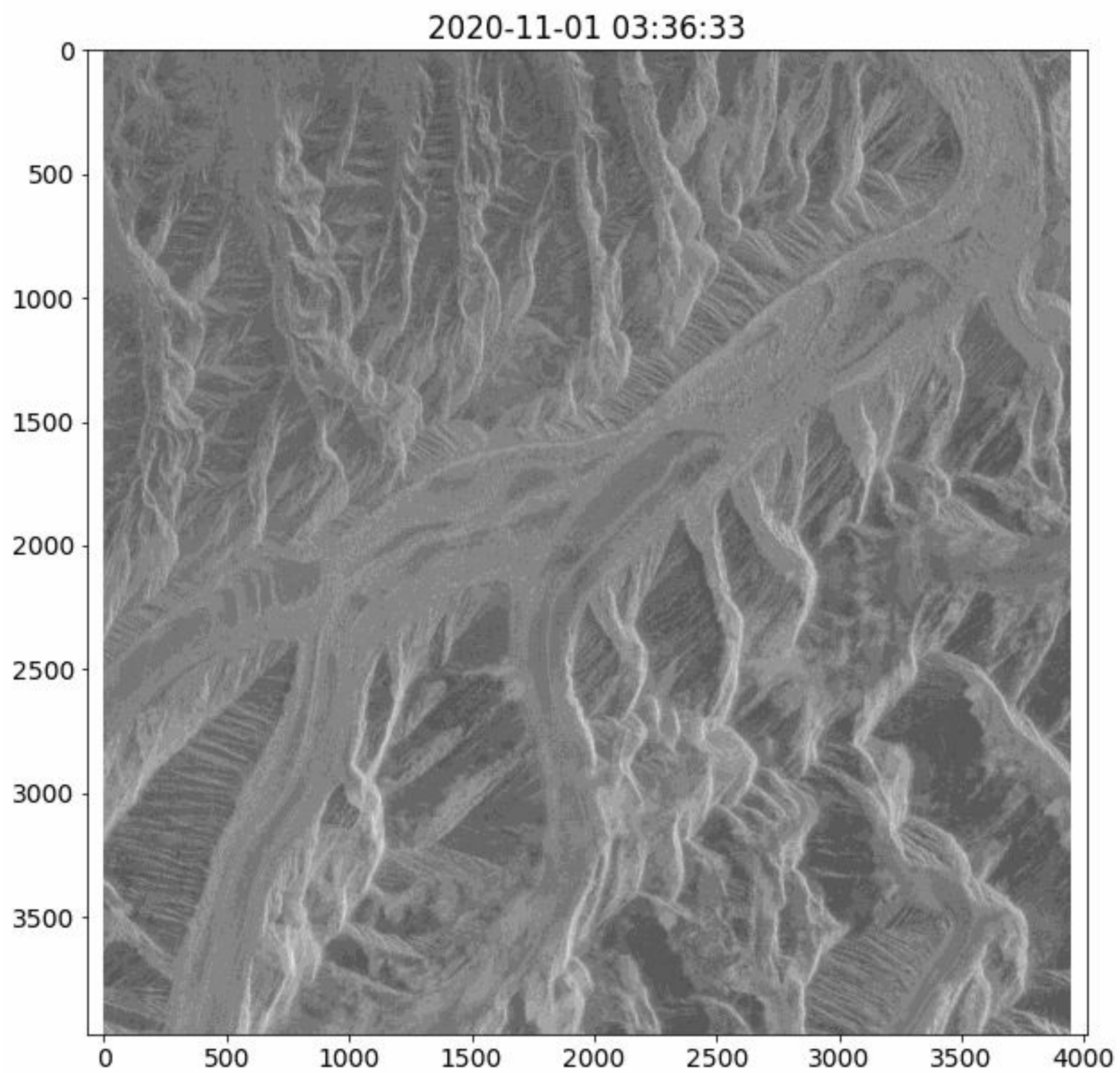
Quantitative measurements of glacier flow over time are an important ingredient for glaciological research, for example to determine the mass balances and the evolution of glaciers. Measuring glacier flow in multi-temporal images involves the estimation of a dense set of corresponding points, which in turn define the flow vectors[1].

The speckle tracking technique has demonstrated great potential in glacier velocity field (GVF) mapping applications. It analyzes the cross correlation between two synthetic aperture radar (SAR) images, which then produces 2-D glacier motion measurements with acceptable accuracy [3].

Aim:

1.Create GVFs between pairs of SAR images
2. Use and explore SAR images
3. Understand different speckle tracking techniques
4. Explore multiple algorithms for velocity tracking (Dense Optical Flow, Sparse Optical Flow, Particle Image Velocimetry)

Figure 1: SAR Time Series over Muldrow Glacier



Methods

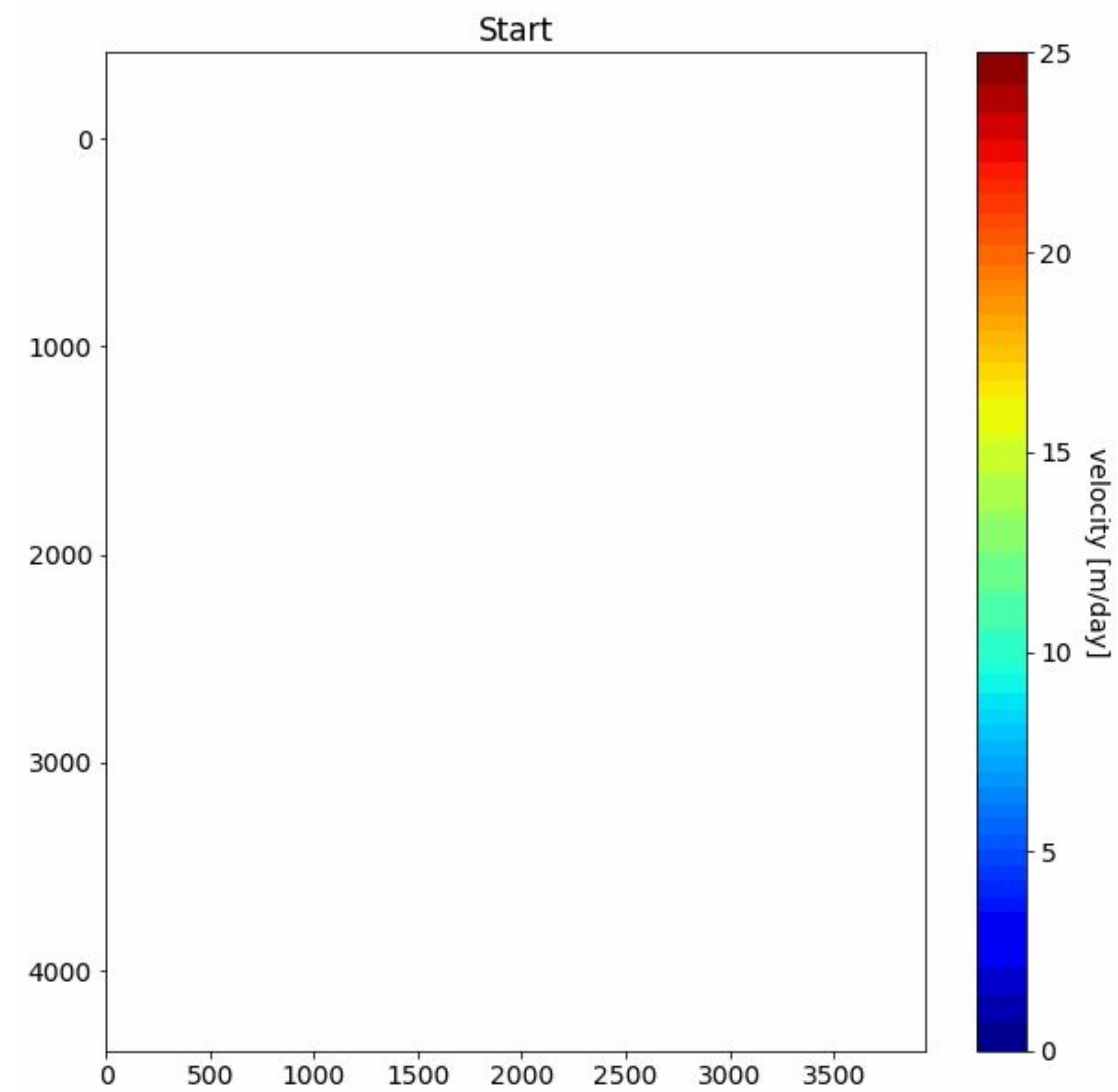
We used Python to implement functions. Jupyter notebook was initially used then converted to Google Collaboratory. We utilized the matplotlib, NumPy, OpenCV, GeoPandas, rioxarray, and pandas python packages. We geocoded and cropped the SAR images, and then read and sorted them by dates using the os module. We created the time series animation of the SAR imagery (figure 1) using matplotlib and NumPy.

To extract the GVFs we tried many algorithms, but the most successful was a Dense Optical Flow algorithm from the OpenCV package. To create the GVF each frame was first converted from the raw SAR backscatter amplitude to grayscale values and then the Farneback implementation of Dense Optical Flow was applied. The resulting pixel displacement values between SAR image pairs were then converted to meters per day.

Results

Of all the attempted approaches, Dense Optical Flow produced the most accurate results when compared to our validation data. This wasn't entirely surprising, as the literature seems to recognize Dense Optical Flow as a great candidate for extracting GVF from optical imagery. However, we can see artifacting in our results, especially towards the end of the time series where the algorithm detects movement where in reality there should be done. Additionally, the velocities are on average 1-2 m/day higher than our validation data. To explore this in the future, we need to project both datasets to similar grids and difference them to isolate the spatial variations. There is not a lot of literature on the Farneback method of Dense Optical Flow parameters applied to different types of imagery, so it is also likely we need to further tune our model parameters.

Figure 2: GVF Time Series over Muldrow Glacier



Interpretation & Conclusion

We can see the evolution of the surge event in our SAR derived GVF (figure 2). Of particular importance is the strong acceleration around February - March when the surge event began. Notice the increasing brightness in the SAR imagery around that time too (figure 1). This is because an increase in surface roughness will increase the radar backscatter reflected back to the radar instrument. Our method reveals a strong increase in velocity about two weeks before the officially determined surge date. This could be some noise in our SAR imagery, a badly parameterized dense optical flow model, or it could potentially mean the surge initiated earlier than first theorized. This has important implications for future glacier surge event detection, as SAR imagery might have the potential to detect surges sooner and more accurately than optical imagery.

References and Acknowledgements

[1] T. Strozzi, A. Luckman, T. Murray, U. Wegmuller and C. L. Werner, "Glacier motion estimation using SAR offset-tracking procedures," in IEEE Transactions on Geoscience and Remote Sensing, vol. 40, no. 11, pp. 2384-2391, Nov. 2002, doi: 10.1109/TGRS.2002.805079.

[2] Sharp M. Surging glaciers: behaviour and mechanisms. Progress in Physical Geography: Earth and Environment. 1988;12(3):349-370. doi:10.1177/030913338801200302

[3]Joughin, I. (2002). Ice-sheet velocity mapping: A combined interferometric and speckle-tracking approach. Annals of Glaciology, 34, 195-201. doi:10.3189/172756402781817978

Photograph by Chris Palm (3/4/2021) looking up the main stem of the Muldrow Glacier with Denali in the top left, McGonagall Pass in the upper right and the Traleika Glacier tributary coming in from top left. Sheer lines of broken ice and abundant crevasses are visible.