A Novel Approach to Measuring Glacier Motion Remotely using Aerial LiDAR

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AGU FALL MEETING, DECEMBER 14, 2016

C34C-07

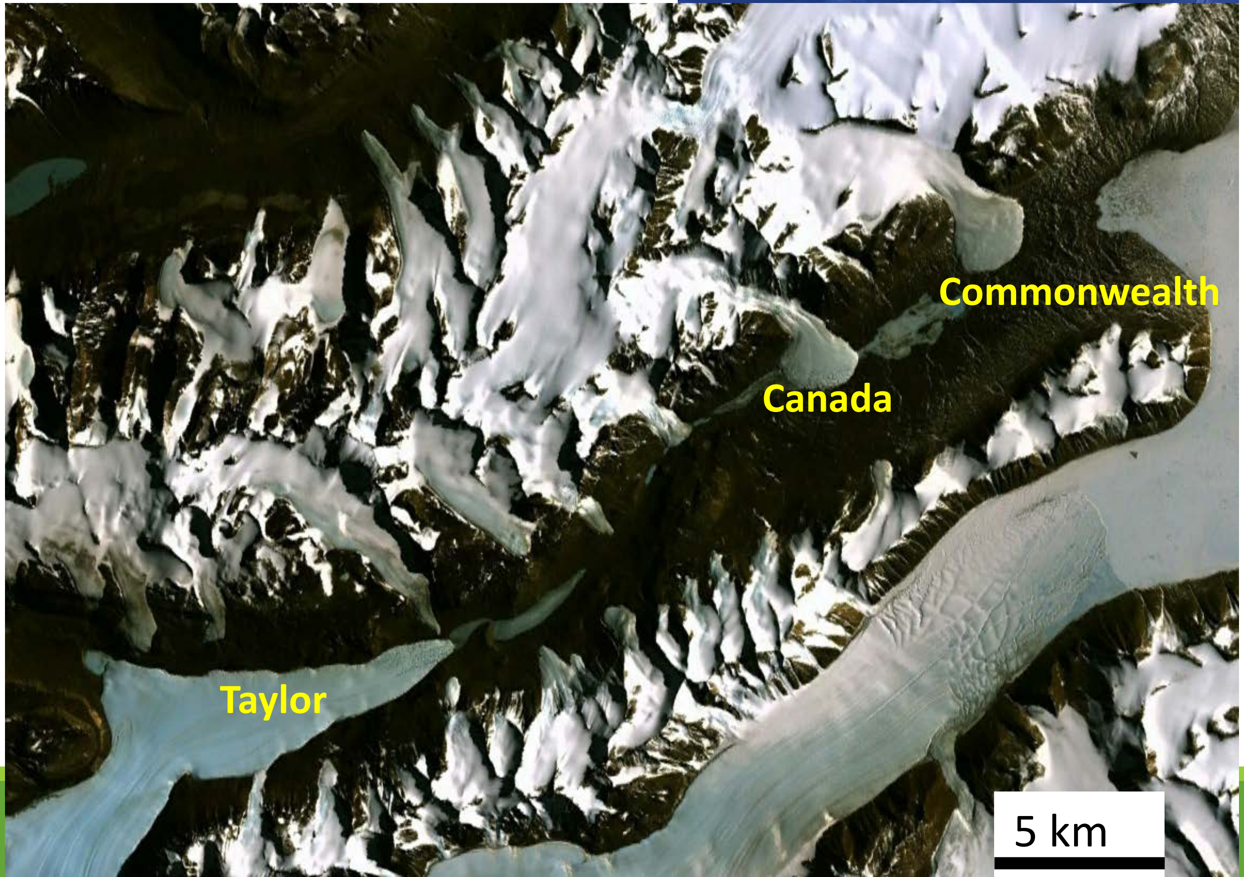
NCALM
The National Center for Airborne Laser Mapping
University of Houston • University of California, Berkeley

Study Area – Taylor Valley, Antarctica

Located in the Taylor Dry Valleys, which are a polar desert (Fountain et al., 2014; Fountain et al., 2016)

Airborne laser scanning (ALS) data collected by NASA in 2001 and by NCALM in 2014

- NASA Resolution 1 point/m^2
- NCALM Resolution 5 – 10 point/m^2



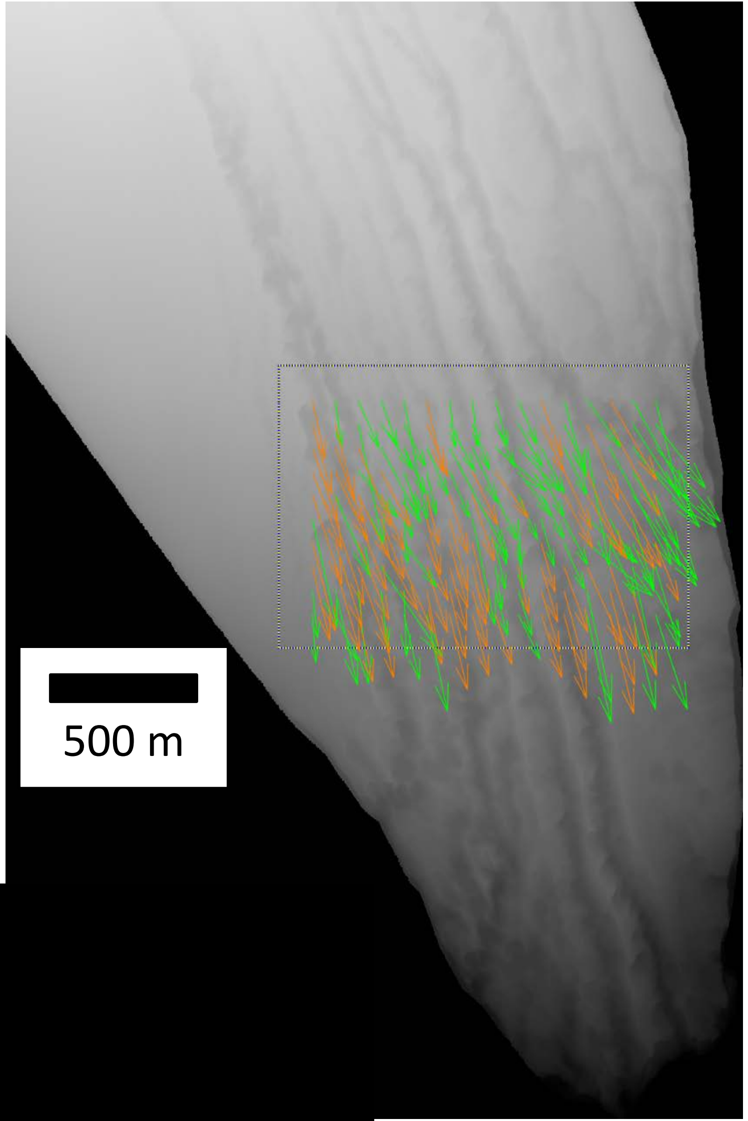
Measurement Methods

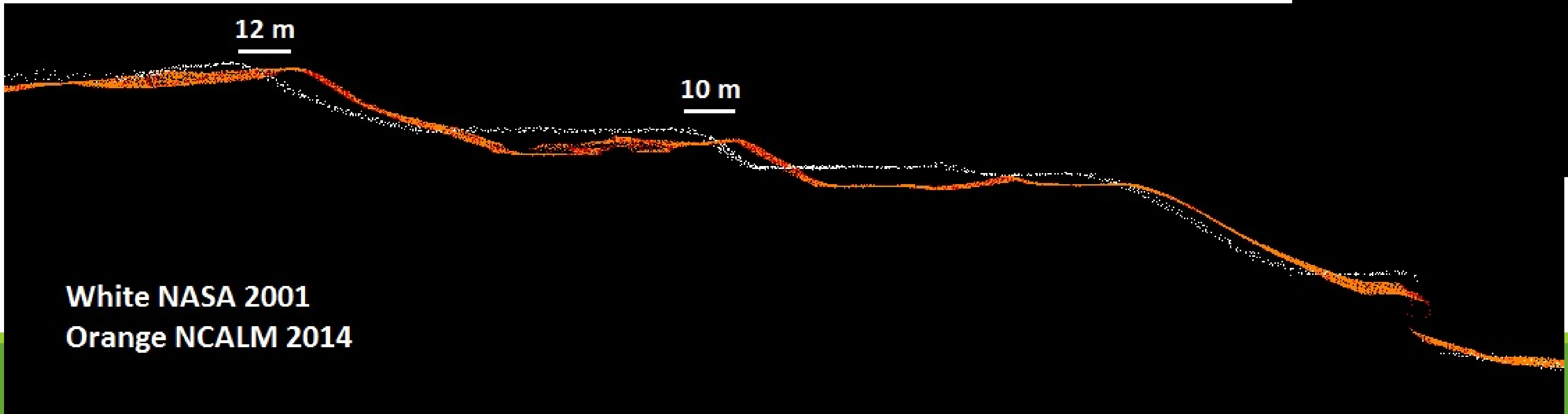
Particle Image Velocimetry (PIV)

- ALS data converted to images, colored by elevation in greyscale, for full glaciers and subset regions
- PIVLab, an open source Matlab application, used for analysis (Thielicke and Stamhuis, 2014 a and b)
- Example of raw PIV results for Taylor Glacier shown to the right

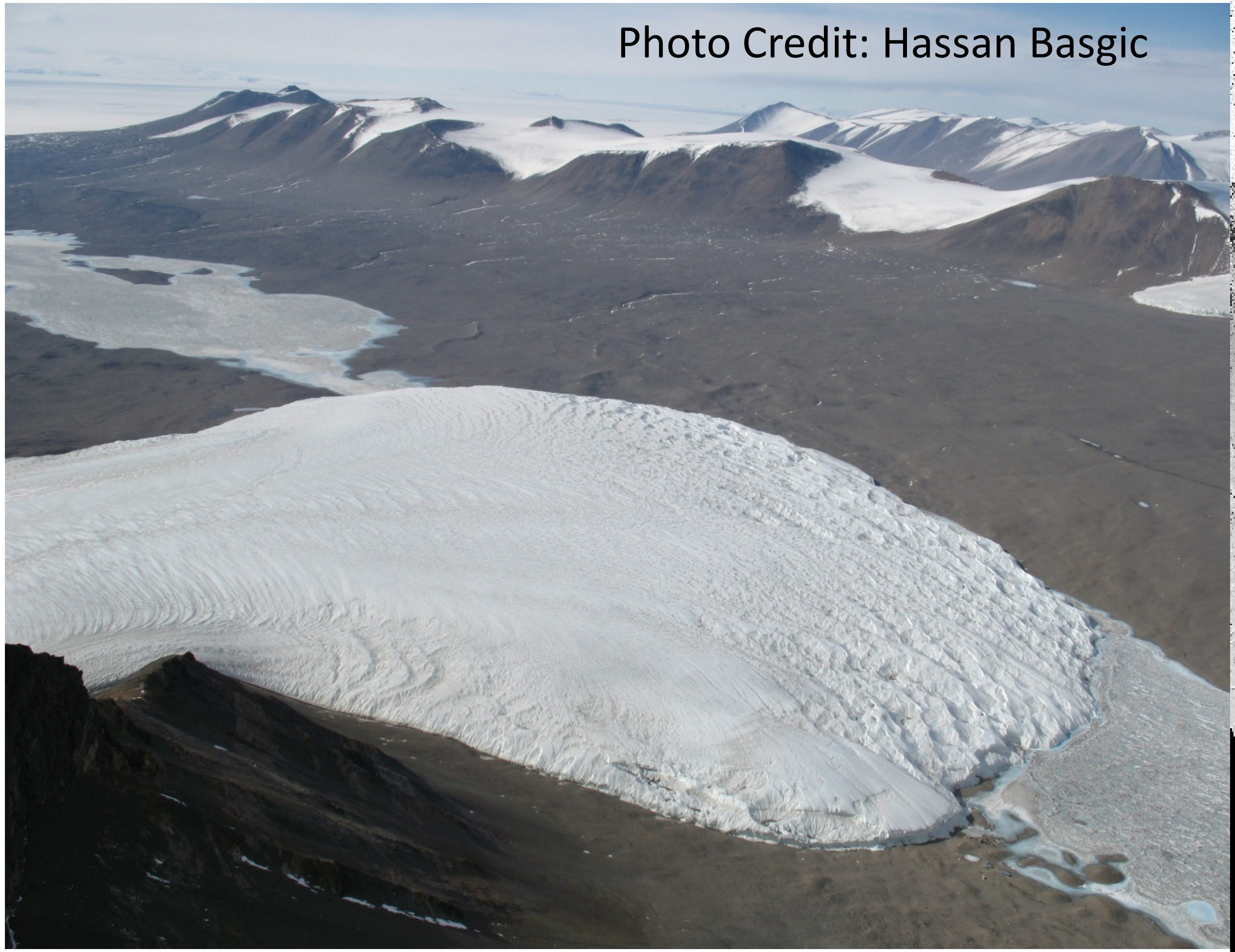
Manual measurements/Hand Tracking

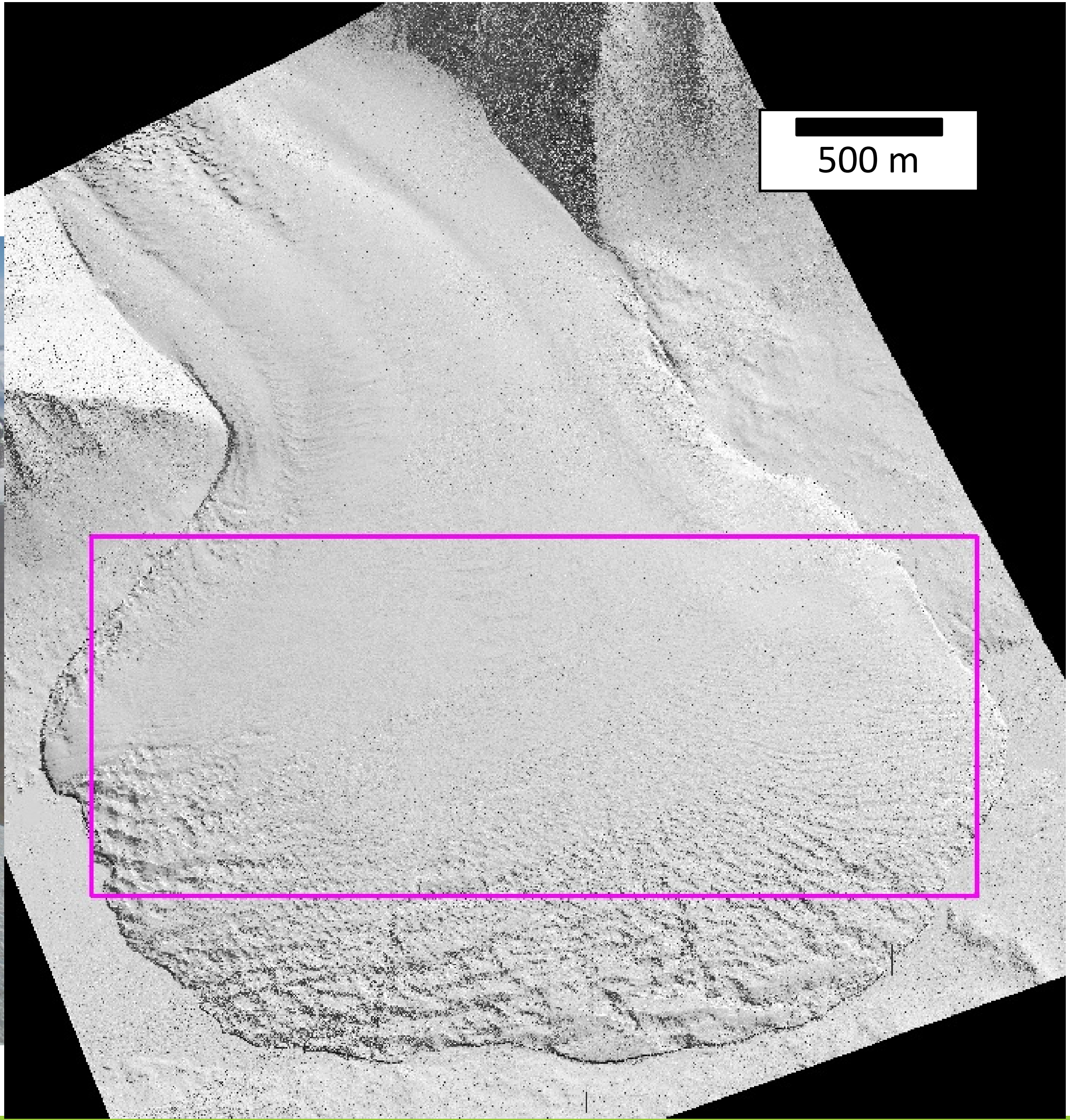
- Used to verify PIV results
- Feature mapping with ALS point cloud
- Example from Canada Glacier below





Canada Glacier

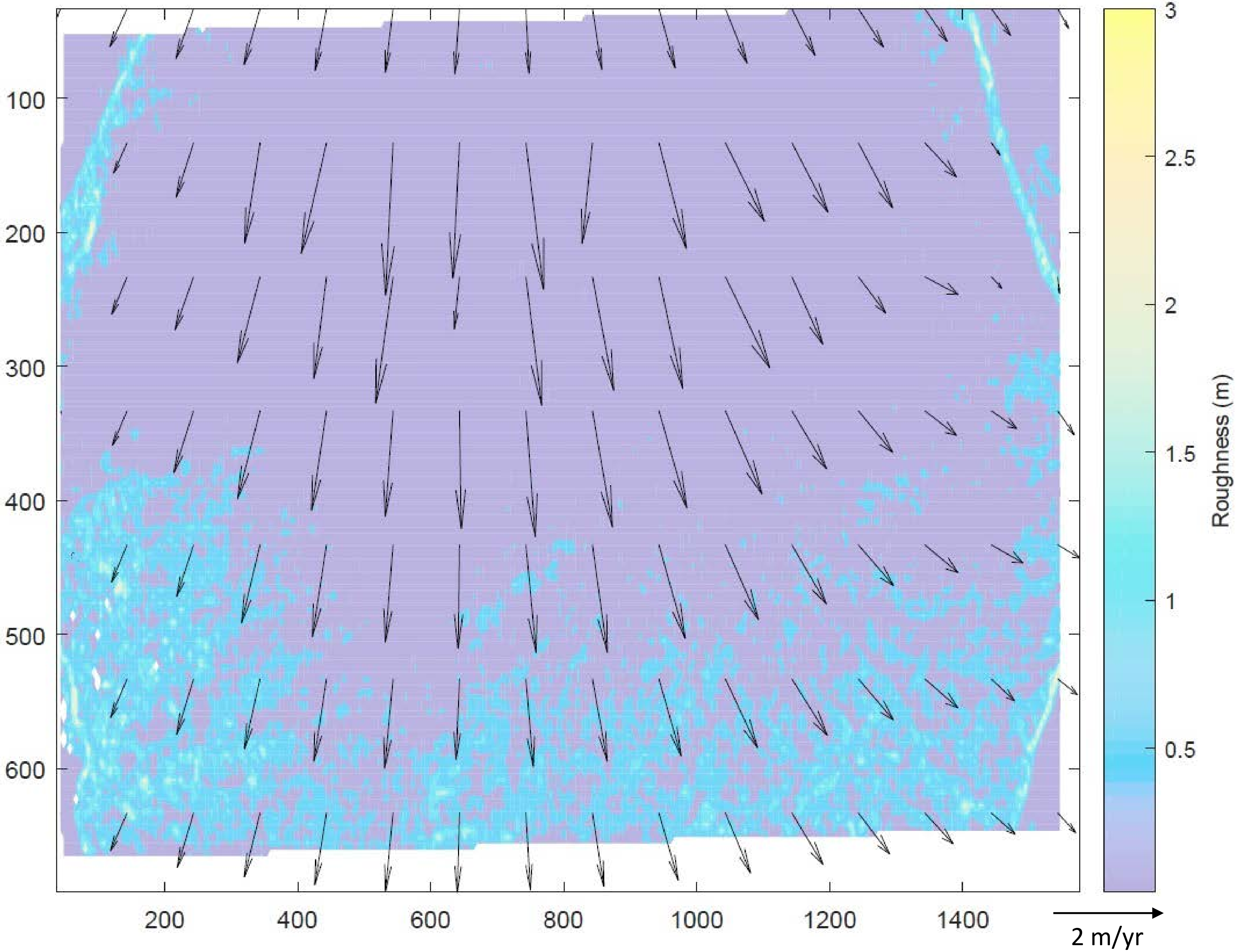




Canada Glacier

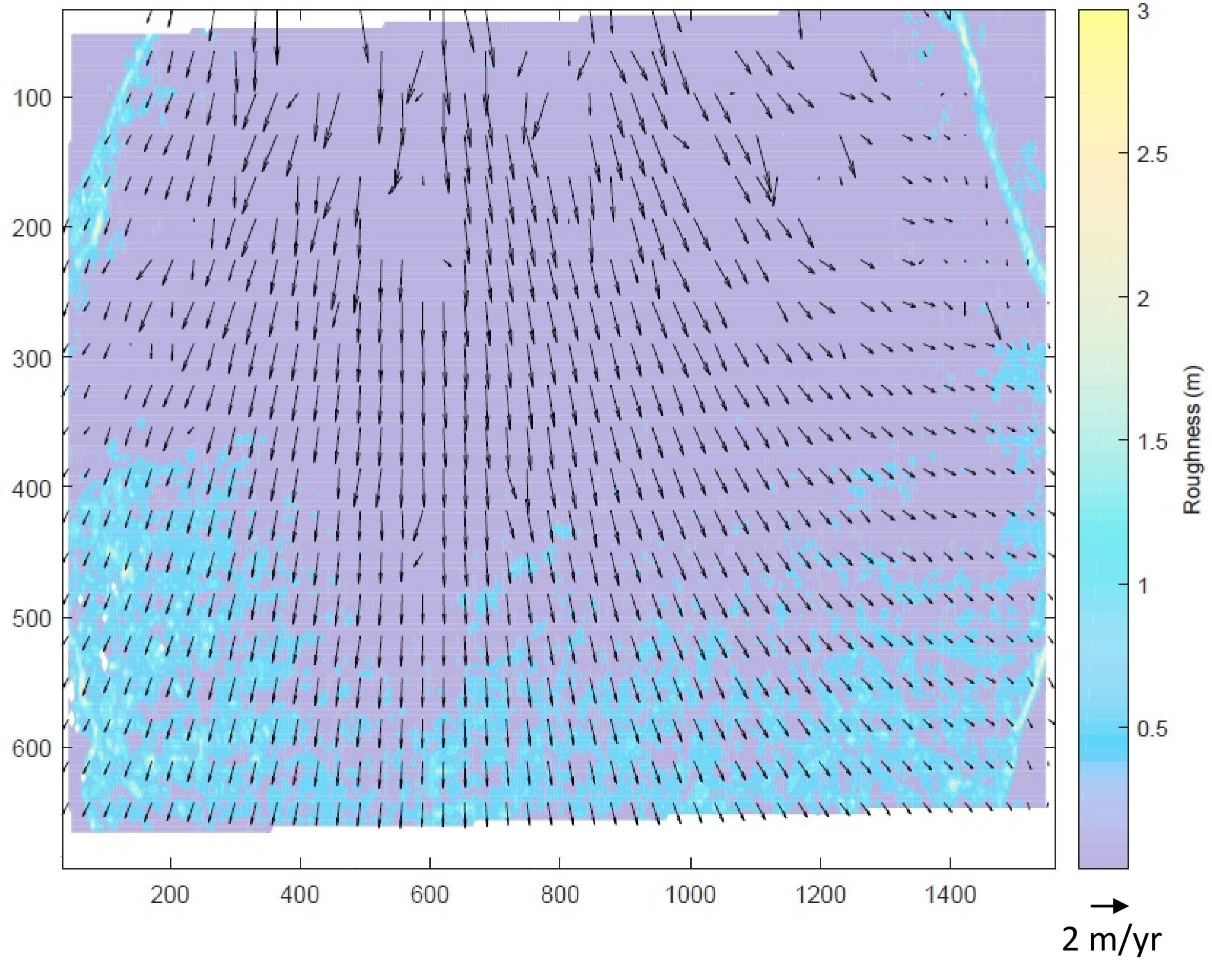
Raw PIV results have been averaged over 100 m x 100 m cells

Smaller cell sizes produce higher resolution velocity fields but also less coherent flow and have greater uncertainty

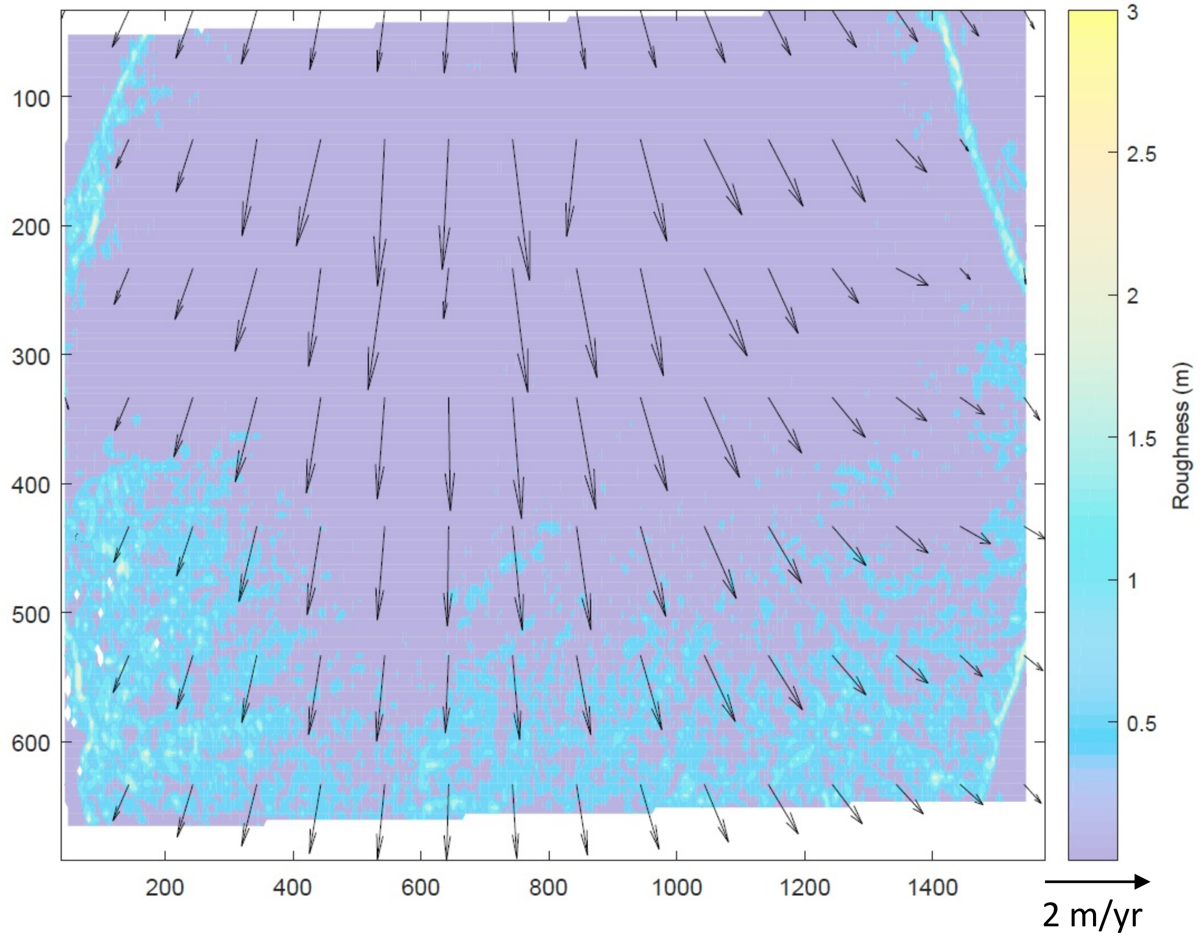


Canada Glacier

Raw Data



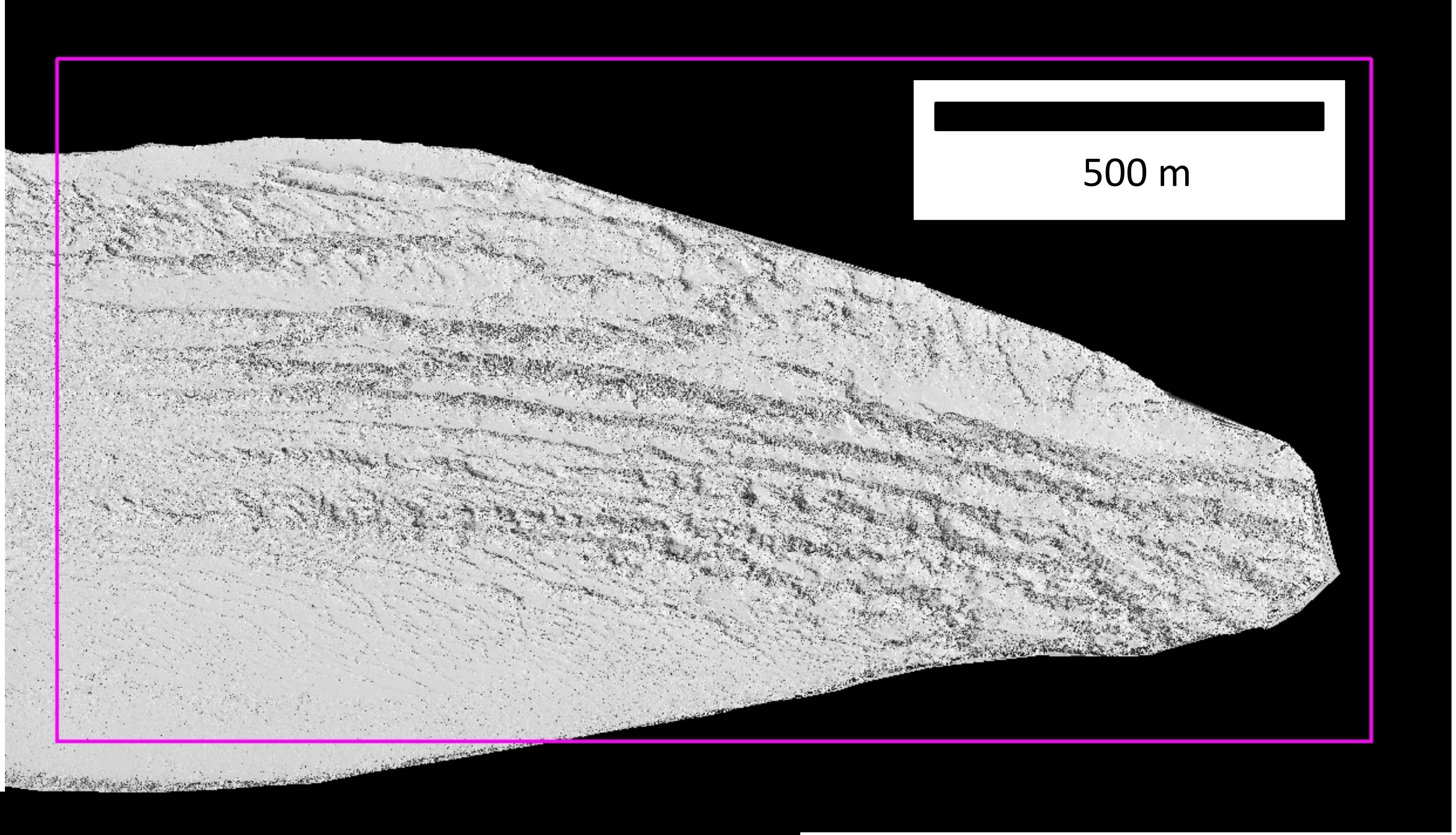
100 m x 100 m cells

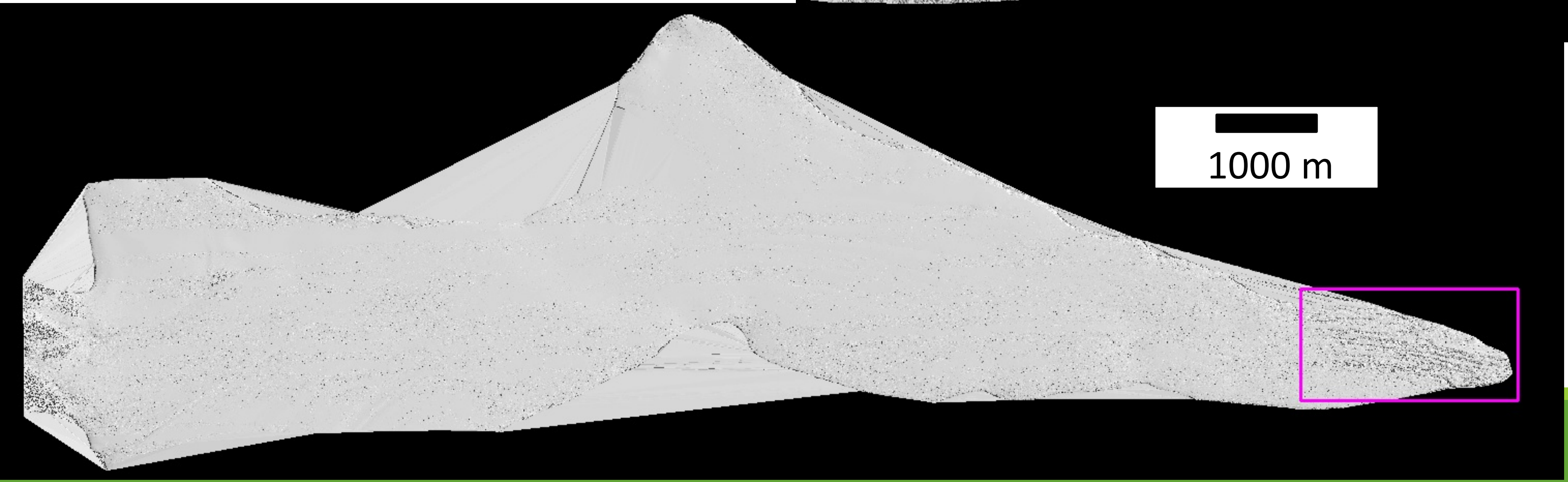


Canada Glacier

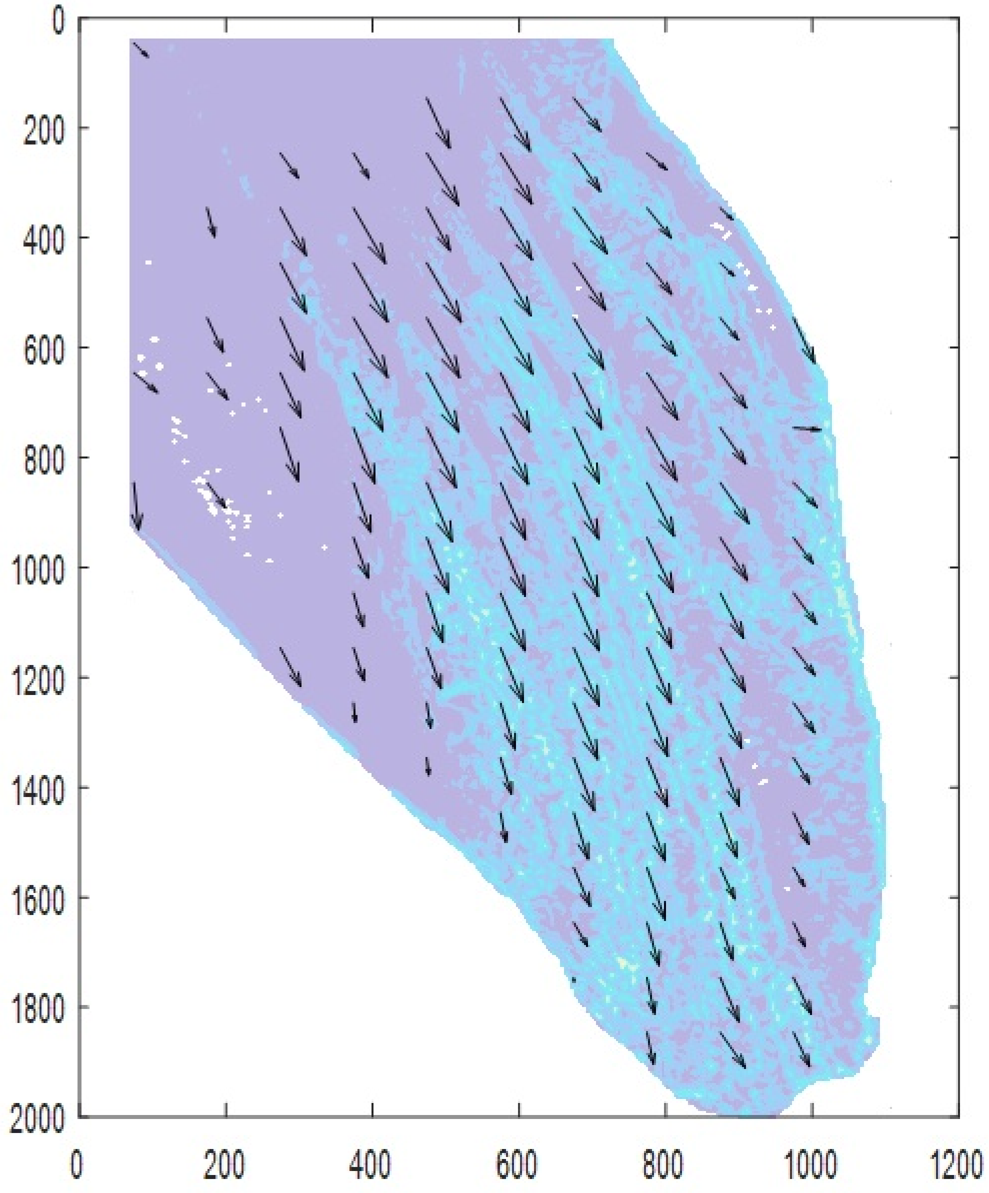
	PIV	Hand Tracking
Average Velocity	1.2 ± 0.5 m/y	1.6 ± 0.5 m/y
Center Velocity	1.3 ± 0.5 m/y	1.8 ± 0.6 m/y
Edge Velocity	0.8 ± 0.5 m/y	1.5 ± 0.3 m/y

Taylor Glacier





Taylor Glacier



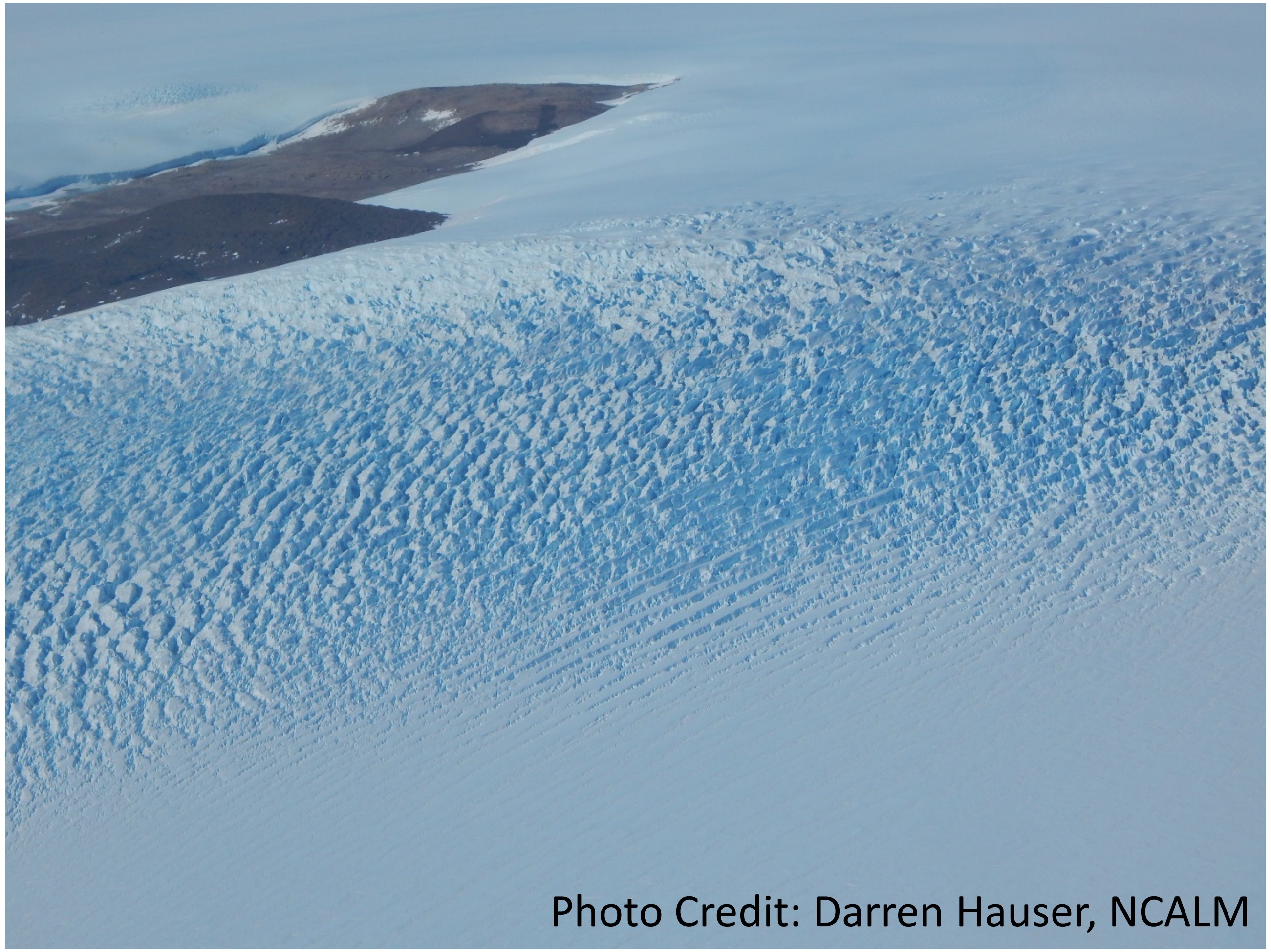
Discussion

Surface roughness is a key factor in being able to apply PIV to glaciers

- Example to the right
- Rougher surface features are relatively easily mapped but the smoother areas cannot yet be mapped with confidence
- This may be a result of data point density, since smaller surface features on smoother regions may not be well defined

PIV velocities tend to be lower than velocities collected by both in situ and hand tracking measurements

- Fountain et al. (2006) found velocities ranging from 0.3 – 9 m/y throughout Taylor Valley
- Smaller features may be identified more readily with PIV than could easily be measured manually
- PIV algorithm may map some small scale features that are not consistent between 2001 and 2014



Conclusions

PIV has been shown to map glacier surface velocities reasonably clearly

Attention in the use of PIV on glaciers should be paid to surface roughness

- The direction of surface features are also likely to play a key role
- Taylor Glacier terminus has far more along glacier ridges and valleys (Johnston et al., 2005) than Canada glacier, where ridge and valley features are primarily cross glacier in nature

Continuing research will apply this technique to other glacier LiDAR data to better understand the effect of surface features and data resolution on PIV

Image of Taylor Glacier terminus shown at right

Photo Credit: Darren Hauser, NCALM

References

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Photo Credit: Darren Hauser, NCALM

In Situ Studies

Johnston et al. (2005)

- 7 m/y for Taylor Glacier
- 1999 - 2001

Robinson (1984)

- 5-15 m/y
- 1975 - 1978

Kavanaugh et al. (2009)

- 5-15 m/y
- 2002 - 2004

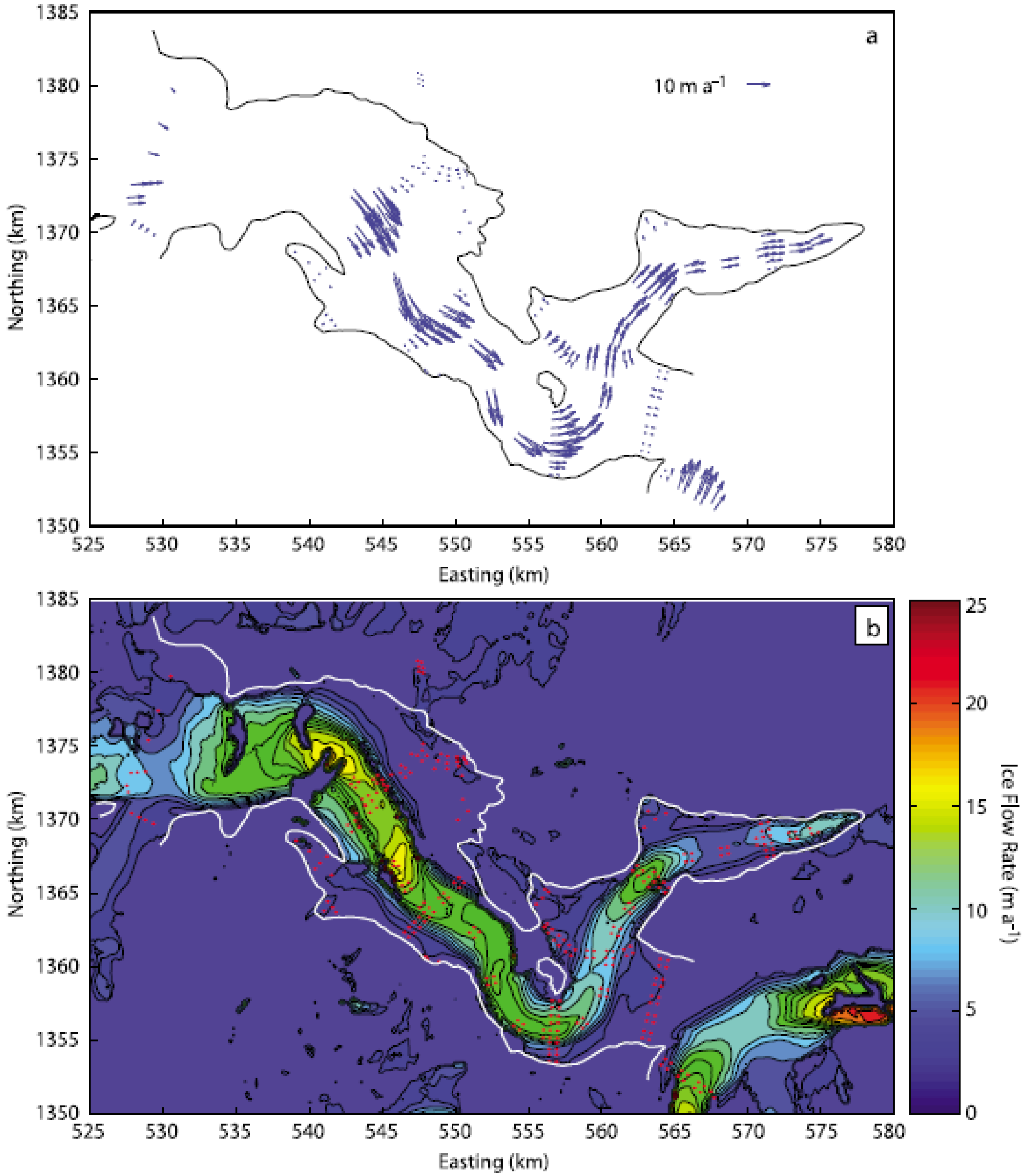
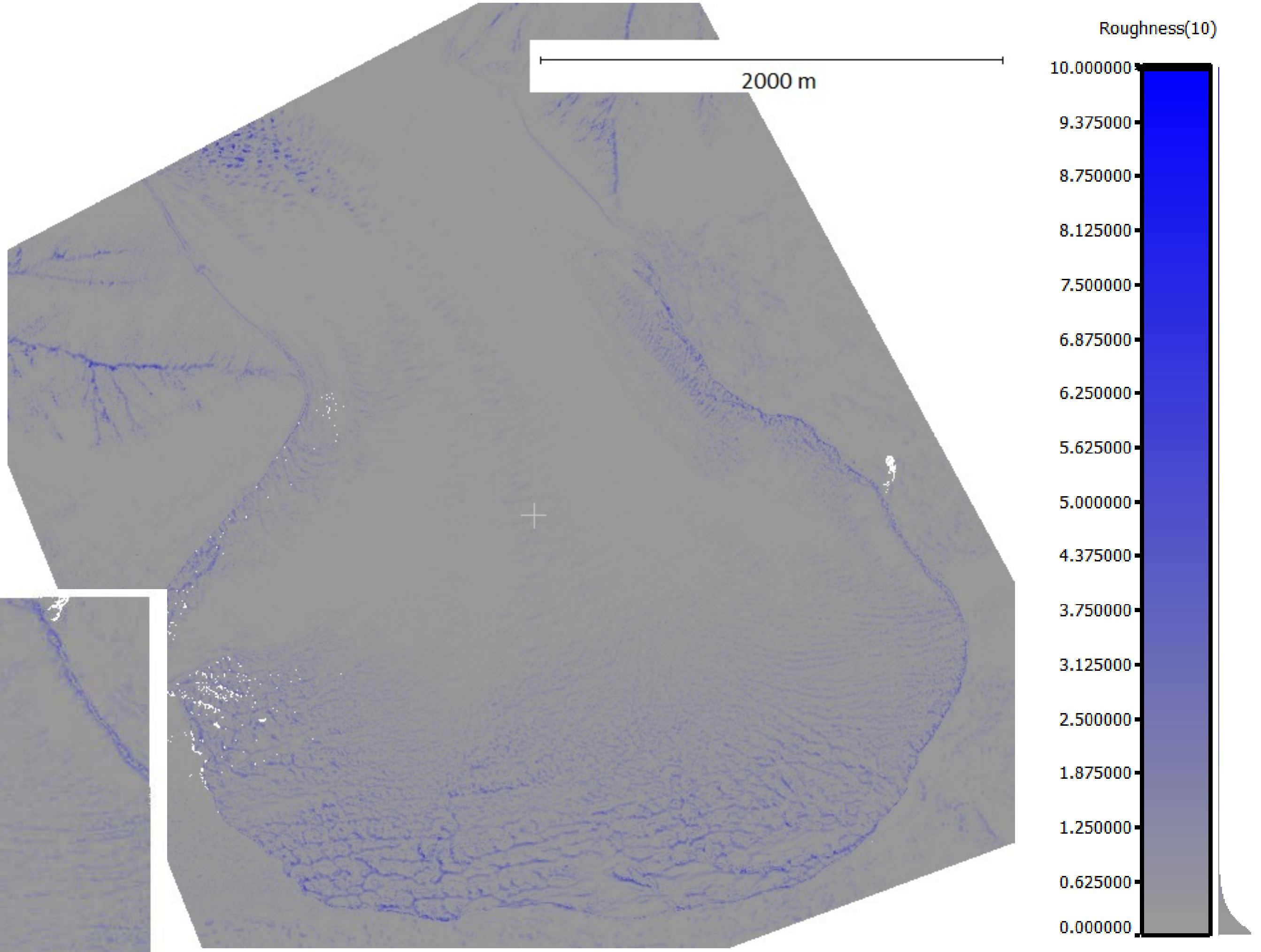
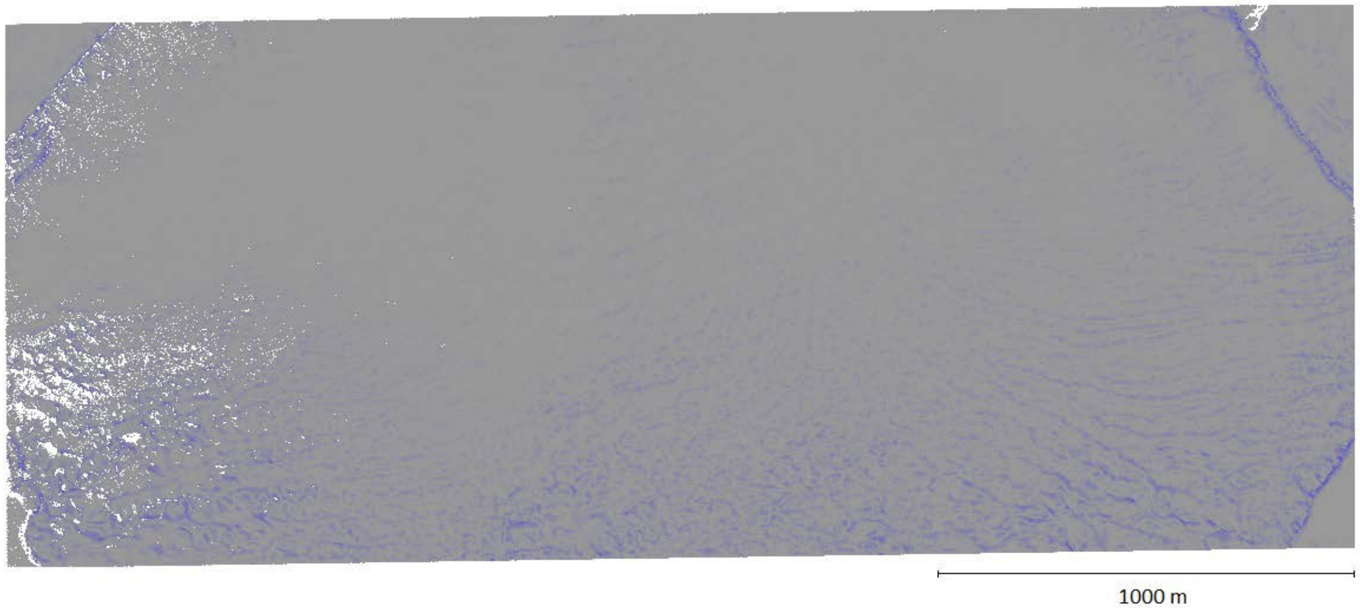


Figure from Kavanaugh et al. (2009)

Canada Glacier





Taylor Glacier