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Using time series of UAV imagery to map landslide displacement

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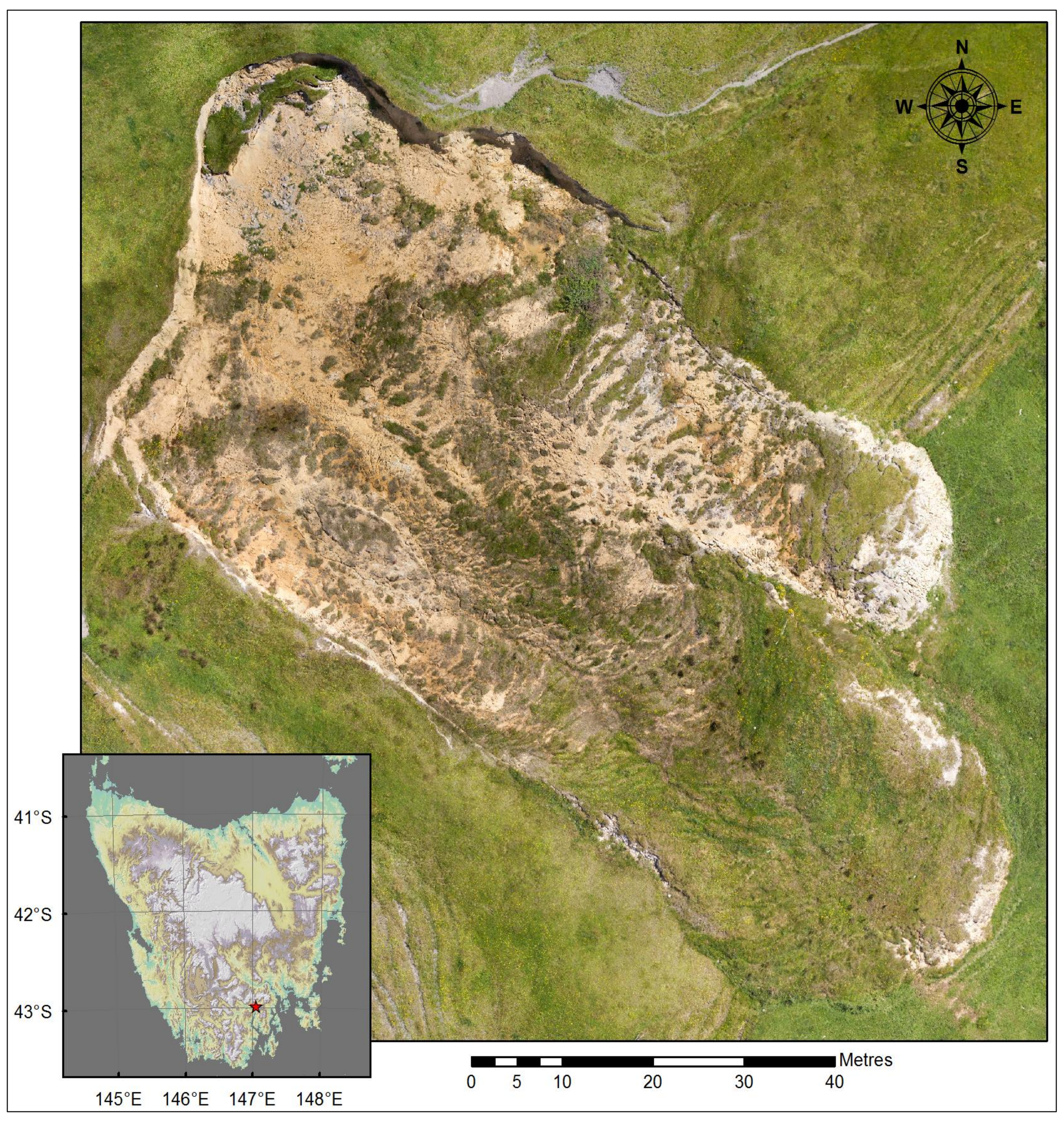
We used an Unmanned Aerial Vehicle (UAV) to collect a time series of high-resolution images over four years at seven epochs to assess landslide dynamics.

Structure from Motion (SfM) was applied to create Digital Surface Models (DSMs) of the landslide surface with an accuracy of 4–5 cm in the horizontal and 3–4 cm in the vertical direction. The accuracy of the co-registration of subsequent DSMs was checked and corrected based on comparing non-active areas of the landslide, which minimized alignment errors to a mean of 0.07 m.

Variables such as landslide area and the leading edge slope were measured and temporal patterns were discovered. Volumetric changes of particular areas of the landslide were measured over the time series.

Surface movement of the landslide was tracked and quantified with the COSI-Corr image correlation algorithm but without ground validation. Historical aerial photographs were used to create a baseline DSM, and the total displacement of the landslide was found to be approximately 6630 m^3.

This study presents a robust and repeatable algorithm allowing to map landslide's dynamics with a UAV over relatively long time series**.**

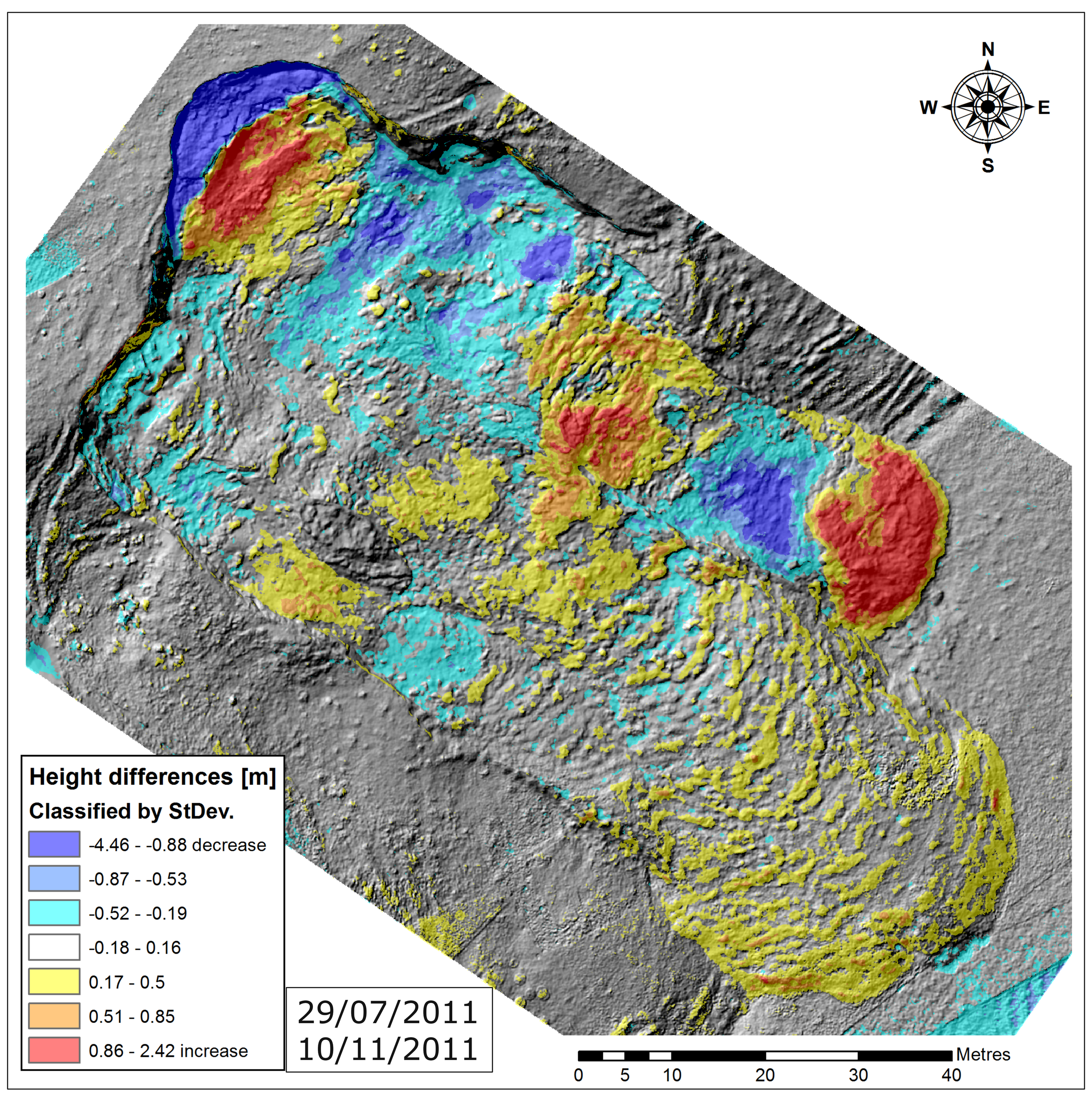


Left: Home Hill landslide Tas, Australia

The landslide formed in 1996 on a steep slope in an agricultural field in strongly weathered colluvium. The scar with a rotational movement and two earthflow toes are visible. The upper right toe is most active.

Above: octocopter for image acquisition

The UAV is equipped with a GPS and a Canon 550 DSLR camera mounted in a stabilized frame to take pictures always at nadir. Flights are controlled by an autopilot and pre-planned on a Google earth image.



Left: height difference map

The image shows a DEM difference map of the landslide based on images acquired on 29 July 2011 and 10 November 2011. The DEMs are generated from approximately 150 individual UAV photos using the Structure from Motion algorithm (AgiSoft package). The spatial resolution of the pixels of the DEMs is 1 cm. The image clearly illustrates the retreat of the main scarp and the expansion of the toe. An invariant island is visible in the lower left part of the landslide. No explanation for this static island was found so far.

Right: surface displacement map

The surface displacement of the landslide was analyzed using all seven sets of UAV images. The relative displacements between two image acquisition dates were computed using the 'image correlation method' using COSI-Corr software of CalTech CA. Window size of 64 pixels, step size of 8 pixels and a 50 pixels search radius provided best results. The image on the right shows vectors of the direction and magnitude of the displacement while the colored layer illustrates the combined N-S and W-E displacement directions.

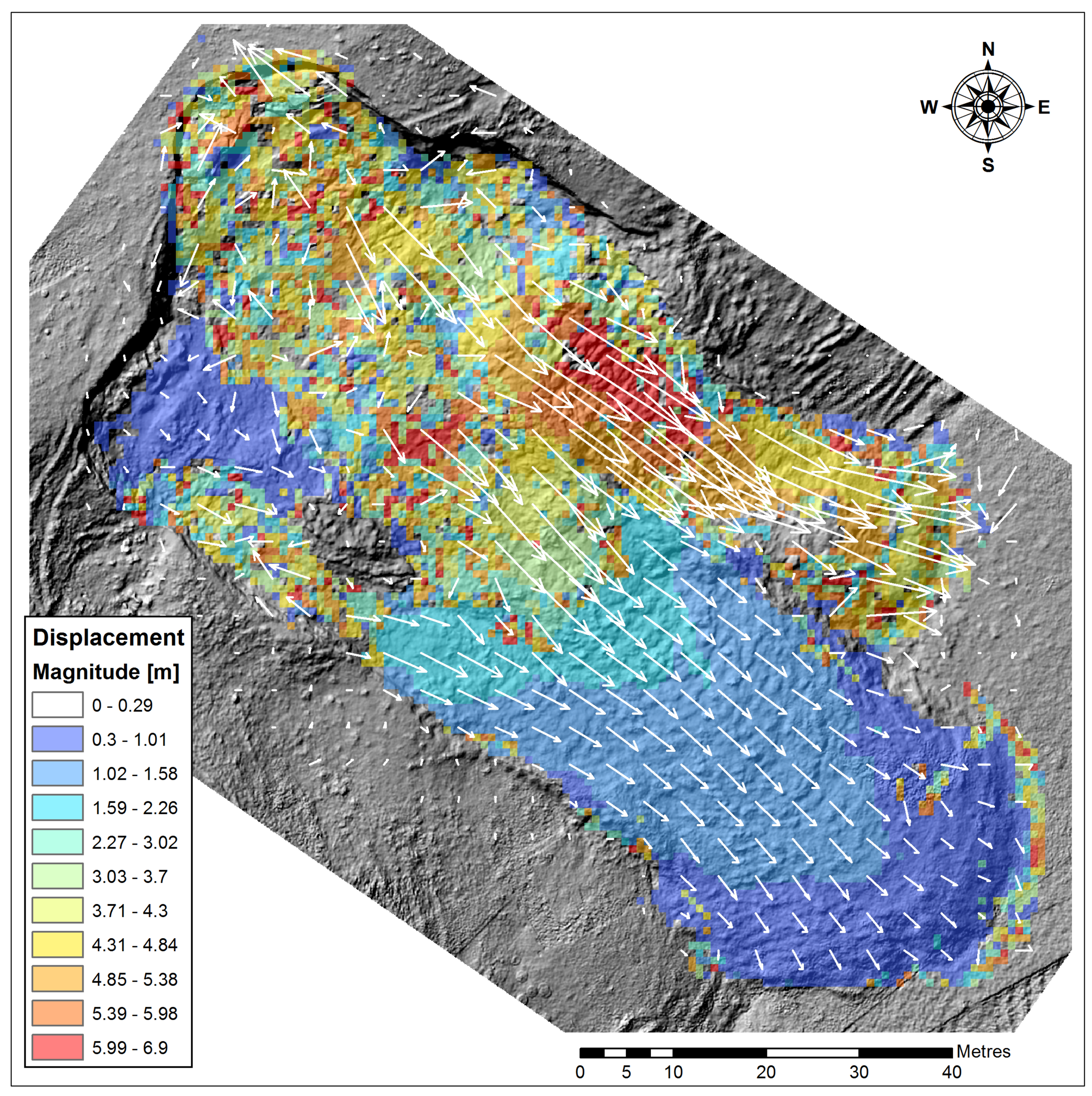


Table 1 Details of aerial surveys of Home Hill landslide, TAS Australia

Survey	Date	Interval (Days)	Weather Conditions
2010A	20 July 2010	-	Sunny, light winds
2011A	19 July 2011	364	Overcast, light rain, wind
2011B	10 Nov 2011	114	Sunny, moderate winds
2012A	27 July 2012	260	Sunny, light winds
2013A	5 April 2013	252	Sunny, moderate winds
2013B	29 July 2013	115	Sunny, moderate winds
2014A	25 July 2014	361	Sunny, no wind

Table 2 Summary of spatial errors for Home Hill landslide DSMs and orthophotos.

Survey	Photos Used	GCPs	Check points	XY RMSE (m)	Z RMSE (m)
2010A	62	56	19	0.046	0.031
2011A	116	41	20	0.045	0.042
2011B	194	23	23	0.021	0.025
2012A	170	66	17	0.047	0.039
2013A	179	29	22	0.058	0.078
2013B	241	23	21	0.076	0.090
2014A	415	16	10	0.031	0.031

Flight details & XYZ accuracies

Table 1 shows details about acquisition days, number of days between the UAV observations and weather conditions. Weather conditions may have a deteriorating effect on the quality of the photos and the accuracy of the SfM process and hence the XYZ accuracy of DEMs and OrthoMosaics.

Table 2 illustrates the obtained accuracy in XYZ directions of the DEMs and the OrthoMosaics. Typical RMSE are 4 to 5 cm in XY horizontal directions and 3 to 4 cm in Z vertical direction. Overall XYZ accuracy is very good.

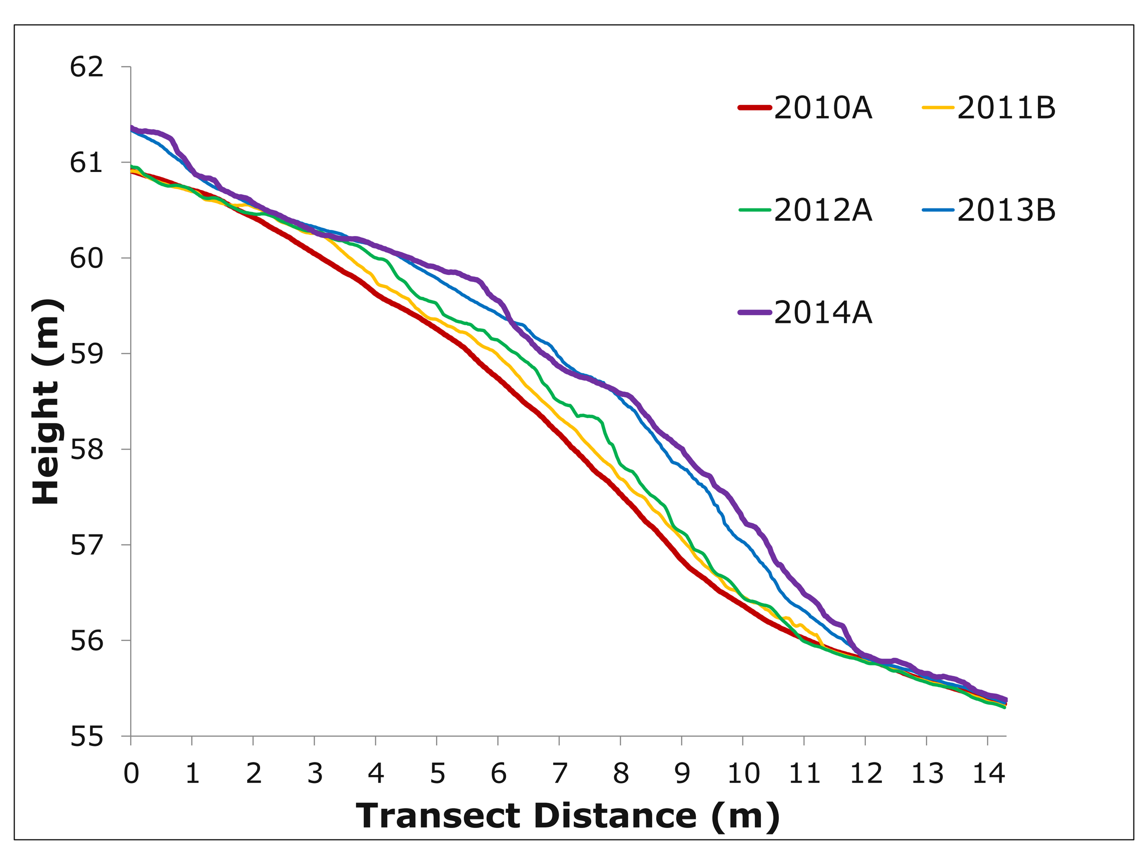
Further reading:

Turner D, A Lucieer & SM de Jong, 2015. Time series analysis of landslide dynamics using an Unmanned Aerial Vehicle (UAV). Remote Sensing 7, 1736-1757.

Lucieer A, SM de Jong & D Turner, 2014. Mapping landslide displacements using Structure from Motion (SfM) and image correlation of multitemporal UAV photography. Progress in Physical Geography 38, 97-116.

Below: increase of the large toe steepness

The figure shows the slope of the leading edge of the large toe calculated from five DSMs. Steepness builds up slowly at the toe as materials flows down eventually leading to the collapse of the toe and a surge forward. Pressure is building up but no surge is yet observed. This trend is not so obvious for the small toe likely because it surged forward 12 m between 2010 and 2011 when pressure was released.



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