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Monitoring landslide dynamics using timeseries of UAV Imagery

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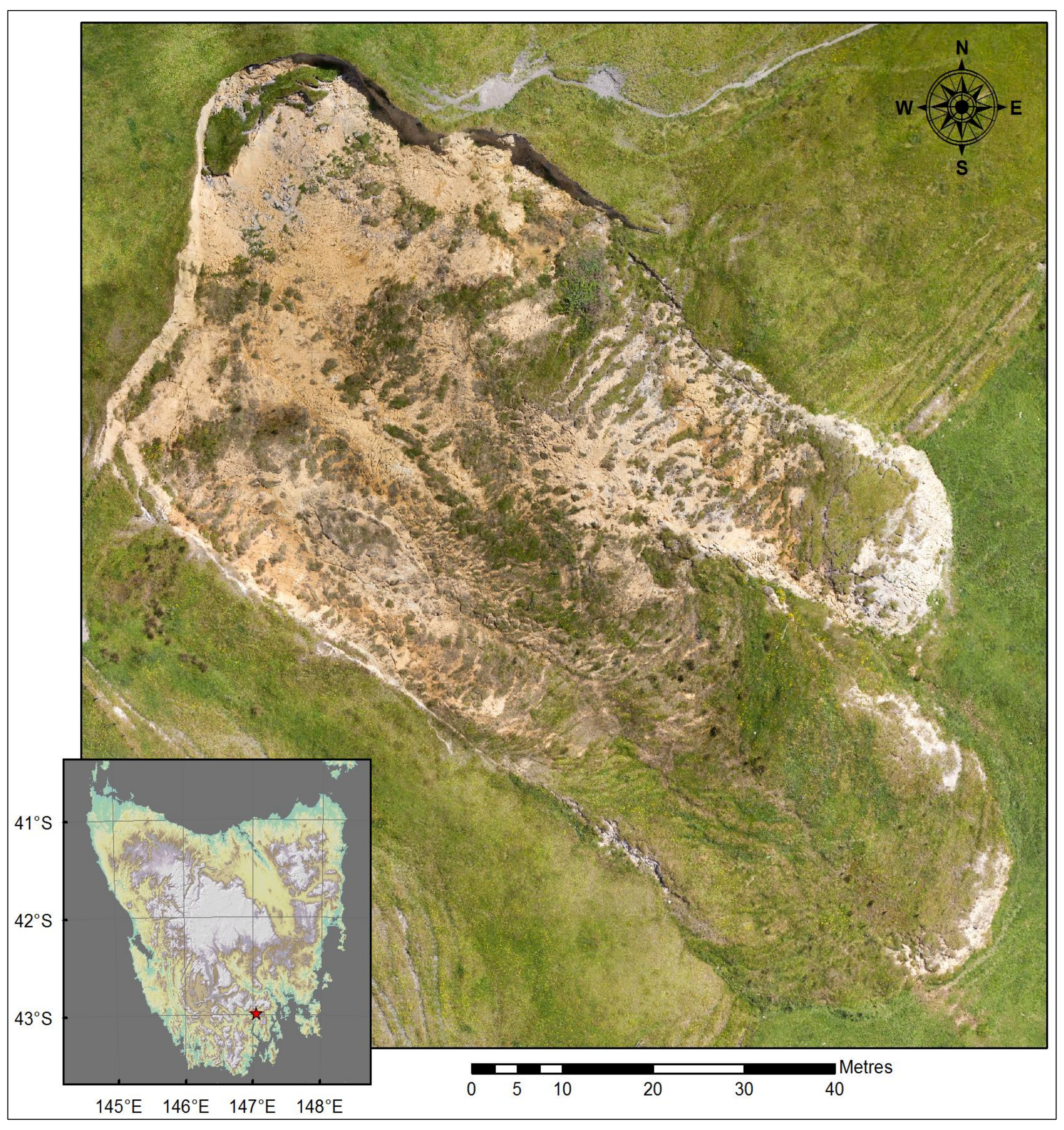
Abstract:

We study landslides using timeseries of high-spatial resolution images acquired by Unmanned Aerial Vehicle (UAVs). We aim at surveying the morphological structure of the landslide, detecting movements and feed stability models to predict possible future movements and run out distance. Structure from Motion (SfM) is the algorithm used to process the UAV images into Digital Surface Models (DSMs) and OrthoMosaics at ~10 cm resolution. Obtained accuracies are around 4 to 5 cm in the horizontal and 3 to 4 cm in the vertical direction. The COSI-Corr image correlation algorithm is applied to detect and quantify surface deformations of the landslides. Variables such as landslide area and the leading edge slope were measured and temporal patterns were discovered. Volumetric changes were measured over the time series. Results are shown here for the Home Hill landslide on Tasmania, Australia and the Charonnier landslide in the Alps, France. Historical aerial photographs were used to create a baseline DSM. Total displacement of the landslide was found to be approximately 6630m^3 for Home Hill and 21000m^3 for Charonnier. This study demonstrates a robust and repeatable approach to survey and quantify landslide's dynamics using UAV time series images. UAV are flexible and easy to use and yield very high spatial resolution imagery.

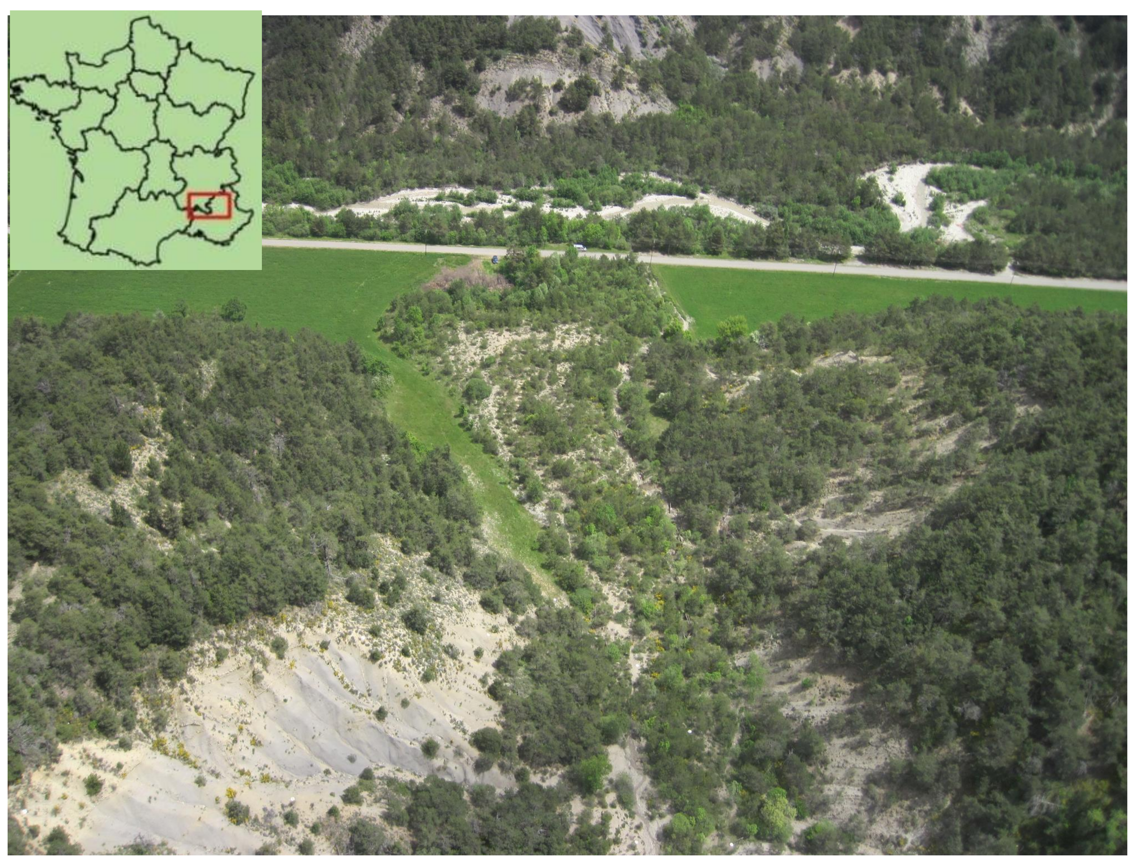


Home Hill landslide Tasmania, Australia

Left: the landslide formed in 1996 on a steep slope in strongly weathered colluviums. The scar with rotational movement and two earth flows are visible.

Fixed-wing UAV & Pilot

Above: the UAV is equipped with a Canon Powershot D10 RGB compact camera with a resolution of 4000 by 3000 pixels. 40 field markers are located with DGPS and used to add a cartographic system, for accuracy assessment and geocoding.



Charonnier landslide, Alps France

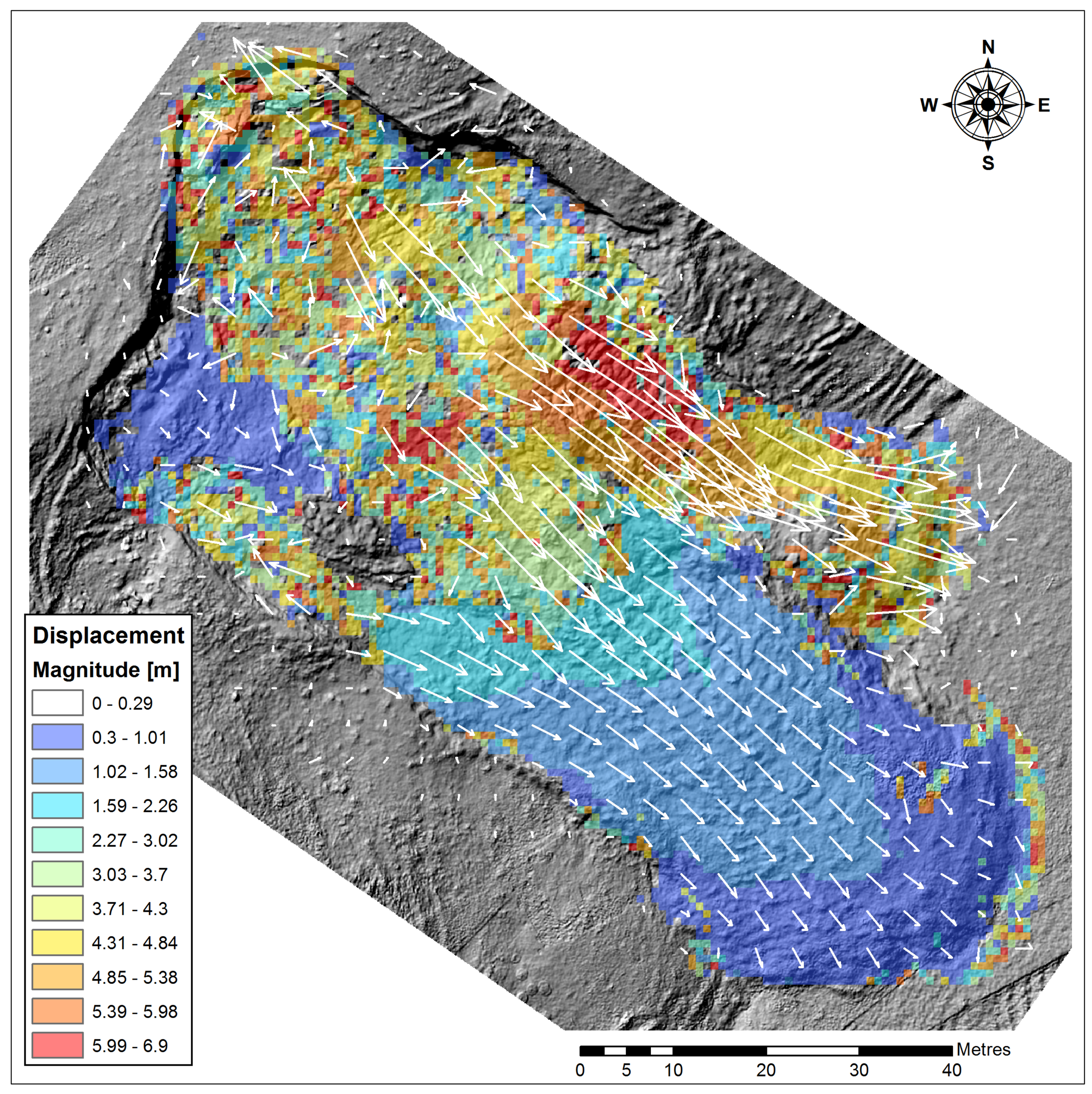
Above: Oblique UAV-image showing an overview of the transport and depositional area of the Charonnier landslide. The landslide formed overnight on 7 January 1994 after a wet period of several months and a triggering rainfall event of 65 mm within a few hours. The deposit was spread out over an agricultural field and vegetation cover is since then rapidly increasing.

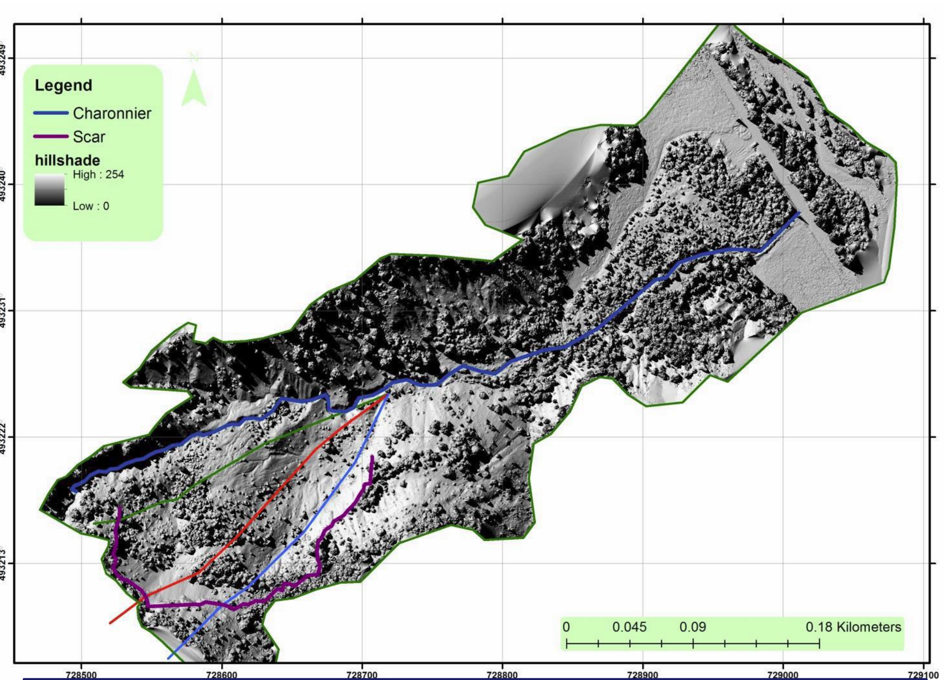
Structure from Motion

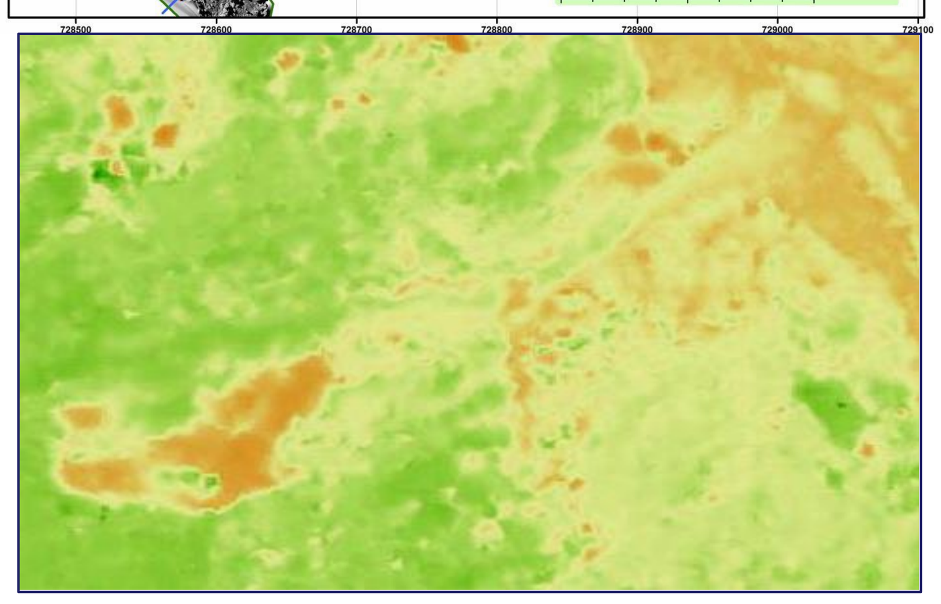
This algorithm search for millions of identical tie points in the sets of UAV photos. Features are recognized regardless of scale and viewing angle by the sub algorithm SIFT: Scale Invariant Feature Transform. Camera parameters are estimated together with camera positions. Markers laid out in the field provide cartographic match points. DEMs and Mosaics are generated using hundreds of individual UAV photos by generating points clouds and filling followed by a conversion into triangulated surface mesh. Smith et al. 2015 provide details.

Surface displacement image (right)

Right: Surface deformations of the landslides are analysed using the multi-temporal sets of UAV images. The relative deformations between two image acquisition dates are computed using the 'image correlation method' of 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 right image shows an example for Home Hill displaying vectors of the direction and magnitude of the displacement while the coloured layer illustrates the combined N-S and W-E displacement directions.







DEM construction & volume estimates

Left, upper: Hillshade OrthoDEM image of the Charonnier landslide based on the UAV images collected in 2016. The scar is indicated in purple. Vegetation cover on the slide is hampering a clear view and volume calculations. Deformations since 1994 are very small.

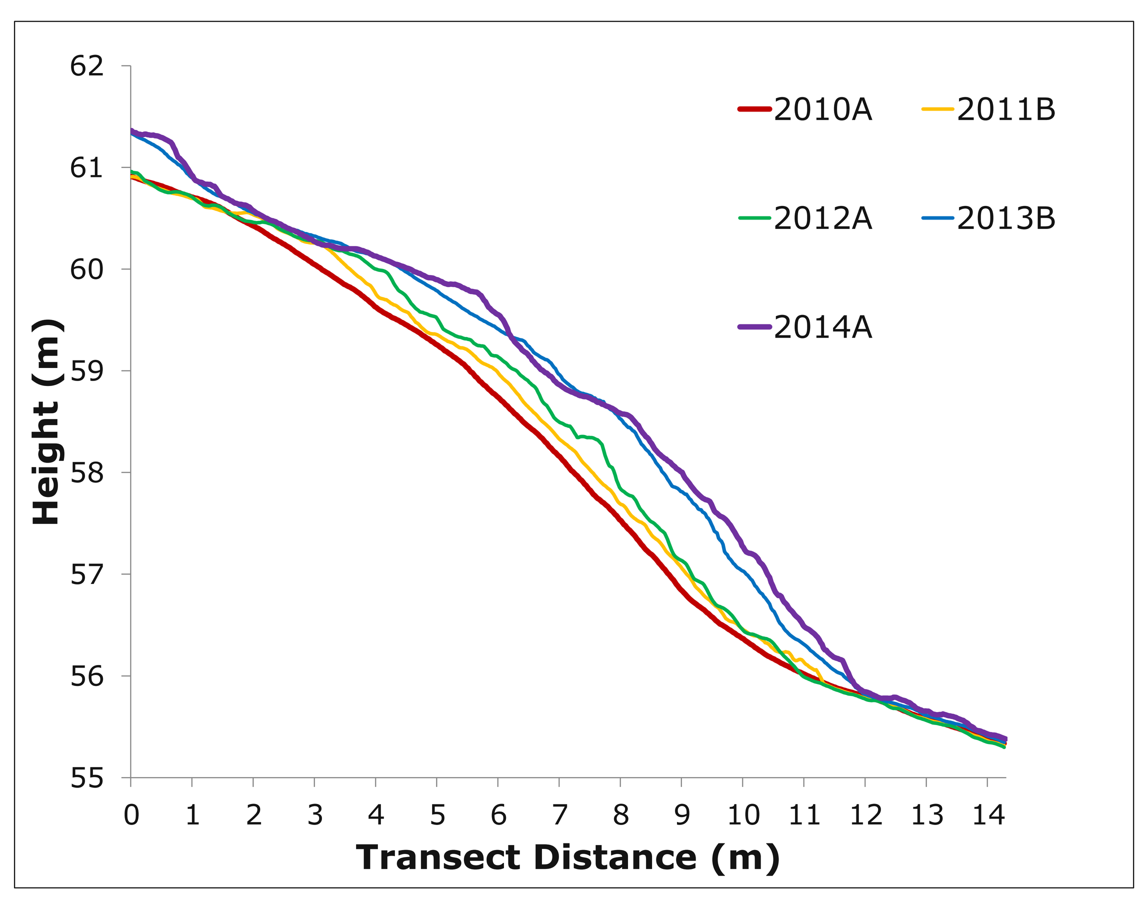
Left, lower: UAV images of Charonnier are only available for 2016 and later. Therefore we used 1993 IGN aerial photos to construct a DEM from before the landslide. A DEM-difference was calculated using the 2016 UAV-Orthomosaic (5cm resolution) and the 1993 IGN Aerial Photo DEM (50 cm resolution). Although the resolution difference is large, a rough estimate of the displaced volume could be made of around 21000m^3.

Further reading:

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.

Smith, M. W., Carrivick, J. L., & Quincey, D. J. (2016). Structure from motion photogrammetry in physical geography. *Progress in Physical Geography*, *40*(2), 247-275.

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.



Surface Movements between dates

Above: The figure shows the Home Hill slope of the leading edge of the large toe calculated from five multi-temporal DSMs. Steepness builds up slowly from 2010 (Red) to 2014 (purple) 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.

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