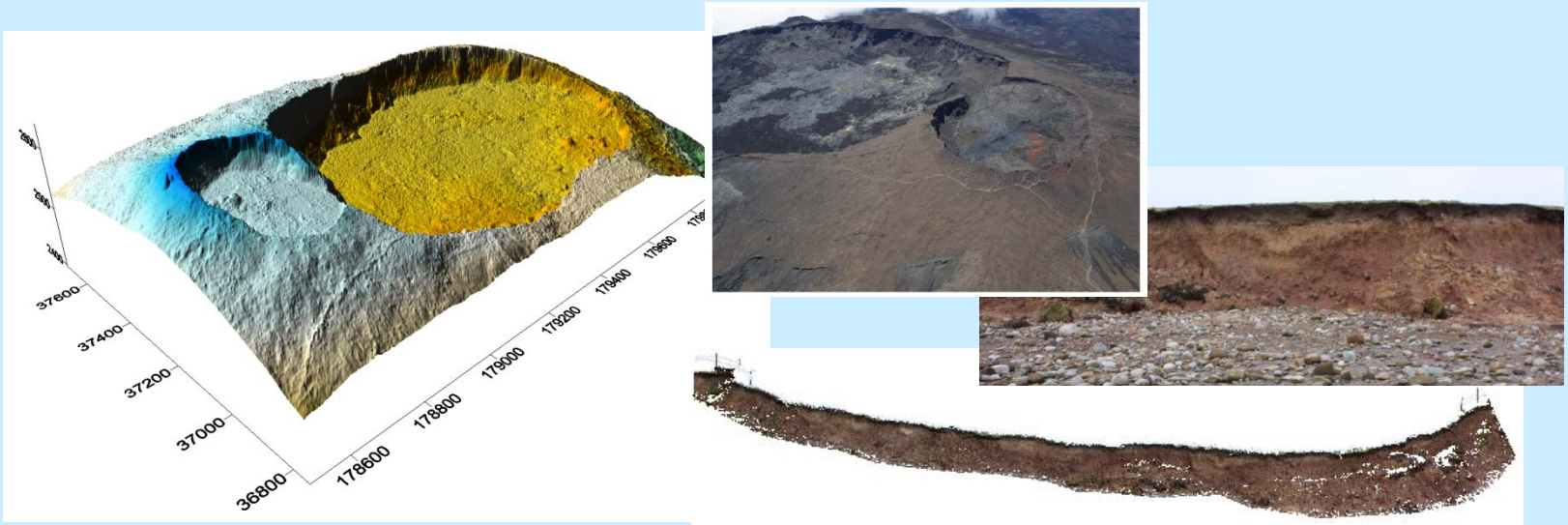
The accuracy of photo-based structure-from-motion DEMs



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LANCASTER UNIVERSITY

The Lancaster Environment Centre

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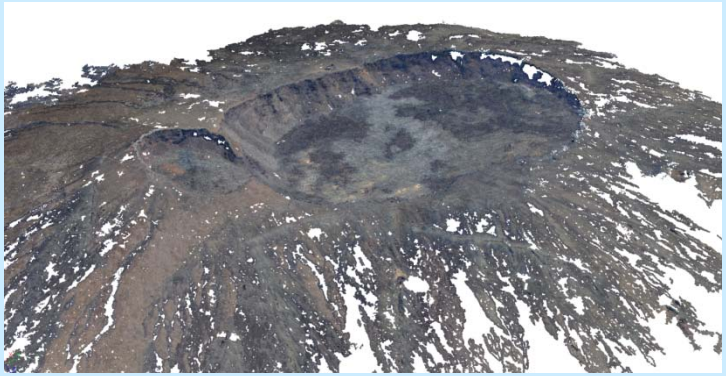
Outline

- structure-from-motion and multi-view stereo
- Study1: volcanic craters



- Study 2: coastal cliff

Structure-from-motion (SfM)

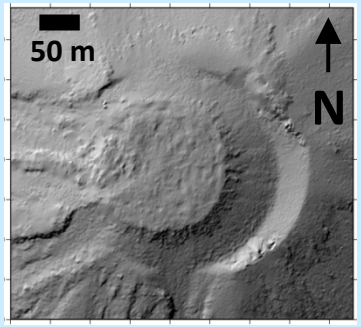
- automatic processing of images into 3D point clouds
  - multiple images from different positions
  - no control points required
  - determines camera data
  - produces a sparse surface point cloud

Multi-view stereo (MVS)

- dense image matching
  - uses camera data from SfM

Georeferencing

- scale, translate and rotate 3D model to real-world coordinate system



Software

SfM-MVS: ‘Bundler photogrammetry package’ (J.Harle)

http://blog.neonascent.net/archives/bundler-photogrammetry-package

- SfM : Bundler (*Snavely et al*., 2006)
- MVS : PMVS2 (*Furukawa & Ponce*, 2010)

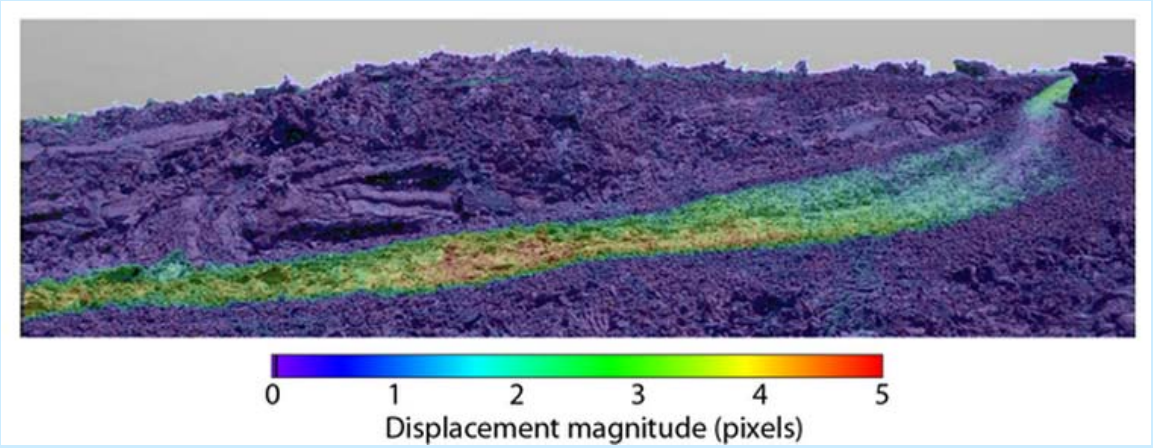
Georeferencing: ‘sfm_georef’ (*James & Robson, JGR, in revision*)

http://www.lancs.ac.uk/staff/jamesm/software/sfm_georef.htm

Applications

SfM (*Dowling*, 2009; *Dandois and Ellis*, 2010; *Stimpson et al,* 2011)

SfM-MVS (*Niethammer et al.* 2010*; Welty et al.,* 2010*, Verhoeven,* 2011*; Falkingham,* 2011, *James et al.*, 2011; *Castillo et al.,* 2012)



James et al. (2011)

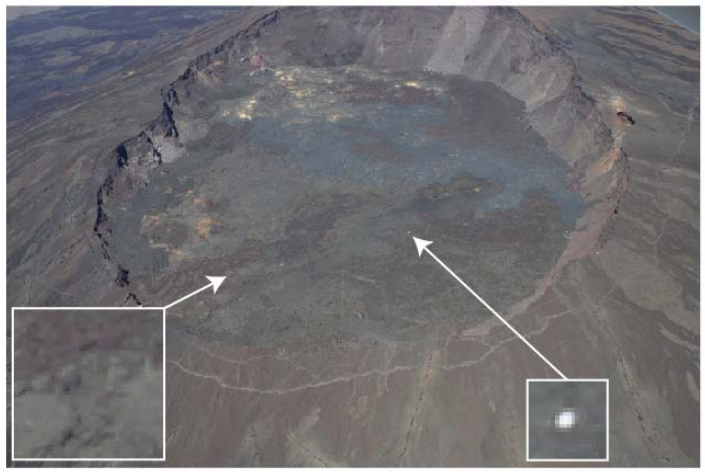
SfM-MVS vs. traditional photogrammetry

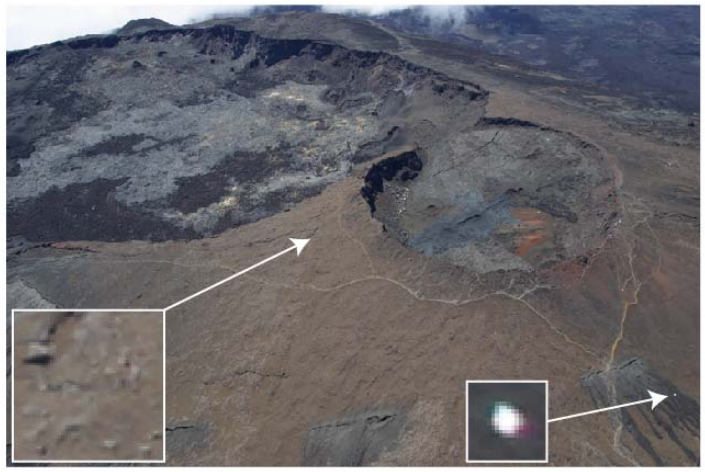
Advantages:

- no initial camera models required
- more flexible image acquisition
- no control required for model generation
- automated processing

Disadvantages:

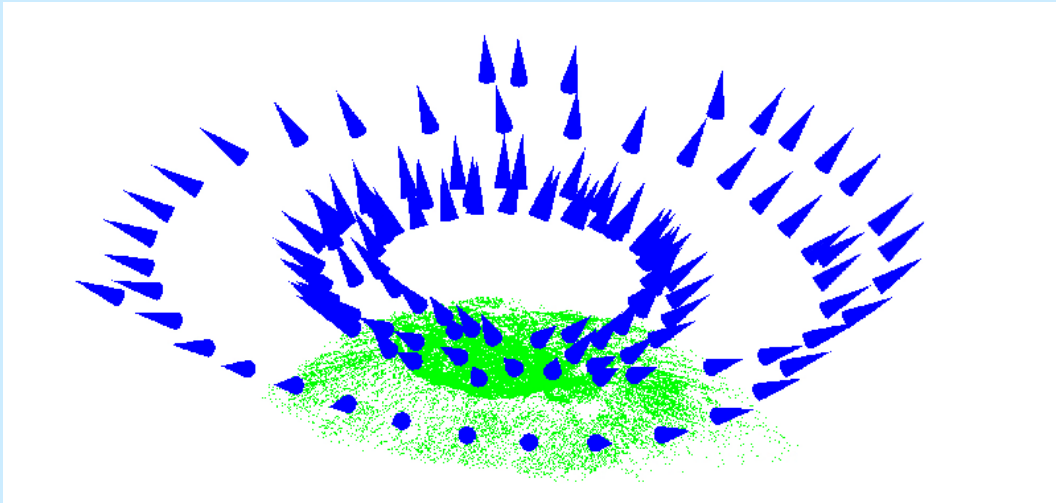
- simplified camera model used
- independent camera models for each photo
- incremental scheme – errors can accumulate
- few integrated error metrics



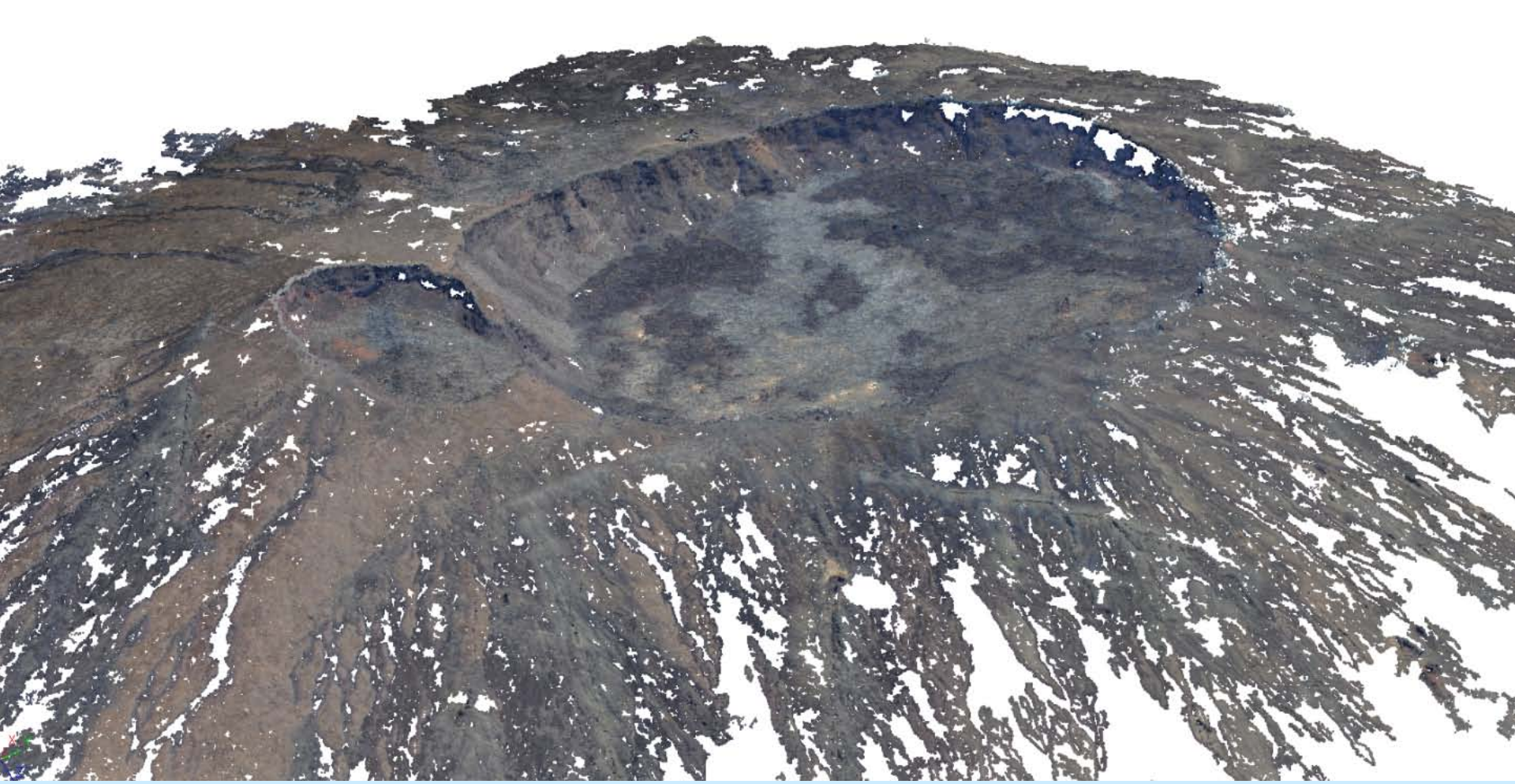


Summit craters of Piton de la Fournaise volcano, Reunion

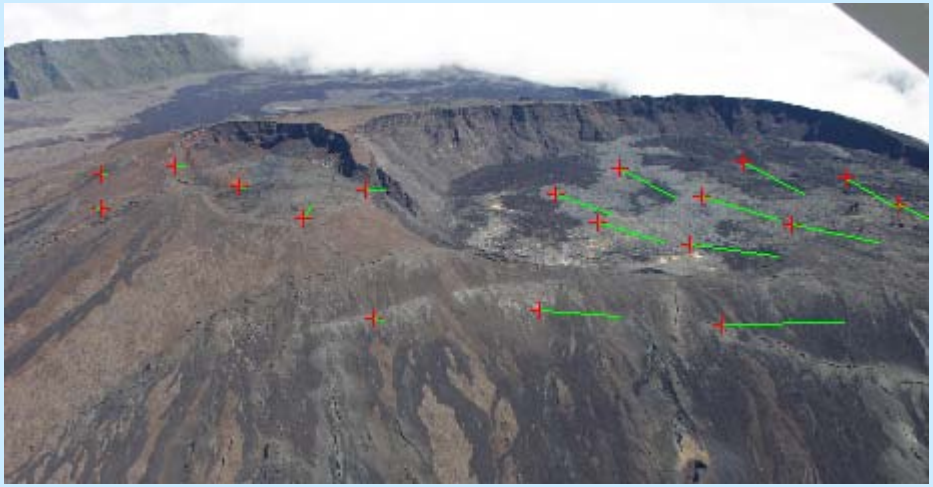
- two over-flights in a microlight
- 133 images, Canon EOS D60, 20 mm lens
- 45 control targets (± ~0.1 m)
- reference DEM from oblique photogrammetry (VMS)

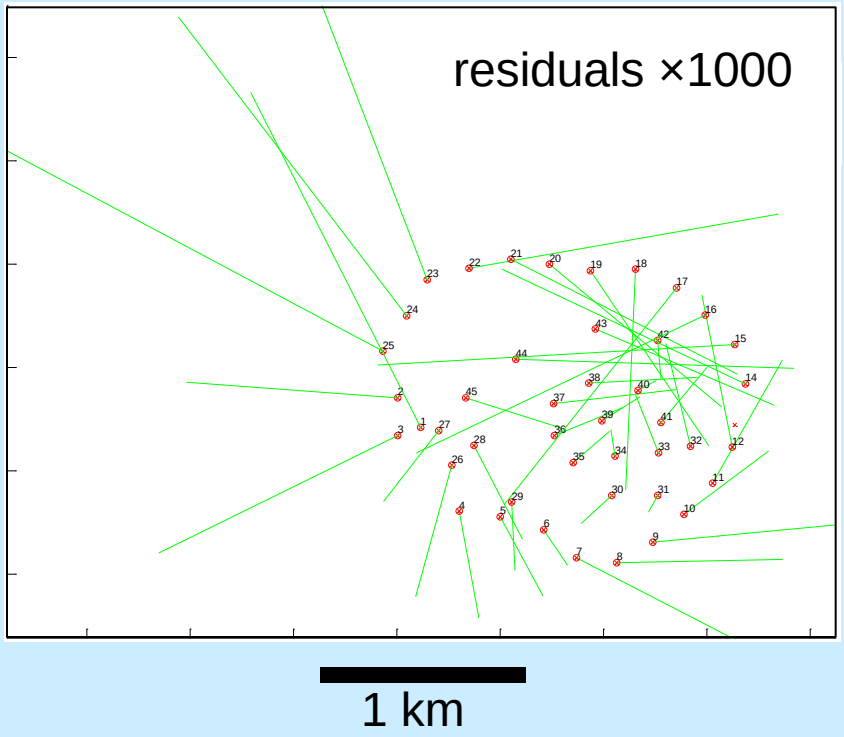


SfM-MVS point cloud

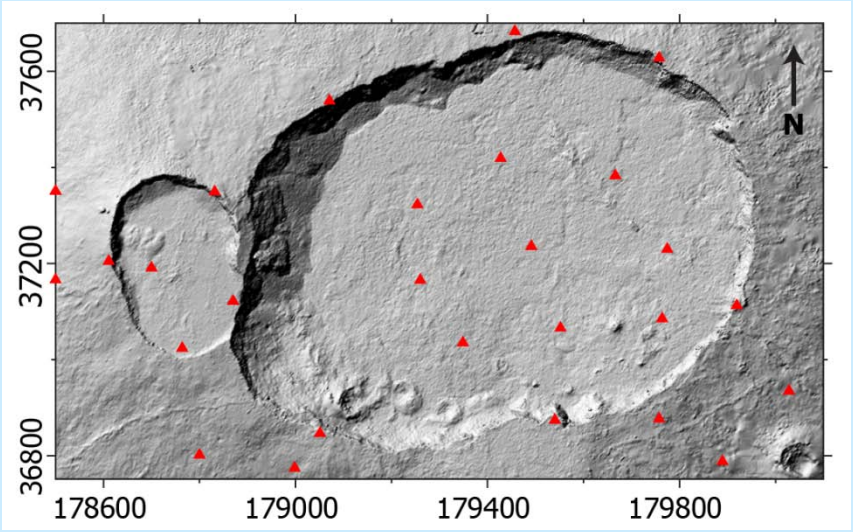


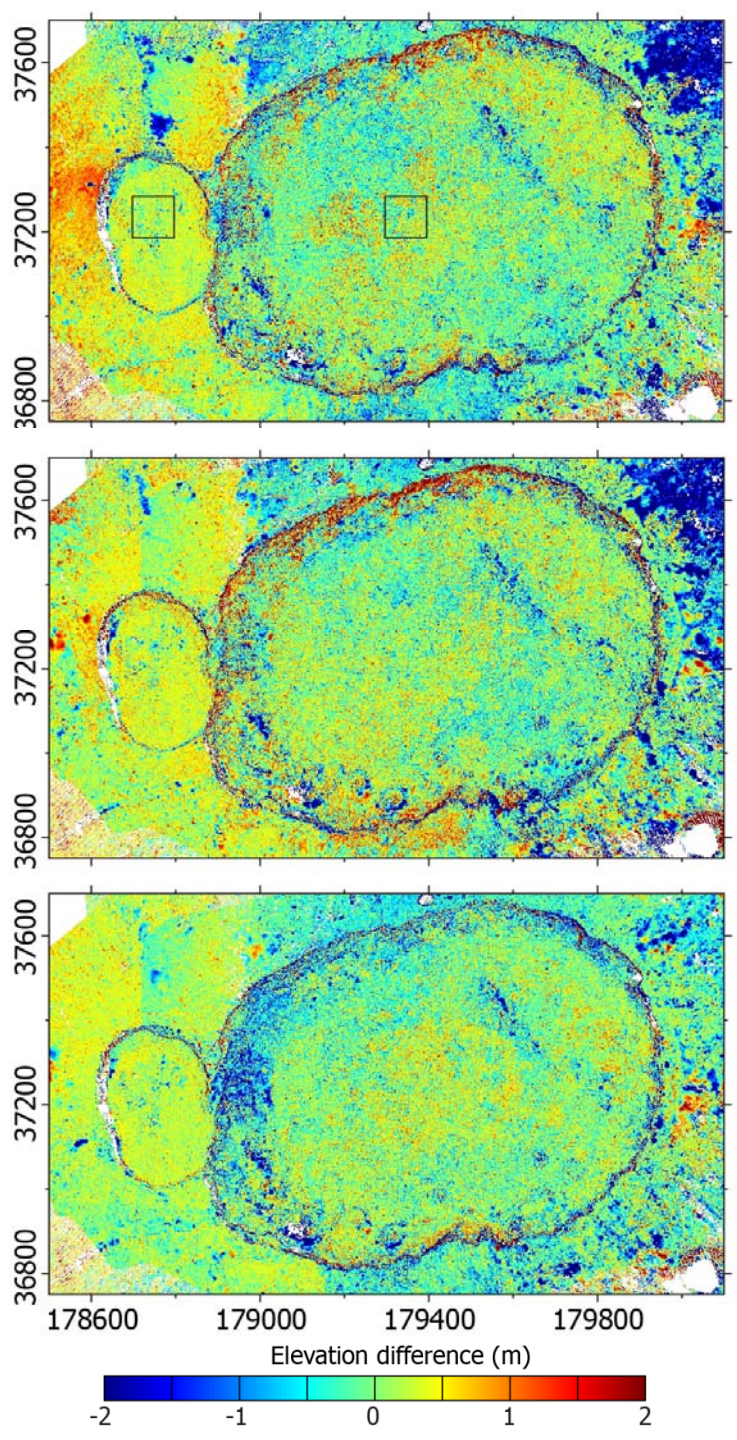
Georeferencing
(sfm_georef)





- RMS error 0.99 m





DEM comparisons

RMS difference: 1.0 m

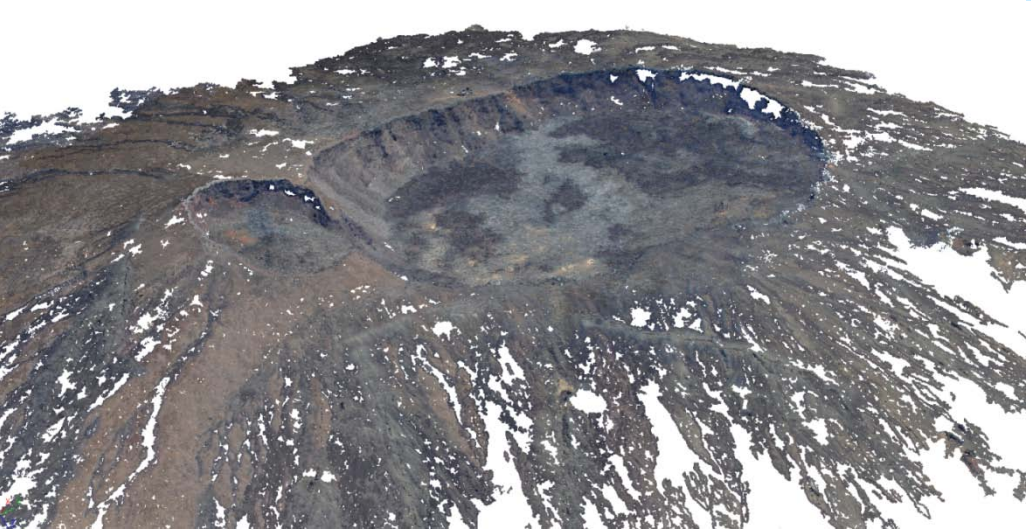
reprocessed for single camera model

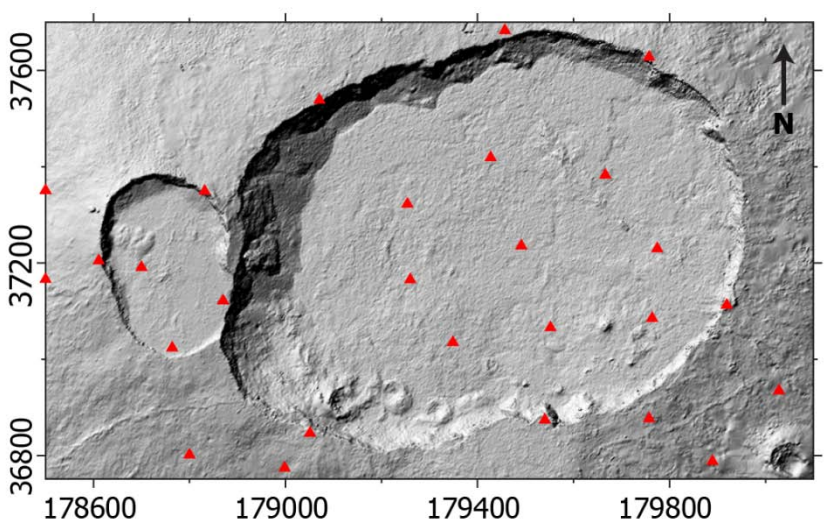
reprocessed for single, extended camera model

RMS difference: 0.87 m

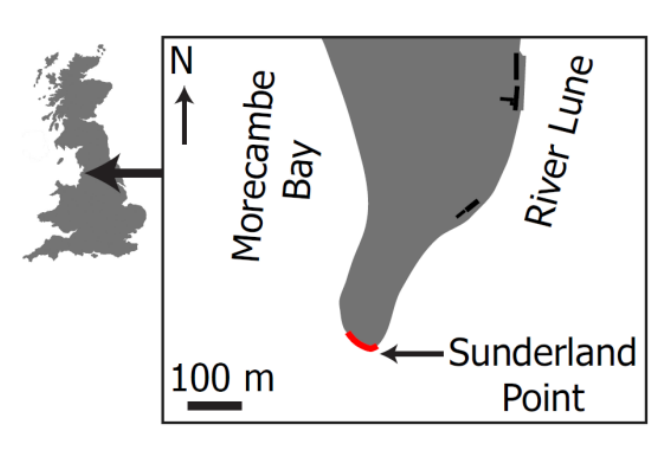
Summary so far…

- SfM-MVS gave metre-level precision over viewing distances of ~1000 m
- precision is being limited by the simple camera model
- independent camera models help accommodate error

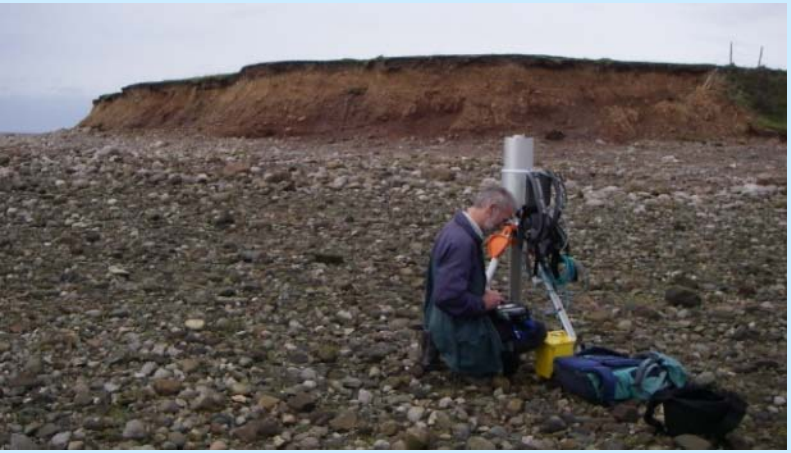




Sunderland Point, U.K.



- arcuate cliff section, 2-3 m high, ~60 m long
- comparison data collected with Riegl LMS-Z210II (TLS)



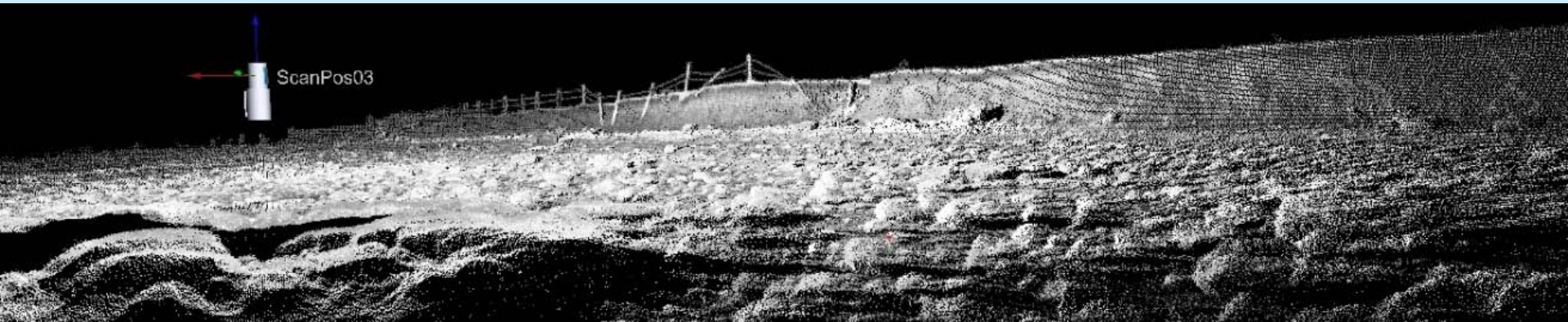
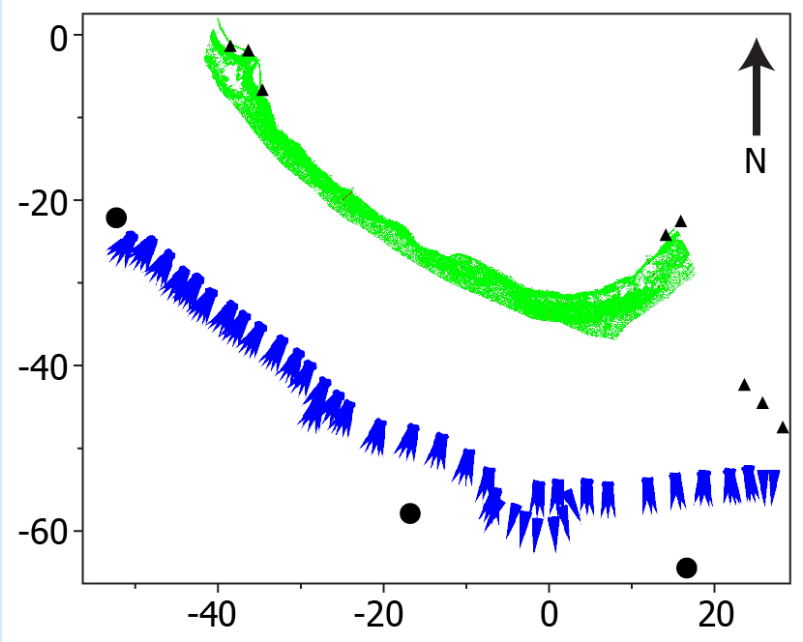
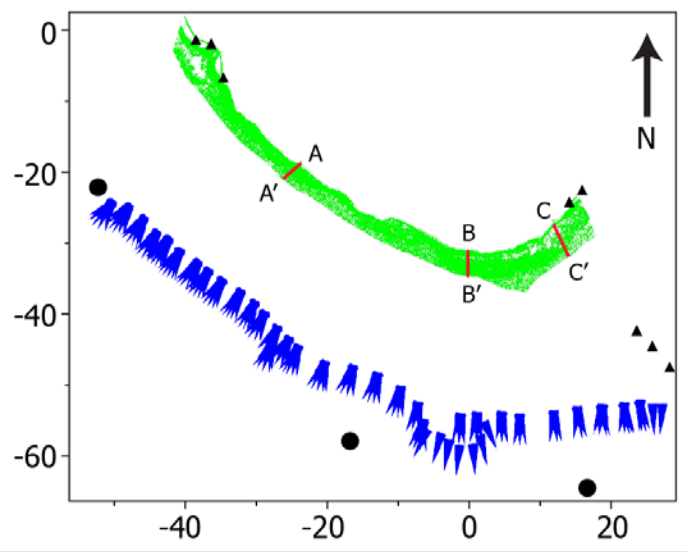


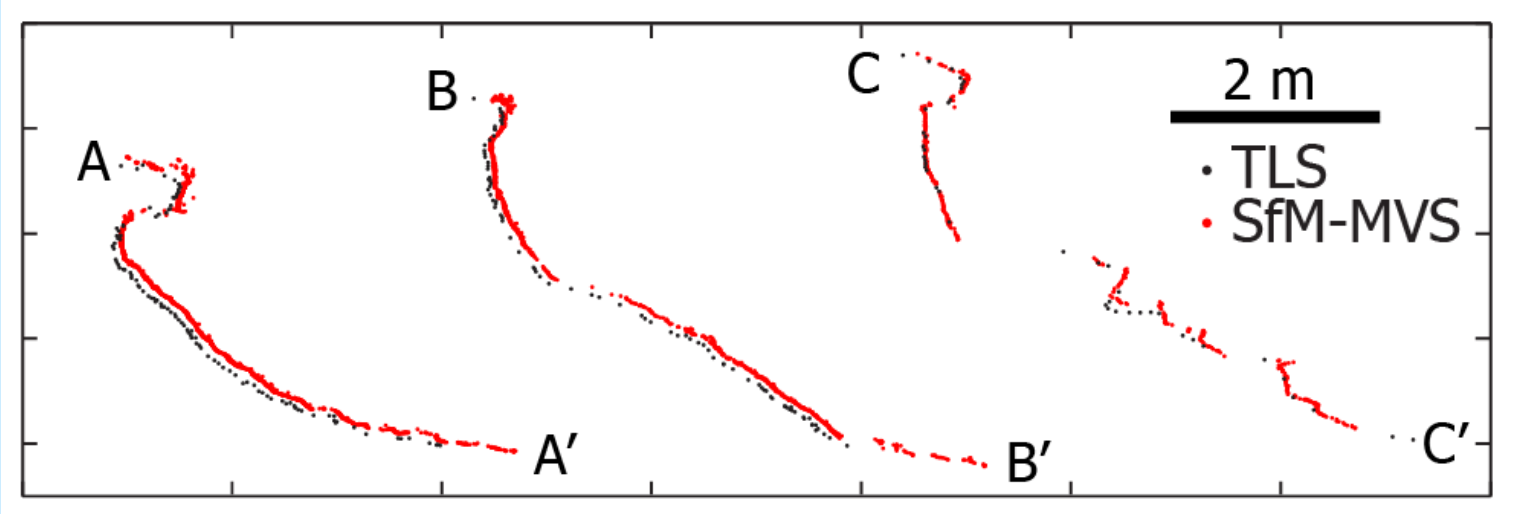
Image collection

- 150 images, Canon EOS 450D, 28 mm lens

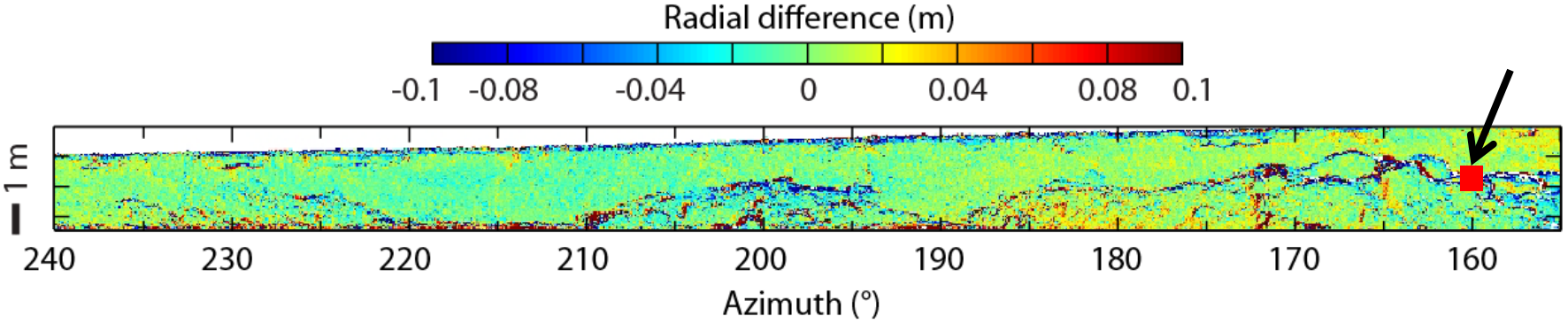


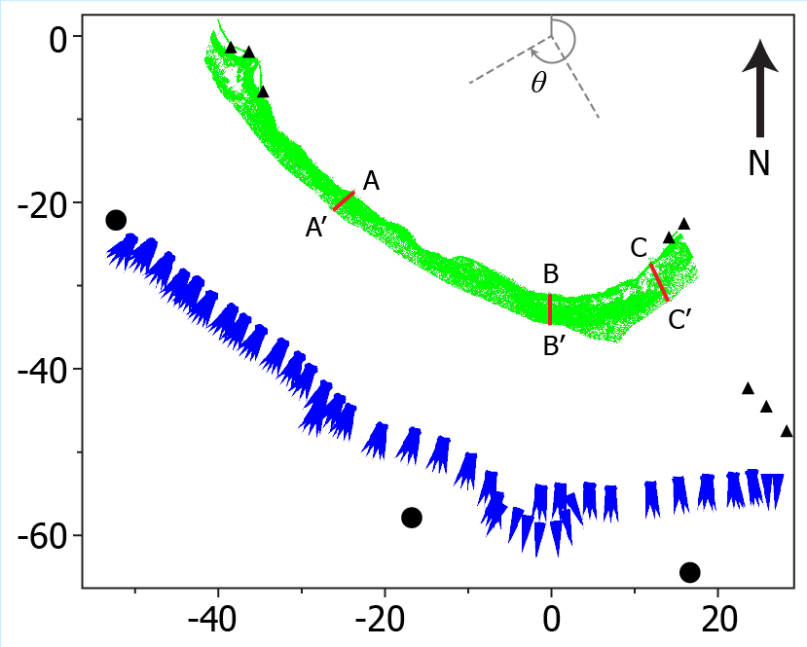
Cross sections





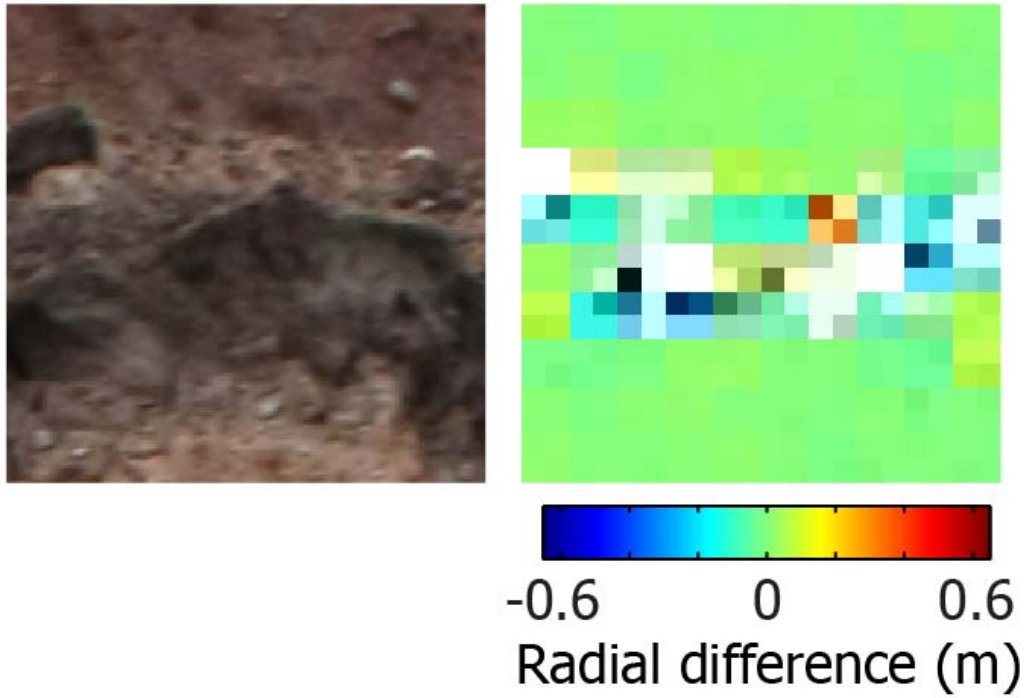
Differences between SfM-MVS and TLS



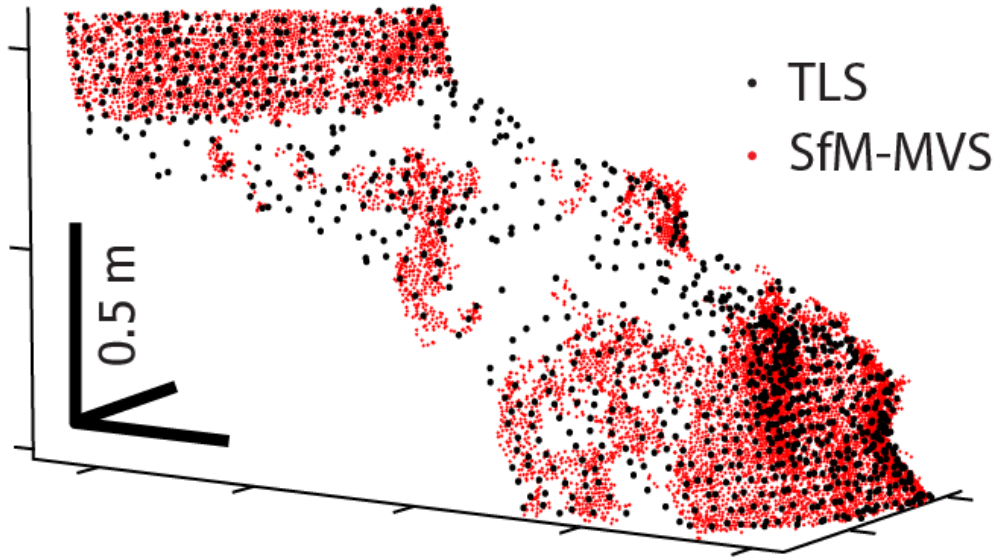


cliff surface gridded in a vertical cylindrical coordinate system

Regions of large apparent error

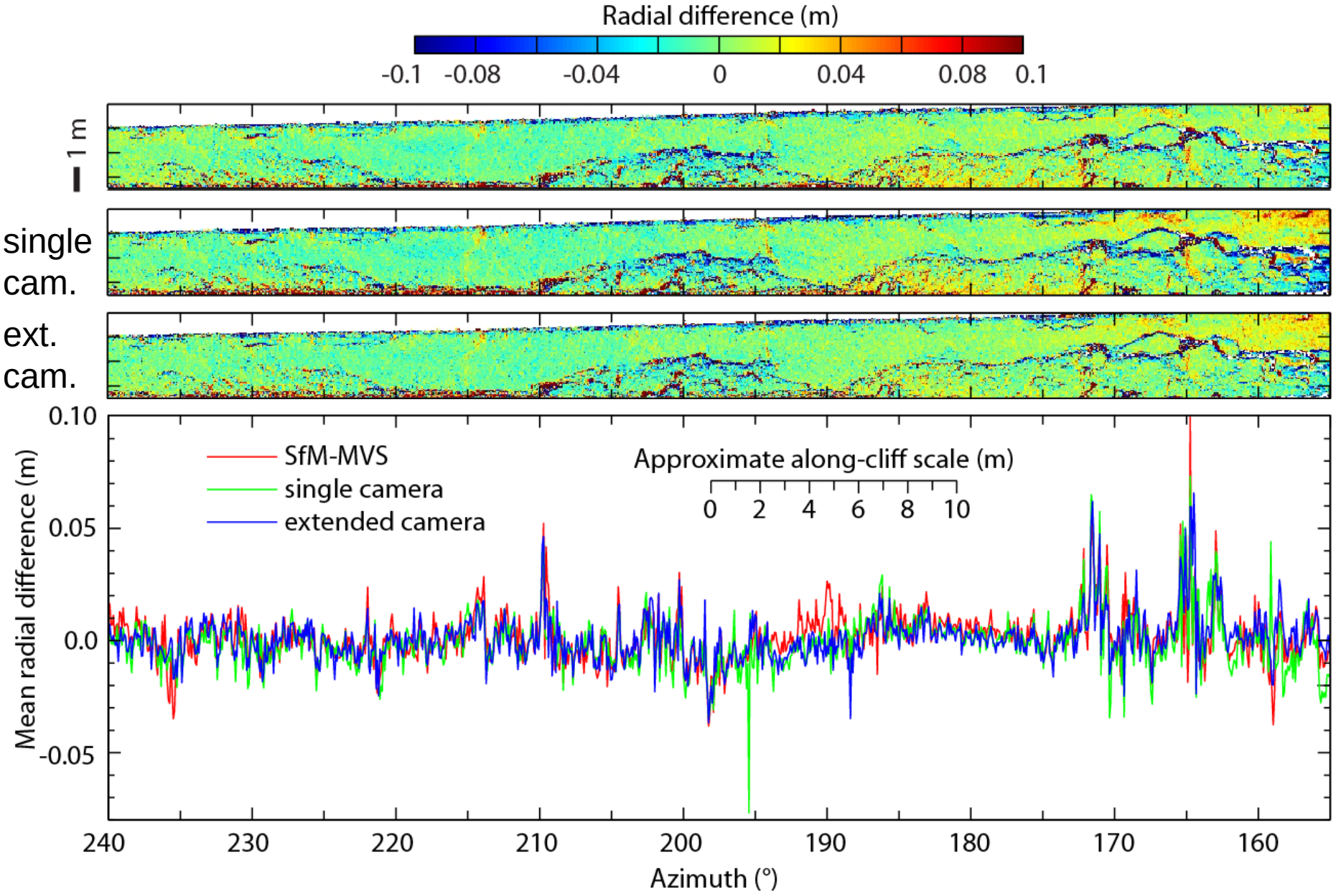


- regions of oblique surface

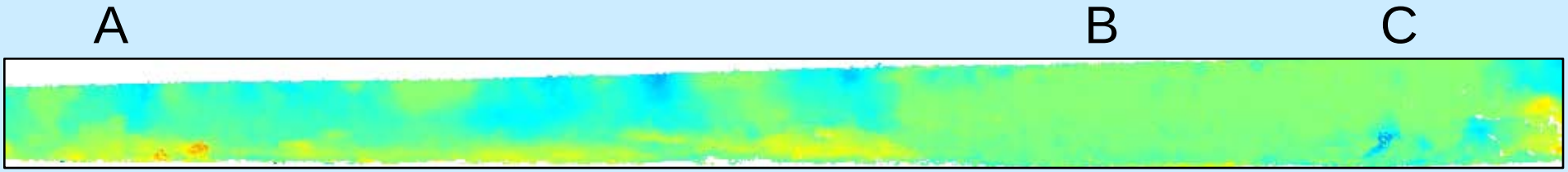


- different techniques give different coverage

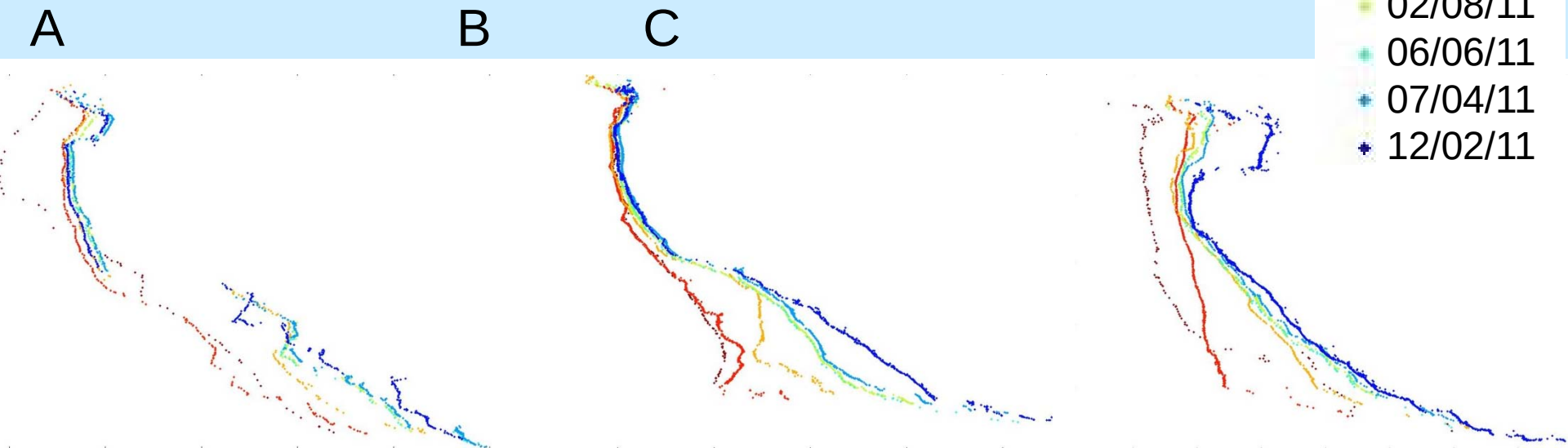
Reprocessing camera models



Erosion rates at Sunderland Point



Sections:



Conclusions

- SfM-MVS can offer advantages over other techniques for topographic measurement
- precision is limited by straightforward camera model
- with digital SLRs, precisions of ~1:1000 can be achieved
  - mm over viewing distances of m
  - cm over viewing distances of 10’s m