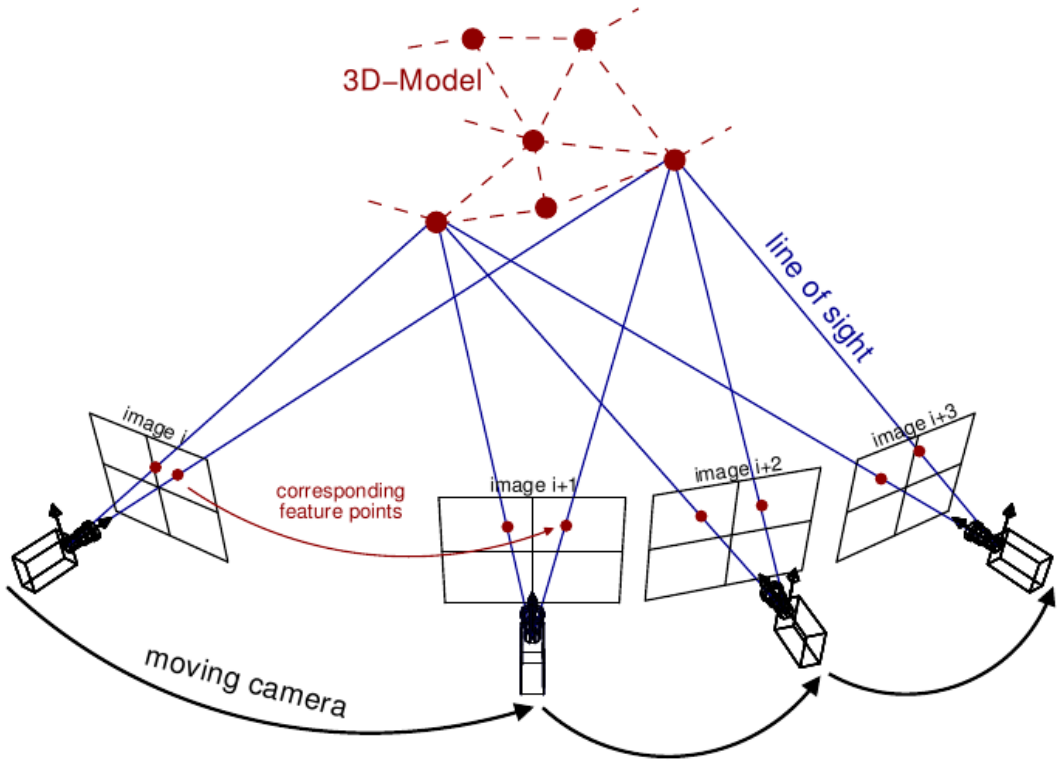
Structure from Motion



- Solves for the scene **structure** using photographs from a **moving** camera
- "Structure" = positions and orientations of camera + positions of targets
- Can also solve for camera parameters like focal length, lens distortion

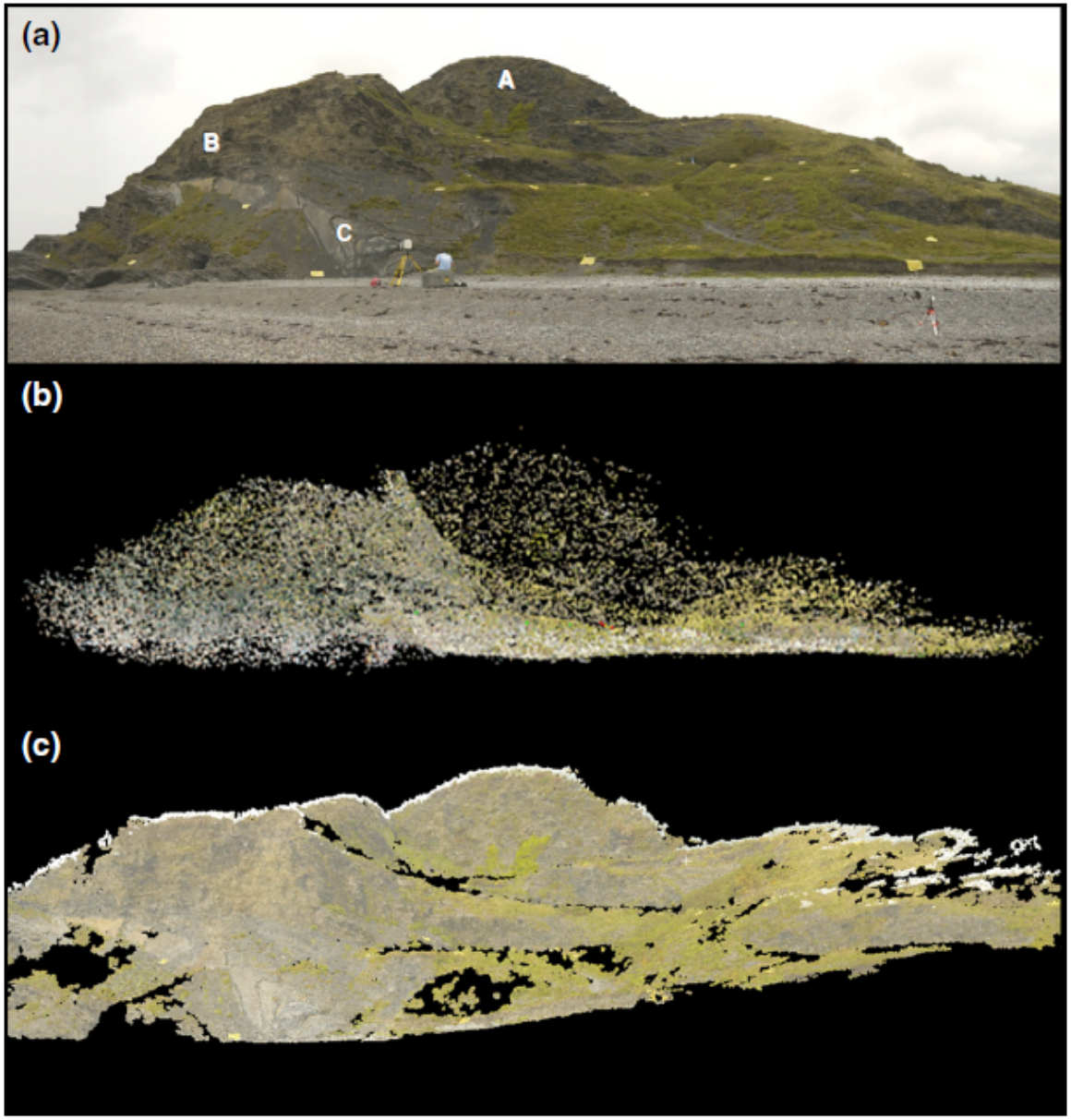
Kinetic depth effect

The three-dimensional shape of an object can be perceived when the object is moving relative to the observer

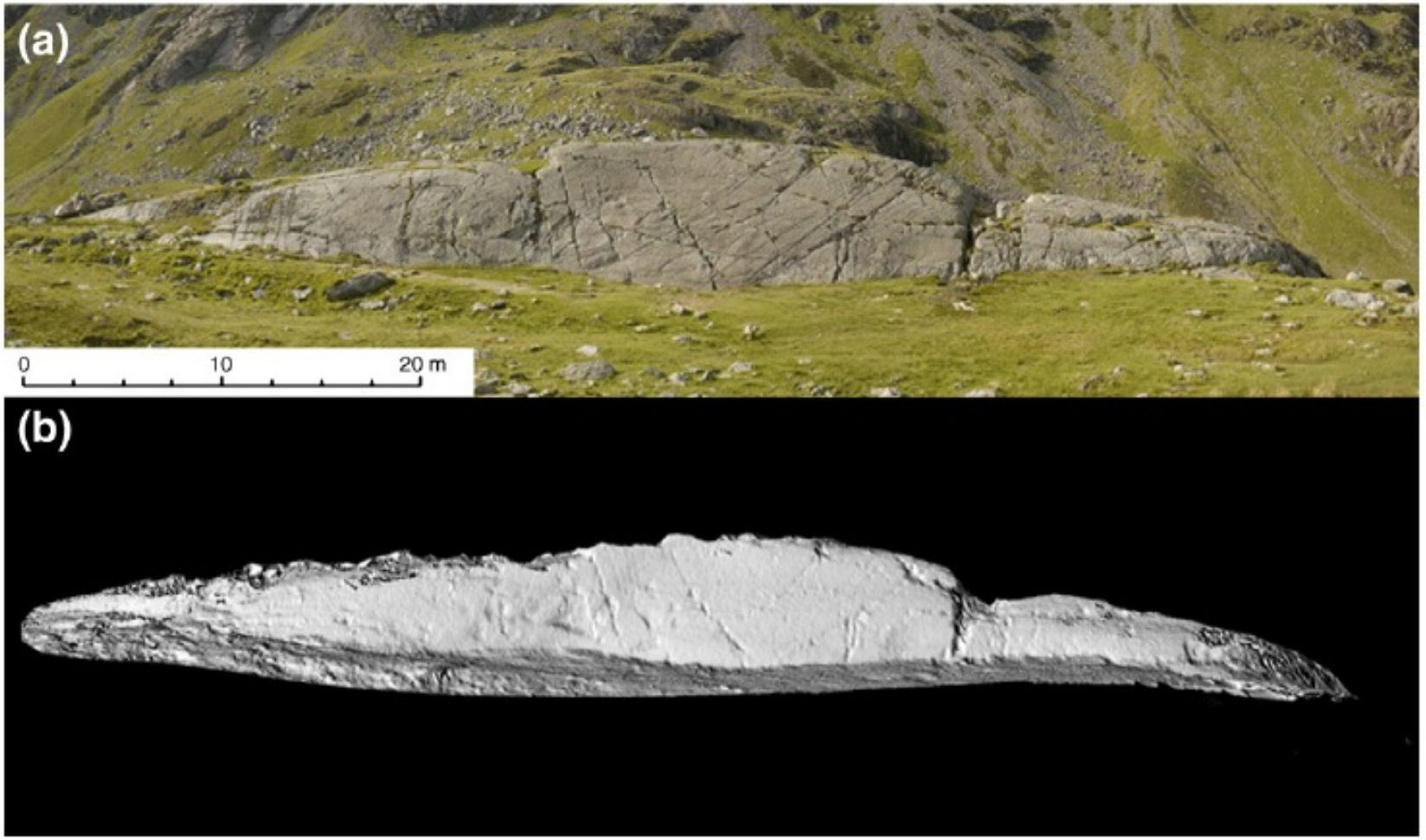
Objects further apart from the observer appear to move more slowly than those that are closer.

Snavely et al. (2007). Modeling the World from Internet Photo Collections, *International Journal of Computer Vision*

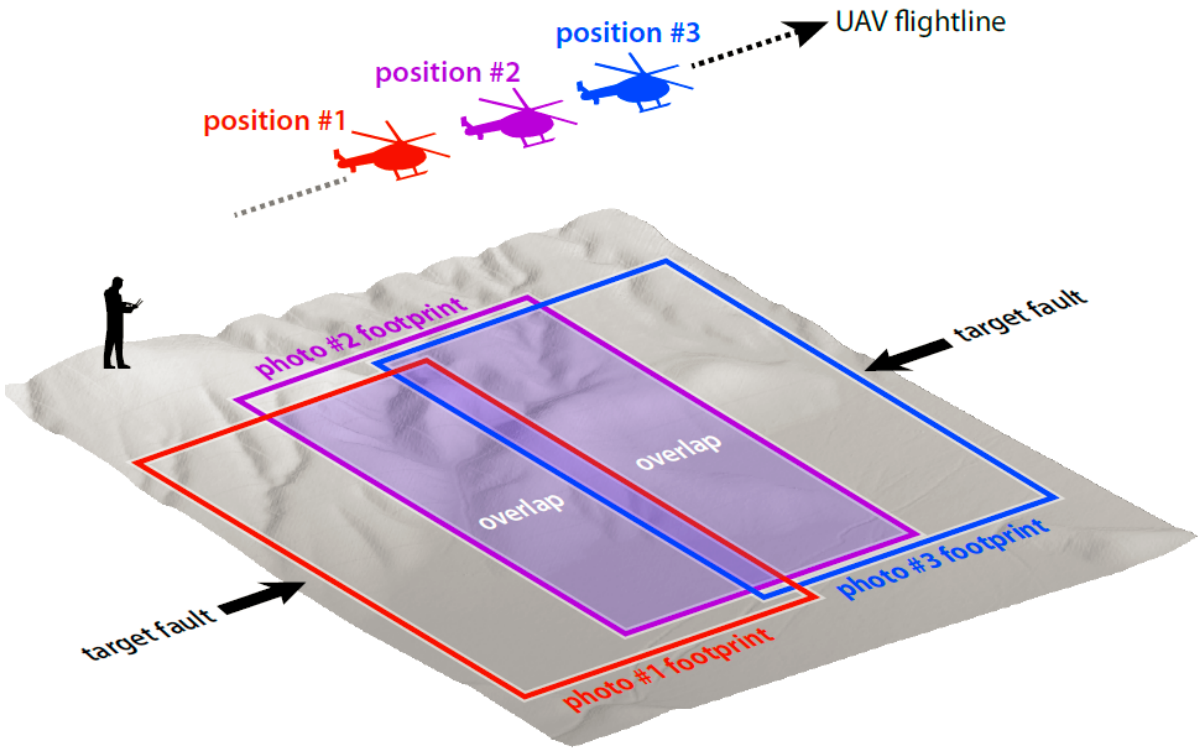
- Development of **Scale Invariant Feature Transform** (Lowe, 1999)
- Allows common features to be detected even with extreme variations in scale (and viewpoint
- Even works under conditions of partial occlusion and changing illumination
- Improvement on photogrammetry: unordered image aquisition



Westoby et al. (2012). ‘Structure-from-Motion’ photogrammetry: A low-cost, effective tool for geoscience applications, *Geomorphology*



Westoby et al. (2012). ‘Structure-from-Motion’ photogrammetry: A low-cost, effective tool for geoscience applications, *Geomorphology*



Structure from Motion using cheap airborne platforms

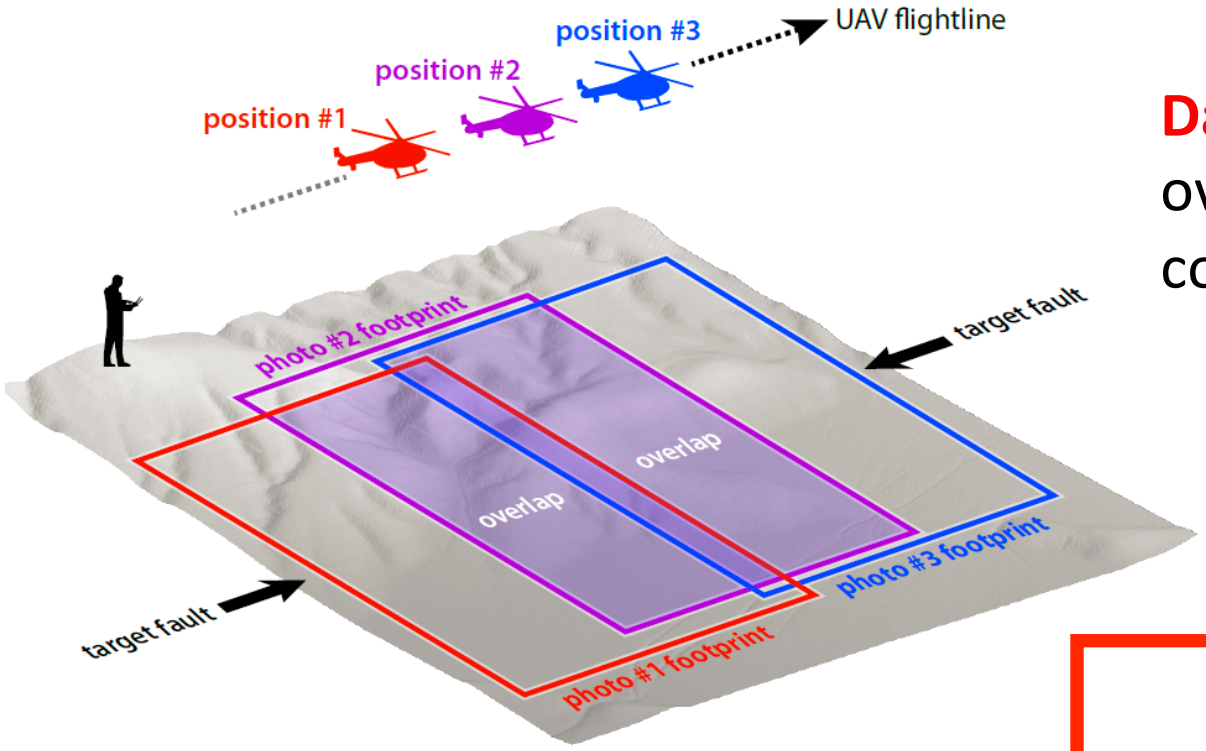
Kendra Johnson, Ed Nissen (Colorado School of Mines)

Ramon Arrowsmith, Sri Saripalli, Emily Kleber, Barrett Salisbury (ASU)

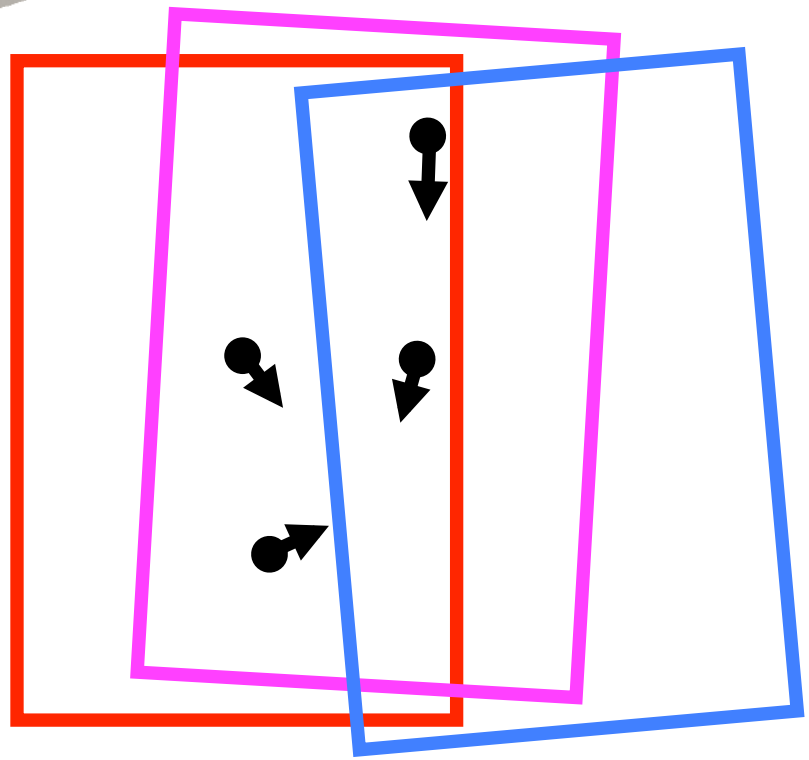
Kate Scharer (USGS), Patrick Williams (SDSU)

SCEC

an NSF + USGS center



Data collection Acquire overlapping photographs covering target area



Processing Identify points which are the same, see how they have moved in the picture overlap, and build topography

SfM Workflow

Aerial platform	Cost, Payload, Flight time, Ease of deployment and navigation, Robustness to conditions
Camera	Internal GPS, Weight vs Image quality
Survey set-up	Flight path, Platform height, Ground Control Points
Build point cloud	Choice of software package, Cost vs Ease of use, Point density and precision
Derivative products	Digital Elevation Model, Orthophoto

SfM Workflow

Aerial platform

Pros once in the air, can follow pre-set flight path. Robust in high wind and can take off and land anywhere. Can carry large SLR camera

Cons needs trained pilot to take-off and land. Needs regular refuelling. Initial costs are high and requires careful maintenance. FAA regulations must be followed.

SfM Workflow

Aerial platform

Pros easy to self- launch and to pilot. Can cope in moderately windy conditions.

Cons can only carry small cameras and is susceptible to damage during landing. Batteries need frequent replacing/recharging.

SfM Workflow

Aerial platform

Pros can be deployed at a >100m providing wider field of view. Easy to drag across target area. Can carry quite large cameras. Once in the air can remain there.

Cons difficult to control even in light breezes and impossible in windy conditions.

SfM Workflow

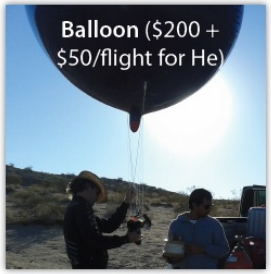
Aerial platform

Pros can be deployed at a >100m providing wider field of view. Easy to drag across target area. Can carry quite large cameras. Once in the air can remain there. Robust in high wind.

Photos: Emily Kleber

SfM Workflow

Aerial platform



Camera Internal GPS, Weight vs Image quality

Survey set-up Flight path, Platform height, Ground Control Points

Build point cloud Choice of software package, Cost vs Ease of use

Derivative products Digital Elevation Model, Orthophoto

SfM Workflow

The camera should have one essential feature and one preferable one:

Essential Time lapse setting – remotely takes photo every *x* seconds

Preferable Internal or external GPS tagging

Camera

Internal GPS, Weight vs Image quality

+ve lightweight (300 g)

-ve SD card needs programming, occasionally turns off mid-flight

+ve high quality photos

-ve heavy (1 kg)

SfM Workflow

Aerial platform

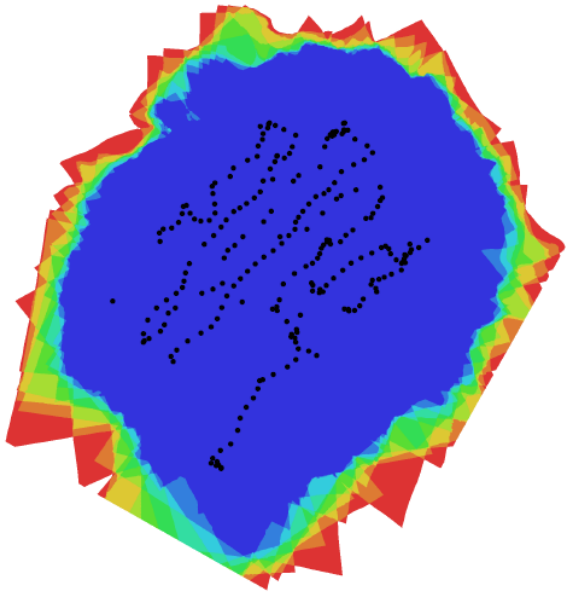
Camera

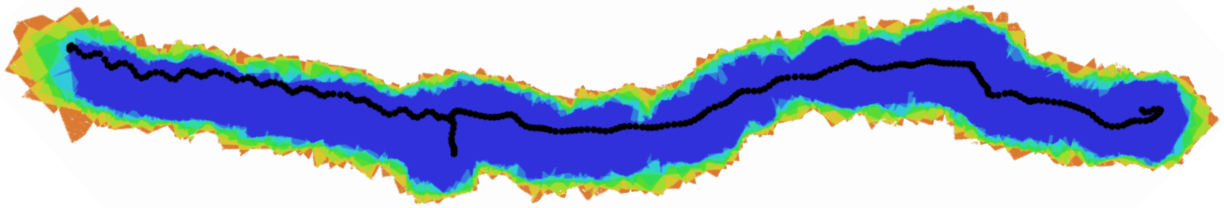
Survey set-up Flight path, Platform height, Ground Control Points

Build point cloud Choice of software package, Cost vs Ease of use

Derivative products Digital Elevation Model, Orthophoto

SfM Workflow



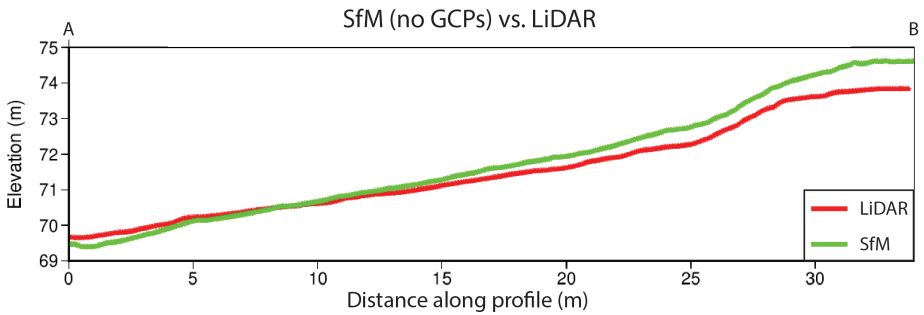


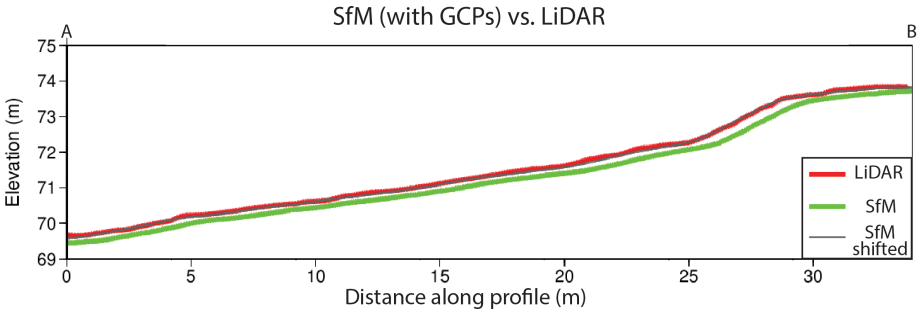
Top: Landers rupture, 1 km x 100 m dataset

Left: Washington fan, 300 m x 300 m dataset

Survey set-up

Flight path, Platform height, Ground Control Points



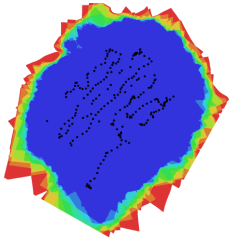


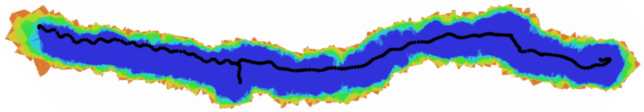
SfM Workflow

Aerial platform

Camera

Survey set-up





Build point cloud Choice of software package, Cost vs Ease of use

Derivative products Digital Elevation Model, Orthophoto

SfM Workflow

Free option

Bundler builds sparse point cloud

CMVS + PVMS2 builds dense point cloud

MATLAB georeferences point cloud with rigid body transformation + scale

Commercial option

Agisoft Photoscan Pro

costs $550 for academic licence

builds georeferenced point cloud using camera GPS stamps (+ optional GCPs)

Build point cloud

Choice of software package, Cost vs Ease of use

SfM Workflow

Commercial option

Agisoft Photoscan Pro

costs $550 for academic licence

builds georeferenced point cloud using camera GPS stamps (+ optional GCPs)

Dell Alienware PC, 32GB RAM, Nvidia GeForce GTX 670 = $3,000

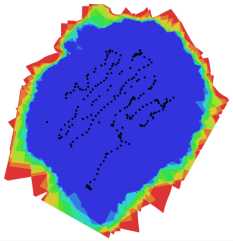
Build point cloud Choice of software package, Cost vs Ease of use

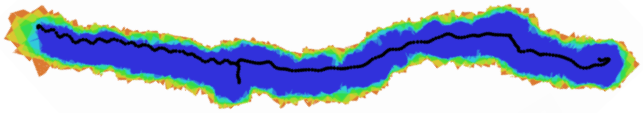
SfM Workflow

Aerial platform

Camera

Survey set-up





Build point cloud

Agisoft
3D Modeling and Mapping

Bundler+CMVS+ PVMS2+MATLAB+

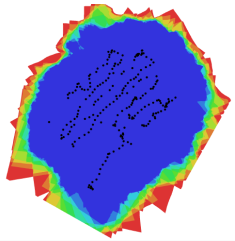
Derivative products Digital Elevation Model, Orthophoto

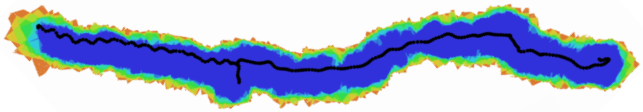
SfM Workflow

Aerial platform

Camera

Survey set-up





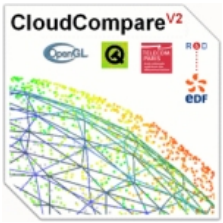
Build point cloud

Agisoft
3D Modeling and Mapping

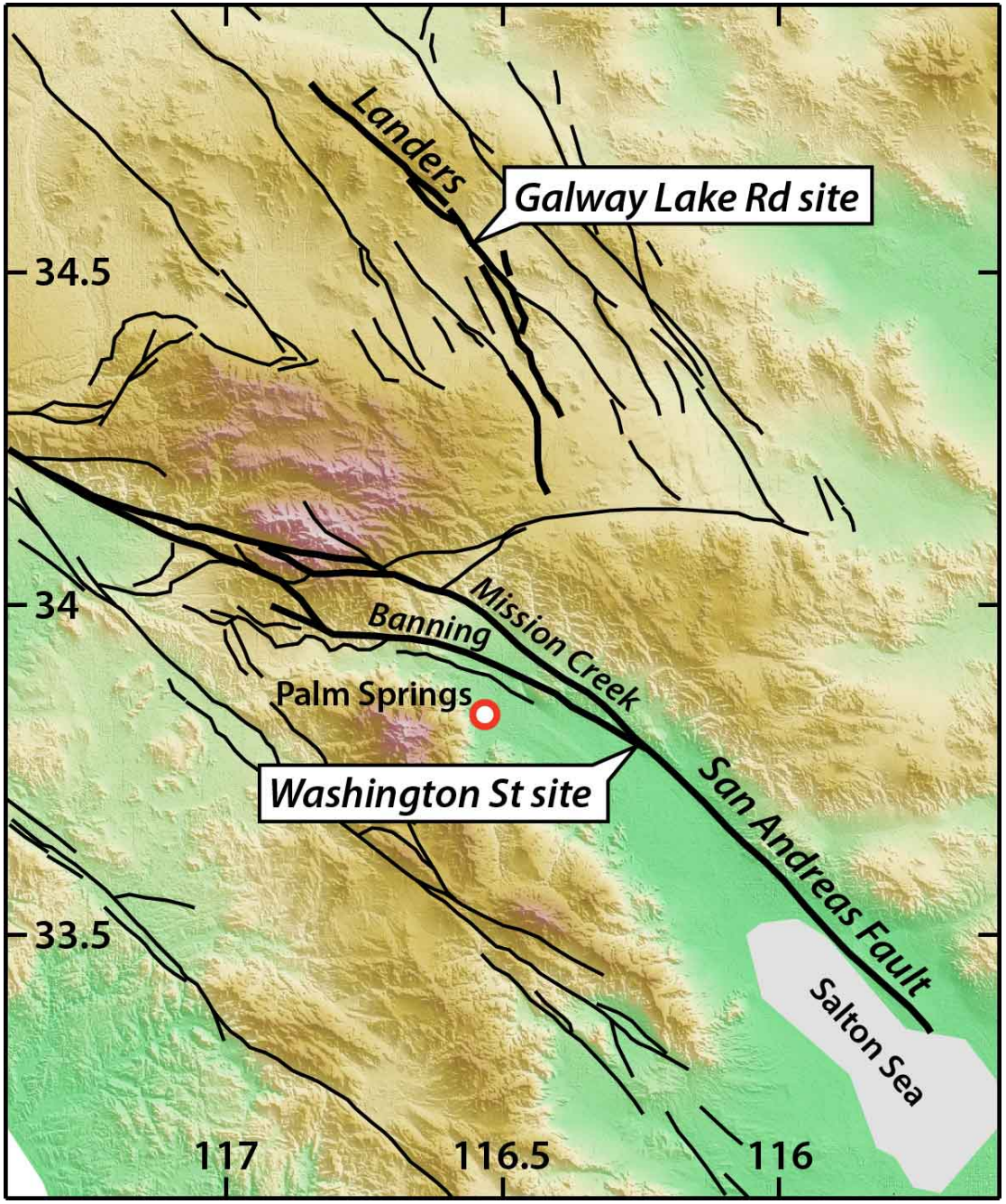
Bundler+CMVS+
PVMS2+MATLAB+

Derivative products

Agisoft
3D Modeling and Mapping



GEON



Galway Lake Rd site

Covers part of the 1992 Landers earthquake rutpure.

Here we are testing SfM's potential as a rapid response mapping tool (e.g. aftermath of an earthquake).

Existing TLS dataset

Washington St site

Argument over which of two SAF strands is active.

Small meter-scale streams offsets >> slip in last event

Larger alluvial fan offsets >> long term slip rates

Existing airborne LiDAR data

230 photos taken in about one hour

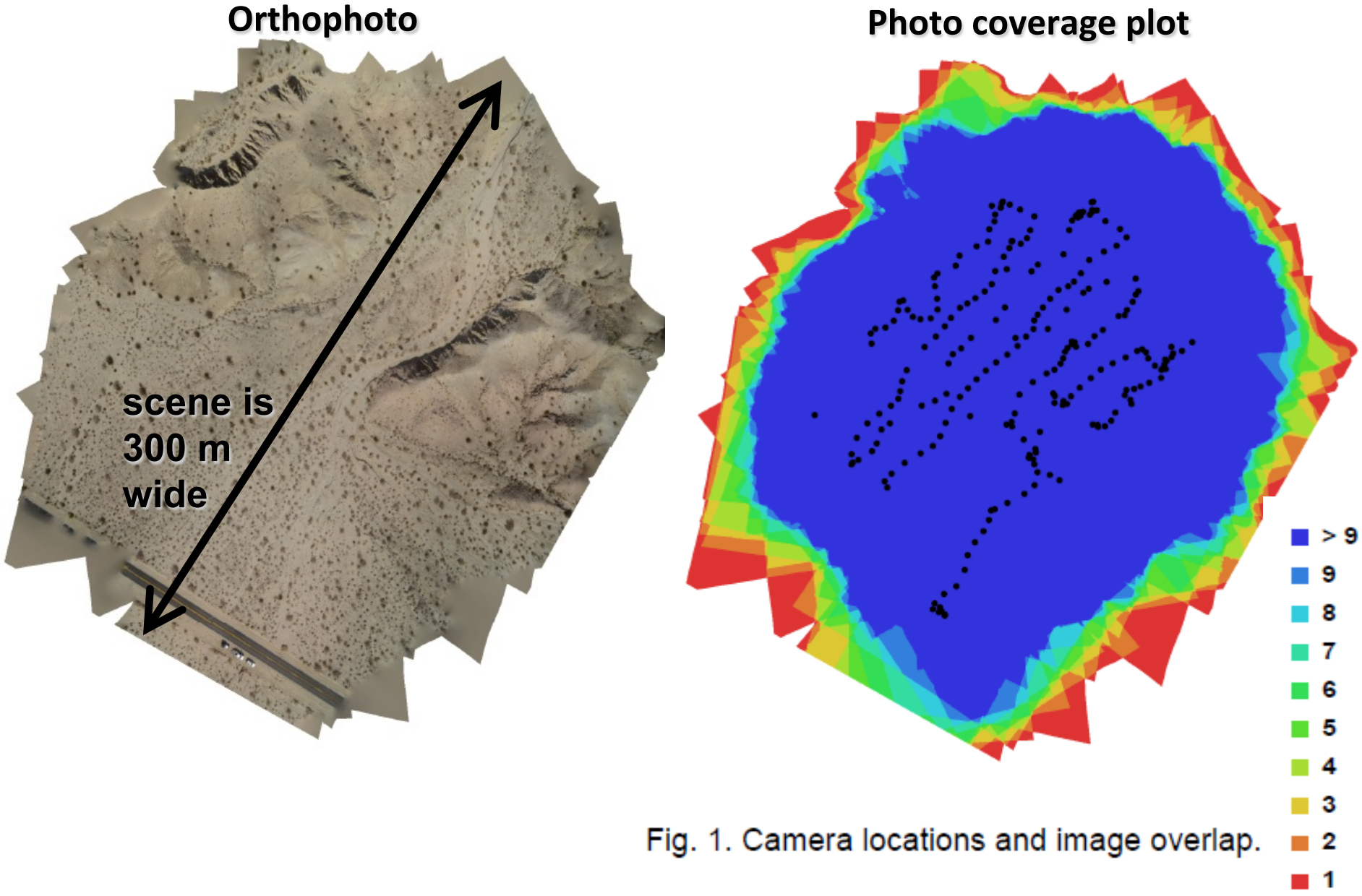
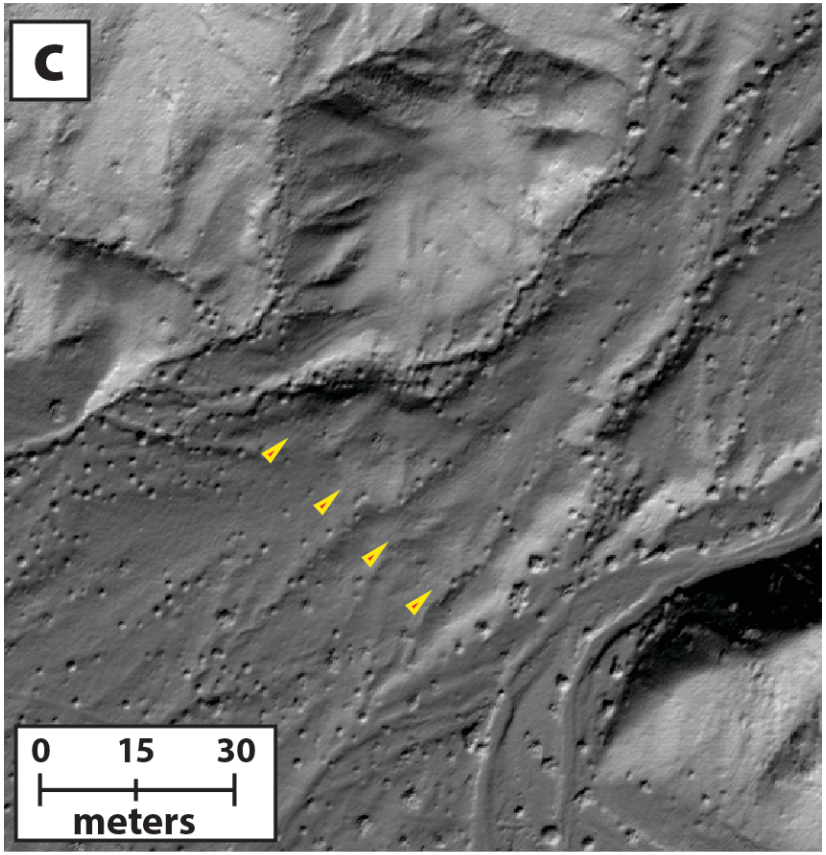
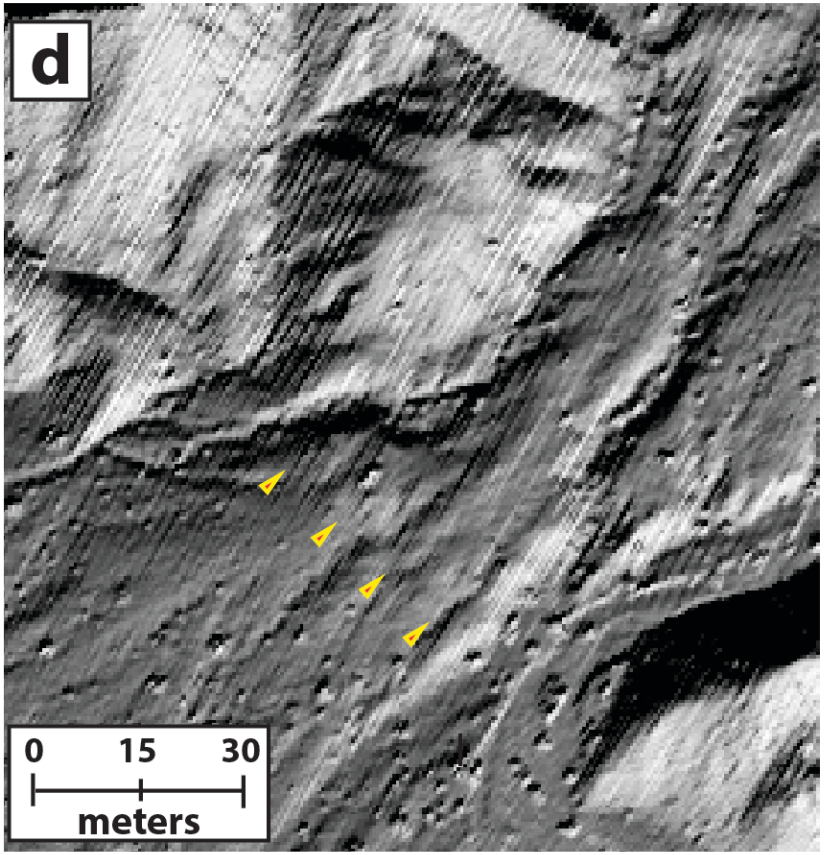


Fig. 1. Camera locations and image overlap.

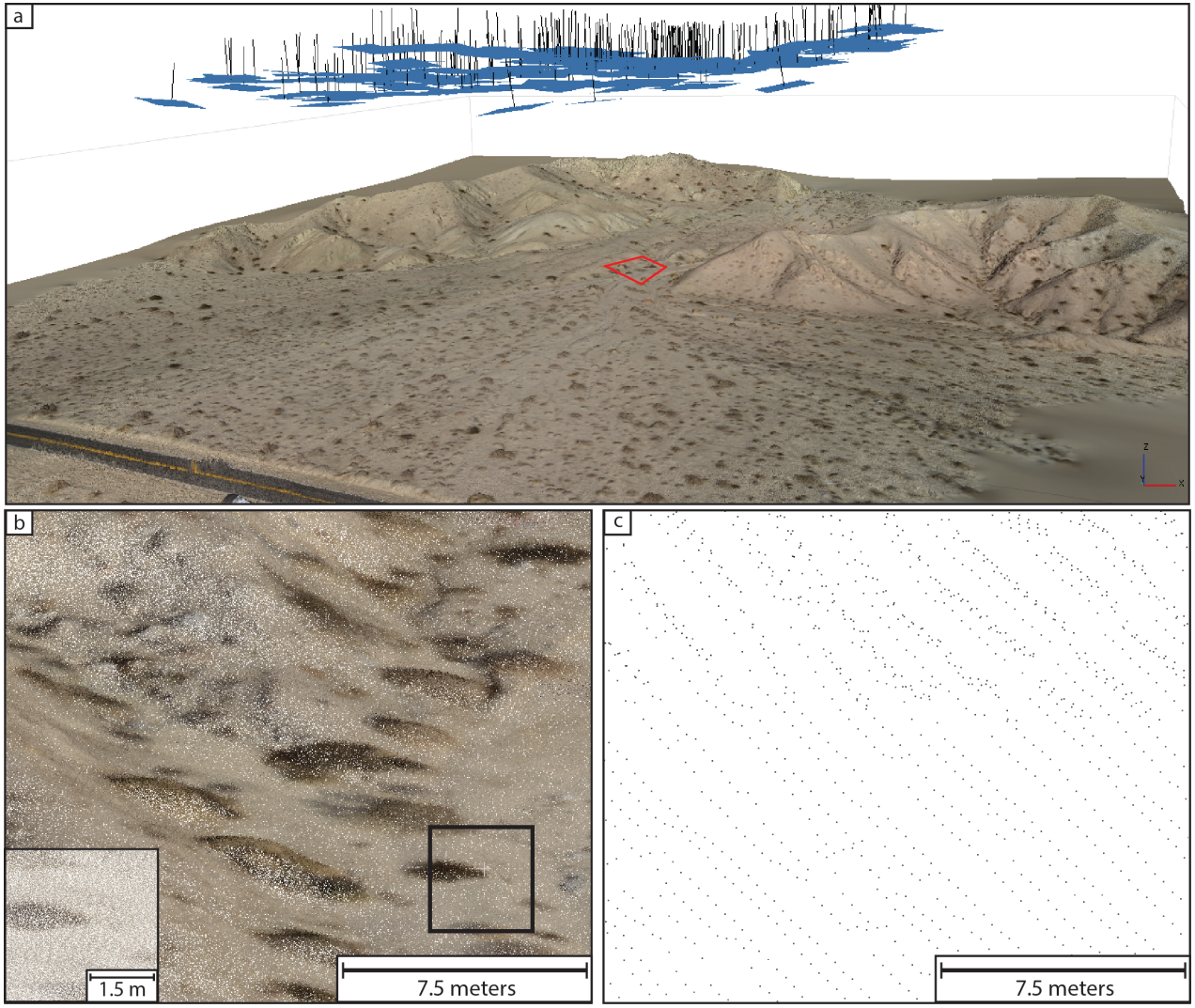




SfM 5 cm resolution DEM

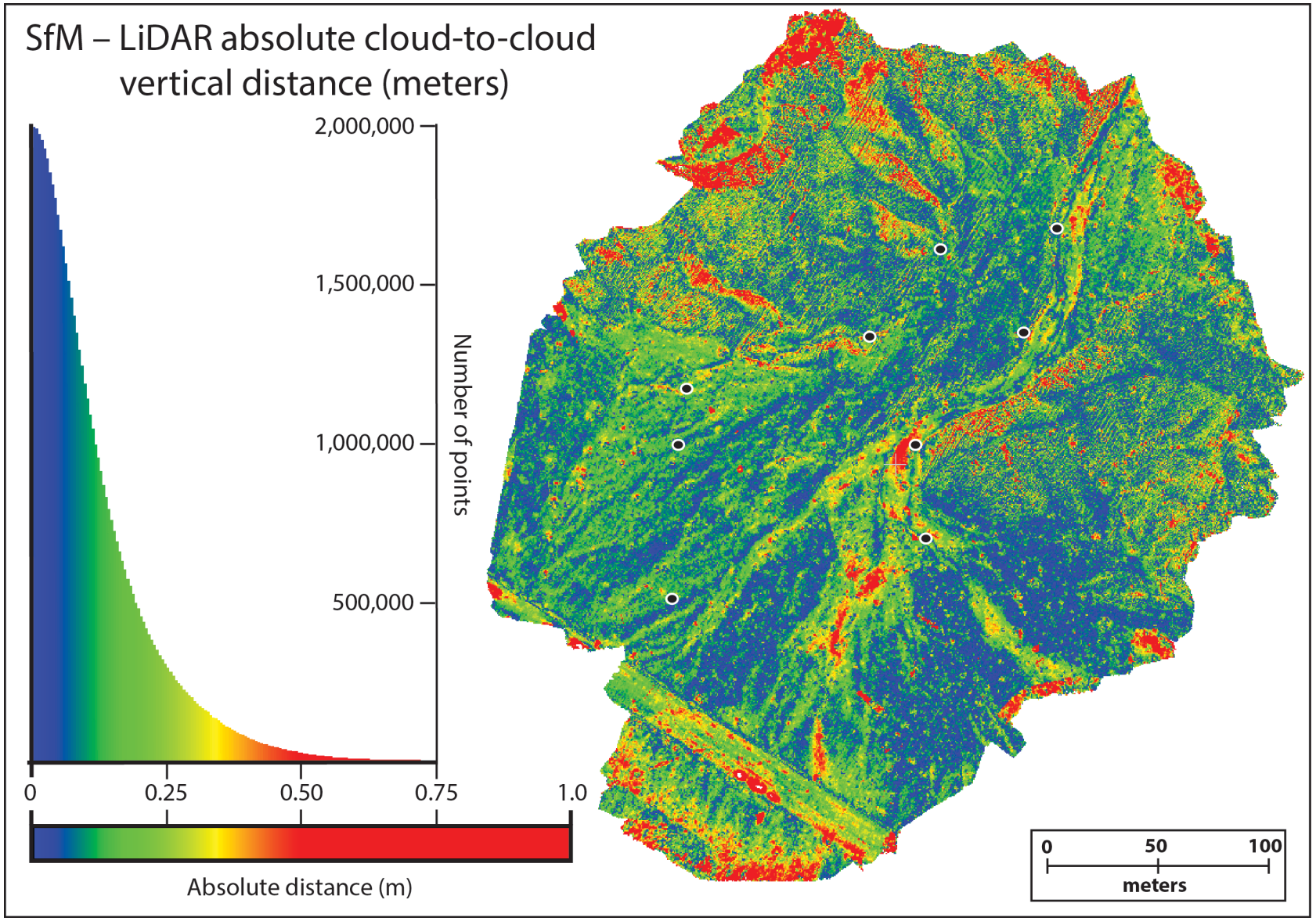
B4 LiDAR 0.5 - 1 m resolution

Kendra Johnson et al., *in prep.*

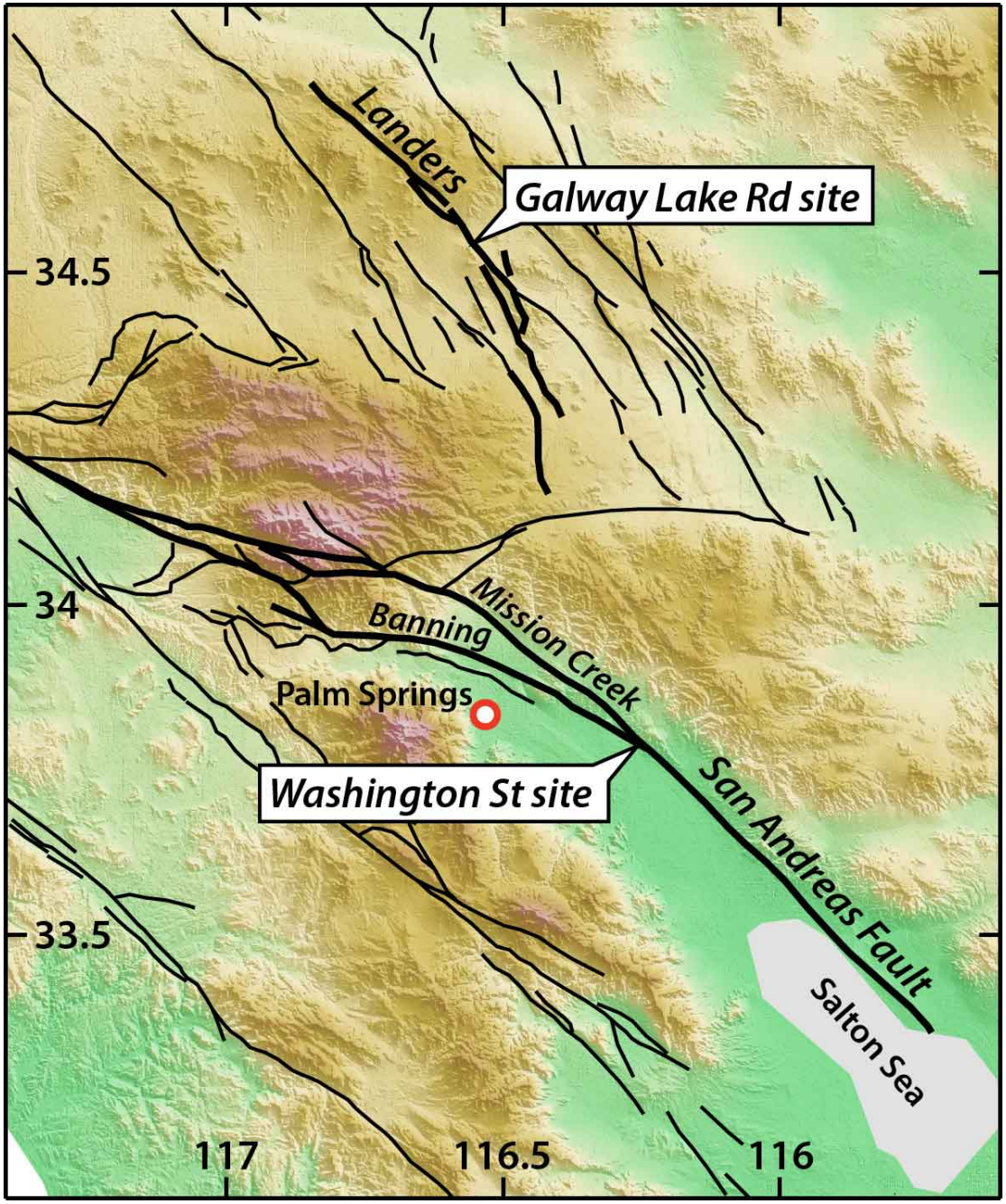


SfM 700 pts/m^2 **B4 LiDAR** 4 pts/m^2

Kendra Johnson et al., *in prep.*



Kendra Johnson et al., *in prep.*


Landers
Galway Lake Rd site
34.5
34
Banning
Mission Creek
Palm Springs
Washington St site
San Andreas Fault
33.5
Salton Sea
117
116.5
116

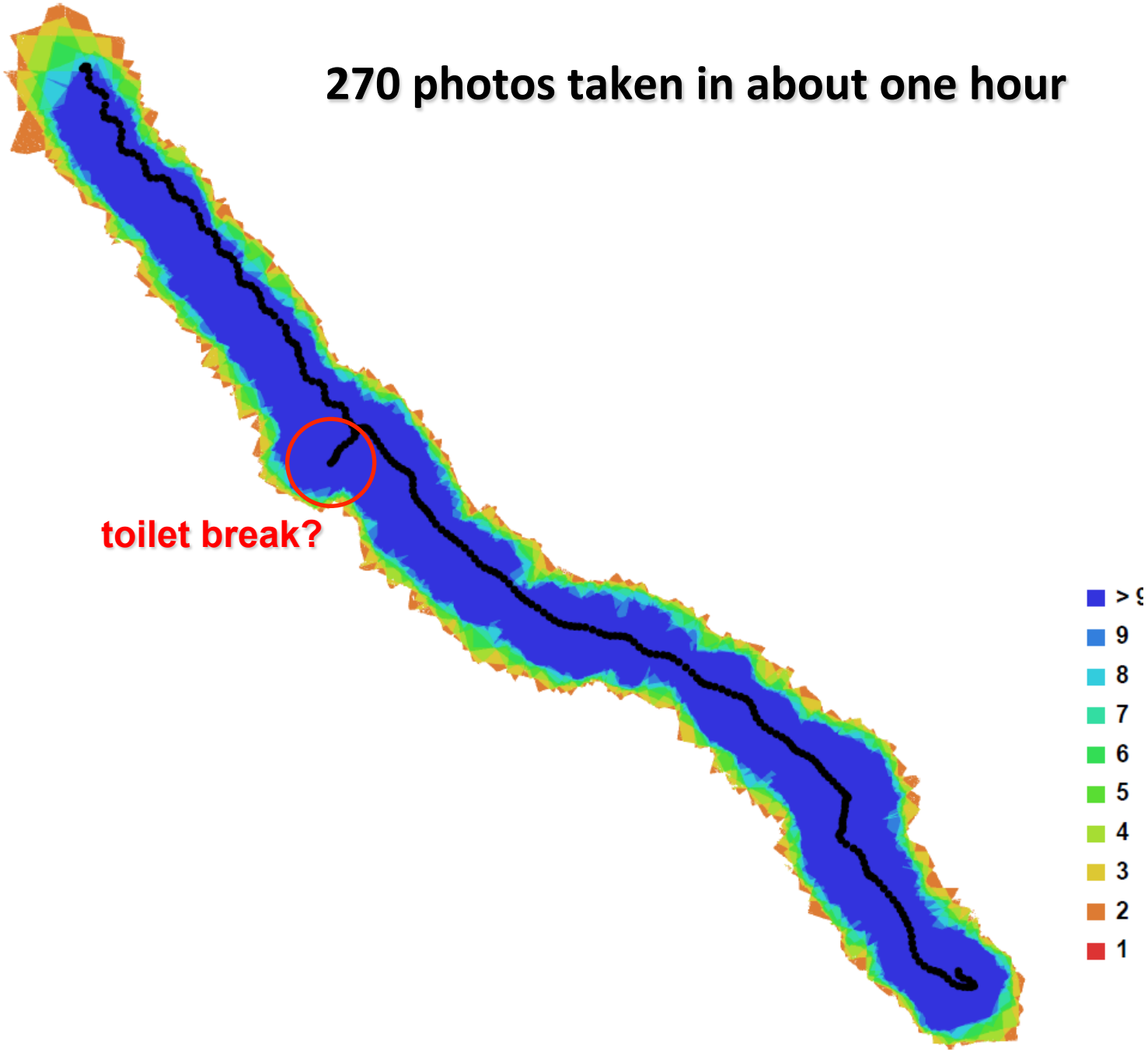
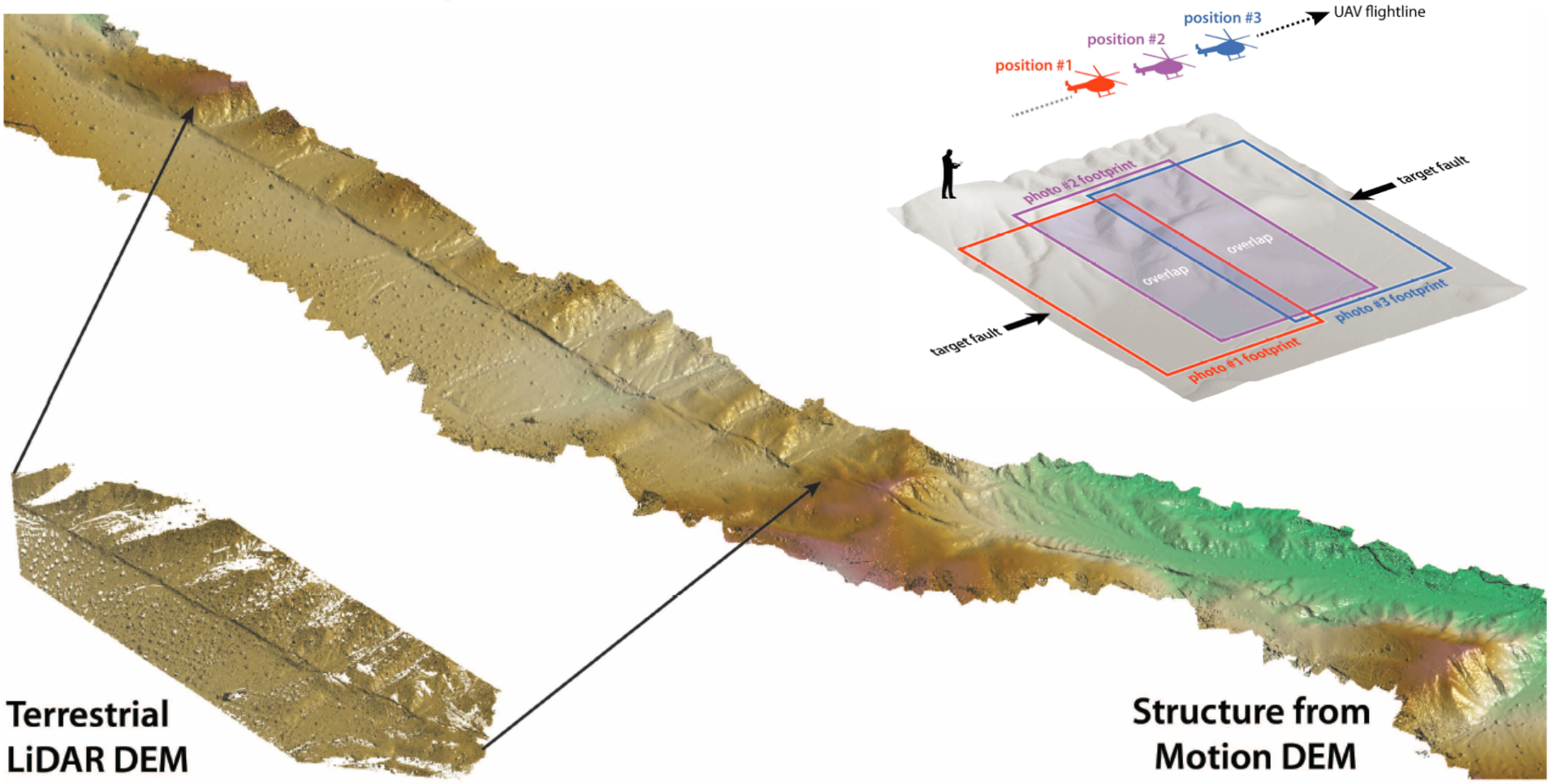


Fig. 1. Camera locations and image overlap.

270 photos taken in about one hour



TLS data took two days to collect