SfM Acquisition Concepts & Applications

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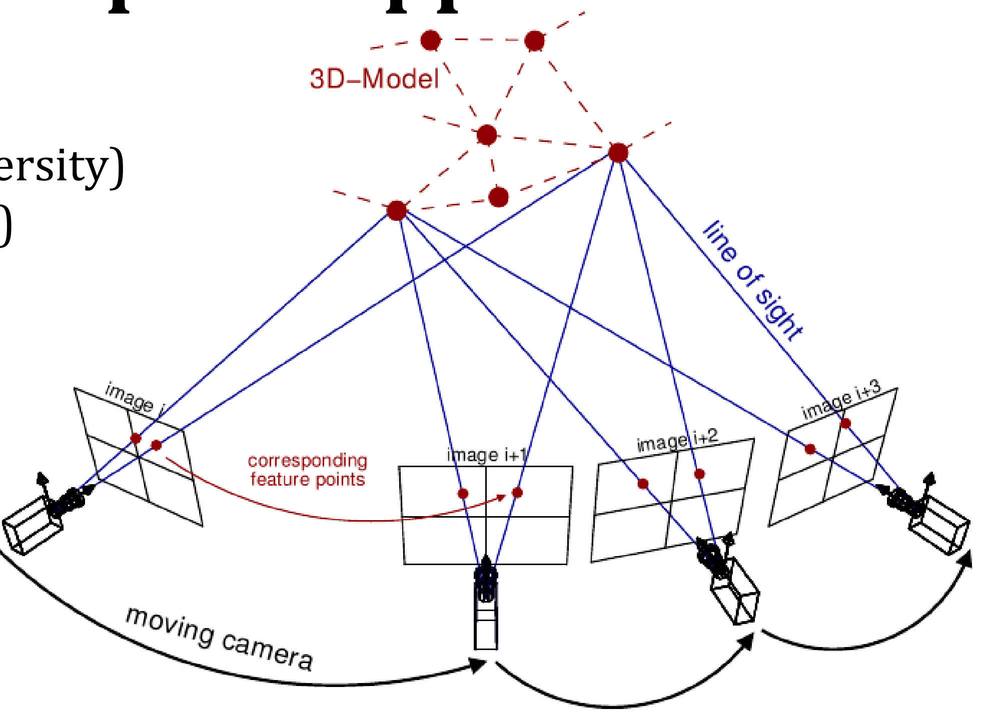


- **Choice of platform**
- **Survey acquisition strategies**
- **Examples of applications**

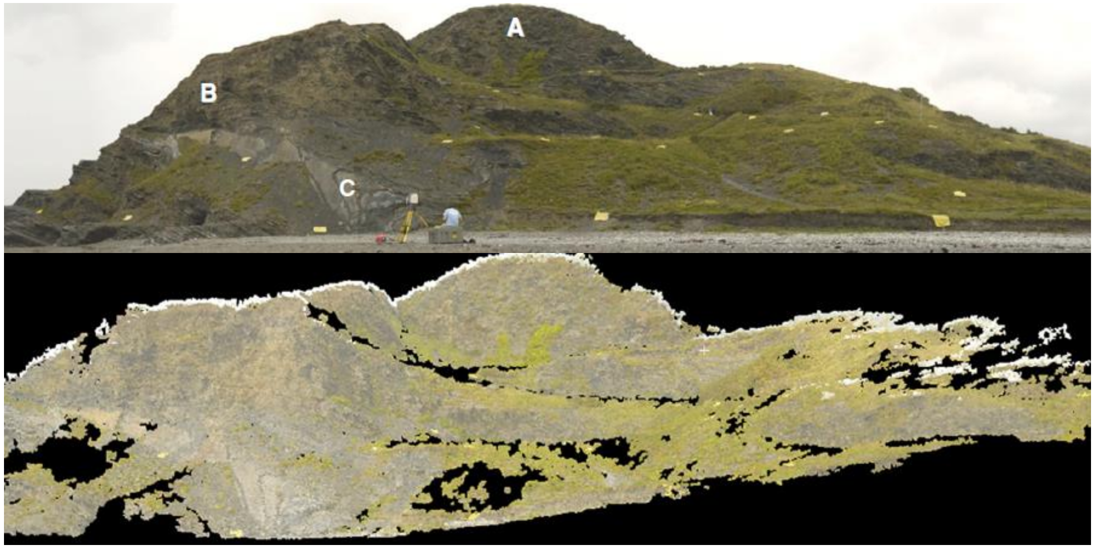
~500 points/m^2 coloured point cloud along a ~1 km section of the 2010 El Mayor-Cucapah earthquake rupture generated from ~500 photographs captured in 2 hours from a helium blimp

SfM from ground-based photographs…
Where it all started

Snavely *et al.* (2006). Photo Tourism: Exploring Photo Collections in 3D, *ACM Transactions on Graphics*

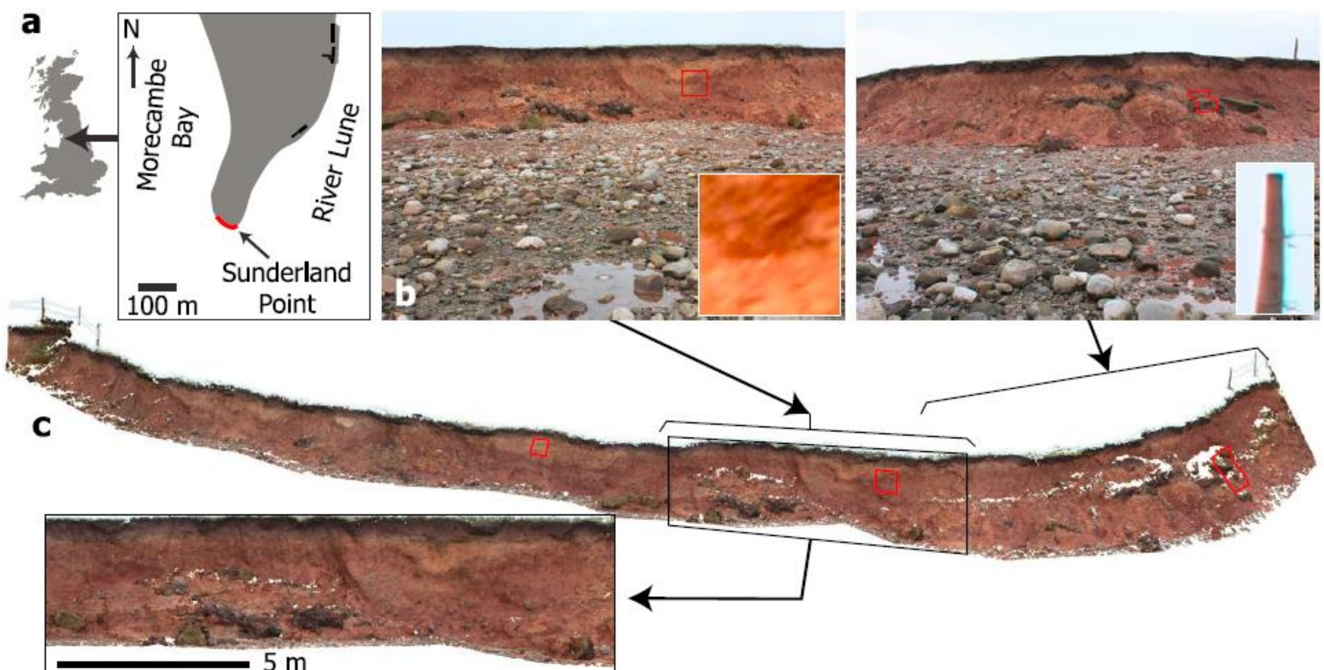
Snavely *et al.* (2007). Modeling the World from Internet Photo Collections, *International Journal of Computer Vision*

SfM from ground-based photographs
First geoscience applications

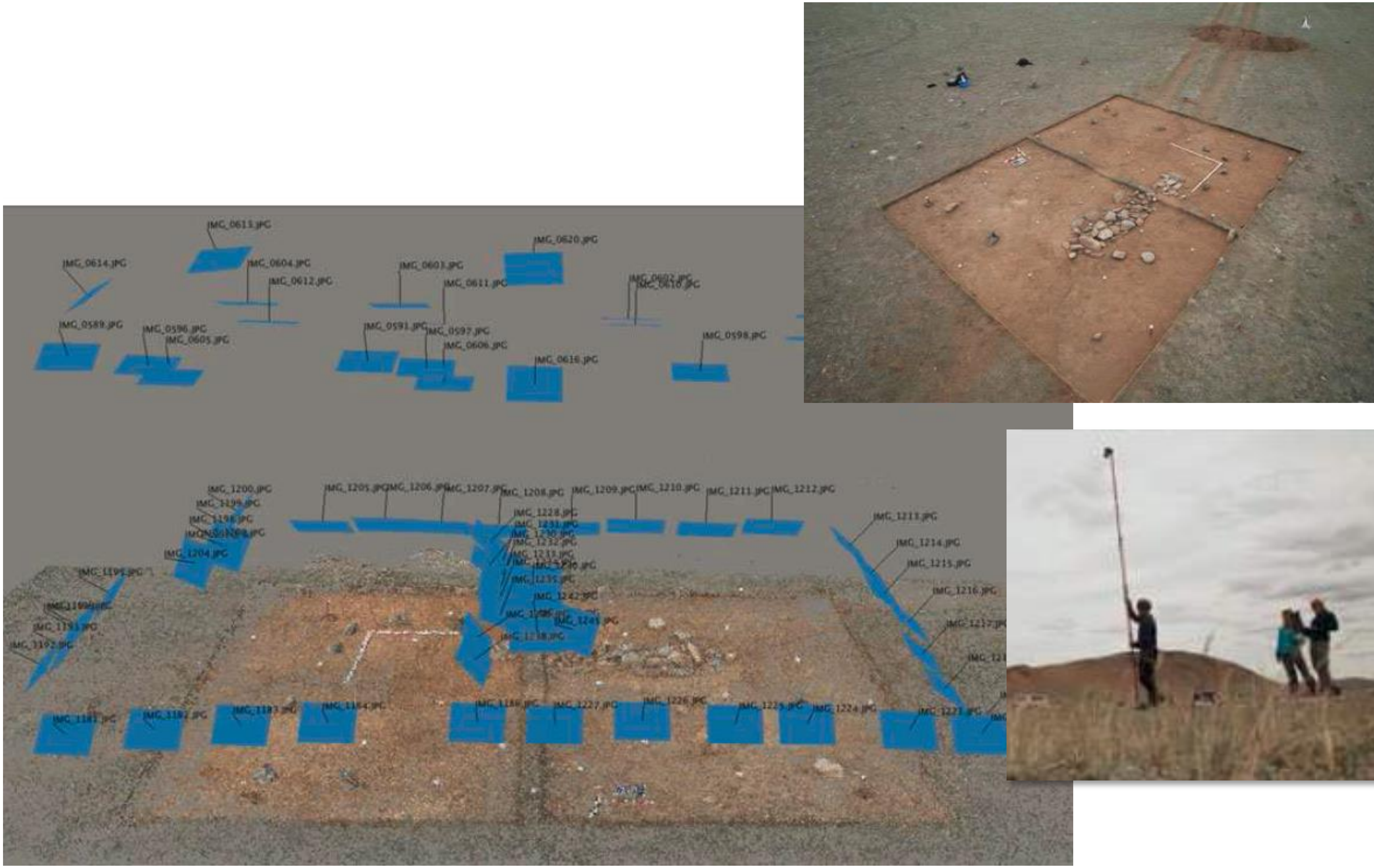


Left. Westoby *et al.* (2012). Structure-from-Motion photogrammetry: A low-cost, effective tool for geoscience applications. *Geomorphology*

Right. James & Robson (2012). Straightforward reconstruction of 3D surfaces and topography with a camera: Accuracy and geoscience application. *Journal of Geophysical Research*



SfM from ground-based photographs



Plets *et al.* (2012). Three-dimensional recording of archaeological remains in the Altai mountains, *Cambridge Univ. Press*

SfM from Unmanned Aerial Vehicles (UAV)


DJI Phantom 2 quadcopter (~$1k)


Custom built helicopter (~$15k)


Autokite (~$1k, discontinued)

Falcon Unmanned fixed wing (~$12k)

SfM from helicopters and multi-rotor UAVs


DJI Phantom 2 quadcopter (~$1k)


Custom built helicopter (~$15k)

Pros Robust in high wind and can take off and land anywhere. Larger helicopters can carry large SLR camera. Smaller multi-rotors cannot, but are easier to fly.

Cons Helicopter needs trained pilot to take-off and land and regular refuelling. Initial costs are high and requires careful maintenance.

Regulations may need to be followed (FAA in the U.S.)

SfM from fixed wing UAVs

Pros Relatively easy to pilot. Can cope in moderate winds. Flight durations are normally longer than copters.

Cons Susceptible to damage during landing.

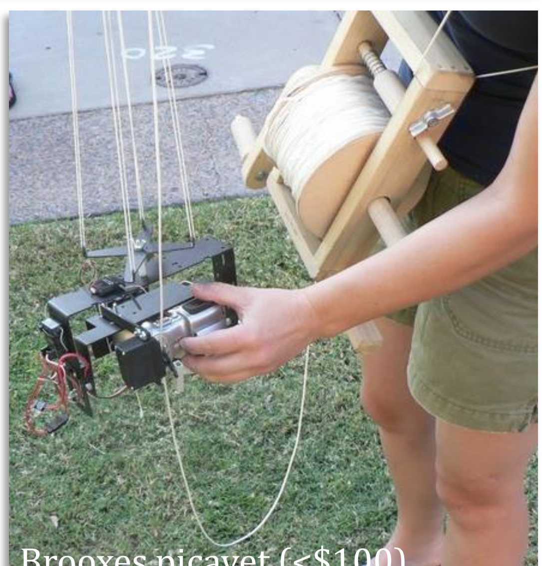
Regulations may need to be followed (FAA in the U.S.)

Autokite (~$1k, discontinued)

Falcon Unmanned fixed wing (~$12k)

SfM from Unmanned Aerial Systems (UAS)

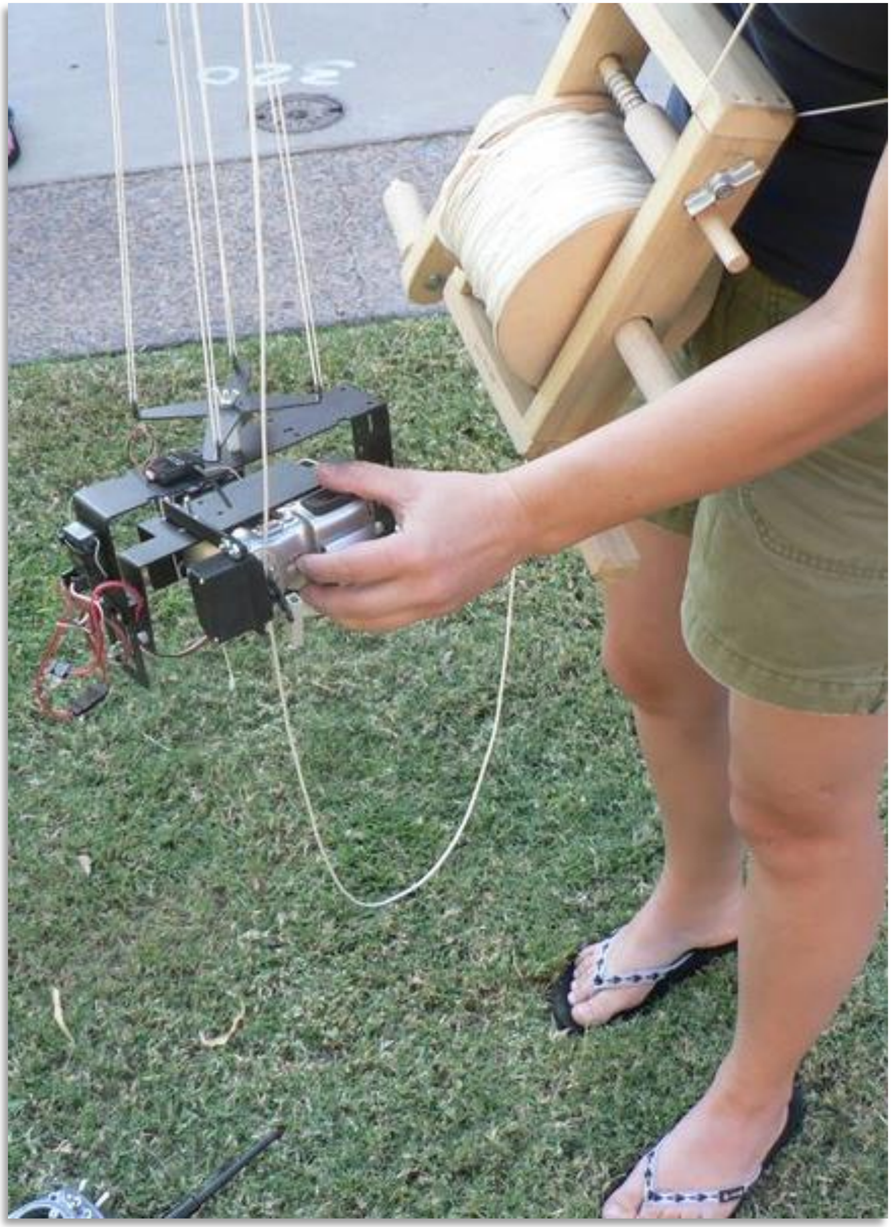
Allsopp helikite (~$2k)



Brooxes picavet (<$100)

Ramon’s balloon (~$100s)

SfM from Unmanned Aerial Systems (UAS)



Pros Easy to drag across target area. Once in the air can remain there. Can carry large SLR cameras. No FAA regulations!

Cons Requires helium, which can be expensive (>$100 per canister), and fiddly picavet. Cannot be automated. Difficult to deploy in windy conditions.

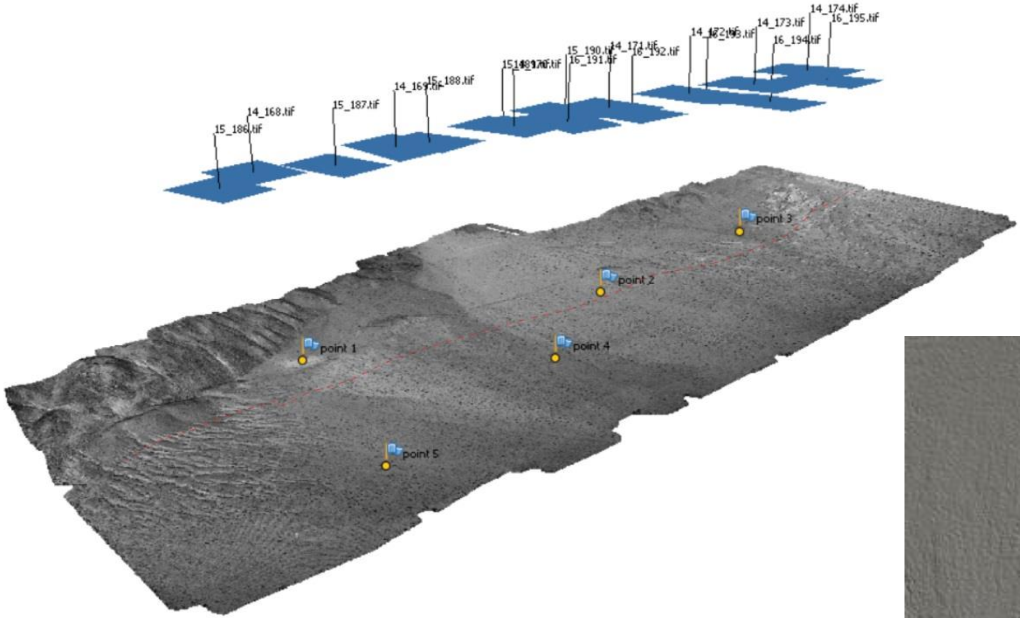
SfM from Unmanned Aerial Systems (UAS)

Pros Easy to drag across target area. Once in the air can remain there. Robust in high wind. No FAA regulations!

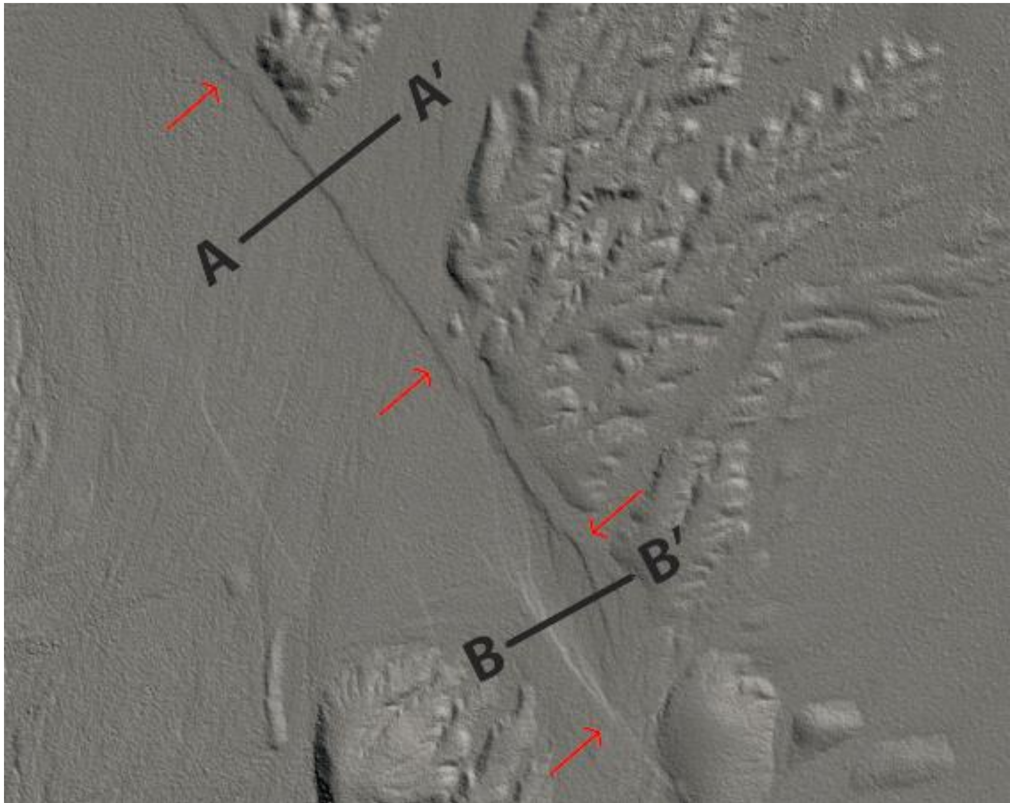
Cons Requires helium, which can be expensive (>$100 per canister). Cannot be automated. Carries small cameras.

SfM from airplane photos

• "Historical topography" and "diachronic geomorphology" possible using legacy air-photos. Requires sufficient photo overlap and georeferencing is a challenge.



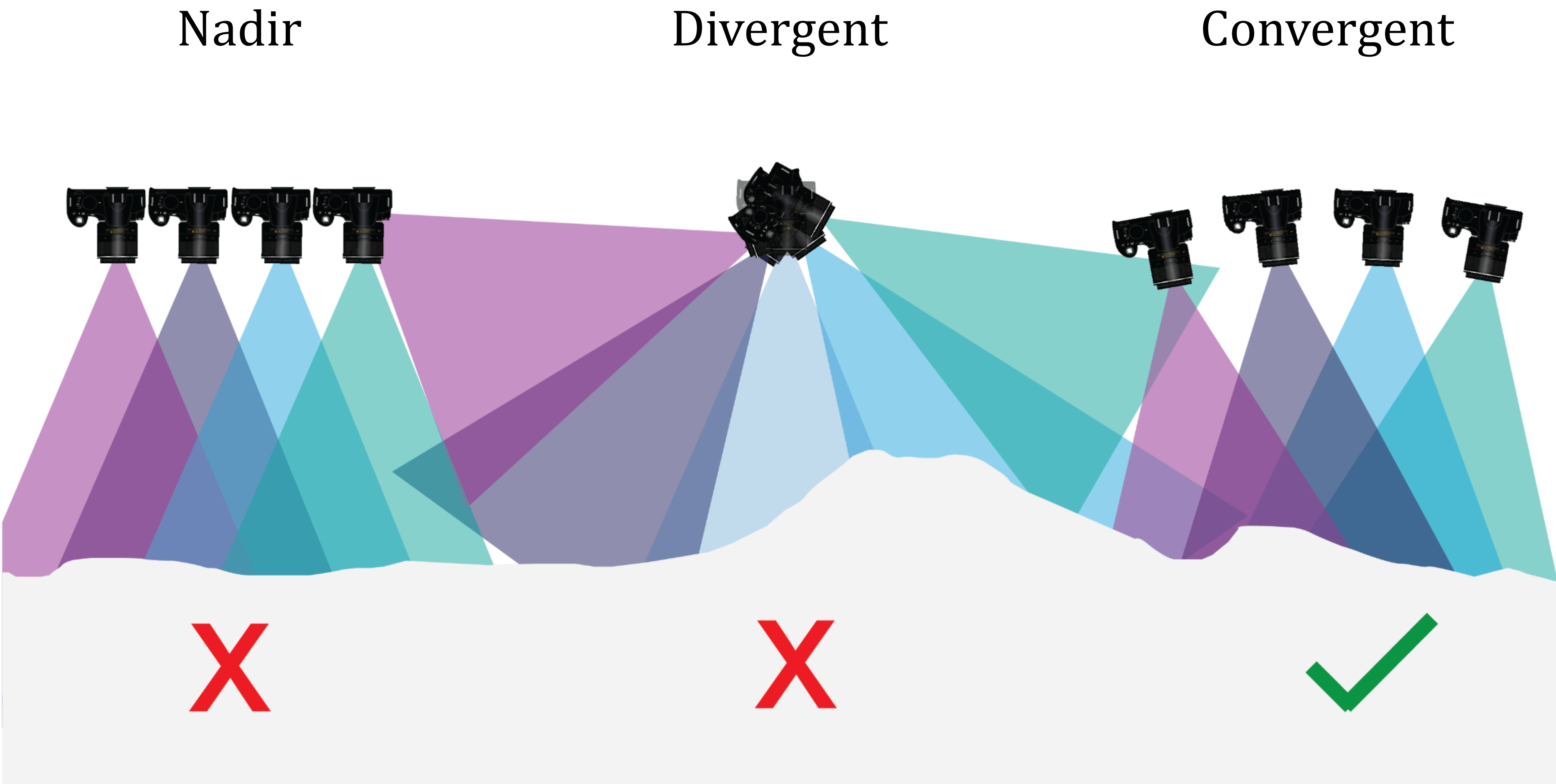
(Left) A short section of the ~85 km-long USGS aerial survey of the 1992 Landers rupture, California.



(Right) Resulting 30 cm-resolution DEM, hillshaded to highlight fine geomorphic features.

Georeferencing was undertaken using modern satellite imagery

Acquisition geometry



Acquisition geometry

Convergent with a range of distances

Choice of camera

- Most cameras work
- DEM/orthophoto resolution is governed by the ground pixel resolution of the raw photos, so high megapixel cameras are preferable
- Better lenses of SLR cameras mean fewer radial distortions…
- but radial artefacts arising from cheap camera lenses can be mitigated by deploying ground control points
- fish-eye lenses (e.g. GoPro) give rise to largest distortions, but latest software seems to cope
- **time lapse setting** is essential if camera is deployed from drone
- internal or external **GPS tagging** is another useful function, as it enables rough geo-referencing without ground control points

Camera lens distortions

f = focal length

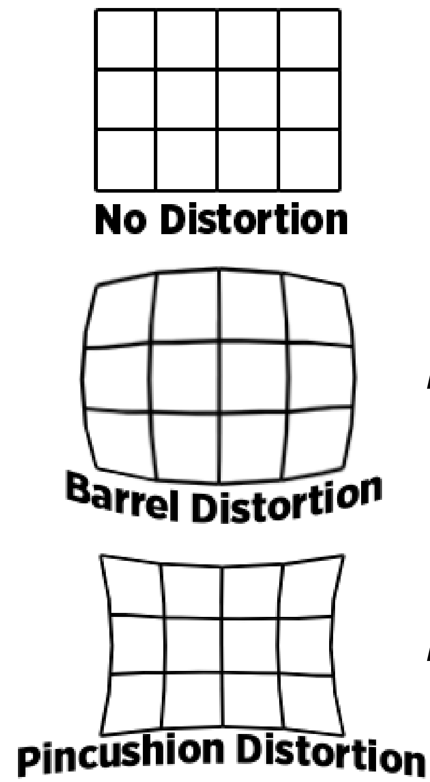
c_x = principal point x coordinate

c_y = principal point y coordinate

k_n = n^{th} radial distortion coefficient

p_n = n^{th} tangential distortion coefficient

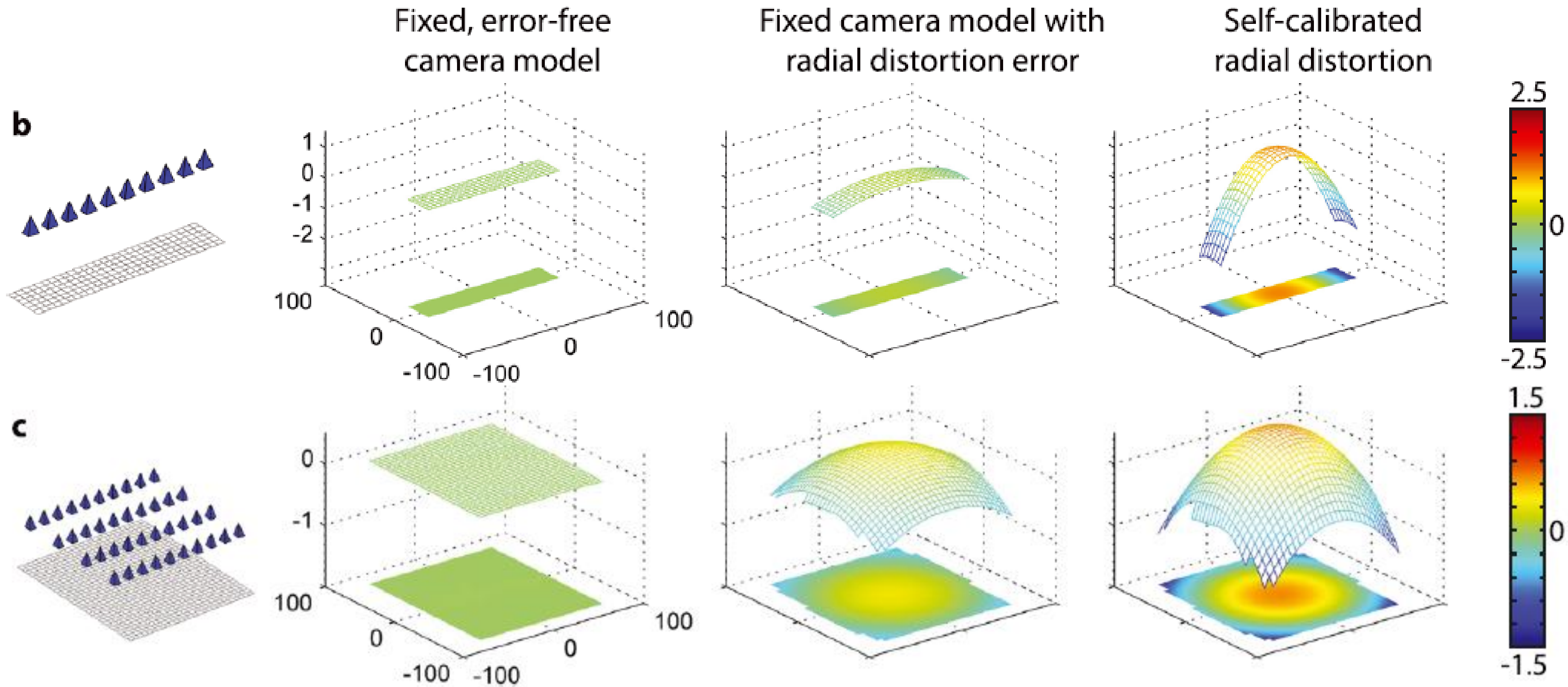
skew coefficient between the x and the y axis.



$k_1 < 1$

$k_1 > 1$

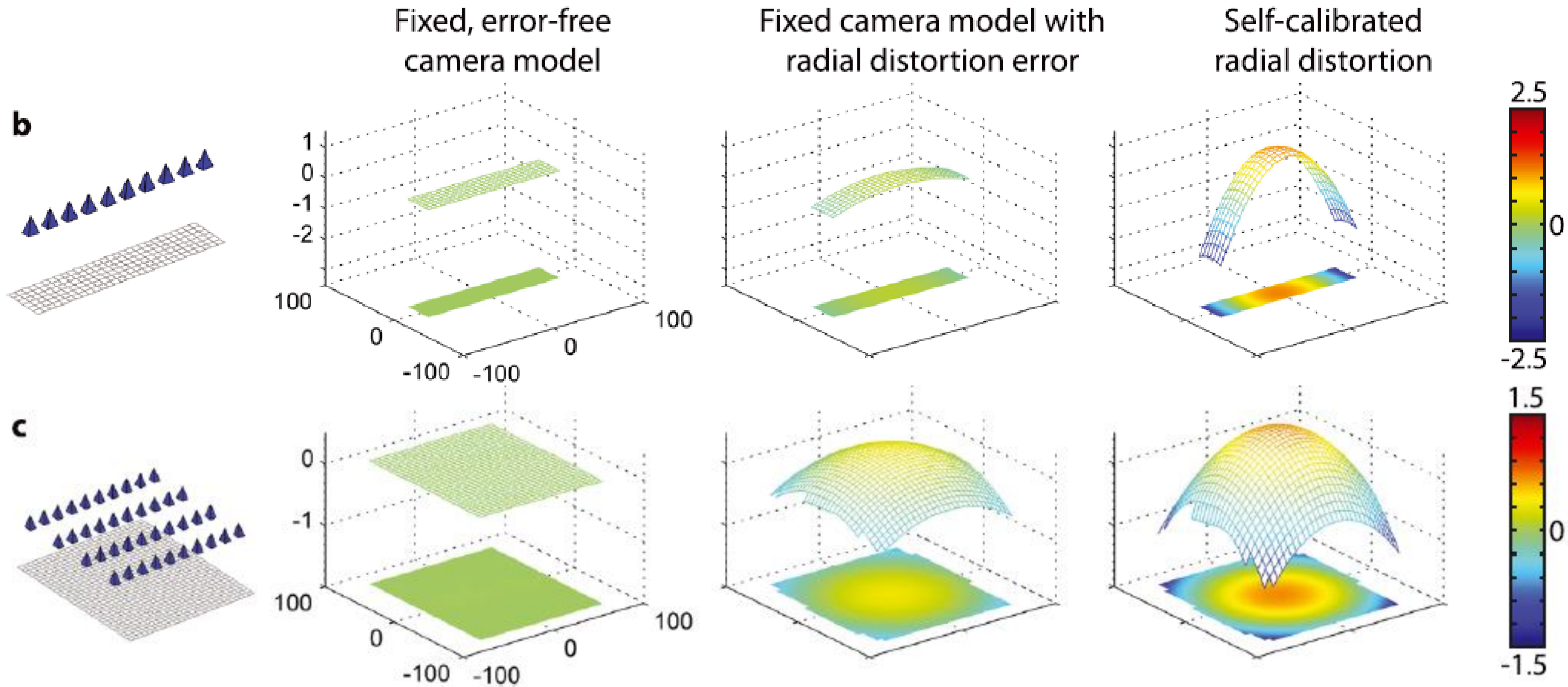
Camera lens distortions



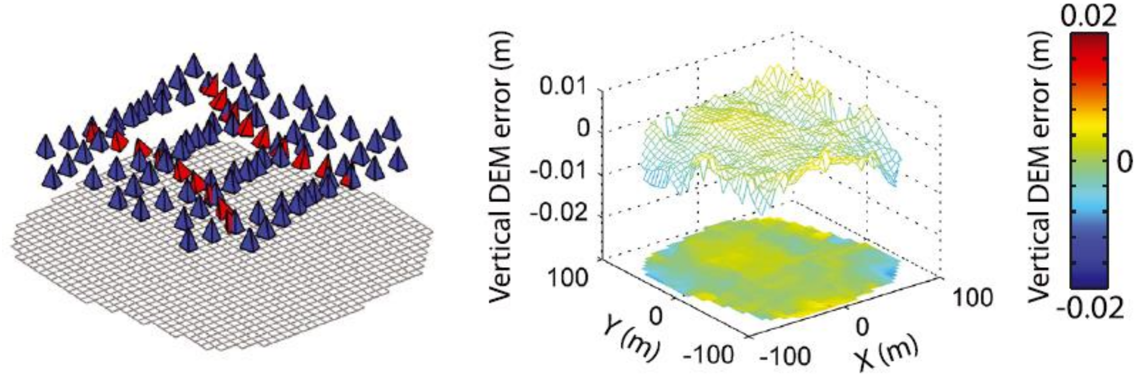
• A trade-off between lens radial distortion term and computed surface form can lead to "doming"

James & Robson (2014), Mitigating systematic error in topographic models derived from UAV and ground-based image networks, *Earth Surface Processes and Landforms*

Camera lens distortions



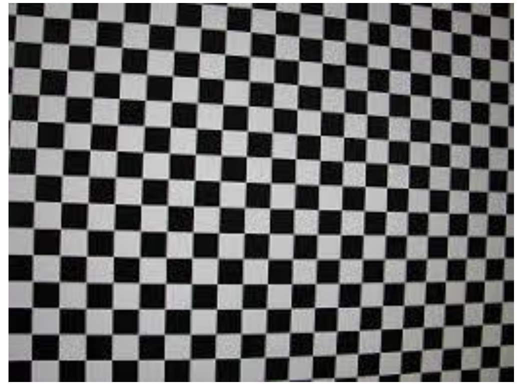
- Doming can be mitigated by incorporating a few oblique camera angles (in red)

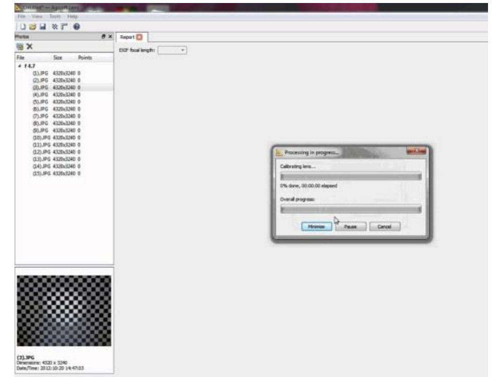


James & Robson (2014), Mitigating systematic error in topographic models derived from UAV and ground-based image networks, *Earth Surface Processes and Landforms*

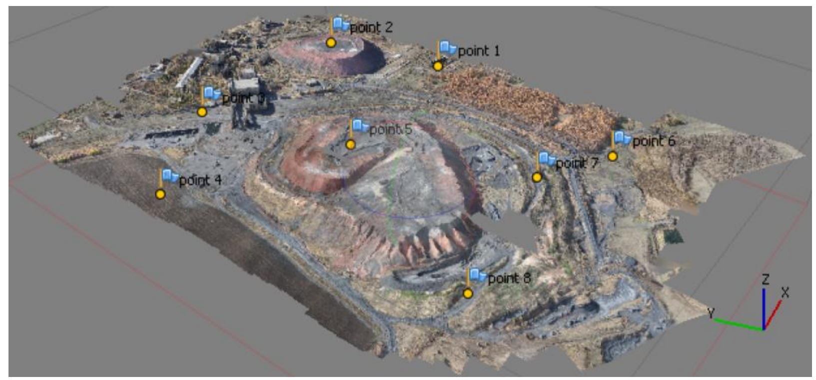
Camera lens distortions

• Doming can be mitigated by calibrating the camera parameters by photographing a calibration target

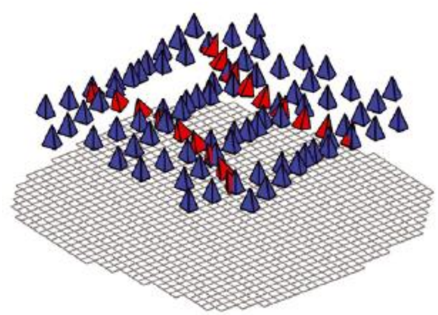


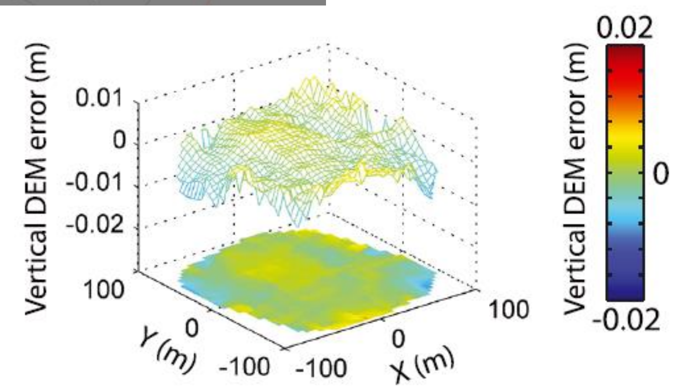


• Doming can be mitigated by georeferencing using ground control points

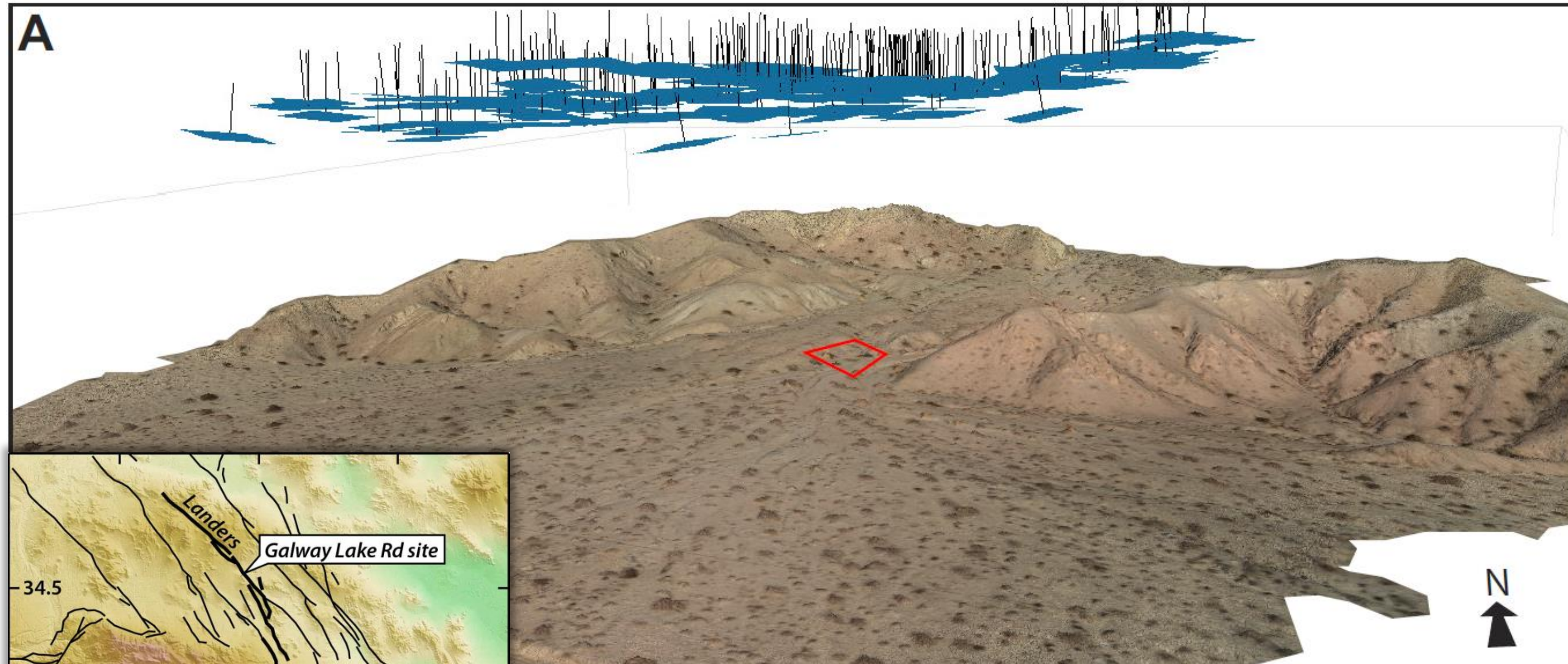


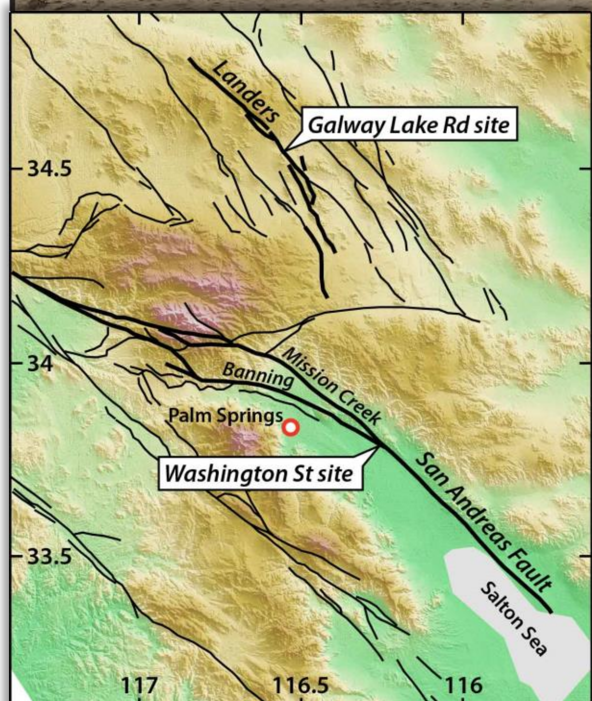
• Doming can be mitigated by incorporating a few oblique camera angles (in red)





Resolution and precision of SfM topography





It is important to capture each part of the target or target area with photos taken from several different locations. There needs to be significant overlap between images.

This image shows a test area in California where we made comparisons between SfM topography and airborne lidar. We used 230 photos taken in ~1 hour from a helium balloon.

Johnson *et al.* (2014), Rapid mapping of ultrafine fault zone topography with structure from motion, *Geosphere*

Resolution and precision of SfM topography

Orthophoto

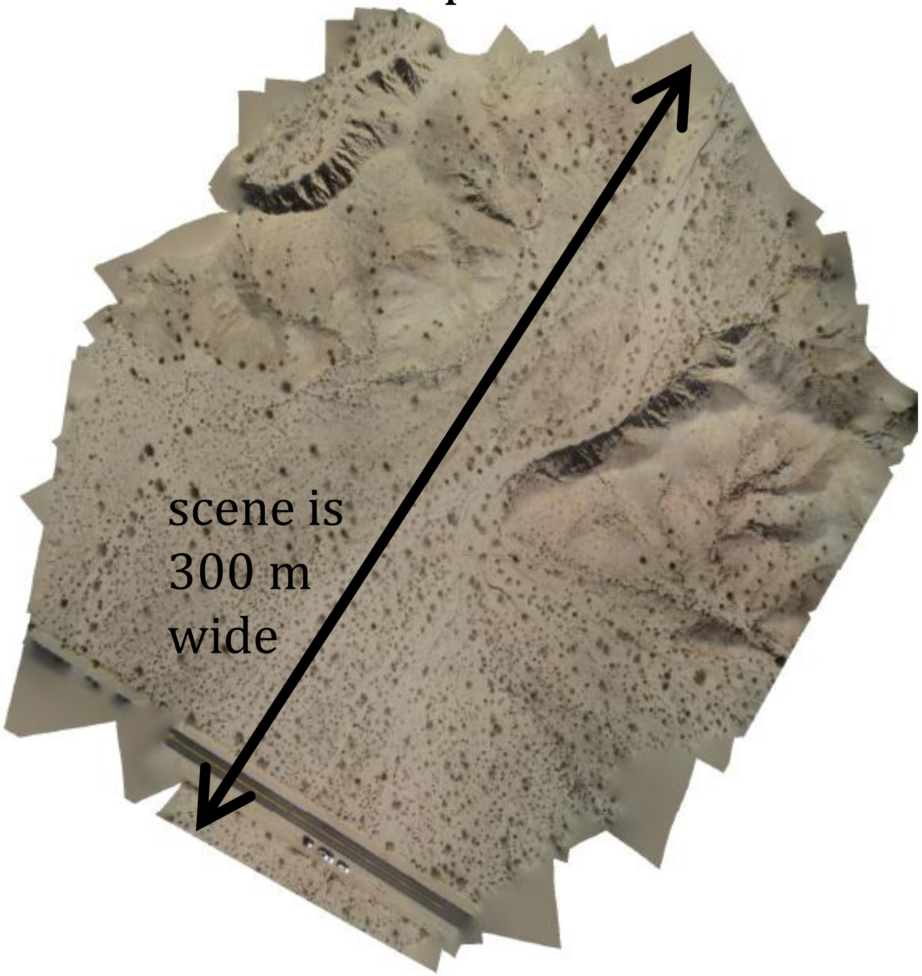


Photo coverage plot

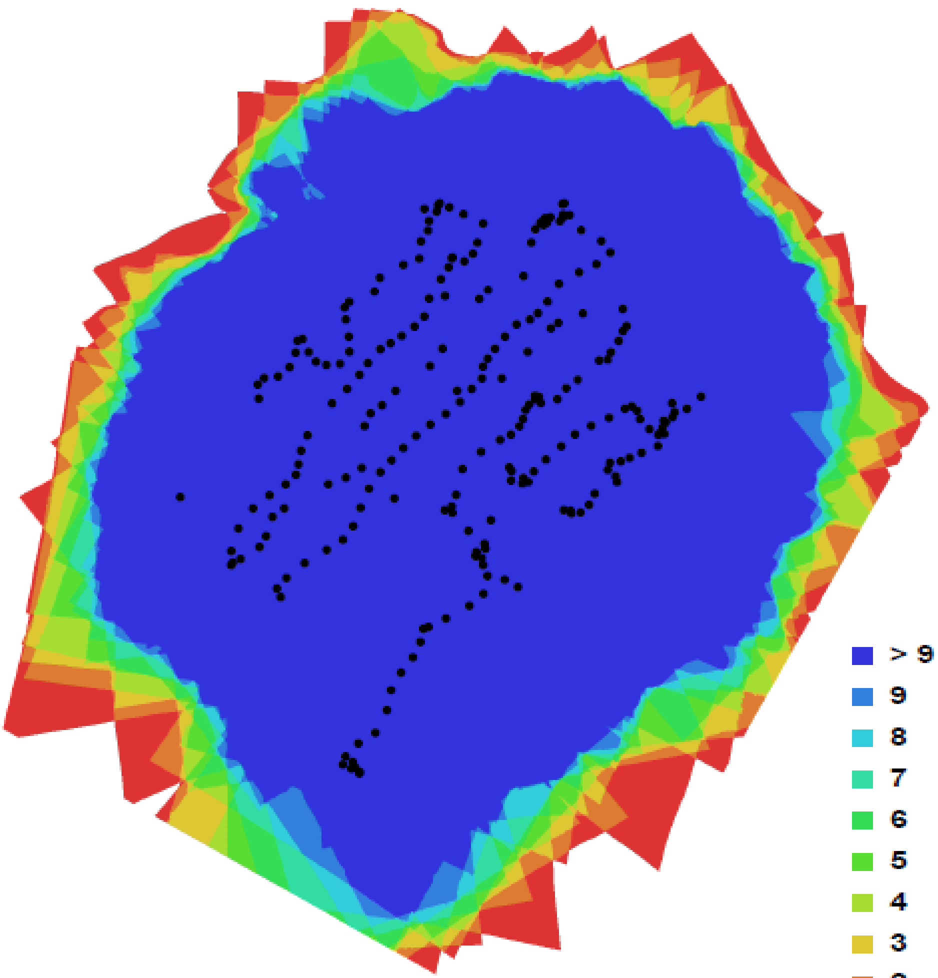
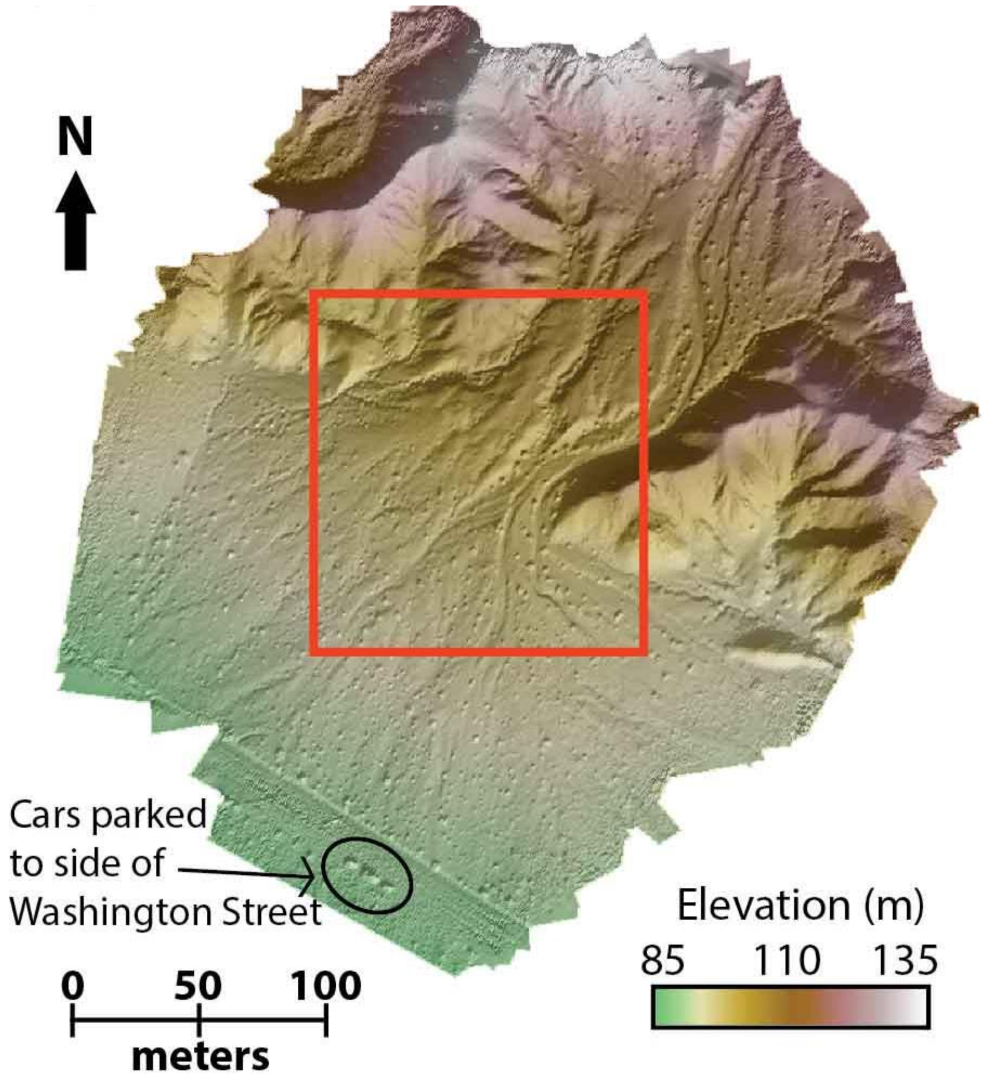
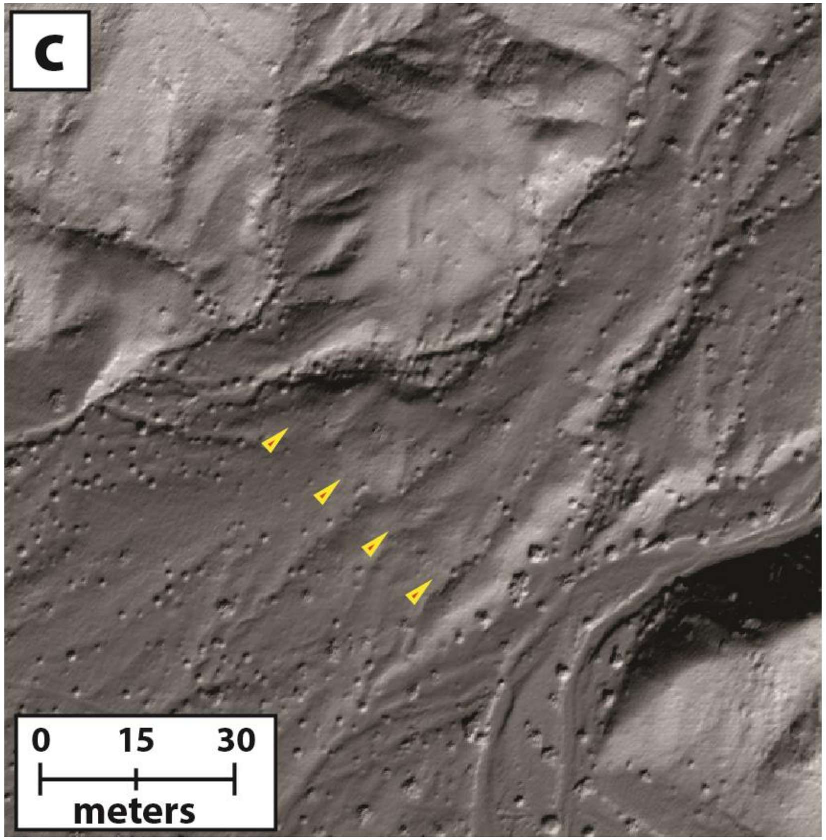


Fig. 1. Camera locations and image overlap.

Johnson *et al.* (2014), Rapid mapping of ultrafine fault zone topography with structure from motion, *Geosphere*

Resolution and precision of SfM topography



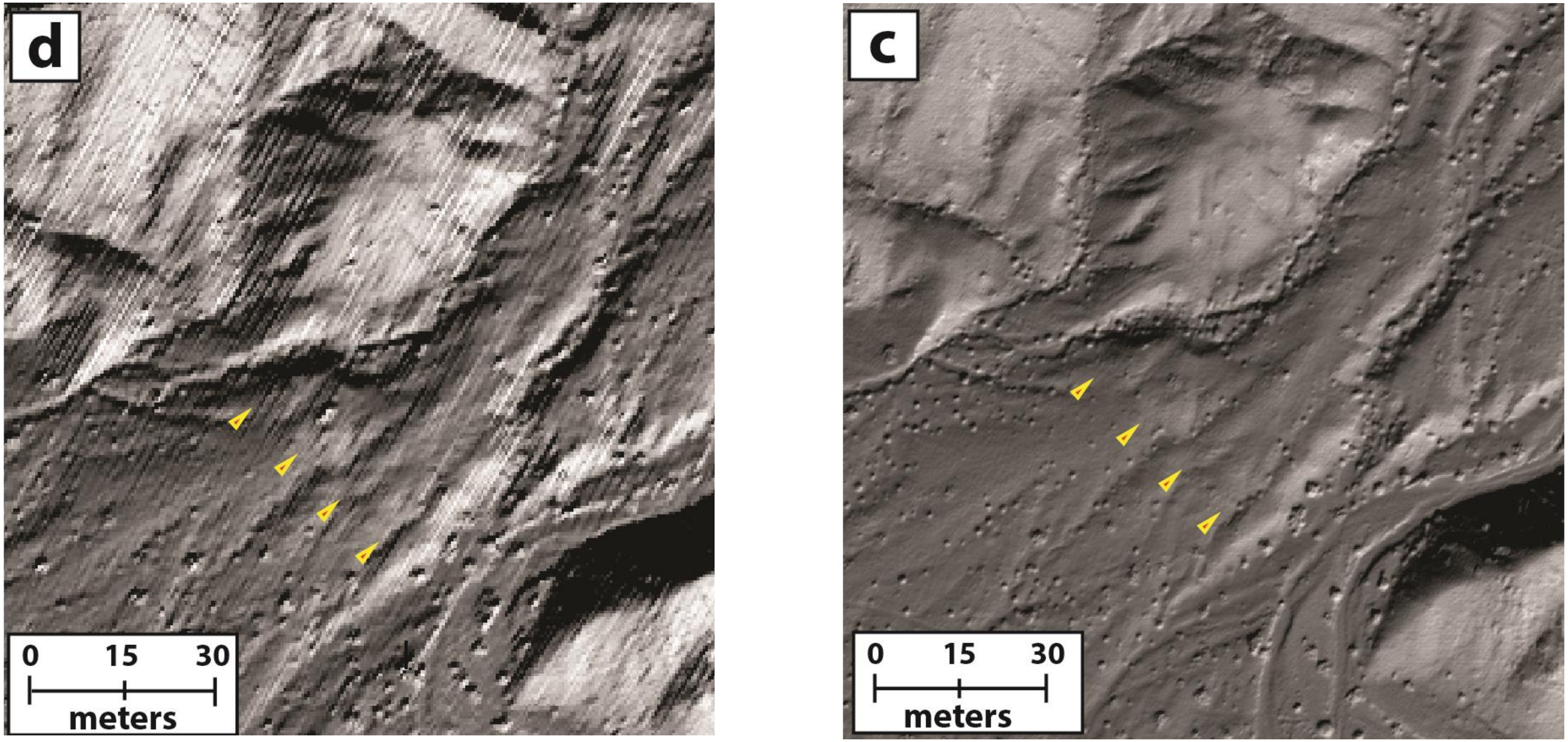


SfM ~700 pts/m^2

5 cm resolution DEM

Johnson *et al.* (2014), Rapid mapping of ultrafine fault zone topography with structure from motion, *Geosphere*

Resolution and precision of SfM topography



B4 LiDAR ~4 pts/m^2

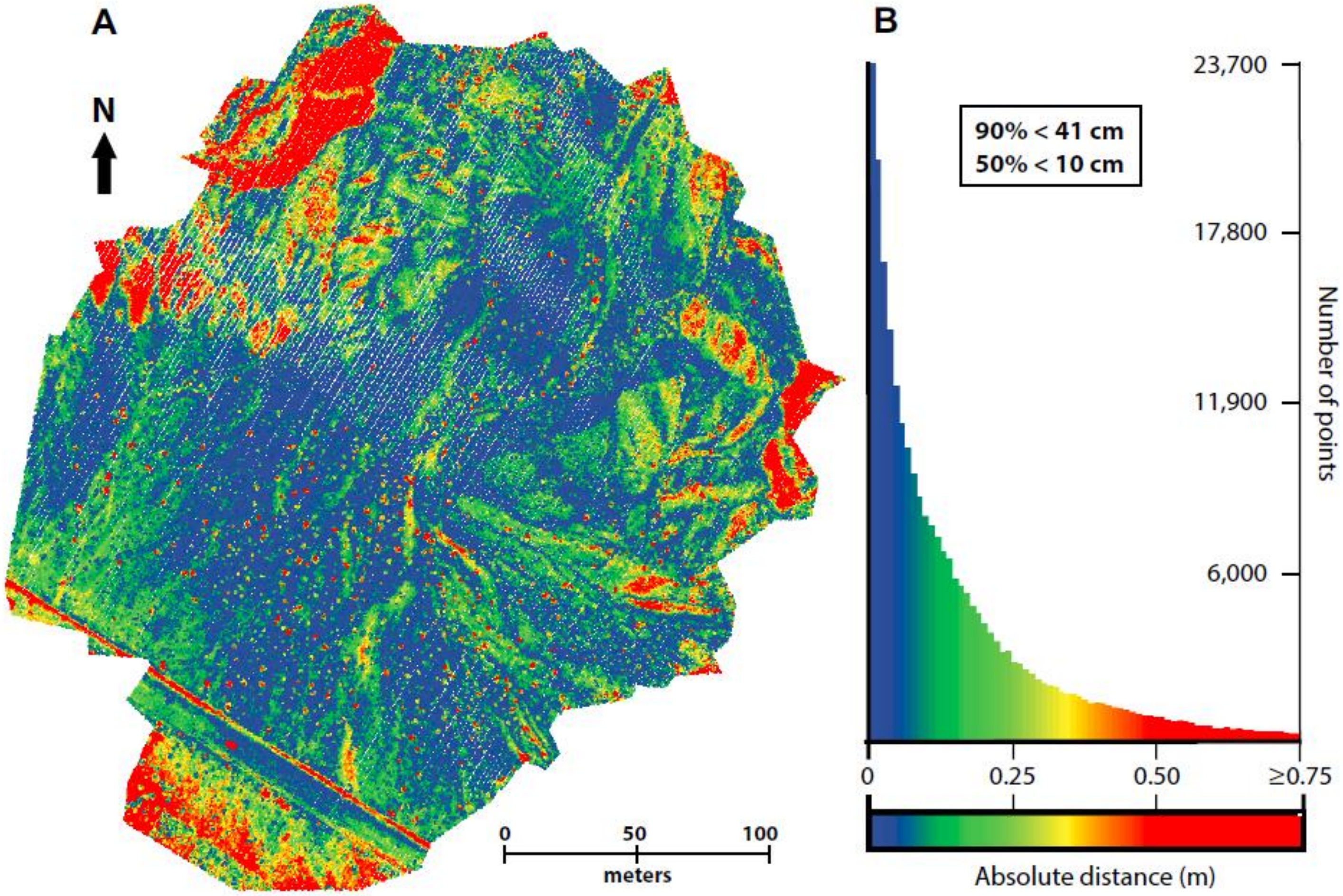
0.5 - 1 m resolution DEM

SfM ~700 pts/m^2

5 cm resolution DEM

Johnson *et al.* (2014), Rapid mapping of ultrafine fault zone topography with structure from motion, *Geosphere*

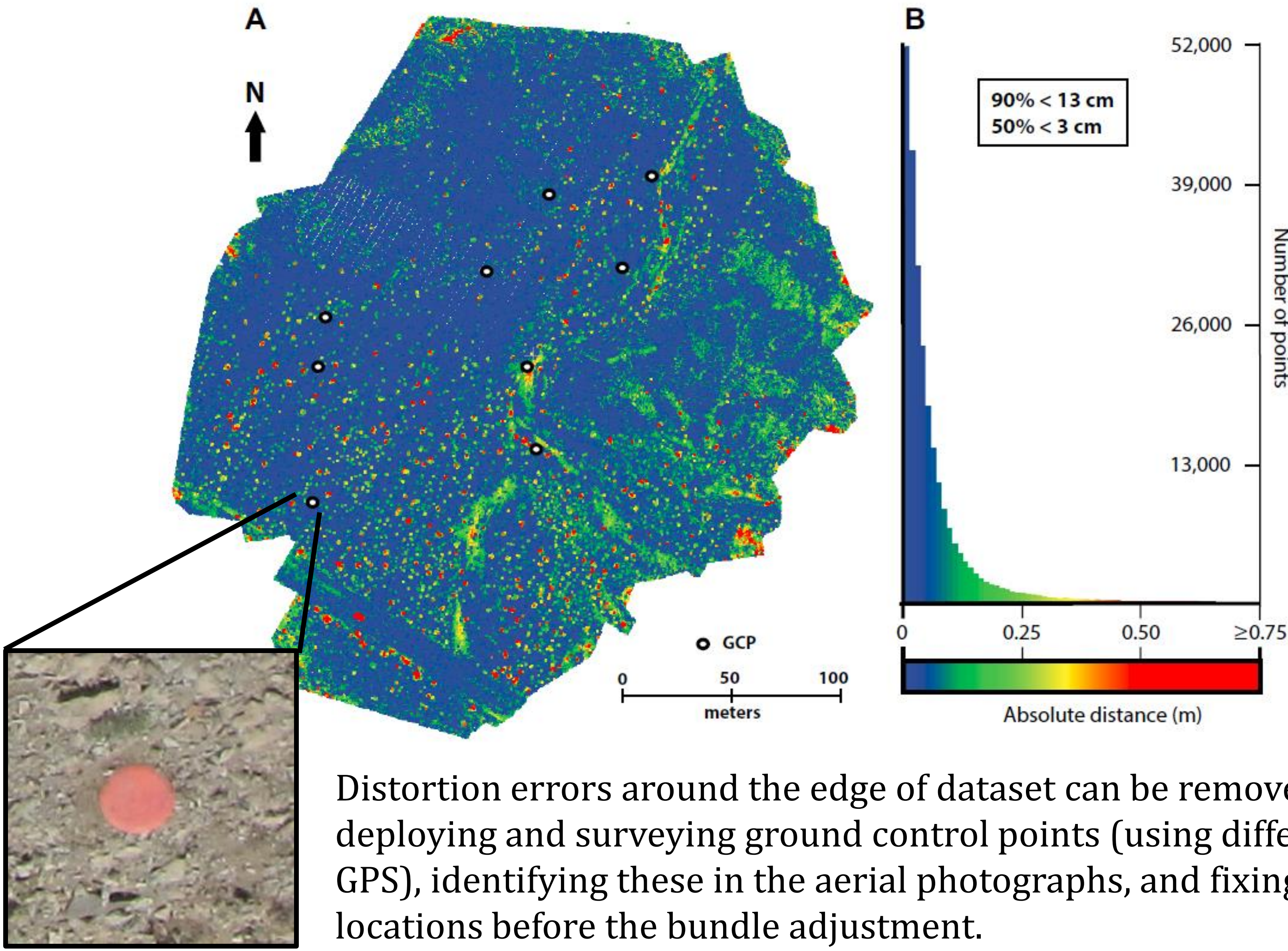
Resolution and precision of SfM topography



Note errors of >50 cm concentrated around edge of dataset. These probably reflect a trade-off in the bundle adjustment between estimates of the radial distortion of the camera lens and the topography

Johnson *et al.* (2014), Rapid mapping of ultrafine fault zone topography with structure from motion, *Geosphere*

Resolution and precision of SfM topography

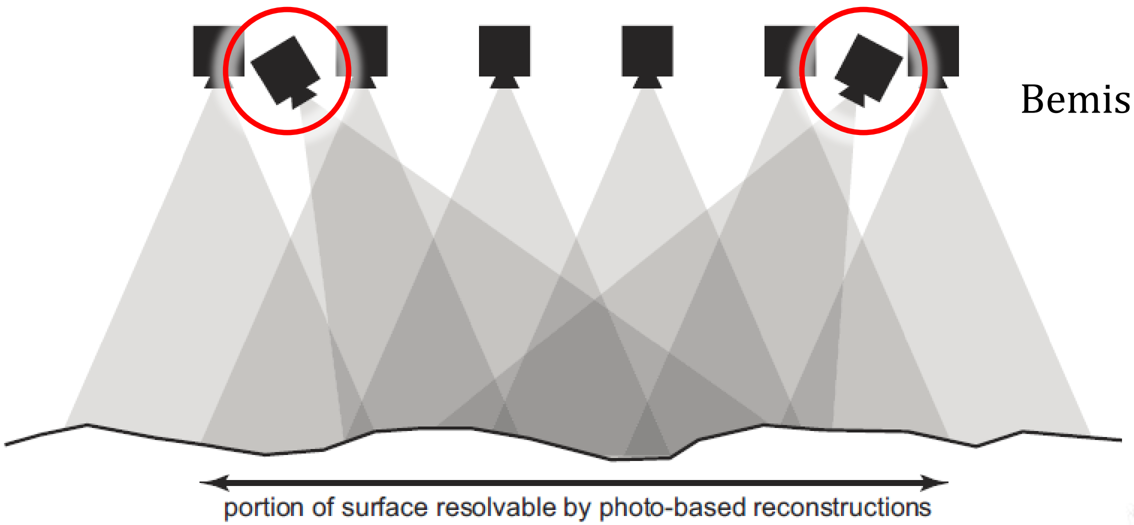


Distortion errors around the edge of dataset can be removed by deploying and surveying ground control points (using differential GPS), identifying these in the aerial photographs, and fixing the locations before the bundle adjustment.

Johnson *et al.* (2014), Rapid mapping of ultrafine fault zone topography with structure from motion, *Geosphere*

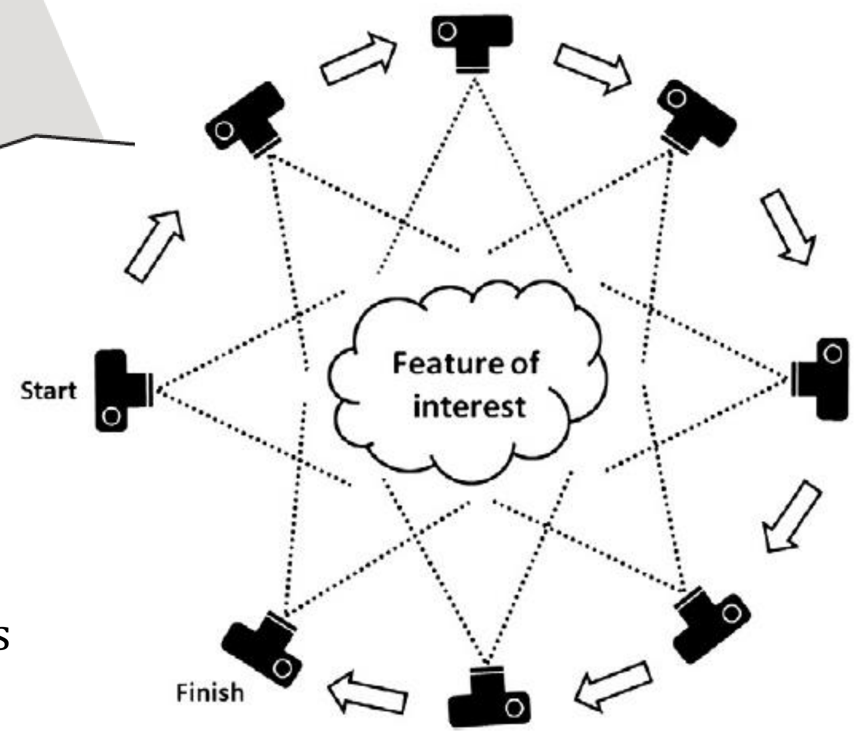
SfM lunch exercise

Build your own model using your own photographs of a target on campus.
Make sure you have a way of transferring your photos onto the computer!



Bemis *et al.* (2014).

Westoby *et al.* (2012).



Tips

- Choose a target with some texture
- Ensure plenty of overlap between photos
- Capture the target from a variety of angles
- Try to capture the object in ~20 – 30 photos