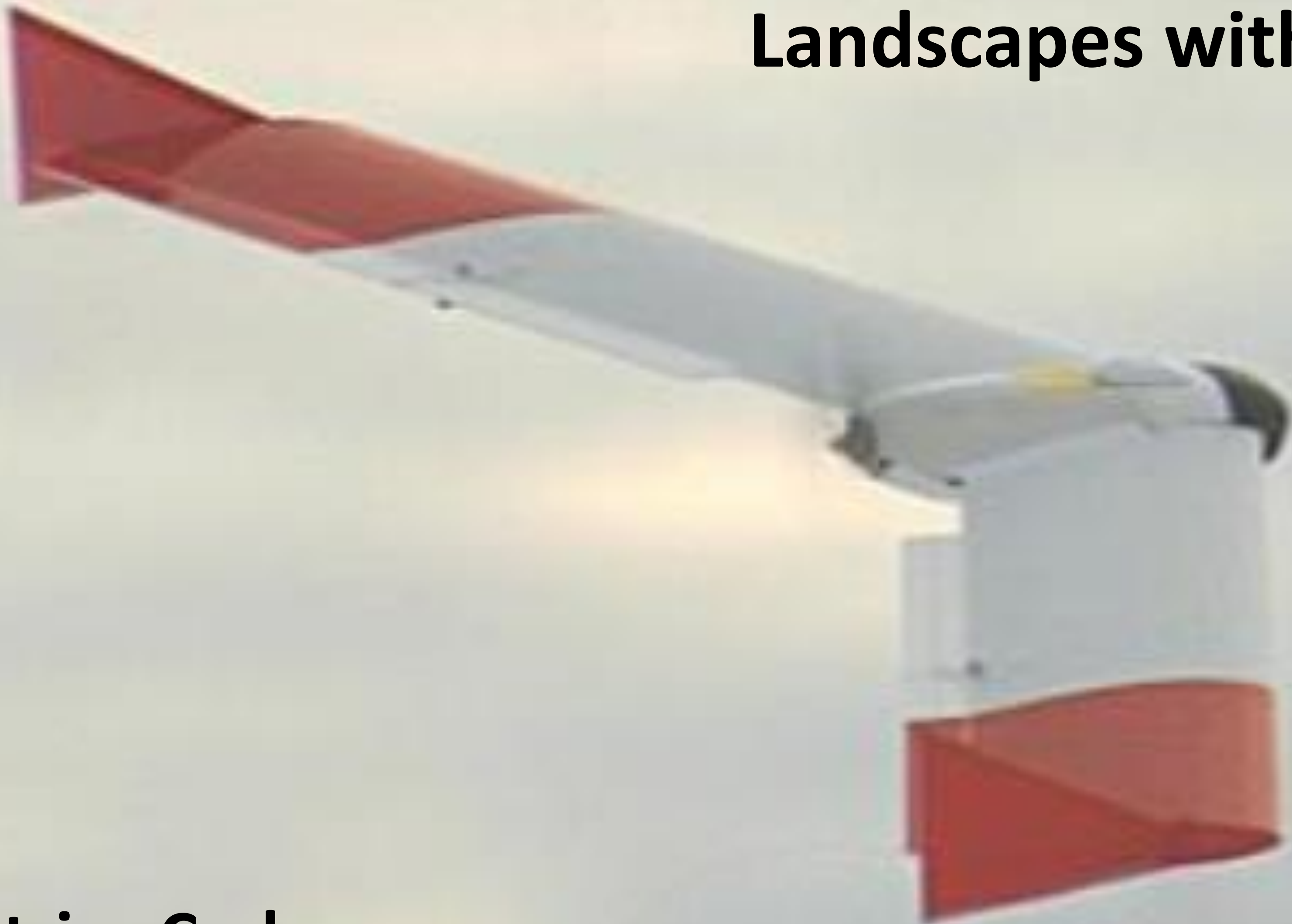
Managing and Researching Fluvial Landscapes with UAVs



Patrice Carbonneau,
Durham University Geography, UK.

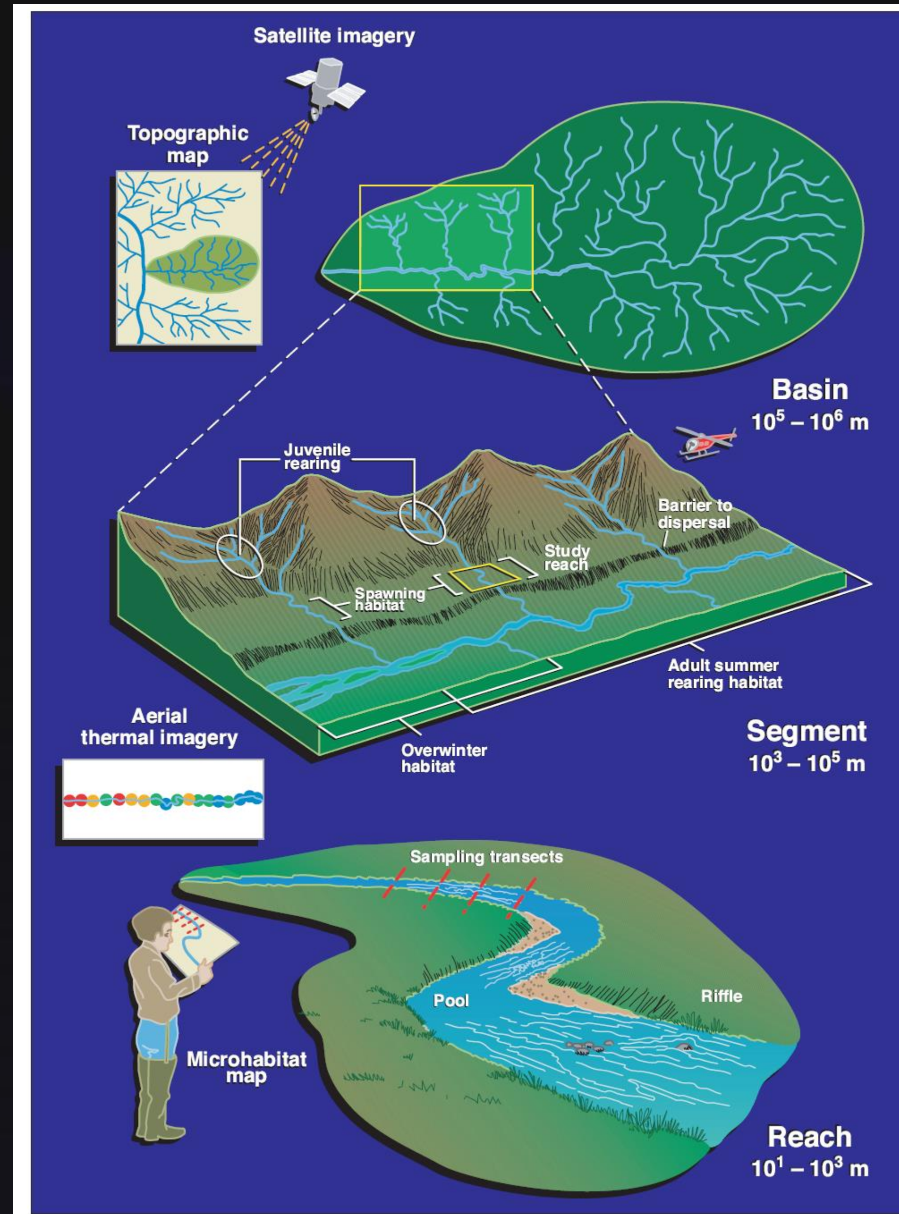
The road from manned to unmanned

Landscapes to Riverscapes: Bridging the Gap between Research and Conservation of Stream Fishes

KURT D. FAUSCH, CHRISTIAN E. TORGERSEN, COLDEN V. BAXTER, AND HIRAM W. LI

June 2002 / Vol. 52 No. 6 • BioScience 483

Fausch et al argued for the need of a multiscalar, even a panscalar, approach to lotic ecology



The road from manned to unmanned

2002: 3cm resolution airborne becoming available

The road from manned to unmanned

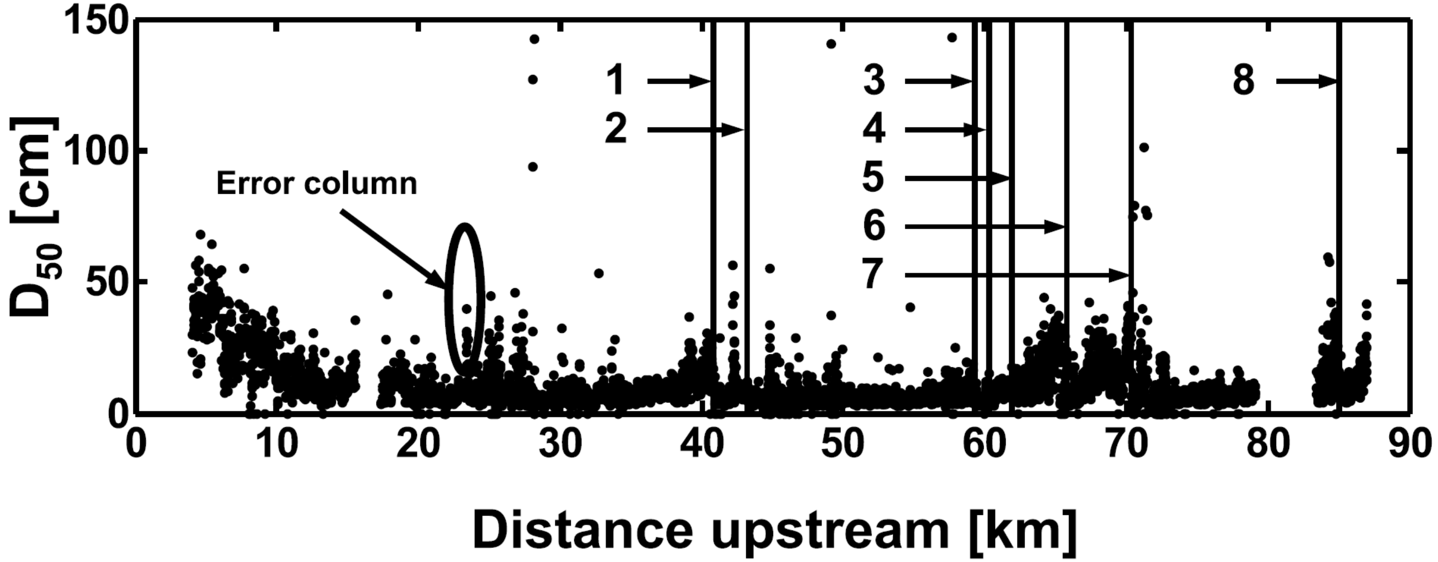


Figure 5. Long profile of median grain size showing link cutoff points (vertical lines), numbered 1–8 as determined by Davey and Lapointe (unpublished report, 2004) and an example of an "error column" structure caused by glare at the water surface.

Carbonneau, Bergreron and Lane, Water Ressources Research
doi:10.1029/2005WR003994, 2005

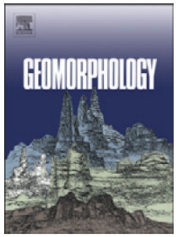
The road from manned to unmanned

Geomorphology 137 (2012) 74–86

Contents lists available at ScienceDirect

Geomorphology

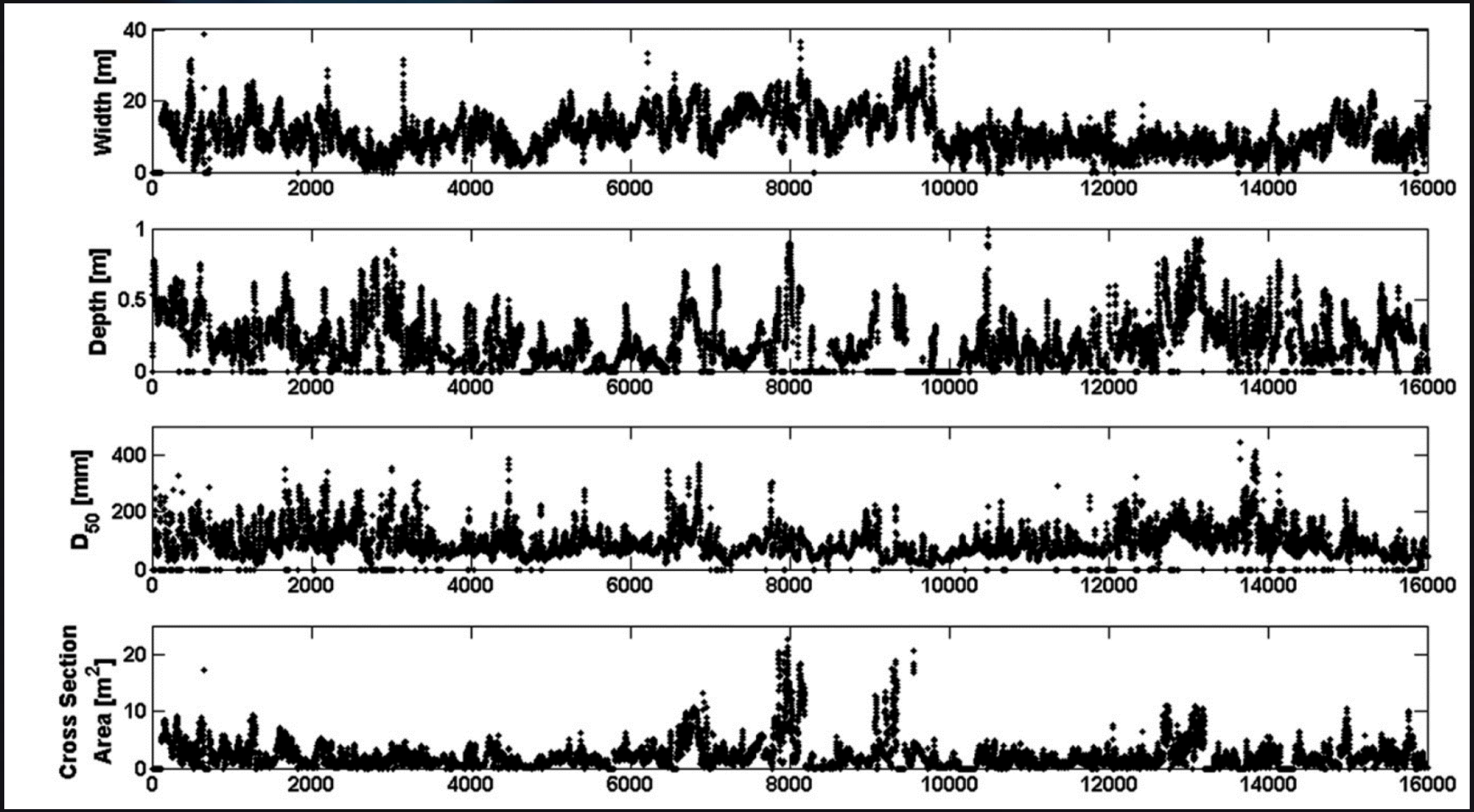
journal homepage: www.elsevier.com/locate/geomorph



Making riverscapes real

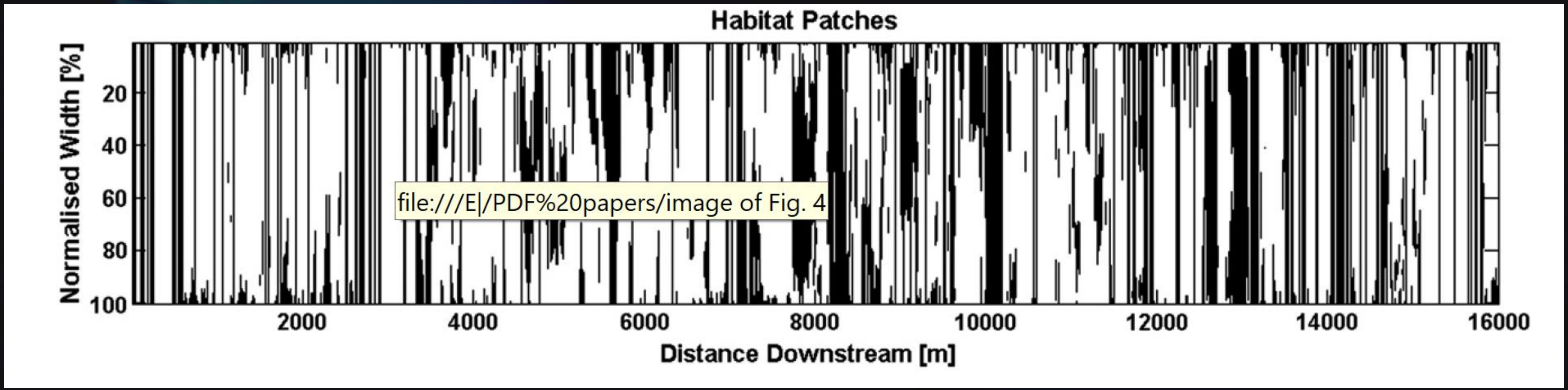
Patrice Carbonneau [a], Mark A. Fonstad [b,*], W. Andrew Marcus [c], Stephen J. Dugdale [d]

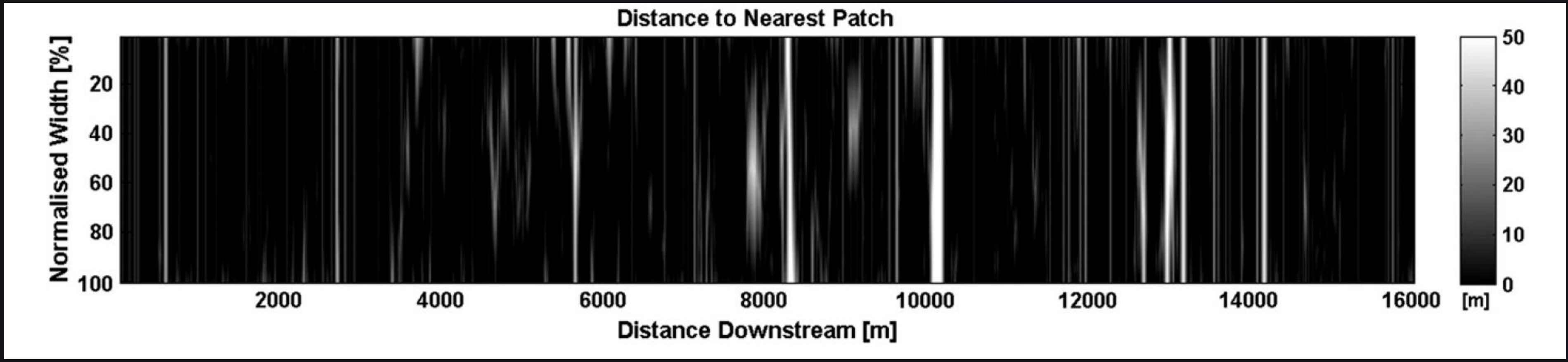
The road from manned to unmanned



From Carbonneau et al 2012, Making Riverscapes Real, Geomorphology

The road from manned to unmanned





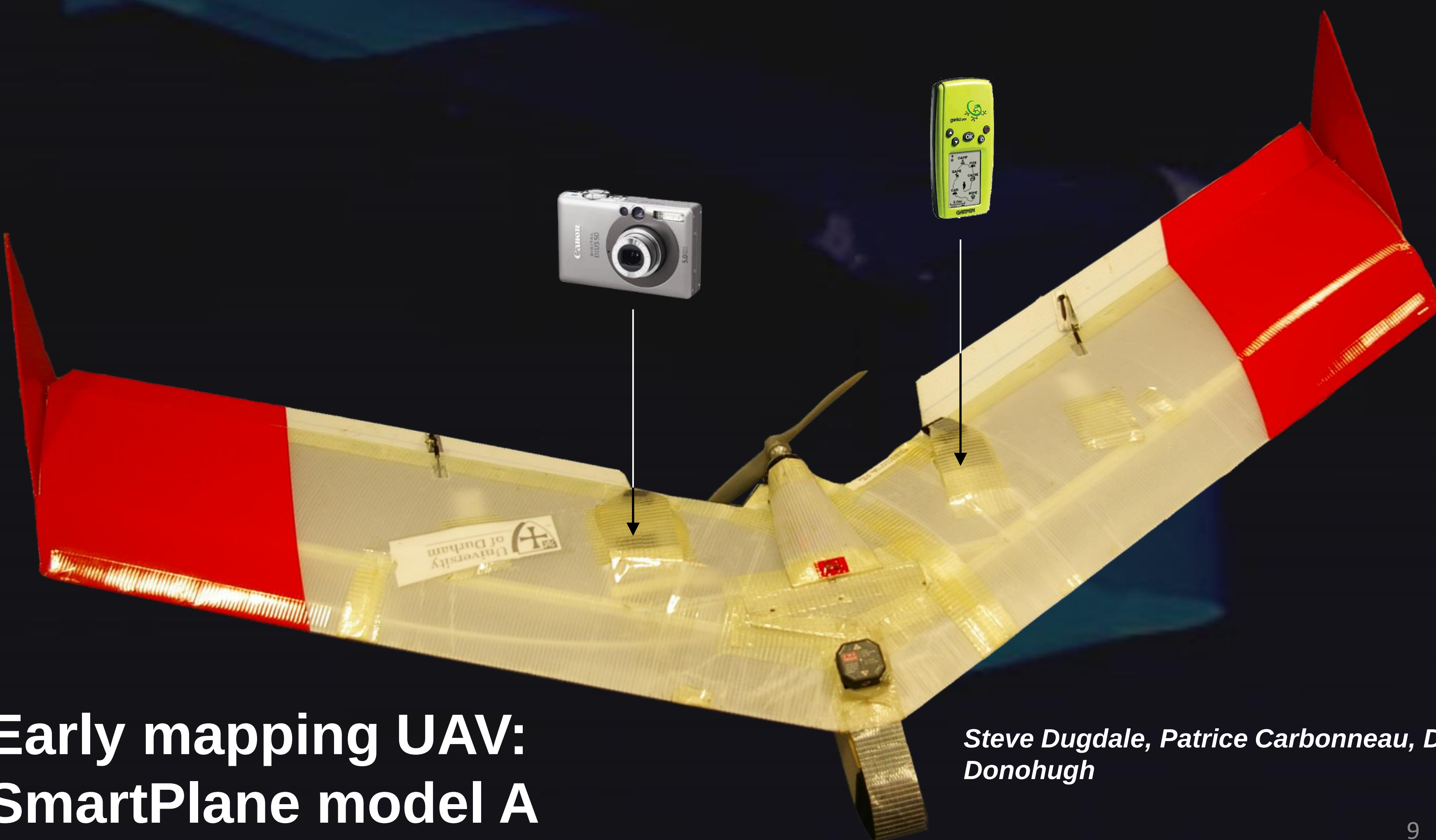
From Carbonneau et al 2012, Making Riverscapes Real, Geomorphology

Where did the 'manned' road take us?

Despite potential, manned airborne is:

- Costly
- Slow to deploy
- Usually not designed for science, priorities in the airborne private sector may differ from academic ones.

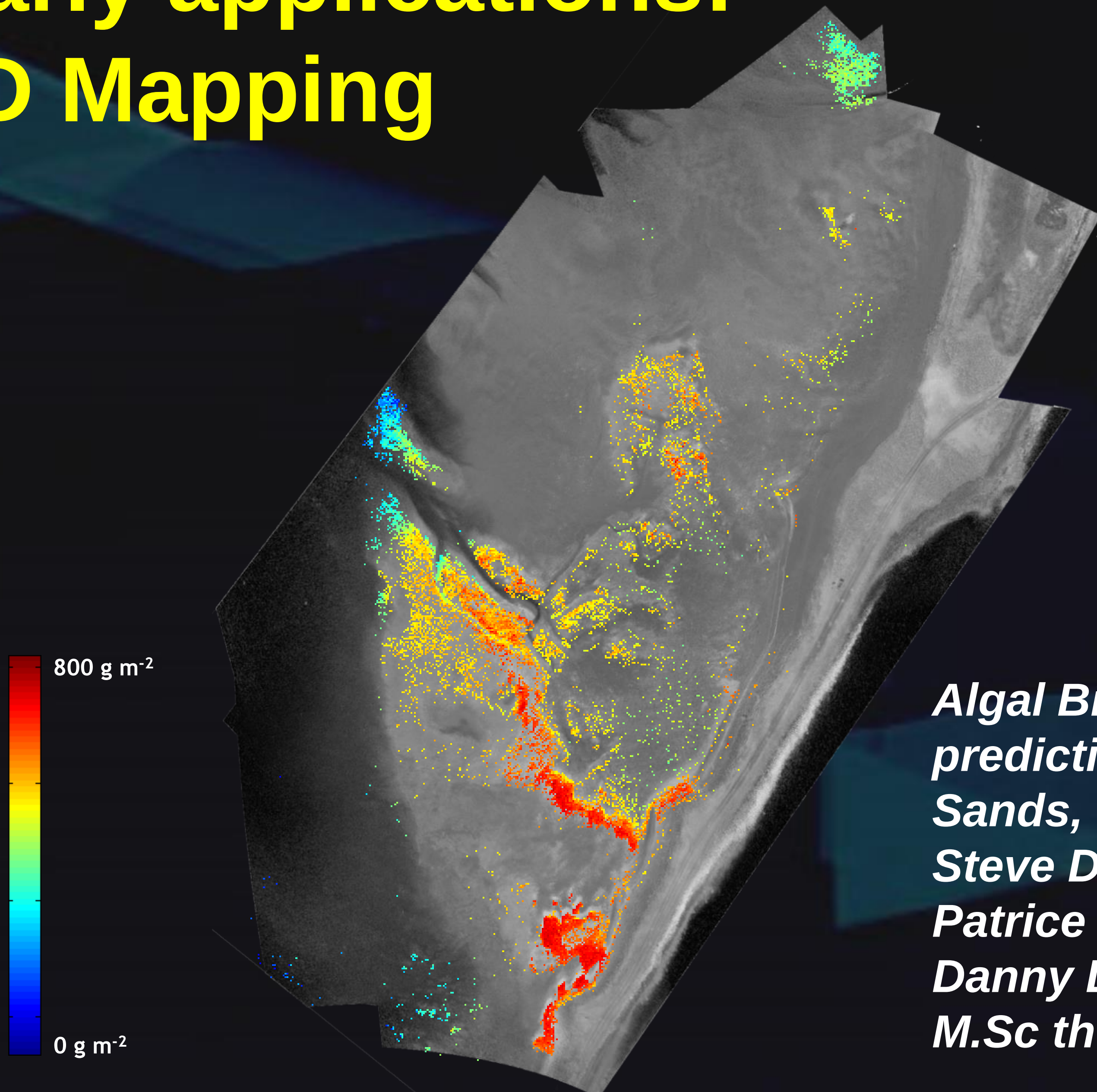
The fork in the road: Unmaned Aerial Vehicles



Early mapping UAV: SmartPlane model A

Steve Dugdale, Patrice Carbonneau, Danny Donohugh

Early applications: 2D Mapping



Algal Biomass prediction for Seal Sands, Teeside. Steve Dugdale, Patrice Carbonneau, Danny Donohugh, M.Sc theses, 2007

Recent applications: Impacts of barriers

My goals today

- Discuss some key developments underpinning the rise of drones in the environmental sector.
- Think about what we have gained and lost
- Think about where we are going

The foundation of modern drone mapping: SfM

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GEOMORPHOLOGY

‘Structure-from-Motion’ photogrammetry: A low-cost, effective tool for geoscience applications

M.J. Westoby [a,*], J. Brasington [b], N.F. Glasser [a], M.J. Hambrey [a], J.M. Reynolds [c]

Topographic structure from motion: a new development in photogrammetric measurement

Mark A. Fonstad,[1]* James T. Dietrich,[1] Brittany C. Courville,[2] Jennifer L. Jensen[2] and Patrice E. Carbonneau[3]

[1] Department of Geography, University of Oregon, Eugene, OR 97403 USA

[2] Department of Geography, Texas State University, TX 78666 USA

[3] Department of Geography, Durham University, Durham, UK

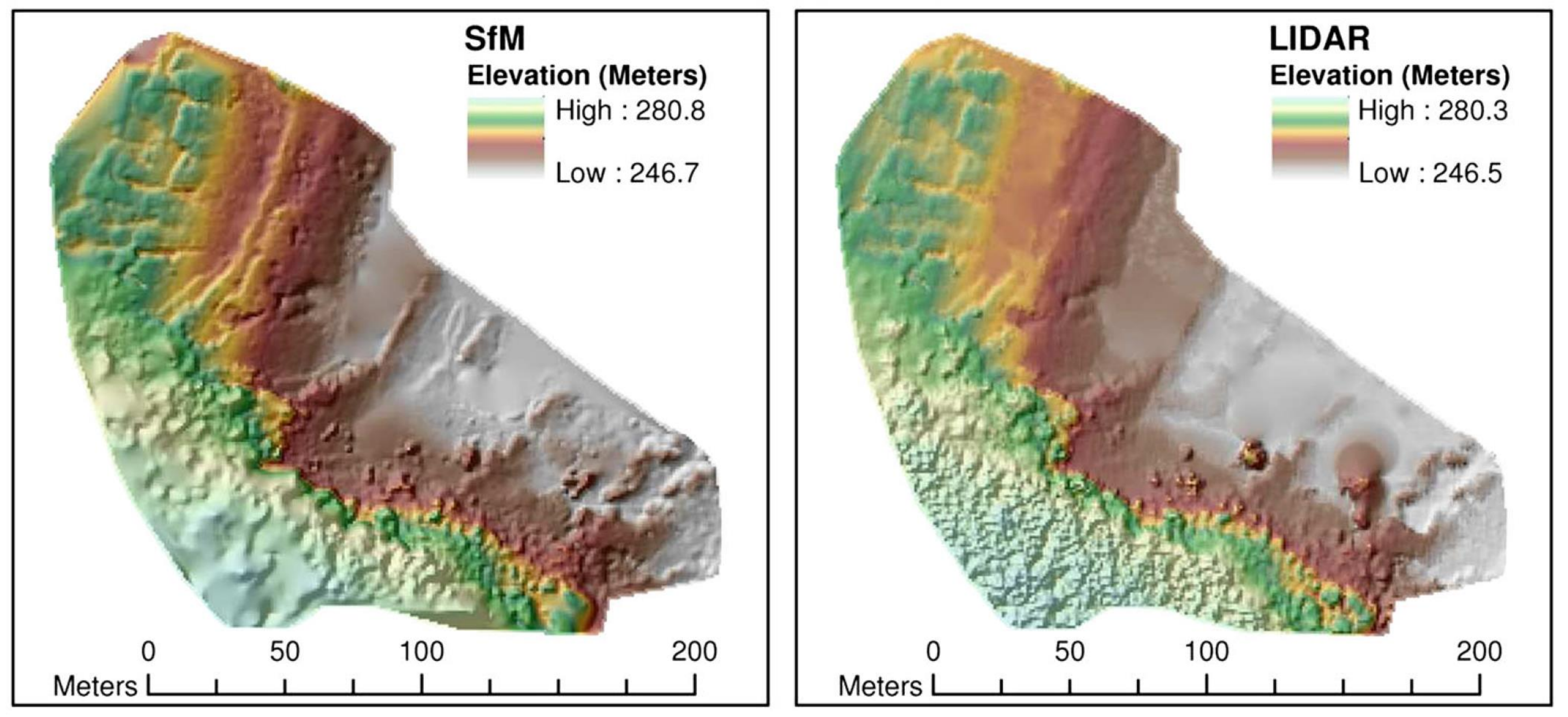
Received 12 December 2011; Revised 29 October 2012; Accepted 1 November 2012

*Correspondence to: Mark A. Fonstad, Department of Geography, University of Oregon, Eugene, OR 97403 USA. E-mail: fonstad@uoregon.edu

ESPL

Earth Surface Processes and Landforms

The foundation of modern drone mapping: SfM



SfM is designed for 'unstructured' imagery. As a result, it has allowed for digital photogrammetry to be easily applied to drone imagery.

Dropping the cost of drone mapping

€1000-€4000 BUT €10000-€40000

Direct Geoferencing

OPEN ACCESS
Remote Sensing
ISSN 2072-4292
www.mdpi.com/journal/remotesensing

Article

An Automated Technique for Generating Georectified Mosaics from Ultra-High Resolution Unmanned Aerial Vehicle (UAV) Imagery, Based on Structure from Motion (SfM) Point Clouds

Darren Turner *, Arko Lucieer and Christopher Watson

Cost-effective non-metric photogrammetry from consumer-grade sUAS: implications for direct georeferencing of structure from motion photogrammetry

Patrice E. Carbonneau[1]* and James T. Dietrich[2]
[1] Department of Geography, Durham University, Durham, UK
[2] William H. Neukom Institute for Computational Science, Dartmouth College, Hanover, NH USA

Received 18 December 2015; Revised 27 July 2016; Accepted 28 July 2016

*Correspondence to: Patrice E. Carbonneau, Department of Geography, Durham University, Lower Mountjoy Site, South Road, Durham, UK. E-mail: patrice.carbonneau@durham.ac.uk

ESPL

Direct Geoferencing basic concept

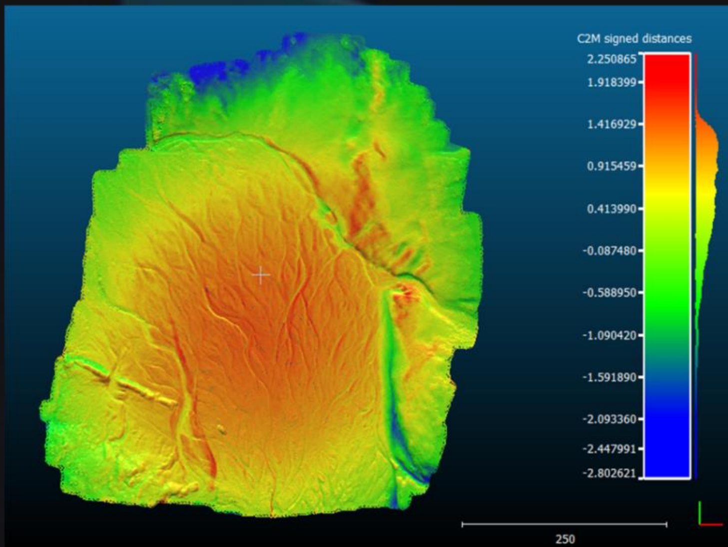
Solve the collinearity equations with tiepoints (generated by SfM) and camera locations.

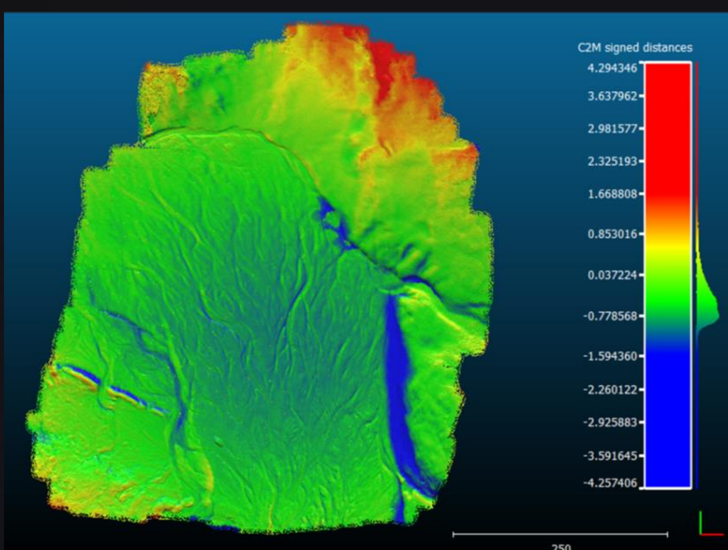
$$x_a = \frac{-c[r_{11}(X_O - X_A) + r_{12}(Y_O - Y_A) + r_{13}(Z_O - Z_A)]}{[r_{31}(X_O - X_A) + r_{32}(Y_O - Y_A) + r_{33}(Z_O - Z_A)]}$$

$$y_a = \frac{-c[r_{21}(X_O - X_A) + r_{22}(Y_O - Y_A) + r_{23}(Z_O - Z_A)]}{[r_{31}(X_O - X_A) + r_{32}(Y_O - Y_A) + r_{33}(Z_O - Z_A)]}$$

Solves the cost issue associated to RTK GPS. At least in theory…

In practice....

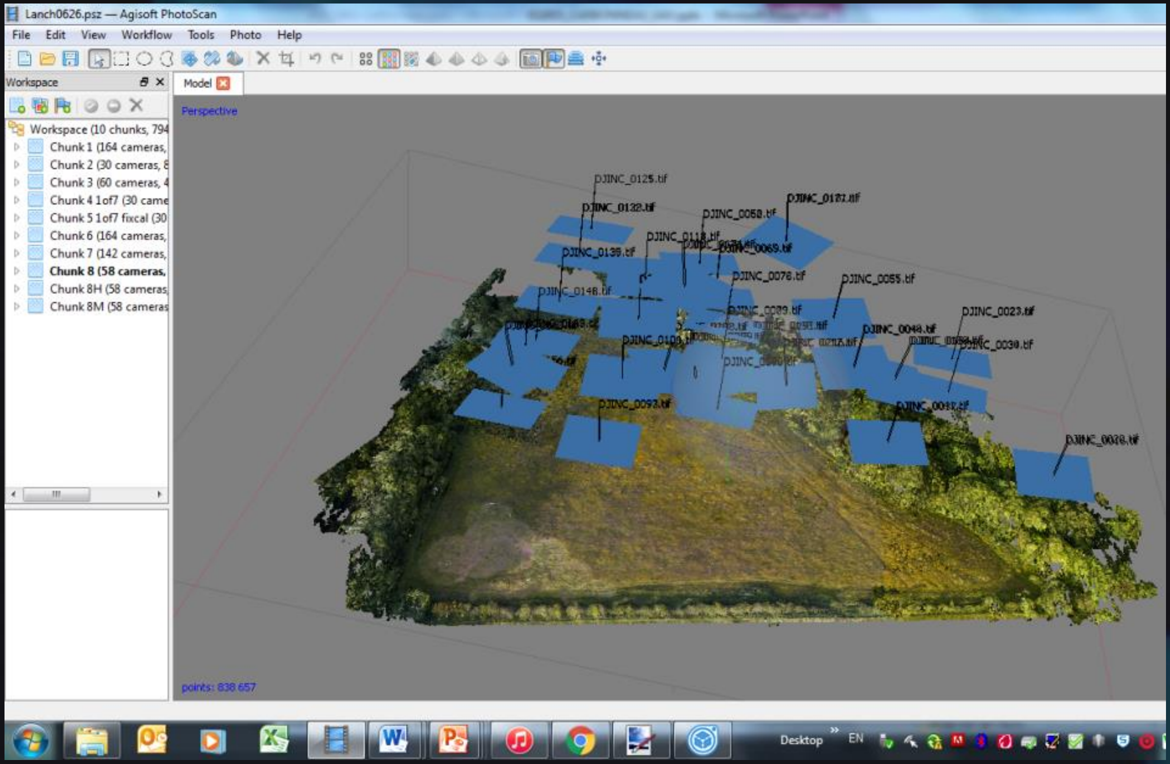




Bypassing traditional GCPs has consequences:

- ***Non-linear: doming from bad correction of lens distortion***
- ***Linear: Absolute position shift, tilt and scale (growth/shrink)***

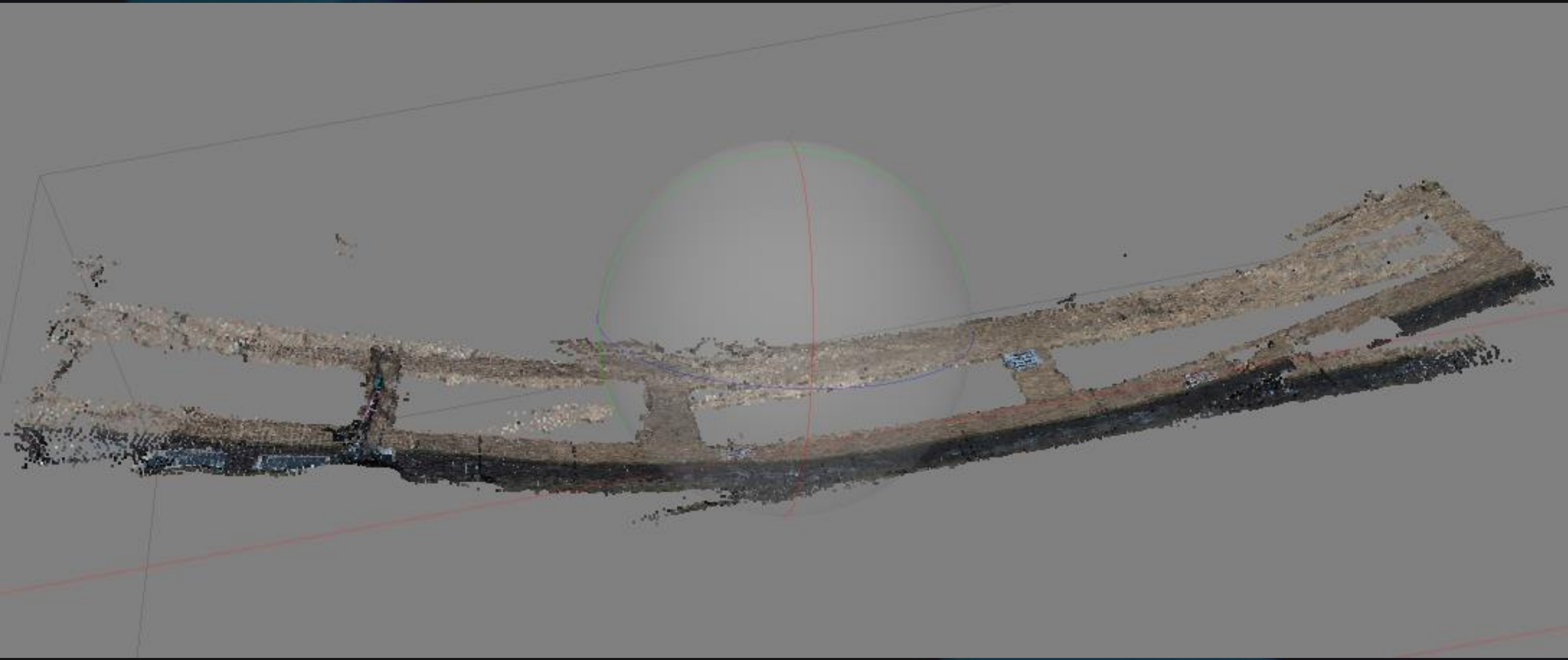
DG Experiment: PS + Python API



Tested 4 flight geometries:

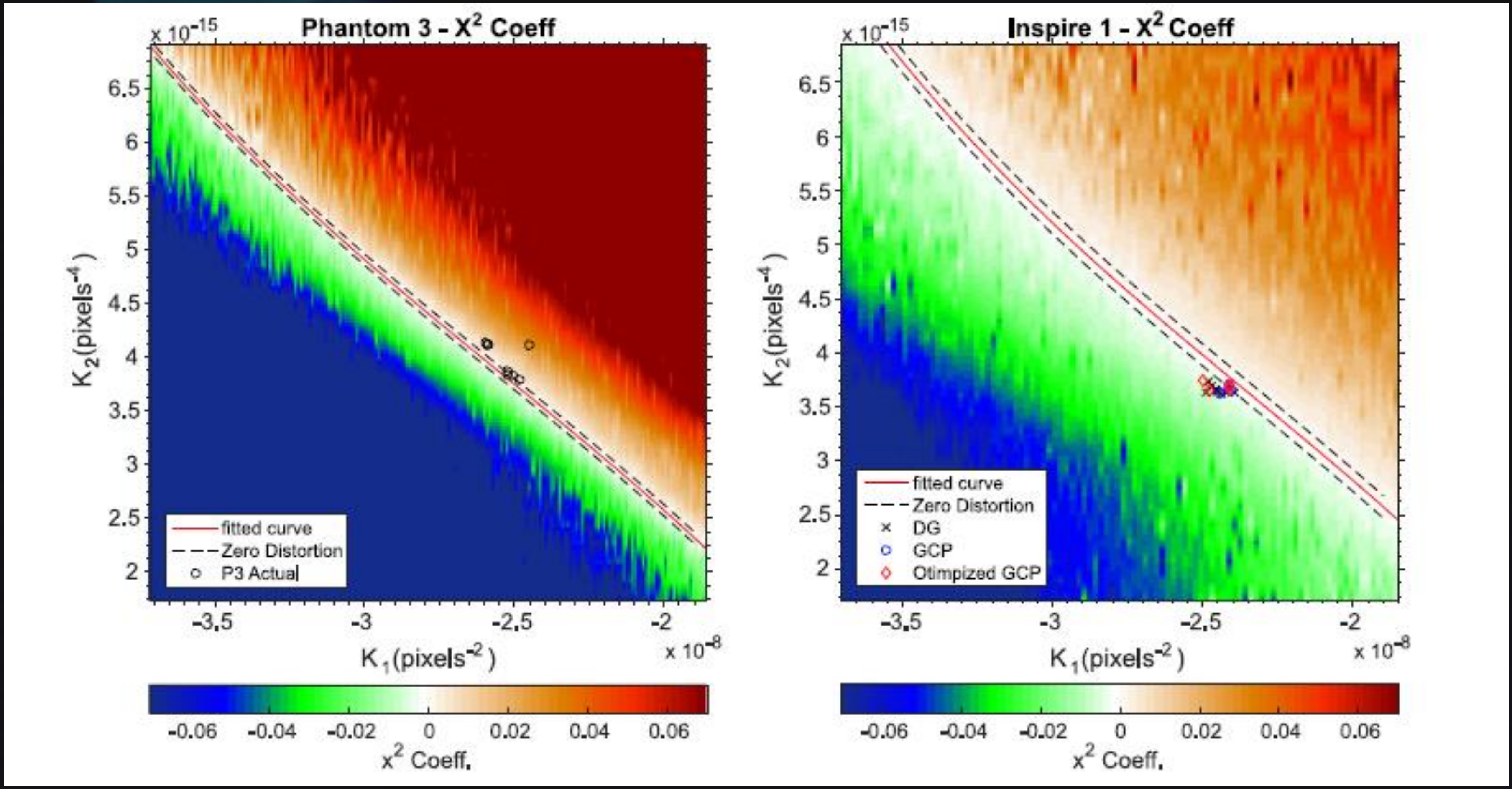
- ***60m AGL nadir***
- ***60+80m nadir***
- ***60m nadir+oblique***
- ***60+80m nadir+oblique***

DG Experiment: ‘lab’

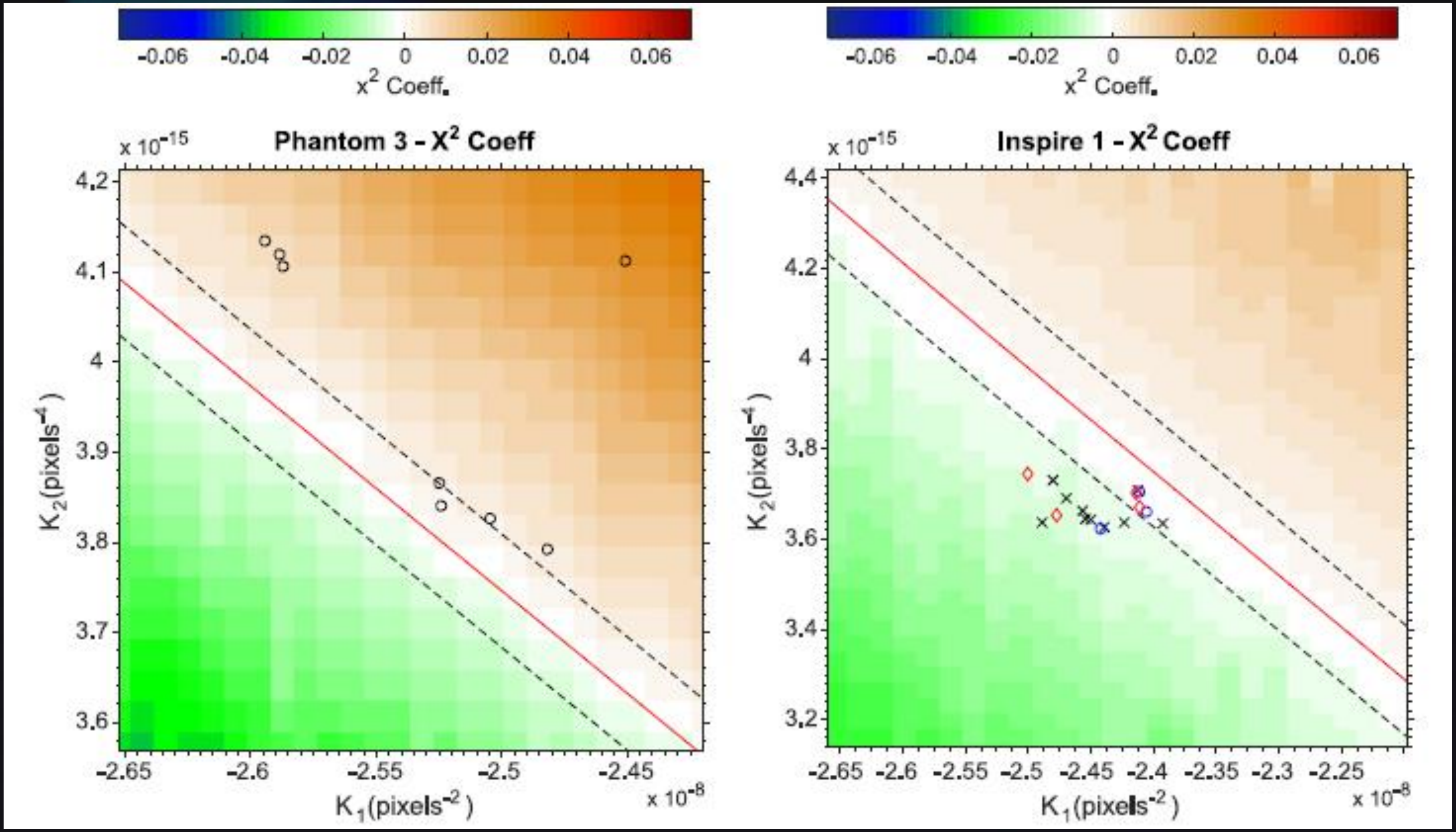


Flat wall in Durham and Dartmouth used to test doming vs camera cal for P3P and I1. Used to simulate degrees of lens distortion.

Results, field and 'lab'



Results, field and 'lab'



Flight Geometry matters!

DG capabilities of low-cost sUAS

Flown with 2 altitudes and mixed views:

- ***Precision : 0.1% of altitude***
- ***Tilt accuracy: < ± 1 degree***
- ***Scale accuracy: 0.5-4%***
- ***Absolute shift ≈ 2-4m***

Applications of DG to fluvial characteristic retrieval

Earth Surface Processes and Landforms
BSG British Society for Geomorphology
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Research Article

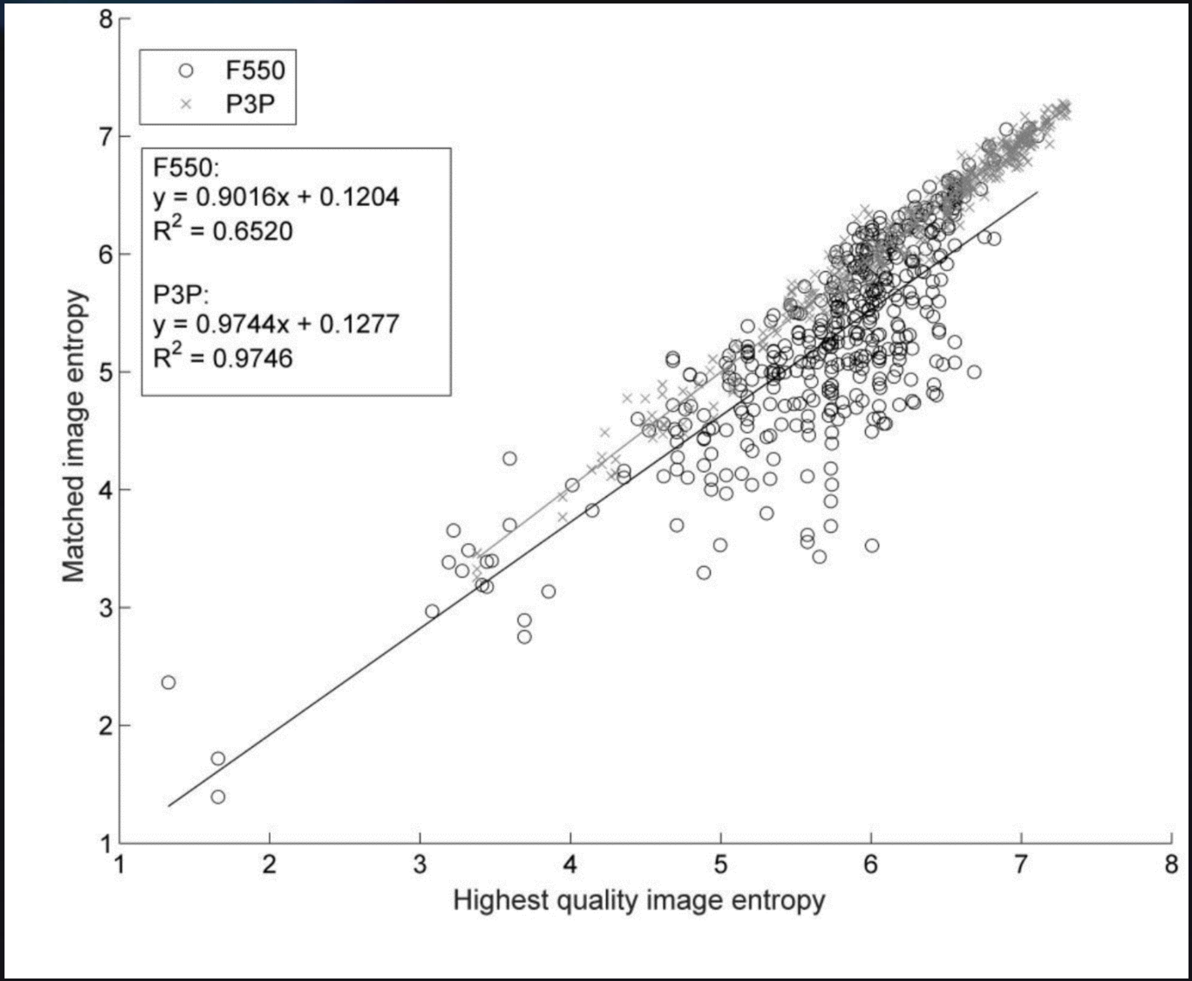
From manned to unmanned aircraft: Adapting airborne particle size mapping methodologies to the characteristics of sUAS and SfM

A.S. Woodget, C. Fyffe, P.E. Carbonneau

Accepted manuscript online: 10 November 2017 Full publication history

DOI: 10.1002/esp.4285 View/save citation

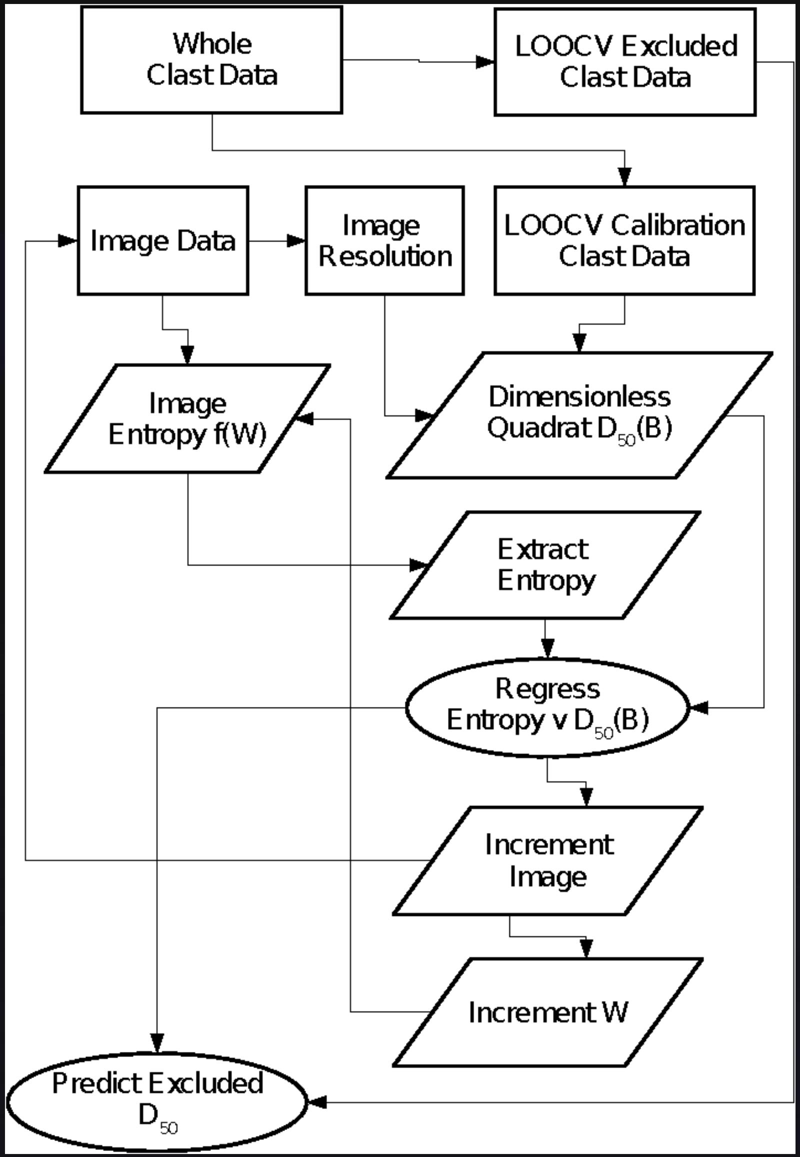
Examining the difficulties of Drone-based grain size mapping



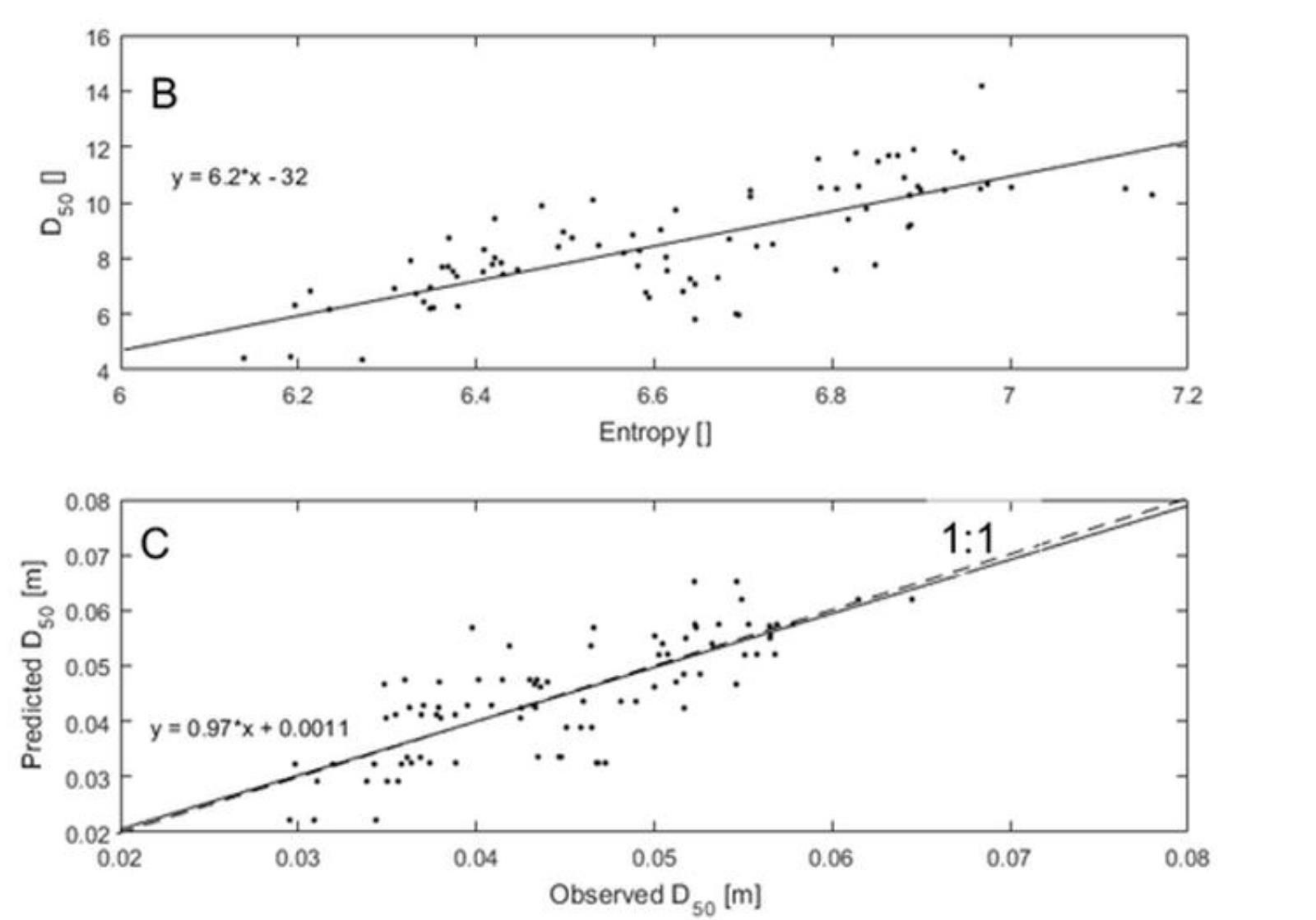
Updating the approach

Key points:

- Mechanical Image stabilisation
- Avoid quantitative analysis of orthoimagery



Results


B
y = 6.2*x - 32
D50 []
Entropy []
C
1:1
y = 0.97*x + 0.0011
Predicted D50 [m]
Observed D50 [m]

Using DG to remove ground data from grain size measurement

Earth Surface Processes and Landforms
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Letters to ESEX

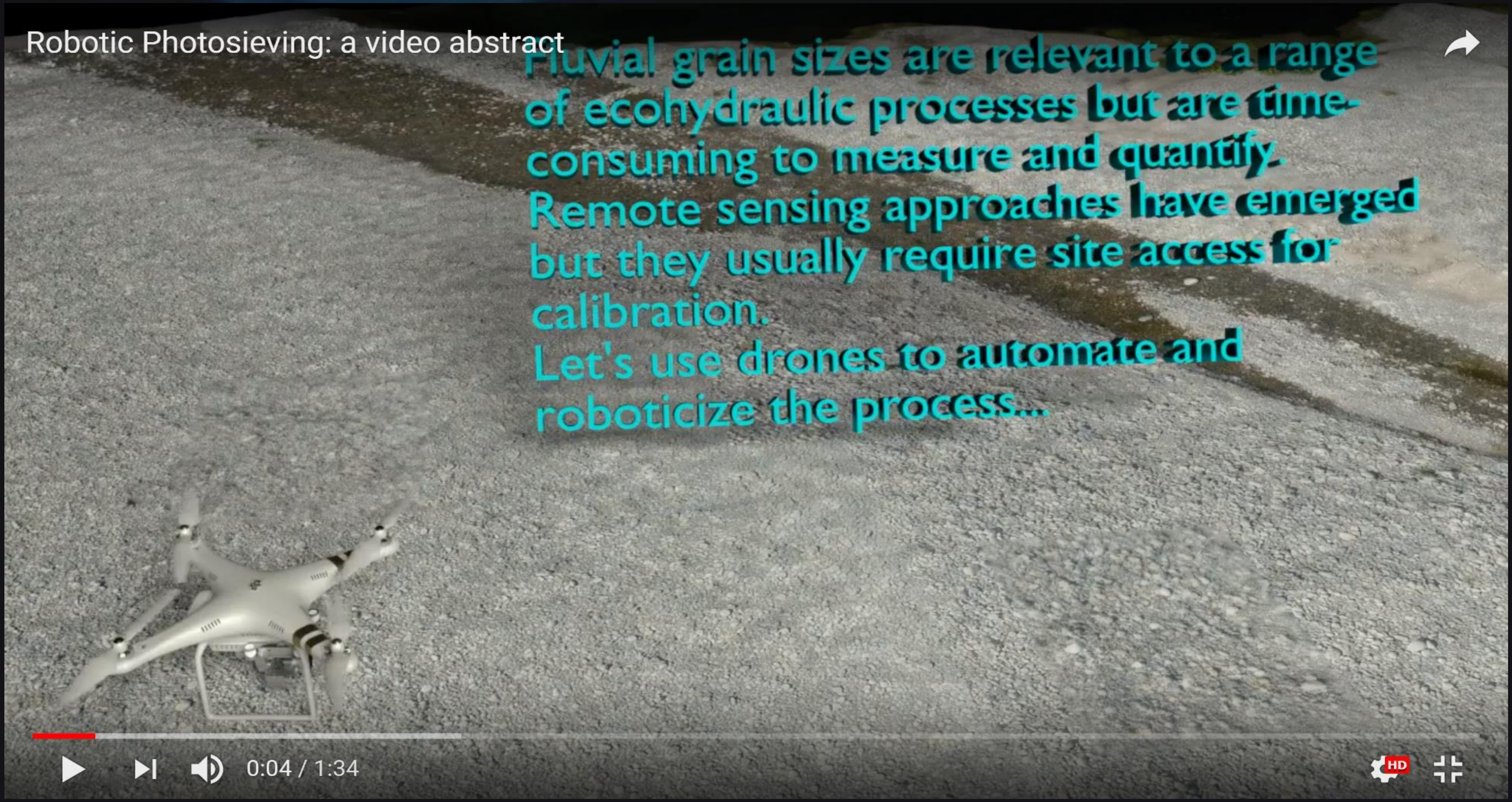
Robotic photosieving from low-cost multirotor sUAS: A proof-of-concept

P.E. Carbonnneau, S. Bizzi, G. Marchetti

Accepted manuscript online: 4 December 2017 Full publication history

DOI: 10.1002/esp.4298 View/save citation

Using DG to remove ground data from grain size measurement



The concept of Robotic Photosieving

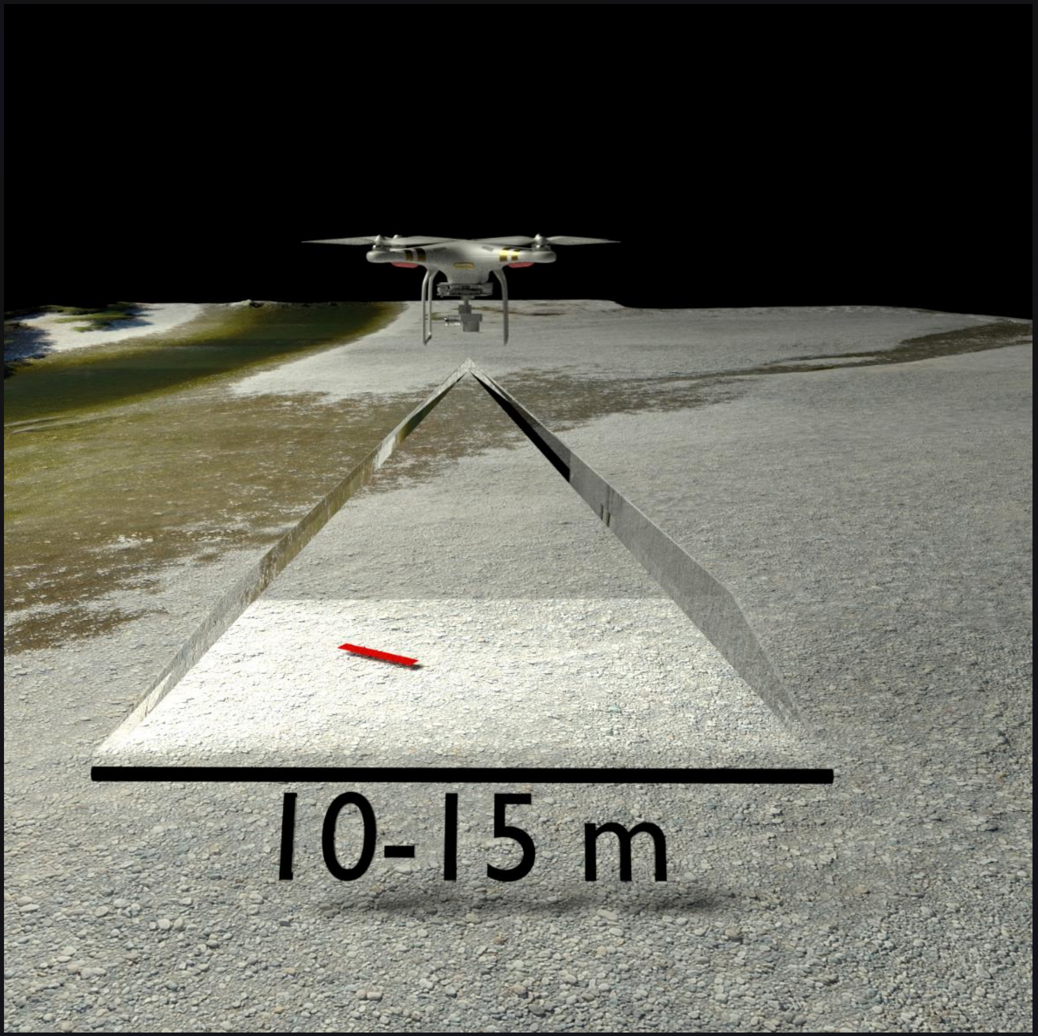
Replace ground samples of grain sizes with near-ground drone images. Use with SfM-photogrammetry to derive scale and particle delineation method to measure grains.

Use Direct Georeferencing to remove the need for ground control and thus remove the need for site access and manually collected calibration data.

Experimental Setup

Near-ground nadir imagery

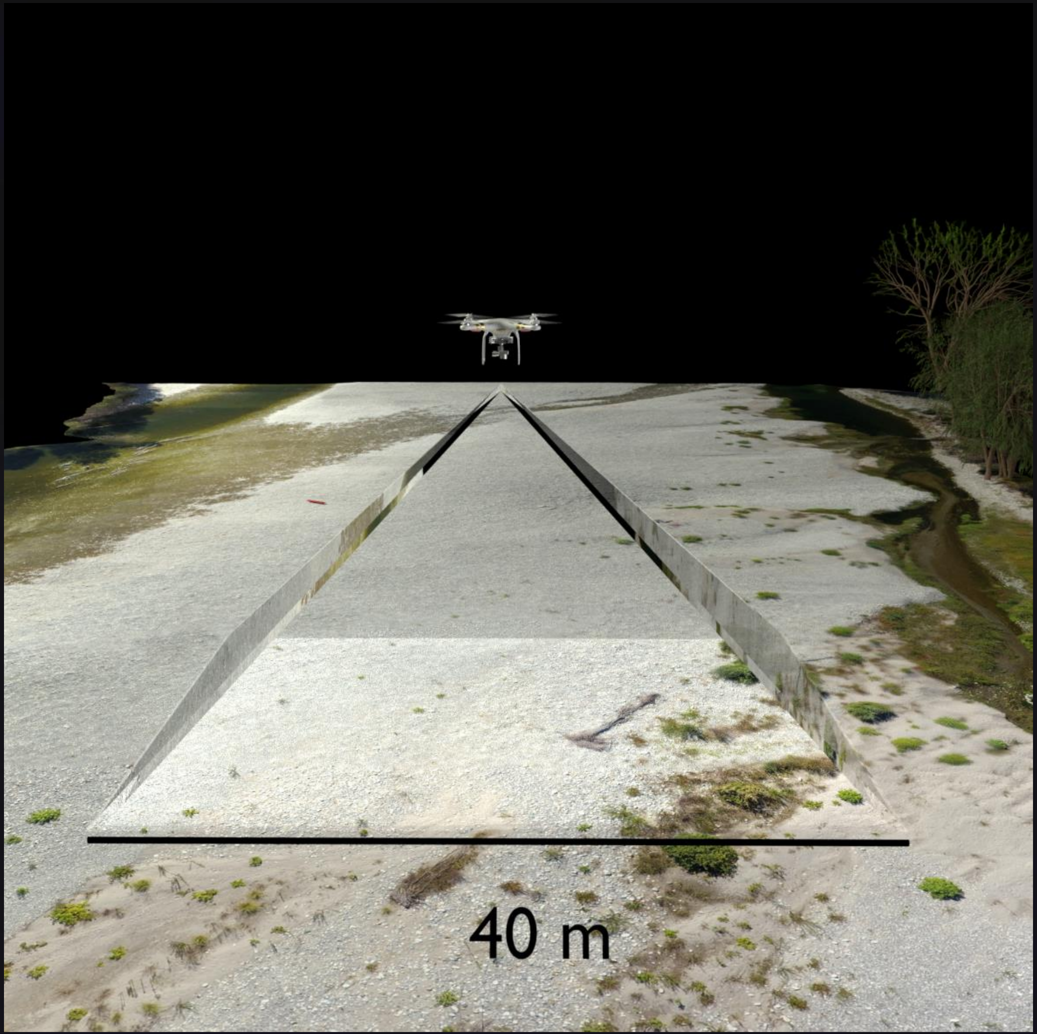
- Field sites in Nothern Italy, rivers Po and Sesia.
- We use 7 m AGL (14m image width)
- 3.3 mm spatial resolution
- 15 images (samples) per site that do not overlap.
- 31cm rulers included in the imagery to test scale predictions.



Experimental Setup

Mid-Altitude nadir imagery

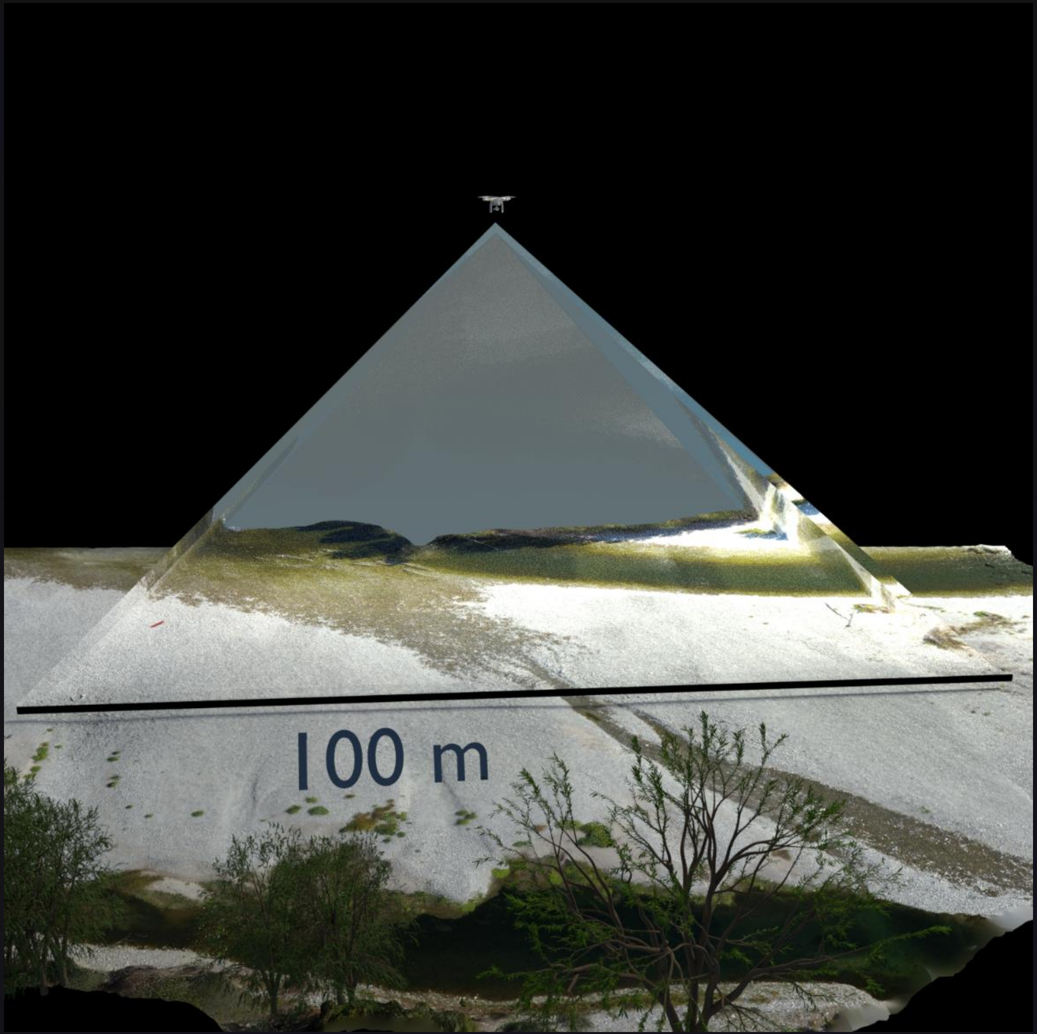
- We follow Carbonneau and Dietrich (2017). A Direct Georeferencing (DG) workflow that produces topography and orthoimagery WITHOUT ground control.
- Mid-altitude set at 20 m AGL (40 m image width). 1cm spatial resolution.
- From 181 to 272 images (depending on site area).
- Images are taken at nadir with 80% forward overlap and 50% sidelap.



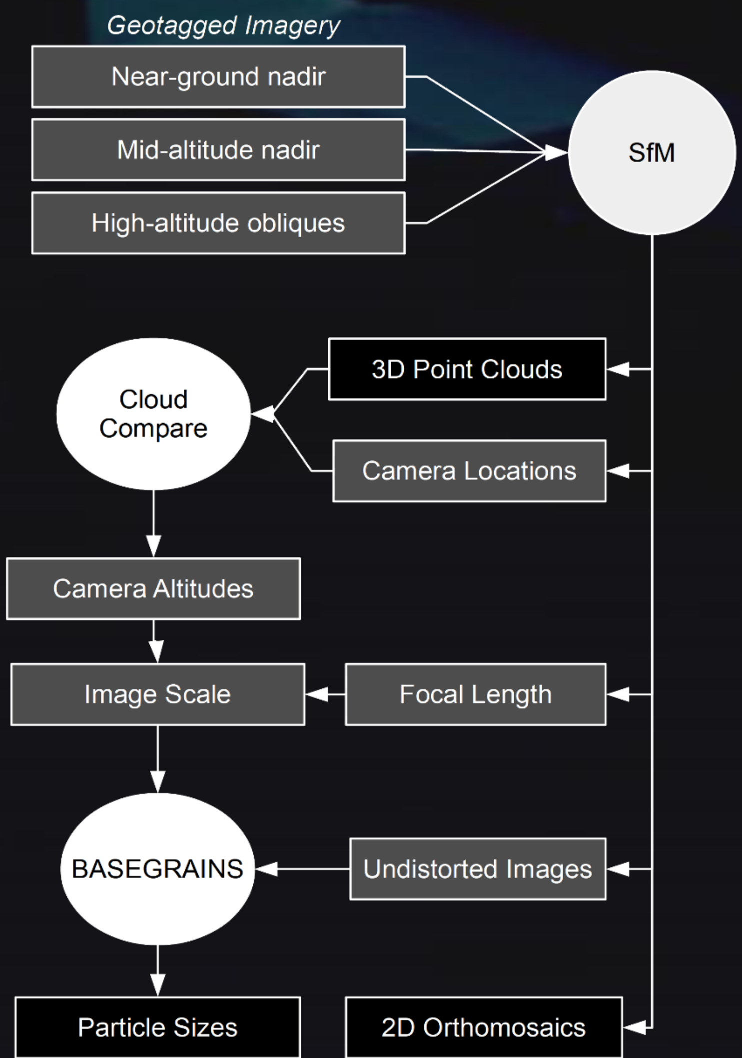
Experimental Setup

<u>High-Altitude oblique imagery</u>

- Required to calibrate drone camera if not using GCPs.
- Set at 50 m AGL (100 m image width) with a 30° off-nadir angle.
- From 30 to 50 images (depending on site area).



Processing Chain



3 key software steps:

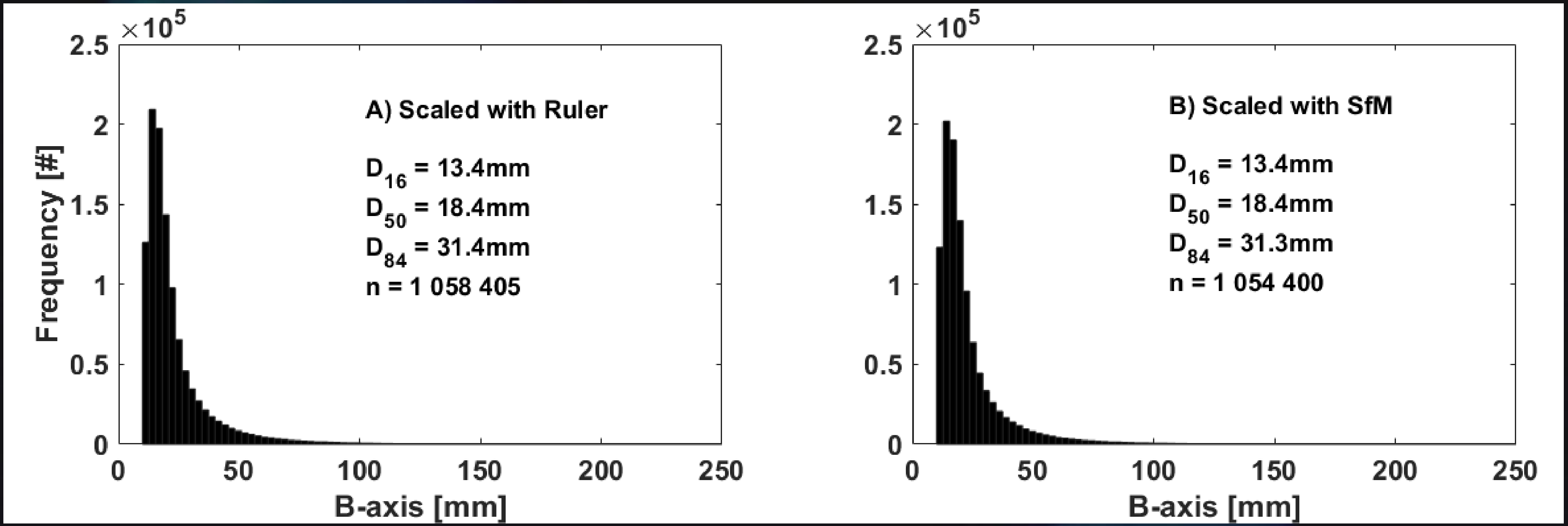
SfM processing of drone images (Photoscan) to derive camera focal (f), camera locations and topography. We also produce undistorted images.

Point Cloud analysis in Cloud Compare to derive exact altitude AGL (H). We can now calculate image scale (S):

$$S=f/H$$

We then use BASEGRAINS to delineate particles and obtain common grain size fractions (D_{16}, D_{50}, D_{84})

Results: Grain Size Prediction



Robotic Photosieving works. The resulting distribution is statistically identical when compared to the equivalent distribution that was scaled with manual ruler measurement.

Future Deployments of Robotic Photosieving

We do NOT need to deploy rulers to calibrate the scale.

We do NOT need to deploy ground control points.

The method is now purely remote, site access is not required.

We can fly much lower to improve the spatial resolution of the near-ground imagery and thus improve the measurement of small grains.

With collision avoidance technology, flights as low as 1-2 meters are safe.

Wider Implications

Robotic Photosieving can be used on its own to sample grain sizes at the reach scale.

It can be used to calibrate statistical methods that can map grain sizes at larger scales.

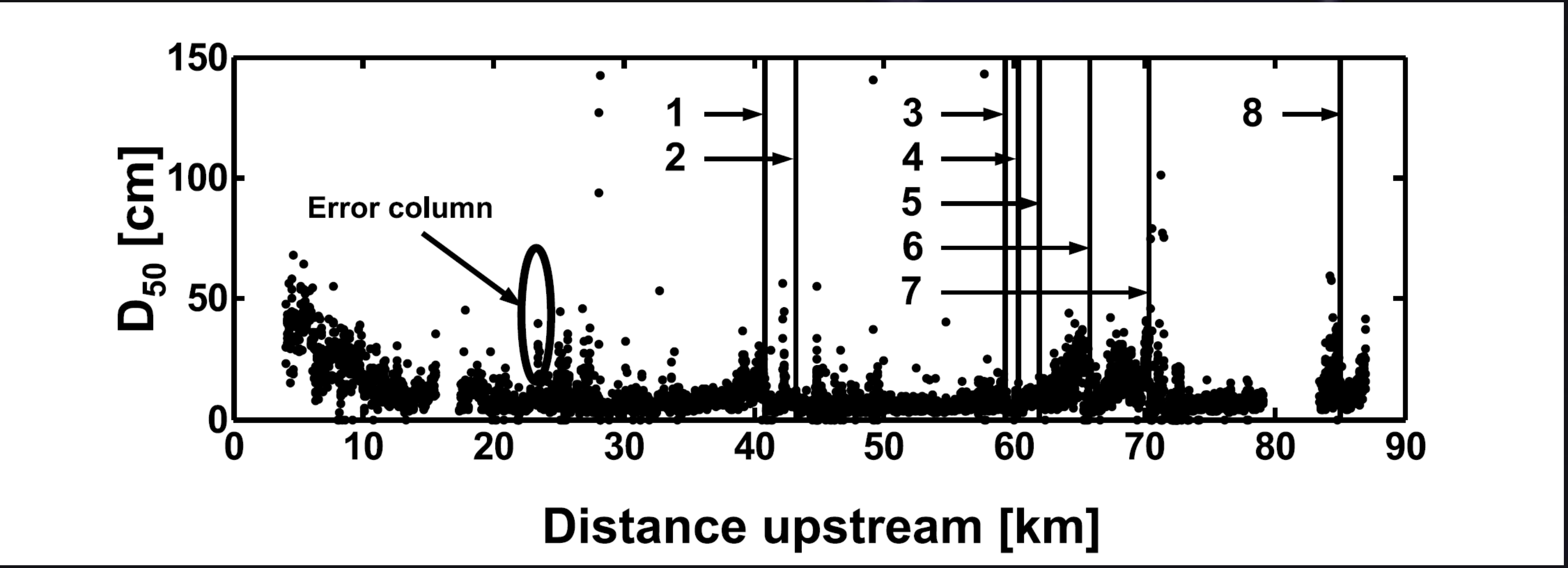
Drones as fieldwork robots.

What have we gained?

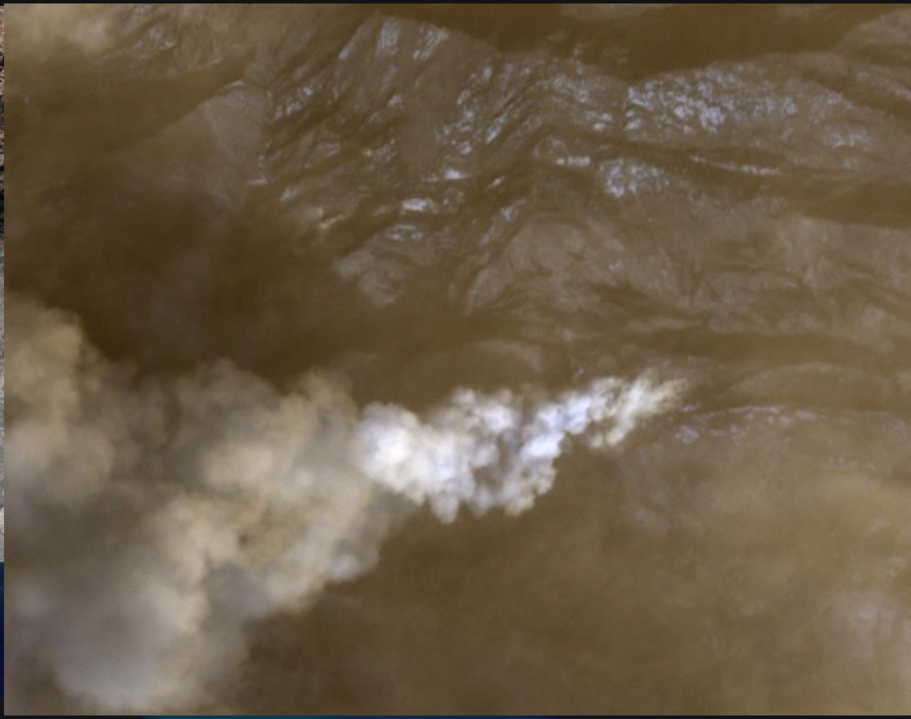
- A low-cost basic mapping methods with a hyperspatial (<5cm) resolution capable of determining channel widths and identifying morphological units (channel types, bars, barriers, etc).
- Methods to measure grain sizes, at leat at low flow on dry sections.
- Methods to characterise depth and velocity (next speaker)
- Methods to map morphological habitats.
- Most of these are very cost-effective and very close to actual deployment outside academia.

What have we lost?

- <u>SCALE</u>!
- Watershed scale science questions.
- Watershed scale management strategies.



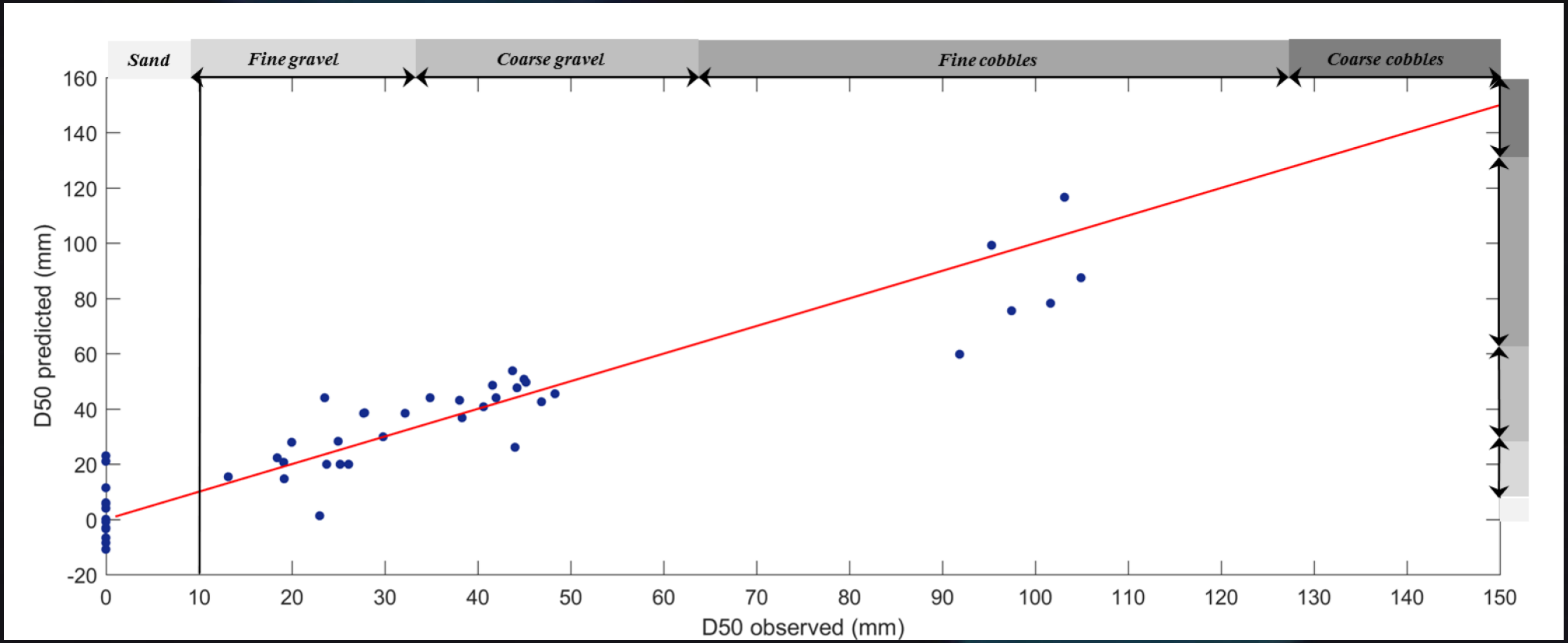
Where do we go now?



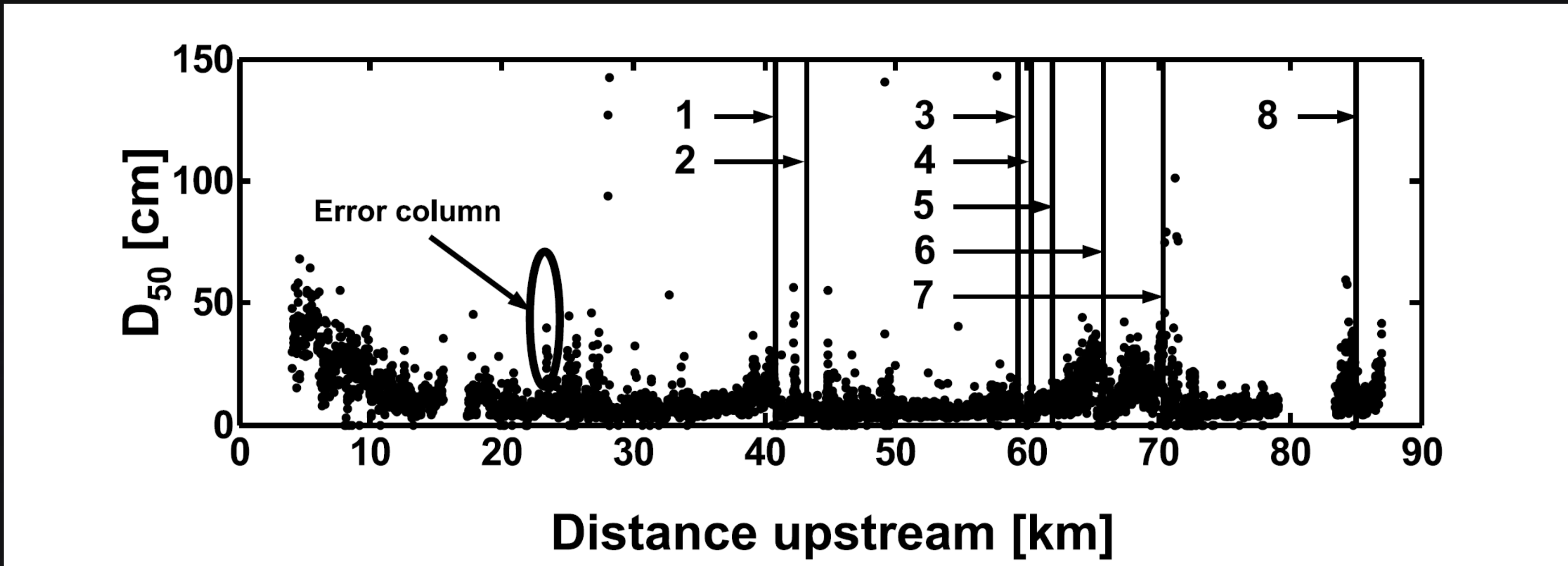
Sentinel 2 image of California fires.
10m RGB-NIR
20+60m multispectral

PlanetScope image.
3m RGB-NIR

Calibrating orbital remote sensing with drone fieldwork robots



Marchetti et al, *in prep for Remote Sensing of Environment*



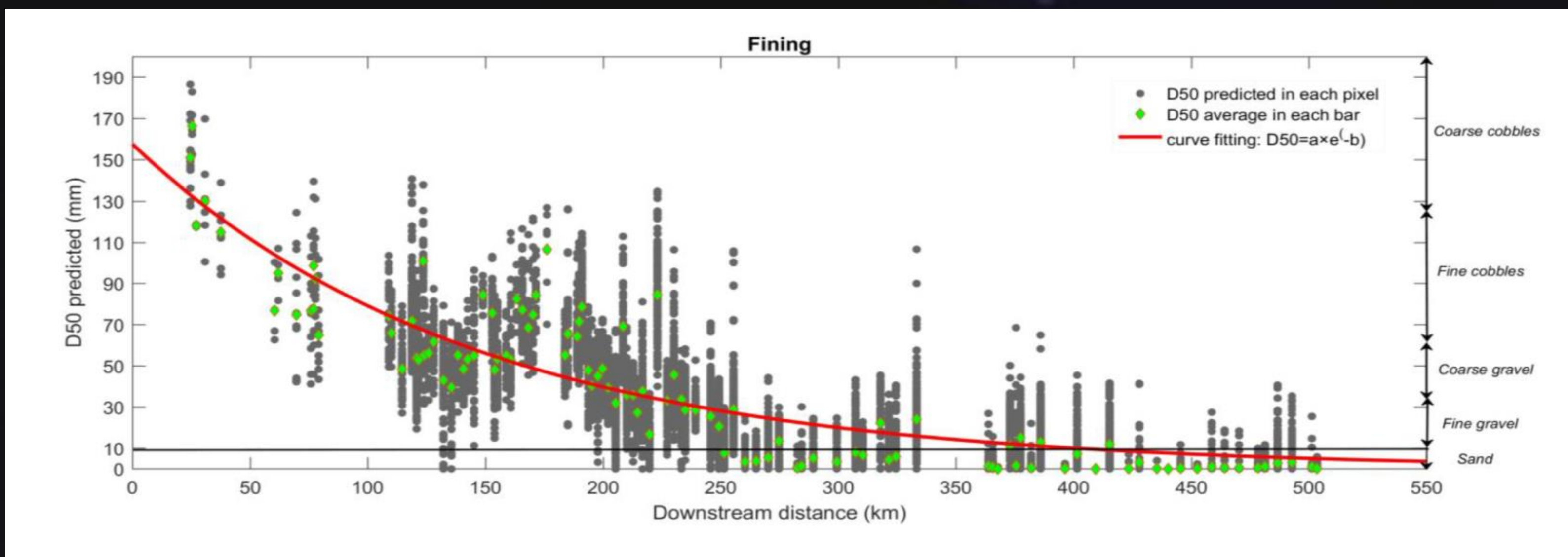


Figure 30. Fining process along the Po river.

Marchetti et al, *in prep for Remote sensing of environment*

Conclusions

- UAVs are delivering unprecedented options for river science and management in terms of basic mapping and more advanced parameter retrieval.
- We need to be honest and realistic about their actual potential. The issue of scale must be resolved, not just mentioned as a minor limitation in our papers.
- Progress of satellite remote offers a possible niche for drones as calibration robots.
- A future of BVLOS robots everywhere, or more controlled VLOS ops?