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The potential of UAVs in monitoring hydro-geomorphological surface processes

Stuart N. Lane
Chrystelle Gabbud, Lisa Ruëger; Jessica Mühlematter, Alice Child, Sébastien Ruttiman

Institute of Earth Surface Dynamics

stuart.lane@unil.ch

| le savoir vivant |

Introduction : some history

Photogrammetry is defined by the American Society of Photogrammetry (in Wolf, 1983; p1) as:

'...*the art, science and technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring and interpreting photographic images and patterns of electro-magnetic radiant energy and other phenomena*...'

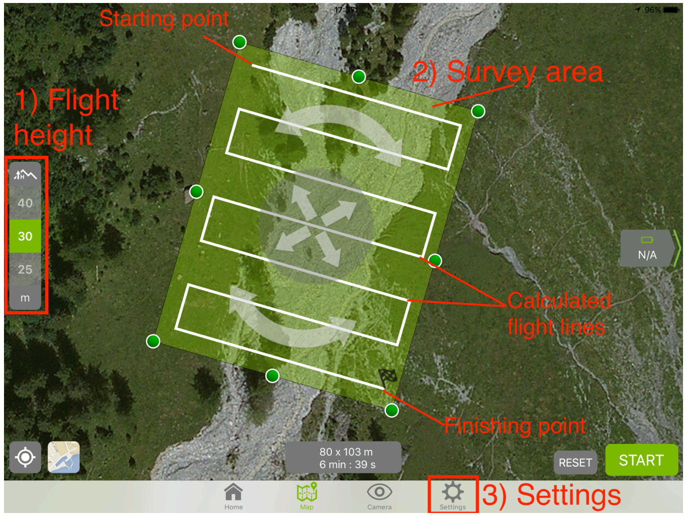
Source: H. Rentsch

Glacier Mass Balance
Finsterwalder: 1899 onwards

Introduction : some history

A long history but with two major recent developments

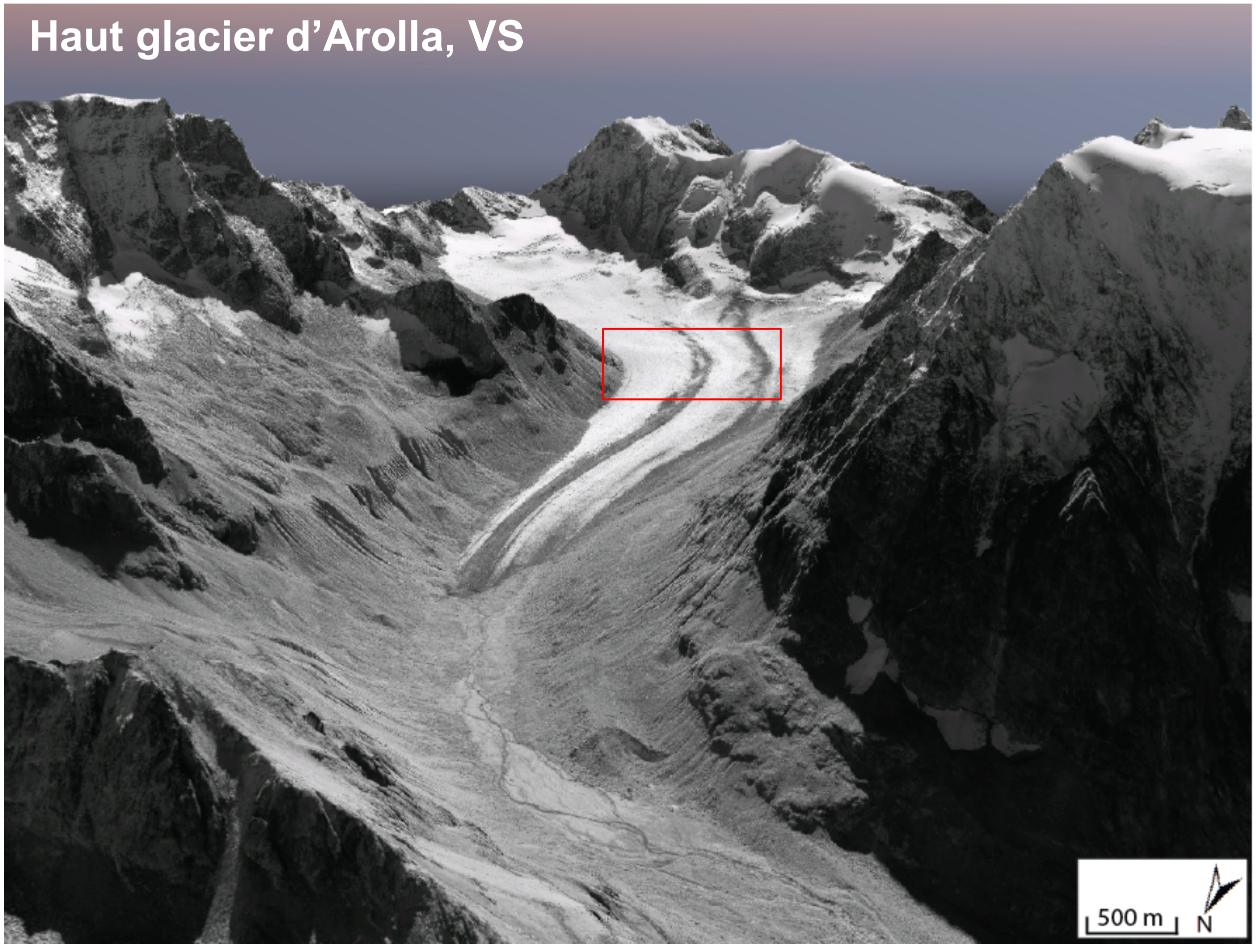
1. Unmanned Airborne Vehicles that can be controlled to collect data that fulfil the requirements of photogrammetric analysis
2. The development of a new approach to photogrammetry within machine vision, *Structure from Motion*, which has substantially improved data handling



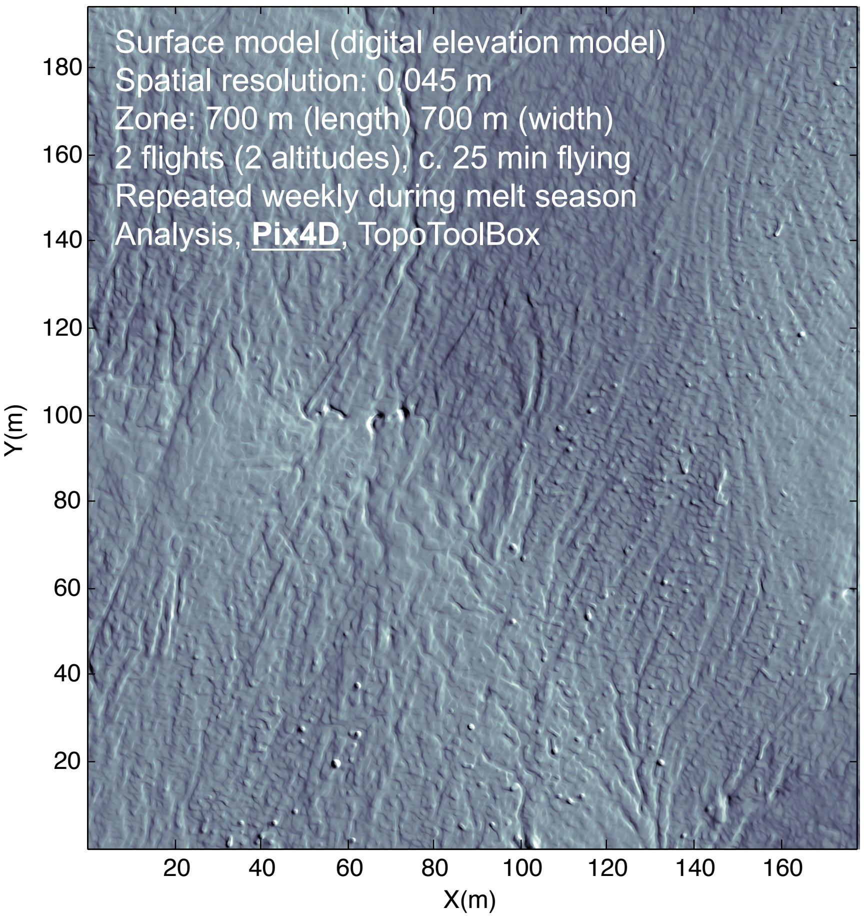
Structure/approach

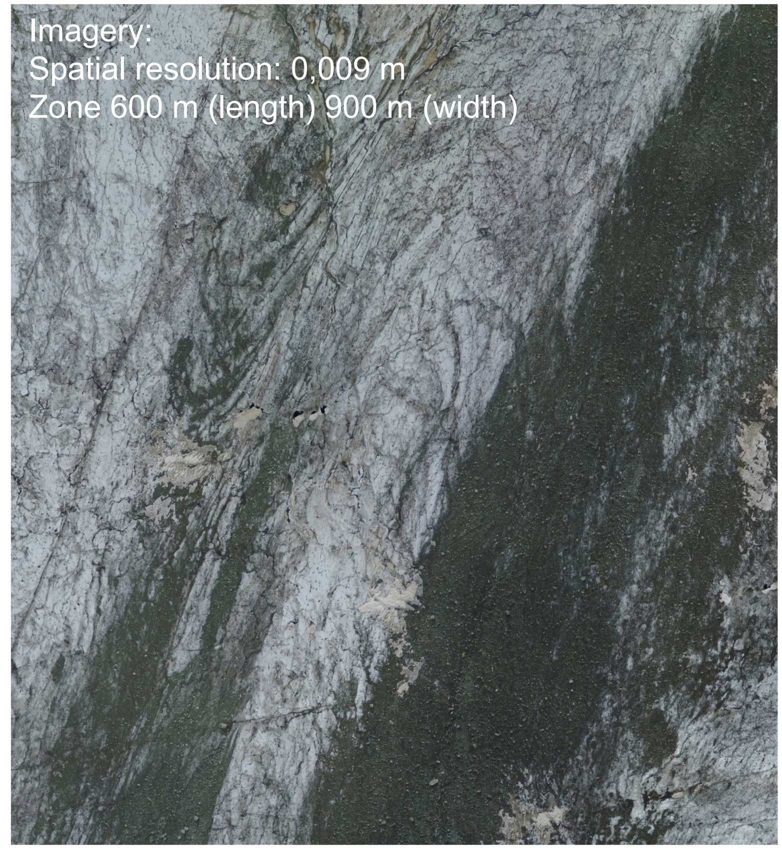
1. **Process hydrology**:
   - ***Illustration***: Quantifying the evolution of glacier surface hydrology, Haut glacier d'Arolla, VS
   - ***Opportunity***: change detection
2. **River restoration:**
   - ***Illustration**:* Following stream restoration projects, Aire, GE
   - ***Problem and solution**:* stream bathymetry
3. **Minimum flow analyses**:
   - ***Illustration***: Rapid and automated stream habitat modelling, Dranse de Bagnes, VS
   - ***Opportunity***: grain size mapping
4. **Sediment flows or "Sed-Flows":**
   - ***Illustration***: Extending minimum flows to account for sediment impacts in high mountain streams, Borgne d'Arolla, VS
   - ***Problem and solution**:* camera calibration

1. Process hydrology



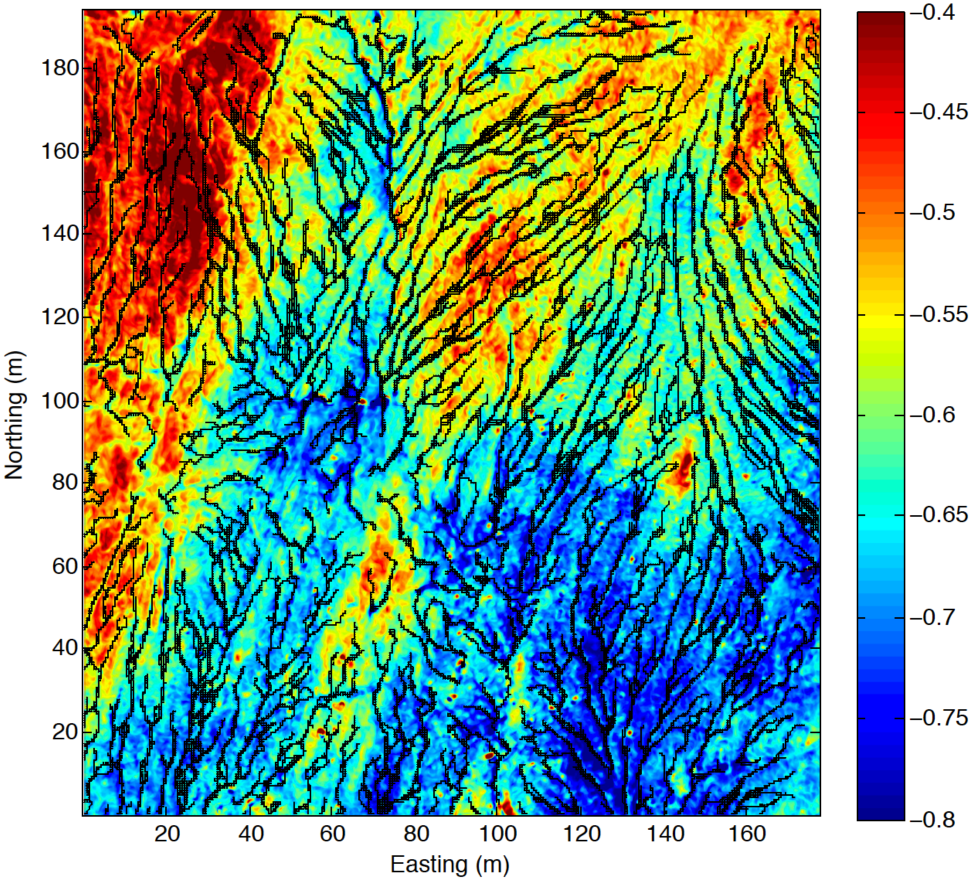
1. Process hydrology



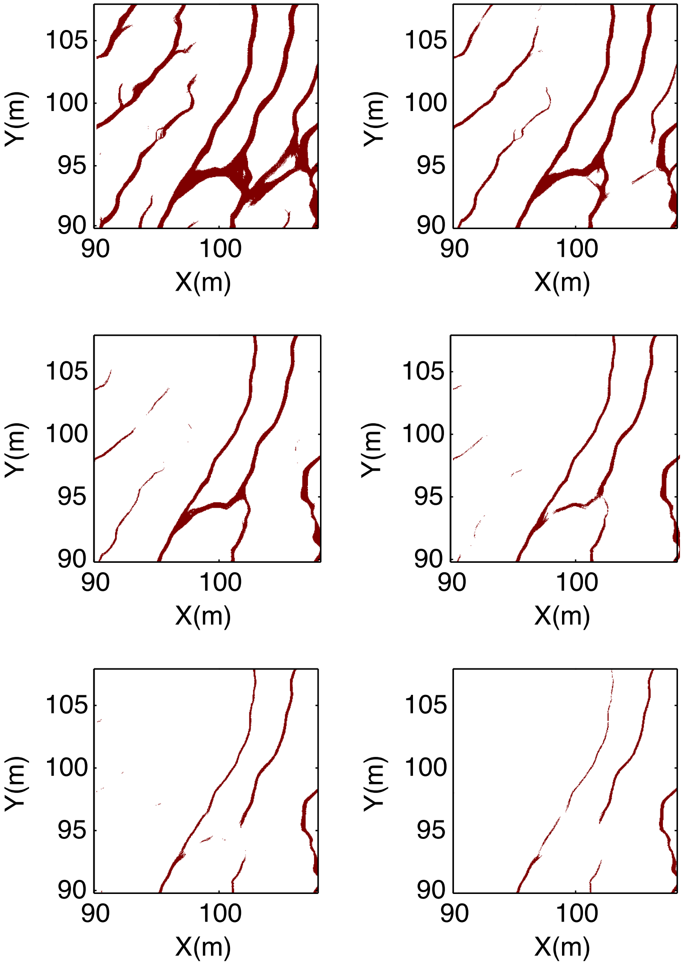


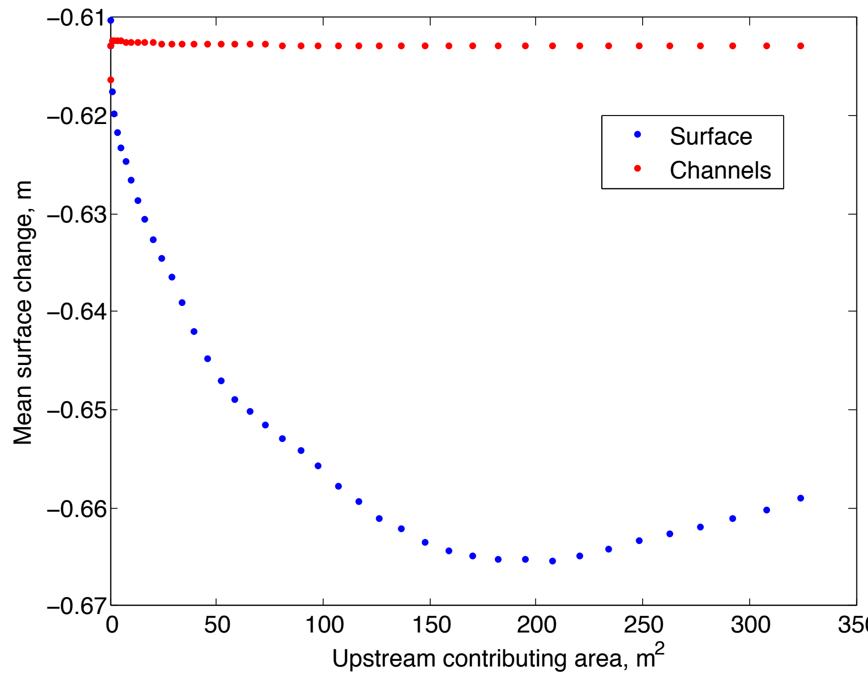
1. Process hydrology

Surface change, 10th – 22nd August 2016
Plus, drainage network

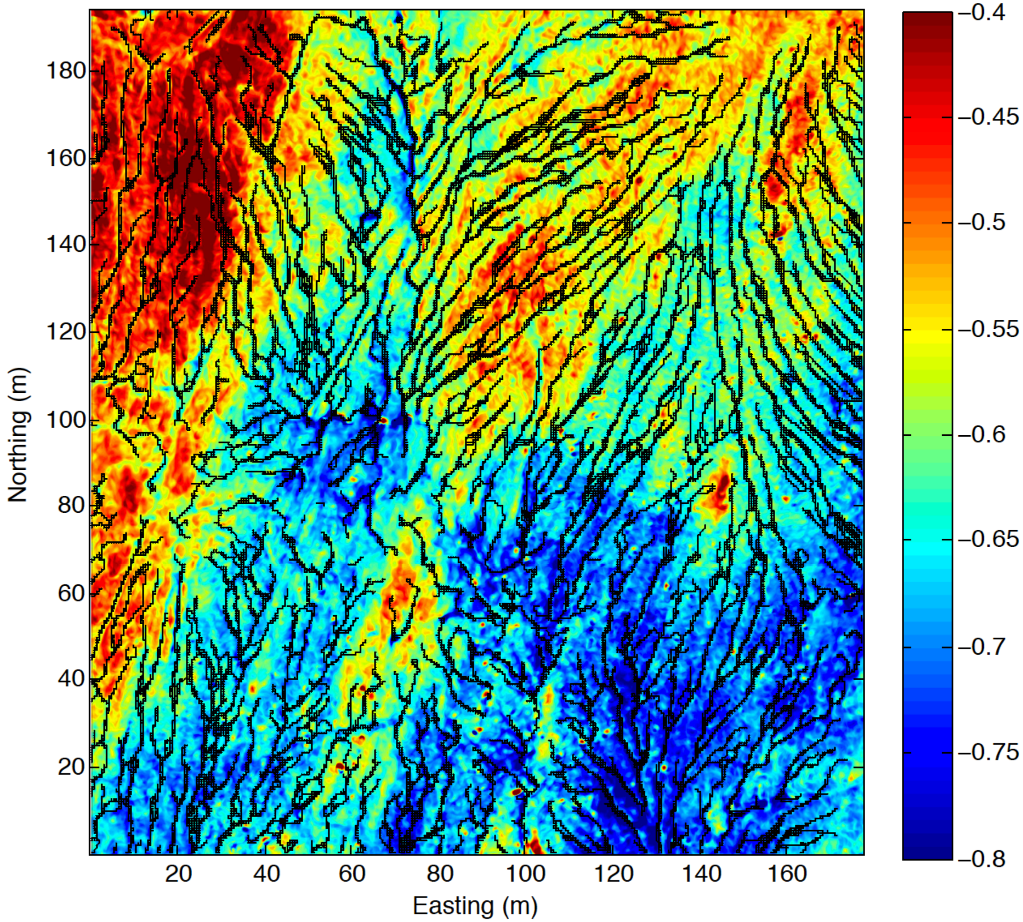


Process hydrology

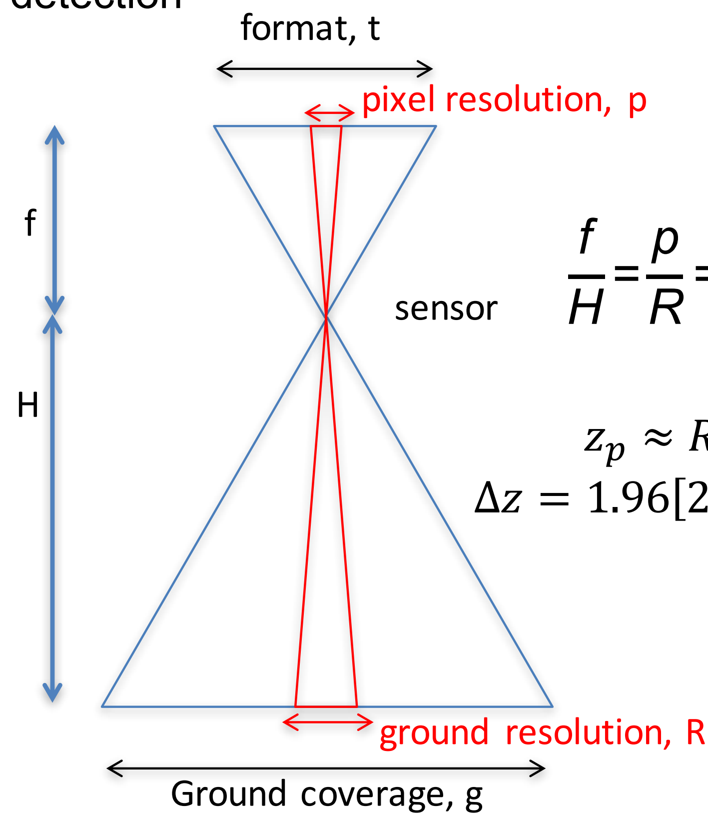




1. Process hydrology:
the opportunity



Key point: user-controlled resolution, altitude precision (z_p), and change detection



$$\frac{f}{H} = \frac{p}{R} = \frac{t}{g}$$

$$z_p \approx R$$

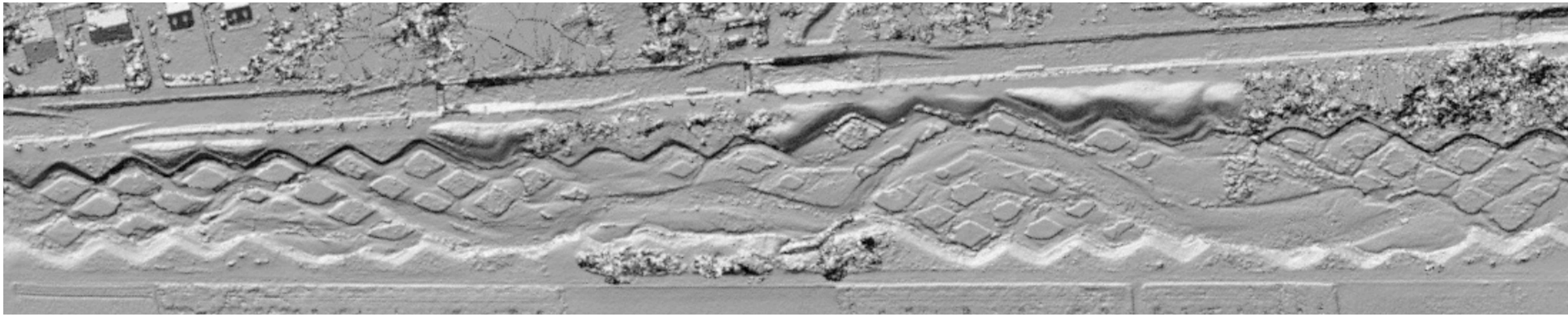
$$\Delta z = 1.96[2R^2]^{0.5}$$

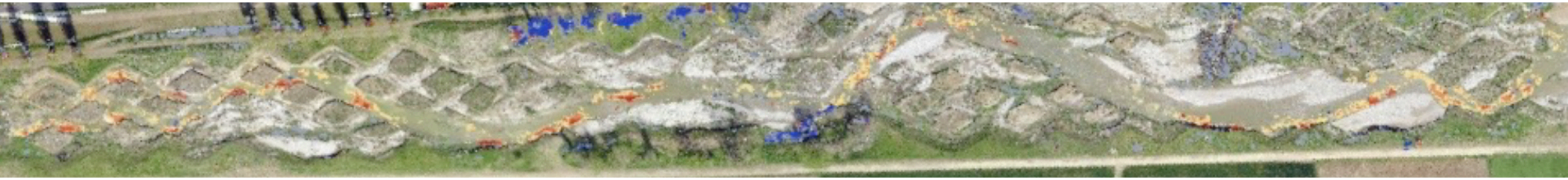
2. Following River Restoration

River Aire, West of Geneva City

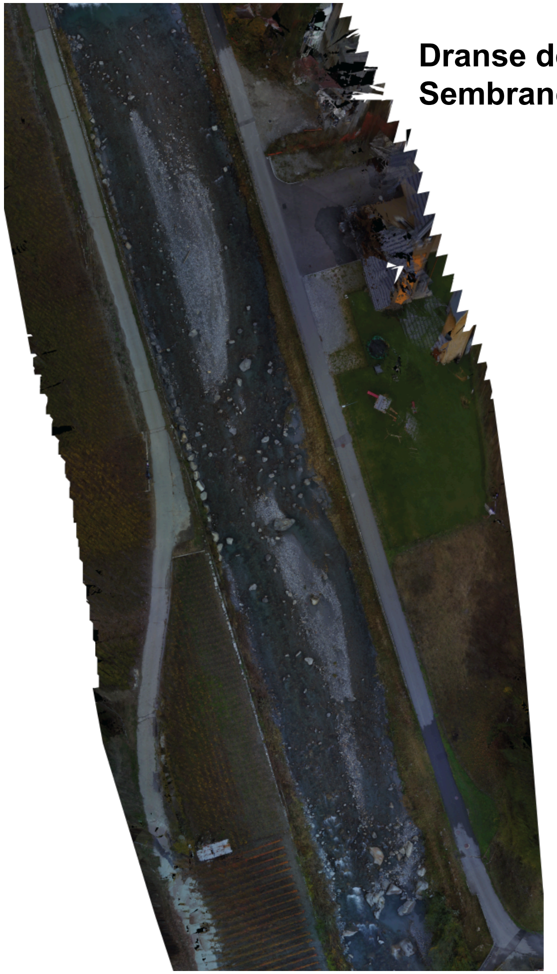
2. Following River Restoration

SenseFly, Ebee





2. Following River Restoration
The stream bathymetry problem



Dranse de Bagnes
Sembrancher VS

Westaway, Lane, Hicks, 2001. *Photogrammetric Engineering and Remote Sensing*, 67, 1271-81

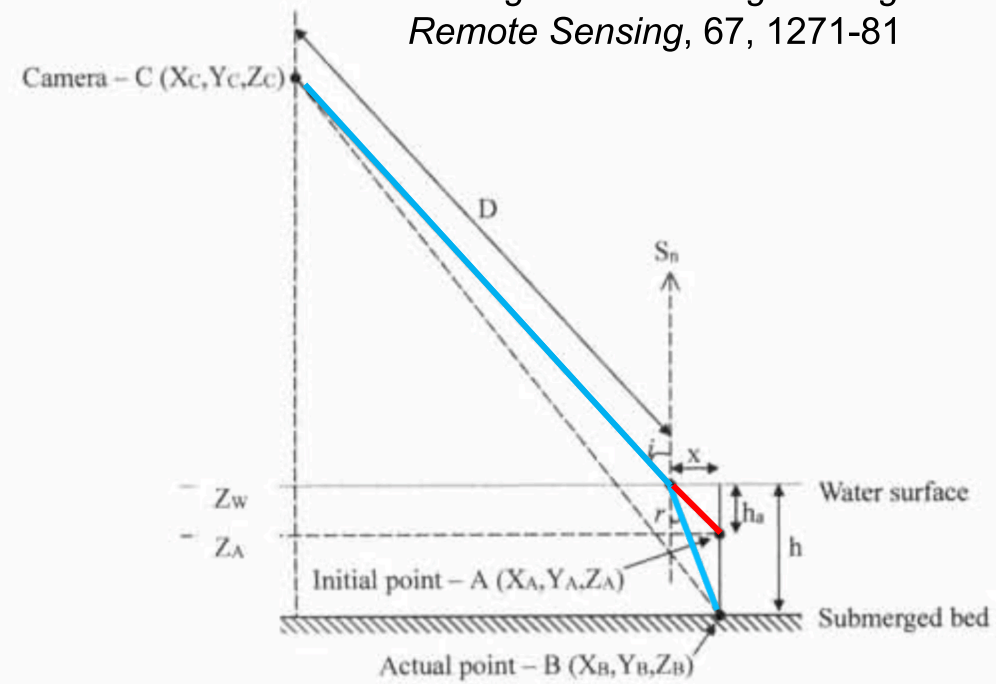


Figure 5. The relationship between camera location, water surface elevation, apparent water depth, and actual water depth.

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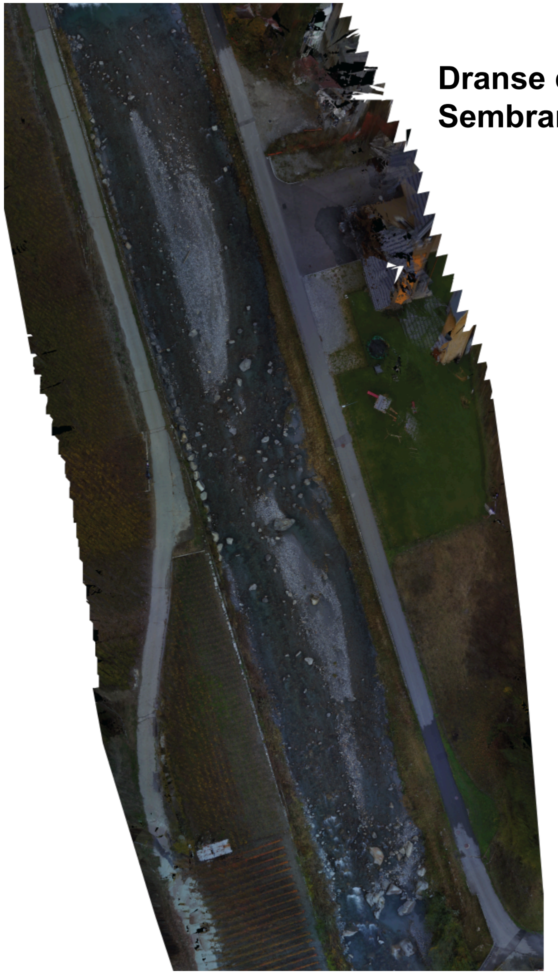
The stream bathymetry problem



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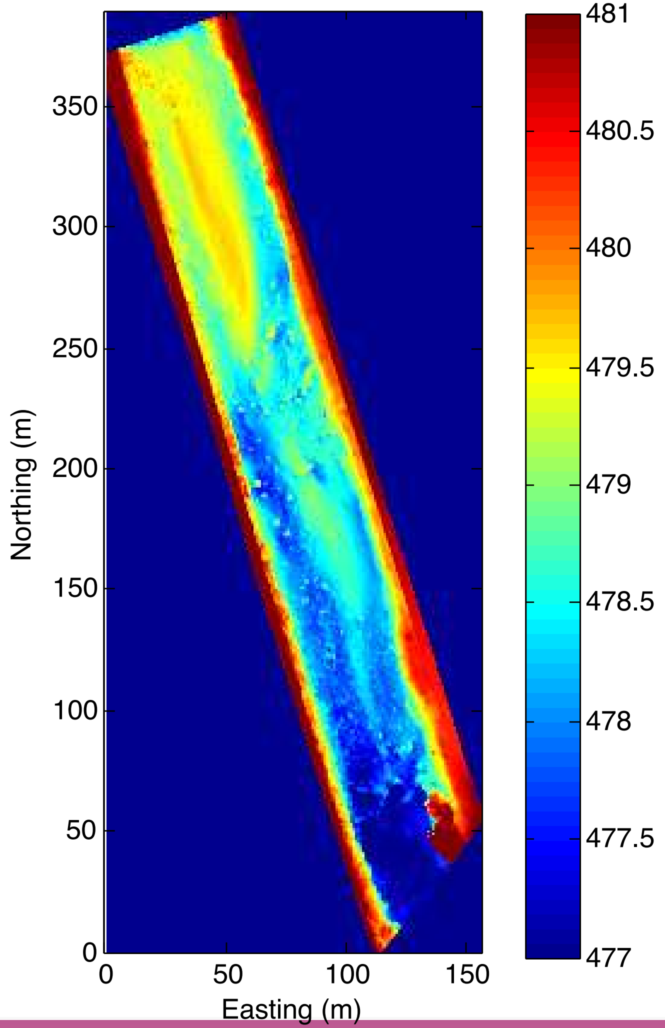


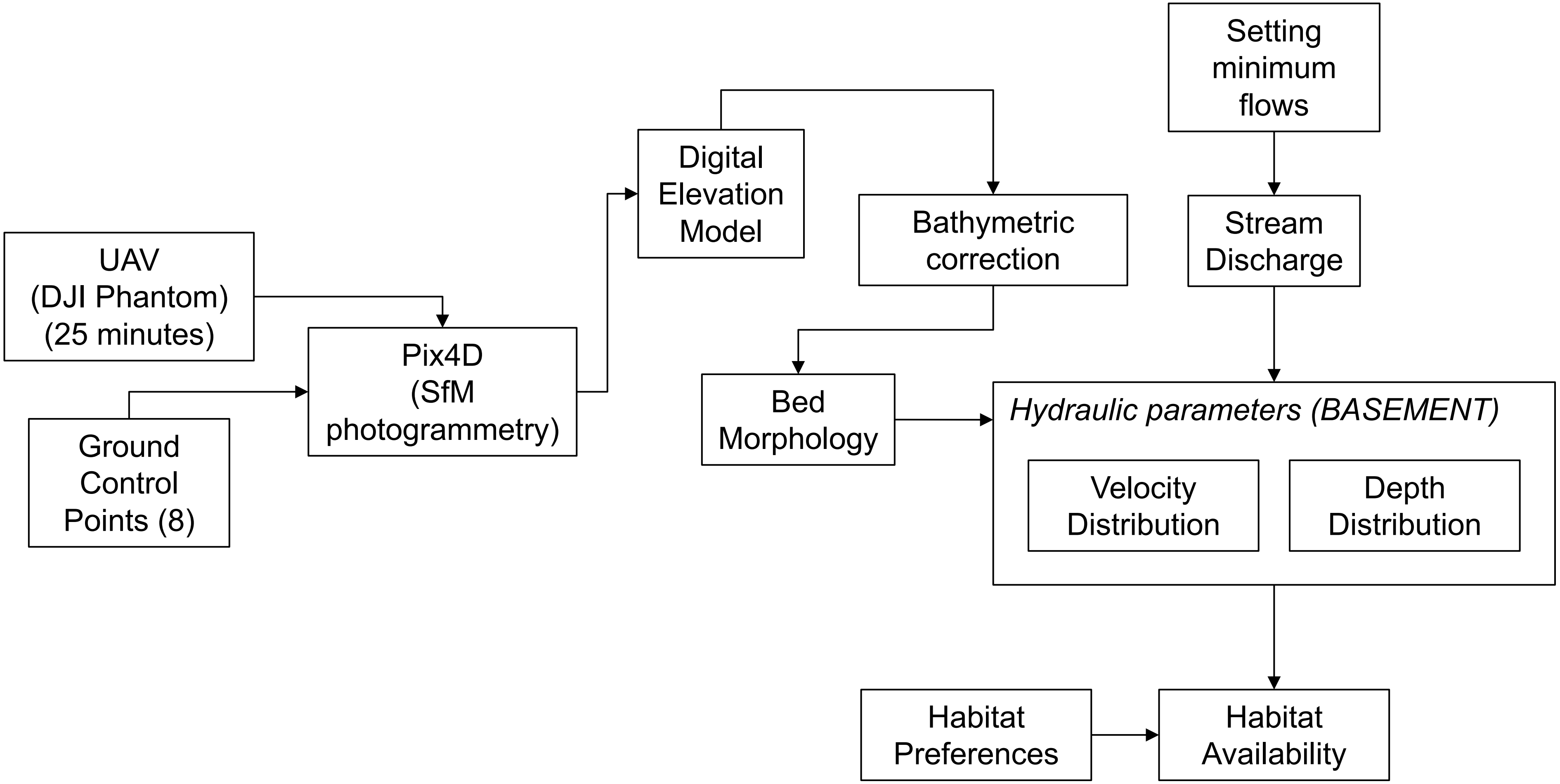
2. Following River Restoration
The stream bathymetry problem

PhD student, UNIL
Gilles Antoniazza
Glacier d'Otemma, Haut Val de Bagnes VS

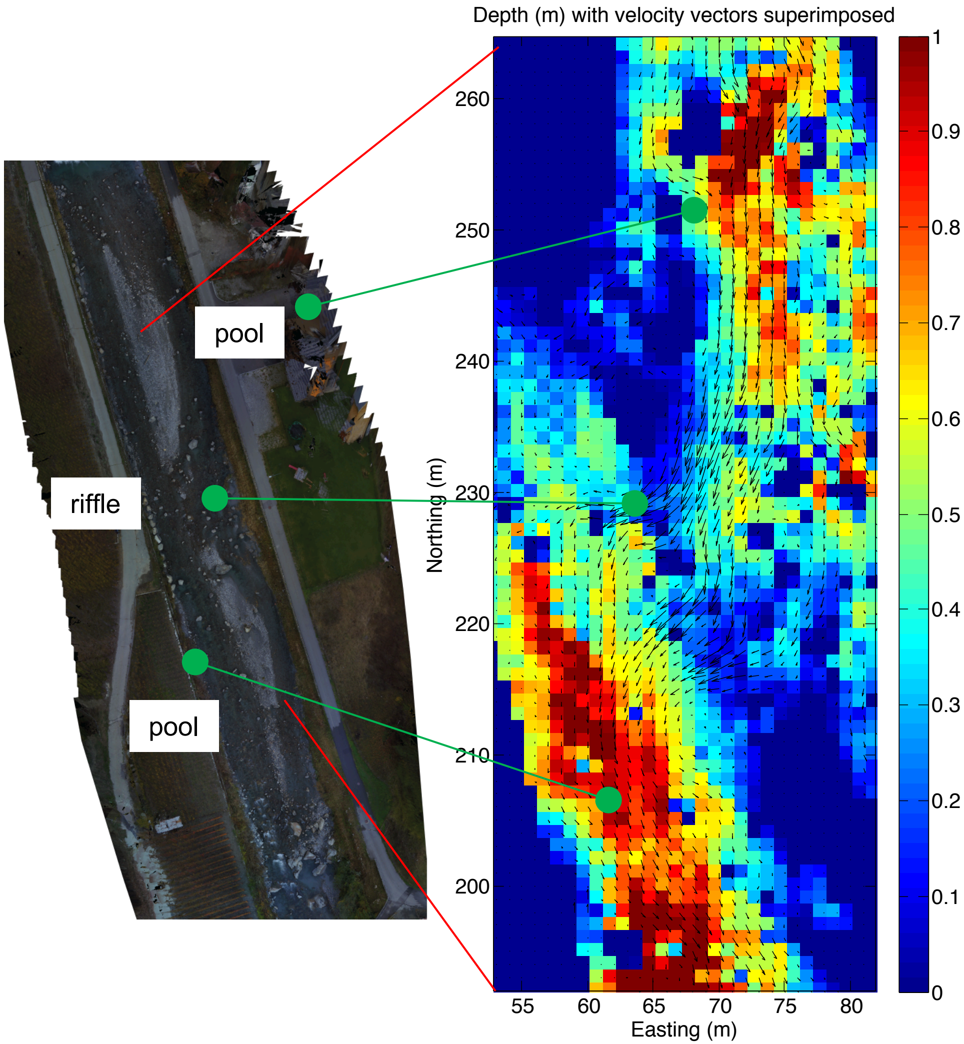
Lane et al., 2010. *Earth Surface Processes and Landforms, 35, 971-85*

3. Setting minimum flows

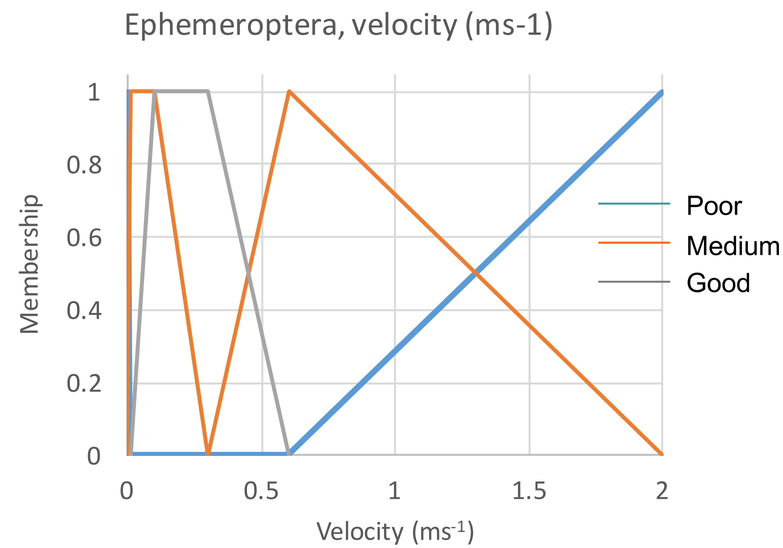
Opportunity :
better application of mathematical models of fluvial processes



3. Setting minimum flows



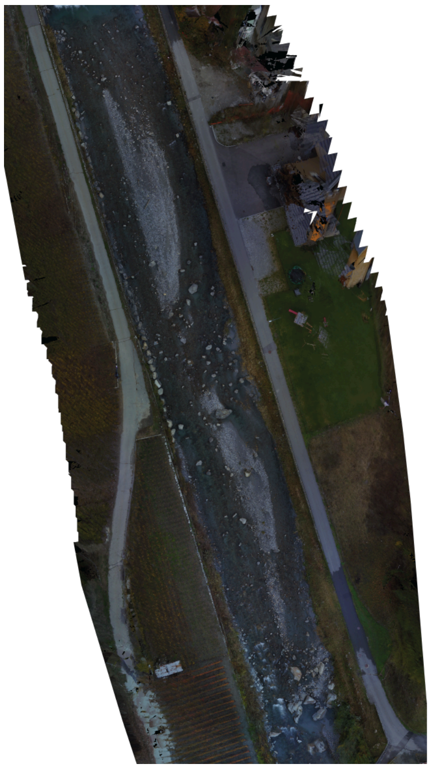
Ecological knowledge

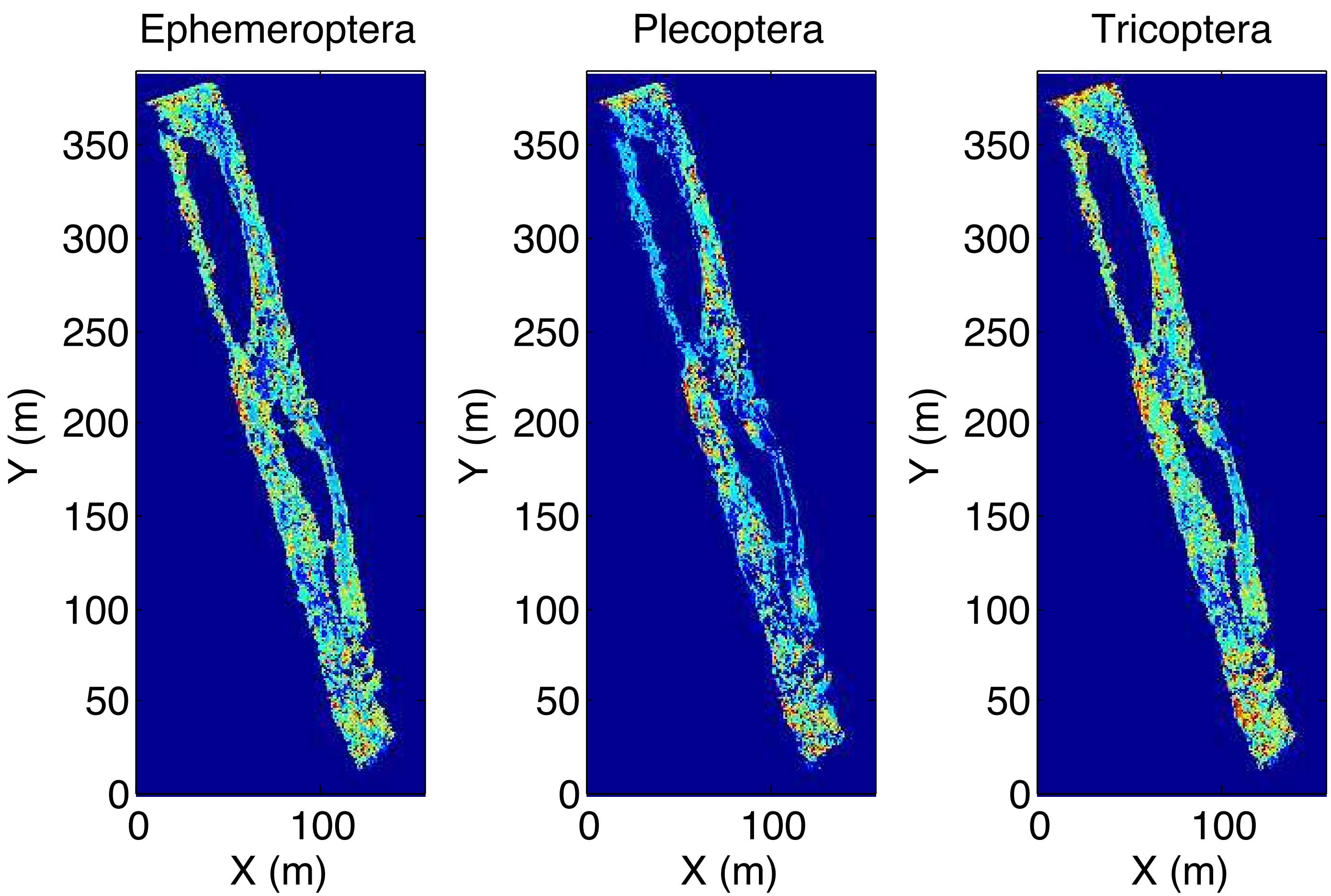


			Velocity	
		Poor	**Medium**	**Good**
	Poor	1	2	3
Depth	**Medium**	2	3	4
	Good	3	4	5

1 Poor to 5 Excellent

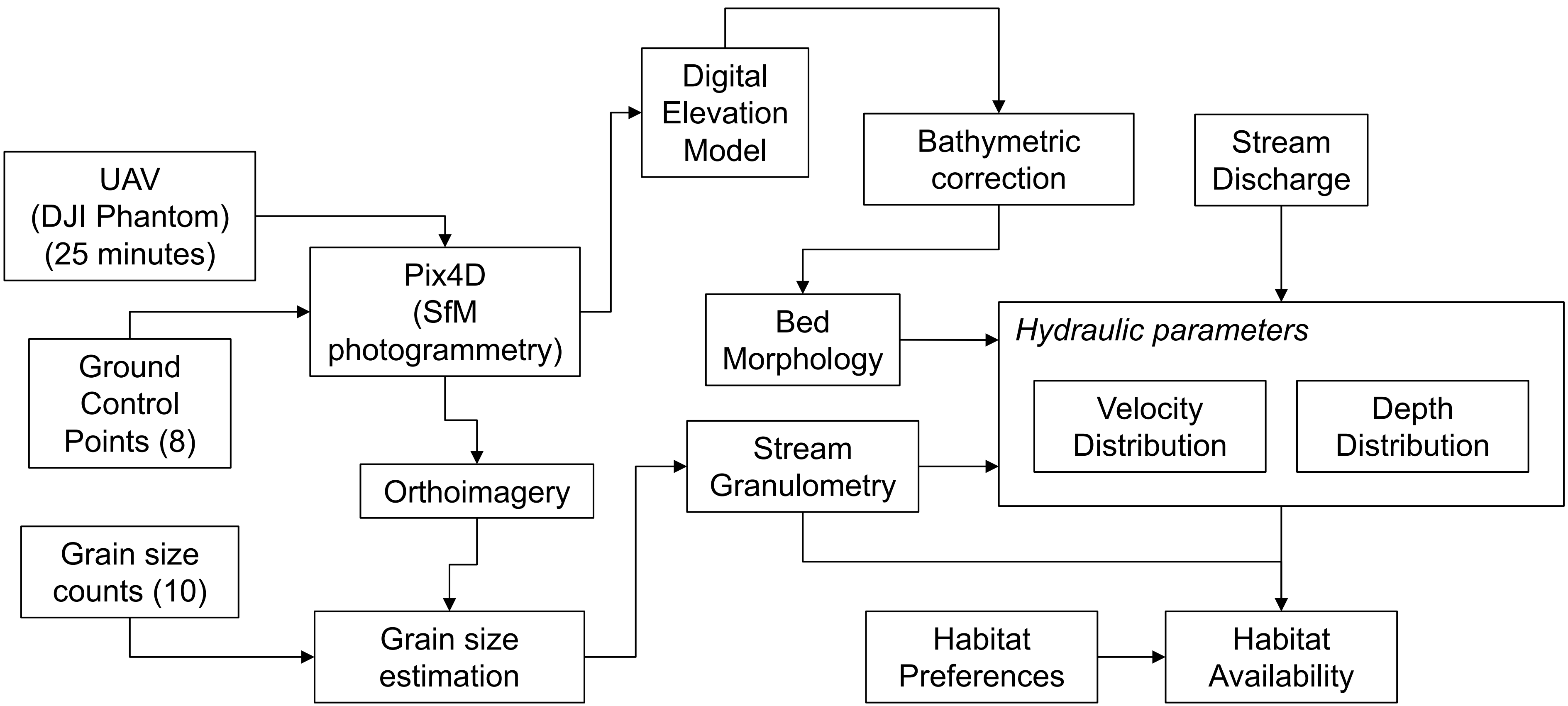
3. Setting minimum flows





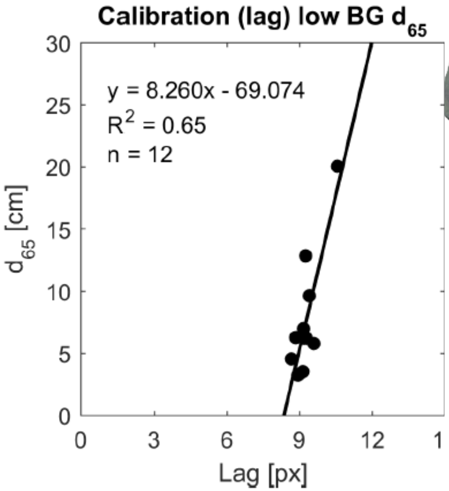
3. Setting minimum flows

Additional opportunity: grain size mapping from UAV imagery

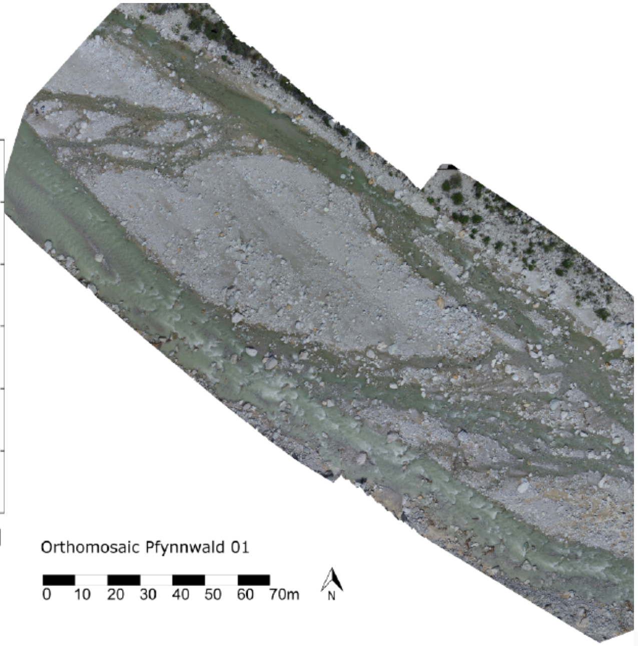


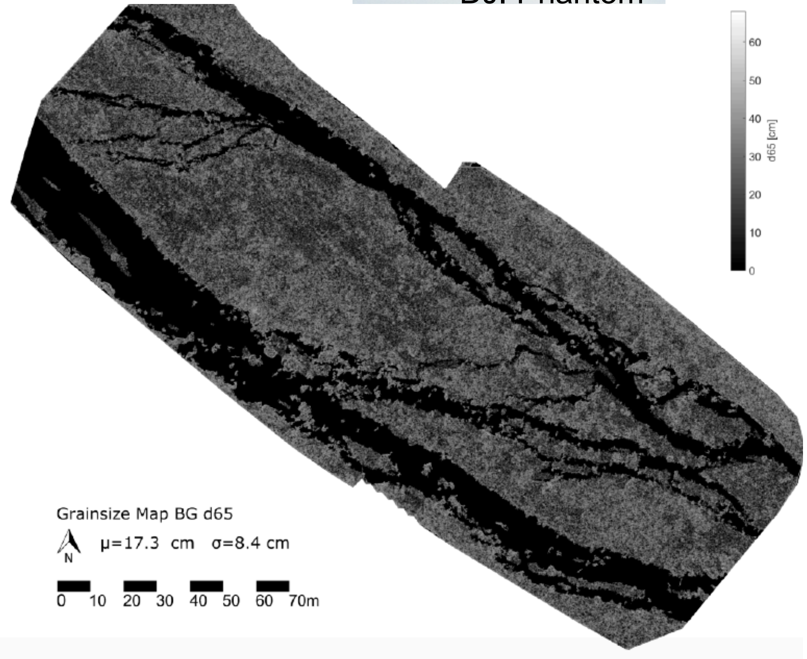
3. Setting minimum flows
Grain size mapping from UAV imagery

Project with Florian Textor, Peter Molnar, ETHZ

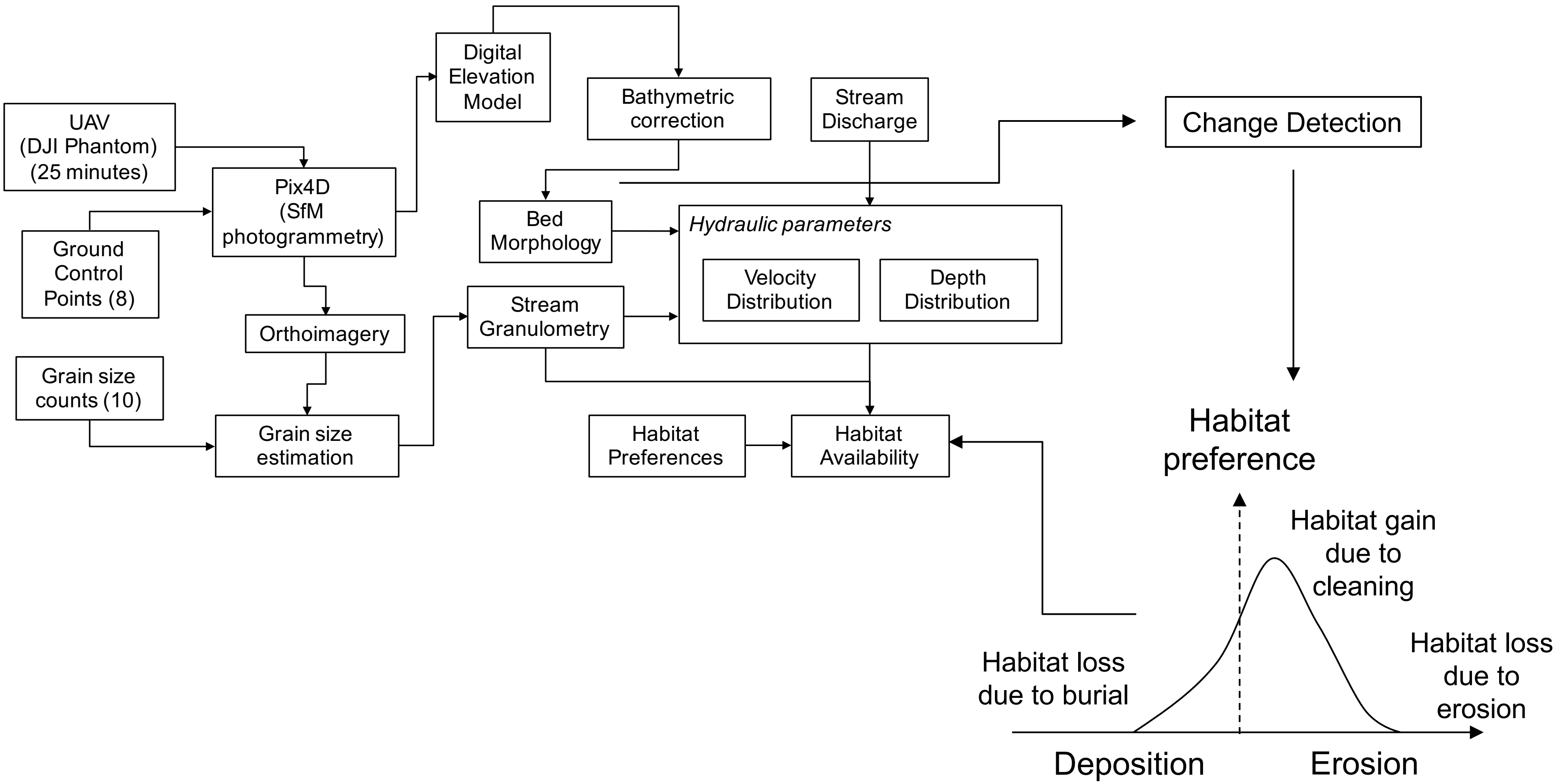


Mesures of 2D surface roughness from the orthoimagery





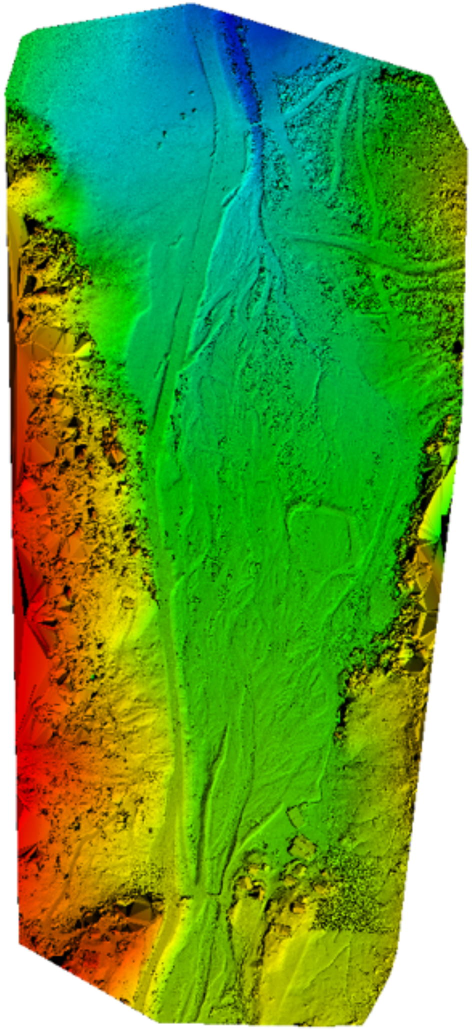
From setting minimum flows to setting sed-flows

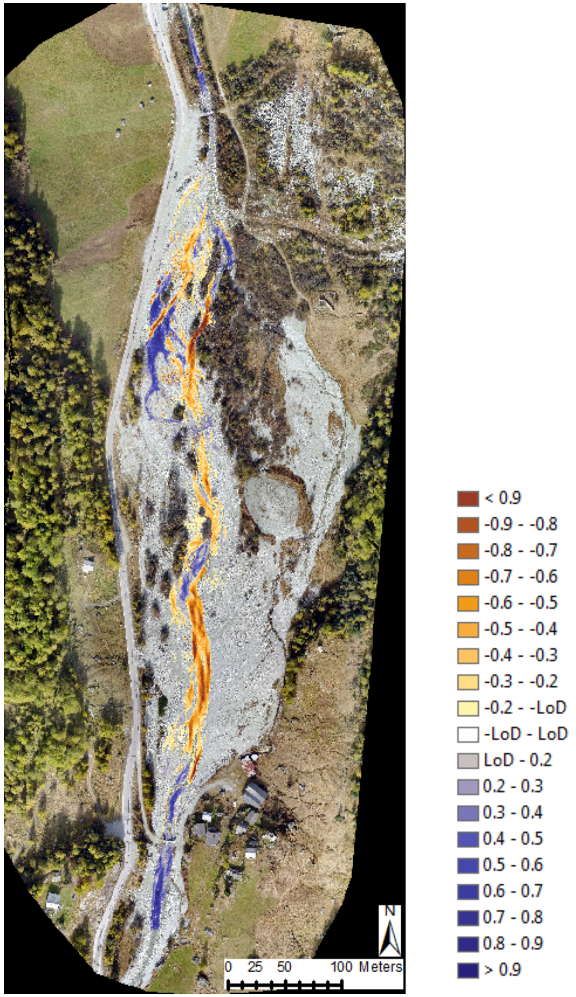


From E-flows to Sed-flows

PNR70 : HydroENV

SenseFly, Ebee



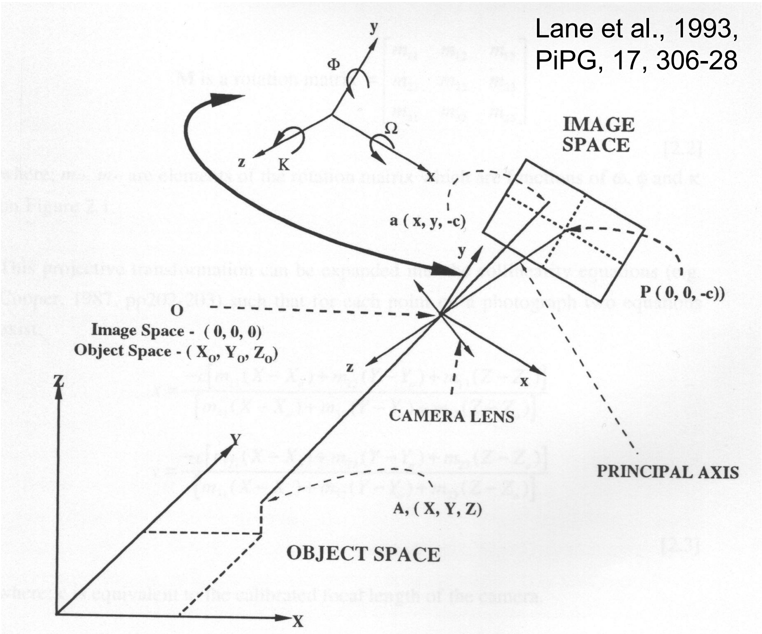


From E-flows to Sed-flows
The problem of camera calibration

The nature of drone-based imagery

a. Technical characteristics of drone-based imagery – commonly acquired using non-metric cameras
b. Structure from Motion photogrammetry (e.g. Pix4D) is the solution
c. But the effectiveness of SfM is critically controlled by the **geometry** of available imagery

Lane et al., 1993, PiPG, 17, 306-28



$$x = \frac{-c\left[m_{11}(X - X_o) + m_{12}(Y - Y_o) + m_{13}(Z - Z_o)\right]}{\left[m_{31}(X - X_o) + m_{32}(Y - Y_o) + m_{33}(Z - Z_o)\right]}$$

$$y = \frac{-c\left[m_{21}(X - X_o) + m_{22}(Y - Y_o) + m_{23}(Z - Z_o)\right]}{\left[m_{31}(X - X_o) + m_{32}(Y - Y_o) + m_{33}(Z - Z_o)\right]}$$

focal length, principal point offsets, lens distortion

$$x_c = x_p + \frac{x - x_p}{1 + K_1 r^2 + K_1 r^4 + \cdots}$$

$$y_c = y_p + \frac{y - y_p}{1 + K_1 r^2 + K_1 r^4 + \cdots}$$

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Robertson et Cipolla (2009)

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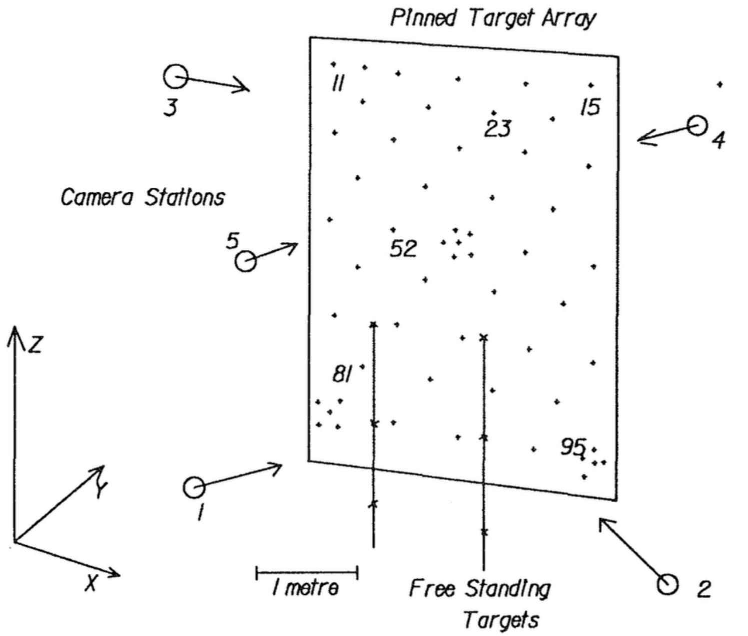

Figure 1. network geometry, detailing target array, all camera stations and survey simulation targets.

Robson, S; (1992) Film deformation in non-metric cameras under weak geometric conditions - an uncorrected disaster? In, *Proceedings, International Society for Photogrammetry and Remote Sensing 29th Congress*, 561-567

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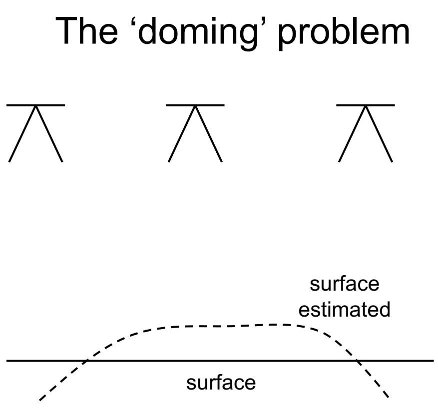

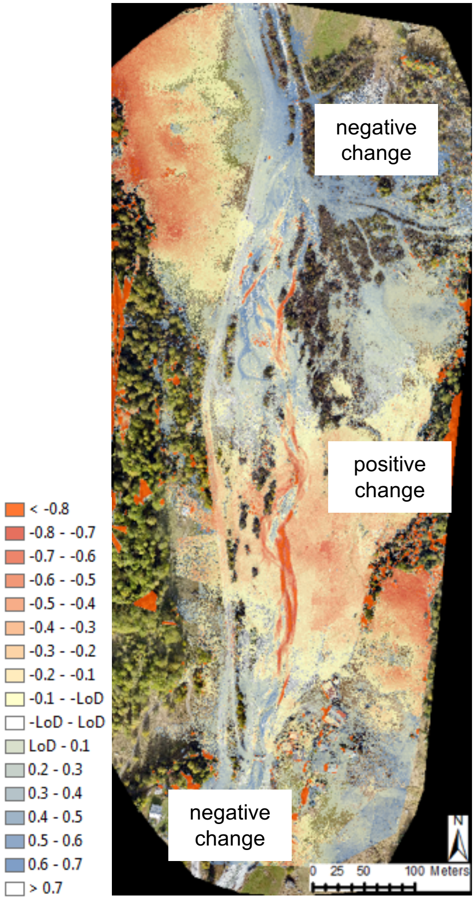

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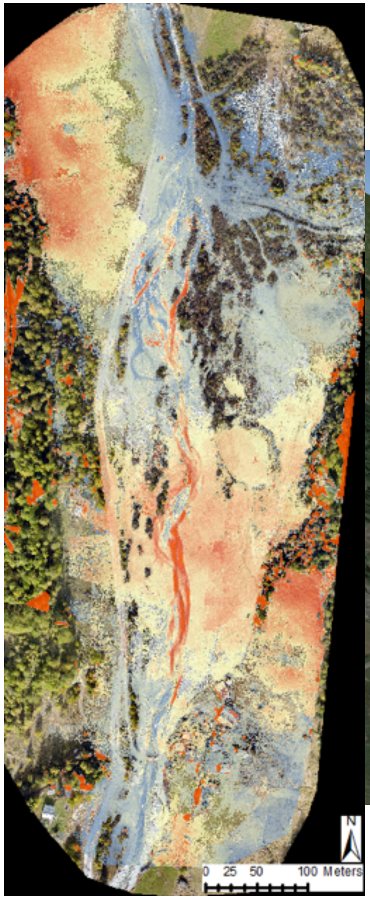

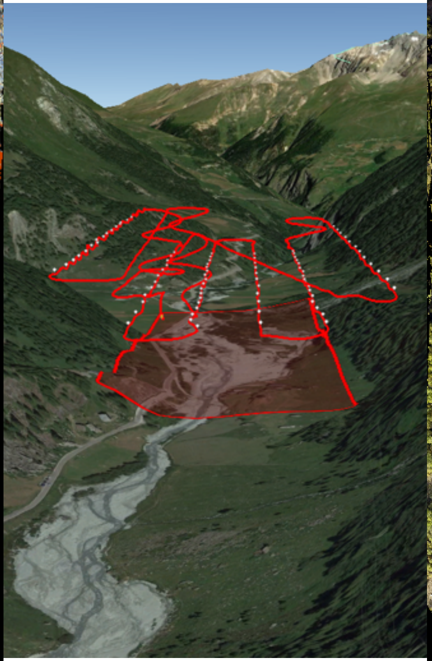

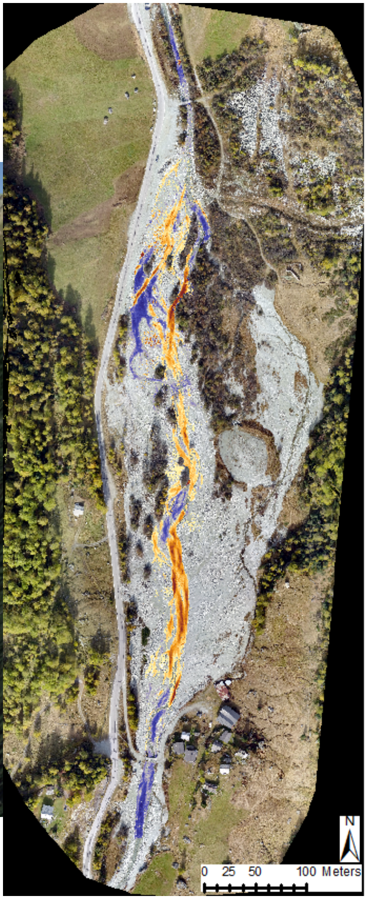

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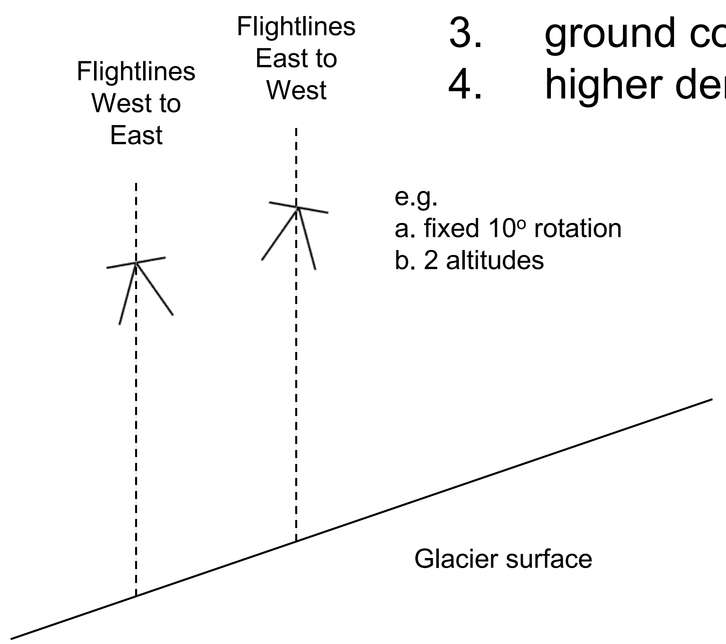
Think photogrammetrically
1. oblique imagery
2. multi-distance imagery
3. ground control
4. higher density imagery



Key messages

1. The advantages of UAVs (drones)
   a. UAVs provide cheap and near-vertical imagery
   b. Frequency of survey is controlled by the user
   c. Spatial resolution is controlled by the user (and a simple function of the camera and drone flying height)
   d. We have the scientific understanding to extract stream bed morphology, granulometry, wetted area, erosion/deposition; and to use these data in simulation models (e.g. for minimum flow assessment)
2. Challenges
   a. Water needs special treatment
   b. It is easy to acquire data at too high a resolution
   c. Acquiring imagery is more straightforward that extracting reliable quantitative data – this requires specialist training

Thank you for listening