DAY 1

Special Course on Point-clouds at UMS University (November 2023)

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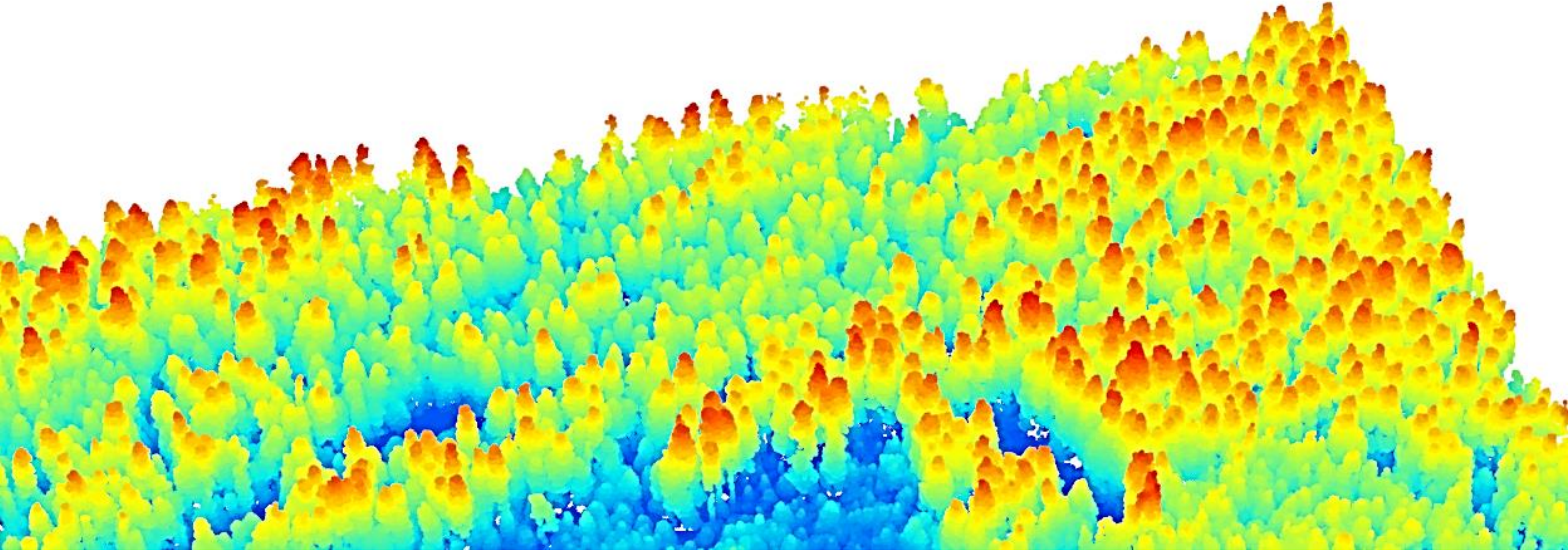

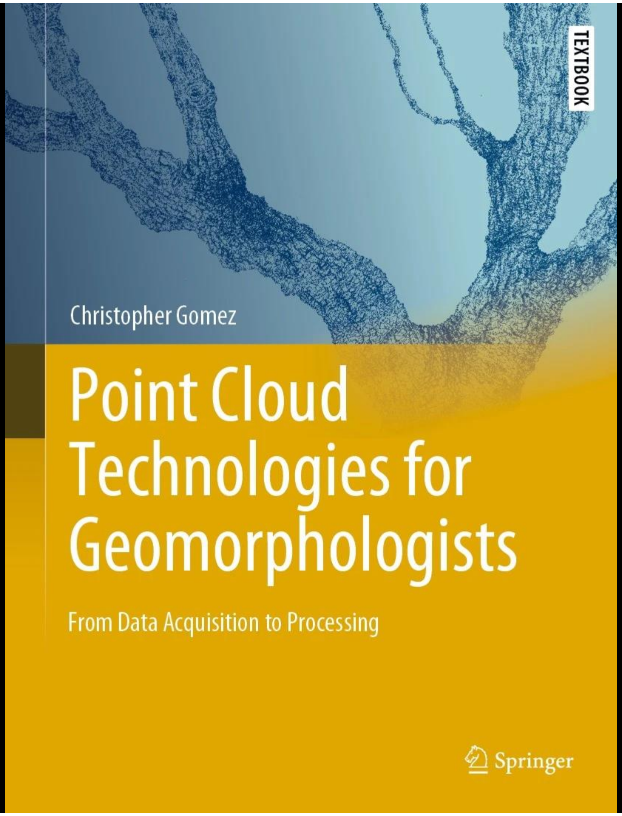

砂防2
点群データ:入門
Introduction to Pointclouds

Christopher Gomez

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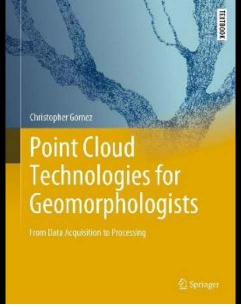

Lecture’s objectives and plan

Lecture’s objectives:

(a) Review super quickly the different types of rocks on Earth based on geotechnical interests;

(b) Know the three main phases of soils;

(c) Be able to manipulate the different soil phases calculations;

Lecture’s plan:

1. Rapid Introduction to pointclouds (especially in Geography/Geomorphology/Geology…)
(5’ break)
2. Pointcloud data acquisition (Laser-based and photogrammetry-based)
3. SfM-MVS on historical aerial photograhs

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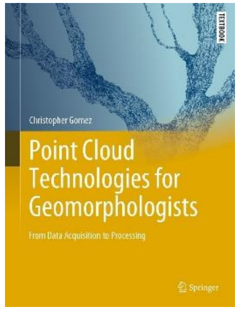

1. Rapid introduction to point-clouds

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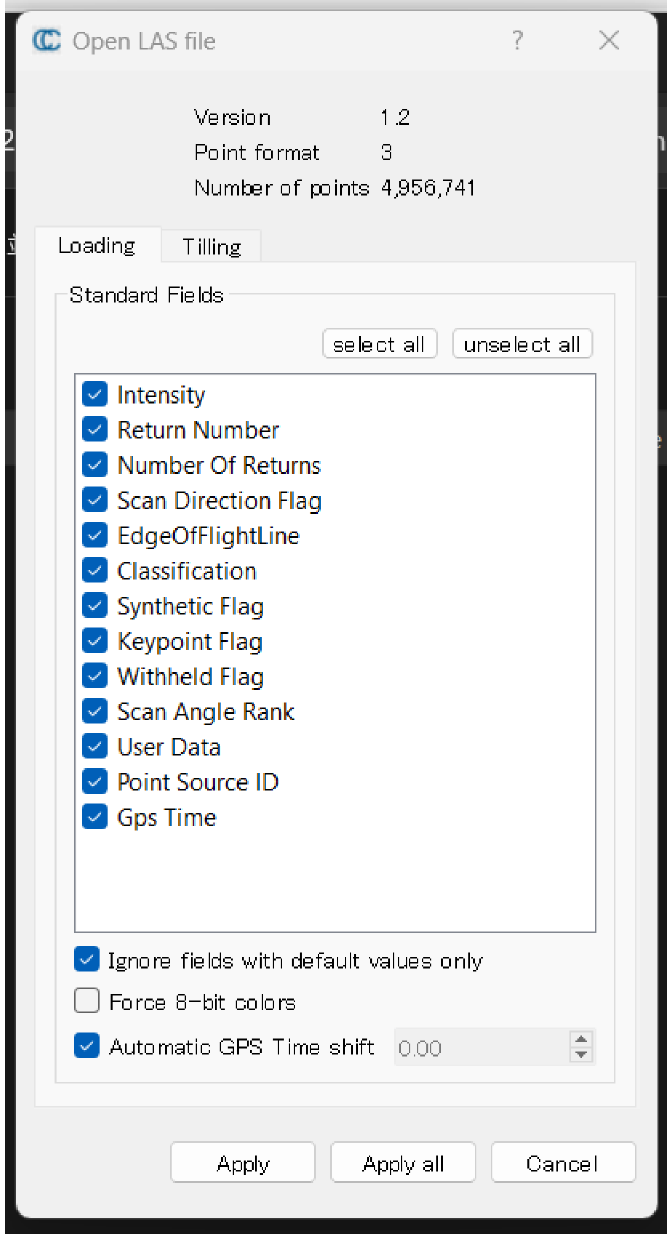
What is a point-cloud?

A pointcloud is a discrete set of points (let say large enough so that you cannot count the points one by one), which represent one or a set of objects by recording their surface, or internal structure.

A pointcloud has at least a set of coordinates to locate each points in a 3D space [x,y,z], so that a pointcloud with n samples is:

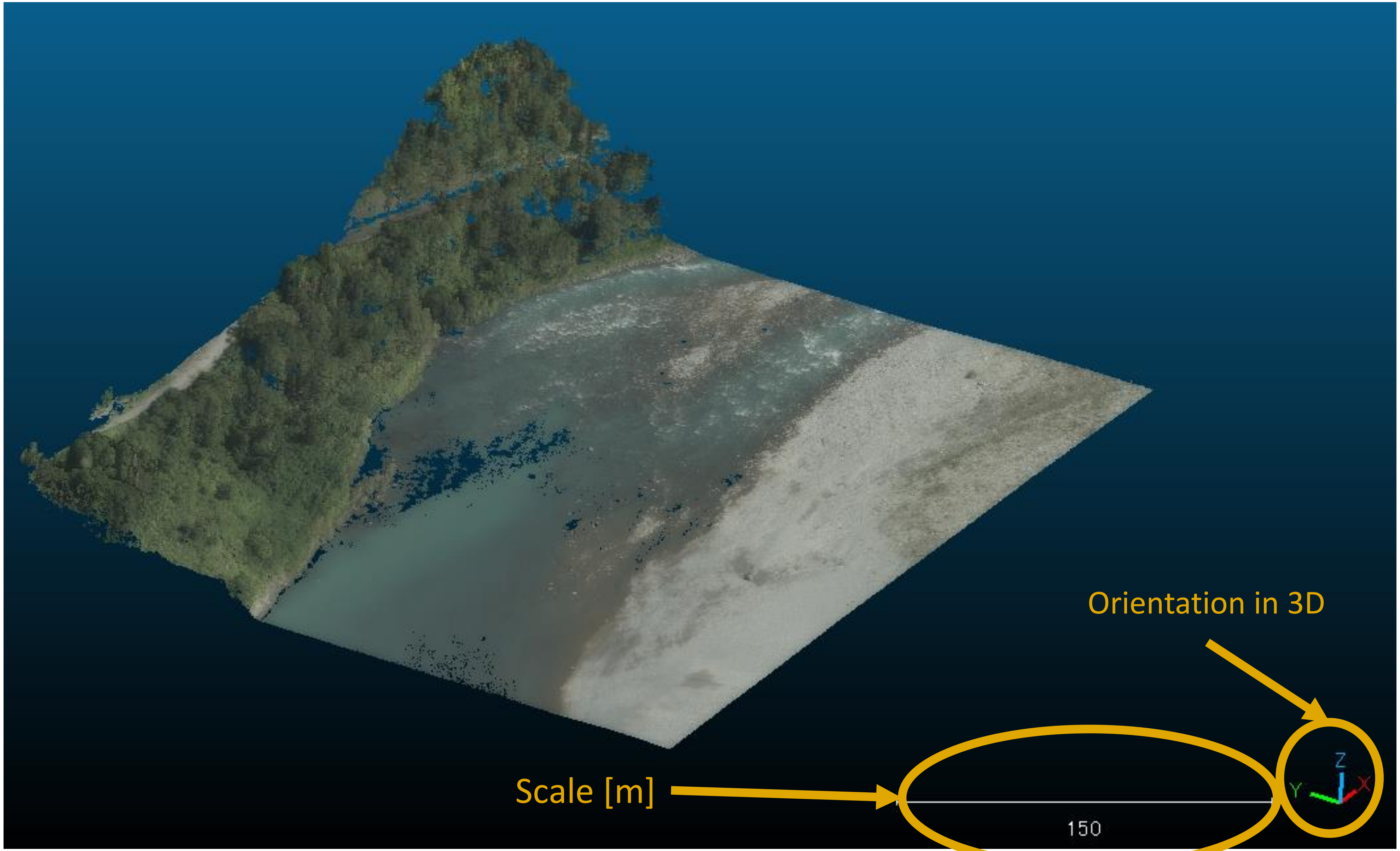
$$P_n = \sum_{i=1}^{n} [X_i, Y_i, Z_i, Att_i]$$

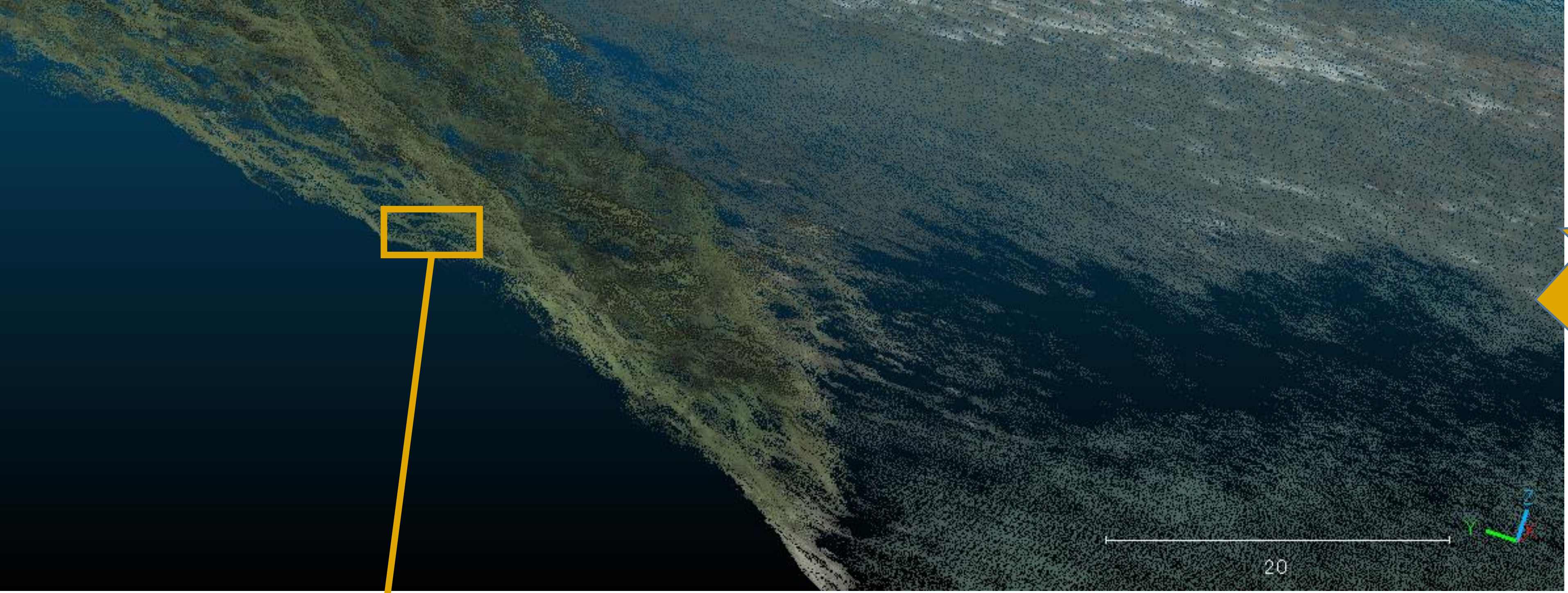
… and the pointclouds have also other attributes, including:

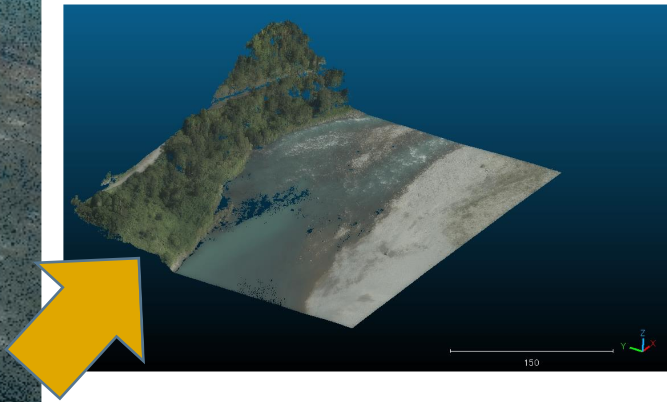


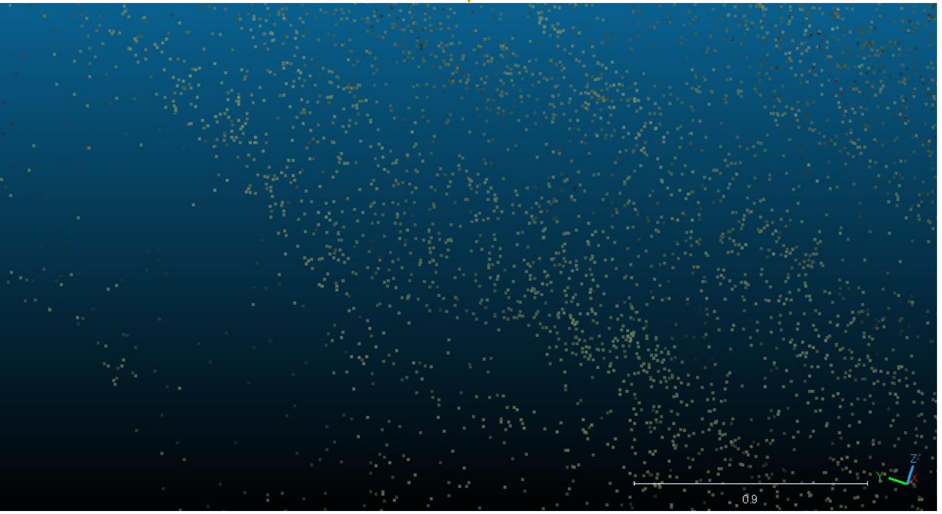
Example of a pointcloud of Fujigawa River in Japan:

Viewed
In the
Open-source
CloudCompare
Program



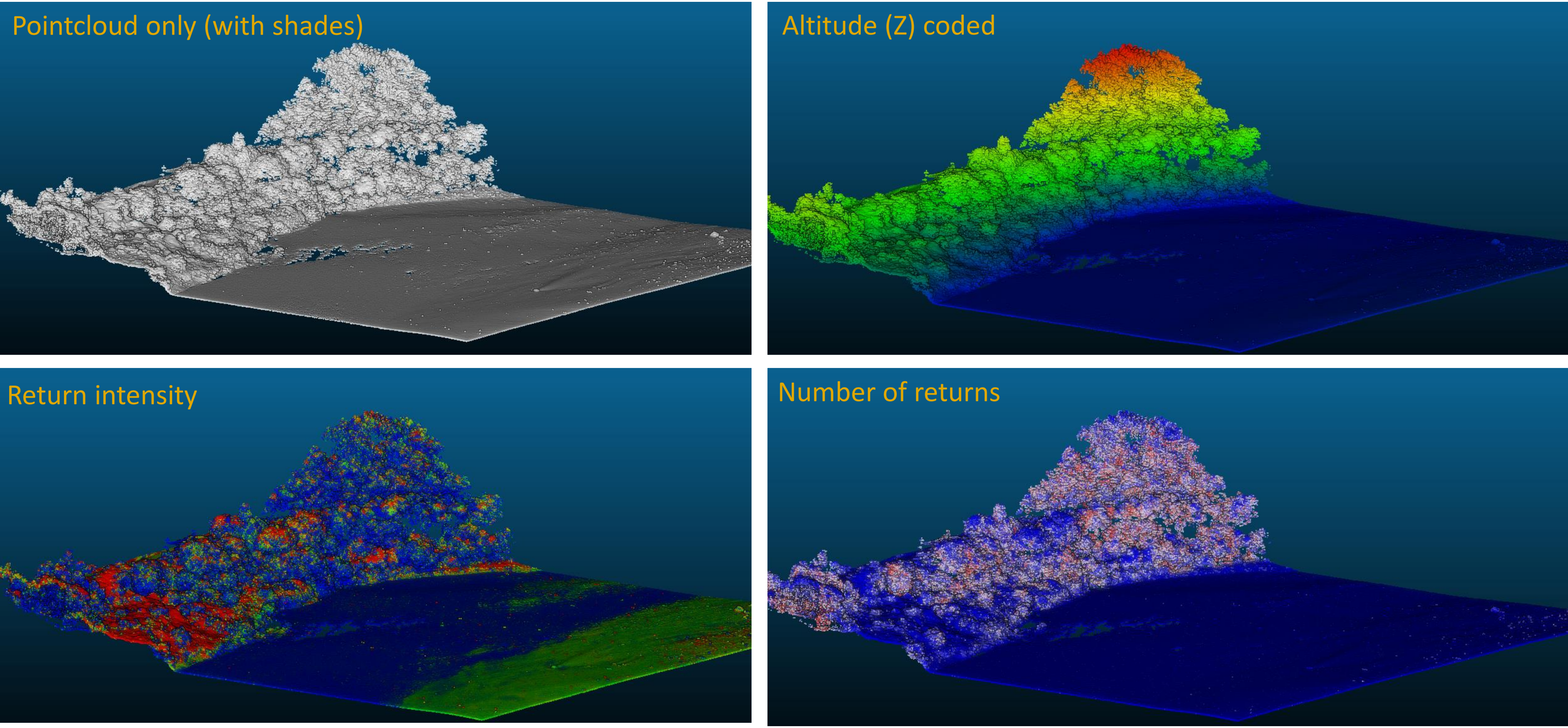




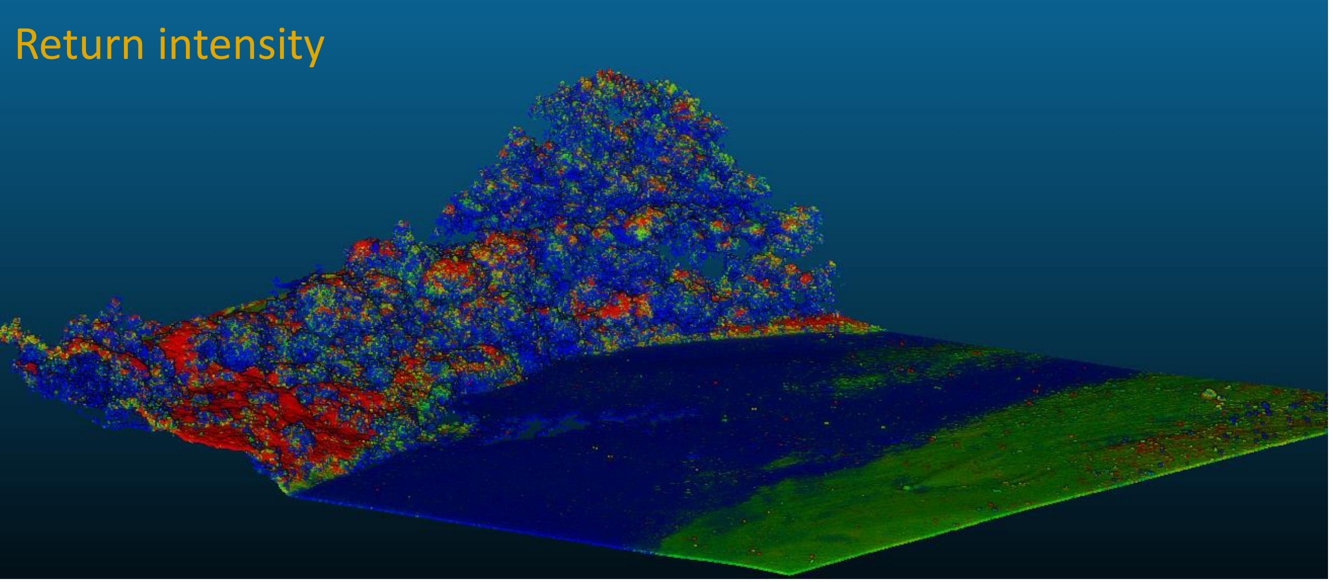


… and if you zoom on the image we had earlier, you can see that it is a pointcloud, made of a plethora of points.

Let’s have a look at it in CloudCompare



1. Rapid introduction to point-clouds



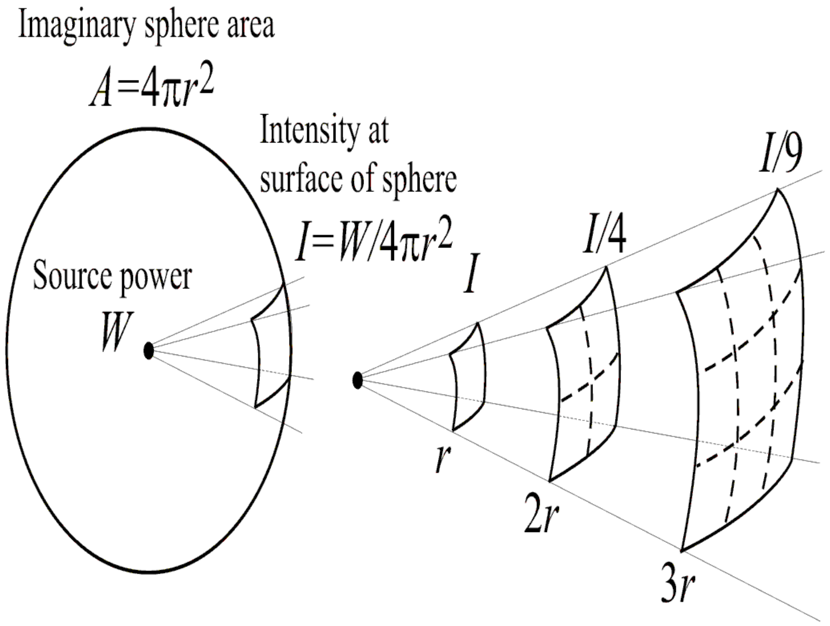
Return intensity

For each return from the LiDAR signal (creating a point), the return intensity, is **the strength of the returned laser-beam** by the surface/object. Therefore, it can be used in remote-sensing to differentiate different types of objects.

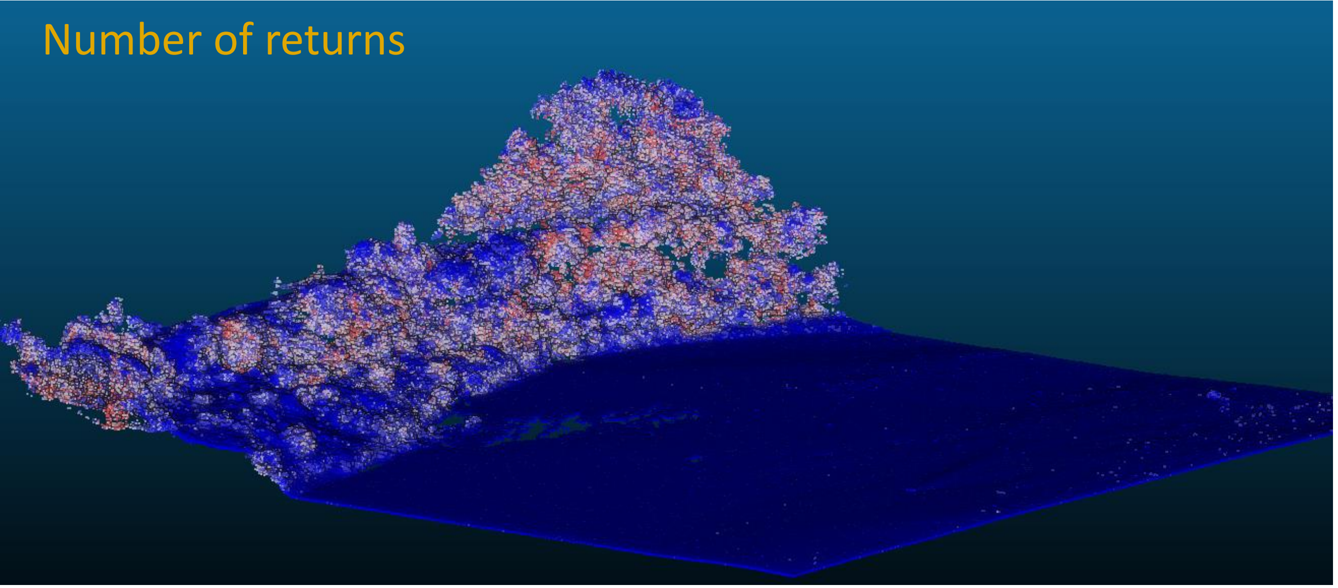
The intensity of a wave (any wave) is the time-averaged power transferred per surface area:

$$\langle P \rangle / A = I$$

And I is expressed in Watt per square meter.



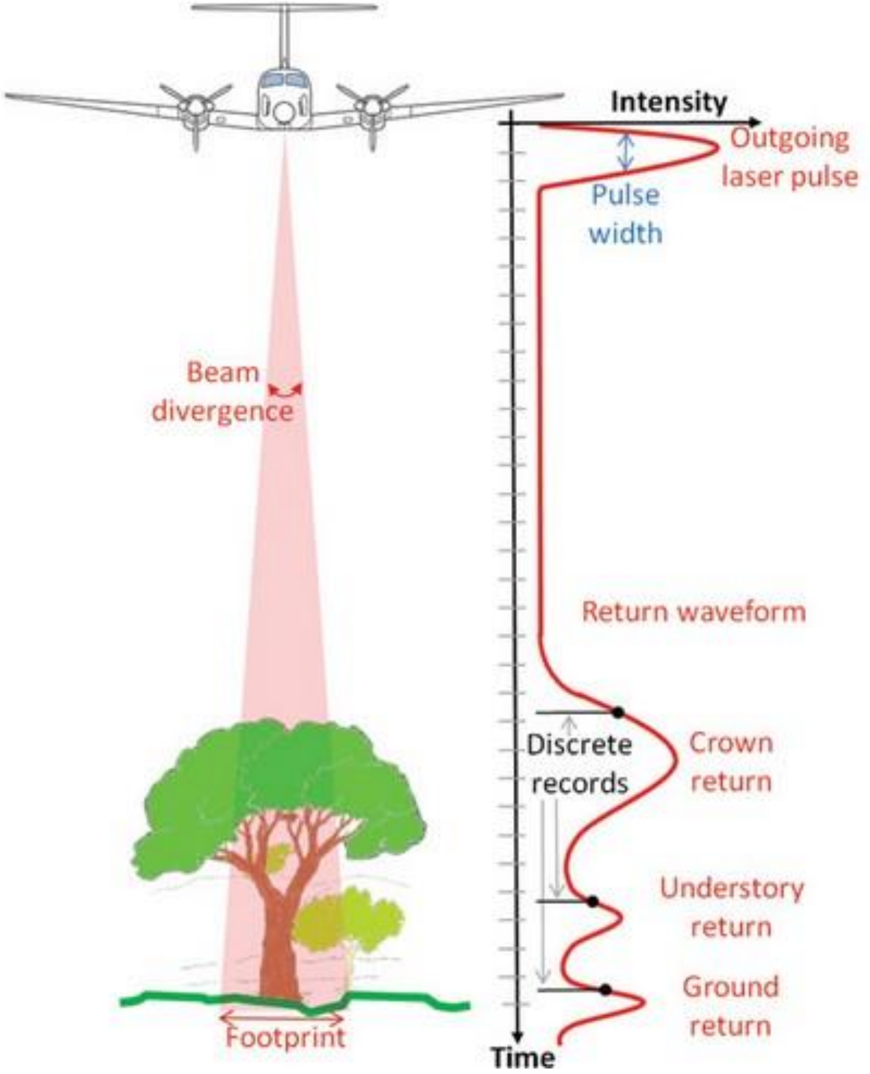
https://blog.soton.ac.uk/soundwaves/wave-basics/point-sources-inverse-square-law/



Number of returns

For LiDAR data, the number of returns for a given pulse is referred as the **number of returns**.

Depending on the structure of the pointcloud and the objects, a LiDAR can generate up to 3 to 5 returns per laser pulse.



Fernandez-Diaz, J. C. (2011). Lifting the Canopy Veil - Airborne LiDAR for Archeology of Forested Areas. Imaging Notes, 26(2).

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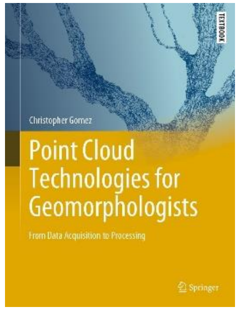
The most common PCl formats:

*.las (compressed *.laz)
*.ply (Stanford ply)
*.obj (3D-Object exchange standard)
*.csv *.dat *.txt (textfiles, no compression)
*.pcl (PCL library standard)



5’ break

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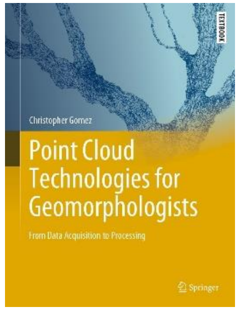

2. Pointcloud data acquisition

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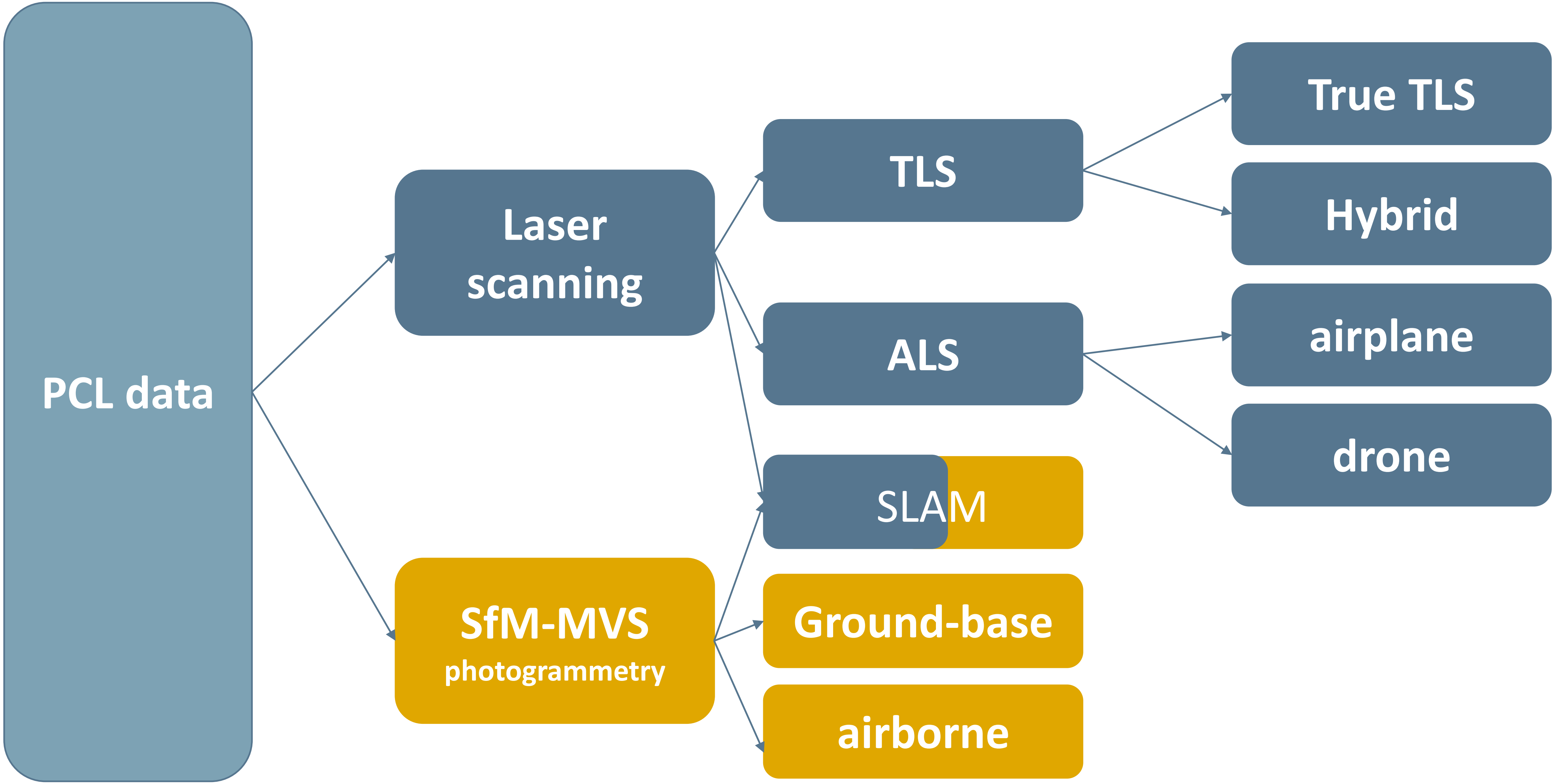
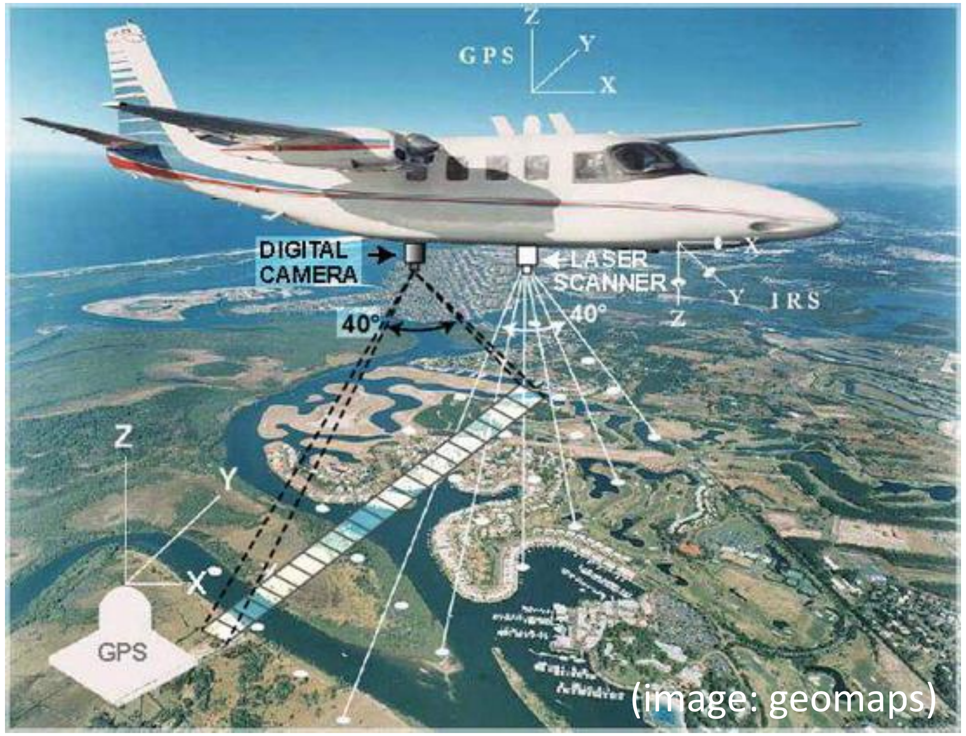


2. Pointcloud data acquisition

Examples of LiDAR sensors

(photo: Queen's university, Belfast)

Bay with the LiDar sensor



(image: geomaps)

The laser data is then combined with the GPS location, the IMU data (acceleration, rolling, direction, orientation) and a digital camera to generate the RGB pointcloud and extract orthophotographs.

2. Pointcloud data acquisition

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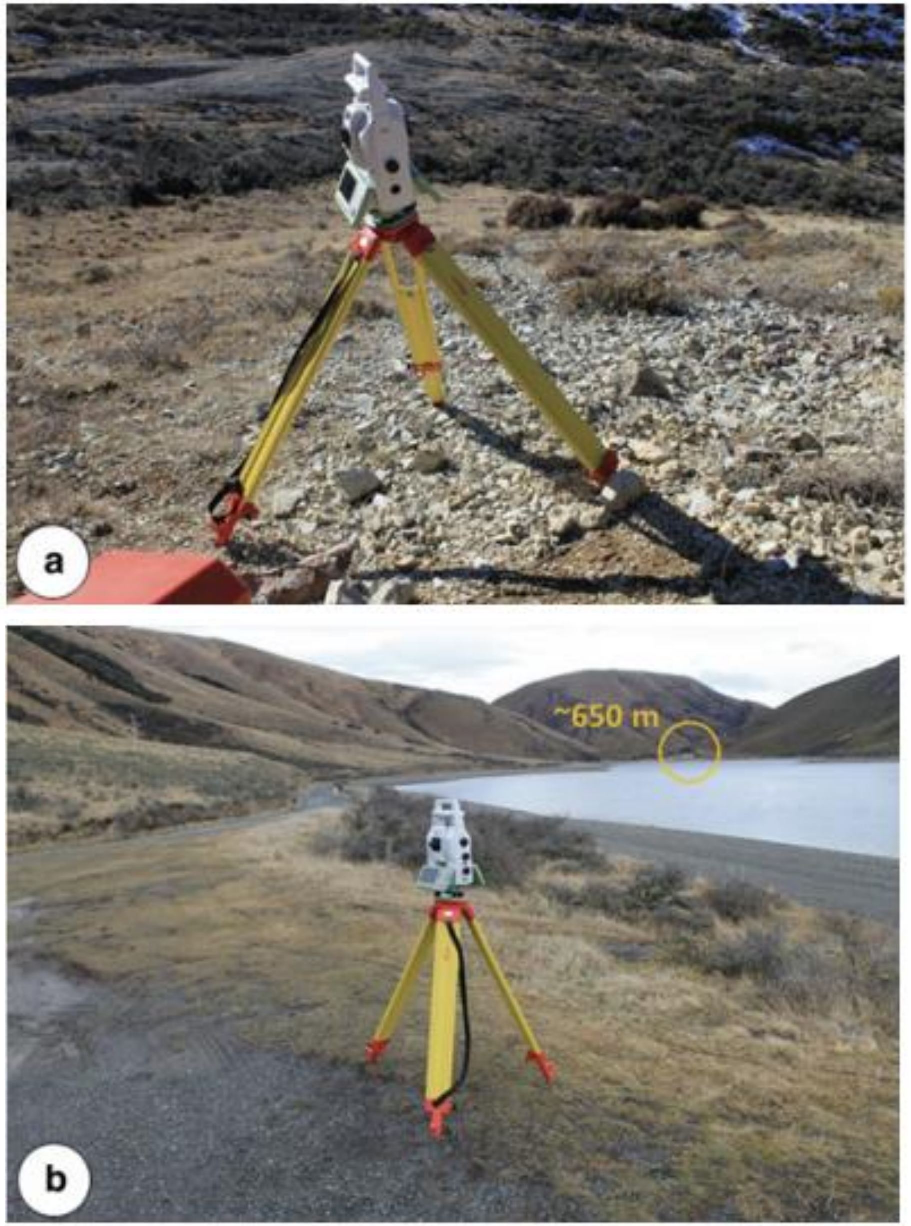
2. Pointcloud data acquisition

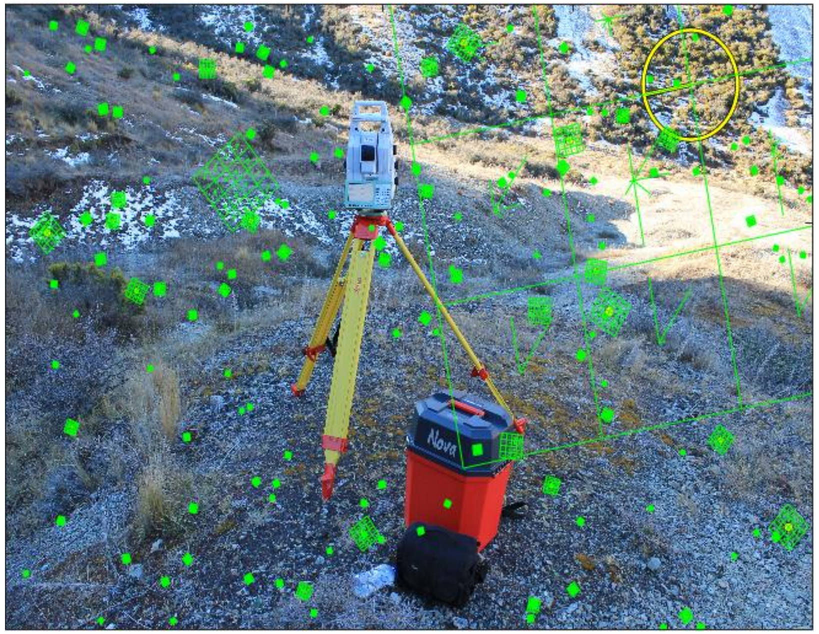


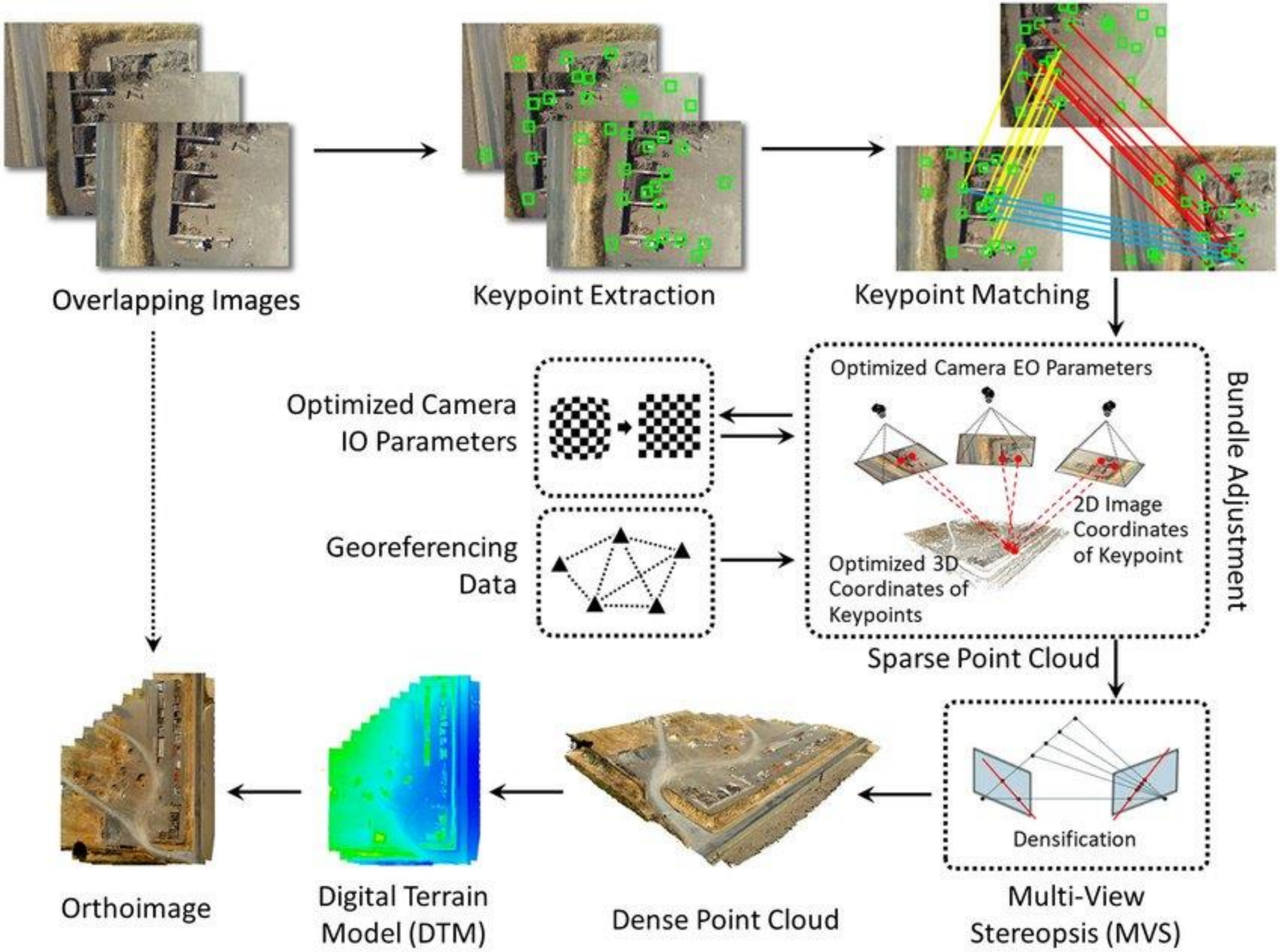
Hybrid solutions, combining total station and laser scanners

Leica MS60

The Leica MS60 in the field in New Zealand (South Island) near Porter skifield (a) and lake Lyndon in the upper country of Canterbury. Although the laser scanning capability has a shorter range, (b) the total station could record control points 650 m away on the wall of a cottage (the reader will note that this performance is subject to illumination, moisture, pollution and other factors that can affect the measurement)

Structure from Motion photogrammetry

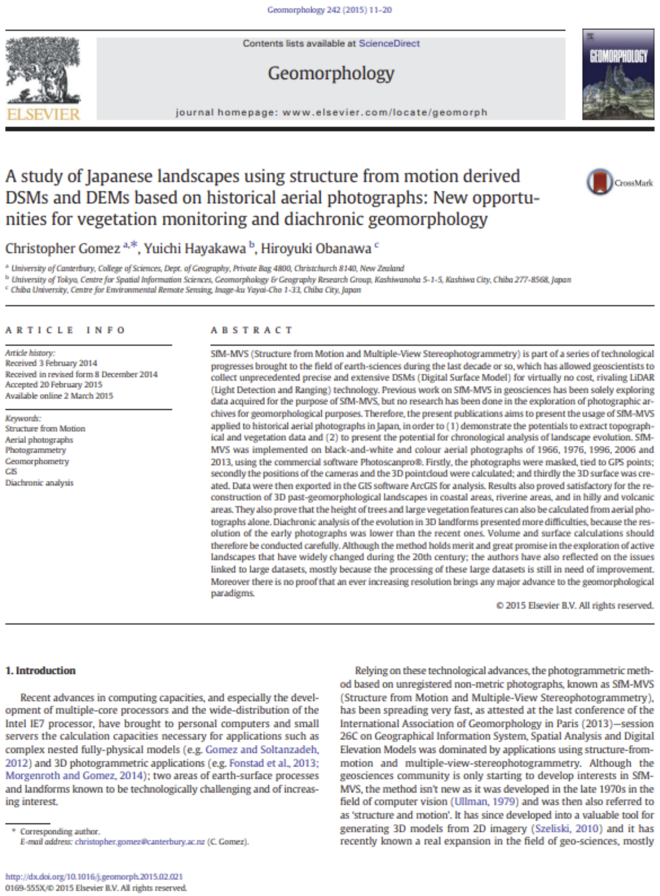




(Graph: Farid Javadnejad et al., 2021)

2. Pointcloud data acquisition

SfM-MVS on Historical Photographs: A time-machine



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A study of Japanese landscapes using structure from motion derived DSMs and DEMs based on historical aerial photographs: New opportunities for vegetation monitoring and diachronic geomorphology

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ABSTRACT

SfM-MVS (Structure from Motion and Multiple-View Stereophotogrammetry) is part of a series of technological progresses brought to the field of earth-sciences during the last decade or so, which has allowed geoscientists to collect unprecedented precise and extensive DSMs (Digital Surface Model) for virtually no cost, rivaling LiDAR (Light Detection and Ranging) technology. Previous work on SfM-MVS in geosciences has been solely exploring data acquired for the purpose of SfM-MVS, but no research has been done in the exploration of photographic archives for geomorphological purposes. Therefore, the present publications aims to present the usage of SfM-MVS applied to historical aerial photographs in Japan, in order to (1) demonstrate the potentials to extract topographical and vegetation data and (2) to present the potential for chronological analysis of landscape evolution. SfM-MVS was implemented on black-and-white and colour aerial photographs of 1966, 1976, 1996, 2006 and 2013, using the commercial software Photoscanpro®. Firstly, the photographs were masked, tied to GPS points; secondly the positions of the cameras and the 3D pointcloud were calculated; and thirdly the 3D surface was created. Data were then exported in the GIS software ArcGIS for analysis. Results also proved satisfactory for the reconstruction of 3D past-geomorphological landscapes in coastal areas, riverine areas, and in hilly and volcanic areas. They also prove that the height of trees and large vegetation features can also be calculated from aerial photographs alone. Diachronic analysis of the evolution in 3D landforms presented more difficulties, because the resolution of the early photographs was lower than the recent ones. Volume and surface calculations should therefore be conducted carefully. Although the method holds merit and great promise in the exploration of active landscapes that have widely changed during the 20th century; the authors have also reflected on the issues linked to large datasets, mostly because the processing of these large datasets is still in need of improvement. Moreover there is no proof that an ever increasing resolution brings any major advance to the geomorphological paradigms.

1. Introduction

Recent advances in computing capacities, and especially the development of multiple-core processors and the wide-distribution of the Intel IE7 processor, have brought to personal computers and small servers the calculation capacities necessary for applications such as complex nested fully-physical models (e.g. Gomez and Soltanzadeh, 2012) and 3D photogrammetric applications (e.g. Fonstad et al., 2013; Morgenroth and Gomez, 2014); two areas of earth-surface processes and landforms known to be technologically challenging and of increasing interest.

Relying on these technological advances, the photogrammetric method based on unregistered non-metric photographs, known as SfM-MVS (Structure from Motion and Multiple-View Stereophotogrammetry), has been spreading very fast, as attested at the last conference of the International Association of Geomorphology in Paris (2013)—session 26C on Geographical Information System, Spatial Analysis and Digital Elevation Models was dominated by applications using structure-from-motion and multiple-view-stereophotogrammetry. Although the geosciences community is only starting to develop interests in SfM-MVS, the method isn't new as it was developed in the late 1970s in the field of computer vision (Ullman, 1979) and was then also referred to as 'structure and motion'. It has since developed into a valuable tool for generating 3D models from 2D imagery (Szeliski, 2010) and it has recently known a real expansion in the field of geo-sciences, mostly

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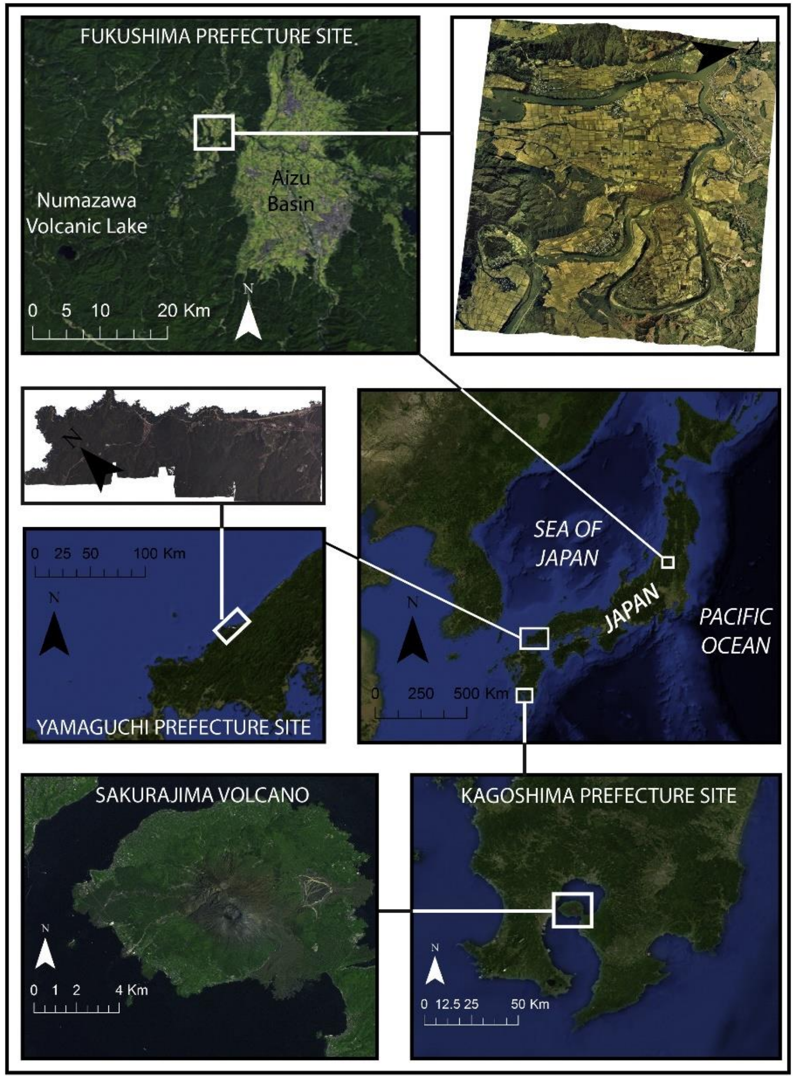


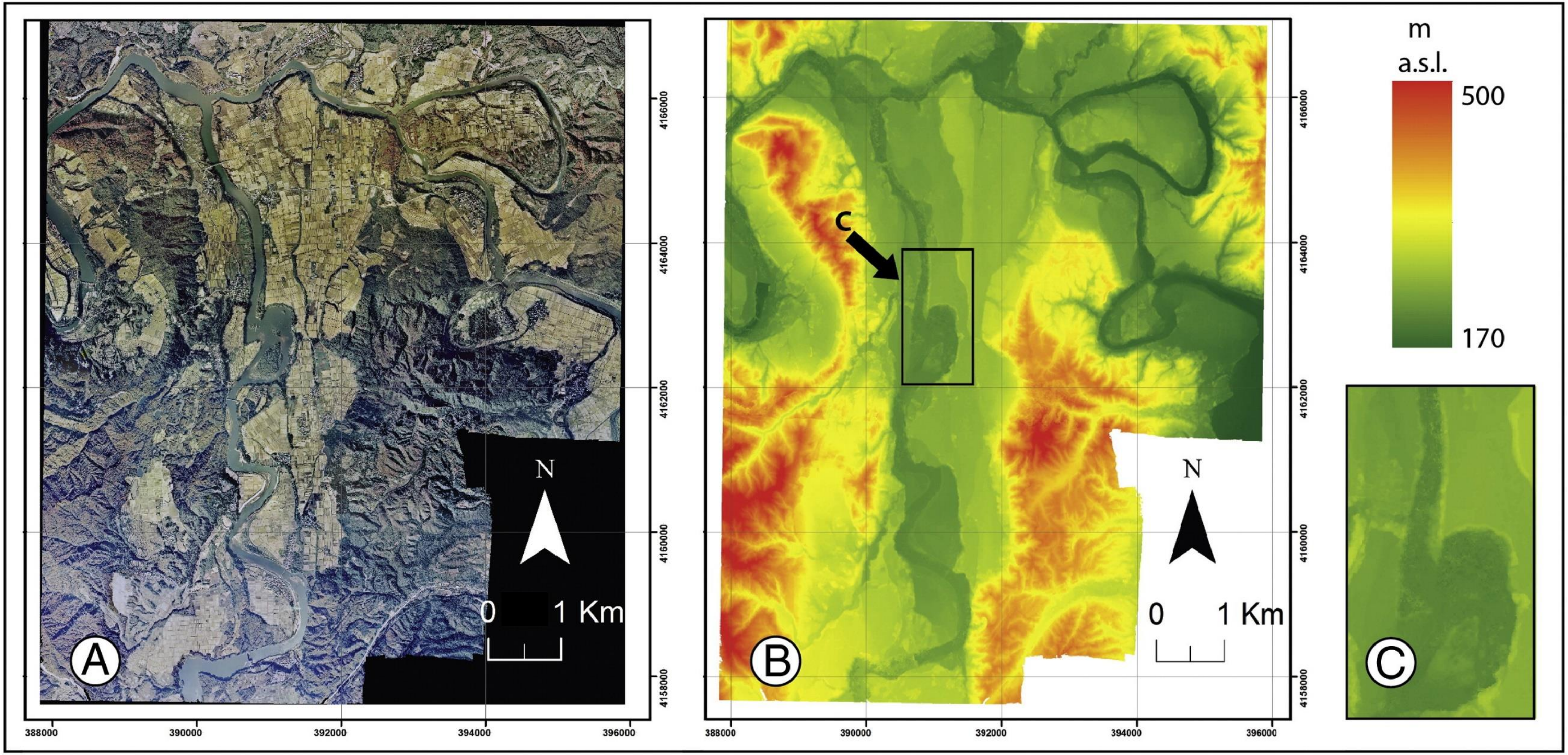
Research locations:

Table 1. Characteristics of the photographs used for the different SfM-MVS case study.

Location	Sakurajima	Aizu	Sakurajima	Sakurajima	Yamaguchi
Year	1966	1976	1996	2006	2013
Flight elevation (m)	3500	2000	3900	4600	3651
Scale of the photograph	1/20,000	1/10,000	1/25,000	1/30,000	1/13,000
Camera	Leica RC8	Leica RC8	Leica RC20	Leica RC30	UCX
Camera type	Analogue	Analogue	Analogue	Analogue	Digital
Photograph	Black and white	Colour	Black and white	Black and white	Colour
Number of photographs used	36	64	34	21	27

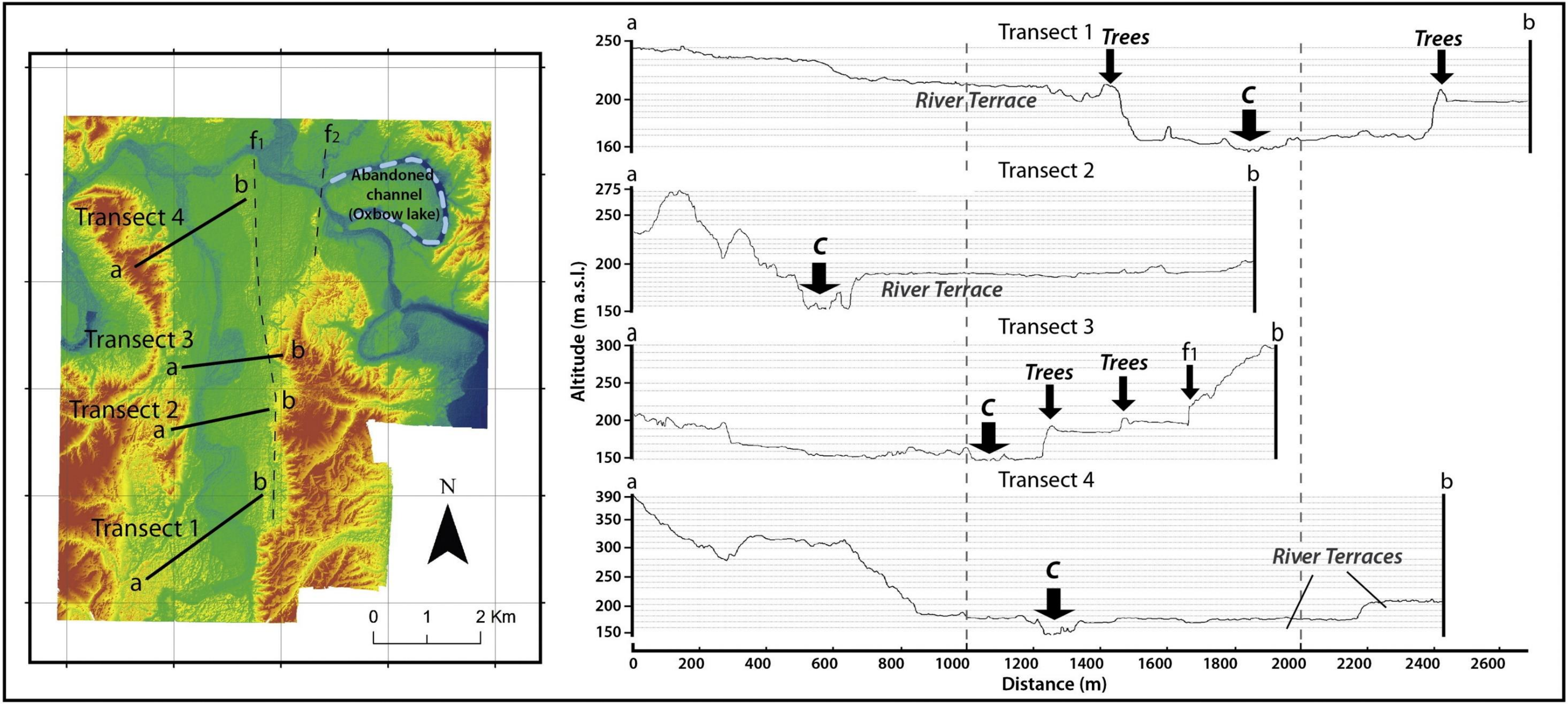
Photographs:

3. SfM-MVS on historical aerial photographs

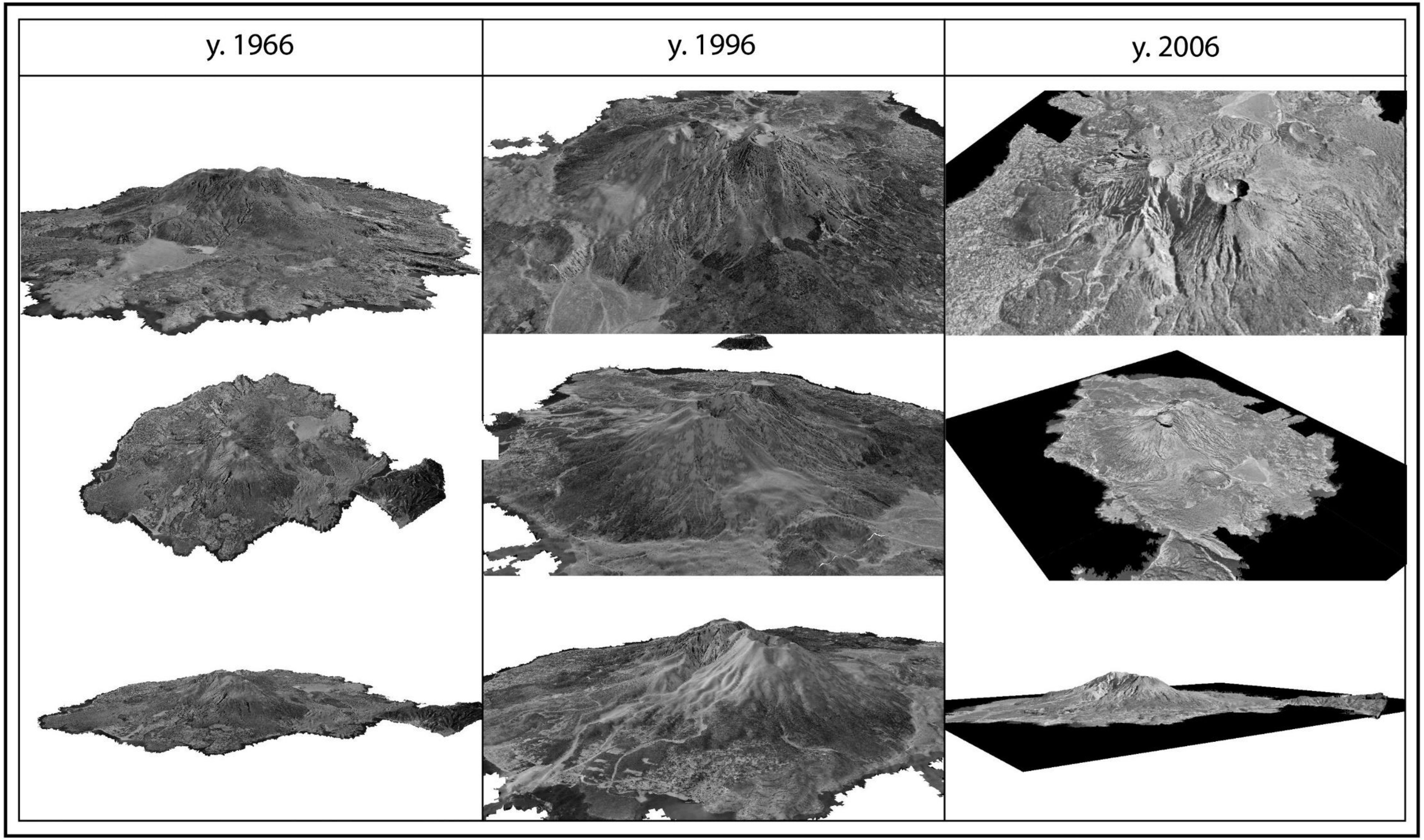


The geomorphology in 1976

3. SfM-MVS on historical aerial photographs

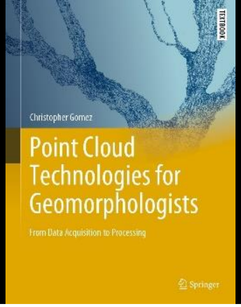


The tree heights in 1976



The Evolution of Sakurajima Volcano from 1966 to 2016

3. SfM-MVS on historical aerial photographs



Conclusion of Lecture 01

What you should know:

(a) What is a pointcloud, what data are stored with it and the different structures
(b) The different types of sensors used to generate 3D from laser data
(c) The SfM-MVS photogrammetric method to generate 3D
(d) Be able to choose one method or another, based on your objectives.
(e) Understand the potential of the SfM-MVS method beyond traditional remote sensing (historical data…)

Lecture's plan:

From this general introduction, we will then start looking at different environments, with specific problems and challenges to pointcloud acquisition and then processing.

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