ALTERNATIVE AU CALCUL DE DIFFÉRENCES SUR MNT : LA COMPARAISON DIRECTE DE NUAGES DE POINTS EN 3D

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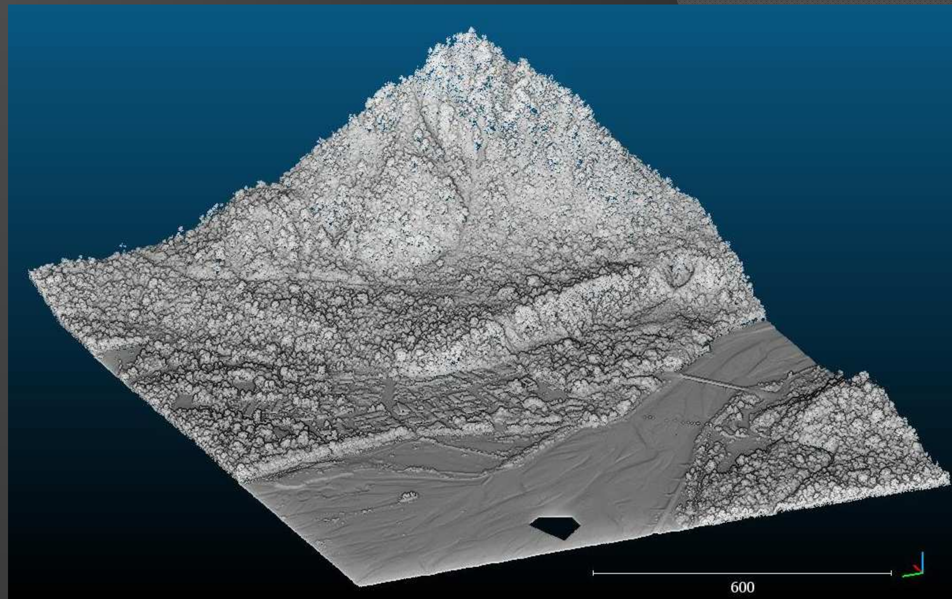
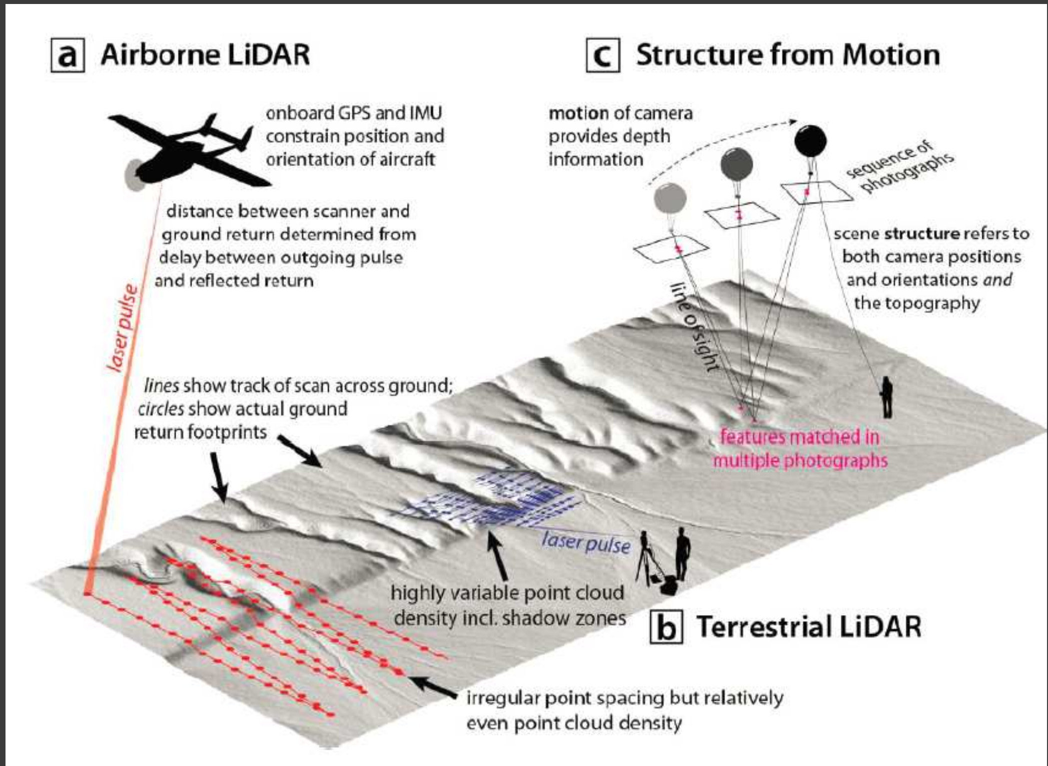
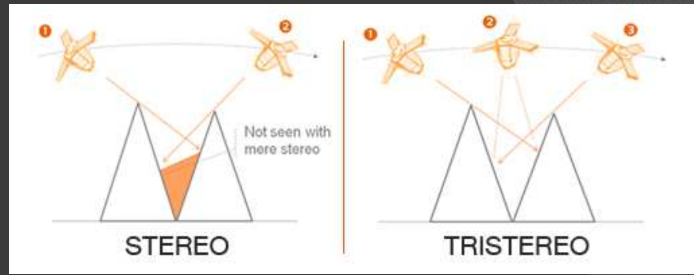


High Resolution Topo (HRT) sources

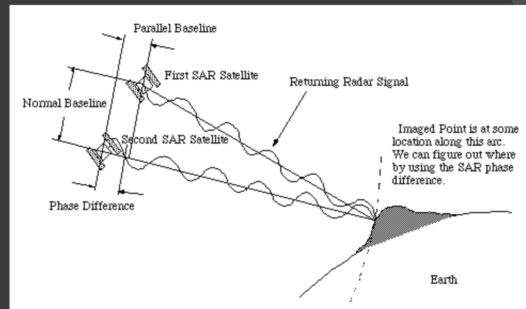


Johnson et al., Geosphere (2014)

Satellite Stereo Imagery



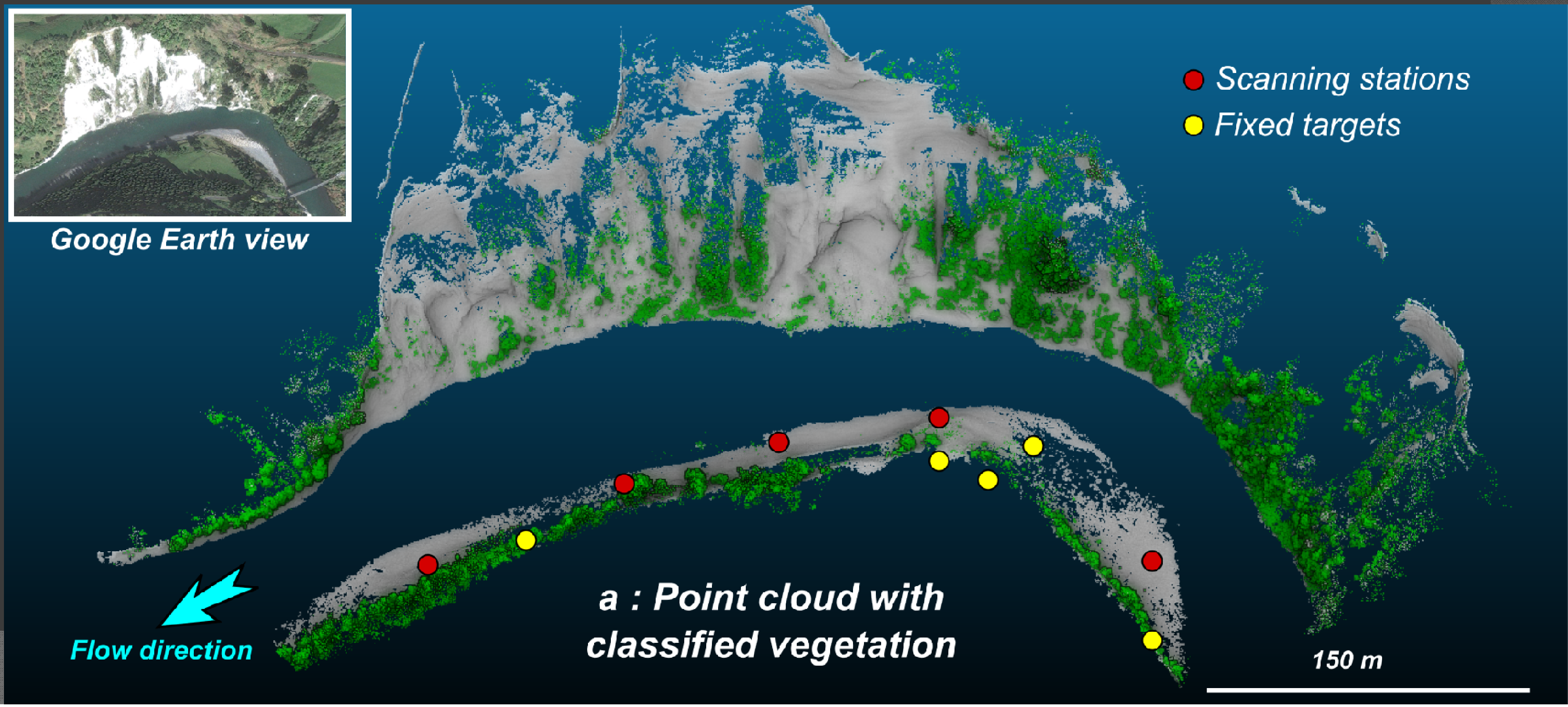
Synthetic Aperture Radar



Raw data = 3D point cloud

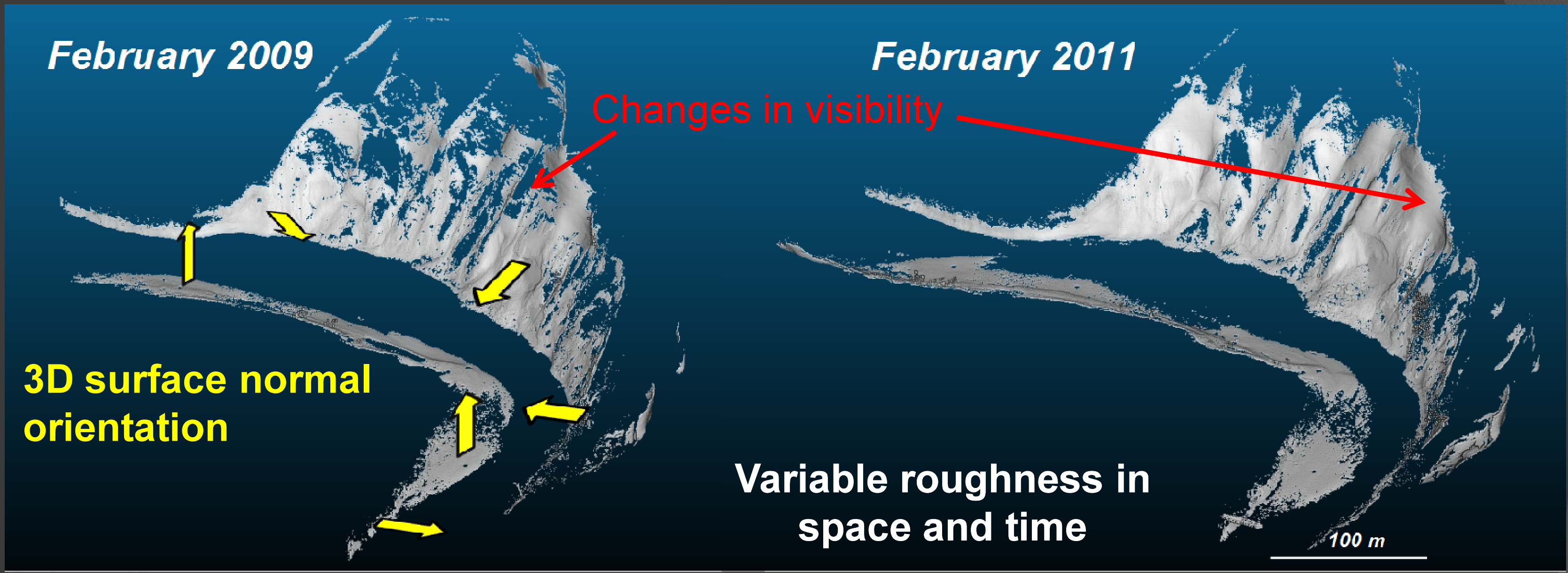
Generic issues with point clouds (PC)

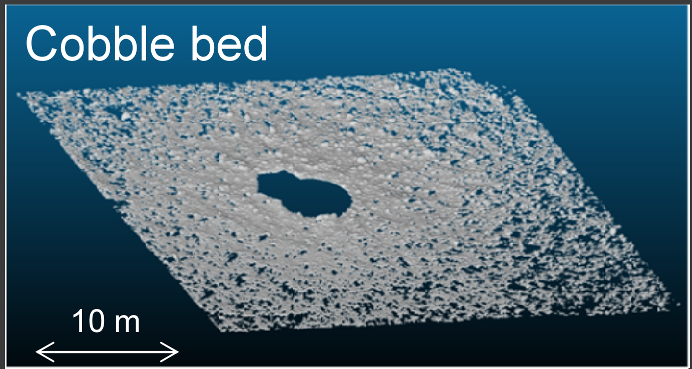
- Non-regular sampling
- Missing data due to lack of correlation, shadows, water, …
- Potentially 3D as opposed to purely 2D (i.e. potentially several points on the same vertical)
- Visualisation (not really an issue anymore, e.g. Cloudcompare)

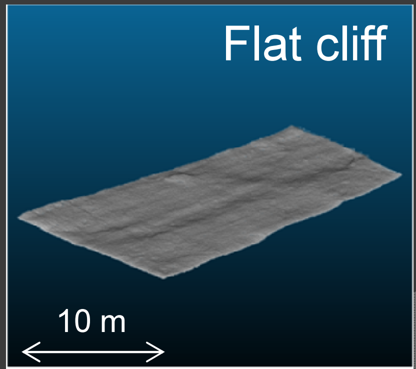


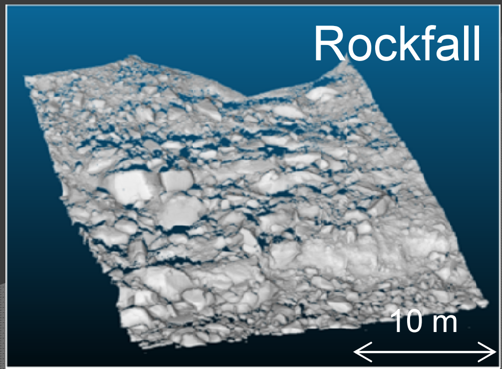
3D point cloud comparison of natural surfaces: issues

Rangitikei river, New-Zealand







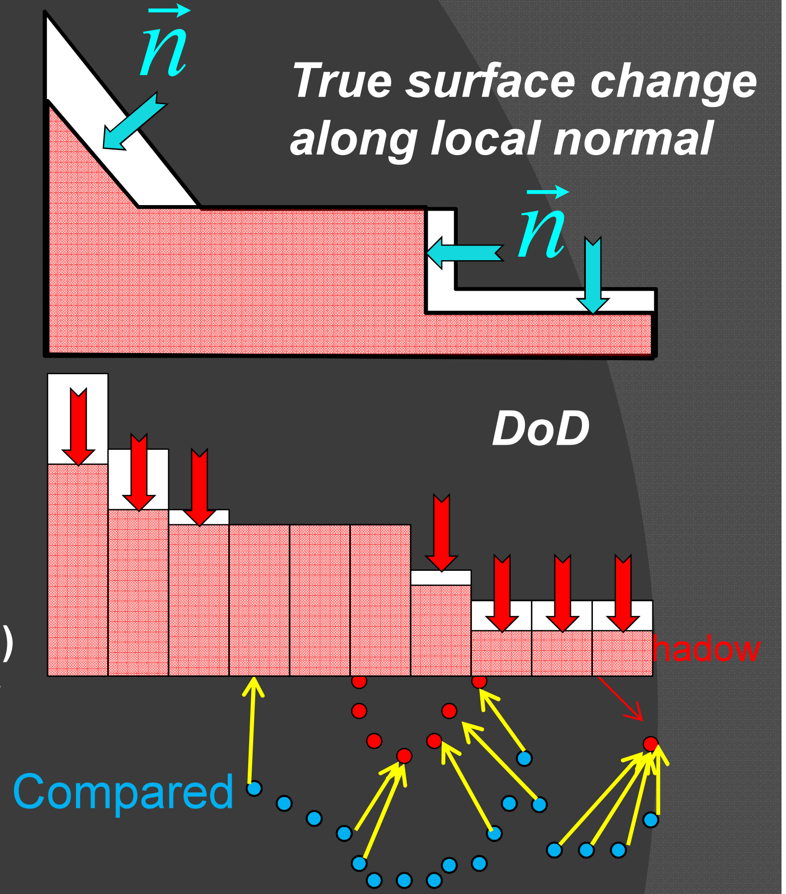


Roughness creates uncertainty in the comparison of surfaces

HRT data comparison

Existing solutions

- **Difference of DTM** (e.g Lane et al., 2003, Wheaton et al., 2009…)
  - **+ Very fast, prediction of confidence intervals**
  - **- NOT 3D, data interpolation (steep slopes, lack of correlation)**



- **3D closest point distance**

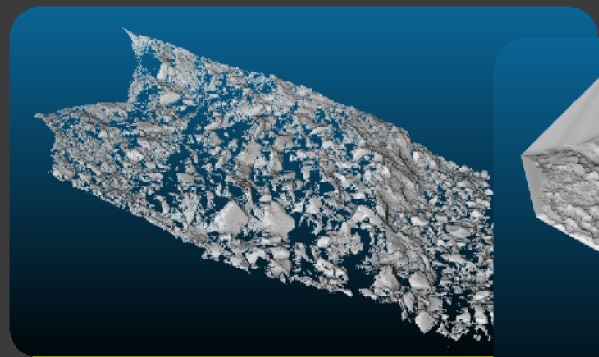
(e.g Girardeau-Montaut et al., 2005, Cloudcompare, ICP)

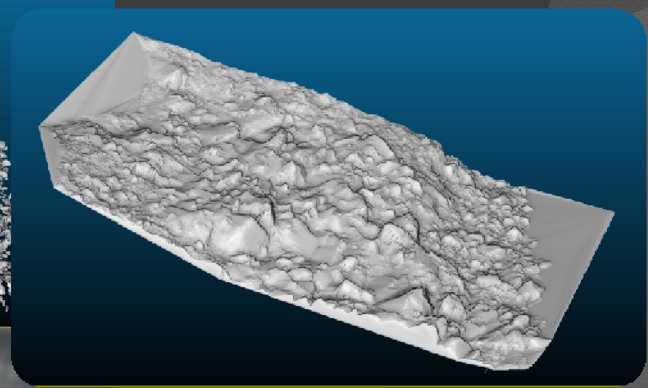
  - **+ Very fast, 3D but not oriented (no normal calculation)**
  - **- dependent on point spacing and changes in visibility**
  - **- no confidence intervals**

- **3D difference of surface mesh**

(e.g. 3D inspection software)

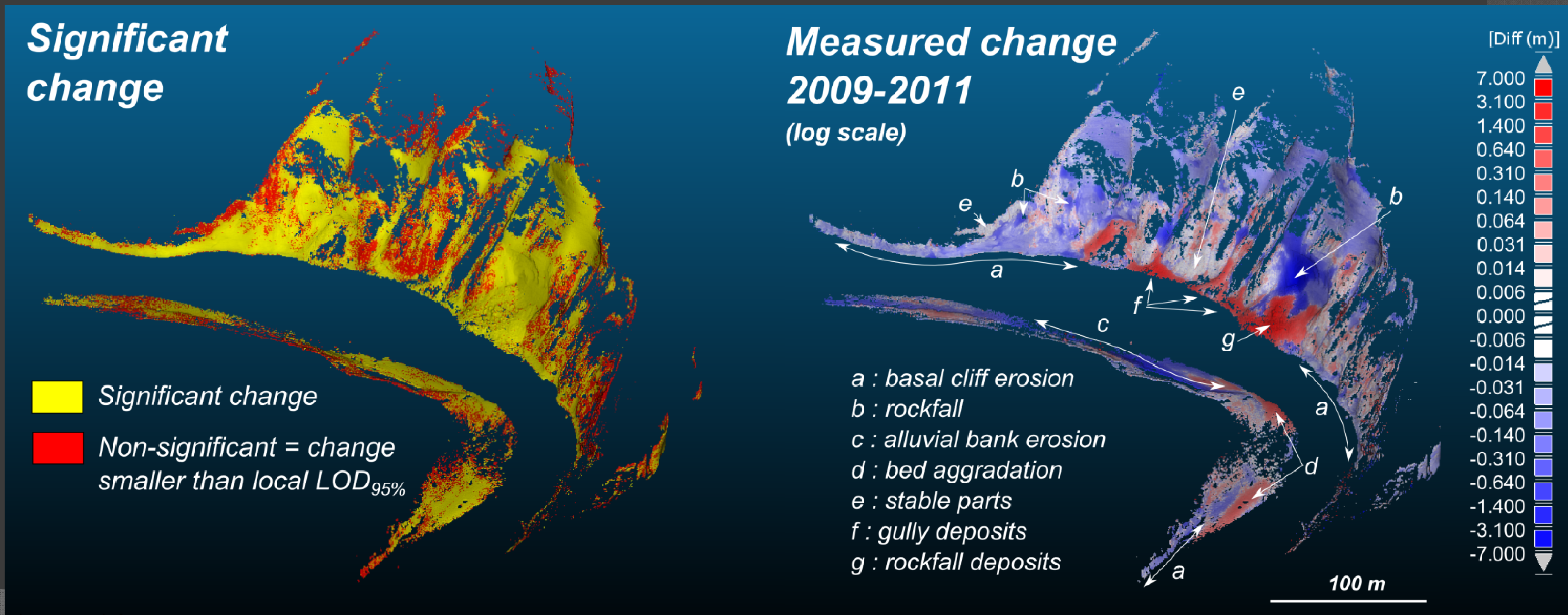
  - **+ 3D normal calculation**
  - **- meshing of rough surfaces**
    - **Uncontrolled interpolation**
  - **- no confidence interval**





M3C2 algorithm for high precision 3D surface change measurement *(Lague et al., ISPRS journal, 2013)*

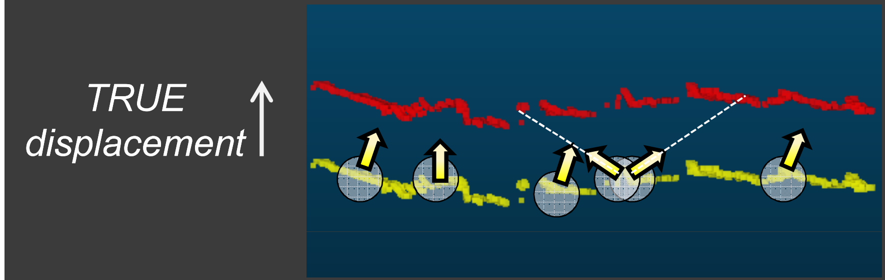
- Orthogonal distance measurement between 2 clouds
- Direct point cloud comparison (no DEM, no mesh)
- Designed for 3D rough surfaces (but also operates on simple 2D ones !)
- Spatial averaging to reduce standard error
- Local estimate of confidence interval
- Robust to changes in visibility and changes in point density
  - No need to manually trim the data



M3C2 algorithm: multiscale normal estimate

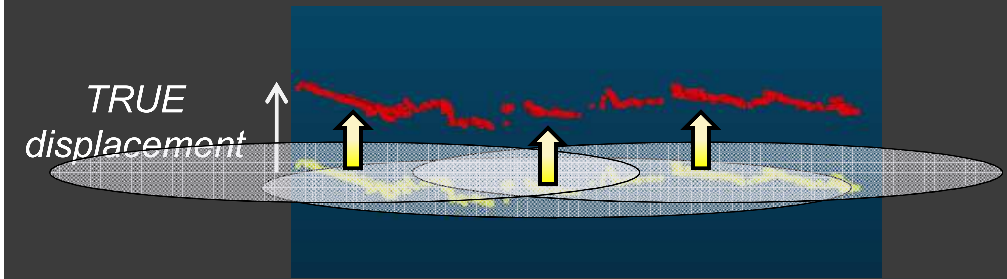
- **Step 1 : 3D normal estimate at a scale D_n consistent with local roughness**

Small scale compared to rougness characteristics



Normal flickering due to roughness -> tendency to overestimate the true distance

Large scale compared to rougness characteristics



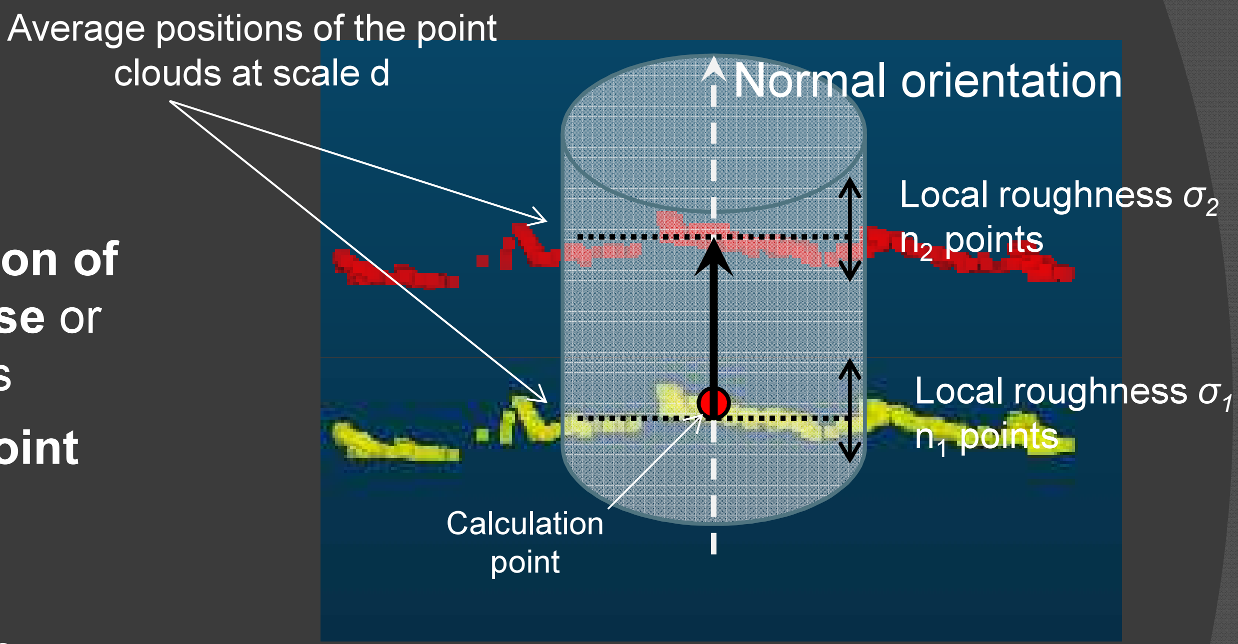
Overestimation of distance is below 1 % if

$$\frac{D_n}{Roughness(D_n)} >\sim 40$$

Flat cliff : D_n ~ 0.1-0.2 m
Cobble bed : D_n ~ 1 – 2 m
Rockfall debris : D_n ~ 10 – 20 m

M3C2 algorithm

◉ Step 2 : distance calculation along the normal direction over a projection scale *d*



Key advantages :

- **Local characterization of roughness** : **data noise** or true surface roughness
- **Local measure of point density**
- **Spatial averaging**
- **Robust to change in visibility** : no projection found -> no calculation

Local 95 % parametric confidence interval (for n>5)

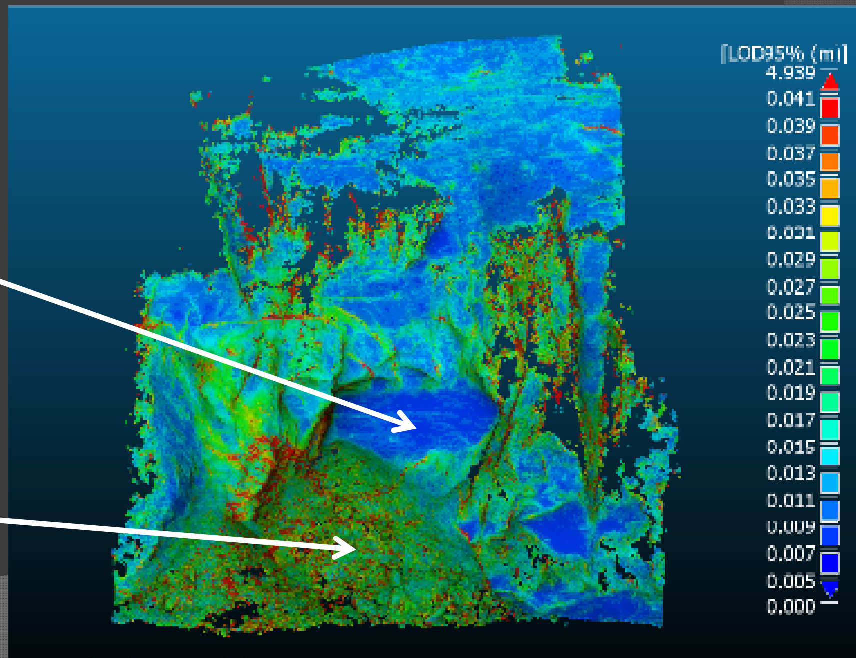
$$c.i_{95\%} = \pm 1.96\left(\sqrt{\frac{\sigma_1^2}{n_1}+\frac{\sigma_2^2}{n_2}} + registration\ error\right)$$

Total budget for level of change detection (LoD) at 95 % confidence (Leica Scanstation 2 or C10)

Lague et al., ISPRS journal, 2013

1. Registration error between 2 surveys : **~ 4 - 6 mm**
2. Scanner noise : 1.41/√n -> 0 mm by spatial averaging
3. Surface roughness effects (d=0.5 m):
   - **Flat rock : 0.5 – 5 mm**
   - **Gravel bed : 1- 30 mm**
   - **Rockfall debris : 5-260 mm**

3D map of confidence interval



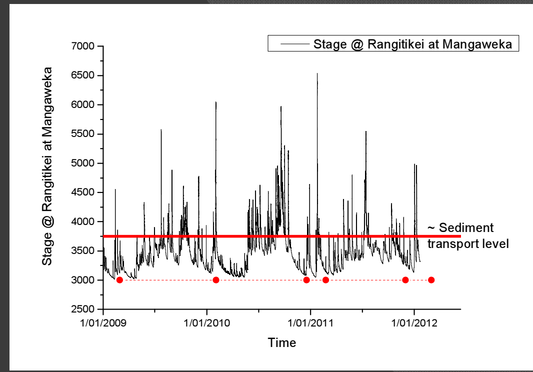
Best case : ±4 mm

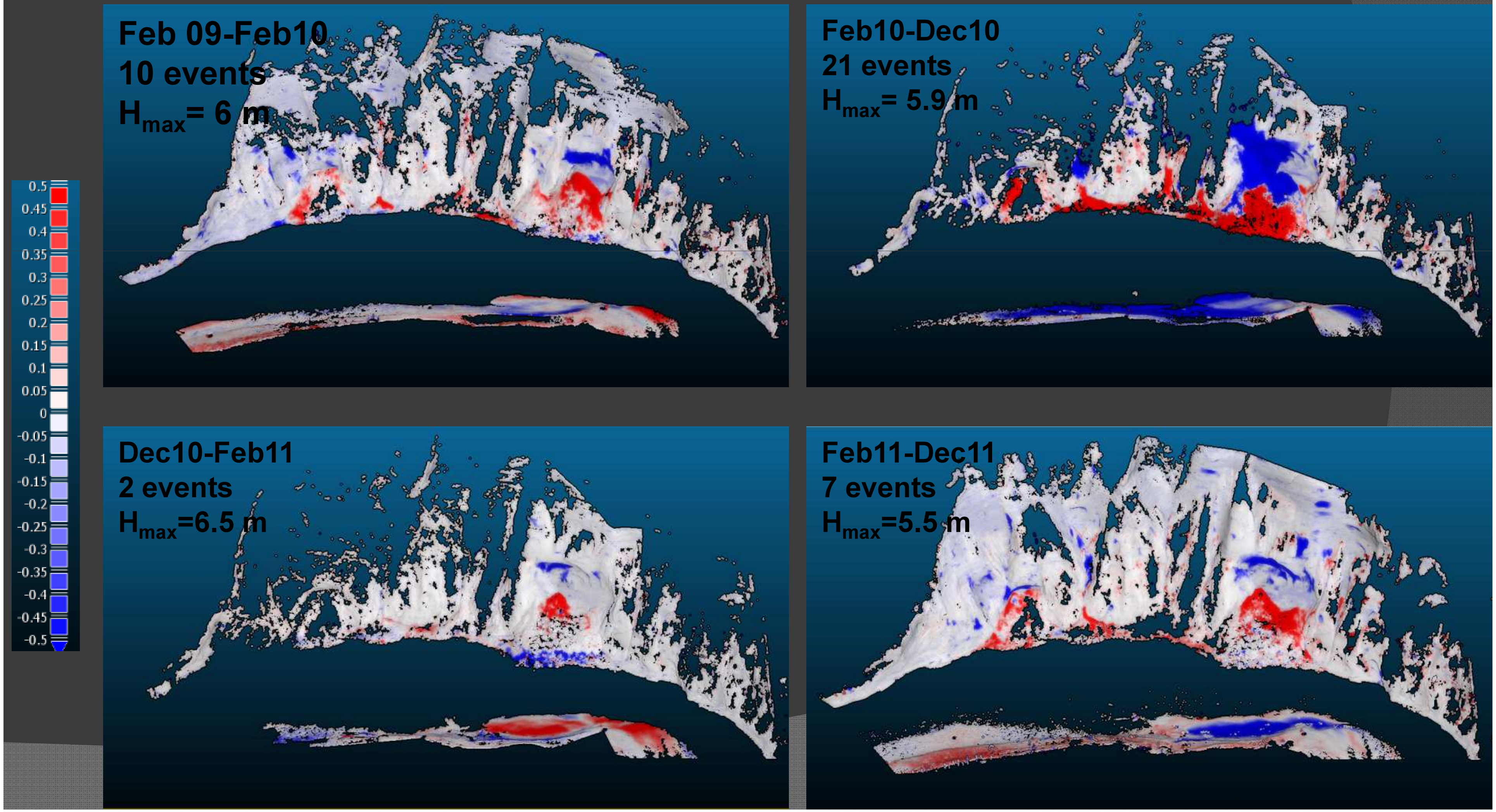
Set by registration error

Debris: ~ 4 cm

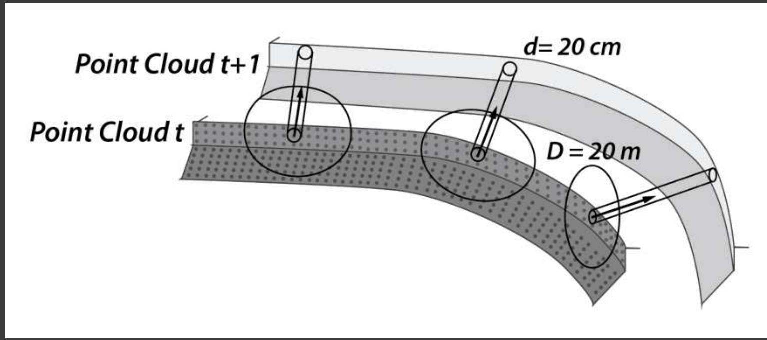
Set by surface roughness

FULL 3D calculation: Bedrock meander evolution over 3 years in NZ

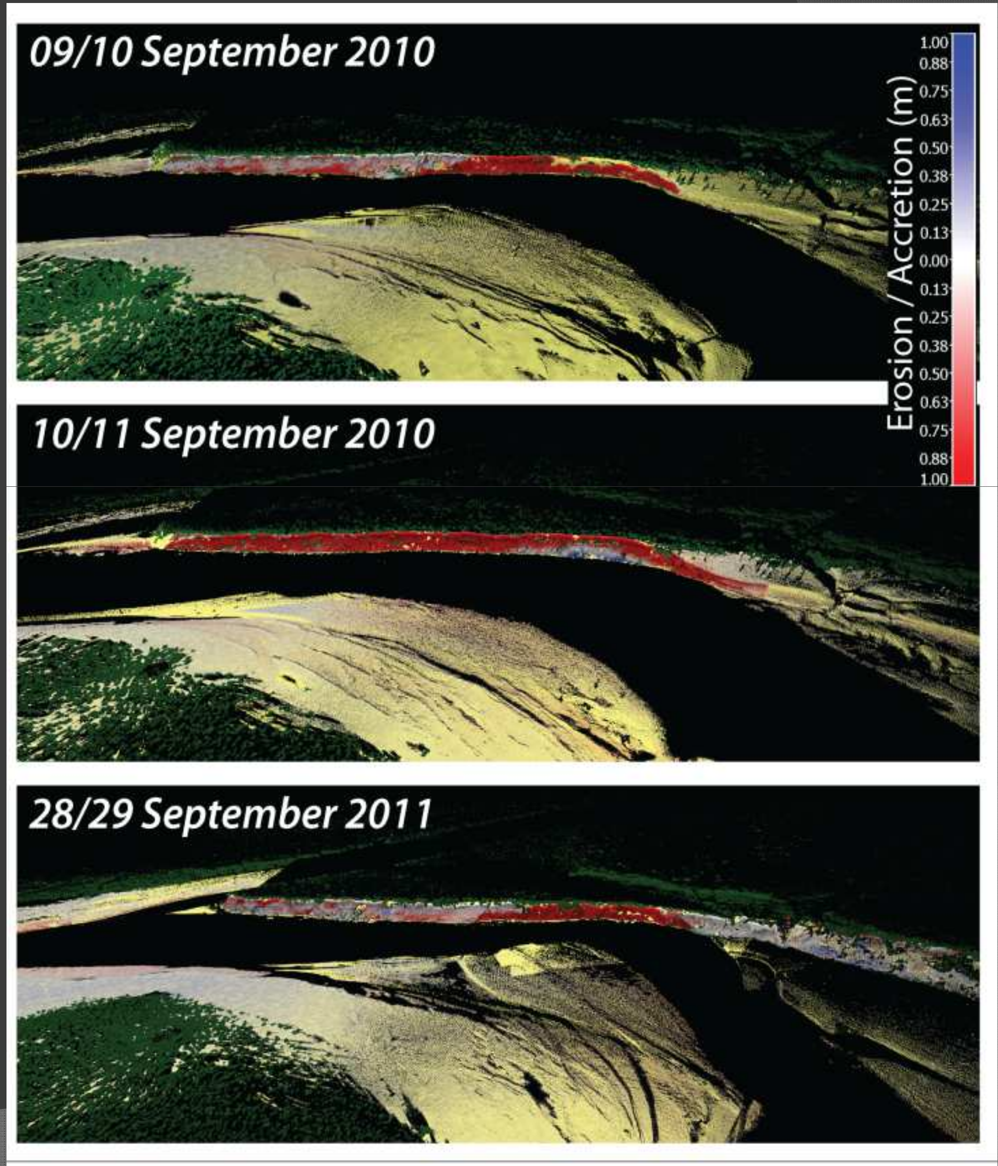




Horizontal measurement
e.g., bank retreat in the Mt St Michel Salt Marshes



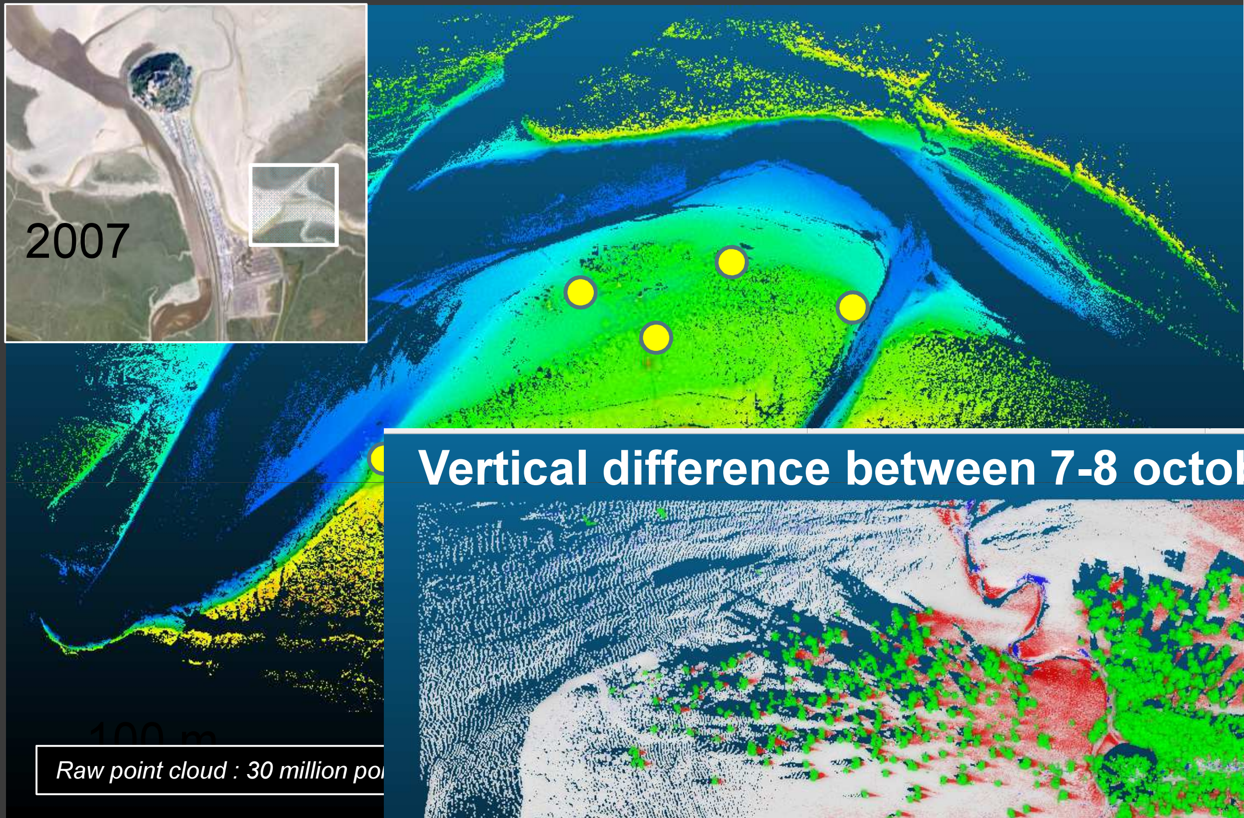
- No need to rotate data

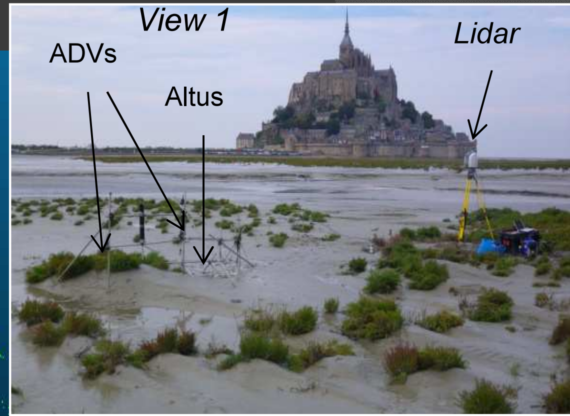


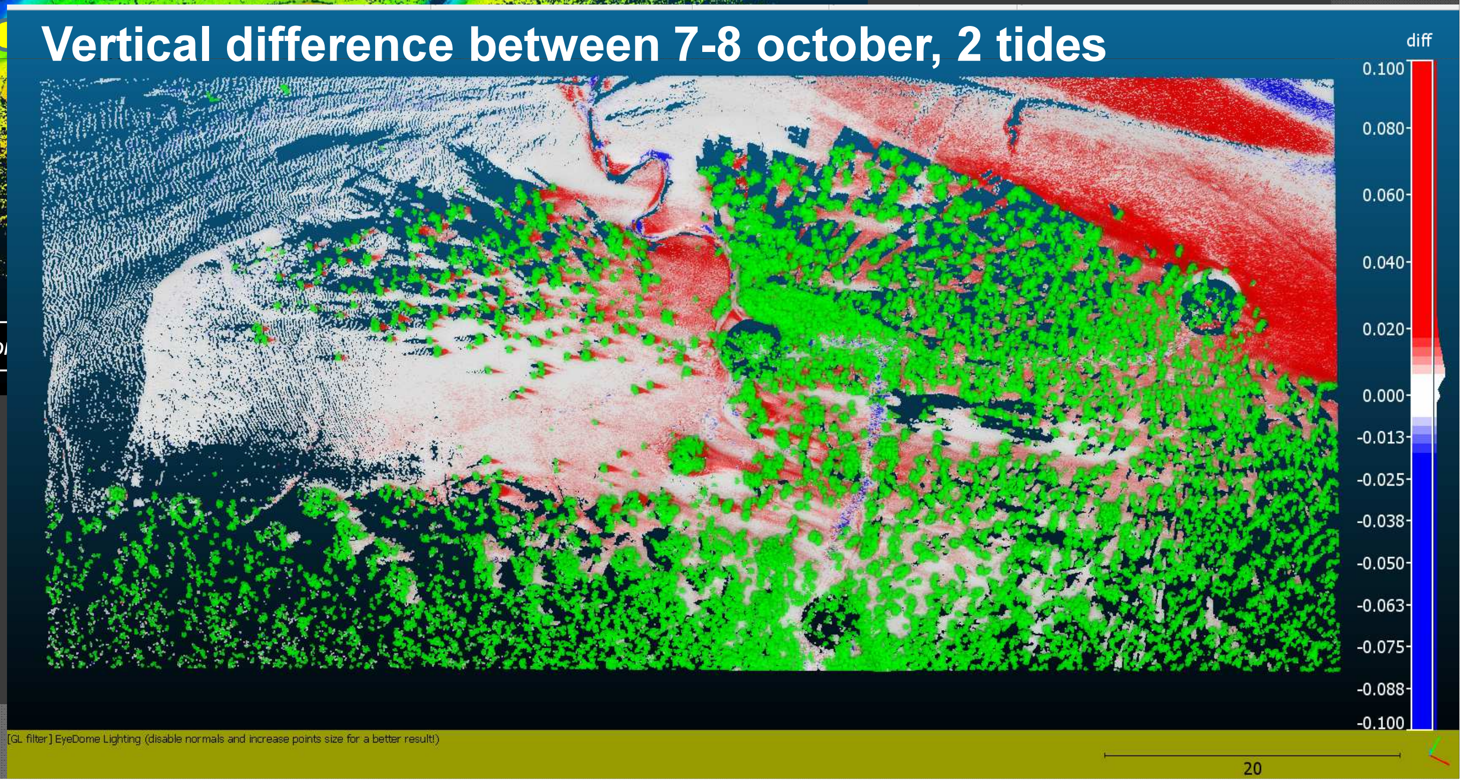
Thèse J. Leroux

Vertical measurement: No normal calculation

e.g., Mt St Michel Salt Marshes

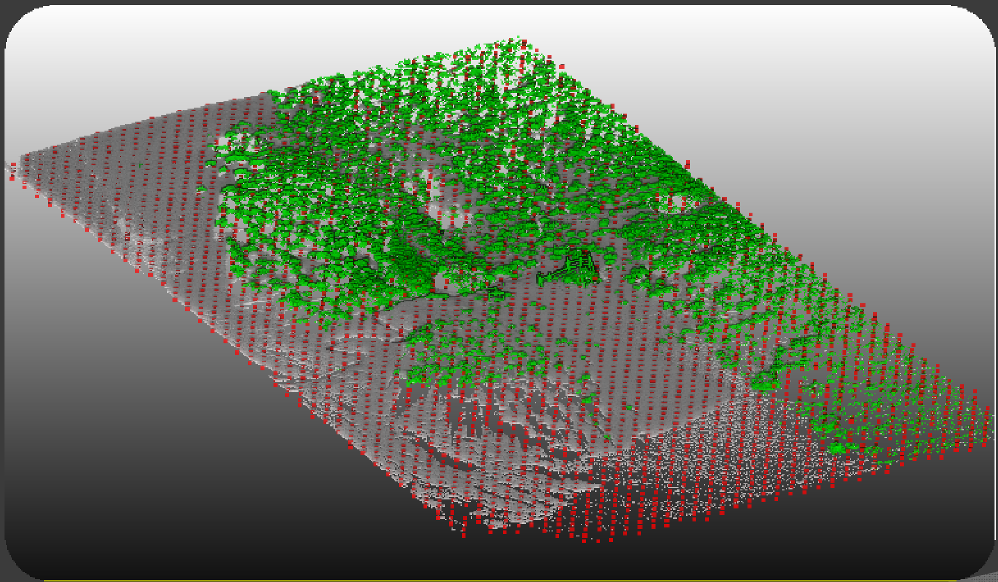




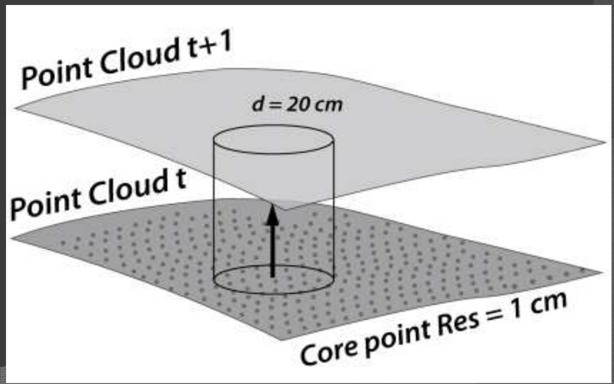


M3C2 as an alternative to DTM differencing using CORE points

- Calculation on a subset of « core » points regularly sampled
- Vertical difference using the raw data at each core point
  - No normal calculation -> very fast
- No calculation when no comparable surface
- Interpolation of the results AFTER the calculation
- Additional grids can be generated (C.I, roughness, pt density)



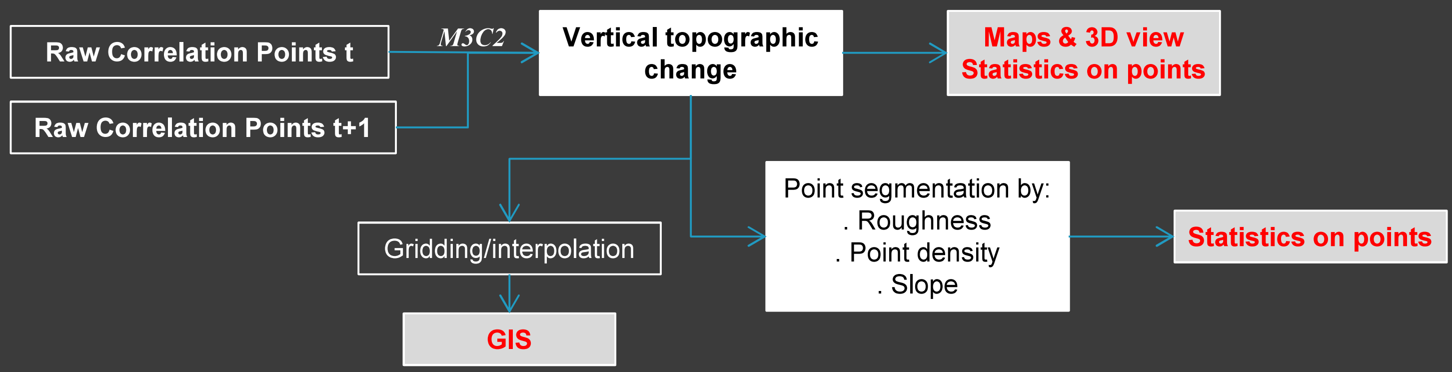
Grey: raw ground points
Green: raw veget points
RED: grid of core points



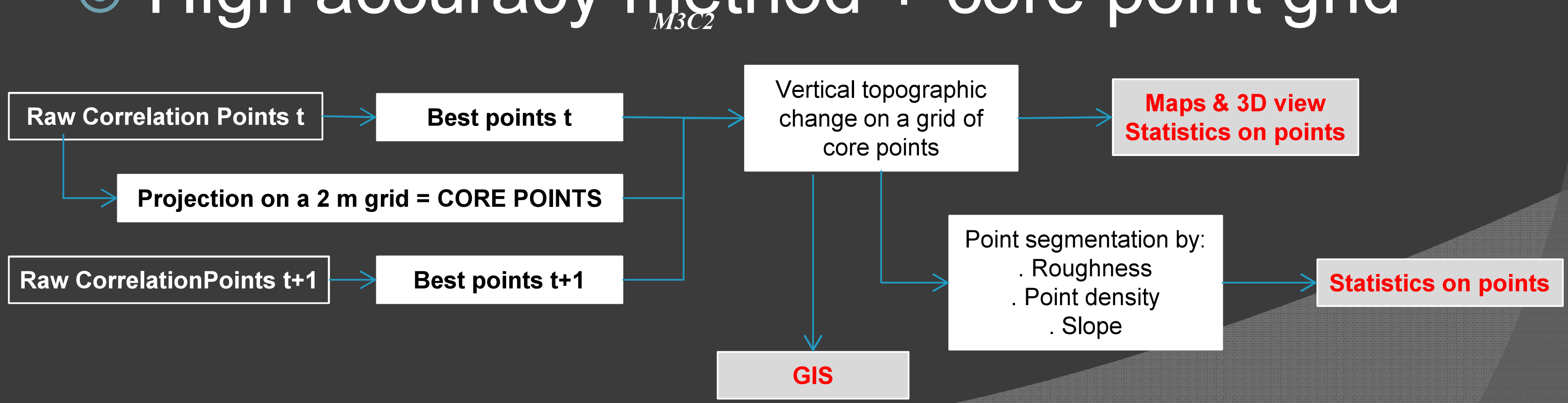
TLS data from Mt St Michel salt marshes

Workflow in the context of Pleiades Comparison Using Cloudcompare + plugin qM3C2

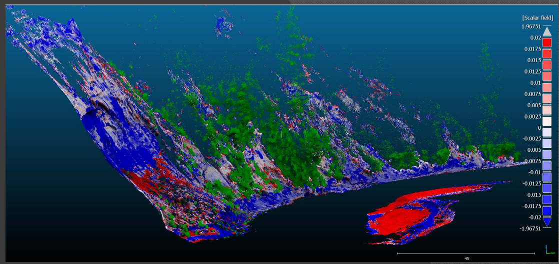
- Quick method



- High accuracy method + core point grid



Conclusions



- Most operations traditionnaly done on DTM can be done on point clouds (with open source software!)
- It can be faster and more direct than DTM comparison
- For high accuracy HRT comparison, point clouds give more handle on the error budget
- Open source methods & implemented in Cloudcompare