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Landslides Detection and Monitoring along Dieppe Coastal Cliffs

Ability of boat-based Mobile Laser Scanning

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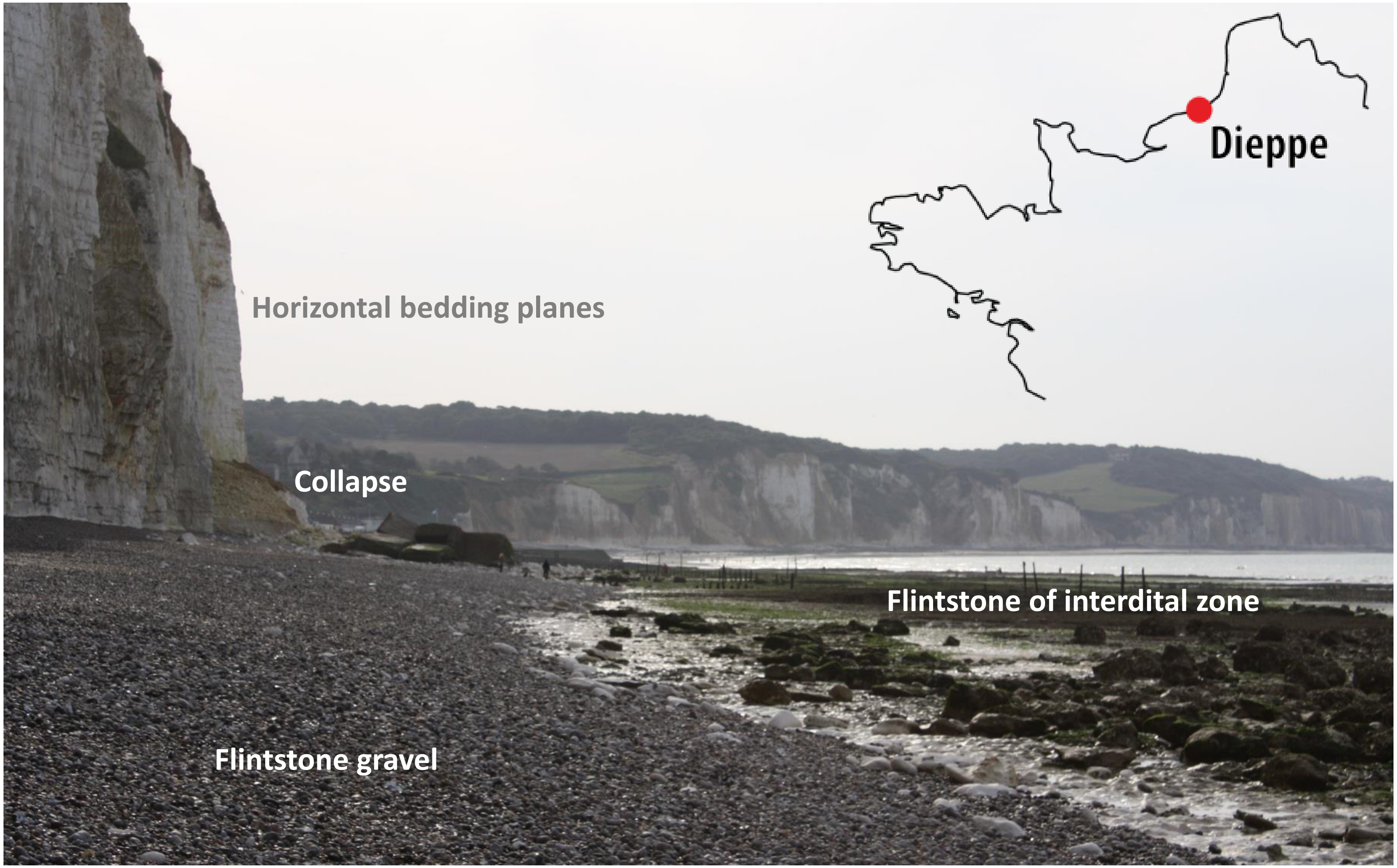
| le savoir vivant |

Context

- In Normandy, France, coastal cliffs are mainly formed by sub-horizontal deposits of soft Cretaceous chalk interlayed by thin bands of biogenic flint.



Context

- Largely destabilized by an intense weathering and the Channel sea erosion, small and large rockfalls and collapses are regularly observed and contribute to retrogressive cliff processes.

Aims

- Integrated in a long-term study, the **main goals** of the Autumn 2012 and 2013 campaigns were to:

  – **Test the feasibility** of Mobile Laser Scanner in open water

  – **Quantify the mean spacing** of point clouds in different acquisition conditions

  – **Test the repeatability** by quantifying the differences between point clouds of the same area acquired several times

  – **Compare 2 sequential acquisitions** to detect and quantify collapses.

Principles of Mobile Laser Scanner

- Same theoretical principles than the ALS, but …
  … can be install on ordinary vehicles (car or boat) thanks to smaller, cheaper and portable devices:
  - 1 Inertial Navigation System:
    - 2 GNSS antennas (position and rough azimuth)
    - 1 Inertial Measurement Unit (orientation)
  - 1 Terrestrial LiDAR (distance)

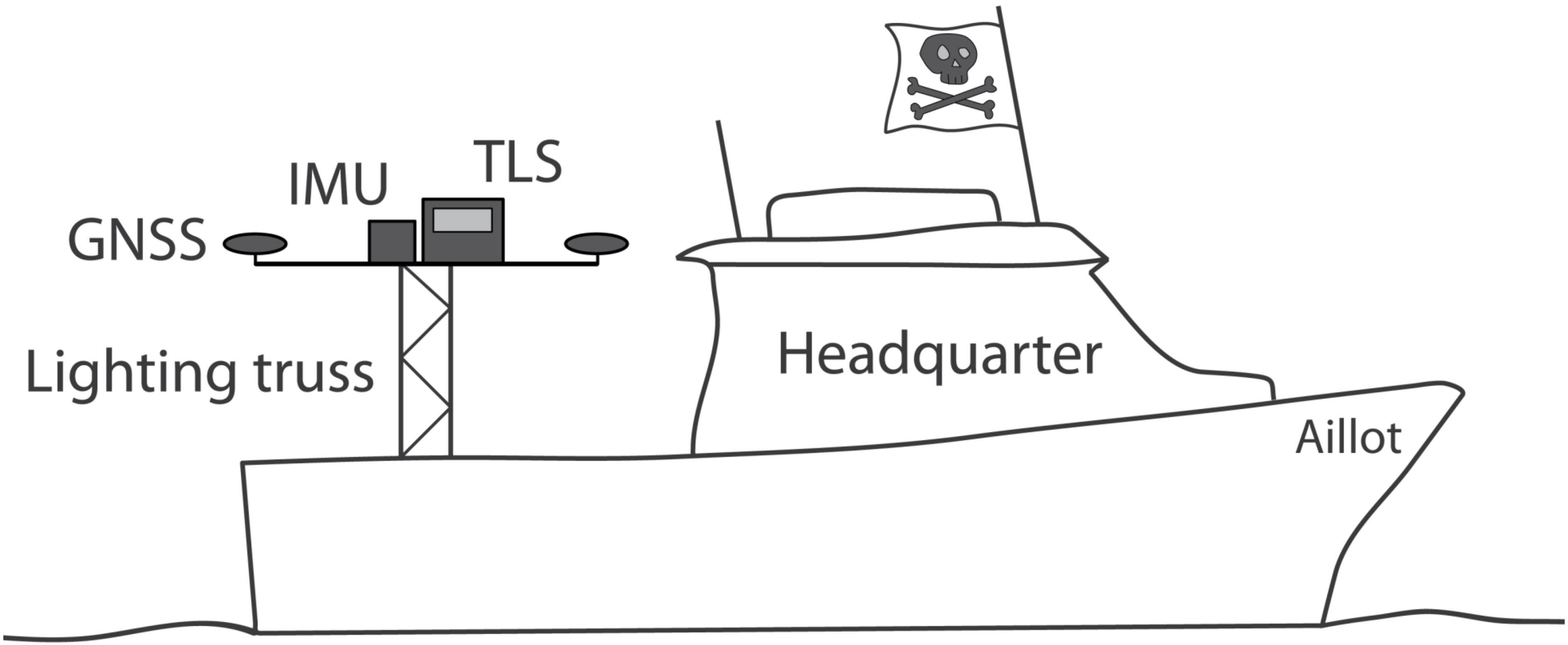
Specs

- LiDAR Ilris 3D Long Range
  - Laser wavelength: 1’064 nm
  - Pulse rate: 10 kHz
  - Maximum range: approx. 2’000 m
  - Mean precision of range estimation: 4 mm at 100 m
  - Angular accuracy: 8 mm at 100 m
  - Beam diameter: 27 mm at 100 m

- Inertial Navigation System Applanix POS-MV 340-v4
  - Acquisition frequency: 1 Hz
  - Angular accuracy: 0.010° with a base station
  - Positioning accuracy: from 0.02 to 0.1 m with a base station

Set up

- The system is mounted on a rigid plate with 2 arms for antennas
- The plate is firmly attached to the marine vessel, in a good place:
  - To ensure a GNSS horizon as best as possible
  - To avoid splash on the system



Set up

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Acquisition at the Cap d'Ailly

- Cap d'Ailly test site: length ~300 m, height ~35 m

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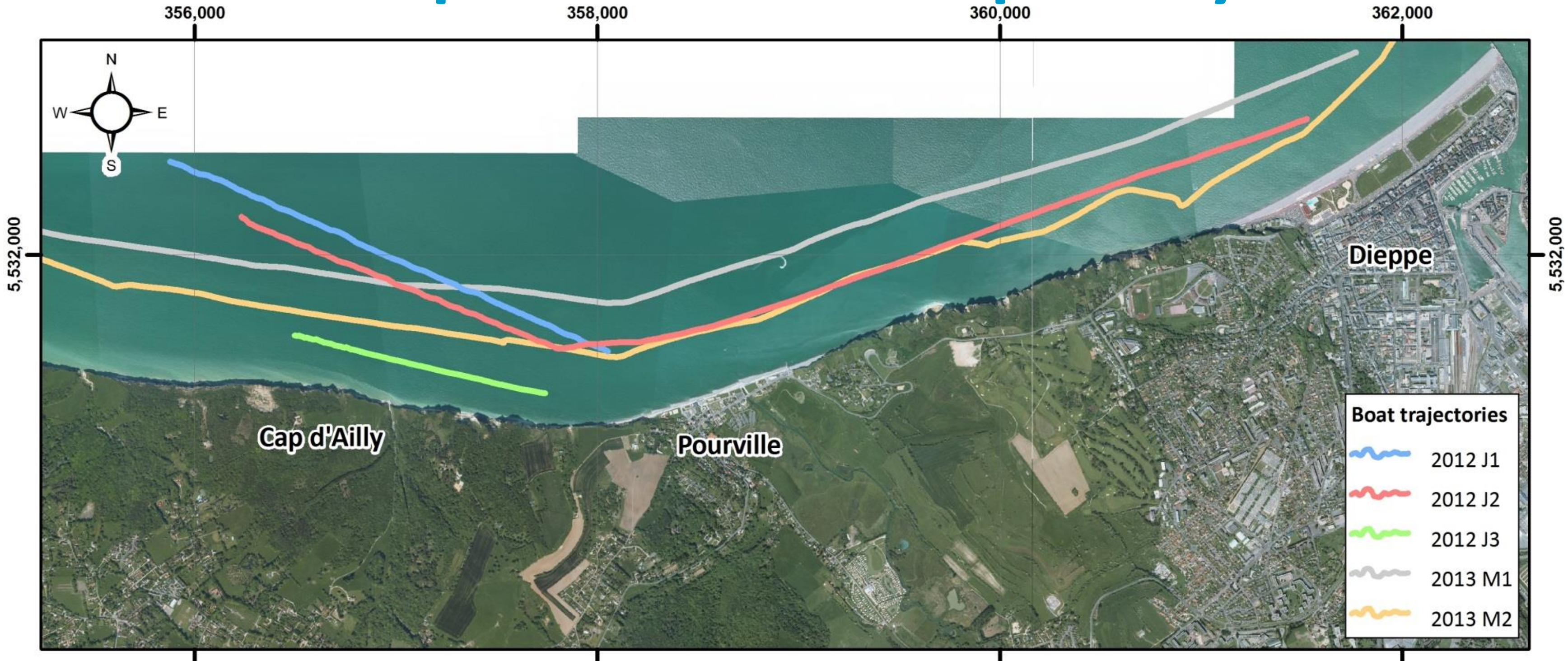
- 3 acquisitions in 2012 during a sunny day with a calm sea (2 Bft)
  - J1: low tide, 4 knots, range 650 m, length 2'500 m
  - J2: low tide, 4 knots, range 500 m, length 5'700 m
  - J3: high tide, 2 knots, range 200 m, length 1'000 m

- 2 acquisitions in 2013 during a sunny day with a calm sea (1.5 Bft)
  - M1: low tide, 4 knots, range 600 m, length 15'700 m
  - M2: high tide, 3.5 knots, range 300 m, length 16'900 m

Acquisition at the Cap d'Ailly



Processing

1. **Improve the positioning:**
   - Filtering GNSS data to delete outliers > accuracy: m to dm
   - Using as base station the permanent GNSS antenna of the IGN located at 10 km, in Ambrumesnil > accuracy: dm to ~3 cm

2. **Coupling positioning, orientation and LiDAR distance data**:
   - GNSS time data is recorded on all files and then used to synchronize data during the post-processing

3. **Create the xyzi text file** of each point cloud

4. **Clean** all point clouds

Processing

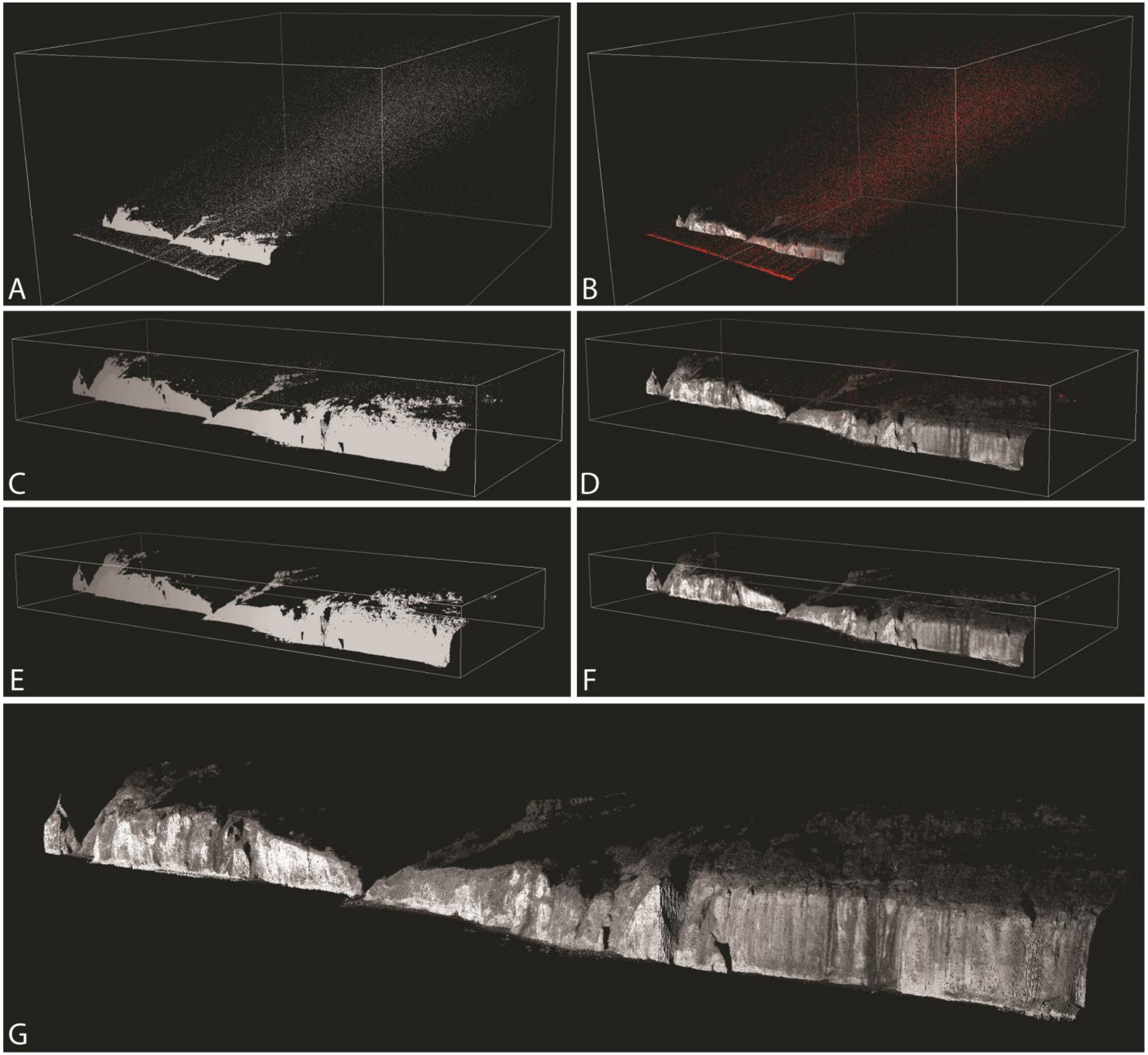
A: raw J3 point cloud

3’176’256 points

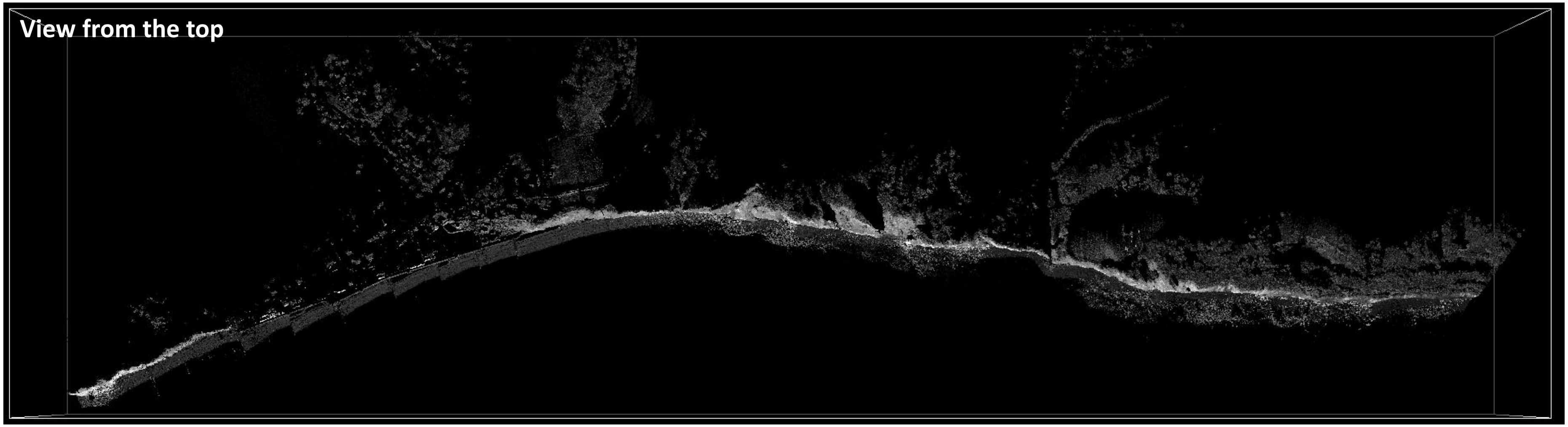
B+D+F: iterative manual selection

G: final cleaned J3 point cloud

3’120’564 points



Final Point Clouds: Example



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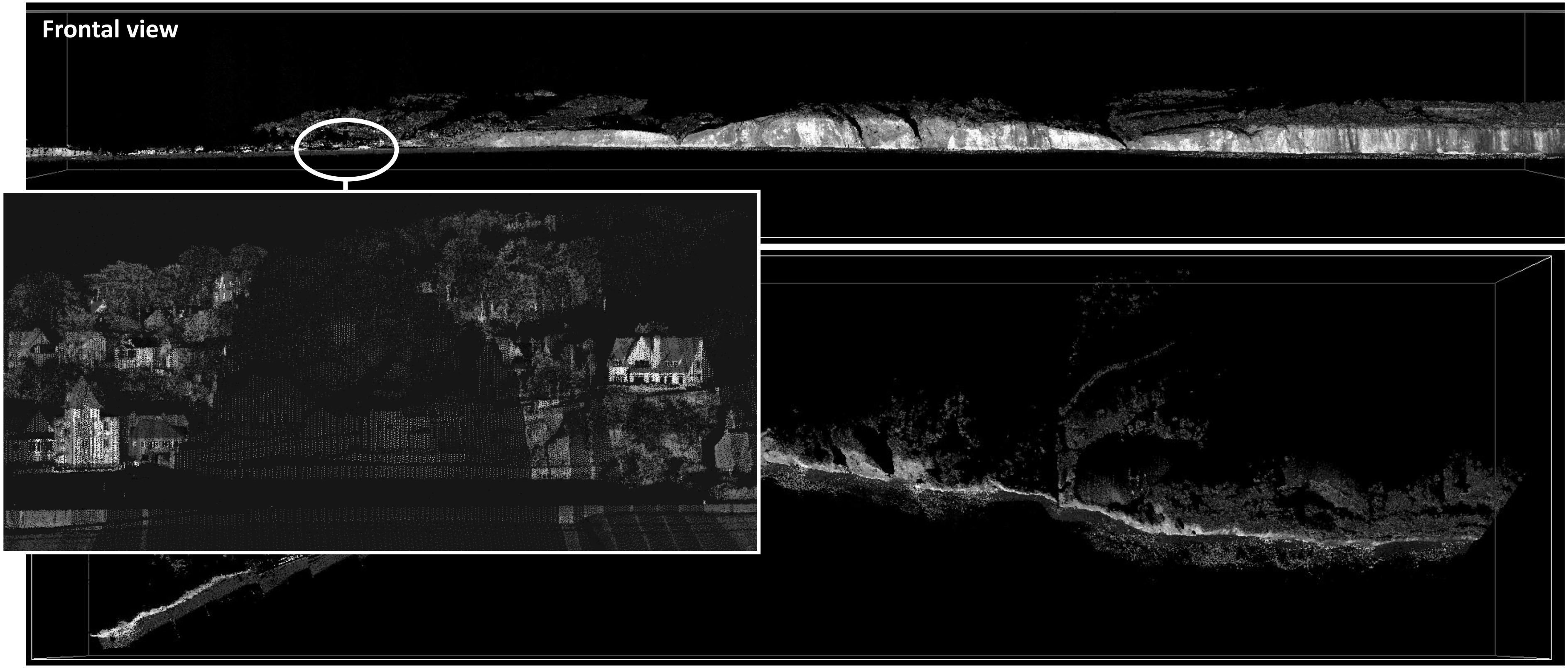

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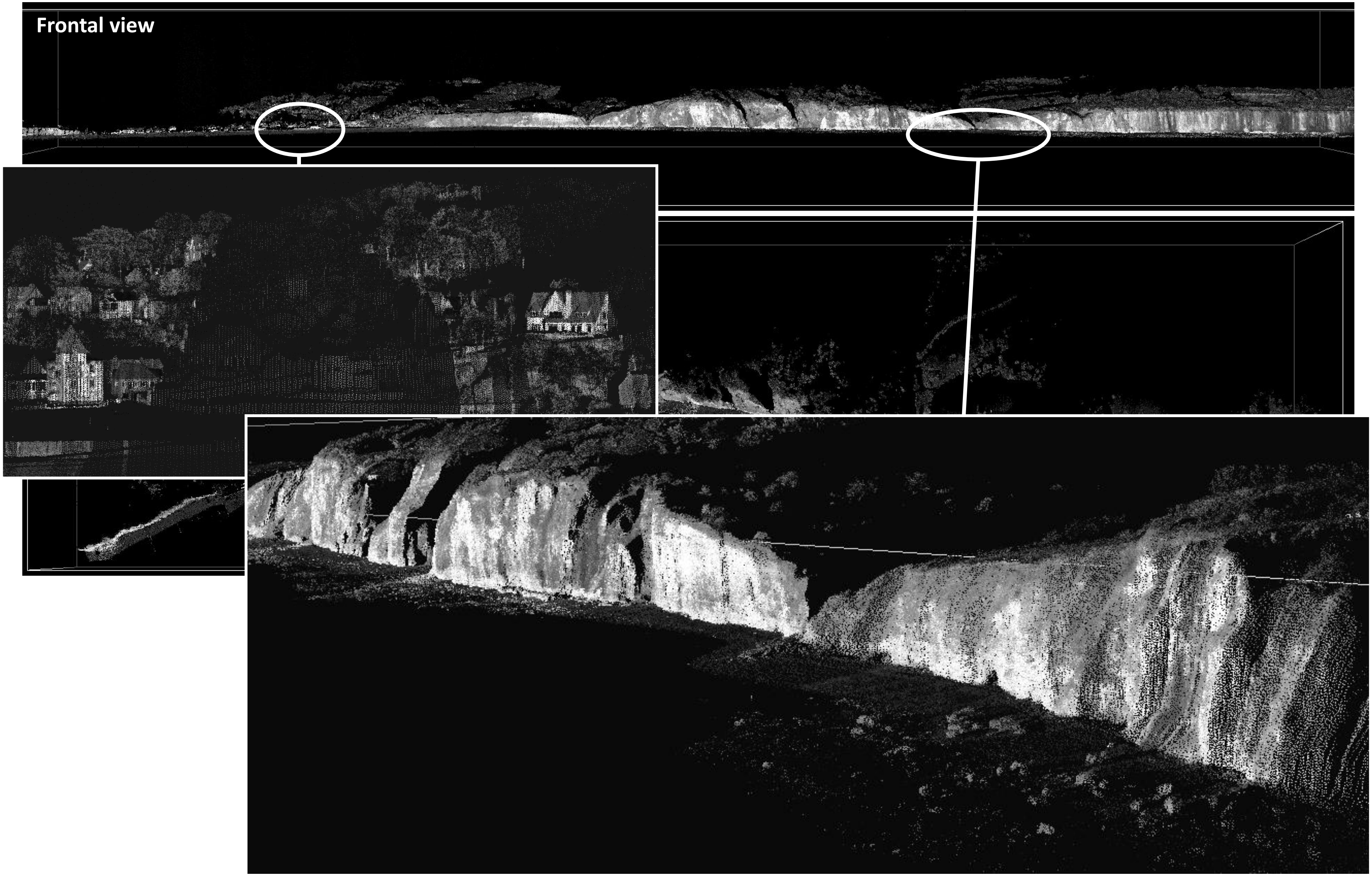
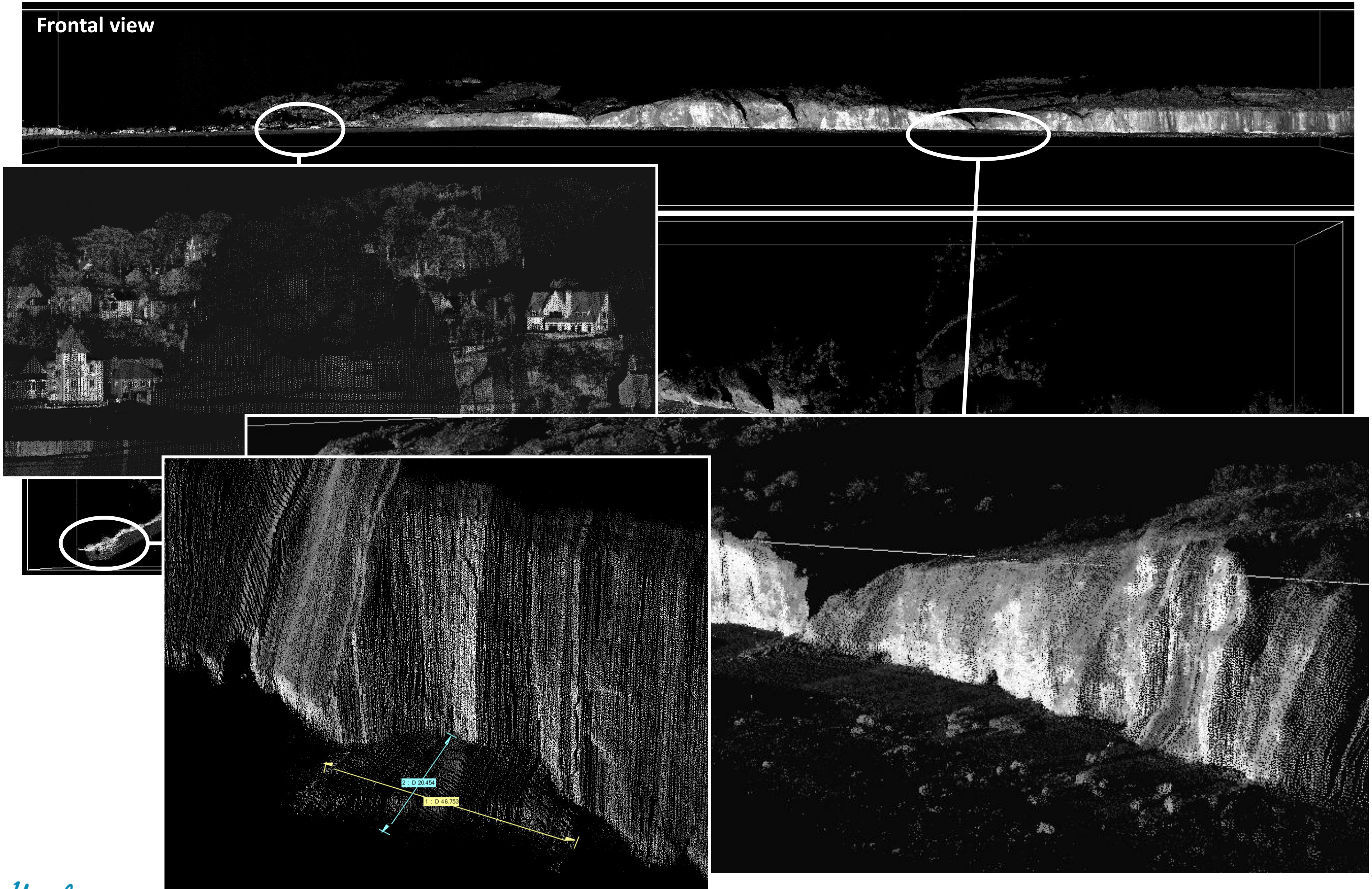
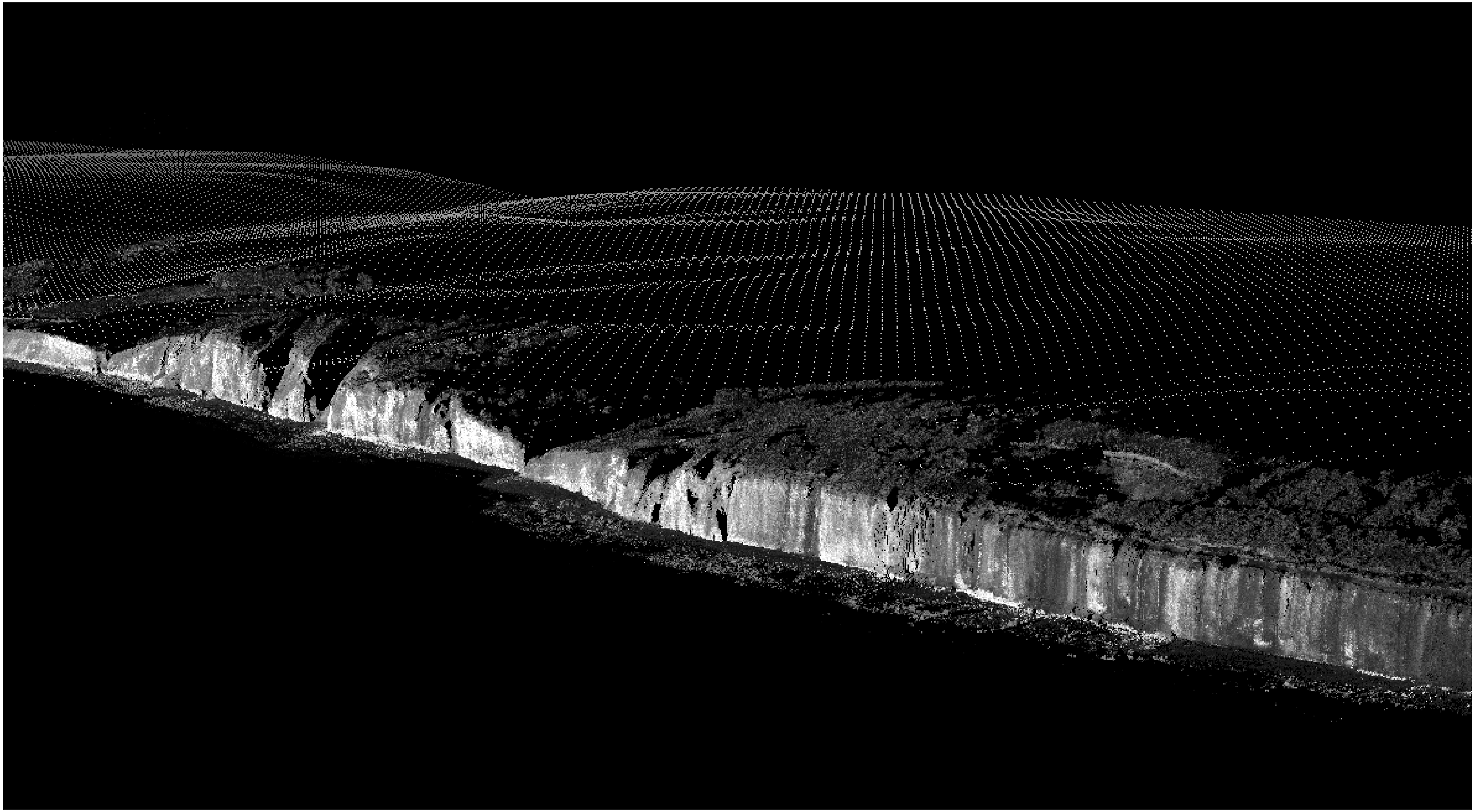


Final Point Clouds: Example



Comparison with the available ALS



Point Spacing

- A MatLab™ routine **extracts for each point the Euclidian distance to its nearest neighbor**. Then **statistical analysis regarding mean spacing** can be considered:

  - **J2 >** from 500 m at 4.2 knots
    - mean spacing: 19.1 cm
    - percentile 68 of the distance to the mean: 15.0 cm

  - **J3 >** from 200 m at 2.2 knots
    - mean spacing: 8.1 cm
    - percentile 68 of the distance to the mean: 5.0 cm

  - **M2 >** from 300 m at 3.5 knots
    - mean spacing: 17 cm
    - percentile 68 of the distance to the mean: 13 cm

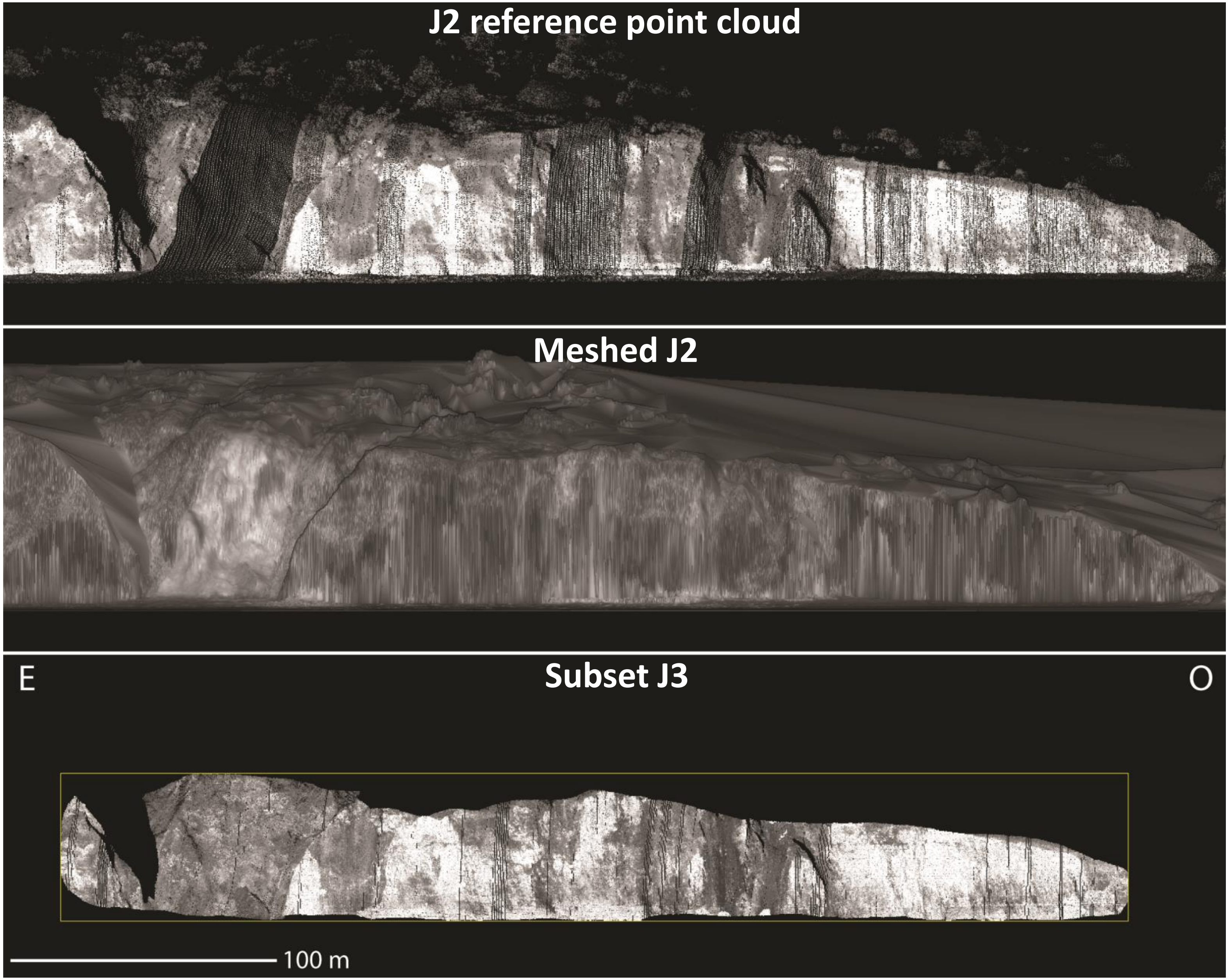
Point Clouds Differences

- We also investigated the **repeatability of acquisitions in real conditions** > **comparisons** between the 3 MLS points clouds:

1. **J2 is used as reference** point cloud (having the best overlap)
2. **A mesh is created** using Delaunay triangulations (in CloudCompare)
3. **The shortest distances** from cloud points to the reference surface of J2 are calculated and the **interesting statistics are extracted**
4. **New statistics** on computed shortest distances **after having performed a best-fit alignment** of J1 and J3 on the meshed reference surface of J2 (in CloudCompare), are also extracted

> EXAMPLE POINTS J3 to MESH J2

Point Clouds Differences



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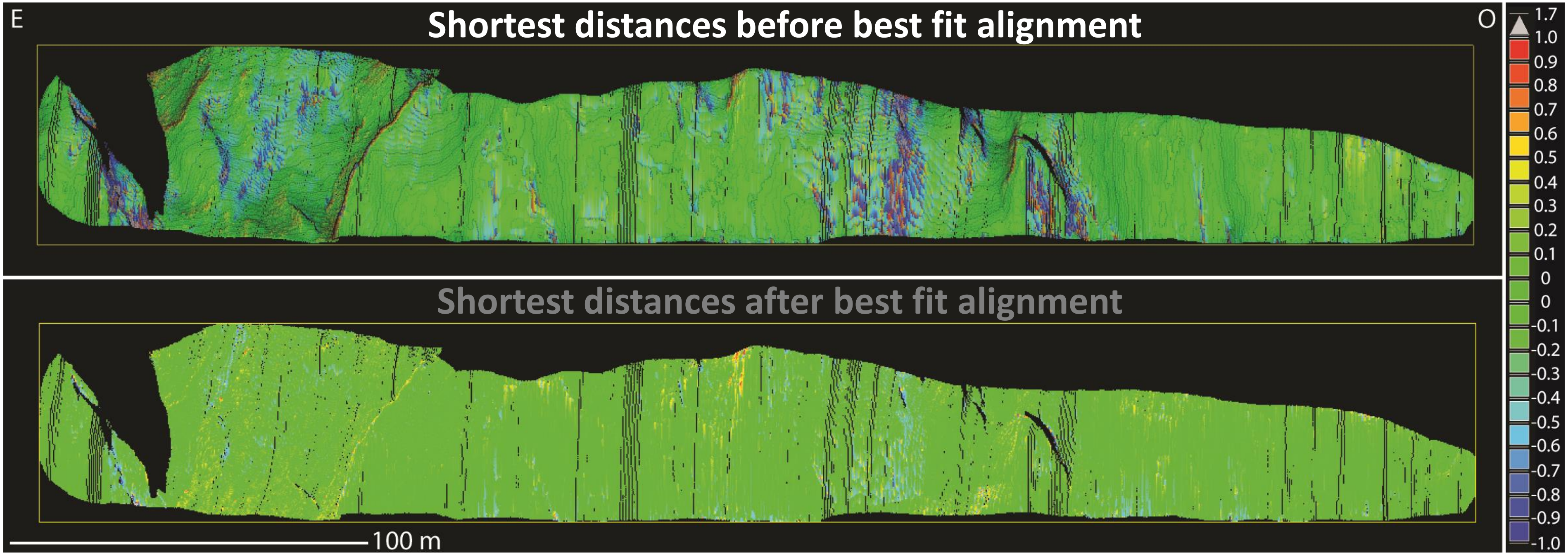

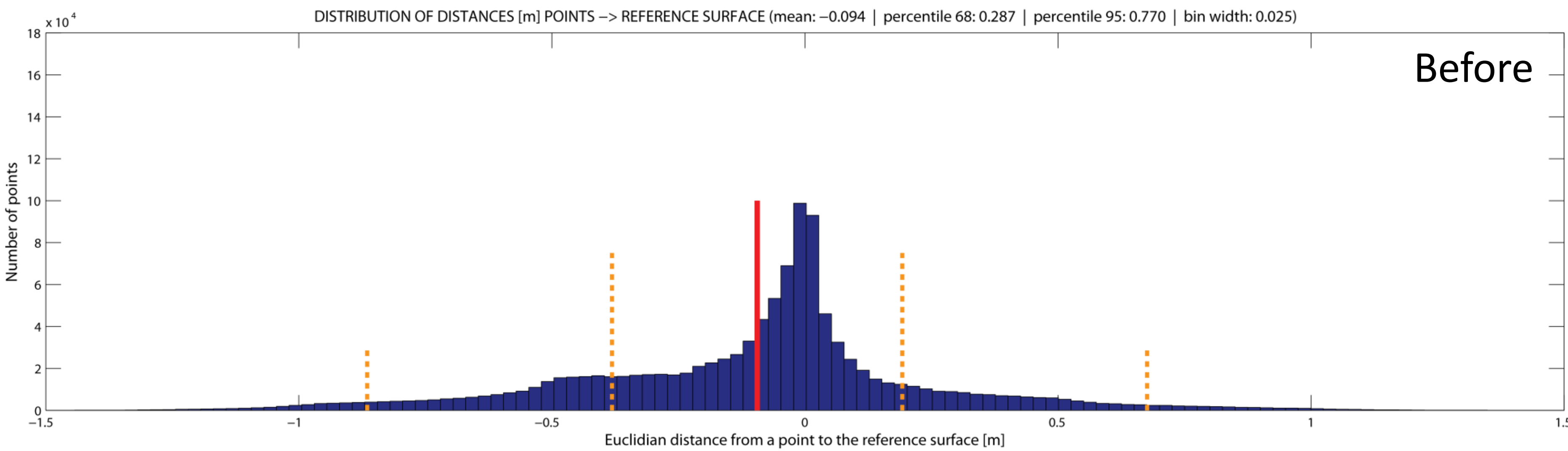

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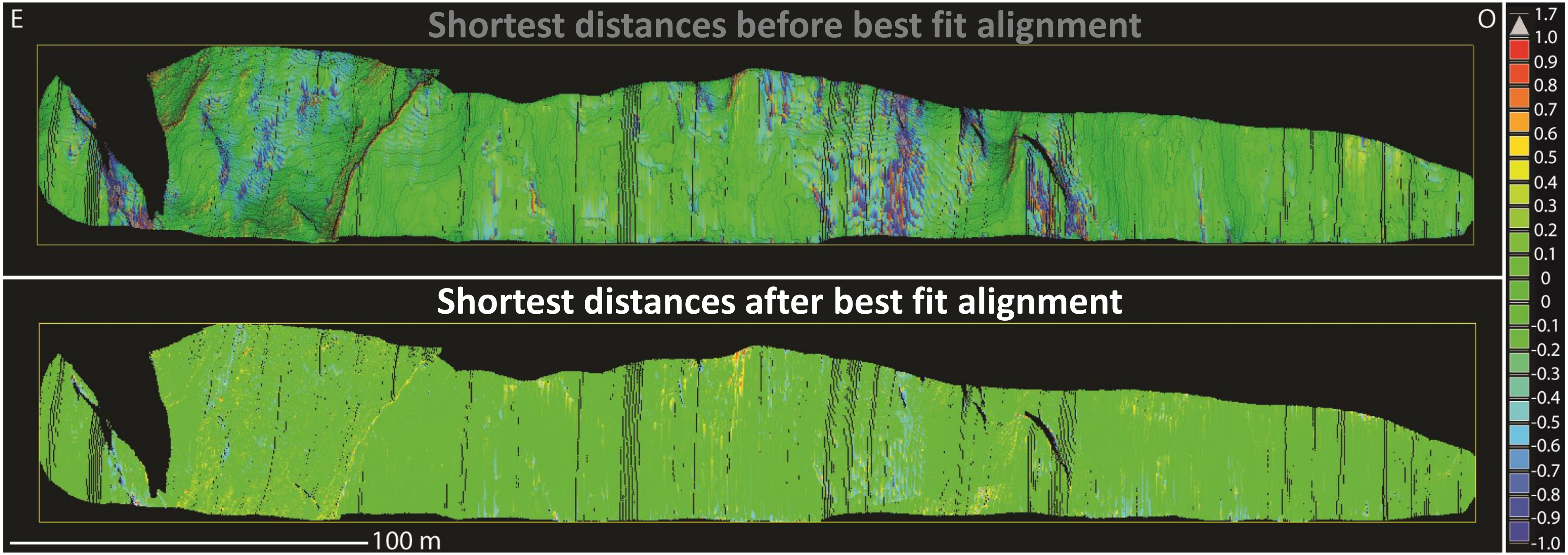
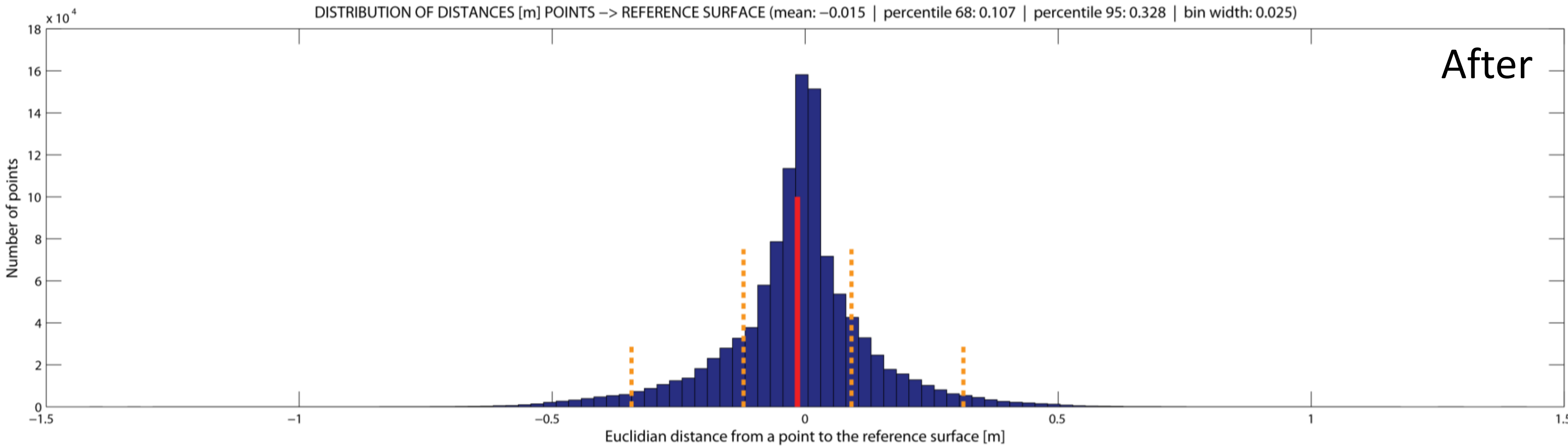


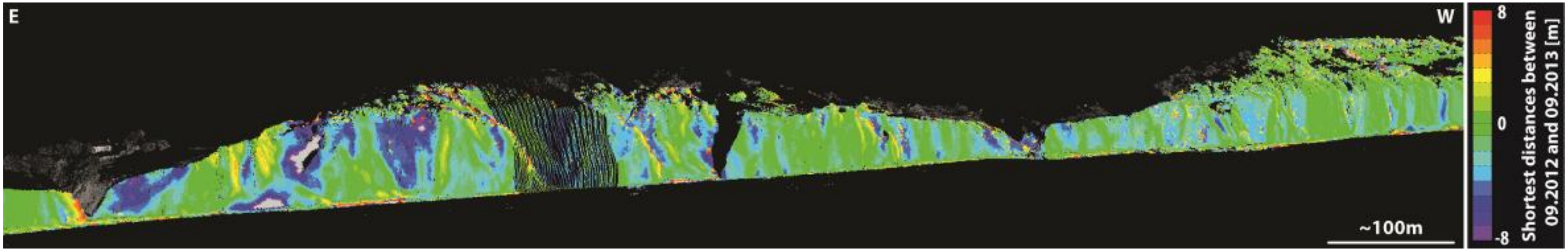


Point Clouds Differences

- **J2's Points** (mean spacing: 19.1 cm) to Mesh J2 > Pilot experiment
  - Mean difference (cm): 0.01
  - Percentile 68 of the distance to the mean (cm): 2.1
- **J1's Points** (mean spacing: 23.8 cm) to Mesh J2
  - Mean difference (cm): 12.5 | 0.4
  - Percentile 68 of the distance to the mean (cm): 30.9 | 15.7
- **J3's Points** (mean spacing: 6.5 cm) to Mesh J2
  - Mean difference (cm): -9.5 | -1.5
  - Percentile 68 of the distance to the mean (cm): 28.7 | 10.7
- **TLS' Points** (mean spacing: 3.8 cm) to Mesh J2
  - Mean difference (cm): 2.25
  - Percentile 68 of the distance to the mean (cm): 20.4

Rough change detection

- Rough shortest distances comparison (ICP algorithm) between 2012 and 2013 point clouds wrapped on the intensities of the 2nd scan
  - Multiple rockfall events can be easily identified and quantified close to the Cap d'Ailly.

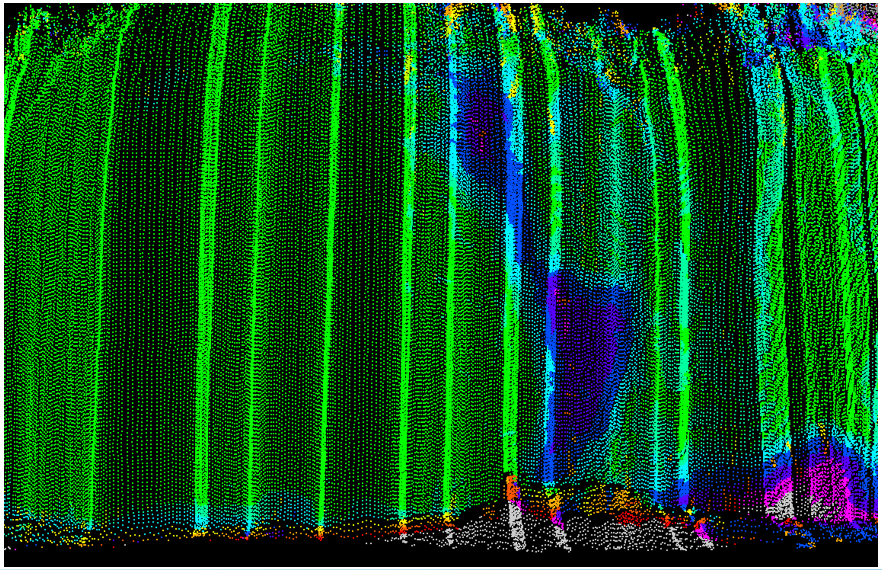


(Negative values: eroded material; Positives values: accumulated material)

We suggest dividing the point clouds in shoreline sections of about 2 km long and with a constant dip direction

> may improve alignments of piecewise data on the interpolated

>> enhance detection mapping



Specific landslide monitoring

- Computation of horizontal distances between the 2 point clouds on a large active retrogressive landslide that have been reactivated during spring 2013 and destroyed several constructions.

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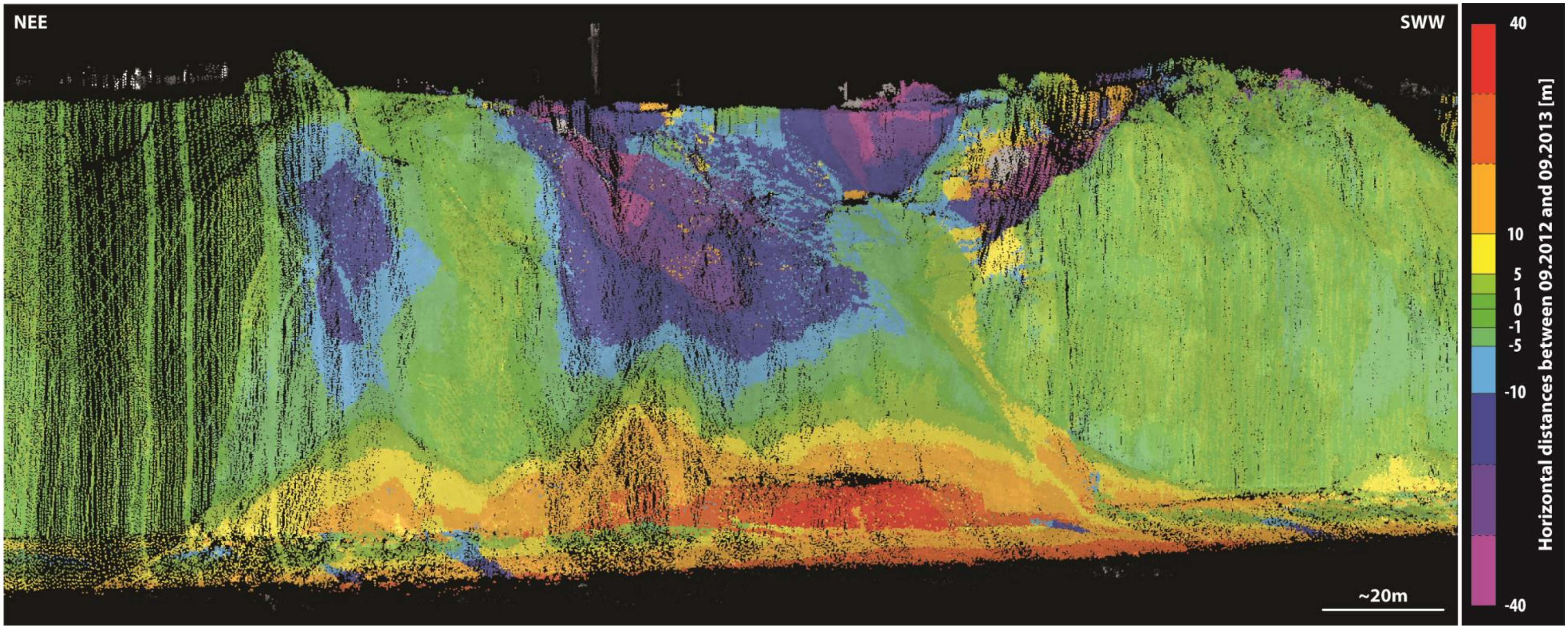

(Negative values: eroded material; Positives values: accumulated material)

> retrogression up to 40 m in few months.

Conclusions

- In **good meteorological conditions**, i.e. calm sea, no rain and close to the coast, **MLS devices** are able to **quickly scan long shoreline** with a **mean point spacing of about 15 cm**.

- For now, the **monitoring with MLS of the constant erosion** with mm and cm rates **seems not yet realistic.** But on the opposite, the **MLS resolution is good enough** to map and **quantify geomorphological features** along coastal cliffs.

- In addition, **its ability to detect rockfalls** and deposit erosions (> m3) **is confirmed with classic ICP algorithms** approaches.

- Finally, **large landslides can also be monitored**, quantifying retrogressive displacements and involved volumes

Feel free to contact me if any question

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thanks

Dieppe International Kite Festival