# Cliff change detection using Siamese KPConv deep network on 3D point clouds

I. de Gélis[1,2]*, Z. Bessin[3,4]*, P. Letortu[4], M. Jaud[5,3], C. Delacourt[3], S. Costa[6], O. Maquaire[6], R. Davidson[6], T. Corpetti[7] and S. Lefèvre[2]

[1] Magellium, F-31000 Toulouse, France
[2] IRISA UMR 6074, Université Bretagne Sud, F-56000 Vannes, France - iris.de-gelis@irisa.fr
[3] Geo-Ocean - UMR 6538, Univ Brest, CNRS, F-29280 Plouzané, France - zoe.bessin@univ-brest.fr
[4] LETG - UMR 6554, Univ Brest, CNRS, F-29280 Plouzané, France
[5] European Institute for Marine Studies (IUEM) - UMS 3113, Univ Brest, CNRS, F-29280 Plouzané, France
[6] IDEES - UMR 6266, Normandie Univ, UNICAEN, CNRS, F-14000 Caen, France
[7] CNRS, LETG UMR 6554, F-35000 Rennes, France

## 1. Motivations

**Context**:

- Cliffs cover **52%** of the world's coastline [1]
- Cliff **erosion likely to increase** with sea level rise [2]
- **Endangering** nearby populations and infrastructures

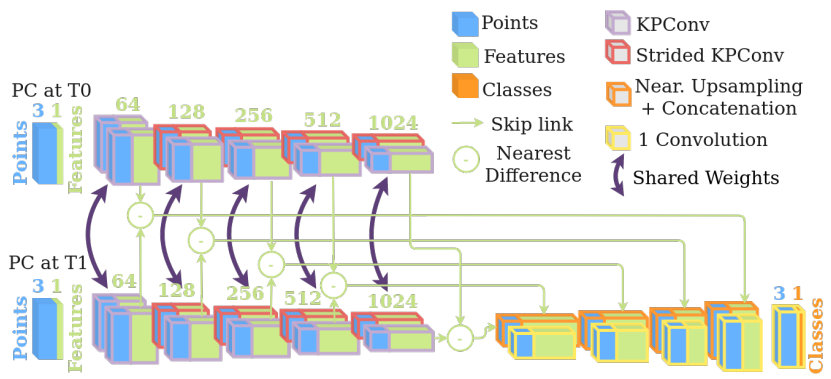
**Challenges**:

- Working **directly on raw 3D point clouds** to avoid the loss of information when rasterizing the vertical cliffs
- **Randomness of natural cliffs** (unlike buildings in urban areas)
- Being able to **study vertical** or very steep **cliffs**

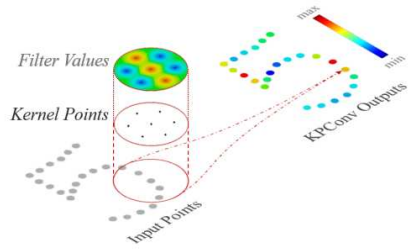
## 2. Objectives

Explore the efficiency of **Siamese KPConv deep learning** algorithm over raw 3D point clouds (PCs) for **change detection** and categorization on **coastal cliff faces.**

## 3. Siamese Kernel Point Convolution Network [4]




Convolution for 3D PCs: Kernel Point Convolution [3]




## 4. Study area


Petit Ailly cliffs are rocky limestone cliffs in Varengeville-sur-Mer (Normandy, France), 40 m high and monitored since 2010 every 4-5 months. Figure modified from [5]

## 5. Data

**5 different 3D point clouds** derived from **2 methods...**

**Terrestrial Laser Scanning (TLS):**

*Riegl® VZ-400*

- Accuracy: 5 mm
- Precision: 3 mm (at a range of 100 m)

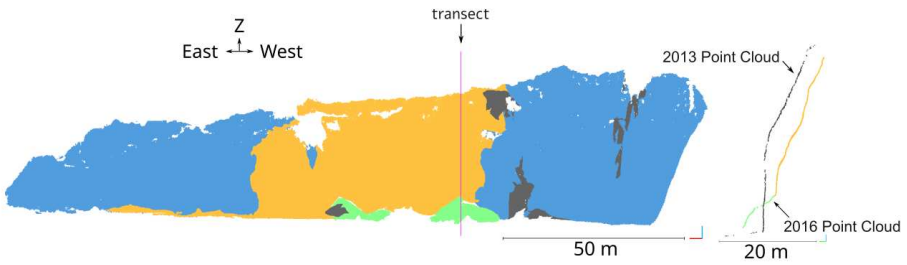
**Terrestrial Photogrammetry (TP):**

*Nikon D800 reflex camera*

- 35 mm focal length
- Overlap $> 60\%$
- Camera positions close to each other and $>$ 20 m from cliff face

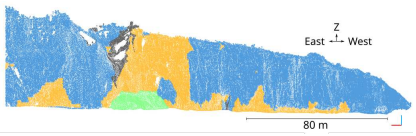
... Forming **4 pairs** of PCs, **manually annotated** by 3 experts.

● Unchanged ● Erosion ● Accumulation ● No data to compare

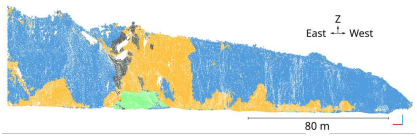


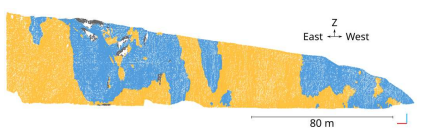

## 6. Results

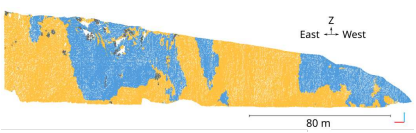
Ground truth



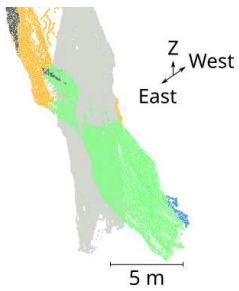

SiameseKPConv prediction



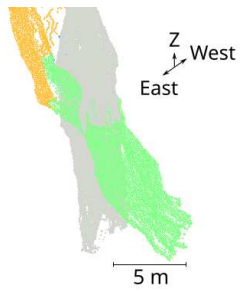



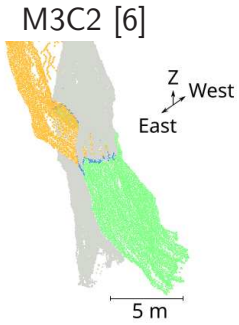

SiameseKPConv




Ground truth




M3C2 [6]




● Older point cloud

| | Per class IoU(%) | | | |
|---|---|---|---|---|
| | Unchanged | Erosion | Accum. | **mIoU**$_{int}$ |
| **Siamese KPConv** | 91.94 | 83.86 | **70.28** | **82.03** |
| M3C2 + threshold | **95.06** | **87.23** | 48.20 | 68.12 |

## 7. Conclusion

- **First study** experimenting a **deep learning** method on **vertical cliffs** without rasterization of PCs for **3D change detection**
- **82.03% of mIoU** over 3 classes of interest (unchanged area, erosion and accumulation)

⇒ **Experimenting** with the Siamese KPConv algorithm on 3D point clouds **from satellite stereo-restitution with lower density** ($\sim$ 2.7 pts/m$^2$ with Pléiades images)

⇒ **Automation of the monitoring of coastal changes**, advocated by governments and coastal observatories in order to improve the management of the associated risks

## References

[1] Adam P Young and Jessica E Carilli. Global distribution of coastal cliffs. *Earth Surface Processes and Landforms*, 44(6):1309–1316, 2019.
[2] Richard P Allan, Ed Hawkins, Nicolas Bellouin, and Bill Collins. Ipcc, 2021: Summary for policymakers. 2021.
[3] Hugues Thomas, Charles R Qi, Jean-Emmanuel Deschaud, Beatriz Marcotegui, François Goulette, and Leonidas J Guibas. Kpconv: Flexible and deformable convolution for point clouds. In *Proceedings of the IEEE/CVF International Conference on Computer Vision*, pages 6411–6420, 2019.
[4] Iris de Gélis, Sébastien Lefèvre, and Thomas Corpetti. 3d urban change detection with point cloud siamese networks. *ISPRS-International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 43: 879–886, 2021.
[5] Pauline Letortu, Marion Jaud, Philippe Grandjean, Jerome Ammann, Stephane Costa, Olivier Maquaire, Robert Davidson, Nicolas Le Dantec, and Christophe Delacourt. Examining high-resolution survey methods for monitoring cliff erosion at an operational scale. *Giscience & Remote Sensing*, 55(4):457–476, 2018. ISSN 1548-1603. doi: 10.1080/15481603.2017.1408931.
[6] D. Lague, N. Brodu, and J. Leroux. Accurate 3D comparison of complex topography with terrestrial laser scanner: Application to the rangitikei canyon (NZ). *ISPRS Journal of Photogrammetry and Remote Sensing*, 82:10–26, 2013.

**ISPRS Congress – Nice – June 6-11th, 2022**