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Assessing proglacial sediment sources evolution of three catchments using the index of connectivity (IC), Plan de l'Aiguille, Chamonix, France

Johan Berthet*, Laurent Astrade*

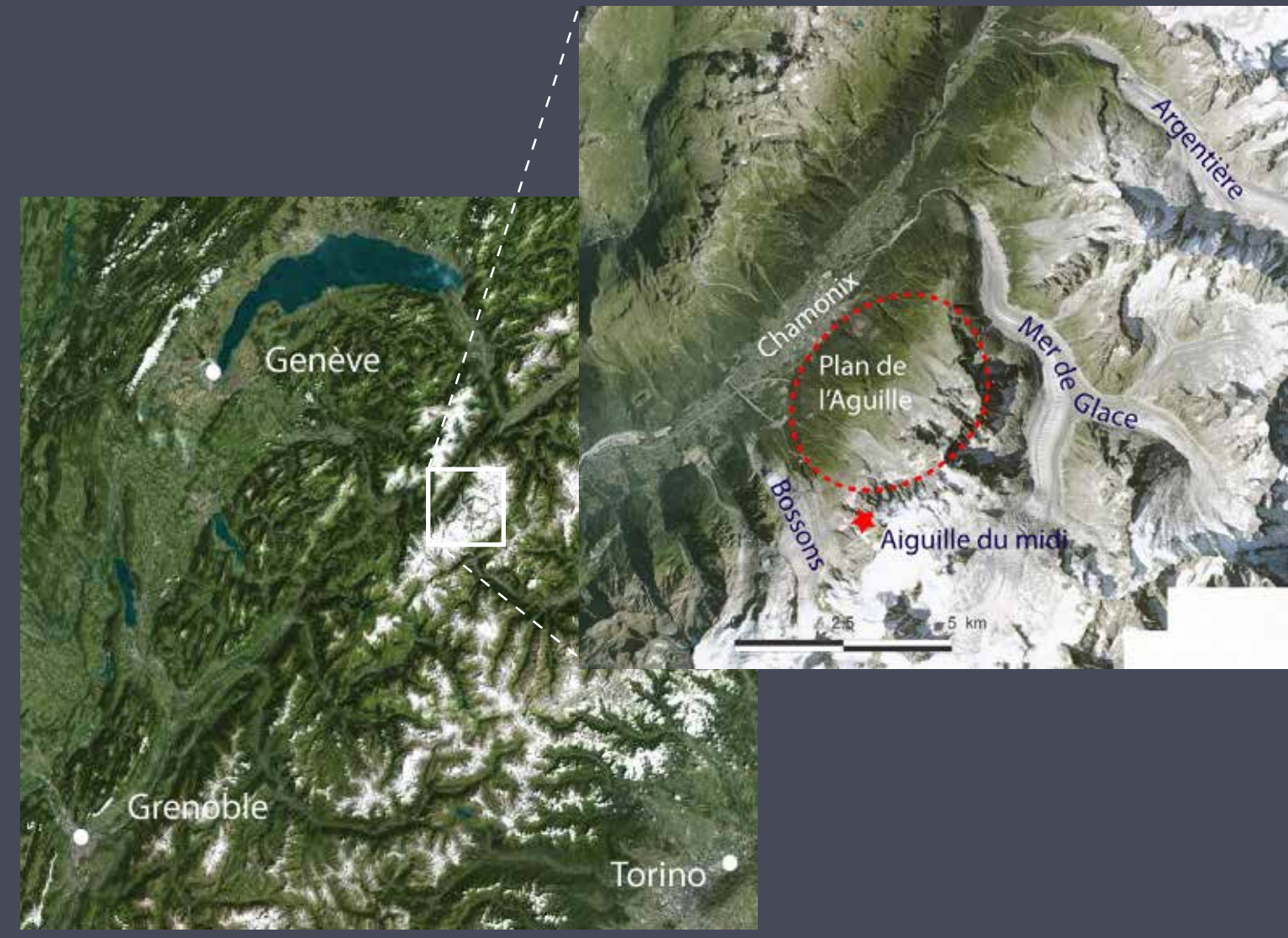
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Introduction

Glacier connexion with stream channel has been evolved since the end of the Little Ice Age. We here investigate a geostatistic approach based on the connectivity index (IC) and glacier shapes extensions (around 1820, 1971 and 2008) in order to assess the spatial sediment connectivity.

The goal of our study is to identify and quantify sediment sources for proglacial streams for these three dates.

We applied the method on three proglacial streams located at the foot of the Aiguille du midi ("plan de l'Aiguille"). The study streams are originating from cirque glaciers with massive morainic bastions.



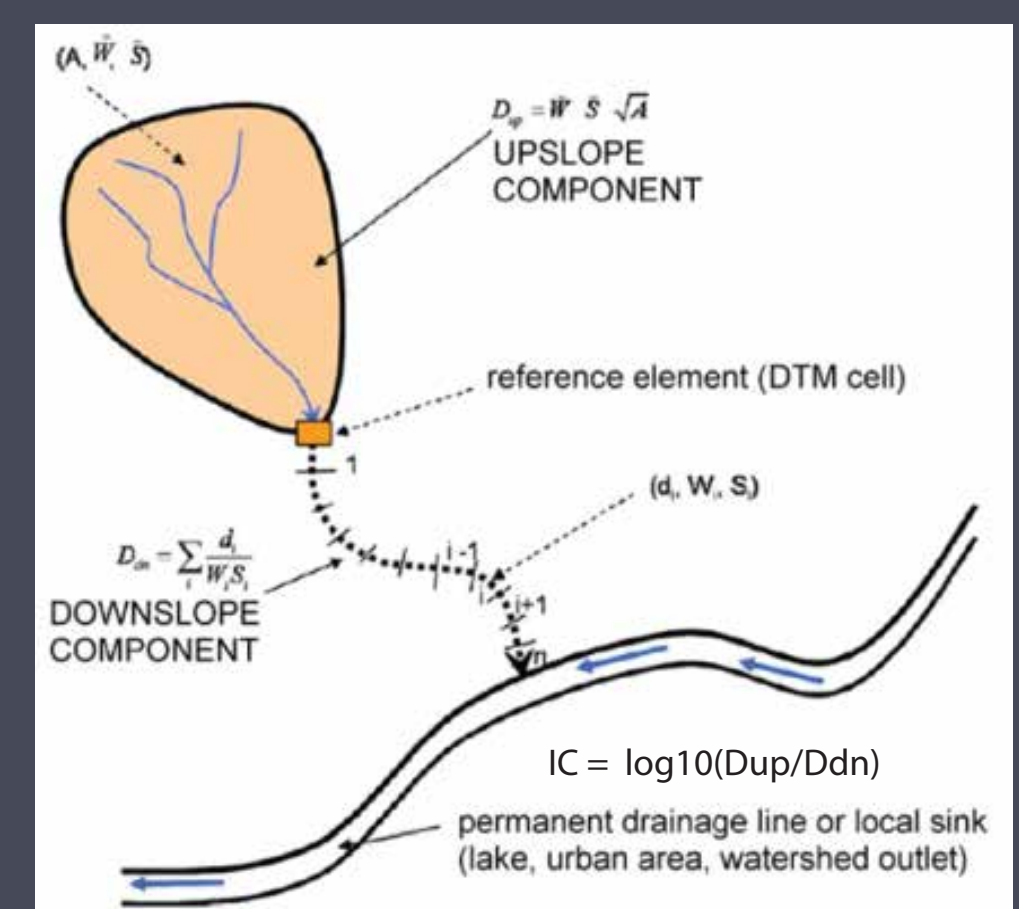
Catchment features

Stream	catchment area (m ²)	LIA glaciation rate (%)	2008 glaciation rate (%)
Favrand	5 786 513	38,8	22,8
Blaitière	3 966 823	26,3	15,3
Grépon	2 595 186	30,2	17,9

Method

IC (Cavalli and al, 2013) is based on high resolution (LiDAR) DEMs. It is calculated with several topographic indexes (slope, residual topography, contributing area and distance to the outlet) integrated into a downslope and an upslope components. We isolated the contributing area (A) which could be supplied by glacier melt water with the glacier spatial extent at different dates: 1820 (LIA), 1971 and 2008. A lower limit of 0.01 is added to the contributing area to get a realistic flow pattern.

Results give the potential level of sediment connectivity of area which could be supplied by glacier melt water

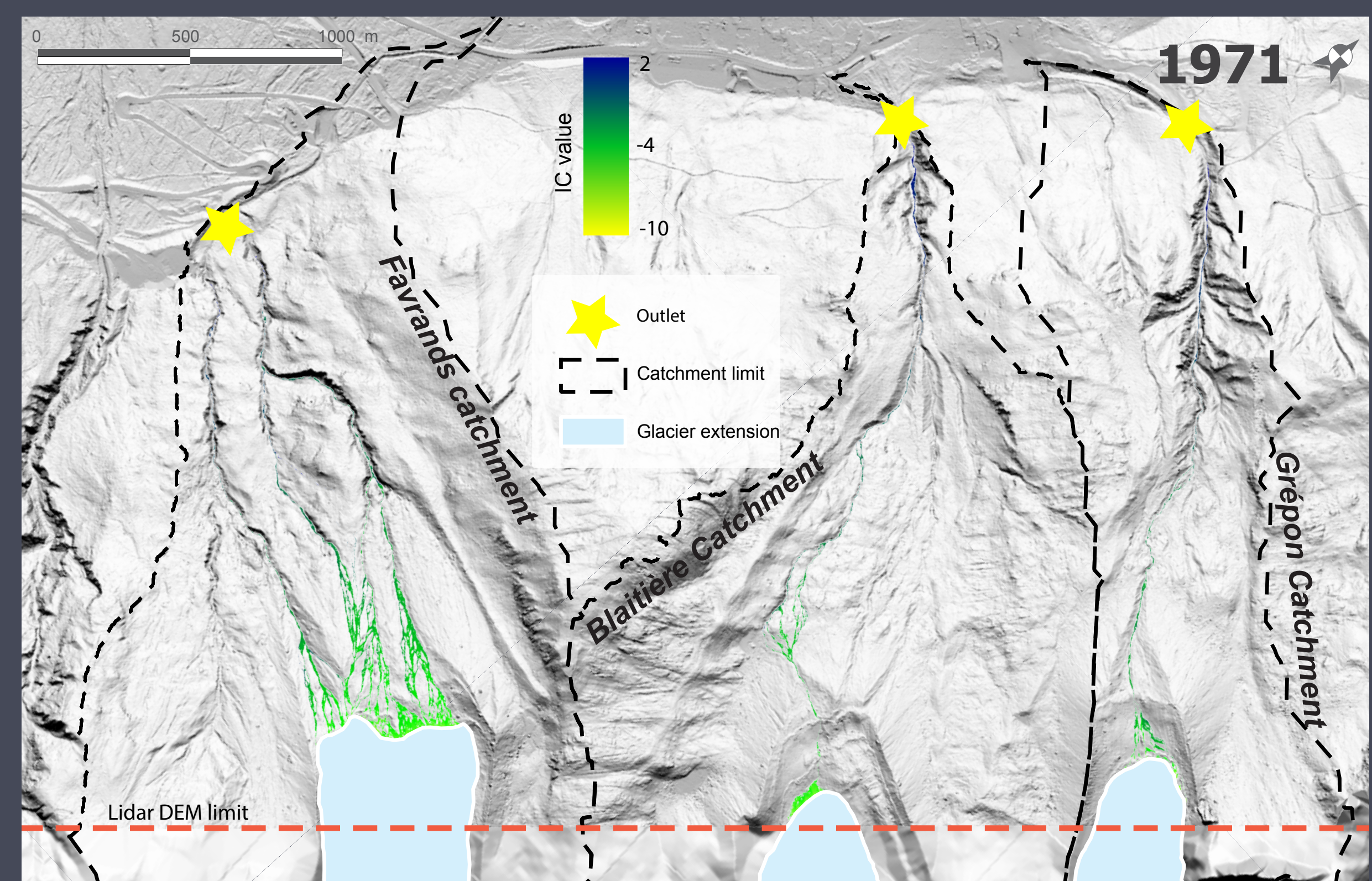
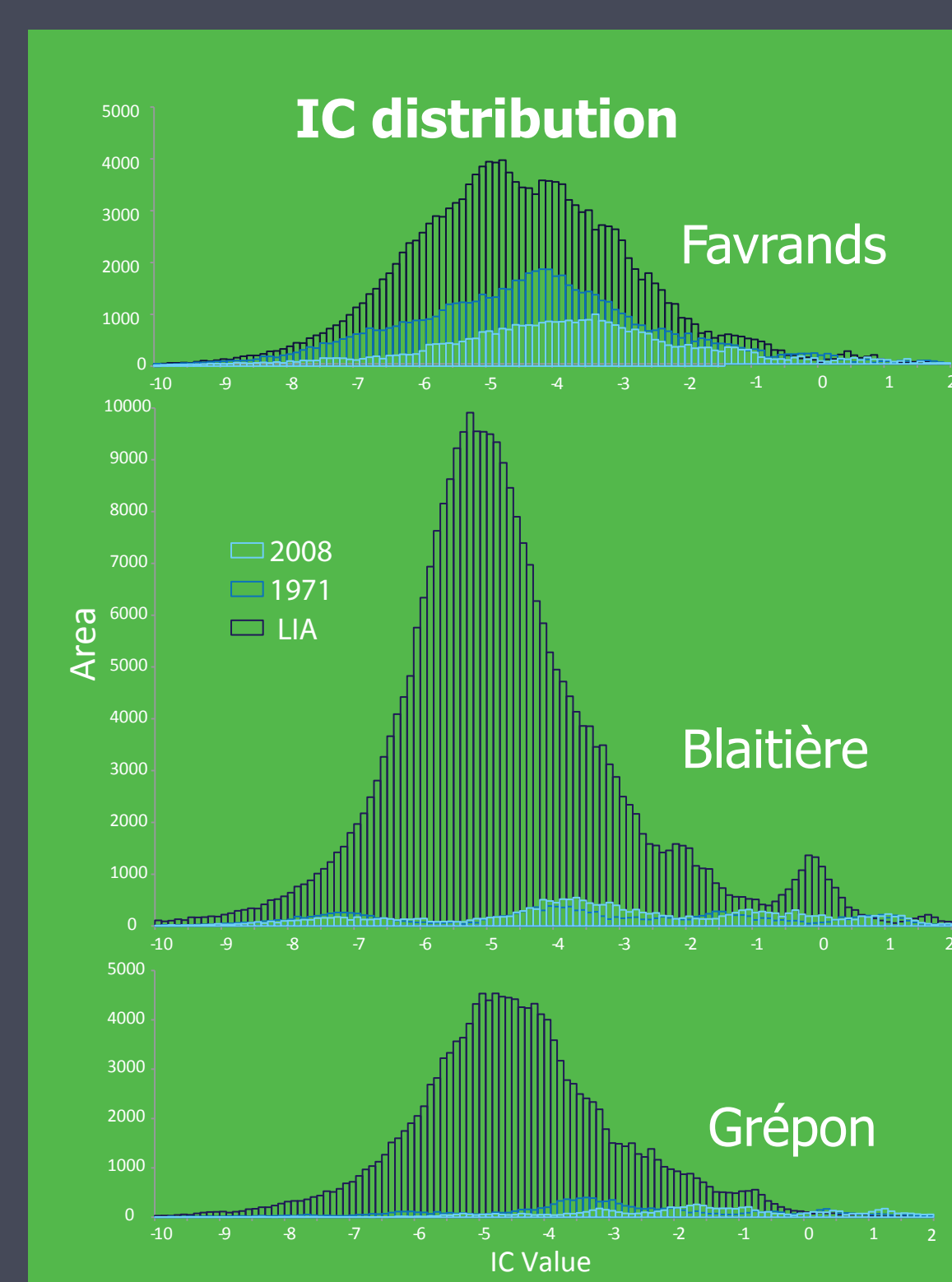
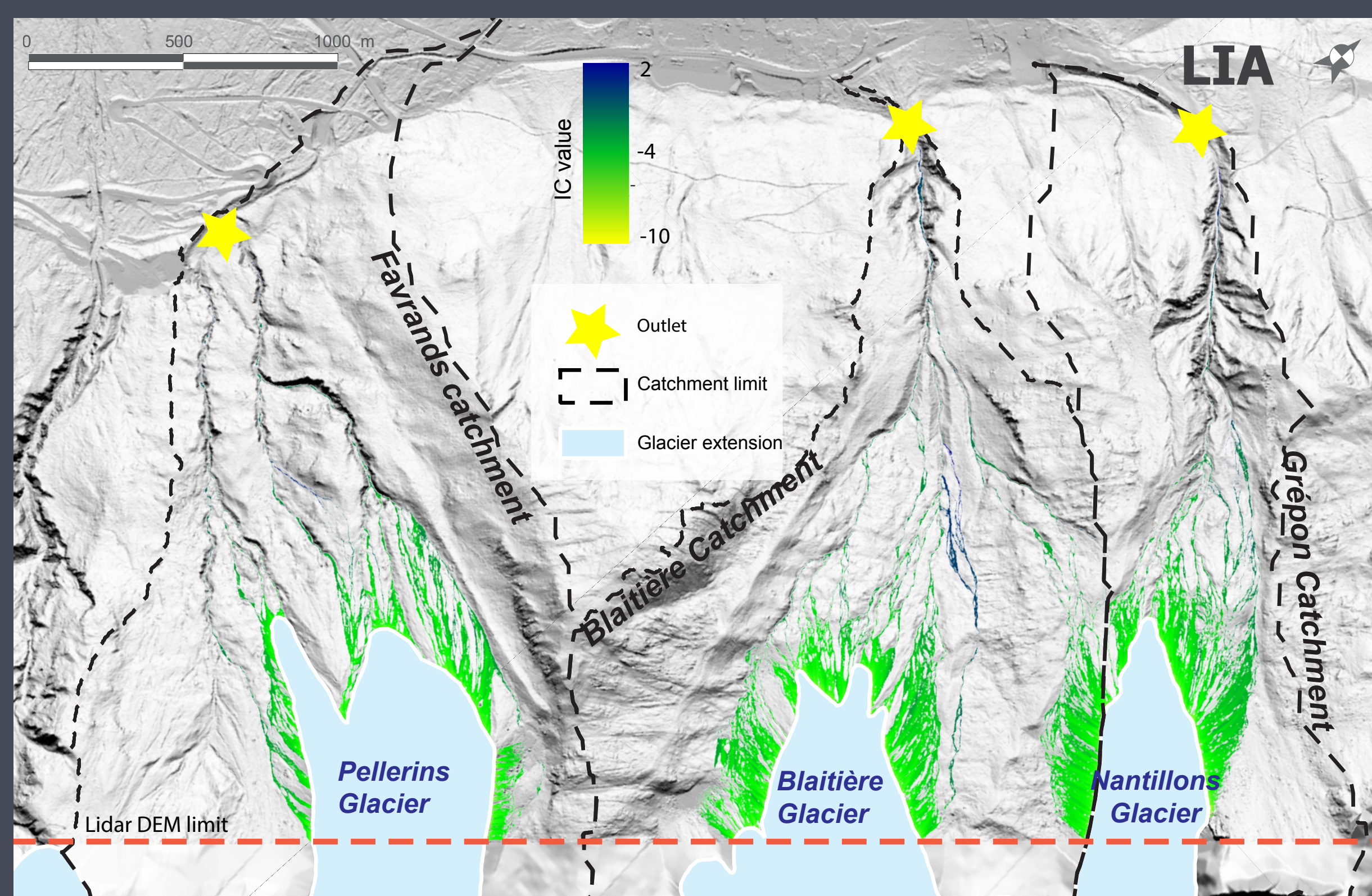


Cavalli and al, 2013

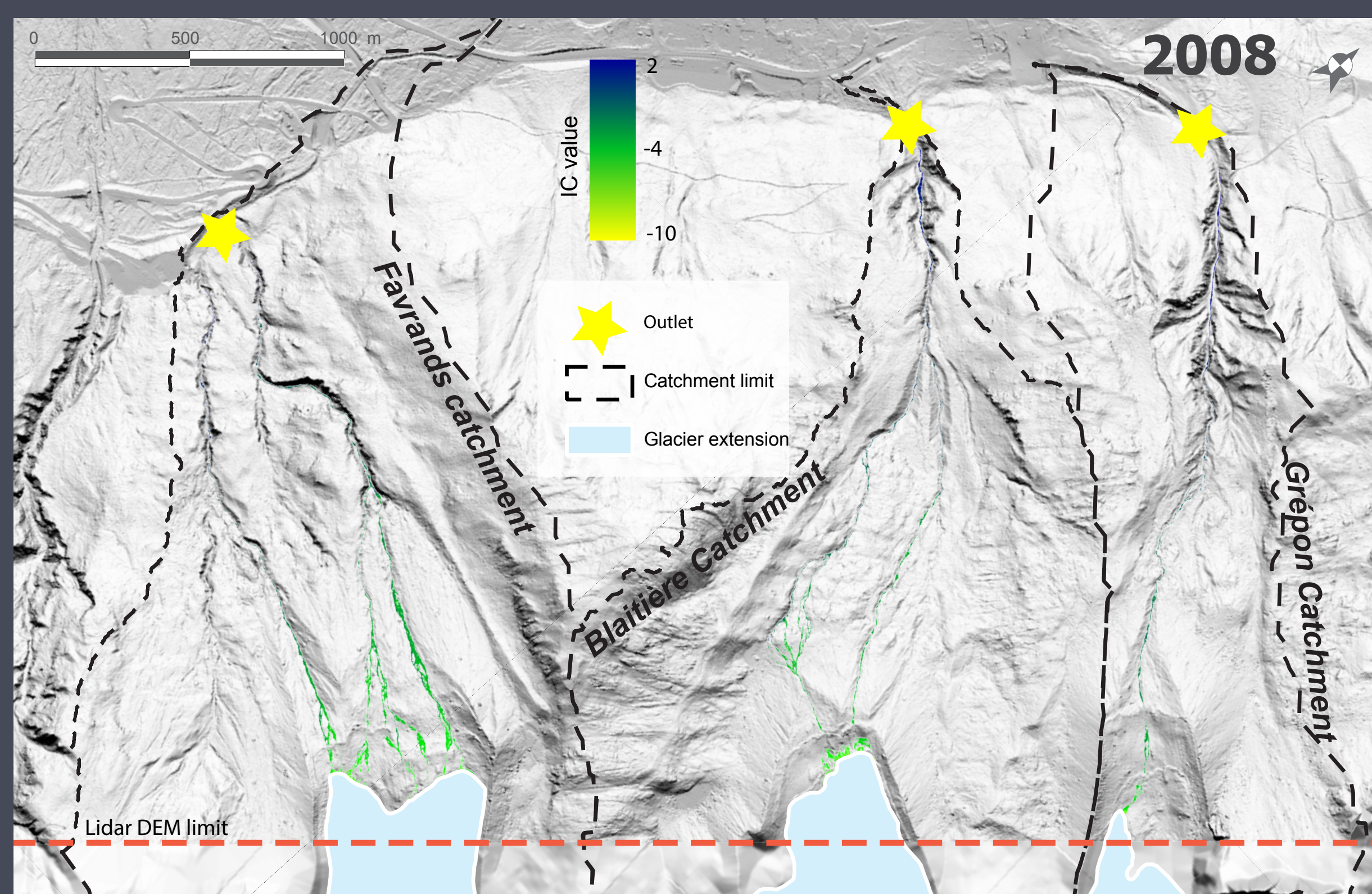
Main limits of the method:

- it implies the hypothesis that topography has not changed since the LIA.
- The LiDAR DEM does not cover the entire stream catchments. It doesn't include the upper part of the Glacier des Pellerins and a small glacier located SW. IC results are thus under-estimated, especially for the latter one.
- Glacier extension accuracy.

Results



Airborne Lidar DEM : IRSTEA Grenoble, 2008 Glacier Extensions : Gardent, 2014

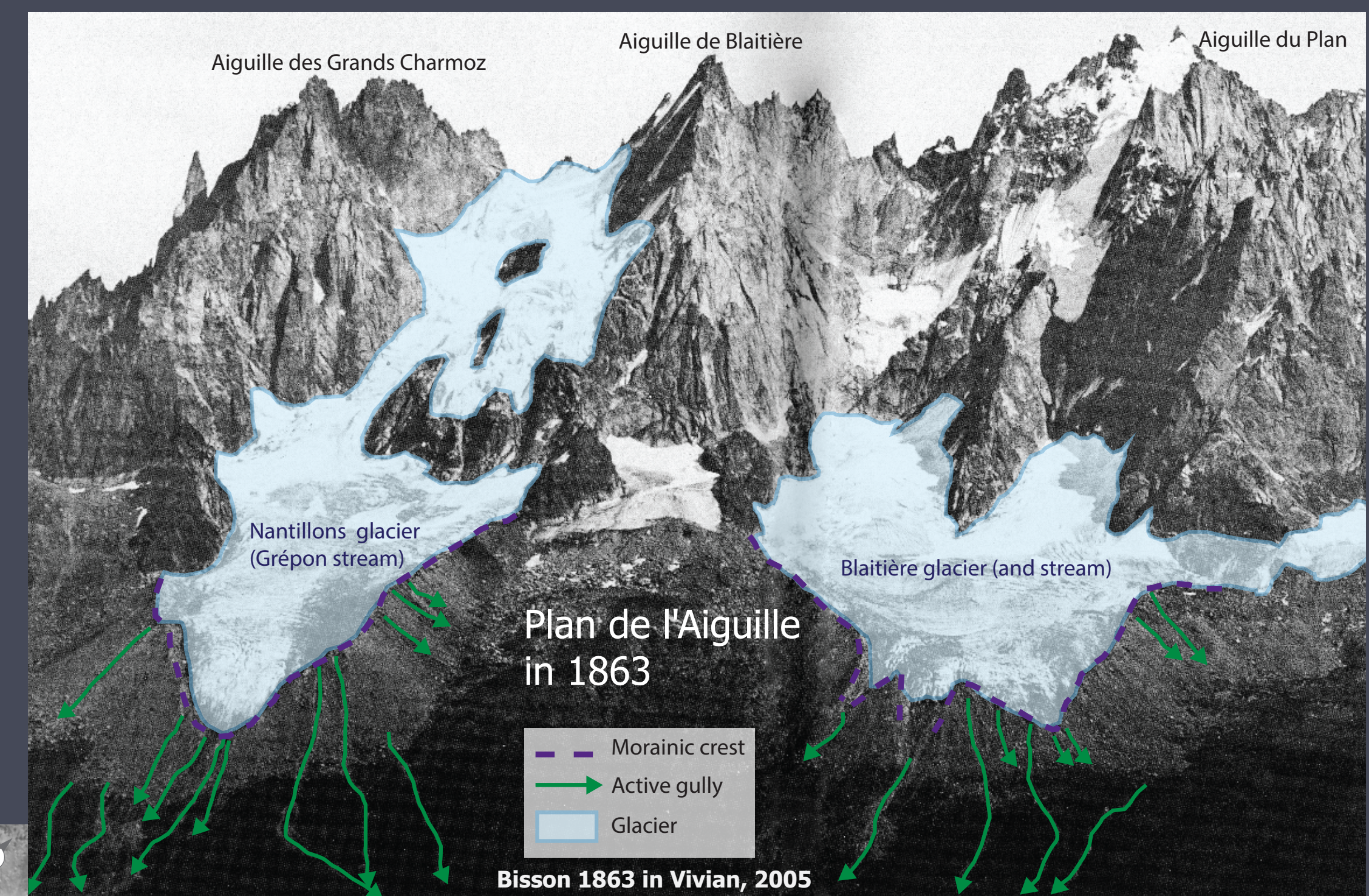


Results checks

The interpretation of the large sets of photographs available in Chamonix allows checking our results, also helped with airborne photographs.

The oldest picture found (1863) shows the Glacier de Blaitière still overflowing the morainic crest while gullies were active on the outer moraine flank as shown by the LIA IC.

Airborne photographs show that the Glacier des Pellerins proglacial area is still drained contrary the two other glaciers. In 2008, Grépon and Blaitière headwaters are almost inactive and moraines are vegetation-covered. It confirms the narrowing sediment sources.



Bisson 1863 in Vivian, 2005

General interpretation

- IC counts have strongly declined for all the streams, mainly because of the decreasing area supplied by glacier water.
- Highest values are consistent with the stream channels that are relatively stable.
- LIA Gaussian distribution is consistent with the outer moraine supply.

Specific interpretation

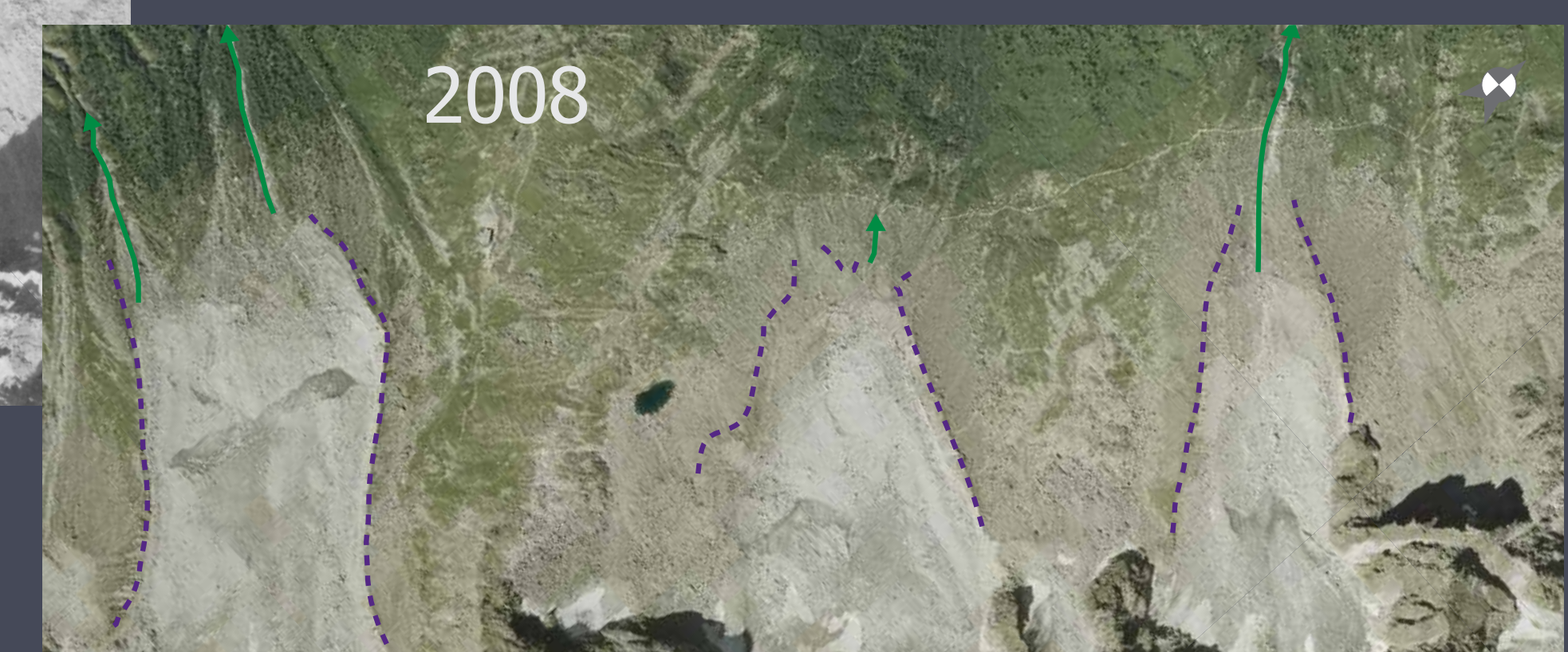
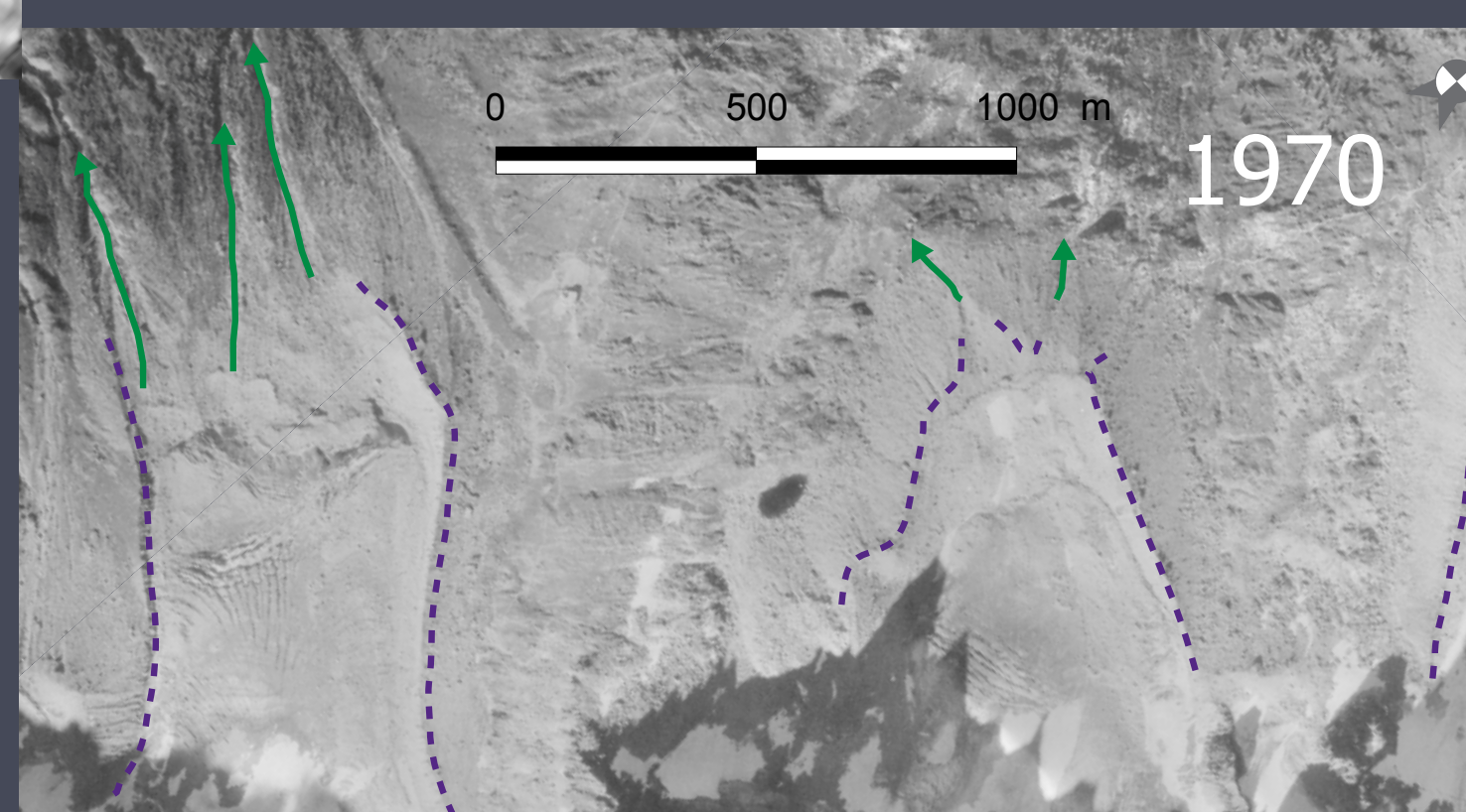
- For Blaitière and Grépon streams, a threshold appears between the LIA and 1971. The glacier doesn't overflow the moraine crest anymore. The outer moraine flank is thus not supplied by the glacier melt water. Sediment sources are constricting into the morainic bastion.

- IC has declined more progressively for the Favrand catchment because of the lack of real terminal moraine. The proglacial area is still efficiently drained.

Conclusion

- This study shows that Plan de l'Aiguille glaciers retreat implies a more or less sudden disconnection from glacial sediment sources to alluvial fan. IC decreasing is confirmed by the analyses of old picture and historical floods archive records.

- The levelod disconnection is directly linked to the glacier morphologies.



Historical flood records

Grépon: 1899, 1934, 1938*, 1942*, 1944*, 1968*, 1994**

Blaitière: 1830, 1900, 1934, 1987**

Favrand: 1818, 1825, 1828, 1834, 1849, 1892, 1898, 1903, 1908, 1938, 1987, 2009

* Only fine sediment transport **no sediment transport

Floods are essentially related to water pocket GLOFs on the three glaciers.

Before the 19th c., alluvial fans were not inhabited because of the torrential activity. Floods were not recorded in the archives.

Favrand stream is the only still active stream. Blaitière and Grépon are still able to produce some flood but without sediment transport.

Method conclusions and perspectives

Although the method could have bias, results give a specific survey of the evolution of sediment sources and their level of connectivity with the alluvial fan.

This method needs to be applied for other cirque glaciers with full LiDAR cover to confirm the findings.

However the method is not adapted for valley glaciers because of the importance of lateral processes (e.g. lateral moraine erosion) and the morphological activity level (topographic changes are too important).