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New insights into 3D calving investigations: use of Terrestrial LiDAR for monitoring the Perito Moreno glacier front (Southern Patagonian Ice Fields, Argentina)

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There exists a great incertitude concerning the processes that control and lead to glaciers' fronts disintegration, including the laws and the processes governing ice calving phenomena. The record of surface processes occurring at glacier's front has proven problematic due to the highly dynamic nature of the calving phenomenon, creating a great uncertainty concerning the processes and forms controlling and leading to the occurrence of discrete calving events. For instance, some common observational errors for quantifying the sudden occurrence of the calving phenomena include the insufficient spatial and/or temporal resolution of the conventional photogrammetric techniques and satellites missions. Furthermore, a lack of high quality four dimensional data of failures is currently affecting our ability to straightforward analyse and predict the glaciers' dynamics.

In order to overcome these limitations, we used a terrestrial LiDAR sensor (Optech Ilris 3D-LR) for intensively monitoring the changes occurred at one of the most impressive calving glacier fronts: the Perito Moreno glacier, located in the Southern Patagonian Ice Fields (Argentina). Using this system, we were able to capture at an unprecedented level of detail the three-dimensional geometry of the glacier's front during five days (from 10th to 14th of March 2014). Each data collection, which was acquired at a mean interval of 20 minutes each, consisted in the automatic acquisition of several million points at a mean density between 100-200 points per square meter. The maximum attainable range for the utilized wavelength of the Ilris-LR system (1064 nm) was around 500 meters over massive ice (showing no-significant loss of information), being this distance considerably reduced on crystalline or wet ice short after the occurrence of calving events. By comparing successive three-dimensional datasets, we have investigated not only the magnitude and frequency of several ice failures at the glacier's terminus, but also the characteristic geometrical features of each failure. We were also able to investigate a growing strain rate on several areas of the glacier's front several days in advance of its final collapse. Furthermore, we carried out a structural analysis of the different sets of crevasses observed at the glacier front using the normal vector of each facet of the glacier front surface. When adapting well-known kinematic test that were originally developed for rock slopes to the investigation of gravity driven instabilities on glaciers' front, toppling emerged as the preferential failure mechanism at this part of the glacier front.

This approach for monitoring glacier's fronts is original and innovative. Up to very recently, characterizing the discrete calving phenomenon and understanding the statistical laws governing the system have gained interest on the scientific community. Our proposed approach may shed light into both the possibility to identify the elusive existence of calving Magnitude-Frequency laws at specific regions and to capture the key spatio-temporal linkages between rates of ice calving, flow, surface lowering and frontal advance/retreat, with clear implications for modeling the global trend of ice mass balance.