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GPR evidence of episodic and areally continuous degradation of high-altitude arid glaciers (Atacama Region, Chile): Remnants of the Little Ice Age?

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Detailed surface and geophysical studies carried out on several high-altitude glaciers located within the arid to hyper-arid Andes, indicate that most of them are undergoing areally-extensive ablation. High resolution GPR survey of the upper ice packages of the Guanaco Glacier and the imaging of its basal structure allowed reconstruction of a complicated history of accumulation and degradation. Besides not showing an accumulation area and hence no equilibrium line, the Guanaco Glacier (the largest of the region) has been loosing mass over most of its area during the last decades. The detailed stratigraphy of the younger ice beds shows a main glacier-forming period represented by internally homogeneous ice followed by four main depositional distinguishable periods separated by important glacier-scale ablation surfaces imaged by truncated ice-bedding structures, which changed glacier's topography. Above these ablation (truncation) surfaces, accumulation periods filled the topography in a very particular progradational-agradational fashion. Near the base, it is possible to distinguish an important but discontinuous reflector parallel to the base interpreted as a debris layer that crops out at the glacier's lower reaches. The base of the ice is located few meters below this reflector. Local glaciers are cold-based, and mean air temperature is quite below 0žC, thus the main control on their behavior is accumulation, instead of temperature. Measured and estimated maximum velocities are 8 m/yr, in a small ice body of 1.12 km along slope direction by 2.24 km wide, suggesting that flow is plastic & laminar and that exposed ice cannot be very old. Thus, the main ice-mass is interpreted to be formed during a period of enhanced precipitations spanning from mid 1700s to c. 1860, as indicated by nearby lake records (Atacama region) and marine offshore cores, called locally the "Little Ice Age". The following four depositional

periods correlate with four periods of enhanced precipitations recorded after 1860, being the last one near 1950. Continuous shrinkage has been observed since that epoch. The presence of the relict debris-covered ice-body underlying the main ice-mass suggests the glacier is evolving into a comparable shape. Other local glaciers were also reported having fossil ice beneath debris layers, as well. The fossil ice underlying the deep discontinuous reflector suggests the Guanaco Glacier attained less than 10% of its present volume, having about 30% of its present area, mostly debris-covered. This is probably a stable size and shape under present day climate conditions. This observation suggest that local glaciers are out of equilibrium and that they probably will continue with the observed contraction and/or retreat, involving the disappearance of many small ice bodies, while larger glaciers may reduce its volumes up to a 90%. This forecast is also supported by tracking the evolution of some arid glaciers on aerial photographs.