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Recent Ice thickness helicopter borne radar surveys in Patagonia

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The Patagonian icefields are the biggest temperate ice bodies in southern hemisphere, which have experienced important areal shrinkage and thinning in recent decades, significantly contributing to sea level rise. The main driving factor behind this retreating condition is recent decade atmospheric warming explaining higher melting rates and equilibrium line altitude upward migration. Ice dynamic is also playing an important role especially in glaciers calving into deep fjords or lakes, type of glaciers that are predominant in the Patagonian icefields. In order to better understand their ice dynamics, several recent works have measured ice velocities using feature tracking and other techniques, however, ice thickness is still barely known. In spite of several on the ground radar measurements successfully detecting several hundred of m of ice thickness at the higher plateaus, this variable remains the great missing part of the equation especially when the thickness is approximately deeper than 600 m or where the glacier surfaces are very crevassed or nearby the Equilibrium line Altitude, where on the ground measurements are logistically constrained. In order to tackle the lack of thickness data, a helicopter borne radar system was used to survey several Patagonian temperate glaciers calving into fjords (Glaciares San Rafael and Jorge Montt) or lakes (Nef, Colonia and Steffen). The radar system is comprised by a hanging bow-tie dipole antenna working at a central frequency of 20 MHz. The antenna is an aluminum structure of 7 x 5 x 1.2 m weighting near 350 kg that is hanging at 20 m below a helicopter, and is connected to the helicopter cabin by an optical fiber cable. At the antenna are installed a 3,200 Volts peak transmitter, a two channel radar receiver, and an integrated GPS registering each trace. The helicopter flying speed was kept at near 40 knots and the antenna was normally hanging at 40 m above the ice. The surveys took place along predefined tracks including several longitudinal and transversal profiles. The system was capable of measuring ice thickness in many of the surveyed tracks, where a maximum of near 800 m was detected at the higher plateau of the San Rafael glacier. Several transversal profiles showed typical U shape subglacial forms with ice thicknesses of several hundred meters. Longitudinal profiles showed rougher subglacial bottom topographies. In general the best results were obtained at glaciers having less crevassed surfaces, such as Colonia, Nef and Steffen. At tidewater calving glaciers San Rafael and Jorge Montt, where the surface topographies of the lower tongues are much more crevassed, very little bedrock returns were obtained. The scattering produced by heavily crevassed surfaces, together with the presence of meltwater at the surface, precluded radar waves penetration in many places near the calving tongues. The results are promising, but new improvements are needed to increase penetration ranges and reduce surface scattering.