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Cryoegg: development and field trials of a wireless subglacial probe for deep, fast-moving ice

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Innovative technological solutions are required to access and observe subglacial hydrological systems beneath glaciers and ice sheets. Wireless sensing systems can be used to collect and return data without the risk of losing data from cable breakage, which is a major obstacle when studying fast flowing glaciers and other high-strain environments. However, the performance of wireless sensors in deep and fast-moving ice has yet to be evaluated formally. We report experimental results from Cryoegg: a spherical probe that can be deployed along an ice borehole and either remain fixed in place or potentially travel through the subglacial hydrological system. The probe makes measurements in-situ and sends them back to the surface via a wireless link. Cryoegg uses very high frequency (VHF) radio to transmit data through up to 1.3 km of cold ice to a surface receiving array. It measures temperature, pressure and electrical conductivity, returning all data in real time. This transmission uses Wireless M-Bus on 169 MHz; we present a simple "radio link budget" model for its performance in cold ice and confirm its validity experimentally. Power is supplied by an internal battery with sufficient capacity for two measurements per day for up to a year, although higher reporting rates are available at the expense of battery life. Field trials were conducted in 2019 at two locations in Greenland (the EastGRIP borehole and the RESPONDER project site on Sermeq Kujalleq/Store Glacier) and on the Rhone Glacier in Switzerland. Our results from the field demonstrate Cryoegg's utility in studying englacial channels and moulins, including estimating moulin discharge through salt dilution gauging with the instrument deployed deep within the moulin. Future iterations of the radio system will allow Cryoegg to transmit through up to 2.5 km of ice.