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Fiber Optic Distributed Temperature Sensing in Avalanche Research

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Being a major driving force for snow metamorphism, thermal properties and temperature gradients in an alpine snow pack influence both, spatial distribution and temporal evolution of its stability throughout a winter season. In avalanche research and forecasting mainly weather station networks and models are employed for temperature-data collection and prediction. Standard temperature measurement devices used in weather stations and for model calibration typically provide point data over time. With fiber-optic Distributed Temperature Sensing (DTS) a laser is pulsed through standard telecommunications optical fibers of up to 30km in length, and uses the cables themselves as a thermometer. DTS allows for continuous observations of temperatures over large spatial scales and with high temporal resolution. Depending on the type of instrument, temperature readings can be provided every 0.25 to 2 meters along the cable and up to six times a minute. Measurement accuracies depend on integration times and can reach +/- 0.1 degrees C or better. Already well established in other environmental applications such as surface water - groundwater hydrology and soil moisture studies, this study assesses applicability and performance of DTS in snow environments and its potential benefits for avalanche research and forecasting. At the CRREL/UCSB research site on Mammoth Mountain, California, 40m fiber-optic cable loops were deployed at different depths in the snow pack to measure temperature and thermal gradient evolution over time and space. Four discrete measurement sessions of 4 to 20 days were conducted during the winter season 2008/2009. Strong horizontal spatial variability of temperatures of up to 3 degrees C within the snow pack over the 40m-sections were resolved. As expected, vertical thermal gradients were influenced by spatial location. Evolution of temperatures and gradients over time could be continuously monitored along the 40m transects during each measurement session. Instrument performance was affected by strongly varying ambient air temperatures, though resulting errors could be easily corrected during post processing. Specific demands when using a DTS system in a snow environment are discussed, as special care must be taken in instrument calibration, site and experimental design. Possible applications of a DTS system in avalanche research are presented.