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Fiber-optic distributed temperature sensing of alpine snow packs

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Measurements of small-scale temperature variations in alpine snow packs using a fiber-optic Distributed Temperature Sensing (DTS) system are presented. Almost 1 km fiber-optic cable was set up in a 20 m long and 2 m tall fence-like structure anchored in the snow pack (snow temperature fence, STF) to obtain 2D snow temperature slices as snow accumulated and covered the STF, at resolutions of 5 min in time, 1 m in horizontal and 10 cm in vertical direction, and 0.05C for temperature. A first installation was realized during winter 2009 at Jungfraufirn glacier, and a second experiment was deployed during winter 2010 at the Plaine Morte glacier (both sites are in the Swiss Alps), on almost flat snow-covered terrain in both cases. During the field campaigns, several weeks of good quality data were obtained showing the diurnal cycle of the temperature profiles at a point and some spatial heterogeneity in the snow pack temperature along the transect. Subsurface heat fluxes were computed based on the Fourier heat equation using the STF, snow depth data, and an effective thermal conductivity of the snow derived from density measurements. A clear diurnal cycle and spatial variability of the heat flux along the STF was observed, with heat flux magnitudes up to 65 W/m2. Meteorological stations and thermocouple arrays were used simultaneously to complement and intercompare the STF temperature measurements and to evaluate variables used to compute energy balance components at the snow/atmosphere interface. STF temperatures in the air were overestimated, as a result of shortwave radiation. Snow accumulation and compaction caused problems such as sagging of the optical fiber between fence poles, and inclination of the support poles of the structure under tension of the cable. There is evidence that heat conduction along the intermediate support poles is also non-negligible. A key issue for heat flux calculation is the precise knowledge of the snow surface, which was taken constant along the fence at a given time. Therefore, variations due to snow surface topography were hard to detect, and the measurement of the small scale variability in the top snow layer is problematic. Future DTS-STF systems should be designed to minimize cable sagging and thermal conduction effects near the fence poles. Also, detailed knowledge of the snow surface topography along the transect is essential.