Name of research institute or organization:

Laboratory of Environmental Fluid Mechanics and Hydrology, EPFL

Title of project:

Snow thermodynamics and pressure driven air movement in the snow pack

Project leader and team:

Dr. Hendrik Huwald, project leader
Dr. Chad Higgins, Marc Diebold, Prof. Marc Parlange

Project description:

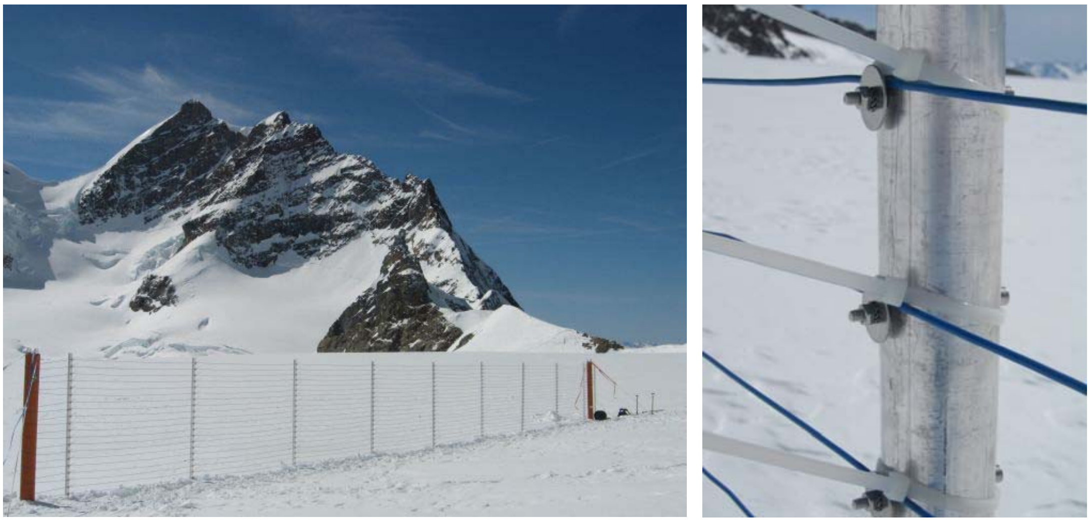
To investigate and understand small-scale spatial variability and physical properties of a mountain snow cover and snow-atmosphere interaction, field experiments were carried out on Jungfraufirn between Jungfraujoch and Mönchsjochhütte from 16 March through 21 May 2009. The experiments aimed at measuring horizontal and vertical snow temperature and gradients (for the calculation of subsurface heat fluxes) on the scale of a few meters and their evolution with time since detailed knowledge is limited, and experimental data acquisition is problematic. Another focus was on turbulence and atmospheric pressure driven air movement in the snow pack (wind pumping) and associated latent heat transport all influencing snow thermodynamics and the energy budget of a snow pack with implications for snow dynamics (e.g. snow drift and avalanche formation), and ultimately on local snow water storage.

From an experimental point of view, the acquisition of distributed temperature data in the snow pack is non-trivial. Processes such as precipitation, accumulation, erosion, compaction, etc., lead to constant changes in the snow surface level. We investigated snow temperature distribution and evolution along a 2D transect using fiber optic distributed temperature sensing (DTS), an emerging technology in environmental sensing, which can provide high resolution temperature measurements in space (up to 1 meter) and time (a few minutes) with a resolution of about 0.1C over distances of several kilometers. In a complimentary experiment, the mechanisms of wind pumping processes were studied with a system of synchronized high frequency measurements of atmospheric turbulence and barometric pressure fluctuations in the snow.

We installed a 25m long straight fence consisting of poles and a fiber optical cable. The structure was then gradually covered by accumulating snow up to the top of the fence, initially 2m above the surface level. For the measurement of high-frequency air pressure fluctuations four 1m long stakes featuring open ports connected to pressure transducers were installed in the snow. Additionally, sonic anemometers were set up just above the pressure poles to simultaneously measure the components of the wind vector at the same sampling frequency.



Figure: Different views of the temperature fence after installation and before removal.



a) 25m temperature fence – picture of the month 04/2009, www.ifjungo.ch ; b) detail

Experience and results:

Innovative technology has been deployed for the first time in a unique configuration. The temperature fence yielded arrays of snow temperature at 1m horizontal, 10cm vertical, and 5min temporal resolution which were used for the calculation of gradients and ultimately heat fluxes in an x-z plain. Results from the wind pumping experiments suggest that pressure fluctuations penetrate deep into the snow and are function of the turbulence intensity. The intensity of the pressure fluctuations decreases with depth, naturally damped by the snow matrix. Some preliminary results are shown in the figures below:

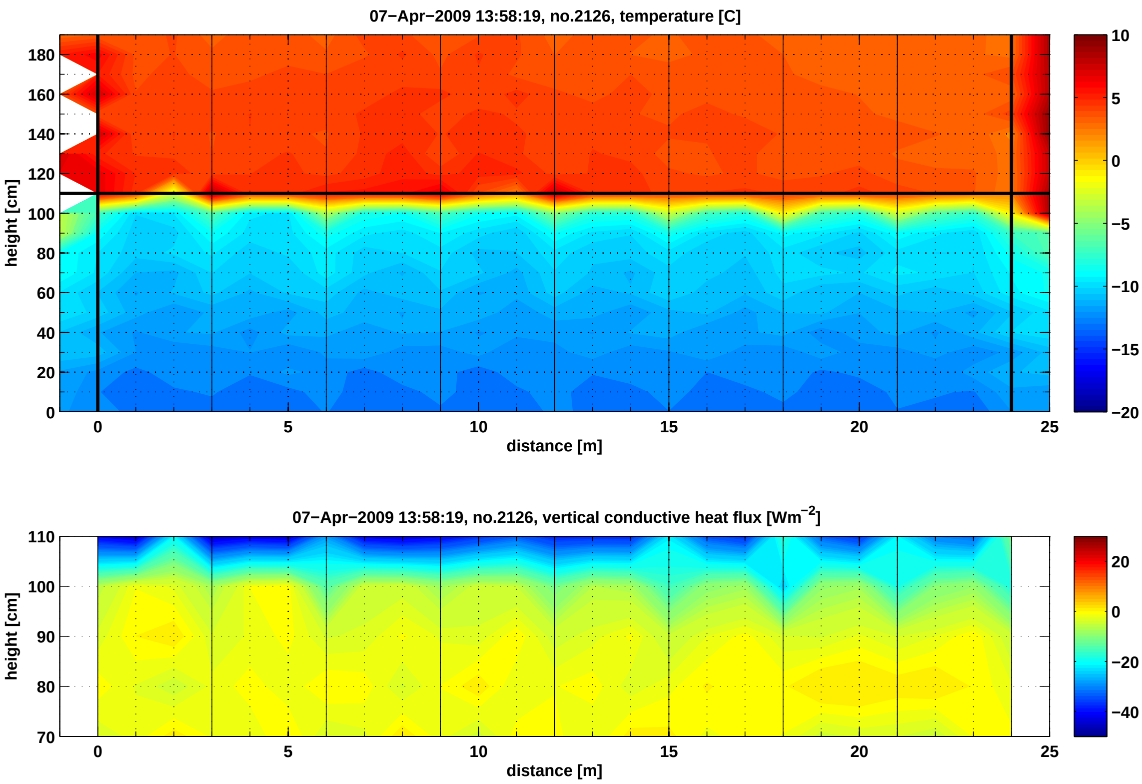


Figure: Temperature transect and corresponding vertical conductive heat flux near the snow surface.

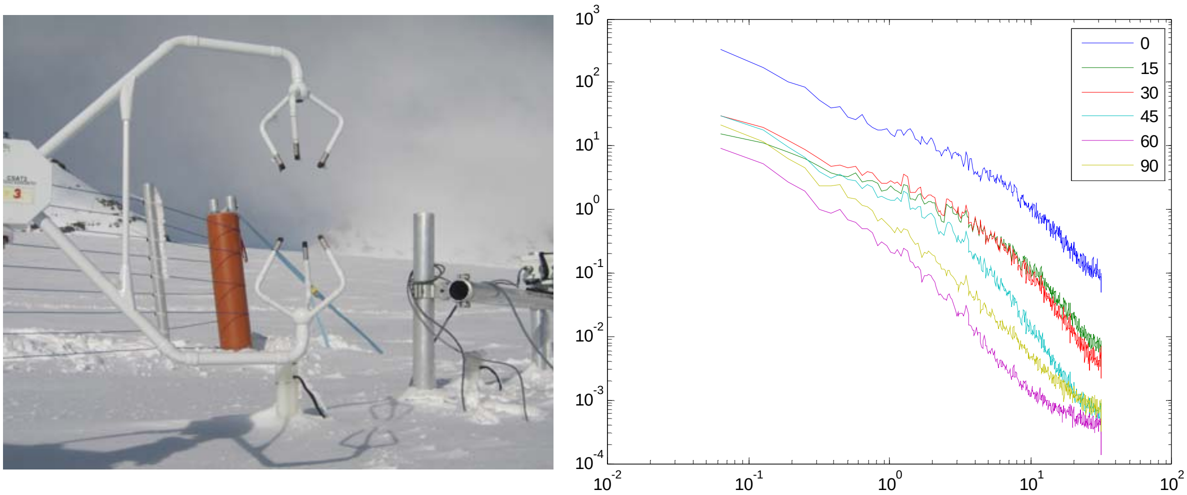


Figure: Setup of pressure poles and sonic anemometer. Example of power spectra at different depths.

Conclusions and lessons learned:

The experimental designs were very challenging and had to demonstrate their proper functioning under difficult conditions. Both sensor systems survived the deployment period, however, some important issues have been noticed: The main problem of the temperature fence is the tensioning given the load and overburden pressure of accumulating snow resulting in sagging of the cable between fence poles. This has an undesired effect on the data and has to be resolved. As a consequence, registration (determination of the exact location of a data point in 2D transect) is a tedious and tricky problem. Concerning the pressure experiment, the main difficulty is the proper installation of the poles without creating gaps between the pole and the snow pack which could act as a shortcut for the propagation of pressure waves. Both setups have proven the feasibility of the respective experiment, and the field experiences will lead to an optimized sensor design, setup configuration, and installation.

Key words:

Snow physics, thermodynamics, snow temperature, heat conduction, wind pumping, near-surface atmospheric turbulence, small-scale variability, fiber optic distributed temperature sensing (DTS), novel measurement techniques, sensor development.

Internet data bases:

http://eflum.epfl.ch

Collaborating partners/networks:

Prof. Scott W. Tyler, University of Nevada, Reno, NV
Prof. John S. Selker, Oregon State University, Corvallis, OR
Dr. Michael Lehning, SLF Davos

Scientific publications and public outreach 2009:

Conference papers

Huwald, H., C.W. Higgins, E. Bou-Zeid, J.S. Selker, S.W. Tyler, M. Lehning, and M.B. Parlange, Snow/atmosphere interaction in the Swiss Alps, Workshop on Alpine Snow Research, Valtournenche, Valle d'Aosta, Italy, 3 December 2009, Invited talk.

Huwald, H., C.W. Higgins, S.R. Williams, M. Diebold, M. Lehning, S.W. Tyler, J.S. Selker, and M.B. Parlange, Fiber optic distributed temperature sensing of snow, AGU Fall Meeting, San Francisco, CA, 2009.

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