**The Cryosphere
Discussions**

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Comment

Interactive comment on "Evaluation of the ground surface Enthalpy balance from bedrock shallow borehole temperatures (Livingston Island, Maritime Antarctic)" by M. Ramos and G. Vieira

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Comments on the discussion process of the paper entitled; EVALUATION OF THE GROUND SURFACE ENTHALPY BALANCE FROM BEDROCK SHALLOW BORE-HOLE TEMPERATURES (LIVINGSTON ISLAND, MARITIME ANTARCTIC) Authors: M. Ramos and G. Vieira Comments related with the referee's 1 suggestions

The paper discusses and applies a thermodynamical method (not a singular heat transfer conduction problem) to study the Enthalpy exchange between the ground surface and the air on a site close to the boundary of continuous permafrost. We apply a conceptual thermodynamic model in the seasonal period not a solution of the heat transmission equation. The borehole has a shallow depth, but allows for the applica-

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tion of a methodology to calculate the heat flux across the ground surface during a seasonal period.

Isothermal ground close to 0žC is a very usual state in regions with polar climate close to 0žC Mean Annual Air Temperature, especially where annual temperature range is moderate (e.g. the Maritime Antarctic). This condition generally occurs twice per year. This is the case in Livingston Island, which is the goal of our work. Despite not being a situation typical of most permafrost regions, it can be applied in a wide area located near the boundary of permafrost. It should be emphasised that our focus is on studying a local scale and the site specific conditions in the Incinerador borehole, and not the regional scale. For this later objective, we have installed different monitoring sites in the vicinity of the Incinerador borehole following other protocols, like the CALM-S (Circum Polar Active Layer Monitoring - South), as well as geomorphological monitoring sites. The results to be obtained will be compared with site-specific values of surface energy exchange and related to variables on the dynamics and ground thermal regimes.

1) We will revise the text carefully and improve the English language. The works indicated by the reviewer will be included. 2) In the model the thermal diffusivity is used to calculate the Enthalpy. This was measured using indirect methods supported on the analysis of the sinusoidal cuasi-stationary thermal regime and on the thermal conductivity. This last parameter, which is function of the diffusivity was obtained from tabulated values and was compared to diffusivity values accounting for the density and heat capacity, also tabulated for better precision. 3) The free boundary layer movement has a temporal variation with the sqrt(t), in the more simple case has analytical solution (Stephan solution) with the following limitations: constant temperature on the ice surface (boundary condition), and an initial condition close to phase change temperature. In the paper we make it clear that our assumption is one of an experimental system without phase change, since the water content is of minor significance. However, when the ground surface temperature (boundary condition) has a temporal variation controlled naturally through the interaction with the atmospheric boundary layer, then the

analytical solution of the Stephan problem is not really available. Therefore, our approach focus on a simplified thermodynamic argument: the Enthalpy exchange in the system between two quasi-equilibrium states, at the initial stage with null gradient into the ground at 0žC, and at the final stage with the minimum or maximum (depending on season) ground temperatures at depth. The transient regime was not studied using the heat transfer equation, since we are interested in the loss or gain of energy in the borehole site during the seasons below 0žC and above 0žC. The lineal speed of the 0žC isothermal boundary was obtained by experimental fitting and it is only used to compare conditions in different seasons. The calculated energy exchange values offer us site-specific information about the climate conditions of the season and are useful to compare with other years and other local climatic parameters. On the other hand the definition of permafrost is not only applied to grounds with water content and is purely a thermal condition (Van Everdingen, R. ed., 1998). An example is the dry permafrost (Bockheim, 2004), or even the permafrost in rock slopes in mountainous terrain. In the sentence: At Incinerador borehole, drilled in quartzite bedrock, a lithology showing high thermal diffusivity (density; 2650 kg/m3, specific heat; 720 J/kgK, thermal diffusivity; 1.23Œ10-6 m2/s, thermal conductivity; 2.35W/mK; Schumlon, 1996) and negligible water content at this site, there is no zero-curtain effect related to latent heat exchanges (Figs. 3 and 4). In these conditions the estimated active layer thickness is in the order of 2 to 5 m. The thermal data corresponds to quartzite and not granite. The active layer itself shows a larger depth than that which the 0žC isotherm has reached in the study period, as calculated with the proposed method using the experimental data. It is noteworthy that the borehole remains unfrozen at all depths. In our working hypothesis, due the experiment is located in a zone close to the limit of permafrost, the regime trend is towards its degradation and the temperature at depth is close to 0žC (Hauck et al., 2007). This is our boundary condition; T(x>XMAX)=0žC. This hypothesis is quite correct and is supported by the preliminary data from a new borehole we did last campaign down to 25m depth at 275 m asl, There, the temperatures at 15m depth are -2žC, a value that when accounted for the lapse rate supports ground tem-

peratures close to 0žC at depth in the Incinerador borehole. Our model is based on the assumption of a zone where the 0žC isotherm moves between the ground surface and a maximum depth (XMAX) for the Summer. Below that depth the temperature is considered constant at 0žC and the heat flux absent. In case of an existing climatic signal, the value of the heat flux would be insignificant when compared to the total heat exchange during the season.

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