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Modelling volcano, climate and permafrost interactions on Deception Island, Maritime Antarctic

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Deception Island (South Shetlands Islands, Maritime Antarctic) is an exceptional island regarding its permafrost distribution and the related processes, because of its volcanic activity. The interactions between the frequency of eruptions, the climate, the snow cover and the permafrost are complex and lead to a specific stratigraphy in the subsurface. The soil temperatures are influenced by a cold-maritime climate in the uppermost levels and by a high geothermal heat flux in the lowermost levels. The soil is mainly composed of volcanic ashes and, in some sites imbedded snow and ice layers, which have been buried during recent volcanic events (1967, 1969 and 1970).

A high-resolution numerical soil-atmosphere transfer model (COUP) was used in order to understand the interactions between the volcanic activity, the climate and the permafrost processes. The challenges of this modelling include the scarcity of long-term, in-situ measured data from Deception Island. Borehole data are only available since 2006, but since then several permafrost related studies have been conducted within a collaboration of the Spanish, Portuguese, Argentinean and Russian Antarctic Programs. The initialisation and the validation of the model has been done by compiling borehole temperature and geophysical data sets, which have been complemented with climate data from stations in the vicinity (South Shetland Islands).

An attempt to determine the ice-content of the soil has been done using a so-called four-phase model (4PM) based on near-surface geophysical measurements. The obtained electrical resistivity and seismic velocity data are then used as input for the model to calculate the ice and unfrozen water content distribution by applying petrophysical relationships. Hereby, it has to be considered that ice content on Deception Island is not only determined by meteorological factors (leading to permafrost) but can also consist of buried snow and glacier-permafrost interactions.

The permafrost of Deception Island is very sensitive to climate change because of subsurface temperatures near the freezing point, a mean annual air temperature of -2.8°C at sea-level, positive summer air temperatures and frequent summer rainfall. In order to evaluate this sensitivity under the combined geothermal and climatic forcing, we run the model under estimated future climate conditions and different geothermal boundary conditions.

This contribution presents first results of the thermal subsurface model, the snow cover, the active layer depth and the permafrost thickness.