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Permafrost hydrology related to nuclear waste repositories in Germany

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Deep geological disposal of nuclear waste implies (1) storage at a depth of several hun-dred metres below surface and (2) a safety assessment that covers a long period of time. In Germany a time span of 1,000,000 years has to be considered. One of the main concerns for such a repository is the detrimental effect of groundwater on the technical and geotechnical barriers, e.g. waste canisters. For the design of the repository, a good knowledge of the local and regional groundwater system is therefore required. This knowledge forms also the basis for predicting radionuclide migration in case of leakage from a damaged waste canister.

Potential sites in Germany have been identified in the North German lowlands and in Southern Germany within or adjacent to the Alpine foothills. During recent cold stages like the Weichselian glacial (Würm glacial stage for the Alpine region) these sites experi-enced partly permafrost conditions, partly coverage by an ice shield. Ground freezing to a large lateral as well as vertical extent has thus to be assumed under these conditions. This may have led to radically different groundwater flow systems compared to those prevailing during warm stages with presently hard to predict consequences for the poten-tial migration of radionuclides through the geosphere. However, work on groundwater flow systems under cold stage conditions has not gone to great detail in Germany yet.

As a first step in that direction, changes in the underground due to freezing under per-mafrost conditions would have to be addressed. Only at a later stage and based on sound understanding of the geohydrology under permafrost conditions, the effect of an approaching ice cap and the subsequent ice coverage can be treated as this introduces additional levels of complexity and is preceded by permafrost conditions anyway.

Neglecting mechanical effects from expansion during freezing and assuming no water flow, ground freezing is a thermal problem that is basically controlled by the mean sur-face temperature, heat production from earth's core and the thermal properties of the geological units. Much more challenging is the simulation of the development of taliki which is a delicate process and requires a thermo-hydraulic (TH-)coupling. Open taliki connect deep aquifers with the rock surface and thus form a key feature in a frozen groundwater flow system. However, development of an open talik may be influenced by the groundwater flow system to an unknown extent which would make this process site specific.

These tasks are intended to be tackled with the code d3f++ which is well suited for this purpose as it is capable of modelling TH-groundwater flow and just needs to be advanced to cope with freezing of water in granular porous media. The general strategy is to start out with simple models in terms of physical complexity while preferably sticking to generic models in order to increase the general understanding of the processes involved. Wherever possible, a comparison with in-situ investigations will be sought.