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# The impact of lateral heat and water fluxes from thermokarst lakes on tundra landscape dynamics and permafrost degradation

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## Abstract

Projected future warming of the Arctic will result in pronounced degradation of permafrost and thereby trigger large-scale landscape and ecosystem changes. In this context, the formation and expansion of thermokarst lakes play a key role as thermokarst dynamics represent a mechanism for abrupt degradation of permafrost soils.

Using the process-based model CryoGrid-3 coupled to a model description of lake dynamics (FLake), we explore how the thermal and hydrological state of different permafrost landscapes is affected by an explicit consideration of the interaction between lakes and surrounding permafrost environments. Hereby we especially investigate the role of lateral fluxes in affecting the landscape heat and water budgets.

**Keywords:** permafrost degradation; thermokarst dynamics; abrupt thaw; lateral fluxes; permafrost modelling; CryoGrid3

## Motivation

State-of-the-art land surface models used for simulating permafrost dynamics generally focus on capturing gradual thaw only (i.e. describing permafrost thaw as a vertical 1D heat conduction process). Yet observations of present-day landscape changes underline that permafrost grounds react much more dynamically to changing environmental conditions manifested e.g. in abrupt thaw features through thermokarst formation and thermal erosion. These changes may trigger significant feedbacks – from local scales by shaping landscape patterns to global scales by affecting the global carbon cycle. Therefore, the omission of abrupt thaw processes in current land surface models leads to an underestimation of projected future permafrost degradation and eventual carbon release (Schneider von Deimling et al., 2015) and improved model representations of permafrost dynamics are needed.

## Modelling approach

Using the permafrost model CryoGrid3 (Westermann et al., 2016), we capture abrupt thaw behaviour by modelling thermokarst lake formation, talik expansion under lakes, and ground subsidence due to melting of excess ice. Our model version includes a description of lake dynamics inferred from the FLake model (Mironov et al., 2003; Kirillin et al., 2011). Based on Langer et al. (2016), we have further developed our model to also represent lateral heat and water exchange between a lake body and its permafrost soil surrounding.

## Modelling analyses

In our study we focus on investigating the effect of lateral fluxes of heat and water on permafrost stability for different realizations of lake sizes and landscape coverage. We run our model for differing 21st century warming scenarios to investigate differences in permafrost degradation between climate mitigation and business-as-usual emission scenarios. Given the computational efficiency of our model, we test a large range of model parameter settings to quantify uncertainty in our simulation results. By comparing model simulations with and without describing lakes in permafrost environments, we discuss the importance of lake dynamics for affecting tundra landscape thermal regimes and future permafrost degradation.

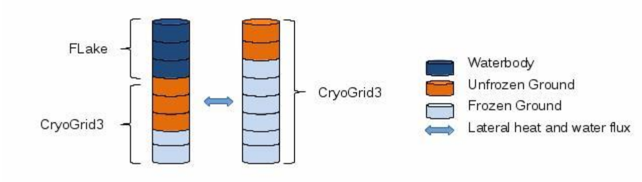


**Figure 1** Sketch of model simulation design. The new model implementations account for lateral exchange of heat and water between a soil column covered by a lake (left) and its non-lake permafrost environment (right). Vertical fluxes are not shown explicitly.

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