Solving Integrated Water and Energy Balance for Modeling Groundwater/Permafrost Interactions

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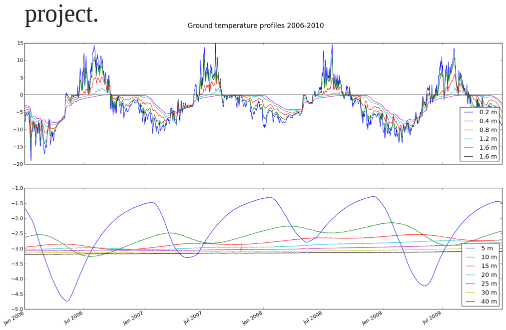
Background

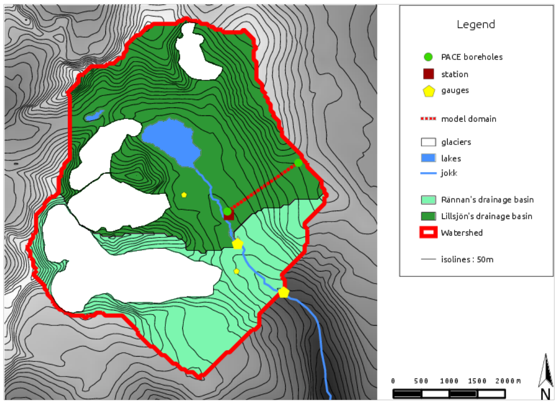
- Permafrost covers ~22% land in northern hemisphere (1).
- Estimated ~1700 Gt carbon stored in permafrost in northern hemisphere only, over twice current atmospheric content (2).
- Arctic systems are sensitive to global warming (3) (4).
- Permafrost thawing affects groundwater storage and flow pathways (5)(6), which can release stored carbon, further impacting climate change.
- Depends strongly on both heat transport and fluid flow in subsurface (7).

Tarfala site data

Tarfala valley has traditionally been studied with emphasis on glacier mass balance.

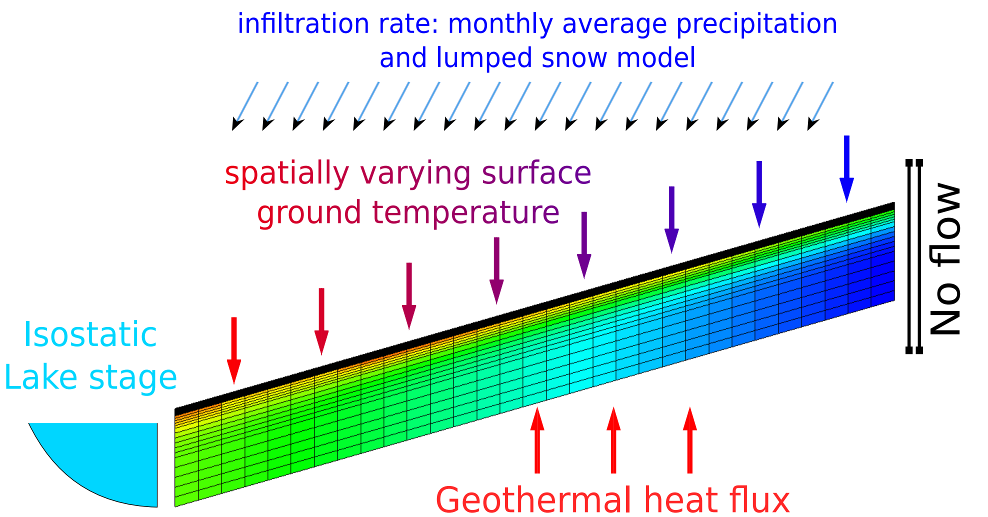
In 2000, a 100m deep borehole equipped with thermistors has been drilled as part of the Permafrost and Climate in Europe (PACE) project.





Other data available at the site include a long air temperature record, liquid precipitation, stream flow at different locations, solar radiation, humidity, wind speed and direction (8).

Model configuration



Overall objective is to quantify past and future permafrost and hydrogeological change in tarfala, northern Sweden, using coupled heat and fluid flow model.

Hereby is a representation of model boundary conditions, which are based on site specific observation and model outputs.

Simulated temperatures will be evaluated against groundtemperature observations from the PACE-boreholes.

Technical description of the model

PFloTran solves the following equations for water and energy balance:

$$\frac{\partial}{\partial t}\left[\phi(s_g\eta_g X_w^g + s_l\eta_l + s_i\eta_i)\right] + \nabla\cdot[\mathbf{v}_l\eta_l] - \nabla\cdot[\phi s_g\tau_g\eta_g D_g\nabla X_w^g] = Q_w$$

$$\frac{\partial}{\partial t}\left[\phi\left(\sum_{j=g,l,i} s_j\eta_j U_j\right) + (1-\phi)\rho_r c_r T\right] + \nabla\cdot[\mathbf{v}_l\eta_l H_l] - \nabla\cdot[\kappa\nabla T] = Q_e$$

It accounts for three-phase partitioning among ice, liquid and vapor, latent heat transfer, and flow in the unsaturated zone using classical soil retention curves (9).

PFloTran is a massively parallelized code, enabeling simulations over multiple scales (10).

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