Los Alamos NATIONAL LABORATORY

The flooding effect on coastal permafrost thaw

Earth & Environmental Sciences

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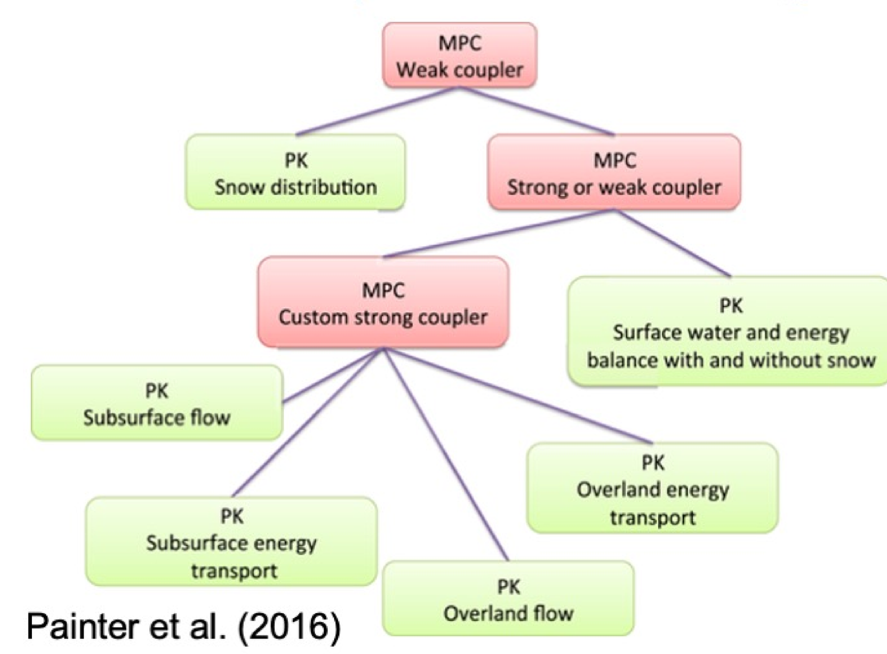
Abstract

Flooding of low-lying Arctic regions has the potential to warm and thaw permafrost by changing the surface reflectance of solar insolation, increasing subsurface soil moisture, and increasing soil thermal conductivity. However, the impact of flooding on permafrost in the continuous permafrost environment has not been tested and remains poorly understood. To address this knowledge gap, we used a combination of available flooding data on the Ikpikpuk delta and a numerical model to simulate the hydro-thermal processes under coastal flooding events. We first constructed the three most common flood events based on water level data on the Ikpikpuk: snowmelt floods in the late spring and early summer, middle and late summer floods, and floods throughout the whole spring and summer. The impact of these flooding events on permafrost was simulated using one-dimensional permafrost columns using the Advanced Terrestrial Simulator (ATSv1.0) fully coupled permafrost-hydrology and thermal dynamic model. Our results show that coastal floods have an important impact on coastal permafrost dynamics with a cooling effect on the surficial soil and a warming effect on the deeper soil. Cumulative flooding events over several years can cause continuous warming of the deep subsurface, but decrease temperatures in the surficial layer. Flooding timing is a primary control of the vertical extent of permafrost thaw and active layer deepening.

Method

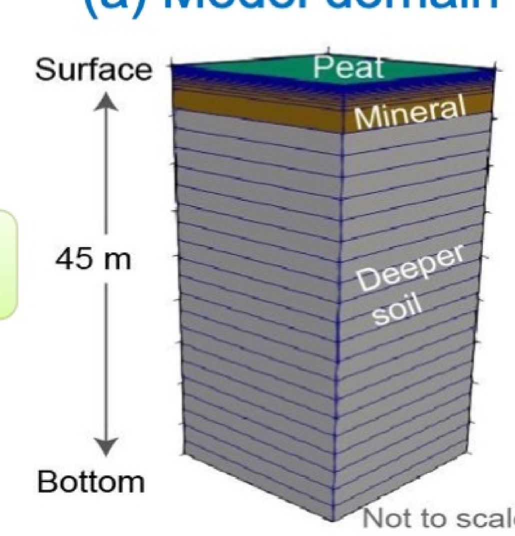
Advanced Terrestrial Simulator (**ATS**)

Permafrost hydro-thermal configuration

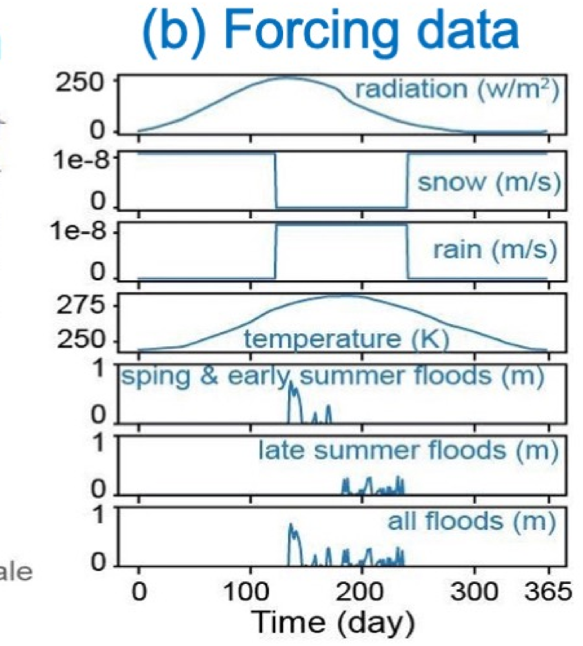


Painter et al. (2016)

(a) Model domain



(b) Forcing data



Model settings

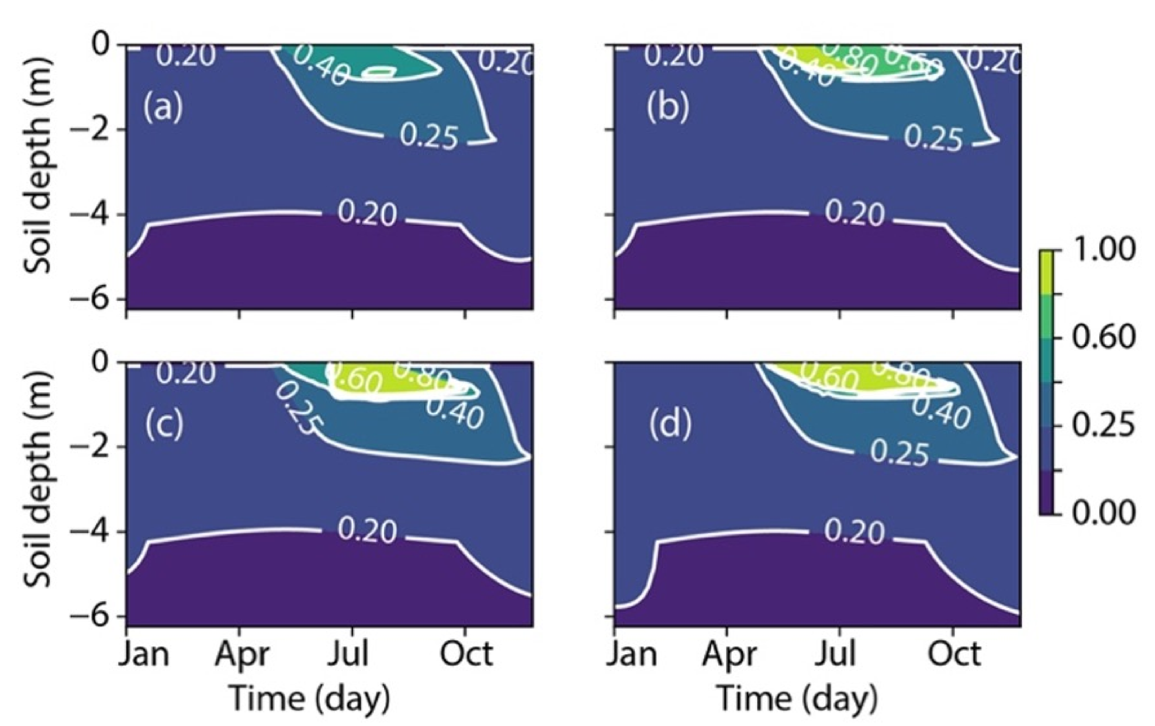
(c) Key parameters

Parameters	Peat	Mineral	Deep soil
Porosity [-]	0.87	0.56	0.005
Permeability [m²]	9.38×10^{-12}	6×10^{-13}	1×10^{-21}
Thermal conductivity (saturated unfrozen) [W m⁻¹ K⁻¹]	0.67	1	1.1
Thermal conductivity (dry, unfrozen) [W m⁻¹ K⁻¹]	0.1	0.3	0.4
van Genuchten α [m⁻¹]	5.1	3.3	2.8
van Genuchten ν [-]	0.19	0.248	0.52

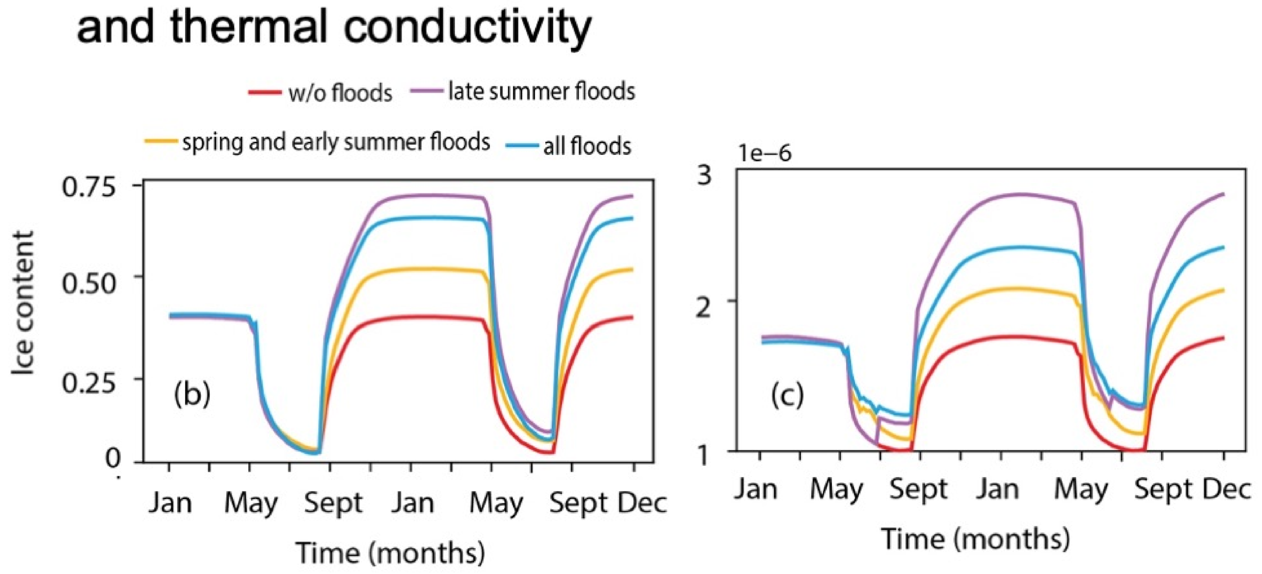
- Three flooding scenarios: spring & early summer floods, middle and late summer floods, and all floods.
- 20-year spin up simulation and 10-year transient simulation with repeated forcing in fig. b above.

Results

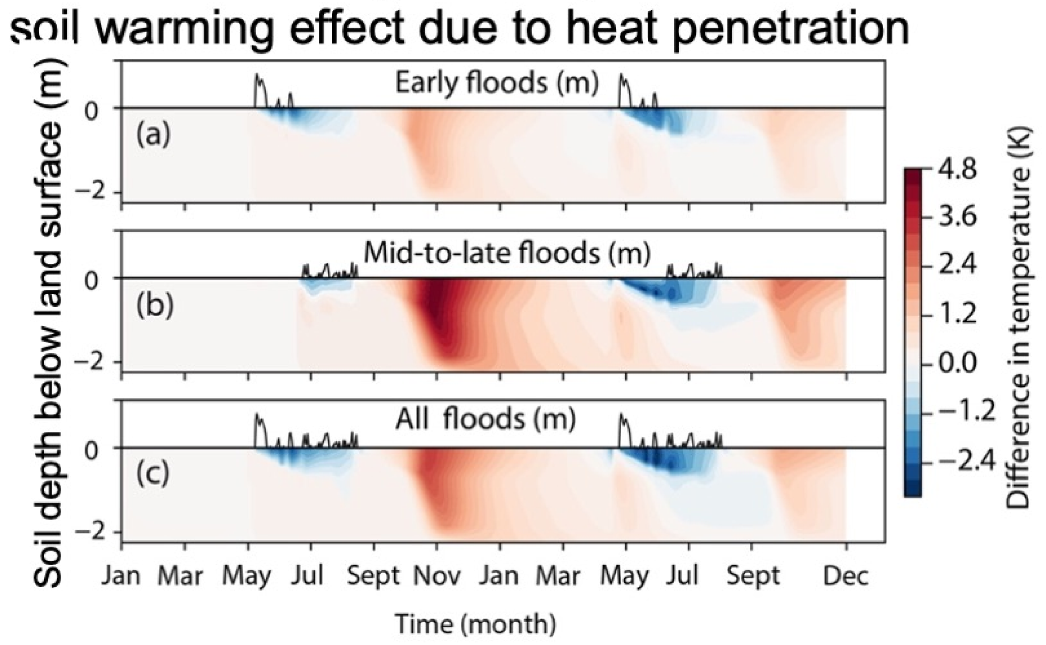
1. Floods increase subsurface liquid water saturation level



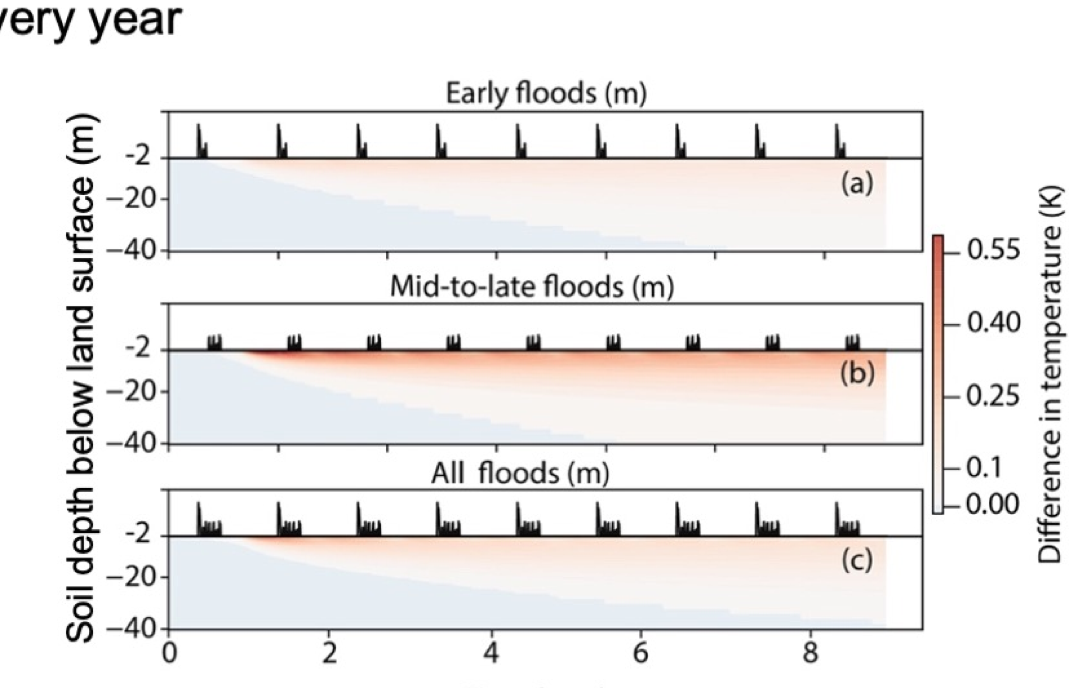
2. Floods lead to large increase of subsurface ice content and thermal conductivity



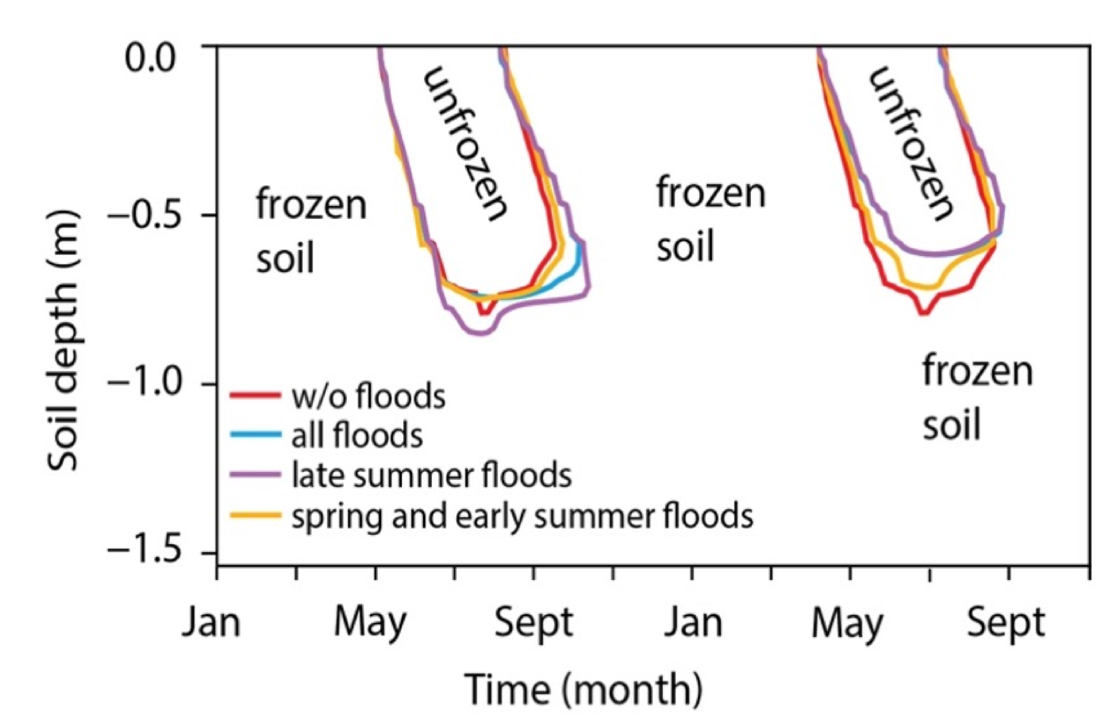
3. Floods cause a soil surface cooling effect due to the increase of latent heat of thawing and evaporation of the wetter soil and deep soil warming effect due to heat penetration



4. Deep soil becomes warmer with floods reoccurring every year



5. Timing of floods is an important factor controlling active layer thickness (ALT). Mid-late summer floods are more likely to cause a deeper ALT, particularly in the first year.



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Take home message

- Floods have an important impact on coastal permafrost dynamics.
- Flooding leads to cooler surficial soil and warmer deeper soil.
- The cooling effect of floods may be intensified in the second flooding year because of the cumulative flooding effect.
- The subsurface warming continues with reoccurring floods year after year.

Ongoing and future work

- Flooding effect on permafrost deformation and subsurface hydro-thermal dynamics
- Salinity effect on permafrost thermal dynamics

Contact information

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