

Assessing the impact of permafrost-vegetation interaction on treeline dynamics in Siberia with the individual-based, spatially explicit treeline model LAVESI coupled to the permafrost land-surface model CryoGrid

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EGU-session BG3.7 - 'Present and future global vegetation dynamics and carbon stocks from observations and models'

Boreal forests will change - but how?

- warming strongest in high latitudes
- treeline is sensitive
 - **colonization of tundra**
- evergreen taxa can replace summergreen
 - **albedo decrease**
 - **permafrost loss**
- **What are the spatial extent and temporal dynamics we will face in future climates?**

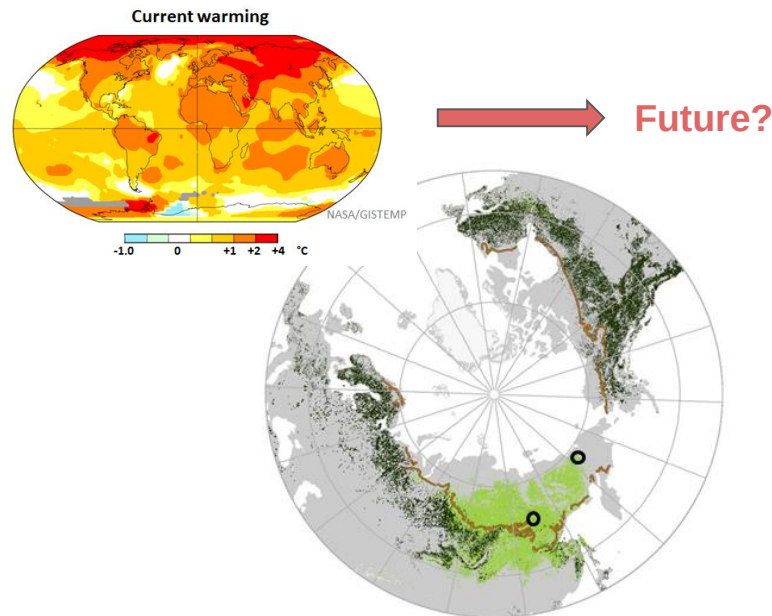
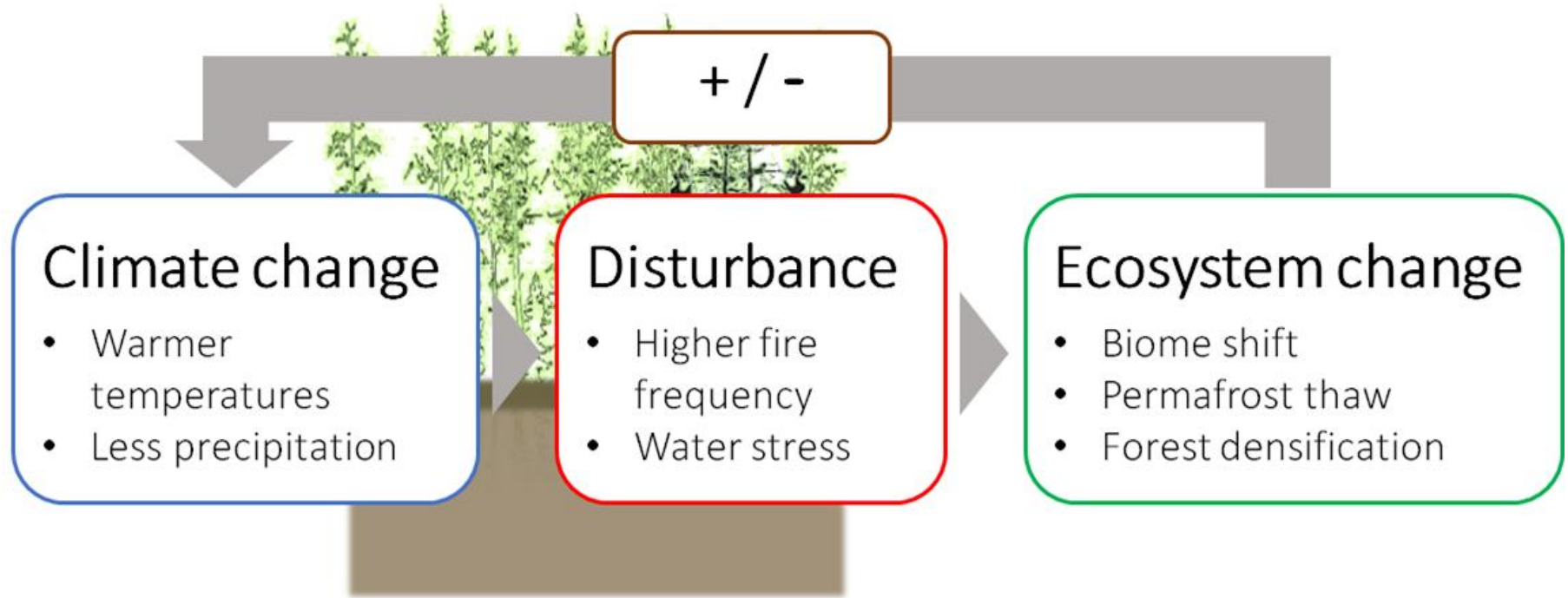
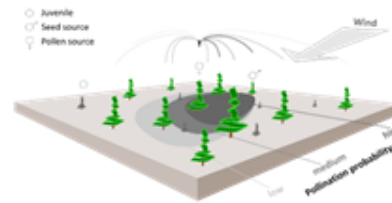


Fig 1: Map of boreal evergreen (dark green) and deciduous /light green forest distribution and the discontinuous permafrost line (brown). Data: ESA CCI Land Cover forest classes. ESA. Land Cover CCI Product User Guide Version 2. Tech. Rep. (2017).

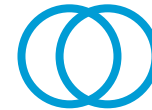
Feedback loops are very important!



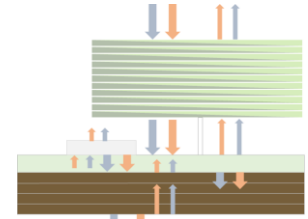
- vegetation models need to be very detailed for population dynamics
 - **include all life stages IBM**
 - **spatially explicit**
- permafrost model needs a dynamic vegetation layer
 - **coupling to IBM**
- **Because of computational constraints not yet available at large scale!**



P: 2D/3D | IBM



1D | Fluxes



F1:

fully coupled model

Individual based forest modelling

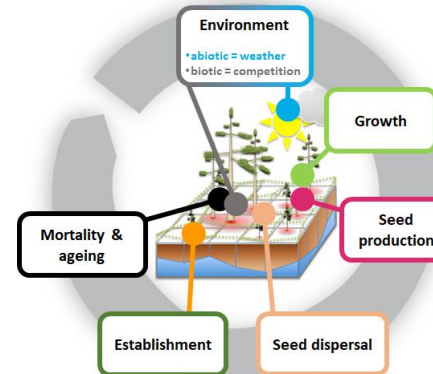
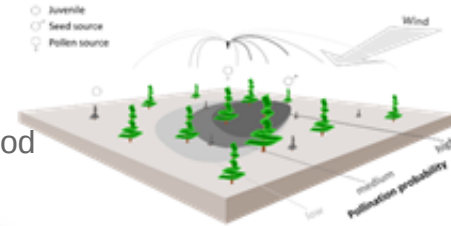
LArix VEgetation SIMulator LAVESI

by Stefan Kruse et al. [Github + e.g. Kruse et al, 2019]

- spatially explicit and individual-based
- full larch life-cycle representation
- seed dispersal in 2D environment
- able to reproduce population dynamics and time lags
- **Only a simple representation of active layer depth spatially homogeneous**

- forced with climate data

$T_{\text{Jul,Jan}}$ $P_{\text{veg period}}$



Heat flux simulation in boreal forests

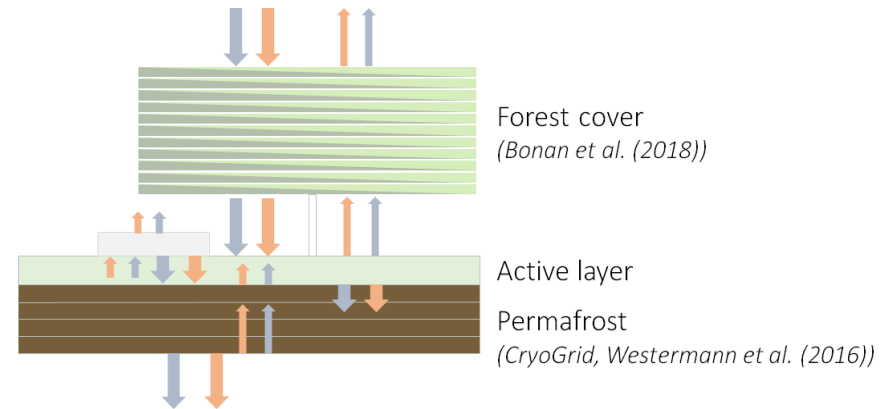
Coupled **CryoGrid** + **Multilayer canopy**

by Simone Stuenzi et al. (2021) [Multilayer canopy: Bonan et al. 2018, CryoGrid: Westermann et al. 2016]

- 1D numerical land surface model
- simulation of energy transfer processes in periglacial landscapes
- successfully used in Tundra and barren ground regions

- **Detailed multilayer canopy representation but only 1D and not dynamic**

→ driven by meteorological data from regional climate models or reanalysis products

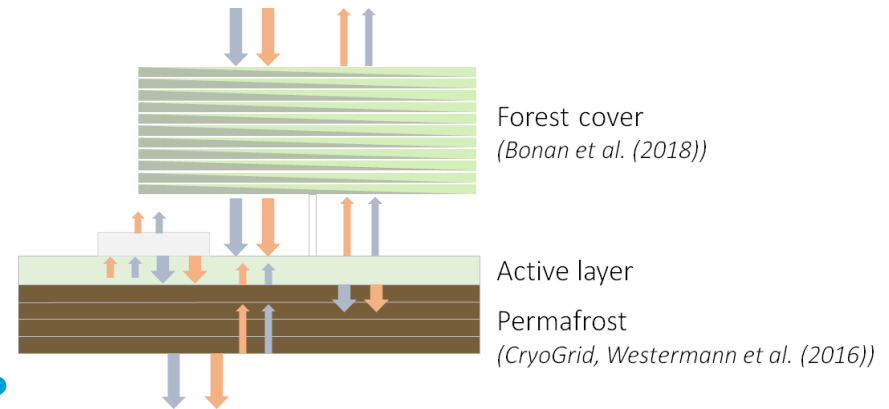


Heat flux simulation in boreal forests

Coupled **CryoGrid** + **Multilayer canopy**

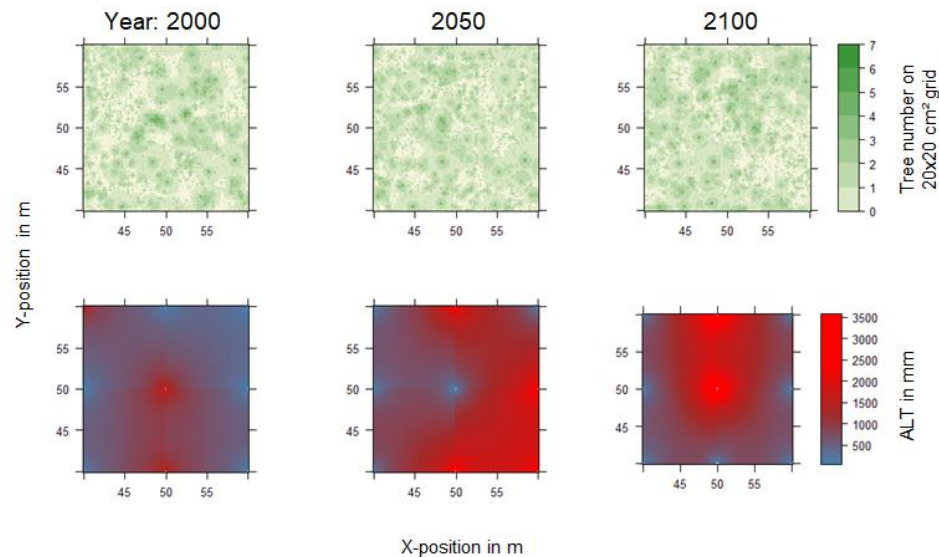
by Simone Stuenzi et al. (2021) [Multilayer canopy: Bonan et al. 2018, CryoGrid: Westermann et al. 2016]

- first simulation results
 - large insulation impact of boreal forests on permafrost
[Stuenzi et al. 2021]
 - insulation highly dependent on the forest type and structure
[Stuenzi et al., manuscript under prep.]
- **Upscaling to 2D and dynamic vegetation-permafrost interaction?**



Coupling vegetation and ALT dynamics

- first simulation results of a coupled LAVESI-CryoGrid model suggest
→ **spatial differences are important**



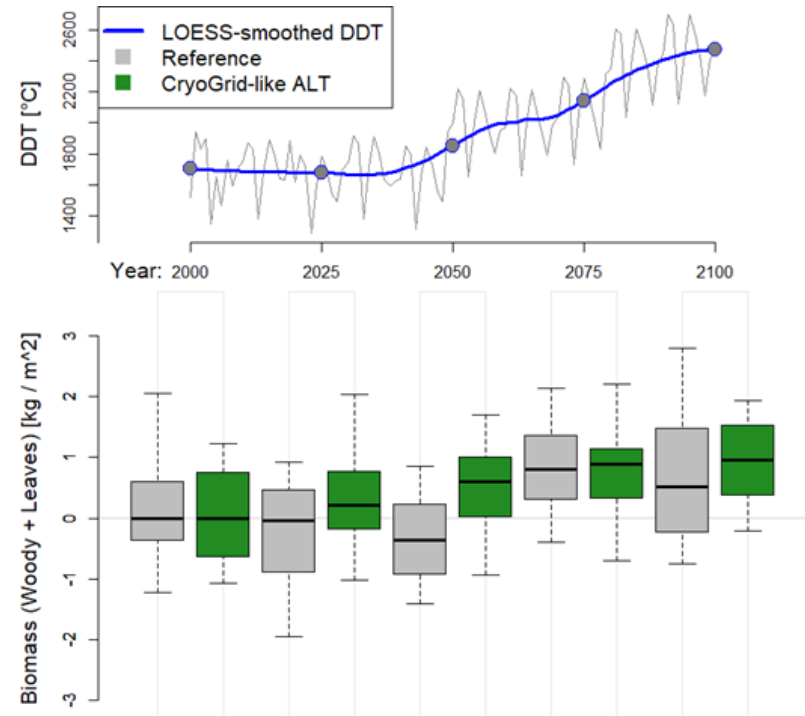
2D-view on the centre of simulated tree stands for 2000, 2050 and 2100. Top: Tree density values. Bottom: Resulting ALT under the forest.

Coupling vegetation and ALT dynamics

- first simulation results of a coupled LAVESI-CryoGrid model suggest

→ **spatial differences are important**

→ **course of biomass development is in contrast to simple model**



Biomass development (bottom) for reference simulation (grey) compared with coupled runs (green) for warming temperatures (top).

Take home message

- implemented irregularly updated ALT estimation based on coupled LAVESI-CryoGrid run
→ **online version is on the way**
- reproducing very low ALT typically found in pure larch stands of Eastern Siberia is very difficult
→ **the coupled model produces more accurate ALT estimations**
→ **strong impact on larch growth and crucial for future projections of ecosystem dynamics**

Next steps ...

- ★ integrate disturbances / fires etc
- ★ test impact of disturbances & population dynamics on permafrost state
- ★ integrate further tree species
- ★ pan-Siberian forest simulation

Thank you for your attention!

Stay in touch

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Github repository LAVESI:

<https://github.com/StefanKruse/LAVESI/tree/LAVESI-CRYOGRID>

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