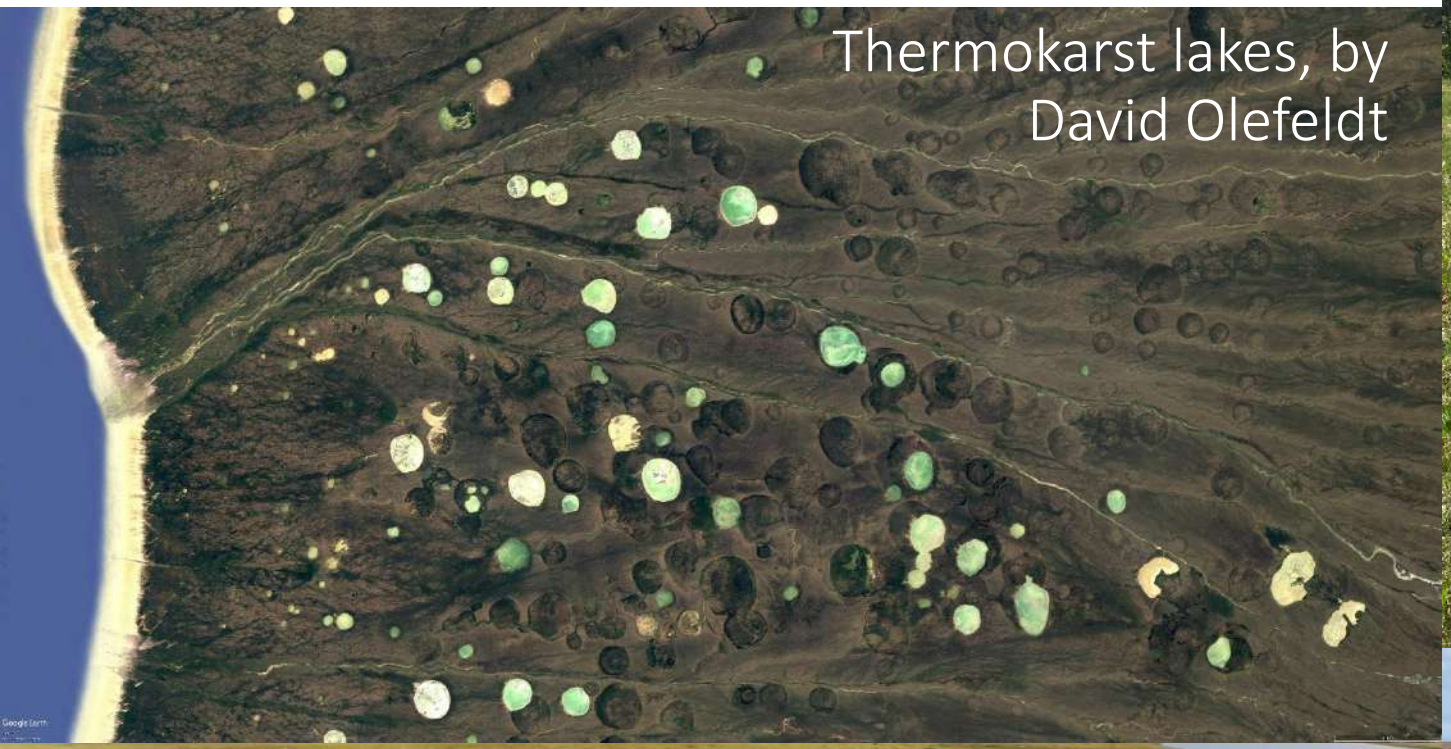
So far: Strengthening the foundations for explicitly modelling microtopography in permafrost landscapes

Noah Smith, Sarah Chadburn, Eleanor Burke,
Rachael Turton & more…

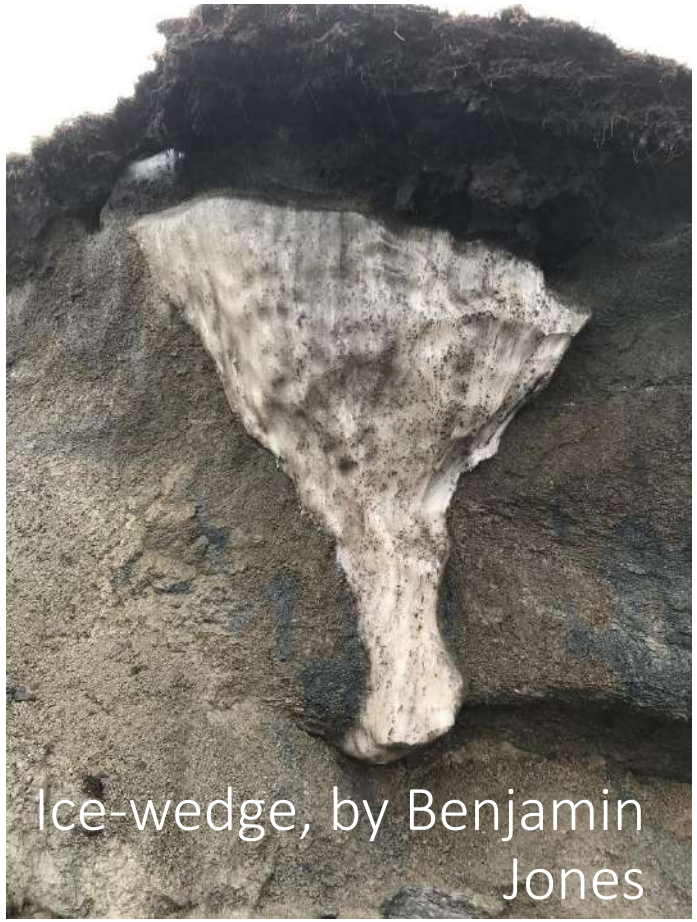
Image by Benjamin Jones (@TundraTime)

To do: Representing thermokarst

Microtopography is widespread (in the permafrost)

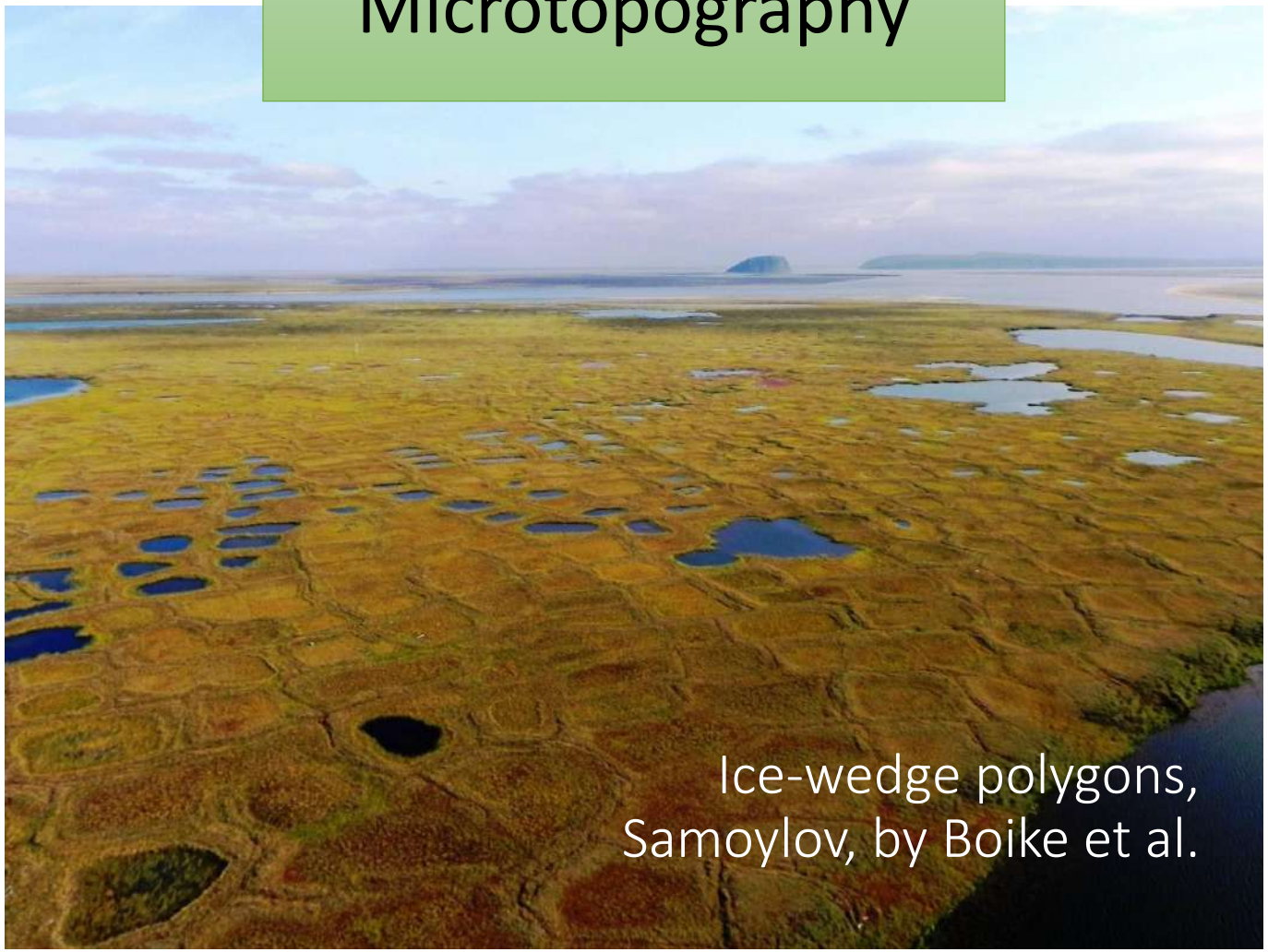


Permafrost



Ice-wedge, by Benjamin Jones

Microtopography

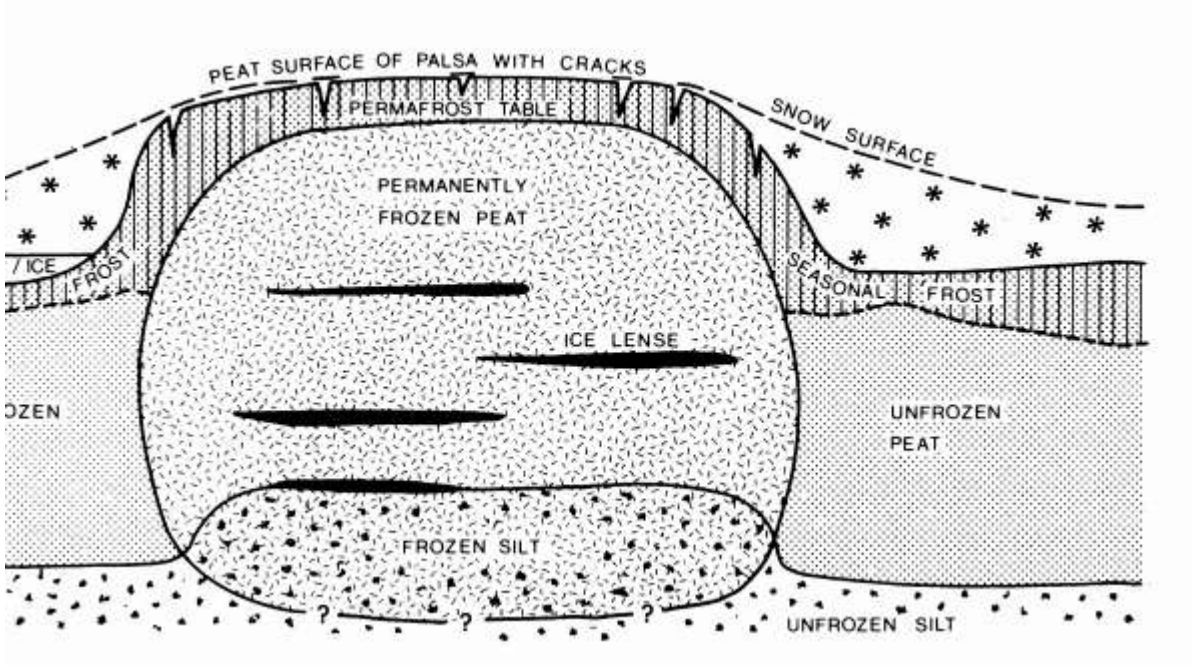


Ice-wedge polygons, Samoylov, by Boike et al.

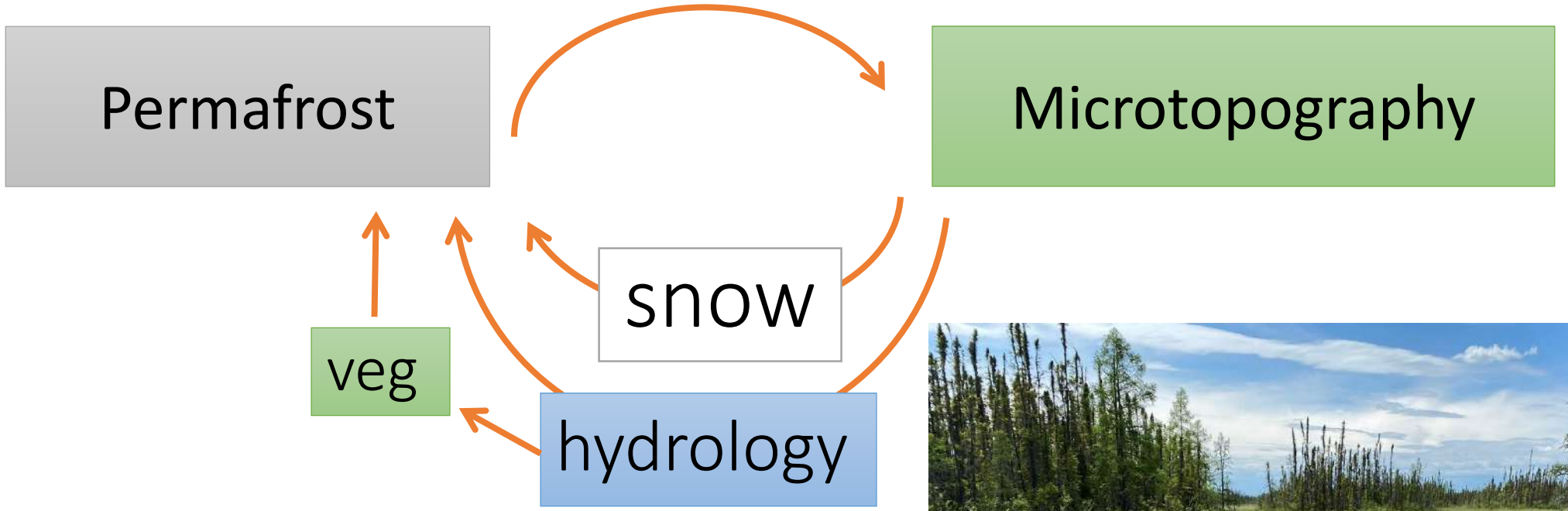
Permafrost

Microtopography

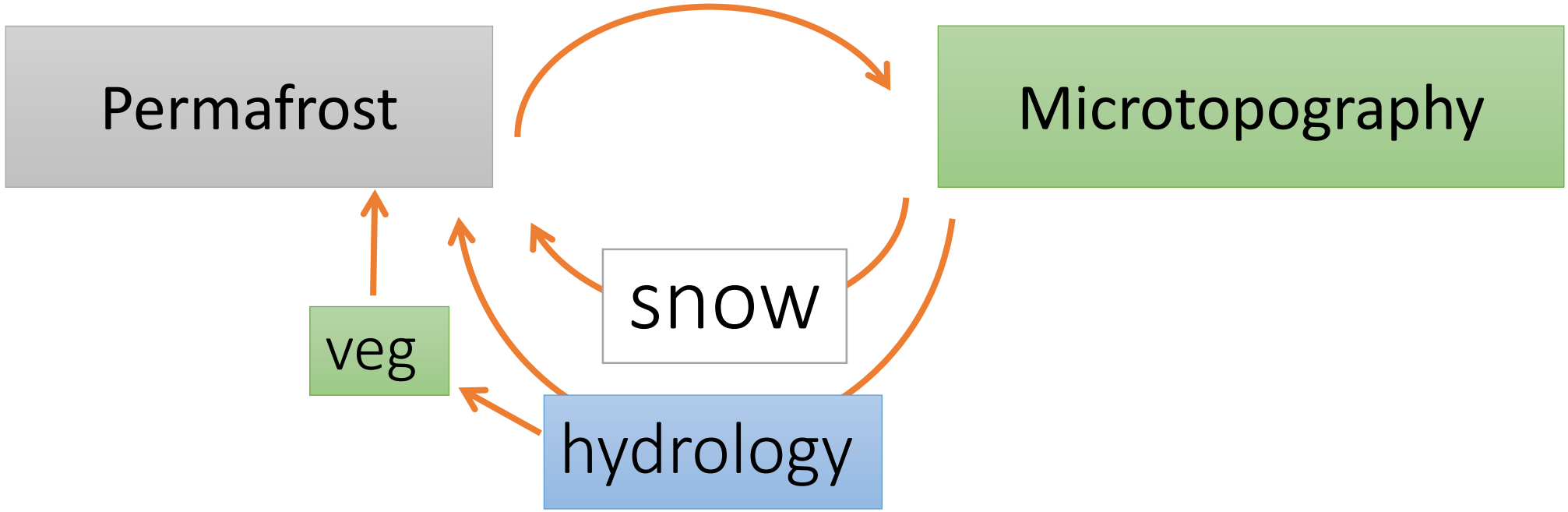
snow

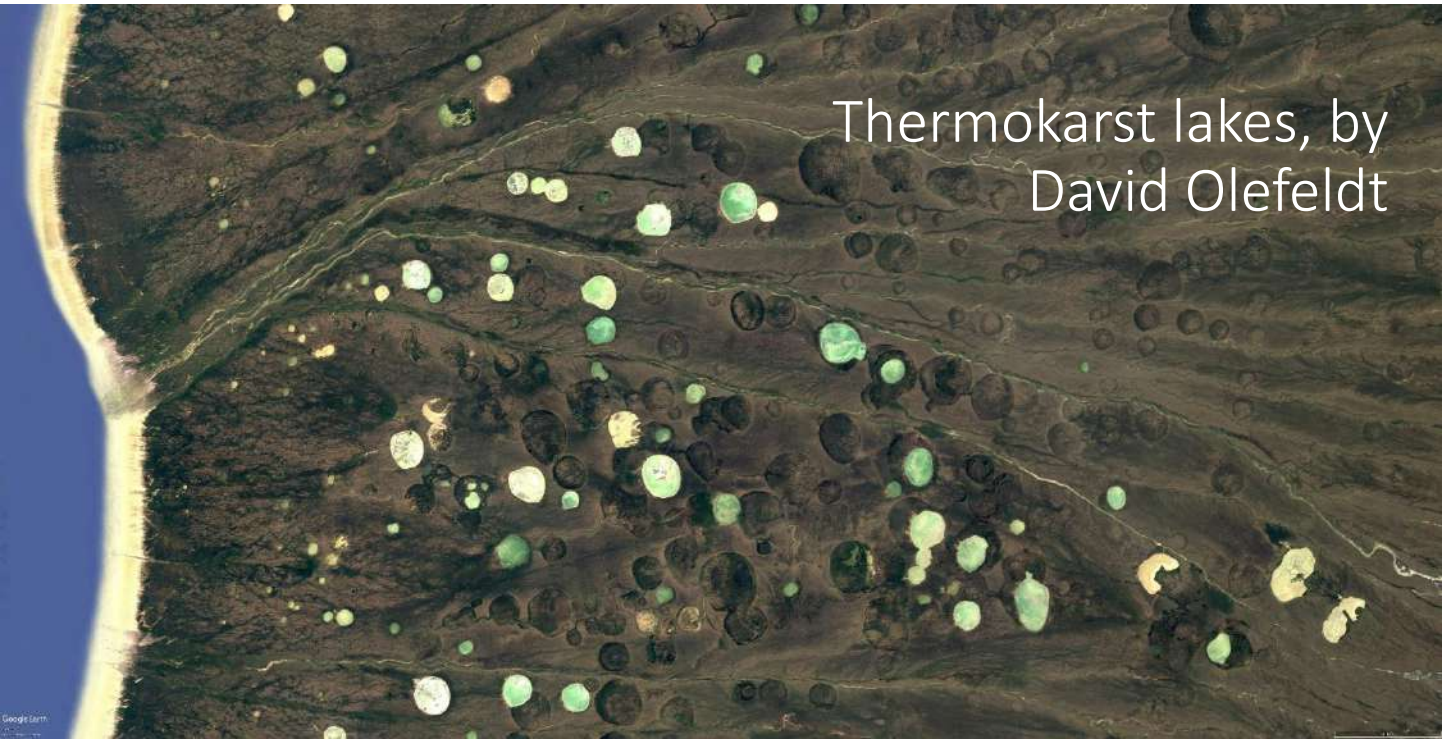


Palsa mires of Nierivuoma,
by Timo Kumpuka

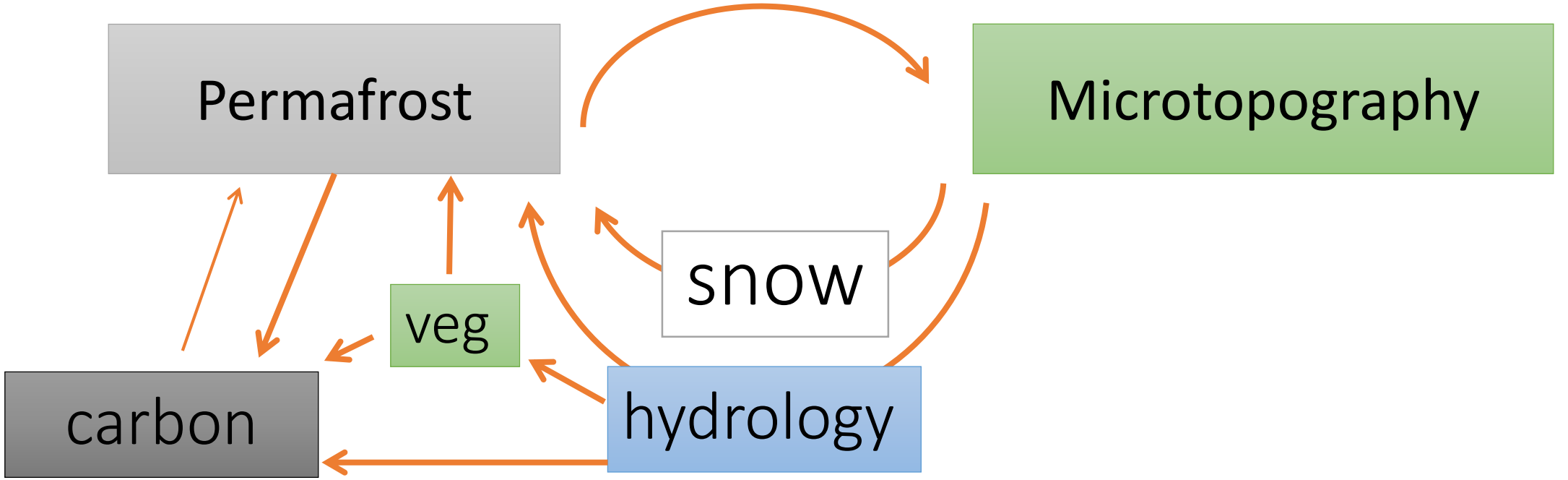

Permafrost
Microtopography
snow
veg
hydrology


Treed palsa islands & fen in Saskatchewan, Canada, by Toby Spiribille


Permafrost
Microtopography
snow
veg
hydrology


Thermokarst lakes, by
David Olefeldt


29.99 inHg
22°C
07/25/10 01:00 PM
makeagif.com


Permafrost
Microtopography
snow
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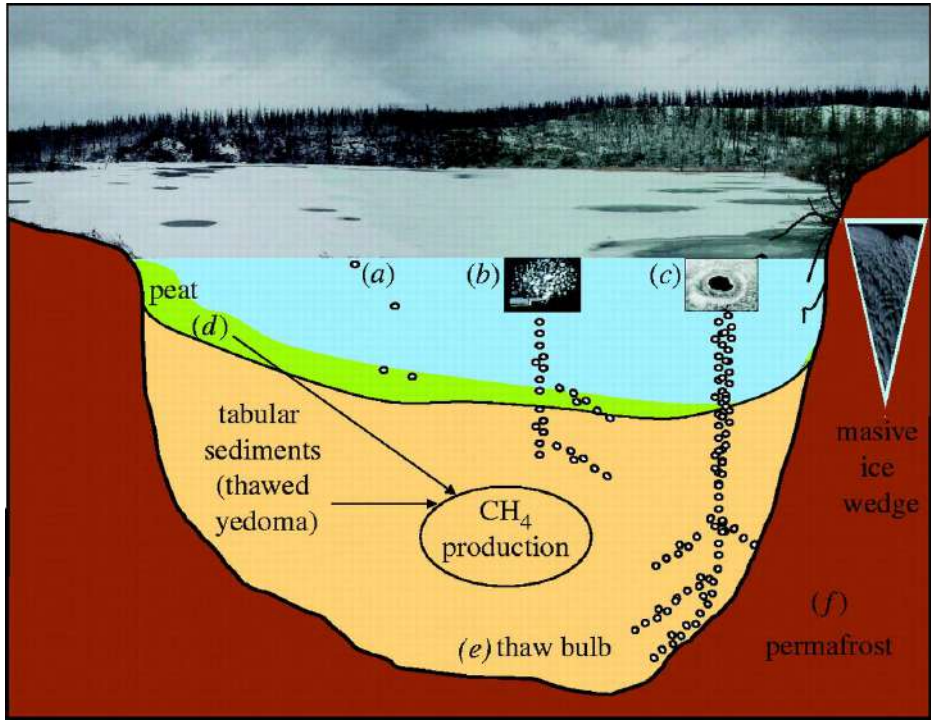
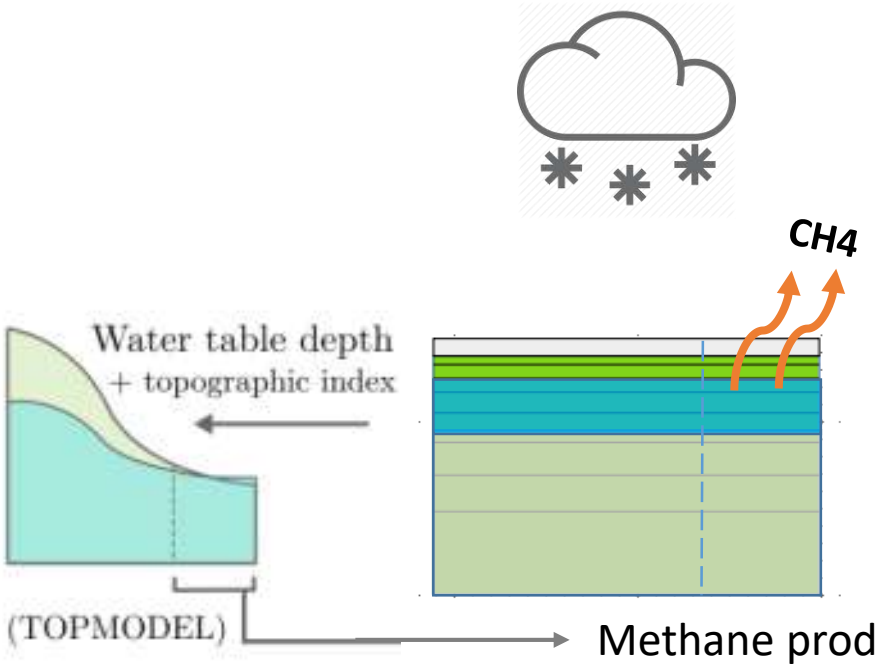
carbon
hydrology

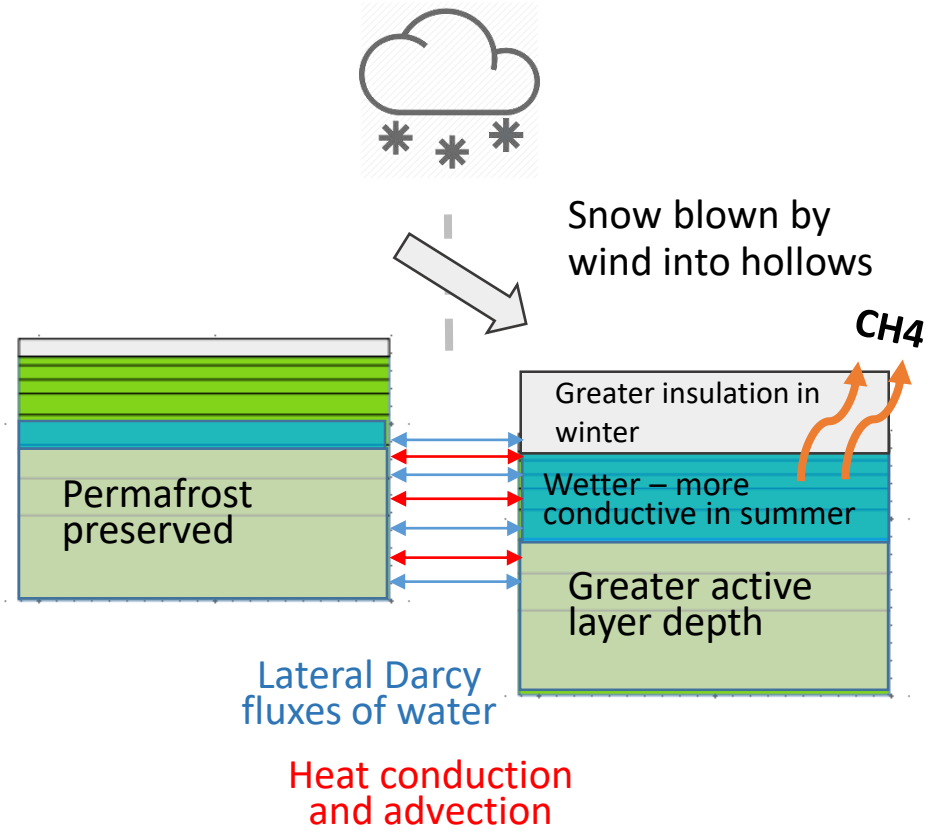

peat
(a)
(b)
(c)
(d)
tabular
sediments
(thawed
yedoma)
CH_4
production
masive
ice
wedge
(e) thaw bulb
(f)
permafrost

How do we model microtopography in JULES?

Single soil column
(Standard JULES)



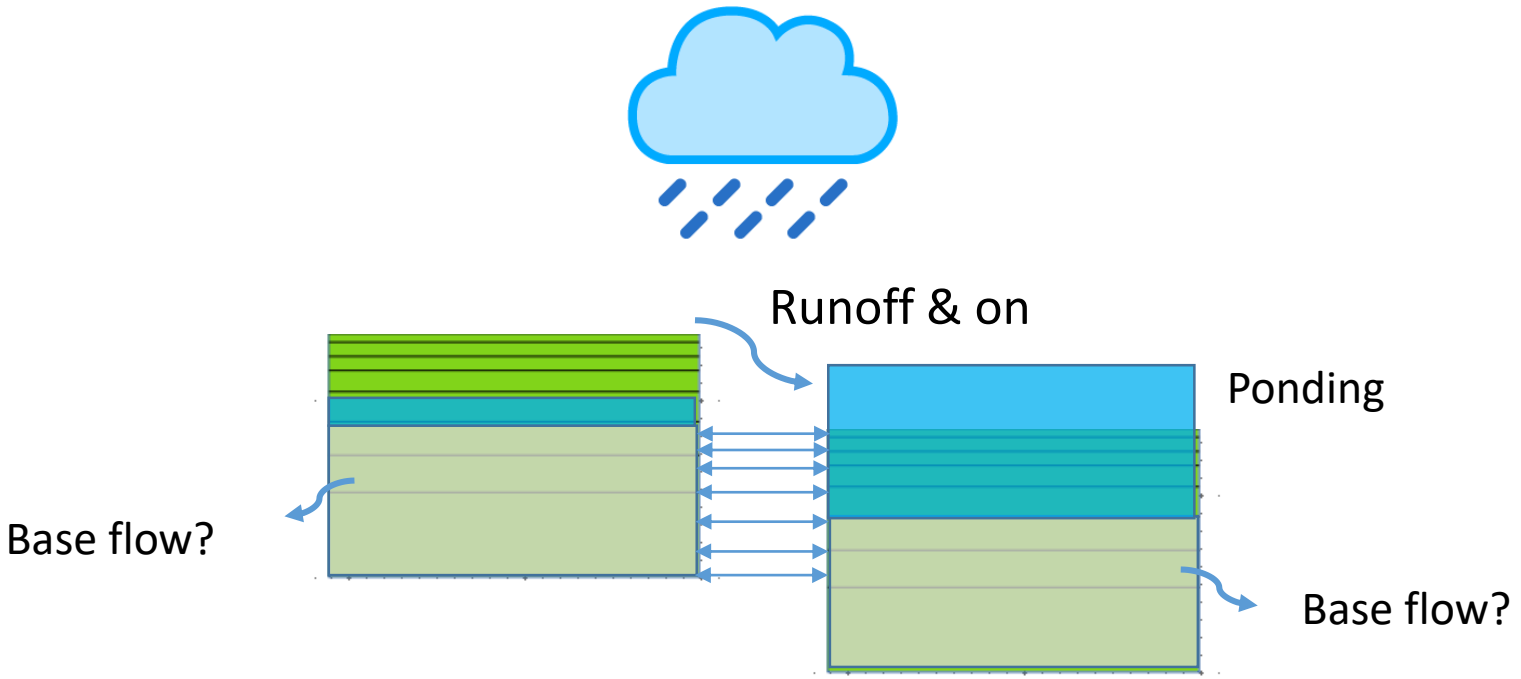
Two interacting columns
with elevation difference



(See also Aas et al. (2019), Nitzbon et al (2019))

Making wetlands wet: further modifications

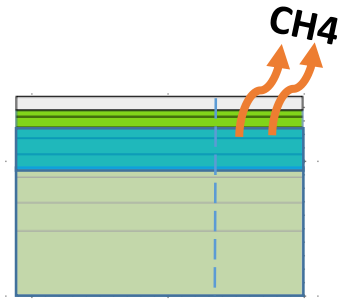
- Run-on
- Surface ponding
- A question over base flow (qbase)

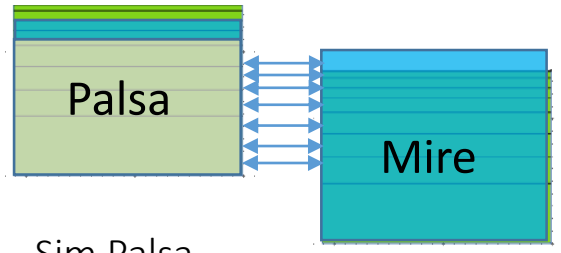


Was it worth it?

(3/4)

Discontinuous permafrost: Palsa mire (Abiskomire)



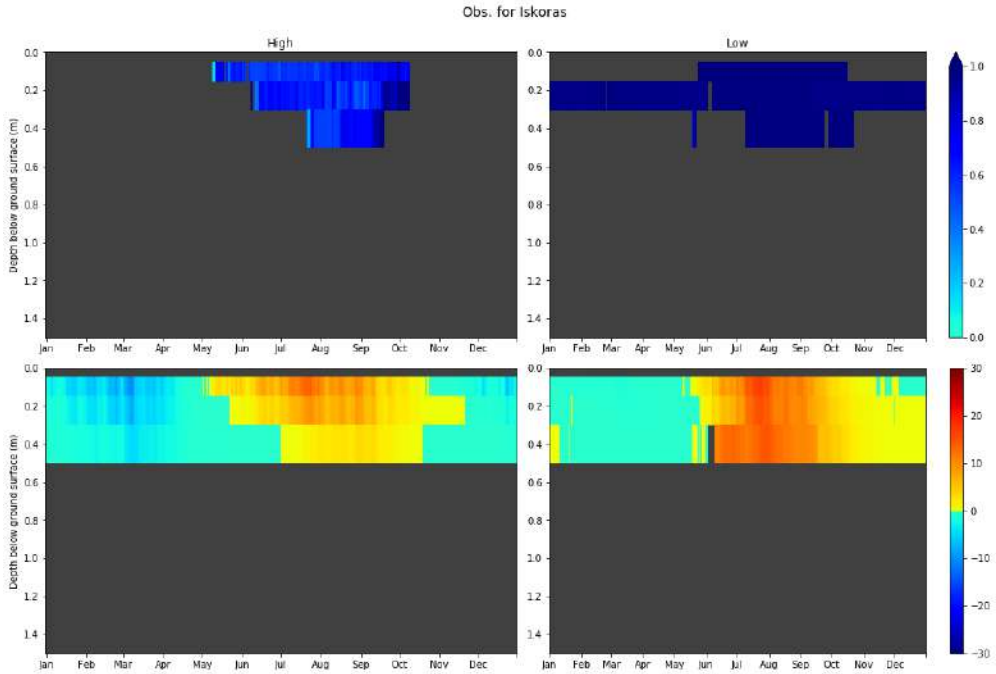


Sim Palsa

Sim Mire

Observed high

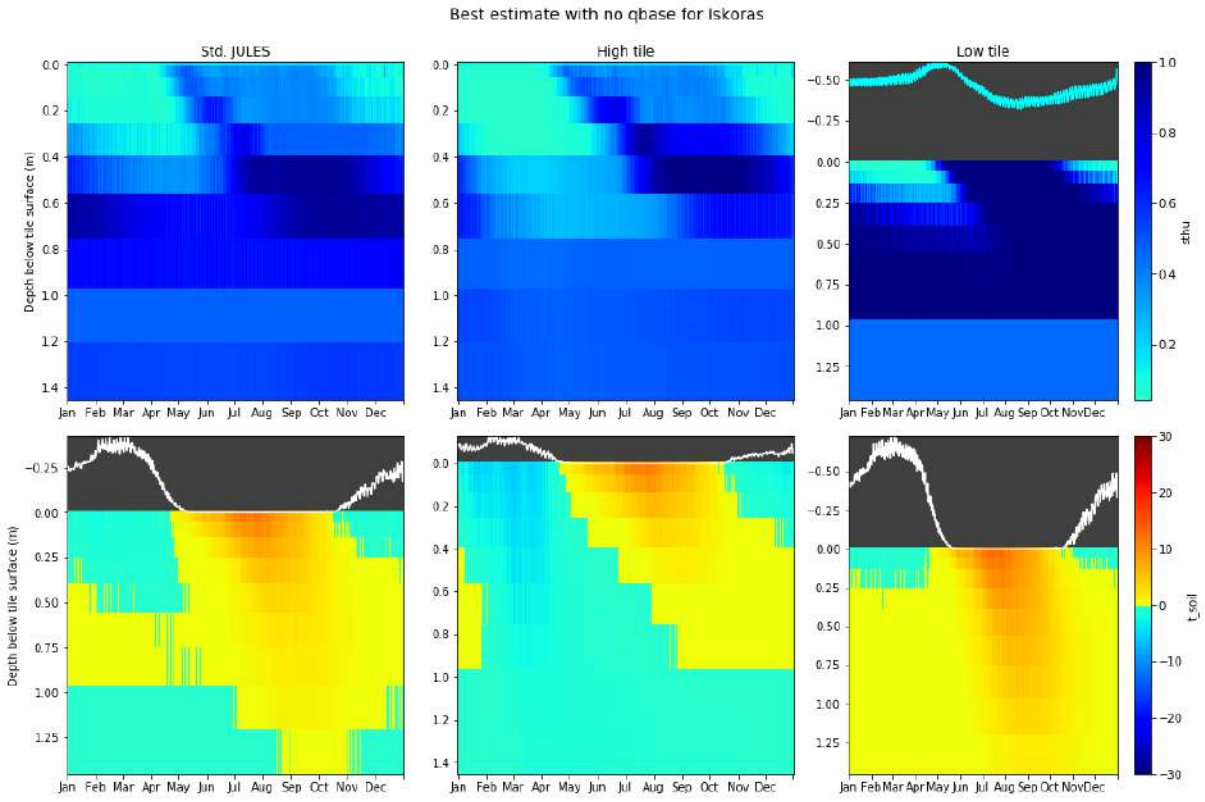
Observed Low



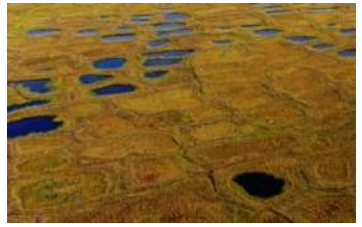
Single tile

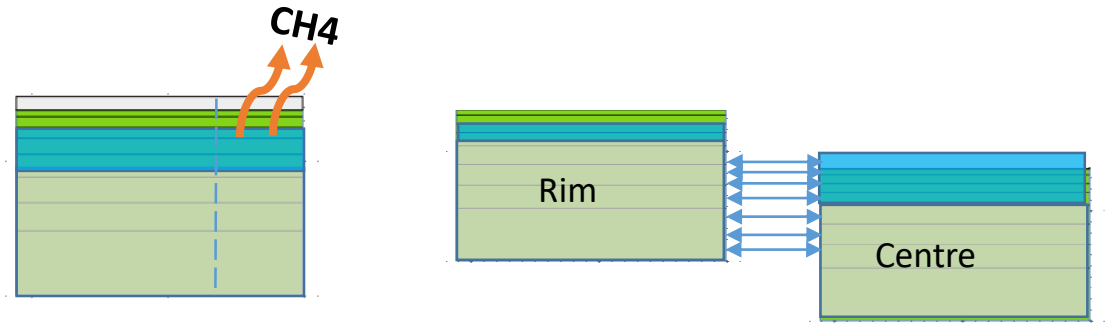
High tile

Low tile



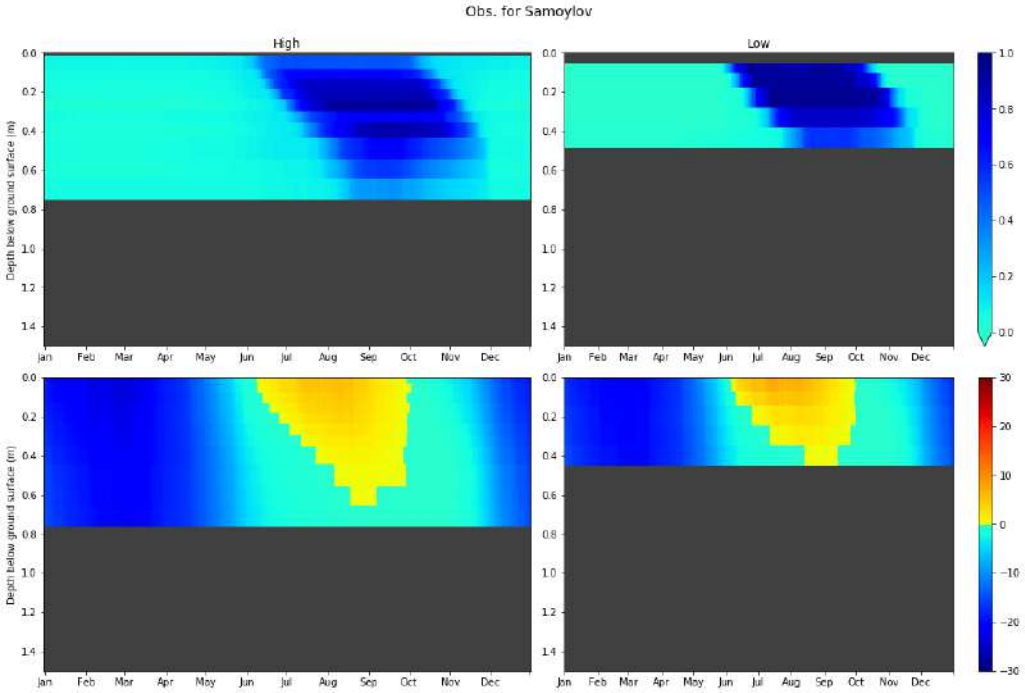
Continuous permafrost:
Ice wedge polygons (Samoylov)





Observed high

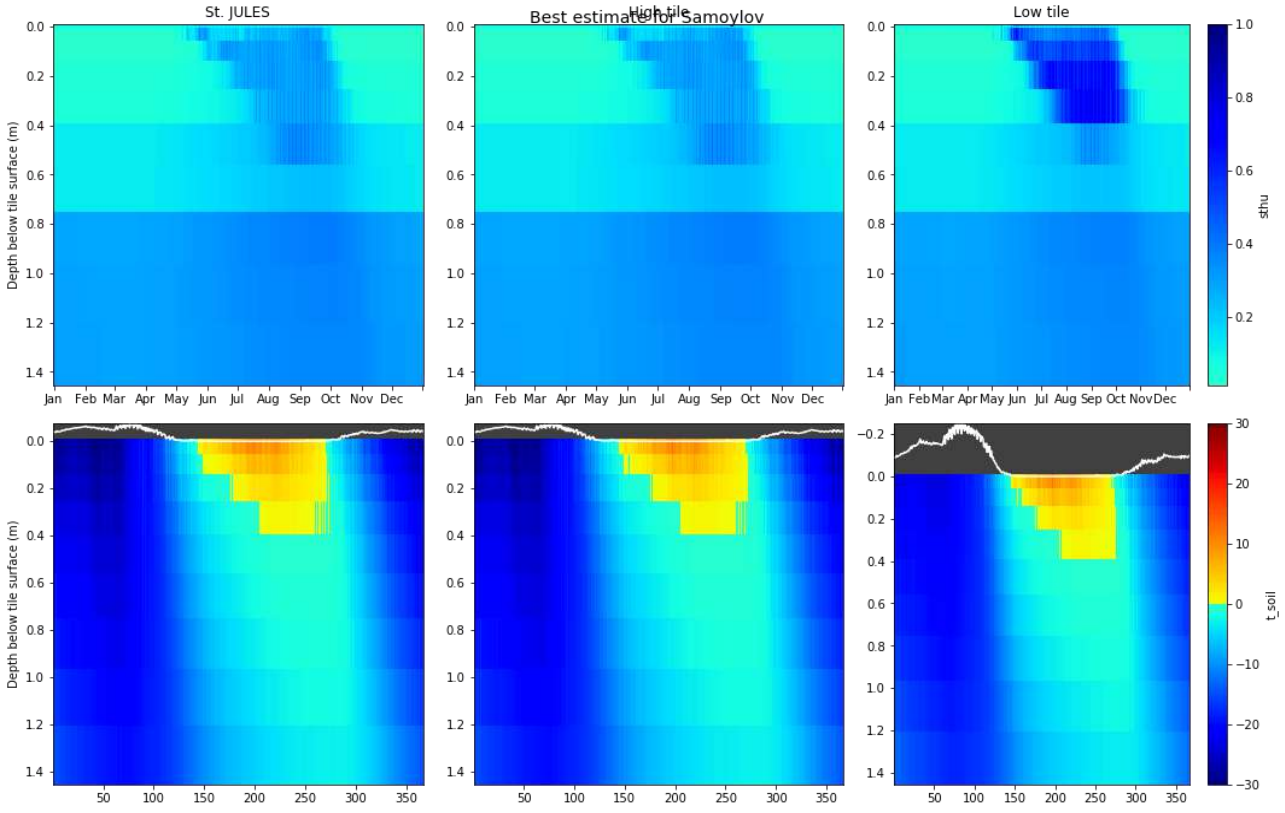
Observed Low



Single tile

High tile

Low tile

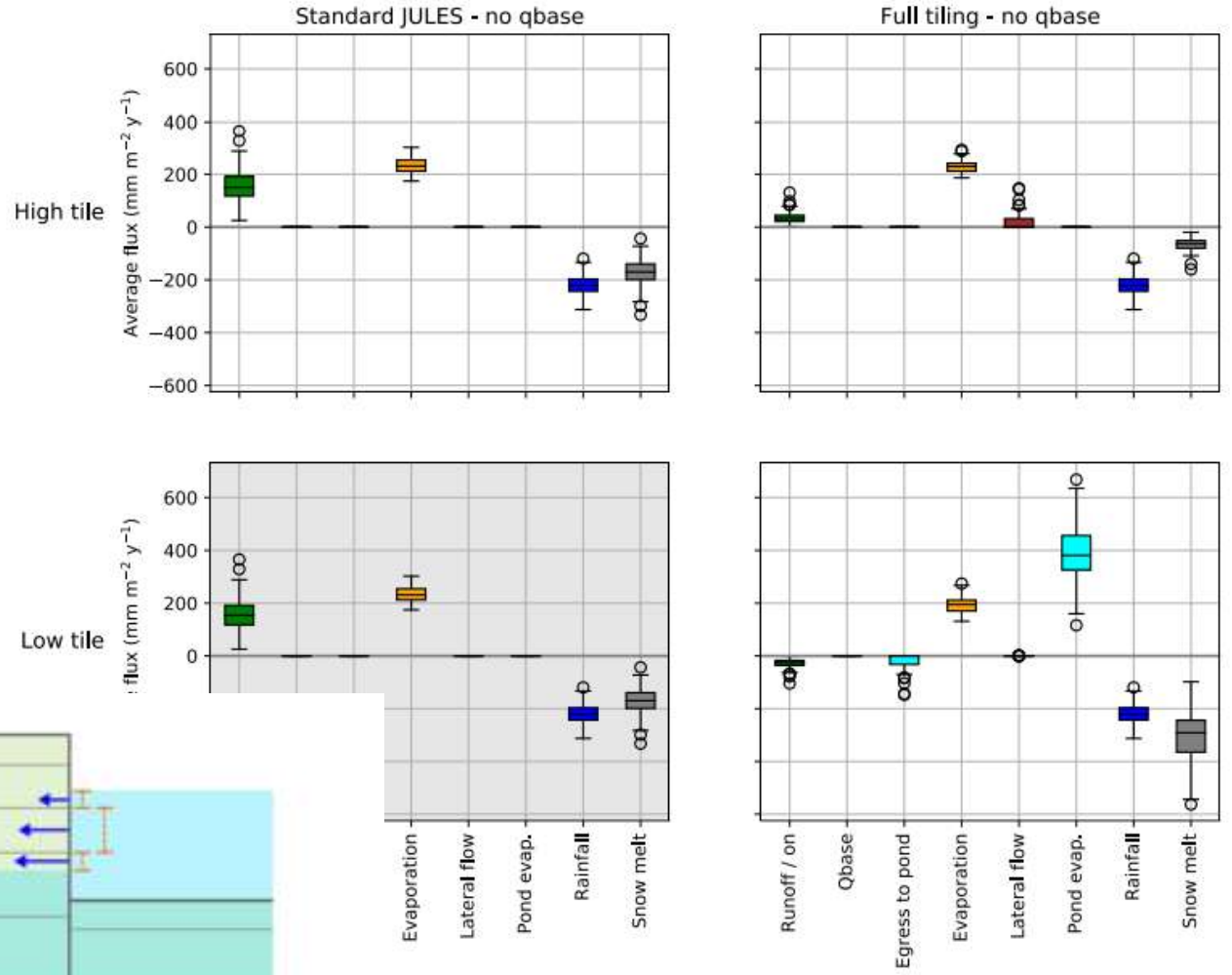


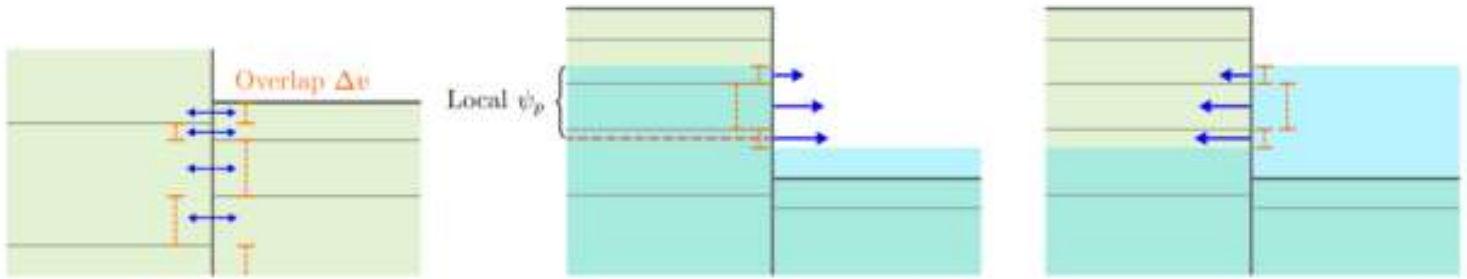
What made the difference to soil moisture?

Aside from qbase:

- Decreased runoff from low tile (and run-on from high tile)
- Differences in snowmelt
- High to low tile water flow

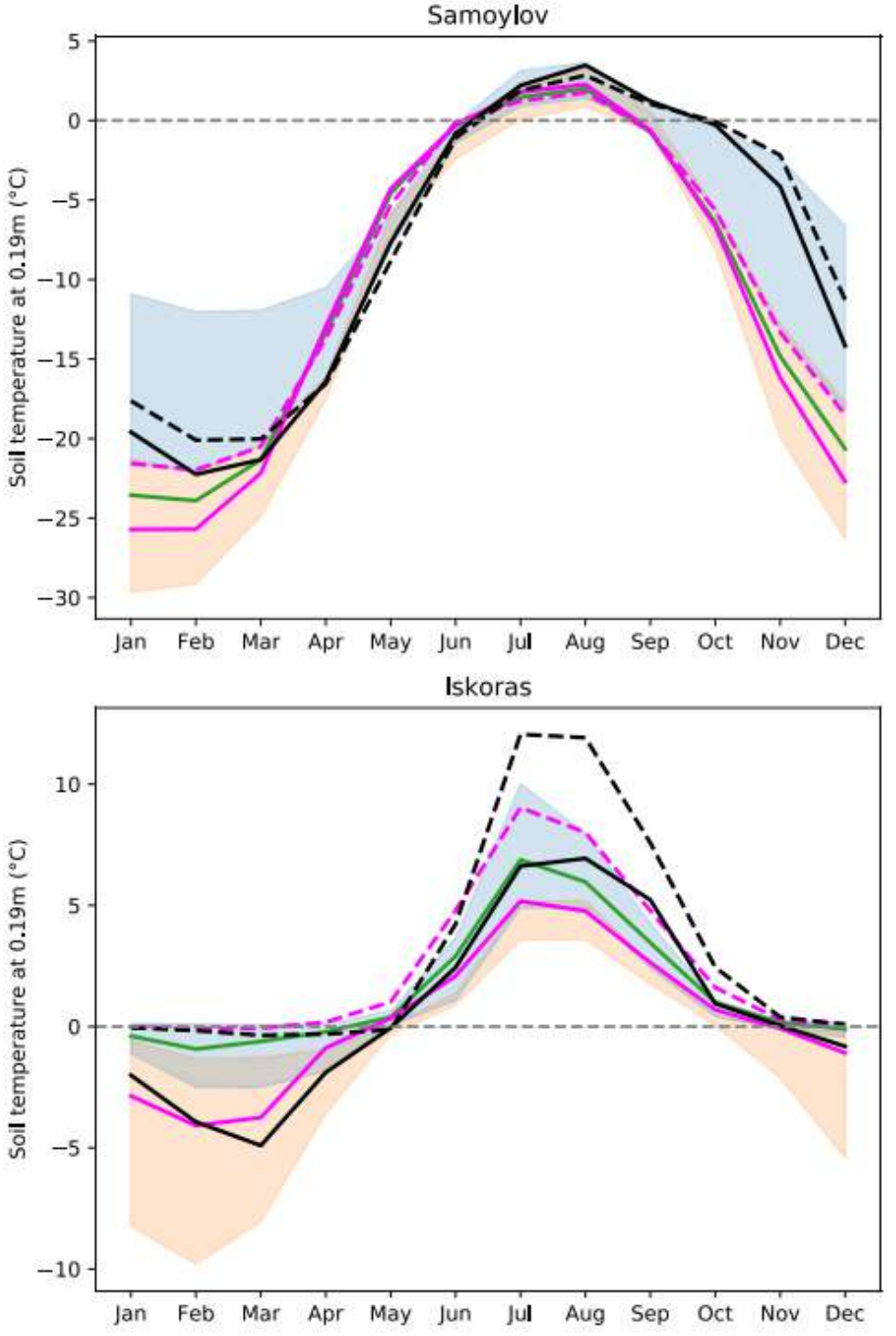
- **Not** unsaturated lateral fluxes





Effect on soil temperatures at 20cm depth

- Temperature difference between high and low tiles for July < observed for palsas (3.2 vs 5.5°C) with mean unchanged
- Little effect on polygons
- Mostly due to snow and (for palsa mires) the saturation of the mire following limining qbase

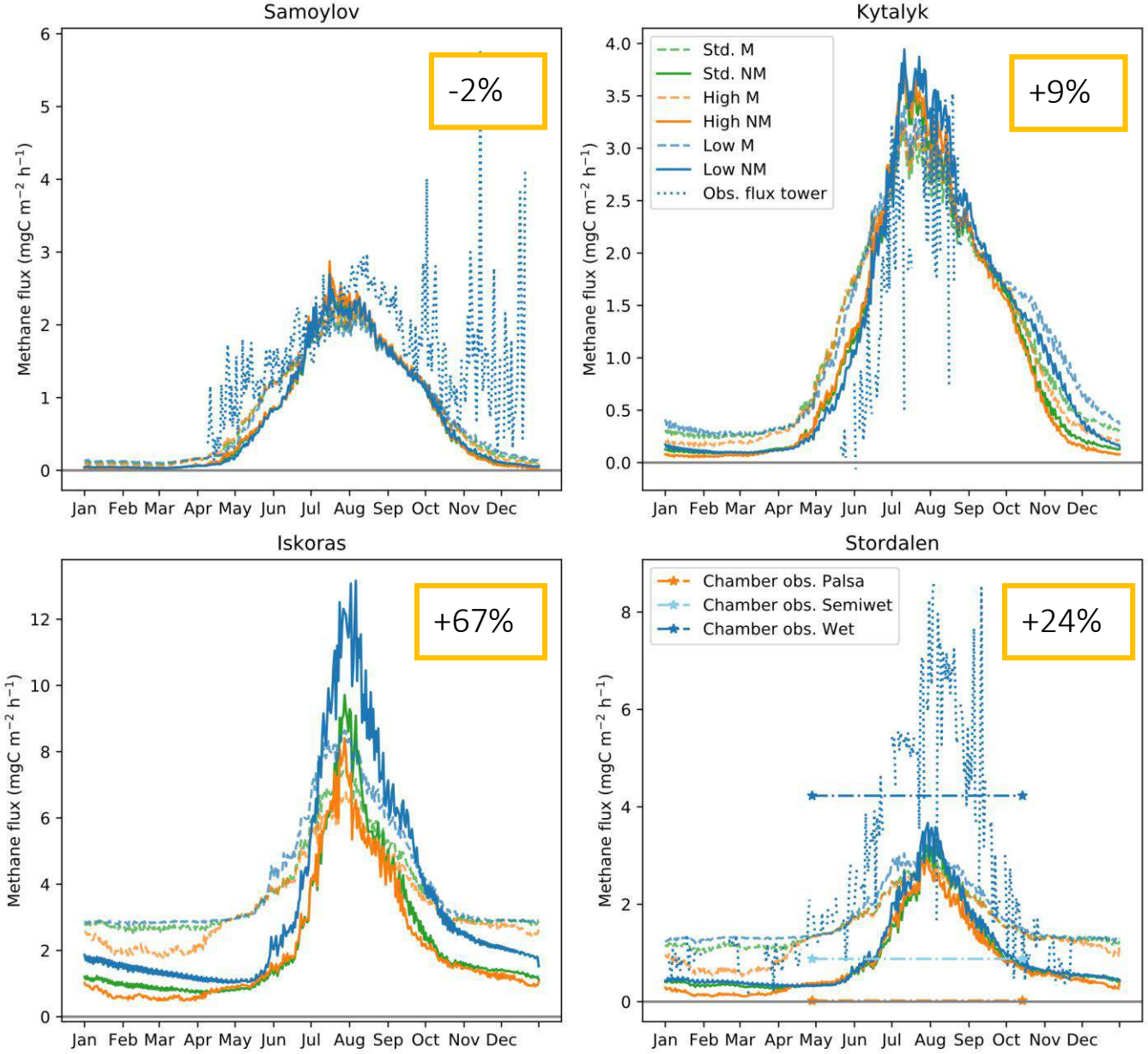


Effect on Methane (vs single tile)

- Little difference for polygons
- Can be around +50% for palsa mires
- These results do not include the effect of differing soil carbon profiles between tiles

Polygons

Palsas



	Samoylov	Kytalyk	Iskoras	Stordalen
M Low vs std. JULES	1.0	1.09	1.49	1.1
M Low vs High	0.98	1.09	1.67	1.24
NM Low vs std. JULES	1.01	1.08	1.1	1.09
NM Low vs High	1.0	1.1	1.21	1.2

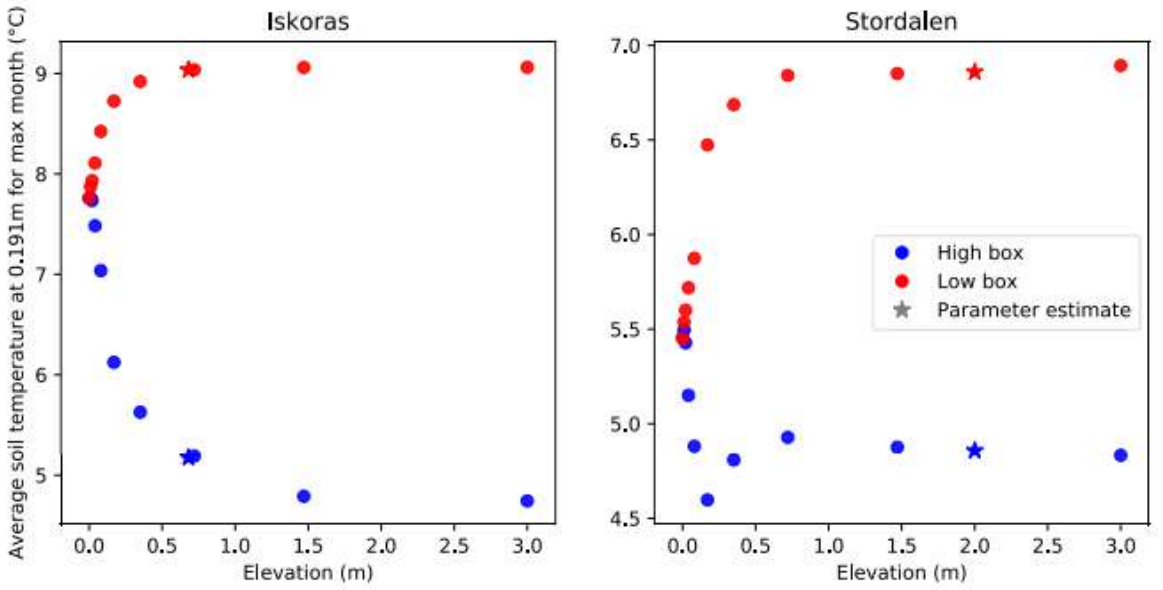
Where to now?

(4/4)

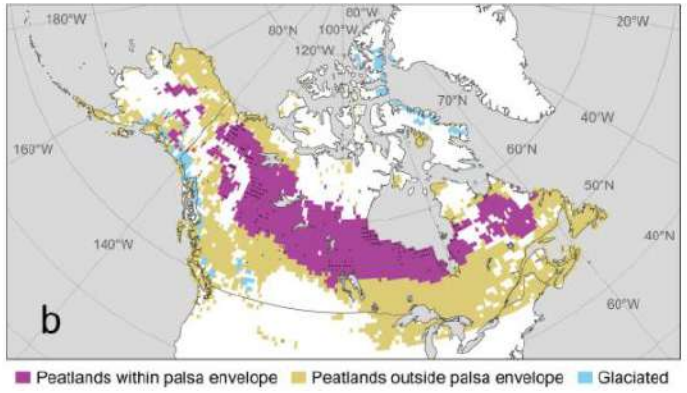
Scaling up

- Sensitivity study shows the modelled July temperature splitting being at most 0.9 or 3°C larger than observed for palsa or polygon sites
- Uncertainty in individual parameters result in at most 1.5°C uncertainty
- For the palsa sites, there is a weak dependence of temperature on elevation for elevations above 0.5 m

- Initialise with climate envelope models?

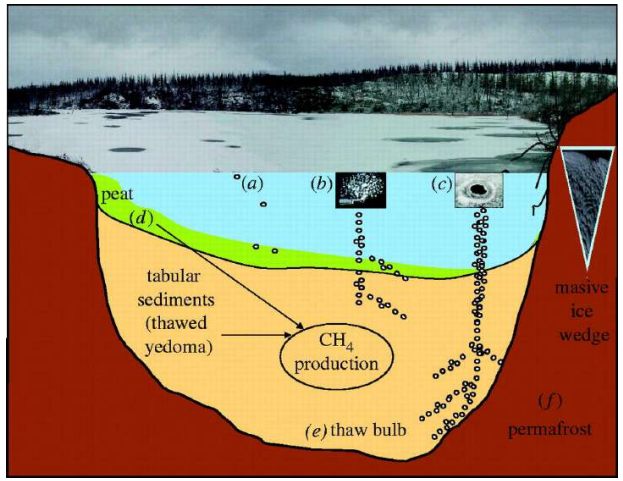


Elevation vs summer soil temperature at 0.19 m.



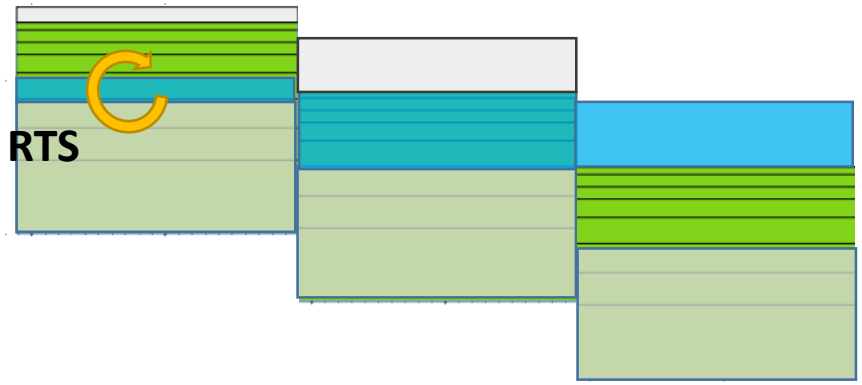
Climate envelope for Palsas in North America - Richard E. Fewster et al (2020)

Abrubt thaw (thermokarst)



Dry tile **Wetland tile** **Lake tile**

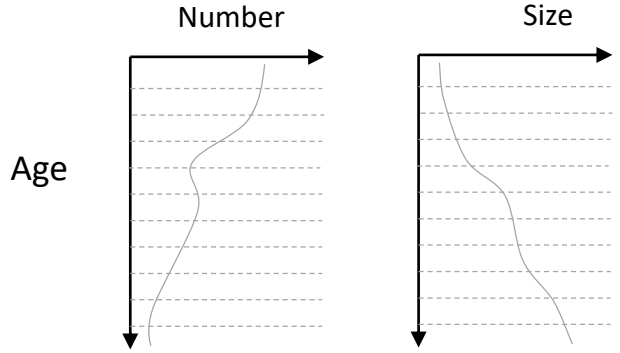
ALD and RTS



Lateral thawing

Driven by temperature difference, excess ice, areal extent

Lake expansion



Lake ensemble

1. Initiation
Using lake bottom temperature, excess ice prevalence, soil type and area.

2. Growth
Talik growth as function of bottom temperature, lateral growth land dependant

3. Drainage
Either due to excessive talik growth or lateral drainage (function of areal extent)

To do

- Landscape scale drainage & water table distribution
- Lateral thaw – remote sensing to validate
- Lakes (FLake?)/ better ponds
- PFTs for arctic wetlands
- Peat integration (for recovery)
- Neater soil tiling