Verification of temperature and humidity conditions of mineral soils in the active layer model

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Soil heat and moisture transfer in the INM RAS-MSU model

$$\rho C \frac{\partial T}{\partial t} = \frac{\partial}{\partial z} \lambda_T \frac{\partial T}{\partial z} + L_i F_i - L_v F_v$$

$$\frac{\partial W}{\partial t} = \frac{\partial}{\partial z} \left(\lambda_W \left(\frac{\partial W}{\partial z} + \delta \frac{\partial T}{\partial z} \right) + \lambda_l \frac{\partial I}{\partial z} \right) + \frac{\partial \gamma}{\partial z} - F_i - F_v - R_f - R_r$$

$$\frac{\partial V}{\partial t} = \frac{\partial}{\partial z} \lambda_V \frac{\partial V}{\partial z} + F_v$$

$$\frac{\partial I}{\partial t} = F_i$$

23 vertical levels from 1 -1000 cm.

Soil heat and moisture transfer in the INM RAS-MSU model

- Global 1ºx1º data on soil properties down to 0.3 m depth.
- The soil/silt/clay ratio is attributed to a layer of 0.15 m.
- Organic content linearly decreases to 0 kg/kg at 0.7 m, independent on soil type.
- In a baseline model version, thermal conductivity coefficient is computed using R.Pielke parameterization:

$$\lambda_T = 418.7\max(\exp\left(-P_f - 2.7\right), 0.00041)$$

$$P_f = \log_{10}(-\psi) \quad \psi = \psi_{max}\left(\frac{W_{max}}{W}\right)^b$$

The Pielke parameterization incorrectly takes into account the influence of the soil moisture characteristics on the thermal conductivity.

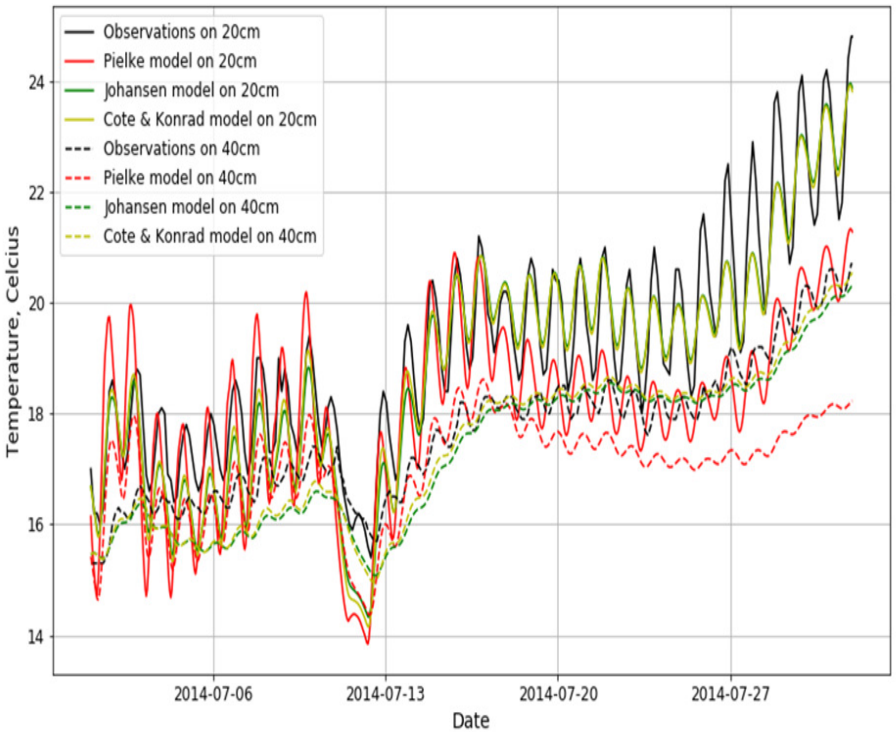
New thermal conductivity parameterization (Johansen, 1975):

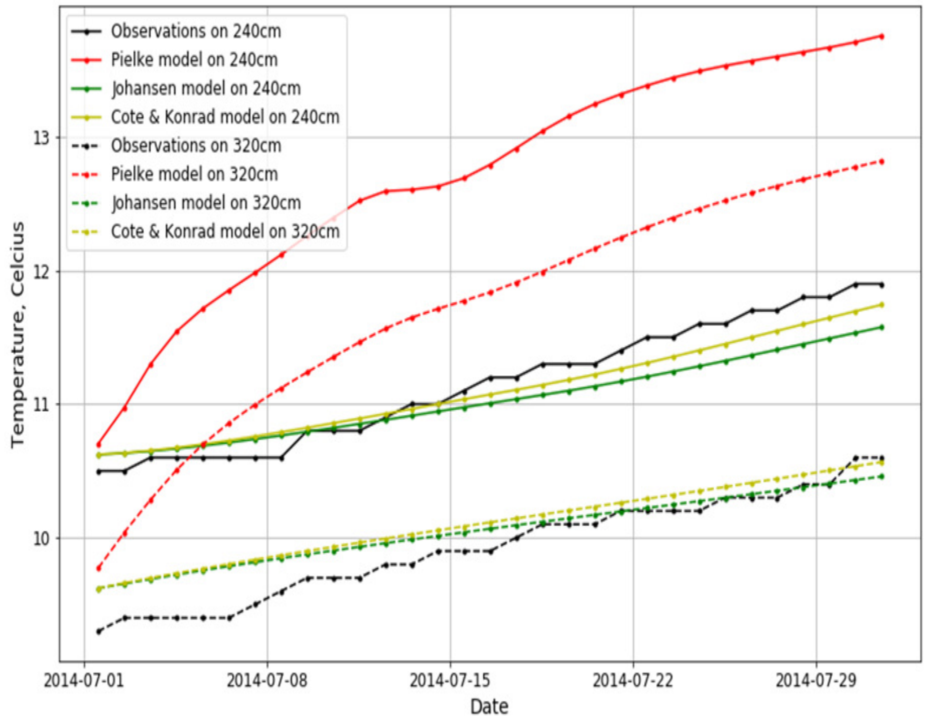
$$\lambda_T = \left(k_w^n k_s^{1-n} - \frac{0.137\rho_d + 64.7}{\rho_s - 0.947\rho_d}\right) k_r + \frac{0.137\rho_d + 64.7}{\rho_s - 0.947\rho_d}$$

n – porosity, k_w, k_s, – thermal conductivity coefficients of water and soil mineral matter, respectively, ρ_d, ρ_s , – density of dry soil and its mineralogical substance, $k_r = S_r$ – Kersten number (dependence on soil moisture (Kersten, 1949)):

- Physically sound theoretical basis
- Simple parameters
- There is direct contribution of porosity and soil density in various states.
- Does not take into account mineralogical and granulometric composition explicitly
- Decent calculation accuracy (Zhang, Wang, 2017)

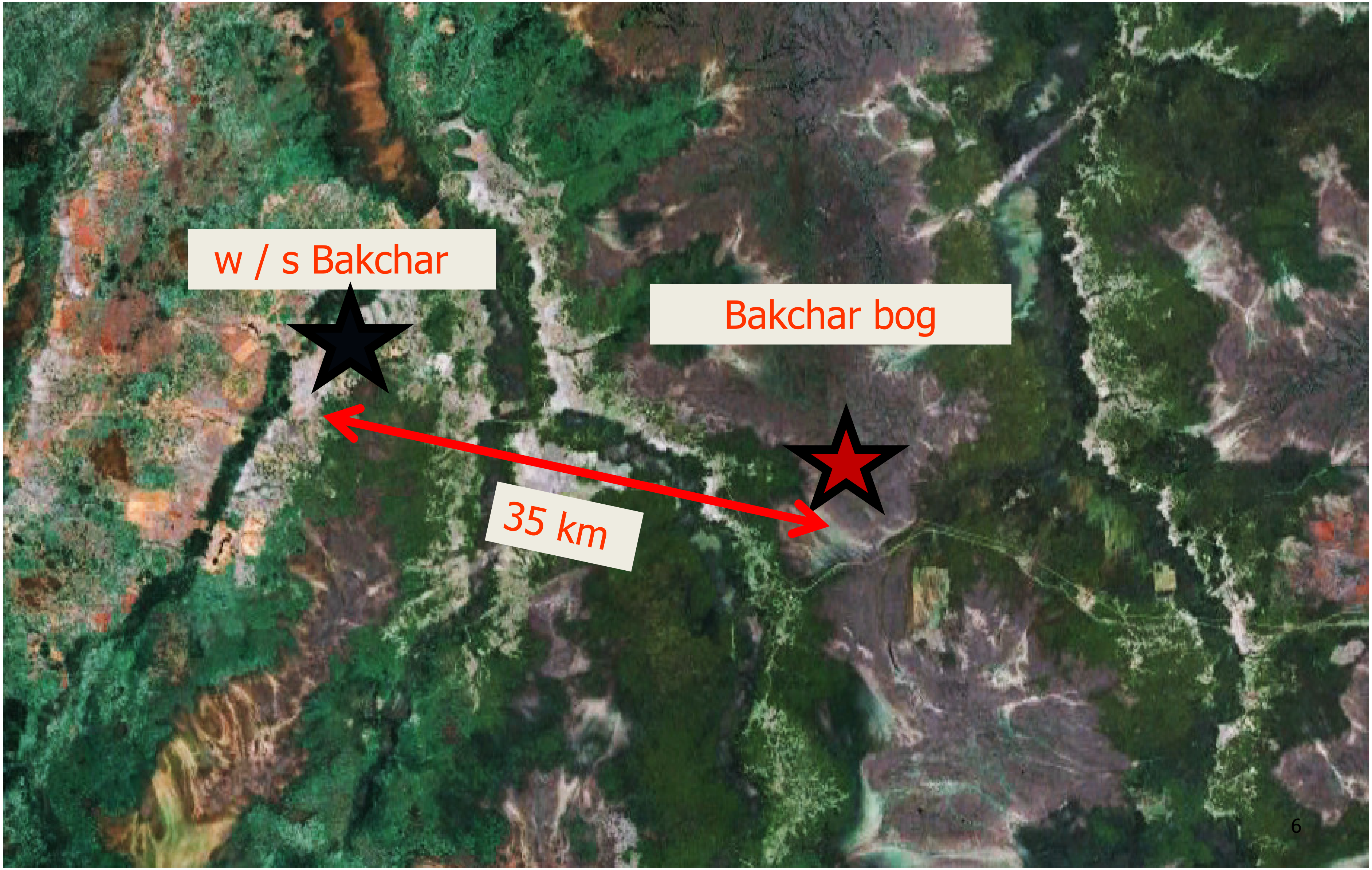
Soil temperature at different depths according to observations at Meteorological Observatory of MSU and model calculations, July 2014





Drozdov E., Stepanenko V.

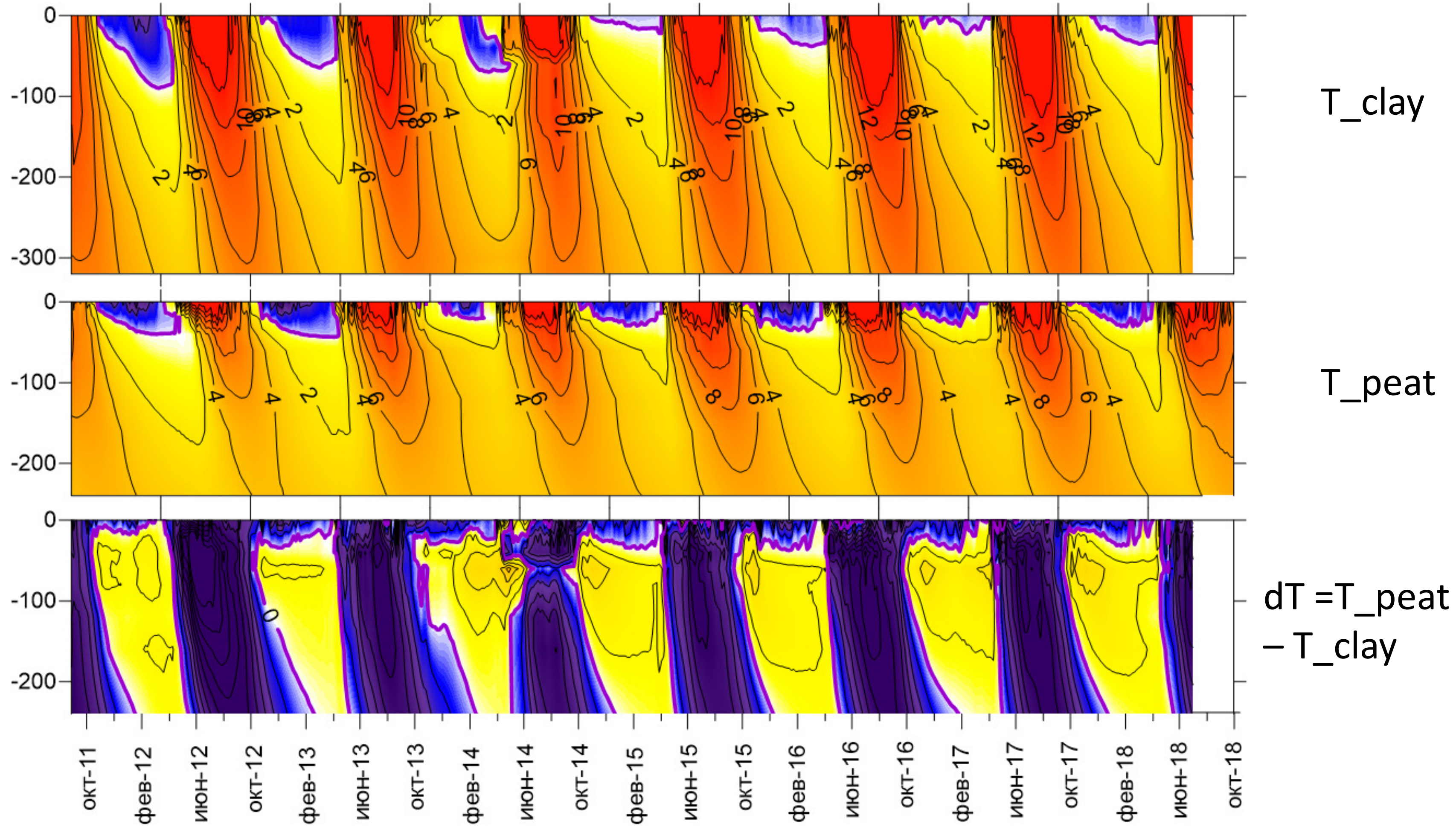
Observation sites



Atmospheric-Soil Measurement Complex, 0-320 cm

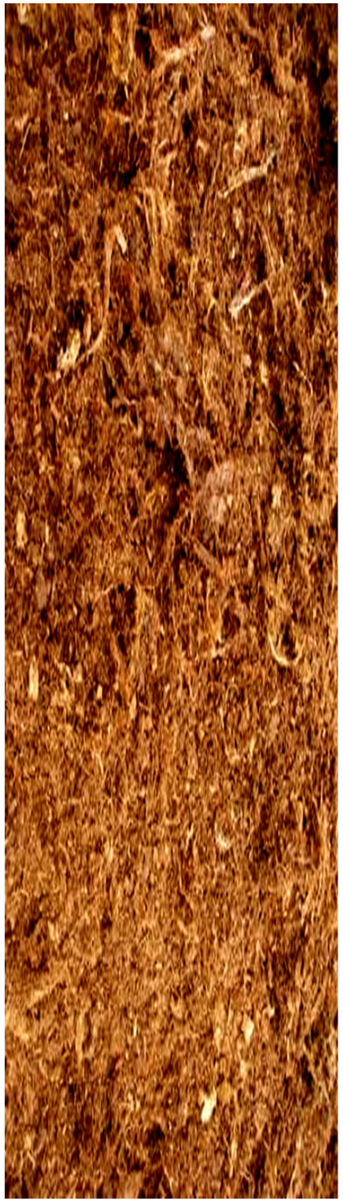
www.imces.ru

Observed soil temperatures fo mineral (clay) and organic (peat) soils for 2011-2018

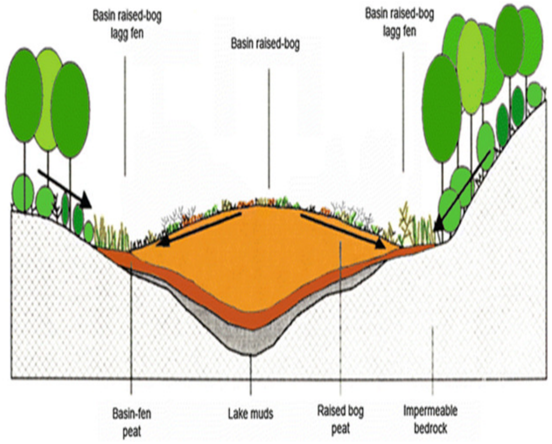


Mineral soil

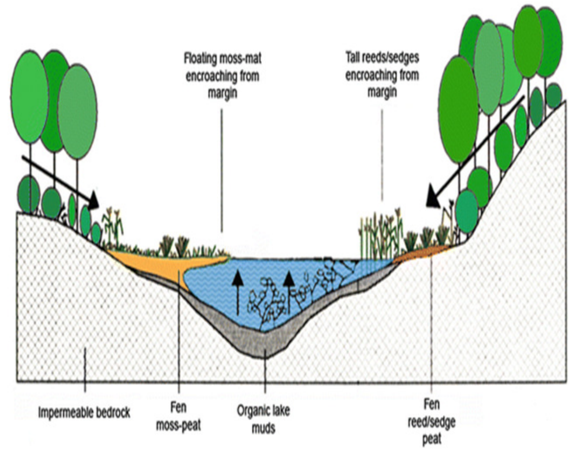
Peat soil



oligotrophic wetland



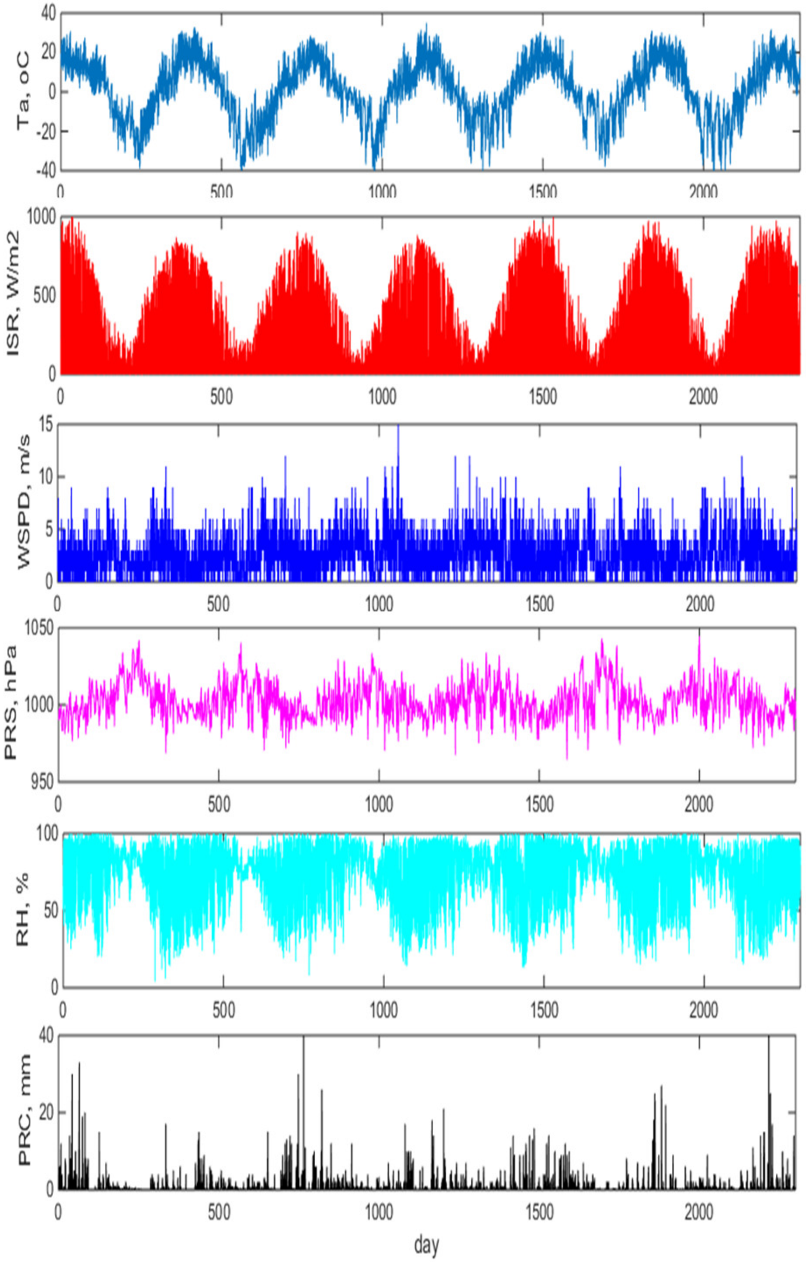
eutrophic wetland



- The thermal regime of peat soils differs significantly from mineral soils.
- In general, peat soil has a smoothed temperature dynamics, compared to mineral.
- In the warm season, peat soil is colder than mineral soil by 5 - 7 ° C, and in cold time - the soil in the swamp is warmer by 0.3 - 1.0 ° C.
- Temperature gradients in peat soil, compared with mineral, are higher in the upper layers.
- Loose top layers of moss tow because of their high thermal insulating ability significantly reduce the amplitude of temperature fluctuations in the underlying layers of peat soil.
- The depth of freezing in bogs almost three times less than in dry land.

Dyukarev, Geogr. and Nat. Res. 2013 No.1.

Input variables for wetland simulation (01 June 2011-31 Dec 2017)



	Clay	Peat
b	5.30	11.40
Ψ**max** $\times$**100**	56.6	18.6
Π	0.31	0.850
γ**max**$\times$**100**	0.00072	0.0001
λ**max** $\times$**10000**	0.20400	0.00926
W0	0.18	0.40
Wm	0.07	0.20

- Clapp-Hornberger dimensionless parameter
- Moisture potential at saturation, m
- Porosity
- Maximum hydraulic conductivity

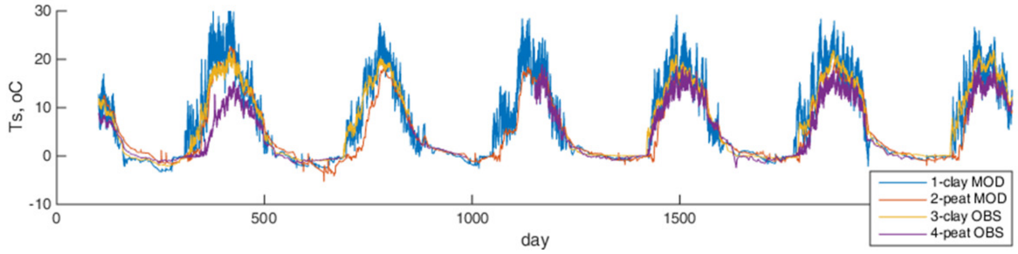
The maximum values of moisture diffusion coefficient

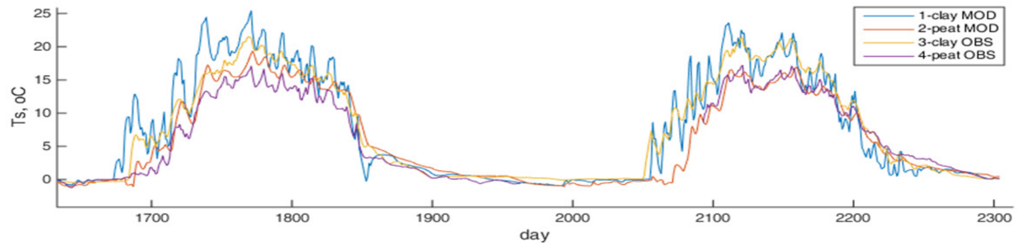
- The amount of water remaining unfrozen at 0 ºC
- The amount of water remaining unfrozen at very low temperature

Modeled temperature and observed data

daily averages

20 cm





Clay propertis:

ρ (dry soil) = 1200 kg/m3

ρ (solids) = 2650 kg /m3

= 3 cal/cm/s/K

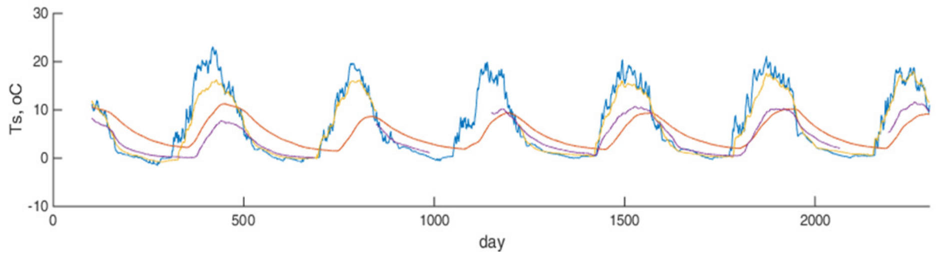
Peat properties:

ρ (dry soil) = 100 kg/m3

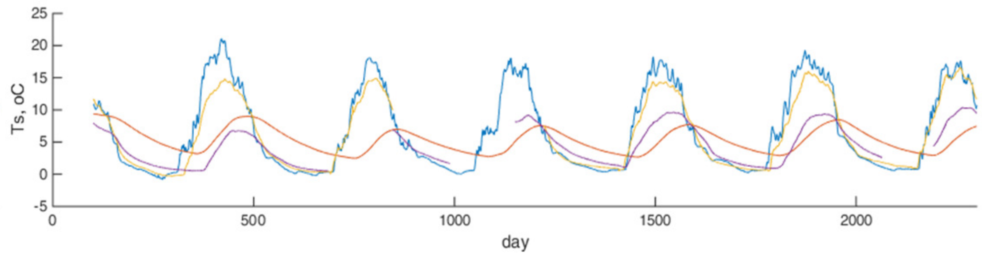
ρ (solids) = 1550 kg /m3

= 0.5 cal/cm/s/K

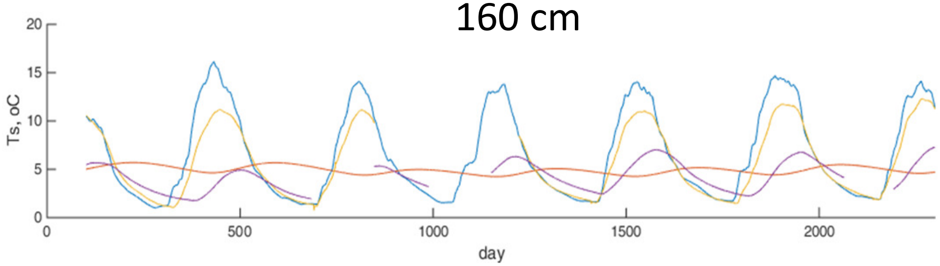
60 cm



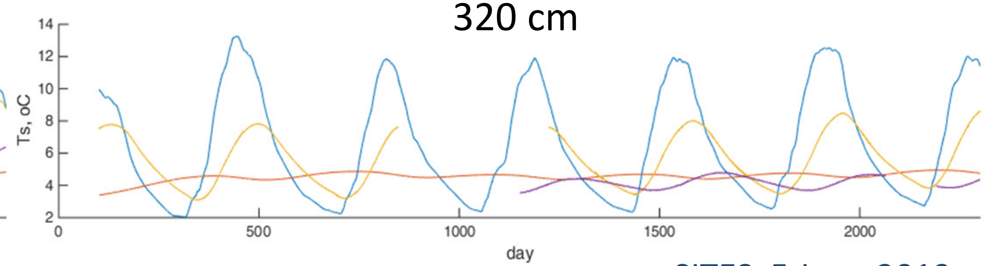
80 см



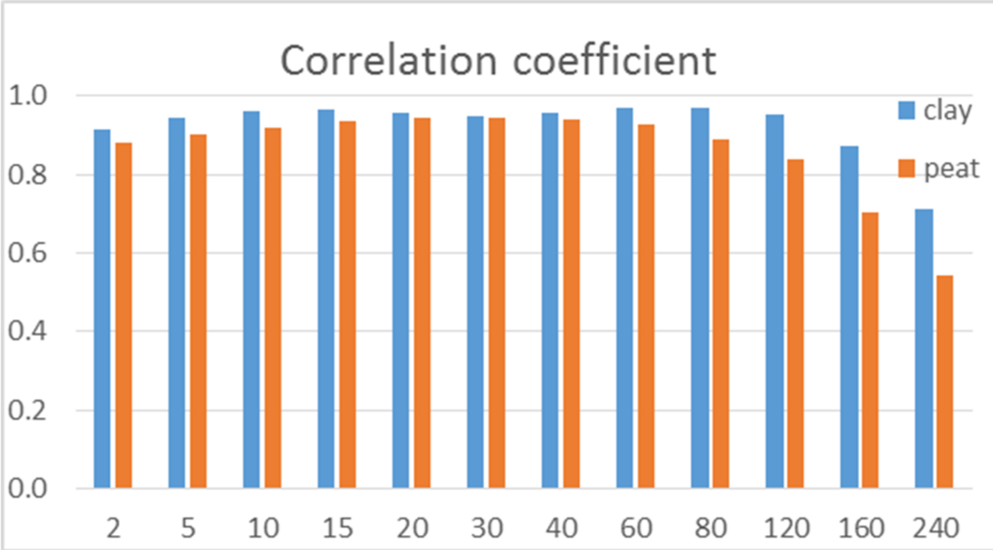
160 cm

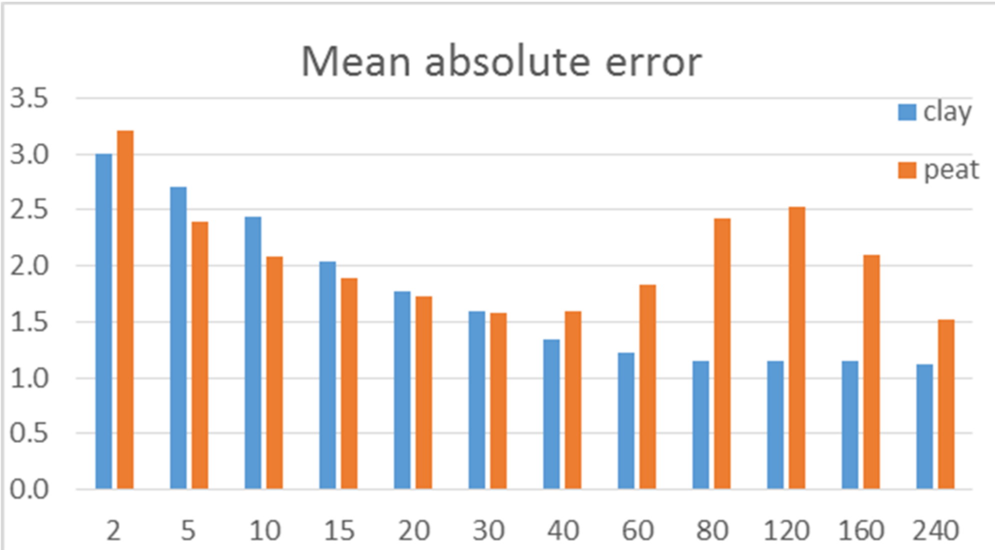


320 cm

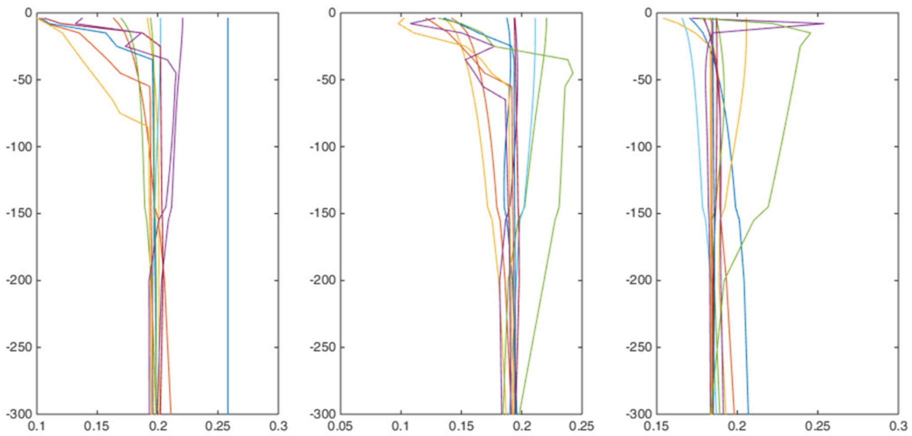


Model performance metrics for soil temperature



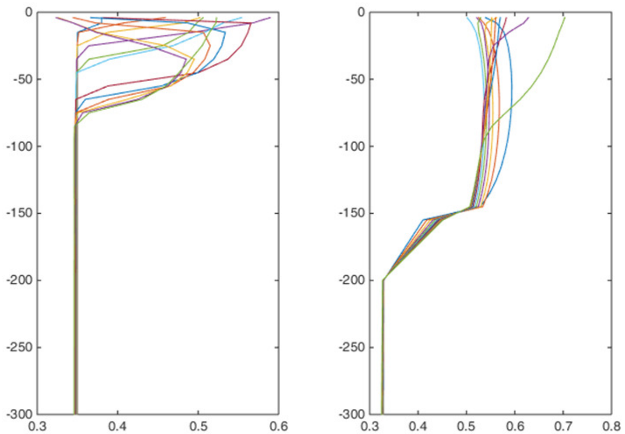


Soil moisture profile for clay

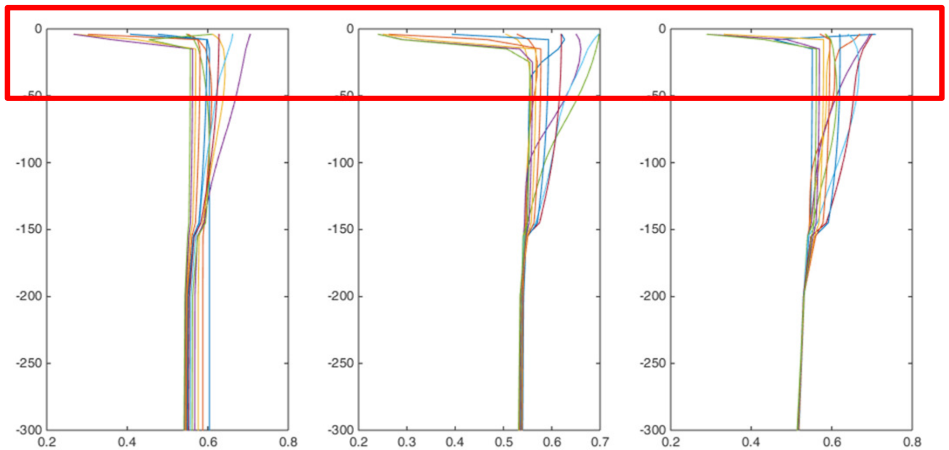


Intensive seepage. Moisture fluctuations are higher than observations.

The sensitivity of the moisture profile to the initial conditions for peat



Peat with very low initial moisture values. The full moisture profile does not come close to real values even after six years.



Peat with initial high moisture values. The moisture profile is established in one year.

Future work

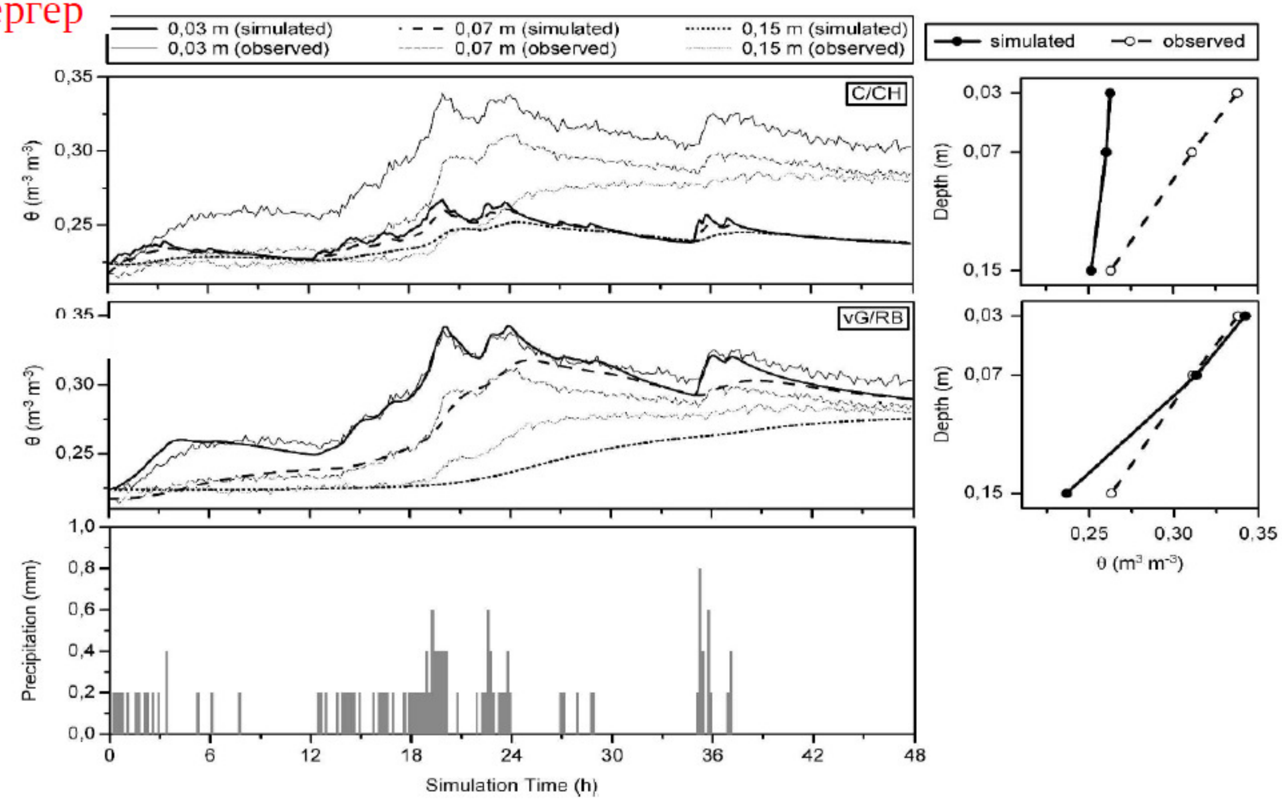
Introduction of the thermodynamic properties of the soil as functions of depth.
Evaluation of the terms responsible for the horizontal flux of moisture, especially in the upper humus layer.

The problem of soil temperature fluctuations at a depth of 10 meters
Increase the depth of modeling, changes in boundary conditions.

Effect of various hydra. soil characteristics

Клапп-Хорнбергер

ван Генухтен



Использование потенциала влаги ван Генухтена существенно улучшает качество моделирования влажности почвы по сравнению с моделью Клаппа-Хорнбергера.

Braun and Schädler, 2005, *J. Appl. Meteorol.*

New input data, classification of oligotrophic and eutrophic wetlands
(Budyko index)

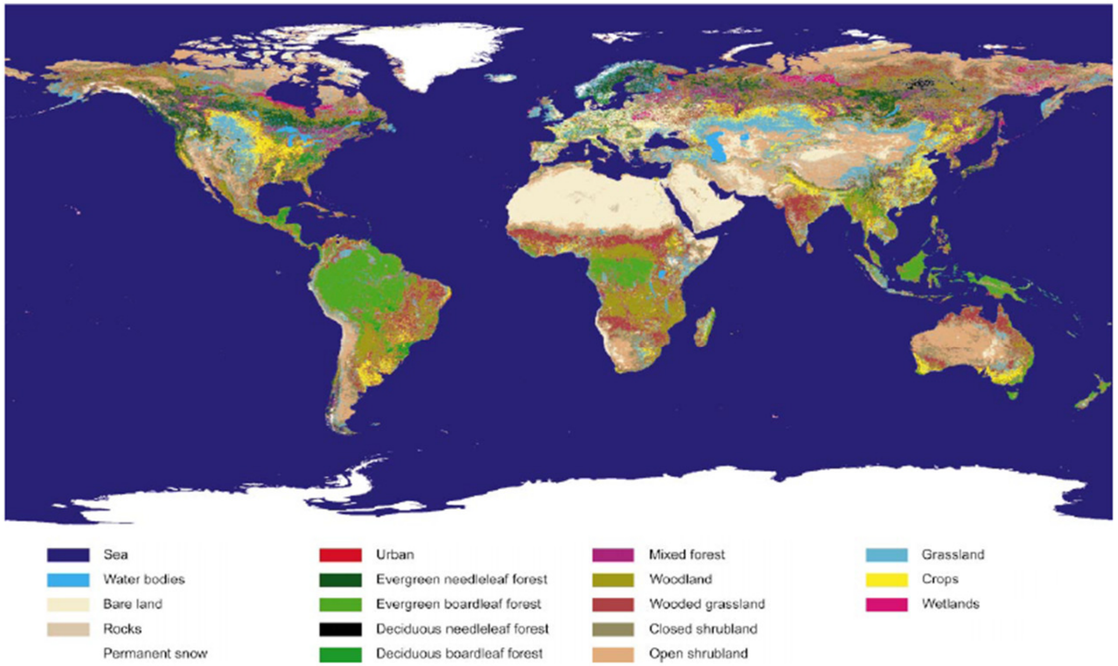
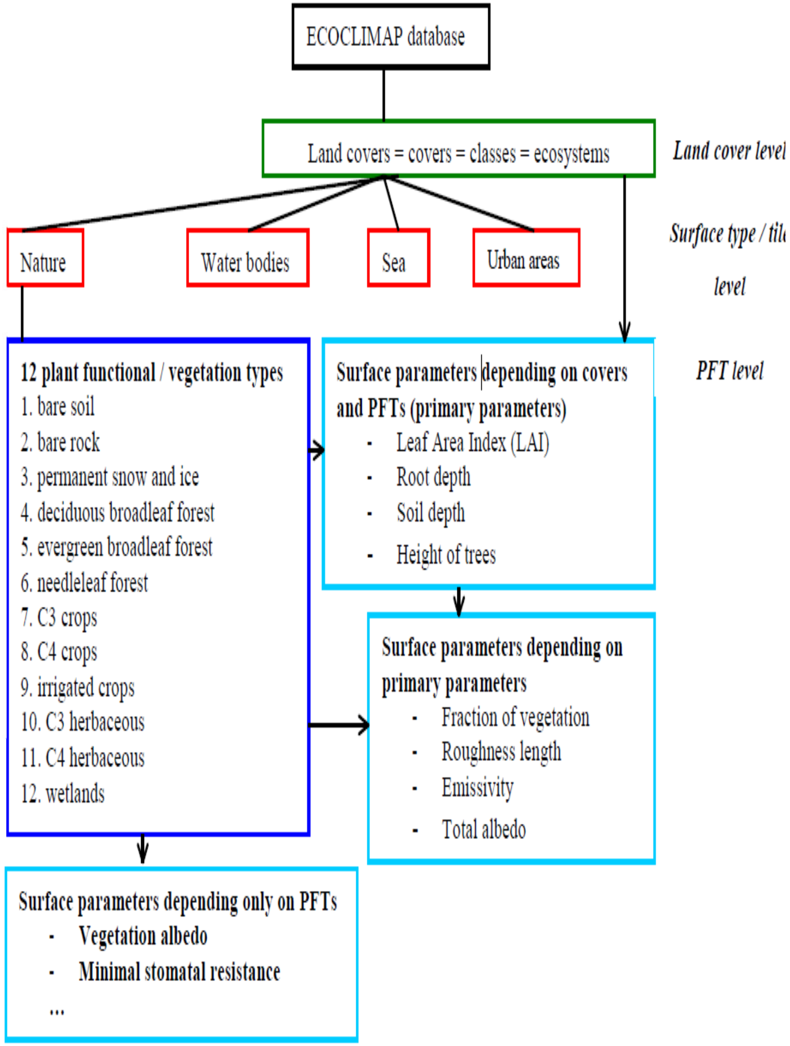


FIG. 1. Land cover map at 1-km resolution, resulting from a merging of the UMD land cover map outside Europe, with the addition of wetland and permanent snow and ice masks from IGBP, CORINE land cover over Europe, and PELCOM over Scandinavia. CORINE land covers are not labeled.



https://opensource.umr-cnrm.fr/projects/ecoclimap

TOPMODEL model of groundwater level calculation depending on precipitation and horizontal flow.

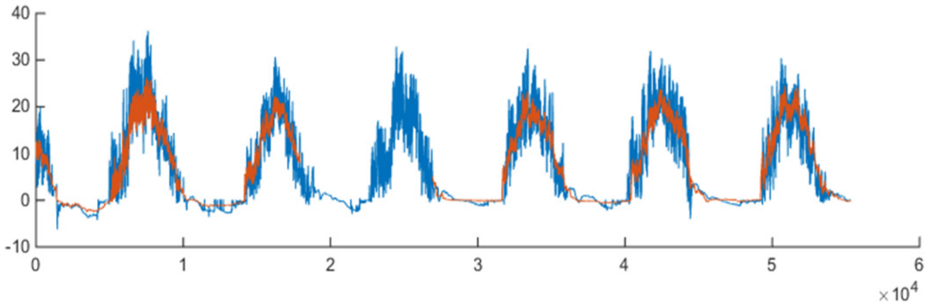
Thanks for attention!

Modelling results (clay)
daily averaged

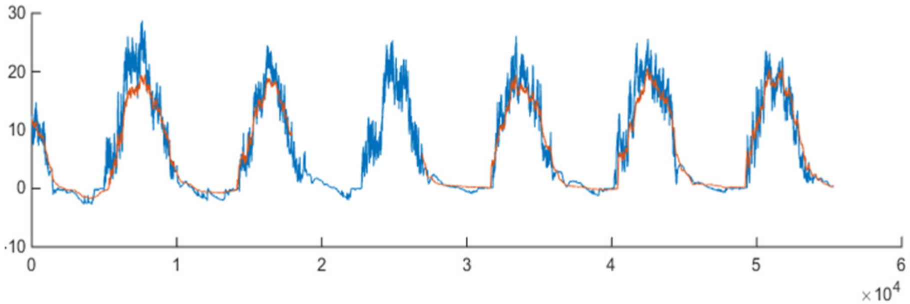
Clay properties
ρ (dry soil) = 1200 kg/m3
ρ (solids) = 2650 kg /m3
= 3 cal/cm/s/K

$R2 = 0.93$, AE= -0.32, MAE = 1.73

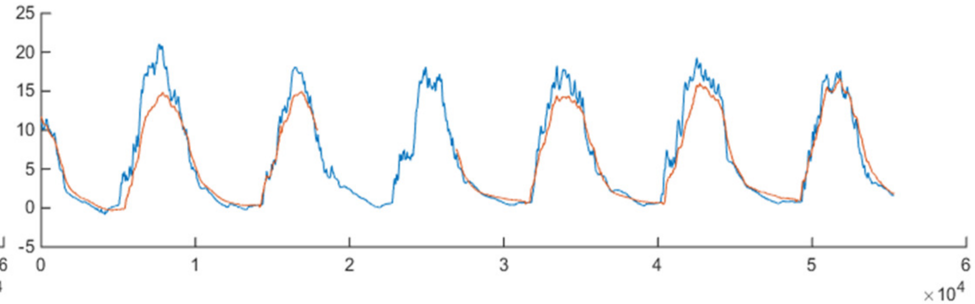
10 cm - Наблюдения (красн) и модель (син)



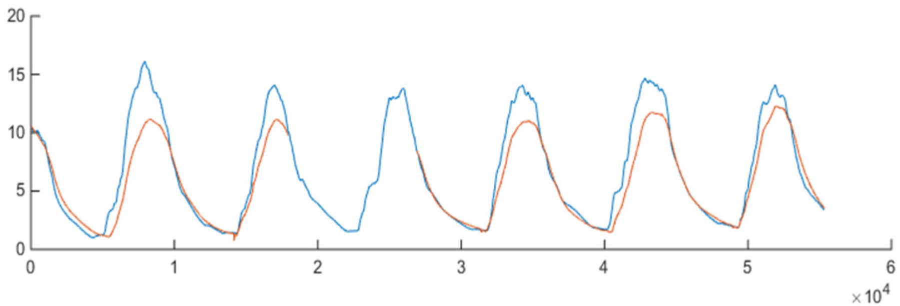
30 cm



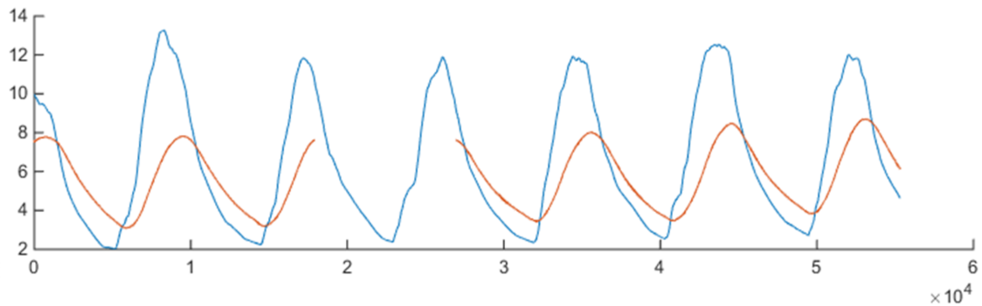
80 cm



160 cm



320 cm

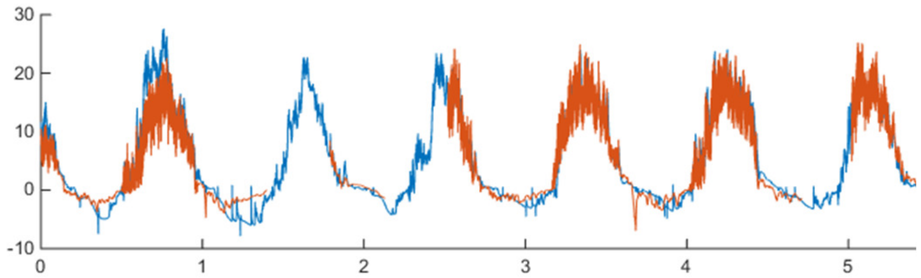


Modelling results (peat)
daily averaged

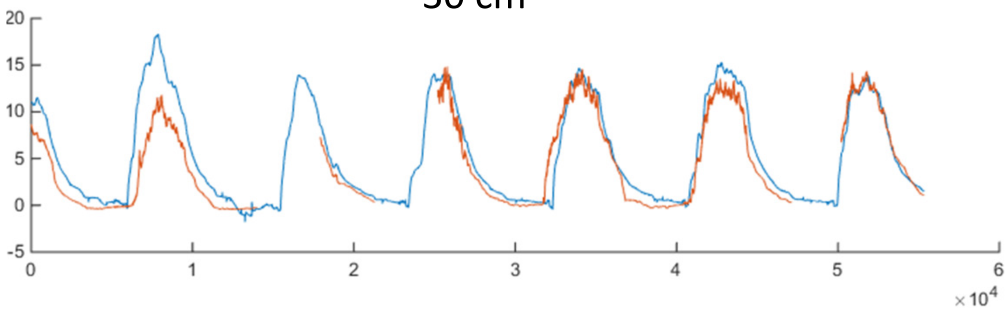
Peat properties
ρ (dry soil) = 100 kg/m3
ρ (solids) = 1550 kg /m3
= 0.5 cal/cm/s/K

R2 = 0.86
AE= -0.71
MAE = 2.07

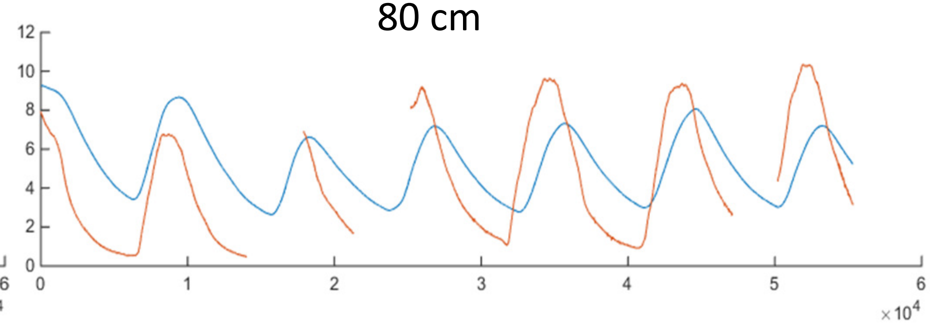
10 cm - Наблюдения (красн) и модель (син)



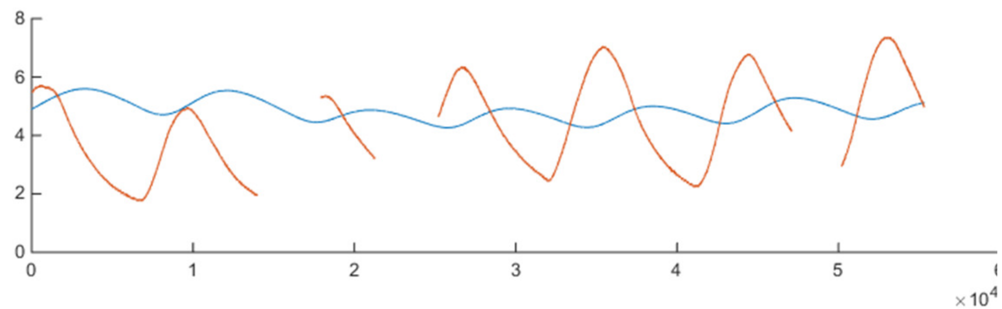
30 cm



80 cm



160 cm



320 cm