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Parameterization of the thermal conductivity of soil in the active land layer block of the INM RAS-MSU model

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Motivation:

Thermal inertia of soil at depths affect atmospheric circulation over land on time scales from weeks to several months [Fatichi et al., 2020]

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In the models of the Earth system, it's necessary to improve parameterization of heat and moisture transfer in the soil cover

Objective:

Improving the description of heat transfer in soil cover in the model of the Earth system of the INM RAS-MSU

Tasks:

- Selection of prospective parameterization of the soil thermal conductivity coefficient;
- Evaluation of the effect of their implementation in the INM RAS-MSU model

Soil thermal conductivity models

OLD

R. Pielke [McCumber, Pielke, 1981]

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

here $P_f = \log_{10}(-\psi)$.

NEW

In soil physics

Johansen [Johansen, 1975]

$$\lambda_T = (\lambda_w^n \lambda_s^{1-n} - \lambda_{dry})k_r + \lambda_{dry},$$

Cote-Konrad [Cote, Konrad, 2005]

$$\lambda_T = (\lambda_w^n \lambda_s^{1-n} - \chi 10^{-\eta n})k_r + \chi 10^{-\eta n}$$

Thermal conductivity of porous media

Fractal model
[Qin et al., 2018]

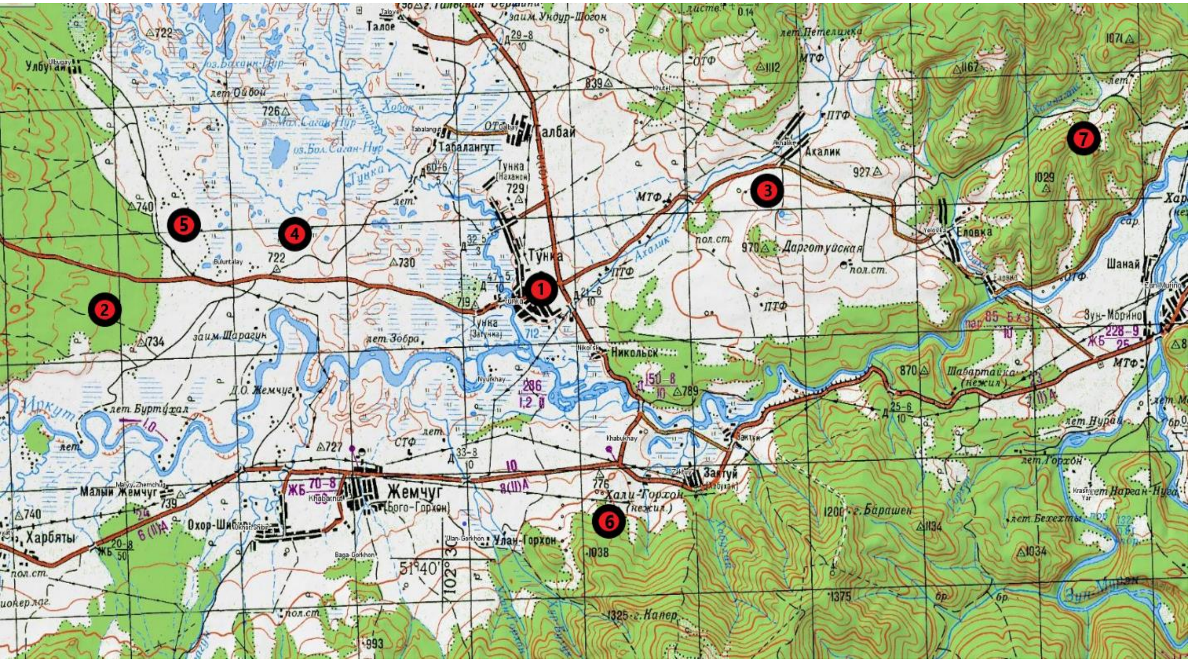
$$\lambda_T = \gamma + \beta \frac{\gamma(\lambda_s - \gamma)}{\lambda_s + 2\gamma}$$

here $\alpha = \frac{D_{Tw} + D_{fw} - 1}{D_{fw}} S_r^{1+\frac{D_{Tw}-1}{D_E - D_{fw}}},$

$$\beta = \frac{3(D_{fs}-1)^3 n}{D_{fs}^2(3-D_{fs})}, \quad \gamma = [\alpha\lambda_w + (1-\alpha)\lambda_a]$$

Was firstly performed for the Earth system models

Field studies in the Tunkinsky depression, Buryatia (August 2019)

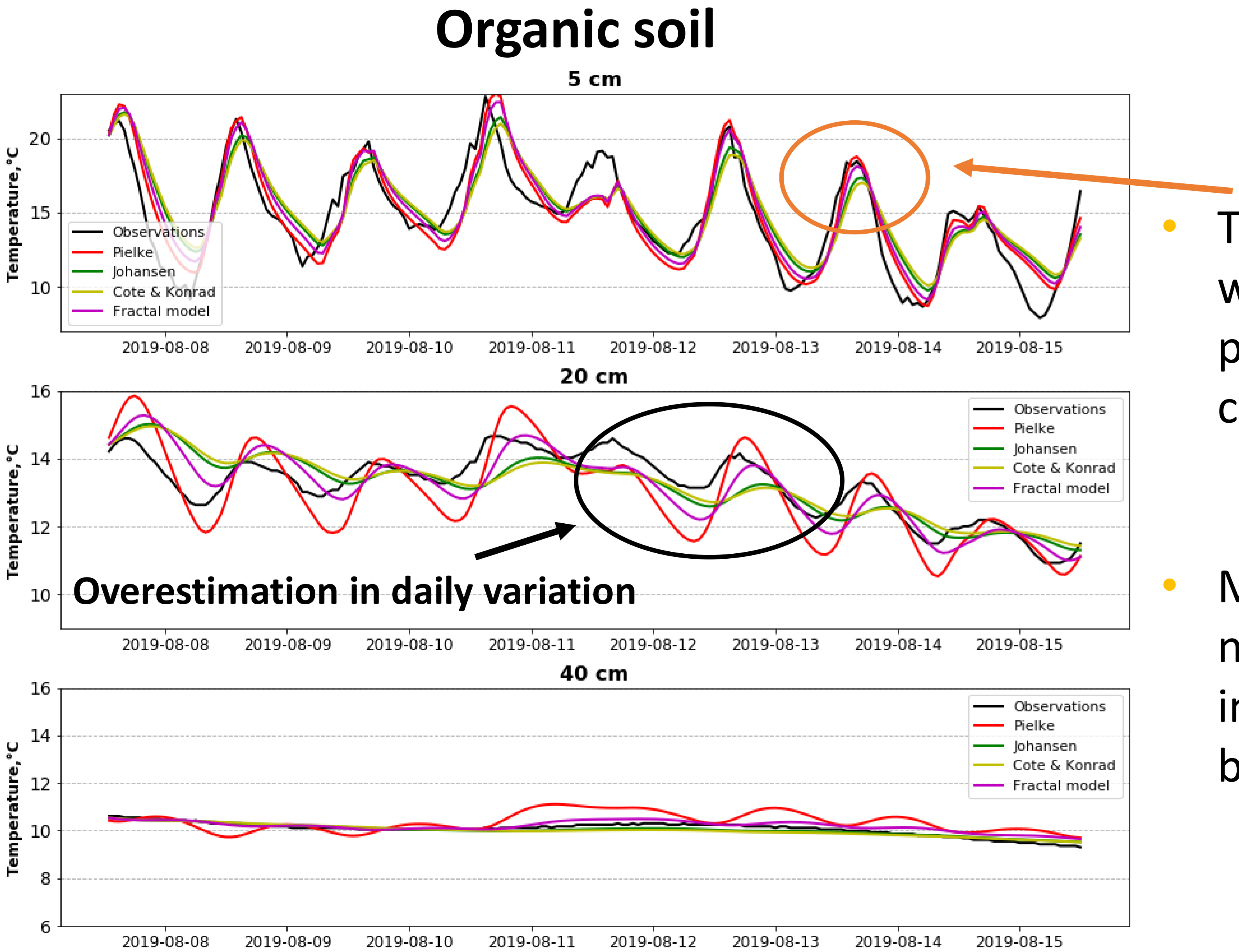


Collected data:

- **7 points** over the basin
- Depths up to **50 cm** with **10 cm** step
- Soil **density, porosity, vertical moisture distribution**
- **3 soil types:** silt and clay, sandy soil, organic soil

Compared with unique measurements of soil temperature at depths up to 10 meters with 1 hour time step

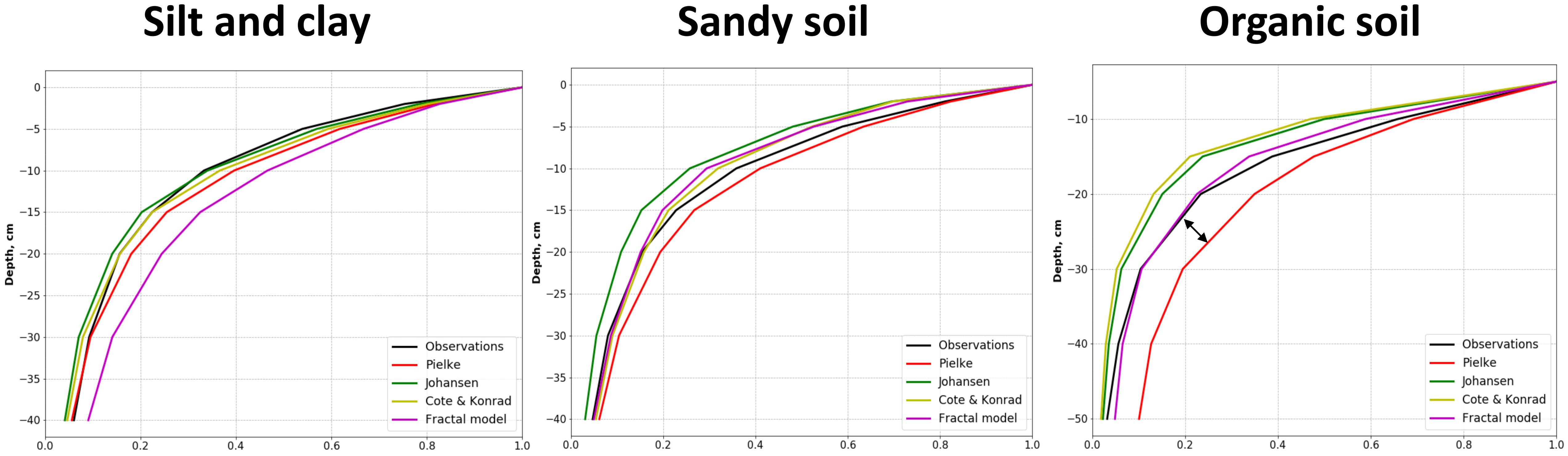
Time variability



- The surface temperature values weakly depend on the parameterization of the thermal conductivity of soil.
- Maximum errors were observed near the surface due to inaccuracies in modeling of heat balance of the surface.

Elimination of errors in determining the thermal balance of the surface

New error metric $\sigma_i / \sigma_{surface}$



- **For all soil types the Pielke parameterization didn't produce the most accurate results.**
- **Choosing the Cote-Konrad parameterization allows to obtain the most approximate results in loam and sandy soils**

Conclusions:

- R. Pielke parameterization used in the basic version of the model is less accurate than more modern parameterizations of thermal conductivity.

- The fractal model of thermal conductivity has a greater potential for improving accuracy, but it’s limited by the lack of global databases for a number of its parameters.

- **For the global grid of the earth system model INM RAS-MSU, is proposed choosing the Cote-Konrad parameterization of the soil thermal conductivity.**

THANK YOU FOR ATTENTION!