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Stochastic modelling for lake thermokarst and peatland patterns in permafrost and near permafrost zones

Timofey Orlov, Sergey Sadkov, Evgeniy Panchenko, and Andrey Zverev
SERGEEV INSTITUTE OF ENVIRONMENTAL GEOSCIENCE RAS (IEG RAS), Russian Federation
(tim.orlov@gmail.com)

Intorduction
Peatlands occupy a significant share of the cryolithozone area. They are currently experiencing an intense affection by oil and gas field development, as well as by the construction of infrastructure. That poses the importance of the peatland studies, including those dealing with the forecast of peatland evolution.

Basic model
Earlier we conducted a similar probabilistic modelling for the areas of thermokarst development. Principle points of that were:
1. Appearance of a thermokarst depression within an area given is the random event which probability is directly proportional to the size of the area (Δs). For small sites the probability of one thermokarst depression to appear is much greater than that for several ones, i.e.

$$p_1 = \gamma\Delta s + o(\Delta s)$$
$$p_k = o(\Delta s) \quad k = 2, 3 \ldots$$

2. Growth of a new thermokarst depression is a random variable independent on other depressions' growth. It happens due to thermoabrasion and, hence, is directly proportional to the amount of heat in the lake and is inversely proportional to the lateral surface area of the lake depression.
By using this model, we are able to get analytically two main laws of the morphological pattern for lake thermokarst plains. First, the distribution of a number of thermokarst depressions (centers) at a random plot obey the Poisson law:

$$P(k, s) = \frac{(\gamma s)^k}{k!} e^{-\gamma s}.$$

where γ is an average number of depressions per area unit, s is a square of a trial sites.
Second, lognormal distribution of diameters of thermokarst lakes is true at any time, i.e. density distribution is given by the equation:

$$f_d(x, t) = \frac{1}{\sqrt{2\pi}\sigma x\sqrt{t}} e^{-\frac{(\ln x - at)^2}{2\sigma^2 t}}$$

where a,σ are distribution parameters, t is time since the process have started.
Thermokarst development in peaty soils is normally accompanied by the formation of ridge-lake patterns.
Ridge-hollow structures (RHS) possess a specific implication in a peatland functioning system. They are associated with the surface and underground water flows, as well as with the contemporary and buried relief. This makes reasonable the probabilistic modelling applied to the RHS. The probabilistic modelling here mainly implies the analysis of an area with the uniformly distributed patterns of RHS. The intersection points of the ridges are here considered as the specific points, describing the RHS pattern.
For the model we picked the following several key parameters: average number of ridges and hollows along a linear profile, average width of ridges and hollows along a linear profile, number and spatial distribute of the ridge intersection points within an elementary block, average area of hollows, distribution of sizes of hollows, local and general curvature of the ridges.
The former are the succeeding generation stage of ridge-hollow patterns. Therefore, in permafrost the transition from the ridge-hollow pattern to the ridge-lake one is a companion process to the process of thermokarst. Probabilistic behavior is typical of ridge-hollow structures.

The hollow sizes follow the lognormal distribution. Ridge junction points' distribution has the Poisson behavior.

Results

Hence, the probabilistic modelling of ridge-hollow structures in cryolithozone can rely on the following parameters: hollow size, ridge size, spatial distribution of hollow centroids and ridge junction points.