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A STOCHASTIC MODEL FOR THE POLYGONAL TUNDRA BASED ON POISSON-VORONOI DIAGRAMS

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Sub-grid and small scale processes occur in various ecosystems and landscapes (e.g., periglacial ecosystems, peatlands and vegetation patterns). These local heterogeneities are often important in regulating land-atmosphere fluxes of water, energy, and greenhouse gases, but they are either ignored or poorly parameterized in regional and global models. This is of particular interest in the northern peatlands, because of the huge amount of carbon stored in these regions.

Because of their small spatial scale, such processes can be well explained and resolved only by local mechanistic models, which, on the other hand, fail to consider the regional or global influences of those features. A challenging problem is then how to deal with these interactions across different spatial scales, and how to improve our understanding of the role played by local soil heterogeneities in the climate system.

We developed a stochastic model for the polygonal tundra using Poisson-Voronoi diagrams. This model is able to upscale statistical large scale properties of the system taking into account the main processes within the single polygons. We compare the results with available recent field studies and demonstrate that the model captures the main statistical characteristics of the landscape and describes its dynamical behavior under climatic forcing (e.g., precipitation and evapotranspiration). We analyze seasonal dynamics of water table variations and the landscape response under different scenarios of precipitation income. We upscale methane fluxes by using a simple idealized model for methane emission. We also investigate hydraulic interconnectivities and large-scale drainage through percolation properties and thresholds in the Voronoi-Deleaunay graph.

The model also captures the main statistical characteristics of the landscape topography, such as polygon area and surface properties as well as the water balance. This approach enables us to statistically relate large-scale properties of the system taking into account the main small-scale processes within the single polygons. Overall, the general agreement between field measurements and model results suggests that such statistical methods and simple parameterizations, could provide information and guidance for larger scale parameterizations, as well as new insights for better understanding processes at a multiplicity of scales in such heterogenous and complex environments.

Cresto Aleina, F., Brovkin, V., Muster, S., Boike, J., Kutzbach, L., Sachs, T., and Zuyev, S.: A stochastic model for the polygonal tundra based on Poisson–Voronoi diagrams, Earth Syst. Dynam., 4, 187-198, doi:10.5194/esd-4-187-2013, 2013.