Geophysical Research Abstracts
Vol. 20, EGU2018-4258, 2018
EGU General Assembly 2018

Dynamics of water stage and runoff of a pristine bog complex in Central West-Siberia calculated with a dynamic, high resolution PCRaster MODFLOW 3D-model

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The water balance of bog systems has been studied by many authors, but data of discharge of water from big pristine complex bogs are scarce and generalized. Data of water discharge dynamics from bog complexes are essential for calculation of DOC discharge. The knowledge of water discharge by overland flow is also important for designing eco-sustainable construction of roads through bogs.

The bog next to the International Mukhrino Field Research Station (21 km SW of Khanty-Mansiysk town) has been studied in detail. The pristine bog complex (ca. 50 km^2) consists of treed raised bogs with ridge-hollow complexes in the centre. By supervised classification of a detailed satellite image (QuickBird) a map with 7 landuse types has been prepared: river, deep lake, hollow lake, hollow lawn, ridge-bog, raised bog and mixed forest.

The hydrology was studied with an integrated PCRaster Modflow model implemented in Python. Recharge data of precipitation and evapotranspiration (Makkink) was calculated from meteorological data of the Airport Khanty-Mansiysk. With a temperature based snow balance model snowmelt volumes were estimated from late winter snow depth. For the period 2008-2016 the volumes of snow melt accounted for about 30 % of the yearly net-precipitation sum. The actual evapotranspiration by landuse type has been calculated with the general approach: E(a) = f·E(ref), where E(ref) is the evapotranspiration according to the Makkink equation and “f” depends on land unit type.

A dynamic 3-dimensional model of a 16.8 km^2 pristine bog area was developed with a time step of 1 day, resolution of 7×7 m, and with 2 layers of Acrotelm, 2 layers of Catotelm and a mineral layer below the peat. The digital elevation model (DEM) has been developed from elevation measurements at the surface and satellite data. The conductivities of the 5 layers were calibrated using model output of water levels and surface elevation data. We limited the 3-D modelling approach to periods from 1/3 to 1/12, because in winter no discharge has been established and the peat soils and lakes are frozen up to 0.5 m depth.

The PCRaster Modflow model produced water levels and water fluxes in X, Y and Z direction per day, distributed over the model area. Averaged waterlevels were calculated by the model at 0.135 m below DEM of Catotelm of raised bogs and 0.046 m above DEM of hollows. The mean contribution of bog water to the brook which runs along the Mukhrino Field station was calculated by the model at 455 m^3d^{-1}. By snowmelt the 8-year average discharge during April was 24 % higher than of other months, which explains the measured 20-50 % lower DOC concentrations compared to the rest of the year (40 mgDOC/L). From the modelling it was proved that almost all water was discharged through the Acrotelm by “overland flow”.