VERIFICATION OF WEMEM MODEL USING FIELD DATA FROM WEST SIBERIAN SOUTH TAIGA WETLANDS

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Regional estimation of the methane emission needs mathematical modeling to provide a spatial extrapolation of obtained results on a region area. But before such an extrapolation it is necessary to verify model using reliable field data. The goal of present study was to provide this verification for WeMEM. The initial version of the model WeMEM (including MATLAB-code) was described in detail earlier (Глаголев, 2010). Now we used the model version 2.1 which has four differences from the initial one: (i) methane oxidation fraction $MOF=MOFmin/(1\text{-}2\cdot WTL/L+WTL^2/L^2)$, where MOFmin=0.63; L (cm) – depth of the peat level or permafrost (if present); WTL (cm) – water table level; (ii) the factor which represents the influence of water table level on methane emission and (iii) the "temperature factor" are given as described in, respectively, (Глаголев и др., 2012, 2015); (iv) the methane flux cannot be less than MERmin=-0.18 mgC/m^2/h (negative value corresponds to the methane consumption).

The initial data for the model are: Lat (°N) – geographical latitude; NPP (mg d.m.·cm^{-2}·h^{-1}) – net primary production; Water Potential (in pF-units representing decimal logarithm of pressure in cm of water column); T (°C) – temperature across a soil profile; L and WTL.

The following information was used for model calculation. The average daily temperature of the soil thaw depth (Oelke et al., 2003) is represented by a vector file in the form of points in the center of square cells with the size of 25.067×25.067 km^2 (projection Northern Hemisphere EASE-Grid) over a period from 1 Sep 1998 to 31 Dec 2000. The vector layer was reprojected into WGS-84 with QGIS (v. 2.2.0), then it was cut off to the West Siberian borders and the arithmetical mean of the soil thaw depth in all cells was calculated for the first and second halves of every month. The average monthly atmospheric temperature and precipitation was taken from WorldClim data base, where they are represented as the raster layers – respectively, "TMEAN" and "PREC" (Hijmans et al., 2003) – with the spatial resolution of ≈1 km^2 (at the equator) and temporal resolution of 1 month. For every cell (25.067×25.067 km^2) of the above mentioned vector layer the arithmetical mean value of the crossing raster pixels was calculated (in QGIS). Based on the monthly average values found this way, the half-monthly values were calculated using the linear interpolation. To find the mean value of meteorological parameters for half of month (X_m) the formula:

$$X_m=a\cdot x_{m-1}+b\cdot x_m+c\cdot x_{m+1}$$

was used, where x_{m-1}, x_m, x_{m+1} are average monthly values of this characteristic for (m-1)-th, m-th, and (m+1)-th month respectively; a=0.25, b=0.75, c=0 if the temperature of the 1st half of month is calculated and a=0, b=0.75, c=0.25 for the temperature of the 2nd half; a=0.125, b=0.375, c=0 if the total precipitation is calculated for 1st half of month and a=0, b=0.375, c=0.125 for the total precipitation of the 2nd half.

The calculation of the mire ecosystem area was carried out based on the typological mire map of the Western Siberia (Terentieva et al, 2016). For this purpose the vector layer of cells was made (25.067×25.067 km^2, projection – WGS84, the cell centers matched with the point coordinates of the vector file of soil thaw depth described above) with the instrument "vector grid" in the QGIS.

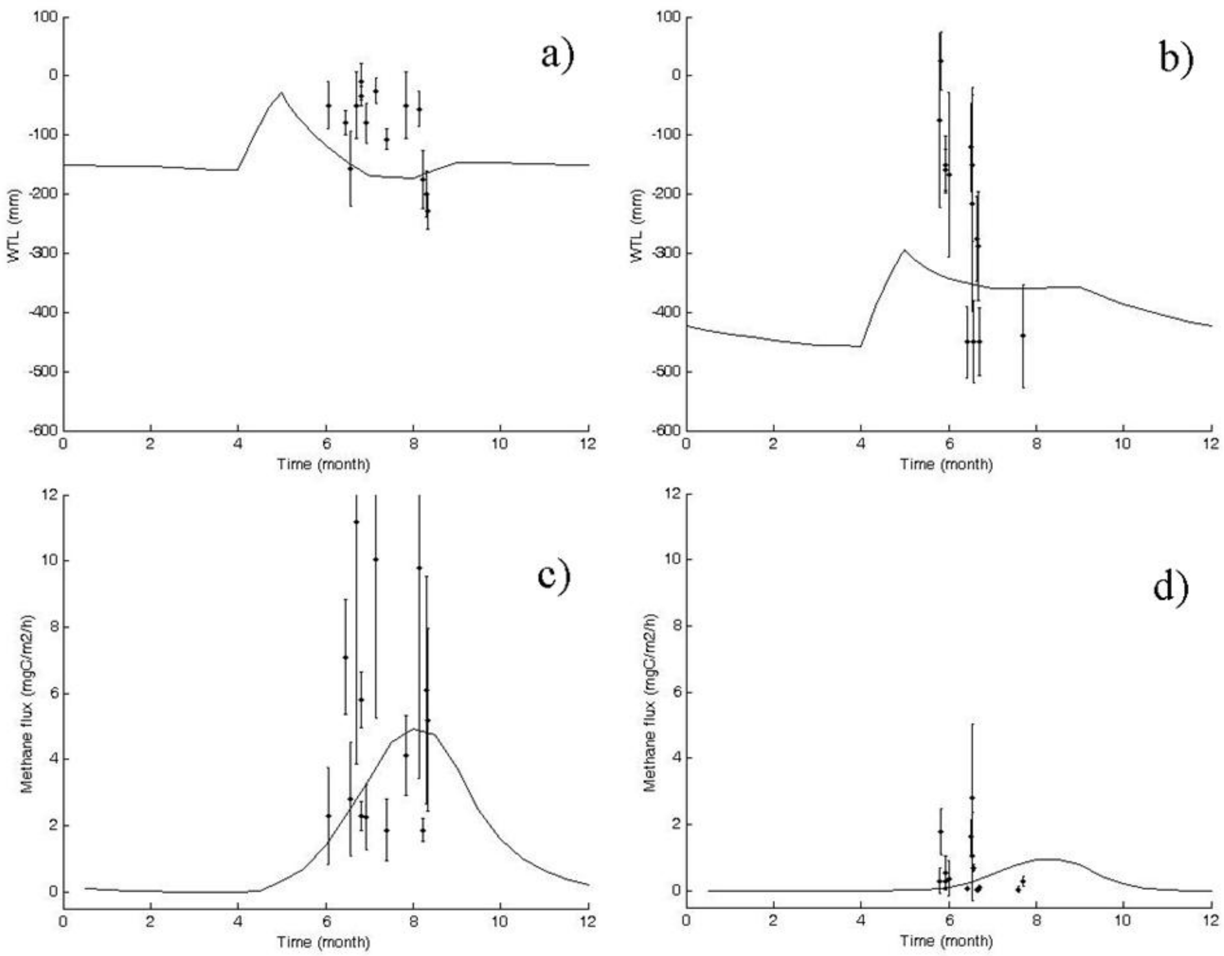

***Fig.** WeMEM (v. 2.1) modeling results in a grid cell with central coordinates 56.824 N, 82.875 E: (a) and (c) – for poor fen, (b) and (d) – for "ryam" (– - model prediction; · - arithmetic mean for observed fluxes;* ï *- confidence interval)*

The annual dynamics of the water table level was calculated based on the water balance equation (Чечкин, 1970), where the water input into the mire (H, cm/month) was parametrized in accordance with (Dingman, 2002); potential evaporation (E_o cm/month) – in accordance with (Давыдов, 1947); the actual evapotranspiration (E, cm/month) – (Frolking and Crill, 1994, eq. 11; Yurova et al., 2007, eq. 7) and runoff (Y, cm/month) – in accordance with (Frolking and Crill, 1994; Методические…, 2011):

$$dWTL/dt = [H(t) - E(t,WTL) - Y(WTL)]/P,$$

where t – time (month); P – porosity;

$$H = RAIN_m + MELT_m, \quad RAIN_m = F_m \cdot P_m, \quad SNOW_m = (1 - F_m) \cdot P_m.$$

Monthly precipitation (P_m, cm/month) is divided into rain ($RAIN_m$, cm/month) and snow ($SNOW_m$, cm/month). F_m is the melt factor computed from monthly temperature (T_m) as follows:

$$\text{if } T_m \le 0\ °C\text{: } F_m = 0; \quad \text{if } 0\ °C < T_m < 6\ °C\text{: } F_m = 0.167 \cdot T_m; \quad \text{if } T_m > 6\ °C\text{: } F_m = 1.$$

The melt factor is also used in a temperature-index snowmelt model to calculate the monthly snowmelt ($MELT_m$, cm/month) from the snowpack water equivalent ($PACK_{m-1}$, cm/month) at the end of month m-1:

$$MELT_m = F_m \cdot (PACK_{m-1} + SNOW_m), \quad PACK_m = (1 - F_m)^2 \cdot P_m + (1 - F_m) \cdot PACK_{m-1}.$$

Runoff was modeled as drainage depending on the water table level:
if $WTL < W_1$: $Y = Qdr\_m \cdot k \cdot \exp(r_1 \cdot [WTL - W_1])$; if $WTL \geq WTL_1$: $Y = Qdr\_m \cdot (1 + r_2 \cdot WTL)$, where $Qdr\_max = r_0 \cdot N(t)$; N(t) – number of days in one month (=28÷31 day/month) and k=1, r_0=0.76 cm/day, r_1=0.39 1/cm, r_2=0.33 1/cm, W_1=0 cm (for open bog); k=0.264, r_0=11.5 cm/day, r_1=0.16 1/cm, r_2=0.046 1/cm, W_1=-16 cm (for "rym" – low pine-ericaceous shrubs-sphagnum moss communities).

Actual evapotranspiration was modeled as evaporation depending on the water table level:
if $WTL \leq Zb$: $E = 0.5 \cdot E_o \cdot \exp(0.02 \cdot WTL)$; if $zET < WTL \leq 0$: $E = 0.5 \cdot E_o \cdot [\exp(0.02 \cdot WTL) + 1]$; if $Zb < WTL \leq zET$: $E = 0.5 \cdot E_o \cdot [\exp(0.02 \cdot WTL) + (WTL - Zb)/(zET - Zb)]$; if $0 < WTL$: $E = E_o$, where Zb=-30 cm; zET=-8 cm.

The idea of calculating the water table annual variation consists in that, if the same meteorological parameters are used for every year, then the mire will become quasistationary and the following obvious assertion will be fair: the water level at the end of the year have to coincide with the water level in the beginning of the next year. And as far as in such model one year does not differ from another, so the specified assertion may apply to the same year (not to different year): the water level in the start of the year has to coincide with the water level in the end of the year, i.e. WTL(0)=WTL(12).

The typical result of calculations in a grid cell with a central coordinates 56.824 N, 82.875 E is shown in the Fig. As it is shown on a Fig., fluxes of such order were observed during the field campaign in this region – West Siberian south taiga wetlands (Naumov, 1999; Глаголев и Шнырев., 2008; Sabrekov et al., 2013).

1. Глаголев М.В. Высокий уровень стояния воды может снижать эмиссию метана из почвы // Динамика окружающей среды и глобальные изменения климата. 2012. Т. 3. № 1(5). С. 1-10.
2. Глаголев М.В. Эмиссия CH_4 болотными почвами Западной Сибири: от почвенного профиля до региона: диссертация на соискание ученой степени кандидата биологических наук / Московский государственный университет им. М.В. Ломоносова (МГУ). Москва. 2010.
3. Глаголев М.В., Сабреков А.Ф., Терентьева И.Е., Максютов Ш.Ш. Температурный фактор продукции метана в модели WeMEM // Проблемы изучения и использования торфяных ресурсов Сибири. Материалы Третьей международной научно-практической конференции. 2015. С. 64-67.
4. Глаголев М.В., Шнырев Н.А. Динамика летне-осенней эмиссии CH4 естественными болотами (на примере юга Томской области) // Вестник Московского университета. Серия 17: Почвоведение. 2007. № 1. С. 8-14.
5. Давыдов Л.К. Водоносность рек СССР, ее колебания и влияние на нее физико-географических факторов. Л.: Гидрометеоиздат. 1947. С. 8, 18.
6. Методические указания по расчетам стока с неосушенных и осушенных болот / М-во природ. ресурсов и экологии Рос. Федерации, Федер. служба по гидрометеорологии и мониторингу окружающей среды (Росгидромет). СПб.: Петербургский модный базар. 2011. 150 с.
7. Чечкин С.А. Водно-тепловой режим неосушенных болот и его расчет. Л.: Гидрометеоиздат. 1970. С. 38.
8. Dingman S.L. Physical hydrology. Upper Saddle River, New Jersey: Prentice Hall. 2002. P. 315.
9. Frolking S., Crill P. Climate controls on temporal variability of methane flux from a poor fen in southeastern New Hampshire: Measurement and modeling // Global Biogeochemical Cycles. 1994. V. 8. P. 385-397.
10. Hijmans R.J., Cameron S.E., Parra J.L., Jones P.G., Jarvis A. Very high resolution interpolated climate surfaces for global land areas // Int. J. of Climatology. 2005. V. 25. P. 1965-1978.
11. Naumov A.V. Components and processes of high peat bog carbon cycle of Western Siberia //

Climates and Carbon Cycle: Past and Present: Abstracts (Moscow, May 19-21, 1998). Moscow: GEOS. 1999. P. 61.
12. Oelke C., Zhang T., Serreze M.C., Armstrong R.L. Regional-scale modeling of soil freeze/thaw over the Arctic drainage basin // J. Geophys. Res. 2003. V. 108. No. D10. 4314.
13. Sabrekov A.F., Glagolev M.V., Kleptsova I.E., Machida T., Maksyutov S.S. Methane Emission from Bog Complexes of the West Siberian Taiga // Eurasian Soil Science. 2013. V. 46. № 12. P. 1182–1193.
14. Terentieva I.E., Glagolev M.V., Lapshina E.D, Sabrekov A.F., Maksyutov S.S. Mapping of West Siberian taiga wetland complexes using Landsat imagery: implications for methane emissions // Biogeosciences. 2016. V 13. № 16. P. 4615-4626.
15. Yurova A., Wolf A., Sagerfors J., Nilsson M. Variations in net ecosystem exchange of carbon dioxide in a boreal mire: Modeling mechanisms linked to water table position // J. Geophys. Res. 2007. V. 112. G02025.