Coupled climate–methane cycle simulation with a climate model of intermediate complexity forced by SRES A2 scenario

A.V. Eliseev, I.I. Mokhov, M.M. Arzhanov,P.F. Demchenko, and S.N. Denisov

A.M. Obukhov Institute of Atmospheric Physics RAS,
3 Pyzhevsky, 1091017 Moscow, Russia, e–mail: eliseev@ifaran.ru

The climate model of intermediate complexity developed at the A.M. Obukhov Insitute of Atmospheric Physics RAS (IAP RAS CM) [6] is extended by modules of soil thaw/freeze cycles [2] and methane cycle. The latter is based on [7] with a prescribed characteristic time of chemical decompostion of methane in the atmosphere $\tau_{CH_4,atm} = 10.5\ yr$. Methane emissions from bogs and swamps are computed based on [1] but with some parameters tuned. Other non–anthropogenic methane sources are prescribed. A simulation with IAP RAS CM is performed which is forced by the anthropogenic emissions of CO_2 and CH_4 and atmospheric concentration of N_2O. These forcings are changed in accordance to the corresponding historical estimations extended back to 1610 for the 17th–20th centuries and in accordance to scenarios SRES A2 [3] for the 21st century. To match the historical and future methane emissions the former are uniformly reduced on 13%. One simulation (CPL) employs a fully coupled model. The other simulation (UCPL) forces the modules of soil thaw/freeze cycles and methane cycle by the monthly mean climatologies of surface air temperature and precipitation obtained from the control preindustrial simulation with IAP RAS CM.

Simulated methane emissions from bogs and swamps $E_{\mathrm{CH_4,bs}}$ amount about 130 $MtCH_4/yr$ before the mid 20th century (Fig. 1). They increase to $\approx 145\ MtCH_4/yr$ to the late 20th century. These values are in agreement with observational estimates $145 \pm 30\ MtCH_4/yr$ [4]. In the 21st century, methane emissions from wetlands increases drastically, up to $\approx 200\ MtCH_4/yr$. This increase is basically due to temperature dependence of apparent methane production.

Simulated concentration of methane in the atmosphere $p\mathrm{CH_{4,a}}$ is overestimated slightly before the middle of the 20th century. This is presumably due to neglection of other external forcings (solar irradiance, volcanos, aerosols) leading to too rapid and too early warming during the 20th century in IAP RAS CM [6] (as well as in other climate models [3]). An agreement improves in the second part of the 20th century. Rapid buildup of methane in the atmosphere due to anthropogenic emissions lead to $p\mathrm{CH_{4,a}} = 3904\ ppbv$ in the end of the 21st century in the simulation CPL. In the simulation UCPL, owing to lack of the enhancement of the methane emissions from wetlands, this value is smaller, 3671 *ppbv*.

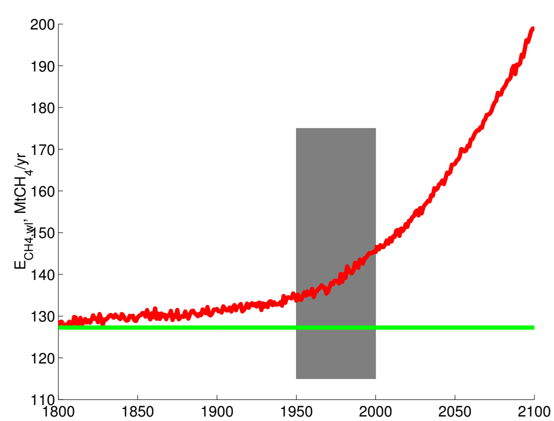

Figure 1: Modelled methane emissions from wetlands for the simulations CPL and UCPL (red and green lines, respectively) together with a corresponding observational range [4] (gray) .

l9cm

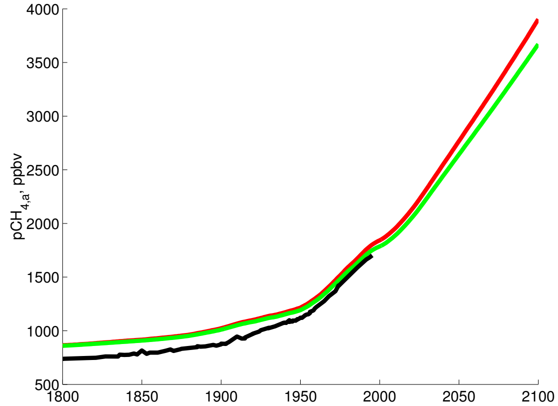

Figure 2: Modelled concentration of methane in the atmosphere for the simulations CPL and UCPL (red and green lines, respectively) together with a historical data [5] (black) .

Annual mean surface air temperature (SAT) in 2071–2100 in the simulation CPL is warmer (by $0.2 - 0.6\ K$) over the subtropical northern land in comparison to that obtained in the simulation UCPL. In contrast, SAT in CPL during the same period is lower over the northernmost land areas, Mideterranean, and North America midlatitudes by the same amount. When SAT is averaged globally, this anomalies are mutually compensated and global SAT for this period is almost indistinguishable between the simulations CPL and UCPL.

This work is supported by the Russian Foundation for Basic Research, by the programs of the Russian Academy of Sciences, and by the Russian President scientific grant.

References

[1] T.R. Christensen and P. Cox. Response of methane emission from arctic tundra to climatic change: results from a model simulation. *Tellus*, 47B(3):301–309, 1995.

[2] A.V. Eliseev, M.M. Arzhanov, P.F. Demchenko, S.N. Denisov, and I.I. Mokhov. Permafrost response to SRES A2 greenhouse forcing in a climate model of intermediate complexity. 2007. (this issue).

[3] J.T. Houghton, Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson, editors. *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge/New York, 2001.

[4] J. Lelieveld, P.J. Crutzen, and F.J. Dentener. Changing concentration, lifetime and climate forcing of atmospheric methane. *Tellus*, 50B(2):128–150, 1998.

[5] C. MacFarling Meure, D. Etheridge, C. Trudinger, P. Steele, R. Langenfelds, T. van Ommen, A. Smith, and J. Elkins. Law dome CO_2, CH_4 and N_2O ice core records extended to 2000 years BP. *Geophys. Res. Lett.*, 33(14):L14810, 2006.

[6] I.I. Mokhov, V.A. Bezverkhnii, A.V. Eliseev, and A.A. Karpenko. Model estimates of global climatic changes in the 21st century with account for different variation scenarios of solar activity. *Doklady Earth Sci.*, 411(8):1327–1330, 2006.

[7] T.J. Osborn and T.M.L. Wigley. A simple model for estimating methane concentration and lifetime variations. *Clim. Dyn.*, 9(4-5):181–193, 1994.