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Are production and emission of N2O decoupled in peat soils? A simulation study of daily N2O emissions.

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Nitrous oxide (N2O) emissions from arable land are characterized by low background emissions and a few, short-lived peak emissions that represent a major part of the annual emission. Although the available models estimate cumulative N2O emissions fairly well, attempts to simulate the dynamics of daily emissions have failed so far. Errors in the simulated emissions have been attributed to errors in the simulated dynamics of the main drivers: soil moisture content, mineral nitrogen (N) content, soil organic matter content, oxygen content. Therefore we tested if accurate simulation of the dynamics of the main drivers in the soil profile, and especially soil moisture, does imply accurate simulation of the dynamics of N2O emissions at daily timescale as well.

To this end, we used the detailed hydrological-biogeochemical model combination SWAP-ANIMO. The hydrological model SWAP has on many occasions shown to accurately predict soil moisture profiles. The biogeochemical model ANIMO has originally been developed for simulation of nutrient leaching, and has been extensively calibrated and validated. It has recently been extended with modules to simulate subsidence of peat land and greenhouse gas emissions.

In our analyses we used daily observations of N2O emission and soil moisture from three managed grassland sites on peat in The Netherlands, and complementary observations of soil moisture, soil mineral N content and N2O concentration. All sites were drained artificially by ditches or tube drainage. Observed soil characteristics and results from former simulation studies on the peat area were used to calibrate the model and to define initial and boundary conditions.

Soil moisture and mineral N were simulated quite well. Also, N2O concentrations were simulated in the right order of magnitude. However, poor results were obtained for daily N2O emissions, with a maximum model efficiency of 0.05. Production could be attributed to three sources: nitrification, denitrification in the top soil and denitrification in the subsoil. In the topsoil all N2O produced was emitted directly, whereas in the subsoil the produced N2O was emitted gradually in the days after production. The main problem appeared to be overestimation of the emission from N2O produced by denitrification in the top soil. Emission of N2O from production by denitrification in the subsoil and from production by nitrification was simulated much better.

Hardly any reduction was simulated in the top soil and all N2O produced was emitted almost immediately. Also, many observed emission peaks are not only overestimated, but also simulated one day too early. Given the satisfactory results for soil mineral N content, and for denitrification and nitrification in the subsoil it is unlikely that the parameterization of the model is far off.

We investigate the possibility that emission from the top soil is too fast and immediate emission of all N2O produced in the top soil prevents further reduction of N2O to N2. We hypothesize that such temporary storage could be caused by disequilibrium between N2O in the water and in the gas phase. N2O production mainly takes place in water-filled micropores, whereas gas diffusion mainly takes place in the larger air-filled pores. Discontinuity in the pores space, a property of organic soils, can hamper degassing of the N2O from soil water to soil air, keeping the produced N2O stored in the soil water. In the subsoil this is less of an issue because denitrification proceeds at higher soil moisture contents and immediate diffusion is much smaller.