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Ecological Controls on N2O Emission in Surface Litter and Near-surface Soil of a Managed Grassland: Modelling and Measurements

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Large variability in N2O emissions from managed grasslands may occur because most emissions originate in surface litter or near-surface soil where variability in soil water content (q) and temperature (Ts) is greatest. To determine whether temporal variability in q and Ts of surface litter and near-surface soil could explain that in N2O emissions, a simulation experiment was conducted with ecosys, a comprehensive mathematical model of terrestrial ecosystems in which processes governing N2O emissions were represented at high temporal and spatial resolution. Model performance was verified by comparing N2O emissions, CO_2 and energy exchange, and q and Ts modelled by ecosys with those measured by automated chambers, eddy covariance (EC) and soil sensors at an hourly time-scale during several emission events from 2004 to 2009 in an intensively managed pasture at Oensingen, Switzerland. Both modelled and measured events were induced by precipitation following harvesting and subsequent fertilizing or manuring. These events were brief (2 – 5 days) with maximum N2O effluxes that varied from < 1 mg N m-2 h-1 in early spring and autumn to > 3 mg N m-2 h-1 in summer. Only very small emissions were modelled or measured outside these events. In the model, emissions were generated almost entirely in surface litter or near-surface (0 – 2 cm) soil, at rates driven by N availability with fertilization vs. N uptake with grassland regrowth, and by O_2 limitation from wetting relative to O_2 demand from respiration. In the model, NO_x availability relative to O_2 limitation governed both the reduction of more oxidized electron acceptors to N2O and the reduction of N2O to N2, so that the magnitude of N2O emissions was not simply related to surface and near-surface q and Ts. Modelled N2O emissions were found to be sensitive to defoliation intensity and timing (relative to that of fertilization) which controlled plant N uptake and soil q and Ts prior to and during emission events. In a model sensitivity study, reducing LAI remaining after defoliation to one-half that under current practice and delaying harvesting by 5 days raised N2O emissions by as much as 80% during subsequent events and by an average of 43% annually. The global warming potential from annual N2O emissions in this intensively managed grassland largely offset those from net C uptake in both modelled and field experiments. However model results indicated that this offset could be adversely affected by suboptimal harvest intensity and timing.