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# A $^{15}$N tracing method to quantify $N_2O$ pathways from terrestrial ecosystems

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To quantify $N_2O$ production pathways from terrestrial ecosystems a $^{15}$N tracing model was developed. The model is based on previous tracing models to quantify gross nitrogen (N) transformations including soil nitrite ($NO_2^-$) dynamics. Four $N_2O$ pathways are considered in the model which are associated with $NO_2^-$ subpools: i) reduction of $NO_2^-$ associated with nitrification ($NO_2^-{}_{nit}$- $N_2O_{nit}$), ii) reduction of $NO_2^-$ associated with denitrification ($NO_2^-{}_{den}$- $N_2O_{den}$), iii) reduction of $NO_2^-$ associated with organic N ($N_{org}$) oxidation ($NO_2^-{}_{org}$ - $N_2O_{org}$), and iv) codenitrification ($N_2O_{cod}$), a hybrid reaction where one N atom in $N_2O$ originates from organic N and the other from $NO_2^-{}_{den}$. The reaction kinetics and emission notations are based on first-order approaches. For all four $N_2O$ sub-pools specific reduction rates to $N_2$ were implemented. Parameters are optimized with the Metropolis algorithm (a Monte Carlo technique). A data set from an old grassland was used to test the $^{15}$N tracing tool. Results show that on average over a 12 day period $N_2O_{nit}$, $N_2O_{den}$, $N_2O_{org}$ and $N_2O_{cod}$ contributed by 9%, 20%, 54% and 18% to the total $N_2O$ emission, respectively. Alternative techniques based on analytical approaches, which consider three $N_2O$ emission pathways, provide similar results. For the first time four $N_2O$ emission pathways, including a hybrid-reaction, can simultaneously be quantified. The analysis for the old grassland study showed that heterotrophic processes related to organic N turnover are the prevailing pathway for $N_2O$ production. The underlying $NO_2^-$ and $N_2O$ reduction kinetics are in agreement with microbial measurements and the calculated $N_2/N_2O$ ratios are in the expected range. The model provides a framework for the development of more realistic representations of soil N cycling in ecosystem models.