Summary

Compilation of a global N_2O emission inventory for tropical rainforest soils using a detailed biogeochemical model

Nitrous oxide (N_2O) is a potent trace gas contributing to approximately 6% to the observed anthropogenic global warming. Soils have been identified to be the major source of atmospheric N_2O and tropical rainforest soils are thought to account for the largest part. Furthermore, various studies have shown that the magnitude of N_2O emissions from tropical rainforest soil is highly variable on spatial and temporal scales. Detailed, process-based models coupled to Geographic Information Systems (GIS) are considered promising tools for the calculation of N_2O emission inventories. This methodology explicitly accounts for the governing microbial processes as well as the environmental controls. Moreover, mechanistic biogeochemical models operating in daily time-steps (e.g. ForestDNDC-tropica) have been shown to capture the observed intra- and inter-annual variations of N_2O emissions. However, detailed N_2O emission datasets are required for model calibration and testing, but are currently few in numbers.

In this study an automated measurement system was used to derive detailed datasets of N_2O, methane (CH_4) and carbon dioxide (CO_2) soil-atmosphere exchange and important environmental parameters from tropical rainforest soils in Kenya and Southwest China. Distinct differences were identified in the magnitude of the C and N soil-atmosphere exchange at the investigated sites and forest types. However, common features such as N_2O pulse emissions after dry season or the pronounced soil moisture dependency of N_2O emissions were observed at both sites. The derived datasets are unique for these tropical regions as so far no information about the source strength of these regions was available and, for the first time, the N_2O, CH_4 and CO_2 soil-atmosphere exchange was recorded in sub-daily resolution.

The datasets were utilized in conjunction with available high-resolution datasets from Australian rainforests for the re-calibration of the ForestDNDC-tropica model using a multi-site, parallel Bayesian calibration approach. Extensive validation and sensitivity studies underlined the good agreement of the improved biogeochemical model with observed N_2O fluxes. Based on a newly developed detailed GIS database for tropical rainforests worldwide, the new model was then used for the calculation of a global N_2O

emission inventory. Daily N_2O emissions for the years 1991 – 2000 were calculated. The results show striking spatial and temporal differences of N_2O source strength. Based on the calculations in this study the source estimate of global N_2O emissions from tropical rainforest soils was revised from previously 1.2 – 3.6 Tg N yr^{-1} (based on a wide range of source areas considered) to 1.3 Tg N yr^{-1}. As the accuracy of the model output is dependant on the data quality driving the models, an uncertainty assessment was performed to quantify the data-induced uncertainty on the presented N_2O emission inventory. Using a Latin hypercube sampling approach, the uncertainty range was calculated to be 0.9 – 2.4 Tg N yr^{-1}.

Another key finding of this study was the strong seasonal and inter-annual variability of N_2O emissions originating from tropical rainforest soils at the global scale. So far, this was not captured by statistical upscaling approaches. Furthermore, these temporal variations were accompanied by significant spatial variations in the N_2O emission strength on a continental scale (e.g., 90% variation between 1993 and 1994 for the African continent). It can be hypothesized that these significant spatial and temporal changes may even be traceable by using inverse modelling studies.

The results of this study clearly show that GIS-coupled, detailed biogeochemical models are an excellent tool for the calculation of large-scale emission inventories. It could also be shown, that the ForestDNDC-tropica model offers the possibility to account for the spatial and temporal heterogeneity of the N_2O soil-atmosphere exchange as observed during field measurements in tropical rainforest worldwide. The presented approach might help to overcome the static concept of previous inventory assessments towards a more dynamic understanding of N_2O biosphere-atmosphere exchange processes on a global scale, thereby also allowing considering feedbacks to changes in climate and land use. Nevertheless, this study also exposed the need for further detailed field studies to better describe the variability involved in the N_2O release from soils.