Geophysical Research Abstracts
Vol. 14, EGU2012-8843-1, 2012
EGU General Assembly 2012

Decadal variability of soil CO_2, NO, N2O,and CH4 fluxes at the Hoeglwald Forest, Germany

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Besides agricultural soils, temperate forest soils have been identified as significant sources of or sinks for important atmospheric trace gases (N2O, NO, CH4, and CO_2). Although the number of studies for this ecosystem type increased more than tenfold during the last decade, studies covering an entire year and spanning more than 1–2 yr remained scarce. This study reports the results of continuous measurements of soil atmosphere C- and N-gas exchange with high temporal resolution carried out since 1994 at the Höglwald Forest spruce site, an experimental field station in Southern Germany.

Annual soil N2O emission, NO emission, CH4 uptake, and CO_2 emission (1994–2010) varied in a range of 0.2–3.2 kg N2O-N ha^{-1} yr^{-1}, 6.4–11.4 kg NO-N ha^{-1} yr^{-1},0.9–3.5 kg CH4-C ha^{-1} yr^{-1}, and 7.0–9.2 t CO_2-C ha^{-1} yr^{-1}, respectively. The observed high fluxes of N-trace gases are most likely a consequence of high rates of atmospheric nitrogen deposition (> 20 kg N ha^{-1} yr^{-1}) of NH3 and NO_x to our site. For N2O cumulative annual emissions were > 0.8kg N2O-N ha^{-1} yr^{-1} high in years with freeze-thaw events (5 out 14 yr). This shows that long-term, multi-year measurements are needed to obtain reliable estimates of N2O fluxes for a given ecosystem. Cumulative values of soil respiratory CO_2 fluxes were highest in years with prolonged freezing periods e.g. the years 1996 and 2006, i.e. years with below average annual mean soil temperatures and high N2O emissions. The results indicate that long freezing periods may even drive increased CO_2 fluxes not only during soil thawing but also throughout the following growing season.

Furthermore, based on our unique database on GHGs we analyzed if soil temperature, soil moisture, or precipitation measurements can be used to approximate GHGs at weekly, monthly, or annual scale. Our analysis shows that simple-to-measure environmental drivers such as soil temperature or soil moisture are suitable to approximate fluxes of NO and CO_2 in weekly and monthly scales with a reasonable uncertainty (accounting for up to 80% of the variance). However, for N2O and CH4 we so far failed to find meaningful correlations and, thus, to provide simple regression models to estimate fluxes. This is most likely due to the complexity of involved processes and counteracting effects of soil moisture and temperature, specifically with regard to N2O production and consumption by denitrification and microbial community dynamics.