Using Isotopic Fingerprints to Trace Nitrous Oxide in the Atmosphere

Joachim Mohn[1], Béla Tuzson[1], Eliza Harris[2], Stephan Henne[1], Benjamin Wolf[3], Erkan Ibraim[1], Longfei Yu[1], Christoph Zellweger[1], Lukas Emmenegger[1]

[1] Empa, Laboratory for Air Pollution / Environmental Technology, CH-8600 Dübendorf, Switzerland; joachim.mohn@empa.ch

[2] University of Innsbruck, Institute of Ecology, Plant, Soil and Ecosystem Processes Research Group, A-6020 Innsbruck, Austria

[3] Karlsruhe Institute of Technology, Institute for Meteorology and Climate Research (IMK-IFU), D-82467 Garmisch-Partenkirchen, Germany

Nitrous oxide (N_2O) is a potent greenhouse gas and the strongest ozone-destroying substance emitted this century. Reliable predictions of future emissions, requires knowledge of the responsible N_2O source processes. Isotopic composition of N_2O is a tracer to distinguish between different emission pathways, as well as constraining the stratospheric N_2O sink. The four most abundant N_2O isotopic species are: $^{14}N^{14}N^{16}O$ (99%), $^{14}N^{15}N^{16}O$ (α, 0.4%), $^{15}N^{14}N^{16}O$ (β, 0.4%) and $^{14}N^{14}N^{18}O$ (0.2%). Due to its asymmetric molecular structure, N_2O (α) and N_2O (β) differ only in the position of the ^{15}N atom, and the difference in their abundance – known as site preference (SP) – is a particularly powerful indicator for different N_2O production mechanisms.

Here we illustrate the potential of laser spectroscopy for real-time, high-precision analysis of isotopic composition in ambient N_2O. Furthermore, we present applications, in agricultural as well as suburban environments, illustrating the advantage and necessity of real-time data of trace gas isotope ratios. In an extensive campaign above a managed grassland, nitrifier-denitrification and denitrification were identified as prevalent sources of N_2O and variations in isotopic composition were attributed to alterations in the extent to which N_2O was reduced to N_2 [1]. In an ongoing project, we validate the real-time N_2O isotope data against a process-based biogeochemical soil model (DNDC) with an isotope sub-module (SIMONE), which is based on published isotope effects [2]. At a suburban site, the isotopic composition of atmospheric N_2O was monitored over 18 months to determine the source isotopic composition, which varied significantly compared to chemical and meteorological parameters. FLEXPART-COSMO transport modelling in combination with modified EDGAR inventory emissions was able to capture variability in N_2O mole fraction well, but simulations of isotopic composition showed little agreement with observations, indicating that the range of literature values of isotopic source signatures significantly underestimates the true variability [3].

In summary, we are convinced that real-time analysis of N_2O isotopic composition is an efficient approach to disentangle N_2O source / sink processes in agricultural as well as suburban / industrial environments. Combination of point measurements with modelling approaches provides spatial resolution and enables validation of emission inventories.

References

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