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Global budgets of nitrous oxide under the Global Carbon Project and the International Nitrogen Initiative

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Extended Abstract

The Global Carbon Project (GCP) provides a comprehensive data base on the global sources and sinks of key greenhouse gases and visualizes the results in a transparent manner. Compiling from the most recent scientific studies and adding research where needed, the balances of carbon dioxide [1] and of methane [2] have been made available. With support of the International Nitrogen Initiative (INI), GCP currently addresses the third of the most important anthropogenically emitted greenhouse gases, nitrous oxide (N_2O).

Numerous previous studies have addressed the sources and sinks of atmospheric N_2O. The most important source is its release from soils as a consequence of microbial conversion of reactive nitrogen compounds, with a focus on tropical soils (where high temperature and humidity accelerate the production process) and on soils with a high availability of reactive nitrogen compounds, from e.g. plant fertilizers [3]. In order to better understand the influencing factors of its formation it seems useful to specifically address soil and vegetation processes by terrestrial biosphere modelling.

The Nitrous Oxide Model-Intercomparison Project (NMIP) brings together 10 different terrestrial biosphere models to globally combine and compare results. The underlying concepts of this comparison [4] and detailed outcomes [5] of this exercise have been published. Not only do the ensemble of models provide a detailed overview on spatial and temporal scale of biosphere emissions, differentiated by biome, furthermore a coordinated effort of model simulations allows to single out contributing factors responsible for the emissions.

Comparing pre-industrial (before 1860) and current emissions (2007-2016), it turns out that cropland soil emissions have increased 11-fold, while other ecosystems have almost not changed. Cropland soils now are responsible for about a third of global soil emissions (which include natural emissions) and thus for the majority of the increase since the 1860s. The latitudinal gradient, previously peaking in the tropics with 70% of all soil emissions occurring in that region, now displays a second, somewhat smaller peak in the northern hemisphere, based on the strong emission densities observed in China, India, the Eastern U.S. and Western/Central Europe.

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NMIP simulations using the model ensemble separate individual factors contributing to these changes. Mineral fertilizer application to soils, atmospheric deposition of nitrogen compounds, climate change, and manure addition to soil all contribute to increased emissions (in this order, with mineral fertilizer responsible for almost half of the increase). Enhanced atmospheric carbon dioxide levels slightly decrease the emissions. In the past decades, the influence of land cover change is regarded as almost neutral.

Together with emission estimations from all other sources (oceans, inland waters, industry, combustion, waste) total global emissions can be assessed. There is, however, an independent pathway to quantify the release of N_2O to the atmosphere. That approach takes ground-based global atmospheric N_2O concentration data in combination with atmospheric transport models in order to perform a Bayesian inversion. Three independent inversion frameworks have been used [6], especially to look into the temporal evolution of emissions for different global regions.

Atmospheric concentrations of N_2O have been increasing steadily over time, as the global source exceeds the global sink, due to stratospheric destruction. The global source is continuing to increase, between the early 2000s and the 2010s by almost 10%. The major part (90%) of this increase occurs over land.

When correcting for non-soil emissions, on global scale and for key world region the increase of N_2O emissions from soils is larger than should be expected from increased fertilizer application in these regions and using the default IPCC emission factor for soil emissions [7]. This result supports, on a global scale and based on atmospheric measurements, previous plot studies of emission fluxes that indicate a quadratic response on N_2O emissions on fertilizer application instead of a proportional increase [8].

As a consequence of this enhanced effect of adding fertilizer, and of a general disposition of high available N substrate, the resulting global emissions observed by inverse modelling exceed the emission estimated projected previously (Fig. 1). Bottom-up projections originally have developed for the IPCC [9], with "RCP8.5" reflecting a business-as-usual case that (in line with the factual climate policy implemented in the past) provides no or little measures of emission reduction for N_2O.

This triggers the need for more and advanced regional efforts to better understand and quantify the release of greenhouse gases on a regional scale, in order to be able to also observe changes in these emissions caused by climate change or anthropogenic drivers. This refers specifically but not exclusively to N_2O. Such a process has been started in the Regional Carbon Cycle Assessment and Processes-2 (RECCAP-2) project, a project that covers all three major anthropogenically emitted greenhouse gases. Evaluating the nationally determined contribution (NDCs) of countries by way of a "global stocktake" in order to fine-tune possible further measures as needed is a cornerstone in the implementation of the Paris Agreement. Thus RECCAP-2, currently in its starting phase, informs and guides policy into the first phase of validating and updating national contributions. With a timeline to publish results by the end of 2021, there is sufficient opportunity for revising national targets and improve wherever needed.

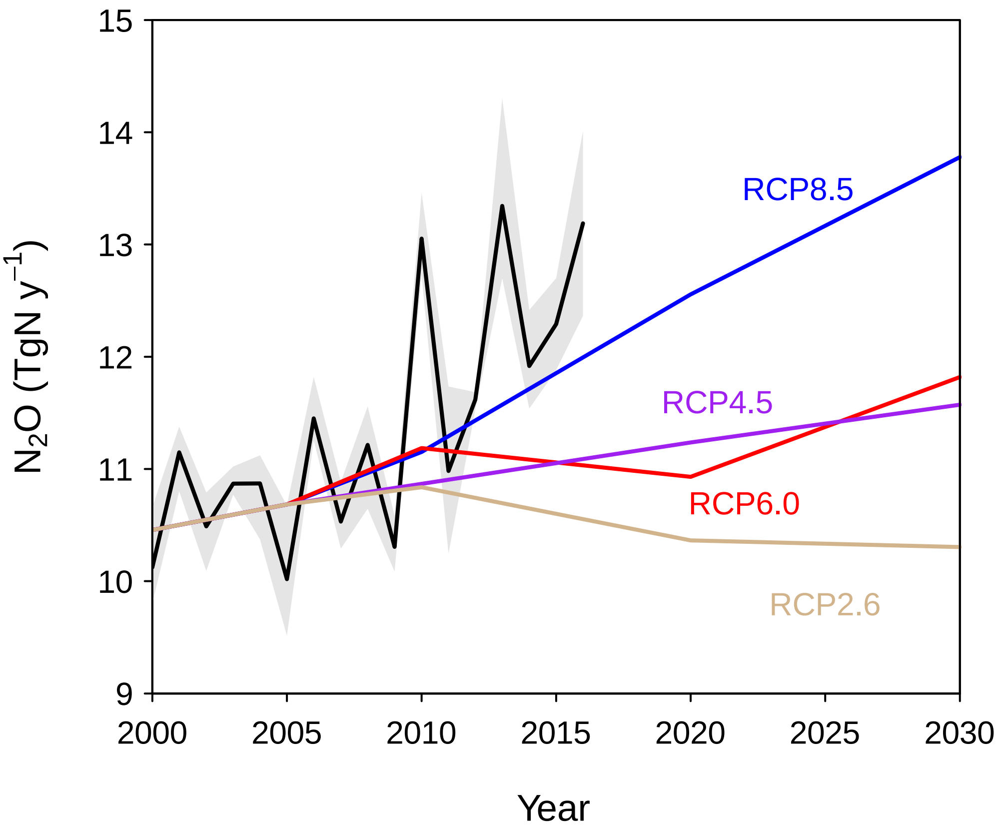

Figure 1. Global N_2O emissions (mean from three inversions) compared to IPCC emission scenarios.

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