Characterization of Atmospheric Reactive Nitrogen Emissions from Global Agricultural Soils

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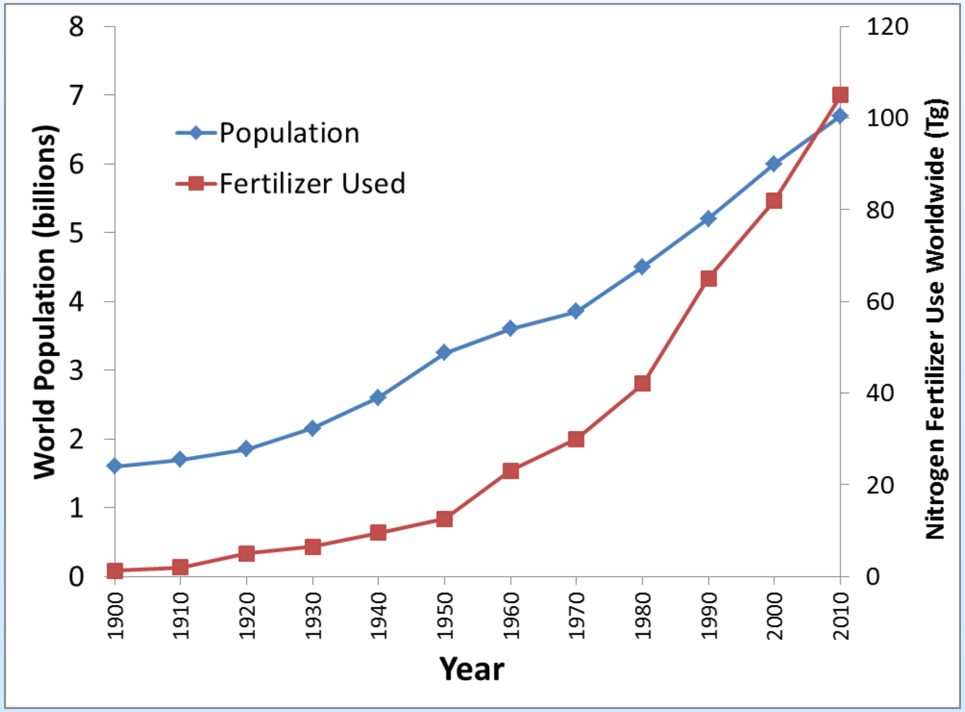
Preamble

- Nitrogen is necessary to sustain all life and is required to sustain agriculture and the global food supply.
- Nitrogen emissions from agricultural (both crop and animal) sources have not been categorized well.
- Satellite measurements can now provide spatial and temporal global coverage for reactive nitrogen.

Population increase and use of nitrogen fertilizer (1900 to 2010)



Source: Aneja et al., *Atmospheric Environment*, 2008.
International Fertilizer Industry Association

Terminology and definitions

Inert
N_2 gas

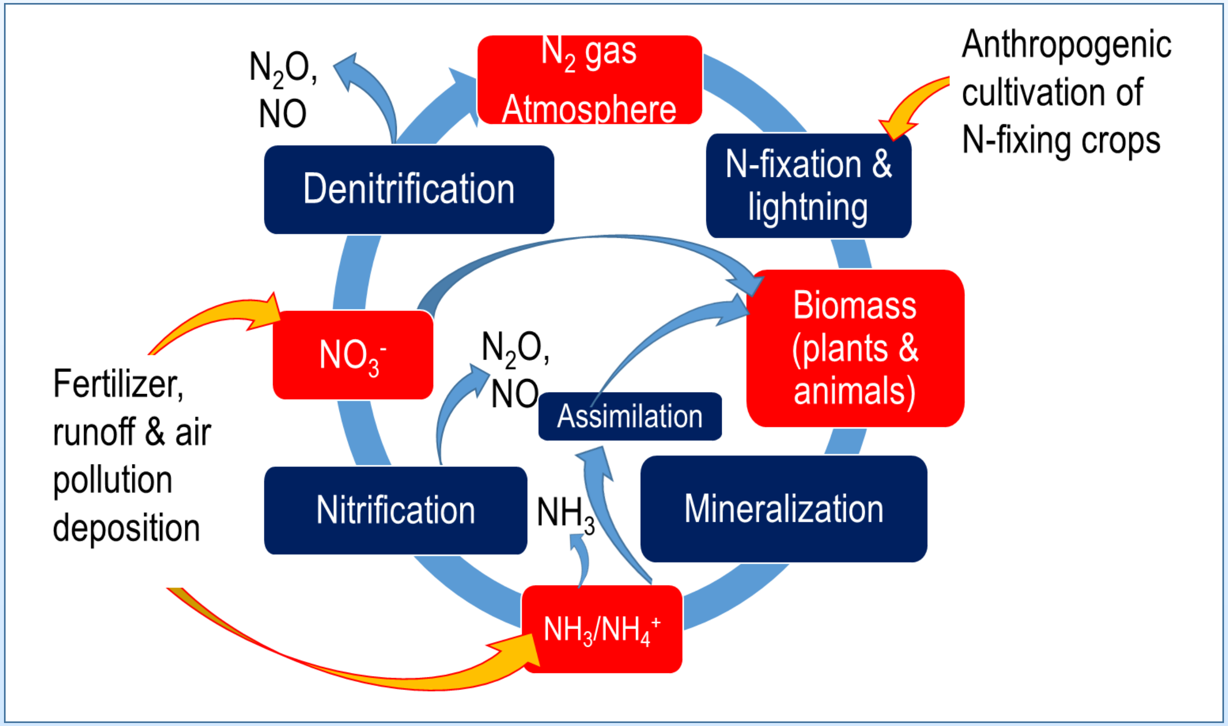
Reactive N includes:

1. Biologically available N compounds
2. Chemically reactive N compounds
3. Radiatively active N compounds

- **Some examples**

1. Important biomolecules containing N: chlorophyll, hemoglobin, all proteins, DNA, …
2. Fertilizers: ammonia (NH_3), ammonium salts (NH_4^+), nitrate salts (NO_3^-), urea [$(NH_4)_2CO$]
3. Nitrous oxide (N_2O) is radiatively active, but chemically and biologically inert

Introduction: The Nitrogen Cycle

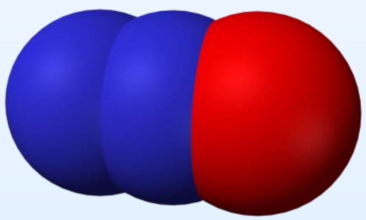


The nitrogen cycle in soils/water/biosphere and its connection with the atmosphere.

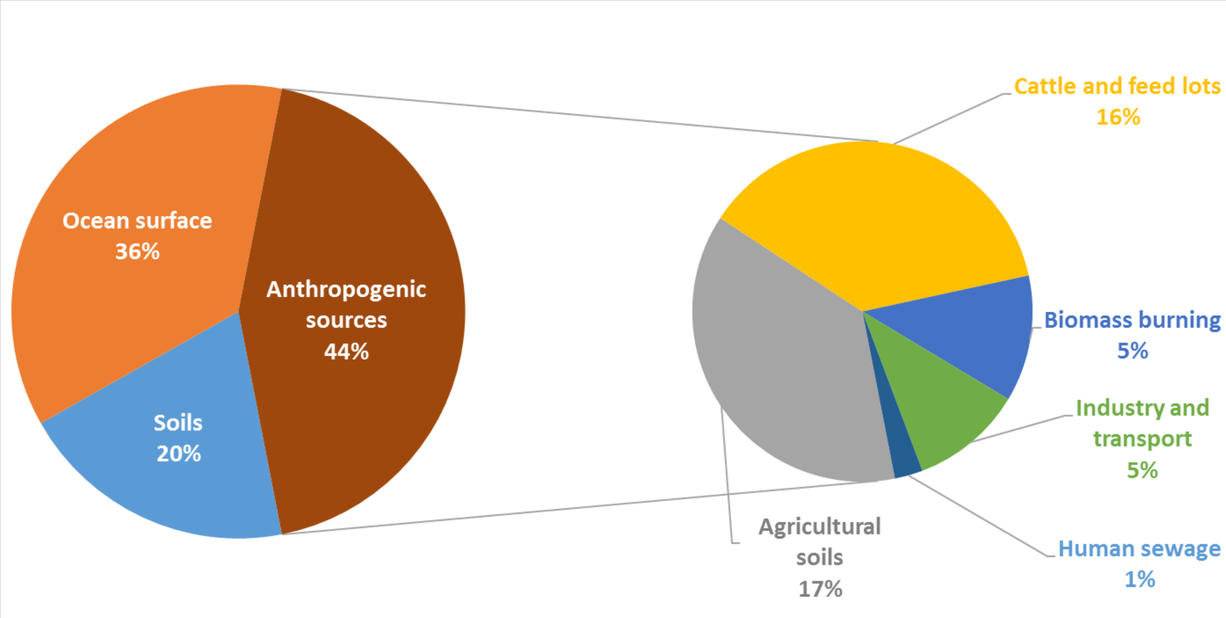
Source: Battye, Aneja, and Schlesinger, 2017.

- The nitrogen cycle is the biogeochemical cycle by which nitrogen is converted into multiple chemical forms as it circulates **among atmosphere, biosphere, hydrosphere and lithosphere** ecosystems.
- Important processes in the nitrogen cycle include **fixation, mineralization, assimilation, nitrification, and denitrification.**

Global N_2O emission



N_2O
Nitrous oxide



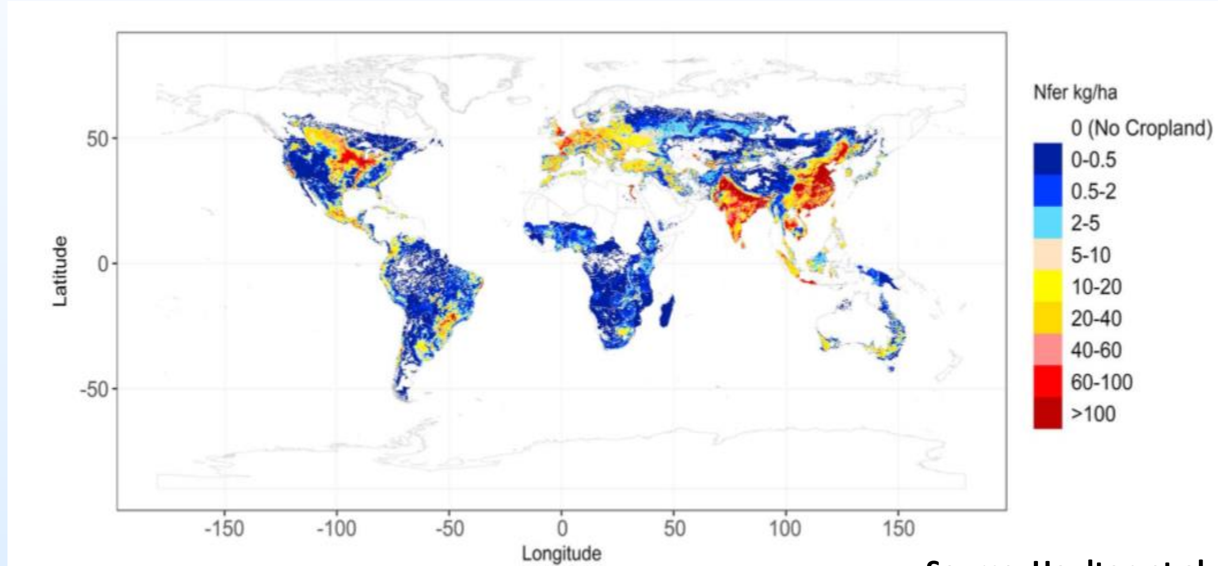
The global budget for N_2O ~17 Tg N/yr

- **In terrestrial ecosystems, N_2O is mainly produced in soils via nitrification and denitrification processes**
- **There has been limited discussion on the importance of agriculture as a major contributor for the increasing atmospheric N_2O**

Source: 2006 IPCC

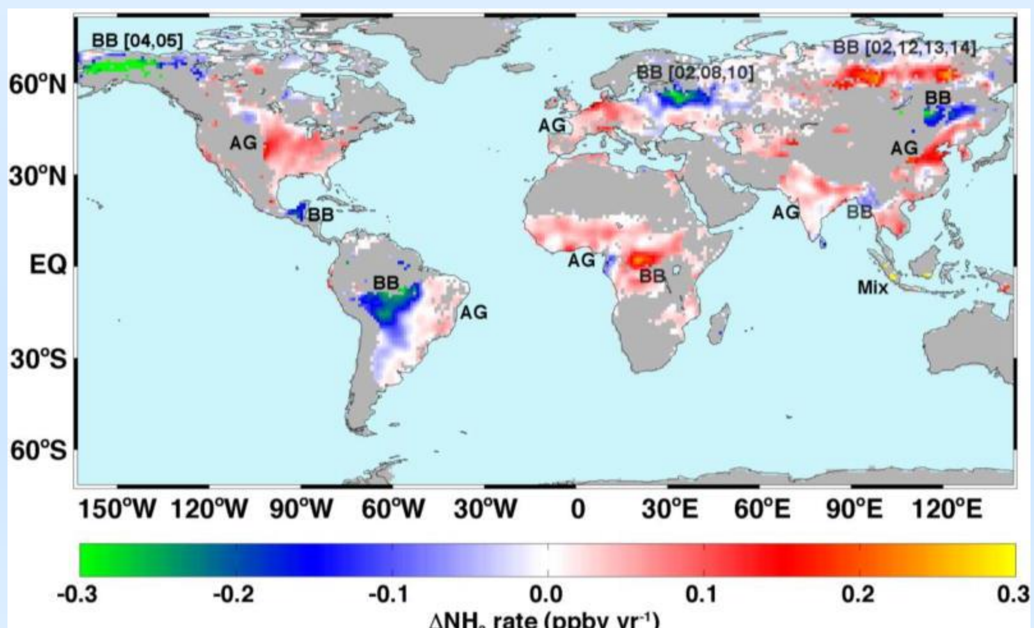
NH_3 Ammonia

Synthetic nitrogen fertilizer rates (kg N/ha) in global croplands for year 2015



Source: Houlton et al., 2019

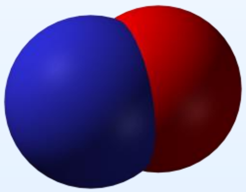
Temporal trends of NH_3 concentration (between 2002 and 2013).
AG: Agriculture
BB: Biomass burning



Source: Warner et al., 2017

The global budget for NH_3 ~53 Tg N/yr

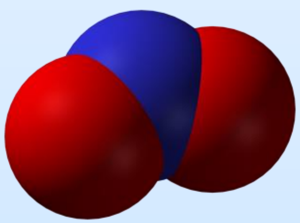
Global NO_x emissions



NO

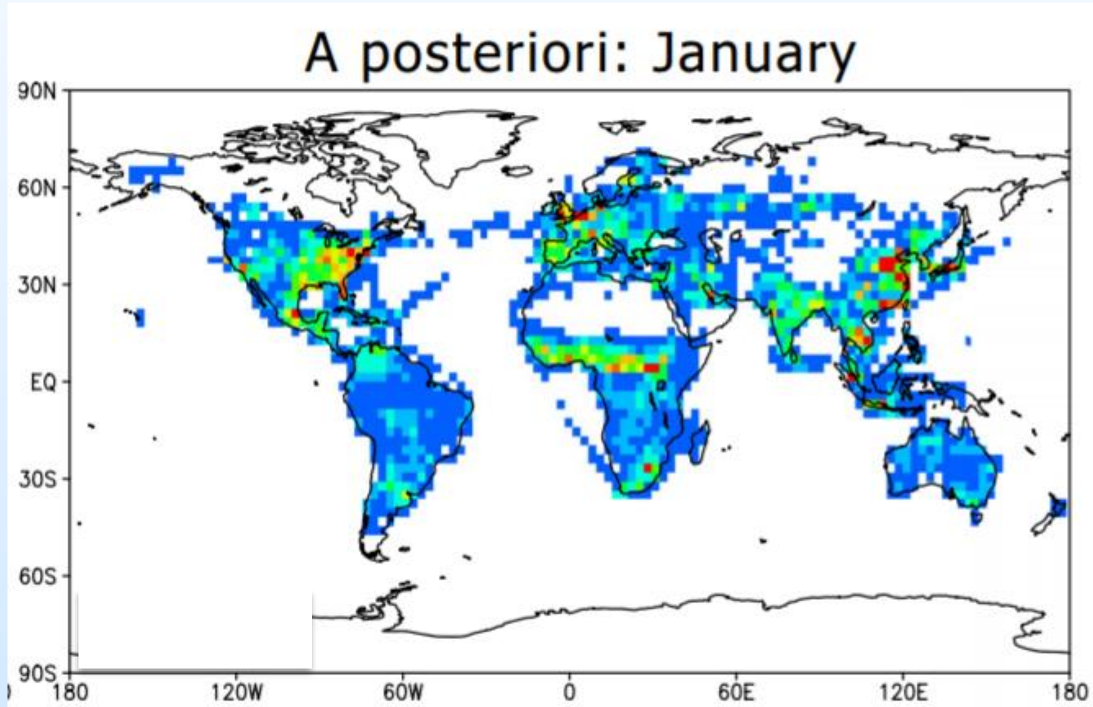
Nitric oxide

NO_x



NO_2

Nitrogen dioxide



Global distributions of the surface NO_x emissions (in kg m^{-2} s^{-1}) derived from an assimilation of OMI tropospheric NO_2 columns

The global budget for NO_x ~53 Tg N/yr

Source: Miyazaki et al, 2012

Objectives

- Develop statistical models to predict Nr emissions and deposition from agricultural soils based on the physical-chemical properties
- Analyze the spatial distribution of global Nr emissions from agricultural soil
- Compare and contrast the results (both global and regional) with other model framework emission inventories

3. Methodology

Literature Reviews

- Identify important factors controlling Nr production in soil
- Gather relevant data from literatures

R-Studio

- Statistical summary of collected data
- Fit data with appropriate regression model with Nr emission as the response and other relevant factors as predictors
- Model diagnostic

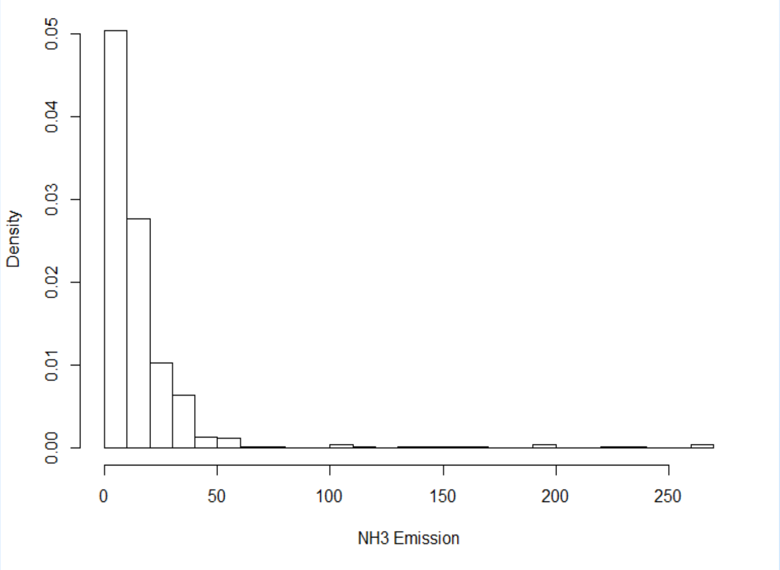
ILWIS 3.31 (GIS)

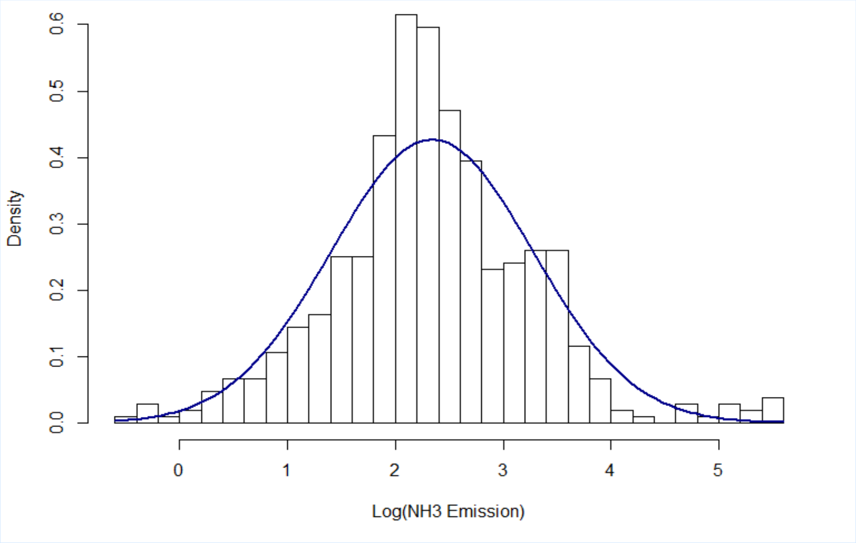
- Global dataset preparation
- Map calculation: apply the model to predict the Nr emissions

Methodology – Statistical Model development

e.g. NH_3_STAT

Right skewed → **Normal distribution**





Statistical Models Based Observations

- N_2O_STAT

$$N_2O\ emission = (\exp[1.34 + 0.03 \times T_{soil} + 0.02 \times SM - 0.35 \times pH_{soil} + 0.0003 \times N\ input + 0.46 \times Fertilizer\ type]) \times \frac{28}{44}$$

- NH_3_STAT

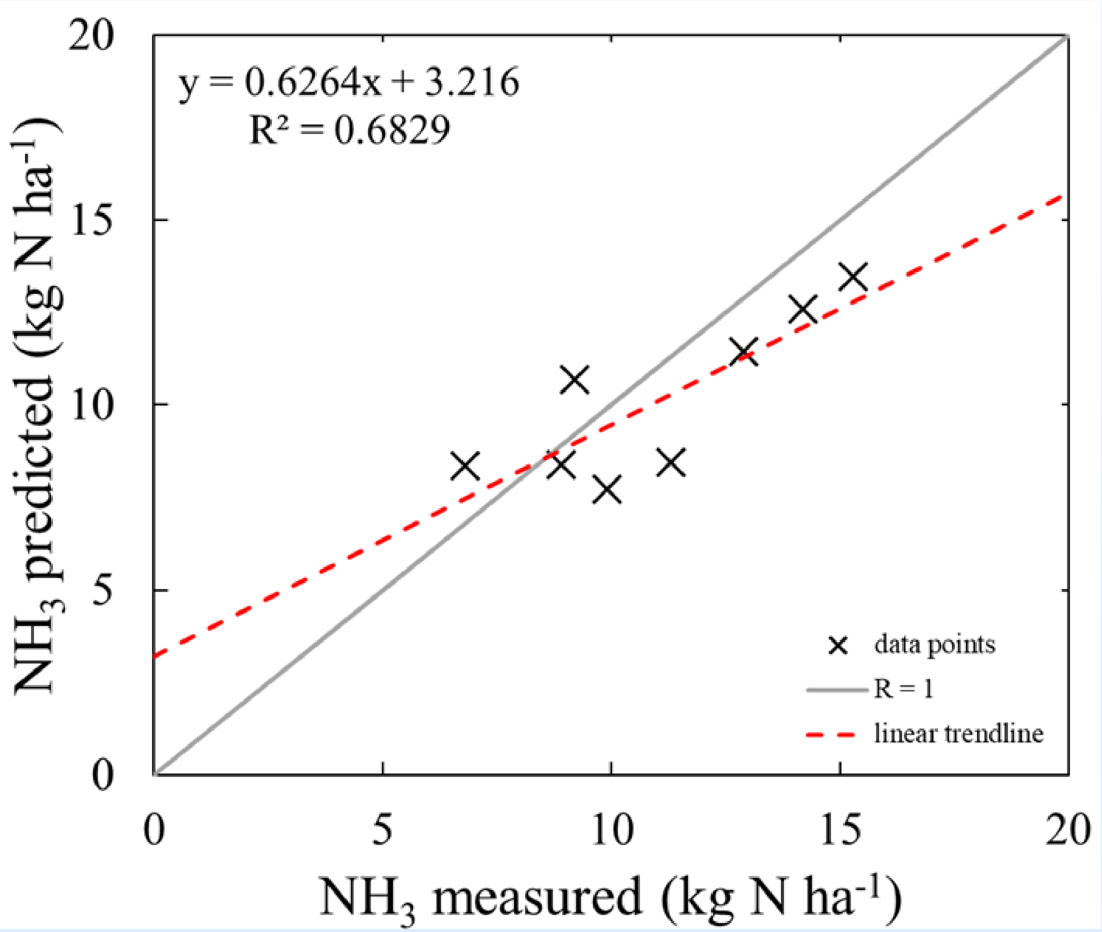
$$NH3\ emission = (\exp[-4.6 + 0.02 \times T_{soil} + 0.01 \times SM + 0.09 \times pH_{soil} + 1.2 \times \log(N\ input) + 0.5 \times Fertilizer\ type]) \times \frac{14}{17}$$

- NO_x_STAT

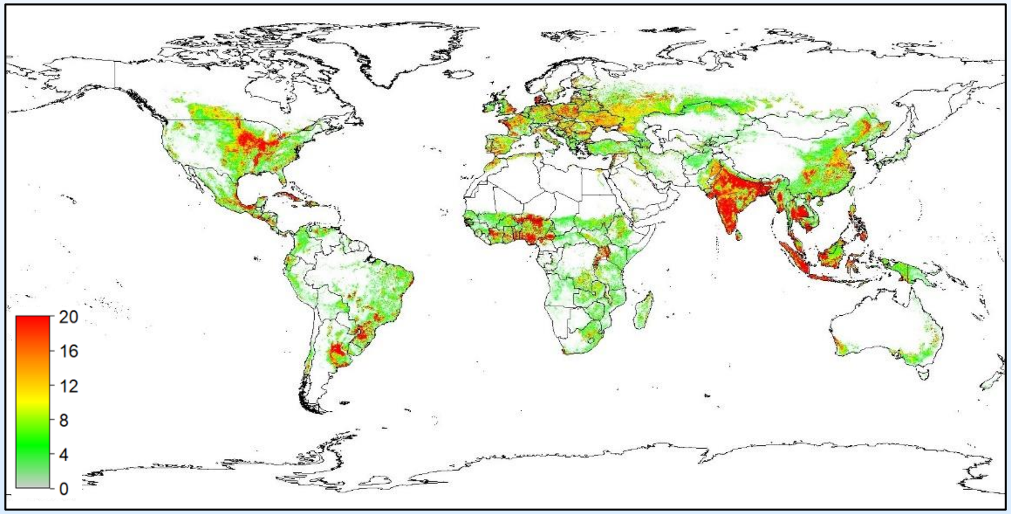
$$NOx\ emission = (\exp[-6.2 + 0.02 \times T_{soil} + 0.02 \times SM - 0.13 \times pH_{soil} + 1.2 \times \log(N\ input) - 0.07 \times Fertilizer\ type]) \times \frac{14}{30}$$

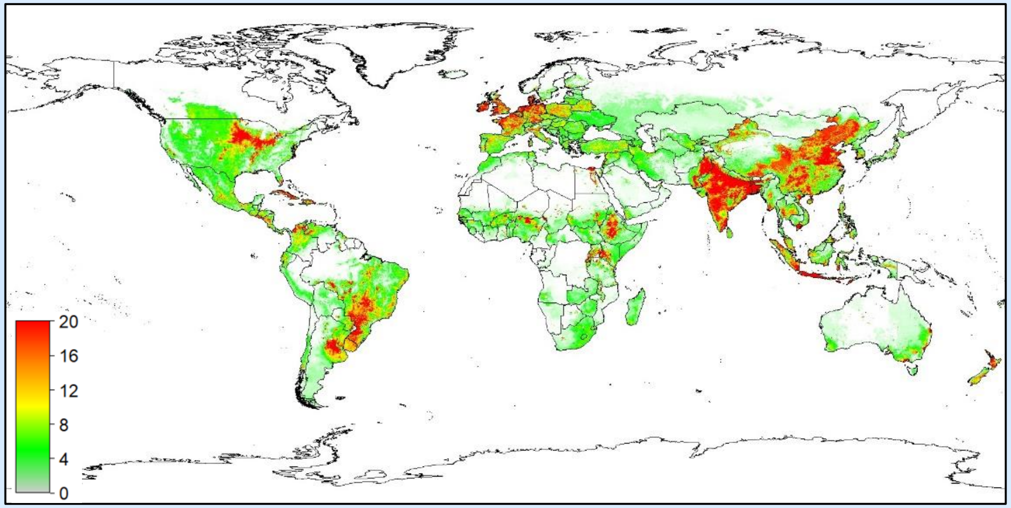
Tsoil refers to soil temperature (° C), SM soil moisture (%), N input is differentiated by synthetic (0) or organic fertilizer (1), and is expressed as kg N ha-1 yr-1. The units for predicted emission are kg N ha-1 yr-1.

Model validation for NH3_STAT against NH_3 emissions from field experiments



N_2O Results – Global



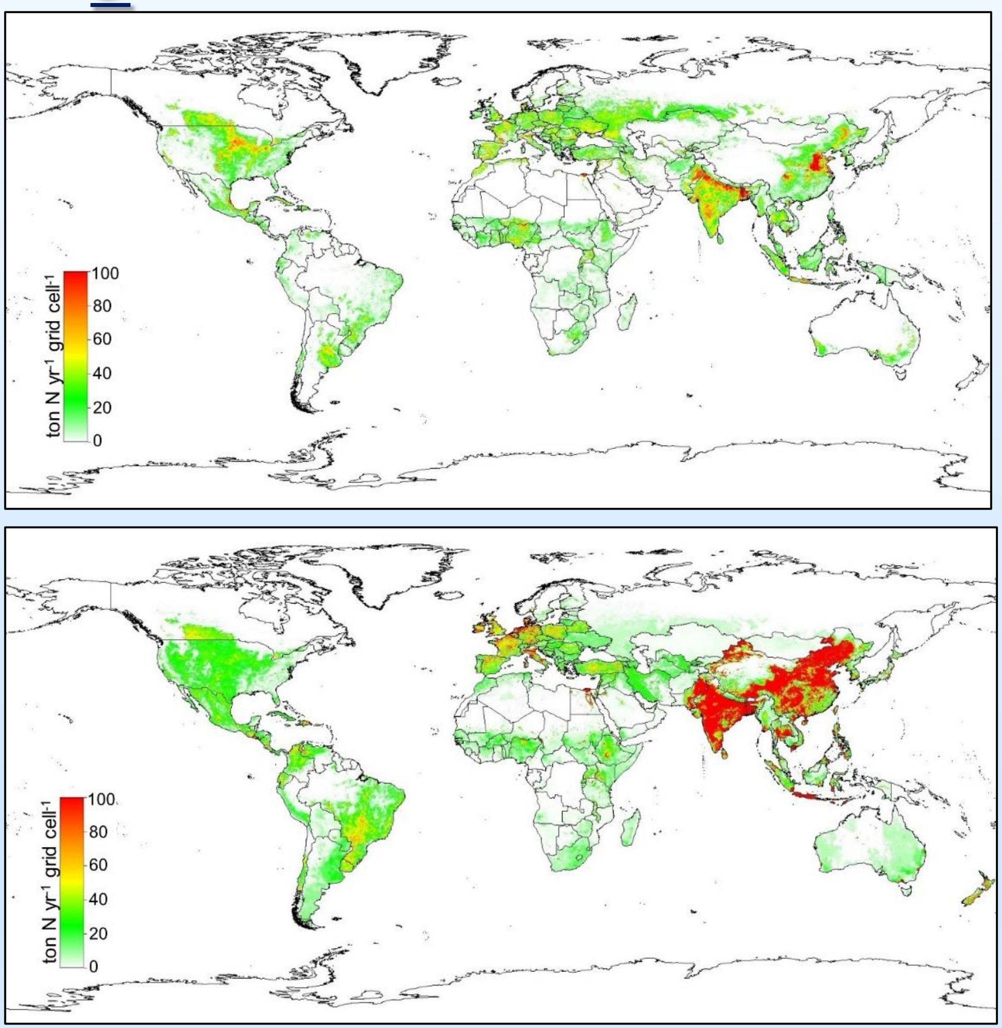


- **Total annual global N_2O emission from agricultural soil**

This study: 3.75 Tg/year

EDGAR 2012: 4.49 Tg/year

NH_3 Results – Global

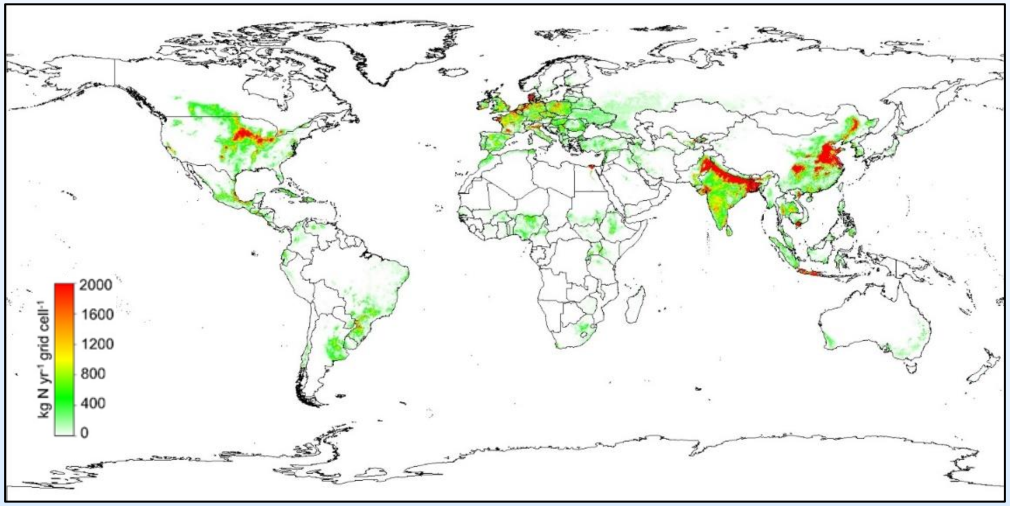


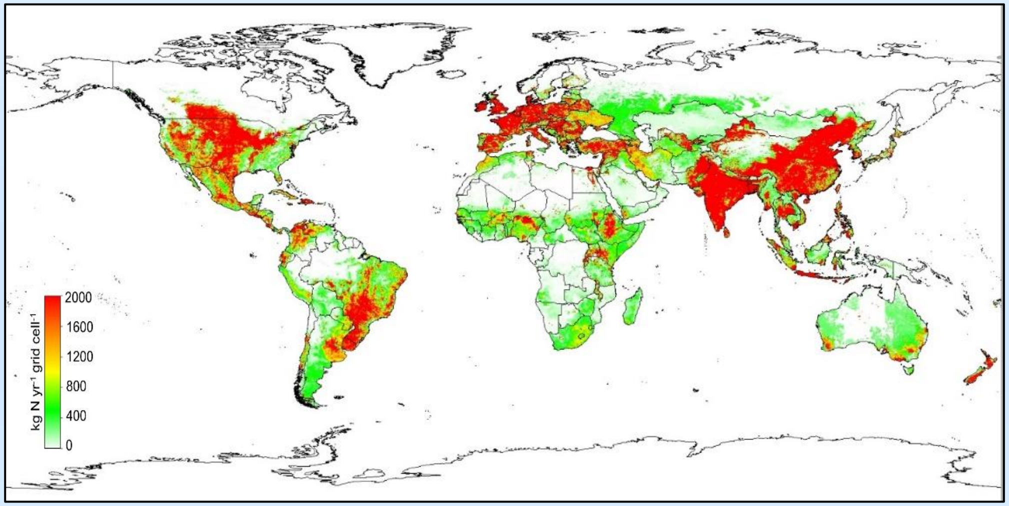
- **Total annual global NH_3 emission from agricultural soil**

This study: 13.9 Tg/year

EDGAR 2012: 33.0 Tg/year

NO_x Results – Global



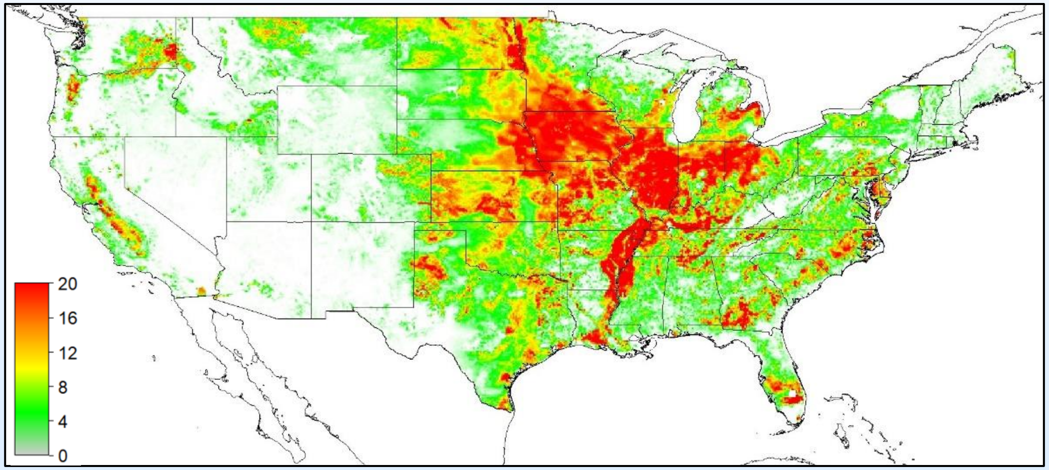


- **Total annual NO emission from agricultural soil**

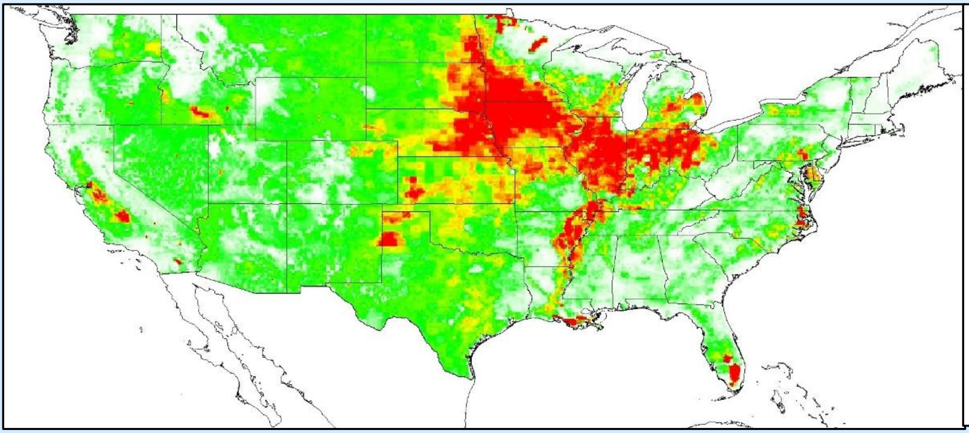
This study: 0.2 Tg/year

EDGAR 2012: 1.6 Tg/year

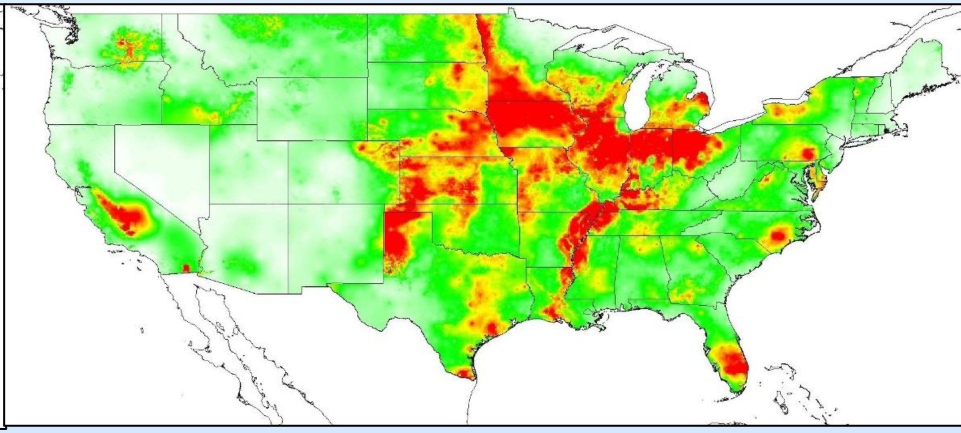
N_2O Results – Regional (US)



N_2O_STAT: 0.35 Tg N yr-1,



EDGAR: 0.43 Tg N yr-1



EPA/USGS: 0.46 Tg N yr-1

Conclusions

- Three statistical models are developed, using only observations, for characterizing atmospheric Nr emissions from agricultural soils.

- Statistical models capture the spatial distribution of global Nr emissions by utilizing an observation-based approach, rather than emission factor and activity approach or inverse modeling approach.

Conclusions

- EDGAR has additional sources in their estimate, whereas our model is exclusive to emissions from fertilizer and manure applied as fertilizer.
- Data sets lies in the methodology of collecting the model inputs
- These statistical models only considers physicochemical variables of the emissions, excluding the soil management practices that might contribute to the emissions.
- Soil biological activity that represent the processes governing the Nr emissions was not included in the model
- Deposition analysis of Nr is currently in progress.

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- *The 3rd International Electronic Conference on Atmospheric Sciences*

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