Global and regional emissions estimates for N_2O

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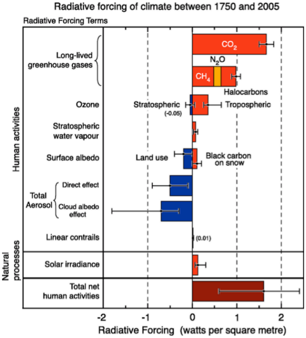
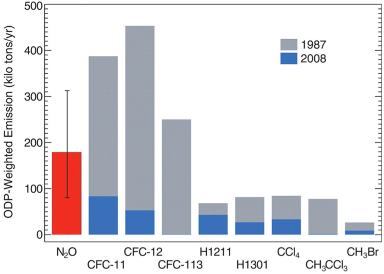
Importance of N_2O

- Major Greenhouse Gas
  - Global Warming Potential: 296
- Becoming a major Ozone-Depleting Substance

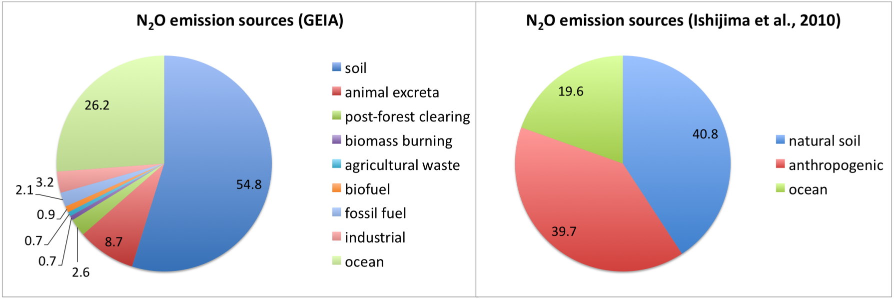




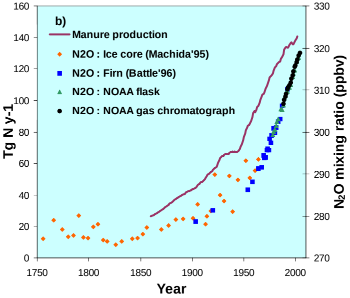
Source IPCC AR4; Ravishankara et al., 2009

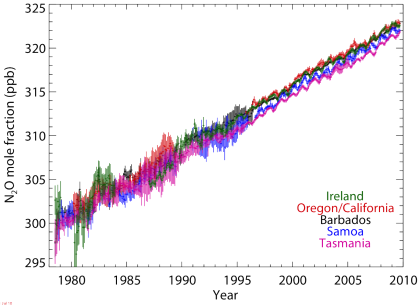
Source and Magnitude of N_2O Emissions

- Large Natural Sources (Soil + Ocean)
- Global Total: 15-20 TgN_2O-N $year^{-1}$



N_2O Mixing Ratio Increasing





Source: Holland et al., 2005; Advanced Global Atmospheric Gases Experiment

Research Questions

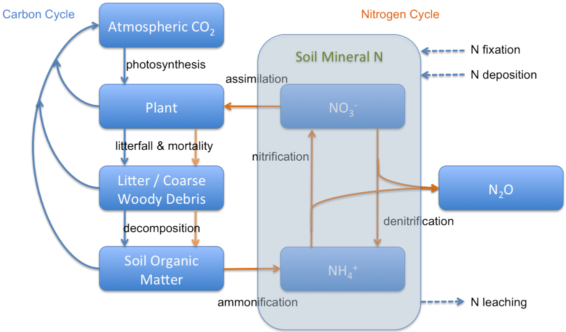
- What are the magnitudes and sources of N_2O emissions?
- Do top-down emissions estimates differ from bottom-up?

Research Overview

- Create bottom-up emissions estimates for natural soil & ocean
- Combine emissions inventories to create prior emissions
- Use observations to constrain emissions (top-down)
- Compare with other emissions estimates

Process Modeling of N_2O using CLM-CN v3.5

- Community Land Model with prognostic Carbon and Nitrogen
- Includes DeNitrification-DeCoposition (DNDC) Model
- 1.9° latitude and 2.5° longitude horizontal resolution

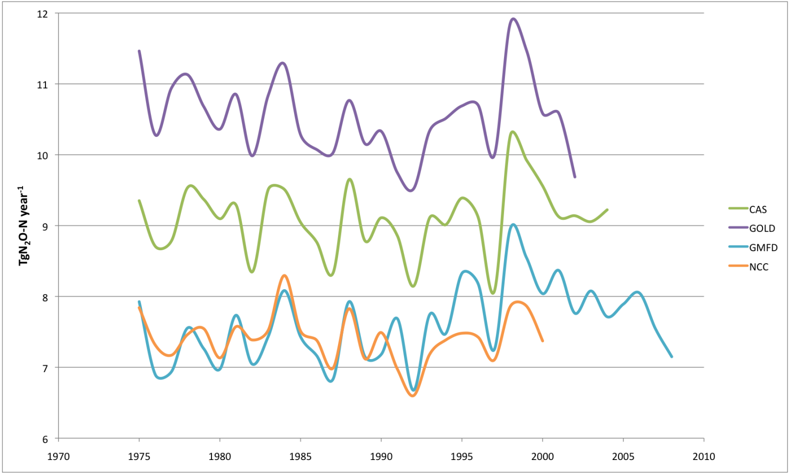


Source: Li et al., 1992; Thornton et al., 2009

CLMCN-N_2O

- Analyzed years 1975-2008.
- Nitrogen deposition is taken from the Community Atmosphere Model (CAM) for the year 2000.
- 4 forcing datasets are used:
  - NCEP Corrected by CRU (NCC)
  - Climate Analysis Section (CAS)
  - Global Offline Land-Surface Dataset (GOLD)
  - Global Meteorological Forcing Dataset (GMFD)

Global Natural Soil N_2O Emissions - Prior

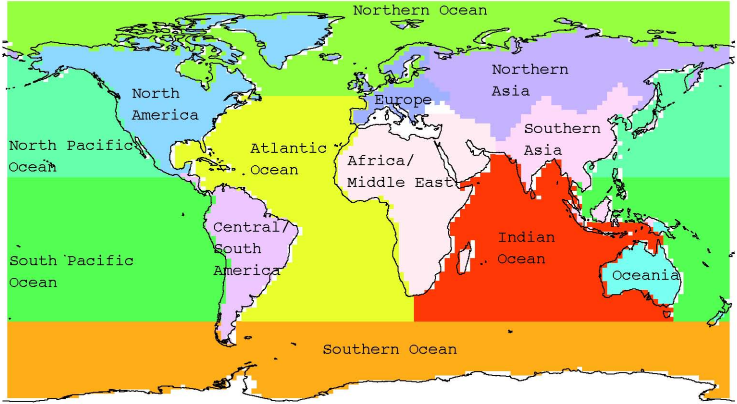


Prior emissions

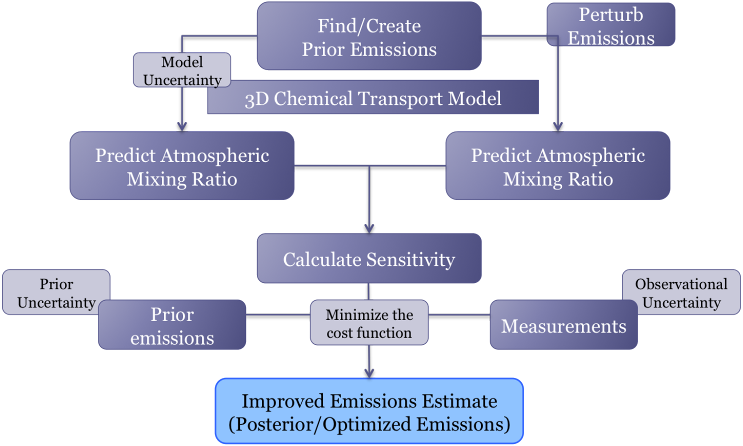
- Natural Soil - CLMCN-N_2O process model
- Ocean - process model by Manfredi Manizza
- Agricultural Soil - EDGARv4.1
- Industrial - EDGARv4.1
- Biomass Burning - GFEDv3

Regions

- 7 regions for land (4 sectors) and 6 regions for ocean



Inverse Modeling Framework



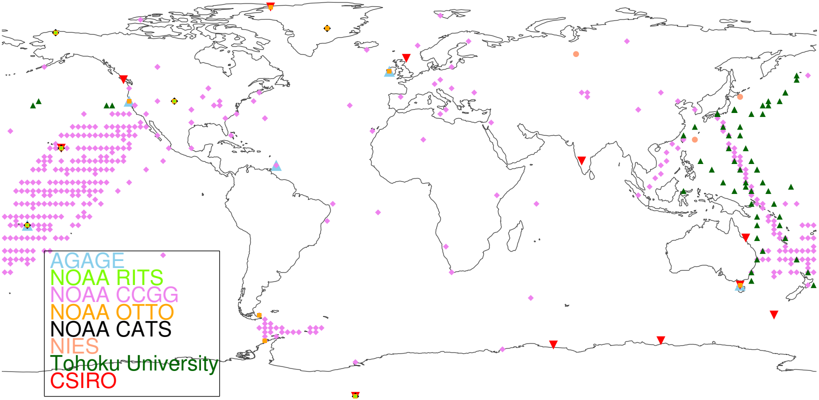
Inverse modeling of N_2O

Global 3-dimensional chemical transport model MOZART v4

- Annual regional emissions 1995 - 2008 for the 5 sectors:
  - agricultural soil, natural soil, industrial, ocean, and biomass burning
- 1.9° latitude x 2.5° longitude
- 56 vertical levels
- meteorological field: MERRA
- Bayesian weighted least-squares:
- Minimizing the cost function:

$$J = (y - Hx)^T W^{-1} (y - Hx) + x^T S^{-1} x \qquad (1)$$

Observations



Calibration among different networks & uncertainty

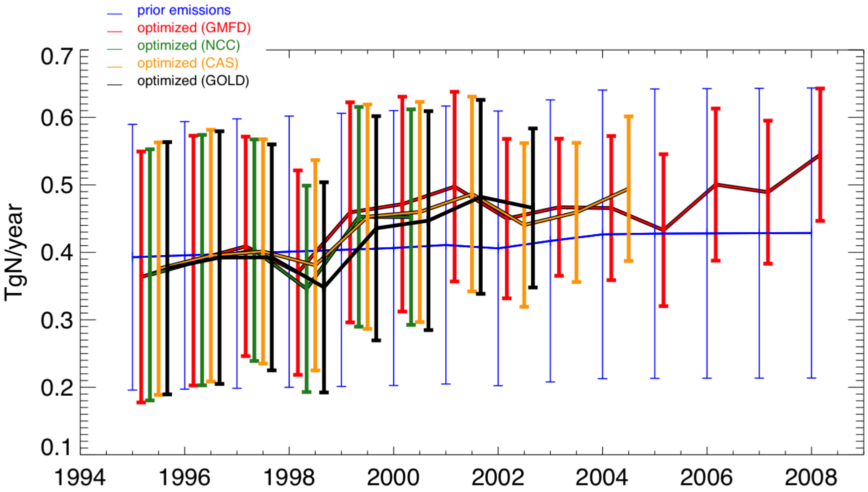
Network	Calibration ratio to AGAGE	measurement error	scale propagation error
AGAGE	1	0.1%	0.012%
NOAA CCGG	0.9994	0.1%	0.07%
NOAA OTTO&RITS&CATS	1.0009*	0.2%	0.07%
NIES	0.9990	0.2%	0.03%
CSIRO	0.9989	0.2%	0.016%
Tohoku University	1.001	0.3% before 2002 and 0.1% since 2002	0.03%

* Offset values are applied to NOAA OTTO network measurements (1.3ppb at SMO and 0.6ppb elsewhere).

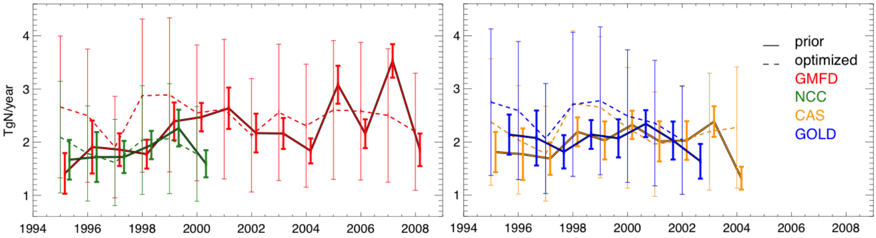
Measurement-model uncertainty:

$$\sigma^2 = \sigma^2_{measurement} + \sigma^2_{scalepropagation} + \sigma^2_{samplingfrequency} + \sigma^2_{mismatch} \quad (2)$$

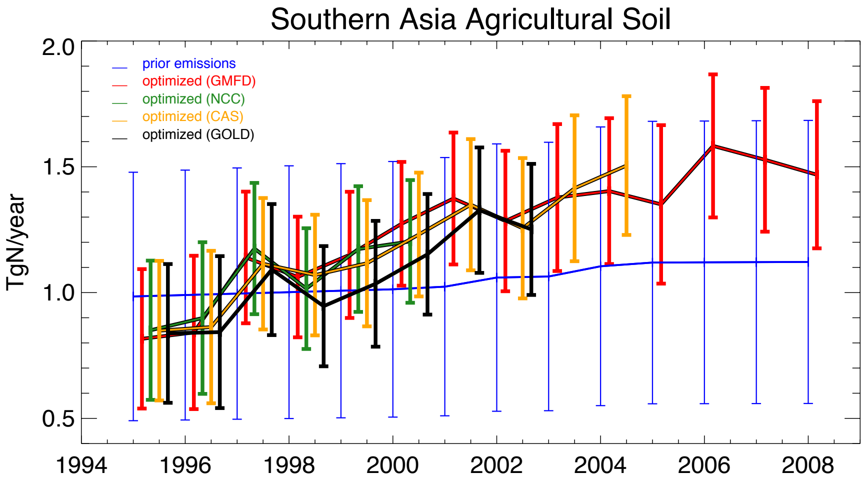
Agricultural soil emissions in North America (Tg year^{-1})



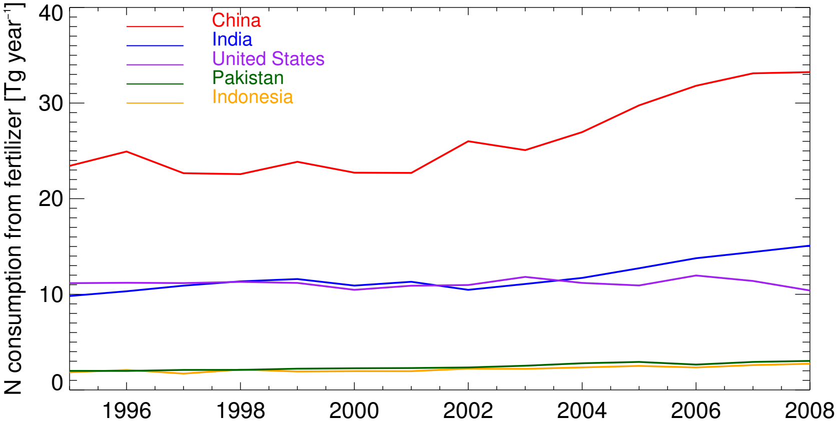
Natural soil in Southern Asia (Tg year^{-1})



Largest growth in the recent years?



Nitrogen fertilizer growth



Comparison with regional estimates (TgN_2O-N $year^{-1}$)

- North America
  - 0.96-1.40 (our estimates for 2004-2008)
  - 2.7 (Kort et al., 2012 for 2007-2009)
  - 5.9-8.0% of total N_2O (our estimates for 2004-2008)
  - 12-15% of total N_2O (Miller et al., 2012 for 2004-2008)
- Europe
  - 0.58-1.04 (our estimate for 1995-2000)
  - 0.84-0.88 (Manning et al., 2003 for 1995-2000)
  - 0.75-0.95 (our estimate for 2006)
  - 0.76 (Corazza et al., 2011 for 2006)
- Asia
  - 0.70-0.94 (our estimate for agricultural soil for 1995)
  - 1.19 (Yan et al., 2003 for agricultural emissions for 1995)

Comparison with global estimates (TgN_2O-N $year^{-1}$)

- Global land
  - 16.39-17.81 (our estimates for 1998-2001)
  - 15.2-20.4 (Hirsch et al., 2006 for 1998-2001)
- Global ocean
  - 4.45-5.31 (our estimate for 1995-2008)
  - 0.90-1.7 (Rhee et al., 2009)
  - 1.2-6.8 (Nevison et al., 1995)
  - 3.8 (Suntharalingam and Sarmiento, 2006)
  - 4.5 (Manizza et al., 2012)
  - 4.5-6.4 (Hirsch et al., 2006)
  - 5.8-7.8 (Nevison et al., 2003)

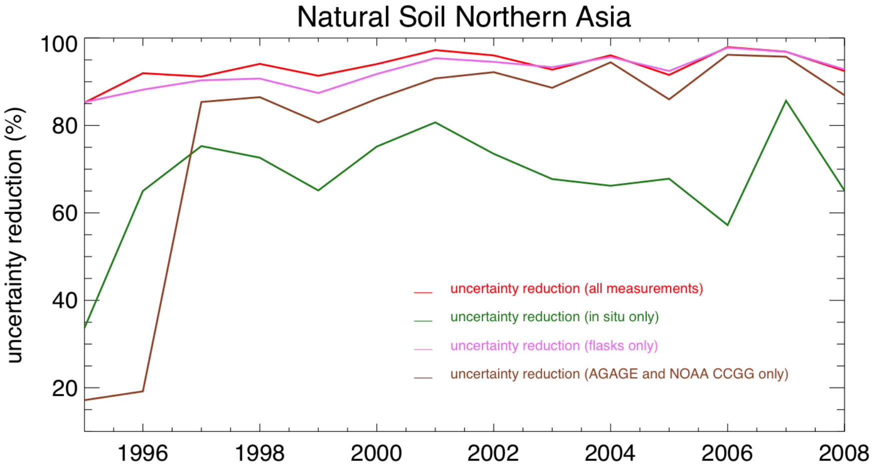
Comparison with global estimates (TgN_2O-N year^{-1})

- Global total
  - 16.28-17.76 (our estimate for 1997-2001)
  - 15.1-17.8 (Huang et al., 2008 for 1997-2001)
  - 17.31-18.69 (our estimate for 2002-2005)
  - 14.1-17.1 (Huang et al., 2008 for 2002-2005)
  - 16.39-17.81 (our estimate for 1998-2001)
  - 15.2-20.4 (Hirsch et al., 2006 for 1998-2001)

Our global total: ODP-weighted emissions of 0.48Mt CFC-11e

- larger than the sum of the ODS emissions of those controlled by the Montreal Protocol (app. 0.45Mt)

Sensitivity Analysis



Conclusion

- We inserted an N_2O module into CLMCNv3.5 and quantified natural soil N_2O emissions between 1975-2008.
- We optimized annual N_2O emissions for 5 sources and 13 regions between 1995-2008 using observations.
- Some influence of ENSO is seen on soil emissions.
- Asian agriculture is the largest increasing emission source for N_2O in the recent years.

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