Nitrous oxide ($N_2O$) emissions estimated with the Carbon Tracker Lagrange North American regional inversion framework

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Nitrous Oxide ($N_2O$)

- Natural, long-lived GHG increasing at about 0.3%/yr in the atmosphere
- Responsible for 6% of anthropogenic radiative forcing (GWP ~ 300)
- Produced mainly by microbial cycling of nitrogen at Earth’s surface and destroyed photochemically in the stratosphere
Motivations

1) Characterize North American $N_2O$ emissions.

2) Examine role of agriculture.
Carbon Tracker Lagrange
Regional inverse modeling framework

- Jan-Dec 2012, 24-hour time step
- North America 1°x1° (10°-80°N, 170°-50°W)
- Ground and aircraft data from NOAA GGGRN (n =7,281)
- $H$ matrix from STILT particle back trajectories

$$L_s = 0.5 \cdot (z - Hs)^T R^{-1} (z - Hs) + 0.5 \cdot (s - s_p)^T Q^{-1} (s - s_p)$$

$s_p =$ prior fluxes. Solve for optimal flux vector $s$  
$z =$ vector of observations – background
NOAA Empirical Background Product

(Arlyn Andrews et al.)

Anomalies after subtracting MLO data

75°-85°N

65°-75°N

55°-65°N

45°-55°N

35°-45°N

25°-35°N

Anomalies after subtracting MLO data
NOAA data compared to Empirical Background

Alaska

2012 brw v Empirical Background

Day of Year

ppb

Iowa

2012 wbi v Empirical Background

Day of Year

ppb
Large Excursions above Background

Iowa (WBI)

Indiana (INX)

Texas (WKT)
Posterior Annual Mean Results: 3 different priors

Saikawa Global Inversion  10% of N Fertilizer  Flat Prior
Crop Area
Maximum N\textsubscript{2}O Flux in Springtime

![Graph showing CTL N\textsubscript{2}O Flux 2012 Midwest 37-44N Corn/Soybean Belt with different flux models: Saikawa prior, Saikawa post, Saikawa post, tight prior, EDGAR prior, EDGAR post. The graph plots N\textsubscript{2}O Flux TgN/yr against Day.]
If $\text{N}_2\text{O}$ all came from N Fertilizer, what would the emission fraction be?

- $\sim 8\%$
- $\sim 20\%$
- $\sim 11\%$
- $\sim 10\%$
- $4-5\%$

Fertilizer Map from University of Wisconsin
N Fertilizer Consumption

Data from FAOSTAT
United States Crop Area

- Wheat: 18%
- Corn: 34%
- Soybeans: 30%
- Cereals, Other: 6%
- Roots and Tubers: 0%
- Fruit & Vegetables: 2%
- Cereals, Other: 6%
- Pulses: 1%
- Oilcrops, Other: 5%
- Nuts: 1%
- Cotton: 3%
- Pulses: 1%
- Oilcrops, Other: 5%
- Nuts: 1%

2013 data from FAOSTAT
“It is a cruel irony that people in rural Iowa can be malnourished amid forests of cornstalks running to the horizon. Iowa dirt is some of the richest in the nation ...”
Conclusions

1. North American $\text{N}_2\text{O}$ emissions, according to CTL inversion, are $1.4 \pm 0.3 \text{ Tg N/yr}$.

2. More than half of these emissions come from the Central U.S. ($105^\circ\text{-}80^\circ\text{W}$), with about $0.35 \pm 0.03 \text{ Tg N/yr}$ from the corn/soybean belt.
Anthropogenic $\text{N}_2\text{O}$ source is relatively well constrained by observed growth rate and the known stratospheric sink

<table>
<thead>
<tr>
<th></th>
<th>Global Anthropogenic $\text{N}_2\text{O}$ source Tg N/yr</th>
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</thead>
<tbody>
<tr>
<td>Box Model (top-down)</td>
<td>~ 6</td>
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<tr>
<td>EDGAR (bottom up inventory)</td>
<td>7</td>
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</tbody>
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Prior vs. posterior fit to observations at individual sites

- Iowa (WBI)
- Texas (WKT)
- California (WGC)