Top-down constraints on global N$_2$O emissions at optimal resolution

N$_2$O Lifetime: ~127 years

Soils [10$^7$ molec cm$^{-2}$ s$^{-1}$]

- 11.0 Tg N
  - EDGARv2 + Saikawa et al. (2013)

- 2.3 Tg N
  - EDGARv2

Industrial [10$^7$ molec cm$^{-2}$ s$^{-1}$]

Biomass Burning [10$^7$ molec cm$^{-2}$ s$^{-1}$]

- 0.6 Tg N
  - EDGARv2

Ocean [10$^7$ molec cm$^{-2}$ s$^{-1}$]

- 3.5 Tg N

2011 a priori flux = 17.4 Tg N

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IGC8, 2 May 2017

NOAA AC4
N$_2$O inversion system: April 2010-April 2012

\[ J(x) = (H(x) - y)^T S_y^{-1} (H(x) - y) + (x - x_a)^T S_a^{-1} (x - x_a) \]
x = Total land and ocean emissions, monthly resolution

Three inversion frameworks:
1. **Standard**: BFGS 4D-Var inversion at grid box scale ($4^\circ \times 5^\circ$)
   - [40 iterations]
2. **Continental-scale**: BFGS 4D-Var inversion on aggregated regions
   - [6 continental, 3 ocean bands]
3. **SVD-based**: BFGS inversion on optimal subspace
   - [100 moments]

Surface flask and hourly obs

- How do different inversion frameworks resolve the spatial-temporal distribution of N$_2$O emissions?
- What do the results tell us about the global N$_2$O budget and underlying emission processes?
Three inversion frameworks for $\text{N}_2\text{O}$

- **Standard inversion**
  - Utilizes existing framework in adjoint
  - More free variables than DOFs
  - $72 \times 46 \times 24 = 79,488$ elements
  - Slow ($100+$ hours)
  - Can be solved analytically
  - Subject to aggregation error
  - Regions determined in an ad hoc way
  - Does not maximize DOFs of inversion

- **Continental-scale inversion**
  - Can be solved analytically
  - Based on information content of inversion
  - Maximizes DOFs, minimizes noise
  - Parallel implementation = fast (~5 hours)

- **SVD-based inversion**
  - (Bousserez and Henze, in revision, QJRMS)
Comparison with HIPPO aircraft data shows reduction of bias in Northern Hemisphere

HIPPO V: 9 Aug – 9 Sept 2011

Kort, Wofsy et al.
Annual global flux well-represented, N$_2$O emissions increased in Tropics, reduced or unchanged at midlatitudes

2011 A priori emissions

2011 Standard emissions

2011 Continental-scale emissions

2011 SVD-based emissions

17.4 Tg N

17.7 Tg N

17.5 Tg N

17.9 Tg N
Annual global flux well-represented, N₂O emissions increased in Tropics, reduced or unchanged at midlatitudes.
Annual global flux well-represented, N\textsubscript{2}O emissions increased in Tropics, reduced or unchanged at midlatitudes.
Annual global flux well-represented, N$_2$O emissions increased in Tropics, reduced or unchanged at midlatitudes

2011 A priori emissions

2011 Standard emissions

2011 SVD-based emissions

Increase in S. America, but observational constraints low
Seasonality of $\text{N}_2\text{O}$ emissions shifts toward earlier spring peak in Northern Hemisphere

Consistent with the timing of emissions associated with:
- Soil thawing/snow melt
- Fertilizer application
- Leaching and runoff