Estimating North American methane emissions with high spatial resolution using GOSAT

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Observing methane from low Earth orbit

Satellites Observing Methane:

- Thermal IR: AIRS, TES, IASI, CrIS
- Shortwave IR: SCIAMACHY, GOSAT, TROPOMI


Map showing methane concentrations and other data.
Prior methane emissions from EDGARv4.2 + LPJ

Major Sources (Tg a\(^{-1}\))

- Wetlands
- Livestock
- Oil/Gas
- Landfills
- Coal

Total: 63.3 Tg a\(^{-1}\)

GEOS-Chem CTM & Adjoint

\(\frac{1}{2}^\circ \times \frac{1}{2}^\circ\) North American grid


Posterior methane emissions
Balancing aggregation and smoothing error

Spatial error correlations are important at fine spatial scales!

Posterior error depends on choice of state vector dimension

Optimal size must balance aggregation and smoothing error

Native resolution \( \frac{1}{2}^\circ \times \frac{2}{3}^\circ \)

State vector \( x \) (\( n = 7366 \))

Reduced-resolution state vector \( x_\omega \) (here \( n = 8 \))

Aggregation Matrix: \( \Gamma_\omega \)

\[
x_\omega = \Gamma_\omega x
\]

Choose \( n = 369 \) for negligible aggregation error; allows analytical inversion with full error characterization
Radial Basis Functions retain high resolution

- Decompose the state vector into Gaussians
  - Group based on correlated prior emission patterns

- Retain high resolution
  - Coarsen weak or uniform signals
Global inversion provides dynamic BCs for North America
Constraining North American methane sources

**Total:** 91.3 Tg a\(^{-1}\)

**Posterior Methane Emissions** (nmol m\(^{-2}\) s\(^{-1}\))

**Emission Scaling Factors (Posterior / Prior)**

\(\Delta CH_4: +27.9\) Tg a\(^{-1}\)

**Posterior**
- \(y = -60 + 1.03x\) \((R^2 = 0.48)\)
- \(y = 125 + 0.94x\) \((R^2 = 0.61)\)
- \(y = -4 + 1.01x\) \((R^2 = 0.67)\)

**Prior**
- \(y = 516 + 0.72x\) \((R^2 = 0.40)\)
- \(y = 468 + 0.75x\) \((R^2 = 0.54)\)
- \(y = 605 + 0.67x\) \((R^2 = 0.60)\)
US methane emissions and source attribution

- US emissions are a factor of 1.5 larger than the US EPA
- Livestock + Oil/Gas are the largest underestimated sources
