Estimating regional CH$_4$ fluxes using GOSAT XCH$_4$ observations.

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Data: UoL GOSAT

★ Greenhouse gases Observing SATellite: launched January 23, 2009
★ Data from June 2009 – December 2011
★ OCO Full Physics Optimal Estimation algorithm
★ CO2 retrieval (full physics):
  • simultaneously fits: 0.76 μm O2 A band, the 1.61 μm and the 2.06 μm CO2 bands
★ CH4 retrieval (CH4/CO2 proxy):
  • Fit to CO2 band at 1.61μm and 1.65μm CH4 band
  • \[ X_{CH_4, \text{proxy}} = \left( \frac{X_{CH_4}}{X_{CO_2}} \right)_{GOSAT} \times X_{CO_2, \text{model}} \]
  • CO2 model is either CarbonTracker (Peters et al., 2007) or GEOS-Chem (Feng et al, 2011) (Both have assimilated surface data.)
Model: GEOS-Chem

★ GEOS-Chem is a 3D chemical transport model, driven by assimilated meteorological fields (GEOS v5.2)
★ Resolution of 4 lat x 5 lon x 47 vertical levels
★ Emissions from global inventories
  • Anthropogenic: EDGAR 3.2FT
  • Biomass burning: GFEDv3.0
  • Wetlands and rice: Bloom et al., 2012
★ Tropospheric OH sink: monthly mean 3D fields

CH4 surface flask measurements 2009-2010

Palmer and Bloom, 2010
In a Kalman filter, the analysis is given by:

\[ x^a = x^f + K \left[ y_{obs} - H(x^f) \right] \]

In our case:

\[ x^a = x^f + K \left( y_{obs} - H(x^f) \right) \]

New emissions: Prior emissions

GEOS-Chem, averaging kernels

GOSAT data

Kalman Gain (weighting function)
EnKF for methane

★ We assimilate XCH4 proxy GOSAT and ESRL and GASLab surface flask CH4 data (57 sites) filtered for:
  • fit quality
  • clouds
  • only H-gain
  • no observations poleward of 60°
★★ Five inversions: surface only, GOSAT only (x2 proxies), GOSAT and surface data (x2 proxies)
★★ Inversion performed on monthly time intervals, for 13 regions taken from Transcom regions (11 land + ice + oceans)
★★ Land regions are further divided into 9 source categories
★★ Prior errors of 50% for the seasonally varying emissions and 25% for the other emissions
★★ We fit a latitudinally-varying bias

\[\text{ESRL sites} \quad \text{GASLab sites}\]
Effect of GOSAT data

\[ \gamma = \left[ 1 - \frac{\text{error}}{\text{error}_0} \right] \times 100\% \]
CH4 (Tg/year)

γ = \left[1 - \frac{\text{error}}{\text{error}}\right] \times 100\%

GOSATv4 GC+surface

prior surface only

GOSATv3 GC+surface

GOSATv4 GC+surface

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South Africa

- **AOD filter:**
  - Filter data where ACOS AOD retrieval > 0.15
- **Three month lag:**
  - Allow fluxes to be affected up to three months after the observation
- **Three regions:**
  - Divide South Africa into three regions latitudinally and perform the inversion
- **OSSEs** show that this region can be problematic for the EnKF
Information content metric

$$\eta = \frac{\text{obs}_{cs}}{\text{obs}_p} \div \frac{\sigma_{region}}{\sigma_{total}}$$

St. dev. of flux within region in month
St. dev. of flux over study period

clear-sky obs possibel obs
Comparisons to independent data

Observations
Prior model
Posterior model (GOSATv3 + surface)

Fraser et al., ACP, 2013
Summary

★ We are assimilating GOSAT XCH4 and XCO2 data with GEOS-Chem using an ensemble Kalman filter

★ Error reductions for inversions using the GOSAT data are at least twice the error reductions if only the surface data are assimilated with two exceptions:
  - In Europe, where the surface network describes fluxes on our spatial and temporal grid
  - In boreal regions, due to the satellite's orbit and a data filter

★ Posterior fluxes from GOSATv3 and v4 are consistent, with some differences that need to be further examined

★ We have defined an information content metric, to help identify regions where the inversion has difficulty

★ We see marginal improvement with independent measurements from the AGAGE and TCCON networks