Estimating global methane emissions in 2010 using a 4D-Var inverse model with GOSAT and IASI retrievals

Contact: c.wilson@leeds.ac.uk

Chris Wilson[1,2], Manuel Gloor[2], Martyn P. Chipperfield[1,2], J. McNorton[2], Hartmut Boesch[1,3], Robert Parker[1,3,], Richard Siddans[1,4], Diane Knappett[1,4]

[1]National Centre for Earth Observation, UK; [2]University of Leeds, Leeds, UK; [3]University of Leicester, Leicester, UK; [4]Rutherford Appleton Lab, Didcot, UK.

Introduction

Methane (CH_4) is an important greenhouse gas which is emitted from a range of anthropogenic and natural sources, and is responsible for around **one-fifth of the anthropogenic increase in radiative forcing** since 1750.

The geographical distribution of surface emissions of methane, along with the magnitude of the total input into the atmosphere, is currently not well constrained.. However, **top-down modelling** can used to constrain surface emission estimates through assimilation of observed concentrations.

CH_4 observation coverage has recently improved due to **multiple satellite missions** (MOPITT, SCIAMACHY, GOSAT, IASI), and we compare the results of inverse modelling using observations from two of these – GOSAT and IASI – in order to assess the impact of each dataset on posterior emission estimates.

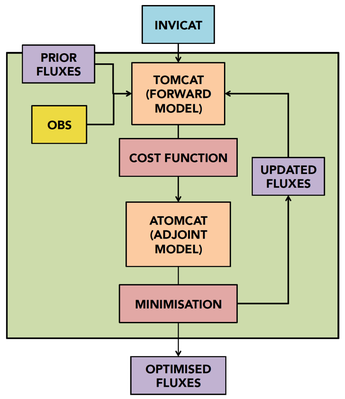

Figure 1. *Flow chart describing the iterative 4D-Variational process used by INVICAT in order to optimise surface fluxes.*

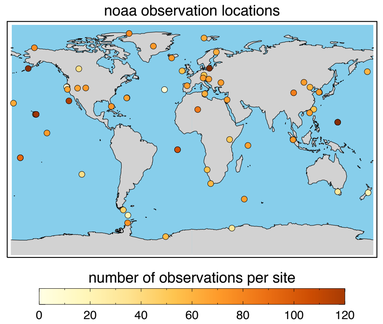

Figure 2. *Location of NOAA surface sites from which in-situ flask observations of CH_4 were assimilated into INVICAT in order to optimise surface emissions of CH_4 in 2010. Colourbar indicates number of independent observations assimilated from each location.*

Methods – Inverse Modelling

- **INVICAT is a 4D-Var inverse model** based on TOMCAT, which optimises surface fluxes of atmospheric species through assimilation of observations (see Figure 1, or Wilson et al., (2014)).
- We assimilate in-situ flask measurements of CH_4 from NOAA GMD at **58 surface sites** (see Figure 2), plus remote sensing observations made by either the **GOSAT or IASI satellite**. 20 minimisation iterations.
- **GOSAT v6 PROXY method** (from Leicester group); **IASI v3** (from RAL group). Both datasets are averaged to produce super-observations on model grid, and have averaging kernels applied to the model data.
- A priori emission errors = **100%** in each model grid cell
- Observation errors = **3ppb + representation error (3-10ppb)** for surface sites.
- **Individual monthly biases** also included in the inversion – 2nd order polynomial by latitude.

Results

- All inversions produce **increased** global emissions compared to prior.
- Surface site inversion **produces the largest increase**, significant increases during June & July, mostly in tropical regions (not shown).
- GOSAT inversion also **significantly increases** emissions, but spread more evenly throughout the year
- **Total annual emissions using IASI are similar to those from GOSAT**– although monthly variation and geographical distribution are different.

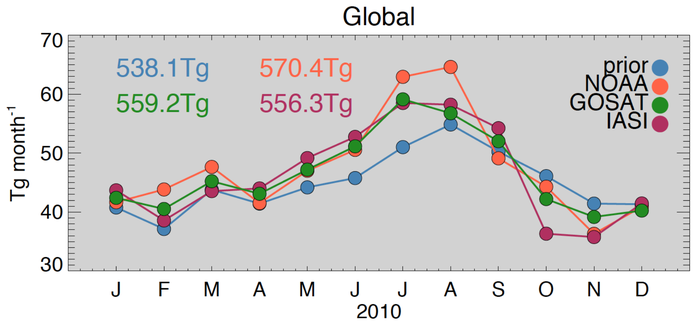

Figure 3. *Monthly global total CH_4 emissions (Tg [CH_4] month^{-1}). Prior emissions in blue. Posterior emissions from inversion using NOAA surface sites ONLY in red. Posterior emissions from inversion using NOAA sites and GOSAT measurements in green. Posterior emissions from inversion using NOAA sites and IASI observations in purple.*

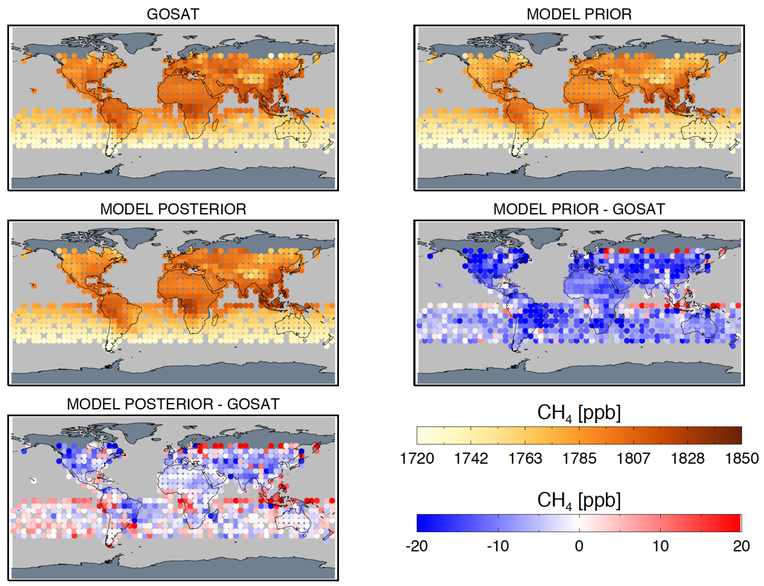

Figure 4. *(a) Column-averaged GOSAT CH_4 observations for August 2010, averaged into 'super-observations' on model grid. (b) Column-averaged simulated CH_4 concentrations using prior emissions, averaging kernels applied. (c) As (b), but with GOSAT-posterior emissions and bias applied. (d) Difference between (b) and (a). (e) Difference between (c) and (a).*

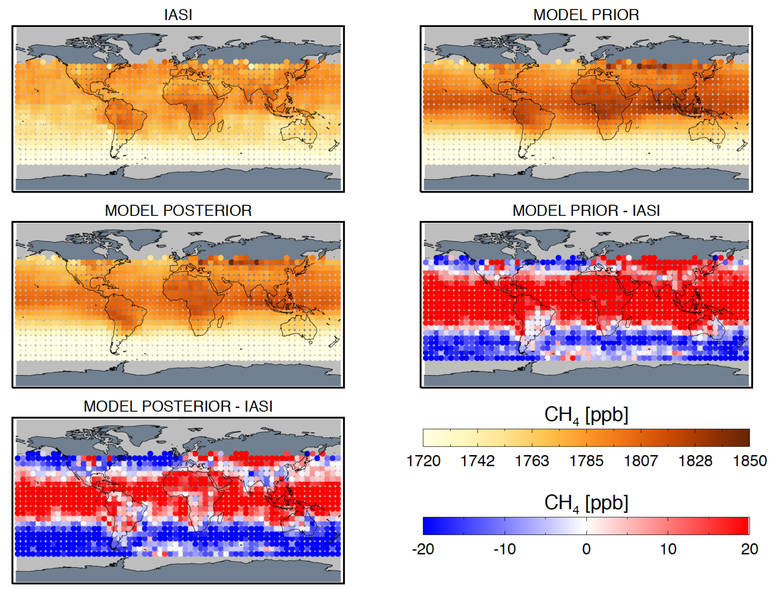

Figure 5. *(a) Column-averaged IASI CH_4 observations for August 2010, averaged into 'super-observations' on model grid. (b) Column-averaged simulated CH_4 concentrations using prior emissions, averaging kernels applied. (c) As (b), but with IASI-posterior emissions and bias applied. (d) Difference between (b) and (a). (e) Difference between (c) and (a).*

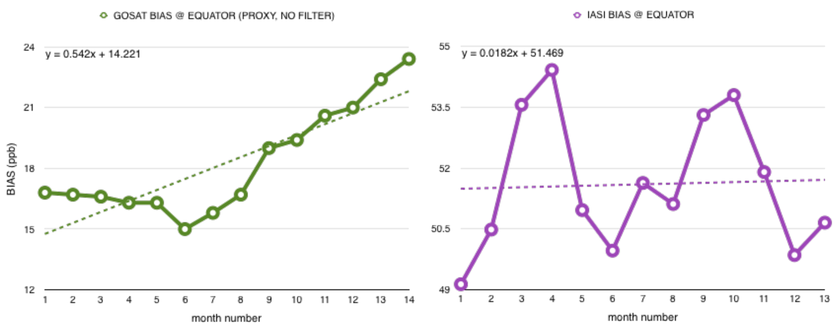

Figure 6. *[Left] Monthly posterior bias between model and GOSAT retrievals at the equator. Prior bias is set as 10 ppb for all months. Note the positive trend in the bias – this is not likely to be correct.*
[Right] Monthly posterior bias between model and IASI retrievals at the equator. Prior bias is set as 60 ppb for all months. No trend in the posterior bias is seen for IASI.

Conclusions

- All inversions inversions **significantly increase global emissions** (by 18.2 – 32.3 Tg/yr) compared to the prior. Total annual emissions in GOSAT and IASI inversions are similar.
- However, **monthly totals and geographical distribution** in the inversions **varies significantly**. Meanwhile, the trend in the GOSAT bias is not likely to be realistic, and should be constrained in the inversion.

References

1. Wilson, C., M. P. Chipperfield, M. Gloor, and F. Chevallier (2014), Development of a variational flux inversion system (INVICAT v1.0) using the TOMCAT chemical transport model, *Geosci. Model Dev.*, *7*, 2485-2500.

UNIVERSITY OF LEEDS

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL