Methane (CH₄) 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 be used to constrain surface emission estimates through assimilation of observed concentrations.

CH₄ 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.

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.

**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 CH₄ 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**

**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 CH₄ were assimilated into INVICAT in order to optimise surface emissions of CH₄ in 2010. Colourbar indicates number of independent observations assimilated from each location.

**Figure 3.** Monthly global total CH₄ emissions (Tg CH₄/month). 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 CH₄ observations for August 2010, averaged into ‘super-observations’ on model grid. (b) Column-averaged simulated CH₄ concentrations using prior emissions, averaging kernels applied. (c) As (b), but with GOSAT posterior emissions and bias applied. (d) Difference between (b) and (c). (e) Difference between (c) and (a).

**Figure 5.** (a) Column-averaged IASI CH₄ observations for August 2010, averaged into ‘super-observations’ on model grid. (b) Column-averaged simulated CH₄ 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