Implications of Overestimated Anthropogenic CO_2 Emissions on East Asian and Global Land CO_2 Flux Inversions

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Summary

Recent inverse modeling studies found a large increase in land CO_2 sink over the East Asia region. The inverse models assume emissions due to fossil fuel consumption and cement production (FFC) as a known quantity, and thus the uncertainties in prior FFC emissions may introduce systematic bias in estimation of the natural (residual) fluxes on the East Asia region as well as for other regions.

We estimate the influence of overestimated anthropogenic CO_2 emissions on natural CO_2 sources and sinks estimations and suggest a method for refining East Asian FFC CO_2 emission increase rate using results from inverse modeling of CH_4. By applying a CH_4 emission-based scaling factor, we found that (1) increase rate of bottom-up FFC emission for East Asia has likely been overestimated, (2) no systematic increase in land CO_2 uptake over East Asia during the 2000s, (3) revised land CO_2 fluxes are more consistent with fluxes from global dynamic vegetation models.

1. Introduction

Recent studies on CO_2 and CH_4 budget for East Asia have shown that:

- **CO_2 inversion**: Annual sink increase in East Asia by 0.56 (0.30–0.81) PgC between 1996–2001 and 2008– 2012 (Thompson et al., 2016) (**Fig. 1**).
- **CH_4 inversion**: Bottom-up East Asian anthropogenic emission is over estimated (mostly Chinese coal industry) (Patra et al., 2016)
- **FFC CO_2 inventories**: Bottom-up FFC emission inventories have large uncertainty in China. e.g. Guan et al., 2012; Liu et al., 2015; Korsbakken et al., 2016

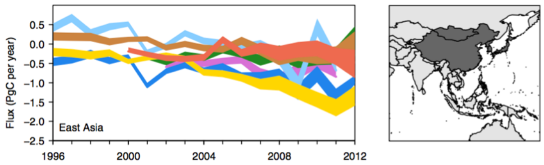

Fig. 1. Land biosphere fluxes estimated by seven atmospheric CO_2 inversions (incl. JAMSTEC's ACTM) in East Asia (Thompson et al., 2016).

Here we introduce a new approach to use the CH_4 inversion results to refine the increase rate of bottom-up FFC CO_2 emissions for East Asia, and show that no systematic increase in land CO_2 uptake over East Asia may be required.

The current study used only surface data for GHG concentrations in inversion analysis, but the results have equal implications for the use of satellite measurements in an inverse modelling system.

2. East Asian CO_2 balance

1. CH_4 inversion (Patra et al., 2016)

Independent results from CH_4 inversion suggested that increase rate of **inverted CH_4 emissions** are 22% (9 Tg) lower than that of **a EDGAR2012FT inventory** during 2002-2012 **(Fig. 2a)**. **China anthropogenic emissions** alone drives the a priori emission increase for East Asia.

The validation using independent aircraft measurement over Sendai (by Tohoku University; Umezawa et al. 2014) showed that forward simulations with the a priori flux overestimated the observed CH_4 variations but that with the inverted flux showed good agreement.

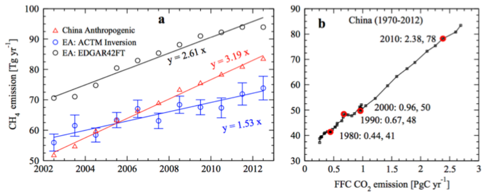

Fig. 2. (a) Comparisons of CH_4 inversion results (**black**: a priori; **blue**: a posteriori) for the East Asia region with the EDGAR estimated FFC emissions for China. The linear fits to the annual mean values are shown as lines, with slopes being marked along the fitted lines. **(b)** Linear relationship of anthropogenic CO_2 and CH_4 emissions for China over the period of 1970-2012 is evident in the emission inventories, e.g., EDGAR42FT.

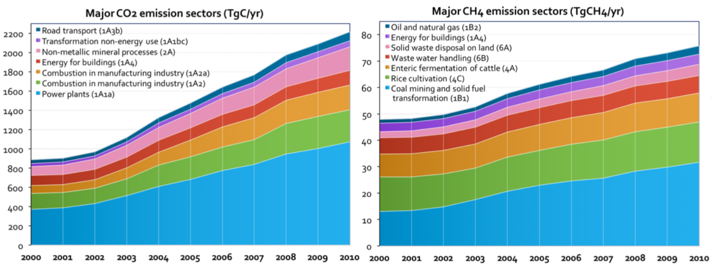

Fig. 3. Time series of Chinese CO_2 and CH_4 emissions for the major anthropogenic activity sectors as provided by the EDGAR database. The CO_2 emission increase rate from power plants sector shows very close correspondence with CH_4 emission increase due to coal mining and solid fuel transformation. The total anthropogenic emissions for CO_2 and CH_4 are also closely correlated in EDGAR.

2. Scaling factor

Since the anthropogenic emissions of both CO_2 and CH_4 increase linearly in the emission inventory **(Figs. 2b and 3)**, using the slopes of the fitted lines to East Asian CH_4 emission time series, we find a scaling factor of 0.59 (=1.53/2.61) to correct FFC CO_2 emission "increase rate" after 2002.

3. Corrected CO_2 emissions

We apply the scaling factor to FFC CO_2 emission for the period 2003-2014, relative to the emissions for 2002 from GCP inventory (**Fig. 4a**). When scaled anthropogenic CO_2 emissions are used, we find no systematic increase in land CO_2 uptake over East Asia during 1993-2010 or 2000-2009 and that there is apparently a need of higher emission increase rate for 2010-2012 compared to those assumed here (**Fig. 4b**).

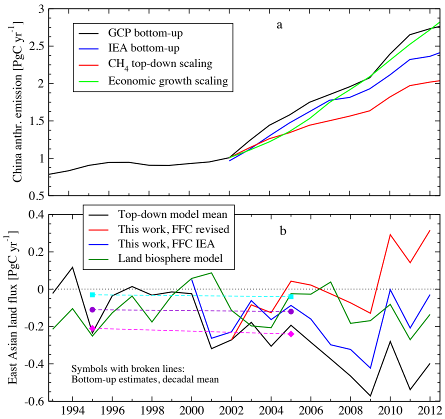

Fig. 4. Effect of FFC CO_2 emission increase rate on regional carbon budget of East Asia. **(a)** Time series of anthropogenic CO_2 emission scenarios for China for 4 scenarios based on **a scaling factor from CH_4 inversion results** for East Asia, the economic (**GDP**) growth, and those estimated by **GCP** (CDIAC) and **IEA** emission inventories. **(b)** Effect of FFC CO_2 emission increase rate on regional carbon budget of East Asia. **The mean inversion flux** of East Asia (from Thompson et al. 2016) is corrected a posteriori for revised China FFC CO_2 emissions using scaling from CH_4 inversion (**This work, FFC revised**) and that from the IEA (**This work, FFC IEA**). The mean CO_2 exchange simulated by **TRENDY** DGVMs are also shown, confirming no significant increase in carbon uptake in East Asia due to CO_2 fertilization and climate (S2 simulation). The forest carbon storage rates based on the country statistics of Land use and land cover to the the U.N. Food and Agriculture Organization - Forest Resource Assessment (FAO-FRA2015; country-level inventory estimates; Calle et al., ERL, 2016) also suggest no signifcant change in carbon sequestraion in the East Asia region (symbols; different colors are for different data sources).

3. Global balance

The corrected anthropogenic CO_2 emissions also produce measurable reductions in the rate of global land CO_2 sink increase post-2002, leading to a better agreement with the terrestrial biospheric model simulations by TRENDY (**Fig. 5**).

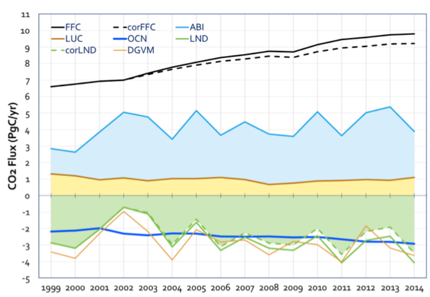

Fig. 5. Time series of CO_2 fluxes as estimated by the Global Carbon Project for fossil fuel and cement (**FFC**), land-use change (**LUC**), atmospheric burden increase (**ABI**), oceanic exchange (**OCN**), residual land biosphere (**LND** = FFC + LUC – ABI – OCN), ensemble mean land fluxes simulated by the global dynamic vegetation models (DGVMs from TRENDY project) during the period 1999–2014. FFC corrected by CH4 inversion scaling (**corFFC**) are also shown. Corrected land fluxes (**corLND**) is based on residuals calculated using corFFC emissions, which show the improved agreement of corLND fluxes with those simulated by the DGVMs.

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