Exploitation of CCI data: GHG-CCI examples

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ECV GHG (GCOS-154*):
“Retrievals of greenhouse gases, such as CO$_2$ and CH$_4$, of sufficient quality to estimate regional sources and sinks.”

*) „SYSTEMATIC OBSERVATION REQUIREMENTS FOR SATELLITE-BASED DATA PRODUCTS FOR CLIMATE“

GHG-CCI satellite retrievals = atmospheric CO$_2$ and CH$_4$, in particular column-averaged dry-air mole fractions XCO$_2$ (in ppm) and XCH$_4$ (in ppb)

Inverse modelling (or other)

Improved information on natural and anthropogenic CO$_2$ and CH$_4$ sources and sinks.
Background and Scientific Justification

A global emission product is produced and updated each year by the Carbon Dioxide Information Analysis Center and the International Energy Agency (Andres et al., 2014), which serves as a basis for the IPCC assessment and for the annual update of the carbon budget by the Global Carbon Project (Le Quéré et al., 2014). Fossil-fuel emission sources in the developed world are known, to better than 10% at country and annual scales, but emissions over individual cities and regions have much larger uncertainties (Duren and Miller, 2012). In the developing world, which now contributes almost 60% of fossil-fuel CO$_2$ emissions, uncertainties are substantially higher (Guan et al., 2012; Andres et al., 2014). The lack of data that are independent from numbers reported by countries themselves has been highlighted as a key source of uncertainty in the current carbon budget (Ballantyne et al., 2012).

Emissions of CO$_2$ from land-use change, mainly deforestation and forest degradation in the Tropics, account for 0.9 Gt C yr$^{-1}$ and have an uncertainty of more than 50%. Global deforestation emissions appear to have been rather constant for the last decade. Satellite observations of areas that have lost forest, however, reveal contrasting trends in different countries. For example, rates of deforestation are decreasing in Brazil, but increasing in Indonesia and Malaysia (Hansen et al., 2013), indicating that deforestation is, in fact, far from stable. Forest degradation is more elusive than deforestation and cannot be easily tracked with land-cover measurements. Degradation is estimated to add another 0.2 Gt C yr$^{-1}$ to the atmosphere (Pütz et al., 2014).

Estimates of the global CO$_2$ ocean sink are partly constrained by ocean measurements collected during the 1990s. Ocean biogeochemistry models are used to estimate the associated trend and variability of this sink (Le Quéré et al., 2014). These models, which simulate the annual exchange of carbon between the sea surface and the atmosphere, as well as the transport of carbon through physical mixing and biological processes, are driven by measurement-derived datasets of climate variables. In the carbon budget assessment of the Global Carbon Project (Le Quéré et al., 2014), ocean-model results must be rescaled to the same decadal-mean value that was derived in the 1990s from ocean observations (Fig. 2.7). This is because individual models cannot reproduce the mean observed sink. In 2004–2013, the ocean sink is estimated to have removed 26% of total CO$_2$ emissions (fossil fuel plus net land-use change), amounting to 2.6 ± 0.5 Gt C yr$^{-1}$. The year-to-year variability of

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**Figure 2.8. Components of the global carbon budget as a function of time (Le Quéré et al., 2014)**

- The increase of CO$_2$ is caused by fossil fuel use and land use change
- Fossil fuel emissions soared from 2 Gt C yr$^{-1}$ in the 1960’s to 10 Gt C yr$^{-1}$ today
- But the ocean and land carbon sinks absorbed on average ≈50% of emissions

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**Land sink:** Computed as residual (Emission – Atmosphere - Ocean), i.e., not observed

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**Source – IPCC AR5**
How large is the European terrestrial carbon sink?
Regional terrestrial carbon fluxes

Based on Peylin et al., 2013

Large discrepancies models vs atmospheric inversions esp. in tropics and northern Africa & large uncertainties (~100%)!

Can we do better using satellite XCO₂?
Regional carbon fluxes (Peylin et al., 2013)

Peylin et al., 2013

No satellite XCO₂ data used
CO$_2$ flux inversions using different GOSAT XCO$_2$ products and models

Toward robust and consistent regional CO$_2$ flux estimates from in situ and spaceborne measurements of atmospheric CO$_2$

Frédéric Chevallier$^1$, Paul I. Palmer$^2$, Liang Feng$^2$, Hartmut Boesch$^3$, Chris and Philippe Bousquet$^1$

Method:
- 3 inversion methods (2x LSCE (LMDZ 19 & 39), 1x Univ. Edinburgh (UoE))
- CO$_2$ surface observations and x2 GOSAT satellite XCO$_2$ products:
  - GHG-CCI UoL (OCFP) v4
  - NASA ACOS v3.3

Conclusions:
- Regional flux time series:
  - Good agreement for phase but NOT amplitude
- Annual regional fluxes:
  - Not considered realistic for all regions, e.g., Europe: inferred sink “significantly too large”
  - Possible issues / to be improved: Inversion method incl. prior fluxes and transport models, satellite data (biases to be further reduced)

Regional natural CO$_2$ fluxes for 2010

Chevallier et al., GRL, 2014
European terrestrial carbon fluxes from SCIAMACHY and GOSAT - I

Goal: Get information on European terrestrial carbon fluxes using satellite data and a method which is not or much less sensitive to potential error sources as discussed in the literature such as

- Potential adverse impact of satellite XCO₂ biases outside of target region (e.g., XCO₂ biases over Africa due to desert dust storm aerosols)
- Potential problems related to long-range transport modelling
- Potential problems related to the used satellite

Approach:
„Europe only“ inversion using STILT-based short range (days) particle dispersion modelling using an ensemble of satellite XCO₂ retrievals

Reuter et al., ACP, 2014

• The satellite minus model (CT2011_oi) difference ΔXCO₂ shows a negative correlation with the integrated European surface influence.
• Interpretation: CarbonTracker’s European carbon sink is too weak.
• Quantitative analysis using the optimal estimation framework (1D-Var) to get optimized European surface fluxes considering satellite XCO₂ retrievals.
European terrestrial carbon fluxes from SCIAMACHY and GOSAT - II

„Continental Europe only“ inversion using STILT-based short range (days) particle dispersion modelling using an ensemble of satellite XCO₂ retrievals:

- 2 satellites
- 5 retrieval algorithms / products
- New flux inversion method insensitive to observations outside Europe, large-range transport & other errors
- Various sensitivity studies

Satellite data suggest a continental (TransCom) European C sink of 1.02 +/- 0.3 GtC/yr (for 2010)

Reuter et al., ACP, 2014
European terrestrial carbon fluxes from SCIAMACHY and GOSAT - III

Summary for continental (TransCom) Europe:

European carbon uptake in gigatons of carbon in 2010

Reuter et al. (ACP, 2014) with satellite CO₂
1.0±0.3

Previous estimate without satellite CO₂
0.4±0.4

Related ESA webstory: Is Europe an underestimated sink for carbon dioxide?
http://www.esa.int/Our_Activities/Observing_the_Earth/Is_Europe_an_underestimated_sink_for_carbon_dioxide
Elevated uptake of CO₂ over Europe inferred from GOSAT XCO₂ retrievals: a real phenomenon or an artefact of the analysis?

L. Faber
I. Matschullat

This discussion paper is/has been under review for the journal Atmospheric Chemistry and Physics (ACP). Please refer to the corresponding final paper in ACP if available.

An intercomparison of inverse models for estimating sources and sinks of CO₂ using GOSAT measurements


Key Points:
- A latitudinal shift in carbon uptake of 1 PgC/yr using GOSAT
- The shift carbon uptake is not supported by background surface measurements
Recent reversal in loss of global terrestrial biomass

Yi Y. Liu\textsuperscript{1,2*}, Albert I. J. M. van Dijk\textsuperscript{3,4}, Jason P. Evans\textsuperscript{1} and Guojie Wang\textsuperscript{8}

Figure 2 | Mean annual change in aboveground biomass carbon between 1993 and 2012.
European carbon sink: Ongoing activities - II

- Microwave sat. ABC-trend (2003–2010; data from Liu et al. 2015)
- Regional sat. inversion NIR (2003–2010; Reuter et al. 2014)
- Global sat. inversion TIR (2006; Nassar et al., 2011)
- Global in situ inversion (2001–2004; Peylin et al., 2013)

CC1 LandCover

Region of largest sink as suggested by Reuter et al. 2014

Reuter et al., Biogeosciences, submitted
Reuter et al., Nature Geoscience, 2014

“Decreasing NO\textsubscript{x} relative to CO\textsubscript{2} emissions in East Asia inferred from satellite observations”

Satellite derived trends of anthropogenic NO\textsubscript{x} and CO\textsubscript{2} emissions

- Anthropogenic CO\textsubscript{2} emission signal from localized sources isolated via simultaneous SCIAMACHY XCO\textsubscript{2} and NO\textsubscript{2} observations & new spatial filtering method
- North America & Europe: Decreasing emissions (but uncertain for CO\textsubscript{2})
- East Asia: Increasing emissions but less NO\textsubscript{x} per CO\textsubscript{2}: Trend towards cleaner technology in East Asia
Methane emissions

www.atmos-chem-phys.net/15/113/2015/
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Inverse modelling of CH₄ emissions for satellite retrieval products from GOSA

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Figure 6. Scenarios S1-GOSAT-SRON-FP, S1-GOSAT-UL-FP and S1-SCIA.
Remote sensing of fugitive methane emissions from oil and gas production in North American tight geologic formations

Oliver Schneising¹, John P. Burrows¹,²,³, Russell R. Dickerson², Michael Buchwitz¹, Maximilian Reuter¹, and Heinrich Bovensmann¹

Schneising et al., Earth’s Future, 2014

Estimated emission increase 2009-2011 relative to 2006-2008:
• Bakken: 990±650 ktCH₄/yr
• Eagle Ford: 530±330 ktCH₄/yr

Emission estimates correspond to leakages of
• Bakken: 10.1±7.3% and
• Eagle Ford: 9.1±6.2%
in terms of energy content.

Exceeds 3.2% “climate benefit” threshold (Alvarez et al., 2012) for switching from coal to natural gas
Likely underestimated in inventories.
And much more ...

... see

http://www.esa-ghg-cci.org/

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