The GHG-CCI project of ESA's Climate Change Initiative (CCI): Overview, status and selected science highlights

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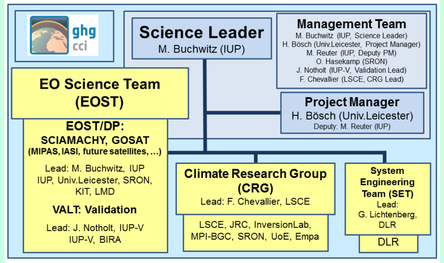
and the GHG-CCI team

GHG-CCI project team

GHG-CCI Phase 2 Team - I



GHG-CCI Phase 2 Team - II

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O. Hasekamp, R. Detmers, I. Aben, S. Houweling, T. T. v. Leeuwen, C. Frankenberg (JPL), **SRON, Utrecht, The Netherlands,** GOSAT CO_2 & CH_4 (in coop. with KIT) & SCIAMACHY CH_4 (in coop. with JPL), S5P CH_4, lead DARD+PSD+PUG+SSD, inverse modelling

A. Laeng, G. Stiller, P. Hahne, A. Butz, **KIT, IMK-ASK, Karlsruhe, Germany,** MIPAS CH_4, GOSAT CO_2 & CH_4 (in coop. with SRON)

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D. Brunner, G. Kuhlmann, B. Buchmann, **EMPA, Switzerland,** User requirements & inter-comparisons, focus CO_2

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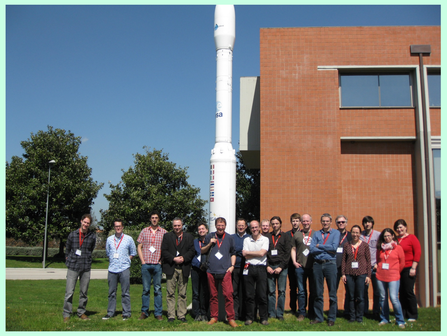
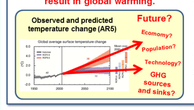


GHG-CCI project overview

ECV Greenhouse Gases

CO_2 and CH_4 are the two most important anthropogenic greenhouse gases and increasing concentrations result in global warming.



Reliable climate prediction requires a good understanding of the natural and anthropogenic (surface) **sources and sinks of CO_2 and CH_4.**

Important questions are, for example:

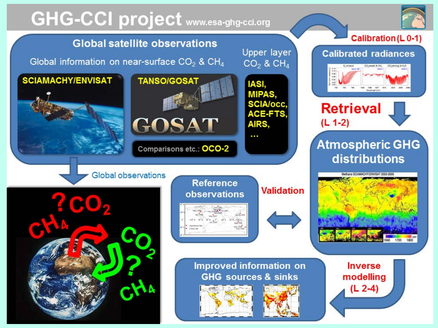
- Where are they ?
- How strong are they ?
- How do they respond to a changing climate ?

A better understanding requires appropriate global observations and (inverse) modelling.

ECV GHG / Product A.8.1 (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 project www.esa-ghg-cci.org



Data & data quality

GHG-CCI: Data sets

GHG-CCI Climate Research Data Package (CRDP#2)

Product ID	Product (Level 2, mole fraction)	Years processed: 2002	03	04	05	06	07	08	09	10	11	12	13	14	15
GHG-CCI Core Products: ECV Core Algorithm (ECA) Products															
XCO2_SCIA	XCO_2														
XCH4_SCIA	XCH_4														
XCO2_GOSAT	XCO_2														
XCH4_GOSAT	XCH_4														
XCO2_EMMA	XCO_2														
Additional Constraints Algorithm (ACA) Products															
CO2_IASI	CO_2 (1)														
CH4_IASI	CH_4 (1)														
CH4_SCIAOCC	CH_4 (2)														
CO2_SCIAOCC	CO_2 (2)														
CO2_ACEFTS	CO_2 (2)														
CH4_MIPAS	CH_4 (2)														
CO2_AIRS	CO_2 (1)														

Comments:
ACA products:
(1) Mid / upper tropospheric column
(2) Upper tropospheric / stratospheric profile
CRDP#2 Also available

ECA Algorithms for column-averaged dry air mole fractions:
XCO2_SCIA: BESD, WFMD
XCH4_SCIA: WFMD, IMAP
XCO2_GOSAT: SRFP (RemoTeC), OCFP (UoL-FP)
XCH4_GOSAT: SRFP & SRPR (RemoTeC), OCPR (UoL-PR)
XCO2_EMMA: Various (SCIA & GOSAT merged)

Details please see: www.esa-ghg-cci.org -> CRDP (Data)

GHG-CCI CRDP#2: Comparison with GCOS Requirements

Variable(*)	Resolution	Accuracy	Stability (§§)
XCO_2	Temporal: GCOS: 4 hours Achieved: Days No existing nor any planned mission meets the GCOS temporal resolution requirement.	GCOS: < 1 ppm URD(#): < 0.5 ppm Achieved(#): 0.4-0.9 ppm(?) (?) Depending on sensor, time period and assessment method	GCOS: < 0.2 ppm/yr URD: < 0.5 ppm/yr Achieved: << 0.5 ppm/yr(+) (+) Derived trends not significant
XCH_4	Spatial: GCOS: 5-10 km Achieved($): 10 km ($) for GOSAT: SCIAMACHY: 30x60 km² URD: SCIAMACHY and GOSAT are useful to generate the ECV GHG.	GCOS: < 10 ppb URD(#): < 10 ppb Achieved(#): 3-8 ppb($) ($) for GOSAT; for SCIAMACHY 8-15 ppb depending on time period (degradation after Oct. 2005)	GCOS: < 2 ppb/yr URD: < 10 ppb/yr Achieved: < 4 ppb/yr(!) (§§) (!) Derived trends mostly not significant but note (§§)
	Note: GCOS requirements are target (maximum) requirements, but URD requirements listed here are threshold (minimum) requirements.	(#) Relative accuracy (i.e., excluding a possible constant global offset) (§§) Stability as used here quantifies only long-term drift and therefore does not capture certain "jumps" due to detector issues as observed when analyzing the global SCIAMACHY XCH_4 (e.g., IMAP product mid 2010) **Estimated by comparison with TCCON ground-based observations; TCCON accuracy (1-sigma): 0.4 ppm for XCO_2 and 3.5 ppb for XCH_4**	

(*) Requirements for column-averaged mole fractions (= air column normalized vertical GHG columns) as required by URD; it is assumed here that this corresponds to GCOS variables „Tropospheric CO_2 column" and „Tropospheric CH_4 column"

References: Requirements for ECV Greenhouse Gases (GHG):
- GCOS-154: „SYSTEMATIC OBSERVATION REQUIREMENTS FOR SATELLITE-BASED DATA PRODUCTS FOR CLIMATE"
- URD: "GHG-CCI User Requirements Document", v2.0

Definition ECV GHG (GCOS-154):
- Product A.8.1: Retrievals of CO_2 and CH_4 of sufficient quality to estimate regional sources and sinks

PVIRv3.2

Selected scientific results

European terrestrial carbon sink

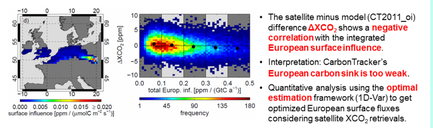
European terrestrial carbon fluxes from SCIAMACHY and GOSAT - I

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 XCO_2 biases outside of target region (e.g., XCO_2 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: Reuter et al., ACP, 2014

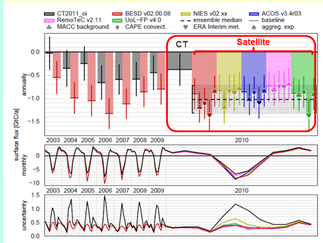
„Europe only" inversion using STILT-based short range (days) particle dispersion modelling using an ensemble of satellite XCO_2 retrievals



- The satellite minus model (CT2011_oi) difference ΔXCO_2 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 XCO_2 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 XCO_2 retrievals: Reuter et al., ACP, 2014

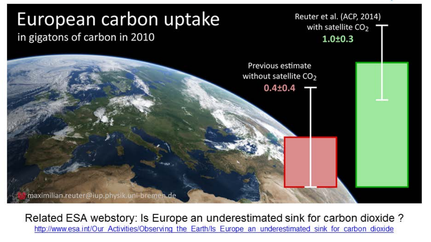


- 2 satellites
- 5 retrieval algorithms / products
- New flux inversion method insensitive to observations outside Europe, large-range transport & other errors
- Various sensitivity studies

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

European terrestrial carbon fluxes from SCIAMACHY and GOSAT - III

Summary for continental (TransCom) Europe: Reuter et al., ACP, 2014



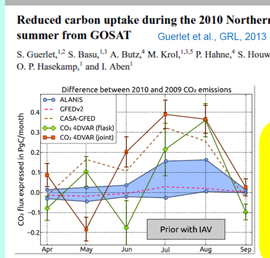
Related ESA webstory: Is Europe an underestimated sink for carbon dioxide ?
http://www.esa.int/Our_Activities/Observing_the_Earth/Is_Europe_an_underestimated_sink_for_carbon_dioxide

N-hemispheric CO_2 Uptake

GOSAT/RemoTeC CO_2: Northern hemisphere summer 2010 carbon fluxes

Reduced carbon uptake during the 2010 Northern Hemisphere summer from GOSAT Guerlet et al., GRL, 2013

S. Guerlet,[1,2] S. Basu,[1,3] A. Butz,[4] M. Krol,[1,3,5] P. Hahne,[4] S. Houweling,[1,3] O. P. Hasekamp,[1] and I. Aben[1]



Reduced carbon uptake in the summer of 2010 most likely due to **Eurasian heat wave** driving biospheric fluxes and fire emissions.

Joint inversion GOSAT & flasks:
Biospheric & fire CO_2 emission anomaly April–September 2010:
0.89±0.20 PgC over Eurasia

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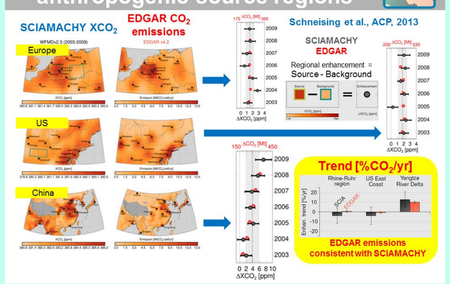
Anthropogenic emissions

SCIAMACHY CO_2 over anthropogenic source regions

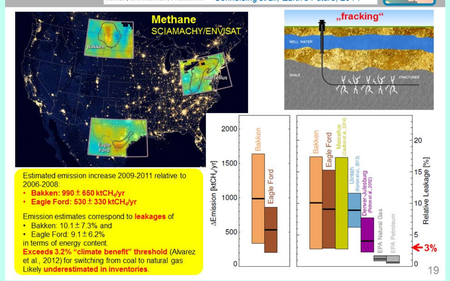


SCIAMACHY methane:

Remote sensing of fugitive methane emissions from oil and gas production in North American tight geologic formations

Oliver Schneising[1], John P. Burrows[1,2,3], Russell R. Dickerson[4], Michael Buchwitz[1], Maximilian Reuter[1], and Heinrich Bovensmann[1]

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**.

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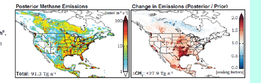
CH_4 Emissions from GOSAT

Estimating global and North American methane emissions with high spatial resolution using GOSAT satellite data

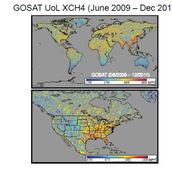
A. J. Turner[1], D. J. Jacob[1], K. J. Wecht[1], J. D. Maasakkers[1], S. C. Biraud[2], H. Boesch[3,4], K. W. Bowman[5], N. M. Deutscher[6,7], M. K. Dubey[8], D. W. T. Griffith[9], F. Hase[6], A. Kuze[10], J. Notholt[6], H. Ohyama[11], R. Parker[3,4], V. H. Payne[5], R. Sussmann[12], V. A. Velazco[9], T. Warneke[6], P. O. Wennberg[13], and D. Wunch[13]

Turner et al., ACPD, 2015

Methane Emissions from GOSAT for 2009-2011



GOSAT UoL XCH4 (June 2009 – Dec 2011)



GOSAT CH_4 Inversion:
Anthropogenic source of CH_4 over N-America is 40.2 - 42.7 Tg a^{-1} which is largely underestimation by EDGAR and EPA with emissions of 24.9 - 27 Tg a^{-1}

GOSAT CH_4 inversions are consistent with independent in-situ inversions

1

Wildfire Emissions

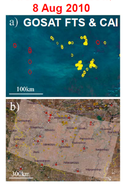
GOSAT/UoL CH_4/CO_2: Wildfire emission ratios

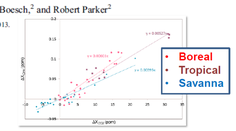
First satellite measurements of carbon dioxide and methane emission ratios in wildfire plumes Ross et al., GRL, 2013

Adrian N. Ross,[1] Martin J. Wooster,[1] Hartmut Boesch,[2] and Robert Parker[2]

Received 29 May 2013; revised 3 July 2013; accepted 10 July 2013.

Fires near Moscow, 8 Aug 2010





First fire emission ratios, ER CH_4/CO_2, from satellite observations:
- boreal forest: 0.00603 mol/mol
- tropical forest: 0.00527 mol/mol
- savanna fires: 0.00395 mol/mol
(uncertainties ~ +/- 0.0003)

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University of Leicester

www.esa-ghg-cci.org/

Contact: Hartmut.boesch@le.ac.uk