

GHG_cci Project



Results of the ESA GHG Climate Change Initiative project

Claus Zehner

Directorate of Earth Observation Programmes

ESA Climate Change Initiative (CCI)

to generate Essential Climate Variables (ECVs)



www.esa-ghg-cci.org/

The screenshot shows the ESA GHG CCI website interface. At the top, there's a navigation bar with links for aerosol, cloud, cmug, fire, ghg, glaciers, land cover, ocean col., ozone, sea ice, sea level, soil mol., sst, and ice sheets. The main content area features a 'ghg' section with a description of Carbon Dioxide (CO₂) and methane (CH₄) as anthropogenic greenhouse gases. Below this is a line graph titled 'Carbon Dioxide (CO₂) - NH (0°-60°N)' showing XCO₂ [ppm] from 2002 to 2013. The graph includes data from SCIAMACHY/ENVISAT, TANSO/GOSAT, WFMDOAS, SRFP(RemoTeC), BESD, and OCFP(UoL-FP). A 'Team photo' section shows a group of people in a meeting room. The website is hosted by IUP at Universität Bremen.

ESA programme

led by Mark Doherty, ESA/ESRIN

ECV projects:

- Aerosol-CCI
- Cloud-CCI
- Fire-CCI
- **GHG-CCI - CO₂ & CH₄**
- Glaciers-CCI
- LandCover-CCI
- OceanColour-CCI
- Ozone-CCI
- SeaLevel-CCI
- SST-CCI
- SoilMoisture-CCI
- SeaIce-CCI
- IceSheets-CCI (Greenland, Antarctica)

+ CMUG (Climate Modelling User Group)

- Lead: Roger Saunders (Met Office Hadley Centre)
- Met Office Hadley Centre, ECMWF, MPI-Meteorology, Météo France, IPSL, SMHI, DLR

European Space Agency

GHG-CCI project www.esa-ghg-cci.org



Global satellite observations

Global information on near-surface CO₂ & CH₄

Upper layer
CO₂ & CH₄

SCIAMACHY/ENVISAT



TANSO/GOSAT

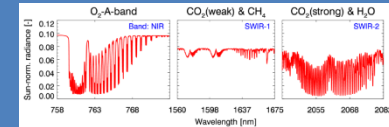


Preparing for: **OCO-2**

**IASI,
MIPAS,
SCIA/occ,
AIRS,
ACE-FTS,
...**

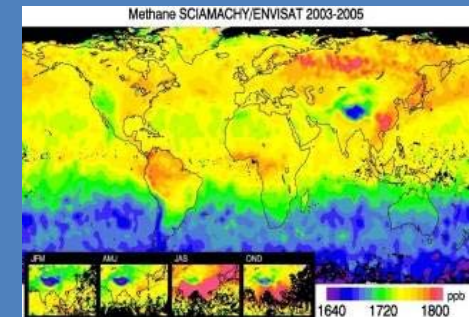
Calibration (L 0-1)

Calibrated radiances



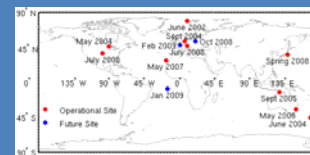
**Retrieval
(L 1-2)**

Atmospheric GHG distributions

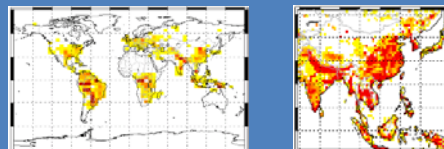


Validation

Reference observations

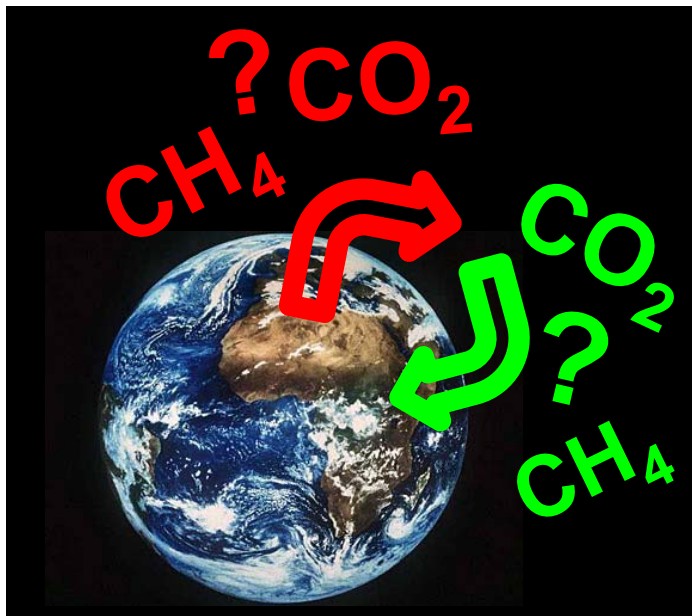


Improved information on GHG sources & sinks



**Inverse
modelling
(L 2-4)**

European Space Agency



GHG-CCI Phase 2 Team



Science Leader

M. Buchwitz (IUP)

Management Team

M. Buchwitz (IUP, Science Leader)
H. Bösch (Univ.Leicester, Project Manager)
M. Reuter (IUP, Deputy PM)
O. Hasekamp (SRON)
J. Notholt (IUP-V, Validation Lead)
F. Chevallier (LSCE, CRG Lead)

Project Manager

H. Bösch (Univ.Leicester)
Deputy: M. Reuter (IUP)

EO Science Team (EOST)

EOST/DP:

SCIAMACHY, GOSAT
(MIPAS, IASI, future satellites, ...)

Lead: M. Buchwitz, IUP
IUP, Univ.Leicester, SRON,
KIT, LMD

VALT: Validation

Lead: J. Notholt, IUP-V
IUP-V, BIRA

Climate Research Group (CRG)

Lead: F. Chevallier, LSCE

LSCE, JRC, InversionLab,
MPI-BGC, SRON, UoE, Empa

System Engineering Team (SET)


Lead:
G. Lichtenberg,
DLR

DLR

URDv2



Several improvements
but key requirements table essentially identical with URDv1:

	ESA Climate Change Initiative (CCI)	Page 1
	User Requirements Document Version 2 (URDv2)	Version 2 – Final
	for the Essential Climate Variable (ECV) Greenhouse Gases (GHG)	28 August 2014

ESA Climate Change Initiative (CCI)
User Requirements Document (URD)
for the Essential Climate Variable (ECV)
Greenhouse Gases (GHG)

Written by:
GHG-CCI project team
Lead author for Version 1: M. Buchwitz, IUP, Univ. Bremen, Germany
Lead author for Version 2: F. Chevallier, LSCE, France

Other contributors:

- P. Bergamaschi, EC-JRC-IES, Italy
- S. Houweling and T. van Leeuwen, SRON, the Netherlands
- P. I. Palmer, Univ. Edinburgh

To be cited as:
GHG-CCI User Requirements Document for the GHG-CCI project of ESA's Climate Change Initiative, pp. 38, version 2, 28 Aug. 2014, 2014.
Available from: <http://www.esa-ghg-cci.org/>

Requirements for regional CO ₂ and CH ₄ source/sink determination					
Parameter	Req. type	Random error ("Precision")		Systematic error	Stability
		Single obs.	1000 ² km ² monthly		
XCO ₂	G	< 1 ppm	< 0.3 ppm	< 0.2 ppm (absolute)	As systematic error but per year
	B	< 3 ppm	< 1.0 ppm	< 0.3 ppm (relative ^{\$1})	--
	T	< 8 ppm	< 1.3 ppm	< 0.5 ppm (relative [#])	--
XCH ₄	G	< 9 ppb	< 3 ppb	< 1 ppb (absolute)	As systematic error but per year
	B	< 17 ppb	< 5 ppb	< 5 ppb (relative ^{\$1})	--
	T	< 34 ppb	< 11 ppb	< 10 ppb (relative [#])	--

Number of Users



Mid 2011 – Oct 2014: **~286**

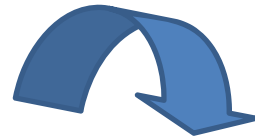
Status Mid March 2015:

~360

Number of Publications



Document Ref: D2.1
CMUG Phase 2 Deliverable
 Number: D2.1: Scientific Impact Report
 Due date: October 2014
 Submission date: February 2015
 Version: 1.1



Climate Modelling User Group

Deliverable 2.1

Scientific Impact Report

Centres providing input: Met Office, MPI-M, ECMWF, MétéoFrance, IPSL, SMHI, DLR

Version nr.	Date	Status
0.1	13 October	First draft for partner input
0.2	4 December	Revised template
0.3	15 December	Inputs on SST, Fire, O3, GHG, Aerosol
0.4	7 January 2015	Inputs on SSH, Land Cover, Fire
0.5	28 January 2015	Inputs on SM, SI, Clouds, OC, Glaciers, IS
1.0	30 January 2015	Submit to ESA
1.1	20 February 2015	Updated with ESA comments

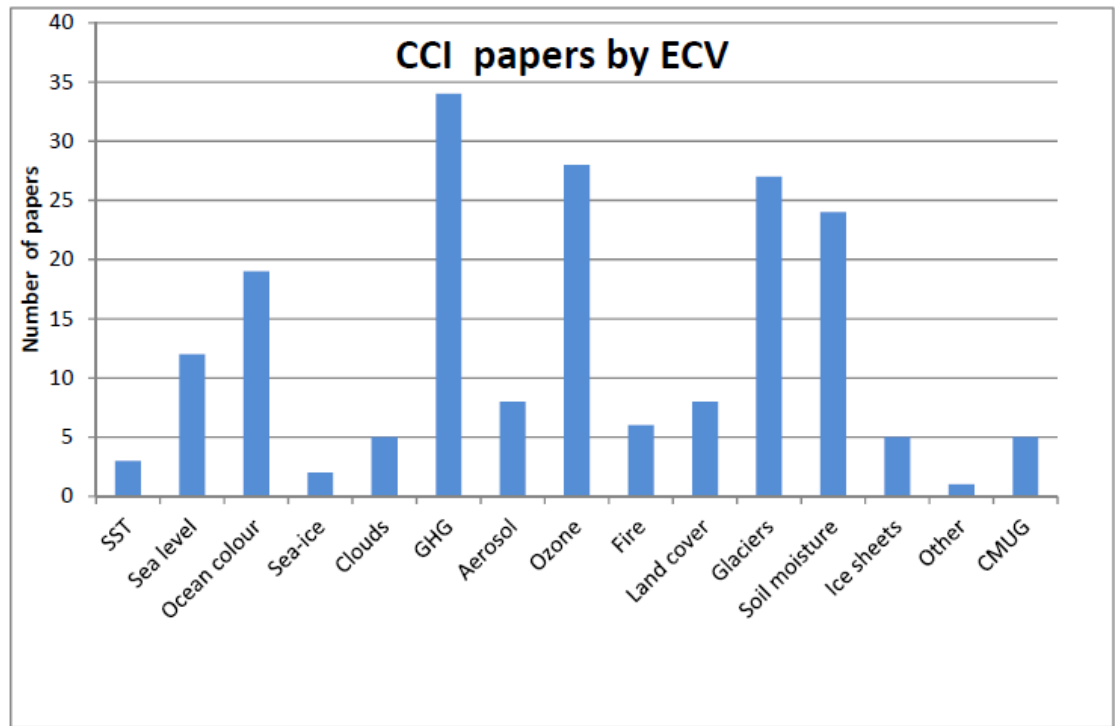


Figure 1: Science papers published in peer reviewed journals by CCI projects (including CMUG) for CCI Phase 1. (Excludes papers in draft or submitted.)

Number of Publications



Status Mid March 2015:

**Number peer-reviewed publications
with GHG-CCI funding explicitly
acknowledged:**

38

See publications with (*) on
<http://www.esa-ghg-cci.org/> -> Publications

ESA GHG CCI website | CO2 will allow our descendants to live under a warmer sky (Arrhenius 1896) - Mozilla

www.esa-ghg-cci.org

esa climate change initiative European Space Agency

ESA | CCI | aerosol | cloud | cmug | fire | ghg | glaciers | land cover | ocean col. | ozone | sea ice | sea level | soil moi. | sst | ice sheets

ghg

GHG-CCI

Carbon dioxide (CO₂) and methane (CH₄) are the two most important anthropogenic greenhouse gases (GHGs). Satellite observations combined with modelling helps to improve our knowledge on CO₂ and CH₄ sources and sinks as required for better climate prediction. GHG-CCI aims at delivering the high quality satellite retrievals needed for this application.

GHG-CCI CRDP#1

Carbon Dioxide (CO₂) - NH (0°-60°N)

Press releases (latest news: 29 Sept 2014): [Click here to read & see more !](#)

Press releases (29 Sept 2014): Decreasing emissions of NO_x relative to CO₂ in East Asia inferred from satellite observations, (Reuter et al., Nature Geoscience): ESA, DLR, Univ. Bremen.

Hosted by IUP

 Universität Bremen

User login
 Username: * michael.buchwitz
 Password: *
 Login

Search
 Search this site:
 Search

Calendar
 « October 2014
 Mon Tue Wed Thu Fri
 1 2 3

CRDP
(Data)



Key to success: Ensemble



CRDP#2: ECA products



GHG-CCI CRDP#2: ECV Core Algorithm (ECA) Products				
Algorithm / Product ID (version)	Product	Sensor Satellite	Algorithm Institute	Comment (Reference)
CO2_SCI_BESD (v02.00.08)	XCO ₂	SCIAMACHY ENVISAT	BESD IUP	SCIAMACHY XCO ₂ baseline product (Reuter et al., 2011)
CO2_SCI_WFMD (v3.8)	XCO ₂	SCIAMACHY ENVISAT	WFM-DOAS IUP	SCIAMACHY XCO ₂ alternative product (Schneising et al., 2011)
CO2_GOS_OCFP (v5.1)	XCO ₂	TANSO GOSAT	UoL-FP UoL	GOSAT XCO ₂ product (baseline not yet decided) (Cogan et al., 2012)
CO2_GOS_SRFP (v2.3.6)	XCO ₂	TANSO GOSAT	RemoTeC SRON/KIT	GOSAT XCO ₂ product (baseline not yet decided) (Butz et al., 2011)
CO2_EMMA (v1.7)	XCO ₂	Merged SCIA and GOSAT	EMMA IUP (lead)	Short time period only (6.2009-7.2010) (Reuter et al., 2013) (*)
CH4_SCI_WFMD (v3.7)	XCH ₄	SCIAMACHY ENVISAT	WFM-DOAS IUP	SCIAMACHY XCH ₄ proxy product (baseline not yet decided) (Schneising et al., 2011)
CH4_SCI_IMAP (v7.0)	XCH ₄	SCIAMACHY ENVISAT	IMAP SRON/JPL	SCIAMACHY XCH ₄ proxy product (baseline not yet decided) (Frankenberg et al., 2011)
CH4_GOS_OCPR (v5.1)	XCH ₄	TANSO GOSAT	UoL-PR UoL	GOSAT XCH ₄ proxy baseline product (Parker et al., 2011)
CH4_GOS_SRPR (v2.3.6)	XCH ₄	TANSO GOSAT	RemoTeC SRON/KIT	GOSAT XCH ₄ proxy alternative product (Butz et al., 2010)
CH4_GOS_SRFP (v2.3.6)	XCH ₄	TANSO GOSAT	RemoTeC SRON/KIT	GOSAT XCH ₄ full physics baseline product (Butz et al., 2011)
Details (temporal coverage, etc.): http://www.esa-ghg-cci.org -> CRDP (Data)				

Tables 2.1: Overview GHG-CCI core data products of the Climate Research Data Package No. 2 (CRDP#2). (*) The latest version, EMMAv2.0, covers 4 years and is also available on the GHG-CCI website.

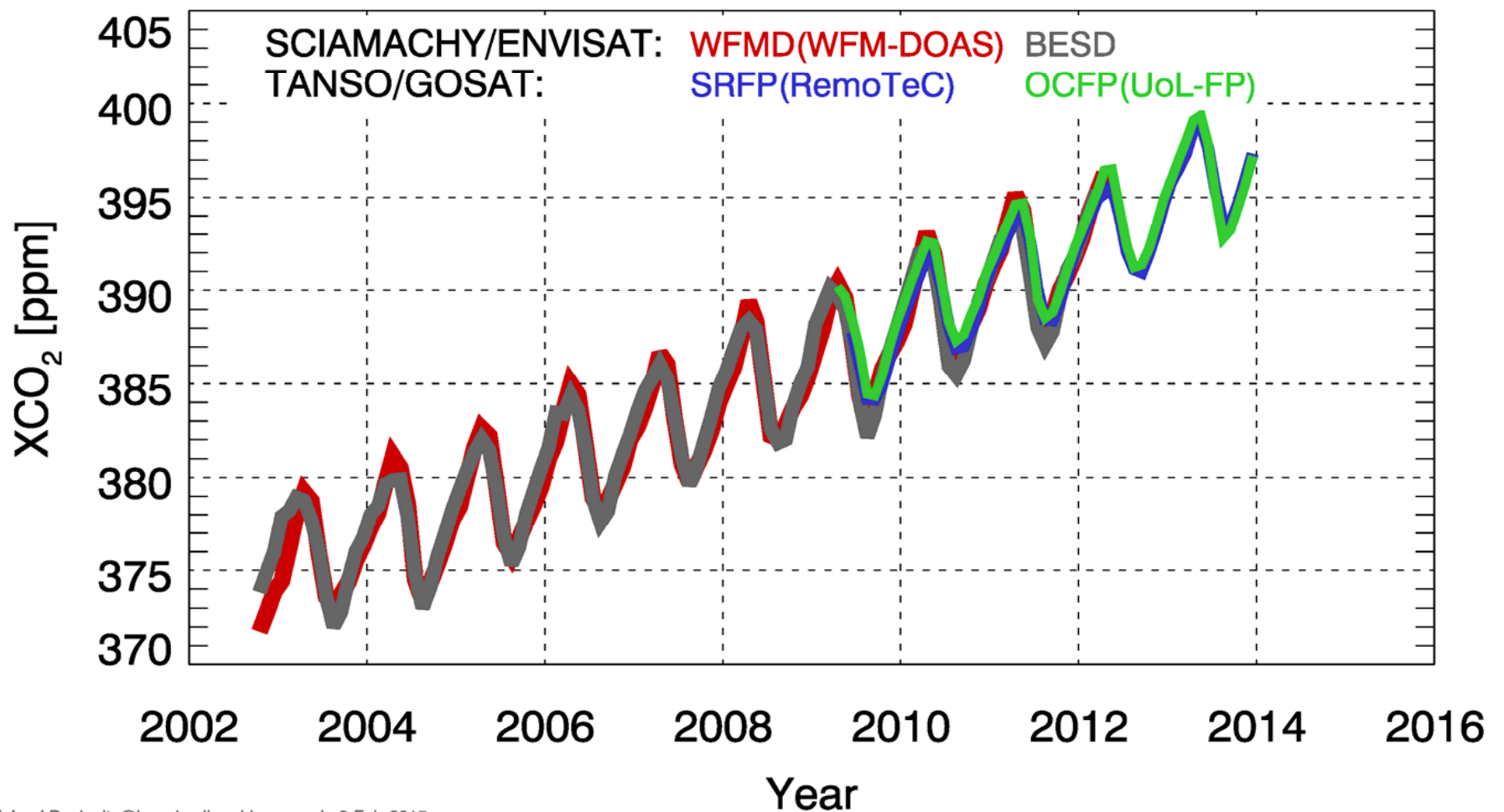
PVIRv3.1

GHG-CCI XCO₂



GHG-CCI CRDP#2

Carbon Dioxide (CO₂) - NH (0°-60°N)



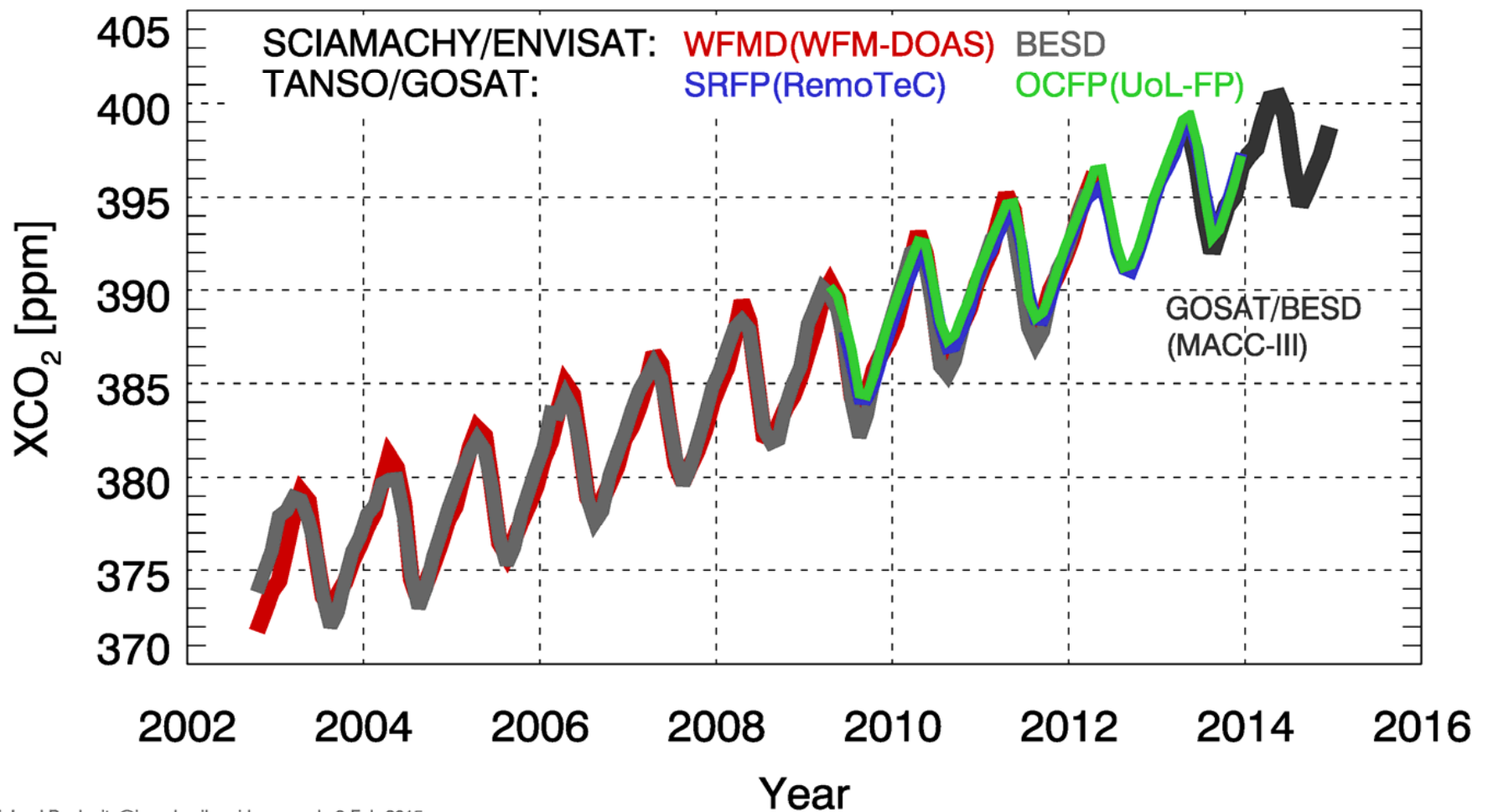
GHG-CCI XCO₂



+ GOSAT/BESD

GHG-CCI CRDP#2

Carbon Dioxide (CO₂) - NH (0°-60°N)



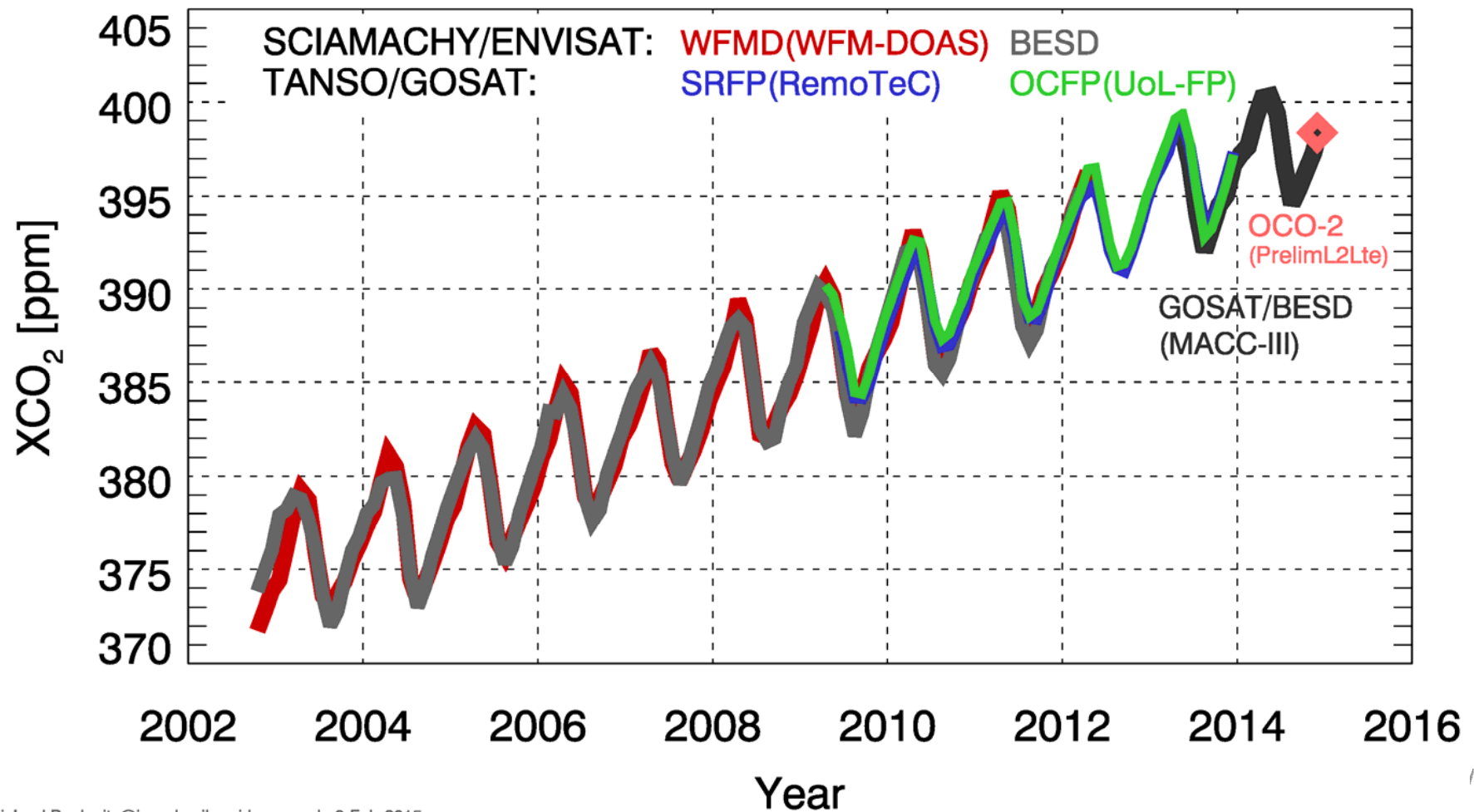
GHG-CCI XCO₂



+ GOSAT/BESD + OCO-2

GHG-CCI CRDP#2

Carbon Dioxide (CO₂) - NH (0°-60°N)



GHG-CCI CRDP#2: Comparison with GCOS Requirements

Variable ^(*)	Resolution	Accuracy	Stability
XCO₂	<p>Temporal: GCOS: 4 hours Achieved: Days</p> <p>No existing nor any planned mission meets the GCOS temporal resolution requirement.</p> <p>Spatial: GCOS: 5-10 km Achieved^(§): 10 km</p> <p>(§) for GOSAT. SCIAMACHY: 30x60 km².</p> <p>URD: SCIAMACHY and GOSAT are useful to generate the ECV GHG.</p> <p>Note: GCOS requirements are target (maximum) requirements but URD requirements listed here are threshold (minimum) requirements.</p>	<p>GCOS: < 1 ppm URD^(#): < 0.5 ppm Achieved^(#): 0.4-0.9 ppm^(?)</p> <p>(?) Depending on sensor, time period and assessment method</p>	<p>GCOS: < 0.2 ppm/yr URD: < 0.5 ppm/yr Achieved: << 0.5 ppm/yr⁽⁺⁾</p> <p>(+) Derived trends not significant</p>
XCH₄	<p>URD: SCIAMACHY and GOSAT are useful to generate the ECV GHG.</p> <p>Note: GCOS requirements are target (maximum) requirements but URD requirements listed here are threshold (minimum) requirements.</p>	<p>GCOS: < 10 ppb URD^(#): < 10 ppb Achieved^(#): 3-8 ppb^(§)</p> <p>(§) for GOSAT; for SCIAMACHY 8-15 ppb depending on time period (degradation after Oct. 2005)</p>	<p>GCOS: < 2 ppb/yr URD: < 10 ppb/yr Achieved: < 4 ppb/yr^(!)</p> <p>(!) Derived trends mostly not significant</p>
		<p>(#) Relative accuracy (i.e., excluding possible constant global offset)</p> <p>Estimated by comparison with TCCON ground-based observations; TCCON accuracy (1-sigma): 0.4 ppm for XCO₂ and 3.5 ppb for XCH₄</p>	

(*) 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 CO₂ column“ and „Tropospheric CH₄ 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):

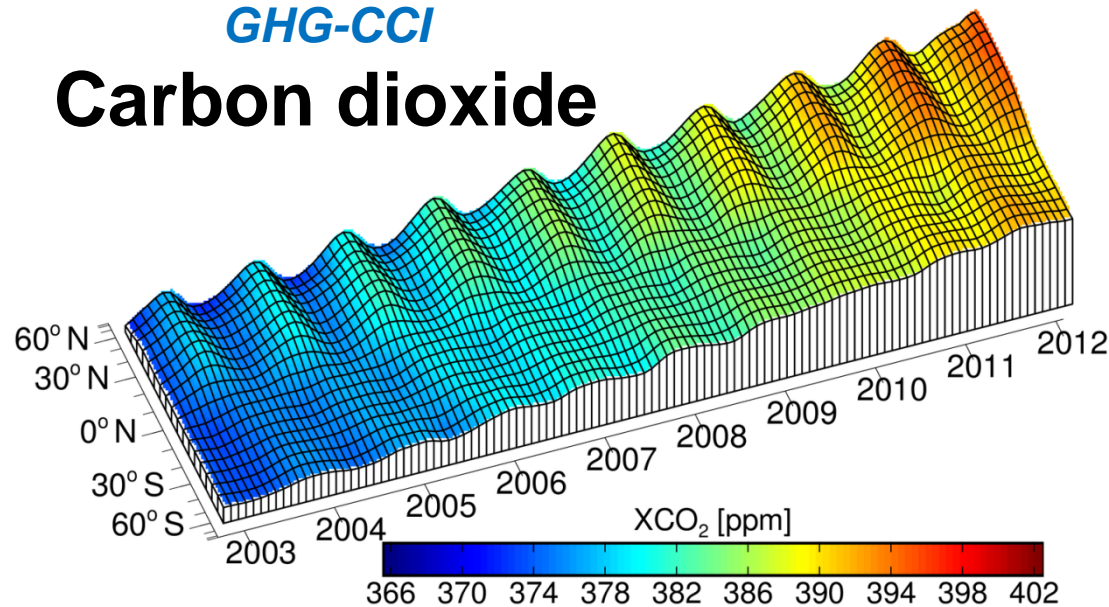
- Product A.8.1: Retrievals of CO₂ and CH₄ of sufficient quality to estimate regional sources and sinks

GHG-CCI: GHG data sets

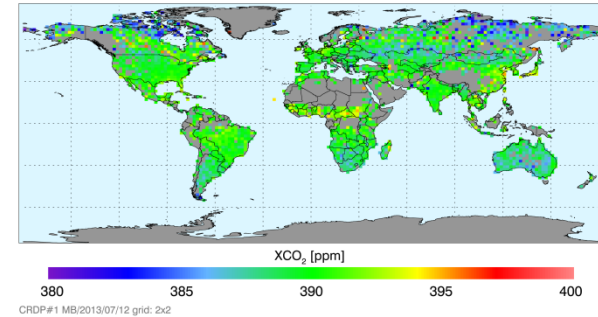


GHG-CCI

Carbon dioxide

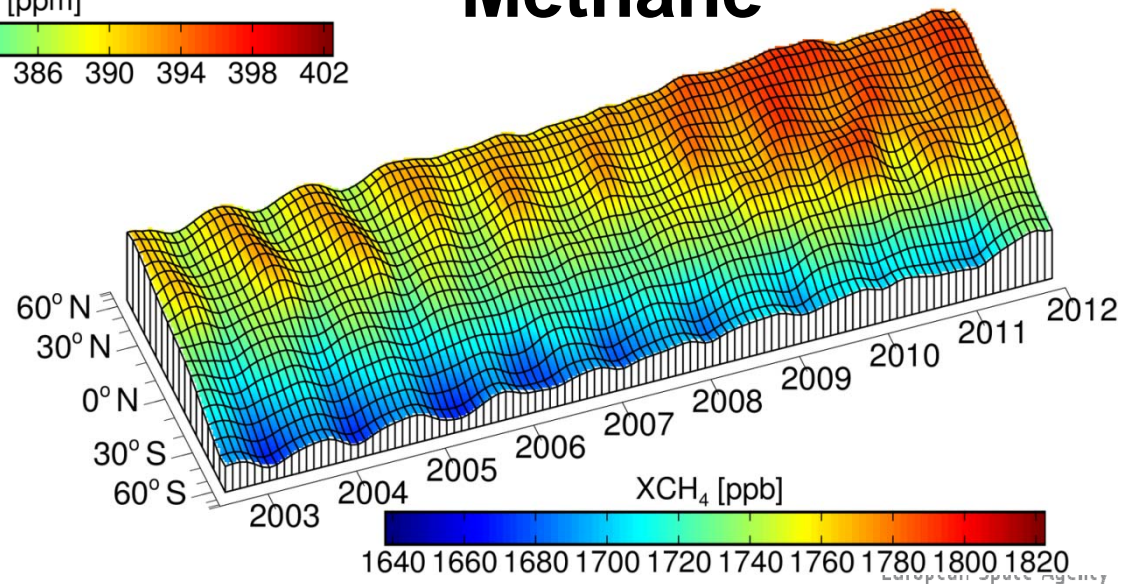


GHG-CCI 2010-2011
Carbon Dioxide TANSO/GOSAT/RemoTeC(SRFP)

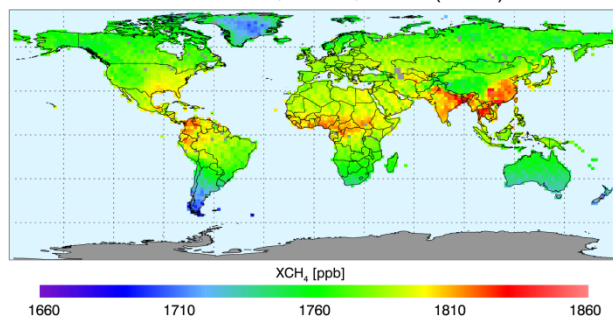


GHG-CCI

Methane



GHG-CCI 2010-2011
Methane TANSO/GOSAT/UoL-PR(OCPR)



Science



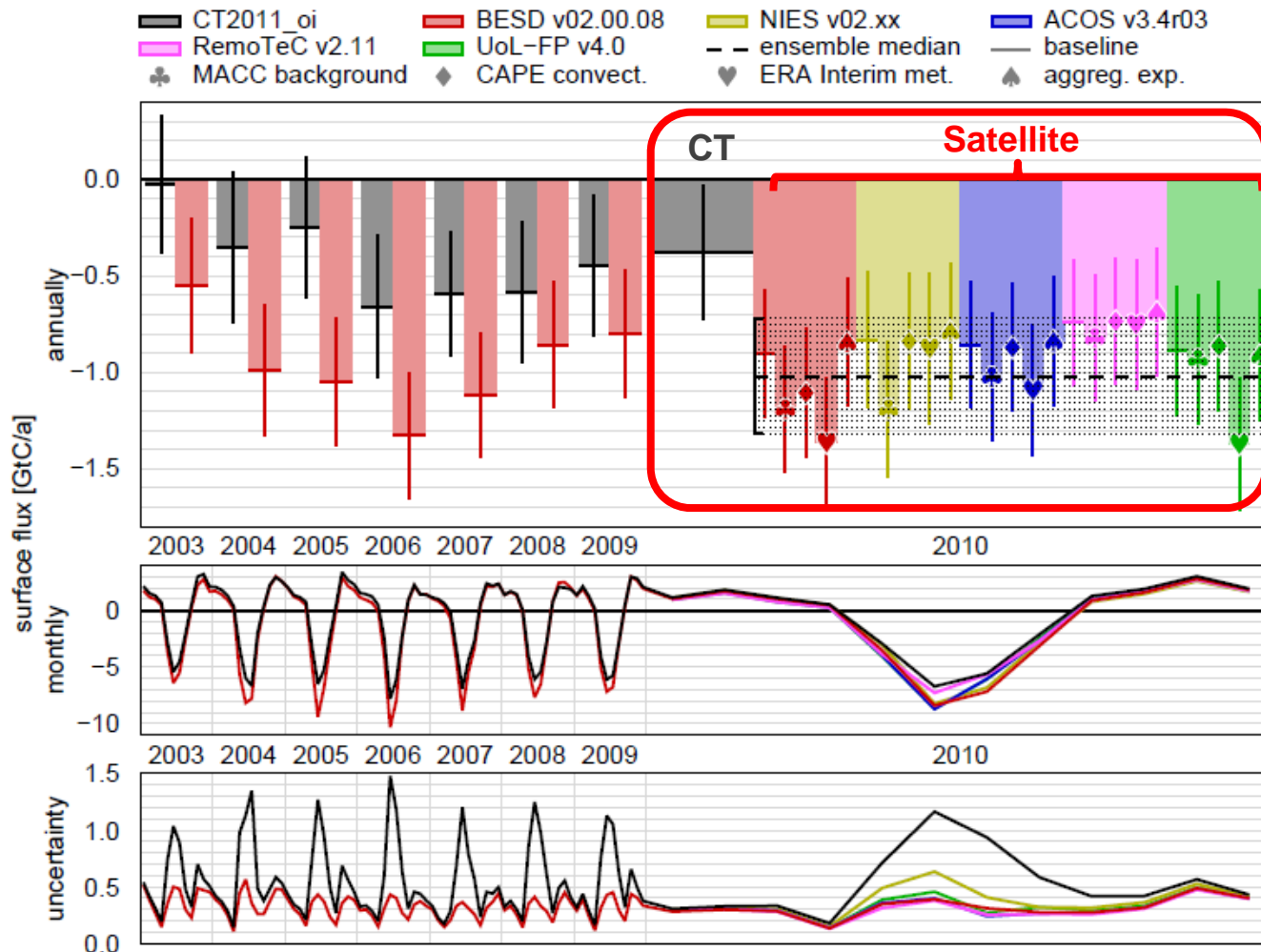
Selected results from recent publications

European terrestrial carbon fluxes from SCIAMACHY and GOSAT - II



„Europe only“ inversion using STILT-based short range (days) particle dispersion modelling using an ensemble of satellite XCO₂ 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 (TransCom region) European C sink of 1.02 +/- 0.3 GtC/yr (for 2010)

European carbon sink



European carbon uptake in gigatons of carbon in 2010



See also

http://www.esa.int/Our_Activities/Observing_the_Earth/Is_Europe_an_underestimated_sink_for_carbon_dioxide

European carbon sink



... research is going on ...

Atmos. Chem. Phys. Discuss., 15, 1989–2011, 2015
www.atmos-chem-phys-discuss.net/15/1989/2015/
doi:10.5194/acpd-15-1989-2015
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Atmospheric
Chemistry
and Physics
Discussions

Open Access



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.

Elevated uptake of CO₂ over Europe inferred from GOSAT X_{CO₂} retrievals: a real phenomenon or an artefact of the analysis?

L. Feng¹, P. I. Palmer¹, R. J. Parker², N. M. Deutscher^{3,4}, D. G. Feist⁵, R. Kivi⁶,
I. Morino⁷, and R. Sussmann⁸

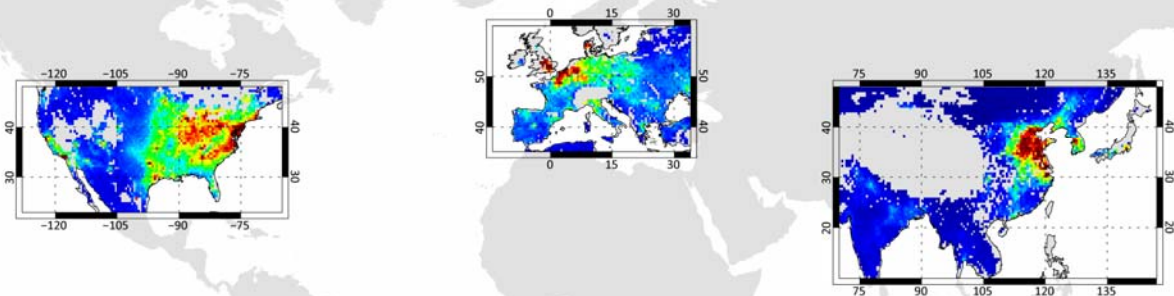
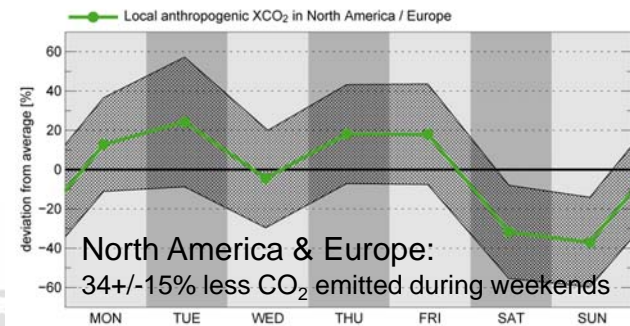
Anthropogenic emissions: Good and bad news



Reuter et al., Nature Geoscience, 2014

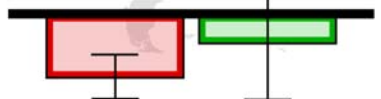
„Decreasing NO_x relative to CO₂ emissions in East Asia inferred from satellite observations“

Satellite derived trends of anthropogenic NO_x and CO₂ emissions



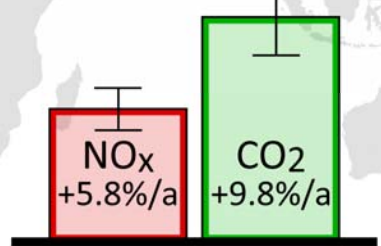
North America
Europe

NO_x -2.7%/a
CO₂ -1.3%/a



East Asia

NO_x +5.8%/a
CO₂ +9.8%/a



- Anthropogenic CO₂ emission signal from localized sources isolated via simultaneous SCIAMACHY XCO₂ and NO₂ observations & new spatial filtering method
- North America & Europe: **Decreasing emissions (but uncertain for CO₂)**
- East Asia: **Increasing emissions but less NO_x per CO₂: Trend towards cleaner technology in East Asia**



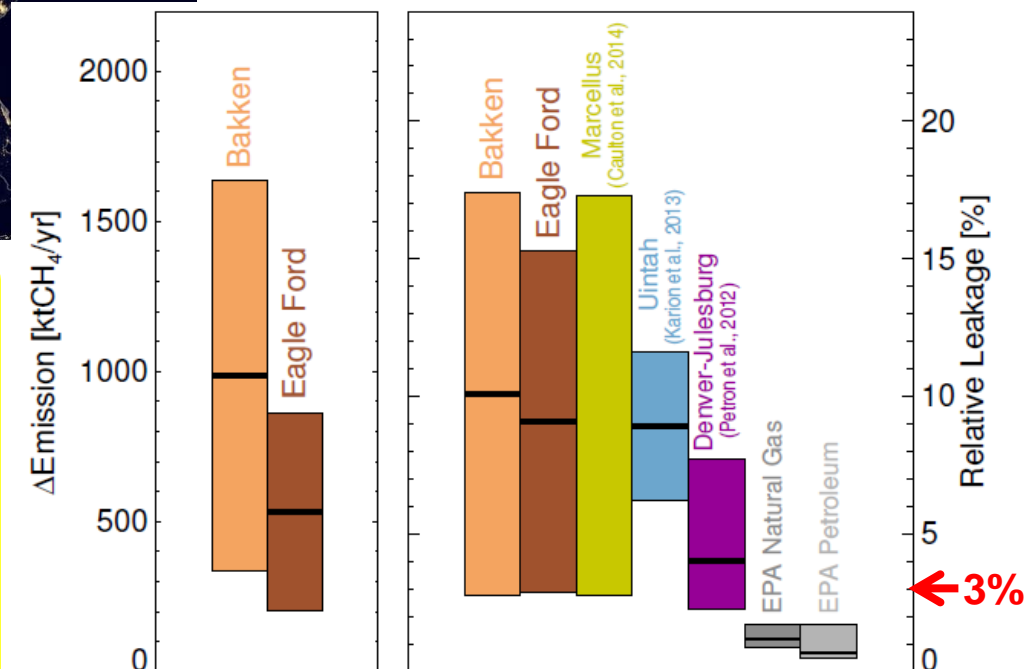
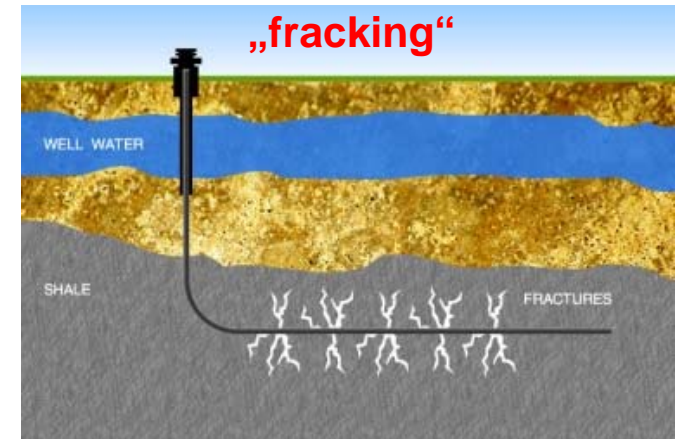
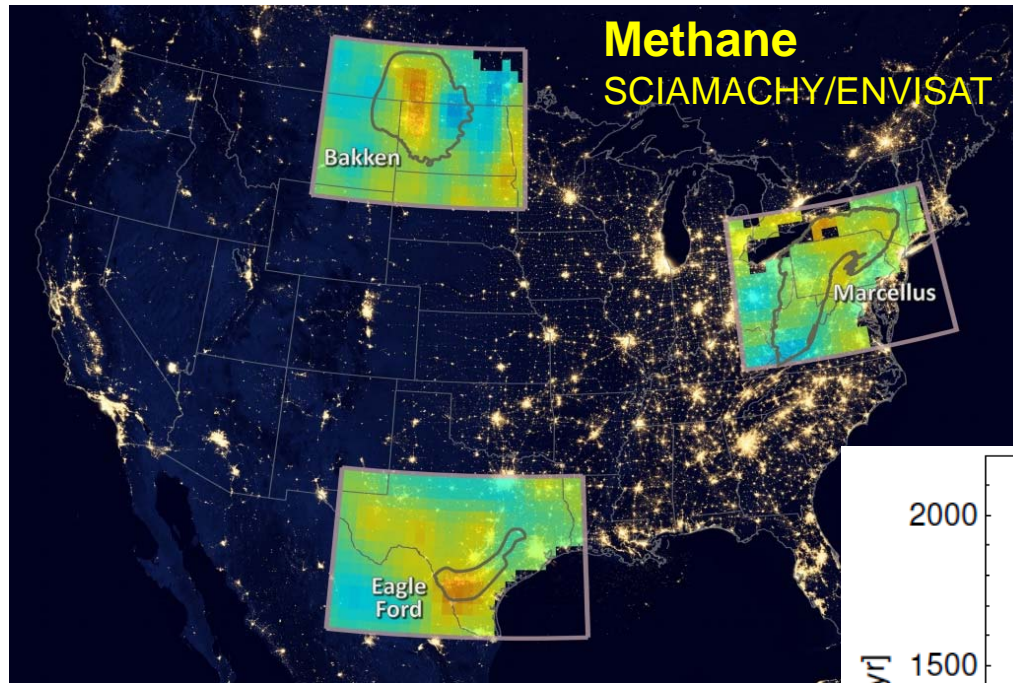
Reuter et al., 2014 (Nature Geoscience)

maximilian.reuter@iup.physik.uni-bremen.de

SCIAMACHY methane:

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

Oliver Schneising¹, John P. Burrows^{1,2,3}, 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: $10.1 \pm 7.3\%$ and
- Eagle Ford: $9.1 \pm 6.2\%$ 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**.