EGU General Assembly 2015, 12.-17.4., Vienna

Satellite observations of carbon dioxide and methane: From SCIAMACHY to CarbonSat

Michael Buchwitz,

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Institute of Environmental Physics (IUP),
University of Bremen, Bremen, Germany

Universität Bremen

& additional contributers (see following slides)

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

Global satellite observations

Global information on near-surface CO_2 & CH_4

Upper layer CO_2 & CH_4

SCIAMACHY/ENVISAT

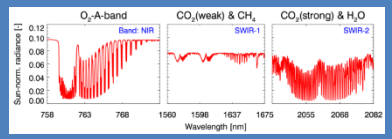
TANSO/GOSAT

Comparisons etc.: OCO-2

IASI, MIPAS, SCIA/occ, ACE-FTS, AIRS, …

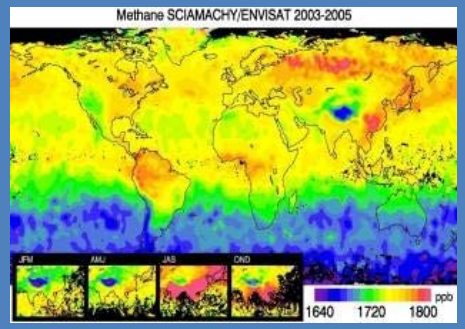
Calibration (L 0-1)

Calibrated radiances



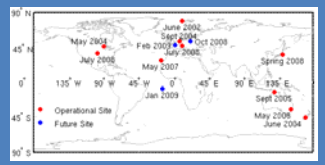
Retrieval
(L 1-2)

Atmospheric GHG distributions

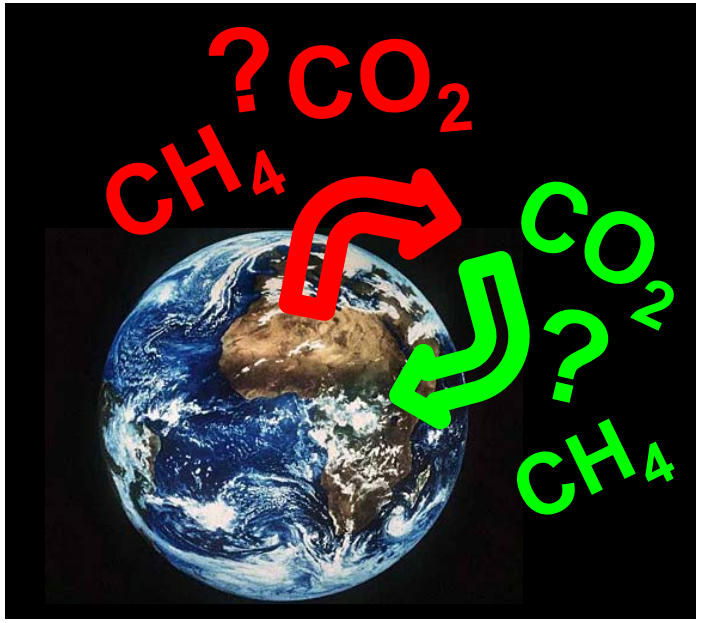


Validation

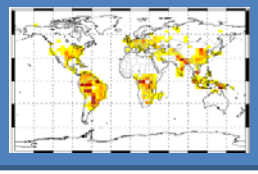
Reference observations

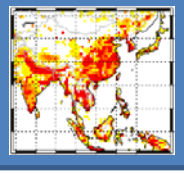


Global observations



Improved information on GHG sources & sinks





Inverse modelling
(L 2-4)

GHG-CCI project team

M. Buchwitz, M. Reuter, O. Schneising, J. Heymann, M. Hilker, S. Noël, H. Bovensmann, J. Notholt, T. Warneke, J. P. Burrows, **IUP, Univ. Bremen, Germany,** Science lead, project management, SCIAMACHY CO_2 & CH_4, S5P CH_4, lead CRDP+ATBD+PVIR, validation (lead)

H. Boesch, W. Hewson, R. Parker, P. Somkuti, **EOS Group, Univ. Leicester (UoL), UK,** Project management, GOSAT CO_2 & CH_4, OCO-2 CO_2, lead SVR+CECR, CRDP data server

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)

C. Crevoisier, R. Armante, A. Chédin, **LMD, CNRS/IPSL, France,** IASI CO_2 & CH_4, ACE-FTS CO_2

B. Dils, E. De Wachter, M. De Mazière, **BIRA, Brussels, Belgium,** Validation

G. Lichtenberg, B. Aberle, **DLR, IMF, Germany,** System engineering (lead), SCIAMACHY calibration

F. Chevallier, **LSCE, France,** Climate Research Group (CRG) lead, lead URD+CAR, user requirements & inverse modelling CO_2

P. Bergamaschi, A. Mihai, **EC-JRC, Air and Climate Unit, IES, Ispra, Italy,** User requirements and inverse modelling CH_4

T. Kaminski, M. Scholze (Lund Univ.), **The Inversion Lab, Germany,** User requirements CO_2 and CCDAS

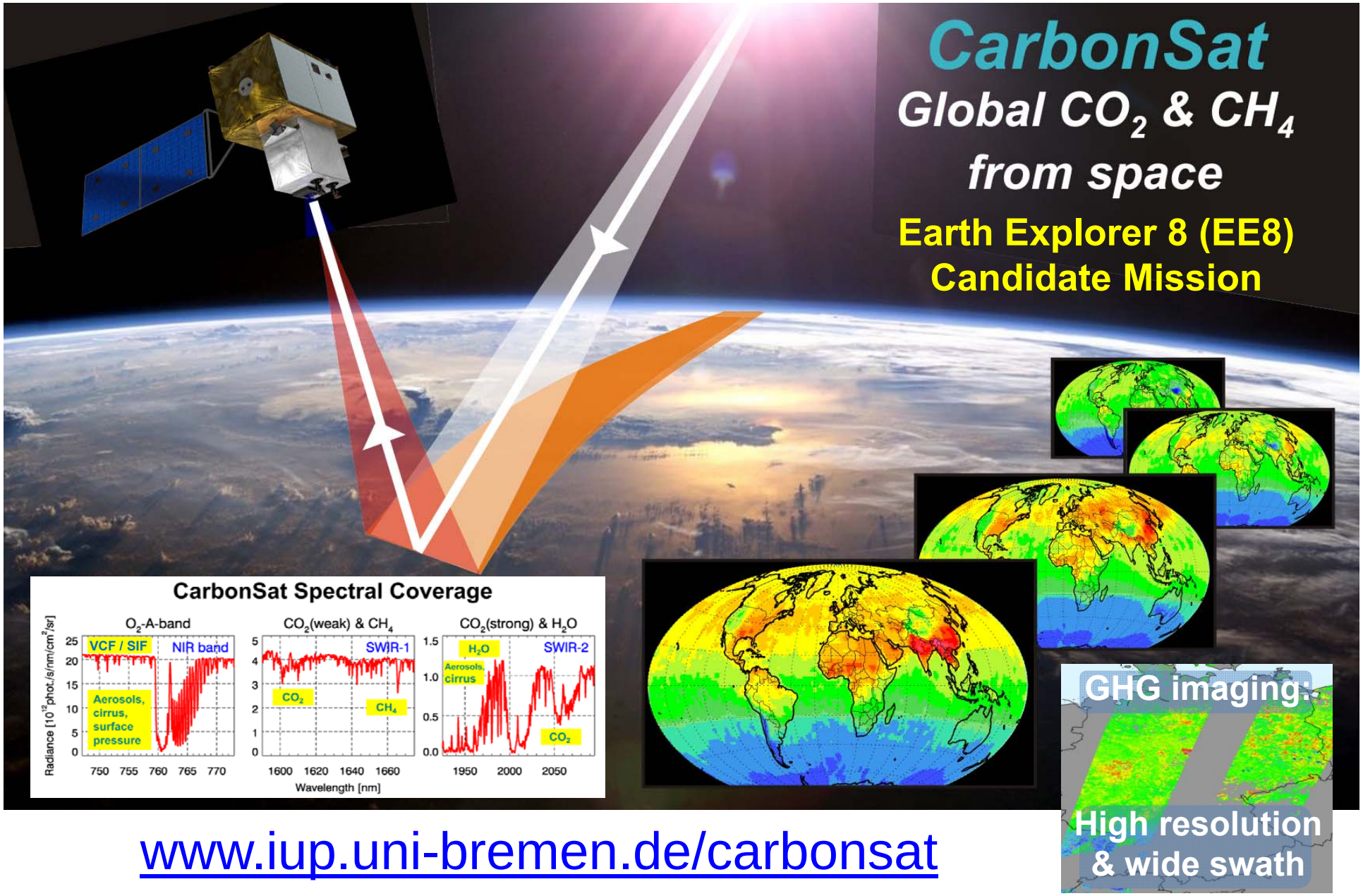
J. Marshall, **MPI-BGC, Jena, Germany,** User requirements and inverse modelling CO_2 and CH_4

P. Palmer, S. Gonzi, **Univ. Edinburgh (UoE), UK,** User requirements and inverse modelling CH_4

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

C. Zehner, **ESA/ESRIN, Frascati, Italy,** ESA technical officer

CarbonSat



www.iup.uni-bremen.de/carbonsat

Contributers: CarbonSat - I

ESA science team: Yasjka Meijer, Paul Ingmann, Dirk Schüttemeyer

ESA system team: Armin Löscher, Bernd Sierk, Pedro Jurado & ad-hoc support

Contributions from **Mission Advisory Group**

Contributions from **Science Study consortia**

Contributions from **Campaign consortia**

Universität Bremen

SRON Netherlands Institute for Space Research

University of Leicester

NOVELTIS

LSCE

MPI-BGC Jena

EMPA

Freie Universität Berlin

metair meteorological airborne observations measurements and expertise

elecnor deimos

VU UNIVERSITY AMSTERDAM

Centre for Ecology & Hydrology NATURAL ENVIRONMENT RESEARCH COUNCIL

CarbonSat

Contributers: CarbonSat - II

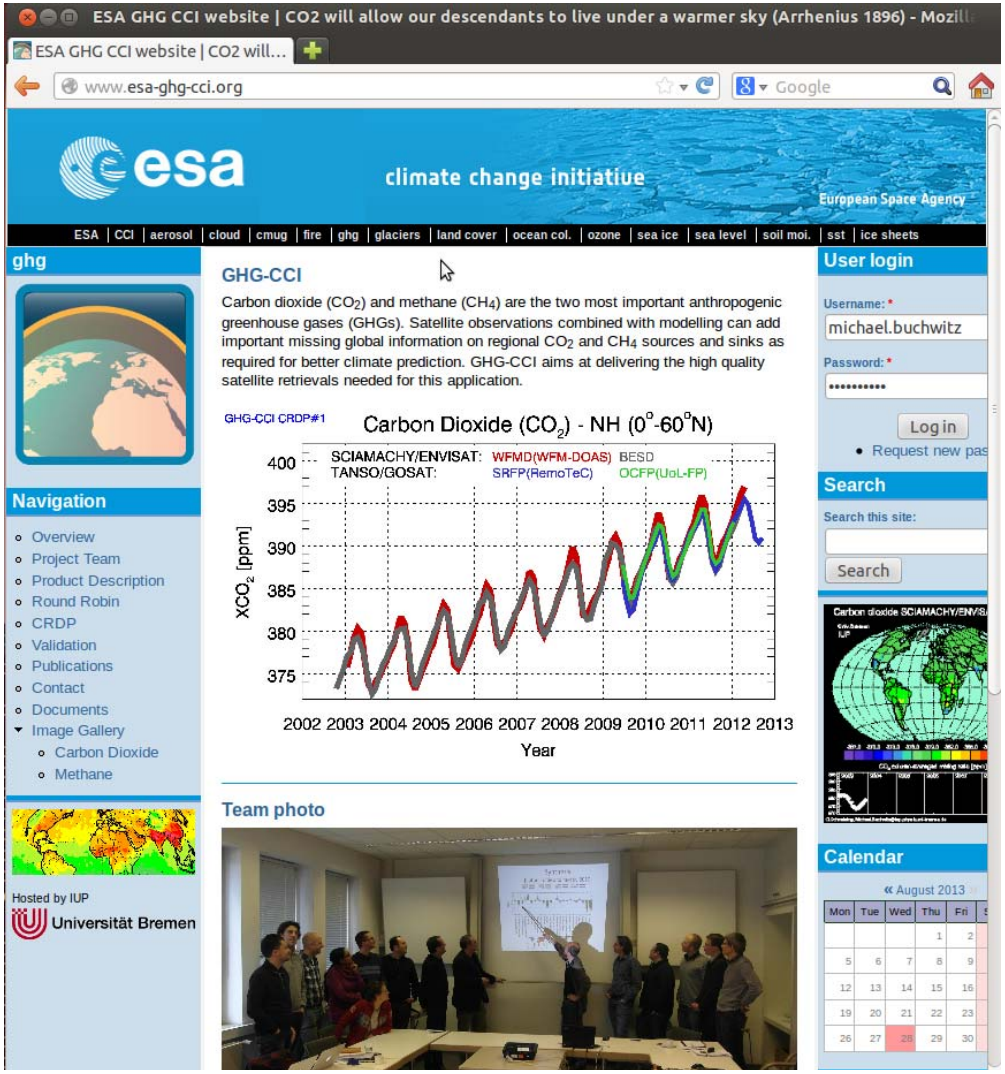
CarbonSat Mission Advisory Group (MAG):

- Heinrich Bovensmann, IUP - University of Bremen, Bremen, DE (Chair)
- Hartmut Bösch, University of Leicester, UK
- Dominik Brunner, EMPA, Dübendorf, CH
- Philippe Ciais, LSCE, Gif-sur-Yvette, FR
- David Crisp, JPL, Pasadena, USA (OCO-2 Science Team Leader)
- Han Dolman, Free University, Amsterdam , NL
- Gary Hayman, CEH, Wallingford, UK
- Sander Houweling, SRON, Utrecht, NL
- Günter Lichtenberg, DLR-IMF, Oberpfaffenhofen, DE

ESA Climate Change Initiative (CCI)

to generate Essential Climate Variables (ECVs)

www.esa-ghg-cci.org/



ESA programme

led by Mark Doherty, ESA/ESRIN

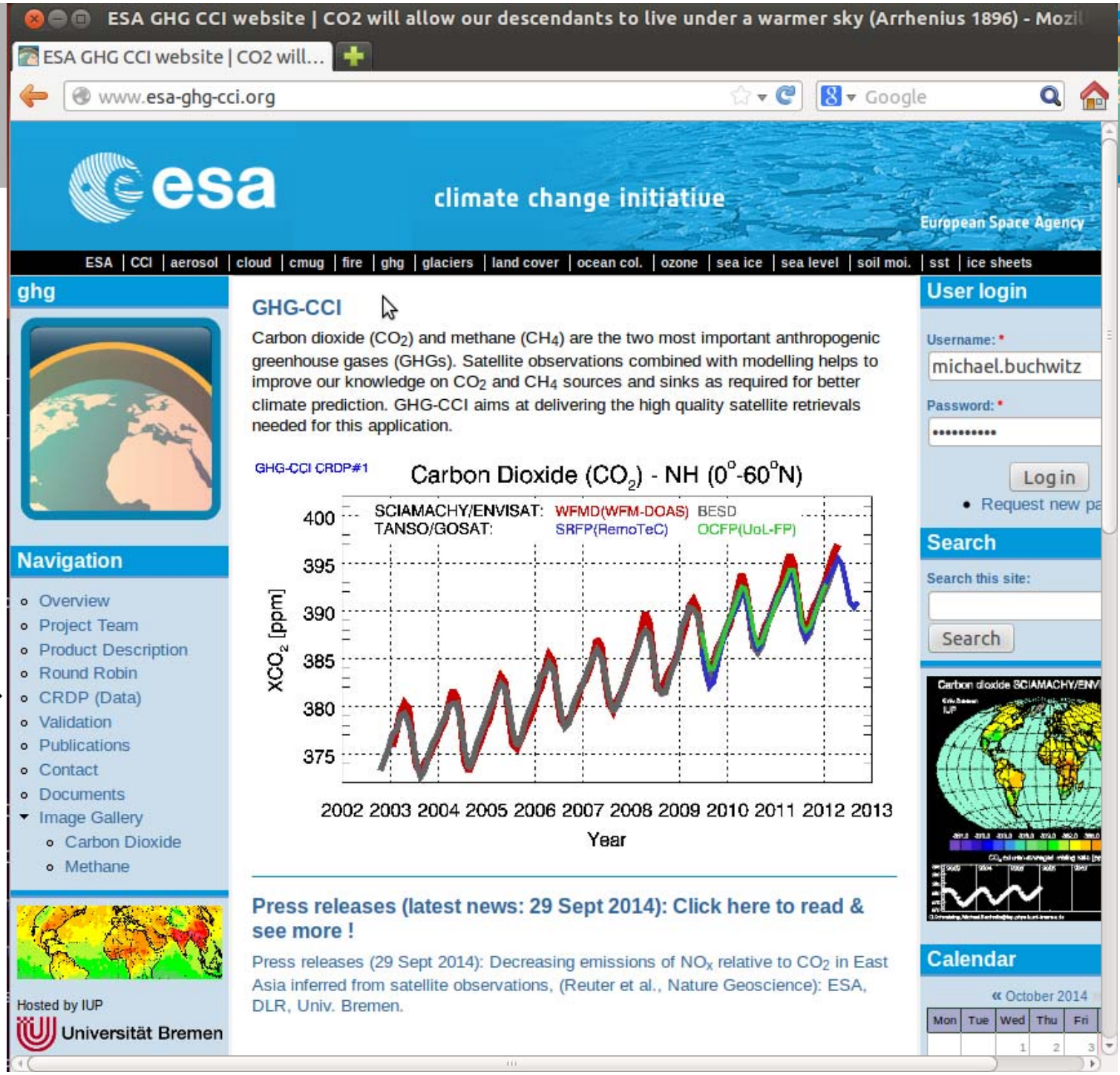
ECV projects:

- Aerosol-CCI
- Cloud-CCI
- Fire-CCI
- **GHG-CCI - CO_2 & CH_4**
- 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

CRDP (Data)


ESA GHG CCI website | CO2 will allow our descendants to live under a warmer sky (Arrhenius 1896) - Mozil
ESA GHG CCI website | CO2 will...
www.esa-ghg-cci.org
Google
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
Navigation
Overview
Project Team
Product Description
Round Robin
CRDP (Data)
Validation
Publications
Contact
Documents
Image Gallery
Carbon Dioxide
Methane
Hosted by IUP
Universität Bremen
GHG-CCI
Carbon dioxide (CO_2) and methane (CH_4) are the two most important anthropogenic greenhouse gases (GHGs). Satellite observations combined with modelling helps to improve our knowledge on CO_2 and CH_4 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 (CO_2) - NH (0°-60°N)
SCIAMACHY/ENVISAT: WFMD(WFM-DOAS) BESD
TANSO/GOSAT: SRFP(RemoTeC) OCFP(UoL-FP)
XCO_2 [ppm]
400
395
390
385
380
375
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
Year
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 CO_2 in East Asia inferred from satellite observations, (Reuter et al., Nature Geoscience): ESA, DLR, Univ. Bremen.
User login
Username: *
michael.buchwitz
Password: *
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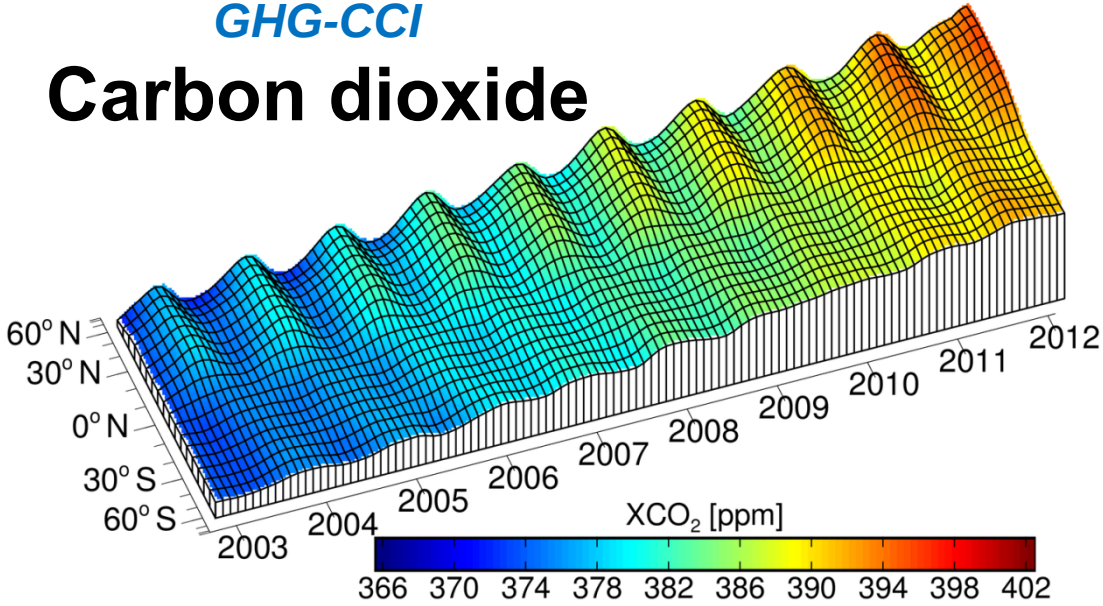
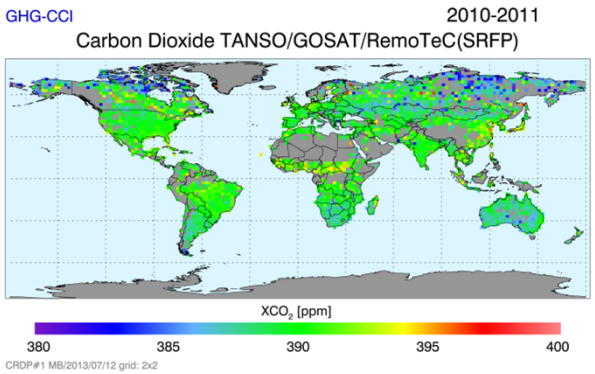
Request new pa
Search
Search this site:
Search
Calendar
« October 2014
Mon Tue Wed Thu Fri

GHG-CCI: GHG data sets

GHG-CCI

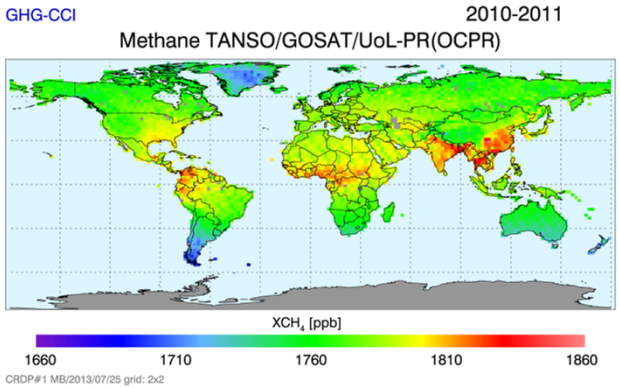
Carbon dioxide

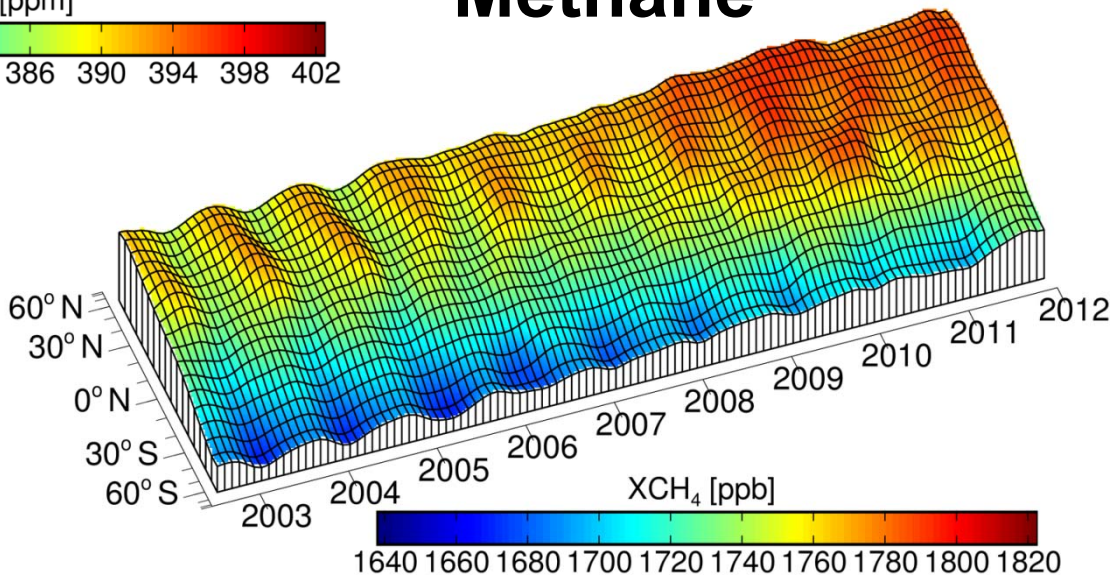




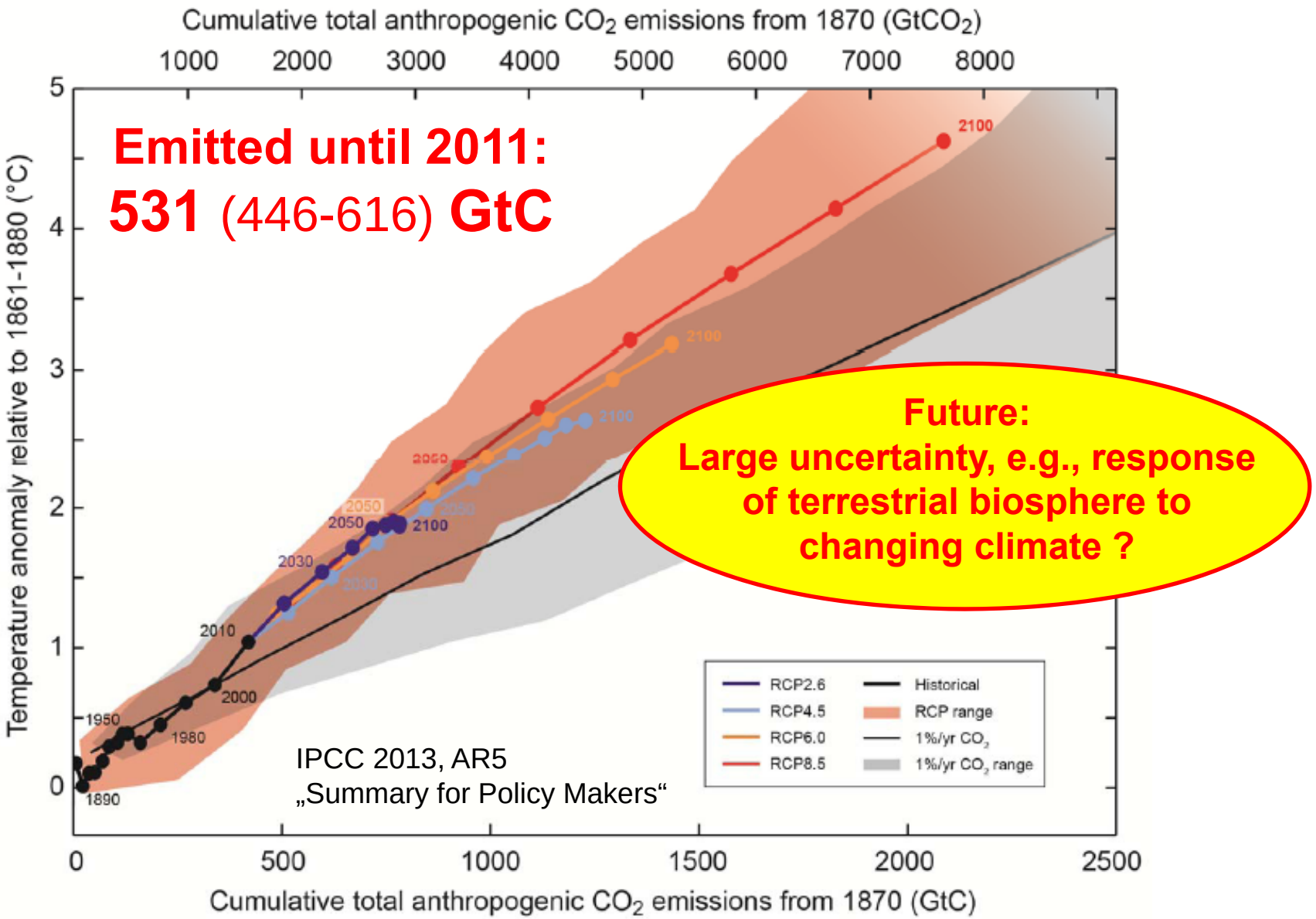
GHG-CCI

Methane



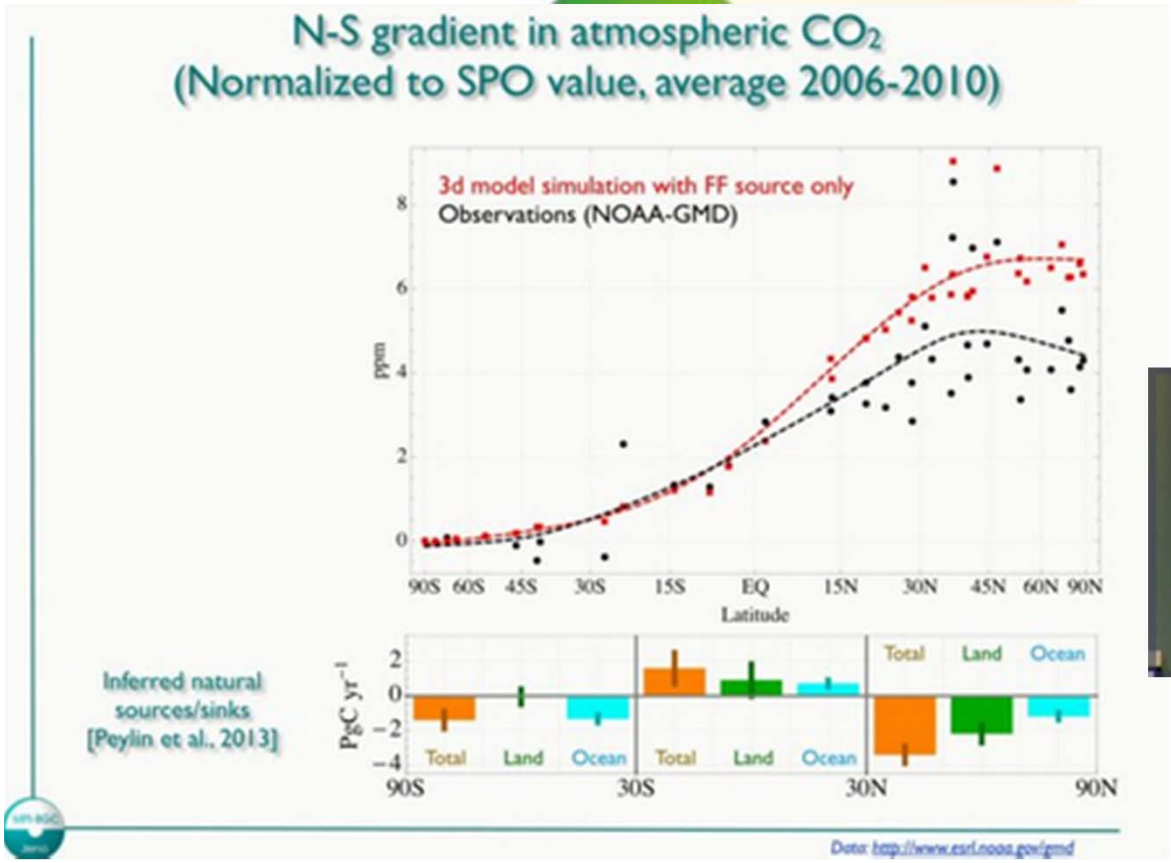


CO_2 emissions -> temperature change



THE CLIMATE SYMPOSIUM 2014

Climate Research and Earth Observations from Space | Climate Information for Decision Making



„Strong carbon sink in northern extra-tropics."

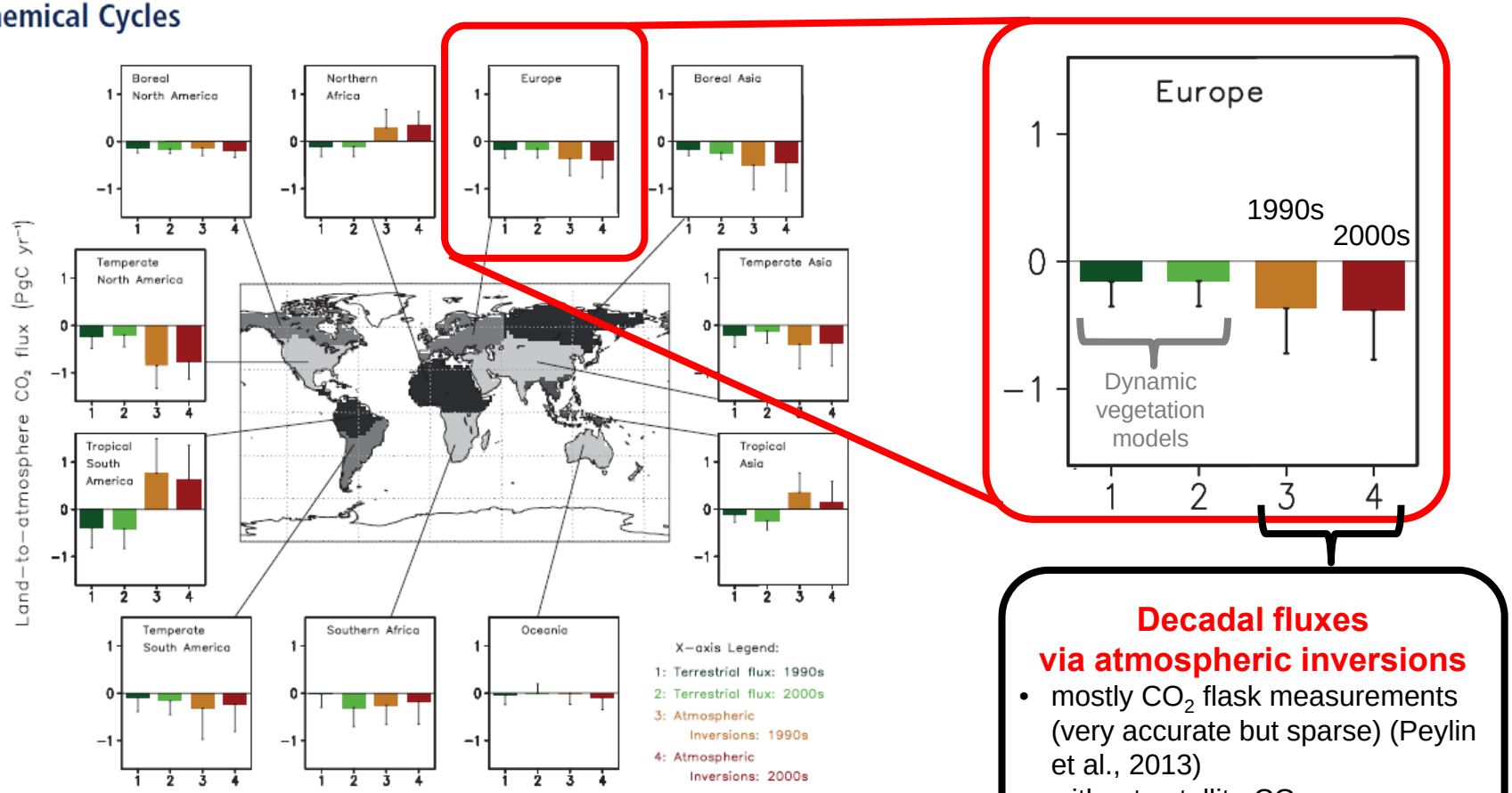
Martin Heimann
@ Climate Symposium 2014

But where exactly is it ???

Watch video @ http://www.theclimatesymposium2014.com
Session: Monday 13th 14:00-15:30 - Setting the scene: Science perspective

Regional terrestrial CO_2 fluxes

IPCC 2013, WG1
Carbon and Other Biogeochemical Cycles



Decadal fluxes via atmospheric inversions

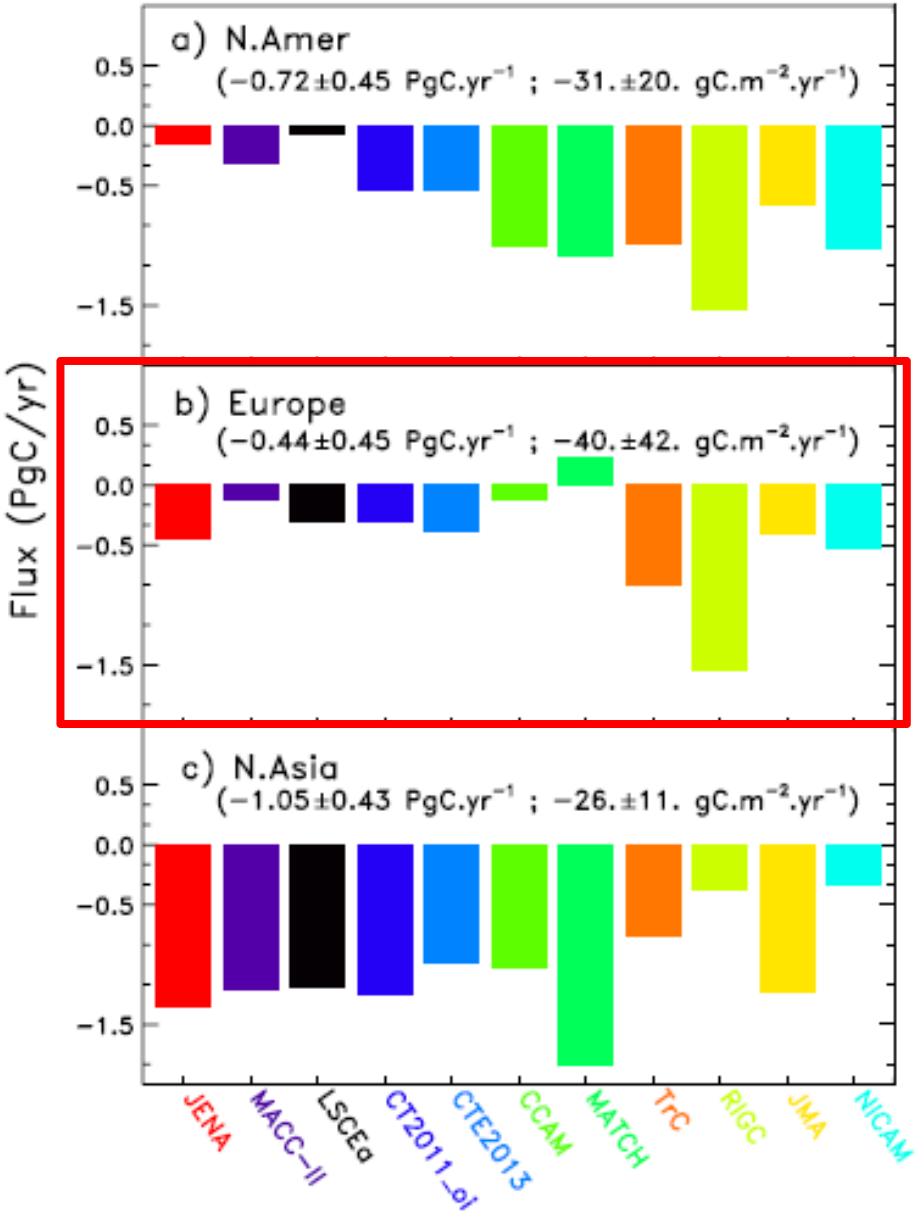
- mostly CO_2 flask measurements (very accurate but sparse) (Peylin et al., 2013)
- without satellite CO_2

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

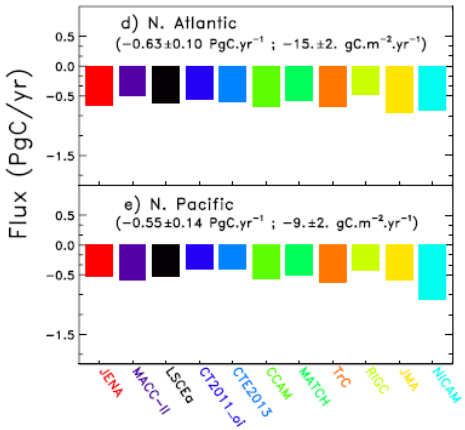
Can we do better using satellite XCO_2 ?

Global atmospheric carbon budget: Peylin et al., 2013

Land



Oceans



Acronym	Reference
LSCEa	Piao et al. (2009)
MACC-II	Chevallier et alal. (2010)
CCAM	Rayner et al. (2008)
MATCH	Rayner et al. (2008)
CT2011_oi	Peters et al. (2007)
CTE2013	Peters et al. (2010)
JENA (s96, v3.5)	Rödenbeck (2005)
RIGC (TDI-64)	Patra et al. (2005a)
JMA	Maki et al. (2010)
TrC	Gurney et al. (2008)
NICAM	Niwa et al. (2012)

No satellite XCO_2 data used

European terrestrial carbon fluxes from SCIAMACHY and GOSAT - I

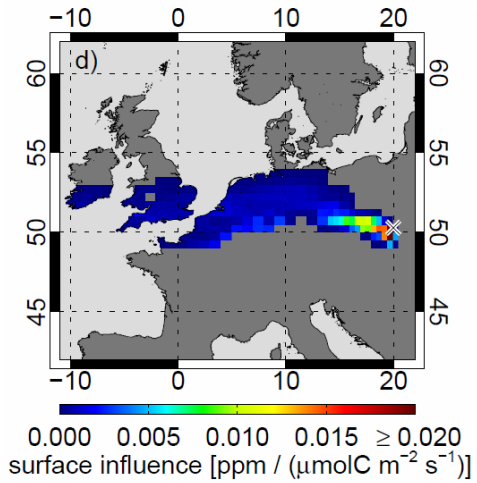
Goal: Get information on European terrestrial carbon fluxes using satellite data and a method which is not or much less sensitive to potential error sources as discussed in the literature such as

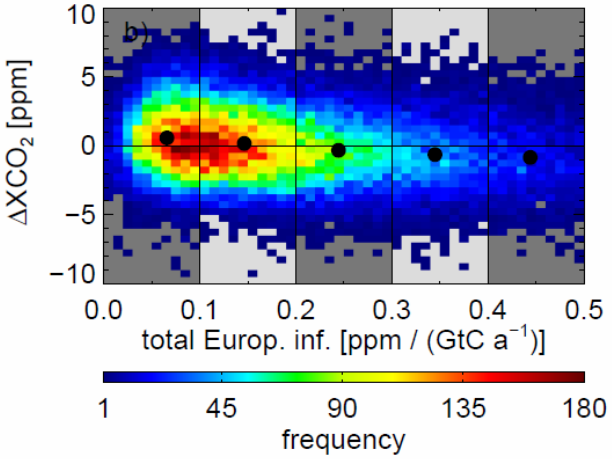
- Potential adverse impact of satellite XCO_2 biases outside of target region (e.g., XCO_2 biases over Africa due to desert dust storm aerosols)
- Potential problems related to long-range transport modelling
- Potential problems related to the used satellite

Reuter et al., ACP, 2014

Approach:

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



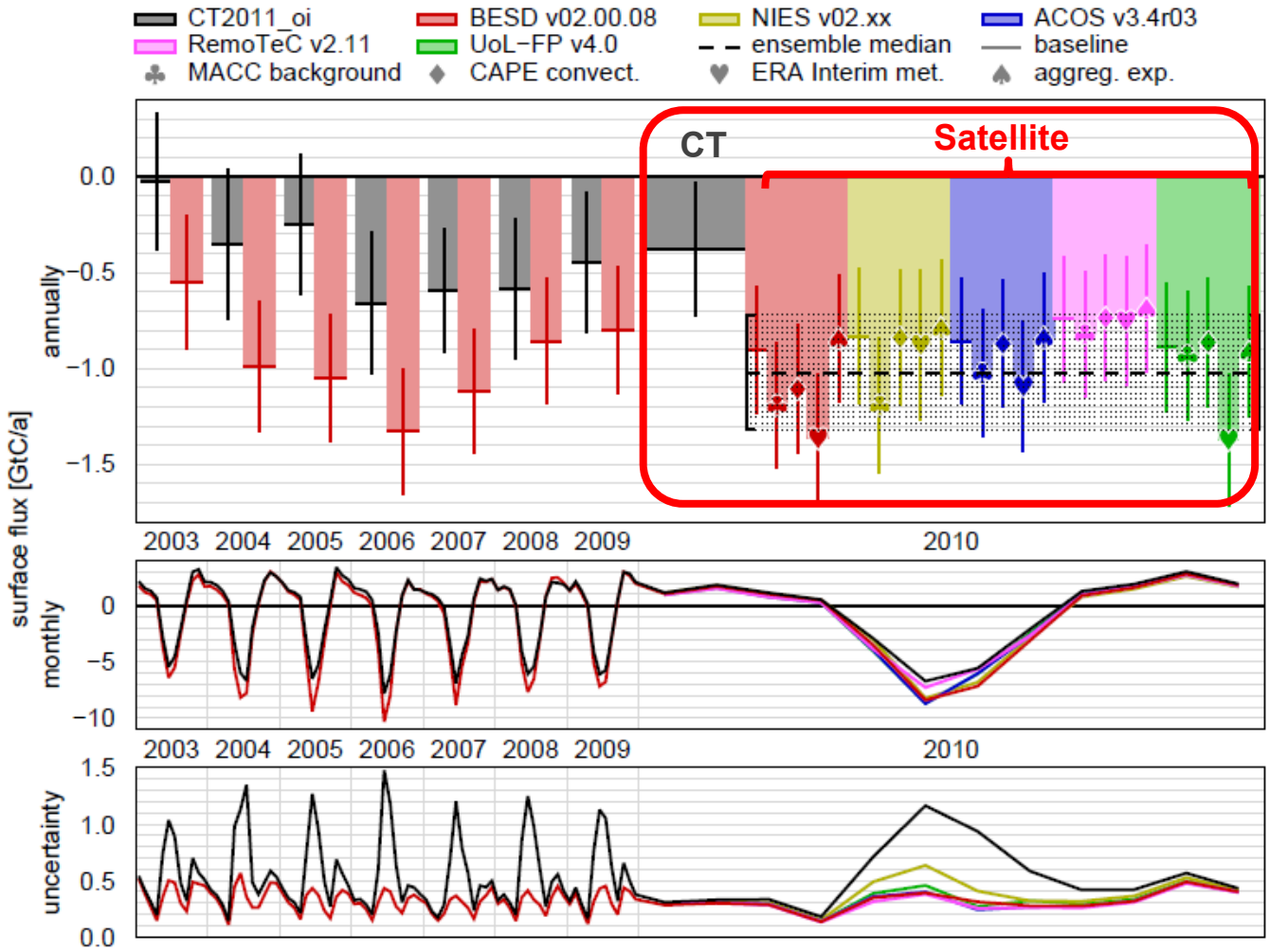


- The satellite minus model (CT2011_oi) difference **ΔXCO_2** shows a **negative correlation** with the integrated **European surface influence**.
- Interpretation: CarbonTracker's **European carbon sink is too weak**.
- Quantitative analysis using the **optimal estimation** framework (1D-Var) to get optimized European surface fluxes considering satellite XCO_2 retrievals.

European terrestrial carbon fluxes from SCIAMACHY and GOSAT - II

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

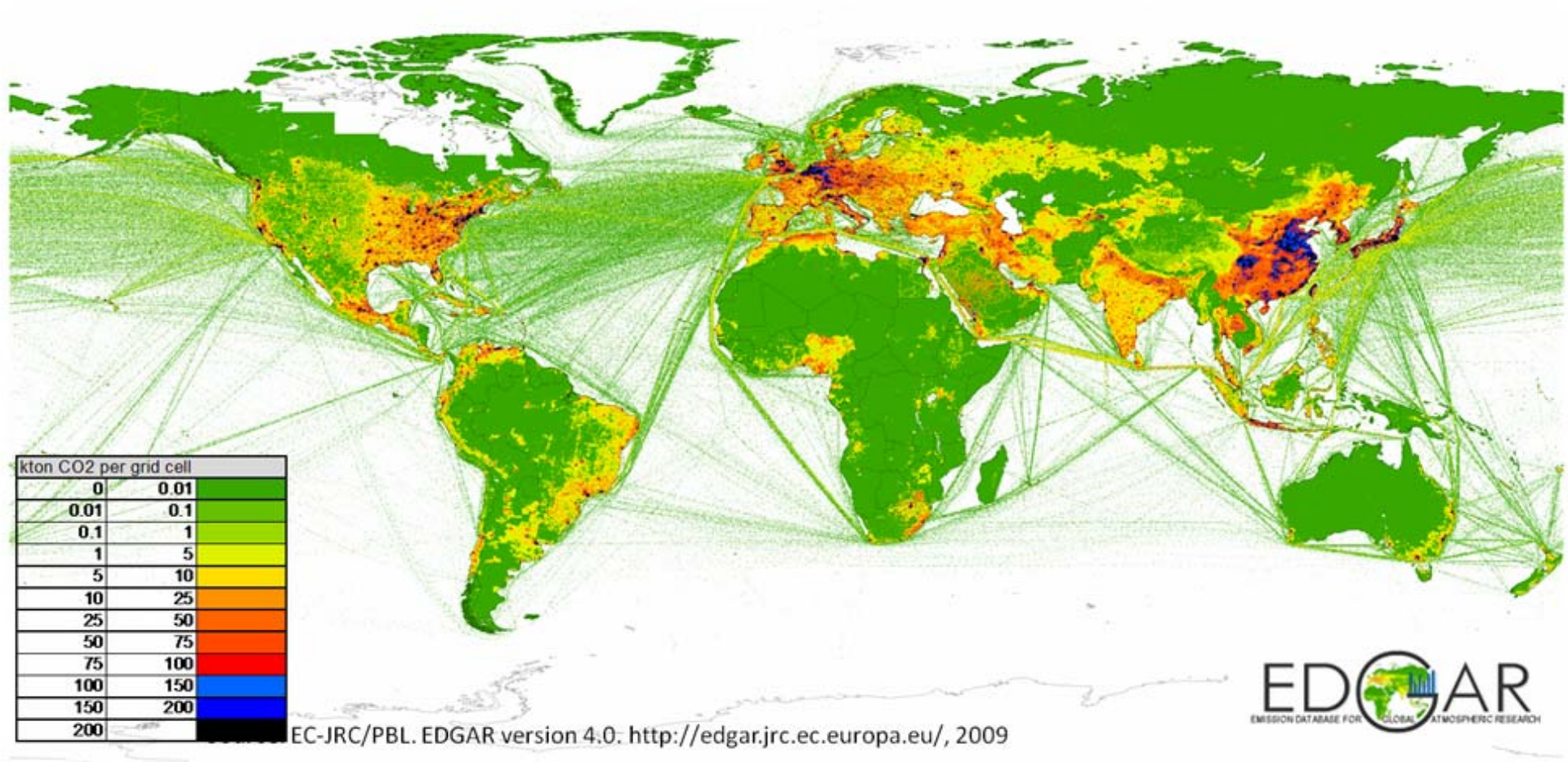
Reuter et al., ACP, 2014



- 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 (TransCom region) European C sink of 1.02 +/- 0.3 GtC/yr (for 2010)

Anthropogenic CO_2

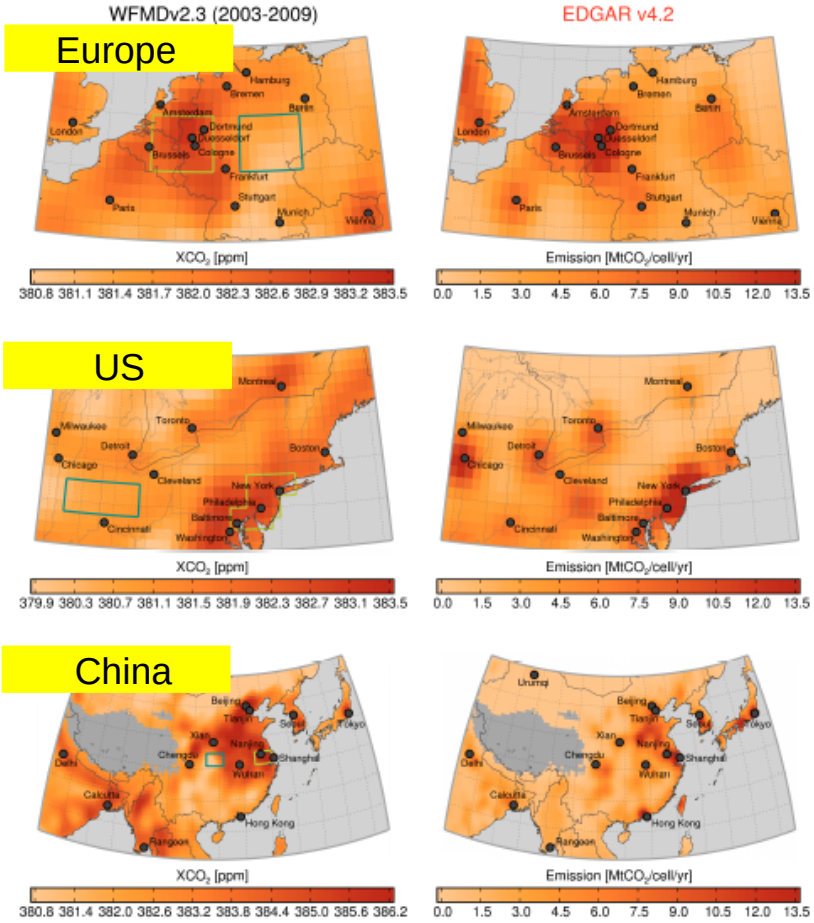


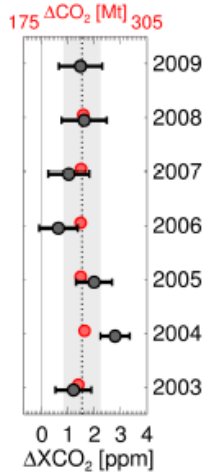
Bottom-up estimate
Currently not possible to verify this using satellite data !?
-> We hope for CarbonSat !

SCIAMACHY CO_2 over anthropogenic source regions

SCIAMACHY XCO_2

EDGAR CO_2 emissions

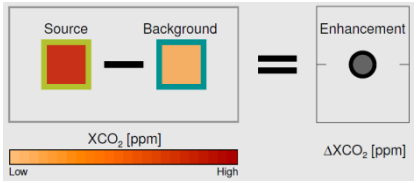


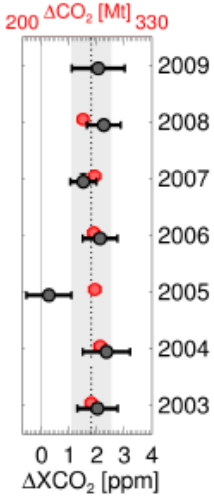


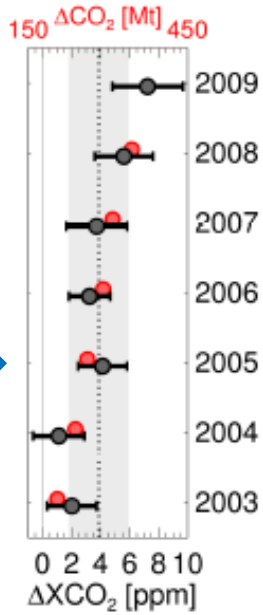
Schneising et al., ACP, 2013

SCIAMACHY
EDGAR

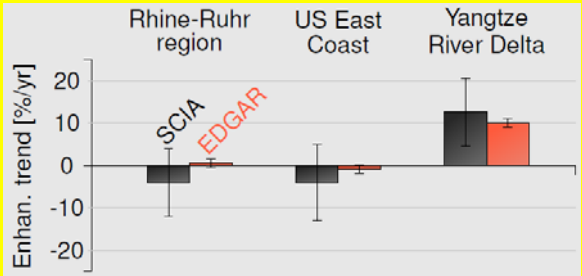
Regional enhancement =
Source - Background







Trend [%CO_2/yr]

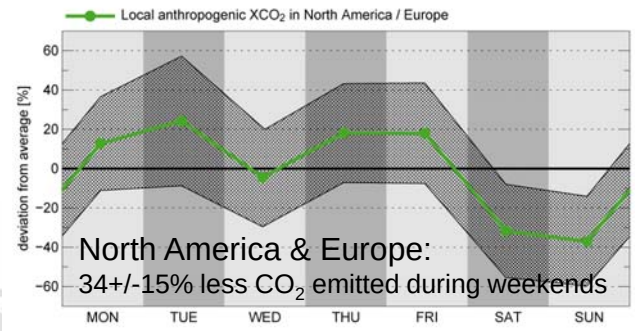


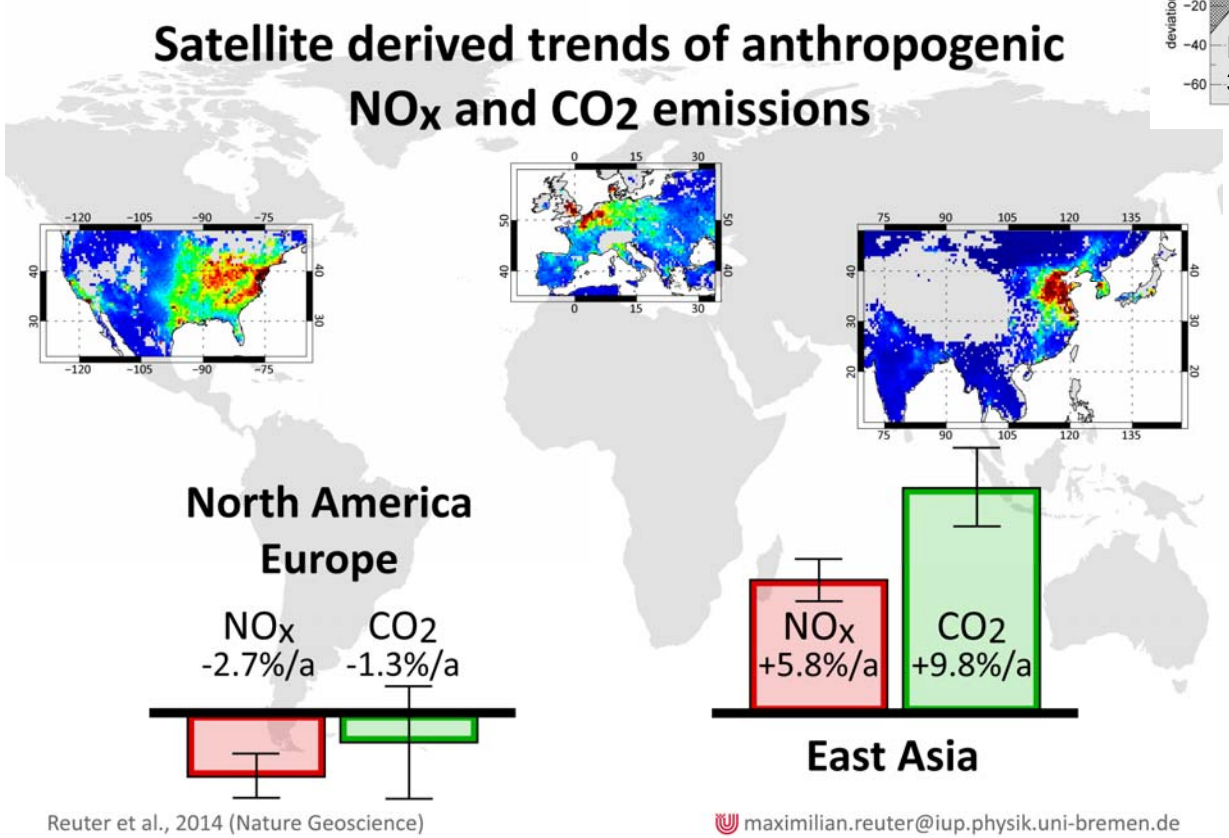
EDGAR emissions consistent with SCIAMACHY

Anthropogenic emissions: Good and bad news

Reuter et al., Nature Geoscience, 2014

„Decreasing NO_x relative to CO_2 emissions in East Asia inferred from satellite observations“





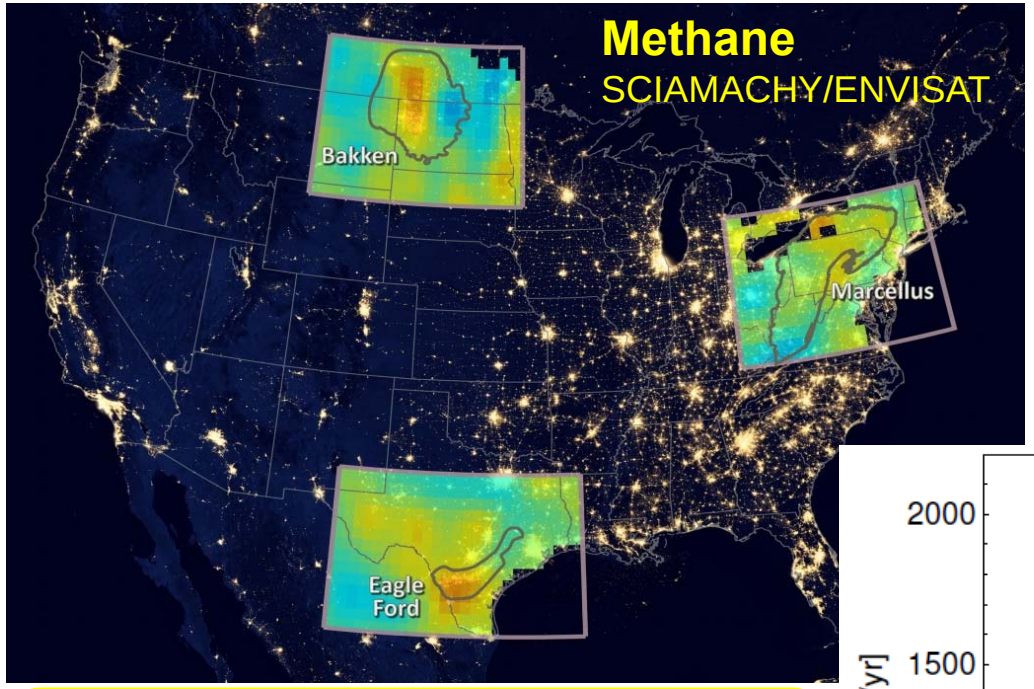
- Anthropogenic CO_2 emission signal from localized sources isolated via simultaneous SCIAMACHY XCO_2 and NO_2 observations & new spatial filtering method
- **North America & Europe: Decreasing emissions (but uncertain for CO_2)**
- **East Asia: Increasing emissions but less NOx per CO_2: Trend towards cleaner technology in East Asia**

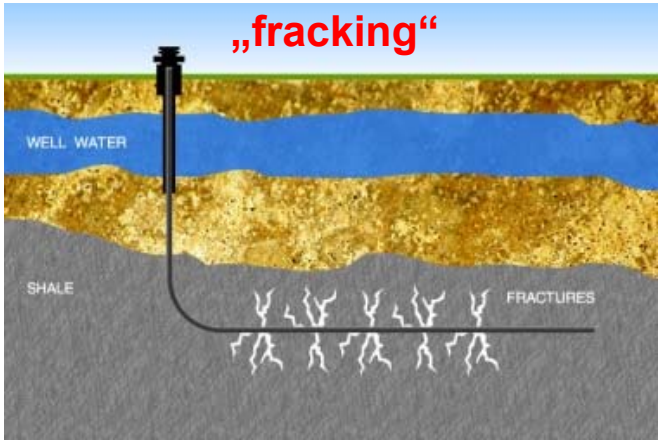
SCIAMACHY methane:

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[2], 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 ktCH_4/yr**
- **Eagle Ford: 530±330 ktCH_4/yr**

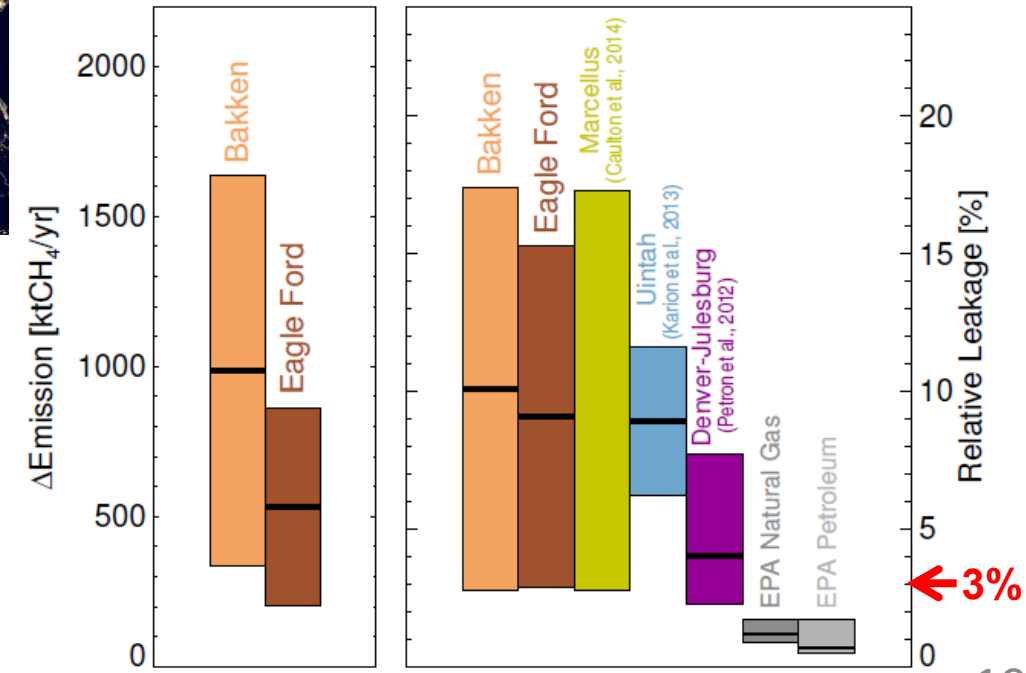
Emission estimates correspond to **leakages** of

- Bakken: 10.1±7.3% and
- Eagle Ford: 9.1±6.2%

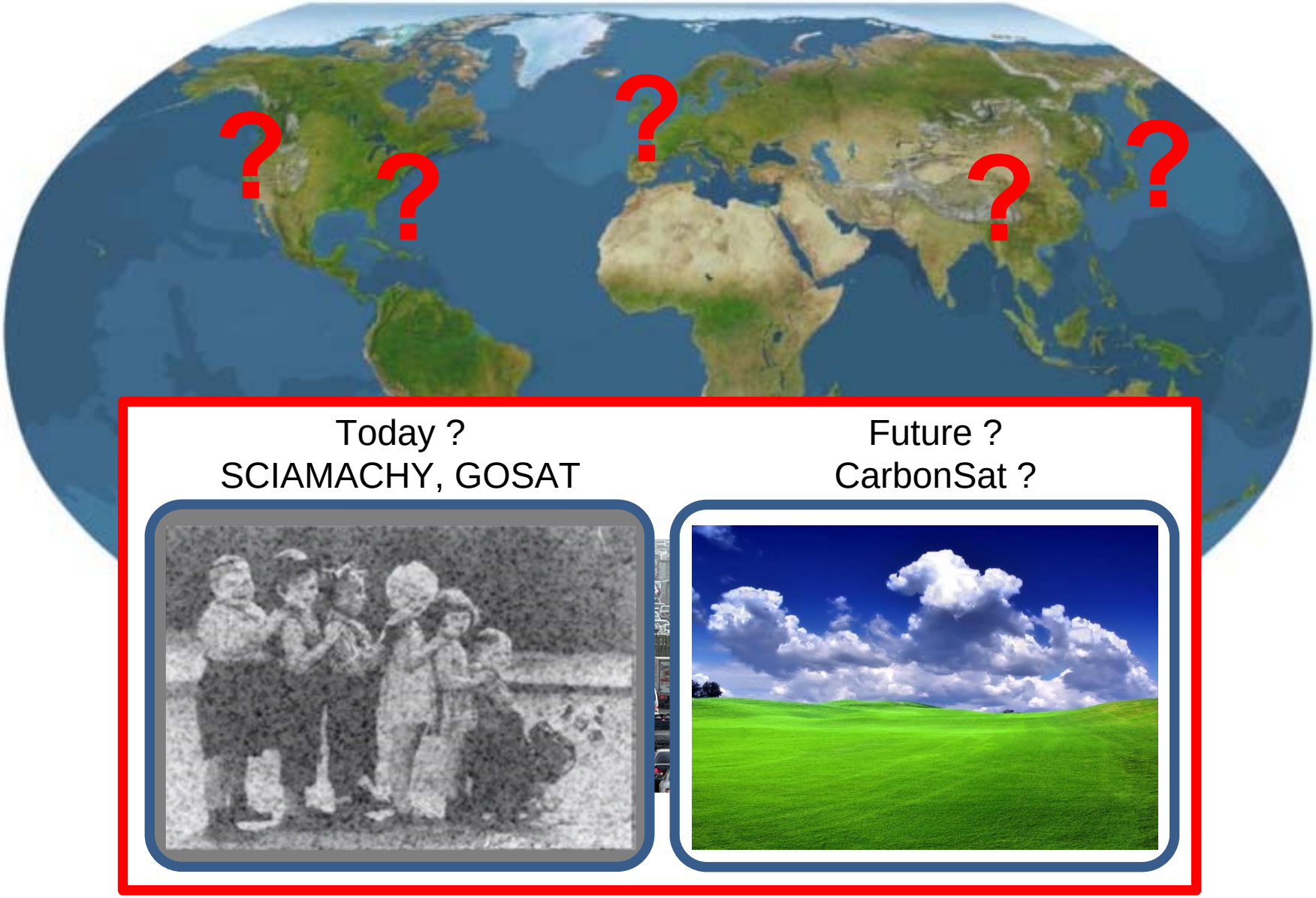
in terms of energy content.

Exceeds 3.2% "climate benefit" threshold (Alvarez et al., 2012) for switching from coal to natural gas

Likely **underestimated in inventories**.



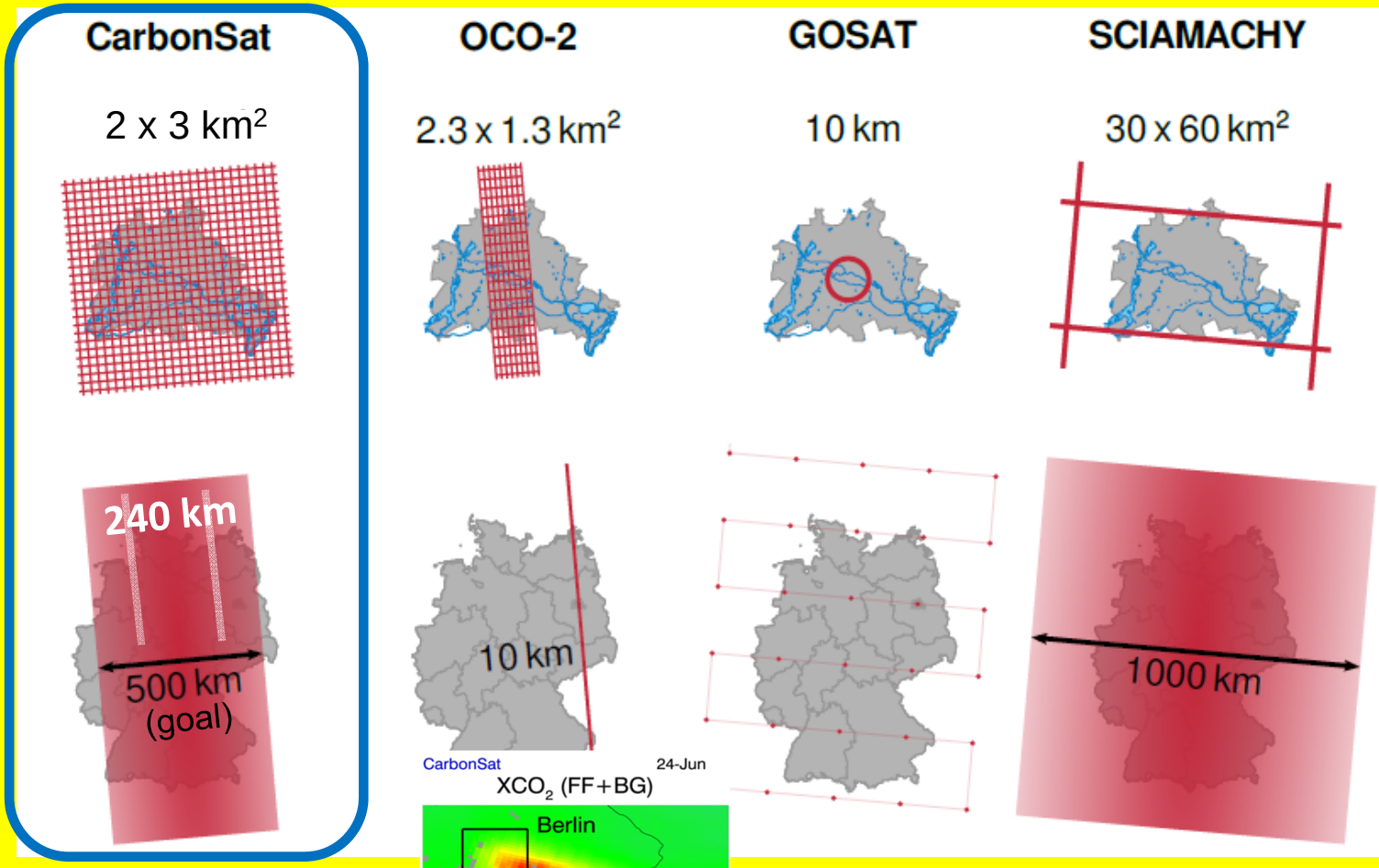
Anthropogenic CO_2 and CH_4 emissions from space

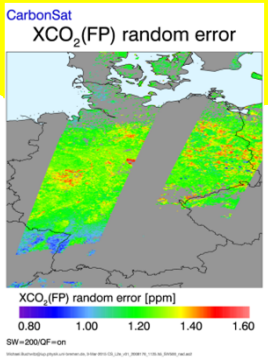


From SCIAMACHY to CarbonSat

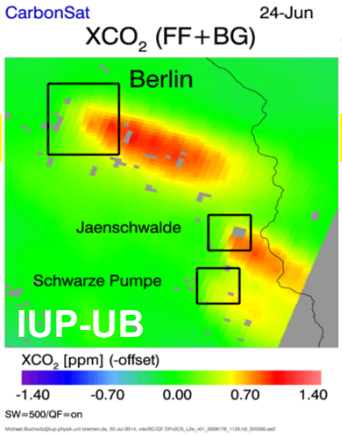
Berlin

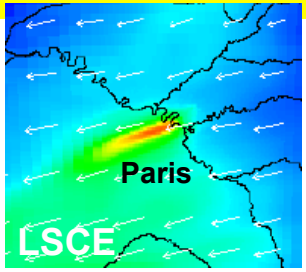
Germany

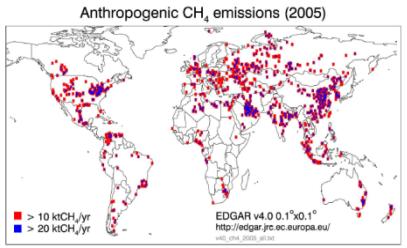




New capabilities:
Cities, power plants, oil & gas fields, geological „point“ sources, …



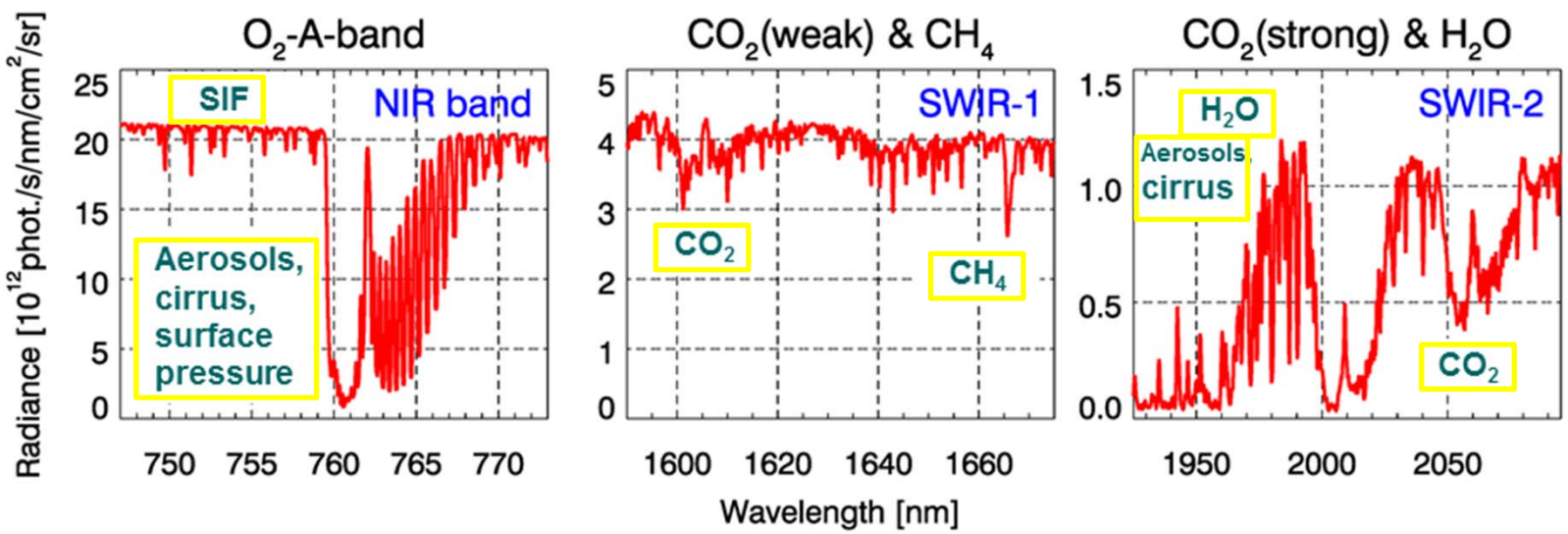




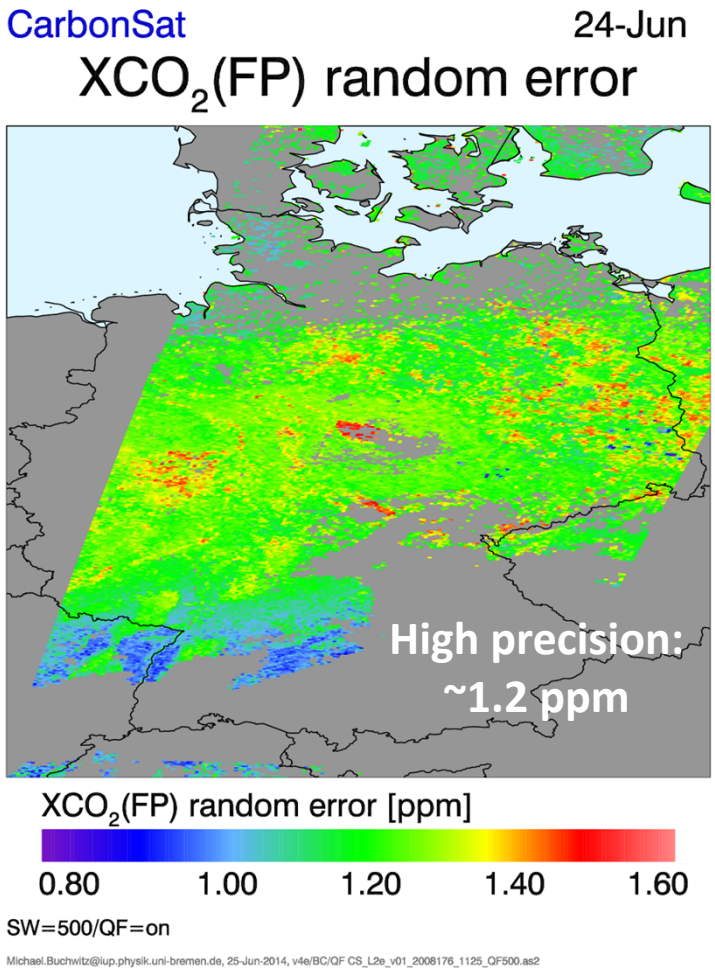
CarbonSat: Spectral Parameters (Level 1)

CarbonSat Spectral Instrument Characteristics			
Parameter	**Spectral band**		
	NIR	**SWIR-1**	**SWIR-2**
Spectral range [nm]	747 – 773	1590 – 1675	1925 – 2095
Spectral resolution FWHM [nm]	0.1	0.3	0.55
Spectral Sampling Ratio (SSR) [1/FWHM]	3	3	3
Threshold Signal-to-Noise Ratio (SNR) for SZA 50° and vegetation surface [-]	473	347	274
Radiance for listed SNR in photons/s/nm/cm^2/steradiant	2.0×10^{13}	4.1×10^{12}	9.9×10^{11}

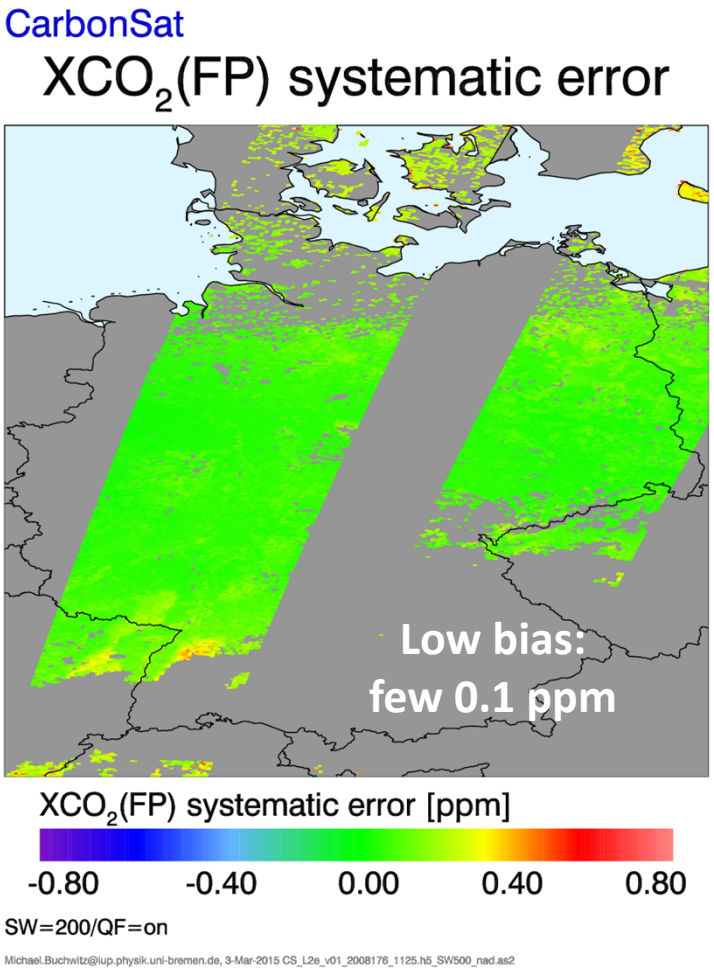
CarbonSat Spectral Coverage



CarbonSat: Single ground pixel XCO_2



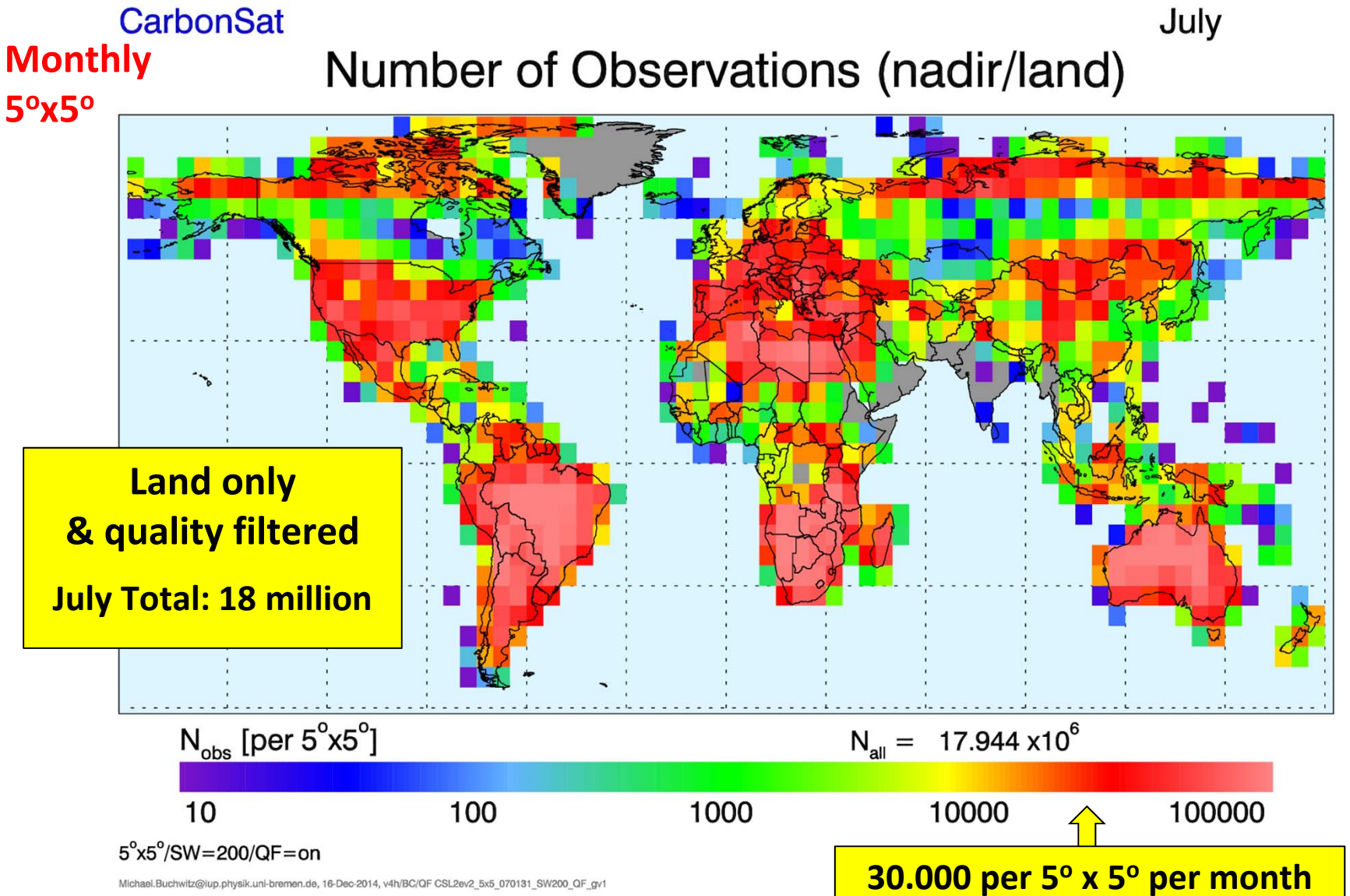
Swath: 500 km (goal)



Swath: 200 km (pessimistic)

Update of Buchwitz et al., AMT, 2013

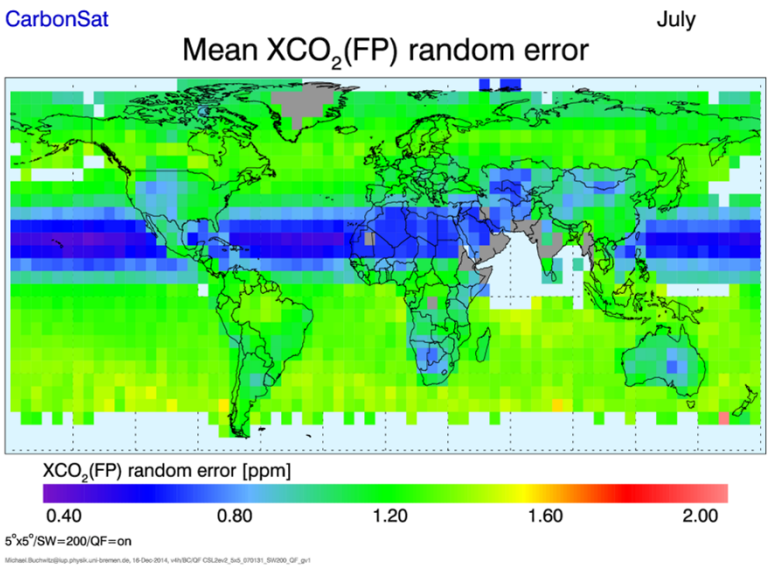
CarbonSat: Number of Observations

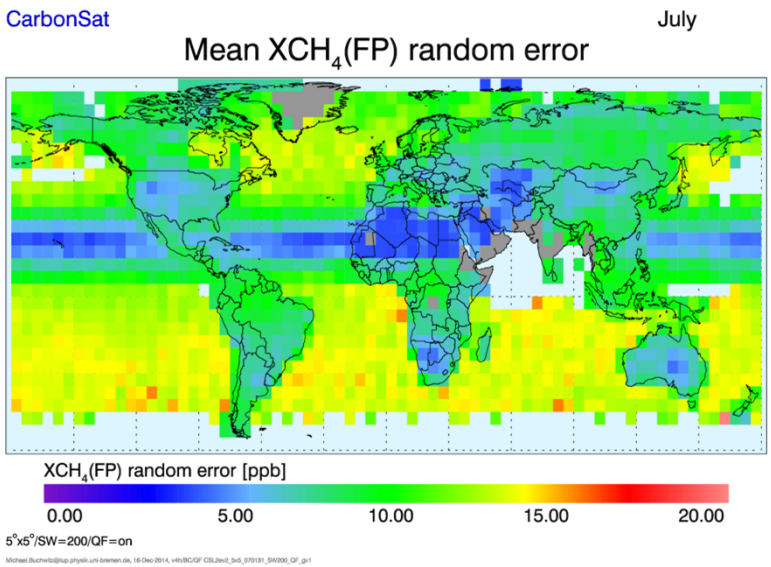


Update of Buchwitz et al., AMT, 2013

Assumptions: swath width 200 km (pessimistic), 2x3 km^2 ground pixel size

CarbonSat: XCO_2 and XCH_4 Precision





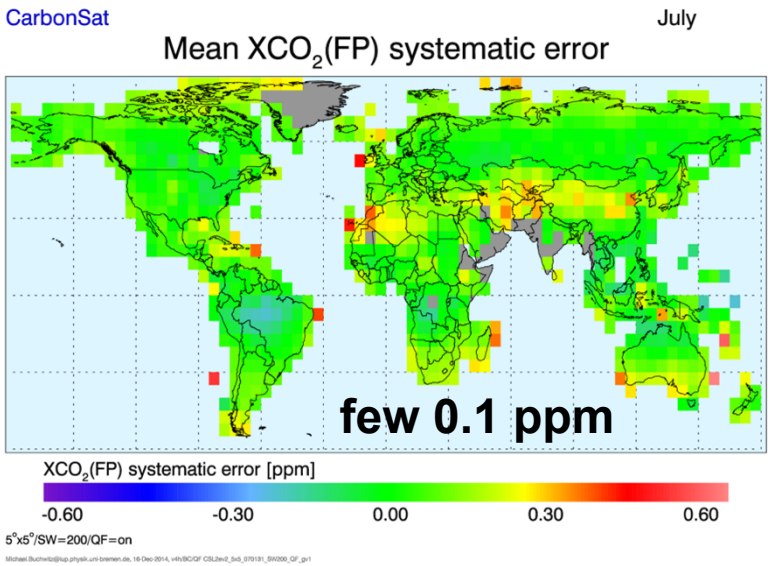
XCO_2 precision:

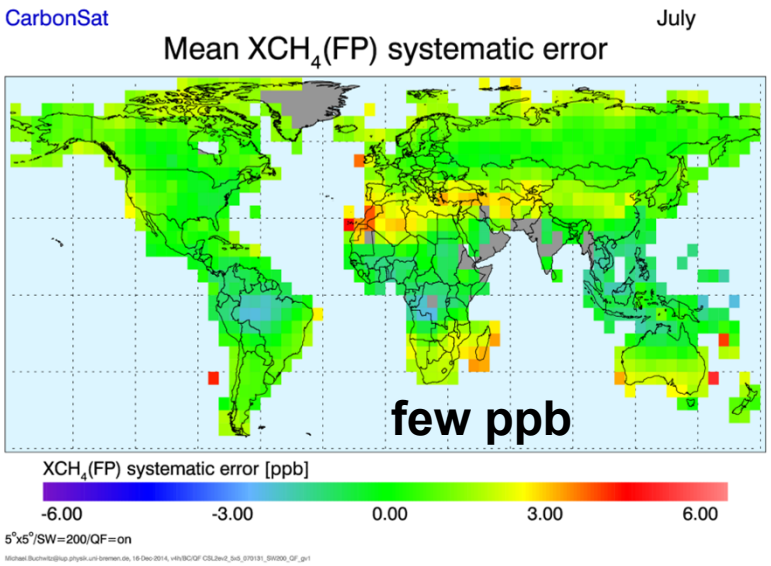
- **Typical: 1.2 ppm**
- Better for
  - Deserts: ~0.5 ppm
  - Ocean glint: ~0.5 ppm
- Worse for
  - Ocean outside glint

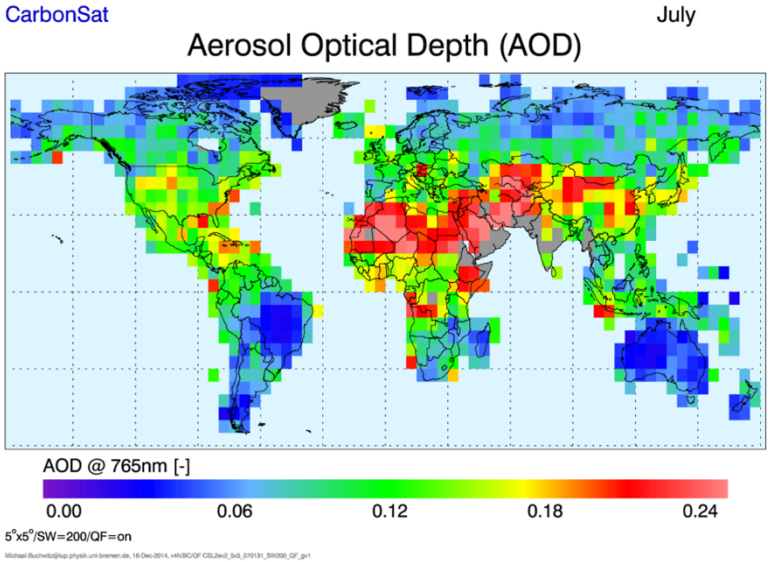
XCH_4 precision:

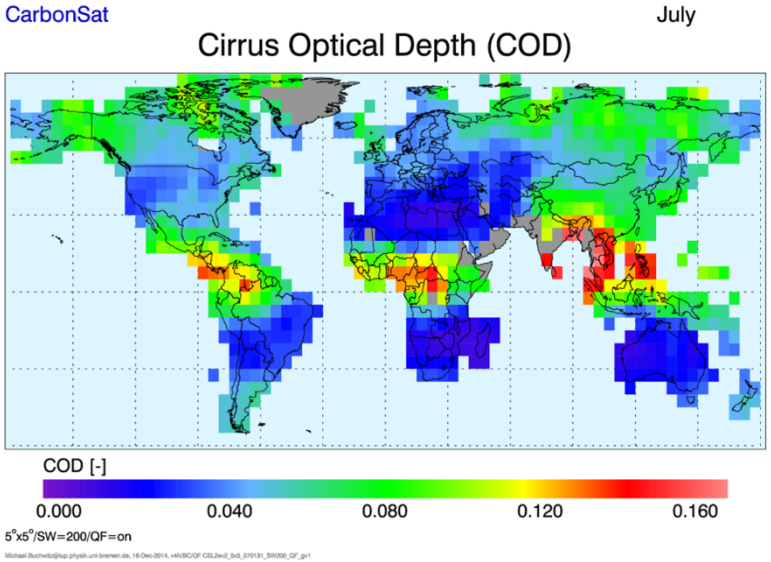
- **Typical: 8 ppb**
- Better for
  - Deserts: ~4 ppb
  - Ocean glint: ~4-6 ppb
- Worse for
  - Ocean outside glint

CarbonSat: XCO_2 and XCH_4 biases nadir/land

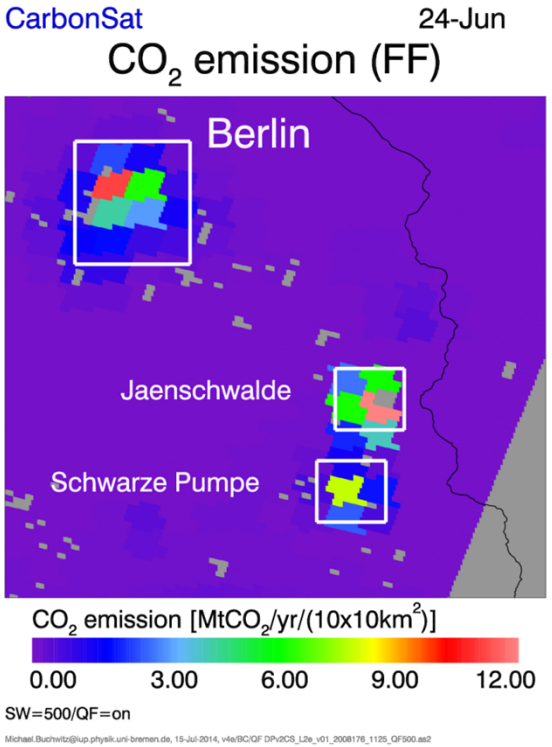


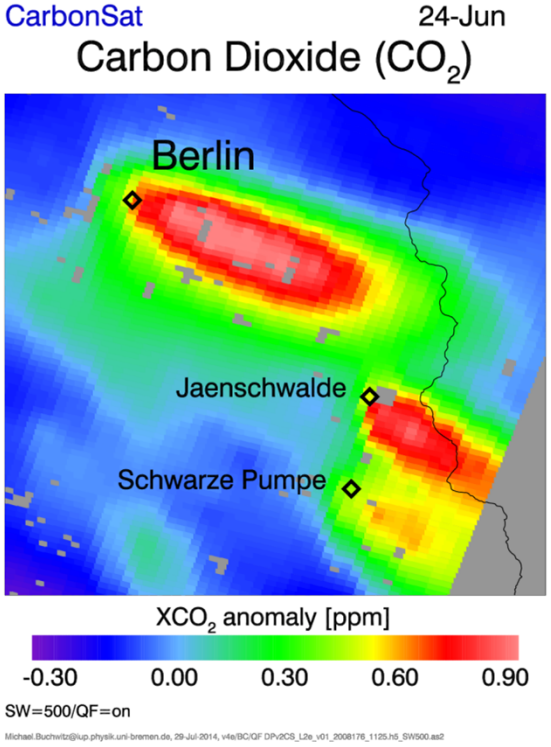






CarbonSat: Emission Hot Spots: Berlin area





CarbonSat: City CO_2 Emissions: Berlin

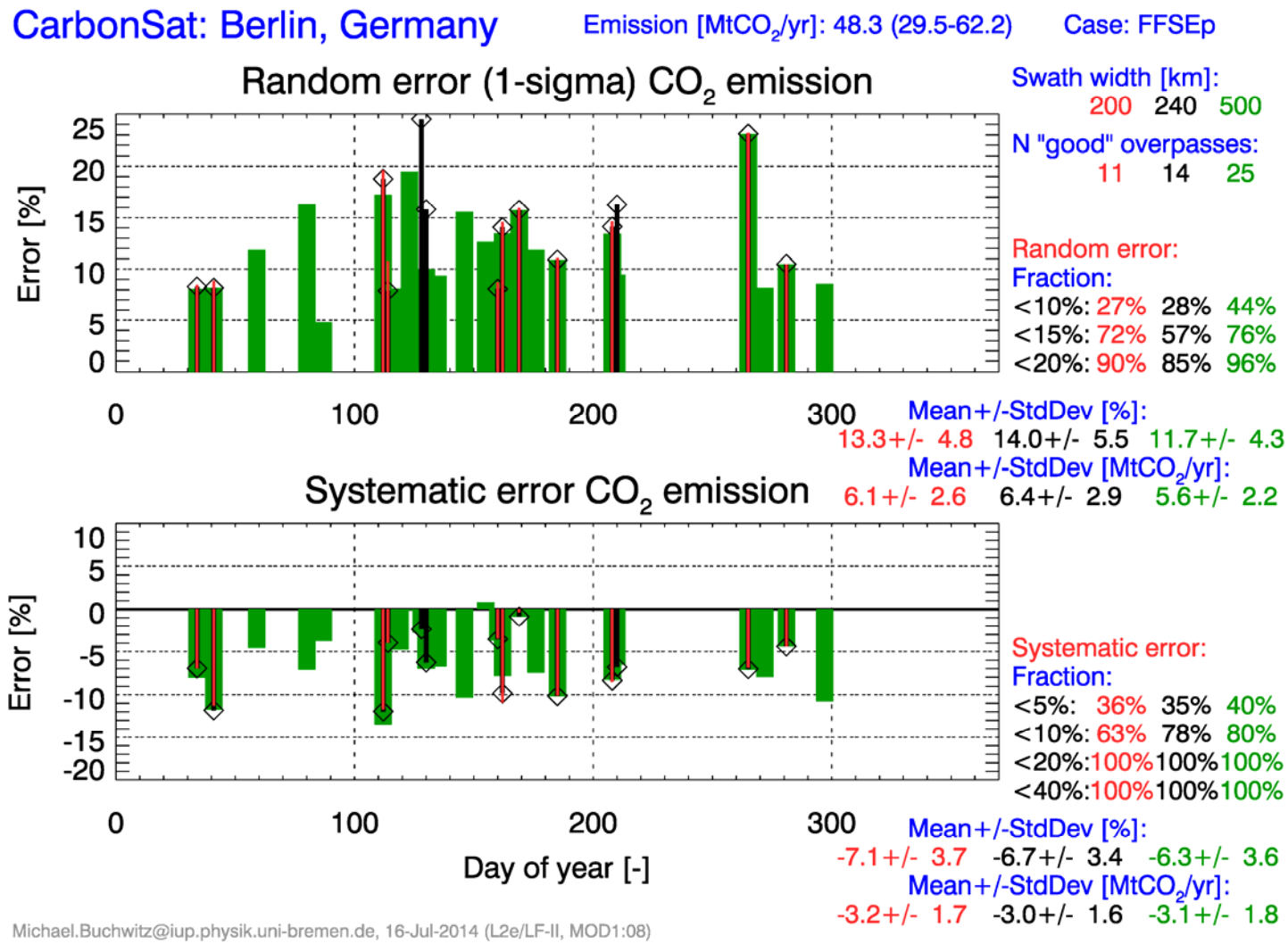
Very strict cloud filtering

Precision:

~7 $MtCO_2$/yr
(~15% for Berlin)

Accuracy:

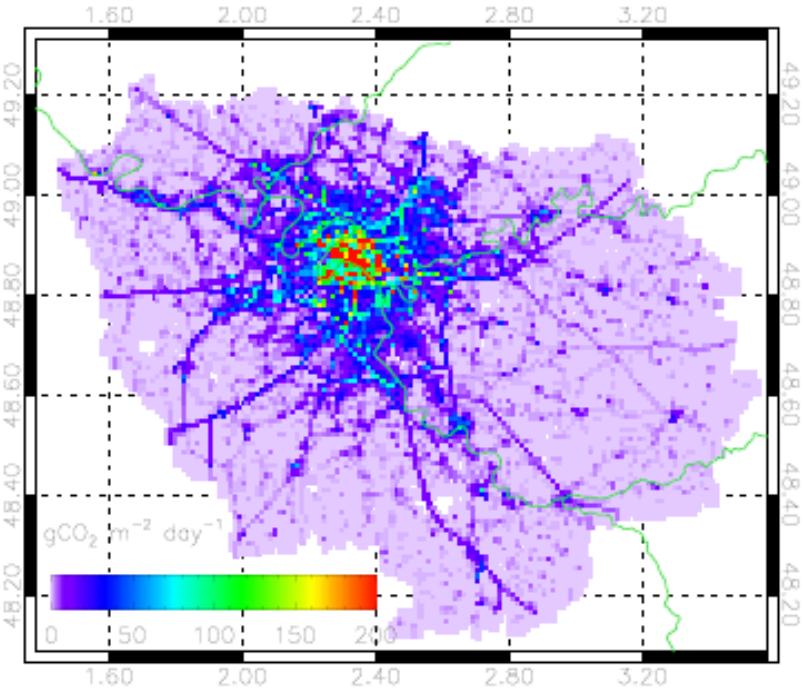
~5 $MtCO_2$/yr
(~10% for Berlin)



Update of Buchwitz et al., AMTD, 2013
(ground-pixel size 2x3 km^2, …)

CarbonSat: City CO_2 Emissions: Paris

Fossil fuel CO_2 emissions
Paris & surroundings



Prior uncertainty vs **CarbonSat**

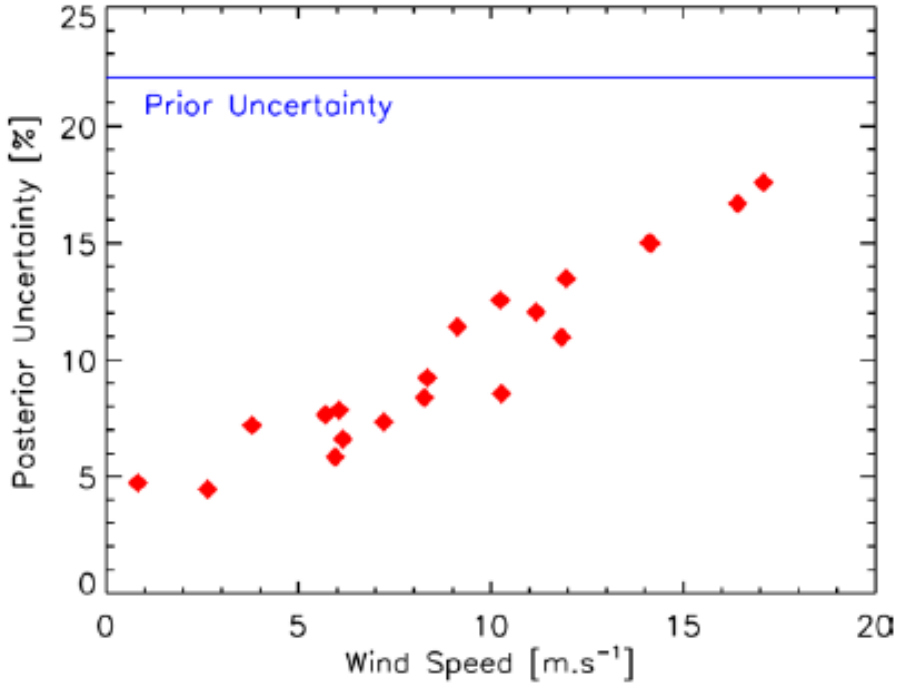
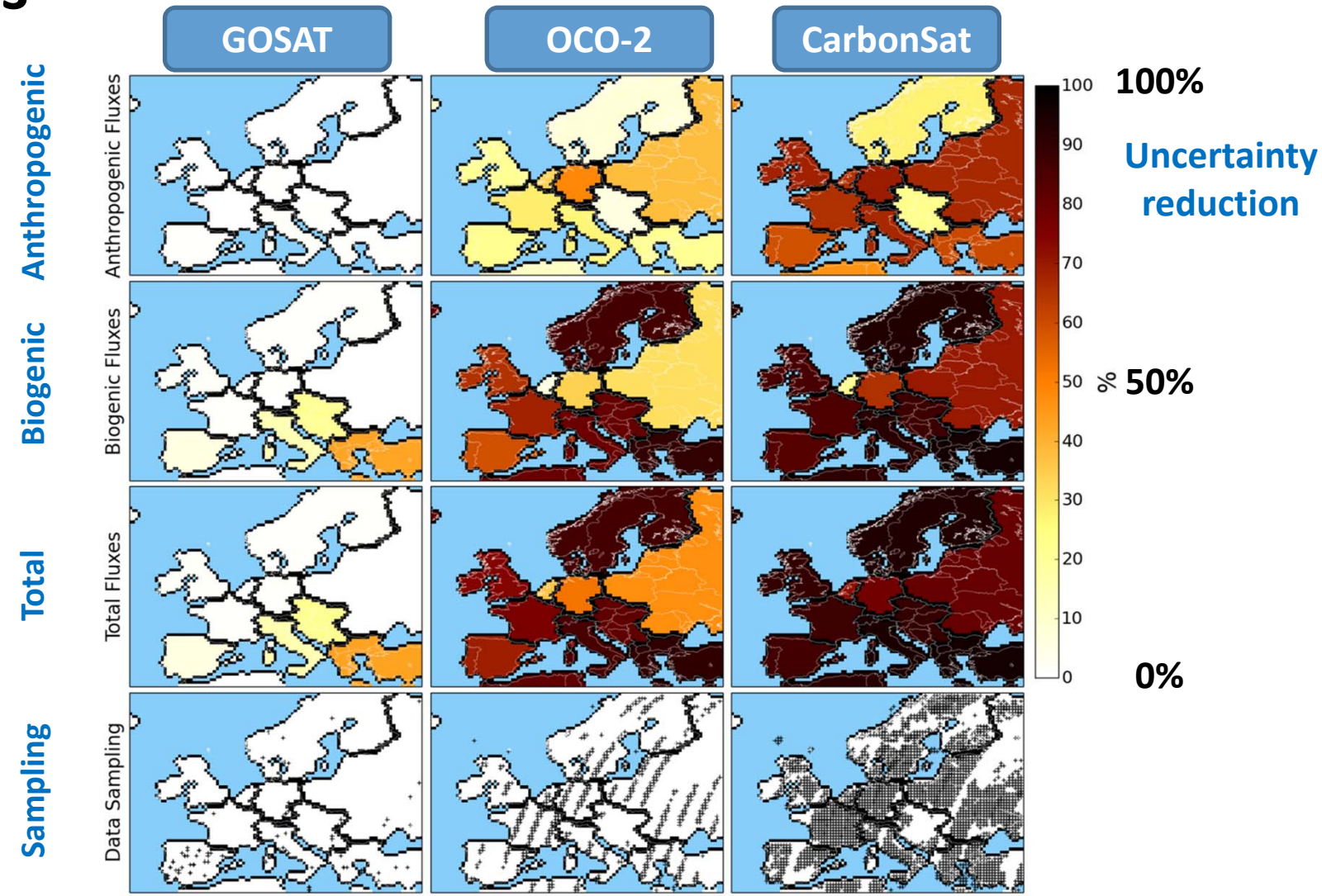


Figure 24: Left: Map of the estimated fossil fuel CO2 emissions in the Ile de France region surrounding Paris. Right: Uncertainty in the 6-11AM fossil fuel emissions for the Paris area as a function of wind speed. The blue line shows the estimated current uncertainty. The red dots are uncertainty when CarbonSat data is applied and account for CarbonSat sampling (clouds) and atmospheric transport conditions.

Courtesy of F.-M. Bréon, LSCE

Evaluation of CarbonSat's contribution at national scales



Preliminary, courtesy of G. Broquet, LSCE

Earth Explorer-8 User Consultation Meeting

http://congrexprojects.com/2015-events/15m24/introduction

- Introduction
- Meeting agenda
- Reports
- Registration
- Venue
- Accommodation
- Contact

Earth Explorer-8 User Consultation Meeting

15–16 September 2015

Academy of Fine Arts, Krakow, Poland

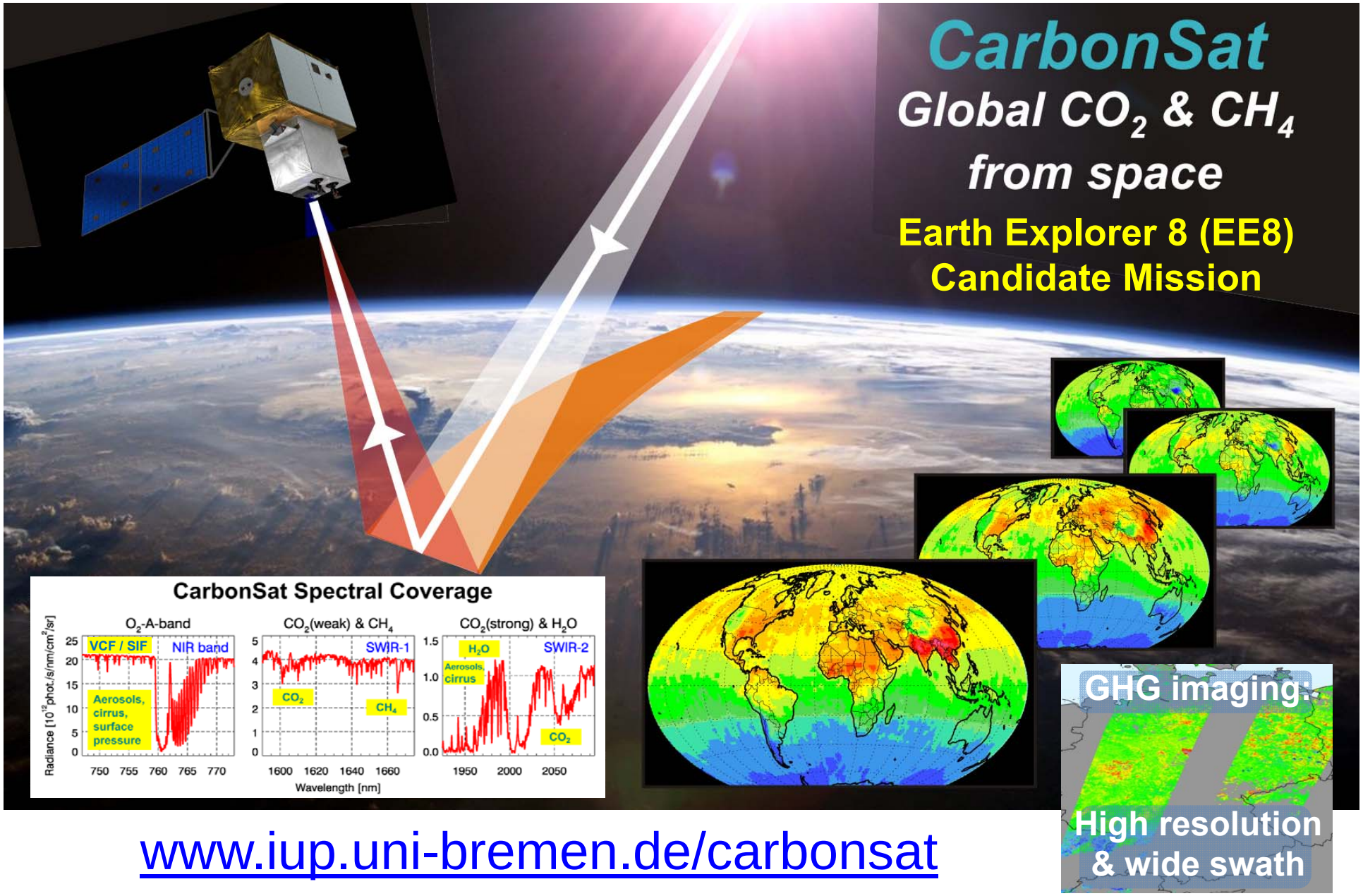
As a critical input to the decision-making process that will lead to the selection of ESA's eighth Earth Explorer mission, the Earth observation scientific community is invited to a User Consultation Meeting at the Academy of Fine Arts in Krakow, Poland on 15–16 September 2015.

Topic: EE8: CarbonSat or FLEX ?

15-16 Sept 2015, Krakow, Poland

Registration deadline: 15 Aug 2015

Thank you very much for your attention



www.iup.uni-bremen.de/carbonsat