GHG-CCI

4th CCI CMUG Integration Meeting
2-4 Jun 2014, Met Office, Exeter, UK

Achievements, plans and ongoing scientific activities

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

and the GHG-CCI project team

GHG-CCI Project Overview

Global satellite observations

Global information on near-surface CO_2 & CH_4

Upper layer CO_2 & CH_4

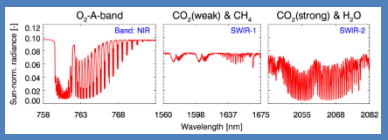
SCIAMACHY/ENVISAT

TANSO/GOSAT

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

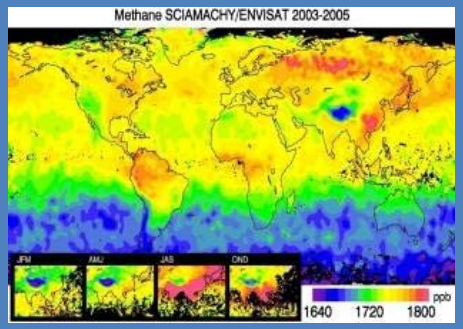
Calibration (L 0-1)

Calibrated radiances

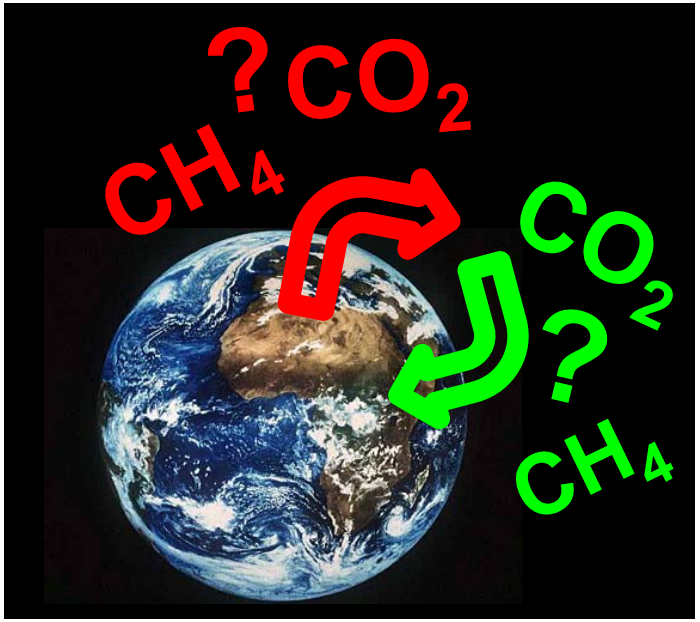


Retrieval
(L 1-2)

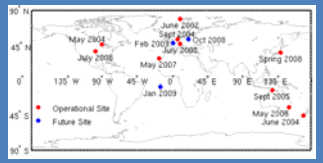
Atmospheric GHG distributions



Global observations

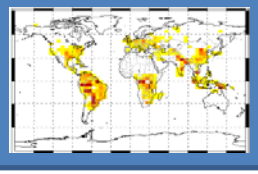


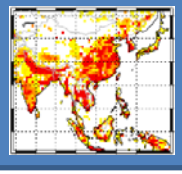
Reference observations



Validation

Improved information on GHG sources & sinks





Inverse modelling (L 2-4)

GHG-CCI: Achievements

- **Phase 1: Extended XCO_2 and XCH_4 data sets with improved quality:**
  - SCIAMACHY/ENVISAT: Entire ENVISAT time period (2002-2012 (*))
  - First TANSO/GOSAT multi-year data sets (2009-2011+)
- **Several publications with GHG-CCI funding acknowledged (status May 2014):**
  - Peer-reviewed: 28
  - In review: at least 8
- **Other, e.g.**
  - (Somewhat) Improved / harmonized data formats (to be significantly further improved in Phase 2 - ongoing)

(*) Not for all methane products due to degradation issues

GHG-CCI: Phase 2 goals

„More & better“ by

Next release: CRDP#2: Oct. 2014

- **Extension of time series**
- **Improved data quality** by algorithm improvements & re-processing
- **Improved data product formats** (standards, meta data, harmonization, …)
- **Improved error characterization** (e.g., not all products report uncertainty estimates fully appropriate for the users)
- **Improved data usage / exploitation** (e.g., via extended CRG)
- **New sensors** (esp. OCO-2 & Sentinel-5-Precursor; incl. detailed comparison with operational products (consistency?), preparation for L1-2 processing, L1-2 processing, …)

Ongoing activities

- Many ongoing activities related to **methane**, …

Alexe et al., ACPD, 2014

Atmos. Chem. Phys. Discuss., 14, 11493–11539, 2014
www.atmos-chem-phys-discuss.net/14/11493/2014/
doi:10.5194/acpd-14-11493-2014

Atmospheric Chemistry and Physics Discussions

Inverse modeling of CH_4 emissions for 2010–2011 using different satellite retrieval products from GOSAT and SCIAMACHY

M. Alexe[1], P. Bergamaschi[1], A. Segers[2], R. Detmers[3], A. Butz[9], O. Hasekamp[3], S. Guerlet[3], R. Parker[4], H. Boesch[4], C. Frankenberg[5], R. A. Scheepmaker[3], E. Dlugokencky[6], C. Sweeney[6,7], S. C. Wofsy[8], and E. A. Kort[10]

Hayman et al., ACPD, 2014

Atmos. Chem. Phys. Discuss., 14, 12967–13020, 2014
www.atmos-chem-phys-discuss.net/14/12967/2014/
doi:10.5194/acpd-14-12967-2014

Atmospheric Chemistry and Physics Discussions

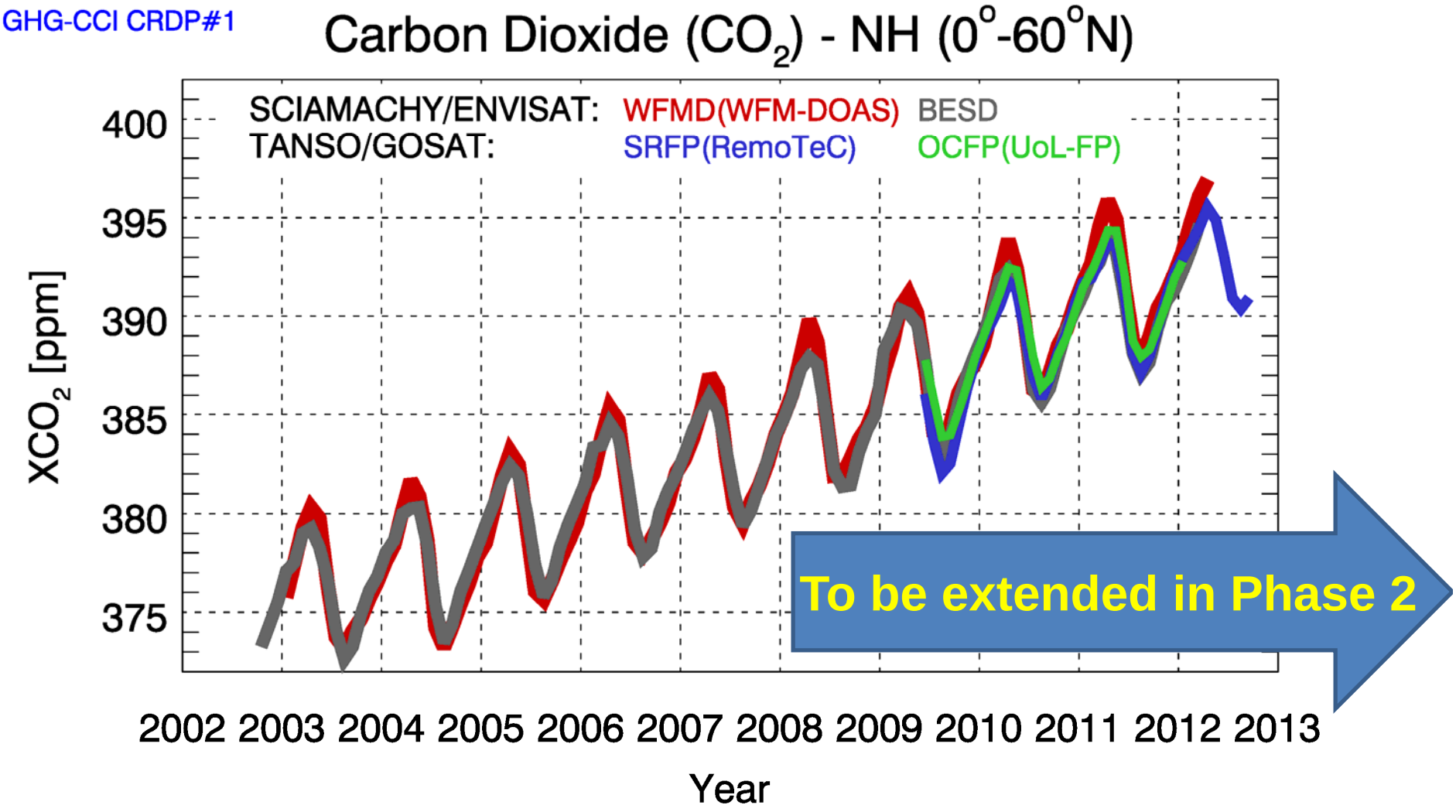
Comparison of the HadGEM2 climate-chemistry model against in-situ and SCIAMACHY atmospheric methane data

G. D. Hayman[1], F. M. O'Connor[2], M. Dalvi[2], D. B. Clark[1], N. Gedney[3], C. Huntingford[1], C. Prigent[4], M. Buchwitz[5], O. Schneising[5], J. P. Burrows[5], C. Wilson[6], N. Richards[6], and M. Chipperfield[6]

- … but in the following let's focus on **CO_2**.

GHG-CCI: XCO_2 time series

GHG-CCI CRDP#1



Ensemble: Key to success

- **Multiple satellite algorithms / products**

http://www.northpacificmusic.com/ensemble.east.west.jpg

- **Multiple models / inverse models**

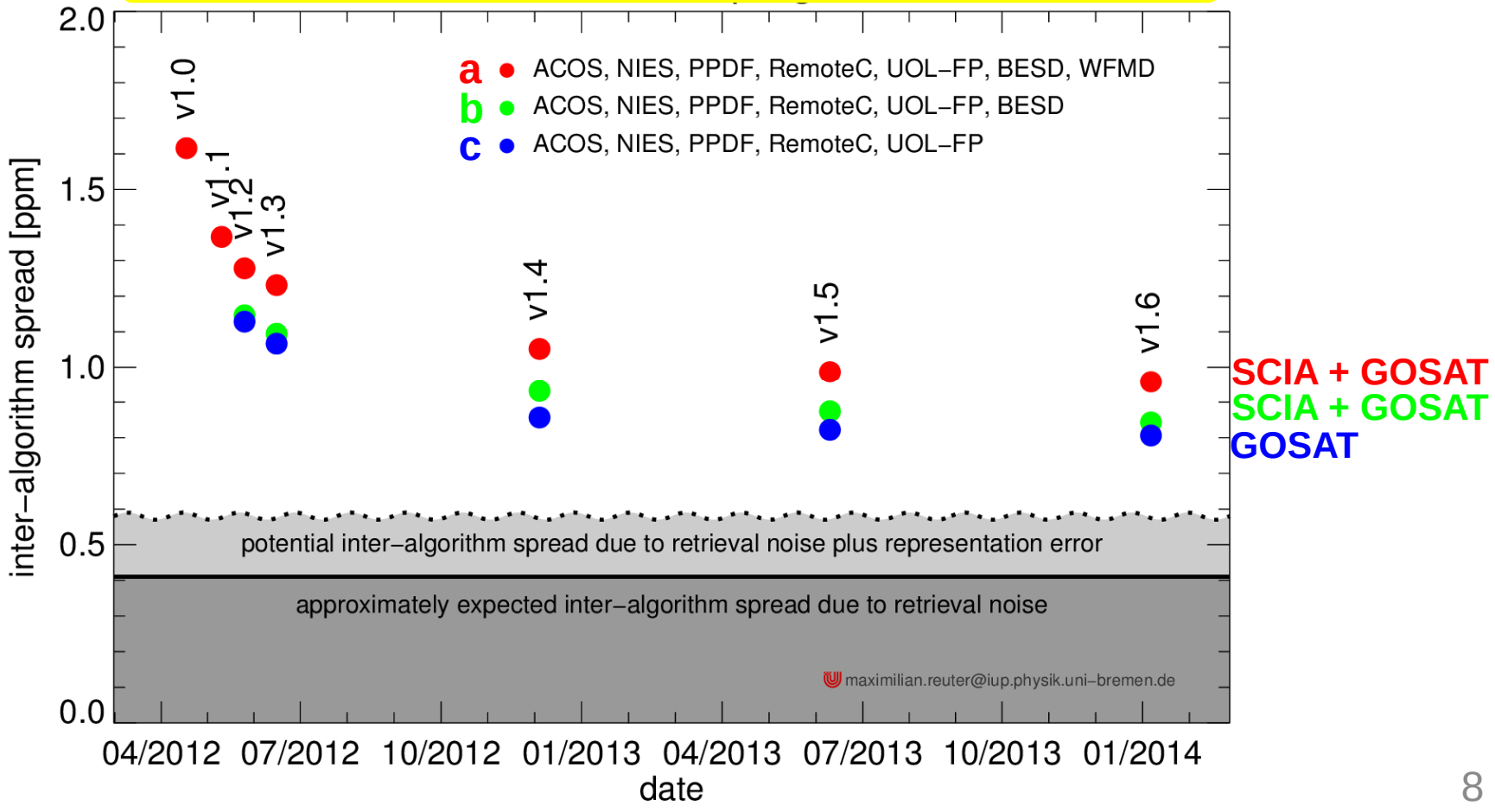
Ensemble algorithm EMMA

A joint effort to deliver satellite retrieved atmospheric CO_2 concentrations for surface flux inversions: the ensemble median algorithm EMMA

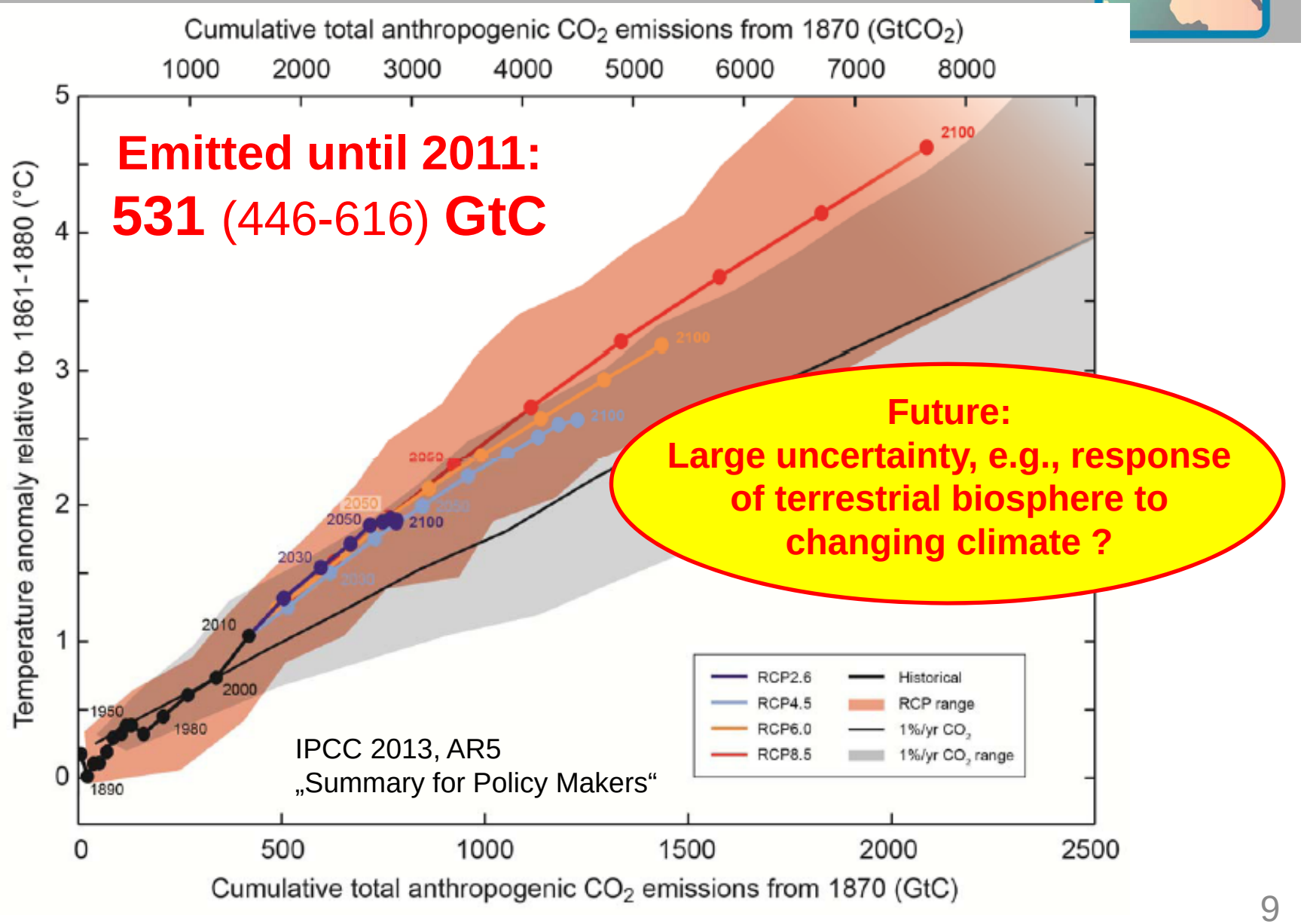
Reuter et al., ACP, 2013

M. Reuter[1], H. Bösch[2], H. Bovensmann[1], A. Bril[3], M. Buchwitz[1], A. Butz[4], J. P. Burrows[1], C. W. O'Dell[5], S. Guerlet[6], O. Hasekamp[6], J. Heymann[1], N. Kikuchi[3], S. Oshchepkov[3], R. Parker[2], S. Pfeifer[7], O. Schneising[1], T. Yokota[3], and Y. Yoshida[3]

„Monitoring" of improvement of global products



CO_2 emissions -> Temperature change



Natural CO_2: Terrestrial C sinks

Houghton, Biologist, 2002:

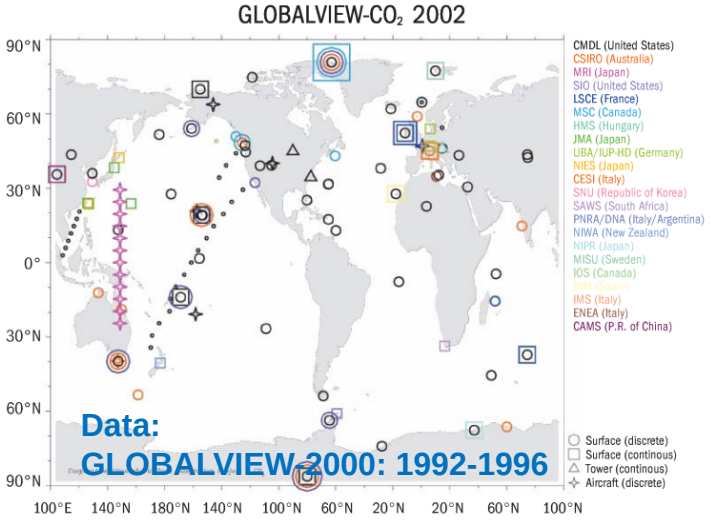
"Strangely, the difference between the net terrestrial sink and the emissions from land-use change **suggests that there is a residual terrestrial sink, not well understood, that locked away as much as 3.0 PgC/yr during the last two decades**. … **The exact magnitude, location and cause of this residual terrestrial sink are uncertain**, …"

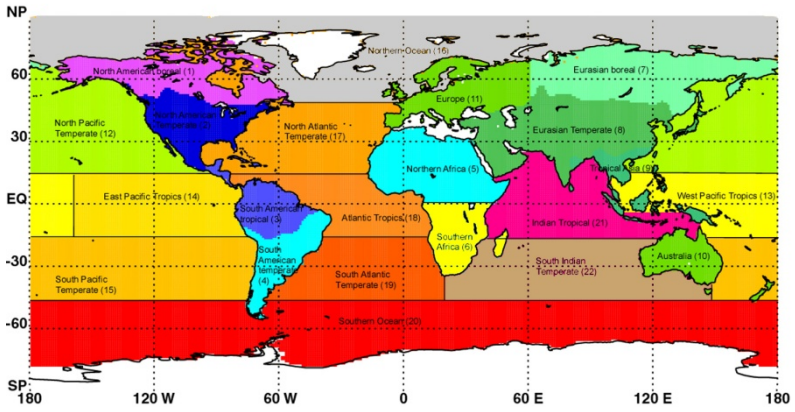
Natural CO_2 fluxes from *in-situ* obs.: Gurney et al., Nature, 2002

Towards robust regional estimates of CO_2 sources and sinks using atmospheric transport models

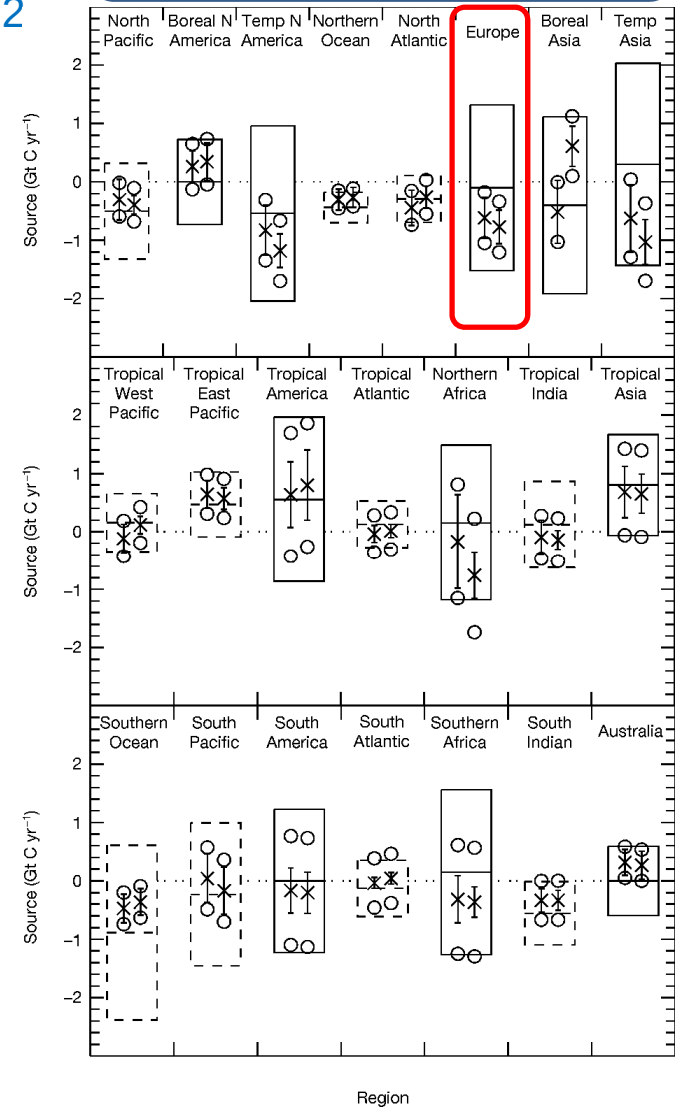
Kevin Robert Gurney*, Rachel M. Law†, A. Scott Denning*, Peter J. Rayner†, David Baker‡, Philippe Bousquet§, Lori Bruhwiler‖, Yu-Han Chen¶, Philippe Ciais§, Songmiao Fan#, Inez Y. Fung☆, Manuel Gloor**, Martin Heimann**, Kaz Higuchi††, Jasmin John☆, Takash
Michae
Jorge S
& Chiu-

Gurney et al., Nature, 2002





TransCom 3 regional CO_2 flux inversions



Observartions: Very accurate but sparse

Information content sources & sinks (excluding fossil fuel fluxes):

Large regions only (continents, ocean basins)

Large uncertainties (often +/- 100%)

A priori land

Inversions:

X Mean flux

○ Within model uncertainty

Left / right: different inversions

Natural CO_2 fluxes from *in-situ* obs. incl. aircraft: Stephens et al., Science, 2007

Stephens et al., Science , 2007

NEWS FEATURES

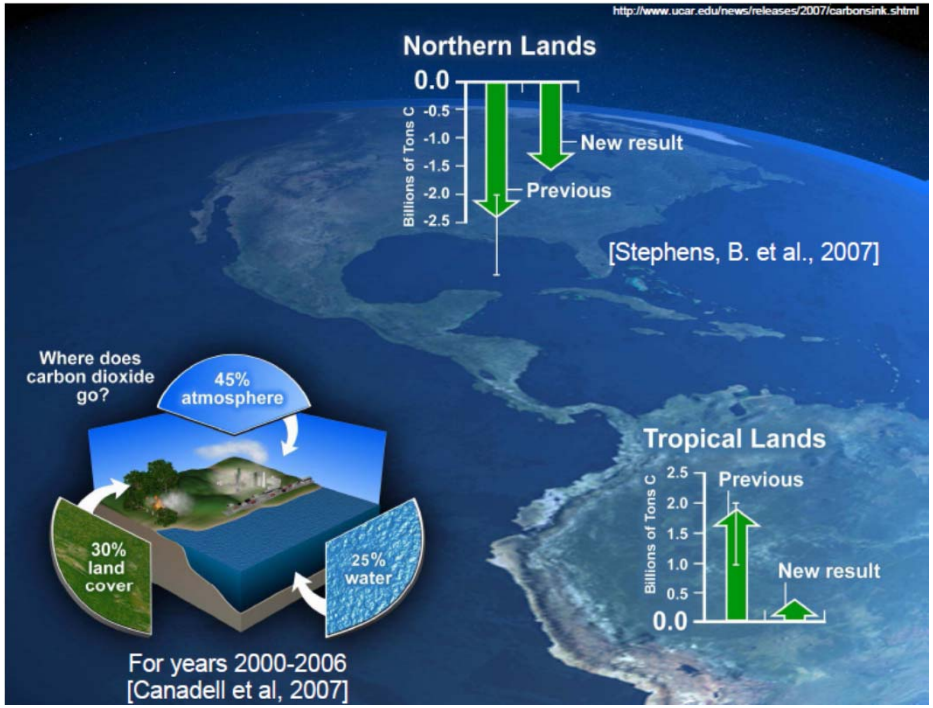
Missing carbon mystery: Case solved?

NH land:
Weaker sink?
(+1 GtC/yr)

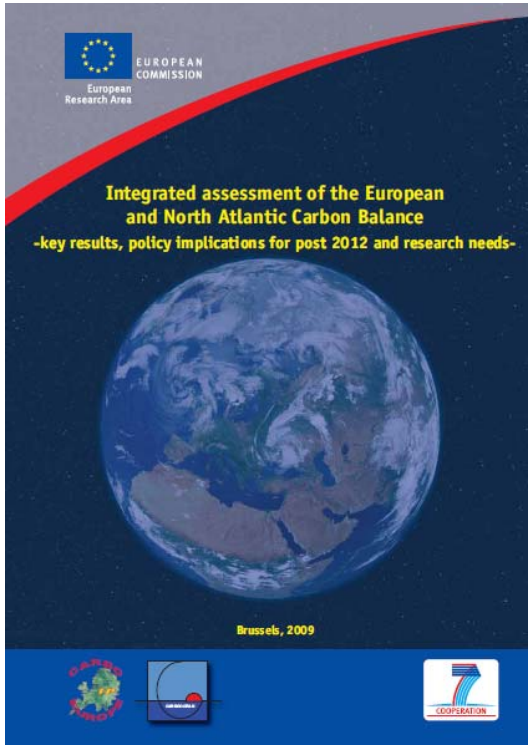
Tropics:
Weaker source?
Net approx. zero ?
(-2 GtC/yr)

Weak Northern and Strong Tropical Land Carbon Uptake from Vertical Profiles of Atmospheric CO_2

Britton B. Stephens,[1]* Kevin R. Gurney,[2] Pieter P. Tans,[3] Colm Sweeney,[3] Wouter Peters,[3] Lori Bruhwiler,[3] Philippe Ciais,[4] Michel Ramonet,[4] Philippe Bousquet,[4] Takakiyo Nakazawa,[5] Shuji Aoki,[5] Toshinobu Machida,[6] Gen Inoue,[7] Nikolay Vinnichenko,[8]† Jon Lloyd,[9] Armin Jordan,[10] Martin Heimann,[10] Olga Shibistova,[11] Ray L. Langenfelds,[12] L. Paul Steele,[12] Roger J. Francey,[12] A. Scott Denning[13]



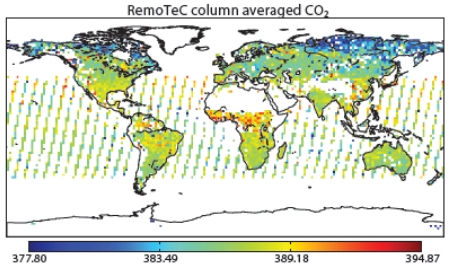
CarboEurope findings (2009)



Executive Summary of the terrestrial carbon balance (CarboEurope-IP)

- The **land surface of continental Europe** (the geographic region between the Atlantic coast and the Ural Mountains) is a **carbon sink for CO_2 of 300 Tg C/yr** (**0.3 GtC/yr**) (as indicated by atmospheric and ground-based measurements). The **estimated sink has almost doubled since 2003, mainly due to additional processes understanding**.
- …
- **Almost 60%** of the continental CO2 sink is located outside the EU-25 in **eastern Europe, mainly European Russia**. …
- …
- **The uncertainty in the magnitude of the terrestrial sink remains high.** This is a consequence of the heterogenous landscape of Europe, and the diversity of management practices at small scale.
- …

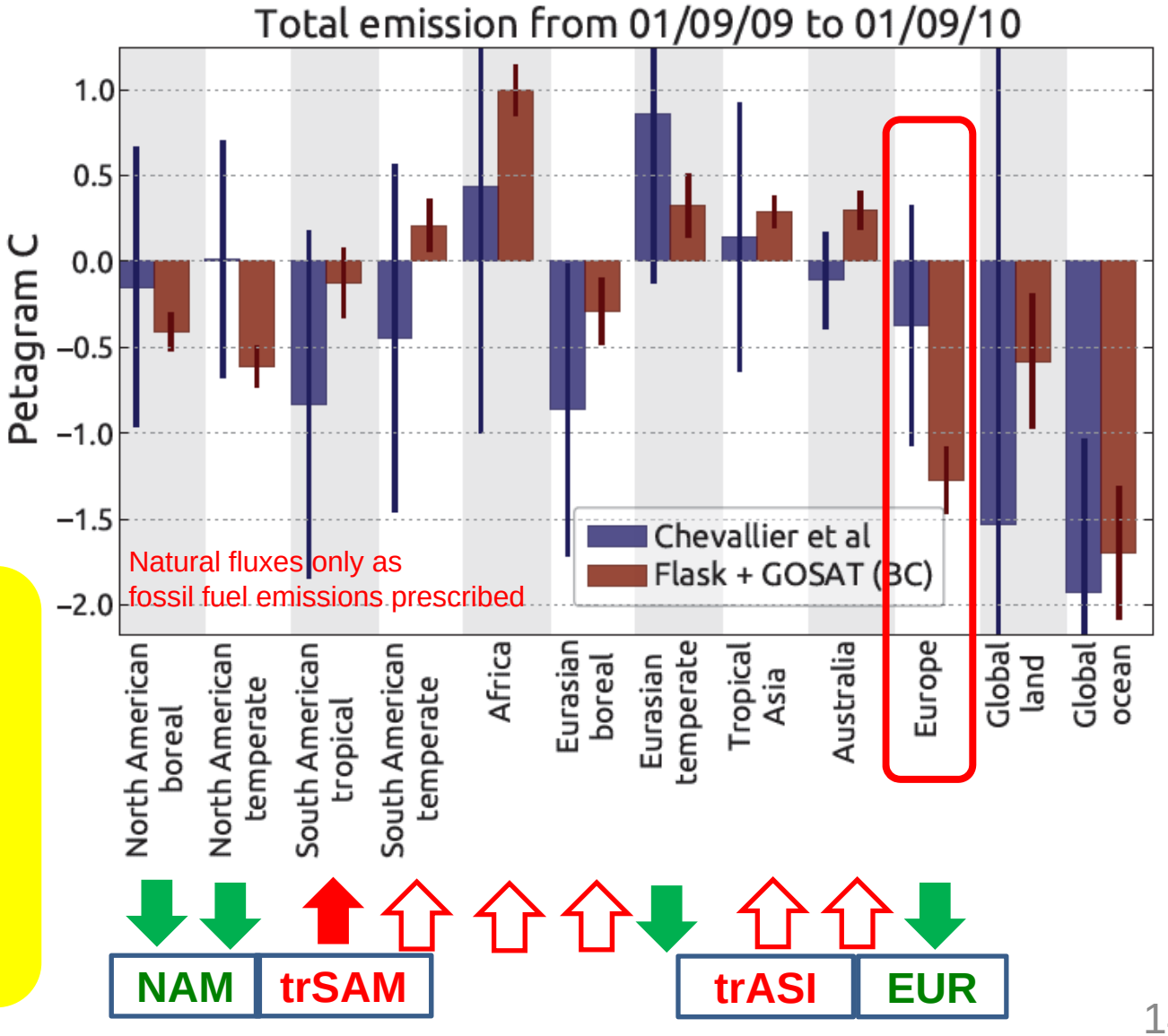
First global regional-scale CO_2 surface fluxes from GOSAT/RemoTeC



Basu et al., ACP, 2013

Chevallier et al., GRL, 2011:

- TCCON-only inversion
- Consistent with flask-only but larger uncertainties

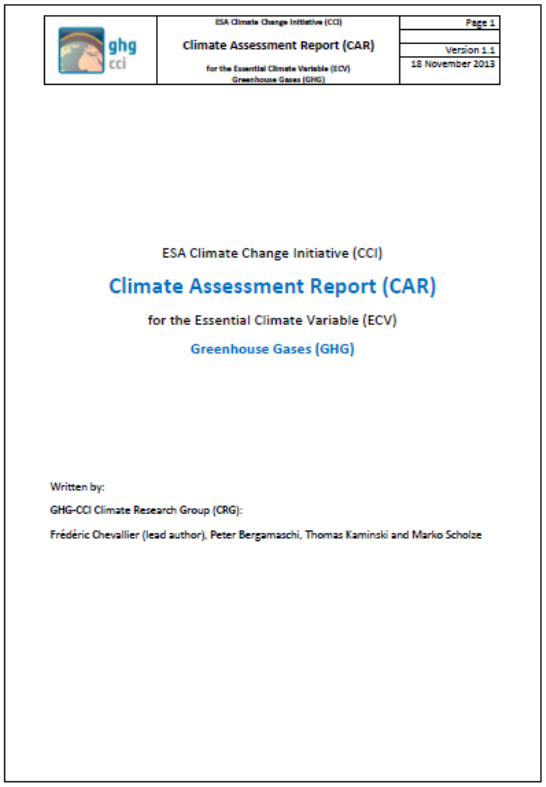


Adding GOSAT:

Shift of terrestrial net carbon uptake from tropics to (northern) extra tropics

But: 1 year only, still bias issues (e.g., land/ocean), …

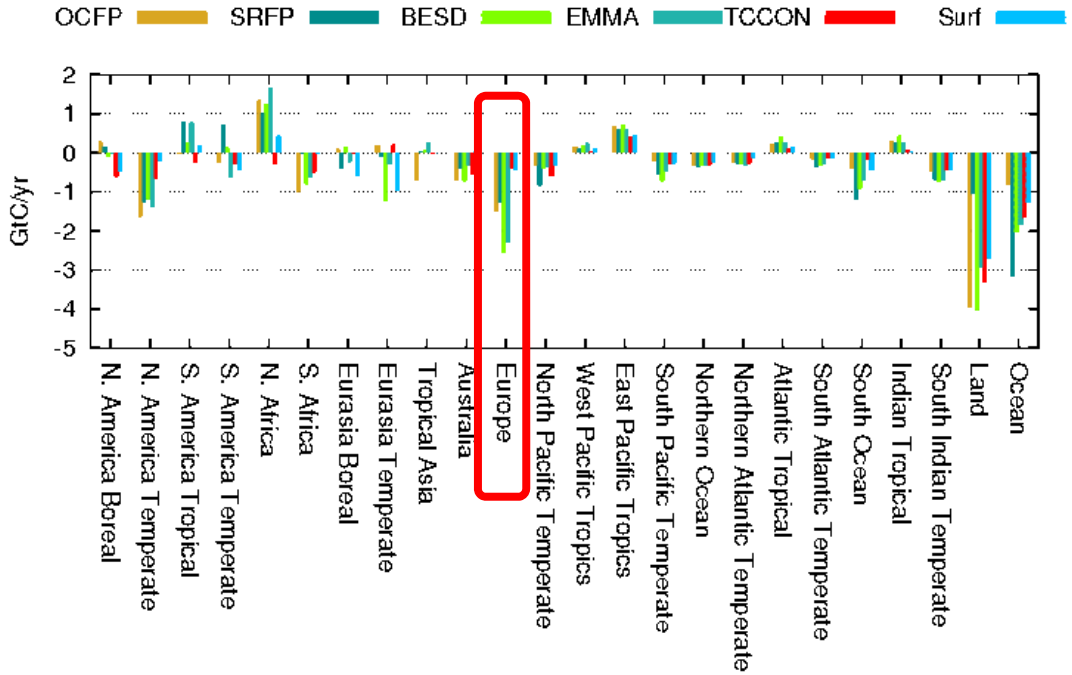
GHG-CCI Phase 1 CAR



http://www.esa-ghg-cci.org/index.php?q=webfm_send/153

CO_2: The **quality of inverted fluxes** using the CRDP products, that merge information from the CRDP retrievals themselves and external information from transport modelling, is **not sufficient yet**. …

The relatively large horizontal gradients of the increments result in estimated **carbon budgets** that are **inconsistent with current knowledge in some regions, like Europe**.

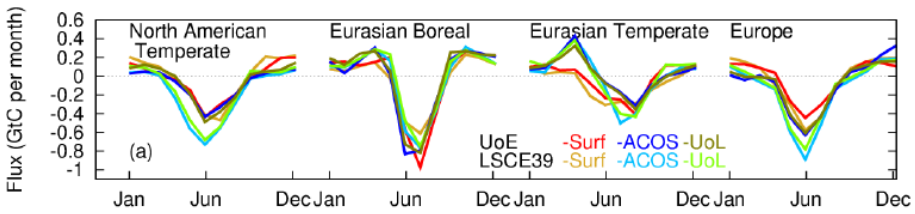


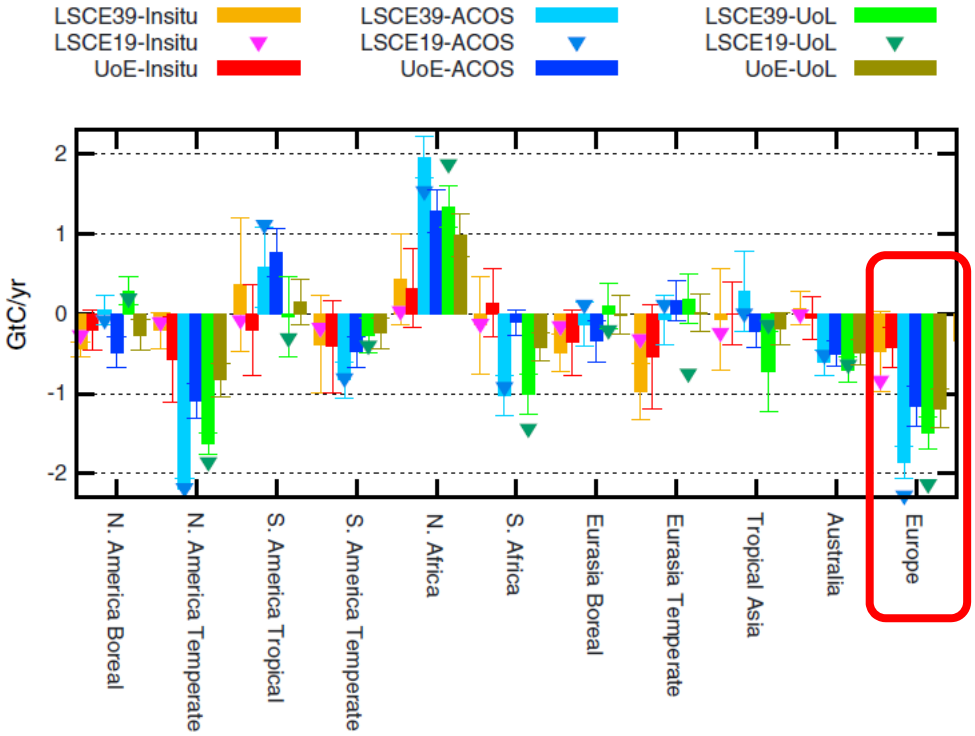
CO_2 flux inversions using different GOSAT XCO_2 products and models

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], Chri and Philippe Bousquet[1]

Chevallier et al., GRL , 2014





Regional natural CO_2 fluxes for 2010

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:

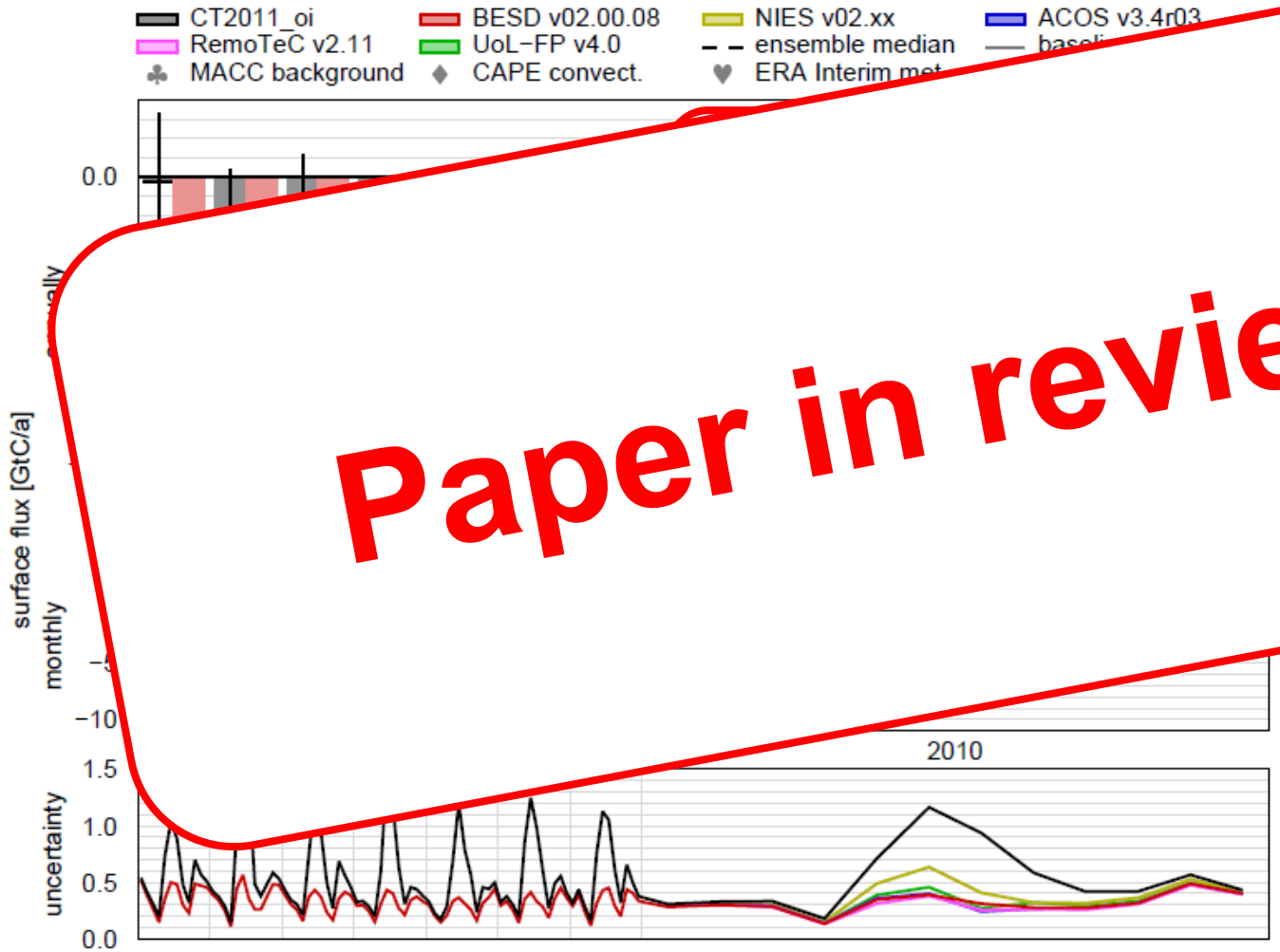
- Not considered realistic for all regions, e.g., Europe: inferred sink „significantly too large“

Possible issues / to be improved: Inversion method incl. prior fluxes and transport models, satellite data (biases to be further reduced)

European terrestrial carbon fluxes from SCIAMACHY and GOSAT

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

Reuter et al., in review



Paper in review

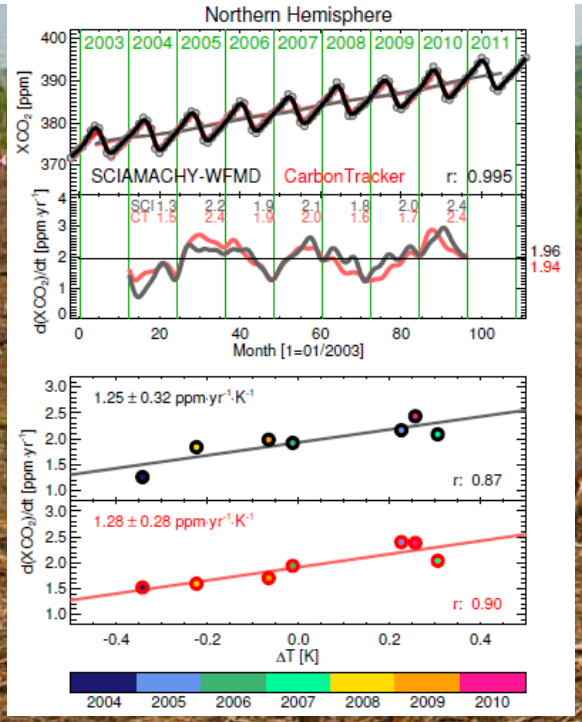
thms

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

More on terrestrial sink, CO_2 from fires, ...

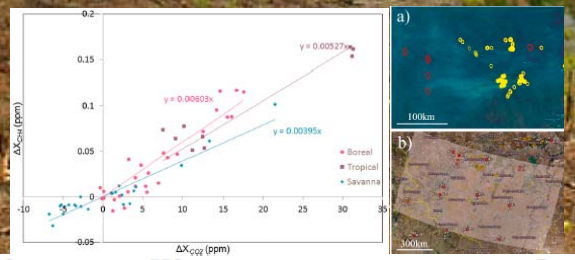
Terrestrial carbon sink observed from space: variation of growth rates and seasonal cycle amplitudes in response to interannual surface temperature variability Schneising et al., ACP, 2014

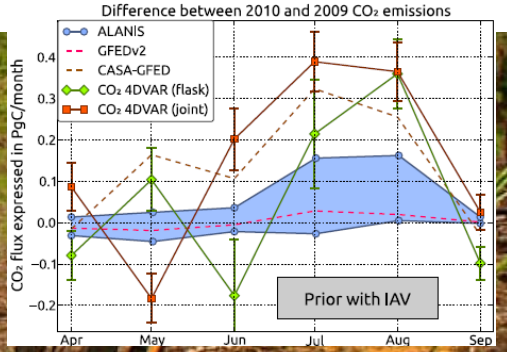
O. Schneising, M. Reuter, M. Buchwitz, J. Heymann, H. Bovensmann, and J. P. Burrows
Institute of Environmental Physics (IUP), University of Bremen FB1, Bremen, Germany



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]





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]

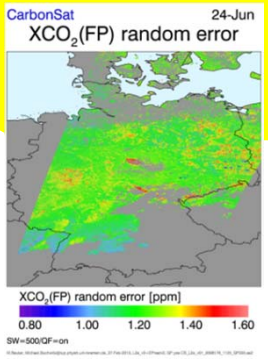
This & more: Please visit www.esa-ghg-cci.org -> Publications

Anthropogenic CO_2

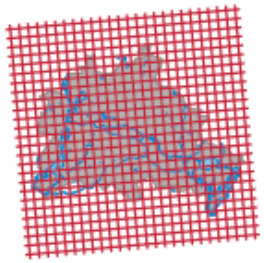
From SCIAMACHY to CarbonSat

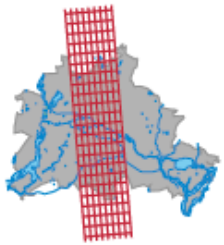
Berlin

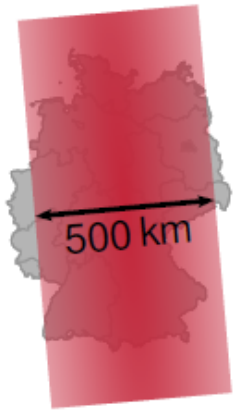
Germany

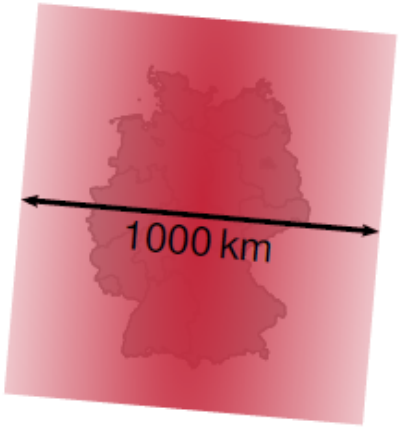


CarbonSat	OCO-2	GOSAT	SCIAMACHY
2 x 2 km²	2.3 x 1.3 km²	10 km	30 x 60 km²

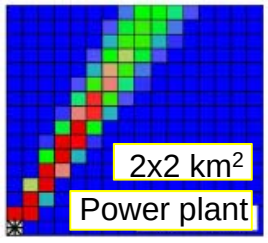


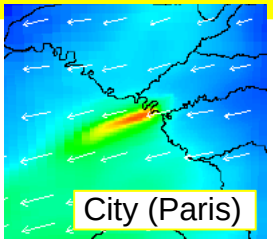


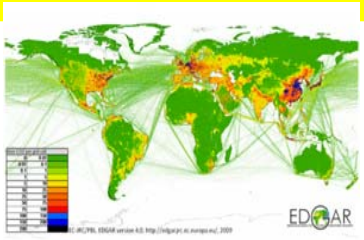




New possibilities: Cities, power plants, geological „point“ sources, …







SCIAMACHY CO_2 over anthropogenic source regions

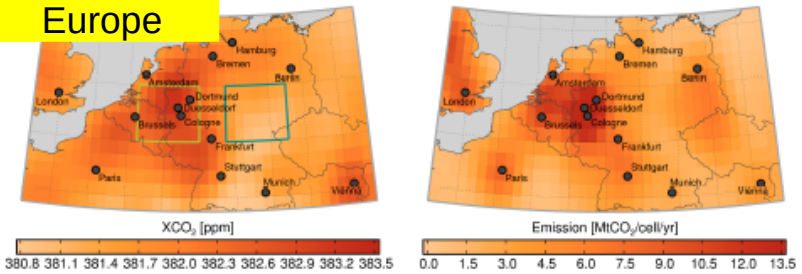
SCIAMACHY XCO_2

EDGAR CO_2 emissions

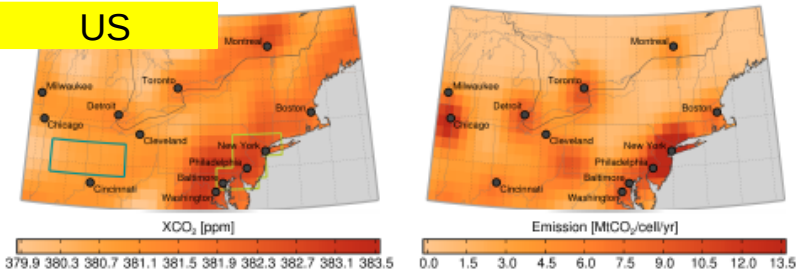
WFMDv2.3 (2003-2009)

EDGAR v4.2

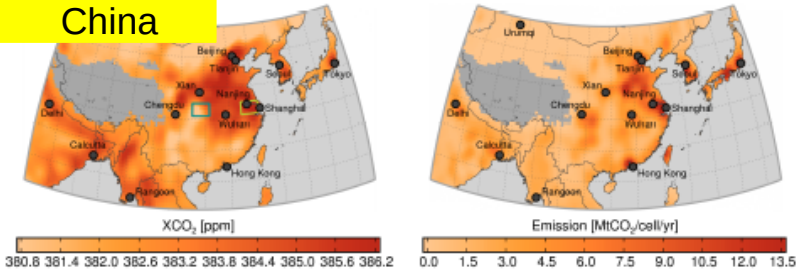
Europe

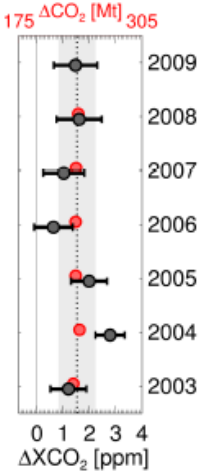


US



China

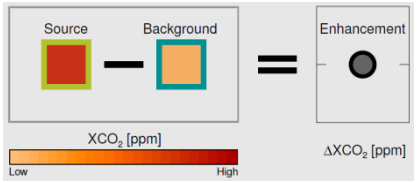


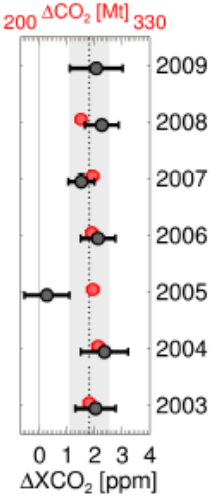


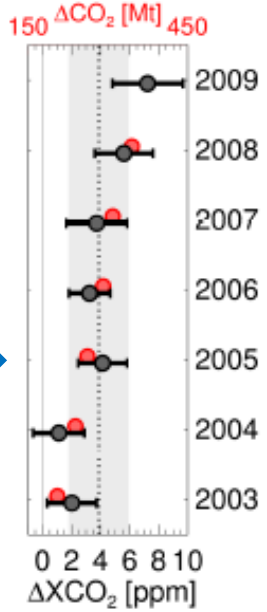
Schneising et al., 2013

SCIAMACHY
EDGAR

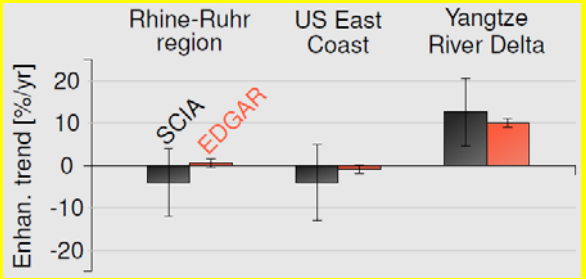
Regional enhancement =
Source - Background







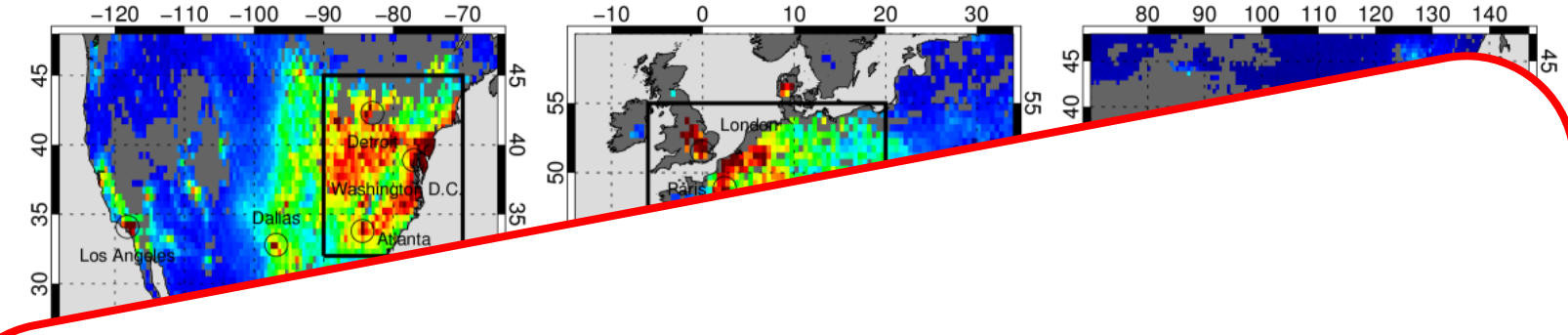
Trend [%CO_2/yr]



EDGAR emissions consistent with SCIAMACHY

SCIAMACHY CO_2 & NO_2 over anthropogenic source regions

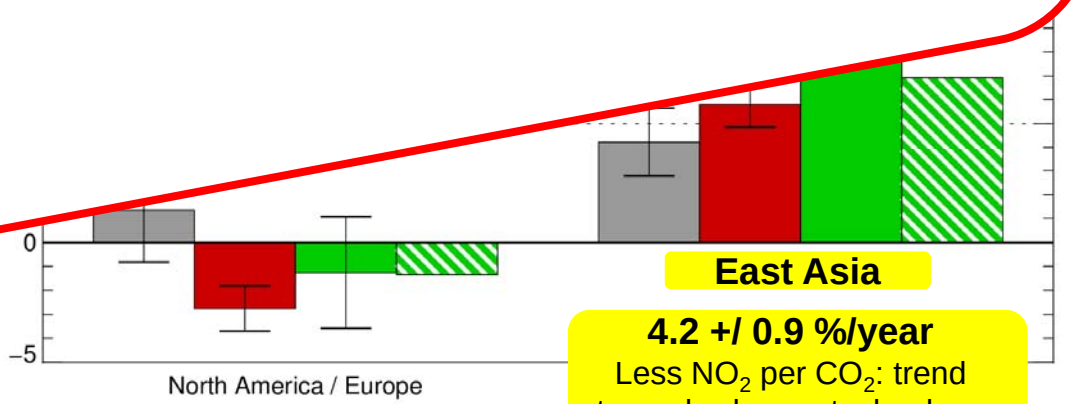
Reuter et al., in review



Paper in review

Sat
XCO
near
sourc
SCIA
during

& NO_2 trends versus
EDGAR emission trends

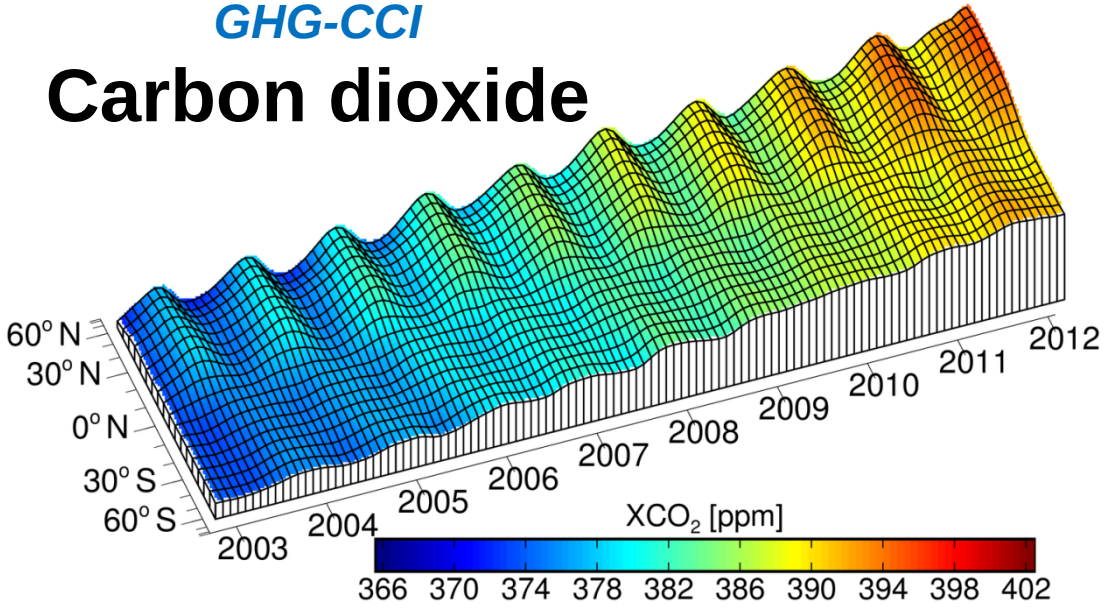


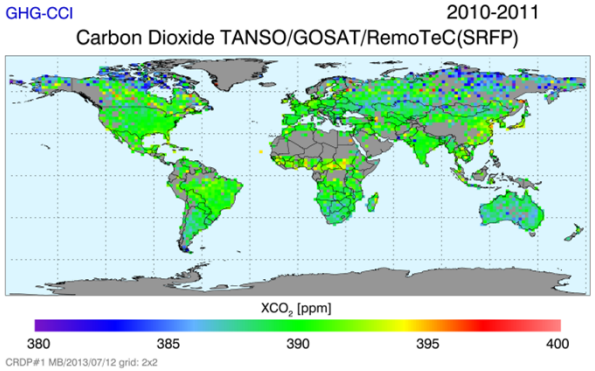
4.2 +/ 0.9 %/year
Less NO_2 per CO_2: trend towards cleaner technology

Many thanks for your attention !

GHG-CCI

Carbon dioxide





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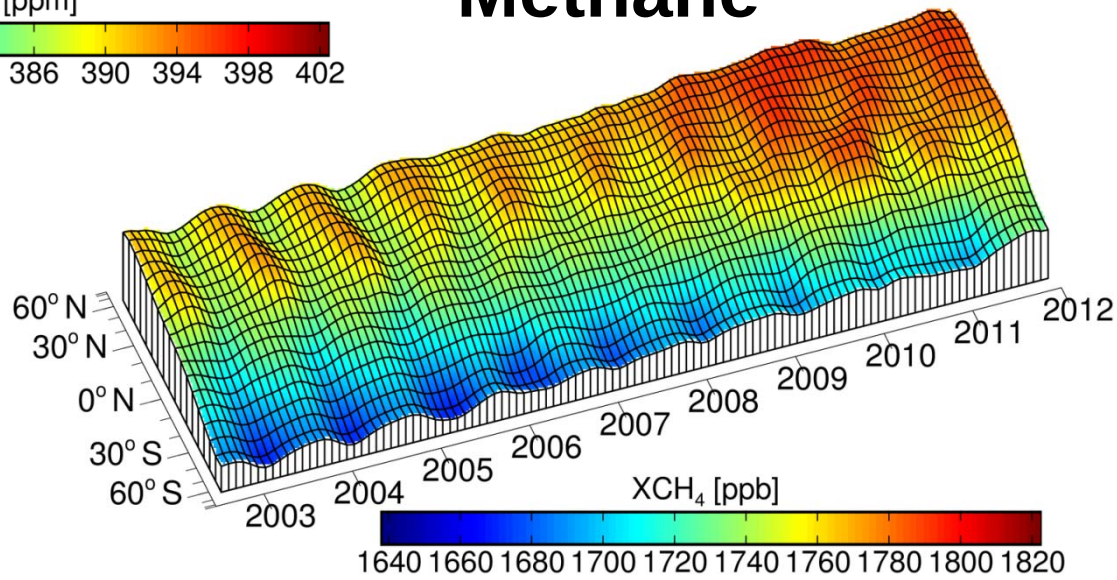
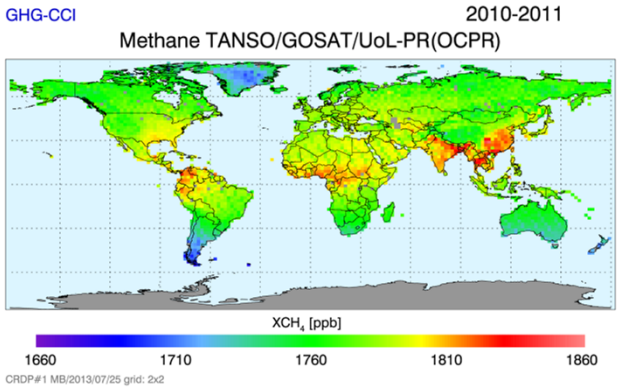
Methane





Backup

GHG-CCI: Phase 1 achievements vs 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. Spatial: GCOS: 5-10 km Achieved($): 10 km ($) for GOSAT. SCIAMACHY: 30x60 km^2. URD: SCIAMACHY and GOSAT are useful to generate the ECV GHG. Note: GCOS requirements are target (maximum) requirements but URD requirements listed here are thresold (minumum) requirements.	GCOS: 1 ppm URD(#): 0.5 ppm Achieved(#): ~1 ppm	GCOS: 0.2 ppm/yr URD: 0.5 ppm/yr Achieved: ~0.2 ppm/yr(+) (+) for SCIAMACHY; for GOSAT: Not yet quantified (time period too short)
XCH_4		GCOS: 10 ppb URD(#): 10 ppb Achieved(#): ~6 ppb(§) (§) for GOSAT; for SCIAMACHY 8-18 ppb depending on time period	GCOS: 2 ppb/yr URD: 10 ppb/yr Achieved: (?) (?) GOSAT: Not yet quantified (time period too short); SCIAMACHY: Not met due to degradation issues
		(#) Relative accuracy	

(*) Requirements for column-averaged dry-air mole fractions as required by URD; it is assumed here that this corresponds to GCOS variables „Tropospheric CO_2 column“ and „Tropospheric CH_4 column“

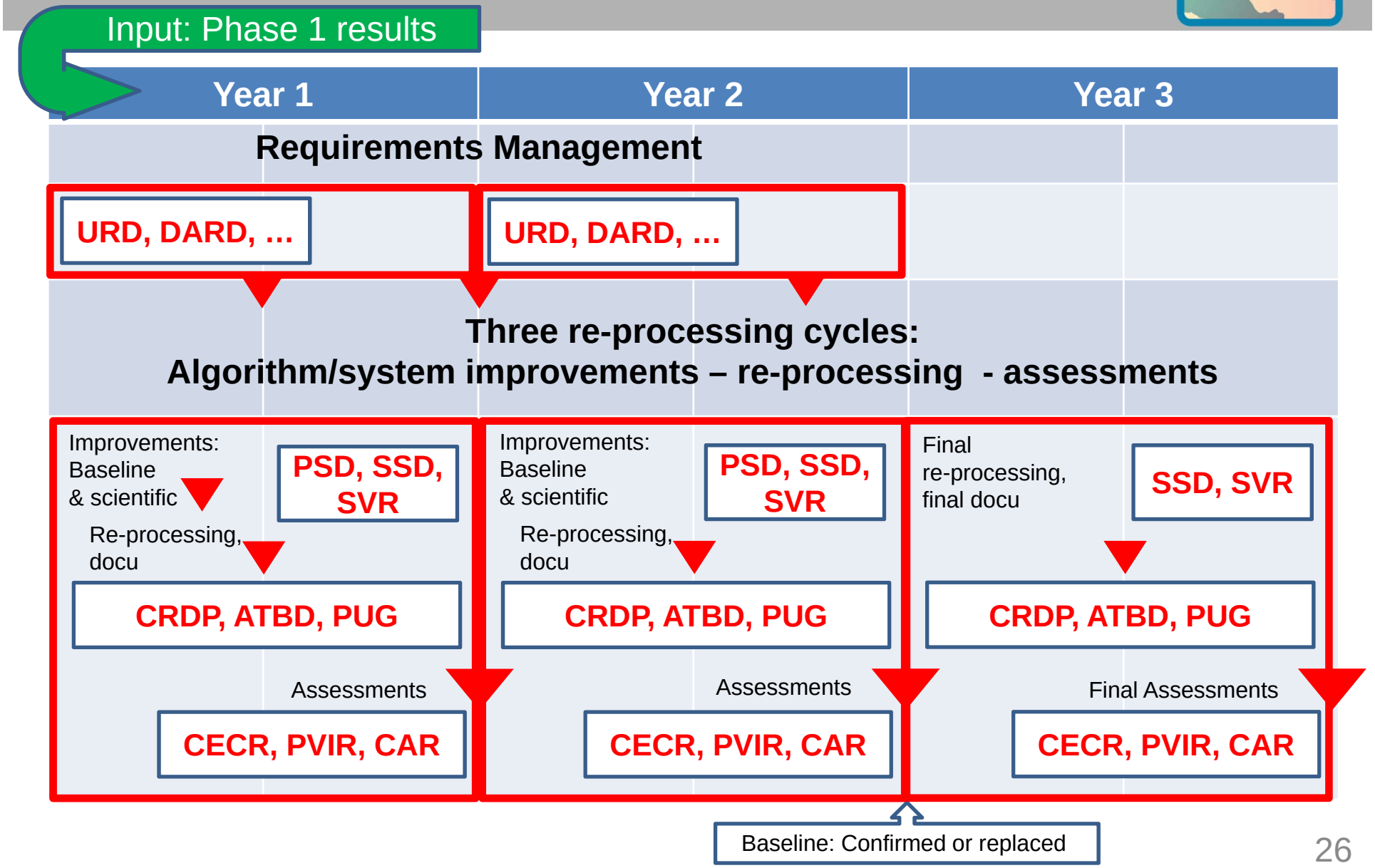
References: Requirements for ECV Greenhouse Gases (GHG):

- **GCOS-154:** „SYSTEMATIC OBSERVATION REQUIREMENTS FOR SATELLITE-BASED DATA PRODUCTS FOR CLIMATE“
- **URD:** “GHG-CCI User Requirements Document”, v1.0

Definition: ECV GHG (GCOS-154):

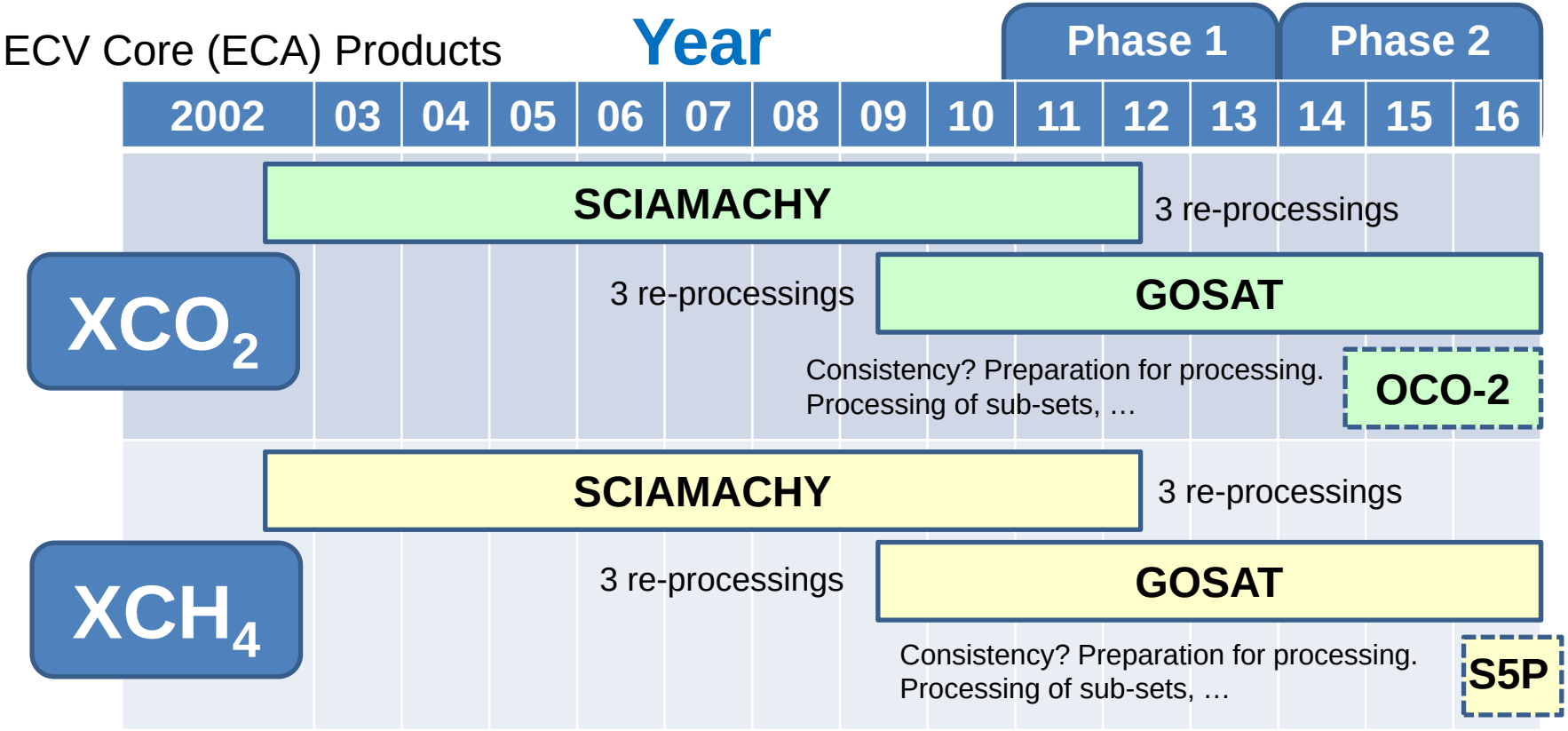
- Product A.8.1: Retrievals of CO_2 and CH_4 of sufficient quality to estimate regional sources and sinks

GHG-CCI Phase 2: Schedule



Phase 2: Time Coverage

Phase 2: Improved accuracy, improved reported uncertainties, time series extension, new sensors, …



Plus: Additional Constraints (ACA) Products
(IASI, MIPAS, SCIAMACHY solar occultation, …)