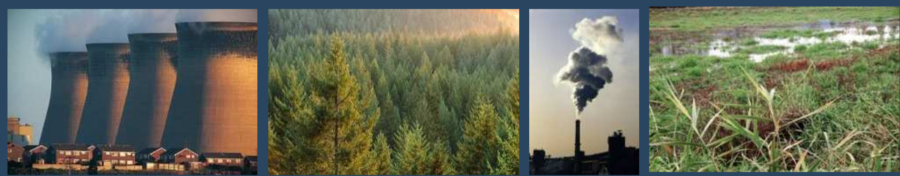
GHG-CCI

2nd CMUG-CCI Integration Meeting, MétéoFrance, Toulouse, 14-16 May 2012

esa

Essential Climate Variable (ECV)
Greenhouse Gases (GHG)



Michael Buchwitz,
Institute of Environmental Physics (IUP),
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and the GHG-CCI team

iup
Universität Bremen
University of Leicester
DLR
SRON Netherlands Institute for Space Research
LMD/CNRS
KIT Karlsruhe Institute of Technology
LSCE
FastOpt
EMPA
JRC EUROPEAN COMMISSION
aeronomie.be

Outline

- Scientific challenges
- How GHG-CCI will respond to these challenges
- "Round Robin" status (focus: CO_2)
- Anticipated outcomes

Carbon source / sink issues

Many important open science questions -> data needed -> satellites

Example: Carbon Dioxide

nature REPORTS climate change
the news behind the science, the science behind the news
home | Nature Climate Change

NEWS FEATURES

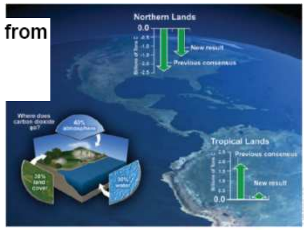
Missing carbon mystery: Case solved?

Stephens, et al., Science, 2007

Scientists claim to have located the 'missing carbon sink' in tropical forests that are absorbing around one billion tonnes more carbon than previously thought. Jane Burgermeister investigates.

Weak Northern and Strong Tropical Land Carbon Uptake from Vertical Profiles of Atmospheric CO_2
Britton B. Stephens, *et al.*
Science **316**, 1732 (2007);

!?



Locating the 'missing carbon sink' in the tropics has implications for the entire global carbon cycle.

Global Carbon Project on CO_2 & CH_4:

Available online at www.sciencedirect.com
ELSEVIER ScienceDirect
Current Opinion in Environmental Sustainability

Canadell, et al., 2010

Interactions of the carbon cycle, human activity, and the climate system: a research portfolio
Josep G Canadell[1], Philippe Ciais[2], Shobhakar Dhakal[3], Han Dolman[4],

A research area for further development relates to multiple constraint approaches, as new observational platforms and multiple-model ensembles become more readily available. Particularly important is the advent of the continuous GHG measurements from satellites. ...

!

Example: Methane

nature International weekly journal of science
Full text access provided to Sta...
Home | News & Comment | Research | Careers & Jobs | Current Issue | Archive | Audio & Video | For
Archive > Volume 476 > Issue 7359 > News & Views > Article

NATURE | NEWS & VIEWS
previous article next article

Atmospheric science: Enigma of the recent methane budget

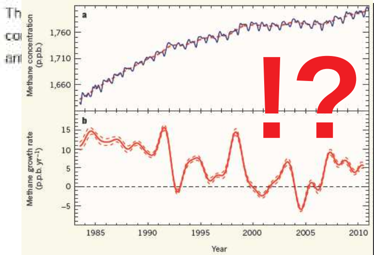
Heimann, Nature, Aug 2011

Martin Heimann

Nature **476**, 157–158 (11 August 2011) | doi:10.1038/476157a
Published online 10 August 2011

The previously increasing atmospheric methane concentration has inexplicably stalled over the past three decades. This may be due to a fall in fossil-fuel emissions or to farming practices that are curtailing microbial sources. See Letters p.194 & p.198

Subject terms: Climate science • Environmental science • Earth science



!?

Can these conflicting inferences on the recent slow-down of global methane growth be reconciled? Because of the limited data...

More extended observations will help too — particularly the mapping of atmospheric methane concentration by current and upcoming satellite missions.

!

Clear need for accurate long-term global CO_2 & CH_4 from satellites !

Why GHG-CCI ?

Background:

Reliable climate prediction requires sufficient knowledge on the sources and sinks of the two major greenhouse gases (GHG) carbon dioxide (CO_2) and methane (CH_4). Currently, this knowledge has large gaps. Important questions need to be answered with confidence such as: Where are the sources & sinks? How strong are they? Do they vary and if yes why? How will they likely respond to a changing climate? Global accurate long-term satellite-derived data sets can make major contributions to answering these questions. Knowledge on greenhouse gas surface fluxes is also increasingly needed to support climate and energy policy.

GHG-CCI aims at delivering the high-quality global long-term satellite-derived atmospheric CO_2 and CH_4 data sets needed to answer important climate change related questions on regional greenhouse gas sources and sinks.

GHG-CCI will significantly strengthen European capabilities in this new & important area of GHG observations from space for better knowledge on regional CO_2 and CH_4 sources and sinks.

GHG-CCI Project Overview

- **Goal:** To deliver global atmospheric CO_2 and CH_4 information needed for a better understanding of regional GHG surface fluxes (sources & sinks) following **GCOS** user requirements and guidelines
- **Core products:** Column-averaged near-surface-sensitive CO_2 and CH_4, i.e., XCO_2 and XCH_4, from SCIAMACHY/ENVISAT & TANSO-FTS/GOSAT; generated with ECV Core Algorithms (**ECAs**); several ECAs per product in competition; the best algorithm for a given product will be selected at the end of a 2 year Round Robin (RR) phase (end of Aug 2012)
- **Additional constraints products:** CO_2 and CH_4 profiles / partial columns from AIRS, IASI, MIPAS, SCIAMACHY solar occultation, ACE-FTS; generated with Additional Constraints Algorithms (**ACAs**)
- **ECV generation:** In year 3 using selected best algorithm(s)
- **Activities:** User requirements, algorithm improvements, data processing and analysis, calibration improvements, validation, ...
- Linked to and complementary with European **GMES** Global Atmospheric Core Service (MACC/MACC-II & follow-ons)

Key Science Issues: Example: CH_4

Global regional-scale methane emissions ?

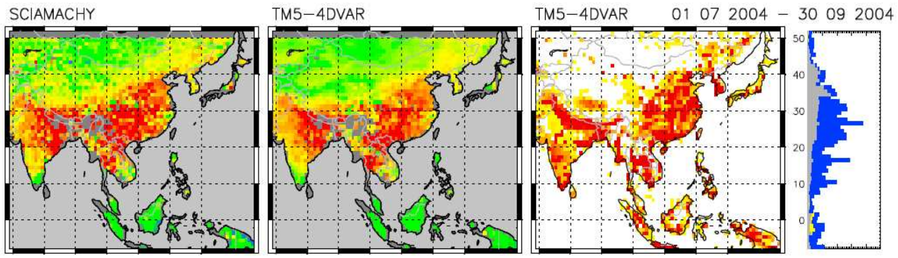
JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 114, D22301, doi:10.1029/2009JD012287, 2009

Click Here for Full Article

Bergamaschi et al., JGR, 2009

Inverse modeling of global and regional CH_4 emissions using SCIAMACHY satellite retrievals

… the **SCIAMACHY data put strong constraints on the smaller-scale spatial distribution of emissions**, while remote surface measurements mainly constrain the emissions of larger regions.



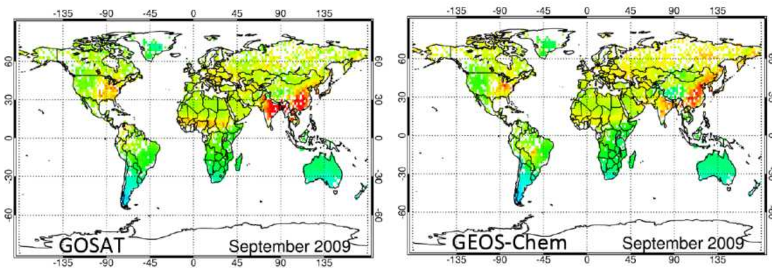
GEOPHYSICAL RESEARCH LETTERS, VOL. 38, L15807, doi:10.1029/2011GL047871, 2011

Methane observations from the Greenhouse Gases Observing SATellite: Comparison to ground-based TCCON data and model calculations

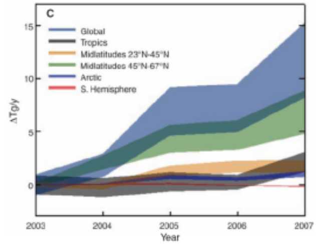
Robert Parker,[1] Hartmut Boesch,[1] Austin Cogan,[1] Annemarie Fraser,[2] Liang Feng,[2] Paul I. Palmer,[2] Janina Messerschmidt,[3] Nicholas Deutscher,[3,4] David W. T. Griffith,[4] Justus Notholt,[3] Paul O. Wennberg,[5] and Debra Wunch[5]

Similar activities are ongoing for **GOSAT**

Parker et al., GRL, 2011



Bloom et al., Science, 2010



Large-Scale Controls of Methanogenesis Inferred from Methane and Gravity Spaceborne Data

A. Anthony Bloom,[1] Paul I. Palmer,[1]* Annemarie Fraser,[1] David S. Reay,[1] Christian Frankenberg[2]

SCIAMACHY CH_4, groundwater depth, skin T

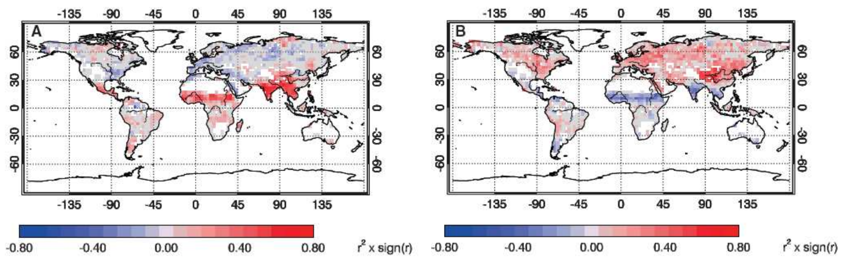


Fig. 1. Correlations (r^2) between cloud-free SCIAMACHY CH_4 column volume mixing ratios (VMRs) (in parts per million) and **(A)** equivalent groundwater depth (in meters), determined from gravity anomaly measurements from the GRACE satellites (*18*) and **(B)** NCEP/NCAR surface skin temperatures (in kelvin), calculated on a 3° × 3° horizontal grid over 2003–2005. The correlation at a given point is determined by at least 15 and typically 60 CH_4, groundwater, and temperature measurements. See SOM for a description of individual data sets.

Two main application areas:

- Improved surface fluxes / emission inventories
- Improved process understanding / modelling

➡ **Better climate prediction, …**

Key Science Issues: CH_4

Reason for recent methane increase ?

Addressed by multi-year global SCIAMACHY methane retrievals and data analysis:

Atmos. Chem. Phys., 11, 2863–2880, 2011
www.atmos-chem-phys.net/11/2863/2011/
doi:10.5194/acp-11-2863-2011

Atmospheric Chemistry and Physics

Schneising et al., ACP, 2011

Long-term analysis of carbon dioxide and methane column-averaged mole fractions retrieved from SCIAMACHY

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

Received: 22 September 2010 – Published in Atmos. Chem. Phys. Discuss.: 11 November 2010
Revised: 23 March 2011 – Accepted: 24 March 2011 – Published: 28 March 2011

Abstract. Carbon dioxide (CO_2) and methane (CH_4) are the two most important anthropogenic greenhouse gases contributing to global climate change. SCIAMACHY onboard ENVISAT (launch 2002) was the first and is now with TANSO onboard GOSAT (launch 2009) one of only ...

... ern Hemisphere, is on average about 1 ppm larger than for CarbonTracker.

An investigation of the boreal forest carbon uptake during the growing season via the analysis of longitudinal gradients shows good agreement between SCIAMACHY and Carbon-...

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 116, D04302, doi:10.1029/2010JD014849, 2011

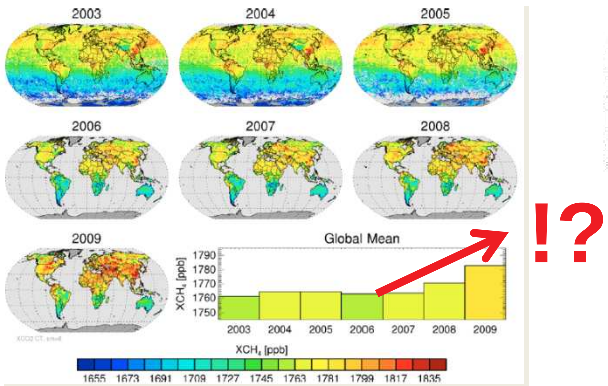
Frankenberg et al., JGR, 2011

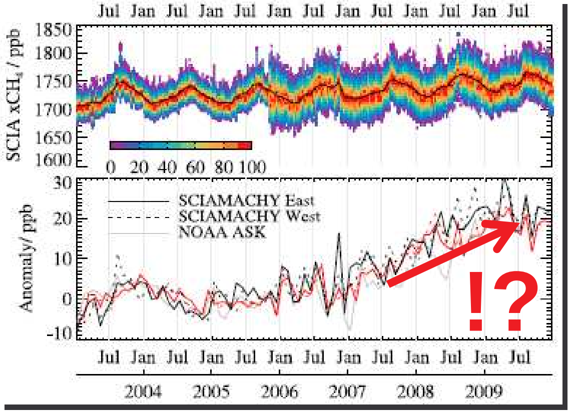
Global column-averaged methane mixing ratios from 2003 to 2009 as derived from SCIAMACHY: Trends and variability

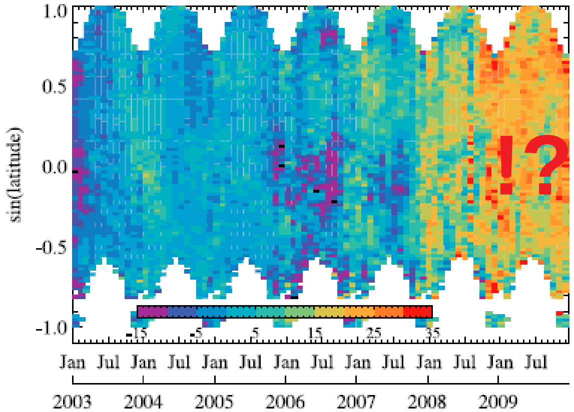
C. Frankenberg,[1,2] I. Aben,[1] P. Bergamaschi,[3] E. J. Dlugokencky,[4] R. van Hees,[1] S. Houweling,[1,5] P. van der Meer,[1] R. Snel,[1] and P. Tol[1]

Received 30 July 2010; revised 19 November 2010; accepted 30 November 2010; published 17 February 2011.

[1] After a decade of stable or slightly decreasing global methane concentrations, ground-based in situ data show that CH_4 began increasing again in 2007 and that this increase continued through 2009. So far, space-based retrievals sensitive to the lower troposphere in the time period under consideration have not been available. Here we report a long-term data set of column-averaged methane mixing ratios retrieved from spectra of the Scanning Imaging Absorption Spectrometer for Atmospheric Cartography (SCIAMACHY) instrument onboard Envisat. The retrieval quality after 2005 was severely affected by degrading detector pixels within the methane 2μ absorption ...







Findings:

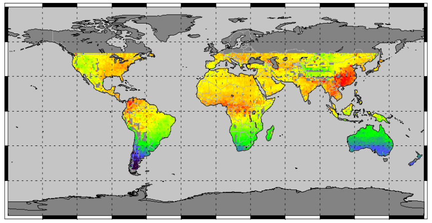
- Recent increase **~7-8 ppb/yr** (in good agreement with NOAA surface observations)
- Origin: **Mainly > 30°S**. 7-8 ppb tropics and NH mid-latitudes. 5 ppb < 30°S. No “regional hot spot” found.
- Main issue: Detector degradation esp. after 2005 (ongoing research how to optimally deal with this)

Key Science Issues: CH_4

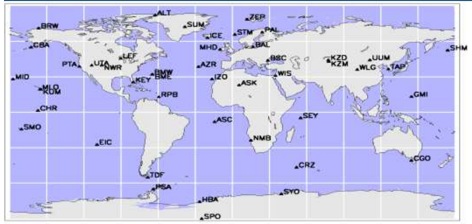
Reason for recent methane increase ?

Ongoing research & use within MACC: Bergamaschi et al., EGU 2012:

SCIAMACHY

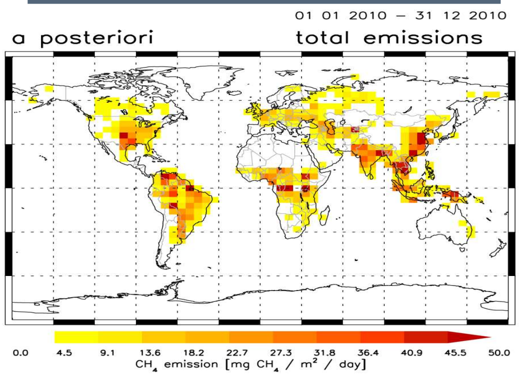


surface sites (NOAA/ESRL)

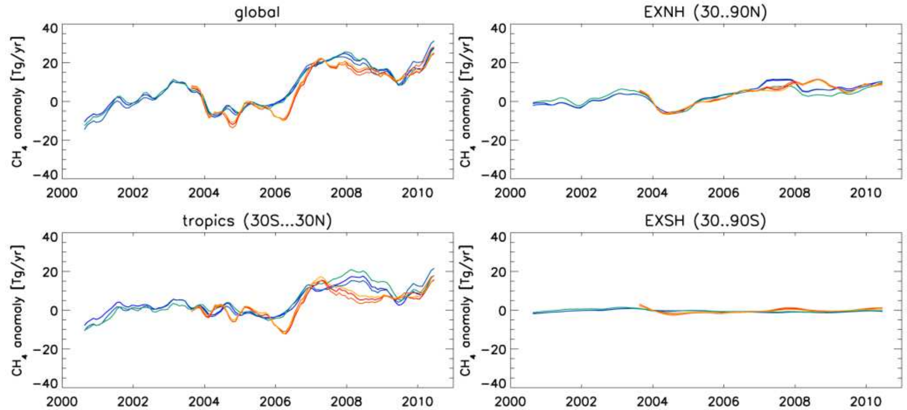


TM5-4DVAR

Methane emissions



Methane emissions



- SCIAMACHY (IMAPv55R1) / LPJ WHyMe
- SCIAMACHY (IMAPv55R1) / Spivakovsky OH
- SCIAMACHY (IMAPv55R1)
- NOAA only / LPJ WHyMe
- NOAA only / Spivakovsky OH
- NOAA only

reference period 2003-2005

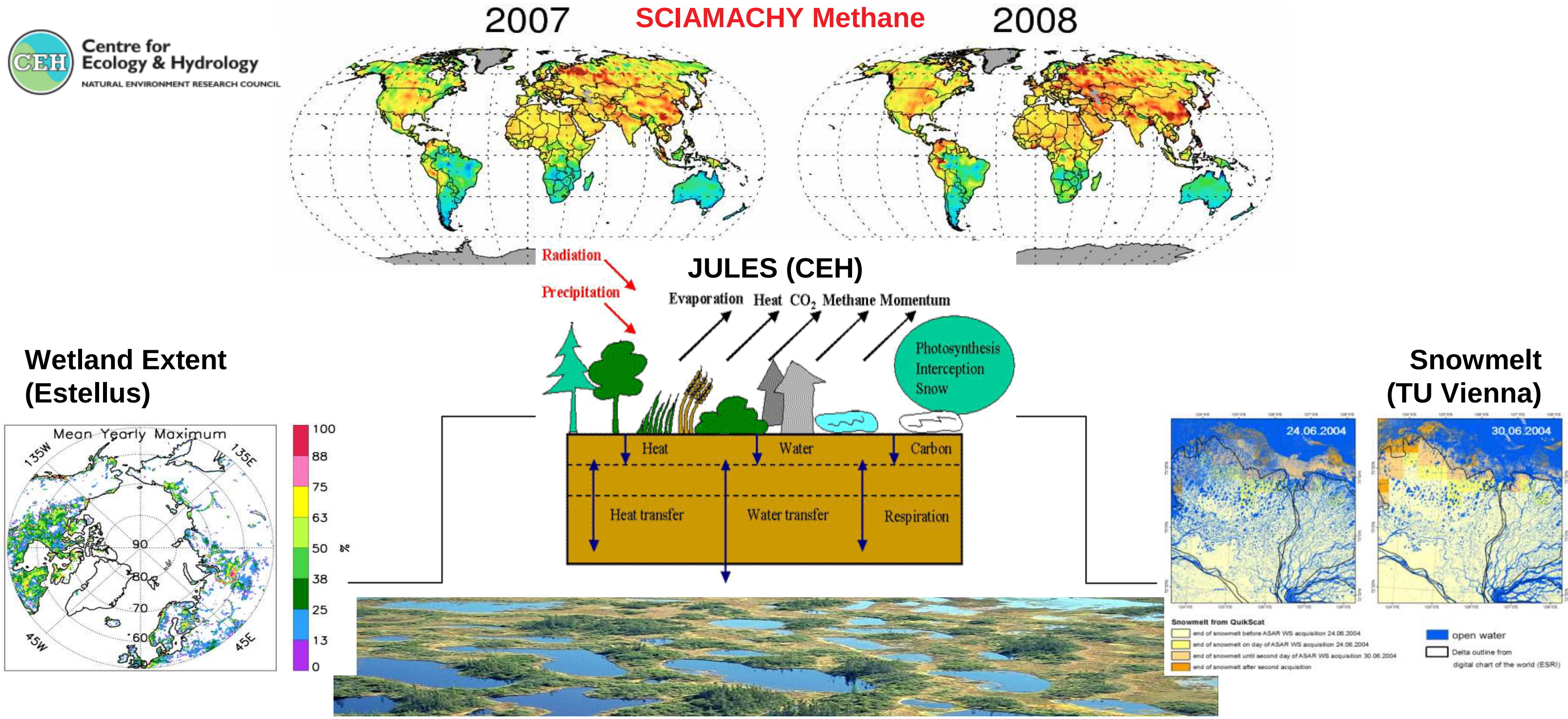
12-month running mean

Findings:

- **Trend mainly tropics and NH mid-latitudes**
- Arctic: No trend and only small IAV

Key Science Issues: CH_4

How to use EO data to improve Climate Models?



Alanis Methane Project:

- Improving methane emissions & modelling (focus: boreal wetlands)
- Improving **JULES** – the Joint UK Land Earth Simulator
- Improving the Met Office Hadley Centre Climate Model **HadGEM** (JULES is the land surface component of HadGEM)

Key Science Issues: CO_2

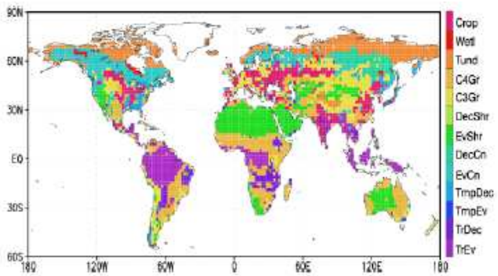
How to use EO data to improve Climate Models?

Instead of „traditional" direct inverse modelling of surface fluxes one can also constrain process parameters of, for example, a terrestrial biosphere model:

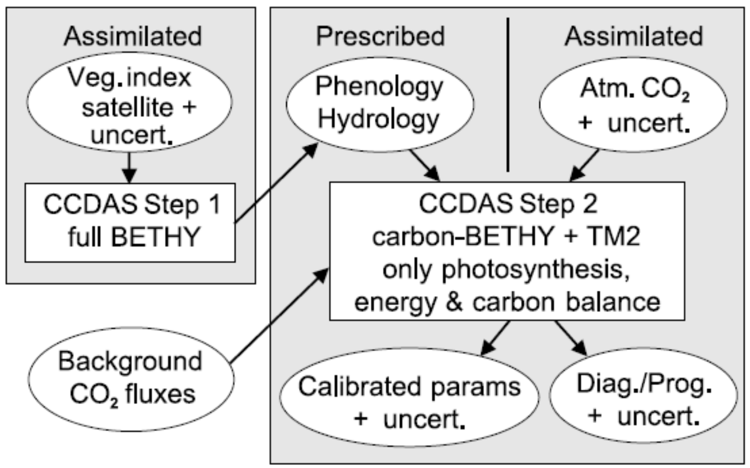
•Carbon Cycle Data Assimilation System (CCDAS)

- Gives optimized process parameters needed to model plant CO_2 uptake and release
- Gives terrestrial fluxes but also fluxes not available from direct (net) flux inversion (e.g., gross carbon fluxes)
- Improved terrestrial biosphere model -> better climate prediction

13 Plant Functional Types (PFT) / 57 Process Parameters



Now also covered by GHG-CCI (new WP)



Click Here for Full Article

Propagating uncertainty through prognostic carbon cycle data assimilation system simulations

M. Scholze,[1] T. Kaminski,[2] P. Rayner,[3] W. Knorr,[1] and R. Giering[2]

Received 9 March 2007; revised 23 May 2007; accepted 20 June 2007; published 14 September 2007.

[1] One of the major advantages of carbon cycle data assimilation is the possibility to estimate carbon fluxes with uncertainties in a prognostic mode, that is beyond the time period of carbon dioxide (CO_2) observations. The carbon cycle data assimilation system is built around the Biosphere Energy Transfer Hydrology Scheme (BETHY) model, coupled to the atmospheric transport model TM2. It uses about 2 decades of observations of the atmospheric carbon dioxide concentration from a global network to constrain 57 process parameters via an adjoint approach. The model's Hessian matrix

Key Science Issues: CO_2

CO_2 seasonal cycle & terrestrial carbon sink ?

Atmos. Chem. Phys., 11, 2863–2880, 2011
www.atmos-chem-phys.net/11/2863/2011/
doi:10.5194/acp-11-2863-2011

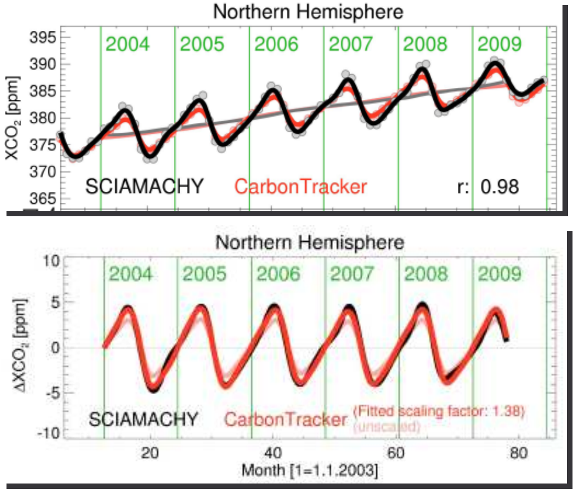
Atmospheric Chemistry and Physics

Schneising et al., ACP, 2011

Long-term analysis of carbon dioxide and methane column-averaged mole fractions retrieved from SCIAMACHY

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

Received: 22 September 2010 – Published in Atmos. Chem. Phys. Discuss.: 11 November 2010
Revised: 23 March 2011 – Accepted: 24 March 2011 – Published: 28 March 2011



SCIA suggests ~38% larger NH CO_2 Seasonal Cycle Amplitude (SCA) compared to CarbonTracker/CASA.

However, contribution from retrieval errors (eg cirrus) could not be ruled out

Biogeosciences, 9, 875–891, 2012
www.biogeosciences.net/9/875/2012/
doi:10.5194/bg-9-875-2012

Biogeosciences

Keppel-Aleks et al., BG, 2012

The imprint of surface fluxes and transport on variations in total column carbon dioxide

G. Keppel-Aleks[1], P. O. Wennberg[1], R. A. Washenfelder[2], D. Wunch[1], T. Schneider[1], G. C. Toon[4], R. J. Andres[3], J.-F. Blavier[4], B. Connor[5], K. J. Davis[6], A. R. Desai[7], J. Messerschmidt[8], J. Notholt[8], C. M. Roehl[1], V. Sherlock[9], B. B. Stephens[10], S. A. Vay[11], and S. C. Wofsy[12]
[1]California Institute of Technology, Pasadena, CA, USA
[2]National Oceanic and Atmospheric Administration, Boulder, CO, USA
[3]Oak Ridge National Laboratory, Oak Ridge, TN, USA
[4]NASA Jet Propulsion Laboratory, Pasadena, CA, USA
[5]BC Consulting, New Zealand
[6]The Pennsylvania State University, University Park, PA, USA
[7]University of Wisconsin, Madison, WI, USA
[8]University of Bremen, Bremen, Germany
[9]National Institute of Water and Atmospheric Research, Wellington, New Zealand
[10]National Center for Atmospheric Research, Boulder, CO, USA
[11]NASA Langley Research Center, Langley, VA, USA
[12]Harvard University, Cambridge, MA, USA

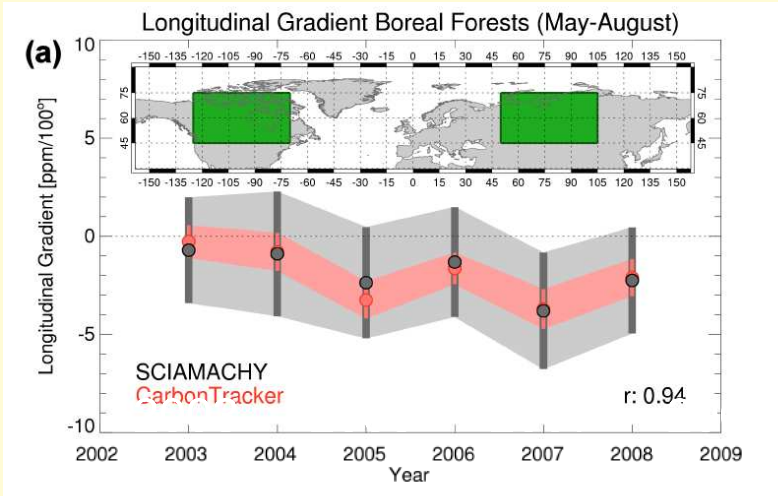
the meridional gradient during the growing season. Simulations using CASA net ecosystem exchange (NEE) with increased and phase-shifted boreal fluxes better fit the observations. Our simulations suggest that climatological mean CASA fluxes underestimate boreal growing season NEE (between 45–65° N) by ~40 %. We describe the implications for this large seasonal exchange on inference of the net Northern Hemisphere terrestrial carbon sink.

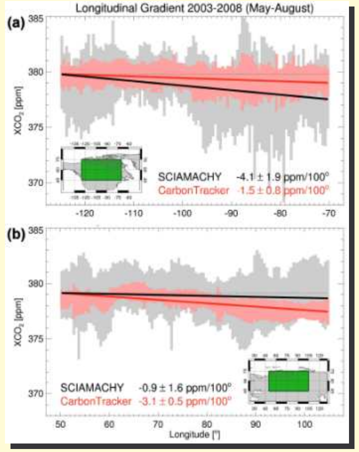
TCCON suggests boreal growing season NEE underestimated by ~40% by biosphere carbon model CASA
-> Implications for net NH terrestrial carbon sink
(correlation of SCA and net fluxes)

Key Science Issues: CO_2
Boreal forest carbon uptake ?

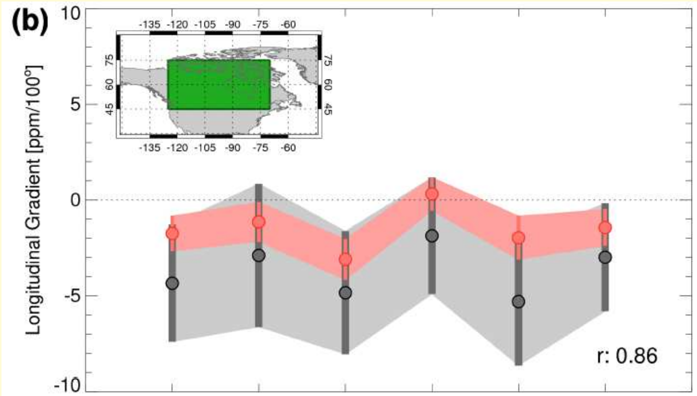
SCIAMACHY vs CarbonTracker

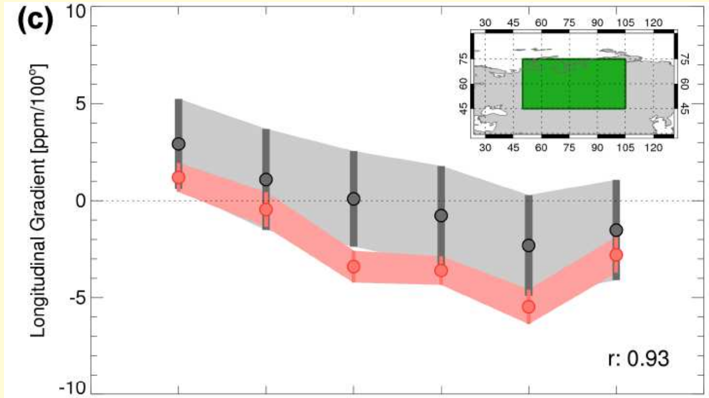
Schneising et al., ACP, 2011





Overall very good agreement !





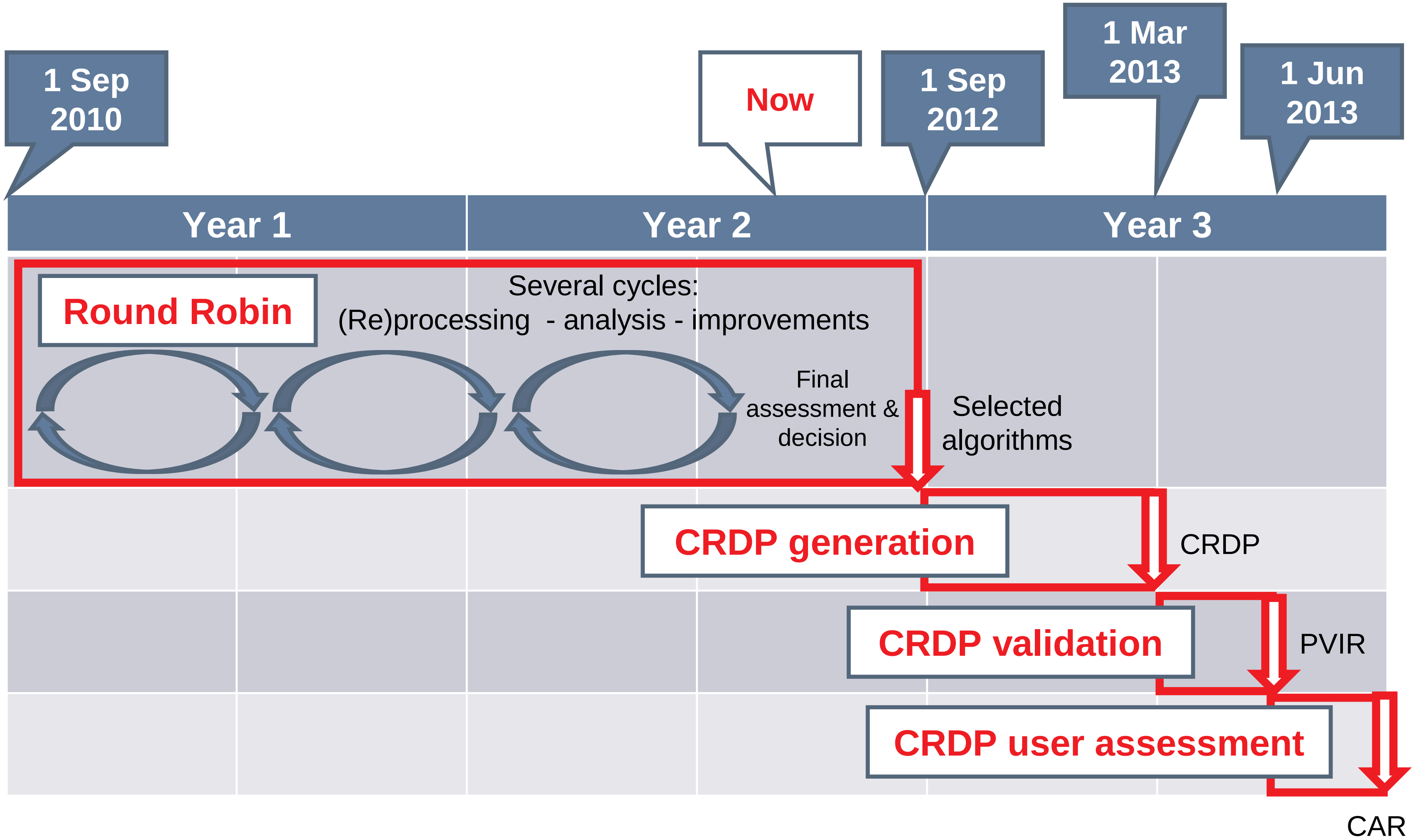
Canada: Stronger CO_2 uptake ?

Russia: Weaker CO_2 uptake ?

Round Robin

http://www.bookperhead.com/images/articles/round-robin-parlays.jpg

GHG-CCI Phase 1 Schedule

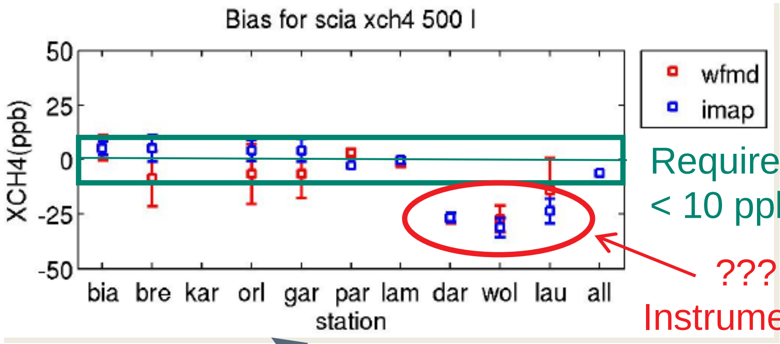


GHG-CCI Round Robin (RR)

- The **goal of the RR exercise** is to find out which algorithms to use to generate the GHG-CCI satellite-based CO_2 and CH_4 data products
- The **evaluation criteria** are described in the GHG-CCI RR Evaluation Protocol (RREPv2) available on http://www.esa-ghg-cci.org/
- The criteria depend on the data product / algorithm type, i.e., **ECA** (in competition) or **ACA** (not in competition)
- The selected algorithms will be used to generate the **CRDP**, which will be the first version of the GHG-CCI ECV „Greenhouse Gases" data base
- Note: What can/will exactly be made/used during CCI Phase 2 will depend on the ITT and related ESA decisions

Status RR: Methane - I

SCIAMACHY XCH_4:



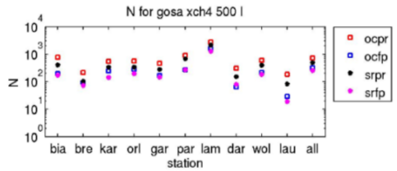
- **Two algorithms**: **IMAP** (v6.0) & **WFMD** (v2.3)
  - Both are „CO_2 light path PRoxy“ (PR) algorithms
  - IMAP is based on Optimal Estimation using model data as *a priori* constraint
  - WFMD is based on unconstrained least-squares
- Key findings at TCCON validation sites:
  - Biases (systematic errors): Nearly identical for both algorithms
  - Scatter (random errors): IMAP ~50 ppb (1-sigma, slg.obs.), WFMD ~80 ppb
- Key findings global data:
  - Ongoing (reprocessing and reanalysis needed) -> final decision not yet possible

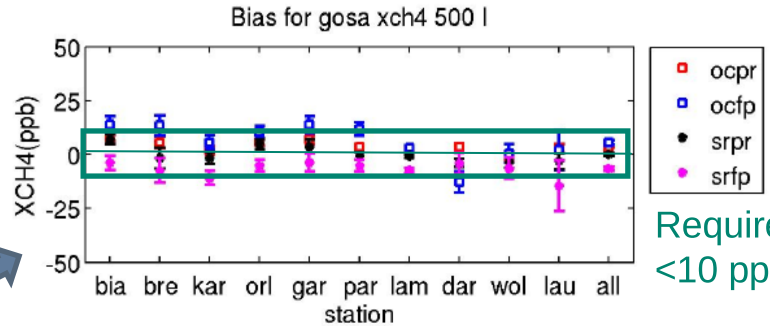
- **Limitations: TCCON:** (i) very sparse, (ii) total error ~10 ppb (Wunch et al., AMT, 2011), (iii) averaging kernels / a priori profiles not (yet) considered

- **Possible RR decision:**
  - Two options:
    - **Option A:** IMAP is the current scientific de-facto standard (e.g., Bergamaschi et al. 2009, Bloom et al., 2010) and the baseline product used by MACC. It has not be demonstated that WFMD is better -> keep baseline -> use **IMAP** for CRDP
    - **Option B:** It cannot be ruled out that WFMD is better at least for certain conditions (e.g., w.r.t. tropical emissions) and/or that using both products helps to get better emissions (e.g. via better error characterization) -> generate a „convenient“ CRDP containing **BOTH** products

Status RR: Methane - II

GOSAT XCH_4:





Requirement: <10 ppb (T)

- **Four algorithms**:
  - 2x „Proxy“ (PR), 2x „Full Physics“ (FP)

- Key findings at TCCON validation sites:
  - Biases & scatter (relative accuracy and precision): Very similar for all four algorithms
  - Number data: PR x 2-4 more data compared to FP

- Key findings overall:
  - Very similar. It cannot be reliably determined which product is better due to the sparseness of the TCCON sites.
  - Nevertheless: FP: SRFP seems slightly better than OCFP; PR: OCPR more data that SRPR

- **Limitations: TCCON:** (i) very sparse, (ii) total error ~10 ppb (Wunch et al., AMT, 2011), (iii) averaging kernels / a priori profiles not (yet) considered

- Other considerations:
  - User would prefer a FP data product as it is independent of modelled CO_2 but important pros for existing PR: (i) (much) more data, (ii) higher accuracy at least for certain conditions (iii) heritage (e.g., peer-reviewed publications discussing inferred methane fluxes using PR applied to SCIAMACHY)

- **RR decision** (PM4, 3-4 May 2012):
  - Further develop & use 1 FP and 1 PR algorithm (as long as not yet demonstrated that FP better than PR): **FP: SRFP** (= RemoteC), **PR: OCPR** (=UoL OCO algorithm)

Status RR: CO_2

SCIAMACHY XCO_2:

- Two algorithms: **WFMD** and **BESD**
- Key findings:
  - WFMD has much more data (x 3-4) but BESD has higher precision and accuracy

GOSAT XCO_2:

- Two algorithms: **OCFP** and **SRFP**
- Key findings:
  - Both very similar precision and accuray at TCCON validation sites -> not possible to determine which algorithm is better
  - Analysis of global data: Differences often exceed relative accuracy requirement (0.5 ppm) especially at non-TCCON locations !? -> TCCON sparse and not covering all situations

RR decision:

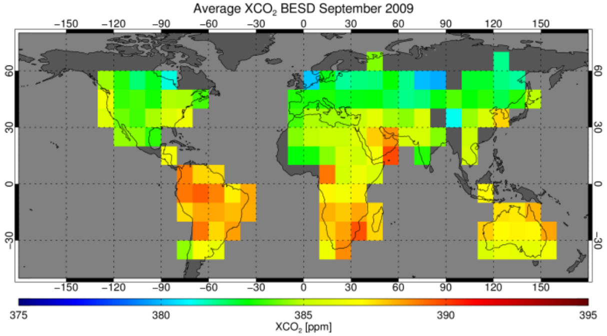
•**Goal:** Further development of all algorithms (at least BESD, OCFP, SRFP) until convergence of global maps or one „clear winner" identified
•**Short / mid term solution:** Ensemble approach (see next slides)

CO_2: Ensemble approach - I

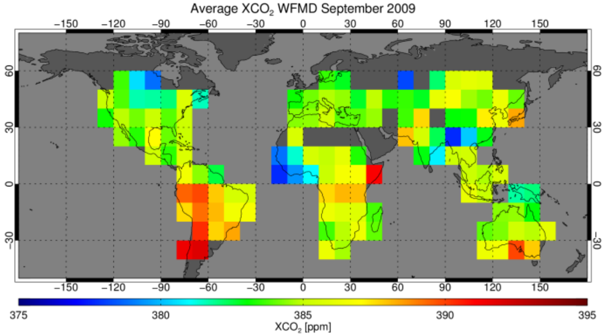
Typical example: Monthly averages (Sept 2009) using 7 different algorithms

(scale: 385 +/- 10 ppm)

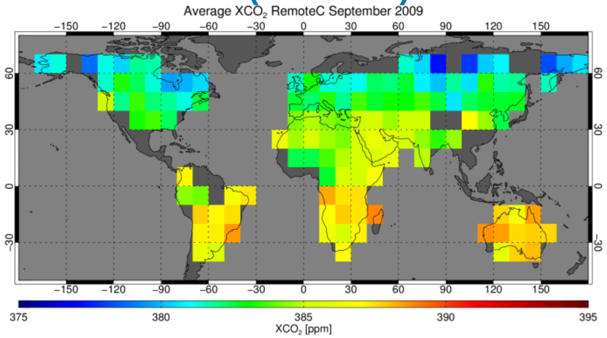
SCIA BESD IUP



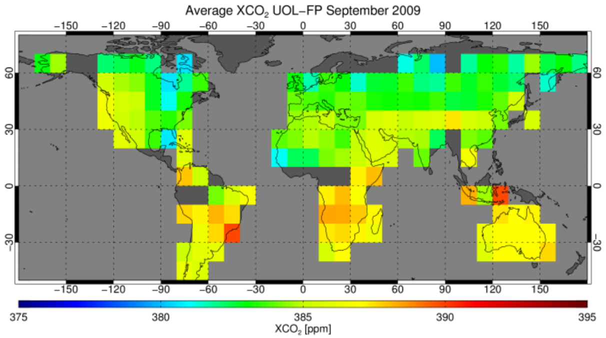
SCIA WFMD IUP



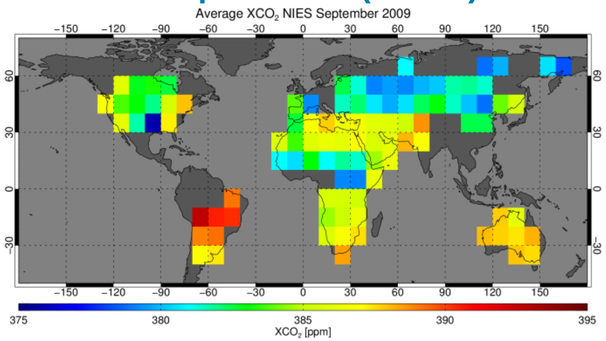
GOSAT SRFP(RemoteC) SRON/KIT



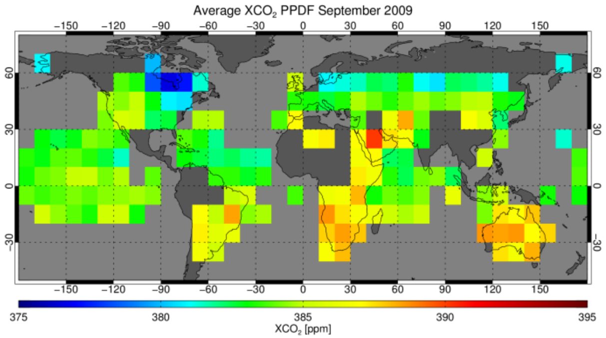
GOSAT OCFP UoL



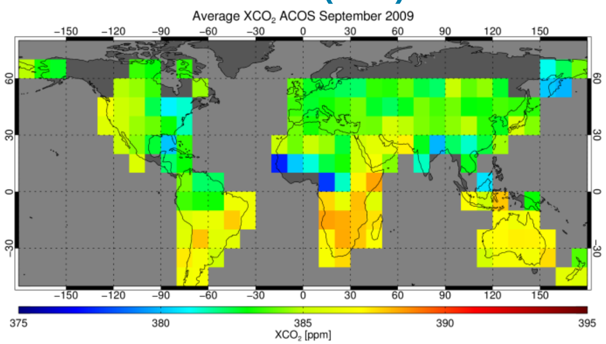
GOSAT Operational (v01.xx) NIES



GOSAT PPDF NIES



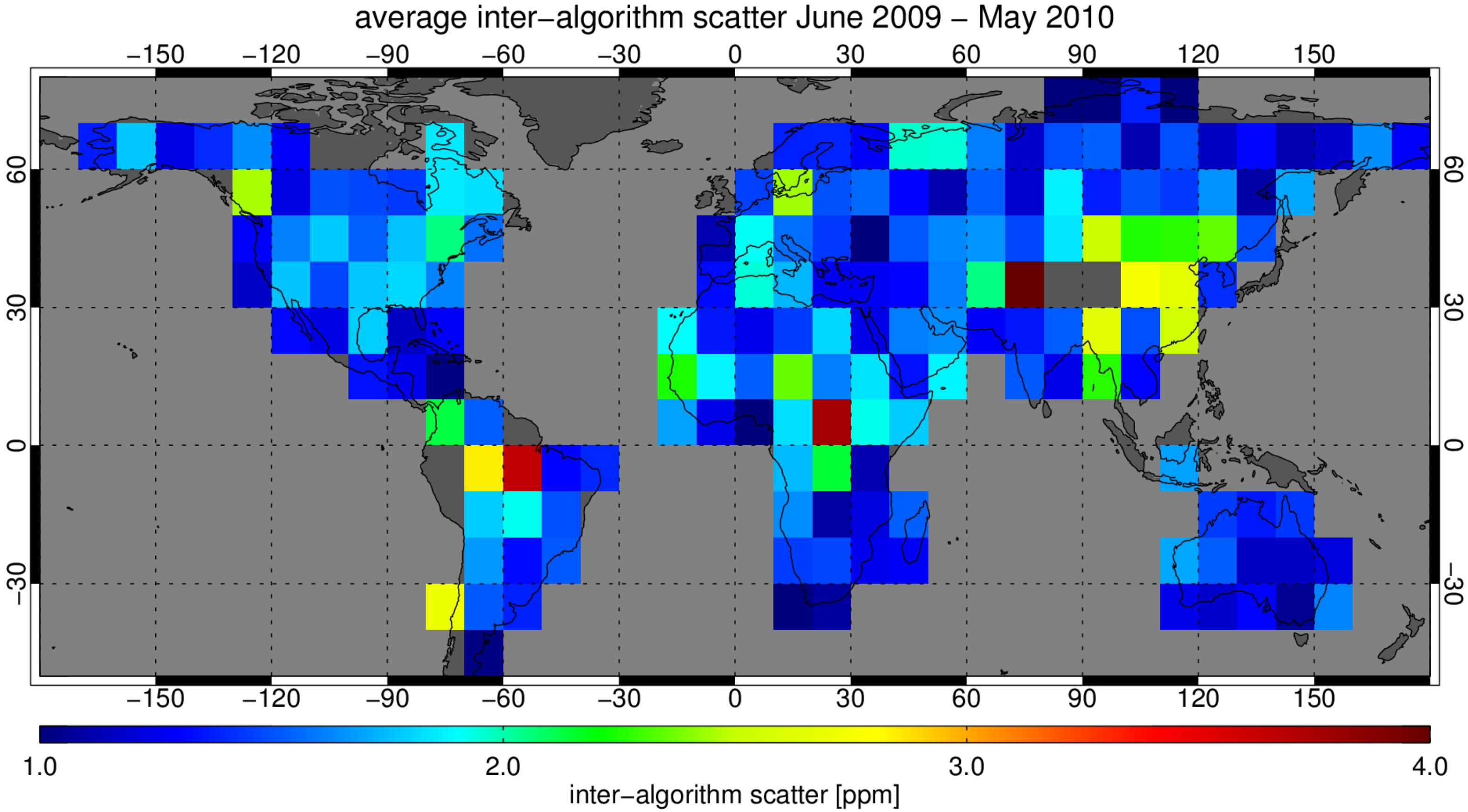
GOSAT ACOS(v2.9) NASA



- All algos capture the interhemispheric gradient
- However, maps differ by often more than 0.5 ppm !?
- All products appear to suffer from outliers but where they appear and when differs for all algorithms
- Comparison @TCCON sites (sparse, not shown): not possible to identify which algo is the best !?
- How to deal with this ? (see following slides)

CO_2: Ensemble approach - II

Inter-algorithm scatter



- Shows us where the products agree and where they disagree
- Ensemble helps to quantify systematic errors (very important for reliable surface flux inversions)

CO_2: Ensemble approach - III

EMMA - EnseMble Median Algorithm

Apparently we have a similar problem as climate modellers

•(At least at present) We cannot trust a single algorithm / data product / model

•We don't know the truth

•An approach discussed in the climate modelling community to deal with this: Use an ensemble, e.g., use the ensemble median

EMMA idea:

•Use the median because its robust wrt outliers

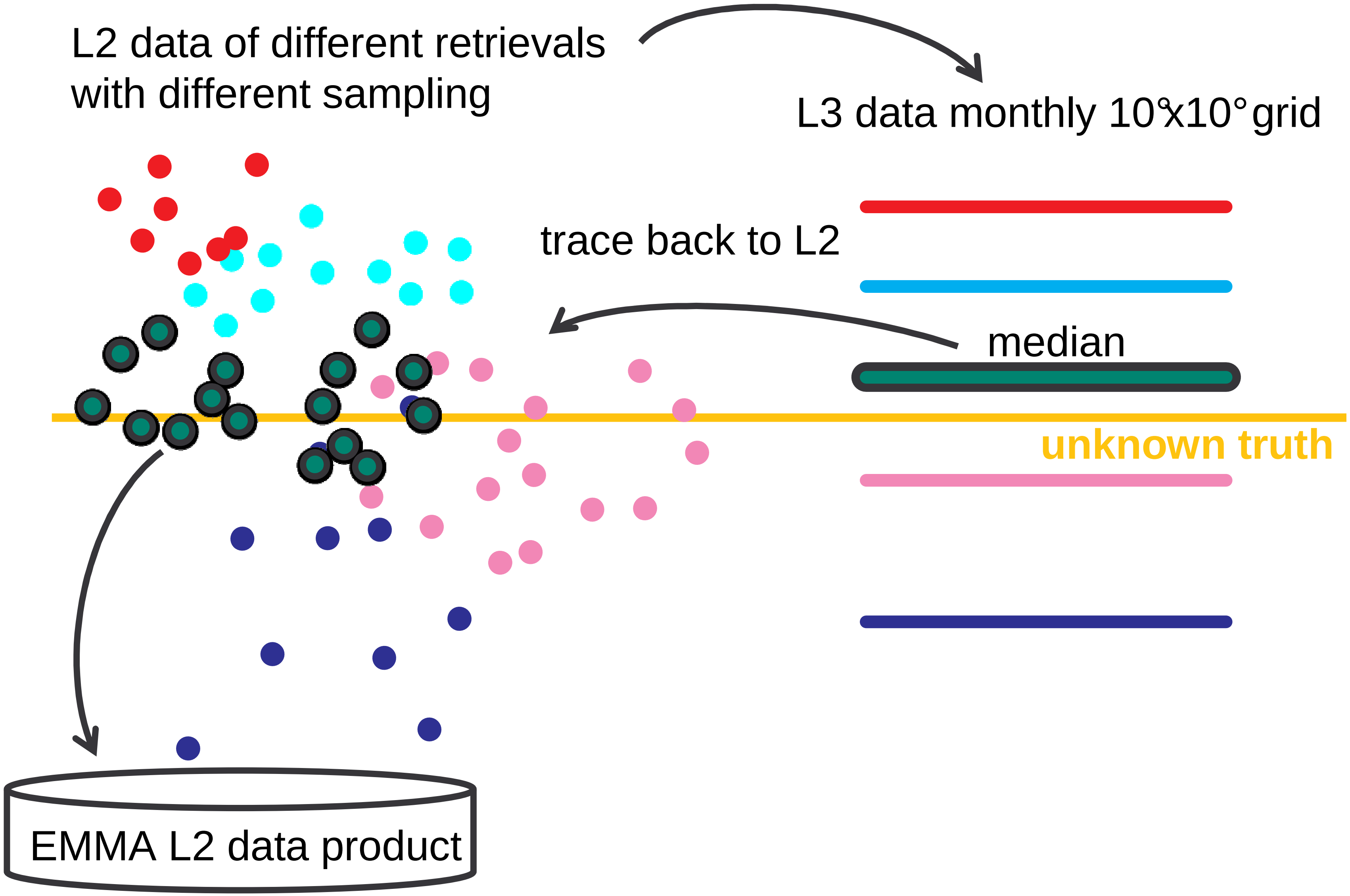
•The **EnseMble Median Algorithm (EMMA)** has been set up to compose a L2 database (i.e., a L2 data product as for the individual products) of "median single soundings"

•EMMA must account for different sampling due to different filtering and satellites (if SCIA and GOSAT combined; GOSAT only is however also possible)

•The decision which individual sounding is the median has to be drawn from L3 data

CO_2: Ensemble approach - IV

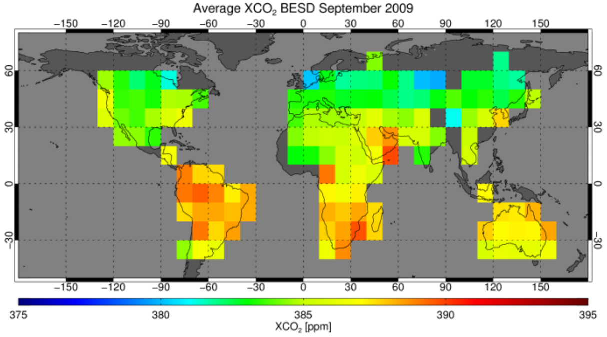
EMMA idea & approach



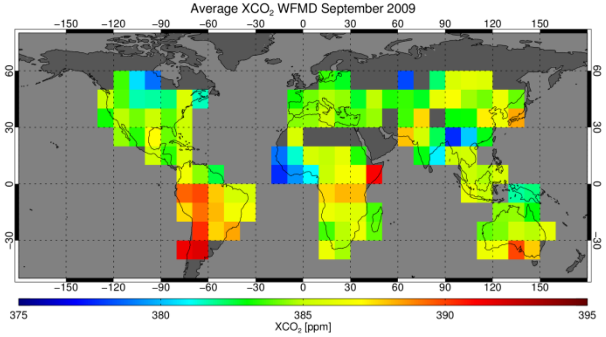
CO_2: Ensemble approach - V

EMMA vs individual algorithms

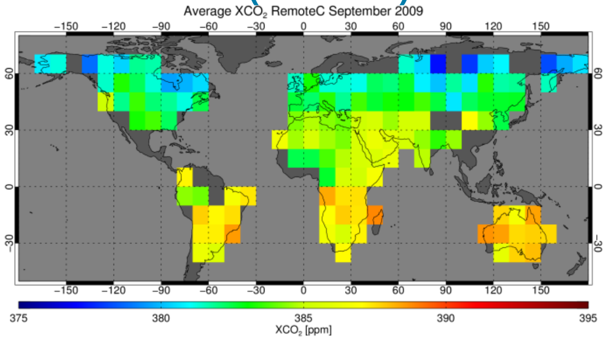
SCIA BESD IUP



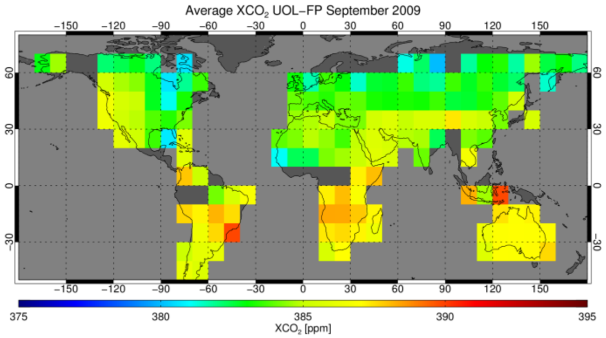
SCIA WFMD IUP



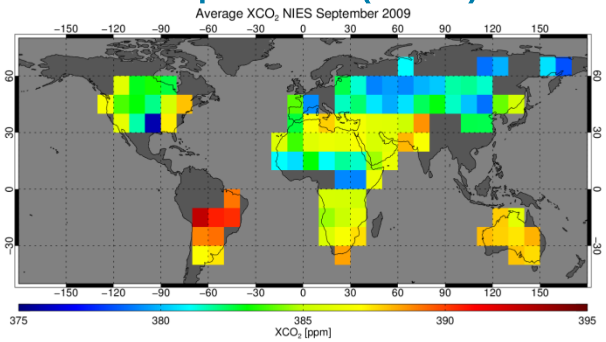
GOSAT SRFP(RemoteC) SRON/KIT



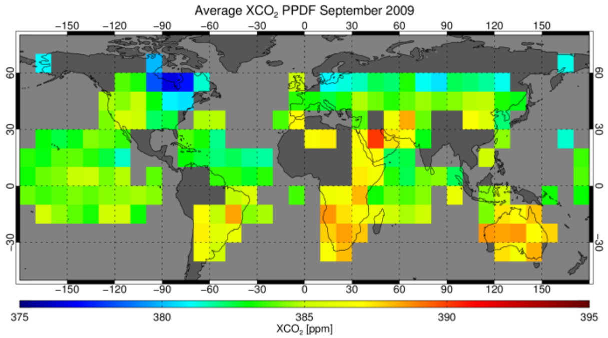
GOSAT OCFP UoL



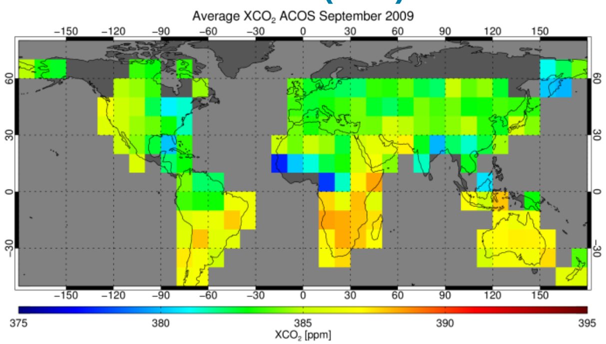
GOSAT Operational (v01.xx) NIES



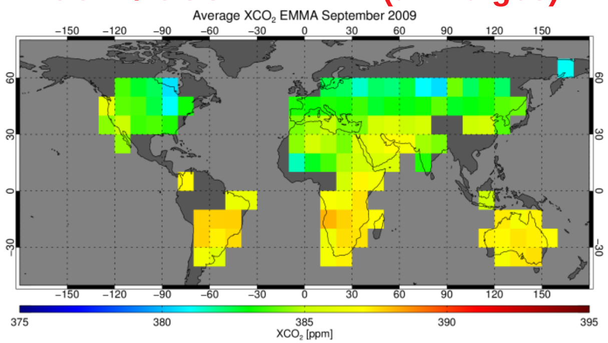
GOSAT PPDF NIES



GOSAT ACOS(v2.9) NASA



SCIA / GOSAT EMMA (all 7 algos)

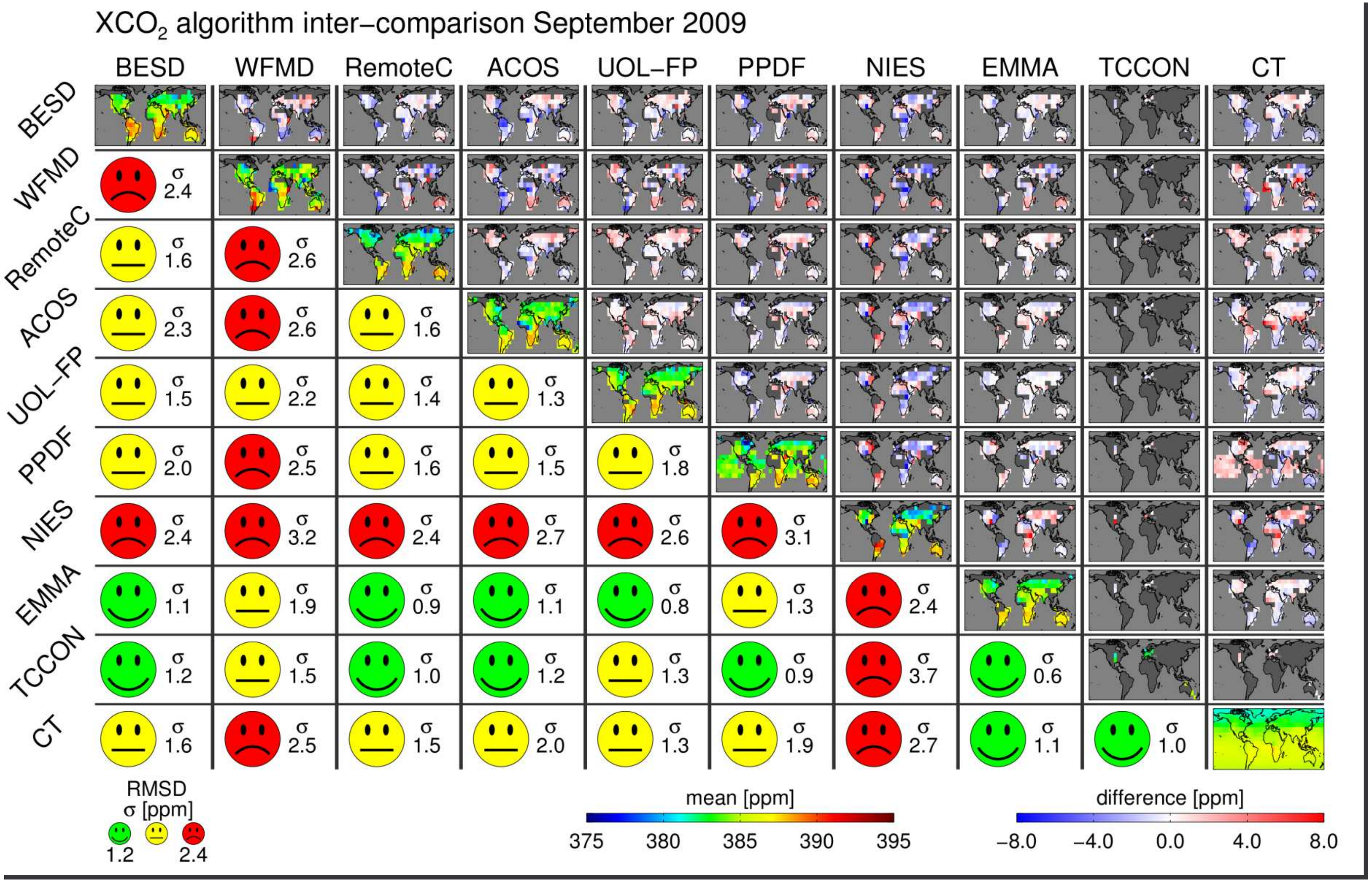


EMMA Level 2 XCO_2:

- A „nice“ smooth product (no obvious outliers)
- Realistic errors from ensemble scatter

CO_2: Ensemble approach - VI

EMMA vs individual algorithms: Global maps



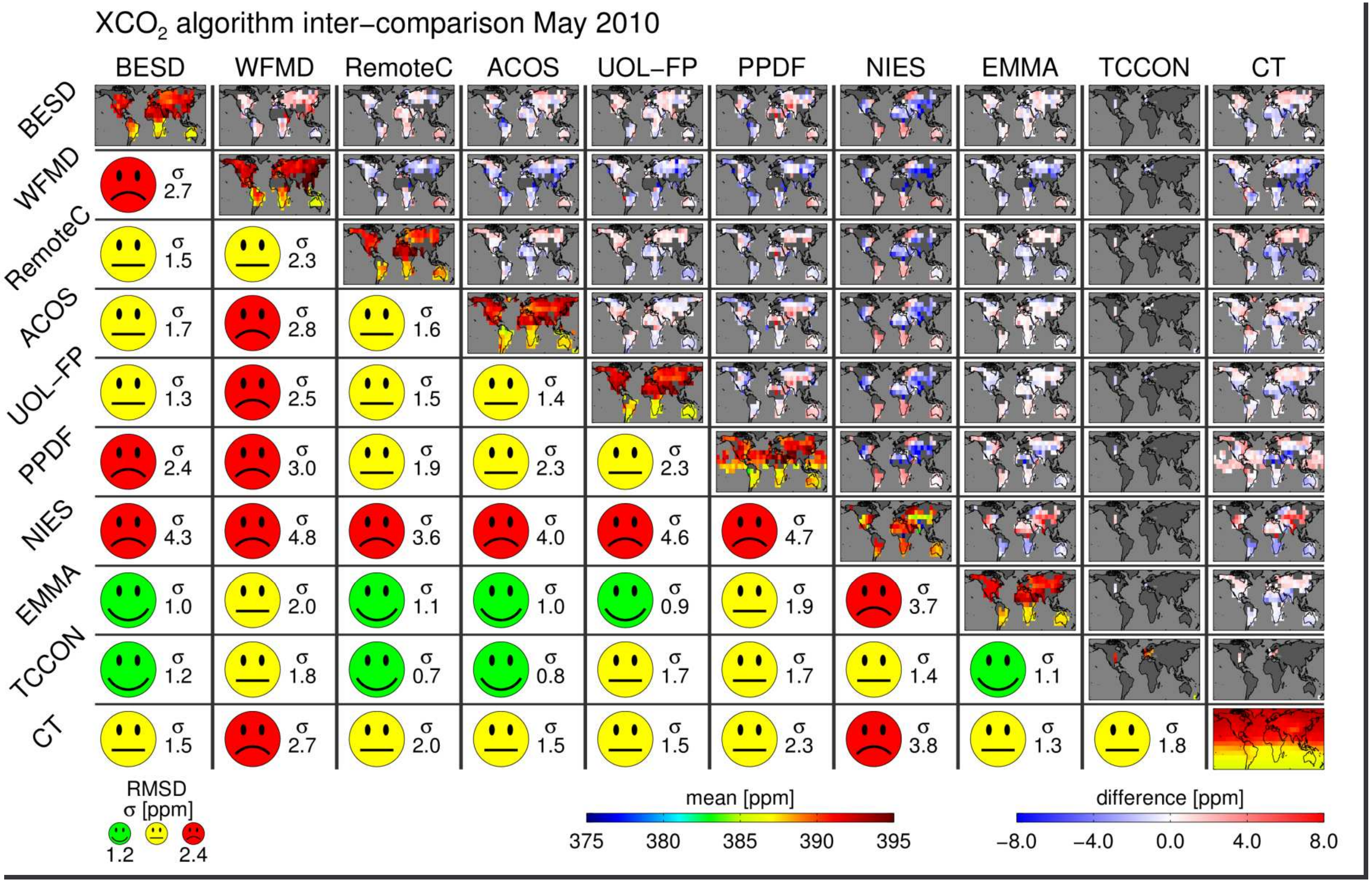
v01.xx (will be better with new version v02.xx)

- Large inter-algorithm differences (esp. remote from TCCON)
- **EMMA often best agreement with TCCON and CT2010**

CO_2: Ensemble approach - VII

EMMA vs individual algorithms: Global maps

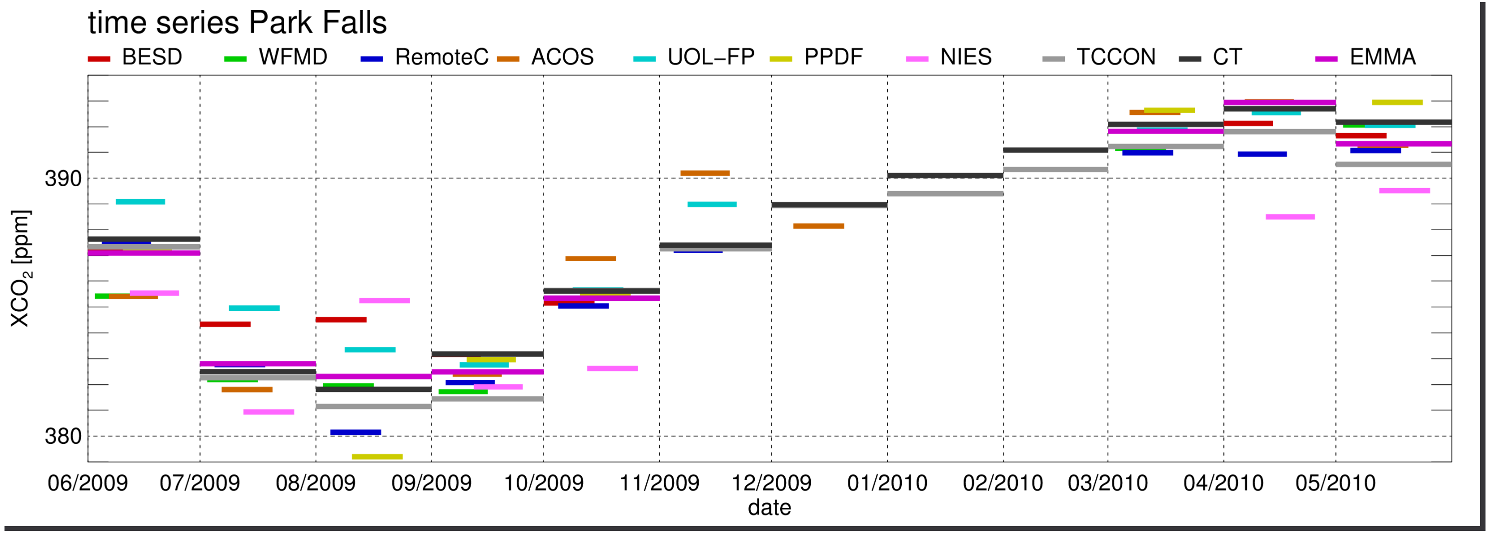
v01.xx
(will be better with new version v02.xx)

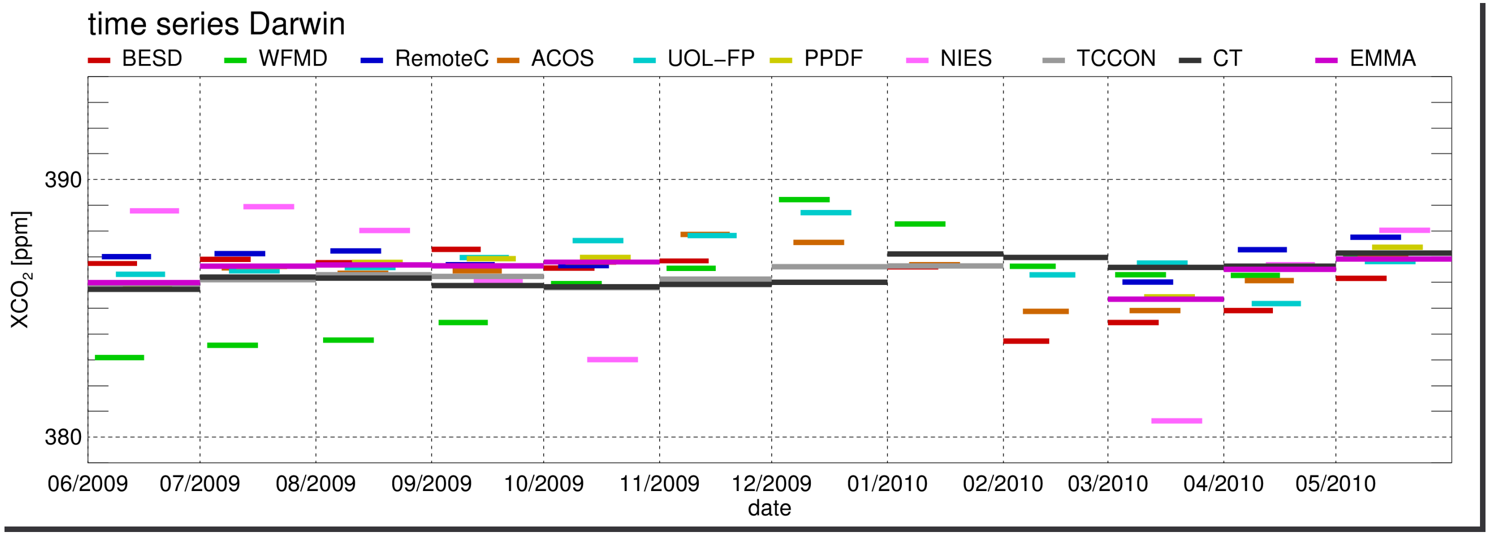


- Large inter-algorithm differences (esp. remote from TCCON)
- **EMMA often best agreement with TCCON and CT2010**

CO_2: Ensemble approach - VIII

EMMA vs individual algorithms: Time series

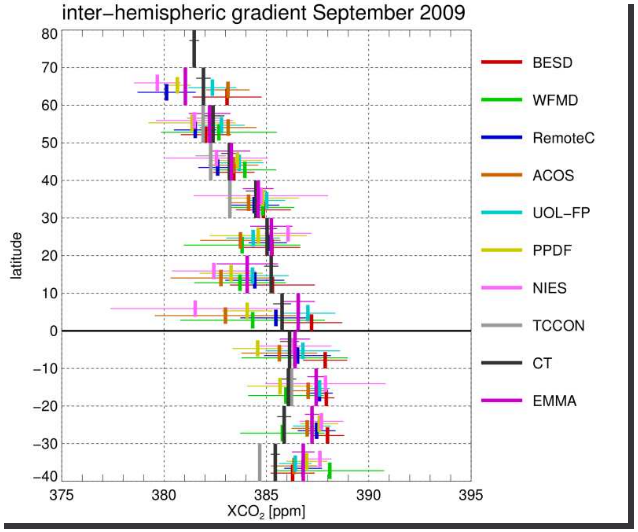


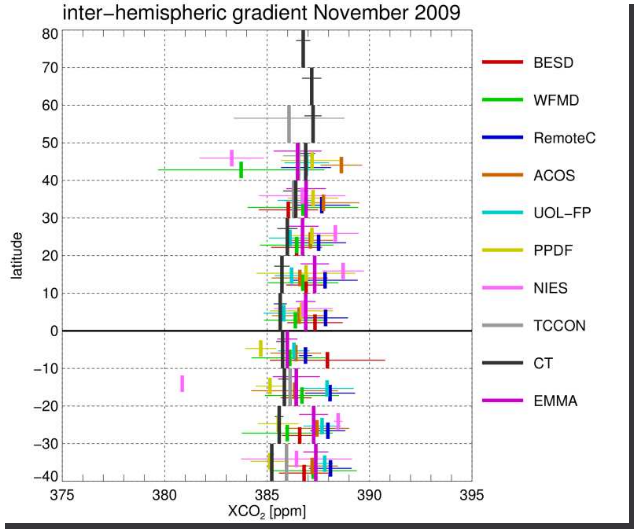


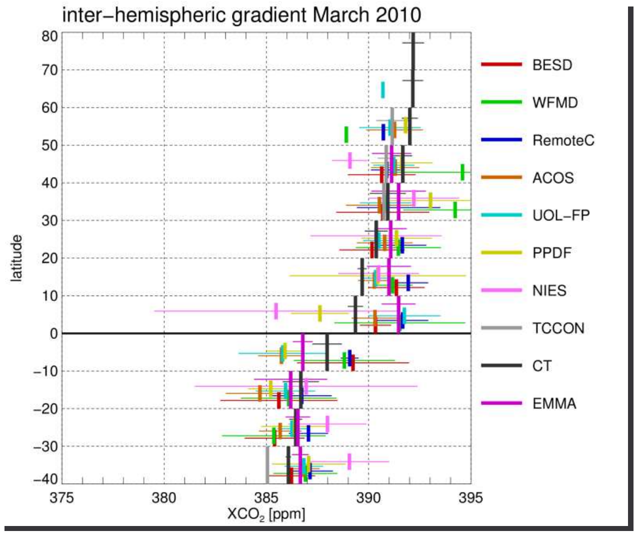
EMMA: No obvious outliers !

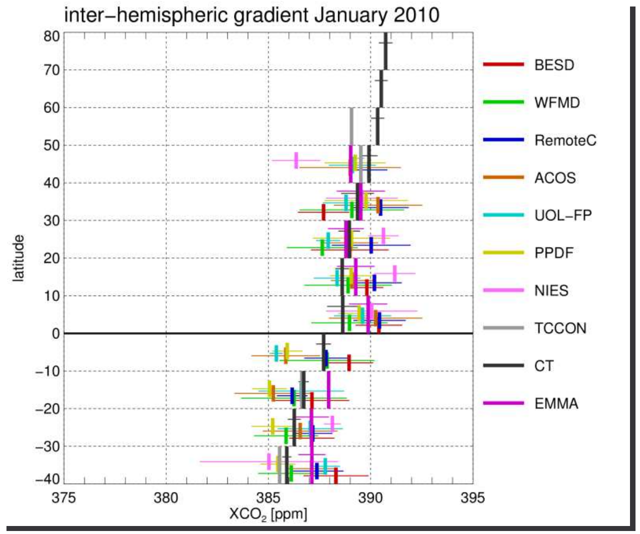
CO_2: Ensemble approach - IX

EMMA vs individual algorithms: Latitudinal averages





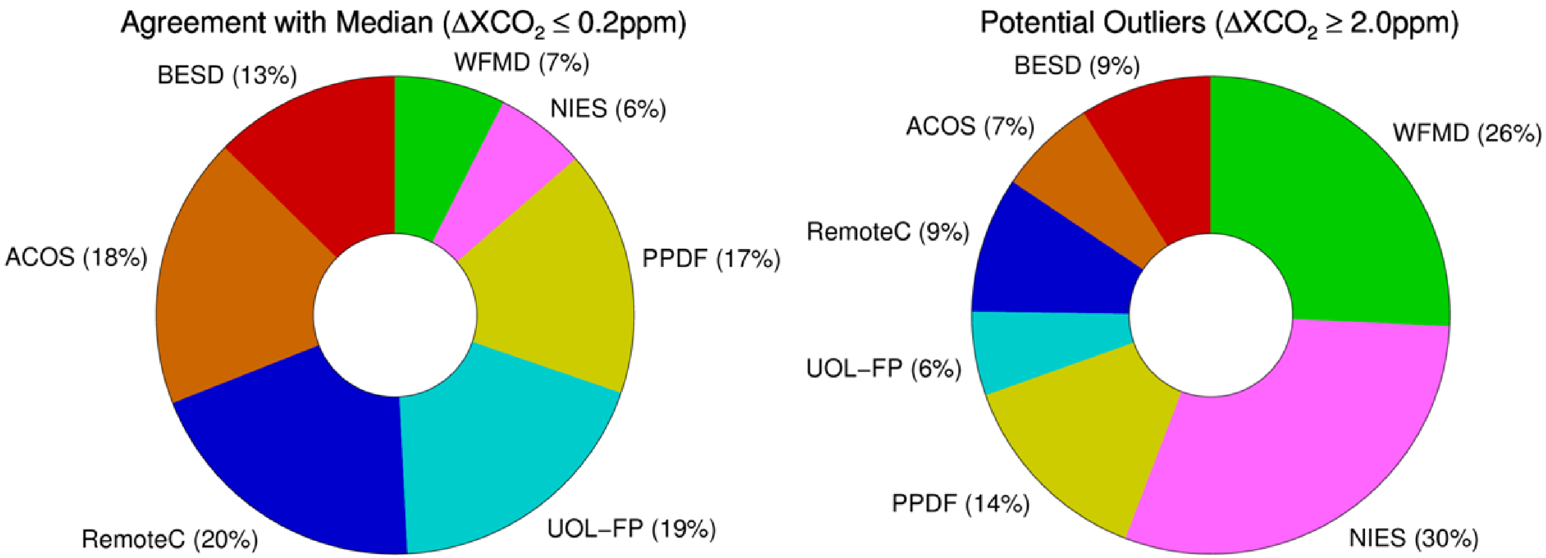




EMMA: No obvious outliers !

CO_2: Ensemble approach - X

EMMA vs individual algorithms: Overall statistics



•SCIAMACHY:

- BESD more often in agreement with EMMA
- WFMD more often outlying from EMMA

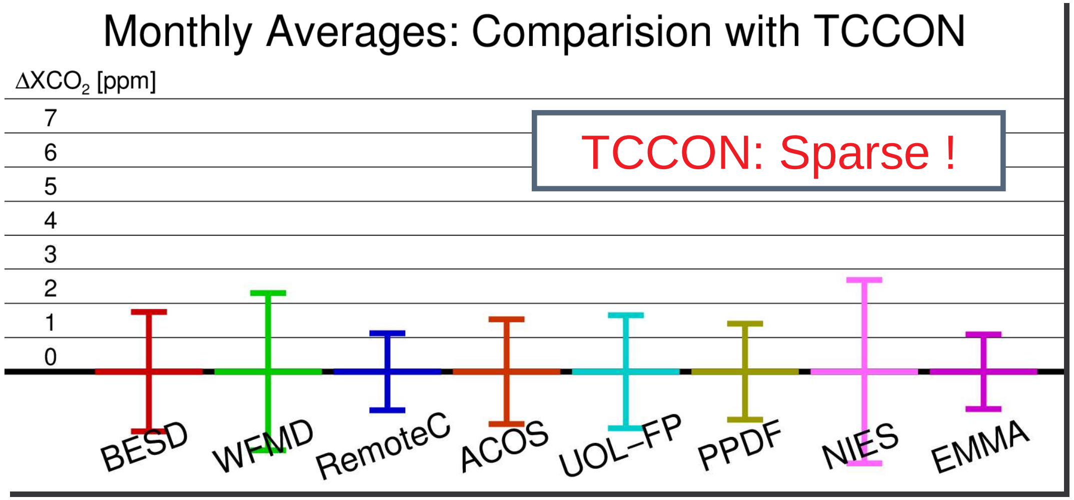
•GOSAT:

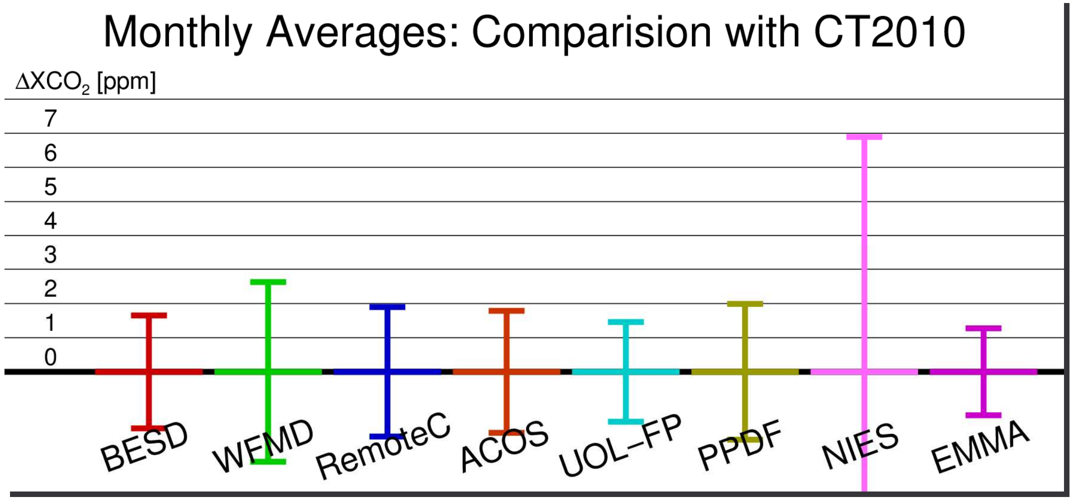
- SPFP/RemoteC vs. OCFP/UOL-FP: similar
- NIES: used version is 01.xx; new version 02.xx much better (will be considered in future updates of EMMA) !

•**Note:** Picture will likely change in the future as all algorithms are under development !

CO_2: Ensemble approach - XI

EMMA vs individual algorithms: Monthly averages



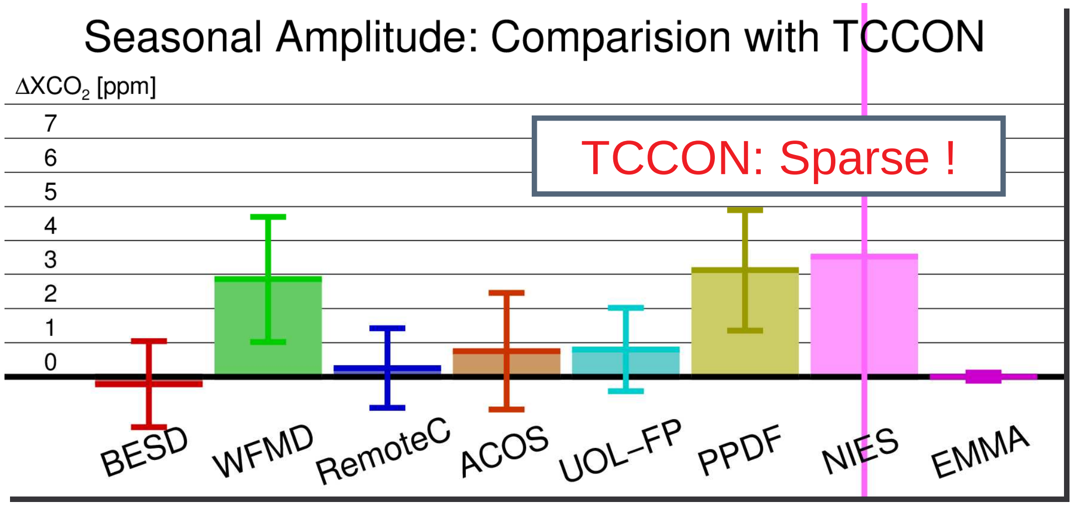


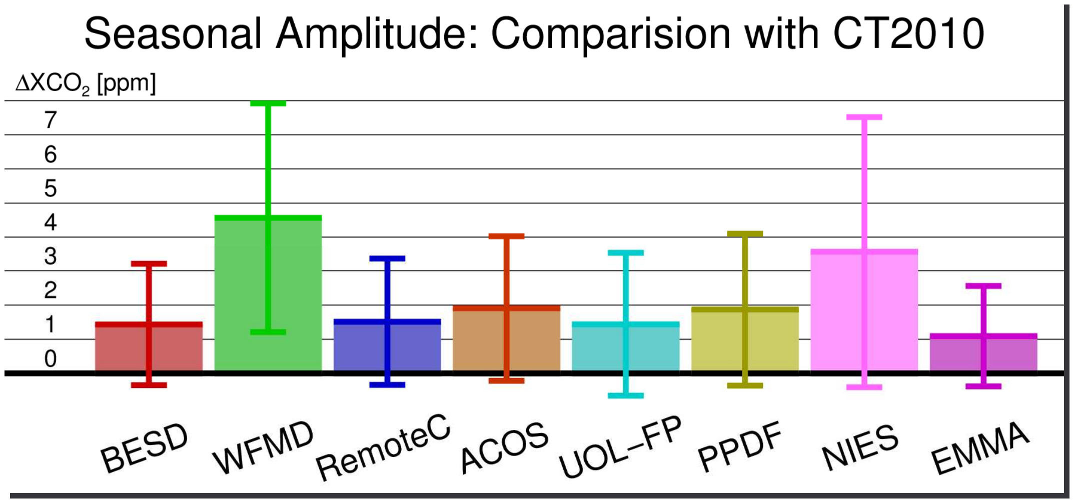
- BESD better agreement than WFMD
- RemoteC and UOL-FP similar
- EMMA best agreement

Note: focus here is relative accuracy (not absolute accuracy); therefore mean bias over all observations subtracted -> **all mean biases are zero here**

CO_2: Ensemble approach - XII

EMMA vs individual algorithms: Seasonal cycle

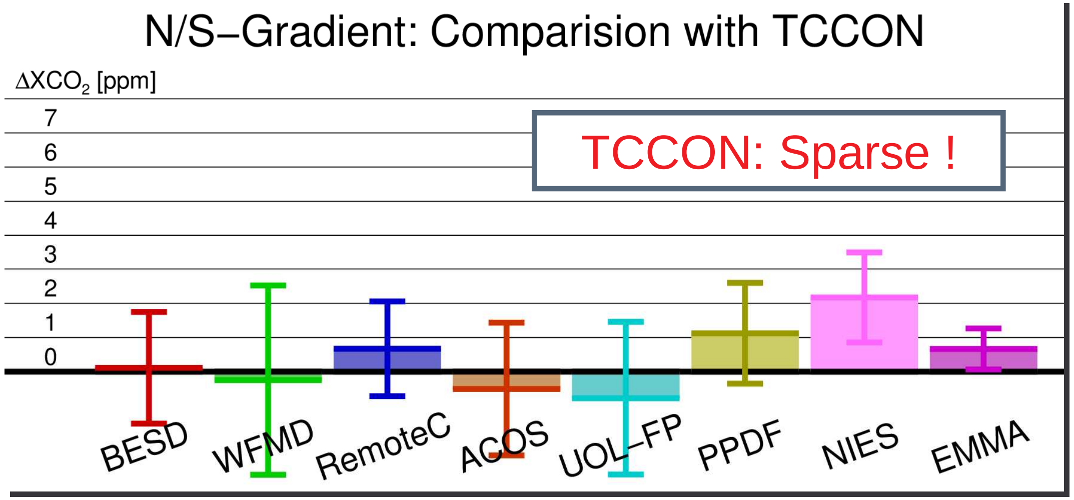


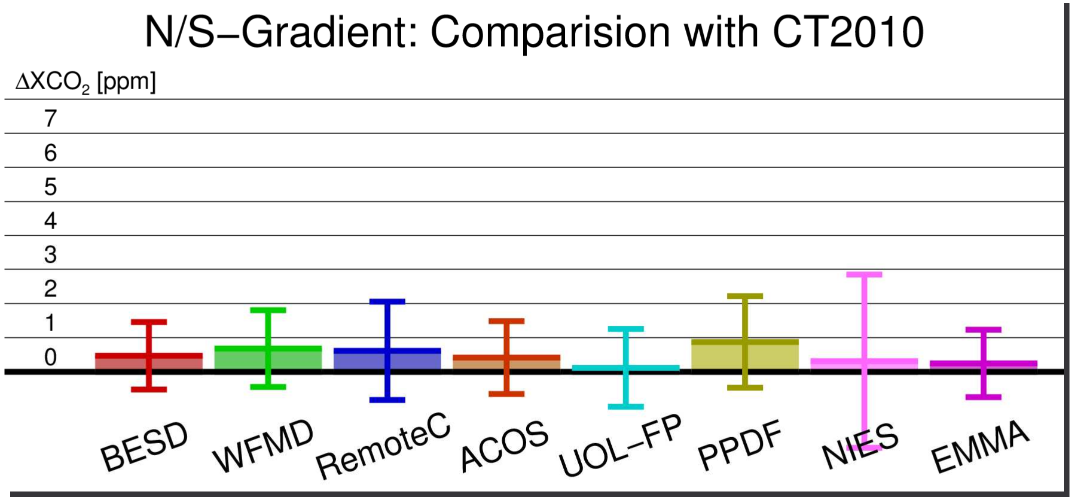


- Sparse TCCON statistics
- BESD better agreement than WFMD
- RemoteC and UOL-FP similar
- EMMA best agreement
- Clear overestimation by WFMD and NIES
- Underestimation by CT2010

CO_2: Ensemble approach - XIII

EMMA vs individual algorithms: North-South Gradient

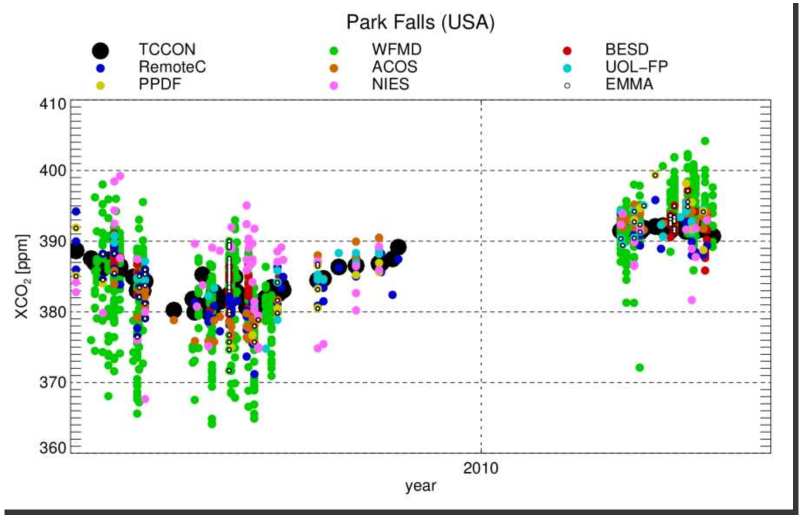


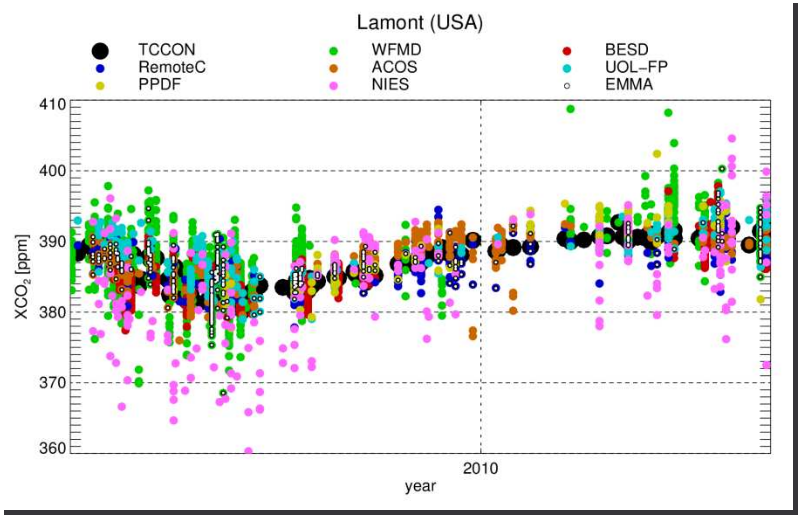


- Sparse TCCON statistics
- BESD and WFMD similar
- RemoteC and UOL-FP similar
- EMMA best agreement

CO_2: Ensemble approach - XIII

EMMA vs individual algorithms @ TCCON sites





Algorithm	Number of Colocations	Single Meas Prec. [ppm]	Regional Biases [ppm]
WFMD	3634	4.62	1.33
BESD	1364	2.21	0.81
RemoteC	611	2.77	1.51
ACOS	816	2.29	1.16
UOL-FP	514	2.15	0.69
PPDF	238	2.93	1.26
NIES	450	5.51	2.35
EMMA	625	2.96	0.78
Required:		**< 3 (B)**	**< 0.5 (T)**

- Statistics not perfectly robust (TCCON = sparse)
- BESD better agreement than WFMD
- OCFP/UoL-FP better agreement than SRFP/RemoteC
- EMMA low regional biases
- EMMA average scatter
- EMMA ToDo: Impact of WFMD ? Use improved NIES ! Use improved BESD, …

Status RR: Summary: CO_2

Summary SCIAMACHY and GOSAT XCO_2:

(from GHG-CCI Progress Meeting 4 (PM4) *))

•**SCIAMACHY**: It has been shown*) that BESD has less scatter (higher precision) and lower biases than WFMD but WFMD has much more data (~ x3); potential uncertainty reduction similar; overall: BESD seems better (but due to L1v7/u issues (biases !) reprocessing needed)

•**GOSAT**: due to the sparseness of the TCCON sites it is not possible to identify which algorithm performs best*)

•It has been shown*) that significant (up to a few ppm) differences exist between the various SCIAMACHY and GOSAT XCO_2 data products (e.g., global maps). Depending on month and region the differences exceed the GHG-CCI relative accuracy requirement (0.5 ppm) and have a spatio-temporal structure that unlikely permits accurate CO_2 surface flux inversions

RR decision *):

•It is therefore necessary to continue with the development & assessment of the GHG-CCI SCIAMACHY and GOSAT XCO_2 algorithms (at least **BESD**, **OCFP**, **SRFP**) until convergence to highly accurate spatio-temporal pattern has been achieved

•At present, the XCO_2 Level 2 data product with the highest quality and most realistic error estimates seems to be the product generated with the EnseMble Median Algorithm (**EMMA**)*). The EMMA product will therefore be added to the GHG-CCI XCO_2 data product portfolio.

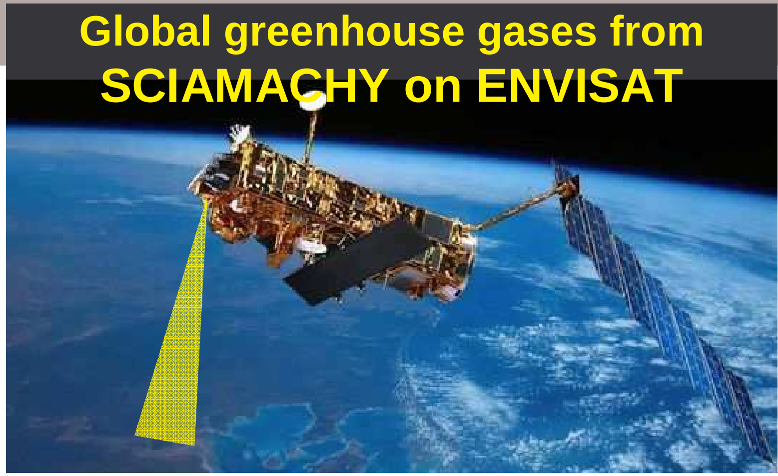
*) GHG-CCI PM4, 3-4 May 2012

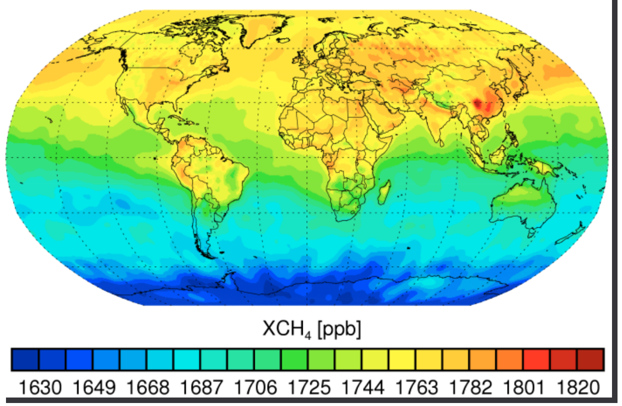
Summary

- GHG-CCI Science Agenda presented
- Some applications have been shown where the GHG-CCI satellite data products are / shall be used to address key carbon cycle science issues
- EMMA: A novel innovative approach to generate a robust satellite-derived XCO_2 data product with very good error characterization
- The better the satellite data quality & the larger the data sets the more science questions can be answered

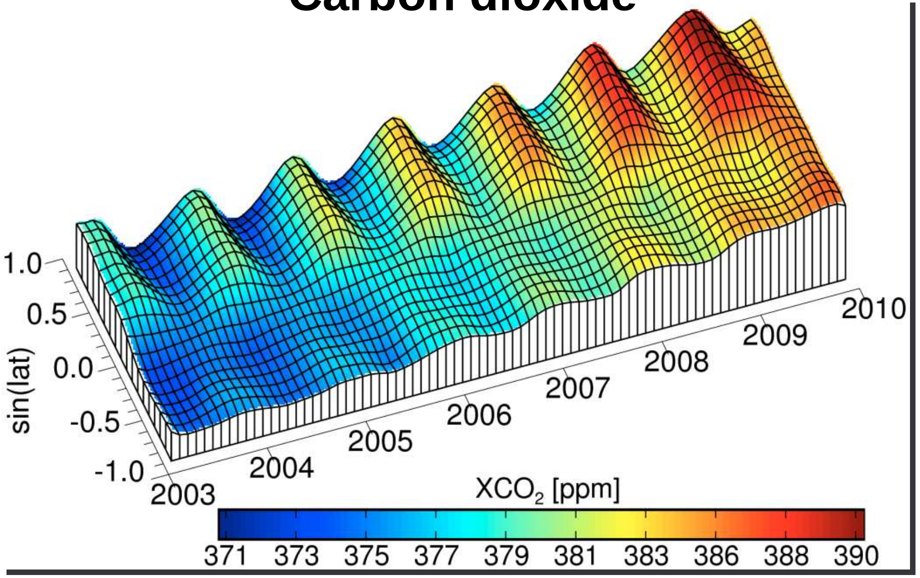
    -> To achieve this is our main goal for GHG-CCI !

Thanks for your attention !

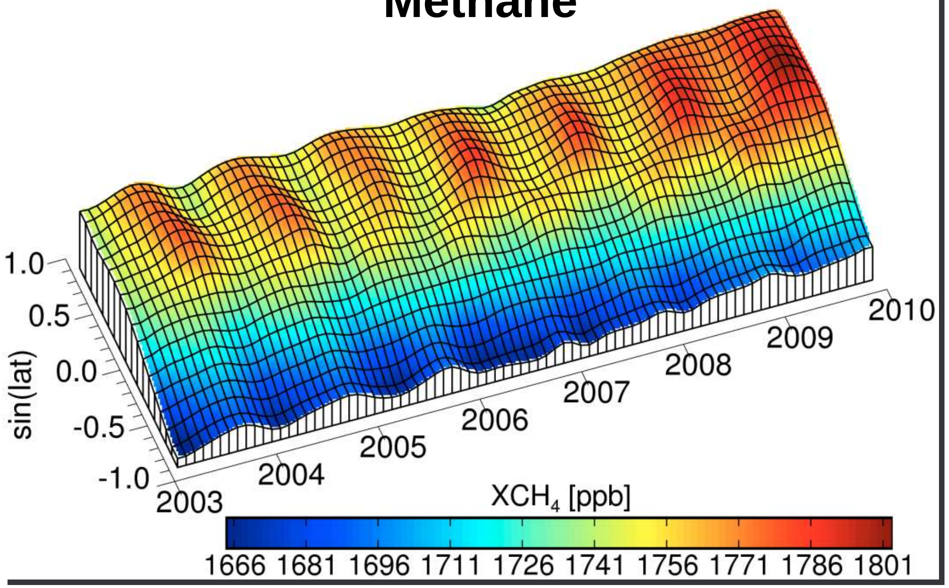




Carbon dioxide



Methane



Algorithm: WFM-DOAS (Schneising et al., 2011, 2012)