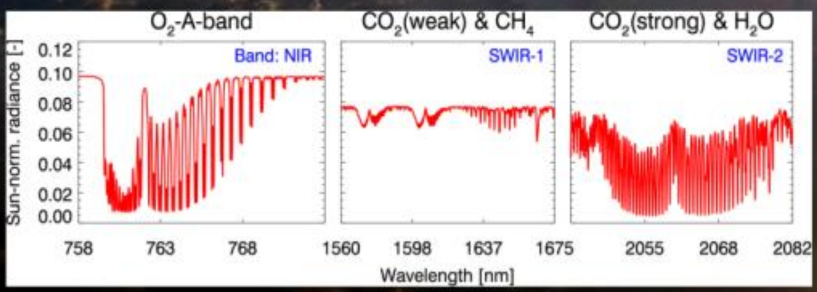
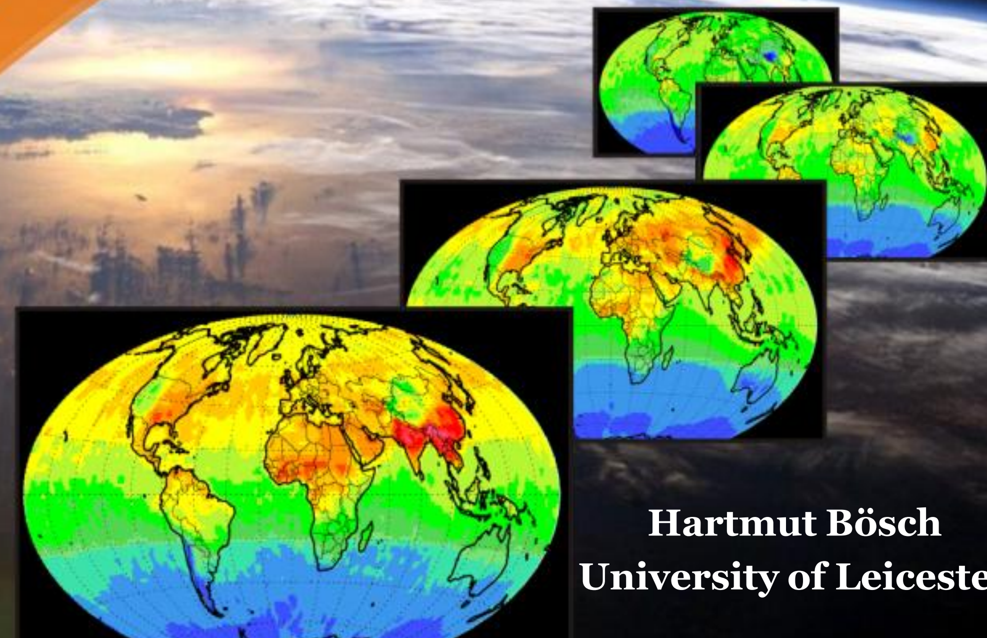
CarbonSat

CarbonSat
Global CO_2 & CH_4 from space

Earth Explorer 8 Candidate





Hartmut Bösch
University of Leicester

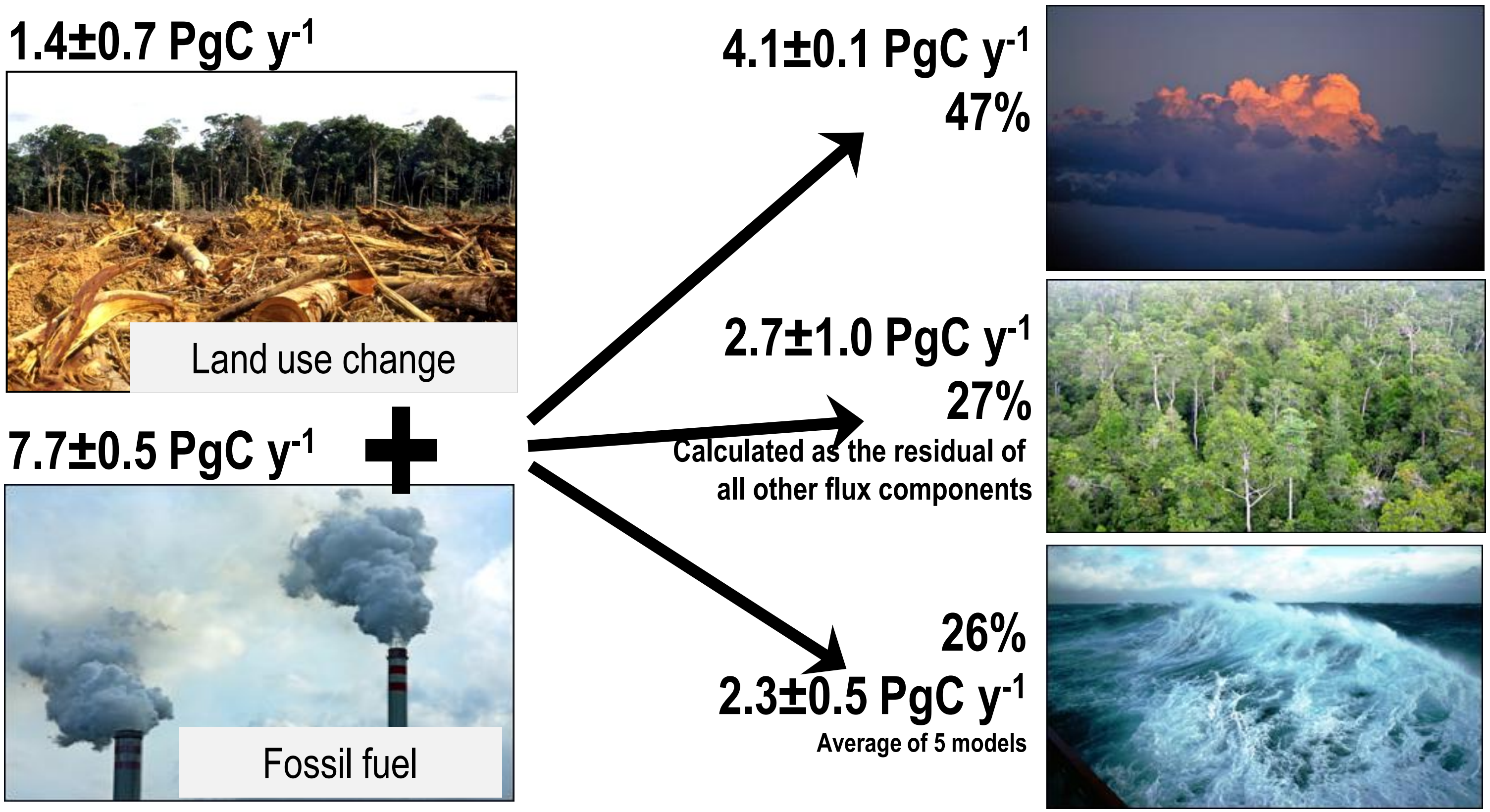
CarbonSat Earth Explorer 8 Mission Advisory Group

- Heinrich Bovensmann, IUP, University of Bremen, Bremen, D (Chair)
- Hartmut Bösch, University of Leicester, UK
- Dominik Brunner, EMPA, Dübendorf, CH
- Philippe Ciais, LSCE, Gif-sur-Yvette, F
- David Crisp, JPL, Pasadena, USA
- Han Dolman, Free University, Amsterdam , NL
- Gary Hayman, Centre for Ecology and Hydrology, Wallingford, UK
- Sander Houweling, SRON, Utrecht, NL
- Günter Lichtenberg, DLR-IMF, Oberpfaffenhofen, D

ESA: Armin Löscher (implementation – system), Paul Ingmann (science) plus Bernd Sierk (optical engineering), Yasjka Meijer (science activities)

Fate of Anthropogenic CO_2 Emissions (2000-2008)

- **CO2 (and CH4) is most important anthropogenic greenhouse gases**
- **Human activates have added > 200 GtC to atmosphere leading to large increase in atmospheric concentrations**



CarbonSat EE8 candidate

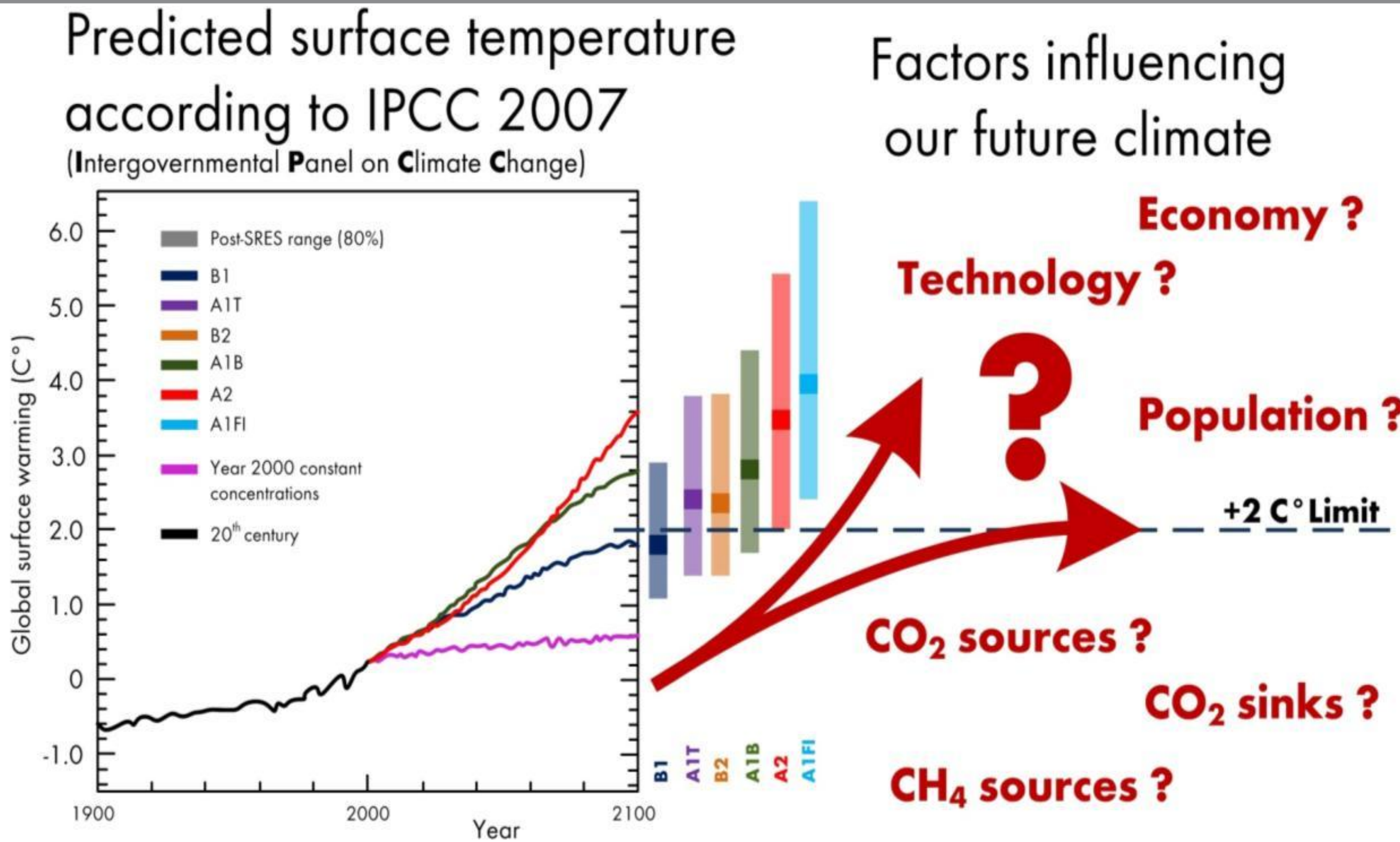
Emissions

„Buffer for Emissions“

European Global Carbon Project

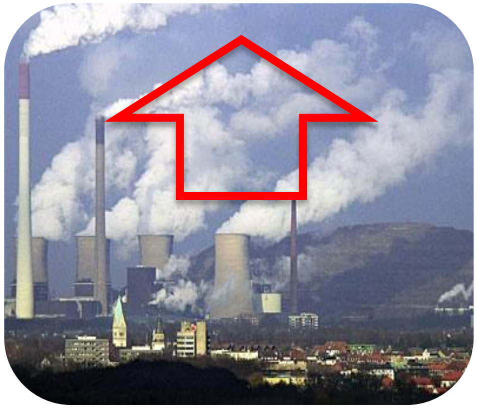
from Le Quéré et al. 2010

Greenhouse Gases are driving Climate Change



Needs to constrain CH_4 and CO_2 fluxes

How much is emitted where, when and by what?



Are the reported Emissions correct?

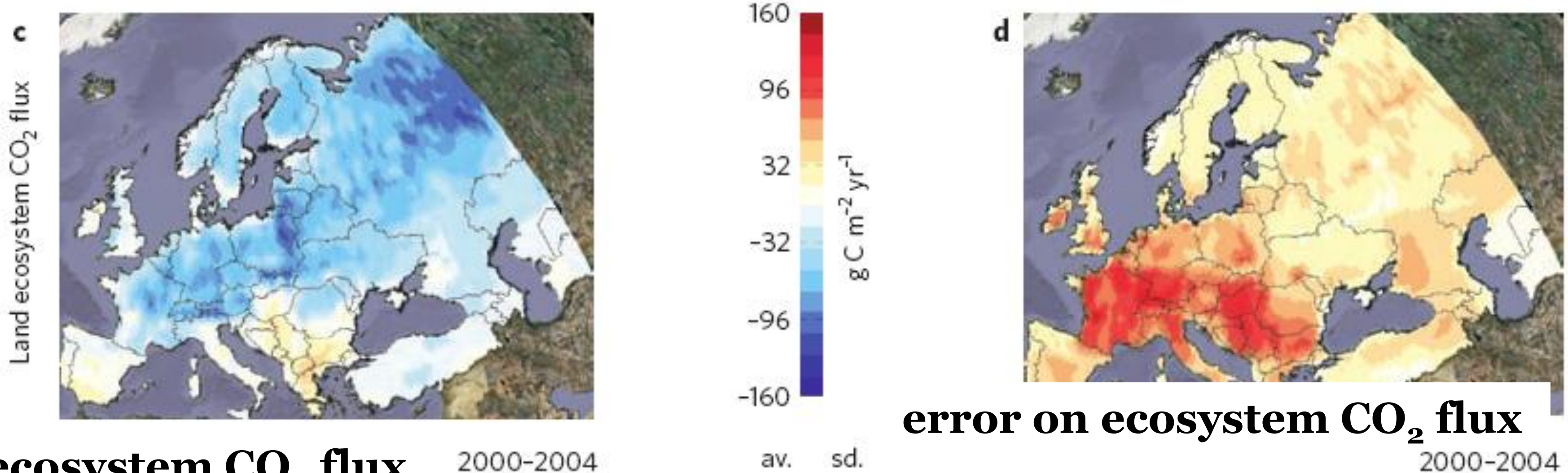
Radiative forcing:
1. CO_2 accounts for ~ 60%
2. CH_4 accounts for ~ 20%

How much CO_2 is absorbed by land and oceans and where? (Sinks)

What is the nature of the CO2 sinks and how will today's CO_2 sinks behave in a changing climate?
Will sinks turn into sources and sources into sinks?

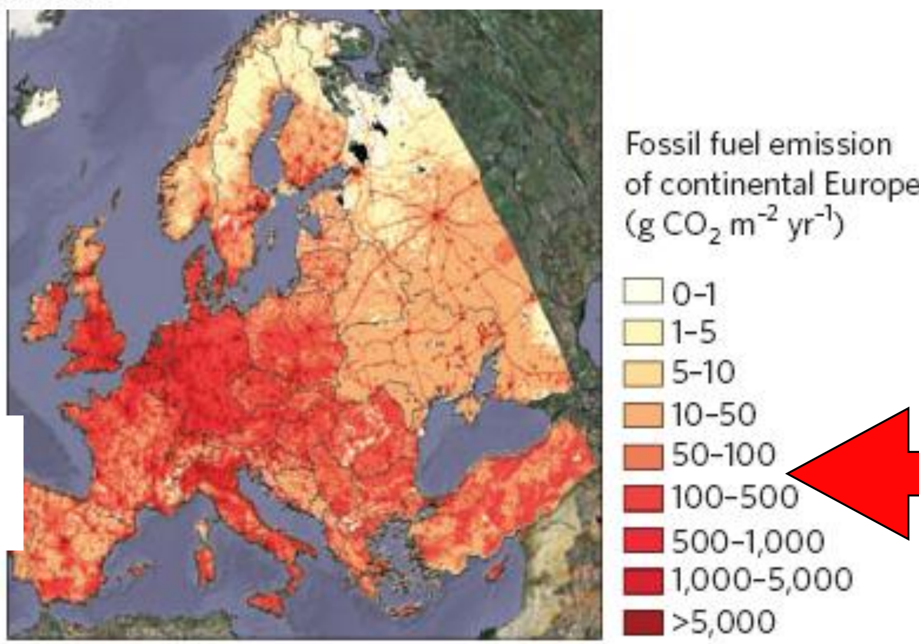
How sources and sinks will behave in a changing climate?

Example: Carbon Balance of Europe



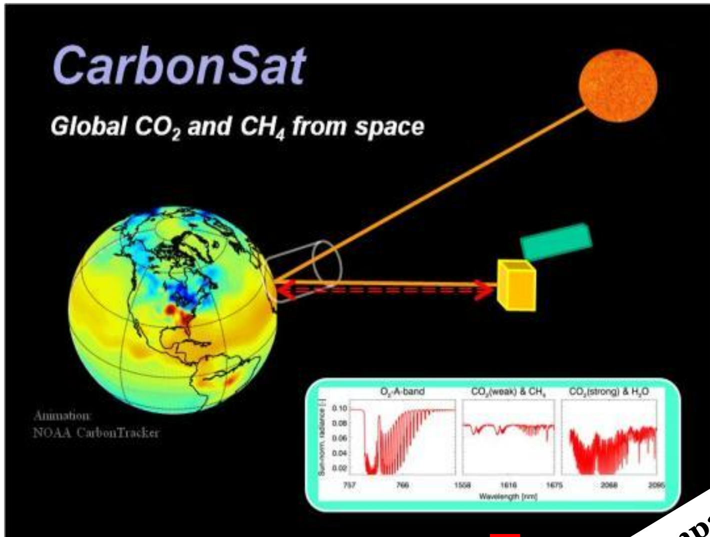
error on ecosystem CO_2 flux

ecosystem CO_2 flux

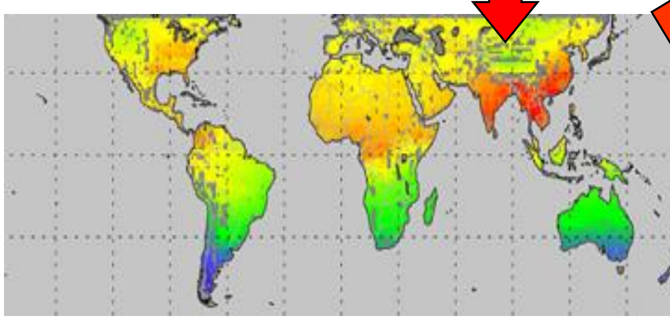


E. D. Schulze, NGEO, 2009

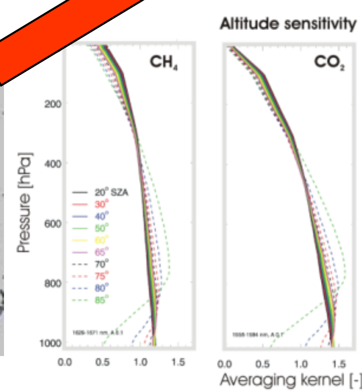
Determine GHG Fluxes by atmospheric measurements



Global distribution of GHG, here CH_4



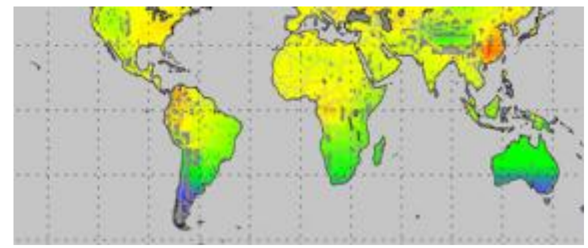
comparison between measurement and model

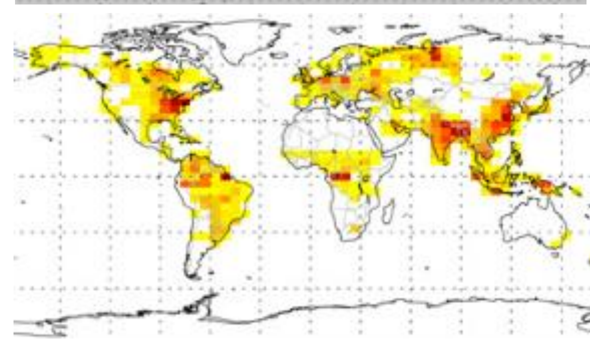


Simulated concentrations using a priori GHG fluxes

Forward simulation

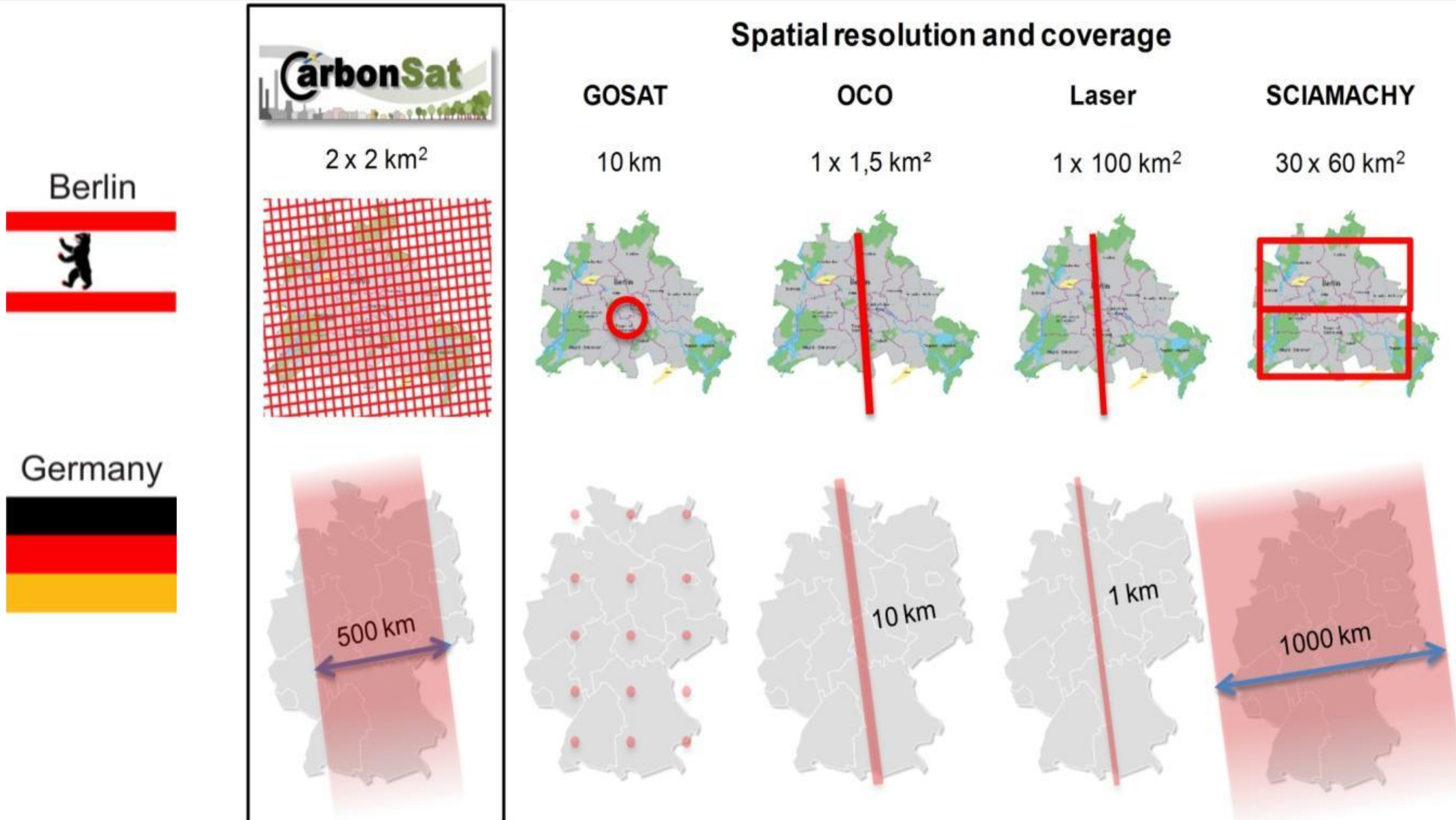
Inverse modelling





Result: True regional GHG fluxes (here CH4) through minimizing the distance between measurement and simulation

CarbonSat Spatial Resolution and Coverage



CarbonSat spatial resolution and coverage enables new important application areas: CO_2 and CH_4 emission from large point sources

Figure: Institute of Environmental Physics, University of Bremen, Germany

Measurement Technique: Solar Absorption Spectroscopy

High-resolution spectra of O2, CO2 and CH4 absorption bands in NIR/SWIR bands

Also used by SCIAMACHY, GOSAT and OCO-2

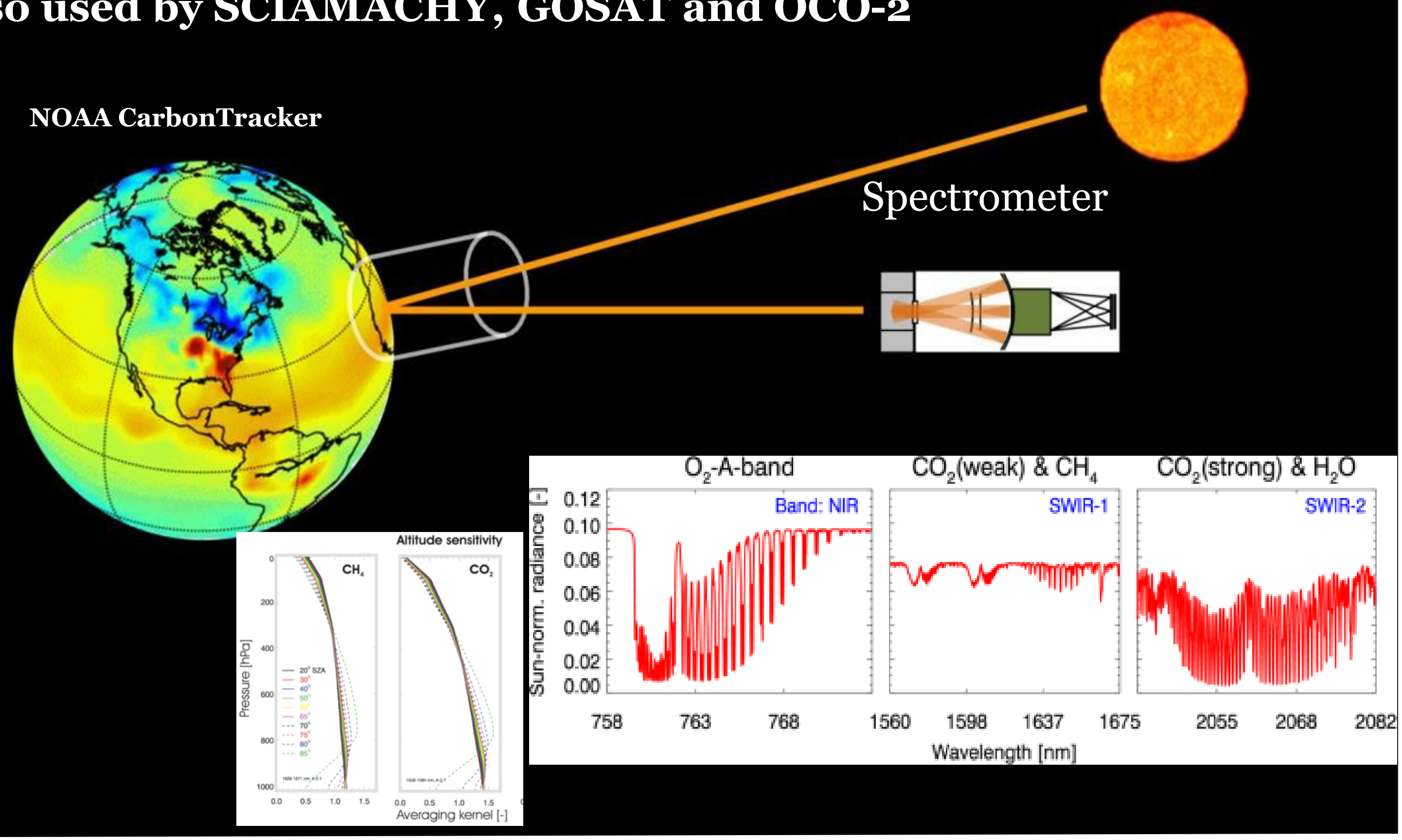


Figure: Institute of Environmental Physics, University of Bremen, Germany

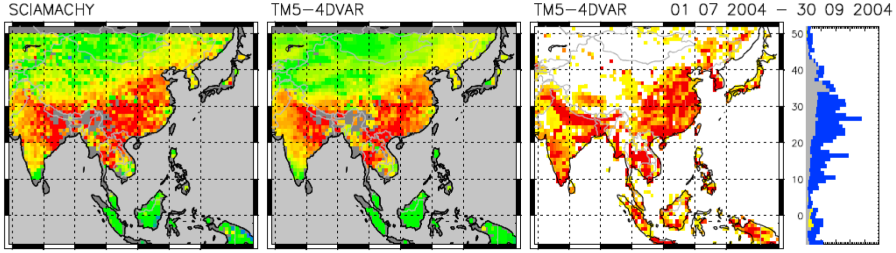
Details: Bovensmann et al. AMT, 2010

SCIAMACHY Methane & methane emissions

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.



Two main application areas:

- Improved emission inventories
  - (for different categories, e.g., wetlands, rice, …)
- Improved process understanding
  - (e.g., land biosphere & related emissions)

➡ **Better climate prediction, …**

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]

Bloom et al., Science, 2010

SCIAMACHY CH_4, groundwater depth, skin T

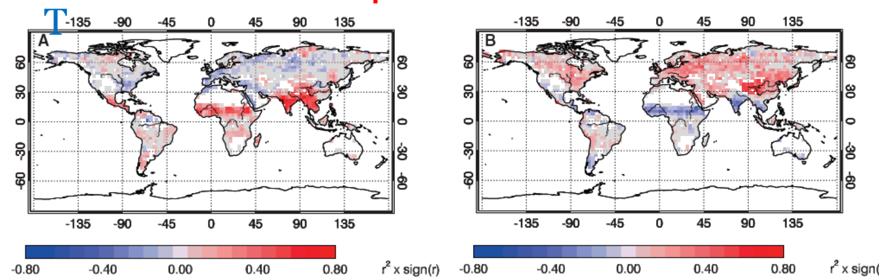
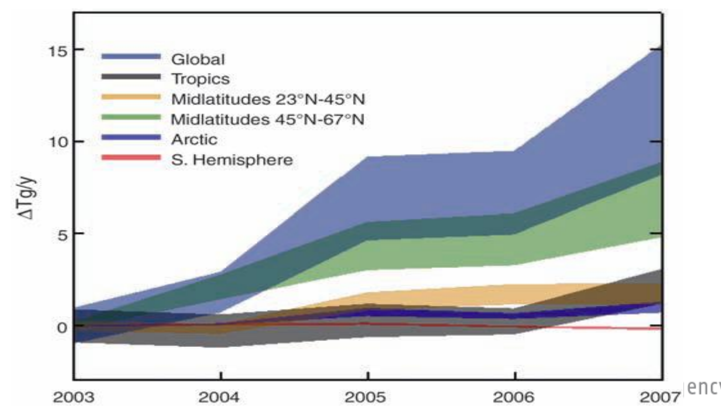
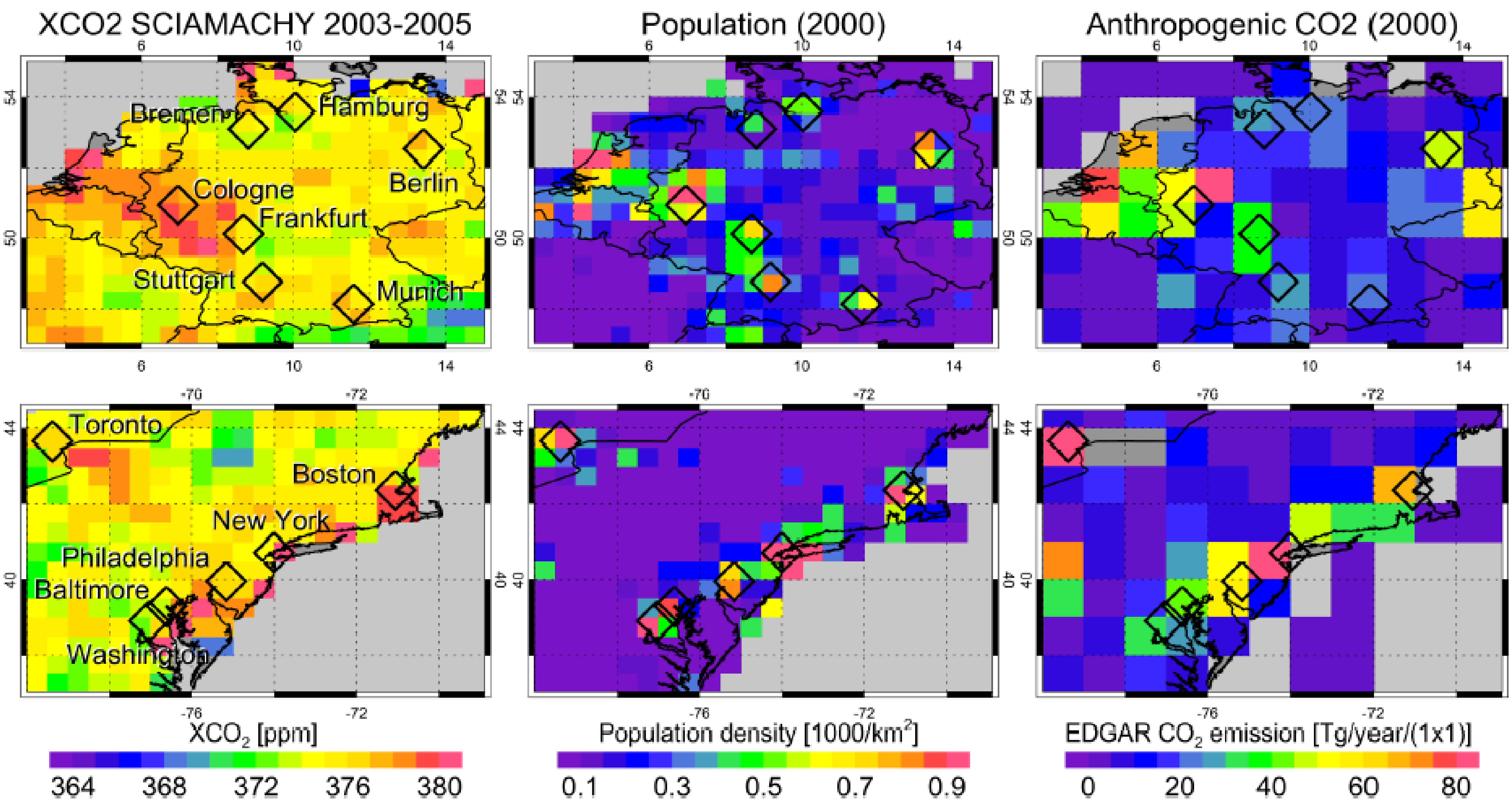


Fig. 1. Correlations (r^2) between cloud-free SCIAMACHY CH_4 column volume mixing ratios (VMRs) (in parts per million) and (**A**) equivalent groundwater depth (in meters), determined from gravity anomaly measurements from the GRACE satellites (18) and (**B**) NCEP/NCAR surface skin temperatures (in 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.



Anthropogenic signatures in SCIAMACHY CO_2

SCIAMACHY XCO_2 | Population | Emissions



CarbonSat EE8 candidate

Schneising et al., ACP, 2008

CarbonSat Mission Requirements Overview

esa

Regional Fluxes

CO_2 : random error monthly fluxes @ 1000 km² in gC/m²/day: < 1 (goal), < 2 (threshold)

CH_4: random error monthly fluxes @ 1000 km² in mgCH_4/m²/day: < 10 (goal), < 20 (threshold)

Local Emission Hot Spots

CO_2: random

CH_4 : random

Level 4

The required r ... ution:

XCO

XCH

The required r

XCO

XCH

Level 3

Column-avera ... und-

pixel resoluti ...

XCO_2: Random Error: < 1 ppm goal (threshold < 3 ppm)

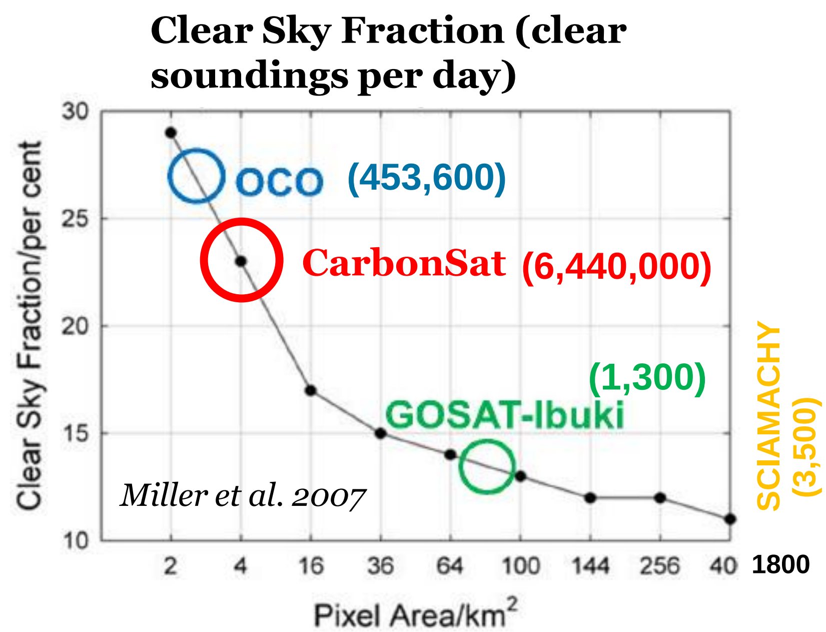
XCH_4: Random Error: < 9 ppb goal (threshold < 17 ppb)

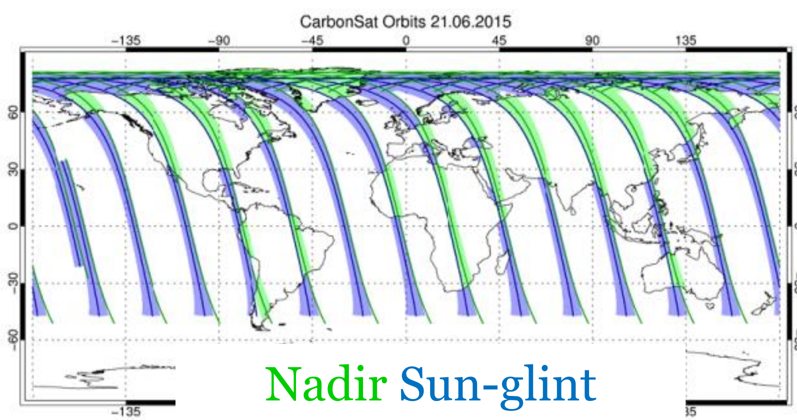
Level 2

Important Note: Requirements may need modifications due to consolidation and revisions during Phase A/B1 studies in 2011-13.

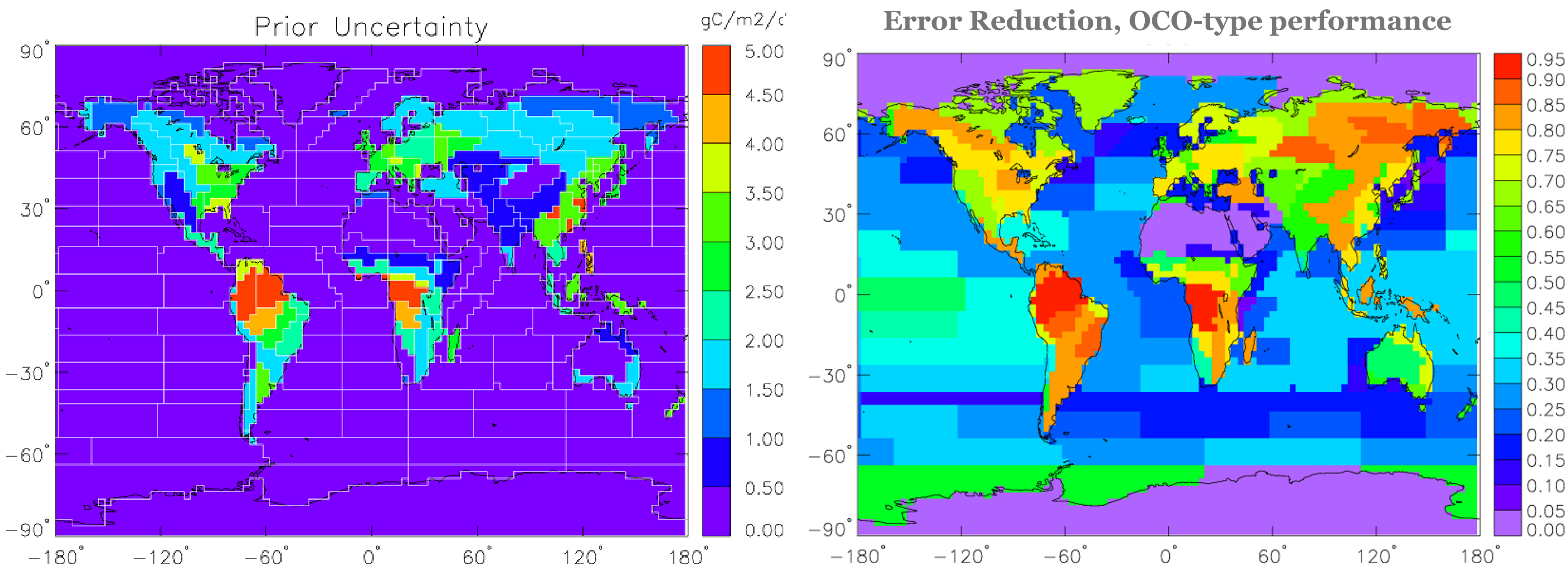
CarbonSat mission requirements survey

- Based on lessons learned from SCIAMACHY, OCO (OCO-2), GOSAT
- Single measurement error
  - XCO2 < 1-3 ppm
  - XCH4: < 9 -17 ppb
- Orbit:
  - LEO polar-sun-sync,
  - Loose formation with Sentinel 3
- **High spatial resolution** and coverage:
  - **2×2 km² ground pixel (T)**
  - **500 km swath width (G)**
- Spectrometer for **O2, CO2 and CH4** absorption bands around **765 nm, 1.6 µm, and 2.0 µm**, **high spectral resolution** **(0.05 – 0.3 nm)**, **high SNR** **(300-600)**
- nadir imaging (main mode), glint mode, cal./val. modes
- 3-5 years mission lifetime





Error Reduction on Weekly Carbon Fluxes – Global View



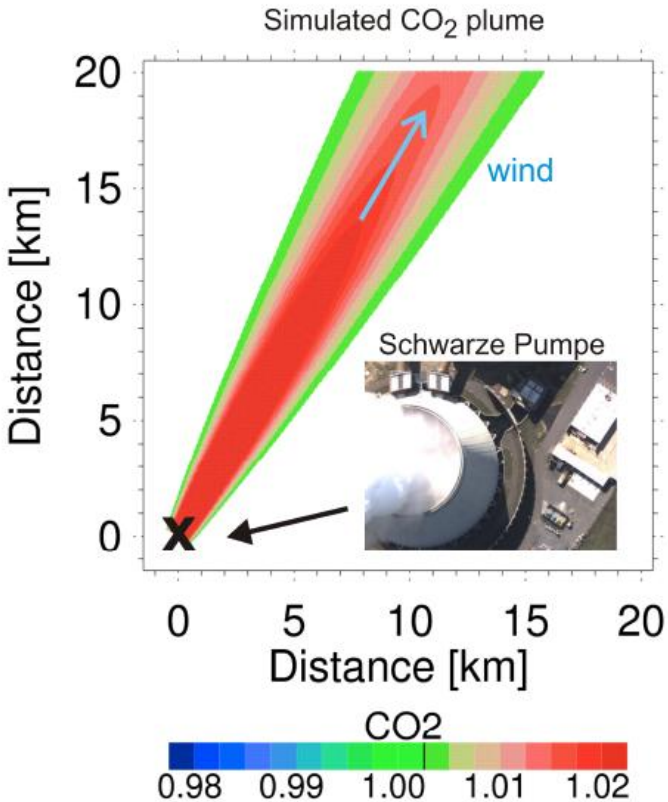
- High values (towards 1) for error reduction indicate that the considered observing system is well suited to improve our knowledge on the CO2 surface fluxes over the considered region.
- CarbonSat error reduction is assumed to be similar or even better then for OCO-type performance

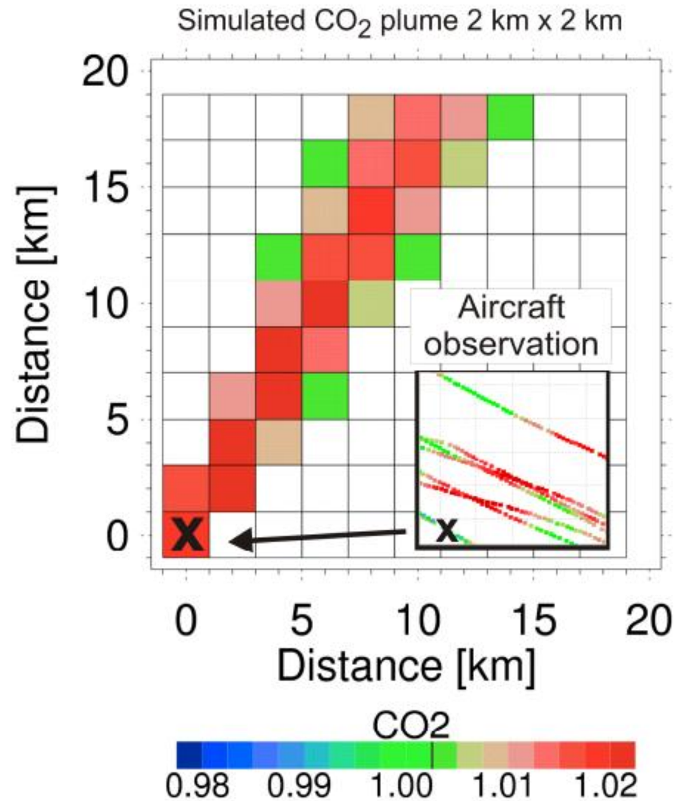
Hungershoefer et al., ACP, 2010

Similar results found by Feng, Palmer, Boesch, Dance, ACP, 2009

CarbonSat: Power Plant CO_2

Simulated CO_2 plume





Emission: **13 MtCO2/year**
(„moderate"; many power plants emit 20-35 MtCO2/year)

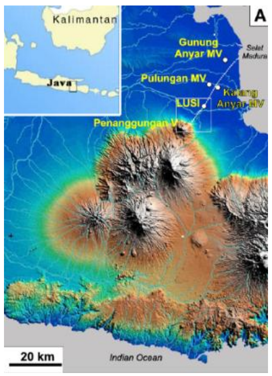
Emission uncertainty single overpass (+/- 2 ppm XCO2 error, u = 1 m/s):
+/- 0.8 MtCO2/year (1-sigma)
Approx. proportional to wind speed u & statistical measurement error

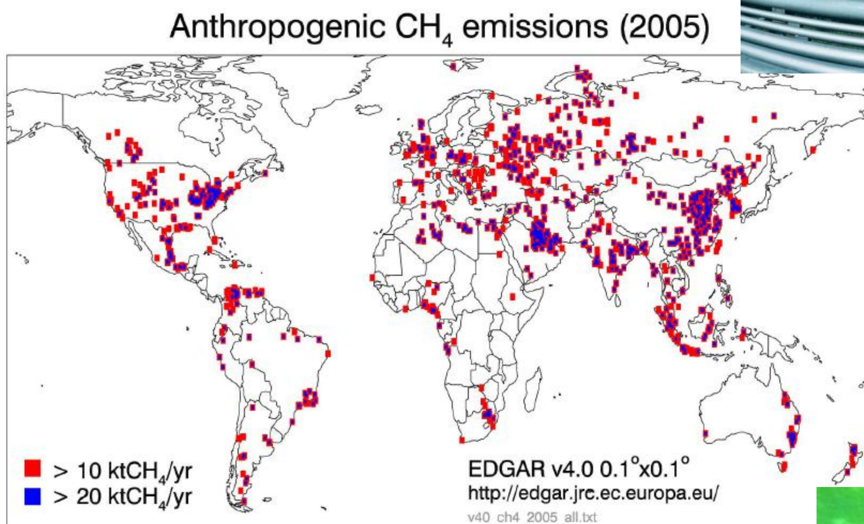
Bovensmann et al., AMT, 2010

Methane Hot Spots

XCH_4 retrieval precision = 9 ppb (0.5%):
Target must produce a detectable methane column enhancement at 2x2 km² resolution:
→ Single overpass detection limit is **4 - 8 ktCH4/year** (u = 2 - 6 m/s, precision 8 ppb)

Mud volcanoes



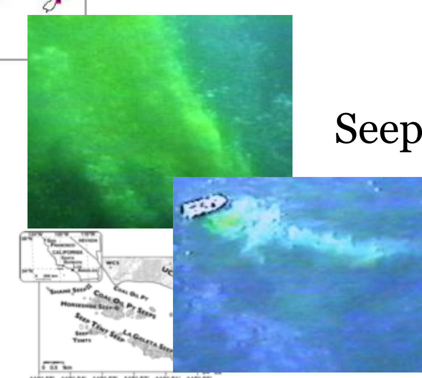


Pipelines incl. compressor stations

Landfills / Waste

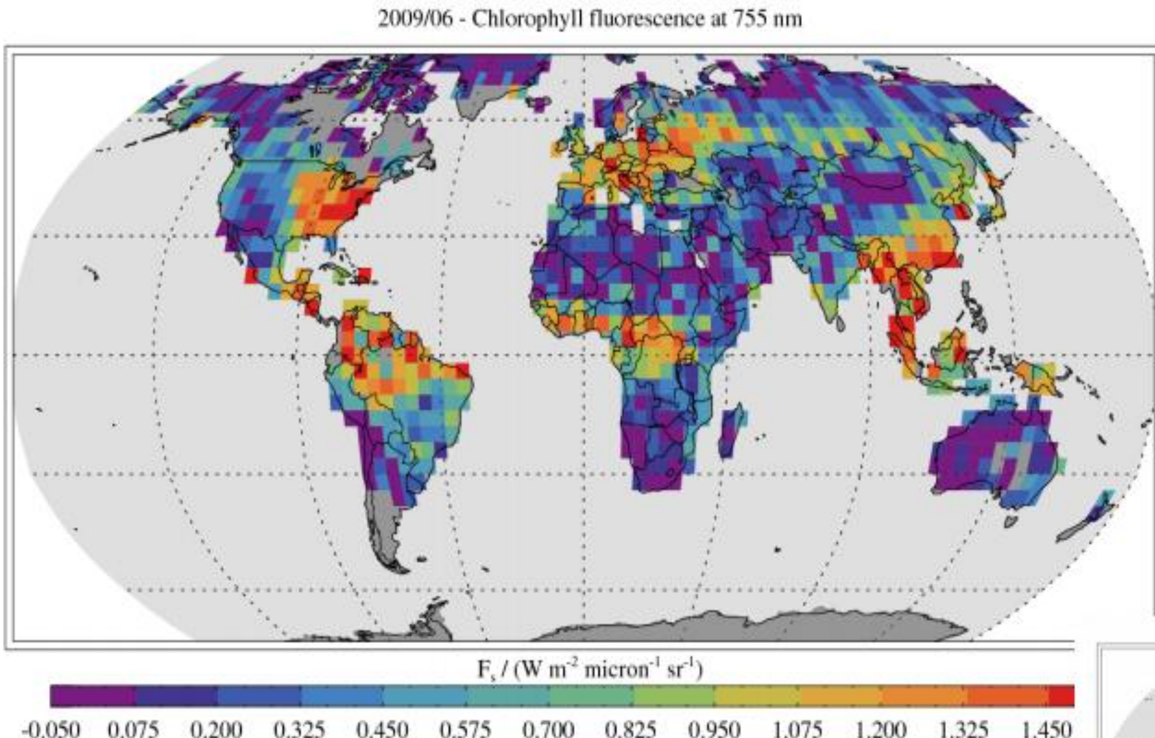
Oil and gas fields

Seeps

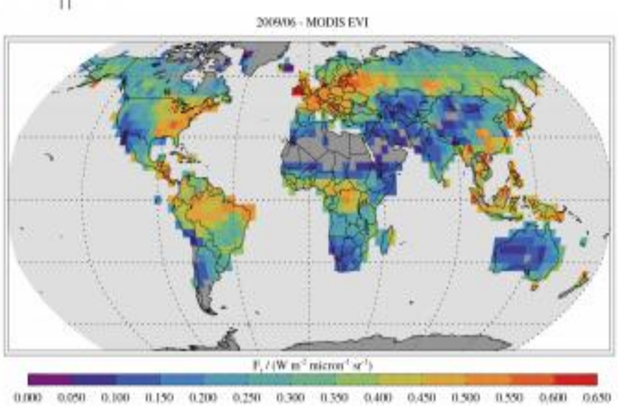


Bovensmann et al. AMT, 2010

CarbonSat Secondary Product: Vegetation Fluorescence from O2 A Band region



Fluorescence can help constraining gross primary production (GPP)



Other potential secondary products:

- **Vertical distribution of aerosol and cirrus**
- **Surface (and cloud top pressure) pressure**

C. Frankenberg et al. GRL, 2011, in press

CarbonSat - Summary

- **CarbonSat aims to better separate biogenic and anthropogenic fluxes by "imaging" regions of strong localised CO_2 and CH_4 emissions.**
- CarbonSat mission concept designed to provide for the first time data on XCO_2 and XCH_4 with local spatial resolution (2 x 2 km2) **AND** good global coverage (goal: 500 km swath)
- In addition and as secondary product CarbonSat will provide data on plant fluorescence, as recently demonstrated (Frankenberg et al. 2011)
- November 2010: CS evaluated and selected by ESA for Phase A/B1 as Earth Explorer #8 (opportunity class)
- Mission & instrument studies, incl. inverse modelling ongoing