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EVALUATING SPACE-BASED CO_2 (AND CH_4) OBSERVATIONS OVER CHINA

Hartmut Boesch, Robert Parker, Jasdeep Anand, Peter Somkuti, Liang Feng, Paul Palmer, Yi Liu, Dongxu Yang, Zhaonan Cai, Jing Wang, Xi Chen, Xiangjung Tian

Monitoring Greenhouse Gases from Space (ID: 32301)

Sub-Project 1: Retrieval algorithm development and CO_2 and CH_4 flux inversion (Lead: H. Boesch & D. Yang)

Sub-Project 2: Validation and uncertainties with focus in China and high latitudes (Lead: J. Tamminen & Y. Liu)

Project Team

- H. Boesch, R. Parker, J. Anand, P. Somkuti
  University of Leicester, UK
- L. Feng, P. Palmer
  University of Edinburgh, UK
- J. Tamminen, E. Kyrola, H. Lindquist, J. Rigel, I. Iolanda
  Finnish Meteorological Institute, Helsinki, Finland
- Y. Liu, D. Yang, X. Tian, Z. Cai, J. Wang , X. Chen, M. Duan, P. Wang, L. Yao
  Institute of Atmospheric Physics, CAS, Beijing, China

The State of the Global Carbon Budget

34.1 $GtCO_2/yr$

91%

9%

3.5 $GtCO_2/yr$

Sources = Sinks

16.4 $GtCO_2/yr$

44%

31%

11.6 $GtCO_2/yr$

26%

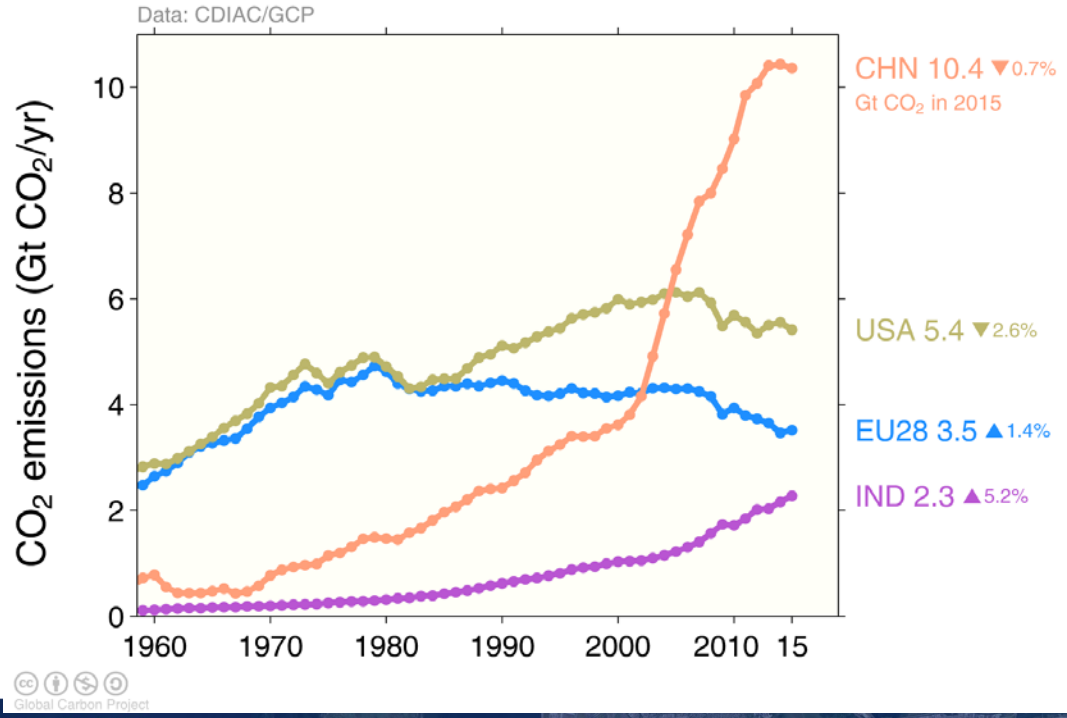
9.7 $GtCO_2/yr$

Calculated as the residual of all other flux components

Source: CDIAC; NOAA-ESRL; Houghton et al 2012; Giglio et al 2013; Le Quéré et al 2016; Global Carbon Budget 2016

Top emitters: fossil fuels and industry

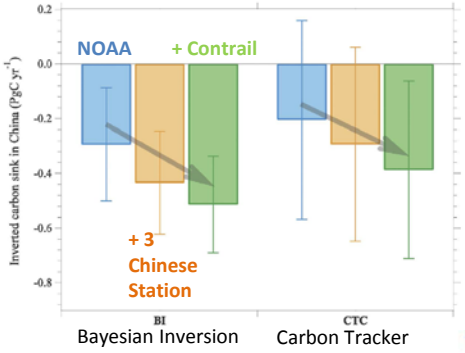
- The top four emitters in 2015 covered 59% of global emissions
- **China (29%),** United States (15%), EU28 (10%), India (6%)



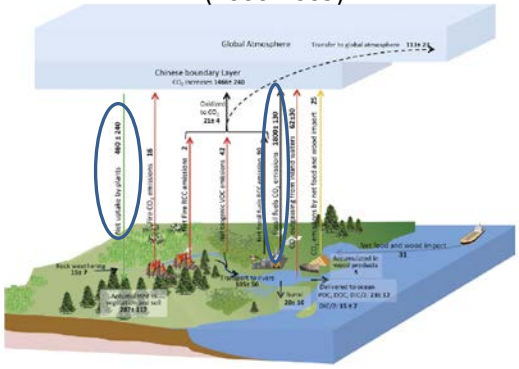
Source: CDIAC; Le Quéré et al 2016; Global Carbon Budget 2016

(Natural) Carbon Budget of China

- Our knowledge about the regional carbon fluxes for China is hampered by lack of data by in-situ networks
- Additional CO_2 monitoring stations in China lead to much improved flux estimates
- Larger biosphere uptake (sink) and better agreement between bottom-up and top-down fluxes but uncertainties remain large



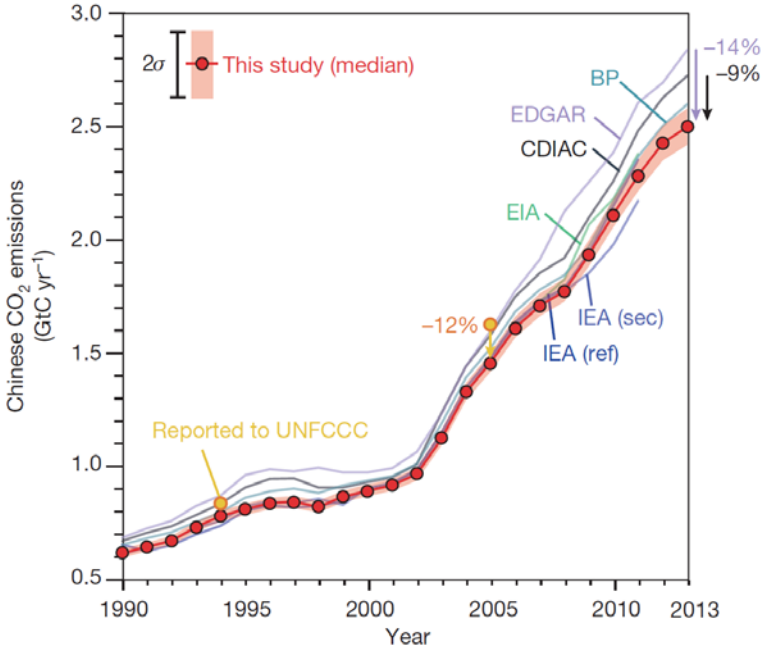
Carbon Budget of China
(2006-2009)



Jiang et al., Scient. Rep. Nature, 2016

China's Carbon Emissions

- China is not largest emitter of carbon with most of the growth of emission in recent years
- Bottom-up emission estimate from China are subject to large uncertainties
- Updates to energy consumption and emission factors leads to lower estimates by 14%
- This overestimate is of same order of magnitude as whole land sink of China

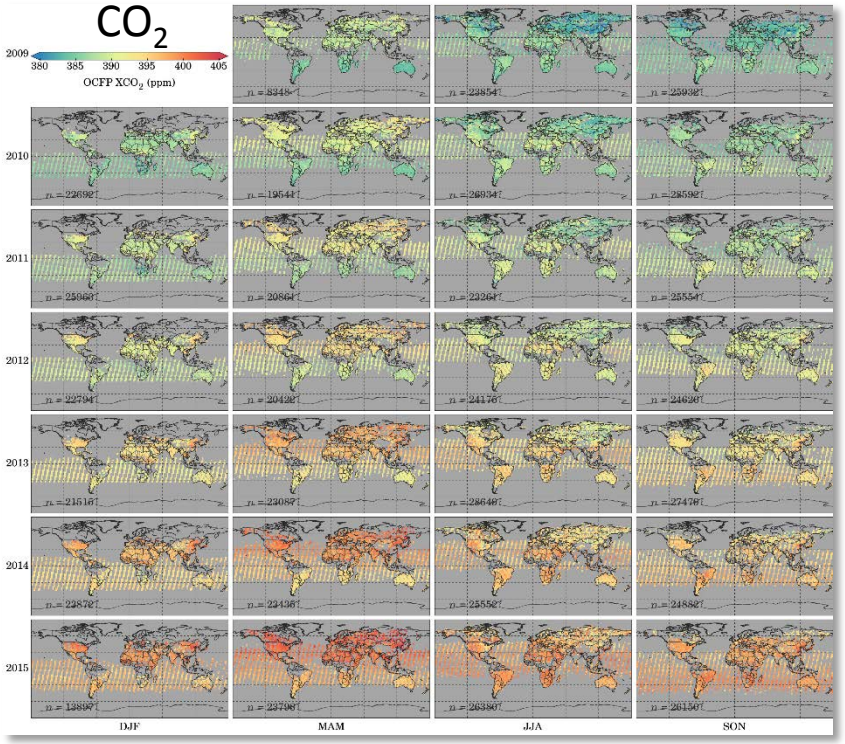


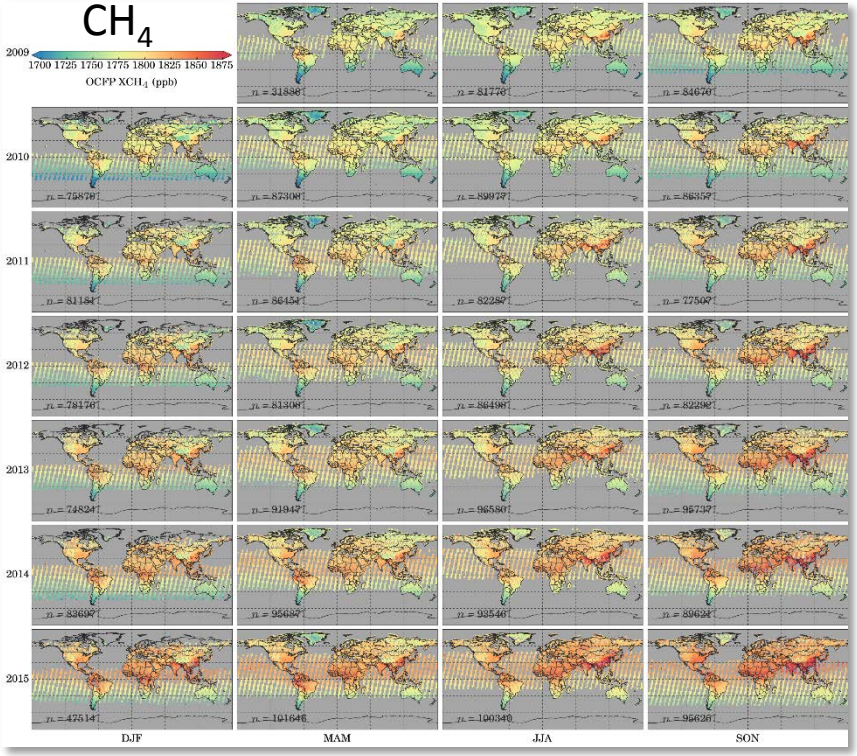
Liu et al., Nature, 2015

The Role of Satellites

- Satellite observations of CO_2 are needed to provide data with sufficient coverage, accuracy and resolution to
  - better constrain the natural carbon sinks and their response to climate
  - help to verify top-down carbon emission from fossil fuel consumption and to provide tools to test the effectiveness of climate policy
- We now have 3 dedicated CO_2 satellites in orbit with sampling strategies aimed at natural, regional carbon fluxes
  - JAXA GOSAT (since 2009)
  - NASA OCO-2 (since 2014)
  - CAS/MOST TanSat (since 2016)
- Exciting results are now coming out of these missions, but still a strong focus on retrieval algorithm improvements, validation and data assimilation methods

6 Years of Global Observations from GOSAT

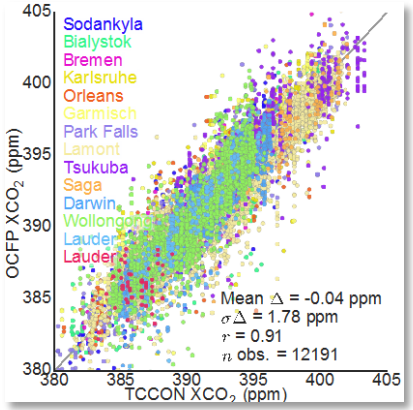


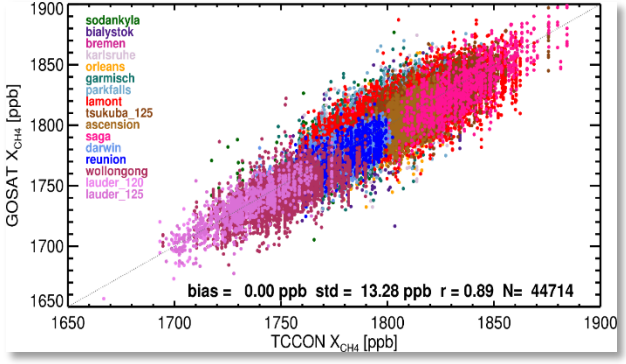


http://www.esa-ghg-cci.org

Validation of GOSAT CO_2 & CH_4

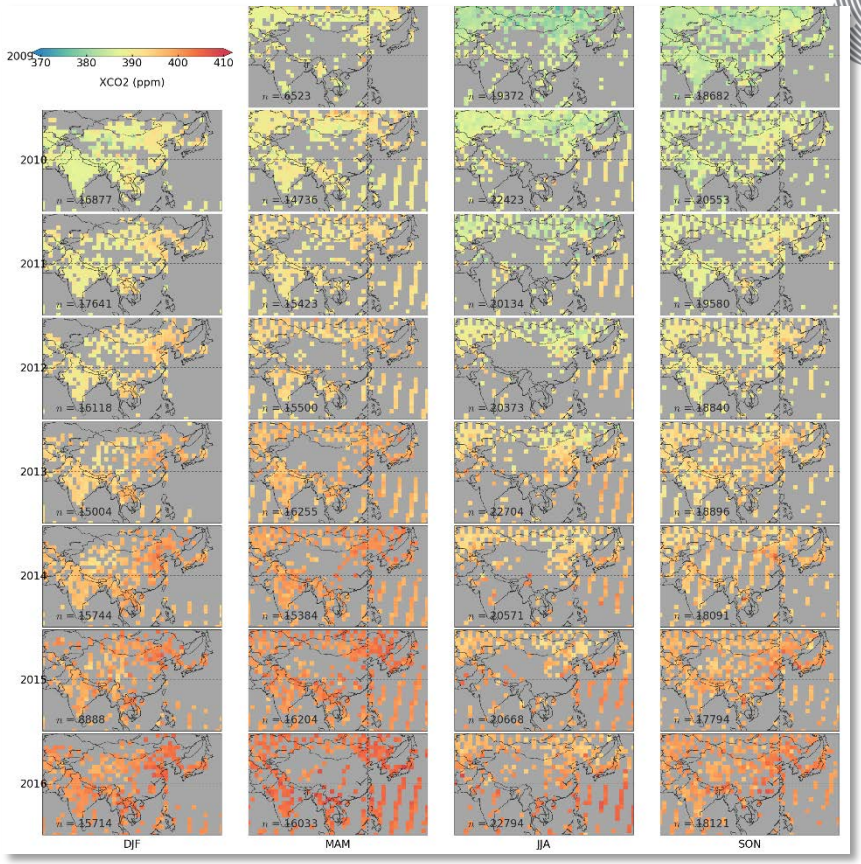
- TCCON (Total Carbon Column Observing Network) is key validation network for GHG satellites
- TCCON comparisons demonstrates the good quality of GOSAT data but no data over China
- TanSat project will help to fill the validation gaps
- Validation is one focus of this project (Sub-project 2)





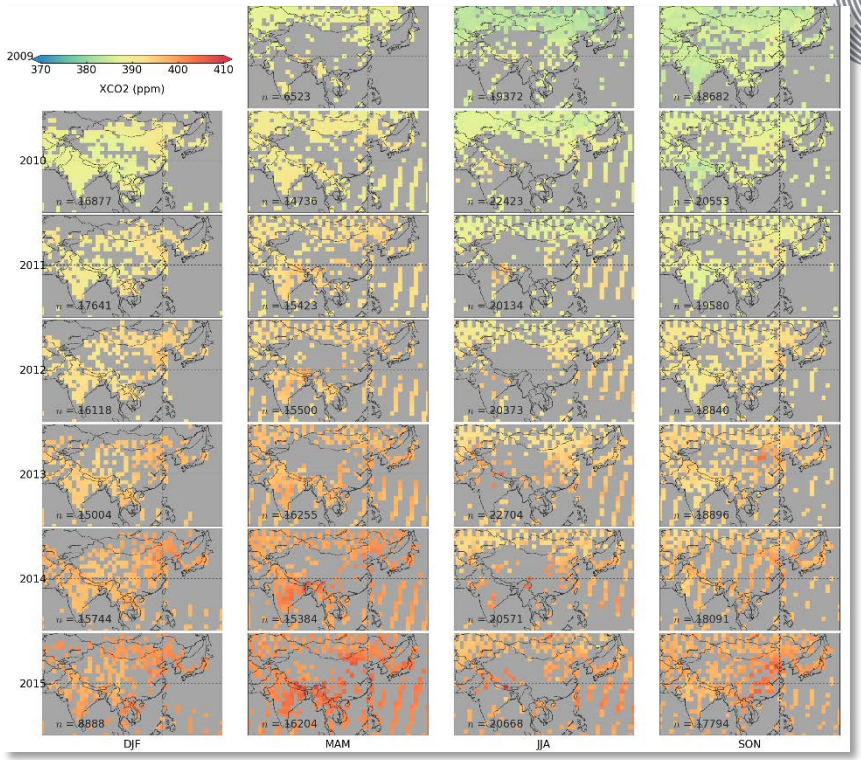
GOSAT CO_2 over China

- GOSAT provides observations of seasonal distribution of CO_2 over China
- Data gaps due to clouds, high aerosol loads and difficult terrain



MACC/CAMS CO_2 over China

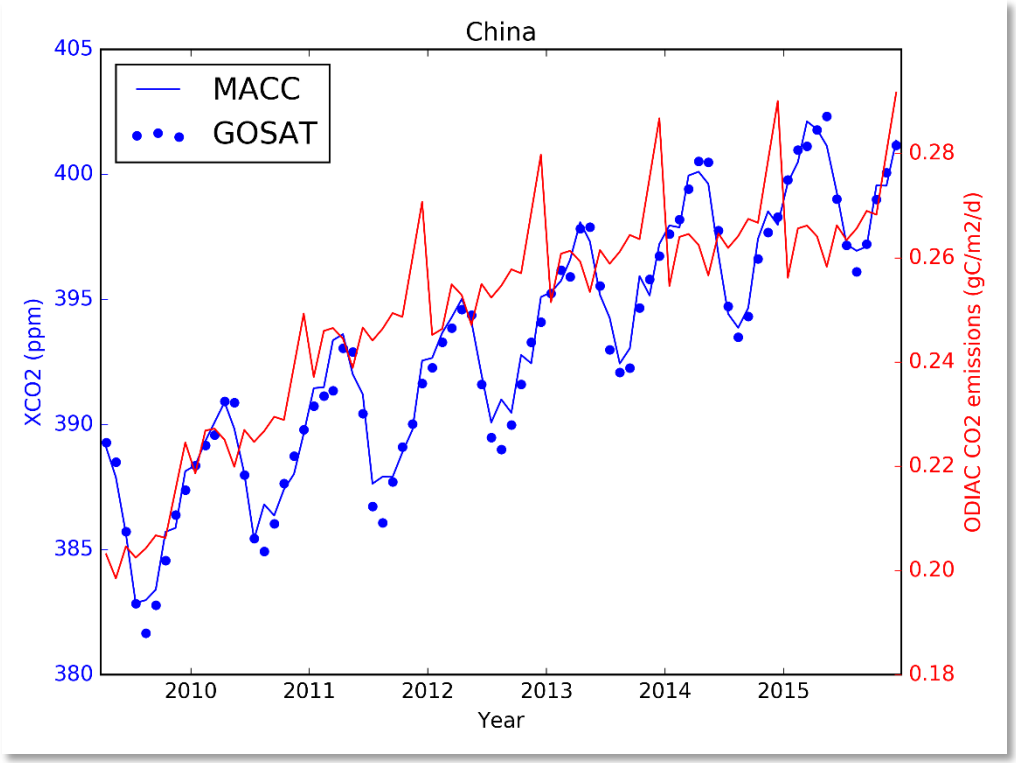
- Copernicus Atmosphere Monitoring Service CAMS model constrained with in-situ stations
- Overall, good agreement with GOSAT



Atmosphere Monitoring Service

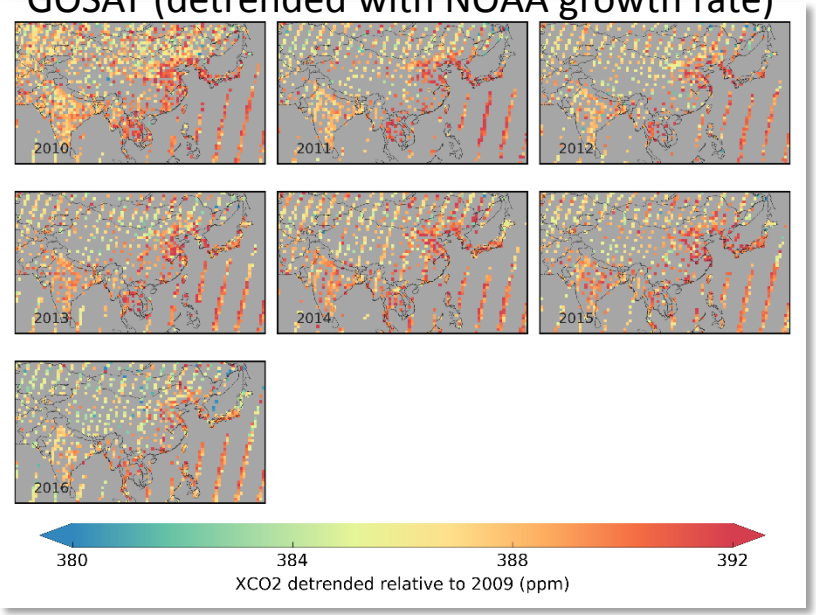
GOSAT – CAMS Comparison

- Good agreement between GOSAT and CAMS Model with GOSAT showing a larger seasonal cycle (stronger uptake)
- Clearly visible is also the strong increase in CO_2 from global emission

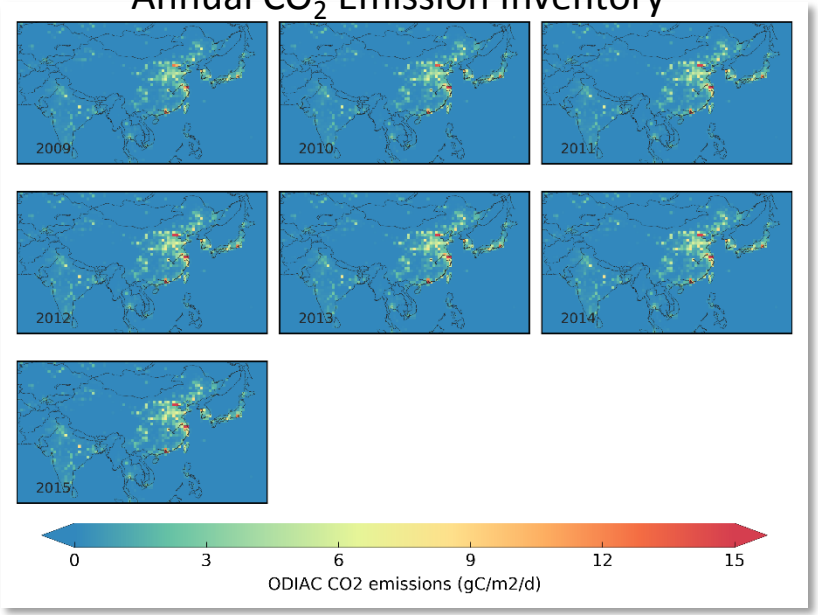


Annual CO_2 Maps to Visualise Emissions

GOSAT (detrended with NOAA growth rate)



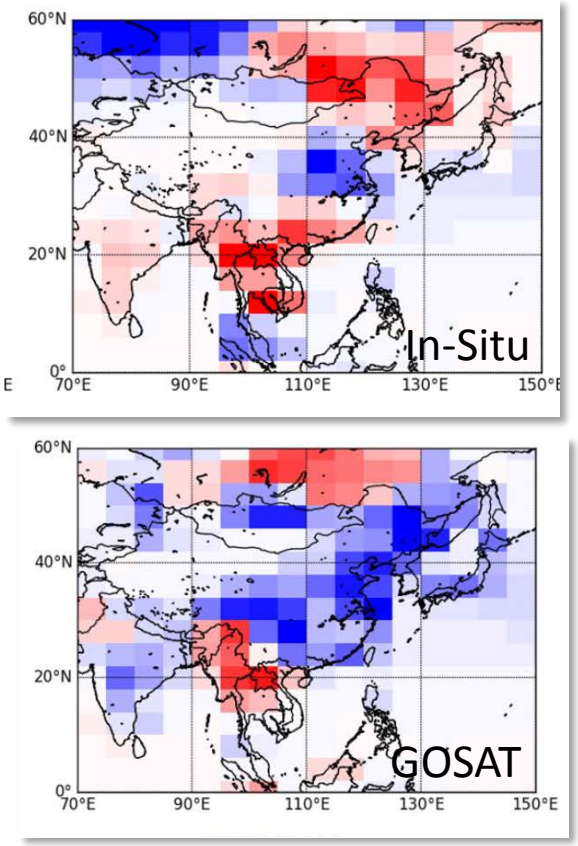
Annual CO_2 Emission Inventory



See also poster by J. Hakkarainen observations of emissions from OCO

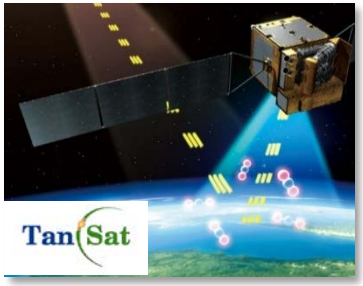
Using GOSAT to Infer CO_2 Fluxes

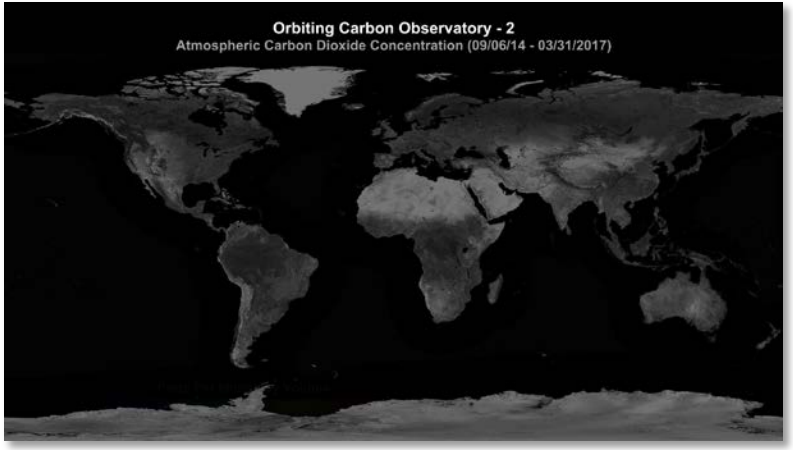
- Estimation of CO_2 surface fluxes with Ensemble Kalman filter in conjunction with GEOS-Chem atmospheric transported model
- GOSAT shows much stronger uptake in Eastern China in 2015 (El Nino year)
- See Poster by J. Wang et al.



OCO-2 and TanSat

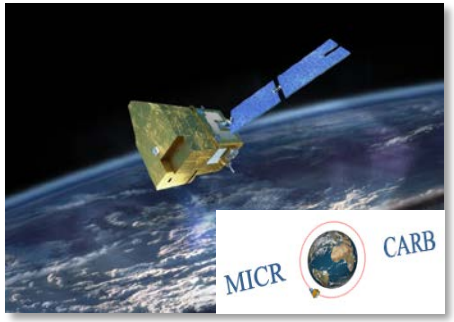
- OCO-2 and TanSat provide increased data volume (x100) and much denser coverage than GOSAT
- They provide data that will allow more reliable flux estimates on regional scale and they give us first glimpse on emission hotspots
- But, OCO-2 and Tansat are not mapping missions



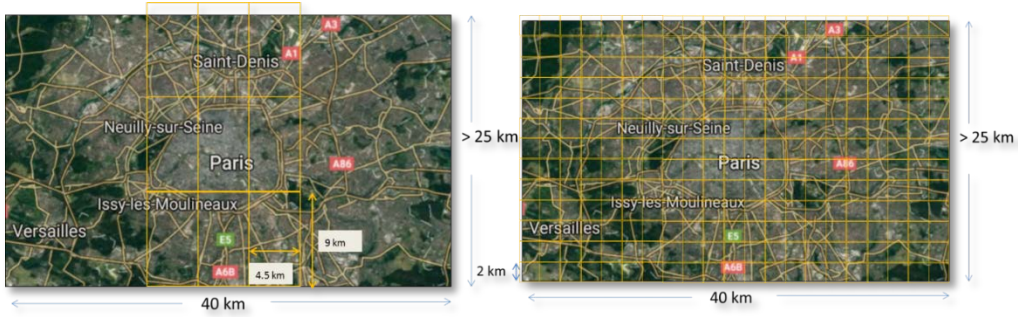


MicroCarb Mission

- MicroCarb will be the first dedicated CO_2 mission from Europe to be launched in 2020
- MicroCarb is a CNES mission with UK as partner
- MicroCarb features an exploratory city mode that will allow to map CO_2 over cities
- Preparation step towards a space-based system for emission monitoring

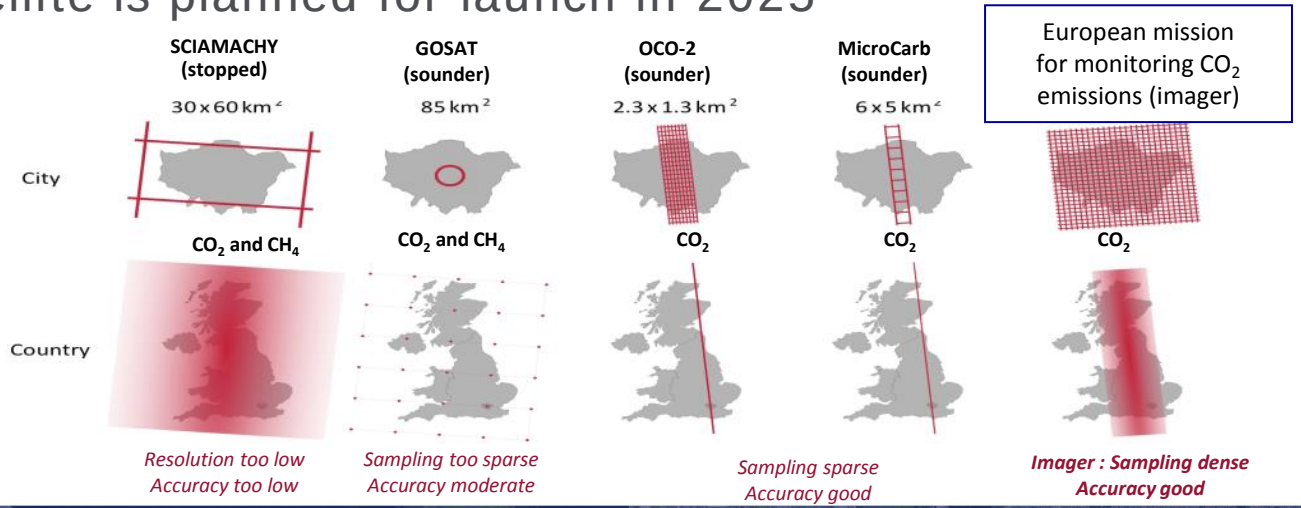


City-Mode of MicroCarb



Towards a European Operational Observing System to Monitor Fossil CO_2 Emissions

- Space component will consist of constellation of imaging satellites providing high coverage combined with high spatial resolution
- System will contribute to monitoring/verification of point sources and cites
- First satellite is planned for launch in 2025



Summary and Outlook

- Satellites are becoming increasingly powerful in their ability to inform on carbon sources and sinks
- With TanSat recently joining GOSAT and OCO-2 in orbit, we have now a first ‘constellation’ in space
- Great opportunity to work with real TanSat for algorithm comparison and validation with a focus on China and Europe
- We will also have a continued focus on inverse modelling; current visit of young researcher from CAS to Edinburgh
- Several publications in preparation and further exchanges are planned