Co-ordinated by ECMWF

CoCO2
Prototype system for a Copernicus CO_2 service

USER CONSULTATION WORKSHOP

How can the Copernicus CO_2MVS capacity support cities?

WP8: Examples of hot spot and city GHG emission budgets through observational methods

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T8.3 Engagement with user communities (policy, industry and others)

Compilation of a catalogue of published studies on hot spot detection of emissions for CO_2 (cities, power plants) and CH_4 (gas leaks etc.) to assist at local scale cities and regional councils in implementing plans for CO_2 emission reductions.

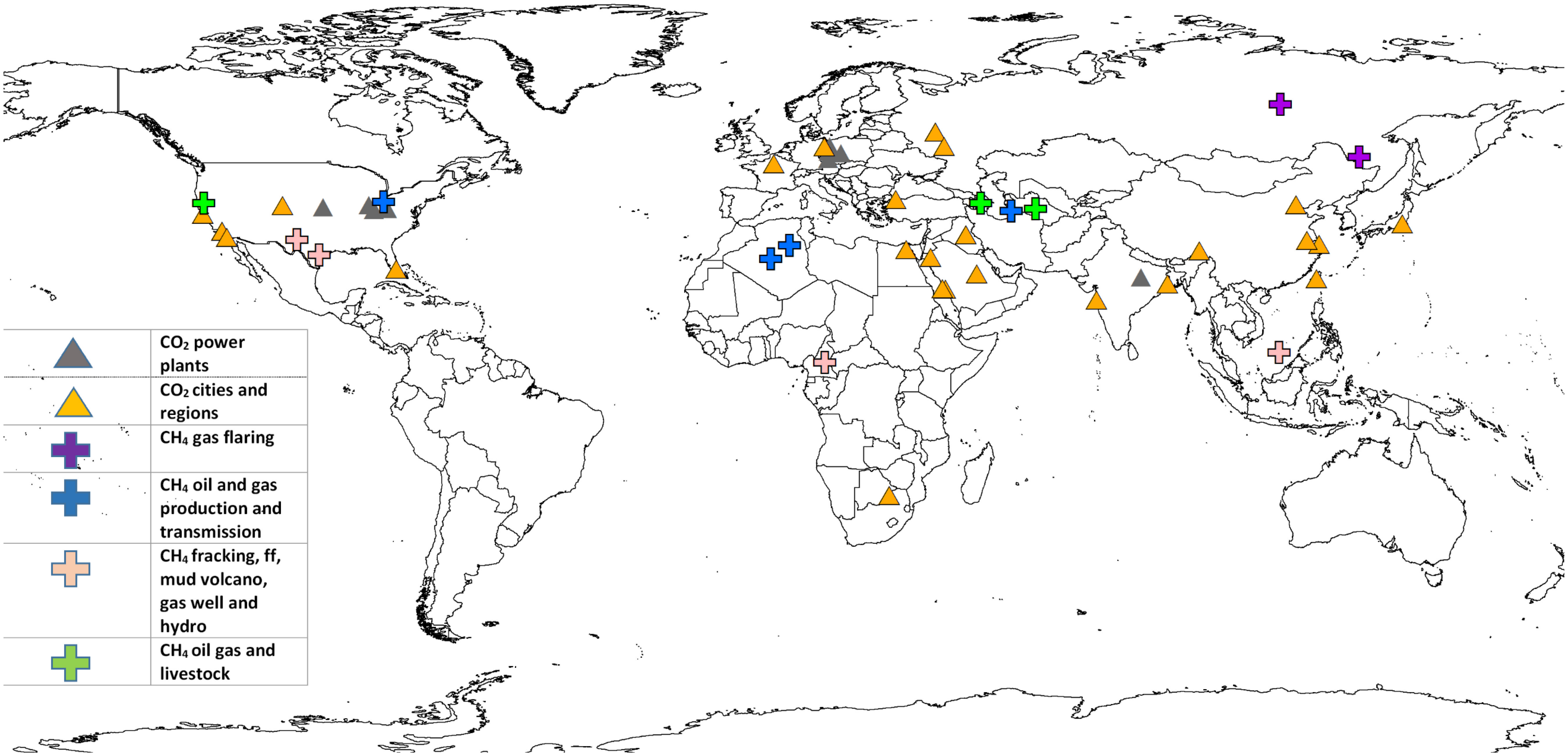
Background information

Hot spot detection of emissions uses independent satellite observations

(*e.g. Orbiting Carbon Observatory-2 (**OCO-2**) for CO_2, Sentinel-5 Precursor **(S5P)** for NO_2**,** Greenhouse gases Observing SATellite **(GOSAT)** CO_2 and CH_4, TROPOspheric Monitoring Instrument (**TROPOMI)** for CH_4 and N_2O**, GHG-Sat, PRISMA, SCIAMACHY/ENVISAT** and **TANSO-FTS/GOSAT** for CH_4, Sentinel 2 Multi Spectral Instrument **(MSI)** for CH_4)*

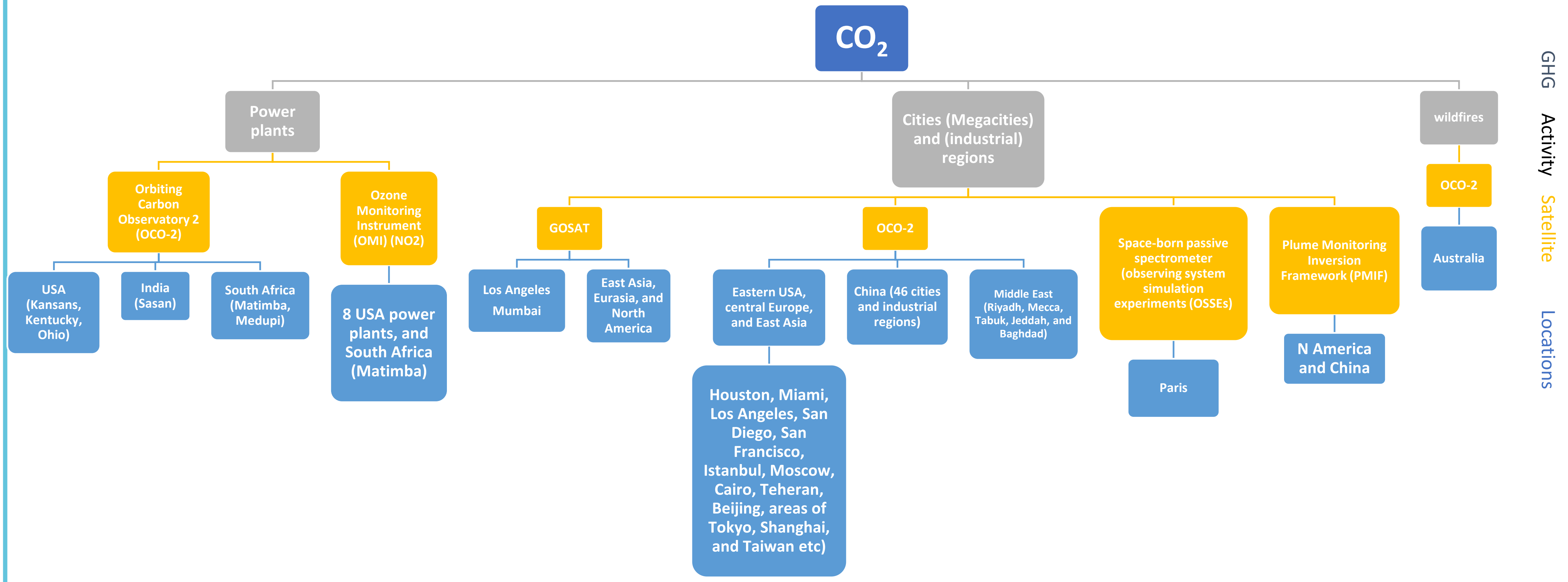
to evaluate the inventory representations of emissions linked to a transport models **(e.g. X-STILT, COSMO-GHG)** to account for atmospheric transport and link emissions to observations.

Mapping of some existing studies on hot-spot GHG detection



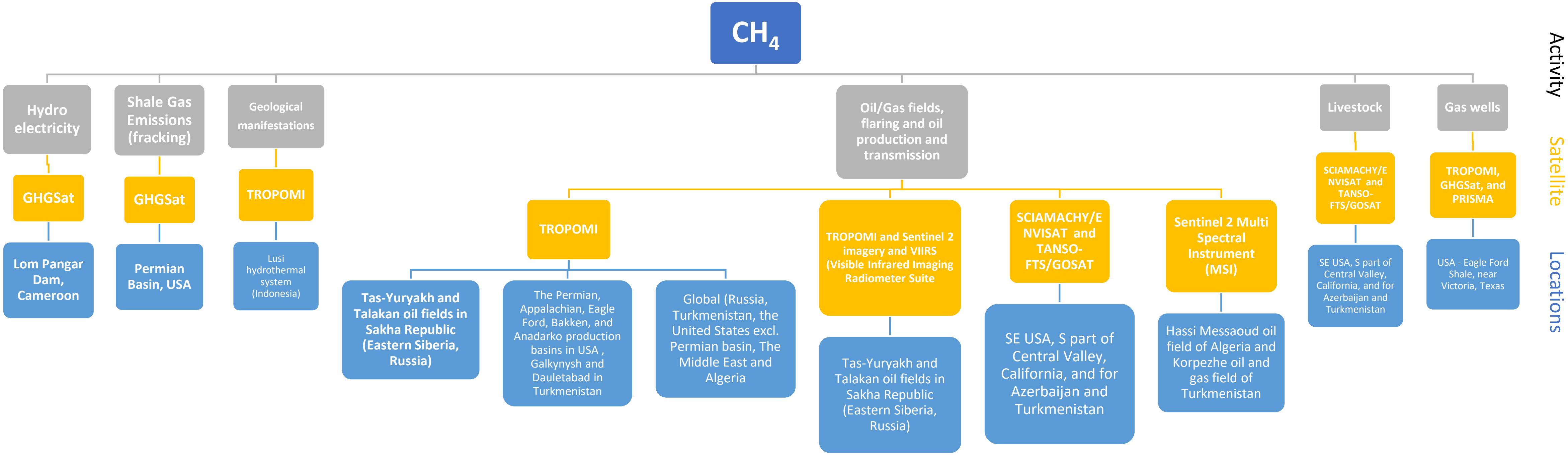
Preliminary results CO_2 hot spot detection

Representation of CO_2 activities detected by satellites and their locations



Preliminary results CH_4 hot spot detection

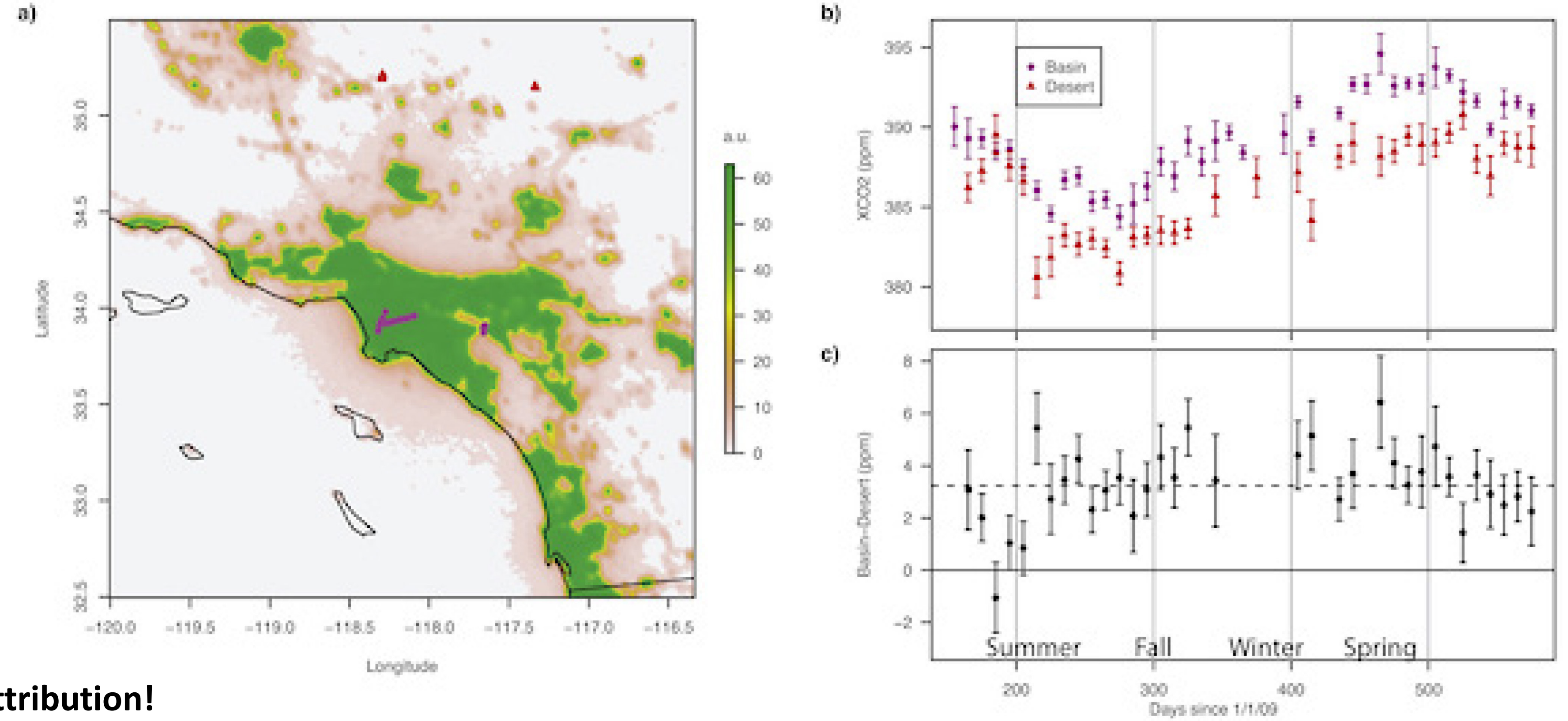
Summary of CH_4 activities detected by satellites and their locations



Case study 1: Space-based observations of megacity CO_2
Kort et al., https://doi.org/10.1029/2012GL052738

Satellite: GOSAT
Aim: To demonstrate the potential of satellite instruments to provide accurate global monitoring of megacity CO_2 emissions using GOSAT observations
Period: June 2009 to August 2010
Country/city: USA, Los Angeles

- Two observations were selected
- Clear indication of seasonality is detected
- Persistent enhancement is found to be 3.2 ± 1.5 (1σ) ppm in line with previous ground based observations on anthropogenic sources

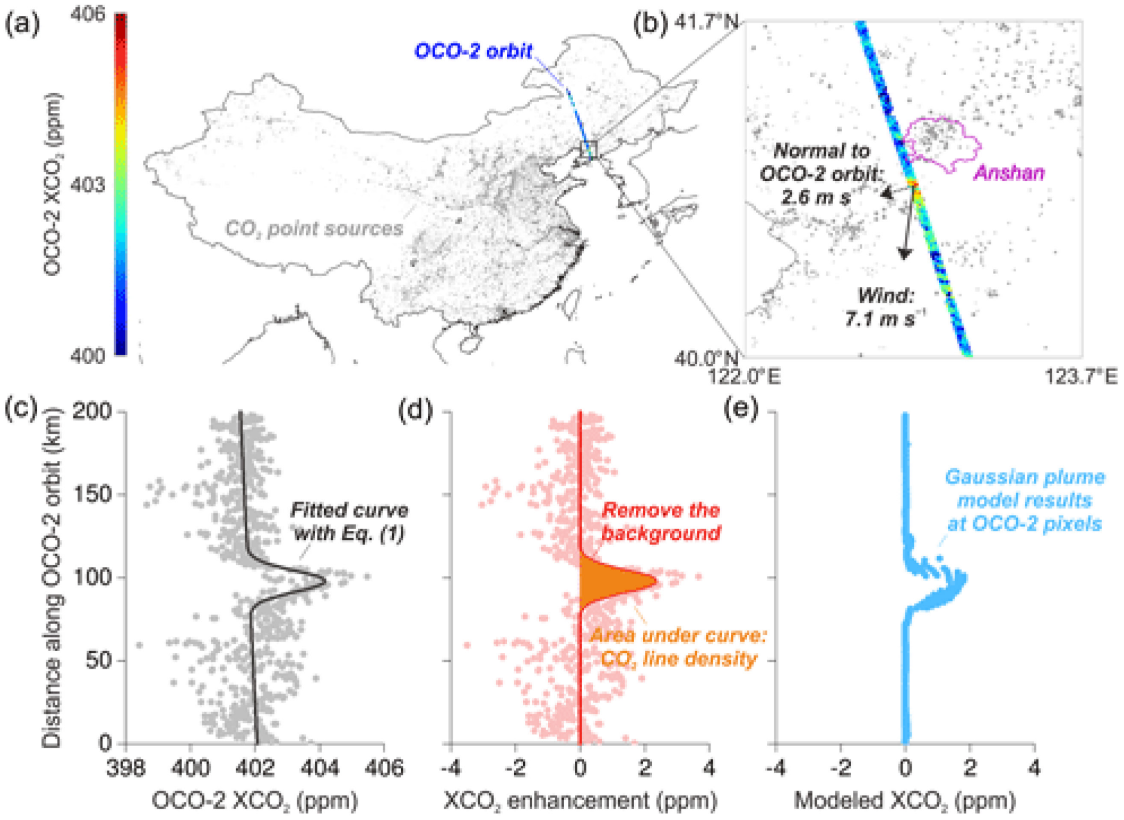


Question remains on the source attribution!

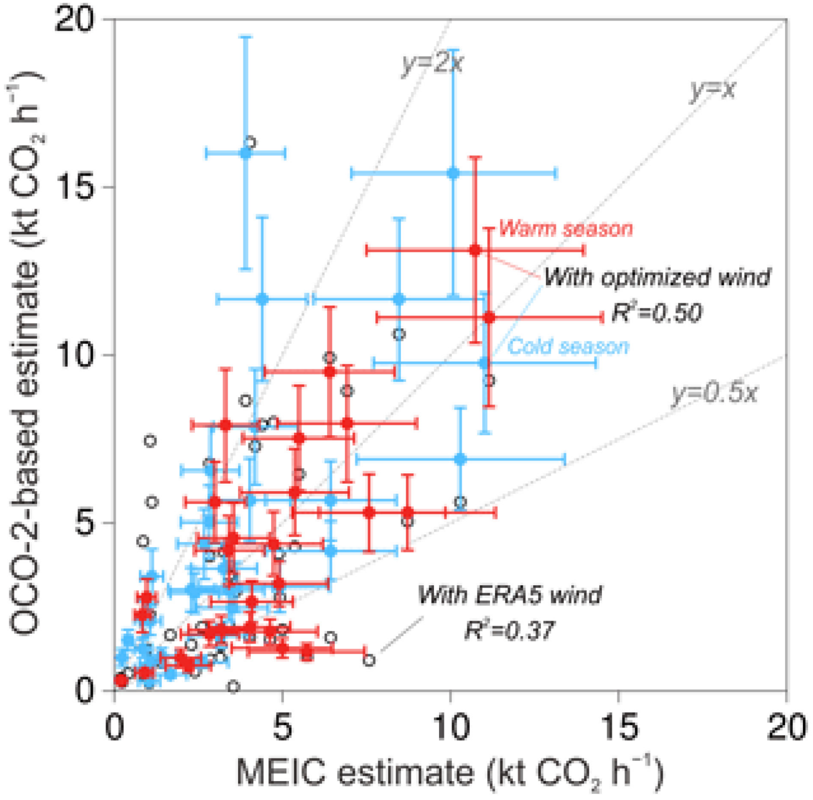
Observed X_{CO2}urban dome of Los Angeles from June 2009 to August 2010.

Case study 2: Observing CO_2 emissions over China's cities and industrial areas
Zheng et al., 2020: https://doi.org/10.5194/acp-20-8501-2020

Satellite: OCO-2
Aim: Quantifies CO_2 anthropogenic emissions at a large spatial extent over China's cities
Period: September 2014 and August 2019
Country/city: China / Anshan



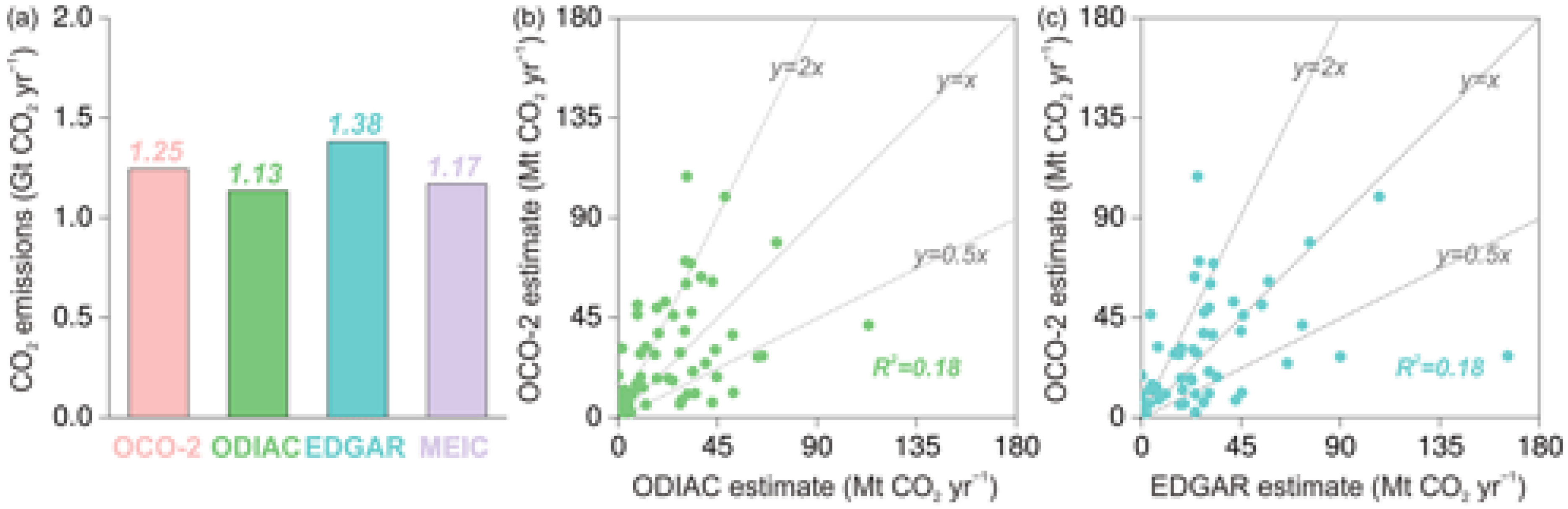
Quantification of CO_2 emissions from Anshan



Quantification of CO_2 emissions corresponding to the 60 CO_2 plumes selected from the 5-year OCO-2 archive compared to the corresponding source emissions given by MEIC (The average of satellite-based estimates is 27.1 % higher than the MEIC values in the cold season while it is 5.2 % lower in the warm season)

Case study 2 (cont.)

Extrapolation of the satellite-based CO_2 hourly fluxes to annual total fluxes using emission time profiles, and comparison to two global bottom-up emission maps: ODIAC (Oda and Maksyutov, 2015; Oda et al., 2018) and EDGAR v4.3.2 (Janssens-Maenhout et al., 2019).



Conclusions:

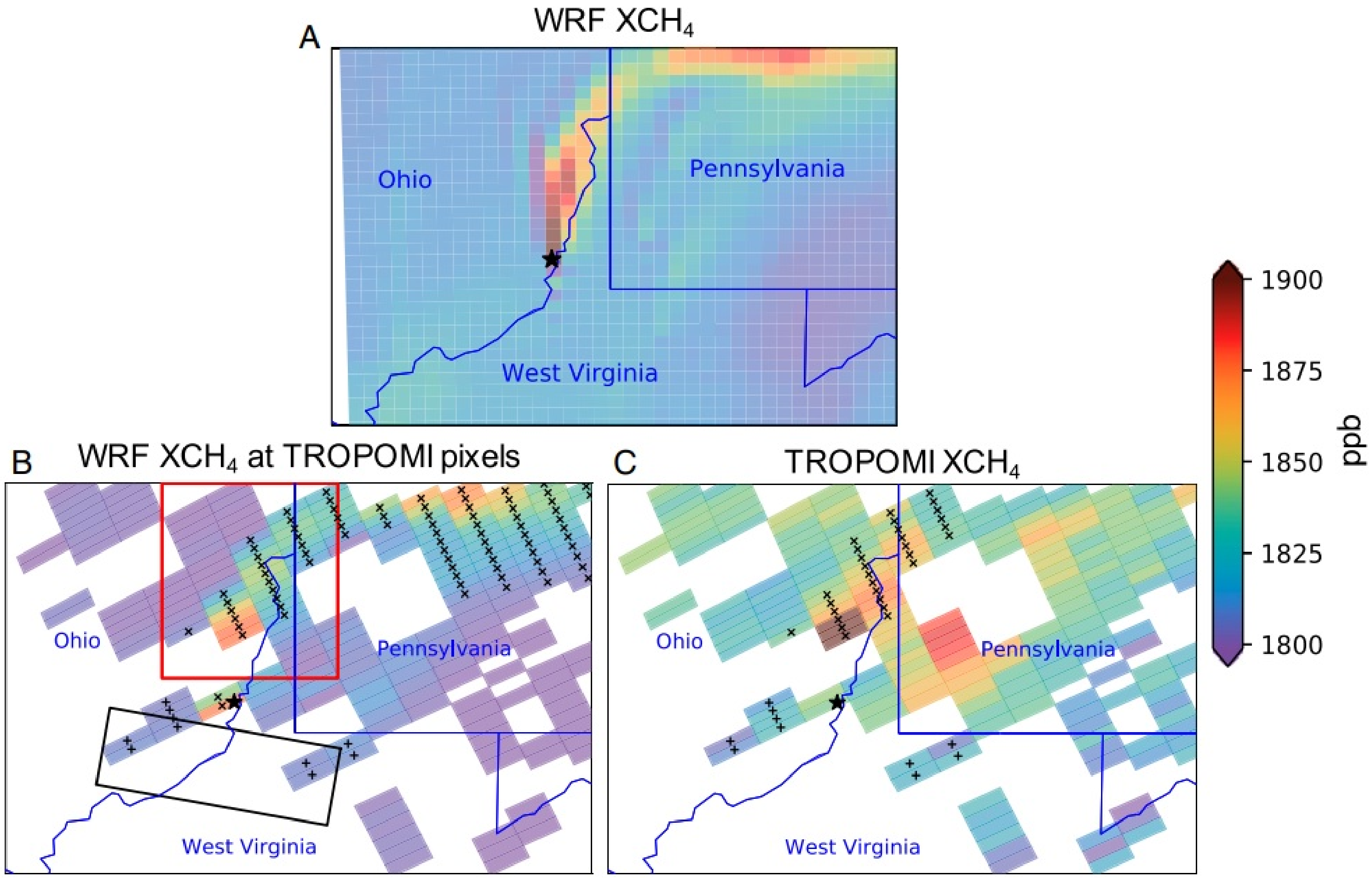
- Conservative selection of the satellite data that can be safely exploited for emission quantification.
- Future developments could aim at using detailed regional atmospheric transport models (refining the data selection, improving the estimation of wind speed or the description of the plume footprint).
- The need for a good knowledge of the emission space-time patterns (not only the emission values) will therefore remain for the comparison between the national inventories and the satellite-based estimates. To assist non-Annex I parties with verification of their submissions, an incremental approach where both bottom-up and top-down estimates are developed together in parallel.

Case study 3: Satellite detect extreme CH_4 leakage from a natural gas well blowout Pandey et al, 2019: https://www.pnas.org/content/116/52/26376

Satellite: TROPOMI
Task: Detection of gas leakages due to accidents in the oil and gas sector
Period: February – March 2018
Country / state: USA, Ohio

- CH_4 emission from this event were detected by TROPOMI instrument and quantified by measuring the CH_4 concentrations before, during and after the blowout.

- the Weather Research and Forecasting (WRF) model was used to enable investigating the atmospheric dispersion of the CH_4 plume at the overpass time of TROPOMI.

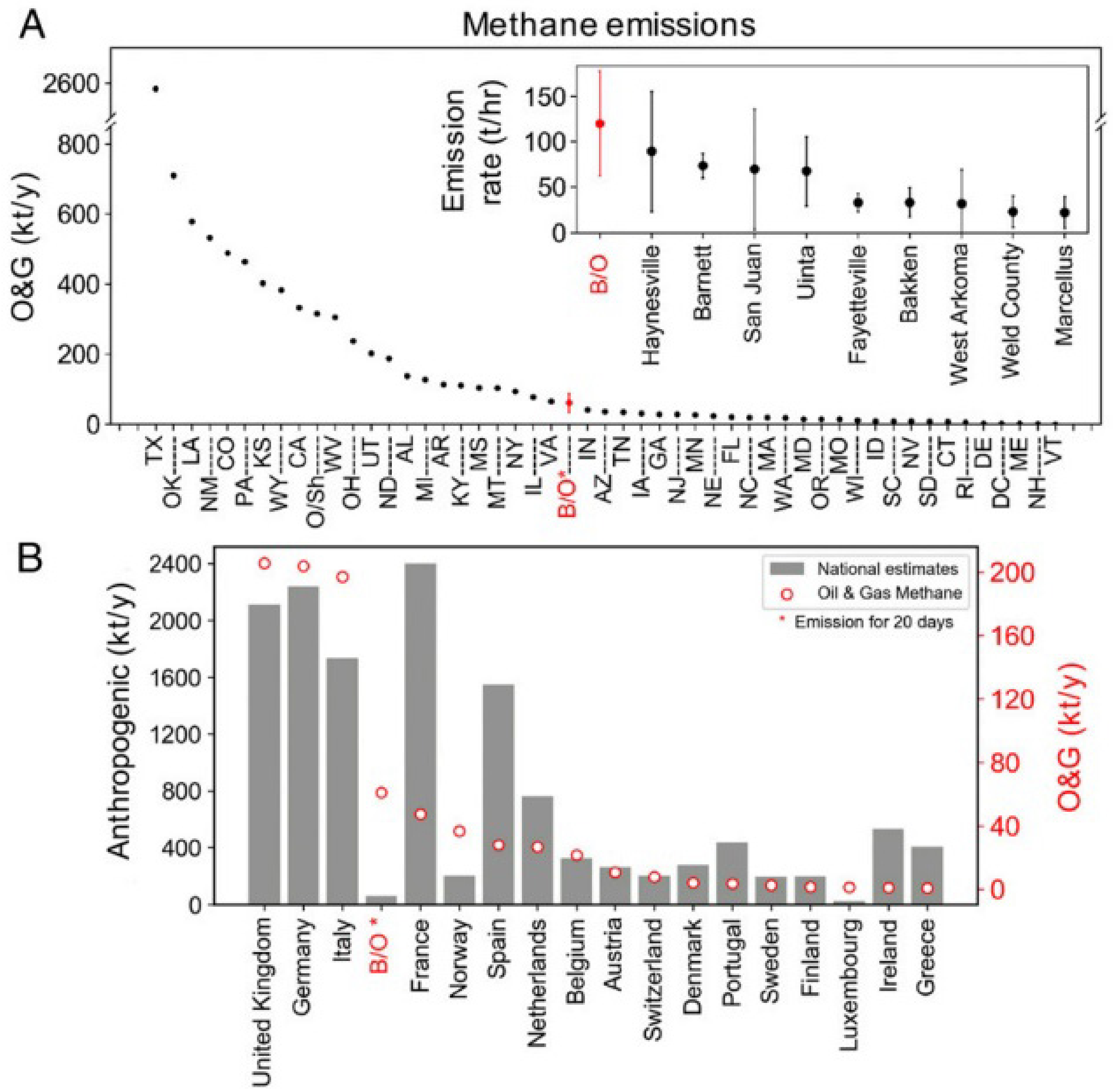


Case study 3 (cont.)

Comparison with previously known accidental and regional emissions across the US O&G sector and EU countries were performed.

Conclusion:

- Lack of incorporating accidental emissions in regional- and national-scale emission reporting and inventories, lead to significant underestimation of overall emissions.
- Detection and quantification of an accidental emission from a satellite during routine operations demonstrates the unique value of satellite remote sensing, and the TROPOMI instrument in particular.



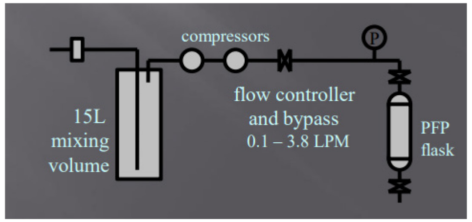
Complementary research

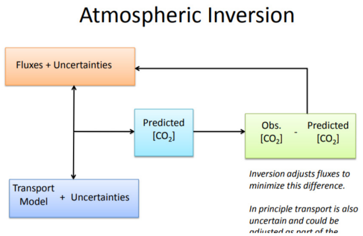
➢ ICOS PAUL

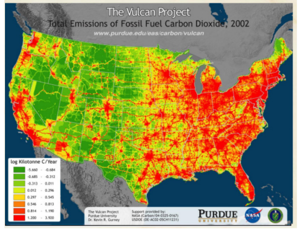
- Newly funded project aiming to evaluate available and develop novel observational approaches, and implement an integrated and comprehensive concept for a city observatory.
- Links to previous Indianapolis USA experiments to lower uncertainty in area/regional GHG flux measurements through improved measurement techniques, comparison to inventory data, and use of carbon isotope ratio data (*The INdianapolis Flux Experiment (INFLUX): Toward Improved Capabilities in Urban-Area Scale Greenhouse Gas Flux Measurements)*

Mix of approaches

- *Aircraft-based flux measurements for both CO_2 and CH_4;*
- *Tower-based fluxes;*
- *^{14}C measurements and flask sampling;*
- *Regional modeling/inverse analysis;*
- *Vulcan/Hestia modeling.*







Complementary research

- Observing system simulation experiments (OSSEs) experiments within the CHE project

https://www.che-project.eu/index.php/resources

Studies on Berlin, Shanghai and Beijing

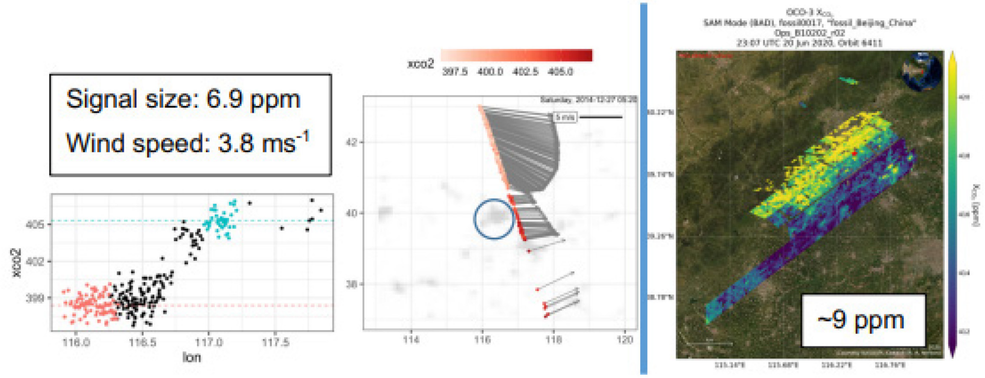


Figure 3: Largest XCO2 enhancement found observed by OCO-2 (left) and OCO-3 (right) downwind of Beijing as of August 2020.

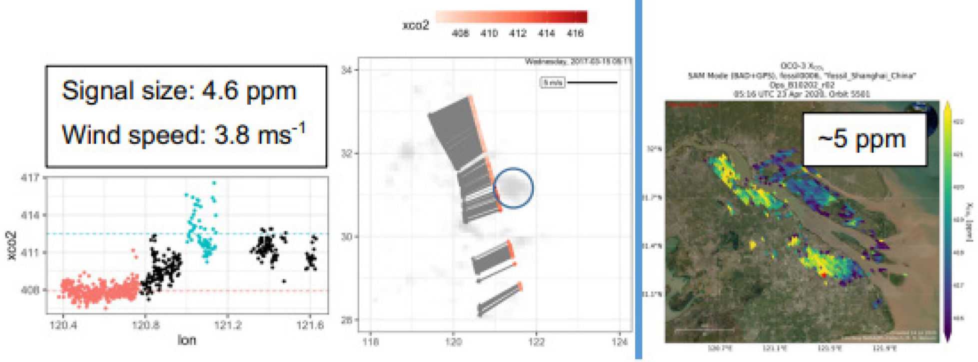


Figure 4: Same as Figure 3, but for Shanghai.

- Estimating the performance of CO_2M over cities: CHE and ongoing $CoCO_2$ WP4

Kuhlmann et al., 2019 https://amt.copernicus.org/articles/12/6695/2019/

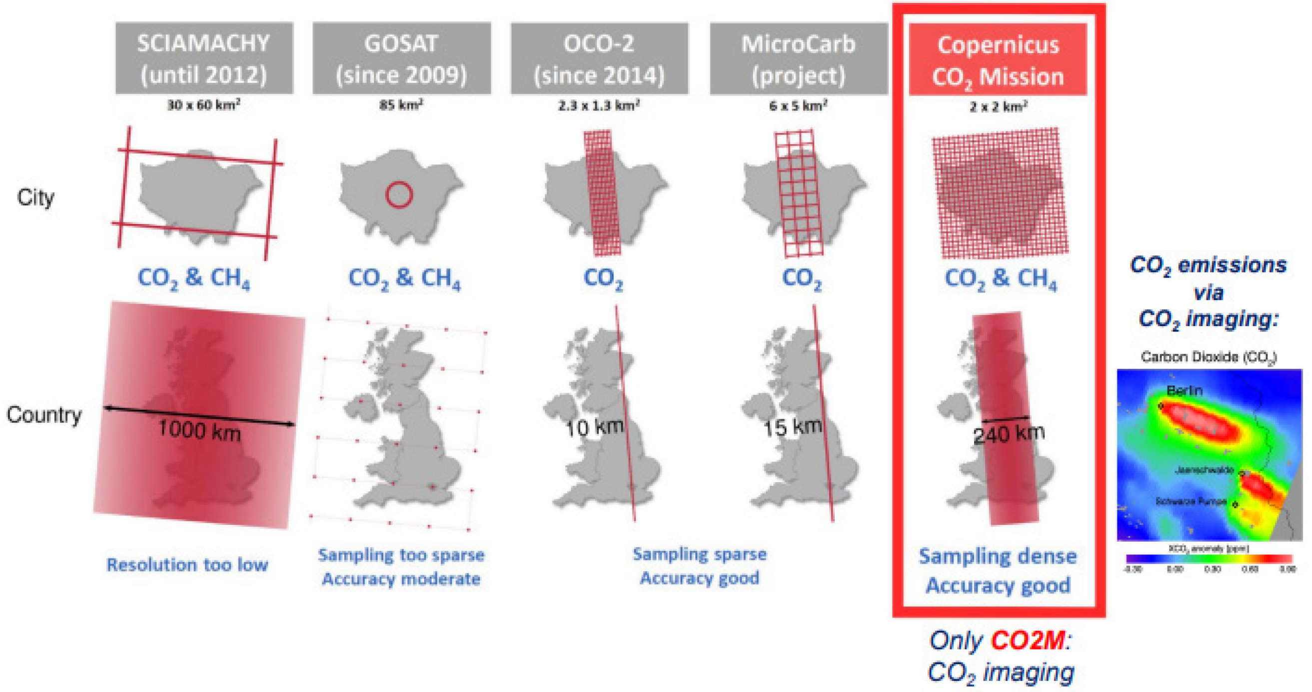
Berlin power stations

Kuhlmann et al., 2020 https://doi.org/10.5194/amt-13-6733-2020 : Berlin city

Lespinas et al., 2020

https://cbmjournal.biomedcentral.com/articles/10.1186/s13021-020-00153-4

Plume Monitoring Inversion Framework (PMIF) global inversion system



Complementary research

➢ The use of ^{14}C and other coemitters (NO_2, CO) to separately address the anthropogenic CO_2 component: $CoCO_2$ WP4

- To be able to separate between the anthropogenic and biogenic signal and to attribute emissions to sources/sectors, satellite information need to be combined with ground-based observations.

Kuhlmann 2020-2021:
SMARTCARB: Synthetic XCO_2, CO and NO_2 observations for the CO_2M and Sentinel-5 satellites
SMARTCARB-2: Use of satellite measurements of auxiliary reactive trace gases for fossil fuel carbon dioxide emission estimation
https://zenodo.org/record/4674167#.YVQkzJ0zbIU

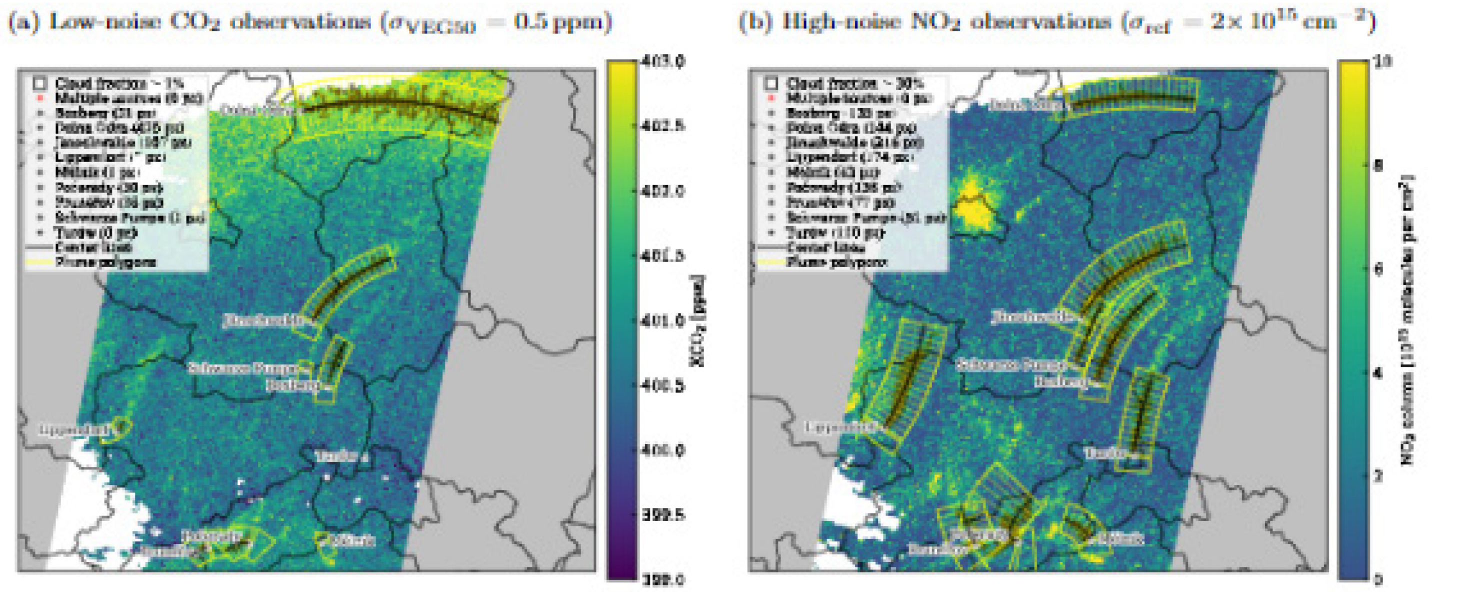


Figure 2.11: Comparing plume detection using CO_2 observations with low noise (σ_{VEG50} = 0.5 ppm) and (b) NO_2 observations with high noise (σ_{ref} = 2× 10^{15} cm^{-2}). For each detected plume, the figure shows detected pixels, plume center line and polygons used in the mass-balance approach. The triangular marker shows the location of the source and the wind direction in the model field.

Thanks for your attention!!!
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With support from:

CO2 Monitoring Task Force

External Expert Group

Inventory Agency Advisory Board

CoCO2 reviewers

REA

Period: January 2021 – December 2023