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Spaceborne monitoring of CO_2 emissions from large cities and the impact of aerosols

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Background and objectives

In this presentation, results are presented of the ESA-AeroCarb scientific support study for CO2M. The results of this theoretical study into the expected performance of CO2M have been updated with new simulations (as part of the CHE project).

The aim is to assess the impacts of XCO2 retrieval errors due to aerosol scattering, and the extent to which these errors can be mitigated using a Multi-Angular Polarimeter (MAP) onboard CO2M for measuring aerosols.

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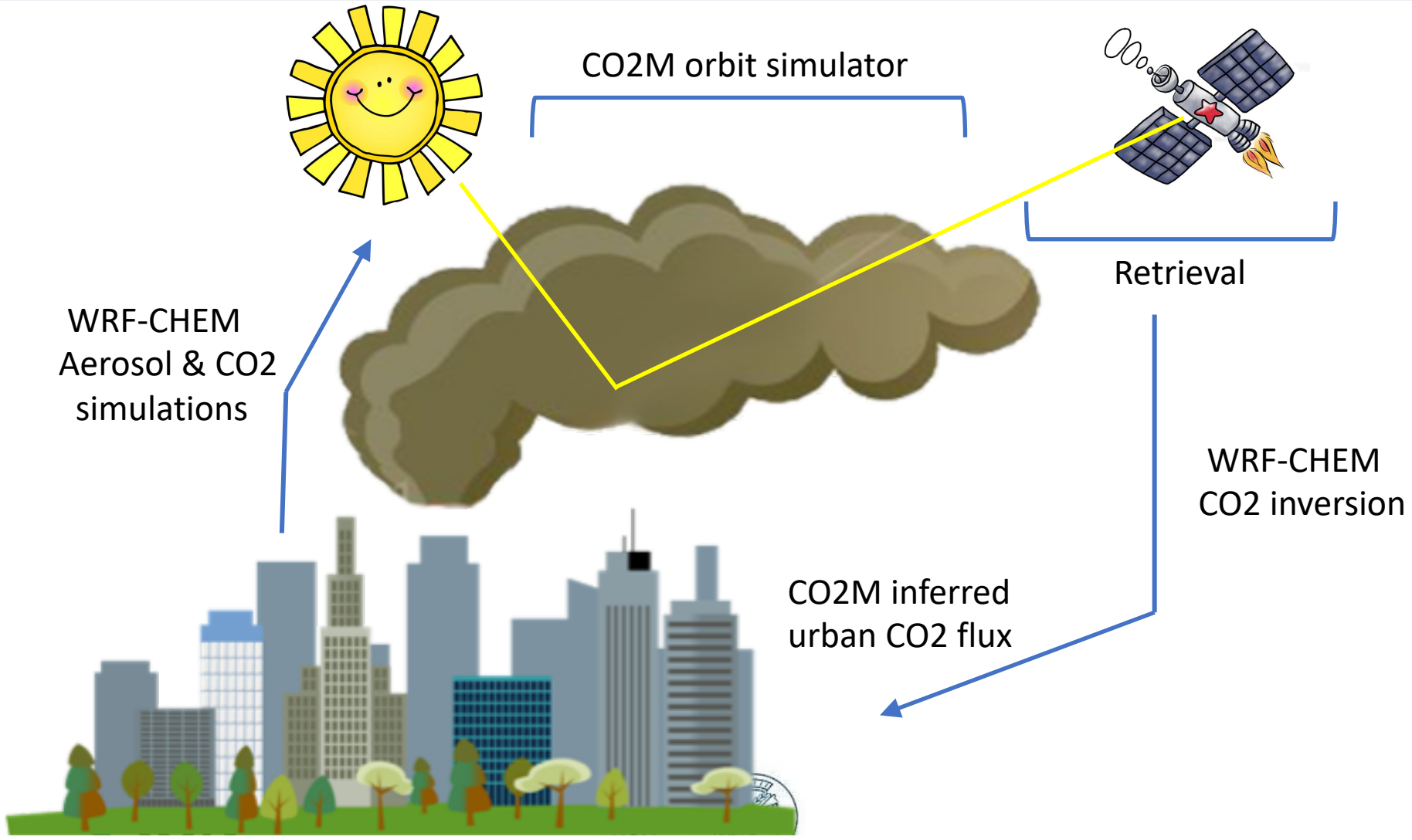
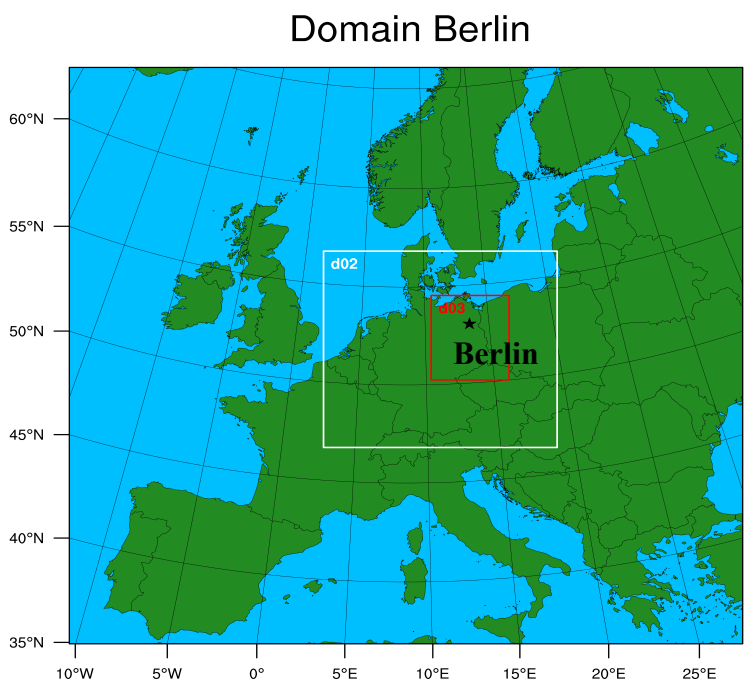
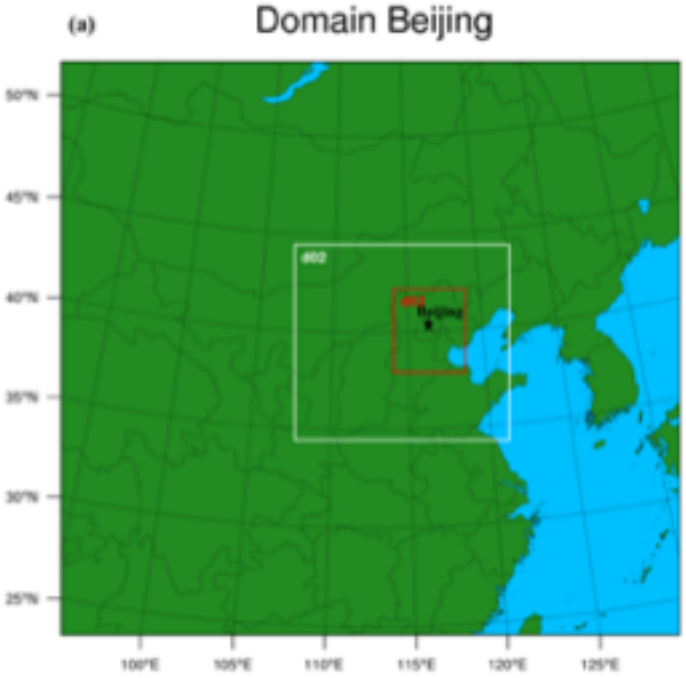
Schematic project outline



Observing System Simulation Experiment for estimating urban CO2 emissions

WRF-CHEM domains





- Summer & winter case, year 2013
- Inner domain at 4x4km^2
- Target: The CO2 emission from Berlin and Beijing

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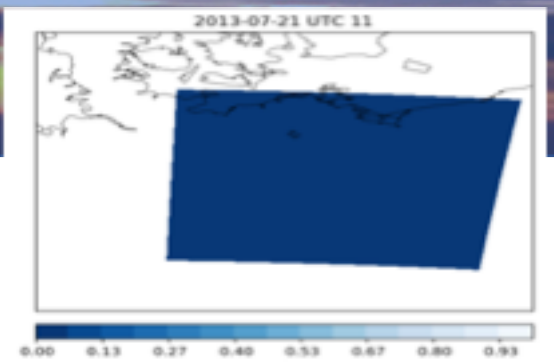
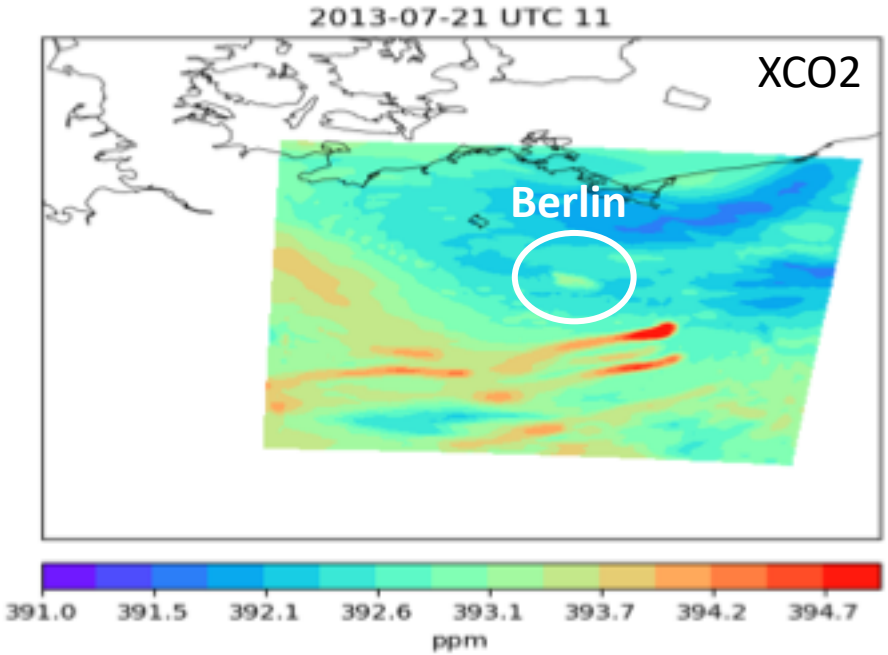
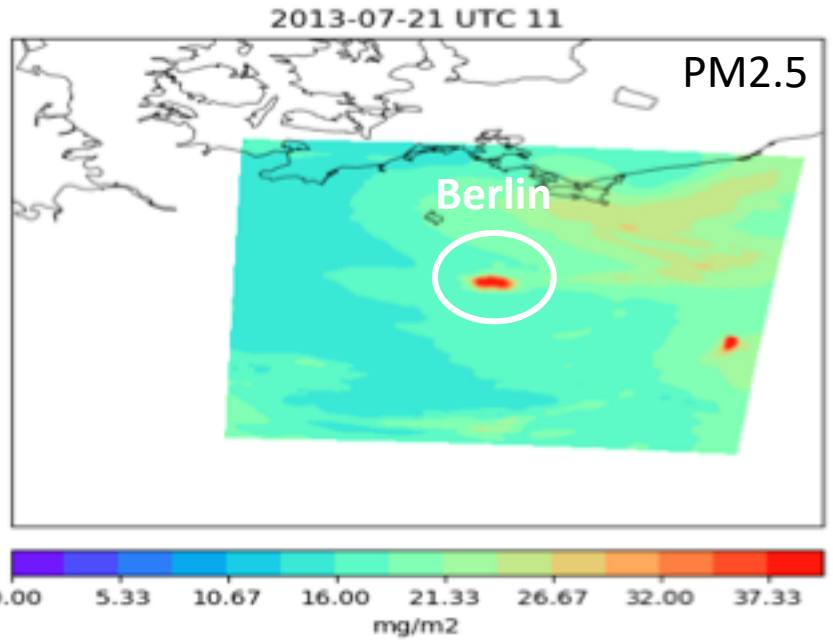
Case: Berlin summer



Cloud fraction

- Clear signal in PM2.5 over Berlin
- For XCO2 powerplants to the south dominate





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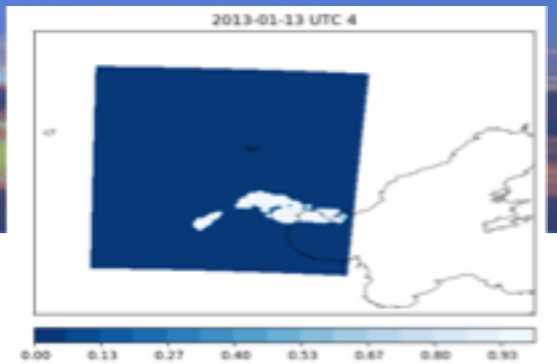
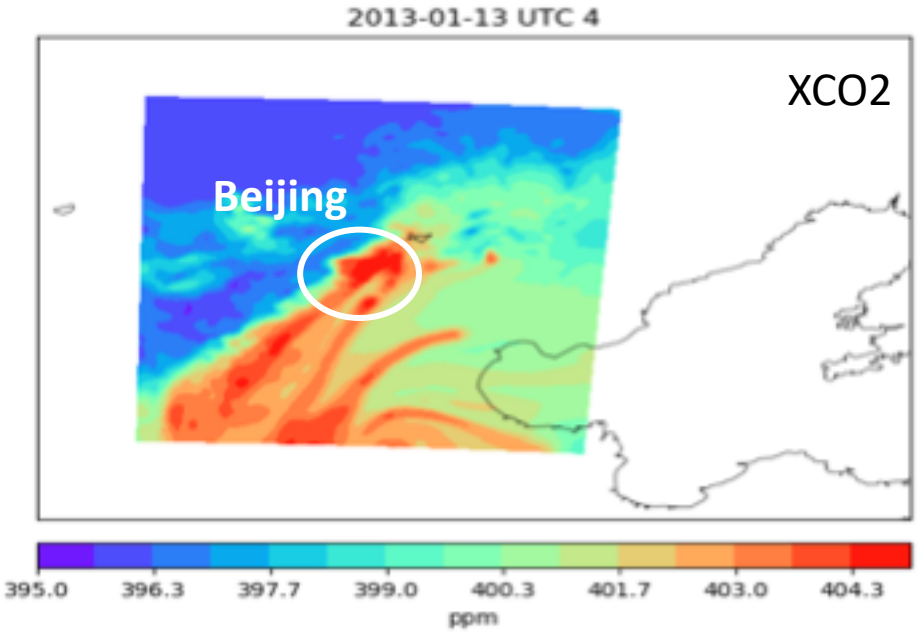
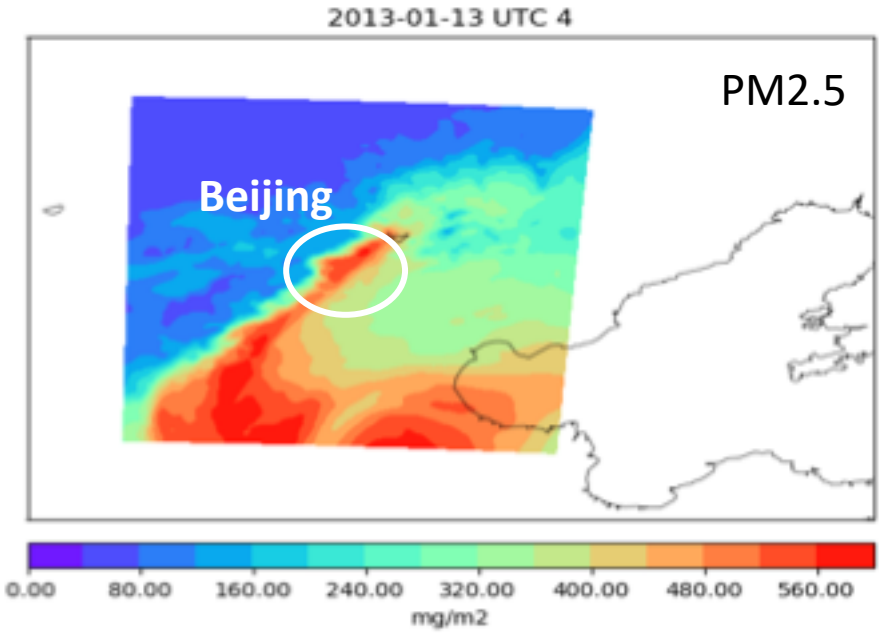
Cases: Beijing winter



Cloud fraction

- Much larger signals in XCO2 & Aerosols!





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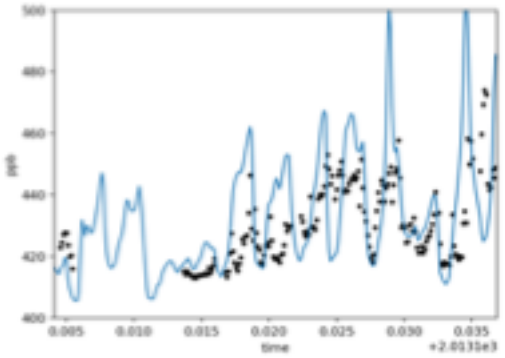
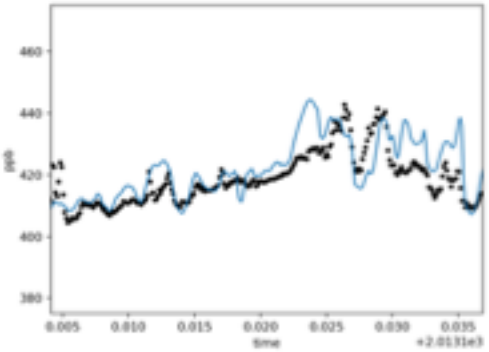
Comparison to surface data

Winter

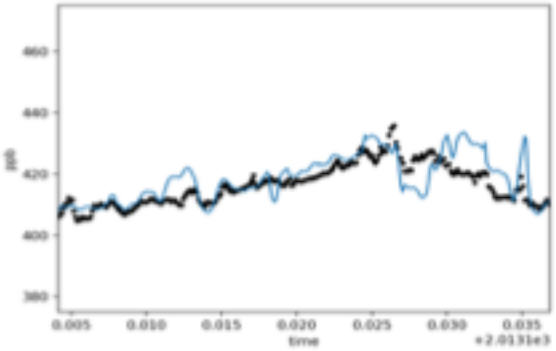
Heidelberg



Hegyhatsal (10m)



Hegyhatsal (100m)

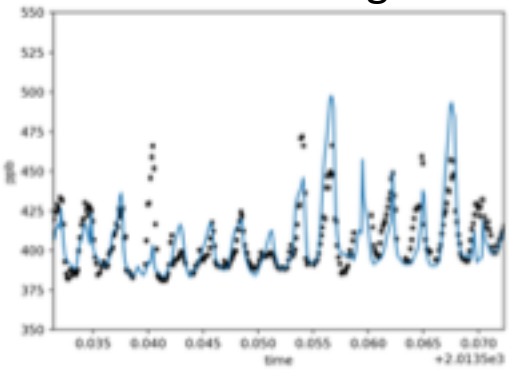


WRF

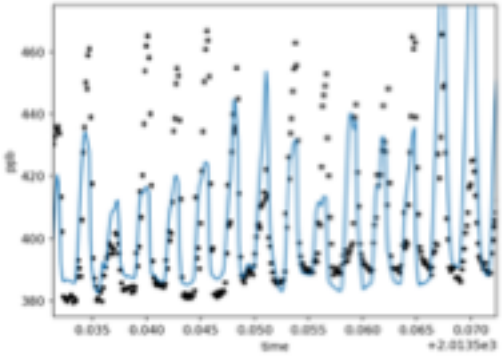
Obs

Summer

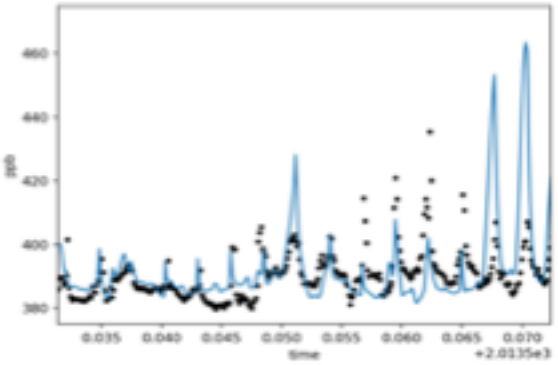
Heidelberg



Hegyhatsal (10m)



Hegyhatsal (100m)



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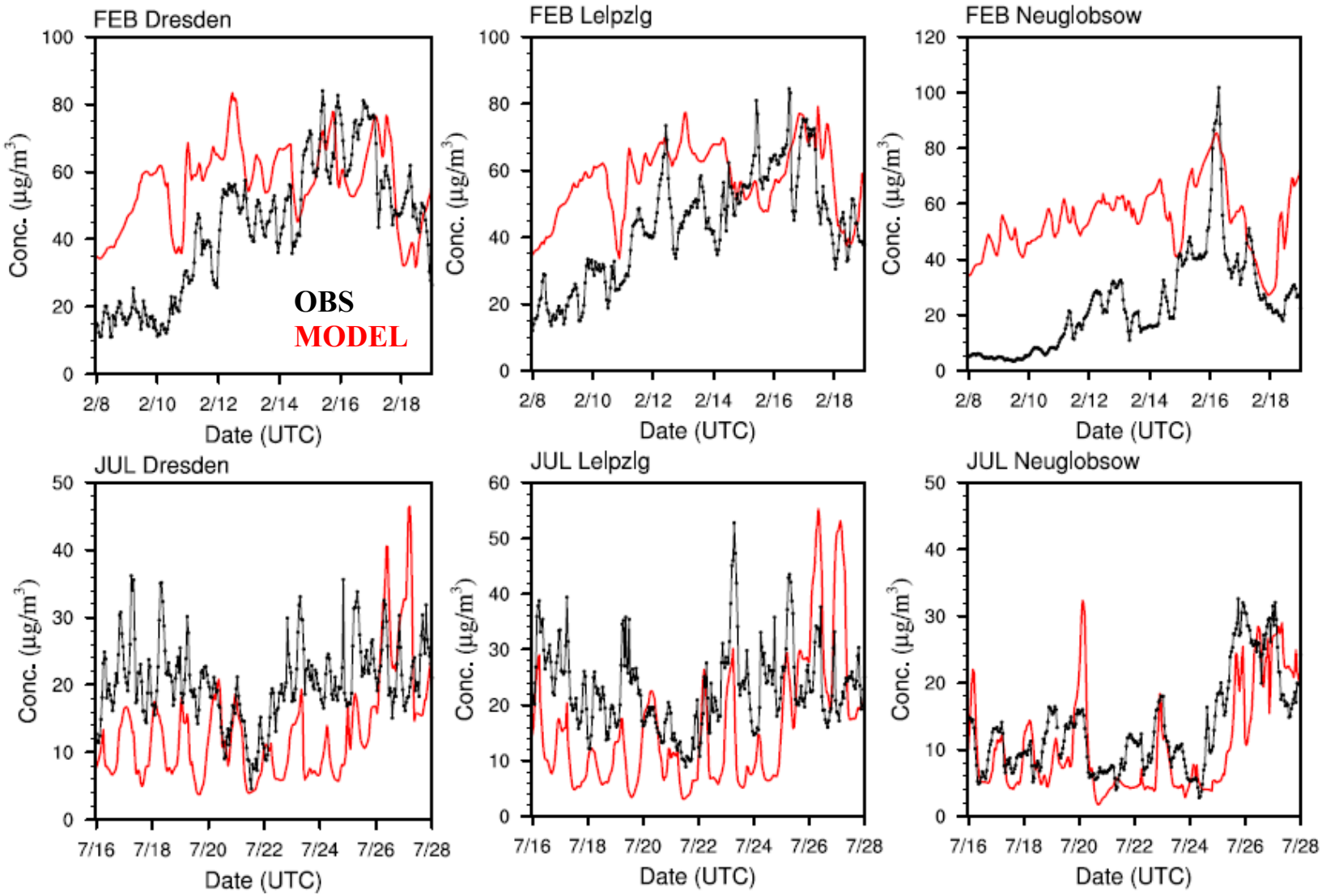
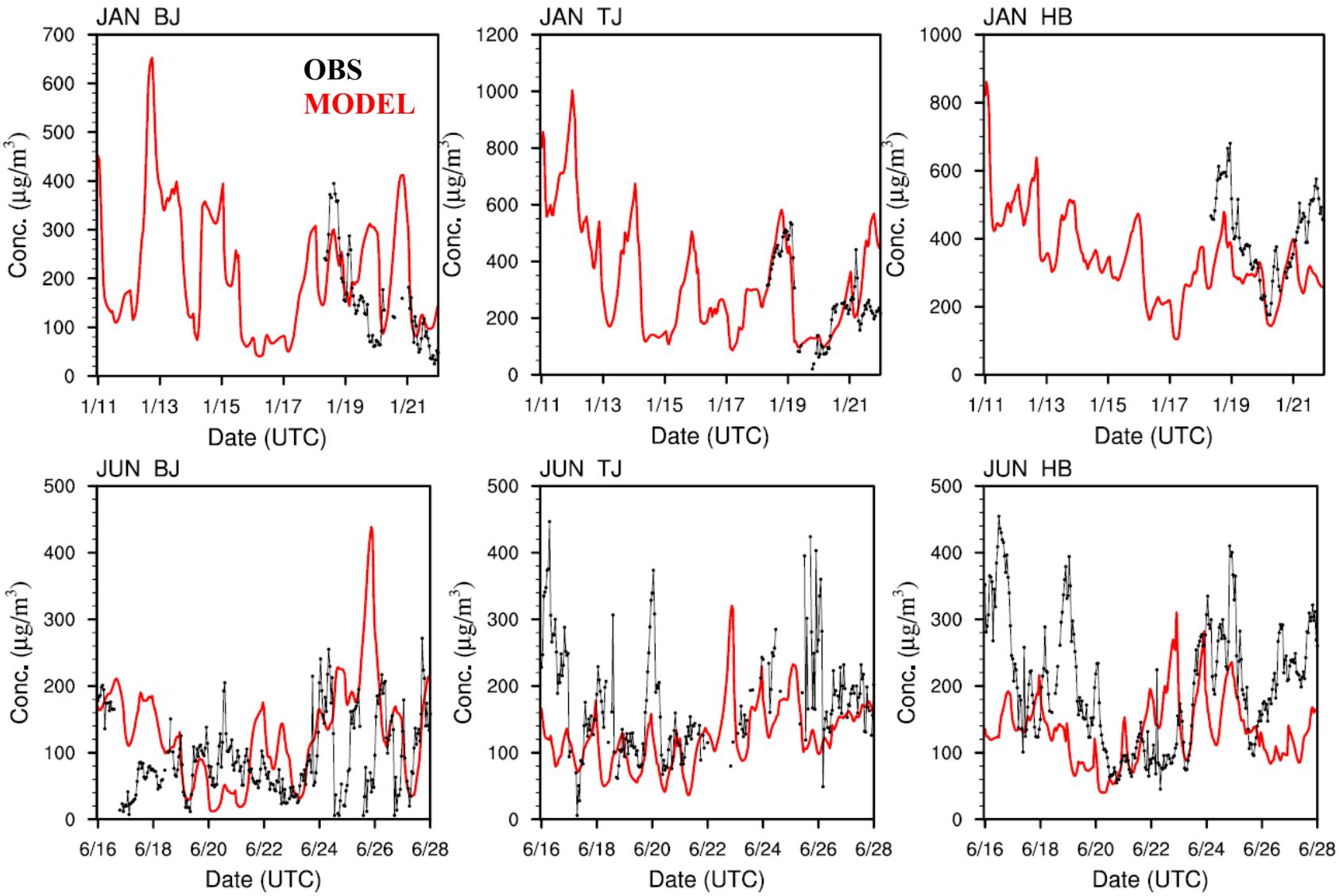
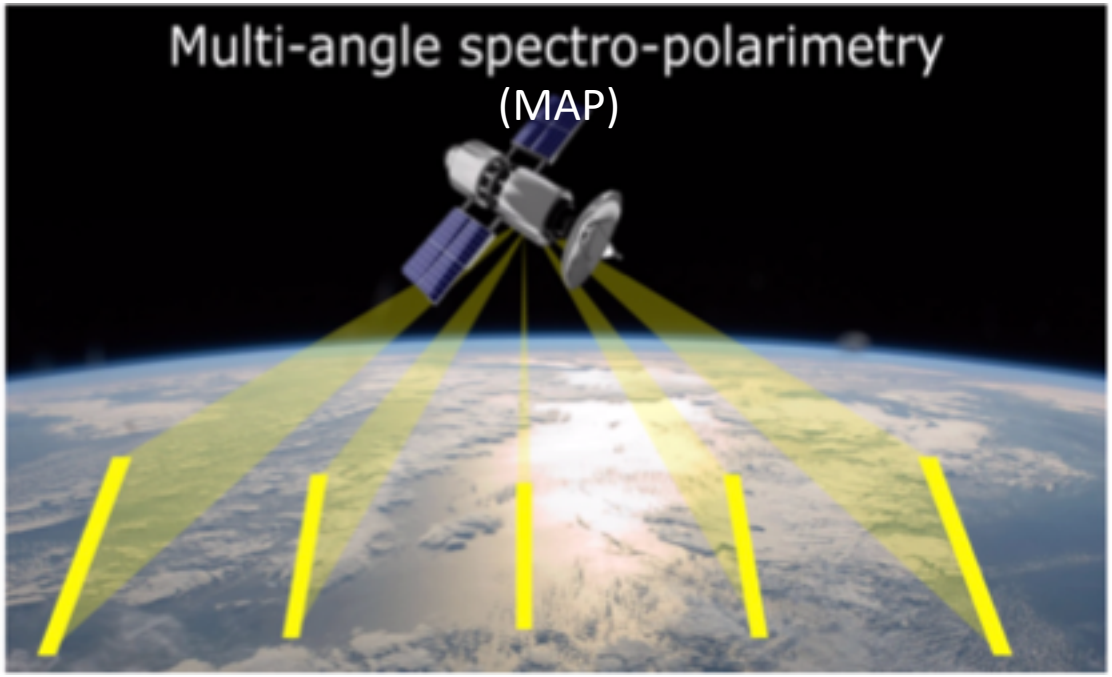
Surface PM_{10} evaluation for Berlin case



Surface PM_{10} evaluation for Beijing case



Aerosol measurements



Spectral radiance:
385 – 765 nm

Multi-angle:
- Samples the scattering phase function at different angles

Polarization:
- Measures the degree of linear polarization (DLP)

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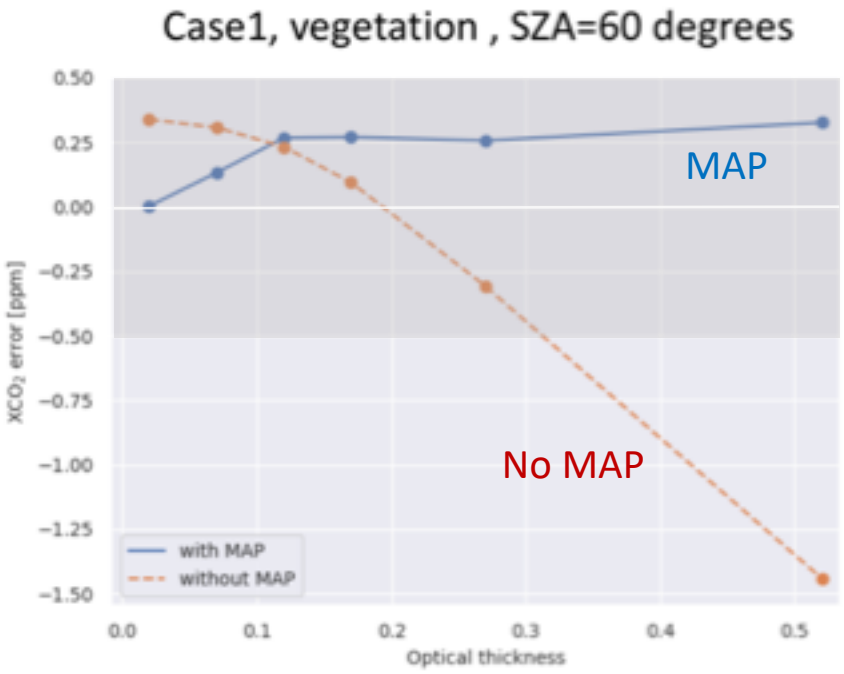
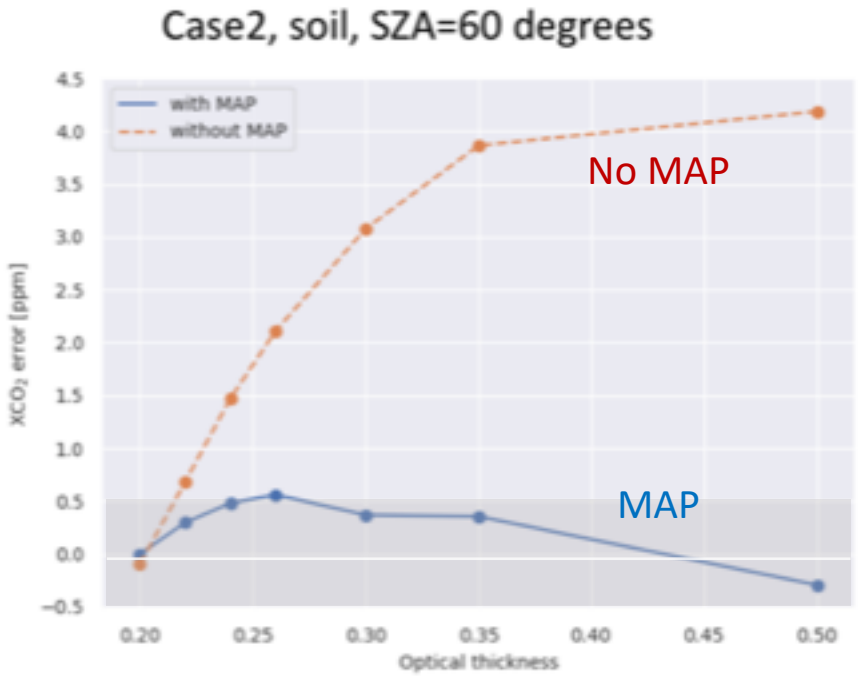
Added value of MAP

Added value of MAP-mod with optimal setup:





> MAP significantly improves the CO2M performance, particularly at higher AOTs

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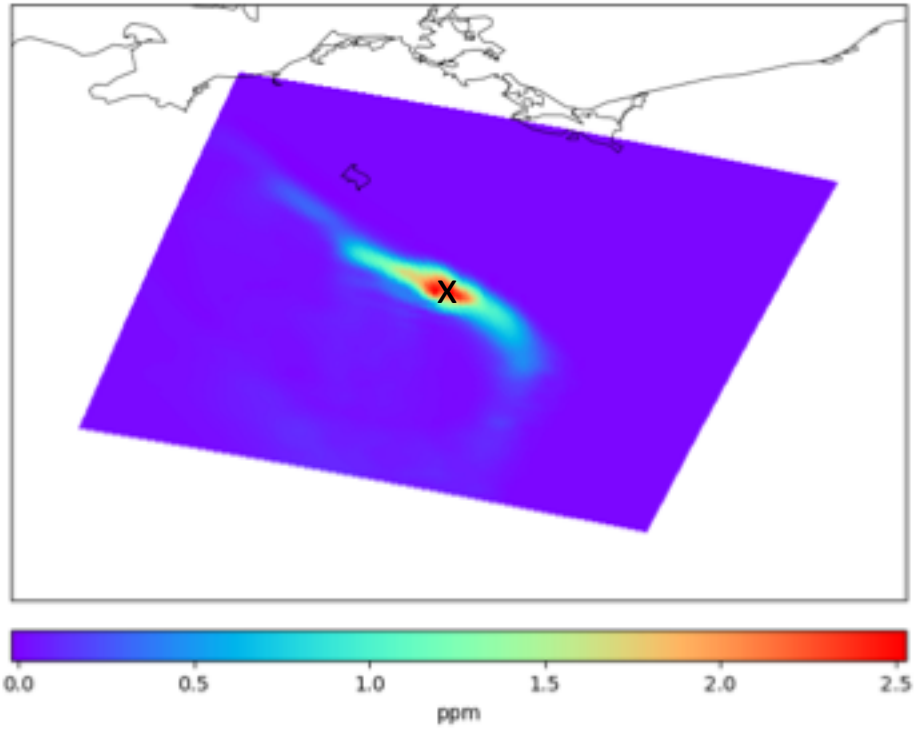
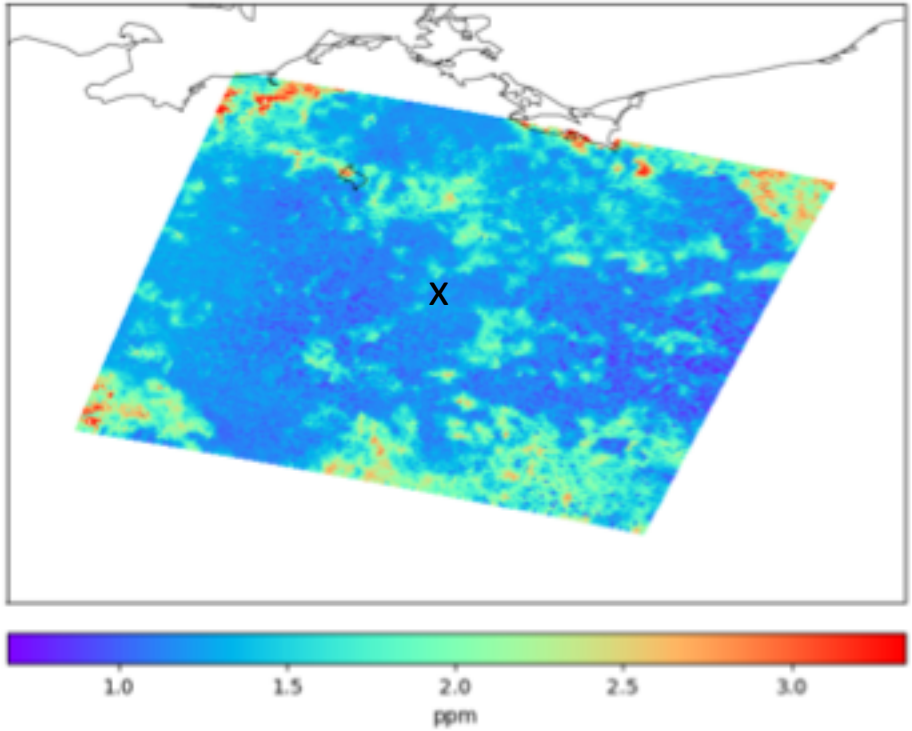
City plume: Berlin Winter

Berlin XCO_2 plume



ε_{syst} CO_2 sensor only



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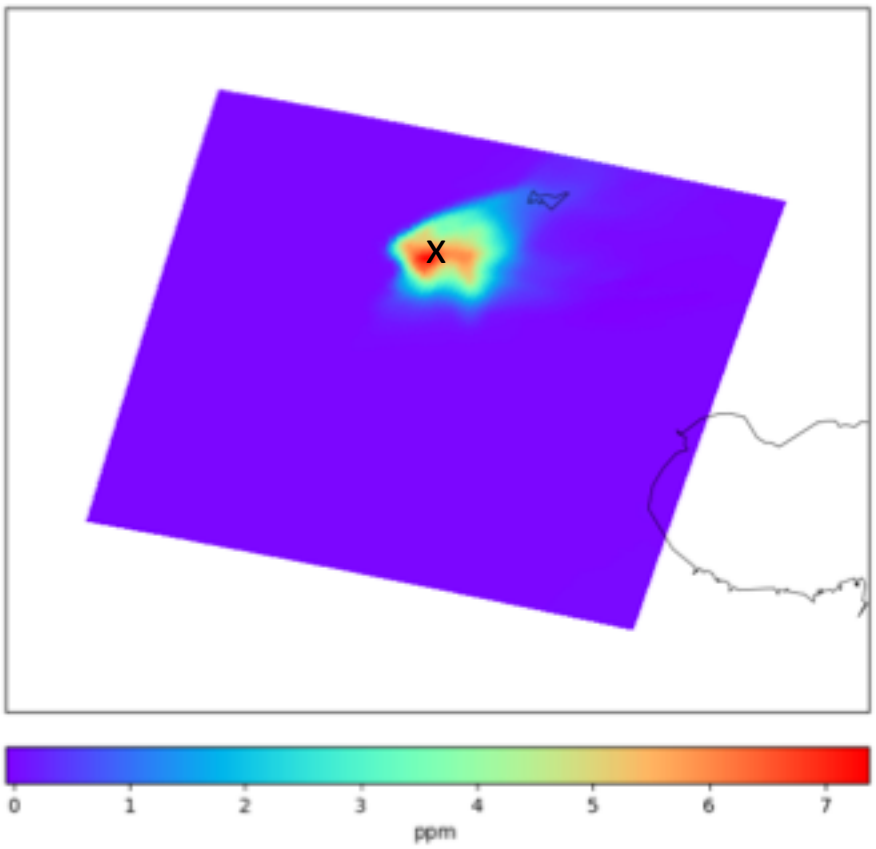
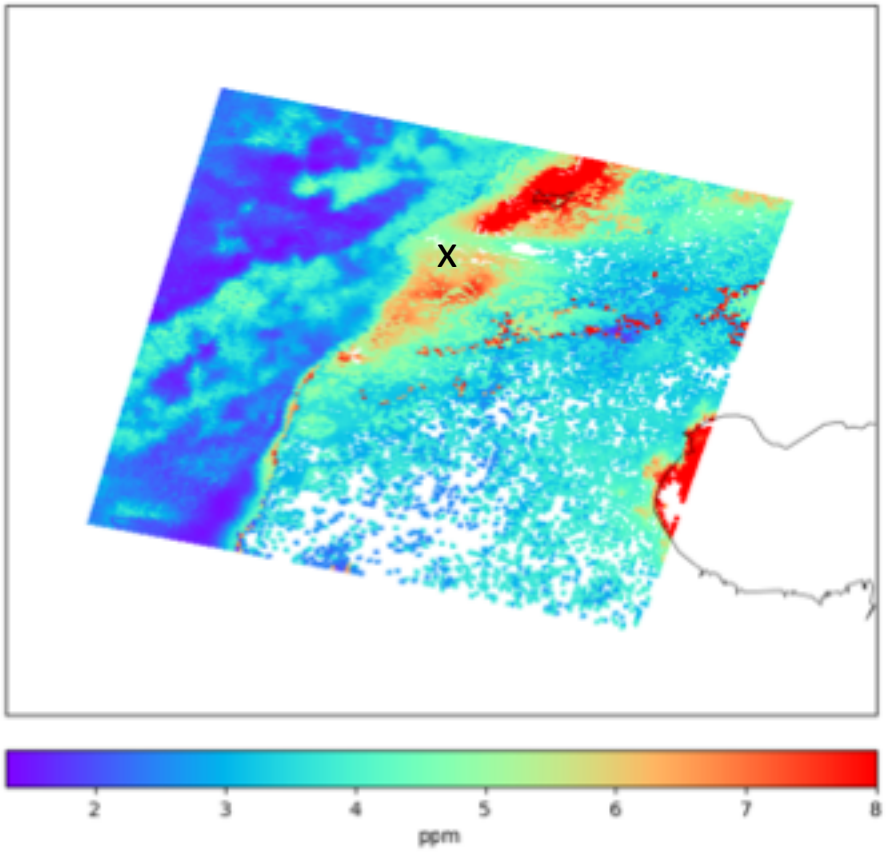
City plume: Beijing summer

Beijing XCO_2 plume



ε_{syst} CO_2 sensor only



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Inversion of city CO_2 emissions

- Matrix inversion:

Solve:

$$J = 0.5[(c - Mx)^T R^{-1} (c - Mx) + (x - x_0)^T B^{-1} (x - x_0)]$$

x: scaling factors =>[E_{city} , $\Delta C_{other\ E + Lat.\ Bounds}$, $C_{background}$]

c: $Mx_0 + \varepsilon_{syst}$

x_0: perfect prior

R (diagonal): $\varepsilon_{syst} + \varepsilon_{rnd}$

B (diagonal): ε_x

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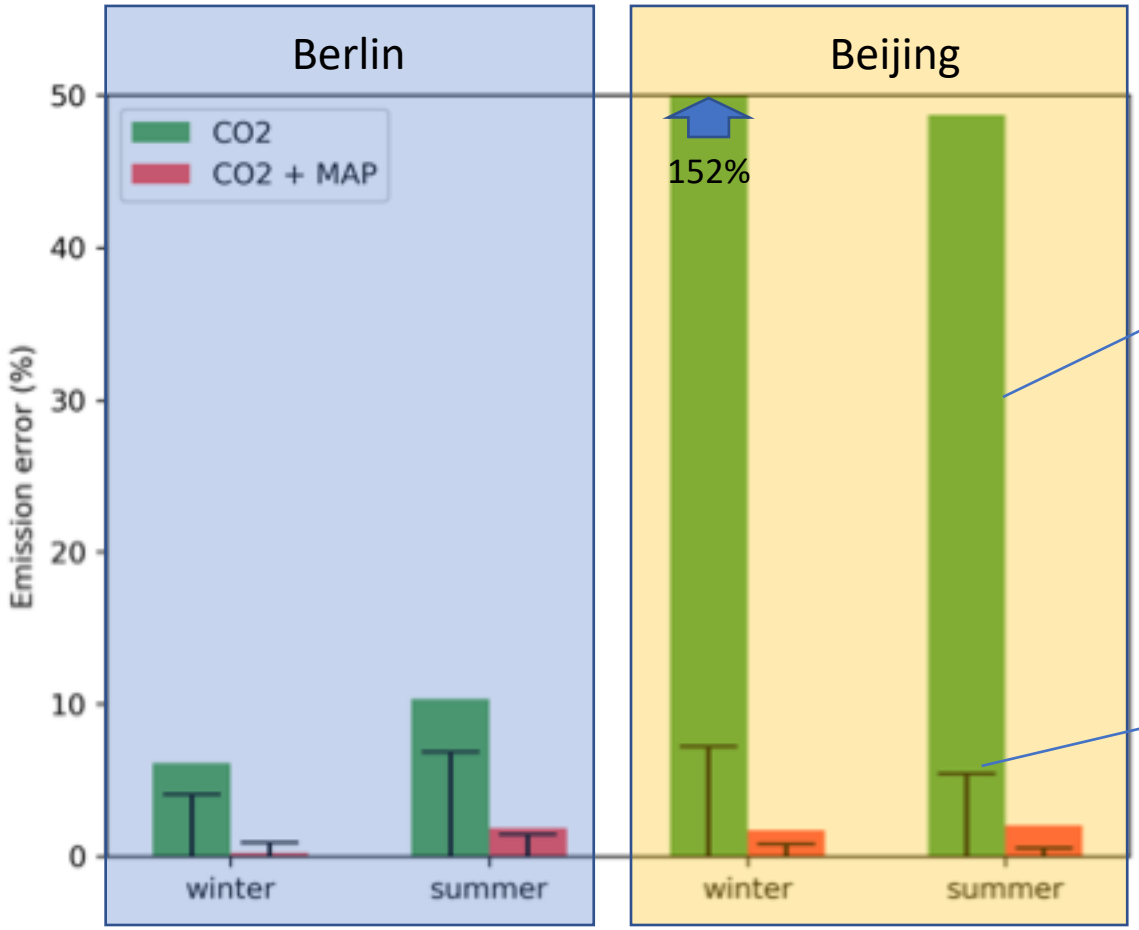
Results reference scenarios



Deviation from The "true" flux

Posterior flux uncertainty

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General outcome and implications

- **Without MAP:** Overall reasonable performance for Berlin, but no useful results for Beijing.

- **With MAP:** Overall much improved performance, including useful results over Beijing.

Within CHE: Extension to other cities / cases using datasets prepared for 2015

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