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CO_2 remote sensing, the role of aerosols, and benefits of dedicated aerosol measurements

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[2]: SRON Netherlands Institute for Space Research

[3]: Max-Planck Institute for Chemistry

[4]: The Royal Netherlands Meteorological Institute (KNMI)

ESA-AeroCarb & CHE

- ESA funded scientific support study for CO2-M (June 2017 – December 2019)

- Application of the approach extended within CHE (WP2.5)

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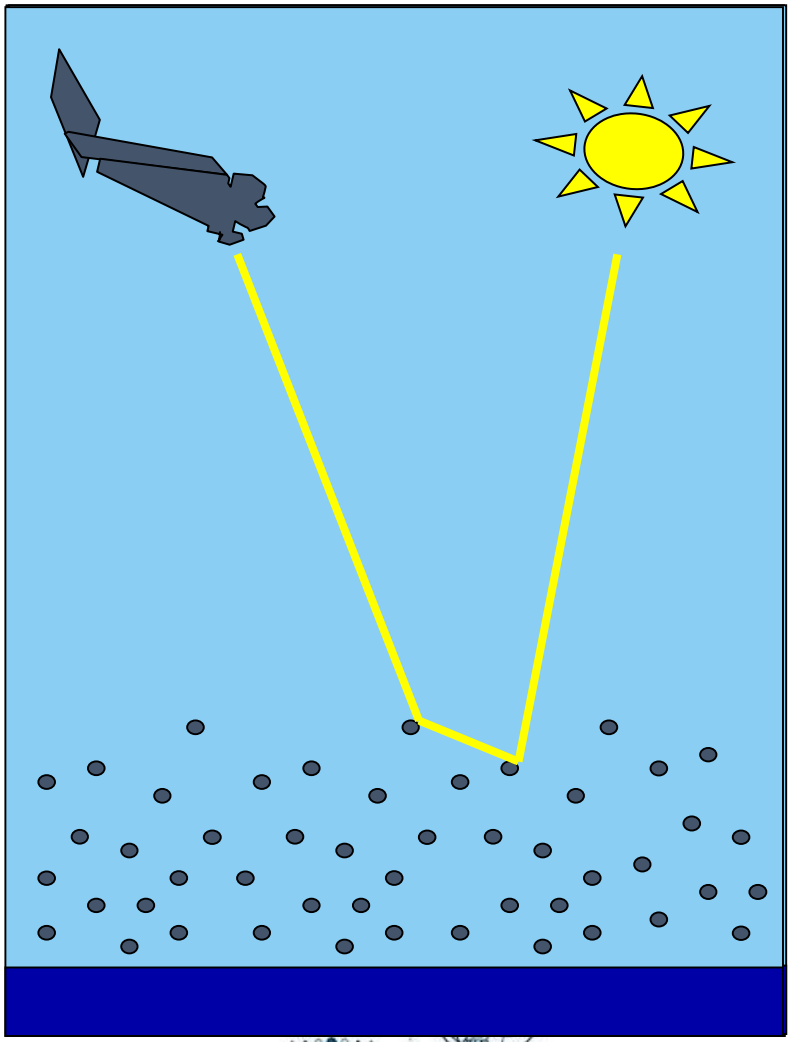
The link between CO2 & aerosols

Path < l



Albedo dependent error of up to a few % if uncorrected

CO2-M requirement: < 0.5 ppm

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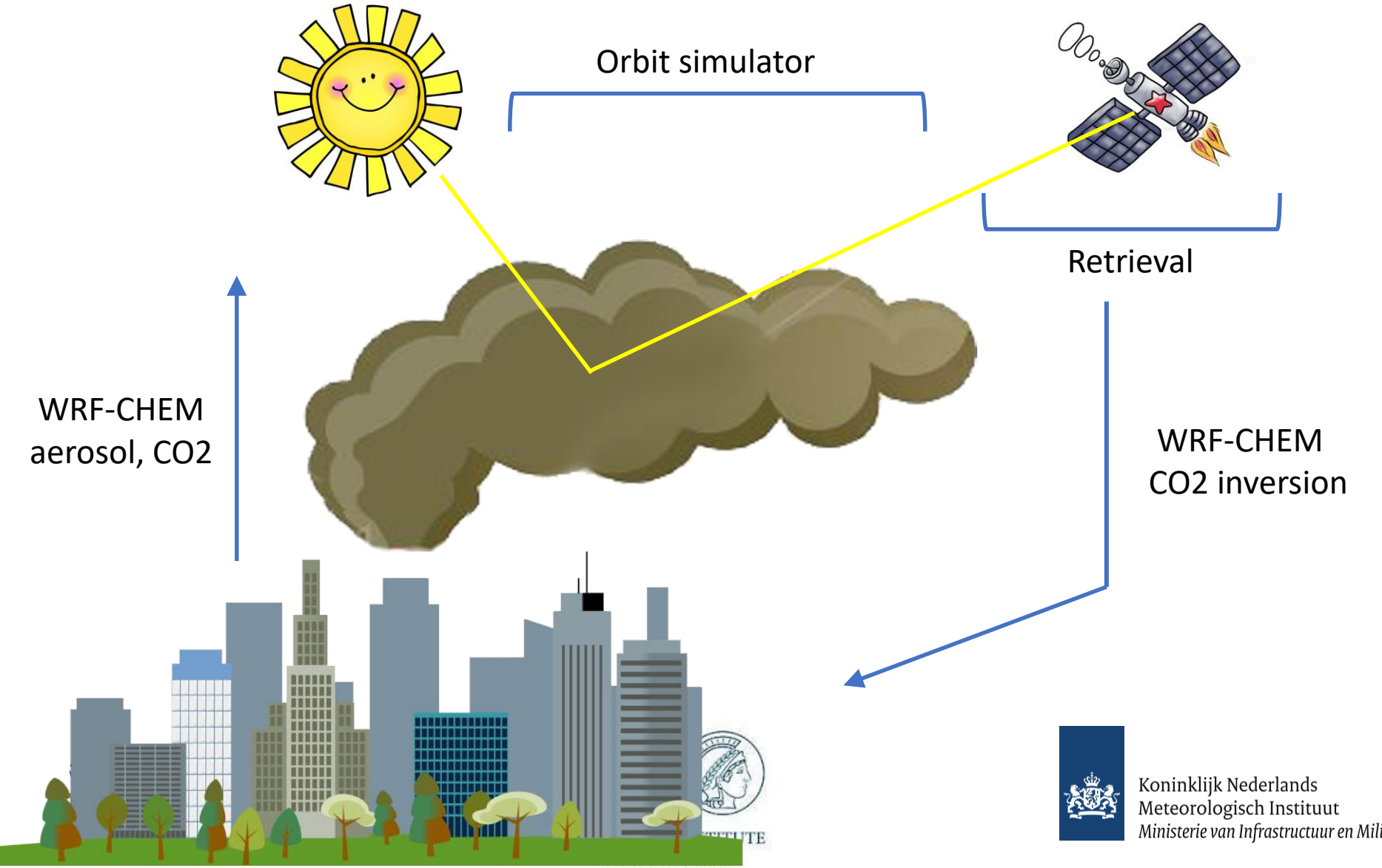
Schematic project outline



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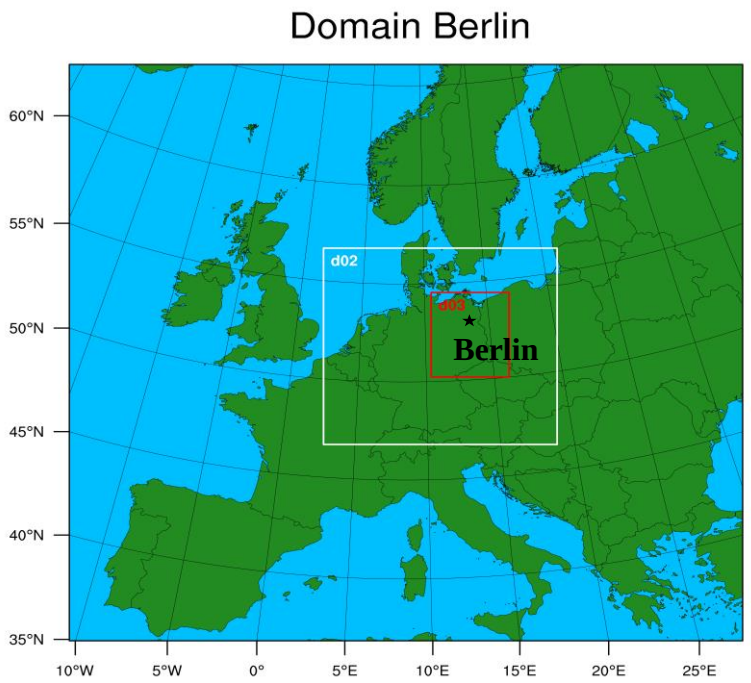
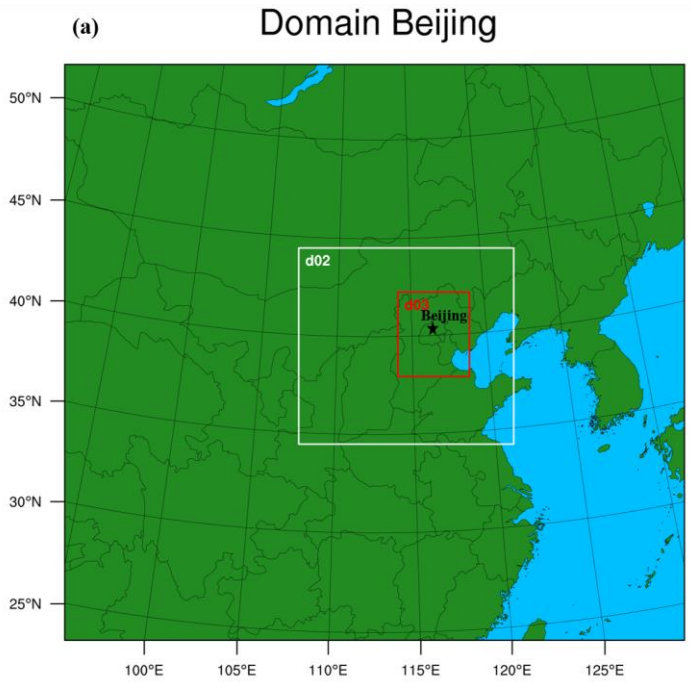
WRF-CHEM domains





- Summer & winter case, year 2013
- Inner domain at 4x4km^2

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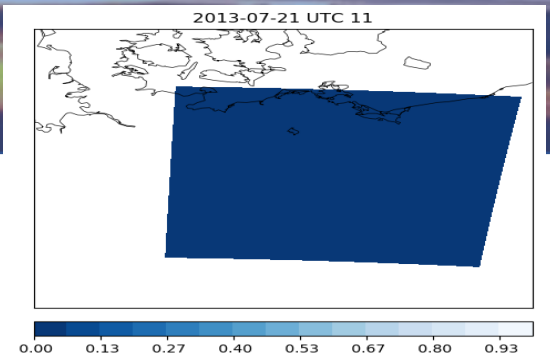
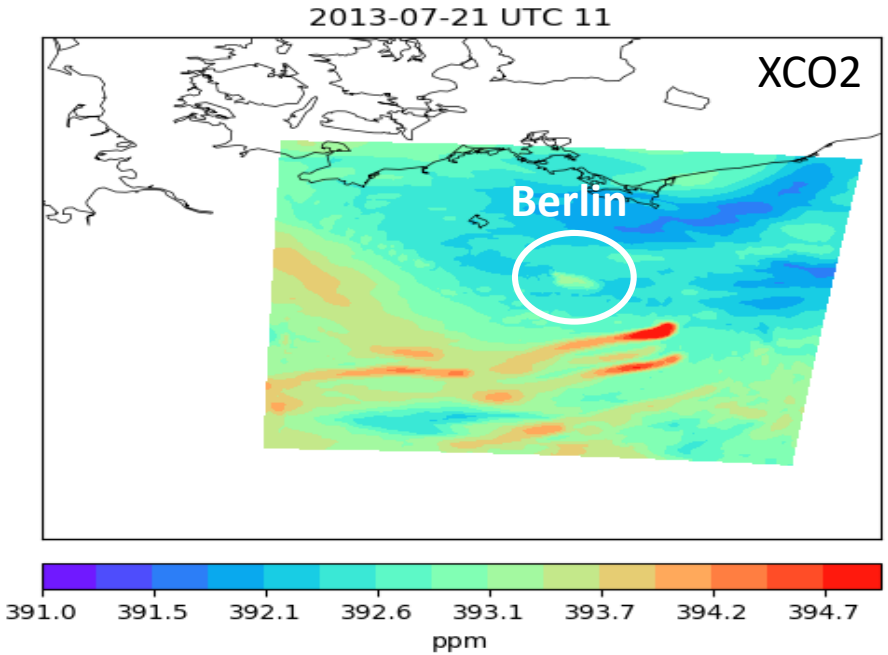
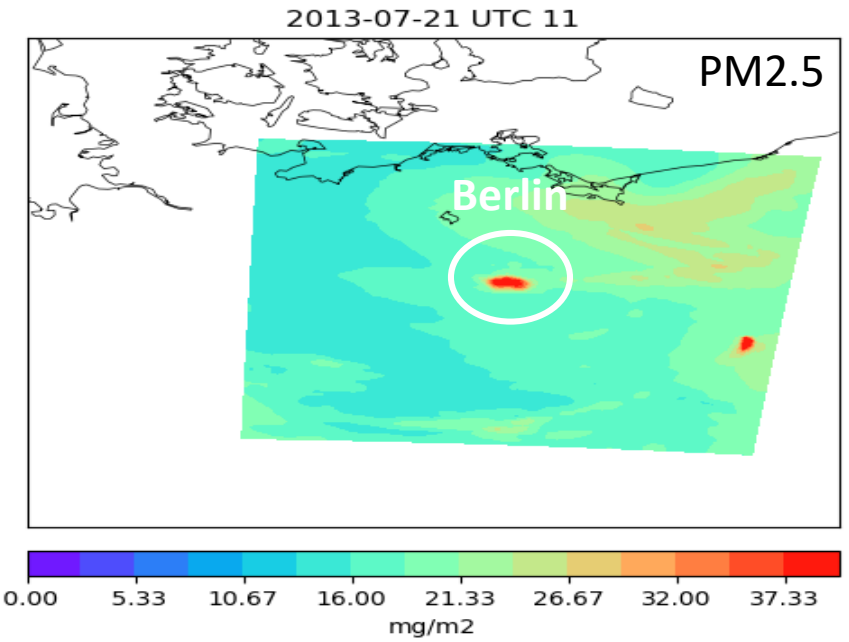
Case: Berlin summer



Cloud fraction

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





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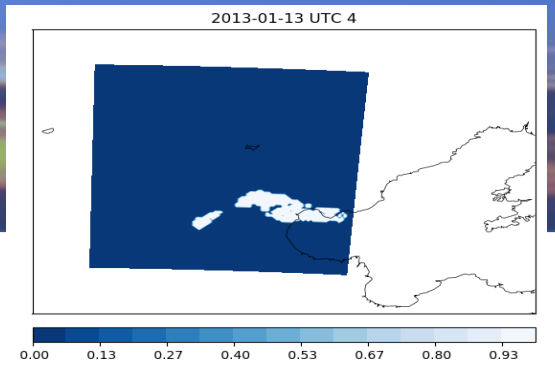
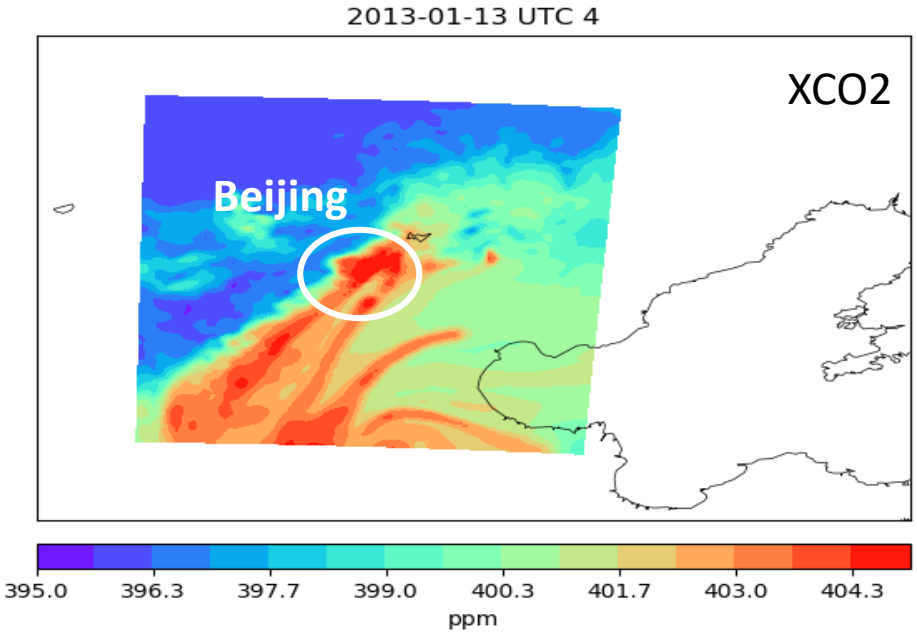
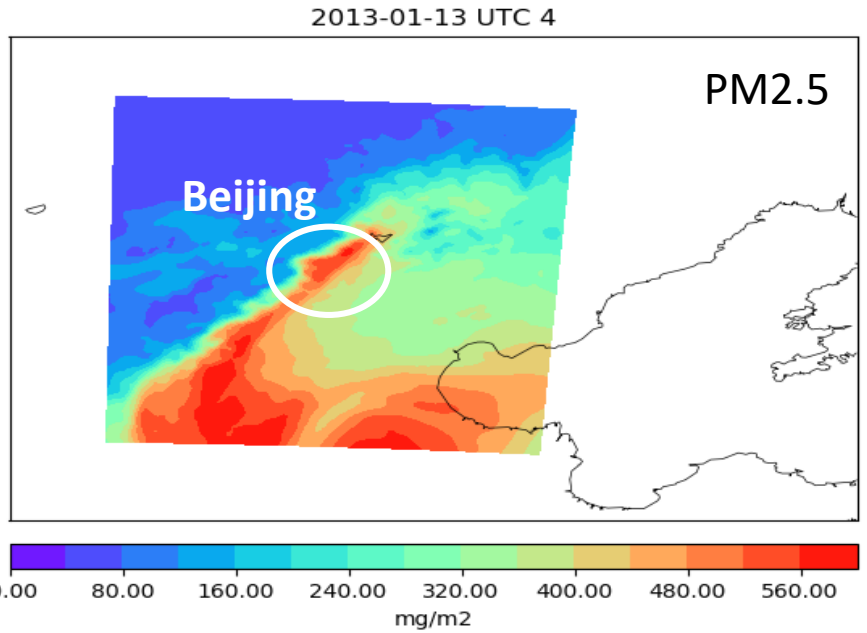
Cases: Beijing winter



Cloud fraction

- Much larger signals in XCO2 & Aerosols





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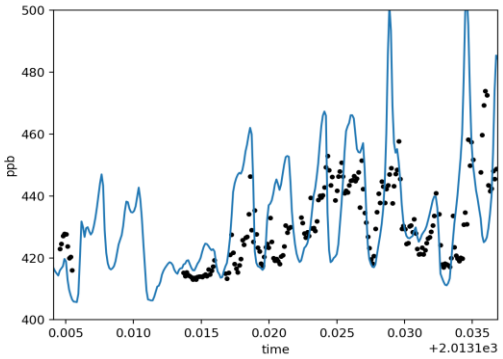
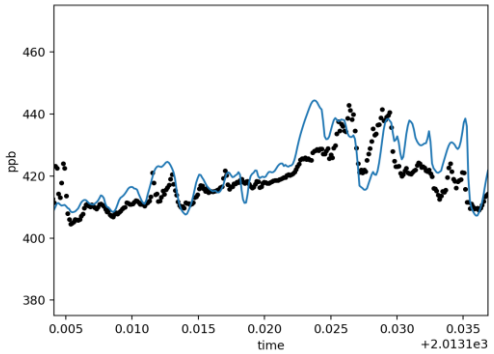
Comparison to surface data

Winter

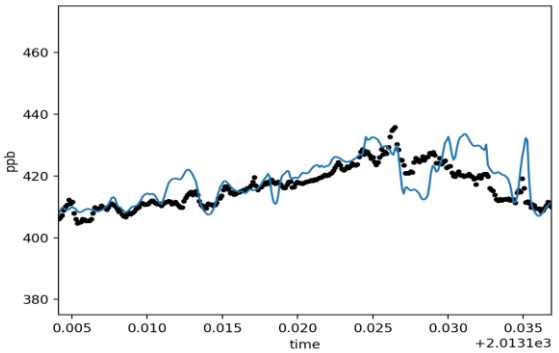
Heidelberg



Hegyhatsal (10m)



Hegyhatsal (100m)

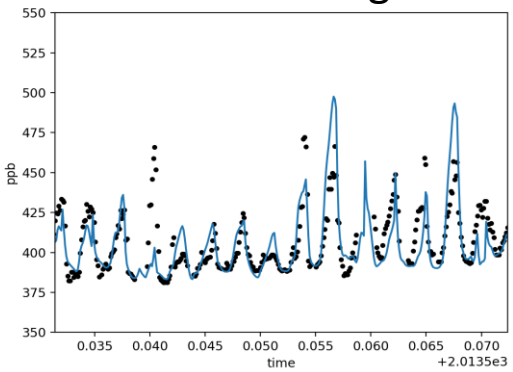


WRF

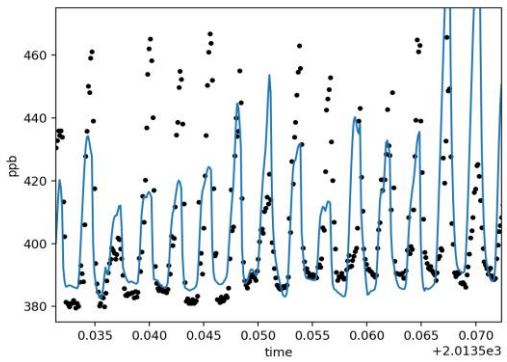
Obs

Summer

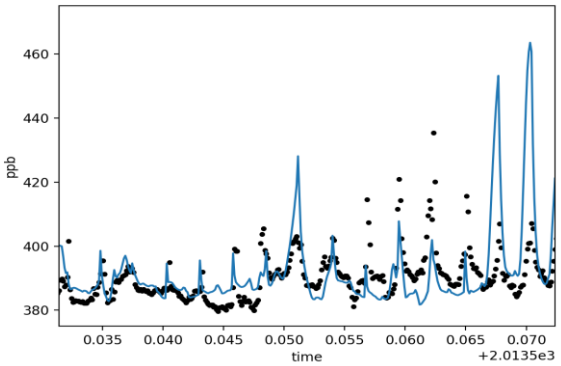
Heidelberg



Hegyhatsal (10m)



Hegyhatsal (100m)



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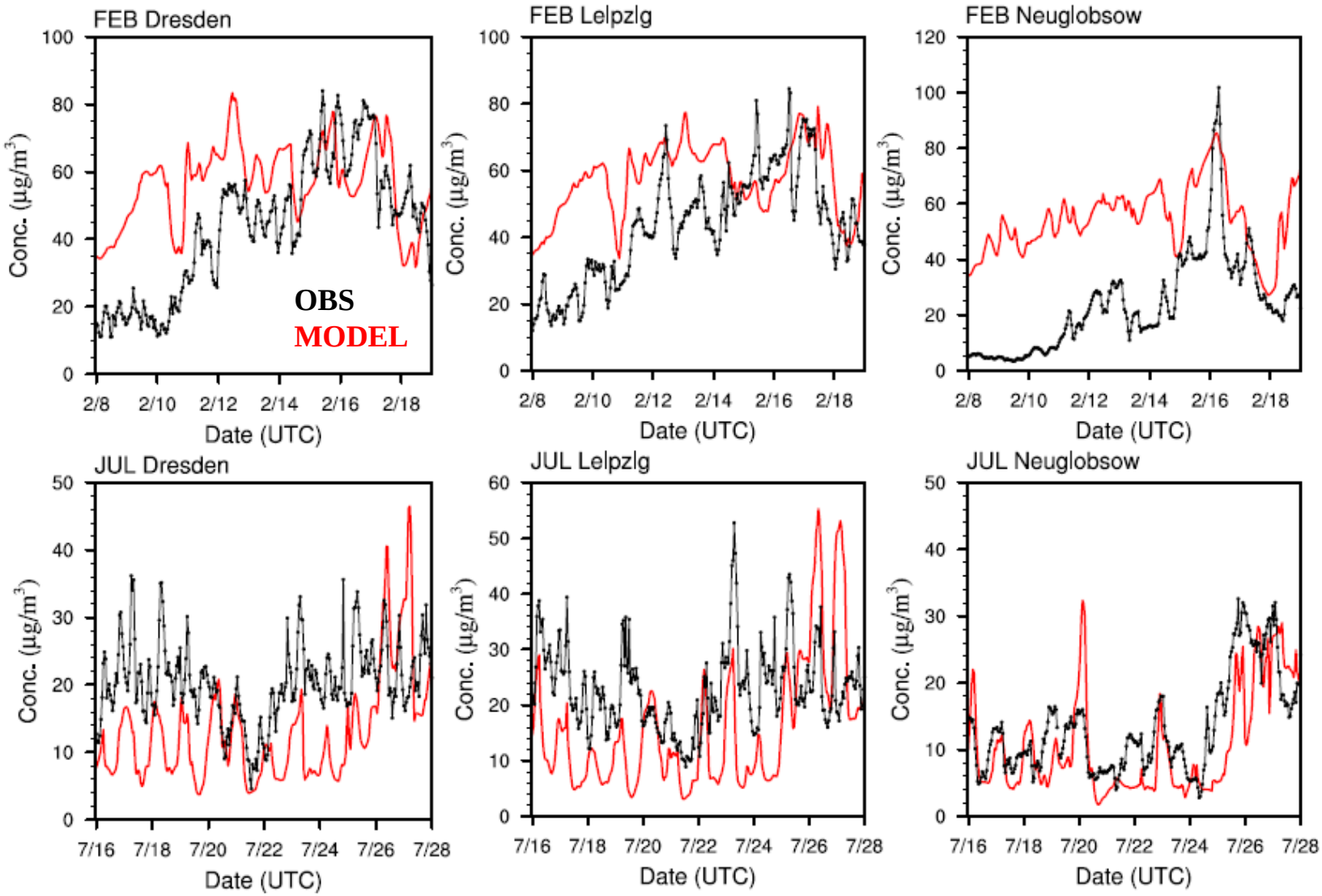
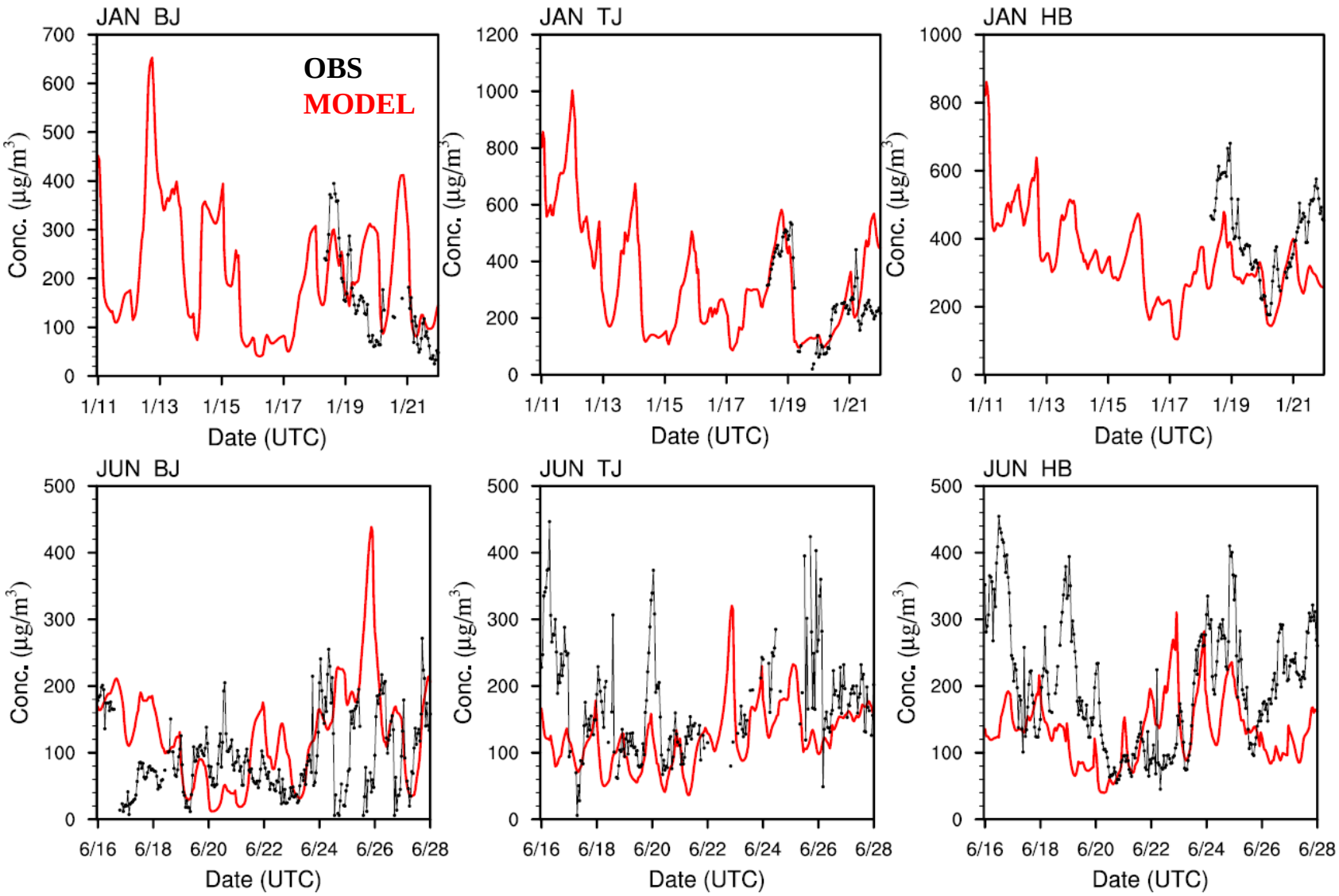
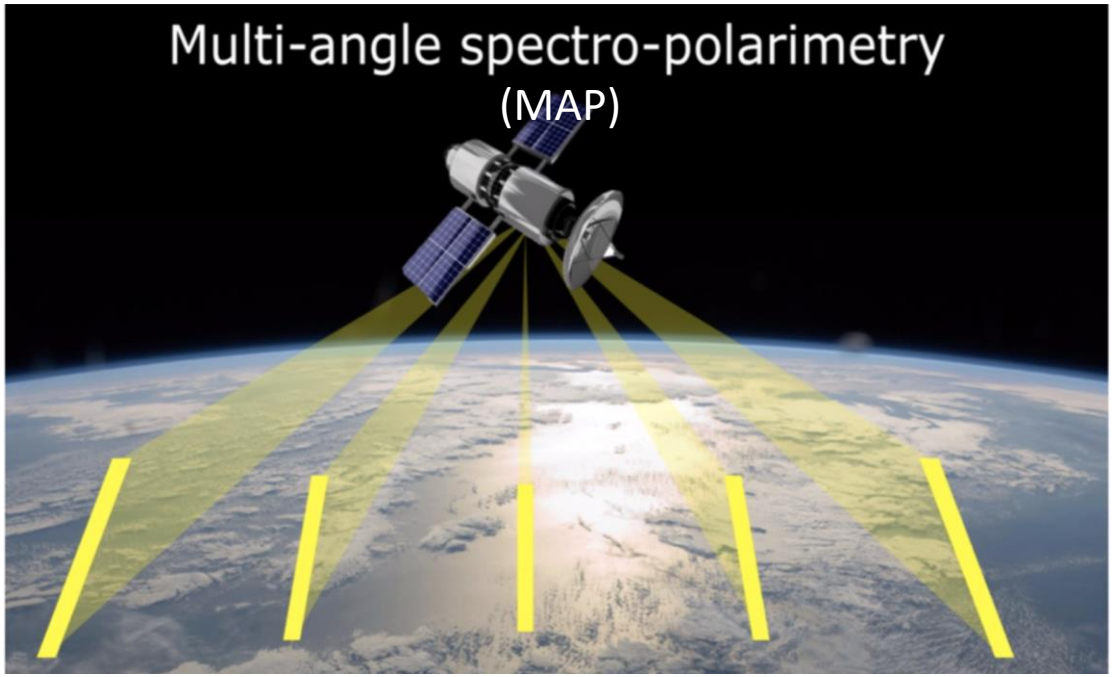
Surface PM_{10} evaluation for Berlin case



Surface PM_{10} evaluation for Beijing case



Aerosol measurements



Spectral radiance:
385 – 765 nm

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

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

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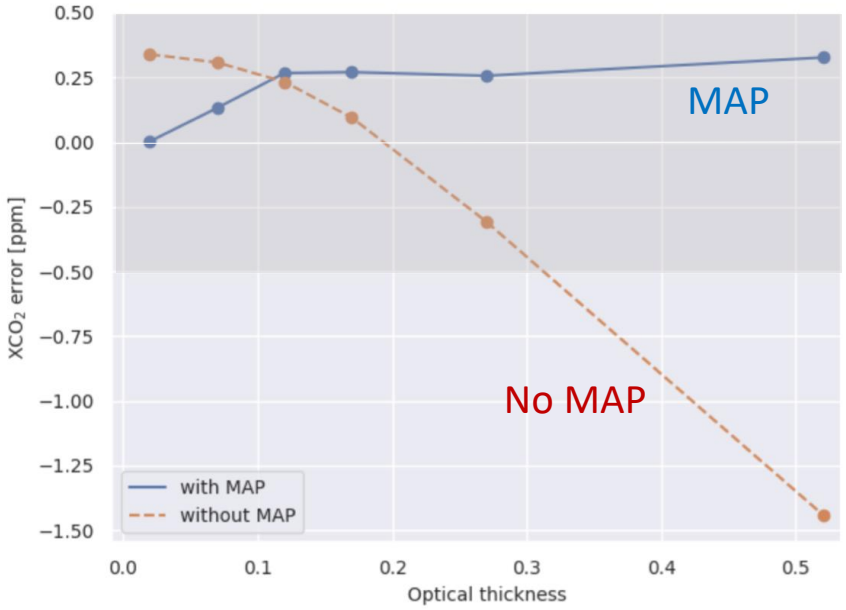
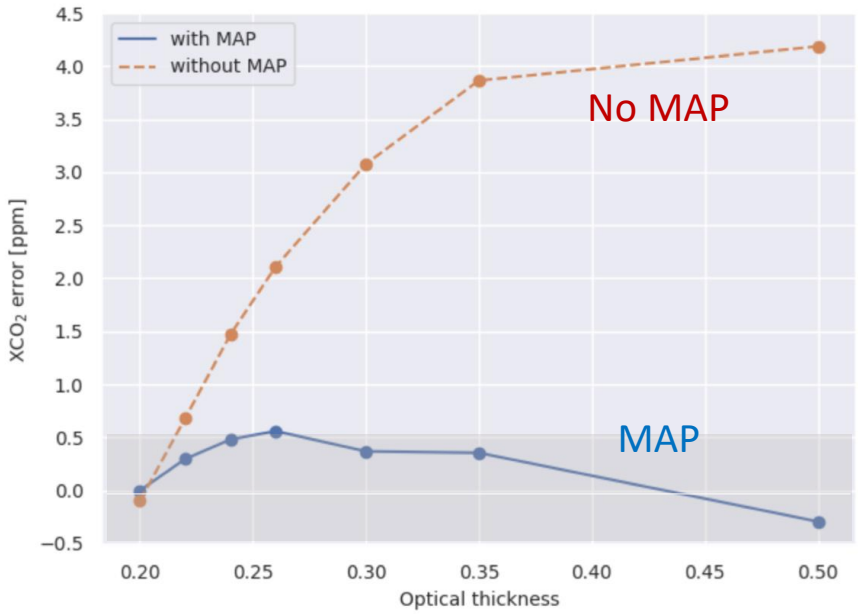
Added value of MAP

Added value of MAP-mod with optimal setup:

Case1, vegetation , SZA=60 degrees



Case2, soil, SZA=60 degrees



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

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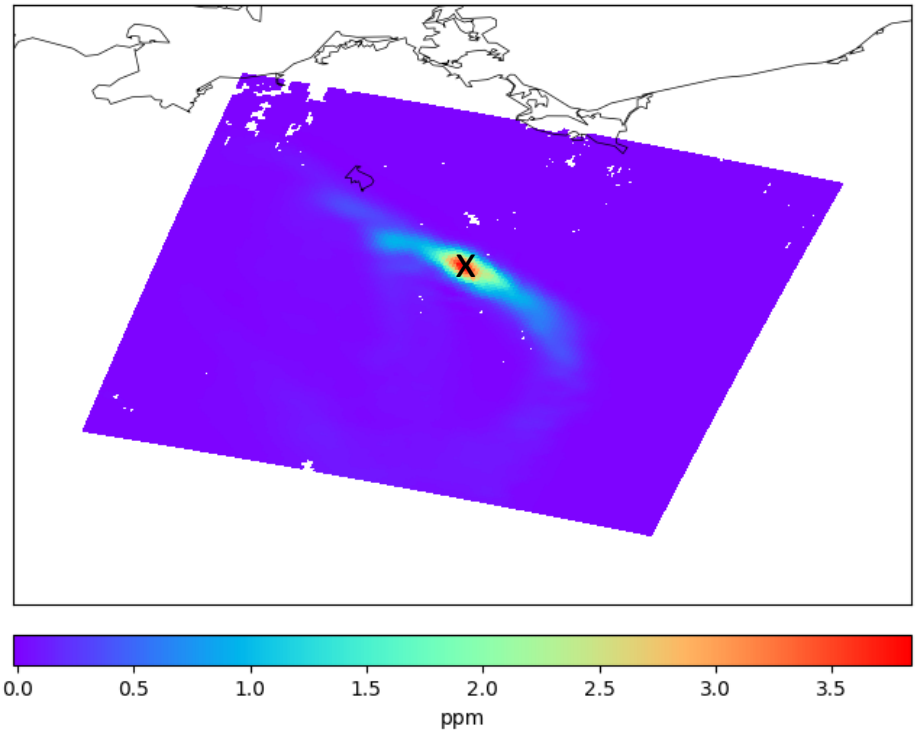
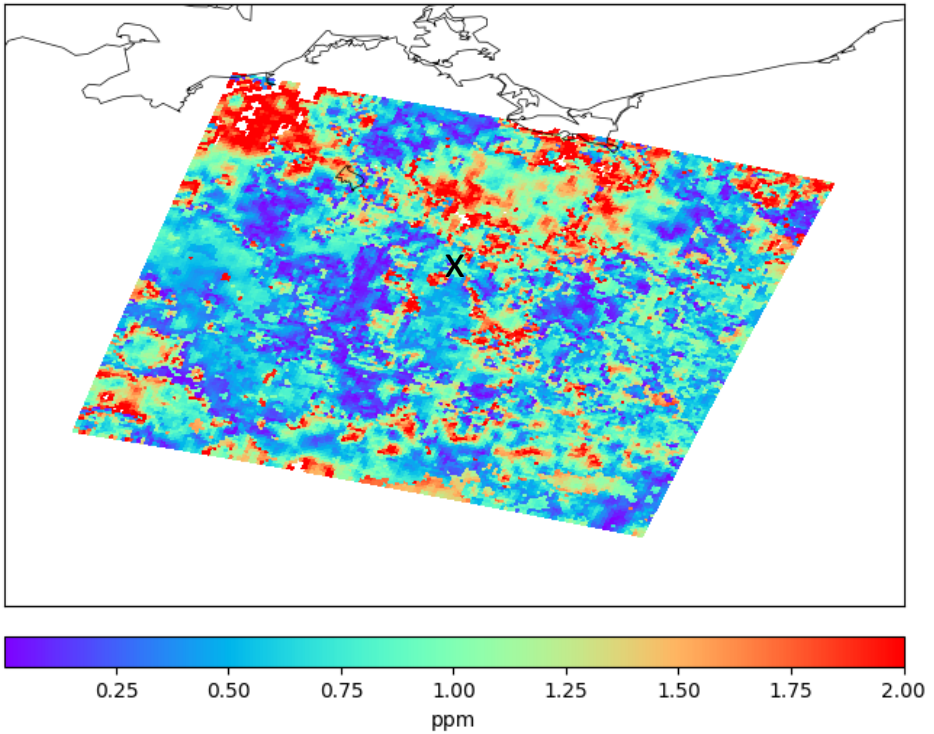
City plume: Berlin Winter

Berlin XCO_2 plume



ε_{syst} CO_2 sensor only



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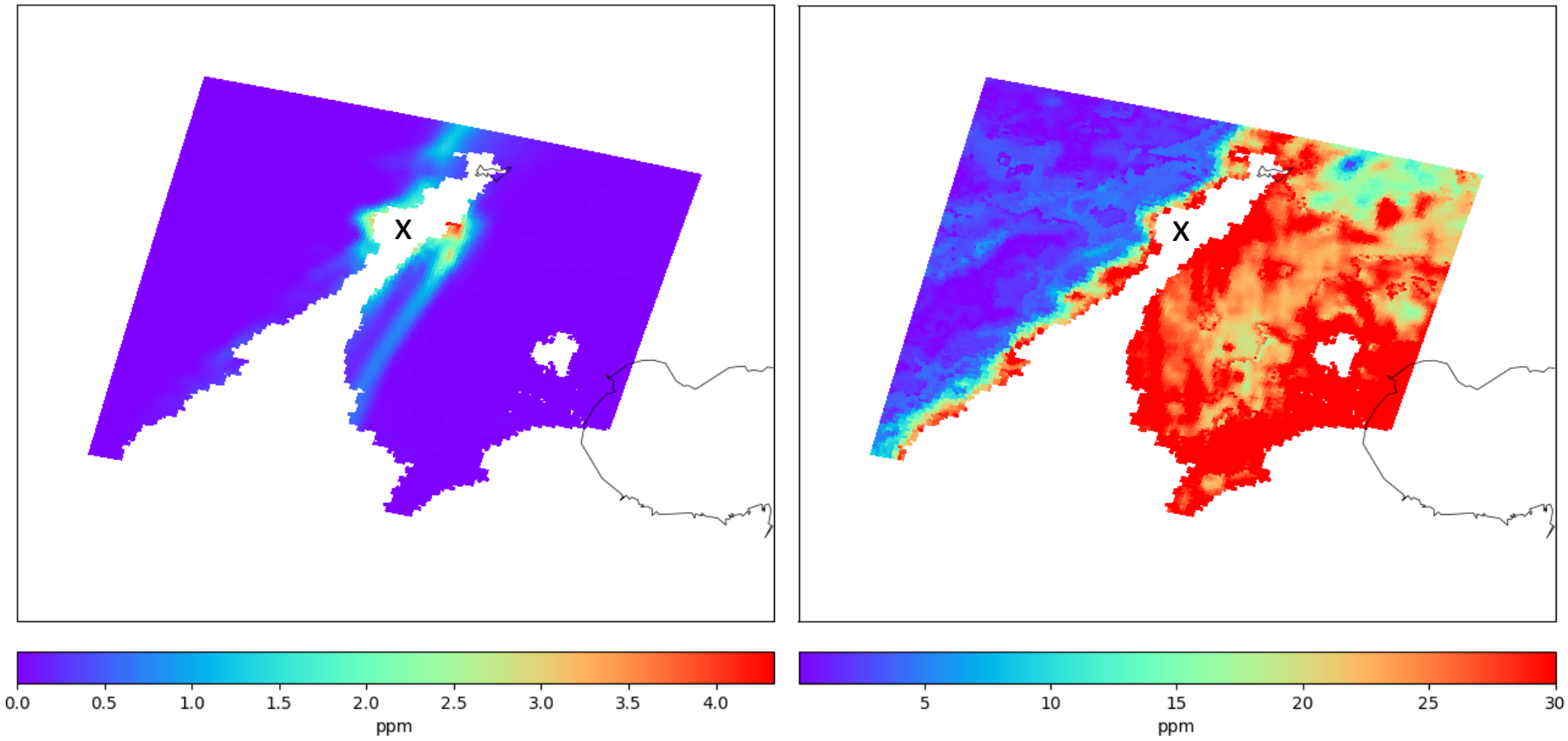
City plume: Beijing winter

Beijing XCO_2 plume

ε_{syst} CO_2 sensor only



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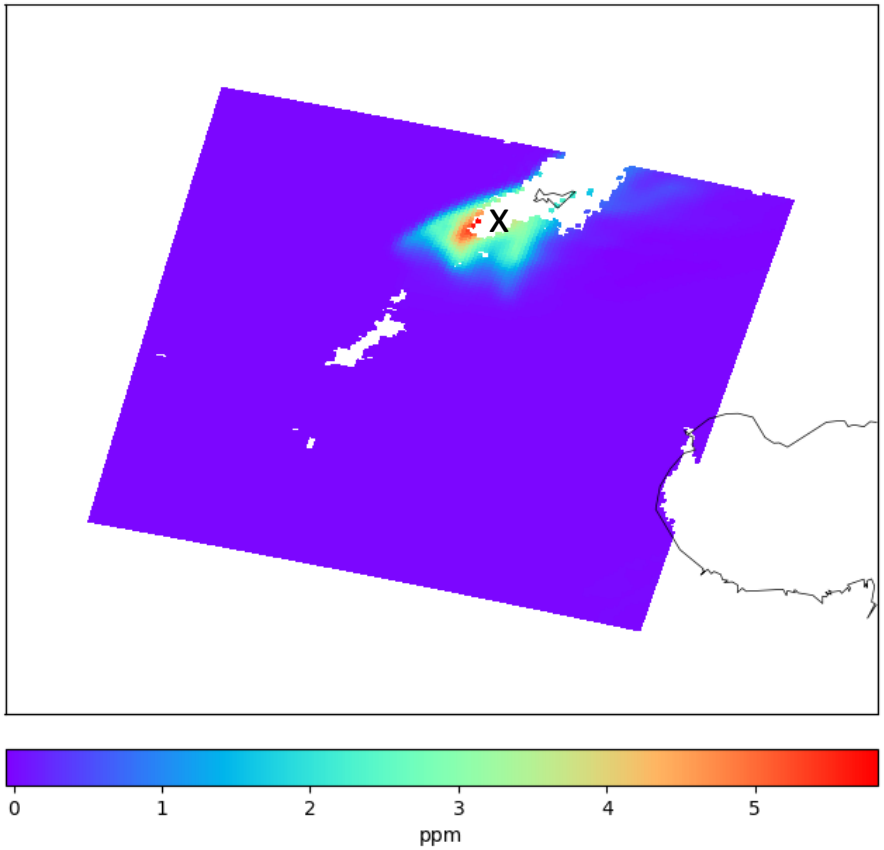
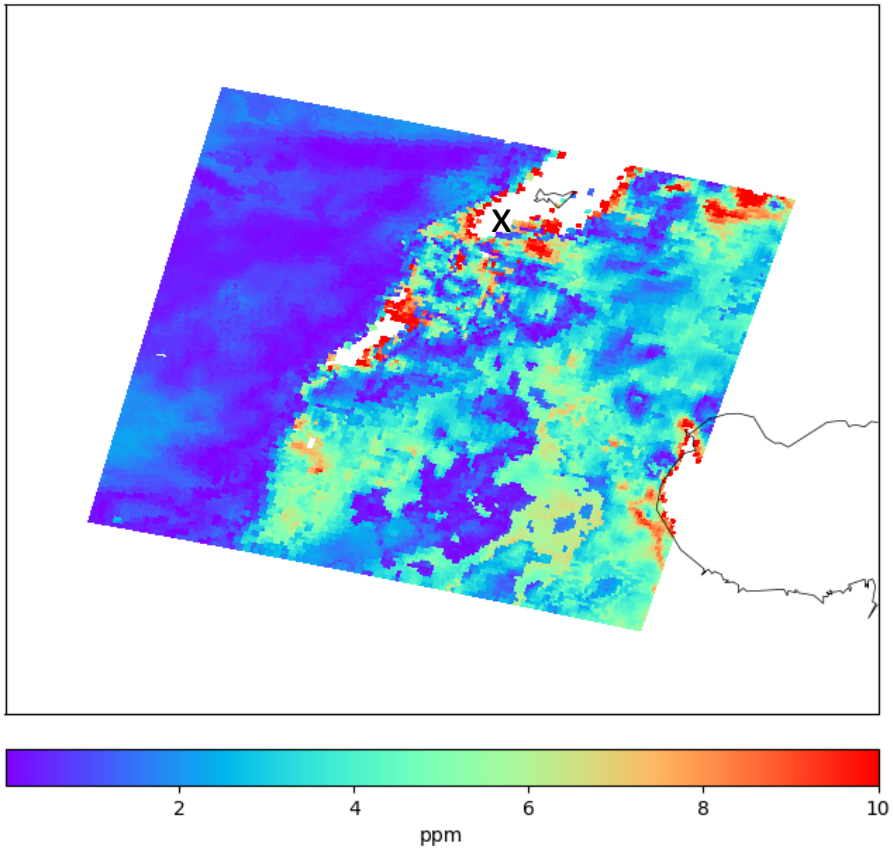
City plume: Beijing summer

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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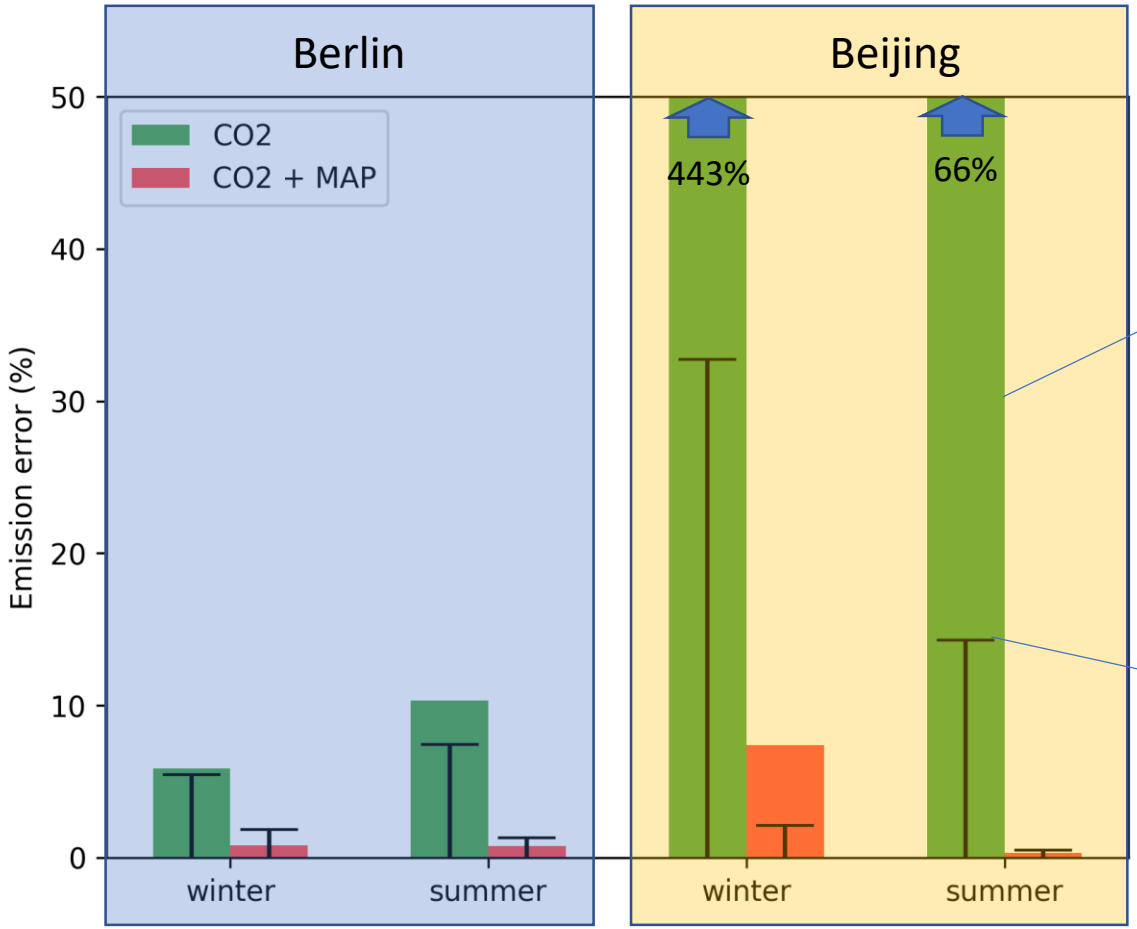
Results reference scenarios



Deviation from The "true" flux

Posterior flux uncertainty

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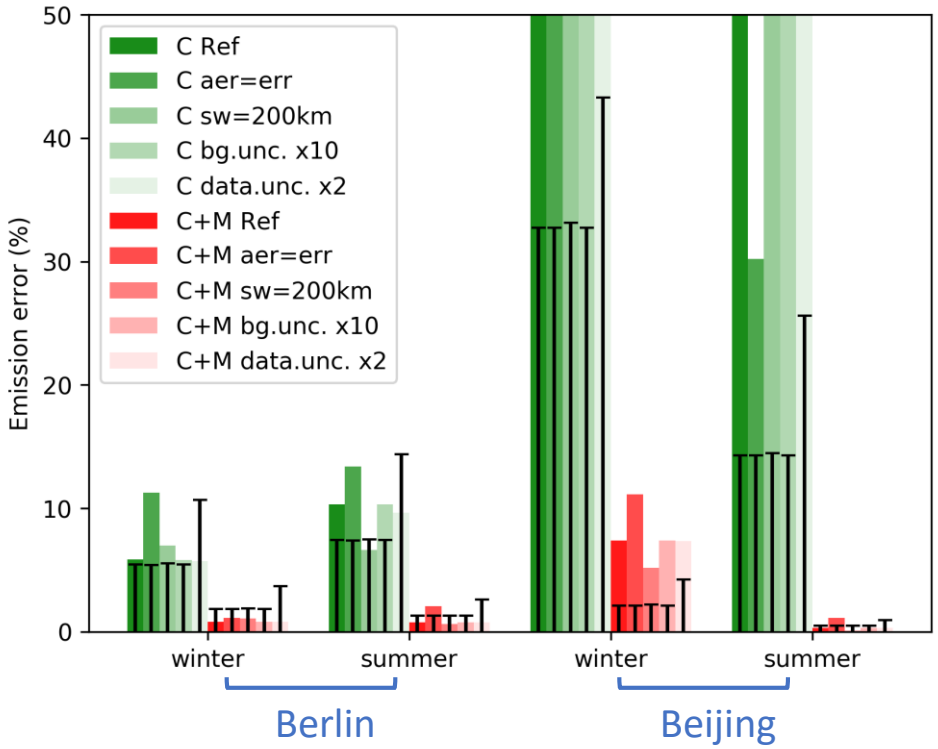
Main Outcomes (2)



> MAP effectively accounts for the impact of systematic error on derived CO2 estimates
> This is critical in particular to improve the CO2M performance for polluted cities

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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