

High-Resolution Accounting for the Urban Biogenic CO₂ Emissions: Insights from the Metropolitan Area of Barcelona

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1. Background

In response to the escalating climate crisis, cities are implementing green infrastructures(GI), such as green rooftops, urban street trees and parks, to offset CO₂ emissions from anthropogenic activities^[1-2],yet accurately quantifying biogenic CO₂ fluxes in urban areas remains challenging due to the interplay of photosynthetic uptake and respiration, seasonal variability, the heterogeneous distribution of GI, urban climate and soil conditions^[3-5]. Biosphere models have been used to quantify carbon exchange processes but often employed at the ecosystem level and coarse spatial resolutions(10-100km) ^[6-7],estimating biogenic CO₂ emissions at high resolution in urban scale (10 m–1 km) is critical. This study aims to provide guidance for creating more robust ways of accounting for the contribution of urban green to aid urban planners and policymakers in the design and implementation of GI.

Research questions:

- 1) How effective is urban greenery in reducing CO₂ emissions in the Metropolitan Area of Barcelona(AMB)?
- 2) To what extent does improved resolution enhance our ability to identify urban biogenic CO₂ emissions?

2. Model Simulations

We use the Vegetation Photosynthesis and Respiration Model (VPRM)^[8] (Defalut DefVPRM), a modified VPRM(ModVPRM; incorporates soil moisture)^[9],WRF-Chemv4.3.3 ^[10] atmospheric model

- VPRM:
- Vegetation indexes: EVI and LSWI from Modis , Sentinel2(S2)
 - Land cover map: Corine land cover , Local land cover with tree classification
 - Temperature, Solar Radiation, and Soil Moisture(WRF)

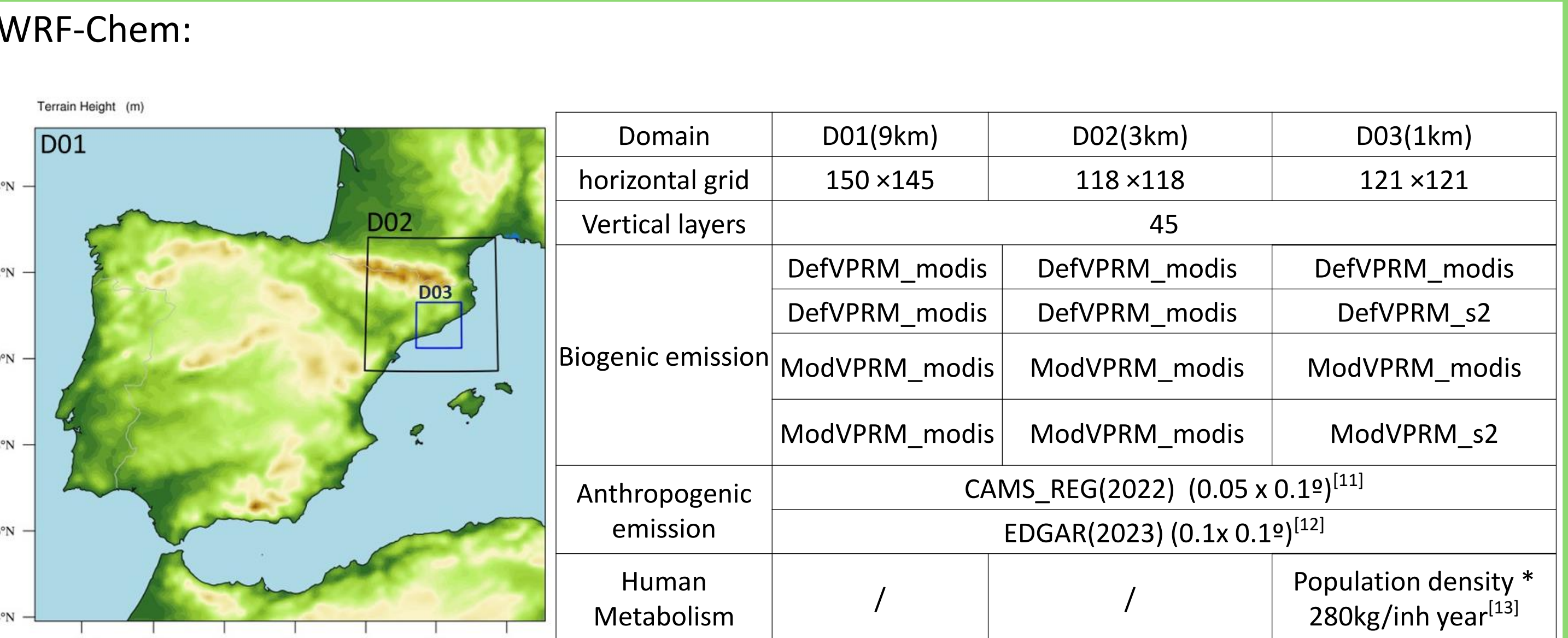


Table 1. model settings and emission inventories

- Figure 1. model domains
- Simulation Period: (spin-up time is 2 days) April and December, 2023
 - Ocean emissions from ICOS portal ^[14]
 - Chemical Boundary from CAMS global inversion dataset ^[15]
 - Different emission inventories are treated as different tracers in WRF-Chem

3. Estimated Emission

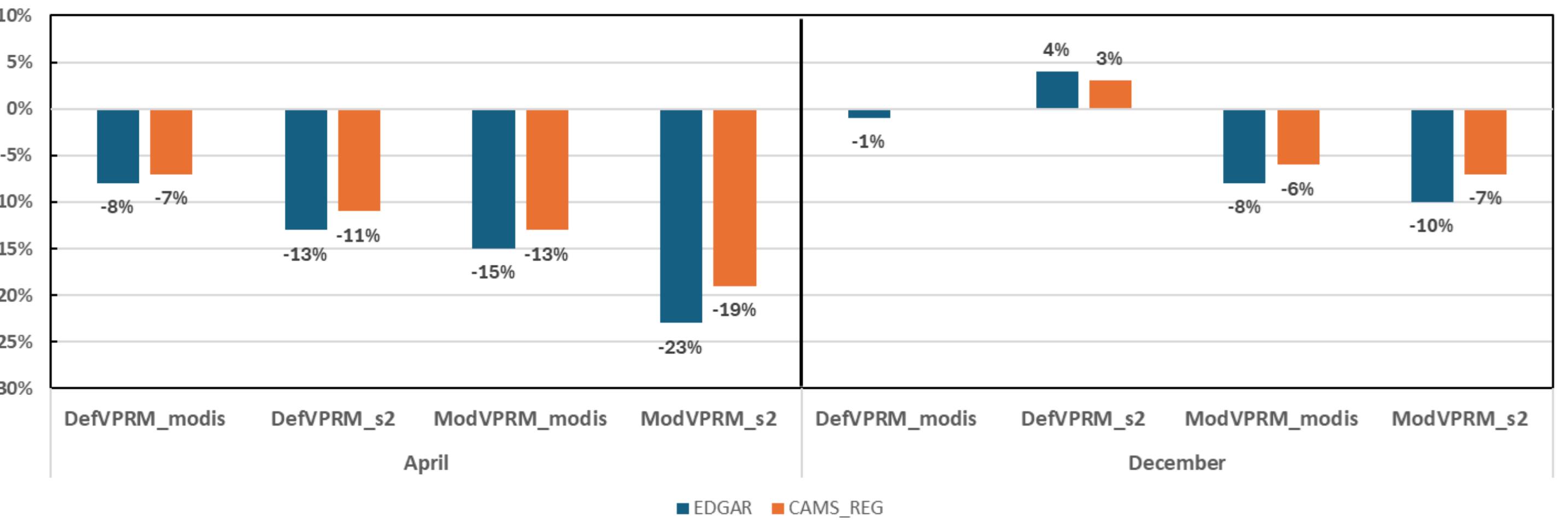


Figure 2. offset percentage of biospheric CO₂ emissions relative to anthropogenic emissions in April and December across different VPRM configurations

• $P_{\text{offset}} = \frac{\text{Biogenic CO}_2 \text{ emissions}}{\text{Anthropogenic CO}_2 \text{ emissions}}$

- Estimated anthropogenic emissions over AMB from CAMS_REG are higher than EDGAR
- Urban vegetation can offset 7%-23% of anthropogenic emissions in April while 1%-10% in December.

- All VPRM configurations show a strong uptake of CO₂ during the daytime in April, S2 versions show slightly higher CO₂ uptake compared to MODIS and Modified VPRM versions show stronger uptake than default versions.

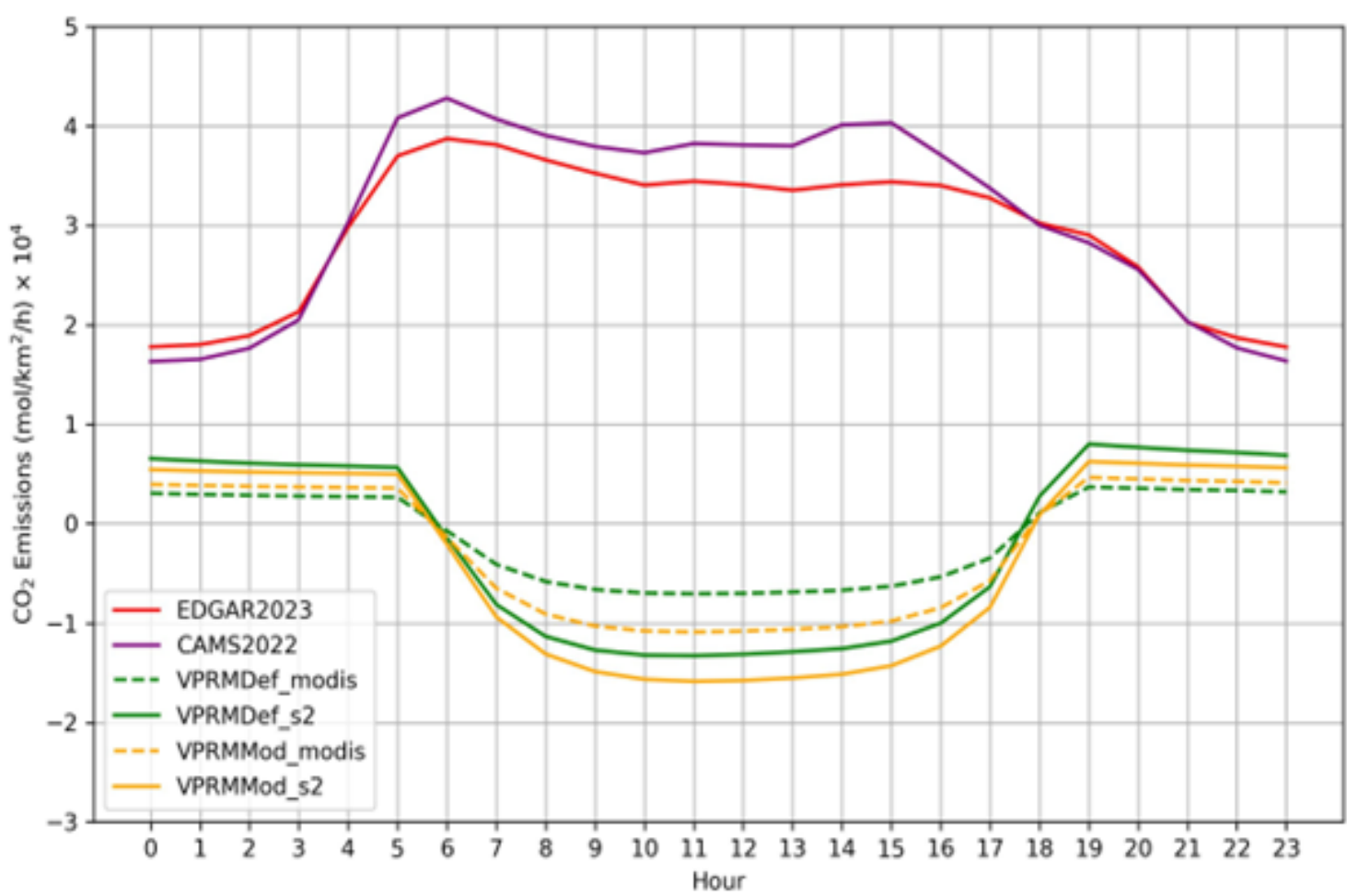


Fig 3. Diurnal change of CO₂ emission from different sections in April

4. Observed and Simulated CO₂ Concentration

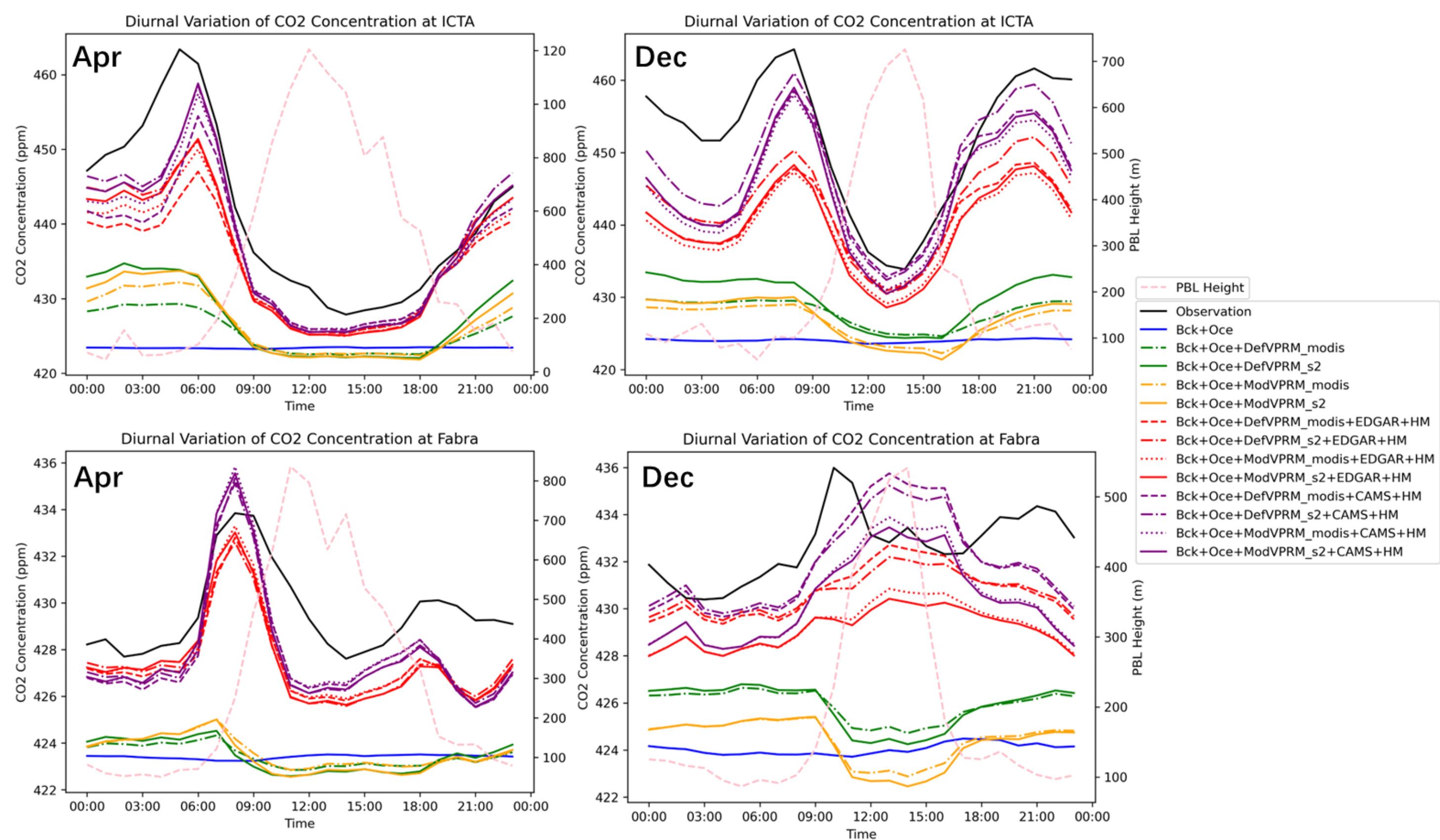


Fig 4. Monthly averaged diurnal cycle of CO₂ concentrations at ICTA(highway)and Fabra(forest) in April and December

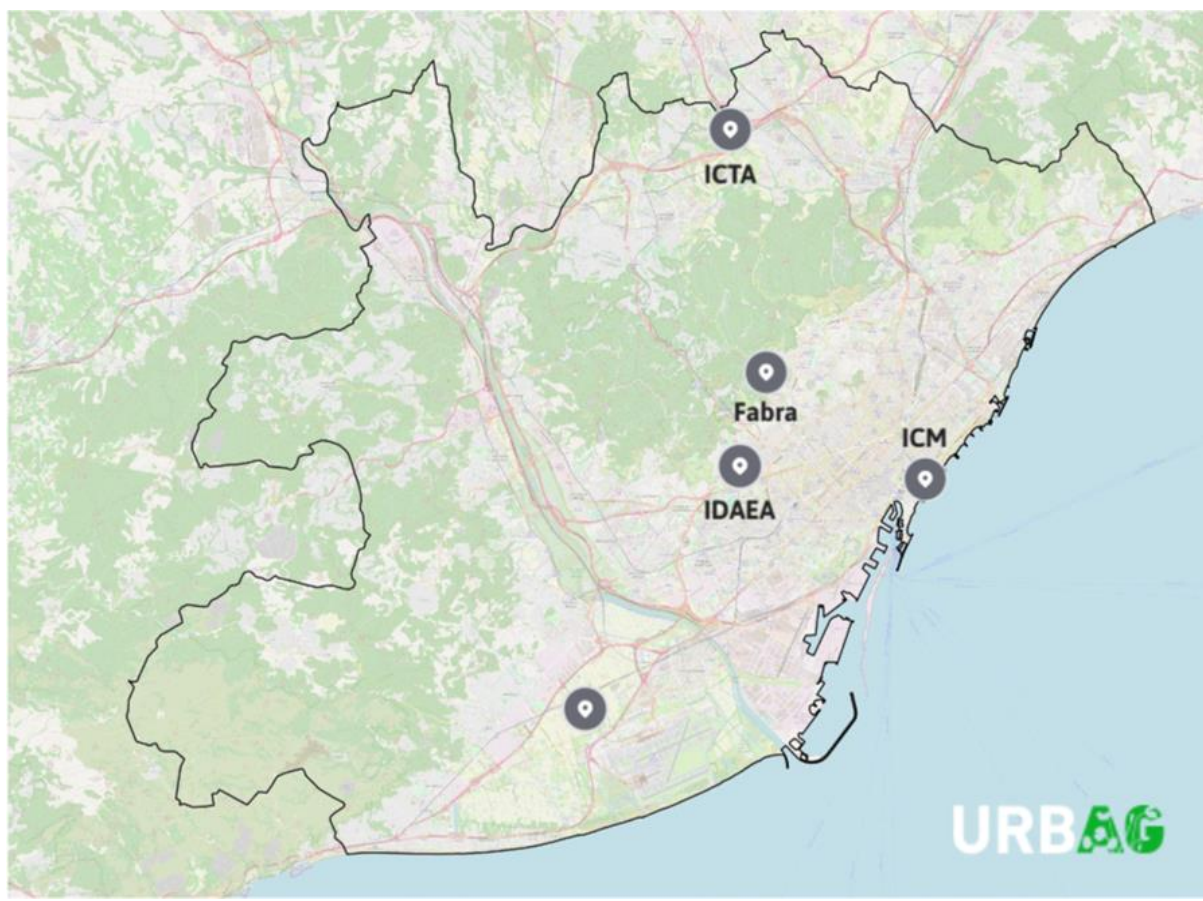


Fig 5. AMB monitoring network

- The model well captures the diurnal trend of CO₂ variation, total concentrations are generally underestimated, this may be attributed to overestimated Planetary Boundary Layer(PBL).
- The contribution of anthropogenic concentrations to the total concentrations from CAMS are generally higher than EDGAR, this is in accordance with the anthropogenic emission characteristics
- There is minor concentration difference between the S2 and MODIS versions, major changes are seen when comparing the default and the modified VPRMs.

5. Conclusions

- Urban vegetation can at most offset 23% of anthropogenic emissions in AMB. CO₂ offsets are much stronger in April compared to December, reflecting the seasonal cycle of vegetation activity.
- The strongest emission offset occurs in ModVPRM_s2, indicating that improved model with high resolution can estimate large CO₂ uptake.
- WRF-Chem well simulates the diurnal trend of total CO₂ concentration. The biospheric concentrations from different VPRM configurations show major difference between the default and the modified VPRMs instead of with different satellite inputs, highlighting the importance of incorporating parameters that influence CO₂ budget.

6. Future Work

- Further simulations over a year to study the annual emissions and concentrations in AMB
- Run different VPRMs with meteorological inputs from WRF at 10 meters, getting the biogenic emissions at finer resolution
- Compare the anthropogenic emissions from global datasets (CAMS, EDGAR) with local high resolution inventory(1km) and the simulated concentrations with more stations in AMB

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