High-Resolution Quantification of Biogenic CO_2 Fluxes over a Metropolitan Area

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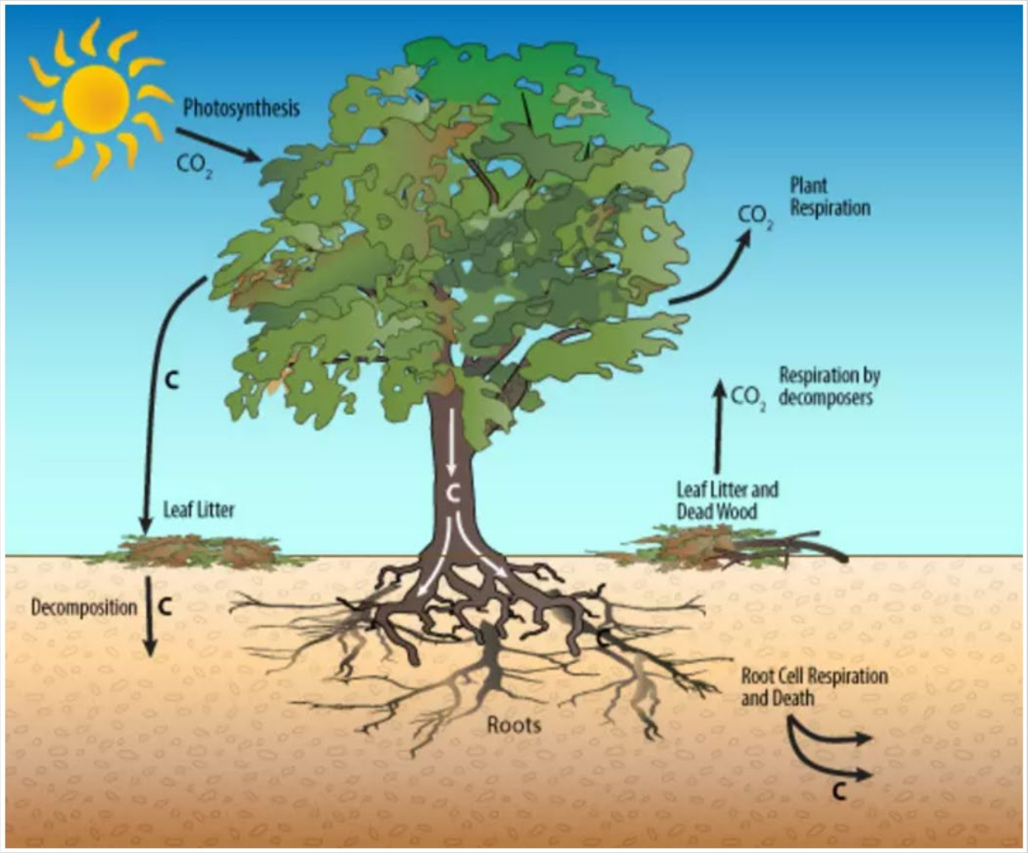
Background



Carbon Cycle of a Single Tree. Credit: Valerie Martin, TERC

Quantify biogenic CO_2 fluxes at the urban scale(10m-1km) is critical and challenging

URBAG Integrated System Analysis of Urban Vegetation and Agriculture

https://urbag.eu/

Motivation

Determine efficacy of mitigation strategies involving Green Infrastructures

1) **How effective is urban greenery in reducing CO_2 emissions in a Metropolitan Area?**

- Biogenic CO_2 fluxes estimation at 1km in the Metropolitan Area of Barcelona (AMB)

Vegetation Photosynthesis and Respiration Model [VPRM]

2) To what extent does the improved resolution and parameterization enhance our ability to identify urban biogenic CO_2 emissions?

- Different VPRM configurations
- Estimated biogenic fluxes are evaluated with atmospheric CO_2 observations

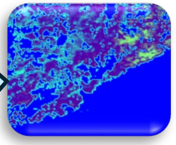
Method

INPUT

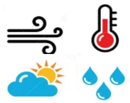
EMISSION

CONCENTRATION

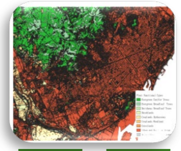
MONITORING NETWORK



Vegetation indexes



Meteorological data (WRF)



Land Cover

Biogenic CO_2 emission

Vegetation Photosynthesis and Respiration Model (VPRM)[1]

calculate biosphere's gross primary production and respiration

Anthropogenic emission inventory datasets

Anthropogenic CO_2 emission

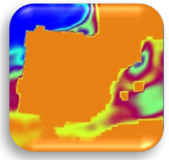
High-Elective Resolution Modelling Emission System(HERMES)[2]

Python-based and multi-scale modelling tool for the processing and computation of atmospheric emissions for air quality and greenhouse modelling

Population density map

Emission factor

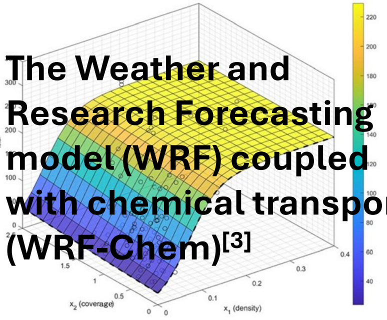
Human Metabolism



Ocean fluxes over Europe

Ocean CO_2 emission

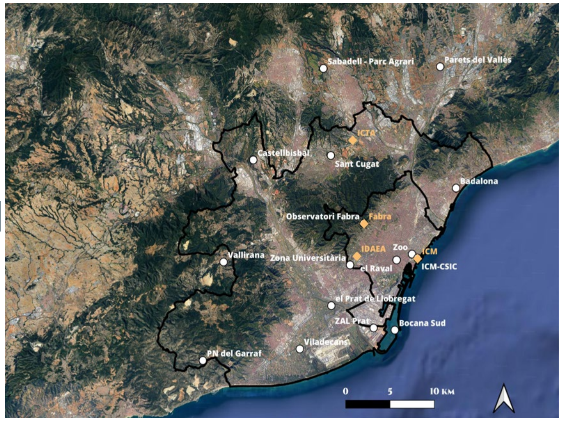
Atmospheric Model



The Weather and Research Forecasting model (WRF) coupled with chemical transport (WRF-Chem)[3]

validate

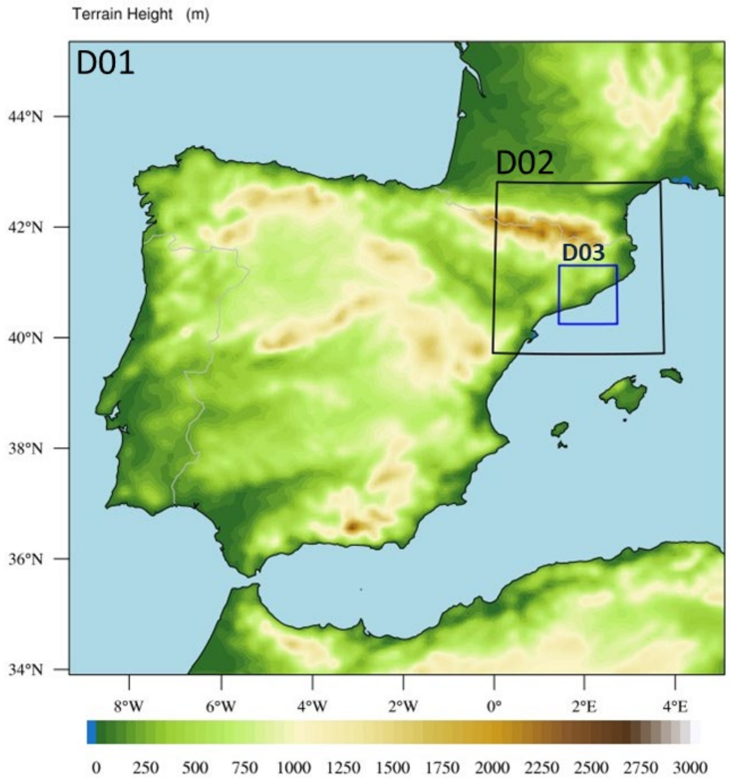
Weather stations GHG stations



* Different emissions are treated as different tracers in WRF-Chem

- Weather stations Meteocat
- GHG stations: https://urbag.eu/ghg/ ICOS cities portal

WRF-Chem Set up



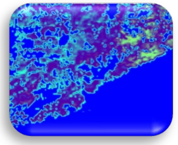
Domain	D01(9km)	D02(3km)	D03(1km)
horizontal grid	150 ×145	118 ×118	121 ×121
Vertical layers	45		
Biogenic emission	VPRMDef_modis	VPRMDef_modis	VPRMDef_modis
	VPRMDef_modis	VPRMDef_modis	VPRMDef_s2
	VPRMMod_modis	VPRMMod_modis	VPRMMod_modis
	VPRMMod_modis	VPRMMod_modis	VPRMMod_s2
Anthropogenic emission	CAMS (2022) (0.05 x 0.1º)[4]		
	EDGAR(2023) (0.1x 0.1º)[5]		
Human metabolism	/	/	Population density * 280kg/inh year[6]
Ocean emission	ICOS[7]		
Chemical boundary	CAMS global inversion dataset[8]		

Simulation period: (spin-up time is 2 days)

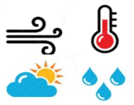
April and **December, 2023**

modis

sentinel2 (s2)

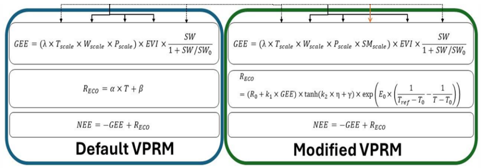


Vegetation indexes (500m;10m[9])

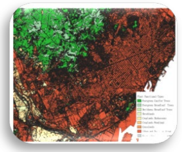


Meteorological data (Temperature, Solar Radiation, and Soil Moisture from WRF at 1km)

VPRMDef VPRMMod

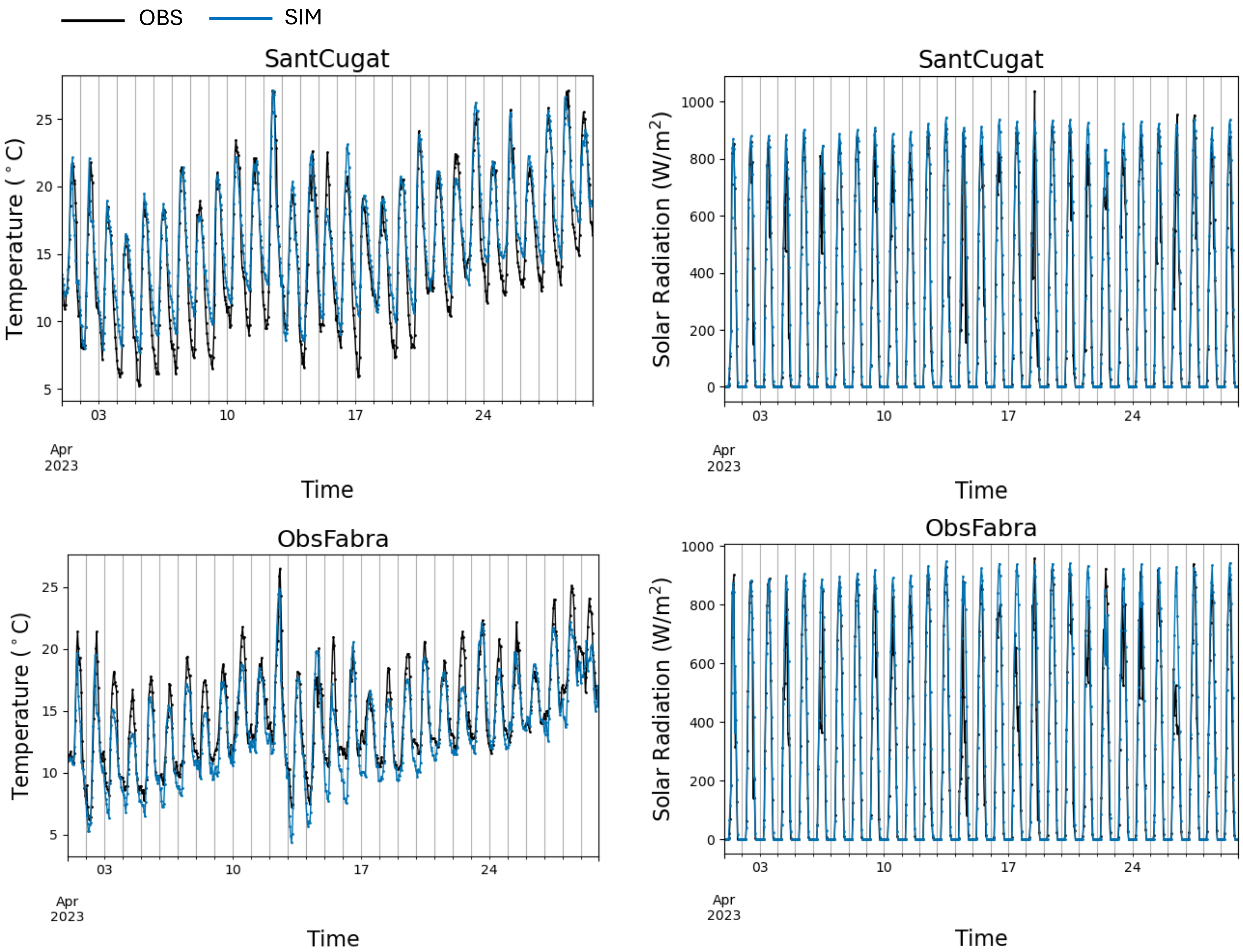


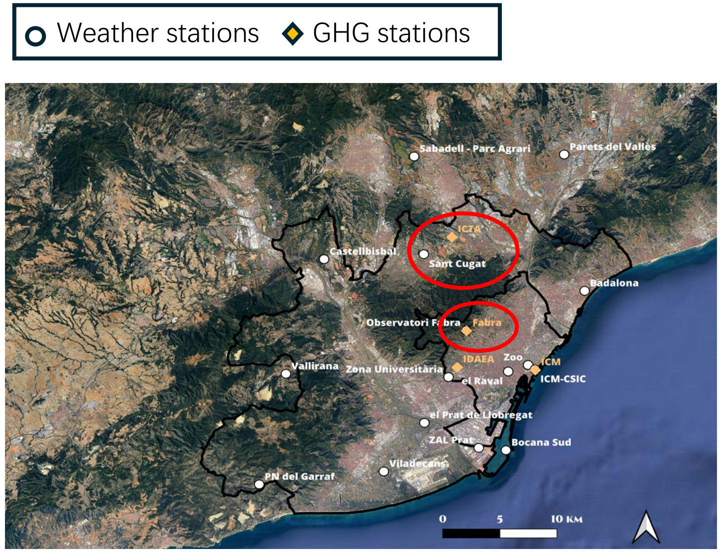
- Modified VPRM accounting for soil moisture effects and a better respiration parameterization[10]



Land Cover (local map with tree classification;10m)

Meteorology validation

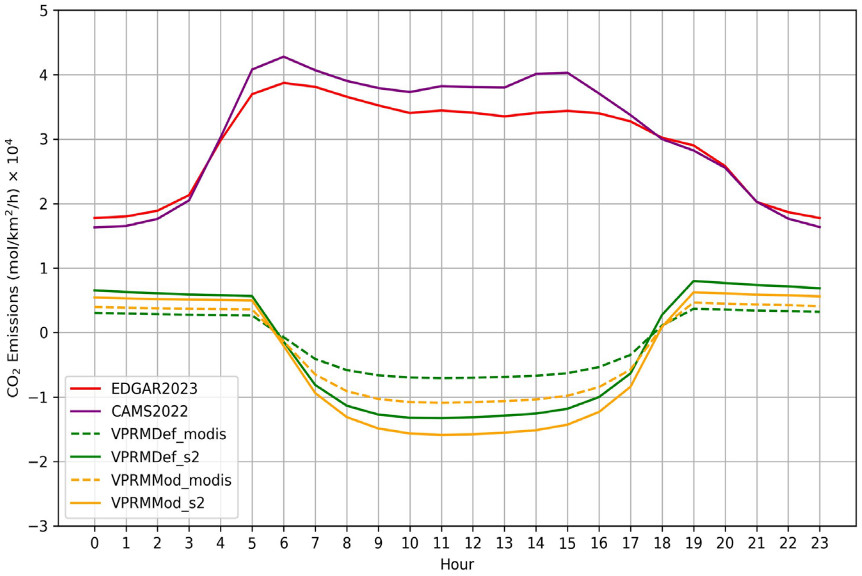




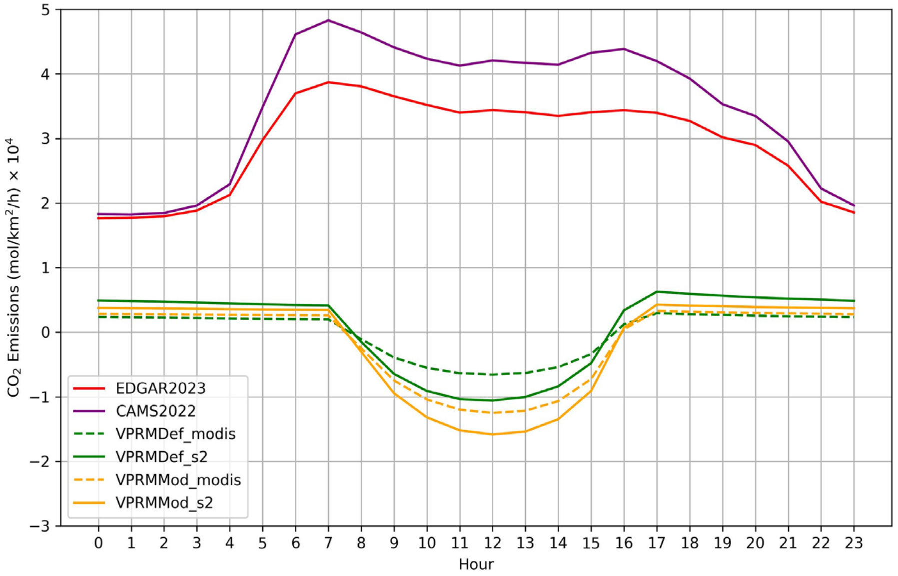
	Temperature			Solar radiation		
	RMSE	MB	R	RMSE	MB	R
April	1.49	0.18	0.94	2.11	0.70	0.88
December	92.51	30.04	0.97	43.11	10.77	0.96

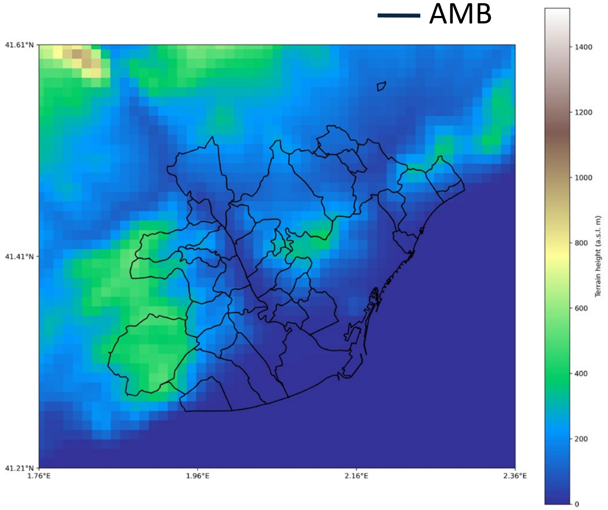
Estimated Emission pattern

April



December





$$\text{Poffset}=\frac{Biogenic\ CO2\ emisssions}{Anthropogenic\ CO2\ emissions}$$

	April		December	
Biospheric offset(%)	EDGAR2023	CAMS2022	EDGAR2023	CAMS2022
VPRMDef_modis	-8%	-7%	-1%	0%
VPRMDef_s2	-13%	-11%	4%	3%
VPRMMod_modis	-15%	-13%	-8%	-6%
VPRMMod_s2	-23%	-19%	-10%	-7%

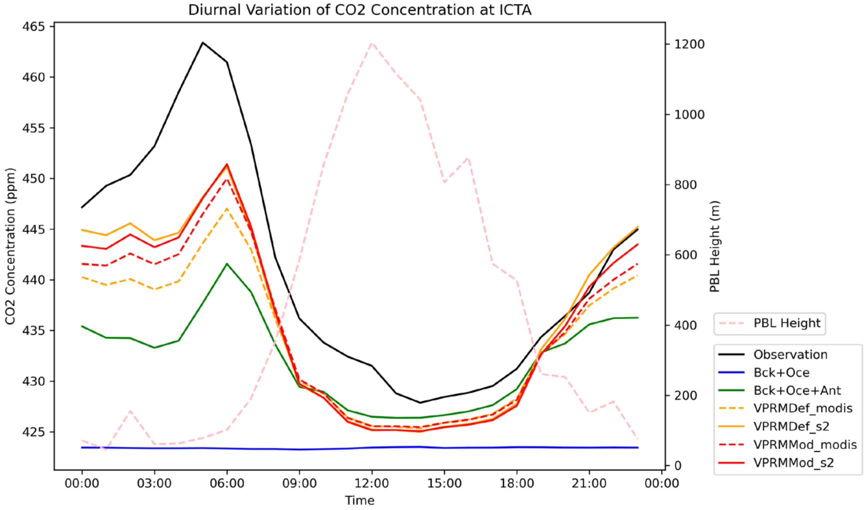
Table . Monthly offset percentage of biospheric CO_2 emissions relative to anthropogenic emissions within AMB(Metropolitan Area of Barcelona)

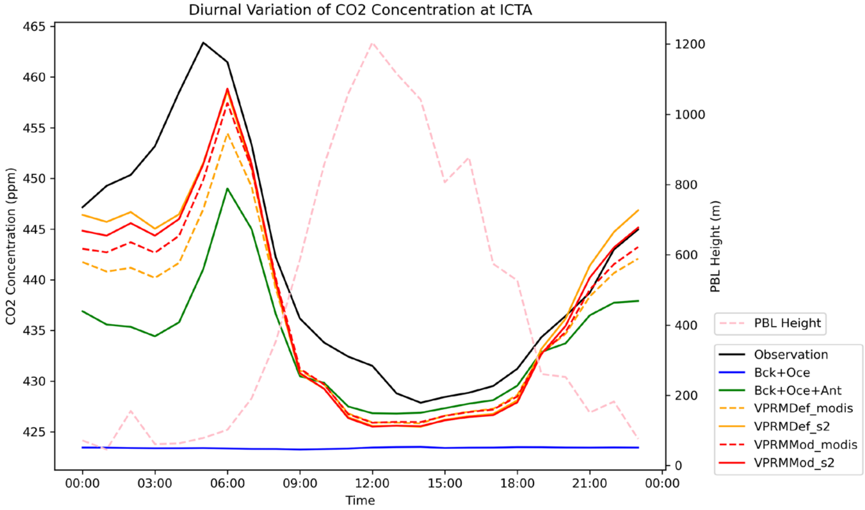
- Estimated anthropogenic emissions in AMB from CAMS are generally higher than EDGAR
- The seasonal difference of vegetation activity are reflected

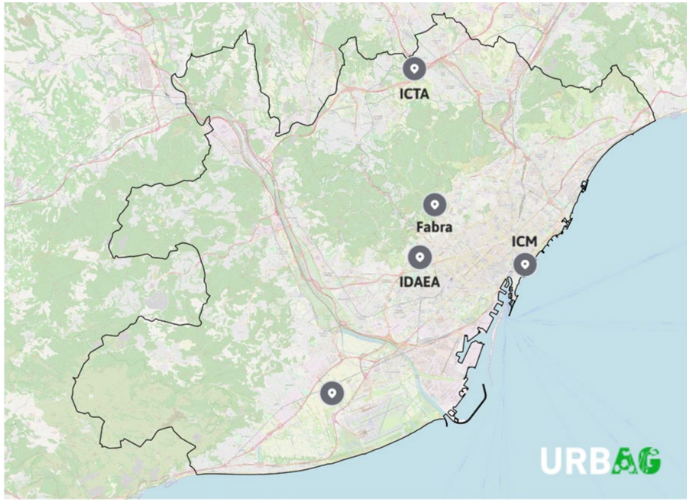
Observed and Simulated CO_2 Concentration_April

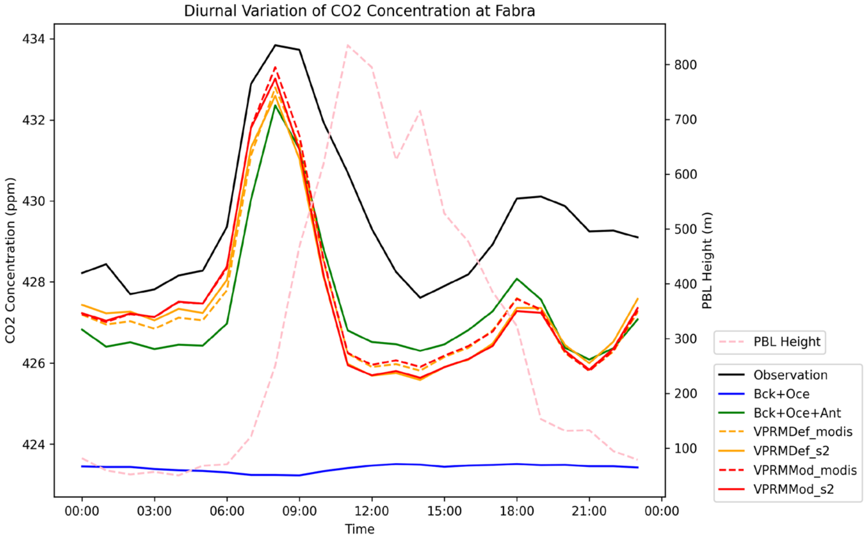
• EDGAR(2023)

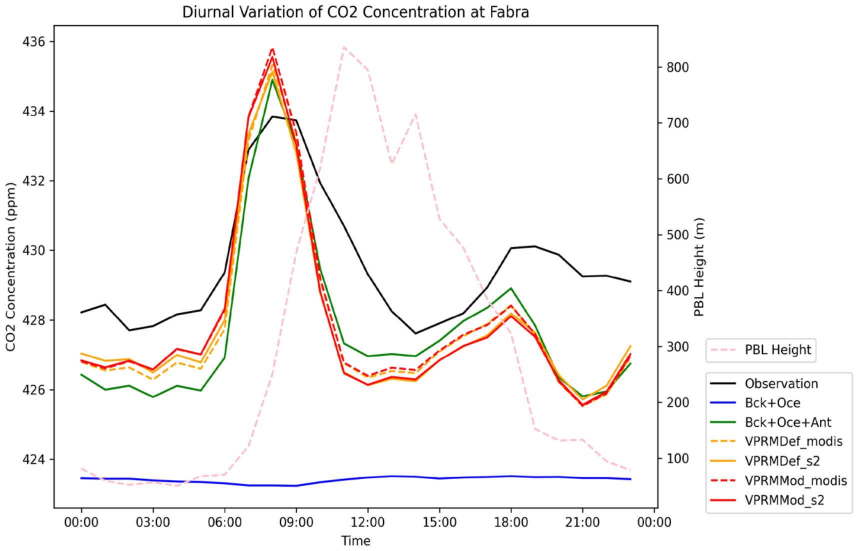
• CAMS (2022)









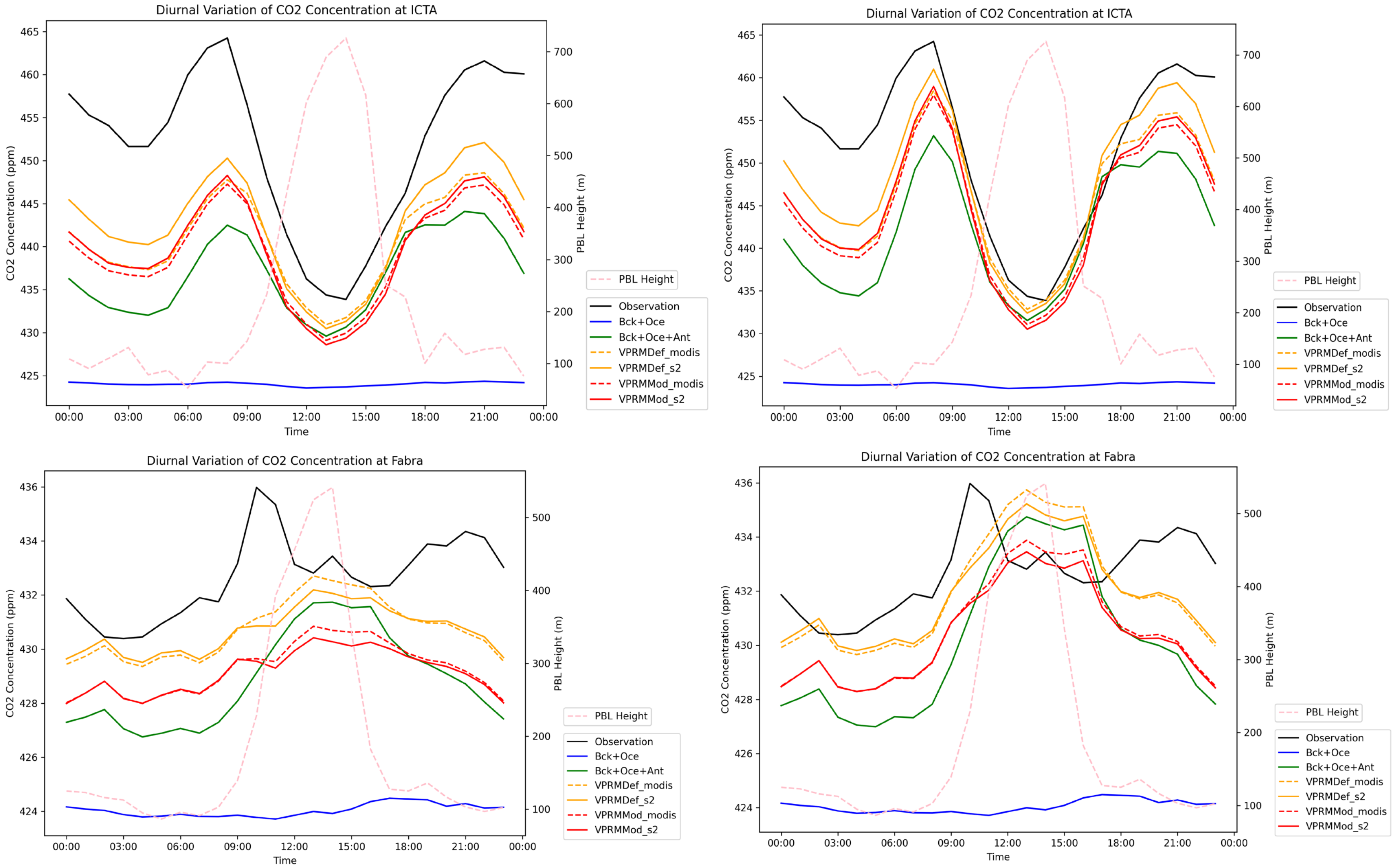


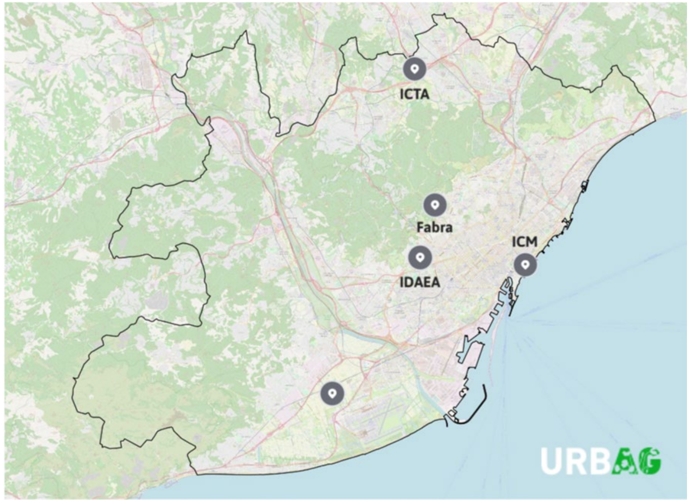
- Contribution of biogenic concentration to the total concentration are negative (uptake), which are mainly constrained by different satellite inputs.

Fig . Monthly averaged diurnal cycle of CO_2 concentrations at ICTA(highway)and Fabra(forest) in April. Concentrations from Observation(black solid), Background and Ocean(blue solid), Background,Ocean,and anthropogenic activities(green solid), total with biosphere fluxes from VPRMdef_modis (orange dashed), total with biosphere fluxes from VPRMdef_s2 (orange solid), total with biosphere fluxes from VPRMmod_modis (red dashed), total with biosphere fluxes from VPRMmod_s2 (red solid). The difference between concentrations of Background,Ocean,and anthropogenic activities(green solid) and total series from VPRM inputs are biogenic contributions. The height of PBL(Planetary Boundary layer) is represented by dashed pink line.

Observed and Simulated CO_2 Concentration_December

- EDGAR(2023)
- CAMS (2022)





- Biogenic contributions derived by default VPRMs are positive(release) while modified VPRMs are negative(uptake)

Fig . Monthly averaged diurnal cycle of CO_2 concentrations at ICTA(highway)and Fabra(forest) in December. Concentrations from Observation(black solid), Background and Ocean(blue solid), Background,Ocean,and anthropogenic activities(green solid), total with biosphere fluxes from VPRMdef_modis (orange dashed), total with biosphere fluxes from VPRMdef_s2 (orange solid), total with biosphere fluxes from VPRMmod_modis (red dashed), total with biosphere fluxes from VPRMmod_s2 (red solid). The difference between concentrations of Background,Ocean,and anthropogenic activities(green solid) and total series from VPRM inputs are biogenic contributions. The height of PBL(Planetary Boundary layer) is represented by dashed pink line.

Summary

1) How effective is urban greenery in reducing CO_2 emissions in a Metropolitan Area?

- Urban vegetation can at most offset 23% of anthropogenic emissions in AMB. CO_2 offsets are much stronger in April compared to December, reflecting the seasonal cycle of vegetation activity.

2) To what extent does the improved resolution and parameterization enhance our ability to identify urban biogenic CO_2 emissions?

- The strongest emission offset occurs in ModVPRM_s2,indicating that improved VPRM with high-resolution satellite inputs can estimate large CO_2 uptake.

- WRF-Chem well simulates the diurnal trend of total CO_2 concentration. In April, negative biospheric contributions are sensitive with different satellite inputs. In December, the biospheric contributions should be estimated more carefully(uptake or release?). Major difference are shown between the default VPRMs(release) and the modified VPRMs(uptake) instead of with different satellite inputs.

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 m, getting the biogenic emissions at 10m
- Compare the anthropogenic emissions from datasets (CAMS, EDGAR) with local inventory(1km)
- Improve human metabolism estimation

Question?

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UAB Universitat Autònoma de Barcelona

URBAG Integrated System Analysis of Urban Vegetation and Agriculture

ICOS Cities

AGAUR Agència de Gestió d'Ajuts Universitaris i de Recerca

Generalitat de Catalunya Departament de Recerca i Universitats

Cofinançat per la Unió Europea

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